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Geotechnical Investigation of In-Lake Sediment Treatment for Megginnis Arm of Lake Jackson, Tallahassee, Florida

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GEOTECHNICAL INVESTIGATION OF IN-LAKE SEDIMENT TREATMENT FOR MEGGINNIS ARM OF LAKE JACKSON, TALLAHASSEE, FLORIDA

BY

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THESIS

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ABSTRACT

Megginnis Arm of Lake Jackson in Tallahassee, Florida, has experienced rapid eutrophication as a result of development within the contributing area watershed. Bottom sediments were sampled for purposes of mapping, classifying and designating for removal. Sediment desiccation studies were performed to determine the percent of consolidation and sealing characteristics of the soils in the event of a lake drawdown.

Restoration alternatives are presented and compared on the basis of field investigations, laboratory testing and analysis, and the desiccation study. Alternative methods are discussed with respect to the cost, the flexibility and the problems inherent in the different proposals.

From the geometry of Megginnis Arm, and construction permit limitations, this study was limited to methods of restoration which include dredging, drawdown and excavation, drawdown and compaction, and drawdown with dredging. By comparing the costs, the practicality, and geotechnical investigation and the flexibility of alternative methods, it is concluded that the drawdown and excavation method is the best alternative.

The dredging and drawdown and dredging alternatives were determined to be uneconomical and risky. These methods are not recommended.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

CHAPTER I

INTRODUCTION

Lake Jackson is located just north of the city of Tallahassee, Florida in the Tallahassee Hills area of Leon County. The surface area of the lake is 4,004 acres at elevation 87 feet msl. The water level has varied from 76 to 96 feet msl from 1955 through 1983. A major watershed contribution to the lake is made through the Megginnis Arm of Lake Jackson. The Megginnis Arm is approximately a mile long and varies in width from 250 to 700 feet. The urbanized watershed that empties into the Megginnis Arm has significantly elevated turbidity, nutrients, suspended solids, and heavy metals.

Lake Jackson has been known for its game fish and has had the distinction of being called the southern bass fishing capital. The main part of the lake has maintained excellent water quality, but the water conditions in the Megginnis Arm of the lake have degraded rapidly since the early 1960's.

The Megginnis Arm of Lake Jackson has experienced rapid eutrophication over the last 20 years. With the construction of Interstate 10, the natural course of the lake aging process for Lake Jackson was first altered. Highway construction through the Megginnis Creek watershed drastically increased the inflow of suspended solids. After the highway was completed, urbanization in the northern portion of Tallahassee accelerated as development grew out from the city toward the Interstate. With this development came the associated stormwater runoff that increases nutrient loading and suspended solids.

As water quality in the Megginnis Arm deteriorated, local citizens and governmental agencies became concerned for the fate of Lake Jackson. In the early 1970's, a number of studies were initiated and conducted to identify the causes and to try and develop a program to arrest the degradation and improve conditions. As the urbanization of the watershed increased, it became physically evident that runoff from major storm events were dumping pollutants into the lake.

With this information concerning the causes of the problem, the regulatory agencies of the state of Florida and the United States Environmental Protection Agency constructed a stormwater treatment facility to limit the inflow of sediments and nutrient-rich water. The focus of concern has now shifted to in-lake treatment of the high nutrient concentrations in the water column and the sediments. This paper will spell out a restoration program that has been developed through research conducted on similar lake improvement projects and field and laboratory investigations of the water quality and the chemistry and physical composition of lake bottom sediments. The project will investigate the feasibility of desiccating and, either compacting and leaving the sediments in place, or removing the sediments by alternative methods.

CHAPTER II

LITERATURE REVIEW

Due to man's activities, many of the world's lakes are experiencing accelerated eutrophication. This has resulted in degradation of water quality, prolific weed growth, obnoxious algae blooms, the deterioration of fisheries, and the infilling of waterbodies with sediment. These concerns have generated research to investigate the nature and causes of eutrophication in lakes, and the development of control structures and techniques. With the present rate of development that Florida is experiencing, there is a great need for studies to compile the documentation of all lake restoration projects.

Lake restoration is the manipulation of a lake ecosystem to effect an in-lake improvement where degraded or undesirable conditions exist. There exists two major categories of lake restoration: (1) methods to eliminate or limit the input of nutrients and/or sedimentations, and (2) the management of eutrophic consequences. The limiting of nutrients and sediments approach addresses and treats the basic point or nonpoint source of lake degradation. The management of the consequences of a degraded lake are merely cosmetic attempts to improve the lake. These management techniques only enhance the usability of lakes while not addressing the source of degradation (Dunst et al, 1974).

The inflow of nutrients and sediments can be limited by wastewater treatment, stormwater diversion, land use practices and stormwater treatment (Wanielista, 1979). Within a lake, limitation techniques can be instrumented to accelerate nutrient removal or to inhibit their recycling. The most prevalent methods, according to the literature, are dredging, sediment exposure and desiccation (drawdown), nutrient inactivation/precipitation, biotic harvesting, selective discharge, dilution/flushing, and lake bottom sealing. Nutrient control methods can accelerate the recovery of a lake that has had a reduction in the external loading.

The pathways of nutrients within a lake are complex and variable. The nutrient exchange processes are dependent on a number of environmental variables that effect biological and chemical interactions. The largest potential source of nutrients in a eutrophic lake are the sediments (Uttormark, 1978). The role of sediments is, therefore, uncertain in the dynamics of sediment-water nutrient interchange. Studies indicate that when phosphorus and nitrogen concentrations are high, the sediments act as a buffer, and they release nutrients when the concentration is low (Keeney, 1972). The Northwest Florida Water Management District has addressed the nutrient inflow problem and has constructed a stormwater treatment facility to handle the flows entering the Megginnis Arm. With this in mind, in-lake limitation techniques will be briefly discussed in the following narrative.

Dredging may improve the trophic condition of a lake by removing a potential nutrient source and exposing a stratum that does not contain or release appreciable quantities of nutrients. Haertel (1972) discovered that the major portion of the nutrient load in shallow lakes, with a predominant wind-induced circulation, can be attributed to the sediment interface.

The reduction of nutrient loading may also be achieved by physical deeping of the lake. Rohlich (1963) demonstrated that nutrient-bearing materials have a tendency to move and settle in the deepest part of a lake.

Sediment exposure and desiccation has been used to stabilize bottom sediments and to retard nutrient releases. It has been found that a thin oxidized layer (1 cm) at the sediment-water interface will retard phosphate release to the overlying water (Mortimer, 1941). Desiccation physically stabilizes the upper flocculent zone of sediments. During drawdown, the fluid sediments either flow to the deeper parts of the lake or consolidate to physically reduce the potential exchange (Smith et al., 1972).

The study of organic solids by Davis and Lucas (1959) indicate that desiccation may accelerate microbial conversion of the organic forms of nutrients to inorganic forms. Once reflooding has taken place, these inorganic forms would then be available for plant growth.

Due to the shallow depths of most Florida lakes, drawdown is an attractive technique for limiting the in-lake recycling of nutrients. By pumping a relatively small volume of water, very large areas of lake bottom can be exposed. The desiccation of bottom sediments usually results in extensive physical consolidation of bottom sediments resulting in deeping of the lake and provisions for spawning areas for game fish. Another positive aspect of lake drawdown is the ability to remove nutrient ladened water and replace it with water having a reduced nutrient content. The drawdown technique approximates natural lake rejuvenation for Florida lakes. Water levels naturally fluctuate in many of the state's shallow lakes, thus causing a periodic sediment exposure and desiccation. Sheffield and Kaleel (1971) conducted field investigations in Lake Apopka. They demonstrated that desiccated sediments consolidated approximately 40% and showed a marked decrease in nutrient release rates after resubmergence, and had a tendency of not being resuspended.

Nutrient inactivation/precipitation inacted within a lake can speed the recovery of a lake dramatically. At present, the most widely used additives are metal ions and polyelectrolytes for phosphorus removal. The most common additive is aluminum sulfate (alum). The alum is applied and dispersed by a mixing action to coagulate suspended solids, whereby they precipitate.

Application of treatment additives can be accomplished through two basic methods. In the case where dry chemicals are to be used, the application can be performed by the use of any mechanical apparatus which will effectively broadcast the chemical. Orange County

Pollution Control Department applied alum by the use of cyclone seeders on the Lake Lawne project in Orlando, Florida. These seeders were capable of spreading 2400 lb/hr. Liquid alum is applied by the use of a centrifugal pump and is injected at the surface.

Biotic harvesting is the physical removal of plant and fish life from the lake ecosystem. When there is a high biomass of macrophytes in relation to a total volume of water, it may be necessary to harvest. This avoids the overcrowding of species that could result in overcrowding, choking itself in the competition for nutrients and then dying and decomposing, thus, adding to and compounding the nutrient load.

Thomas (1965) promoted fish harvesting, but this method has been used as a nutrient removal technique in very few restoration attempts and has always been in conjunction with other methods. Many factors affect the necessary amount for removal (size of crop, population dynamics and nutrient content). These factors could result in sizable quantities of nutrients or in insignificant amounts.

The selective discharge method is generally used to improve low dissolved oxygen conditions at or near the bottom of a lake. This will remove anaerobic nutrient-rich waters from the lake. Most selective discharge applications are in lakes with outlet control structures which can siphon waters from any selected depth. The major criticism of selective discharge is the release of anaerobic nutrient-rich water on the downstream waterbodies.

Dilution/flushing has been used primarily in cases where lakes have an excessive growth of algae, and in problem lakes where a reduction of nutrient-rich water is needed. Born et al. (1973) showed that bottom sediments play a significant role in determining nutrient levels and they may negate dilution/flushing efforts. Another important aspect of flushing is the morphology of the lake which determines the flow regime through the lake (Lomax and Osborne, 1971).

The most desirable means of dealing with nutrient-rich soil deposits is to remove them. This method is not always the most economical and feasible. Therefore, methods of sealing the bottom have been developed which can provide control at a reduced cost.

Rubber liners, plastic sheeting, sand, flyash, clays, hydrous metal oxides and, in some instances, certain gels, have been used as sediment coverings. The rubber and plastic liners can aid in control of macrophyte growth. Sand has proven effective in retarding nutrient exchange as has clay, but the clay has poor settling characteristics, thus requiring the application of a coagulant. The hydrous metal oxide aluminum sulphate has proven to be effective in the reduction of phosphorus levels in the water column and the flocculent has effectively sealed the bottom sediments that would normally exchange nutrients at the lake bottom-water interface (Brownman and Harris, 1973). Gels have been used as sediment control aids for oceanographic salvage operations, but have not been used in lake restoration applications. Future studies are needed to research the nutrient uptake properties of gels as bottom sealants.

The implementation of one or a combination of these lake improvement techniques involves a comprehensive study of climatology for the vicinity of the Megginnis Arm. When considering lake restoration techniques, the most important aspects of the climate are temperature and rainfall.

Tallahassee has a mild climate typical of states around the Gulf of Mexico. The average yearly temperature is 68° F. During the winter months, the area will experience freezing temperatures approximately 20 times. About three times per winter, temperatures will be 25° or less. The average date for the first occurrence of a 32° temperature is November 26. The average date of the last occurrence of a 32° temperature is February 28. During the summer months, temperatures are 90° or higher on at least 80 occasions. Monthly variations of temperature for a ten-year period of record are shown in Figure 1 (Bishop, 1973).

The average annual rainfall in Tallahassee is 57 inches. July is the wettest month of the year and October and November are the driest. Droughts (i.e., rainfall deficiencies for extended periods) are infrequent. Short-term droughts occur commonly and are just as significant, because of their effect on the drying up of lakes and cypress wetlands. Monthly precipitation data for a ten-year period of record are shown in Figure 2 (Bishop, 1973).

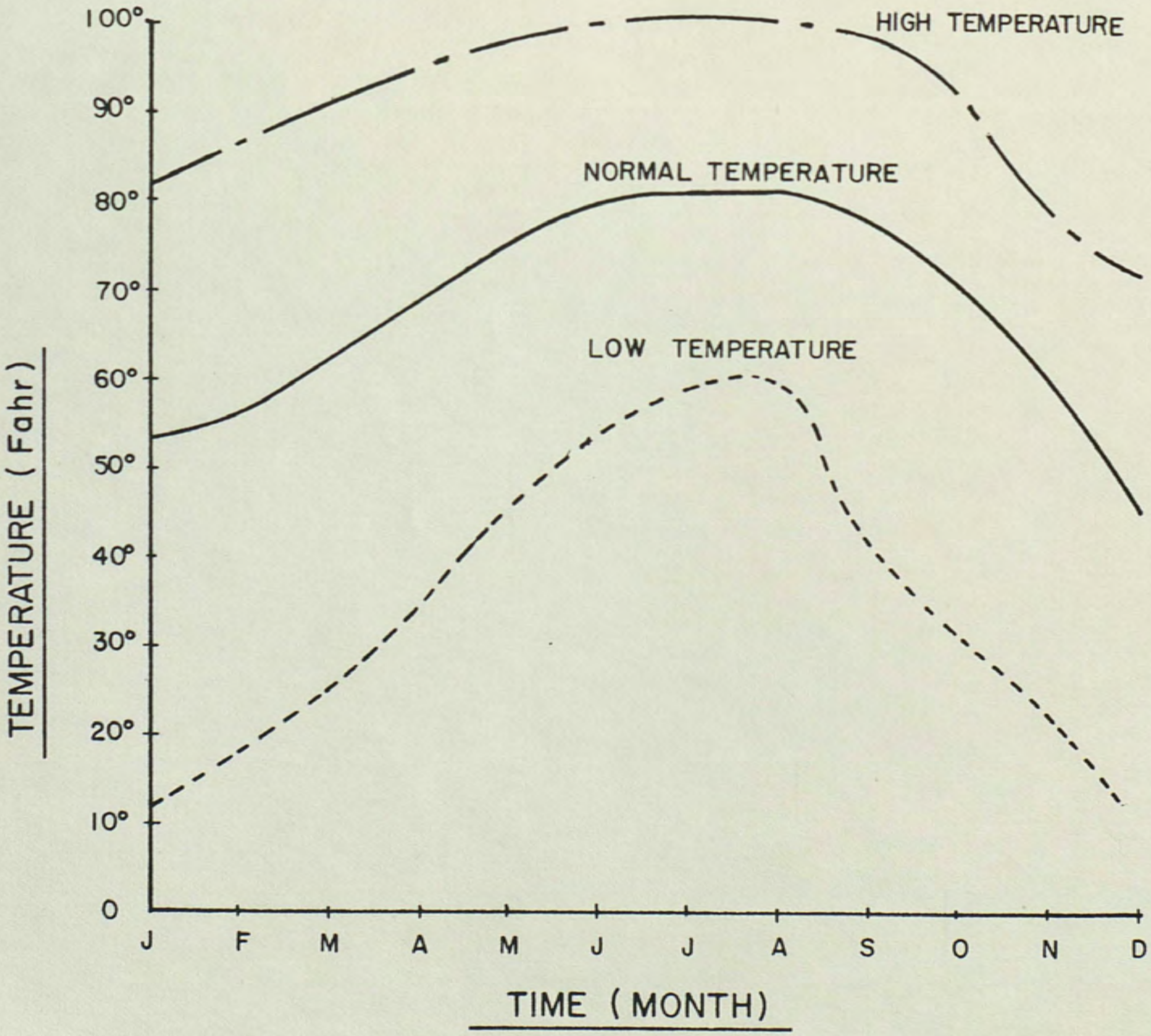


Fig. 1. Tallahassee temperature.

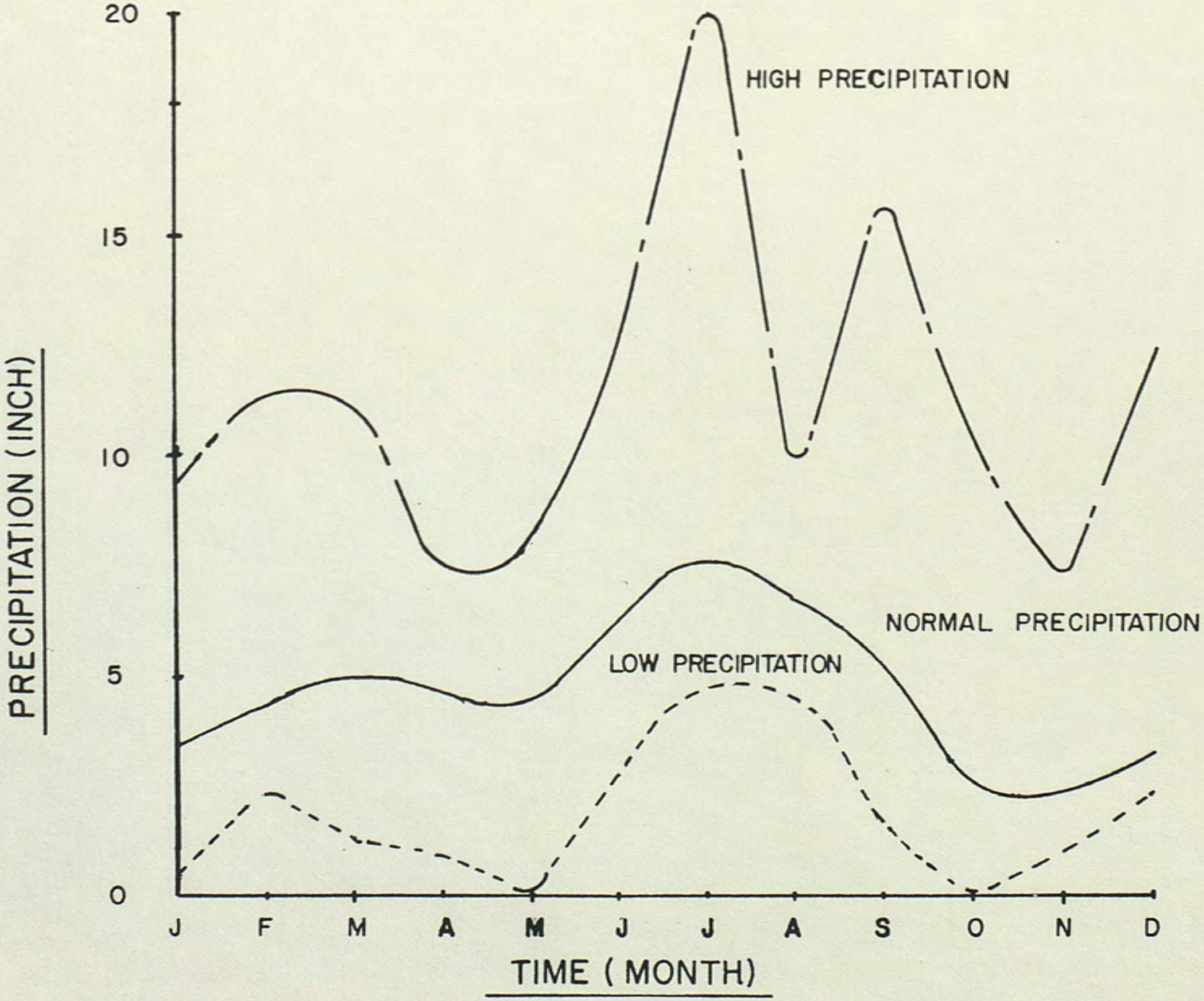


Fig. 2. Tallahassee precipitation.

Numerous lakes, sinks and depressions exist in Leon County that range in size from one acre to several thousand acres. The majority of the lakes are in the Tallahassee Hills area, north and east of Tallahassee, and in the Woodville-Karst Plain area, located south and southeast of the city. The larger lakes are located in the northern part of the county and the smaller lakes are in the Woodville area. It is interesting to note that most of the larger lakes are shallow and the smaller lakes are generally the deepest. In most cases, the deeper lakes are sinkholes that open into the underlying limestone.

The shallow group of lakes, of which Lake Jackson belongs, periodically drys up due to a combination of low rainfall, evaporation or sinkholes which act as a natural drain. In a shallow lake basin, large areas of the lake bottom are exposed to evaporation (Bishop, 1973).

Lake Jackson is approximately 10 miles long, from north to south, and the width varies from 0.5 to 2 miles. At elevations 87 feet msl, the surface area of the lake is 4,004 acres (Bishop, 1973).

Sinkholes are located in a number of places within the lake, and these have drained the lake on occasion in the past. The piezometric level of the Floridan Aquifer beneath the lake ranges from 25-40 feet msl. Florida State University stated in a report to the Florida Game and Freshwater Fish Commission, "water quality in mid-lake was exceptionally good (near oligotrophic), but declined sharply on entering Megginnis Arm", and later in the report, "the degraded water quality in Megginnis Arm is at least partially a natural consequence of the large drainage area served by this small and constructed part of Lake Jackson, but Tallahassee urbanization has clearly accelerated both the siltation and eutrophication of Megginnis Arm. It is unlikely that anything practical can be done at this point to restore Megginnis Arm to its pre-urbanization condition, but it serves as a preview of the ultimate fate of Lake Jackson if efficient preventative steps are not soon taken to protect it".

The Megginnis Arm of Lake Jackson is where Megginnis Creek empties into the lake. A 2,230 acre watershed which is 80% urbanized produces large volumes of nutrient-rich runoff water with high concentrations of sediments. Within the watershed is a portion of Interstate 10, two large shopping malls, retail stores, office complexes, city streets, schools, apartments, theaters and numerous high density housing units still in construction phase. The watershed drains through Megginnis Creek and several days after a major storm, distinct plumes of sediments and suspended clay could be seen in the Megginnis Arm.

In a joint effort, the Florida Department of Environmental Regulation, the U.S. Environmental Protection Agency Clean Lakes Program and the Northwest Florida Water Management District funded and supervised construction of a stormwater treatment facility involving a filtration system and an artificial marsh. A filtration impoundment can store nearly 50 million gallons of stormwater and has 4.5 acres of gravity flow sand filters that can discharge 8000 gallons per minute of filtered stormwater. Filtered water exits the impoundment and flows to an artificial marsh. Final treatment takes place in the marsh via aquatic plants that take up dissolved nutrients and metals and further remove clays and colloids. This treatment facility was completed in July, 1983 and has been put into operation (The Pump, 1983).

With this facility in operation, the inflow of degrading water to Megginnis Arm has been attenuated. The emphasis has shifted to the investigation of in-situ sediments, their characteristics and what method or methods of treatment should be enacted in order to restore the Megginnis Arm to the most aesthetically pleasing and the ultimate usability of the Arm.

CHAPTER III

SAMPLING AND LABORATORY TESTING AND ANALYSIS

Geotechnical investigations of sediments were conducted within Megginnis Arm for the purpose of identifying soil types by visual description, moisture content, grain size distribution, uniformity and curvature coefficients, friction angle, soil permeability, dimensions of sediment strata and water depth for mapping lake profiles. The objective is to (1) identify sediments to be removed, (2) select methods of sediment treatment, (3) determine the volume of water and/or sediments to be treated, and (4) identify alternative uses of sediments for construction fill material.

Sampling

Initially, sample stations were designated by using a random numbers program to select elements from a finite population of 100. A plot plan of the arm was gridded with 10 rows and 10 columns. Elements of the grid were labeled 1 through 100 from the upper left (northwest) to the lower right (southeast) corner of the arm. Stations were established within the grid elements based upon accessibility and the proximity of the other previously determined stations.

After preliminary review and laboratory analysis of sedimentary stratification of initial samples, subsequent sample sights were for additional information to assist in mapping and obtaining sectional views.

Figure 3 shows the location of initial sample stations. Samples were obtained by driving 1-1/2" clear plastic tubes with a cap and a six pound hammer. Each tube was driven until firmly imbedded in the hard bottom. The top of the tube was sealed with a rubber stopper and then extracted and the bottom capped. The samples were kept in an upright position and returned to the University of Central Florida laboratory for analysis. Coring profiles are depicted in Figures 37 through 39 in Appendix A.

Additional coring samples were necessary for mapping and sectional profiles. Sample locations of these corings are depicted in Figure 4 and profiles are shown in Figure 40 through 42 in Appendix A. Each core sample was photographed (Figure 5) and measurements and descriptions of the sample strata were recorded in the field. Spacing for transect corings was approximately 50 feet. From these core profiles, the cross-sectional profiles of Megginnis Arm were obtained as shown in Figures 6 through 16.

Corings were also obtained in the area of the gas line at the north end of the arm (see Figure 17). The additional samples were collected over and around the pipe with a hand auger. The hand auger technique was also used to locate the pipeline. A surveyor's level was used to determine elevations of the pipe and topography across the earth berm that covers the pipe. Core profiles are shown in Figure 43 in Appendix A.

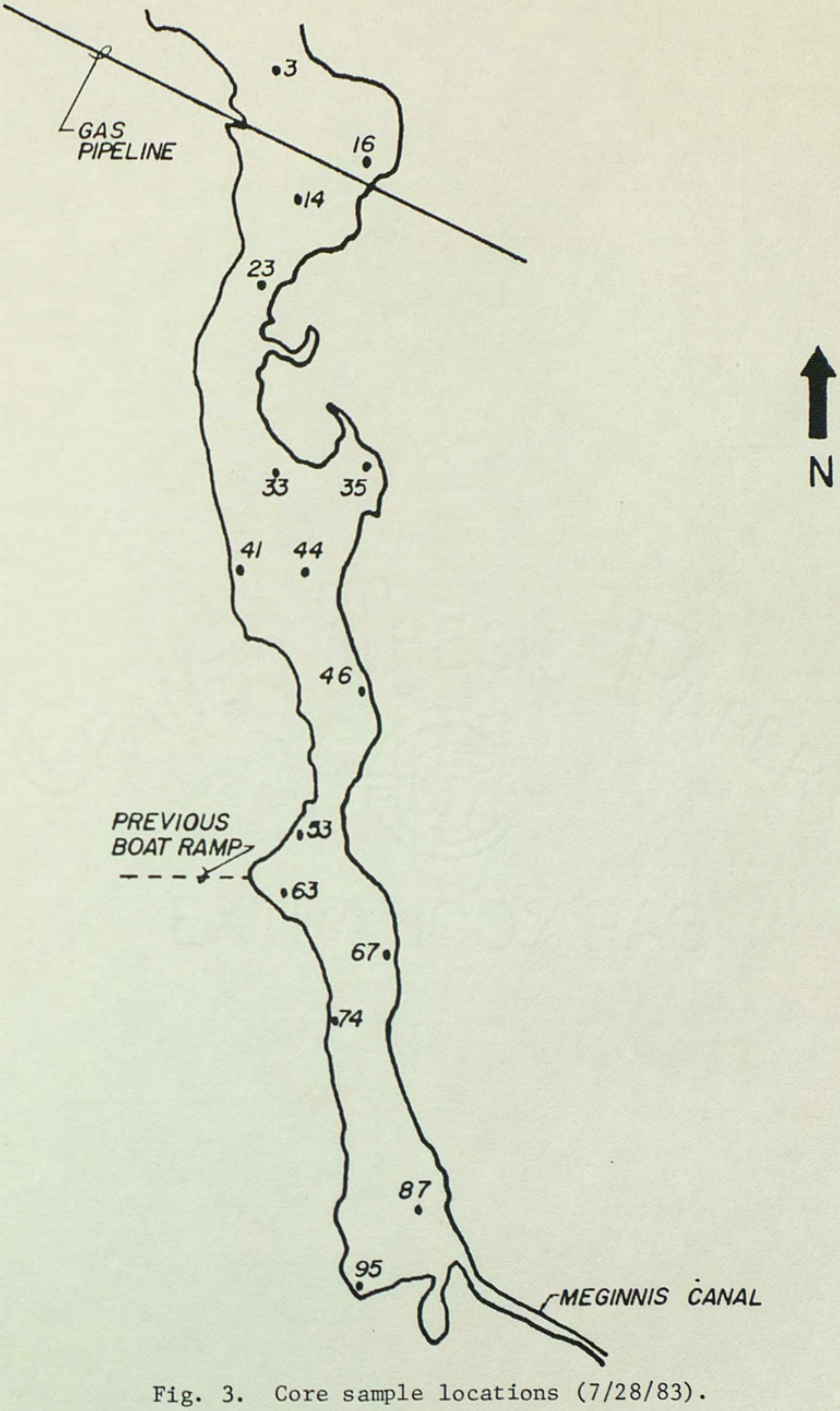


Fig. 3. Core sample locations (7/28/83).

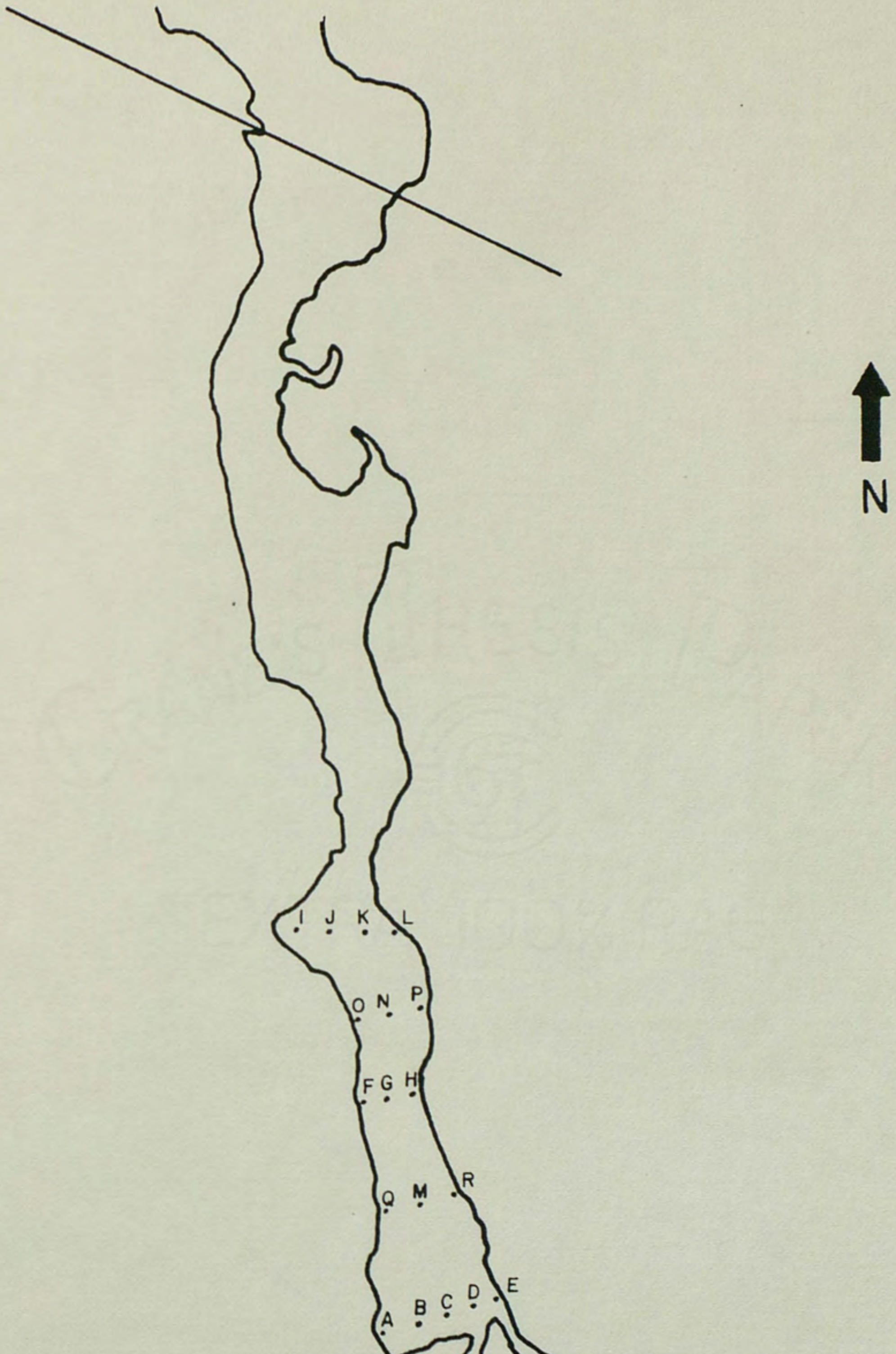


Fig. 4. Core sample locations (9/8/83).

Fig. 5. Photograph of core sample.

