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NEW MEXICO WATER RESOURCES RESEARCH INSTITUTE
New Mexico State University
Box 30001, Dept. 3167
Las Cruces, New Mexico 88003-0001
Telephone (505) 646-4337 FAX (505) 646-6418

DEVELOPING CRITERIA FOR SMALL ON-SITE SEWAGE TREATMENT SYSTEMS: TWO CASE STUDIES

By

J. Phillip King
Principal Investigator
Assistant Professor
Department of Civil, Agricultural, and Geological Engineering
New Mexico State University

Hazem S. Fahmy
Graduate Research Assistant
Department of Civil, Agricultural, and Geological Engineering
New Mexico State University

A. W. Blair
Associate Professor
Department of Civil, Agricultural, and Geological Engineering
New Mexico State University

Ricardo Jacquez
Associate Professor
Department of Civil, Agricultural, and Geological Engineering
New Mexico State University

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TABLE OF CONTENTS

ABSTRACT

Two sites in Doña Ana County, the Lyons Country Estates Evapotranspiration (ET) bed and the Mesa Village sewage lagoons, were chosen as case study sites for evaluating the design criteria, operation, and impacts on groundwater of troubled on-site sewage systems.

The failure of the Lyons Country ET bed was due to inadequate design. Specifically, the bed was too small to accommodate the low winter ET rates. The bed saturated during the winter months, killing off the vegetation, thereby reducing the summertime ET. The system could not recover, and remained under ponded effluent for several months each year. This ponding presents an immediate public health risk. Soil samples from near the ET bed showed extremely elevated levels of Total Kjeldahl Nitrogen (TKN), indicating a risk of nitrate contamination of nearby groundwater. Monitoring wells installed around the perimeter of the ET bed showed little or no detectable nitrogen; the causes of the conflicting results are unclear. Tierra del Sol Housing Corporation has applied for a discharge permit to allow the release of the ponded effluent into the surrounding soil. They are also pursuing funding for the installation of a constructed wetlands.

The Mesa Village lagoon system was not built as designed. The four cells were not lined as required. However, the limited results of this study indicate that the groundwater beneath the system was not impaired. The regional groundwater is deep (100-150 m), and a near-surface layer of fine-textured soil induced a lateral flow. Increased vegetative growth in the area suggested plant uptake of water and nutrients was significant. Unfortunately, the investigators were unable to obtain sufficient geohydrological data to model the subsurface movement of water and nutrients as intended.

Keywords: Groundwater quality, Lagoons, Sewer systems

JUSTIFICATIONS OF WORK PERFORMED

In many rural areas of New Mexico, population density is increasing rapidly, but improvements in necessary infrastructure are not keeping pace. Small on-site sewage treatment systems are often used because no large-scale water treatment plant is accessible. On-site systems in Doña Ana County include septic tank leach fields, evapotranspiration (ET) beds, and aerated lagoons. Where no system is installed, residents may use illegal disposal methods such as open cesspools or even discharge raw sewage into agricultural drains. The New Mexico Environment Department (NMED) is charged with protecting the state's groundwater from contamination by sewage nutrients and pathogens. However, NMED has limited capacity to conduct research on the suitability of various disposal methods and evaluate existing design criteria for on-site treatment systems. The results of this study are intended to assist housing developers and engineers in the selection and design of ET beds and aerated lagoons, and to provide evaluation criteria for NMED in the authorization and inspection of these systems.

Two troubled small sewage treatment systems were investigated. A one-acre ET bed servicing Lyon Country Estates in the Village of Doña Ana initially was designed to service 38 homes. The system failed to work as intended, and has ponded effluent on the surface for up to eight months of the year. This presents immediate health risks to area residents due to possible pathogens. The system also is leaking, which may cause nitrate contamination of local groundwater supplies. The second system is a four-cell aerated lagoon system which was approved for use at the Mesa Village housing development on the mesa east of Las Cruces. However, the owner/operator did not build the system as approved. One cell was partially lined, and the others were unlined. Aeration equipment was not maintained, and the system fell into disrepair.

The case study sites represent a unique research opportunity. Each site services multiple residences, is typical of other systems in New Mexico, and has been operated for six years or more. While the study was site-specific, many general conclusions can be applied elsewhere and to different types of systems.

Objectives

The original goal of this project was to develop improved regulatory and design procedures and specifications for ET beds and aerated lagoons based on the two study sites' impacts on local groundwater quality. This goal was to be accomplished through the following objectives:

- reconstruct the operational history of each site
- quantify the magnitude and nature of groundwater contamination at each site
- identify the processes by which pollutants migrate to groundwater
- determine the local and regional movement of contaminated groundwater
- outline procedures for cleanup at the sites
- recommend modifications to design methods and regulations concerning these systems

Achievement of Objectives

All objectives were accomplished except for the determination of local and regional movement of contaminated groundwater. Details are given in the methodology and results sections of this report. Specific recommendations for ET bed design in New Mexico have been developed and are the subject of a Master's thesis (Fahmy, 1992).

As the project progressed, the project personnel worked cooperatively with the owners of the systems and NMED. Students and faculty in NMSU's Department of Civil, Agricultural, and Geological Engineering (CAGE) installed a liner and aeration system in one of the cells of the Mesa Village system, bringing it into compliance with NMED regulations. Dr. King also assisted Tierra del Sol Housing Corporation in preparing a discharge permit application and in evaluating designs for a system to replace the ET bed. Drs. King and Blair presented preliminary results and conclusions on ET bed design and suitability for New Mexico to NMED personnel in Santa Fe.

LITERATURE REVIEW

This portion of the literature review contains three sections. The first discusses the main features of evapotranspiration (ET) beds and evaluates some of the criteria that are currently used in the U.S. for the design of these systems. The second section presents and evaluates research which directly involves either ET beds or ET absorption beds. The third section presents research which addresses other related systems that could be beneficial in the design of ET beds.

Existing ET Bed Design Criteria

United States Environmental Protection Agency (EPA)

In its *Design Manual for Onsite Wastewater Treatment and Disposal Systems* (EPA, 1980), the EPA included design criteria for ET beds. Every state must meet these design criteria guidelines, but state guidelines can be more strict to allow protection for vulnerable sites. EPA standards state that the approximate area of a single-home bed should range from 4,000 to 6,000 square feet, depending on the region in which it is installed. Specifications have not been established concerning the slope of the terrain where the bed is built. For systems that will operate throughout the year, storage volume should be provided to accommodate the accumulation of water that is expected to occur during negative net evaporation months. This usually requires large areas and sometimes restricts the installation of ET bed systems to arid and semi-arid areas. The factors that determine the performance of the ET bed are as follows:

- climate
- hydraulic loading
- sand capillary rise characteristics
- depth of free water surface in the bed
- cover soil and vegetation
- construction techniques
- salt accumulation

The acceptance of any ET system should be based on its conformance to established standards. These standards may deviate from one location to another. One such rule could be that no discharge from the bed will be allowed for a period of ten years, with infrequent exception during wet years. Also, the vegetation type and/or solid surface might require the free water level to be 10 inches below the ground surface. The main design rule recommended in the EPA manual for all cases, is that the pan evaporation must exceed the precipitation in all months of a wet year (based on 10-year weather data) for year-round systems. Vegetation's effect on increasing evaporation is not yet certain. The optimal sand type for reasonable capillary rise is achieved by using sand of size D_{50} = 0.1 mm. (by weight). The hydraulic rate is determined according to the following equation:

$$Hydraulic\ Loading = Pan\ Evaporation \times Local\ Factor - Precipitatio$$

where precipitation is based on the wettest year of the last 10 year period.

The New Mexico Environment Department (NMED) (formerly the State of New Mexico Health and Environmental Department Environmental Improvement Division (SNMHEDEID))

The NMED recommends that ET systems not be installed in areas where the general ground slope exceeds 8%, where there is potential for flooding, or where continuous freezing temperatures and snow covers are extremely severe during the months of December through March. The key design features are stated by the NMED (SNMHEDEID, 1981) as follows:

- For each ET system, a septic tank or aerobic tank must be installed.
- A dosing chamber may be required to pump wastewater from the septic tank to the ET bed.
- An additional area equivalent to half of the ET bed must be available for future expansion.
- The system must conform to the New Mexico plumbing code.
- The system must be sealed to prevent seepage unless the depth to the seasonal water table and depth requirement are met or exceeded.
- The vegetative species must be suited to the climatic and soil conditions of the site and to the wastewater quality and quantity.

The area required for an ET bed by the NMED is determined according to the following equation:

$$A = 391 \times \left(\frac{Q}{E_L}\right)$$

where
- A is the bed area (sq ft)
- Q is the design flow (gpd)
- E_L is average annual lake evaporation for the site (in/yr).

The depth of the bed should be 24 to 36 inches.

Requirements for construction materials are:

- A liner must be installed to prevent seepage.
- Filtering material must be installed around distribution pipes.
- The bed material must allow substantial capillary rise.
- The vegetation must be suitable for the site specifications (water quality and quantity).

California State Water Resources Control Board

California published its guidelines for the design of ET systems in January 1980. According to these standards, ET systems must be designed by civil engineers, engineering geologists, or sanitarians, who have experience in small wastewater flow technology and are licensed in California. The site for a system should be well exposed to wind and be used exclusively for the system. The site also should be graded to minimize the accumulation of rainfall water and the groundwater flow. All rainfall precipitating directly onto the system should infiltrate into the system. Design flow rate is 75 gal/capita/day or 150 gal/bedroom/day, whichever is greater. The ET rate, used in design of the system, should be the minimum monthly winter class A Pan Evaporation, based on the records from the past ten years (State Water Resources Control Board, California, 1980). If other evaporation rates are used, this use must be justified, and the system's ability to accommodate the storage of accumulated water during the winter season must be proved. Other system characteristics which were standardized include the following:

- minimum distances from various types of structures

- characteristics of the septic tank and mechanical components
- gravel and sand type selection
- liner and vegetation type

Salt accumulation is to be taken into consideration, and the rate of concentration increase is given as 1250 mg/l/yr (.025 mg/yr/g of sand fill), assuming wastewater loading of .04 gal. per square foot per day. A free board was also recommended to prevent saturation of the bed. The depth of the bed was calculated based on detailed water balance.

Research on ET Beds

Salvato (1983)

Salvato presented what he called a rational method for ET design. He states that the proper design of the bed requires that the total outflow from the system (surface vegetation transpiration and ground surface evaporation) exceed the total inflow (sewage flow and precipitation infiltration). In addition to the detailed water balance, Salvato suggests that the calculation of the exact precipitation-infiltration be included. However, most researchers and agencies require that all direct precipitation be considered as input into the system. This tends to err on the safe side of the calculation, but, according to Salvato, could prohibit the installation of the ET systems in areas where they would function satisfactorily. The method suggested by Salvato was published and used by the Soil Conservation Service (SCS). The equation used to calculate the runoff is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

- Q is accumulated direct runoff (inches)
- P is accumulated rainfall (potential maximum runoff, inches)
- I_a is the initial abstraction including surface storage interception and infiltration prior to runoff (I_a = .2 * S, inches)
- S is the potential maximum retention (S = (1000 / CN) - 10, inches)

CN is a constant that varies with soil types. Values for CN for average prior soil moisture conditions were published in SCS tables and can be obtained for different hydrologic parameters. Salvato used the following mass balance equation as a base for the system operation:

$$ET \times A + E \times A = Q + I \times A$$

The equation incorporates the ET of the system in gallons per square foot during the growing season; the area of the bed (A), in square feet; the land evaporation from the bed (E), in gallons per square foot during the non-growing season; the septic tank inflow (Q), in gallons per day; and, finally, the precipitation infiltration (I), in gallons per square foot per year.

A detailed mass balance is performed using this equation to determine the bed volume, depth and area.

Tanner and Bouma (1975)

Tanner and Bouma (1975) stated that the disposal of sewage effluent is influenced by the maximum ET losses and the amount of direct precipitation on the field. In the Great Lakes region, the net difference between precipitation and ET is so great that drainage through the soil underlying the system is necessary. The amount that must be drained through the soil is estimated according to the following equation:

$$D = \frac{V}{A} - ET - P$$

where
- D is the depth of the drainage water (cm), ET is the annual evapotranspiration (cm)
- P is the annual precipitation (cm)
- V/A is the depth of effluent applied (cm)

The ET is estimated, using the Taylor method, as follows:

$$ET_{\max} = 1.28 \frac{s}{s + y} R_n$$

where
- s is the slope of the saturation vapor pressure curve corresponding to ambient air temperature
- y is a psychometric constant
- R_n is solar radiation in evaporation units (mm/day)

R_n is calculated as

$$R_n = (1 - r) R_g - R_{Tn}$$

where
- R_g is solar radiation
- r is albedo (reflectance) of solar radiation by the surface
- R_{Tn} is net long wave thermal radiation loss

R_{Tn} is calculated as

$$R_{Tn}\ (clear) = T^4 \times 0.261 e^{(-7.77 \times 10^{-4}) T_c^2}$$

where
- TC is mean air temperature in degrees celsius
- T4 is black body radiation, corresponding to absolute temperature (T)

Then the correction for cloudiness:

$$R_{Tn} = R_{Tn}\ (clear) \times \frac{R_G}{R_G\ (clear)}$$

Beck (1979)

Beck (1979) collected data from twelve experimental ET systems in San Antonio, Texas. Measurements were taken twice a day and included water depth, temperature, rainfall, and pan evaporation. He found that the ET rate increases as the water depth decreases and may reach high values up to 10 times the pan evaporation. He also found that ET takes place even with rain or with temperatures low enough to freeze the water in the pan. He discovered that the depth of the water in the bed and the ET rate from the system can be related using regression analysis.

$$Depth = A + B \times \log(ET)$$

where A and B are constants of regression. Beck stated that the following design criteria should be followed in the design:

- The daily inflow into the system must equal daily ET.
- The depth of water in the bed must not be less than the depth of one day's input.
- The depth of the sand layer must be greater than or equal to the depth of largest pan evaporation rate.

To achieve the first criterion, a trial and error procedure is used according to the following equations:

$$ET\ rate = 10 \times e^{\left(\frac{10.03\ C\ -\ A}{B}\right)}$$

$$D' = \frac{C}{ET\ rate}$$

where
- ET is evapotranspiration (gallons per square foot per day)
- A and B are equation coefficients
- C is daily input (gallons per day)
- D is the assumed bed area (square feet)
- D' is calculated bed area (square feet)

The second criterion is achieved by using the first equation. The author did not account for the case in which the net outflow is less than the inflow, requiring extra storage depth.

Lomax (1982)

Ken M. Lomax (1982) studied ET systems along the eastern shore of Chesapeake Bay. The elevation of the study area was approximately twelve feet above sea level. The groundwater table was between one and six feet below the ground surface. According to EPA guidelines, ET systems should be feasible in the area but would be expensive and require intensive management. The systems in the area were designed based on common values recommended by the EPA. Detailed water balance analyses, to provide sufficient depth for the storage, were not performed. Loading rates were from .04 to .12 gpd per square foot. To avoid construction problems and the use of heavy equipment during construction, bed widths were less than 20 feet, and bed lengths were less than 100 feet. To fully utilize the vegetation on the bed, Lomax found that it has to be at complete growth before the bed is incorporated into the sewer network. The vegetation has to have sufficient water at all the times. This limits the applicability of the system for use with vacation homes.

Wilson et al. (1982a,b)

Wilson et al. (1982a,b) studied the applicability of ET systems in the arid and semi-arid regions of central and eastern Oregon. The soils in these areas have very low permeability, and the groundwater is very shallow. These factors prohibit the installation of standard surface treatment and disposal systems. Sixteen ET bed systems were installed in Jackson County and one in Baker County. The ET rate in the area was found to exceed the precipitation rate by more than 10 inches. The systems were lined with 4-mil plastic liners. The tank was located at the center of the system. The depth of the beds was 36 inches in two layers, 12 inches of rock covered with 24 inches of sand. The slope of the bed surfaces was 3% with surface area of 1200 to 3000 square feet. The report does not describe the derivations of these bed dimensions. Thirteen systems were found to be leaking, although the leakage did not create a health hazard. However, the authors concluded that the use of ET systems is not feasible for the area. It was noted that the liners were of such poor quality that they allowed leakage. Also, the bed surface area was underestimated.

Scott (1982)

Scott (1982) studied a system, similar to the one proposed by Bernhart (1979), at Fayetteville, Arkansas in February of 1980. The system was 3.4 m long, 1.4 m wide, and 1.95 m deep, with a surface slope of 3%. The surface area was 4.8 square meters and the total volume was 8.8 cubic meters. The loading rate was .0067 m/day. Seepage was prevented by a 30-mil, reinforced pit liner. The system was monitored closely to record temperature fluctuations, chemical composition, and the moisture status of the ET bed. The vegetation was established in March of the same year (tall fescue). The daily water balance for the system was calculated as follows:

$$ET = R + I + S - W$$

where

- R is rainfall (cm)
- I is depth of irrigation (cm)
- S is wastewater load (cm)
- ET is evapotranspiration loss (cm)
- W is change in the water content of the system (cm)

The rainfall runoff was neglected. Scott studied the relationship between the depth of water in the bed and the depth to groundwater which can be interpreted as the relationship between the depth of the water in the bed and the climatic conditions in the area. The conclusion was that the system is not a viable alternative for the area.

Gunn (1988)

In his study, Gunn (1988) described the history of the first engineered evapotranspiration and seepage (ETS) system in New Zealand. The system was built in 1976 for an Auckland house, located in a steep, bush-covered gully with very tight upper soil layers. It was designed with a detailed water balance for a loading rate of 10 mm/day. The subsequent 12 years showed a lot of design variations. The area of the bed was determined with Bernhart's approach from the following equation:

$$A = \frac{F\,L}{S}$$

where
- A is the bed area (m^2)
- F is the daily wastewater flow (liters)
- S is the ETS disposal rate or bed loading rate ($l/m^2/day$)
- L is pollution load factor dependent on the degree of the pretreatment

Gunn recommended that the L values be .9 to 1.2 for good aeration tanks, 1.8 to 2.8 for good septic tanks, and 3.0 to 3.8 for small septic tanks. A full water balance was performed for an entire year to determine the bed depth. The system had to maintain aerobic conditions in order to perform satisfactorily and to use the previous L values. The aerobic conditions were established through the low loading rate.

Another of Gunn's studies (Gunn 1987) describes a system that was designed for University of Auckland Marine Research Station's Leigh Laboratory, located on the Pacific coastline, 100 km north of Auckland. An ETS system was installed in 20 bed units, each 15 m long and 1.5 m wide, crowned, and planted with grass. The effluent from the septic tank was drained into 4 groups of 5 beds. Using this system, each group of beds had a one-week loading period followed by three weeks with no loading. Rain water runoff and groundwater flows were directed away from the system. The system was again designed according to Bernhart's equation as well as the detailed water balance. The successful performance of the system was attributed to the low loading rates (10 mm/day for daily flow of 4,565 liters) and to the drainage network that was constructed to control both surface water and groundwater flows in the location.

Other On-Site Treatment Systems

Norman Torkelson and Michael Zavoda (1983) constructed an experimental, solar-assisted wastewater disposal system that allowed no water to be discharged into the groundwater or onto the surface. The system utilized the concept of ET beds with the addition that it was built as a greenhouse instead of as an outdoor system. The existence of the greenhouse maximized the solar effect and allowed no rainwater to enter the system. The effect of the wind was eliminated, but the bed was never allowed to freeze. The authors, through a monitoring program, were able to demonstrate the success of the system. The scientific basis for the design of the bed was not given in their report.

Conley et al. (1991) described a wastewater treatment system which consisted of a constructed wetland with subsurface wastewater flow. The media in the root zone of bed are responsible for pollutant removal, directly, through chemical and physical interactions and, indirectly, by providing a solid substrate for the growth of the wetland plants and supporting the microbial growth. The plants remove some of the nutrients but since they are not harvested, absolute removal of nutrients is not achieved in this system. The plants usually adapt to the characteristics of the municipal wastewater. Removal efficiencies in the system are:

Biochemical Oxygen Demand (BOD):	64 to 96%
TSS:	71 to 98%
Nitrogen:	24 to 61%
Phosphorous:	13 to 68%

The design of the bed includes specifications which describe the length, width, and depth of the system. The biological kinetics control the required volume of the bed, the type of vegetation controls the depth, and the hydraulics of the system control the length/width relationship of the bed. The governing biological process is the BOD removal. The authors used a first-order kinetics equation to determine the fate of the BOD in the system.

$$\frac{C_e}{C_o} = e^{-K_t t}$$

where
- C_e is influent BOD
- C_o is effluent BOD
- K_t is the temperature-dependent rate constant, in day^{-1}
- t is the hydraulic detention time (days).

Knowing the flow rate (hydraulic loading rate of the wastewater) and the appropriate detention time required to achieve a certain level of removal, the volume of the system can be calculated according to the following equation:

$$Vn = Qt$$

where
- V is the bed volume
- n is the porosity of the bed material
- Q is the loading rate
- t is the detention time of the wastewater in the bed

The K_T is adjusted for the temperature of the system, according to the following equation:

$$K_t = K_{20} \times 1.06^{(T-20)}$$

where
- K_T is the rate constant at temperature T
- K_{20} is the rate constant at 20° C
- T is the operating temperature in °C

The depth is determined according to the type of plant used. For example, cattails require .3 m, reeds require .6 m, and brushes require .76 m. From the volume and the depth we can determine the surface area of the bed. The length/width relationship is determined by Darcy's law:

$$A_c = \frac{Q}{K_s \frac{\Delta h}{\Delta L}}$$

where

- A_c is the cross-sectional area of the bed (m^2)
- K_s is the soil's saturated bed hydraulic conductivity (m/d)
- $\Delta h/\Delta L$ is the hydraulic gradient

The study showed that suspended solids removal efficiency was linearly related to the loading rate of the system. The biodegradation equation for the BOD was a major contribution of this study to the ET design criteria.

Sewage Lagoons

Sewage lagoon systems have been used formally for wastewater treatment since the 1920s. These systems consist of constructed, shallow basins that are designed to retain wastewater for a period of time prior to discharge. Currently, over 10,000 sewage lagoon systems are utilized by municipalities, housing developments, and industries in the U.S. The literature presents a comprehensive picture of these lagoons' characteristics, their description as engineering systems, and the regulations related to their construction and operation. The references used to gain background knowledge of sewage lagoons included Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, Middlebrooks, et. al. (1978). These references are listed in the bibliography.

The nature of the influent wastewater divides lagoons into three classes: aerobic, anaerobic, and facultative. Influent wastewater that contains large amounts of organic materials are treated in aerobic lagoons. These lagoons are designed to maximize the conversion of organic matter to algal cells by maintaining aerobic conditions. Anaerobic lagoons are designed to treat concentrated wastes such as sludge and manures. Their effluent usually require additional treatment. Facultative lagoons have top layers that are aerobic and bottom layers that are anaerobic.

Sewage lagoons are classified, according to their treatment objectives as raw, primary, secondary, tertiary, or polishing or maturation lagoons. Lagoons which receive previously untreated or "raw" wastes are known as raw lagoons. A primary lagoon is the first in a series of several lagoons receiving raw wastewater. Secondary lagoons further treat the settled and partially treated effluent from primary lagoons. Well-stabilized effluent may be treated once more in tertiary lagoons. Polishing and maturation lagoons are tertiary lagoons specially designed to reduce settleable solids, fecal organisms, and ammonia.

The categories of sewage lagoons that are based on their hydraulic characteristics include continuous-overflow, intermittent-overflow, and non-overflow lagoons. Lagoons designed for continuous discharge of effluent into other receiving bodies are described as being continuous-overflow lagoons; whereas, intermittent-overflow lagoons discharge effluent only during specified periods. Non-overflow lagoons have no discharge, relying on evaporation and seepage to exceed inflow.

Sewage lagoons are also classified according to aeration methods. These methods include photosynthetic aeration, atmospheric aeration, and mechanical aeration. Photosynthetic lagoons receive oxygen through algal activity within the aerobic portions of a system. Atmospheric aeration lagoons rely on the natural diffusion and of atmospheric oxygen into the water of the system. This process increases with atmospheric pressure. Mechanical aeration involves the use of mechanical aides to accelerate the natural transfer of oxygen from the atmosphere to the lagoon.

The physical parameters that influence systems' effectiveness include pond geometry, mixing, detention period, temperature, light, and wind action. The depth of the lagoons in a system is critical to its ability to treat wastewater. Because increased depth decreases light for photosynthetic activity, depth directly affects the lagoons' aerobic conditions. It is also important that depths not cause the bottom of the lagoon to be below or near groundwater level to prevent contamination. Surface area affects evaporation and oxygen concentration in the lagoon. These parameters vary directly with the surface area of the lagoons. The overall shape of the lagoon affects mixing, which, in turn, affects the aerobic levels of the lagoons. The amount of time bacteria have to decompose wastes within a system is determined by the detention time of the lagoons, and the performance of bacteria and the overall effectiveness of the lagoon which are greatly affected by the water temperature and available light. Wind action can have both positive and negative effects. On one hand, the action of wind can increase mixing and surface reaeration. On the other hand, however, it can also lead to the erosion of banks.

The lagoons' performance is also affected by chemical factors, including nutrients, pH values of the wastewater, sulfur, dissolved oxygen, and toxicity. Organic carbon, nitrogen, and phosphorus are the main nutrients for microorganisms in sewage lagoons, and the concentrations of these nutrients, in combination, greatly affect the performance of algae and other organisms. A lagoon's pH depends upon the organic loading rate and the algal activity of the system. A low pH value adversely affects the lagoon's performance. The dissolved oxygen level in the water varies directly with microbic and photosynthetic activity in the lagoon and increases system productivity. Toxicity problems may occur in lagoons that are subject to sudden loadings of wastes.

The biological factors that influence the lagoons' performance include aerobic, acid forming, methane, and purple sulfur bacteria, algae, zooplankton, invertebrates, worms, and insects. Bacteria play a major role in the operation of sewage lagoons. Aerobic bacteria decompose organic materials in the aerobic zone into oxidized and products. Acid-forming bacteria convert complex organic materials to volatile acids, maintaining an optimum pH range within the lagoon. These volatile acids bacteria are then converted to methane and carbon dioxide by methane bacteria. Lastly, sulfides are converted to elemental sulfur or sulfates by photosynthetic, purple sulfur bacteria. Bacteria also play a major role in odor control. Algae produce oxygen, a critical component in the operation of a lagoon, as a by product of respiration. Although bacteria and algae are the primary organisms involved in waste stabilization, larger organisms play an important role in lagoons as well. Plankton and other predatory organisms, such as worms and insects, feed on algae and control population levels in the lagoon.

METHODOLOGY

Methodology roughly followed the sequence of project objectives. The sites were evaluated independently, with the investigation modified for each according to conditions.

Lyons Country ET Bed

The first phase in the analysis of the ET bed at Lyons Country included three steps. The first step was to conduct a detailed literature review concerning the design and operation of evapotranspiration beds. The results of this review can be seen in the previous section. The original designs for the system were obtained from Tierra del Sol (TDS), and were evaluated using the information from the literature review as guidelines. Finally, site history was reviewed, from construction to the time when we joined the project. All communications pertaining to the site were obtained from TDS and the Las Cruces NMED office. A summary of relevant events follows.

From 1979 to 1980, the Tierra del Sol Housing Corporation assisted 38 low-income families in building their own homes by the self-help method. The subdivision, named Lyons Country Estates, is located at the north end of the Village of Dona Ana, New Mexico.

In 1978 Kent Breese from the NMED suggested that the ET bed be a minimum of 41,800 square feet in area if it were to manage 300 gpd of influent per connection, which was the projected usage during winter months. TDS decided to install a 43,560 sq. ft. ET bed and a 10,000 gallon septic tank. Lyendecker, the engineer who designed the system, certified that the system was constructed in accordance with plans and specifications approved by the NMED.

At the end of 1980, the ET bed system was working well, with good distribution of the effluent throughout the bed. Pooling was beginning at the west end of the bed, however, and it was suggested by Lyendecker that Alta Fescue and Perennial Rye grasses be planted to increase the transpiration rate. By March of 1981, Lyendecker was suggesting that TDS construct a leach line adjacent to the existing bed to help with the ponding problems. On April 10, 1981, in a letter to Maxine S. Goad, the Program Manager of the Ground Water

Section of the NMED, Rose Garcia, the executive director of TDS, said that if the pooling problem persisted in the winter, TDS would like to perforate the lining of the ET bed and discharge the effluent as a conventional leach field.

On May 6, 1981, Rose Garcia received a letter and inspection report from Lyendecker. Lyendecker's main criticism was the lack of system maintenance. He had these comments to make about the state of the system:

- The plant site was in need of a general cleanup.
- The holding pond was full.
- The chlorinator was not being used and appeared inoperative.
- The mixed liquor in the aeration tanks was at an inadequate level to provide treatment, causing an odor problem.
- The check valve on the irrigation pump was missing, allowing back flow through the air and vacuum relief valve.
- The required concrete pad for the irrigation discharge piping was not constructed.

He also made several recommendations:

- The plant site should be cleaned up and grass should be planted around the plant and holding tank.
- The holding pond should be pumped back to the irrigation chamber.
- The chlorinator should be reactivated, and the solid chlorine should be mixed in a separate tank and decanted to the solution tank.
- The mixed liquor concentration in the aeration tanks should be built up to adequate levels (2000 mg/l) to provide adequate treatment.
- The check valve on the irrigation discharge line should be installed.
- The concrete pad (3' X 3') for the irrigation discharge piping should be constructed, and this piping should be secured to it with straps.
- Only 3 to 5 sprinkler heads should be used at a time.
- The irrigation pump supplier should check the installation to make sure it was correct.
- The timer on the compressors should be set so that they operated at least 30 minutes per hour during the day, and at least 15 minutes every other hour

during the night.

At the beginning of May, 1981, the ponding problem continued, and Rose Garcia sent a letter to Thomas E. Baca, the Director of the NMED in Santa Fe, which informed him of the steps that TDS was taking to correct any violations. These steps included pumping the ponded water off the ET bed, berming the area around the southwest corner of the bed, and pumping the septic tank periodically to insure that ponding did not occur. TDS was in the process of submitting a discharge plan in order to discharge the effluent below ground. The original ET bed design bed was being challenged by the NMED, and Rose Garcia rebutted these challenges by reminding Baca that TDS followed all design criteria presented by the NMED and, in fact, surpassed the criteria for the size of the ET bed (43,500 sq. ft. vs. 41,800 sq. ft.).

On June 17, 1981, Lyendecker sent a letter to Doug Jones of the NMED in which he included a discharge plan for Lyon's Country. TDS proposed to allow the effluent to enter the ground by perforating the 30 mil liner under the bed. Although the entire discharge (7700 gpd) of the septic tank would be considered as ground discharge, Lyendecker suggested that with a good stand of grass only one-third to one-half of the bed would require perforation. The ET bed would remain in use as designed. Depth to groundwater was estimated at 50 feet.

On July 17, 1981, John Thomas of the Farmers' Home Administration (FmHA) conducted an inspection of the ET bed site. He stated that the bed was hydraulically overloaded causing raw sewage effluent to stand in the lower portion of the bed. The problem was further complicated by the fact that the dike on the west side of the bed was washed out, allowing the effluent to flow onto the land west of the ET bed. The odor of the raw sewage was a persistent nuisance in the area. Also, flooding in the area had almost washed out the protective dike on the north side of the ET bed. Additional flooding would threaten to cut through the ET bed, rendering it useless. Thomas simply recommended that, because the area in which the bed was located was flood-prone, another site for the bed be found.

