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Boyle, William C. (William Charles), 1936-; Doran, Frederic J.
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Wisconsin Groundwater Management Practice Monitoring Project

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GROUNDWATER
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Title: **Treatment of Cheese Processing Wastewater by Ridge and Furrow Disposal-Nitrogen Transformations (Study No. 26)**

Investigators:

Principal Investigator

William Boyle, Professor
University of Wisconsin-Madison
Dept. of Civil and Environmental Engineering

Graduate Research Assistant

Frederic J. Doran
University of Wisconsin-Madison
Dept. of Civil and Environmental Engineering

Objectives:

This project was undertaken to determine the nitrogen transformations in wastewater from two dairy products industries as it percolated from the furrows to the groundwater. Ridge and furrow land treatment effectiveness was evaluated under various soil and loading conditions. Operation, maintenance and accuracy of the monitoring equipment used were also studied.

Background/Need:

A ridge and furrow land treatment system consists of a series of ditches which allow for the distribution, infiltration and treatment of wastewater. Two ridge and furrow systems were studied: a cheese factory in Brodhead, Wisconsin which discharged an average of 39,500 gallons per day (gpd) of wastewater, and a creamery in Mindoro, Wisconsin which discharged an average of 14,000 gpd of processing wastewater.

Methods:

Groundwater monitoring wells and lysimeters were installed and soil grab samples taken during the initial soils borings. Flow composited influent wastewater samples were collected monthly. Furrow samples were taken during intensive sampling periods at Brodhead in October and Mindoro in November of 1984. Samples were also collected routinely from the wells and lysimeters.

Wastewater, furrow, lysimeter, groundwater and stream samples were analyzed for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), chlorides (Cl^-), total Kjeldahl nitrogen (TKN), ammonium nitrogen (NH_3-N), nitrate and nitrite nitrogen (NO_3-N+NO_2-N) and pH. Soil and plant samples were also analyzed. Other monitoring included observation of load/rest cycles, reading monthly groundwater and surface water elevations, taking monthly 30-day average wastewater flow readings, cutting periodic grass samples during the growing season to determine nitrogen uptake and performance of infiltration studies to determine unsaturated zone flow rates.

Results:

Wastewater nitrogen loss was attributed to denitrification and leaching at both sites. Plant uptake was also a factor for Mindoro. Both Brodhead and Mindoro had average BOD_5 loading rates over the 100 lb/acre/day Department of Natural Resources limit. COD was greatly reduced as wastewater infiltrated into the groundwater. The nitrogen content of the wastewater at both sites was mainly in the organic form. It mineralized to ammonium nitrogen in the settled solids which accumulated in the furrows. The ammonium-nitrogen was oxidized to nitrate-nitrogen as it infiltrated through the unsaturated zone.

Wastewater treatment and disposal in a ridge and furrow system was influenced by wastewater distribution and infiltration, load/rest cycling, winter operation and annual cover crop burning. Grass overgrowth and leaky header gates caused poor wastewater distribution at Mindoro, though this was not a problem at Brodhead. The Brodhead system experienced decreased nitrogen concentrations in the groundwater and improved soil aeration and infiltration due to a short load/rest cycle. Ponding resulted in part from a longer load/rest cycle at the Mindoro system. Annual grass burning enabled a modest nitrogen loss at both locations. Winter operation proceeded adequately at both sites, though Brodhead fared better during subzero temperatures.

Downgradient groundwater concentrations of contaminants were impacted to a greater extent at Brodhead than Mindoro. Nitrogen and COD reductions in the unsaturated zone were similar at Brodhead and Mindoro, though a greater percentage were removed at Brodhead than Mindoro. This difference was attributed to sandy soils at Brodhead which allowed for faster unsaturated travel times than silty loam soils at Mindoro.

Conclusions:

Investigators concluded that nitrogen losses around the unsaturated zone were attributable to denitrification at both sites. BOD_5 tests indicate that wastewater loading did not produce an oxygen demand high enough to inhibit denitrification. Nitrogen and COD reductions were dependent on infiltrative capacities. The nitrogen in wastewater applied at both sites was mainly in the organic nitrogen form, which ammonified and eventually diffused into the overlying furrow wastewater. Dissolved ammonium was the primary form of nitrogen in the wastewater applied to the furrows. Surface water remained unaffected from the operation of the ridge and furrow systems at both sites.

Recommendations/ Implications:

Further research is suggested to better determine the impact of loading changes on groundwater quality and to better quantify unsaturated flow times by the installation of tensiometers. Nitrogen loading rates should be met by dischargers to reduce or maintain groundwater nitrogen concentrations. Solids accumulation in the furrows at Brodhead should be reduced with wastewater pretreatment. Chloride concentrations in the Brodhead wastewater should be reduced by brine removal in the plant or prior removal. Annual spring grass burning is suggested for all ridge and furrow systems where feasible. A downgradient well nest should be installed at Mindoro to better define the movement of contaminants off-site. Also suggested is an improved lysimetry method to obtain a more instantaneous sample and allow for winter sampling.

Availability of Report: This report is available for viewing and loan at:

The Water Resources Center
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(608) 262-3069
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TABLE OF CONTENTS

List of Figures

Page

Page

List of Tables

CHAPTER 1: INTRODUCTION

What is a Ridge and Furrow?

For many years the ridge and furrow land treatment process has been a popular and simple method of industrial wastewater disposal. A ridge and furrow system is simply described as a series of interconnected ditches (furrows) which allow for the distribution, infiltration, and treatment of wastewater. Ridges between the ditches support a cover crop which takes up nutrients and water and protects the ditches during the winter. In Wisconsin, there are 83 dairies, four meat packers, a rendering plant, and a pet food manufacturer, which utilize the ridge and furrow process (Rodenberg, 1980). Site areas range from 0.1 to 56 acres.

There are three advantages in selecting the ridge and furrow treatment process. They are 1) ease of operation; 2) cost (capital and operation and maintenance), and 3) year around operation. Design of these systems is based on hydraulic loading rates and BOD_5 loading rates. Nitrogen loading rates are currently not considered. Two or more cells are preferred to allow for loading flexibility. A healthy cover crop is also an important feature of a ridge and furrow site.

Nitrogen Concerns at Ridge and Furrow Systems

Nitrogen, in its organic, ammonium, and nitrate forms, is a major parameter of concern in State groundwater protection programs. The United States Environmental Protection Agency has set a 10 mg/l drinking water standard for nitrate-nitrogen. Such standards are set to reduce the occurrence of animal and human disease and to control environmental pollution. These concerns will be discussed in Chapter 2.

Project Description

This report presents the results of a study supported by the Wisconsin Department of Natural Resources (WDNR) and conducted at two ridge and furrow sites treating cheese processing wastewater. One system, operated by Universal Foods in Brodhead, Wisconsin, receives 39,000 gallons per day and is located on 4.7 acres of sandy soil. The other system, operated by the Mindoro Co-op Creamery in Mindoro, Wisconsin, receives 14,000 gallons per day and is located on 3.0 acres of silty loam soil. This is the oldest ridge and furrow system in the state.

The project had four objectives. The primary objective was to determine the nitrogen transformations in the wastewater as it percolated from the furrows to the groundwater. In relation to these transformations, a nitrogen budget estimate was attempted at each site. Other project goals were: 1) to analyze ridge and furrow treatment effectiveness under different soil and loading conditions, 2) to examine the operation and maintenance at these systems, and 3) to evaluate the monitoring equipment used.

To complete these objectives, groundwater monitoring wells and lysimeters were installed and a sampling program was initiated in August of 1983. Until November of 1984, well, lysimeter, furrow-water, wastewater, and bounding surface water samples were taken and analyzed for five day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), chlorides (Cl^-), total Kjeldahl nitrogen (TKN), ammonium nitrogen (NH_3-N), nitrate and nitrite nitrogen (NO_3-N+NO_2-N), and pH. Periodic analysis for alkalinity, total phosphorus (P), sulfate (SO_4^{2-}), potassium (K^+), sodium (Na^+), magnesium (Mg^{2+}), and calcium (Ca^{2+}) was also done. Analysis was performed by the Wisconsin State Laboratory of Hygiene.

Other work performed included: 1) changing the load/rest cycles at one site to observe effects, 2) reading monthly groundwater and surface water elevations, 3) taking monthly 30-day average wastewater flow readings, 4) cutting periodic grass samples during the growing season to determine nitrogen uptake, 5) performing infiltration studies to determine unsaturated zone flow rates, and 6) making general site observations.

CHAPTER 2: LITERATURE REVIEW

Introduction

Nitrogen is ubiquitous in our environment. The atmosphere contains 78% nitrogen and topsoils typically contain 4,000 to 200,000 lb N/acre (Winneberger, 1982). Figure 1 illustrates the classical nitrogen cycle indicating the many transformations involved. The nitrogen cycle and its relationship to the soil and groundwater are shown in Figure 2. Nitrogen inputs to the soil system occur through precipitation, waste and fertilizer application, plant residue deposition, and atmospheric nitrogen fixation. System losses occur through ammonia volatilization, plant uptake, and denitrification. Ammonification (or mineralization), assimilation (or immobilization), nitrification, denitrification, adsorption, and leaching are internal processes.

A large portion (90%) of soil nitrogen is organically bound and contained in the first 40 inches of soil (Tusneem & Patrick, 1971; Winneberger, 1982). Warmer climates favor the breakdown of organic matter and soil N accumulates less rapidly than in cooler climates. Nitrogen and organic matter also increase with effective moisture. Stored N is released when a soil is disturbed (eg. heavy rainfall or fire) with leaching losses ranging from 80 to 4,000 lb N/acre/year.

The inorganic-N soil fraction is in the NO_3^- or NH_4^+ form and constitutes an immediate source for plant uptake (Tusneem and Patrick, 1971). Most of the inorganic-N is water soluble or adsorped on the soil exchange complex. Approximately five percent, and possibly as high as 30%, of soil NH_4^+ may be fixed in the lattice of silicate minerals in a non-

FIGURE 2.1

THE NITROGEN CYCLE

(AFTER SAWYER AND McCARTY, 1967)

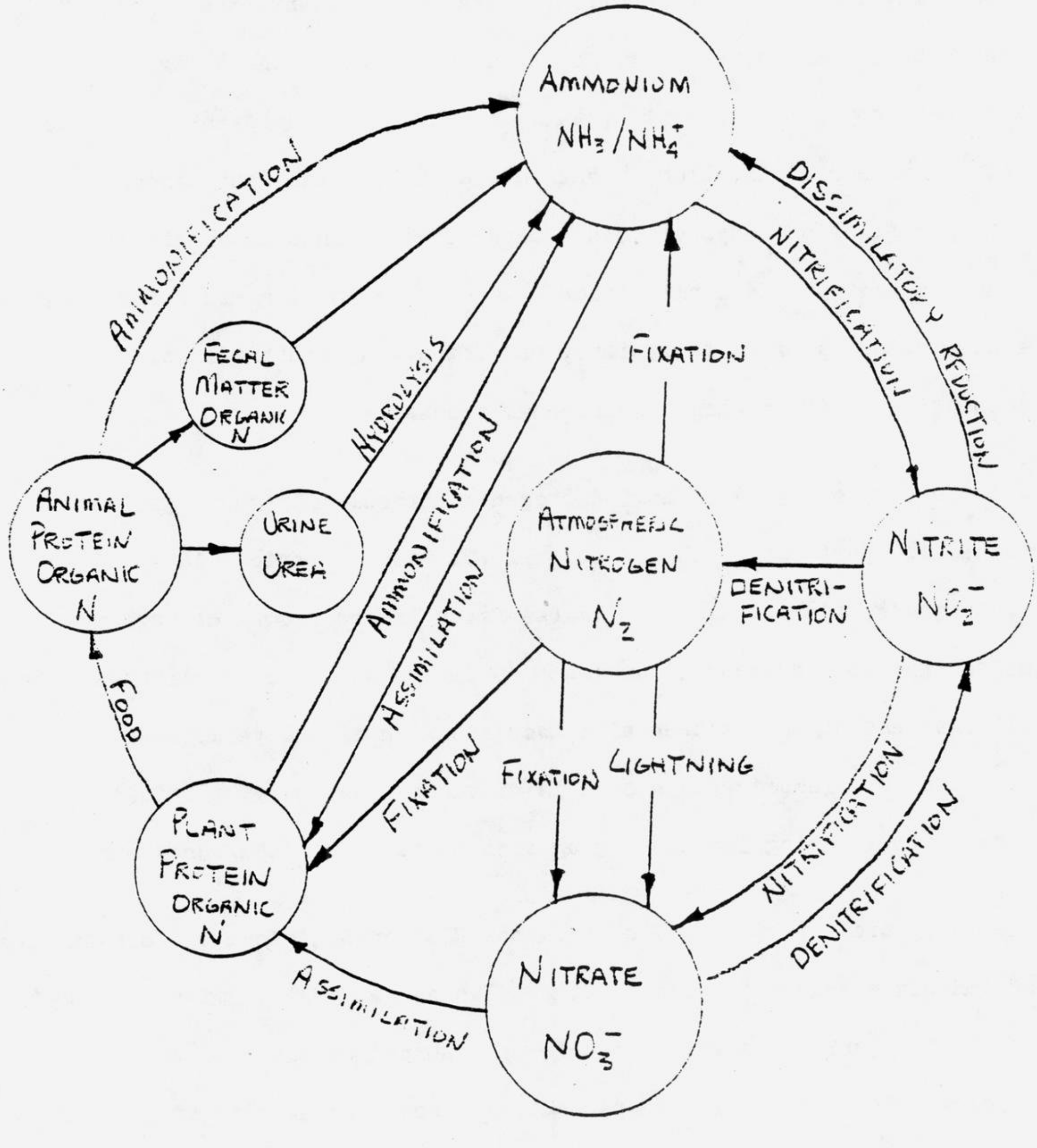
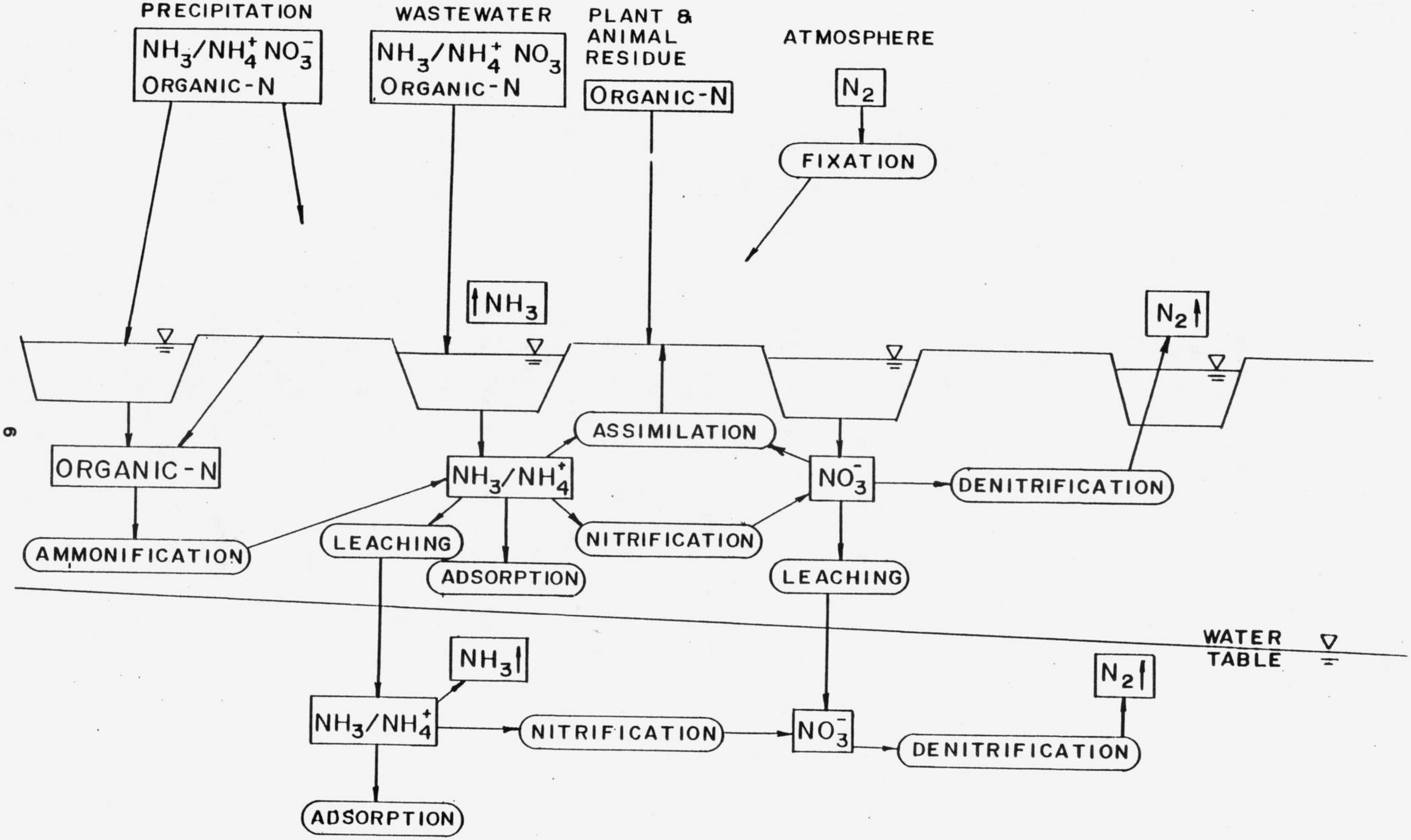


FIGURE 2.2: THE N-CYCLE FOR A RIDGE AND FURROW SETTING (ADAPTED FROM SEPP, 1970)



exchangeable form. Ammonium may be oxidized to nitrate through nitrification. Nitrate in soil may be removed by leaching, denitrification, or plant uptake. It is possible that the reduction of NO_3^- to NH_4^+ could occur but this process is not common (Tiedje, Sorenson, and Chang; 1979).

Inorganic-N in waterlogged soils is high in ammonium and low in nitrate (Tusneem and Patrick, 1971). Waterlogged nitrate concentrations range from 0-3 mg/l. Ammonium in waterlogged soils can be taken up by plants, immobilized in bacterial cells, adsorped on soil particles, and volatilize under alkaline conditions.

The goal of many studies of soil nitrogen is to develop a nitrogen budget at a given site. However, it is not as easy as counting the number of marbles dropped over a given area. It is more like trying to balance a checking account when others have made deposits and withdrawals without giving notice of the transactions. Keeping this in mind, general rate ranges for the various nitrogen transformations have been made and are as follows (Winneberger, 1982):

1. N Fixation - 2 to 500 lb N/acre/yr,
2. Fertilizer Leaching - 0 to 200 lb N/acre/yr,
3. Rainfall Input - 4 to 12.5 lb N/acre/yr,
4. Denitrification - 0 to all lb N/acre/yr,
5. Storage Losses - 80 to 4,000 lb N/acre/yr, and
6. Plant uptake - few quantifications.

Since nitrification does not lead to a loss or gain of soil nitrogen, it was not considered in the budget.

There are several undesirable effects of nitrification (Alexander, 1977). Nitrate is an anion very susceptible to leaching, which takes an essential nutrient away from plants. Nitrate also has a role in methemoglobinemia in infants and animals, eutrophication, and the formation of nitrosamines. Wastewater, wastewater sludges, fertilizers, and manure are all potential sources of nitrate. Nitrosamines are not common soil constituents but are in pesticides. They are carcinogenic, mutagenic, and teratogenic.

Nitrogen is a concern in the environment when its nitrate form enters groundwater aquifers. Young infants lack stomach acidity and at pH values greater than four, nitrite formers can exist in the gut. Nitrite, formed from nitrate, then combines with hemoglobin in the blood instead of oxygen, causing oxygen starvation. This illness is termed methemoglobinemia (Winneberger, 1982).

Since 1945, 2,000 cases of methomoglobinemia were reported in North America and Europe with 7-8% fatalities (Winneberger, 1982). There were no fatalities between 1960 and 1972. Possibly only 10% of all cases have been reported. Compared to other causes of infant death, however, methemoglobinemia is rare. In 1975 alone, about 9,000 infant fatalities were reported in the United States, 178 by homocide.

Considering the rarity of methemoglobinemia, the 10 mg/l drinking water standard has received criticism. Nitrate ingestion and methemoglobinemia occurrence may be separate events and setting a NO_3^--N standard may have no effect on the disease rate. Scientists have been limited to correlative studies since direct studies on babies are not ethical.

The 10 mg/l standard was established using a correlative study. Researchers found that the incidence of methemoglobinemia was insignificant in infants whose drinking water supply contained less than 10 mg/l nitrate. A recent study shows, however, that there is no higher incidence of the disease in babies drinking high nitrate concentrations than in a control group (Winneberger, 1982). The infants had high methemoglobin (NO_2-hemoglobin) levels no matter what the nitrate concentration was in the water source.

Denitrification is related to environmental pollution (Alexander, 1977). Once nitrate passes through the root zone, denitrification is desired to reduce subsurface nitrate concentrations for reasons stated earlier. This process is possible with depth when carbonaceous nutrients are present. This is the case in waste treatment when production of nitrate coexists with available C.

Current data also suggest that microbial release of N_2, N_2O, and NO far exceeds that by human activity (Alexander, 1977). NO reacts with O_3 (ozone) and light to destroy the ozone layer which protects the earth from ultraviolet rays.

With this introduction to the nitrogen cycle and its environmental concerns, this review discusses in more detail the processes of mineralization/immobilization, nitrification, dissimilatory reduction, N_2 fixation, plant uptake, volatilization, leaching, and adsorption. This is followed by sections which summarize current research of the nitrogen cycle as it affects land treatment, which present the history of ridge and furrow systems, and which discuss the design of these systems.

Mineralization and Immobilization

Mineralization (or ammonification) is the conversion of organic-N to ammonia or ammonium. Immobilization is the assimilation of inorganic-N (NH_4^+, NO_3^-, and NO_2^-) by microorganisms into the nitrogeneous constituents of their cells. The two processes work simultaneously and either net immobilization or net mineralization results. This relationship controls the amount of available N in the soil. In natural systems, mineralization usually exceeds immobilization. (Tusneem and Patrick, 1971; Alexander, 1977).

The decomposition of organic-N in soils is done by general purpose heterotrophs, fungi, and actinomycetes. These organisms use the organic-N compounds as an energy source and produce NH_3, carboxylic acids, amines, mercaptans, and H_2S (Tusneem and Patrick, 1971). During immobilization, ammonium and nitrate are incorporated into cell amino acids, amino sugars, nucleic acids, and other organic complexes (Alexander, 1977; Paul and Juma, 1979). Immobilization results in depressed plant uptake of nitrogen and decreased plant yield.

Mineralization and immobilization are dependent on several environmental factors including C:N ratio, waterlogging, wetting and drying cycles, temperature, pH, soil moisture, and soil clay content. The ratio of carbonaceous material (energy source) and nitrogen in substances undergoing decomposition usually dictates whether net mineralization or net immobilization occurs. With similar C available, a source rich in N results in net mineralization while a source poor in N results in net immobilization (Tusneem and Patrick, 1971). When C:N falls below the 20-30:1 range, net mineralization occurs and inorganic-N will appear (Alexander, 1977).

In waterlogged (anaerobic) soils, less efficient and more restricted bacteria take over (Tusneem and Patrick, 1971). Both mineralization and immobilization are retarded. The features of this anaerobic decomposition are the following:

1. incomplete decomposition of carbohydrates into CH_4, organic acids, H_2, and CO_2;

2. lower energy of fermentation leading to less cell production; and

3. a low N requirement leading to a more rapid release of ammonium.

If wetting and drying cycles occur, mineralization proceeds at a faster rate upon rewetting than if the soil had been wet all along (Tusneem and Patrick, 1971). This rate declines in later cycles. Also, the longer the drying period, the faster the rate upon wetting. The wetting/drying process may make substrates readily accessible or drying may cause cell disintegration.

Since mineralization is catalyzed by a temperature sensitive enzyme, temperature also affects this process (Alexander, 1977). Mineralization occurs between the temperatures of two to 60^{o}C with an optimum rate between 40 and 60^{o}C. Thawing/freezing action also has a similar effect as wetting/drying.

Soil pH, moisture, and clay content have influences on the mineralization rate as well (Alexander, 1977). Mineralization is favored by a neutral pH environment and increasing soil moisture content. Clay minerals have the ability to adsorb cell enzymes, pulling them away from the decomposition process.

In the land treatment of dairy wastes, the mineralization of proteins is a concern. Proteins are broken down into smaller amino acid chains by the extracellular enzyme protease (Alexander, 1977). Once broken down, these acids enter the cell where they serve as N, C, and energy sources. The four paths of amino acid (AA) breakdown are:

1. deamination by direct removal of NH_3,

   $AA \rightarrow RCH{=}CHCOOH + NH_3$

2. oxidative deamination,

   $AA + 0.5\ O_2 \rightarrow RCOCOOH + NH_3$

3. reductive deamination, and

   $AA + 2H^+ \rightarrow RCH_2COOH = NH_3$

4. decarboxylation.

   $AA \rightarrow RCH_2NH_2 + CO_2$

where: AA is RCH_2CHNH_2COOH in Equation 1 and $RCHNH_2COOH$ in Equations 2, 3, and 4.

Nitrification

Nitrification is the biological formation of nitrate or nitrite from reduced N compounds, namely ammonium. Nitrification occurs in two steps, the conversion of ammonium to nitrite and the conversion of nitrite to nitrate. The genera of Nitrosomonas, Nitrosococcus, Nitrosospira, and Nitrosolobus are the principal nitrite formers while Nitrobacter is the principal nitrate former (Alexander, 1977). Heterotrophs and fungi are also capable of oxidizing inorganic nitrogen.

Nitrosomonas and Nitrobacter are the most frequently encountered nitrifying chemotrophs and they are usually found together. These bacteria typically obtain their energy from the oxidation of inorganic-N. Carbon is obtained from CO_2 or carbonates. Nitrobacter requires low amounts of molybdenum for its metabolism. (Alexander, 1977).

In oxidizing NH_4^+ to NO_2^-, the N oxidation state changes from -3 to +3. The pathway is unclear but is hypothetically as follows (Alexander, 1977):

$$NH_3 \text{ --> } NH_2OH \text{ --> } HNO \text{ --> } NO \text{ --> } NO_2^-$$

Overall reaction: $NH_4^+ + 1.5\ O_2 \text{ --> } NO_2^- + 2H^+ + H_2O$

Nitrite accumulation is rare. It only results from high alkalinity and high ammonium levels. High ammonium concentrations are toxic to Nitrobacter. Nitrobacter oxidizes N from +3 to +5 yielding two electrons as follows:

$$NO_2^- + H_2O \text{ --> } H_2O \cdot NO_2^- \text{ --> } NO_3^- + 2H^+$$

Many environmental factors affect nitrification. The process is slow in acid habitats (Alexander, 1977). Rates typically fall at pH values below six and are negligible at pH less than five since the nitrifier population is decreased.

Aeration is essential to nitrification and moisture is also a factor (Tusneem and Patrick, 1971; Alexander, 1977). Waterlogged environments lead to complete suppression of nitrification by limiting oxygen diffusion. On the other hand, the process does not work in arid conditions due to a lack of water. Generally, nitrate appears at 1/2 to 2/3 of a soil's moisture holding capacity.

In temperate regions, nitrate formation is most rapid in spring and fall and lowest in the summer and winter (Alexander, 1977). Nitrifier populations are decreased during extreme heat or cold. Rates slow at temperatures less than 4°C or greater than 40°C with an optimum between 30 and 35°C. Soil temperatures are not this warm, however. In-field research is needed to better quantify this assertion.

Nitrification is also affected by the type of crop and the soils cation exchange capacity (CEC) (Alexander, 1977). Roots of some grasses excrete compounds deleterious to the process. Once ammonium is adsorbed to a clay mineral, the availability of this fixed cation to chemoautotrophs is low with less than 25% nitrified within several months.

Denitrification

Denitrification is the bacterial reduction of NO_3^- and NO_2^- with the liberation of N_2O and N_2. During this nitrate reduction, nitrogen fails to enter the cell structure and is lost to the atmosphere. Denitrification is encouraged by a supply of decomposable organic matter, high nitrate supply, and anaerobic (reduced) conditions (Winneberger, 1982; Tusneem and Patrick, 1971). In anaerobic environments, facultative anaerobes use nitrate as an electron acceptor and nitrogen escapes as N_2O or N_2 (Stanford, Vander Pol, and Dzienia, 1975).

Denitrifying bacteria growth is not dependent on nitrate reduction (Alexander, 1977). There presence indicates denitrification potential but not that conditions are favorable. Denitrifiers are facultative aerobes which use nitrate as an electron acceptor for growth in the absence of oxygen. Most organisms get less energy using NO_3^-, ie. fewer cells/unit substrate oxidized (Alexander, 1977). Energy conservation is attained by the electron transport phosphorylation (ETP) process (Tiedje, Sorensen, and Chang, 1979).

Denitrification is done by Paracoccus denitrificans, Pseudomonas aeruginosa, and Bacillus licheniformis. Facultative autotrophic denitrifiers, such as Paracoccus denitrificans, use either organic matter or H_2 as an energy source and O_2 or NO_3^- as an electron acceptor. One group of denitrifiers is photosynthetic (Alexander, 1977; Knowles, 1979).

Alexander (1977) and Knowles (1979) present the following overall denitrification reaction:

$$NO_3^- \xrightarrow[\text{NaR}]{} NO_2^- \xrightarrow[\text{Nir}]{} NO \xrightarrow[\text{NOR}]{} N_2O \xrightarrow[N_2OR]{} N_2 \quad \text{or}$$

$$4NO_3^- + 5CH_2O + 4H^+ \longleftrightarrow 2N_2 + 5CO_2 + 7H_2O$$

NaR, NiR, NOR, and N_2OR are the catalyzing enzymes nitrate reductase, nitrite reductase, NO reductase, and nitrous oxide reductase, respectively. N_2OR seems most sensitive to low pH and the presence of oxygen, nitrate, and sulfide. In these cases, N_2O will be a significant product. All reductases are repressed by oxygen presence. Small amounts of molybdenum is required by nitrate reductase.

Denitrification is dependent on many environmental factors including soil moisture, aeration, wetting/drying cycles, available organic matter, waste loading rates, nitrate concentration, pH, temperature, and the presence of sulfur or acetylene (Standord, Vander Pol, and Dzienia, 1975; Tusneem and Patrick, 1971; Alexander, 1977; Knowles, 1979; Winneberger, 1982).

In well drained soils, nitrogen loss is related to a soil's moisture content with higher denitrification rates occurring at higher water levels. Losses usually do not occur at moisture contents less than 60% of the soil water holding capacity regardless of the carbohydrate or nitrate supply, or the pH. Moisture content governs the diffusion of oxygen to sites of activity. As soil moisture increases, N_2O content will decrease as N_2 is formed. Denitrification is high in waterlogged soils and low in drier soils since inorganic-N is immobilized. Rates can be significant in dry soils as well if water pockets develop. These pockets can create anaerobic micro-environments to promote nitrate reduction.

Aeration is necessary in nitrate production, the basic substrate in denitrification. Oxygen presence must not be so great, however, as to inhibit denitrification. Since total nitrogen losses do occur in aerated soils, the existence of anaerobic micro-environments is again proposed. This theory is also reflected by large nitrogen losses at sites undergoing cycles where oxygen is alternately available and then absent.

Tusneem and Patrick (1971) suggest that moisture fluctuations as a result of flooding and draining create ideal conditions for nitrogen loss. Two layers or zones develop: a surface oxidizing layer and an underlying reducing layer. Applied ammonium is nitrified in the oxidizing layer by aerobic bacteria. Nitrate then percolates to the reduced layer and is subsequently denitrified biologically and possibly chemically to gaseous N.

Greenland (1962) reported that nitrification and denitrification could occur simultaneously in wet soil due to aerobic and anaerobic microzones. Russell and Richards (1917) determined that alternate wetting and drying would create an ideal environment for denitrification. Patrick and Wyatt (1964) observed a 20% N loss from this cycle. The frequency of wetting/drying affected total N loss as well as the rate of nitrate reduction in subsequent cycles. Major losses occurred during the first two to three cycles, decreasing as cycles progressed.

Winneberger (1982) believes that denitrification is best facilitated by environments alternately exposed to anaerobic and aerobic conditions. This can be done through loading and resting cycles or by adding energy rich organics to create microanaerobic areas.

Denitrification rates positively correlate with the amount of soil water extractable organic-C (Knowles, 1979). Stanford, Vander Pol, and Dzienia (1975) and Alexander (1977) suggest that low carbon containing soils (eg. sand) support a lower rate of denitrification. At wastewater disposal sites, extra organic matter is supplied as reflected by the wastes BOD or COD.

Waste loading rates also affect denitrification. McMicneal and McKee (1966) spread two feet/day of wastewater and most of the applied N was accounted for at depth. Lesser loadings have given high nitrogen removals. Kardos, Sopper, and Myers (1965) reported 68 to 82% N removal by sprinkle irrigation of wastewater at one to two inches/week. In the former case, low nitrogen losses resulted from soil saturation which inhibited the necessary production of nitrate. High nitrogen losses were promoted by the aeration provided by the irrigation and the lower loading rate.

The nitrate concentration in the soil pore water is also a factor in denitrification. According to Knowles (1979), at relatively high NO_3 concentrations, the denitrification reaction is frequently zero order. Depending on the environment of the reaction, the denitrification rate increases linearly to a given nitrate concentration, after which, rates level off and little gaseous nitrogen is liberated.

Many denitrifiers are sensitive to low pH and therefore denitrification rates are positively correlated with soil pH (Alexander, 1977; and Knowles, 1979). An optimum range is between pH 7 and 8. Acidity also governs the abundance of certain gases (Alexander, 1977). N_2O liberation is pronounced in the pH range of 6.0 to 6.5 while NO only appears at low pH. These differences may result from the acid sensitivity of the enzyme system for N_2O reduction.

Rates of nitrate reduction are also temperature dependent. Alexander (1977) stated that increasing the temperature from 2°C enhances denitrification, with an optimum at approximately 25°C. Knowles (1979) found that denitrification is temperature dependent between 10 and 35°C with maximum rates at 60-75°C. Rates have been measured between 0-5°C. Low temperatures reportedly result in relatively more N_2O and NO.

Sulfur compounds affect denitrification by inhibiting the reduction of NO and N_2O to N_2 (Knowles, 1979). Acetylene also inhibits nitrous oxide reduction.

Dissimilatory Reduction

Dissimilatory reduction is the bacterial conversion of nitrate back to an ammonia form. This reduction could occur in anaerobic habitats since oxygen inhibits enzymes and represses sythesis (Tiedje, Sorensen, and Chang, 1979). Microorganism genera responsible for dissimilatory reduction include Bacillus, Enterobacter, Klebsiella, Erwina, and Clostridia. These organisms are more prevalent than the denitrifiers soil. Anaerobic environments have abundant electron donors and a scarcity of electron acceptors. Therefore, the eight electron reduction to NH_4^+ should be favored over the five electron reduction in denitrification. Also, since this reduction is respiratory rather than assimilatory related, one would expect more NO_3^- to NH_4^+ reduction than assimilatory reduction.

Dissimilatory reduction does not dominate denitrification in most cases, however. Where the oxygen status is more transient or where the redox potential is less reduced, denitrification dominates. Tiedje, Sorenson, and Chang (1979) incubated an organic muck soil (pH 5.7) anaerobically with and without glucose (C) addition. Labeled nitrate and ammonium were added. In the sample without C addition, the dissimilatory reduction rate was 0.3-0.6 ug/g/day while the denitrification rate was 15 ug/g/day. With C addition, the dissimilatory reduction rate was

1 ug/g/day while the denitrification rate was 25 ug/g/day. The obvious conclusion of the study was that denitrification was the major nitrate reduction process in an organic muck soil.

Nitrogen Gas Fixation

Nitrogen fixation is performed by bacteria or blue-green algae, which use N_2 by non-symbiotic means and by symbiotic associations between microorganisms and a higher plant (Alexander, 1977). Non-symbiotic fixation is performed by actinomycetes, fungi, yeasts, aerobic bacteria, facultative anaerobes photosynthetic bacteria (nonsulfur purple, purple sulfur, green sulfur), and blue green algae.

Azotobacter has been the most intensely studied non-symbiotic N fixer but it is not very common in soils. The dominate anaerobes are Clostridia which proliferate when organic matter is added. They are numerous around plant roots at sites with pH values of five and they are capable of fixing N up to pH nine. Fixing efficiency is low with 2-10 mg N fixed/gram carbohydrate consumed. Blue green algae are common in flooded soils and are stimulated by increasing light intensity. Its fixation of nitrogen is less rapid than in Azotobacter or Clostridia. All photosynthetics are affected favorably by light and inhibited by oxygen. Their rate of assimilation is also quite slow. Non sulfur purples are found in flooded soils, ditches, lake muds, and sea bottoms.

Many factors affect the non-symbiotic fixation of gaseous nitrogen. The presence of nitrate or ammonium can reduce fixation. Nitrogen fixers have the ability to use NO_3^- and NH_4^+ and sometimes prefer them to N_2.

Fixation is also dependent on certain metals. Molybdenum, iron, calcium, and cobalt are all critical for the reaction. The availability of energy sources (sugar, cellulose) also limits the rate and extent of fixation by heterotrophs. Typically one to 30 mg of N are assimilated per gram of carbon source.

Bacterial nitrogen fixers are affected by soil acidity. Azotobacter, as well as blue-green algae, are sensitive to pH values less than six. The fixation rate is also determined by soil moisture. Nitrogen assimilation is insignificant when little water is available but activity can be especially great under waterlogged conditions. The optimum water level varies with soil type and quantity or organic matter. Increasing temperature also promotes gas uptake with an optimum of about 35 degrees C. Deliberate vegetation burning seems to promote nitrogen fixation as well and grasslands generally have low activity.

The classic example of symbiotic N fixation is the relationship between leguminous plants and bacteria of the genus Rhizobium. The seat of the symbiosis is in nodules on the plant roots. Rhizobia are gram negative, non-spore forming, aerobic rods which are typically motile. Several carbohydrates are used in its metabolism with occasional acid accumulation. Gas is never liberated. Rhizobia grow readily in media containing a C source, NH_4^+ or NO_3 to supply needed N, several inorganic salts, several B vitamins, and cobalt. Symbiotic N_2 fixation rates range from 65-335 kg N/ha/year. Non-legumenous plants (eg. alder trees) are also capable of nodule formation and N_2 fixation.

The many environmental influences of symbiotic N_2 fixation include type of legume, inorganic-N content of soil, level of phosphorous and potassium which are essential host nutrients, pH, presence of secondary nutrients, and climate as it affects the host plant. As in non-symbiotic fixation, symbiotic fixation is inhibited by the presence of inorganic-N. Little nodule formation occurs at pH less than five. This is probably due to iron or aluminum toxicity rather than pH sensitivity. There is some evidence that a calcium deficiency is important in its effects of acidity on fixation. Molybdenum, whose availability is affected by pH, and cobalt also stimulate fixation.

Plant Uptake

As mentioned earlier in this chapter, research findings regarding plant uptake of nitrogen has been limited. A general rule of thumb is that 1 to 4% of a soil's organic-N is released to plants during the growing season in temperate climates (Alexander, 1977). Nitrate is the preferred form of nitrogen taken up by plants. Factors favoring uptake include vigorous root aeration, low initial salt content in plant tissues, high external nitrate concentrations, and an absence of ions which compete for uptake. Unfavorable factors to uptake include low light intensity and a limited carbohydrate level in the plant. Woodmansee, Vallis, and Mott (1979) determined that nitrogen is taken up to above ground plant parts during the growing season and then, during the fall, nitrogen is translocated back to the plant's crown and roots.

Volatilization

Ammonia is a gas at normal temperatures and pressures and its partial pressure is usually low. Volatilization of ammonia is insignificant, however, when the pH of the soil is less than 7.0 (Alexander, 1977). High concentrations of ammonia with high pH, high temperatures, and low CEC are necessary for NH_3 volatilization (Tusneem and Patrick, 1971).

Ammonia sources include organic-N compounds which decompose to release NH_3 (eg. wastewater), fertilizers, ammonia salts, and urea. Most sources provide ammonium which applies to the following equations:

$$NH_4^+ + OH^- \longleftrightarrow NH_3 + H_2O$$

$$K_b = [NH_4^+][OH^-]/[NH_3] = 1.774 \times 10^{-5} \text{ at } 25°C$$

$$K_w = [H^+][OH^-] = 1.007 \times 10^{-14} \text{ at } 25°C$$

where:
- K_b is the dissociation constant of the ammonium reaction,
- K_w is the dissociation constant for water,
- $[NH_4^+]$ is the ammonium concentration,
- $[NH_3]$ is the ammonia concentration,
- $[OH^-]$ is the hydroxide ion concentration, and
- $[H^+]$ is the hydrogen ion concentration.

When dividing K_b by K_w, one gets a relationship between $[NH_4^+]$, $[NH_3]$, and pH (Freney, Simpson, and Denmead, 1979). Note that pK values are constant with temperature. The relation is:

$$\log([NH_4^+]/[NH_3]) = (pK_w - pK_b) - pH$$

TABLE 2.1

pH AND PERCENT AMMONIA RELATIONSHIP

pH	%NH_3
6	0.0
7	1.0
8	10.0
9	50.0

One can see from Table 2.1, derived from the above relationship, that ammonia concentrations are not significant until pH values are greater than eight.

Since the reaction is pH dependent, the buffering capacity (eg. calcium carbonate content) of the soil play an important role. Since hydrogen ions are released with volatilization, a soil will acidify without buffering. High temperatures also enhance volatilization. Besides increasing the pK's, increasing temperatures decrease NH_3 solubility and increase its diffusion rate which all promote volatilization. Since the concentration of ammonium drives the reaction, volatilization is indirectly affected by plant uptake, leaching, application rate, nitrification rate, mineralization, immobilization, and cation exchange. (Freney, Simpson, and Denmead, 1979)

Ammonium Adsorption

Isomorphous substitution in clay minerals gives clay particles a net negative charge. (Isomorphous substitution is the occupation of a clay matrix position by a cation other than the one normally found, without

change in the crystal structure.) To preserve electrical neutrality, cations are attracted and held on the surfaces and edges of clay particles. These cations are "exchangeable" since cations of one type may be replaced by cations of another type. The quantity of exchangeable cations required to balance the charge deficiency is called cation exchange capacity and is expressed as milliequivalents per 100 grams of dry soil. (Mitchell, 1976). During this ordinary exchange, larger and high charged cations are preferentially adsorbed as follows:
$Al^{3+} > Ca^{2+} > Mg^{2+} > K^{+} = NH_4^{+} > Na^{+}$ (Bohn, McNeal, and O'Connor, 1979).

Besides adsorption of cations to clay surfaces, cations can be "fixed" inside spaces within the layering of clay particles. Ammonium takes part in this reaction. Fixed ammonium is defined as the NH_4^+ ions which are not replaceable by prolonged extraction and leaching of a soil by potassium salt solutions (Nommik, 1979). Tusneem and Patrick (1971) stated that the presence of montmorillinite and illite leads to chemical fixation of NH_4^+ into a non-exchangeable form. These ions are then withdrawn from entering ordinary exchange and have restricted biological activity. Generally less than one-third of fixed NH_4^+ is available for nitrification. It has been established that these ammonium ions can slowly be replaced by cations which expand the interlayer (K, Mg, Ca).

Adsorbed ammonium contents in the topsoil are typically 1-25% of the total N; they are 10-90% of the total soil N in lower horizons (Kudeyarov, 1979). The soils capacity to adsorb NH_4^+ depends on the soil's mineral composition, texture, and pH. The amount of fixed ammonium increases with NH_4^+ concentration in the soil solution as described by the following equilibrium equation:

$$[NH_4^+]_f \longleftrightarrow [NH_4^+]_{ss}$$

where: -$[NH_4^+]_f$ is the fixed ammonium concentration, and

-$[NH_4^+]_{ss}$ is the ammonium concentration in the soil solution.

There is also a relationship between soil moisture content and the amount of adsorbed ammonium (Kudeyarov, 1979; Nommik, 1979). Increasing the moisture content influences the degree of expansion of the lattice of clay minerals, causing the release and migration of adsorbed NH_4^+ from the interlayer space. On the other hand, flooding decreases nitrification and as ammonification continues, the ammonium concentration increases in the soil solution. This increase shifts the equilibrium equation towards fixation.

In non-flooded, non-fertilized soils, the maximum ammonium is adsorbed in early spring and late autumn with minimum fixation at the end of the growing season (Kudeyarov, 1979). In the summer, plants assimilate more mineral N than is produced. Therefore, nitrate and ammonium concentrations decrease in the soil. (It was stated earlier that nitrate is assimilated more rapidly by crops than added ammonium. Perhaps NH_4^+ adsorption delays its uptake.) After the vegetation period, nitrogen assimilation and nitrification decline and, as ammonification continues, a net increase in soil NH_4^+ occurs. Therefore, a seasonal pattern exists where the minimum amount of fixed ammonium is during the period of high nitrification and plant uptake.

Leaching of Soil Nitrogen

Nitrogen leaching, or migration of N into deeper soil horizons, is serious when rainfall exceeds evapotranspiration (Khanna, 1979). Organic-N, which usually makes up more than 90% of the total soil nitrogen, is considered to have low mobility and leaching potential. Normally 40-50% of total rainwater-N is ammonium. Ammonium leaching is considered unlikely, however, except under heavy rainfall or sewage disposal. The reasons for low NH_4^+ leaching are:

1. NH_4^+ adsorption by CEC,
2. microbial immobilization,
3. nitrification,
4. plant uptake, and
5. NH_3 volatilization.

Nitrates and nitrites are leached the easiest since their negative change prohibits ion adsorption. Khanna (1979) reported an average spring to autumn mineral-N loss leaching rate of 0.6-1.45 kg N/ha/day. In a clay loam soil, Khanna (1979) reported a nitrate leaching rate of 1.9 mm/day.

Vertical solute movement is described by the following equation (Khanna, 1979):

$$\frac{\partial C}{\partial t} = \bar{D}\,\frac{\partial^2 C}{\partial C^2} - V_0\,\frac{\partial C}{\partial z}$$

where: C = NO_3 concentration in mg/l,

$\bar{D}$ = apparent mean diffusion coefficient in cm/d,

V_o = average pore velocity in cm/d,

z = linear flow distance in cm, and

t = time in days.

This equation may underestimate vertical flow because macropores, created by plants and animals, will act as direct conduits to flow.

Leaching fluctuates with season (Khanna, 1979). Nitrate concentrations rise in streams in autumn and peak in winter or early spring. There is no relation to individual rainfalls. A drought can often lead to an upward migration of nitrate. Increases in stream and soil water nitrate from leaching have been seen after fires as well.

Land Treatment of Nitrogen: Case Study Summary

Losses of 7 to 94% of applied nitrogen through denitrification were indicated in several lab and field studies. Patrick and Gotoh (1974) observed 67% denitrification loss of applied-N in a silt loam soil mixed with $(NH_4)_2SO_4$ and incubated in the dark for 120 days at 30°C. Up to 68% losses of added nitrogen resulted when Tusneem and Patrick (1971) incubated a silt loam at 30°C in water saturated air. These losses were attributed to denitrification since they were too large to result from volatilization or adsorption. Reddy and Graetz (1981) observed 58 to 71% applied-N losses in aerobic lab conditions and 94% losses in anaerobic lab conditions using a muck soil. These losses resulted from denitrification since pH values were low (less than 9). The same conclusion was reached by Chen and Patrick (1981) during a lab scale overland flow study where 53 to 61% of added ammonium was lost. Ammonium reduction of 93% were witnessed by Olson et.al. (1980) at a sandy rapid infiltration site treating municipal primary effluent. This loss occurred through 22 feet of unsaturated zone. Lab scale lysimeters were used by Leach and Enfield (1983) to determine 30 and 79% denitrification losses in sand and a sand/clay mixture, respectively. Ryden and et.al. (1981) found only 7-9% loss of total applied-N at a secondary effluent disposal field. One-third of this loss was from volatilization since wastewater pH was high and the buffering capacity was low. Soil aeration, low soil nitrate and high redox potential (600 mV) were also reasons for the low losses at this sandy loam site.

Leaching of nitrate or ammonium was also seen as a potential sink for applied nitrogen. Lund et.al. (1981), while studying a loamy sand pasture irrigated with secondary treated wastewater, determined that 51-76% of the applied-N leached to the groundwater. This was a rate of 833 kg NO_3^--N/acre/yr. Denitrification was not considered due to aerobic soil conditions and the fast percolation rates. Chen and Patrick (1981) observed 10-30% of applied ammonium in the underflow of a lab scale overland flow system.

Crop uptake was a third major sink of applied nitrogen cited in the literature. King (1982) found that 20-30% of applied nitrogen was recovered in a crop irrigated with wastewater from a fiberboard mill. Chen and Patrick (1981) observed 11-22% uptake of added ammonium during simulated overland flow. Palazzo (1981) determined that 50-85% of applied nitrogen was taken up by orchardgrass planted on a silt loam soil and irrigated with municipal wastewater. Palazzo also stated that highest plant yield and nitrogen uptakes occurred during late spring and concluded that higher loading rates could be applied during this period.

Many case studies indicated parameters such as C:N ratio, load/rest cycling, soil moisture content, and soil oxygen content which affected nitrogen transformations. Lab studies by Patrick and Gotoh (1974), Tusneem and Patrick (1971), and Chen and Patrick (1981) all determined that nitrogen losses increased with decreasing C:N and immobilization increased with added carbon. Highest nitrogen losses were observed at C:N equal to 15:1.

Tusneem and Patrick (1971), Chen and Patrick (1981), King (1982), and Leach and Enfield (1983) all found that nitrogen losses were stimulated by alternate submergence and drying of soils in both lab and field situations. Leach and Enfield also observed that NO_3^--N concentrations increased in soil pore water during resting and were flushed downward during loading causing nitrate peaks to appear.

Soil moisture content and soil pore air oxygen content also were found to have an effect on denitrification. Ryden et.al. (1981) observed maximum denitrification rates at moisture contents of 15-18% at a secondary effluent disposal area. Patrick and Gotoh (1974) found that nitrogen loss increased with oxygen contents up to 20%. Minimal losses occurred at higher O_2 contents. This indicated that the earth's atmospheric content of 21% is adequate for nitrogen loss.

The History of Ridge and Furrow Treatment

The historical perspective of the ridge and furrow treatment of wastewater was provided in two reports by Schraufnagel (1956, 1962) and one by Monson (1956). The following discussion was based on their findings.

Ridge and furrow irrigation, in the form of sewage farms in the 1870's, was one of the earliest methods of sewage disposal. Several canneries in Iowa began operation of ridge and furrow sites in the 1930's; during the late 1940's and early 1950's, Minnesota and Illinois canneries also began ridge and furrow disposal. Seasonal flows ranged from 136 to 250,000 gallons per day and site areas range from 2 to 40 acres.

In 1930, a dairy in Phoenix, Arizona, reportedly discharged 60,000 gpd of effluent to eight furrows which were plowed under every other day. A creamery in Minnesota installed a ridge and furrow system in 1950 on a 2.8 acre site divided into three cells and underlain by a line of drain tile. The total cost of the system, exclusive of land, was $800. The first ridge and furrow system in Wisconsin was developed at the Mindoro Cooperative Creamery in 1954. The three acre site was similar in design to the Minnesota system. A pumping system was necessary and the total initial cost, including $2000 for land, was $8000. In 1962, the system treated 23,300 gallons/acre/day and 50 lb BOD_5/acre/day. (It should be noted that the drain tile outlet at this site has since been closed.)

Several meat processing and wood pulping plants have also used the ridge and furrow treatment process.

Ridge and Furrow System Design Concerns

Before operation of a ridge and furrow treatment system, many design concerns must be considered. They include site selection, system size, operation, cell layout, and cover crop (Rodenberg, 1980).

Site selection is the initial step. A suitable site must be located through a site survey which considers soil classification, topography, and proximity to residences. Relatively permeable soils are needed to provide adequate treatment and hydraulic disposal of wastewater. Low permeability will result in wastewater ponding and high permeability will result in limited contaminant (eg. BOD_5, TKN, etc.) treatment. Soil suitability is quantified through soil borings and percolation tests.

From a construction view point, the cost of ridge and furrow installation is lower if the topography is fairly level. This also limits cuts and fills which could affect the infiltrative capacity of the soil. Control of wastewater flow is also better on flat systems.

In Wisconsin, the minimum separation distance between ridge and furrow systems and residences is 500 feet. A designer must consider this distance closely. Many proposed designs have been delayed or dropped because of homeowner challenges. Sites must also be located 250 feet from water supply wells in Wisconsin.

Hydraulic and BOD_5 loading rates are currently used to size a ridge and furrow system (Rodenberg, 1980). Clayey soils should generally have hydraulic rates from 2500 to 5000 gallons/acre/day. Sandy soils may receive up to 10,000 gallon/acre/day. Hydraulic overload has historically been the primary failure at these systems in Wisconsin (WDNR, 1984). A conservative design approach is therefore recommended. Wisconsin Code NR 214 states that BOD_5 loading rates at ridge and furrow sites should not exceed 100 lb BOD_5/acre/day. In summary, there are two methods to size a potential system provided that wastewater flow and BOD_5 estimates are available.

Once the loading rates have been determined, the number, loading schedule, and size of cells (or sections) must be determined (Rodenberg, 1980). It is important to have more than one cell, even in small systems, to allow for alternate loading and resting. Resting helps maintain aerobic conditions beneath the furrows, upholds the adsorptive capacity of the soil, and enhances biodegradation of the wastewater. A cell should not come into service until the previously loaded wastewater has seeped away. A load/rest time period is, therefore, dependent on site soils. Cell size is affected by site topography as well and smaller cells are recommended on steeper slopes. Wastewater distribution efficiency should also be considered in cell sizing. Waste application should be uniform in all loaded furrows.

Figure 2.3 and Figure 2.4 show typical ridge and furrow layouts and furrow construction detail, respectively (Rodenberg, 1980). One typical system layout is to have a header ditch along one side of the site with all furrows, separated eight feet on center, perpendicular to it. Flow is directed to the desired cell by a diversion structure. Another possible layout is to have several header ditches crossing the furrows at right angles within each cell. Flow is directed in valved pipes. Furrows are recommended to be one foot deep, one foot wide at the bottom, and two feet wide at the top. To maintain slope stability, shallower furrow side slopes may be necessary in sandy soils.

FIGURE 2.3

RIDGE & FURROW

Diversion Structure
Lay-Out

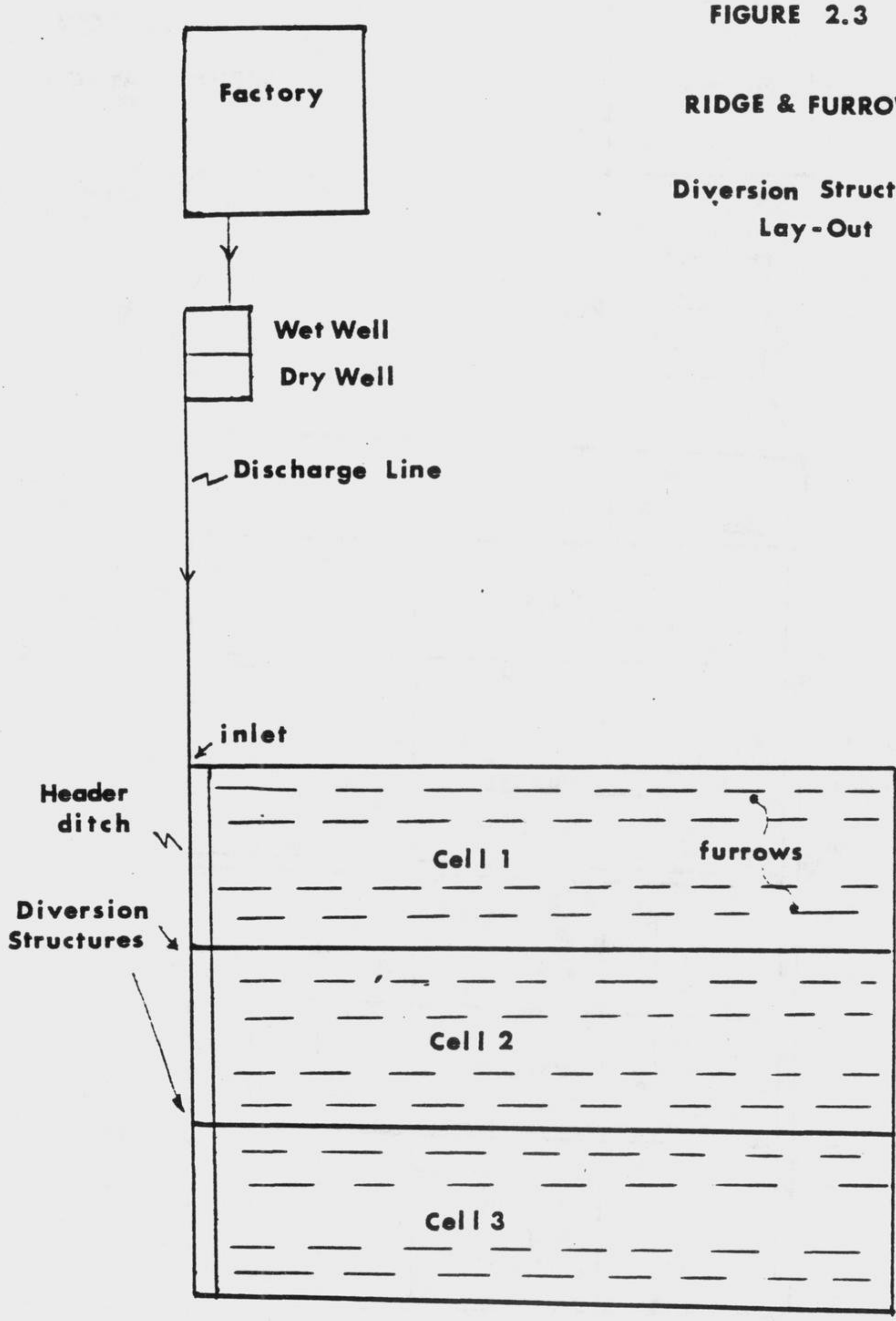


FIGURE 2.3

RIDGE & FURROW

PUMPING LAY-OUT

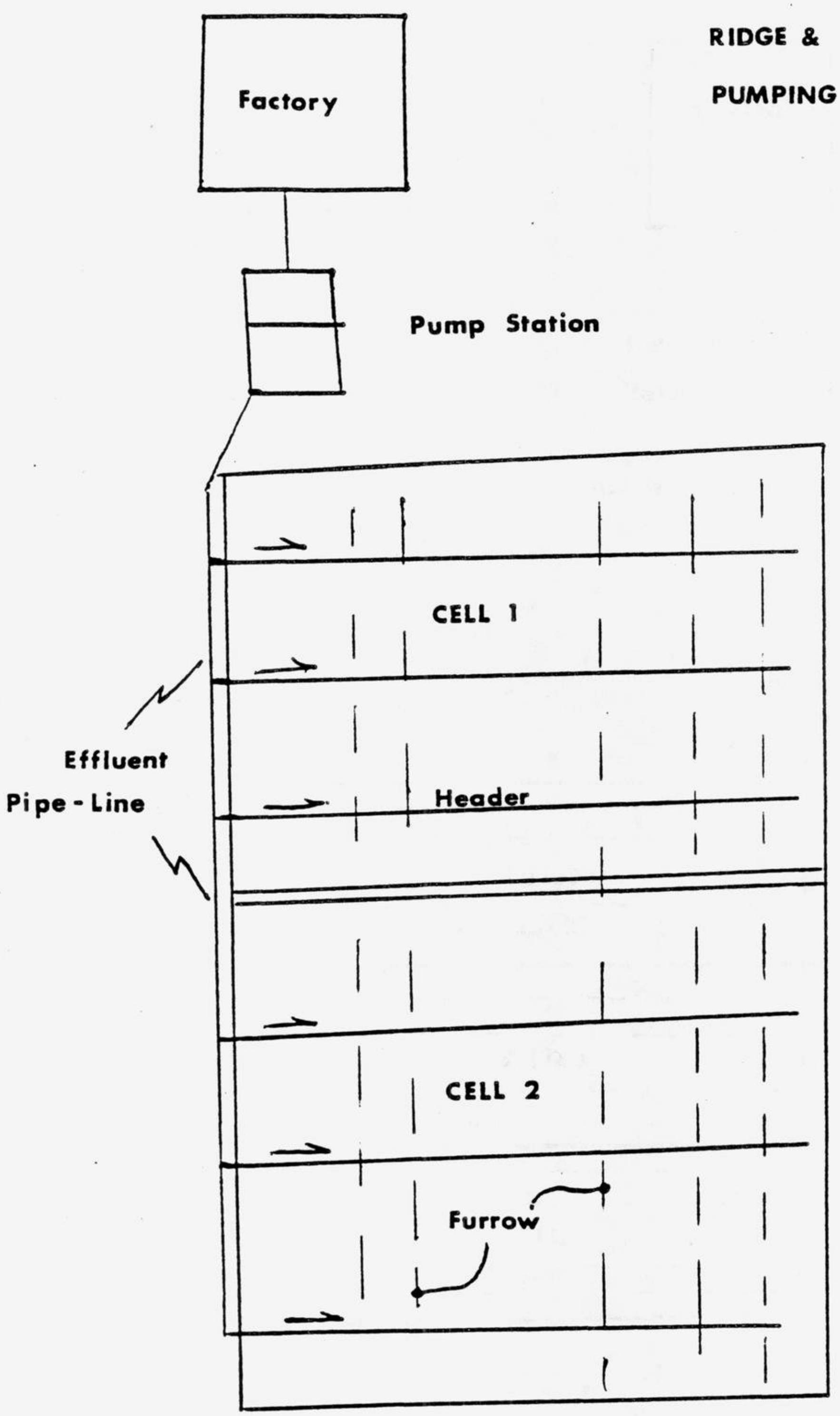
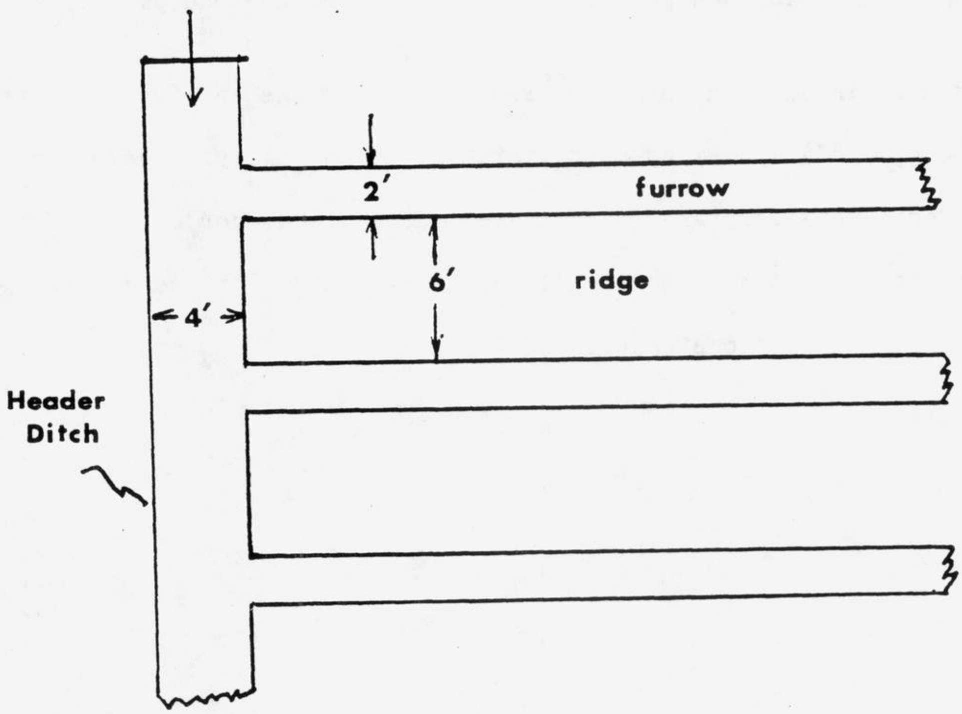
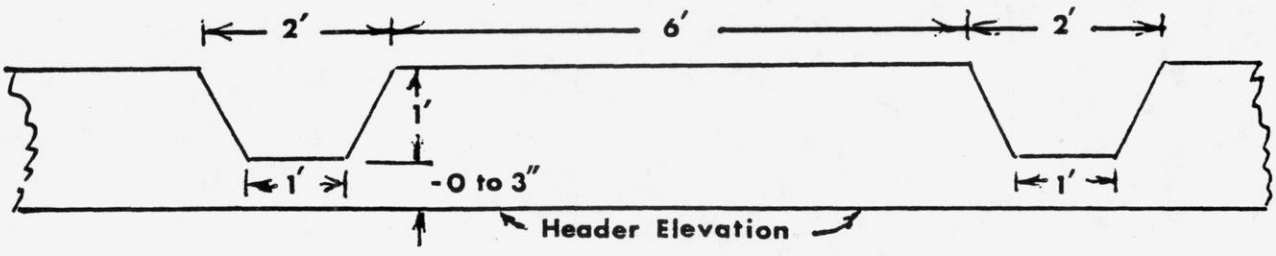


FIGURE 2.4

HEADER & FURROW DETAIL





A ridge and furrow system commonly is surrounded by a berm several feet high and cells within a site are usually separated by an embankment eight feet wide (Rodenberg, 1980). These dikes prevent surface runoff from entering the system, contain wastewater during temporary cell flooding conditions, and permit access of maintenance equipment.

A cover crop is also an important feature of a ridge and furrow system (Rodenberg, 1980). Besides maintaining ridge stability, a cover crop allows for nutrient uptake, evapotranspiration, and odor control. A crop should be able to tolerate flooded conditions. In the Midwest, reed canary grass is preferred.

CHAPTER 3: MATERIALS AND METHODS

Materials

Wells, lysimeters, stage markers, and infiltration stations were installed at each site for use in gathering information for the project. Locations of this instrumentation will be discussed in the respective site chapters.

During August and September of 1983, 2 inch I.D. PVC wells were installed at each site. These wells were used to collect groundwater samples and measure groundwater elevations. A typical installation is shown in Figure 3.1. Six inch diameter boreholes were drilled to the desired depth using a rotary auger drill rig provided by the State of Wisconsin Geologic and Natural History Survey. A six inch hand auger was used at locations not accessible to the rig. Screens of two and one-half and five feet were used (slot width = 0.006 inches); the longer screens were used in shallow water-table installations and shorter screens were used in deep wells. Silica sand was placed around the screen and a bentonite seal was packed about a foot above the screen to retard migration downward of surface contaminants. The upper portion of the borehole was backfilled with natural soil and bentonite and compacted. A concrete cap and protective casing were placed at the surface to secure the well. Elevations were shot on the tops of all wells for reference in groundwater elevation measurements.

Vacuum lysimeters were installed in September and October of 1983 at both sites. These were employed to draw samples of pore water at given

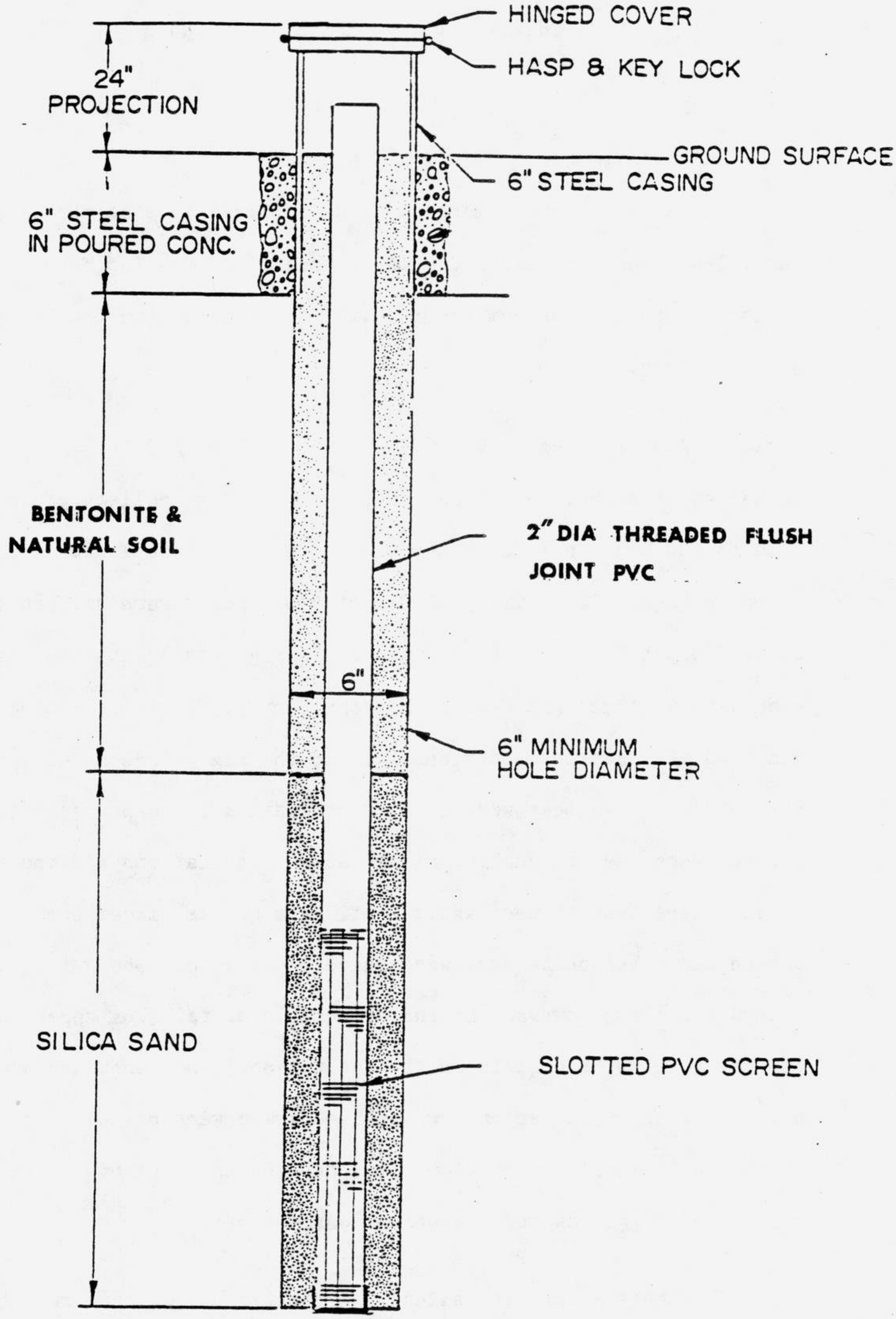


FIGURE 3.1

PIEZOMETER WELL DETAIL

NOT TO SCALE

depths in the unsaturated zone. A typical Teflon lysimeter installation with specifications is illustrated in Figure 3.2. A six inch hand auger was used to drill a borehole to the desired depth. The lysimeter was then lowered into the borehole and a silica flour slurry was poured around it. The silica pack allowed for a continuum between the soil and the lysimeter. After the silica pack hardened, the hole was backfilled with natural soil. A concrete cap and protective casing were installed at the surface to secure the lysimeter.

Stage markers were installed in March and April of 1984 for use in stream elevation measurements. A typical marker is shown in Figure 3.3. A metal stake was driven into the stream sediments and protected by a short length of PVC pipe. Elevations were recorded at the top of the stakes for a reference.

Infiltration stations were constructed in October and November of 1984 to determine the infiltration rate of wastewater into the unsaturated zone. A typical station, with dimensions, is shown in Figure 3.4. A station consisted of two sheets of plywood, hand-driven into a furrow, which isolated a short length of furrow.

Methods

Procedures followed during this ridge and furrow project were based on the objectives listed in Chapter 1 which were:

1) to determine the nitrogen transformation in the wastewater during treatment,
2) to perform a nitrogen budget at each site,

FIGURE 3.2

TYPICAL LYSIMETER INSTALLATION

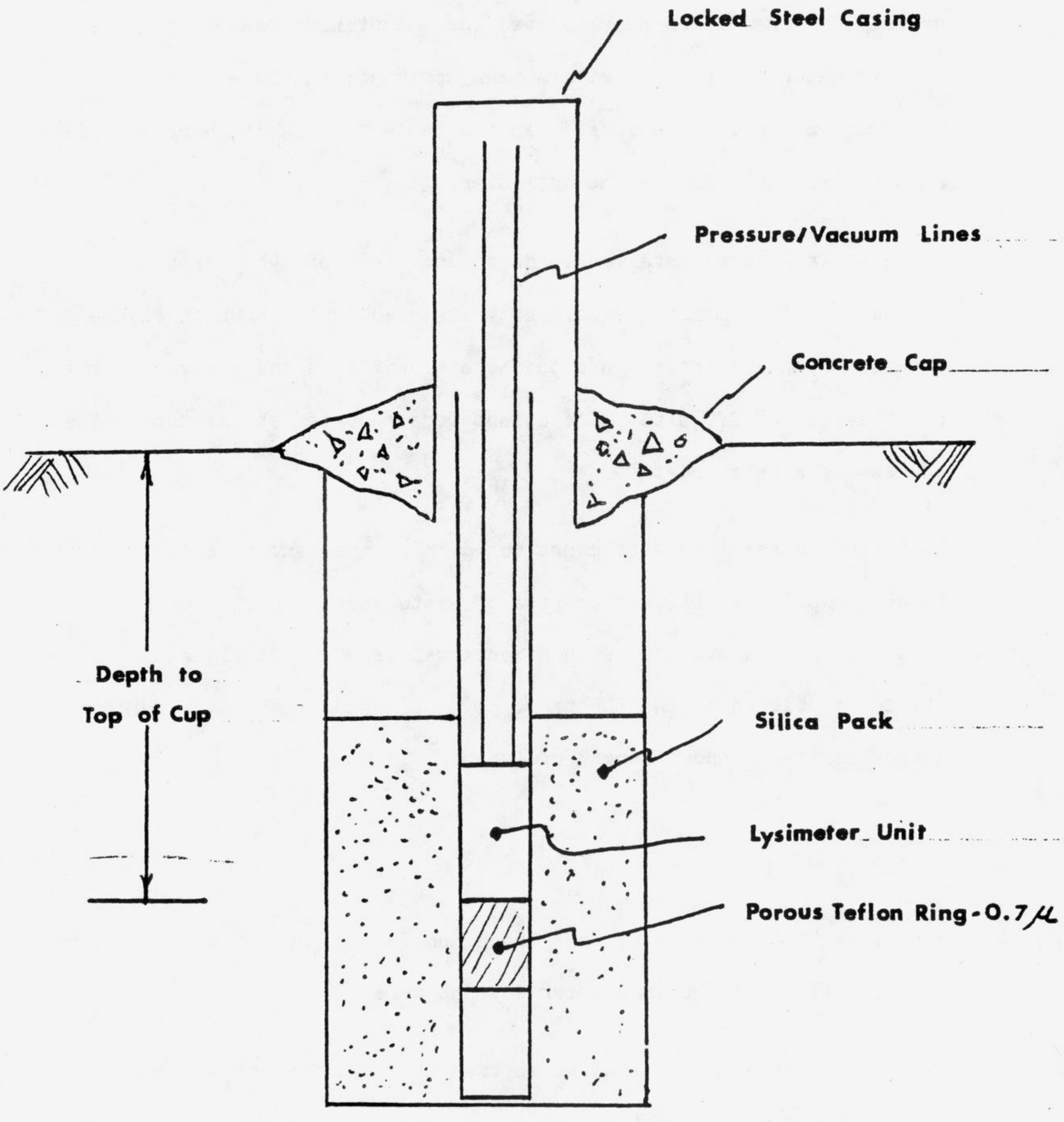


FIGURE 3.3

TYPICAL STAGE MARKER

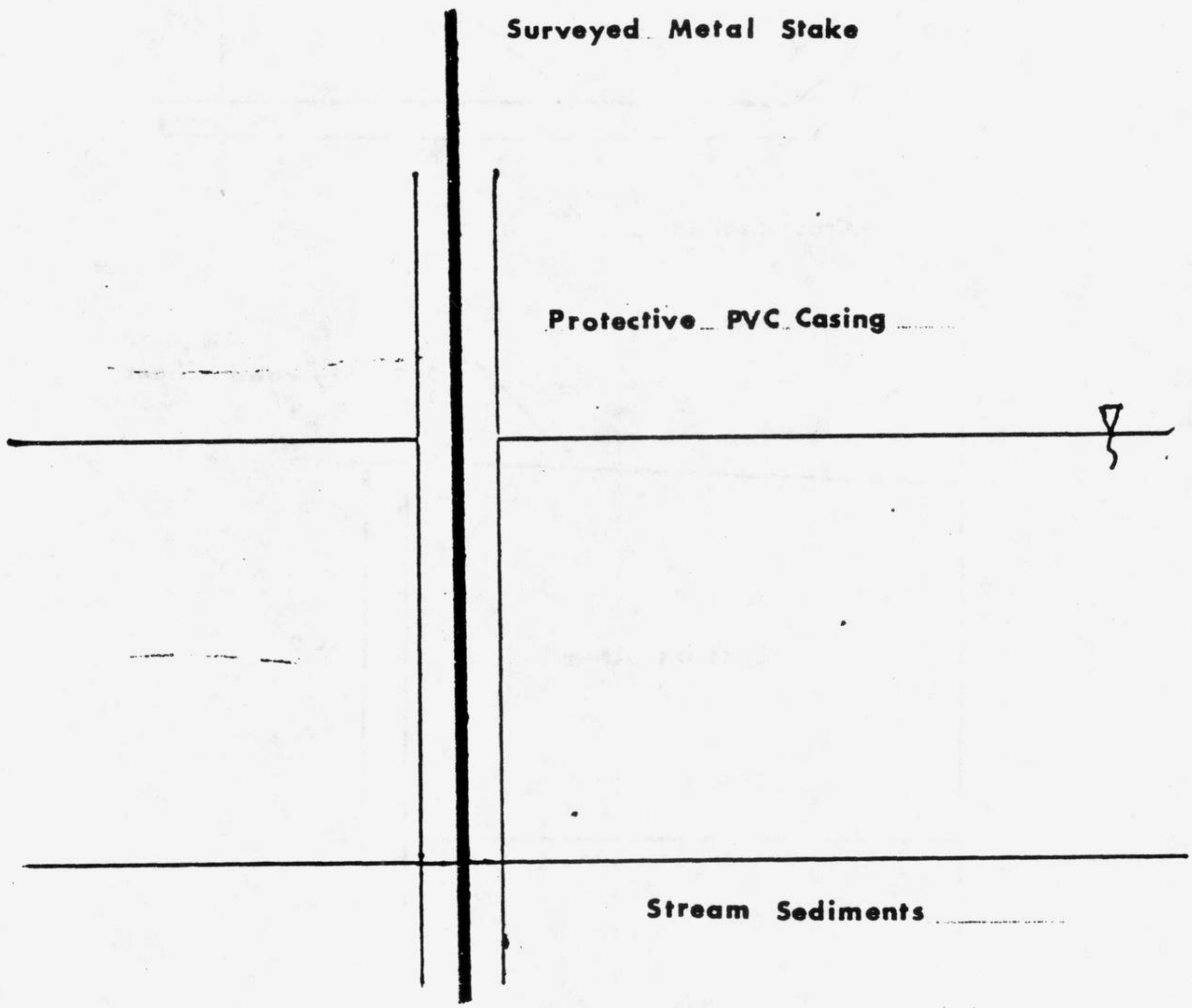
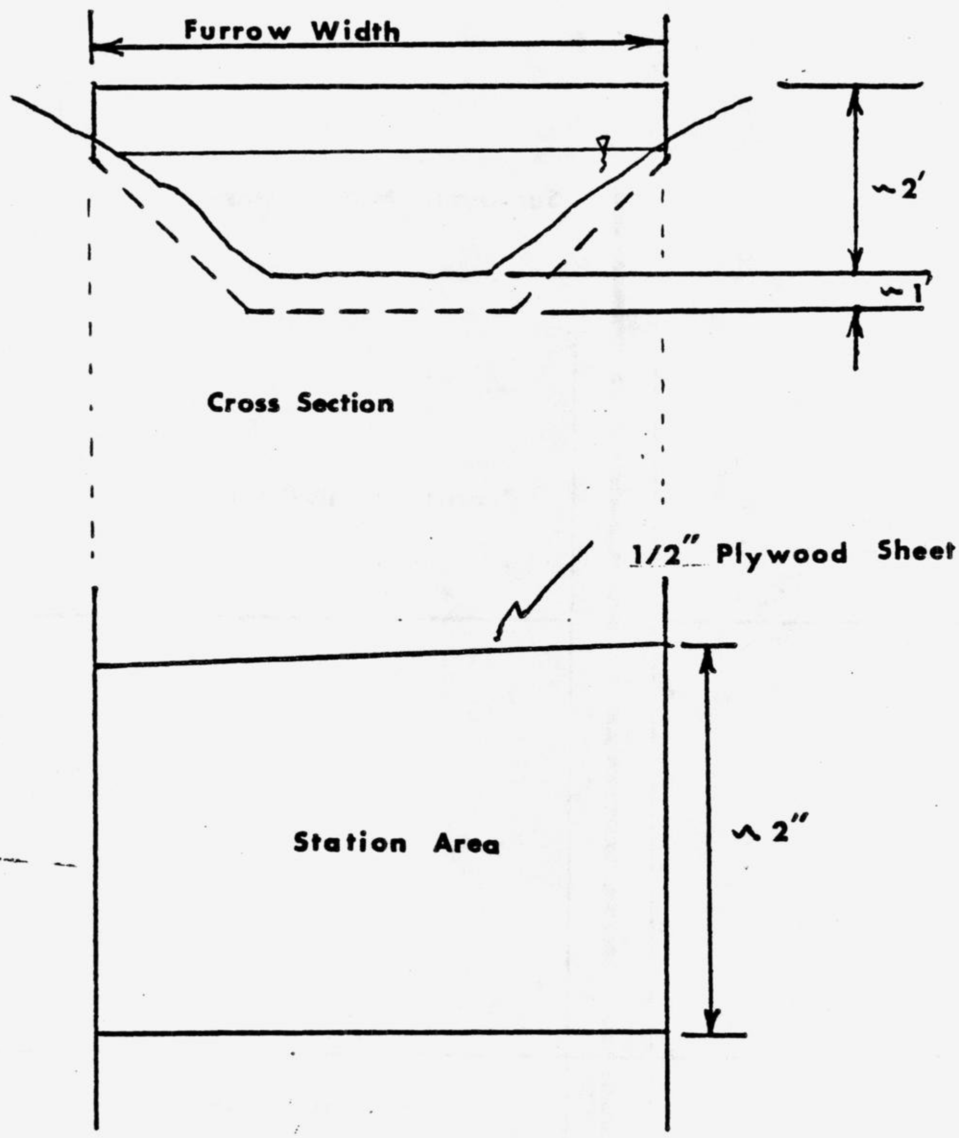


FIGURE 3.4

TYPICAL INFILTRATION STATION



Plan View

3) to analyze ridge and furrow treatment effectiveness under different soil and loading conditions,

4) to examine the operation and maintenance at these systems, and

5) to evaluate the monitoring equipment used.

This chapter describes these procedures.

The primary task before field work began, was to determine the number and location of well and lysimeter installations. This was done by personnel at WDNR during the summer of 1983. Wells were positioned to detect contamination migrating from each site (shallow and deep) to better define groundwater movement, and to describe background groundwater quality. Additional wells were installed later in the project based on groundwater flow and detected contamination. Lysimeters were placed in centralized areas within site cells which appeared to receive a typical wastewater loading. Background lysimeters were also installed away from the ridge and furrow systems.

Beginning in October of 1983, after initial well and lysimeter installation, a monthly field visit to each site was performed. During a typical visit, groundwater, lysimeter, and wastewater samples were collected, water table elevations were measured, and site observations were conducted.

As the project progressed and questions about the data arose, adjustments in this routine were made. In March and April of 1984, additional wells were installed at each site to better quantify the polluted area. In June of 1984, monthly sampling was discontinued at wells with predictable or non-useful chemical trends. At Brodhead, during July-August and October-November of 1984, an intense sampling program was conducted to better quantify nitrogen transformations with depth and time during a loading cycle. July and August sampling occurred during a two week load/rest cycle and the October-November sampling took place during a one-week load/rest cycle. During these sampling periods, wells and lysimeters located inside the system and selected furrows were sampled two or three times per week. An additional well was installed in October 1984 at Brodhead to better define groundwater quality immediately beneath the site.

A complete description of field methods is presented in the following section.

Field Methods

Soil samples were taken during initial borehole drilling. Grab samples were removed from the rotary or hand auger at desired depths. Samples were sealed in labeled plastic bags for travel.

During each monthly trip, a flow composite wastewater sample (typically 24-hour) was collected. Each time the pump would run, a fraction of the flow was diverted through a hose, tapped into the discharge side of the pump, which led to a collection reservoir stored in ambient conditions. Non filtered samples were collected. Nitrogen and COD samples were acidified with sulfuric acid to pH<2; metal samples (when taken) were acidified with nitric acid to pH<2.

As composite waste samples were collected, wastewater flows to the ridge and furrow systems were also determined. At Brodhead, flow was calculated by subtracting the volume of cooling water discharge (to river) from the total production water pumped into the plant. Both of these pumps were metered. At Mindoro, this calculation was made by dividing the volume pumped by the hours of metered pumping time during sample collection. Also, 30-day monthly wastewater flow averages, as reported to the Wisconsin DNR, were recorded at both sites.

Furrow samples were taken during the intensive sampling periods at Brodhead and during October and November of 1984 at Mindoro. Grab samples taken from selected furrows were field filtered and acidified unless travel time to the lab was short (less than 1 hour).

Field filtering was done with a peristaltic pump, powered by a 12 volt D.C. battery, and pressure filter stand. Samples were filtered through a 0.45 micron filter. As described earlier, all nitrogen and COD samples were preserved with sulfuric acid to pH<2; all metals samples were acidified with nitric acid to pH<2. Samples were packed in ice for transport.

Lysimeter samples were taken monthly with accelerated collection during "intense" sampling periods at Brodhead. Twenty inches of mercury vacuum was applied with a two-way hand pump, to draw a pore water sample into the lysimeter. At Brodhead, an adequate volume of sample was obtained after a 48 to 72 hour vacuum period. At Mindoro, adequate volumes could be obtained from the operating lysimeters within 24 hours. Samples were removed from the lysimeter's sample reservoir by pressurization with a hand pump. Samples were field filtered and acidified unless travel time to the lab was short.

Well sampling was performed monthly with accelerated collection during "intense" sampling periods at Brodhead. Wells at Brodhead were purged and sampled with a diaphragm pump or PVC bailer while wells at Mindoro were purged and sampled with a PVC bailer. Apparatus was rinsed with deionized water before purging and sampling. For quickly refilling wells, three well volumes were removed before sampling. For slowly refilling wells, water was purged until the well was dry. The latter wells were located at Mindoro and were sampled the following day. Samples were field filtered and acidified.

Periodically, upstream, midstream, and downstream grab samples were taken of neighboring rivers at each site. Non-filtered samples were acidified in the field as described earlier.

Groundwater elevations were taken each time a well was sampled. This was done with a fiberglass surveying tape with a "popper" attached. The popper was a formed metal cup which produced a pop sound as it contacted standing water within a well. Surface water elevations of neighboring streams were taken periodically after stage markers were installed.

Slug tests, as described by Cooper, Bredehoeft, and Papadopulas (1967, 1973), were attempted at each site to determine hydraulic conductivities in the saturated zone. Briefly, this method involves removing or adding a quantity of water to a well and recording the rise/fall of head with time. These curves can be related to type curves to determine conductivity and a storage coefficient. This procedure is presented in Appendix E.

During October and November of 1984, plywood infiltration stations were constructed. A volume of wastewater was taken from a neighboring furrow and added to a dry "station." Water elevation drops were measured with time to determine the flow rate of wastewater through the furrow bottom.

Grass samples were collected during the spring, early summer, and late fall to determine plant nitrogen uptake during the growing season. Cuts were made at about two inches above the ground surface and the area of the sample was recorded. Samples were stored in paper bags for transport.

Site observations were made during each visit. These observations included 1) the extent of freezing conditions during the winter, 2) the extent of plant growth during the growing season, 3) the distribution of wastewater to the furrows, 4) cell loading, 5) the amount of solids build-up in the furrow bottoms, and 6) the operation of the monitoring equipment used.

Analytical Methods

Chemical analysis of wastewater, furrow, lysimeter, groundwater, and stream samples were performed by the Wisconsin State Laboratory of Hygiene. Complete lab procedures are described in the "Manual of Analytical Methods-Inorganic Chemistry Unit" written by the Lab of Hygiene in 1980. As mentioned before, the lab also filtered and acidified samples if travel time from a site was short (less than 1 hour). Table 3.1 lists the frequency of analysis and sample source (waste, furrow, etc.) for each chemical parameter. Readings of pH were made in the field with a Tripar Industries, Inc. three-parameter digital meter.

TABLE 3.1

CHEMICAL ANALYSIS DONE

PARAMETER	SAMPLE SOURCE	FREQUENCY*
DISS BOD_5	furrow, lysimeter, groundwater	4,4,3
TOTAL BOD_5	wastewater, furrow, stream	1,4,4,
DISS COD	furrow, lysimeter, groundwater	2,3,3,
TOTAL COD	wastewater, stream	1,4
TSS	wastewater	1
TDS	wastewater, furrow, lysimeter, groundwater	4,4,4,1
DISS TKN	wastewater, furrow, lysimeter, groundwater	2,2,3,3
TKN	wastewater, furrow, stream	1,2,4
DISS NH_3-N	wastewater, furrow, lysimeter, groundwater, stream	1,2,3,3,4
DISS NO_2-N+NO_3-N	wastewater, furrow, lysimeter, groundwater, stream	1,2,3,3,4
Cl^-	wastewater, furrow, lysimeter, groundwater, stream	1,2,3,3,4
pH	wastewater, furrow, lysimeter, groundwater, stream	1,1,1,1,1
DISS ALK	groundwater	4
TOTAL ALK	wastewater, stream	4,4

TABLE 3.1 (Continued)

PARAMETER	SAMPLE SOURCE	FREQUENCY*
DISS TOTAL P	groundwater	4
TOTAL P	wastewater, stream	4,4
DISS SO_4^{2-}	groundwater	4
TOTAL SO_4^{2-}	wastewater, stream	4,4
DISS Na^+	groundwater	4
TOTAL Na^+	wastewater, stream	4,4
DISS K^+	groundwater	4
TOTAL K^+	wastewater, stream	4,4
DISS Mg^{2+}	groundwater	4
TOTAL Mg^{2+}	wastewater, stream	4,4
DISS Ca^{2+}	groundwater	4
TOTAL Ca^{2+}	wastewater, stream	4,4

*Frequencies:
1 - monthly
2 - intense periods only
3 - 1 and 2
4 - periodically

Soil and plant analysis was performed by the Soil & Plant Analysis Laboratory, University of Wisconsin Extension. Complete lab procedures are described in "Wisconsin Procedures for Soil Testing, Plant Analysis, and Feed and Forage Analysis" (1980). Soil samples were analyzed for percent sand, silt, clay, and total nitrogen; CEC; and pH. Plant samples were analyzed for sample weight; percent ash; percent nitrogen of dry and ash sample; and percent P, K, Ca, Mg, and S; and Zn, B Mn, Fe, Cu, Al, and Na concentrations.

CHAPTER 4: BRODHEAD SITE - RESULTS AND DISCUSSION

Site Description

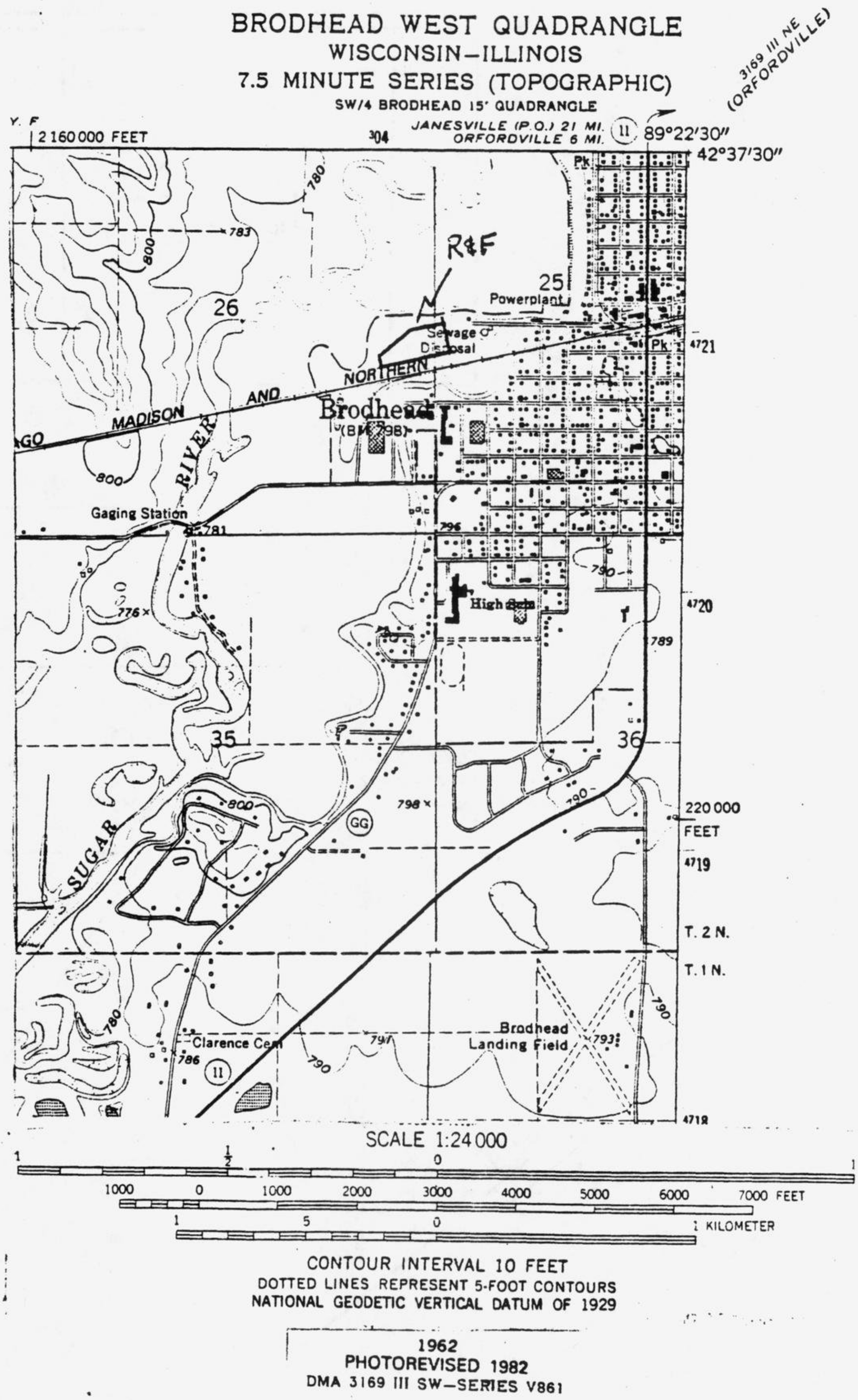
The Universal Foods cheese factory is located in Brodhead, Wisconsin in eastern Green County. The plant receives 260,000 pounds of milk per day and discharges 39,500 gpd (average) of processing wastewater which is treated by a 4.7 acre ridge and furrow system consisting of two cells. This treatment system began operation in 1972. Figure 4.1 is a topographical map showing the general location of the system.

A plan view of the treatment system is illustrated in Figure 4.2. Well, lysimeter, stream stage, and infiltration station locations are indicated as well as cell locations and areas. General information concerning well and lysimeter depths and location is presented in Table 4.1. Complete well and lysimeter logs are given in Appendix A.

The ridge and furrow site is located on an unconfined aquifer consisting of glacial outwash material along the Sugar River. This sandy material extends approximately 70 feet deep and overlays a sandstone aquifer. The Soil Conservation Service describes this Maumce, Orion soil as a poorly drained sandy loam soil over a fine to medium sand. It is formed on low stream terraces and somewhat poorly drained soils formed in silty alluvium (DNR, 1984).

Results of the soil analysis at Brodhead indicated the following parameter ranges:

FIGURE 4.1



BRODHEAD WEST QUADRANGLE
WISCONSIN-ILLINOIS
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 BRODHEAD 15' QUADRANGLE
3169 III NE (ORFORDVILLE)
JANESVILLE (P.O.) 21 MI.
ORFORDVILLE 6 MI.
2 160 000 FEET
89°22'30"
42°37'30"
R&F
Powerplant
Sewage Disposal
MADISON AND NORTHERN
Brodhead
(BM 798)
SUGAR RIVER
Gaging Station
High Sch
Clarence Cem
Brodhead Landing Field
220 000 FEET
T. 2 N.
T. 1 N.
SCALE 1:24 000
1 MILE
7000 FEET
1 KILOMETER
CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
1962
PHOTOREVISED 1982
DMA 3169 III SW—SERIES V861

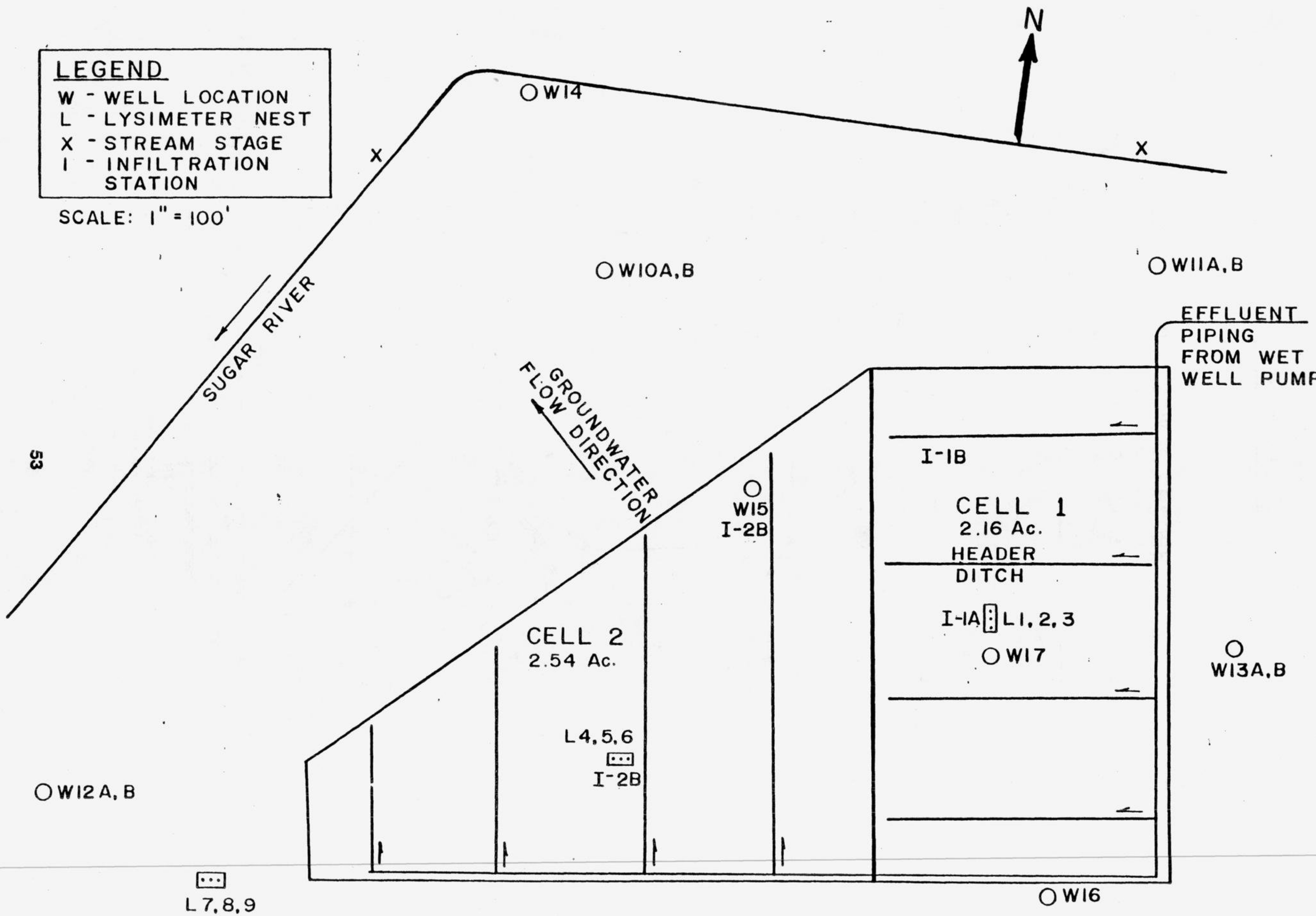


FIGURE 4.2: BRODHEAD PLAN VIEW

-sand: 81-99%

-silt: 0-16%

-clay: 1-5%

-Total N: 0-0.11%

-CEC: 1-13 meg/100g soil

-pH: 6.5-8.6

The higher silt, clay and total N fractions occurred in shallow samples. Also CEC tended to decrease with depth and soil pH tended to increase with depth. Complete soil analysis data are presented in Appendix B. After reviewing the data, it may be concluded that the soil below the treatment system is predominantly sand with an average CEC of 3 meg/100g.

Soil borings during well and lysimeter installation also produced the following information. First, profiles outside the system showed a one to four foot silty topsoil layer overlying the sand. Second, cell 1 borings indicated a dark saturated organic layer beneath the furrows. This layer was absent in the extremities of cell 1 and was about one foot thick in the center of the cell. Finally, cell 2 only had these organic layers around the header ditches. The largest thickness found under this cell was three inches.

WASTEWATER CHEMISTRY

Universal Food's wastewater was strong with an average BOD_5 of 1780 mg/l, COD of 2390 mg/l, TKN of 42 mg/l, and chloride of 930 mg/l. Means, medians, and ranges of these and other chemical parameters of the wastewater are provided in Table 4.2. Values of a strong typical domestic waste are provided for comparison. A complete tabulation of data is provided in Appendix C.

TABLE 4.1a

WELL SPECIFICATIONS

AT BRODHEAD SITE

WELL*	WELL TOP ELEVATION	DEPTH (ft)	WELL POINT ELEVATION	APPROXIMATE SURFACE ELEVATION	SCREEN LENGTH(ft)	LOCATION
10A	778.37	13.2	763.37	776.6	5	Downstream
10B	777.86	26.2	750.36	776.6	2.5	Downstream
11A	775.80	8.8	765.80	774.6	5	Adjacent to cell 1
11B	776.41	24.0	750.61	774.6	2.5	Adjacent to cell 1
12A	778.06	9.9	766.06	776.0	5	Background
12B	777.37	26.1	749.87	776.0	2.5	Background
13A	776.75	9.3	766.75	776.0	5	Adjacent to cell 1
13B	777.40	26.3	749.90	776.0	2.5	Adjacent to cell 1
14	776.29	5.8	769.00	774.8	2.5	Downstream
15	780.15	8.5	769.80	778.3	2.5	Cell 2
16	780.05	11.0	769.99	781.0	2.5	Upstream of cell 1
17	780.18	9.8	770.35	778.7	2.5	Cell 1

*All Wells PVC, 2 inch inside diameter

TABLE 4.1b

LYSIMETER SPECIFICATIONS

AT BRODHEAD SITE

LYSIMETER	DEPTH BELOW* FURROW (FT)	LOCATION
1	1.0	Cell 1
2	3.0	Cell 1
3	4.8	Cell 1
4	1.0	Cell 2
5	1.8	Cell 2
6	3.6	Cell 2
7	1.7	Background
8	3.7	Background
9	4.7	Background

* Depth is to top of teflon cup

TABLE 4.2

BRODHEAD WASTEWATER CHEMISTRY

PARAMETER	# OF SAMPLES	MEAN	MEDIAN	RANGE	SD	STRONG TYPICAL DOMESTIC
Total BOD_5	11	1780*	1700	980-3200	650	400
Total COD	9	2390*	2300	2000-3400	440	1000
TSS	10	876	869	464-1570	344	350
Total TKN	11	42	40	28-78	13	85
Dissolved TKN	3	26	21	21-37	9	---
NH_3-N	11	2.5	2.5	1.4-4.1	0.7	50
NO_2-N+NO_3-N	11	2.7	2.7	0.2-5.8	1.9	0
Cl^-	11	930	890	32-2300	700	100
pH	7	7.5	7.4	6.6-9.4	0.9	---

- All units mg/l except pH; typical domestic values from Metcalf and Eddy, 1979

* - Average contains samples which exceeded detection limit, see Appendix C for specific days

SD - Standard Deviation

In addition to the wastewater's general high strength, four other observations were made. First, the chemical data were highly variable. For example, the average chloride was 930 mg/l but the standard deviation was 700 mg/l and the range was 32-2300 mg/l. These variations, which did but occur seasonly, were most likely due to the changes in the amount of rinse water used in the plant. Days of higher rinsing resulted in lower concentrations and vice versa.

Second, the wastewater was high in chloride and sodium content (930 and 843 mg/l, respectively). The source of this brine was from the salt drippings resulting from cheese block formation and from the water softener. It is suggested that waste pretreatment or an in-plant process change be considered to limit the amount of brine pumped to the ridge and furrow system. As will be discussed later, the chloride concentrations in the groundwater downstream from the site were high.

Third, the pH of the wastewater was slightly above neutral(7.5 average). Since volatilization of ammonia predominant at pH > 9, as stated in Chapter 2, one would expect little loss of ammonia from the wastewater.

Fourth, the nitrogen fraction of the wastewater was principally organic-N. This was expected since the wastewater was derived from milk which contains protein. About one-half of this organic -N was in the solid fraction. This was seen by comparison of total and dissolved TKN.

Wastewater Hydraulic Loading

All flow to the ridge and furrow system was derived from cheese production. Flow was calculated by subtracting the cooling discharge (to the

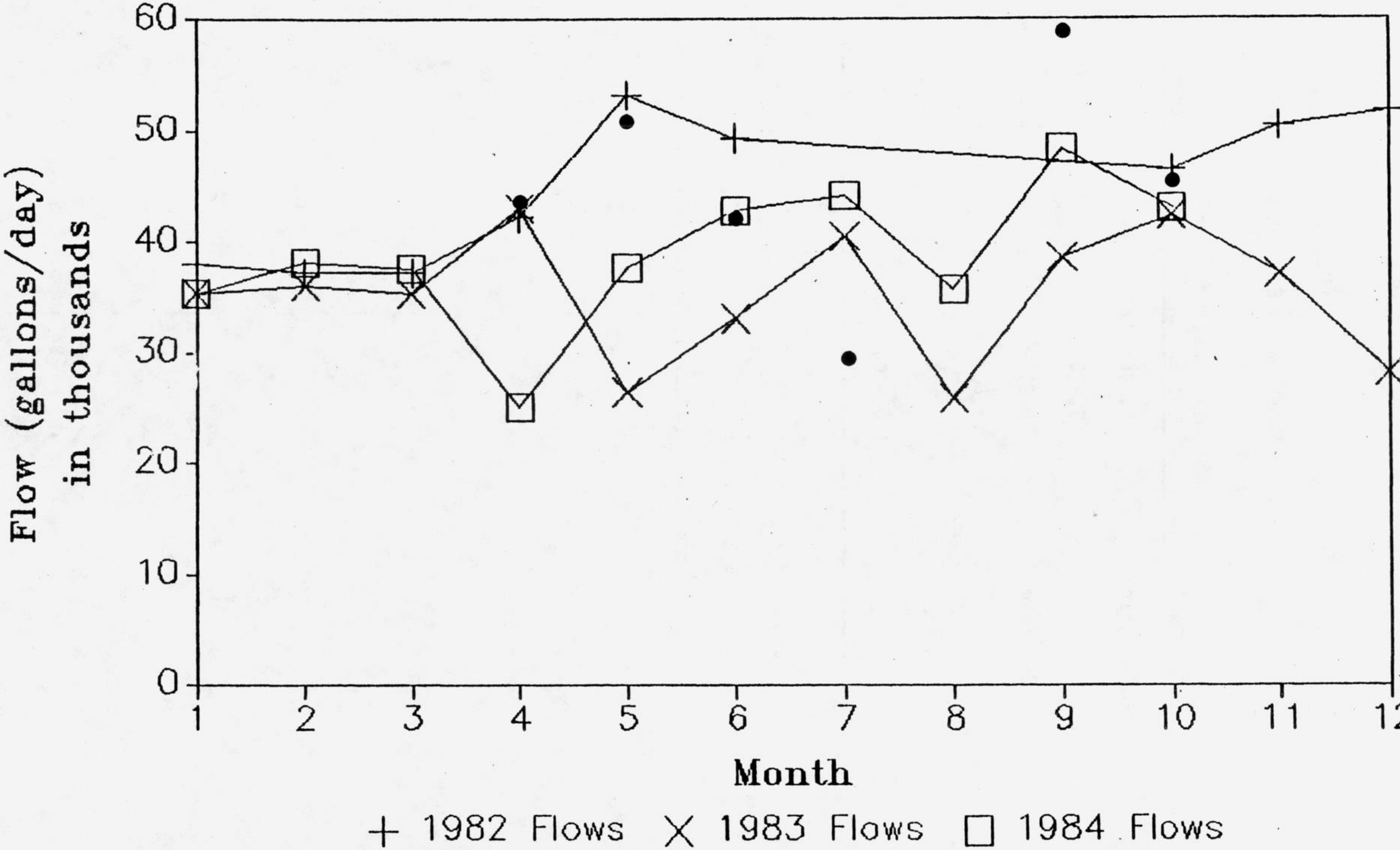
Sugar River) from the total water pumped into the production end of the plant. Both pumps were metered. Drinking and lavatory water was obtained from the city and these wastewaters were discharged to the city treatment plant.

Figure 4.3 illustrates the 30-day average wastewater flow values for the years 1982-1984 as well as 24-hour flows measured on project sampling days. A complete listing of flow data for the past six years is given in Appendix D. The 30-day monthly flows averaged 39,500 gallons per day since 1979. One can see from Figure 4.3 that from 1982 to 1984, flows ranged from 25,056 to 48,414 gallons per day. This was well under the DNR permit flow of 55,000 gpd. Flows during the years 1979 to 1981 were more variable with ranges from 12,700 to 61,500 gpd.

Prior to 1980, cell 1 received most of the wastewater with cell 2 serving as a back-up during high flow periods or when odor problems occurred. After 1980, a flexible 2-week load/2-week rest cycle was employed. A strict 2-week load/rest cycle began on 7/9/84. This scheme was followed until 10/15/84 when a week to week load/rest cycle was instituted. After 11/20/84, cell 2 was loaded for two weeks while cell 1 was loaded for one week. This last change was made based on project observations and will be discussed later. As mentioned in Chapter 2, load/rest cycles help aerate the soil and promote wastewater treatment.

In ridge and furrow systems, as well as other land treatment sites, it is useful to look at hydraulic loading rates in terms of inches per day or gallons/ acre/day. These rates for Brodhead shown in Table 4.3. Using the total site area, the average hydraulic loading rate was

FIGURE 4.3
Brodhead Average Monthly
Wastewater Flows



24—HR flows determined on sampling days indicated by ●

TABLE 4.3

BRODHEAD HYDRAULIC LOADING

FLOW (GAL)	TOTAL AREA LOADED	CELL 1 LOADED	CELL 2 LOADED
25,056 (min)	0.196	0.427	0.363
	(5,330)	(11,600)	(9,860)
39,500 (ave)	0.310	0.673	0.573
	(8,400)	(18,290)	(15,550)
48,414 (max)	0.379	0.825	0.702
	(10,300)	(22,410)	(19,060)

Cell 1 = 2.16 acres

Cell 2 = 2.54 acres

Units inches/day; or (units) gallons/acre/day

0.31 inch/day (8400 gpad) with a range of 0.196-0.379 inch/day (5,330-10,300 gpad). This is classified as a high rate system (Rodenberg, 1980). Since single cells were loaded during a load/rest cycle, single cell hydraulic loading rates are also shown in Table 4.3 for comparison. These rates were about double the total area rates.

Organic Loading Rates (BOD_5, TKN)

Code NR 214 of the Wisconsin DNR states that a ridge and furrow system should receive no greater than 100 lb BOD_5/acre/day. Using the average flow rate and BOD_5 concentration of the wastewater, however, the Brodhead site received 125 lb/acre/day. Using the minimum and maximum hydraulic rates and the average wastewater BOD_5 concentration, the BOD_5 loading rate range was 79-153 lb/acre/day. These numbers, as well as individual cell BOD_5 loading rates, are given in Table 4.4.

TABLE 4.4

BRODHEAD ORGANIC LOADING RATES
(lb/day/acre)

LOAD	TOTAL AREA LOADED	CELL 1 LOADED	CELL 2 LOADED
BOD_5(min-flow)	79	172	146
BOD_5(ave-flow)	125	271	231
BOD_5(max-flow)	153	333	283
TKN(min-flow)	1.9	4.1	3.4
TKN(ave-flow)	2.9	6.4	5.4
TKN(max-flow)	3.6	7.8	6.7

Ave. BOD_5 Conc = 1780 mg/l

Ave. TKN Conc = 42 mg/l

Similar calculations for TKN loading rates were performed and are also presented in Table 4.4. There is currently no Wisconsin DNR code for nitrogen loading. Using the range of hydraulic flows presented in Table 4.3 and the average wastewater TKN concentration, TKN loading rates at Brodhead ranged from 1.9 to 3.6 lb/acre/day with an average of 2.9 lb/acre/day. Suggestions for possible loading rates will be made later in this report.

Groundwater Elevations and Flow

In general, groundwater flow at the Brodhead ridge and furrow was northwesterly toward the Sugar River with a gradual gradient of 0.0025 ft/ft from well 16 to the river. With the exception of well nest 11, no vertical gradients were indicated. Wells 11A and 11B were located within 50 feet of the Sugar River, which was considered a discharge zone boundary for this groundwater flow system. This was verified by the higher head readings in well 11B (than 11A), indicating upward flow gradients into the river.

Since a well nest was not located inside the system, it was not possible to determine whether downward gradients existed due to mounding. Figure 4.4 shows the groundwater contours measured on June 7, 1984. Appendix E contains a complete list of elevation and contour data.

Groundwater (water table) elevations tended to fluctuate with seasonal recharge but not with changes in wastewater flow. Readings decreased during the winter of 1984, increased during the spring (1984) thaw, decreased during the drier late summer months, and increase again during fall rains. This pattern is shown for well 13A in Figure 4.5.

