# Research for Reduction of Nitrate Leaching Into Columbia Basin Groundwater

## Final Report

Upper Grant Conservation District
Ephrata, Washington

October, 1992

951011739

# Research for Reduction of Nitrate Leaching Into Columbia Basin Groundwater

## Final Report

October, 1992

Prepared by

**Max Ward Hammond, Ph.D.**
Cooperating Research Agronomist
Cenex/Land O'Lakes Agronomy Company

**Roxanne Neilan**
Upper Grant Conservation District

for

Upper Grant Conservation District
2145 Basin SW
Ephrata, WA 98823

# ACKNOWLEDGEMENTS

Appreciation is expressed to:

Washington State Department of Ecology
for award of Centennial Clean Water Funds
for support of this research project.
(Project Grant No. TAX 91081)

Cenex/Land O'Lakes Agronomy Company
St. Paul, Minnesota
for cash match and in-kind services
provided to support and conduct
this research project.

Dr. Robert G. Stevens
Extension Soil Scientist
Washington State University
for technical advice.

Robert A. Hammond
Farm Cooperator
Quincy, Washington

## TABLE OF CONTENTS

# INTRODUCTION

## GROUNDWATER ACTIVITIES RESEARCH STUDY AREA

This research report pertains to work carried out in the northern area of the Columbia Basin on farmlands that are part of the Columbia Basin Irrigation Project developed by the United States Bureau of Reclamation. This area is also referred to as the Quincy Basin as shown in Figure 1 (46). The majority of this area is under the jurisdiction of the Upper Grant Conservation District.

## GEOLOGY, GROUNDWATER, SOILS, AND DRAINAGE OF THE QUINCY BASIN

### Geology

The geological development of this area has provided soils which are highly productive with the advent of irrigation water. These soils have developed from parent materials that constitute the surface of unconsolidated deposits which overlay various basalt formations. These deposits are composed of glacio-fluvial, fluvial, lacusterine, eolian, and ash-fall materials (46). In the area of the Quincy Basin, as with much of the rest of the Columbia Basin Project, the materials of the deposits originated with the Spokane floods of geologic history (10). The heterogeneity of these materials along with the means by which they were deposited over geologic time contributes to wide variations of properties of soil and the intermediate region of the vadose zone.

### Groundwater

The groundwater system has been classified as part of the Columbia Lava Plateau groundwater region by the United States Geological Survey (27). It consists primarily of basalt formations forming a multilayered aquifer system where groundwater moves horizontally between basalt layers in interflow zones and sedimentary interbeds and vertically through fractures and faults in the basalt (46, 27). An analysis of groundwater levels in the basalt formations and overlying materials reveals that there is considerable movement vertically between the various aquifers and horizontally across the whole aquifer complex (11). Work by the Washington State Department of Ecology depicts the aquifer system as having two basic levels which may be broken down further based on various geologic criteria. The unconsolidated deposits are regarded as part of the upper aquifer (39). Prior to the advent of the irrigation waters, much of the unconsolidated overlying materials were not part of the aquifer. Due to input from irrigation project waters, the groundwater elevation levels have increased significantly (13). In many cases the water tables are close to the surface of the unconsolidated overlying materials which comprise the soils being farmed. In some cases the water levels have risen high enough to require groundwater pumping to prevent saturation of soil profiles. In non-farm areas the groundwater has surfaced to create bodies of surface water that are utilized for wildlife and recreational purposes.

## Soils

The soils which have formed on the upper layer of the unconsolidated deposits are as diverse as the parent materials from which they have been formed. The parent materials are the products of glacio-water erosion and water and wind deposition (20). As diverse as these soils are, they have several common characteristics. First, these soils are geologically young and do not have extensive profile development. Due to the arid climate in which they have developed, there is little organic matter in the top-soil horizon (20). The second common characteristic is that most of them are highly permeable to percolating water movement and have relatively low water-holding capacities (21). The third common characteristic of Columbia Basin soils is that they are highly susceptible to wind and water erosion. Often during periods of high wind erosion conditions when there is little vegetative ground cover, sprinkler irrigation systems are operated for the exclusive purpose of reducing wind erosion. A fourth common characteristic of many of the Columbia Basin soils is low colloidal clay content which along with low organic matter contributes to low cation exchange capacities (5). This in effect, contributes to more rapid downward movement of many plant nutrients in percolating irrigation water. Plant nutrient nitrogen is supplied primarily through nitrogen fertilizer forms and is highly susceptible to leaching when it exists in the soil in the nitrate form.

A further important consideration on soils is the distribution of different textural soil types across crop production fields. There is often a diversity of soil types within production fields. Considerable research has addressed this phenomenon of spacial variation of soils in Columbia Basin fields with most of the emphasis being directed at phosphorus and potassium fertility management (17, 18, 30, 34).

In addition to spacial variability due to natural processes, there are man-made contributions due to land leveling to accommodate irrigation and combinations of smaller acreages into larger fields to accommodate larger and more automated sprinkler irrigation systems.

The spacial variations of soil textures and fertility levels in production fields contribute significant challenges to effective environmental management while providing adequate nitrogen nutrition for crop production.

## Drainage

Drainage of many irrigated fields is essential to continued agricultural production. Due to low rainfall conditions during the growing season (16) and low water holding capacities, high irrigation rates are prerequisite for crop production. This requires intensive drainage of some fields where the groundwater table is high. A further complication that necessitates drainage in some fields is the existence of impervious layers that are below the soil profile and prevent further downward water movement. The most common layer is caliche accumulation which is a layer of calcium carbonate deposit. These layers contribute to saturation of the soil profile. The drainage waters are conducted to various wasteways (open drains) which in turn contribute the drainage of water back to groundwater as well as bodies of surface water that are further utilized for irrigation purposes (4).

In summary, the geology, groundwater, soils, and irrigation and drainage practices found in the Quincy Basin of the Columbia Basin Irrigation Project combine phenomena which potentially subject groundwater to degradation by soil nitrates.

## GROUNDWATER QUALITY AS AFFECTED BY IRRIGATION AND NITROGEN FERTILIZERS

### Soil Nitrogen Transformations and Movement

All nitrogen forms added to the soil, whether organic crop residues, livestock manures or inorganic fertilizers, eventually end up in the inorganic nitrate ($NO_3$) form as depicted in Figure 2 (23). In most cases, this is the form that is most readily utilized by plants for their mineral nutrition. Of the three major mineral nutrients; nitrogen, phosphorus, and potassium, nitrogen is generally the nutrient required in the largest amounts and exerts considerable effect on yield and quality of agricultural crops. Because of this, it is the most widely applied of the fertilizer nutrients. Nitrate exists as a negatively charged ion and as such is not readily adsorbed in Columbia Basin soils. This fact combined with the high water solubility of nitrate provides for high mobility in irrigated soils. Nitrate movement occurs as a result of three transport processes: (A) convection, (B) diffusion, and (C) dispersion (14). The process of convection is that process that contributes to nitrate leaching. The interaction of the other processes tend to make nitrate move downward with soil water percolation in a manner that is preceded and followed by lower concentrations than the main dissolved mass of nitrate. Thus any leaching assessments require both the measurement of soil water volumes as well as nitrate concentrations in the soil solution. Due to heterogenous conditions in soil profiles, intensive sampling is required to get accurate indications of soil nitrate levels for any given depth.

Since water percolation in soil profiles is usually seasonal in nature, the assessment of nitrate leaching requires monitoring of soil moisture movement and nitrate concentrations across all seasons of the year. The periods of highest downward leaching are found to be from late fall to early spring when crop consumptive use of both soil moisture and nitrogen are lowest and natural seasonal precipitation is often highest (31). For the same reasons, excessive early or late season irrigation will contribute the most to nitrate leaching into groundwater.

### Nitrate and Groundwater Degradation

U.S. Environmental Protection Agency water quality standards for use in human consumption set the maximum acceptable level at 10 parts per million (ppm) nitrate-nitrogen ($NO_3$-N) (6). In soil solution, 10 ppm is equal to 10 milligrams/liter (mg/L). Most analytical studies report data in metric units of mg/L.

Consideration needs to be given to the interpretation of groundwater analysis results from the viewpoint of relative changes in $NO_3$-N concentration as well as values for any given point in time. Sampling of groundwater must be looked at as a snapshot in time. Long term monitoring is needed to be able to draw any conclusions about changes in water quality over time (44). Groundwater movements are dynamic by nature and concentrations can change over time. Also, short-term changes may not be as significant as long-term trends that may more truly depict increases in nitrate contamination from agricultural practices. It should also be realized that contamination in shallow groundwater may not appear in deeper aquifers for some time. Finally, when contamination does appear, it may persist and increase over time because of downward influx of the groundwater having a higher level of contamination.

## DATA ON LEACHING OF AGRICULTURAL NITRATES INTO GROUNDWATER

### 1990 National Survey

Findings of the recent 1990 National Survey of Pesticides in Drinking Water Wells conducted by the United States Environmental Protection Agency (7) indicate a very small percentage of wells having any significant level of nitrate contamination. Statistical analysis of the results projects 50.9% of community wells have detectable nitrates below the health advisory level of 10 mg/L and 1.2% have nitrates above the level. For domestic wells the results are projected at 54.6% and 2.4% respectively. The survey report indicates a major source of nitrates in cultivated soils is from inorganic fertilizers and that other sources include animal wastes, septic systems, plant residues, and atmospheric fixation. Aside from this information, there is no association to leaching of agricultural nitrates.

### Data From Other Regions

Studies in Iowa, Minnesota, and Ohio report $NO_3$-N concentrations in tile drain lines ranging from 5 to 120 mg/L (32).

Studies in the Georgia coastal plain used shallow test wells under center-pivot irrigated crops to assess leached nitrates. Concentrations in the waters sampled ranged from less than 1 to 133 mg/L with a mean of 20 mg/L $NO_3$-N (29).

A Nebraska study on irrigated corn found $NO_3$-N concentrations in extracted soil water ranging from 28 to 75 mg/L (28).

Studies in California in the Upper Santa Ana River Basin, Southern San Joaquin Valley and Santa Maria Valley provide data indicating extensive leaching of nitrates in irrigated regions. The data suggests that 45% to 55% of the applied nitrogen from commercial fertilizers and livestock manures was lost to leaching. Data from the San Joaquin Valley on $NO_3$-N in drainage waters gave a range of 9 to 163 mg/L with an average of 38.6 mg/L. The report on these studies states that nitrate leaching has contributed to the nitrate levels found in California groundwaters (38).

## Data from the Pacific Northwest

Groundwater studies of adjacent northwestern states, in arid regions having intensive irrigation and nitrogen application for crop production, provide data substantiating the concern of nitrate degradation of groundwater.

A 1989-90 study conducted by the Soil Conservation Service, United States Department of Agriculture, in Bingham County, Idaho, provides data from an area of agricultural environmental conditions similar to the Columbia Basin of central Washington. Of 208 samples found to contain measurable $NO_3$-N, the maximum level was 28 ppm with a mean of 7.3 mg/L (15).

Studies in Oregon also indicate significant groundwater contamination with $NO_3$-N. Findings in northern Malheur County for 118 wells sampled indicate an average of 10.8 mg/L with a maximum of 48 mg/L and a level of 16.9 mg/L for the 75th percentile (8). Groundwater examination in the Boardman-Hermiston area of Umatilla County revealed of 25 wells tested, 11 wells had $NO_3$-N levels greater than 10 mg/L with the maximum being 80 mg/L (37).

## Data on Water Quality in the Columbia Basin Project

Irrigation water studies in the upper region of the Columbia Basin Irrigation Project show a 40 to 100-fold increase in $NO_3$-N between introduction to the project at Pinto Ridge Dam and return flow to the Potholes Reservoir (4). This area is the major portion of the Quincy Basin area. This does not necessarily reflect nitrate movement into groundwater but part of the return flow is from shallow groundwater collected in the irrigation drainage system. Results from this same study give a mean of 6.2 mg/L and a range of 0.28 to 22.0 mg/L $NO_3$-N in tile-collected drainage water (4). This data does substantiate the potential of nitrates being leached from the crop root zone into the upper groundwater aquifer. Using the average of 6.2 mg/L this gives a 207-fold increase in water released for the upper project at Pinto Ridge Dam having a concentration of 0.03 mg/L $NO_3$-N.

Seasonal data collected by the U.S. Bureau of Reclamation during 1973 from a "typical buried pipe drain system" in the Quincy, Washington area gave $NO_3$-N concentrations in the percolating drainage water ranging from 1.65 to 2.90 mg/L for ten monthly sampling dates (3). These levels are not high when compared to other studies but it should be realized that these numbers represent a "point in time" and do not reflect the total $NO_3$-N leached in the total volume of drainage water. The data does show the seasonal variation in nitrate leaching that is experienced in irrigated agriculture.

Shallow groundwater from tile drains in a field in Grant County was sampled by Cenex/Land O'Lakes Agronomy Research on a monthly basis from September, 1990 to September, 1991. The range was 5.0 to 13.0 mg/L and fluctuated on a seasonal basis (24).

Results from a study by the U.S. Geological Survey of groundwater quality in the Columbia Basin that was conducted in 1983 indicated for 47 wells sampled in Grant County, a range of less than 0.1 to 21 mg/L. The median was 1.2 mg/L. Historic data gave a range of 0.0 to 14 mg/L with a median of 0.83 mg/L. The historic data came from 152 wells (40). While some of the wells were withdrawing water from unconsolidated deposits and others from basalt formations, it is not likely that any wells were tapping shallow groundwater.

In Franklin County, the USGS groundwater quality study conducted in 1983 listed 29 wells with a range of less than 0.1 to 13 mg/L and a median of 1.9 mg/L $NO_3$-N (40). Another groundwater study was conducted in Franklin and Benton Counties by the United States Geological Survey in 1989. Results from this study indicate that about 20% of the wells examined have $NO_3$-N levels greater than 10 mg/L with the maximum measured at 100 mg/L (45). In 1988 the Washington State Department of Ecology conducted a groundwater study for selected areas in Washington including 27 wells sampled in Franklin County which lies at the south end of the Columbia Basin Irrigation Project. The range of $NO_3$-N detected was 0.5 to 18.8 mg/L with 11 of the 27 wells testing above the health standard of 10 mg/L $NO_3$-N (19). It is significant that the production agriculture irrigation and fertilization practices in Franklin County are practically identical to the Quincy Basin with many of the same soil types.

In the spring of 1991 the Washington State Department of Ecology conducted a study in the Quincy Basin of Grant County. A total of 23 domestic wells were sampled plus 4 groundwater monitoring wells. Preliminary results indicate all wells had detectable nitrates with a range of 1.0 to 13.6 mg/L and 2 wells were greater than 10 mg/L (45).

Washington State University conducted studies of potato production irrigation and nitrogen fertilization practices in an extremely sandy soil of the Columbia Basin. Analysis of the soil solution found 509 mg/L and 495 mg/L $NO_3$-N at the 4 and 6 foot depths respectively. This data was for an early August sampling (33). The maximum rooting depth for potatoes is usually about 2 feet. Thus the concentrations of nitrates were well below rooting zone and beyond retrieval by potato roots. Under such conditions the nitrates have nowhere to go but to groundwater.

## SUMMARY OF INTRODUCTION

The environmental conditions found in the geology, groundwater, soils, irrigation and drainage of the Quincy Basin of the Columbia Basin indicate an extreme potential for groundwater degradation by nitrate contamination. Soil nitrogen transformations and nitrate movement in percolating irrigation waters are very much a result of intensive nitrogen fertilization and irrigation practices. Potato production is one of the major cropping systems throughout the Columbia Basin area. This crop is one of the most sensitive to reduction in yield and quality due to deficiencies of soil moisture and nitrogen (36). It is estimated that 30 to 50 percent of the nitrogen applied is not recovered by the crop. A large portion of this nitrogen loss is probably destined for groundwater contamination. Available groundwater data does indicate some increase in the levels of nitrates in the aquifers. Limited drainage and soil profile studies indicate nitrates are being leached past the root zones. There is a need for more intensive studies of nitrate leaching through the soil into the intermediate region of the vadose zone. The study should be conducted in production fields across variations in soil types and under the conditions of current nitrogen fertility and irrigation management practices. While appreciation of soil spacial variability is increasing, there is a need for extension of these concepts into nitrogen fertility practices to provide improved environmental management (12).

## RESEARCH OBJECTIVE

The objective of the groundwater protection research covered in this report was to examine the extent of nitrate leaching under representative sprinkler irrigated soils. The research results should function as a data base with a two-fold purpose: (1) Support for continued research on nitrate leaching beyond root absorption zones, (2) A basis for making recommendations for irrigated nitrogen management that can be further developed into best management practices for various crops.

## EXPERIMENTAL

### SCOPE OF WORK

The following list of research tasks provides a brief synopsis of the groundwater protection research covered in this report.

| | |
|---|---|
| Task 1 | Study Field Selection, Evaluation of Textural Spacial Variation in Study Field, and Establishment of Three Textural Zones in Field Having Soil Types of Different Water Permeabilities |
| Task 2 | Selection of Study Sites Within Textural Zones of Different Water Permeabilities and Development of Study Sites for Monitoring Water and Nitrogen Movement |
| Task 3 | Collection of Climatic and Irrigation Data |
| Task 4 | Collection of Nitrogen Application Records |
| Task 5 | Collection of Soil Water at Each Study Site and Analysis of Percolating Soil Water for $NO_3$-N |
| Task 6 | Processing of Test Data for Percolation Rates and Nitrate Concentrations |
| Task 7 | Soil Sample Collection for Soil Nitrogen Status and Analysis of Soil Samples for Soil Nitrogen Forms |
| Task 8 | Final Report Preparation and Interpretation of Results |
| Task 9 | Interaction With Other Research Programs on Projects of Similar Nature and Continuing Literature Review |
| Task 10 | Project Administration |

For the purpose of continuity, the field research tasks are combined into the four following research components:

1. Assessment of field spacial variability and study site development.
2. Collection of climatic, irrigation, and nitrogen fertilizer application data.
3. Soil water investigations
4. Soil nitrogen status investigations

Each of these research components will be discussed under experimental procedures as an independent part of the research field work.

In addition to the work done at the study sites as listed under research tasks, rooting systems were examined post-harvest for depth of root growth.

Tasks 6 and 8 become part of the interpretation and discussion section of this report.

## EXPERIMENTAL PROCEDURES

### Assessment of Field Spacial Variability and Study Site Development

### Study Field Selection

The study field selected is Unit 53-54 Block 71 located in SW 1/4 Section 21 Township 20N, Range 25E. Based on Grant County Soil Survey data (5) and as indicated in Figure 3, the field contains appreciable acreage of three soil types representative of irrigated agriculture conditions in the Columbia Basin: Quincy loamy fine sand, Timmerman coarse sandy loam, and Ephrata gravelly sandy loam. USDA-SCS water permeability data from the Grant County Soil Survey is given in Table 1.

Depth to groundwater is sufficient to not influence nitrate percolation below the root zone. Depth to groundwater in the SE corner of the field is approximately 27 feet based on a domestic well log (1). Depth to groundwater on the west side of the field is approximately 8 feet based on tile drain data (2). The lower elevations of the west half of the study field are drained by tiles and tile drainage water can possibly indicate nitrate movements on a seasonal basis.

The irrigation system consists of a center-pivot system committed to one pump that facilitates accurate record keeping of water application timings and rates as well as nitrogation rates.

The crop rotation program is representative of an intensive nitrogen fertilization program with a wheat, corn, potato rotation which is very common to the Columbia Basin.

### Evaluation of Field Textural Spacial Variation

The study field was intensively sampled on a 200 foot x 200 foot grid (Figure 4). Samples were pulled at 1 foot increments and where possible, to a depth of 5 feet. Due to the rocky profile in the Ephrata soil type, subsoil samples were obtained by digging profile pits with a backhoe. Depth to rocks, which may well affect soil moisture movement, was recorded to develop a map depicting subsoil characteristics. Sampling was done using SCS bucket augers. Three holes were bored for each grid intersection and the depth increments from each hole were composited for the grid sample. Where rocks or gravel prevented sampling by auger in the Quincy and Timmerman zones, sample holes were bored with a tractor-powered posthole auger to 5 feet. The sides of the holes were then cleaned and sampled at 1 foot increments.

Soil sampling, handling, analysis, and resulting data processing was conducted in accordance with good field and laboratory procedures.

Surface soil samples (top foot) for soil characterization were analyzed for nitrate-nitrogen ($NO_3$-N), ammonium-nitrogen ($NH_4$-N), phosphorus, potassium, organic matter, pH, and soil particle size distribution. In addition, due to the nature of the laboratory analysis system, a soil carbonate index value per sample was given to provide insight into the interpretation of nitrate movement as an interaction between crop growth and nitrogen removal patterns associated with phosphorus availability. Subsoil samples for soil characterization were analyzed for $NO_3$-N, pH and soil texture.

Data from surface sample analysis was statistically analyzed via computer utilizing a geostatistical mapping package (22). This determined field spacial variations of the textural and soil chemical components which have influence on crop utilization of soil nitrogen and nitrate leaching. The results of the analysis are depicted graphically by two methods: (1) line-contour maps showing the distribution level of each soil test parameter, and (2) three-dimensional images provided to visualize the relative difference in soil test levels. These graphic representations are depicted as follows:

| | |
|---|---|
| Nitrate-Nitrogen | Figure 5 |
| Ammonium-Nitrogen | 6 |
| Organic Matter | 7 |
| Phosphorus | 8 |
| Potassium | 9 |
| pH | 10 |
| Soil Carbonates | 11 |
| % Sand | 12 |
| % Silt | 13 |
| % Clay | 14 |

Based on soil sampling data, a map showing depth to rocks in the subsoil is shown in Figure 15. The nitrate levels found to the 5 foot depth in the three representative soil types are given in Table 2.

Establishment of Three Textural Zones and Study Site Development

Based on the soil sampling data, soil analysis data, and interactions between various soil characteristics, three soil "textural zones" were selected for Quincy, Timmerman, and Ephrata soil types as depicted in Figure 16.

Study site areas for the Quincy and Timmerman textural zones were selected from the field notes and sample results. Final study sites were selected based on soil textural data from additional soil samples collected on a 50 foot grid to a 12 inch depth of the study site area. To reduce variability between study sites within a textural zone, the study sites were selected for uniform silt content which has been shown to best correlate to nitrate levels in Quincy and Timmerman soils (35). The study site area for the Ephrata textural zone was based on the results of soil tests on 200 foot grid samples taken from the profile pits dug by backhoe as well as other data obtained from examination of the profile pits. Final study site selections for the Ephrata zone were also based on soil textural data from additional soil samples collected on a 50 foot grid to a 12 inch depth of the study site area.

At the time of study site selection, backhoe pits were dug for soil profile examination. The profiles were photographed and representative soil profile monoliths were prepared for each textural zone. Photographs of the representative profiles are shown in Plates 1-3.

Study site areas are depicted in Figure 16. Study sites selected within the areas are shown in Figures 17, 20, and 23. There were three study sites in each textural zone.

Results of the geostatistical analysis of 50 foot grid sample data from study site areas is given as follows:

| | | | |
|---|---|---|---|
| Quincy | Silt | Figure | 17 |
| | Sand | | 18 |
| | PPM $NO_3$-N | | 19 |
| Timmerman | Silt | | 20 |
| | Sand | | 21 |
| | PPM $NO_3$-N | | 22 |
| Ephrata | Silt | | 23 |
| | Sand | | 24 |
| | PPM $NO_3$-N | | 25 |

Sweet corn was planted on May 21-23 as specified by the processing contractor. Study sites could not be established until after the corn was planted and preliminary post-emergence tillage was completed. Study sites were fully established by the end of June prior to post-plant irrigation.

During site development care was taken to protect the established crop and prevent soil compaction. Study sites for the Quincy and Timmerman zones were organized similarly as shown in Figure 26. In each study site three locations were established for vacuum lysimeter placement. Central to the lysimeter locations, a neutron probe access tube was placed for measuring soil moisture contents (Plate 4). Adjacent to the neutron probe tube, a recording precipitation gauge (Plate 5) was placed for recording precipitation and irrigation applications for that location. There were three locations per study site and three study sites per textural zone.

Vacuum lysimeters were constructed of the basic design shown in Figure 27. Materials used in the construction of the vacuum lysimeters are listed in Table 3.

In the Quincy and Timmerman study sites, surface access vacuum lysimeters (Plate 6) were placed at depths of 12, 24, 36, 48, and 60 inches at each location (See Figure 26). Basically, installation as shown in (Figure 28) was accomplished by boring holes with SCS bucket augers and/or a hydraulically powered Giddings soil auger to the specified depths. The vacuum lysimeter tubes were put into place by inserting the ceramic tips into a silica flour slurry poured into the bottom of each hole. Then soil from the respective depths was added around the lysimeter tubes and tamped firmly into place up to the top 12 inches. Surface soil was used to prepare a soil slurry which was then poured into the top of the holes to provide a good seal at the soil surface. For the 12 inch depth lysimeters, the slurry was added to the top of the silica flour level. Water for the slurries was at very low $NO_3$-N content (less than 0.1 ppm).

The lysimeters and neutron probe tubes were installed in the established corn rows shortly after emergence to allow for field mechanical cultivation between rows. The tubes were left in their original locations, undisturbed throughout the research period.

Study sites for the Ephrata zone were arranged as shown in Figure 29. Due to the very rocky subsoil of the Ephrata study sites, lysimeters (Plate 7) were installed as shown in Figure 30 by hand digging trenches to 5' depths. Soils from the trenches were kept separate by depth for placement back into trenches. Holes were bored at 60° angles into the sides of the trenches. The lysimeters were then inserted into the holes with the ceramic tips immersed in silica flour slurry. To seal the lysimeters and prevent channelized flow around them, the tops of the holes were sealed with a water-bentonite clay mix. Vent and vacuum extraction tubing was extended up out of the trench and the trenches were then refilled with the soil materials in the same sequence they were removed from the trenches. In this manner, it was possible to place lysimeters below the heavy rocky zone that extends from about 18 inches to 3 feet in the Ephrata zone. It was not possible to install lysimeters in this rocky area of the soil profile. Sites 1 and 3 had lysimeters buried in 3 locations at 48 and 60 inches. Due to deeper rocks at site 2, it was not possible to install lysimeters at 48 inches but only at 60 inches. At all 3 locations, lysimeters for 12 and 24 inches were installed in the same manner as for the Quincy and Timmerman sites. Due to the subsurface rocks, neutron probe tubes could only be established to 24 inch depths at the Ephrata sites. For deeper water monitoring, tensiometers were installed at 48 and 60 inch depths in the sides of the lysimeter installation trenches.

The lysimeters were left alone for one week after installation to allow installation water to come to equilibrium with the surrounding soil. The lysimeters were then put under 50 kPa (1/2 bar) vacuum for 48 hours and then evacuated of soil water to remove initial soil moisture adjacent to the lysimeters.

To prevent soil compaction about the lysimeters and neutron probe tubes, "anti-compaction platforms" were constructed from 2" X 4" lumber and placed alongside each row of lysimeters (Plate 8) and each neutron probe (Plate 4).

Throughout the sampling period the sites were protected from foot traffic which would contribute to soil compaction in critical areas. Maps were prepared and traffic was only in designated areas. During crop growth, clearings were maintained about the recording precipitation gauges to prevent irrigation water interception by crop canopy.

## Collection of Climatic, Irrigation, and Nitrogen Application Data

### Climatic Data

An automated on-site weather station was set up in the northeast corner of the study field. The station specifications are listed in Table 4. Periodic quality assurance checks were made on sensor performance. Climatic data is listed in Tables 5-11.

### Irrigation Data

Irrigation data was obtained from grower records as well as the recording precipitation gauges located at each study site. Irrigation data is listed in Tables 12-14. Specifications for the recording precipitation gauges are listed in Table 4.

### Nitrogen Application Data

Nitrogen application data was obtained from all pre-plant, side-dress, and nitrogation application records and is listed in Table 15.

## Soil Water Investigations

### Soil Water Sample Collection and Analysis

Soil water samples for each site were collected on a weekly basis beginning July 10th through December 26th. Samples were extracted using a portable 12-volt vacuum pump system (Plate 9) with an evacuation chamber constructed to hold water sample bottles. Care was taken to avoid contamination and maintain accurate identity of the samples. Samples were collected by releasing the existing vacuum and evacuating the water collected in the lysimeter tubes into containers individually labeled for each lysimeter. Following the water removal, a suction of 30 kPa (1/3 bar) was placed on each lysimeter while the vacuum system was still attached to the lysimeter. In this manner a continued vacuum was maintained on the lysimeter tubes.

The samples were transferred to disposable specimen containers, stored at 4°C and shipped via Federal Express courier the following day to the laboratory contracted for analysis. Overnight delivery in packed insulation was used each time. The water samples were analyzed for $NO_3$-N. Initially, and periodically through the sampling period, all samples were submitted for analysis and the results given are averages across locations per study site. The remainder of the time the sample volumes collected in the field were recorded for each lysimeter. This data was then used to prepare weighted composite samples to provide average results across each set of locations per study site. The results are given in Tables 16, 17, and 18.

### Soil Moisture Content Measurements

At each sampling, soil moisture contents for the various depths were measured using neutron probe (Plate 10) and also the tensiometers established at the Ephrata study sites. The soil moisture data is given in Tables 19, 20, and 21.

### Determination of Gravimetric Moisture Data and Soil Bulk Densities

At the end of the research period, additional soil moisture measurements were made with the neutron probe in each soil textural zone and soil samples were collected per depth and analyzed for gravimetric moisture analysis. Soil core samples were taken per depth and analyzed for soil bulk density. Gravimetric soil moisture contents and bulk densities were determined for the respective depths where neutron probe measurements were made. This data was then used to calculate soil moisture content on a volumetric basis as given in the neutron probe data. The results of this work are given in Table 22 and may be used to more accurately define neutron probe soil moisture data with regard to variations in soil bulk density across the measurement depths. This work was done at the end of the research period to insure representative soil bulk densities during the moisture measurement time period.

## Seasonal Soil Nitrogen Status Determinations

Soil samples at 1 foot increments were taken to assess distribution of the soil nitrogen forms over time in the different textural zones. The samples were analyzed for nitrate, ammonium, and total kjeldahl nitrogen (total KJDL-N).

### Pre-Plant

For the pre-fertilization period, the samples from the intensive 200 foot grid samples were used. These samples are most representative of what existed in the textural zones at the beginning of the farming season. The results of analysis for these samples are given in Table 23 which give soil test averages for grid sample data from the soil textural zones.

### Mid-Season

Samples for mid-growing season (August 23, 1991) were taken in areas adjacent to each of the lysimeter locations at each study site and half-way between corn rows. The samples were taken by SCS bucket auger and could only be taken to the depth that could be sampled with this apparatus. Gravel in part of the Quincy zone and the rocks in the subsoil of the Ephrata zone limited access to the depths shown for analysis results in Tables 24, 25, 26.

### Post-Harvest

Post-harvest (September 27, 1991) samples were also taken via SCS bucket auger in the areas adjacent to lysimeter locations at each study site. However, since the crop was no longer present, samples in the rocks or gravel were taken from backhoe pits. The results of sample analysis are given in Tables 27, 28, 29.

### Early-Winter

Winter period (December 20, 1991) samples were taken in the same manner as those taken for the post-harvest period. Results of sample analysis are given in Tables 30, 31, 32.

## Post-Harvest Examination of Root Systems

Shortly after harvest of the sweet corn (August 31 - September 1, 1991) a study site was chosen in each of the textural zones for post-harvest examination of the crop root growth. Rooting patterns were examined in trenches dug across the corn rows to observe root patterns beneath and between rows. The patterns were examined after using a pressurized water spray to wash the soil away from the roots. The root masses were examined qualitatively, looking primarily at root masses with respect to depth. The results of the root study are give in Table 33.

## RESULTS AND INTERPRETATION

The intent of this section is to examine the data from the research described under Experimental. The results will then be combined from all aspects of research to complete Task #6 - Processing of Test Data for Percolation Rates and Nitrate Concentrations.

The data given in the results is to be interpreted from the viewpoint of showing trends of nitrate movement in the soil textural zones. As with most studies of soil moisture and soil nitrogen, there is a natural variation contributing to experimental error. It should also be remembered that the results of this study are from a point in time, one growing season and one location. While the results may contribute to reduction of nitrate leaching, further verification of such results strengthens the validity of results and concepts to be used for development of best management practices.

### FIELD SPACIAL VARIABILITY

The results of the intensive grid sampling and subsequent analysis of the soil samples indicates substantial variations within the field as shown in Figures 5-15. The results of geostatistical analysis of the soil test data closely parallel the soil series map found in the SCS soil survey and shown in Figure 3. The spacial variations of soil textural components affect soil-water relationships which in turn affect soil nitrate variations. Soil textural components, primarily percent silt, show a relationship to nitrate content in the topsoil.

The variations of soil pH and carbonate index account for lower soil-test phosphorus levels on the west area of the field. Phosphorus fixation resulting in lower availability contributes to decreased crop growth and removal of soil nitrates. Decreased nitrate uptake coupled with higher silt contents contributing to decreased soil permeability, result in higher nitrate levels in the soil profile as is indicated in Table 2. It is apparent that both soil chemical and soil physical variability affect variable nitrate movement within the soil.

Nitrate-nitrogen data for the pre-fertilization period, as shown in Table 2, indicates similar patterns across the depths of each soil with the Quincy soil having slightly higher levels than the Timmerman and the Ephrata soil being much higher. The high proportions of $NO_3$-N in the lower profile, (36 to 60 inches) as shown in Table 2, reflect appreciable nitrate accumulations below the crop root zone.

### SOIL WATER NITRATES

The results of using vacuum lysimeters to assess $NO_3$-N contents of soil solution give considerable insight into $NO_3$-N concentrations, both in changes with depth and over time. The results are reasonably consistent across study sites within the Quincy and Ephrata zones. Sites 1 and 3 are consistent in the Timmerman zone with greater variation in Site 2.

For the purposes of assessing these results, the data from all study sites within each textural zone were averaged together and depicted graphically in Figures 31, 32, and 33.

## Quincy and Timmerman Zones

Soil solution nitrate levels in the Quincy and Timmerman zones follow similar patterns over time. Both zones exhibit an early and rapid drop of nitrate levels in the top 12 inches of the profile. This is probably related to both crop uptake, nitrogen immobilization by soil microorganisms and downward movement with percolating soil moisture. The lowest levels for 0 to 12 inches are found at harvest time (9 weeks) and then levels begin to increase steadily up to the end of the study period at the end of December. This increase is most likely due to mineralization of crop residues incorporated immediately after harvest.

Nitrates in the 12 to 24 inch zone show an initial increase followed by a rapid decrease that tends to follow the decrease in the top foot of the profile. The initial increase is probably due to downward movement from overlying soil with the decreases attributable to crop uptake and downward movement of soil moisture. The nitrates decrease more rapidly and to a lower level in the Timmerman zone. This may be due to the greater permeability below 24 inches in the Timmerman zone. Both zones show a buildup during the post-harvest and early-winter periods.

At the 24 to 36 inch level of the profiles there is an initial increase, more rapid in the Timmerman soil which is probably associated with greater permeability of that soil. The levels decrease until just after harvest and then tend to slowly level off for the rest of the season. The initial increase is most likely due to downward movement from the upper soil zone and all decrease is due to downward movement in soil solution since no roots were found at this depth for crop uptake as will be noted later.

Nitrate content of solutions from 36 to 48 and 48 to 60 inch depths parallel each other quite closely for 16 to 17 weeks and then the lowest depth increases. Both depths show an initial increase which levels and then begins to gradually decline at about 9 weeks. The decline slowly levels with an increase at the 48 to 60 inch depth. The overall pattern at the lower depths reflects downward movement of nitrates to that level with a buildup and then decline as nitrates leach out of the bottom of the soil profile into the intermediate zone.

Decreases in nitrate content due to denitrification below 24 inches are unlikely due to lack of organic carbon to sustain such microbial activity.

## Ephrata Zone

As with the Quincy and Timmerman Zones, there is a rapid decrease in the top 12 inches although there is an increase prior to decline. Following harvest, there is a slight increase which tends to then level out. Again the decrease would be for the same reasons as in the other soils, namely crop uptake, nitrogen immobilization, and downward movement in percolating water. Levels in the second foot increase slowly until just after harvest and then show a gradual decline. This is in contrast to the Quincy and Timmerman soils. Apparently downward movement is restricted which would also be reflected by higher soil moisture contents to be discussed later. Any decrease in percolation would also translate into slower movement into lower levels of the soil profile. No data is available for the 24 to 36 inch level due to the extreme rockiness of this level. Nitrates slowly accumulate in the 36 to 48 inch and 48 to 60 inch levels with higher concentrations in the 36 to 48 inch level. This would substantiate a gradual downward movement of nitrates past the root zone with accumulations at lower levels if downward movement of gravitational water is restricted. Examination of the soil profile during site establishment revealed compacted and cemented zones in the lower profile with mottled soil colors which indicate anaerobic conditions over time due to saturated soils. With time the gravitational water will move into the intermediate area of the vadose zone which in this case is drained by a tile drainage system in the region of the Ephrata Zone. This appears to be indicated by a beginning decline at the end of December. The overall pattern appears to be a rapid decrease of nitrates in the upper root zone followed by a long buildup and late decrease in the lower root zone due to restricted downward movement of percolating soil moisture.

## SOIL NITROGEN STATUS

Soil samples were collected periodically during the research period to assess the status of $NH_4$-N and total KJDL-N over time as well as provide soil nitrate data in regard to nitrate movement in the soil profiles. The latter is in contrast to using soil solution nitrate data to indicate nitrate movement.

Since both $NH_4$-N and total KJDL-N were often below detection limits, it is not possible to average location and site data to represent the trends in the zones. Some general observations can be made from Tables 24-26.

Total KJDL-N represents nitrogen found in more stable organic forms as well as $NH_4$-N. Organic nitrogen levels are appreciable in the soil in contrast to $NO_3$-N or $NH_4$-N. For example, 0.1% total KJDL-N represents approximately 10,000 lbs. of organic nitrogen if $NH_4$-N is subtracted out. This nitrogen is mostly unavailable for plant use and what becomes available does so at a very slow rate. The total KJDL-N in the soil samples did not provide any insight into nitrogen movement. It is not subject to leaching in the profile to any appreciable extent.

The levels of $NH_4$-N in the soil are considerably lower when compared to $NO_3$-N. This is because $NH_4$-N is rapidly oxidized to $NO_3$-N by soil bacteria in the process of nitrification. Ammonium-N is usually transient following applications of ammonium-containing nitrogen fertilizer or following microbial mineralization of organically bound nitrogen in plant residues incorporated into the soil. The levels of $NH_4$-N remained very low except for the post-harvest sample time which was about four weeks after crop residue incorporation following harvest of the sweet corn crop. The $NH_4$-N levels at that time indicate potential for further nitrate movement into the lower profile during early winter and early spring when soil temperatures sustain nitrification and there is no established cover crop. The increase in $NO_3$-N levels in soil solution from the top foot of the profiles confirm the mineralization-nitrification transformation of crop residue nitrogen.

Seasonal distribution of $NO_3$-N levels for the three soil textural zones is represented by the data averages for soil nitrogen status samples as given in Table 34 and depicted graphically in Figures 34, 35 and 36. The pre-fertilizer samples show high initial levels of soil nitrates coming into the cropping season. Apparently this is carryover from the previous cropping season.

Mid-season soil sample results show similar patterns in the root zone of the Quincy and Timmerman soils with a greater buildup of nitrates below the root zone of the Quincy soil. This agrees with the soil solution nitrate data for this time period. The mid-season data for the Ephrata root zone agrees with soil solution nitrate data with the bottom of the root zone having a higher level of $NO_3$-N.

Post-harvest soil sample data again shows similar patterns in the Quincy and Timmerman root zones. When compared to mid-season, root-zone nitrates increased in response to mineralization of crop residues. Data for below the root zone shows a decrease in $NO_3$-N at 24 to 60 inches indicating downward movement of nitrates in the percolating water. The Ephrata zone data also shows an increase in nitrates for the root zone. Comparison of 24 to 60 inch levels to mid-season levels is not possible due to lack of samples from the lower level for that time period.

Early-winter soil sample data shows a decline in the nitrate levels for the top of the root zone of the Quincy and Timmerman soils. The bottom of the root zone appears to increase slightly. The lower profile shows a continued downward movement of nitrates at all three lower depths. Ephrata zone values for the early-winter period shows a significant drop throughout the profile.

## EXAMINATION OF CROP ROOT SYSTEMS

The results of root examination shown in Table 33, for each of the textural zone profiles, indicate the root zone is in the upper two feet. These results led to the designation of 0 to 24 inches as the root zone and 24 to 60 inches as sub-root zone. It is unlikely that nitrates in the lower zone were utilized by the sweet corn crop in this field during this research.

## CLIMATIC, IRRIGATION, AND NITROGEN APPLICATION DATA

Totals for monthly precipitation and evaporation are given in Table 35. The precipitation data is compared to historical monthly averages for Ephrata, Washington (16). Overall the precipitation is lower throughout the research period. Evaporation data was recorded only during post-emergence and post-harvest irrigation.

Data on irrigation rates from grower records are based on center pivot revolution times and calculated application rates. During the post-emergence to harvest period, the entire field was irrigated at the same rate as indicated in Tables 12, 13, and 14. Pre-plant and post-harvest application rates varied slightly between textural zones. The pre-plant rates were varied to accommodate seedbed preparation. With respect to post-harvest applications, 5.0 inches were applied for metham sodium application, a water applied soil fumigant for the 1992 potato crop. This is an excessive rate but normal for this practice.

Values for estimated crop use during post-emergence to harvest are given in Table 36. These values are based on multiplying on-site pan evaporation values by water use coefficients for field corn (25) that have been modified for the growth stages of sweet corn. The estimated crop use values are compared to actual measured irrigation and precipitation to reflect agreement of irrigation rates to crop use. Irrigation during crop production was conservative.

Nitrogen application records show compensation for higher pre-fertilizer soil test levels found in the Ephrata zone. The nitrogen application rates are conservative.

## COMPARISON OF NEUTRON PROBE TEST DATA TO GRAVIMETRIC SOIL TEST DATA

The results given in Table 22 indicate discrepancies between soil moisture content data determined by neutron probe versus volumetric moisture contents determined by gravimetric soil analysis. Neutron probe results for the top foot in all soil types gave lower moisture contents than gravimetric analysis. This is often the case when the neutron emitter is centered in the middle of the upper foot as was the case in this research. Data for the second foot of the Timmerman and Quincy profiles agrees quite closely by both analysis techniques. Data showing higher moisture content by neutron probe in the lower profiles is likely to be associated with neutron interaction with accumulated soil carbonates which will result in higher moisture readings. In considering the results of this comparison between gravimetric and neutron probe assessment of soil moisture, it should be pointed out that this data is very limited as reported here. The results are "micro-site" specific and the larger number of probe locations will tend to reduce some error in the lower profile. The surface foot error is probably consistent and soil moisture data at that level should be considered with that in mind. In addition, the neutron probe data, as considered over time, indicates soil moisture trends which may be more important than absolute values when examining nitrate leaching relationships and in irrigation management in production agriculture.