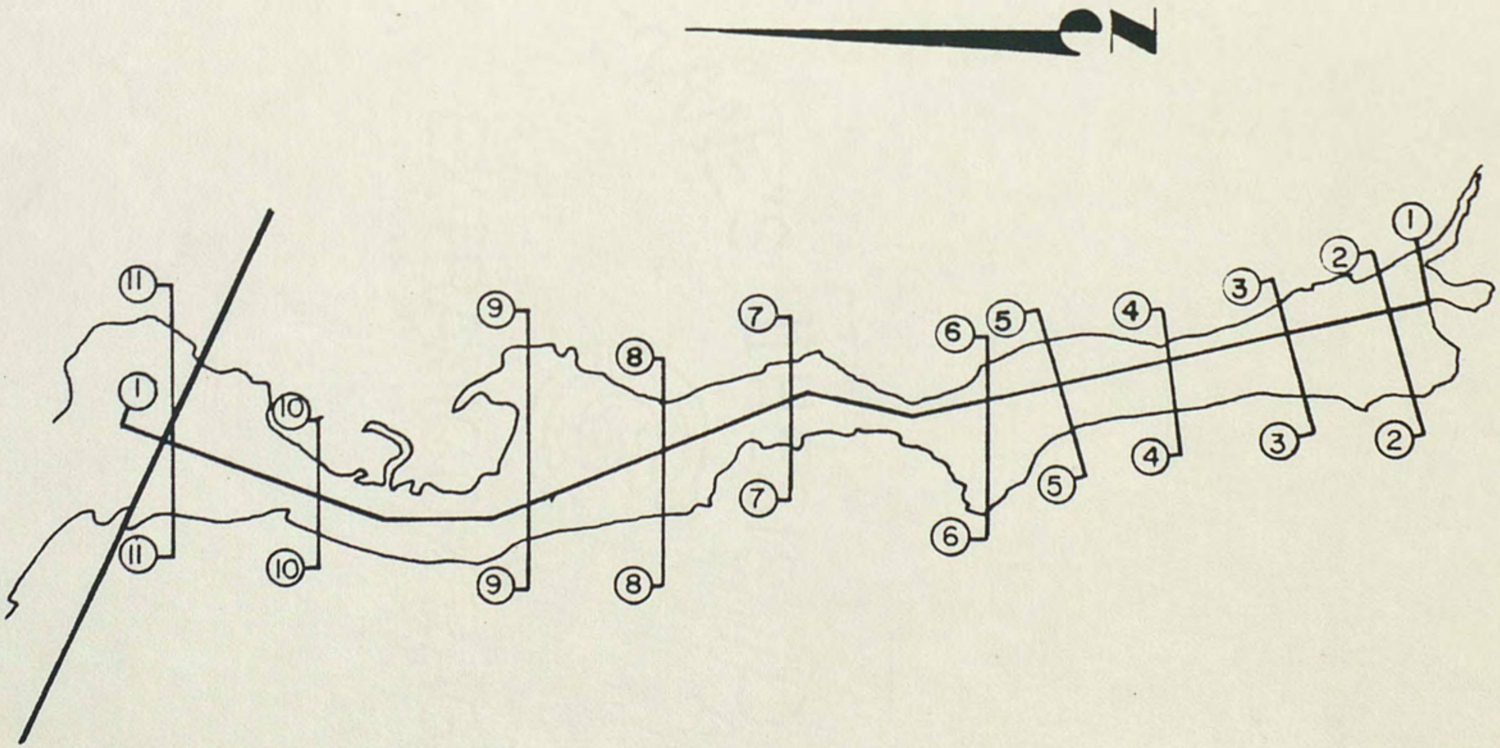


Fig. 6. Megginnis Arm plan view.

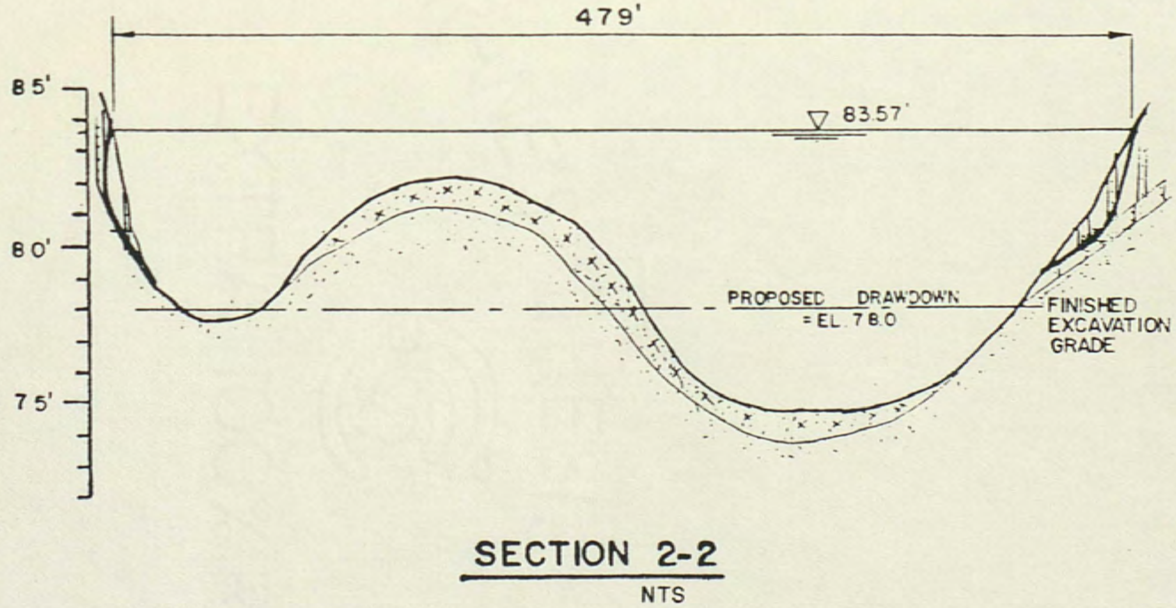
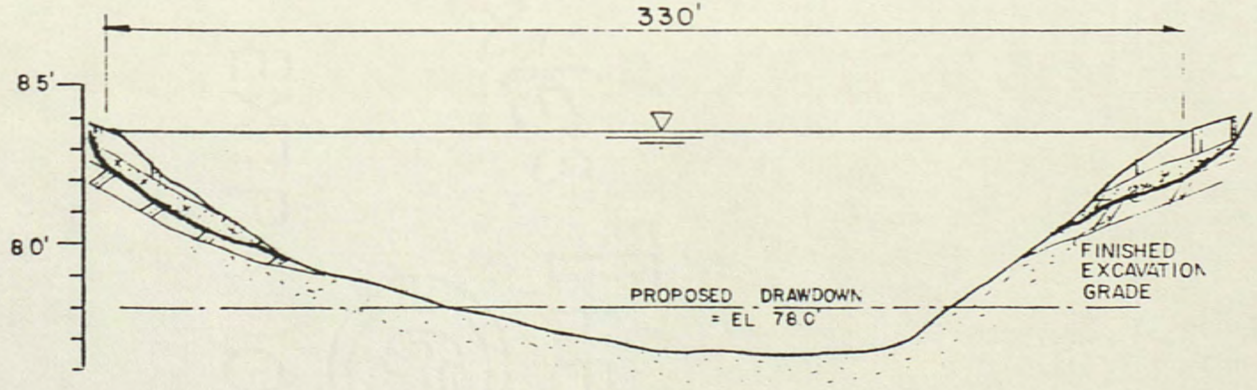


Fig. 7. Section 2-2.



SECTION 3-3
NTS

Fig. 8. Section 3-3.

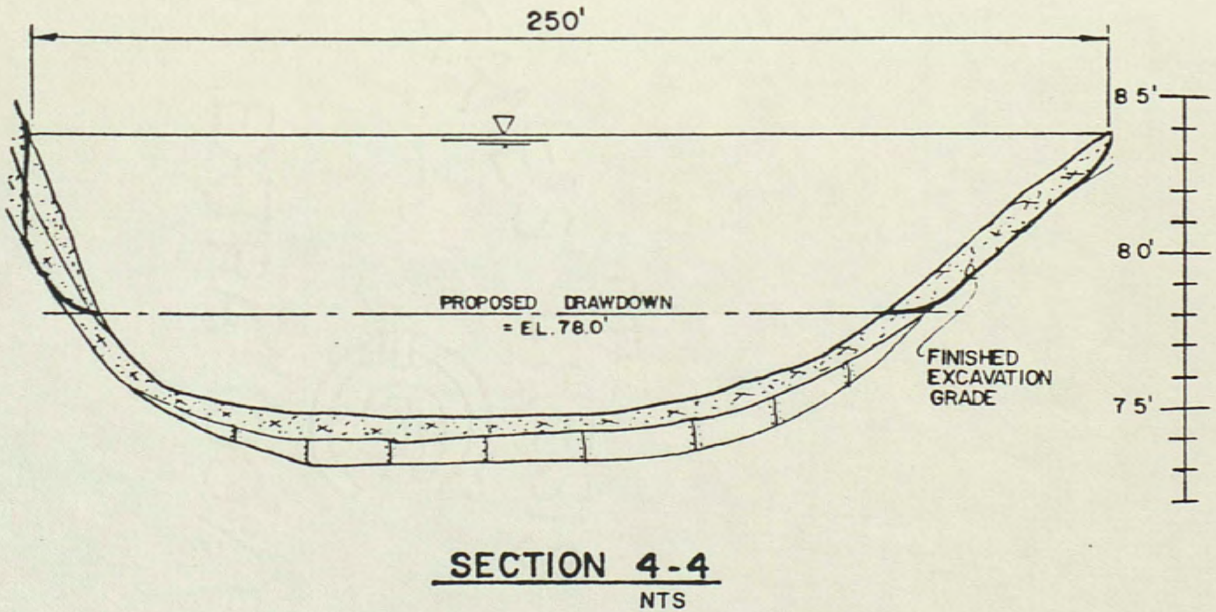
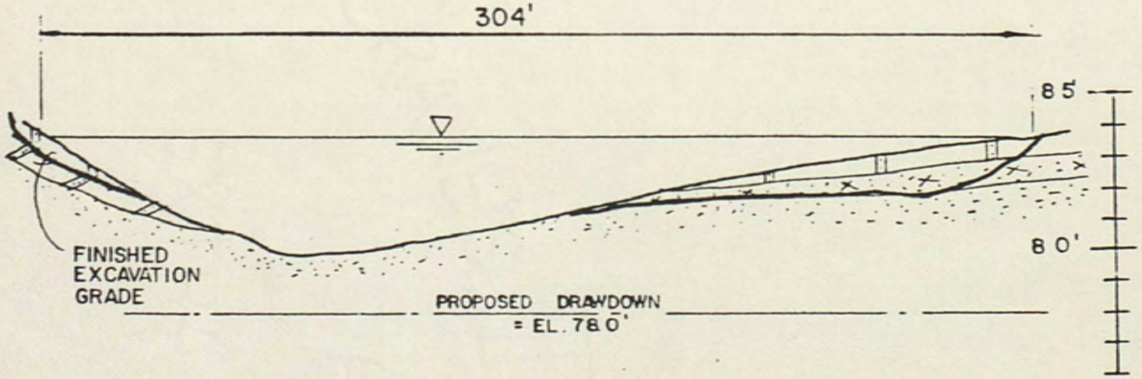


Fig. 9. Section 4-4.



SECTION 5-5
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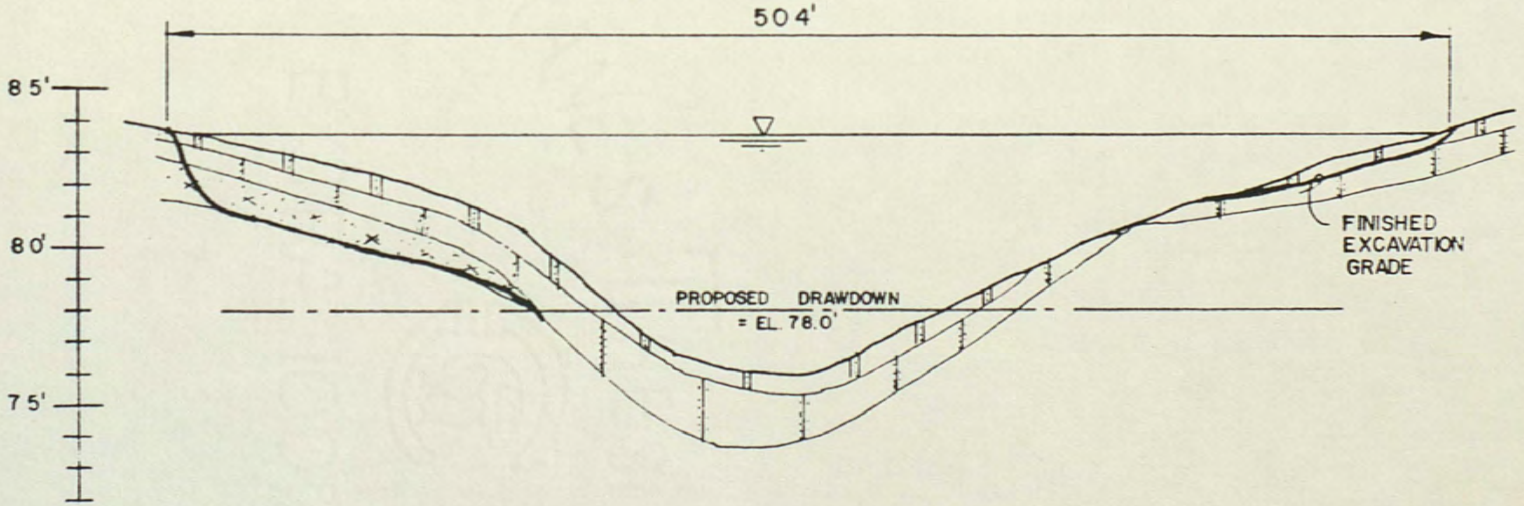
Fig. 10. Section 5-5.



SECTION 6-6
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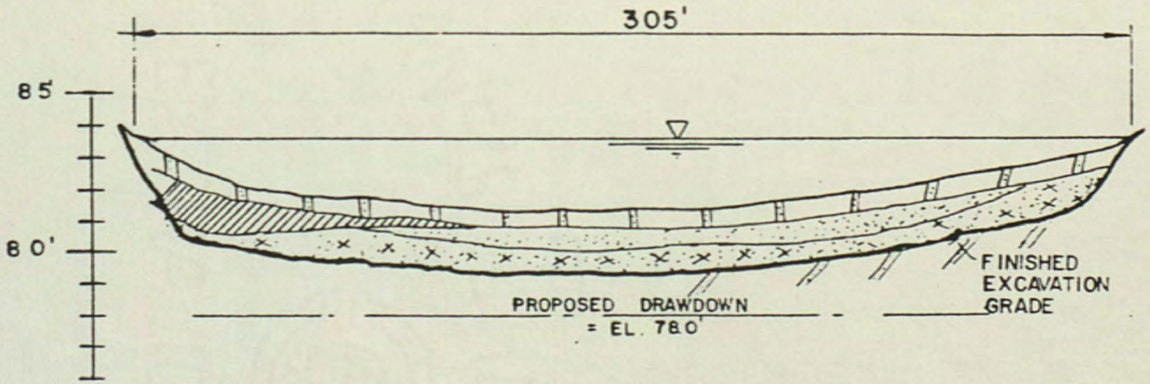
Fig. 11. Section 6-6.



SECTION 7-7
NTS

Fig. 12. Section 7-7.

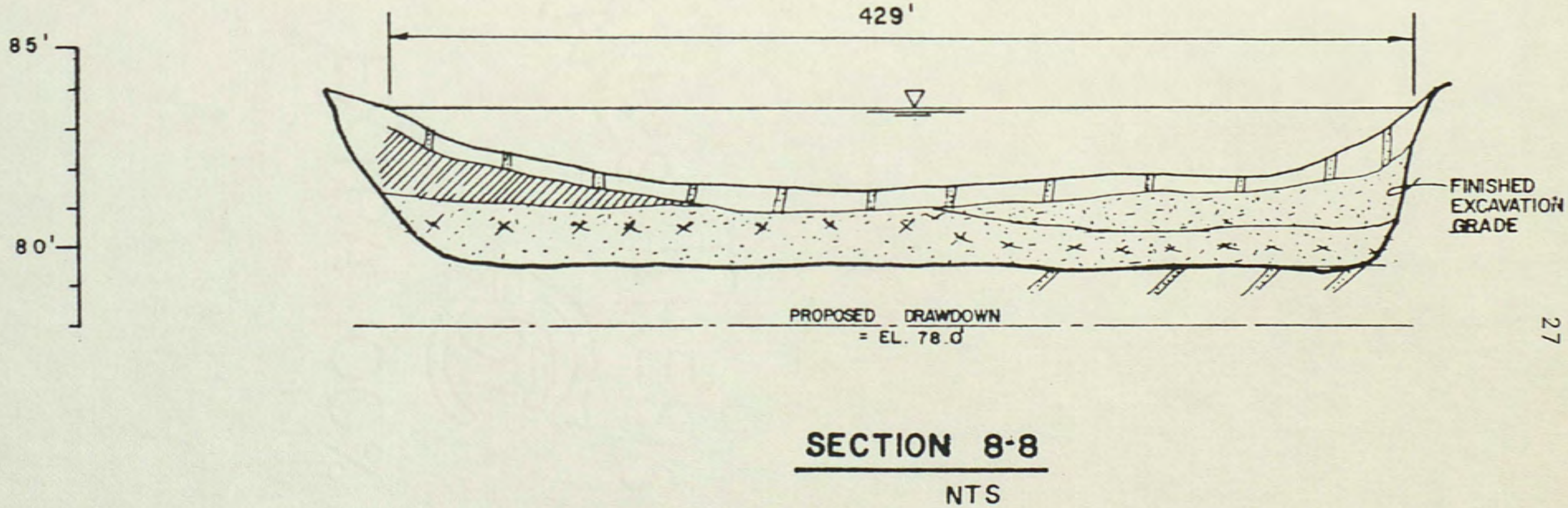


Fig. 13. Section 8-8.

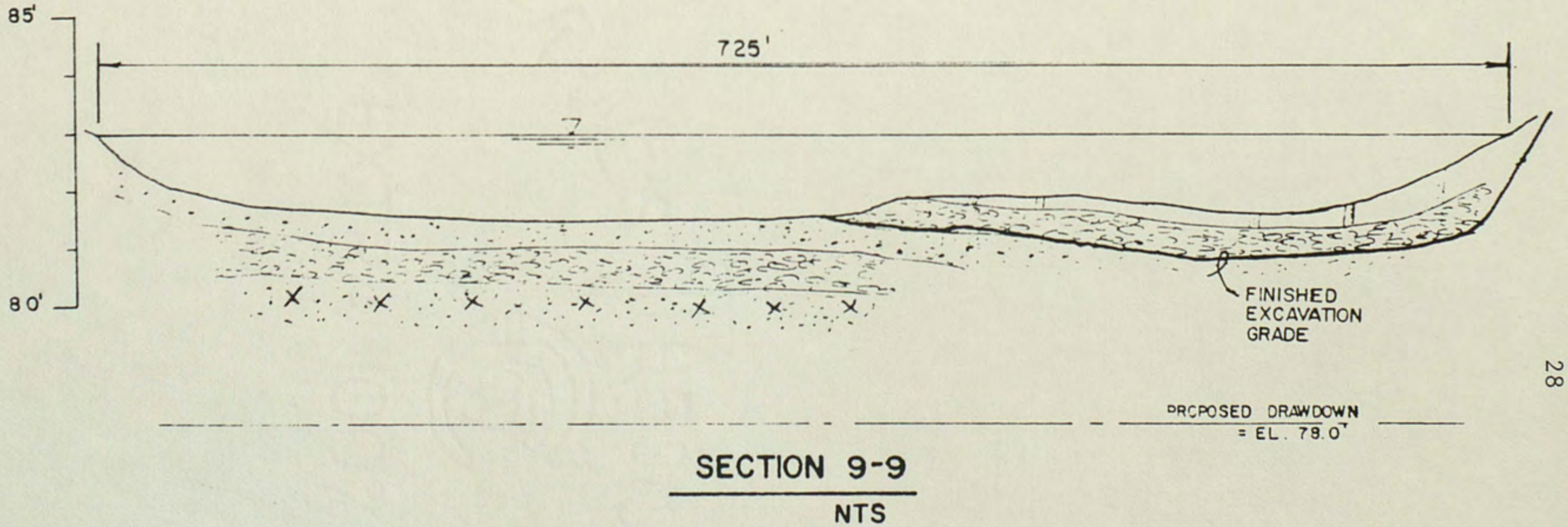


Fig. 14. Section 9-9.

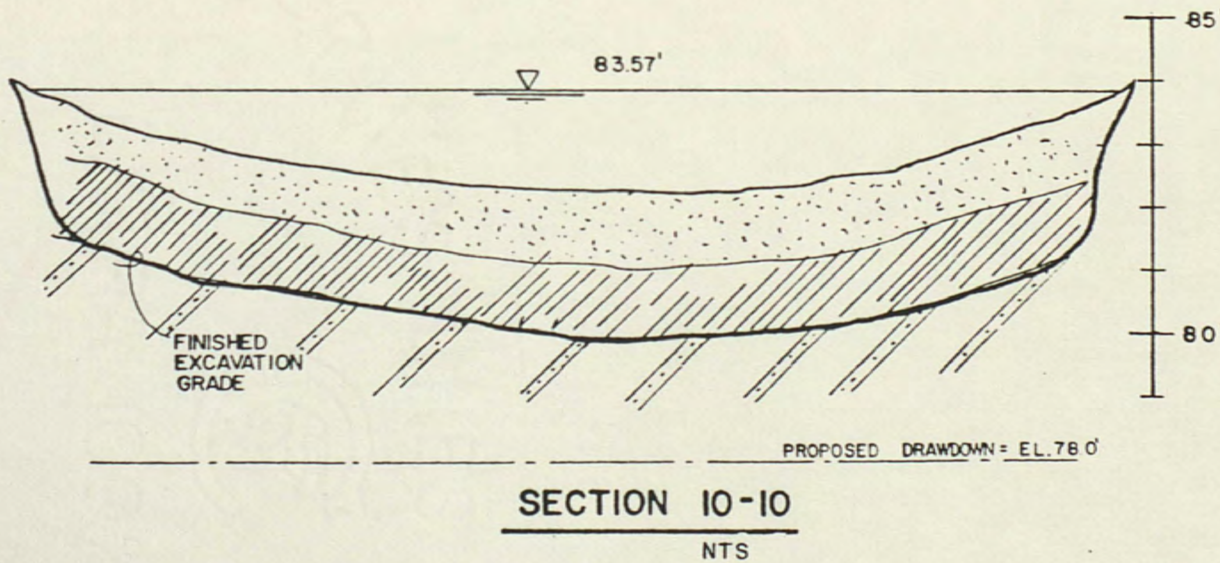


Fig. 15. Section 10-10.

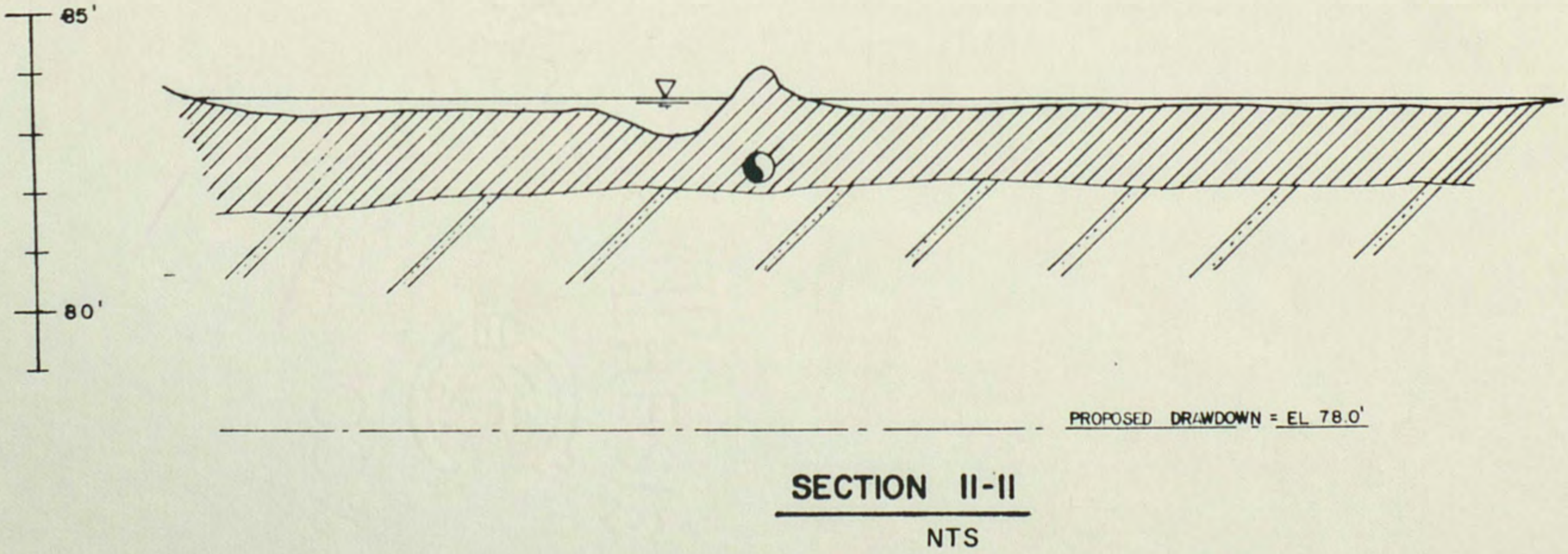


Fig. 16. Section 11-11.

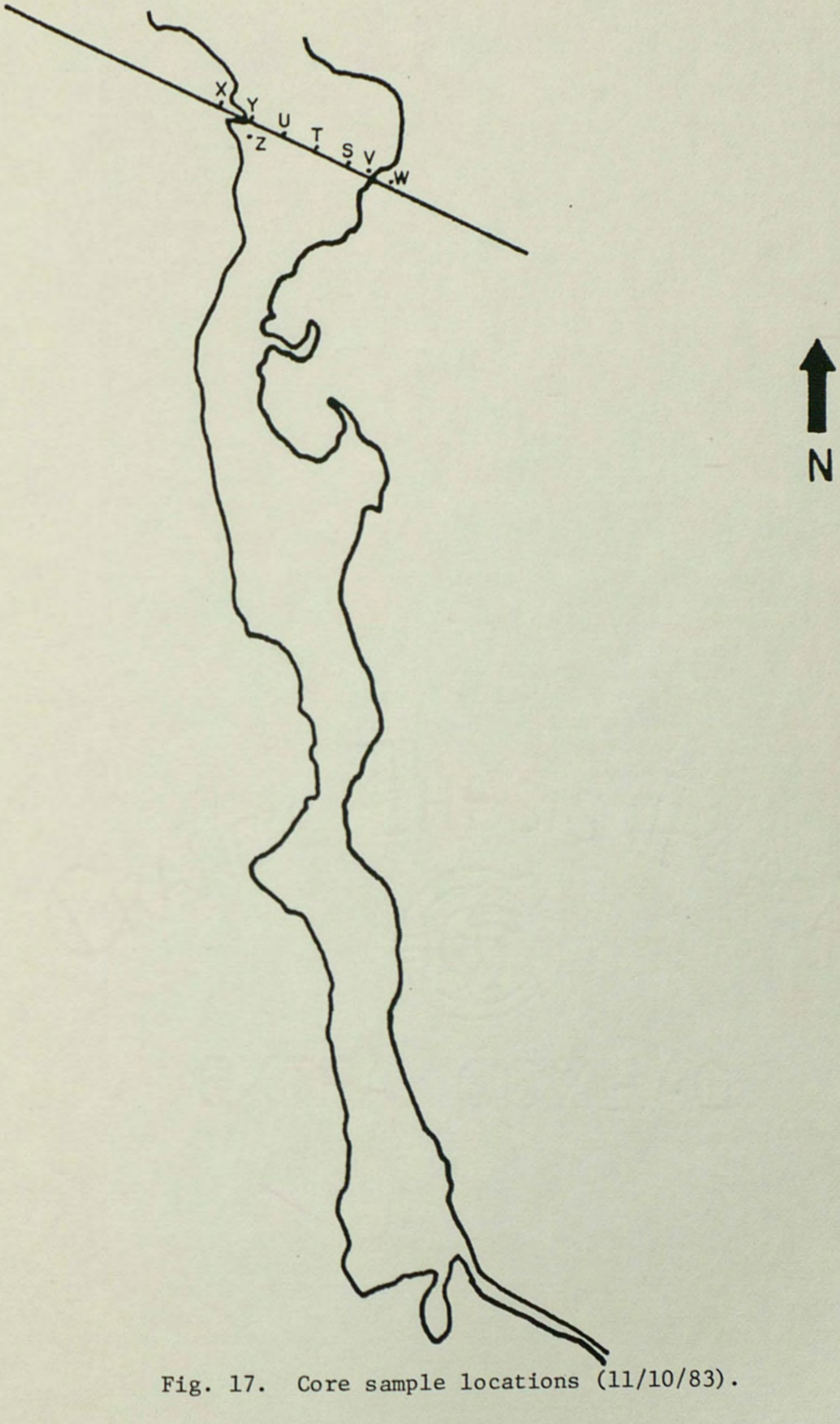


Fig. 17. Core sample locations (11/10/83).

Laboratory Testing and Analysis

Core samples collected on 7/28/83 were returned to the UCF geotechnical laboratory where the cores were marked and divided according to stratification. Each core was labeled a, b, c, or d from top to bottom. The core strata, height, color and visual description are shown in Table 1.

Moisture Content

The moisture content in geotechnical terms is defined as the weight of water divided by the dry weight of the soil sample and is expressed as a percent. The moisture content of most soils is under 60%, but it is not uncommon for organic lake soils to have values as high as 300-400%. The water content in a soil depends on the void ratio and the location of the sample (Bowles, 1979). The moisture content is indicative of dredging characteristics of a soil and dewatering capabilities.

Moisture content as obtained for each chosen sample is shown in Table 2. Moisture contents ranged from 21.8% to 234.5%. The upper values of moisture content were in loose soils with some silt. The average moisture content for all samples was 66.2%. If the three silty samples (16b, 44b, 87a) are excluded, then the average moisture content for the remaining sandy samples is 43.3%. This is considered a high moisture content and bucket type dredging would result in dredge material washing out of the bucket when it is lifted through the water (Turner, 1974).

TABLE 1

PHYSICAL PROPERTIES AND VISUAL DESCRIPTION

Core #	Depth (mm)	Color	Visual Description*
3a	420	Black	Silty sand
3b	130	Dark gray	Fine sand
3c	147	Gray	Clayey fine sand
14a	446	Black	Silty sand
14b	239	Gray	Clayey fine sand
16a	56	Greenish-brown	Silty sand with organics
16b	280	Black	Silty sand with organics
16c	40	Gray	Clayey fine sand
23a	358	Brown	Fine sand with organics
23b	391	Black	Silty sand
23c	48	Gray	Clayey fine sand
33a	158	Brown	Fine sand with organics
33b	45	Dark gray	Fine sand with organics
33c	176	Dark bronw	Clayey sand with organics
33d	170	Dark gray	Fine sand
35a	164	Greenish-brown	Silty sand with organics
35b	197	Dark brown	Sand
35c	160	Light gray	Clayey fine sand
41a	138	Green-brown	Silty sand with organics
41b	296	Black	Silty sand
41c	184	Dark gray	Fine sand
44a	169	Green-brown	Silty sand with organics
44b	208	Brown-gray	Fine sand with organics
44c	210	Dark gray	Fine sand
44d	103	Gray	Clayey fine sand
46a	223	Green-Brown	Silty sand with organics
46b	230	Brown-gray	Fine sand with organics
46c	119	Dark gray	Fine sand
46d	11	Gray	Clayey fine sand
53a	161	Green-brown	Silty sand with organics
53b	233	Dark gray	Fine sand
53c	289	Light gray	Clayey fine sand
63a	114	Greenish-brown	Silty sand with organics
63b	168	Dark gray	Fine sand with organics
67a	31	Gray-black	Silty sand
67b	315	Light gray	Clayey fine sand
74a	63	Green-brown	Silty sand with organics
74b	199	Brown	Fine sand with organics
74c	100	Gray	Clayey fine sand

TABLE 1 (Continued)

Core #	Depth (mm)	Color	Visual Description*
87a	390	Yellowish-gray	Silty sand
87b	589	Grayish-brown	Fine sand
87c	104	Dark gray	Fine sand
97a	739	Green-brown	Silty sand
97b	389	Dark gray	Fine sand
97c	508	Green-brown	Silty sand with organics
97d	161	Dary gray	Fine sand

* Determined by visual observation and further verified by tests for organic content.