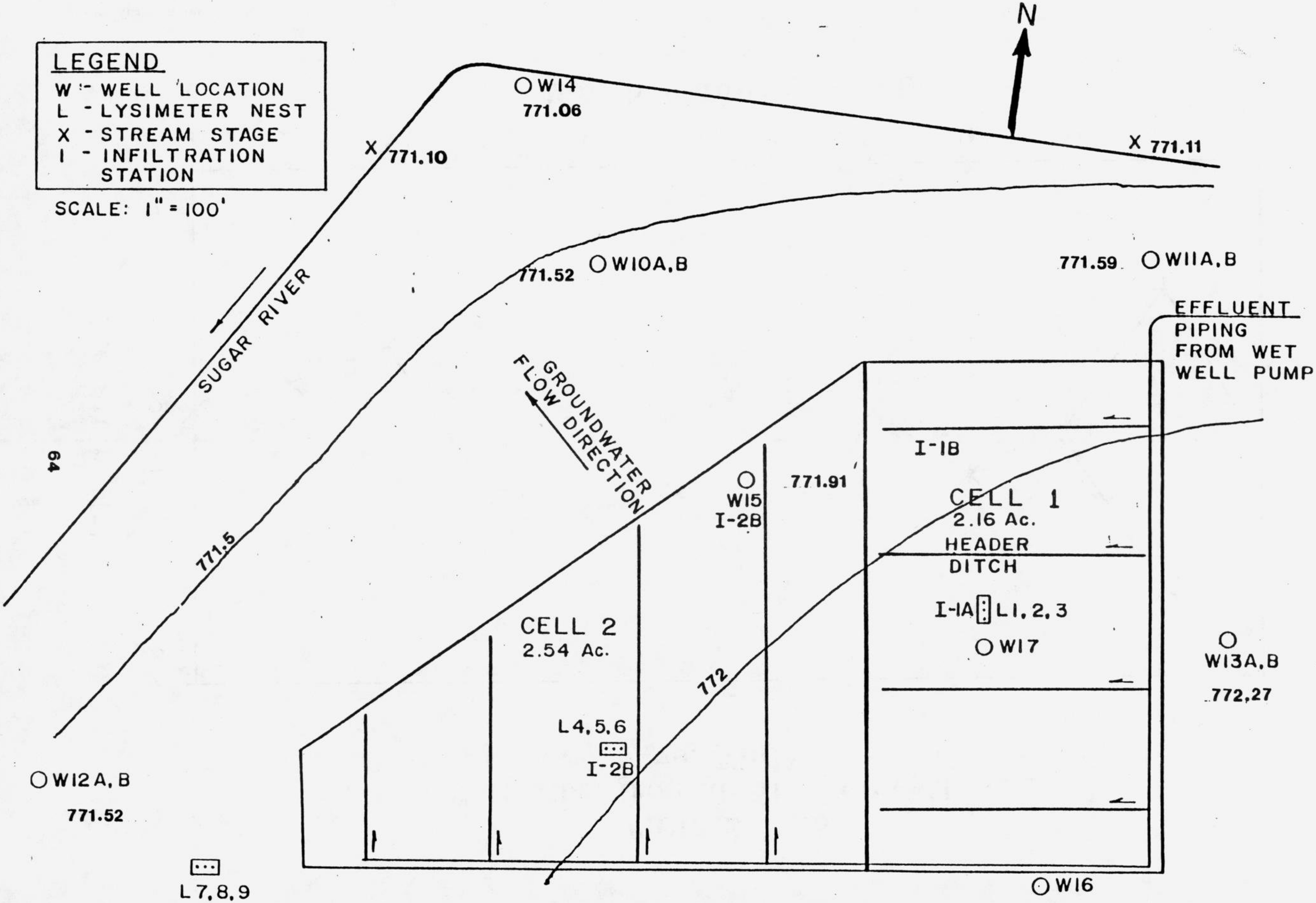
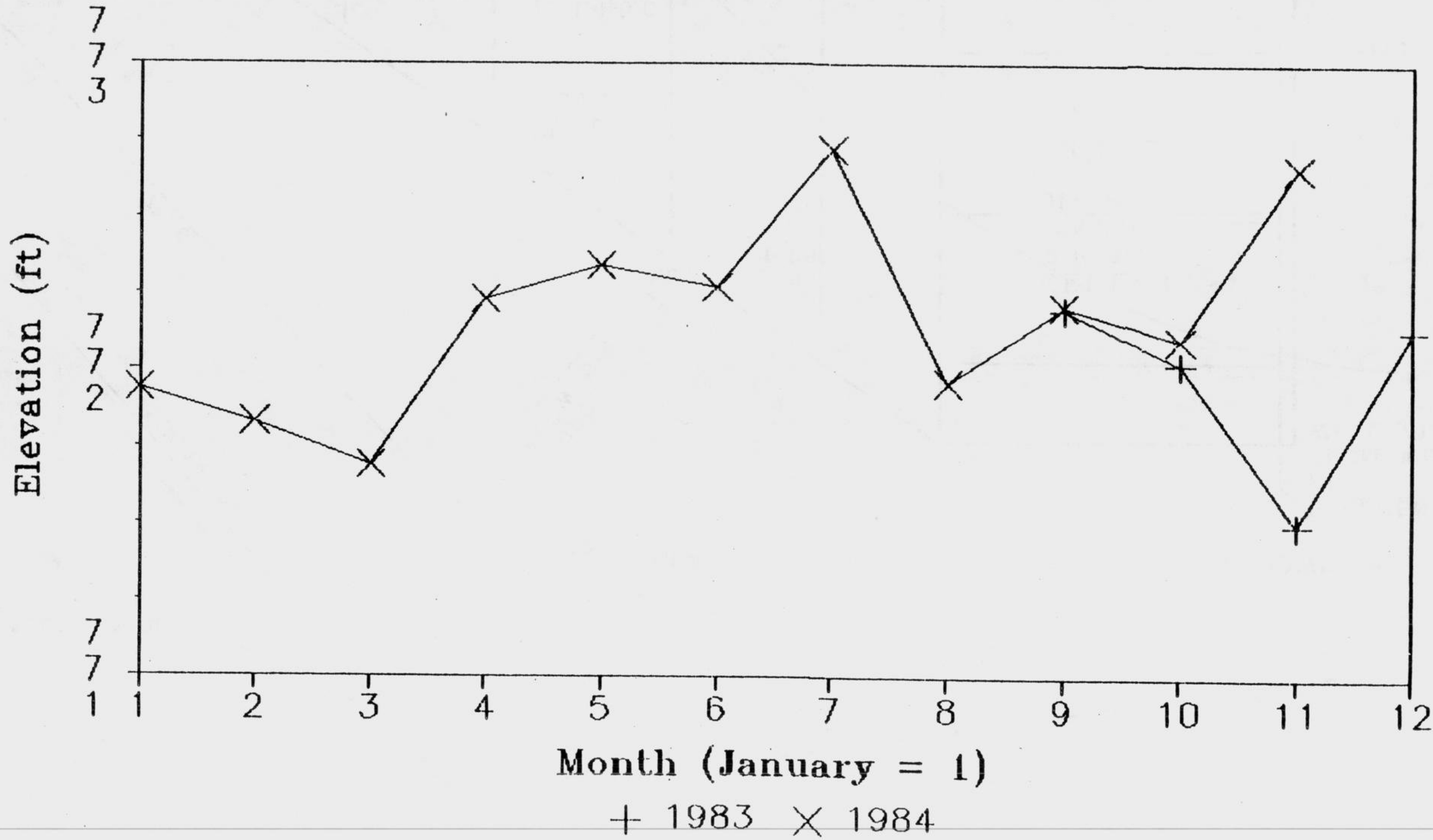


FIGURE 4.4: BRODHEAD PLAN VIEW

FIGURE 4.5
Well 13A Groundwater Elevations
vs. Time



Elevations mean sea level

The water table response to rainfall events was rapid occurring within one to two days. This is illustrated in Figure 4.6 where head readings in wells 15 and 17 were plotted against time during October and November of 1984. These similar responses were not due to cell loading since groundwater elevations in different cells responded identically to the rainfall. It should also be noted that a two inch rainfall is over three times the average single cell loading rates and that rainfall can also enter the unsaturated zone from the ridges.

Another task in defining the groundwater hydraulic characteristics was to determine horizontal flow velocities. This was done using Darcy's Law:

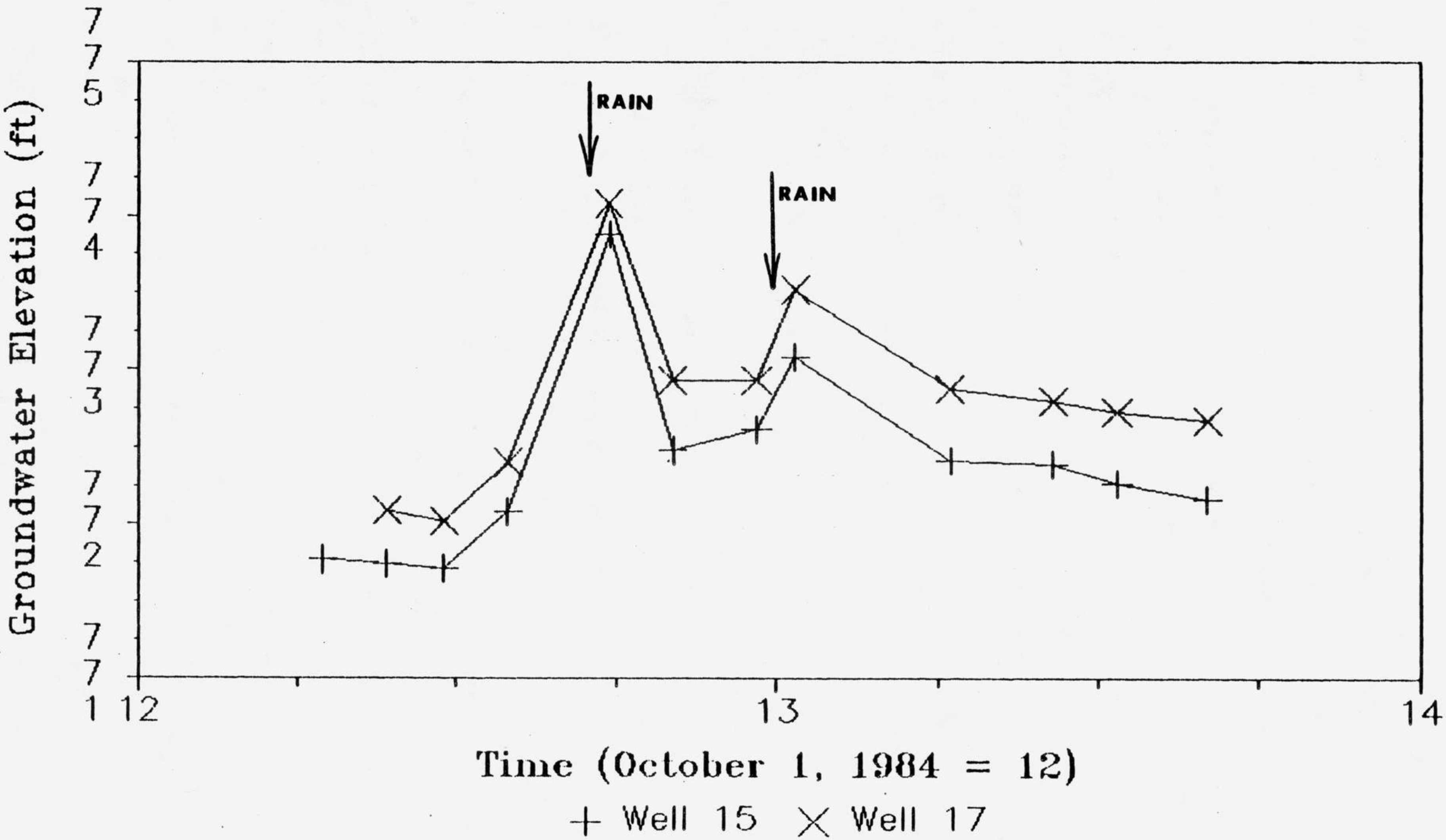
$$V = KI/n$$

where:

- V = average linear groundwater velocity (L/T),
- K = hydraulic conductivity of aquifer (L/T),
- I = hydraulic gradient dH/dL (L/L), and
- n = porosity.

Unsuccessful slug and bail tests to determine K were attempted on wells 10B, 11B, and 12B at Brodhead in April of 1984. The wells returned to equilibrium too quickly to acquire meaningful data. Therefore a value of 0.0005 ft/s, obtained from a local pumping test record on file at the Wisconsin DNR, was used for hydraulic conductivity. As mentioned earlier, the aquifer beneath the ridge and furrow is principally sand. For this project, the aquifer was assumed to be homogeneous and isotropic. (This meant that K did not vary in space or direction.) A

FIGURE 4.6
Well 15 and 17 Ground water Elevation Response to Rainfall Events



Elevations are mean sea level

hydraulic conductivity of 0.0005 ft/s is reasonable for this type of medium (see Freeze and Cherry, 1979).

Two different hydraulic gradients were used. For flow between wells 16 and 10, I was 0.0018 ft/ft; for flow between wells 10 and 14, I was 0.0046 ft/ft. It is reasonable to find that gradients increase near surface waters. A porosity of 0.35 for a typical sand was used (Freeze and Cherry, 1979).

With the above input data, velocities of 0.22 ft/day between wells 16 and 10 and 0.57 ft/day between wells 10 and 14 were calculated. These velocities gave the following travel times:

- from W16 to W17: 2.5 years,
- from W17 to W15: 2.7 years,
- cell 1 boundary to W15: 1.9 years,
- from W15 to W10A: 2.5 years, and
- from W10A to W14: 0.5 years.

One would expect the travel times in this sandy medium to be shorter but since the hydraulic gradient was shallow, the travel times were longer. One should realize, however, that the K value used could realistically be off by an order of magnitude, altering the travel times by a factor of ten.

Groundwater Chemistry

Mean and standard deviations for selected parameters at each well for Brodhead are listed in Table 4.5. Complete data listings are given in Appendix F. When looking at the chloride data, a good indicator of con-

TABLE 4.5

MEAN AND STANDARD DEVIATION OF

GROUNDWATER CHEMICAL PARAMETERS

AT BRODHEAD

WELL	DISSOLVED BOD_5	DISSOLVED COD	TDS	DISSOLVED TKN	DISSOLVED NH_3-N	DISSOLVED NO_2-N+NO_3-N	Cl^-	FIELD pH
10A	7.5±4.6(13)*	17±2.3(13)	1020±163(12)	13±2.0(13)	13±1.8(13)	0.5±0.4(13)*	380±92(14)	6.9±0.13(8)
10B	10±6.5(13)*	24±6.9(13)	1680±157(12)	12±6.8(13)	12±6.9(13)	0.3±0.4(13)*	630±120(13)	6.8±0.09(8)
11A	4.0±1.7(13)*	23±7.6(13)	516±151(12)	3.3±0.58(13)	2.8±0.55(13)	0.1±0.0(13)*	140±63(14)	6.8±0.18(8)
11B	6.0±5.4(13)*	11±16(13)*	434±256(12)	0.41±0.31(13)	0.27±0.24(13)*	0.1±0.0(13)*	73±110(13)	7.1±0.15(8)
12A	3.1±0.89(8)*	9.5±7.0(8)*	373±45.0(7)	0.50±0.63(8)	0.10±0.0(8)	8.6±1.6(8)	27±3.6(8)	7.0±0.15(3)
12B	2.8±0.47(9)*	5.4±0.73(9)*	383±42.6(8)	0.20±0.0(9)*	0.10±0.0(9)*	10.8±2.70(9)	38±1.4(9)	7.5±0.10(3)
13A	2.8±0.61(13)*	23±6.5(13)	313±95.6(12)	0.83±0.22(13)	0.18±0.07(13)	0.38±0.51(13)*	3.8±2.0(14)	7.0±0.18(8)
13B	2.8±0.66(11)*	5.1±0.3(11)*	317±15.4(10)	0.20±0.0(11)*	0.10±0.0(11)*	4.2±0.33(11)	35±2.3(11)	7.2±0.16(6)
14	5.2±5.2(8)*	18±7.4(8)	648±111(8)	1.8±0.64(8)	1.4±0.83(8)	1.4±1.6(8)	190±68(8)	7.1±0.08(7)
15	51±55(12)*	57±50(19)	1640±216(12)	16±21(23)	15±20(23)*	17±21(23)*	570±110(23)	6.4±0.12(8)
16	57±57(12)*	83±62(19)	1600±436(12)	5.0±2.5(20)	3.9±2.6(20)	0.10±0.0(20)*	580±180(20)	6.4±0.10(7)
17	34±37(2)*	54±5.8(7)	2540±643(2)	31±2.6(11)	30±1.8(11)	0.92±0.27(11)*	650±77(11)	---

* means contain data that was above or below a detection limit; limit was used in average

All values mg/l except pH; ( ) indicates # of observations.

tamination, one can catagorize the wells into three types. Wells 12A, 12B, 13A, and 13B were not influenced by the ridge and furrow system; wells 11A, 11B, and 14 were moderately affected by the site, and wells 10A, 10B, 15, 16 and 17 were highly impacted by the system. This grouping matched the observed flow pattern. It should be realized that averages and standard deviations of well data at this site do not fully describe the contamination. Parameters were variable with time which resulted in high standard deviations (eg. W15 TKN). Averages were only used for relative comparisons.

Figure 4.7 presents a plan view of chloride contours at the water table on October 9, 1984. The contours are approximate but they generally represent the contaminated area. Well 16, which was installed on the south berm, exhibited high chloride concentrations throughout the project. Even though the well was upgradient of the system, it was close enough to be affected by dispersion (or diffusion). Also, in well 10B, at 21 feet depth below the water table, chloride concentrations were about 1.5 times greater than well 10A concentrations at the water table during the study. Well 10B and well 15 values were of the same relative magnitude, indicating that the contaminant was sinking as it traveled downstream due to the density of the plume. This was reasonable since the linear groundwater velocity was slow.

A similar contour pattern existed for COD concentrations at the water table and is shown in Figure 4.8. Again, note the elevated value for well 16 and the deep well 10B concentration relatively higher than the surface well 10A.

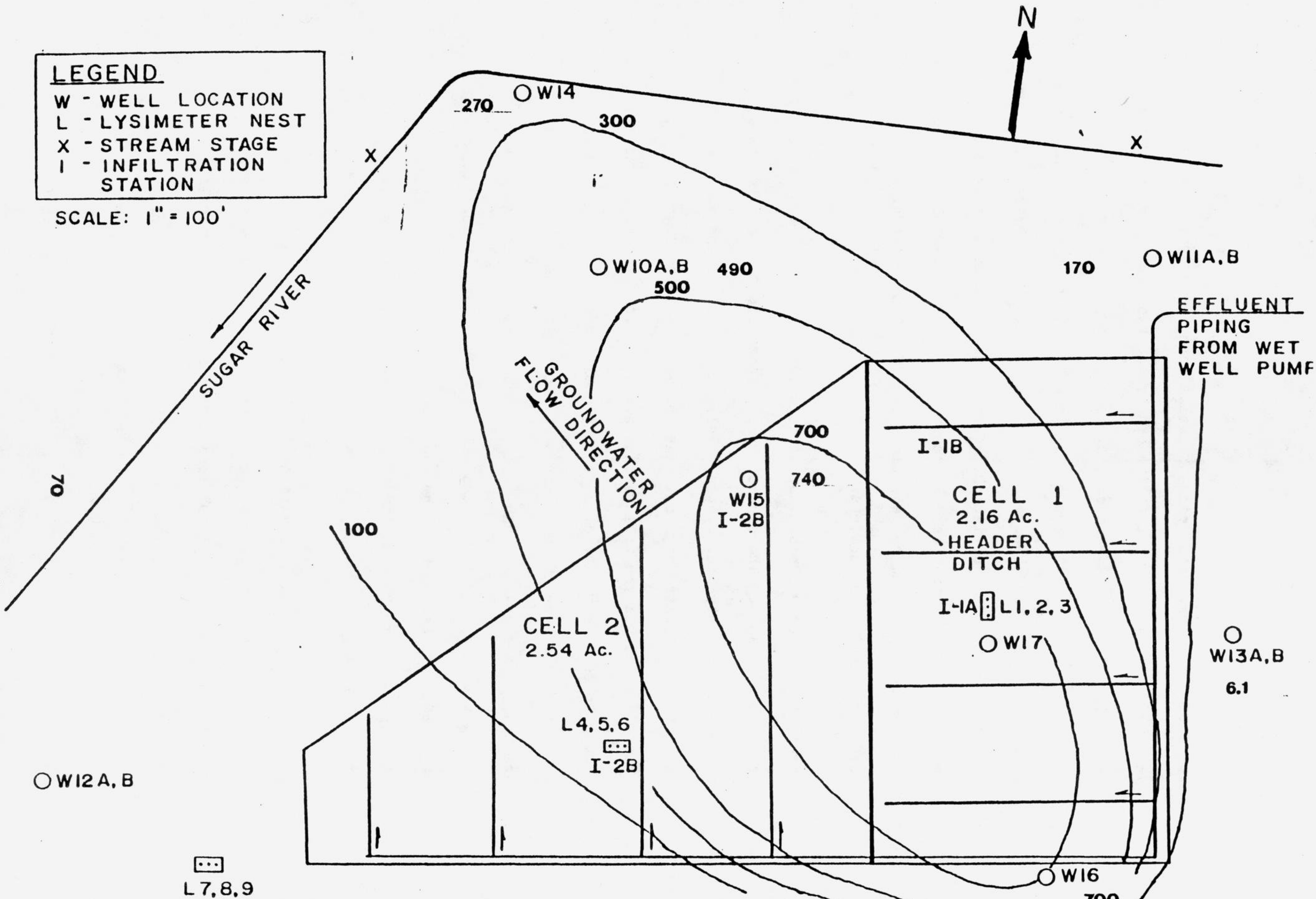


FIGURE 4.7: BRODHEAD PLAN VIEW

WATER TABLE CHLORIDE CONTOURS – OCTOBER 9, 1984

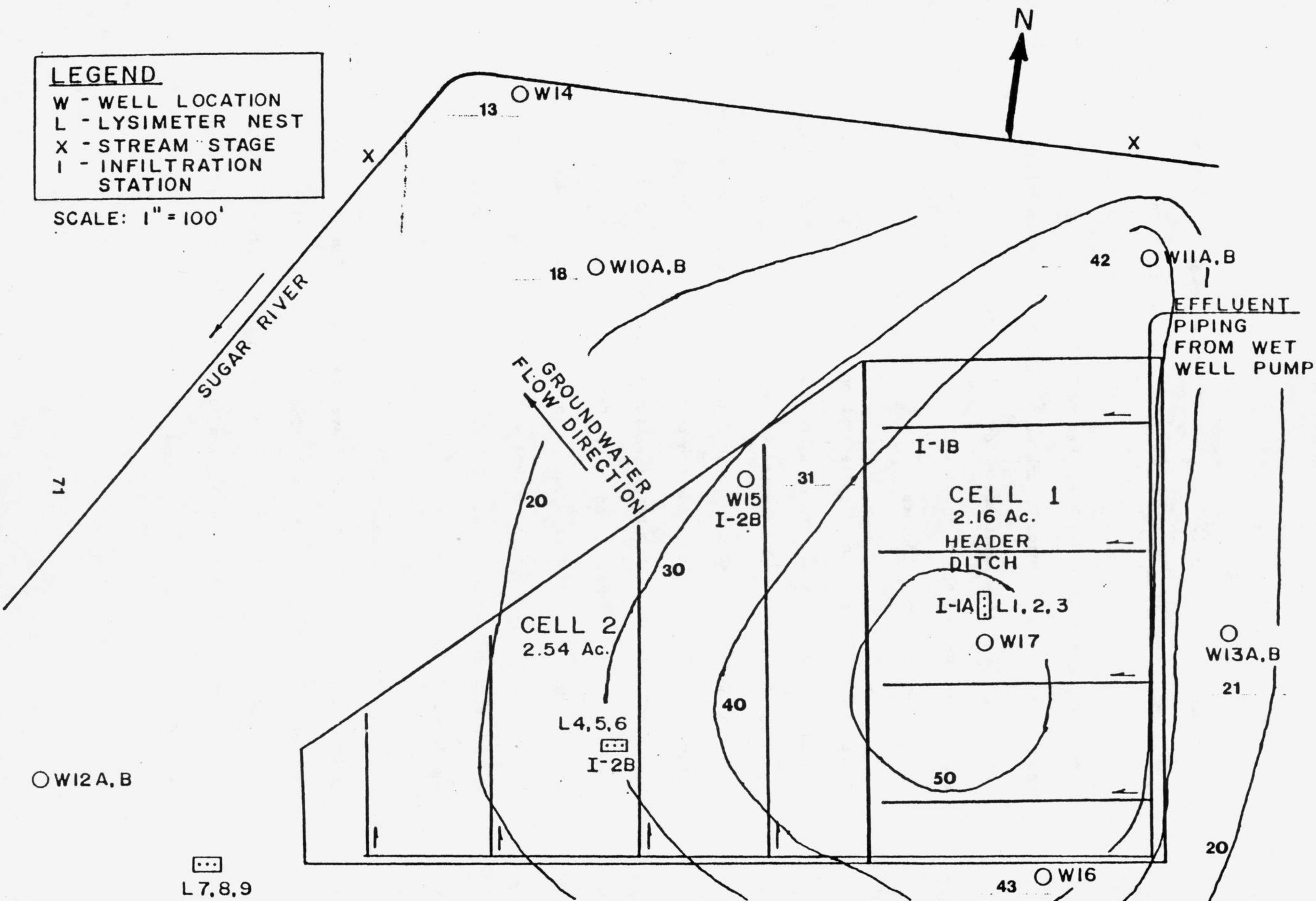


FIGURE 4.8: BRODHEAD PLAN VIEW

WATER TABLE COD CONTOURS - OCTOBER 9, 1984

Plan views for the parameters TKN, NH_3-N, and NO_2-N+NO_3-N (from 10/9/84) are shown in Figures 4.9, 4.10, and 4.11, respectively. The TKN and NH_3-N maps are quite similar with high concentrations underneath the middle of the system, a sag area near well 15, and relatively high concentrations near well 10A. Figure 4.11 shows high nitrate values in the vicinity of well 15. Again, note that TKN and NH_3-N values in wells 16 and 10B were relatively high but wells 15 and 10B do not correspond as they did for COD and chlorides.

Previous to 10/9/84, nitrate concentration in well 15 were low and ammonium was the principal form of nitrogen. In early October (1984), nitrification of this ammonium in the unsaturated zone began, as depicted by the nitrate contours on Figure 4.11. These contours were estimates and more wells would have been necessary to completely define the nitrifying area. This nitrification is also responsible for the sag areas shown in Figures 4.9 and 4.10. Cell 2 was loaded (to allow cell 1 to completely dry) for four weeks prior to 10/9/84 and this wastewater flushed out a majority of soil pore water nitrate into the groundwater. Nitrate concentrations subsequently decreased at well 15 in late October and November (see Figure 4.12).

The pH in the background wells (12A, 12B, 13A, 13B) was slightly above neutral, ranging from 7.0 to 7.5 on average. Both wells 15 and 16, located within the system, had a pH of 6.4 on average. Downgradient wells (10A, 10B, 11A, 11B, and 14) exhibited pH values nearing neutrality, indicating dilution of this groundwater by water of background quality.

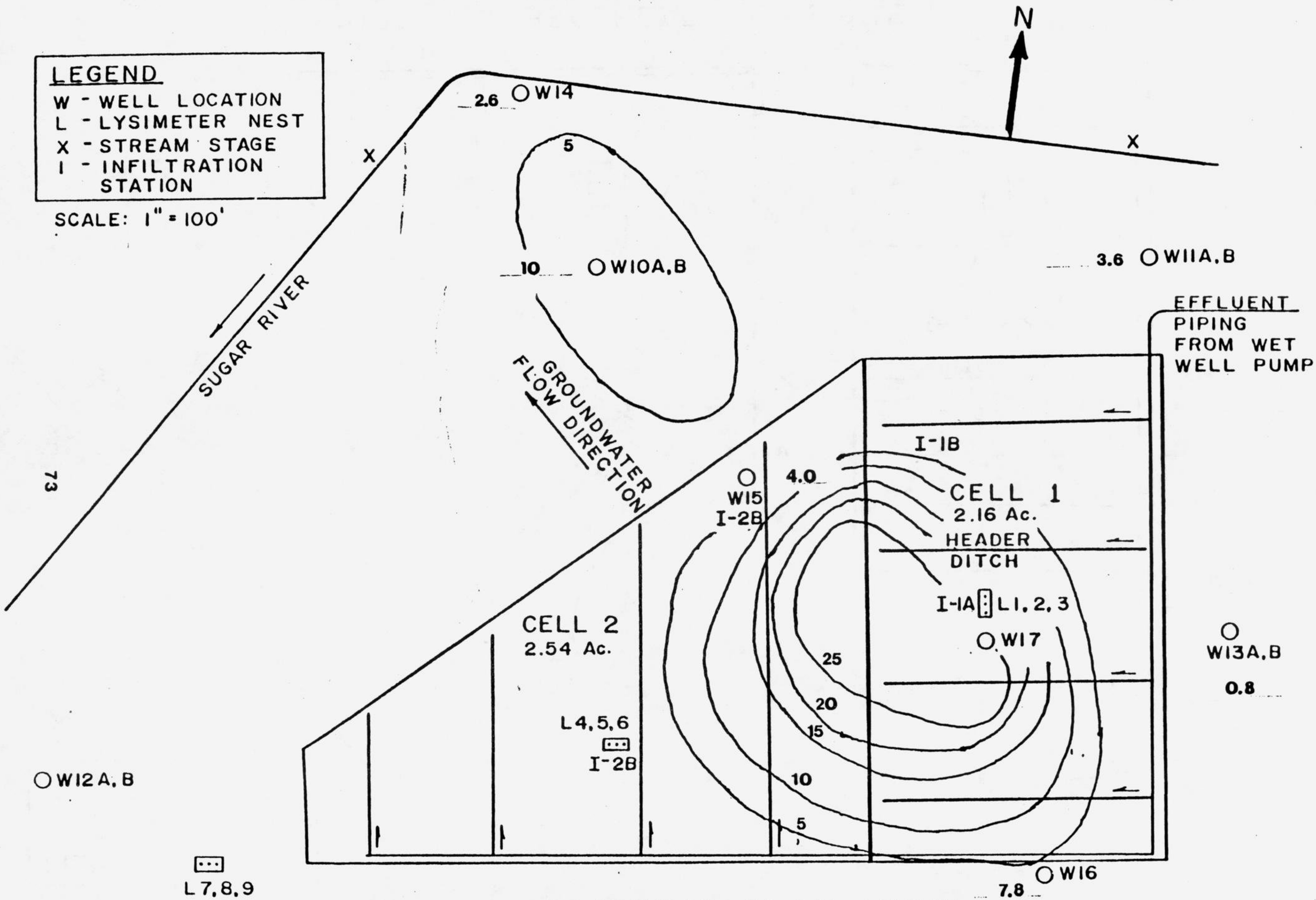


FIGURE 4.9 : BRODHEAD PLAN VIEW

WATER TABLE TKN CONTOURS - OCTOBER 9, 1984

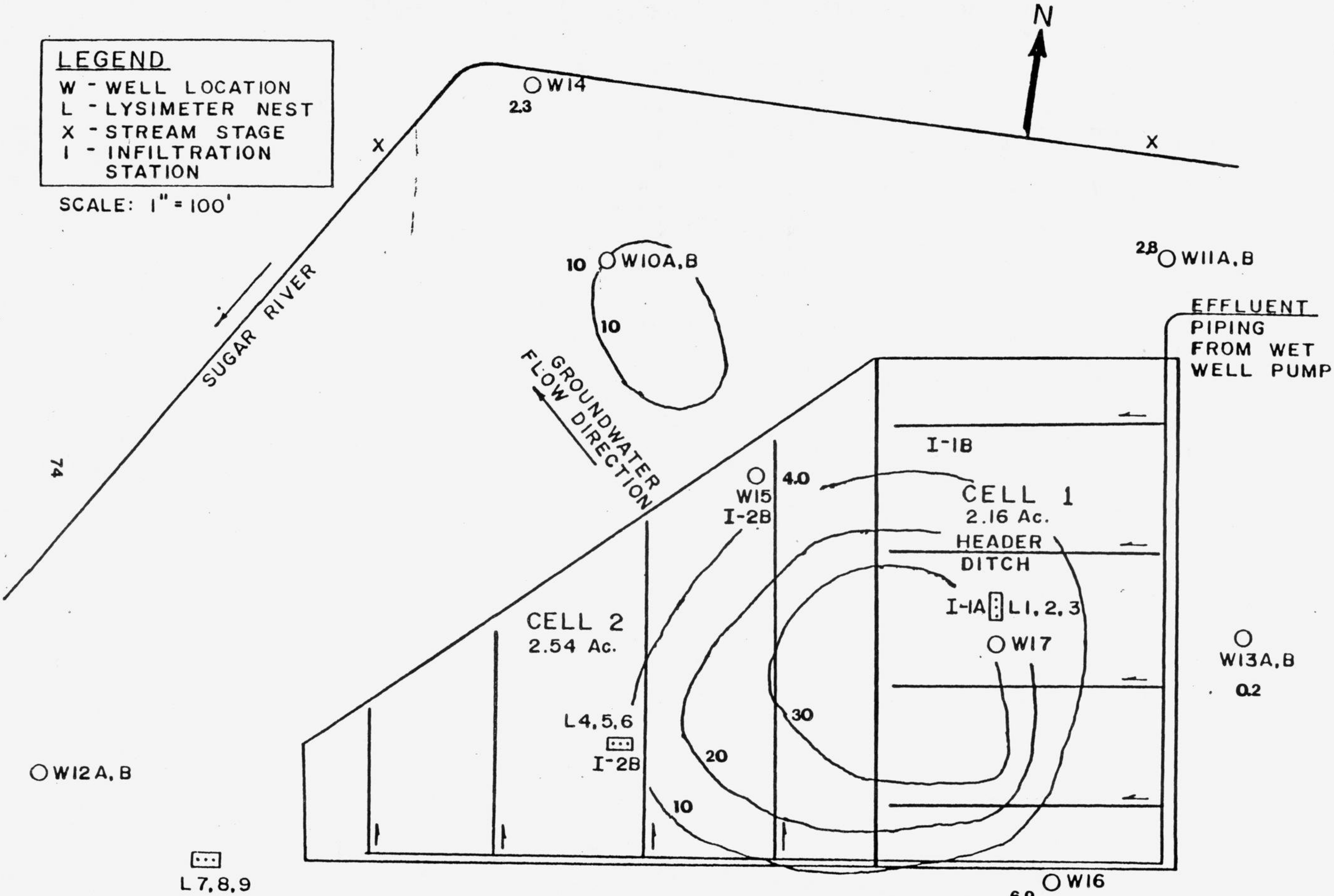


FIGURE 4.10: BRODHEAD PLAN VIEW

WATER TABLE AMMONIUM CONTOURS - OCTOBER 9, 1984

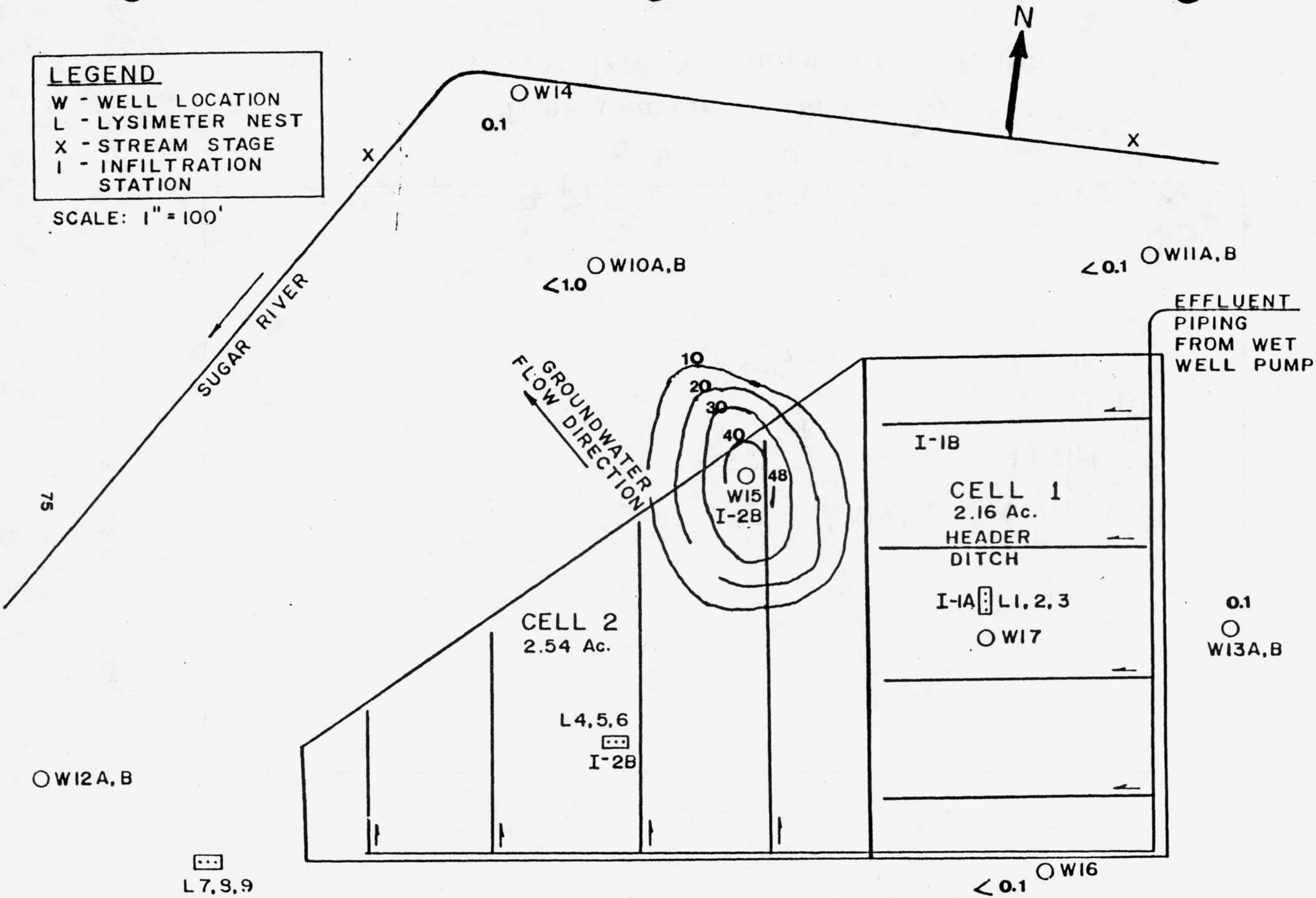
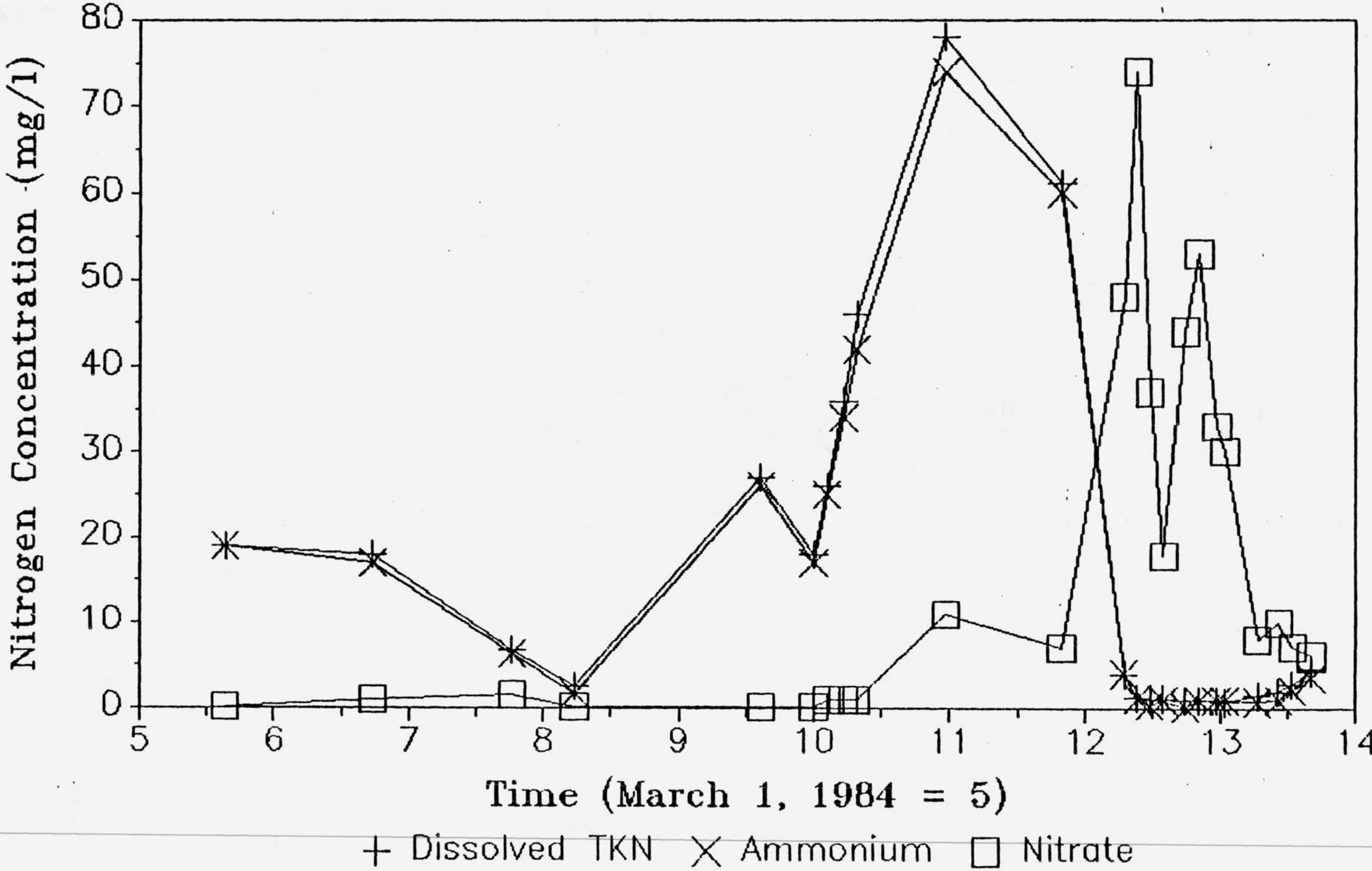


FIGURE 4.11: BRODHEAD PLAN VIEW

WATER TABLE NITRATE CONCENTRATIONS - OCTOBER 9, 1984

FIGURE 4.12
Well 15 Nitrogen Concentrations



An attempt was made to match chemical changes in space with time between wells. Due to the slow groundwater velocities, however, this was not possible. A longer sampling period would be needed to properly evaluate the data. General observations of temporal trends in the groundwater follow.

Wells 16 and 17 responded similarly with time. This was expected since both wells were directly affected by cell 1 loading. Direct increases in Cl^- or N concentration with cell 1 loading were not detected, however. Chloride concentrations with time for wells 16 and 17 appear in Figure 4.13. Nitrogen concentrations with time for well 16 appear in Figure 4.14; Figure 4.15 presents nitrogen concentrations with time for well 17. Chloride data from wells 16 and 17 both had concentration decreases in late October (1984) and early November (1984) with a peak on November 1. These decreases were the result of heavy rains on October 18 and October 31. Note that well 16 values were lower than well 17 due to background dilution. TKN and NH_3-N concentrations followed a similar pattern. Little nitrate was present in these wells.

Well 15 (cell 2) chloride and nitrogen concentrations did not respond in the same fashion as well 16 and 17 values. Well 15 chloride concentrations are plotted in Figure 4.13; nitrogen values for well 15 are presented in Figure 4.12. The most obvious difference between well 15 and wells 16 and 17 was the nitrogen transformation which was occurring in well 15 during October of 1984. Well 15 nitrogen concentrations, which were quite high, changed from primarily NH_3-N to primarily NO_3-N. Nitrogen values then reduced to concentrations of relatively good

FIGURE 4.13
Chloride Concentrations
Wells 15, 16, and 17

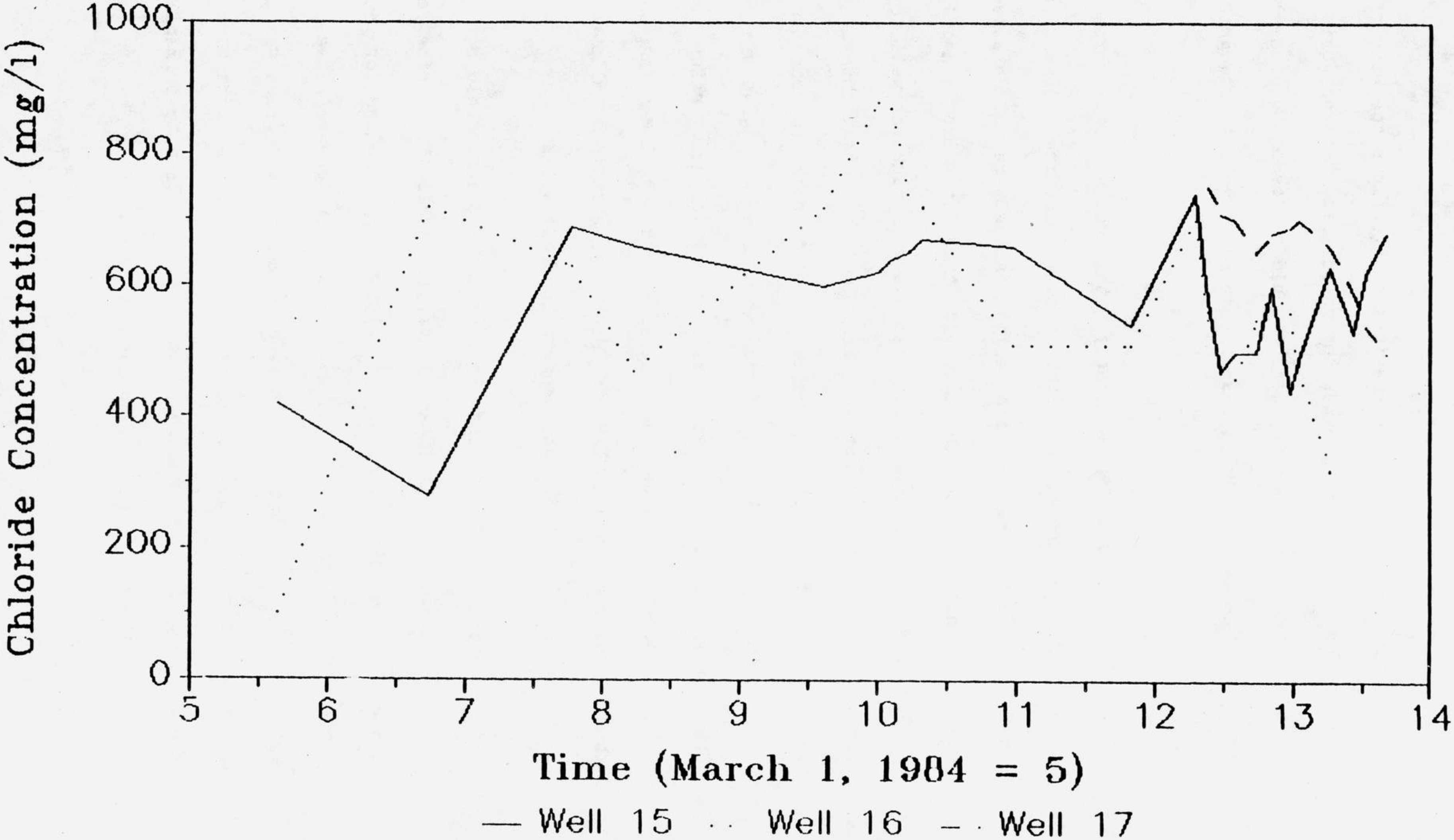


FIGURE 4.14
Well 16 Nitrogen Concentrations

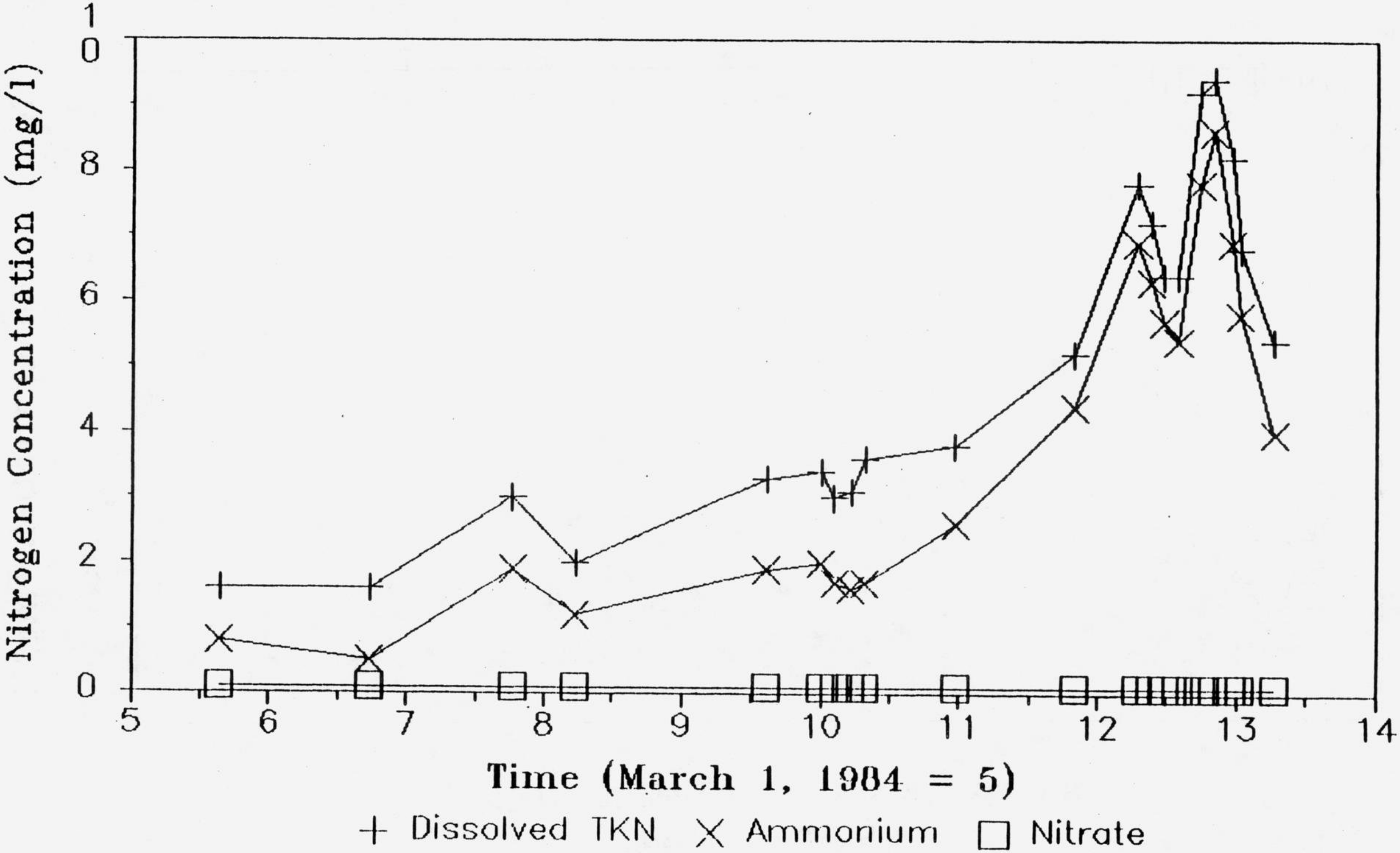
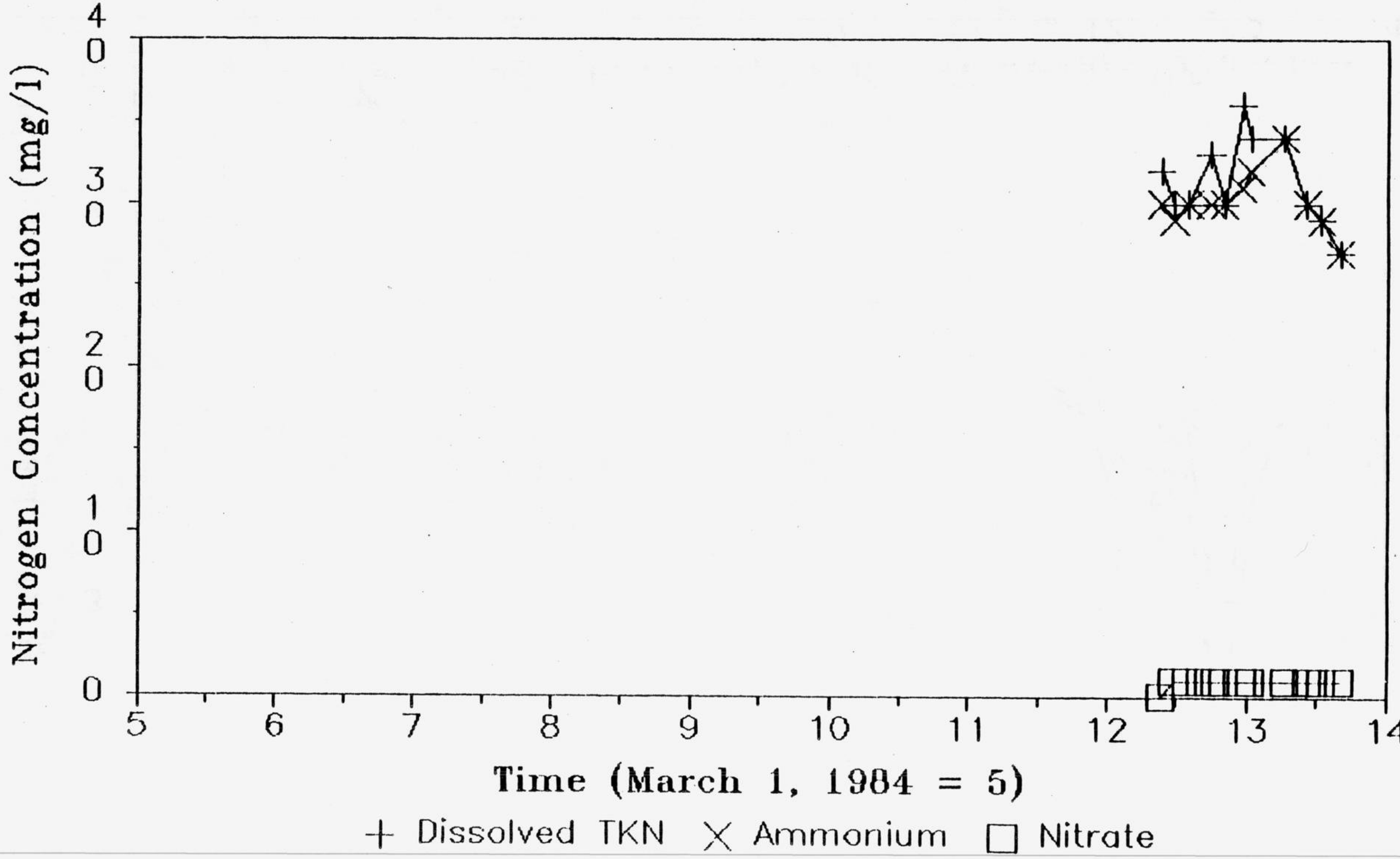


FIGURE 4.15
Well 17 Nitrogen Concentrations



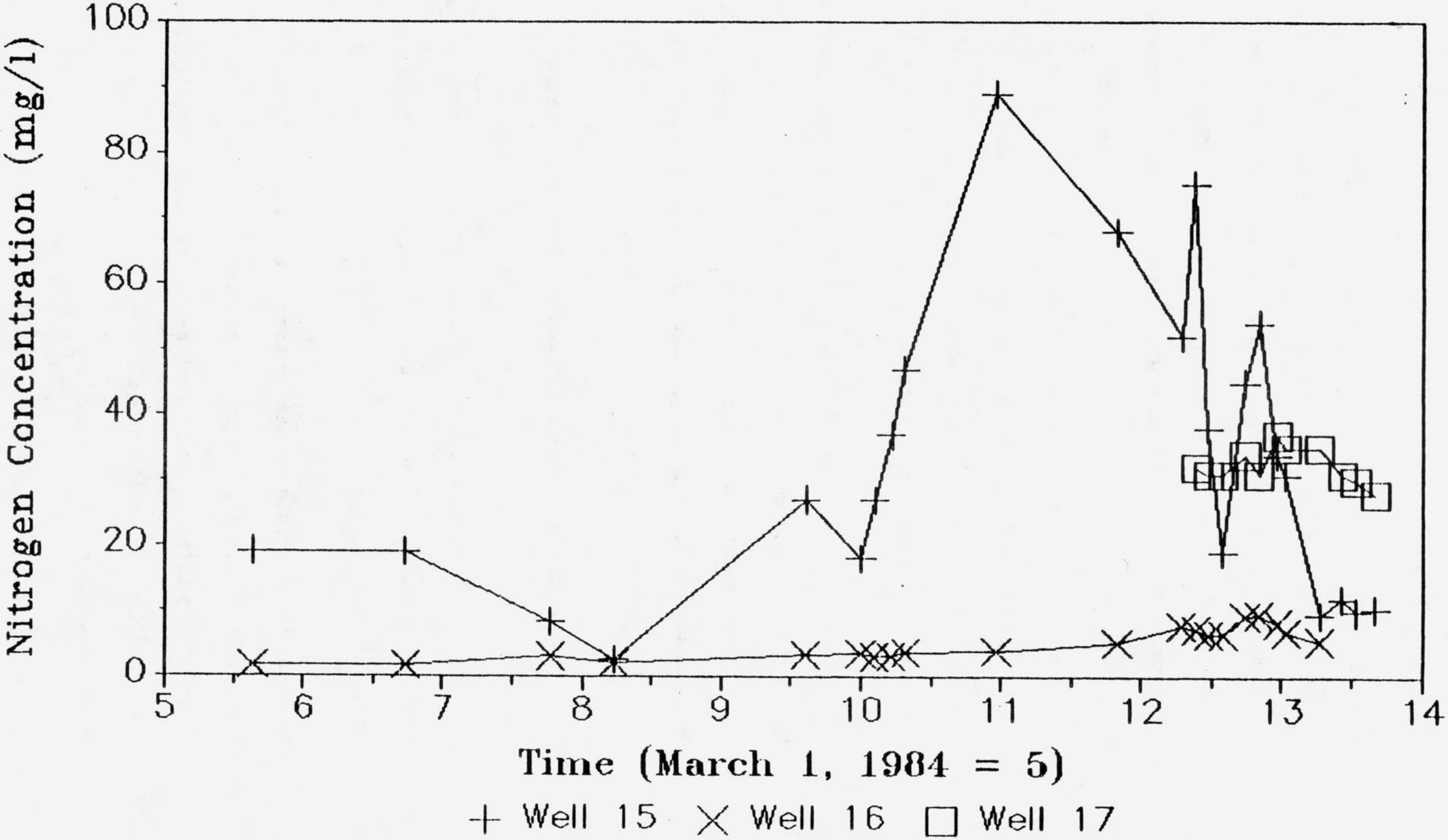
quality (less than 10 mg-N/l). The most likely cause of this transformation was the loading schedule changes initiated in July of 1984. The two week, and later, one week load/rest cycles allowed for aeration of the percolate and in turn, nitrification of the ammonia fraction. As mentioned earlier, the nitrate was flushed out by a four week cell 2 loading while cell 1 was allowed to dry in late September (1984). It was not understood why well 17 did not respond similarly after loading continued in October. Further sampling is necessary to determine if well 15 nitrogen concentration would remain low or whether large concentration variance would continue.

Nitrate decreases in well 15 occurred in late October (1984) and early November (1984) during the periods of heavy rain. When comparing the nitrate decreases to the chloride decreases, however, the nitrogen declines were relatively larger than the chloride declines. This was most likely a result of denitrification losses.

When looking at Figure 4.13, one can see that the relative magnitude of chloride concentrations for wells 15, 16, and 17 was similar. When studying Figure 4.16, which plots total nitrogen concentrations for these three wells, it is clear that the relative magnitude of nitrogen concentrations was not similar.

One final point should be made concerning the groundwater chemistry at Brodhead. The possibility of the contaminant plume sinking exists. Groundwater quality at 30-50 feet below the water table at well 14 is likely similar to quality in well 10B. A deep well near well 14 would be needed to make this conclusion.

FIGURE 4.16
Total Nitrogen Concentrations
Wells 15, 16, and 17



Unsaturated Zone Flow Rates

Since the furrows contained up to six inches of settled solids, vertical unsaturated flow rates were divided into two parts: percolation through the furrow "organic barrier" and travel through the underlying unsaturated zone. Furrow side wall flow was considered part of the "barrier" flow.

The infiltration stations, installed in October (1984), were used to determine barrier flow-through times. Barrier thicknesses ranged from less than one inch in cell 2 and outer cell 1 furrows, to two inches in inner cell 1 furrows, to six inches in the header ditches. Station 1A (see Figure 4.2) was located near cell 1 lysimeters in a two inch barrier region. Station 1B was located in the outer northwest corner of cell 1 in a 0.5 inch barrier region. Station 2A was located near cell 2 lysimeters in a one inch barrier region. Station 2B was located near well 15 in cell 2 in a one inch barrier region. Rates were measured three times (or three rounds).

Figure 4.17 illustrates the barrier infiltration rates at station 1A. Steady-state was reached after about 1.5 days with a flow rate of about 4 cm/day. With a two inch barrier at this rate, a barrier travel time of 1.3 days was calculated at this location.

Figure 4.18 presents barrier infiltration rates at station 1B. Steady-state was reached after 0.5 days with a rate of 6 cm/day. With a one inch barrier at this rate, a travel time of 0.4 days was calculated at this location. Round 1 results were omitted since furrow dryness caused the rate to be nearly infinite.

FIGURE 4.17
Infiltration Station 1A – Cell 1
Barrier Flows

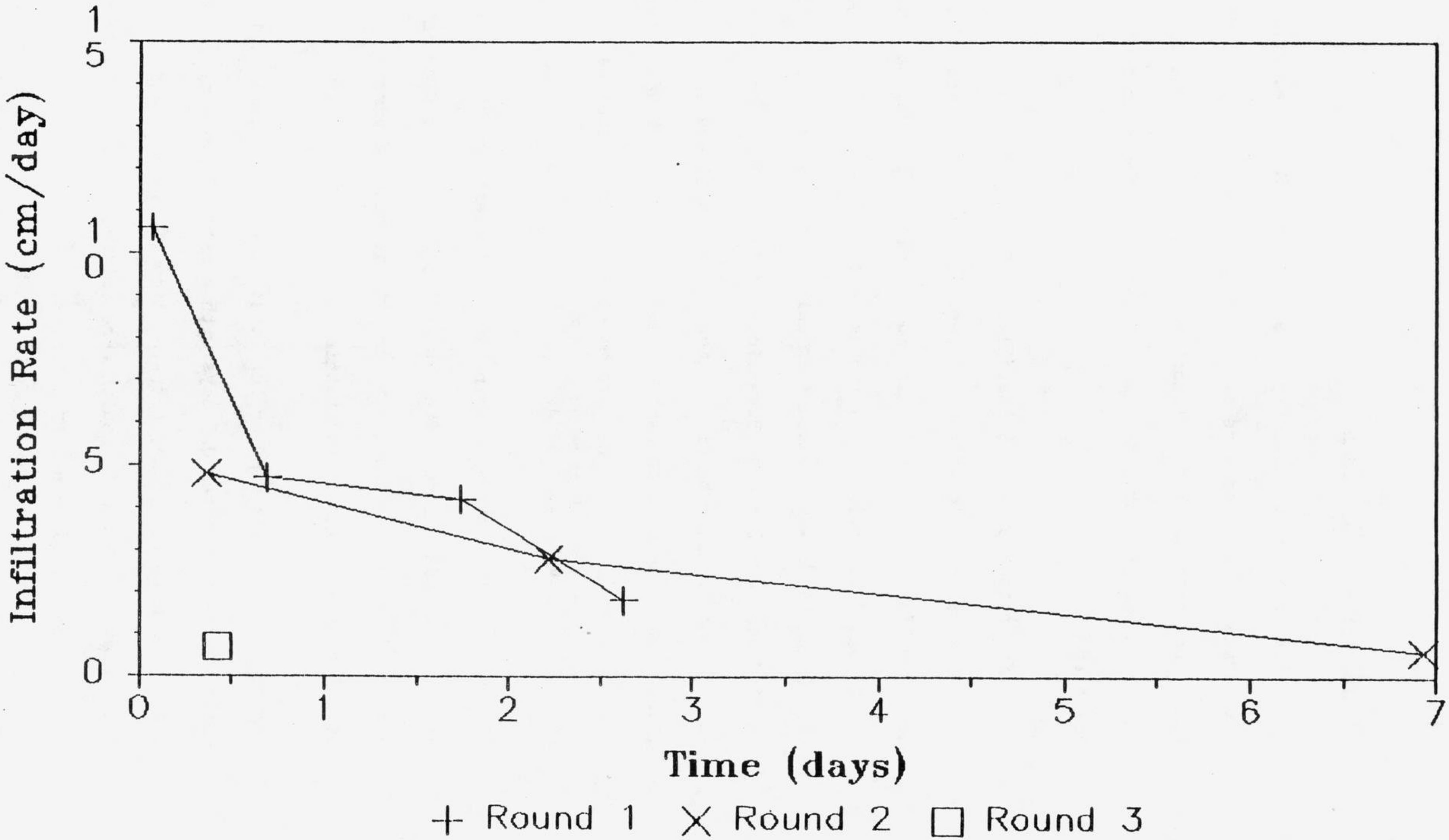
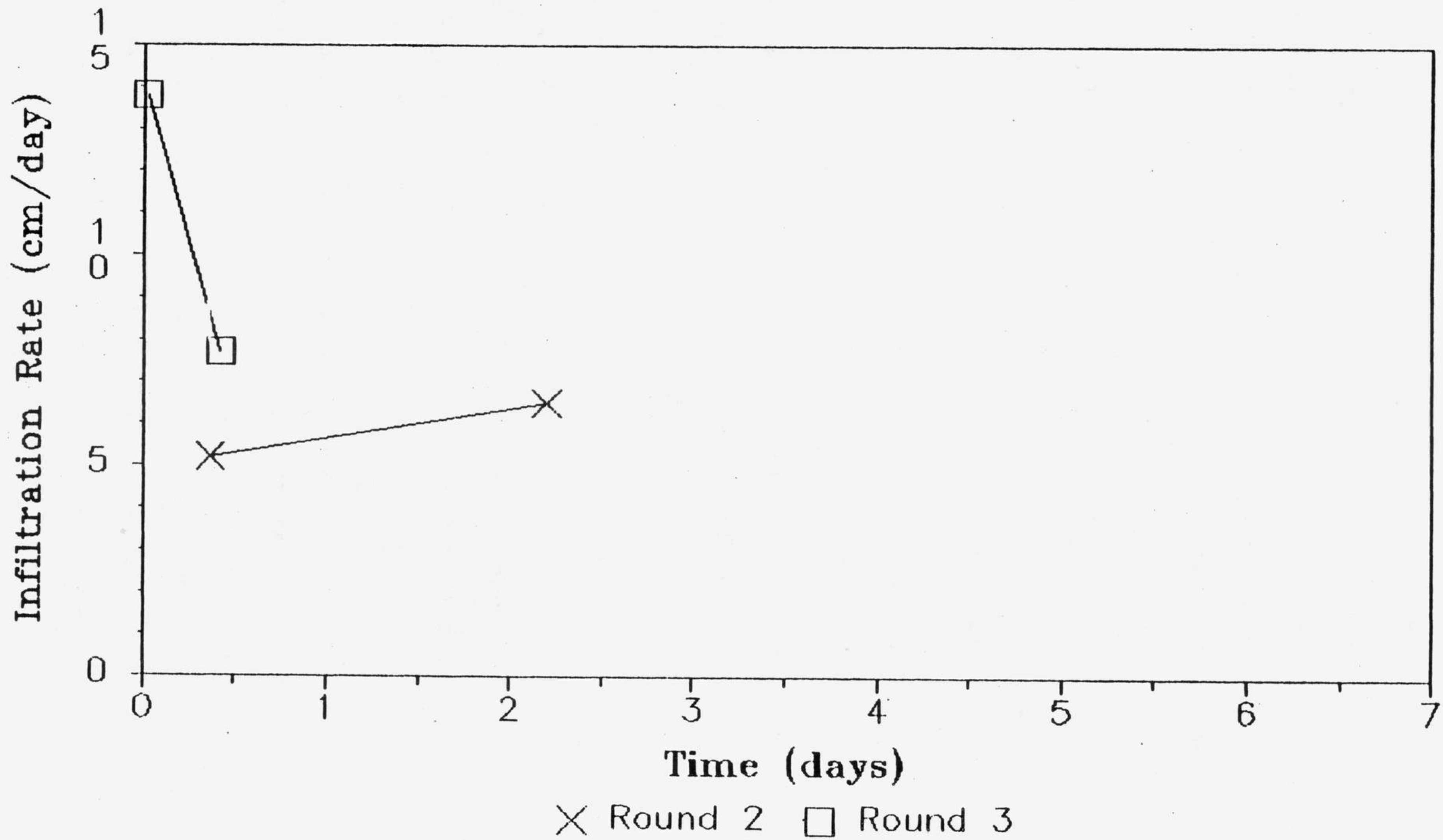


FIGURE 4.18
Infiltration Station 1B - Cell 1
Barrier Flows



Station 2A infiltration rates are plotted in Figure 4.19. Steady-state was reached after about two days with a percolation rate of 2 cm/day. With a one inch barrier, a travel time through the barrier of 1.3 days was calculated at this point.

Figure 4.20 illustrates barrier infiltration rates at station 2B. Steady-state was achieved after approximately two days with a rate of 2 cm/day. With a one inch barrier, a travel time of 1.3 days was determined at this location.

Assuming that an infiltration rate of 2 cm/day was applied to the header ditch, travel through the six inch organic barrier would be 7.6 days.

When considering these barrier travel times for the furrows and header ditches, an approximate time range of 0.5-8.0 days was developed for infiltration through the barrier.

Once wastewater percolated through the furrow barriers, it traveled approximately 5.5 feet through the unsaturated zone to the groundwater. Methods by Bouma (1975) were used to calculate these travel times. A graph and table (from Bouma, 1975), used to determine hydraulic conductivity and soil moisture tension, are presented in Appendix G.

From Table 2 of Appendix G, a typical soil moisture tension, in a sandy soil below a seepage system barrier, of 20 cm H_2O was estimated. It was also assumed that this tension was constant with depth. Using a 20 cm (H_2O) soil moisture tension, a hydraulic conductivity of 100 cm/day was estimated from Figure 1 (Appendix G) for a sandy soil. This K value was used to calculate travel times through the unsaturated zone to the

FIGURE 4.19
Infiltration Station 2A – Cell 2
Barrier Flows

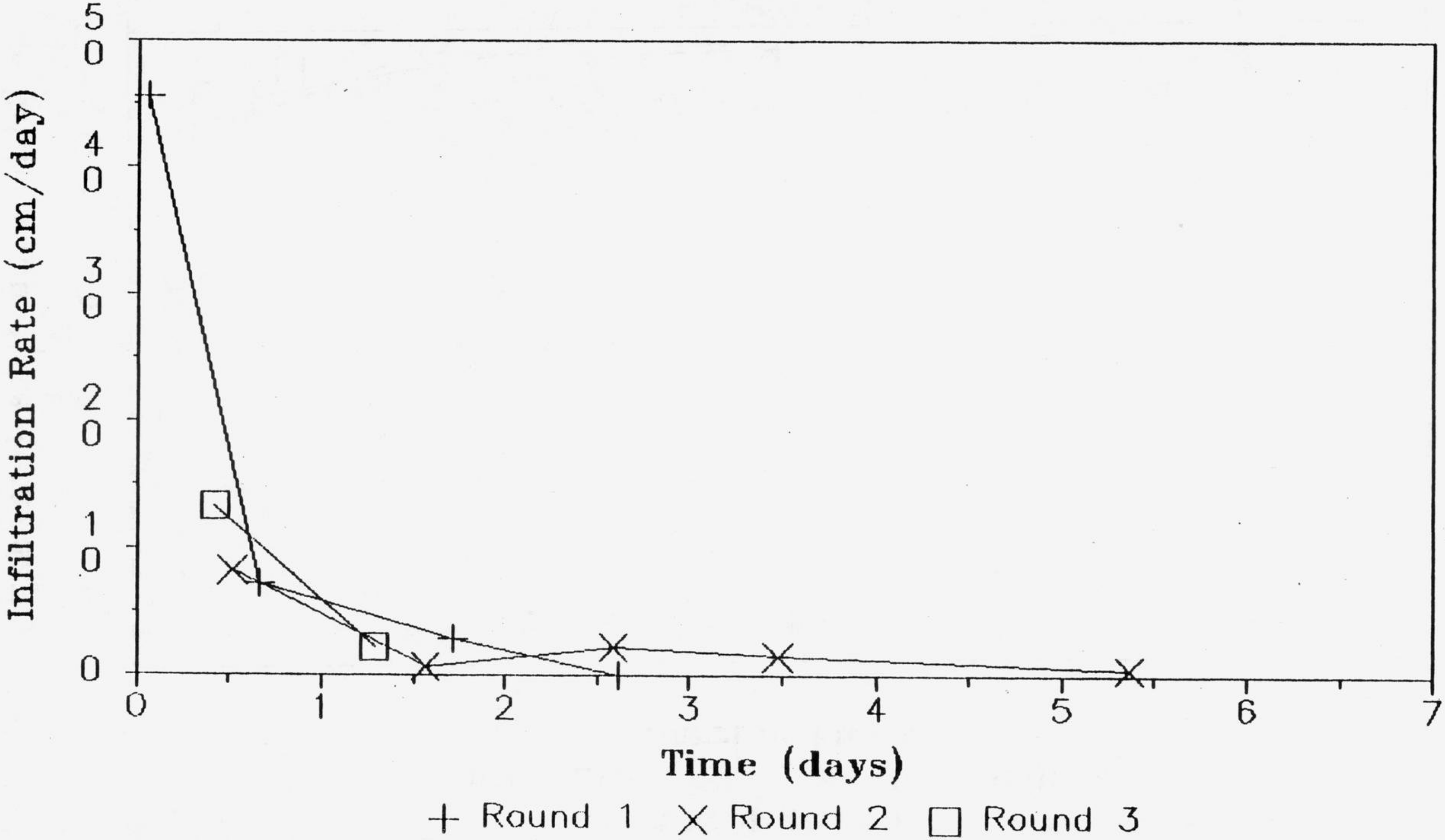


FIGURE 4.20
Infiltration Station 2B - Cell 2
Barrier Flows

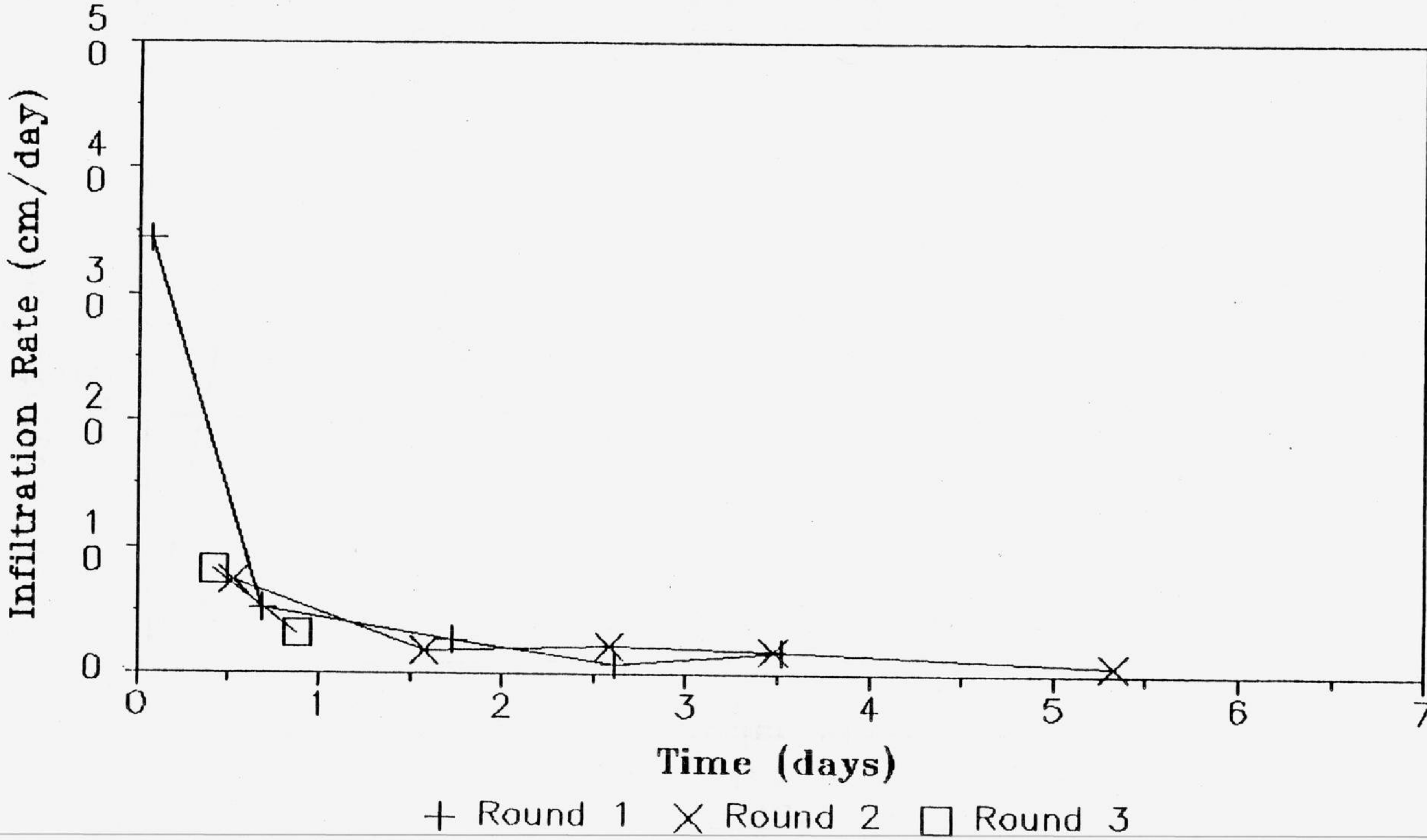


TABLE 4.6

BRODHEAD UNSATURATED ZONE TRAVEL TIMES

LOCATION	DEPTH BELOW FURROW(ft)	BARRIER(a) TRAVEL TIME(Day)	UNSAT(b) ZONE TRAVEL TIME(Days)	TOTAL TRAVEL TIME(Days)
Lysimeter 1 Cell 1	1.0	1.3	0.3	1.6
Lysimeter 2 Cell 1	3.0	1.3	0.9	2.2
Lysimeter 3 Cell 1	4.8	1.3	1.5	2.8
Lysimeter 5 Cell 2	1.8	1.3	0.6	1.9
Lysimeter 6 Cell 2	3.6	1.3	1.1	2.4
Groundwater	5.5	1.3	1.7	3.0

(a) Based on infiltration tests: site 1A represented flow near cell 1 lysimeters
site 2A represented flow near cell 2 lysimeters

(b) Based on Bouma (1975), Appendix G.

depths of the various lysimeters. These results are tabulated in Table 4.6. Travel of percolate in the unsaturated zone to the groundwater took 1.7 days as calculated by the latter method.

Results shown in Table 4.6, combining barrier and unsaturated zone flow times, indicated that it took approximately three days for furrow wastewater to reach the groundwater near the lysimeters. This matched the water table response time to precipitation recharge that was presented in Figure 4.6. Considering the range of barrier flow through times discussed earlier, the range of combined (barrier plus unsaturated zone) travel time at the Brodhead system was 2.2 to 9.7 days. In future work, it is recommended that soil moisture tension instrumentation be used to better define hydraulic conductivity with unsaturated depth.

Furrow Wastewater and Lysimeter Chemistry

Mean and standard deviations of chemical parameters for wastewater at each furrow sampling point and lysimeter are listed in Table 4.7. Complete data listings are given in Appendix H.

When comparing chloride averages, one can see that all lysimeter points were contaminated by the ridge and furrow wastewater except lysimeters 8 and 9, which were intended to be located in an area of background quality. Large data variations existed in furrows and lysimeters affected by cell loading. This resulted in large standard deviations. Therefore, it was realized that these average values do not fully describe the contamination and were only used for relative comparisons.

The chloride averages from cell 1 indicate no dilution from the furrows to the depth of lysimeter 3, and yet considerable reduction of other

TABLE 4.7

BRODHEAD MEAN AND STANDARD DEVIATION OF

FURROW WASTEWATER AND LYSIMETER CHEMICAL PARAMETERS

(Units in mg/l except pH)

LOCATION	DISS BOD_5	TOTAL BOD_5	DISS COD	DISS TKN	TOTAL TKN	DISS NH_3-N	DISS NO_2+NO_3	Cl^-	TDS	FIELD pH
Furrow-Cell 1	330±310 (4)	660±490 (5)	490±290 (16)	20±12 (20)	31±18 (9)	14±12 (20)	0.4±0.5* (20)	560±190 (19)	1780±280 (3)	7.1±0.56 (2)
Lysimeter 1 (1' depth)	---	---	55±12 (14)	22±8.6 (18)	---	16±10 (22)	0.6±0.4* (22)	700±170 (16)	2130±184 (2)	7.1±0.30 (3)
Lysimeter 2 (3' depth)	4.1±0.0 (1)	---	51±6.6 (21)	12±10 (27)	---	9.8±10* (30)	8.6±9.3* (30)	690±100 (17)	2040±191 (2)	7.2±0.33 (4)
Lysimeter 3 (4.8' depth)	---	---	56±4.2 (2)	2.7±0.80 (8)	---	2.5±3.9* (17)	6.3±4.7 (17)	780±100 (10)	---	7.6±0.0 (1)
Well 17@	34±37* (2)	---	54±5.8 (7)	31±2.6 (11)	---	30±1.8 (11)	0.92±0.27* (11)	650±77 (11)	2540±643 (2)	---
Furrow-Cell 2	580±120* (3)	2400±0.0 (1)	910±530 (12)	26±14 (16)	70±100 (11)	14±10 (16)	1.5±2.9* (16)	620±200 (15)	2630±127 (2)	6.7±0.0 (1)
Lysimeter 5 (1.8' depth)	3.0±0.0* (1)	---	32±11 (16)	0.9±0.3 (22)	---	0.3±0.4* (22)	11±9.0 (22)	400±170 (14)	---	7.4±0.0 (1)
Lysimeter 6 (3.6' depth)	3.3±0.69* (11)	---	20±4.0 (14)	0.7±0.2 (19)	---	0.4±0.4* (21)	21±10 (21)	390±150 (19)	1400±162 (10)	6.8±0.0 (1)
Well 15@	51±55* (12)	---	57±50 (19)	16±21 (23)	---	15±20* (23)	17±21* (23)	570±110 (23)	1640±216 (12)	6.4±0.12 (8)
Lysimeter 8 (3.7' depth)	3.4±0.47* (4)	---	12±1.6 (9)	0.4±0.06 (11)	---	0.1±0.0* (13)	0.1±0.1* (13)	1.2±0.29 (11)	267±19.9 (6)	---
Lysimeter 9 (4.7' depth)	3.2±0.37* (7)	6±0.0 (1)	24±3.7 (14)	0.6±0.2 (17)	0.6±0.2 (2)	0.1±0.0* (19)	0.1±0.02* (19)	1.3±0.34 (16)	323±24.9 (8)	6.8±0.07 (2)

@ Well data added to observe transformations of groundwater; ( ) - # of observations.

* Mean includes data above or below a detection limit, limit was used in average.

chemical parameters was seen at this depth. Dissolved COD values were reduced 88% and dissolved total nitrogen (TKN + NO_3 + NO_2) concentrations were reduced by 56%. Groundwater quality underneath cell 1, as shown by well 17 data, did not reflect these reductions, however. Dissolved COD concentrations were reduced 89% at the water table, but, dissolved total nitrogen values in the groundwater were higher than furrow concentrations. This was attributed to past overuse of cell 1 prior to 1980. Since the groundwater velocity was slow, the zone beneath cell 1 did not flush out during the course of this project, as the region around well 15 did. A similar discussion for cell 2 average concentration reductions could not be made since values varied too greatly in well 15.

Another important observation from Table 4.7 concerned the transformation of organic-N in the wastewater to NH_3-N in the furrow water. Ammonium comprised only 10% of the dairy wastewater TKN while the TKN in the furrow wastewater contained 54-70% ammonium. From Table 4.5, one can see that TKN values in the wells downstream of the ridge and furrow system were almost 100% NH_4^+-N. This transformation will be discussed in more detail later in this chapter.

Figures 4.21 and 4.22 show typical chloride and nitrogen profiles, respectively, in both of the cells. Concentration movement in the unsaturated zone could not be correlated with travel time since the travel times presented earlier were less than the time period between sampling. The profiles do illustrate the following points:

1) no dilution of wastewater occurred as it percolated beneath cell 1,
2) slight dilution of percolate occurred beneath cell 2,

FIGURE 4.21a
Unsaturated Zone Chloride Profile
Cell 1

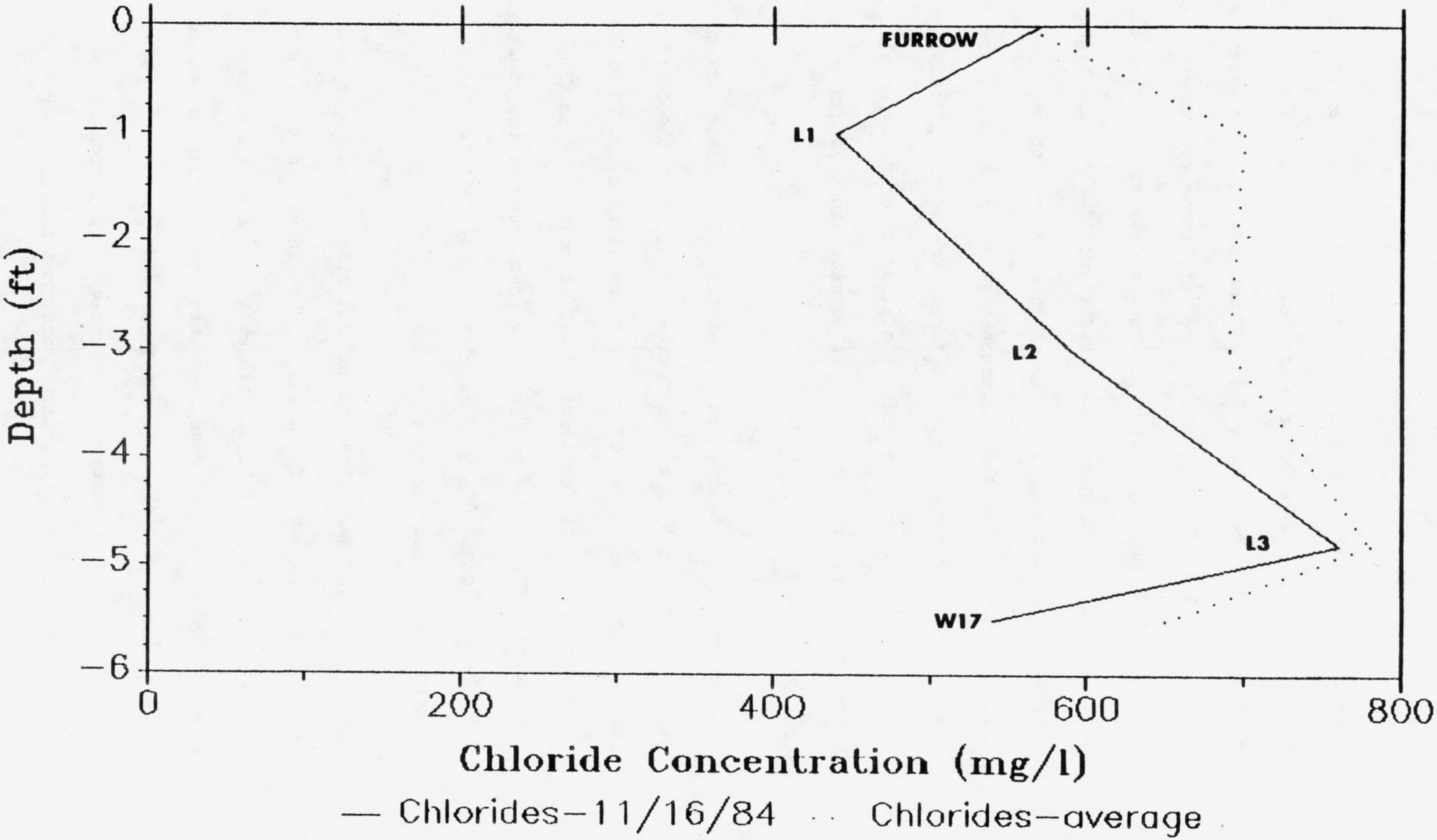


FIGURE 4.21b
Unsaturated Zone Chloride Profile
Cell 2

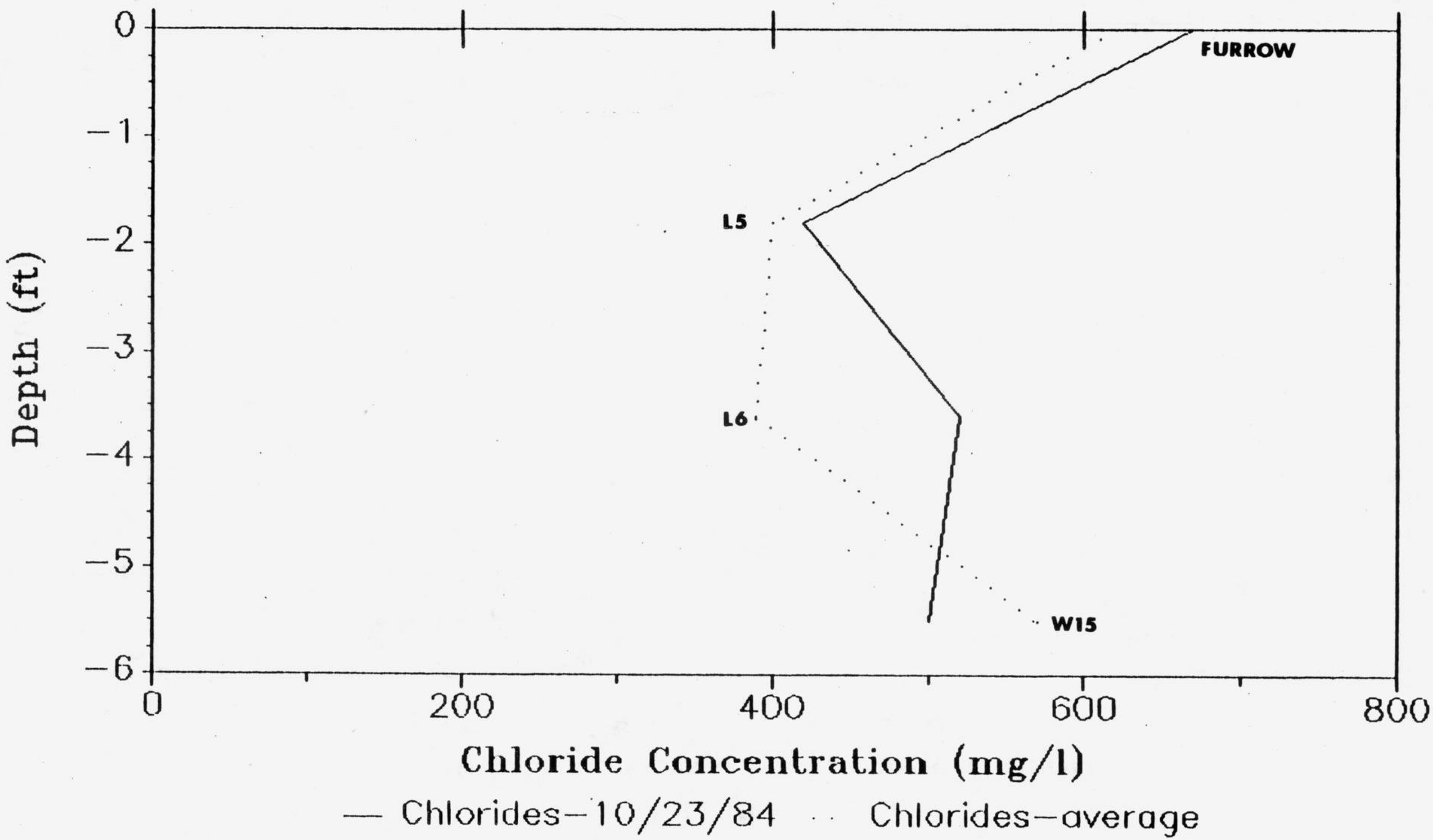


FIGURE 4.22a
Unsaturated Zone Nitrogen Profile
Cell 1 - 11/16/84

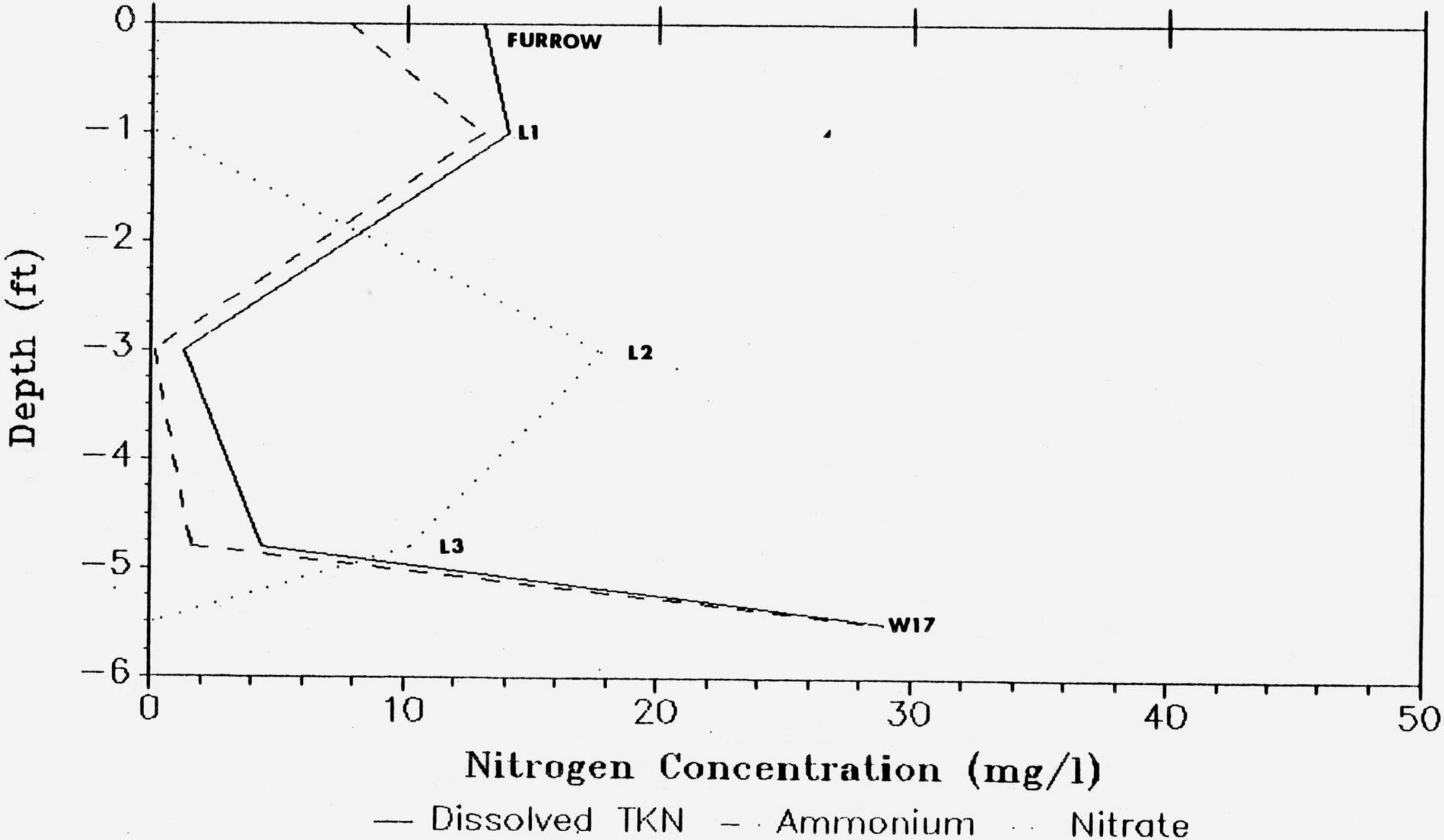
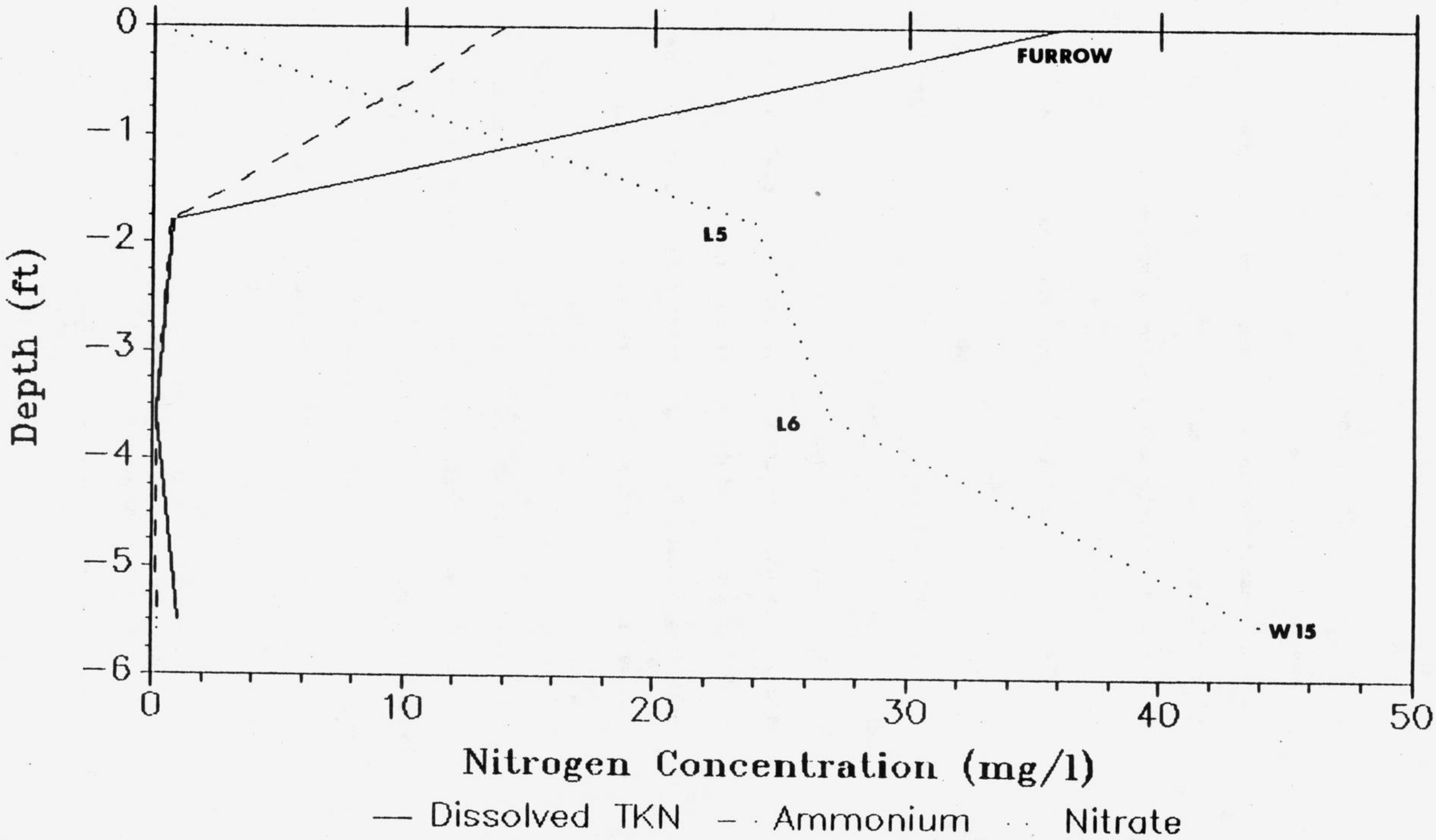


FIGURE 4.22b
Unsaturated Zone Nitrogen Profile
Cell 2 - 10/23/84



3) TKN was transformed to NH_4^+-N after one foot depth in cell 1 and two foot depth in cell 2,

4) nitrification occurred beneath 1 and 3 feet depth underneath cell 1,

5) nitrification occurred along the whole profile underneath cell 2,

6) possible denitrification occurred between the 3 and 5 feet depth underneath cell 1, and

7) high TKN and NH_4^+-N concentrations were observed at the water table beneath cell 1.

Furrow and unsaturated zone pH values (Table 4.7) ranged from 6.7 in a cell 2 furrow to 7.6 in lysimeter 3. These values are somewhat higher than the average pH values seen in wells 15 and 16, immediately underneath the system. The lower pH values (about 6.4) in the contaminated groundwater were attributed to the past use of the system when overloading caused anaerobic conditions and lower pH values. The low groundwater velocity has delayed the flush out of this zone.

Chloride and nitrogen time plots for furrow, lysimeter, and well data were compared with depth in both cell 1 and cell 2 at Brodhead. Figure 4.23 illustrates chloride concentrations versus time for cell 1 furrow wastewater; lysimeters 1, 2, and 3; and well 17. Figure 4.24 presents total nitrogen concentrations versus time for these respective sampling points. The reader is referred to Figures 4.25 to 4.28 and 4.15 for TKN, NH_3-N, and NO_3-N plots of respective points.

These cell 1 chloride and nitrogen plots were compared to determine if nitrogen decreases were mainly due to dilution (as seen by comparing chlorides) or if unsaturated zone nitrogen losses were actually greater

FIGURE 4.23a
Chloride Concentration vs. Time
Cell 1 Furrow, Lysimeters 1 and 2

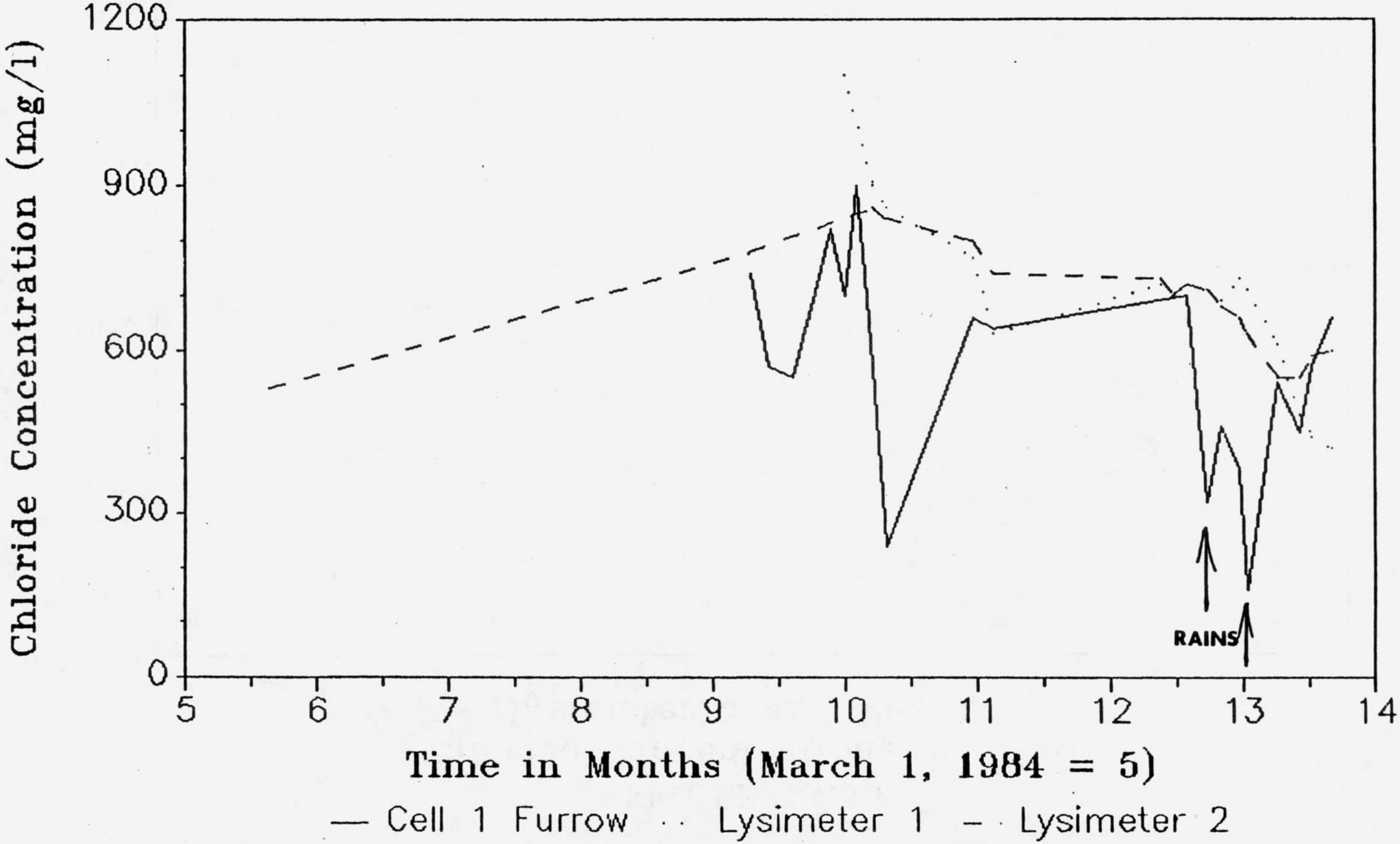


FIGURE 4.23b
Chloride Concentrations vs. Time
Lysimeter 3 and Well 17

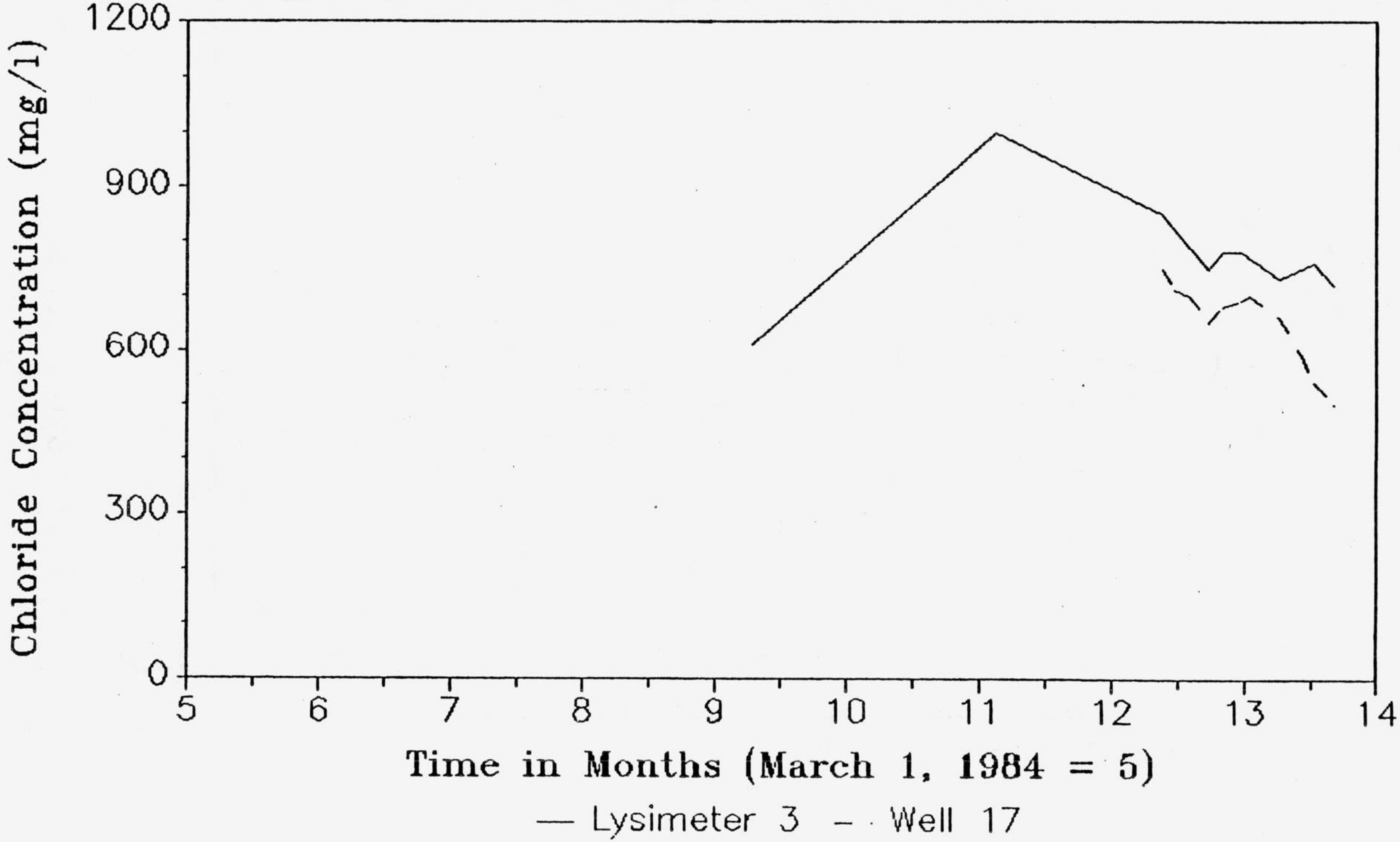


FIGURE 4.24a
Total Nitrogen Concentration vs. Time
Cell 1 Furrow, Lysimeters 1 and 2

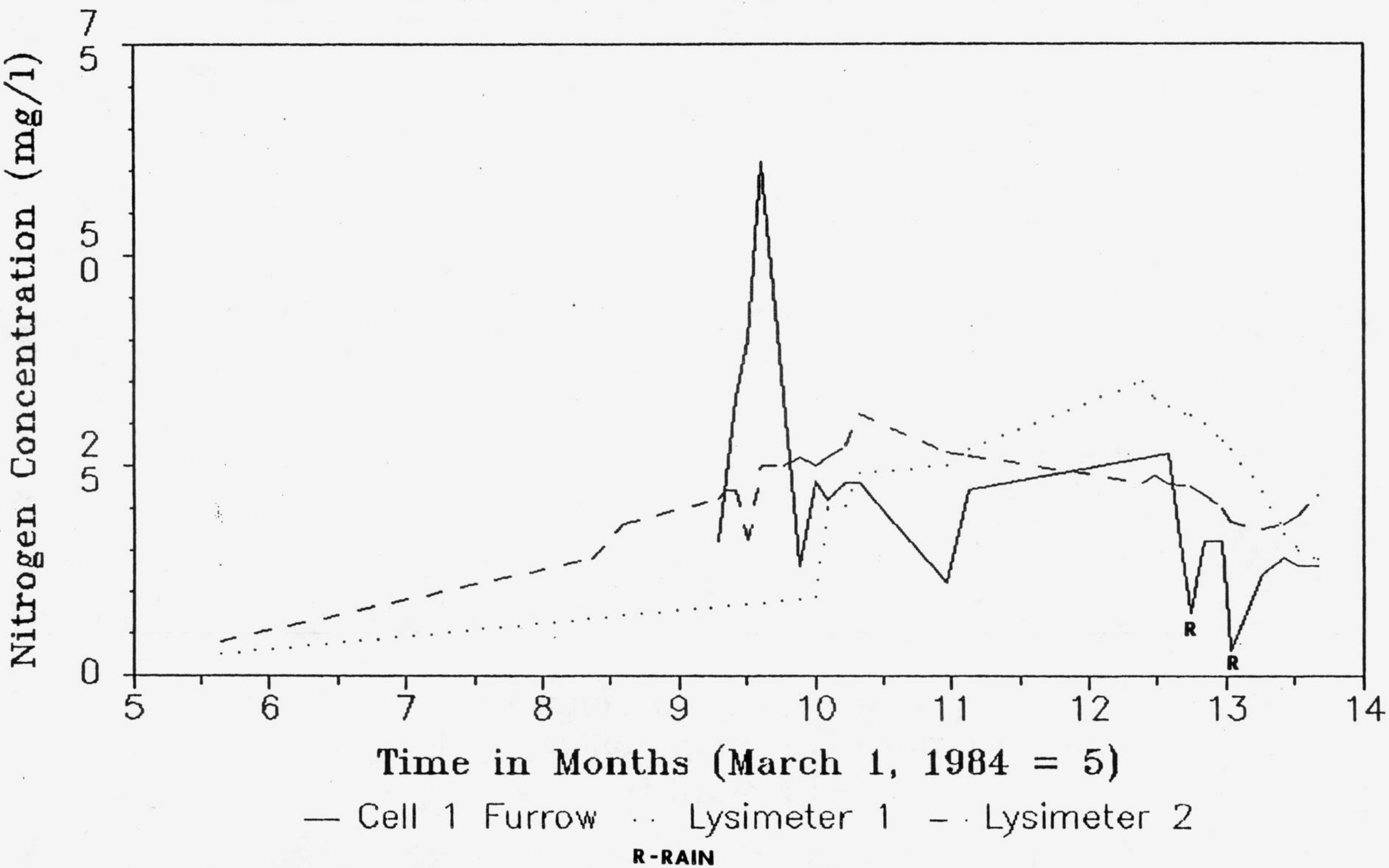


FIGURE 4.24b
Total Nitrogen Concentration vs. Time
Lysimeter 3 and Well 17

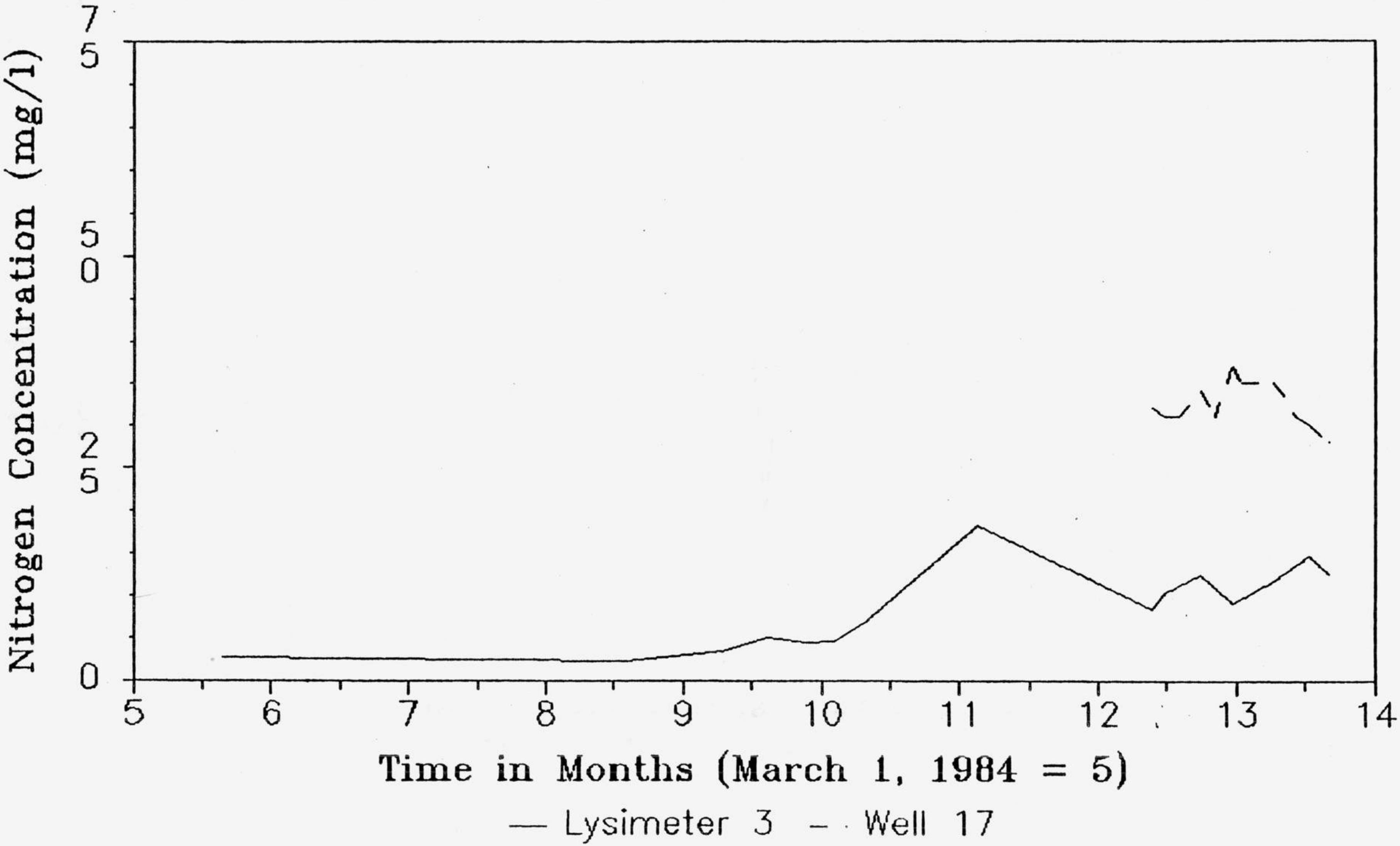
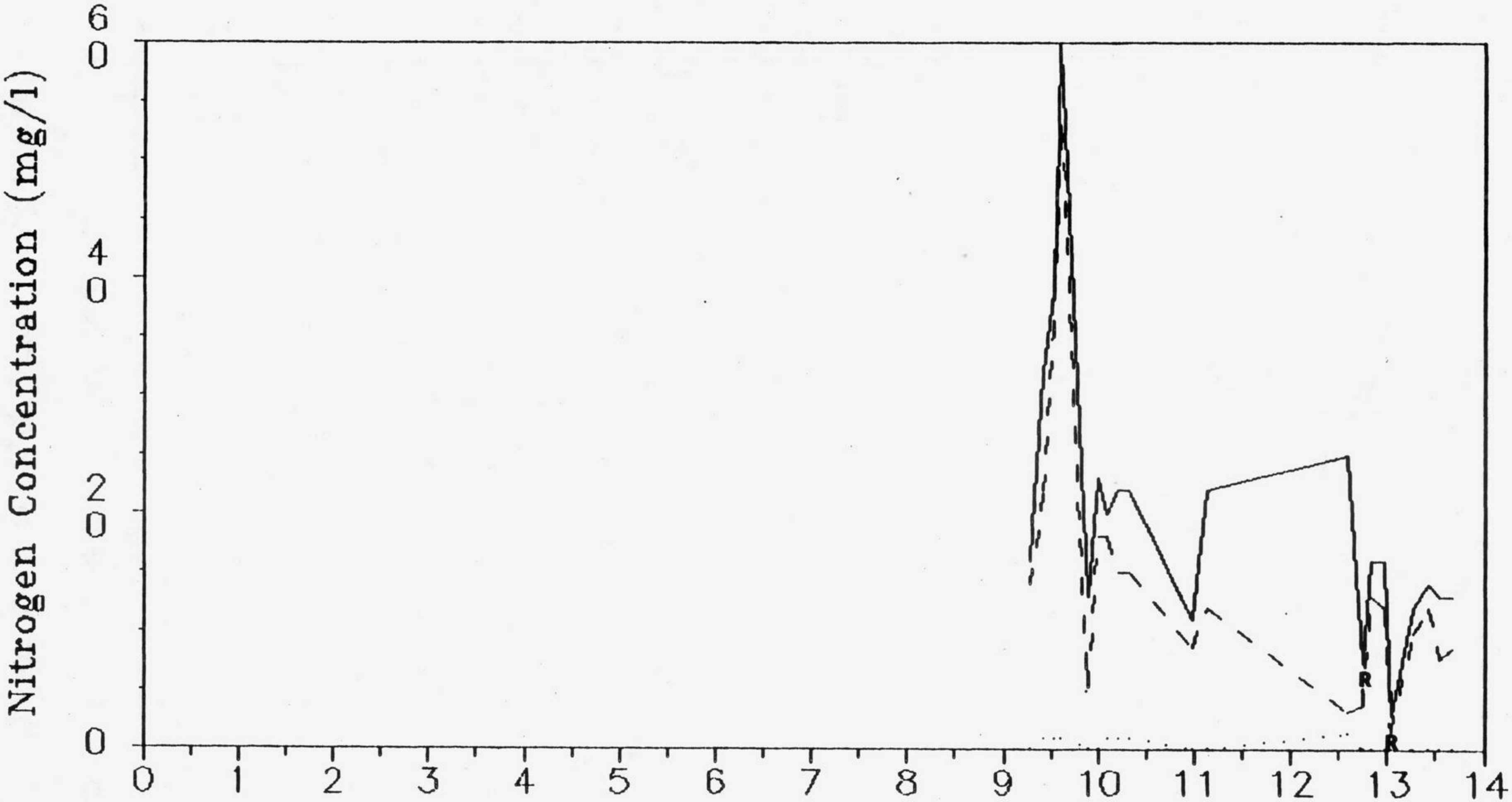


FIGURE 4.25
Cell 1 Furrow Wastewater Nitrogen



Time in Months (October 1, 1983 = 0)

— Dissolved TKN - - Ammonium · · Nitrate

R-RAIN

FIGURE 4.26
Lysimeter 1 Nitrogen vs. Time

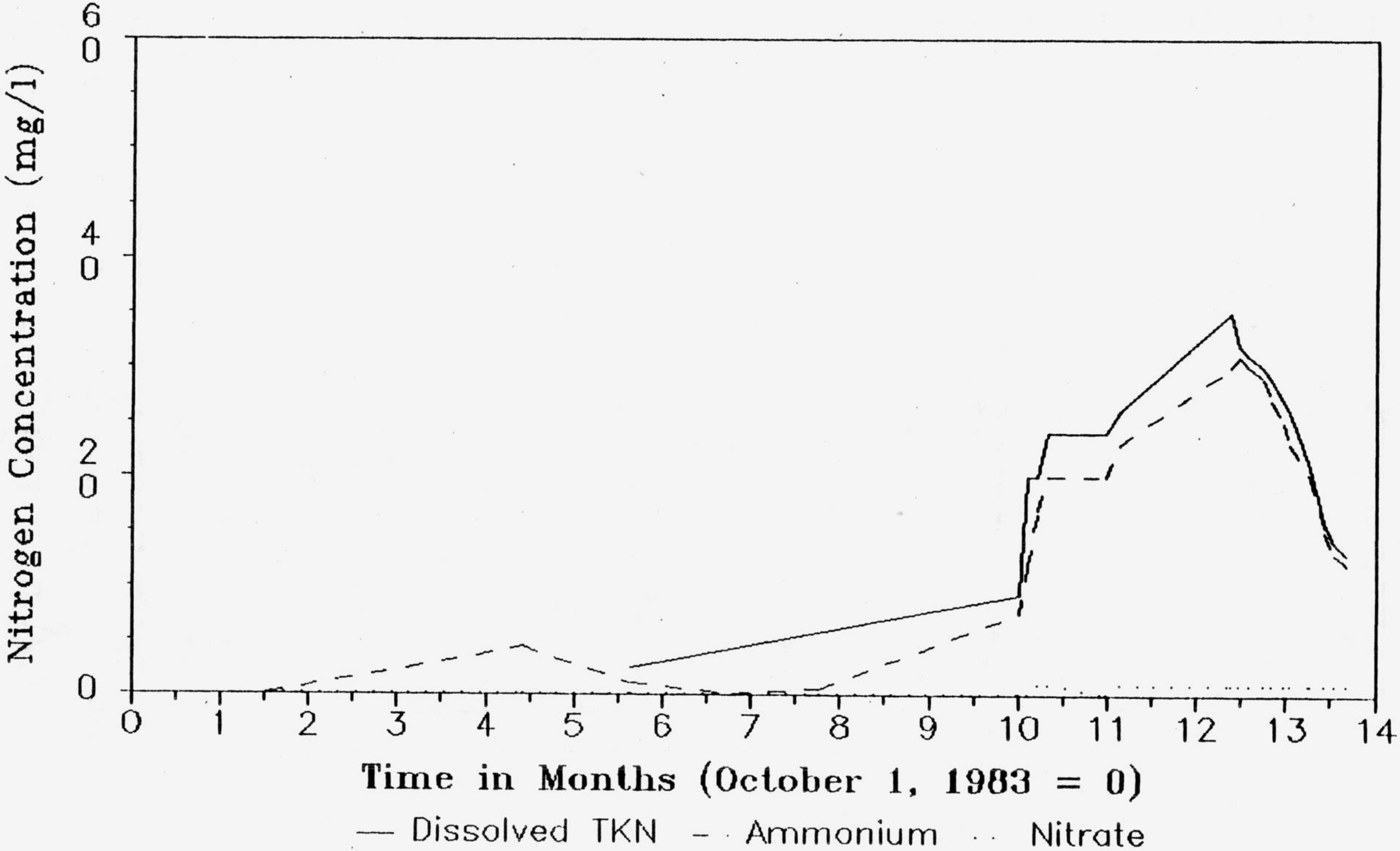


FIGURE 4.27
Lysimeter 2 Nitrogen vs. Time

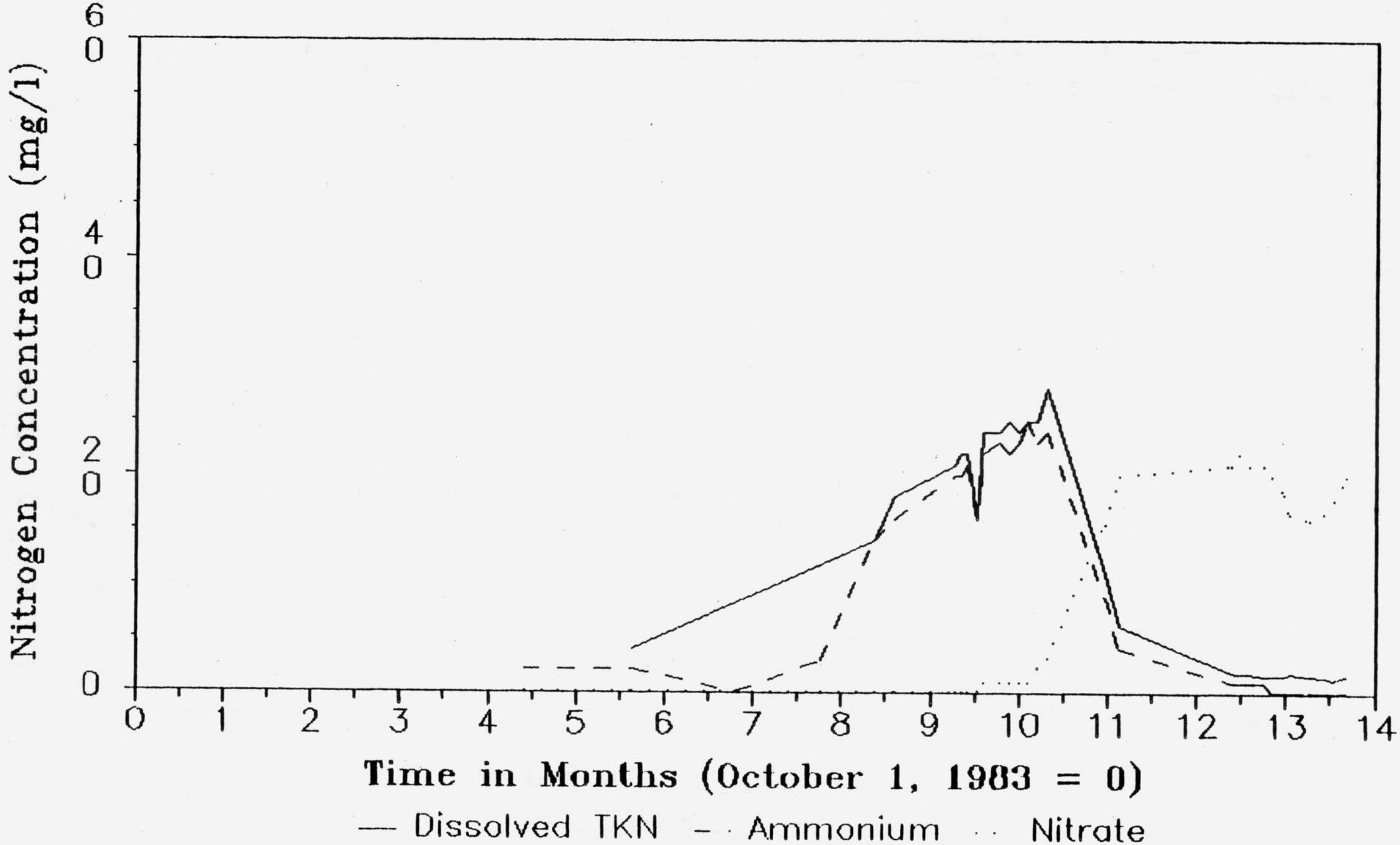
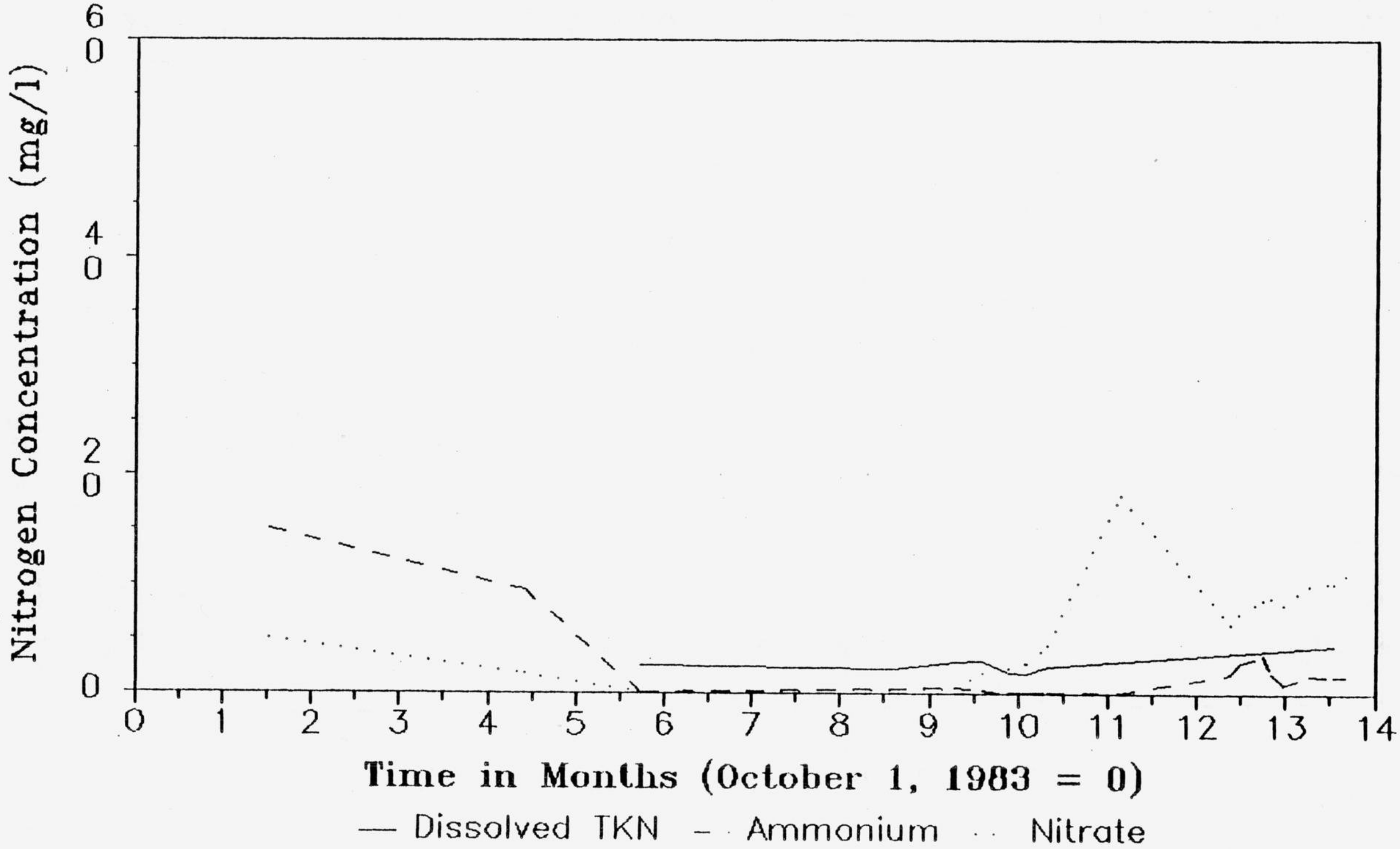


FIGURE 4.28
Lysimeter 3 Nitrogen vs. Time



than chloride decreases. Late October and November (1984) was the best period to compare chloride concentrations with depth in cell 1. As mentioned earlier, heavy rains occurred on October 18 and November 1. This was reflected by a decrease in furrow chloride concentration on these dates as shown in Figure 4.23. After the November 1 rain, a 42% drop in chloride values in lysimeter 1 occurred. A 24% decrease with a subsequent 8% increase in chloride concentrations occurred in lysimeter 2 during the same period. A 28% drop which began November 1, was observed in well 17 as well. Figure 4.23 shows these declines. These results complement the unsaturated zone travel time of less than 3 days calculated earlier. It was not known why a decrease in chloride concentration was not seen in lysimeter 3.