## INTERPRETATION OF RESEARCH RESULTS FOR ASSESSMENT OF NITRATE LEACHING

The intent of this section is to utilize soil moisture contents in the soil profiles along with soil solution $NO_3$-N data to estimate nitrate leaching by percolating soil water. The objective is not to come up with absolute values but trends and relationships that can be considered in further research and be used for development of best management practices.

### Conversion of Soil Solution Nitrate-Nitrogen Data to Soil Nitrate-Nitrogen Levels

The vacuum lysimeter water sample data reflects short-term changes and long-term trends of $NO_3$-N in the soil solution. Most research in soil fertility management for crop production and resulting best management practices express $NO_3$-N in the soil as PPM or mg/Kg on an oven-dry-weight basis. Also, to assess the extent of nitrate movement down the soil profile, it is essential to express mass of nitrates in soil solution. It is necessary therefore to convert the data obtained from the vacuum lysimeter samples to dry-weight mass.

Conversion is accomplished by utilizing two components of the soil solution system: (1) the <u>volume</u> of soil solution existing in soil volume being considered, and (2) the <u>concentration</u> of $NO_3$-N of the soil solution.

The volume component comes from the soil moisture contents as measured by neutron probe and expressed as inches of soil moisture per 12 inches of soil depth. The depth used in conjunction with the area of soil being considered, usually expressed in acres, gives volume of soil solution.

The concentration component comes directly from soil solution analysis conducted on water samples from the vacuum lysimeters as expressed in ppm.

Conversion of the soil solution data to oven-dry-soil data is accomplished as follows:

Soil Moisture Content (Neutron Probe Data) X Soil Solution $NO_3$-N Concentration (Vacuum Lysimeter Data) X

0.0568 (Conversion Constant) = Soil $NO_3$-N Content in ppm

Results of the conversion of the soil solution data to oven-dry-soil data for the averages of the three textural zones are shown in Figures 37, 38, and 39.

In processing the research data for percolation of soil solution and $NO_3$-N concentrations, consideration must be given to depth of the root zone and fate of solution nitrates at various depths of the soil profile. This matter should be examined over time to allow for root growth and development and also rates of plant uptake during the growth stages of the crop.

## Root Zone and Crop Utilization

For the purpose of this study, the root zone is defined as the top 24 inches of the soil profile. Undoubtedly there was extension of roots into the third foot but their contribution to nitrate uptake was probably minimal. Root growth was not assessed during the growing period of the crop but root extension was probably complete by the end of the rapid vegetative growth phase about mid-July (26, 9). The rate of nitrate uptake throughout the root zone probably remained high until the final stages of grain development as the grain accounts for about 60% of the nitrogen found in corn plants at harvest (42). Part of this nitrogen comes from other plant parts during the final stages of yield formation. Final stages of grain development concluded about mid-August.

## Estimates of Nitrate Loss Via Leaching

Taking into consideration the root zone, nitrates found in the profile from 36 to 60 inches below the root zone were beyond the zone of plant uptake in an area considered as sub-root zone.

Based on this premise, an examination of nitrate levels found at the beginning and during crop growth as well as post-harvest and early-winter reflect a "balance" of nitrogen remaining in the soil profile below the root zone. While nitrates in the lower profile are not available for utilization by shallow-rooted crops, the assumption is being made in this report that deep-rooted crops can utilize nitrate-nitrogen down to 5 feet. Based on this assumption, nitrates that move downward past the bottom of the 5 foot soil profile and into the intermediate area of the vadose zone are defined as leached and pose a potential for groundwater contamination.

The nitrate balance for the sub-root zone is estimated from the average $NO_3$-N data across all study sites for each textural soil zone. The results are given in Table 37 and depicted graphically in Figure 40. To express the results in more meaningful terminology, the soil nitrate contents have been converted to lbs./A by multiplying by a conversion factor of 4. The change in balance for estimating nitrate leaching from the sub-root zone is calculated as the difference between the highest levels found at about 4 weeks (July 31, 1991) and the lowest level found at 25 weeks (December 26, 1991). The estimates are indicated in Table 37.

Data for the upper level of the Ephrata sub-root zone (24 to 36 inches) is unavailable due to the rockiness of that portion of the soil profile. In addition, the downward movement of nitrates from 36 to 60 inches appeared to just begin at the end of December, 1991. Thus, no data is available to reflect a decrease in nitrate levels during the research period. Undoubtedly with time there were decreases due to nitrate leaching.

In addition to nitrates which moved beyond the sub-root zone during the study period, the nitrates remaining in the upper levels of the soil after harvest have the potential of leaching loss during the fall, winter, and spring periods when no crop is established in the soil. The extent of such movement is a function of irrigation and natural precipitation rates during this period as well as other climatic parameters interacting with crop residues and the soil microbial community. It is significant that there were increases in soil nitrates in the upper profile during the post-harvest period after crop residues were incorporated into the soil. This is shown in the soil solution nitrate data and also from the soil $NO_3$-N levels derived from that data as given in Table 37 and Figure 40. These increases were the result of nitrogen mineralization from crop residues by the soil microorganisms. In many ways, the potential for nitrate leaching is greater during the post-harvest and pre-plant periods because of this phenomenon.

## SUMMARY AND RECOMMENDATIONS

The following are concepts and recommendations supported by the results of this research.

Concept: Field spacial variation of soil physical and chemical properties that influence nitrate leaching were demonstrated and are common to other fields of the same geologic origin in the Columbia Basin.

Recommendation: Site-specific fertilization and irrigation practices need to be developed and implemented in nitrogen fertility management.

Concept: There was definite downward nitrate movement within the three soil series studied. This is evidenced by the changes of soil solution $NO_3$-N over time and across the different profile depths as well as periodic soil samples collected from different depths.

The trends of nitrate movement sustain the variations between soil series and substantiate the need for site-specific crop management research and subsequent practices.

As indicated by decreases of nitrate levels in the bottom of the soil profile, nitrates are being leached into the intermediate region of the vadose zone. This appears to be the destiny of nitrates which are not utilized by the crop and move down during the crop growth and post-harvest periods.

Recommendation: Techniques of positionally stabilizing nitrogen in the root zone of the soil need further development and implementation. Concepts of variable rate applications of fertilizer nitrogen, split applications timed and located for most efficient uptake and utilization by crops, use of slow-release materials early in the production season, and use of chemical nitrogen stabilization all contribute to positional stabilization of nitrogen in the upper soil profile.

Concept: Mineralization of organic nitrogen from crop residues was evidenced by transient increases in $NH_4$-N and significant increases in soil nitrates in the top foot following crop residue incorporation. Subsequent soil solution data indicated movement of the nitrates to the lower part of the profile where they will undoubtedly be leached into the vadose zone.

Recommendation: Utilization of cover crops for soil nitrogen retrieval in the post-harvest period would assist in keeping nitrogen in the upper profile in a more stable organic form. Post-harvest irrigation can easily contribute to nitrate losses.

Concept: The sweet corn crop had a much shallower root system than was expected. Corn roots often extend to much deeper depths (26). The shallow root system, as is the case with many Columbia Basin crops, reduces the soil zone for effective nitrate uptake and increases potential for nitrate leaching.

Recommendation: A better awareness of rooting depths is needed. This should be utilized for soil moisture management in the effective root zone. Perhaps in some cases, changes in soil moisture management can contribute to deeper root growth at times where moisture stress will not appreciably affect crop quality and yield. Mild moisture stress has been reported to stimulate deeper root growth in corn (41). The idea of promoting deeper root growth must be carefully balanced against crop sensitivity to yield and quality losses due to moisture stress during critical periods of growth and development.

Concept: The results do not show excessive irrigation during crop production. However, there was sufficient soil moisture to promote downward percolation of soil solution as evidenced by soil moisture contents throughout the profile over time. While there is downward movement of soil moisture when soils are at the upper end of available water holding capacities, significant leaching does not occur unless the moisture contents are greater than field capacity (43).

Recommendation: Irrigation management is a key component to nitrogen fertility management. However, irrigation rates need to be soil-specific and based on site specific climatic data. Effective utilization of computerized irrigation management programs requires input of accurate data. Utilization of irrigation water management programs are essential to reduction of nitrate leaching.

# REFERENCES

1. Anon. Well Log for James Larsen. 6/22/61. SE1/4, SW1/4, Sec. 21, T20N, R25E. Washington State Department of Ecology.

2. Anon. Drain Tile Records. U. 53-54 Blk. 71. Bureau of Reclamation. U.S. Dept. of Interior.

3. Anon. 1976. Final Environmental Statement. Columbia Basin Project, WA. Vol. 1. Bureau of Reclamation, U.S. Dept. of Interior, Boise, ID.

4. Anon. 1982. Columbia Basin project water quality. Bureau of Reclamation, U.S. Dept. of the Interior.

5. Anon. 1984. Soil Survey of Grant County Washington. Soil Conservation Service, U.S. Dept. of Agriculture.

6. Anon. 1989. Federal Register. 54FR 22062, 22 May. U.S. EPA. Washington, DC.

7. Anon. 1990. National Pesticide Survey, Summary Results of EPA's National Survey of Pesticides in Drinking Water Wells. Office of Water and Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Washington, D.C.

8. Anon. 1991. Northern Malheur County Groundwater Management Action Plan, Malheur Groundwater Management Committee, Ontario, OR.

9. Aldrich, S.R., W.O. Scott, and E.R. Long. 1975. Modern Corn Production. 2nd Ed. pp. 6-7. A&L Publications. Champaign, IL.

10. Alt, D.D. and D.W. Hyndman. 1984. Roadside Geology of Washington. pp. 160-182. Mountain Press Publishing Company. Missoula, MT.

11. Bauer, H.H., J.J. Vaccaro, and R.C. Lane. 1984. Ground-water levels in the Columbia River Basalt Group and overlying materials, Spring, 1983, Southeastern Washington State. U.S. Geological Survey Water-Resources Investigations Report 84-4360. U.S. Geological Survey, Washington, D.C.

12. Biggar, J.W. 1978. Spacial variability of nitrogen in soils. In: Nielsen, D.R. and J.G. MacDonald (ed) Nitrogen In the Environment. Vol. 1, Nitrogen Behavior In Field Soil. pp. 201-211. Academic Press. New York, NY.

13. Brown, R.E. 1979. A review of water-well data from the unconfined aquifer in the eastern and southern parts of the Pasco basin: Rockwell International, Contract number DE-AC06-77RL10130, 63 p.

14. Cameron, K.C. and R.J. Haynes. 1986. Retention and movement of nitrogen in soils. In: Kozlowski, T.T. (ed) Mineral Nitrogen In The Plant - Soil System. pp. 166-241. Academic Press, Inc., New York, N.Y.

15. DeTullio, D. 1991. Fort Hall Groundwater Quality Report - Preliminary Investigation Report, Bingham County, Idaho. USDA-SCS, Boise, ID, and Shoshone-Bannock Tribes, Fort Hall Indian Reservation, ID.

16. Donaldson, W.R. 1979. Washington climate for these counties - Grant, Kittitas, Klickitat, Yakima. EM 4422. Cooperative Extension Service, College of Agriculture, Washington State University.

17. Dow, A.I. and A.R. Halverson. 1966. The need for intensive soil sampling in central Washington. WA Agr. Exp. Sta. Bull. EM2611, WSU, Pullman, WA.

18. Dow, A.I., D.W. James, and T.S. Russell. 1973. Soil variability in central Washington and sampling for soil fertility tests. WA Agr. Exp. Sta. Bull. 788, WSU, Pullman, WA.

19. Erickson, D. and D. Norton. 1990. Washington State Agricultural Chemicals Pilot Study - Final Report. Ecology Publication 90-46. WA State Department of Ecology. Olympia, WA

20. Gilkeson, R.A. 1958. Washington soils and related physiography - Columbia Basin Irrigation Project. Stations Circular 327. WA Ag Expt. Stations, Institute of Agricultural Sciences, State College of Washington.

21. Hagood, M.A., D.E. Miller, and E.C. Larsen. 1970. Water-holding capacities of Columbia Basin Irrigation Project Soils. Circular 517. WA Ag Expt. Station. College of Agriculture, Washington State University.

22. Hammond, M.W. 1988. Program handbook for computerized soil fertility mapping utilizing intensive grid soil test data. Cenex/Land O'Lakes Agronomy Technical Services, St. Paul, MN.

23. Hammond, M.W. 1990. Nitrogen reactions in the soil as a base for best management practices. Proc. 1990 Irrigated Agriculture Fertilizer Conf. Jan. 4, 1990. Pasco, WA. WA-OR Soil Improvement Committee, IRAEC, Prosser, WA.

24. Hammond, M. 1991. Unpublished data - Cenex/Land O'Lakes Agronomy Research, Ephrata, WA.

25. Hane, D.C. and F.V. Pumphrey. 1984. Crop Water Use Curves for Irrigation Scheduling. Agr. Expt. Sta. Special Report 706. Oregon State University, Corvallis, OR.

26. Hanway, D.G. 1966. Irrigation. In: Pierre, W.H., S.R. Aldrich, and W.P. Martin (eds). Advances in Corn Production: Principles and Practices. pp. 157-170. The Iowa State University Press. Ames, IA.

27. Heath, R.C. 1984. Ground-Water Regions of the United States. pp. 28-31. USGS Water Supply Paper 2242. United States Government Printing Office. Washington, D.C.

28. Hergert, G.W. 1986. Nitrate leaching through sandy soil as affected by sprinkler irrigation management. J. Environ. Qual. 15:272-278.

29. Hubbard, R.K., L.E. Asmussen, and H.D. Allison. 1984. Shallow groundwater quality beneath an intensive multiple-cropping system using center pivot irrigation. J. Environ. Qual. 13:151-156.

30. James, D.W. and A.I. Dow. 1972. Source and degree of soil variation in the field: The problem of sampling for soil tests and estimating soil fertility status. WA Agr. Exp. Sta. Bull. 749, WSU, Pullman, WA.

31. Legg, J.O. and J.J. Miesinger. 1982. Soil nitrogen budgets. In: Stevenson, F.J. (ed) Nitrogen In Agricultural Soils. pp. 503-566. Agronomy 22. American Society of Agronomy, Madison, WI.

32. Logan, T.J., G.W. Randall and D.R. Timmons. 1980. Nutrient content of tile drainage from cropland in the North Central Region. NC Regional Publ. 268. Res. Bull. 1119. OARDC, Wooster, OH.

33. McNeal, B.L. and R. Kunkel. 1973. Nitrate leaching following potato fertilization. Proc. 12th Annual Washington State Potato Conference. WA State Potato Comm., Moses Lake, WA.

34. Mulla, D. and M. Hammond, 1988. Mapping of soil test results from large irrigation circles. Proc. Far West Reg. Fert. Conf., Bozeman, MT.

35. Mulla, D.J. and Annandale, J.G. 1989. Assessment of field scale leaching patterns for management of nitrogen fertilizer application. Proc. of Workshop on Field Scale Transport. Ascano, Switzerland. Sept. 25-29, 1989. Swiss Federal Institute of Technology, Zurich, Switzerland.

36. Ojala, J.C., J.C. Stark and G.E. Kleinkopf. 1990. Influence of irrigation and nitrogen management on potato yield and quality. American Potato Journ. 67:29-43.

37. Pettit, G. 1987. Assessment of Oregon's Groundwater for Agricultural Chemicals. State of Oregon, Dept. of Environ. Qual., Water Qual. Div., Portland, OR.

38. Pratt, P.E. 1984. Nitrogen use and nitrate leaching in irrigated agriculture. In: Hauck, R.D. (ed) Nitrogen In Crop Production. pp. 319-333. Amer. Soc. of Agron., Madison, WI.

39. Tanaka, H.H., A.J. Hansen, and J.A. Skrivan. 1974. Digital-model study of ground-water hydrology, Columbia Basin Irrigation Project Area, Washington. Washington Department of Ecology Water Supply Bulletin 40. Washington DOE, Olympia, WA.

40. Turney, G.L. 1986. Quality of ground water in the Columbia Basin, Washington, 1983. Water Resources Investigations Report 85-4320. U.S. Geological Survey, U.S. Dept. of Interior.

41. Rhoads, F.M. and J.M. Bennett. 1990. Corn Irrigation. In: Steward, B.A. and D.R. Nielsen (eds). Irrigation of Agricultural Crops. pp. 569-596. Am. Soc. Agron., Madison, WI.

42. Ritchie, S.W. and J.J. Hanway. 1984. How a Corn Plant Develops. Special Report No. 48. Cooperative Extensive Service, Iowa State University, Ames, IA.

43. Smith, S.J. and D.K Cassel. 1991. Estimating Nitrate Leaching in Soil Materials. In. Follett, R.F., D.R. Keeney, and R.M. Cruse (eds). Managing Nitrogen for Groundwater Quality and Farm Profitability. pp. 165-188. Soil Sci. Soc. Amer., Inc. Madison, WI.

44. Stevens, R. 1989. Groundwater Sampling in the Northwest: What is it? What is it Telling Us? Proc. 40th Ann. Regional Fert. Conf., Far West Research Committee. Far West Fert. & Agri-Chem. Assn., Spokane, WA.

45. Stratton, D.A. 1992. Protecting Groundwater: A Strategy for Managing Agricultural Pesticides and Nutrients. Ecology Publication 91-42. Washington State Department of Ecology. Olympia, WA.

46. Vaccaro, J. 1986. Columbia Plateau Basalt Regional Aquifer-System Study. In: Sun, R.J. (ed) Regional Aquifer-System Analysis Program of The U.S. Geological Survey Summary of Projects, 1978-84. pp. 141-145. U.S. Geological Survey Circular 1002. United States Government Printing Office, Washington, D.C.

# APPENDIX A

# PLATES

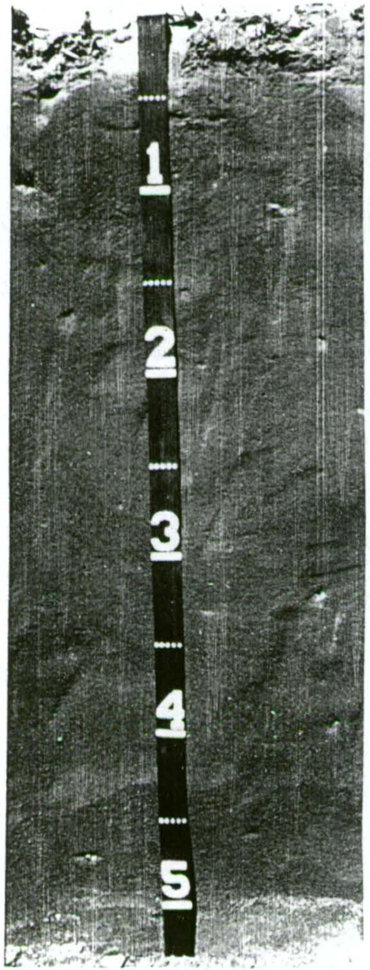


PLATE 1. QUINCY

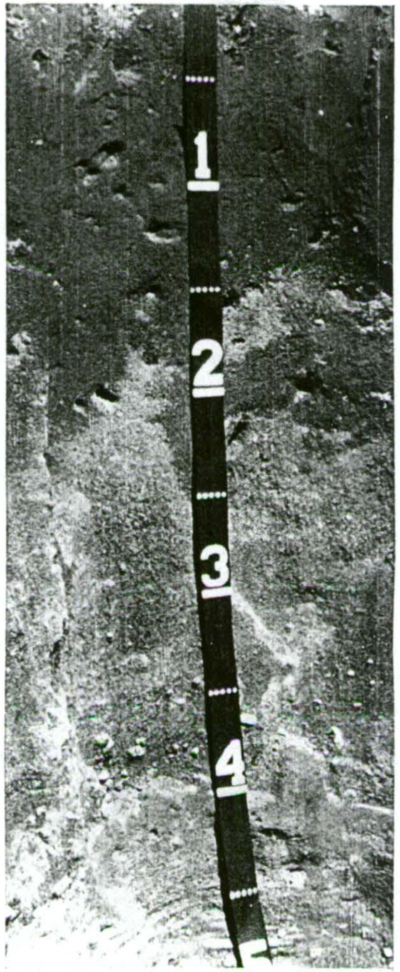


PLATE 2. TIMMERMAN

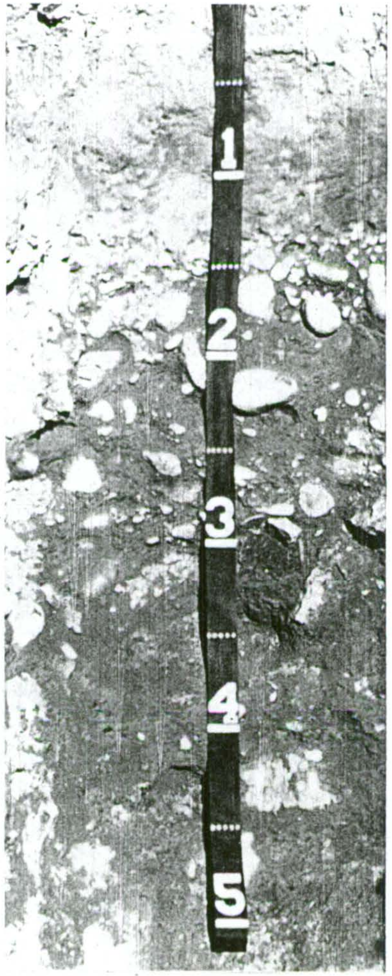
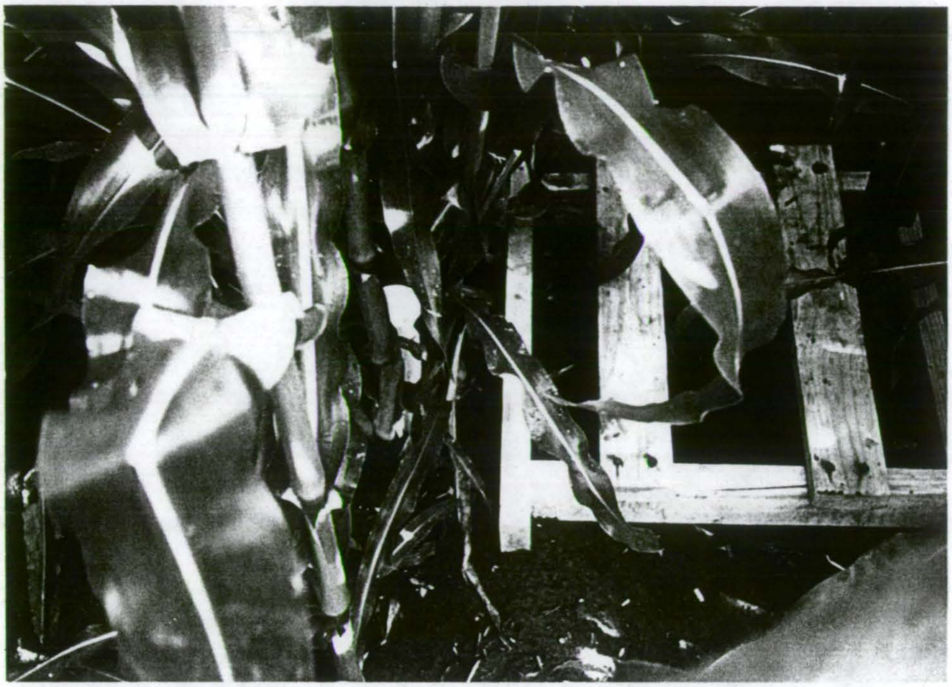


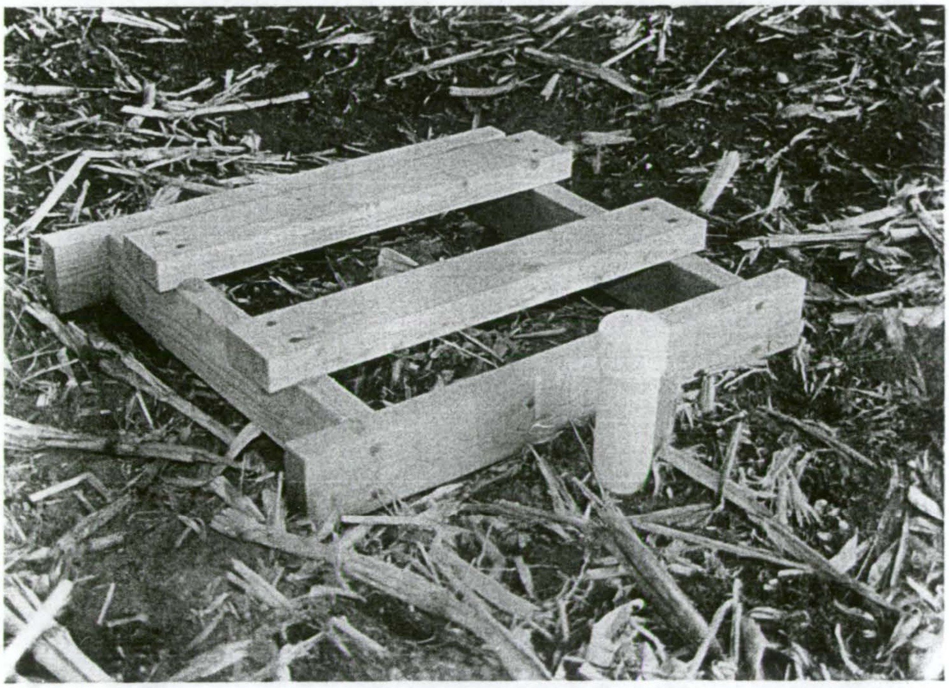
PLATE 3. EPHRATA

Photographs of representative soil profiles for the three soil textural zones. Numbers on tape are one-foot depth increments.

PLATE 4.  NEUTRON PROBE ACCESS TUBE



Access tube in corn row with anti-compaction platform.



Access tube with anti-compaction platform in field after post-harvest incorporation of crop residue.

PLATE 5. RECORDING PRECIPITATION GAUGE

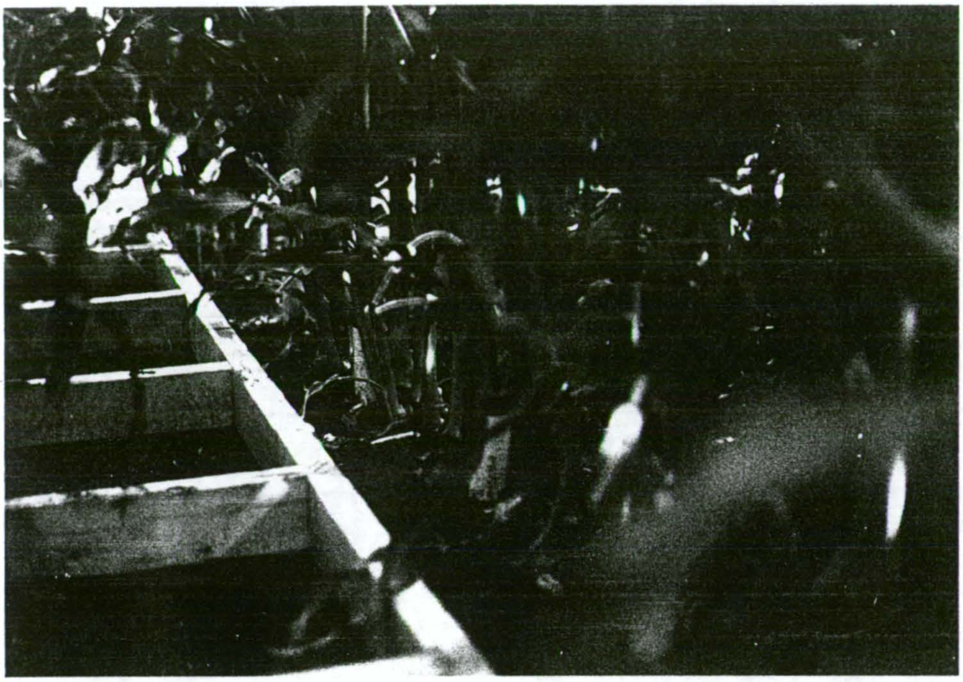
Recording precipitation gauge on site within crop clearing.

Recording precipitation gauge (catch pan and recorder).

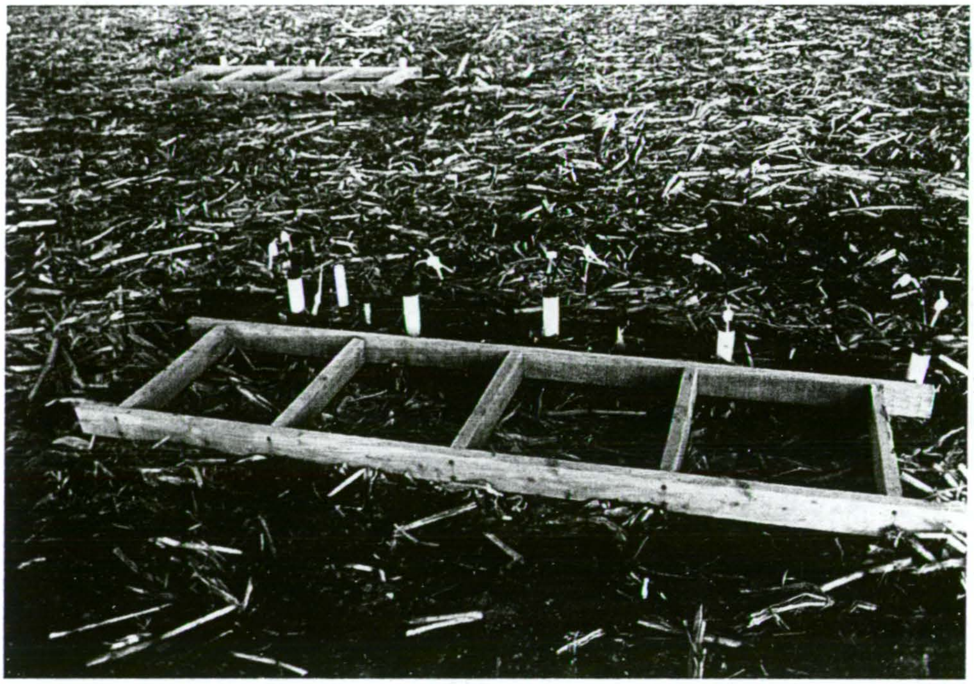
PLATE 6. SURFACE ACCESS VACUUM LYSIMETER

PLATE 7. BURIED VACUUM LYSIMETER WITH EXTENSION TUBING

PLATE 8. ANTI-COMPACTION PLATFORM

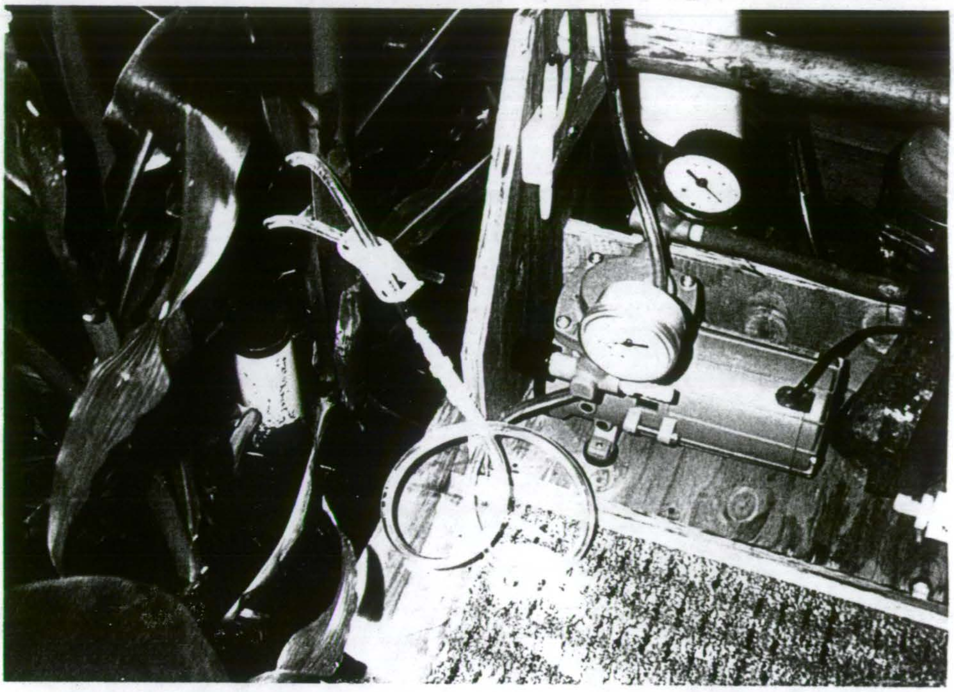


Platform between corn rows adjacent to vacuum lysimeters.

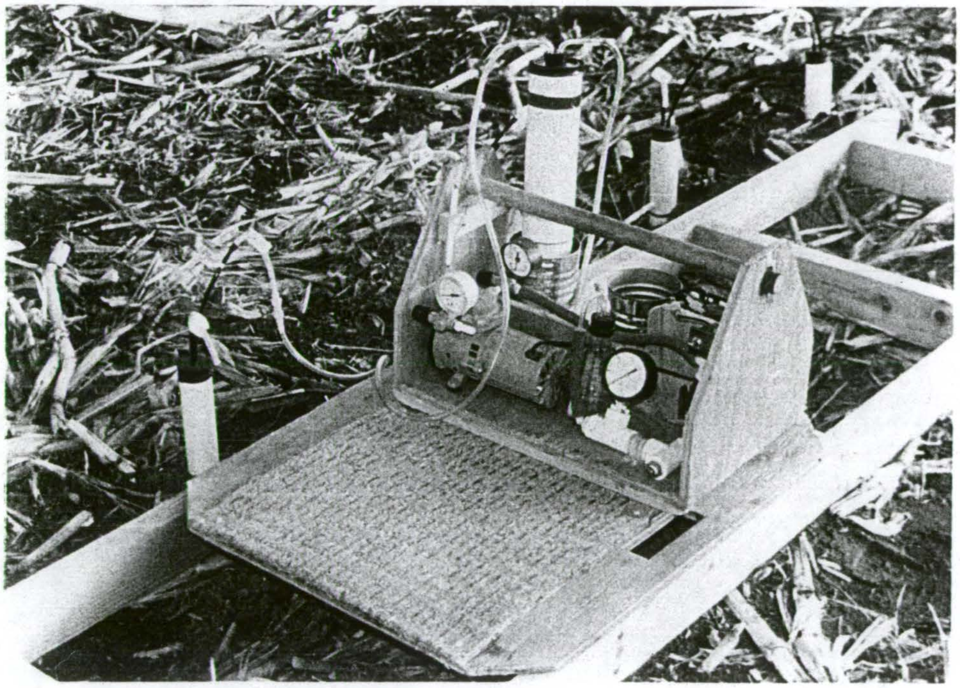


Platform in field after post-harvest incorporation of crop residue. Note second location in background.

PLATE 9. VACUUM LYSIMETER EVACUATION SYSTEM



Evacuation system with lysimeter in corn row. Note 12-volt vacuum pump.



Evacuation system with lysimeters and anti-compaction platform after post-harvest crop residue incorporation. Note 12-volt vacuum pump, collection chamber, and carrying platform.

## PLATE 10. NEUTRON PROBE

Neutron Probe on access tube in corn row. Note anti-compaction platform.

Neutron probe mounted on PVC access tube.

# APPENDIX B

## TABLES

TABLE 1. PHYSICAL PROPERTIES OF SOIL TYPES OF CCWF PROJECT SEE REF (5).

| SOIL TYPE | DEPTH (IN) | PERMEABILITY (IN)* | % CLAY |
|---|---|---|---|
| QUINCY LOAMY | 0-9 | 6-20 | 1-6 |
| FINE SAND | 9-60 | 6-20 | 1-7 |
| | | | |
| TIMMERMAN COARSE | 0-8 | 2-6 | 0-5 |
| SANDY LOAM | 8-23 | 2-6 | 3-8 |
| | 23-60 | >20 | 0-5 |
| | | | |
| EPHRATA GRAVELLY | 0-9 | 2-6 | 4-8 |
| SANDY LOAM | 9-23 | 2-6 | 4-8 |
| | 23-60 | >20 | 0-2 |

*Permeability is defined as the quality of the soil that enables water to move downward through the profile. Permeability is measured as the number of inches/hour that water moves downward through the saturated soil.

TABLE 2. NITRATE-NITROGEN DATA FOR SELECTED TEXTURAL ZONES
UGCD-WA DOE CCWF PROJECT, 1991

| TEXTURAL ZONE SOIL TYPE | DEPTH (IN) | $NO_3$-N (PPM) | $NO_3$-N/A (LBS) | $NO_3$-N/A (LBS) 0-24" | $NO_3$-N/A (LBS) 24-60" |
|---|---|---|---|---|---|
| QUINCY LFS | 0-12 | 16.0 | 64.0 | | |
| | 12-24 | 14.7 | 58.8 | | |
| | 24-36 | 13.5 | 54.0 | | |
| | 36-48 | 7.1 | 28.4 | | |
| | 48-60 | 3.9 | 15.6 | | |
| | | TOTAL | 220.8 | 120.4 | 98.0 |
| | | | | | |
| TIMMERMAN CSL | 0-12 | 14.2 | 56.8 | | |
| | 12-24 | 11.3 | 45.2 | | |
| | 24-36 | 8.6 | 37.4 | | |
| | 36-48 | 5.4 | 21.6 | | |
| | 48-60 | 3.1 | 12.4 | | |
| | | TOTAL | 170.4 | 102.0 | 68.4 |
| | | | | | |
| EPHRATA GSL | 0-12 | 32.6 | 130.4 | | |
| | 12-24 | 35.3 | 141.2 | | |
| | 24-36 | 24.8 | 99.2 | | |
| | 36-48 | 18.5 | 74.0 | | |
| | 48-60 | 14.1 | 56.4 | | |
| | | TOTAL | 501.2 | 271.6 | 232.0 |

## TABLE 3. MATERIALS FOR VACUUM LYSIMETERS

SURFACE ACCESS LYSIMETERS CERAMIC CUPS    1 BAR, HIGH FLOW #653X02-BIMS*

BURIED LYSIMETERS CERAMIC CUPS - 1 BAR, HIGH FLOW #653X07-BIMS*

PVC TUBING - 1.5" PRESSURE RATING 160

RUBBER STOPPERS - 2 HOLE #10

EXTRACTION AND VENT TUBING - AIR BRAKE, SAE J844, TYPE A - 1/4" OD

*Soilmoisture Equipment Corporation
PO Box 30025
Santa Barbara, CA 93105
(805)964-3525

## TABLE 4. WEATHER DATA APPARATUS

### ON-SITE WEATHER STATION

| | |
|---|---|
| OMNIDATA* | E1-824-GP FIELD UNIT<br>EA-136 MET TOWER<br>FEEL STEEL FIELD ENCLOSURE<br>ES-120 RELATIVE HUMIDITY AND TEMPERATURE SENSOR<br>EA-130 RADIATION SHIELD<br>ES-040 WIND SPEED DIRECTION SENSOR<br>ES-160 SIERRA MISCO TIPPING BUCKET<br>ES-060-SW TEMPERATUE SENSOR<br>EL-0097.1 WEATHERTRONICS EVAPORATION PAN AND GAUGE<br>MODEL ES-230 LI-COR PYRANOMETER |

*Omnidata International, Inc.
PO Box 3489
Logan, UT 84321
(801)753-7760

### INFIELD RECORDING PRECIPITATION GAUGES

RAINWISE AUTOMATIC ELECTRONIC RAIN GAUGE*
(MEASURES TO 0.01" WITH COLLECTING PAN)

**Forestry Suppliers, Inc.
205 W Rankin ST
PO Box 8397
Jackson, MS 39284-8397
(601)354-3565

TABLE 5. ON-SITE WEATHER DATA* - JUNE, 1991
UGCD-WA DOE CCWF PROJECT

|  | AIR TEMPERATURES |  |  | SOIL TEMPERATURE 4 INCHES |  |  | SOIL TEMPERATURE 12 INCHES |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DAY | MIN | MAX | AVG | MIN | MAX | AVG | MIN | MAX | AVG | PPTN | EVAP |
| 1 | 9.9 | 28.4 | 19.6 | 19.1 | 25.9 | 22.2 | 19.6 | 22.2 | 20.6 | 0 | 0.37 |
| 2 | 8.2 | 27.7 | 17.8 | 20.4 | 26.2 | 23.3 | 20.8 | 22.8 | 21.7 | 0 | 0.39 |
| 3 | 6.1 | 18.8 | 12.3 | 19.4 | 24.2 | 21.9 | 20.6 | 22.8 | 21.5 | 0 | 0.31 |
| 4 | 6.1 | 20.6 | 13.4 | 18.7 | 23.4 | 20.75 | 20 | 22.2 | 21 | 0 | 0.24 |
| 5 | 10.9 | 17.9 | 13.6 | 18 | 22.6 | 19.6 | 19.4 | 21.6 | 20.4 | 0.05 | 0.21 |
| 6 | 10.1 | 21.1 | 14.3 | 16.3 | 22.2 | 18.7 | 18.1 | 20 | 18.8 | 0.24 | -0.16 |
| 7 | 8.7 | 22 | 15.2 | 16.7 | 22.6 | 19.6 | 18.4 | 20.3 | 19.3 | 0 | 0.16 |
| 8 | 8.7 | 24 | 17.3 | 17.4 | 25 | 20.9 | 18.8 | 21.5 | 19.9 | 0 | 0.19 |
| 9 | 6.8 | 26.4 | 17.5 | 18.9 | 26.4 | 22.4 | 19.9 | 22.6 | 21 | 0 | 0.18 |
| 10 | 8.9 | 31.5 | 20.6 | 20.4 | 28.1 | 24 | 21 | 23.9 | 22.2 | 0 | 0.2 |
| 11 | 8.9 | 21.1 | 15 | 20.1 | 26.3 | 23 | 21.2 | 23.9 | 22.2 | 0 | 0.28 |
| 12 | 5.9 | 19.5 | 13 | 19.7 | 24.4 | 22 | 21.3 | 23.8 | 22.2 | 0 | 0.23 |
| 13 | 6.3 | 19.3 | 13.3 | 18.4 | 24 | 21.2 | 20.2 | 22.1 | 21.1 | 0 | 0.29 |
| 14 | 5.5 | 21.2 | 14.4 | 18.4 | 24.5 | 21.4 | 20.1 | 22.1 | 21 | 0 | 0.3 |
| 15 | 6.6 | 21.8 | 15.3 | 19.4 | 24.1 | 21.8 | 20.5 | 22.1 | 21.4 | 0 | 0.33 |
| 16 | 7.6 | 19 | 12.6 | 18.7 | 22.5 | 20.4 | 20.3 | 22 | 20.9 | 0.16 | 0.23 |
| 17 | 5.8 | 22 | 14.6 | 15.2 | 24.4 | 19.2 | 18.2 | 21.2 | 19.4 | 0 | 0.15 |
| 18 | 5.3 | 26.2 | 17.1 | 18.1 | 25.9 | 21.8 | 19.6 | 22.4 | 20.7 | 0 | 0.11 |
| 19 | 12.2 | 26.4 | 19.3 | 20.9 | 24.3 | 22.4 | 21.2 | 22.4 | 21.7 | 0.12 | 0.2 |
| 20 | 11.3 | 16 | 13.9 | 18.4 | 21.5 | 19.3 | 19.7 | 21.8 | 20.4 | 0.11 | 0.23 |
| 21 | 9.4 | 17.2 | 13.3 | 17.5 | 21.9 | 19.3 | 18.9 | 21 | 19.7 | 0.11 | 0.11 |
| 22 | 8.7 | 20.2 | 14.9 | 16.5 | 22.2 | 19.3 | 18 | 20.1 | 18.9 | 0 | 0.2 |
| 23 | 9.8 | 24.1 | 16.7 | 17.9 | 24.2 | 20.6 | 18.9 | 21.1 | 19.7 | 0 | 0.14 |
| 24 | 12.1 | 24.9 | 18 | 19.5 | 25.4 | 22.1 | 20 | 22.1 | 20.8 | 0.02 | 0.2 |
| 25 | 12.1 | 26.2 | 19.3 | 20.6 | 26.6 | 23.3 | 20.9 | 23.1 | 21.8 | 0 | 0.24 |
| 26 | 12 | 24.7 | 18.1 | 21.3 | 27.3 | 24.1 | 21.7 | 23.8 | 22.6 | 0 | 0.26 |
| 27 | 8.7 | 27.4 | 19.1 | 21.4 | 28.1 | 24.6 | 22.1 | 24.5 | 23.2 | 0 | 0.23 |
| 28 | 11.7 | 29.9 | 21.4 | 22.7 | 29.3 | 25.8 | 23.1 | 25.5 | 24.1 | 0 | 0.25 |
| 29 | 14.6 | 24.6 | 19.4 | 24 | 28 | 26 | 24 | 25.5 | 24.8 | 0 | 0.25 |
| 30 | 11.9 | 26.3 | 18.9 | 22.4 | 27.6 | 24.9 | 23.3 | 25.2 | 24.2 | 0 | 0.22 |

*TEMPERATURE IN DEGREES CENTIGRADE - EVAPORATION AND PRECIPITATION IN INCHES.