TABLE 2

MOISTURE CONTENT OF SAMPLES

Sample	Visual Description	Moisture Content (%)
3b	Fine sand	21.8
14a	Silty sand	33.9
16b	Silty sand with organics	234.5
23a	Fine sand with organics	70
33c	Clayey and with organics	40.7
35c	Clayey fine sand	21.8
41b	Silty sand	42.1
44b	Fine sand with organics	168.3
46b	Fine sand with organics	91.1
53c	Clayey fine sand	24.1
63b	Fine sand with organics	31.8
67b	Clayey fine sand	32.5
74b	Fine sand with organics	52.2
87a	Silty sand	99.6
95a	Silty sand	47.8
95d	Fine sand	46.5

Grain Size Analysis

Grain size analysis was performed in order to generate a grain size distribution curve for the classification of soils. Grain size analysis is obtained by mechanically shaking an oven dried sample through a series of square mesh sieves that have successfully smaller openings. The total mass of the sample is weighed before sieving, and after sieving the mass retained on each sieve is weighed and expressed as a percentage of the total mass (ASTM, 1980). The results of the grain size distribution curves are attached in Figures 44 through 59 in Appendix B.

In evaluating grain size distribution curves, a curve which is nearly vertical is said to represent a uniform or poorly-graded soil. In the case where the curve extends over a large range of particle diameters, the soil is considered well-graded or non-uniform. The distinction between a poorly-graded and a well-graded soil can be indicated numerically.

Gradation indicators are the coefficient of uniformity (C_u) and the coefficient of curvature (C_z) which are defined as

$$C_u = \frac{D_{60}}{D_{10}} \quad \text{and} \quad C_z = \frac{{D_{30}}^2}{D_{10}(D_{60})}$$

where: D_{10}, D_{30} and D_{60} are the grain sizes of 10%, 30% and 60% passing, respectively, as determined from the grain size distribution curve. Values for each sample are tabulated in Table 3. When C_u is less than 4, the soil is considered uniform. If C_u is greater

TABLE 3

COEFFICIENTS OF UNIFORMITY AND CURVATURE

Sample	C_u	C_z
3b	3.8	1.05
14a	3.2	1.3
16b	27.5	11.1
23a	22.7	1.2
33c	18.9	1.05
35c	2.6	1.02
41b	5.2	.86
44b	26	8.1
46b	7.3	1.1
53c	4.9	1.1
63b	6.2	1.7
67b	7.1	.93
74b	8.3	1.1
87a	8.4	1.5
95a	3.6	1.6
95d	3.5	1.1

$$C_u = \frac{D_{60}}{D_{10}} \qquad C_z = \frac{D_{30}^{\;2}}{D_{10}D_{60}}$$

D = grain size diameter at the subscripted percent finer than 4 (6 for sand) and the grain size distribution curve is smooth and reasonably symmetrical, the soil is said to be well-graded. C_z is the indicator of symmetry and shape of the gradation curve. The coefficient will be between 1 and 3 for a well-graded soil (Dunn et al., 1980).

On the basis of moisture content and gradation indicators obtained from the individual grain size distribution curves and the soil types at each sampling station, the description of soils within the Megginnis Arm is as follows.

At station 3, approximately 1.5 feet of silty sand overlying a loose sand is poorly-graded. The underlying soil is a medium to dense fine sand. There is a top layer of 1.6 feet of uniform silty sand at station 14 that covers 1 foot of dense fine sand. Above the pipeline (station 16), there is a 0.3 feet layer of silty sand with some small organic materials. Below that, there is 1 foot of loose silty fine sand that has dense fine sand.

In the mid-channel of the upper arm, there is a well-graded loose sand to a depth of 1.3 feet at station 23. This covers 1.3 feet of silty sand. From a depth of 2.6 feet, there is a dense uniform fine sand. Station 33 is also mid-channel and had a water depth of 1 foot. A 0.5 foot layer of clayey sand with some organics covers a well-graded sand.

In the extreme east portion of the arm (station 35), a loose to very loose moderately well-graded sand covers two feet of well-graded medium sand. On the west side of the arm (stations 41, 53 and 63), a silty fine, moderately well-graded sand covers loose to very loose fine sand that has some organics.

At station 46 on the east side of the arm, the water depth is approximately 3.5 feet with a 0.75 foot top layer of soil consisting of a well-graded fine loose sand. Below that is 0.5 feet of fine loose sand with organics. The lower east side where station 67 is located has 2.5 feet of water with 0.2 feet of loose and poorly-graded silty fine sand. Below that is a well-graded medium dense fine sand.

To the east of the mid-channel, at station 87, there is 3 feet of water with 1.5 feet of uniform silty fine sand with organics. The next layer consists of 2 feet of loose fine well-graded material.

The extreme southern portion of the arm is the deepest part as evidenced by station 95 where there is 5 feet of water. The top 2.5 feet of sediments is poorly-graded silty fine sand that is loose to very loose. Below that is 1$\pm$ foot of moderately well-graded fine sand. Two feet of poorly-graded silty fine loose sand is beneath that. The lowermost layer is moderately well-graded fine sand.

Direct Shear Tests

Direct shear tests were then performed to develop the strength envelope of the soil sample which is a function of material relative density, grain size, shape and distribution. The strength envelope will yield a friction angle (ϕ) which can be evaluated to further classify the soil. The shear strength of soil is due to friction between the particle-to-particle contacts and is a function of the coefficient of friction ($\tan \phi$) and the intergranular stress (σ). The Mohr-Coulomb Strength envelope is shown in Figure 18.

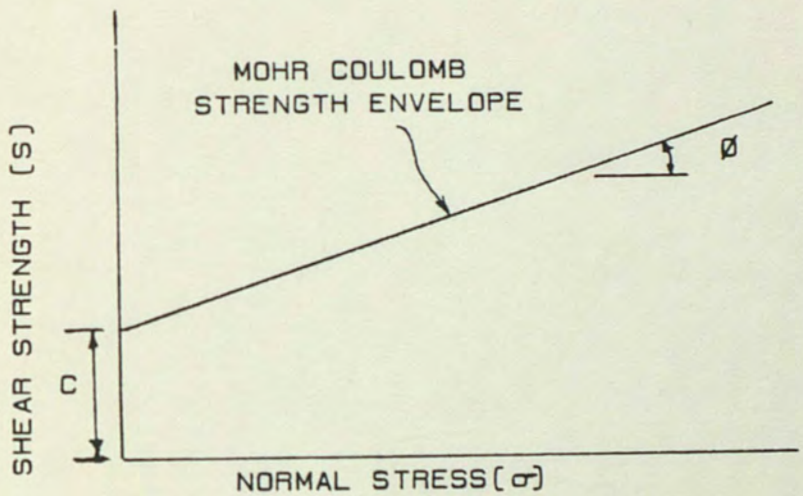


Fig. 18. Mohr-Coulomb strength envelope.

The most practical method for describing the strength of a soil has been found to be the Mohr strength theory. The Coulomb equation for shear strength is expressed as:

$$S = C + \sigma \quad (\tan \phi)$$

where:

S = shear strength

C = cohesion intercept

σ = normal stress

ϕ = slope of strength envelope in degrees

The parameters C and ϕ are dependent upon the material and the test conditions. The direct shear test is used because it is a relatively simple test to perform and gives accurate results for the strength of granular soil. This information is essential in evaluation of materials to be considered for construction purposes.

The resulting plots from direct shear tests are shown in Appendix C in Figures 60 through 67. Since the majority of the soil samples are granular, the cohesion intercept, C, was found to be zero. Thus, the shear strength envelope passes through the origin. As seen from the plots, the friction angles for the samples ranged from 28° to 35°. Terzaghi and Peck (1967) presented values of ϕ for sands and silts as shown in Table 4 (Dunn et al., 1980). According to Table 4, the soil is representative of silty sands.

Hydraulic Conductivity

The coefficient of hydraulic conductivity is dependent upon fluid and soil properties. In geotechnical literature, the

TABLE 4

SANDS AND SILTS VALUES FOR ϕ

Material	Degrees	
	Loose	Dense
Sand, round grains, uniform	27.5	34
Sand, angular grains, well-graded	33	45
Sandy gravels	35	50
Silty sand	27-33	30-34
Inorganic silt	27-30	30-35

SOURCE: Terzaghi and Peck, 1967.

coefficient of hydraulic conductivity is called permeability, due to a small differential temperature of water in soils.

Soil permeability is dependent upon grain-size distribution, fluid viscosity, pore size distribution, void ratio, mineral particle roughness, and the degree of saturation. For sandy soil, the coefficient of permeability, k, can be determined mathematically by using the following equation:

$$k = \frac{2g}{C_s} \frac{D^2}{v} \frac{e^3}{1+e}$$

where:

g = gravity constant

v = kinematic viscosity

C = a particle shape factor

D = a weighted particle diameter

e = void ratio

D can be obtained from a grain size analysis and the following equation:

$$D = \frac{\Sigma\ M_i}{\Sigma\ (M_i/D_i)}$$

where:

$\Sigma\ M_i$ = mass retained between consecutive sieves

$\Sigma\ D_i$ = mean diameter of consecutive sieves (Dunn et al., 1980)

For all samples at 20°C, the kinematic viscosity, v, is 1.01 mm^2/sec. The value of C_s for fine sand is approximately 400. Void ratio, e, was determined on a basis of a value of 2.65 specific gravity (G_s).

Results for calculated permeability are shown in Table 5. High coefficients of permeability were evidenced in some samples with high organic content. This phenomenon can be attributed to the fact that calculations are based on oven dried samples and their respective grain size analysis.

TABLE 5

PERMEABILITY OF SOILS

Sample	Visual Description	Permeability, k(cm/s)*
3b	Fine sand	.040
14a	Silty sand	.038
16b	Silty sand with organics	1.6
23a	Fine sand with organics	.82
33c	Clayey sand with organics	2.5
35c	Clayey fine sand	.16
41b	Silty sand	.19
44b	Fine sand with organics	6.4
46b	Fine sand with organics	.67
53c	Clayey fine sand	.13
63b	Fine sand	.25
67b	Clayey fine sand	.11
74b	Fine sand with organics	.36
87a	Silty sand	.40
95a	Silty sand	.19
95d	Fine sand	.055

* Dried samples

CHAPTER IV

MAPPING

Mapping of the Megginnis Arm was done by the use of three different methodologies. The data from the method was used to cross check for verification of actual profiles. The water surface elevation of the arm was determined from the benchmark elevation of 94.0 feet msl on the top of the holding basin outfall structure at the last station of the Northwest Water Management District's stormwater treatment facility (see Figure 19)(Editors, 1983).

Fathometer Technique

The arm was transected lengthwise (section 1-1) and across the arm at sections 2-2, 4-4, and 6-6 with a fathometer. The fathometer is a sounding device that has a transducer mounted on the boat and emits and receives a sound signal. The fathometer recorder charts the configuration of the lake bottom, based on the time it takes the emitted signal to travel to and return from the bottom. The recorder chart is scaled and a continuous transect will depict the shape of the bottom, indicating hard or soft bottom according to the thickness of the bottom band. A thin distinct band indicates a hard bottom, whereas a thick band represents a soft sedimentary bottom. The printed chart of a fathometer transect is shown in Figure 68 of Appendix D.

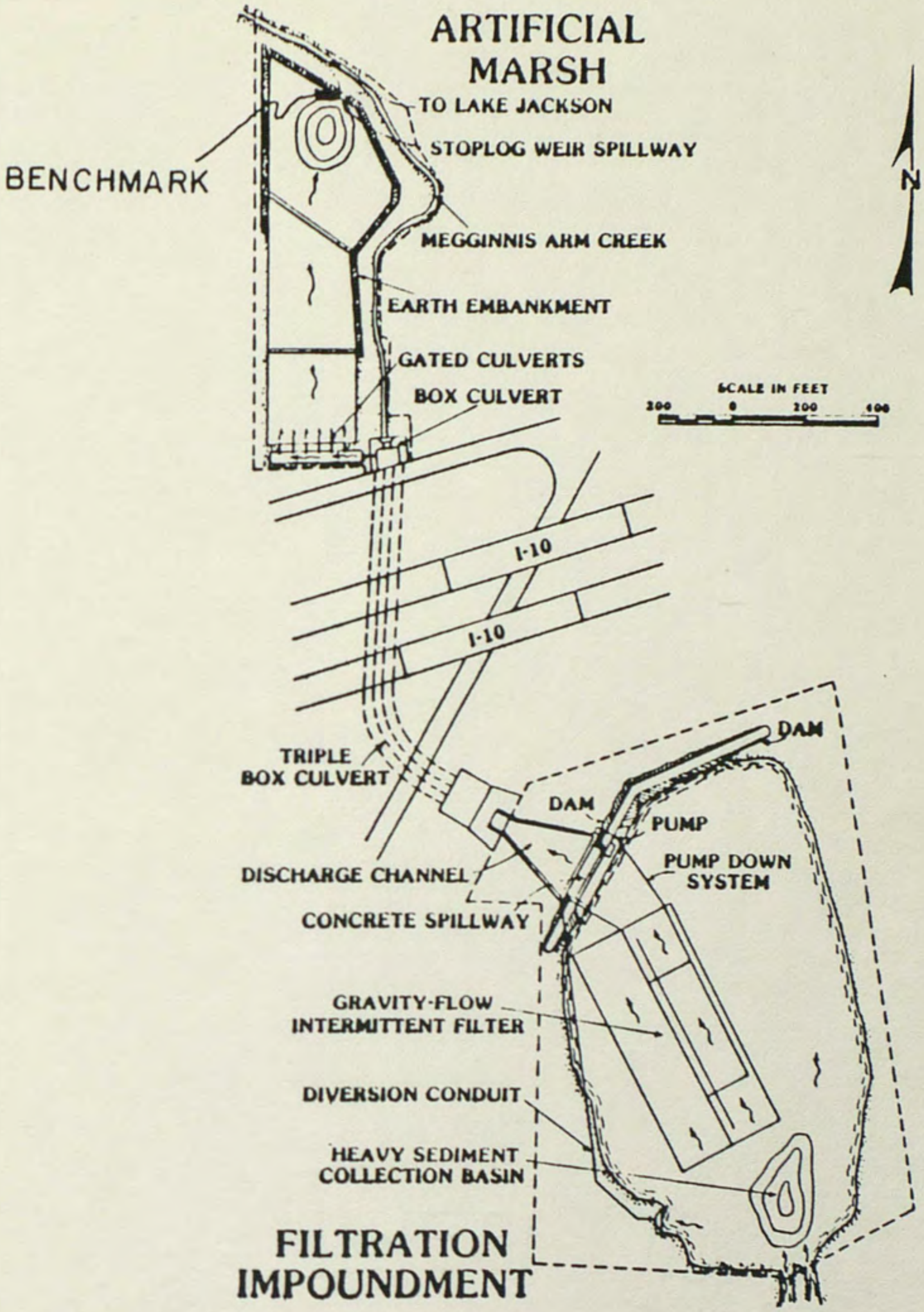


Fig. 19. Schematic diagram of Lake Jackson project stormwater treatment facility (Northwest Florida Water Management District, 1983).

Coring Technique

Coring samples were taken, for mapping lake profiles, through the same fathometer transects. The water depth and soil stratification measured in each core sample was used to map the Arm. This was the predominant method of investigation adopted in the upper arm because the boat could only navigate the mid-channel of the northern portion of the arm. The east and west sides of the upper part of the arm and the areas along the pipeline were mapped exclusively by core samples.

Ground Penetrating Radar Technique

The Megginnis Arm was also transected lengthwise and across by ground penetrating radar. The ability of radar signals to penetrate water makes it possible to profile the lake bottoms. In Appendix D, Figures 69 to 79 show the longitudinal profile along the center of the arm (section 1) and transverse profiles at sections 2, 3, 4, 5, and 6. Also shown is section 3.5 between sections 3 and 4. Depth profiles were reasonably constant and any discrepancy can be attributed to the assumed dielectric constant which may actually be different due to poor water quality. The ground penetrating radar is an impulse radar system which radiates a repetitive short-time duration electromagnetic pulse into the medium from a broad band width antenna. When an electromagnetic pulse traveling a medium strides another medium with different electrical properties, part of the pulse is reflected and the rest of the pulse continues to travel through the new medium. The reflected signal is processed by the control unit and sent to the graphic recorder for a hard-copy display.

The depth scale in Figures 69 through 79 is based on the dielectric constant of water equal to 81, which corresponds to a pulse velocity of 9 ns/ft. The pulse velocity in the underlying lake bottom and sediment deposits is not known. However, from the strength of reflected signals in the lake bottom, it is possible to determine the densification of the soil material. The relatively weak signal, as displayed by the lighter band on the radar profile, indicates the soft sedimentary deposit, while the strong signal, as displayed by the dark band, indicates the firm lake bottom.

The ground penetrating radar can also identify the different soil material at the lake bottom by distinguishing the different dielectric constants. If material 2 has a dielectric constant higher than material 1, the reflection coefficient (band) will be negative (opposite to transmitted pulse). If the dielectric constant of material 2 varies greatly from the material 1, most of the incident energy will be reflected. The dielectric constant of fresh water, saturated clay, saturated silt, and saturated sand are 81, 40, 30, and 20, respectively. With the above concepts in mind, one can describe the change of soil material from the transition of radar profile. The areas with dark bands and incident energy completely reflected are described as firmly saturated clayey bottom, because of its higher value of dielectric constant.

The double reflection from the lake bottom as seen from the figures are attributed to "echo" caused by the entrapment of the radar signal between two high reflection interfaces. At several sections of profiles, the subsurface interfaces are identified below the lake bottom.

Discussion of Lake Profile from Mapping

At the extreme south end of the Arm, the flow of stormwater enters the arm from Megginnis Creek. This is the deepest part of the arm, as evidenced by sections 1-1 and 2-2 of Figure 6. The deepest water depth was 10.5 feet when the project was conducted. The upper layer of soil in this vicinity was a loose fine sand with an underlying medium dense fine sand. The southern area has remained relatively deep and free from the heavy sedimentation evident in upper areas of the arm. This may be attributed to high water velocity, due to a heavy storm, which scour and flush suspended solids downstream into the northern portions of Megginnis Arm.

The water depth in mid-channel of the arm was 4 to 5 feet deep with medium dense sand on the bottom until another deep area is encountered in the vicinity of section 4-4. Directly north of this area the channel gets considerably shallower. Fine sand has mounded across the arm to a depth of 3 to 4 feet. As the water flows north, velocity decreases because of dissipation of the flush phenomenon. At section 6-6, a cross flow enters from the west, where runoff enters the arm from the overgrown and no longer utilized boat ramp.

At section 6-6, there is silty sands with high organic material in the main channel of the Arm. A deeper area that is approximately 4.5 to 5 feet deep may be the result of scouring from the cross flow during heavy rains. The silt sediments in the main channel may be the result of moderate storms when water velocity is low enough so that there is no flush or scour tendency. Therefore, during normal storms, settlement of silts takes place. North of section 6-6, the arm becomes narrow, but gradually widens again further north. In these surrounding areas, contours are relatively flat. When the water level rises, the side boundaries of the arm spread out drastically. This shallow and wide area has a low water velocity and is very conducive to the settlement of suspended soil particles. This is evident from the layers of loose to very loose silty sands with organics in the core sample profiles.

In the northern portion of the Arm, water depth continues to get shallower until only a couple of inches of water existed. This area could dry up during the dry season. There is a mixture of dryland grasses and weeds with littoral community species that predominate in the wet season.

In the area where the pipeline is located, there is 1.5 to 2 feet of silty sand. From soil profiles and hand auger corings, it was determined that the pipeline is only covered by 1 to 1.5 feet of sand and is at approximately an elevation of 82.27 feet. From the existing conditions, it is presumed that the pipe was laid on top of the grade during installation and then covered with soil which was excavated along the south side of the pipe. The pipe and berm have cut off any exchange of water between the Megginnis Arm and the main part of Lake Jackson except during the wet season or an unusually large storm. The soil cover over the pipe has washed away at the east end of the pipeline. Sand bags were placed in this area and additional fill has been obtained from the north side of the pipeline. Due to the silty nature of the soils in this area, the soil cover for the pipeline will remain very unstable. If the arm is to be opened up to boat traffic to the main part of the lake, the pipeline will have to be lowered or removed.

CHAPTER V

DESICCATION STUDIES

Sediment samples were collected from the south, central and northern sections of Megginnis Arm (see Figure 20). These samples were placed in desiccation chambers and allowed to air dry. The purpose of this study is to determine the feasibility of compaction of desiccated sediments versus non-compaction of air dry sediments. The percent consolidation between the compacted and non-compacted sediments will be compared. The data will be analyzed in regards to possible differences in resuspension of soil after reflooding the chambers. In addition, the study will investigate whether compaction would:

1. be less costly than sediment removal
2. eliminate the space and expense of a spoil site
3. provide a better sealing effect for the bottom sediments to minimize the resuspension of sediments

Desiccation

Four square desiccation chambers were constructed using 1" x 6" and 1" x 12" #1 white pine. The inside dimension of the chambers were 15" x 15". The corner joints were glued with carpenter's wood glue and secured with 8d finishing nails. The inside of the corners

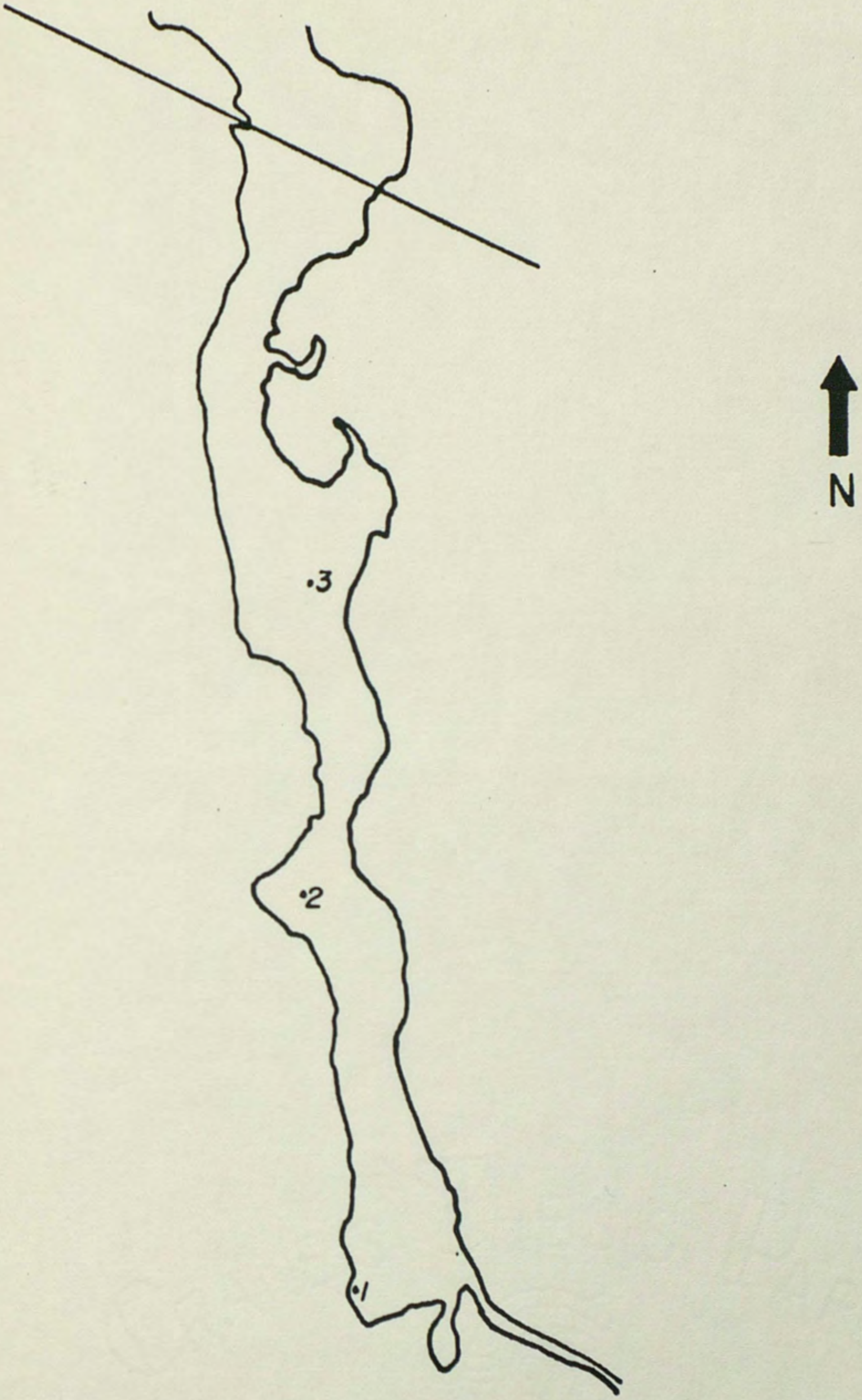


Fig. 20. Sediment sample sites for desiccation study.

were caulked to make the joint water-tight. The sediment samples 1, 2 and 3 were placed in desiccation chambers 1, 2, 3a and 3b, respectively.

The experiment initiated on April 11, 1984. Figure 21 shows a photograph of one 15" x 15" x 11-3/8" chamber and three 15" x 15" x 5-3/8" chambers being installed. The underlying soil where the chambers were to be set was removed to a depth of 3", compacted and covered with a 1.2 mil plastic liner. The chambers were placed in the ground and secured by compacting the soil around the outside wall (Figure 22). The plastic liner was punctured with a 10d nail, in the four corners and one in the center. The idea is to simulate the natural desiccation conditions where low permeability soil conditions will exist and drying of sediments will be more of an evaporation process rather than drying due to drainage. The chambers were left exposed to the natural climatic elements (Figure 23), as a best effort simulation study.

The sediments, with approximately 1" cover of water from Megginnis Arm, were placed in the chambers. For the first 15 days, chambers were checked every day and the distances from the top of the chamber to the surface of the sediments were measured. Thereafter, the data was recorded every other three or four days. The data was used to compute the percent of consolidation. The percent of consolidation was calculated based on the ratio of differential volume versus initial volume. The total desiccation period consisted of 30 days.

Fig. 21. Installation of desiccation chambers.

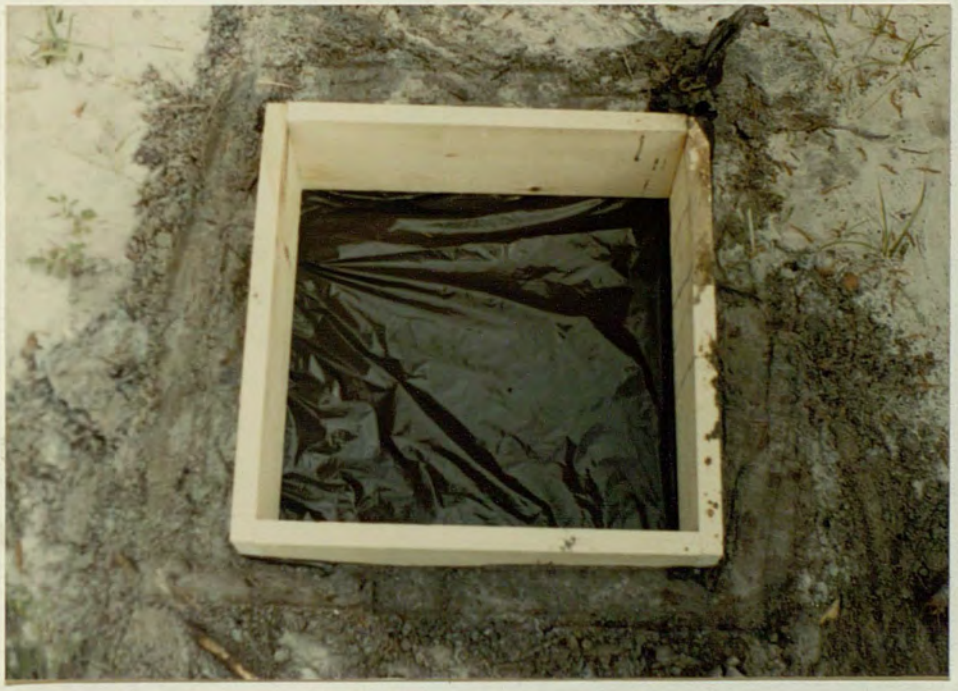


Fig. 22. Desiccation chamber plastic liner.

Fig. 23. Exposed sediment desiccation chamber.

On the thirtieth day, the moisture content and dry and wet density of desiccated sediments were obtained using a nuclear moisture/density gauge (Figure 24). The gauge was placed in the desiccation chambers and the probe was set at an appropriate depth in the sediment (Figure 25). Sample No. 1 was tested at a 2" depth while samples 2, 3a and 3b were tested at the surface because these samples had dryed to a hard cake.

Compaction

Sample No. 1 was used for the compaction test, because sediments had dryed to a condition where compaction equipment would not get stuck. The moisture content in sample number one was high enough to

Fig. 24. Nuclear density testing equipment.

Fig. 25. Sediment density test.

attain compaction. The sample was compacted by using a ten pound weight falling twenty-seven inches. After compaction was completed, the density was recorded again with the nuclear gauge. The percent of consolidation for each sample is tabulated by date in Table 6. Figure 26 shows the compacted sediments in desiccation chamber number 1.

Fig. 26. Compacted sediment.

Results of Desiccation Study

Initial consolidation of sediments was slow for the first five days because consolidation consisted of drainage effects as water drained through the sediments in the chambers (Figure 27). After

TABLE 6

SEDIMENT CONSOLIDATION

Date	1	2	3a	3b	Precipitation
4/11	0	0	0	0	
4/12	06	16	06	09	
4/13	13	22	15	17	
4/14	13	22	15	29	
4/15	13	22	15	34	.04"
4/16	13	22	15	34	.32"
4/17	13	27	18	40	
4/18	13	27	21	40	.07"
4/19	15	27	27	43	
4/20	19	30	36	48	
4/21	19	35	36	51	
4/22	24	41	36	51	
4/23	28	43	36	51	
4/24	29	49	39	51	
4/25	--	--	--	--	.02"
4/27	31	49	48	51	
4/30	35	54	48	63	
5/03	--	--	--	--	.01"
5/04	38	65	58	69	
5/07	--	--	--	--	.11"
5/08	38	65	58	69	
5/10	--	--	--	--	.89"
5/11	42	65	61	69	
5/11*	59	--	--	--	
5/23	--	--	--	--	.03"
5/24	--	--	--	--	.03"
5/26	--	--	--	--	.02"
5/27	--	--	--	--	.04"
5/28	--	--	--	--	.55"
5/29	--	--	--	--	.51"
5/30	--	--	--	--	.11"
6/05	70	66	62	69	

* After compaction

Fig. 27. Exposed sediment after day 5.

day seven, the sediments appeared to have no excess water in the chambers (Figure 28). From day 1 to day 25, consolidation and rainfall were recorded. It was noted that there were only two days of rain, and rainfall was negligible (see Table 6). The data indicates that consolidation is a function of the evaporation of moisture within the sediments. At the end of day 25, sample 1 had consolidated 38% and samples 2, 3a, and 3b had consolidated 65%, 58% and 69%, respectively.