By August of 1981, grass had been planted on the bed twice; however, the planting time was not good, and the grass did not germinate. TDS planned to replant the grass when the weather became cool, and the ponding problem was eliminated. This problem was compounded because the ET bed surface was very uneven and was 6 to 10 inches lower at the southwest corner than at the opposite end where the wastewater entered the bed. Thunderstorms kept the bed very wet and augmented the problem. As a temporary solution, the bed was filled with sand to contain the water and keep it from flowing to nearby fields. The drainage problem caused by rainfall appeared to have been overlooked in the project planning. The discharge plan submitted to the NMED was awaiting approval. All funds for the project were expended at this time, and TDS was seeking more funding.

In August of 1981, the neighboring farmer and landowner, Frank Romero, dammed the mouth of the arroyo that runs north of the ET bed. On August 19, flood waters travelling west in the arroyo washed out the southwest corner of the ET bed. In the next two days, TDS repaired the arroyo bank and bermed an approximately five-foot levee at the southwest corner to contain the subsurface and wastewater runoffs. On August 21, Rose Garcia requested permission to discharge water into a temporary holding pond at the southwest end of the bed to buy time to repair and modify the existing bed. TDS planned to install a 3200 sq. ft. leach bed north of the ET bed to help as an overflow measure. Also, they planned to ask the county to reinforce the southwest bank of the arroyo and request that Romero not dam up the mouth of the arroyo. Additionally, permission was requested to install and maintain an 18-inch deep and 4-foot wide drainage ditch from the northeast corner of the ET field across to the southeast corner as a drainage for the two small surface drain-offs. At the end of 1981, TDS received permission to continue discharging to the holding pond without an approved discharge plan. This was applicable for up to 120 days.

Romero was not willing to let the arroyo be reinforced so it was suggested that the arroyo be lined with "Enkamat." This would stabilize the soil on the arroyo bank and protect the bank from erosion until the grass grew. The grass on the bed was to be replanted before the cold weather began, and a fence was erected around the holding pond.

On October 29 1981, in a letter written to Ken McCallum, Water Resource Specialist for the NMED, Rose Garcia stated that the fescue and ryegrass were growing very well. These grasses were planted in lieu of bermuda grass because the latter has a tendency to become dormant during the winter months. TDS also planned to plant evergreen afghan pine trees. At this point, they were waiting for the trees to take root and for the proper tree planting season.

On November 5, 1981, Rose Garcia wrote a letter to Thomas E. Baca which included the statement that Baca had revoked the temporary discharge permit. Garcia asked that Baca review his decision and added that if, in the future, groundwater contamination was registered by either of the two monitoring wells in the area, TDS would discontinue subsurface discharge and implement an alternate treatment technique. One of two methods would be used in that case: 1) secondary treatment and surface discharge, or 2) total retention of septic tank effluent. A secondary plant could be constructed at the site with effluent used for land application to adjacent farm lands. Total retention would consist of expanding the ET bed to dispose of the entire 11,000 gpd of septic tank effluent.

By the Fall of 1981, two things were clear. First, it was obvious that the original bed was too small to provide treatment for the amount of sewage it was receiving. It was determined that the ET bed was approximately 75% of the size it should have been to dispose adequately of the septic tank effluent. To increase the size of the system, a conventional leach bed was to be installed which would have an area of 4,725 sq. ft. Second, the flood which was caused by the damming of the adjacent arroyo damaged the ET bed very badly. Much erosion had occurred and was facilitating ponding in the bed. To quell the threat of further flooding, the channel dikes were to be rebuilt, and the arroyo was to be rechannelled.

By April 15, 1982, the repair work on the bed was done except for the building of a flood protection dike. The liner was replaced where necessary and repaired where possible. Damaged piping was replaced and capped. The new liner was covered with rocks, and the distribution pipes were leveled. The grass was growing well, and the effluent was being reused to water the grass. The leach field had not yet been constructed, but the bed was doing well on its own.

By May 3 1982, the bed was ponding again, partially because of heavy rains. Sand was applied to any low spots found in the bed. It was hoped that this would create a fully operational bed. Throughout the spring and summer, the ponding was intermittent. Sand was continually applied in an attempt to keep the bed dry. It is not clear exactly what kept happening to the grass, but at this point, they had just replanted it, hoping it would fill some of the bare spots and help prevent ponding. By fall the ponding was more consistent, and the water was deeper. On October 1, 1982, Rose Garcia received a memo from Mike

Malbourne, Water Utilities Operator, mentioning the possibility of using a rapid infiltration (RI) system to remove nitrates from the ponded effluent, in lieu of the previously proposed leach field. The area prepared for use in the RI process was designed to be approximately 1500 sq ft. At this point, the results of water quality analyses showed the nitrate level in the standing water to be less than 1 mg/l. Under the law, the nitrate level of drinking water must be below 10 mg./l.

On December 7, 1982, Mike Malbourne dispatched a memo to Antonio Silva, TDSs attorney, informing him that the ponding was constant and that the overflow was becoming difficult to contain in the drainage ditch south of the bed. As of December 20, there was no overflow onto Romero's property adjacent to the bed. With the upcoming holidays and school vacation, the flow into the bed was expected to increase by at least 10%. On April 20, 1983, TDS submitted a new plan to the NMED for approval. This plan involved the installation of an individual septic tank and drain field in each of the 38 lots. It was thought that these would pose no threat to the groundwater in the area. The depth to groundwater was estimated at over 50 feet, and the nitrogen loading rate was calculated to be below 200 lbs. per acre per year, which is the maximum rate allowed by the NMED. Also, the ground in the residents' yards should not become overloaded because the percolation rate was good at 7.33 minutes per inch. In addition to the safety-related motivations toward the individual septic tanks, TDS also considered the fact that they would demand fewer resources and be more convenient in the future if the bed were abandoned immediately. The response from the NMED stated that a plan using the existing ET bed and installing a septic tank and drain field in every other yard could be approved. This would mean the complete reconstruction and leveling of the bed due to damage it had received in recent floods. This was undesirable to TDS.

As of July 28, 1983, TDS had decided to install only 20 septic tanks and continue to use the ET bed for the other lots. Although this would halve the amount of flow into the ET bed, it would still require that the bed be refurbished. By August 12, that number was down to 19, half the number of homes originally using the ET bed. Two monitor wells were to be installed south of the bed, and the north levy area was to be protected from flooding by rip-rapping. The NMED agreed that no overflow structure was necessary.

On March 8, 1984, Rose Garcia sent a letter to Doug Jones of the NMED asking that some modification to the sewage system be considered. The landowner, Frank Romero, had cut back the terrace on which the ET bed is located to within three feet of the southwest corner of the bed. TDS was worried about a possible collapse of the terrace due to the weight of the ET bed. Also, it was likely that flooding similar to that in 1981 might reoccur. If this happened, the southwest corner might be irreparably damaged. The modification that Rose Garcia suggested was the construction of an underground leach field east of the Lyon's Subdivision and the elimination of the ET bed from the discharge system. A lift station would be constructed on Lyon's Subdivision lot number 7 below the septic tank. Effluent from the septic tank would be pumped to the leach field which would consist of 5000 feet of perforated pipe in 2-foot wide trenches 4 feet deep, with 6-foot intervals between trenches.

On July 5, 1984, TDS received approval from the NMED for a plan which included the installation of 18 onsite septic tanks. It is not clear what caused the modifications from the plans mentioned above.

On November 13, 1985, TDS had just finished repairing the arroyo berm and leveling the bed, and they were planning to wait until the spring to plant new grass.

Photos taken on January 6, 1986 show a broken embankment on the west side of the ET bed and water ponding west of the bed and on the bed itself. There seemed to be overflow from the manhole covers. There was also runoff onto the adjacent farm, owned by Frank Romero. These photos were corroborated by a letter from Gabe Garcia of the NMED to his file. In this letter of January 17, Gabe Garcia stated that there was a great deal of flooding onto Romero's fields, that the septic tank overflowed, and that the ET bed was ponded almost completely. Another complaint was registered on March 25 about overflow from the septic tanks. Apparently nothing had been done since January in any attempt to correct the problem. In May of 1986 it was discovered that a 4-inch pipe which formed the manifold was cracked at a tee joint. The broken tee joint was replaced, and throughout May no overflow from the septic tank or ponding on the bed was seen.

In a letter on July 15, 1988, from the NMED to Susan Allen, the following statement was made, "The facility was designed as an evapotranspiration bed; however, it is now functioning as a lagoon." The grass was replaced by cattails due to the high water. Maintenance appeared to be minimal as tumbleweeds were growing around the pond perimeter. The water appeared to be between 12 and 18 inches deep at that time. On August 12, 1988, 3,240 gallons of water were removed from the pond by Johnny's Septic tank. On August 15, the water level was checked again, and it was still too high. Johnny's Septic Tank removed 1,620 gallons more, but the water still remained too high.

On September 2, 1988, the NMED approved the construction of an overflow pond adjacent to the ET bed. At this point, the overflow pond did not have to be lined.

The first action taken was the performance of a BOD_5 analysis on the ponded water inside of the bed. This test was performed by the research assistants involved with the project, following the procedure described in Standard Methods (Franson et al, 1980). The samples were gathered on July 31, 1991. Test results can be seen in the results section (Table B-31). Another BOD_5 analysis was performed on the water ponded within the bed, with samples being taken on August 7, 1991 (Table B-32).

Also during the summer of 1991, four piezometers were installed inside the ET bed, one in the center of each quarter (Figure A-1). Each piezometer consisted of a PVC pipe that was 4 inches in diameter, 2.5 feet long, and perforated for a foot on one end. The perforated end of each piezometer was pounded into the ET bed. The piezometers were to be used to monitor the water level inside the bed; however, shortly after they were installed, water began to pond on the surface of the bed, and the piezometers became inaccessible. This condition persisted throughout the project period.

In October of 1991, five monitoring wells were installed around the perimeter of the ET bed (Figure A-1). Each well was 2 inches in diameter with 3 feet of well point screen, and the depths varied from 45 to 60 feet. Soil samples were collected for soil characterization as well as for nitrogen and phosphorous analyses of the moisture in the soil. The static water level in each well was also monitored. the results of the soil-characterization analyses are listed in tables B-1 through B-26 and can be seen graphically in figures A-2 through A-25, and the data from the nitrogen, phosphorous, and moisture analyses are listed in tables B-27 through B-30.

In the Fall of 1991, a complete survey of the ET bed was performed. From this survey, the contours of the region were developed (Figure A-1).

In the Spring of 1992, the ET bed was badly overloaded. There was a threat of overflow, and the berms around the bed were eroding. A discharge permit was required to allow the excess water to flow into a special holding pond just north of the bed. Soil type maps were digitized by the SCS and were submitted with the results of water chemistry analyses to acquire a discharge permit for Lyons Country. Although the discharge has occurred, no permit has been granted.

Some analyses were performed throughout the entire study period. Soil and water chemical analyses, for instance, were performed regularly. These tests included analyses for nitrates, nitrogen (TKN), and phosphorous. Tests results are listed in tables B-27 through B-30. Sieve analyses were also performed throughout the study period for the soil surrounding the ET bed. The first series of samples was taken in July 1991, and more samples were taken from various depths during the drilling of the monitoring wells. The results from the sieve analyses are listed in tables B-1 through B-26.

Mesa Village Sewage Lagoons

The first phase of the analysis for the Mesa Village system was very similar to that for the ET bed. Again, a detailed literature review was performed, in which the previous research concerning sewage lagoons systems was gathered and studied. Next, the original plans for the system were obtained from Jerry Stomberg the owner of Mesa Village, and these plans were evaluated based on the literature review. Finally, this information was coupled with information gathered concerning the history of the site. As with the Lyons Country study, this first phase of the analysis for Mesa Village was completed during the summer of 1991. A summary of the relevant events in the history of the lagoon system follows.

The wastewater treatment plant for the Mesa Village subdivision was designed as three treatment lagoons, one detention lagoon, a blower house, an irrigation pump station, a chlorine treatment station, and a spray irrigation system located in the Mesa Village Park. The project was modeled after the treatment facilities at the town of Ganado, Arizona. The design specifications for the project are located in document #4 of the Mesa Village documents file. The Mesa Village plant was sized at 50,000 gpd which will support 143 homes.

On October 10, 1975, a letter was mailed from Kent Breese, Environmental Engineer of the NMED, to Carl Salas, Doña Ana County Manager, which discussed the proposed

Mesa Village facility. The letter stated that the existing storage capacity of the facility projected for use in the following two years was inadequate for the projected 200 homes. Also, the letter stated that sufficient information was not provided for evaluation of the proposed design, materials, construction, testing, operation, and maintenance of the sewage collection and disposal systems.

The system was inspected on November 13, 1978 by the New Mexico State Health and Environment Department. A small pump was being used to pump effluent from lagoon one to lagoon two. The liner on lagoon one was torn, had missing sections, and had slipped down the banked lagoon sides. Lagoons two, three, and four were unlined and all lagoons had vegetation growing on their embankments. This indicated the poor upkeep of the system. Although the disclosure statement indicates that the sewage facilities would be completed prior to first residency, this commitment was broken. Two houses were occupied, and construction was not complete.

When the site was inspected by the NMED on November 16, 1979, the same conclusions were reached. Stomberg received a letter from the NMED suggesting that he contact them immediately. There were now four homes being occupied and two under construction. In his reply to the NMED, Stomberg agreed with all of their allegations against the facility. He justified his tardiness, however, by the fact that for all practical purposes the demands on the facility thus far did not justify full implementation of the 50,000 gpd system. He also said that all equipment required for the full treatment package was in storage and would be installed and put into effect within 60 days. Stomberg supported the presence of the vegetation around the banks of the lagoons as a way to prevent soil erosion. Once the liner material was replaced, the vegetation would be removed. The opening of the first lagoon for full operation was scheduled for January 15, 1980. Due to poor weather conditions, the schedule was pushed back, and as of January 31, 1980, Stomberg planned to have the lagoons fully operable by March 20.

An Addendum Report, written on February 11, 1980, again changed the schedule for the project's completion. The Mesa Village subdivision was expanding much more slowly than was originally predicted. For this reason, Stomberg proposed a staged development of the system in which each lagoon would be put into use as necessary and left dormant until that time. Apparently, the growth of the subdivision remained very slow, due to high interest rates, and the sewer system was not developed. By November of 1980, the NMED complained to Stomberg that he was not maintaining the schedule that he had filed with them. Stomberg claimed that while his temporary system of septic treatment was unorthodox, it was still satisfactory. Stomberg also pointed out that he had completed lining lagoon one.

By the end of March, 1981, the stabilizing pond in lagoon four was not built. This was partially due to bad weather and partially due to vandals diverting the flow of the effluent into lagoon four. Both conditions restricted the construction of the temporary stabilizing pond. At the end of March, the construction was just about to begin.

A memo written by Gabe Garcia to Roy D. McKeag on September 24, 1981, indicated that Garcia planned to initiate litigation against Stomberg for his lack of cooperation over the preceding year. Garcia had the following complaints:

- A November 1979 inspection of the Mesa Village site found the facility to be in violation of its original disclosure statement.
- The inspection revealed inadequate maintenance, a torn liner in pond one and no liners in the others, and that the aerators were not installed at all.
- From November 1979 to October 1980, the NMED had requested that Stomberg correct the violations. He had replied that they would be corrected.
- A notice of intent to discharge, required by the Water Quality Control Commission Regulations, was never submitted. Since the effluent from the system was to be disposed of by land application, a discharge plan was required.

An inspection on May 3, 1982 found the site to be in worse condition than ever. The fence had collapsed allowing entrance into the area, and the distribution box previously used as a septic tank was no longer being used. The pipe carrying the sewage to the box was disconnected and raw sewage was allowed to flow on the ground surface into the southwest and southeast lagoons. By August 16, 1982, the disposal of the untreated wastewater was changed to the northwest cell of the disposal facility. All four cells were still unlined, but the fence around the area was repaired.

A November 16, 1982 memo to the county planner of Dona Ana announced that for the first time, pond one would be put into operation. The effort would include the repair of the liner and replacement of a large portion of the liner. The aeration and treatment equipment were in storage and ready for use. The tentative schedule was that the pond would be operational within three months. Until completion of the system in pond one, the temporary pond would continue to be in use.

On September 12, 1983, wastewater was still disposed in the northwest pond, and, with the increased number of houses, wastewater was ponding throughout the cell. The cell was not lined, but it appeared not to be a nuisance.

On January 30, 1984, a complaint was received that sewage was overflowing from a manhole in the Mesa Village subdivision. The sewage was, indeed, overflowing and running several hundred feet down the road. Gabe Garcia warned that the overflow was to be stopped immediately, and that if the problem was not corrected, legal action would be taken.

In a letter written to Les Olsen on March 6, 1984, Garcia updated Olsen on the status of the Mesa Village project. Pond one was still not operational. Construction was behind schedule by one more month due to a blockage in the main sewer line. While the blockage was removed, Stomberg was forced to allow the sewage to flow into pond one. Pond one had to be pumped out and allowed to dry so that construction could begin. Once the water flow was high enough, the aeration process would be implemented.

As of January 13, 1986, three of the four ponds had effluent in them, and the last appeared to be drying up. The fence was intact, no odors were noticeable, and there was a low but continuous flow into pond one.

On February 26, 1990, Stomberg wrote a letter to Tracy M. Hughes, Assistant General Counsel for the New Mexico Health and Environment Department, announcing that he and a business associate intended to develop 125 acres of land adjacent to and part of the Mesa Village Subdivision. Stomberg claimed that the expansion would eliminate the lagoons, and the area of development, including Mesa Village, would be connected to the City of Las Cruces sewage system.

On April 30, 1991, the New Mexico Water Quality Control Commission filed suit against Stomberg for civil penalties. The complaints were as follows:

- no notice of intent to discharge
- no revised plan filing
- no notification of discharge

- no discharge plan
- common law public nuisance
- statutory nuisance

The first step in the field study of the sewage lagoons system was the installation of three level gauges, one in each active pond. Fluctuations in the water levels were recorded frequently and were used as indicators of the flow into the system. These fluctuations were minimal and indicated steady-state conditions throughout the study period.

During the fall of 1991, a remote sensing and image processing study was performed for the area of the sewage lagoons. Aerial photographs revealed an area of dark tone and rough texture located at the southeast corner of the ponds, which implied some leakage in that direction. The regional groundwater flow is directed toward the northwest (USGS survey, 1964); however, micro-relief near the surface could alter the leakage flow. A narrow line of lightly-toned area extends from the dark corner toward the west until it joins another area of the same texture and tone with a rectangular shape. This stood out as an irregular vegetation pattern from the regular desert vegetation in the area. A land-verification field trip revealed that the narrow line and the suspected rectangular area was cleared of bushes. The difference in tone and texture for that area was from the recovering grass that grew after the clearing process. The dark, more densely textured corner was further examined in the November 19, 1987 photo. The scales of the two pictures were different so AutoCAD software was used to digitize both photos and match the scale (Figure C-13). The size of this area of vegetative growth appeared to be larger in the later picture; however, this difference in area was not conclusive evidence of contaminant leakage because it might have been due to changes in seasonality and the response of weeds to the hydrological conditions in the area.

A satellite image of the area was obtained from the digital lab of New Mexico State University's Earth Science Department. The scene was loaded and saved as an image file that could be processed by the computer package ERDAS. The Normalized Difference Vegetation Index, NDVI, was calculated for each pixel within the area of study. The NDVI indicates vegetation density and plant growth activity, which helps identify plant types. The vegetation absorbs visible energy for photosynthesis, and mesophile in the plants' leaves reflects near infrared radiation (NIR). Therefore, actively growing plants absorb more visible energy and reflect more NIR. The form of the vegetation index is as follows:

$$NDVI = \frac{NIR - R}{NIR + R}$$

where NIR is near infrared intensity and R is red intensity.

The index was normalized, allowing it to be used for a base comparison between the different areas. Unsupervised classification of vegetation was done using ERDAS for the area of study, with fifty different classes being defined. These classes were then grouped manually (Figure C-12).

The digitized maps that contained the suspected area of leakage were transferred to ERDAS format and used as the base in a comparison with the NDVI file. The autocad file was exported to a DXF file format, which is an acceptable format for ERDAS. The file was then imported to ERDAS. The modeling capabilities in the ERDAS software package were used to search for similarities and to compare the NDVI file with three different base maps. The first base map was constructed with the lagoons system at its origin point, and concentric circles were developed from that center point out to thirty pixels away from the system. Then a summary file was generated to show the characteristics of the NDVI values in these circles. It provided information through histograms of the NDVI values within the circles. Figure C-14 shows the maximum NDVI value for each circle, the average, and the standard deviation. The second map was similar to the first, except that the northwest part of the file was excluded in an attempt to have half circles that represented only the suspected corner. Again, the maximum and average values and the standard deviation were graphed for each circle (Figure C-15). The third base file was constructed using the transformed AutoCAD file after classification of the area. The histograms of the NDVI values in the suspected area of leakage, in an adjacent arroyo, and in the surrounding desert were graphed (Figure C-17).

Tests for BOD_5 and for nitrogen content of the wastewater were conducted several times throughout the study period.

One of the major planned sampling activities was to be core sampling to a depth of 100 feet in several locations to characterize the spread of nutrients from the lagoons into the underlying soil. However, after one hole was drilled in the empty cell, the drill rig was heavily damaged by vandalism. The damage included cut wires and hoses, bullet holes in the engine and other critical parts of the vehicle, and theft of sampling equipment. This brought all drilling activities to an immediate halt, and the financial burden of repairing the rig limited the further work on the project.

From the one hole that was drilled, soil samples were collected from various depths and analyzed for particle size distribution using standard sieve and hydrometer tests.

The investigation of potential nitrate contamination of groundwater due to the sewage lagoons was divided into three sections. First, the nitrate concentration and volume of wastewater leaching from any lagoon into the underlying soil was estimated. Second, a one-dimensional, unsaturated hydraulic flow model was used to estimate the time necessary for the wastewater to reach the groundwater table. Finally, a two-dimensional groundwater transport model was used to predict the direction of movement of contaminated water if it reached the aquifer.

Because of the loss of the drill rig, approximations and literature reviews were used extensively. No laboratory or field tests were performed for estimating parameters. Model parameters were chosen as carefully as possible under these conditions. All assumptions, approximations, and appeals to "typical values" are noted with our calculations.

Sewage lagoons employed by rural housing developments and small municipalities in New Mexico are usually aerobic, raw (single) or primary and secondary (two) cell systems that rely on photosynthetic and atmospheric aeration. This is the type of system that was modeled for this project. The sewage lagoon system at Mesa Village is composed of four individual cells with dimensions as shown in Figure C-1. The steady state depth of wastewater was assumed to be two feet in three of the cells. The other cell was unused and represent future capacity should the housing development expand in the future. In the case of the total neglect of the lagoons' upkeep and management, the liner could eventually become breached and no longer prevent infiltration of wastewater into the soil. Because of the danger of groundwater contamination due to seepage from the sewage lagoons, the worst-case scenario was assumed. To maintain mass balance, the volume of water leaching into the soil must be equal to the volume of water entering the lagoon minus the amount of water evaporated from the lagoon. The average daily wastewater flow from a typical residential area is approximately 45 gpcd. This value varies considerably from one residential area to another but is typically no greater than 60 gpcd and seldom exceeds 75 gpcd. See the attached summary tables of average daily residential wastewater flows, obtained from EPA's "Design Manual, Onsite Wastewater Treatment and Disposal Systems," (1980). It was assumed that the lagoon was utilized by 30 households with an average of four residents per household. The inflow volume was, therefore, estimated as:

$$V_{inflow} = 30 \text{ houses} * 4 \text{ residents/house} * 45 \text{ gpcd}$$
$$= 5{,}400 \text{ gpd}$$

To estimate the volume of wastewater that evaporated from the lagoon, the surface area of the lagoon was estimated. Assuming a side slope of 1:1.5 and a depth of two feet of wastewater in each cell:

Surface Length	= (2 ft * 1.5) * 2 + 80 ft	= 86 ft
Surface Width	= (2 ft * 1.5) * 2 + 60 ft	= 66 ft
Surface Area/Cell	= 86 ft * 66 ft	= 5,676 sq ft
Total Surface Area of Three Cells		= 17,028 sq ft

According to the NMED, the net evaporation for a body of water in the Las Cruces area is 72 inches per year. This is equivalent to 0.0164 feet per day. Using this value, the evaporation volume can be obtained:

$$V_{evap} = 17{,}028 \text{ sq ft} * 0.0164 \text{ ft/day}$$
$$= 279 \text{ cubic ft/day}$$
$$= 2090 \text{ gpd}$$

The volume of water that infiltrates into the soil from the lagoon was, therefore, estimated as

$$V_{infil} = V_{inflow} - V_{evap}$$

= 5,400 gal/day - 2090 gal/day

= 3311 gal/day (from 3 cells)

Concentration of Nitrogen in the Lagoon

To estimate the nitrogen concentration of the wastewater in the lagoon, the detention time of water in the lagoon must first be known. To accomplish this, the steady state volume in the lagoon was first estimated:

Volume/Cell = 1/2 * (A_1 + A_2) * Depth

where

- A_1 = Top Surface Area = 5,676 sq ft/cell
- A_2 = Bottom Surface Area = 80 ft * 60 ft = 4,800 sq ft/cell
- Depth = 2 ft

Therefore, the steady state volume is

Volume = 10,476 cubic ft/cell

= 78,360 gal/cell

= 156,720 gal

Then the time necessary to fill this volume with a flow rate equal to that of the inflow is calculated. This value is used to estimate the time needed for a complete "turn over" of the wastewater in the lagoon. This value is referred to as the detention time for the lagoon.

Approximate Detention Time = Volume / Q_{inflow}

= 78,360 gal / 5,400 gal/day

= 29 days

With this value for the detention period, the steady-state concentration of nitrogen in the lagoon was estimated:

$$\ln (C_o/C_e) = -k * \text{Detention Time}$$

where,
- C_o = Influent Concentration
- C_e = Effluent Concentration
- k = nitrogen decay rate in sewage lagoons

Following EPA estimates, the influent concentration was approximately 100 mg/l (100 ppm) and the decay rate was approximately 0.0129. The nitrogen concentration was estimated as

$$C_e = C_o^{-k*DT} = 100\ e^{-0.0129 * 29} = 69 \text{ ppm}$$

The fourth and final phase of the study consisted of installing a liner and an aeration system in the southeast pond. This system was meant to be included in the initial construction of the sewage lagoons system but was not implemented until the spring of 1992. Students and faculty from the Department of Civil, Agricultural, and Geological Engineering spread the liner in the lagoon, and some students assisted in the installation of the aeration system.

RESULTS

Raw data from the various analyses are included in the appendices, with Lyons Country ET Bed in appendices A and B and Mesa Village Lagoons in appendices C and D.

Lyons Country ET Bed

The ET bed clearly ceased to function as intended. The ponded effluent and seepage from the edges pose a health risk to nearby residents. The positive fecal coliform test from the ponded effluent indicates that pathogenic organisms are a present hazard. Dog and cat tracks around the site showed that pets from the nearby houses enter the effluent, and may track pathogens back to the residents. Joggers frequently run the perimeter, and may risk exposure as well.

The high concentrations of nitrogen (TKN) in the soil samples from the monitoring well drilling indicate that a great deal of nitrogen is available for nitrate formation. While we were unable to drill additional holes further down dip, it is very likely that nitrate was being formed and transported to the regional groundwater. Several domestic wells in the area could be affected in the long-term. Water samples from the monitoring wells did not show elevated concentrations of nitrogen or nitrate. The difference between the soil and water samples is perplexing. One possibility is that since the water samples were stored for a month or more before testing, the results may be invalid.

The results of the Lyons Country Estates study are:

1. During the winter months, the ponded effluent in the bed rose to a level within two inches of the top of the berm around the bed. If it overtops the berm, it will wash out the side, and dump about one acre-foot of effluent into the lower lying areas. TDS raised the berms and began draining effluent into the overflow basin, where it infiltrates. This operation may contain and lower the ponding, but a permanent solution will require taking the ET bed out of service. A replacement treatment system will be necessary. TDS is pursuing funding for a constructed wetland as well as a forced-main hook-up to the City of Las Cruces water treatment facility.
2. It is likely that the soil and aquifer around the ET bed are contaminated with nitrogen that may be converted to nitrate. Cleanup is not economically feasible. The logical approach is to eliminate further contamination by shutting down the ET bed.

3. Any system will require regular maintenance. Examination of the solids chamber on the existing septic tank showed that it had not been cleaned out for years. The chamber was completely full, with only four inches of freeboard below the manhole cover. TDS has since cleaned it out. A mat of dead vegetation, primarily cattails, now covers the surface of the bed, reducing free surface evaporation from the ponded effluent. If a constructed wetland is built as a replacement, it must be maintained better than the ET bed was, or irreversible damage may occur, as it did with the ET bed.
4. The ET bed design guidelines used for the construction at Lyons Country Estates are inadequate. If NMED's guidelines were used to handle 300 gpd from 38 units and assuming 72 inches of net ET, the area of the bed should have been 61,908 square feet, roughly 50% larger than the one built. Even if these guidelines were followed, the volume balance calculation indicates that the area would still be inadequate for wintertime flows.

An examination of ET versus inflow explains why the ET bed failed and raises serious questions about the suitability of ET beds for New Mexico's climate. According to the design assumptions for the Lyons Country ET bed, the average ET rate in the area varies from about 2 mm/day in December to 11.4 mm/day in June. Inflow of sewage effluent is essentially constant throughout the year, so a simple mass balance suggests that if the system is designed to match inflow with ET rate in June, the inflow in December will be nearly six times the ET, causing ponding or spilling of effluent and die-off of the vegetation. If the bed is sized for December ET, the vegetation will require additional irrigation in June. Design considerations need to include consideration of seasonal variation in ET, and some assurance that the vegetation on the bed will be kept alive and functioning. Recommendations for improved design procedures and criteria can be seen in Hazem Fahmy's Master's thesis, completed during the summer of 1992 (Fahmy, 1992).

Mesa Village Lagoons

The Mesa Village Lagoon system was not constructed as designed and approved, yet it is unlikely that it was a hazard to local groundwater. Underlying layers containing significant clay, shown in the particle size distribution curves in figures C-5 through C-8, and caliche inhibited vertical infiltration of effluent. The unlined ponds probably sealed themselves, as lagoons are known to do, further reducing infiltration. USGS well logs indicated that groundwater is at a depth of 350 to 500 feet, so it would be some time before the contaminated water could reach the aquifer. Unfortunately, vandalism of the drill rig prevented positive proof of this hypothesis.

Satellite image analysis showed a significantly higher level of plant vigor in the vicinity of the lagoon system. While the evidence is not conclusive, the seepage from the lagoons may have been moving laterally rather than vertically, and the native plants in the area were utilizing the nutrients and water.

This suggests an interesting concept for an effluent disposal system. Many desert plants, such as mesquite and creosote, are deeply rooted and drought tolerant. If effluent were applied to desert vegetation, the deep root zone would provide a great deal of storage capacity for the winter months when ET is low, and the plants would not die off or require irrigation during the summer when ET is high. The weaknesses of ET beds identified in the study of Lyons Country Estates would not be a problem with such a system. This "dryland" system needs further research and development, and would probably be applicable to a limited number of sites, with a deep vadose zone and a large available area.

CONCLUSIONS

The work completed concerning the ET bed and sewage lagoons wastewater treatment systems of Lyons Country and Mesa Village estates provided an insight into the strengths and weaknesses of these systems. The information collected here will provide the basis for decisions relating to the future use of these systems in arid climates. The following conclusions are drawn from this work and can be applied in the future:

1. ET beds in New Mexico have an inherent weakness: the large variation in ET during the year makes them poorly suited to handle a constant inflow. If they are designed for winter ET rates, they will dry out in summer. If they are designed for summer ET rates, they saturate and pond in winter. If they are designed for annual average ET rates, they may do both. Either failure mode is irreversible since die-off of vegetation drastically reduces ET.