TABLE 6. ON-SITE WEATHER DATA* - JULY, 1991
UGCD-WA DOE CCWF PROJECT

| | AIR TEMPERATURES | | | SOIL TEMPERATURE 4 INCHES | | | SOIL TEMPERATURE 12 INCHES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DAY | MIN | MAX | AVG | MIN | MAX | AVG | MIN | MAX | AVG | PPTN | EVAP |
| 1 | 10.8 | 29.3 | 21 | 22.7 | 29.5 | 25.8 | 23.4 | 25.9 | 24.4 | 0 | 0.26 |
| 2 | 12.1 | 32.9 | 23.5 | 24.2 | 31.1 | 27.4 | 24.5 | 27.1 | 25.5 | 0 | 0.27 |
| 3 | 13.9 | 36.2 | 25.3 | 25.6 | 32 | 28.6 | 25.6 | 28 | 26.6 | 0 | 0.24 |
| 4 | 15.7 | 32.2 | 24.4 | 26.1 | 31.2 | 28.6 | 26.3 | 28 | 27.2 | 0 | 0.45 |
| 5 | 12.7 | 29.5 | 21.8 | 25.4 | 30.4 | 27.9 | 26 | 28 | 26.9 | 0 | 0.32 |
| 6 | 9.5 | 28 | 19.8 | 24.4 | 30.1 | 27.2 | 25.5 | 27.6 | 26.5 | 0 | 0.31 |
| 7 | 12.8 | 29.1 | 21.8 | 24.9 | 30.6 | 27.6 | 25.7 | 27.6 | 26.6 | 0 | 0.29 |
| 8 | 11.6 | 31.8 | 22.6 | 25.3 | 31.4 | 28.2 | 26 | 28.2 | 27 | 0 | 0.28 |
| 9 | 12.3 | 31.4 | 22.5 | 26.1 | 30.8 | 28.5 | 26.6 | 28.2 | 27.4 | 0 | 0.3 |
| 10 | 14.2 | 29.2 | 21.8 | 25.7 | 30.7 | 28.1 | 26.4 | 28.2 | 27.3 | 0 | 0.28 |
| 11 | 10.7 | 30.4 | 21.4 | 25.5 | 31 | 28.2 | 26.4 | 28.2 | 27.3 | 0 | 0.25 |
| 12 | 15.1 | 29.7 | 22.9 | 27.6 | 31.2 | 29.4 | 26.7 | 29 | 28.3 | 0 | 0.26 |
| 13 | 9.7 | 26.4 | 18.9 | 25.6 | 30.2 | 27.8 | 26.6 | 28.7 | 27.5 | 0 | 0.25 |
| 14 | 13.3 | 26.3 | 18.7 | 25.4 | 29.1 | 27.2 | 26.3 | 28.1 | 27 | 0 | 0.26 |
| 15 | 12.9 | 22.4 | 16.9 | 24.4 | 27.9 | 25.5 | 25.4 | 27.3 | 26.1 | 0.2 | 0.21 |
| 16 | 13.2 | 25.5 | 19.1 | 22.4 | 28.5 | 25 | 24.1 | 26.1 | 24.9 | 0.01 | 0.17 |
| 17 | 10 | 25.9 | 18.2 | 22.2 | 28.9 | 25.4 | 24.1 | 26.3 | 25.2 | 0 | 0.19 |
| 18 | 11.1 | 27.9 | 20.5 | 23.5 | 29.7 | 26.4 | 24.8 | 26.9 | 25.7 | 0 | 0.17 |
| 19 | 11.5 | 30.4 | 21.4 | 24.1 | 30.4 | 27.1 | 25.3 | 27.4 | 26.2 | 0 | 0.21 |
| 20 | 12.6 | 29 | 21.8 | 25.2 | 30.4 | 27.8 | 26 | 27.8 | 26.8 | 0 | 0.27 |
| 21 | 16.8 | 33.6 | 25.4 | 25.5 | 31.9 | 28.4 | 26.3 | 28.6 | 27.2 | 0 | 0.24 |
| 22 | 19.3 | 36.4 | 28.4 | 27.2 | 32.7 | 29.7 | 27.4 | 29.4 | 28.2 | 0 | 0.27 |
| 23 | 16.6 | 34.8 | 25.6 | 27.9 | 32.2 | 30.1 | 28.1 | 29.4 | 28.8 | 0 | 0.3 |
| 24 | 17.9 | 28.6 | 23.1 | 27.5 | 31.6 | 29.5 | 27.9 | 29.4 | 28.6 | 0 | 0.25 |
| 25 | 12.6 | 28.8 | 21.3 | 26.1 | 31.2 | 28.6 | 27.2 | 29.2 | 28.2 | 0 | 0.39 |
| 26 | 13.1 | 30.7 | 22.2 | 26.2 | 31.4 | 28.7 | 27.2 | 28.9 | 28.1 | 0 | 0.22 |
| 27 | 13.9 | 32.3 | 22.8 | 26.4 | 31.9 | 29 | 27.3 | 29.2 | 28.2 | 0 | 0.25 |
| 28 | 14.9 | 31.5 | 23.5 | 26.9 | 31.9 | 29.4 | 27.7 | 29.3 | 28.5 | 0 | 0.26 |
| 29 | 11.9 | 30.8 | 22.2 | 26.5 | 31.8 | 29.1 | 27.5 | 29.3 | 28.4 | 0 | 0.34 |
| 30 | 11.8 | 33 | 23.5 | 26.8 | 32.2 | 29.4 | 27.7 | 29.5 | 28.6 | 0 | 0.2 |
| 31 | 14.9 | 29.9 | 22.1 | 26.8 | 31.1 | 29.2 | 27.8 | 29.6 | 28.6 | 0 | 0.3 |

*TEMPERATURE IN DEGREES CENTIGRADE - EVAPORATION AND PRECIPITATION IN INCHES.

TABLE 7. ON-SITE WEATHER DATA* - AUGUST, 1991
UGCD-WA DOE CCWF PROJECT

|  | AIR TEMPERATURES |  |  | SOIL TEMPERATURE 4 INCHES |  |  | SOIL TEMPERATURE 12 INCHES |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DAY | MIN | MAX | AVG | MIN | MAX | AVG | MIN | MAX | AVG | PPTN | EVAP |
| 1 | 10.6 | 32.2 | 22.1 | 26.1 | 31.7 | 28.8 | 27.3 | 29.2 | 28.2 | 0 | 0.22 |
| 2 | 12.6 | 34.2 | 24.3 | 26.9 | 32.5 | 29.5 | 27.7 | 29.7 | 28.6 | 0 | 0.20 |
| 3 | 12.7 | 31.6 | 22.8 | 27.3 | 31.4 | 29.1 | 28.1 | 29.7 | 28.8 | 0 | 0.21 |
| 4 | 19.6 | 30.6 | 23.1 | 26.7 | 29.4 | 27.9 | 27.4 | 28.9 | 27.9 | 0 | 0.26 |
| 5 | 16.1 | 31.7 | 23.5 | 26.2 | 31.4 | 28.5 | 27 | 28.9 | 27.7 | 0 | 0.18 |
| 6 | 16.2 | 30.5 | 23 | 26.9 | 31.4 | 29.1 | 27.6 | 29.1 | 28.3 | 0 | 0.23 |
| 7 | 15.5 | 33.7 | 24.4 | 27.1 | 32.2 | 29.5 | 27.8 | 29.6 | 28.6 | 0 | 0.21 |
| 8 | 16.4 | 30.5 | 23.3 | 27.7 | 31.1 | 29.6 | 28.2 | 29.6 | 28.9 | 0 | 0.22 |
| 9 | 11.2 | 25.5 | 19.1 | 26 | 29.8 | 27.8 | 27.4 | 29.3 | 28.1 | 0 | 0.30 |
| 10 | 12.4 | 24.9 | 17.9 | 24.5 | 28.4 | 26.5 | 26.2 | 28 | 27 | 0 | 0.23 |
| 11 | 9.1 | 26.3 | 18.9 | 23.8 | 28.5 | 26.1 | 25.6 | 27.2 | 26.4 | 0 | 0.17 |
| 12 | 12.4 | 28 | 19.6 | 24.6 | 29 | 26.7 | 25.8 | 27.2 | 26.5 | 0 | 0.20 |
| 13 | 11.4 | 30 | 21.6 | 24.6 | 29.9 | 27.1 | 25.8 | 27.6 | 26.6 | 0 | 0.17 |
| 14 | 14.4 | 32.1 | 24.3 | 25.9 | 30.9 | 28.2 | 26.6 | 28.3 | 27.3 | 0 | 0.21 |
| 15 | 13.9 | 33.6 | 23.7 | 26.2 | 31.2 | 28.6 | 27 | 28.7 | 27.8 | 0 | 0.33 |
| 16 | 14.8 | 35.1 | 25.6 | 26.9 | 31.9 | 29.3 | 27.4 | 29.2 | 28.2 | 0 | 0.26 |
| 17 | 15 | 35.6 | 25.8 | 27.6 | 32.3 | 29.9 | 28 | 29.6 | 28.7 | 0 | 0.26 |
| 18 | 18.6 | 35.1 | 26.9 | 28 | 32.5 | 30.2 | 28.4 | 29.9 | 29.1 | 0 | 0.21 |
| 19 | 15.4 | 34.6 | 25.9 | 27.6 | 32.3 | 30 | 28.3 | 29.9 | 29.1 | 0 | 0.32 |
| 20 | 16.2 | 34.9 | 26 | 27.7 | 32.3 | 30 | 28.4 | 29.9 | 29.2 | 0 | 0.26 |
| 21 | 16 | 34.4 | 25.9 | 27.8 | 32.3 | 30 | 28.5 | 29.9 | 29.2 | 0 | 0.30 |
| 22 | 17.4 | 30.9 | 23.4 | 27.6 | 31.3 | 29.5 | 28.4 | 29.9 | 29.1 | 0 | 0.27 |
| 23 | 10.5 | 28.1 | 20 | 26.1 | 30.1 | 28.2 | 27.5 | 29.4 | 28.3 | 0 | 0.30 |
| 24 | 12 | 25.1 | 18.5 | 25.4 | 29.2 | 27.4 | 26.9 | 28.6 | 27.7 | 0 | 0.26 |
| 25 | 13.9 | 25 | 19.5 | 24.7 | 28.6 | 26.8 | 26.4 | 28.3 | 27.3 | 0 | 0.26 |
| 26 | 5.7 | 26 | 16.7 | 23.9 | 28 | 26.1 | 25.9 | 27.9 | 26.8 | 0 | 0.20 |
| 27 | 8.9 | 27.3 | 18.3 | 23.8 | 27.4 | 25.8 | 25.5 | 27 | 26.2 | 0 | 0.24 |
| 28 | 13.8 | 21.1 | 17.3 | 24.1 | 26.6 | 24.9 | 25.2 | 26.6 | 25.8 | 0 | 0.21 |
| 29 | 12.5 | 28.9 | 19.4 | 22.4 | 26.7 | 24.2 | 24.1 | 25.5 | 24.7 | 0 | 0.11 |
| 30 | 13.3 | 31.4 | 22.2 | 23.7 | 28.2 | 25.7 | 24.7 | 26.3 | 25.3 | 0 | 0.28 |
| 31 | 11.5 | 29.5 | 21.2 | 24.2 | 27.7 | 26 | 25.2 | 26.3 | 25.8 | 0 | 0.30 |

*TEMPERATURE IN DEGREES CENTIGRADE - EVAPORATION AND PRECIPITATION IN INCHES.

TABLE 8. ON-SITE WEATHER DATA* - SEPTEMBER, 1991
UGCD-WA DOE CCWF PROJECT

| | AIR TEMPERATURES | | | SOIL TEMPERATURE 4 INCHES | | | SOIL TEMPERATURE 12 INCHES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DAY | MIN | MAX | AVG | MIN | MAX | AVG | MIN | MAX | AVG | PPTN | EVAP |
| 1 | 9.4 | 24.3 | 17.8 | 23.5 | 27.2 | 25.5 | 24.9 | 26.3 | 25.6 | 0 | 0.22 |
| 2 | 10.8 | 25.7 | 18 | 22.8 | 27.1 | 24.9 | 24.4 | 25.9 | 25.1 | 0 | 0.20 |
| 3 | 8.3 | 29.6 | 19.4 | 22.6 | 27.2 | 24.8 | 24.2 | 25.7 | 24.9 | 0 | 0.19 |
| 4 | 12.4 | 31.2 | 21.5 | 23.2 | 27.9 | 25.4 | 24.5 | 26 | 25.2 | 0 | 0.22 |
| 5 | 9.2 | 31.1 | 21 | 23.4 | 27.9 | 25.6 | 24.7 | 26.1 | 25.4 | 0 | 0.15 |
| 6 | 9 | 32.1 | 20.7 | 23.4 | 27.9 | 25.7 | 24.7 | 26.1 | 25.4 | 0 | 0.22 |
| 7 | 15.5 | 27.6 | 21.2 | 24.3 | 27.3 | 25.9 | 25.1 | 26.1 | 25.7 | 0 | 0.31 |
| 8 | 9.4 | 23.5 | 17.4 | 23.4 | 26.2 | 24.8 | 24.6 | 26 | 25.2 | 0 | 0.26 |
| 9 | 9.4 | 25.9 | 17.3 | 21.6 | 25.7 | 23.6 | 23.5 | 25.2 | 24.2 | 0 | 0.27 |
| 10 | 7.7 | 28.7 | 18.4 | 21.4 | 25.4 | 23.5 | 23.2 | 24.6 | 23.9 | 0 | 0.27 |
| 11 | 12.2 | 28.4 | 20.1 | 22.1 | 25.9 | 23.9 | 23.4 | 24.6 | 23.9 | 0 | 0.27 |
| 12 | 8.4 | 28.9 | 18.6 | 21.7 | 25.5 | 23.7 | 23.3 | 24.6 | 23.9 | 0 | 0.22 |
| 13 | 11.1 | 22.4 | 17.3 | 22.3 | 24.7 | 23.5 | 23.4 | 24.4 | 23.8 | 0 | 0.38 |
| 14 | 8.5 | 23.8 | 15.9 | 20.3 | 24.4 | 22.3 | 22.3 | 23.9 | 23 | 0 | 0.13 |
| 15 | 5.1 | 25.6 | 15.1 | 20 | 24.4 | 22.2 | 21.9 | 23.4 | 22.7 | 0 | 0.13 |
| 16 | 6.4 | 29 | 18.2 | 20.2 | 24.8 | 22.4 | 21.9 | 23.3 | 22.7 | 0 | 0.22 |
| 17 | 15.8 | 27.6 | 21.3 | 22 | 25.5 | 23.6 | 22.8 | 23.9 | 23.2 | 0 | 0.26 |
| 18 | 11.1 | 27.9 | 20.3 | 21.9 | 25.7 | 23.7 | 22.9 | 24.1 | 23.5 | 0 | 0.20 |
| 19 | 6.7 | 28.4 | 17.1 | 20.9 | 25 | 23.1 | 22.5 | 24.1 | 23.3 | 0 | 0.15 |
| 20 | 9.2 | 24.9 | 17.8 | 21 | 24.1 | 22.7 | 22.4 | 23.7 | 23 | 0 | 0.28 |
| 21 | 6.6 | 21.7 | 14.2 | 19.8 | 23.3 | 21.6 | 21.6 | 23.2 | 22.3 | 0 | 0.20 |
| 22 | 1.2 | 21.9 | 11.8 | 18.3 | 22.2 | 20.3 | 20.7 | 22.5 | 21.5 | 0 | 0.11 |
| 23 | 9.1 | 25.5 | 17.6 | 19 | 23 | 20.8 | 20.6 | 21.9 | 21.2 | 0 | 0.10 |
| 24 | 8.6 | 26.9 | 18.6 | 19.7 | 23.9 | 21.7 | 21 | 22.4 | 21.6 | 0 | 0.11 |
| 25 | 9.9 | 29.3 | 19 | 20.2 | 23.1 | 21.5 | 21.4 | 22.4 | 21.8 | 0 | 0.05 |
| 26 | 8.7 | 29.7 | 18.7 | 19.6 | 22 | 20.9 | 21.1 | 22 | 21.5 | 0 | 0.13 |
| 27 | 8.3 | 29.9 | 18.3 | 19.4 | 21.7 | 20.6 | 20.8 | 21.7 | 21.2 | 0 | 0.15 |
| 28 | 10.1 | 29.9 | 18.8 | 19.4 | 21.6 | 20.6 | 20.8 | 21.5 | 21.1 | 0.05 | 0.22 |
| 29 | 10.8 | 28.7 | 21.3 | 20.1 | 21.9 | 20.9 | 21 | 21.5 | 21.2 | 0.02 | 0.19 |
| 30 | 7.5 | 28.1 | 16.4 | 18.8 | 21.3 | 20 | 20.4 | 21.6 | 20.9 | 0.01 | 0.14 |

*TEMPERATURE IN DEGREES CENTIGRADE - EVAPORATION AND PRECIPITATION IN INCHES.

TABLE 9. ON-SITE WEATHER DATA* - OCTOBER, 1991
UGCD-WA DOE CCWF PROJECT

| | AIR TEMPERATURES | | | SOIL TEMPERATURE 4 INCHES | | | SOIL TEMPERATURE 12 INCHES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DAY | MIN | MAX | AVG | MIN | MAX | AVG | MIN | MAX | AVG | PPTN | EVAP |
| 1 | 9.3 | 28.3 | 19.2 | 18.4 | 20.5 | 19.5 | 20 | 20.9 | 20.4 | 0 | 0.31 |
| 2 | 7.3 | 26 | 17.5 | 18.1 | 20.1 | 19.1 | 19.7 | 20.5 | 20.1 | 0 | 0.18 |
| 3 | 7.9 | 22 | 14.9 | 17.4 | 19.5 | 18.3 | 19.2 | 20.1 | 19.6 | 0 | 0.17 |
| 4 | 3.1 | 19.7 | 12.1 | 16.3 | 18.2 | 17.1 | 18.4 | 19.4 | 18.8 | 0 | 0.10 |
| 5 | 0.1 | 22.5 | 10.6 | 14.5 | 17 | 15.7 | 17.2 | 18.6 | 17.7 | 0 | 0.11 |
| 6 | 2.3 | 19.7 | 10.2 | 14.2 | 16.4 | 15.4 | 16.7 | 17.6 | 17.1 | 0 | 0.08 |
| 7 | 0.8 | 22.4 | 10.7 | 13.8 | 16.1 | 15 | 16.3 | 17.2 | 16.7 | 0 | 0.07 |
| 8 | 0.8 | 21.6 | 10.4 | 13.2 | 15.5 | 14.5 | 15.8 | 16.7 | 16.2 | 0 | 0.08 |
| 9 | 2.1 | 22.2 | 10.6 | 13.1 | 15.2 | 14.2 | 15.5 | 16.3 | 15.9 | 0 | 0.06 |
| 10 | 2.8 | 25.4 | 12.4 | 13.2 | 15.3 | 14.2 | 15.4 | 16 | 15.7 | 0 | 0.07 |
| 11 | 3 | 24.4 | 12.4 | 13.1 | 15.2 | 14.2 | 15.2 | 15.9 | 15.6 | 0 | 0.05 |
| 12 | 3.4 | 24.5 | 15.2 | 13.4 | 16.6 | 14.9 | 15.3 | 16.3 | 15.7 | 0 | 0.19 |
| 13 | 2.3 | 22.8 | 12.8 | 14.1 | 17 | 15.6 | 15.8 | 16.6 | 16.2 | 0 | 0.16 |
| 14 | 2.1 | 22.4 | 11.6 | 13.9 | 16.9 | 15.4 | 15.8 | 16.7 | 16.2 | 0.01 | 0.09 |
| 15 | 2.8 | 22.7 | 11.7 | 13.9 | 16.9 | 15.4 | 15.8 | 16.6 | 16.2 | 0.02 | 0.08 |
| 16 | 2.5 | 18.2 | 11.9 | 14.7 | 16.3 | 15.4 | 16 | 16.6 | 16.3 | 0.01 | 0.22 |
| 17 | -0.4 | 13.9 | 6.5 | 13.3 | 15.6 | 14.5 | 15.3 | 16.4 | 15.7 | 0 | 0.00 |
| 18 | -0.8 | 15.2 | 6.6 | 12.8 | 15.1 | 14 | 14.8 | 15.7 | 15.2 | 0 | 0.04 |
| 19 | 2.6 | 17.6 | 8.7 | 13.2 | 15.4 | 14.3 | 14.8 | 15.4 | 15.1 | 0 | 0.08 |
| 20 | 0.7 | 17.8 | 8.7 | 13.1 | 15.5 | 14.3 | 14.7 | 15.4 | 15.1 | 0 | 0.03 |
| 21 | 0.5 | 19.2 | 12.4 | 14.4 | 15.9 | 15 | 15.2 | 15.7 | 15.4 | 0 | 0.18 |
| 22 | -1.9 | 12.7 | 5.3 | 12.4 | 15.2 | 13.5 | 14.4 | 15.7 | 14.9 | 0 | 0.01 |
| 23 | -2.7 | 12.6 | 5.7 | 11.9 | 13.6 | 12.7 | 13.8 | 14.6 | 14.2 | 0 | 0.05 |
| 24 | 1.3 | 10.2 | 4.9 | 11.6 | 12.9 | 12.1 | 13.3 | 14 | 13.6 | 0 | 0.00 |
| 25 | 0.3 | 8.3 | 4.1 | 10 | 11.6 | 10.7 | 12.3 | 13.3 | 12.7 | 0.11 | 0.00 |
| 26 | 3.4 | 9.3 | 5.1 | 9.7 | 11 | 10.3 | 11.8 | 12.4 | 12.1 | 0.01 | 0.00 |
| 27 | -2 | 6 | 2.9 | 8.9 | 10.2 | 9.5 | 11.1 | 11.8 | 11.4 | 0 | 0.00 |
| 28 | -4.6 | -0.4 | -2.6 | 7.3 | 9.2 | 7.9 | 9.8 | 11.2 | 10.4 | 0 | 0.14 |
| 29 | -5 | 4.9 | -0.4 | 6.4 | 7.4 | 6.8 | 8.9 | 9.8 | 9.3 | 0 | 0.26 |
| 30 | -8.7 | 4 | -2.4 | 4.6 | 6.5 | 5.3 | 7.8 | 8.9 | 8.2 | 0 | 0.02 |
| 31 | -1.9 | 0.4 | -0.4 | 5 | 5.4 | 5.1 | 7.4 | 7.8 | 7.6 | 0.11 | 0.01 |

*TEMPERATURE IN DEGREES CENTIGRADE - EVAPORATION AND PRECIPITATION IN INCHES.

TABLE 10. ON-SITE WEATHER DATA* - NOVEMBER, 1991
UGCD-WA DOE CCWF PROJECT

| | AIR TEMPERATURES | | | SOIL TEMPERATURE 4 INCHES | | | SOIL TEMPERATURE 12 INCHES | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY | MIN | MAX | AVG | MIN | MAX | AVG | MIN | MAX | AVG | PPTN |
| 1 | -1.4 | 2.7 | 0.9 | 4.7 | 5.5 | 5 | 7 | 7.4 | 7.2 | 0.11 |
| 2 | -7.8 | 2.8 | -2.5 | 4.4 | 5.4 | 4.7 | 6.8 | 7.3 | 7 | 0 |
| 3 | -7.4 | 2.2 | -1.8 | 4 | 5.2 | 4.4 | 6.5 | 7.2 | 6.8 | 0 |
| 4 | -1 | 3.8 | 1.1 | 3.8 | 5.3 | 4.4 | 6.1 | 6.5 | 6.3 | 0 |
| 5 | -0.4 | 3.9 | 1.3 | 4.8 | 5.9 | 5.2 | 6.5 | 6.9 | 6.6 | 0.09 |
| 6 | -0.2 | 5.5 | 2.8 | 5.1 | 6.5 | 5.6 | 6.7 | 7.1 | 6.8 | 0.21 |
| 7 | -0.1 | 4.5 | 2.8 | 4.9 | 5.9 | 5.4 | 6.6 | 7.1 | 6.8 | 0.01 |
| 8 | 3.6 | 6.6 | 5 | 5.7 | 7 | 6.2 | 6.9 | 7.4 | 7 | 0.03 |
| 9 | 3.5 | 6.7 | 5.4 | 6.6 | 7.2 | 6.9 | 7.4 | 7.8 | 7.6 | 0.04 |
| 10 | 3 | 6.8 | 5.7 | 6.6 | 7.2 | 6.9 | 7.6 | 7.8 | 7.7 | 0.02 |
| 11 | 5 | 7.8 | 6.3 | 7 | 7.7 | 7.3 | 7.8 | 8.1 | 7.9 | 0 |
| 12 | 4.3 | 7.9 | 6.1 | 7.2 | 7.7 | 7.5 | 8.1 | 8.2 | 8.1 | 0.03 |
| 13 | 3.7 | 16.3 | 9.7 | 6.7 | 9.2 | 7.7 | 7.9 | 8.8 | 8.2 | 0 |
| 14 | -1.2 | 12.2 | 5 | 5.9 | 8.8 | 7.3 | 7.8 | 8.8 | 8.3 | 0 |
| 15 | -1.8 | 11.6 | 6 | 6.5 | 8.5 | 7.3 | 7.8 | 8.4 | 8.1 | 0 |
| 16 | -4 | 3 | 0.1 | 4.8 | 7.2 | 5.5 | 6.9 | 8.3 | 7.4 | 0 |
| 17 | -0.3 | 1.4 | 0.7 | 4 | 5.2 | 4.6 | 6.1 | 6.9 | 6.5 | 0.17 |
| 18 | 0.6 | 9.1 | 4.2 | 3.5 | 5.5 | 4.3 | 5.6 | 6.1 | 5.8 | 0.03 |
| 19 | -1.4 | 10.6 | 2.9 | 3.7 | 6.1 | 4.8 | 5.6 | 6.3 | 5.9 | 0 |
| 20 | 2 | 7.8 | 4.8 | 4.8 | 5.5 | 5.2 | 6.1 | 6.3 | 6.2 | 0.12 |
| 21 | -0.7 | 11.1 | 7.2 | 5.4 | 6.5 | 5.9 | 6.3 | 6.8 | 6.5 | 0 |
| 22 | -2.6 | 9.4 | 2.2 | 3.7 | 5.7 | 4.7 | 5.7 | 6.7 | 6.1 | 0 |
| 23 | -6.1 | 6.1 | -0.7 | 3 | 4.5 | 3.6 | 5.1 | 6 | 5.4 | 0 |
| 24 | -0.9 | 2.5 | 1 | 2.7 | 3.5 | 3 | 4.5 | 5.1 | 4.8 | 0 |
| 25 | -0.2 | 3.5 | 1.8 | 3 | 4.1 | 3.4 | 4.5 | 4.9 | 4.6 | 0.1 |
| 26 | 1.3 | 4.4 | 2.9 | 3.8 | 4.9 | 4.3 | 4.9 | 5.3 | 5 | 0.02 |
| 27 | 1.7 | 3.4 | 2.7 | 4.4 | 4.8 | 4.6 | 5.3 | 5.4 | 5.4 | 0.35 |
| 28 | -0.2 | 8.7 | 3.2 | 3.8 | 5.4 | 4.4 | 5 | 5.5 | 5.2 | 0.02 |
| 29 | -2.7 | 8.8 | 1.5 | 2.9 | 4.5 | 3.4 | 4.5 | 5.5 | 4.9 | 0.01 |
| 30 | -2.8 | 5.8 | 2.3 | 2.5 | 3.3 | 2.9 | 4.1 | 4.6 | 4.3 | 0 |

*TEMPERATURE IN DEGREES CENTIGRADE - EVAPORATION AND PRECIPITATION IN INCHES.

TABLE 11. ON-SITE WEATHER DATA* - DECEMBER, 1991
UGCD-WA DOE CCWF PROJECT

|  | AIR TEMPERATURES |  |  | SOIL TEMPERATURE 4 INCHES |  |  | SOIL TEMPERATURE 12 INCHES |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY | MIN | MAX | AVG | MIN | MAX | AVG | MIN | MAX | AVG | PPTN |
| 1 | -6 | 3.1 | -2.3 | 2 | 2.8 | 2.2 | 3.5 | 4.2 | 3.9 | 0 |
| 2 | -3.5 | 10.3 | 1.9 | 1.8 | 2 | 1.9 | 3.2 | 3.5 | 3.4 | 0 |
| 3 | -1.8 | 8.1 | 2.9 | 1.9 | 3.1 | 2.3 | 3.2 | 3.6 | 3.3 | 0 |
| 4 | -0.8 | 8.6 | 3 | 2.2 | 3.9 | 2.9 | 3.4 | 4 | 3.6 | 0 |
| 5 | 1.1 | 10.3 | 4.5 | 3.3 | 4.8 | 3.9 | 4 | 4.7 | 4.2 | 0 |
| 6 | 1.6 | 9.7 | 5.4 | 4 | 5.1 | 4.5 | 4.7 | 5 | 4.7 | 0.05 |
| 7 | 2.4 | 8.9 | 6.4 | 4.8 | 5.4 | 5.1 | 5 | 5.4 | 5.2 | 0.07 |
| 8 | -1.7 | 9.8 | 3.2 | 3.3 | 5.1 | 4.1 | 4.6 | 5.4 | 5 | 0.01 |
| 9 | -0.1 | 11.5 | 5.9 | 3.3 | 5.2 | 4.2 | 4.5 | 5.1 | 4.8 | 0 |
| 10 | 1 | 10.5 | 6.4 | 4.5 | 5.4 | 4.8 | 5.1 | 5.4 | 5.2 | 0 |
| 11 | -5.3 | 4.2 | 0 | 2.9 | 4.7 | 3.4 | 4.3 | 5.4 | 4.7 | 0 |
| 12 | -2.2 | 12 | 4.5 | 2.3 | 4 | 2.9 | 3.8 | 4.3 | 4 | 0 |
| 13 | -3.1 | 9.4 | 3.9 | 2.6 | 4 | 3.3 | 3.9 | 4.3 | 4.1 | 0 |
| 14 | -5.2 | 4.1 | -0.2 | 2.2 | 3.6 | 2.7 | 3.6 | 4.3 | 3.9 | 0 |
| 15 | -6.4 | 4.3 | -2.1 | 1.7 | 2.4 | 1.9 | 3.1 | 3.6 | 3.3 | 0 |
| 16 | -9.4 | 1.1 | -4.2 | 1.2 | 1.7 | 1.4 | 2.6 | 3.1 | 2.8 | 0 |
| 17 | -7.4 | 2.3 | -3.2 | 0.9 | 1.2 | 1 | 2.2 | 2.6 | 2.4 | 0 |
| 18 | -8.7 | 0.6 | -4.3 | 0.6 | 0.9 | 0.7 | 1.9 | 2.2 | 2.1 | 0 |
| 19 | -3.7 | 1.1 | -1.3 | 0.5 | 0.6 | 0.6 | 1.8 | 1.9 | 1.8 | 0.03 |
| 20 | -4.3 | -1.4 | -2.8 | 0.6 | 0.6 | 0.6 | 1.7 | 1.8 | 1.7 | 0 |
| 21 | -6.4 | -0.5 | -3.2 | 0.6 | 0.7 | 0.6 | 1.7 | 1.7 | 1.7 | 0 |
| 22 | -3.4 | 0.1 | -1.2 | 0.7 | 0.7 | 0.7 | 1.7 | 1.7 | 1.7 | 0.01 |
| 23 | -0.3 | 4.1 | 1.9 | 0.7 | 0.7 | 0.7 | 1.7 | 1.7 | 1.7 | 0.04 |
| 24 | 0.7 | 2.4 | 1.2 | 0.7 | 0.8 | 0.7 | 1.7 | 1.7 | 1.7 | 0 |
| 25 | 0.4 | 2 | 1.1 | 0.8 | 1.1 | 0.9 | 1.7 | 1.8 | 1.7 | 0 |
| 26 | 0.5 | 4.6 | 2 | 1.1 | 2.3 | 1.6 | 1.8 | 2.4 | 2 | 0.04 |
| 27 | -0.7 | 5.9 | 1.5 | 1.5 | 2.4 | 1.9 | 2.2 | 2.5 | 2.4 | 0 |
| 28 | -1.5 | 7.4 | 2.2 | 1.5 | 2.7 | 2 | 2.3 | 2.7 | 2.5 | 0 |
| 29 | -3.7 | 7.1 | 0.7 | 1.3 | 2.2 | 1.6 | 2.3 | 2.7 | 2.4 | 0 |
| 30 | -3 | 7 | 2.1 | 1.4 | 2.6 | 1.9 | 2.2 | 2.7 | 2.4 | 0 |
| 31 | 0.2 | 5.2 | 2.5 | 2.1 | 3.2 | 2.6 | 2.7 | 3.1 | 2.8 | 0 |

*TEMPERATURE IN DEGREES CENTIGRADE - EVAPORATION AND PRECIPITATION IN INCHES.

TABLE 12. QUINCY ZONE IRRIGATION DATA*

| GROWER RECORDS: | | |
|---|---|---|
| | PRE-PLANT IRRIGATION | 4.23 |
| | POST-EMERGENCE IRRIGATION | 23.38 |
| | POST-HARVEST IRRIGATION | 5.95 |
| | TOTAL | 33.56 |

STUDY SITE PRECIPITATION GAUGE READINGS

| DATE | SITE<br>1 | 2 | 3 | AVERAGE |
|---|---|---|---|---|
| 7/10/91 | 2.17 | 2.38 | 2.60 | 2.38 |
| 7/17/91 | 2.08 | 2.06 | 2.36 | 2.17 |
| 7/24/91 | 1.96 | 1.26 | 1.82 | 1.68 |
| 7/31/91 | 1.72 | 1.60 | 1.79 | 1.70 |
| 8/7/91 | 0.03 | 0.04 | 0.04 | 0.04 |
| 8/15/91 | 2.19 | 2.39 | 2.33 | 2.30 |
| 8/21/91 | 1.10 | 1.17 | 1.02 | 1.10 |
| 8/28/91 | 1.12 | 1.03 | 1.30 | 1.15 |
| 9/4/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9/11/91 | 0.87 | 0.88 | 0.87 | 0.87 |
| 9/18/91 | 1.05 | 1.21 | 1.43 | 1.23 |
| 9/24/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10/2/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10/9/91 | 1.23 | 1.31 | 1.09 | 1.21 |
| 10/16/91 | 1.05 | 1.10 | 0.96 | 1.04 |
| 10/23/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10/30/91 | 0.21 | 0.27 | 0.25 | 0.24 |
| 11/6/91 | 0.52 | 0.69 | 0.60 | 0.60 |
| 11/13/91 | 0.12 | 0.14 | 0.13 | 0.13 |
| 11/20/91 | 0.30 | 0.39 | 0.36 | 0.35 |
| 11/27/91 | 0.47 | 0.59 | 0.52 | 0.53 |
| 12/4/91 | 0.01 | 0.02 | 0.01 | 0.01 |
| 12/10/91 | 0.11 | 0.14 | 0.13 | 0.13 |
| 12/18/91 | 0.07 | 0.10 | 0.08 | 0.08 |
| 12/26/91 | 0.10 | 0.16 | 0.08 | 0.11 |
| | | | TOTAL | 19.06 |

*DATA IN INCHES

## TABLE 13. TIMMERMAN ZONE IRRIGATION DATA*

| GROWER RECORDS: | | |
|---|---|---|
| | PRE-PLANT IRRIGATION | 3.13 |
| | POST-EMERGENCE IRRIGATION | 23.38 |
| | POST-HARVEST IRRIGATION | 5.95 |
| | TOTAL | 32.46 |

STUDY SITE PRECIPITATION GAUGE READINGS

| DATE | SITE 1 | SITE 2 | SITE 3 | AVERAGE |
|---|---|---|---|---|
| 7/10/91 | 1.89 | 2.46 | 1.88 | 2.08 |
| 7/17/91 | 1.85 | 1.58 | 1.70 | 1.71 |
| 7/24/91 | 2.62 | 1.97 | 2.20 | 2.26 |
| 7/31/91 | 2.62 | 2.17 | 2.49 | 2.43 |
| 8/7/91 | 0.88 | 1.17 | 1.11 | 1.05 |
| 8/15/91 | 2.37 | 2.28 | 2.48 | 2.38 |
| 8/21/91 | 1.64 | 1.46 | 1.53 | 1.54 |
| 8/28/91 | 2.27 | 2.39 | 2.16 | 2.27 |
| 9/4/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9/11/91 | 0.76 | 0.88 | 0.97 | 0.87 |
| 9/18/91 | 1.43 | 1.40 | 1.41 | 1.41 |
| 9/24/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10/2/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10/9/91 | 1.64 | 1.86 | 2.04 | 1.85 |
| 10/16/91 | 1.89 | 2.27 | 2.10 | 2.09 |
| 10/23/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10/30/91 | 0.24 | 0.23 | 0.23 | 0.23 |
| 11/6/91 | 0.59 | 0.61 | 0.60 | 0.60 |
| 11/13/91 | 0.15 | 0.14 | 0.15 | 0.15 |
| 11/20/91 | 0.39 | 0.37 | 0.37 | 0.38 |
| 11/27/91 | 0.54 | 0.55 | 0.01 | 0.37 |
| 12/4/91 | 0.02 | 0.02 | 0.02 | 0.02 |
| 12/10/91 | 0.15 | 0.14 | 0.15 | 0.15 |
| 12/18/91 | 0.08 | 0.09 | 0.80 | 0.32 |
| 12/26/91 | 0.10 | 0.07 | 0.90 | 0.36 |
| | | | TOTAL | 24.51 |

*DATA IN INCHES

TABLE 14. EPHRATA ZONE IRRIGATION DATA*

| | | |
|---|---|---|
| GROWER RECORDS: | PRE-PLANT IRRIGATION | 1.88 |
| | POST-EMERGENCE IRRIGATION | 23.38 |
| | POST-HARVEST IRRIGATION | 5.1 |
| | TOTAL | 30.36 |

STUDY SITE PRECIPITATION GAUGE READINGS

| | SITE | | | |
|---|---|---|---|---|
| DATE | 1 | 2 | 3 | AVERAGE |
| 7/10/91 | 1.19 | 1.44 | 1.33 | 1.32 |
| 7/17/91 | 1.88 | 2.40 | 2.31 | 2.20 |
| 7/24/91 | 1.26 | 1.64 | 1.16 | 1.35 |
| 7/31/91 | 1.94 | 2.63 | 2.30 | 2.29 |
| 8/7/91 | 0.84 | 1.04 | 0.96 | 0.95 |
| 8/15/91 | 1.94 | 2.56 | 0.70 | 1.73 |
| 8/21/91 | 1.37 | 1.76 | 1.85 | 1.66 |
| 8/28/91 | 2.05 | 2.47 | 2.51 | 2.34 |
| 9/4/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9/11/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9/18/91 | 1.20 | 1.52 | 1.45 | 1.39 |
| 9/24/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10/2/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10/9/91 | | 3.49 | 3.38 | 3.44 |
| 10/16/91 | 0.90 | 1.00 | 1.03 | 0.98 |
| 10/23/91 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10/30/91 | 0.22 | 0.24 | 0.25 | 0.24 |
| 11/6/91 | 0.56 | 0.60 | 0.62 | 0.59 |
| 11/13/91 | 0.14 | 0.15 | 0.15 | 0.15 |
| 11/20/91 | 0.35 | 0.36 | 0.37 | 0.36 |
| 11/27/91 | 0.51 | 0.54 | 0.56 | 0.54 |
| 12/4/91 | 0.02 | 0.02 | 0.02 | 0.02 |
| 12/10/91 | 0.13 | 0.15 | 0.14 | 0.14 |
| 12/18/91 | 0.09 | 0.08 | 0.09 | 0.09 |
| 12/26/91 | 0.08 | 0.17 | 0.14 | 0.13 |
| | | | TOTAL | 21.90 |

*DATA IN INCHES

TABLE 15. NITROGEN FERTILIZATION RECORD
UNIT 53-54, BLOCK 71, 1991

| DATE | MATERIAL | RATE | LOCATION |
|---|---|---|---|
| 5/21/91 | PRE-PLANT FERTILIZER | 50 LBS N/A | W 1/2 |
| 5/22/91 | PRE-PLANT FERTILIZER | 60 LBS N/A | E 1/2 |
| 7/2/91 | POST-EMERGENCE SIDE DRESS | 30 LBS N/A | E 1/2 |
| 7/12/91 | NITROGATION-UAN | 26 LBS N/A | E 1/2 |
| 7/22/91 | NITROGATION-UAN | 10 LBS N/A | E 1/2 |

| TOTAL NITROGEN APPLIED | |
|---|---|
| QUINCY ZONE | 126 LBS N/A |
| TIMMERMAN ZONE | 126 LBS N/A |
| EPHRATA ZONE | 50 LBS N/A |