Days 26 through 30 had relatively no further consolidation. Table 7 shows the moisture contents and wet and dry densities of the samples at the completion of a 30-day desiccation period. Sample 2 had 65% consolidation at a moisture content of 65.8%. It is

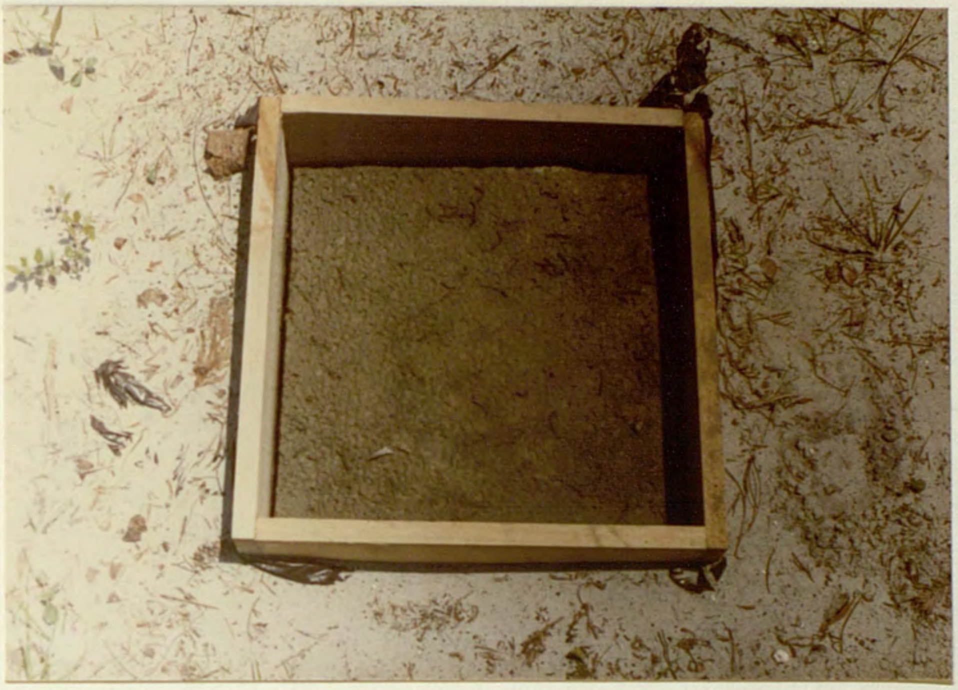


Fig. 28. Exposed sediment after day 7.

TABLE 7

SEDIMENT MOISTURE CONTENT - DENSITY

Sample Number	Moisture Content (%)	Wet Density (PCF)	Dry Density (PCF)
1	97.56	81	41
1*	89.89	84.5	44.5
2	65.8	63	38
3a	35.71	66.24	48.81
3b	23.87	68.75	55.50

* After compaction.

important to note in samples 3a and 3b that at respective moisture contents of 36% and 24% there was no appreciable difference in consolidation. This indicates that at approximately 65% moisture content virtually all consolidation had taken place.

Additionally, in sample 1 where the moisture content was 98%, the compactive force obtained an additional 17% consolidation from 42% to 59%. The results yielded a similar consolidation value as samples with the lower moisture contents. However, there was a corresponding change in the moisture content from 98% to 90%. This eight percent drop of the moisture content was attributed to the compactive force which drove the moisture out of the soil voids.

The desiccation chambers were then reflooded and kept full of water. The chambers were kept flooded for 14 days. There was no evidence of resuspension of sediments in either the compacted or the uncompacted sediment chambers (see Figures 29 and 30). It is important to note that the water remained very clear and there was virtually no swelling of the submerged consolidated sediments in any of the chambers.

The chambers were then allowed to drain. After an eleven day drying period, the sediments were checked for additional consolidation. Sample 1 was 70% consolidated, but the uncompacted sediments in chambers 2, 3a and 3b were 66, 62 and 69%, respectively. These results indicate that compaction has a very small influence on the final consolidation.

Fig. 29. Compacted sample - reflooded.

Fig. 30. Uncompacted sample - reflooded.

Figures 31 through 34 are graphical plots showing consolidation versus time. As can be noted in the figures, the sediments were placed in the chambers and there was an initial consolidation for the first two days. This is attributed to the time necessary for the sediments to conform to the shape of the chamber. The following four to five days indicate no consolidation occurred due to the saturated sediments.

This 7-day time frame is encouraging due to the fact that it simulates an actual drawdown of Megginnis Arm because this is the time estimated to expose much of the shallower portion of the Arm. Until this stage of the drawdown is reached, there will be virtually no consolidation of the undisturbed soils. Once the excess water is removed, and the sediments are exposed to sunlight and wind, then actual consolidation will begin.

During the time of exposure, two small rainfall events took place, but there was no apparent influence from the precipitation. Consolidation was relatively consistent for the next eighteen days. Thereafter, consolidation tapered off as evidenced by the flattening out of the curves in the consolidation time plots.

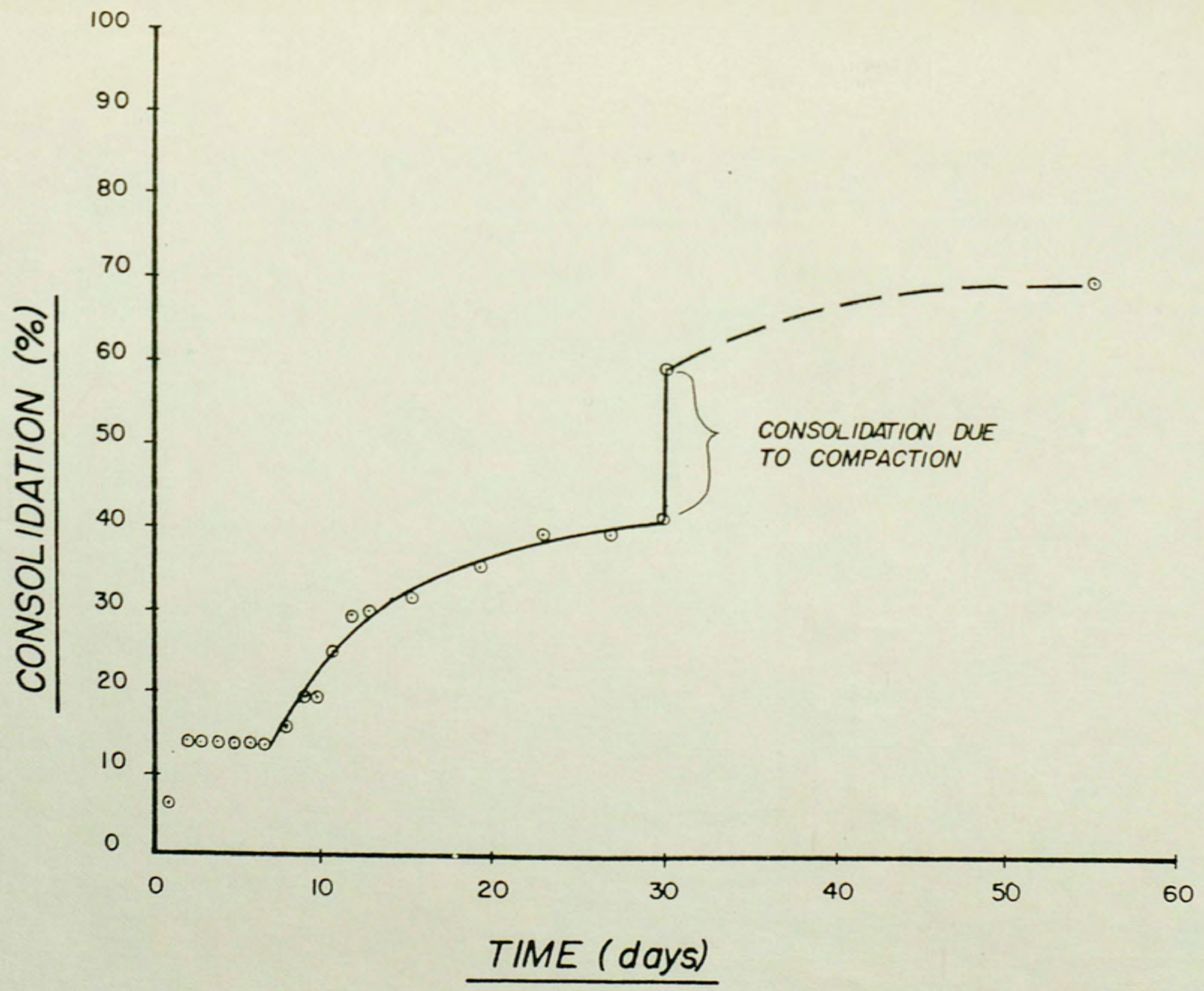


Fig. 31. Consolidation versus time curve - sample 1.

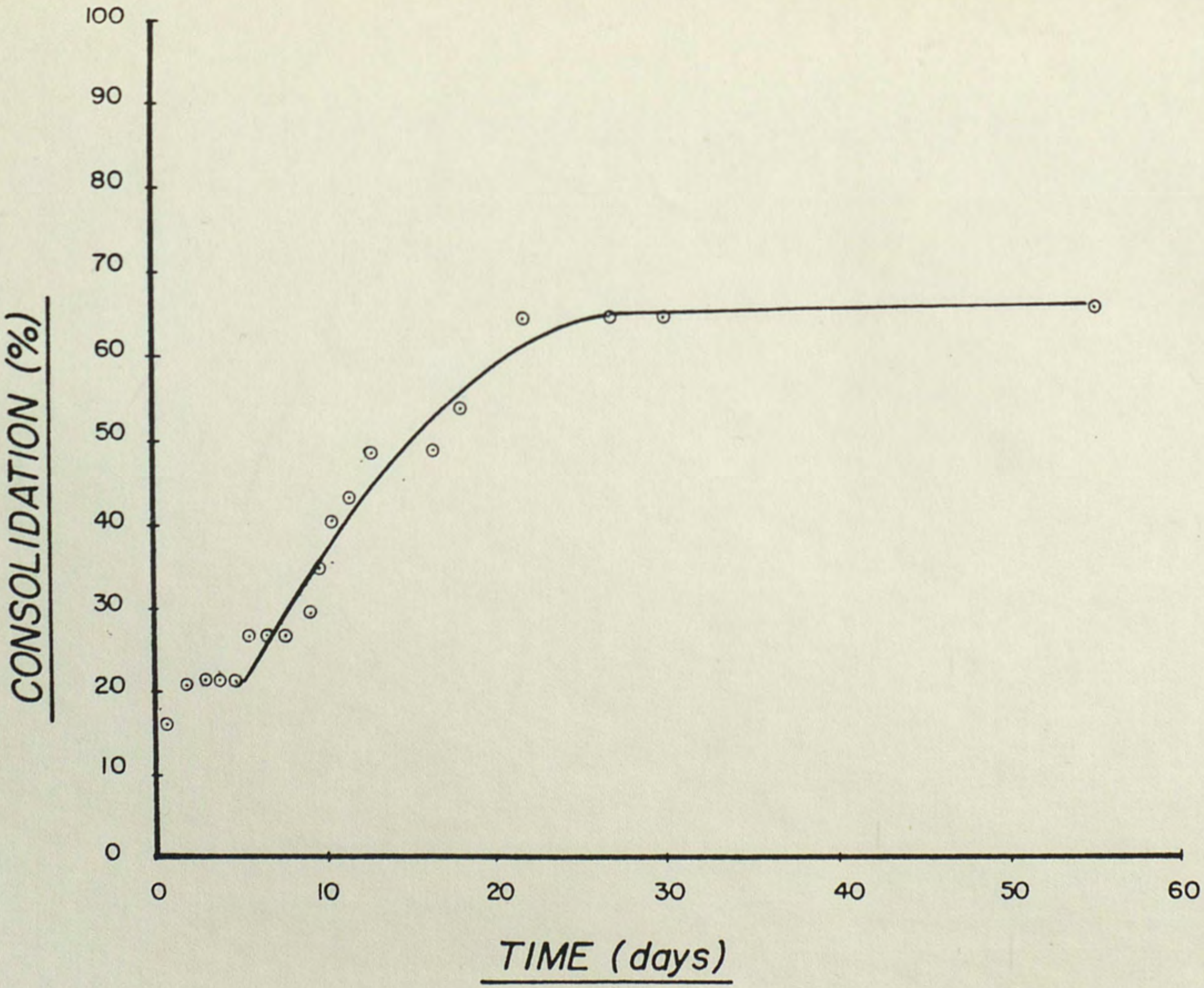


Fig. 32. Consolidation versus time curve - sample 2.

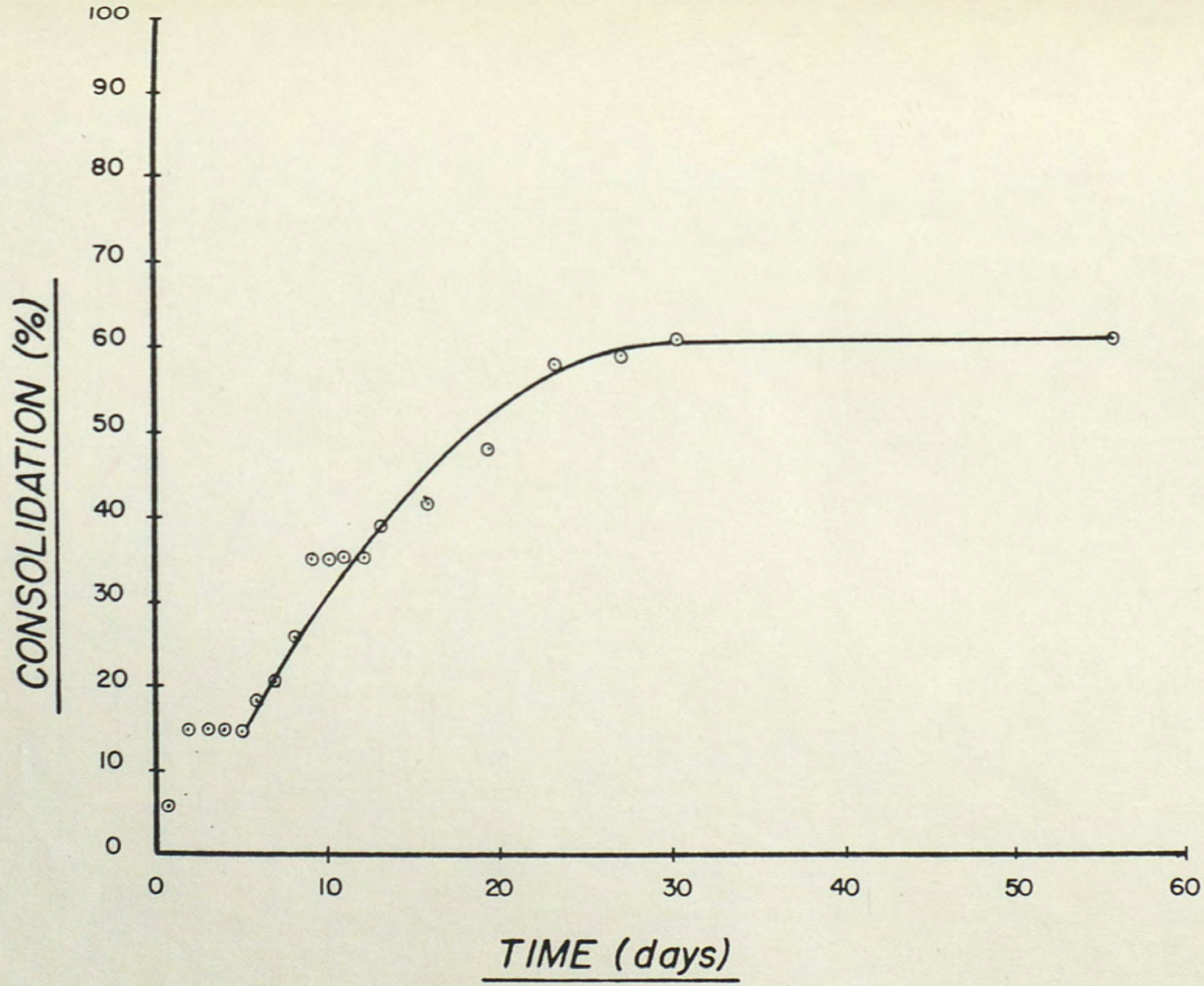


Fig. 33. Consolidation versus time curve - sample 3a.

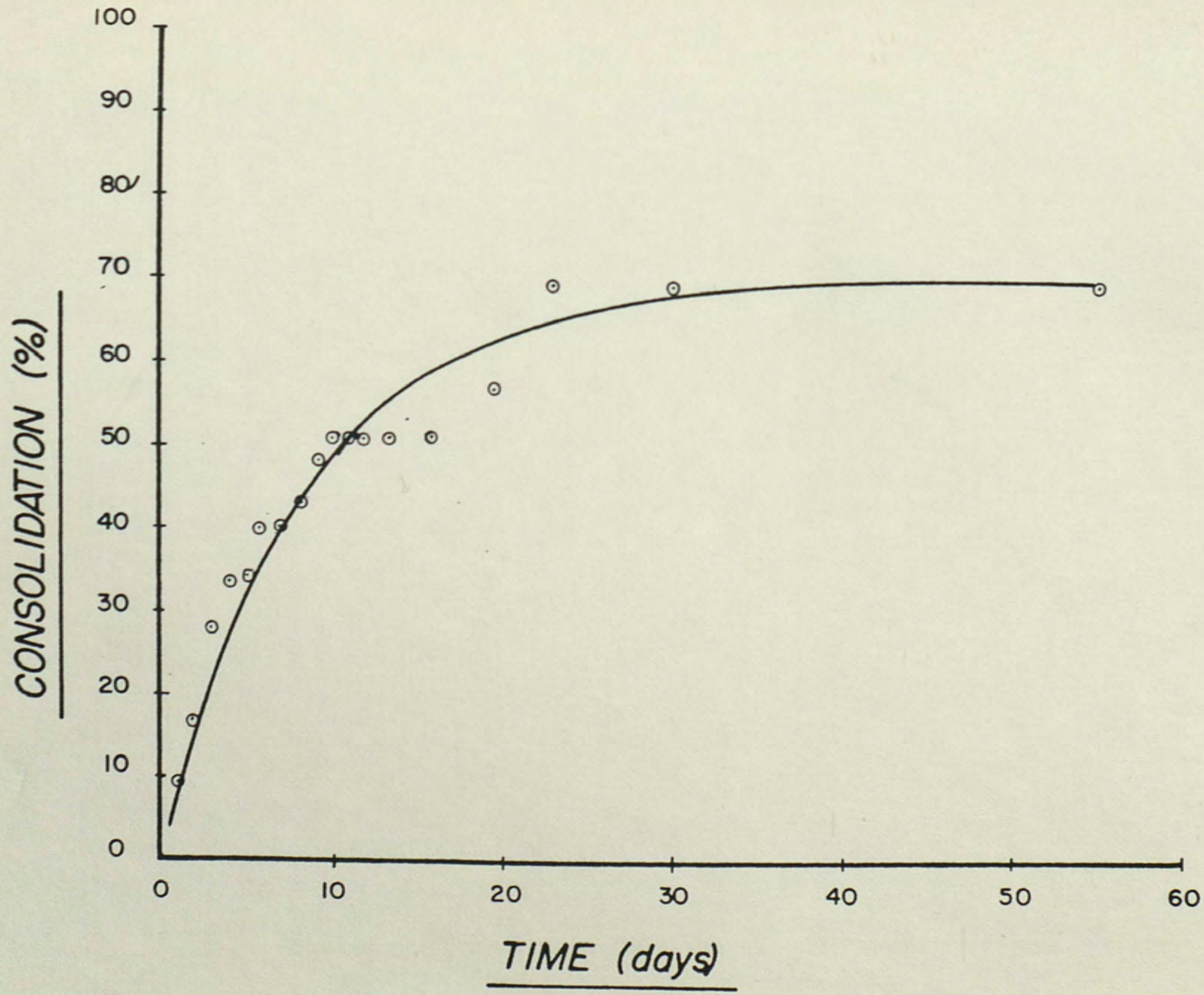


Fig. 34. Consolidation versus time curve - sample 3b.

CHAPTER VI

METHODS OF SEDIMENT RESTORATION

As discussed in the Literature Review of Chapter II, a number of methods are currently in practice for lake restoration efforts. From the geometric configuration of Megginnis Arm and the construction permit limitations, the possible restoration methods are dredging, drawdown, drawdown and excavation, drawdown and compaction, or drawdown and dredging. Alternatives will be analyzed for costs, practicality, and the flexibility of the approach. Before one can specify the alternative methods of sediment treatment, the volume and area of the sediments to be treated must be determined.

Method of Volume Calculations

Volumetric calculations for the amount of water and sediments to be removed in the Megginnis Arm were obtained by the use of cross-sectional depths and plan view areas between sections. The depth in each section was obtained by summing the areas of cross-sectional rectangles and triangles drawn and scaled in that particular section. The total area was divided by the cross-sectional width, to obtain an average depth for each section. Each pair of adjacent sections were evaluated for an average depth between them.

The surface area was calculated by a summation of plan rectangles and triangles between adjacent cross-sections. The volume computed for that portion of the arm was based on the area between sections multiplied by the average depth. The summation of each portion yielded a total volume for the Megginnis Arm.

Volume of Water

The volumetric method described previously yielded a volume of 4,288,568 ft^3 (98.5 acre-ft) of water at water elevation 83.57 ft. If the water in the arm is pumped down to elevation 78.0' msl, it would be necessary to have a holding area to accommodate this 90.6 ac-ft of removed water. The selection of the 78.0' is the most appropriate elevation for drawdown and will be discussed in a later section. This volume can be made available in the filtration impoundment area of the stormwater treatment facility and slowly returned to the lake via the filters and marshland. This process would assure good quality water returning to the arm at a controlled rate.

Volume of Sediments

The volume of sediments in the arm was calculated by the same method as described previously. The materials to be removed were based on Table 1 and the grain size distribution curves. The total volume of sediments in the arm totaled 53,100 cubic yards. If the arm is drawn down to elevation 78.0 ft, a corresponding exposure of 92% of the sediments would result. This translated to 44,700 cubic yards of sediments being desiccated and exposed to evaporation and consolidation. From the results of the desiccation study, it was determined that consolidation would be 60 to 70 percent. Assuming an average percent of consolidation is 65% with a 1.3 safety factor, a conservative value of 50% consolidation would be the result. Therefore, if a final drawdown elevation of 78.0 ft is achieved, the desiccated sediments will consolidate to a volume of 22,350 cubic yards.

Dredging

Dredging operations are done either by mechanical or hydraulic equipment. Mechanical dredging removes bottom sediments using various types of mechanical buckets. This method is not recommended for soft materials like in Megginnis Arm because much of the soil would wash out of the bucket when it is lifted through the water (Turner, 1974). If mechanical dredging is selected, the removed material must be barged for transportation to the spoil site.

Hydraulic dredging has a vacuum sweeper effect which continuously removes sediments by high velocity water entrainment. A slurry of water and sediment is discharged by the dredge pipe to the spoil site. The problem with hydraulic dredging would be in the turbidity when returning transport water from the spoil site. Treatment of return water would require either terraced impoundment settling basins, an impoundment settling basin controlled by a series of weirs, or through an infiltration drain-pipe.

The feasibility of dredging Megginnis Arm is questionable for the following reasons:

1. From the above discussion, it would be very difficult to obtain a permit for mechanical dredging.

2. Both mechanical and hydraulic dredging techniques would face the problem of space availability for an impoundment site. The Johnson property at the southwest end of the Megginnis Arm previously used as a fill site for excavations during construction of the stormwater treatment facility could accept additional fill on a limited basis, but written verification is needed. Additional land would be needed to handle a complete dredging program.

An alum inactivation of suspended solids within the water column would also need to be included in a dredging program. This would coagulate and precipitate colloids that would otherwise remain in suspension almost indefinitely due to wind and wave action.

Drawdown

Drawdown of a water body is dependent on the location of water control structures, groundwater elevation, characteristics of the sediments, and the portion of the bottom that can be economically exposed (Schamel, 1974). The exposure of sediments to desiccation by drainage and/or evaporation can considerably consolidate the materials collected on the lake bottom.

Florida lakes, which experience periodic fluctuation in water levels that result in exposure of sediment areas to desiccation, undergo considerable consolidation of materials compared to undrained materials (Edmiston and Myers, 1983). Depending upon the soils and water content, the volume of exposed sediments could be reduced considerably.

From analysis of the lake sections, it was determined that if the water level was drawn down to elevation 78.0 ft, all of the bottom would be exposed except two deep holes in the south end of the Arm. Low permeabilities of the soils determined that by keeping the water level at or above 78.0 ft, groundwater would not excessively infiltrate the Arm. But, during the drawdown, it is inevitable that water from Lake Jackson would seep through the pipeline berm into Megginnis Arm. To eliminate this inflow, it is recommended that sheet piling be installed along the north side of the berm. The sheet piling should be driven to an elevation approximately 70.0 ft where the Hawthorne Formation exists. This would shut off a return flow to Megginnis Arm during the drawdown period.

If Megginnis Arm is drawn down by pumps operating at 2000 gallons per minute for a period of 10 to 11 days, a volume of 4.0 million cubic feet (90.6 ac-ft) could be pumped to the treatment facility impoundment area. This volume in the impoundment area is available if the water level can be held at elevation 95.0 ft or lower. Otherwise, the spillway at elevation 101.0 ft will overflow the excess volume. Table 8 (Northwest Florida Water Management District, 1983) illustrates the storage volume at varying elevations in the impoundment area.

TABLE 8

FILTRATION FACILITY IMPOUNDMENT STORAGE ELEVATION DATA

Elevation (msl)	Area (Acres)	Volume (Acre-feet)
88	.123	.08
89	1.370	.826
90	3.001	3.016
91	5.592	7.316
92	6.658	13.441
93	7.526	20.533
94	8.250	28.421
95	8.900	36.996
96	9.514	46.203
97	17.100	59.513
98	17.728	76.923
99	18.162	94.873
100	18.622	113.263
101	19.205	132.177
102	19.825	151.692
103	21.142	172.176
104	22.004	193.749

The water pumped to the impoundment area can be stored until the restoration of the Arm is completed. When the rainy season begins, the impounded water will return to the Arm by passing through the filters and marshland facilities. This method processes and returns only treated water, direct rainfall, and immediate vicinity runoff to Megginnis Arm.

The technique of drawdown and desiccation of bottom sediments would result in exposure of approximately 44,700 cubic yards of sediments, and 50% consolidation as presented in the desiccation study. This method would also seal the sediments of the Arm from resuspension after reflooding occurs. During the drawdown, the pipeline could be relocated to a lower depth, in order to allow boat traffic between Lake Jackson and Megginnis Arm.

Drawdown and Excavation

The drawdown and excavation of desiccated sediments by means of draglines, earthmovers, front-end loaders, and other equipment can be done when the drawdown process is completed. This alternative could be performed only if the desiccated soil is dry enough to work on and a storage site is available for 22,350 cubic yards of removed sediments.

The advantages of this method are to rework the lake bottom and to provide a reverse swale/berm around the perimeter of the Arm, at the mean high water elevation. The swale/berm will serve as retention and treatment of stormwater runoff from the immediate vicinity. Runoff would collect in the swale and percolate through the berm before entering the lake (see Figure 35). Additionally, the removed desiccated sediments could be sold for construction material. The data from grain size distribution curves and direct shear tests provide information concerning the appropriate construction application.

Drawdown and Compaction

Instead of the removal of sediments, the drawdown and compaction technique is to compact the desiccated sediments in place. This alternative would be applicable, if the moisture content of the desiccated sediments is not less than 65% after an extended period (45 days). On the basis of the desiccation study, at 90% moisture content the soil would be firm enough that compaction equipment could work in the area without getting stuck. The study also indicated that compaction showed no advantage over merely allowing the sediments to dry to a moisture content of 65% or less. The study results show that with compaction, the consolidation went from 42% to 59%. This consolidation can be achieved if the sediments do not dry to less than 95-100% moisture content.

Drawdown and Dredging

A final alternative is to drawdown the Arm and dredge the two deeper water holes. If this method is selected, a site would be

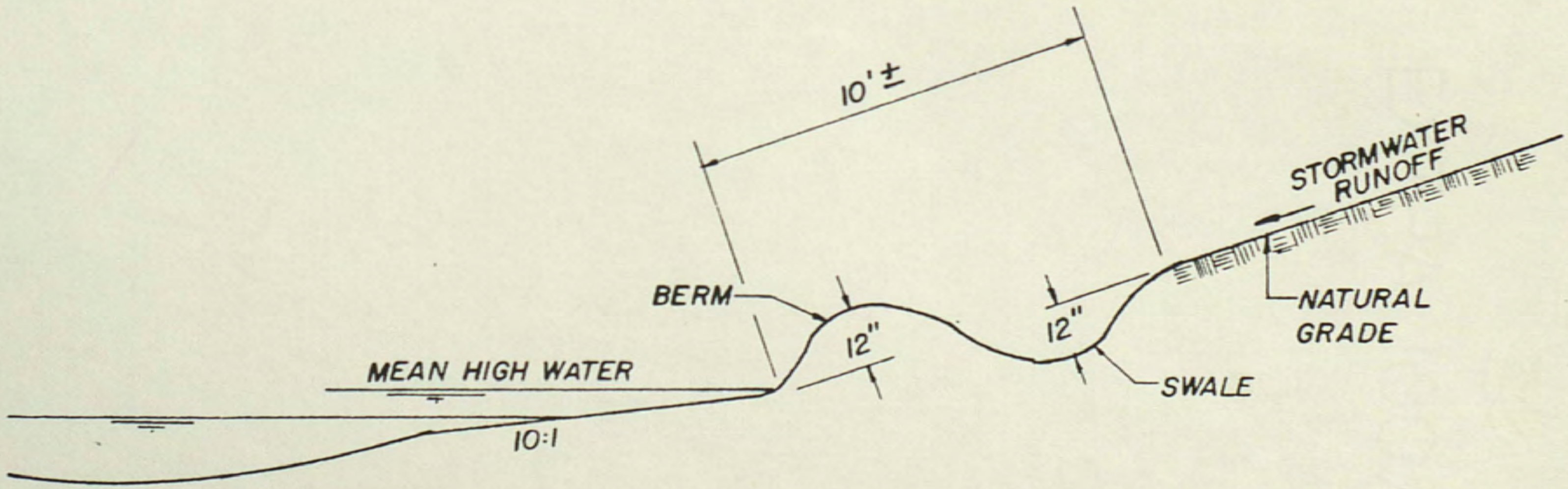


Fig. 35. Swale/berm detail.

needed to store 8,400 cubic yards of spoil. An impoundment could be constructed with one side of the impoundment berm containing 5" perforated drainpipe imbedded in gravel pack which will dewater the dredge material. The dimensions of the spoil site would need to be 240' by 400', with a fill heighth of 4' (Figure 36). A berm 6' high with 2:1 side slopes and 4.5' across at the top would contain the spoil. This impoundment would fit on the Johnson property adjacent to the Megginnis Arm and would be the shortest distance for a dredge disposal pipe.

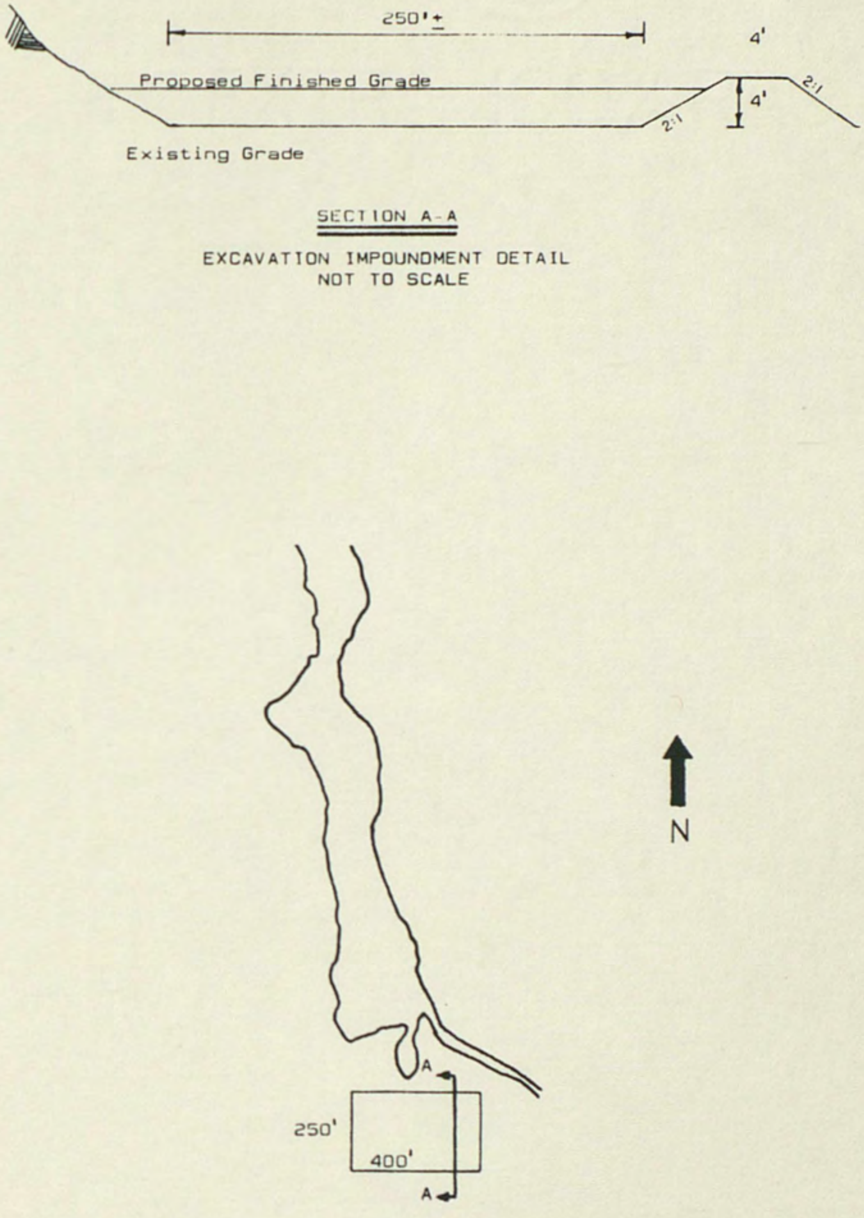


Fig. 36. Dredge impoundment plan and section views.