Similar decreases were observed in the total nitrogen concentrations of cell 1 furrow wastewater; lysimeters 1 and 2; and well 17 as shown in Figure 4.24. Decreases in furrow nitrogen occurred on 10/18 and 11/1 as expected. A 52% drop in total nitrogen was observed in lysimeter 1 during the same time period as a 42% chloride decrease. It was not feasible to attribute the additional 10% loss to denitrification since no nitrate was present in the first one foot of depth. Plant uptake of NH_4^+-N was possible since lush growth was occurring on furrow fringes in late November. In lysimeter 2, total nitrogen concentrations decreased by 27% (similar to chloride dilution) and then increased by 20% (compared to a 8% chloride increase). This 12% addition was attributed to nitrate production. Total nitrogen losses in well 17 declined by 20% during this period (compared to 28% for Cl^-). Lysimeter 3 nitrogen values increased 20% during this period. A decreasing denitrification rate could have accounted for this since nitrate values increased and chloride concentrations were fairly level.

Figure 4.24 indicates that nitrogen losses, most likely through denitrification, occurred from lysimeter 2 to lysimeter 3 after September 1. Prior to this time, both nitrification and denitrification occurred between these two points (see Figures 4.27 and 4.28) since total nitrogen decreased in lysimeter 3 but little nitrate was present.

After September 1, nitrification occurred between lysimeters 1 and 2 as seen in Figures 4.26 and 4.27. Prior to 9/1, however, lysimeter 2 samples contained high nitrogen values (in ammonia form) which did not appear in lysimeter 1 samples. Since nitrogen can not be created, this phenomenon may have been the result of the horizontal positioning of the lysimeters. Since the lysimeters were located adjacent to one another (2 to 3 feet apart), the possibility of the device receiving wastewater of different initial quality existed. Local channeling in the unsaturated zone created by organic barrier heterogenetities may also have caused these anomalies.

As in cell 1, late October and November (1984) was the best period to compare chloride concentrations with nitrogen concentrations through the unsaturated depth of cell 2 to analyze dilution and possible denitrification losses. Figure 4.29 presents chloride data versus time for cell 2 furrow wastewater; lysimeters 5 and 6; and well 15. Figure 4.30 illustrates total nitrogen values versus time for these respective sampling points. TKN, NH_3-N, and NO_3-N plots for these points appear in Figures 4.31 to 4.33 and 4.12, respectively.

FIGURE 4.29a
Chloride Concentrations vs. Time
Cell 2 Furrow and Lysimeter 5

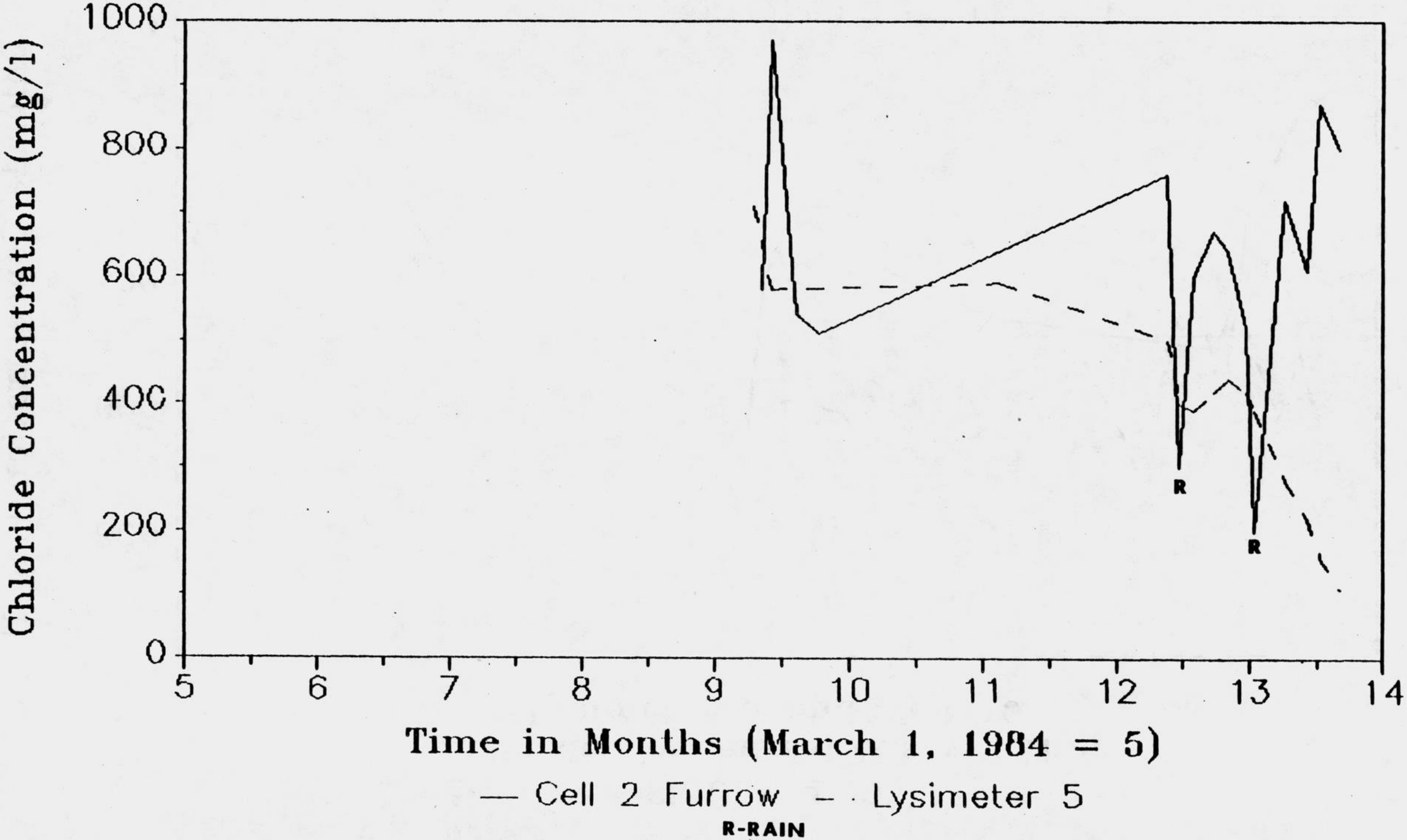


FIGURE 4.29b
Chloride Concentrations vs. Time
Lysimeter 6 and Well 15

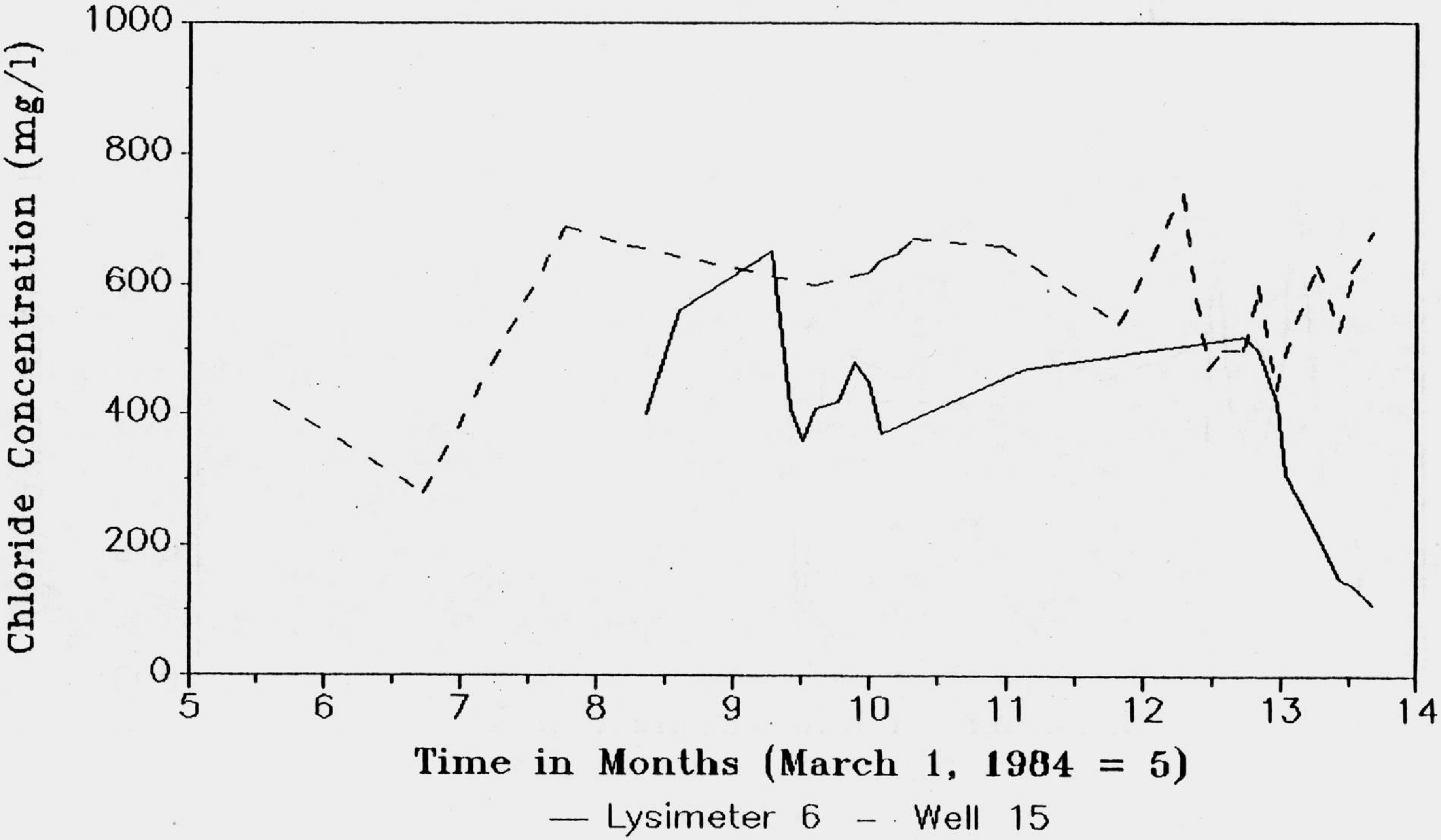


FIGURE 4.30a
Total Nitrogen Concentration vs. Time
Cell 2 Furrow and Lysimeter 5

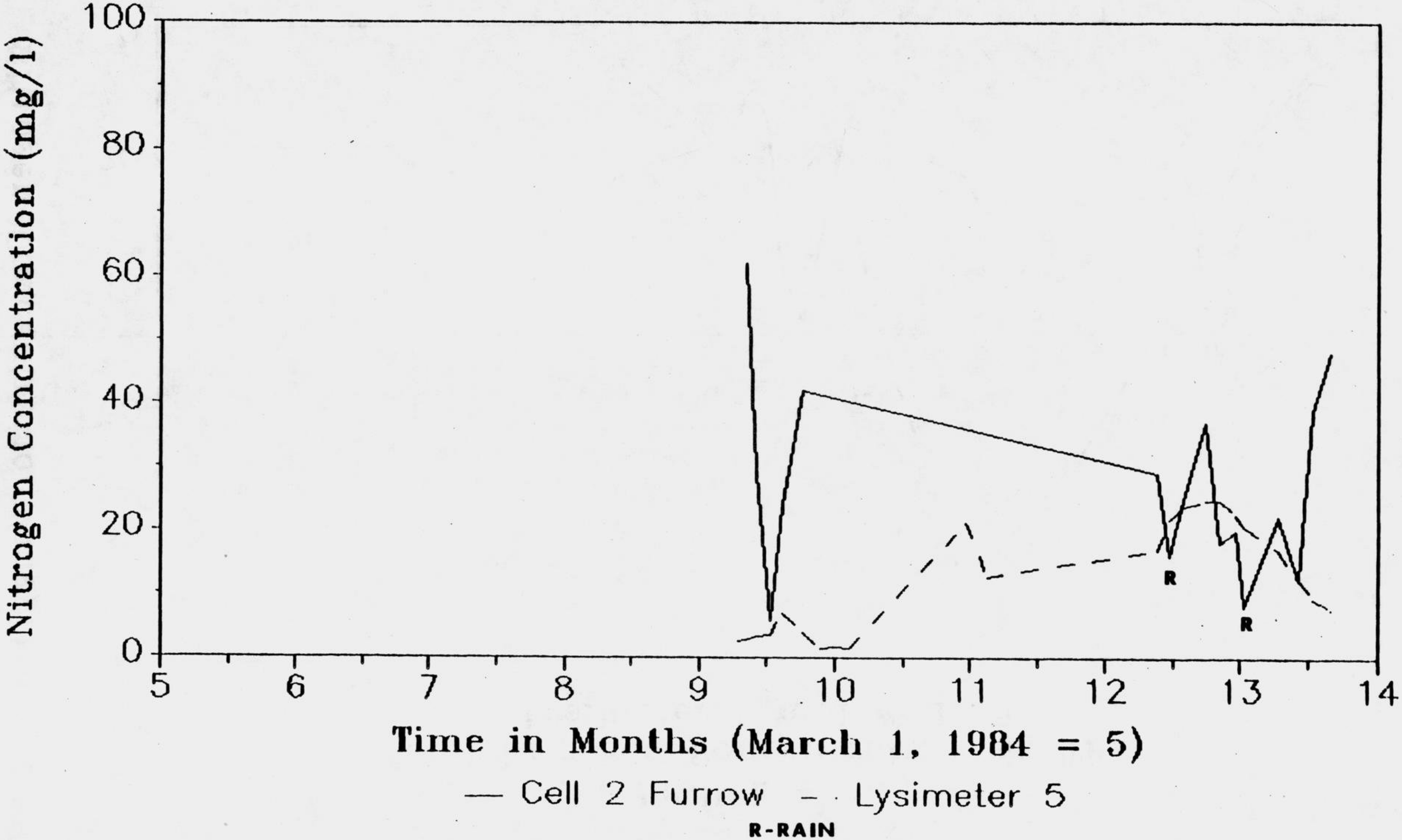


FIGURE 4.30b
Total Nitrogen Concentration vs. Time
Lysimeter 6 and Well 15

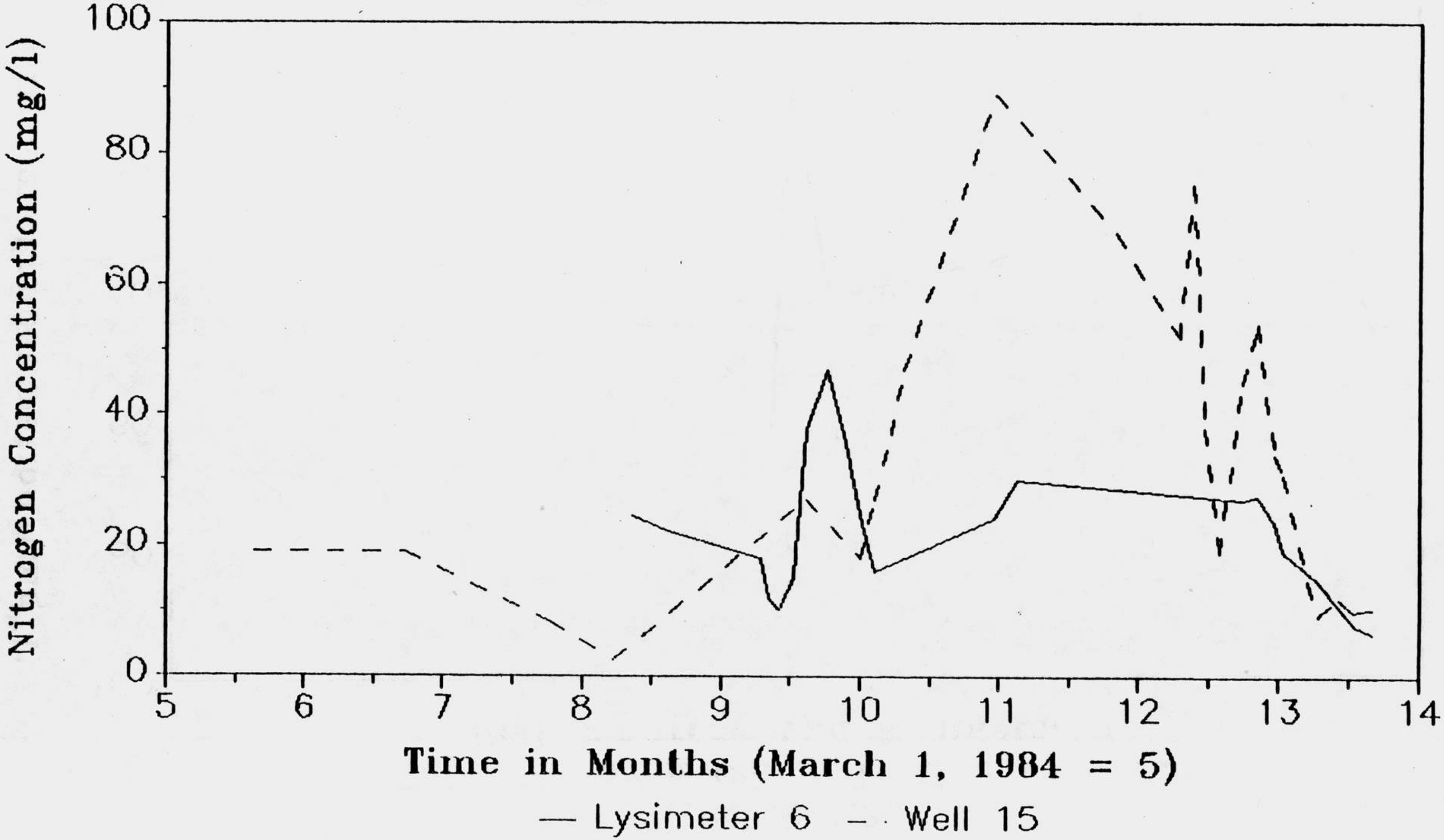


FIGURE 4.31
Cell 2 Furrow Wastewater Nitrogen Concentrations

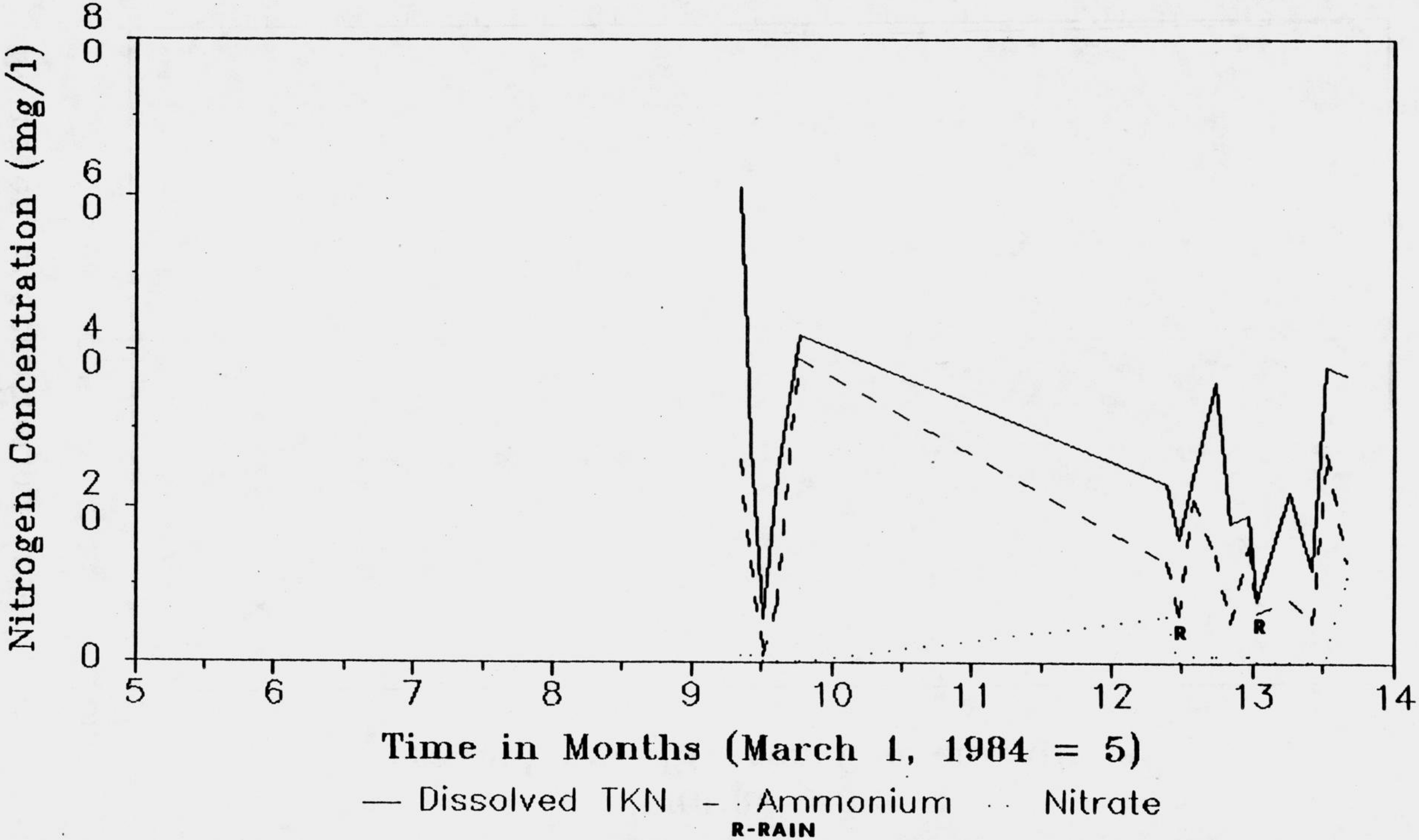


FIGURE 4.32
Lysimeter 5 Nitrogen Concentrations

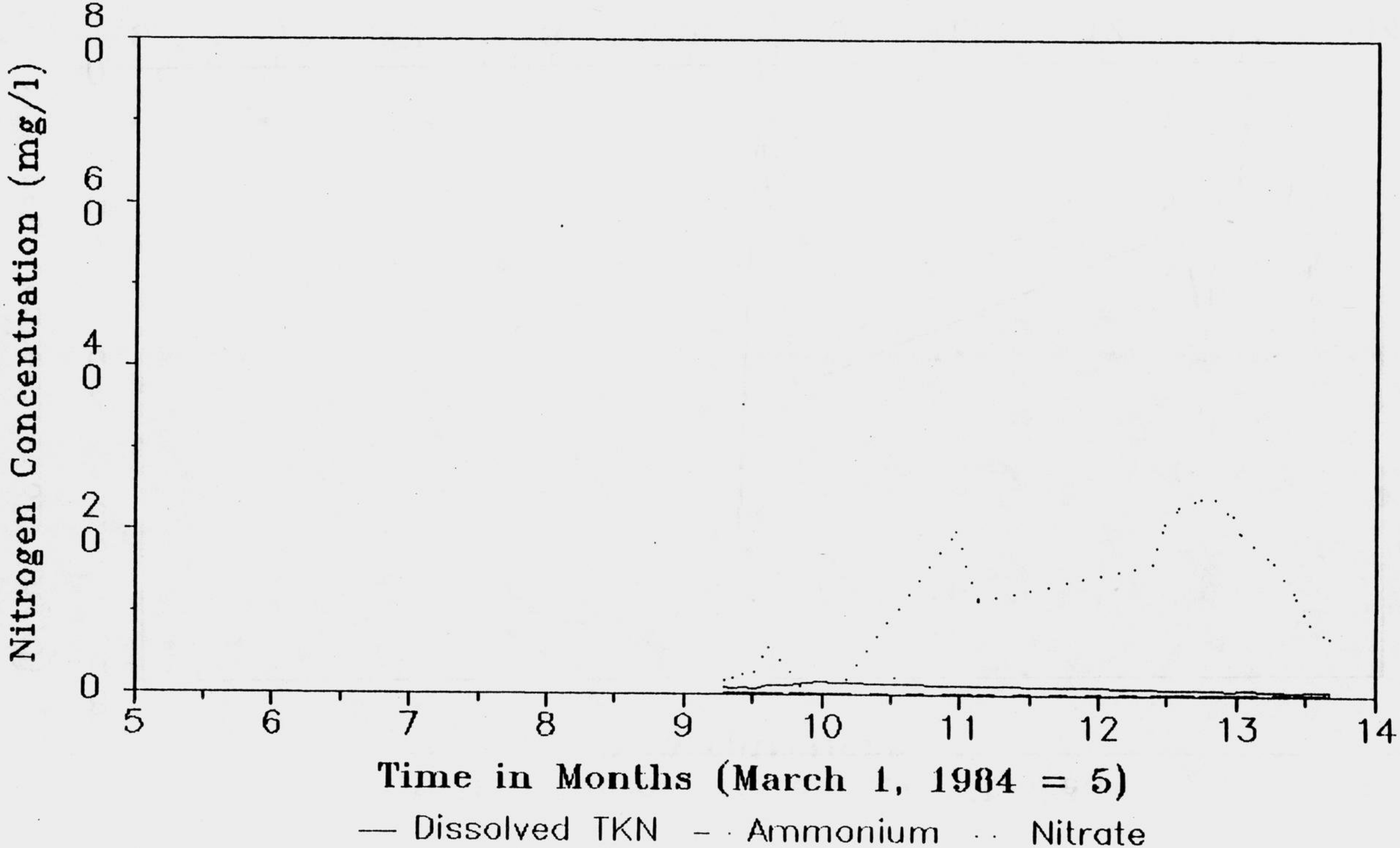
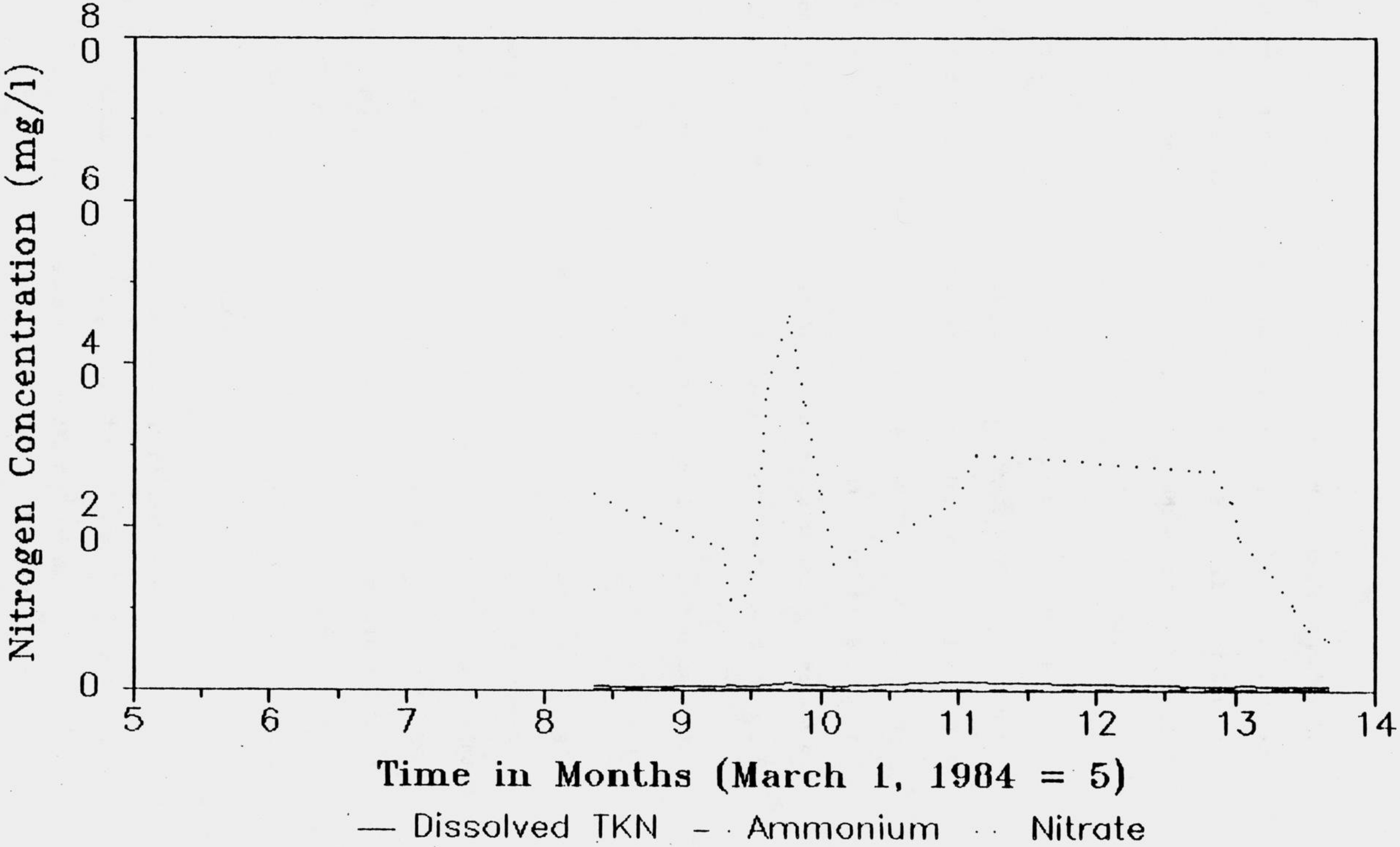


FIGURE 4.33
Lysimeter 6 Nitrogen Concentrations



Cell 2 furrow chloride values decreased sharply on rainy days just as they did in cell 1. A 75% decrease in chloride concentrations was observed in lysimeter 5 after October 26. Lysimeter 6 chloride values declined 79% after October 23. Similar decreases were not observed in well 15 during this period.

Similar declines during this time were witnessed in total nitrogen concentrations for lysimeters 5 and 6, as well as, well 15 (see Figure 4.30). Dilution (75% chloride decrease) accounted for most of a 71% drop in total nitrogen concentrations in lysimeter 5 after October 6. A 77% decrease in lysimeter 6 N values was also caused by the dilution rainwater. During this period, an 88% decline of N concentrations occurred in well 15. These losses were likely the result of denitrification since well 15 Cl^- concentrations did not decrease. Underneath cell 2, all denitrification losses occurred below 3.6 feet depth.

Figure 4.30 gives the illusion that nitrogen concentrations did not decrease but actually increased. There were three possible reasons for this. First, lysimeters 5 and 6 are located about ten feet apart and may not have received an identical quality waste. Second, local channeling resulting from unsaturated zone heterogeneities (eg. organic barrier) may have occurred. Third, since groundwater flowed from underneath cell 1 past cell 2, water quality in well 15 was directly affected by the past water quality underneath cell 1.

Nitrate peaks were observed in lysimeter and well data for both cells. These peaks (see lysimeter nitrogen series plots) appeared either late in a loading cycle or just after. Increased vertical flow from loaded wastewater tended to flush out nitrate which accumulated in unsaturated pore spaces during rest cycles.

Figures 4.25 and 4.31 present TKN, NH_3-N, and NO_3-N concentrations versus time for cell 1 and cell 2 furrow wastewater samples, respectively. Figures 4.34 and 4.35 present total and dissolved TKN versus time for furrow samples in cells 1 and 2, respectively. The following sequence of furrow nitrogen transformations were established from these results. As stated previously, the wastewater discharges contained nitrogen primarily in organic-N form. Thirty to 90% of this organic-N was tied up in wastewater solids. This was seen by comparing total and dissolved TKN results (Table 4.2). Depending on furrow mixing, total TKN concentrations were quite variable and of the same magnitude as wastewater TKN's.

Dissolved TKN showed a distinctive pattern, however, especially during the dry period of July and August (1984). During initial cell loading, dissolved TKN's were lowest since the solids contained much of the nitrogen. Toward the end of a loading cycle and during the rest cycle, dissolved TKN concentrations increased. This was possibly the result of mineralization of settled furrow solids and diffusion of ammonium into the overlying water column. Reddy and Graety .1981) recognized a similar occurance in their study. These transformations were not as apparent during shorter load/rest cycles.

Crop Uptake of Nitrogen

Seven grass samples were cut at the Brodhead ridge and furrow system during the 1984 growing season. One sample was collected in April

FIGURE 4.34
Cell 1 Furrow Wastewater
Total and Dissolved TKN Concentrations

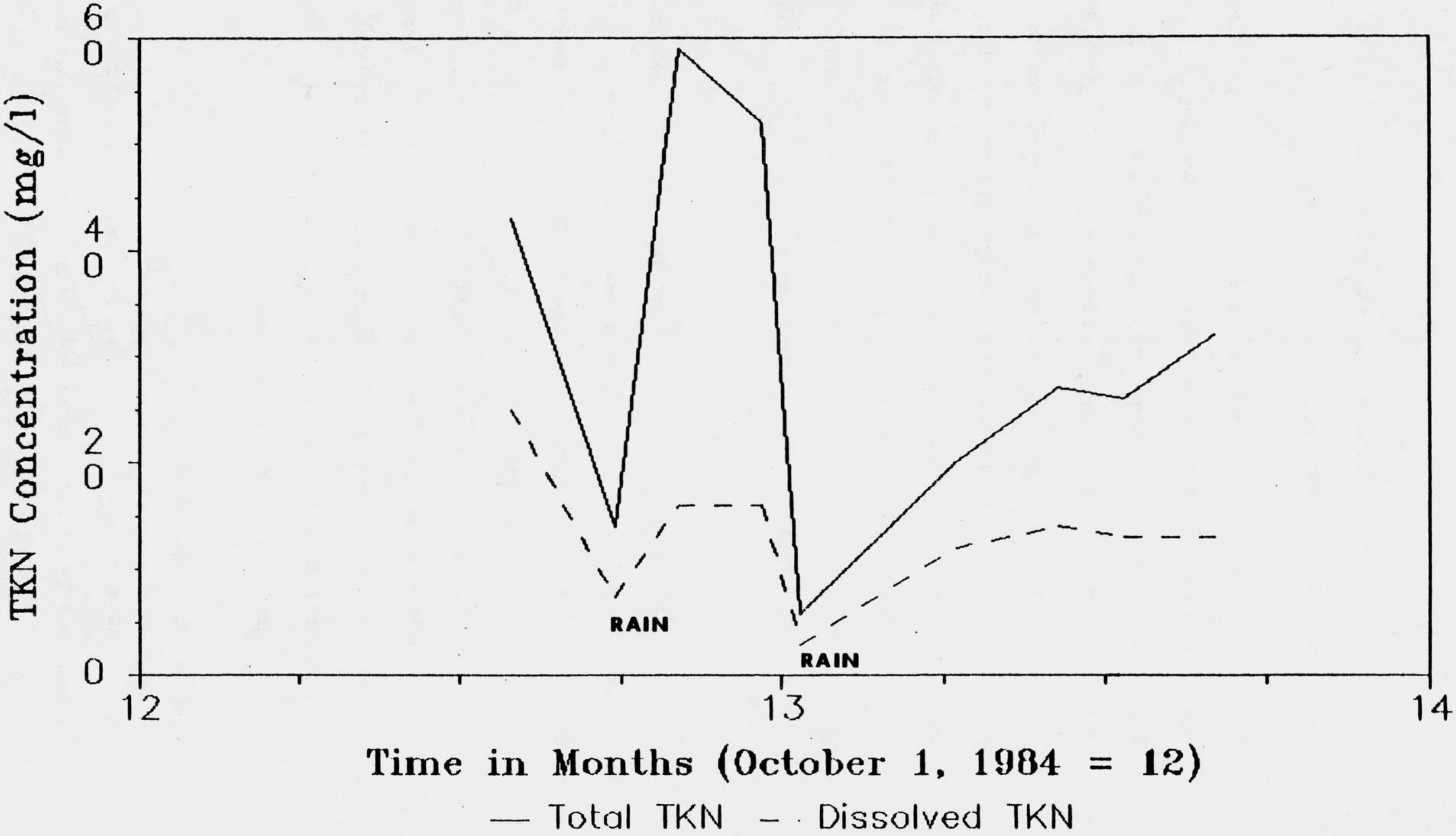


FIGURE 4.35
Cell 2 Furrow Wastewater
Total and Dissolved TKN Concentrations

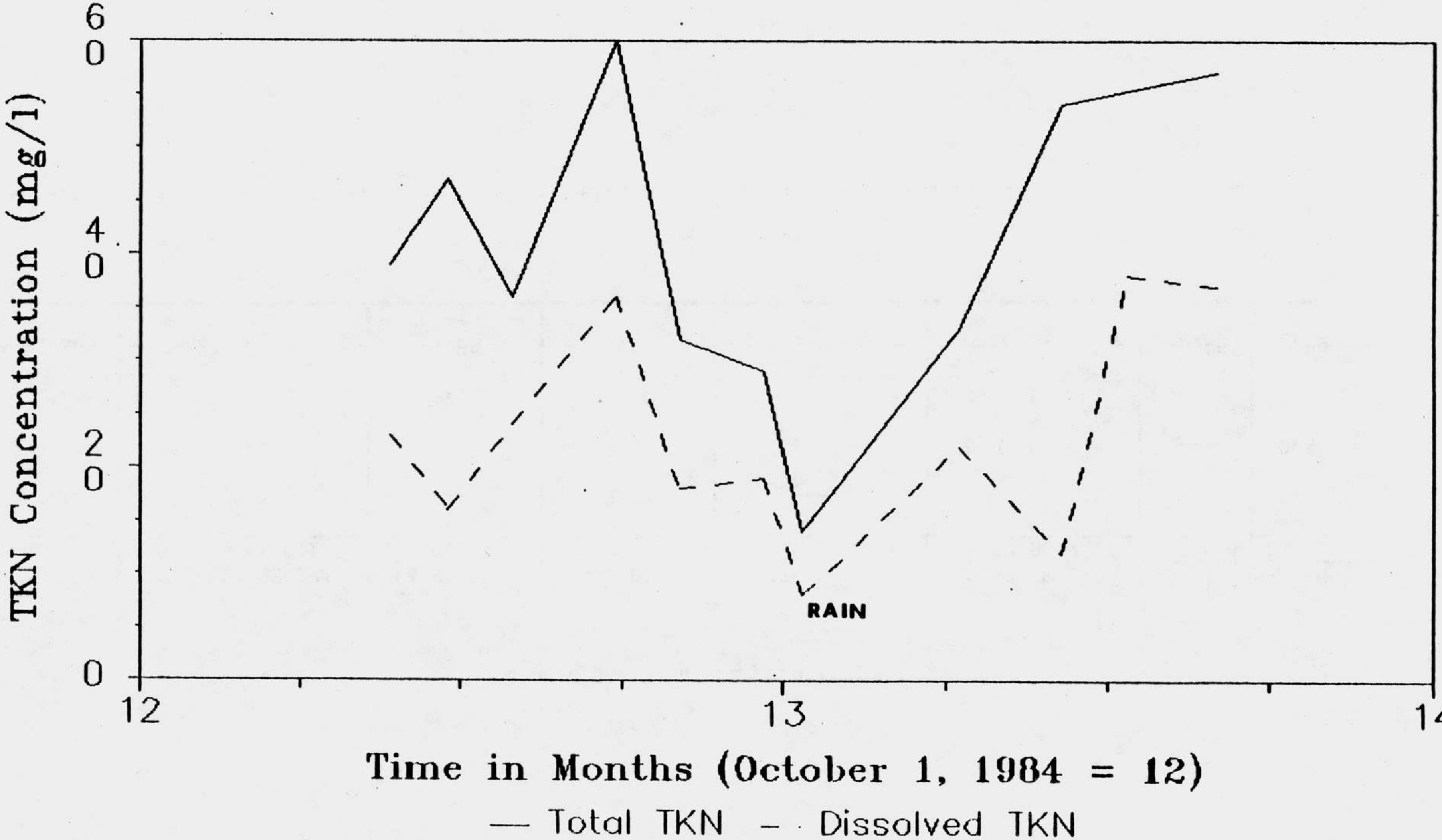


TABLE 4.8

BROTHEAD GRASS SAMPLE RESULTS

DATE	TOTAL DRY WT OF GRASS ON SITE(lb)	% N DRY WT-CELL 1	% N DRY WT-CELL 2	% ASH-CELL 1 AFTER BURNING	% ASH-CELL 2 AFTER BURNING	% N OF ASH	
						CELL 1	CELL 2
4/24/84	11,646	---	1.44	---	10.1	---	2.64
7/13/84	22,847	1.28	---	---	5.9	---	0.48
9/25/84	9,171	2.70	3.50	5.5	5.6	0.72	0.50
11/20/84	23,282	1.59	1.41	3.9	3.1	0.45	0.49

- weights extrapolated to total site area from weights corresponding to sample areas

TABLE 4.8 Cont.

DATE	TOTAL N ON SITE BEFORE BURNING(lb)	TOTAL N ON SITE AFTER BURNING(lb)	% N LOST BY BURNING
4/24/84	168	31.0	81.5
7/13/84	292	6.5	97.8
9/25/84	276	3.2	98.9
11/20/84	347	3.7	98.9

- weights extrapolated to total site area from weights corresponding to sample areas before growth began, two were taken in July at peak growth, two were cut in September during declining growth, and two were taken in November during rejuvenated growth. Results of these analyses are shown in Table 4.8. Calculations are presented in Appendix I. These results were used for the following three purposes: 1) to determine the plant nitrogen uptake during the growing season, 2) to calculate the effect of grass burning on nitrogen losses, and 3) to estimate a nitrogen plant uptake value for a nitrogen budget.

When looking at the total weight of nitrogen on site before burning in Table 4.8, plant uptake of nitrogen appeared to be highest in late spring, slightly declining in summer and slightly increasing in late fall. Heavy rainfall in late October and early November stimulated new growth in November.

The nitrogen taken up over the total area of the ridge and furrow system, by the cover crop during the growing season was 347 lbs. This corresponded to the grass nitrogen content on 11/20/84. Since grass from the previous year died and was immobilized in the soil, the April site grass nitrogen content of 168 lb was not considered a loss to the treatment system nor was it subtracted from the final grass nitrogen weight (347 lb.). Since the Brodhead system operator did not burn site grasses, all grass nitrogen returned to the soil. This meant that grass uptake losses were not a part of a system nitrogen budget. Some operators of land treatment systems do burn the site grasses in the spring to eliminate dead grass accumulation and stimulate new growth. Besides stimulating new luxerient growth, Woodmansee and Wallach (1979) stated that nitrogen losses and nitrogen transformation rate increases occur after fires. Nitrogen losses depend on plant biomass and elemental composition, fire intensity and duration, and winds. Since spring fires at land treatment sites are of low intensity, plant roots are not killed and growth will continue. Dead grasses contain most of their N in the root zone, so nitrogen losses are lowest when these grasses are burned.

Knowing this information, grass samples were burned and analyzed for percent ash and percent N in ash. Total pounds of ash-nitrogen were highest in April at 31 lbs. as shown in Table 4.8. The July ash sample indicated 6.5 lbs. of nitrogen on site after burning, the September sample indicated 3.2 lbs., and the November sample indicated 3.7 lbs. A range of 82%-99% nitrogen loss by burning was observed when comparing total nitrogen in the site grasses before and after burning. The lowest loss occurred in April.

After studying the data, one could conclude that it would be best to burn the cover crop of a ridge and furrow site in late fall since grass N losses of 99% would be seen. This would not be advisable, however, since the cover crop provides a vital function in the winter. Dead grasses insulate the soil from freezing thereby providing for wastewater percolation during the winter, protect the furrows from direct exposure to cold weather, and provide ridge stability during the spring thaw. It must also be realized that the grass burning may not be practical at all treatment sites. The operator must be able to access the site with fire fighting equipment in case burning gets out of control.

TABLE 4.9

SUGAR RIVER QUALITY

LOCATION	TOTAL BOD_5	TOTAL COD	Cl^-	TKN	NH_3-N	NO_3-N	TSS	FIELD pH
Upstream	3.4±0.49* (2)	14±6.4 (2)	23±2.0 (3)	1.0±0.21 (2)	0.3±0.1 (2)	3.8±0.07 (2)	382±0.0 (1)	7.9±0.14 (2)
Midstream	3.1±0.0 (2)	14±4.9 (2)	25±6.8 (3)	0.8±0.0 (2)	0.2±0.07 (2)	3.6±0.07 (2)	380±0.0 (1)	7.9±0.14 (2)
Downstream	3.5±0.71* (2)	14±4.9 (2)	19±1.4 (3)	0.8±0.28 (2)	0.1±0.0 (2)	3.4±0.07 (2)	366±0.0 (1)	8.0±0.07 (2)

- All values mg/l except pH

- ( ) is # of observations

* Mean includes data below detection limit, limit used in average

Sugar River Chemistry

Mean and standard deviations of upstream, midstream, and downstream Sugar River samples are tabulated in Table 4.8. Complete data are located in Appendix J. All values were typical of a river of this size and were uniform upstream to downstream. The Brodhead ridge and furrow system did not adversely affect the Sugar River. It must be remembered, however, that the contaminant plume could be sinking below the river due to density effects (see discussion in groundwater chemistry section).

Site Observations

During the course of the project, the following site observations were made at the Brodhead ridge and furrow facility: 1) wastewater distribution and solid build-up, 2) cover crop, 3) winter operation, and 4) monitoring equipment performance.

Wastewater distribution at Brodhead was 100%. That is, during a cell loading, furrows and headers contained wastewater. The grid pattern of headers, crossed by furrows, was a very efficient distribution design. At times during the study, however, furrows became flooded to the point where the water level was as high as the ridge tops. This was especially true after heavy rainfalls. A lower hydraulic loading rate (ie. more system area) may be necessary if wastewater flows increase in the future.

Settled solids build-up was also a problem. Equipment was used to clear the furrows in the spring of 1983 and within a year, one to six inches of solids build-up had reoccurred. The need to remove suspended solids at the plant was discussed earlier.

The cover crop of canary grass and weeds at Brodhead flourished with the additional water and nutrients provided by the wastewater. During early spring, grasses were brown and knocked down to about knee high. Grasses grew hip high and weeds grew head high during late spring and early summer. In July and August, grasses and weeds began dying and were blown over. Regrowth along the furrow edges occurred during fall rains. The cover crop did not protect the furrows from the elements that well during the winter at Brodhead since the furrows were wide (about four feet).

Winter operation at the Brodhead ridge and furrow facility was not a problem since wastewater effluent temperatures were about 90°F. No matter what the ice or snow conditions were in the furrow, once cell loading began, the ice would melt and infiltration would begin. No change in hydraulic loading occurred during winter conditions. Ice conditions ranged from no ice near header inlets, to two inches at the extremities of a loaded cell, to completely frozen in resting furrows.

The monitoring equipment used at this site (wells, lysimeters, bailers, etc.) was quite adequate. The only problems which occurred concerned the teflon lysimeters. To obtain a sample of sufficient volume (greater than 50 ml) for chemical analysis, a 20 inch (mercury) vacuum was applied to a lysimeter and a two to three day vacuum period was used. This technique was used on lysimeters 1, 2, 3, 5, 6, 8, and 9. Remembering that the flow times through the unsaturated zone were about 3 days, a lysimeter sample was not really instantaneous as was assumed in the previous analysis.

Lysimeters did not operate in shallow, drier regions (about one foot) at Brodhead as well. Lysimeters 4 and 7 never provided samples during the study. This was most likely the result of easy air entry form the surface, after vacuum application, and low soil moisture in these particular locations. Teflon is hydrophobic and, therefore, at low soil moisture contents, a high, continuous vacuum may have been necessary.

Winter conditions also caused trouble with lysimeter operation. During sub-freezing weather, ice droplets would form in the tygon tubing and the tubing itself would contract. The tubing near the clamps actually closed. The pressure provided by the hand pump typically could not overcome these blockages. Lysimeter samples were obtained on sunny, 20^{o}F days after working the tygon tubing open. A wider diameter tubing (one quarter inch) and a different type of tube closing valve could help overcome these problems.

Brodhead Nitrogen Budget

A nitrogen balance was estimated for the unsaturated zone of each cell at the Brodhead ridge and furrow system. Wastewater flow readings, waste nitrogen data, plant uptake results and, deep lysimeter nitrogen data were used in this estimate. The balance was on a total pounds per year basis.

Additions to the budget came from applied wastewater nitrogen. Total TKN plus NO_3-N was used assuming all N would have eventually entered the soil. Nitrogen fixation and rainfall N addition were assumed to be negligible. In chapter 2, a large input estimate of 12.5 lb N/acre/yr was given for rainfall. This quantity would have been added by the wastewater in about four days. Nitrogen losses in the balance were by plant uptake and leaching. The difference between these additions and losses was accounted for by denitrification. It was further assumed that precipitation and evaportranspiration water volumes canceled out each other (ie. all leaching vertical flow was from wastewater), no volatilization occurred (pH < 9), and all NH_4^+-N adsorption sites were saturated (ie. no soil storage). Results of the budget are shown in Table 4.10; calculations appear in Appendix K.

TABLE 4.10

NITROGEN BUDGET ESTIMATE - BRODHEAD SITE

(4.7 acres)

ADDITION/LOSS	CELL 1		CELL 2		TOTAL	
	lb/yr	% of added N	lb/yr	% of added N	lb/yr	% of added N
Wastewater	2687	100	2687	100	5375	100
Net Plant Uptake[a]	0	0	0	0	0	0
Leaching	541	20	1304	49	1845	34
Denitrification	2146	80	1273	51	3529	66

a: net uptake loss = Grass N before burning - Grass ash N after burning (no burning at Brodhead)

With this procedure, a denitrification loss of 80% of applied N calculated for cell 1 and 51% for cell 2 as shown in Table 4.10. Leaching accounted for 20% of applied N loss in cell 1 and 49% of applied N loss in cell 2. Plant uptake was zero because of reasons discussed earlier. Considering the total Brodhead site area, leaching accounted for 34% of applied-N and denitrification accounted for 66% of nitrogen losses.

The difference in denitrification losses between the cells made sense considering the past use of the system. Prior to 1980, cell 2 was used only as a backup. This cell still provided good aeration to percolating wastewater and probably contained fewer anaerobic microzones than cell 1. These zones, as described in Chapter 2, would have enhanced denitrification.

CHAPTER 5: MINDORO SITE - RESULTS AND DISCUSSION

Site Description

The Mindoro Co-op Creamery is located in Mindoro, Wisconsin, in northern La Crosse County. The plant produces 10,000 lb of colby cheese per day with 14,000 gpd (average) of processing wastewater being treated by a 3.0 acre ridge and furrow system consisting of three cells. As mentioned in Chapter 2, this system was the first such treatment installation in Wisconsin beginning operation in 1954. A topographical map showing the general location of the system appears in Figure 5.1.

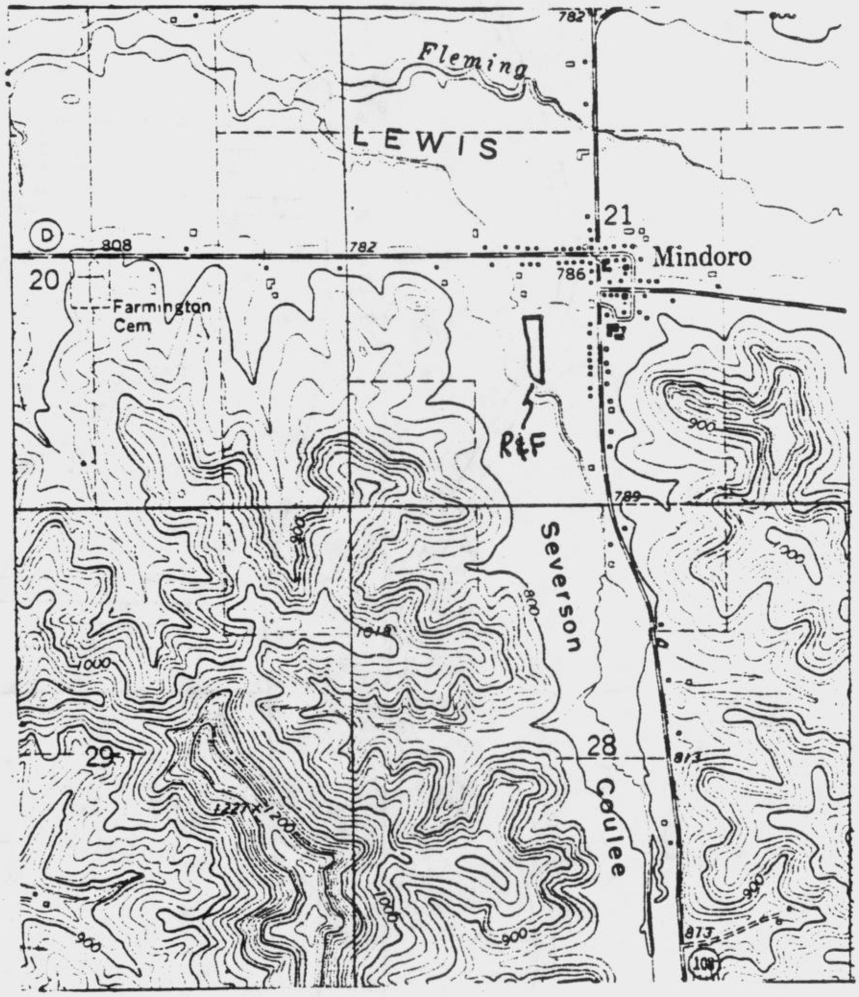
A plan view of the treatment system is illustrated in Figure 5.2. Well, lysimeter, stream stage, and infiltration station locations are indicated as well as cell locations and areas. General information concerning well and lysimeter depths and location is presented in Table 5.1. Complete well and lysimeter logs are given in Appendix AA.

The ridge and furrow site is located over about 12 feet of silt loam soil underlain by a sand and gravel aquifer next to Severson Coulee. This sand and gravel material extends to a depth of approximately 85 feet and overlays a sandstone containing shale seams. The Soil Conservation Service describes the overlying loam as a Toddville loam which is a deep, well to moderately well drained, silty soil formed on stream terraces (WDNR, 1984).

Results of this study's soil analysis at Mindoro indicated the following parameter ranges for the overlying silt loam:

FIGURE 5.1

NORTH BEND QUADRANGLE
WISCONSIN
7.5 MINUTE SERIES (TOPOGRAPHIC)
SE/4 NORTH BEND 15' QUADRANGLE



SCALE 1:24000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

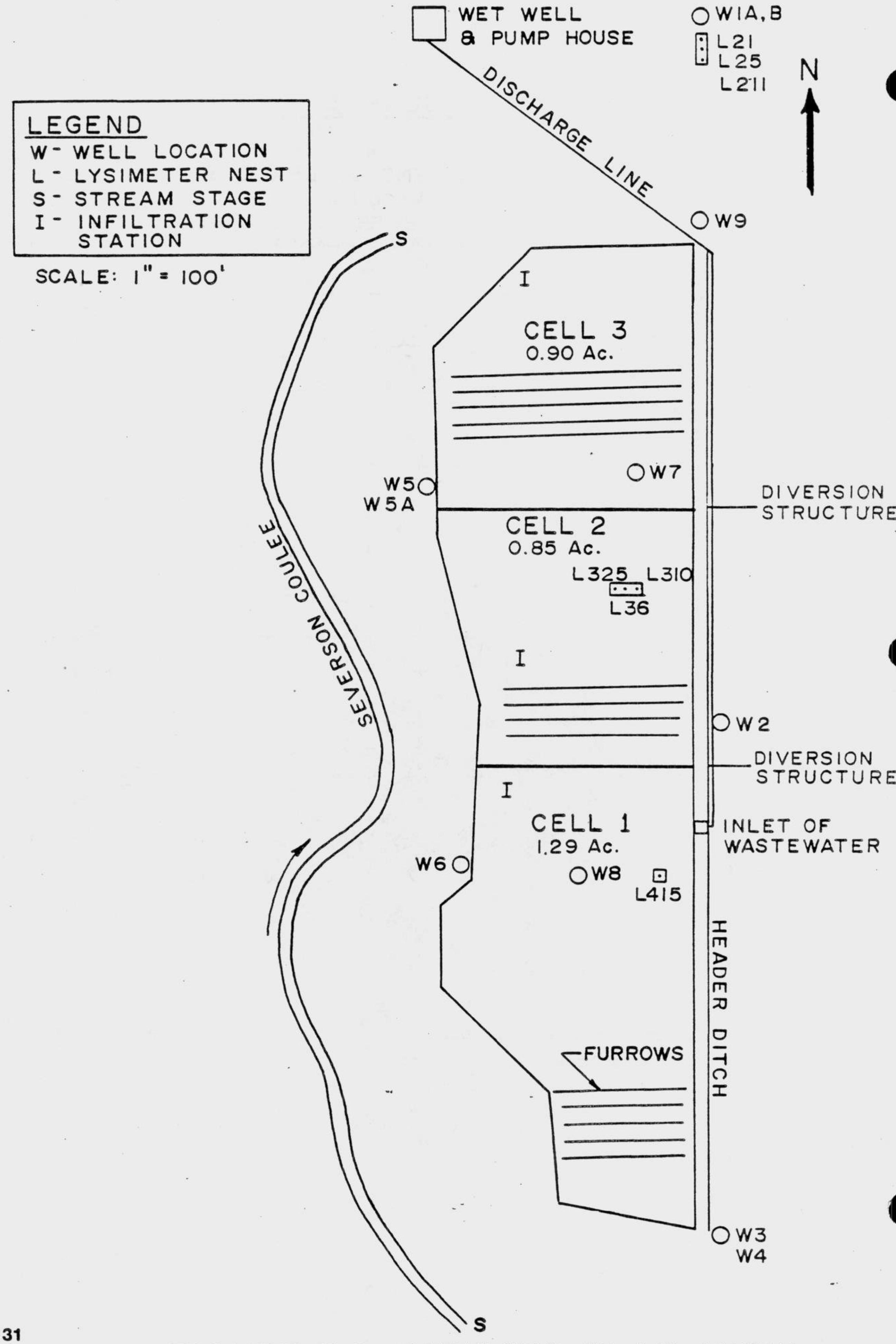


FIGURE 5.2: MINDORO PLAN VIEW

TABLE 5.1a

WELL SPECIFICATIONS

AT MINDORO CREAMERY

Well*	Well Top Elevation	Depth (ft)	Well Point Elevation	Approximate Surf. Elev.	Screen Length (ft)	Location
1A	781.59	13.0	766.59	779.6	5	Background
1B	781.36	35.5	744.16	779.7	2.5	Background
2	783.61	13.2	768.61	781.8	5	Adjacent to Cell 2
3	785.32	15.2	768.49	783.6	5	Adjacent to Cell 1
4	785.28	35.7	747.78	783.4	2.5	Adjacent to Cell 1
5	782.63	15.0	765.80	780.8	5	Downstream of Cell 3
5A	782.31	31.9	749.01	780.9	2.5	Downstream of Cell 3
6	785.69	17.5	765.79	783.3	5	Downstream of Cell 1
7	782.00	14.0	766.80	780.8	2.5	Cell 3
8	783.85	9.5	772.05	781.6	2.5	Cell 1
9	779.68	12.2	765.98	778.2	2.5	Adjacent to Cell 3

*All wells PVC, 2 inch inside diameter.

TABLE 5.1b

LYSIMETER SPECIFICATIONS

AT MINDORO CREAMERY

Lysimeter	Depth Below Furrow (ft)*	Location
21	1.0	Background
25	5.0	Background
211	11.0	Background
325	2.5	Cell 2
36	6.0	Cell 2
310	10.0	Cell 2
415	1.5	Cell 1

*Depth is to top of Teflon cup

- sand : 11-15%
- silt : 64-68%
- clay : 19-25%
- total N: 0.01-0.31%
- CEC : 11-22 mg/100 gram soil
- pH : 5.5-7.9

The higher silt and total N fractions occurred in shallow samples. Also CEC tended to decrease with depth and soil pH increased with depth. Complete soil analysis data are presented in Appendix BB. In summary, the soil immediately below the treatment system is primarily silt with some clay. The silt loam had an average CEC of 14.5 mg/100 gram of soil.

Soil borings during well and lysimeter installation also brought out the following five points.

1) moist, sticky clays appeared deeper in bore holes,
2) some holes had a blue-gray clay just above the sand layer
3) the top of the sand tended to be greenish-blue in color,
4) in-cell borings had 5-10 feet of gray mottled clay, indicating a flucuating water table, and
5) in-cell borings near the north end of cell 3 had groundwater elevations within 1 to 2 feet of the surface.

Wastewater Chemistry

Mindoro Creamery's wastewater had mild strength when compared to the Brodhead site. Mindoro's average wastewater BOD_5, COD, TKN, and chloride

TABLE 5.2

MINDORO WASTEWATER CHARACTER

(all units mg/l except pH)

Parameter	Samples	Mean	Median	Range	SD	Strong Typical[a] Domestic
TOTAL BOD_5*	14	830	860	430-1300	280	400
TOTAL COD	12	1200	1300	660-1900	360	1000
TSS	14	262	194	80-616	163	350
TOTAL TKN	14	32	34	14-52	11	85
DISSOLVED TKN	2	24	24	16-31	11	---
NH_3-N	10	0.9	1.1	0.1-1.8	0.6	50
NO_3-N+NO_2-N*	10	0.4	0.2	0.1-1.6	0.5	0
Cl^-	14	100	91	70-210	34	100
pH	8	7.5	7.8	5.1-9.5	1.4	---

[a] from Metcalf and Eddy, 1979

* - Mean contains data below or above a detection limit; the limit was included in average

SD - Standard Deviation

concentrations were 830 mg/l, 1200 mg/l, 32 mg/l, and 100 mg/l, respectively. Means, medians and ranges of these and other chemical parameters of the wastewater are provided in Table 5.2. Values of a strong typical domestic waste are provided for comparison. A complete list of data is given in Appendix CC.

There were three general observations made concerning the Mindoro wastewater chemistry. First, the results were highly variable and this variance was not seasonal. For example, the average total suspended solids value was 262 mg/l but the standard deviation was 163 mg/l and the range was 80-616 mg/l. These variations, as mentioned in Chapter 4, were most likely due to the variation in the amount of rinse water used in the plant.

Second, the average pH (7.5) of the wastewater was slightly above neutral. Since major volatilization of NH_3 occurs at pH greater than nine, one would expect negligible gaseous loss of ammonia from this wastewater.

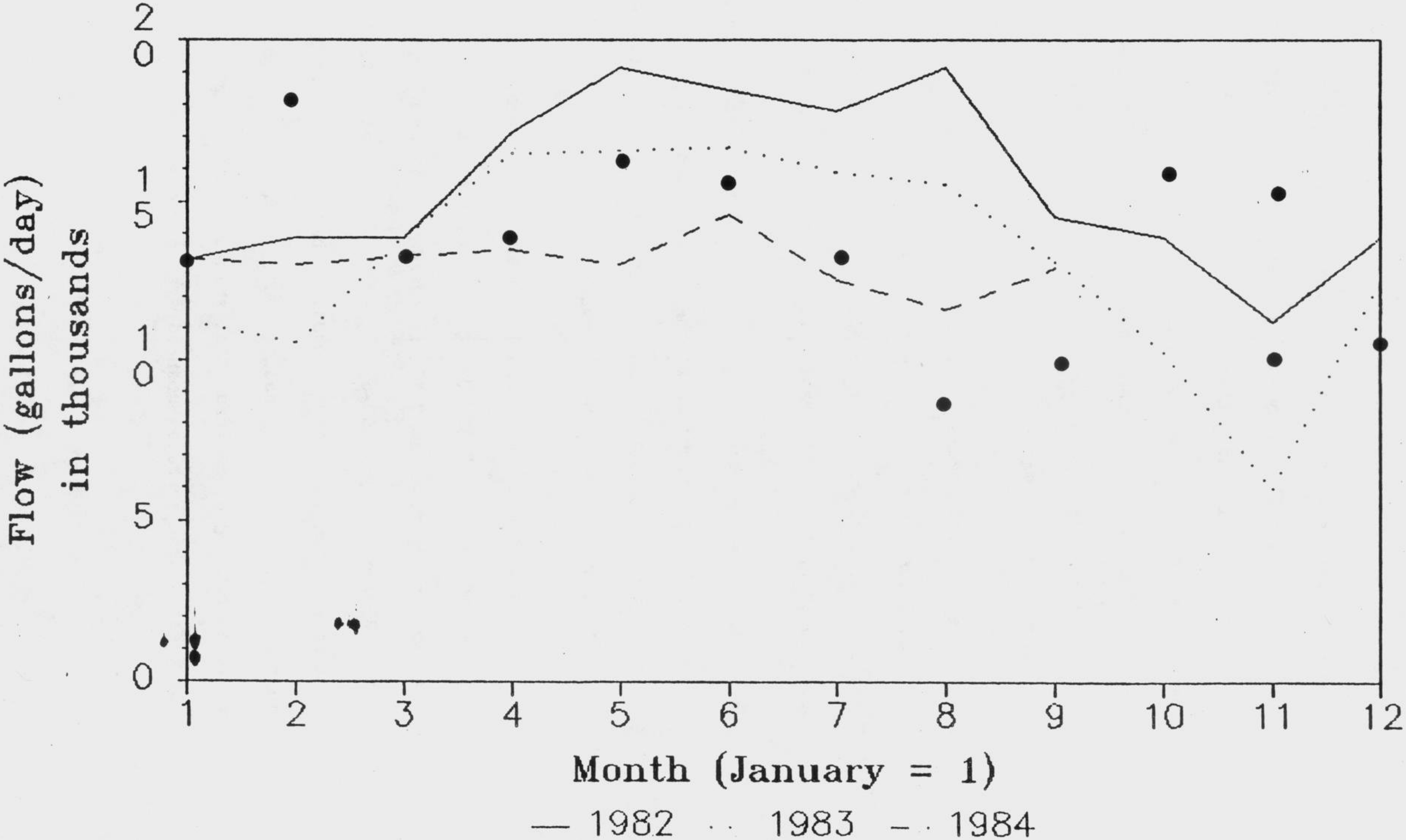
Finally, the nitrogen fraction of the wastewater was primarily organic-N. This was expected since the wastewater was derived from cheese production. Unlike the Brodhead wastewater, however, only around 25% of this organic-N was tied up in the solid fraction. This was seen by comparing total and dissolved TKN concentration averages (Table 5.2).

Wastewater Hydraulic Loading

All flow to the Mindoro ridge and furrow system was derived from cheese production. A low and a high speed pump, alternated periodically, were used to convey flow to the system. Discharge was calculated two ways. During sampling days, the flow was found by first dividing the average pump time, in minutes, into the total wet well volume discharged (260 gallons) per pump run. Then, using the pump's hour meter, this value was multiplied by a pumping hours per day factor and a time conversion to obtain the gallons per day value. For example, the average pump time to remove 260 gallons from the wet well was 3.09 minutes. If the pump ran 2.59 hours during the 24 hour sampling period, the wastewater flow during that day was 13,100 gallons (ie. 260 gal/3.09 min ^{x}2.59^{x} 60 min/hr = 13,100 gal). Wastewater volume flowing into the wet well during pumping was neglected. Thirty-day monthly averages were obtained by relating the monthly metered pumping time to a pump time versus discharge curve.

Figure 5.3 presents the 30-day average, monthly Mindoro wastewater flow readings for the years 1982-1984 as well as 24-hour flows measured on project sampling days. A complete listing of flow data for the past three years is given in Appendix DD. Thirty-day monthly flows averaged 14,000 gallons per day since 1982. One can see from Figure 5.3 that from 1982 to 1984, flows ranged from 6006 to 19,140 gallons per day. These discharges were well under the WDNR permit flow of 25,000 gpd.

FIGURE 5.3
Mindoro Average Monthly
Wastewater Flows



--24-HR flows determined on sampling days indicated by ●

A seasonal trend existed in flow volumes to the Mindoro system. Flows were high from April to July with values decreasing during the hot summer months, fall, and winter. Cheese production at Mindoro was more dependent on local milk supply than Brodhead. The most productive milking period is in spring and early summer. Summer flow readings in 1984 were lower due to a process change made in March which allowed for recycling of cooling water.

A flexible load/rest cycle was followed at this site. The intent was to load a cell for one month and rest it for two months. Each month, the longest rested cell was placed on line. It was not uncommon during this study, however, to see the same cell loaded for three to four months.

Due to inefficient header ditch flow control and blocked furrow openings, wastewater distribution at the Mindoro site was poor. Typically, 1/3 of cell 1, 1/5 of cell 2, and 1/3 of cell 3 were loaded no matter which cell was technically being loaded.

Total area and actual area hydraulic loading rates were calculated and are presented in Table 5.3. Using the total site area, the average hydraulic loading rate was 0.172 inches/day (4670 gpad) with a range of 0.074-0.235 inches/day (2000-6380 gpad). This is classified as a fairly medium rate system (Rodenberg, 1980). A high rate classification would result if actual hydraulic loadings were considered. These values were over three times greater than total area calculations and almost two times greater than average Brodhead system rates.

TABLE 5.3

MINDORO HYDRAULIC LOADING RATES

units: in/day
(gal/acre/day)

Flow (gal)	Total Area Loaded	Actual Area Loaded
6006 (min)	0.074 (2000)	0.246 (6670)
14,000 (ave)	0.172 (4670)	0.573 (15,600)
19,140 (max)	0.235 (6380)	0.783 (21,300)

Total Area = 3.0 acres
Actual Area = 0.9 acres

Organic Loading Rates (BOD_5, TKN)

Code NR 214 of the Wisconsin DNR states that a ridge and furrow system should receive no more than 100 lb BOD_5/acre/day. Using the average total area hydraulic loading rate and the average BOD_5 concentration of the wastewater, the Mindoro site received 32 lb BOD_5/acre/day. Using the minimum and maximum total area flow rates and the average wastewater BOD_5 concentration, the BOD_5 loading rate range was 14-44 lb BOD_5/acre/day. These numbers were well under the code requirement.

If the actual area hydraulic loading rates were used, however, higher BOD_5 loading rates resulted. The average rate was 108 lb BOD_5/acre/day with a range of 46-147 lb BOD_5/acre/day. These results are presented in Table 5.4.

Similar calculations for TKN loading rates were performed and are also presented in Table 5.4. There is currently no Wisconsin DNR code for nitrogen loading. Using the range of total area hydraulic flows presented in Table 5.3 and the average wastewater TKN concentration, TKN loading rates at Mindoro ranged from 0.53-1.7 lb N/acre/day with an average of 1.2 lb N/acre/day. Using the range of actual area hydraulic flows and the average wastewater TKN concentration, TKN loading rates ranged from 1.8-5.7 lb N/acre/day with an average of 4.2 lb N/acre/day. Suggestions for possible loading rates will be made in Chapter 6.

TABLE 5.4

MINDORO ORGANIC LOADING RATES

(Units are lb/day/acre)

Load	Total Area Loaded	Actual Area Loaded
BOD_5 (Min-Flow)	14	46
BOD_5 (Ave-Flow)	32	108
BOD_5 (Max-Flow)	44	147
TKN (Min-Flow)	0.53	1.8
TKN (Ave-Flow)	1.2	4.2
TKN (Max-Flow)	1.7	5.7

Ave BOD_5 Conc = 830 mg/l
Ave TKN Conc = 32 mg/l
Total Area = 3.0 acres
Actual Area = 0.9 acres

Groundwater Elevations and Flow

In general, groundwater flow at the Mindoro ridge and furrow was north northwesterly, following in the direction of Severson Coulee. An approximate gradient in the sand layer from well 4 to well 5A was 0.006 ft/ft. Vertical gradients were observed between wells 1A and 1B, 5 and 5A, and 3 and 4 and mounding of groundwater within the system was detected during borings. When standing water was present in well 1A, its elevations were higher than elevations in well 1B, indicating downward flow from the silt to the sand layer. Elevation differences between wells 5 and 5A were variable during the study. If cell 2 was loaded, the groundwater beneath the northern section of cell 2 would mound, and a downward gradient would result. As cell 2 rested, the mound dissipated and upward gradients would begin. The gradients near wells 3 and 4 were unexplainable. The southern section of cell 1 was continually ponded during the project, yet, oscillating elevation differences between these two wells indicated both upward and downward gradients. Downward gradients at Mindoro ranged from 0.01 to 0.04 ft/ft. A well nest within the system would have better defined these gradients. Figure 5.4 shows the groundwater contours on November 5, 1984. Appendix EE contains a complete list of elevation and contour data.

Groundwater (water table) elevations varied 0.7 to 4.7 feet during the project. Time plots for the elevations of wells 5, 6, and 7 are graphed in Figure 5.5. High level values in September (1983) with a subsequent decrease were most likely the result of high summer wastewater flow

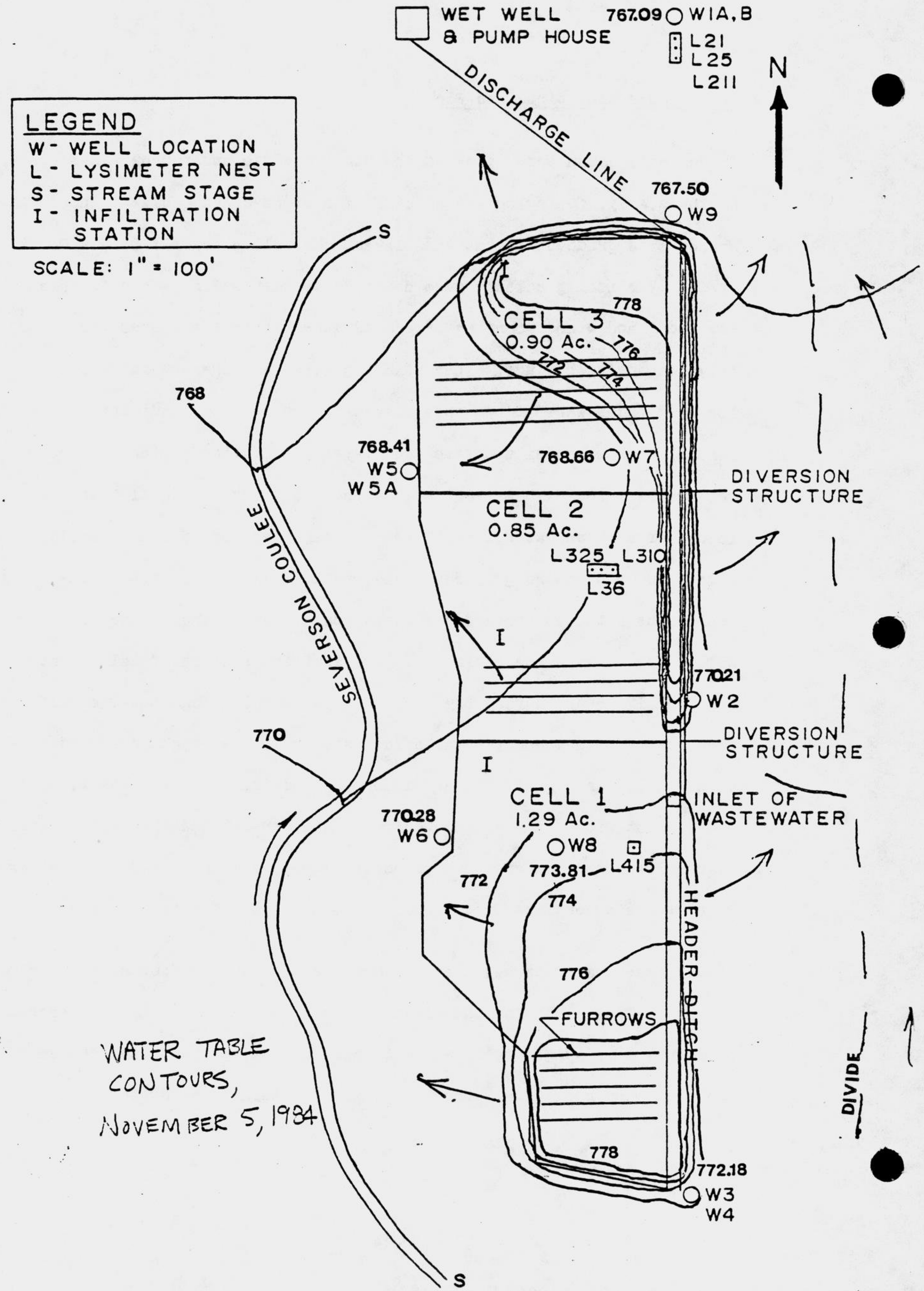
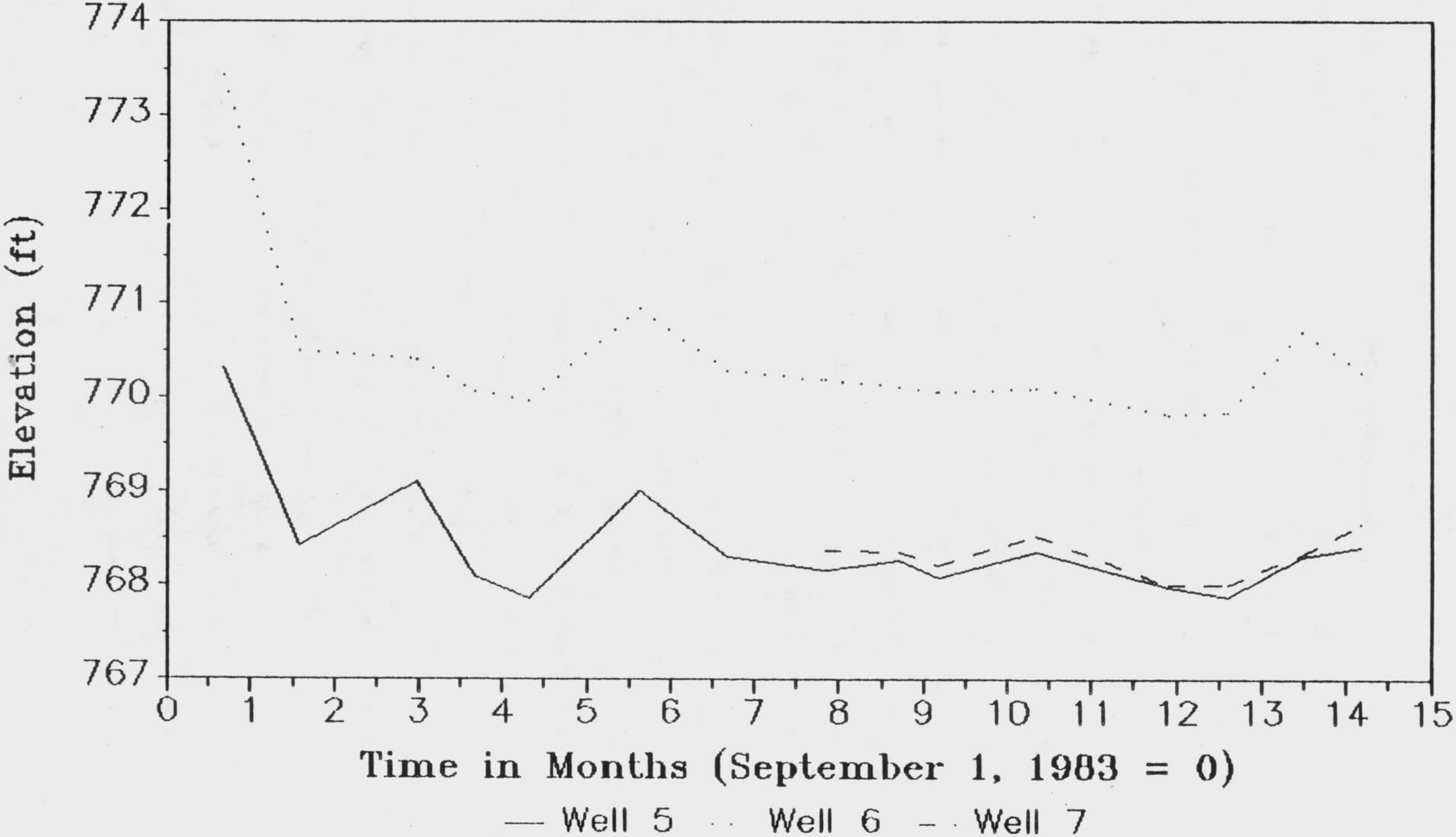


FIGURE 5.4: MINDORO PLAN VIEW

FIGURE 5.5
Mindoro Groundwater Elevation vs. Time
for wells 5, 6, and 7



Elevations are mean sea level

followed by lower fall waste flows. Elevation changes could not be correlated with wastewater flow after this period though. No seasonal pattern of water table fluctuation was observed.

Once percolated wastewater entered the saturated zone at Mindoro, its flow regime was complex. In the silt loam layer, flow within the system was principally vertical with some horizontal movement away from the mound. Flow in the silt and upper sand layers beneath the site was totally derived from recharge (wastewater) to the system. This meant a flow divide was created east and south of the site, separating background groundwater flow from wastewater derived flow. This is depicted on Figure 5.4. Upon entering the sand layer, the groundwater flow was horizontal to the northwest.

Determination of flow velocities through the silt layer and the sand layer was difficult and only estimates were made. Darcy's Law (V=KI/n) was used to find the average vertical velocity in the silt loam layer. Slug tests were performed in November (1984) to determine the hydraulic conductivity near wells 1A, 2, and 8. Calculations are presented in Appendix EE. Results of the tests provided K values of 7×10^{-7} ft/s, 2×10^{-5} ft/s, and 2×10^{-7} ft/s for wells 1A, 2, and 8, respectively. It must be realized that these values were for horizontal hydraulic conductivity. Therefore, it was assumed that the silt loam was homogeneous and isotropic. A spatially averaged vertical K of 7×10^{-6} ft/s was used. An average vertical gradient of 0.025 ft/ft (from 0.01-0.04 ft/ft range) and a typical porosity for silt of 0.4 (Freeze and Cheng, 1979) were also assumed.

With the above input data, a vertical velocity of 0.04 ft/day was determined. Assuming that the sand layer is one to 10 feet below the water table, travel times through the saturated silt strata of between 25 and 250 days were calculated. These values were reasonable.

Unsuccessful slug and bail tests to determine K in the sand layer were attempted on well 1B in April (1984). The well returned to equilibrium too quickly to acquire meaningful data. Since this response was similar to the slug tests attempted at Brodhead, an estimated hydraulic conductivity of 0.0005 ft/s was used. Imputing the gradient of 0.006 ft/ft and a porosity of 0.35 (for sand) into Darcy's Law provided a horizontal linear velocity of 0.7 ft/day in the sand layer. At this velocity, it would take about three years for groundwater to flow from the south end to the north end of the site.

Groundwater Chemistry

Chemical analyses of groundwaters for each well at Mindoro are listed in Table 5.5. Complete data listings are given in Appendix FF. When reviewing chloride data, a good indicator of contamination, one can categorize the wells into two types. Wells 1B and 4 were not affected by the ridge and furrow system whereas wells 2, 3, 5, 6, 7, 8, and 9 were influenced by the system. Except for well 2, all of the affected wells contained 77 to 92% of the wastewater chloride concentration on average and demonstrated low standard deviations. This verified the assertion made earlier that the groundwater below the system was primarily derived from applied wastewater. The average wastewater concentration was 100 mg/l. Well 2 chloride values decreased about 70%

TABLE 5.5

MEAN AND STANDARD DEVIATION OF
GROUNDWATER CHEMICAL PARAMETERS
AT MINDORO

Well	Dissolved BOD_5	Dissolved COD	TDS	Dissolved TKN	Dissolved NH_3-N	Dissolved NO_2-N+NO_3-N	Cl^-	Field pH
1A	---	---	---	---	0.1 ± 0.0 (1)	1.9 ± 0.0 (1)	---	---
1B	3.3 ± 1.1* (8)	5.2 ± 0.71* (8)	350 ± 11.2 (8)	0.2 ± 0.1* (8)	0.1 ± 0.0* (8)	3.3 ± 0.61 (8)	9.3 ± 0.54 (3)	7.4 ± 0.15
2	9.1 ± 14* (10)	18 ± 20 (11)	537 ± 127 (10)	1.5 ± 0.88 (11)	0.3 ± 0.2 (13)	0.1 ± 0.06* (13)	59 ± 20 (9)	7.5 ± 0.20 (8)
3	3.0 ± 0.56* (13)	11 ± 3.1 (13)	692 ± 51.2 (13)	0.6 ± 0.2 (13)	0.1 ± 0.06 (13)	0.1 ± 0.06* (13)	77 ± 7.3 (13)	6.9 ± 0.17 (8)
4	3.1 ± 0.28* (13)	5.0 ± 0.0* (13)	278 ± 5.34 (13)	0.2 ± 0.07* (13)	0.1 ± 0.0* (13)	0.2 ± 0.09 (13)	2.1 ± 0.19 (13)	7.3 ± 0.20 (8)
5	11 ± 7.7* (13)	31 ± 9.5 (12)	715 ± 42.4 (13)	4.0 ± 0.74 (13)	3.0 ± 1.0 (13)	0.1 ± 0.0* (13)	91 ± 2.3 (13)	6.7 ± 0.14 (8)
6	4.5 ± 2.2* (13)	25 ± 3.6 (12)	737 ± 26.8 (13)	1.8 ± 0.66 (13)	1.0 ± 0.40 (13)	0.1 ± 0.0* (13)	77 ± 3.7 (13)	6.8 ± 0.13 (8)
7	7.6 ± 6.9* (7)	18 ± 10 (7)	690 ± 88.6 (7)	2.5 ± 0.50 (7)	1.9 ± 0.42 (7)	0.1 ± 0.0* (7)	85 ± 5.7 (7)	6.6 ± 0.21 (7)
8	3.2 ± 0.42* (7)	25 ± 4.3 (7)	774 ± 201 (7)	2.5 ± 1.1 (7)	0.3 ± 0.16 (8)	0.2 ± 0.1* (8)	84 ± 0.1 (7)	6.8 ± 0.21 (3)
9	16 ± 12* (7)	47 ± 28 (7)	607 ± 89.9 (7)	2.8 ± 0.73 (7)	1.5 ± 0.34 (7)	0.1 ± 0.04 (7)	92 ± 12 (7)	6.7 ± 0.14 (7)

--->All values mg/l except pH; ( ) indicates # of observations
* - means include values above or below a detection limit; the limit was included in average

during the last five months of the project. This may have been caused by a shift of the groundwater divide to the west (Figure 5.4), diluting the region of well 2 with groundwater of background quality. It should be realized that averages and standard deviations of well data at this site do not fully describe the contamination and should only be used for relative comparisons.

The pH in wells 1B, 2 and 4 was slightly above neutral, ranging from 7.3 to 7.5 on average. Wells which were affected by the Mindoro ridge and furrow system (3, 5, 6, 7, 8, and 9) had pH values slightly less than neutral, ranging from 6.6 to 6.9. This was the same trend that was witnessed at Brodhead. Since wells were not placed north of the system, it is not known if pH increased again downstream.

Using average chloride and total nitrogen (TKN+NO_3-N) concentrations for the wastewater and wells 5, 6, 7, 8, and 9, one can calculate the well nitrogen losses not caused by dilution. These results are presented in Table 5.6. In these wells, total nitrogen losses ranged from 71-83%. A sample calculation is shown in Appendix FF.

Figure 5.6 presents a plan view of chloride contours at the water table on July 12, 1984. The contours are approximate but they generally represent the contaminated area. These results indicated a high chloride contamination in the southern section of cell 1 (about 80 mg/l) and in the northern section of cell 3 (about 90 mg/l). These areas were ponded with wastewater throughout the project. Concentrations decreased along the eastern boundary of the system as groundwater traveled away from the mounded area and mixed with background quality flow. Chloride

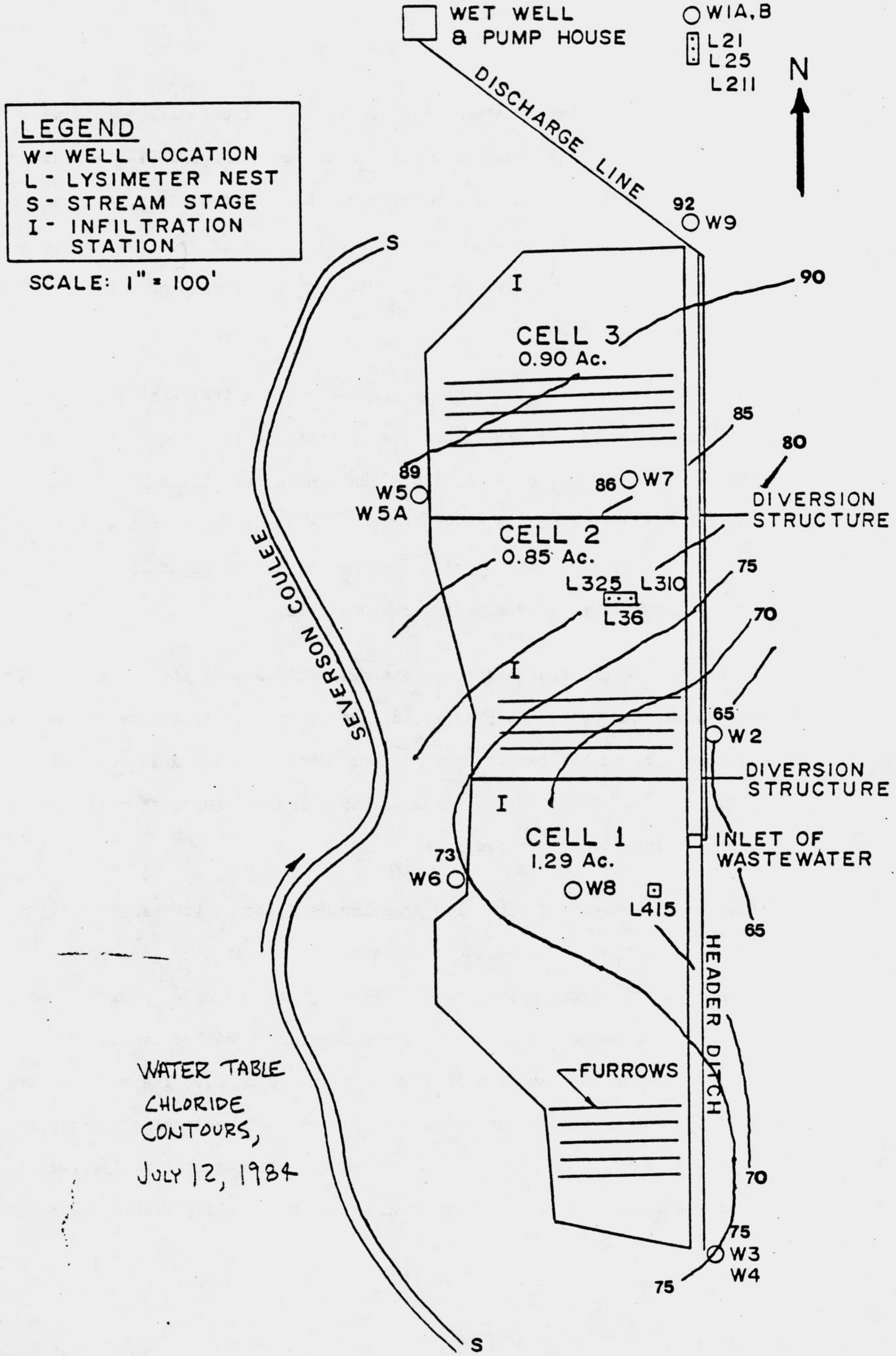


FIGURE 5.6: MINDORO PLAN VIEW

concentration for wells 1B and 4 were considered background quality. Since wells were not installed northwest of the system, chloride values were unknown downstream of the ridge and furrow system.

TABLE 5.6

AVERAGE GROUNDWATER NITROGEN LOSSES

AT MINDORO

Well	Cl^-	Total N	% Reduction of Chloride	% Reduction of Total N	% N Losses
WW	100	32.2	0	0	0
5	91	4.1	9	87	78
6	77	1.9	23	94	71
7	85	2.6	15	92	77
8	84	2.7	16	92	76
9	92	2.9	8	91	83

WW = Wastewater

- chloride and total nitrogen in mg/l

A similar contour pattern existed for COD concentrations (on 7/12/84) at the water table and is shown in Figure 5.7. Again, concentrations increased from south to north in the general direction of groundwater flow in the sand layer. COD concentration changes were not known downstream of the system.

Plan views for the parameters TKN, NH_3-N, and NO_2-N+NO_3-N (from 7/12/84) are shown in Figures 5.8, 5.9, and 5.10, respectively. The TKN and NH_3-N maps are quite similar with concentrations increasing to the

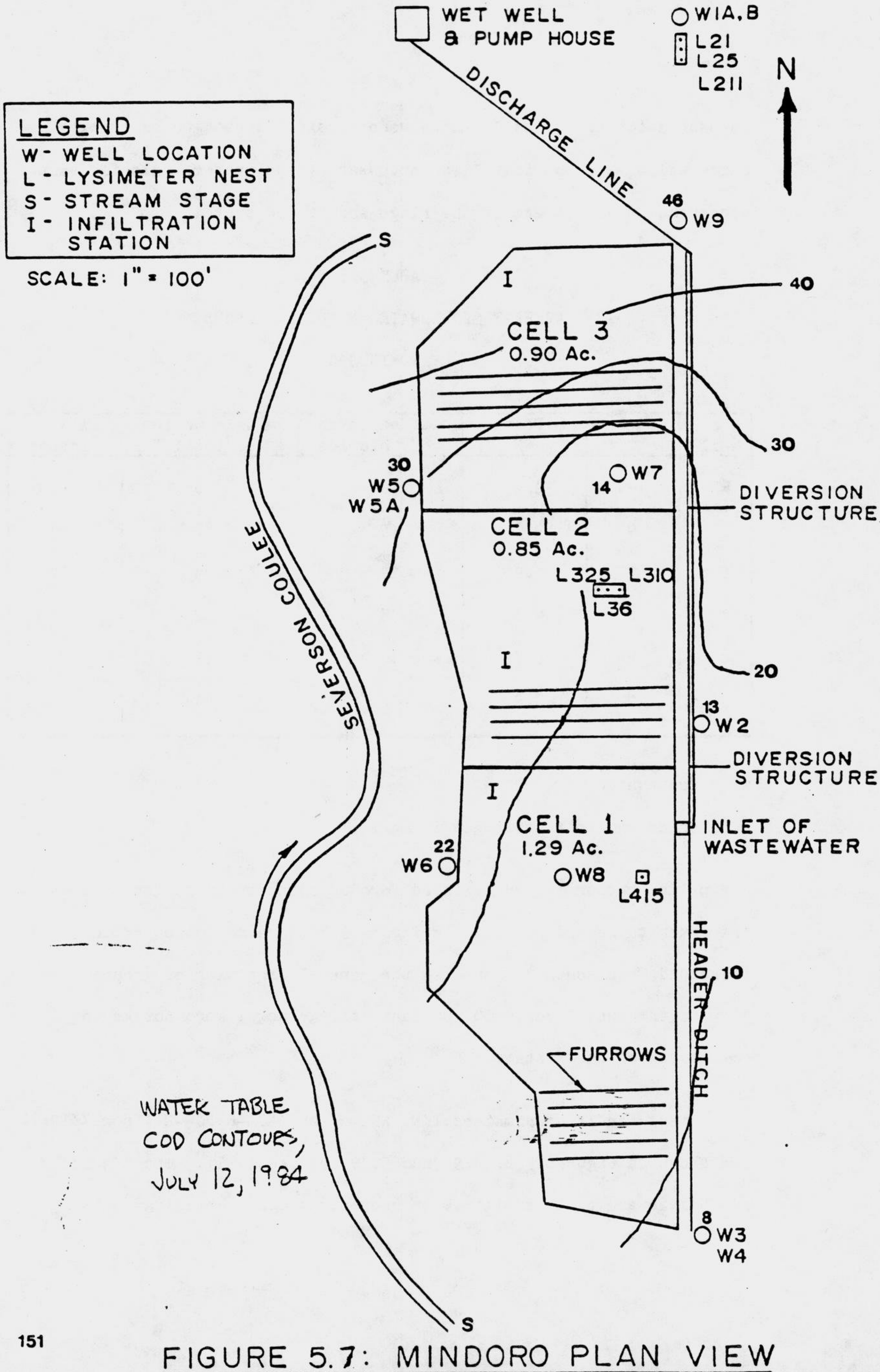


FIGURE 5.7: MINDORO PLAN VIEW

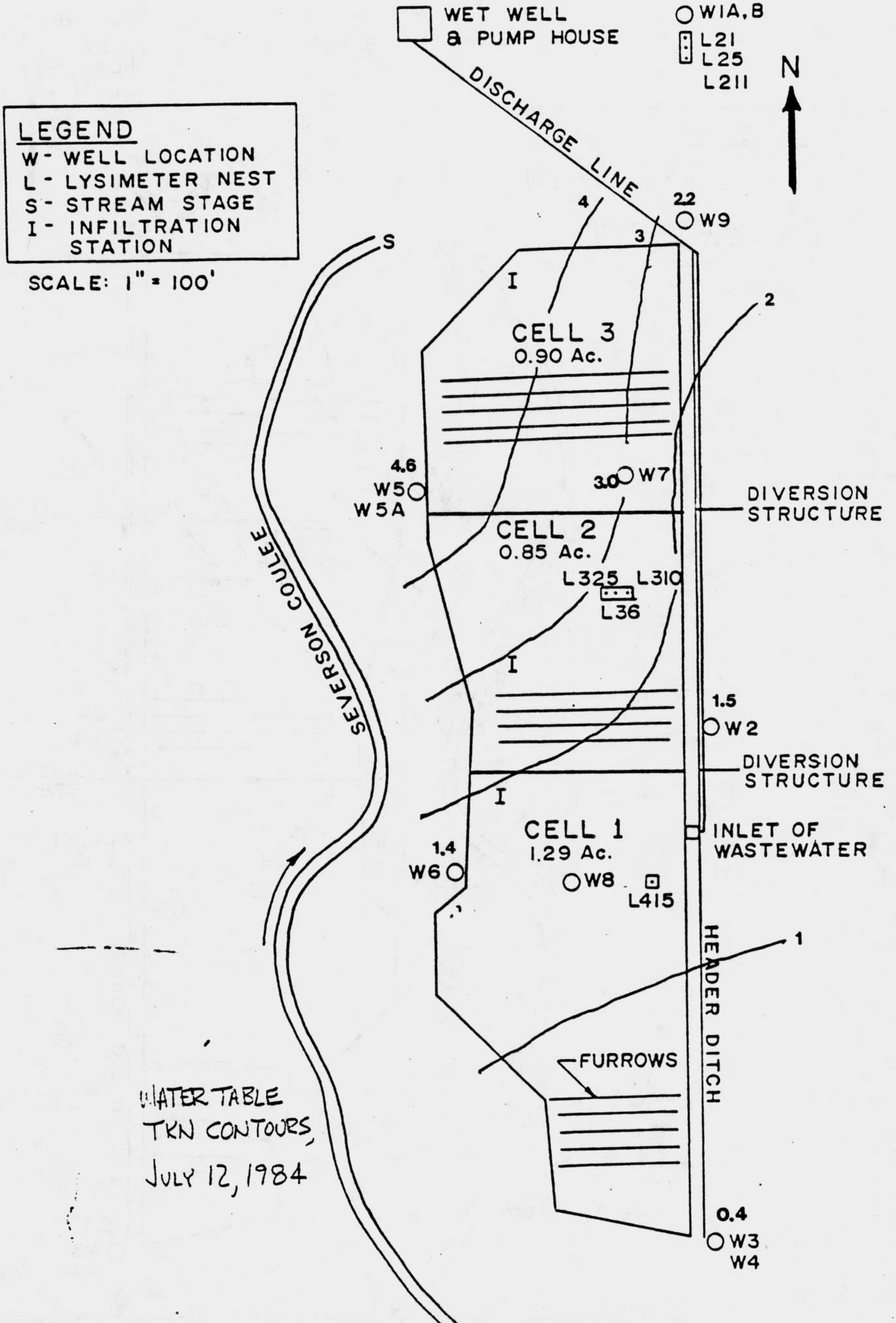


FIGURE 5.8: MINDORO PLAN VIEW

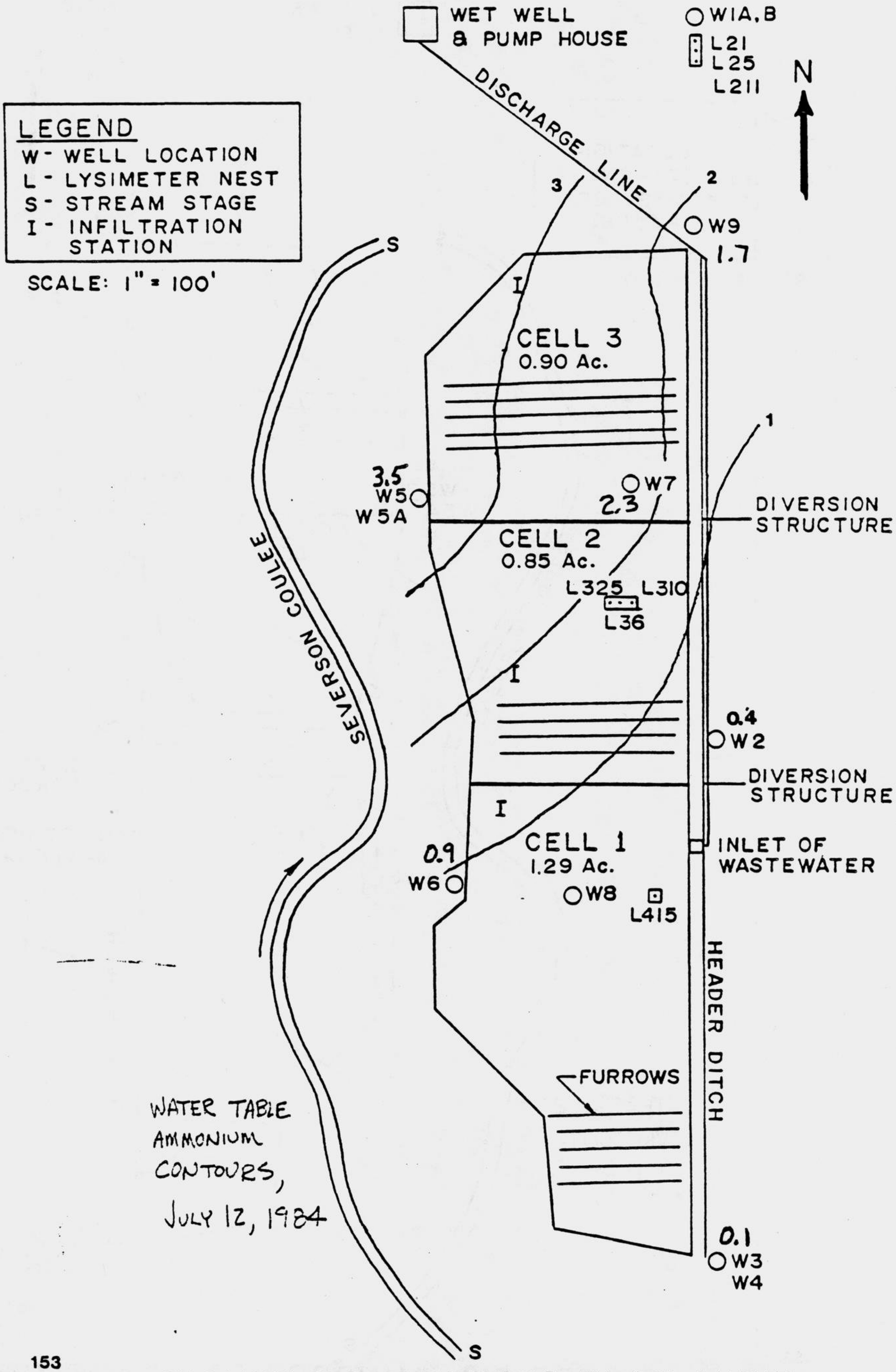


FIGURE 5.9: MINDORO PLAN VIEW

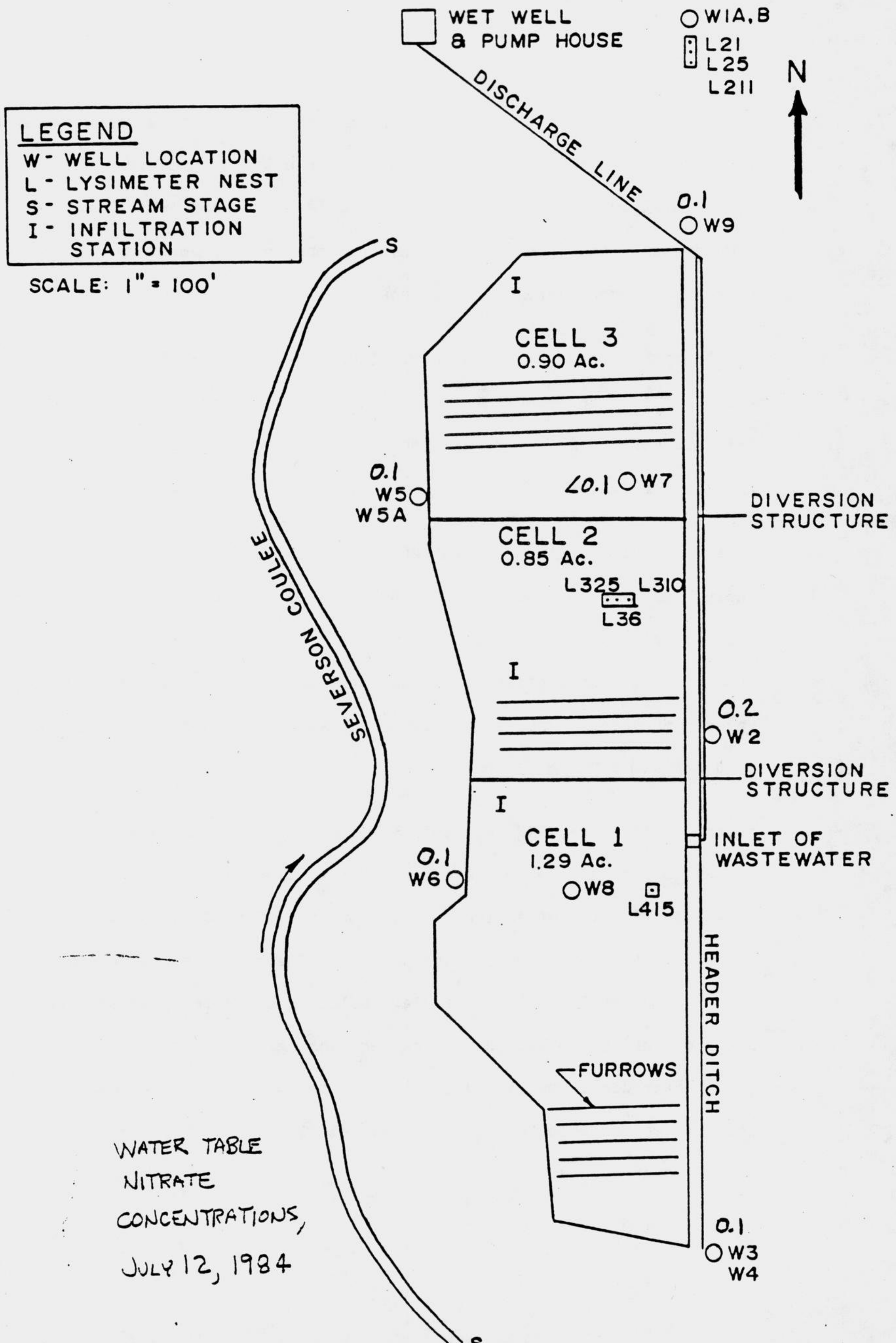


FIGURE 5.10: MINDORO PLAN VIEW

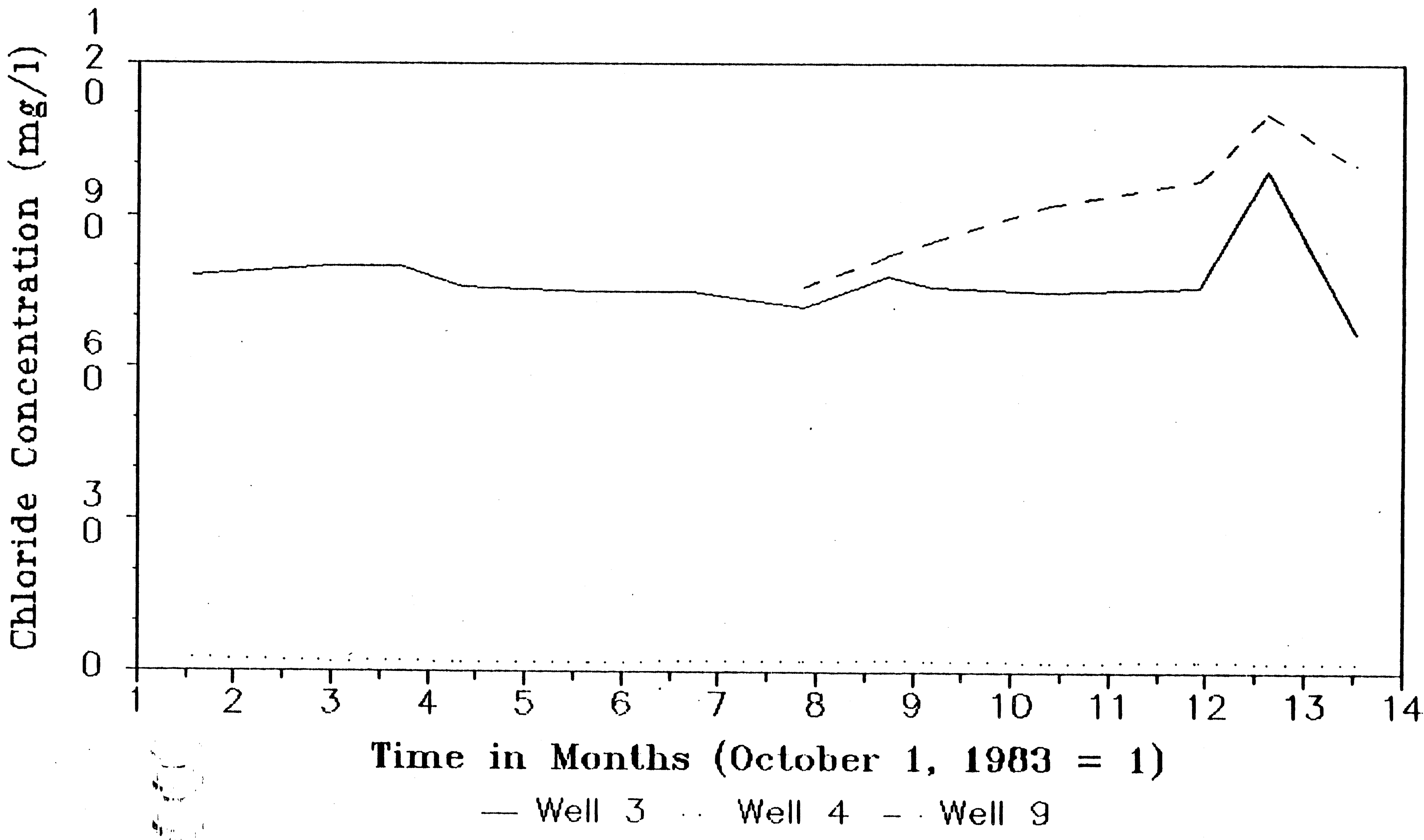
northwest in the groundwater beneath the system. Ammonium values were 75% lower than TKN values on this day. The nitrate concentrations, as shown in Figure 5.10, were low ($\leq$ 0.2 mg/l) everywhere in the shallow groundwater. Again, nitrogen concentrations downstream of the Mindoro ridge and furrow system where unknown.