TABLE 16. SOIL WATER NITRATE-NITROGEN DATA*
QUINCY ZONE

| DATE, 1991 | | 7/10 | 7/17 | 7/24 | 7/31 | 8/7 | 8/15 | 8/21 | 8/28 | 9/4 | 9/11 | 9/18 | 9/24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| SITE | DEPTH | | | | | | | | | | | | |
| 1 | A | 74.7 | 49.8 | 13.4 | 5.9 | 2.2 | 2.1 | 2.9 | 2.7 | 7.0 | 6.3 | 20.1 | 31.1 |
| | B | 92.4 | 111.1 | 102.3 | 45.5 | 17.7 | 11.9 | 8.2 | 6.5 | 6.5 | 7.7 | 10.5 | 37.3 |
| | C | 114.3 | 120.2 | 118.3 | 122.1 | 113.8 | 117.4 | 123.9 | 103.0 | 78.0 | 57.0 | 68.5 | 60.3 |
| | D | 112.1 | 137.5 | 141.2 | 144.3 | 146.1 | 138.2 | 137.9 | 127.0 | 127.0 | 110.1 | 112.0 | 102.7 |
| | E | 90.5 | 115.3 | 123.5 | 126.3 | 125.8 | 123.3 | 131.5 | 113.0 | 116.8 | 102.4 | 108.6 | 127.6 |
| 2 | A | 130.5 | 124.2 | 66.6 | 24.6 | 13.8 | 9.3 | 5.8 | 9.0 | 10.6 | 18.5 | 31.3 | 54.2 |
| | B | 155.3 | 122.6 | 156.5 | 151.8 | 143.8 | 149.3 | 132.3 | 122.4 | 110.2 | 98.2 | 92.3 | 83.0 |
| | C | 103.0 | 115.5 | 112.2 | 109.9 | 99.8 | 105.7 | 111.9 | 108.7 | 94.9 | 83.9 | 86.7 | 81.1 |
| | D | 125.5 | 136.7 | 137.4 | 134.7 | 135.3 | 136.6 | 138.2 | 140.4 | 142.7 | 119.0 | 114.2 | 120.9 |
| | E | 81.4 | 104.1 | 111.5 | 116.0 | 119.1 | 118.6 | 121.3 | 127.4 | 132.8 | 122.6 | 134.8 | 130.0 |
| 3 | A | 175.2 | 146.8 | 130.2 | 103.4 | 144.8 | 45.2 | 13.2 | 18.2 | 12.6 | 31.0 | 42.1 | 60.4 |
| | B | 169.6 | 179.6 | 167.6 | 158.5 | 144.0 | 170.2 | 138.6 | 115.1 | 100.0 | 87.0 | 82.4 | 74.1 |
| | C | 141.7 | 153.1 | 149.2 | 137.6 | 125.0 | 121.8 | 105.6 | 103.8 | 95.8 | 90.7 | 103.6 | 118.5 |
| | D | 100.2 | 129.7 | 131.7 | 132.6 | 125.7 | 121.1 | 123.1 | 120.7 | 124.2 | 107.4 | 111.2 | 102.8 |
| | E | 117.4 | 134.7 | 138.4 | 164.8 | 153.4 | 149.9 | 152.3 | 146.9 | 137.7 | 137.3 | 132.6 | 123.8 |

*TEST DATA IS IN PPM

TABLE 16. SOIL WATER NITRATE-NITROGEN DATA*
(CONT) QUINCY ZONE

| DATE, 1991 | 10/2 | 10/9 | 10/16 | 10/23 | 10/30 | 11/6 | 11/13 | 11/20 | 11/27 | 12/4 | 12/10 | 12/18 | 12/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| SITE DEPTH | | | | | | | | | | | | | |
| 1 A | 36.1 | 36.2 | 39.3 | 41.2 | 42.1 | 42.9 | 45.8 | 47.8 | 51.1 | 54.7 | 56.1 | 60.6 | 58.0 |
| B | 20.6 | 22.3 | 22.5 | 26.7 | 31.7 | 35.2 | 37.9 | 39.0 | 42.5 | 46.3 | 49.3 | 53.1 | 49.9 |
| C | 47.8 | 56.6 | 43.7 | 50.4 | 43.5 | 41.6 | 41.3 | 41.3 | 42.1 | 42.6 | 43.0 | 42.3 | 38.7 |
| D | 89.7 | 100.2 | 83.3 | 62.1 | 58.0 | 58.2 | 56.0 | 54.8 | 53.7 | 56.7 | 60.2 | 54.5 | 53.8 |
| E | 94.8 | 96.7 | 95.1 | 72.2 | 66.0 | 68.3 | 70.7 | 70.1 | 66.4 | 65.1 | 69.4 | 66.4 | 62.2 |
| | | | | | | | | | | | | | |
| 2 A | 47.0 | 64.0 | 52.0 | 52.6 | 55.5 | 56.8 | 61.8 | 67.1 | 70.1 | 74.8 | 81.6 | 77.0 | 79.4 |
| B | 72.3 | 89.7 | 62.9 | 54.1 | 48.3 | 43.3 | 44.7 | 44.3 | 46.3 | 46.6 | 56.3 | 49.2 | 46.6 |
| C | 73.6 | 69.9 | 64.1 | 54.1 | 54.9 | 55.7 | 56.8 | 54.4 | 54.6 | 53.9 | 59.5 | 52.7 | 51.0 |
| D | 108.5 | 128.7 | 99.1 | 90.9 | 80.9 | 83.8 | 81.2 | 79.3 | 76.6 | 78.4 | 78.4 | 69.0 | 66.2 |
| E | 124.5 | 131.7 | 120.9 | 117.7 | 55.3 | 106.6 | 112.3 | 111.4 | 106.3 | 102.5 | 104.5 | 103.4 | 95.1 |
| | | | | | | | | | | | | | |
| 3 A | 54.2 | 74.6 | 51.7 | 53.0 | 54.5 | 58.0 | 64.2 | 69.9 | 72.9 | 77.7 | 90.9 | 46.8 | 85.1 |
| B | 65.7 | 65.1 | 53.9 | 52.6 | 49.0 | 50.0 | 53.5 | 53.7 | 54.3 | 55.0 | 65.4 | 56.5 | 58.1 |
| C | 97.6 | 95.2 | 93.2 | 89.4 | 79.8 | 73.9 | 68.7 | 62.6 | 58.7 | 55.7 | 57.9 | 49.9 | 43.6 |
| D | 98.2 | 108.9 | 95.4 | 89.5 | 83.7 | 76.4 | 75.0 | 68.4 | 63.0 | 60.3 | 64.6 | 54.4 | 53.9 |
| E | 117.9 | 127.5 | 108.8 | 99.6 | 103.8 | 101.5 | 103.1 | 102.4 | 99.0 | 98.9 | 101.1 | 98.1 | 92.2 |

*TEST DATA IS IN PPM

TABLE 17. SOIL WATER NITRATE-NITROGEN DATA*
TIMMERMAN ZONE

| DATE, 1991 | | 7/10 | 7/17 | 7/24 | 7/31 | 8/7 | 8/15 | 8/21 | 8/28 | 9/4 | 9/11 | 9/18 | 9/24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| SITE | DEPTH | | | | | | | | | | | | |
| 1 | A | 66.9 | 54.9 | 84.5 | 14.8 | 3.3 | 1.7 | 1.9 | 6.3 | 10.9 | 15.0 | 29.0 | 34.6 |
| | B | 105.8 | 132.9 | 123.0 | 72.5 | 39.2 | 31.7 | 25.3 | 22.3 | 14.9 | 16.4 | 22.4 | 29.6 |
| | C | 52.9 | 90.3 | 100.6 | 110.4 | 95.1 | 96.9 | 84.5 | 74.1 | 57.6 | 41.7 | 35.5 | 21.7 |
| | D | 59.4 | 89.8 | 97.1 | 97.6 | 89.3 | 92.6 | 92.7 | 93.7 | 85.1 | 65.5 | 61.3 | 55.6 |
| | E | 69.8 | 88.8 | 94.3 | 103.7 | 95.7 | 90.0 | 89.9 | 66.8 | 59.3 | 44.3 | 55.4 | 45.2 |
| 2 | A | 68.2 | 87.0 | 95.9 | 101.0 | 119.0 | 94.8 | 20.2 | 57.6 | 50.1 | 60.1 | 73.5 | 73.9 |
| | B | 103.3 | 123.8 | 102.2 | 70.8 | 53.8 | 64.9 | 78.7 | 48.6 | 42.3 | 31.4 | 42.5 | 36.9 |
| | C | 39.1 | 73.1 | 75.8 | 73.8 | 43.7 | 32.3 | 26.5 | 23.0 | 51.8 | 25.4 | 29.2 | 46.2 |
| | D | 44.6 | 63.8 | 72.7 | 93.0 | 79.7 | 76.3 | 68.7 | 55.5 | 61.4 | 40.6 | 40.7 | 43.5 |
| | E | 64.5 | 89.3 | 94.8 | 96.9 | 99.8 | 94.0 | 100.7 | 97.5 | 86.0 | 70.3 | 93.5 | 65.9 |
| 3 | A | 91.1 | 92.5 | 59.1 | 32.0 | 20.5 | 11.8 | 5.6 | 5.5 | 7.1 | 16.2 | 20.9 | 40.1 |
| | B | 139.2 | 158.6 | 145.3 | 126.3 | 88.4 | 97.3 | 31.3 | 18.4 | 12.1 | 14.9 | 21.6 | 22.3 |
| | C | 94.9 | 133.8 | 142.6 | 167.7 | 165.1 | 152.2 | 142.3 | 130.1 | 99.2 | 80.4 | 76.1 | 55.9 |
| | D | 68.3 | 106.0 | 114.0 | 110.2 | 112.8 | 116.4 | 126.4 | 136.1 | 127.6 | 135.9 | 117.0 | 107.6 |
| | E | 64.0 | 92.0 | 102.5 | 104.5 | 91.5 | 94.7 | 94.4 | 106.9 | 117.8 | 92.3 | 90.2 | 85.2 |

*TEST DATA IS IN PPM

TABLE 17. SOIL WATER NITRATE-NITROGEN DATA*
(CONT) TIMMERMAN ZONE

| DATE, 1991 | | 10/2 | 10/9 | 10/16 | 10/23 | 10/30 | 11/6 | 11/13 | 11/20 | 11/27 | 12/4 | 12/10 | 12/18 | 12/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| SITE | DEPTH | | | | | | | | | | | | | |
| 1 | A | 39.9 | 46.9 | 43.6 | 38.4 | 39.4 | 42.5 | 45.8 | 46.2 | 48.4 | 49.3 | 61.0 | 56.0 | 51.3 |
| | B | 20.9 | 26.5 | 39.1 | 31.1 | 32.8 | 35.5 | 37.8 | 37.8 | 39.3 | 42.8 | 44.7 | 31.1 | 40.3 |
| | C | 22.8 | 30.9 | 34.9 | 33.8 | 35.0 | 37.9 | 34.9 | 37.3 | 39.6 | 41.6 | 48.7 | 41.0 | 38.5 |
| | D | 51.1 | 55.5 | 47.2 | 34.5 | 35.2 | 35.6 | 36.2 | 36.9 | 38.9 | 42.4 | 44.7 | 41.9 | 38.3 |
| | E | 34.3 | 54.0 | 42.1 | 36.6 | 32.4 | 35.0 | 31.8 | 32.0 | 34.2 | 40.5 | 39.5 | 32.9 | 36.8 |
| 2 | A | 78.4 | 83.8 | 93.3 | 70.4 | 75.4 | 79.2 | 86.1 | 91.2 | 94.4 | 103.6 | 108.7 | ** | 85.9 |
| | B | 31.8 | 44.4 | 43.0 | 30.4 | 33.5 | 36.0 | 34.6 | 30.2 | 29.0 | 31.8 | 33.9 | 27.5 | 25.2 |
| | C | 45.2 | 56.9 | 57.2 | 45.3 | 43.3 | 38.1 | 43.8 | 43.3 | 43.0 | 38.6 | 45.0 | 41.0 | 33.4 |
| | D | 50.3 | 60.3 | 67.0 | 48.1 | 48.8 | 50.4 | 53.6 | 54.1 | 55.5 | 57.9 | 69.7 | 54.0 | 49.9 |
| | E | 58.3 | 68.6 | 58.1 | 62.0 | 77.3 | 67.1 | 87.4 | 85.6 | 87.0 | 74.1 | 119.1 | 96.4 | 71.3 |
| 3 | A | 30.9 | 36.7 | 49.2 | 48.5 | 51.3 | 55.0 | 57.9 | 59.5 | 58.6 | 62.4 | 69.8 | ** | 58.2 |
| | B | 33.1 | 45.8 | 35.1 | 52.5 | 60.6 | 63.0 | 64.3 | 62.4 | 59.7 | 59.1 | 61.5 | 56.3 | 50.4 |
| | C | 44.3 | 48.6 | 38.1 | 37.2 | 40.8 | 40.0 | 42.7 | 43.1 | 44.8 | 48.4 | 56.5 | 54.5 | 49.4 |
| | D | 106.9 | 101.3 | 101.0 | 69.7 | 48.5 | 45.1 | 45.3 | 43.4 | 43.0 | 47.8 | 52.9 | 55.3 | 54.1 |
| | E | 86.7 | 101.0 | 90.1 | 74.3 | 63.9 | 64.7 | 54.9 | 82.9 | 49.1 | 61.0 | 52.1 | 60.0 | 52.6 |

*TEST DATA IS IN PPM
**SAMPLE NOT AVAILABLE DUE TO FROZEN LYSIMETER TUBES

TABLE 18. SOIL WATER NITRATE-NITROGEN DATA*
EPHRATA ZONE

| DATE, 1991 | | 7/10 | 7/17 | 7/24 | 7/31 | 8/7 | 8/15 | 8/21 | 8/28 | 9/4 | 9/11 | 9/18 | 9/24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| SITE | DEPTH | | | | | | | | | | | | |
| 1 | A | 231.1 | 226.8 | 225.3 | 278.8 | 207.6 | 165.3 | 118.7 | 82.5 | 48.7 | 32.4 | 44.4 | 53.9 |
| | B | 168.8 | 159.8 | 156.5 | 167.9 | 190.0 | 201.7 | 202.8 | 202.8 | 214.7 | 216.0 | 222.4 | 193.0 |
| | D | 71.2 | 79.0 | 92.0 | 107.5 | 104.6 | 100.9 | 103.4 | 110.1 | 124.5 | 107.4 | 82.4 | 111.5 |
| | E | 86.7 | 94.5 | 96.1 | 102.1 | 99.0 | 94.9 | 96.0 | 100.2 | 75.8 | 87.9 | 74.0 | 85.8 |
| 2 | A | 153.9 | 172.1 | 192.2 | 238.5 | 234.4 | 151.7 | 72.3 | 27.7 | 13.7 | 21.2 | 25.2 | 69.7 |
| | B | 160.4 | 164.4 | 168.0 | 175.9 | 185.2 | 174.8 | 172.4 | 173.8 | 165.9 | 167.9 | 189.3 | 180.2 |
| | E | 75.2 | 82.4 | 86.3 | 92.6 | 96.7 | 92.8 | 96.5 | 101.7 | 102.8 | 101.8 | 108.2 | 105.7 |
| 3 | A | 218.1 | 224.8 | 210.9 | 205.9 | 137.4 | 125.8 | 95.8 | 50.9 | 26.3 | 36.2 | 44.0 | 40.8 |
| | B | 182.1 | 169.2 | 169.1 | 164.9 | 169.1 | 168.0 | 185.5 | 217.5 | 249.5 | 222.9 | 206.7 | 166.3 |
| | D | 111.6 | 123.9 | 135.2 | 141.3 | 152.5 | 141.2 | 151.3 | 154.3 | 157.3 | 146.1 | 160.9 | 149.5 |
| | E | 65.9 | 72.9 | 80.1 | 89.1 | 81.2 | 94.7 | 96.3 | 106.3 | 114.8 | 108.9 | 115.2 | 105.3 |

*TEST DATA IS IN PPM

TABLE 18. SOIL WATER NITRATE-NITROGEN DATA*
(CONT) EPHRATA ZONE

| DATE, 1991 | | 10/2 | 10/9 | 10/16 | 10/23 | 10/30 | 11/6 | 11/13 | 11/20 | 11/27 | 12/4 | 12/10 | 12/18 | 12/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| SITE | DEPTH | | | | | | | | | | | | | |
| 1 | A | 51.7 | 66.5 | 50.8 | 38.1 | 36.0 | 36.9 | 38.4 | 39.8 | 42.0 | 50.6 | 53.5 | 46.7 | 45.0 |
| | B | 187.4 | 244.9 | 187.9 | 132.1 | 100.8 | 92.4 | 87.1 | 81.1 | 76.9 | 78.6 | 85.0 | 66.2 | 62.0 |
| | D | 111.9 | 97.4 | 136.1 | 130.3 | 143.1 | 159.3 | 159.8 | 168.0 | 164.2 | 205.3 | 199.1 | 145.5 | 166.8 |
| | E | 83.8 | 90.9 | 96.3 | 103.5 | 103.4 | 113.6 | 117.2 | 123.5 | 127.5 | 151.4 | 153.0 | 139.0 | 140.4 |
| 2 | A | 39.6 | 43.2 | 50.6 | 37.5 | 31.0 | 37.5 | 29.9 | 28.6 | 29.9 | 34.0 | 30.5 | 32.7 | 28.4 |
| | B | 182.7 | 156.9 | 153.6 | 149.3 | 101.7 | 87.9 | 76.6 | 67.8 | 58.6 | 66.5 | 63.3 | 48.5 | 41.4 |
| | E | 109.3 | 115.2 | 139.9 | 116.9 | 121.6 | 130.2 | 139.8 | 146.1 | 146.0 | 191.6 | 185.7 | 162.3 | 162.8 |
| 3 | A | 41.1 | 44.5 | 28.4 | 23.0 | 29.7 | 32.9 | 37.0 | 38.3 | 40.9 | 54.3 | 59.4 | 47.9 | 45.8 |
| | B | 143.7 | 102.3 | 40.6 | 32.5 | 29.5 | 26.7 | 26.7 | 25.9 | 27.1 | 34.9 | 32.3 | 27.8 | 26.7 |
| | D | 147.0 | 169.8 | 213.5 | 175.4 | 179.4 | 181.2 | 188.1 | 189.4 | 182.2 | 226.1 | 213.6 | 153.5 | 170.3 |
| | E | 112.9 | 144.1 | 143.4 | 130.8 | 143.4 | 157.3 | 163.8 | 171.3 | 173.0 | 222.8 | 175.7 | 182.9 | 182.2 |

*TEST DATA IS IN PPM

TABLE 19. QUINCY ZONE
SOIL MOISTURE DATA*

| DATE, 1991 | 7/10 | 7/17 | 7/24 | 7/31 | 8/7 | 8/15 | 8/21 | 8/28 | 9/4 | 9/11 | 9/18 | 9/24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| SITE DEPTH | | | | | | | | | | | | |
| 1 A | 2.024 | 2.419 | 2.525 | 2.836 | 1.886 | 2.797 | 2.576 | 2.345 | 2.058 | 2.427 | 2.373 | 2.158 |
| B | 2.068 | 2.126 | 2.211 | 2.254 | 2.007 | 2.230 | 2.167 | 2.170 | 2.071 | 2.098 | 2.315 | 2.264 |
| C | 1.185 | 1.329 | 1.435 | 1.359 | 1.258 | 1.305 | 1.414 | 1.372 | 1.291 | 1.254 | 1.462 | 1.400 |
| D | 1.174 | 1.207 | 1.209 | 1.356 | 1.316 | 1.285 | 1.337 | 1.386 | 1.322 | 1.267 | 1.411 | 1.383 |
| E | 1.156 | 1.128 | 1.162 | 1.343 | 1.385 | 1.282 | 1.282 | 1.385 | 1.389 | 1.336 | 1.251 | 1.386 |
| 2 A | 1.305 | 1.540 | 1.865 | 2.241 | 1.310 | 2.412 | 2.247 | 2.013 | 1.541 | 1.882 | 2.239 | 1.972 |
| B | 1.984 | 1.979 | 1.948 | 2.042 | 1.945 | 2.077 | 2.091 | 2.112 | 2.008 | 2.007 | 2.049 | 2.057 |
| C | 1.904 | 1.971 | 1.943 | 2.012 | 1.977 | 1.942 | 2.066 | 2.097 | 2.022 | 2.016 | 2.066 | 2.050 |
| D | 1.779 | 1.837 | 1.812 | 1.849 | 1.849 | 1.855 | 1.949 | 2.020 | 2.031 | 1.977 | 2.033 | 2.061 |
| E | 1.499 | 1.494 | 1.446 | 1.485 | 1.446 | 1.471 | 1.487 | 1.492 | 1.527 | 1.497 | 1.545 | 1.548 |
| 3 A | 1.556 | 2.121 | 2.202 | 2.453 | 1.546 | 2.529 | 2.485 | 2.250 | 1.755 | 2.198 | 2.477 | 2.160 |
| B | 2.218 | 2.295 | 2.325 | 2.326 | 2.221 | 2.296 | 2.408 | 2.381 | 1.312 | 2.298 | 2.391 | 2.352 |
| C | 2.547 | 2.556 | 2.624 | 2.592 | 2.540 | 2.531 | 2.633 | 2.696 | 2.639 | 2.610 | 2.700 | 2.670 |
| D | 2.011 | 2.028 | 2.055 | 2.073 | 2.034 | 2.028 | 2.105 | 2.141 | 2.088 | 2.054 | 2.151 | 2.158 |
| E | 1.443 | 1.460 | 1.470 | 1.505 | 1.510 | 1.438 | 1.478 | 1.651 | 1.618 | 1.529 | 1.550 | 1.634 |

*MEASURED BY NEUTRON PROBE - DATA IN INCHES/FOOT

TABLE 19. QUINCY ZONE
(CONT) SOIL MOISTURE DATA*

| DATE, 1991 | 10/2 | 10/9 | 10/16 | 10/23 | 10/30 | 11/6 | 11/13 | 11/20 | 11/27 | 12/4 | 12/10 | 12/18 | 12/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| SITE DEPTH | | | | | | | | | | | | | |
| 1 A | 2.011 | 2.375 | 2.446 | 2.106 | 2.096 | 2.378 | 2.312 | 2.345 | 2.514 | 2.337 | 2.210 | 2.095 | 2.263 |
| B | 2.295 | 2.329 | 2.355 | 2.298 | 2.224 | 2.260 | 2.255 | 2.257 | 2.276 | 2.301 | 2.223 | 2.236 | 2.205 |
| C | 1.331 | 1.483 | 1.494 | 1.365 | 1.342 | 1.315 | 1.398 | 1.397 | 1.369 | 1.402 | 1.373 | 1.351 | 1.287 |
| D | 1.319 | 1.317 | 1.532 | 1.379 | 1.328 | 1.302 | 1.276 | 1.293 | 1.291 | 1.342 | 1.317 | 1.294 | 1.279 |
| E | 1.301 | 1.277 | 1.438 | 1.374 | 1.305 | 1.263 | 1.253 | 1.249 | 1.227 | 1.232 | 1.235 | 1.253 | 1.246 |
| 2 A | 1.774 | 2.249 | 1.438 | 1.992 | 1.911 | 2.220 | 2.110 | 2.184 | 2.385 | 2.172 | 2.102 | 1.973 | 2.092 |
| B | 2.014 | 2.105 | 2.138 | 2.091 | 2.070 | 2.047 | 2.086 | 2.091 | 2.053 | 2.082 | 2.058 | 2.063 | 2.062 |
| C | 2.031 | 2.131 | 2.238 | 2.156 | 2.126 | 2.055 | 2.126 | 2.097 | 2.116 | 2.137 | 2.111 | 2.081 | 2.064 |
| D | 2.045 | 2.135 | 2.287 | 2.187 | 2.134 | 2.096 | 2.142 | 2.108 | 2.129 | 2.158 | 2.176 | 2.151 | 2.094 |
| E | 1.562 | 1.505 | 1.618 | 1.620 | 1.639 | 1.591 | 1.531 | 1.559 | 1.571 | 1.583 | 1.584 | 1.518 | 1.527 |
| 3 A | 1.972 | 2.399 | 2.475 | 2.116 | 2.121 | 2.254 | 2.241 | 2.311 | 2.442 | 2.247 | 2.242 | 2.079 | 2.179 |
| B | 2.326 | 2.355 | 2.449 | 2.319 | 2.353 | 2.316 | 2.319 | 2.345 | 2.373 | 2.351 | 2.349 | 2.357 | 2.269 |
| C | 2.638 | 2.671 | 2.743 | 2.677 | 2.677 | 2.645 | 2.621 | 2.610 | 2.603 | 2.655 | 2.612 | 2.614 | 2.554 |
| D | 2.090 | 2.161 | 2.196 | 2.130 | 2.123 | 2.114 | 2.122 | 2.121 | 2.117 | 2.113 | 2.132 | 2.114 | 2.105 |
| E | 1.563 | 1.528 | 1.728 | 1.638 | 1.562 | 1.583 | 1.525 | 1.565 | 1.569 | 1.595 | 1.586 | 1.558 | 1.507 |

*MEASURED BY NEUTRON PROBE - DATA IN INCHES/FOOT

TABLE 20. TIMMERMAN ZONE
SOIL MOISTURE DATA*

| DATE, 1991 | 7/10 | 7/17 | 7/24 | 7/31 | 8/7 | 8/15 | 8/21 | 8/28 | 9/4 | 9/11 | 9/18 | 9/24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| SITE DEPTH | | | | | | | | | | | | |
| 1 A | 2.132 | 2.287 | 2.375 | 2.732 | 2.440 | 2.642 | 2.515 | 2.862 | 1.918 | 2.303 | 2.525 | 2.333 |
| B | 1.705 | 1.869 | 2.071 | 2.166 | 1.985 | 2.108 | 2.105 | 2.130 | 1.992 | 1.999 | 2.143 | 2.084 |
| C | 1.042 | 1.123 | 1.282 | 1.399 | 1.173 | 1.272 | 1.368 | 1.392 | 1.266 | 1.227 | 1.503 | 1.391 |
| D | 0.901 | 0.876 | 0.874 | 0.910 | 0.924 | 0.934 | 0.919 | 0.966 | 1.015 | 0.990 | 1.015 | 1.105 |
| E | 1.274 | 1.253 | 1.254 | 1.275 | 1.277 | 1.299 | 1.296 | 1.336 | 1.358 | 1.380 | 1.399 | 1.458 |
| 2 A | 2.679 | 2.601 | 2.622 | 2.824 | 2.678 | 2.772 | 2.590 | 2.915 | 2.164 | 2.533 | 2.752 | 2.586 |
| B | 1.857 | 1.885 | 1.968 | 2.024 | 1.901 | 2.008 | 1.958 | 2.025 | 1.282 | 1.878 | 1.944 | 1.889 |
| C | 1.375 | 1.747 | 1.830 | 1.875 | 1.637 | 1.842 | 1.797 | 1.842 | 1.595 | 1.638 | 1.816 | 1.712 |
| D | 0.883 | 0.998 | 1.386 | 1.375 | 1.111 | 1.428 | 1.360 | 1.256 | 1.184 | 1.088 | 1.351 | 1.239 |
| E | 1.172 | 1.170 | 1.564 | 1.577 | 1.408 | 1.621 | 1.541 | 1.517 | 1.441 | 1.384 | 1.541 | 1.482 |
| 3 A | 2.753 | 2.383 | 2.575 | 2.858 | 2.806 | 2.838 | 2.686 | 2.991 | 2.345 | 2.579 | 2.735 | 2.584 |
| B | 2.450 | 2.393 | 2.465 | 2.501 | 2.470 | 2.584 | 2.486 | 2.582 | 2.431 | 2.435 | 2.524 | 2.485 |
| C | 1.254 | 1.331 | 1.468 | 1.543 | 1.443 | 1.616 | 1.557 | 1.560 | 1.420 | 1.430 | 1.583 | 1.493 |
| D | 0.912 | 0.944 | 0.929 | 1.018 | 1.062 | 1.169 | 1.270 | 1.224 | 1.149 | 1.097 | 1.153 | 1.172 |
| E | 0.996 | 0.973 | 1.010 | 1.021 | 1.002 | 1.077 | 1.265 | 1.340 | 1.334 | 1.261 | 1.232 | 1.281 |

*MEASURED BY NEUTRON PROBE - DATA IN INCHES/FOOT

TABLE 20. TIMMERMAN ZONE
(CONT) SOIL MOISTURE DATA*

| DATE, 1991 | 10/2 | 10/9 | 10/16 | 10/23 | 10/30 | 11/6 | 11/13 | 11/20 | 11/27 | 12/4 | 12/10 | 12/18 | 12/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 1 A | 2.248 | 2.599 | 2.665 | 2.378 | 2.376 | 2.660 | 2.554 | 2.561 | 2.770 | 2.548 | 2.527 | 2.479 | 2.658 |
| B | 2.024 | 2.157 | 2.196 | 2.109 | 2.000 | 2.081 | 2.112 | 2.126 | 2.141 | 2.144 | 2.091 | 2.073 | 2.049 |
| C | 1.332 | 1.580 | 1.573 | 1.388 | 1.292 | 1.313 | 1.428 | 1.439 | 1.494 | 1.466 | 1.460 | 1.360 | 1.283 |
| D | 1.090 | 1.384 | 1.374 | 1.133 | 1.109 | 1.055 | 1.070 | 1.112 | 1.102 | 1.193 | 1.175 | 1.155 | 1.121 |
| E | 1.476 | 1.730 | 1.860 | 1.716 | 1.670 | 1.612 | 1.564 | 1.567 | 1.606 | 1.634 | 1.636 | 1.634 | 1.624 |
| 2 A | 2.480 | 2.735 | 2.789 | 2.593 | 2.533 | 2.724 | 2.673 | 2.671 | 2.785 | 2.661 | 2.610 | 2.509 | 2.651 |
| B | 1.827 | 1.973 | 1.971 | 1.912 | 1.873 | 1.877 | 1.945 | 1.916 | 1.952 | 1.908 | 1.905 | 1.836 | 1.856 |
| C | 1.624 | 1.793 | 1.792 | 1.668 | 1.654 | 1.619 | 1.766 | 1.755 | 1.753 | 1.759 | 1.712 | 1.689 | 1.617 |
| D | 1.144 | 1.300 | 1.332 | 1.194 | 1.123 | 1.103 | 1.130 | 1.164 | 1.209 | 1.293 | 1.263 | 1.204 | 1.105 |
| E | 1.402 | 1.571 | 1.600 | 1.421 | 1.393 | 1.320 | 1.326 | 1.380 | 1.389 | 1.417 | 1.442 | 1.443 | 1.397 |
| 3 A | 2.506 | 2.767 | 2.787 | 2.607 | 2.543 | 2.712 | 2.655 | 2.666 | 2.833 | 2.669 | 2.650 | 2.568 | 2.595 |
| B | 2.470 | 2.578 | 2.561 | 2.478 | 2.469 | 2.477 | 2.466 | 2.466 | 2.522 | 2.498 | 2.447 | 2.471 | 2.464 |
| C | 1.446 | 1.641 | 1.623 | 1.472 | 1.474 | 1.432 | 1.537 | 1.523 | 1.530 | 1.541 | 1.514 | 1.438 | 1.440 |
| D | 1.099 | 1.333 | 1.341 | 1.151 | 1.149 | 1.087 | 1.127 | 1.126 | 1.149 | 1.182 | 1.172 | 1.163 | 1.085 |
| E | 1.273 | 1.537 | 1.545 | 1.309 | 1.248 | 1.196 | 2.141 | 1.217 | 1.237 | 1.236 | 1.277 | 1.279 | 1.239 |

*MEASURED BY NEUTRON PROBE - DATA IN INCHES/FOOT

# TABLE 21. EPHRATA ZONE
# SOIL MOISTURE DATA*

| DATE, 1991 | 7/10 | 7/17 | 7/24 | 7/31 | 8/7 | 8/15 | 8/21 | 8/28 | 9/4 | 9/11 | 9/18 | 9/24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| SITE DEPTH | | | | | | | | | | | | |
| 1 A | 2.737 | 2.970 | 2.760 | 2.832 | 2.683 | 2.814 | 2.873 | 3.052 | 2.692 | 2.622 | 2.872 | 2.708 |
| B | 2.554 | 2.567 | 2.593 | 2.588 | 2.571 | 2.576 | 2.566 | 2.644 | 2.497 | 2.490 | 2.578 | 2.509 |
| D | 20 | 18 | 19 | 20 | 20 | 20 | 19 | 18 | 20 | 21 | 20 | 20 |
| E | 18 | 17 | 17 | 18 | 18 | 18 | 18 | 16 | 18 | 18 | 17 | 18 |
| 2 A | 2.572 | 2.794 | 2.522 | 2.614 | 2.340 | 2.644 | 2.640 | 2.085 | 2.340 | 2.353 | 2.675 | 2.464 |
| B | 2.950 | 3.069 | 3.011 | 3.010 | 2.931 | 3.052 | 3.095 | 3.155 | 2.953 | 2.913 | 3.020 | 2.972 |
| D | 20 | 18 | 22 | 22 | 22 | 22 | 22 | 20 | 22 | 22 | 18 | 22 |
| E | 20 | 18 | 20 | 20 | 20 | 20 | 19 | 18 | 19 | 20 | 20 | 19 |
| 3 A | 2.570 | 2.777 | 2.583 | 2.695 | 2.493 | 2.776 | 2.771 | 2.913 | 2.397 | 2.388 | 2.709 | 2.573 |
| B | 3.148 | 3.235 | 3.293 | 3.257 | 3.212 | 3.320 | 3.332 | 3.341 | 3.178 | 3.115 | 3.089 | 3.187 |
| D | 18 | 18 | 18 | 18 | 18 | 18 | 17 | 16 | 18 | 18 | 21 | 18 |
| E | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 18 | 20 | 20 | 21 | 20 |

*DEPTHS A & B ARE MEASURED BY NEUTRON PROBE - DATA IN INCHES/FOOT
DEPTHS D & E ARE MEASURED BY TENSIOMETER - DATA IN KILOPASCALS (kPa)

TABLE 21. EPHRATA ZONE
(CONT) SOIL MOISTURE DATA*

| DATE, 1991 | 10/2 | 10/9 | 10/16 | 10/23 | 10/30 | 11/6 | 11/13 | 11/20 | 11/27 | 12/4 | 12/10 | 12/18 | 12/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEK NUMBER | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 1 A | 2.395 | 3.357 | 3.120 | 2.849 | 2.788 | 2.900 | 2.867 | 2.896 | 2.979 | 2.893 | 2.854 | 2.826 | 2.826 |
| B | 2.517 | 2.728 | 2.637 | 2.590 | 2.580 | 2.538 | 2.553 | 2.591 | 2.575 | 2.599 | 2.525 | 2.543 | 2.560 |
| D | 20 | 18 | 17 | ** | 22 | 19 | 17 | 23 | 17 | ** | ** | ** | 23 |
| E | 19 | 17 | 15 | ** | 15 | ** | 24 | 22 | 23 | ** | ** | ** | 20 |
| 2 A | 2.407 | 3.179 | 2.818 | 2.532 | 2.488 | 2.660 | 2.605 | 2.620 | 2.734 | 2.576 | 2.557 | 2.447 | 2.557 |
| B | 2.908 | 3.266 | 3.167 | 3.018 | 2.990 | 2.984 | 3.004 | 3.002 | 2.990 | 2.989 | 2.998 | 2.977 | 2.969 |
| D | 22 | 20 | 19 | 21 | 22 | 25 | ** | ** | ** | ** | ** | ** | ** |
| E | 20 | 18 | 17 | 20 | ** | 18 | ** | ** | ** | ** | ** | ** | ** |
| 3 A | 2.501 | 3.064 | 2.882 | 2.670 | 2.592 | 2.651 | 2.636 | 2.669 | 2.761 | 2.644 | 2.693 | 2.577 | 2.580 |
| B | 3.114 | 3.382 | 3.345 | 3.218 | 3.180 | 3.202 | 3.188 | 3.192 | 3.196 | 3.183 | 3.173 | 3.176 | 3.082 |
| D | 19 | 18 | 16 | ** | 16 | ** | ** | ** | ** | ** | ** | ** | ** |
| E | 20 | 19 | 18 | ** | 23 | 16 | ** | ** | ** | ** | ** | ** | ** |

*DEPTHS A & B ARE MEASURED BY NEUTRON PROBE - DATA IN INCHES/FOOT
DEPTHS D & E ARE MEASURED BY TENSIOMETER - DATA IN KILOPASCALS (kPa)

**DATA NOT AVAILABLE DUE TO FREEZING TEMPERATURES PREVENTING USE OF LIQUID FILLED VACUUM GAUGES ON TENSIOMETERS. DATA FOR 1D & 1E ON 12/26/91 WAS COLLECTED BY PROTECTING GAUGES FROM FREEZING LONG ENOUGH TO GET DATA. THIS DATA REFLECTS LITTLE CHANGE IN THE WATER POTENTIALS AT THE 48 & 60 INCH

TABLE 22. COMPARISON OF NEUTRON PROBE DATA TO GRAVIMETRIC SOIL TEST DATA

| SOIL TEXTURAL ZONE | DEPTH (INCHES) | NEUTRON PROBE AVERAGE | SOIL TEST AVERAGE | NP-ST AVERAGE |
|---|---|---|---|---|
| QUINCY | 12 | 2.008 | 2.285 | -0.277 |
| | 24 | 2.007 | 2.014 | -0.007 |
| | 36 | 1.309 | 2.134 | -0.825 |
| | 48 | 1.301 | 1.04 | 0.261 |
| TIMMERMAN | 12 | 2.475 | 3.471 | -0.996 |
| | 24 | 2.217 | 2.246 | -0.029 |
| | 36 | 1.666 | 1.072 | 0.594 |
| | 48 | 1.131 | 1.342 | -0.211 |
| EPHRATA | 12 | 2.551 | 3.636 | -1.085 |
| | 24 | 3.551 | 4.277 | -0.726 |

TABLE 23. PRE-FERTILIZATION SOIL NITROGEN STATUS RESULTS*

| TEXTURAL ZONE | PROFILE DEPTH (FT) | ANALYSIS RESULTS** | | |
|---|---|---|---|---|
| | | $NO_3$-N PPM | $NH_4$-N PPM | TOTAL KJDL-N % |
| QUINCY | 1 | 16.0 | 6.9 | 0.11 |
| | 2 | 14.7 | 2.5 | 0.06 |
| | 3 | 13.5 | 1.9 | 0.04 |
| | 4 | 7.1 | 1.2 | 0.03 |
| | 5 | 3.9 | 1.2 | 0.05 |
| TIMMERMAN | 1 | 14.2 | 6.3 | 0.12 |
| | 2 | 11.3 | 1.0 | 0.09 |
| | 3 | 8.6 | 1.0 | 0.06 |
| | 4 | 5.4 | 2.5 | 0.07 |
| | 5 | 3.1 | 3.1 | 0.05 |
| EPHRATA | 1 | 32.6 | 5.1 | 0.11 |
| | 2 | 35.3 | 2.7 | 0.06 |
| | 3 | 24.8 | 1.6 | 0.04 |
| | 4 | 18.5 | 1.5 | 0.04 |
| | 5 | 14.1 | 1.9 | 0.02 |

*Data is from analysis of the initial grid samples used to characterize the soil textural zones.

**Since study sites were not identified until after preplant fertilization and planting, the data given is the averages of grid sample data for the entire textural zones.