CHAPTER VII

COST ANALYSIS

The costs for each alternative will be briefly discussed and a cost comparison for each alternative will be summarized and presented in Table 9.

Dredging

To dredge the entire Arm would involve removing 53,100 cubic yards of sediment. Cost of hydraulic dredging is based on the necessary length of disposal pipe. A current price for hydraulic dredging is approximately $6 per cubic yard as quoted by Parkhill Goodloe Company, Inc. of Jacksonville, Florida. Crew mobilization would be $2,000 and removal costs would be $318,600.

The cost of the impoundment would be $18 per foot of a dewatering berm for 600', and $3 per cubic yard of containment berm consisting of 6,667 cubic yards. Therefore, the total construction cost for the impoundment area would be $30,800. Dosing the water column at 125-250 mg/l would result in a cost of approximately $150,000 to treat the Arm by alum inactivation.

Drawdown

To draw Megginnis Arm down would entail 400' of sheet piling to a depth of 15'. Industrial Contracting Company of Sanford,

TABLE 9

COST COMPARISON

Alternative	Cost
Dredging	
Mobilization	$ 2,000.00
Dredging	318,000.00
Impoundment area	30,800.00
Alum inactivation	150,000.00
TOTAL COST:	$500,800.00
Drawdown	
Sheet piling	$ 72,000.00
Pump rental	17,500.00
Piping	8,000.00
TOTAL COST:	$ 97,500.00
Drawdown and Excavation	
Drawdown	$ 97,500.00
Excavation	67,050.00
TOTAL COST:	$164,550.00
Drawdown and Compaction	
Drawdown	$ 97,500.00
Compaction	1,750.00
TOTAL COST:	$ 99,250.00
Drawdown and Dredging	
Drawdown	$ 97,500.00
Dredging	50,400.00
Impoundment area	12,320.00
Alum inactivation	12,000.00
TOTAL COST:	$172,220.00

Florida has estimated sheet piling costs of $12 per square foot. Therefore, the total cost of sheet piling would be $72,000. Pumps to dispose of 2,000 gpm would cost approximately $2,500 per week for a total cost of $17,500 for a period of 7 weeks. Pipe to transport the drawdown water to the impoundment area would cost approximately $8,000. It is assumed that the gas company will bear the cost to bury their own pipeline to a proper depth.

Drawdown and Excavation

The cost of removing sediments with earth work equipment is $3 per cubic yard. To remove 22,350 cubic yards would cost $67,050. Other drawdown costs of sheet piling, pump rental, and piping are included. The total cost for this alternative is $164,500.

Drawdown and Compaction

Meridith Corporation of Orlando, Florida estimated $350 per day for an operator and compaction equipment. In addition to the $97,500 cost associated with a drawdown, the cost for five days of compaction with a smooth steel roller will be $1,750. The total cost for drawdown and compaction will be $99,250.

Drawdown and Dredging

All costs delineated for drawdown would pertain. Dredging of 8,400 cubic yards would cost $50,400. An impoundment area would cost $8,000 for containment berms and $4,320 for a dewatering trench. Alum inactivation treatment of the wetted areas would cost approximately \$12,000 at a dosage of 125 mg/l to 250 mg/l according to Wanielista, et al. (1983). The final cost for this alternative is \$172,220.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The following summary statements are made to emphasize major results of this research study.

1. A brief history of the contributing factors to the degradation of Megginnis Arm was discussed.

2. Various methods of previous lake restoration projects were studied, explained and reviewed.

3. The climate and geography of the Tallahassee area was explored to determine a time of year and time period to attempt restoration.

4. Florida Department of Environmental Regulation, U.S. Environmental Protection Agency, and the Northwest Florida Water Management District have jointly constructed a stormwater treatment facility for the solution of pollutant inflow to Megginnis Arm.

5. The current problem is the in-lake treatment of sediments that have already washed into the Arm.

6. A sampling program was developed and initiated to collect and analyze sediments for identification, to select treatment alternatives, to determine the volume of water and sediment to be treated, and to classify alternative uses for the sediment.

7. Megginnis Arm was mapped by the use of a fathometer, test corings and ground penetrating radar equipment. Ten cross-sectional transects were made using the various mapping techniques in order to pictorially represent the amount of sediments that exist.

8. Sediment desiccation studies were done to determine whether compaction of the desiccated sediments was advantageous and favorable for air dry natural consolidation.

9. Compaction is beneficial if the desiccated materials do not obtain an acceptable moisture content of approximately 65%. At 65% moisture content, the maximum percent of consolidation will take place. If the moisture content is above 65%, some additional consolidation may be achieved by compaction.

10. Compacted sediments have no advantage over the non-compacted sediments for sealing the sediments from resuspension.

11. At water elevation of 83.57 ft msl, there is 98.5 ac-ft of water in the Arm. A drawdown of 78.0 feet would remove 90.6 ac-ft of water and this volume can be stored in the impoundment area of the stormwater treatment facility. Water returning to the arm would flow through the treatment process.

12. A drawdown to elevation 78.0' would expose 44,700 cubic yards of sediment. From the desiccation study, an average percent of consolidation was 65%. If a 1.3 safety factor is applied, it will reduce to 50% consolidation. Therefore, the desiccated sediments would be approximately 22,350 cubic yards.

13. From the geometry of Megginnis Arm and the construction permit limitations, it is determined that feasible methods of restoration are dredging, drawdown, drawdown and excavation, drawdown and compaction, and drawdown and dredging.

14. By comparing the costs, the practicality, and the flexibility of alternative methods, it is concluded that the drawdown and excavation method is the best alternative. A portion of the cost can be off-set if the removed desiccated soil can be sold as material for construction purposes. The second best alternative is drawdown and compaction.

15. The cost of these two alternatives are $164,500 and $99,250, respectively. Assuming that the excavated material can be sold at $2 per cubic yard, the cost of drawdown and excavation would be $119,850.

16. The dredging and drawdown and dredging alternatives were determined to be uneconomical and risky. These methods are not recommended.

CHAPTER IX

RECOMMENDATIONS

A lake restoration project has many physical, geographical, and climatic variables that effect the project. The best approach is a flexible program that can adapt to as many conditions as possible. Flexibility in a project of this nature depends upon a series of alternative plans to support the proposed restoration method.

The least flexible and the most costly plan would be the dredging alternative. This alternative is not recommended.

The most desirable and flexible approach is the drawdown and excavation alternative. In a typical dry season, the Arm can be drawn down and desirable desiccation (i.e., 65% or less moisture content) will take place. Excavation equipment can then remove the dried sediments. The cost of removal could be off-set by the sale of the material for construction purposes.

If the exposed sediments maintain a moisture content of 95-100%, then compaction equipment can compact the sediments for an additional cost of $1,750. Maximum consolidation can be obtained in approximately 5 days. This is an attractive alternative to the drawdown and excavation program because of the short time period required and the relatively small additional cost.

If the rainy season proceeding the drawdown is wetter than usual, or if the dry season is unseasonably wet during the drawdown, only partial desiccation may occur. In this event, the drawdown alternative may be the only program of restoration that can be achieved. A 20-30% consolidation of sediments would be the maximum value expected. This would be an equivalent value for 14 days of desiccation, as shown in Table 6.

The drawdown and dredging alternative is not recommended. The timing and sequencing of tasks for this alternative are critical. The additional cost is considerable compared with similar results from other alternatives.

A great deal remains to be learned about the consolidation of desiccated sediments. Additional desiccation research could be done with chambers maintained in a pre-determined heighth of water, to simulate a steady-state groundwater elevation. In waterbodies with sediment accumulation problems, an in-depth understanding of consolidation and characteristics of soil types will be beneficial in the specification of in-lake treatment methods.

APPENDICES

APPENDIX A

CORE PROFILES

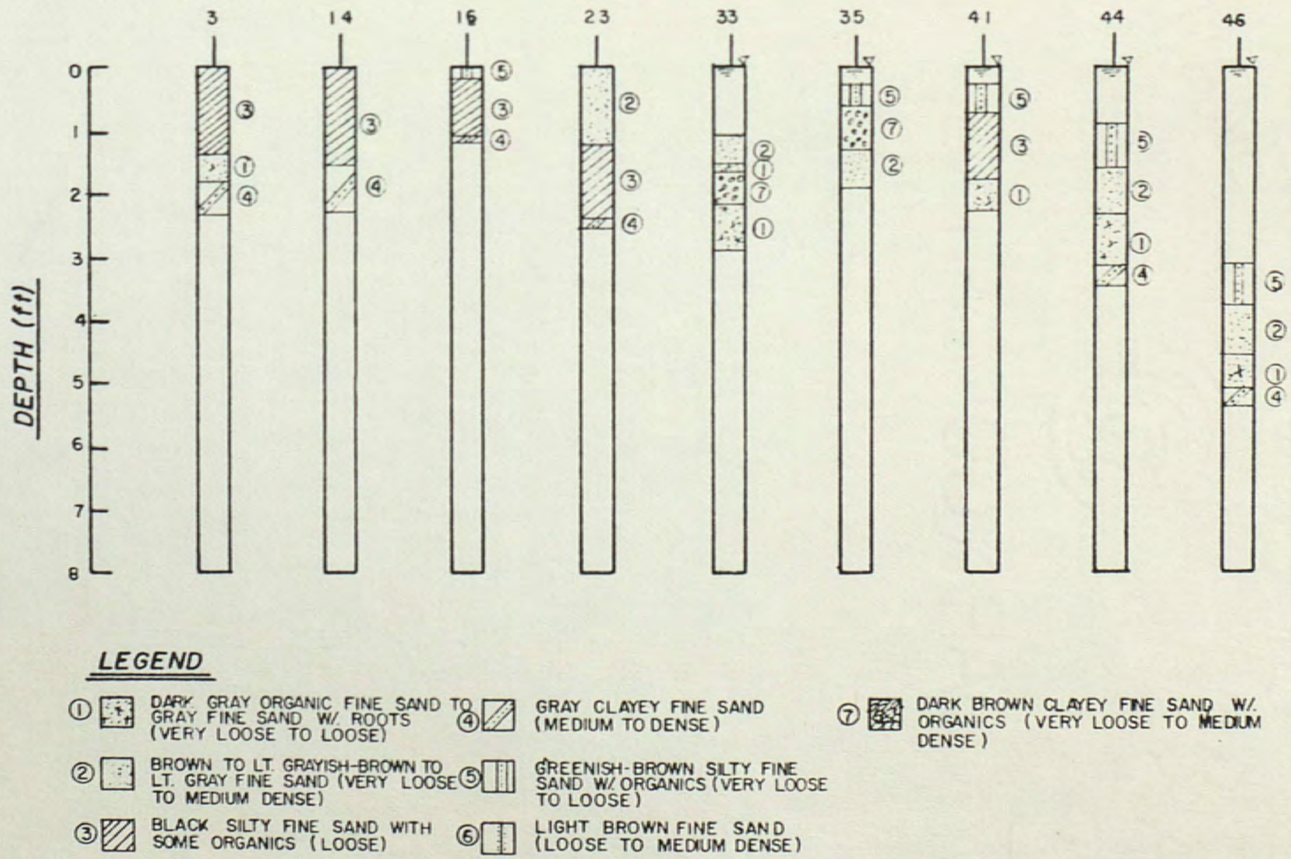


Fig. 37. Core profiles (7/28/83).

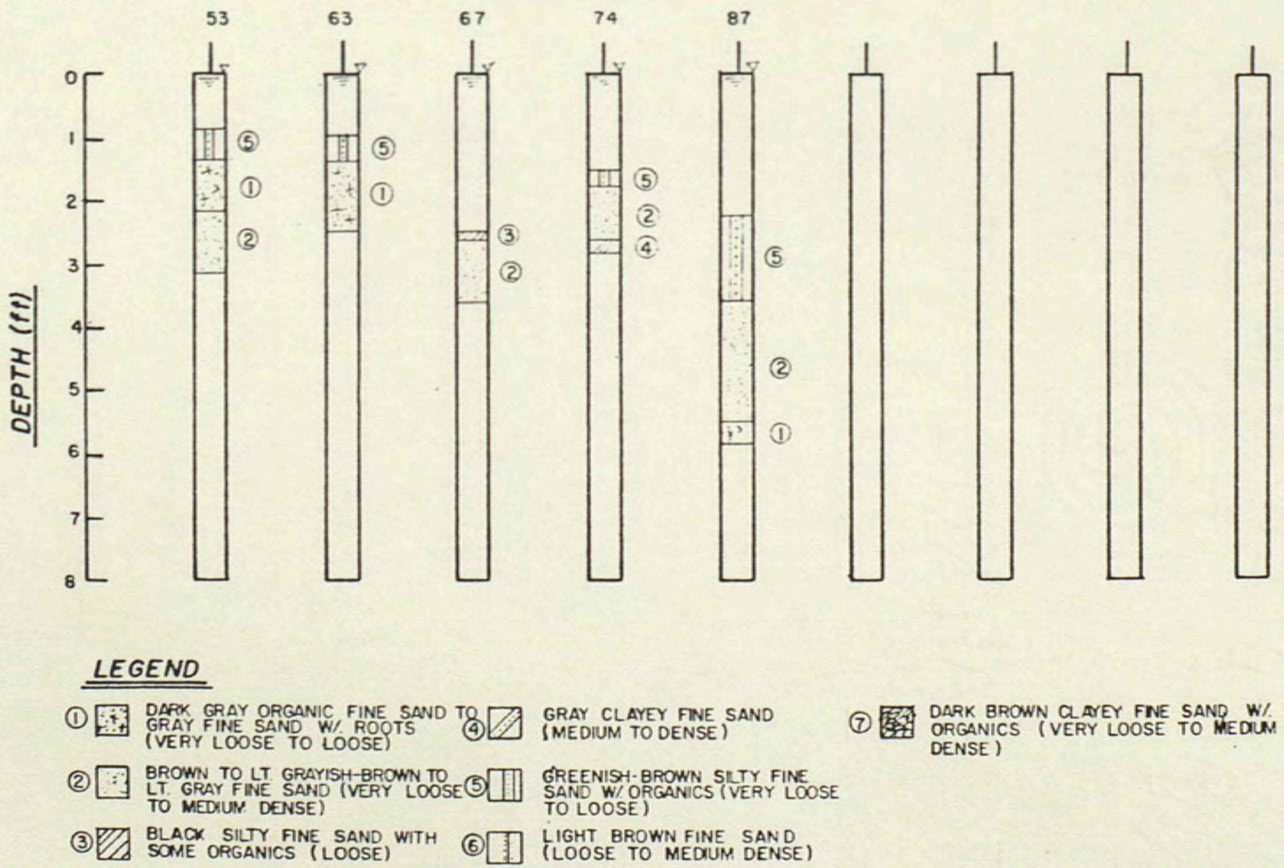


Fig. 38. Core profiles (7/28/83) continued.

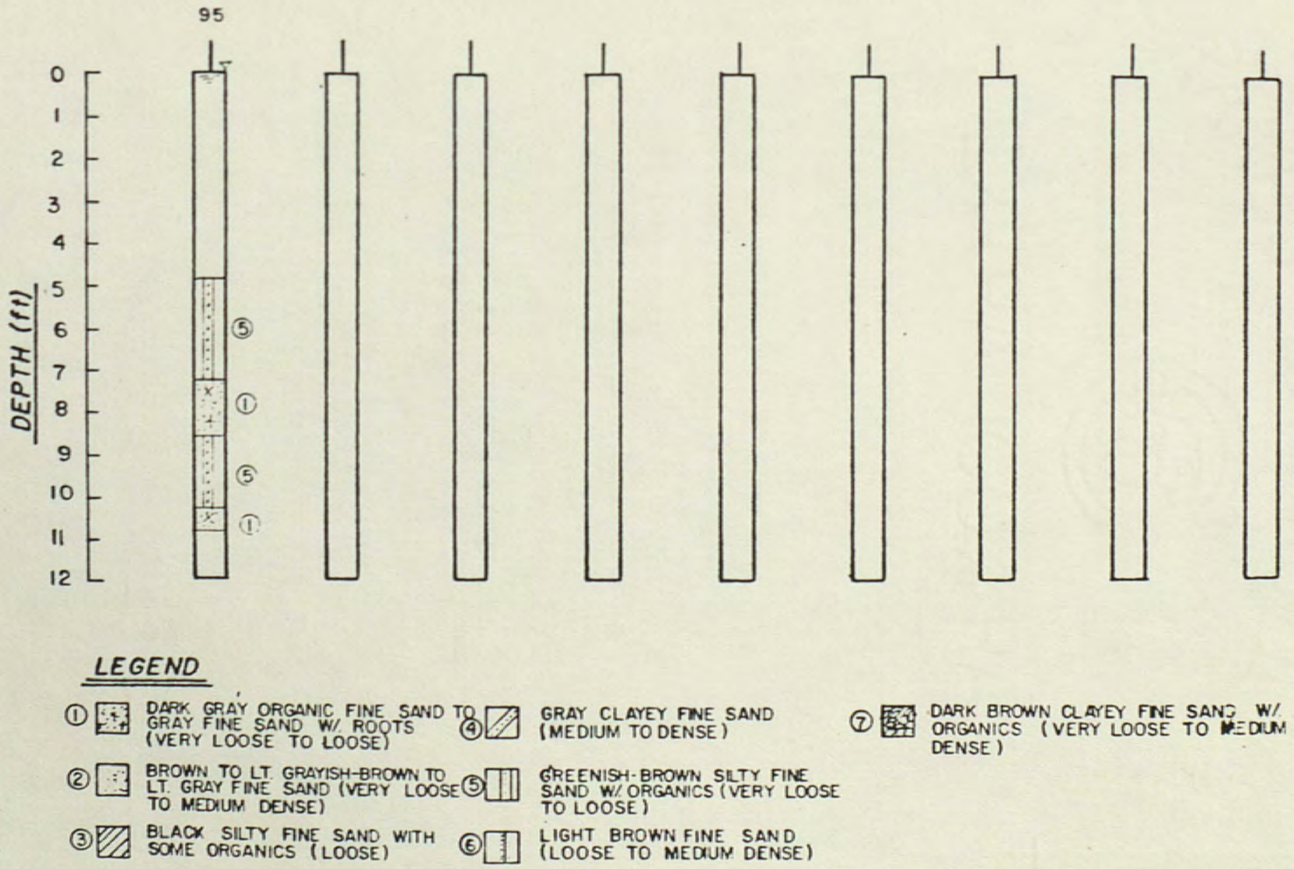


Fig. 39. Core profiles (7/28/83) continued.

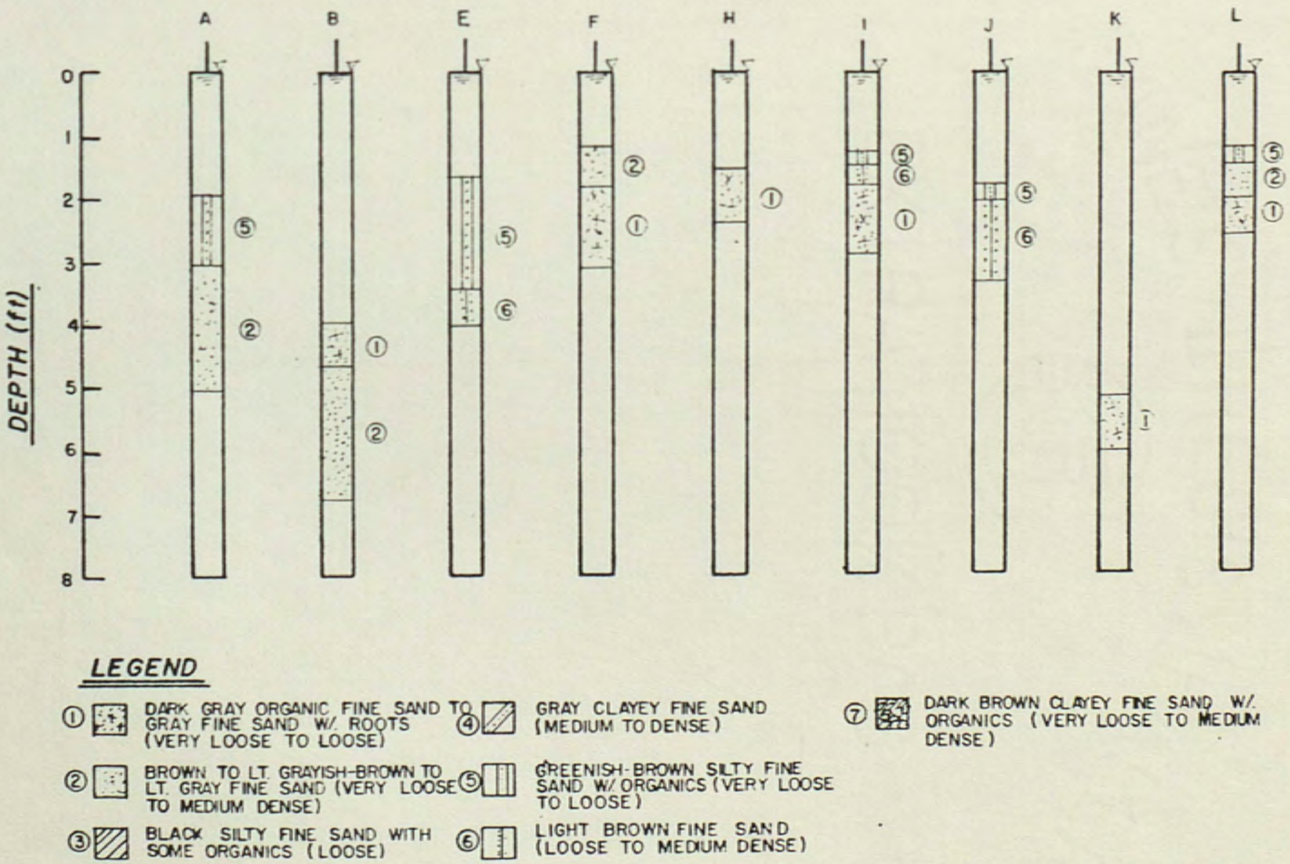


Fig. 40. Core profiles (9/8/83).

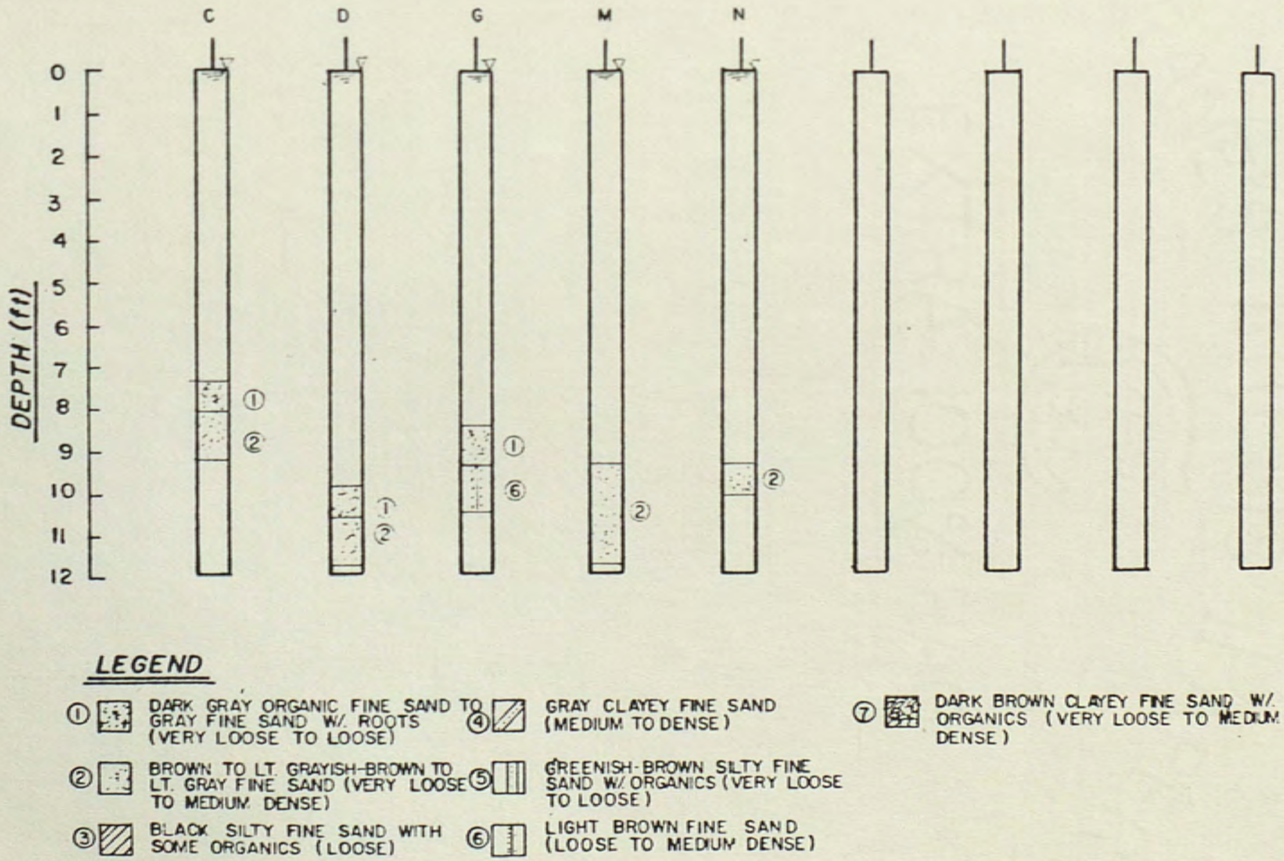


Fig. 41. Core profiles (9/8/83) continued.

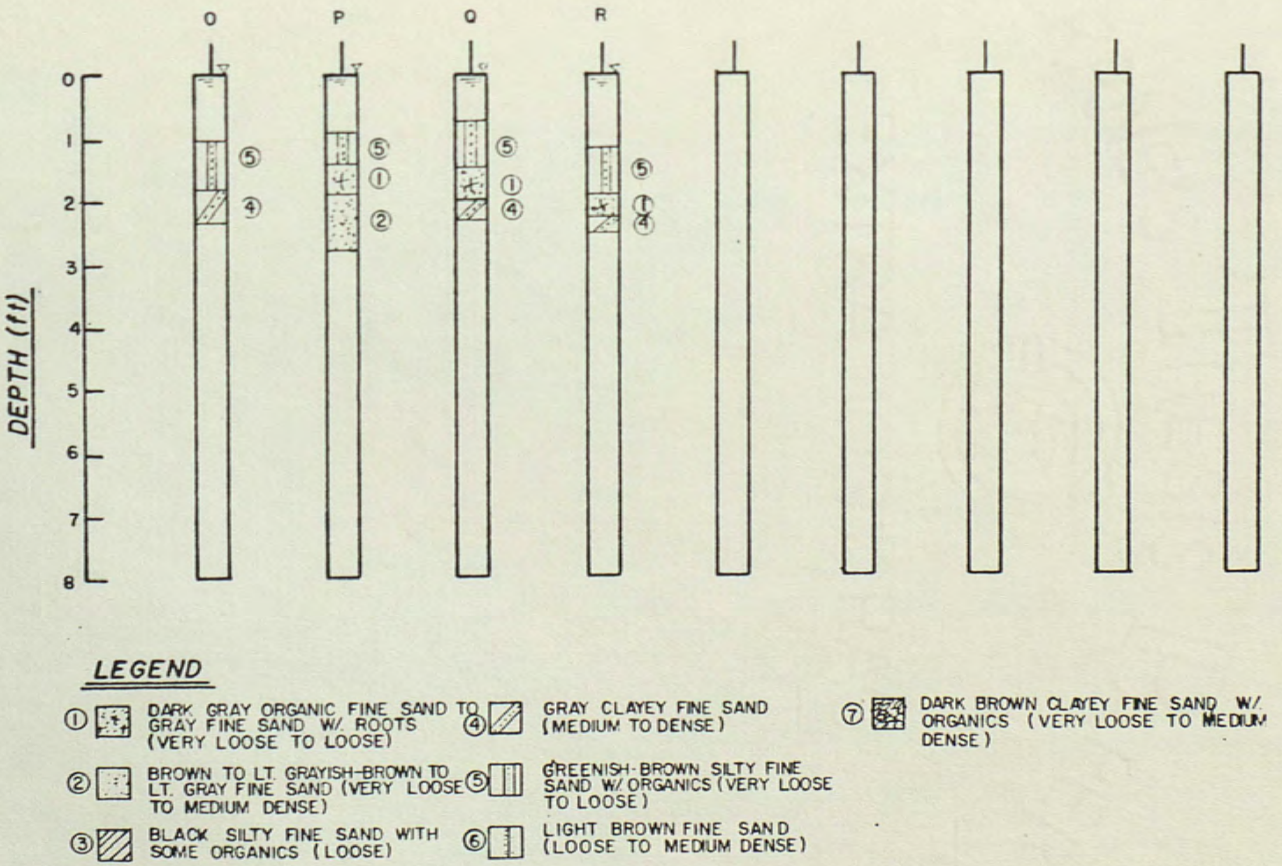


Fig. 42. Core profiles (9/8/83) continued.