An attempt was made to match chemical changes in space with time between wells. Due to the complexity of the groundwater flow regime, however, this was not possible. General observations of temporal trends in the groundwater follow.

First, chloride and TDS concentrations in the wells were not variable during the Mindoro study. This can be seen in Figure 5.11a and b where chloride and TDS data are plotted versus time for wells 3, 4, and 9, respectively. This graph also shows that downstream well chloride values were of the same magnitude as the wastewater and that no dilution occurred along the groundwater flow path (well 3 to well 9).

Second, well 2 TDS, TKN, and chloride concentrations decreased from June (1984) to October (1984). These plots are illustrated in Figure 5.12a, 5.12b, and 5.12c, respectively. TDS concentrations declined 42%, TKN's decreased 44%, and chlorides dropped 73%. These declines were attributed to the cell loading schedule. Cell 1 had not been loaded since September of 1983. With no wastewater recharge to the cell, the groundwater divide mentioned earlier shifted west and background quality groundwater was able to penetrate the well 2 region, diluting contaminant concentrations.

FIGURE 5.11a
Mindoro Groundwater Chloride Values
Wells 3, 4, and 9



156

FIGURE 5.11b
Mindoro Groundwater TDS Concentrations
Wells 3, 4, and 9

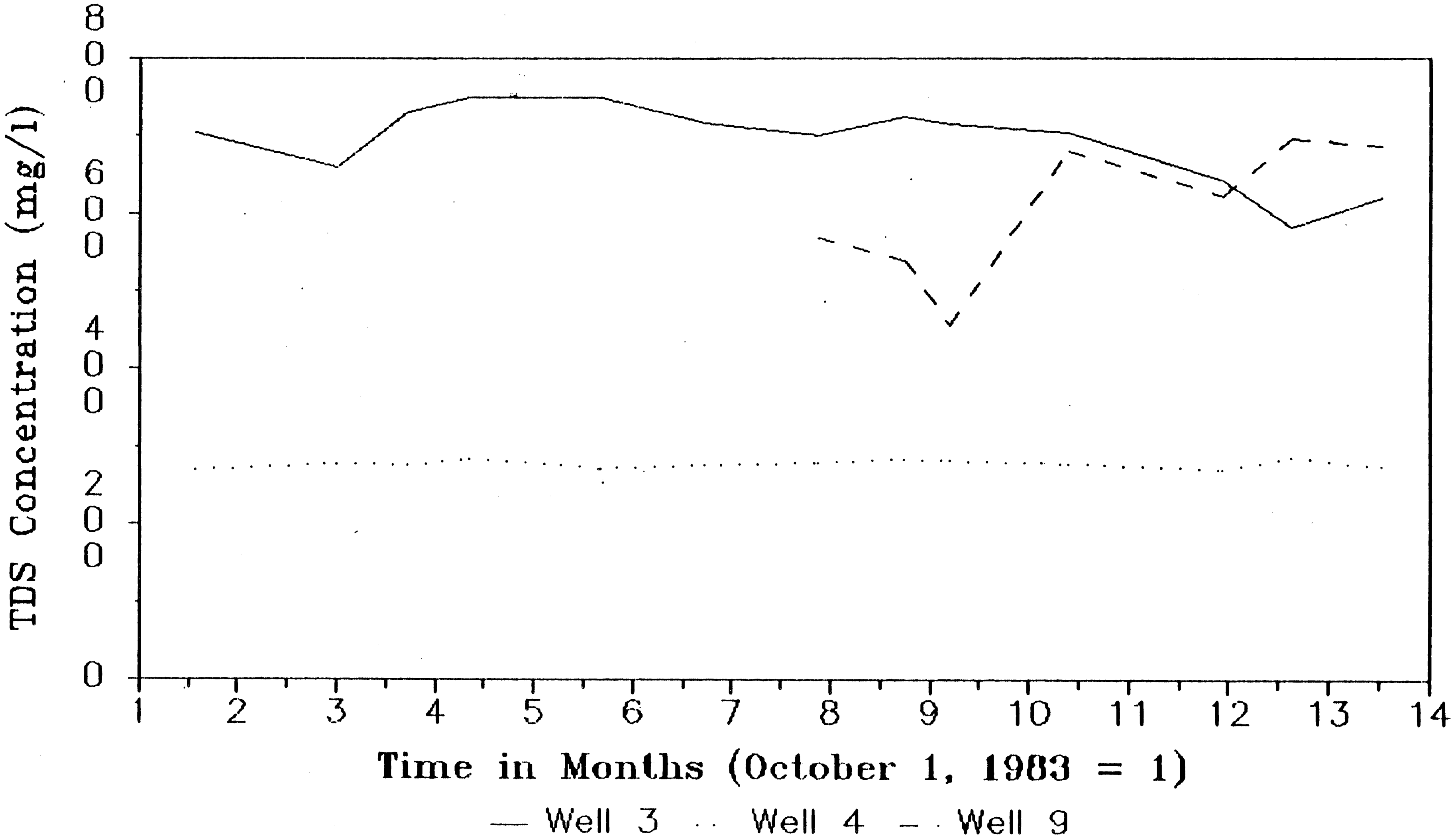


FIGURE 5.12a
Well 2 TDS Concentrations

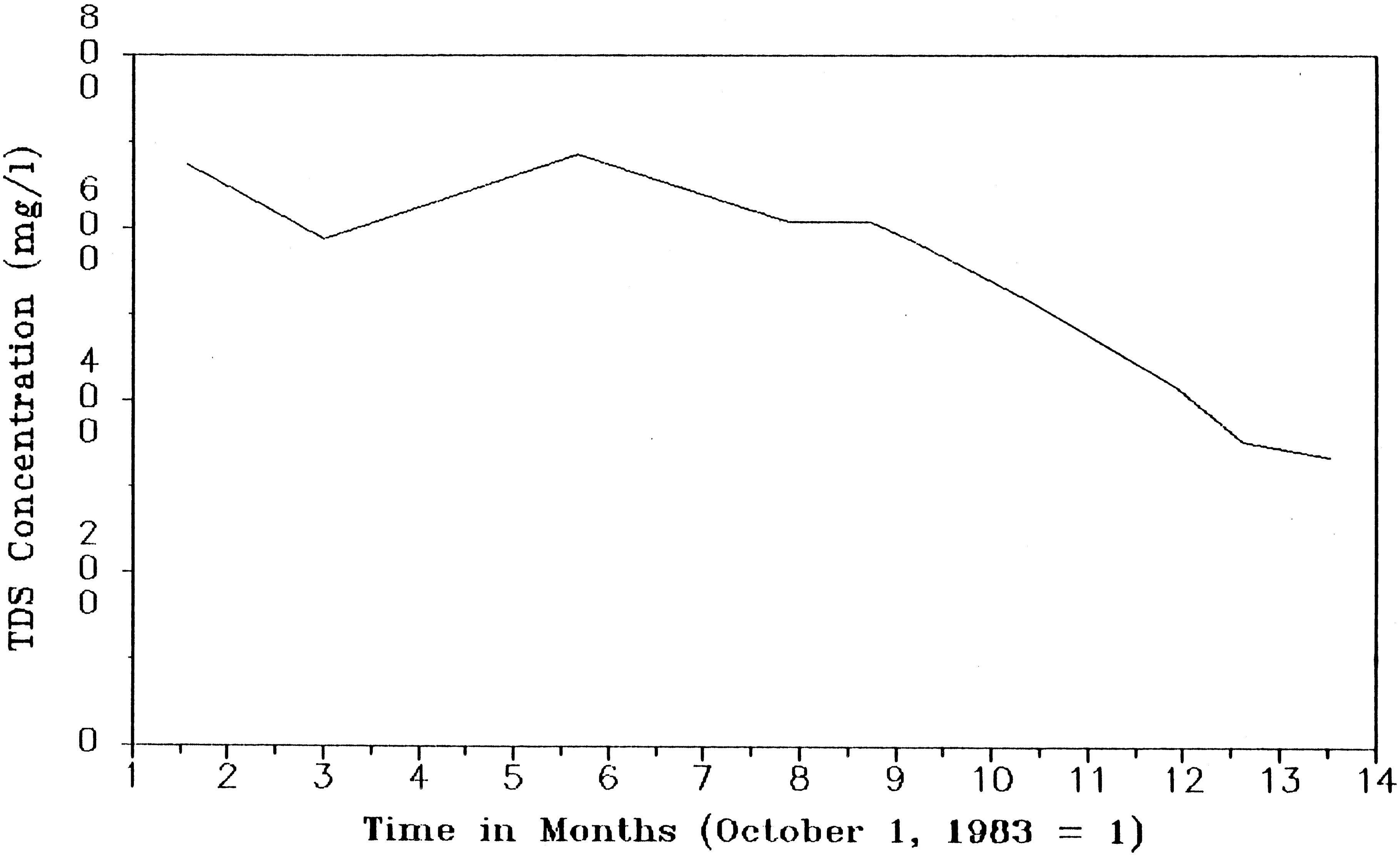


FIGURE 5.12b
Well 2 Dissolved TKN Concentration

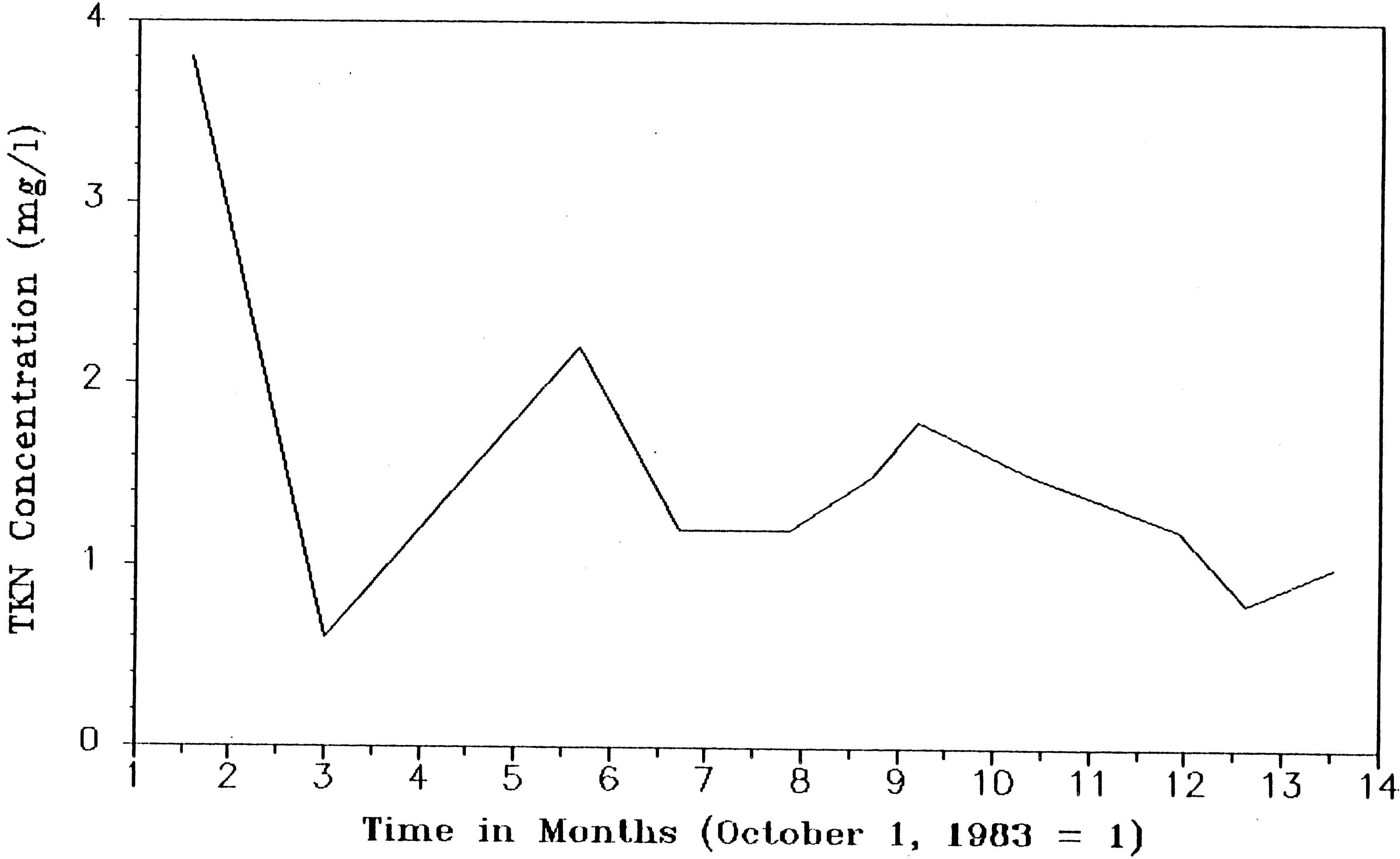
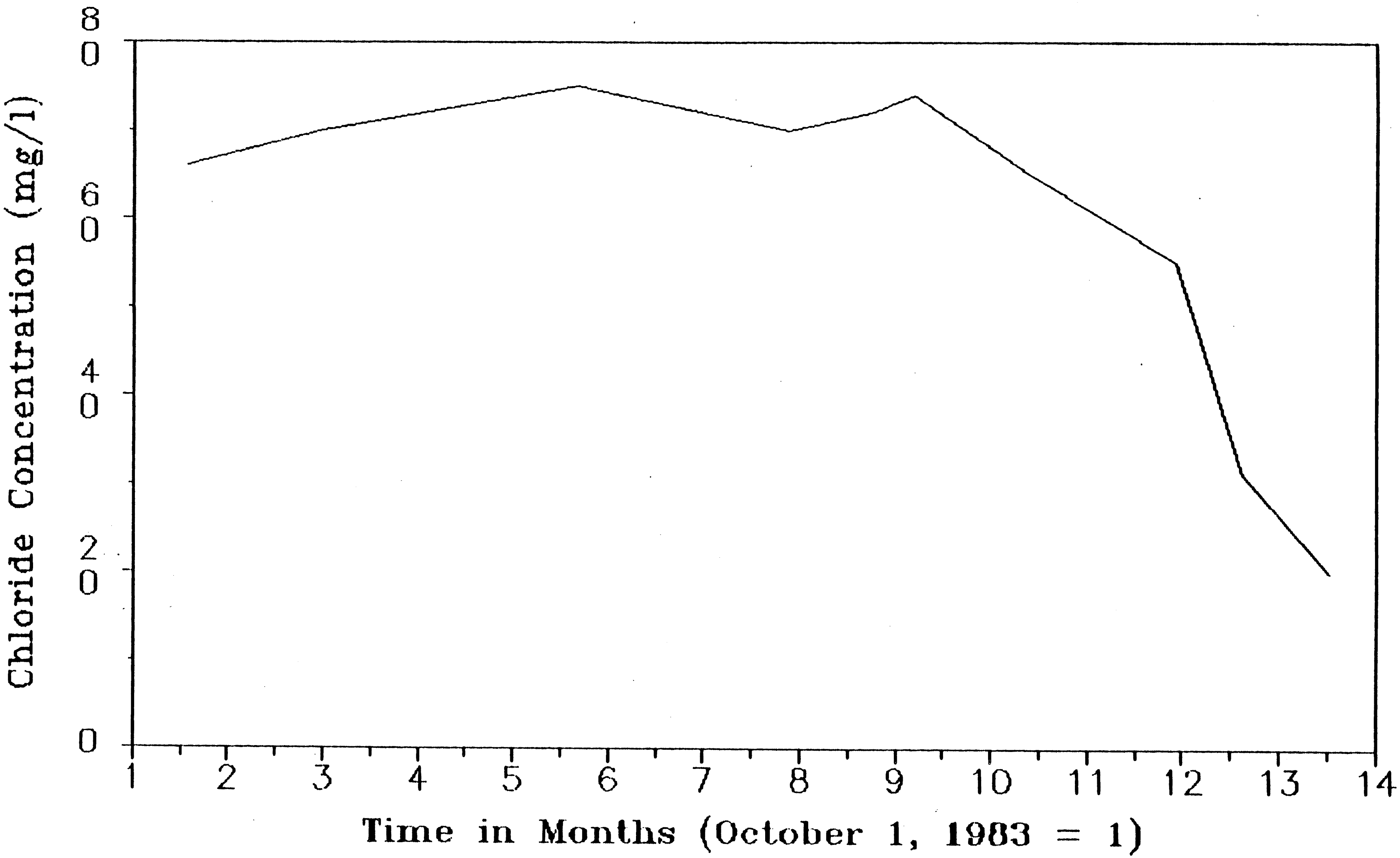


FIGURE 5.12c
Well 2 Chloride Concentration



Finally, nitrogen concentrations were more variable than chlorides values. This can be seen in Figure 5.13 where total nitrogen data are plotted versus time for wells 3, 5, and 9. This plot also shows that nitrogen values increased downstream. Nitrate time plots shown for these three wells in Figure 5.14 indicated that little NO_3^--N was present in the groundwater and no changes in time were apparent.

One final comment on the groundwater chemistry at Mindoro is in order. To completely define the chemistry at this site, the installation of a well nest is recommended downstream of the ridge and furrow. This would indicate whether there was nitrification occurring or if a sinking plume existed.

Unsaturated Zone Flow Rates

Since furrows at the Mindoro ridge and furrow did not contain a solids barrier, one vertical unsaturated flow rate range was estimated. Two methods were used for this calculation; infiltration station results and the methods of Bouma (1975).

Infiltration stations, installed in November (1984), were used as one method of determining unsaturated zone flow-through times. Results of this work for cells 1 and 2 are presented in Figures 5.15 and 5.16 and summarized in Table 5.7. Cell 3 was loaded in November and water head in this infiltration station did not decline. Cell 1 and cell 2 stations were located in areas that were not loaded during the project. The cell 3 station was representative of unsaturated hydraulic conductivities in a heavily loaded area.

FIGURE 5.13
Mindoro Groundwater Total N Values
Wells 3, 5, and 9

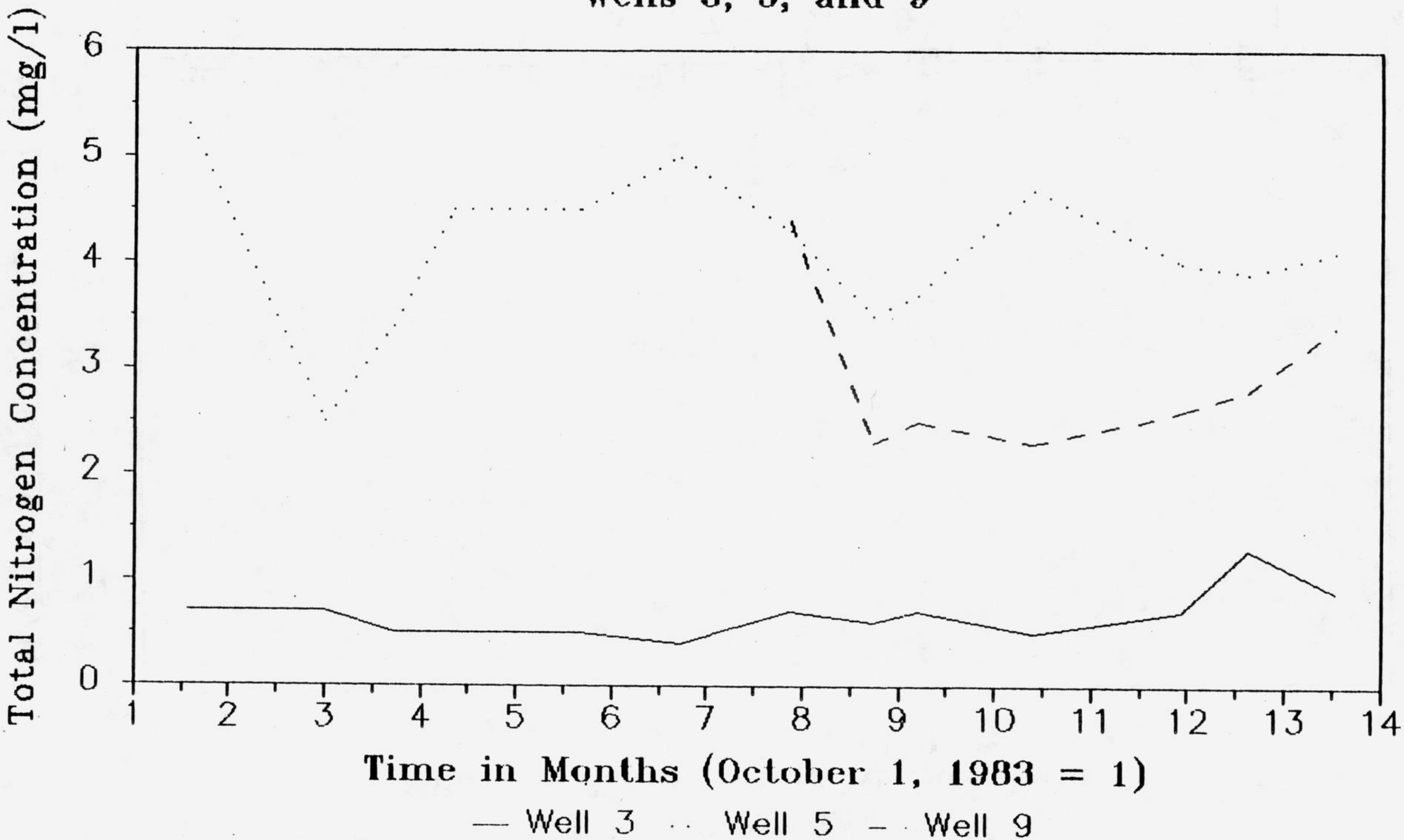


FIGURE 5.14
Mindoro Groundwater Nitrate Values
Wells 3, 5, and 9

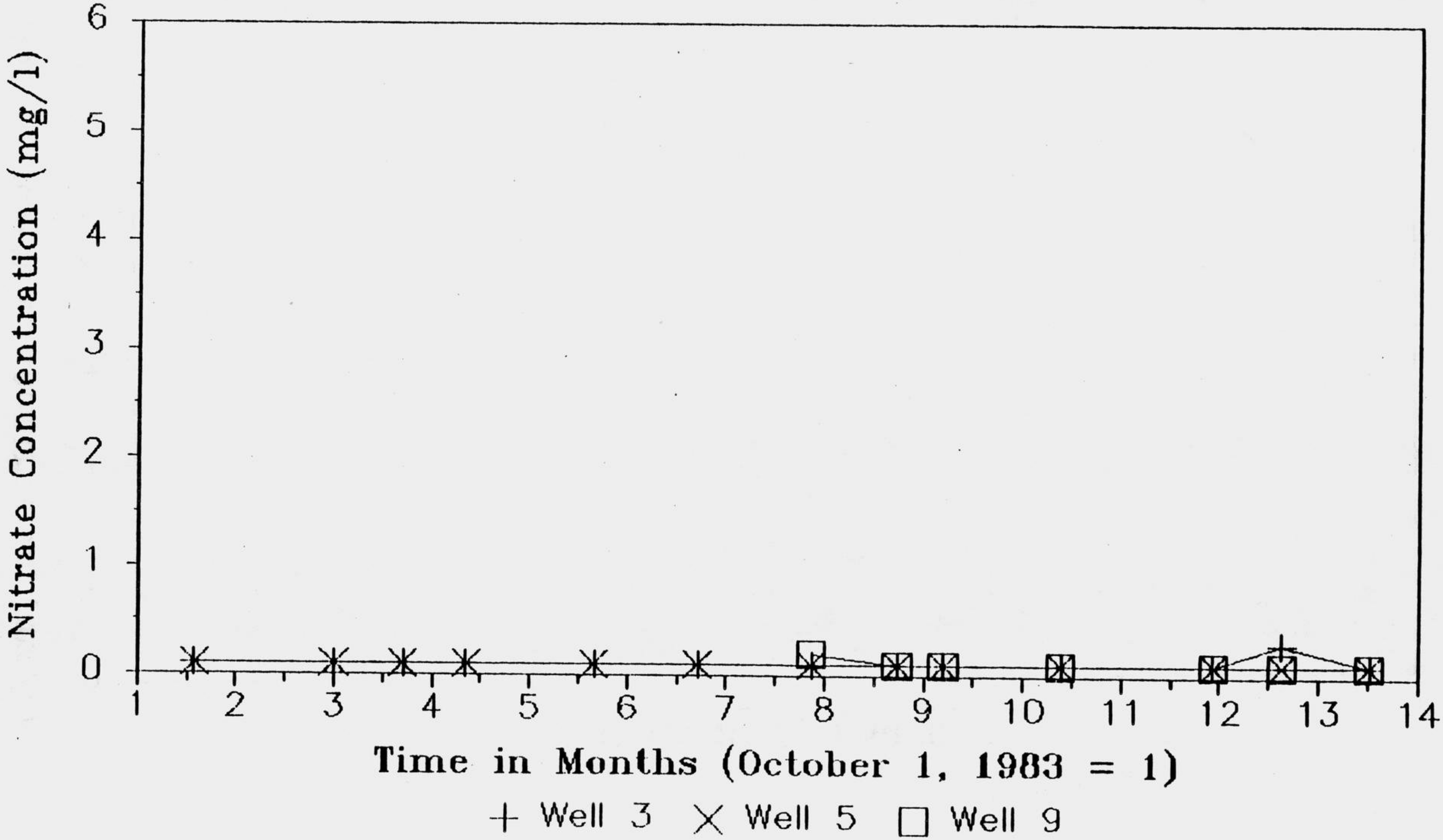


FIGURE 5.15a
Cell 1 Infiltration Results
Rounds 1 thru 3 - 11/5/84

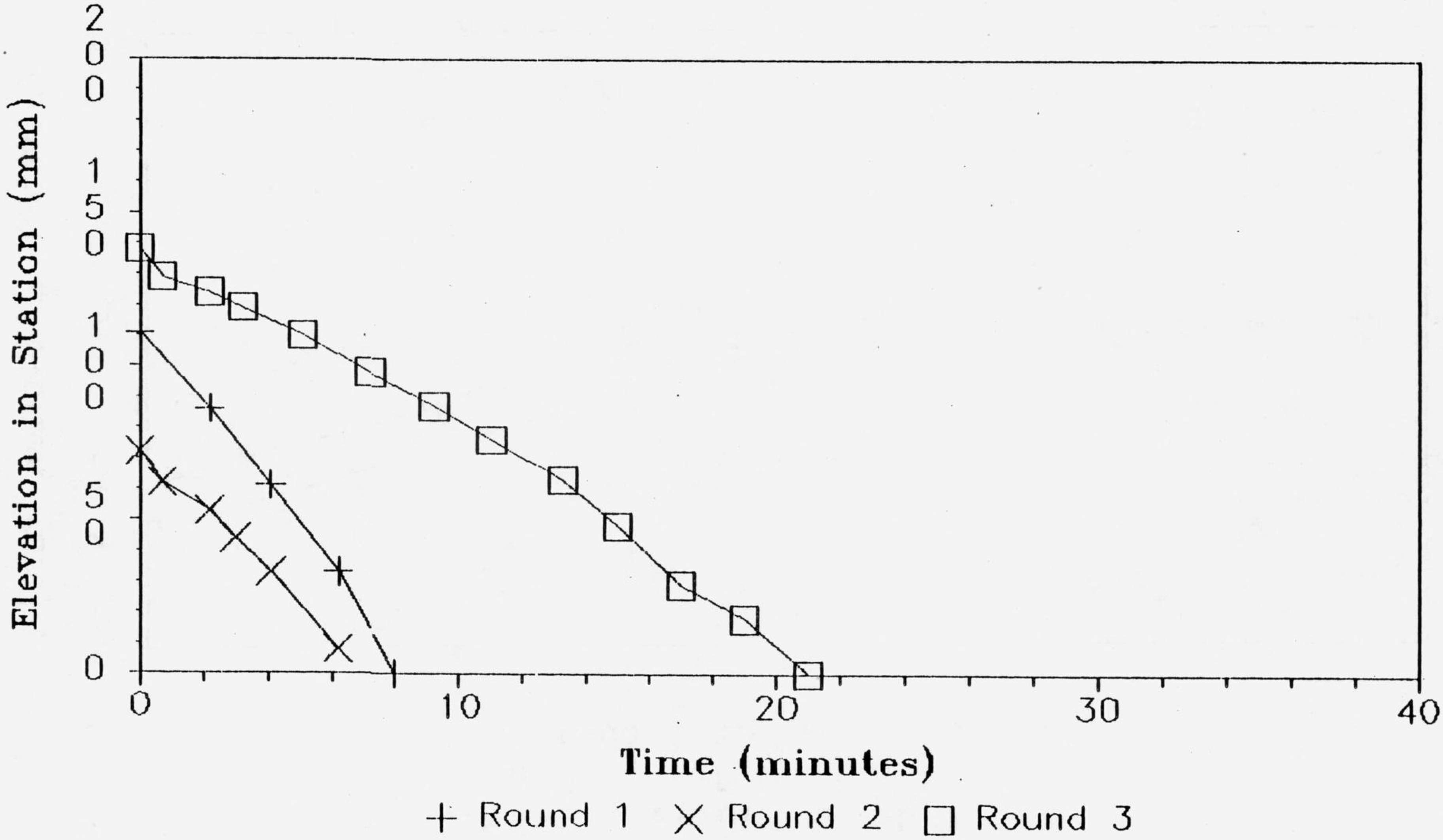


FIGURE 5.15b
Cell 1 Infiltration Results
Rounds 4 and 5 - 11/5/84

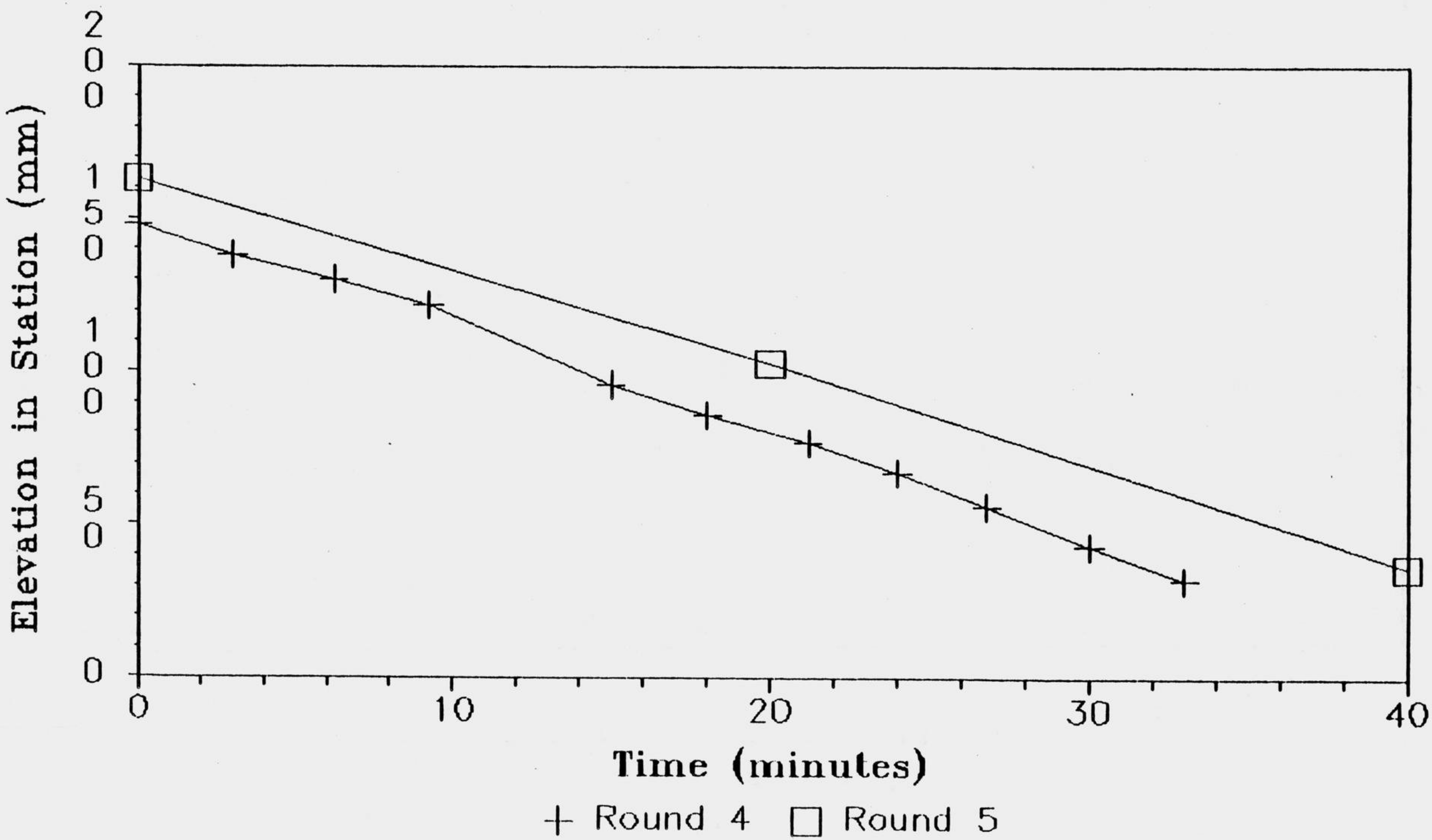


FIGURE 5.15c
Cell 1 Infiltration Results
Rounds 6 and 7 - 11/6/84

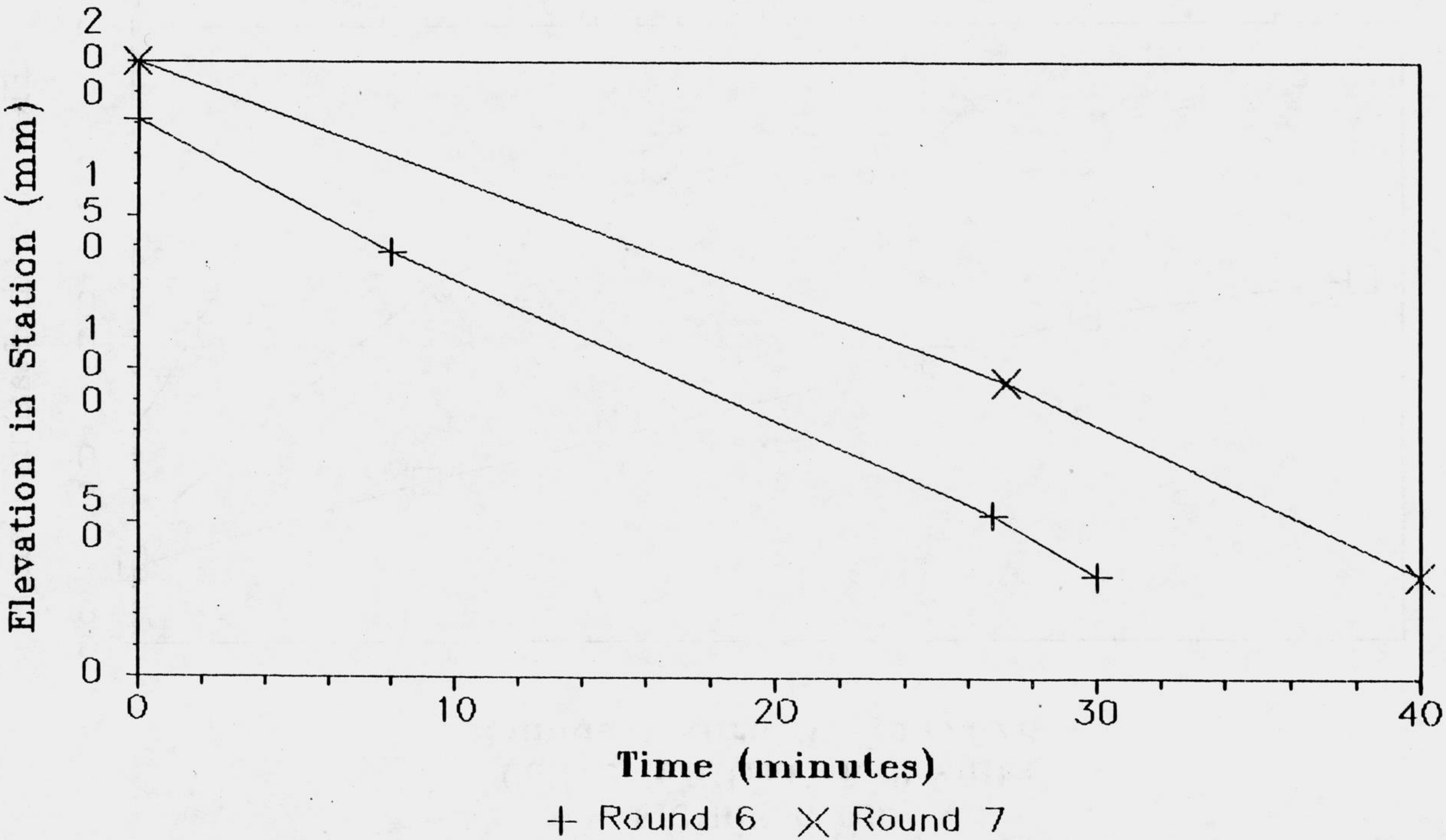


FIGURE 5.16a
Cell 2 Infiltration Results
Rounds 1 thru 3 - 11/5/84

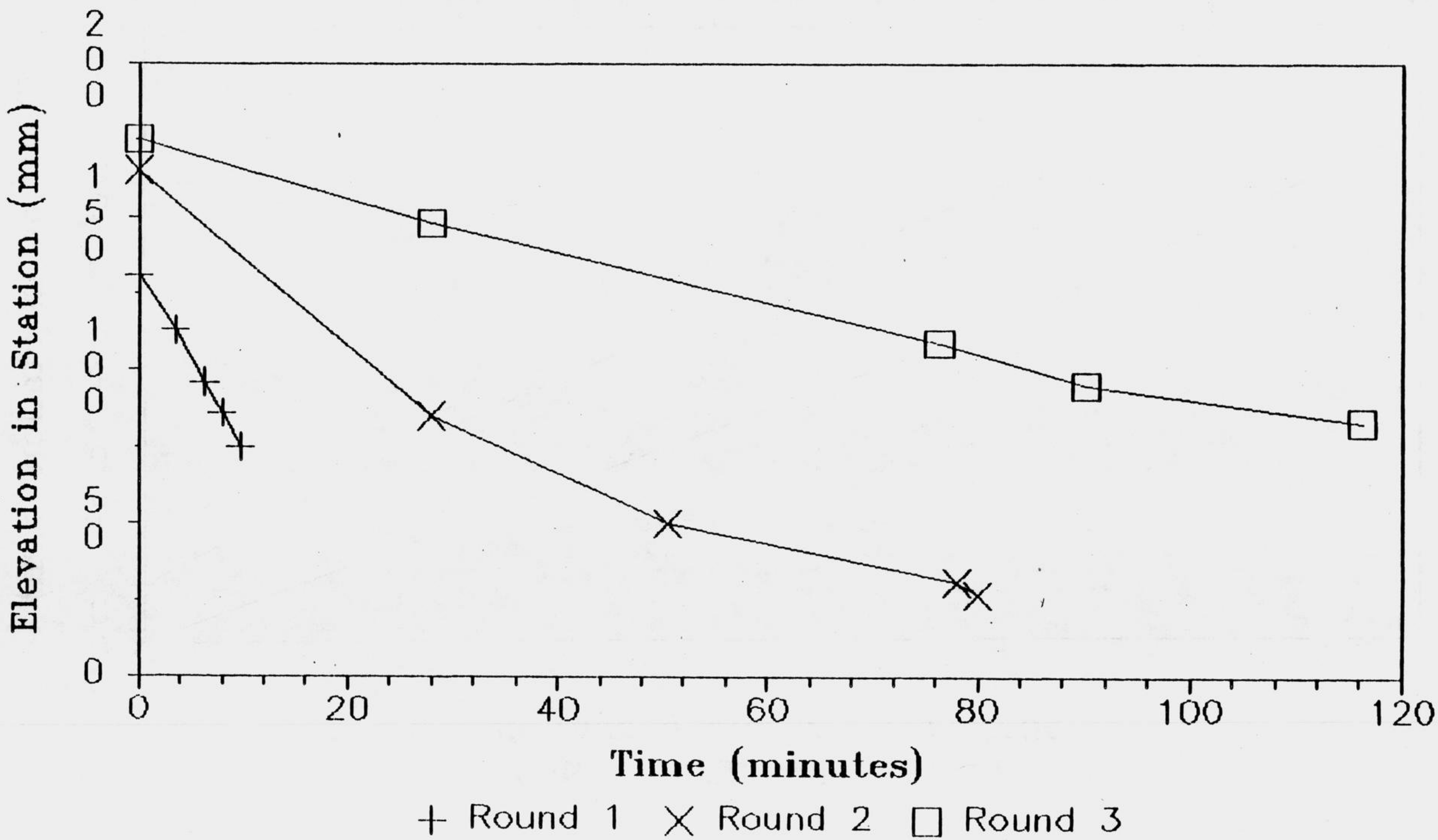


FIGURE 5.16b
Cell 2 Infiltration Results
Rounds 4 and 5 - 11/6/84

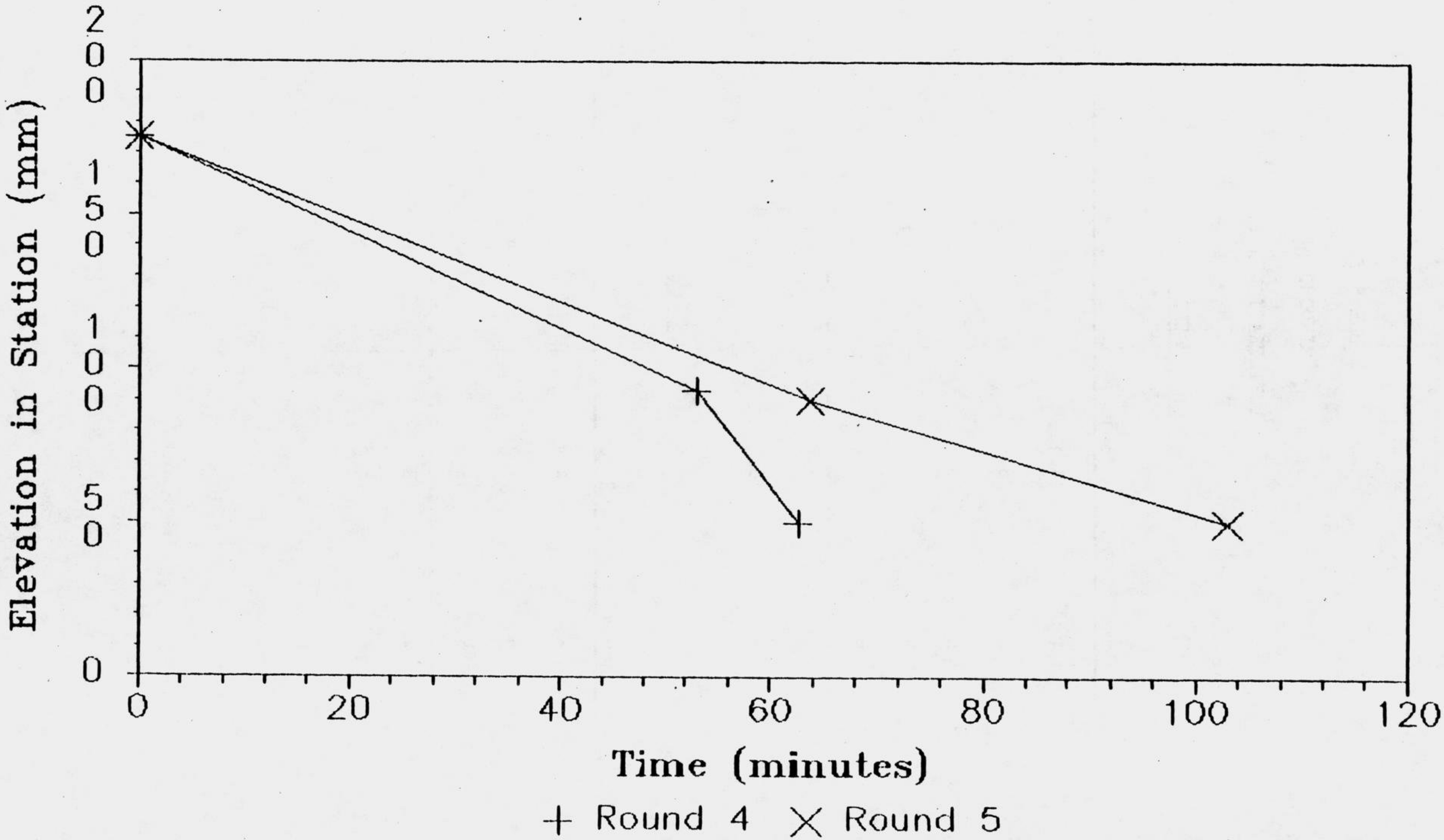


TABLE 5.7

MINDORO

INFILTRATION RATES

CELL 1

Round	H (cm)	t (min)	cm/d	
1	11.1	8	1998	
2	6.4	6	1536	
3	13.8	21	946	11/5/84
4	11.6	33	506	
5	12.7	40	457	
6	14.8	30	710	11/6/84
7	16.7	30	802	

CELL 2

Round	H (cm)	t (min)	cm/d	
1	8.4	10	1210	
2	20.6	80	371	11/5/84
3	13.9	116	173	
4	18.8	62.5	433	
5	18.8	103.5	262	

Results plotted in Figures 5.15 and 5.16 show that head decline with time was linear and that infiltration rates decreased with each new test (round). Rates were faster in cell 1. These rates would have continued to decrease with time (to a rate similar to cell 3) had time allowed for more tests. Since a lower steady-state infiltration rate was not found, the lowest rate for each cell was used to calculate flow through times. It should be realized, however, that these times were on the high side.

For cell 1, with an unsaturated flow rate of 457 cm/d, the following travel times were determined:

1) Between the furrow and lysimeter 325 (at 2.5 feet depth) - 4 hours,

2) between the furrow and a water table at 5 feet depth - 8 hours,

3) between the furrow and a water table at 12 feet depth - 19 hours.

For cell 2, with an unsaturated flow rate of 173 cm/d (Table 5.7), the following travel times were determined:

1) between the furrow and lysimeter 415 (1.5 feet depth) - 6 hours,

2) between the furrow and a water table at 5 feet depth - 21 hours,

3) between the furrow and a water table at 12 feet depth - 51 hours

A technique based on work by Bouma (1975) was the second method used to determine unsaturated zone flow rates. Assuming a constant soil tension of 20 cm H_2O and using Figure 1 (Appendix G) of Bouma (1975), a flow rate of 1.5 cm/day was found. This value was considerably lower than rates determined in the field, but it was representative of a heavily loaded area such as the ponded regions of this system. Use of this infiltration rate, therefore, provided low travel time estimates.

Using a 1.5 cm/d flow rate, the following travel times were determined:

1) between the furrow and lysimeter 415 (1.5 feet depth) - 30 days

2) between the furrow and lysimeter 325 (2.5 feet depth) - 51 days,

3) between the furrow and a water table at 5 feet depth - 102 days, and

4) between the furrow and a water table at 12 feet depth - 244 days.

Based on these calculations, a realistic infiltration rate would have occurred between 1.5 and 457 cm/d and a realistic travel time to a 12 foot deep water table would have been between 2 and 244 days. Loaded areas at this site, however, most likely had unsaturated zone travel times (for 12 feet) on the order of hundreds of days. Installation of tensiometers and further infiltration station work would have better defined unsaturated flow rates at Mindoro.

<u>Furrow and Lysimeter Chemistry</u>

Mean and standard deviations of chemical parameters for each Mindoro furrow wastewater sampling point and lysimeter are listed in Table 5.8. Complete data listings are given in Appendix HH. When comparing chloride averages, one can see that all sampling points in Table 5.8 were contaminated by the ridge and furrow wastewater. Lysimeters 325 and 415 were the only lysimeters providing samples. The reasons for the

TABLE 5.8

MINDORO MEAN AND STANDARD DEVIATION OF FURROW WASTEWATER AND LYSIMETER CHEMICAL PARAMETERS (unit mg/l except pH)

LOCATION	DISS BOD_5	TOTAL BOD_5	DISS COD	DISS TKN	TOTAL TKN	DISS NH_3-N	DISS NO_2+NO_3	Cl^-	TDS	Total pH
Lysimeter 415 (1.5' depth)	4±0.6* (3)	---	10±1.3 (4)	1.6±0.66 (5)	---	0.1±0.0* (5)	8.0±8.0 (5)	53±21 (8)	491±43.8 (2)	6.2±0.1 (4)
Well 8@	3.2±0.42* (7)	---	25±4.3 (7)	2.5±1.1 (7)	---	0.3±0.16 (8)	0.2±0.1* (8)	84±8.2 (7)	744±201 (7)	6.8±0.2 (3)
Header-Cell 2	---	1400±0.0 (1)	3600±0.0 (1)	30±12 (2)	86±32 (2)	11±0.0 (1)	0.1±0.0 (2)	100±27 (2)	---	6.1±0.1 (2)
Furrow-Cell 2	220±0.0 (1)	---	320±0.0 (1)	16±0.0 (1)	---	16±0.0 (1)	1.0±0.0* (1)	99±0.0 (1)	796±0.0 (1)	6.6±0.0 (1)
Lysimeter 325 (2.5' depth)	4±0.7* (2)	---	35±33 (5)	2.0±1.3 (5)	---	0.4±0.6 (5)	3.9±3.3 (5)	92±16 (4)	588±33.9 (2)	6.6±0.17 (4)
Well 5@	11±7.7* (13)	---	31±9.5 (12)	4.0±0.74 (13)	---	3.0±1.0 (13)	0.1±0.0* (13)	91±2.3 (13)	715±42.4 (13)	6.7±0.1 (8)
Header-Cell 3	---	250±0.0 (1)	1200±0.0 (1)	15±2.8 (2)	42±25 (2)	12±2.8 (2)	0.7±0.4* (2)	82±0.71 (2)	---	6.4±0.0 (1)
Furrow-Cell 3	---	94±0.0 (1)	160±0.0 (1)	15±1.4 (2)	20±3.5 (2)	14±2.1 (2)	0.6±0.6* (2)	77±1.4 (2)	---	6.6±0.0 (1)
Well 9@	16±12* (7)	---	47±28 (7)	2.8±0.73 (7)	---	1.5±0.34 (7)	0.1±0.04 (7)	92±12 (7)	607±89.9 (7)	6.7±0.14 (7)

( ) indicates # of observations

@ Well values added for comparison of furrow & lysimeter concentrations to downstream well concentrations

* Mean contains values above or below a detection limit; limit used in average

inability of the other lysimeters to provide samples will be discussed later in this chapter. Large data variations existed in the furrow wastewater and lysimeters affected by cell loading, resulting in large standard deviations. Therefore, it was realized that these numbers do not fully describe the contamination and the averages were only used for relative comparisons.

To determie unsaturated zone COD and total nitrogen losses in comparison to chloride dilution, the flow at the Mindoro ridge and furrow system was broken into three paths. They were:

1) from the inlet, to lysimeter 415, to well 8;
2) from the inlet, to the cell 2 header ditch, to the cell 2 furrows, to lysimeter 325, to well 5; and
3) from the inlet, to the cell 2 header ditch, to the cell 3 header ditch, to the cell 3 furrows, to well 9.

Along the first flow path, chloride concentrations were diluted 16% from the wastewater (100 mg/l) to well 8. COD and total nitrogen averages declined 98 and 92 percent, respectively, along the same path. This implied that actual average COD and total nitrogen reductions were 82 and 76 percent, respectively. Reduction along this flow path are completely listed in Table 5.9.

From Table 5.8, one notices that the lysimeter 415 chloride average was relatively lower than other furrow and lysimeter averages and its standard deviation was high. This difference was the result of the loading schedule. Since cell 1 was not loaded after September of 1983, the furrows adjacent to lysimeter 415 did not receive fresh wastewater during the study. Chloride concentrations decreased in lysimeter 415 from 82 mg/l on 5/23/84 to 35 mg/l on 9/19/84.

Along the second flow path at Mindoro, chloride concentrations were diluted 9% from the wastewater to well 5. COD and total nitrogen averages declined 97 and 87 percent, respectively, along the same path. This meant that actual average COD and total nitrogen reductions were 88 and 78 percent, respectively. Reduction along this flow path are completely listed in Table 5.10.

Along the third flow path at Mindoro, chloride averages were diluted 8% from the wastewater to well 9. COD and total nitrogen averages decreased 96 and 91 percent, respectively, along the same path. This implied that actual average COD and total nitrogen reductions were 88 and 83 percent, respectively. Reductions along this flow path are completely listed in Table 5.11.

Nitrogen transformations observed in the applied wastewater at Mindoro were similar to trends observed at Brodhead. As at Brodhead, Mindoro's wastewater nitrogen was principally in organic form. While this waste traveled in the header ditch, the organic-N mineralized to NH_4^+-N. In the cell 2 header ditch, the average TKN concentration contained approximately 40% NH_4^+-N and in the cell 3 header ditch, the average TKN value contained 80% NH_4^+-N. As mentioned in the previous discussion, N losses occurred along the header ditch. These were attributed to plant uptake of NH_4^+ since pH values were not conducive to NH_3 volatilization and little NO_3-N was produced in the header ditch to promote denitrification.

TABLE 5.9

REDUCTIONS ALONG FIRST MINDORO FLOW PATH

LOCATION	Cl⁻	COD	TOTAL N	% Cl REDUCTION FROM WASTE	% COD REDUCTION FROM WASTE	RELATIVE COD LOSS	% TOTAL REDUCTION FROM WASTE	RELATIVE N LOSS
Wastewater	100	1200	32.4	0	0	0	0	0
Lysimeter 415	53	10	9.6	47	99	52	70	23
Well 8	84	25	2.7	16	98	82	92	76

TABLE 5.10

REDUCTIONS ALONG SECOND MINDORO FLOW PATH

LOCATION	Cl⁻	COD	TOTAL N	% Cl REDUCTION FROM WASTE	% COD REDUCTION FROM WASTE	RELATIVE COD LOSS	% TOTAL REDUCTION FROM WASTE	RELATIVE N LOSS
Wastewater	100	1200	32.4	0	0	0	0	0
Cell 2-Header	100	3600	30.1	0	---	---	7	7
Cell 2-Furrows	99	320	17	1	73	72	47	46
Lysimeter 325	92	35	5.9	8	97	89	82	74
Well 5	91	31	4.1	9	97	88	87	78

- average concentrations used
- % Relative loss = % total reduction - % chloride dilution

TABLE 5.11

REDUCTIONS ALONG THIRD MINDORO FLOW PATH

LOCATION	Cl^-	COD	TOTAL N	% Cl REDUCTION FROM WASTE	% COD REDUCTION FROM WASTE	RELATIVE COD LOSS	% TOTAL REDUCTION FROM WASTE	RELATIVE LOSS
Wastewater	100	1200	32.4	0	0	0	0	0
Cell 2-Header	100	3600	30.1	0	---	---	7	7
Cell 3-Header	82	1200	15.7	18	0	---	52	34
Cell 3-Furrow	77	160	15.6	23	87	64	52	29
Well 9	92	47	2.9	8	96	88	91	83

- average concentrations used
- % Relative loss = % total reduction - % chloride dilution

Once wastewater entered the furrows from the header ditch at Mindoro, this ammonification to NH_4^+-N was completed. Furrow sample TKN's collected contained 85 to 100% ammonium. Nitrogen losses, as previously discussed, were also observed in furrow samples as compared to the applied wastewater. Since furrow pH values were low and no nitrate was produced, these N losses were most likely the result of plant uptake of NH_4^+-N. Nitrogen losses were higher in cell 2 furrows than in cell 3 furrows on average.

As the wastewater percolated from the furrows, through the unsaturated zone, to the groundwater, simultaneous nitrification and denitrification were found to occur at Mindoro. Both lysimeter 325 and 415 samples contained nitrate (see Table 5.8) and total N values were lower in these lysimeters than the overlying furrow samples. Samples from wells 5, 8, and 9 indicated a further decrease in total nitrogen averages, as well as nitrate losses, in the unsaturated zone. Nitrification occurred in the upper aerated section of the unsaturated zone. This section also contained anaerobic microenvironments which facilitated denitrification losses. Plant uptake of nitrate and ammonium could also have accounted for N losses in this upper layer. As flow continued to the water table, denitrification losses continued. Ammonium adsorption was neglected assuming that all exchange sites were saturated.

By comparing total and dissolved TKN results for wastewater, header, and furrow samples, the same nitrogen solids dissolution pattern that was observed at Brodhead was established at Mindoro. These data are presented in Table 5.12. As mentioned earlier, the Mindoro wastewater contained nitrogen primarily in organic-N form. Twenty to 45% of this organic-N was tied up in wastewater solids. Total TKN concentrations in the header ditch were quite variable and were usually higher than wastewater values. In the cell 2 header, 40-80 percent of the TKN was tied up in solids. In the cell 3 header, 45-70 percent of the TKN was tied up in solids.

TABLE 5.12

MINDORO WASTEWATER, HEADER, AND FURROW WASTEWATER NITROGEN RESULTS

DATE	TOTAL TKN	DISS TKN	DISS NH_3-N	DISS NO_3-N+NO_2-N
		WASTEWATER		
10/16/84	40	31	0.9	0.8
11/6/84	29	16	1.4	0.6
		HEADER - CELL 2		
10/16/84	108	21	11	0.1
11/6/84	63	38	--	0.1
		HEADER - CELL 3		
10/16/84	59	17	14	0.4
11/6/84	24	13	10	<1.0
		FURROW - CELL 3		
10/16/84	17	14	12	0.1
11/6/84	22	16	15	<1.0

Due to the poor distribution of wastewater at Mindoro, suspended solids settled in the header ditch. Ammonium concentration in the header ditch were the result of ammonification of these settled solids and diffusion of NH_4^+-N into the overlying water column. This was the same event that was observed at Brodhead. Due to plugging of furrow inlets, flow entering the furrows was analogous to the overflow of wastewater over the weir of a clarifier. Furrow samples were low in solids and only 20-30 percent of the total TKN was tied up in solids. Also, about 70% of the TKN was in ammonium form.

A final comment on furrow and lysimeter chemistry at Mindoro concerned pH. Even though the mean wastewater pH was 7.5, header, furrow, and lysimeter pH values were consistently between 6.1 and 6.6. Since negligible nitrite was found in header and furrow samples, this pH lowering was not the result of nitrification. Tusneem and Patrick (1971) attributed a similar pH reduction to volatile acid production. In aerobic and anaerobic degradation of organic matter, organic acids are the final product of glycolysis. In anaerobic environments (eg. header and furrow water), terminal oxidation is suppressed and organic acids accumulate. This process was most likely the reason for lower pH in downstream wells at Mindoro and Brodhead as well.

Grass Uptake of Nitrogen

Six grass samples were cut at the Mindoro ridge and furrow system during the 1984 growing season. Two samples were collected in April before growth began, two were taken in July at peak growth, and two were taken in November during declining growth. Average results of these analyses are shown in Table 5.13. Calculations are presented in Appendix II. These results were used for the following purposes: 1) to determine the plant nitrogen uptake during the growing season; 2) to calculate the effect of grass burning on nitrogen losses, and 3) to estimate a plant nitrogen uptake value for a nitrogen budget.

TABLE 5.13

MINDORO GRASS NITROGEN RESULTS

Date	lb of Dry Grass on Site (lb)	% N Dry Wt Basis	% Ash After Burning	% N of Ash	lb N On Site Before Burning	lb N On Site After Burning	% N Lost Due to Burning
4/26/84	22,255	1.56	17.1	2.49	347	95	72.6
7/12/84	29,962	2.15	8.5	0.64	644	16.3	97.5
11/6/84	44,439	1.0	8.9	0.31	444	12.2	97.2

- weights are for total site area (3 acre) extropolated from sample area results

The mass of nitrogen on site calculations indicate that plant uptake of nitrogen was high in late spring and early summer. Plant nitrogen content decreased in the fall as plants died and nitrogen moved to the root zone. At the end of the growing season, 444 lb nitrogen was contained on site in the standing cover crop.

The operator of the Mindoro ridge and furrow system burns site grasses in the spring to eliminate dead grass accumulation and to stimulate new growth. Collected grass samples were burned and analyzed for percent ash and percent N in ash to determine the effect of grass burning.

Total pounds of ash-nitrogen on site were highest in April at 95 lbs as shown in Table 5.13. The July ash sample indicated 16.3 lbs of nitrogen on site after burning and the November sample indicated 12.2 lbs. A range of 72-98% nitrogen loss by burning was observed when comparing total nitrogen in the site grasses before and after burning. The lowest loss occurred in April.

Since site grasses were burned in early spring, the 95 lbs of nitrogen on site after burning was immobilized into the soil. Since this mass did not leave the material balance, it was not a loss or an addition to the budget. Grass nitrogen losses during the growing season studied (4/26/84-11/6/84) were those lost from burning in April or 252 lb. This mass was used in the nitrogen budget estimate.

TABLE 5.14

MINDORO: SEVERSON COULEE CREEK QUALITY

Location	Total BOD_5	Total COD	Cl^-	TKN	NH_3-N	NO_3-N	Field pH
Upstream	3±0.0* (2)	6±0 (2)	7.4±0.71 (2)	0.2±0.0 (2)	0.1±0.0 (2)	0.8±0.07 (2)	8.0±0.0 (1)
Midstream	3±0.0* (2)	5±0* (2)	7.8±1.2 (2)	0.2±0.0 (2)	0.1±0.0 (2)	0.8±0.0 (2)	8.0±0.0 (1)
Downstream	3±0.0* (2)	7±0.0 (2)	7.6±0.56 (2)	0.4±0.07 (2)	0.1±0.0 (2)	0.8±0.0 (2)	8.0±0.0 (1)

- all values mg/l except pH
- ( ) is # of observations
* mean includes data below detection limit; limit used in average

Severson Coulee Creek Chemistry

Mean and standard deviations of upstream, midstream, and downstream Severson Creek samples are tabulated in Table 5.14. Complete data are located in Appendix JJ. All values were low and were uniform upstream to downstream. The Mindoro ridge and furrow system did not adversely affect this creek.

Site Observations

During the course of this study, the following site observations were made at the Mindoro ridge and furrow: 1) wastewater distribution and solids build-up in furrows, 2) cover crop, 3) winter operation, 4) monitoring equipment performance, and 5) slope stability.

At Mindoro, only 40% of the furrows received wastewater and only 30% of the total area was loaded during the project. Dead grass accumulation has plugged furrows in the northern half of cell 1, the southern 75% of cell 2, and the southern half of cell 3. The header ditch design was not efficient as well. Since the inlet was located in cell 1, the southern half of this cell continually received wastewater. The stop gates between cells were in need of attention. Wastewater flow either went through or underneath them, causing cells 2 and 3 to also receive a continuous load. An improvement of wastewater distribution at this site could considerably improve treatment by spreading the load over more area and providing more soil aeration. Since many of the furrow openings were plugged, most of the wastewater suspended solids settled in the header ditch. There was no noticeable solids accumulation in the furrows.

The cover crop of canary grass at Mindoro flourished with the additional water and nutrients provided by the wastewater. During early spring, before site burning, grasses were brown and knocked down to about knee high. Thick grasses grew head high during spring and early summer in used portions of the system. In August and September, grasses were browning and knocked down by wind. Grass was completely brown and knocked down to about hip high in November. Grasses in unused portions of the system were not as thick and only knee high. Since furrows were only two feet wide, these tall grasses provided furrow protection during the winter months.

Winter operation at the Mindoro ridge and furrow was not a major problem since wastewater effluent temperatures were warm. The southern quarter of cell 1 and northern quarter of cell 3 received wastewater during sub-zero weather. During above-zero whether, however, most of the area normally treating wastewater was operable. Once system loading began, the ice would melt and infiltration would continue. Header ice conditions ranged from no ice near the inlet to six inches at the far north end. Furrow ice conditions ranged from no ice near the header, to one inch thick ice with wastewater or air underneath, to completely (two inches thick) frozen.

The monitoring equipment used at this site was quite adequate. The only problems which occurred concerned the Teflon lysimeters. To obtain a sample of sufficient volume (greater than 50 ml) for chemical analysis, a 20-inch (mercury) vacuum was applied to a lysimeter and a two to 24 hour vacuum period was used. This technique was successful for lysimeters 325 and 415 only. The background lysimeters (21, 25, 211) lost a vacuum within 15 minutes. This was most likely the result of easy air entry from the surface or low soil moisture. A high, continuous vacuum or a bentonite seal may have been necessary to obtain a sample. Lysimeters 36 and 310, located in cell 2, did not provide samples but did maintain a 20 inch (mercury) vacuum for more than a month. These units were installed in soils with a higher clay content. A high soil moisture tension, caused by low moisture content, was most likely the reason for the failure of these lysimeters to obtain samples.

Winter conditions also caused trouble with lysimeter operation. During sub-freezing weather, ice droplets would form in the Tygon tubing and the tubing itself would contract. The pressure provided by the hand pump could not overcome these blockages. Lysimeters were not used from December (1983) to March (1984) at this site.

A final site observation concerned slope stability along the southern half of the west system boundary. Site topography from well 6 to the creek drops at least 20 feet. Obvious soil creep was noticed near well 6. This slope movement should be monitored in the future so the integrity of the cell 1 berm can be maintained.

Mindoro Nitrogen Budget

A nitrogen balance was estimated for the unsaturated zone at the Mindoro ridge and furrow system. Wastewater flow readings, wastewater nitrogen data, plant uptake results, and well 5 nitrogen data were used in this estimate. The balance was on an annual total pounds basis.

Additions to the budget came from applied wastewater nitrogen. Total TKN plus NO_3-N averages were used assuming all N eventually entered the soil. As with the Brodhead budget, additions to the system by nitrogen fixation, rainfall, and organic soil debris mineralization were assumed negligible. Nitrogen losses in the balance were be plant burning and leaching. The difference between these additions and losses was accounted for by denitrification. It was further assumed that precipitation and evapotranspiration were approximately equal (ie. all vertical flow was from wastewater), no volatilization occurred (pH less than 9), and all soil NH_4^+-N adsorption sites were saturated (ie. no soil storage). Table 5.15 tabulates the results of this budget; calculations are presented in Appendix KK.

TABLE 5.15

NITROGEN BUDGET ESTIMATE - MINDORO SITE

Addition/Loss	lb/yr	% of Applied N
Wastewater Applied N	1381	100
Plant Uptake Loss	252	18
Leaching	175	13
Denitrification	954	69

With this procedure, a denitrification loss of 69% of applied nitrogen was calculated for the Mindoro site. This figure was similar to flow path losses discussed previously in this chapter. Leaching accounted for 13% of applied N loss and plant uptake accounted for 18%.

CHAPTER 6: COMPARATIVE DISCUSSION OF THE BRODHEAD AND MINDORO RIDGE AND FURROW SITES

Brodhead and Mindoro ridge and furrow system nitrogen budgets, wastewater organic loadings, nitrogen transformations, and operation and maintenance were compared in order to discuss the treatment and performance of ridge and furrow systems.

Nitrogen Budget

On a total pounds/year basis, the Brodhead ridge and furrow received 5375 lb N/yr while Mindoro treated 1381 lb N/yr, almost four times less. If actual area loading rates are used, however, the nitrogen applied at Brodhead and Mindoro was 1144 lb N/acre/year (3.1 lb N/acre/day) and 1534 lb N/acre/year (4.2 lb N/acre/day), respectively. With improved distribution at Mindoro, the nitrogen loading rate could have been 460 lb N/acre/year (1.3 lb N/acre/day).

The nitrogen budget estimates for the Brodhead ridge and furrow sites showed that denitrification was the major sink for applied wastewater nitrogen. Denitrification accounted for 66% of wastewater-N loss at Brodhead and 69% of the applied-N loss at Mindoro. These percentages matched those cited earlier in the literature (Patrick and Goth, 1974; Tusneem and Patrick, 1971; Reddy and Graetz, 1981; Chen and Patrick, 1981; Olson et. al., 1980; and Leach and Enfield, 1983). Respective denitrification rates were 751 lb/acre/year at Brodhead and 1060 lb/acre/year at Mindoro using actual loaded areas. If the total Mindoro site area was used, a denitrification rate of 318 lb/acre/day resulted. As stated earlier, improved wastewater distribution may have increased denitrification loss by providing soil aeration and lowering the groundwater mound. Lowering the mound would increase the unsaturated zone travel time.

Plant uptake losses accounted for 0% of applied wastewater nitrogen at Brodhead and 18% (or 280 lb N/acre/year) at Mindoro. Even though a crop nitrogen uptake of 74 lb N/acre/year was observed at Brodhead, grass nitrogen losses were zero since the crop was not burned in the spring. Whatever nitrogen that was taken up during the growing season was returned again by the dead plants resulting in a zero net loss. Spring burning of the dead grass at Mindoro removed 73% of the nitrogen contained in the crop. A nitrogen uptake of 493 lb N/acre/year, using the actual loaded area was found at Mindoro for the 1984 growing season. Uptake using the total site area was 148 lb N/acre/year. Higher crop uptakes at Mindoro were attributed to the silt loam soil. The soil's lower infiltrative capacity improved the availability of nutrients and water to the plants. Burning may also have enhanced nutrient uptake.

The remaining loss of applied wastewater nitrogen was through leaching from the unsaturated zone to the groundwater. Leaching losses accounted for 34% (392 lb N/acre/year) of applied nitrogen at Brodhead and 13% (193 lb N/acre/year) of added nitrogen at Mindoro. A rate of 58 lb N/acre/year was calculated if total site area was used for Mindoro. Higher leaching losses at Brodhead resulted from the higher travel times through the sandy soils. These faster travel times meant a shorter contact time between the percolating wastewater and the denitrifying soil bacteria.

Finally, it should be remembered that inputs of nitrogen by fixation and precipitation, losses by volatilization, and soil absorption were assumed negligible. These assumptions seemed practical and were discussed previously.

Wastewater Organic Loading Rates

As stated in the last section, Brodhead received 1144 lb N/acre/year (3.1 lb N/acre/day) while Mindoro treated 1534 lb N/acre/year (4.2 lb N/acre/day). Currently, the Wisconsin DNR does not have a nitrogen loading limit. Using the nitrogen budget results, a suggested total nitrogen loading rate was suggested for each site in order to meet a 5 mg/l total nitrogen increase above background quality in the groundwater beneath the site. The choice of 5 mg/l was arbitrary; the intent was to present two procedures in which to calculate a loading rate. Proposed loading rates were determined using both the percentage of denitrification loss and the rate of denitrification loss. It was assumed that denitrification and leaching rates would remain constant under changes in the nitrogen loading rate.

At Brodhead, 34% of the applied wastewater nitrogen leached to the groundwater and 66% of the added nitrogen was lost through denitrification. At the current loading rate, the concentrations in lysimeters 3 and 6 were 9.0 and 21.7 mg/l total nitrogen on average. These lysimeters were considered to represent unsaturated pore water upon entering the groundwater. In order to set a necessary wastewater concentration to meet a 5 mg/l increase, this value was divided by the leaching percentage, or 0.34. This was based on an earlier assumption that wastewater flow volume and leaching flow volume were essentially equal. With this procedure, a wastewater concentration of 15 mg/l total nitrogen would be needed to meet a 5 mg/l groundwater concentration increase. Using the average wastewater flow of 39,500 gpd, this would result in a nitrogen loading rate of 384 lb N/acre/year (1.05 lb N/acre/day). This rate is about a third of the present rate. In order to meet this rate, the Brodhead ridge and furrow system would have to be expanded or wastewater pretreatment before application to the furrows would be needed.

The denitrification loss rate of 751 lb N/acre/year at Brodhead was also used to suggest a nitrogen loading rate at this site. Assuming that the average wastewater flow rate of 39,500 gpd equals the leaching flow rate, a nitrogen leaching rate of 128 lb N/acre/year would increase the lysimeter total nitrogen concentration 5 mg/l above background. The summation of these two rates (751 + 128) would account for a new suggested wastewater loading rate of 879 lb N/acre/year. This corresponds to an average wastewater total nitrogen concentration of 34 mg/l which is 75% of the current nitrogen concentration.

At Mindoro, 13% of the applied wastewater nitrogen leached to the groundwater and 69% of the added nitrogen was lost through denitrification. At the current loading rate, the highest average total nitrogen concentration in the groundwater beneath the system was 4.1 mg/l. The current rate of 1534 lb N/acre/year (or 4.2 lb N/acre/day) was adequate to meet a 5 mg/l total nitrogen groundwater concentration increase above background. With improved wastewater distribution and proper load/rest cycling, the Mindoro site could most likely treat a higher nitrogen loading rate if necessary.

It should be remembered that these suggested rates do not apply to all ridge and furrow systems but only those with similar hydrogeological characteristics to Brodhead or Mindoro, respectively.

Using the actual site area loaded during the study, both Brodhead and Mindoro had average BOD_5 loading rates over the 100 lb/acre/day DNR limit. Brodhead's average rate was 125 lb/acre/day while Mindoro's rate was 108 lb/acre/day. Site expansion, pretreatment, and wastewater distribution improvement are all possible methods to meet this standard.

Based on project results, however, the COD concentrations (which follow BOD_5 values) were greatly reduced as wastewater infiltrates from the furrows, through the unsaturated zone, and down gradient in the groundwater. Tables 6.1 and 6.2 summarize COD reductions at Brodhead and Mindoro, respectively. Both ridge and furrow systems had high COD reductions (96-99%) at the sampling locations indicated but these site decreases were achieved differently. Brodhead reductions were aided by dilution, as indicated by the chloride data (16-80% chloride dilution). Cell 1 unsaturated zone actual COD reductions, as indicated in lysimeters 2 and 3, were relatively high at 72-82%. With contined use of the 2 week/1 week load/rest cycle, the groundwater most likely will reflect these losses as well. Mindoro declines were mainly biological, with 52-89% actual COD losses. Since nitrification was observed at both

TABLE 6.1

SUMMARY OF RELATIVE COD

REDUCTIONS AT BRODHEAD

LOCATION	AVE* Cl^-	AVE* COD	% Cl^- REDUCTION	% COD REDUCTION	% ACTUAL COD LOSS
Wastewater	930	2390	0	0	0
Lysimeter 2	690	51	26	98	72
Lysimeter 3	780	56	16	98	82
Lysimeter 5	400	32	57	99	42
Lysimeter 6	390	20	58	99	41
Well 15	570	57	39	98	59
Well 10A	380	17	59	99	40
Well 10B	630	24	32	99	67
Well 14	190	18	80	99	19

* units: mg/l

TABLE 6.2

SUMMARY OF RELATIVE COD

REDUCTIONS AT MINDORO

LOCATION	AVE* Cl^-	AVE* COD	% Cl^- REDUCTION	% COD REDUCTION	% ACTUAL COD LOSS
Wastewater	100	1200	0	0	0
Lysimeter 325	92	35	8	97	89
Lysimeter 415	53	10	47	99	52
Well 5	91	31	9	97	88
Well 9	92	47	8	96	88

* units: mg/l

sites, it was determined that applied BOD_5 (or COD) did not impart a high oxygen demand on the soil system which would have inhibited this transformation.

The present BOD_5 loadings at both sites are, therefore, not overtaxing the treatment capacity of the soil. COD reductions of 96-99% occurred at both sites and nitrogen reductions were not impaired by the applied oxygen demand. Load/rest cycle most likely aided in controlling O_2 demand, especially at Brodhead.

NITROGEN TRANSFORMATIONS

A similar nitrogen transformation pattern was observed at both the Brodhead and Mindoro ridge and furrow systems. Little ammonia rolatilization occured since wastewater pH values were less than nine. Both site wastewater samples had average pH values of 7.5.

The nitrogen content of the wastewater at both sites was mainly in the organic form. On average, the total nitrogen concentration at Brodhead contained 88% organic-N while the Mindoro total N concentration contained 96% organic-N. Twenty-five to 40% of this organic nitrogen was associated with the solid form as well. These solids subsequently settled and accumulated in the furrows at Brodhead and the header ditch at Mindoro.

The organic-N in these settled solids mineralized to ammonium and this diffused into the overlying furrow water column. Dissolved organic nitrogen also mineralized to NH_4^+-N in the furrows. Furrow TKN samples

FIGURE 6.1
Mindoro Site
Lysimeter 325 Nitrogen Concentrations

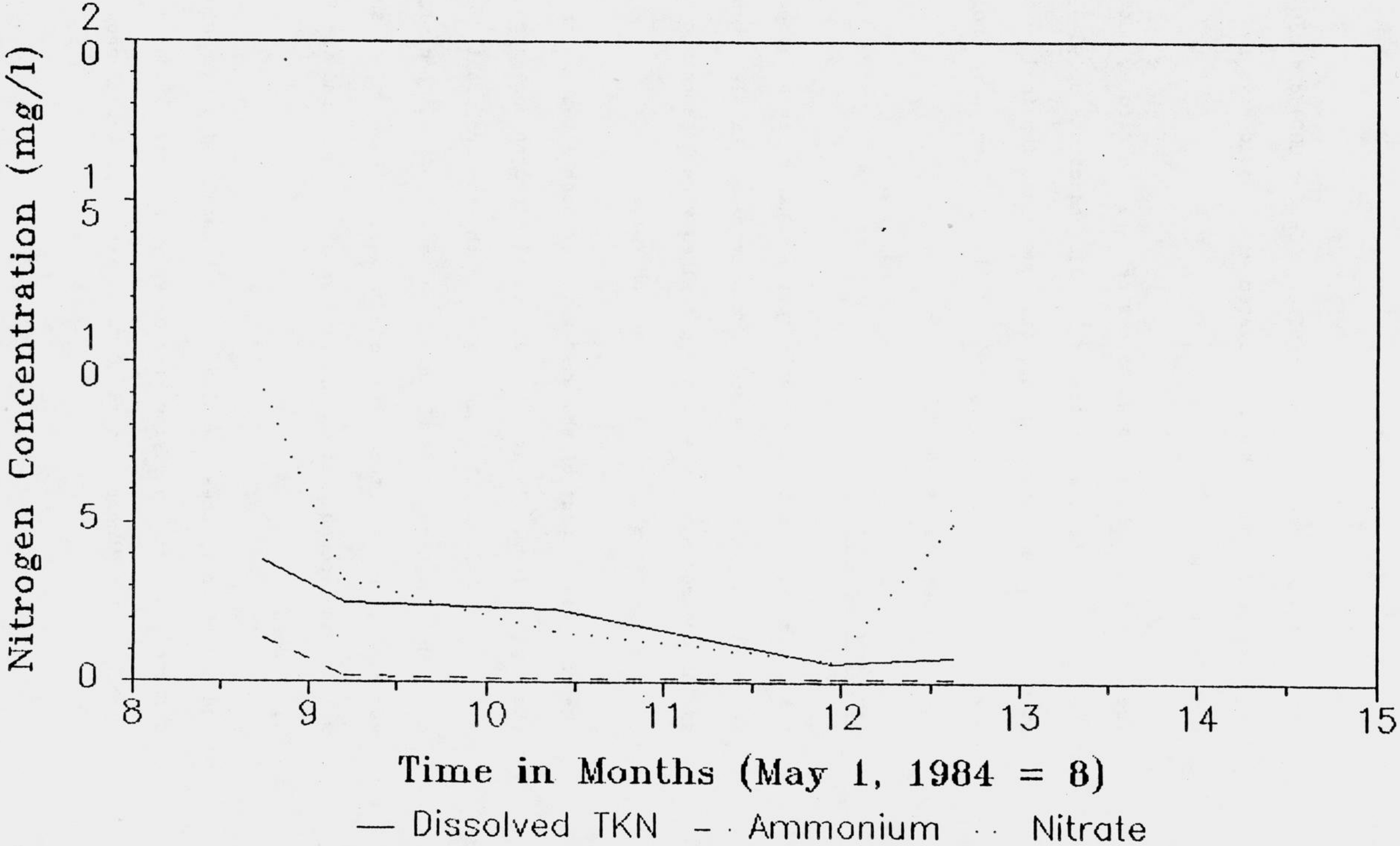


FIGURE 6.2
Mindoro Site
Lysimeter 415 Nitrogen Concentrations

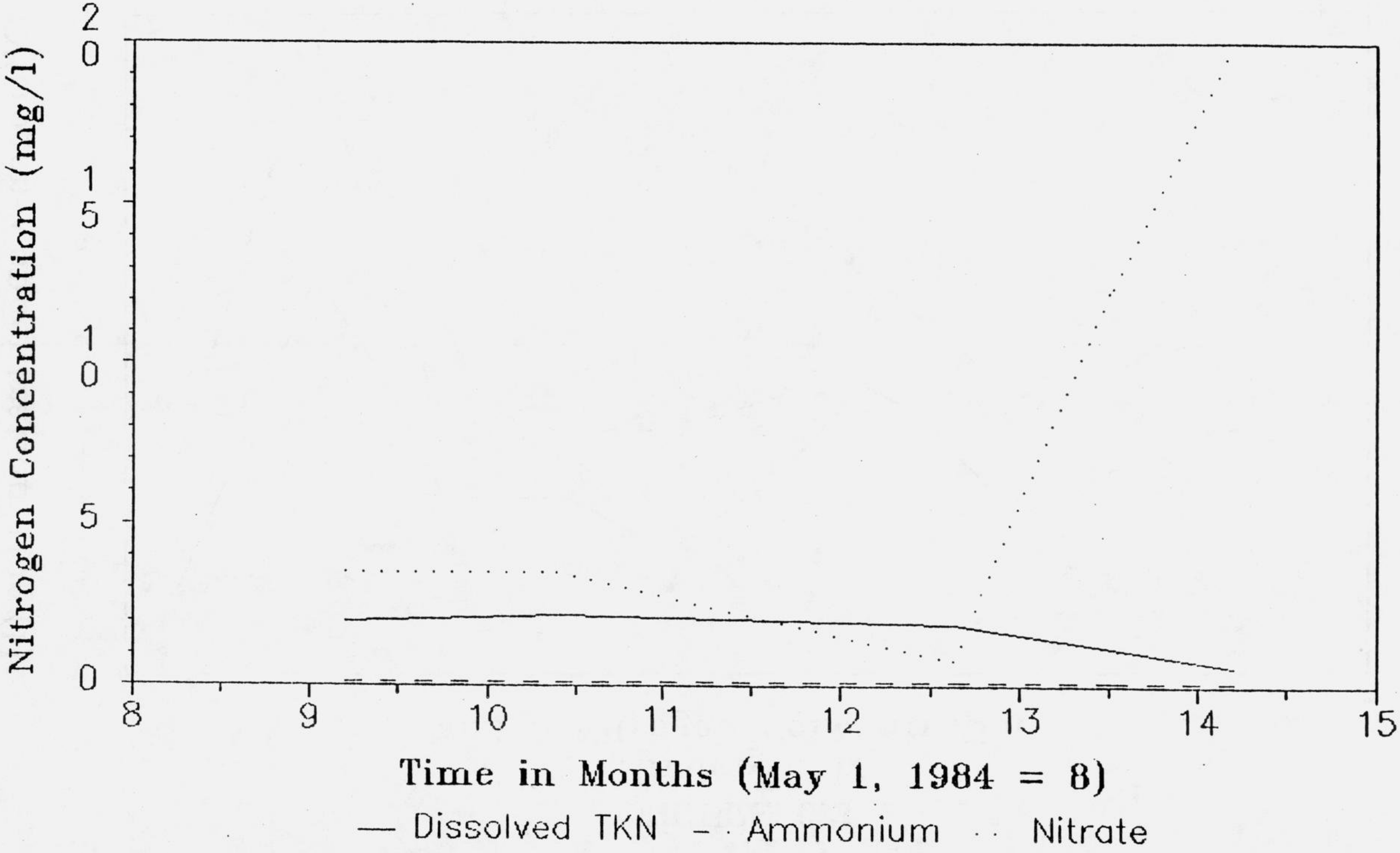
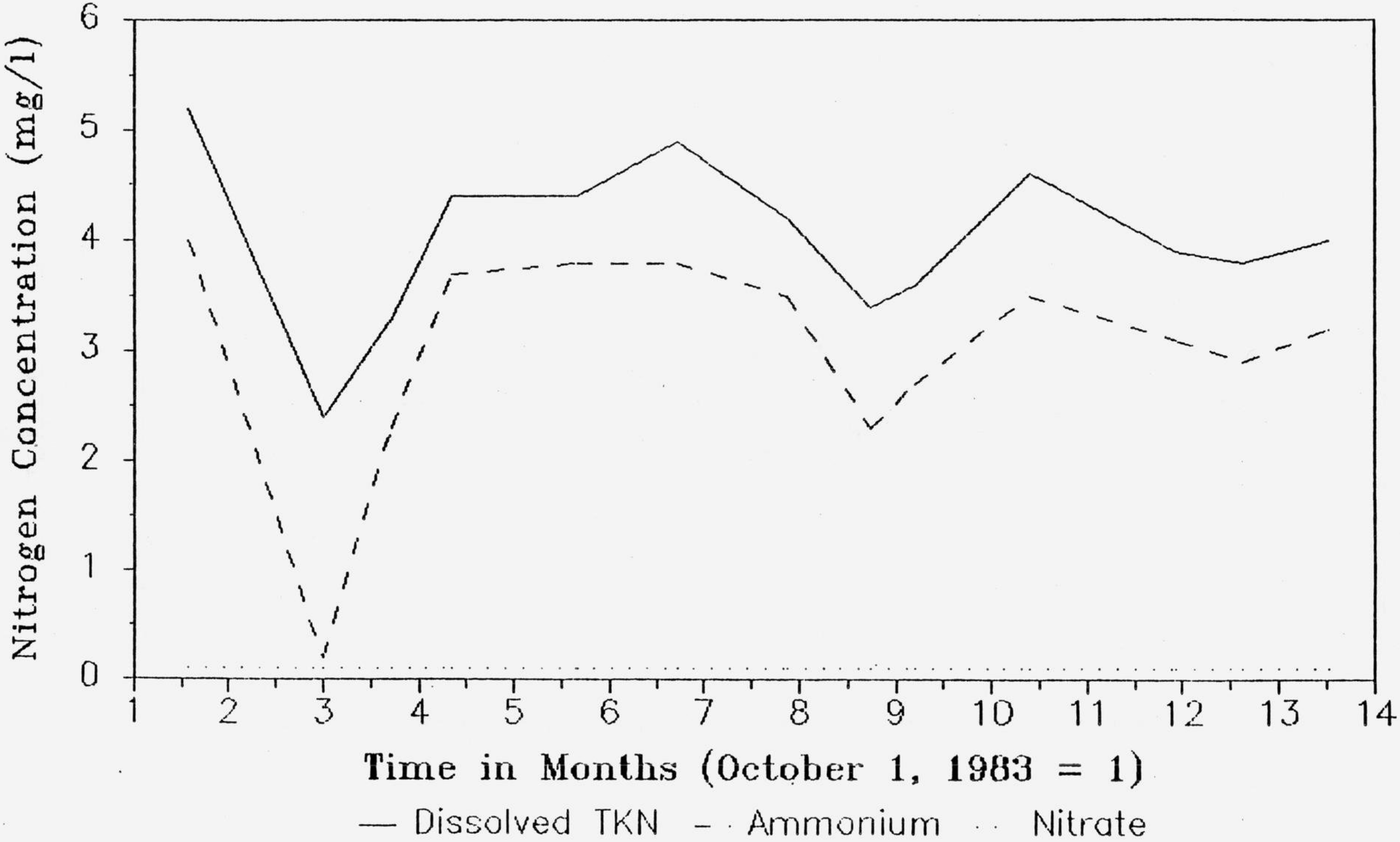


FIGURE 6.3
Mindoro Site
Well 5 Nitrogen Concentrations



at both sites contained 54 to 100% ammonium. The literature in Chapter 2 stated that mineralization was favored at C:N ratios below 20 to 30:1. For wastewater, this ratio was represented by the ratio BOD_5:TKN (EPA, 1975). The BOD_5:TKN ratios in this project were 42:1 and 26:1 for the Brodhead and Mindoro wastewater, respectively. The Brodhead C:N ratio was high but furrow samples had BOD_5:TKN ratios ranging from 21 to 34:1, which would promote mineralization. Furrow wastewater pH values were not condusive to ammonia volatilization.

As ammonium infiltrated the unsaturated zone, it was aerated to nitrate at both sites. This transformation occured between lysimeters 1 and 2 (or 1 and 3 feet depth) underneath cell 1 at Brodhead, between the furrow and the water table (or 0 and 5.5 feet depth) underneath cell 2 at Brodhead, and the upper few feet of the unsaturated zone at Mindoro. Tables 4.7 and 5.8 and Figures 4.26, 4.27, 4.31, 4.32, 4.33, 6.1, 6.2, and 4.12 illustrate this change.

This nitrate denitrified to nitrogen gas (NO, N_2O, or N_2) as the percolate ecountered anaerobic microzones in the unsaturated zone at both ridge and furrow sites. This transformation was verified by observing nitrate decreases between lysimeters 2 and 3 (between 3 and 4.8 feet depth) beneath cell 1 at Brodhead, between lysimeter 6 and well 15 (between 3.6 and 5.5 feet depth) in November (1984) at Brodhead, and between the shallow lysimeters (L325 and L415) and the water table at Mindoro. These changes were illustrated in Tables 4.7 and 5.8 and Figures 4.27, 4.28, 4.33, 4.12, 6.1, 6.2, and 6.3. As mentioned in

Chapter 4, well 17 nitrogen concentrations did not reflect recent well 1 nitrification or denitrification due to the slow groundwater velocities. Ammonium concentrations averaged 30 mg/l in this well.

It should finally be noted that the nitrogen transformations were quite dynamic at Brodhead. Nitrogen species in certain lysimeters or wells did not remain consistantly nitrate or consistantly ammonium during the project. Data from lysimeter 2, lysimeter 3, and well 15 were good examples (Figures 4.27, 4.28, 4.12). During the late summer (1984), nitrogen values switched from being mainly ammonium to being mainly nitrate in these lysimeters. In well 15 ammonium concentrations increased dramatically in late summer (1984). This was followed by a dramatic rise in nitrate values, with concurrent ammonium decreases in October (1984). Nitrate decreases in November (1984) subsequently followed. Such radical changes were not observed at Mindoro.

The dynamic nature of nitrogen transformations was most likely the result of the load/rest cycle. Nitrate production was encouraged by soil aeration during resting and inhibited by cell overloading. These transformations or increases/decreases could not be especially related to the load/rest cycle when comparing time concentration plots to the loading schedule, however.

Ridge and Furrow Operation and Maintenance

Operation and maintenance is an important yet often neglected aspect of a ridge and furrow treatment system. Wastewater distribution and infiltration, load/rest cycling, winter operation, and annual cover crop burning are all aspects of operation and maintenance which influence wastewater treatment and disposal.

Wastewater distribution at the Brodhead site was complete, meaning that all cell furrows received waste during a loading cycle. This allowed for even distribution of liquid and centaminants over the entire site area which improved the hydraulic (infiltrative) capacity and contaminant reductions (eg. nitrogen reduction) of the site. Due to grass overgrowth and leaky header gates, the wastewater distribution at Mindoro was poor. Even though cell loading changes were made, the same area (0.9 acres) was loaded throughout the study. As a result, ponding of wastewater occurred in the far north and south ends of the system with other regions receiving little or no wastewater. Overloading of waste in the ponded areas reduced the soils infiltrative capacity and could also have decreased the soil's ability to reduce contaminant concentrations.

Load/rest cycling of cells at a ridge and furrow site is also an important part of system operation. It alternately aerates and deaerates the soil which stimulates nitrogen reductions by nitrification and denitrification. After strictly loading cell 1 before 1980, the Brodhead system had utilized a consistant two week load/rest pattern. This was modified during the project to determine the effect of a shorter cycle (one week beginning October 1984) on wastewater treatment in the unsaturated zone. The impact of a shorter cycle was favorable beneath cell 2 as well 15 total nitrogen concentrations decreased from almost 80 mg/l to less than 10 mg/l during October (1984). Future sampling would be needed to determine if low levels would continue or if well 15 concentrations were inherintly variable.

After November 20, 1984, the Brodhead system has been on a cycle which loads cell 1 for one week and rests it for two. Cell 2 has been operated in the opposite mode. This was done to improve the soil aeration beneath cell 1 and also improve the cell's infiltrative capacities. As mentioned in Chapter 4, the cell 1 infiltration rates were slower than those in cell 2. Improved soil aeration may cause groundwater around well 17 to nitrify as those around well 15.

The Mindoro ridge and furrow has been on a one month loading, two month resting schedule for each of its three cells. The site operator has not followed this pattern strictly, however. This, combined with the slower unsaturated flow rates and poor wastewater distribution, has resulted in the observed ponding. Following the 2/1 schedule more closely would result in better soil aeration and possibly improved contaminant reduction.

Winter operation was not a problem at the ridge and furrow sites studied. Both had wastewater effluent temperatures warm enough to melt existing ice and snow and to allow percolation into the soil. Distribution of wastewater remained excellent at Brodhead and fair at Mindoro during subzero temperatures.

Annual grass burning at ridge and furrow sites is also an important maintenance procedure at some systems and could be at other sites. Besides volatilizing cover crop nitrogen, burning clears the furrows of dead grass and enhances new spring crop growth. An 18% nitrogen loss occurred during burning at Mindoro and a possible 3% nitrogen loss could have occurred at Brodhead had the operator burned at that site. Spring burning of grass is recommended for all sites where it is feasible.

System Performance

When comparing downgradient contaminant concentrations at both sites, the Mindoro ridge and furrow system appeared to impact groundwater quality less than the Brodhead system. Downstream wells at Brodhead contained total nitrogen concentrations greater then 10 mg/l on average. This nitrogen was also in NH_4^+-N form. Nitrogen concentrations averages in downstream wells at Mindoro were consistantly below 5 mg/l. These downgradient values do not provide the complete picture however. Brodhead concentrations in wells 10A, 10B, and 14 were indicative of past use. Loading changes made during the course of this project would not be reflected in these wells until the spring of 1987 due to the travel times involved.

During this study, nitrogen and COD reductions in the unsaturated zone, as demonstrated by nitrogen budgets and data comparisons (Tables 6.1 and 6.2), were similar at Brodhead and Mindoro. The percentage of applied wastewater nitrogen leached was the major difference in the unsaturated zone treatment provided at these sites. At Brodhead, 34% of applied -N was leached; at Mindoro, 13% of applied -N was leached. This difference was attributed to the different soil types at the respective sites. At Brodhead, the sandy soil allowed for faster unsaturated travel times. This limited the available nitrification and denitrification time which allowed ammonium and nitrate to reach the groundwater only partially treated. Uniform wastewater distribution and proper load/rest operation were critical to treatment at Brodhead to keep the soil alternately aerated and deaerated. Considering the infiltrative capacities of cell 1 and cell 2, the 2 week cell 2 loading followed by a 1 week cell 1 loading would optimize nitrogen and COD reduction at Brodhead. Higher nitrate concentrations in lysimeters 5 and 6 and well 15 could be reduced if cell 2 received a longer loading; high ammonium values in well 17 could be nitrified if cell 1 underwent a longer resting period.

The Mindoro site provided good treatment of wastewater nitrogen even though flow distribution and load/rest operation were poor. The silty loam soil, with its slower unsaturated and saturated zone travel times, overcame these operational problems. Better treatment could have been obtained with improved distribution and a strict load/rest cycle.

In general, nitrogen reductions at ridge and furrow sites are dependent on the soils infiltrative capacity, the wastewater distribution efficiency, and the load/rest cycle.

CHAPTER 7: CONCLUSIONS

The following were conclusions of the ridge and furrow study at Brodhead and Mindoro:

1) Sixty-six to 69% nitrogen losses were observed in nitrogen budgets around the unsaturated zone at both sites. These were attributed to denitrification. Leaching accounted for the fate of 34% and 13% of applied nitrogen at Brodhead and Mindoro, respectively. Plant uptake losses accounted for 0% and 18% at Brodhead and Mindoro, respectively. These budgets are summarized in Table 7.1.

2) Since nitrification occurred in the unsaturated zone at each site, it was concluded that the BOD_5 wastewater loading did not place an oxygen demand high enough to inhibit this transformation.

3) Actual COD (after dilution) reduction in the unsaturated zone ranged from 41-82% at Brodhead and 52-89% at Mindoro.

4) Nitrogen and COD reductions were dependent on infiltrative capacity, which affected travel times, wastewater distribution efficiency, and the load/rest cycle. The distribution and load/rest cycling were more critical at Brodhead, where unsaturated zone flow times were fast (three days).

5) The wastewater nitrogen applied at both sites was mainly in organic-N form. Much of this organic-N was contained in the suspended solids of the wastewater and settled in furrows upon loading. This organic-N then ammonified to dissolved ammonium and diffused into the overlying furrow wastewater.

TABLE 7.1

SUMMARY OF RIDGE AND FURROW

NITROGEN BUDGETS

	BRODHEAD			MINDORO		
	lb/yr	lb/acre/yr*	%	lb/yr	lb/acre/yr*	%
Total N Loading	5375	1144	100	1381	1534	100
Losses Due to						
Denitrification	3529	751	66	954	1060	69
Leaching	1845	392	34	175	193	13
Plant Uptake	0	0	0	252	280	18

*Areas: Brodhead - 4.7 acres

Mindoro - 0.9 acres

6) Dissolved ammonium was the primary form of nitrogen in the furrow wastewater. As this percolated into the unsaturated zone, nitrification occurred within 3 feet (cell 1) and 3.6 feet (cell 2) at Brodhead and 1.5 feet at Mindoro. Denitrification of this nitrate was observed below 3 feet depth (cell 1) and 3.6 feet depth (cell 2) at Brodhead and through the entire unsaturated profile at Mindoro.

7) In order to meet a 5 mg/l total nitrogen arbitrary increase above background quality in the groundwater immediately beneath the ridge and furrow systems, it was determined that Brodhead's wastewater nitrogen loading rate be reduced to 384 lb N/acre/year (1.05 lb N/acre/day) on a percent basis and 879 lb N/acre/year (2.4 lb N/acre/day) on a denitrification rate basis. Mindoro's present 1534 lb N/acre/year (4.3 lb N/acre/day) was adequate.

8) No surface water contamination resulted from operation of these ridge and furrow systems.

9) Winter operation at ridge and furrow systems is possible if effluent temperatures are warm.

10) Spring burning of grass removed a significant portion of applied nitrogen at Mindoro (18%) and also stimulated new growth.

CHAPTER 8: RECOMMENDATIONS

The following recommendations were based on results of the ridge and furrow study at Brodhead and Mindoro:

1) Continued research at Brodhead should be done to:

   a) better determine whether loading changes impacted the groundwater quality or whether the dynamic nature of concentrations occur every year by sampling wells 10A, 10B, 14, and 15 and lysimeters 1, 2, 3, 5, and 6 twice a year,

   b) better quantify unsaturated flow times by installing tensionmeters (or some other appropriate method), and

   c) evaluate the sinking contaminant plume by installing a deep well in the location of well 14, which would be sampled twice annually.

2) The factories should meet the suggested nitrogen loading rates, on average, to reduce or maintain groundwater nitrogen concentrations.

3) Wastewater pretreatment at Brodhead would reduce solids accumulation in the furrows and lower the amount of applied nitrogen. Changes inside the plant could also be made to reduce the amount of lost product.

4) The chloride concentrations in the Brodhead wastewater should be reduced by brine removal in the plant to reduce groundwater chloride values.

5) Annual spring grass burning is suggested for all ridge and furrow systems where it is feasible.

6) An improved lysimetry method is necessary to obtain a more "instantaneous" sample and to allow for winter sampling.

7) A downstream well nest should be installed at Mindoro to better define the movement of contaminants off-site.