## TABLE 24. MID-SEASON SOIL NITROGEN STATUS RESULTS QUINCY ZONE

| SITE | DEPTH | LOCATION 1 | | | LOCATION 2 | | | LOCATION 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N |
| 1 | A | 4 | <2 | 0.03 | 5 | <2 | 0.13 | 6 | <2 | 0.13 |
| | B | 1 | <2 | <0.01 | 3 | <2 | 0.09 | 1 | <2 | 0.06 |
| | C | 2 | <2 | 0.01 | 3 | <2 | 0.05 | 1 | <2 | 0.03 |
| | D | 4 | <2 | <0.01 | 3 | <2 | 0.06 | 2 | 2 | 0.03 |
| | E | 4 | <2 | 0.05 | 5 | <2 | 0.05 | 1 | <2 | <0.01 |
| 2 | A | 5 | <2 | 0.14 | 5 | <2 | 0.09 | 7 | <2 | 0.08 |
| | B | 5 | <2 | 0.08 | 4 | <2 | 0.07 | 4 | <2 | 0.03 |
| | C | 10 | <2 | 0.07 | 5 | <2 | 0.04 | 13 | <2 | 0.07 |
| | D | 12 | <2 | 0.03 | 7 | <2 | 0.05 | ** | ** | ** |
| | E | 8 | <2 | 0.08 | 4 | <2 | 0.04 | ** | ** | ** |
| 3 | A | 9 | <2 | 0.02 | 8 | <2 | 0.14 | 7 | <2 | 0.13 |
| | B | 4 | <2 | 0.04 | 2 | <2 | 0.08 | 2 | <2 | 0.07 |
| | C | 15 | <2 | 0.07 | 10 | <2 | 0.04 | 4 | <2 | 0.05 |
| | D | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| | E | ** | ** | ** | ** | ** | ** | ** | ** | ** |

**GRAVEL IN SUBSOIL SAND PREVENTED GETTING SAMPLES WITH HAND AUGERS.

TABLE 25. MID-SEASON SOIL NITROGEN STATUS RESULTS
TIMMERMAN ZONE

| SITE | DEPTH | LOCATION 1 | | | LOCATION 2 | | | LOCATION 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N |
| 1 | A | 4 | <2 | 0.04 | 10 | <2 | <0.01 | 6 | <2 | <0.01 |
| | B | 2 | <2 | 0.12 | 3 | <2 | <0.01 | 1 | <2 | <0.01 |
| | C | 3 | <2 | 0.35 | 4 | <2 | <0.01 | 3 | <2 | <0.01 |
| | D | 3 | <2 | 0.04 | 4 | <2 | 0.03 | 4 | <2 | 0.03 |
| | E | 3 | <2 | <0.01 | 5 | <2 | <0.01 | 3 | <2 | <0.01 |
| 2 | A | 7 | <2 | <0.01 | 6 | <2 | <0.01 | 7 | <2 | <0.01 |
| | B | 2 | <2 | <0.01 | 2 | <2 | <0.01 | 5 | <2 | 0.01 |
| | C | 1 | <2 | 0.01 | 2 | <2 | <0.01 | 7 | <2 | <0.01 |
| | D | 1 | <2 | 0.06 | 3 | <2 | 0.04 | 3 | <2 | 0.07 |
| | E | 1 | <2 | <0.01 | 3 | <2 | 0.01 | 4 | <2 | 0.03 |
| 3 | A | 7 | <2 | <0.01 | 6 | <2 | 0.04 | 5 | <2 | 0.01 |
| | B | 3 | <2 | <0.01 | 2 | <2 | 0.01 | 1 | <2 | 0.03 |
| | C | 6 | <2 | <0.01 | 1 | <2 | 0.01 | 2 | <2 | <0.01 |
| | D | 4 | <2 | 0.06 | 3 | <2 | <0.01 | 4 | <2 | 0.03 |
| | E | 6 | <2 | 0.01 | 5 | <2 | 0.05 | 6 | <2 | 0.06 |

## TABLE 26. MID-SEASON SOIL NITROGEN STATUS RESULTS EPHRATA ZONE

| SITE | DEPTH* | LOCATION 1 NO3-N PPM | LOCATION 1 NH4-N PPM | LOCATION 1 % TOTAL KJDL-N | LOCATION 2 NO3-N PPM | LOCATION 2 NH4-N PPM | LOCATION 2 % TOTAL KJDL-N | LOCATION 3 NO3-N PPM | LOCATION 3 NH4-N PPM | LOCATION 3 % TOTAL KJDL-N |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 8 | <2 | 0.08 | 10 | <2 | 0.06 | 8 | <2 | 0.09 |
|  | B | 3 | <2 | 0.03 | 26 | <2 | 0.12 | 3 | <2 | 0.07 |
| 2 | A | 7 | <2 | 0.49 | 7 | <2 | 0.15 | 11 | <2 | 0.15 |
|  | B | 13 | <2 | 0.14 | 8 | <2 | 0.15 | 26 | <2 | 0.15 |
| 3 | A | 10 | <2 | 0.14 | 9 | <2 | 0.16 | 9 | <2 | 0.16 |
|  | B | 20 | <2 | 0.13 | 18 | 4 | 0.15 | 3 | 4 | 0.18 |

*HAND SAMPLED 1ST AND 2ND FOOT ONLY

TABLE 27. POST-HARVEST SOIL NITROGEN STATUS RESULTS
QUINCY ZONE

| SITE | DEPTH | LOCATION 1 | | | LOCATION 2 | | | LOCATION 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N |
| 1 | A | 4 | 5.5 | 0.11 | 11 | <2 | 0.11 | 5 | 4 | 0.10 |
| | B | 1 | <2 | 0.05 | 1 | <2 | 0.05 | 1 | 2 | 0.03 |
| | C | 1 | <2 | 0.07 | 1 | <2 | 0.03 | 1 | 2 | 0.03 |
| | D | 3 | <2 | 0.05 | 1 | <2 | 0.03 | 1 | 2 | 0.01 |
| | E | 3 | <2 | 0.05 | 1 | <2 | 0.01 | 1 | 2 | 0.04 |
| 2 | A | 5 | 2 | 0.02 | 11 | 3 | 0.10 | 7 | 4 | 0.07 |
| | B | 1 | 2 | 0.01 | 8 | 2 | 0.05 | 2 | 2 | 0.04 |
| | C | 1 | 2 | 0.01 | 8 | 2 | 0.04 | 6 | 2 | 0.04 |
| | D | 2 | 2 | 0.01 | 4 | 2 | 0.01 | 3 | 2 | 0.02 |
| | E | 4 | 2 | 0.01 | 3 | 2 | 0.03 | 1 | 2 | 0.03 |
| 3 | A | 9 | 6 | 0.10 | 6 | 6 | 0.07 | 6 | 2 | 0.07 |
| | B | 10 | 6 | 0.04 | 1 | 4 | 0.02 | 5 | 4 | 0.09 |
| | C | 10 | 4 | 0.05 | 3 | 2 | 0.02 | 7 | 4 | 0.02 |
| | D | 1 | <2 | 0.02 | 6 | 2 | 0.01 | 2 | <2 | 0.09 |
| | E | 2 | <2 | 0.02 | 3 | <2 | 0.01 | 2 | <2 | 0.01 |

### TABLE 28. POST-HARVEST SOIL NITROGEN STATUS RESULTS TIMMERMAN ZONE

| SITE | DEPTH | LOCATION 1 | | | LOCATION 2 | | | LOCATION 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N | NO3-N PPM | NH4-N PPM | % TOTAL KJDL-N |
| 1 | A | 13 | 6 | 0.04 | 9 | 8 | 0.06 | 8 | 12 | 0.01 |
| | B | 1 | 2 | 0.02 | 3 | 4 | 0.02 | 2 | 4 | 0.04 |
| | C | 2 | 2 | 0.03 | 2 | 4 | 0.01 | 2 | <2 | 0.01 |
| | D | 2 | 4 | 0.01 | 4 | 4 | 0.01 | 1 | 4 | 0.01 |
| | E | 4 | 2 | 0.02 | 2 | 2 | 0.01 | 1 | 2 | 0.01 |
| 2 | A | 7 | 10 | 0.01 | 9 | 6 | 0.08 | 11 | 10 | 0.11 |
| | B | 1 | 4 | 0.01 | 4 | 4 | 0.05 | 10 | 6 | 0.02 |
| | C | 1 | 4 | 0.06 | 1 | 4 | 0.03 | 10 | 4 | 0.07 |
| | D | 1 | <2 | 0.05 | 1 | 4 | 0.05 | 8 | 6 | 0.02 |
| | E | 1 | 2 | 0.05 | 1 | 2 | 0.04 | 8 | 6 | 0.01 |
| 3 | A | 15 | 8 | 0.11 | 6 | <2 | 0.07 | 5 | 14 | 0.06 |
| | B | 4 | 6 | 0.06 | 2 | 6 | 0.04 | 2 | 10 | 0.03 |
| | C | 4 | 8 | 0.02 | 1 | 2 | 0.02 | 1 | 4 | 0.01 |
| | D | 4 | 2 | 0.02 | 2 | 4 | 0.04 | 1 | 4 | 0.01 |
| | E | 4 | 4 | 0.02 | 3 | 6 | 0.03 | 1 | <2 | 0.01 |

TABLE 29. POST-HARVEST SOIL NITROGEN STATUS RESULTS
EPHRATA ZONE

| SITE | DEPTH | LOCATION 1 NO3-N PPM | LOCATION 1 NH4-N PPM | LOCATION 1 % TOTAL KJDL-N | LOCATION 2 NO3-N PPM | LOCATION 2 NH4-N PPM | LOCATION 2 % TOTAL KJDL-N | LOCATION 3 NO3-N PPM | LOCATION 3 NH4-N PPM | LOCATION 3 % TOTAL KJDL-N |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 18 | 8 | 0.12 | 5 | 6 | 0.07 | 10 | 8 | 0.10 |
|  | B | 34 | 4 | 0.05 | 5 | 4 | 0.09 | 30 | 4 | 0.11 |
| 2 | A | 9 | 10 | 0.06 | 5 | 6 | 0.12 | 8 | 6 | 0.12 |
|  | B | 24 | 4 | 0.09 | 5 | 4 | 0.12 | 20 | 4 | 0.05 |
| 3 | A | 11 | 10 | 0.16 | 11 | 6 | 0.11 | 10 | 4 | 0.12 |
|  | B | 11 | 4 | 0.05 | 13 | 4 | 0.12 | 32 | 2 | 0.12 |
|  |  | COMPOSITE* LOCATIONS 1, 2, & 3 |  |  |  |  |  |  |  |  |
| 1 | C | 1 | 2 | 0.03 |  |  |  |  |  |  |
|  | D | 1 | 2 | 0.02 |  |  |  |  |  |  |
|  | E | 18 | <2 | 0.01 |  |  |  |  |  |  |
| 2 | C | 10 | <2 | 0.01 |  |  |  |  |  |  |
|  | D | 5 | <2 | 0.01 |  |  |  |  |  |  |
|  | E | 27 | 2 | 0.01 |  |  |  |  |  |  |
| 3 | C | 39 | 2 | 0.03 |  |  |  |  |  |  |
|  | D | 11 | 2 | 0.03 |  |  |  |  |  |  |
|  | E | 22 | 2 | 0.01 |  |  |  |  |  |  |

*LOWER DEPTH SAMPLES COLLECTED FROM AN EXTENDED TRENCH DUG INTERMEDIATE TO ALL THREE STUDY SITES.

TABLE 30. EARLY-WINTER SOIL NITROGEN STATUS RESULTS
QUINCY ZONE

| SITE | DEPTH | LOCATION 1 NO3-N PPM | LOCATION 1 NH4-N PPM | LOCATION 1 % TOTAL KJDL-N | LOCATION 2 NO3-N PPM | LOCATION 2 NH4-N PPM | LOCATION 2 % TOTAL KJDL-N | LOCATION 3 NO3-N PPM | LOCATION 3 NH4-N PPM | LOCATION 3 % TOTAL KJDL-N |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 5 | 7 | 0.10 | 6 | 4 | 0.12 | 3 | 6 | 0.15 |
|  | B | 4 | <2 | 0.08 | 5 | 2 | 0.07 | 5 | <2 | 0.14 |
|  | C | 4 | <2 | 0.01 | 2 | <2 | 0.04 | 2 | <2 | 0.04 |
|  | D | 1 | <2 | 0.02 | 1 | 2 | 0.03 | 2 | <2 | 0.05 |
|  | E | 2 | <2 | 0.03 | 1 | <2 | 0.03 | 1 | 2 | 0.03 |
| 2 | A | 4 | 6 | 0.17 | 6 | 4 | 0.06 | 6 | <2 | 0.09 |
|  | B | 5 | <2 | 0.10 | 5 | <2 | 0.05 | 6 | <2 | 0.08 |
|  | C | 3 | 2 | 0.06 | 2 | <2 | 0.03 | 2 | <2 | 0.05 |
|  | D | 3 | <2 | 0.06 | 2 | <2 | 0.05 | 2 | <2 | 0.02 |
|  | E | 3 | <2 | 0.04 | 3 | <2 | 0.01 | 3 | <2 | 0.01 |
| 3 | A | 4 | 4 | 0.11 | 5 | 6 | 0.10 | 7 | <2 | 0.09 |
|  | B | 7 | <2 | 0.05 | 6 | <2 | 0.02 | 5 | <2 | 0.04 |
|  | C | 3 | <2 | 0.04 | 4 | <2 | 0.07 | 2 | <2 | 0.08 |
|  | D | 2 | <2 | 0.04 | 7 | <2 | 0.03 | 3 | <2 | 0.06 |
|  | E | 2 | <2 | 0.01 | 3 | <2 | 0.04 | 1 | <2 | 0.07 |

## TABLE 31. EARLY-WINTER SOIL NITROGEN STATUS RESULTS TIMMERMAN ZONE

| SITE | DEPTH | LOCATION 1 NO3-N PPM | LOCATION 1 NH4-N PPM | LOCATION 1 % TOTAL KJDL-N | LOCATION 2 NO3-N PPM | LOCATION 2 NH4-N PPM | LOCATION 2 % TOTAL KJDL-N | LOCATION 3 NO3-N PPM | LOCATION 3 NH4-N PPM | LOCATION 3 % TOTAL KJDL-N |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 3 | <2 | 0.07 | 8 | <2 | 0.14 | 4 | 4 | 0.17 |
|  | B | 4 | <2 | 0.05 | 3 | <2 | 0.06 | 3 | <2 | 0.07 |
|  | C | 2 | <2 | 0.06 | 2 | <2 | 0.06 | 2 | <2 | 0.06 |
|  | D | 2 | <2 | 0.06 | 2 | <2 | 0.06 | 2 | <2 | 0.06 |
|  | E | 2 | <2 | 0.05 | 2 | <2 | 0.04 | 1 | <2 | 0.04 |
| 2 | A | 1 | 4 | 0.13 | 3 | <2 | 0.12 | 13 | <2 | 0.09 |
|  | B | 1 | <2 | 0.09 | 3 | <2 | 0.08 | 9 | <2 | 0.07 |
|  | C | 1 | <2 | 0.06 | 2 | <2 | 0.05 | 5 | <2 | 0.05 |
|  | D | 1 | <2 | 0.02 | 2 | <2 | 0.06 | 4 | <2 | 0.04 |
|  | E | 1 | <2 | 0.03 | 2 | <2 | 0.07 | 5 | <2 | 0.02 |
| 3 | A | 4 | 4 | 0.04 | 2 | 4 | 0.07 | 4 | 4 | 0.13 |
|  | B | 3 | <2 | 0.06 | 2 | <2 | 0.05 | 5 | <2 | 0.01 |
|  | C | 2 | <2 | 0.08 | 1 | <2 | 0.06 | 1 | <2 | 0.03 |
|  | D | 1 | <2 | 0.09 | 1 | <2 | 0.05 | 1 | <2 | 0.03 |
|  | E | 2 | <2 | 0.09 | 1 | <2 | 0.05 | 1 | <2 | 0.03 |

## TABLE 32. EARLY-WINTER SOIL NITROGEN STATUS RESULTS EPHRATA ZONE*

| SITE | DEPTH | LOCATION 1 NO3-N PPM | LOCATION 1 NH4-N PPM | LOCATION 1 % TOTAL KJDL-N | LOCATION 2 NO3-N PPM | LOCATION 2 NH4-N PPM | LOCATION 2 % TOTAL KJDL-N | LOCATION 3 NO3-N PPM | LOCATION 3 NH4-N PPM | LOCATION 3 % TOTAL KJDL-N |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 7 | <2 | 0.14 | 5 | <2 | 0.16 | 6 | <2 | 0.17 |
|  | B | 3 | <2 | 0.14 | 7 | <2 | 0.19 | 7 | <2 | 0.20 |
| 2 | A | 5 | 4 | 0.16 | 4 | 4 | 0.15 | 6 | <2 | 0.10 |
|  | B | 5 | <2 | 0.13 | 5 | <2 | 0.11 | 8 | <2 | 0.09 |
| 3 | A | 4 | 8 | 0.16 | 6 | 9 | 0.16 | 6 | 12 | 0.19 |
|  | B | 5 | 4 | 0.13 | 4 | 4 | 0.14 | 5 | 2 | 0.14 |
|  |  | COMPOSITE LOCATIONS 1, 2, & 3 |  |  |  |  |  |  |  |  |
| 1 | C | 2 | <2 | 0.02 |  |  |  |  |  |  |
|  | D | 3 | <2 | 0.08 |  |  |  |  |  |  |
|  | E | 3 | <2 | 0.14 |  |  |  |  |  |  |
| 2 | C | 5 | <2 | 0.06 |  |  |  |  |  |  |
|  | D | 6 | 2 | 0.08 |  |  |  |  |  |  |
|  | E | 8 | <2 | 0.03 |  |  |  |  |  |  |
| 3 | C | 6 | 4 | 0.07 |  |  |  |  |  |  |
|  | D | 6 | <2 | 0.07 |  |  |  |  |  |  |
|  | E | 6 | 2 | 0.04 |  |  |  |  |  |  |

*HAND SAMPLED 1ST AND 2ND FOOT ONLY. LOWER DEPTHS WERE TAKEN AS COMPOSITE SAMPLES FROM TRENCHES DUG FOR EACH OF THE STUDY SITES.

TABLE 33. APPROXIMATE ROOTING DEPTHS (INCHES) OF SWEET CORN CROP AT STUDY SITES*

| | STUDY SITES | | |
|---|---|---|---|
| | QUINCY | TIMMERMAN | EPHRATA |
| FOR 75% OF ROOT MASS | 16 | 12 | 14 |
| MAXIMUM | 20 | 16 | 22 |

*Observations were based on depth measurements and a qualitative examination of rooting patterns.

TABLE 34. SEASONAL DISTRIBUTION OF AVERAGE SOIL NO3-N AS INDICATED BY SOIL NITROGEN STATUS SAMPLE ANALYSIS (DATA IN PPM)

| ZONE | DEPTH | PRE-FERTILIZER | MID-SEASON | POST-HARVEST | EARLY-WINTER |
|---|---|---|---|---|---|
| QUINCY | A | 16.0 | 6.2 | 7.1 | 5.1 |
| | B | 14.7 | 2.9 | 3.3 | 5.3 |
| | C | 13.5 | 7.0 | 4.2 | 2.7 |
| | D | 7.1 | 6.3 | 2.6 | 2.5 |
| | E | 3.9 | 4.7 | 2.2 | 2.1 |
| TIMMERMAN | A | 14.2 | 6.5 | 9.2 | 4.7 |
| | B | 11.3 | 2.3 | 3.2 | 3.6 |
| | C | 8.6 | 3.2 | 2.7 | 2.0 |
| | D | 5.4 | 3.2 | 2.6 | 1.8 |
| | E | 3.1 | 4.0 | 2.8 | 1.9 |
| EPHRATA | A | 32.6 | 8.8 | 9.7 | 5.4 |
| | B | 35.3 | 13.7 | 19.3 | 5.5 |
| | C | 24.8 | | 16.7 | 4.3 |
| | D | 18.5 | | 5.7 | 5.0 |
| | E | 14.1 | | 22.3 | 5.7 |

TABLE 35. TOTAL MONTHLY PRECIPITATION AND EVAPORATION*

| MONTH | TOTAL MONTHLY PRECIPITATION | HISTORICAL MONTHLY AVERAGE PRECIPITATION | TOTAL EVAPORATION |
|---|---|---|---|
| MAY | 1.16 | 0.70 | ---- |
| JUNE | 0.81 | 1.00 | 6.54 |
| JULY | 0.21 | 0.20 | 8.26 |
| AUGUST | 0.00 | 0.30 | 7.36 |
| SEPTEMBER | 0.08 | 0.40 | 5.95 |
| OCTOBER | 0.27 | 0.70 | 2.84 |
| NOVEMBER | 1.36 | 1.00 | ---- |
| DECEMBER | 0.25 | 1.20 | ---- |
| TOTAL | 4.14 | 5.50 | 30.95 |

*DATA IN INCHES

TABLE 36. COMPARISON OF ESTIMATED CROP USE TO IRRIGATION APPLICATIONS*

| WEEK | SITE IRRIGATION DATA | | | WEATHER STATION DATA | | CROP WATER USE CO-EFFICIENT | EST CROP WATER USE | PPTN + IRR - CROP USE | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Q | T | E | PPTN | EVAP | | | Q | T | E |
| 7/10/91 | 2.38 | 2.08 | 1.32 | 0.00 | 2.19 | 0.93 | 2.04 | 0.34 | 0.04 | -0.72 |
| 7/17/91 | 1.96 | 1.50 | 1.99 | 0.21 | 1.68 | 0.95 | 1.60 | 0.57 | 0.11 | 0.60 |
| 7/24/91 | 1.68 | 2.26 | 1.35 | 0.00 | 1.65 | 1.00 | 1.65 | 0.03 | 0.61 | -0.30 |
| 7/31/91 | 1.70 | 2.43 | 2.29 | 0.00 | 1.91 | 1.00 | 1.91 | -0.21 | 0.52 | 0.38 |
| 8/7/91 | 0.04 | 1.05 | 0.95 | 0.00 | 1.60 | 0.95 | 1.52 | -1.48 | -0.47 | -0.57 |
| 8/15/91 | 2.30 | 2.38 | 1.73 | 0.00 | 1.71 | 0.80 | 1.37 | 0.93 | 1.01 | 0.36 |
| 8/21/91 | 1.10 | 1.54 | 1.66 | 0.00 | 1.64 | 0.65 | 1.07 | 0.03 | 0.47 | 0.59 |
| 8/28/91 | 1.15 | 2.27 | 2.34 | 0.00 | 1.83 | 0.58 | 1.06 | 0.09 | 1.21 | 1.28 |
| TOTALS | 12.31 | 15.51 | 13.63 | 0.21 | 14.21 | | 12.21 | 0.31 | 3.51 | 1.63 |

*DATA IN INCHES

TABLE 37. CHANGES OF NITRATE CONTENTS IN SOIL PROFILES OVER TIME*

| ROOT ZONE (0-24 INCHES) | TEXTURAL ZONE | | |
|---|---|---|---|
| | QUINCY | TIMMERMAN | EPHRATA |
| WEEK 1 | 112.9 | 96 | 253 |
| WEEK 9 | 33.6 | 21 | 163.1 |
| WEEK 25 | 62.2 | 57.5 | 56.6 |

| SUB ROOT ZONE (24-60 INCHES) | TEXTURAL ZONE | |
|---|---|---|
| TIME | QUINCY | TIMMERMAN |
| WEEK 1 | 123.2 | 46.2 |
| WEEK 4 | 154.9 | 97.7 |
| WEEK 25 | 70.7 | 42.5 |
| ESTIMATED LEACHING LOSS | 84.2 | 55.2 |

*DATA IN LB NO3-N/A

# APPENDIX C

# FIGURES

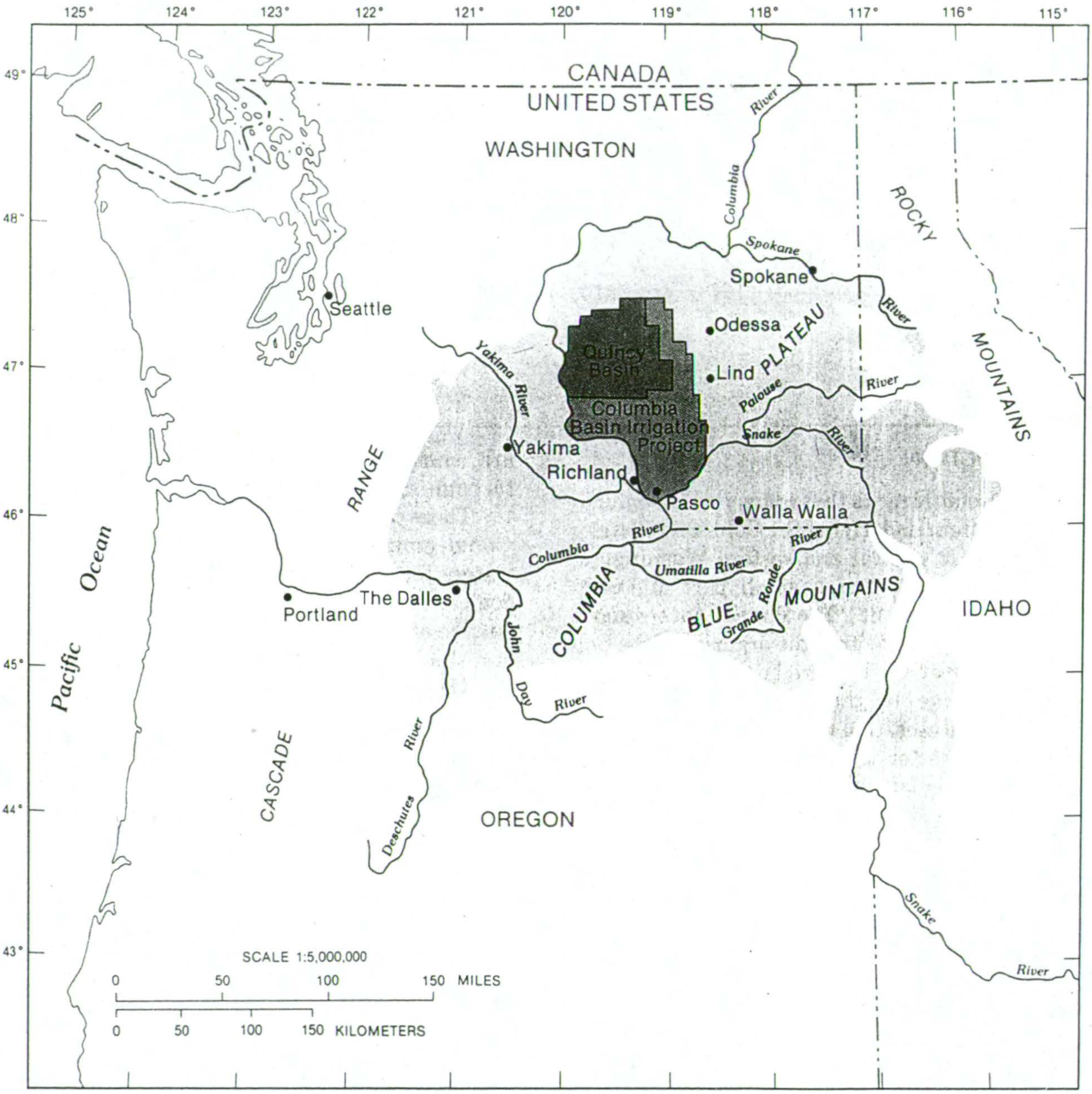


FIGURE 1. QUINCY BASIN GROUNDWATER ACTIVITIES RESEARCH STUDY AREA. SEE REF (46).

FIGURE 2. NITRATE IN SOIL NITROGEN TRANSFORMATIONS.
SEE REF (23).

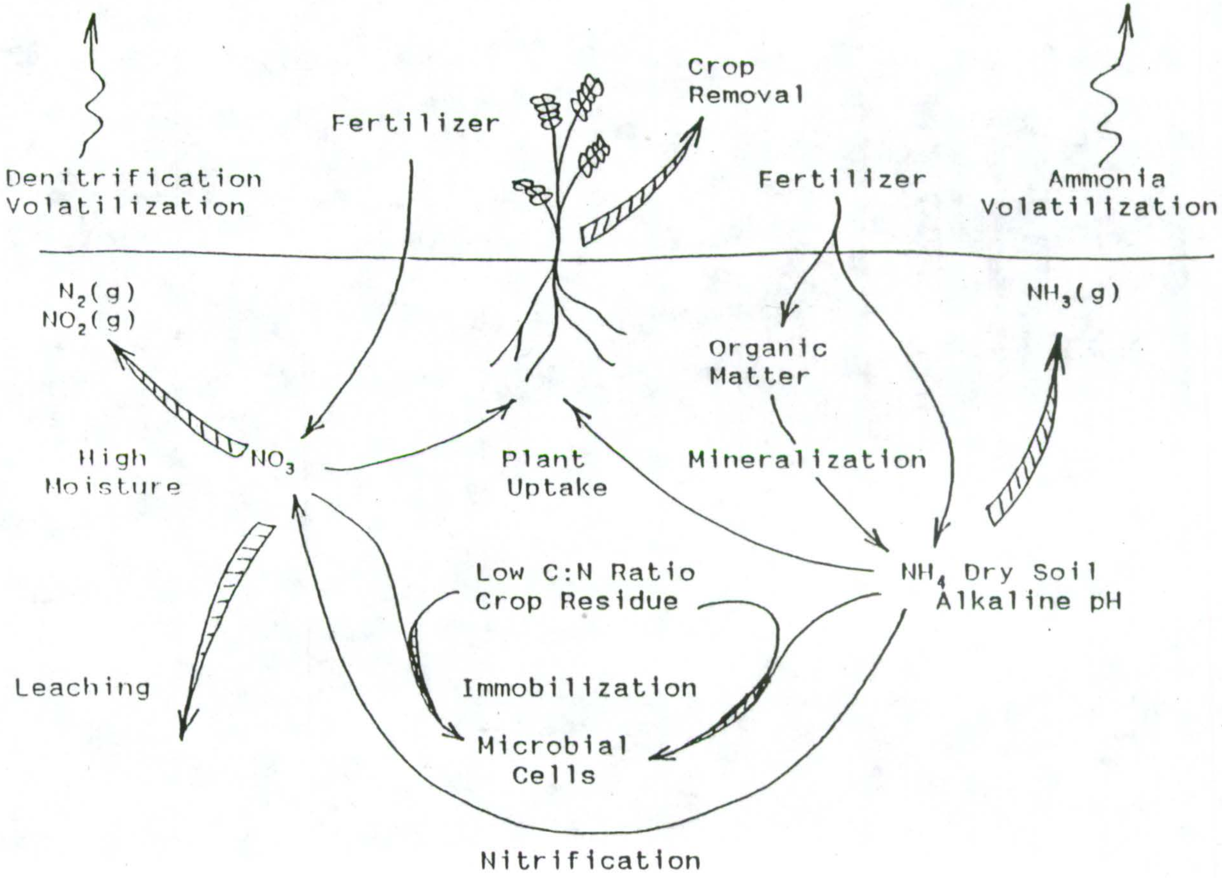
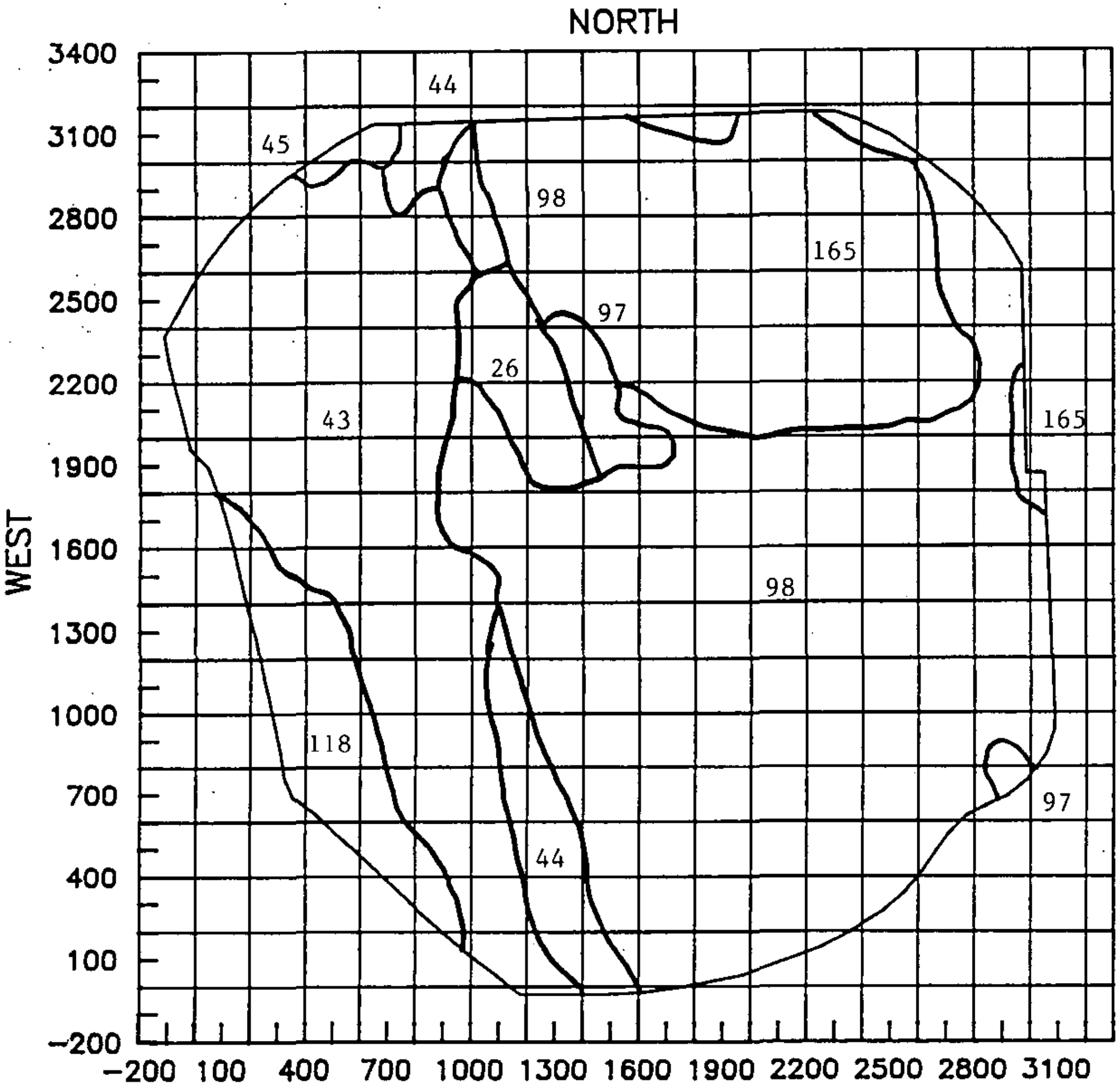


FIGURE 3. SOIL TYPES IN STUDY FIELD - UNIT 53-54, BLK 71



USDA-SCS SOIL CLASSIFICATIONS
SEE REF (5).

Soil survey of Grant County Washington, January, 1984

| | |
|---|---|
| 26 | Burbank loamy fine sand<br>0 to 5% slopes |
| 43 | Ephrata gravelly sandy loam<br>0 to 2% slopes |
| 44 | Ephrata gravelly sandy loam<br>2 to 5% slopes |
| 45 | Ephrata-Malaga complex<br>0 to 5% slopes |
| 97 | Quincy fine sand<br>2 to 15% slopes |
| 98 | Quincy loamy fine sand<br>0 to 15% slopes |
| 118 | Royal very fine sandy loam<br>cemented substratum<br>2 to 5% slopes |
| 165 | Timmerman coarse sandy loam<br>0 to 2% slopes |