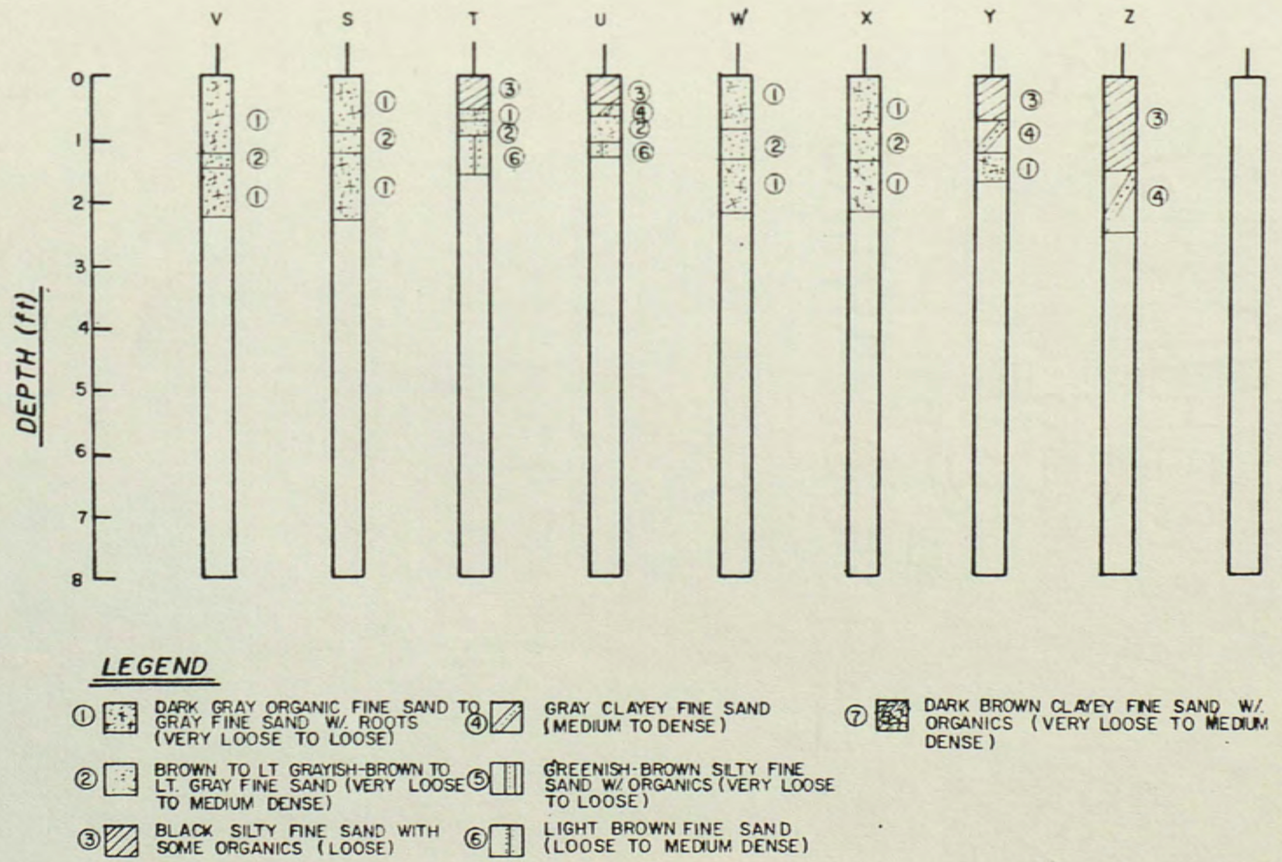


Fig. 43. Core profiles (11/10/83).

APPENDIX B

GRAIN SIZE DISTRIBUTION CURVES

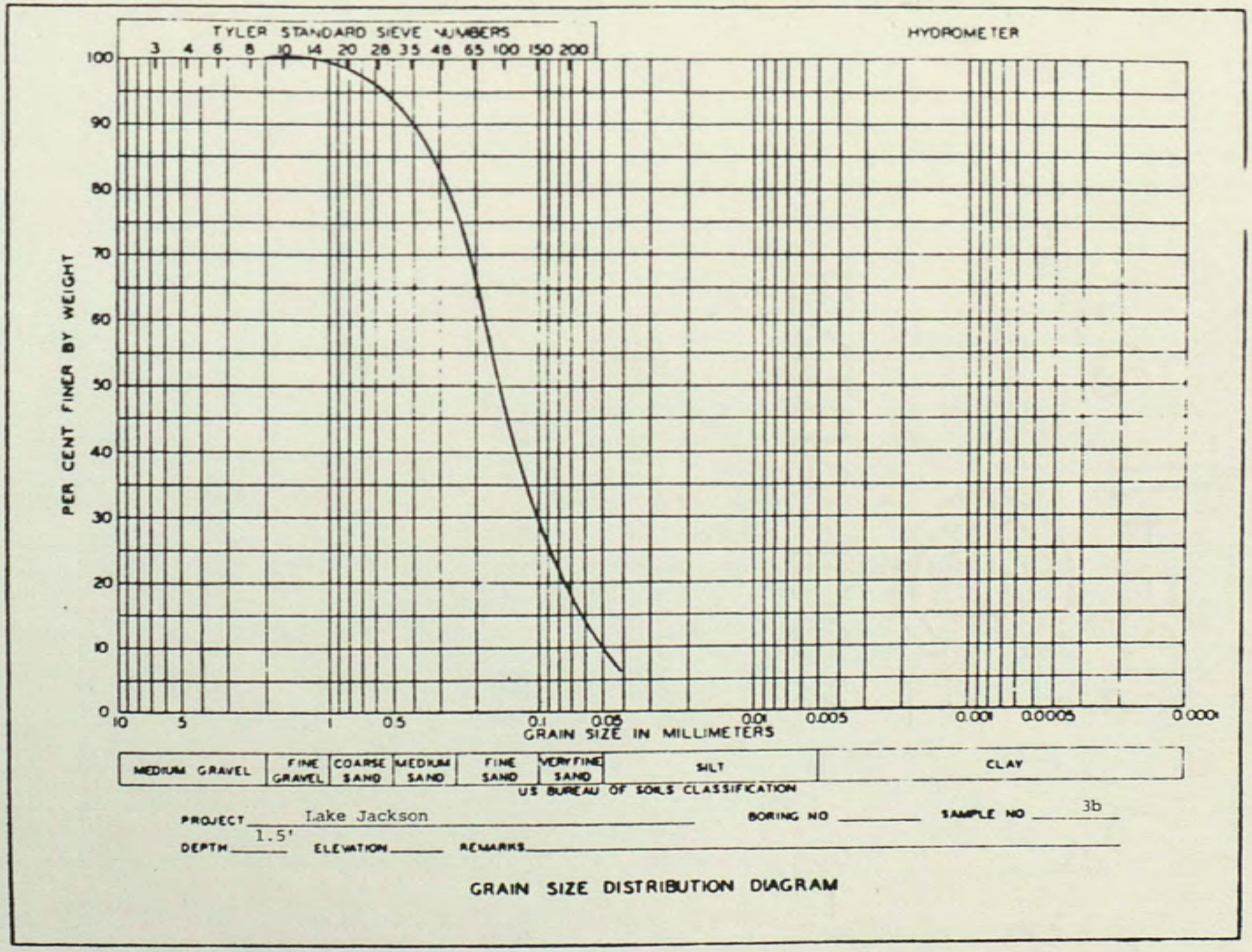


Fig. 44. Sample 3b grain size distribution curve.

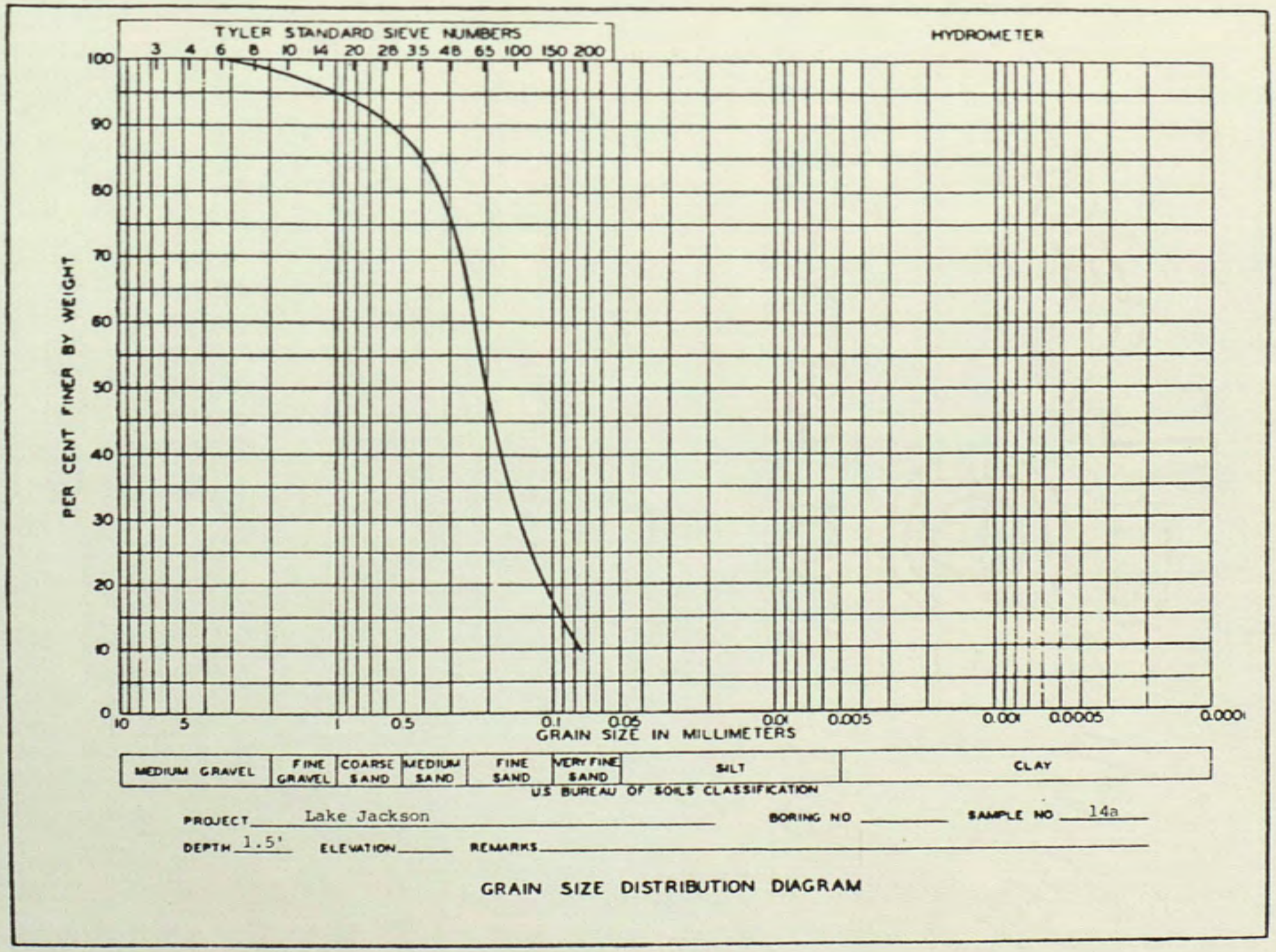


Fig. 45. Sample 14a grain size distribution curve.

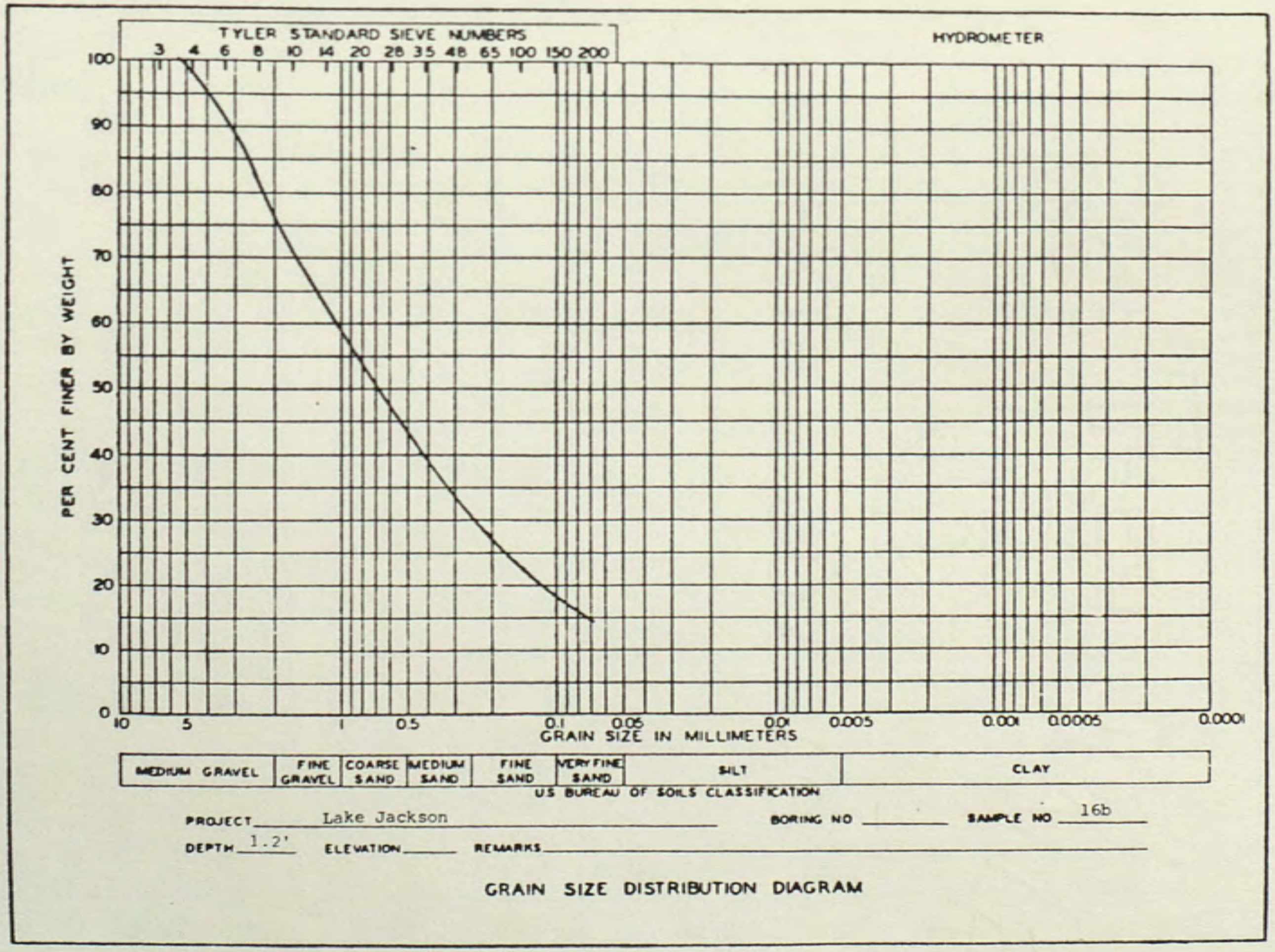


Fig. 46. Sample 16b grain size distribution curve.

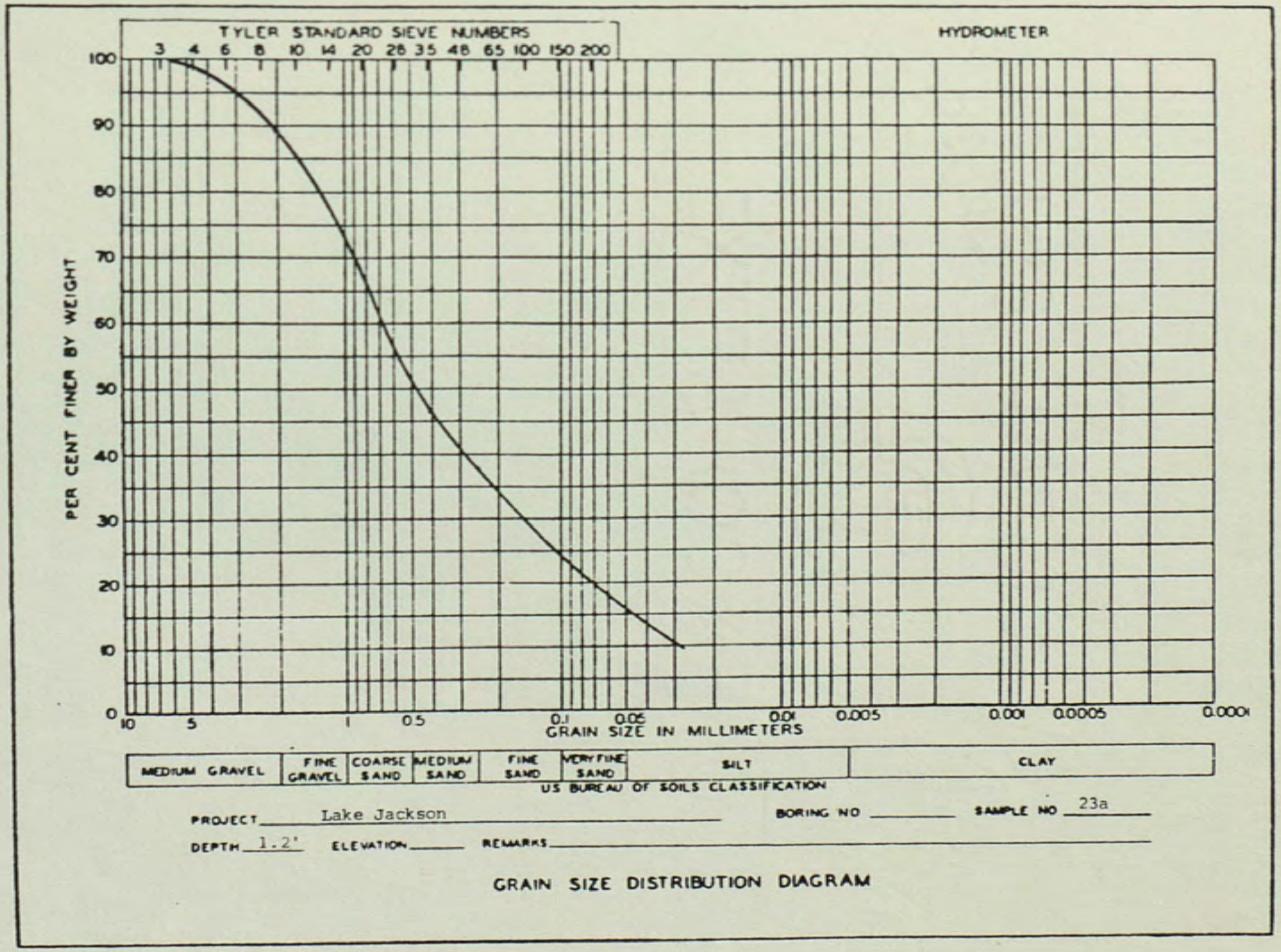


Fig. 47. Sample 23a grain size distribution curve.

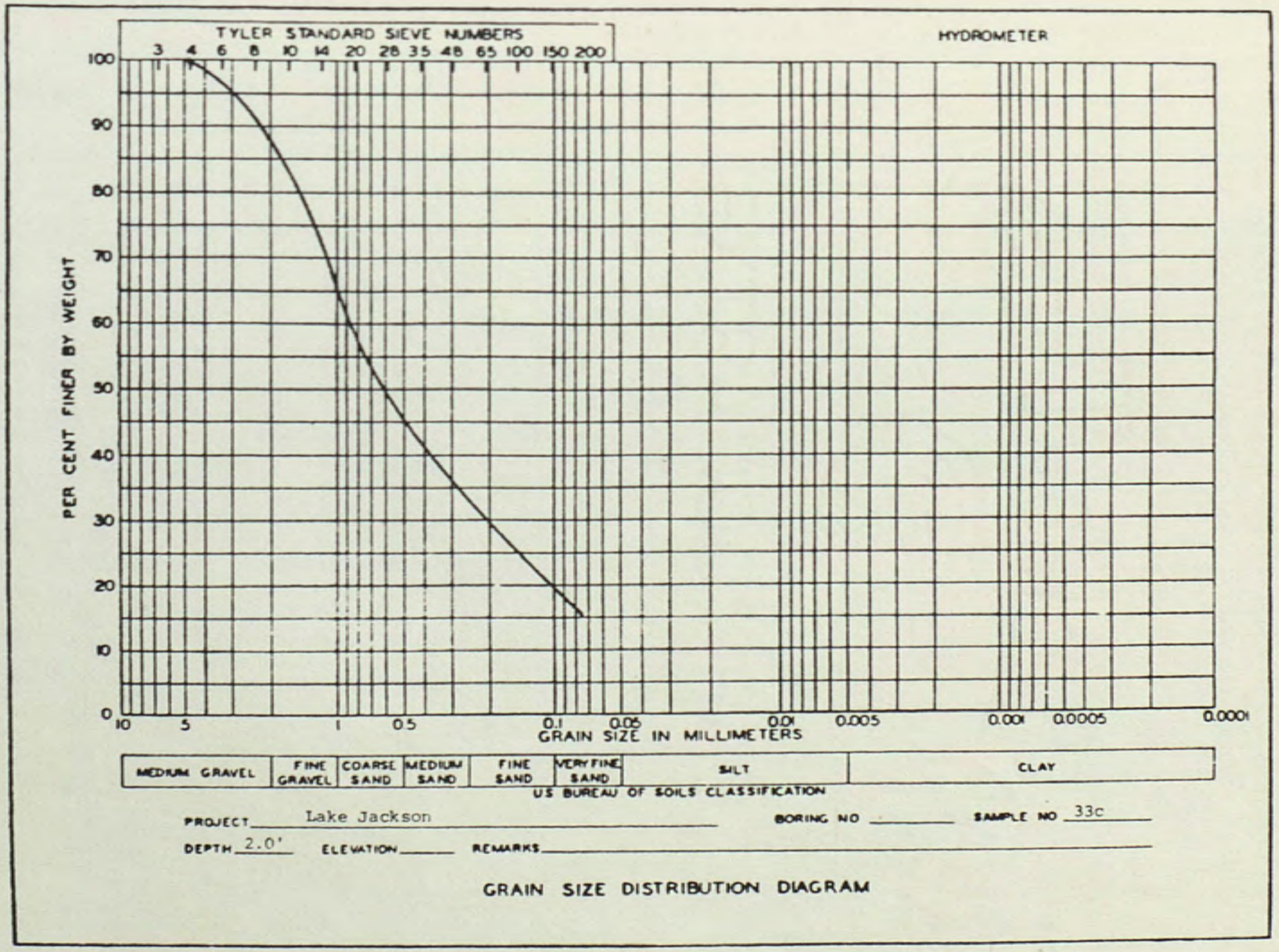


Fig. 48. Sample 33c grain size distribution curve.

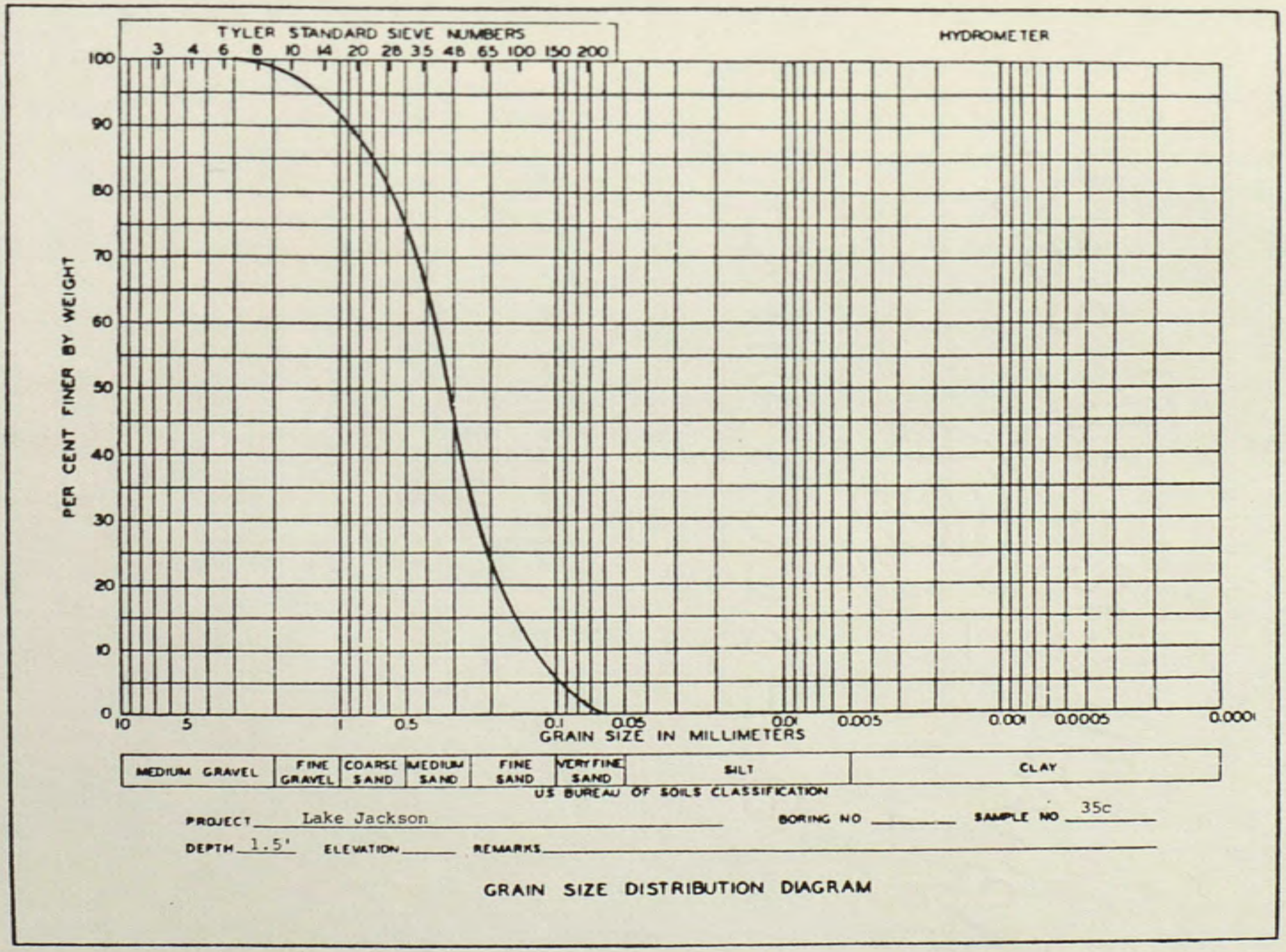


Fig. 49. Sample 35c grain size distribution curve.

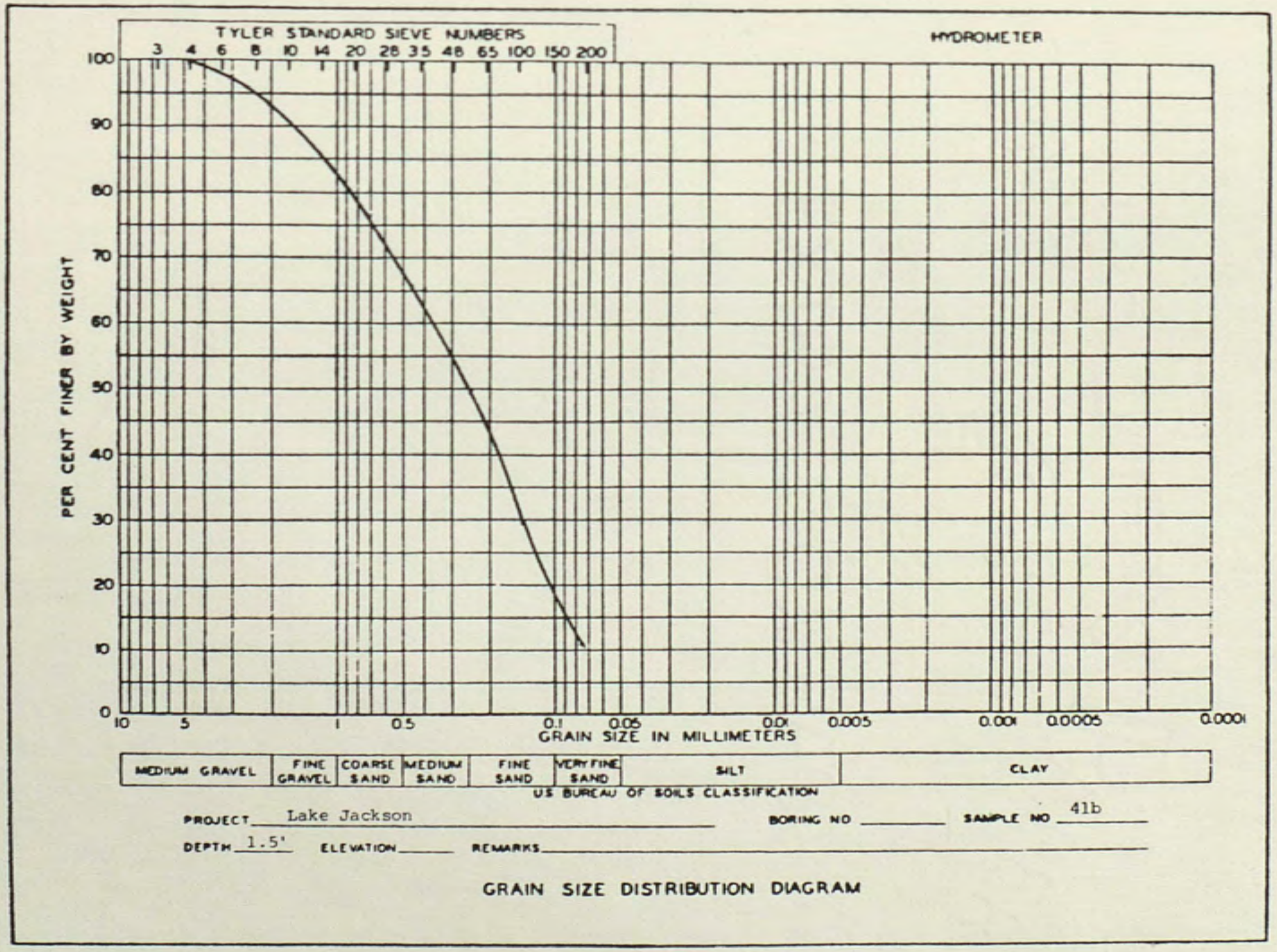


Fig. 50. Sample 41b grain size distribution curve.

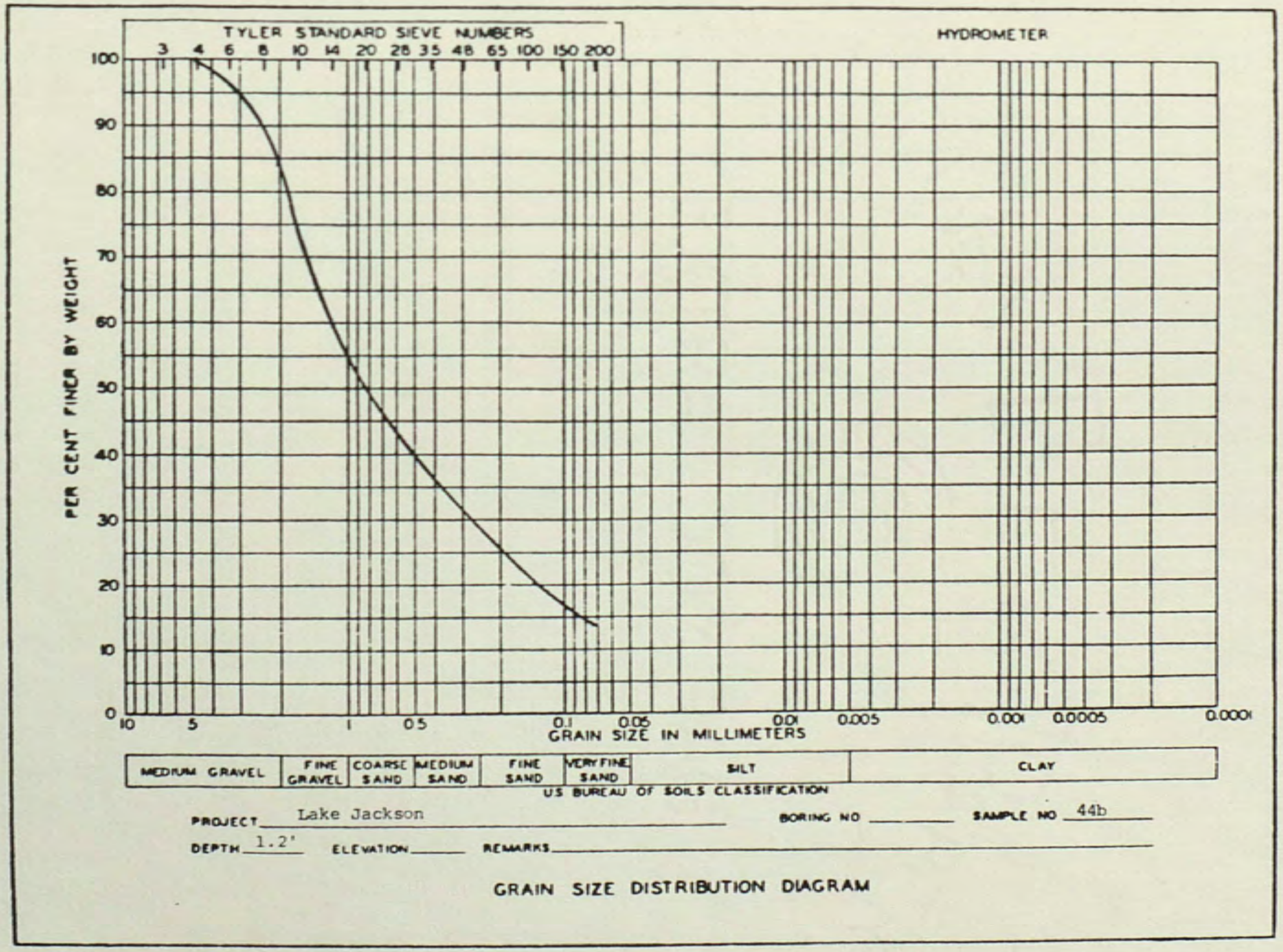


Fig. 51. Sample 44b grain size distribution curve.