Appendix A1: List of References

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APPENDIX A

BRODHEAD:

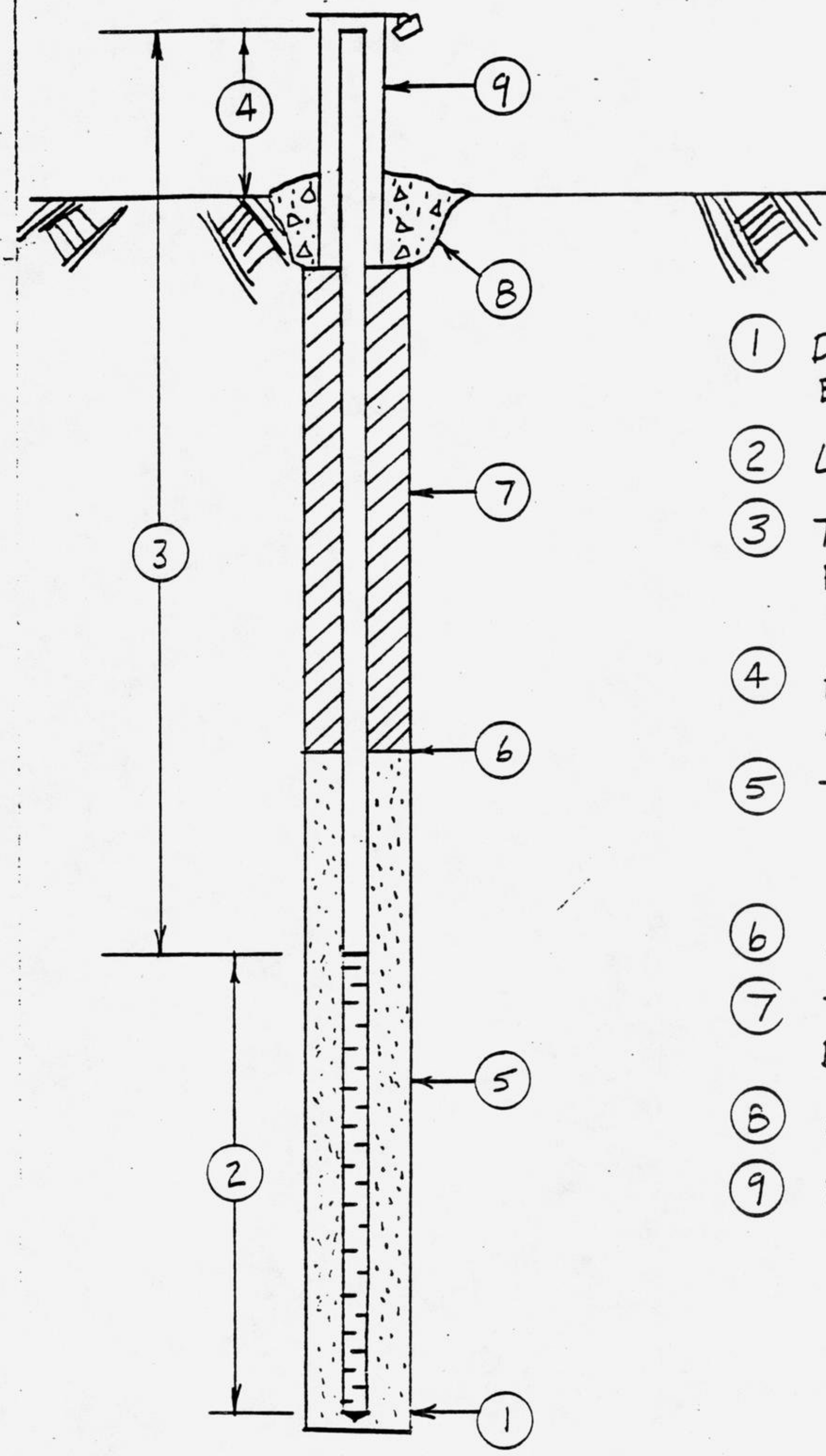
WELL AND LYSIMETER LOGS

WELL DETAIL INFORMATION

BRODHEAD SITE
WELL # 10A (SHALLOW, NORTH OF SYSTEM, MIDWAY)
DRILLED 8/30/83

SCALE: 1" = 2'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE

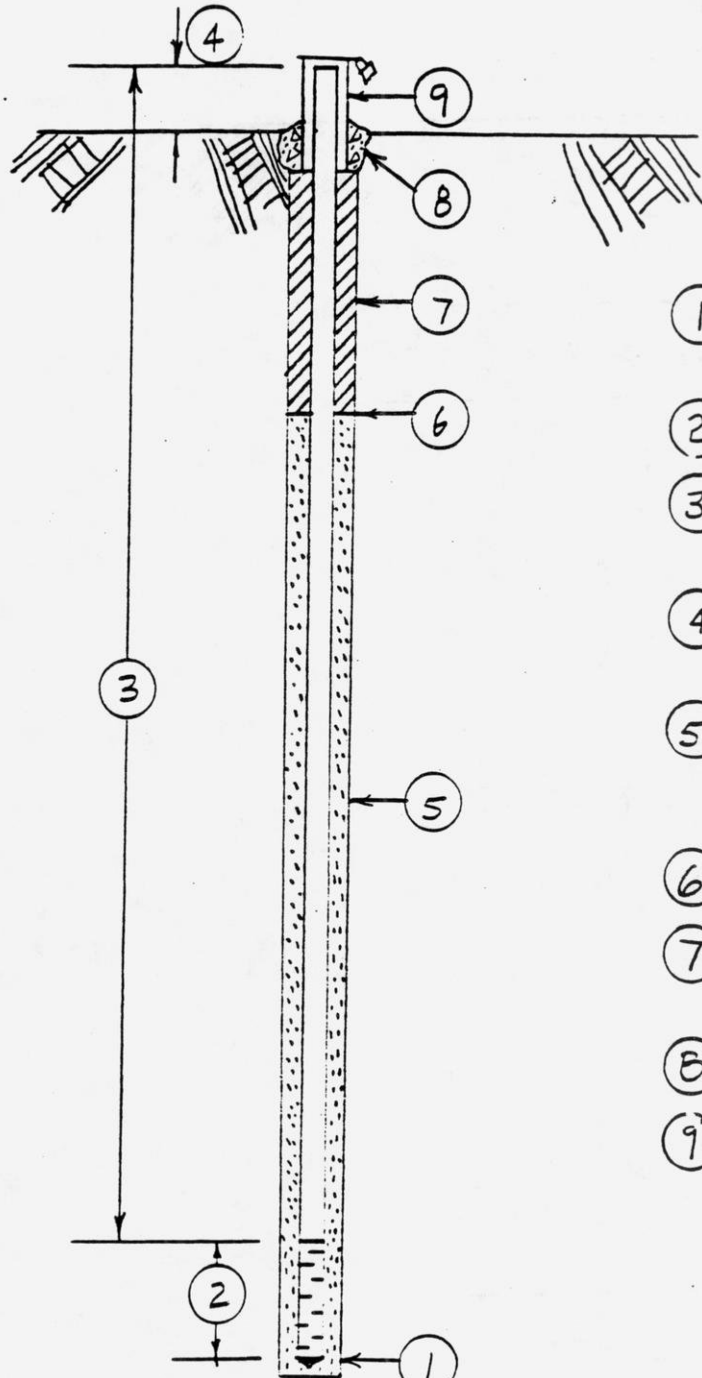


1. DEPTH TO BOTTOM OF BORE HOLE, 13.2'
2. LENGTH OF WELL SCREEN, 5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 10' @ 2" INSIDE DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 1.8'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE.
6. DEPTH OF SEAL, 6'
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

WELL DETAIL INFORMATION

BRODHEAD SITE
WELL #10B (DEEP, NORTH OF SYSTEM, MIDWAY)
DRILLED 8/30/83

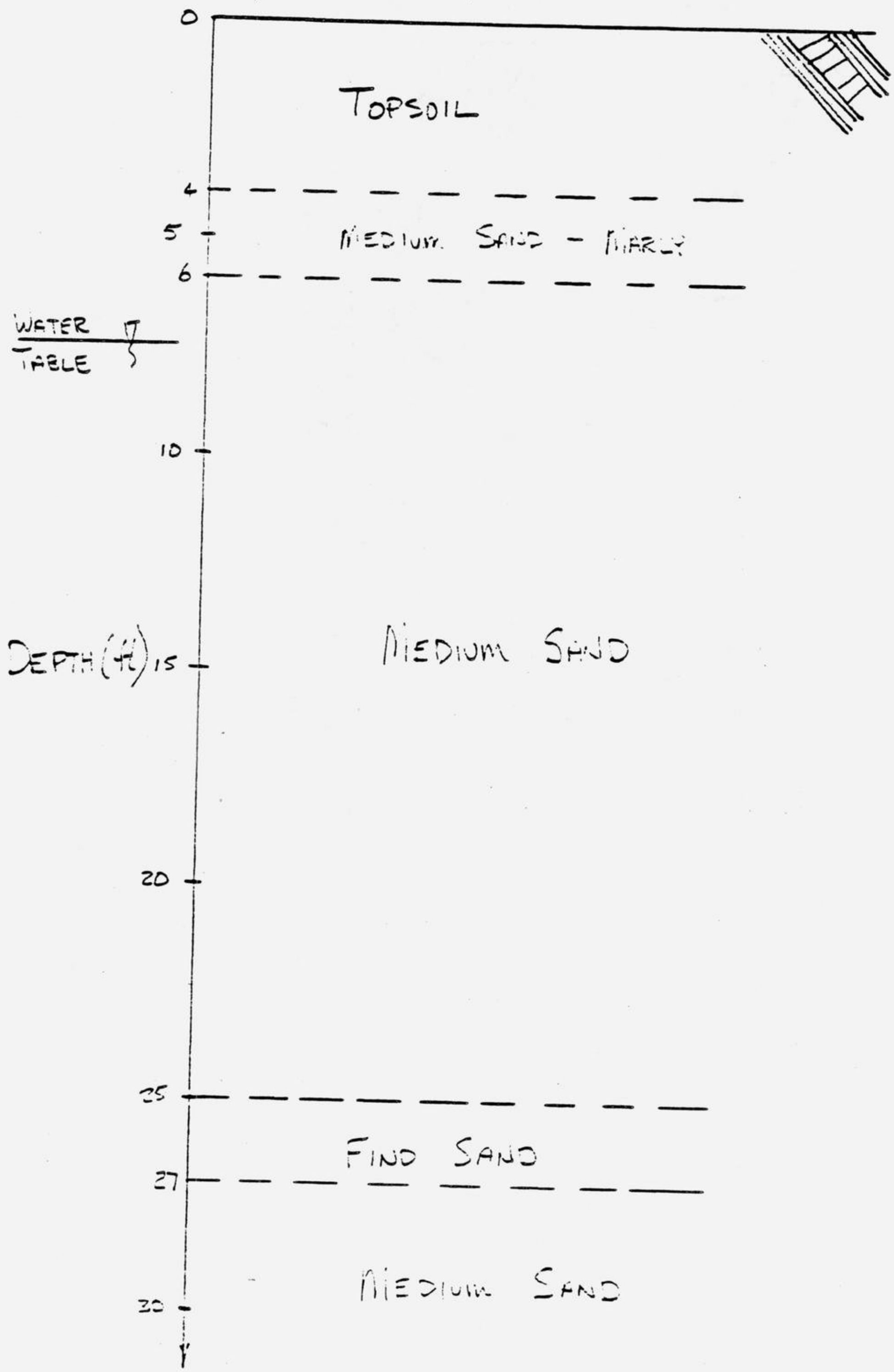
SCALE: 1" = 4' * ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



1. DEPTH TO BOTTOM OF BOREHOLE, 26.2'
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 25' @ 2" INSIDE DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 1.3'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE
6. DEPTH OF SEAL, 6'
7. TYPE OF BACKFILL, BENTONITE AND SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

SOIL PROFILE SCALE: 1" = 4'

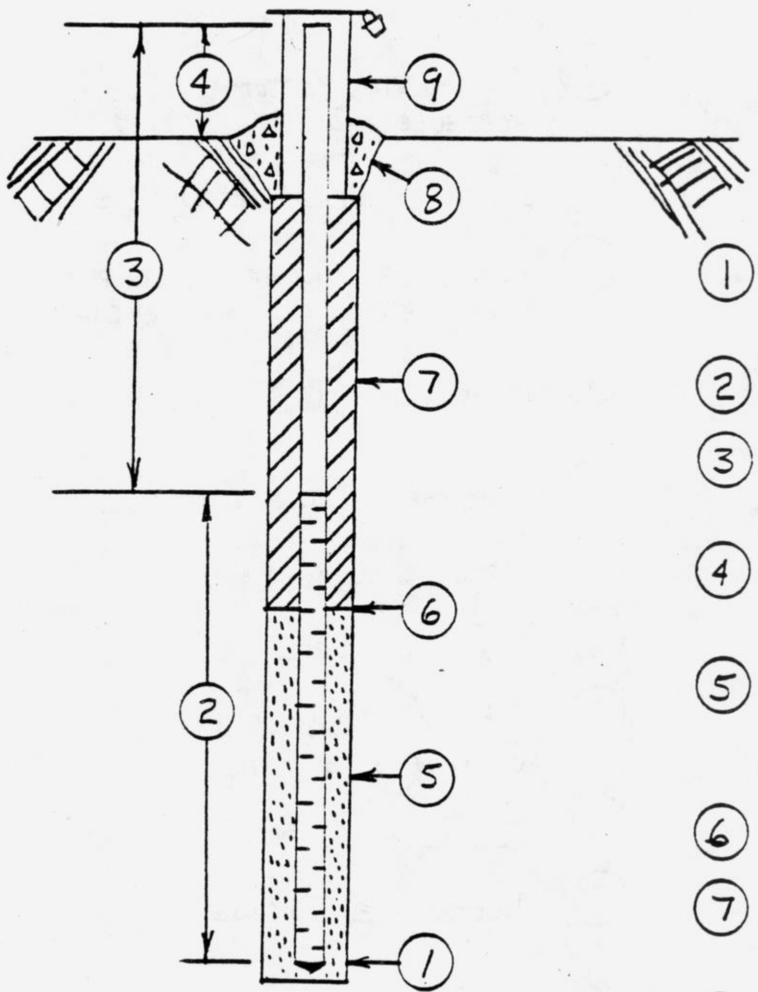
BRODHEAD SITE
WELL #10 A, #10B
DRILLED 8/30/83



WELL DETAIL INFORMATION

BRODHEAD SITE
WELL #11A (SHALLOW, NE OF SYSTEM)
DRILLED 8/30/83

SCALE: 1" = 2' * ALL DEPTH MEASUREMENTS FROM GROUND SURFACE

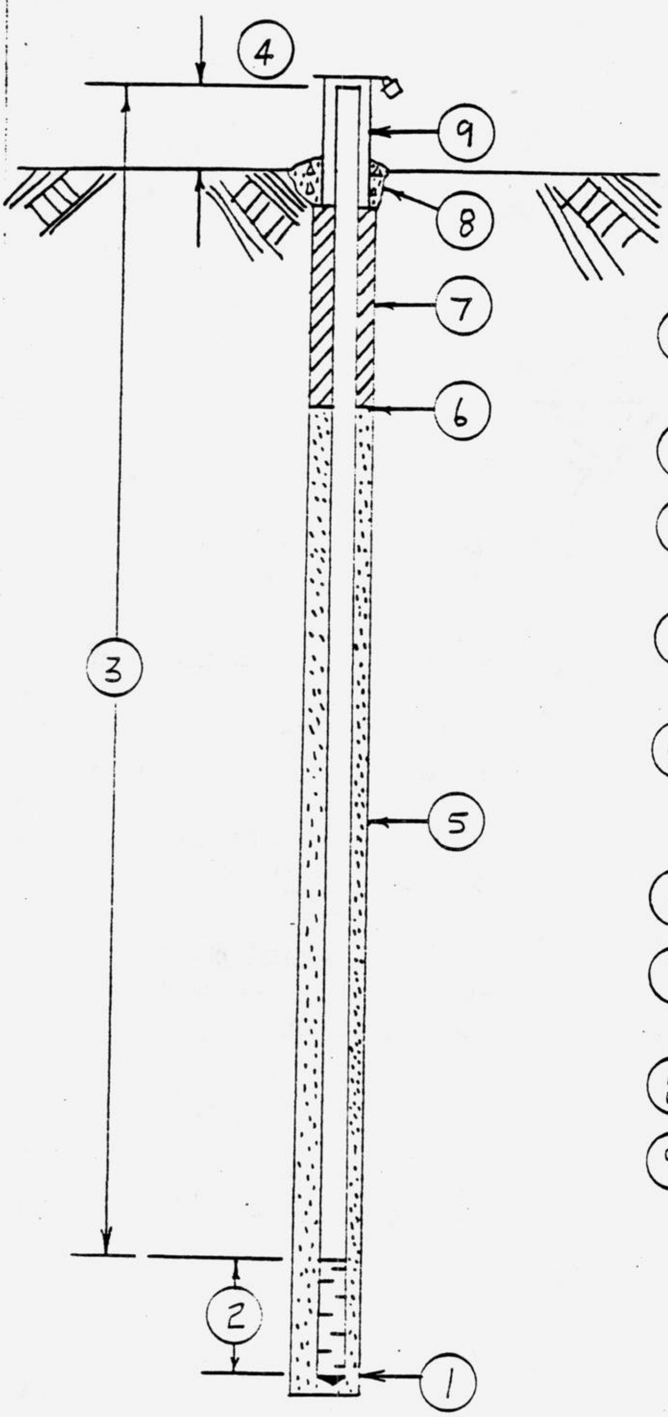


1. DEPTH TO BOTTOM OF BOREHOLE, 8.5'
2. LENGTH OF WELL SCREEN, 5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 5' @ 2" INSIDE DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 1.2'.
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE
6. DEPTH TO SEAL, 5'
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

WELL DETAIL INFORMATION

BRODHEAD SITE
WELL # 11B (DEEP, NE OF SYSTEM)
DRILLED 8/30/83

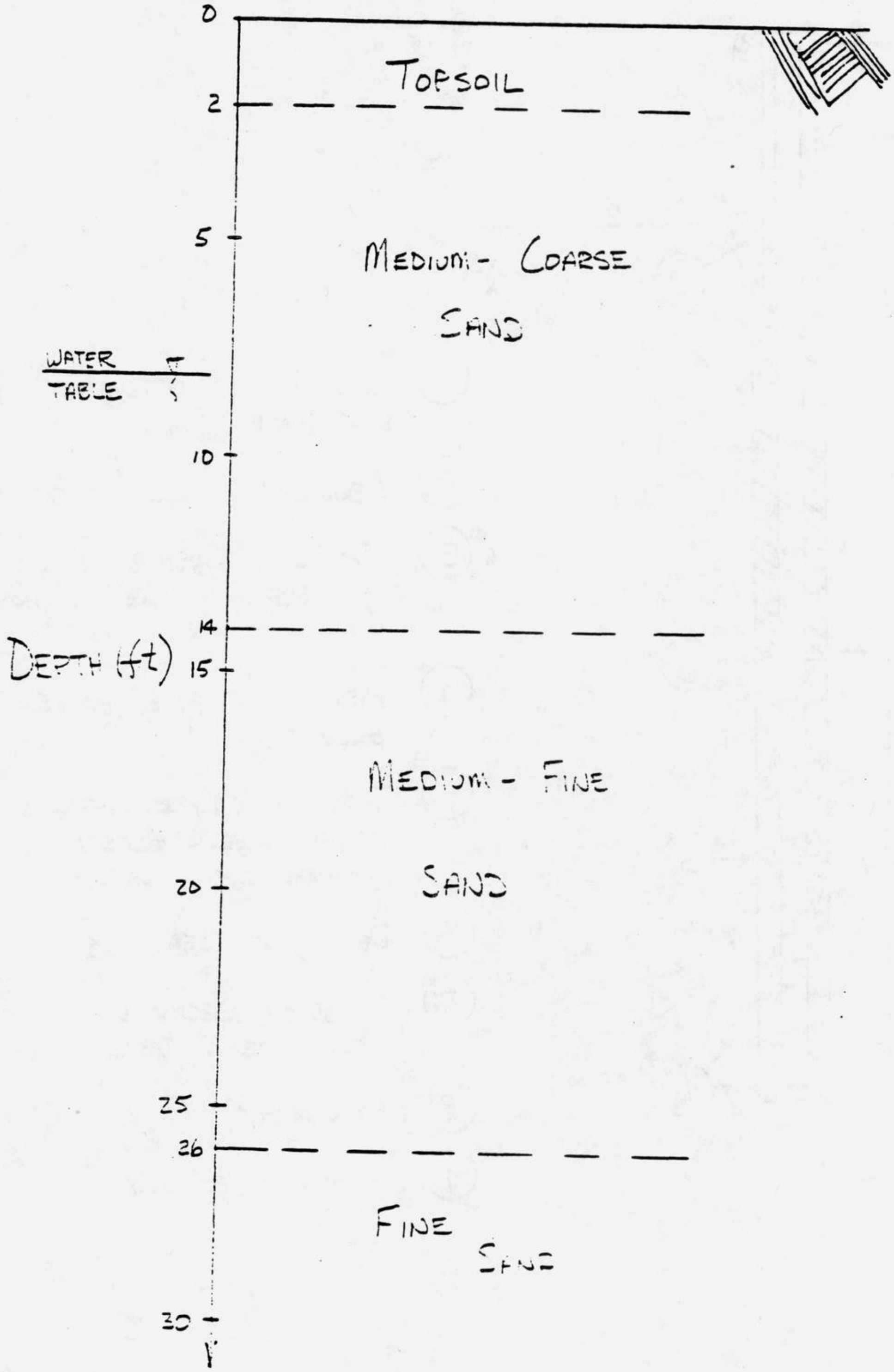
SCALE: 1" = 4' * ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



1. DEPTH TO BOTTOM OF BOREHOLE, 24.0'
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 23.3' @ 2" INSIDE DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 1.8'.
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE
6. DEPTH OF SEAL, 5'.
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

Soil Profile Scale: 1" = 4'

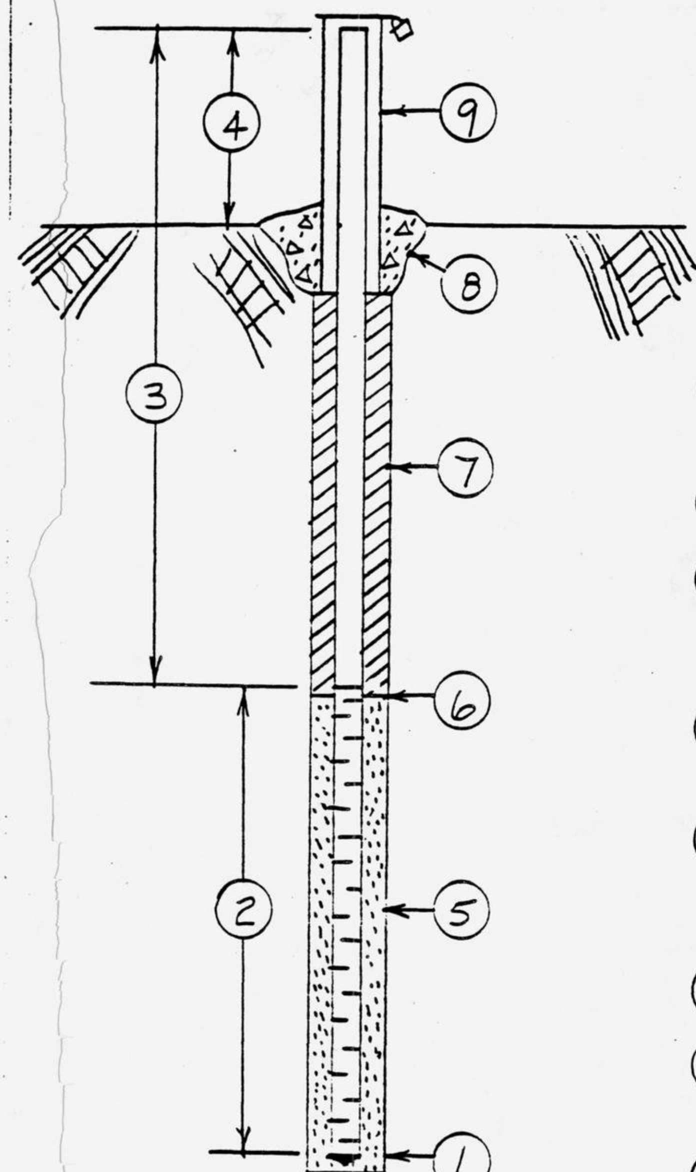
Brodhead Site
Well # 11A, #113
Drilled 8/30/83



WELL DETAIL INFORMATION

BRODHEAD SITE
WELL # 12A (SHALLOW, NW OF SYSTEM, BACKGROUND)
DRILLED 8/30/83

SCALE: 1" = 2' * ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



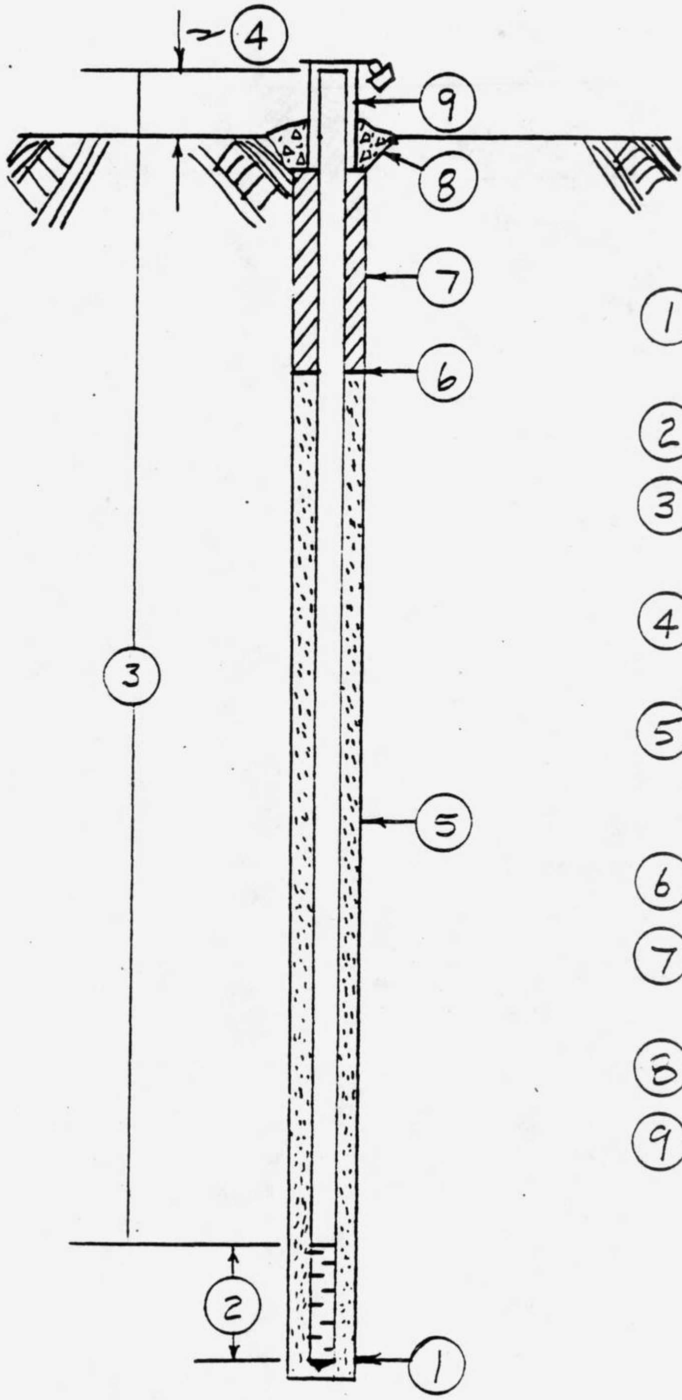
1. DEPTH TO BOTTOM OF BOREHOLE, 9.9'.
2. LENGTH OF WELL SCREEN, 5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 7' @ 2" INSIDE DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 2.1'.
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE
6. DEPTH OF SEAL, 5'.
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

WELL DETAIL INFORMATION

BRODHEAD SITE
WELL #12B (DEEP, NW OF SYSTEM, BACKGROUND)
DRILLED 8/30/83

SCALE: 1" = 4'

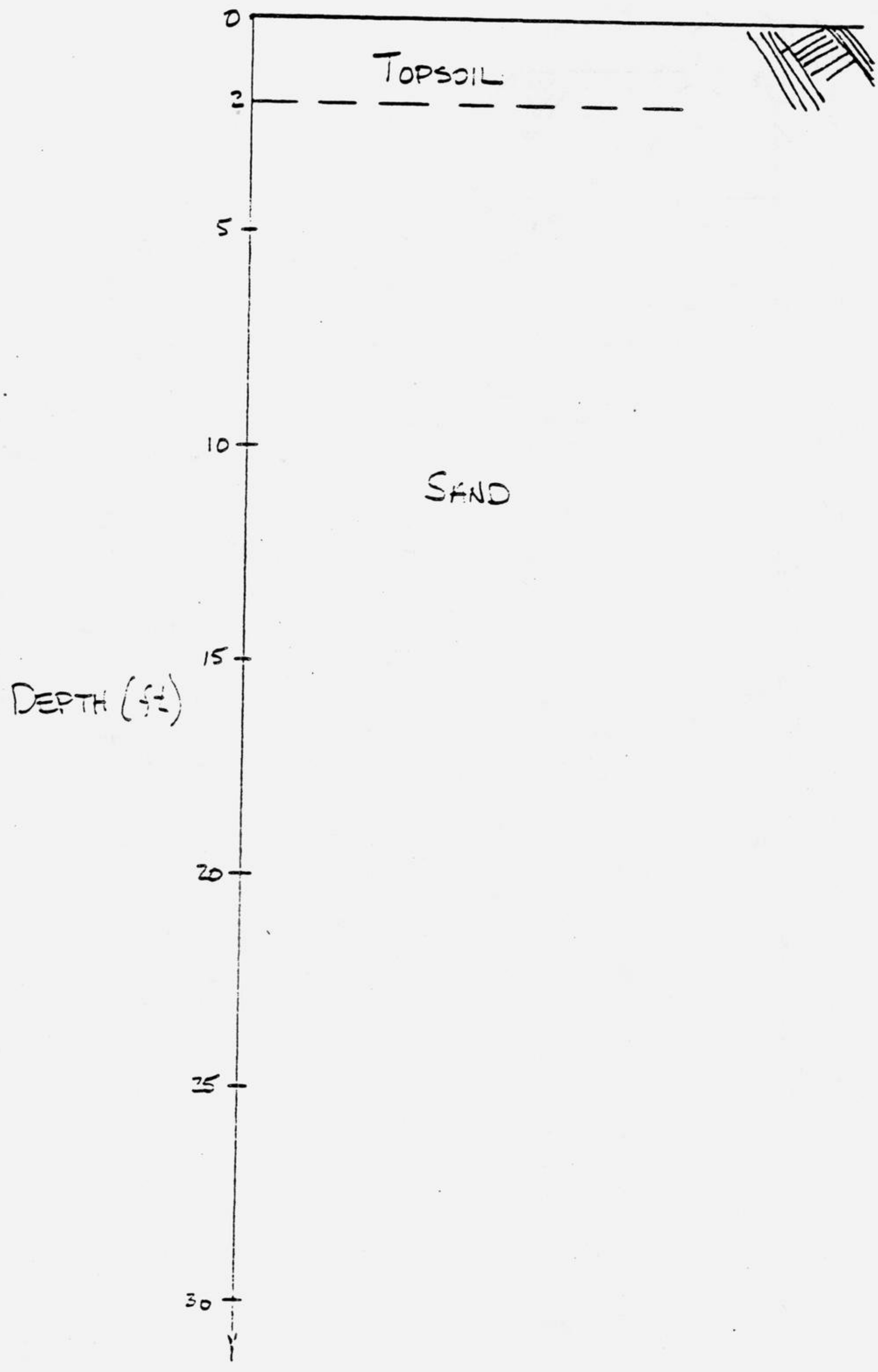
* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



1. DEPTH TO BOTTOM OF BOREHOLE, 26.1'.
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 25' @ 2" INSIDE DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 1.4'.
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE
6. DEPTH OF SEAL, 5'.
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

SOIL PROFILE | SCALE ' = 4'

BRODHEAD SITE
WELL #12A #123
DRILLED 5/30/83

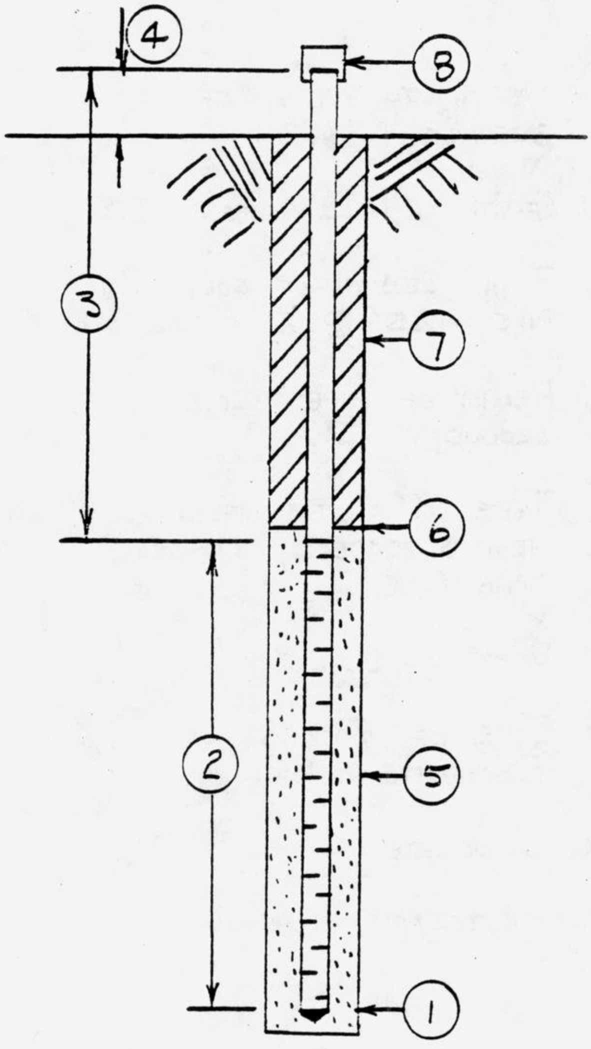


WELL DETAIL INFORMATION

BRODHEAD SITE
WELL #13A (SHALLOW, SE OF SYSTEM)
DRILLED 8/30/83

SCALE : 1" = 2'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



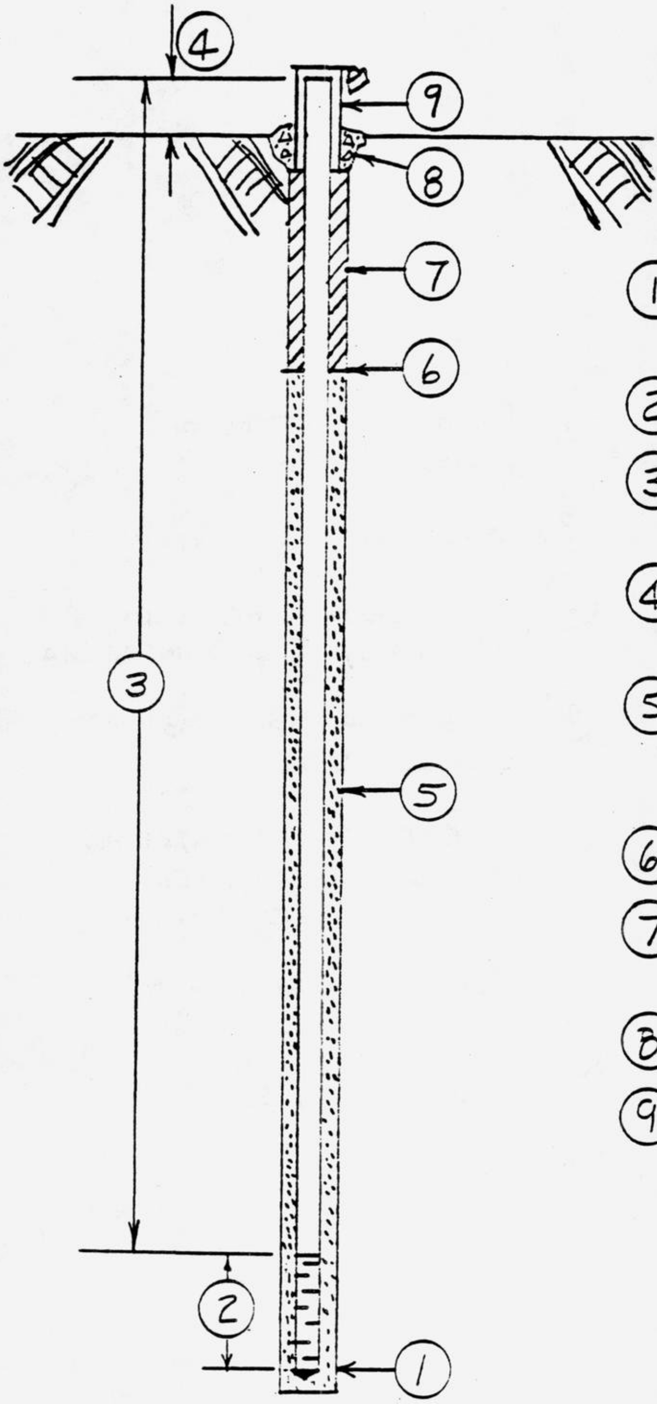
1. DEPTH TO BOTTOM OF BOREHOLE, 9.3'
2. LENGTH OF WELL SCREEN, 5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 5' @ 2" INSIDE DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 0.7'.
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE
6. DEPTH OF SEAL, ~4'
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. PROTECTIVE CAP

WELL DETAIL INFORMATION

BRODHEAD SITE
WELL # 13B (DEEP, SE OF SYSTEM)
DRILLED 8/30/83

SCALE: 1" = 4'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE

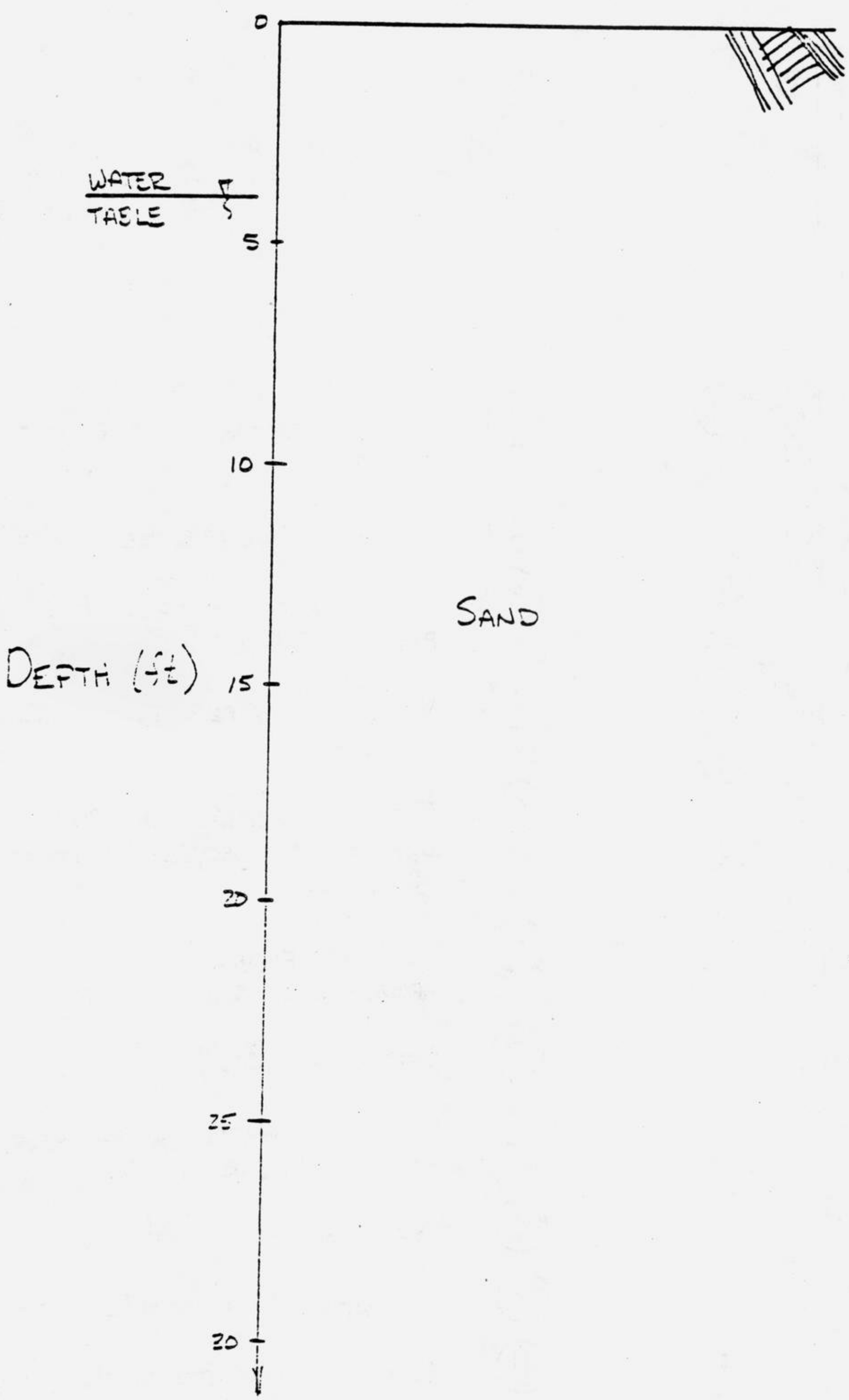


1. DEPTH TO BOTTOM OF BOREHOLE, 26.3'.
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 25' @ 2" INSIDE DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 1.2'.
5. TYPE OF FILTER MATERIAL AROUND SCREEN, NATURAL SAND CAVE
6. DEPTH OF SEAL, 5'
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

SOIL PROFILE | SCALE: 1" = 4'

BRODHEAD SITE
WELL #13A, #13B
DRILLED 8/30/83

* NOTE: NO TOPSOIL

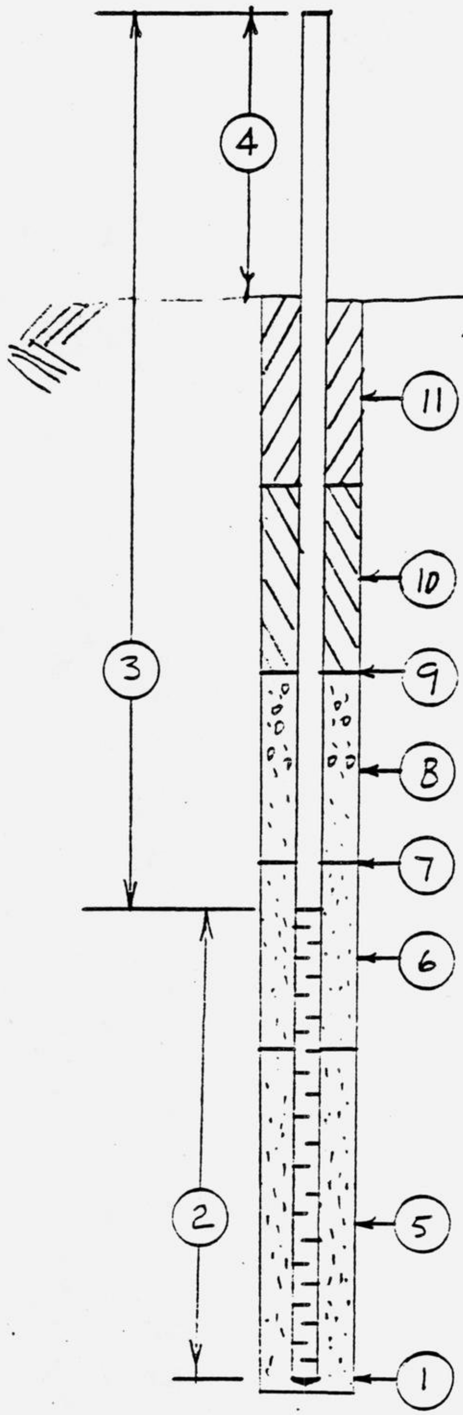


WELL DETAIL INFORMATION

BRODHEAD SITE
WELL # 14 (SHALLOW, DOWN GRADIENT PLUME WELL NEAR SUGAR RIVER)
DRILLED 3/20/84

SCALE: 1" = 1'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



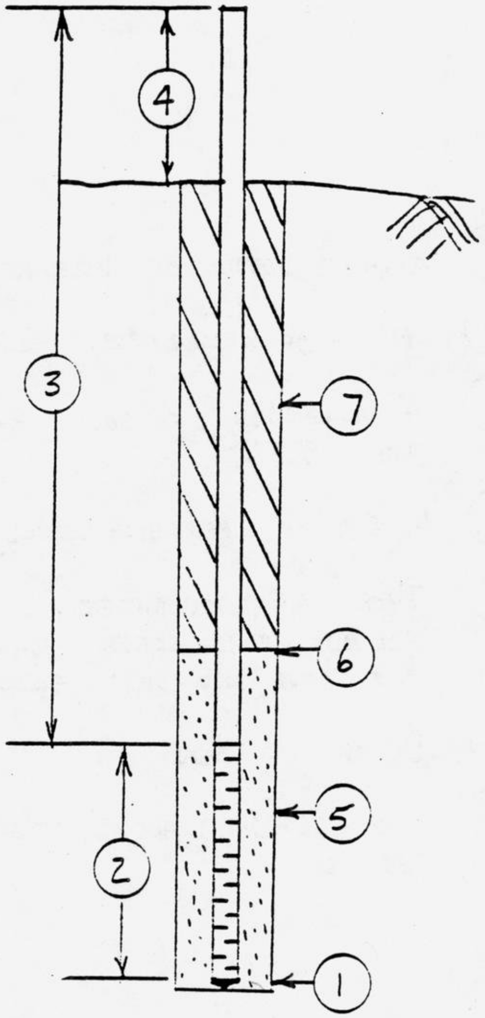
1. DEPTH TO BOTTOM OF BOREHOLE, 5.75'
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 4.79'
4. HEIGHT OF PIPE ABOVE GROUND, 1.54'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE
6. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, SILICA SAND
7. DEPTH OF SEAL, 3'
8. NATURAL SAND BACKFILL WITH BENTONITE NEAR TOP
9. DEPTH OF SEAL, 2'
10. BENTONITE WITH NATURAL TOPSOIL
11. TOPSOIL WITH BENTONITE

WELL DETAIL INFORMATION

BRODHEAD SITE
WELL #15 (SHALLOW, IN CELL #2 NEAR NE HEADER)
DRILLED 3/20/84

SCALE 1" = 2'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



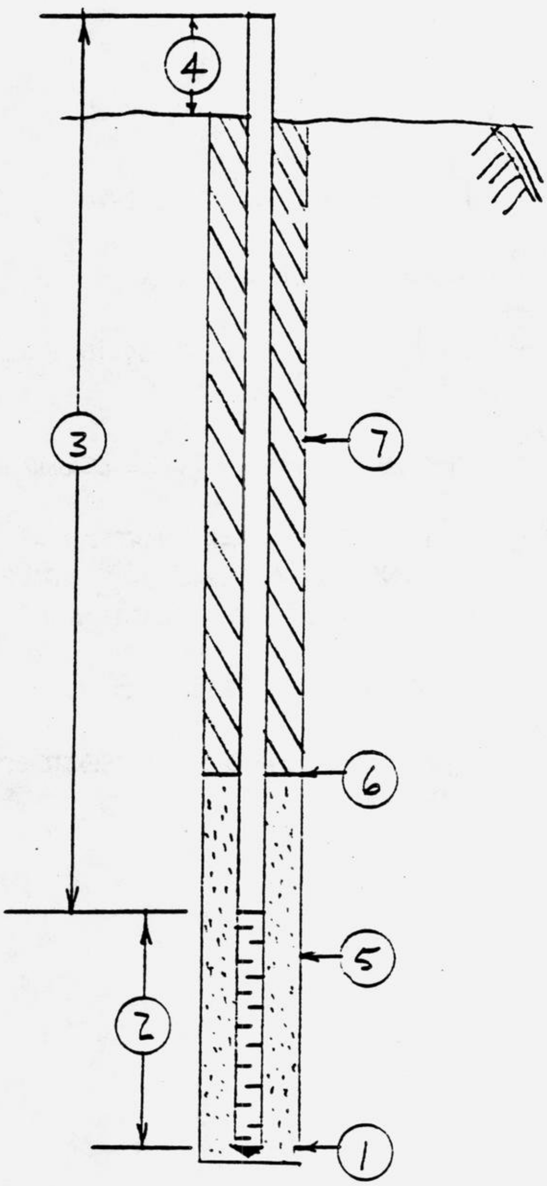
1. DEPTH TO BOTTOM OF BOREHOLE, 8.5'
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 7.85'
4. HEIGHT OF PIPE ABOVE GROUND, 1.85'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE AND SILICA SAND
6. DEPTH OF SEAL, 5'
7. NATURAL SAND AND BENTONITE BACKFILL

WELL DETAIL INFORMATION

BRODHEAD SITE
WELL #16 (SHALLOW, ON SOUTH BERM, SE CORNER OF SYSTEM)
DRILLED 3/20/84

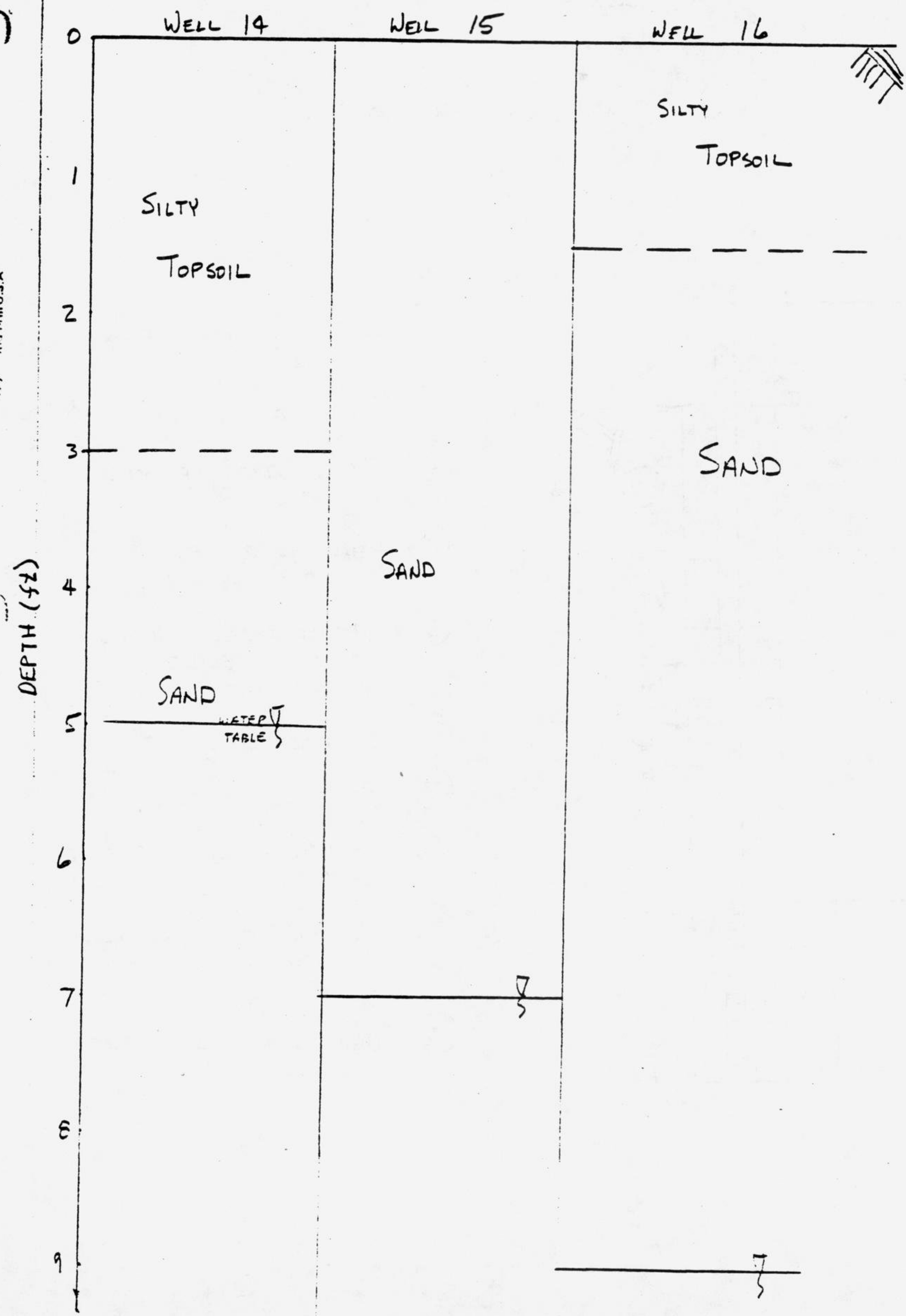
SCALE 1" = 2'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



1. DEPTH TO BOTTOM OF BOREHOLE, 11'
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 9.56'
4. HEIGHT OF PIPE ABOVE GROUND, 1.06'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE AND SILICA SAND
6. DEPTH OF SEAL, 7'
7. NATURAL SAND AND BENTONITE BACKFILL

SOIL PROFILE SCALE: 1" = 1' WELLS 14, 15, 16 DRILLED 3/20/84

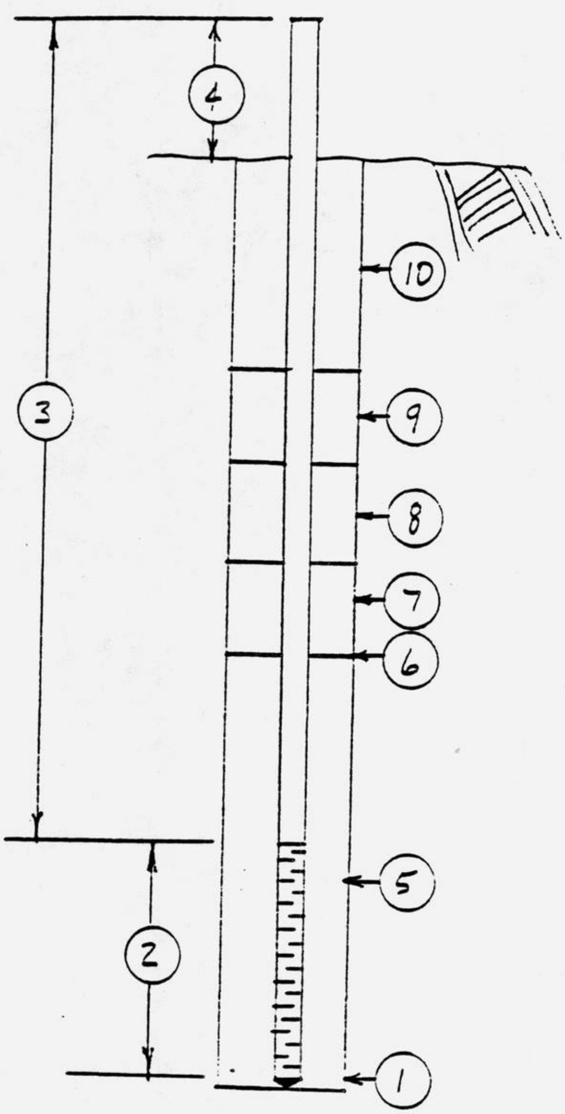


WELL DETAIL INFORMATION

BRODHEAD SITE
WELL #17 (SHALLOW, LOCATED NEAR LYSIMETERS IN CELL 1)
DRILLED 10/10/84

SCALE: 1" = 2'

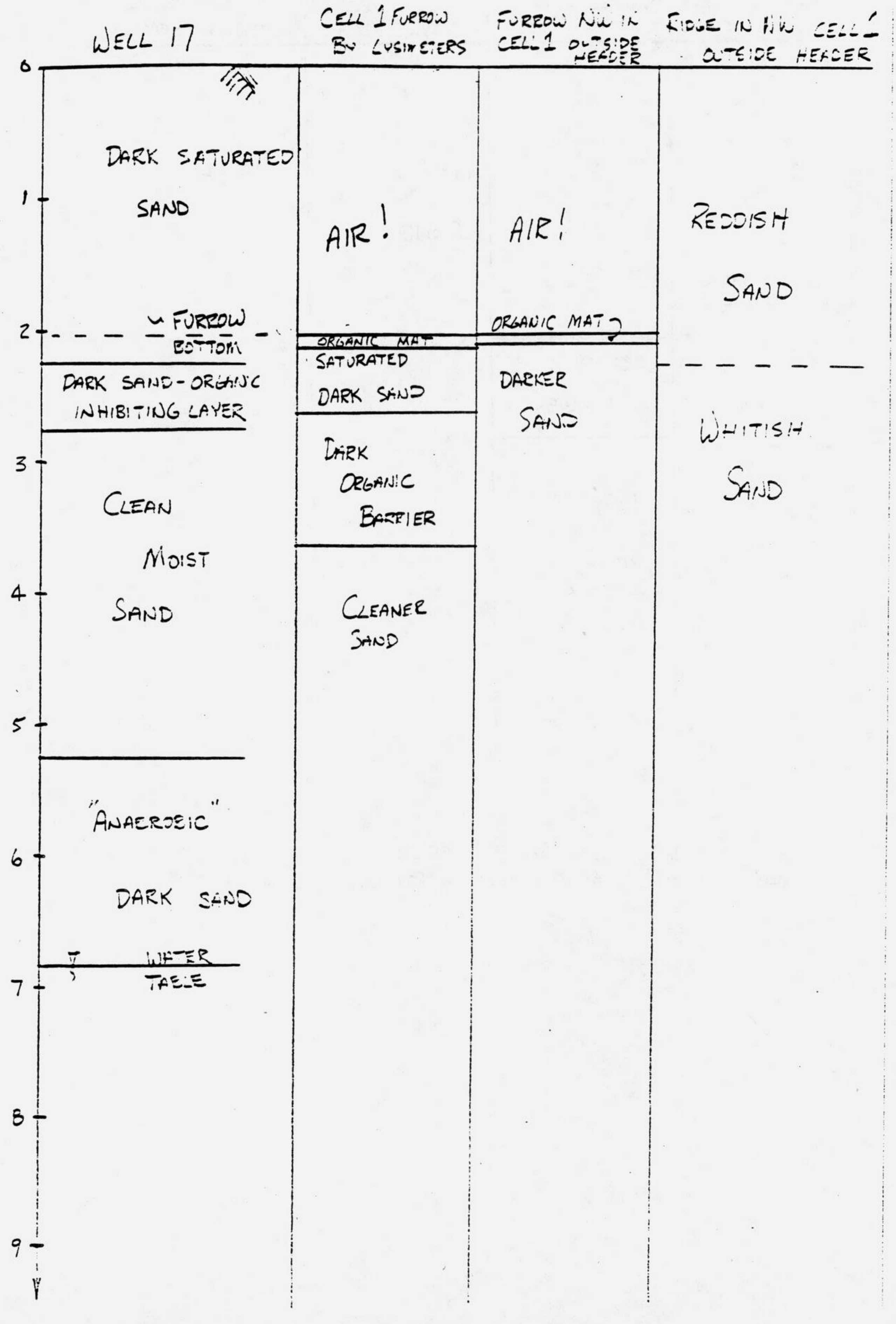
* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



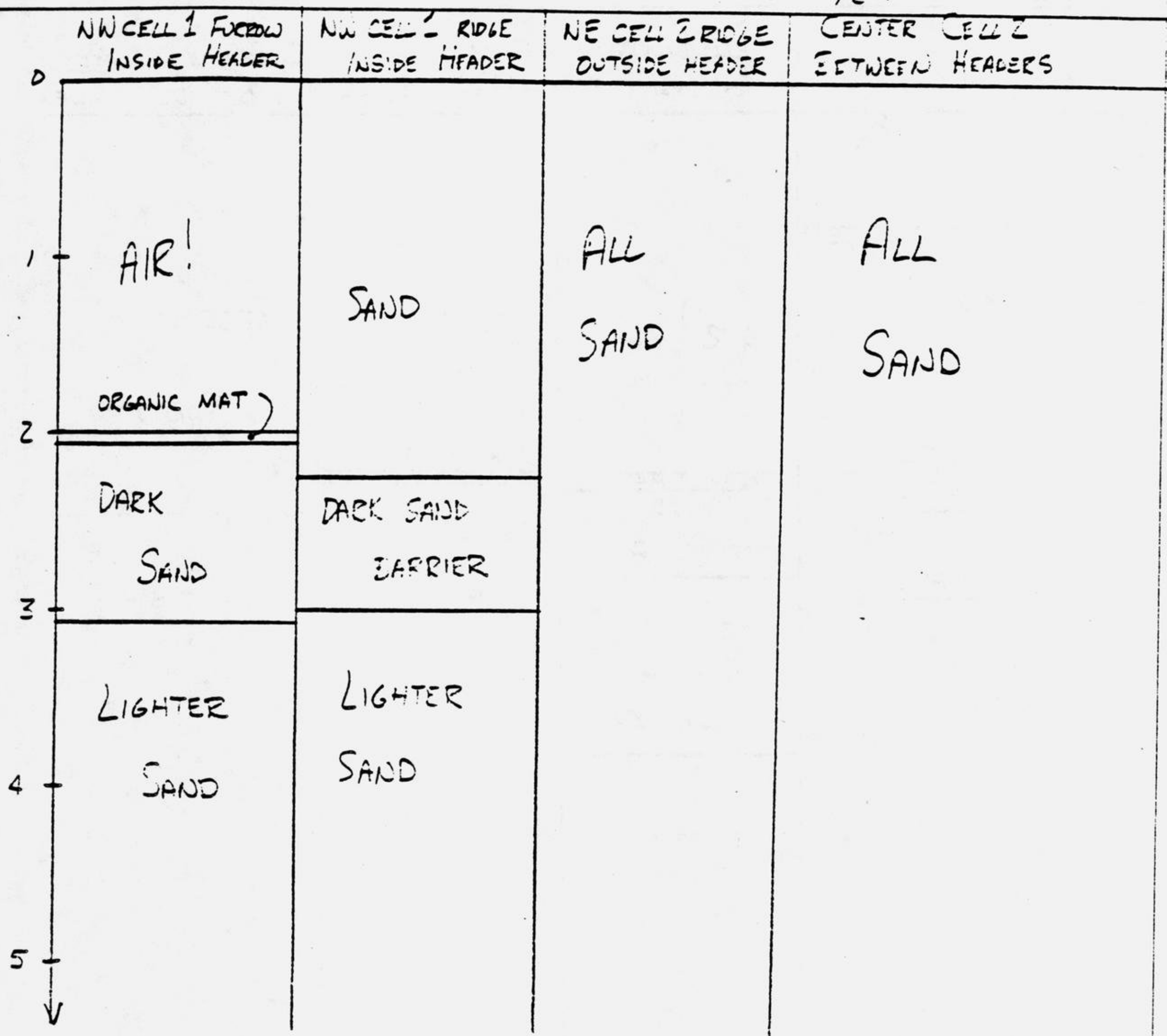
1. DEPTH TO BOTTOM OF BOREHOLE, 9'10"
2. LENGTH OF WELL SCREEN, 2'6"
3. TOTAL LENGTH OF SOLID PVC PIPE, 8.79'
4. HEIGHT OF PIPE ABOVE GROUND, 1.46'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND
6. DEPTH OF SEAL, 5.3'
7. BENTONITE BACKFILL
8. NATURAL SAND AND BENTONITE BACKFILL
9. BENTONITE BACKFILL BELOW DEPTH OF INHIBITING SOIL LAYER
10. NATURAL AND SILICA SAND BACKFILL

SOIL PROFILES

5/10/84



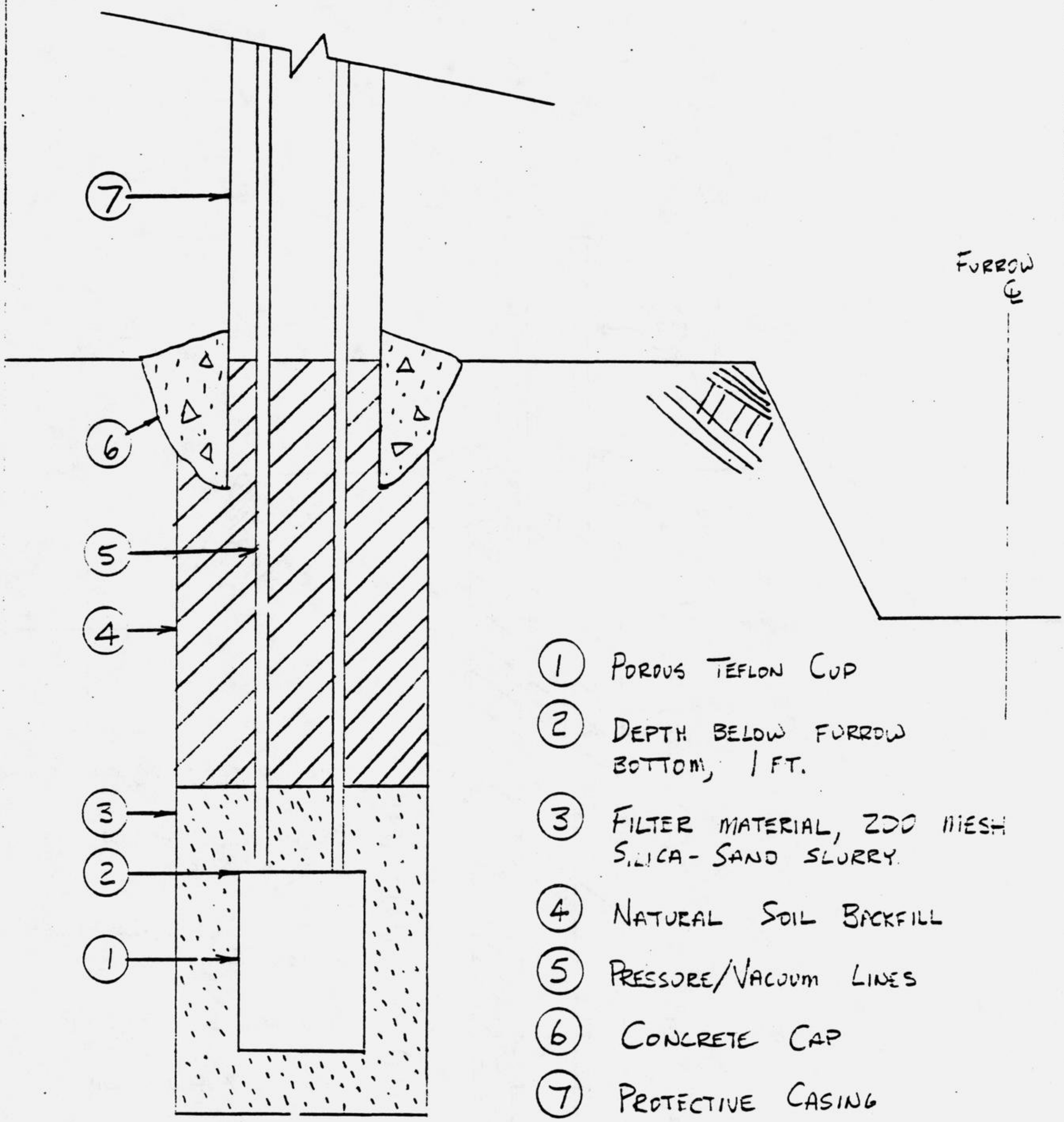
SOIL PROFILES 10/10/84



→ CELL 2 HAS SUBSURFACE BARRIERS ONLY AROUND HEADER AS SEEN WHEN INSTALLING LYSIMETER #4A

INFORMATION # 1 PLACED 9/9/83

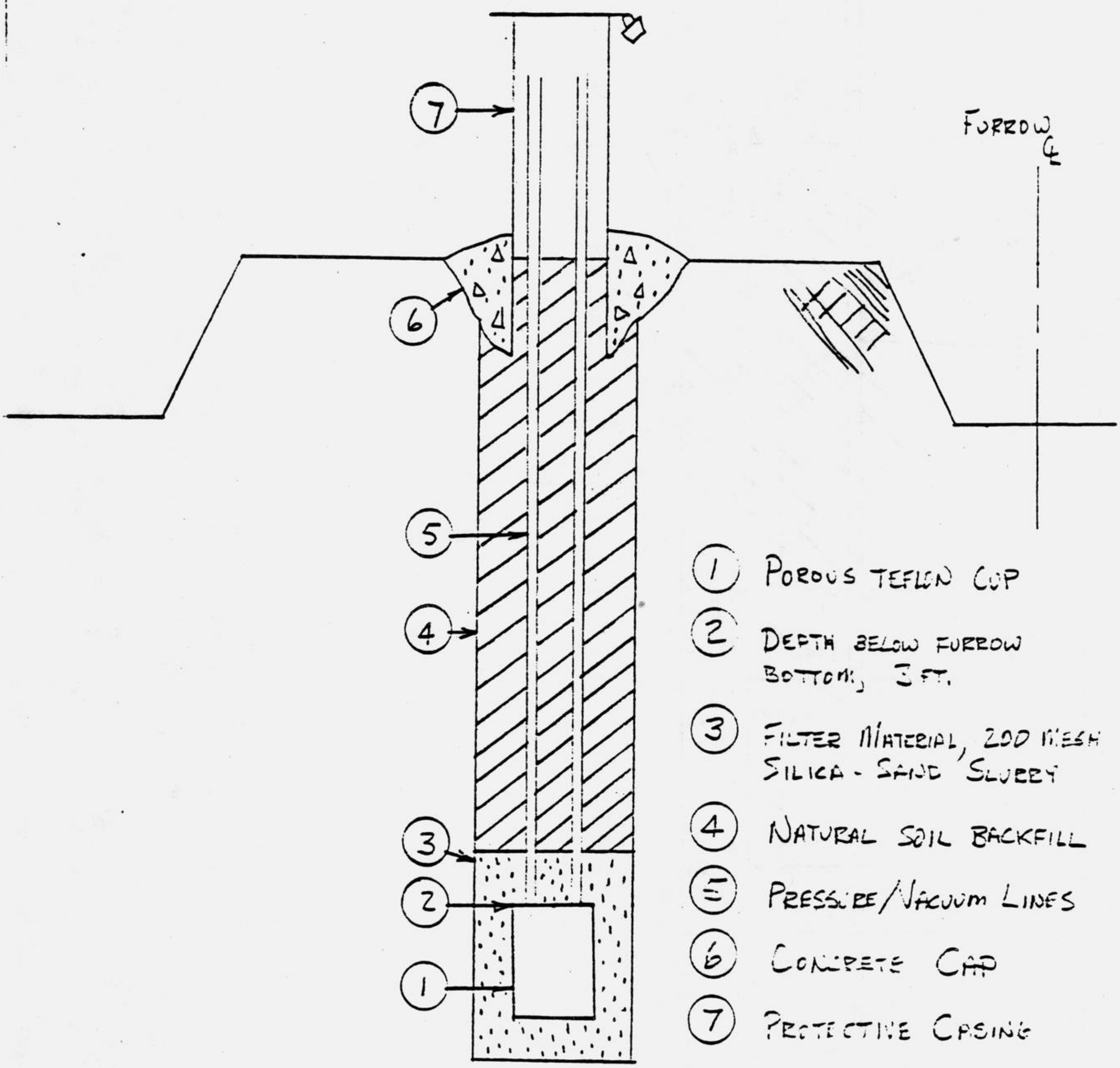
SCALE 1" = 0.6' IN SILTY SAND



1. POROUS TEFLON CUP
2. DEPTH BELOW FURROW BOTTOM, 1 FT.
3. FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

INFORMATION # 2 PLACED 9/9/83

SCALE: 1" = 1' IN SAND

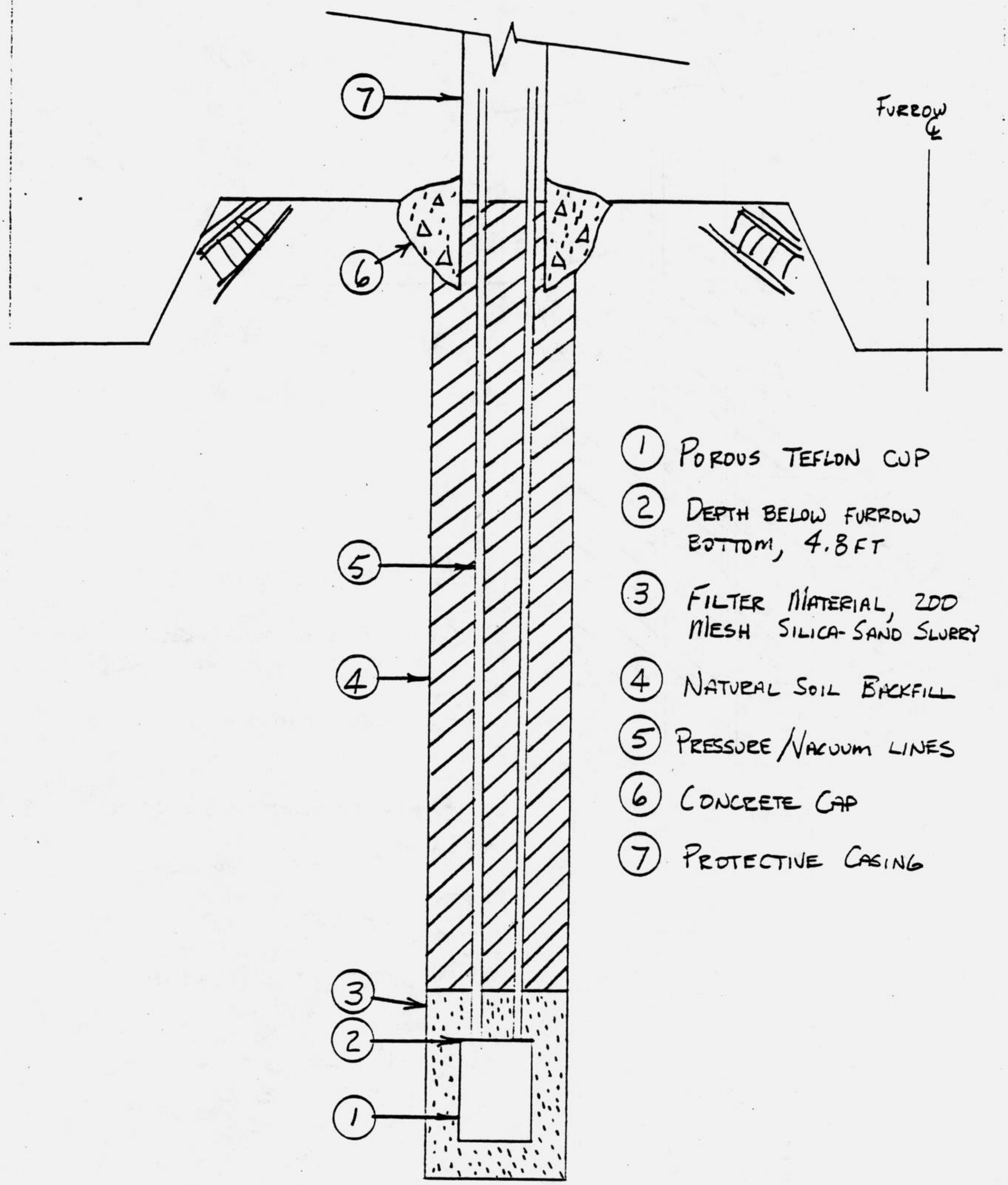


1. POROUS TEFLON CUP
2. DEPTH BELOW FURROW BOTTOM, 3 FT.
3. FILTER MATERIAL, 200 MESH SILICA - SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

LYSIMETER INFORMATION | BRODHEAD SITE # 3 | CELL 1 PLACED 9/9/83

SCALE: 1" = 1'

IN SAND



(1) POROUS TEFLON CUP

(2) DEPTH BELOW FURROW BOTTOM, 4.8 FT

(3) FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY

(4) NATURAL SOIL BACKFILL

(5) PRESSURE/VACUUM LINES

(6) CONCRETE CAP

(7) PROTECTIVE CASING

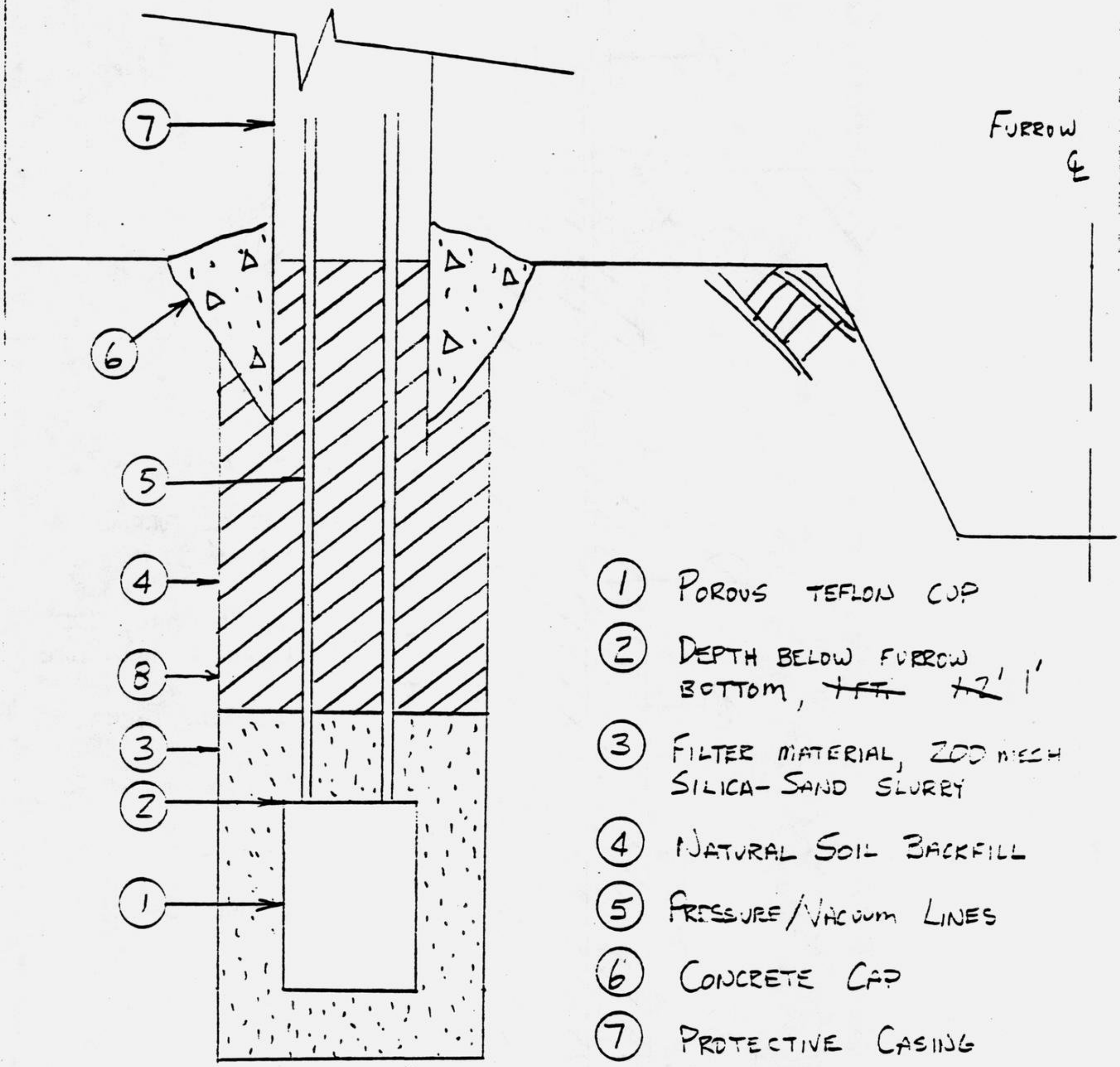
INFORMATION

#4

PLACED 9/14/83

REPLACED 7/27/84

SCALE: 1" = 0.6' IN SILTY SAND

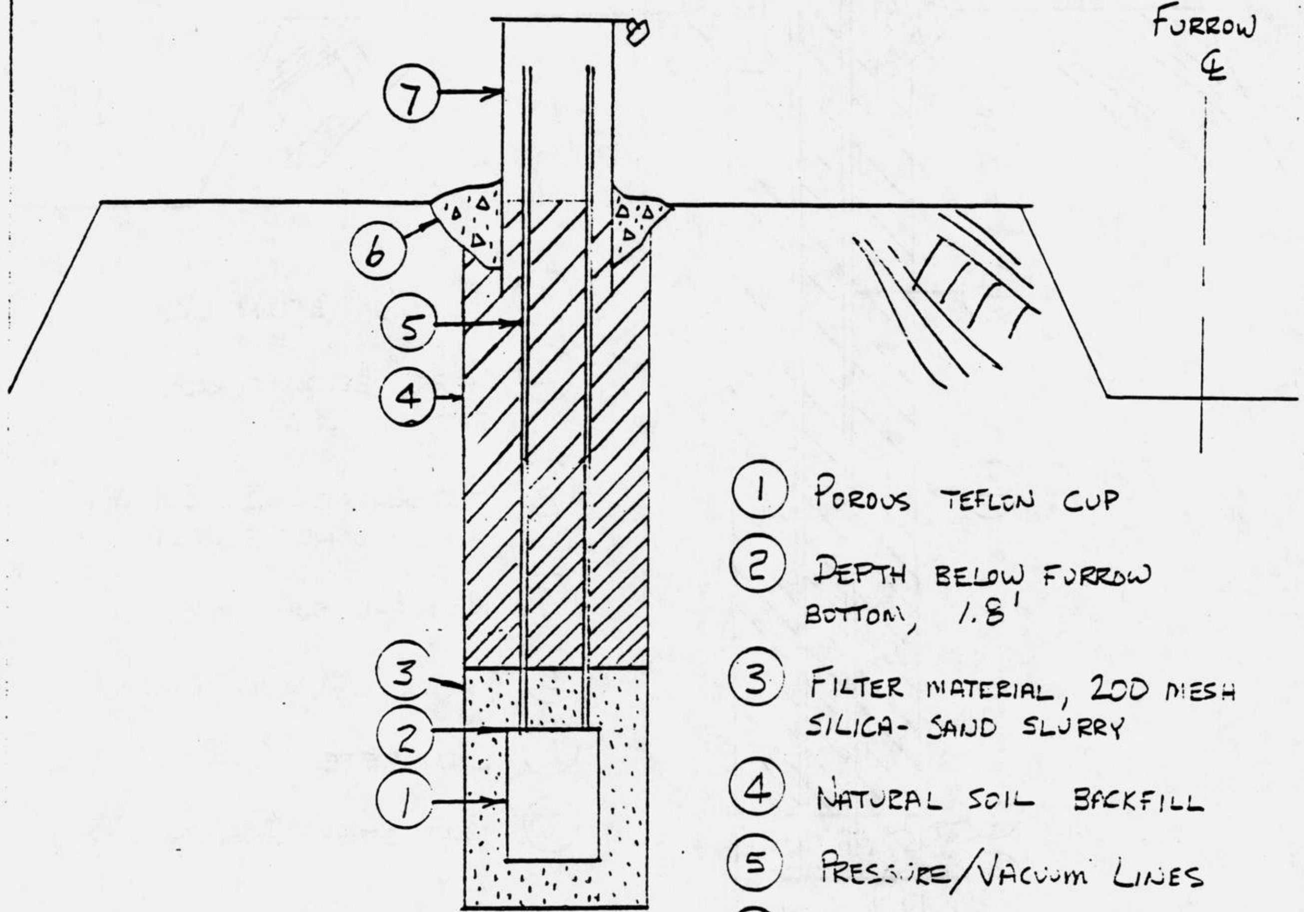


1. POROUS TEFLON CUP
2. DEPTH BELOW FURROW BOTTOM, ~~1 FT~~ ~~1.2'~~ 1'
3. FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING
8. REPLACEMENT 4A HAS BENTONITE SEAL ABOVE SILICA PACK

LYSIMETER DETAIL BROADHEAD SITE CELL 2

INFORMATION #5 PLACED 11/16/83

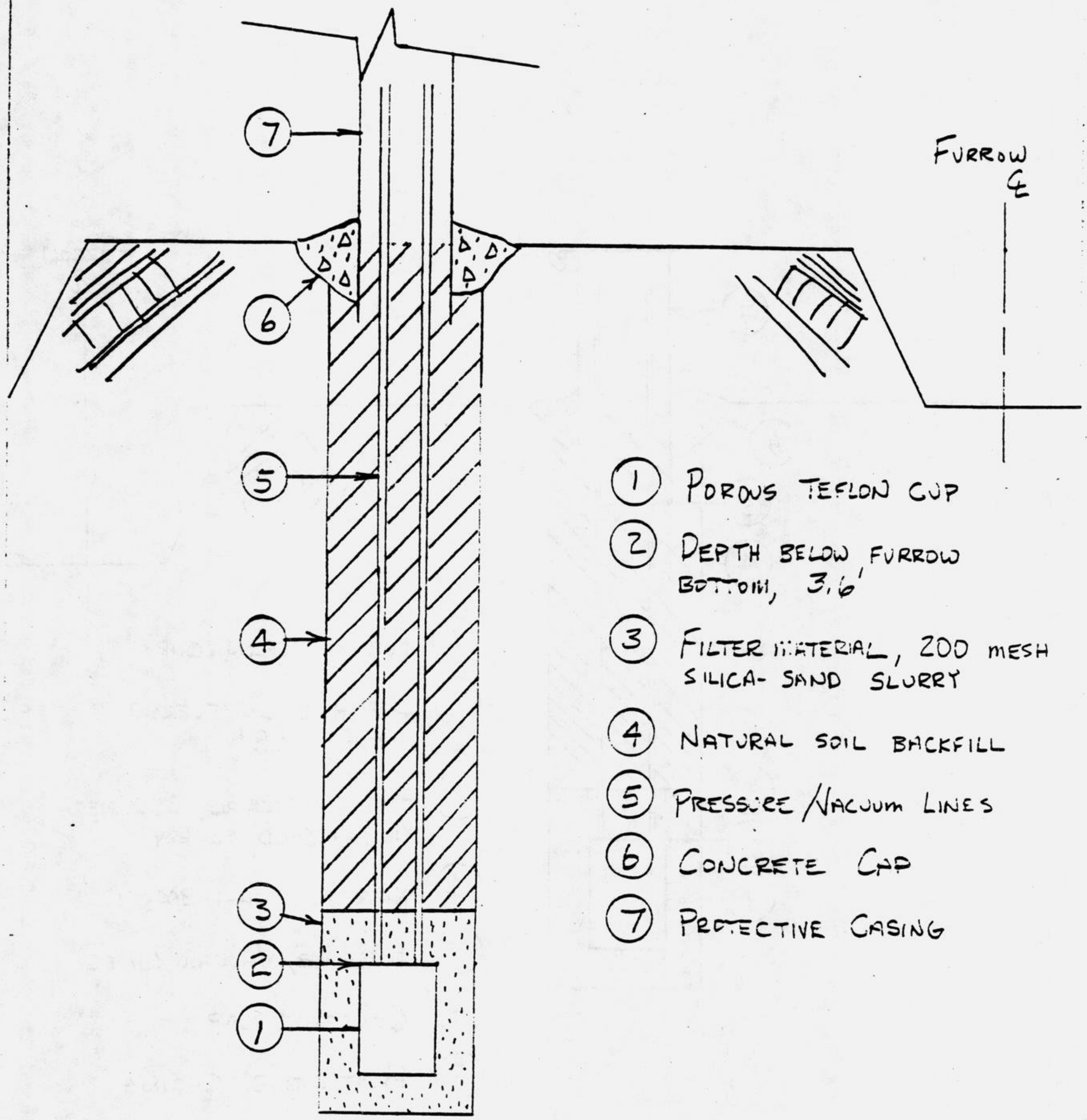
SCALE: 1" = 1'



1. POROUS TEFLON CUP
2. DEPTH BELOW FURROW BOTTOM, 1.8'
3. FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

INFORMATION #6 PLACED 11/16/83

SCALE 1" = 1'



1. POROUS TEFLON CUP
2. DEPTH BELOW FURROW BOTTOM, 3.6'
3. FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE /VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

LYSIMETER DETAIL INFORMATION

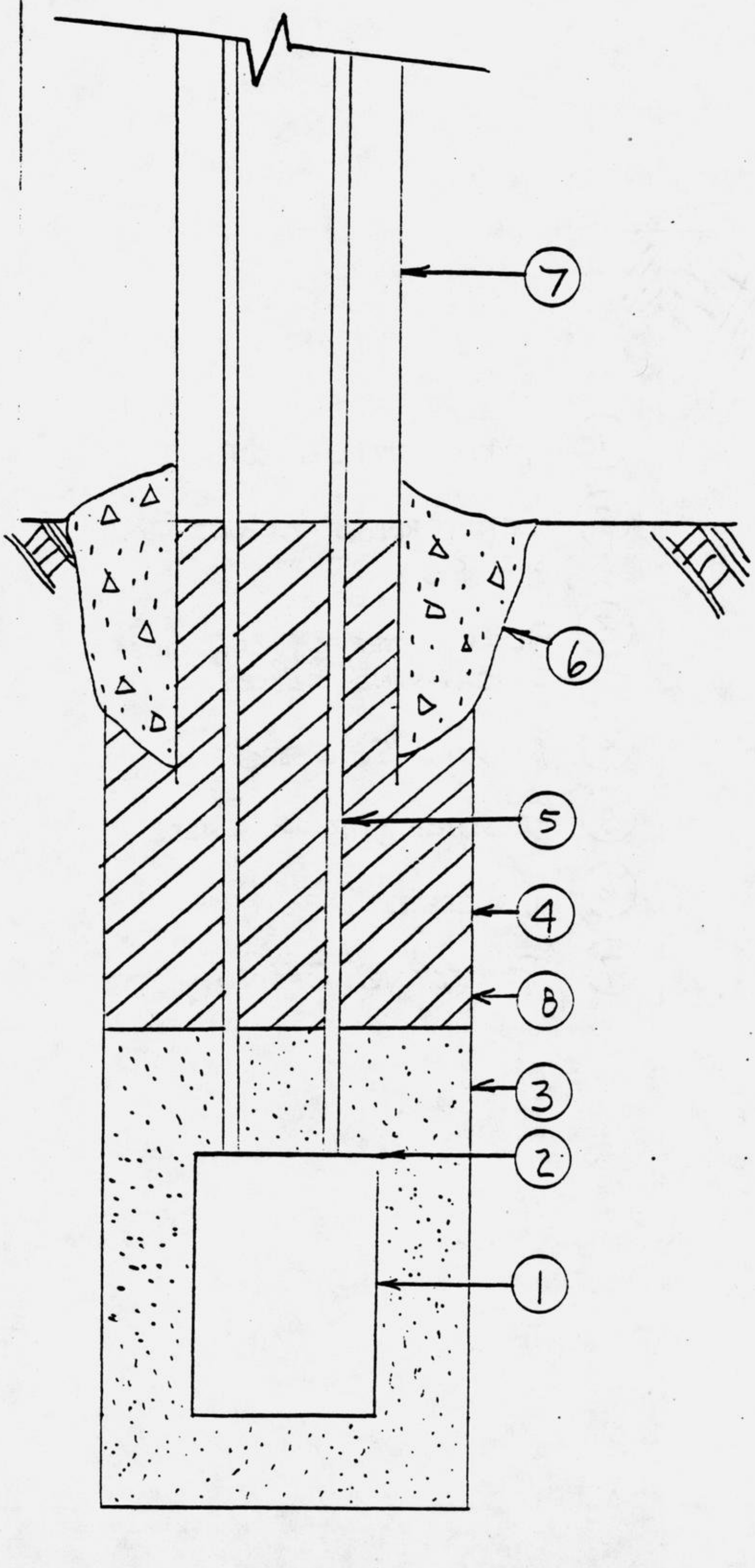
BROADHEAD SITE #7

BACKGROUND PLACED 9/14/83

SCALE: 1" = 0.5'

IN SANDY TOPSOIL

REPLACED 7/27/84

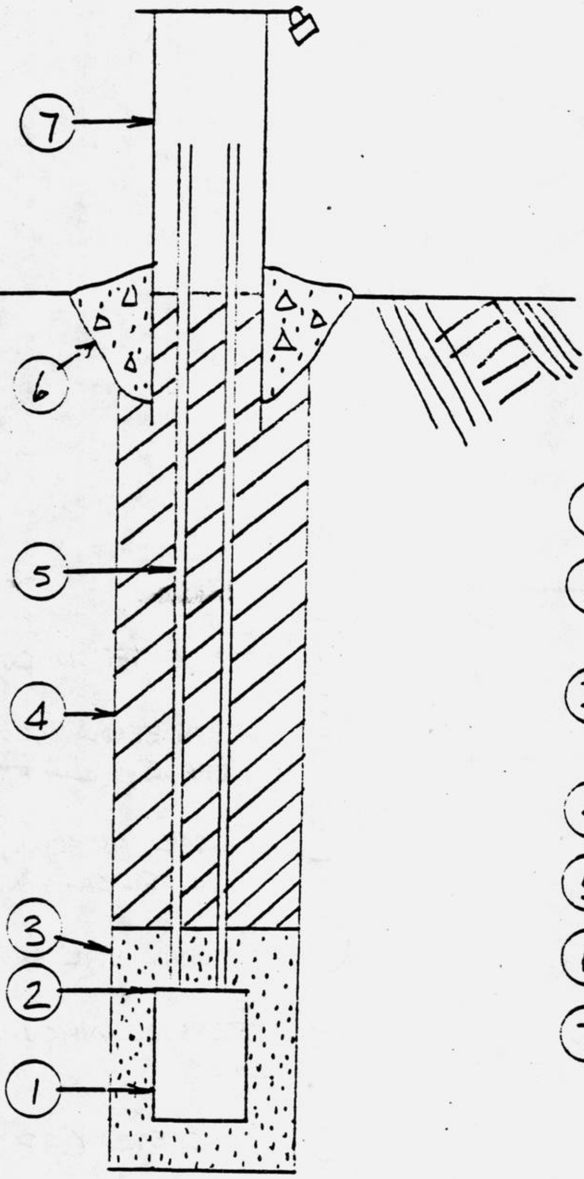


1. POROUS TEFLON CUP
2. DEPTH BELOW GROUND SURFACE, ~~1.7 FT.~~ 1.5'
3. FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING
8. REPLACEMENT 7A HAS BENTONITE SEAL ABOVE SILICA PACK

INFORMATION | # 8 | PLACED 9/14/83

SCALE: 1" = 1'

IN CLAYEY SAND



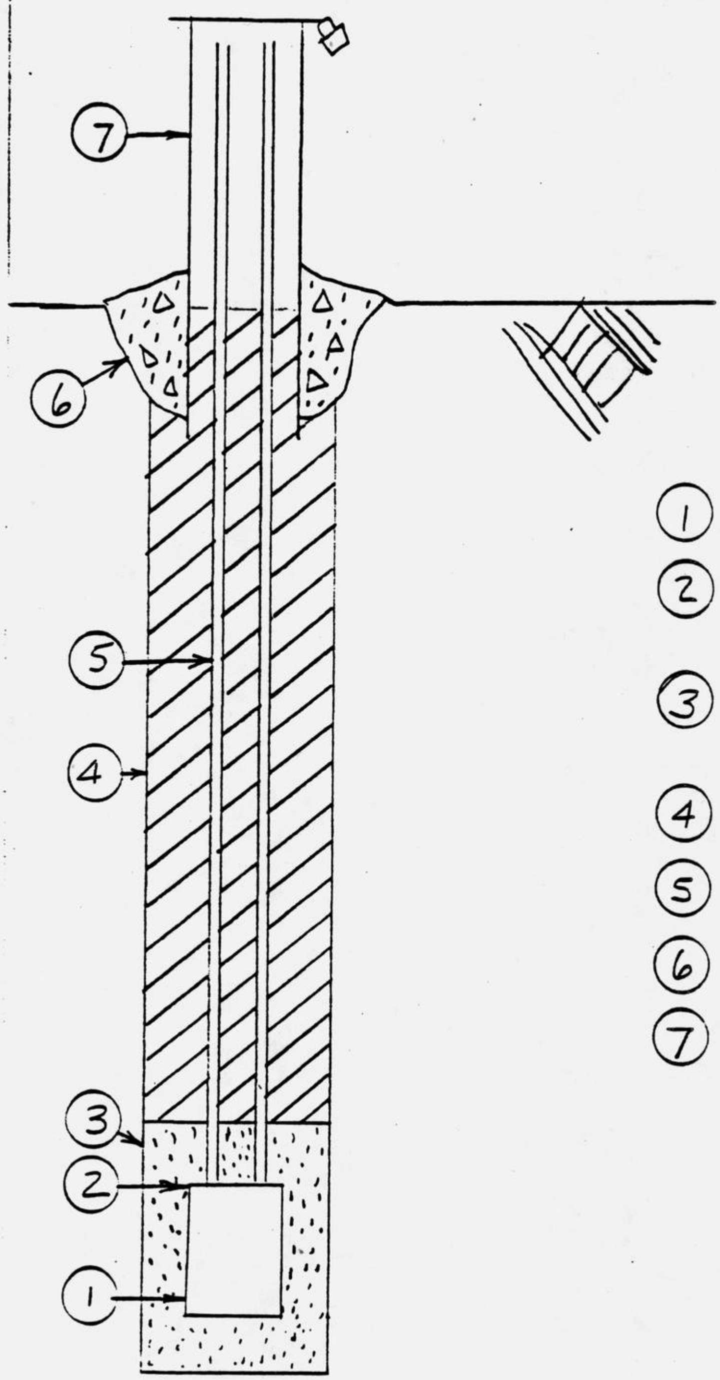
1. POROUS TEFLON CUP
2. DEPTH BELOW GROUND SURFACE, 3.7 FT.
3. FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

SITE

Information	#9	Placed 9/14/83

Scale: 1" = 1'

In sand



1. Porous Teflon cup
2. Depth below ground surface, 4.7 ft.
3. Filter material, 200 mesh silica-sand slurry
4. Natural soil backfill
5. Pressure/Vacuum lines
6. Concrete cap
7. Protective casing

APPENDIX B

BRODHEAD:

SOIL ANALYSIS

COOPERATIVE EXTENSION PROGRAMS
UWEX University of Wisconsin—Extension
University of Wisconsin—Madison
Soil & Plant Analysis Laboratory, 806 South Park Street, Madison, Wisconsin 53715; 608-262-4364

INSTRUCTION EXTENSION
College of Agricultural and Life Sciences
RESEARCH

DEPARTMENT OF SOIL SCIENCE
October 7, 1983
Acct. 900
Lab No. 00290

MEMORANDUM

TO: David Sauer
Wis. DNR
Box 7921
Madison, WI 53707

FOR BRODHEAD

FROM: Soil/Plant Analysis Lab

RE: Results of analyses on 5 soil samples submitted Sept. 15, 1983.

WELL #2

Sample No.	Sand	Silt	Clay	Total N
	%			
0-1' 1	91	4	5	0.04
2' 2	81	16	3	0.11
3-4' 3	96	1	3	0.01
5' 4	93	5	2	0.01
6' 5	95	3	2	-0.01

"-" values = less than.

All additional analyses are attached.

Your invoice for these analyses is enclosed.

Encls.

/sf

0-00290

LAB. FARM NO.	
STATE COUNTY	ACCOUNT NO
WI 13	900
DATE RECEIVED	DATE PROCESSED
09-21-83	09-21-83

SOIL & PLANT ANALYSIS LAB
806 S PARK
MADISON WI
53715

SOIL TEST REPORT

Samples Analyzed By:
SOIL & PLANT ANALYSIS LAB
806 S. PARK
MADISON WI
53715

THIS REPORT IS FOR:

DAVID SAUER
WIS DNR-BOX 7921
MADISON WI
53707

COOPERATIVE EXTENSION PROGRAMS
UWEX University of Wisconsin - Extension, University of Wisconsin - Madison
Soils Department, Madison, Wis.

WISCONSIN DHI COOPERATIVE

FARMER COPY

IDENTIFICATION

FIELD	1
ACRES	
SOIL NAME	GROUP XE
PLOW DEPTH	

YIELD GOALS

CORN	ALFALFA
OATS	70.0

LABORATORY ANALYSIS FOR EACH SAMPLE

Sample Number	Soil Test Code	Est CEC	Soil pH	Organic Matter Ton / A	P Phosphorus lbs / A	K Potassium lbs / A	Ca Calcium lbs / A	Mg Magnesium lbs / A	B Boron lbs / A	Mn Manganese lbs / A	Zn Zinc lbs / A	S Sulfur lbs / A	Lab Use Buffer Code
1	1	3	7.5	7	91 EH	140 LM	950 M	350 M					
2	2	13	7.8	45	210 EH	230 HM	4200 H	550 M					
3	1	3	7.9	2	94 EH	90 L	1600 M	210 M					
4	1	2	7.9	2	130 EH	90 L	1000 M	210 M					
5	1	3	8.6	1	55 VH	100 L	1600 M	260 M					

SOIL TEST LEVEL CODES VL (Very Low), L (Low), LM (Low Medium), M (Medium), HM (High Medium), H (High), VH (Very High), EH (Excessively High).

LIME PROGRAM

LIME GRADE USED	TONS PER ACRE TO CORRECT TO pH 6.6	OR	pH 6.9
60-69	NONE	OR	NONE
80-89	NONE	OR	NONE

FOR OTHER LIME GRADES SEE LIME SECTION ON BACK

CORRECTIVE FERTILIZER PROGRAM

CROP YEAR	PLANT NUTRIENTS P_2O_5 lbs / A	K_2O lbs / A
FIRST	0	110
SECOND	0	110
THIRD	0	0

MAINTENANCE FERTILIZER PROGRAM

CORN YIELD GOAL BU/A	N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
61-80	100	0	20
81-100	120	0	25
101-120	140	0	30

ALFALFA YIELD GOAL T/A	P_2O_5 lbs / A	K_2O lbs / A
1.1-2.0	0	75
2.1-3.0	0	150
3.1-4.0	0	200

OTHER CROPS AND YIELD GOAL	N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
OATS 61-90 BU	70	0	30

WORKSPACE FOR CALCULATING YOUR TOTAL ANNUAL FERTILIZER REQUIREMENTS

CROP:			
FERTILIZATION PROGRAM	YEAR 19 PLANT NUTRIENTS N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
CORRECTIVE			
MAINTENANCE			
NUTRIENT ADJUSTMENT (S)			
TOTAL			
FERTILIZATION RECORD DATE AND/OR METHOD OF APPLICATION	RATE lbs / A	GRADE N - P_2O_5 - K_2O	

CROP:			
FERTILIZATION PROGRAM	YEAR 19 PLANT NUTRIENTS N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
CORRECTIVE			
MAINTENANCE			
NUTRIENT ADJUSTMENT (S)			
TOTAL			
FERTILIZATION RECORD DATE AND/OR METHOD OF APPLICATION	RATE lbs / A	GRADE N - P_2O_5 - K_2O	

CROP:			
FERTILIZATION PROGRAM	YEAR 19 PLANT NUTRIENTS N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
CORRECTIVE			
MAINTENANCE			
NUTRIENT ADJUSTMENT (S)			
TOTAL			
FERTILIZATION RECORD DATE AND/OR METHOD OF APPLICATION	RATE lbs / A	GRADE N - P_2O_5 - K_2O	

COMMENTS SECTION

RETEST THIS FIELD AT LEAST EVERY 2 YEARS BECAUSE OF THE LOW POTASSIUM BUFFERING CAPACITY OF ITS SOILS.

COOPERATIVE EXTENSION PROGRAMS
UWEX University of Wisconsin—Extension
University of Wisconsin—Madison
Soil & Plant Analysis Laboratory, 806 South Park Street, Madison, Wisconsin 53715; 608-262-4364

INSTRUCTION EXTENSION
College of Agricultural and Life Sciences
RESEARCH

DEPARTMENT OF SOIL SCIENCE

September 21, 1983
Acct. 900
Lab No. 00221

MEMORANDUM

TO: Dave Sauer
Wis. DNR
Box 7921
Madison, WI 53707

BRODHEAD

FROM: Soil/Plant Analysis Lab

RE: Results of analyses on 7 soil samples submitted Sept. 1, 1983.

Sample No.	Sand	Silt	Clay	Total N.
	%	%	%	%
1 W10 4-6'	95	2	3	0.04
2 W10 6-8'	97	0	3	0.02
3 W10 9-14'	96	1	3	0.03
4 W10 26-29'	99	0	1	-0.01
5 W11 2-4'	95	2	3	0.04
6 W11 9-14'	99	0	1	-0.01
7 W12 2-4'	95	0	5	0.03

Note: "-" values = less than.

If you have any questions concerning these analyses, please feel free to contact us.

Additional analyses attached.

/sf

IL & PLANT ANALYSIS LAB
6 S PARK
DISON WI
53715

SOIL TEST REPORT

Samples Analyzed By:
SOIL & PLANT ANALYSIS LAB
806 S. PARK
MADISON WI
53715

THIS REPORT IS FOR:

CAVE SAUER
WIS DNR BOX 7921
MADISON WI
53707

COOPERATIVE EXTENSION PROGRAMS
UWEX University of Wisconsin — Extension
University of Wisconsin — Madison
Soils Department, Madison, Wis

WISCONSIN DHI COOPERATIVE

ASCS COPY

YIELD GOALS

N	ALFALFA
S	70.0

LABORATORY ANALYSIS FOR EACH SAMPLE

Sample Number	Soil Texture (Code)	Est. CEC	Soil pH	Organic Matter Tons/A	P Phosphorus lbs/A	K Potassium lbs/A	Ca Calcium lbs/A	Mg Magnesium lbs/A	B Boron lbs/A	Mn Manganese lbs/A	Zn Zinc lbs/A	S Sulfur lbs/A	Lab Use Buffer Code
1	1	2	6.5	3	15 VL	65 L	700 M	200 M	W10 4-6'				7.5
2	1	1	7.1	2	23 VL	75 L	600 M	180 M	W10 6-8'				
3	1	2	7.3	2	14 VL	75 L	900 M	190 M	W10 7-14'				
4	1	2	8.0	2	11 L	50 L	900 M	100 L	W10 16-21'				
5	1	3	7.4	11	23 VL	45 L	1250 M	250 M	W11 2-4'				
6	1	1	7.5	2	14 L	55 L	550 M	100 L	W11 7-14'				

SOIL TEST LEVEL CODES: VL (Very Low), L (Low), LM (Low Medium), M (Medium), HM (High Medium), H (High), VH (Very High), EH (Excessively High)

CORRECTIVE FERTILIZER PROGRAM

P R	PLANT NUTRIENTS P_2O_5 lbs/A	K_2O lbs/A
T		
OND		
D		

MAINTENANCE FERTILIZER PROGRAM

CORN YIELD GOAL BU/A	N lbs/A	P_2O_5 lbs/A	K_2O lbs/A	ALFALFA YIELD GOAL T/A	P_2O_5 lbs/A	K_2O lbs/A	OTHER CROPS AND YIELD GOAL	N lbs/A	P_2O_5 lbs/A	K_2O lbs/A

WORKSPACE FOR CALCULATING YOUR TOTAL ANNUAL FERTILIZER REQUIREMENTS

YEAR 19
PLANT NUTRIENTS
N lbs/A | P_2O_5 lbs/A | K_2O lbs/A

CROP: YEAR 19
FERTILIZATION PROGRAM
PLANT NUTRIENTS
N lbs/A | P_2O_5 lbs/A | K_2O lbs/A
CORRECTIVE

CROP: YEAR 19
FERTILIZATION PROGRAM
PLANT NUTRIENTS
N lbs/A | P_2O_5 lbs/A | K_2O lbs/A
CORRECTIVE

L & PLANT ANALYSIS LAB

SOIL TEST REPORT

Samples Analyzed By:
SOIL & PLANT ANALYSIS LAB

THIS REPORT IS FOR: DAVE SAUER

COOPERATIVE EXTENSION PROGRAMS
University of Wisconsin — Extension
University of Wisconsin — Madison
Soils Department, Madison, Wis.

WISCONSIN DHI COOPERATIVE

ASCS COPY

YIELD GOALS

ALFALFA
70.0

LABORATORY ANALYSIS FOR EACH SAMPLE

Sample Number	Soil Texture (Code)	Est. CEC	Soil pH	Organic Matter Tons/A	P Phosphorus lbs/A	K Potassium lbs/A	Ca Calcium lbs/A	Mg Magnesium lbs/A	B Boron lbs/A	Mn Manganese lbs/A	Zn Zinc lbs/A	S Sulfur lbs/A	Lab Use Buffer Code
7	1	2	6.9	2	17 VL	60 L	800 M	210 M	W12 2-4'				

SOIL TEST LEVEL CODES: VL (Very Low), L (Low), LM (Low Medium), M (Medium), HM (High Medium), H (High), VH (Very High), EH (Excessively High)

CORRECTIVE FERTILIZER PROGRAM

	PLANT NUTRIENTS P₂O₅ lbs/A	K₂O lbs/A
T	60	110
OND	60	110
D	60	0

MAINTENANCE FERTILIZER PROGRAM

CORN YIELD GOAL BU/A	N lbs/A	P_2O_5 lbs/A	K_2O lbs/A
61-80	100	30	20
81-100	120	35	25
101-120	140	40	30

ALFALFA YIELD GOAL T/A	P_2O_5 lbs/A	K_2O lbs/A
1.1-2.0	20	75
2.1-3.0	35	150
3.1-4.0	50	200

OTHER CROPS AND YIELD GOAL	N lbs/A	P_2O_5 lbs/A	K_2O lbs/A
OATS 61-90 BU	70	[illegible]	[illegible]

APPENDIX C

BRODHEAD:

WASTEWATER CHEMISTRY DATA

BRODHEAD CUMMULATIVE DATA SHEET — CHEMICAL (mg/l) PARAMETERS — BWWNSER — RAW WASTEWATER — TAKEOFF Spreadsheet

DATE	TOTAL BOD_5 X	TOTAL COD	TSS ~~TDS~~ X	8 TKN X	9 / 10 NH_3-N X	11 NO_2-N + NO_3-N X	Cl⁻ X	(LAB) pH	OTHER
10/20/83	3200	—	—	46.0	1.4	3.0	890	10.4	—
3/7/84	1700	2300	~~596~~ 1570	34	2.7	4.1	32	US —	TSS 1570
4/23/84	1200	2400	964	41	2.5	5.8	1600	6.6	TDS 3770
5/24/84	1600	2100	808	40	2.2	0.7	2300	7.4	7.4 LAB pH
6/7/84	1600	>2000 ?	930	45	2.5	2.7	90	6.8	
7/19/84	1800	2700	470	44	4.1	1.6	1300	7.1	—
7/31/84	1700	2400	464	36	2.8	2.4	980	—	—
8/30/84	>1100	2100	764	32	1.5	0.4	620	7.4	—
9/25/84	2500	3400 3200 DISS	1110	75 TOT 37 DISS	2.9 2.9	0.2 0.1	940	7.4	
10/9/84	980	2100	555	28 TOT 21 DISS	2.6	4.2	1400	7.8	
11/20/84	2200	—	1130	38 TOT 21 DISS	2.0	5.0	180		

~DHEAD CUMMULATIVE DATA SHEET | CHEMICAL PARAMETERS (mg/l) | RAW WASTEWATER

DATE	TOTAL ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	OTHER
10/20/83	~814*	120.	14.	170	840	78	—	—
3/7/84	—	29	<10	69	86	32	35	—
4/23/84	352	44	—	110	1100	49	51	—
5/24/84	672	46	INT	89	1700	28	47	—
6/7/84	—	—	—	—	—	—	—	—
7/19/84	—	—	—	—	—	—	—	—
7/31/84	—	—	—	—	—	—	—	—
8/30/84	530	49		110	490	52	22	—
				109.6	343.2	47.8		
				1.37	36.68	0.98		

* APPROXIMATE

APPENDIX D

BRODHEAD:

WASTEWATER FLOWS TO RIDGE & FURROW

- 30-DAY AVERAGES
- 24 HR PROJECT FLOWS

BRODHEAD
WASTEWATER FLOW (GALLONS/DAY)
YEARS 1979 - 1984

MONTH	1979	1980	1981	1982	1983	1984	1984*
JANUARY	26496	54740	43214	37966	35371	35289	—
FEBRUARY	36459	55575	48502	37212	36024	38162	—
MARCH	39979	59618	51924	37174	35347	37548	—
APRIL	19054	49288	31206	42200	43000	25056	43070
MAY	12734	32466	27764	53220	26429	37656	50400
JUNE	16785	39547	28506	49348	33035	42891	42064
JULY	43178	22780	33018	—	40441	44145	29167
AUGUST	42821	27567	40489	—	25855	35664	—
SEPTEMBER	41895	—	50317	—	38578	48414	58600
OCTOBER	54664	36849	49852	46469	42342	43075	45000
NOVEMBER	55658	35616	61427	50389	37065	—	—
DECEMBER	45124	41563	22339	51731	28197	—	—
YEARLY AVERAGE	36237	41436	40713	45082	35140	38783	44717
COMMULATIVE AVERAGE	36237	38723	39406	40567	39404	39507	X

* 24-HR FLOWS DETERMINED ON SAMPLING DAYS

APPENDIX E

BRODHEAD:

GROUNDWATER ELEVATIONS

AND CONTOURS

DATA SHEET: WELL 10A LENGTH: 15'/14.67/14.64 SHALLOW

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/23/83	6.37	772.00	—	—	—	—
10/20/83	7.00	771.37	~8	4	5	—
11/16/83	7.54	770.83	7.1	3.6	5	GRAY TINT, SLIGHT ODOR, NO DRAWDOWN
12/20/83	6.67	771.70	~8	4	4	LIGHT BROWN, SMELLY LOOKS OILY
1/12/84	7.00	771.37	7.7	3.8	4	BROWN-GRAY ODOR
2/12/84	7.18	771.19	7.5	3.7	4	LIGHT-BROWN ODOR
3/20/84	7.40	770.97	7.2	3.6	4	CLEAR TO YELLOW ODOR
4/22/84	6.84	771.53	7.8	3.9	4	LIGHT BROWN SLIGHT ODOR
5/24/84	6.73	771.64	7.9	4.0	4	LIGHT BROWN
6/7/84	6.85	771.52	7.8	3.9	4	BROWNISH-YELLOW
7/19/84	6.38	771.99	8.3	4.1	5	YELLOW
8/30/84	7.18	771.19	7.5	3.8	4	YELLOW
9/25/84	7.06	771.31	7.6	3.8	4	YELLOW-ODOR
10/9/84	6.92	771.45	7.7	3.9	4	YELLOW
11/20/84	6.59	771.78	—	—	—	

DATA SHEET : WELL 10B LENGTH : 27.5'/26.78/26.76 DEEP

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/23/83	6.87	770.99	—	—	—	—
10/20/83	6.51	771.35	~21	10.5	15	—
11/16/83	7.06	770.80	~19.7	9.9	15	GRAY TINT, SLIGHT ODOR, NO DRAWDOWN
12/20/83	6.21	771.65	20.6	10.3	12	CLEAR, SMELLY
1/12/84	6.50	771.36	20.3	10.1	12	YELLOW, STRONG ODOR
2/12/84	6.69	771.17	20.2	10.1	12	LIGHT BROWN ODOR
3/20/84	6.90	770.96	19.9	9.9	12	YELLOW TO GREEN ODOR
4/22/84	6.35	771.51	20.4	10.2	12	LIGHT BROWN SLIGHT ODOR
5/24/84	6.22	771.64	20.5	10.3	12	LIGHT BROWN SLIGHT ODOR
6/7/84	6.35	771.51	20.4	10.2	12	YELLOW - ODOR
7/19/84	5.88	771.98	20.9	10.4	12	YELLOW
8/30/84	6.68	771.18	20.1	10.1	12	LIGHT YELLOW - ODOR
9/25/84	6.56	771.30	20.2	10.1	12	LIGHT YELLOW - ODOR
10/9/84	6.43	771.43	20.3	10.2	12	LIGHT YELLOW - ODOR
11/20/84	6.12	771.74	—	—	—	

DATA SHEET : WELL 11A LENGTH: 10'/9.81/9.78 SHALLOW

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/23/83	4.15	771.65	—	—	—	—
10/20/83	4.22	771.58	5.5	2.8	5	—
11/16/83	4.86	770.94	4.95	2.5	5	FAIRLY CLEAR, SLIGHT ODOR, NO DRAWDOWN
12/20/83	4.07	771.73	5.75	2.9	4	BROWN-GRAY SLIGHT ODOR
1/12/84	4.38	771.42	5.4	2.7	4	BROWN-GRAY SLIGHT ODOR
2/12/84	4.48	771.32	5.3	2.7	4	LIGHT BROWN SLIGHT ODOR
3/20/84	4.78	771.02	5.0	2.5	4	YELLOW ODOR
4/22/84	4.10	771.70	5.7	2.8	4	LIGHT GREY
5/24/84	4.06	771.74	5.7	2.9	4	CLEAR
6/7/84	4.21	771.59	5.6	2.8	4	WHITISH YELLOW
7/19/84	3.82	771.98	6.0	3.0	4	LIGHT YELLOW
8/30/84	4.42	771.38	5.4	2.7	4	DULL WHITE - ODOR
9/25/84	4.37	771.43	5.4	2.7	4	LIGHT YELLOW - ODOR
10/9/84	4.25	771.55	5.5	2.8	4	YELLOW
11/20/84	3.97	771.83	—	—	—	

DATA SHEET: WELL 11B LENGTH: 27.5'/25.52/25.49 DEEP

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/23/83	4.72	771.69	—	—	—	—
10/20/83	4.81	771.60	~21	10.5	15	
11/16/83	5.45	770.96	20.1	10.0	15	FAIRLY CLEAR, SLIGHT ODOR, NO DRAWDOWN
12/20/83	4.66	771.75	20.86	10.4	12	CLEAR, SLIGHT ODOR
1/12/84	4.98	771.43	20.5	10.3	12	FAIRLY CLEAR SLIGHT ODOR
2/12/84	5.07	771.34	20.4	10.2	12	CLEAR SLIGHT ODOR
3/20/84	5.33	771.08	20.2	10.1	12	DULL CLEAR
4/22/84	4.66	771.75	20.3	10.4	12	CLEAR
5/24/84	4.62	771.79	20.9	10.4	12	CLEAR
6/7/84	4.77	771.64	20.7	10.4	12	FAIRLY CLEAR
7/19/84	4.36	772.05	21.1	10.6	12	CLEAR
8/30/84	4.99	771.42	20.6	10.3	12	DULL CLEAR
9/25/84	4.94	771.47	20.6	10.3	12	CLEAR
10/9/84	4.81	771.60	20.7	10.3	12	CLEAR
11/20/84	4.54	771.87	—	—	—	

DATA SHEET: 12 A LENGTH: 12'/12.14/12.11 SHALLOW, BACKGROUND

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/23/83	6.57	771.49	—	—	—	—
10/20/83	6.76	771.30	5.3	2.7	5	—
11/16/83	7.32	770.74	4.8	2.4	5	CLEAR, NO ODOR NO DRAWDOWN
12/20/83	6.39	771.67	5.75	2.9	5	BROWN, SILTY
1/12/84	6.73	771.33	5.4	2.7	4	YELLOW-BROWN
2/12/84	6.93	771.13	5.2	2.6	4	BROWN SILTY
3/20/84	7.11	770.95	5.0	2.5	4	CLEAR
4/22/84	6.58	771.48	5.6	2.3	4	CLEAR
5/24/84	6.43	771.63	5.7	2.8	4	CLEAR
6/7/84	6.54	771.52	—	—	—	—
7/19/84	6.03	772.03	—	—	—	—
8/30/84	6.89	771.17	—	—	—	—
9/25/84	6.75	771.31	—	—	—	—
10/9/84	6.67	771.39	—	—	—	—
11/20/84	6.25	771.81	—	—	—	—

DATA SHEET: 12 B LENGTH: 27.5'/26.86, 20.83 DEEP, BACKGROUND

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/23/83	5.93	771.44	—	—	—	—
10/20/83	6.10	771.27	~21	10.5	15	
11/16/83	6.65	770.72	20.2	10.1	15	CLEAR, NO ODOR NO DRAWDOWN
12/20/83	5.72	771.65	21.15	10.6	12	CLEAR, ODORLESS
1/12/84	6.03	771.34	20.8	10.4	12	FAIRLY CLEAR
2/12/84	6.25	771.12	20.6	10.3	12	CLEAR
3/20/84	6.43	770.94	20.4	10.3	12	CLEAR
4/22/84	5.92	771.45	20.9	10.5	12	CLEAR
5/24/84	5.75	771.62	21.1	10.5	12	CLEAR
6/7/84	5.85	771.52	—	—	—	—
7/19/84	5.36	772.01	—	—	-	—
8/30/84	6.21	771.16	—	—	—	—
9/25/84	6.06	771.31	—	—	—	—
10/9/84	5.98	771.39	—	—	—	—
11/20/84	5.57	771.30	—	—	—	—

DATA SHEET: WELL 13A LENGTH 10'/9.78/9.76 SHALLOW

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/22/83	4.55	772.20	—	—	—	—
10/20/83	4.73	772.02	~5	2.5	5	—
11/16/83	5.26	771.49	4.5	2.3	5	LIGHT BROWN TINT, NO ODOR, NO DRAWDOWN
12/20/83	4.62	772.13	5.2	2.6	4	SLIGHTLY CLOUDY ODORLESS
1/12/84	4.81	771.94	5.0	2.5	4	BROWN-GRAY
2/12/84	4.92	771.83	4.8	2.4	4	LIGHT BROWN
3/20/84	5.06	771.69	4.7	2.4	4	YELLOW TO CLEAR
4/22/84	4.52	772.23	5.2	2.6	4	LIGHT GREY
5/24/84	4.41	772.34	5.4	2.7	4	CLEAR
6/7/84	4.48	772.27	5.3	2.6	4	LIGHT YELLOW
7/19/84	4.03	772.72	5.8	2.9	4	CLEAR
8/30/84	4.79	771.96	5.0	2.5	4	LIGHT YELLOW
9/25/84	4.54	772.21	5.3	2.6	4	LIGHT YELLOW
10/9/84	4.65	772.10	5.1	2.6	4	LIGHT YELLOW
11/20/84	4.08	772.66	—	—	—	—

DATA SHEET : WELL 13B LENGTH: 27.5'/26.87/26.84 DEEP

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/23/83	5.20	772.20	—	—	—	—
10/20/83	5.42	771.98	~21	10.5	15	—
11/16/83	5.89	771.51	20.9	10.5	15	CLEAR, NO ODOR NO DRAWDOWN
12/20/83	5.23	772.17	21.64	10.82	12	CLEAR, ODORLESS
1/12/84	5.46	771.94	21.4	10.7	12	CLEAR
2/12/84	5.54	771.86	21.3	10.7	12	CLEAR
3/20/84	5.71	771.69	21.1	10.6	12	CLEAR
4/22/84	5.14	772.26	21.7	10.9	12	CLEAR
5/24/84	5.02	772.38	21.8	10.9	12	CLEAR
6/7/84	5.12	772.28	—	—	—	—
7/19/84	4.66	772.74	—	—	—	—
8/30/84	5.42	771.98	21.5	10.7	12	CLEAR
9/25/84	5.18	772.22	21.7	10.9	12	CLEAR
10/19/84	5.27	772.13	21.6	10.8	12	CLEAR
11/20/84	4.72	772.68	—	—	—	—

DATA SHEET : WELL 14 | LENGTH : 7.29'/7.26 | SHALLOW

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
3/20/84	5.84	770.45	1.45	—	—	LIGHT BROWN
4/22/84	5.12	771.17	2.2	1.1	2	BROWN
5/24/84	5.06	771.23	2.2	1.1	2	LIGHT BROWN
6/7/84	5.23	771.06	2.0	1.0	2	LIGHT BROWN
7/19/84	4.83	771.46	2.5	1.2	2	BROWN
8/30/84	5.46	770.83	1.9	0.9	2	BROWN
9/25/84	5.56	770.73	1.8	0.9	1	BROWN
10/9/84	5.24	771.05	2.0	1.0	2	LIGHT BROWN
11/20/84	5.08	771.20	—	—	—	—

PADMASTER® / Made in U.S.A.