2. The existing ET bed is an immediate as well as long-term health hazard. A positive fecal coliform test indicates the presence of pathogens such as typhoid, cholera, hepatitis. Houses are within a few hundred feet of the ET bed, and residents are at risk of exposure to disease. Nitrogen compounds are present at very elevated levels in the soil outside the ET bed. The potential for nitrate contamination of regional groundwater is a long-term threat.

3. The ET bed should be replaced, either with an effective on-site treatment facility or a hook-up to the City of Las Cruces water treatment plant. If an on-site system is used, it must be properly operated and maintained.

4. While the Mesa Village lagoon was in gross violation of NMED regulations and design requirements, it is unlikely that contamination of regional groundwater occurred. The area's soil and the sealing action of the lagoon limited infiltration from the unlined ponds, and the groundwater is 350 to 500 feet deep. Unsaturated flow modeling suggests that it would take many years for contaminated water to reach the groundwater. Some water and

nutrients were taken up by local vegetation.

5. The project involved a great deal of interaction with site owners and NMED. This type of applied research can serve as a model for university assistance to regulatory agencies and on-site system owners who often lack the resources or expertise to assess environmental damage and remediation options.

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APPENDICES

LIST OF FIGURES AND TABLES

Appendix A contains all of the figures for the study of the Lyon's Country ET bed. All tables in Appendix B refer to the Lyon's Country study, also. The figures and tables for the Mesa Village lagoons study are located in Appendices C and D, respectively.

Figures for Lyon's Country Study

Tables for Lyon's Country Study

Figures for Mesa Village Study

Tables for Mesa Village Study

APPENDIX A

Fig. A-1
Topography & Monitoring Well Locations

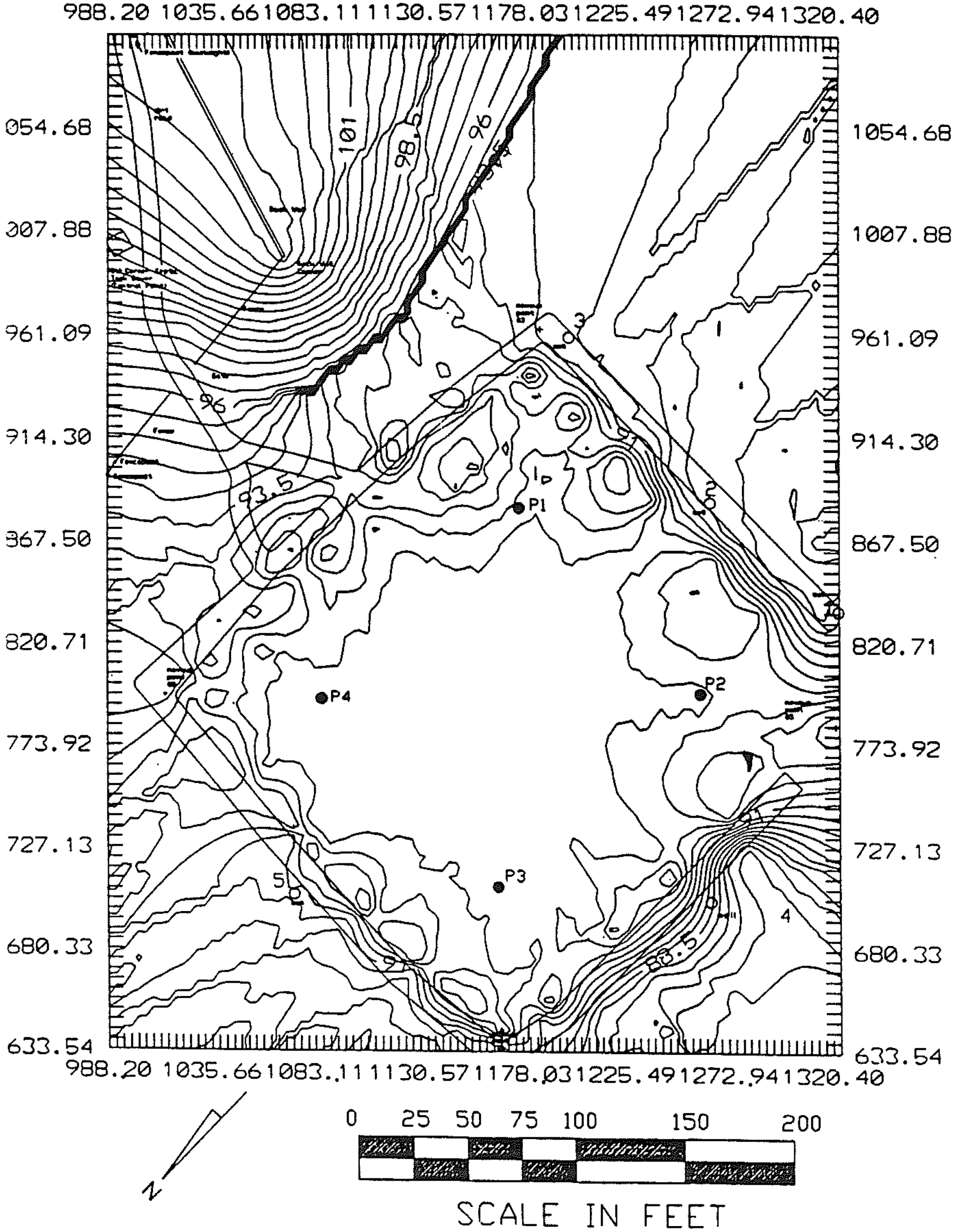


Figure A-2

Lyon's ET Bed Sieve Tests

East Side

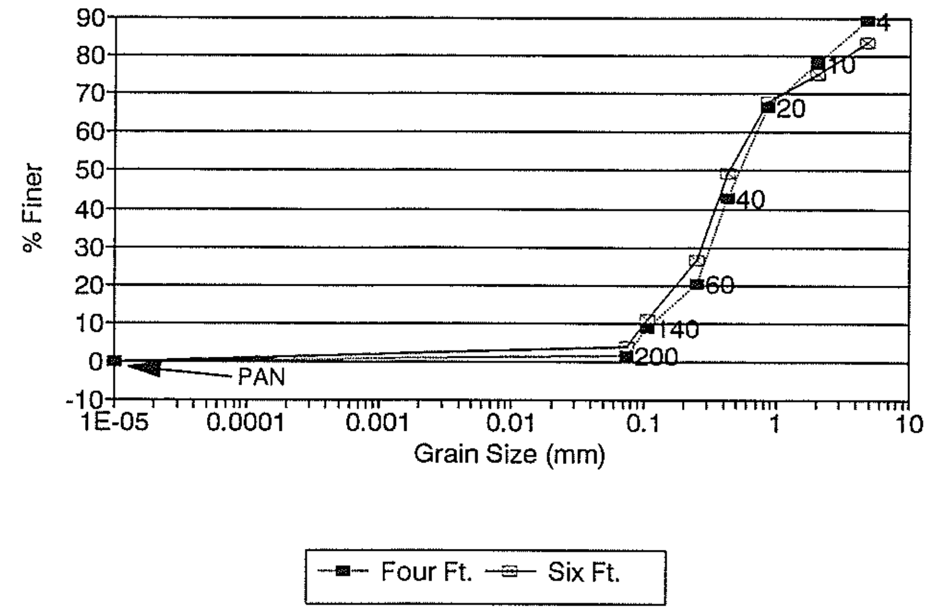


Figure A-3

Lyon's ET Bed Sieve Tests

West Side

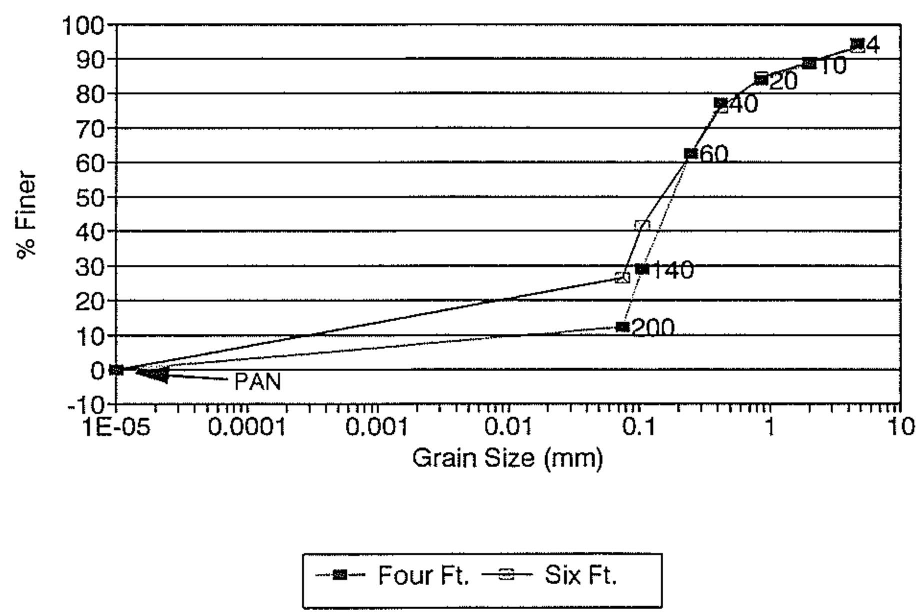


Figure A-4

Lyon's ET Bed Sieve Tests

North Side

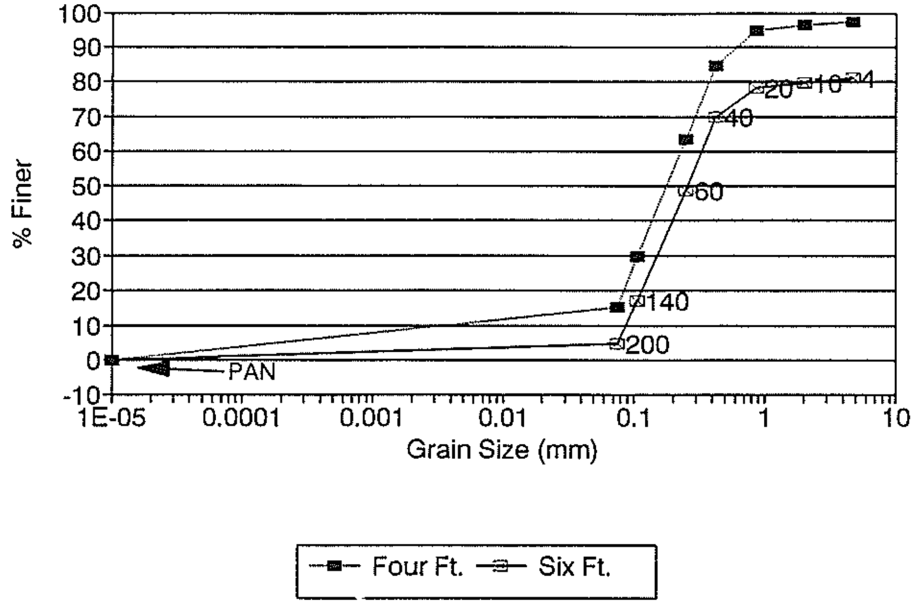


Figure A-5

Lyon's ET Bed Sieve Tests

South Side

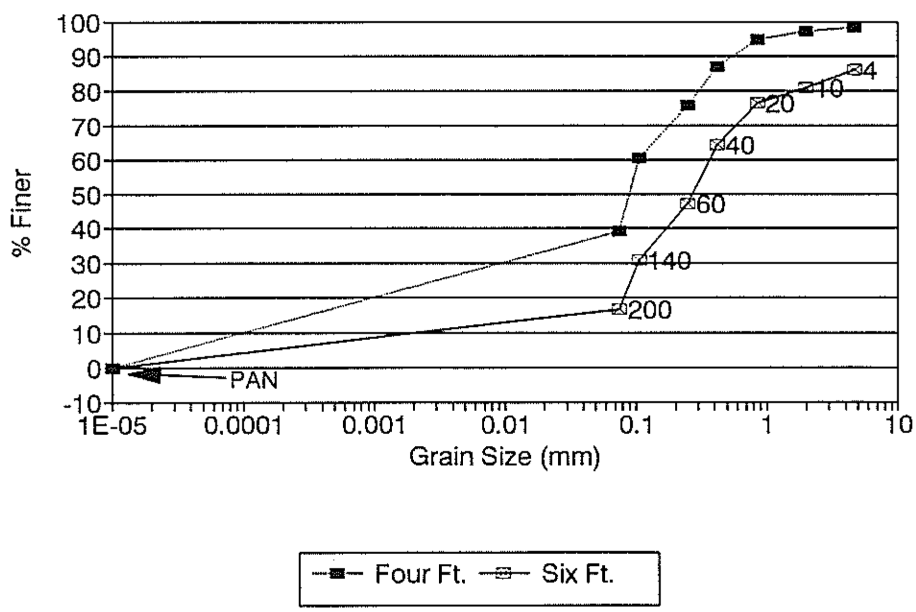


Figure A-6

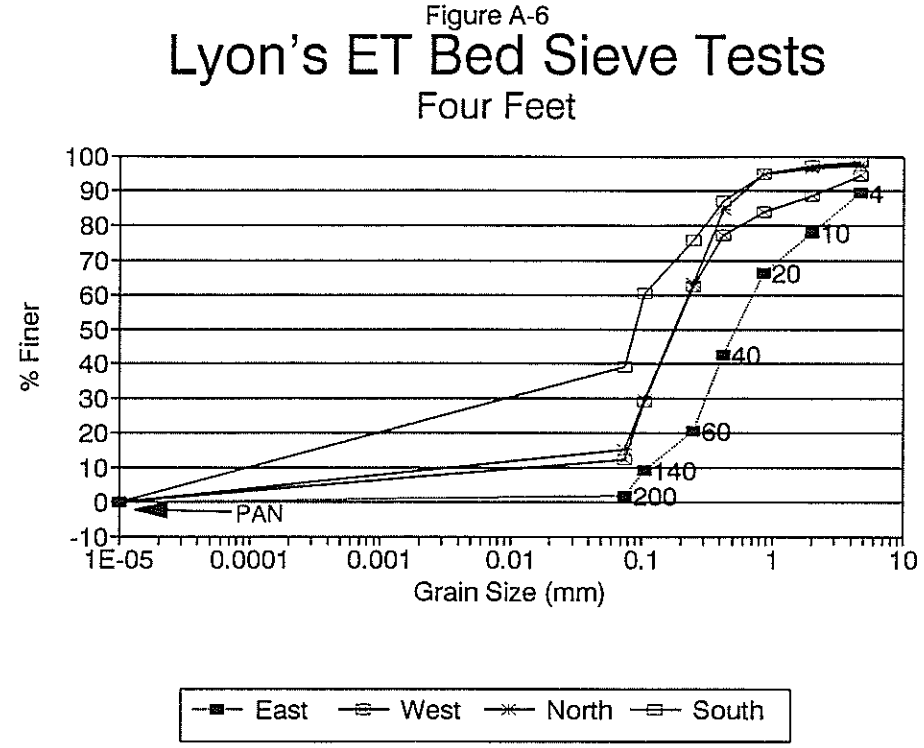


Figure A-7

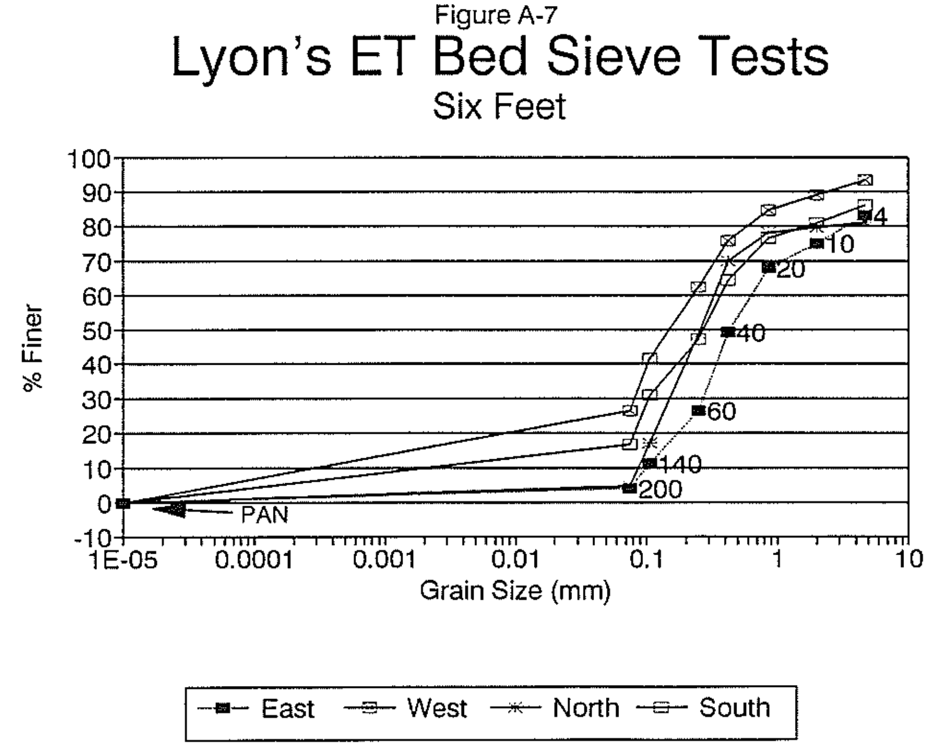


Figure A-8

Lyon's Country Well #1
Depth: 5 FT.