FIGURE 4. STUDY FIELD INTENSIVE SAMPLE GRID

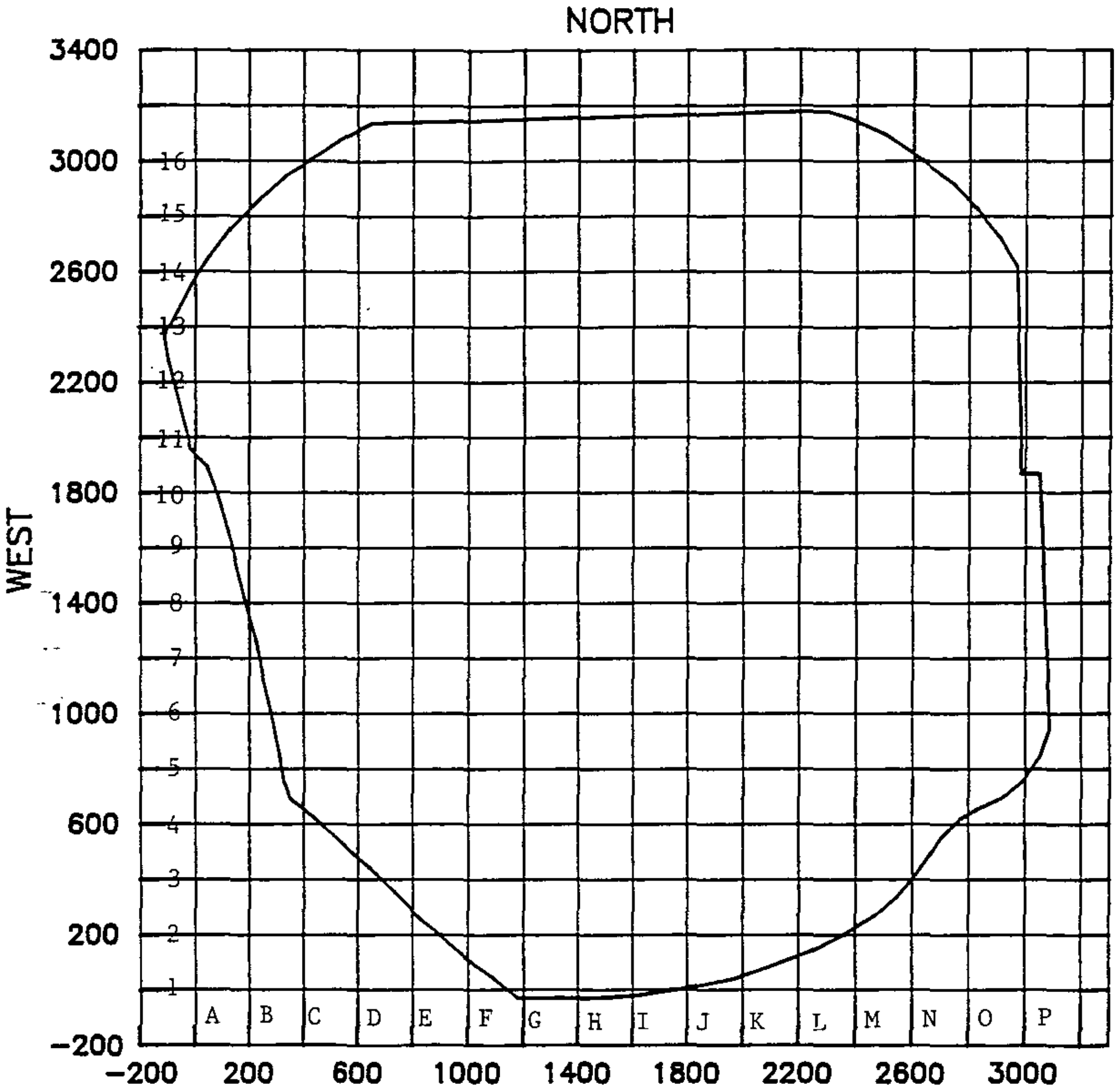


FIGURE 5. STUDY FIELD PPM $NO_3$-N

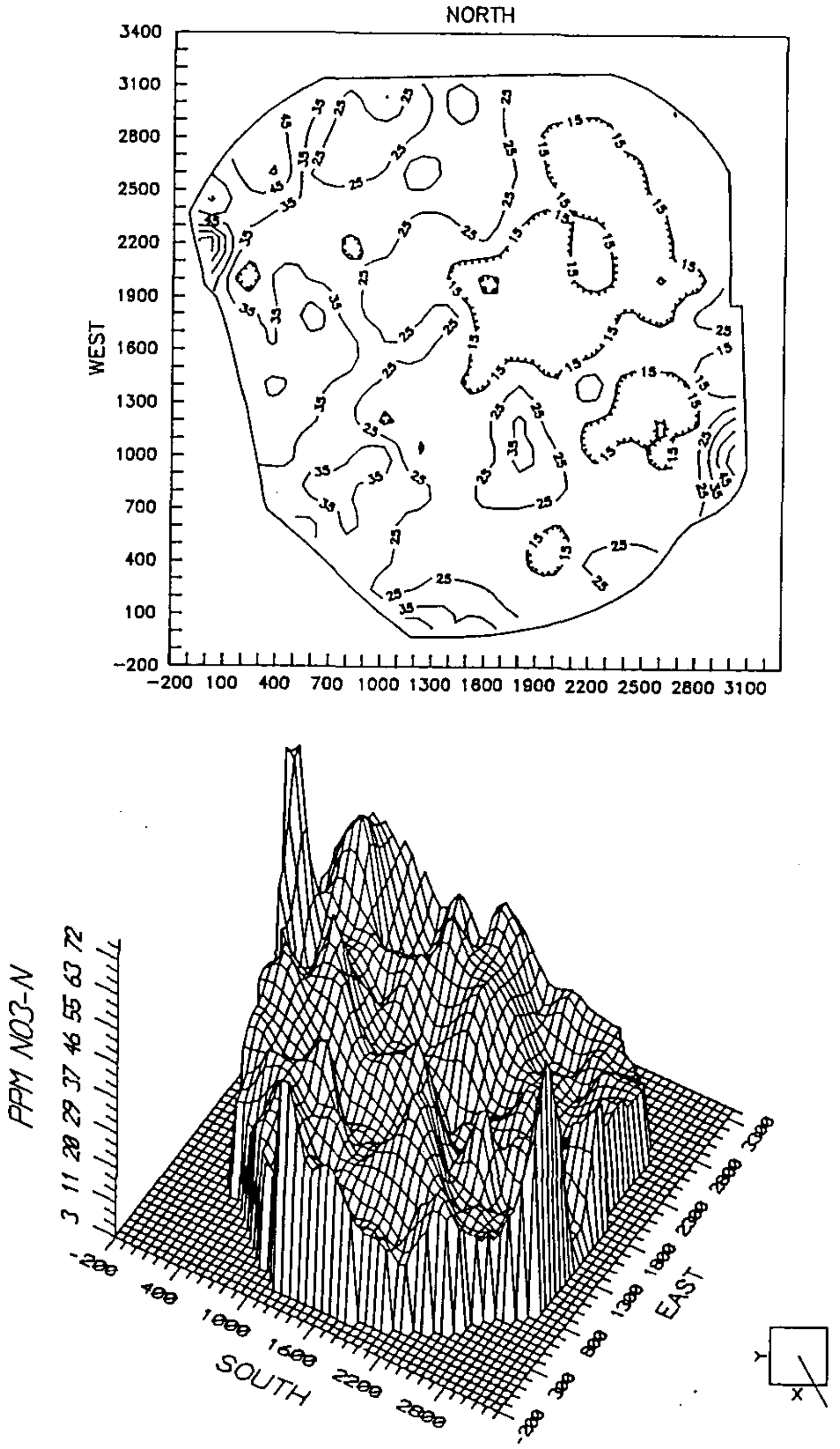


FIGURE 6. STUDY FIELD PPM $NH_4$-N

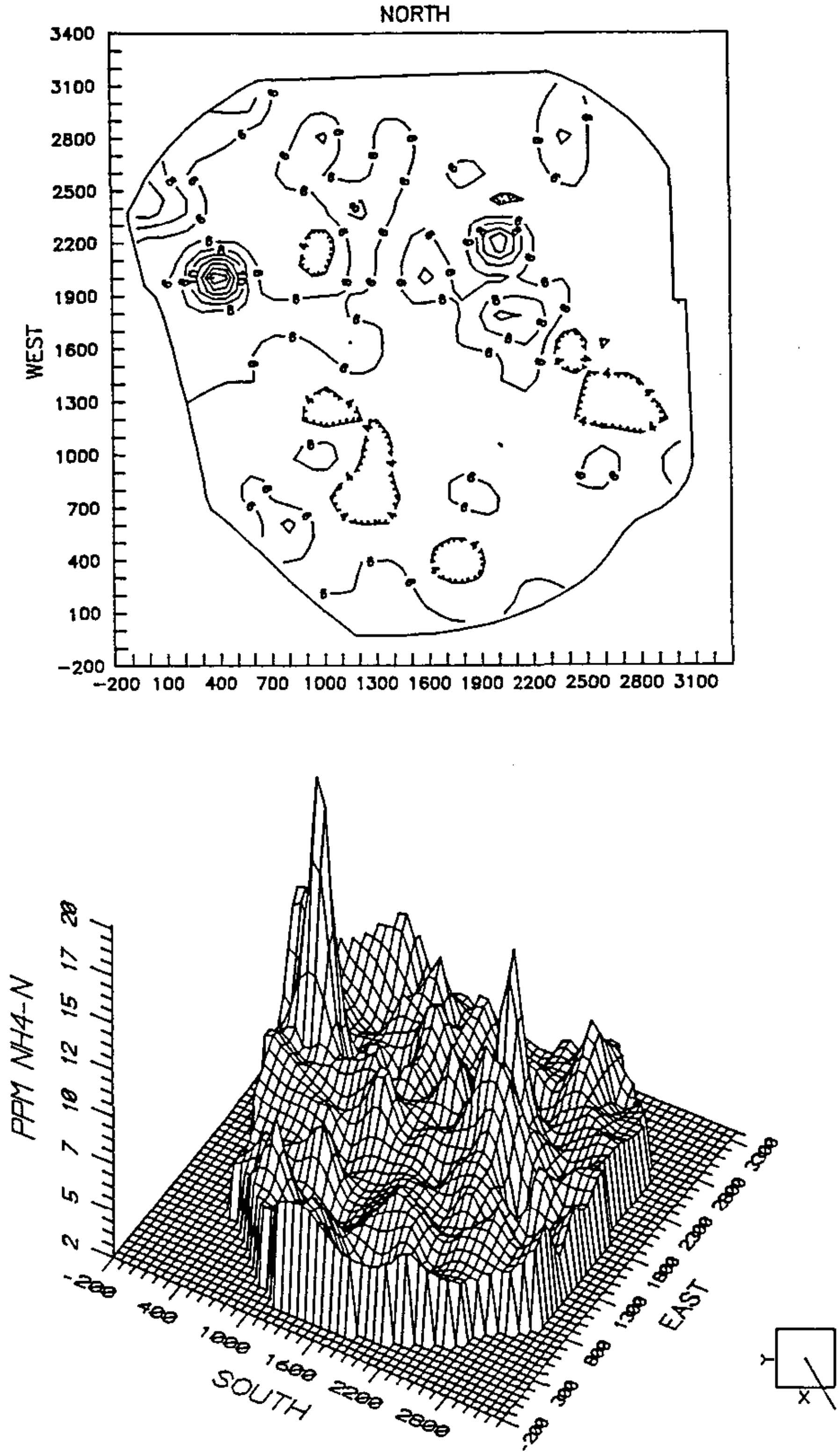


FIGURE 7. STUDY FIELD % ORGANIC MATTER

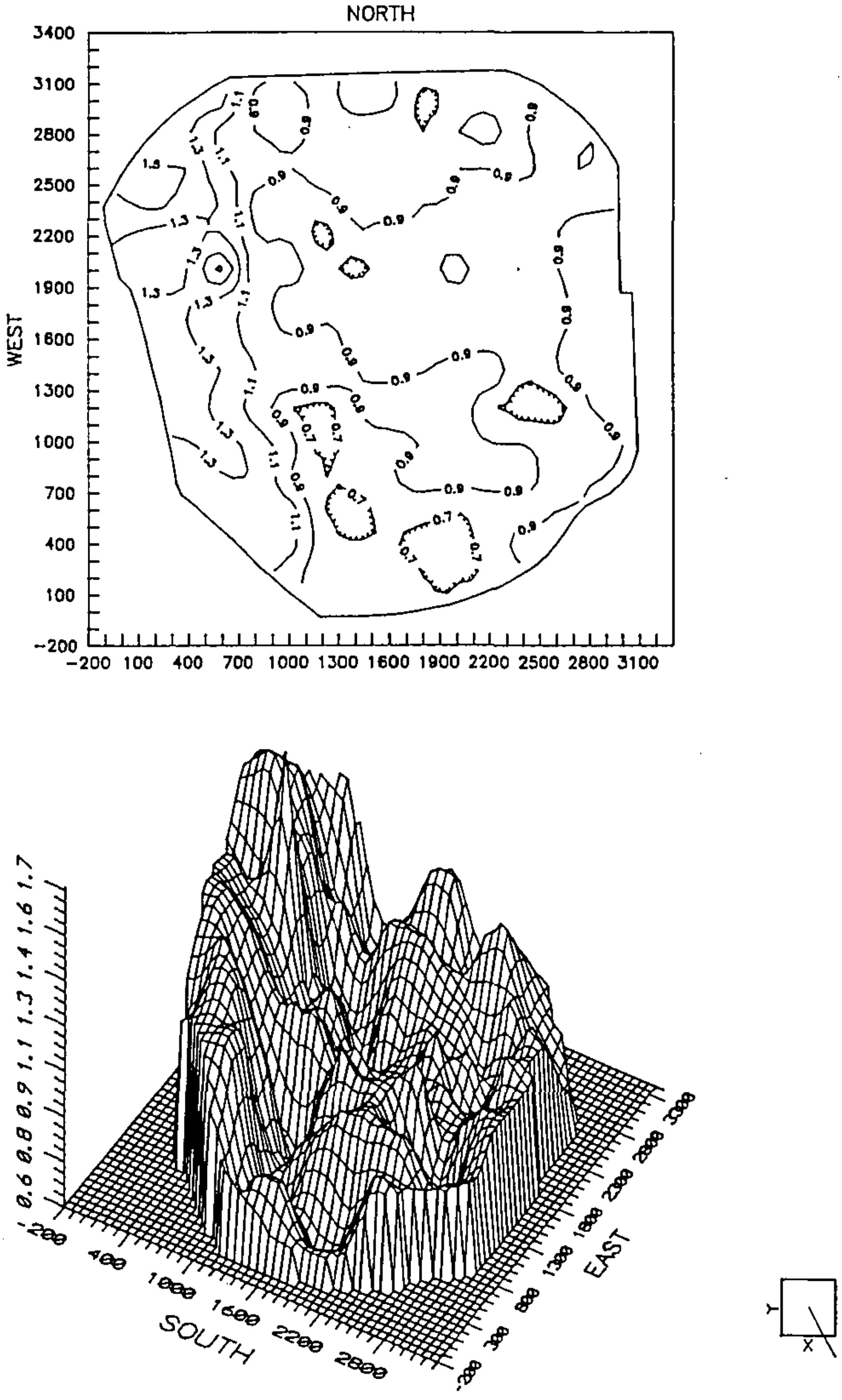


FIGURE 8. STUDY FIELD PPM PHOSPHORUS

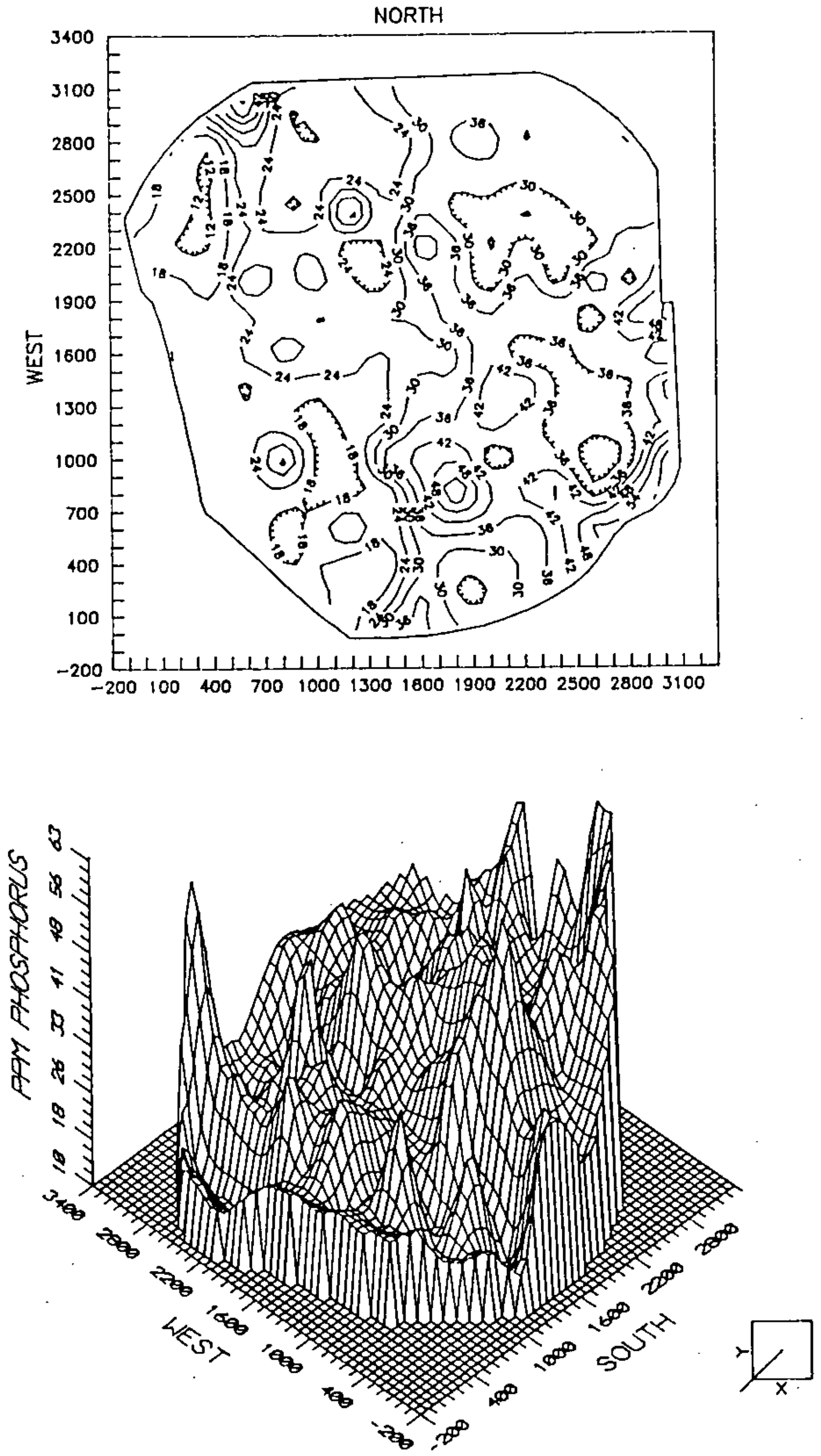


FIGURE 9. STUDY FIELD PPM POTASSIUM

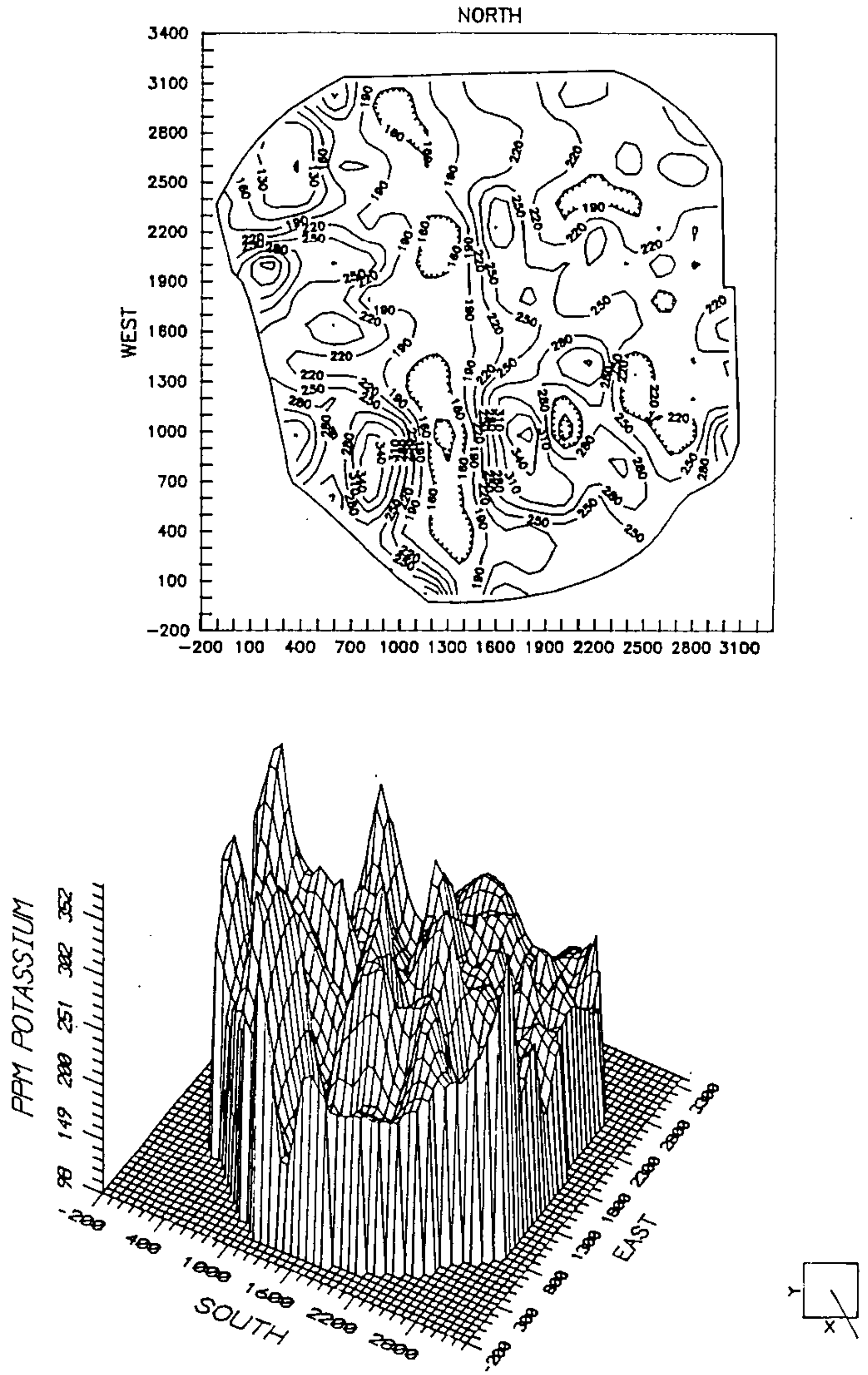


FIGURE 10. STUDY FIELD pH LEVELS

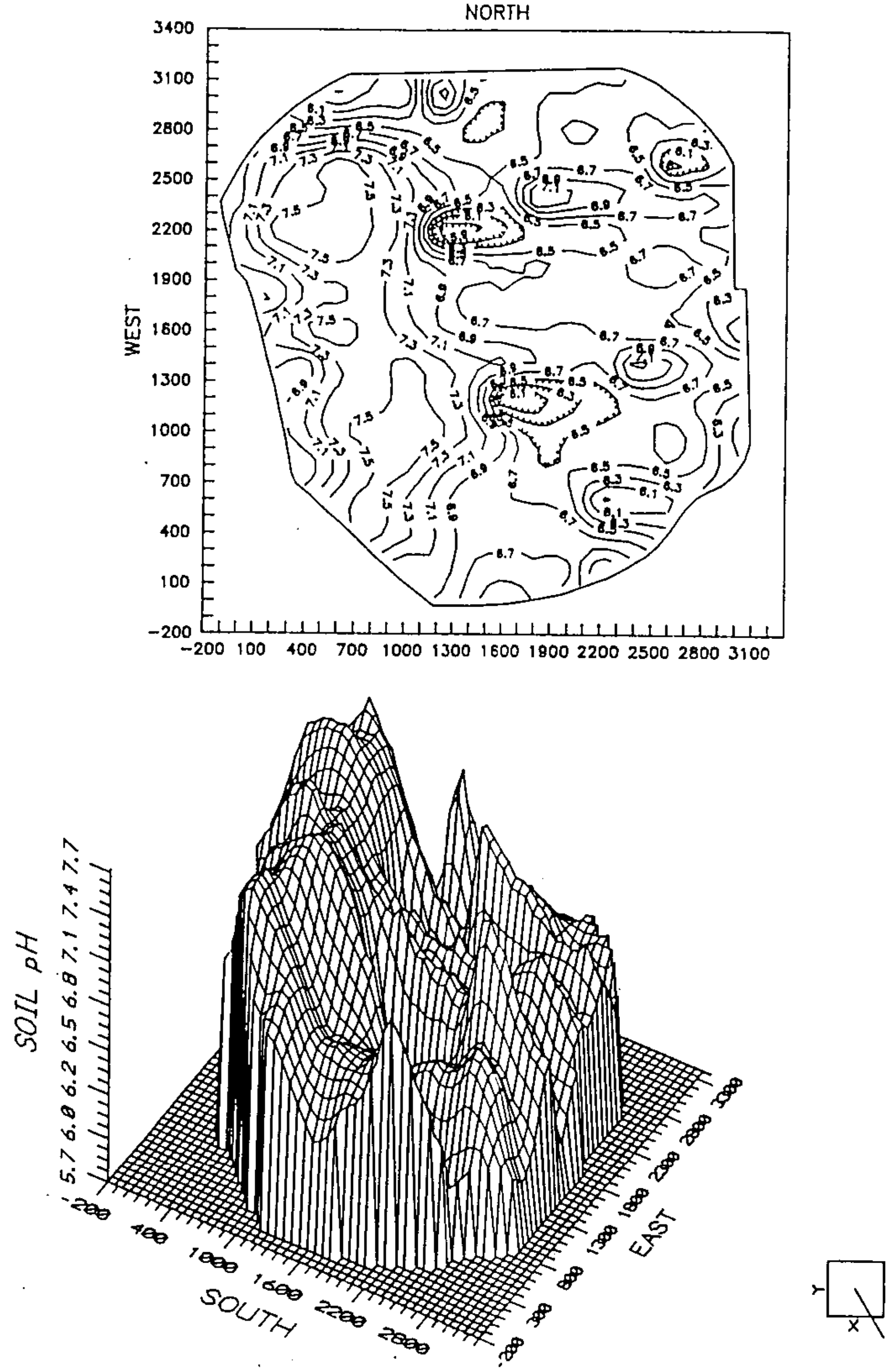


FIGURE 11. STUDY FIELD SOIL CARBONATE INDEX

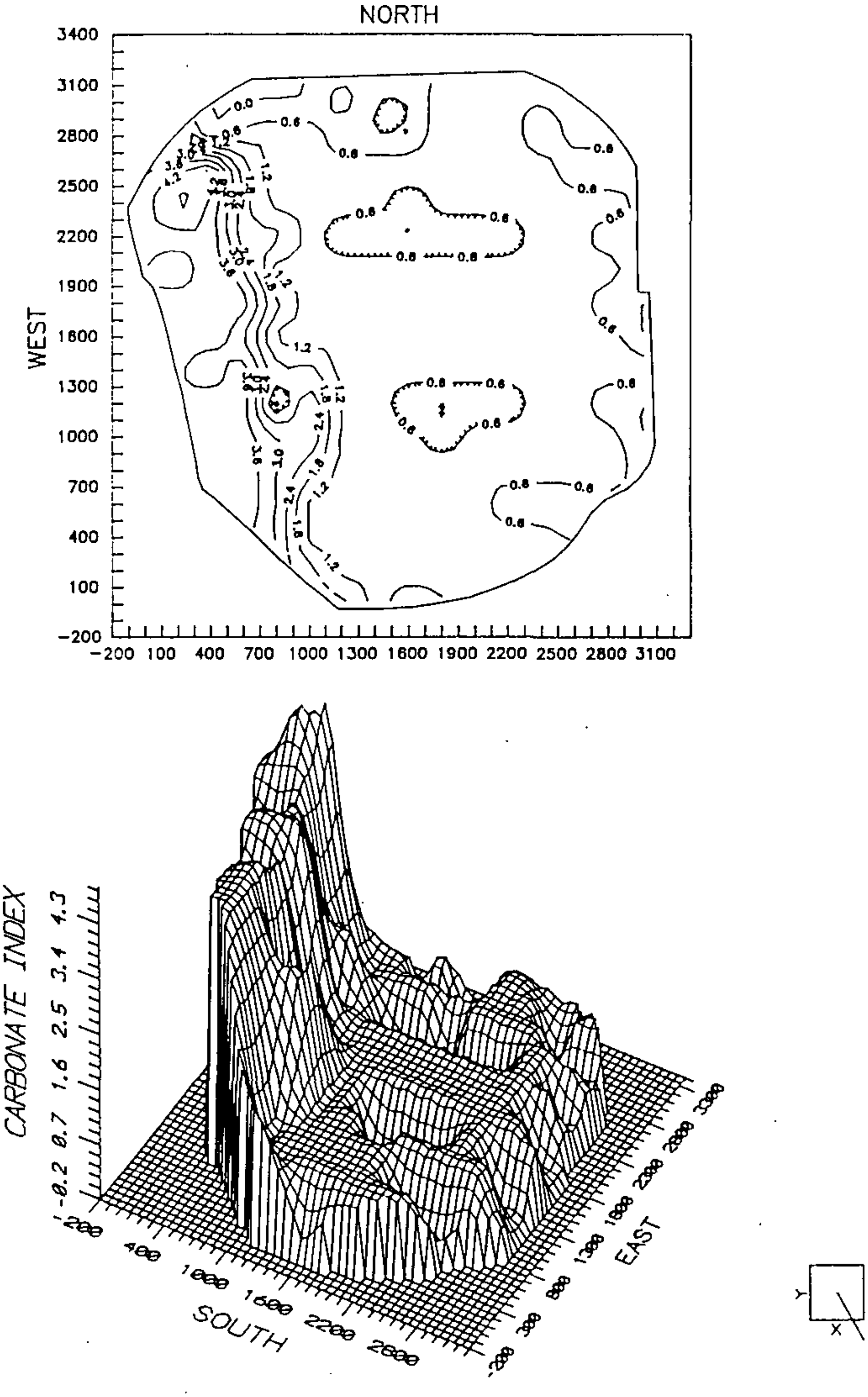


FIGURE 12. STUDY FIELD % SAND

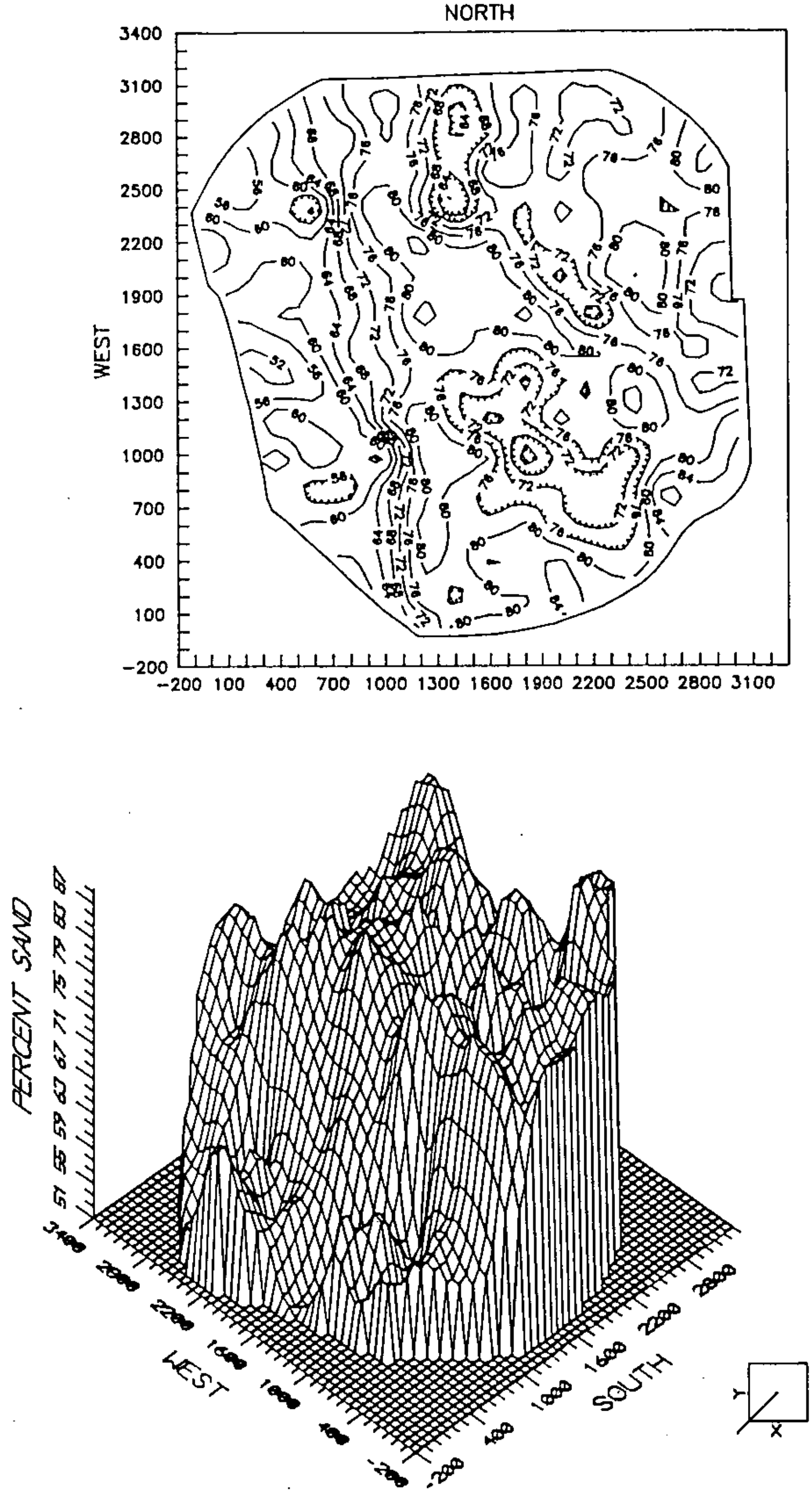


FIGURE 13. STUDY FIELD % SILT

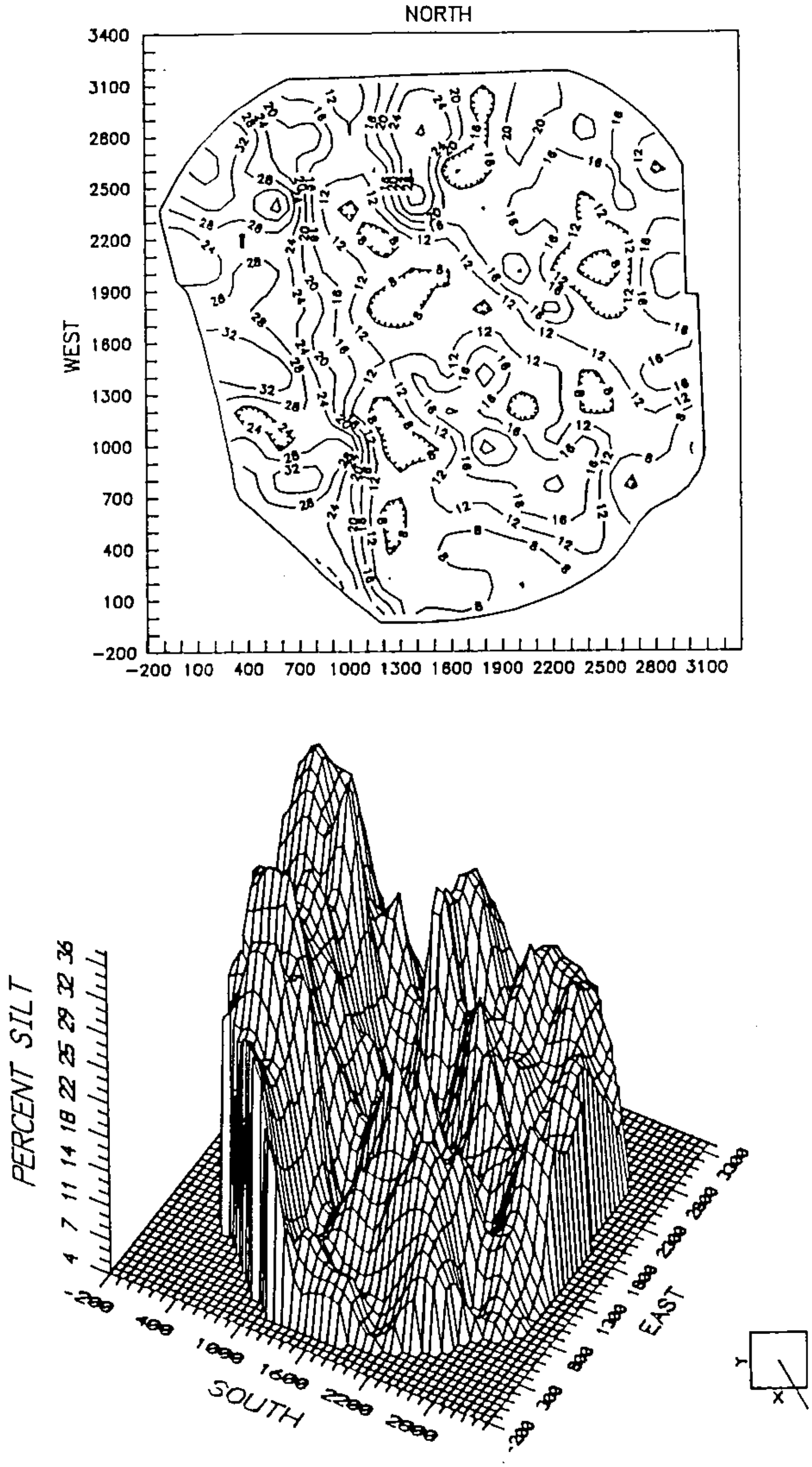


FIGURE 14. STUDY FIELD % CLAY

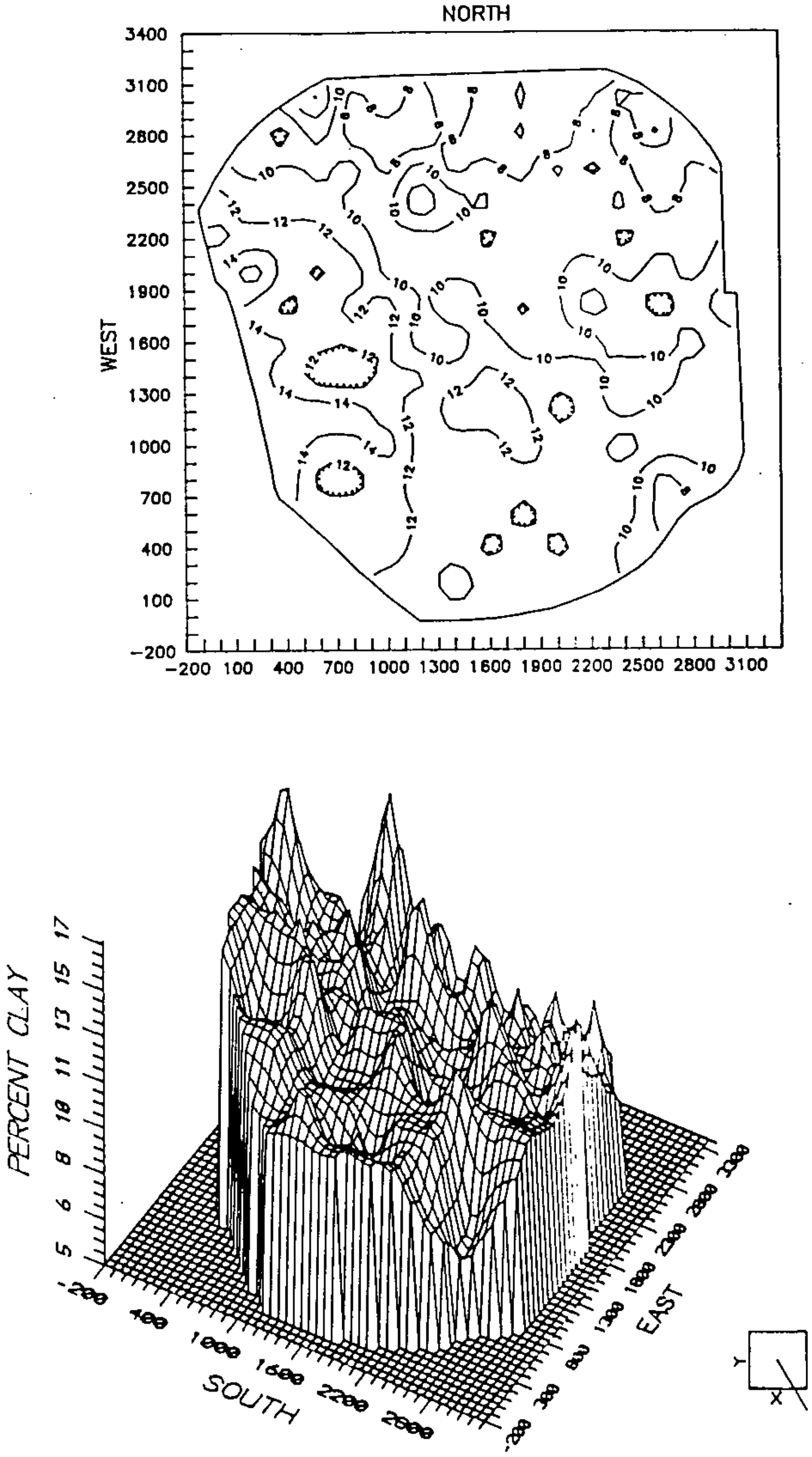


FIGURE 15. STUDY FIELD DEPTH TO ROCKS

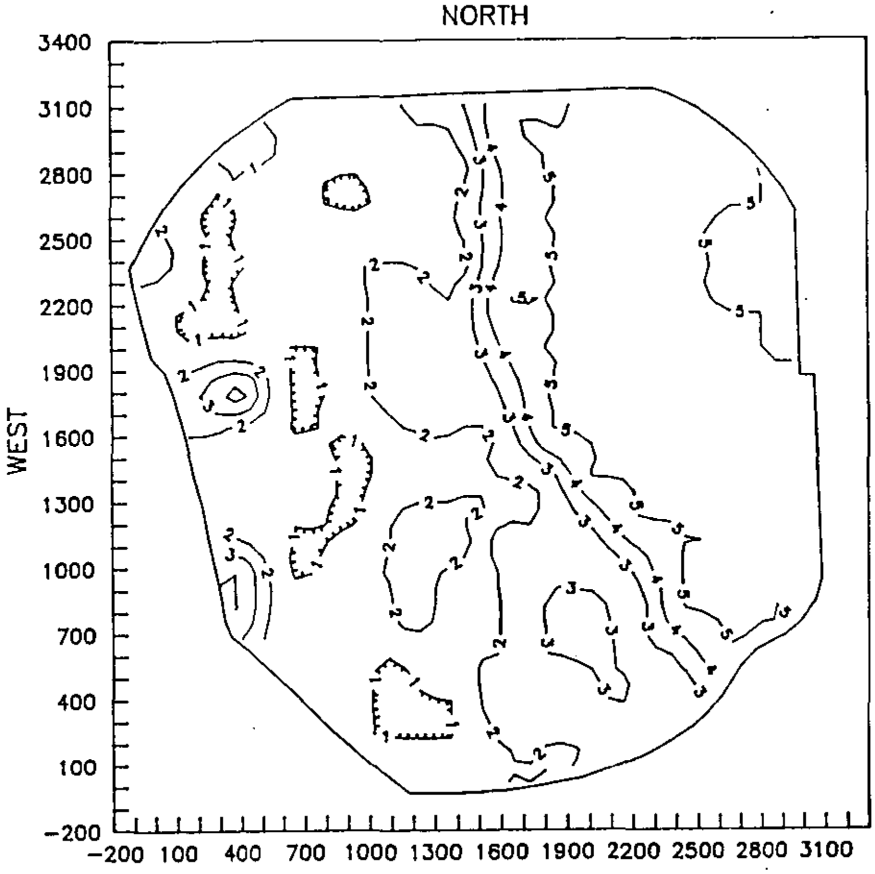


FIGURE 16. SOIL TEXTURAL ZONES AND STUDY SITE AREAS IN TEXTURAL ZONES

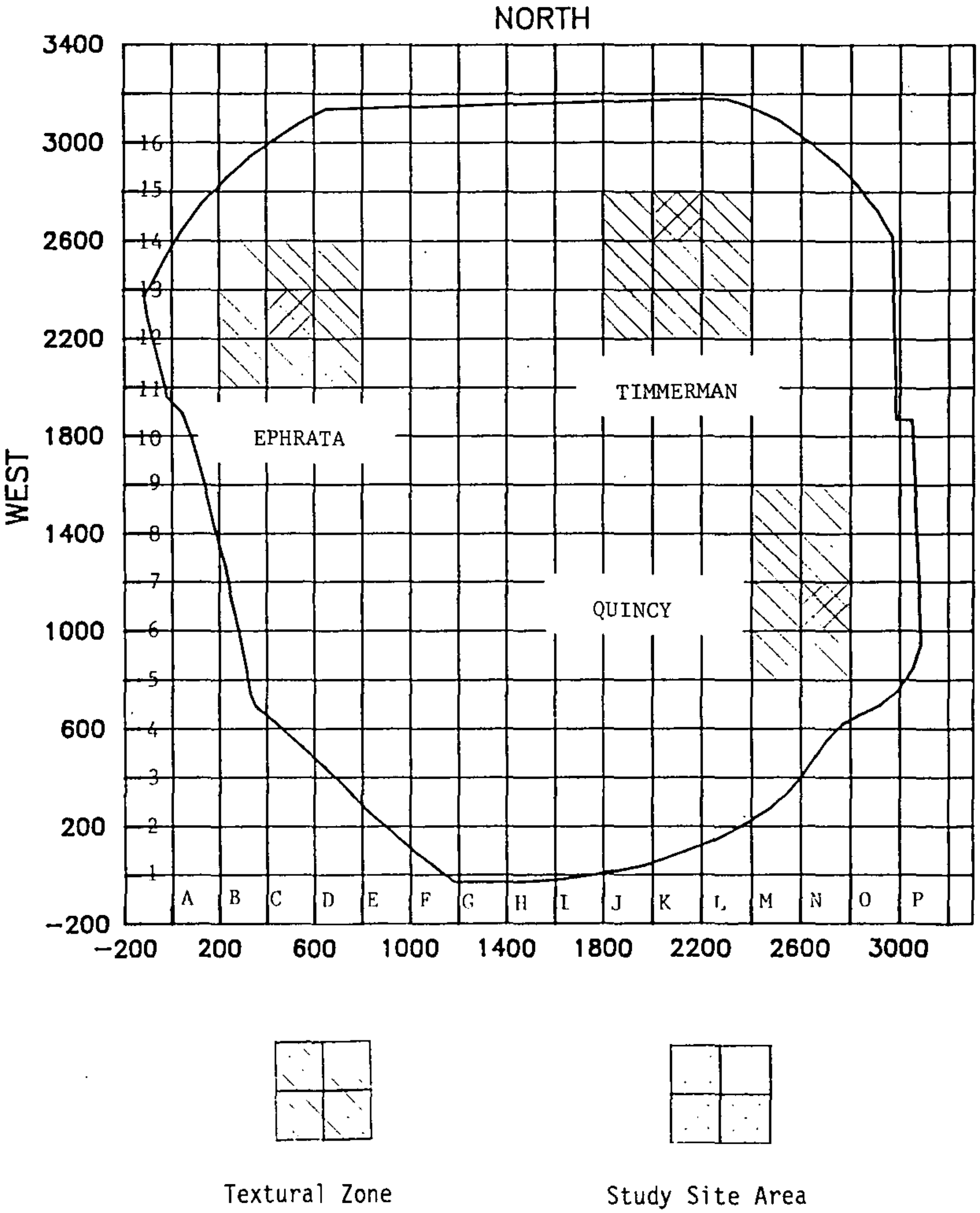


FIGURE 17. QUINCY SITE AREA % SILT WITH STUDY SITE LOCATIONS