Data Sheet : Well 15 Length 10.35 Shallow, Cell 2

Date	Depth to GW	GW Elevation	Volume H_2O (ft)	3 Volumes (gal)	Volume Removed	Comment
3/20/84	8.87	771.28	1.48	—	—	Light brown strong odor
4/22/84	8.35	771.80	2.0	1.0	2	Grey, strong odor
5/24/84	8.15	772.00	2.2	1.1	2	Dull clear, odor
6/7/84	8.24	771.91	2.1	1.0	2	White - odor
7/17/84	7.72	772.43	2.6	1.3	2	Dull - odor
8/30/84	8.61	771.54	1.8	0.9	2	Dull - odor
9/25/84	8.32	771.83	2.1	1.0	1.5	Yellow - odor
10/9/84	8.37	771.77	2.0	1.0	1.5	Foggy clear - odor
10/12/84	8.42	771.73	1.9	1.0	1.5	
10/15/84	8.44	771.71	1.9	1.0	1.5	
10/18/84	8.07	772.08	2.2	1.1	1.5	
10/23/84	6.28	773.87	4.1	2.0	3.5	
10/26/84	7.67	772.48	2.7	1.3	2	
10/30/84	7.54	772.61	2.8	1.4	2	
11/1/84	7.07	773.08	3.3	1.6	2	
11/8/84	7.74	772.41	2.6	1.3	2	
11/13/84	7.76	772.39	—	-	-	
11/16/84	7.89	772.26	2.5	1.2	2	
11/20/84	7.99	772.16	2.4	1.2	2	

PADMASTER® / Made in U.S.A

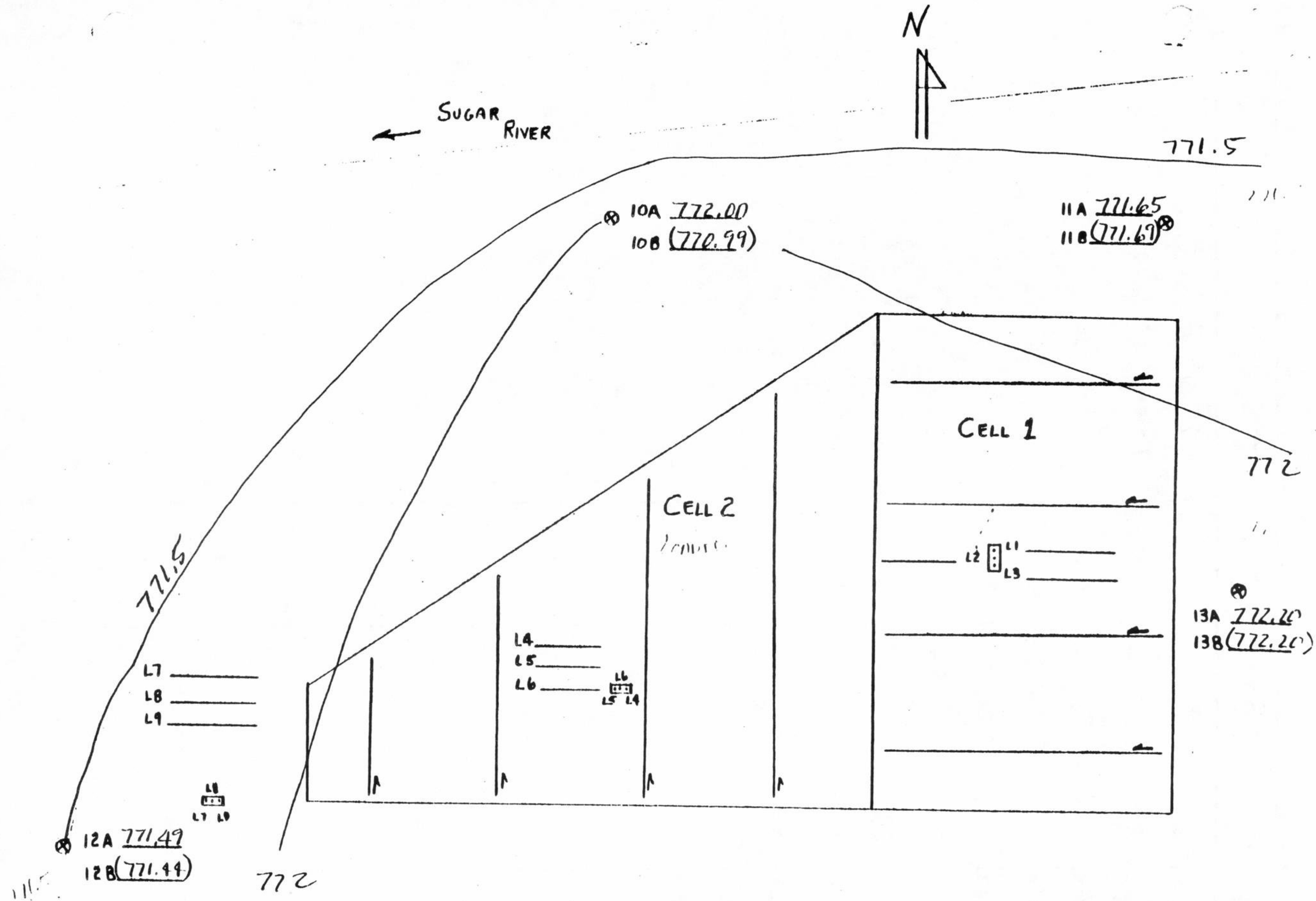
BROWNHEAD CONSULTING PIPE TOP ELEVATION: [illegible]

DATA SHEET: WELL 16 | LENGTH 12.06' SHALLOW, SE BERM

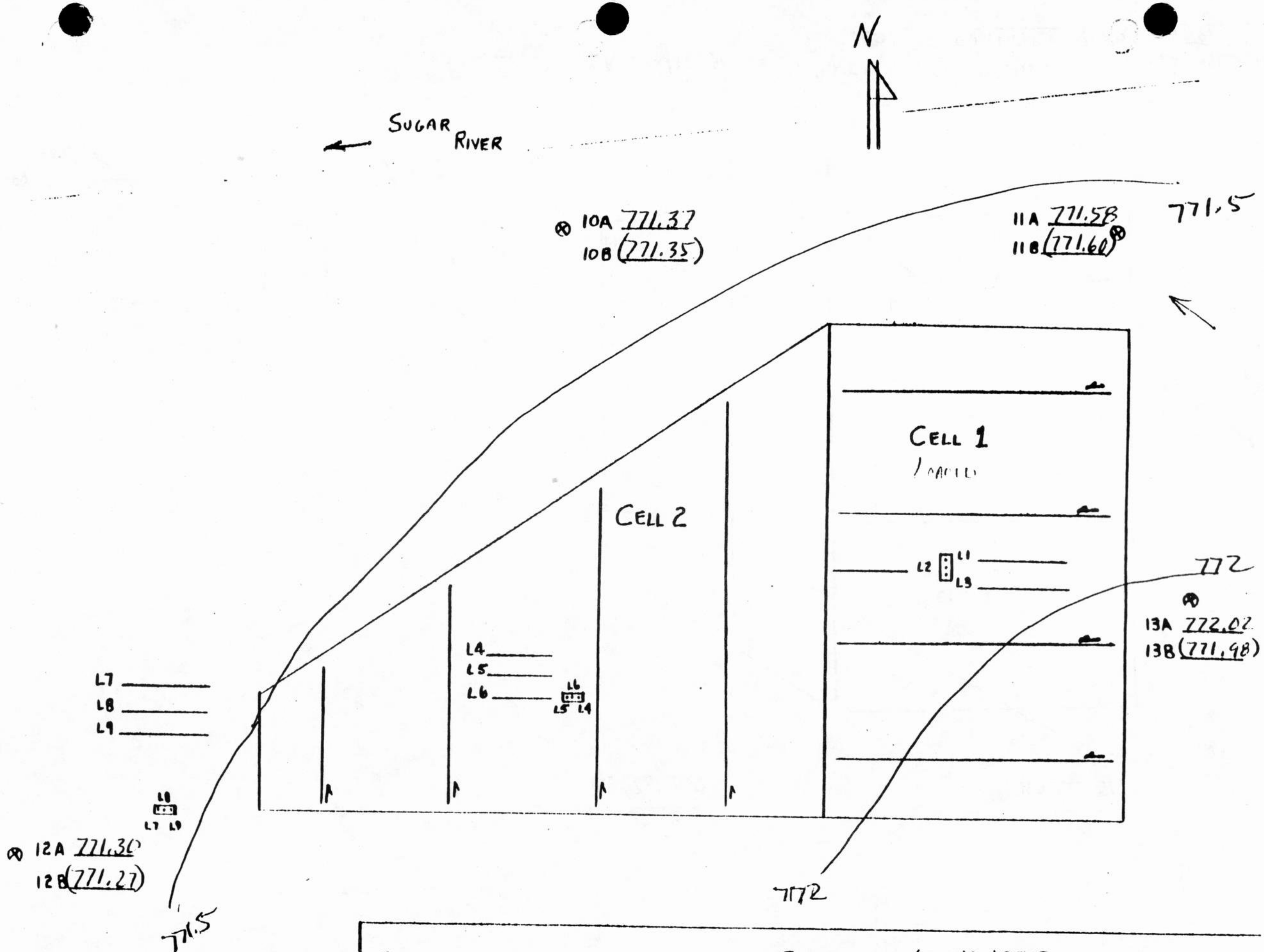
DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
3/20/84	10.06	771.99	2.0	—	—	BROWN
4/22/84	9.60	772.45	2.5	1.2	2	GREEN, GREY, ODOR
5/24/84	9.43	772.62	2.6	1.3	2	LIGHT BROWN SLIGHT ODOR
6/7/84	9.49	772.56	2.6	1.3	2	BROWN, SLIGHT ODOR
7/19/84	8.95	773.10	3.1	1.6	2	BROWN
8/30/84	9.78	772.27	2.3	1.2	2	DULL
9/25/84	9.55	772.50	2.5	1.2	2	DARK GREEN
10/9/84	9.73	772.32	2.3	1.2	2	BROWN
10/12/84	9.75	772.30	2.3	1.2	2	
10/15/84	9.75	772.30	2.3	1.2	1.5	
10/18/84	9.42	772.63	2.7	1.3	2	
10/23/84	7.81	774.24	4.3	2.1	3	
10/26/84	8.71	773.34	3.4	1.7	2	
10/30/84	8.79	773.26	3.3	1.6	2	
11/1/84	8.12	773.93	4.0	2.0	2.5	
11/8/84	8.76	773.29	3.3	1.7	2	
11/20/84	9.00	773.05	—	—	—	—

DATA SHEET: WELL 17 LENGTH: 11.53' SHALLOW, IN CELL 1

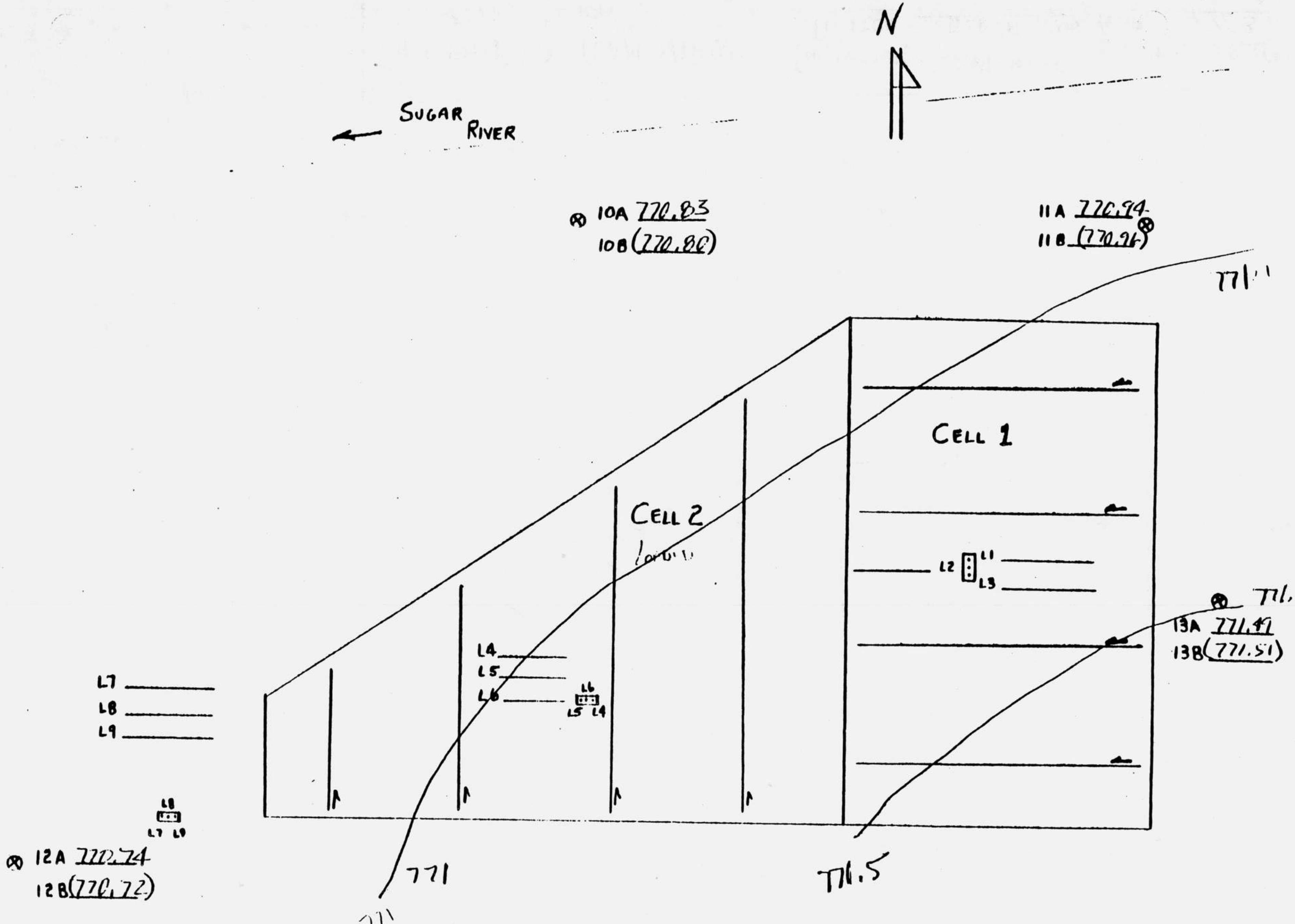
DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (GAL)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
10/12/84	8.09	772.09	3.4	1.7	6	BLACK
10/15/84	8.16	772.02	3.4	1.7	2	
10/18/84	7.78	772.40	4.2	2.1	3	
10/23/84	6.10	774.08	5.4	2.7	4	
10/26/84	7.25	772.93	4.3	2.1	3	
10/30/84	7.25	772.93	4.3	2.1	3	
11/1/84	6.66	773.52	4.9	2.4	3	
11/8/84	7.30	772.88	4.2	2.1	3	
11/13/84	7.38	772.80	—	—	—	
11/16/84	7.45	772.73	4.1	2.0	2.5	
11/20/84	7.51	772.67	4.0	2.0	2.5	



BRODHEAD PLAN VIEW – PARAMETER GROUNDWATER MONTH SEPTEMBER
PLOTTED ELEVATIONS YEAR [illegible]83
SCALE: 1" = 100'

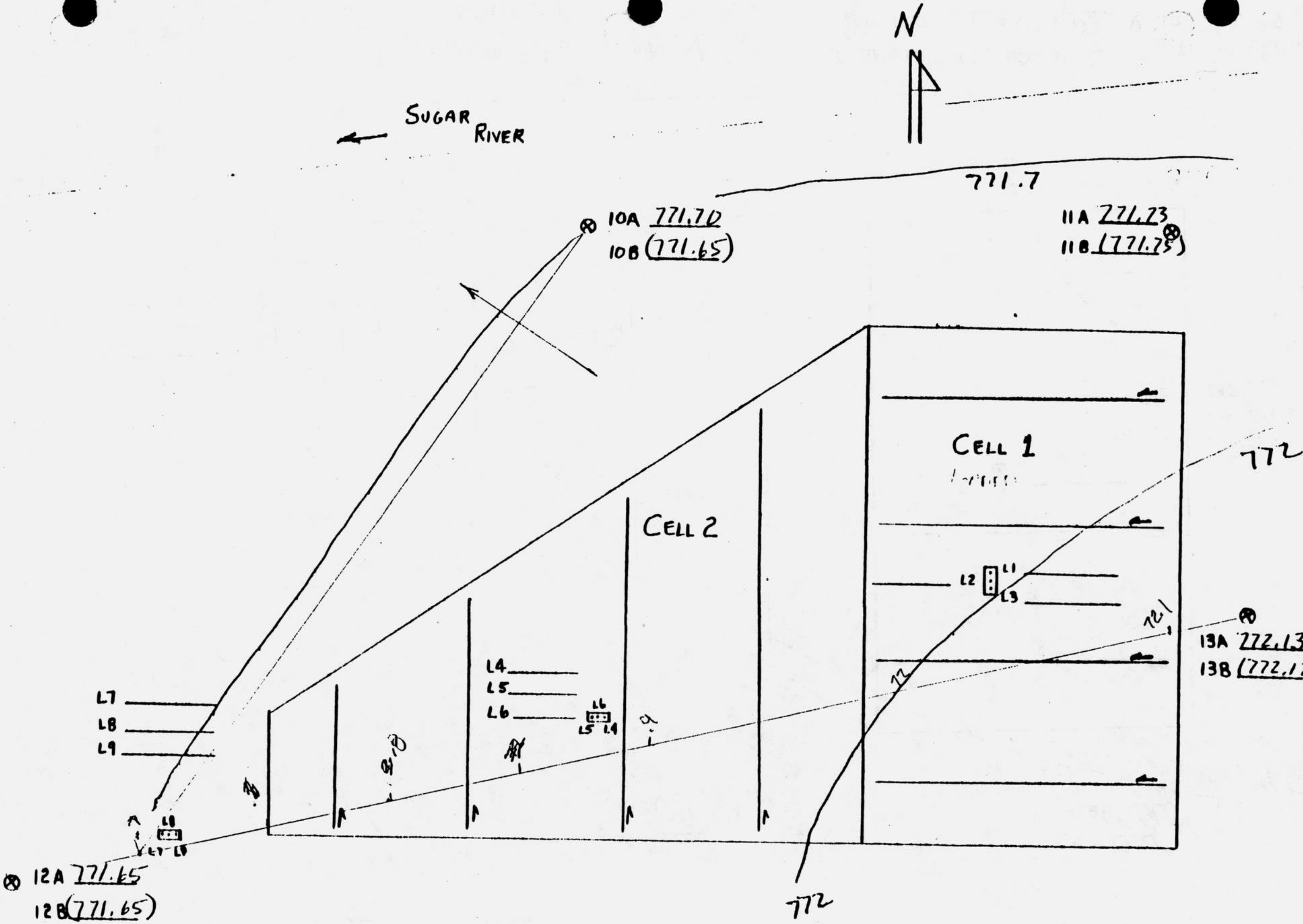


BRODHEAD PLAN VIEW - PARAMETER GROUNDWATER MONTH OCTOBER 20
PLOTTED ELEVATIONS YEAR 1983
SCALE: 1" = 100'



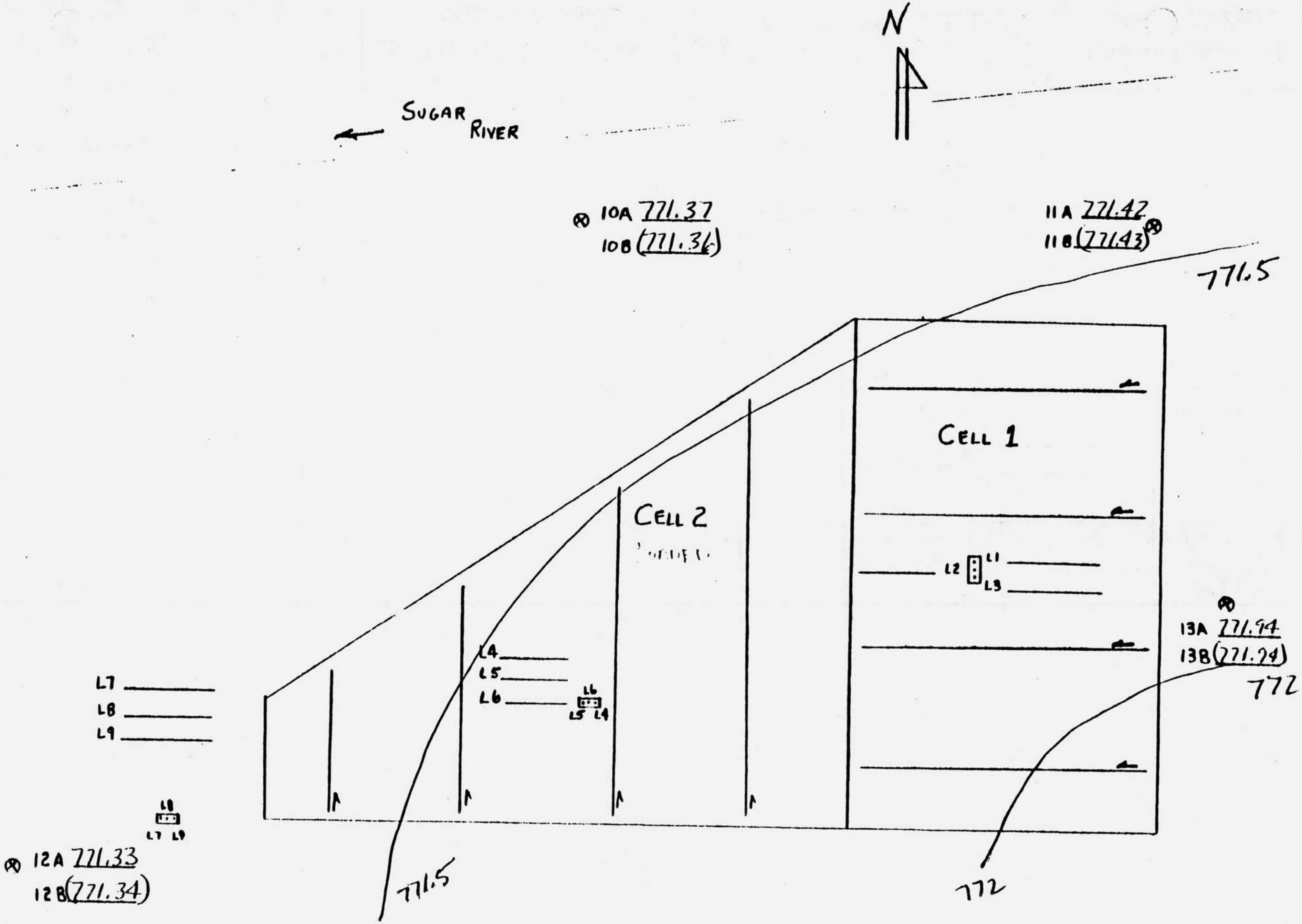
BRODHEAD PLAN VIEW - PARAMETER GROUNDWATER PLOTTED ELEVATIONS MONTH NOVEMBER 11 YEAR 1983

SCALE: 1" = 10[illegible]



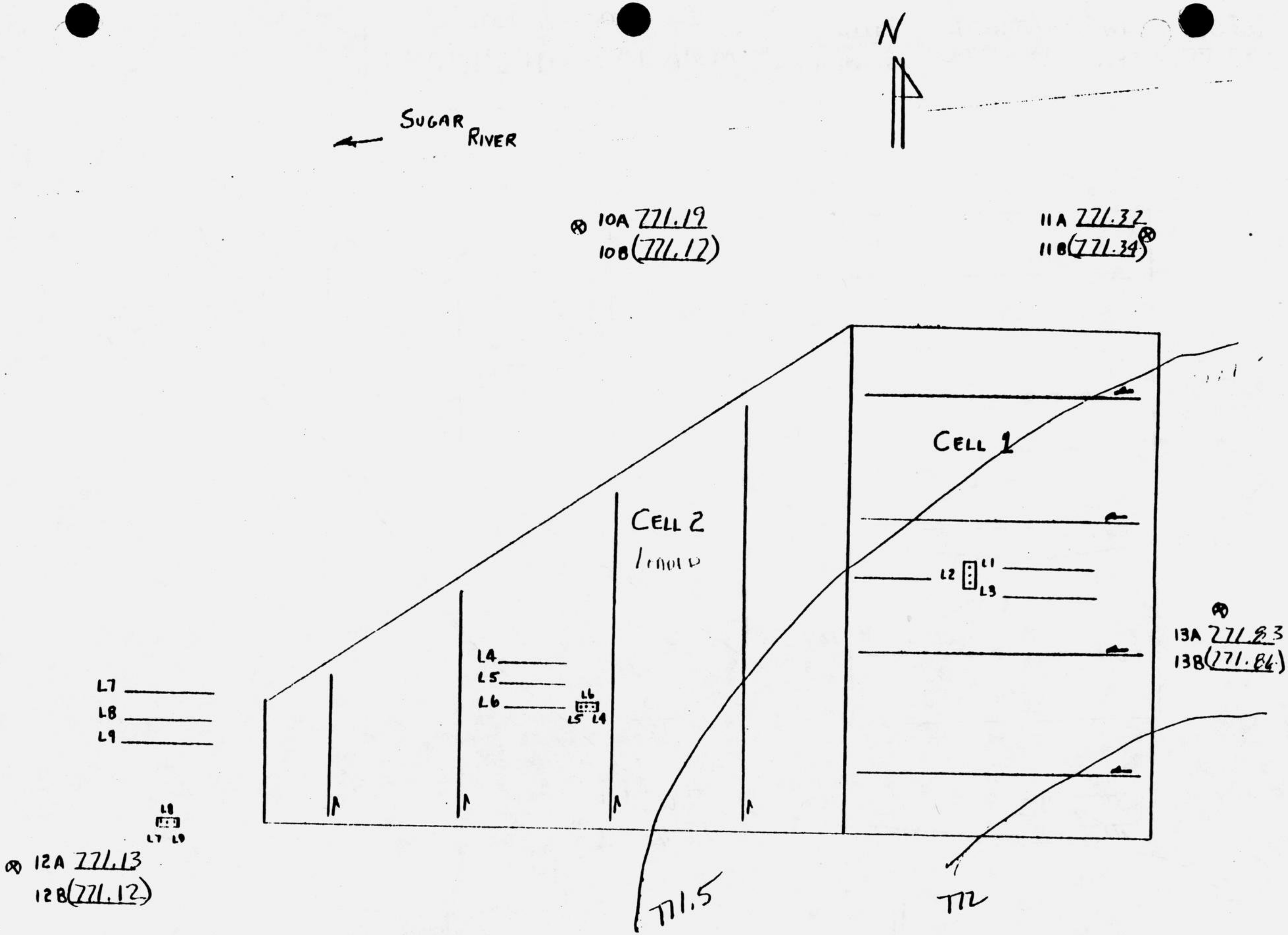
BRODHEAD PLAN VIEW - PARAMETER PLOTTED GROUNDWATER ELEVATIONS MONTH DECEMBER YEAR 198

SCALE: 1" = 100'

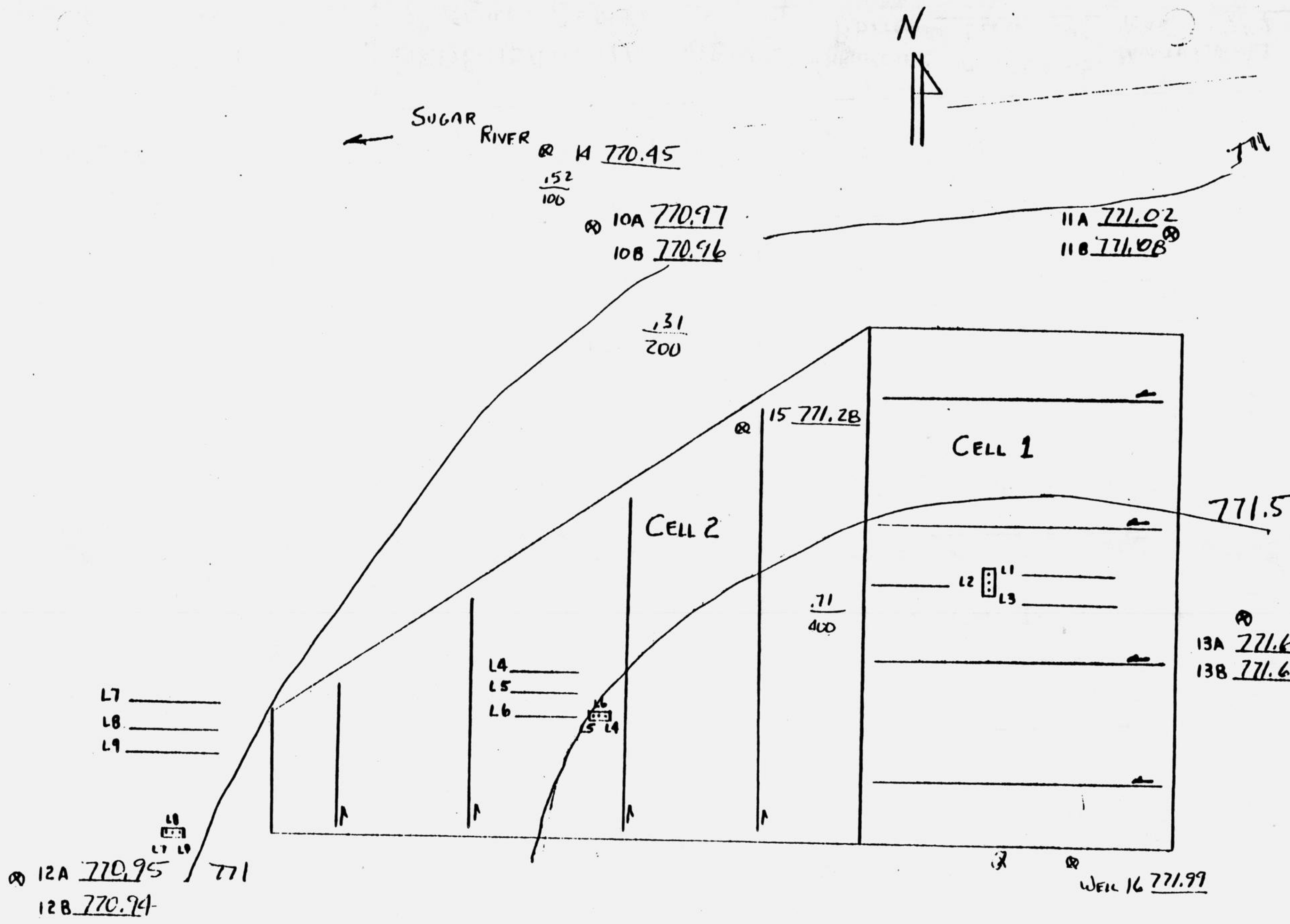


BRODHEAD PLAN VIEW - PARAMETER PLOTTED GROUNDWATER ELEVATIONS MONTH: JANUARY 12 YEAR 1984

SCALE: 1" = 10

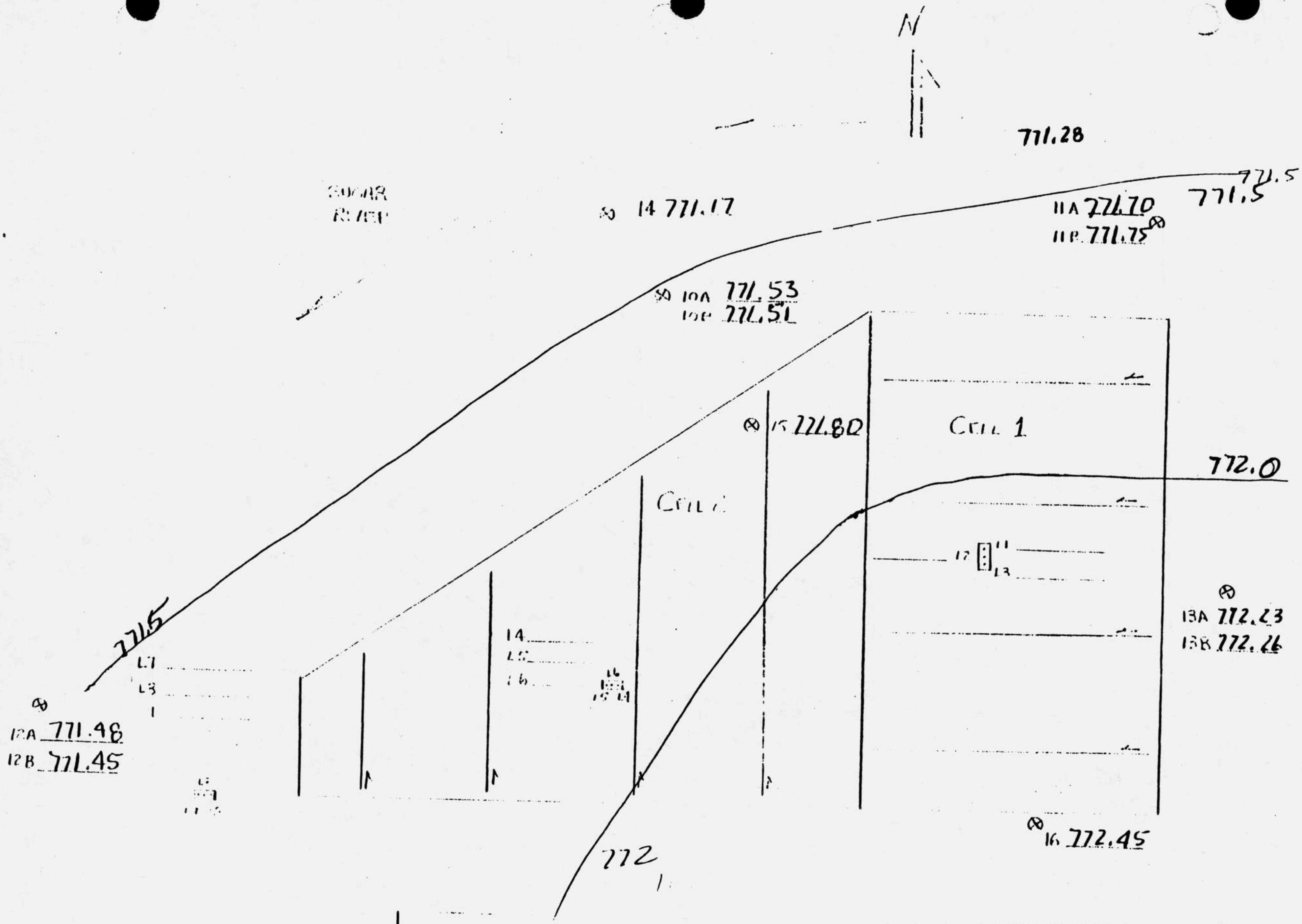


BRODHEAD PLAN VIEW - PARAMETER GROUNDWATER MONTH FEBRUARY 12
SCALE: 1" = 100'
PLOTTED ELEVATIONS YEAR 1984

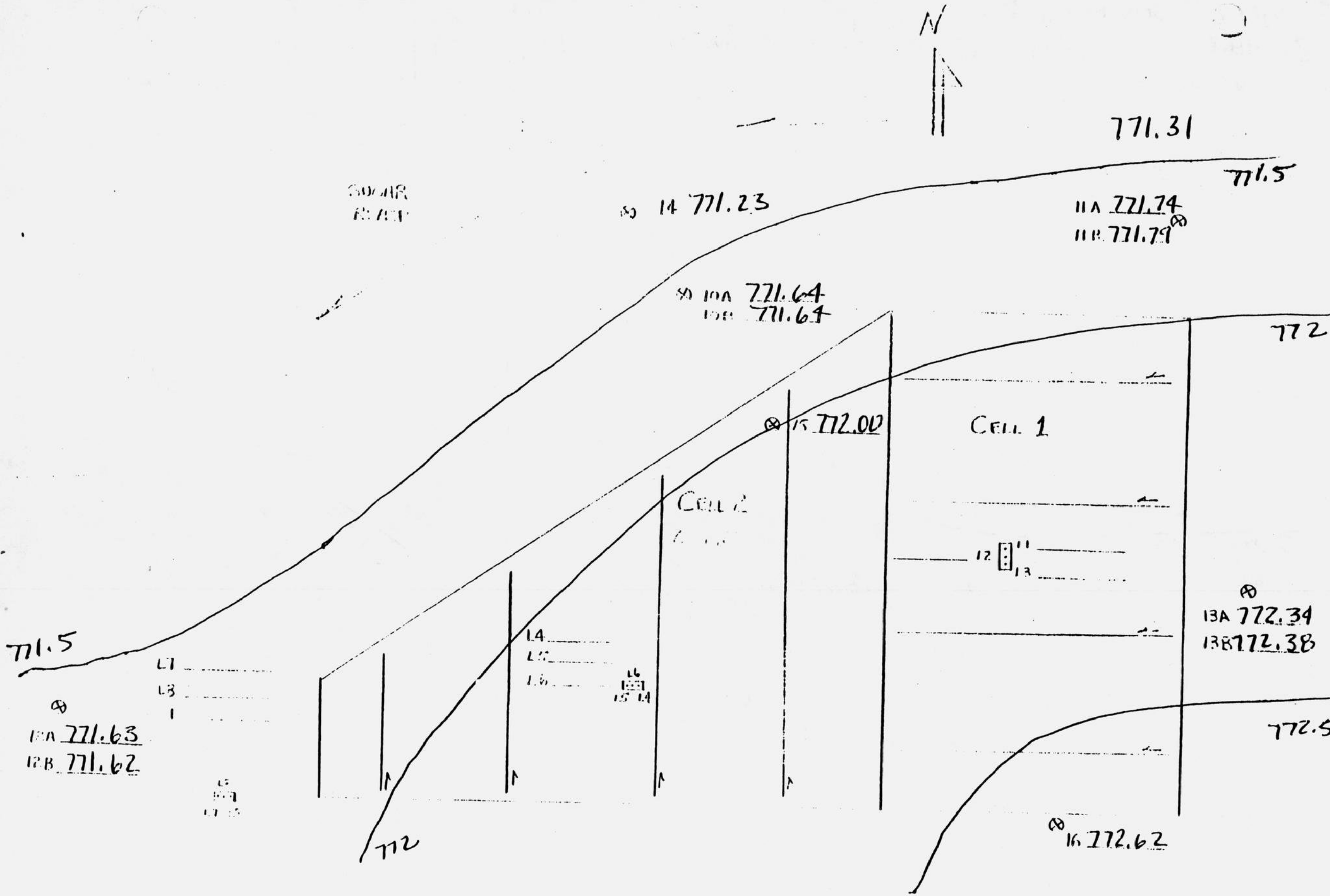


BRODHEAD PLAN VIEW - PARAMETER PLOTTED GROUNDWATER ELEVATIONS MONTH MARCH 20 YEAR 1989

SCALE: 1" = 100'



BRODHEAD PLAN VIEW – GROUNDWATER ELEVATIONS APRIL 22 1984



BRODHEAD PLAN VIEW – PARAMETER GW MONTH MAY 24
ELEVATIONS YEAR 198[illegible]

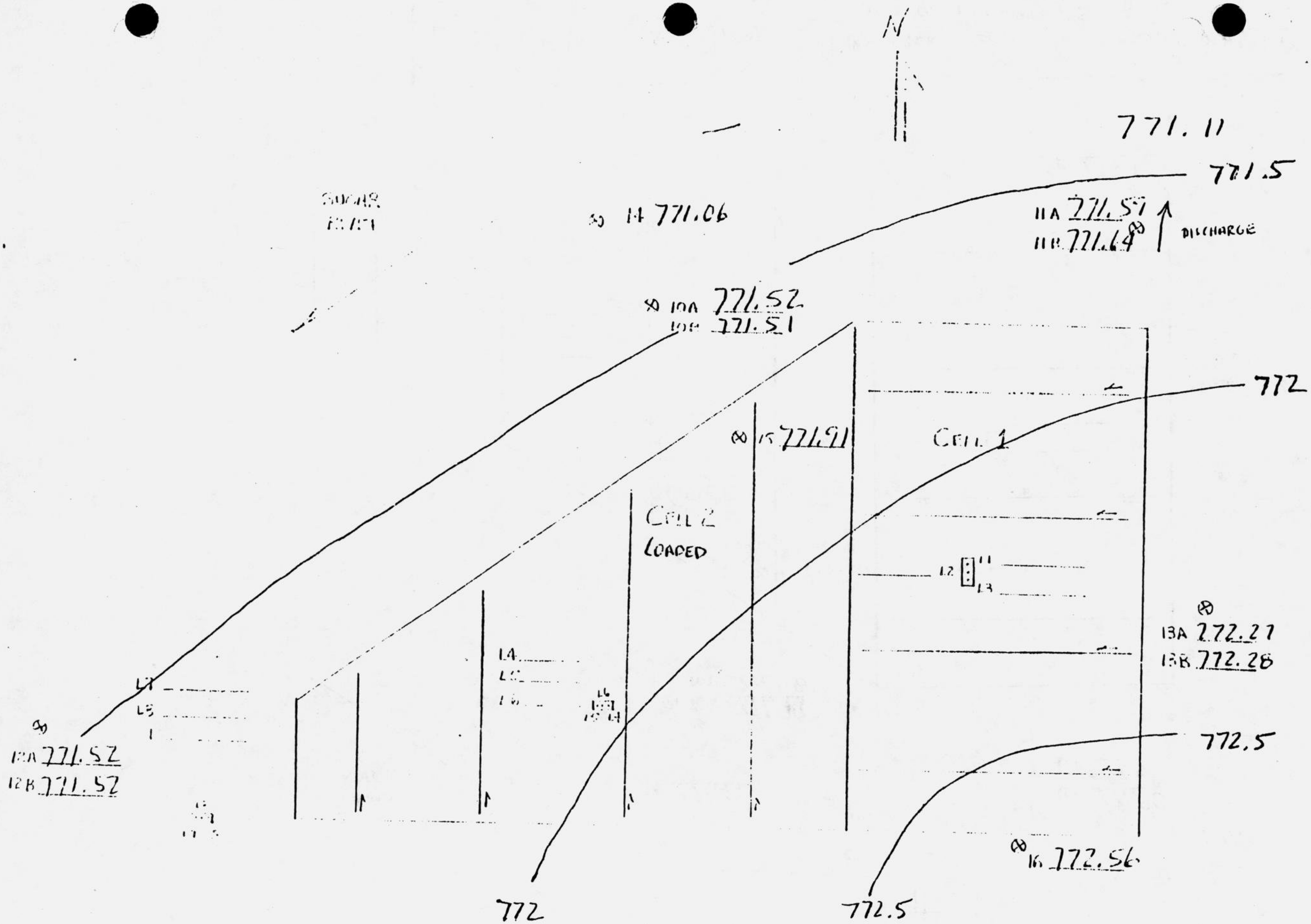
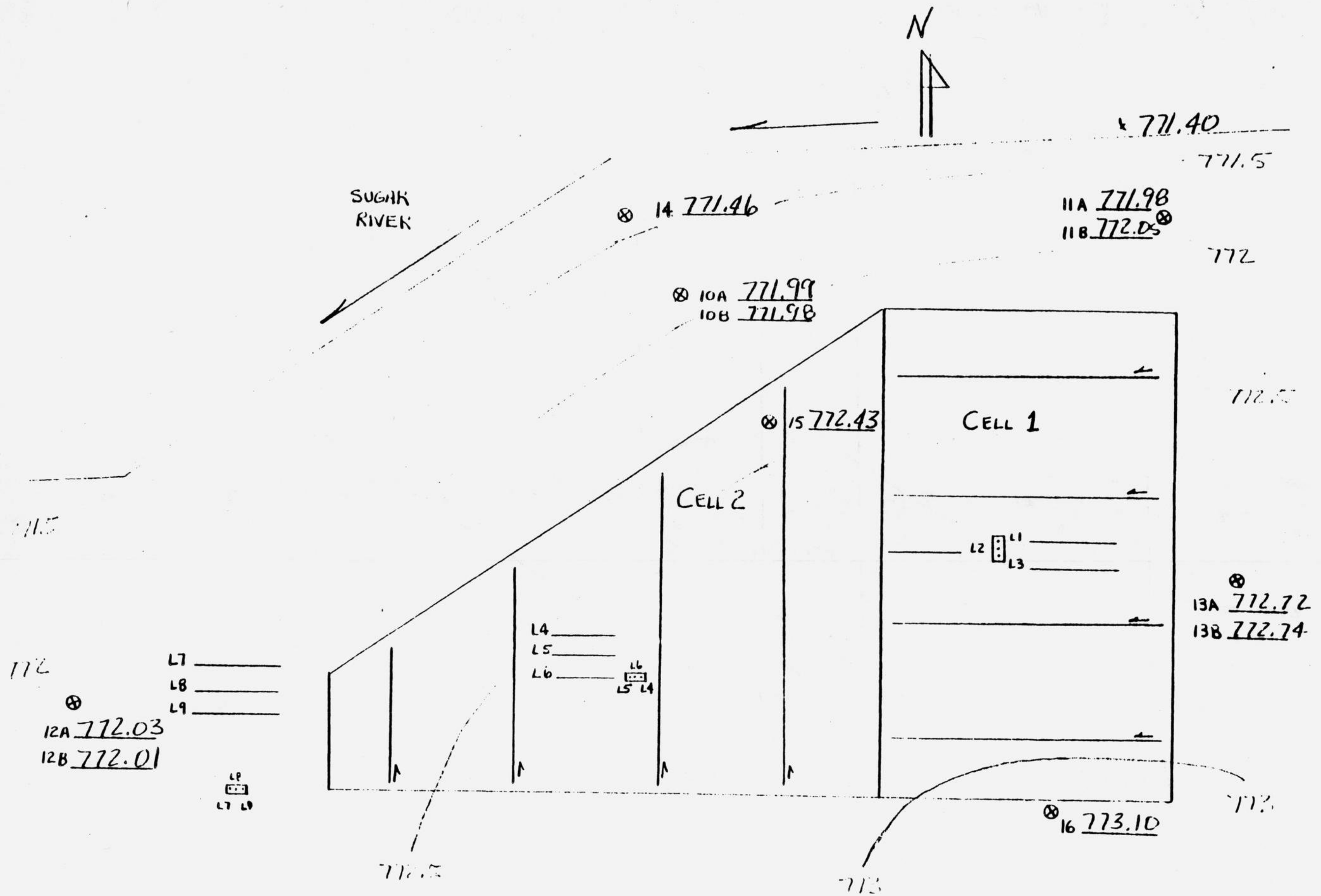


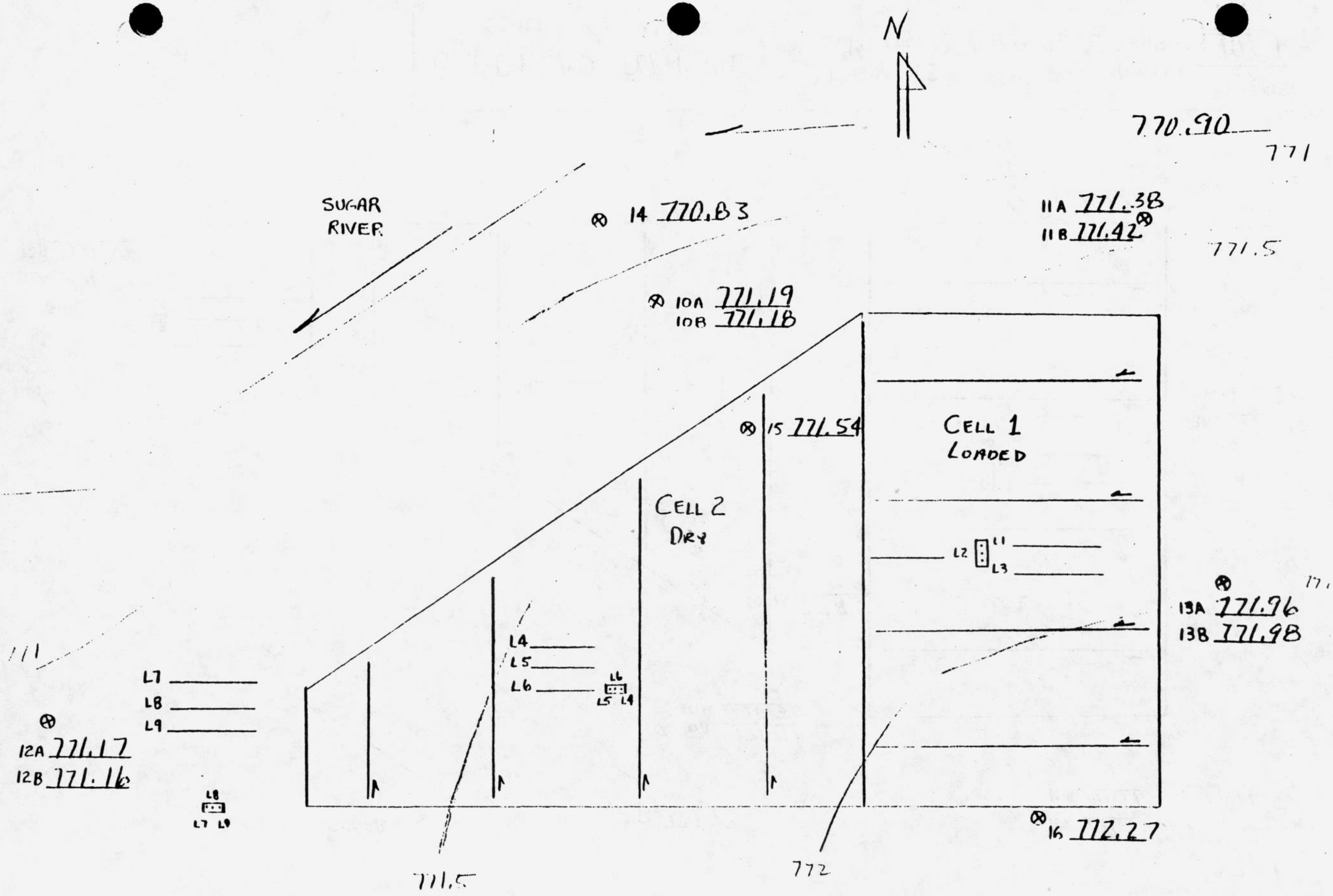
FIG 4.4

BRODHEAD PLAN VIEW – [illegible] GROUNDWATER [illegible] JUNE 7

[illegible] ELEVATIONS [illegible] 1984



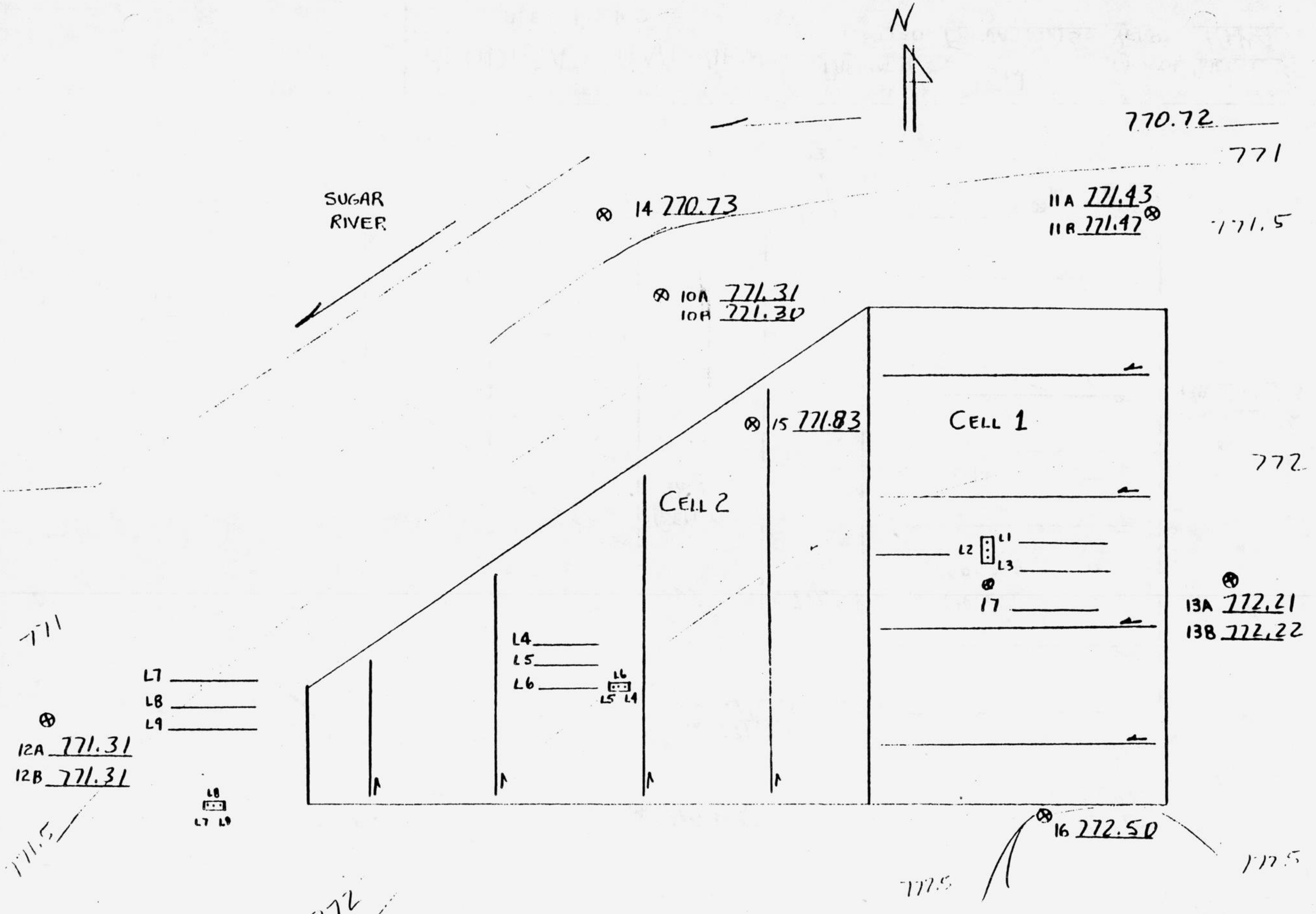
BRODHEAD PLAN VIEW - PARAMETER GW
PLOTTED ELEVATIONS
MONTH JULY 19
YEAR 84



BRODHEAD PLAN VIEW – PARAMETER GW PLOTTED ELEVATIONS

SCALE: 1" = 100'

MONTH August 30 YEAR 1984



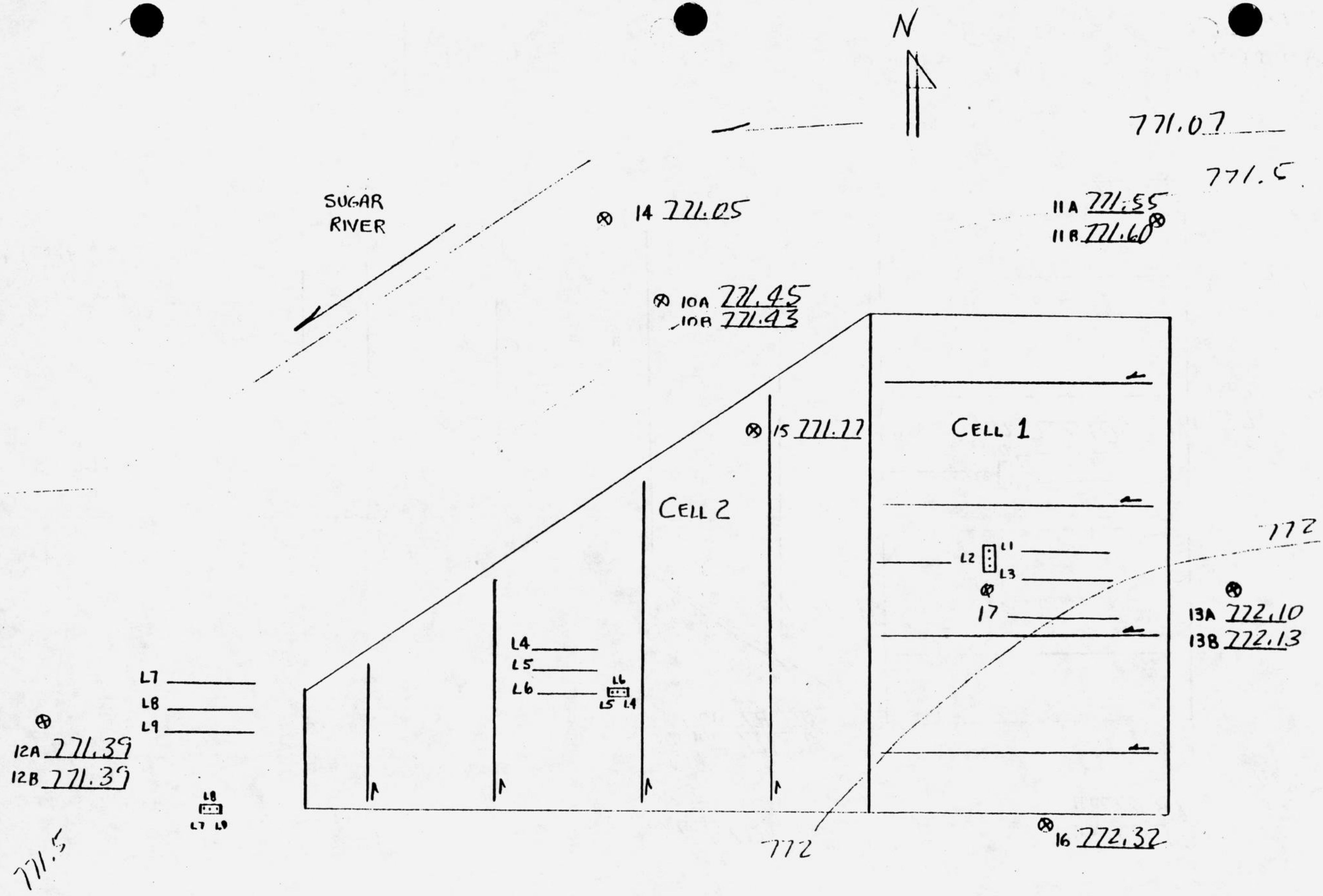
BRODHEAD PLAN VIEW – PARAMETER GW

SCALE: 1" = 100'

PLOTTED ELEVATIONS

MONTH SEPTEMBER 25

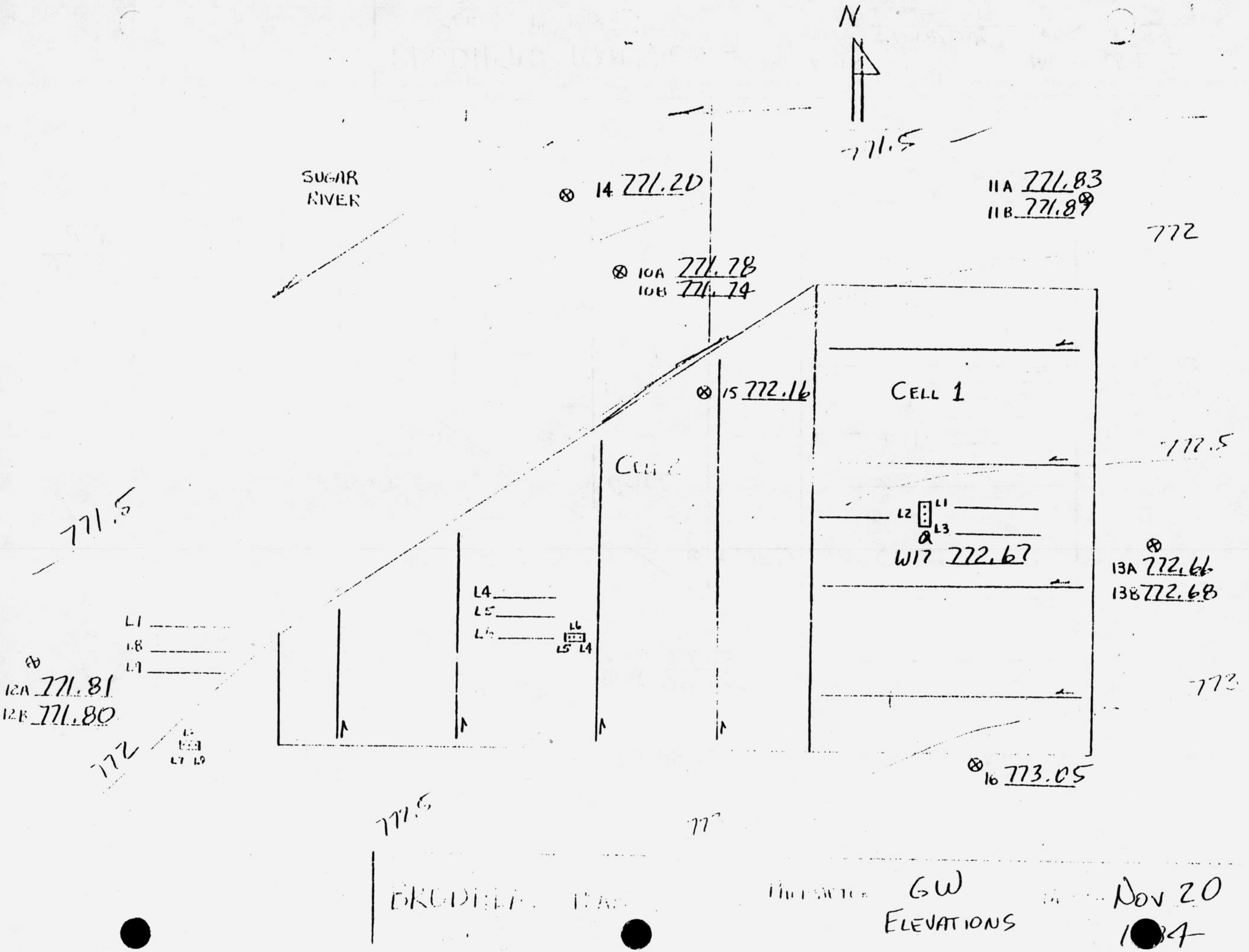
YEAR 1984



BRODHEAD PLAN VIEW - PARAMETER GW MONTH Oct 9

PLOTTED ELEVATIONS YEAR 1984

SCALE: 1" = 100'



N
771.5
SUGAR
RIVER
14 771.20
11A 771.83
11B 771.89
772
10A 771.78
10B 771.74
15 772.16
CELL 1
772.5
771.5
L2 L1
L3
W17 772.67
13A 772.66
13B 772.68
L4
L5
L6
L1
L8
L9
12A 771.81
12B 771.80
773
772
16 773.05
771.5
GW
ELEVATIONS
Nov 20

APPENDIX F

BRODHEAD:

GROUNDWATER CHEMISTRY

DATA

BRODHEAD CUMMULATIVE CHEMICAL

DATA SHEET PARAMETERS (mg/l) WELL 1DA - SHALLOW

DATE	DISSOLVED BOD_5	DISSOLVED COD	TDS (180°C)	DISSOLVED TKN	DISS. NH_3-N	DISS. $NO_2-N + NO_3-N$	Cl^-	(LAB) pH	OTHER
10/20/83	1.8	14.	—	15.	14.	<0.1	230.	8.5	—
11/16/83	9.8	18.	672	13.	12.	< 1	230	—	—
12/20/83	6.5	17.	922	14.	14.	< 1.0	350	—	—
12/20/83	TOTAL <4	TOTAL 19	TOTAL SS 2020	TOTAL 14.	—	—	340	—	—
1/12/84	3.4	17	920	13	12	0.1	340	—	—
2/12/84	<3	16	888	12	12	0.1	310	—	—
3/20/84	<3	15	960	11	11.0	<0.1	350	6.9	—
4/22/84	>18	14	1010	13	13	0.1	360	7.1	—
5/24/84	4.9	14	1020	15	15	0.2	380	7.0	7.8 (LAB pH)
6/7/84	10	19	1000	14	14	0.1	380	6.9	
7/19/84	12	17	1220	17	16	<1.0	530	6.8	—
8/30/84	6.5	20	1230	13	12	<0.5	500	6.7	—
9/25/84	6.2	21	1160	10	10	<1.0	460	6.5	—
10/9/84	11	18	1180	10	10.	<1.0	490	6.5	—

GROUNDWATER CUMULATIVE DATA SHEET — CHEMICAL PARAMETERS (mg/l) — WELL 10A - SHALLOW

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	OTHER
10/20/83	~250*	<0.02	16.	52	130	30	–	–
11/16/83	–	–	–	–	–	–	–	–
12/20/83	–	–	–	–	–	–	–	–
1/12/84	–	–	–	–	–	–	–	–
2/12/84	–	–	–	–	–	–	–	–
3/20/84	–	–	–	–	–	–	–	–
4/22/84	–	–	–	–	–	–	–	–
5/24/84	352	0.02	0.8	45	270	23	30	–
6/7/84	–	–	–	–	–	–	–	–
7/19/84	–	–	–	–	–	–	–	–
8/30/84	406	<0.02	<1.0	53	360	27	26	–

* APPROXIMATE

BRODHEAD CUMULATIVE CHEMICAL

DATA SHEET PARAMETERS (mg/l) WELL 10B - DEEP

DATE	DISSOLVED BOD_5	DISS COD	TDS	DISS TKN	DISS NH_3-N	DISS NO_2-N + NO_3-N	Cl^-	PH (LAB)	OTHER
10/20/83	2.5	9	—	6.0	5.1	<0.1	350	8.4	—
11/16/83	11.	27.	1390	10.	9.3	0.1	520	—	—
12/20/83	12	24	1570	9.6	9.7	<0.1	580	—	—
1/12/84	4.9	25	1538	7.5	6.7	0.1	560	—	—
2/12/84	<3	21	1670	7.0	7.0	<0.1	650	—	—
3/20/84	5.3	18	1550	5.4	5.2	0.1	580	6.8	—
4/22/84	>18	13	1650	7.4	7.2	0.1	640	6.9	—
5/24/84	8.9	19	1660	10	10	0.1	690	6.8	7.5 LAB pH
6/7/84	11	23	1770	15	15	<0.1	740	6.7	—
7/19/84	21	25	1810	17	16	<1.0	750	6.7	-
8/30/84	<12	33	1980	17	17	<0.5	790	6.6	—
9/25/84	21	31	1820	24	24	<1.0	710	6.5	
10/9/84	3.7	34	1730	26	26	<1.0	680	6.7	

BROADHEADS CUMMULATIVE CHEMICAL

DATA SHEET PARAMETERS (mg/l) WELL 1DB - DEEP

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	OTHER
10/20/83	~220	<0.02	5.9	59	230	24	–	–
11/16/83	–	–	–	–	–	–	–	–
12/20/83	–	–	–	–	–	–	–	–
1/12/84	–	–	–	–	–	–	–	–
2/12/84	–	–	–	–	–	–	–	–
3/20/84	–	–	–	–	–	–	–	–
4/22/84	–	–	–	–	–	–	–	–
5/24/84	436	<0.02	1.0	80	440	37	30	–
6/7/84	–	–	–	–	–	–	–	–
7/19/84	–	–	–	–	–	–	–	–
8/30/84	608	0.02	10	73	570	39	47	–

DATA SHEET — PARAMETERS (mg/l) — WELL 11A - SHALLOW

DATE	DISSOLVED BOD_5	DISS COD	DISS TDS	DISS TKN	DISS NH_3-N	DISS NO_2-N + NO_3-N	Cl^-	pH (LAB)	OTHER
10/20/83	1.8	19	—	4.0	3.2	<0.1	96.	8.5	—
11/16/83	<6	13	312	2.4	2.0	<0.1	49	—	—
12/20/83	<4	15	494	3.8	3.6	<0.1	120	—	—
12/20/83	TOTAL 18	TOTAL 26	TOTAL SS 1980	TOTAL 5.2	—	—	110	—	—
1/12/84	<3	30	640	4.0	3.4	<0.1	160	—	—
2/12/84	<3	13	514	3.2	3.0	<0.1	110		
3/20/84	<3	19	476	2.6	2.1	0.1	100	6.7	—
4/22/84	<3	20	493	3.4	2.9	0.1	110	7.0	-
5/24/84	<3	22	526	3.5	3.0	0.1	110	6.9	8.1 LAB pH
6/7/84	<3	25	578	3.3	2.9	0.1	140	6.5	—
7/19/84	4.3	23	552	2.9	2.3	<0.1	130	6.9	
8/30/84	<6	26	848	2.2	1.5	0.1	280	6.5	—
9/25/84	4.9	30	838	3.5	2.9	<0.1	260	6.5	
10/9/84	7.7	42	640	3.6	2.8	<0.1	170	6.7	-

DATA SHEET PARAMETERS (mg/l) WELL 11A - SHALLOW

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/20/83	~191	0.72	43.	47	81	20	—	—
11/16/83	—	—	—	—	—	—	—	—
12/20/83	—	—	—	—	—	—	—	—
1/12/84	—	—	—	—	—	—	—	—
2/12/84	—	—	—	—	—	—	—	—
3/20/84	—	—	—	—	—	—	—	—
4/22/84	—	—	—	—	—	—	—	—
5/24/84	270	0.39	24	57	95	24	5	—
6/7/84	—	—	—	—	—	—	—	—
7/19/84	—	—	—	—	—	—	—	—
8/30/84	358	1.07	5.2	74	210	30	6	—

DATA SHEET — CHEMICAL PARAMETERS (mg/l) WELL 11B - DEEP

DATE	DISSOLVED BOD_5	DISS. COD	DISS TDS	DISS TKN	DISS NH_3-N	DISS NO_2-N + NO_3-N	Cl^-	pH (LAB)	OTHER
10/20/83	1.2	<5	—	0.4	0.2	0.1	94.	8.2	—
11/16/83	<6	5	326	0.2	0.1	0.1	29	—	—
12/20/83	<4	<5	308	0.2	0.1	<0.1	12	—	—
1/12/84	<3	<5	316	0.3	0.1	<0.1	12	—	—
2/12/84	<3	<5	304	0.2	0.1	<0.1	12	—	—
3/20/84	<3	<5	304	0.2	0.2	0.1	15	7.2	—
4/22/84	<3	<5	308	0.2	0.1	0.1	13	7.2	—
5/24/84	<3	<5	336	0.2	0.1	0.1	17	7.3	8.2 LAB pH
6/7/84	18	62	752	0.2	0.1	<0.1	190	7.0	
7/19/84	15	17	1140	1.2	0.8	0.1	390	6.9	—
8/30/84	<12	6	324	0.6	0.5	0.1	46	6.9	—
9/25/84	<4	<5	358	0.6	0.5	<0.1	34	7.0	
10/9/84	<3	8	432	0.8	0.6	<0.1	75	7.0	

DATA SHEET PARAMETERS (mg/l) WELL 11B-DEEP

DATE	ALKALINITY	TOTAL F	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/20/83	~212	0.07	23.	70	47	35	–	–
11/16/83	–	–	–	–	–	–	–	–
12/20/83	–	–	–	–	–	–	–	–
1/12/84	–	–	–	–	–	–	–	–
2/12/84	–	–	–	–	–	–	–	–
3/20/84	–	–	–	–	–	–	–	–
4/22/84	–	–	–	–	–	–	–	–
5/24/84	222	<0.02	31	61	5	27	2	–
6/7/84	–	–	–	–	–	–	–	–
7/19/84	–	–	–	–	–	–	–	–
8/30/84	252	<0.02	26	66	34	24	6	–

[illegible]

DATA SHEET PARAMETERS (mg/l) WELL 2A - SHALLOW, EG

DATE	DISSOLVED BOD_5	DISS COD	DISS TDS X	DISS TKN X	DISS NH_3-N	DISS NO_2-N + NO_3-N X	Cl^- X	(LAB) pH	OTHER
10/20/83	1.6	<5	—	0.2	<0.1	12.0 *	~~65~~ 24	8.4	—
11/16/83	<3	9	356	0.2	<0.1	8.3	29	—	—
12/20/83	4.9	14	470	0.7	0.1	8.7	33	—	—
1/12/84	<3	8	378	0.3	<0.1	7.9	29	—	—
2/12/84	<3	25	346	2.0	<0.1	7.6	29	—	—
3/20/84	<3	<5	343	0.2	0.1	7.3	25	6.8	—
4/22/84	<3	<5	340	0.2	0.1	7.6	23	7.1	—
5/24/84	<3	<5	372	0.2	0.1	9.7	23	7.0	8.3 LAB pH
6/7/84	—	—	—	—	—	—	—	—	—
7/19/84	—	—	—	—	—	—	—	—	—
8/30/84	—	—	—	—	—	—	—	—	—

DRUDHEAD CUMMULATIVE CHEMICAL DATA SHEET PARAMETERS (mg/l) WELL 12A-SHALLOW EG

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/20/83	~200	0.02	17.	65	14	30	—	—
11/16/83	—	—	—	—	—	—	—	—
12/20/83	—	—	—	—	—	—	—	—
1/12/84	—	—	—	—	—	—	—	—
2/12/84	—	—	—	—	—	—	—	—
3/20/84	—	—	—	—	—	—	—	—
4/22/84	—	—	—	—	—	—	—	—
5/24/84	214	<0.02	20	61	12	28	2	—
6/7/84	—	—	—	—	—	—	—	—
7/19/84	—	—	—	—	—	—	—	—
8/30/84	—	—	—	—	—	—	—	—

DATA SHEET PARAMETERS (mg/l) WELL 12B- DEEP, BG

DATE	DISSOLVED BOD_5	DISS COD	TDS	DISS TKN	DISS NH_3-N	DISS NO_2-N + NO_3-N	Cl^-	pH (LAB)	OTHER
10/20/83	1.6	<5	—	0.2	<0.1	10.1*	39.	8.7	—
11/16/83	<3	6	330	<0.2	<0.1	8.4	40	—	—
12/20/83	<3	<5	396	0.2	<0.1	13.2	37	—	—
1/12/84	<3	7	432	0.2	<0.1	13.6	36	—	—
SPLIT SAMPLE	<3	6	438	<0.2	<0.1	14.2	36	—	—
2/12/84	<3	<5	414	<0.2	<0.1	12.7	37	—	—
3/20/84	<3	<5	368	0.2	0.1	9.4	39	7.4	—
4/22/84	<3	<5	350	<0.2	0.1	8.3	38	7.5	—
5/24/84	<3	<5	338	<0.2	0.1	6.9	38	7.6	8.3 LAB pH
6/7/84	—	—	—	—	—	—	—	—	—
7/19/84	—	—	—	—	—	—	—	—	—
8/30/84	—	—	—	—	—	—	—	—	—

GROUNDWATER CUMULATIVE CHEMICAL
DATA SHEET PARAMETERS (mg/l) WELL 12B-DEEP, 3G

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/20/83	~214	0.04	23.	56	24	32	—	—
11/16/83	—	—	—	—	—	—	—	—
12/20/83	—	—	—	—	—	—	—	—
1/12/84	—	—	—	—	—	—	—	—
2/12/84	—	—	—	—	—	—	—	—
3/20/84	—	—	—	—	—	—	—	—
4/12/84	—	—	—	—	—	—	—	—
5/24/84	166	0.02	24	42	21	26	2	—
6/7/84	—	—	—	—	—	—	—	—
7/19/84	—	—	—	—	—	—	—	—
8/30/84	—	—	—	—	—	—	—	—

DATA SHEET — PARAMETERS (mg/l) — WELL 13A – SHALLOW

DATE	DISSOLVED BOD5	DISS COD	TDS	DISS TKN	DISS NH_3-N	DISS NO_2-N + NO_3-N	Cl^-	(LAB) pH	OTHER
10/20/83	0.8	20	—	1.0	0.1	1.6	2.4	8.6	—
11/16/83	<3	18	212	0.6	0.1	<0.1	2.8	—	—
12/20/83	<3	17	216	0.6	0.1	<0.1	2.1	—	—
12/20/83	TOTAL <3	TOTAL 18	TOTAL SS 334	TOTAL 0.8	—	—	2.0	—	—
1/12/84	<3	17	222	0.6	0.1	0.1	1.5	—	—
2/12/84	<3	16	236	0.6	0.2	<0.1	1.6	—	—
3/20/84	<3	21	286	0.7	0.2	0.2	2.3	6.7	—
4/12/84	<3	22	320	0.5	0.2	0.1	3.0	7.1	—
5/24/84	<3	25	384	0.9	0.3	0.2	4.3	7.0	8.0 LAB pH
6/7/84	<3	31	438	1.0	0.2	0.2	5.5	7.0	—
7/19/84	<3	36	476	1.2	0.2	0.1	6.1	7.3	
8/30/84	<3	33	432	1.2	0.3	1.3	6.4	6.9	—
9/25/84	<3	20	280	0.5	0.2	0.7	7.2	7.2	
10/9/84	<3	21	254	0.8	0.2	0.1	6.1	7.1	

DATA SHEET PARAMETERS (mg/l) WELL 13A - SHALLOW

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/20/83	~196	0.14	33	48	3	27	–	–
11/16/83	–	–	–	–	–	–	–	–
12/20/83	–	–	–	–	–	–	–	–
1/12/84	–	–	–	–	–	–	–	–
2/12/84	–	–	–	–	–	–	–	–
3/20/84	–	–	–	–	–	–	–	–
4/22/84	–	–	–	–	–	–	–	–
5/24/84	244	0.03	71	67	3	35	2	–
6/7/84	–	–	–	–	–	–	–	–
7/19/84	–	–	–	–	–	–	–	–
8/30/84	250	DISS PO_4 @ P 0.04	100	–	4	39	3	–

[illegible]HEAD CUMULATIVE CHEMICAL DATA SHEET PARAMETERS (mg/l) WELL 13B- DEEP

DATE	DISSOLVED BOD$_5$	DISS COD	TDS	DISS TKN	DISS NH_3-N	DISS NO_2-N+ NO_3-N	Cl^-	pH	OTHER
10/20/83	0.8	<5	—	<0.2	<0.1	4.6	32.	8.6	—
11/16/83	<3	<5	300	0.2	<0.1	4.7	33	—	—
12/20/83	<3	<5	292	0.2	<0.1	4.6	36	—	—
1/12/84	<3	6	322	0.2	<0.1	4.3	40	—	—
2/12/84	<3	<5	316	0.2	<0.1	4.5	35	—	—
3/20/84	<3	<5	314	0.2	0.1	4.2	33	7.1	—
4/22/84	<3	<5	312	0.2	0.1	3.9	33	7.4	—
5/24/84	<3	<5	344	<0.2	0.1	3.7	34	7.0	8.2 LAB pH
6/7/84	—	—	—	—	—	—	—	—	—
7/19/84	—	—	—	—	—	—	—	—	—
8/30/84	<3	<5	316	0.2	0.1	3.9	34	7.3	—
9/25/84	<3	<5	338	0.2	<0.1	4.1	35	7.4	
10/9/84	<3	5	316	0.2	<0.1	4.2	37	7.3	

CUMULATIVE CHEMICAL
DATA SHEET PARAMETERS (mg/l) WELL 13B - DEEP

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/20/83	~178	<0.02	25.	52	17	22	-	-
11/16/83	-	-	-	-	-	-	-	-
12/20/83	-	-	-	-	-	-	-	-
1/12/84	-	-	-	-	-	-	-	-
2/14/84	-	-	-	-	-	-	-	-
3/20/84	-	-	-	-	-	-	-	-
4/22/84	-	-	-	-	-	-	-	-
5/24/84	183	<0.02	25	49	21	23	5	-
6/7/84	-	-	-	-	-	-	-	-
7/19/84	-	-	-	-	-	-	-	-
8/30/84	193	<0.02	24	54	23	22	8	-

BRODHEAD CUMMULATIVE CHEMICAL PARAMETERS (mg/l) WELL 14 - SHALLOW

DATA SHEET

DATE	DISS BOD_5 X	DISS COD	TDS X	DISS TKN X	DISS NH_3-N X	DISS NO_2-N + NO_3-N X	Cl^- X	FIELD pH (LAB)	OTHER
3/20/84	4.6	15	638	1.4	1.1	0.4	180	7.2	—
4/22/84	18	30	634	1.3	0.3	1.5	160	7.0	—
5/24/84	<3	14	646	1.3	1.0	4.5	150	7.0	8.1 LAB pH
6/7/84	<4	14	634	1.4	1.0	2.4	180	7.1	—
7/19/84	<3	30	410	1.2	0.2	1.8	80	7.2	
8/30/84	<3	13	710	2.1	2.0	0.1	250	7.0	—
9/25/84	<3	17	774	2.8	2.6	0.1	230	7.1	
10/9/84	<3	13	742	2.6	2.3	0.1	270	7.1	

GEOCHEMICAL COMPARATIVE CHEMICAL
DATA SHEET PARAMETERS (mg/l) WELL 14 - SHALLOW

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
5/24/84	238	0.02	43	45	120	29	9	—
6/7/84	—	—	—	—	—	—	—	—
7/19/84	—	—	—	—	—	—	—	—
8/30/84	230	0.05	19	48	180	23	11	—

[illegible] CUMMULATIVE DATA SHEET — CHEMICAL PARAMETERS (mg/l) — WELL 15 - SHALLOW, CELL 2

DATE	DISS BOD_5 x	DISS COD	TDS x	DISS TKN x	DISS NH_3-N x	DISS NO_3-N + NO_2-N x	Cl^- x	FIELD pH	OTHER
3/20/84	160	170	1390	19	19	0.1	420	6.4	—
4/22/84	120	130	1360	18	17	<1.0	280	6.4	—
5/24/84	<15	28	1620	6.8	6.3	1.6	690	6.2	7.2 LAB pH
6/7/84	<30	30	1560	2.5	1.7	0.1	660	6.3	—
7/19/84	12	42	1610	27	26	0.1	600	6.6	—
7/31/84	12	34	1570	18	17	0.1	620	—	—
8/3/84	30	51	1660	26	25	<1.0	640	—	—
8/7/84	87	120	1800	36	34	<1.0	650	—	—
8/10/84	120	150	1880	46	42	<1.0	670	—	—
8/30/84	11	100	1910	78	74	11	660	6.5	—
9/25/84	7.8	23	1320	61	60	7.0	540	6.5	—
10/9/84	11	31	1960	4.0	4.0	48	740	6.4	
10/12/84	—	27	—	1.3	1.2	74	580	—	—
10/15/84	—	27	—	1.1	0.4	37	470	—	—
10/18/84	—	25	—	1.2	<1.0	17.8	500	—	—
10/23/84	—	21	—	1.0	0.2	44	500	—	—
10/26/84	—	25	—	1.0	<1.0	53	600	—	—
10/30/84	—	23	—	1.0	<1.0	33.	440	—	—
11/1/84	—	24	—	0.8	<1.0	30	490	—	—
11/8/84	—	—	—	1.5	0.8	8.0	630	—	—
11/13/84	—	—	—	2.0	1.0	10	530	—	—
11/16/84	—	—	—	2.8	2.1	7.2	620	—	—
11/20/84	—	—	—	4.3	3.6	6.2	680	—	—

BRODHEAD [illegible] CHEMICAL [illegible] WELL 15 - [illegible]
DATA SHEET PARAMETERS [illegible]

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	OTHER
5/24/84	348	10	36	92	350	51	26	
6/7/84	—	—	—	—	—	—	—	—
7/19/84	—	—	—	—	—	—	—	—
7/31/84	—	—	—	—	—	—	—	—
8/3/84	—	—	—	—	—	—	—	—
8/7/84	—	—	—	—	—	—	—	—
8/10/84	—	—	—	—	—	—	—	—
8/30/84	563	22	190	48	540	26	43	—

BRODHEAD CUMULATIVE CHEMICAL ANALYSES (mg/l) WELL 16 - SHALLOW, SE BERM

DATA SHEET

DATE	DISS BOD_5 X	DISS COD	TDS X	DISS TKN X	DISS NH_3-N	DISS NO_3-N + NO_2-N	Cl⁻ X	FIELD pH	OTHER
3/20/84	7.7	34	550	1.6	0.8	0.1	100	(LAB) 7.0	—
4/22/84	743	160	1650	1.6	0.5	0.1	720	6.4	—
5/24/84	83	130	1500	3.0	1.9	0.1	630	6.4	7.4 LAB pH
6/7/84	10	38	1140	2.0	1.2	0.1	470	6.4	
7/19/84	140	200	1870	3.3	1.9	0.1	720	6.6	
7/31/84	42	96	1990	3.4	2.0	0.1	380	—	—
8/3/84	73	130	2030	3.0	1.7	0.1	370	—	
8/7/84	35	92	1900	3.1	1.6	0.1	740	—	—
8/10/84	190	240	2010	3.6	1.7	0.1	720	—	
8/30/84	39	100	1460	3.3	2.6	0.1	510	6.4	—
9/25/84	9.2	38	1350	5.2	4.4	<0.1	510	6.4	
10/9/84	11	43	1730	7.8	6.9	<0.1	700	6.6	
10/12/84	—	41	—	7.2	6.3	<0.1	550	—	—
10/15/84	—	41	—	6.4	5.7	0.1	480	—	—
10/18/84	—	34	—	6.4	5.4	<0.1	460	—	—
10/23/84	—	41	—	9.2	7.8	0.1	550	—	—
10/26/84	—	40	—	9.4	8.6	0.1	600	—	—
10/30/84	—	48	—	8.2	6.9	0.1	560	—	—
11/1/84	—	41	—	6.5	5.5	0.1	480	—	—
11/8/84	—	—	—	5.4	4.0	0.1	320	—	—

DATA SHEET | CHEMICAL PARAMETERS (MG/L) | WELL 16 - SE BERM

DATE	ALKALINITY	TOTAL S	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
5/24/84	328	14	INT	35	450	20	24	–
6/7/84	–	–	–	–	–	–	–	–
7/19/84	–	–	–	–	–	–	–	–
7/31/84	–	–	–	–	–	–	–	–
8/3/84	–	–	–	–	–	–	–	–
8/7/84	–	–	–	–	–	–	–	–
8/10/84	–	–	–	–	–	–	–	–
8/30/84	433	11	7.4	44	460	25	27	–

[illegible]

DATA SHEET (mg/l) WELL 17 - CELL 1

DATE	DISS BOD_5	DISS COD	TDS	DISS TKN	DISS NH_3	DISS NO_3+NO_2	Cl^-	pH	OTHER
10/12/84	<3	55	2090	32	30	<0.1	750	—	—
10/15/84	—	49	—	30	29	<1.0	710	—	—
10/18/84	<61	63	3000	30	30	<1.0	700	—	—
10/23/84	—	60	—	33	30	<1.0	650	—	—
10/26/84	—	50	—	30	30	<1.0	680	—	—
10/30/84	—	51	—	36	31	<1.0	690	—	—
11/1/84	—	43	—	34	32	<1.0	700	—	—
11/8/84	—	—	—	34	34	<1.0	660	—	—
11/13/84	—	—	—	30	30	<1.0	590	—	—
11/16/84	—	—	—	29	29	<1.0	540	—	—
11/20/84	—	—	—	27	27	<1.0	500	—	—

DATA SHEET (mg/l) DI WATER

DATE	DISSOLVED BOD_5	DISSOLVED COD	TDS	DISSOLVED TKN	DISSOLVED NH_3-N	DISSOLVED NO_2-N + NO_3-N	Cl^-	pH	OTHER
11/16/83	<3	<5	6	<0.2	<0.1	0.1	<0.3	–	–
12/20/83	<3	6 (?)	4	<0.2	<0.02	<0.02	<0.3	–	–
1/12/84	<3	<5	8	<0.2	<0.1	0.1	<0.3		

APPENDIX 6

BRODHEAD:

UNSATURATED ZONE REFERENCES

– BOUMA, 1975

Table 2. Monitoring data obtained *in situ* with tensiometry and derived performance characteristics for twelve subsurface seepage systems.

System no.	Subcrust tension (cm) bottom	Subcrust tension (cm) sidewall	R_b (days) bottom	R_b (days) sidewall	Calculated flow in gals/sq ft/day (cm/day) bottom	Calculated flow in gals/sq ft/day (cm/day) sidewall
1	23	35	6.9	35	1.8(7.5)	0.4(1.7)
2	24	24	6.5	6.5	1.4(5.8)	1.4(5.8)
3	25	21	4.6	3.2	1.6(6.6)	2.2(9.2)
4	25	28	7.1	9	1.8(7.5)	1.1(4.6)
5	80	60	267	74	0.09(0.4)	0.2(0.8)
6	120	100	9000	4000	0.007(0.03)	0.011(0.04)
7	65	--	34	--	0.45(1.9)	--
8	34	37	73	82	0.16(0.67)	0.14(0.6)
9	n.d.	20	n.d.	97	n.d.	0.16(0.7)
10	20	20	52	47	0.22(0.92)	0.20(0.8)
11	6	6	115	115	0.04(0.17)	0.04(0.17)
12	15	20	28	30	0.18(0.75)	0.15(0.62)
13	4	--	20	--	0.15(0.62)	--

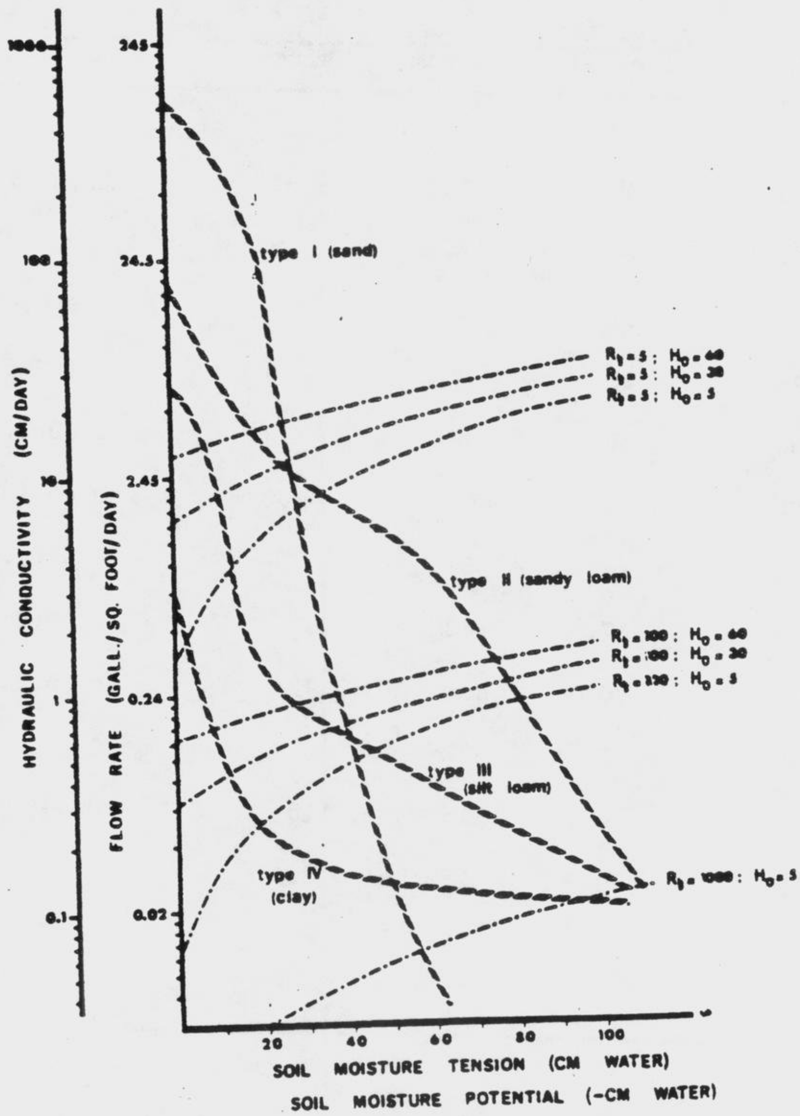


Fig. 1. Hydraulic conductivity curves for four major types of soil and curves expressing the hydraulic effects of impeding barriers and different hydraulic heads (see text).

APPENDIX H

BRODHEAD :

FURROW WASTEWATER AND

LYSIMETER CHEMISTRY

DATA

[illegible] DATA SHEET — [illegible] (mg/l) — FURROW WASTEWATER - CELL 1

DATE	TOTAL BOD_5	DISS COD	DISS TKN	DISS NH_3-N	DISS NO_2+NO_3	Cl^-	pH	OTHER	OTHER
7/9/84	DISS 400	460	16	14	0.1	740		TDS 2100	
7/13/84	DISS 56	300	32	22	<1.0	570	—	TDS 1620	—
7/16/84		180	39	35	<1.0				
7/19/84	DISS 130	160	60	53	<1.0	550	7.5	TDS 1610	—
7/27/84	DISS 710	810	13	5.3	0.1	820	—	—	—
7/31/84	1000 TOT	870	23	13	0.1	700	—	—	—
8/2/84	DISS 750	740	20	15	<1.0	900	—	—	—
8/7/84	TOT 110	230	22	15	<1.0	570	—	—	—
8/10/84	TOT 300	370	22	15	<1.0	240	—	—	—
8/30/84	TOTAL 590	710	11	8.7	0.1	660	6.7	—	—
9/4/84	TOT 1300	1000	22	12	0.1	640	—	—	—
10/12/84	—	—	—	—	—	—	—	—	—
10/15/84	—	—	—	—	—	—	—	—	—
10/18/84	—	790	25 DISS 43 TOT	3.3	1.4	700	—	—	—
10/23/84	—	390	14 TOT 7.4 DISS	[illegible]	0.1	320	—	—	—
10/26/84	—	470	16 DISS 59 TOT	13	0.1	460	—	—	—
10/30/84	—	350	33 TOT 16 DISS	12	0.1	350	—	—	—
11/1/84	—	87	5.8 TOT 2.9 DISS	1.6	0.1	160	—	—	—
11/8/84	—	—	[illegible] TOT 12 DISS	9.3	0.1	540	—	—	—
11/13/84	—	—	27 TOT 14 DISS	12	0.1	450	—	—	—
11/16/84	—	—	26 TOT 13 DISS	7.7	<0.1	570	—	—	—
11/20/84	—	—	32 TOT 13 DISS	8.5	<0.1	660	—	—	—

[illegible]

DATA SHEET (mg/ℓ) WASTEWATER - CELL 2

DATE	TOTAL BOD_5	DISS COD	DISS TKN	DISS NH_3-N	DISS NO_2+NO_3	Cl^-	pH	OTHER	OTHER
7/11/84	DISS >700	1100	61	26	<1.0	580	—	TDS 2540	—
7/13/84	DISS >450	1300	25	13	<1.0	970	—	TDS 2720	—
7/16/84	—	570	5.7	0.9	0.1	—	—	—	—
7/19/84	2400	480	24	7.4	0.1	540	6.7	—	—
7/24/84	DISS 580	2300	42	39	0.1	510	—	—	—
10/12/84	—	850	[illegible] DISS [illegible] TOT	13	6	760	—	—	—
10/15/84	—	600	16. DISS 47 TOT	6.1	0.1	300	—	—	—
10/18/84	—	830	36 TOT 24 DISS	21	<1.0	600	—	—	—
10/23/84	—	1200	60 TOT 36 DISS	14.	<1.0	670	—	—	—
10/26/84	—	800	32 TOT 18 DISS	5.2	0.1	640	—	—	—
10/30/84	—	710	29 TOT 19 DISS	15	<1.0	520	—	—	—
11/1/84	—	230	14 TOT 8.0 DISS	6.5	0.1	200	—	—	—
11/8/84	—	—	33 TOT 22 DISS	8.2	0.1	720	—	—	—
11/13/84	—	—	54 TOT 12 DISS	5.3	0.1	610	—	—	—
11/16/84	—	—	370 TOT 33 DISS	27	<1.0	870	—	—	—
11/[illegible]/84	—	—	57 TOT 37 DISS	13	11.0	800	—	—	—

DATA SHEET (mg/l) LYSIMETER #1 - CELL 1

DATE	BOD5	COD	TDS	DISS TKN	DISSOLVED NH_3-N	DISSOLVED NO_2-N + NO_3-N	Cl^-	pH	OTHER
11/16/83	—	LOW LEVEL 250 TOTAL	—	$\boxed{1.3}$	<0.1	0.1	—	—	—
2/12/84	—	TOTAL 760	— ~~TOTAL~~	$\boxed{7.2}$	4.4	<0.1	—	—	—
3/20/84	—	SOLUBLE 51	—	2.5	1.1	<0.1	—	6.8	—
4/24/84	—	LOWLEVEL 61 TOTAL	—	TOTAL 2.4	0.1	<0.1	—	—	—
5/24/84	—	TOTAL 30	—	TOTAL 4.3	0.6	0.1	—	7.4	—
7/31/84	—	SOLUBLE 76	—	9.2	7.5	0.1	1100	—	—
8/3/84	—	SOL 62	—	20	12	<0.1	—	—	—
8/7/84	—	67	—	20	17	0.2	900	—	—
8/10/84	—	SOL 66	2260	24	20	0.1	860	—	—
8/30/84	—	SOL 63	—	24	20	<1.0	770	7.1	—
9/4/84	—	SOL 70	—	26	23	<1.0	630	—	—
10/12/84	—	50	—	35	30	0.1	720	—	—
10/15/84	—	43	—	32	31	<1.0	700	—	—
10/18/84	—	44	—	31	30	<1.0	720	—	—
10/23/84	—	42	2000	30	29	<1.0	710	—	—
10/26/84	—	40	—	29	27	<1.0	690	—	—
10/30/84	—	47	—	27	25	<1.0	730	—	—
11/1/84	—	46	—	26	23	<1.0	710	—	—
11/8/84	—	—	—	21	20	<1.0	610	—	—
11/13/84	—	—	—	16	15	<1.0	480	—	—
11/16/84	—	—	—	14	13	<1.0	440	—	—
11/20/84	—	—	—	13	12	<1.0	420	—	—

DATA SHEET (mg/l) LYSIMETER #1 CELL 1

DATE	DISS BOD_5	DISS COD	TDS	DISS TKN	DISSOLVED NH_3-N	DISSOLVED NO_3+NO_2-N	Cl^-	pH	OTHER
2/12/84	—	TOTAL 410	—	TOTAL 6.8	2.2	<0.1	—	—	—
3/20/84	—	SOLUBLE 56	—	4.0	3.2	0.1	530	6.7	—
4/24/84	—	TOTAL 62	—	TOTAL 2.6	0.1	<0.1	—	—	—
5/24/84	—	TOTAL 62	—	TOTAL 6.0	3.0	0.1	—	7.4	—
6/11/84		48	—	14	14	0.0	—	—	—
6/18/84	—	42	—	18	16	<0.1	—	—	—
7/9/84	4.1	43	1910	21	20	<0.1	780	—	—
7/11/84	—	53	—	22	20	0.1	—	—	—
7/13/84	—	51	2180	22	21	0.1	—	—	—
7/16/84	—	37	—	16	16	0.2	—	—	—
7/19/84	—	49	—	24	22	<1.0	—	7.4	—
7/24/84	—	58	—	24	23	<1.0	—	—	—
7/27/84	—	52	—	25	22	<1.0	—	—	—
7/31/84	—	52	—	24	23	<1.0	—	—	—
8/3/84	—	54	—	25	25	<1.0	—	—	—
8/7/84	—	56	—	25	23	2.4	800	—	—
8/10/84	—	62	—	25	24	3.2	840	—	—
8/30/84	—	—	—	11	8.8	15.6	800	7.2	—
9/4/84	—	63	—	6.2	4.1	20	740	—	—
10/12/84	—	52	—	2.0	<1.0	21	730	—	—
10/15/84	—	55	—	1.8	<1.0	22	700	—	—
10/18/84	—	46	—	1.8	<1.0	21	720	—	—
10/23/84	—	45	—	1.6	<1.0	21	710	—	—
10/26/84	—	43	—	1.6	0.1	20	690	—	—

[illegible] DATA SHEET

CHEMICAL VARIABLES

LYSIMETER #2, CELL 1

DATE	DISS BOD_5	DISS COD	TDS	DISS TKN	DISS NH_3	DISS NO_3+NO_2	Cl^-	pH	OTHER
10/30/84	—	IS	—	1.6	0.1	18.4	660	—	—
11/1/84	—	50	—	1.9	0.1	16.5	630	—	—
11/5/84	—	—	—	1.6	0.1	16.0	550	—	—
11/13/84	—	—	—	1.5	0.1	16.6	550	—	—
11/16/84	—	—	—	1.3	0.1	17.8	590	—	—
11/20/84	—	—	—	1.6	<0.1	20	600	—	—

DATA SHEET (mg/l) LYSIMETER # 3- CELL-1

DATE	BOD_5	COD	TDS	DISS TKN	DISSOLVED NH_3-N	DISSOLVED NO_2-N + NO_3-N	Cl^-	pH	OTHER
11/16/83	—	LOWLEVEL 44 TOTAL	—	TOTAL 18	15	5.0	—	—	—
2/12/84	—	TOTAL 520	—	TOTAL 14	9.5	1.8	—	—	—
3/23/84	—	TOTAL 190	—	2.6	<0.1	0.1	—	—	—
6/18/84	—	—	—	2.3	—	—	—	—	—
7/9/84	—	53	—	2.9	0.6	0.5	610	—	—
7/19/84	—	—	—	3.0	0.3	2.0	—	7.6	—
7/27/84	—	—	—	2.0	0.1	2.4	—	—	—
8/3/84	—	59	—	1.8	0.1	2.8	—	—	—
8/10/84	—	—	—	2.5	0.1	4.4	—	—	—
9/4/84	—	—	—	IS	0.1	18.2	1000	—	—
10/12/84	—	—	—	IS	1.9	6.4	850	—	—
10/15/84	—	—	—	IS	2.8	7.4	920	—	—
x 10/18/84		NO	SAMPLE						
10/23/84	—	~~IS~~	—	~~IS~~	3.6	8.7	750	—	—
10/26/84	—	IS	—	IS	2.0	8.9	780	—	—
10/30/84	—	—	—	IS	0.9	8.2	750	—	—
x 11/1/84		NO	SAMPLE						
11/8/84	—	—	—	IS	1.7	10.0	730	—	—
11/16/84	—	—	—	4.4	1.6	10.2	760	—	—
11/20/84	—	—	—	IS	1.6	10.9	720	—	—

[illegible]
Data Sheet

Chemical Parameters (mg/l)

Lysimeter #5 - Cell 2

DATE	DISS BOD_5	DISS COD	TDS	DISS TKN	DISS NH_3-N	DISS NO_2+NO_3-N	Cl^-	pH	OTHER
7/9/84	<3	24	—	0.9	0.1	1.3	710	—	—
7/11/84	—	24	—	0.8	<0.1	2.1	—	—	—
7/13/84	—	27	—	0.9	0.1	2.5	580	—	—
7/16/84	—	23	—	0.8	0.1	2.7	—	—	—
7/19/84	—	30	—	1.1	0.1	5.8	—	7.4	—
7/24/84	—	40	—	1.2	0.1	2.8	—	—	—
7/27/84	—	58	—	1.4	0.1	0.1	—	—	—
7/31/84	—	51	—	1.6	0.1	0.1	—	—	—
8/2/84	—	43	—	1.4	0.1	0.1	—	—	—
8/30/84	—	—	—	1.2	0.1	20	—	—	—
9/4/84	—	39	—	1.2	0.1	11.5	590	—	—
10/12/84	—	—	—	0.9	0.1	16.1	500	—	—
10/15/84	—	31	—	0.8	0.1	21	400	—	—
10/18/84	—	24	—	0.8	<1.0	23	390	—	—
10/23/84	—	23	—	0.8	<1.0	24	420	—	—
10/26/84	—	19	—	0.7	<1.0	24	440	—	—
10/30/84	—	27	—	0.6	<1.0	[illegible]	420	—	—
[illegible]/84	—	23	—	0.3	<0.1	19.9	390	—	—
11/8/84	—	—	—	0.6	0.1	16.3	280	—	—
11/13/84	—	—	—	0.5	<0.1	12	220	—	—
11/16/84	—	—	—	0.6	<0.1	8.8	160	—	—
11/2[illegible]/84	—	—	—	0.6	0.1	7.0	110	—	—

Data Sheet (mg/l) Lysimeter #6 - Cell 2

Date	Diss BOD_5	Diss COD	TDS	Diss TKN	Diss NH_3-N	Diss NO_2+NO_3	Cl^-	pH	Other
6/11/84	<3	18	1230	0.6	0.1	24	400		
6/13/84	2.5	19	1490	0.4	<0.1	22	560	—	—
7/9/84	<3	17	1680	0.6	0.1	17.5	652	—	—
7/11/84	<3	18	—	0.8	0.1	11.1	—	—	—
7/13/84	<4	14	1210	0.6	0.1	9.6	410	—	—
7/16/84	<3	13	1170	0.6	0.1	14.5	360	—	—
7/19/84	<3	24	1400	0.5	0.1	37	410	6.8	—
7/24/84	4.9	30	1470	1.0	0.1	46	420	—	—
7/27/84	<4	24	1540	0.5	<1.0	35	430	—	—
7/31/84	<3	22	1480	0.5	<1.0	24	450	—	—
8/3/84	<3	17	1370	0.6	0.1	15.5	370	—	—
8/30/84	—	—	—	1.2	<1.0	23	—	—	—
9/4/84				IS	<1.0	29	470		
10/12/84									
10/15/84									
10/18/84									
10/23/84	—	~~IS~~	—	~~IS~~	0.1	27	520	—	—
10/26/84	—	20	—	0.6	<1.0	27	500	—	—
10/30/84	—	21	—	0.6	<1.0	23.0	420	—	—
11/1/84	—	20	—	0.5	<0.1	18.4	310	—	—
11/8/84	—	—	—	0.6	0.1	14.1	220	—	—
11/13/84	—	—	—	0.6	<0.1	10	150	—	—
11/16/84	—	—	—	0.6	<0.1	7.5	140	—	—
11/20/84	—	—	—	0.6	<0.1	6.2	110	—	—

GEOCHEMICAL CUMULATIVE DATA SHEET

CHEMICAL PARAMETERS (mg/l)

LYSIMETER #8 - 56

DATE	DISS BOD_5	DISS COD	TDS	DISS TKN	DISS NH_3-N	DISS NO_2+NO_3-N	Cl^-	pH	OTHER
7/24/84	3.4	14	236	0.4	0.1	0.1	1.2	—	—
7/27/84	<4	12	276	0.4	<0.1	0.1	1.4	—	—
7/31/84	<3	10	254	0.4	0.1	0.1	0.6	—	—
8/3/84	<3	12	280	0.4	0.1	0.1	0.9	—	—
8/30/84	—	—	—	0.6	0.1	0.5	—	—	—
10/12/84	—	14	278	0.4	0.1	0.1	1.3	—	—
10/15/84	—	11	—	0.4	<0.1	<0.1	1.5	—	—
10/18/84	—	12	—	0.4	<0.1	<0.1	1.5	—	—
10/23/84	—	12	243	0.4	<0.1	0.1	1.4	—	—
10/2[illegible]/84	—	15	—	0.4	0.1	0.1	1.3	—	—
10/30/84	—	—	—	IS	0.1	<0.1	1.5	—	—
11/1/84	—	—	—	IS	<0.1	0.1	IS	—	—
11/8/84	—	—	—	0.4	0.1	<0.1	1.0	—	—

[illegible]

DATA SHEET (mg/l) LYSIMETER #9 - B6

DATE	DISS BOD_5	COD	TDS	DISS TKN	DISSOLVED NH_3-N	DISSOLVED NO_2-N + NO_3-N	Cl^-	pH	OTHER
11/16/83	—	LOW LEVEL TOTAL 27	—	TOTAL 0.7	<0.1	0.2	—	—	—
3/23/84	<3	TOTAL 20	360	0.5	0.1	0.1	2.4	—	—
4/24/84	TOTAL <6	TOTAL 16	—	TOTAL 0.4	0.1	0.1	1.4	—	—
5/24/84	—	15	—	0.4	<0.1	0.1	—	6.7	0.03 DISS TOT.
6/11/84	<3	21	320	0.5	<0.1	0.1	1.3	—	—
6/18/84	3.1	25	330	0.6	0.1	0.1	1.2	—	—
7/19/84	<3	20	—	0.6	<0.1	0.1	1.4	6.8	—
7/24/84	<3	25	296	0.6	0.1	0.1	1.2	—	—
7/27/84	<4	23	320	0.6	<0.1	0.1	1.4	—	—
8/3/84	<3	26	356	0.6	0.1	0.1	1.7	—	—
8/30/84	—	—	—	1.2	0.1	0.1	—	—	—
10/12/84	—	25	304	0.6	0.1	0.1	1.2	—	—
10/15/84	—	23	—	0.6	<0.1	<0.1	1.3	—	—
10/18/84	—	19	—	0.6	<0.1	<0.1	1.2	—	—
10/23/84	—	24	296	0.7	<0.1	0.1	1.1	—	—
10/26/84	—	27	—	0.6	0.1	0.1	1.0	—	—
10/30/84	—	23	—	0.6	0.1	<0.1	1.0	—	—
11/1/84	—	28	—	0.8	<0.1	0.1	1.1	—	—
11/8/84	—	—	—	0.7	<0.1	<0.1	1.3	—	—

APPENDIX I

BRODHEAD:

CROP UPTAKE ANALYSES

AND CALCULATIONS

SAUER *non-ash*

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

DATE OF ANALYSIS: 5/23/84

Grass

		%					PPM						
SAMPLE		P	K	CA	MG	S	ZN	B	MN	FE	CU	AL	NA
1	1A	0.190	0.154	0.417	0.099	0.163	45.71	6.421	165.1	815.3	5.778	256.8	< 63.2
2	1B	0.203	0.166	0.544	0.110	0.175	46.97	7.501	173.0	929.2	5.598	1032	< 64.6
3	2	0.149	0.335	0.300	0.077	0.153	22.22	5.303	34.83	230.2	4.390	239.7	< 61.7

% N (on dry weight basis)

1A	1.56
2	1.44

Ashed

1B	0.42
2	0.26

% N of Ash

1B	2.49
2	2.64

Weight of oven dried sample (grams)		% Ash
1A	87.3	----
1B	67.2	17.1
2	311.3	10.1

1A, 1B → MINPORE
2 → BRODHEAD

APRIL SAMPLES OF GRASS

SAUER ASHED SAMPLES ASL

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

DATE OF ANALYSIS: 7/6/84

SAMPLE	%					PPM						
	P	K	CA	MG	S	ZN	B	MN	FE	CU	AL	NA
1 1B	0.187	0.149	0.495	0.096	0.071	36.51	5.330	157.6	638.2	4.711	662.2	< 61.3
2 2B	0.140	0.352	0.278	0.072	0.072	20.33	3.249	32.65	243.4	4.448	243.8	< 62.5

COOPERATIVE EXTENSION PROGRAMS

UWEX University of Wisconsin—Extension
University of Wisconsin—Madison

Soil & Plant Analysis Laboratory, 5711 Mineral Point Road, Madison, Wisconsin 53705; 608-262-4364

DEPARTMENT OF SOIL SCIENCE

September 14, 1984
Acct. 900
Lab No. S0035

July samples

MEMORANDUM

TO: Dave Sauer--DNR
101 S. Webster, Box 7921
Madison, WI 53707

FROM: Soil/Plant Analysis Lab

RE: Results of analyses on 4 canary (+grass) samples submitted July 24, 1984.

Sample Identification		Sample Weight	Ash	Nitrogen of Tissue	Nitrogen of Ash
		grams	%	%	%
Mindoro	1	87	---	2.15	----
Brodhead	1	134	---	1.28	----
Mindoro	2	121	8.5	----	0.64
Brodhead	2	110	5.9	----	0.48

Additional analyses are attached.

If you have any questions concerning these analyses, please feel free to contact either Todd Kaehler or Ita Steingraeber at 262-4364.

Encl.

/ss

S35 DAVE SAUER DNR

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

DATE OF ANALYSIS: 9/14/84

SAMPLE	%					PPM						
	P	K	CA	MG	S	ZN	B	MN	FE	CU	AL	NA
1 MIN.1	0.255	2.443	0.314	0.216	0.252	12.73	5.361	43.93	60.01	3.843	< 36.7	< 63.8
2 BRO.1	0.229	1.632	0.235	0.128	0.144	12.43	3.736	54.69	42.23	3.828	< 35.8	294.7
3 MIN.2	0.327	2.632	0.298	0.214	0.249	16.72	4.708	88.24	56.14	4.626	< 36.4	< 63.3
4 BRO.2	0.306	1.953	0.300	0.180	0.182	20.50	4.709	40.22	62.70	3.724	< 36.2	296.0

35 DAVE SAUER (ASHED)

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

..TE OF ANALYSIS: 9/14/84

SAMPLE	P (%)	K (%)	CA (%)	MG (%)	S (%)	ZN (PPM)	B (PPM)	MN (PPM)	FE (PPM)	CU (PPM)	AL (PPM)	NA (PPM)
1 MIN.2	0.318	2.509	0.296	0.204	0.145	16.88	5.042	85.15	63.52	6.397	< 36.1	99.24
2 BRO.2	0.293	1.813	0.289	0.165	0.056	18.51	4.301	39.88	70.66	3.827	< 36.0	295.8

5134 DAVE SAUER
Oct samples

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

...E OF ANALYSIS: 12/28/84

SAMPLE	%					PPM						
	P	K	CA	MG	S	ZN	B	MN	FE	CU	AL	NA
1 BROD.1	0.264	2.081	0.277	0.142	0.199	16.03	4.999	47.97	79.14	4.834	59.96	219.6
2 BROD.2	0.300	1.909	0.323	0.209	0.231	14.14	4.598	96.42	66.52	5.836	46.27	118.7
1 BROD.1 ash	0.258	1.819	0.278	0.139	0.073	15.98	4.959	47.48	79.84	4.681	71.31	426.4
2 BROD.2 ash	0.300	1.808	0.329	0.209	0.071	14.44	3.662	95.97	70.06	5.610	50.63	404.0

Sample Id.	Sample Wt. grams	%Ash	%N of Tissue
Brodhead Cell 1	64.2	5.5	2.70
Brodhead Cell 2	67.5	5.6	3.50

* Results for %N of Ash will follow in several days.

5235 DAVE SAUER
Dec Samples

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

DATE OF ANALYSIS: 12/28/84

SAMPLE	% P	% K	% CA	% MG	% S	PPM ZN	PPM B	PPM MN	PPM FE	PPM CU	PPM AL	PPM NA
1 BROD.1	0.189	0.651	0.201	0.092	0.158	14.20	4.326	56.47	87.73	3.712	65.37	896.3
2 BROD.2	0.197	0.491	0.146	0.136	0.117	40.26	3.188	79.76	57.89	4.060	42.81	430.5
3 MIND.1	0.139	0.497	0.230	0.094	0.086	23.59	4.866	139.9	106.8	4.450	102.9	< 61.0
4 MIND.2	0.172	0.549	0.177	0.097	0.158	28.68	4.610	70.91	79.80	3.719	64.15	184.6
1 BROD.1 ash	0.183	0.603	0.194	0.088	0.065	11.36	3.085	48.61	82.87	3.032	68.71	992.6
2 BROD.2 ash	0.197	0.472	0.142	0.135	0.046	38.19	2.927	74.83	55.44	3.273	43.73	555.2
3 MIND.1 ash	0.135	0.431	0.225	0.089	0.048	28.92	3.336	128.6	103.0	4.723	126.2	< 59.3
4 MIND.2 ash	0.165	0.480	0.175	0.092	0.077	25.42	< 3.56	67.28	81.79	4.276	33.32	242.9

Sample Id.	Sample Wt. grams	%Ash	%N of Tissue
Brodhead Cell 1	54.5	3.9	1.59
Brodhead Cell 2	61.0	3.1	1.41
✓ Mindoro Cell 1	88.7	9.2	0.58
✓ Mindoro Cell 2	219.8	8.6	1.42

*Results for %N of Ash will follow in several days.

COOPERATIVE EXTENSION PROGRAMS
UWEX University of Wisconsin—Extension
University of Wisconsin—Madison

Soil & Plant Analysis Laboratory, 5711 Mineral Point Road, Madison, Wisconsin 53705, 608-262-4364

DEPARTMENT OF SOIL SCIENCE

INSTRUCTION EXTENSION College of Agricultural and Life Sciences RESEARCH

January 7, 1985
Acct. No. 900
Lab Nos. S134; S235

MEMORANDUM

TO: Dave Sauer
Wis. Dept. of Natural Resources
Box 7921
Madison, WI 53707

FROM: Soil/Plant Analysis Lab

RE: Results of %N of Ash on 5 samples. All other analyses have been reported.

Sample Identification		%N of Ash
(S134) Oct samples		
BRODHEAD CELL 1	1	0.72
BRODHEAD CELL	2	0.50
(S235) Dec samples		
BRODHEAD CELL	1	0.45
BRODHEAD CELL	2	0.49
MINDORO CELL	1	0.15
MINDORO CELL	2	0.47

If you have any questions concerning these analyses, please feel free to contact us.

The invoice for all of the tissue analyses is enclosed.

/ss

Encl.

BRODHEAD - GRASS NITROGEN CALCULATIONS

<u>APRIL 21, 1984</u>

<u>CELL 2</u> (AREA - 110,000 ft^2)

AREA OF SAMPLE = $3' \times 4' = 12\ ft^2$

WEIGHT OF SAMPLE = 311.3 g (OVEN DRIED)

TOTAL WEIGHT OF GRASS - CELL 2 =

$$\frac{311.3\,g}{12\,ft^2} \times 110{,}000\,ft^2 \times \frac{lb}{453.8\,g} = 6288\ lb$$

% N (DRY WEIGHT BASIS) = 1.44

AMOUNT OF N IN CELL 2 GRASS PRIOR TO BURNING =

$$6288\,(0.0144) = 90.6\ lb$$

% ASH AFTER BURNING = 10.1

WEIGHT OF ASH - CELL 2 = 6288(0.101) = 635 lb

% N OF ASH = 2.64

AMOUNT OF ASH N ON CELL 2 AFTER BURNING = 635(0.0264)

= 16.8 lb

<u>EXTRAPOLATE VALUES TO TOTAL SITE AREA</u>

$$\frac{\text{TOTAL AREA}}{\text{CELL 2 AREA}} = 1.85$$

TOTAL WEIGHT OF GRASS =

$$6288 \times 1.85 = 11{,}646\ lb$$

AMOUNT OF GRASS N PRIOR TO BURNING = 90.6 (1.85) = 168 lb

AMOUNT OF ASH N ON SITE AFTER BURNING = 16.8(1.85)

= 31.0

$$\%\ N\ LOST = \frac{168 - 31}{168}(100) = \underline{81.5\%}$$

JULY 13, 1984

AREA OF GRASS SAMPLES — CELL 1 = $1' \times 2' = 2 ft^2$

CELL 2 = $1' \times 3' = 3 ft^2$

WEIGHT OF GRASS SAMPLES - CELL 1 = 134g

CELL 2 = 110g

TOTAL WEIGHT OF GRASS ON SITE =

NOTE: CELL 1 IS 46% OF TOTAL AREA; CELL 2 IS 54%

$$\frac{0.46\,(4.7\text{ ACRES})(43{,}560\ ft^2/\text{ACRE})(134g)}{453.8\ g/lb \times 2\ ft^2}$$

$$+ \quad \frac{0.54(4.7)(43{,}560)(110)}{453.8(3)} = 22{,}847\ lb$$

% N (DRY WEIGHT BASIS) = 1.28

AMOUNT OF N ON SITE PRIOR TO BURNING = 22,847(0.0128) = 292 lb

% ASH AFTER BURNING = 5.9

WEIGHT OF ASH ON SITE = 22,847(0.059) = 1347 lb

% N OF ASH = 0.48

AMOUNT OF N ON SITE AFTER BURNING = 1347(0.0048)

= 6.5 lb

% N LOST BY BURNING = $\frac{292 - 6.5}{292}(100) = 97.8\%$

SEPTEMBER 25, 1984

AREA OF GRASS SAMPLES – CELL 1 = 20" x 17" = 2.36 ft^2

CELL 2 = 24" x 28" = 4.67 ft^2

WEIGHT OF GRASS SAMPLES – CELL 1 = 64.2 g

CELL 2 = 67.5 g

TOTAL WEIGHT OF GRASS ON SITE =

$$\frac{(0.46)(4.7)(43560)(64.2)}{453.8\,(2.36)} + \frac{(0.54)(4.7)(43560)(67.5)}{453.8\,(4.67)}$$

$$= 5648.0 + 3522.8 \doteq 9171 \text{ lb}$$

% N (DRY WEIGHT BASIS) – CELL 1 = 2.70

CELL 2 = 3.50

AMOUNT OF N ON SITE PRIOR TO BURNING =

$$5648(0.0270) + 3522.8(0.0350) = 276 \text{ lb}$$

% ASH AFTER BURNING – CELL 1 = 5.5

CELL 2 = 5.6

WEIGH OF ASH ON SITE = 5648(0.055) + 3522.8(0.056)

= 507.9 lb

% N OF ASH ⇒ CELL 1 = 0.72

CELL 2 = 0.50

AMOUNT OF N ON SITE AFTER BURNING = 5648(0.055)(0.0072)

+ 3522.8(0.056)(0.0050)

= 3.2 lb

% N LOST BY BURNING = $\frac{276 - 3.2}{276}(100) = 98.9\%$

NOVEMBER 20, 1984

AREA OF GRASS SAMPLES - CELL 1 = 14" x 11" = 1.07 ft^2

CELL 2 = 12" x 14" = 1.17 ft^2

WEIGHT OF GRASS SAMPLES - CELL 1 = 54.5 g

CELL 2 = 61.0 g

TOTAL WEIGHT OF GRASS ON SITE =

$$\frac{(0.46)(4.7)(43560)(54.5)}{453.8\,(1.07)} + \frac{(0.54)(4.7)(43560)(61.0)}{453.8\,(1.17)}$$

$$= 10{,}575 + 12{,}707 =$$

% N (DRY WEIGHT BASIS) = CELL 1 = 1.59

CELL 2 = 1.41

AMOUNT OF N ON SITE PRIOR TO BURNING =

$$10{,}575(0.0159) + 12{,}707(0.0141) = 347 \text{ lb}$$

% ASH AFTER BURNING ⇒ CELL 1 = 3.9

CELL 2 = 3.1

WEIGHT OF ASH ON SITE = 10,575(0.039) + 12,707(0.031)

= 412 + 394 = 806 lb

% N OF ASH - CELL 1 = 0.45

CELL 2 = 0.49

AMOUNT OF N ON SITE AFTER BURNING =

$$412(0.0045) + 394(0.0049) = 3.7 \text{ lb}$$

$$\% \text{ N BURNING LOSS} = \frac{347 - 3.7}{347}(100) = \underline{\underline{98.9\%}}$$

APPENDIX J

BRODHEAD:

SUGAR RIVER

CHEMISTRY DATA

BROADHEAD CUMMULATIVE CHEMICAL PARAMETERS SUGAR RIVER

DATA SHEET (mg/ℓ) UPSTREAM

DATE	TOTAL BOD_5	TOTAL COD	Cl^-	TKN	TSS	OTHER
12/20/83	41	470	25	22	2600	-
4/22/84	<3	9	21	0.9	382	pH - 8.0 NO_2+NO_3 - 3.7 NH_3 - 0.4
8/30/84	3.7	18	23	1.2		TALK - 260 TCa# - 66 pH - 7.8 TMg# - 36 D NO_2+NO_3 - 3.8 DTKN - 0.6 TNa^+ - 12 $TSO_4^=$ - 22 TPO_4 - 0.32 (@ P - 0.24) D NH_3 - 0.2 TK^+ - 3

DESCHEFS SUMMARY — CHEMICAL PARAMETERS — SUGAR RIVER

DATA SHEET — (mg/l) — MIDSTREAM

DATE	TOTAL BOD_5	TOTAL COD	Cl^-	TKN	TSS	OTHER
12/20/83	15	150	33	6.4	510	—
4/22/84	3.1	11	20	0.8	380	pH - 8.0; NO_2-NO_3 - 3.6; NH_3 - 0.2
8/30/84	3.1	18	23	0.8		T ALK - 262 T $Ca^{\#}$ - 66 pH - 7.8 T $Mg^{\#}$ - 36 D NO_2+NO_3 - 3.5 D TKN - 0.4 T Na^+ - 12 T $SO_4^=$ - 21 T PO_4 - 0.28 (@ P - 0.20) D NH_3 - 0.1 T K^+ - 3

[illegible] CHEMICAL PARAMETERS SUGAR RIVER

DATA SHEET (mg/l) DOWNSTREAM

DATE	TOTAL BOD_5	TOTAL COD	Cl^-	TKN	TSS	OTHER
12/20/83	6.8	29	30	1.6	132	—
4/22/84	<3	10	18	0.6	366	pH - 8.0 NO_2+NO_3 - 3.5 (3.6 ?) NH_3 - 0.1
8/30/84	<4	17	20	DISS 0.4 TOTAL 1.0	- - -	TALK - 262 TCa^+ - 66 pH - 7,9 TMg^{++} - 36 DISS NO_2+NO_3 - 3.4 TNa^+ - 70 $TSO_4^=$ - 21 T PO_4 - 0.26 (@P - 0.17) D NH_3 - 0.1 TK^+ - 2

APPENDIX K

BRODHEAD :

NITROGEN BUDGET CALCULATIONS

WASTE WATER ADDITION (EACH CELL RECEIVED 1/2 OF FLOW)

CELL 1 = $\dfrac{19750 \text{ gal/day}}{10^6} \times 44.7 \dfrac{\text{mg-N}}{\ell} \times 8.34 \times \dfrac{365 \text{DAY}}{\text{YR}} =$

$= 2687 \text{ lb/yr}$

CELL 2 = SAME AS CELL 1

TOTAL = CELL 1 + CELL 2 = 5375 lb/yr

PLANT UPTAKE LOSS

→ NO BURNING AT SITE MEANT ALL PLANT N RETURNED TO THE SOIL.