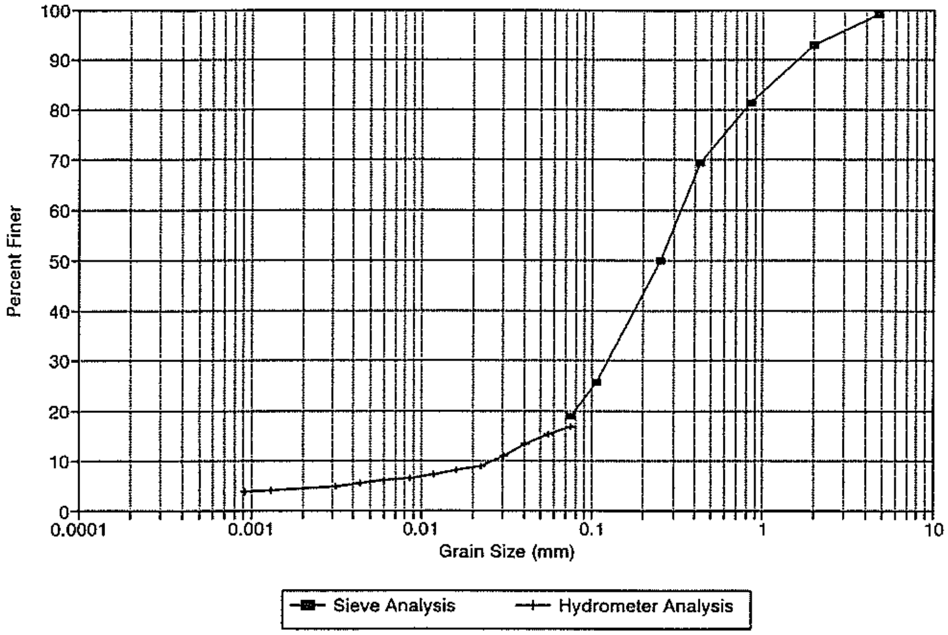


Figure A-9

Lyon's Country Well #2
Depth: 5 feet

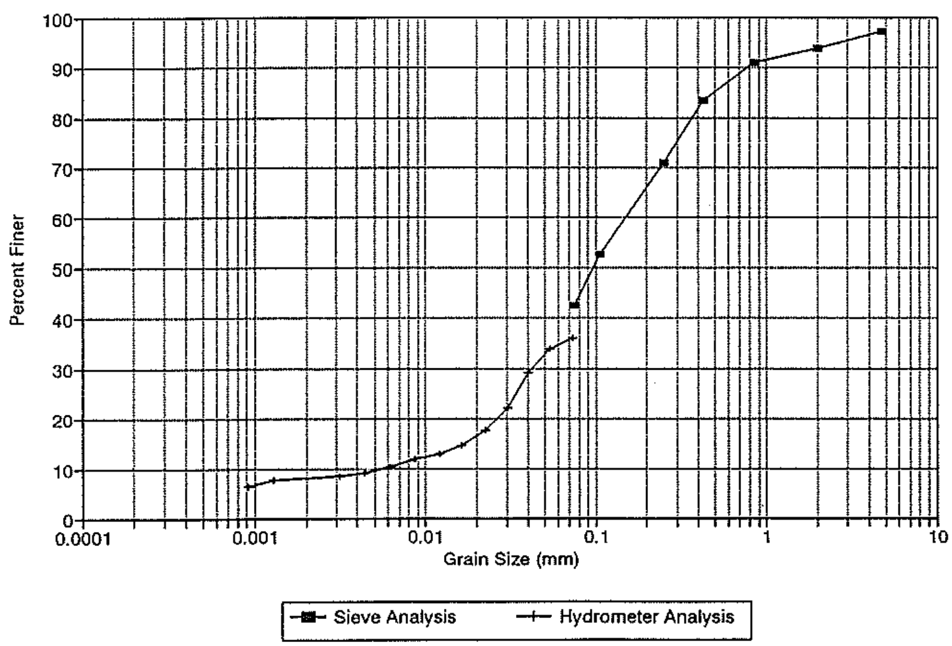


Figure A-10

Lyon's Country Well #2
Depth: 15 feet

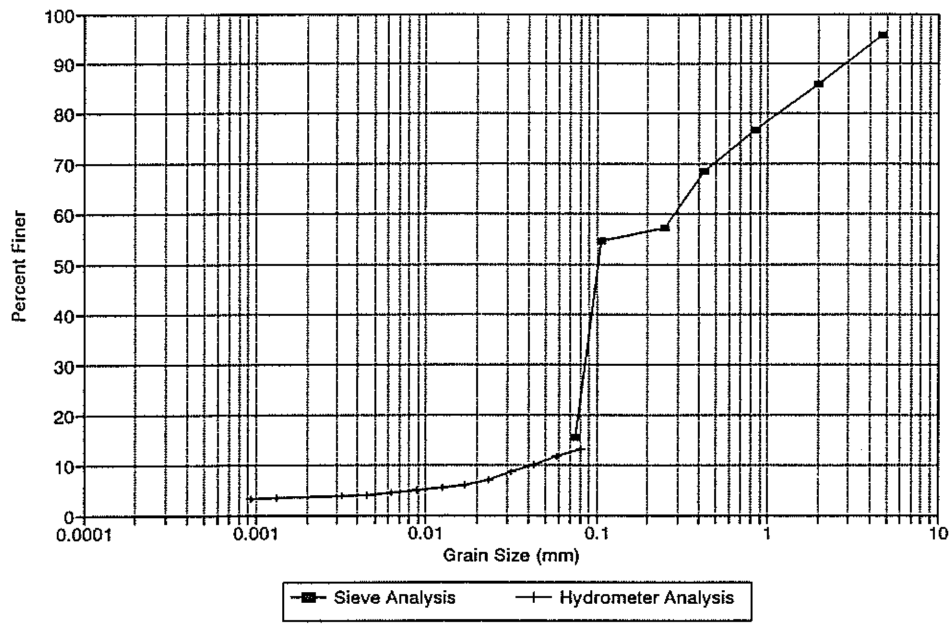


Figure A-11

Lyon's Country Well #3
Depth: 5 feet

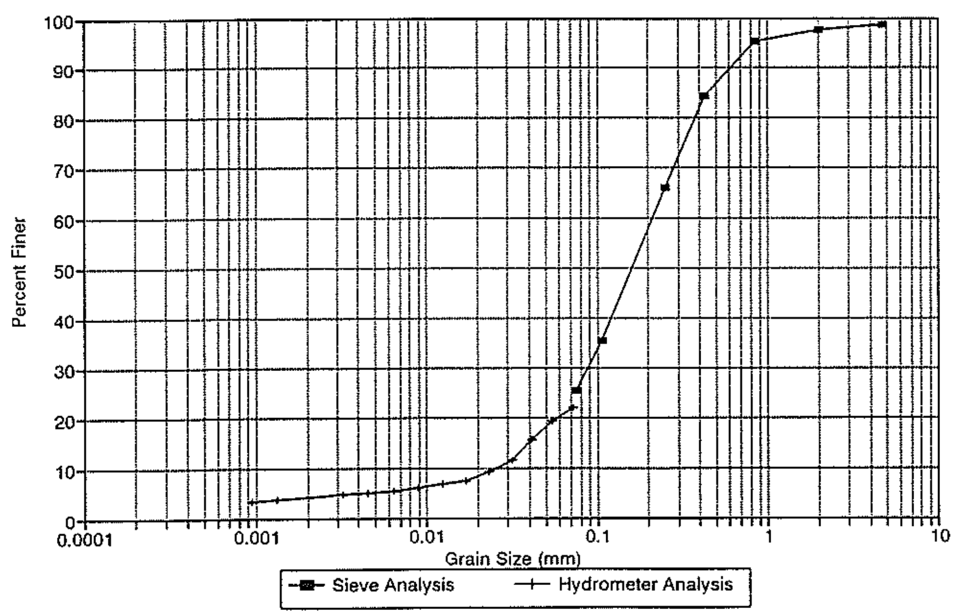


Figure A-12

Lyon's Country Well #3
Depth: 10 feet

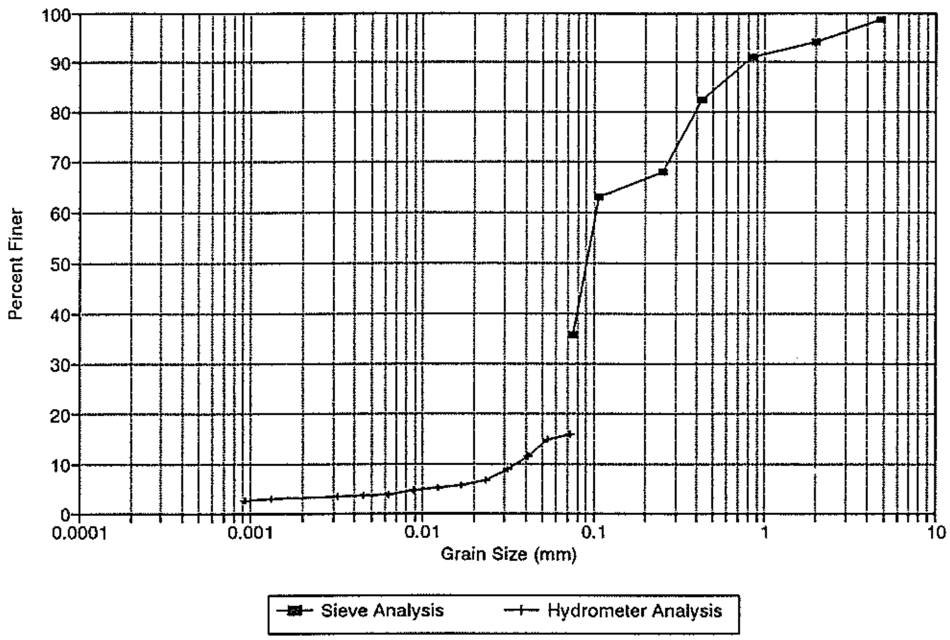


Figure A-13

Lyon's Country Well #3
Depth: 15 feet

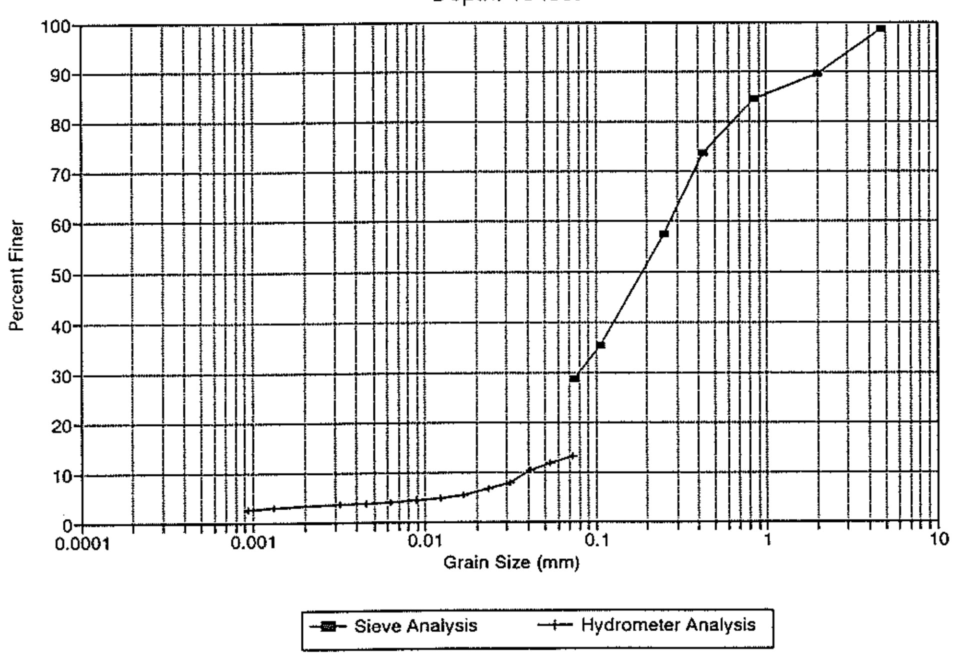


Figure A-14
Lyon's Country Well #3
Depth: 20 feet

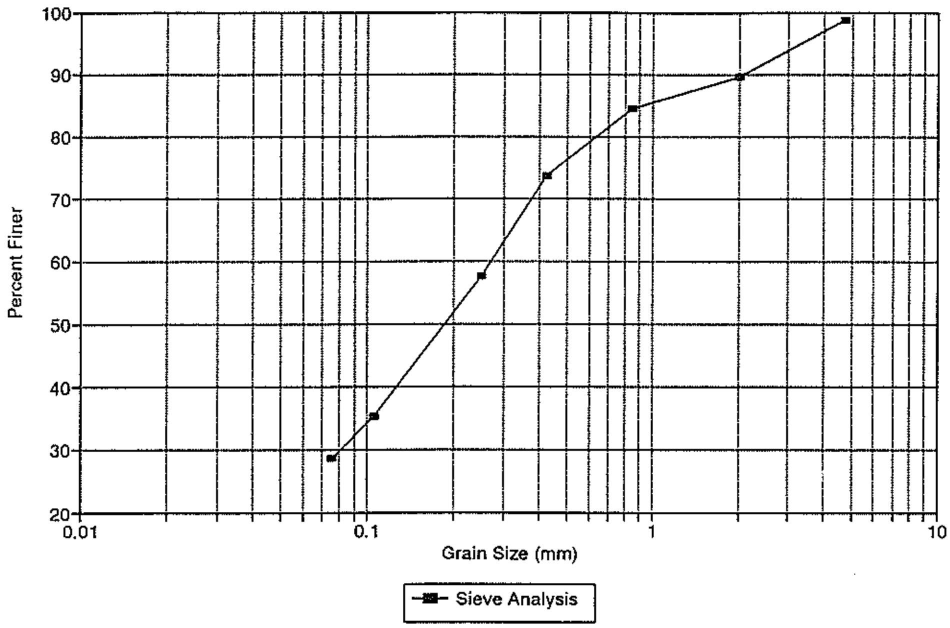


Figure A-15
Lyon's Country Well #3
Depth: 25 feet

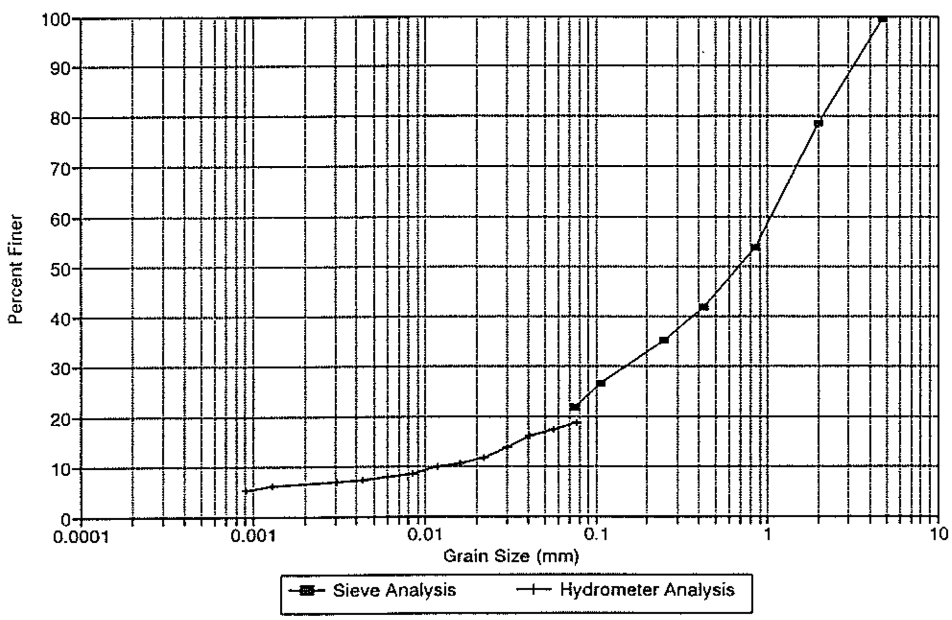


Figure A-16

Lyon's Country Well #3
Depth: 30 feet

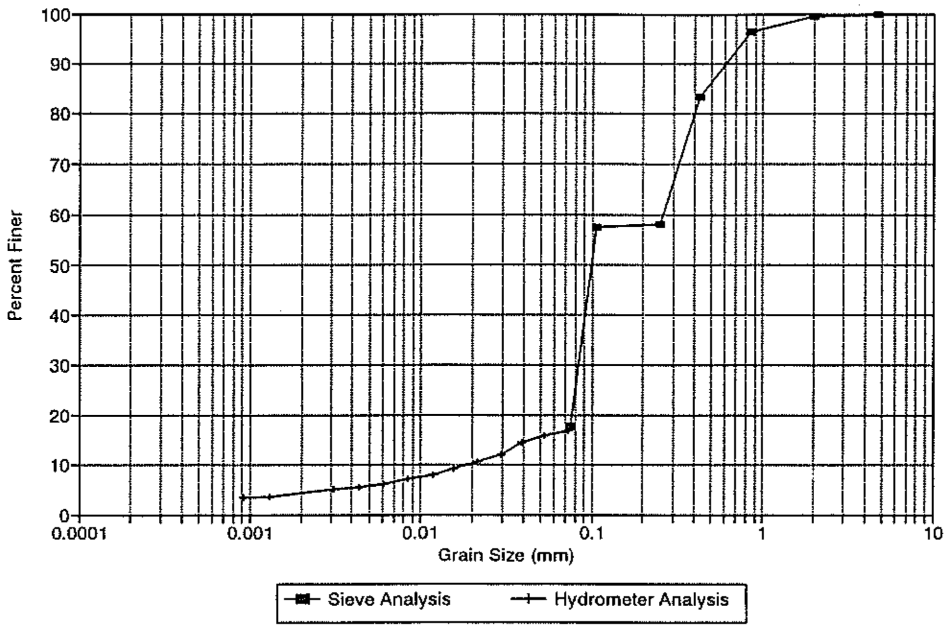


Figure A-17

Lyon's Country Well #4
Depth: 10 feet

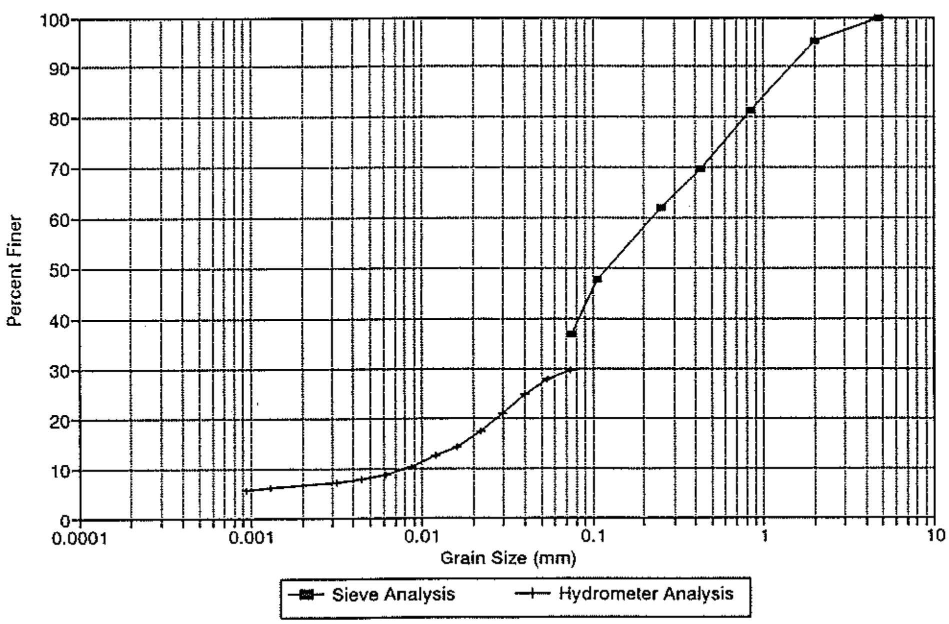


Figure A-18
Lyon's Country Well #4
Depth: 15 feet

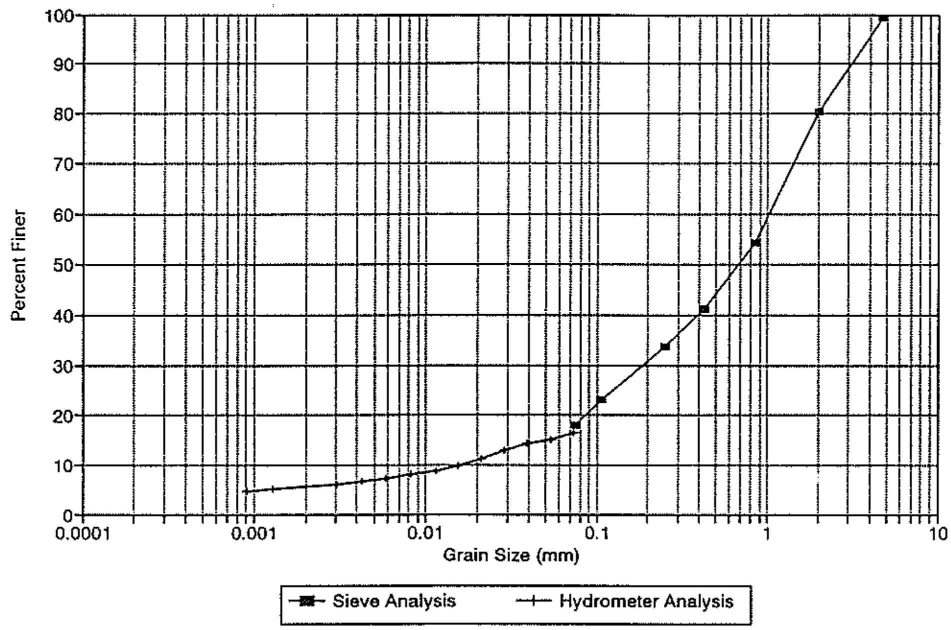


Figure A-19
Lyon's Country Well #4
Depth: 20 ft

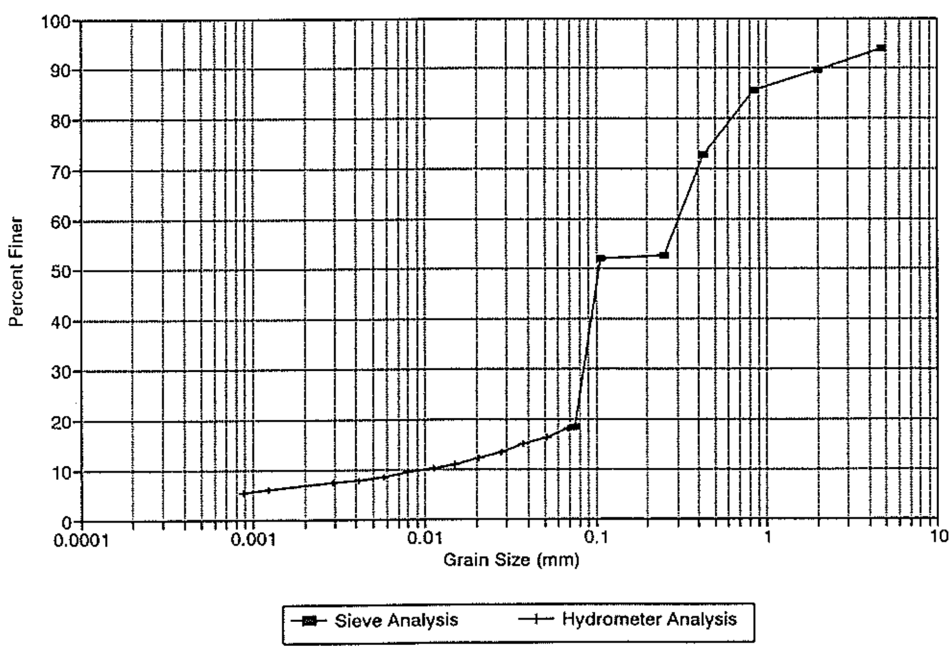


Figure A-20

Lyon's Country Well #4
Depth: 30 feet

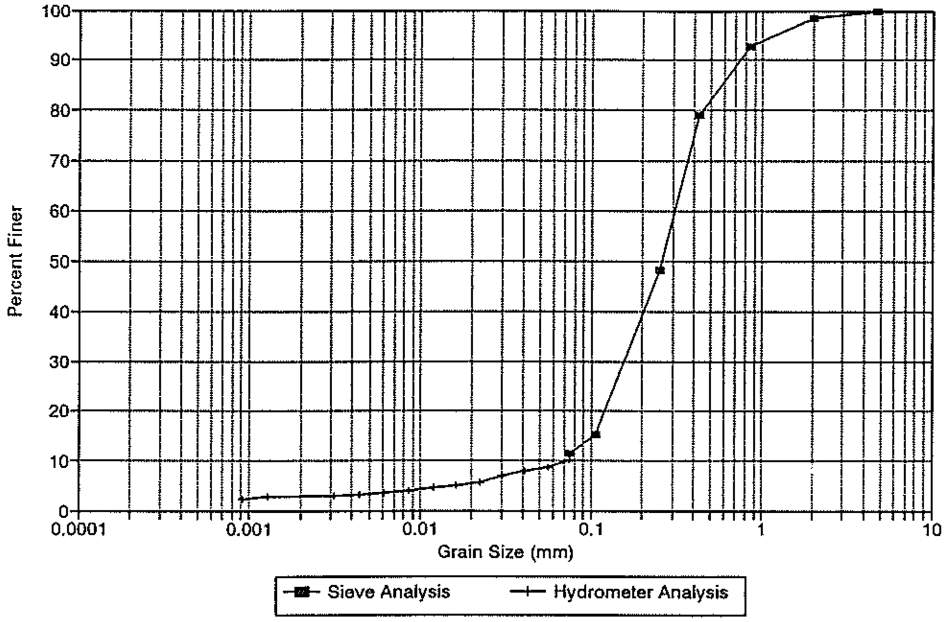


Figure A-21

Lyon's Country Well #5
Depth: 5 feet

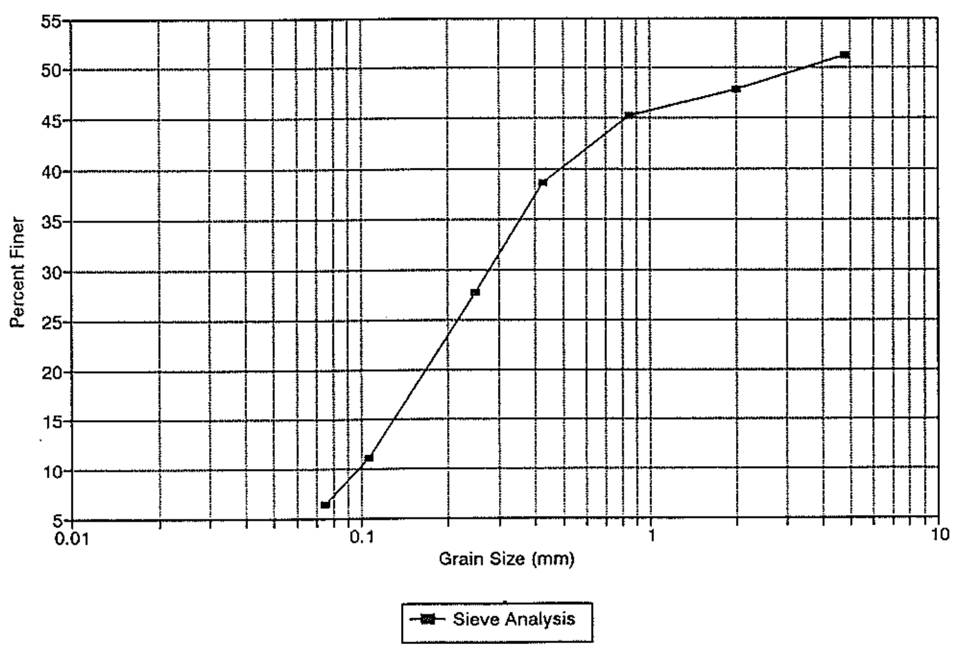


Figure A-22

Lyon's Country Well #5
Depth: 10 feet

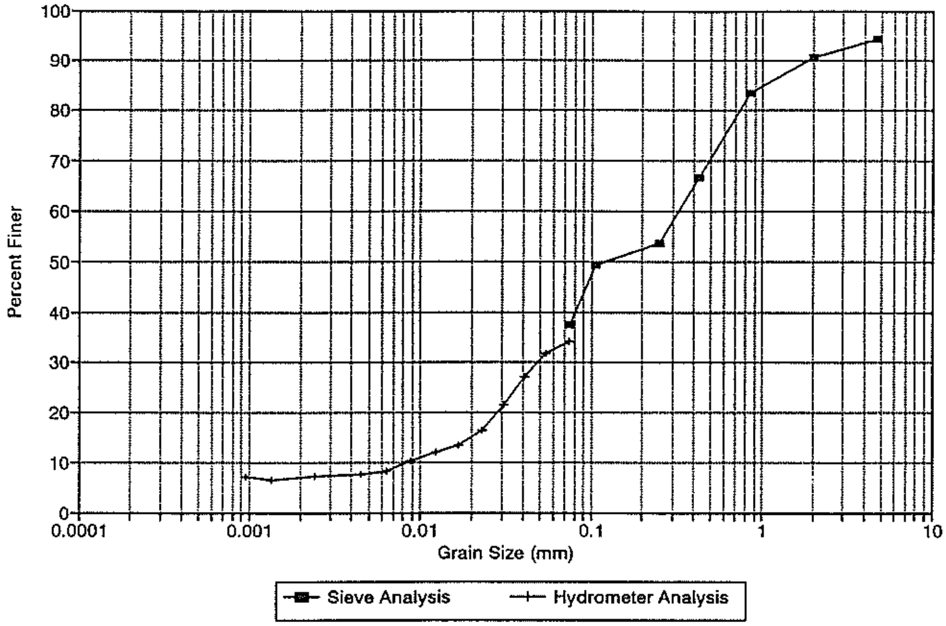


Figure A-23

Lyon's Country Well #5
Depth: 15 feet

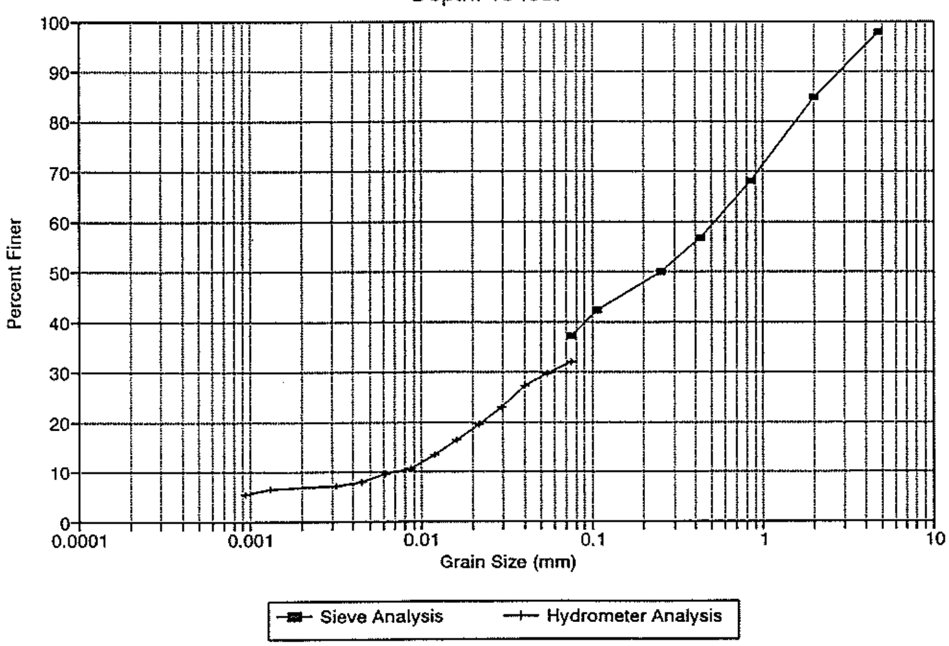


Figure A-24

Lyon's Country Well #5
Depth: 25 feet

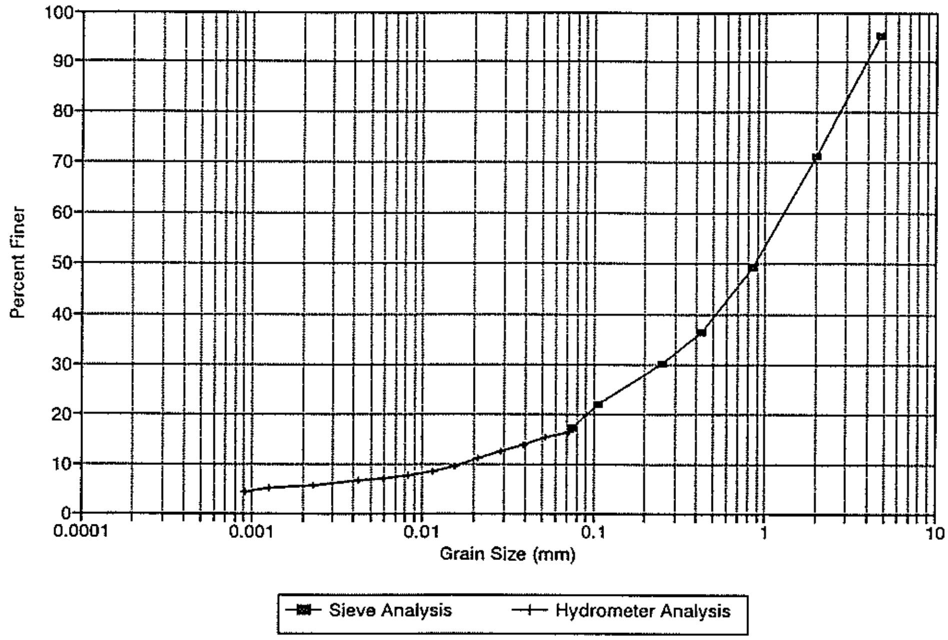
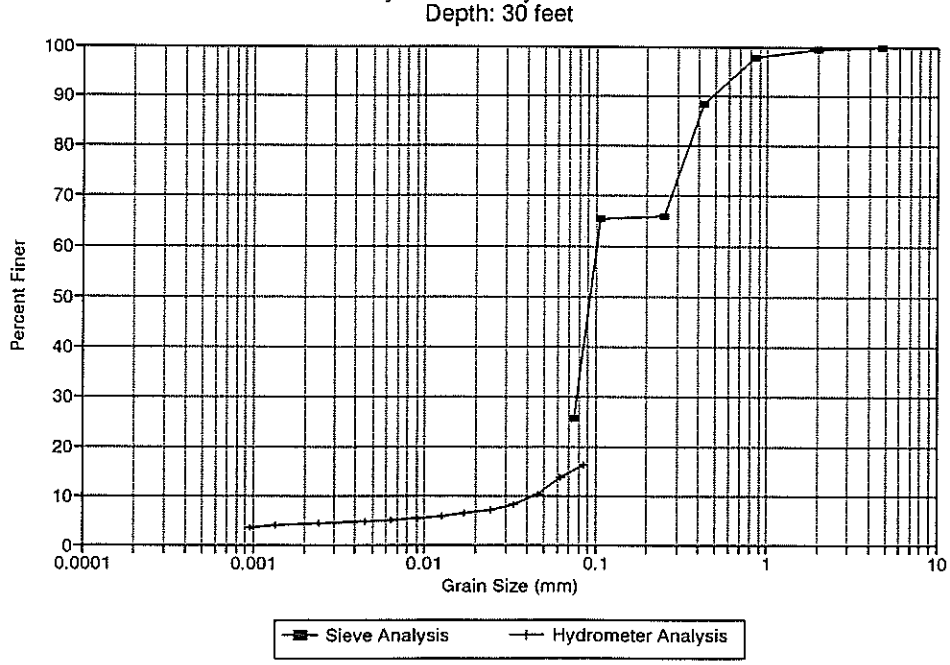


Figure A-25

Lyon's Country Well #5
Depth: 30 feet



APPENDIX B

Table B-1

Lyon's East 4ft.
Sample Date: 7/10/91

Pan + Sample:	1078
Empty Pan:	87
Sample Wt.:	991

Open mm:	Sieve #:	Sieve + Sample:	Empty Sieve:	Tentative Sample Wt:	Final Sample Wt:	Percent Retained:	Percent Finer:
4.75	4	719.6	616.2	103.4	103.4	10.61929	89.38071
2	10	595.5	483.8	111.7	111.7	11.47171	77.90901
0.85	20	588.3	478	110.3	110.3	11.32792	66.58108
0.425	40	739.6	508.1	231.5	231.5	23.77529	42.80579
0.25	60	597.4	381	216.4	216.4	22.2245	20.58129
0.106	140	520	407.2	112.8	112.8	11.58468	8.996611
0.075	200	438.3	358.9	79.4	72.3	7.425285	1.571326
1E-05	Pan:	405.5	397.3	8.2	15.3	1.571326	2.04E-14
					973.7		

Weight of Evap. Dish:	166.6
Weight of E. Dish and Sample:	238.9
Weight of Sample:	72.3
Weight Lost in Cleaning Sieve #200:	7.1

Table B-2

Lyon's East 6ft.
Sample Date: 7/10/91

Pan + Sample:	1419
Empty Pan:	88.3
Sample Wt.:	1330.7

Open mm:	Sieve #:	Sieve + Sample:	Empty Sieve:	Tentative Sample Wt:	Final Sample Wt:	Percent Retained:	Percent Finer:
4.75	4	834.4	616.2	218.2	218.2	16.63363	83.36637
2	10	592.3	483.8	108.5	108.5	8.271078	75.09529
0.85	20	572.1	478	94.1	94.1	7.17335	67.92194
0.425	40	753.4	508.1	245.3	245.3	18.6995	49.22244
0.25	60	676.9	381	295.9	295.9	22.55679	26.66565
0.106	140	609.9	407.2	202.7	202.7	15.45205	11.2136
0.075	200	454.8	351.8	103	92.4	7.043757	4.169843
1E-05	Pan:	441.4	397.3	44.1	54.7	4.169843	-9.8E-15
					1311.8		

Weight of Evap. Dish:	161
Weight of E. Dish and Sample:	253.4
Weight of Sample:	92.4
Weight Lost in Cleaning Sieve #200:	10.6

Table B-3

Lyon's West 4ft.
Sample Date: 7/11/91

Pan + Sample:	994.7
Empty Pan:	90.8
Sample Wt.:	903.9

Open mm:	Sieve #:	Sieve + Sample:	Empty Sieve:	Tentative Sample Wt:	Final Sample Wt:	Percent Retained:	Percent Finer:
4.75	4	665.7	616.2	49.5	49.5	5.595749	94.40425
2	10	535.1	483.8	51.3	51.3	5.799231	88.60502
0.85	20	521	478	43	43	4.860954	83.74407
0.425	40	565.6	508.1	57.5	57.5	6.500113	77.24395
0.25	60	510.1	381	129.1	129.1	14.59417	62.64979
0.106	140	702.6	407.2	295.4	295.4	33.39362	29.25616
0.075	200	519.6	358.9	160.7	150.5	17.01334	12.24282
1E-05	Pan:	495.4	397.3	98.1	108.3	12.24282	-1.8E-15
					884.6		

Weight of Evap. Dish:	169.6
Weight of E. Dish and Sample:	320.1
Weight of Sample:	150.5
Weight Lost in Cleaning Sieve #200:	10.2

Table B-4

Lyon's West 6ft.
Sample Date: 7/11/91

Pan + Sample:	910.6
Empty Pan:	88
Sample Wt.:	822.6

Open mm:	Sieve #:	Sieve + Sample:	Empty Sieve:	Tentative Sample Wt:	Final Sample Wt:	Percent Retained:	Percent Finer:
4.75	4	669.4	616.2	53.2	53.2	6.628458	93.37154
2	10	517.9	483.8	34.1	34.1	4.248692	89.12285
0.85	20	512.7	478	34.7	34.7	4.323449	84.7994
0.425	40	579.1	508.1	71	71	8.84625	75.95315
0.25	60	490.5	381	109.5	109.5	13.64316	62.30999
0.106	140	572.5	407.2	165.3	165.3	20.59556	41.71443
0.075	200	486.3	351.8	134.5	121.1	15.08846	26.62597
1E-05	Pan:	597.6	397.3	200.3	213.7	26.62597	-1.1E-14
					802.6		

Weight of Evap. Dish:	166.9
Weight of E. Dish and Sample:	288
Weight of Sample:	121.1
Weight Lost in Cleaning Sieve #200:	13.4

Table B-5

Lyon's North 4ft.
Sample Date: 7/11/91

Pan + Sample:	1174.9
Empty Pan:	87.1
Sample Wt.:	1087.8

Open mm:	Sieve #:	Sieve + Sample:	Empty Sieve:	Tentative Sample Wt:	Final Sample Wt:	Percent Retained:	Percent Finer:
4.75	4	644.4	616.2	28.2	28.2	2.639955	97.36004
2	10	493.1	483.8	9.3	9.3	0.870623	96.48942
0.85	20	497.1	478	19.1	19.1	1.788055	94.70137
0.425	40	613.1	508.1	105	105	9.82962	84.87175
0.25	60	610.4	381	229.4	229.4	21.47538	63.39637
0.106	140	767.9	407.2	360.7	360.7	33.76708	29.62928
0.075	200	511.2	351.8	159.4	151.7	14.20146	15.42782
1E-05	Pan:	554.4	397.3	157.1	164.8	15.42782	-8.9E-15
					1068.2		

Weight of Evap. Dish:	166.5
Weight of E. Dish and Sample:	318.2
Weight of Sample:	151.7
Weight Lost in Cleaning Sieve #200:	7.7

Table B-6

Lyon's North 6ft.
Sample Date: 7/11/91

Pan + Sample:	1044.9
Empty Pan:	88.2
Sample Wt.:	956.7

Open mm:	Sieve #:	Sieve + Sample:	Empty Sieve:	Tentative Sample Wt:	Final Sample Wt:	Percent Retained:	Percent Finer:
4.75	4	791.4	616.2	175.2	175.2	18.69797	81.30203
2	10	497.7	483.8	13.9	13.9	1.483458	79.81857
0.85	20	492.3	478	14.3	14.3	1.526147	78.29242
0.425	40	584.8	508.1	76.7	76.7	8.185699	70.10672
0.25	60	581.4	381	200.4	200.4	21.38741	48.71932
0.106	140	703.1	407.2	295.9	295.9	31.57951	17.13981
0.075	200	475	358.7	116.3	116.3	12.41195	4.727855
1E-05	Pan:	441.6	397.3	44.3	44.3	4.727855	1.24E-14
					937		

The amount of soil in #200 was so small that I didn't feel it was necessary to use the evaporation dish method.

Table B-7

Lyon's South 4ft.
Sample Date: 7/11/91

Pan + Sample:	861.1
Empty Pan:	90.7
Sample Wt.:	770.4

Open mm:	Sieve #:	Sieve + Sample:	Empty Sieve:	Tentative Sample Wt:	Final Sample Wt:	Percent Retained:	Percent Finer:
4.75	4	627.8	616.2	11.6	11.6	1.548525	98.45148
2	10	492.3	483.8	8.5	8.5	1.134695	97.31678
0.85	20	497.1	478	19.1	19.1	2.549726	94.76705
0.425	40	566.3	508.1	58.2	58.2	7.769323	86.99773
0.25	60	463.9	381	82.9	82.9	11.06661	75.93112
0.106	140	523.7	407.2	116.5	116.5	15.552	60.37912
0.075	200	524.2	358.7	165.5	158.2	21.11868	39.26045
1E-05	Pan:	684.1	397.3	286.8	294.1	39.26045	1.42E-14
					749.1		

Weight of Evap. Dish:	169.5
Weight of E. Dish and Sample:	327.7
Weight of Sample:	158.2
Weight Lost in Cleaning Sieve #200:	7.3

Table B-8

Lyon's South 6ft.
Sample Date: 7/11/91

Pan + Sample:	930.4
Empty Pan:	88
Sample Wt.:	842.4

Open mm:	Sieve #:	Sieve + Sample:	Empty Sieve:	Tentative Sample Wt:	Final Sample Wt:	Percent Retained:	Percent Finer:
4.75	4	729.8	616.2	113.6	113.6	13.84016	86.15984
2	10	526.4	483.8	42.6	42.6	5.190058	80.96979
0.85	20	513.6	478	35.6	35.6	4.337232	76.63255
0.425	40	608.1	508.1	100	100	12.18324	64.44932
0.25	60	523	381	142	142	17.30019	47.14912
0.106	140	539.8	407.2	132.6	132.6	16.15497	30.99415
0.075	200	481.8	358.9	122.9	118	14.37622	16.61793
1E-05	Pan:	528.8	397.3	131.5	136.4	16.61793	-1.1E-14
					820.8		

Weight of Evap. Dish:	166.8
Weight of E. Dish and Sample:	284.8
Weight of Sample:	118
Weight Lost in Cleaning Sieve #200:	4.9

Table B-9

Lyon's Country Well #1
Depth: 5ft

*NOTE: Moisture content test not performed on this sample.

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	3.50	0.84	0.84	99.16
10	2.00	25.90	6.22	7.06	92.94
20	0.85	47.70	11.46	18.52	81.48
40	0.43	50.50	12.13	30.66	69.34
60	0.25	80.10	19.25	49.90	50.10
140	0.11	101.60	24.41	74.32	25.68
200	0.08	28.20	6.78	81.09	18.91
Pan		78.70	18.91	100.00	
Sum		416.20			

Fz	5
Fm	1
Gs	2.7
Ws	50
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	49.00	23.50	1.03	45.03	89.05	50.00	8.14	0.0131	0.0745
0.5	44.50	23.50	1.03	40.53	80.15	45.50	8.88	0.0131	0.0550
1	40.00	23.50	1.03	36.03	71.25	41.00	9.61	0.0131	0.0405
2	33.50	23.50	1.03	29.53	58.39	34.50	10.67	0.0131	0.0301
4	28.00	23.50	1.03	24.03	47.52	29.00	11.57	0.0131	0.0222
8	25.50	23.50	1.03	21.53	42.57	26.50	11.98	0.0131	0.0160
15	23.50	23.50	1.03	19.53	38.62	24.50	12.31	0.0131	0.0118
30	21.00	23.50	1.03	17.03	33.67	22.00	12.72	0.0131	0.0085
60	20.00	23.50	1.03	16.03	31.69	21.00	12.88	0.0131	0.0060
120	19.00	22.00	0.65	14.65	28.97	20.00	13.04	0.0133	0.0044
240	17.00	22.00	0.65	12.65	25.02	18.00	13.37	0.0133	0.0031
1417	15.00	22.00	0.65	10.65	21.06	16.00	13.70	0.0133	0.0013
2857	14.50	22.00	0.65	10.15	20.07	15.50	13.78	0.0133	0.0009

Table B-10

Lyon's Country Well #2
Depth: 5ft

*NOTE: Moisture content test not performed on this sample.