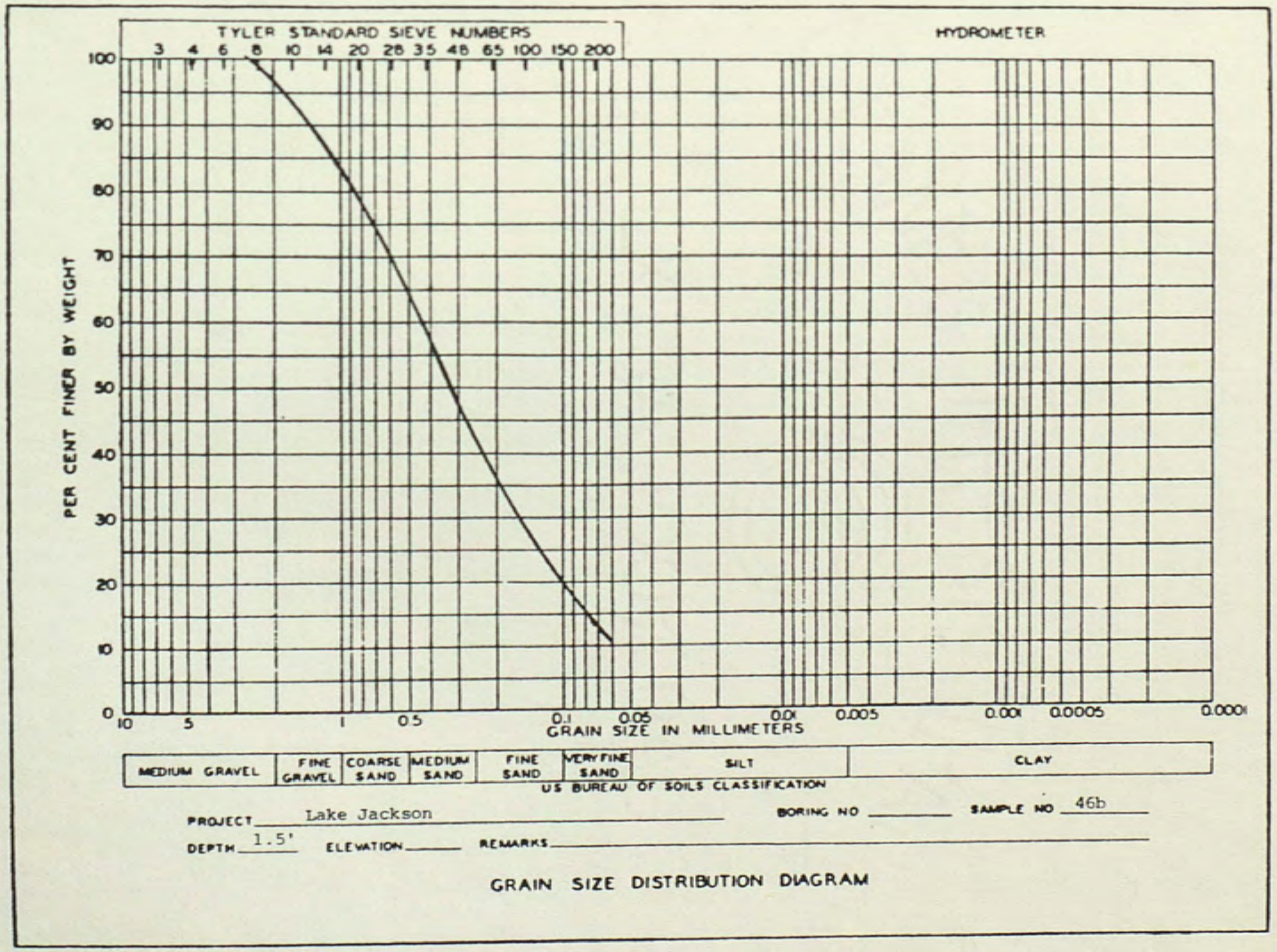


Fig. 52. Sample 46b grain size distribution curve.

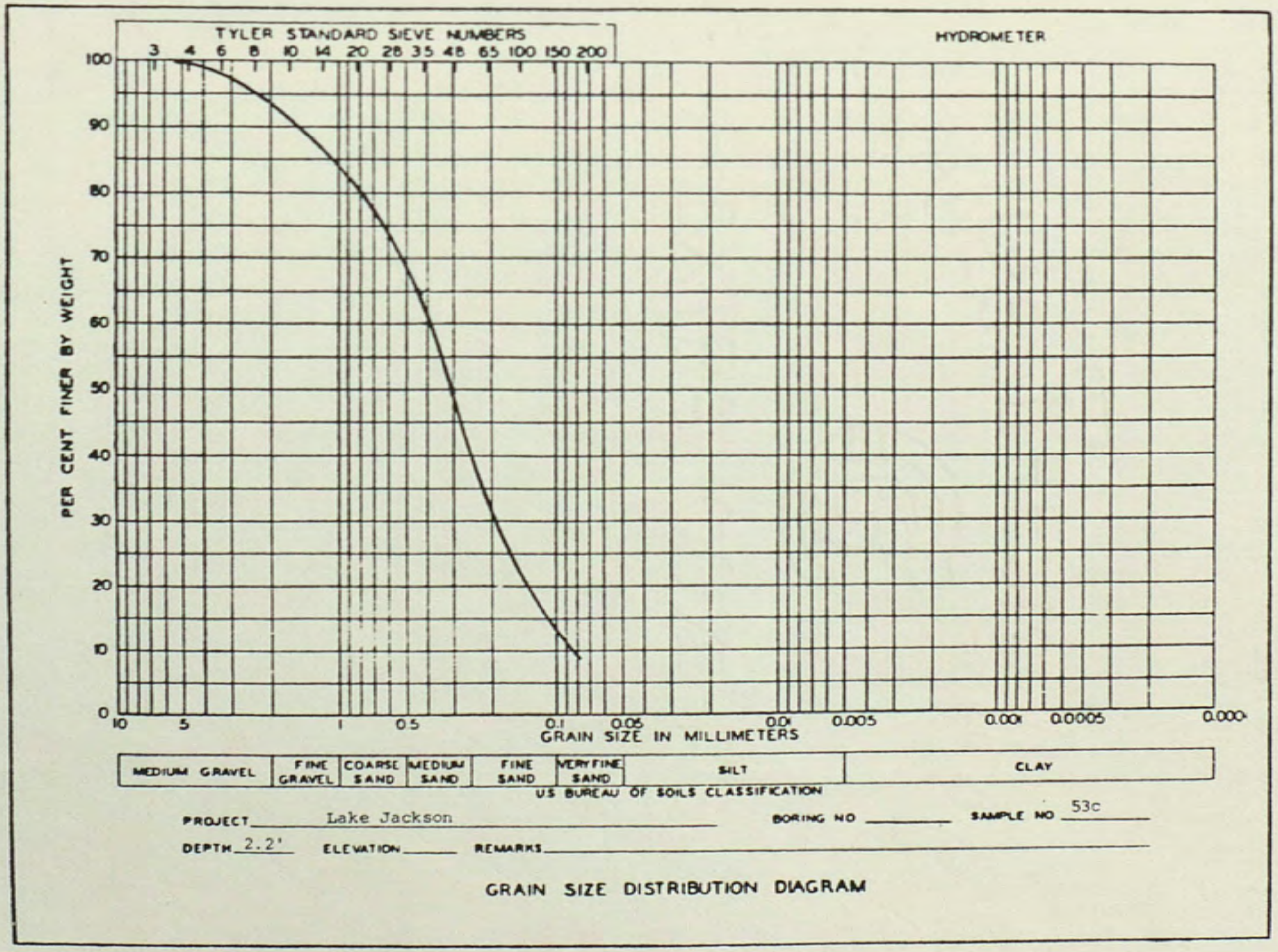


Fig. 53. Sample 53c grain size distribution curve.

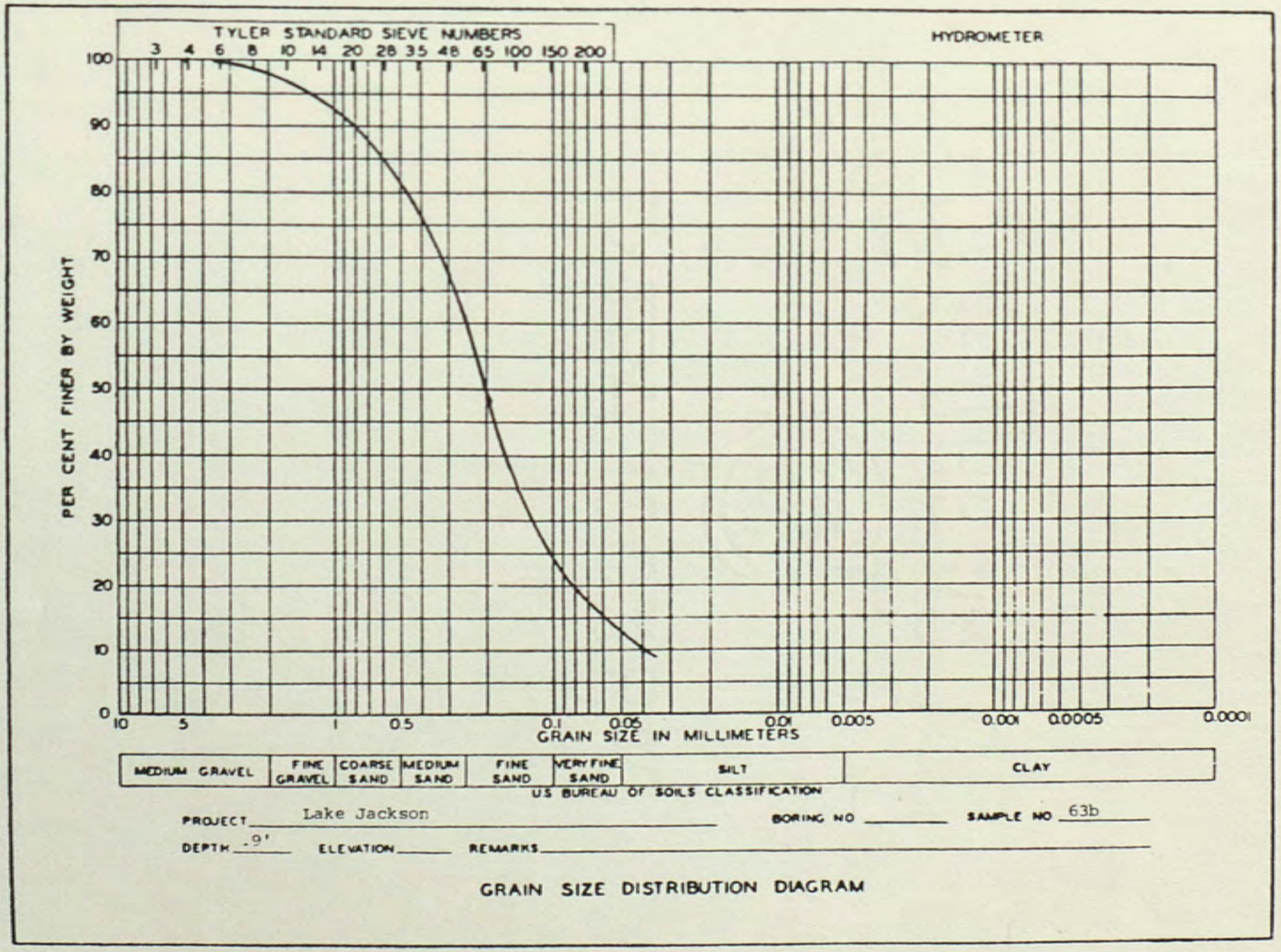


Fig. 54. Sample 63b grain size distribution curve.

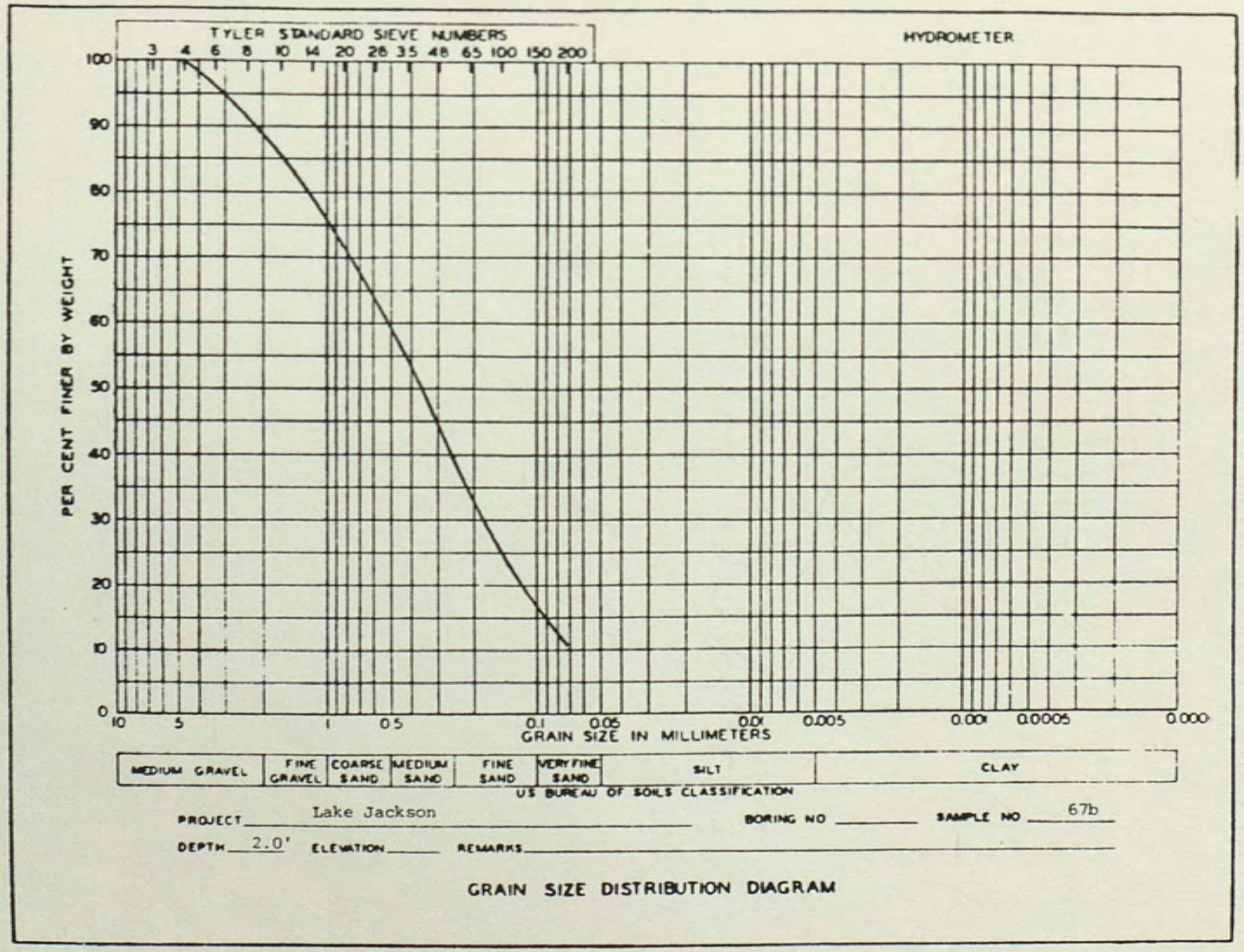


Fig. 55. Sample 67b grain size distribution curve.

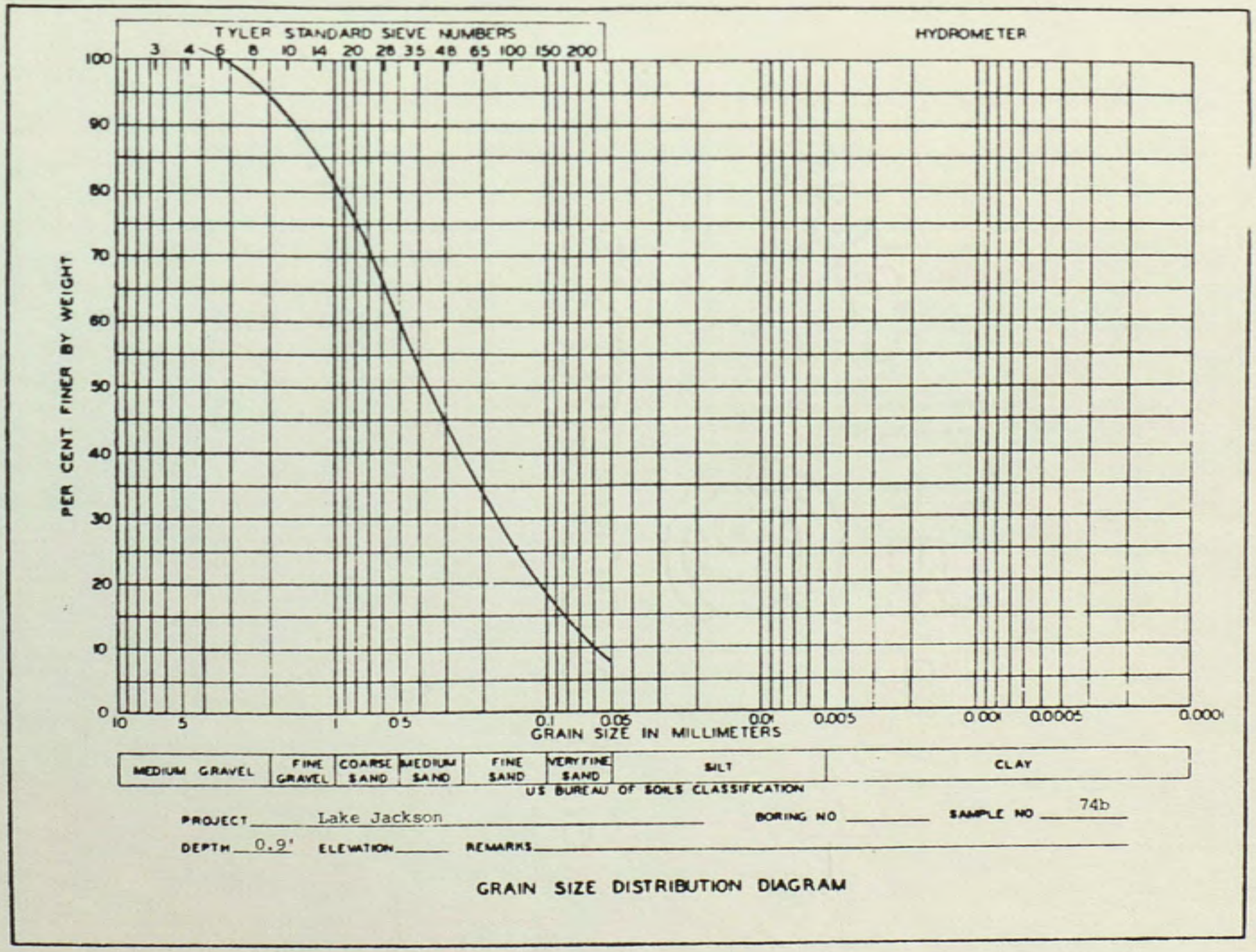


Fig. 56. Sample 74b grain size distribution curve.

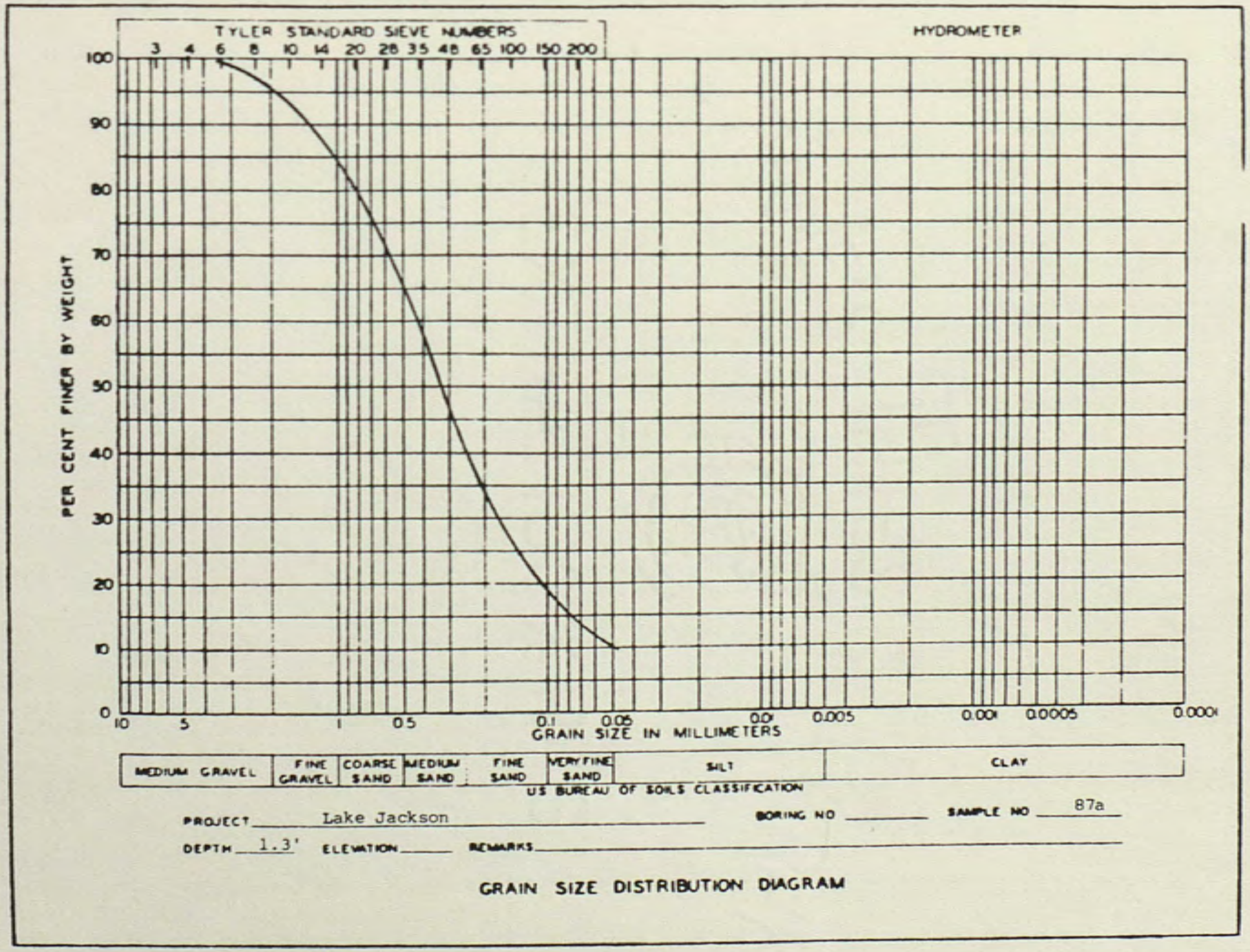


Fig. 57. Sample 87a grain size distribution curve.

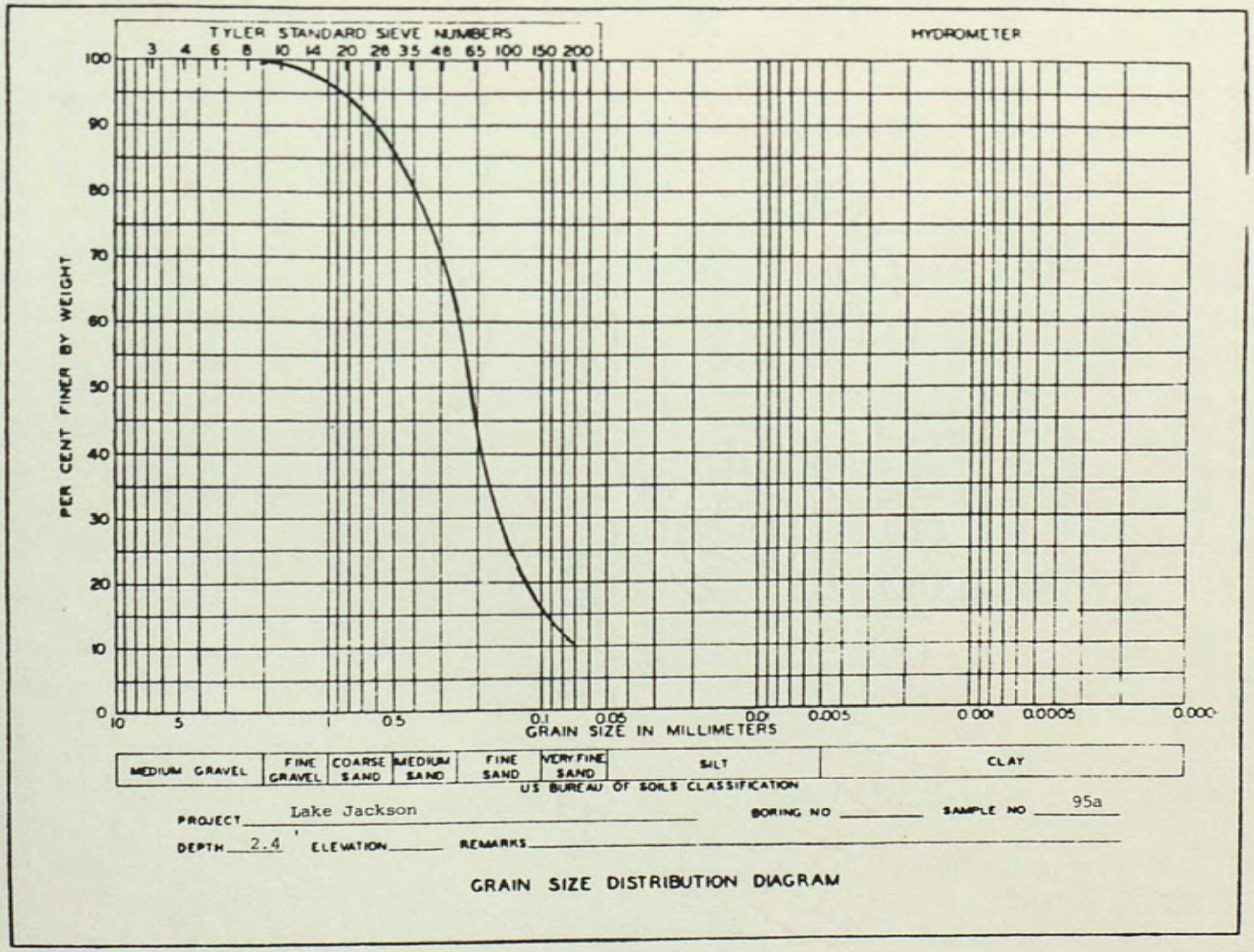


Fig. 58. Sample 95a grain size distribution curve.

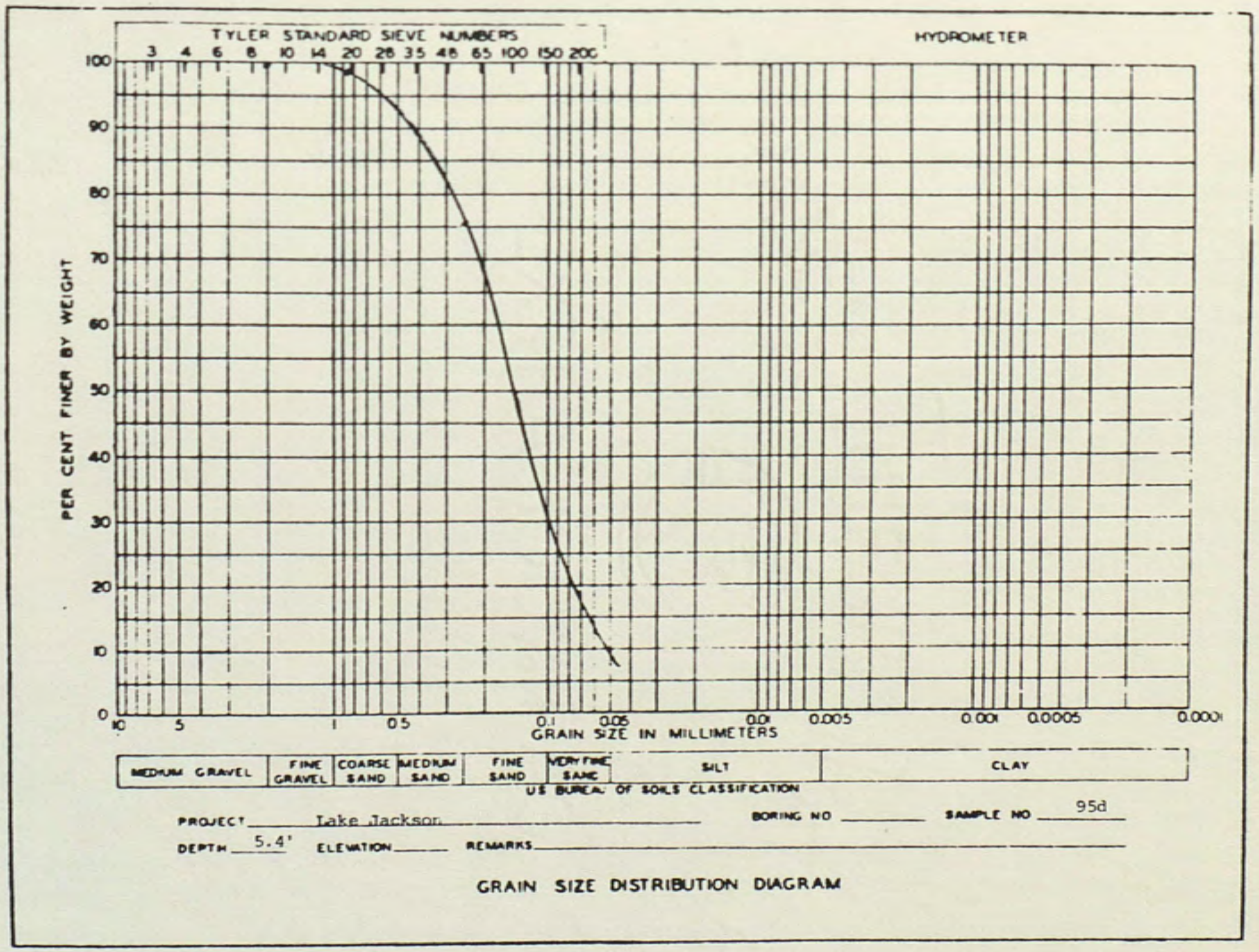


Fig. 59. Sample 95d grain size distribution curve.

APPENDIX C

DIRECT SHEAR TEST PLOTS

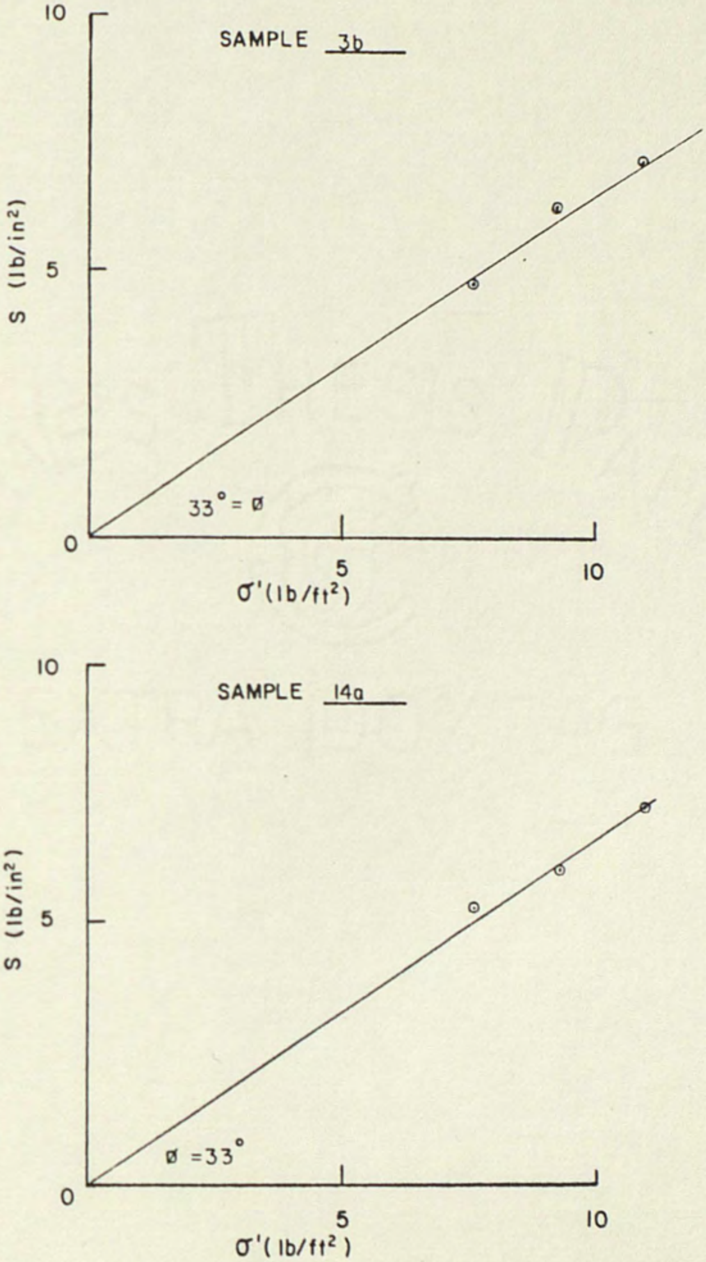


Fig. 60. Strength envelope for samples 3b and 14a.