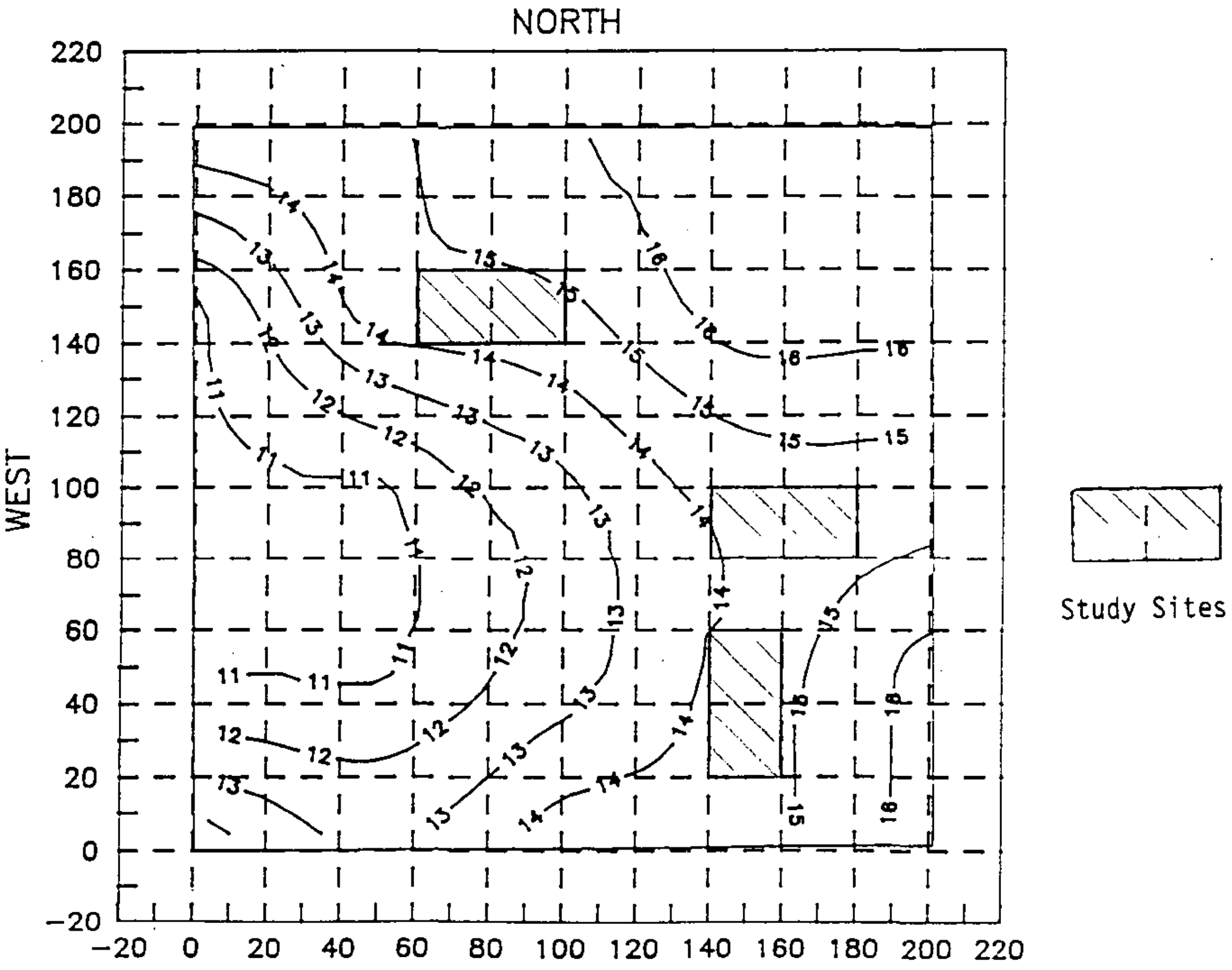


FIGURE 18. QUINCY SITE AREA % SAND

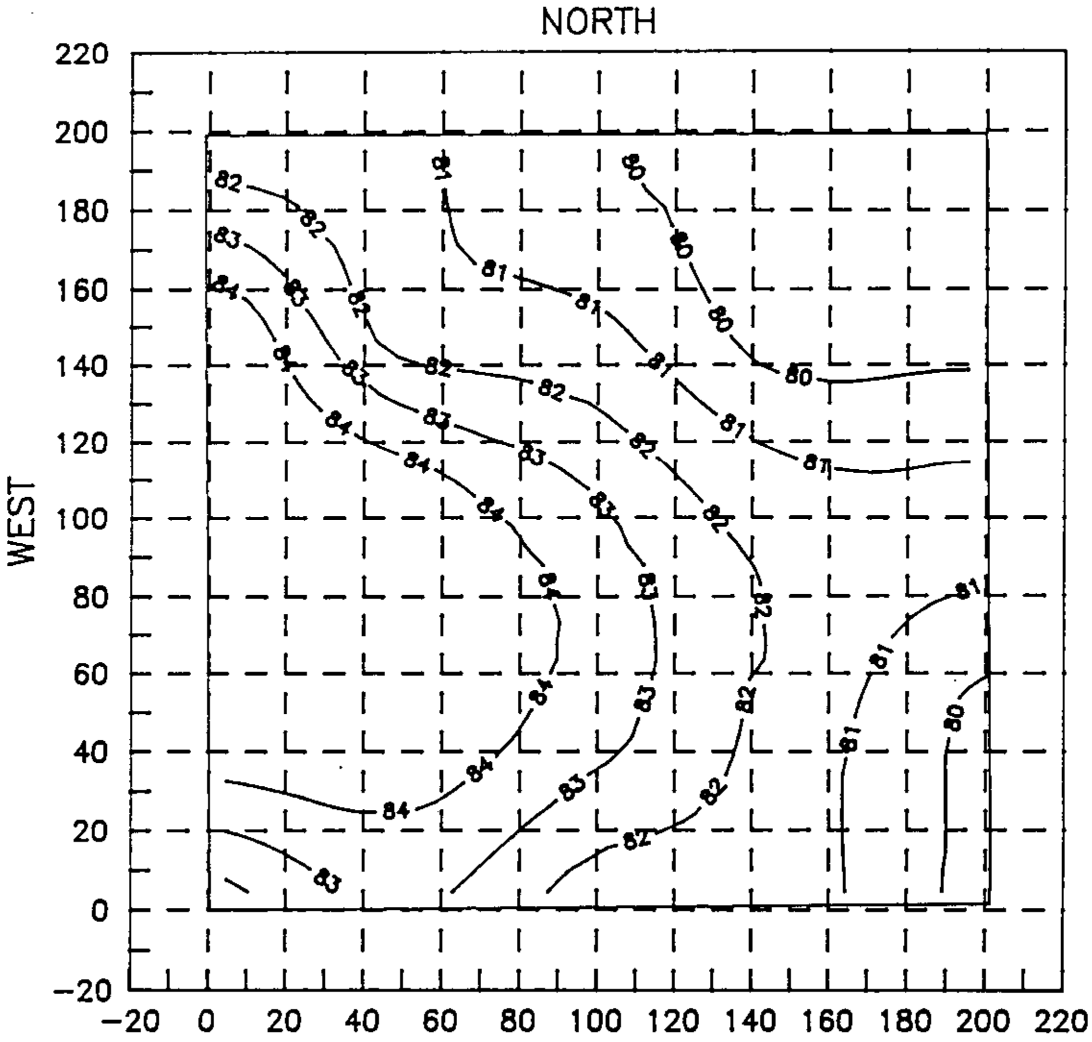


FIGURE 19. QUINCY SITE AREA PPM $NO_3$-N

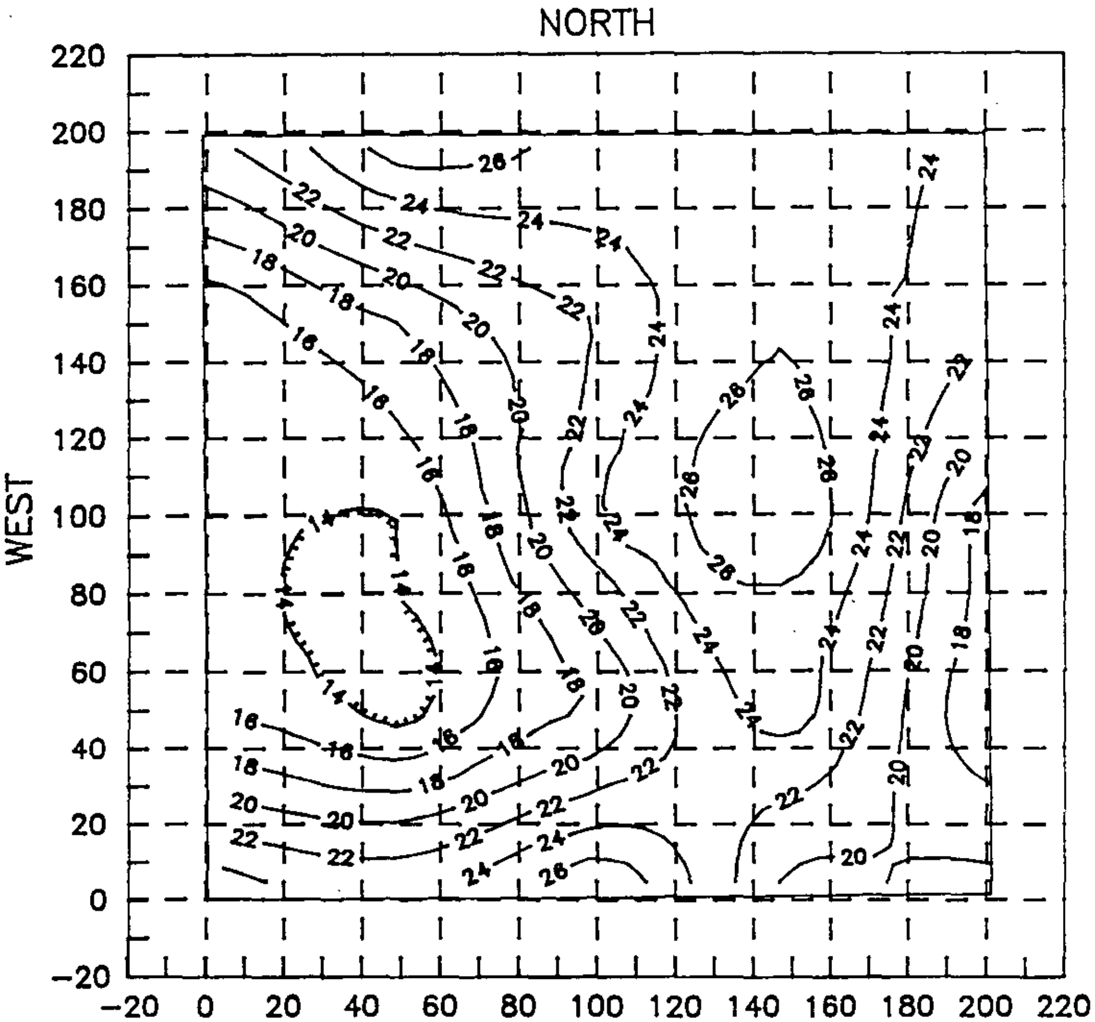


FIGURE 20. TIMMERMAN SITE AREA % SILT WITH STUDY SITE LOCATIONS

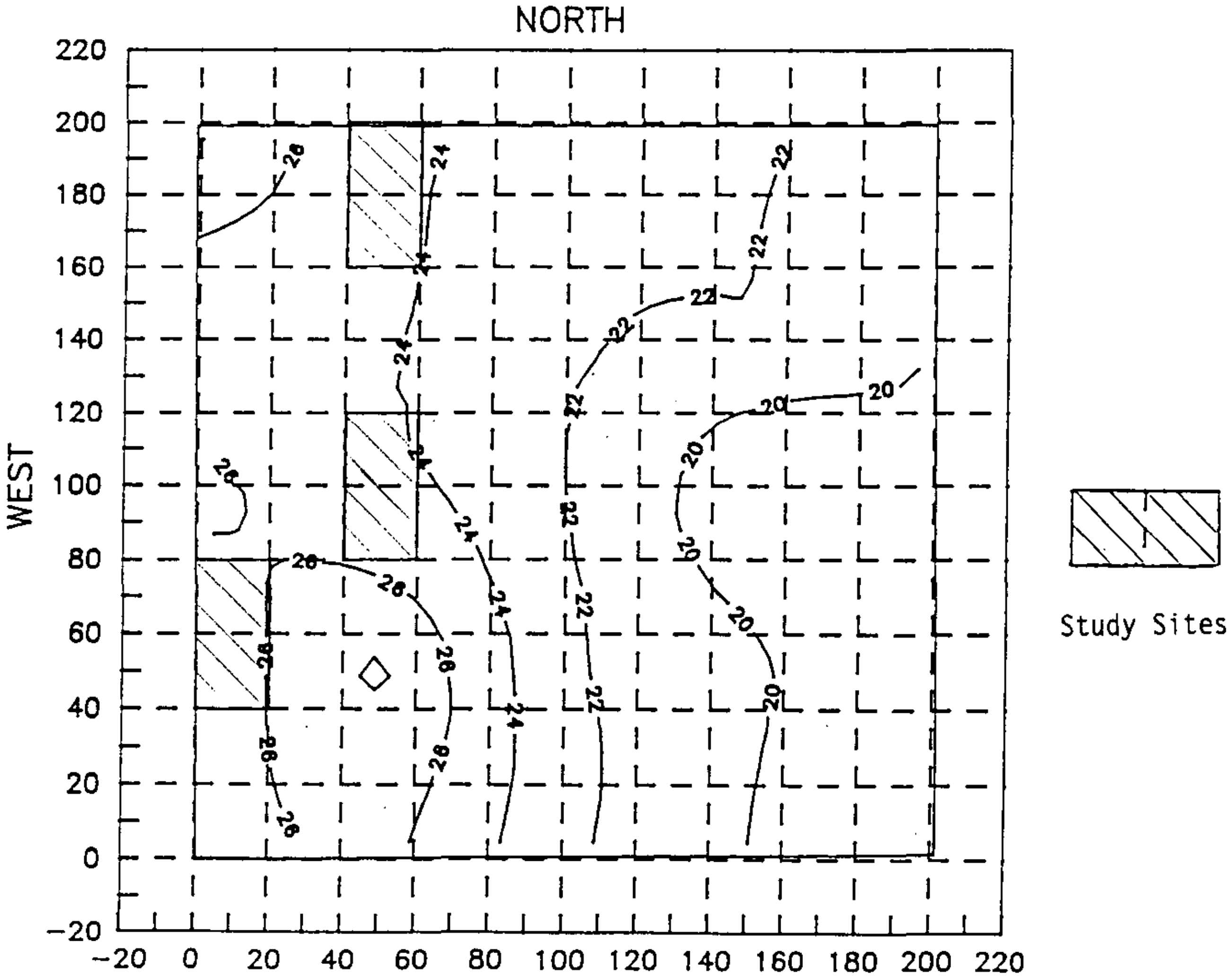


FIGURE 21. TIMMERMAN SITE AREA % SAND

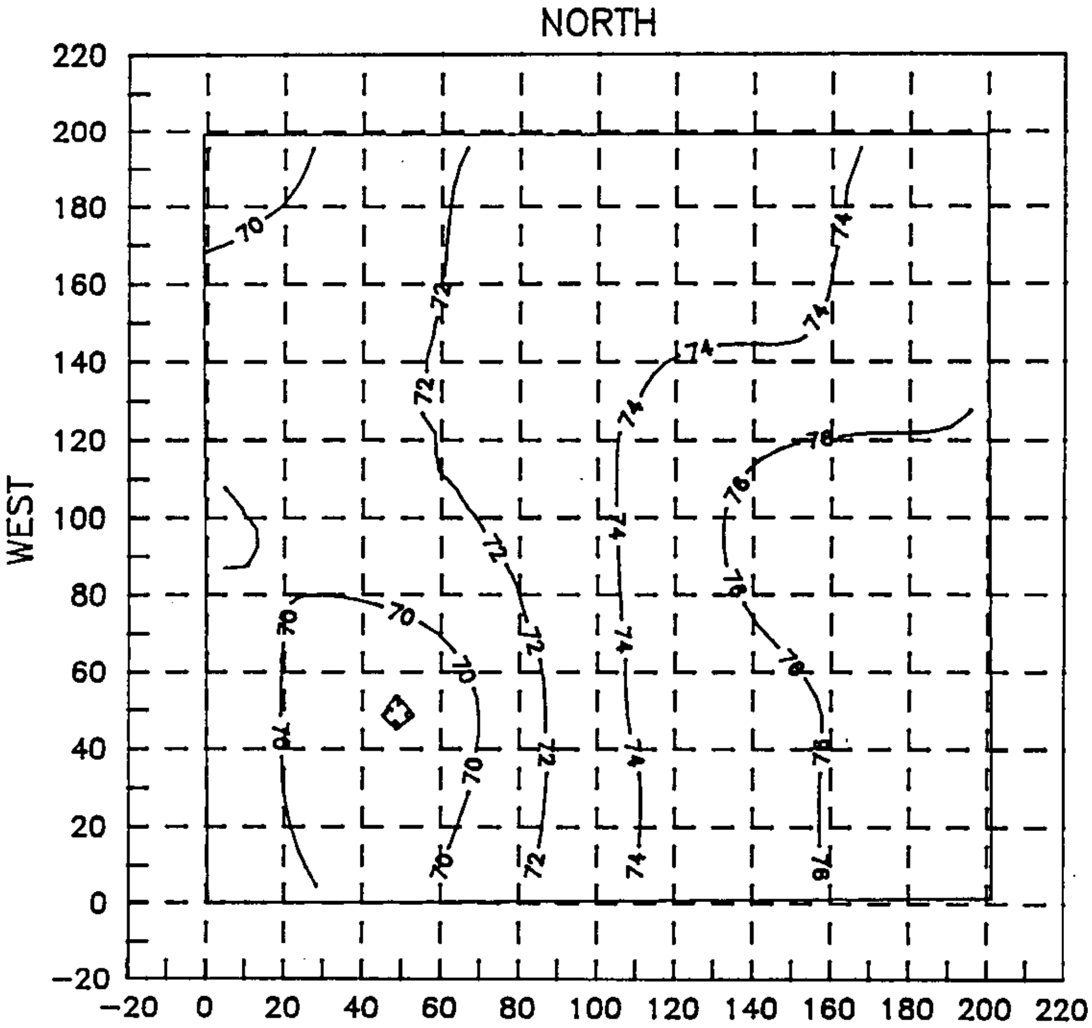


FIGURE 22. TIMMERMAN SITE AREA PPM $NO_3$-N

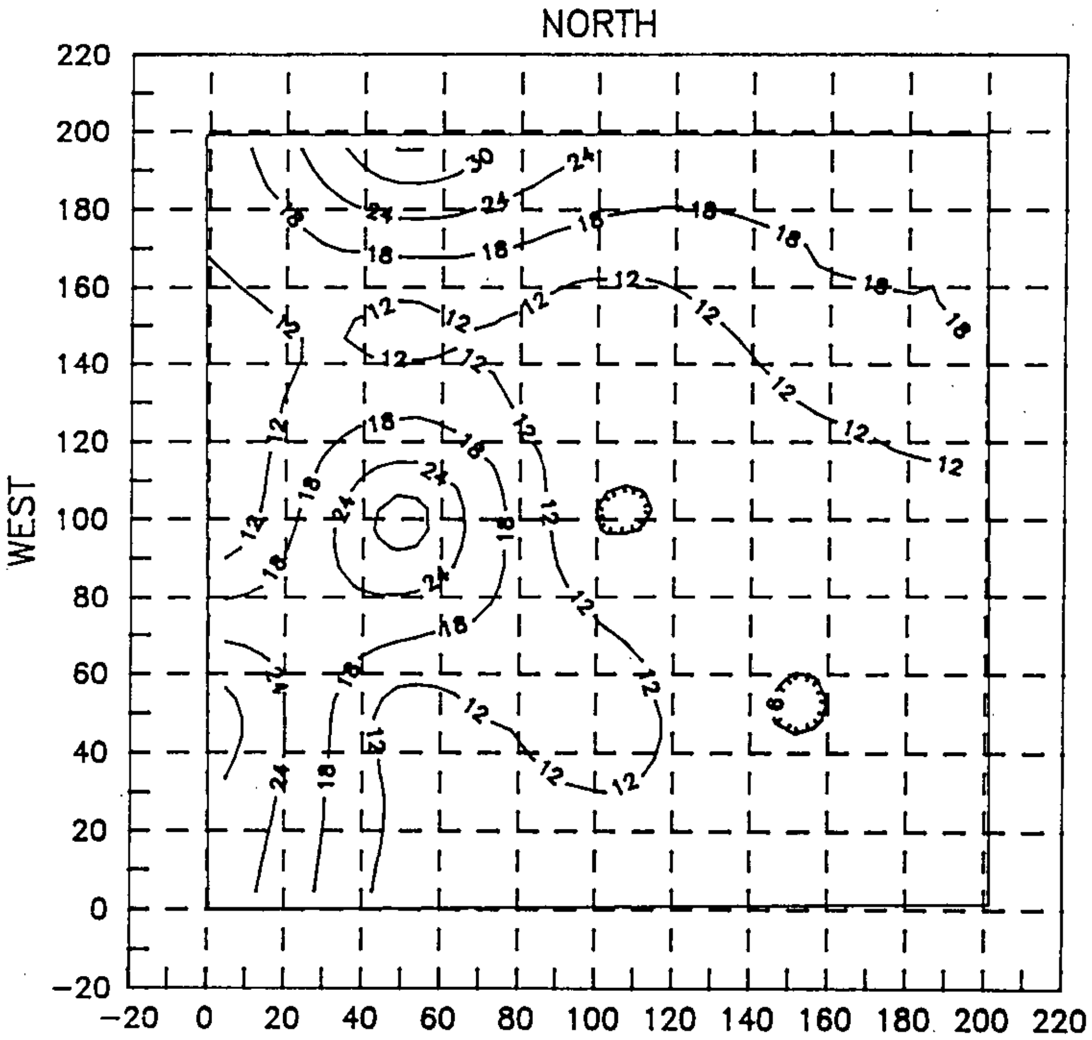


FIGURE 23. EPHRATA SITE AREA % SILT WITH STUDY SITE LOCATIONS

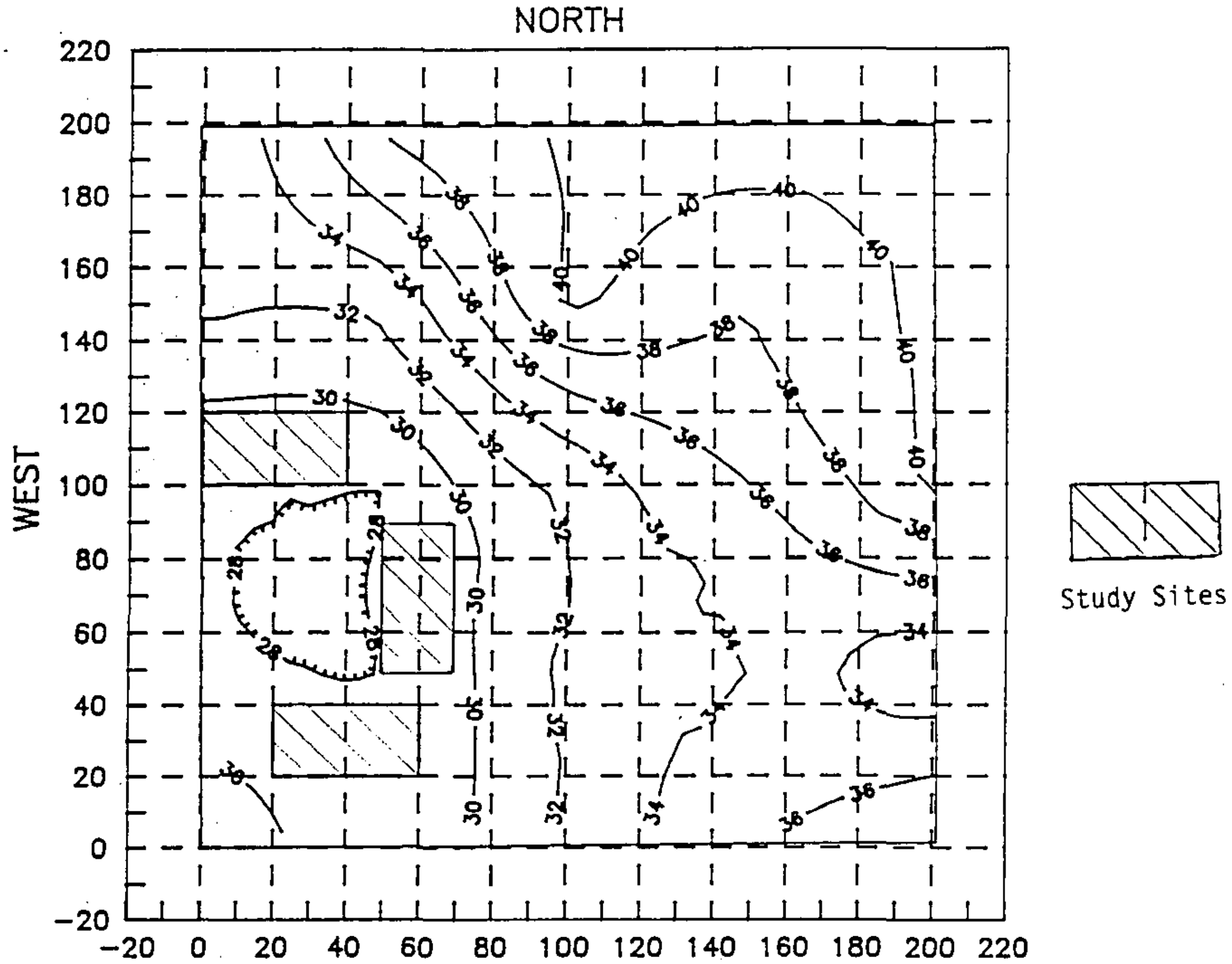


FIGURE 24. EPHRATA SITE AREA % SAND

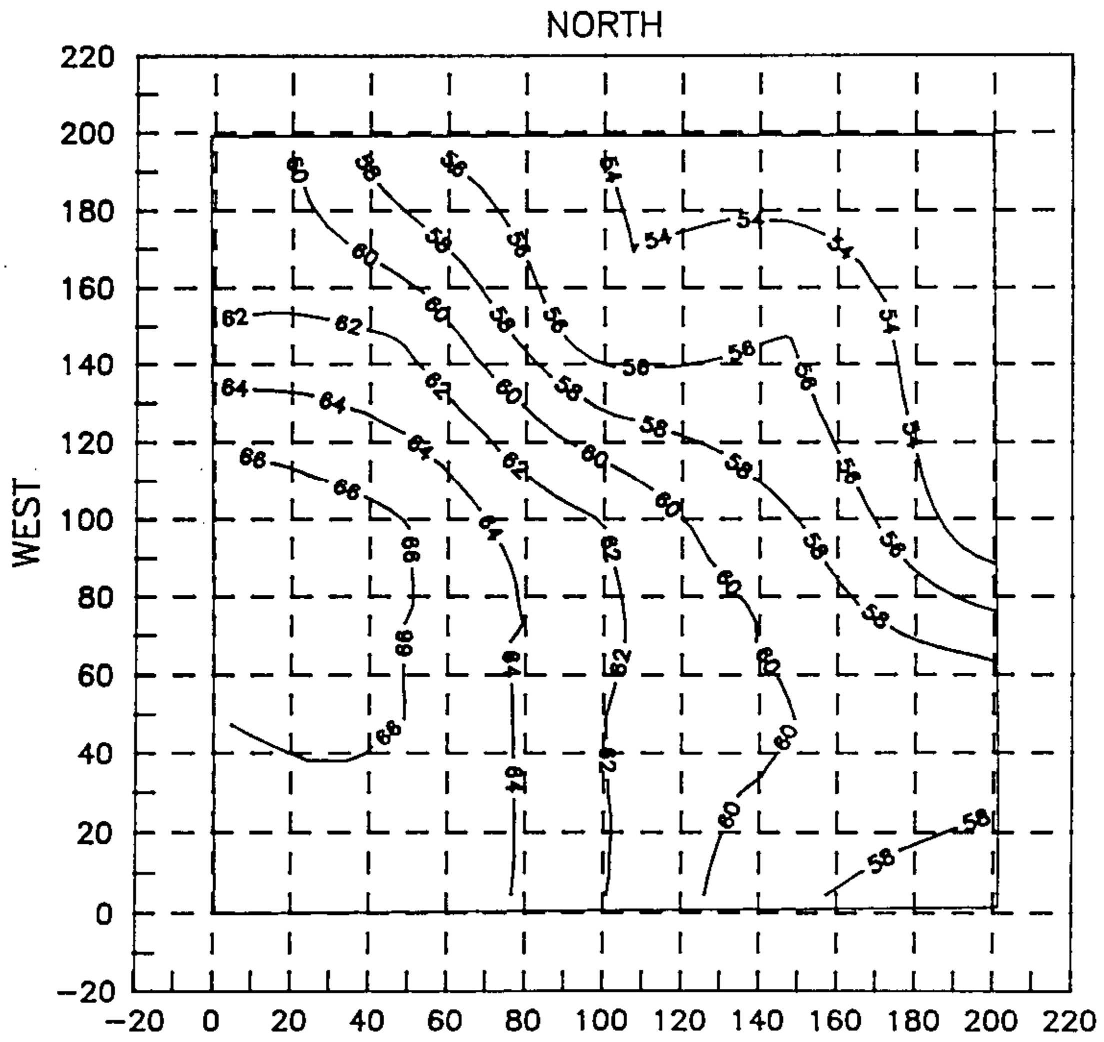


FIGURE 25. EPHRATA SITE AREA PPM $NO_3$-N

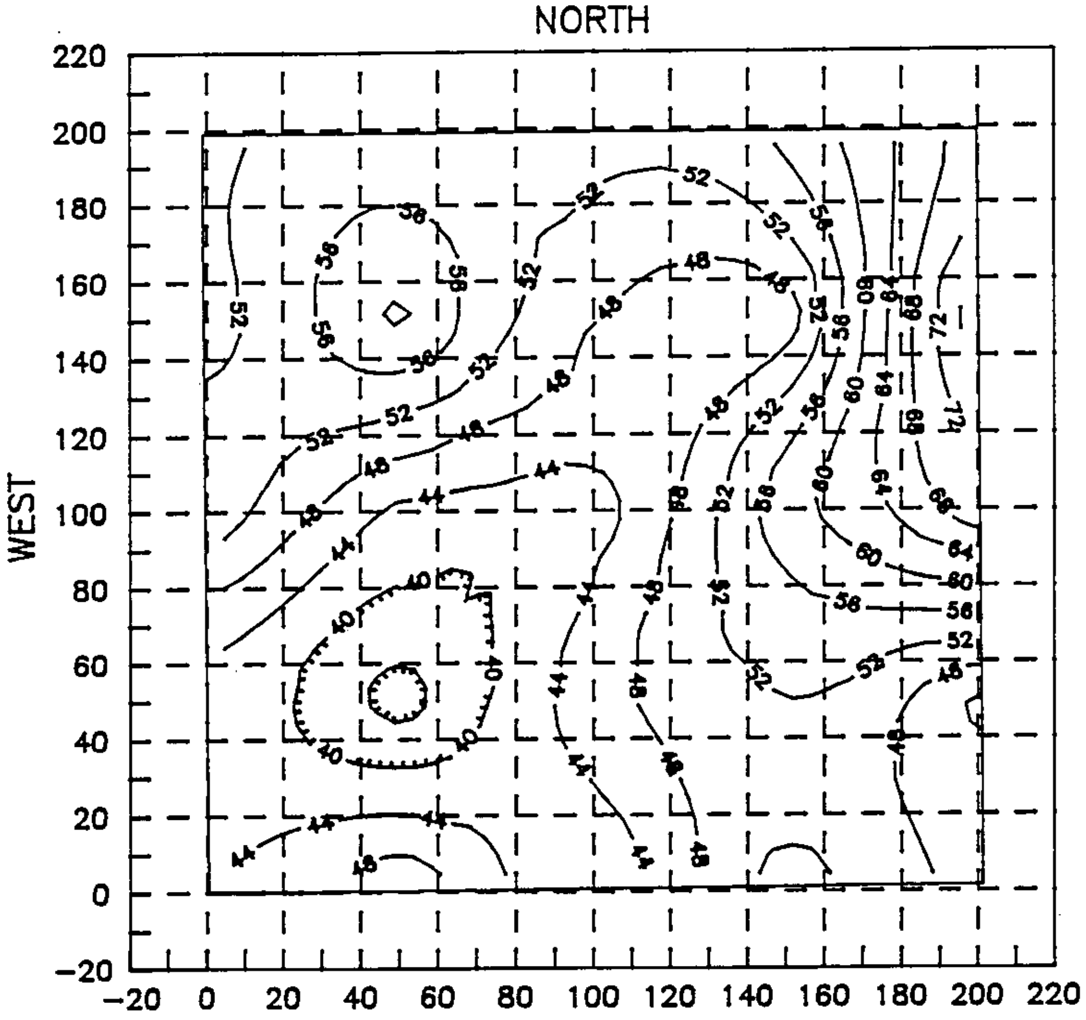


FIGURE 26. EXAMPLE OF STUDY SITE WATER AND NITROGEN APPARATUS - QUINCY AND TIMMERMAN SITES.

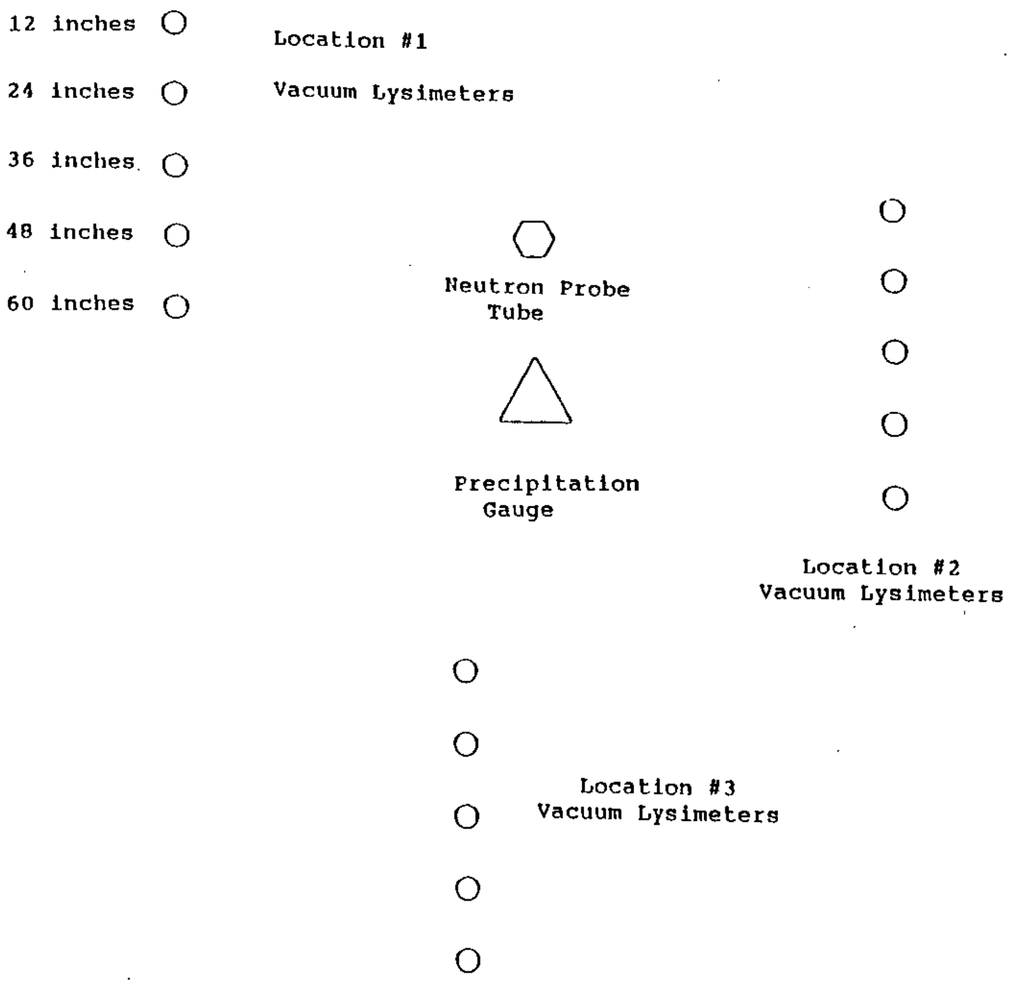


FIGURE 27. VACUUM LYSIMETER

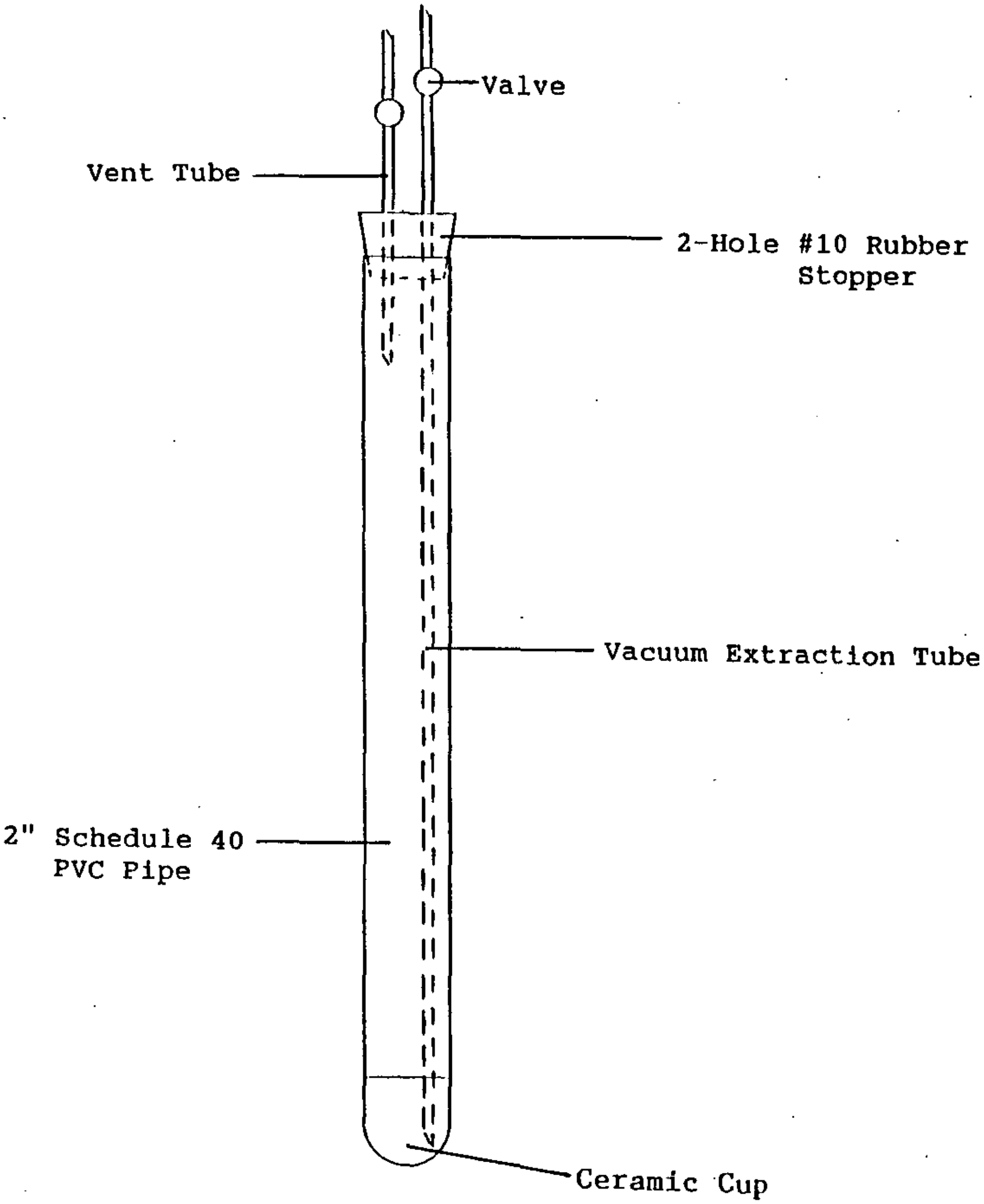


FIGURE 28. SURFACE ACCESS VACUUM LYSIMETER

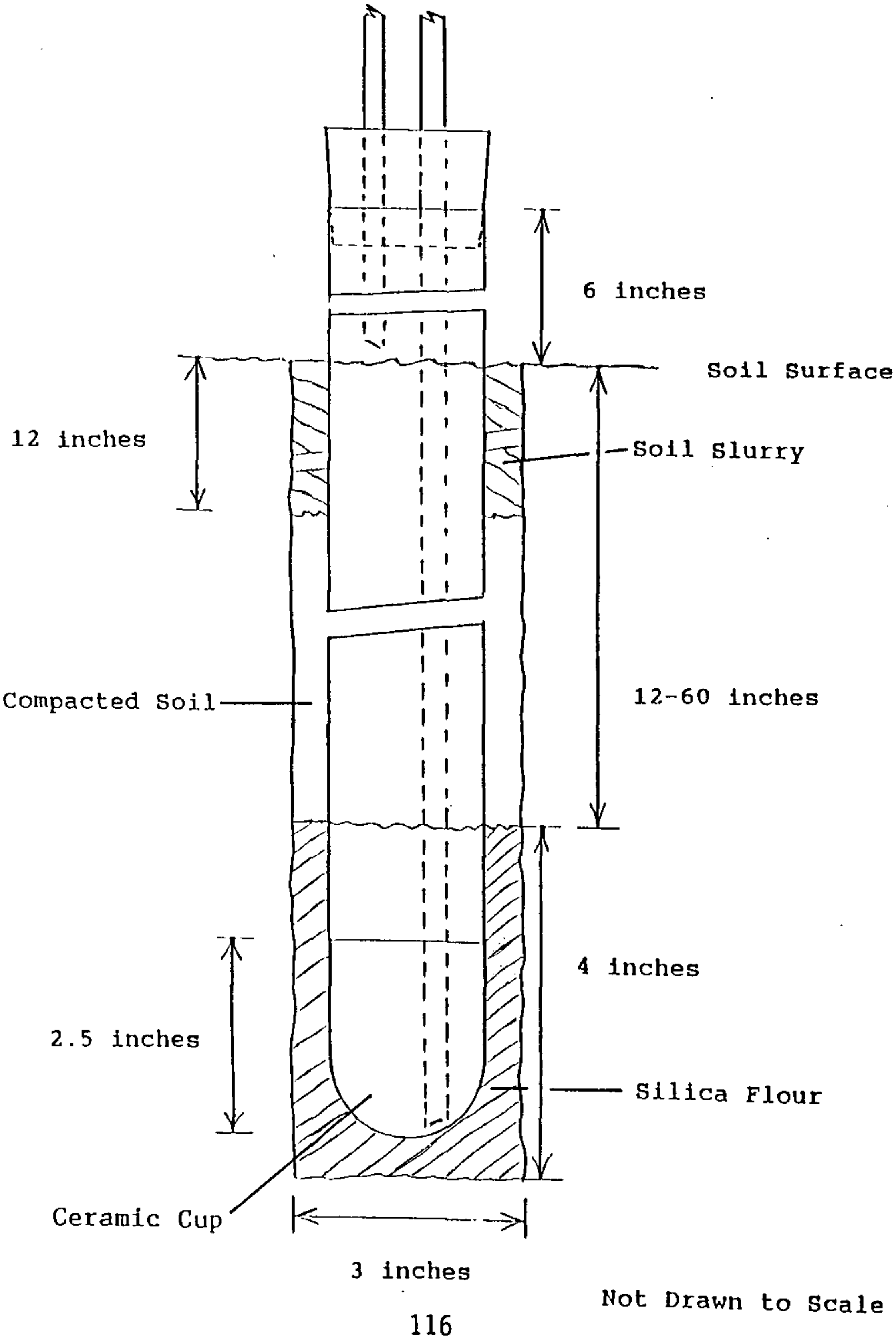


FIGURE 29. EXAMPLE OF STUDY SITE WATER AND NITROGEN APPARATUS - EPHRATA SITES.