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	8.30	2.72	2.72	97.28
10	2.00	9.80	3.22	5.94	94.06
20	0.85	9.20	3.02	8.96	91.04
40	0.43	22.60	7.42	16.38	83.62
60	0.25	38.30	12.57	28.96	71.04
140	0.11	56.30	18.48	47.44	52.56
200	0.08	30.70	10.08	57.52	42.48
Pan		129.40	42.48	100.00	
Sum		304.60			

Fz	5
Fm	1
Gs	2.7
Ws	54.5
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	51.00	23.00	0.90	46.90	85.10	52.00	7.81	0.0131	0.0732
0.5	48.00	23.00	0.90	43.90	79.66	49.00	8.30	0.0131	0.0534
1	42.00	23.00	0.90	37.90	68.77	43.00	9.28	0.0131	0.0399
2	33.00	23.00	0.90	28.90	52.44	34.00	10.75	0.0131	0.0304
4	27.00	23.00	0.90	22.90	41.55	28.00	11.73	0.0131	0.0224
8	23.00	23.00	0.90	18.90	34.29	24.00	12.39	0.0131	0.0163
15	21.00	23.00	0.90	16.90	30.67	22.00	12.72	0.0131	0.0121
30	19.50	23.00	0.90	15.40	27.94	20.50	12.96	0.0131	0.0086
60	17.50	23.00	0.90	13.40	24.31	18.50	13.29	0.0131	0.0062
120	16.00	23.00	0.90	11.90	21.59	17.00	13.53	0.0131	0.0044
240	15.00	23.00	0.90	10.90	19.78	16.00	13.70	0.0131	0.0031
1440	14.00	23.00	0.90	9.90	17.96	15.00	13.86	0.0131	0.0013
2880	12.50	23.00	0.90	8.40	15.24	13.50	14.10	0.0131	0.0009

Table B-11

Lyon's Country Well #2
Depth: 15ft

*NOTE: Moisture content test not performed on this sample.

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	12.70	4.15	4.15	95.85
10	2.00	30.30	9.91	14.07	85.93
20	0.85	27.80	9.09	23.16	76.84
40	0.43	25.90	8.47	31.63	68.37
60	0.25	34.40	11.25	42.89	57.11
140	0.11	7.60	2.49	45.37	54.63
200	0.08	119.80	39.19	84.56	15.44
Pan		47.20	15.44	100.00	
Sum		305.70			

Fz	5
Fm	1
Gs	2.7
Ws	47.1
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	45.00	21.50	0.53	40.53	85.09	46.00	8.79	0.0135	0.0801
0.5	41.00	21.50	0.53	36.53	76.69	42.00	9.45	0.0135	0.0587
1	36.00	21.50	0.53	31.53	66.19	37.00	10.26	0.0135	0.0433
2	31.00	21.50	0.53	26.53	55.69	32.00	11.08	0.0135	0.0318
4	26.00	21.50	0.53	21.53	45.19	27.00	11.90	0.0135	0.0233
8	23.00	21.50	0.53	18.53	38.89	24.00	12.39	0.0135	0.0168
15	21.00	21.50	0.53	16.53	34.70	22.00	12.72	0.0135	0.0124
30	20.00	21.50	0.53	15.53	32.60	21.00	12.88	0.0135	0.0088
60	18.00	21.50	0.53	13.53	28.40	19.00	13.21	0.0135	0.0063
120	17.00	21.50	0.53	12.53	26.30	18.00	13.37	0.0135	0.0045
240	16.00	21.50	0.53	11.53	24.20	17.00	13.53	0.0135	0.0032
1440	15.00	21.50	0.53	10.53	22.10	16.00	13.70	0.0135	0.0013
2880	14.00	21.50	0.53	9.53	20.00	15.00	13.86	0.0135	0.0009

Table B-12

Lyon's Country Well #3
Depth: 5ft

Weight of Wet Soil (g) 900.7
Weight of Dry Soil (g) 873

Moisture Content 0.03173

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	11.10	1.27	1.27	98.73
10	2.00	9.70	1.11	2.38	97.62
20	0.85	19.70	2.26	4.64	95.36
40	0.43	95.60	10.96	15.60	84.40
60	0.25	159.60	18.29	33.90	66.10
140	0.11	267.30	30.64	64.53	35.47
200	0.08	87.90	10.08	74.61	25.39
Pan		221.50	25.39	100.00	
Sum		872.40			

Fz	5
Fm	1
Gs	2.7
Ws	55.6
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	53.00	22.50	0.78	48.78	86.75	54.00	7.49	0.0132	0.0720
0.5	47.00	22.00	0.65	42.65	75.86	48.00	8.47	0.0133	0.0545
1	39.00	22.00	0.65	34.65	61.63	40.00	9.77	0.0133	0.0414
2	30.00	22.00	0.65	25.65	45.62	31.00	11.24	0.0133	0.0314
4	25.00	21.50	0.53	20.53	36.51	26.00	12.06	0.0135	0.0234
8	21.00	21.50	0.53	16.53	29.39	22.00	12.72	0.0135	0.0170
15	19.50	21.50	0.53	15.03	26.72	20.50	12.96	0.0135	0.0125
30	18.00	21.50	0.53	13.53	24.06	19.00	13.21	0.0135	0.0089
60	16.50	21.50	0.53	12.03	21.39	17.50	13.45	0.0135	0.0064
120	15.50	21.50	0.53	11.03	19.61	16.50	13.61	0.0135	0.0045
240	15.00	21.50	0.53	10.53	18.72	16.00	13.70	0.0135	0.0032
1440	13.00	21.50	0.53	8.53	15.16	14.00	14.02	0.0135	0.0013
2880	12.00	21.50	0.53	7.53	13.38	13.00	14.19	0.0135	0.0009

Table B-13

Lyon's Country Well #3
Depth: 10ft

Weight of Wet Soil (g)	899.3
Weight of Dry Soil (g)	870.8
Moisture Content	0.032729

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	160.70	18.45	18.45	81.55
10	2.00	39.70	4.56	23.01	76.99
20	0.85	26.70	3.07	26.08	73.92
40	0.43	74.40	8.54	34.62	65.38
60	0.25	127.10	14.59	49.21	50.79
140	0.11	41.90	4.81	54.02	45.98
200	0.08	239.90	27.55	81.57	18.43
Pan		160.50	18.43	100.00	0.00
Sum		870.90			

Fz	5
Fm	1
Gs	2.7
Ws	54.6
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	52.00	22.00	0.65	47.65	86.30	53.00	7.65	0.0133	0.0733
0.5	49.00	22.00	0.65	44.65	80.87	50.00	8.14	0.0133	0.0535
1	39.00	22.00	0.65	34.65	62.76	40.00	9.77	0.0133	0.0414
2	31.00	22.00	0.65	26.65	48.27	32.00	11.08	0.0133	0.0312
4	24.00	22.00	0.65	19.65	35.59	25.00	12.23	0.0133	0.0232
8	21.50	22.00	0.65	17.15	31.06	22.50	12.63	0.0133	0.0167
15	20.00	22.00	0.65	15.65	28.34	21.00	12.88	0.0133	0.0123
30	18.00	22.00	0.65	13.65	24.72	19.00	13.21	0.0133	0.0088
60	16.00	21.50	0.53	11.53	20.87	17.00	13.53	0.0133	0.0063
120	15.00	21.50	0.53	10.53	19.06	16.00	13.70	0.0133	0.0045
240	14.50	21.50	0.53	10.03	18.16	15.50	13.78	0.0133	0.0032
1440	13.50	21.00	0.40	8.90	16.12	14.50	13.94	0.0134	0.0013
2880	12.50	21.00	0.40	7.90	14.31	13.50	14.10	0.0134	0.0009

Table B-14

Lyon's Country Well #3
Depth: 15ft

Weight of Wet Soil (g)	975
Weight of Dry Soil (g)	942.9
Moisture Content	0.034044

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	148.80	15.83	15.83	84.17
10	2.00	86.00	9.15	24.98	75.02
20	0.85	48.10	5.12	30.09	69.91
40	0.43	100.50	10.69	40.78	59.22
60	0.25	151.50	16.12	56.90	43.10
140	0.11	209.40	22.27	79.17	20.83
200	0.08	62.30	6.63	85.80	14.20
Pan		133.50	14.20	100.00	0.00
Sum		940.10			

Fz	5
Fm	1
Gs	2.7
Ws	50.4
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	52.00	21.50	0.53	47.53	93.25	53.00	7.65	0.0133	0.0736
0.5	47.00	21.50	0.53	42.53	83.44	48.00	8.47	0.0133	0.0736
1	41.50	21.50	0.53	37.03	72.65	42.50	9.37	0.0133	0.0736
2	33.00	21.50	0.53	28.53	55.97	34.00	10.75	0.0133	0.0736
4	28.00	21.50	0.53	23.53	46.16	29.00	11.57	0.0133	0.0736
8	24.00	21.50	0.53	19.53	38.31	25.00	12.23	0.0133	0.0736
15	22.00	21.50	0.53	17.53	34.39	23.00	12.55	0.0133	0.0736
30	20.00	21.50	0.53	15.53	30.46	21.00	12.88	0.0133	0.0736
60	19.00	21.50	0.53	14.53	28.50	20.00	13.04	0.0133	0.0736
120	18.00	21.50	0.53	13.53	26.54	19.00	13.21	0.0133	0.0736
240	17.00	21.50	0.53	12.53	24.58	18.00	13.37	0.0133	0.0736
1440	15.00	21.50	0.53	10.53	20.65	16.00	13.70	0.0133	0.0736
2880	13.50	21.50	0.53	9.03	17.71	14.50	13.94	0.0133	0.0736

Table B-15

Lyon's Country Well #3
Depth: 20ft

Weight of Wet Soil (g) 862.9
Weight of Dry Soil (g) 828.7

Moisture Content 0.041269

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	102.50	12.42	12.42	87.58
10	2.00	98.00	11.88	24.30	75.70
20	0.85	61.50	7.45	31.75	68.25
40	0.43	95.70	11.60	43.35	56.65
60	0.25	139.60	16.92	60.26	39.74
140	0.11	52.40	6.35	66.61	33.39
200	0.08	185.70	22.50	89.12	10.88
Pan		89.80	10.88	100.00	0.00
Sum		825.20			

Table B-16

Lyon's Country Well #3
Depth: 25ft

Weight of Wet Soil (g)	378.8
Weight of Dry Soil (g)	368.1
Moisture Content	0.029068

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	2.20	0.60	0.60	99.40
10	2.00	75.90	20.67	21.27	78.73
20	0.85	90.90	24.75	46.02	53.98
40	0.43	44.30	12.06	58.09	41.91
60	0.25	24.00	6.54	64.62	35.38
140	0.11	32.50	8.85	73.47	26.53
200	0.08	17.20	4.68	78.16	21.84
Pan		80.20	21.84	100.00	0.00
Sum		367.20			

Fz	5
Fm	1
Gs	2.7
Ws	50.2
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	48.00	21.50	0.53	43.53	85.74	49.00	8.30	0.0133	0.0766
0.5	45.00	21.50	0.53	40.53	79.83	46.00	8.79	0.0133	0.0558
1	42.00	21.50	0.53	37.53	73.92	43.00	9.28	0.0133	0.0405
2	36.50	21.50	0.53	32.03	63.09	37.50	10.18	0.0133	0.0300
4	32.00	21.50	0.53	27.53	54.22	33.00	10.92	0.0133	0.0220
8	29.00	21.50	0.53	24.53	48.31	30.00	11.41	0.0133	0.0159
15	27.50	21.50	0.53	23.03	45.36	28.50	11.65	0.0133	0.0117
30	24.50	21.50	0.53	20.03	39.45	25.50	12.14	0.0133	0.0085
60	23.00	21.50	0.53	18.53	36.49	24.00	12.39	0.0133	0.0060
120	21.50	21.50	0.53	17.03	33.54	22.50	12.63	0.0133	0.0043
244	20.50	21.50	0.53	16.03	31.57	21.50	12.80	0.0133	0.0030
1410	18.50	21.50	0.53	14.03	27.63	19.50	13.12	0.0133	0.0013
2880	16.50	21.50	0.53	12.03	23.69	17.50	13.45	0.0133	0.0009

Table B-17

Lyon's Country Well #3
Depth: 30ft

Weight of Wet Soil (g) 1083.3
Weight of Dry Soil (g) 885.8

Moisture Content 0.222962

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	0.70	0.08	0.08	99.92
10	2.00	5.00	0.56	0.64	99.36
20	0.85	27.30	3.08	3.72	96.28
40	0.43	115.40	13.02	16.74	83.26
60	0.25	223.70	25.23	41.97	58.03
140	0.11	3.90	0.44	42.41	57.59
200	0.06	354.20	39.95	82.36	17.64
Pan		156.40	17.64	100.00	0.00
Sum		886.60			

Fz	5
Fm	1
Gs	2.7
Ws	50.4
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	53.00	21.50	0.53	48.53	95.21	54.00	7.49	0.0133	0.0728
0.5	50.00	21.50	0.53	45.53	89.32	51.00	7.98	0.0133	0.0531
1	46.00	21.50	0.53	41.53	81.48	47.00	8.63	0.0133	0.0391
2	39.00	21.50	0.53	34.53	67.74	40.00	9.77	0.0133	0.0294
4	35.00	21.50	0.53	30.53	59.89	36.00	10.43	0.0133	0.0215
8	31.00	21.50	0.53	26.53	52.04	32.00	11.08	0.0133	0.0157
15	27.00	21.50	0.53	22.53	44.20	28.00	11.73	0.0133	0.0118
30	25.00	21.50	0.53	20.53	40.27	26.00	12.06	0.0133	0.0084
60	22.00	21.50	0.53	17.53	34.39	23.00	12.55	0.0133	0.0061
120	20.00	21.50	0.53	15.53	30.46	21.00	12.88	0.0133	0.0044
240	19.00	21.50	0.53	14.53	28.50	20.00	13.04	0.0133	0.0031
1440	15.00	21.50	0.53	10.53	20.65	16.00	13.70	0.0133	0.0013
2880	14.00	21.50	0.53	9.53	18.69	15.00	13.86	0.0133	0.0009

Table B-18

Lyon's Country Well #4
Depth: 10ft

Weight of Wet Soil (g)	311.5
Weight of Dry Soil (g)	253.7
Moisture Content	0.227828

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	0.00	0.00	0.00	100.00
10	2.00	12.20	4.81	4.81	95.19
20	0.85	35.30	13.92	18.73	81.27
40	0.43	29.70	11.71	30.44	69.56
60	0.25	18.80	7.41	37.85	62.15
140	0.11	36.40	14.35	52.21	47.79
200	0.08	27.80	10.96	63.17	36.83
Pan		93.40	36.83	100.00	
Sum		253.60			

Fz	5
Fm	1
Gs	2.7
Ws	55.9
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	50.00	22.50	0.78	45.78	80.98	51.00	7.98	0.0132	0.0743
0.5	47.00	22.50	0.78	42.78	75.67	48.00	8.47	0.0132	0.0541
1	42.50	22.50	0.78	38.28	67.71	43.50	9.20	0.0132	0.0399
2	36.50	22.50	0.78	32.28	57.10	37.50	10.18	0.0132	0.0297
4	31.00	22.50	0.78	26.78	47.37	32.00	11.08	0.0132	0.0219
8	26.00	22.50	0.78	21.78	38.52	27.00	11.90	0.0132	0.0160
15	23.50	22.50	0.78	19.28	34.10	24.50	12.31	0.0132	0.0119
30	20.00	22.50	0.78	15.78	27.91	21.00	12.88	0.0132	0.0086
60	17.50	22.50	0.78	13.28	23.48	18.50	13.29	0.0132	0.0062
120	16.50	21.50	0.53	12.03	21.27	17.50	13.45	0.0133	0.0045
240	15.50	21.50	0.53	11.03	19.50	16.50	13.61	0.0133	0.0032
1440	14.00	21.50	0.53	9.53	16.85	15.00	13.86	0.0133	0.0013
2880	13.00	21.50	0.53	8.53	15.08	14.00	14.02	0.0133	0.0009

Table B-19

Lyon's Country Well #4
Depth: 15ft

Weight of Wet Soil (g)	353.3
Weight of Dry Soil (g)	286.4
Moisture Content	0.233589

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	2.10	0.73	0.73	99.27
10	2.00	54.00	18.87	19.60	80.40
20	0.85	74.50	26.03	45.63	54.37
40	0.43	37.70	13.17	58.81	41.19
60	0.25	21.10	7.37	66.18	33.82
140	0.11	30.90	10.80	76.97	23.03
200	0.08	14.70	5.14	82.11	17.89
Pan		51.20	17.89	100.00	
Sum		286.20			

Fz	5
Fm	1
Gs	2.7
Ws	51.2
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	52.00	22.50	0.78	47.78	92.27	53.00	7.65	0.0132	0.0727
0.5	48.00	22.50	0.78	43.78	84.55	49.00	8.30	0.0132	0.0536
1	45.50	22.50	0.78	41.28	79.72	46.50	8.71	0.0132	0.0388
2	41.00	22.50	0.78	36.78	71.03	42.00	9.45	0.0132	0.0286
4	36.50	22.50	0.78	32.28	62.34	37.50	10.18	0.0132	0.0210
8	32.50	22.50	0.78	28.28	54.61	33.50	10.84	0.0132	0.0153
15	29.50	22.50	0.78	25.28	48.82	30.50	11.33	0.0132	0.0114
30	27.50	22.50	0.78	23.28	44.95	28.50	11.65	0.0132	0.0082
60	25.50	22.50	0.78	21.28	41.09	26.50	11.98	0.0132	0.0059
120	23.50	21.50	0.53	19.03	36.75	24.50	12.31	0.0133	0.0043
240	22.00	21.50	0.53	17.53	33.85	23.00	12.55	0.0133	0.0030
1400	19.50	21.50	0.53	15.03	29.02	20.50	12.96	0.0133	0.0013
2880	17.50	21.50	0.53	13.03	25.16	18.50	13.29	0.0133	0.0009

Table B-20

Lyon's Country Well #4
Depth: 20ft

Weight of Wet Soil (g) 454.8
Weight of Dry Soil (g) 354.7

Moisture Content 0.28221

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	21.20	5.99	5.99	94.01
10	2.00	15.20	4.29	10.29	89.71
20	0.85	14.50	4.10	14.38	85.62
40	0.43	44.90	12.69	27.07	72.93
60	0.25	71.40	20.18	47.24	52.76
140	0.11	2.50	0.71	47.95	52.05
200	0.08	119.70	33.82	81.77	18.23
Pan		64.50	18.23	100.00	
Sum		353.90			

Fz	5
Fm	1
Gs	2.7
Ws	54.5
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	59.00	21.50	0.53	54.53	98.94	60.00	6.51	0.0133	0.0678
0.5	53.50	21.50	0.53	49.03	88.96	54.50	7.40	0.0133	0.0512
1	50.00	21.50	0.53	45.53	82.61	51.00	7.98	0.0133	0.0376
2	45.00	21.50	0.53	40.53	73.53	46.00	8.79	0.0133	0.0279
4	41.00	21.50	0.53	36.53	66.27	42.00	9.45	0.0133	0.0204
8	37.50	21.50	0.53	33.03	59.92	38.50	10.02	0.0133	0.0149
15	35.00	21.50	0.53	30.53	55.39	36.00	10.43	0.0133	0.0111
30	33.00	21.50	0.53	28.53	51.76	34.00	10.75	0.0133	0.0080
60	30.00	21.50	0.53	25.53	46.32	31.00	11.24	0.0133	0.0058
120	28.00	21.50	0.53	23.53	42.69	29.00	11.57	0.0133	0.0041
240	27.00	21.50	0.53	22.53	40.87	28.00	11.73	0.0133	0.0029
1440	22.50	21.50	0.53	18.03	32.71	23.50	12.47	0.0133	0.0012
2880	21.00	21.50	0.53	16.53	29.98	22.00	12.72	0.0133	0.0009

Table B-21

Lyon's Country Well #4
Depth: 30ft

Weight of Wet Soil (g)	1142.2
Weight of Dry Soil (g)	905.1
Moisture Content	0.26196

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	0.00	0.00	0.00	100.00
10	2.00	14.10	1.56	1.56	98.44
20	0.85	51.90	5.73	7.29	92.71
40	0.43	123.30	13.62	20.90	79.10
60	0.25	278.90	30.80	51.70	48.30
140	0.11	298.70	32.98	84.68	15.32
200	0.08	36.50	4.03	88.71	11.29
Pan		102.20	11.29	100.00	
Sum		905.60			

Fz	5
Fm	1
Gs	2.7
Ws	50.2
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	50.00	21.50	0.53	45.53	89.68	51.00	7.98	0.0133	0.0751
0.5	44.00	21.50	0.53	39.53	77.86	45.00	8.96	0.0133	0.0563
1	40.00	21.50	0.53	35.53	69.98	41.00	9.61	0.0133	0.0412
2	35.00	21.50	0.53	30.53	60.13	36.00	10.43	0.0133	0.0304
4	30.00	21.50	0.53	25.53	50.28	31.00	11.24	0.0133	0.0223
8	27.00	21.50	0.53	22.53	44.37	28.00	11.73	0.0133	0.0161
15	25.00	21.50	0.53	20.53	40.43	26.00	12.06	0.0133	0.0119
30	22.00	21.50	0.53	17.53	34.52	23.00	12.55	0.0133	0.0086
60	20.50	21.50	0.53	16.03	31.57	21.50	12.80	0.0133	0.0061
120	19.00	21.50	0.53	14.53	28.61	20.00	13.04	0.0133	0.0044
240	18.00	21.50	0.53	13.53	26.64	19.00	13.21	0.0133	0.0031
1440	16.50	21.50	0.53	12.03	23.69	17.50	13.45	0.0133	0.0013
2880	15.00	21.50	0.53	10.53	20.73	16.00	13.70	0.0133	0.0009

Table B-22

Lyon's Country Well #5
Depth: 5ft

Weight of Wet Soil (g) 340.3
Weight of Dry Soil (g) 330.8

Moisture Content 0.0287183

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	161.00	48.77	48.77	51.23
10	2.00	11.00	3.33	52.11	47.89
20	0.85	8.40	2.54	54.65	45.35
40	0.43	22.10	6.69	61.35	38.65
60	0.25	36.10	10.94	72.28	27.72
140	0.11	55.00	16.66	88.94	11.06
200	0.08	15.50	4.70	93.64	6.36
Pan		21.00	6.36	100.00	
Sum		330.10			

Table B-23

Lyon's Country Well #5
Depth: 10ft

Weight of Wet Soil (g) 351.6
Weight of Dry Soil (g) 295.6

Moisture Content 0.189445

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	15.80	5.56	5.56	94.44
10	2.00	10.40	3.66	9.23	90.77
20	0.85	20.80	7.32	16.55	83.45
40	0.43	47.40	16.69	33.24	66.76
60	0.25	37.10	13.06	46.30	53.70
140	0.11	12.50	4.40	50.70	49.30
200	0.08	33.20	11.69	62.39	37.61
Pan		106.80	37.61	100.00	
Sum		284.00			

Fz	3
Fm	1
Gs	2.7
Ws	51.9
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	50.00	22.50	0.78	47.78	91.03	51.00	7.98	0.0132	0.0743
0.5	46.50	22.50	0.78	44.28	84.36	47.50	8.55	0.0132	0.0544
1	40.00	22.50	0.78	37.78	71.98	41.00	9.61	0.0132	0.0408
2	32.00	22.50	0.78	29.78	56.73	33.00	10.92	0.0132	0.0307
4	25.00	22.50	0.78	22.78	43.40	26.00	12.06	0.0132	0.0228
8	21.00	22.50	0.78	18.78	35.77	22.00	12.72	0.0132	0.0166
15	19.00	22.50	0.78	16.78	31.96	20.00	13.04	0.0132	0.0123
30	16.50	22.50	0.78	14.28	27.20	17.50	13.45	0.0132	0.0088
60	14.00	22.00	0.65	11.65	22.20	15.00	13.86	0.0133	0.0064
120	13.00	22.00	0.65	10.65	20.29	14.00	14.02	0.0133	0.0045
420	12.50	22.00	0.65	10.15	19.34	13.50	14.10	0.0133	0.0024
1440	11.50	21.00	0.40	8.90	16.96	12.50	14.27	0.0134	0.0013
2880	12.50	20.50	0.28	9.78	18.63	13.50	14.10	0.0135	0.0009

Table B-24

Lyon's Country Well #5
Depth: 15ft

Weight of Wet Soil (g)	391.2
Weight of Dry Soil (g)	370.7
Moisture Content	0.055301

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	7.70	2.08	2.08	97.92
10	2.00	48.10	13.00	15.09	84.91
20	0.85	62.20	16.82	31.90	68.10
40	0.43	41.70	11.27	43.17	56.83
60	0.25	25.10	6.79	49.96	50.04
140	0.11	28.30	7.65	57.61	42.39
200	0.08	19.40	5.24	62.85	37.15
Pan		137.40	37.15	100.00	
Sum		369.90			

Fz	5
Fm	1
Gs	2.7
Ws	51.5
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	49.00	22.50	0.78	44.78	85.98	50.00	8.14	0.0132	0.0750
0.5	46.00	22.50	0.78	41.78	80.22	47.00	8.63	0.0132	0.0546
1	42.50	22.50	0.78	38.28	73.50	43.50	9.20	0.0132	0.0399
2	36.50	22.50	0.78	32.28	61.97	37.50	10.18	0.0132	0.0297
4	31.50	22.50	0.78	27.28	52.37	32.50	11.00	0.0132	0.0218
8	27.00	22.50	0.78	22.78	43.73	28.00	11.73	0.0132	0.0159
15	23.00	22.50	0.78	18.78	36.05	24.00	12.39	0.0132	0.0120
30	19.00	22.50	0.78	14.78	28.37	20.00	13.04	0.0132	0.0087
60	17.50	22.50	0.78	13.28	25.49	18.50	13.29	0.0132	0.0062
120	15.50	21.50	0.53	11.03	21.17	16.50	13.61	0.0133	0.0045
240	14.50	21.50	0.53	10.03	19.25	15.50	13.78	0.0133	0.0032
1440	13.50	21.50	0.53	9.03	17.33	14.50	13.94	0.0133	0.0013
2880	12.00	21.50	0.53	7.53	14.45	13.00	14.19	0.0133	0.0009

Table B-25

Lyon's Country Well #5
Depth: 25ft

Weight of Wet Soil (g) 517.7
Weight of Dry Soil (g) 446.9

Moisture Content 0.158425

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	20.20	4.53	4.53	95.47
10	2.00	107.60	24.11	28.64	71.36
20	0.85	99.40	22.28	50.92	49.08
40	0.43	55.90	12.53	63.45	36.55
60	0.25	28.20	6.32	69.77	30.23
140	0.11	37.00	8.29	78.06	21.94
200	0.08	20.80	4.66	82.72	17.28
Pan		77.10	17.28	100.00	
Sum		446.20			

Fz	3
Fm	1
Gs	2.7
Ws	52.8
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	53.00	22.50	0.78	50.78	95.10	54.00	7.49	0.0132	0.0720
0.5	50.00	22.50	0.78	47.78	89.48	51.00	7.98	0.0132	0.0525
1	45.00	22.50	0.78	42.78	80.11	46.00	8.79	0.0132	0.0390
2	41.00	22.50	0.78	38.78	72.62	42.00	9.45	0.0132	0.0286
4	36.50	22.50	0.78	34.28	64.19	37.50	10.18	0.0132	0.0210
8	31.50	22.50	0.78	29.28	54.83	32.50	11.00	0.0132	0.0154
15	28.50	22.50	0.78	26.28	49.21	29.50	11.49	0.0132	0.0115
30	26.00	22.50	0.78	23.78	44.53	27.00	11.90	0.0132	0.0083
60	24.00	22.00	0.65	21.65	40.55	25.00	12.23	0.0133	0.0060
120	23.00	22.00	0.65	20.65	38.68	24.00	12.39	0.0133	0.0043
420	20.00	22.00	0.65	17.65	33.06	21.00	12.88	0.0133	0.0023
1440	19.00	21.00	0.40	16.40	30.72	20.00	13.04	0.0134	0.0013
2880	16.50	20.50	0.28	13.78	25.80	17.50	13.45	0.0135	0.0009

Table B-26

Lyon's Country Well #5
Depth: 30ft

*NOTE: Moisture content test not performed on this sample.