∴ NO LOSS

LEACHING LOSS

CELL 1 = $\dfrac{19750}{10^6} \times \underbrace{9.0 \text{ mg/}\ell}_{\text{lysimeter 3 Total N Average}} \times 8.34 \times 365 = 541 \text{ lb/yr}$

(or 20% of CELL 1 APPLIED-N)

CELL 2 = $\dfrac{19750}{10^6} \times \underbrace{21.7}_{\text{Lysimeter 6 Total-N Ave.}} \times 8.34 \times 365 = 1304 \text{ lb/yr}$

(or 49% of CELL 2 APPLIED-N)

TOTAL = CELL 1 + CELL 2 = 1845 lb/yr (or 34% of TOTAL APPLIED-N)

DENITRIFICATION LOSS

CELL 1 = 2687 − 541 = 2146 lb/yr (or 80% OF CELL 1 APPLIED N)

CELL 2 = 2687 − 1304 = 1383 lb/yr (or 51% OF CELL 2 APPLIED-N)

TOTAL = CELL 1 + CELL 2 = 3529 lb/yr (or 66% OF TOTAL APPLIED-N)

Appendix AA

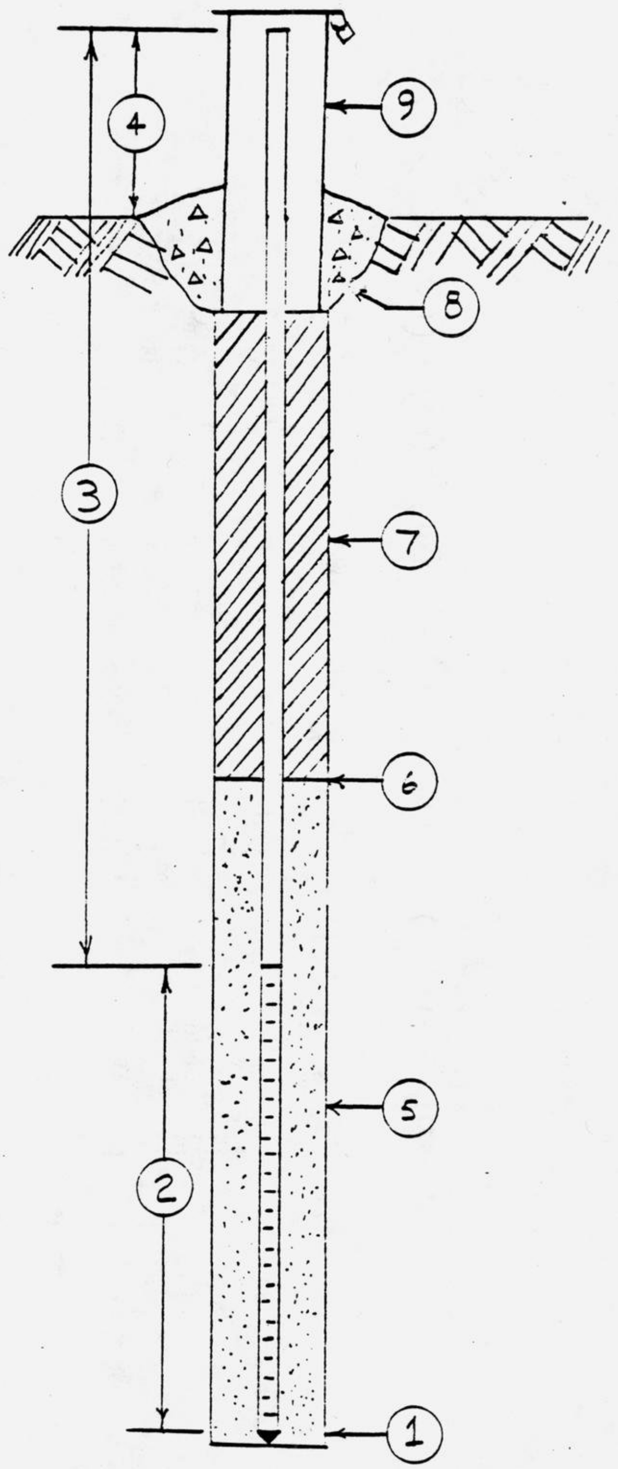
Mindoro:

Well and Lysimeter Logs

WELL DETAIL INFORMATION

MINDORO SITE
WELL # 1-A (SHALLOW, BACKGROUND) – NORTH, NEAR BLDGS.
DRILLED 8/16/83
PLACED 8/17/83

SCALE : 1" = 20' *ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



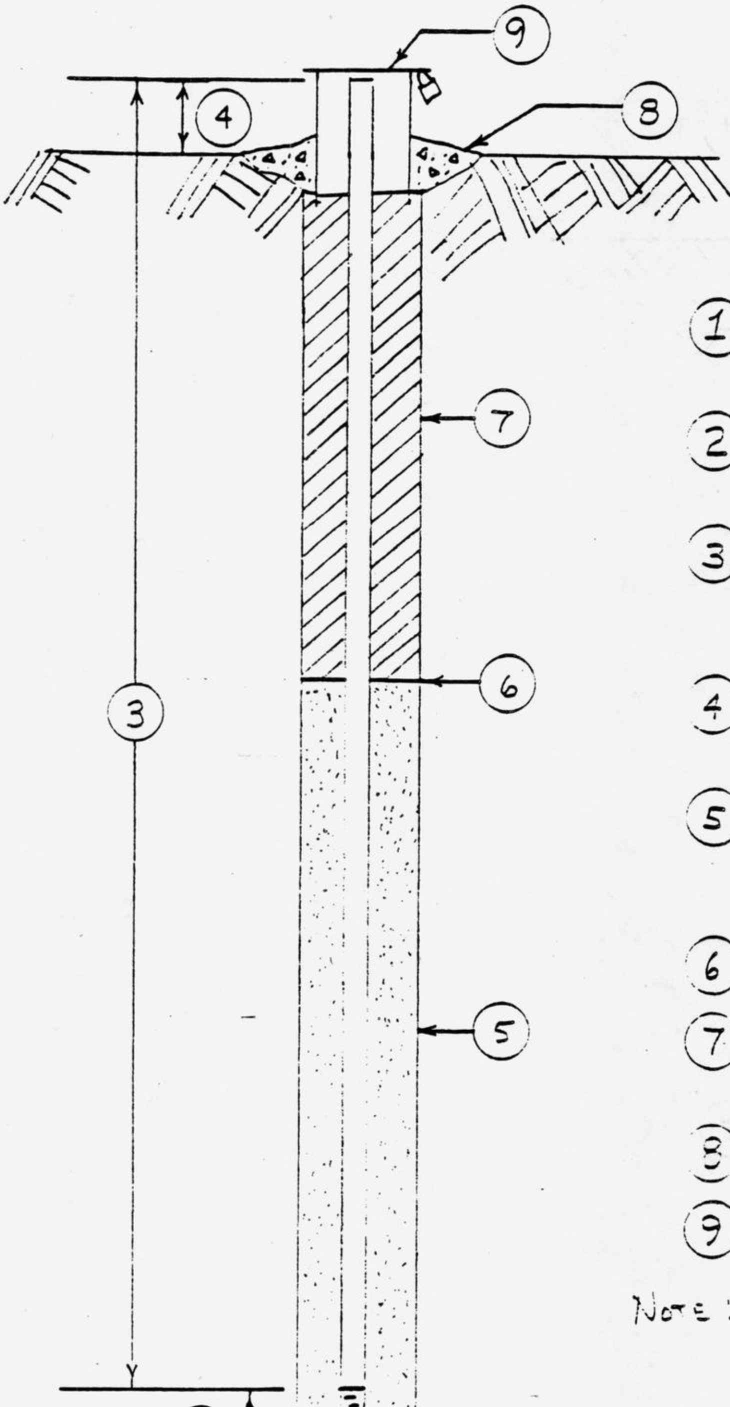
1. DEPTH TO BOTTOM OF BOREHOLE, 13 FT.
2. LENGTH OF WELL SCREEN, 5 FT.
3. TOTAL LENGTH OF SOLID PVC PIPE, 10 FT @ 2 IN. DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 2 FT.
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, SILICA SAND (7')
6. DEPTH OF SEAL, 6 FT
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

WELL DETAIL INFORMATION

MINDORO SITE
WELL #1B (DEEP, BACKGROUND) – NORTH, NEAR BLDGS.
DRILLED 8/17/83
PLACED 8/17/83

VERTICAL SCALE: 1" = 5'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



1. DEPTH TO BOTTOM OF BOREHOLE, 35.5 FT.
2. LENGTH OF WELL SCREEN, 2.5 FT.
3. TOTAL LENGTH OF SOLID PVC PIPE, 34.7 FT @ 2 IN. DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 1.7 FT.
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, NATURAL SAND CAVE
6. DEPTH OF SEAL, 14 FT.
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

NOTE: PUSHED 15' INTO SOIL

SOIL PROFILE

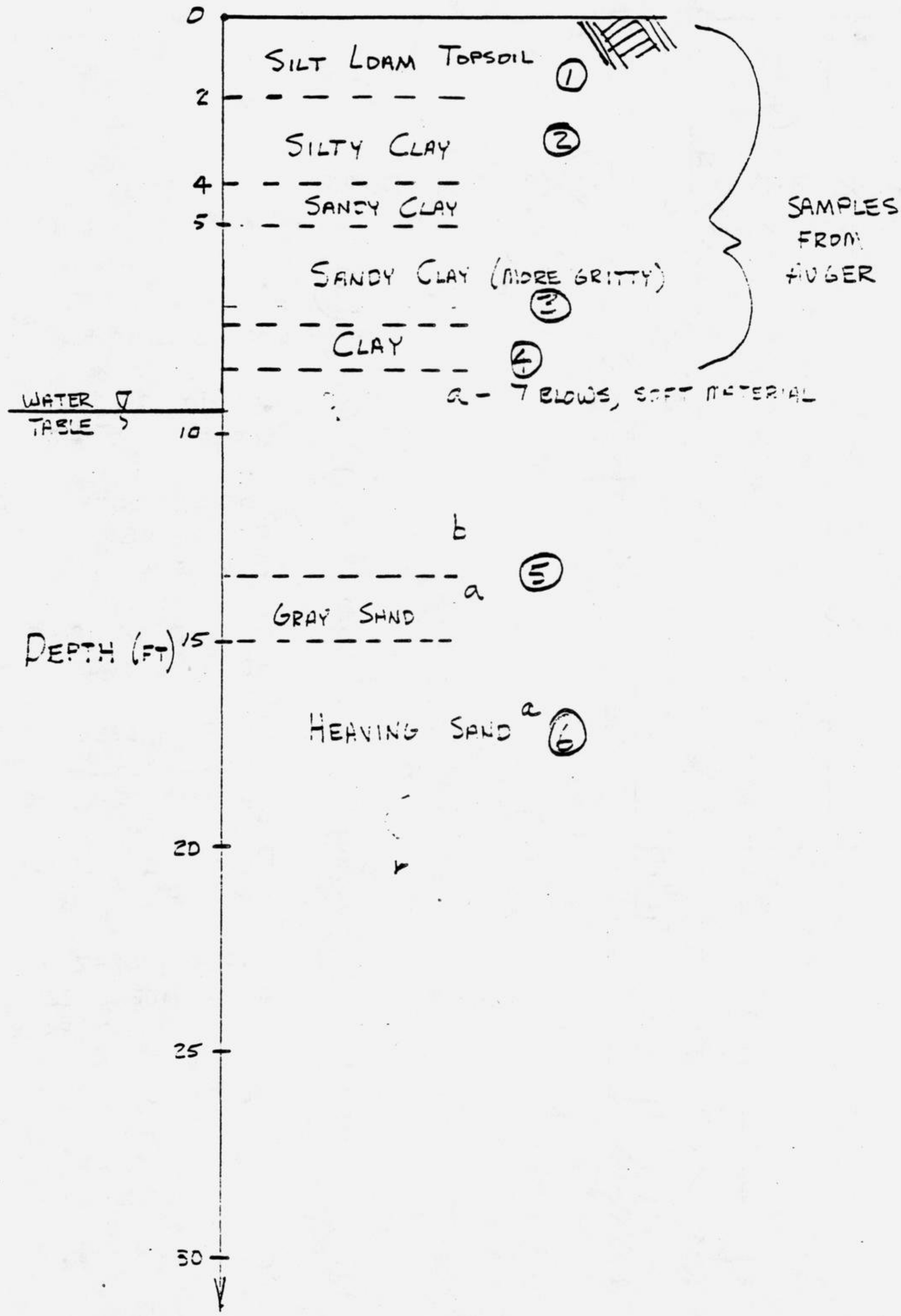
MINDERO SITE
WELL # 1A, # 1B
DRILLED 8/16/83

SCALE: 1" = 4'

NOTES: a - SPLIT SPOON SAMPLE TAKEN
b - @ 13', CHANGE IN DRILLING SPEED; SOMEWHAT TOUGHER

SPLIT SPOON PROCEDURE: # OF BLOWS TO PENETRATE 18"

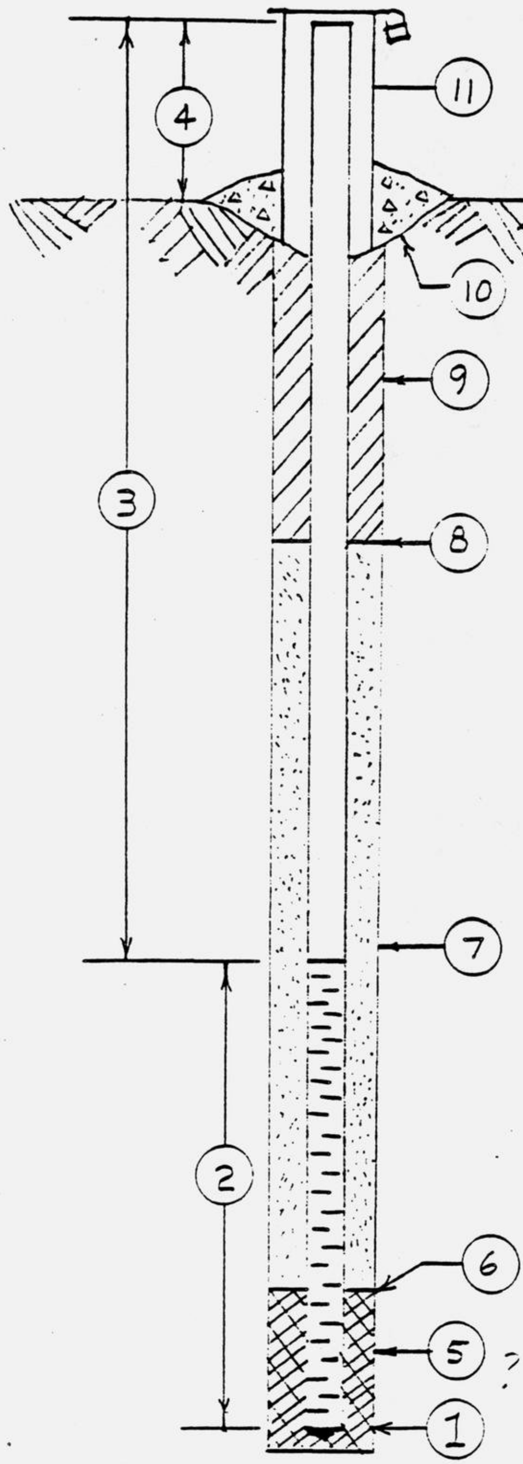
SAMPLE # → 1



Mindoro Site
Well #2 - Shallow - East of system, midway
Drilled 8/16/83
Placed 8/17/83

Scale: 1" = 2'

* All depth measurements from ground surface

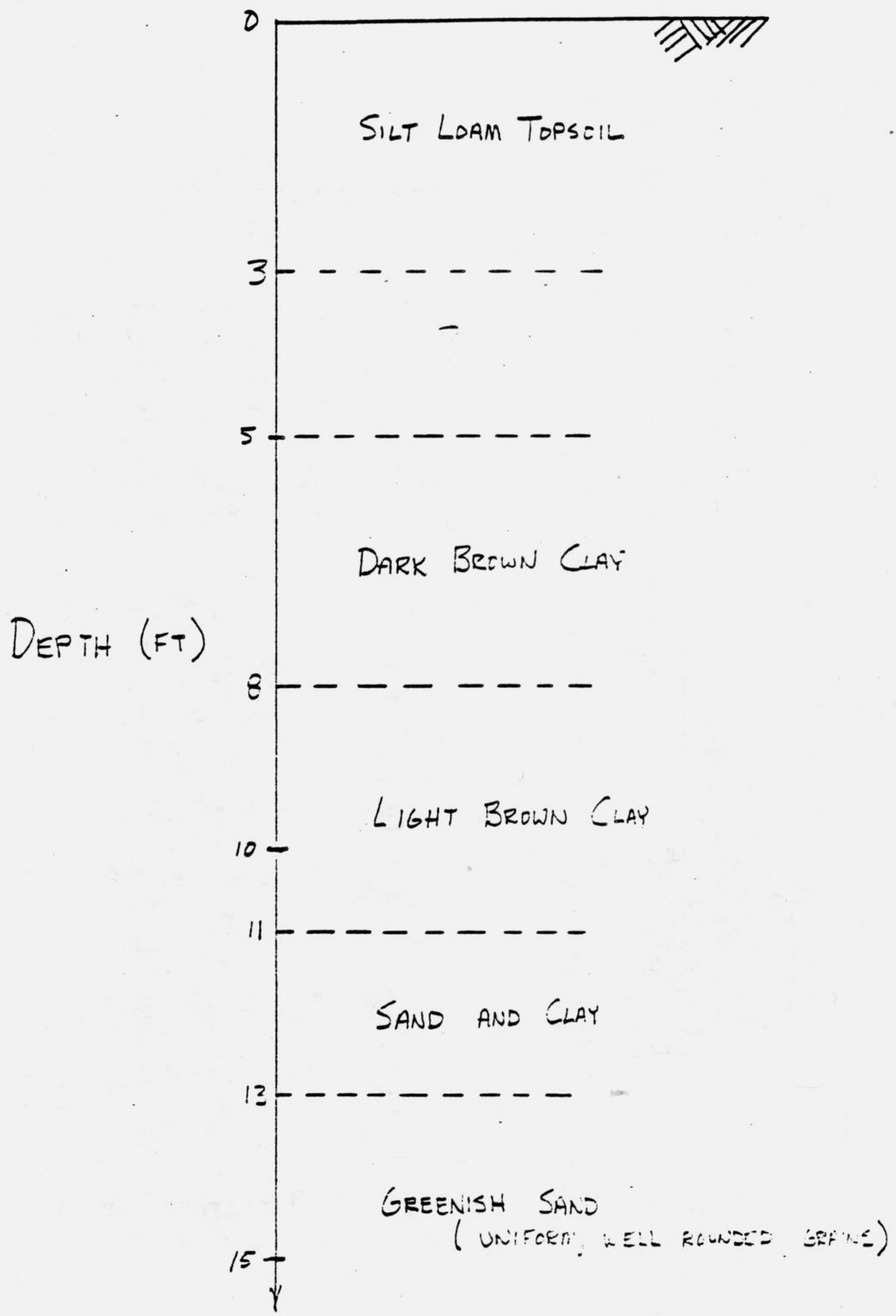


1. Depth of bottom of borehole, 13'-2"
2. Length of well screen, 5 ft.
3. Total length of solid PVC pipe, 10 ft. @ 2 in. dia.
4. Height of pipe above ground, 1'-10"
5. Deep filter material around well screen, natural sand cave
6. Depth of silica sand pack, 11'-8"
7. Upper filter material around well screen, silica sand pack
8. Depth of seal, 3'-5"
9. Type of backfill, Bentonite
10. Concrete cap
11. Protective casing

Soil Profile

Mindoro Site
Well #2
Drilled 8/16/83

Vertical Scale: 1" = 2'

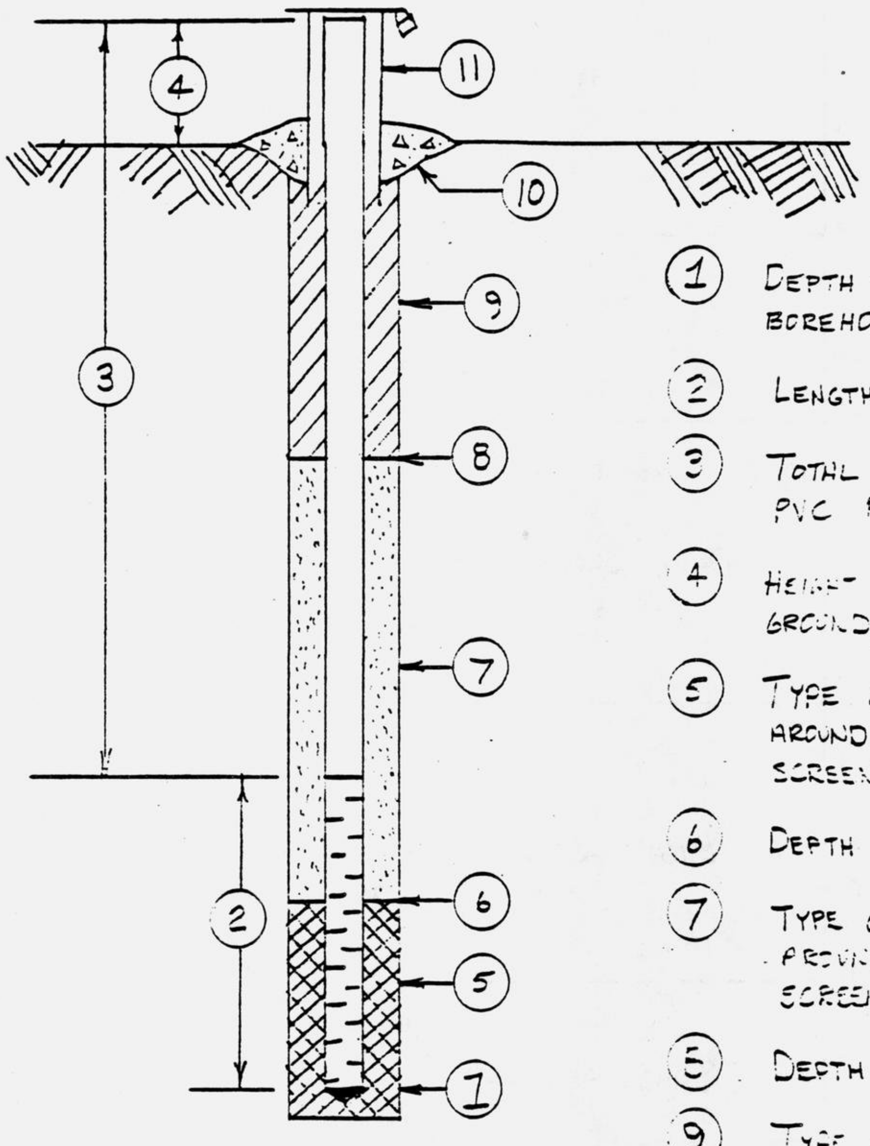


WELL DETAIL INFORMATION

MINDORO SITE
WELL #3 (SHALLOW, SE CORNER OF R&F)
DRILLED 8/17/83
PLACED 8/17/83

SCALE: 1" = 3'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



(1) DEPTH TO BOTTOM OF BOREHOLE, 15'-2"

(2) LENGTH OF WELL SCREEN, 5 FT.

(3) TOTAL LENGTH OF SOLID PVC PIPE, 11'-10" @ 2 IN DIA.

(4) HEIGHT OF PIPE ABOVE GROUND, 1'8" FT.

(5) TYPE OF FILTER MATERIAL AROUND LOWER WELL SCREEN, NATURAL SAND CAVE

(6) DEPTH OF SAND PACK, 12 FT

(7) TYPE OF FILTER MATERIAL AROUND UPPER WELL SCREEN, SILICA SAND PACK

(8) DEPTH OF SEAL, 5 FT.

(9) TYPE OF BACKFILL, BENTONITE

(10) CONCRETE CAP

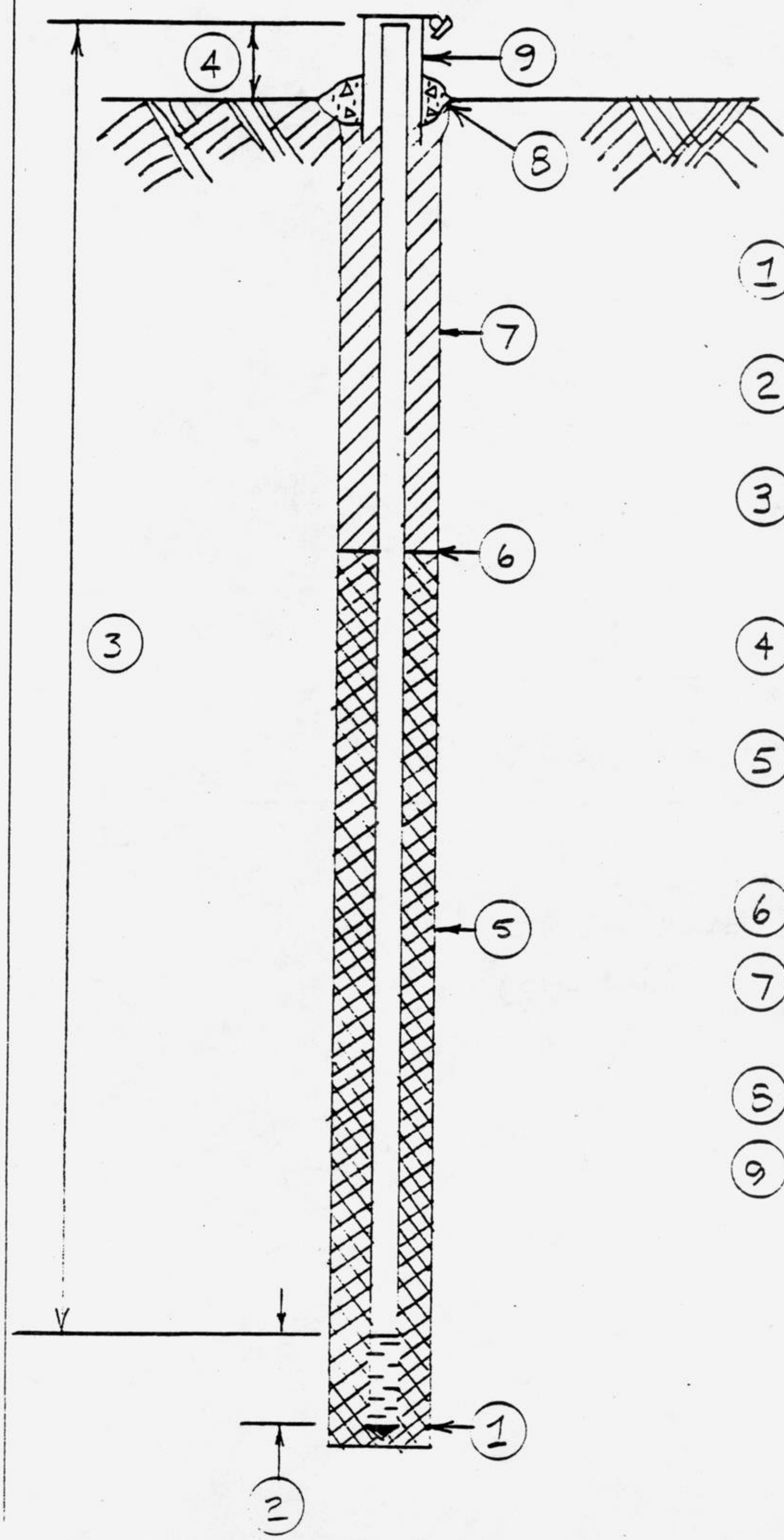
(11) PROTECTIVE CASING

WELL DETAIL INFORMATION

Mindoro Site
Well #4 (Deep, SE corner of R&F)
Drilled 8/17/83
Placed 8/17/83

Scale: 1" = 5'

* All depth measurements from ground surface

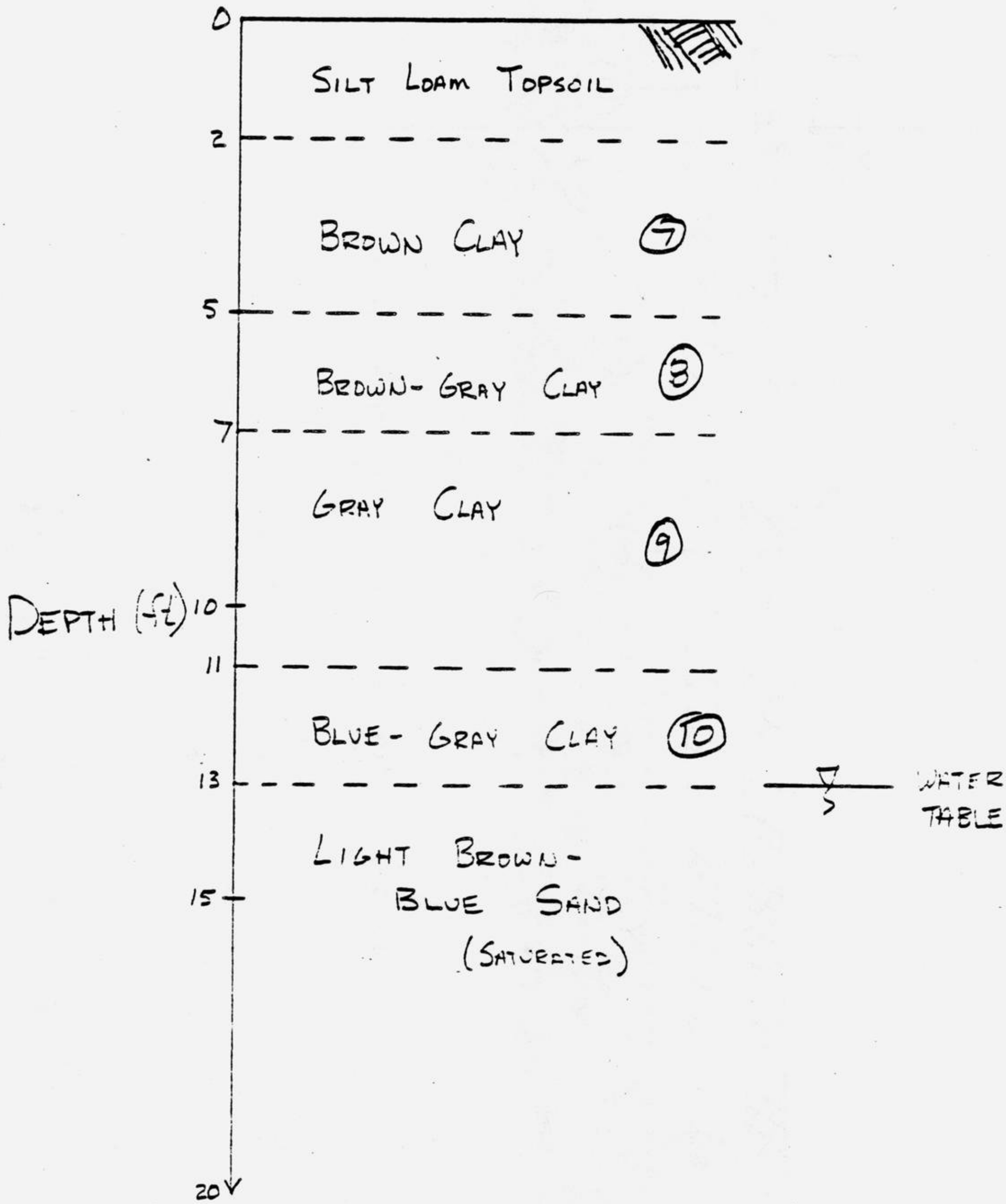


1. Depth to bottom of borehole, 35'-8"
2. Length of well screen, 2.5'
3. Total length of solid PVC pipe, 35' @ 2 in dia
4. Height of pipe above ground, 1'-10"
5. Type of filter material around well screen, natural sand cave
6. Depth of seal, 12'
7. Type of backfill, Bentonite & Sand
8. Concrete cap
9. Protective casing

SOIL PROFILE

MINDORO SITE
WELL #3 & #4
DRILLED 8/17/83

SCALE: 1" = 3'

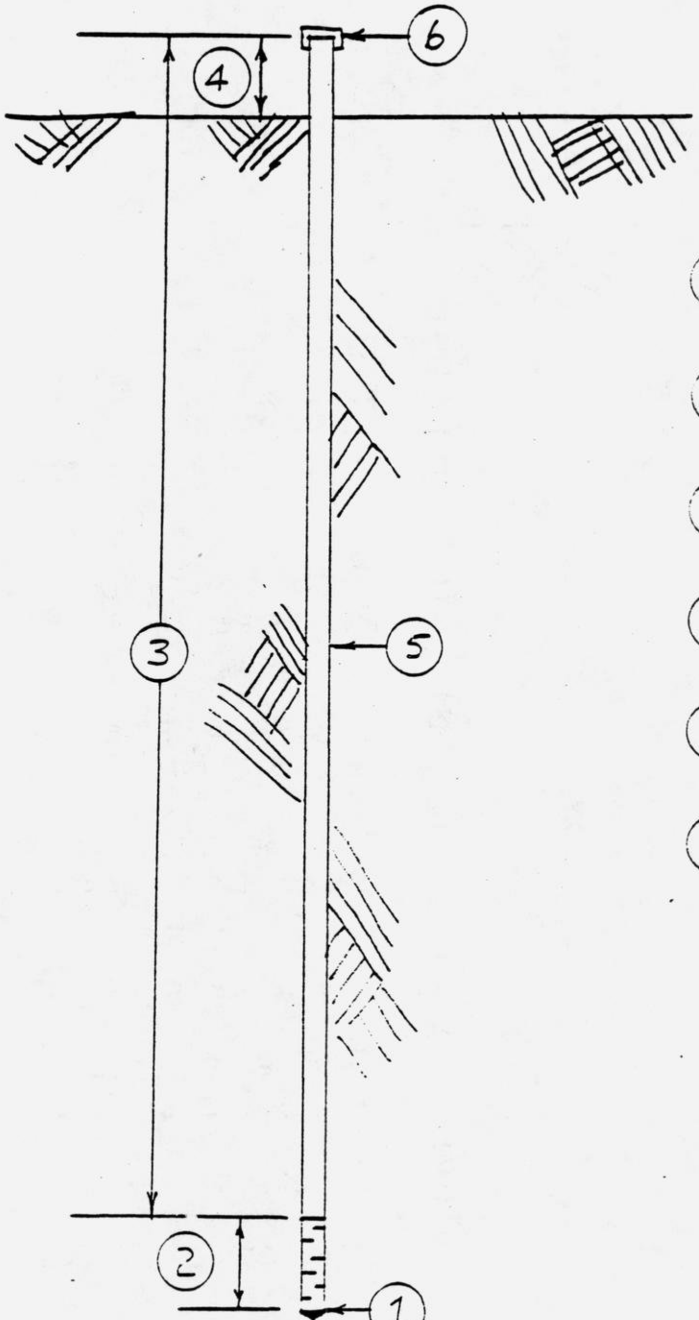


WELL DETAIL INFORMATION

MINDORO SITE
WELL # 5A (DEEP, WEST SIDE OF R&F NEAR WELL 5)
DRILLED: 8/17/83
PLACED: 8/17/83
SCALE: 1" = 5'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE

→ WELL PUSHED IN ←



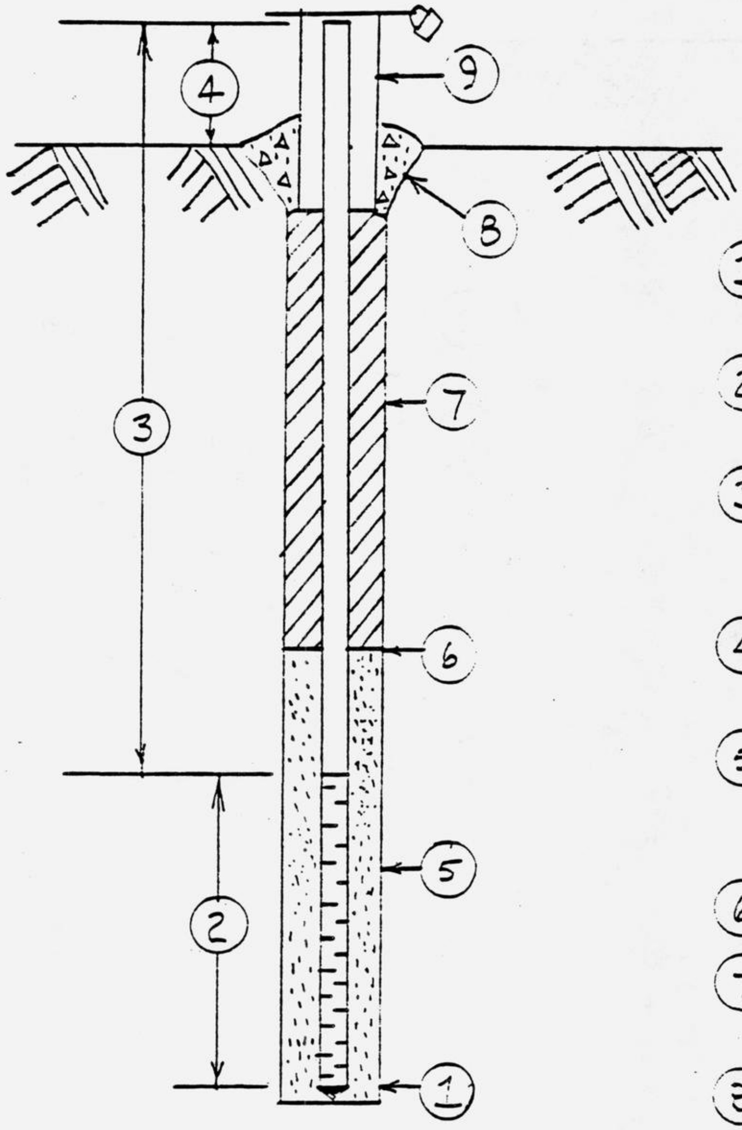
1. DEPTH TO BOTTOM OF WELL, 31.9'
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 30.8
4. HEIGHT OF PIPE ABOVE GROUND, 1.4'
5. TYPE OF BACKFILL, NATURAL SOIL
6. PROTECTIVE CAP

WELL DETAIL INFORMATION:

MINDORO SITE
WELL #5 (SHALLOW, WEST SIDE OF R&F BY BERM SEPARATING CELL 2&3)
DRILLED: 8/17/83
PLACED: 8/17/83

VERTICAL SCALE: 1" = 3'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE

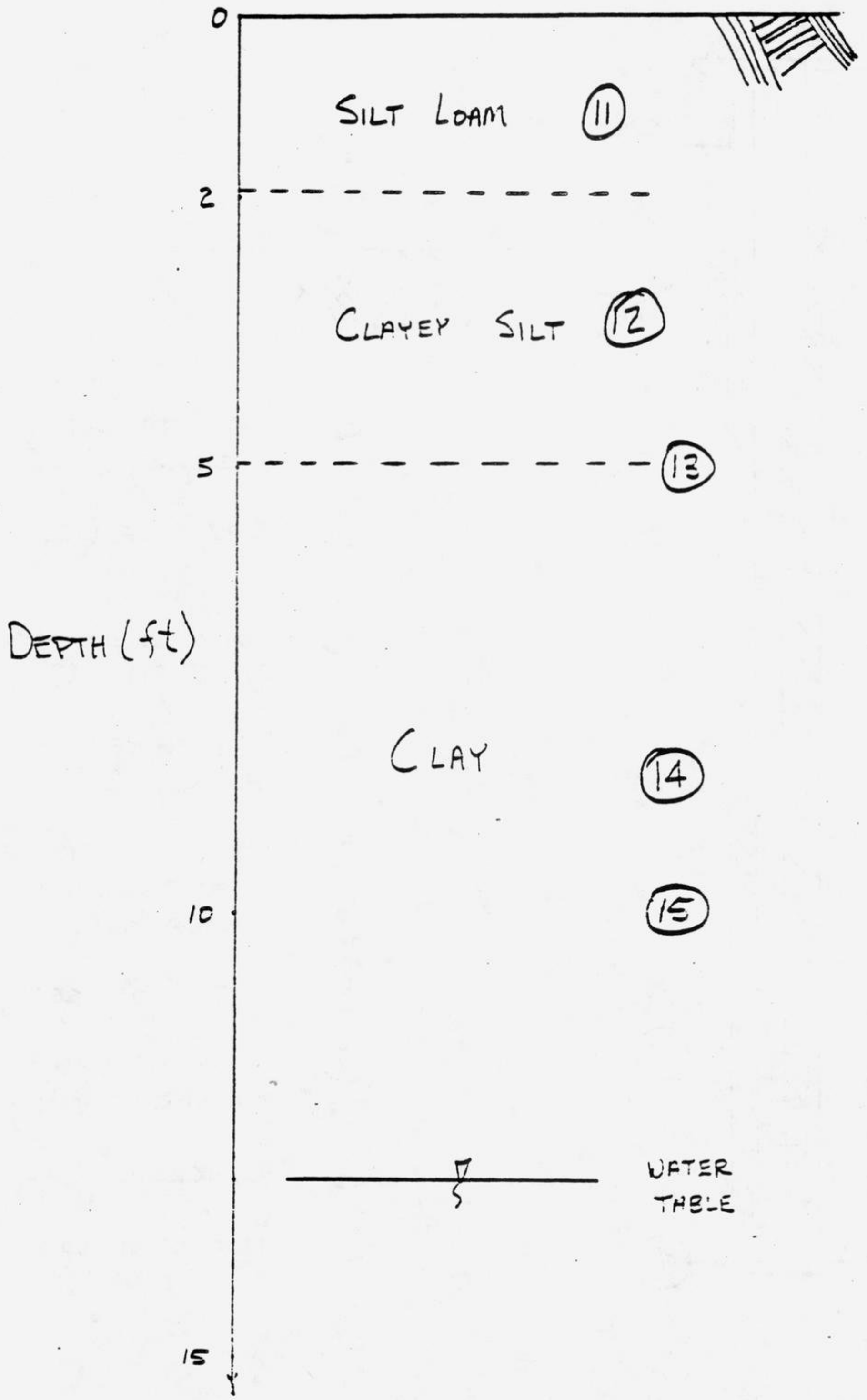


1. DEPTH TO BOTTOM OF BOREHOLE, 15'
2. LENGTH OF WELL SCREEN, 5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 11'-10" @ 2 IN DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 1'-10"
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, SILICA SAND (7')
6. DEPTH OF SEAL, 5'
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

SOIL PROFILE

MINDORO SITE
WELL # 5
DRILLED 8/17/83

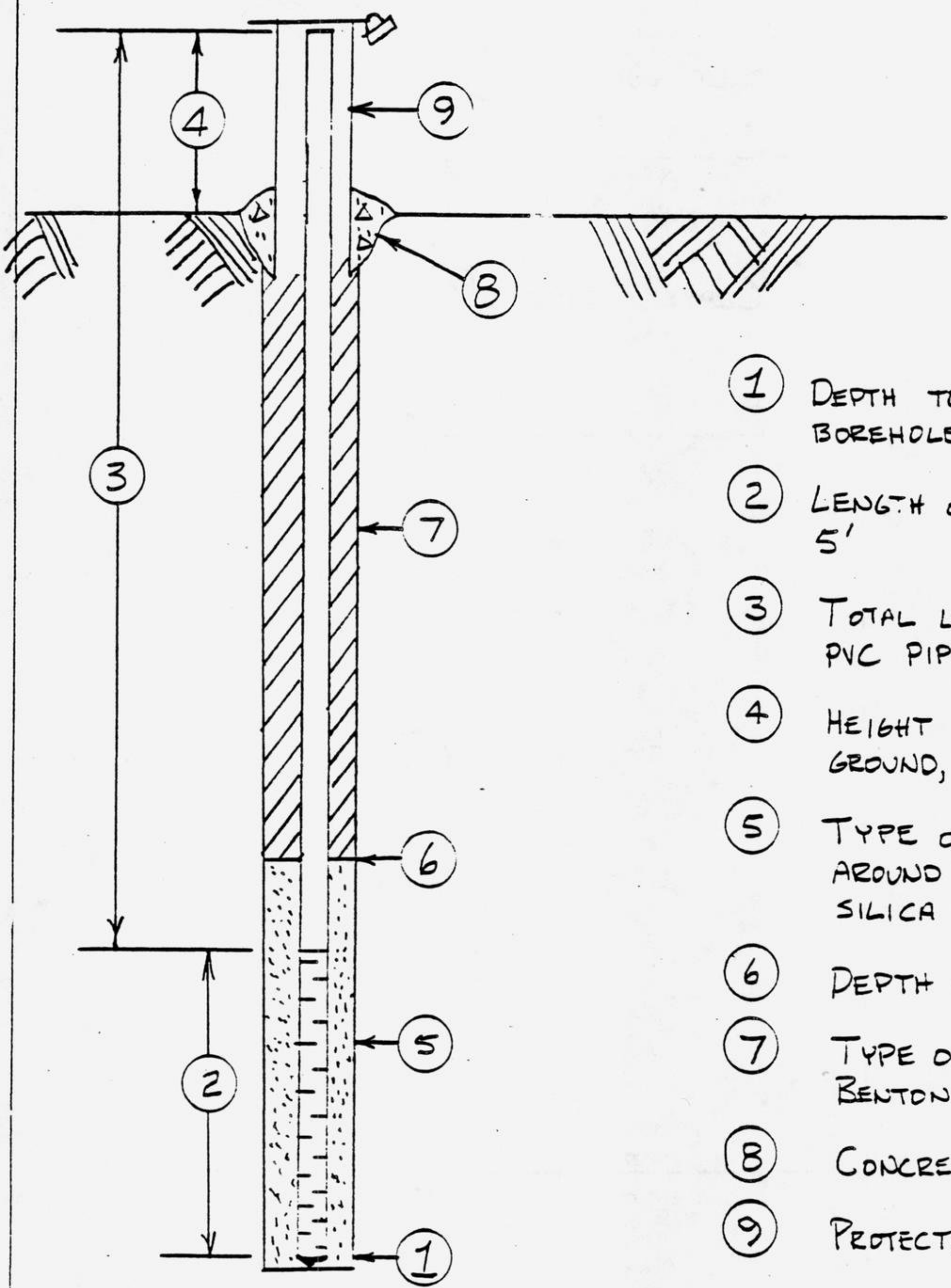
SCALE: 1" = 2'



MINDORO SITE
WELL #6 (SOUTHWEST SIDE OF SYSTEM ADJACENT TO CELL #1, SHALLOW - HAND AUGERED)
DRILLED: 8/16/83
PLACED: 8/17/83

VERTICAL SCALE: 1" = 3'

*ALL DEPTH MEASUREMENTS FROM GROUND SURFACE

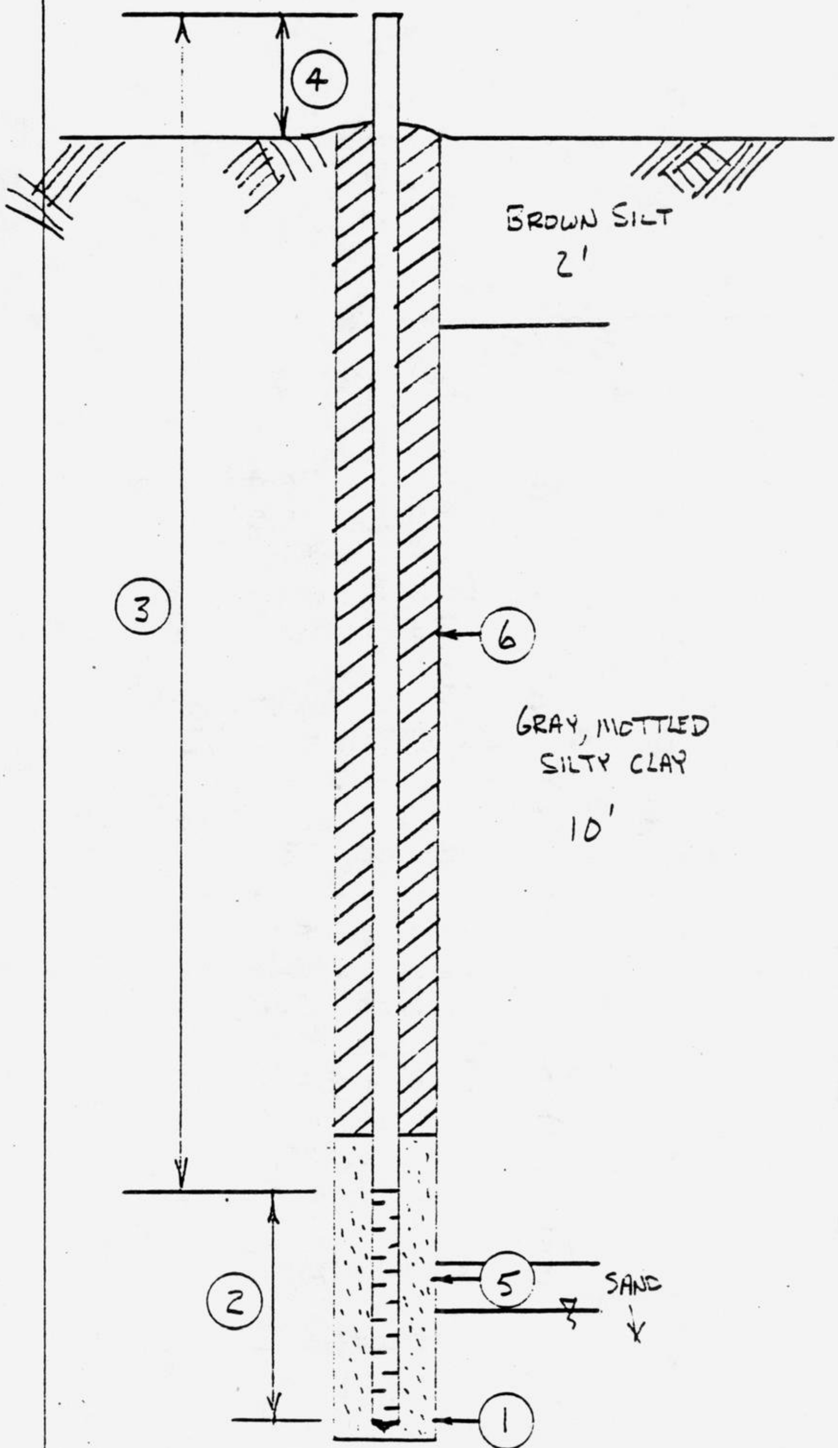


1. DEPTH TO BOTTOM OF BOREHOLE, 17.5'
2. LENGTH OF WELL SCREEN, 5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 14.9' @ 2 IN DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 2.4'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, SILICA SAND, 6.5'
6. DEPTH OF SEAL, 11'
7. TYPE OF BACKFILL, BENTONITE AND SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

INFORMATION

MINDORO SITE
WELL #7 (SHALLOW, INSIDE CELL #3)
DRILLED 4/25/84
PLACED 4/25/84

SCALE: 1" = 2'   * ALL DEPTH MEASUREMENTS FROM GROUND SURFACE



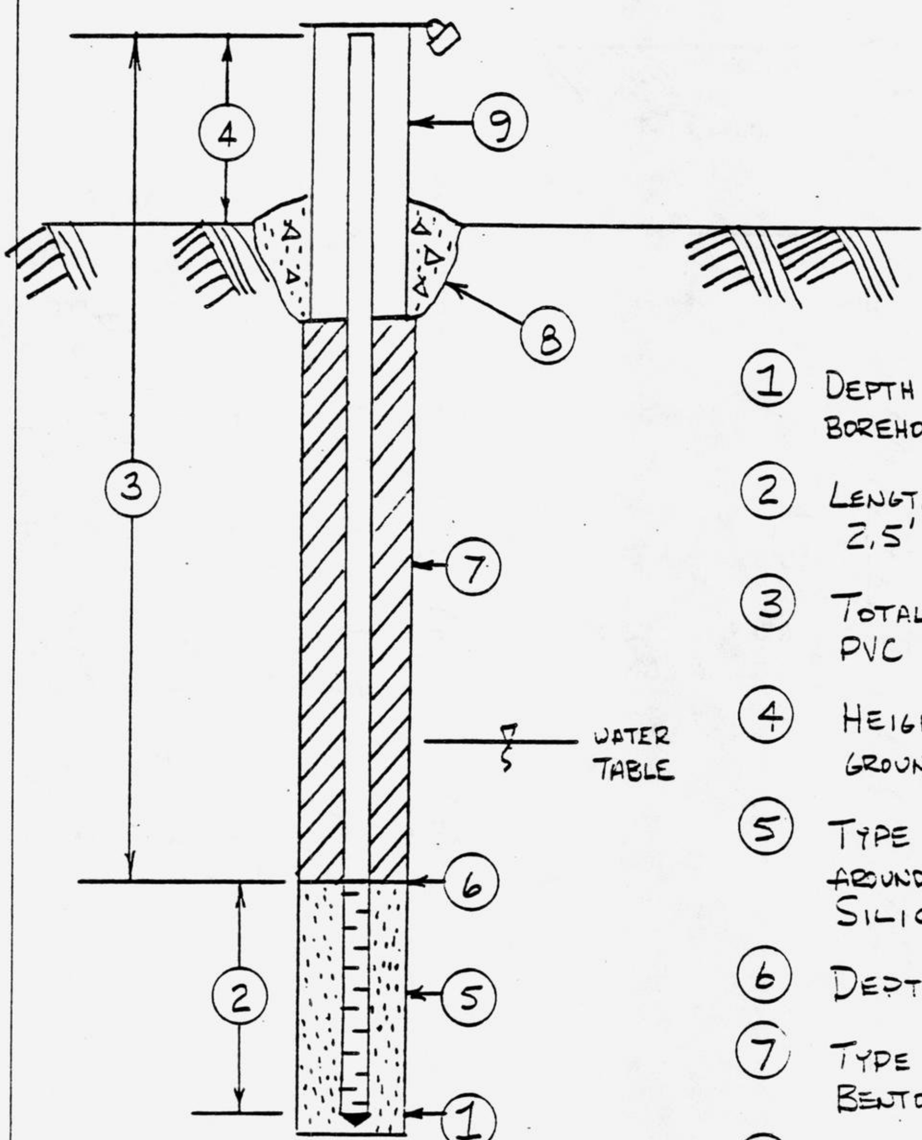
1. DEPTH TO BOTTOM OF BOREHOLE, 14'
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 12.7' @ 2" DIA
4. HEIGHT OF PIPE ABOVE GROUND, 1.2'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, SILICA SAND AND NATURAL SAND CAVE
6. TYPE OF BACKFILL, BENTONITE & SOIL

WELL DETAIL INFORMATION

MINDORO SITE
WELL #8 (SHALLOW, IN CELL #1, 61' FROM WELL #6)
DRILLED 10/18/83 TOP OF RIDGE
PLACED 10/18/83

SCALE: 1" = 2'

* ALL DEPTH MEASUREMENTS FROM GROUND SURFACE

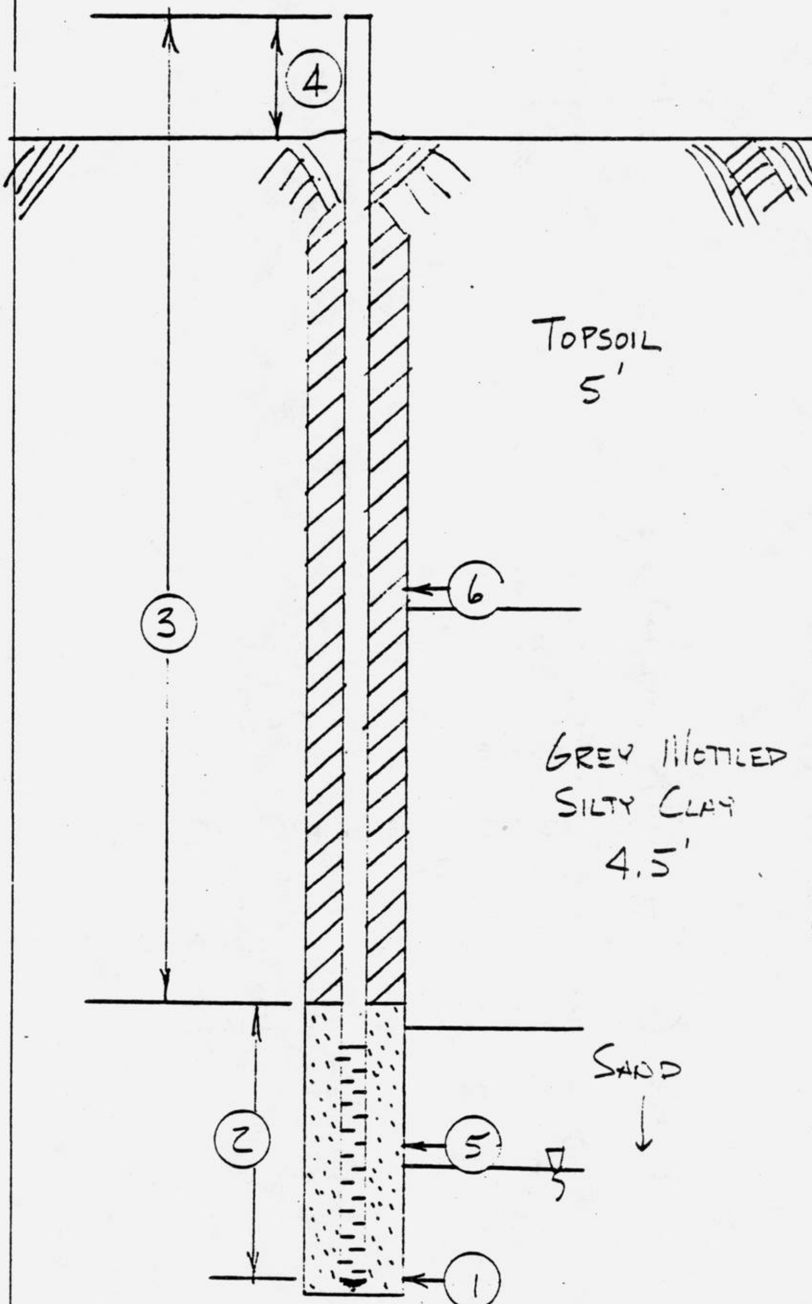


1. DEPTH TO BOTTOM OF BOREHOLE, 9.5'
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 9.3' @ 2 IN DIA.
4. HEIGHT OF PIPE ABOVE GROUND, 2.3'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, SILICA SAND, 2.5'
6. DEPTH OF SEAL, 7'
7. TYPE OF BACKFILL, BENTONITE & SOIL
8. CONCRETE CAP
9. PROTECTIVE CASING

WELL DETAIL INFORMATION

MINDORO SITE
WELL #9 (BETWEEN CELL #3 AND BACKGROUND WELL NEST)
DRILLED 4/25/84
PLACED 4/25/84

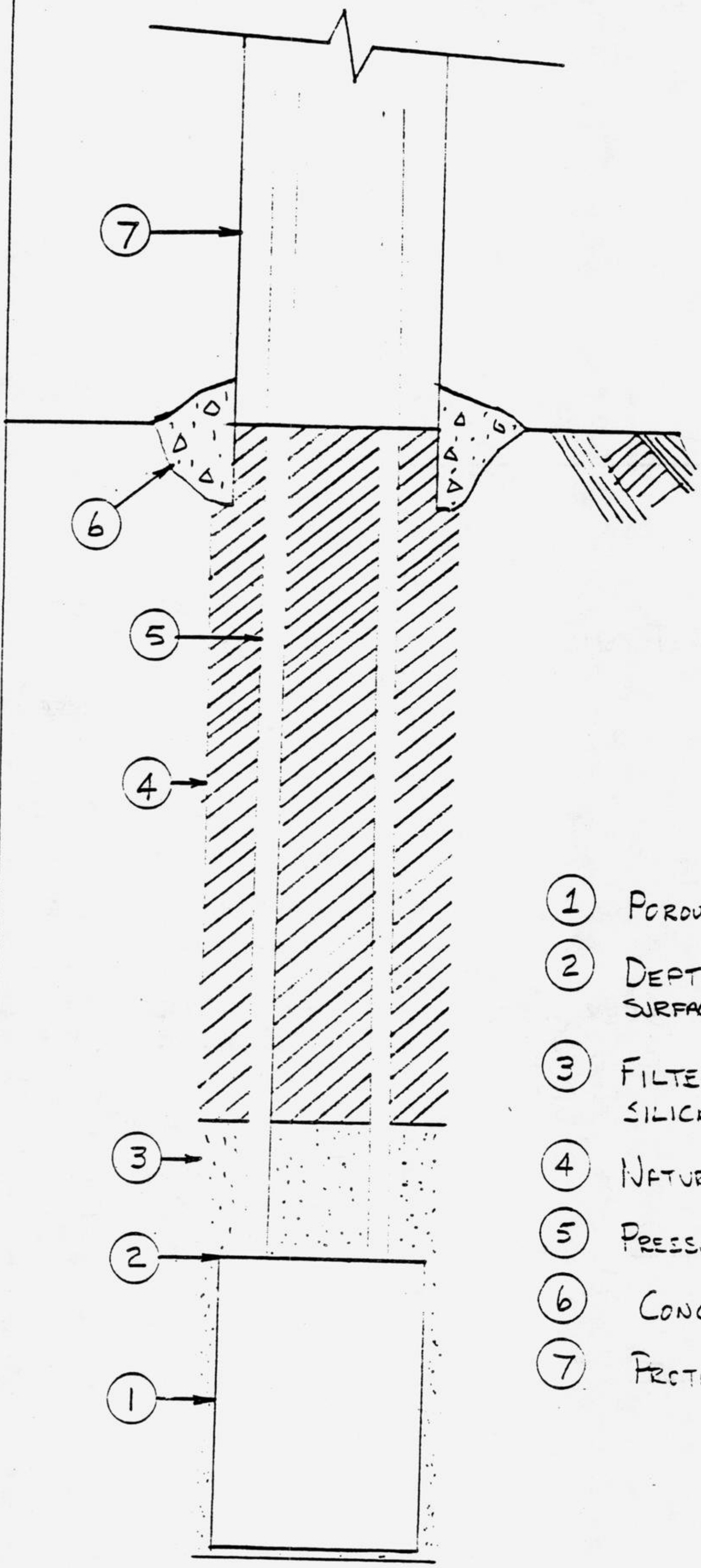
SCALE: 1" = 2'



1. DEPTH TO BOTTOM OF BOREHOLE, 12.2'
2. LENGTH OF WELL SCREEN, 2.5'
3. TOTAL LENGTH OF SOLID PVC PIPE, 11½ @ 2" DIA
4. HEIGHT OF PIPE ABOVE GROUND, 1.5'
5. TYPE OF FILTER MATERIAL AROUND WELL SCREEN, SILICA SAND & NATURAL SAND CAVE
6. TYPE OF BACKFILL, BENTONITE & SOIL

INFORMATION	# 21	BACKGROUND PLACED 9/20/83

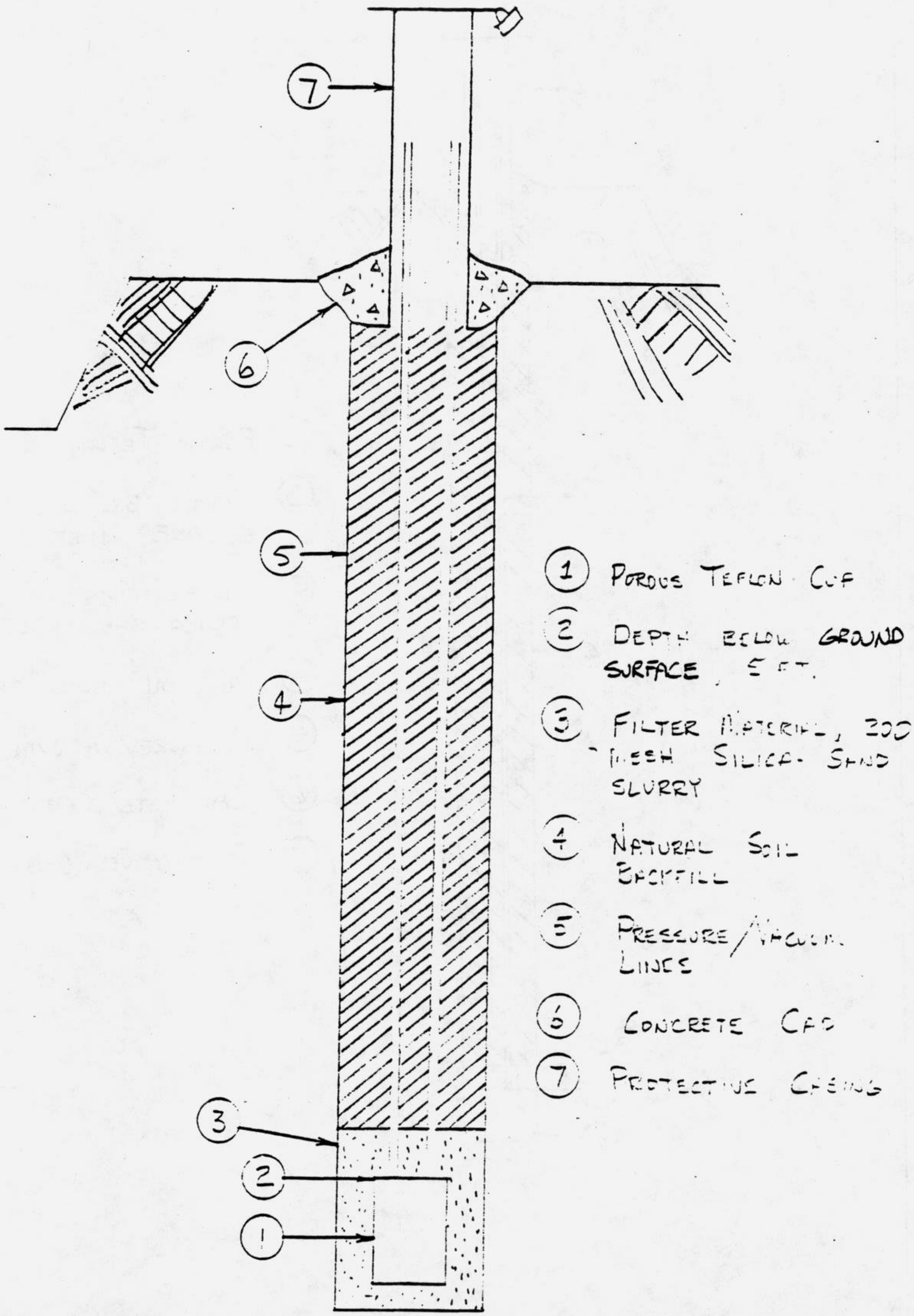
SCALE: 1" = 0.4'



1. POROUS TEFLON CUP
2. DEPTH BELOW GROUND SURFACE, 1 FT.
3. FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

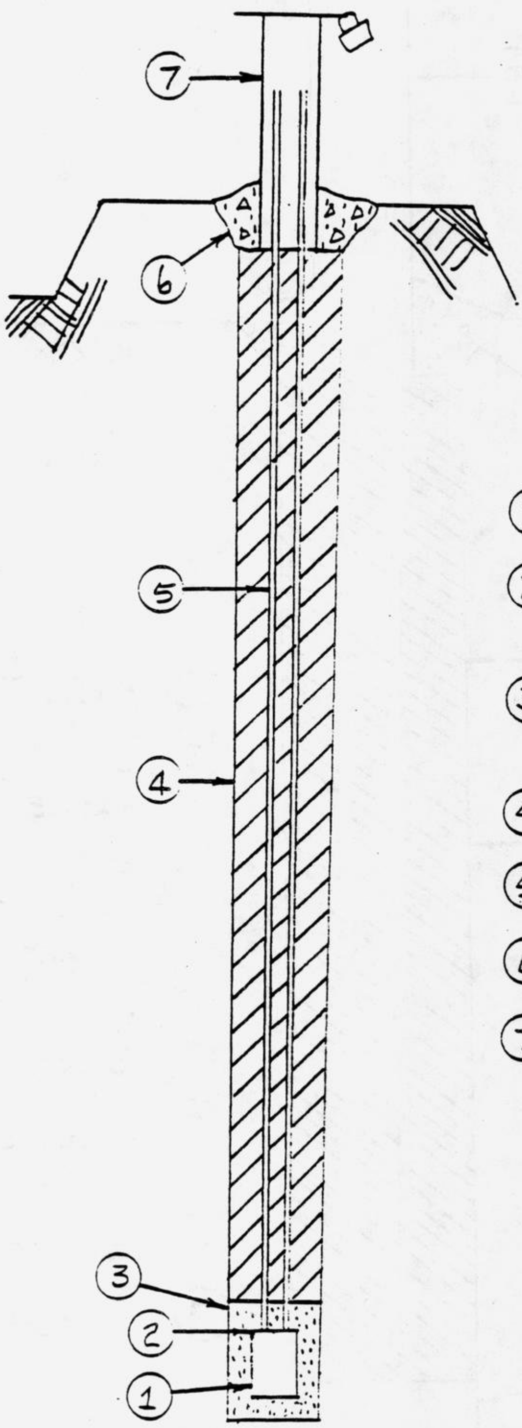
INFORMATION | # 25 | PLACED 9/20/83

SCALE: 1" = 1'



INFORMATION | # 211 | PLACED 9/20/83

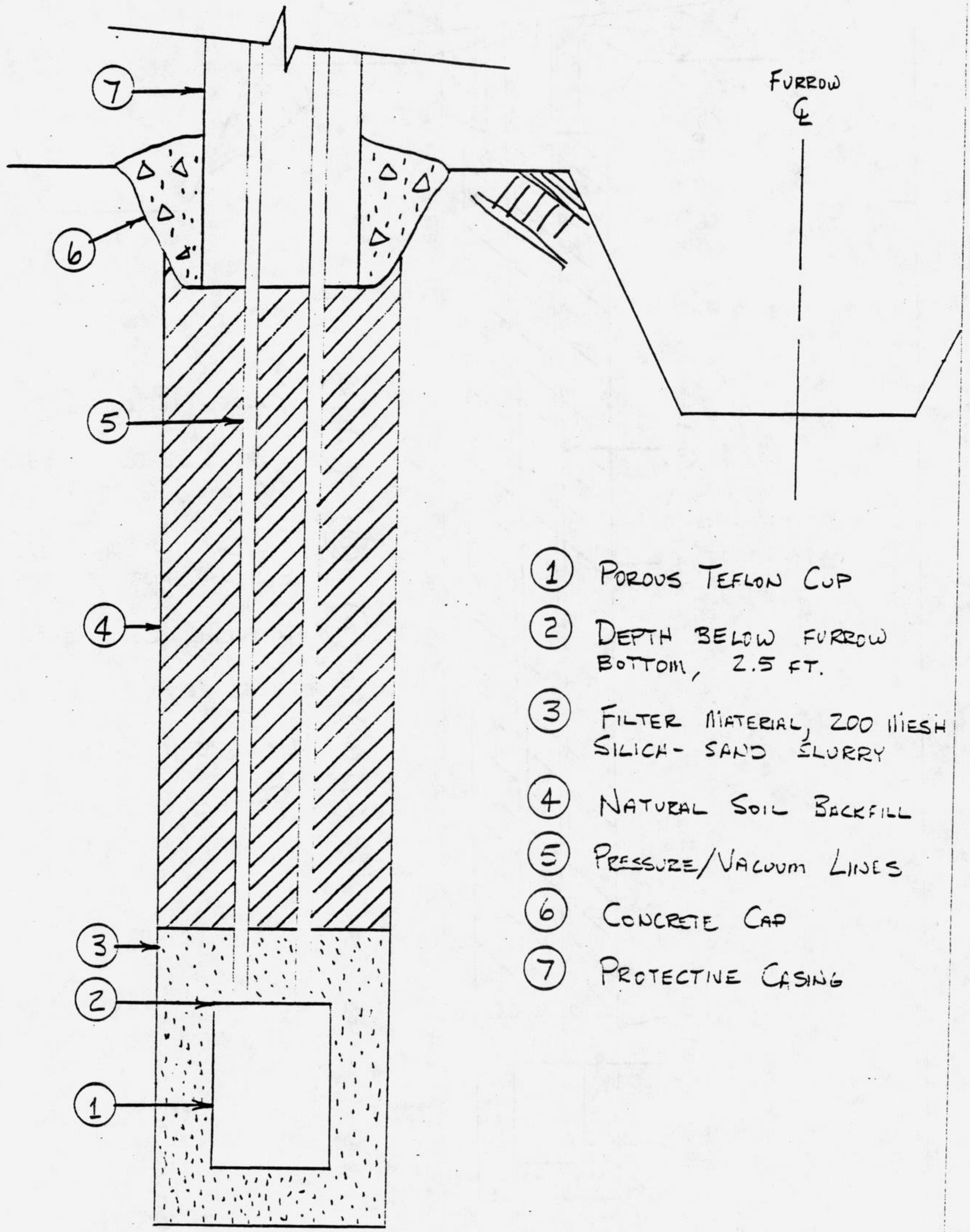
SCALE: 1" = 2'



1. POROUS TEFLON CUP
2. DEPTH BELOW GROUND SURFACE; 11 FT.
3. FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

LYSIMETER DETAIL INFORMATION	[illegible] = 325	CELL 2 PLACED 9/20/83

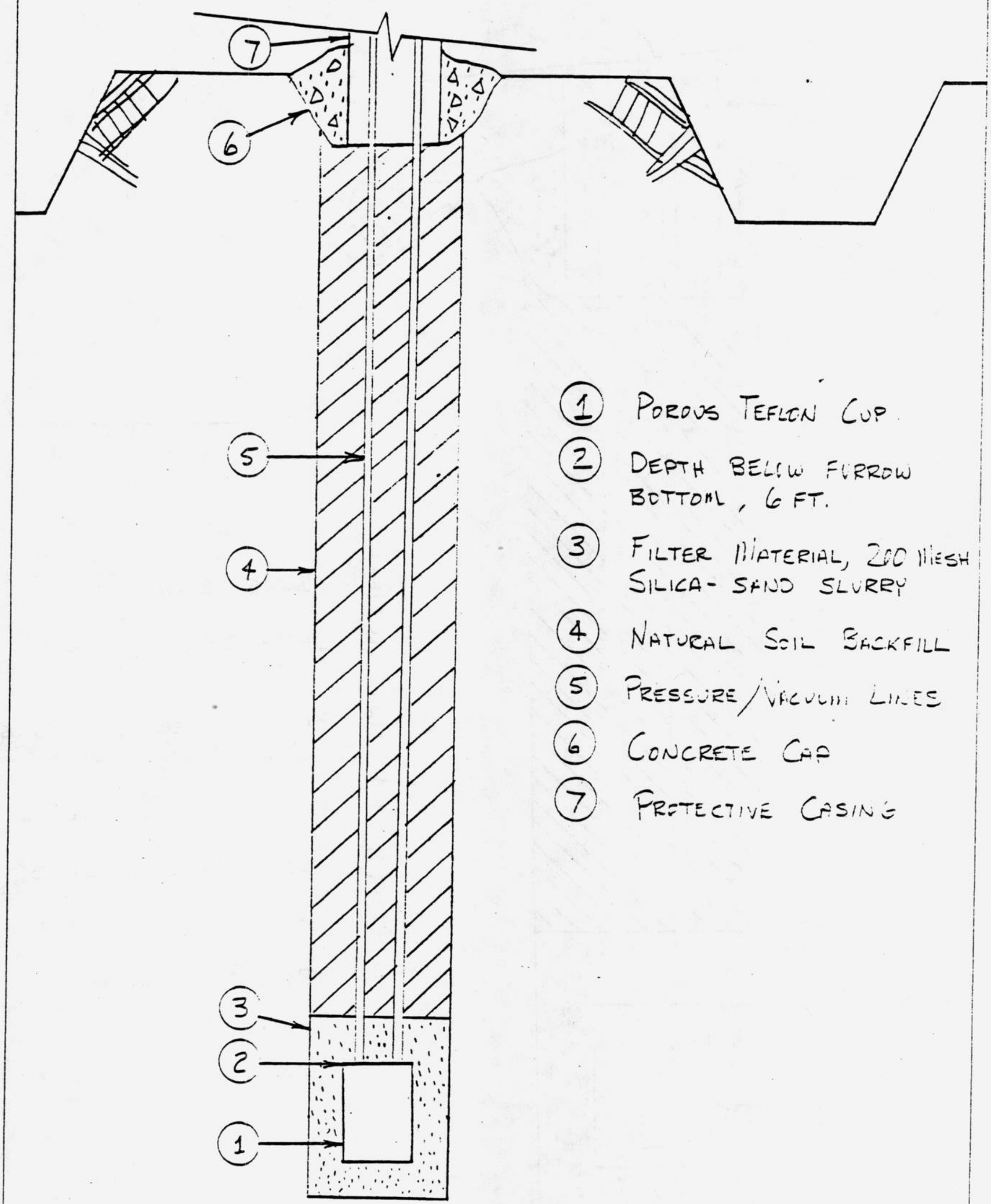
SCALE: 1" = 0.6'



1. POROUS TEFLON CUP
2. DEPTH BELOW FURROW BOTTOM, 2.5 FT.
3. FILTER MATERIAL, 200 MESH SILICA - SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

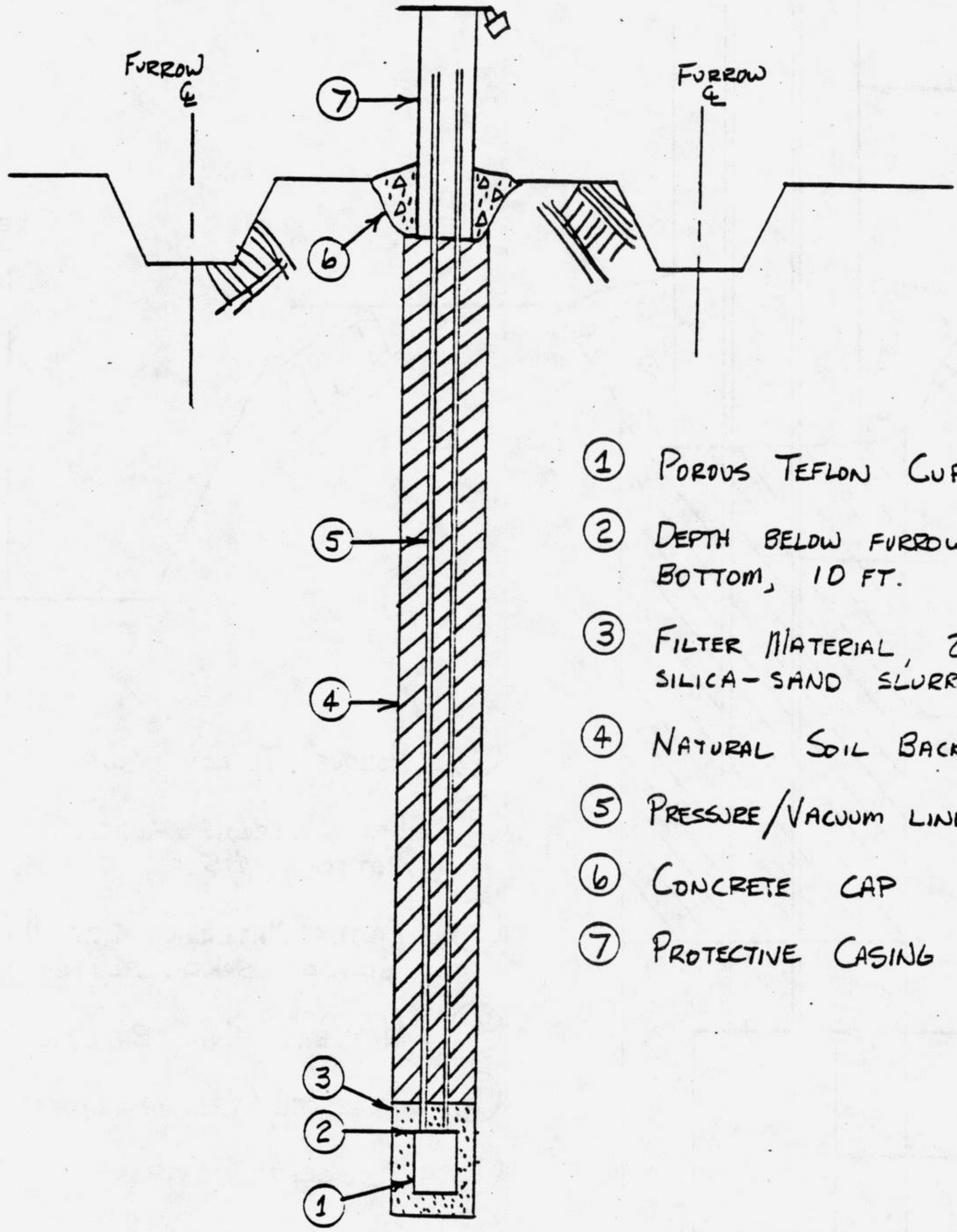
LYSIMETER DETAIL INFORMATION	[illegible] SITE # 36	CELL 2 PLACED 9/20/83

SCALE: 1" = 1'



LYSIMETER DETAIL INFORMATION | # 310 | CELL 2 PLACED 9/20/83

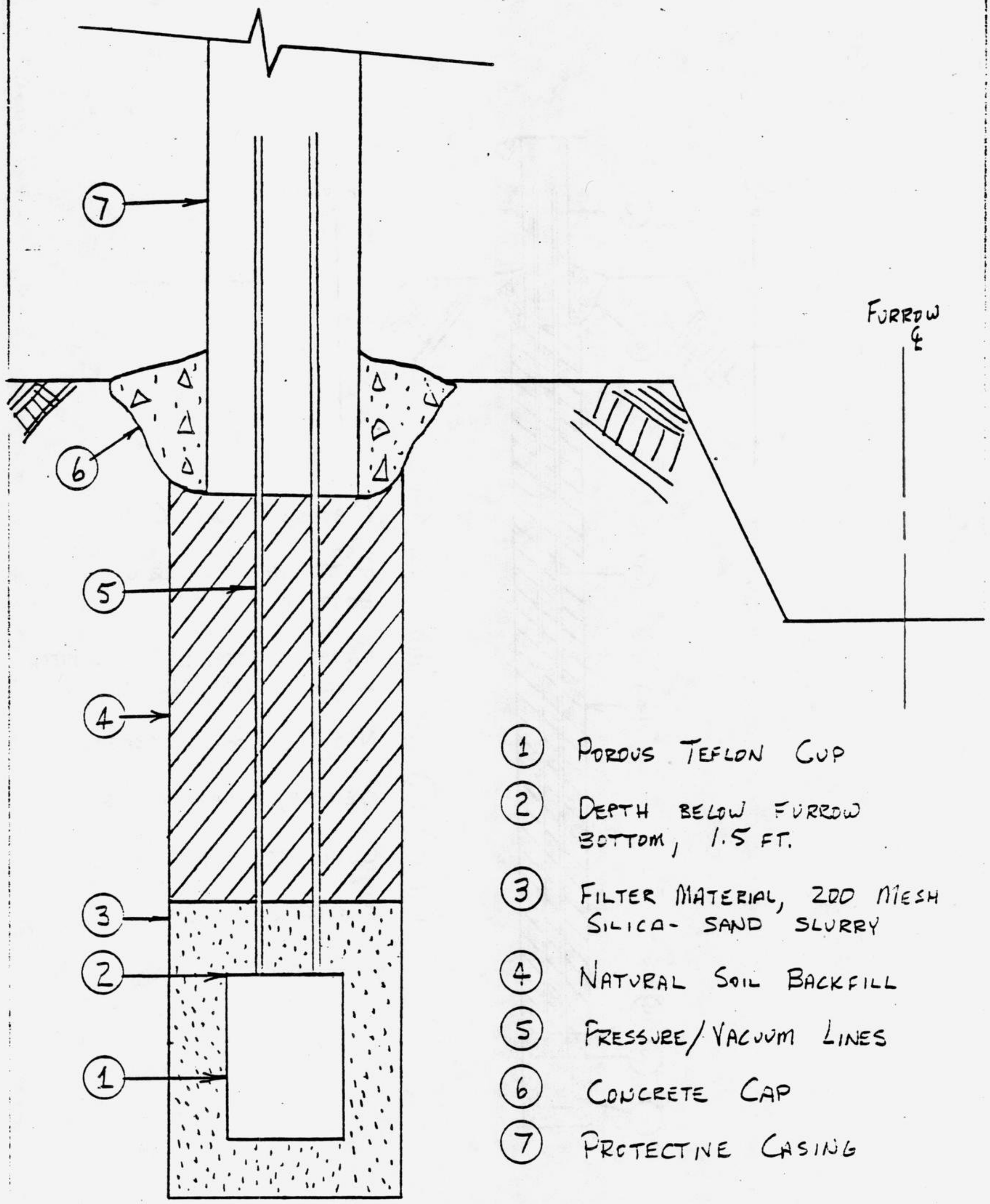
SCALE: 1" = 2'



1. POROUS TEFLON CUP
2. DEPTH BELOW FURROW BOTTOM, 10 FT.
3. FILTER MATERIAL, 200 MESH SILICA-SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

INFORMATION | # 415 | PLACED 10/18/83

SCALE: 1" = 0.6'



1. POROUS TEFLON CUP
2. DEPTH BELOW FURROW BOTTOM, 1.5 FT.
3. FILTER MATERIAL, 200 MESH SILICA- SAND SLURRY
4. NATURAL SOIL BACKFILL
5. PRESSURE/VACUUM LINES
6. CONCRETE CAP
7. PROTECTIVE CASING

Appendix BB

Mindoro:

Soil Analyses

COOPERATIVE EXTENSION PROGRAMS

UWEX University of Wisconsin–Extension
University of Wisconsin–Madison

Soil & Plant Analysis Laboratory, 806 South Park Street, Madison, Wisconsin 53715; 608-262-4364

DEPARTMENT OF SOIL SCIENCE

August 31, 1983
Acct. 900
Lab No. S0052

MEMORANDUM

TO: Dave Sauer
Wis. DNR - Box 7921
Madison, WI 53707

FROM: Soil/Plant Analysis Lab

RE: Results of analyses on 15 soil samples submitted August 19, 1983.

SEE PROFILES - # → ①

	Sample No.		pH	SMP	O.M.	P	K	Ca	Mg	Est CEC	Total N
					T/A	lbs/A					%
TOPSOIL	1	WELL #1	5.5	6.2	55	54	155	4050	880	14	0.31
CLAY-SILT	2		6.0	6.9	6	30	230	4050	800	14	0.03
CLAY-SAND	3		6.3	7.2	5	34	190	3000	800	11	0.02
CLAY	4		7.2	---	4	5	205	3450	1250	11	0.05
SAND	5		8.0 x	---	1 x	8 x	105 x	3000 x	300 x	9 x	0.01 x
HEAVING SAND	6		8.0 x	---	1	17	155	2000	280	6 x	0.01 x
CLAY SILT	7	WELL #3	7.2	---	7	36	200	4200	980	15	0.07
CLAY	8		7.5	---	3	91	245	3600	1120	14	0.01
CLAY	9		7.7	---	4	40	240	3450	1090	13	0.02
SILT-CLAY	10		7.7	---	10	6	285	7000	1080	22	0.04
TOPSOIL	11	WELL #5	6.0	6.3	55	40	155	4500	1020	16	0.28
CLAY-SILT	12		5.8	6.5	17	13	200	4900	1120	17	0.10
CLAY	13		6.8	7.1	4	52	160	4000	1090	15	0.02
CLAY	14		7.7	---	5	7	250	3550	1220	14	0.01
CLAY	15		7.9	---	4	5	225	3450	1180	14	0.02

Physical analyses will follow.

If you have any questions concerning these analyses, please feel free to contact us.

Encl.

/sf

COOPERATIVE EXTENSION PROGRAMS
UWEX University of Wisconsin—Extension
University of Wisconsin—Madison
Soil & Plant Analysis Laboratory, 806 South Park Street, Madison, Wisconsin 53715; 608-262-4364

INSTRUCTION EXTENSION
College of Agricultural and Life Sciences
RESEARCH

DEPARTMENT OF SOIL SCIENCE

October 7, 1983
Acct 900
Lab No. 00341

MEMORANDUM

TO: David Sauer
Wis. DNR
Box 7921
Madison, WI 53707

FORM: Soil/Plant Analysis Lab

RE: Results of analyses on ~~8~~ 3 soil samples submitted Sept. 22, 1983.

Sample No.		Sand	Silt	Clay	Total N
		%			
LYSIMETER 36 @ 1.5' 1	BROWN SILT	11	64	25	0.11
LYSIMETER 36, @ 2.5' 2	GREY/BLUE CLAY (SMELLY)	13	68	19	0.07
LYSIMETER 3C @ 9.5' 3	"	15	64	21	0.03

All additional analyses are attached.

You invoice for these analyses is enclosed.

Encls.

/sf

0-00341

LAB / FARM NO	
STATE COUNTY	ACCOUNT NO
WI 32	900
DATE RECEIVED	DATE PROCESSED
09-28-83	09-28-83

SOIL & PLANT ANALYSIS LAB
806 S PARK
MADISON WI
53715

SOIL TEST REPORT

Samples Analyzed By:
SOIL & PLANT ANALYSIS LAB
806 S. PARK
MADISON WI
53715

THIS REPORT IS FOR:
DAVE SAUER
WIS DNR BOX 7921
MADISON WI
53707

COOPERATIVE EXTENSION PROGRAMS
UWEX University of Wisconsin -- Extension
University of Wisconsin -- Madison
Soils Department, Madison, Wis.

WISCONSIN DHI COOPERATIVE

FARMER COPY

IDENTIFICATION

FIELD	1
ACRES	
SOIL NAME	GROUP XA
PLOW DEPTH	

YIELD GOALS

CORN	ALFALFA
OATS	70.0

LABORATORY ANALYSIS FOR EACH SAMPLE

Sample Number	Soil Text (Code)	Est CEC	Soil pH	Organic Matter Ton / A	P Phosphorus lbs / A	K Potassium lbs / A	Ca Calcium lbs / A	Mg Magnesium lbs / A	B Boron lbs / A	Mn Manganese lbs / A	Zn Zinc lbs / A	S Sulfur lbs / A	Lab Use Buffer Code
1	2	16	6.5	11	73 VH	275 H	4000 H	1300 H	BROWN	SILT	L36	@1.5	6.9
2	2	12	6.9	4	126 EH	310 H	3000 M	1000 M	GREY/	BLUE CLAY	1'	@2.5	
3	2	14	7.6	4	8 L	260 H	3250 H	1300 H	"	" "	L310	@9.5	

SOIL TEST LEVEL CODES VL (Very Low), L (Low), LM (Low Medium), M (Medium), HM (High Medium), H (High), VH (Very High), EH (Excessively High)

LIME PROGRAM

LIME GRADE USED	TONS PER ACRE TO CORRECT TO pH 6.6	or	pH 6.9
60-69	NONE	or	NONE
80-89	NONE	or	NONE

FOR OTHER LIME GRADES SEE LIME SECTION ON BACK

CORRECTIVE FERTILIZER PROGRAM

CROP YEAR	PLANT NUTRIENTS P_2O_5 lbs / A	K_2O lbs / A
FIRST	0	0
SECOND	0	0
THIRD	0	0

MAINTENANCE FERTILIZER PROGRAM

CORN YIELD GOAL BU/A	N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
101-120	140	40	30
121-140	160	45	35
141-160	190	50	40

ALFALFA YIELD GOAL T/A	P_2O_5 lbs / A	K_2O lbs / A
3.1-4.0	50	200
4.1-5.0	65	250
5.1-6.0	75	300

OTHER CROPS AND YIELD GOAL	N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
OATS 61-90 BU	70	30	30

WORKSPACE FOR CALCULATING YOUR TOTAL ANNUAL FERTILIZER REQUIREMENTS

CROP:	YEAR 19		
FERTILIZATION PROGRAM	N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
CORRECTIVE			
MAINTENANCE			
NUTRIENT ADJUSTMENT (S)			
TOTAL			
FERTILIZATION RECORD DATE AND/OR METHOD OF APPLICATION	RATE lbs / A	GRADE N - P_2O_5 - K_2O	

CROP:	YEAR 19		
FERTILIZATION PROGRAM	N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
CORRECTIVE			
MAINTENANCE			
NUTRIENT ADJUSTMENT (S)			
TOTAL			
FERTILIZATION RECORD DATE AND/OR METHOD OF APPLICATION	RATE lbs / A	GRADE N - P_2O_5 - K_2O	

CROP:	YEAR 19		
FERTILIZATION PROGRAM	N lbs / A	P_2O_5 lbs / A	K_2O lbs / A
CORRECTIVE			
MAINTENANCE			
NUTRIENT ADJUSTMENT (S)			
TOTAL			
FERTILIZATION RECORD DATE AND/OR METHOD OF APPLICATION	RATE lbs / A	GRADE N - P_2O_5 - K_2O	

COMMENTS SECTION

APPENDIX CC

MINDORO:

WASTEWATER CHEMISTRY DATA

DATA SHEET CHEMICAL PARAMETERS (mg/ℓ) RAW WASTEWATER

DATE	TOTAL BOD_5	TOTAL COD	TSS	TKN	DISS ~~TOTAL~~ NH_3-N	DISS NO_2-N + NO_3-N	Cl^-	pH (LAB)	OTHER
10/18/83	< 600	—	110	17.	1.7	0.1	96.	6.9	—
11/30/83	1200	1300	332	40	1.3	0.2	210	9.2	
12/22/83	430	LOW LEVEL 660	80	14.	—	—	70.	—	—
1/11/84	470	770	110	20	—	—	80	—	—
2/19/84	1300	1600	440	52	—	—	86	9.3	—
3/22/84	730	1300	192	40	–	–	120	(FIELD) 6.2	–
4/26/84	920	1000	616	40	(DISS) 1.5	0.5	53	9.5	pH 7.3 LAB
5/23/84	920	1400	472	34	(DISS) 0.9	1.6	95	8.6	–
6/6/84	890	1300	404	33	DISS 0.6	0.1	110	8.1	–
7/12/84	550	850	192	23	DISS 0.1	0.1	87	6.4	–
8/29/84	930	1300	212	35	0.4	0.1	110	5.1	
9/19/84	640	1000	165	25	0.1	<0.1	86	6.5	
10/16/84	1200	1900	145	31 DISS 40 TOT	0.9	0.3	100	7.5	
11/6/84	830	—	195	29 TOT 16 DISS	1.4	0.6	87	—	—

[illegible] CHEMICAL

DATA SHEET PARAMETERS (mg/l) RAW WASTEWATER

DATE	TOTAL ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/18/83	394	17.	100.	73	160	38	—	—
11/30/83	294	34	—	—	—	—	—	—
12/22/83	—	—	—	—	—	—	—	—
1/11/84	—	—	—	—	—	—	—	—
2/19/84	—	—	—	—	—	—	—	—
3/22/84	—	—	—	—	—	—	—	—
4/26/84	446	37	57	95	200	33	23	
5/23/84	—	—	—	—	—	—	—	—
6/6/84	—	—	—	—	—	—	—	—
7/12/84	—	—	—	—	—	—	—	—
8/29/84	266	45	—	82	130	35	36	
				53.3	46.3	[illegible]		
				1.04	7.10	6.73		

APPENDIX DD

MINDORO :

WASTEWATER FLOWS TO RIDGE AND FURROW

- 30 DAY AVERAGES
- 24-HR ON SAMPLING DAYS

Mindoro
Wastewater Flow
(Gallons/Day)

Month	1982	1983	1984	1984*	1983*
January	13200	11220	13200	13012	
February	13860	10560	13011	18175	
March	13860	13860	13294	13099	
April	17160	16500	13482	13921	
May	19140	16594	13011	16155	
June	18480	16688	14614	15613	
July	17820	15934	12540	13086	
August	19140	15557	11597	8582	
September	14520	13105	12917	9808	
October	13860	10227		15766	
November	11220	6006		15379	9978
December	13860	12634			10263
Yearly Average	15510	13244	13074	13295+	X
Cumulative Average	15510	14377	14022	X	X

* 24 HR flows determined on sampling days

+ Project 24-HR flow average

APPENDIX EE

MINDORO:

→ GROUNDWATER ELEVATIONS AND CONTOURS

→ SLUG TEST DATA AND CALCULATIONS

DATA SHEET: WELL 1A LENGTH: 15'/14.63 SHALLOW, BACKGROUND

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/20/83	10.40'	771.19'	—	—	—	—
10/18/83	14.49	767.10	0.14	0.07	0.02	—
11/29/83	14.28	767.31	0.35	0.2	ALL	@ 2:30 PM TOO DRY
11/30/83	14.57	767.02	—	—	—	@ 10.30 AM TOO SAMPLE
12/21/83	14.59	767.00	0.05	0.02	NONE	@ 12:18 PM TOO DRY
12/22/83	14.61	766.98	—	—	—	@ 9:55 AM TO SAMPLE
1/10/84	DRY	—	—	—	—	@ 11:55 AM TOO DRY
1/11/84	DRY	—	—	—	—	@ 9:11 AM TO SAMPLE
2/18/84	13.89	767.70	0.73	0.36	1 VOLUME	LIGHT BROWN (10:40)
2/19/84	14.02	767.57	—	—	—	(9:25)
3/21/84	14.50	767.09	0.12	0.06	NONE	TOO DRY TOO SAMPLE
3/22/84	14.55	767.01	—	—	—	"
4/25/84	DRY	—	—	—	—	
5/[illegible]/84	DRY	—	—	—	—	-
6/5/84	DRY	—	—	—	—	—
7/11/84	DRY	—	—	—	—	—
8/25/84	DRY	—	—	—	—	—
9/18/84	DRY	—	—	—	—	—
10/15/84	DRY	—	—	—	—	—
11/5/84	14.50	767.09	—	—	—	—

DATA SHEET : WELL 1B | LENGTH : 37.2'/37.13/37.11 | DEEP, BACKGROUND

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/20/83	11.55'	769.51	—	—	—	—
10/15/83	14.69	766.67	22.6	11.3	—	—
11/29/83	14.36	767.00	22.77	11.4	—	@12:40 pm
11/30/83	14.53	766.83	—	—	15	@10:40 am LIGHT BROWN
12/21/83	15.02	766.34	22.10	11.05	12	@12:20 pm
12/22/83	15.14	766.22	—	—	—	@9:57 AM CLEAR NO SMELL
1/10/84	15.30	766.06	21.8	10.9	12	@11:56 AM
1/11/84	15.29	766.07				@9:11 AM CLEAR
2/18/84	13.85	767.51	23.3	11.6	12	(12:40) LIGHT BROWN
2/19/84	13.80	767.56	—	—	—	(9:30)
3/21/84	14.64	766.72	22.5	11.2	—	CLEAR
3/22/84	14.77	766.59	—	—	12	
4/25/84	14.87	766.49	22.2	11.1	12	—
5/22/84	14.89	766.47	—	—	—	NOT SAMPLED
6/5/84	15.08	766.28	—	—	—	"
7/11/84	14.66	766.70	—	—	—	"
8/28/84	15.34	766.02	21.8	10.9	12	CLEAR
8/29/84	15.37	765.99	—	—	—	
9/18/84	15.31	766.05	—	—	—	—
10/15/84	15.19	766.17	—	—	—	—
11/5/84	14.55	766.81	—	—	—	—

DATA SHEET : WELL 2 | LENGTH ; 15'/14.73/14.69 | SHALLOW

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/20/83	9.30'	774.31	—	—	—	—
10/18/83	11.90	771.71	3.0	1.5	—	—
11/29/83	10.76	772.85	~~4~~ 3.97	~~4~~ 2	ALL	@ 2:50
11/30/83	12.73	770.88	—	—	—	@ 10:50 BLACK, TURBID
12/21/83	13.32	770.29	1.39	0.7	WELL VOLUME	@ 1:00 PM
12/22/83	13.69	769.92	—	—	—	@ 10:12 AM GREY, NO SMELL
1/10/84	13.85	769.76	0.8	0.4	WELL VOLUME	@ 12:04 PM
1/11/84	13.83	769.78	—	—	—	@ 9.49 AM GRAY
2/18/84	12.48	771.13	2.2	1.1	1 VOLUME	(10:53) BROWN
2/19/84	12.48	771.13	—	—	—	(10:07)
3/21/84	13.47	770.14	1.2	0.6	1 VOLUME	LIGHT BROWN
3/22/84	13.55	770.06	—	—	—	
4/25/84	13.59	770.02	1.1	0.6	1 VOLUME	—
4/26/84	13.60	770.01	—	—	—	—
5/22/84	13.62	769.99	1.1	0.5	1 VOLUME	LIGHT BROWN
5/23/84	13.65	769.96	—	—	—	
6/5/84	13.72	769.89	1.0	0.5	1 VOLUME	LIGHT BROWN
6/6/84	13.75	769.86	—	—	—	
7/11/84	13.56	770.05	1.1	0.6	1 VOLUME	LIGHT BROWN
7/12/84	13.63	769.98	—	—	—	
8/28/84	14.02	769.59	0.7	0.4	1 VOLUME	BROWN
8/29/84	14.02	769.59	—	—	—	
9/18/84	14.01	769.60	0.7	0.4	1 VOLUME	LIGHT BROWN
10/15/84	13.52	770.09	1.2	0.6	1 VOLUME	BROWN
11/5/84	13.40	770.21	—	—	—	—

DATA SHEET: WELL 3 | LENGTH: 16'-10"/16.51/16.48 SHALLOW

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/20/83	10.95'	774.37	—	—	—	—
10/18/83	13.16	772.16	3.52	1.76	—	—
11/29/83	13.01	772.31	3.5	1.75	~5	@ 3:25
11/30/83	13.08	772.24	—	—	—	@ 10:55 BROWN TURBID
12/21/83	13.37	771.95	3.12	1.56	WELL VOLUME	@ 1:15 PM LIGHT BROWN
12/22/83	13.40	771.92	—	—	—	@ 10:25 AM NO SMELL
1/10/84	13.46	771.86	3.0	1.5	WELL VOLUME	@ 12:19 AM WELL CAP OFF
1/11/84	13.47	771.85	—	—		@ 10:00 AM LIGHT BROWN
2/18/84	12.37	772.95	4.1	2.1	1 VOLUME	(11:05) BROWN
2/19/84	12.36	772.96	—	—	—	(10:20)
3/21/84	13.15	772.17	3.3	1.7	1 VOLUME	LIGHT BROWN
3/22/84	13.24	772.08	—	—	—	
4/25/84	13.19	772.13	3.3	1.6	1 VOLUME	—
4/26/84	13.19	772.13	—	—	—	—
5/22/84	13.28	772.04	3.2	1.6	1 VOLUME	CLEAR
5/23/84	13.32	772.00	—	—	-	
6/5/84	13.36	771.96	3.1	1.5	1 VOLUME	LIGHT BROWN
6/6/84	13.36	771.96	—	—	—	
7/11/84	13.44	771.88	3.0	1.5	1 VOLUME	LIGHT BROWN
7/12/84	13.48	771.84	—	—	—	
8/28/84	13.70	771.62	2.8	1.4	1 VOLUME	LIGHT BROWN
8/29/84	13.66	771.66	—	—	—	
9/18/84	13.33	771.99	3.2	1.6	1 VOLUME	VERY LIGHT BROWN
10/15/84	12.97	772.35	3.5	1.8	1 VOLUME	LIGHT BROWN
11/5/84	13.14	772.18	—	—	—	—

DATA SHEET: WELL 4 | LENGTH: 37.5/36.53/36.49 DEEP

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/20/83	10.93	774.35	—	—	—	—
10/18/83	13.09	772.19	17.7	5.85	—	—
11/29/83	12.98	772.30	23.55	~12	—	@ 3:25
11/30/83	13.01	772.27	—	—	15	@ 11:05 YELLOW-BROWN TURBID
12/21/83	13.29	771.99	23.22	11.61	12	@ 1:17 PM
12/22/83	13.31	771.97	—	—	—	@ 10:26 AM CLEAR NO SMELL
1/10/84	13.38	771.90	—	—	—	@ 12:21 PM
1/11/84	13.37	771.91	23.1	11.5	12	@ 10:01 AM CLEAR
2/18/84	12.35	772.93	—	—	—	(11:05) BROWN
2/19/84	12.31	772.97	24.1	12.1	12+	(10:21)
3/21/84	13.07	772.21	23.4	11.7	—	BROWN
3/22/84	13.13	772.15	—	—	12	
4/25/84	13.11	772.17	—	—	—	—
4/26/84	13.12	772.16	23.4	11.7	12	—
5/22/84	13.20	772.05	23.3	11.6	12	LIGHT BROWN
5/23/84	13.23	772.05	—	—	—	
6/5/84	13.27	772.01	—	—	—	
6/6/84	13.27	772.01	23.2	11.6	12	LIGHT BROWN
7/11/84	13.34	771.94	—	—	—	
7/12/84	13.38	771.90	23.1	11.6	12	LIGHT BROWN
8/28/84	13.63	771.65	22.8	11.4	—	
8/29/84	13.58	771.70	—	—	12	CLEAR
9/18/84	13.58	771.70	23.0	11.5	—	
9/19/84	13.55	771.73	—	—	12	CLEAR
10/15/84	12.80	772.48	23.7	11.8	12	BROWNISH CLEAR
11/5/84	13.16	772.12	—	—	—	—

DATA SHEET; WELL 5 | LENGTH: 16'-10"/6.53/16.51 | SHALLOW

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/20/83	12.32'	770.31	—	—	—	—
10/18/83	14.21	768.42	2.5	1.25	—	—
11/29/83	13.53	769.10	3	1.5	ALL	@ 4:10
11/30/83	14.03	768.60	—	—	—	@ 11.50 FAIRLY CLEAR
12/21/83	14.53	768.10	2	1	3	@ 2:45 PM
12/22/83	14.63	768.00	—	—	—	@ 11:18 AM BROWN-GRAY SMELLY
1/10/84	14.77	767.86	1.8	0.9	2	@ 1:05 PM
1/11/84	14.73	767.90	—	—	—	@ 11:05 AM BROWN-GRAY
2/18/84	13.62	769.01	2.9	1.4	4	(11:35) BROWN-GREEN
2/19/84	13.51	769.12	—	—	—	(11:25) ODOR
3/21/84	14.33	768.30	2.2	1.1	—	BLACK-GREEN ODOR
3/22/84	14.38	768.25	—	—	1.5	
4/25/84	14.47	768.16	—	—	—	—
4/26/84	14.45	768.18	2.0	1.0	2	—
5/22/84	14.36	768.27	—	—	—	DULL CLEAR ODOR
5/23/84	14.40	768.23	2.1	1.1	2	
6/5/84	14.55	768.08	—	—	—	
6/6/84	14.55	768.08	1.9	1.0	2	GREY BROWN - ODOR
7/11/84	14.27	768.36	—	—	—	
7/12/84	14.34	768.29	2.2	1.1	1.5	WHITISH, ODOR
8/28/84	14.65	767.95	1.9	0.9	—	
8/29/84	14.65	767.95	—	—	1	YELLOW, ODOR
9/18/84	14.75	767.88	1.8	0.9	—	
9/19/84	14.73	767.90	—	—	1	YELLOW - ODOR
10/15/84	14.33	768.30	2.2	1.1	1.5	LIGHT YELLOWISH BROWN
11/5/84	14.22	768.41	--	—	—	—

DATA SHEET: WELL 5A LENGTH: 33.3/32.09/32.05 DEEP (OBSERVATION WELL)

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
10/18/83	13.97	768.34	18.2	9.1	—	—
11/30/83	13.87	768.44				—
12/21/83	14.25	768.06				@ 2:46 PM
1/10/84	14.41	767.90				@ 1:06PM
2/18/84	13.07	769.24				(11:35)
3/21/84	13.99	768.32				—
4/25/84	14.13	768.15				—
5/22/84	14.16	768.15				—
6/5/84	14.24	768.07				—
7/11/84	13.98	768.33				—
8/28/84	14.41	767.90				—
9/18/84	14.43	767.88				
10/15/84	14.05	768.26				
11/5/84	13.90	768.41				

DATA SHEET : WELL 6 | LENGTH : 19.9'/1.48 | SHALLOW

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
9/20/83	12.26'	773.43	—	—	—	—
10/18/83	15.20	770.49	5.0	2.5	—	—
11/29/83	15.28	770.41	4.2	2.1	~5	@ 4:00
11/30/83	15.38	770.31	—	—	—	@ 11:40 FAIRLY CLEAR
12/21/83	15.62	770.07	3.86	1.93	4	@ 2:10 PM BLACK SILT
12/22/83	15.64	770.05	—	—	—	@ 10:58 AM LITTLE SMELLY
1/10/84	15.72	769.97	3.76	1.9	4	@ 12:45 PM
1/11/84	15.71	769.98	—	—	—	@ 10:54 AM BLACKISH
2/18/84	14.74	770.95	—	—	—	(11:30) BLACK
2/19/84	14.68	771.01	4.7	2.4	4	(11:10) ODOR
3/21/84	15.40	770.29	4.1	2.0	—	GREY ODOR
3/22/84	15.47	770.22	—	—	4	
4/25/84	15.50	770.19	—	—	—	—
4/26/84	15.50	770.19	4.0	2.0	3	—
5/22/84	15.57	770.12	—	—	—	GREY
5/23/84	15.61	770.08	3.8	1.9	2	
6/5/84	15.63	770.06	—	—	—	
6/6/84	15.64	770.05	3.8	1.9	3	GREY
7/11/84	15.59	770.10	—	—	—	
7/12/84	15.66	770.03	3.9	1.9	2	DARK GREY
8/28/84	15.87	769.82	3.6	1.8	—	
8/29/84	15.87	769.82	—	—	2	GREY
9/18/84	15.85	769.84	3.7	1.8	2	LIGHT GREY
9/19/84	15.82	769.87	—	—	—	
10/15/84	14.98	770.71	4.5	2.2	3	GREYISH
11/5/84	15.41	770.28	—	—	—	—

DATA SHEET: WELL 7 | LENGTH: 15.22 | SHALLOW, CELL 3

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
4/26/84	13.63	768.37	1.6	0.8	2	—
5/22/84	13.64	768.36	—	—	—	
5/23/84	13.68	768.32	1.6	0.8	1.5	DULL CLEAR ODOR
6/5/84	13.78	768.22	—	—	—	
6/6/84	13.80	768.20	1.0	0.5	1.5	GREY BROWN
7/11/84	13.47	768.53	—	—	—	
7/12/84	13.56	768.44	1.8	0.9	1.0	LIGHT BROWN
8/28/84	14.00	768.00	1.3	0.6	—	
8/29/84	13.99	768.01	—	—	1	YELLOW-BROWN, ODOR
9/18/84	13.99	768.01	1.3	0.6	—	
9/19/84	13.99	768.01	—	—	1	LIGHT YELLOW
10/15/85	13.67	768.33	1.6	0.8	1.5	YELLOW BROWN
11/5/84	13.33	768.66	—	—	—	—

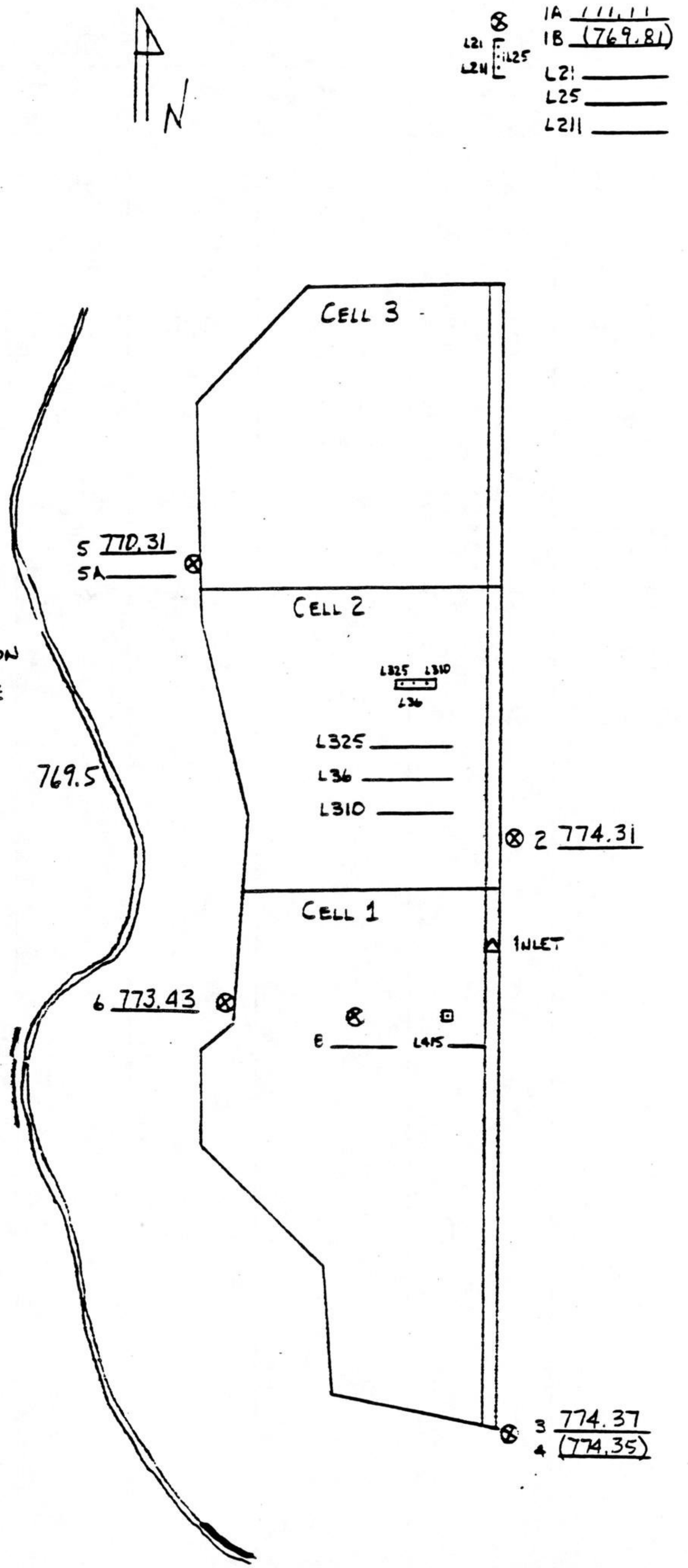
[illegible]

DATA SHEET : WELL 8 | LENGTH: 11.8/11.[illegible]/ | SHALLOW

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUME REMOVED	COMMENT
10/19/83	8.43	775.42	3.2	1.6	—	—
11/29/83	9.86	773.99	1.8	0.9	ALL	@ 3:50
11/30/83	10.23	773.62	—	—	—	@ 11:35 LIGHT BROWN
12/21/83	9.96	773.89	1.72	0.86	WELL VOLUME	@ 1:50PM
12/22/83	10.35	773.50	—	—	—	@ 10:46AM LIGHT BROWN NO SMELL
1/10/84	9.99	773.86	1.7	0.8	WELL VOLUME	@ 12:56PM
1/11/84	9.66	774.19	—	—	—	@ 10:44AM BIG OVERNITE INCREASE - LIGHT BROWN
2/18/84	8.74	775.11	2.9	1.5	1 VOLUME	(11:20)
2/19/84	9.12	774.73	—	—	—	(11:00) BROWN
3/21/84	8.94	774.91	2.7	1.4	1 VOLUME	LIGHT BROWN
3/22/84	8.99	774.86	—	—	—	
4/25/84	9.38	774.47	2.3	1.1	1 VOLUME	—
4/26/84	9.76	774.09	—	—	—	—
5/22/84	10.15	773.70	1.5	0.8	1 VOLUME	LIGHT [illegible]
5/23/84	10.54	773.31	—	—	—	
6/5/84	11.35	772.50	0.3	0.2	1 VOLUME	TOO DRY
6/6/84	11.50	772.35	—	—	—	
7/11/84	DRY	—	—	—	—	—
8/28/84	DRY	—	—	—	—	—
9/13/84	DRY	—	—	—	—	—
10/15/84	DRY	—	—	—	—	—
11/5/84	10.04	773.81	—	—	—	—