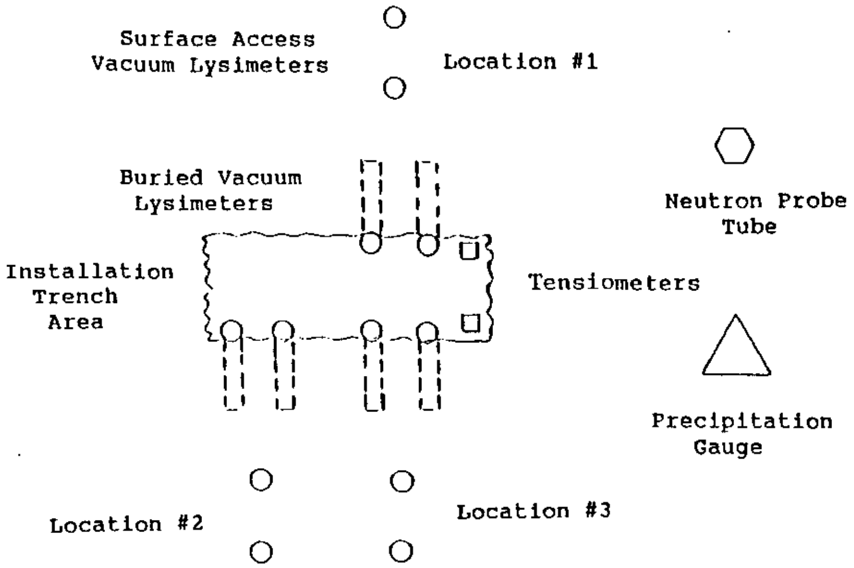
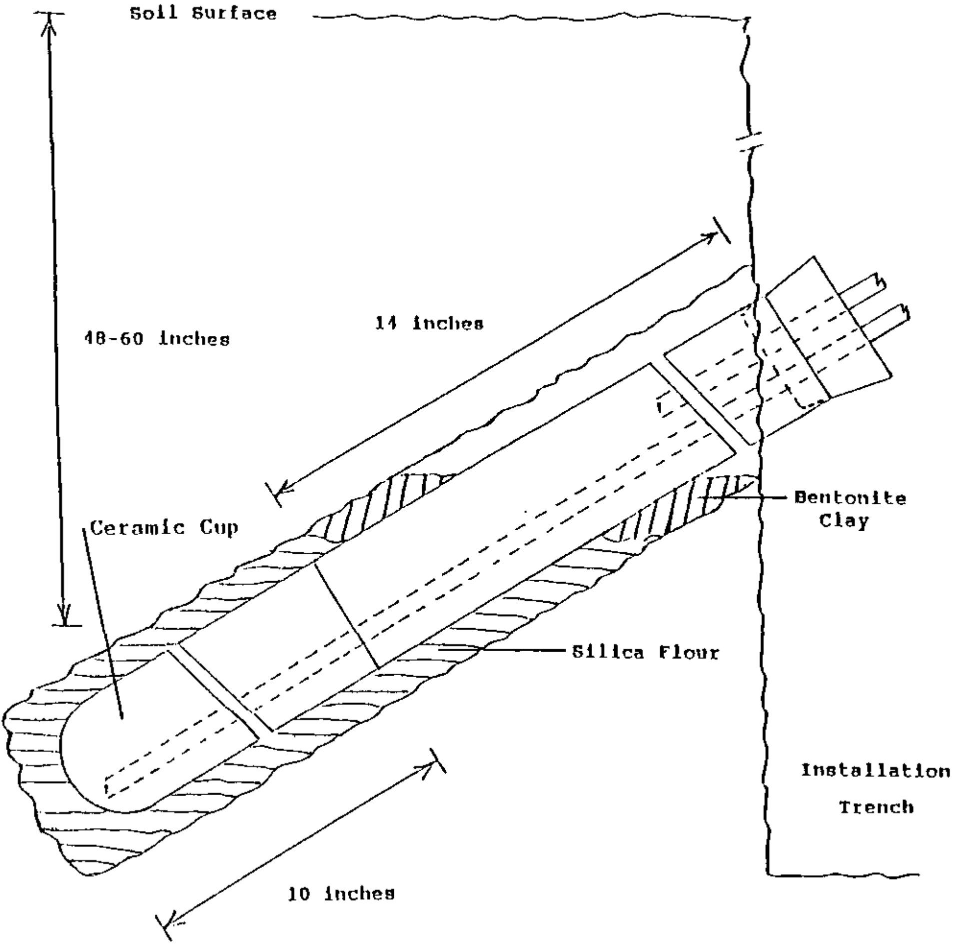


FIGURE 30. BURIED VACUUM LYSIMETER



# FIGURE 31. SOIL SOLUTION NO3-N LEVELS

QUINCY SITE AVERAGES

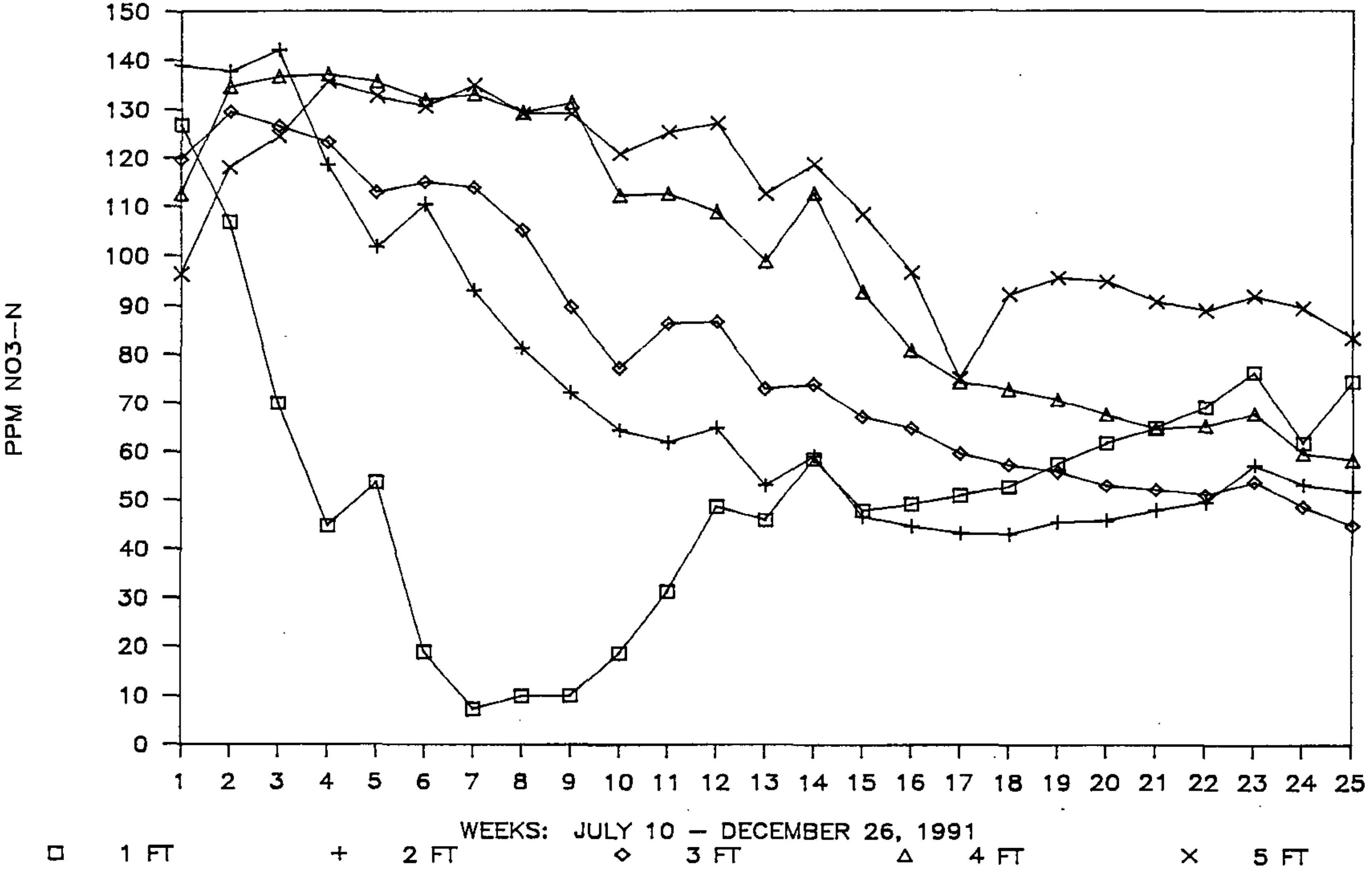
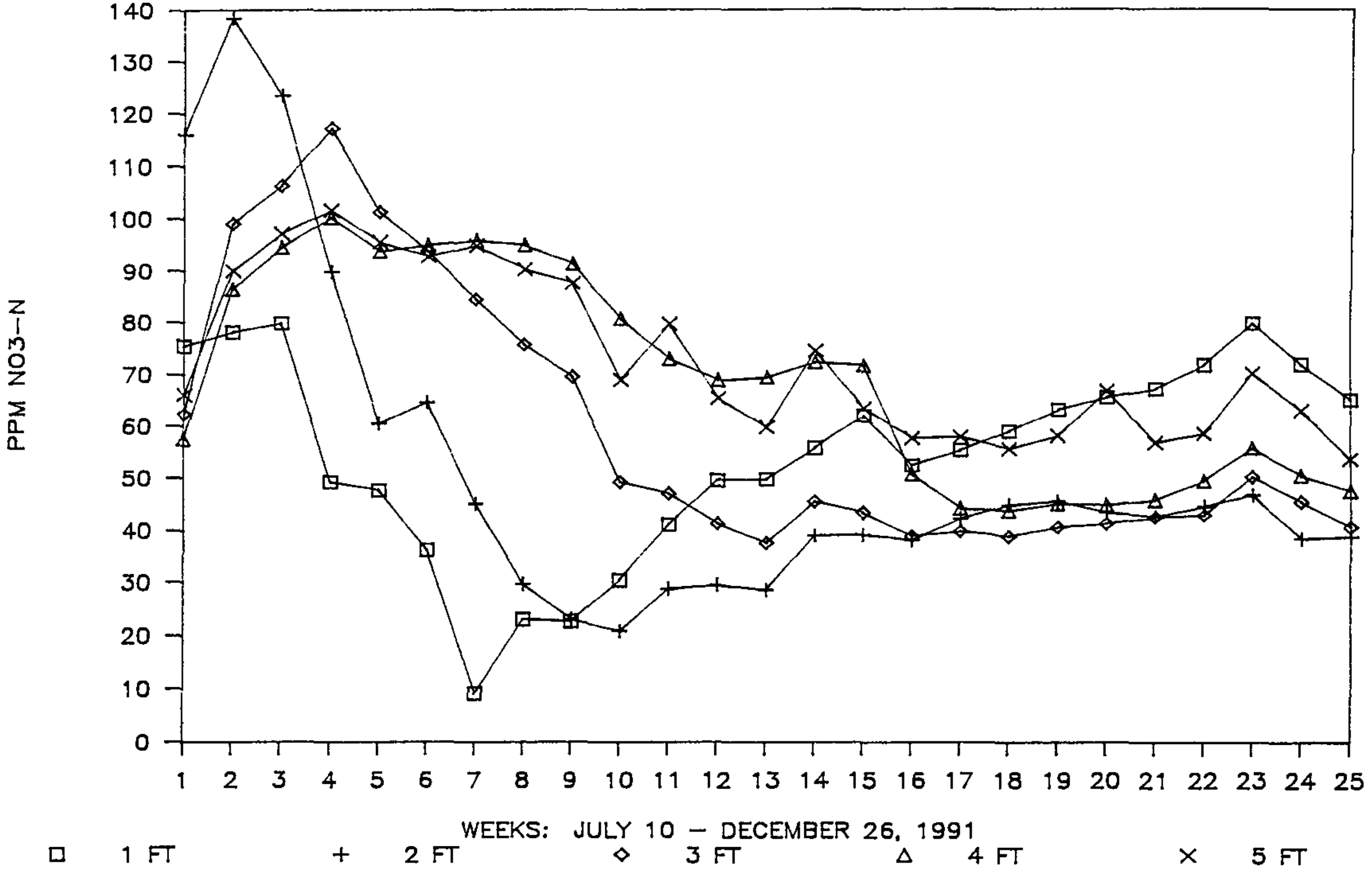


FIGURE 32. SOIL SOLUTION NO3-N LEVELS

TIMMERMAN SITE AVERAGES



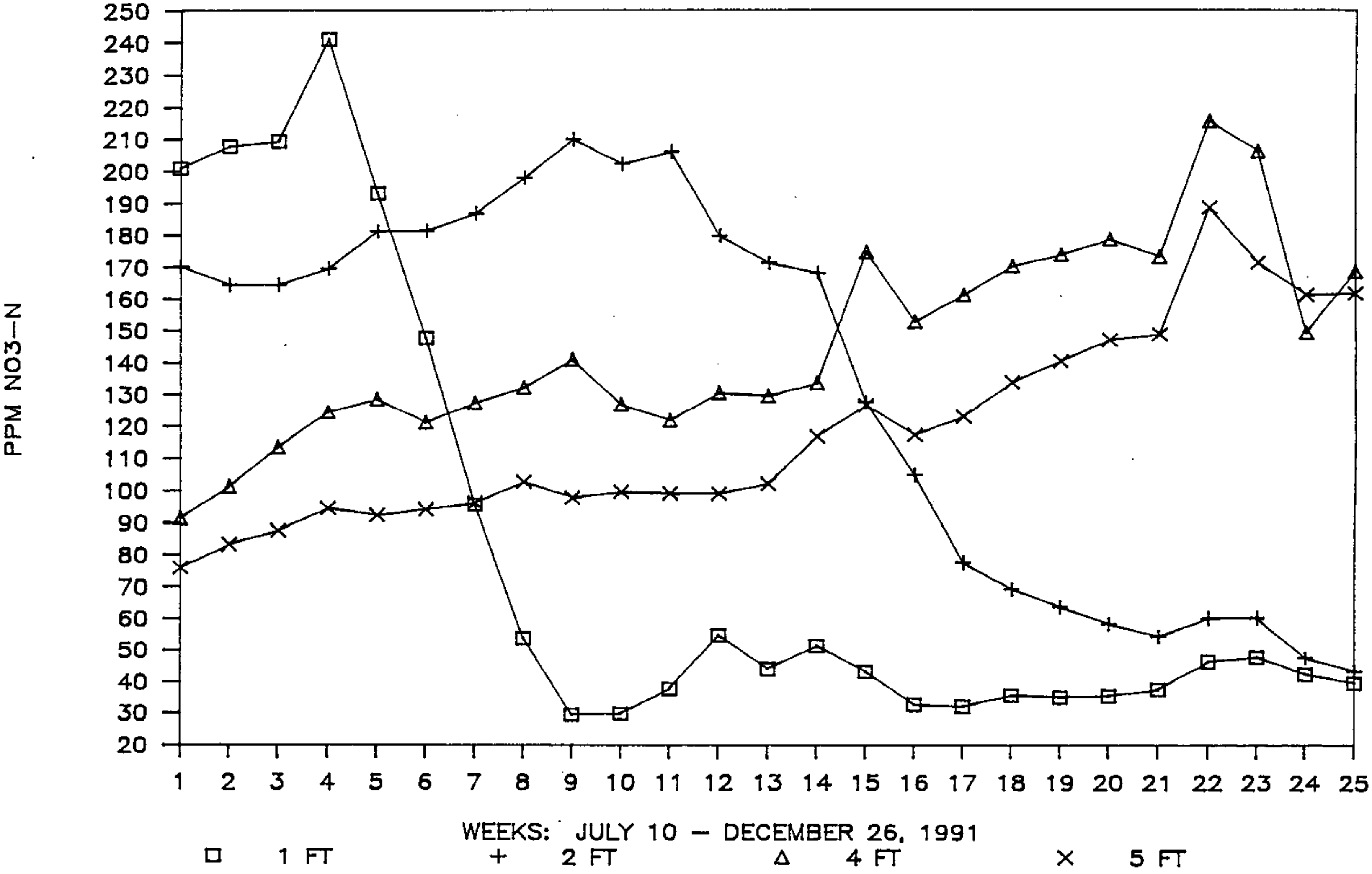


FIGURE 33. SOIL SOLUTION NO3-N LEVELS

FIGURE 34. SEASONAL SOIL NO3-N LEVELS

QUINCY SITES

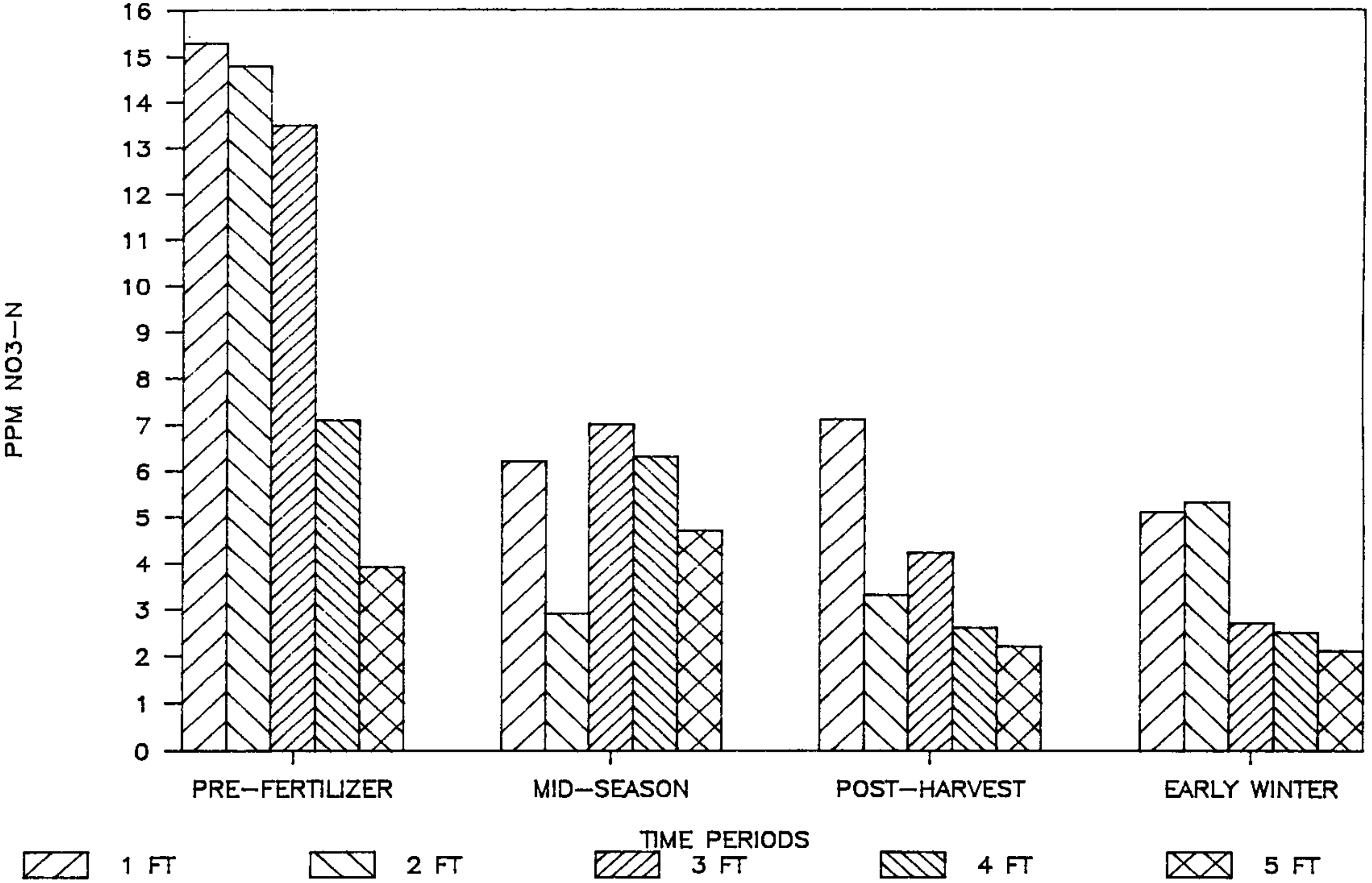


FIGURE 35. SEASONAL SOIL NO3–N LEVELS

TIMMERMAN SITES

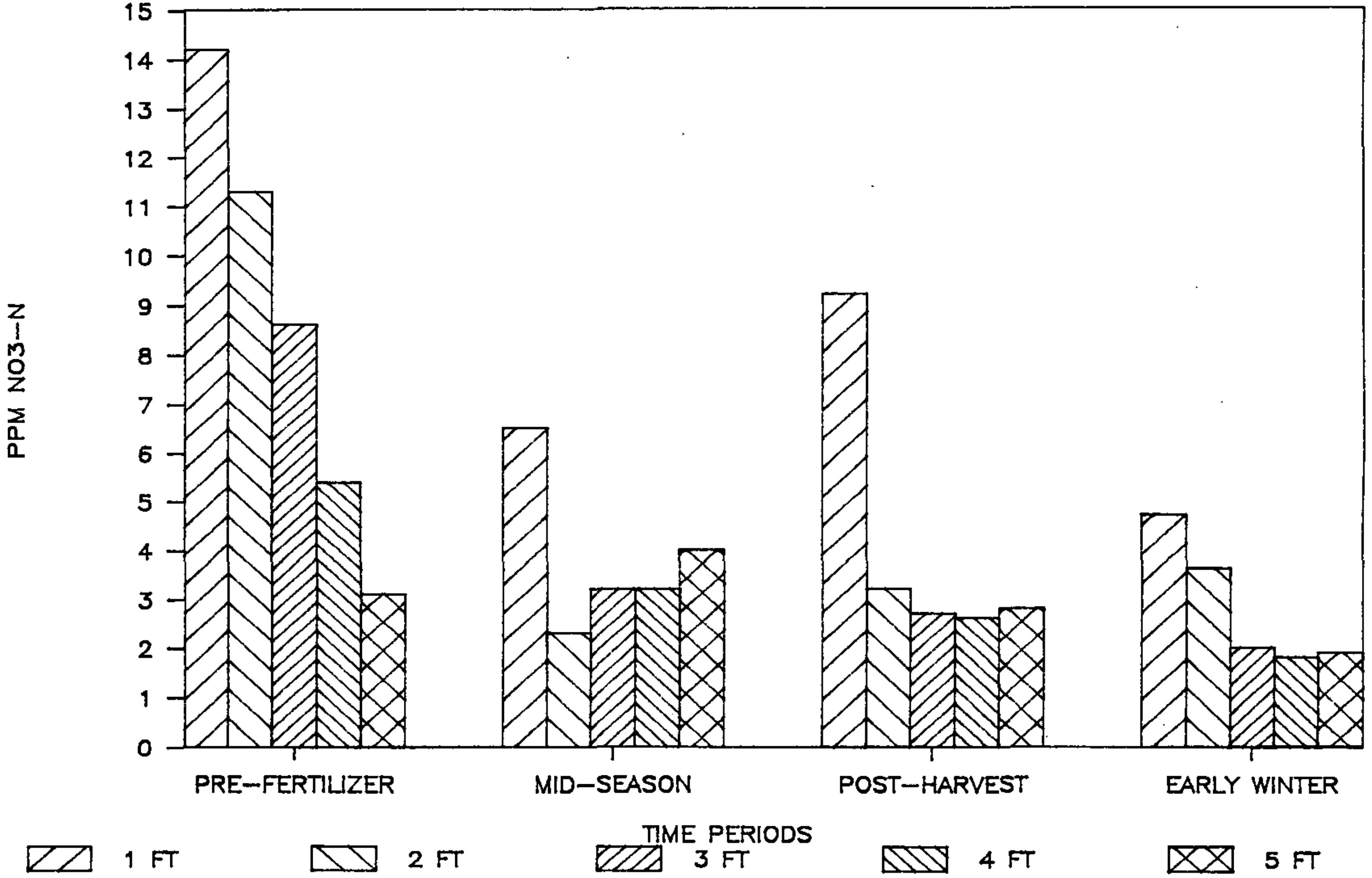


FIGURE 36. SEASONAL SOIL NO3–N LEVELS

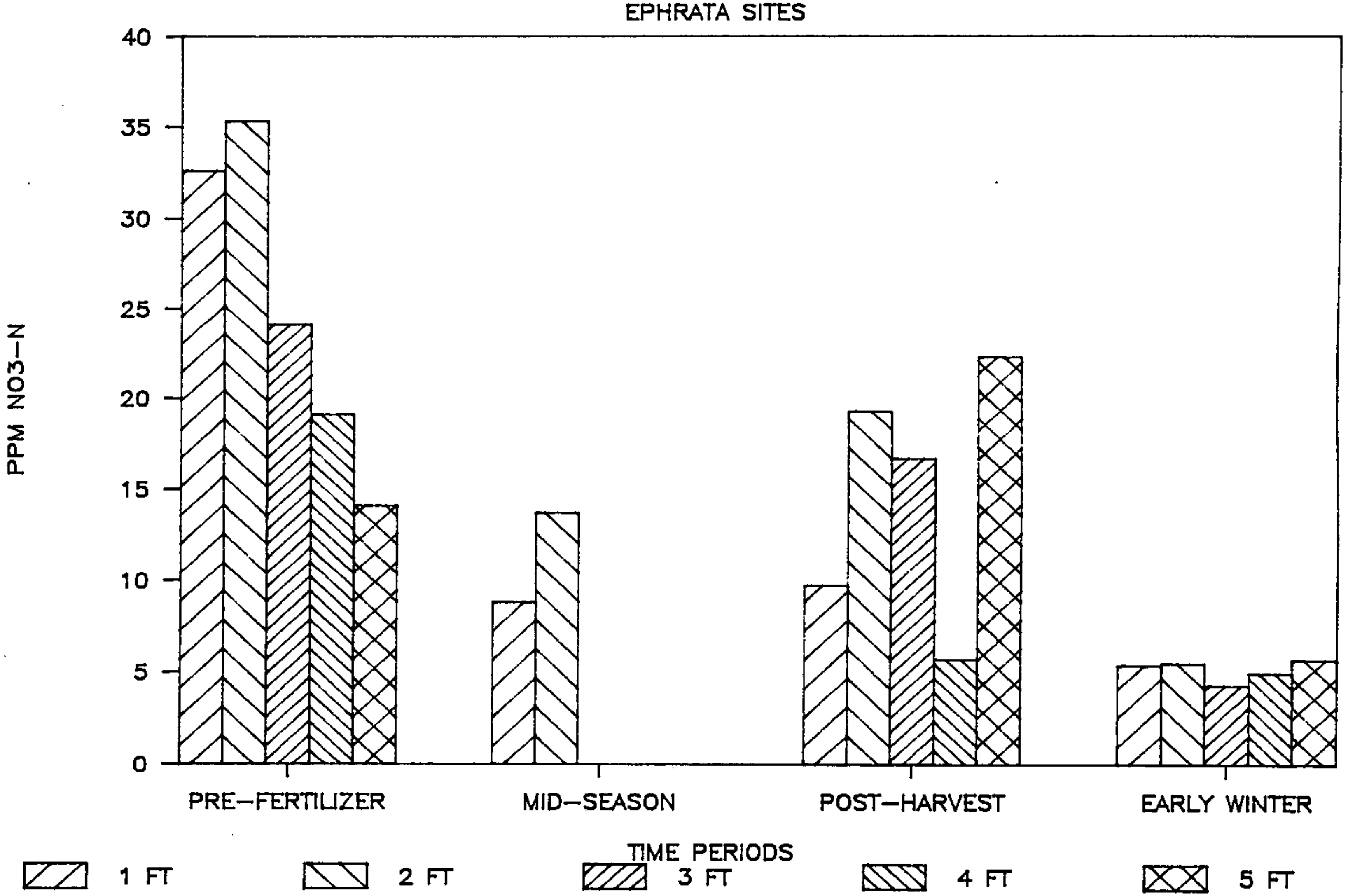


FIGURE 37. SOIL NO3-N LEVELS

QUINCY SITE AVERAGES

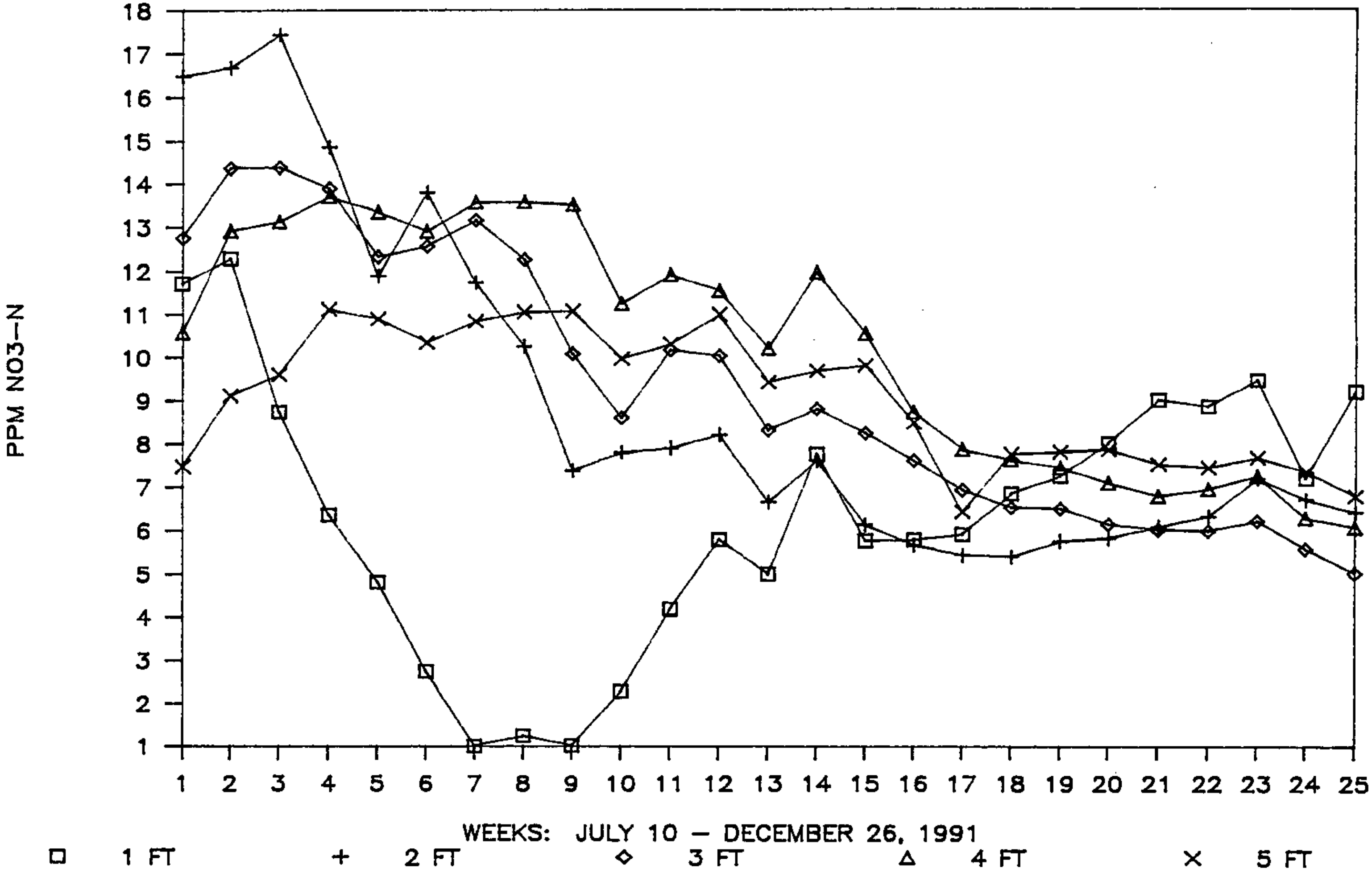


FIGURE 38. SOIL NO3-N LEVELS

TIMMERMAN SITE AVERAGES

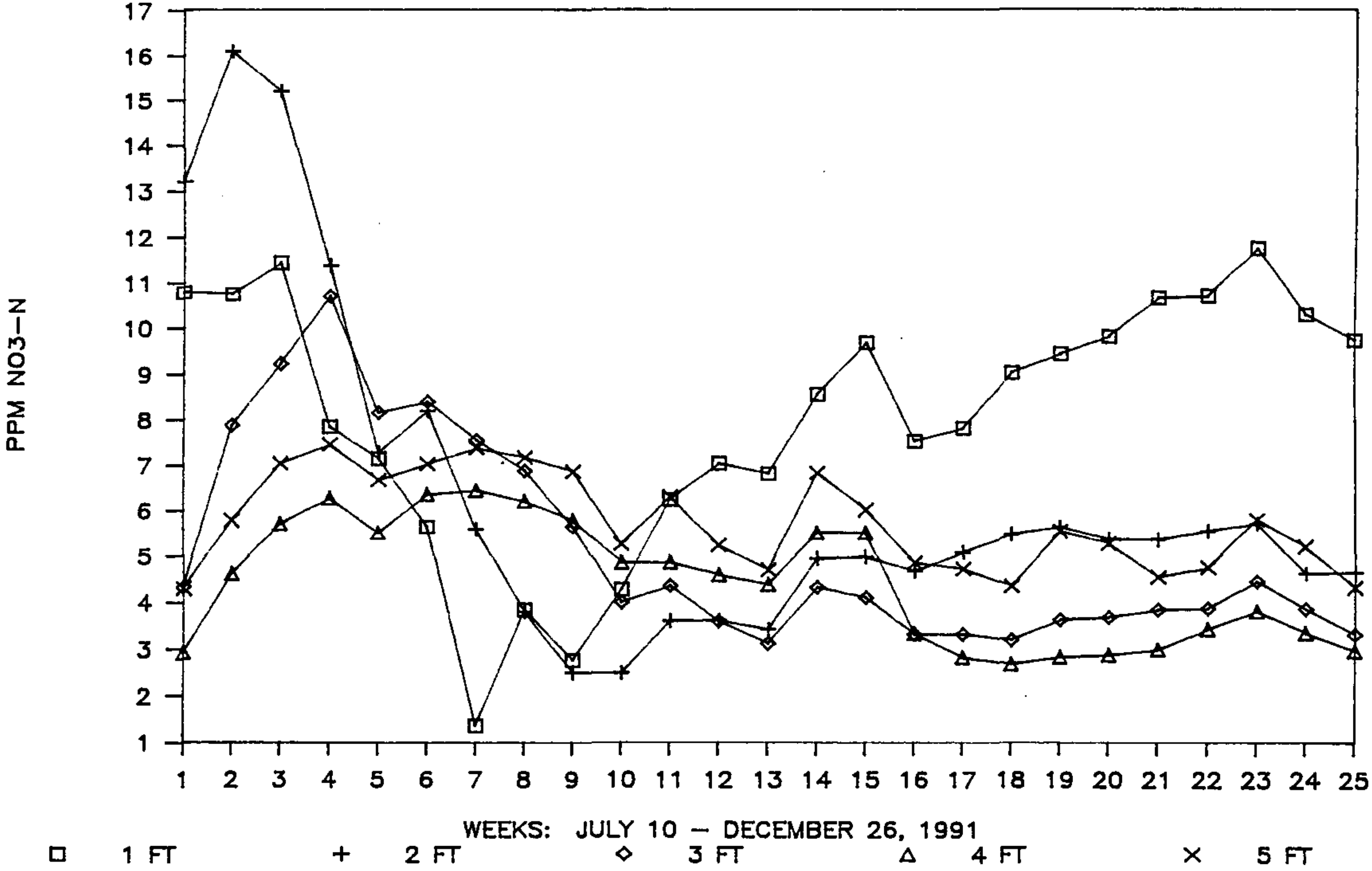


FIGURE 39. SOIL NO3-N LEVELS

EPHRATA SITE AVERAGES

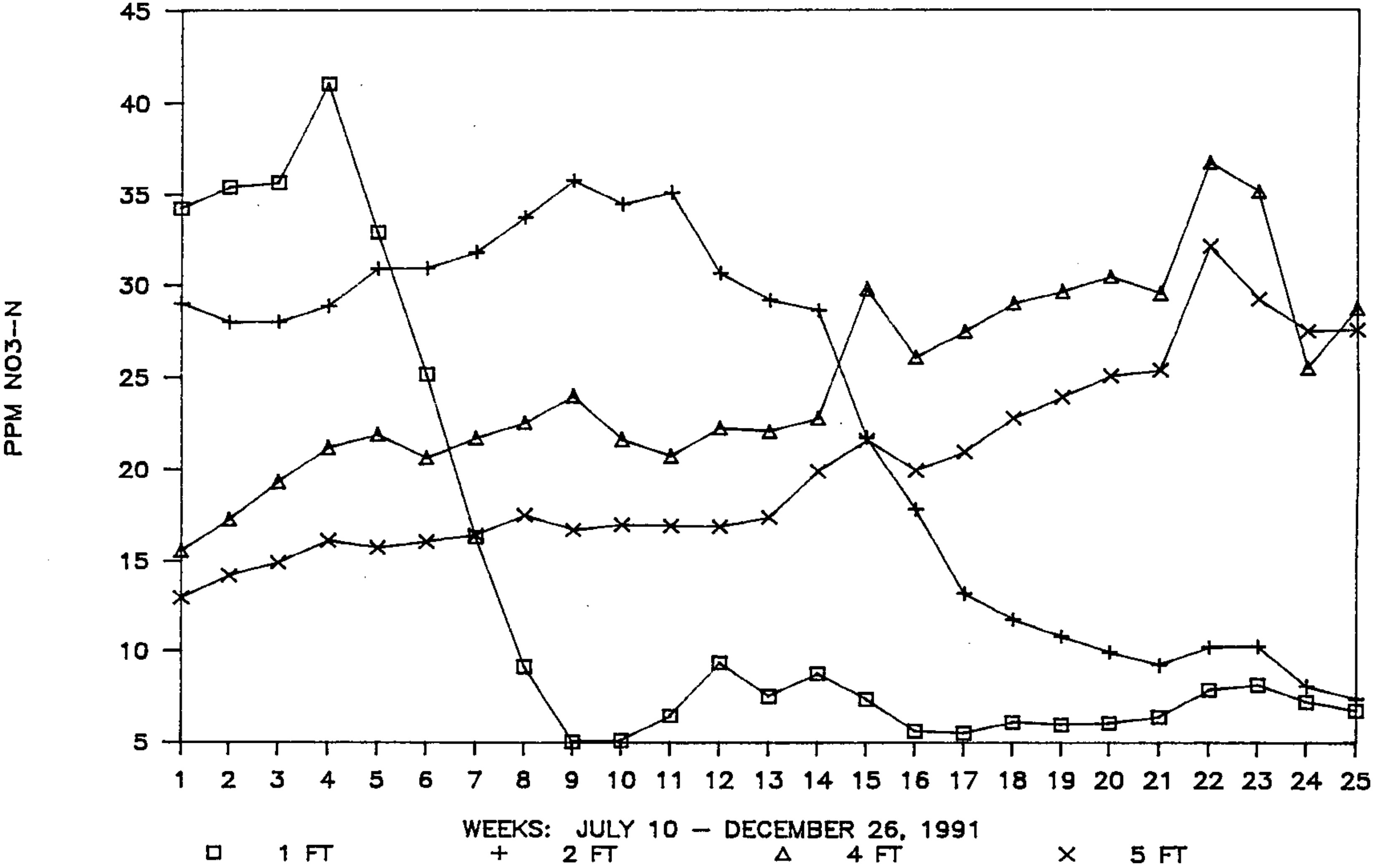
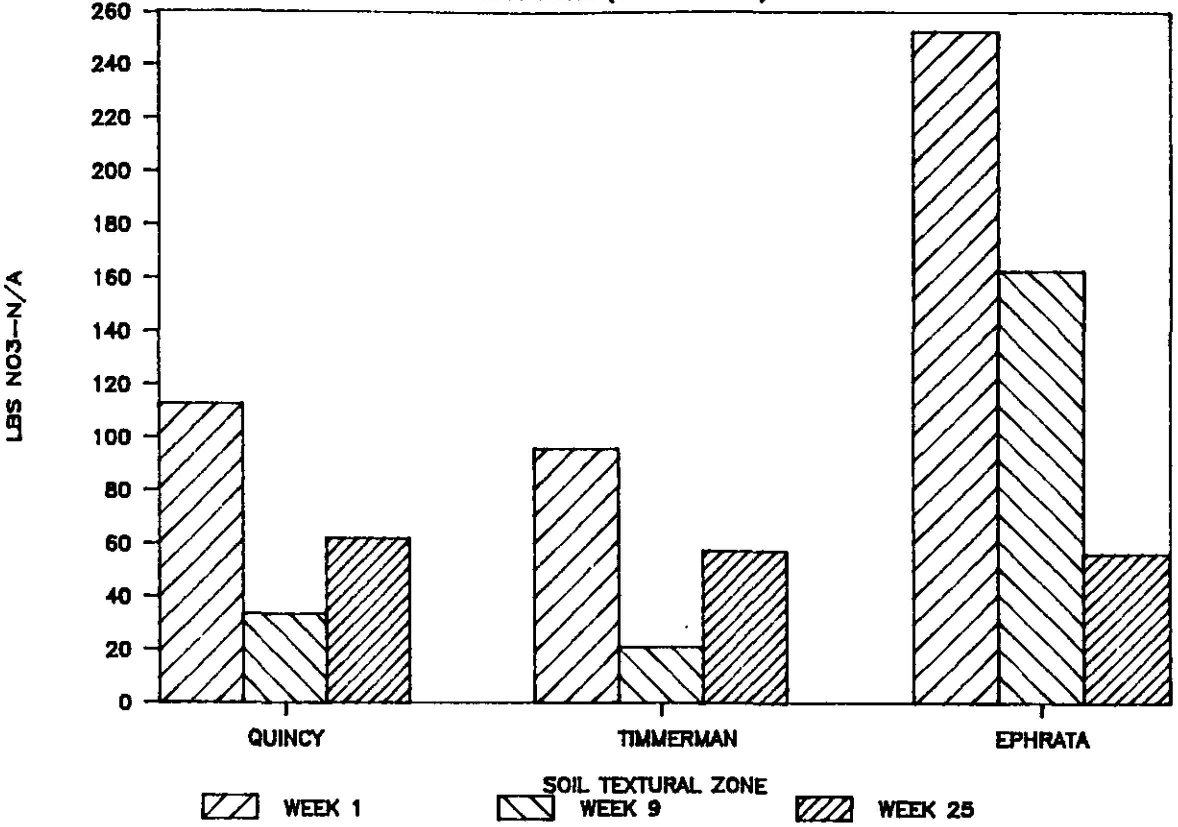
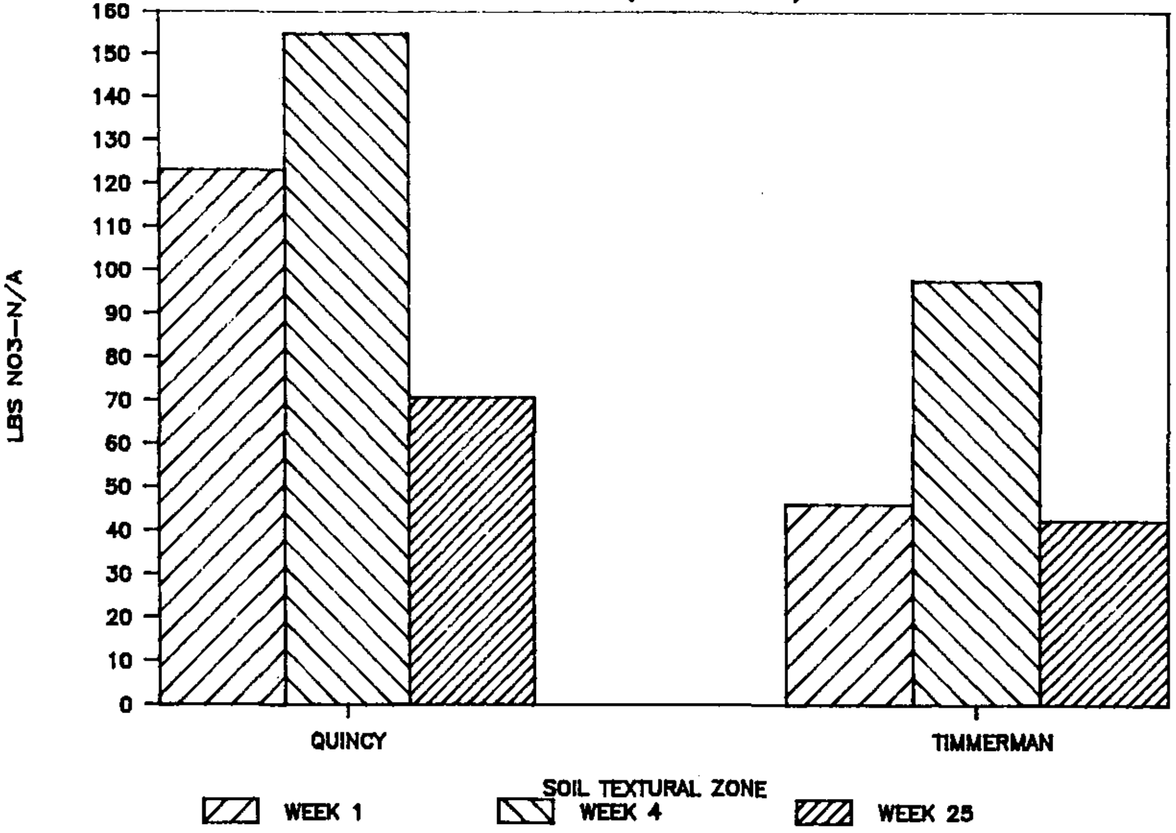


FIGURE 40. SOIL NO3–N LEVELS

ROOT ZONE (0–24 INCHES)



SUB ROOT ZONE (24–60 INCHES)



FOR INFORMATION ON THIS REPORT CONTACT:

Upper Grant Conservation District
2145 Basin SW
Ephrata, WA  98823
(509)754-0195