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulativ Percent Retained	Percent Finer
4	4.75	0.00	0.00	0.00	100.00
10	2.00	3.30	0.59	0.59	99.41
20	0.85	9.20	1.65	2.25	97.75
40	0.43	51.20	9.21	11.46	88.54
60	0.25	126.10	22.68	34.14	65.86
140	0.11	1.90	0.34	34.48	65.52
200	0.08	221.20	39.78	74.26	25.74
Pan		143.10	25.74	100.00	
Sum		556.00			

Fz	3
Fm	1
Gs	2.7
Ws	51.1
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	35.00	22.50	0.78	32.78	63.43	36.00	10.43	0.0132	0.0849
0.5	30.00	22.50	0.78	27.78	53.75	31.00	11.24	0.0132	0.0624
1	23.00	22.50	0.78	20.78	40.20	24.00	12.39	0.0132	0.0463
2	19.00	22.50	0.78	16.78	32.46	20.00	13.04	0.0132	0.0336
4	16.50	22.50	0.78	14.28	27.63	17.50	13.45	0.0132	0.0241
8	15.00	22.50	0.78	12.78	24.72	16.00	13.70	0.0132	0.0172
15	14.00	22.50	0.78	11.78	22.79	15.00	13.86	0.0132	0.0126
30	13.00	22.50	0.78	10.78	20.85	14.00	14.02	0.0132	0.0090
60	12.50	22.00	0.65	10.15	19.64	13.50	14.10	0.0133	0.0064
120	12.00	22.00	0.65	9.65	18.67	13.00	14.19	0.0133	0.0046
420	11.00	22.00	0.65	8.65	16.74	12.00	14.35	0.0133	0.0024
1440	10.50	21.00	0.40	7.90	15.29	11.50	14.43	0.0134	0.0013
2880	10.00	20.50	0.28	7.28	14.08	11.00	14.51	0.0135	0.0010

Table B-27

Lyon's Country Estates Soil Analysis August 6, 1991				
Location	Depth	NO3-N mg/Kg	TKN mg/Kg	NH4-N mg/Kg
East	4 ft.	43.20	802	2.80
East	6 ft.	8.00	84	3.80
North	4 ft.	5.20	50	2.80
North	6 ft.	7.00	172	2.80
West	4 ft.	9.00	161	2.70
West	6 ft.	12.00	293	3.00
South	4 ft.	89.90	583	4.10
South	6 ft.	30.20	262	2.80

Table B-28

Lyon's Country Estates Soil Analysis November 1, 1991				
Location	Depth (ft.)	*Dry wt.(mg/Kg)* NO3-N	*Dry wt.(mg* TKN	% Moisture
Well #3	40	1.3	159	25.29
Well #4	40	1.5	57	22.36
Well #5	35	2.3	33	23.93

Table B-29

Lyon's Country Estates Water Analysis November 25, 1991	
Location	NO3-N (ppm)
Blank	0.02
B1 south	1.33
B2 west	0.13
B3 east	0.19
B4 north	1.00
Well #1	2.73
Well #2	4.75
Well #3	5.14
Well #4	2.47
Well #5	6.17

Table B-30

LYON'S COUNTRY ESTATES

DATE	TEST (mg/L)	# 1	# 2	# 3	# 4	# 5	Blank
1-6-92	Nitrate NO3-N	2.47	0.34	3.34	2.06	4.08	0.03
1-6-92	TKN	0.20	0.20	0.30	0.20	0.30	0.20
1-6-92	Phosphate	0.13	0.23	0.30	0.09	0.09	0.28
1-10-92	Nitrate NO3-N	3.22	4.40	5.19	2.84	7.04	0.02
1-10-92	TKN	0.20	0.20	0.20	0.20	0.20	0.10
1-15-92	Nitrate NO3-N	2.96	4.16	4.97	3.73	7.44	0.02
1-15-92	TKN	0.50	0.70	0.70	0.70	0.50	0.40
1-22-92	Nitrate NO3-N	3.12	4.83	6.46	3.78	7.74	0.03
1-22-92	TKN	0.50	0.80	0.70	0.70	0.50	<.1
2-20-92	Nitrate NO3-N	3.07	4.75	7.32	3.64	8.33	0.07
2-20-92	TKN	0.90	1.40	1.30	1.20	1.30	0.70
2-26-92	Nitrate NO3-N	6.10	8.08	5.28	3.01	0.05	10.74
2-26-92	TKN	3.30	3.10	2.80	2.40	2.20	2.80
3-4-92	Nitrate NO3-N	2.05	4.89	5.96	4.80	7.68	0.02
3-4-92	TKN	2.10	2.10	0.40	0.60	0.90	0.60
3-9-92	Nitrate NO3-N	2.08	4.76	6.12	5.16	8.07	0.02
3-9-92	TKN	0.10	0.30	1.30	1.40	2.20	2.10

Table B-31

Sampling Date : 7-31-91
DO1 Date: 8-1-91
DO5 Date: 8-6-91

LYON'S COUNTRY ESTATES : INFLOW

Sample ID	Dilution	Dil. Ratio	Dil. FR.	DO1	DO5	BOD 5
Blank	NA	NA	NA	7.750	6.650	1.100
Blank	NA	NA	NA	7.750	6.950	0.800
Lyons ET	10.000	1: 30.000	0.033	7.600	4.700	58.500
Lyons ET	15.000	1: 20.000	0.050	7.500	1.100	109.000
Lyons ET	20.000	1: 15.000	0.067	7.450	0.015	97.275
Lyons ET	23.000	1: 13.043	0.077	7.400	0.250	80.870
Lyons ET	26.000	1: 11.538	0.087	7.200	0.250	69.231

Table B-32

Sampling Date : 8-7-91
DO1 Date: 8-8-91
DO5 Date: 8-13-91

LYON'S COUNTRY: PONDED WATER

Sample ID	Dilution	Dil. Ratio	Dil. FR.	DO1	DO5	BOD 5
WEST	5.000	1: 60.000	0.017	7.850	6.800	21.000
WEST	10.000	1: 30.000	0.033	7.900	6.800	12.000
WEST	15.000	1: 20.000	0.050	7.850	6.500	13.000
WEST	20.000	1: 15.000	0.067	7.800	6.220	13.200
MIDDLE *	5.000	1: 60.000	0.017	7.850	4.300	171.000
MIDDLE	10.000	1: 30.000	0.033	7.900	6.100	33.000
MIDDLE *	15.000	1: 20.000	0.050	7.900	2.100	102.000
MIDDLE	20.000	1: 15.000	0.067	7.900	5.050	32.250
EAST	5.000	1: 60.000	0.017	7.900	1.700	330.000
EAST	10.000	1: 30.000	0.033	7.900	0.500	201.000
EAST	15.000	1: 20.000	0.050	7.800	0.250	137.000
EAST	20.000	1: 15.000	0.067	7.650	0.200	101.250
BLANK	NA	NA	NA	7.900	7.200	0.700
BLANK	NA	NA	NA	7.900	7.200	0.700

* had a bug swimming in the BOD bottle

APPENDIX C

Figure C-1 Dimensions of Sewage Lagoon Cells

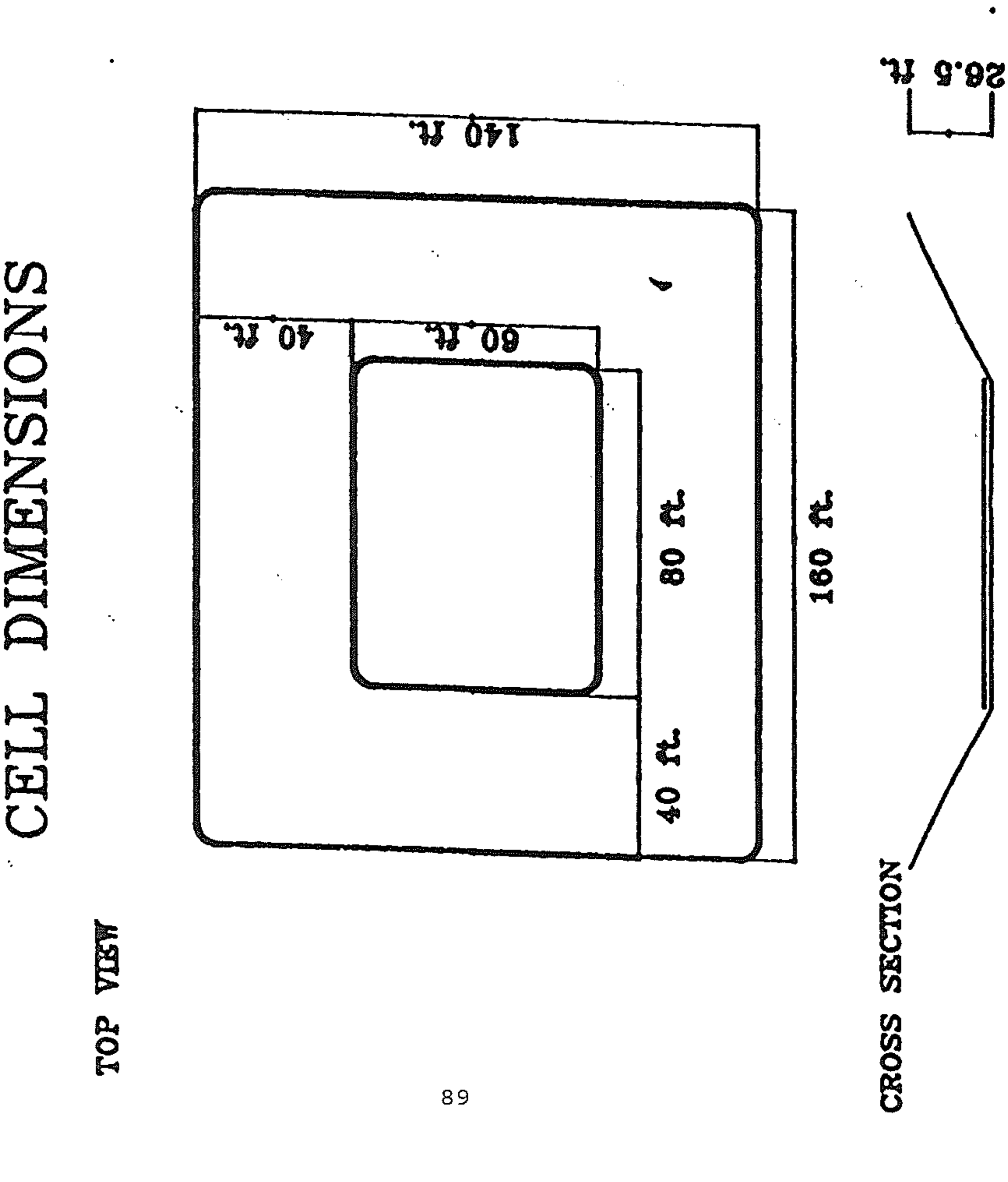


Figure C-2
Mesa Village: Depth 2 ft

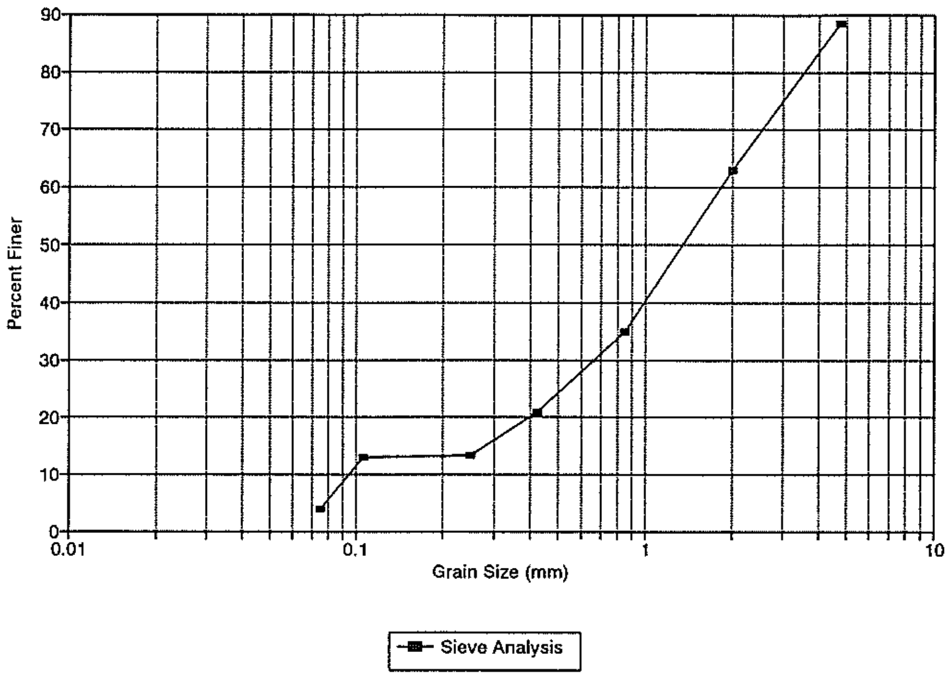


Figure C-3
Mesa Village Depth: 15 ft

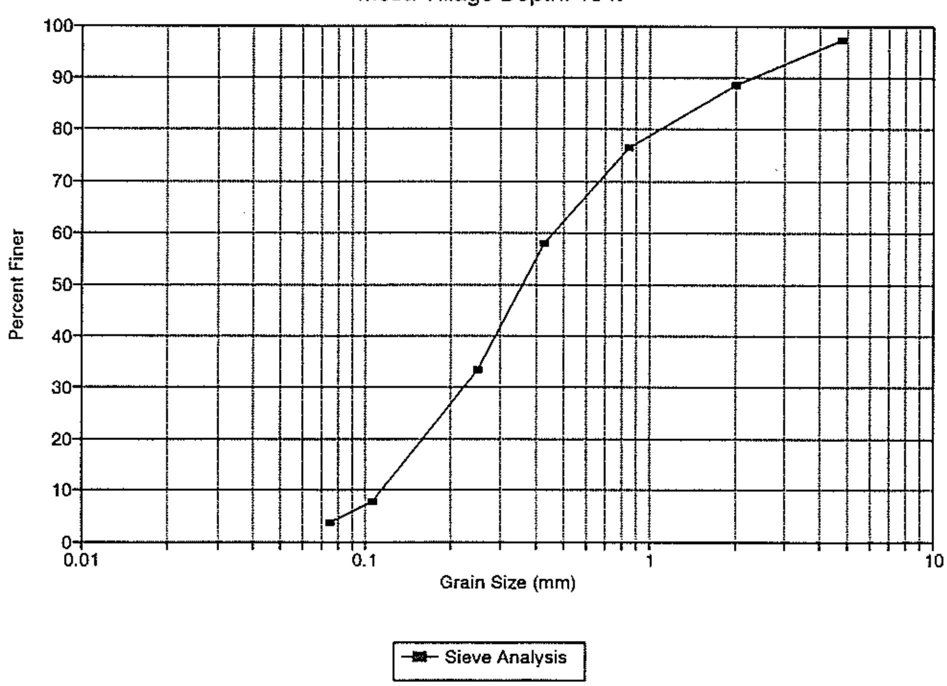


Figure C-4
Mesa Village: Depth 20 ft

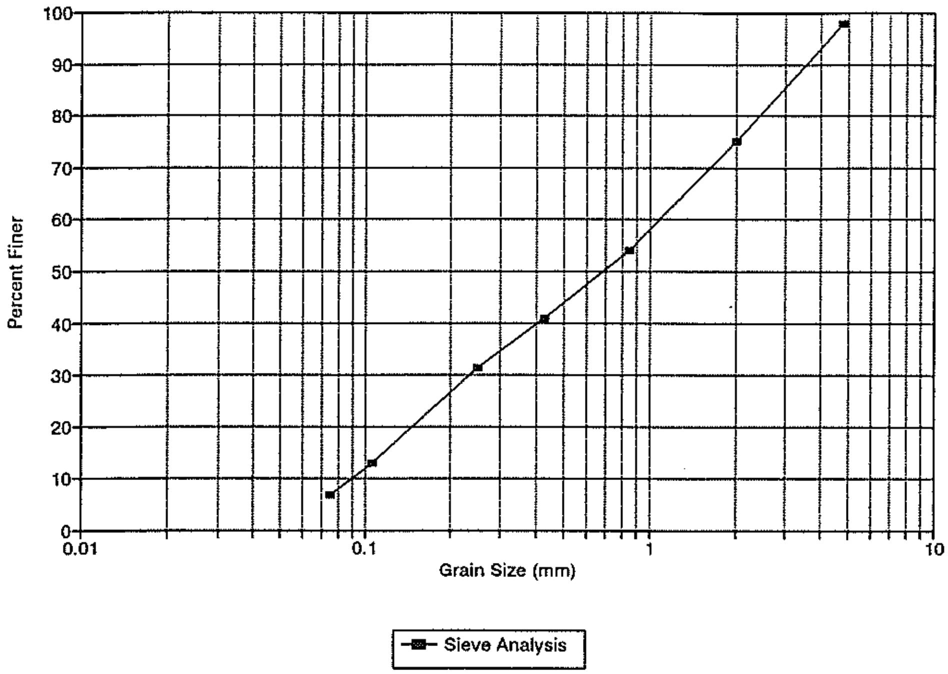


Figure C-5
Mesa Village: Depth 40 ft

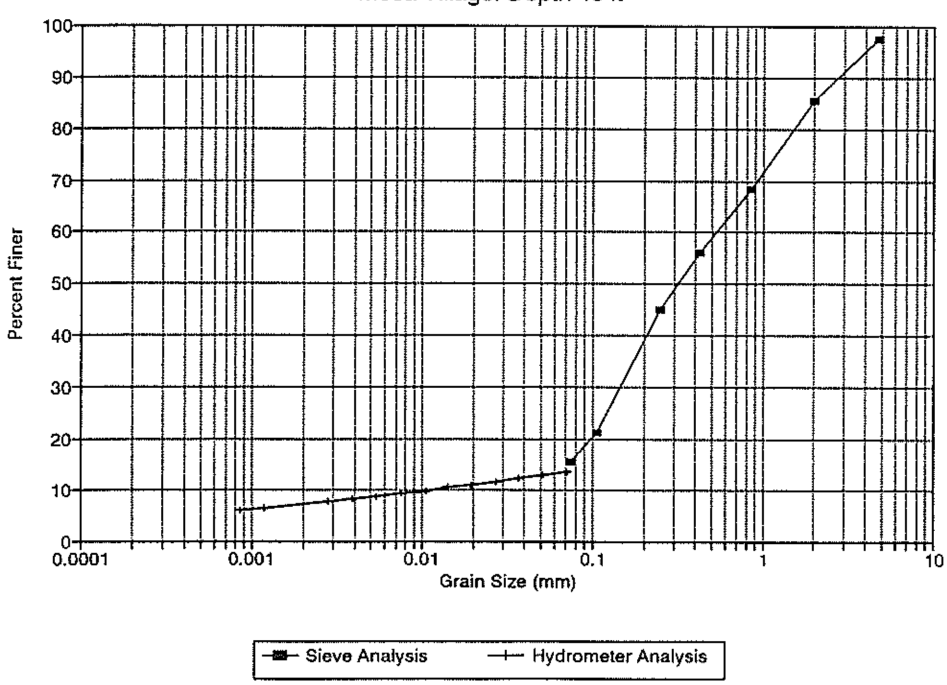


Figure C-6
Mesa Village: Depth 45 ft

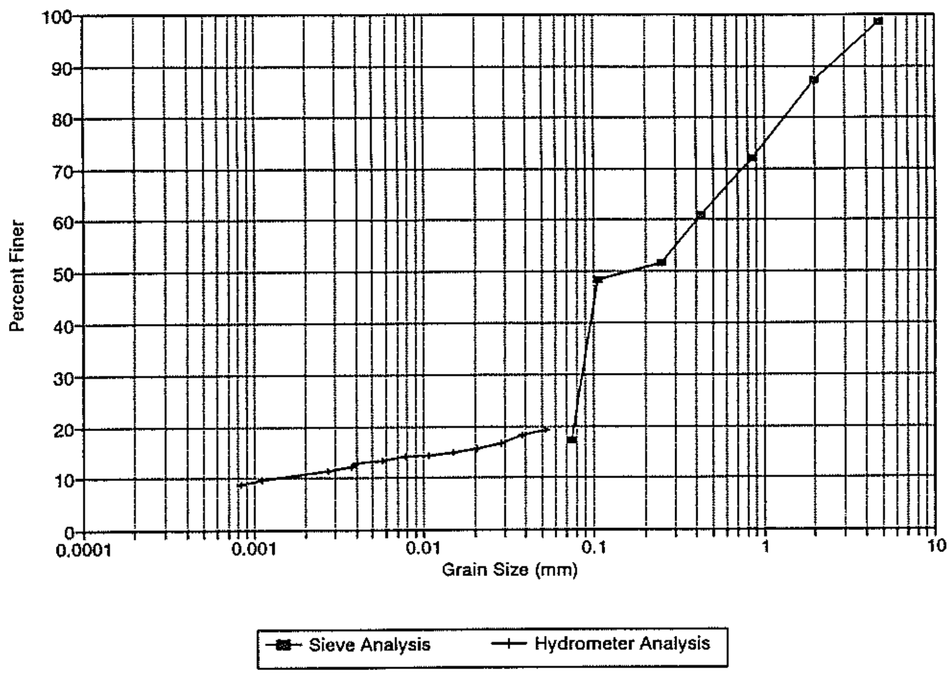


Figure C-7
Mesa Village: Depth 50 ft

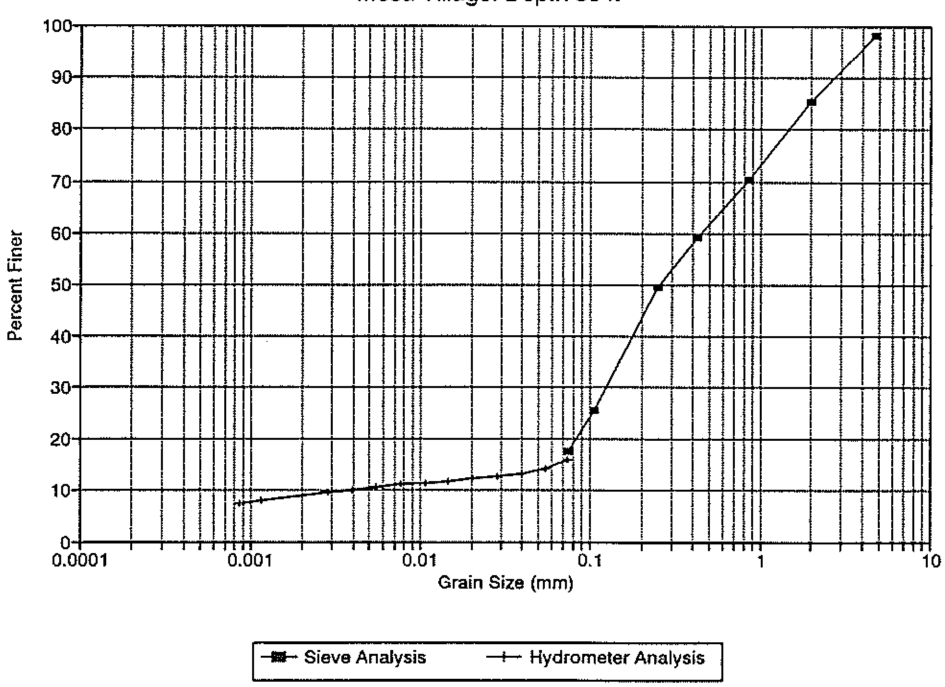


Figure C-8
Mesa Village Depth: 55 ft

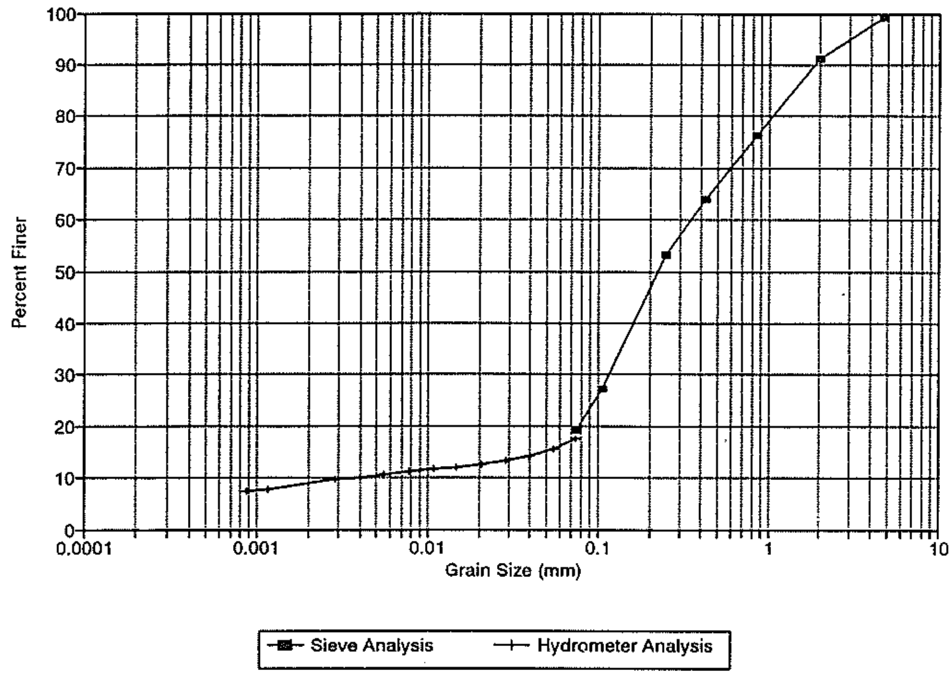


Figure C-9
Mesa Village: Depth 60 ft

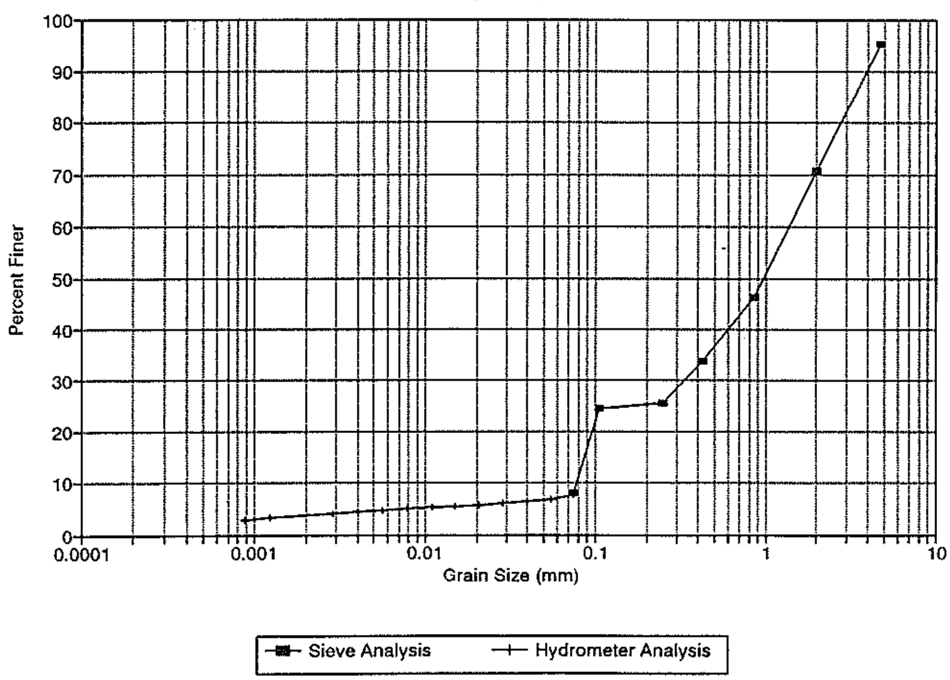


Figure C-10
Mesa Village: Depth 65 ft

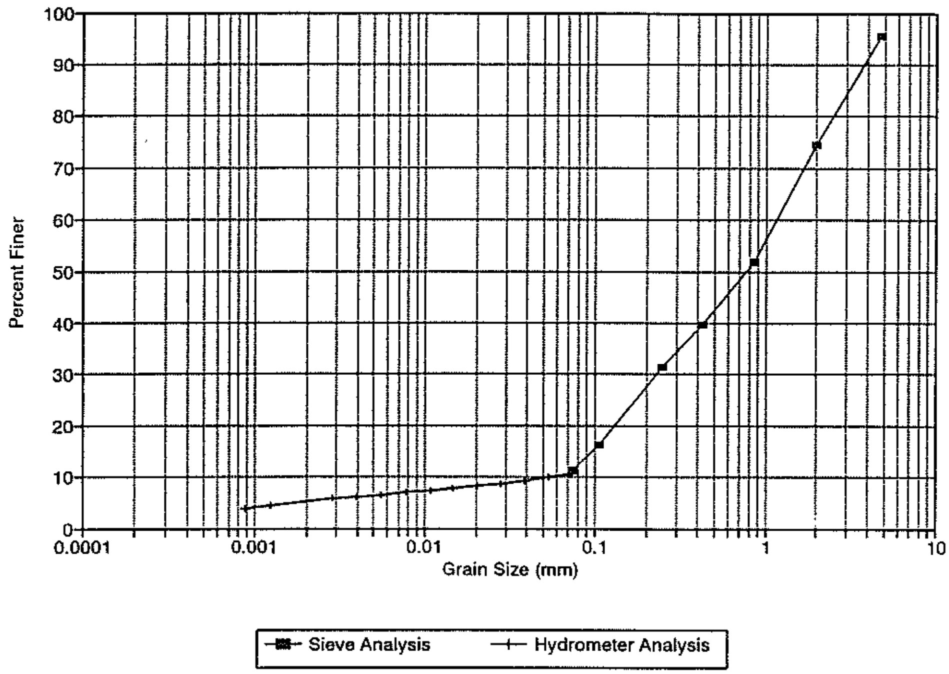
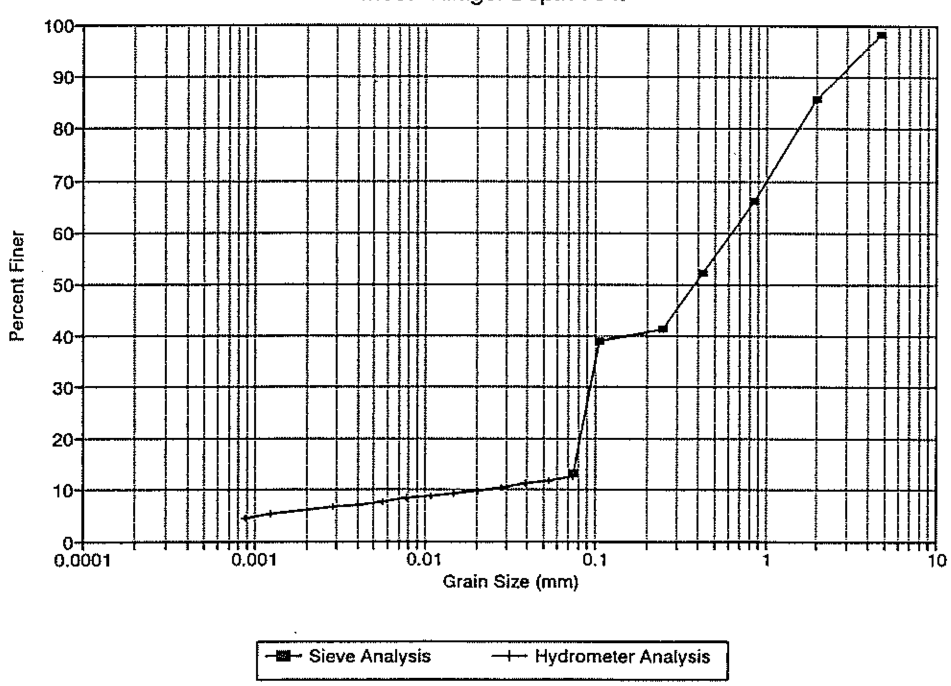


Figure C-11
Mesa Village: Depth 70 ft



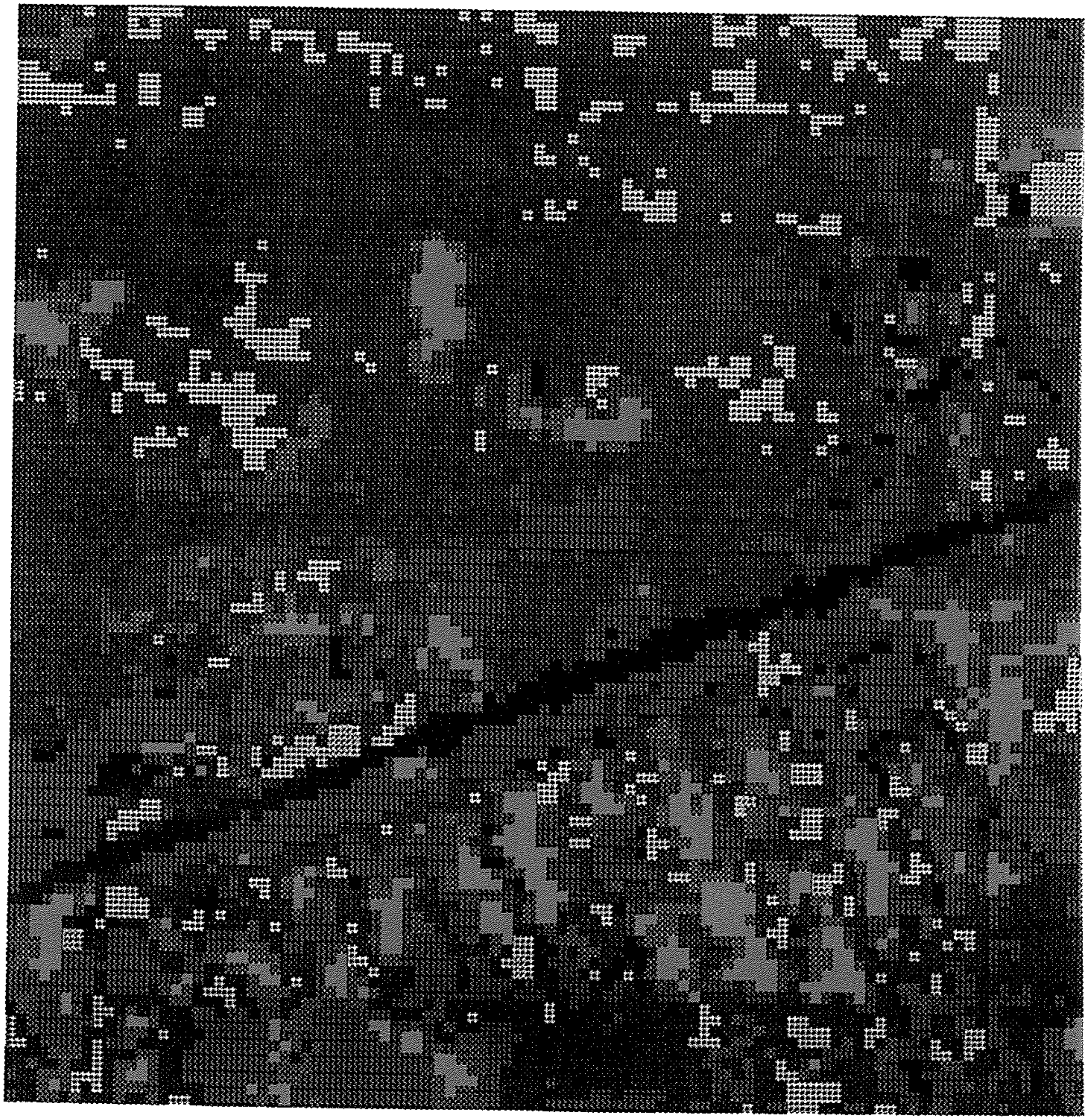


Figure C-12 Unsupervised Classification.