DATA SHEET: WELL 9 | LENGTH: 13.71 | SHALLOW, NORTH OF CELL 3 BERM

DATE	DEPTH TO GW	GW ELEVATION	VOLUME H_2O (ft)	3 VOLUMES (GAL)	VOLUMES REMOVED	COMMENT
4/26/84	12.48	767.20	1.2	0.6	1 VOLUME	—
5/22/84	12.53	767.15	1.2	0.6	1 VOLUME	BROWN
5/23/84	12.58	767.10	—	—	—	
6/5/84	12.69	766.99	1.0	0.5	1 VOLUME	RUSTY
6/6/84	12.72	766.96	—	—	—	
7/11/84	12.30	767.38	1.4	0.7	1.0	RUSTY
7/12/84	12.42	767.26	—	—	—	
8/25/84	12.95	766.73	0.8	0.4	1 VOLUME	RUSTY
8/27/84	12.97	766.71	—	—	—	
9/18/84	12.89	766.79	0.9	0.4	1 VOLUME	RUSTY
10/15/84	12.73	766.95	1.0	0.5	1 VOLUME	RUSTY
11/5/84	12.18	767.50	—	—	—	—

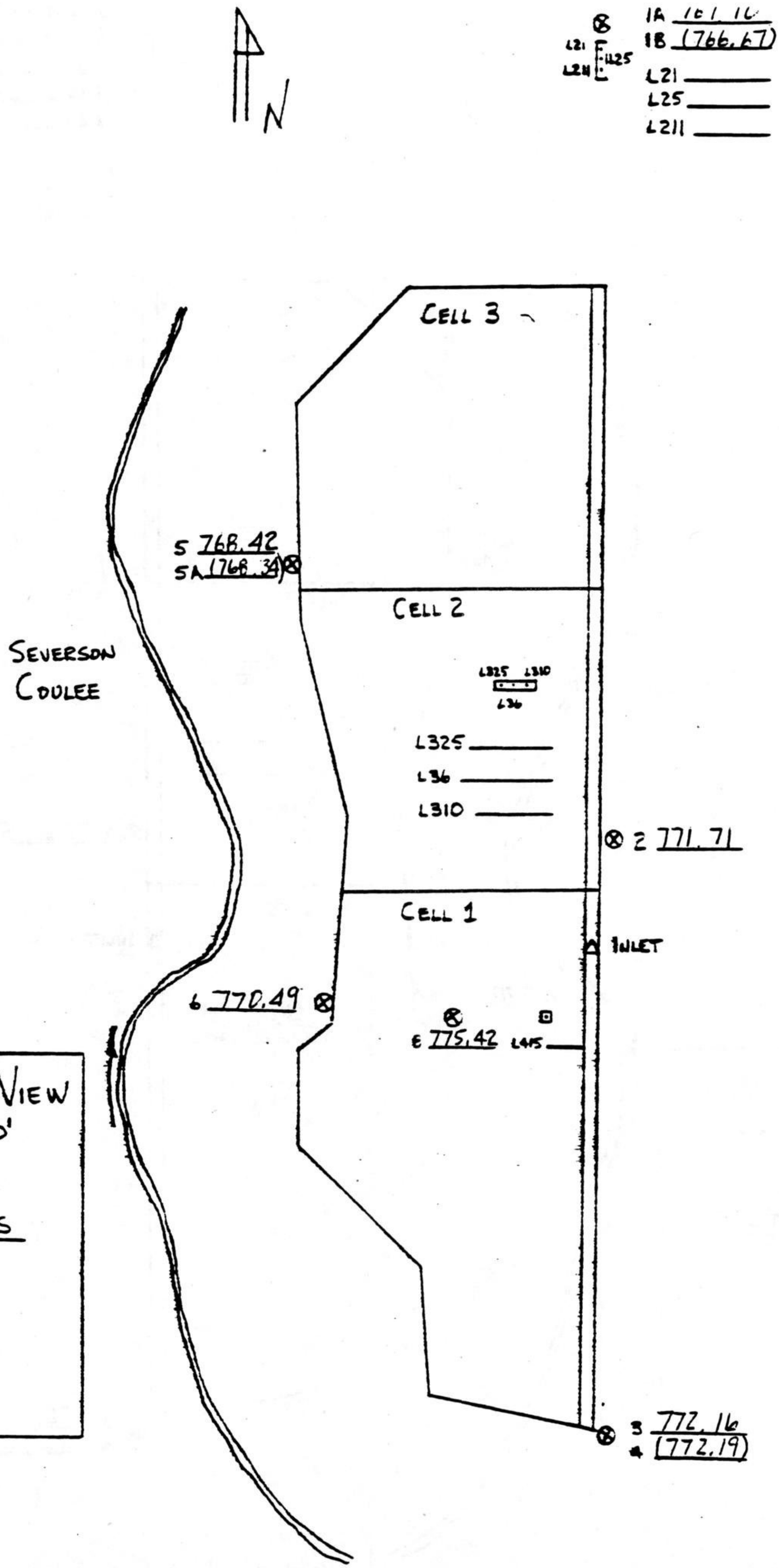


INDORO PLAN VIEW
SCALE: 1" = 100'

PARAMETER PLOTTED: GROUND WATER ELEVATION

MONTH: SEPTEMBER 20

YEAR: 1983

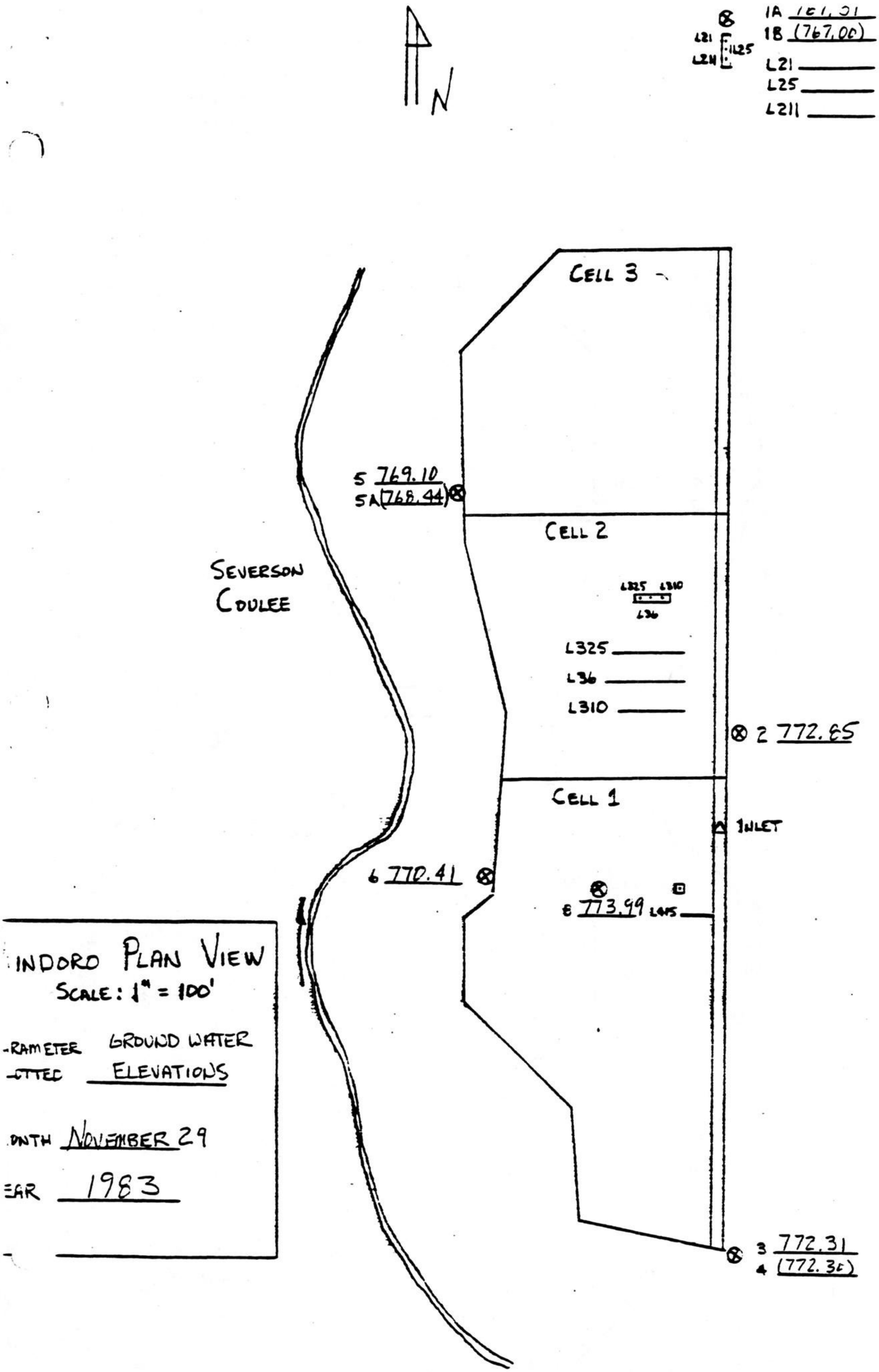


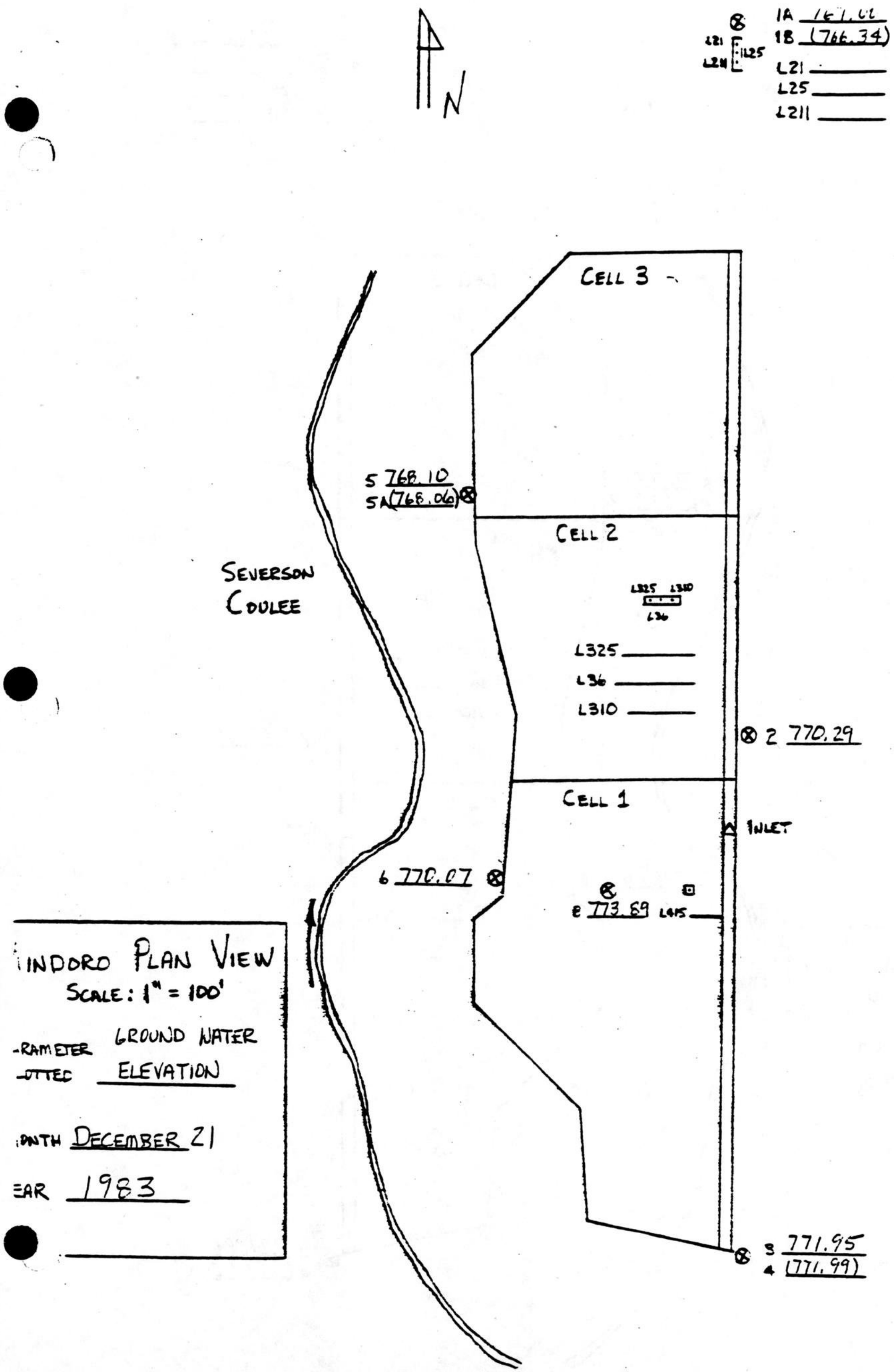
INDORO PLAN VIEW
SCALE: 1" = 100'

RAMETER OTTED GROUND WATER ELEVATIONS

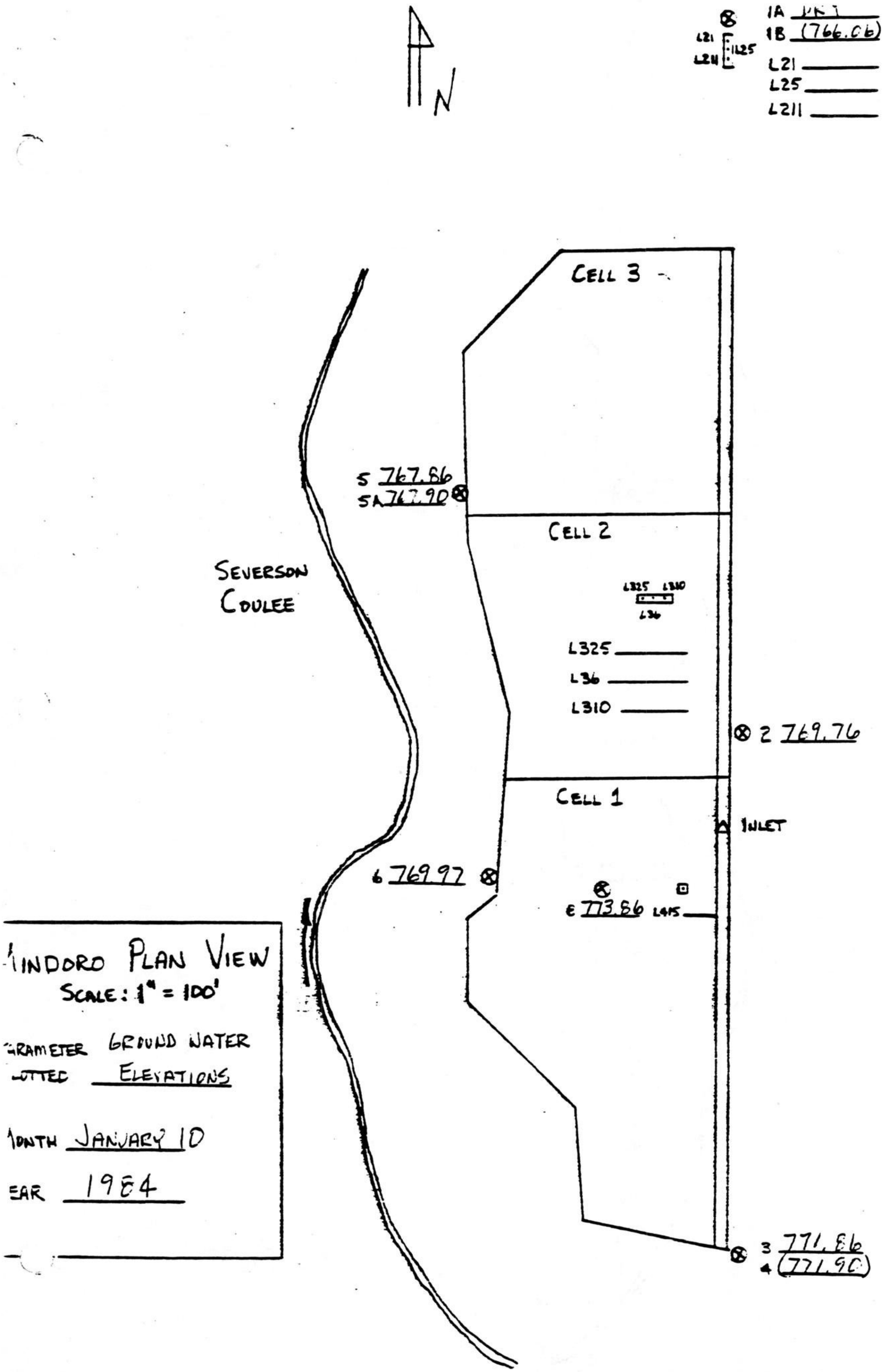
ONTH OCTOBER 18

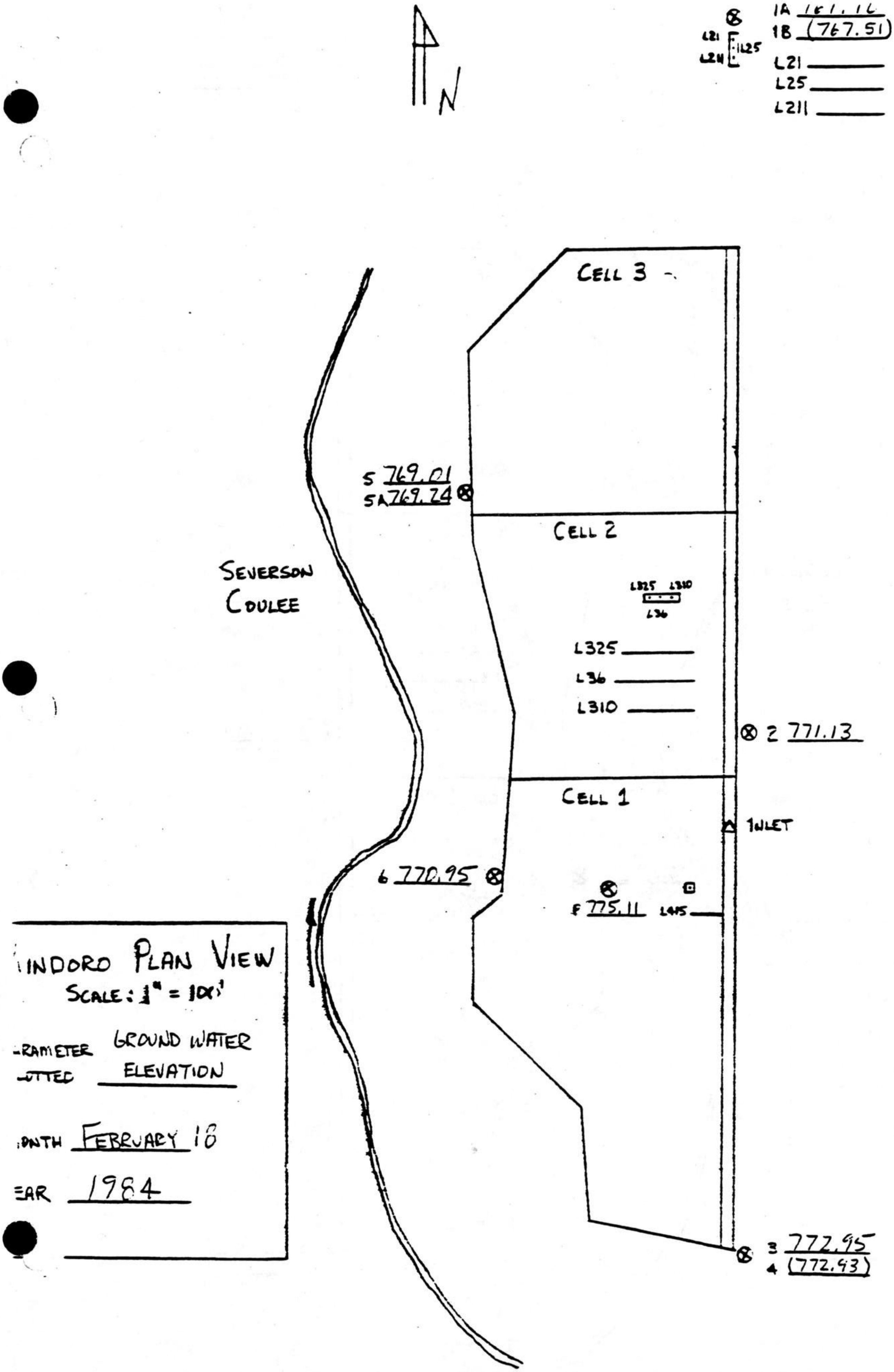
EAR 1983

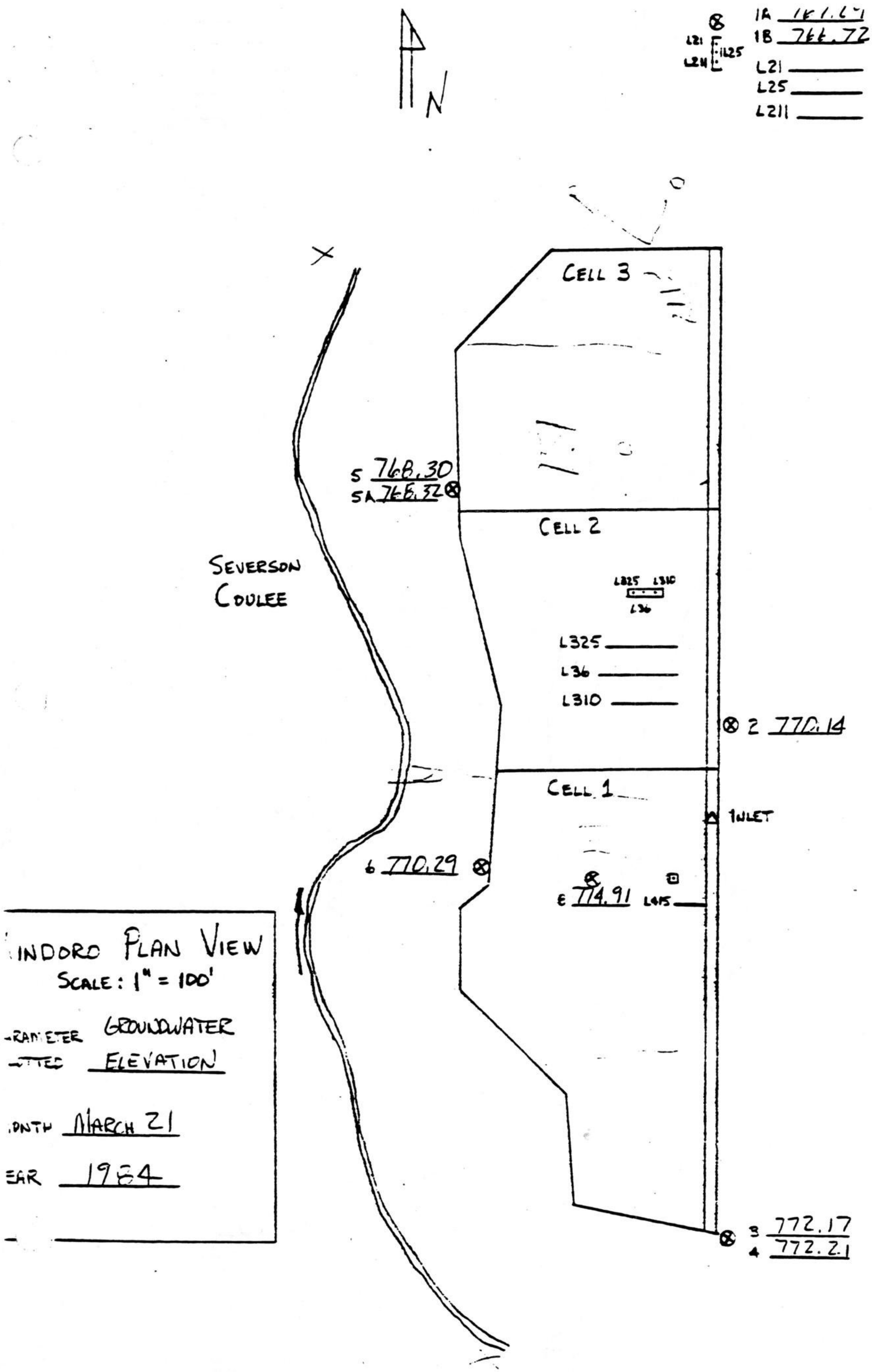

N
1A
1B (767.00)
L21
L24
L125
L21
L25
L211
CELL 3
5 769.10
5A (768.44)
CELL 2
SEVERSON COULEE
L325 L310
L36
L325
L36
L310
2 772.85
CELL 1
INLET
6 770.41
8 773.99
L45
3 772.31
4 (772.30)
INDORO PLAN VIEW
SCALE: 1" = 100'
RAMETER GROUND WATER
OTTED ELEVATIONS
ONTH NOVEMBER 29
EAR 1983



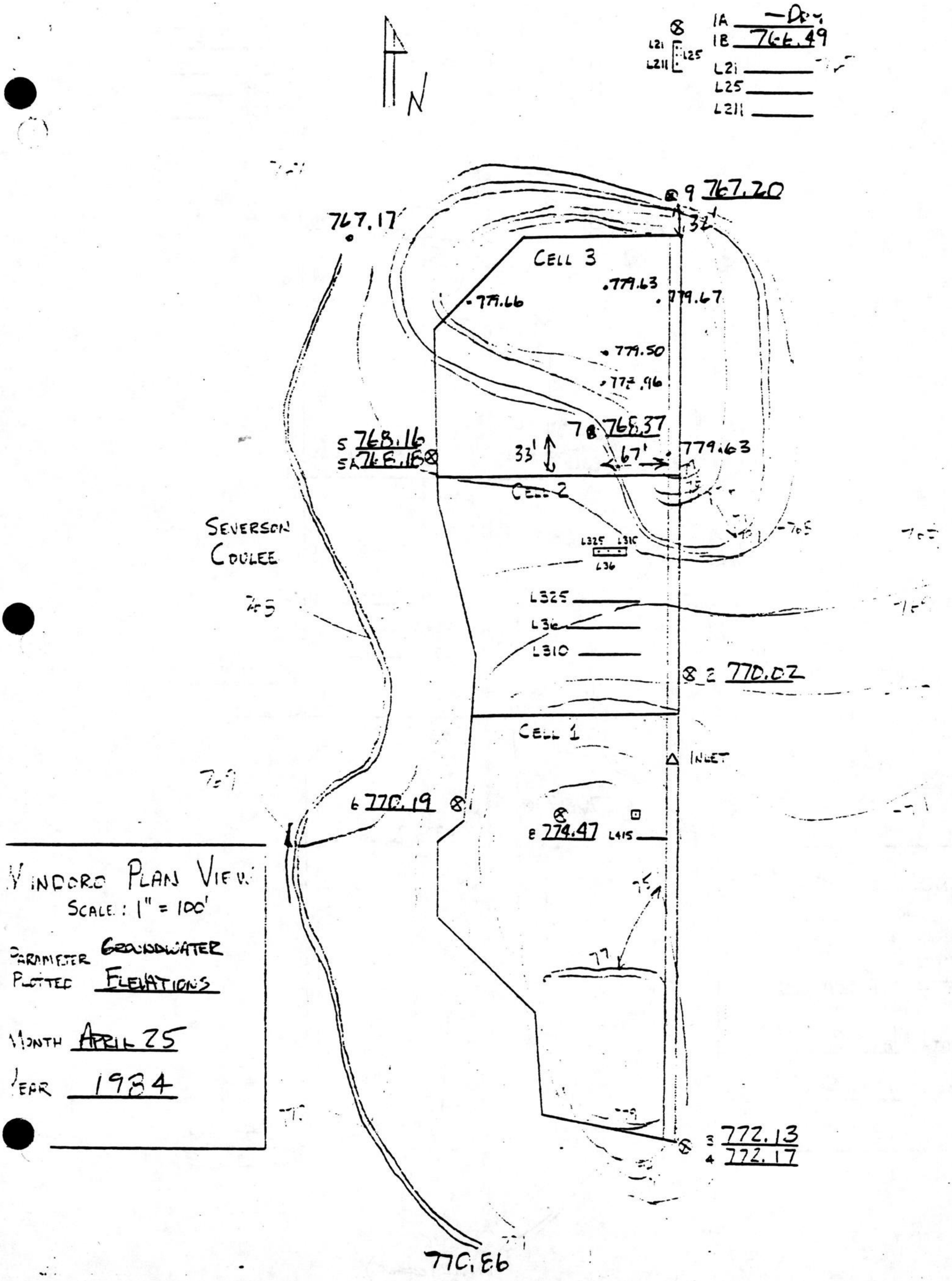
N
1A
1B (766.34)
L21
L25
L211
CELL 3
5 768.10
5A (768.06)
CELL 2
SEVERSON
COULEE
L325
L36
L310
L325
L36
L310
2 770.29
CELL 1
INLET
6 770.07
8 773.89
L615
3 771.95
4 (771.99)
INDORO PLAN VIEW
SCALE: 1" = 100'
-RAMETER GROUND WATER
-OTTED ELEVATION
-ONTH DECEMBER 21
-EAR 1983

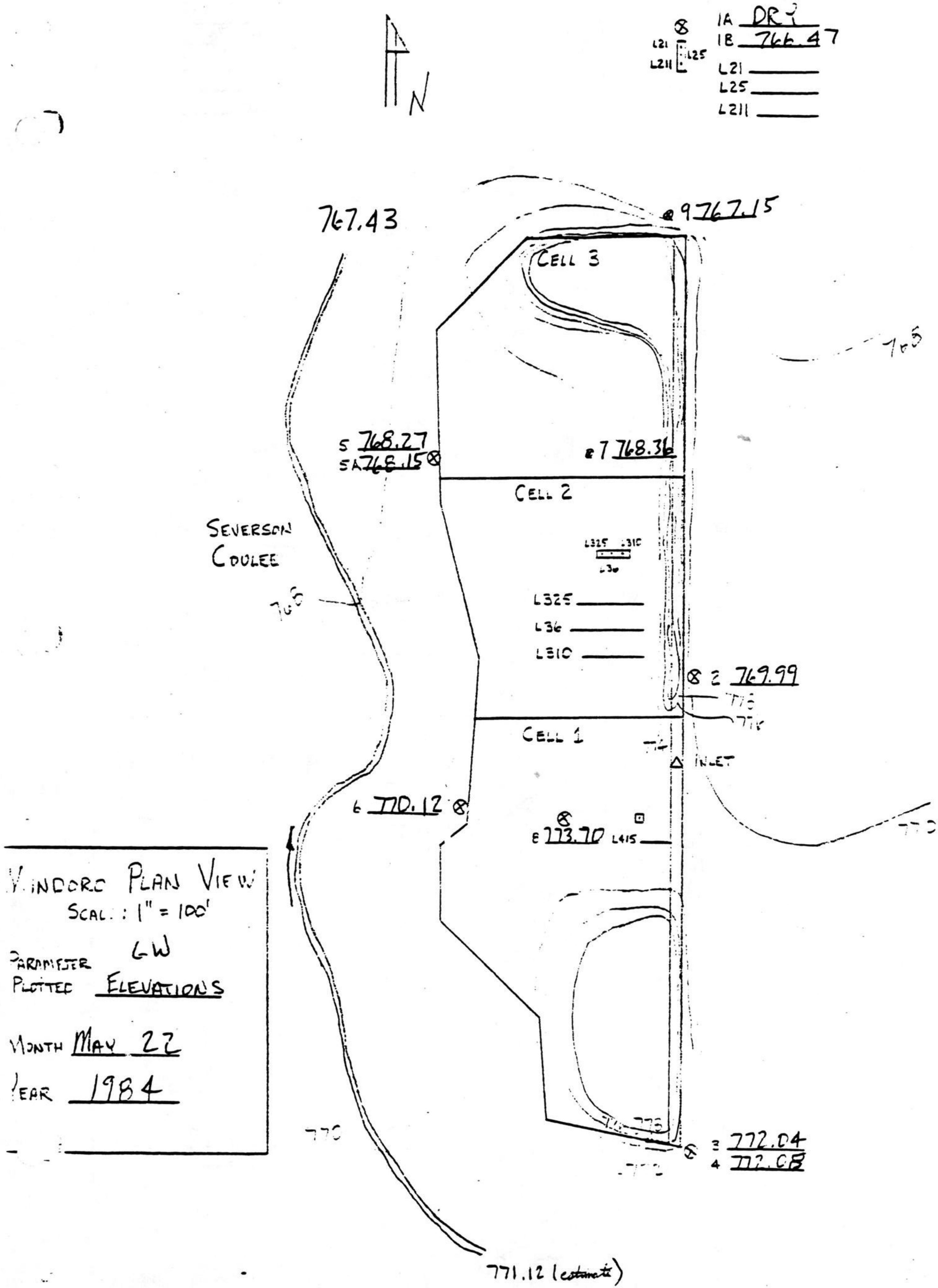

N
1A
1B (766.06)
L21
L25
L211
CELL 3
5 767.86
5A 767.90
CELL 2
SEVERSON COULEE
L325 L310
L36
L325
L36
L310
2 769.76
CELL 1
INLET
6 769.97
E 773.86
L415
3 771.86
4 (771.90)
INDORO PLAN VIEW
SCALE: 1" = 100'
RAMETER GROUND WATER
LOTTED ELEVATIONS
IONTH JANUARY 10
EAR 1984

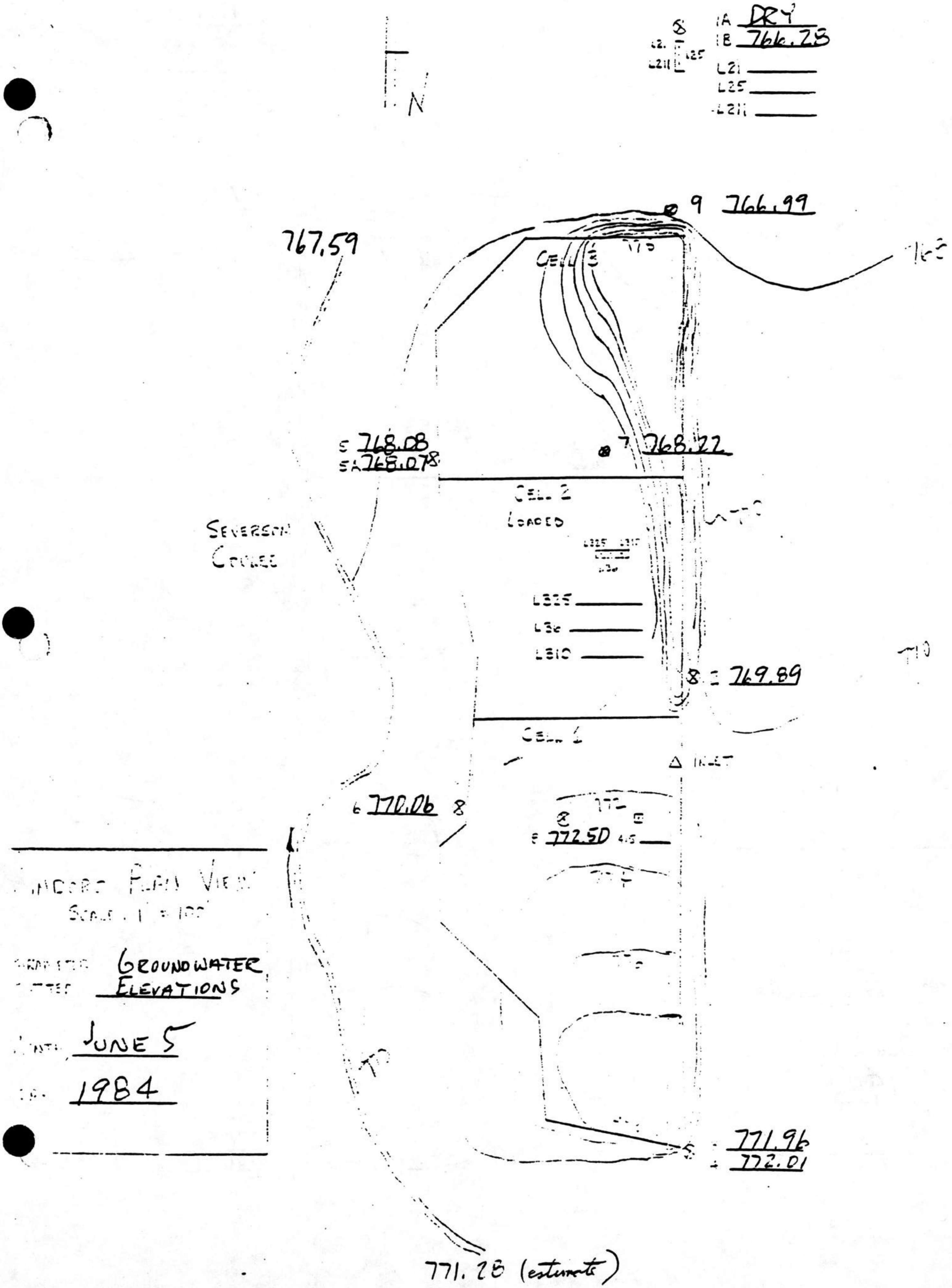

N
1A
1B (767.51)
L21
L25
L211
CELL 3
5 769.01
5A 769.24
CELL 2
SEVERSON COULEE
L325 L310
L36
L325
L36
L310
2 771.13
CELL 1
INLET
6 770.95
F 775.11
L415
INDORO PLAN VIEW
SCALE: 1" = 100'
RAMETER GROUND WATER
OTTED ELEVATION
ONTH FEBRUARY 18
EAR 1984
3 772.95
4 (772.43)



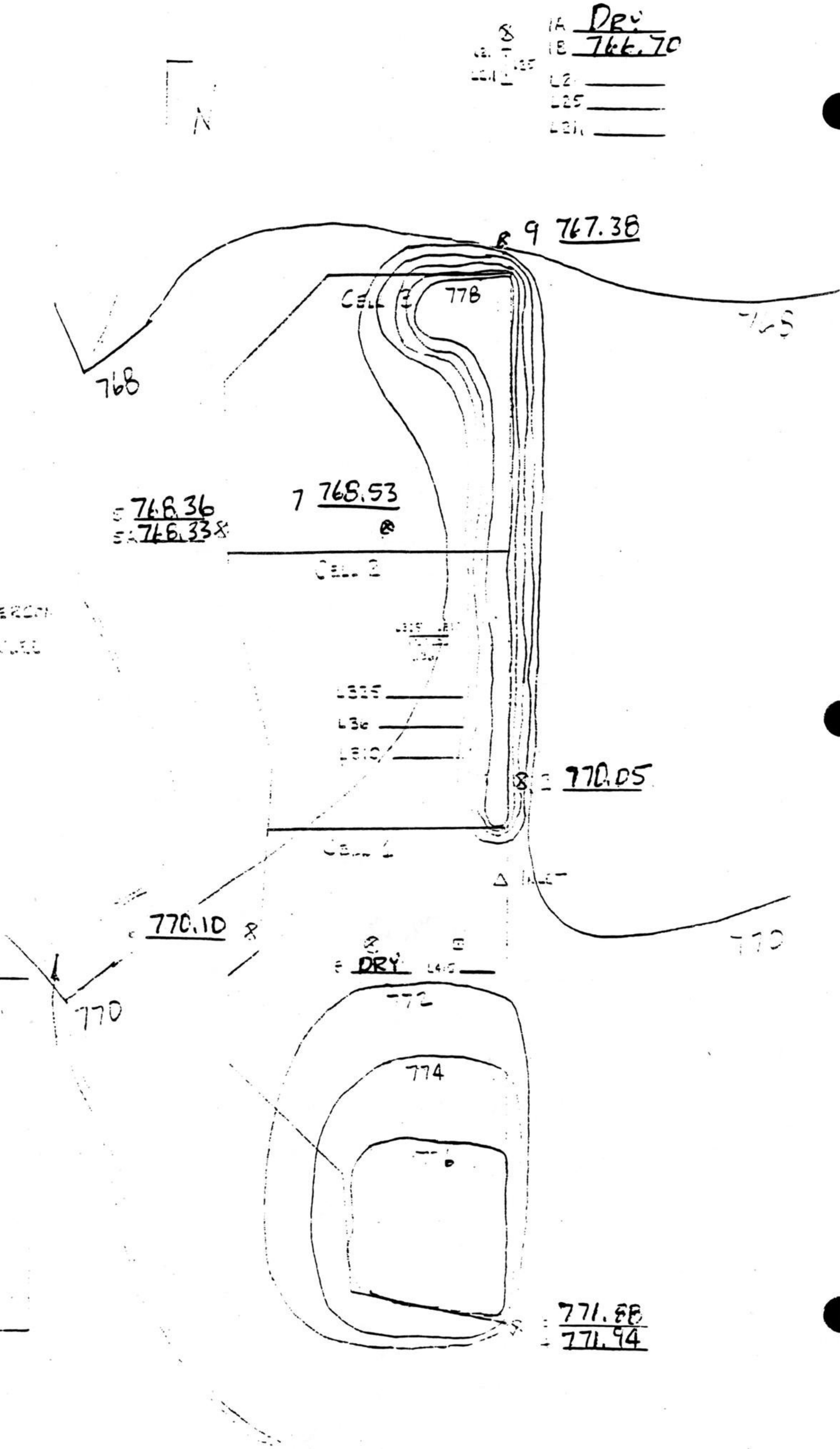
N
1B 766.72
L21
L24
L25
L21
L25
L211
CELL 3
5 768.30
5A 768.32
CELL 2
SEVERSON
COULEE
L325 L310
L36
L325
L36
L310
2 770.14
CELL 1
INLET
6 770.29
E 774.91
L415
3 772.17
4 772.21
INDORO PLAN VIEW
SCALE: 1" = 100'
RAMETER GROUNDWATER
TTED ELEVATION
ONTH MARCH 21
EAR 1984


N
1A — Dry
1B 766.49
L21
L25
L211
9 767.20
32'
767.17
CELL 3
.779.63
.779.67
.779.66
.779.50
.779.96
7 768.37
5 768.16
5A 768.16
33'
67'
.779.63
CELL 2
SEVERSON
COULEE
L325 L310
L36
L325
L36
L310
2 770.02
CELL 1
INLET
6 770.19
8 774.47
L415
3 772.13
4 772.17
770.86
WINDORO PLAN VIEW
SCALE: 1" = 100'
PARAMETER PLOTTED GROUNDWATER ELEVATIONS
MONTH APRIL 25
YEAR 1984


1A DRY
1B 766.47
L21
L25
L211
L21
L25
L211
N
767.43
9 767.15
CELL 3
765
5 768.27
5A 768.15
7 768.36
CELL 2
SEVERSON
COULEE
L325 L310
L36
L325
L36
L310
765
2 769.99
775
770
CELL 1
INLET
6 770.12
8 773.70 L415
770
V.INDORF PLAN VIEW
SCALE: 1" = 100'
PARAMETER GW
PLOTTED ELEVATIONS
MONTH MAY 22
YEAR 1984
770
3 772.04
4 772.08
771.12 (estimate)

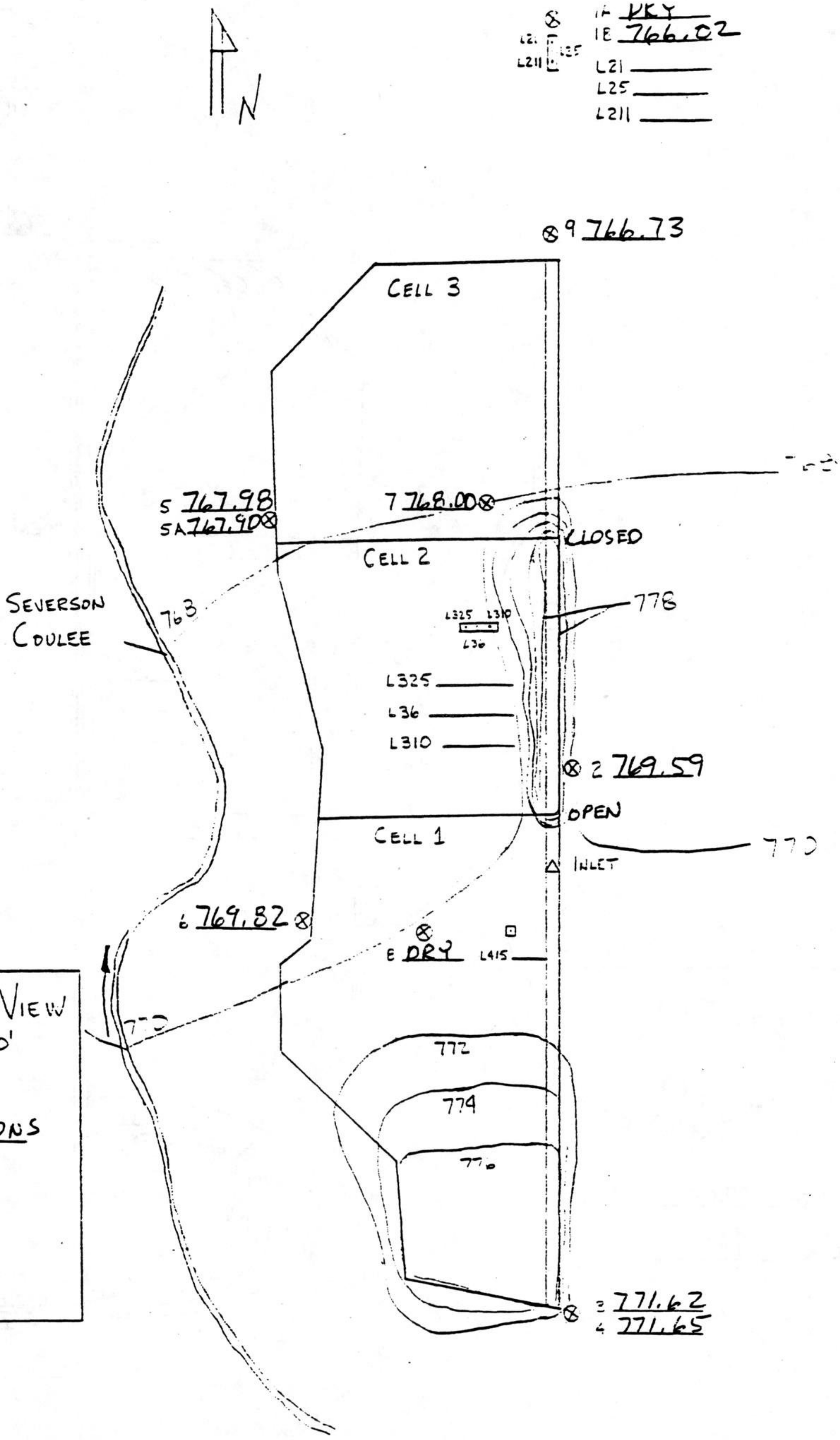


N
1A DRY?
1B 766.28
L21
L25
L211
9 766.99
767.59
CELL 3
5 768.08
5A 768.078
7 768.22
CELL 2
LOADED
SEVERSON
COULEE
L325
L36
L310
8 769.89
CELL 1
INLET
6 770.06
772.50
PLAN VIEW
GROUNDWATER
ELEVATIONS
JUNE 5
1984
771.96
772.01
771.28 (estimate)



LW
ELEVATIONS

July 11
1984

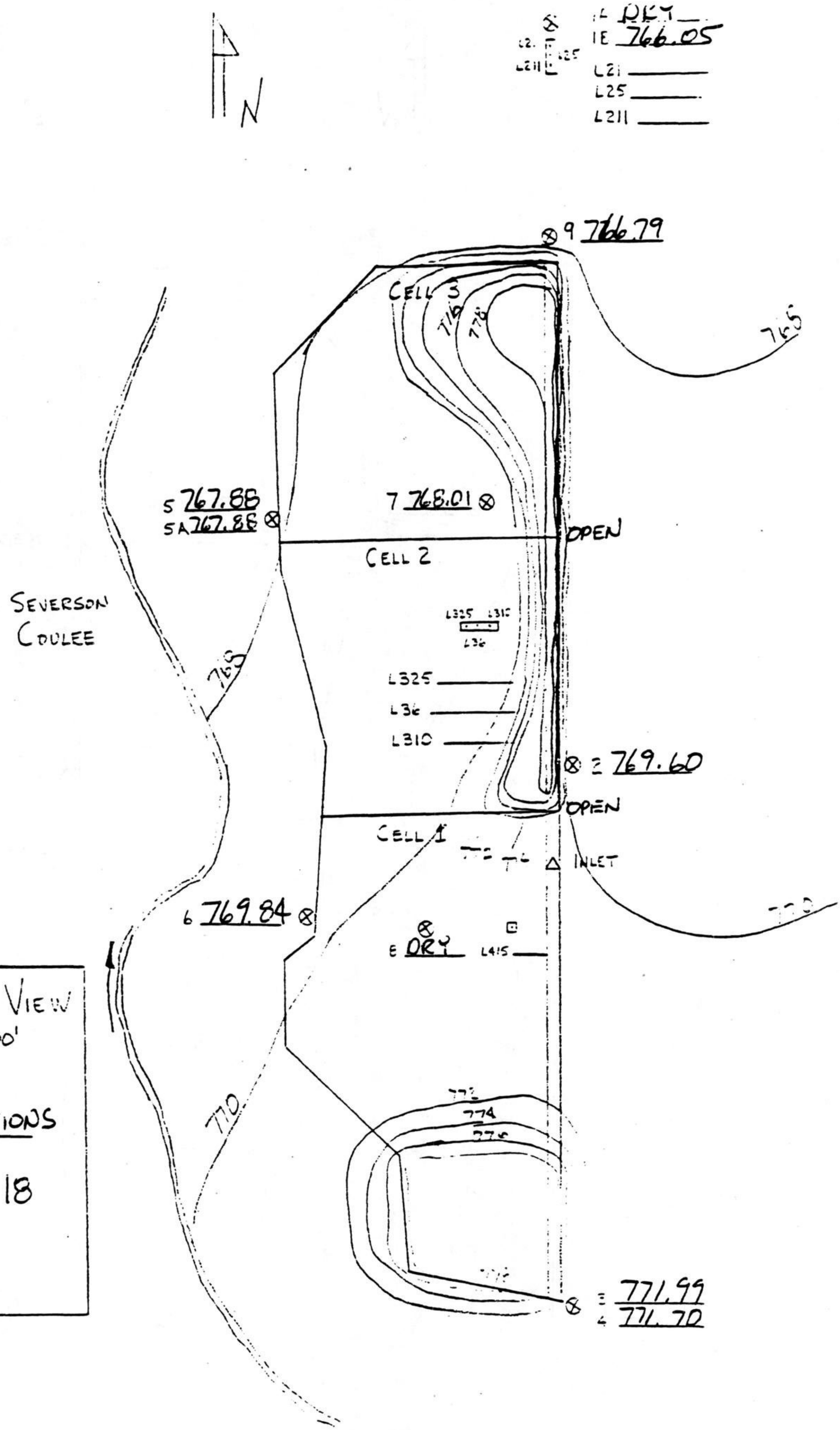


MINDORO PLAN VIEW
SCALE: 1" = 100'

PARAMETER PLOTTED: GW ELEVATIONS

MONTH: AUGUST 28

YEAR: 1984

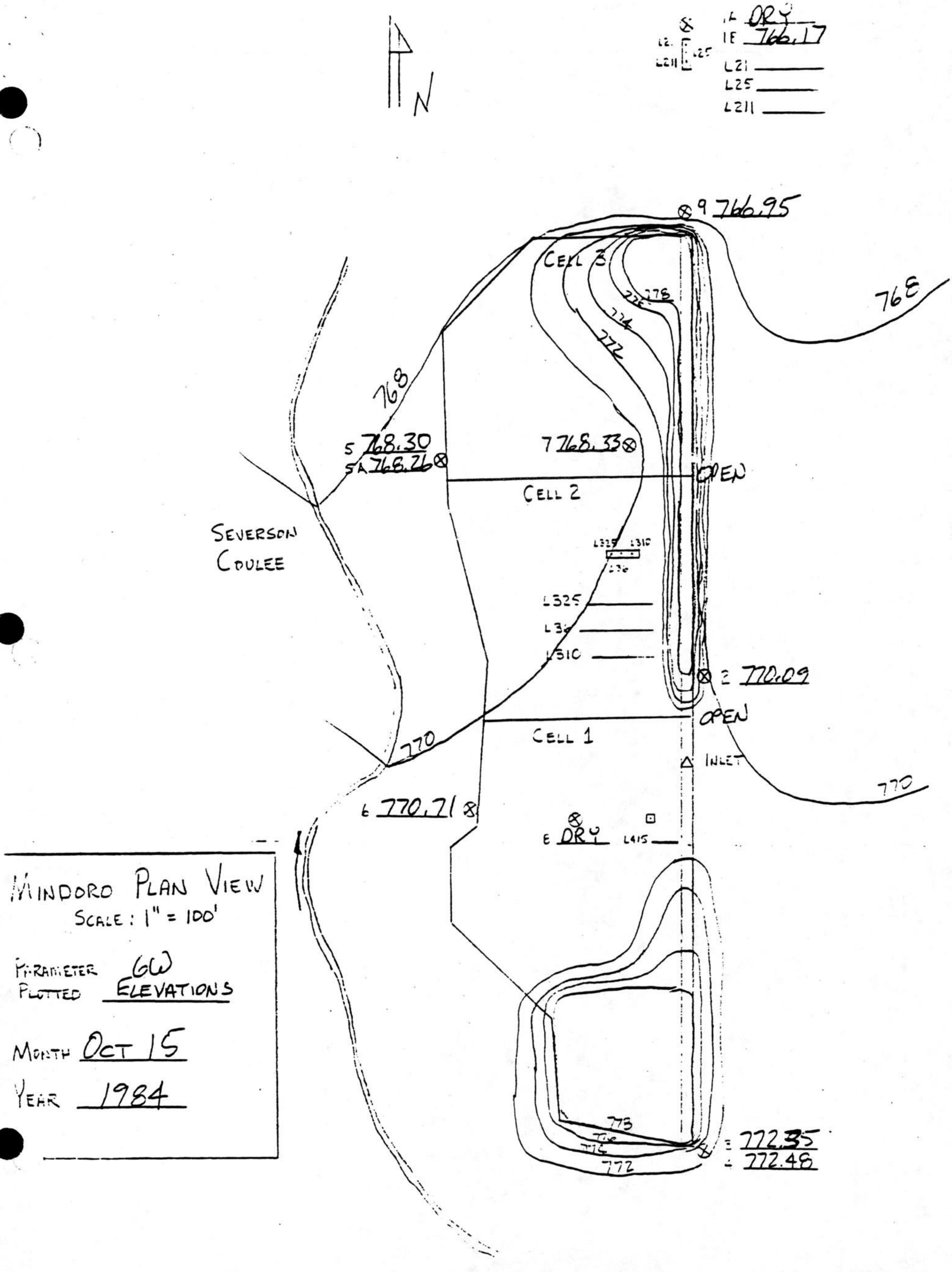


MINDORO PLAN VIEW
SCALE: 1" = 100'

PARAMETER PLOTTED: GW ELEVATIONS

MONTH: SEPTEMBER 18

YEAR: 1984



N
DRY
766.17
L21
L25
L211
9 766.95
CELL 3
778
776
774
772
768
768
5 768.30
5A 768.26
7 768.33
OPEN
CELL 2
SEVERSON
COULEE
L325
L310
L36
L325
L310
770.09
OPEN
CELL 1
770
INLET
770
6 770.71
E DRY
L415
773
774
772
772.35
772.48
MINDORO PLAN VIEW
SCALE: 1" = 100'
PARAMETER PLOTTED GW ELEVATIONS
MONTH Oct 15
YEAR 1984

SLUG TEST
RESULTS

TESTS | SITE: MINDORO | WELL: 2

INITIAL DEPTH TO GW: 13.48 (H_o)

Round 2

TRIAL 1

t (sec)	DEPTH (t)	H (t)	H/H_0
0		H_0=12.17	1.00
~~0~~1		11.75	0.96
5		11.50	0.94
9		11.25	0.92
15		10.92	0.90
21		10.50	0.86
31		10.00	0.82
36		9.75	0.80
40		9.50	0.78
45		9.25	0.76
50		9.00	0.74
57		8.75	0.72
62		8.50	0.70
68		8.25	0.68
75		8.00	0.66
80		7.75	0.64
9[illegible]		7.42	0.61
98		7.08	0.58
106		6.75	0.55
112		6.50	0.53
120		6.25	0.51
129		6.00	0.49
136		5.75	0.47
142		5.50	0.45
154		5.25	0.43
161		5.00	0.41
169		4.75	0.39

TRIAL ~~2~~ 1 cont.

t	D(t).	H(t)	H/H_0
188		4.50	0.37
201		4.25	0.35
212		4.00	0.33
225		3.75	0.31
241		3.50	0.29
254		3.25	0.27
273		3.00	0.25
290		2.75	0.22
308		2.50	0.20
327		2.25	0.18
360		2.00	0.16
376		1.75	0.14
425		1.50	0.12
466		1.25	0.10
504		1.00	0.08
556		0.83	0.07
642		0.50	0.04
981		0.25	0.02
1220		0.08	0.01
1356		0.04	0.00

TESTS | SITE: MINDORO | WELL: 2

INITIAL DEPTH TO GW: ~~14.68~~ 13.48 (H_0)

TRIAL 1 t (sec)	Depth (t)	H(t)	H/H_0	TRIAL 2 t	D(t).	H(t)	H/H_0
-1	13.48	0	0	182		4.25	0.39
0	2.65	H_0= 10.83	1.00	189		4.08	0.38
14	3.40	10.08	0.93	197		3.92	0.36
18		9.83	0.91	205		3.75	0.35
22		9.58	0.88	215		3.58	0.33
27		9.25	0.85	224		3.42	0.32
32		9.00	0.83	230		3.25	0.30
37		8.75	0.81	245		3.17	0.29
42		8.50	0.78	251		3.08	0.28
45		8.25	0.76	255		3.00	0.28
65		7.58	0.70	260		2.92	0.27
75		7.25	0.67	263		2.83	0.26
85		6.92	0.64	268		2.75	0.25
92		6.58	0.61	273		2.67	0.25
95		6.42	0.59	280		2.58	0.24
118		5.75	0.53	315		2.25	0.21
126		5.50	0.51	338		2.00	0.18
131		5.33	0.49	366		1.75	0.16
136		5.25	0.48	398		1.50	0.14
140		5.17	0.48	454		1.25	0.12
145		5.00	0.46	502		1.00	0.09
153		4.75	0.44	582		0.75	0.07
162		4.67	0.43	646		0.50	0.05
168		4.50	0.42	750		0.42	0.04
176		4.33	0.40	870		0.29	0.03
				[illegible]		[illegible]	[illegible]

Tests | Site: Mindoro | Well: 1A

Initial Depth to GW: 14.50 (H_o)

Trial 1

t (sec)	Depth (t)	H(t)	H/H_0
-1	14.50	0	0
0	0.73	H_0 ← 13.77	1.00
10		13.60	0.99
21		13.44	0.98
31		13.27	0.96
46		13.02	0.94
64		12.77	0.93
77		12.52	0.91
98		12.27	0.89
123		12.02	0.87
146		11.77	0.85
162		11.52	0.84
184		11.27	0.82
216		11.02	0.80
235		10.77	0.78
258		10.52	0.76
295		10.27	0.74
321		10.02	0.73
367		9.69	0.70
384		9.52	0.69
431		9.27	0.67
475		9.02	0.66
524		8.73	0.63

Trial 1 cont.

t	D(t)	H(t)	H/H_0
553		8.52	0.62
604		8.27	0.60
663		8.02	0.58
719		7.77	0.56
790		7.52	0.55
851		7.27	0.53
941		7.02	0.51
1018		6.77	0.49
1136		6.52	0.47
1243		6.27	0.46
1379		6.02	0.44
1514		5.77	0.42
2024		5.06	0.37
2936		4.19	0.30
3358		4.10	0.30
			#2
1145		0.17	0.02
1256		0.08	0.01
1820		0.04	0.00

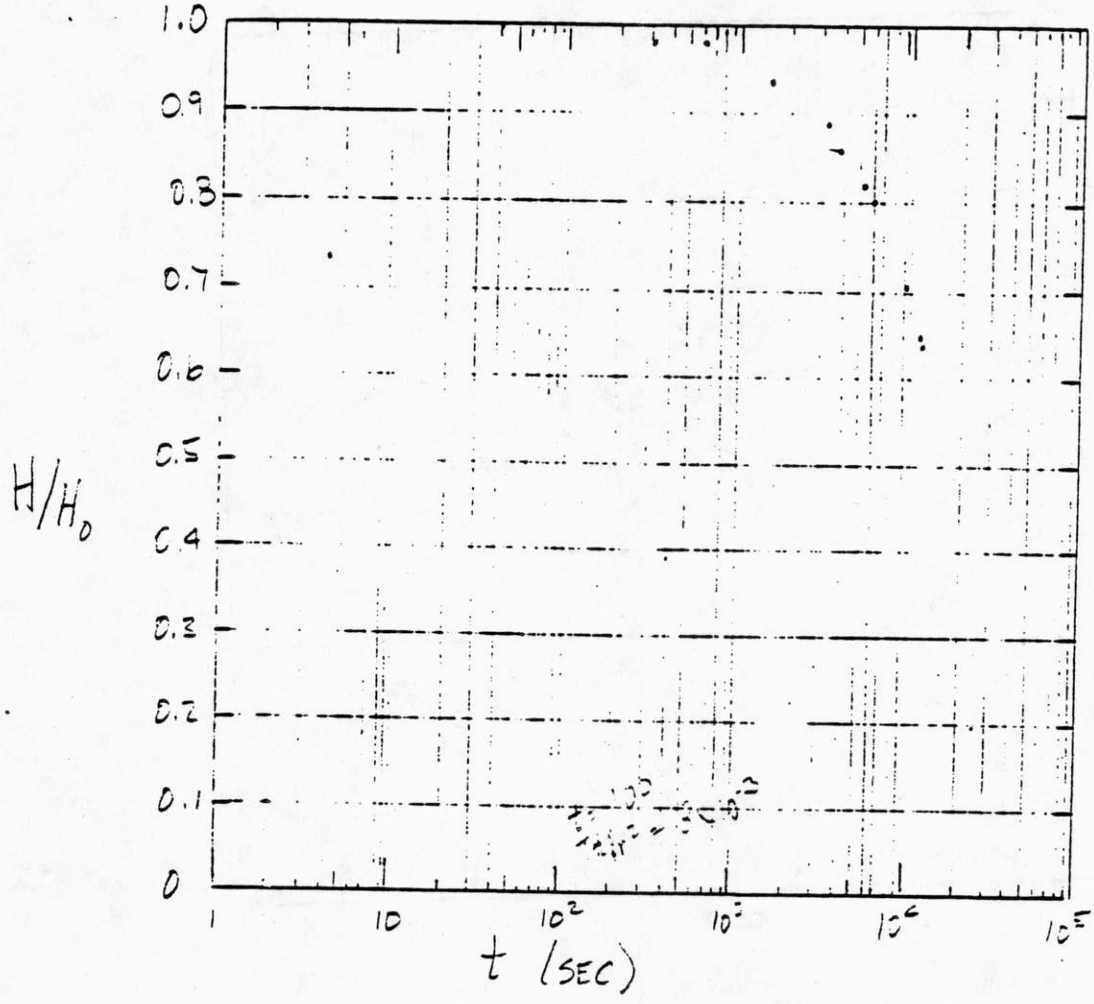
TESTS | SITE: MINDORO | WELL: 8

INITIAL DEPTH TO GW: 10.17

TRIAL 1				TRIAL 2			
t (sec)	DEPTH (t)	H(t)	H/H₀	t	D(t)	H(t)	H/H₀
0		H_0 = 10.04	1.00				
300		9.89	0.98				
600		9.80	0.98				
1680		9.40	0.94				
3210		8.90	0.89				
3869		8.68	0.86				
5400		8.23	0.82				
6060		8.04	0.80				
9540		7.15	0.71				
12,360		6.52	0.65				
12,780		6.44	0.64				

Slug Test Well 8

H/H_0 vs t



$\boxed{S = 10^{-4}}$

$Tt/r^2 = 8\times10^{-3}$

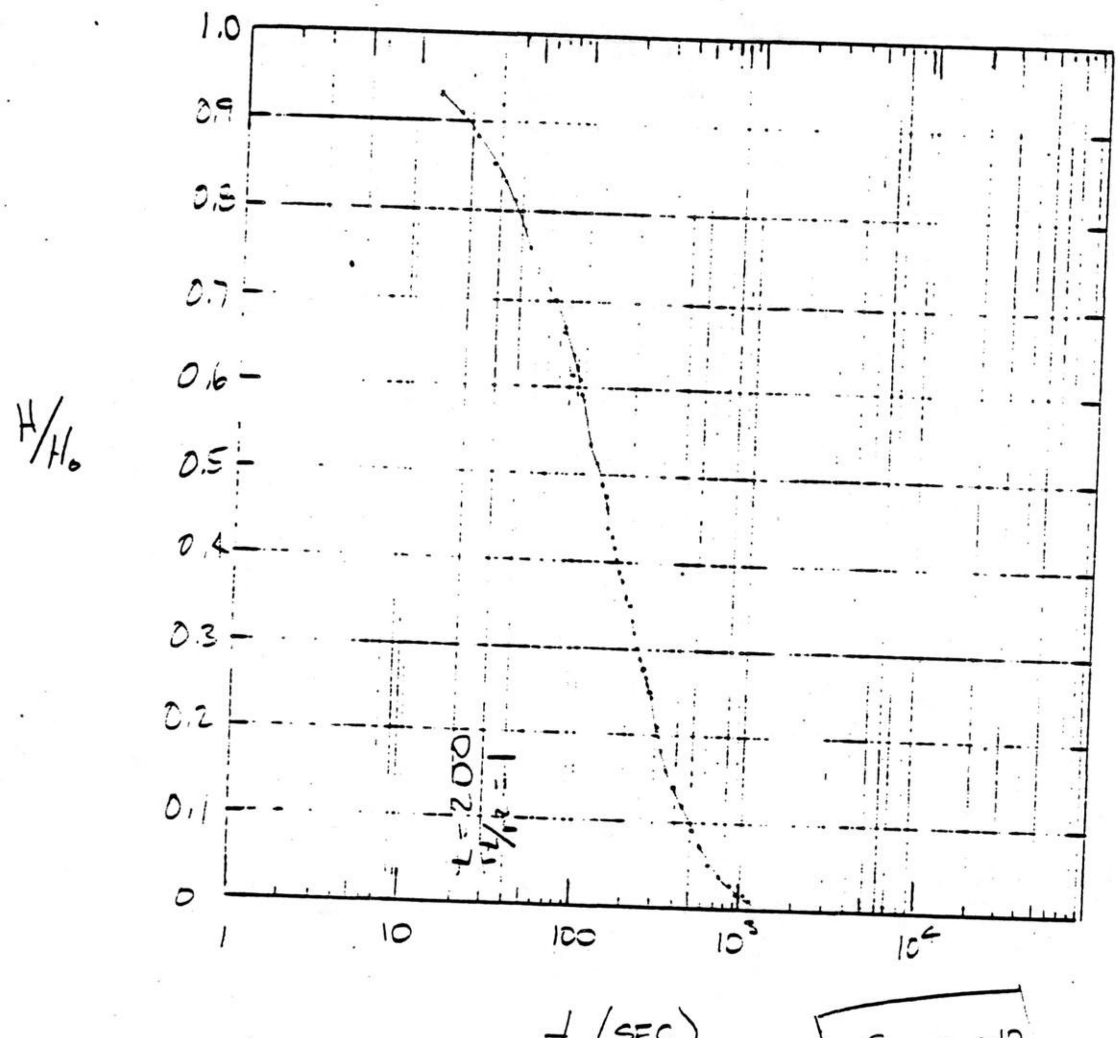
$$T = \frac{8\times10^{-3}\,(1/2)^2}{100} = 5.5\times10^{-7}\ \text{ft}^2/\text{s}$$

$$K = T/b = T/25 = 2.2\times10^{-7}\ \text{ft/s}$$

cm/s

Slug Test

H/H_0 vs t Well 2 Round 1



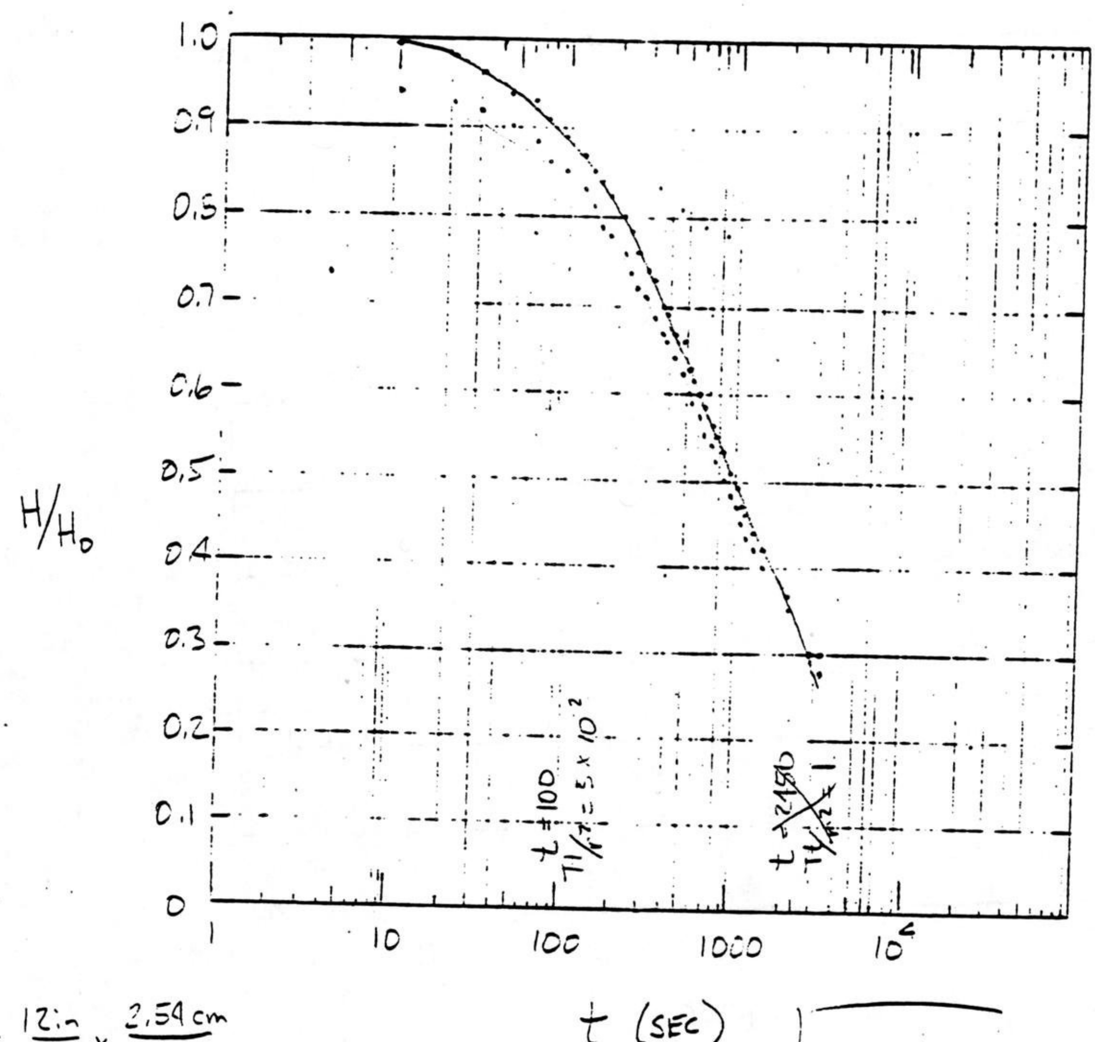
$\boxed{S = 10^{-10}}$

$Tt/r^2 = 1.0$

$$T = \frac{1.0\,(r^2)}{t} = \frac{1.0\,(1/12)^2}{200} = 3.472 \times 10^{-5}\ ft^2/s$$

$$\boxed{K = T/B = \frac{3.472 \times 10^{-5}}{5} = 6.94 \times 10^{-6}\ ft/s}$$

H/H_0 vs t Mindoro 1A



$\frac{ft}{s} \times \frac{12 in}{1 ft} \times \frac{2.54 cm}{in}$.

$\boxed{S = 10^{-1}}$

screen length 5'

$T = KB$

$Tt/r^2 = 5 \times 10^{-2}$

$$T = \frac{5 \times 10^{-2} (r_c^2)}{t} = \frac{5 \times 10^{-2} (1/12)^2}{100} = 3.472 \times 10^{-6} \ ft^2/s$$

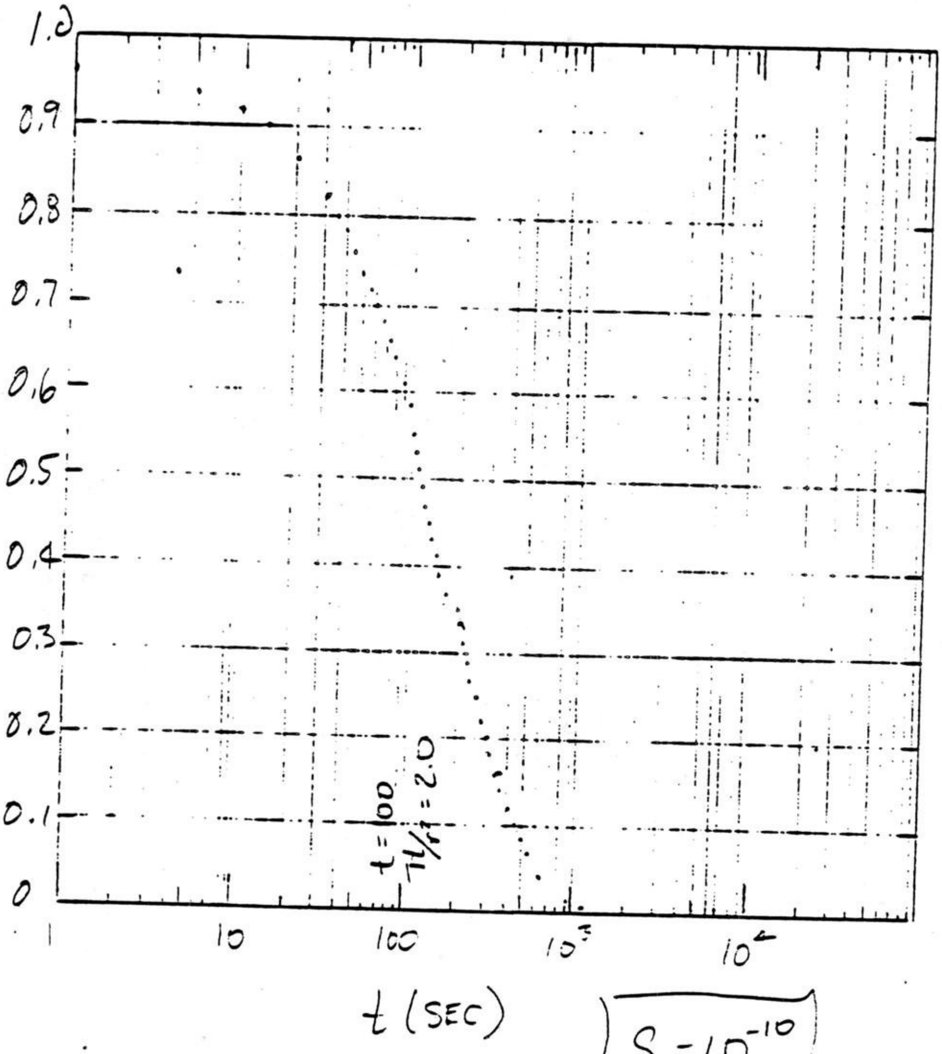
$$K = \frac{T}{B} = \frac{3.472 \times 10^{-6}}{5} = 6.944 \times 10^{-7} \ ft/s$$

$= 2.12 \times 10^{-5}$ cm/s

Slug Test

H/H_0 vs t Well 2

Round 2



$\boxed{S = 10^{-10}}$

$Tt/r^2 = 2.0$

$$T = \frac{2.0(1/12)^2}{100} = 1.3\overline{8} \times 10^{-4} \ ft^2/s$$

$K = T/B = 2.\overline{7} \times 10^{-5} \ ft/s$

$= 8.4\overline{6} \times 10^{-4} \ cm/s$

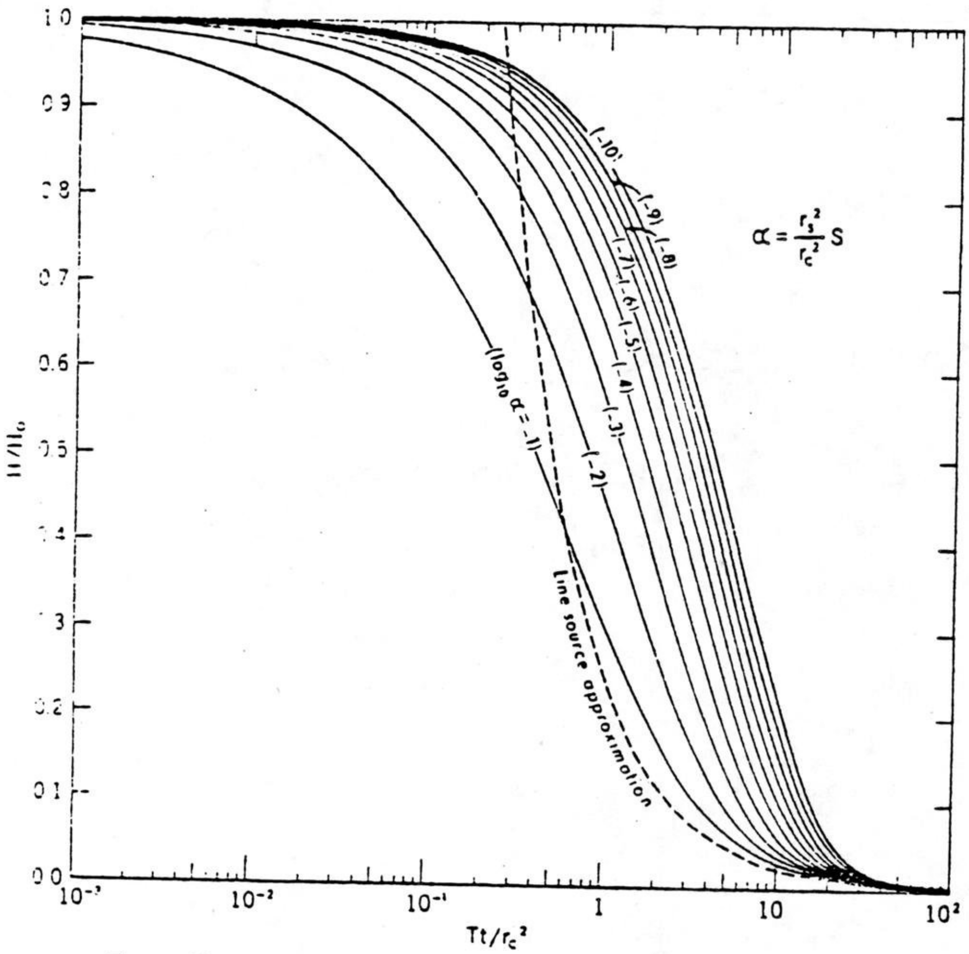


Fig. 1. Type curves for instantaneous change in a well of finite diameter.

mination of S by this method has questionable reliability'; reliability becomes even more questionable when α is smaller than 10^{-6} Of course, the similarity of the type curves in this range of α also affects the determinations of transmissivity. Even the most carefully and accurately collected test data could easily be matched with more than one of the type curves. The best one could expect is to be within one or two orders of magnitude of the actual α. An analysis in the range $\alpha < 10^{-6}$ indicates that, if the value of α for the chosen type curve is within two orders of magnitude of its actual value, the error in the determined T would be less than about 30%. This possible error should be kept in mind when one is making use of transmissivities determined by this method.

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Ferris, J. G., and D. B. Knowles, The slug test for estimating transmissibility, *U.S. Geol. Surv. Ground Water Note 26*, 1–7, 1954.

Ferris, J. G., D. B. Knowles, R. H. Brown, and R. W. Stallman, Theory of aquifer tests, *U.S. Geol. Surv. Water Supply Pap. 1536-E*, 104–105, 1962.

Kohlhaas, C. A., A method for analyzing pressures measured during drillstem-test flow periods, *J. Petrol. Technol.* *24*, 1278–1282, 1972.

(Received February 23, 1973.)

APPENDIX FF

MINDORO:

→ GROUNDWATER CHEMISTRY DATA

→ TABLE 5.6 SAMPLE CALCULATION

[illegible] [illegible] CHEMICAL
DATA SHEET PARAMETERS (mg/l) WELL 1A - SHALLOW, B6

DATE	DISSOLVED BOD_5	DISS COD	TDS	TKN	DISS NH_3-N	DISS NO_2-N + NO_3-N	Cl^-	pH (LAB)	OTHER
10/18/83	DRY →								
11/30/83	DRY →								
12/22/83	DRY →								
1/11/84	DRY →								
2/19/84	–	TOTAL 10	–	4.5	0.1	1.9	–	–	–
3/22/84	DRY →								
4/26/84	DRY →								
5/23/84	DRY →								
6/6/84	DRY →								
7/12/84	DRY →								
8/29/84	DRY →								
9/19/84	DRY →								
10/16/84	DRY →								

DATA SHEET CHEMICAL PARAMETERS (mg/l) WELL 1A - SHALLOW, B

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/18/83	DRY							
11/30/83	DRY							
12/22/83	DRY							
1/11/84	DRY							
2/19/84	–	–	–	–	–	–	–	–
3/22/84	DRY							
4/26/84	DRY							
5/23/84	DRY							
6/6/84	DRY							
7/12/84	DRY							

DATA SHEET PARAMETERS (mg/l) WELL 1B - DEEP, 3G

DATE	DISSOLVED BOD_5	DISS COD	+ TDS *	DISSOLVED TKN	DISSOLVED NH_3-N	DISSOLVED NO_2-N + NO_3-N + *	+ Cl^- *	pH (LAB)	OTHER
10/18/83	2.4	7	336	0.4	0.1	2.3	8.9	8.5	–
11/30/83	<6	<5	340	<0.2	<0.1	2.8	9.7	–	–
12/22/83	<3	SOLUBLE <5	340	<0.2	0.1	3.5	9.7	–	–
1/11/84	<3	<5	358	<0.2	<0.1	3.8	9.8		
2/19/84	<3	<5	366	<0.2	<0.1	3.5	8.9		
3/22/84	<3	<5	362	<0.2	0.1	3.2	8.3	(FIELD) 7.2	–
4/26/84	<3	<5	346	<0.2	0.1	3.1	9.4	7.5	pH LAB 8.2
5/23/84	–	–	–	–	–	–	–	–	–
6/6/84	–	–	–	–	–	–	–	–	–
7/12/84	–	–	–	–	–	–	–	–	–
8/29/84	<3	<5	352	0.2	0.1	4.3	9.7	7.4	

[illegible]

DATA SHEET PARAMETERS (mg/l) WELL 1B-DEEP, BG

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/18/83	254	0.06	43.	65	6	33	—	—
11/30/83	—	—	—	—	—	—	—	—
12/22/83	—	—	—	—	—	—	—	—
1/11/84	—	—	—	—	—	—	—	—
2/19/84	—	—	—	—	—	—	—	—
3/22/84	—	—	—	—	—	—	—	—
4/26/84	262	0.06	37	72	6	32	1	—
5/23/84	—	—	—	—	—	—	—	—
6/6/84	—	—	—	—	—	—	—	—
7/12/84	—	—	—	—	—	—	—	—
8/29/84	250	0.06	48	70	7	34	1	—

CHEMICAL

DATA SHEET PARAMETERS (mg/l) WELL 2 - SHALLOW

DATE	DISSOLVED BOD_5	DISS COD	TDS	DISS TKN	DISS NH_3-N	DISS NO_2-N + NO_3-N	Cl^-	pH (LAB)	OTHER
10/18/83	49	76	674	3.8	0.1	0.1	66.	8.4	–
11/30/83	7.4	22	588	0.6	0.1	<0.1	~~30~~ 70	–	–
12/22/83	–	LOW LEVEL 150 TOTAL	–	TOTAL 12.	0.4	0.1	–	–	–
1/11/84	–	TOTAL 96	–	TOTAL 6.5	0.6	0.1	–	–	–
2/19/84	<3	16	686	2.2	0.4	0.1	75	–	–
3/22/84	–	10	–	1.2	0.1	0.2	–	(FIELD) 7.3	–
4/26/84	<3	7	608	1.2	0.1	0.3	70	7.5	–
5/23/84	<3	12	608	1.5	0.1	<0.1	72	7.3	-
6/16/84	4.0	11	584	1.8	0.3	0.1	74	7.7	–
7/12/84	4.9	13	516	1.5	0.4	0.2	65	7.6	-
8/29/84	3.7	10	416	1.2	0.7	0.1	55	7.8	
9/19/84	<3	9	354	0.8	0.5	0.1	31	7.4	
10/16/84	10	17	336	1.0	0.4	0.1	20	7.3	
			42%	44.4%	~~[illegible]~~		73%		

MINDORO CUMMULATIVE DATA SHEET CHEMICAL PARAMETERS (mg/l) WELL 2 - SHALLOW

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/18/83	402	0.04	76.	87	110	32	—	—
11/30/83	—	—	—	—	—	—	—	—
12/22/83	—	—	—	—	—	—	—	—
1/11/84	—	—	—	—	—	—	—	—
2/19/84	—	—	—	—	—	—	—	—
3/22/84	—	—	—	—	—	—	—	—
4/26/84	415	0.02	120	—	—	—	—	—
5/23/84	—	—	—	—	—	—	—	—
6/6/84	—	—	—	—	—	—	—	—
7/12/84	—	—	—	—	—	—	—	—

Data Sheet Chemical Parameters (mg/l) Well 3 – Shallow

Date	Dissolved BOD_5	Diss COD	TDS	Diss TKN	Diss NH_3-N	Diss NO_2-N + NO_3-N	Cl^-	pH (lab)	Other
10/18/83	1.6	11	704	0.6	0.1	0.1	78.	8.1	—
11/30/83	<3	16	660	0.6	0.1	<0.1	80	—	—
12/22/83	<3	Soluble 9	730	0.4	0.1	<0.1	80	—	—
1/11/84	<3	Soluble 10	750	0.4	0.1	<0.1	76	—	—
2/19/84	<3	10	750	0.4	0.1	<0.1	75	-	-
3/22/84	<3	10	716	0.3	0.1	<0.1	75	(Field) 6.8	-
4/26/83	<3	7	700	0.6	0.1	0.1	72	7.1	Lab pH 7.9
5/23/84	<3	10	724	0.5	0.1	0.1	73	6.6	—
6/6/84	<3	10	714	0.6	0.1	0.1	76	6.9	-
7/12/84	<3	8	704	0.4	0.1	0.1	75	7.0	—
5/29/84	3.3	9	642	0.6	0.1	0.1	76	7.0	
9/19/84	<3	15	530	1.0	0.3	0.3	99	6.3	
10/16/84	4.3	17	620	0.3	0.1	0.1	67	7.1	

DATA SHEET — CHEMICAL PARAMETERS (mg/l) — WELL 3 - SHALLOW

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/18/83	430	0.02	48.	100	120	44.	—	—
11/30/83	—	—	—	—	—	—	—	—
12/22/83	—	—	—	—	—	—	—	—
1/11/84	—	—	—	—	—	—	—	—
2/19/84	—	—	—	—	—	—	—	—
3/22/84	—	—	—	—	—	—	—	—
4/26/84	473	<0.02	62	100	110	3.5	1	—
5/23/84	—	—	—	—	—	—	—	—
6/6/84	—	—	—	—	—	—	—	—
7/12/84	—	—	—	—	—	—	—	—
8/29/84	472	0.02	63	95	120	38	1	

DATA SHEET — CHEMICAL PARAMETERS (mg/l) — WELL 4 - DEEP

DATE	DISSOLVED BOD_5	COD	TDS	DISS TKN	DISS NH_3-N	DISS NO_2-N + NO_3-N	Cl^-	pH (LAB)	OTHER
10/18/83	3.1	<5	270	0.4	<0.1	0.3	2.6	8.5	—
11/30/83	<3	<5	273	<0.2	<0.1	0.1	2.0	—	—
12/22/83	<3	SOLUBLE <5	276	<0.2	<0.1	0.2	2.1	—	—
1/11/84	<3	<5	284	<0.2	<0.1	0.2	1.9		
2/19/84	<3	<5	272	<0.2	<0.1	0.3	2.0	—	—
3/22/84	<3	<5	276	<0.2	0.1	0.4	2.1	(FIELD) 7.2	—
4/26/84	<3	<5	280	<0.2	0.1	0.3	2.1	7.5	pH LAB 8.2
5/23/84	<3	<5	284	0.2	0.1	0.3	2.4	7.0	
6/6/84	<3	<5	282	0.2	<0.1	0.3	2.2	7.3	
7/12/84	<3	<5	278	0.1	<0.1	0.2	2.0	7.5	
8/29/84	<4	<5	270	0.2	<0.1	0.1	2.1	7.5	
9/19/84	<3	<5	286	0.2	<0.1	0.2	2.0	7.1	
10/16/84	<3	5	274	0.1	0.1	0.3	2.0	7.4	

MINDOKO COMMUNITY ... CHEMICAL
DATA SHEET PARAMETERS (mg/l) WELL 4 - DEEP

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/18/83	240	0.06	21.	55	3	28	—	—
11/30/83	—	—	—	—	—	—	—	—
12/22/83	—	—	—	—	—	—	—	—
1/11/84	—	—	—	—	—	—	—	—
2/19/84	—	—	—	—	—	—	—	—
3/22/84	—	—	—	—	—	—	—	—
4/26/84	242	0.06	22	55	2	28	1	—
5/23/84	—	—	—	—	—	—	—	—
6/6/84	—	—	—	—	—	—	—	—
7/12/84	—	—	—	—	—	—	—	—
8/29/84	246	0.06	23	60	3	30	1	

[illegible] CHEMICAL

DATA SHEET PARAMETERS (mg/l) WELL 5 – SHALLOW

DATE	DISSOLVED BOD_5 X	DISS COD	TDS X	DISS TKN X	DISS NH_3-N X	DISS NO_2-N + NO_3-N	Cl^- X	pH (LAB)	OTHER
10/18/83	3.1	—	664	5.2	4.0	<0.1	89.	8.4	—
11/30/83	12	30	608	2.4	0.2	<0.1	92	-	—
12/22/83	15	SOLUBLE 28	708	3.3	2.3	<0.1	87	—	—
1/11/84	12	36	726	4.4	3.7	<0.1	91	—	—
2/19/84	3.7	25	716	4.4	3.8	<0.1	90	—	—
3/22/84	<3	25	722	4.9	3.3	<0.1	94	(FIELD) 6.7	—
4/26/84	<3	22	694	4.2	3.5	0.1	88	6.9	pH LAB 7.4
5/23/84	12	33	762	3.4	2.3	0.1	95	6.6	—
6/6/84	32	59	704	3.6	2.7	0.1	92	6.8	—
7/12/84	13	30	764	4.6	3.5	0.1	89	6.8	—
8/29/84	<12	27	734	3.9	3.1	0.1	92	6.8	—
9/19/84	<12	23	750	3.3	2.9	<0.1	91	6.5	
10/16/84	9	31	736	4.0	3.2	<0.1	93	6.6	

DATA SHEET — CHEMICAL PARAMETERS (mg/l) — WELL 5 - SHALLOW

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/18/83	492	0.02	2.3	76	130	34	—	—
11/30/83	—	—	—	—	—	—	—	—
12/22/83	—	—	—	—	—	—	—	—
1/11/84	—	—	—	—	—	—	—	—
2/19/84	—	—	—	—	—	—	—	—
3/22/84	—	—	—	—	—	—	—	—
4/26/84	452	<0.02	30	77	110	32	2	—
5/22/84	—	—	—	—	—	—	—	—
6/6/84	—	—	—	—	—	—	—	—
7/12/84	—	—	—	—	—	—	—	—
8/29/84	532	<0.02	3.3	87	140	36	2	

…INDORO CUMULATIVE CHEMICAL DATA SHEET | PARAMETERS (mg/l) WELL 6 - SHALLOW

DATE	DISSOLVED BOD_5	DISSOLVED COD	TDS	DISSOLVED TKN	DISS. NH_3-N	DISS. NO_2-N + NO_3-N	Cl^-	pH (LAB)	OTHER
10/18/83	4.6	—	684	3.2	1.4	<0.1	51.	8.2	—
11/30/83	<6	34	750	3.2	2.2	<0.1	83	—	—
12/22/83	<3	SOLUBLE 29	724	1.8	1.1	<0.1	80	—	—
1/11/84	3.1	24	770	1.6	0.8	<0.1	83	—	-
2/19/84	<3	27	778	1.6	0.9	<0.1	79	—	—
3/22/84	<3	26	750	1.6	0.8	<0.1	78	(FIELD) 6.8	—
4/26/84	<3	23	716	2.4	0.5	<.1	72	7.0	LAB pH 7.4
5/23/84	<3	25	710	1.4	0.5	<0.1	77	6.6	—
6/6/84	3.1	23	720	1.4	0.8	<0.1	75	6.3	—
7/12/84	<6	22	736	1.4	0.9	0.1	73	7.0	—
8/29/84	<10	23	724	1.5	0.9	0.1	74	6.9	
9/19/84	<7	21	760	1.4	0.3	<0.1	75	6.3	
10/16/84	4.1	26	756	1.5	0.9	<0.1	75	6.9	

DATA SHEET — CHEMICAL PARAMETERS (mg/l) — WELL 6 - SHALLOW

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/18/83	456	2.3	49.	88	120	38	—	—
11/30/83	—	—	—	—	—	—	—	—
12/22/83	—	—	—	—	—	—	—	—
1/11/84	—	—	—	—	—	—	—	—
2/19/84	—	—	—	—	—	—	—	—
3/22/84	—	—	—	—	—	—	—	—
4/26/84	466	<0.02	56	89	110	36	1	—
5/23/84	—	—	—	—	—	—	—	—
6/6/84	—	—	—	—	—	—	—	—
7/12/84	—	—	—	—	—	—	—	—
8/29/84	476	<0.02	77	93	120	40	1	—

[illegible] Data Sheet — Chemical Parameters (mg/l) — Well 7 - Shallow, Cell 3

Date	Diss BOD_5	Diss COD	TDS	Diss TKN	Diss NH_3-N	Diss NO_3+NO_2	Cl^-	Field pH	Other
4/21/84	>23	40	735	2.5	6	0.1	79	7.0	Lab 7.5
5/23/84	4.6	16	820	2.8	2.3	<0.1	93	6.5	—
6/6/84	<3	12	680	3.0	2.4	<0.1	33	6.6	—
7/12/84	<6	14	764	3.0	2.3	<0.1	86	6.8	—
3/29/84	<6	14	574	2.0	1.7	0.1	77	6.5	
9/19/84	<4	11	605	1.8	1.4	<0.1	85	6.4	
10/16/84	6.5	23	644	2.2	1.6	<0.1	90	6.5	

[illegible] CUMULATIVE DATA SHEET

CHEMICAL PARAMETERS (mg/l)

WELL 7 - SHALLOW CELL 3

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
4/26/84	572	0.02	19	120	95	46	1	–
5/23/84	–	–	–	–	–	–	–	–
6/6/84	–	–	–	–	–	–	–	–
7/12/84	–	–	–	–	–	–	–	–
8/29/84	376	<0.02	32	82	73	35	<1	

Chemical

Data Sheet — Parameters (mg/l) — Well 8 - Shallow

Date	Dissolved BOD_5	Diss. COD	TDS x	Diss. TKN x	Diss. NH_3-N x	Diss. NO_3-N + NO_2-N	Cl^- x	pH (Lab)	Other
10/18/83	4.1	34	373	4.4	0.6	0.2	69.	8.2	—
11/30/83	<3	20	654	1.4	0.1	0.5	81	—	—
12/22/83	—	Low level 55	—	Total 3.3	0.2	<0.1	—	—	—
1/11/84	<3	Soluble 25	888	1.4	0.2	<0.1	82	—	—
2/19/84	<3	24	970	1.6	0.1	<0.1	84	—	—
3/22/84	<3	25	894	2.5	0.3	<0.1	89	(Field) 6.6	—
4/26/84	<3	26	336	3.2	0.3	0.1	94	7.0	—
5/23/84	<3	23	793	2.8	0.3	<0.1	90	6.7	—
6/6/84	Dry →								
7/12/84	Dry →								

DATA SHEET | PARAMETERS (mg/l) | WELL 8 - SHALLOW

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^+	Mg^{2+}	K^+	OTHER
10/18/83	130	0.04	62.	N.B.	N.B.	N.B.	N.B.	—
11/30/83	—	—	—	—	—	—	—	—
12/22/83	—	—	—	—	—	—	—	—
1/11/84	—	—	—	—	—	—	—	—
2/19/84	—	—	—	—	—	—	—	—
3/22/84	—	—	—	—	—	—	—	—
4/26/84	372	<0.02	130	—	—	—	—	—
5/23/84	—	—	—	—	—	—	—	—
6/6/84	DRY →							
7/12/84	DRY →							

[illegible] DATA SHEET CHEMICAL PARAMETERS (mg/l) WELL 9 - SHALLOW, N OF CELL 3

DATE	DISS BOD_5	DISS COD	TDS	DISS TKN	DISS NH_3-N	DISS NO_3+NO_2	Cl^-	FIELD pH	OTHER
4/26/84	>23	76	568	4.2	1.4	0.2	76	6.9	[illegible]
5/23/84	4.3	20	540	2.2	1.1	0.1	82	6.6	—
6/6/84	>22	93	456	2.4	1.1	0.1	85	6.7	—
7/12/84	38	46	680	2.2	1.7	0.1	92	6.8	—
8/29/84	<7	20	622	2.5	1.3	0.1	97	6.8	
9/19/84	4.5	26	696	2.7	1.9	0.1	110	6.6	
10/16/84	12	47	636	3.3	1.3	0.1	100	6.5	

[illegible] CUMULATIVE DATA SHEET — CHEMICAL PARAMETERS (mg/l) — WELL 9 - SHALLOW [illegible] CELL 3

DATE	ALKALINITY	TOTAL P	SO_4^{2-}	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	OTHER
4/26/84	368	0.02	5.2	—	—	—	—	—
5/23/84	—	—	—	—	—	—	—	—
6/6/84	—	—	—	—	—	—	—	—
7/12/84	—	—	—	—	—	—	—	—
8/29/84	—	—	—	—	—	—	—	—

MINDUCKS [illegible] CHEMICAL [illegible]

DATA SHEET (mg/l) DI WATER

DATE	DISS. BOD_5	SOLUBLE COD	Cl^-	DISS. NO_2-N + NO_3-N	DISS TKN	TDS	DISS. NH_3-N	OTHER
12/22/83	<3	<5	<0.3	<0.1	<0.2	10	<0.1	—
1/11/84	<3	<5	<0.3	<0.1	<0.2	12	<0.1	—

TABLE 5.6 CALCULATION

EXAMPLE - WELL 5

Cl^- CONCENTRATION = 91 mg/l

TOTAL N CONCENTRATION = 4.1 mg/l

[WASTEWATER HAD Cl^- = 100 mg/l
TOTAL N = 32.2 mg/l]

% REDUCTION (DILUTION) OF CHLORIDE AT WELL 5 (FROM WASTE) =

$$\frac{100-91}{100} \times 100 = 9\%$$

% REDUCTION ( ) TOTAL N AT WELL 5 (FROM WASTE) =

$$\frac{32.2-4.1}{32.2} = 87\%$$

ACTUAL % N LOSSES AT WELL 5 =

$$87 - 9 = \underline{78\%}$$

Appendix HH

Mindoro:

Furrow Wastewater and Lysimeter Chemical Data

... CUMULATIVE CHEMICAL PARAMETERS FURROW

DATA SHEET (mg/l) WASTEWATER - CELL 2

DATE	DISS BOD5	DISS COD	Cl⁻	pH	DISS NO_2+NO_3	DISS TKN	TDS	DISS NH_3-N	OTHER
7/12/84	220	320	99	6.6	<1.0	16	796	16	—
			FURROW WW - CELL 3						
10/16/84	(TOT) 94	160	76	6.6	0.1	14. DISS 17 TOT	—	12.	–
11/6/84			78		<1.0	22 TOT 16 DISS		15	
			HEADER WW - CELL 2						
10/16/84	(TOT) 1400	3600	82	6.0	0.1	21.0 108 TOT	—	11	—
11/6/84	—	—	120	6.2	0.1	63 TOT 38 DISS	—	—	—
			HEADER WW - CELL 3						
10/16/84	(TOT) 250	1200	82	6.4	0.4	17.0 DISS 59 TOT	—	14	—
11/6/84	—	—	81	—	<1.0	24 TOT 13 DISS	—	10	—

[illegible] CHEMICAL

DATA SHEET PARAMETERS (mg/l) LYSIMETER = 325 - CELL 2

	DATE	DISS COD	NO_2+NO_3 DISS	DISS TKN	DISS NH_3	DISS BOD5	Cl^-	pH	TDS
2.5 ~~X~~	5/23/84	94	9.1	3.5	~~1.4~~				
144	6/6/84	20	3.2	2.5	0.2	<3	55	6.4	612
1mo X	7/11/84	~~22~~	~~4.3~~	~~1.5~~	~~<0.1~~	—	73	—	—
6.5	7/12/~~84~~	22	1.6	2.3	0.1	—	—	6.8	—
23	8/29/84	15	0.7	0.6	0.1	<4	110	6.6	564
3wk ~~[illegible]~~	9/18/84	~~N9~~	~~0.6~~	~~0.6~~	~~<0.1~~	~~<4~~	100	—	IS
18	9/19/84	24	5.0	0.5	0.1	—	IS	6.7	—

[illegible] DATA SHEET | CHEMICAL PARAMETERS (mg/L) | LYSIMETER = 415. CELL [illegible]

	DATE	DISS BOD_5	DISS COD	Cl^-	pH	DISS NO_2+NO_3	DISS TKN	TDS	DISS NH_3-N	OTHER
1 mo	5/23/84	~~<3~~	~~10~~	82	~~5.8~~	~~6.0~~	~~2.3~~	522	~~0.1~~	—
14	6/6/84	<4	11	81	6.1	3.5	2.0	—	0.1	—
1 mo +	7/12/84	~~16~~	—	—	—	~~1.7~~	~~2.4~~	—	~~0.1~~	—
6.5	7/12/84	<3	9	73	6.3	3.5	2.2	460	0.1	—
1 mo	10/15/84	—	~~12~~	36	—	~~1.3~~	~~1.5~~	—	~~0.1~~	—
18	10/16/84	—	10	39.0	6.3	12.4	1.2	—	0.1	—
20	9/19/84	<4	12	35	6.3	0.5	1.9	IS	0.1	—
1 mo	11/5/84	—	—	39	—	~~1.5~~	~~1.6~~	—	~~<0.1~~	—
1 day	11/6/84	—	—	42	—	20	0.6	—	<0.1	—

APPENDIX II

MIDCRO:

CROP NITROGEN UPTAKE AND CALCULATIONS

SAUER

non-Ash

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

DATE OF ANALYSIS: 5/23/84

Grass

SAMPLE		% P	% K	% CA	% MG	% S	ppm ZN	ppm B	ppm MN	ppm FE	ppm CU	ppm AL	ppm NA
1	1A	0.180	0.154	0.417	0.099	0.163	45.71	6.421	165.1	815.3	5.778	856.8	< 68.2
2	1B	0.203	0.166	0.544	0.110	0.175	46.97	7.501	173.0	929.2	5.596	1032	< 64.6
3	2	0.149	0.335	0.300	0.077	0.153	22.22	5.303	34.83	280.2	4.390	299.7	< 61.7

% N (on dry weight basis)

1A	1.56
2	1.44

Ashed

1B	0.42
2	0.26

% N of Ash

1B	2.49
2	2.64

Weight of oven dried sample (grams)		% Ash
1A	87.3	17.1
1B	67.2	10.1
2	311.3	

1A, 1B → MINDORO

2 → BRODHEAD

APRIL SAMPLES OF GRASS

SAUER ASHED SAMPLES Ash

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

DATE OF ANALYSIS: 7/6/84

SAMPLE		P	K	CA	MG	S	ZN	B	MN	FE	CU	AL	NA
		%					PPM						
1	1B	0.187	0.149	0.495	0.096	0.071	38.51	5.330	157.6	638.2	4.711	662.2	< 61.3
2	2B	0.140	0.352	0.278	0.072	0.072	20.93	3.249	32.65	243.4	4.448	243.8	< 62.5

COOPERATIVE EXTENSION PROGRAMS
UWEX University of Wisconsin—Extension
University of Wisconsin—Madison
Soil & Plant Analysis Laboratory, 5711 Mineral Point Road, Madison, Wisconsin 53705; 608-262-4364

DEPARTMENT OF SOIL SCIENCE

INSTRUCTION EXTENSION RESEARCH
College of Agricultural and Life Sciences

September 14, 1984
Acct. 900
Lab No. S0035

July samples

MEMORANDUM

TO: Dave Sauer--DNR
101 S. Webster, Box 7921
Madison, WI 53707

FROM: Soil/Plant Analysis Lab

RE: Results of analyses on 4 canary (+grass) samples submitted July 24, 1984.

Sample Identification		Sample Weight grams	Ash %	Nitrogen of Tissue %	Nitrogen of Ash %
Mindoro	1	87	---	2.15	----
Brodhead	1	134	---	1.28	----
Mindoro	2	121	8.5	----	0.64
Brodhead	2	110	5.9	----	0.48

Additional analyses are attached.

If you have any questions concerning these analyses, please feel free to contact either Todd Kaehler or Ita Steingraeber at 262-4364.

Encl.

/ss

S35 DAVE SAUER DNR

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

DATE OF ANALYSIS: 9/14/84

SAMPLE	%					PPM						
	P	K	CA	MG	S	ZN	B	MN	FE	CU	AL	NA
1 MIN.1	0.255	2.443	0.314	0.216	0.252	12.73	5.361	43.93	60.01	3.843	< 36.7	< 63.8
2 BRO.1	0.229	1.632	0.235	0.128	0.144	12.43	3.736	54.69	42.23	3.828	< 35.8	294.7
3 MIN.2	0.327	2.632	0.298	0.214	0.249	16.72	4.708	88.24	56.14	4.626	< 36.4	< 63.3
4 BRO.2	0.306	1.953	0.300	0.180	0.182	20.50	4.709	40.22	62.70	3.724	< 36.2	296.0

DAVE SAUER (ASHED)

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

OF ANALYSIS: 9/14/84

	%					PPM						
E	P	K	CA	MG	S	ZN	B	MN	FE	CU	AL	NA
1IN.2	0.318	2.509	0.296	0.204	0.145	16.88	5.042	85.15	63.52	6.397	< 36.1	99.24
3RO.2	0.293	1.813	0.289	0.165	0.056	18.51	4.301	39.88	70.66	3.827	< 36.0	295.8

S235 DAVE SAUER
Dec Samples

DATE OF ANALYSIS: 12/28/84

UWEX SOIL AND PLANT ANALYSIS LAB
5711 MINERAL POINT ROAD
MADISON WI 53705

SAMPLE	%					PPM						
	P	K	CA	MG	S	ZN	B	MN	FE	CU	AL	NA
1 BROD.1	0.189	0.651	0.201	0.092	0.158	14.20	4.326	56.47	87.73	3.712	65.37	886.3
2 BROD.2	0.197	0.491	0.146	0.136	0.117	40.26	3.188	79.76	57.89	4.060	42.81	430.5
3 MIND.1	0.139	0.497	0.230	0.094	0.086	28.59	4.866	139.9	106.8	4.450	102.9	< 61.0
4 MIND.2	0.172	0.549	0.177	0.097	0.158	28.68	4.610	70.91	79.80	3.719	64.15	184.6
1 BROD.1 ash	0.183	0.603	0.194	0.088	0.065	11.36	3.085	48.61	82.87	3.032	68.71	992.6
2 BROD.2 ash	0.197	0.472	0.142	0.135	0.046	38.19	2.927	74.83	55.44	3.273	43.73	555.2
3 MIND.1 ash	0.135	0.431	0.225	0.089	0.048	28.92	3.336	128.6	103.0	4.723	126.2	< 59.3
4 MIND.2 ash	0.165	0.480	0.175	0.092	0.077	25.42	< 3.56	67.28	81.79	4.276	89.32	242.9

Sample Id.	Sample Wt. grams	%Ash	%N of Tissue
Brodhead Cell 1	54.5	3.9	1.59
Brodhead Cell 2	61.0	3.1	1.41
✓ Mindoro Cell 1	88.7	9.2	0.58
✓ Mindoro Cell 2	219.8	8.6	1.42

*Results for %N of Ash will follow in several days.

COOPERATIVE EXTENSION PROGRAMS
UWEX **University of Wisconsin—Extension**
University of Wisconsin—Madison

Soil & Plant Analysis Laboratory, 5711 Mineral Point Road, Madison, Wisconsin 53705, 608-262-4364

DEPARTMENT OF SOIL SCIENCE

January 7, 1985
Acct. No. 900
Lab Nos. S134; S235

MEMORANDUM

TO: Dave Sauer
Wis. Dept. of Natural Resources
Box 7921
Madison, WI 53707

FROM: Soil/Plant Analysis Lab

RE: Results of %N of Ash on 5 samples. All other analyses have been reported.

Sample Identification		%N of Ash
(S134) [illegible] samples		
BRODHEAD CELL 1	1	0.72
BRODHEAD CELL	2	0.50
(S235) [illegible] Samples		
BRODHEAD CELL	1	0.45
BRODHEAD CELL	2	0.49
MINDORO CELL	1	0.15
MINDORO CELL	2	0.47

If you have any questions concerning these analyses, please feel free to contact us.

The invoice for all of the tissue analyses is enclosed.

/ss

Encl.

APRIL 26, 1984

		Weight g
AREA OF SAMPLES ⇒	CELL 3 = 1' x 1' = 1 ft^2	87.3
	CELL 3 = 1' x 1' = 1 ft^2	67.2

AVERAGE WEIGHT OF GRASS SAMPLE $= \frac{87.3 + 67.2}{2} = 77.25 g$

SYSTEM AREA $=$ 3 ACRE $\times 43560 \frac{ft^2}{ACRE} = 130,680 \; ft^2$

TOTAL WEIGHT OF GRASS ON SITE =

$$\frac{77.25 g}{1 \; ft^2} \times 130,680 \; ft^2 \times \frac{1 \; lb}{453.8 g} = 22,255 \; lb$$

% N (DRY WEIGHT BASIS) = 1.56

AMOUNT OF N ON SITE PRIOR TO BURNING = 22,255 (0.0156)
= 347 lb

% ASH AFTER BURNING = 17.1

WEIGHT OF ASH ON SITE = 22,255 (0.171) = 3806 lb

% N OF ASH = 2.49

AMOUNT OF N ON SITE AFTER BURNING = 3806 (0.0249)
= 95 lbs

% N LOST BY BURNING =

$$\frac{347 - 95}{347} (100) = 72.6\%$$

JULY 12, 1984

		WEIGHT g
AREA OF SAMPLES $\rightarrow$	CELL 2 = $1' \times 1' = 1 ft^2$	87
	CELL 2 = $1' \times 1' = 1 ft^2$	121

AVERAGE WEIGHT OF GRASS SAMPLE $= \dfrac{87 + 121}{2} = 104 g$

TOTAL WEIGHT OF GRASS ON SITE $= \dfrac{104 g}{1 ft^2} \times 130{,}680\ ft^2 \times \dfrac{1\ lb}{453.8 g}$

$= 29{,}962\ lb$

% N (DRY WEIGHT BASIS) = 2.15

AMOUNT OF N ON SITE (PRIOR TO BURNING) = $29{,}962(0.0215) = 644\ lb$

% ASH AFTER BURNING = 8.5

WEIGHT OF ASH ON SITE = $29{,}962(0.085) = 2547\ lb$

% N OF ASH = 0.64

WEIGHT OF N ON SITE AFTER BURNING = $2547(0.0064)$

$= 16.3\ lb$

% N LOSS BY BURNING = 97.5%

$= \dfrac{644 - 16.3}{644}(100)$

NOVEMBER 6, 1984

AREA OF GRASS SAMPLES — CELL 2 = $1' \times 1' = 1 ft^2$ — WEIGHT g 88.7

CELL 2 = $1' \times 1' = 1 ft^2$ — 219.8

AVE. Wt. OF GRASS SAMPLE = $\frac{88.7 + 219.8}{2} = 154.2$

TOTAL Wt. OF SITE GRASS = $\frac{154.2\,(130{,}680)}{1\ \ (453.8)} = 44{,}439$ lb

% N (DRY Wt. BASIS) = $\frac{1.42 + 0.58}{2} = 1.0$

AMOUNT OF N ON SITE PRIOR TO BURNING = $44{,}439\,(0.01) = 444$ lb

% ASH AFTER BURNING = $\frac{9.2 + 8.6}{2} = 8.9$

Wt OF ASH ON SITE = $44{,}439\,(0.089) = 3955$ lb

% N OF ASH = $\frac{0.15 + 0.47}{2} = 0.31$

AMOUNT OF N ON SITE AFTER BURNING = $3955\,(0.0031) = 12.2$ lb

% N LOST BY BURNING = $\frac{444 - 12.2}{444}\,(100) = \underline{\underline{97.2\%}}$

APPENDIX JJ

MINDORO:

SEVERSON COULEE CREEK

CHEMISTRY DATA

[illegible] CHEMICAL PARAMETERS

DATA SHEET (mg/l) CREEK UPSTREAM

DATE	BOD_5	LOW LEVEL COD	Cl^-	DISSOLVED NO_2-N + NO_3-N	TKN	DISSOLVED NH_3-N	OTHER
11/30/83	<3	6	7.9	0.7	0.2	0.1	—
8/29/84	<3	6	6.9	0.8	0.2 DISS 0.2 TOT	0.1	ALK = 250 Ca^{++} = 53 Mg^{++} = 30 pH = 8.0 Na^+ = 4 $SO_4^=$ = 14 TOT P = 0.06 K^+ = 2

DATA SHEET (mg/l) CREEK MIDWAY

DATE	BOD$_5$	LOW LEVEL COD	Cl$^-$	DISSOLVED NO_2-N + NO_3-N	TKN	DISSOLVED NH_3-N	OTHER
11/30/83	< 3	< 5	8.6	0.8	0.2	0.1	—
8/29/84	< 3	< 5	6.9	0.8	0.2 DISS 0.2 TOT	0.1	ALK = 252 Ca^{++} = 59 Cl^- = 6.9 Mg^{++} = 30 pH = 8.0 Na^+ = 4 $SO_4^=$ = 14 TOT P = 0.06 K^+ = 2

ILLINOIS CUMULATIVE DATA SHEET — CHEMICAL PARAMETERS (mg/l) — CREEK DOWNSTREAM

DATE	BOD_5	LOW LEVEL COD	Cl^-	DISSOLVED NO_2-N NO_3-N	TKN	DISSOLVED NH_3-N	OTHER
11/30/83	<3	7	8.0	0.8	0.3	0.1	—
8/29/84	<3	7	7.2	0.8	0.3 DISS 0.4 TOT	0.1	ALK = 250 Ca^{++} = 58 pH = 8.0 Mg^{++} = 30 Na^+ = 4 $SO_4^=$ = 15 TOT P = 0.06 K^+ = 2
BELOW SEEP OF DRY WELL							
8/29/84	<3	8	7.2	0.8	0.2 DISS 0.2 TOT	0.1	ALK = 252 Ca^{++} = 59 pH = 7.9 Mg^{++} = 30 Na^+ = 4 $SO_4^=$ = 15 TOT P = 0.15 (DISS) = 0.17 (TOT) K^+ = 2

APPENDIX KK

MINDORO:

NITROGEN BUDGET CALCULATIONS

WASTEWATER ADDITION (APPLIED)

$$lb/yr = \frac{14{,}000 \ gal/day}{10^6} \times 32.4 \ \frac{mg\text{-}N}{l} \times 8.34 \times 365 \ \frac{DAY}{YR} =$$

$$= 1381 \ lb/yr$$

PLANT UPTAKE LOSS

252 lb/yr PER DISCUSSION IN CHAPTER 5
(OR 18% OF APPLIED-N)

LEACHING LOSS (BASED ON WELL 5 TOTAL-N CONCENTRATION AVERAGE)

$$lb/yr = \frac{14{,}000 \ g/day}{10^6} \times 4.1 \ mg\text{-}N/l \times 8.34 \times 365 \ \frac{DAY}{YR} = 175 \ lb/yr$$

(OR 13% OF APPLIED N)

DENITRIFICATION LOSS

$$lb/yr = 1381 - 252 - 175 = 954 \ lb/yr$$ (OR 69% OF APPLIED-N)