Fig. C-13

Orthophoto-Topographic Map for Vegetation Changes at Mesa Lagoons

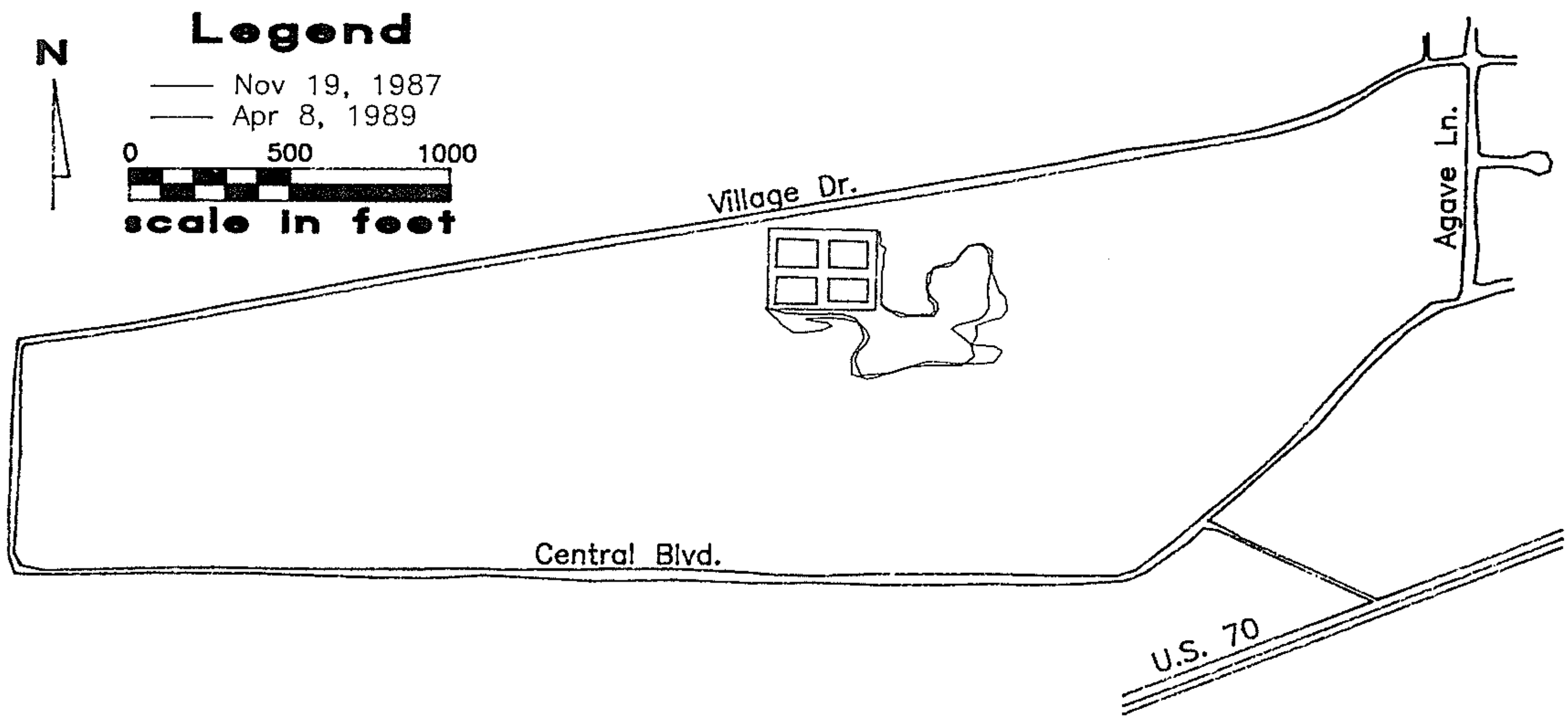


Figure C-14 NDVI VALUES
MEASURED AWAY FROM THE SYSTEM

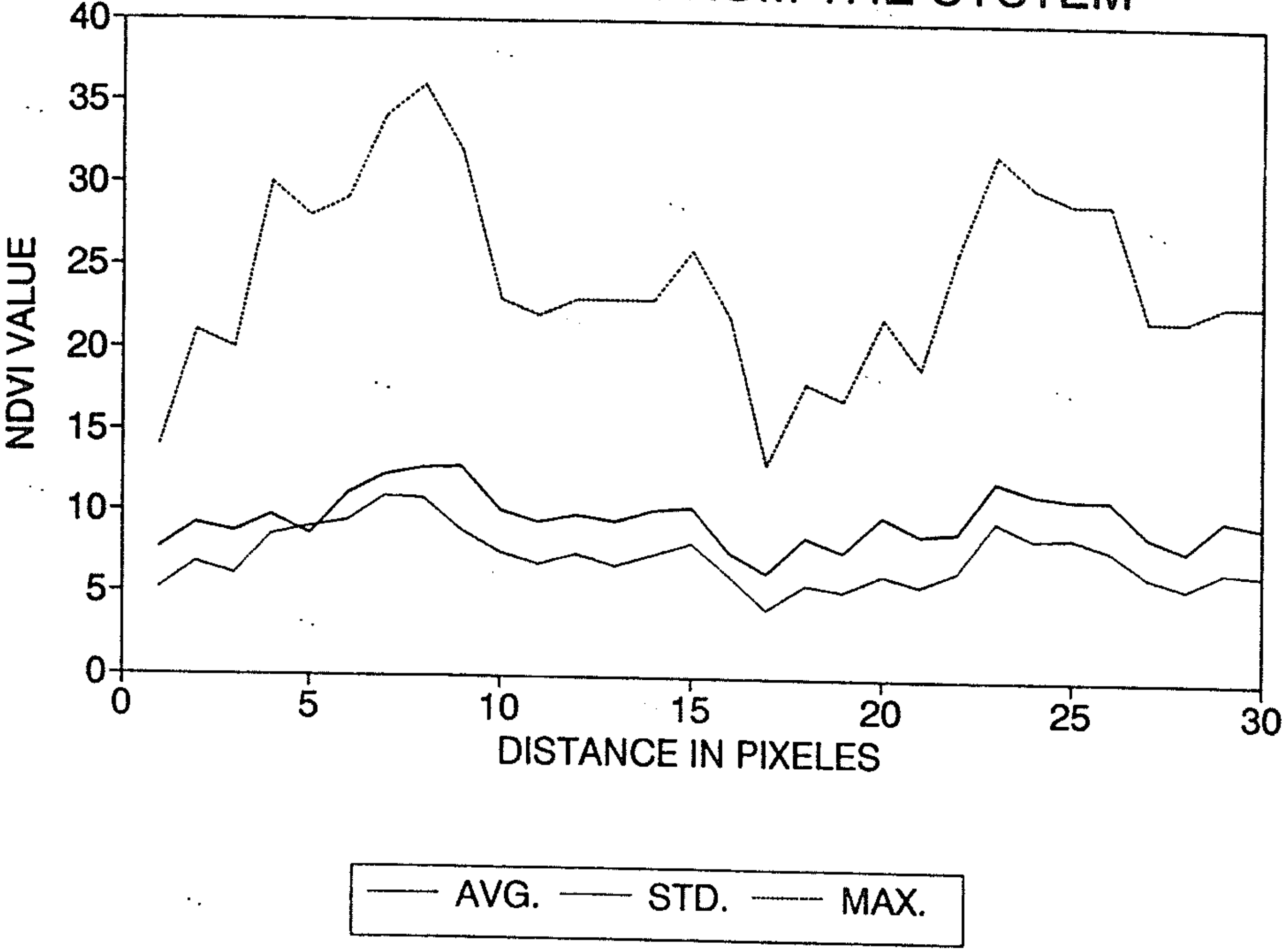


Figure C-15 NDVI VALUES

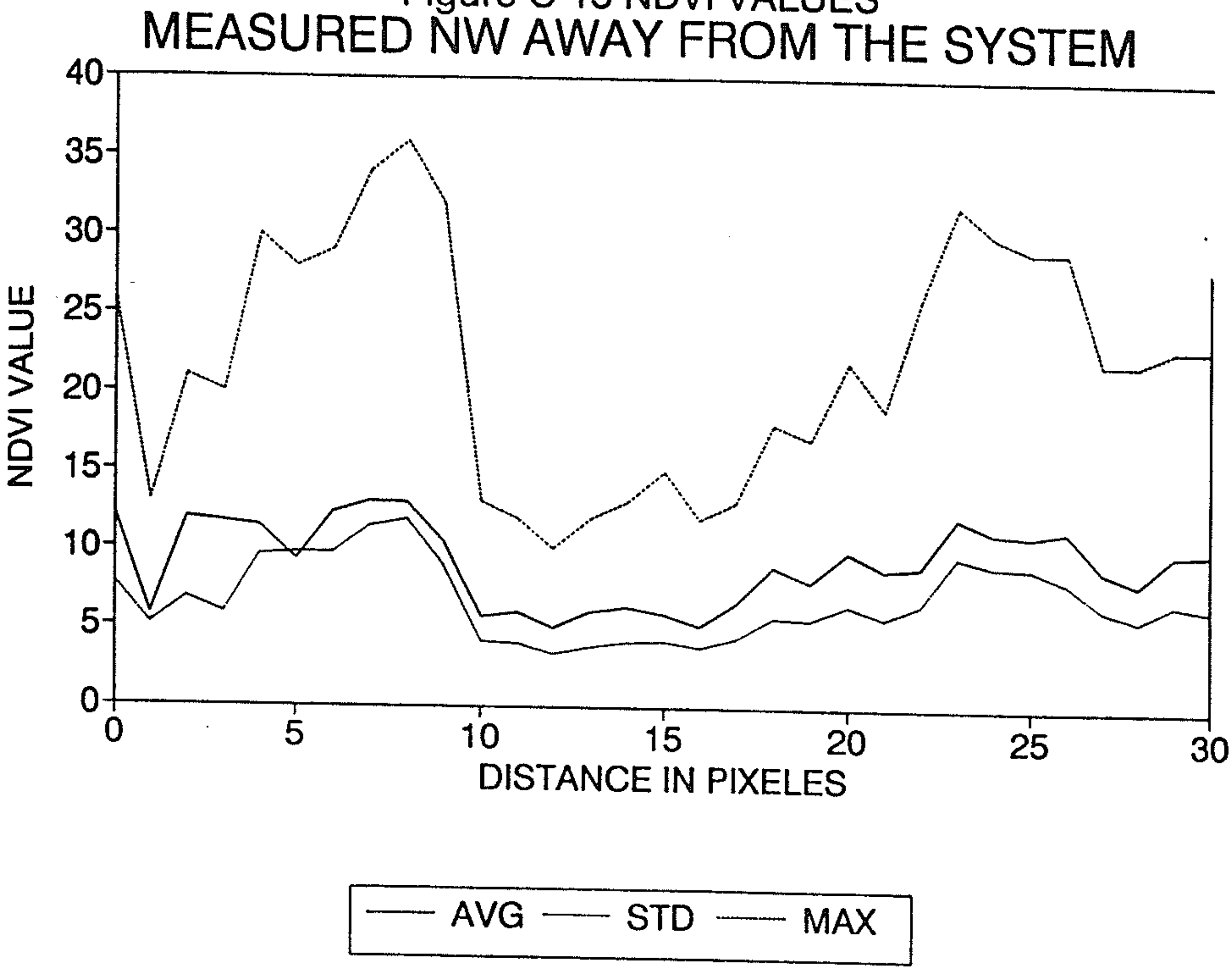


Figure C-16 HISTOGRAM OF THE NDVI

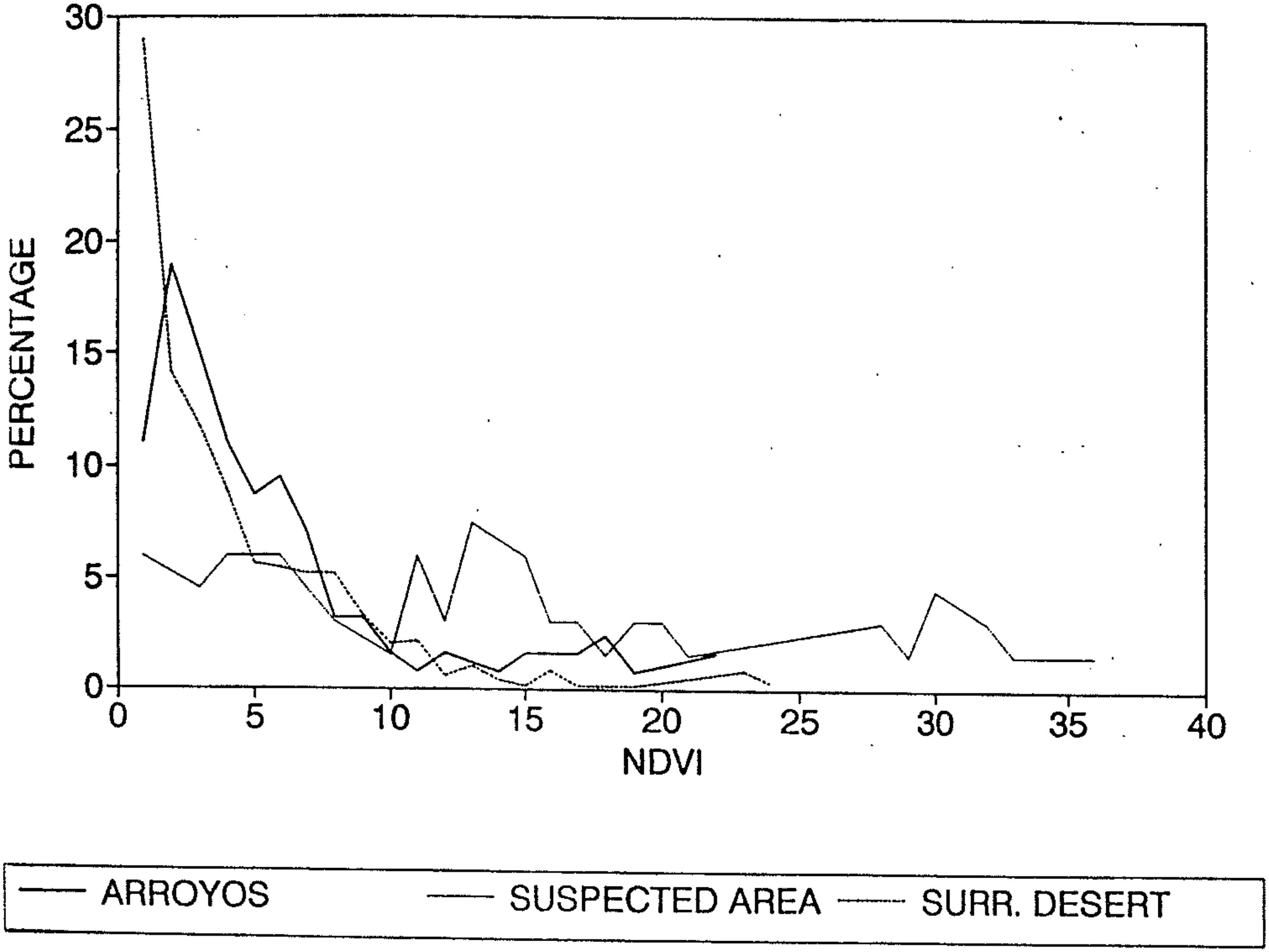


Fig. C-17

Circles at 8 & 24 Pixels away from the center

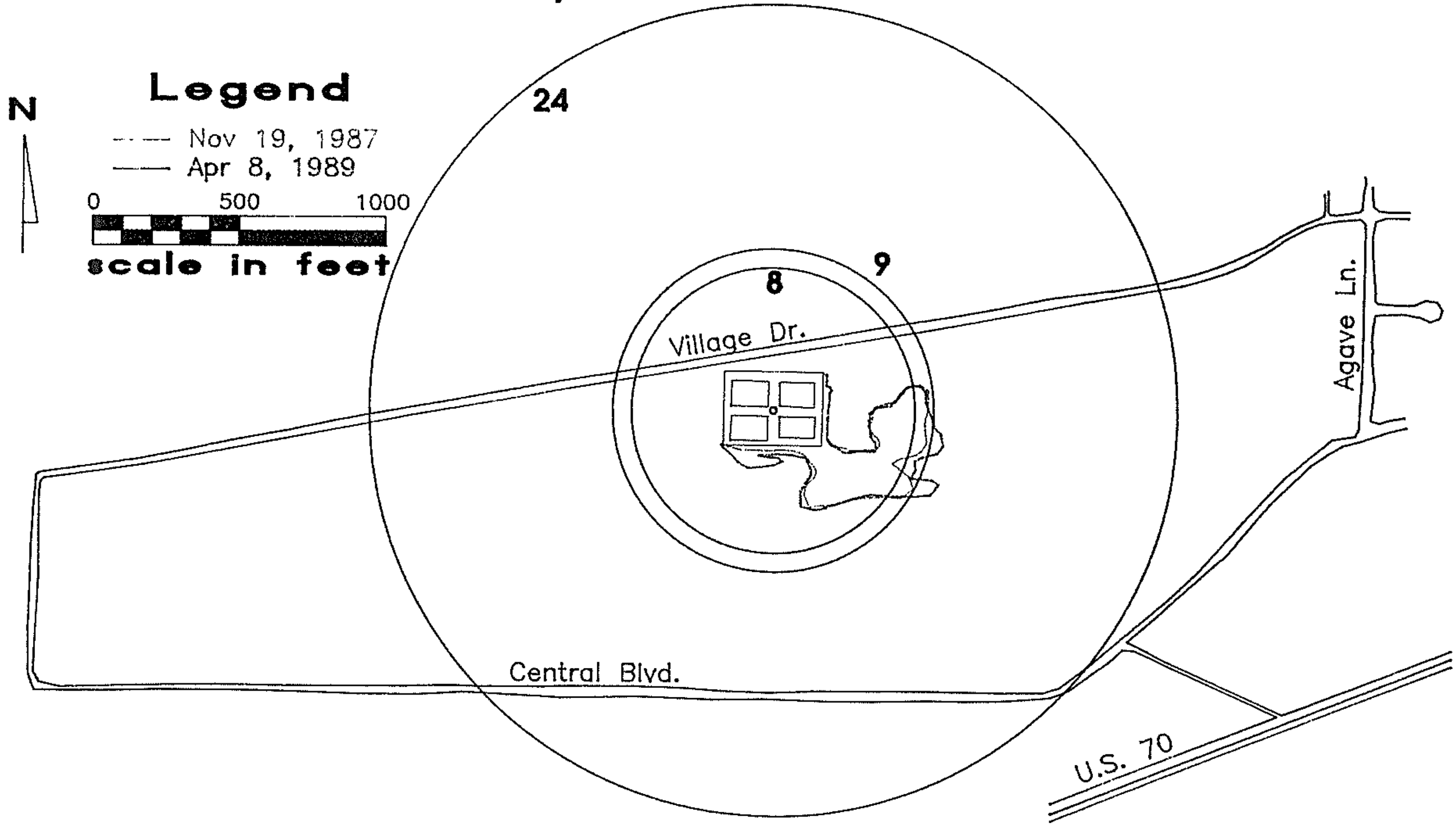


Figure C-18 Node Structure and Initial Boundary Conditions for the 1-D Model

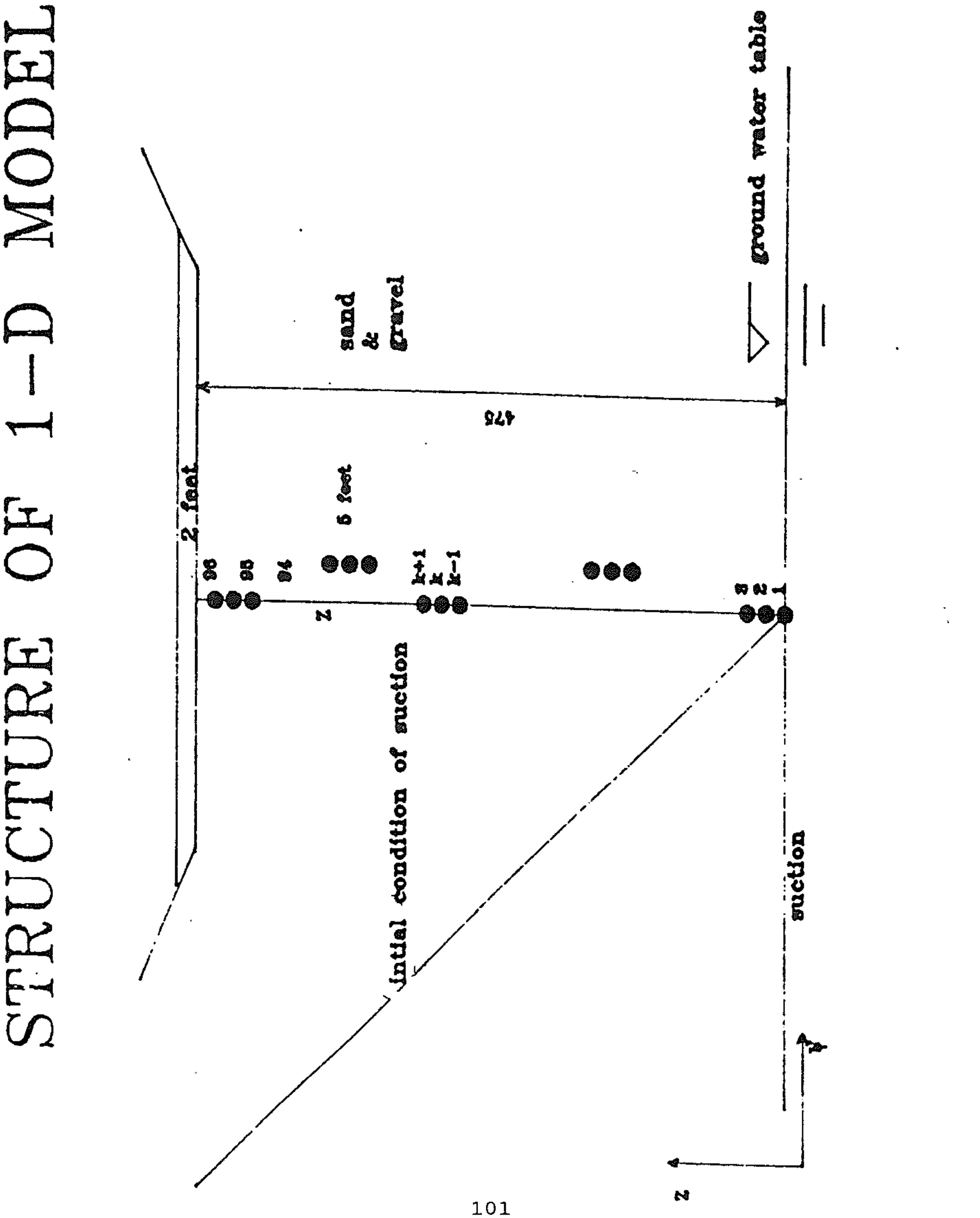


Figure C-19 Groundwater Contours for the study Area

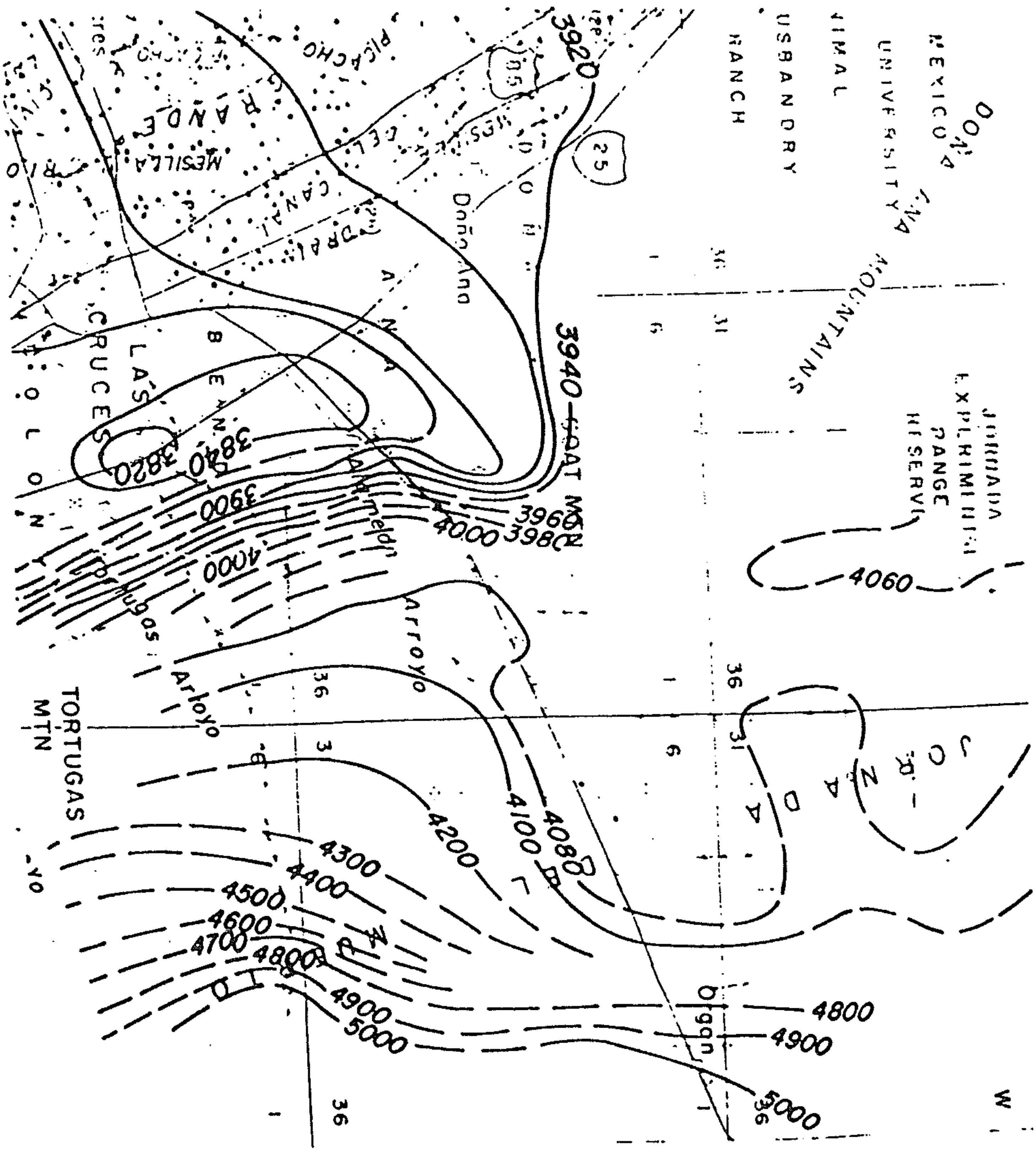


Figure C-20 Domain Coding and Boundary Head Levels

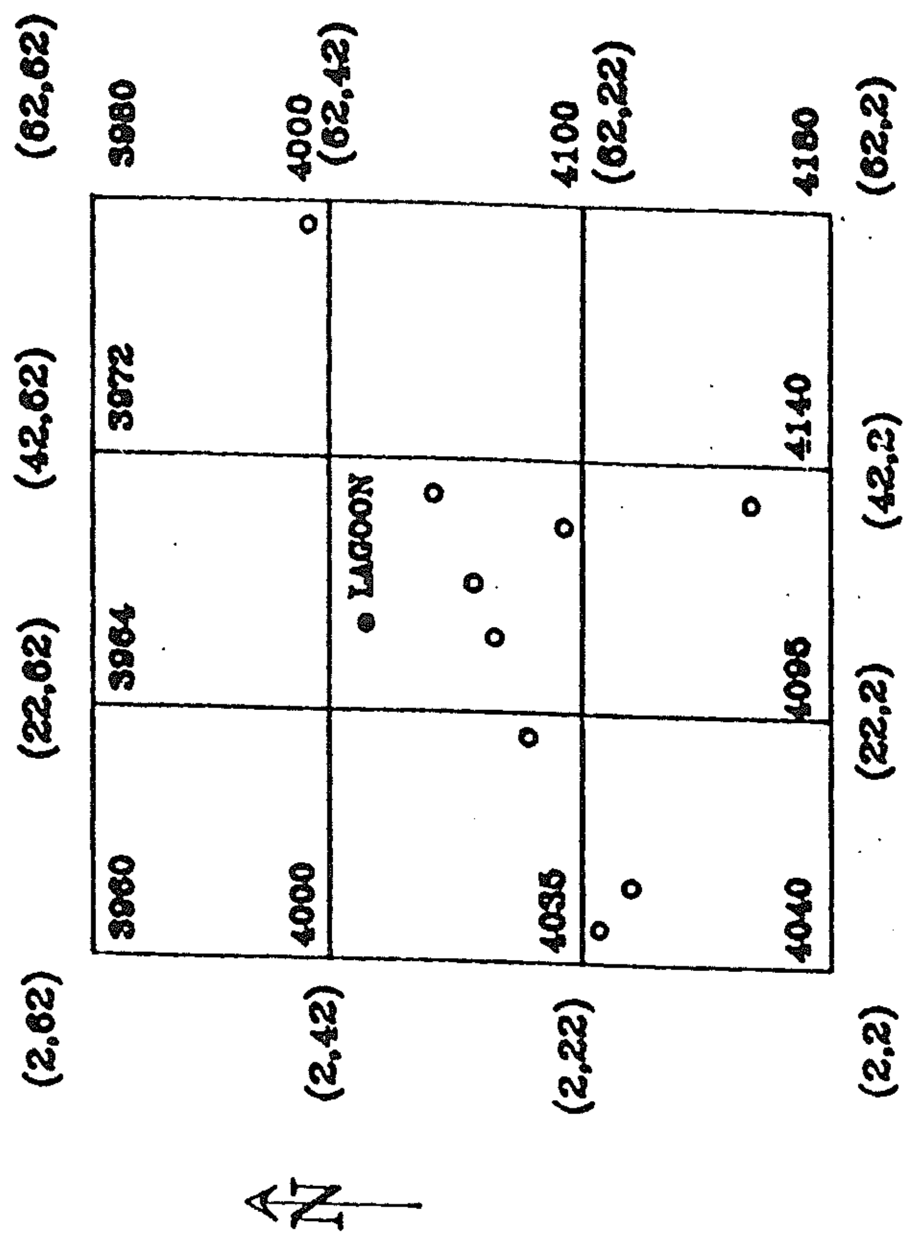


Figure C-21 Water Table in the Lagoon Area

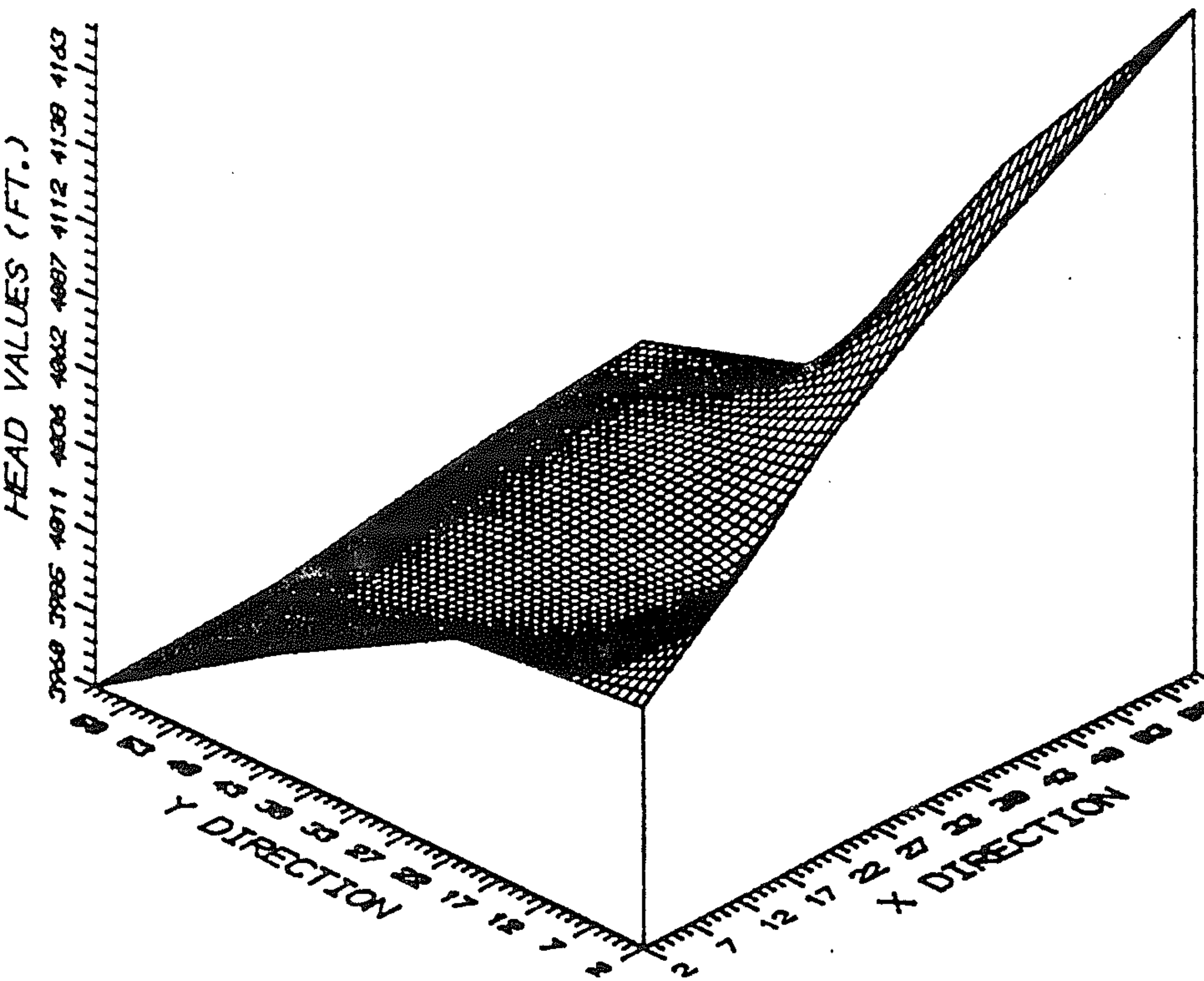


Figure C-22 Head Values Around the Lagoon

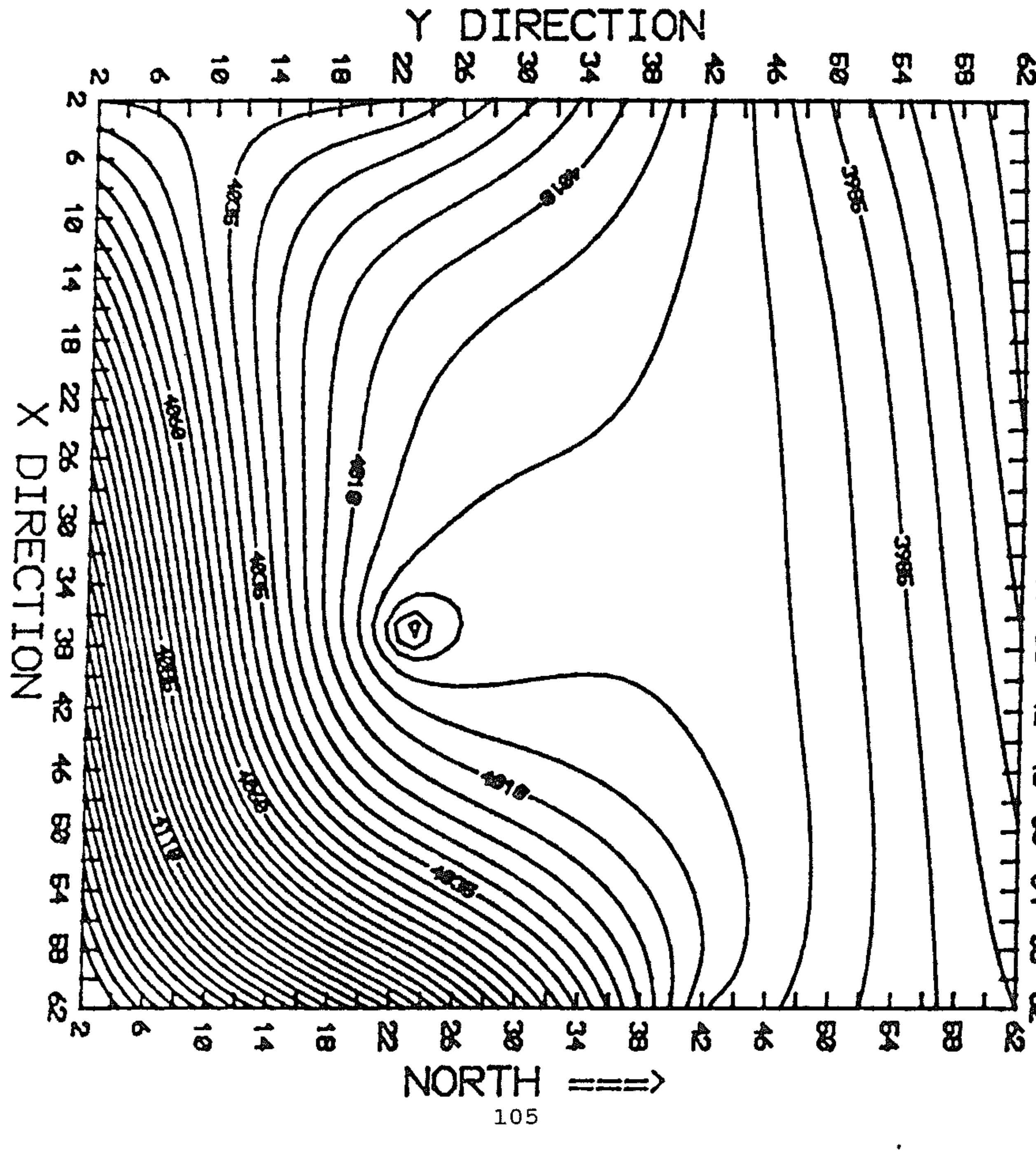


Figure C-23 Velocity Contours in the East-West Direction

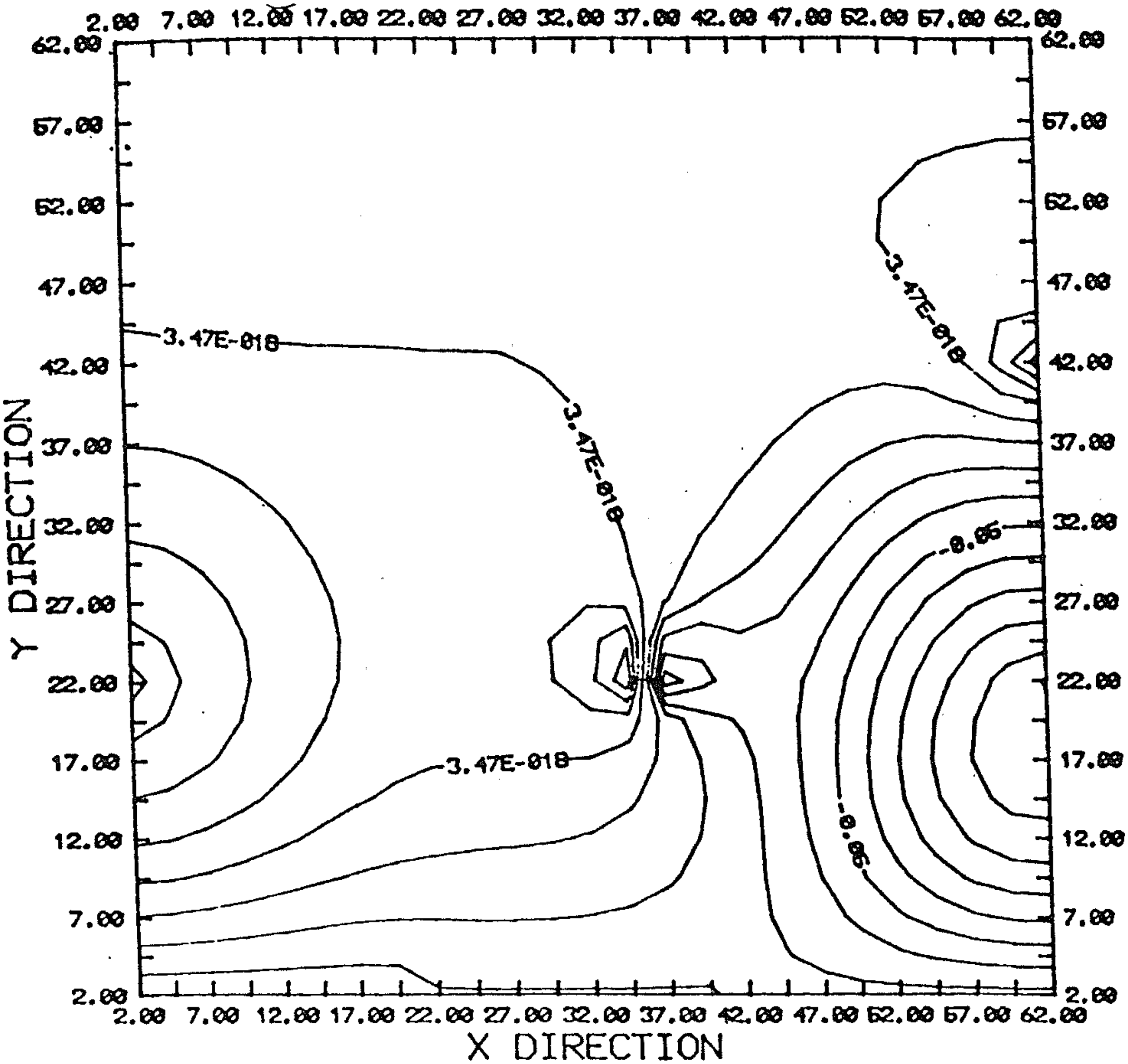
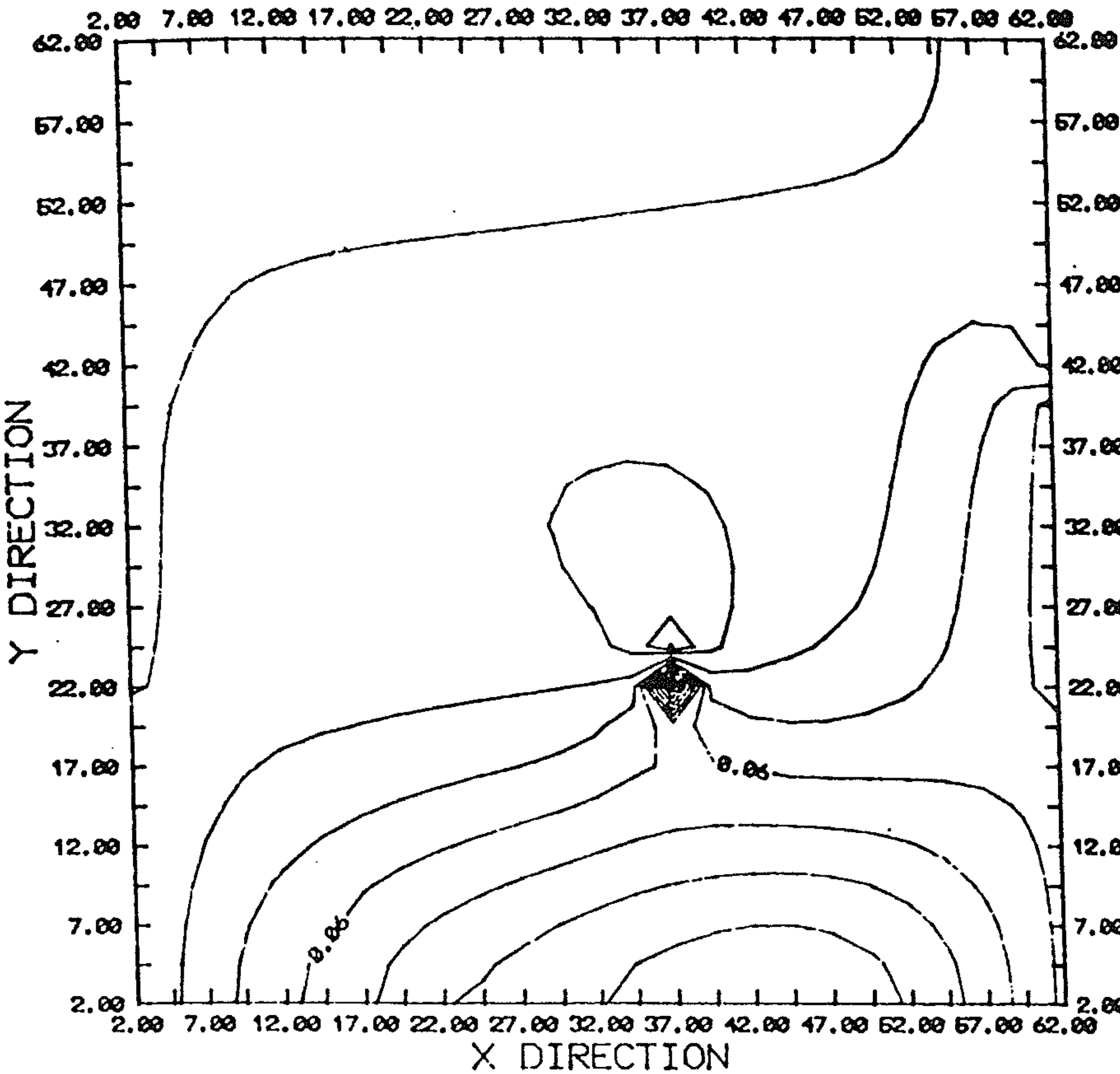


Figure C-24 Velocity Contours in the North-South Direction



APPENDIX D

Table D-1

Mesa Village
Depth: 2ft

Weight of Wet Soil (g) 207.8
Weight of Dry Soil (g) 174.1

Moisture Content 0.193567

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	19.90	11.44	11.44	88.56
10	2.00	44.50	25.57	37.01	62.99
20	0.85	48.90	28.10	65.11	34.89
40	0.43	24.60	14.14	79.25	20.75
60	0.25	13.00	7.47	86.72	13.28
140	0.11	0.70	0.40	87.13	12.87
200	0.08	15.70	9.02	96.15	3.85
Pan		6.70	3.85	100.00	
Sum		174.00			

Table D-2

Mesa Village
Depth: 15ft

Weight of Wet Soil (g)	307.7
Weight of Dry Soil (g)	281.6
Moisture Content	0.092685

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	7.50	2.68	2.68	97.32
10	2.00	24.30	8.69	11.38	88.62
20	0.85	34.00	12.16	23.54	76.46
40	0.43	51.40	18.39	41.93	58.07
60	0.25	68.90	24.65	66.58	33.42
140	0.11	71.50	25.58	92.16	7.84
200	0.08	11.70	4.19	96.35	3.65
Pan		10.20	3.65	100.00	
Sum		279.50			

Table D-3

Mesa Village
Depth: 20ft

Weight of Wet Soil (g) 248.5
Weight of Dry Soil (g) 219.6

Moisture Content 0.131603

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	4.70	2.15	2.15	97.85
10	2.00	49.90	22.82	24.97	75.03
20	0.85	45.90	20.99	45.95	54.05
40	0.43	28.80	13.17	59.12	40.88
60	0.25	20.60	9.42	68.54	31.46
140	0.11	40.50	18.52	87.06	12.94
200	0.08	13.20	6.04	93.10	6.90
Pan		15.10	6.90	100.00	
Sum		218.70			

Table D-4

Mesa Village
Depth: 40ft

Weight of Wet Soil (g)	955.9
Weight of Dry Soil (g)	826.6
Moisture Content	0.156424

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	19.80	2.40	2.40	97.60
10	2.00	99.20	12.04	14.44	85.56
20	0.85	142.00	17.24	31.68	68.32
40	0.43	102.00	12.38	44.06	55.94
60	0.25	90.10	10.94	54.99	45.01
140	0.11	195.10	23.68	78.67	21.33
200	0.08	47.80	5.80	84.48	15.52
Pan		127.90	15.52	100.00	
Sum		823.90			

Fz	5
Fm	1
Gs	2.7
Ws	57
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	55.00	22.00	0.65	50.65	87.87	56.00	7.16	0.0133	0.0709
0.5	52.50	22.00	0.65	48.15	83.54	53.50	7.57	0.0133	0.0515
1	50.50	22.00	0.65	46.15	80.07	51.50	7.89	0.0133	0.0372
2	47.50	22.00	0.65	43.15	74.86	48.50	8.39	0.0133	0.0271
4	45.00	22.00	0.65	40.65	70.52	46.00	8.79	0.0133	0.0196
8	43.50	22.00	0.65	39.15	67.92	44.50	9.04	0.0133	0.0141
15	41.00	22.00	0.65	36.65	63.58	42.00	9.45	0.0133	0.0105
30	39.00	22.00	0.65	34.65	60.11	40.00	9.77	0.0133	0.0076
60	37.00	22.00	0.65	32.65	56.64	38.00	10.10	0.0133	0.0054
120	35.00	22.00	0.65	30.65	53.18	36.00	10.43	0.0133	0.0039
240	33.50	22.00	0.65	29.15	50.57	34.50	10.67	0.0133	0.0028
1440	28.50	22.00	0.65	24.15	41.90	29.50	11.49	0.0133	0.0012
2880	26.50	22.00	0.65	22.15	38.43	27.50	11.82	0.0133	0.0008

Table D-5

Mesa Village
Depth: 45ft

Weight of Wet Soil (g)	805.7
Weight of Dry Soil (g)	701.5
Moisture Content	0.148539

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	10.30	1.47	1.47	98.53
10	2.00	77.30	11.03	12.50	87.50
20	0.85	107.90	15.40	27.90	72.10
40	0.43	79.20	11.30	39.20	60.80
60	0.25	65.40	9.33	48.54	51.46
140	0.11	22.10	3.15	51.69	48.31
200	0.08	216.40	30.88	82.57	17.43
Pan		122.10	17.43	100.00	
Sum		700.70			

Fz	5
Fm	1
Gs	2.7
Ws	50
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	60.00	23.50	1.03	56.03	110.81	61.00	6.34	0.0104	0.0521
0.5	57.00	23.50	1.03	53.03	104.87	58.00	6.83	0.0104	0.0383
1	52.50	23.50	1.03	48.53	95.97	53.50	7.57	0.0104	0.0285
2	50.00	23.50	1.03	46.03	91.03	51.00	7.98	0.0104	0.0207
4	47.50	23.50	1.03	43.53	86.08	48.50	8.39	0.0104	0.0150
8	46.00	23.50	1.03	42.03	83.12	47.00	8.63	0.0104	0.0107
15	45.00	23.50	1.03	41.03	81.14	46.00	8.79	0.0104	0.0079
30	43.00	23.50	1.03	39.03	77.18	44.00	9.12	0.0104	0.0057
60	41.50	23.50	1.03	37.53	74.22	42.50	9.37	0.0104	0.0041
120	39.50	22.00	0.65	35.15	69.52	40.50	9.69	0.0133	0.0038
240	37.50	22.00	0.65	33.15	65.56	38.50	10.02	0.0133	0.0027
1546	32.00	22.00	0.65	27.65	54.69	33.00	10.92	0.0133	0.0011
2866	30.00	22.00	0.65	25.65	50.73	31.00	11.24	0.0133	0.0008

Table D-6

Mesa Village
Depth: 50ft

Weight of Wet Soil (g)	648.6
Weight of Dry Soil (g)	563.6
Moisture Content	0.150816

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	10.50	1.87	1.87	98.13
10	2.00	70.80	12.62	14.49	85.51
20	0.85	85.50	15.24	29.74	70.26
40	0.43	62.40	11.12	40.86	59.14
60	0.25	54.00	9.63	50.49	49.51
140	0.11	134.30	23.94	74.43	25.57
200	0.08	44.80	7.99	82.42	17.58
Pan		98.60	17.58	100.00	
Sum		560.90			

Fz	5
Fm	1
Gs	2.7
Ws	50
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	50.00	23.50	1.03	46.03	91.03	51.00	7.98	0.0131	0.0737
0.5	45.00	23.50	1.03	41.03	81.14	46.00	8.79	0.0131	0.0547
1	42.00	23.50	1.03	38.03	75.21	43.00	9.28	0.0131	0.0398
2	41.00	23.50	1.03	37.03	73.23	42.00	9.45	0.0131	0.0284
4	39.50	23.50	1.03	35.53	70.26	40.50	9.69	0.0131	0.0203
8	38.00	23.50	1.03	34.03	67.29	39.00	9.94	0.0131	0.0145
15	37.00	23.50	1.03	33.03	65.32	38.00	10.10	0.0131	0.0107
30	36.00	23.50	1.03	32.03	63.34	37.00	10.26	0.0131	0.0076
60	34.50	23.50	1.03	30.53	60.37	35.50	10.51	0.0131	0.0055
120	33.00	22.00	0.65	28.65	56.66	34.00	10.75	0.0133	0.0040
240	32.00	22.00	0.65	27.65	54.69	33.00	10.92	0.0133	0.0028
1560	27.50	22.00	0.65	23.15	45.79	28.50	11.65	0.0133	0.0011
2880	25.50	22.00	0.65	21.15	41.83	26.50	11.98	0.0133	0.0009

Table D-7

Mesa Village
Depth: 55ft

Weight of Wet Soil (g)	647.3
Weight of Dry Soil (g)	574.2
Moisture Content	0.127308

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	3.90	0.68	0.68	99.32
10	2.00	46.90	8.18	8.86	91.14
20	0.85	85.00	14.83	23.70	76.30
40	0.43	70.60	12.32	36.01	63.99
60	0.25	61.00	10.64	46.66	53.34
140	0.11	149.50	26.09	72.74	27.26
200	0.08	46.20	8.06	80.81	19.19
Pan		110.00	19.19	100.00	0.00
Sum		573.10			

Fz	5
Fm	1
Gs	2.7
Ws	50
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	50.00	23.50	1.03	46.03	91.03	51.00	7.98	0.0131	0.0737
0.5	45.00	23.50	1.03	41.03	81.14	46.00	8.79	0.0131	0.0547
1	41.50	23.50	1.03	37.53	74.22	42.50	9.37	0.0131	0.0399
2	39.00	23.50	1.03	35.03	69.27	40.00	9.77	0.0131	0.0288
4	37.00	23.50	1.03	33.03	65.32	38.00	10.10	0.0131	0.0207
8	35.50	23.50	1.03	31.53	62.35	36.50	10.35	0.0131	0.0148
15	35.00	23.50	1.03	31.03	61.36	36.00	10.43	0.0131	0.0109
30	33.50	23.50	1.03	29.53	58.39	34.50	10.67	0.0131	0.0078
60	32.00	23.50	1.03	28.03	55.43	33.00	10.92	0.0131	0.0056
120	31.00	22.00	0.65	26.65	52.71	32.00	11.08	0.0133	0.0040
240	30.00	22.00	0.65	25.65	50.73	31.00	11.24	0.0133	0.0029
1571	25.00	22.00	0.65	20.65	40.84	26.00	12.06	0.0133	0.0012
2890	24.00	22.00	0.65	19.65	38.86	25.00	12.23	0.0133	0.0009

Table D-8

Mesa Village
Depth: 60ft

Weight of Wet Soil (g) 878.6
Weight of Dry Soil (g) 780.1

Moisture Content 0.126266

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	36.10	4.64	4.64	95.36
10	2.00	190.90	24.53	29.17	70.83
20	0.85	189.90	24.40	53.57	46.43
40	0.43	97.80	12.57	66.14	33.86
60	0.25	63.20	8.12	74.26	25.74
140	0.11	10.20	1.31	75.57	24.43
200	0.08	127.50	16.38	91.96	8.04
Pan		62.60	8.04	100.00	0.00
Sum		778.20			

Fz	5
Fm	1
Gs	2.7
Ws	48.2
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	50.00	22.50	0.78	45.78	93.91	51.00	7.98	0.0132	0.0743
0.5	46.00	22.00	0.65	41.65	85.45	47.00	8.63	0.0133	0.0550
1	44.00	22.00	0.65	39.65	81.35	45.00	8.96	0.0133	0.0397
2	41.50	22.00	0.65	37.15	76.22	42.50	9.37	0.0133	0.0287
4	39.00	22.00	0.65	34.65	71.09	40.00	9.77	0.0133	0.0207
8	37.00	21.50	0.53	32.53	66.73	38.00	10.10	0.0133	0.0149
15	36.00	21.50	0.53	31.53	64.68	37.00	10.26	0.0133	0.0110
30	35.00	21.50	0.53	30.53	62.63	36.00	10.43	0.0133	0.0078
60	32.50	21.50	0.53	28.03	57.50	33.50	10.84	0.0133	0.0057
120	31.00	21.50	0.53	26.53	54.42	32.00	11.08	0.0133	0.0040
240	29.50	21.50	0.53	25.03	51.34	30.50	11.33	0.0133	0.0029
1440	24.50	21.50	0.53	20.03	41.08	25.50	12.14	0.0133	0.0012
2880	22.00	21.50	0.53	17.53	35.96	23.00	12.55	0.0133	0.0009

Table D-9

Mesa Village
Depth: 65ft

Weight of Wet Soil (g)	858.9
Weight of Dry Soil (g)	765
Moisture Content	0.122745

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	33.30	4.38	4.38	95.62
10	2.00	161.30	21.21	25.59	74.41
20	0.85	171.10	22.50	48.09	51.91
40	0.43	92.70	12.19	60.28	39.72
60	0.25	62.20	8.18	68.45	31.55
140	0.11	116.50	15.32	83.77	16.23
200	0.08	36.30	4.77	88.55	11.45
Pan		87.10	11.45	100.00	
Sum		760.50			

Fz	5
Fm	1
Gs	2.7
Ws	51.9
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	53.00	21.50	0.53	48.53	92.46	54.00	7.49	0.0133	0.0728
0.5	50.00	21.50	0.53	45.53	86.74	51.00	7.98	0.0133	0.0531
1	47.00	21.50	0.53	42.53	81.03	48.00	8.47	0.0133	0.0387
2	44.00	21.50	0.53	39.53	75.31	45.00	8.96	0.0133	0.0281
4	42.00	21.50	0.53	37.53	71.50	43.00	9.28	0.0133	0.0203
8	40.00	21.50	0.53	35.53	67.69	41.00	9.61	0.0133	0.0146
15	38.00	21.50	0.53	33.53	63.88	39.00	9.94	0.0133	0.0108
30	36.50	21.50	0.53	32.03	61.02	37.50	10.18	0.0133	0.0077
60	34.00	21.50	0.53	29.53	56.26	35.00	10.59	0.0133	0.0056
120	32.50	21.50	0.53	28.03	53.40	33.50	10.84	0.0133	0.0040
240	31.00	21.50	0.53	26.53	50.54	32.00	11.08	0.0133	0.0029
1440	24.50	21.50	0.53	20.03	38.16	25.50	12.14	0.0133	0.0012
2880	22.00	21.50	0.53	17.53	33.39	23.00	12.55	0.0133	0.0009

Table D-10

Mesa Village
Depth: 70ft

Weight of Wet Soil (g)	724.7
Weight of Dry Soil (g)	654.6
Moisture Content	0.107088

Sieve Number	Sieve Opening (mm)	Weight Retained (g)	Percent Weight Retained	Cumulative Percent Retained	Percent Finer
4	4.75	11.50	1.76	1.76	98.24
10	2.00	81.90	12.52	14.28	85.72
20	0.85	127.40	19.48	33.76	66.24
40	0.43	91.40	13.98	47.74	52.26
60	0.25	71.70	10.96	58.70	41.30
140	0.11	15.50	2.37	61.07	38.93
200	0.08	166.70	25.49	86.56	13.44
Pan		87.90	13.44	100.00	
Sum		654.00			

Fz	5
Fm	1
Gs	2.7
Ws	50
a	0.99

Time (min)	Hydrom. Reading	Temp. (deg C)	Ft	Rcp	Percent Finer	Rcl	L (cm)	A	D (mm)
0.25	52.00	21.50	0.53	47.53	94.00	53.00	7.65	0.0133	0.0736
0.5	49.00	21.50	0.53	44.53	88.06	50.00	8.14	0.0133	0.0537
1	47.00	21.50	0.53	42.53	84.11	48.00	8.47	0.0133	0.0387
2	44.00	21.50	0.53	39.53	78.17	45.00	8.96	0.0133	0.0281
4	41.50	21.50	0.53	37.03	73.23	42.50	9.37	0.0133	0.0204
8	39.00	21.50	0.53	34.53	68.28	40.00	9.77	0.0133	0.0147
15	38.00	21.50	0.53	33.53	66.31	39.00	9.94	0.0133	0.0108
30	36.00	21.50	0.53	31.53	62.35	37.00	10.26	0.0133	0.0078
60	33.00	21.50	0.53	28.53	56.42	34.00	10.75	0.0133	0.0056
120	31.00	21.50	0.53	26.53	52.46	32.00	11.08	0.0133	0.0040
240	29.50	21.50	0.53	25.03	49.49	30.50	11.33	0.0133	0.0029
1440	24.00	21.50	0.53	19.53	38.62	25.00	12.23	0.0133	0.0012
2880	21.00	21.50	0.53	16.53	32.68	22.00	12.72	0.0133	0.0009

Table D-11

Mesa Village West Side Soil Analysis October 8, 1991		
Sample #	NO3-N (ppm)	Moisture
1	5.6	7.7
2	4.5	3.7
3	4.1	9.7
4	6.8	7.8
5	4.7	11.8
6	3.9	2.7
7	4.4	13.4
8	4.9	15.5
9	20.3	2.1
10	6	6.4
11	5.7	4.9

Table D-12

Mesa Village Water Analysis September 4, 1991			
Location	NO3-N (mg/L)	NH4-N (mg/L)	TKN (mg/L)
Pond #1	0.03	7.33	26.6
Pond #2	0.04	0.92	18.1
Pond #3	0.03	0.53	6.7