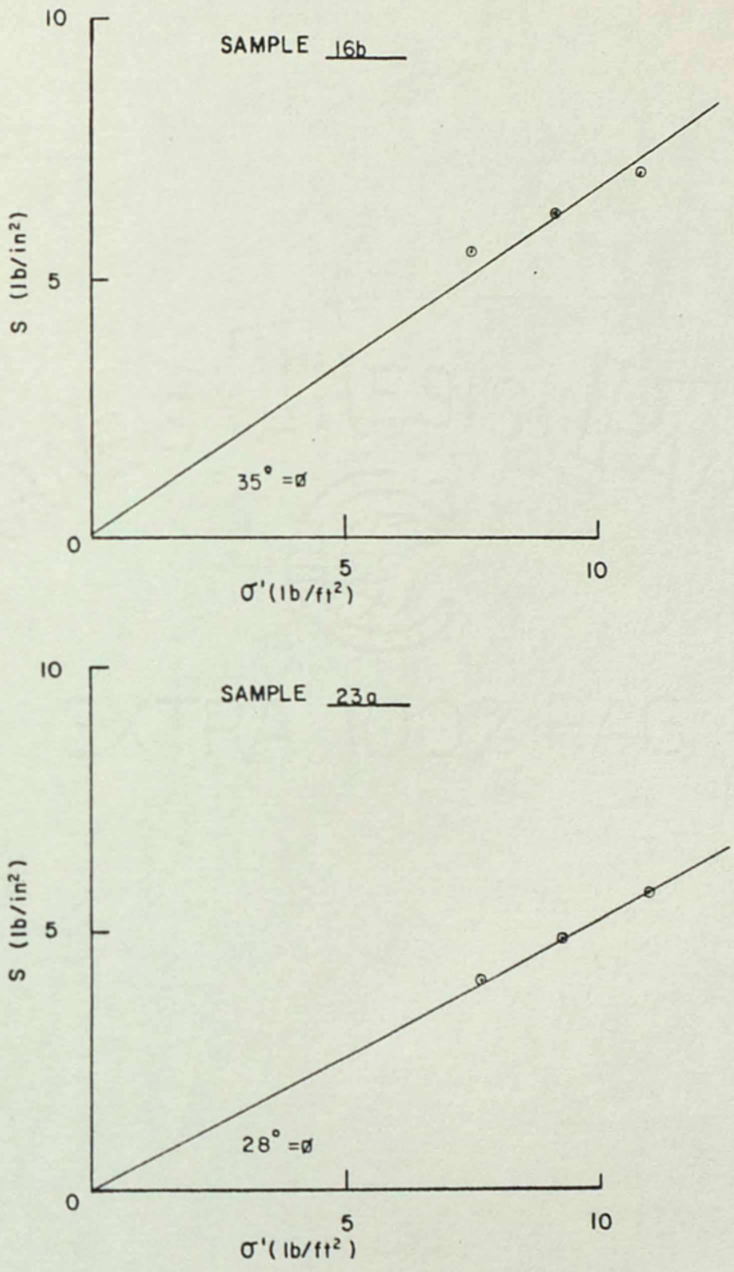


Fig. 61. Strength envelope for samples 16b and 23a.

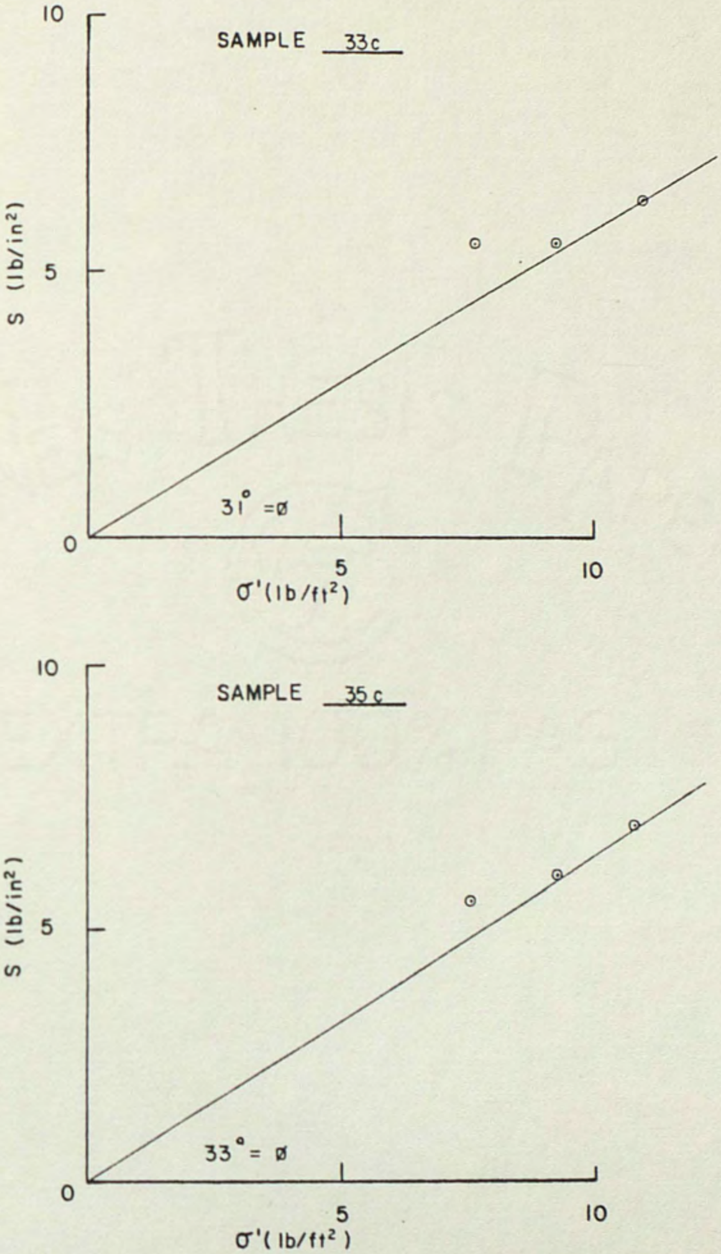


Fig. 62. Strength envelope for samples 33c and 35c.

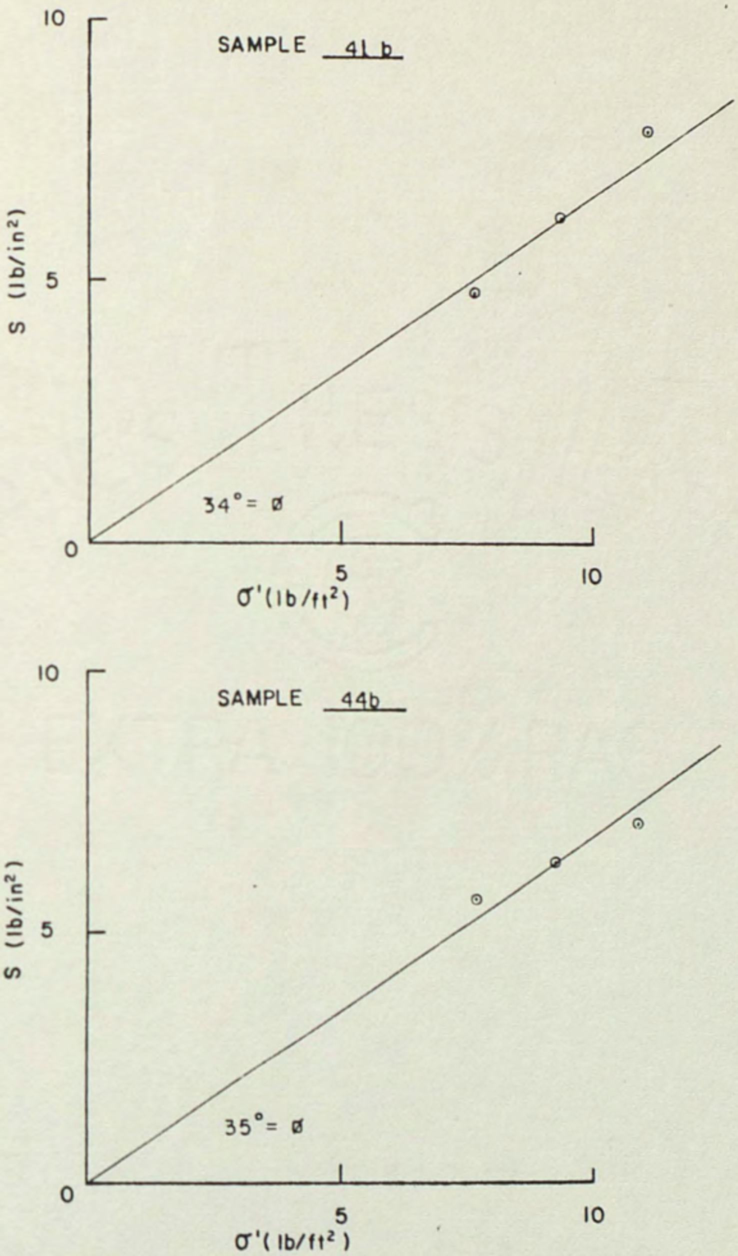
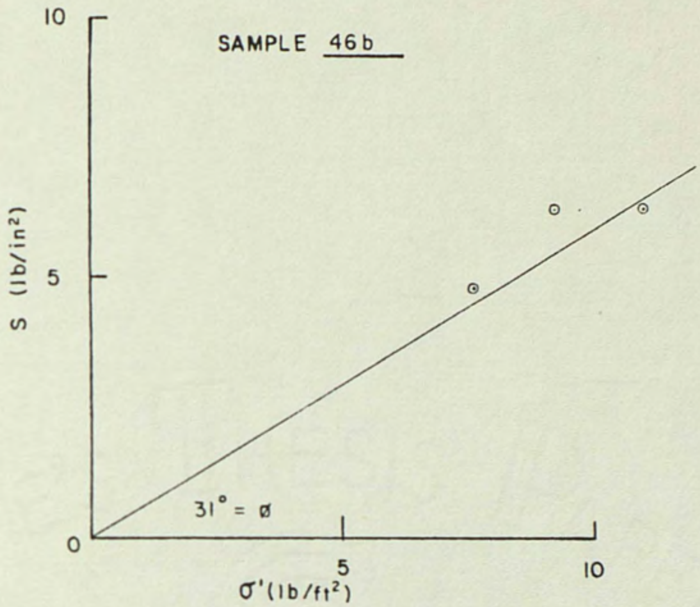


Fig. 63. Strength envelope for samples 41b and 44b.



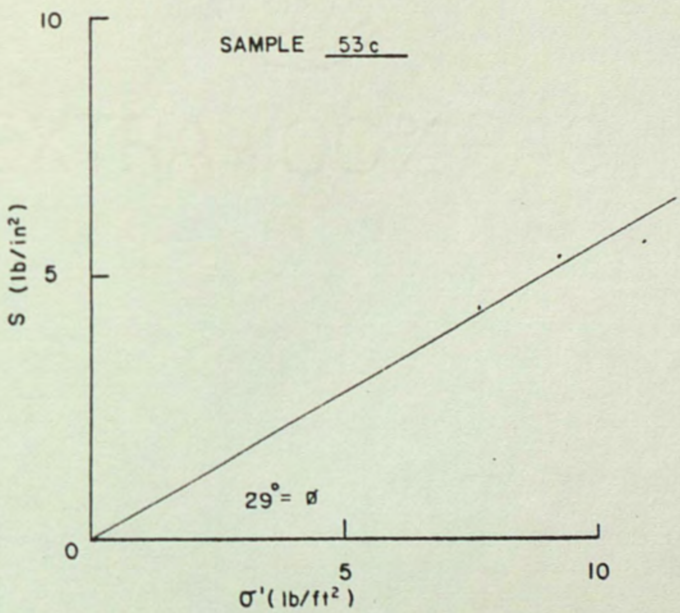


Fig. 64. Strength envelope for samples 46b and 53c.

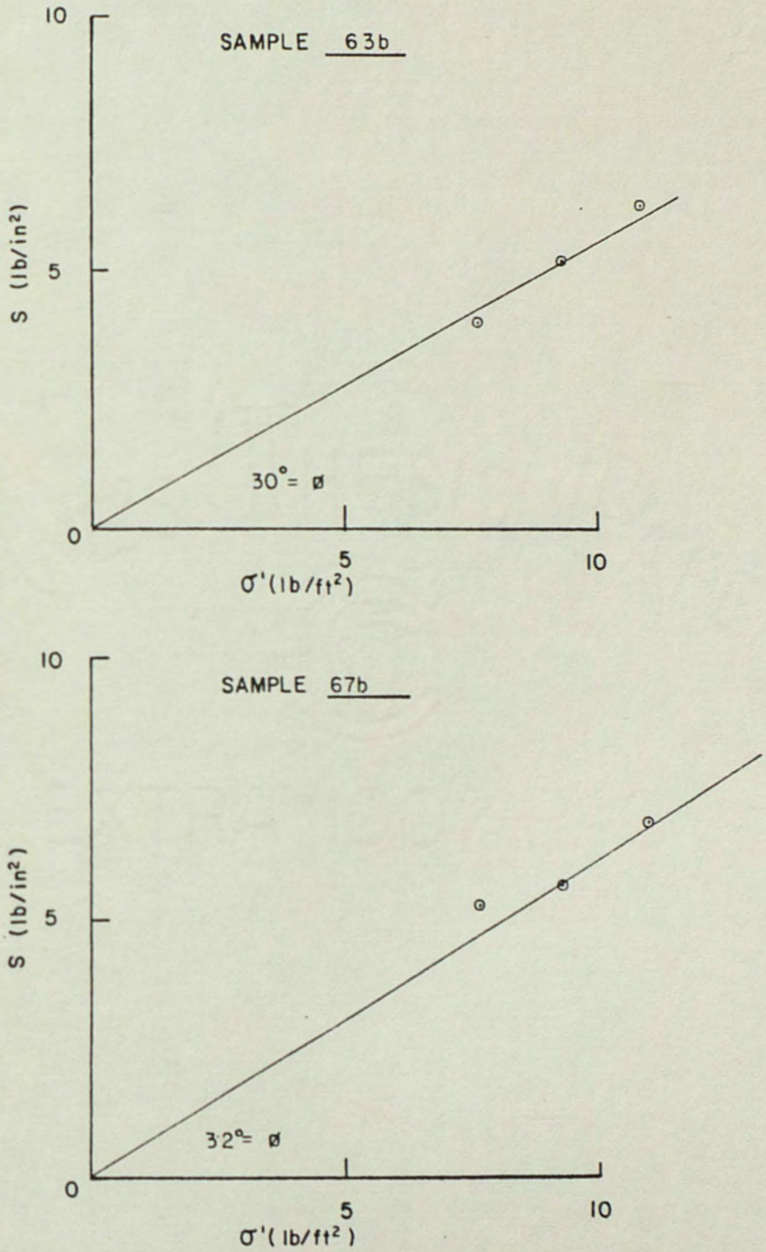


Fig. 65. Strength envelope for samples 63b and 67b.

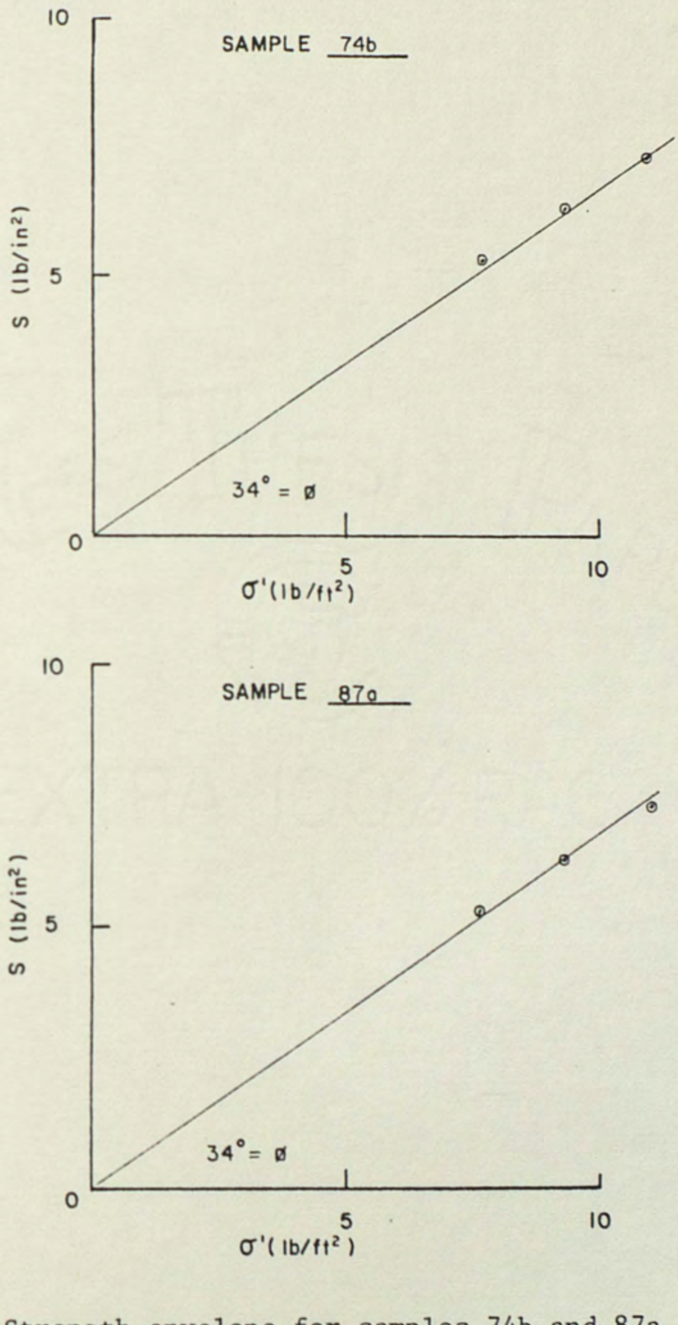


Fig. 66. Strength envelope for samples 74b and 87a.

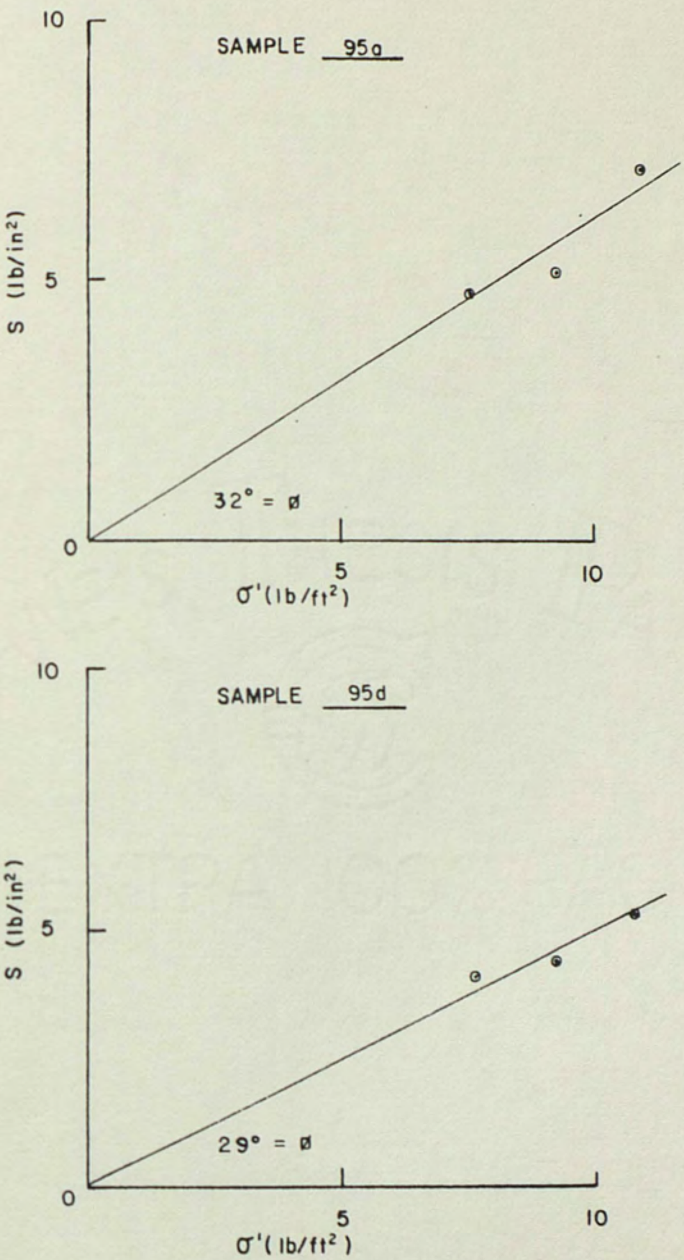


Fig. 67. Strength envelope for samples 95a and 95d.

APPENDIX D

FATHOMETER AND GROUND PENETRATING RADAR

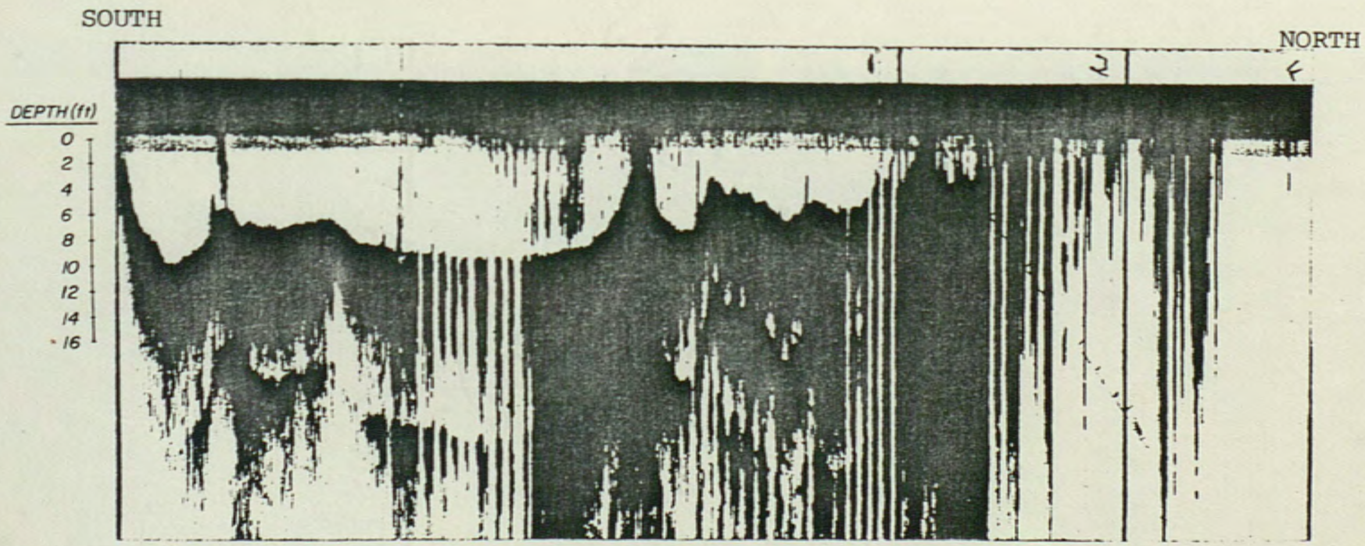


Fig. 68. Fathometer Chart for Section 1-1.

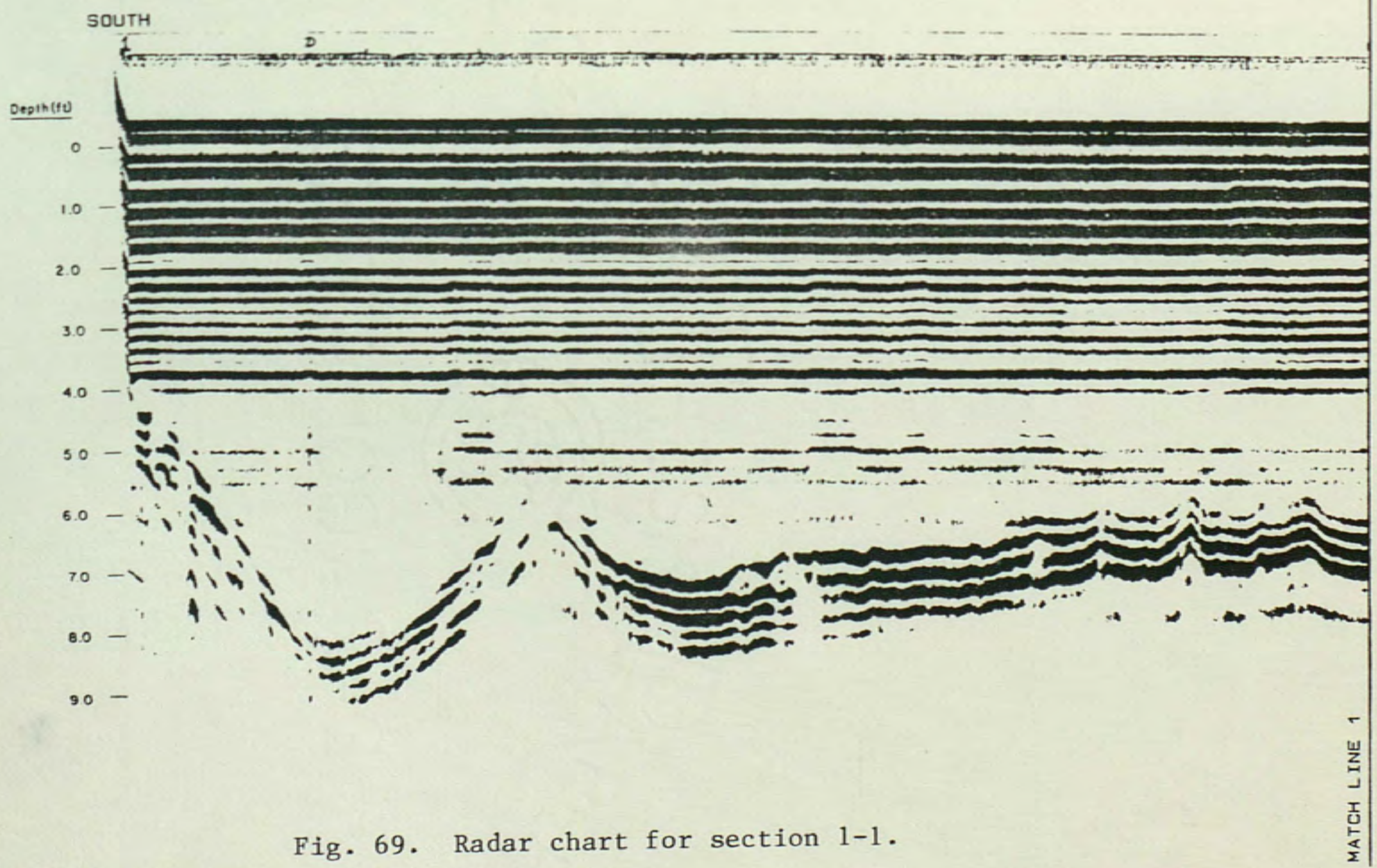


Fig. 69. Radar chart for section 1-1.

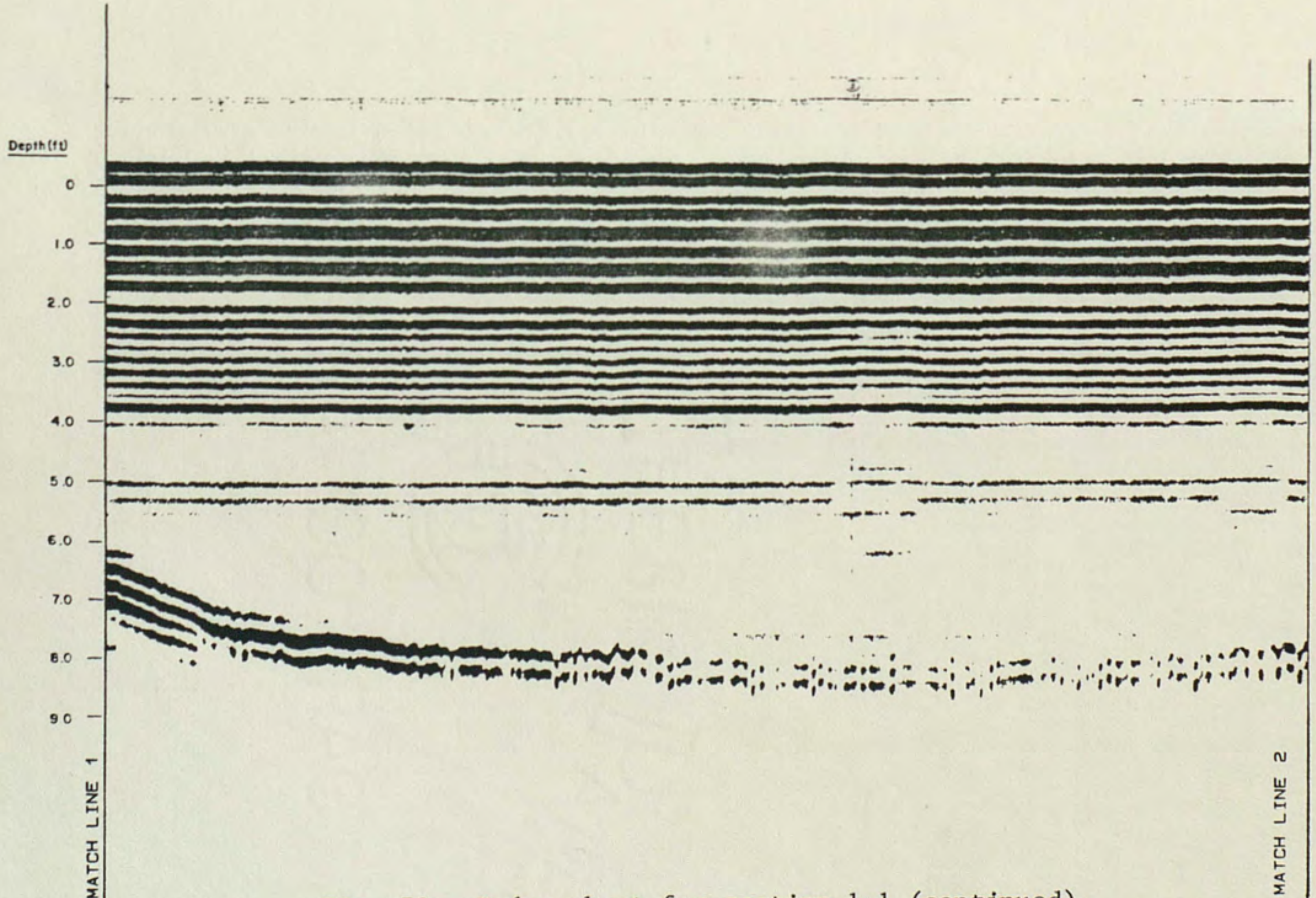


Fig. 70. Radar chart for section 1-1 (continued).

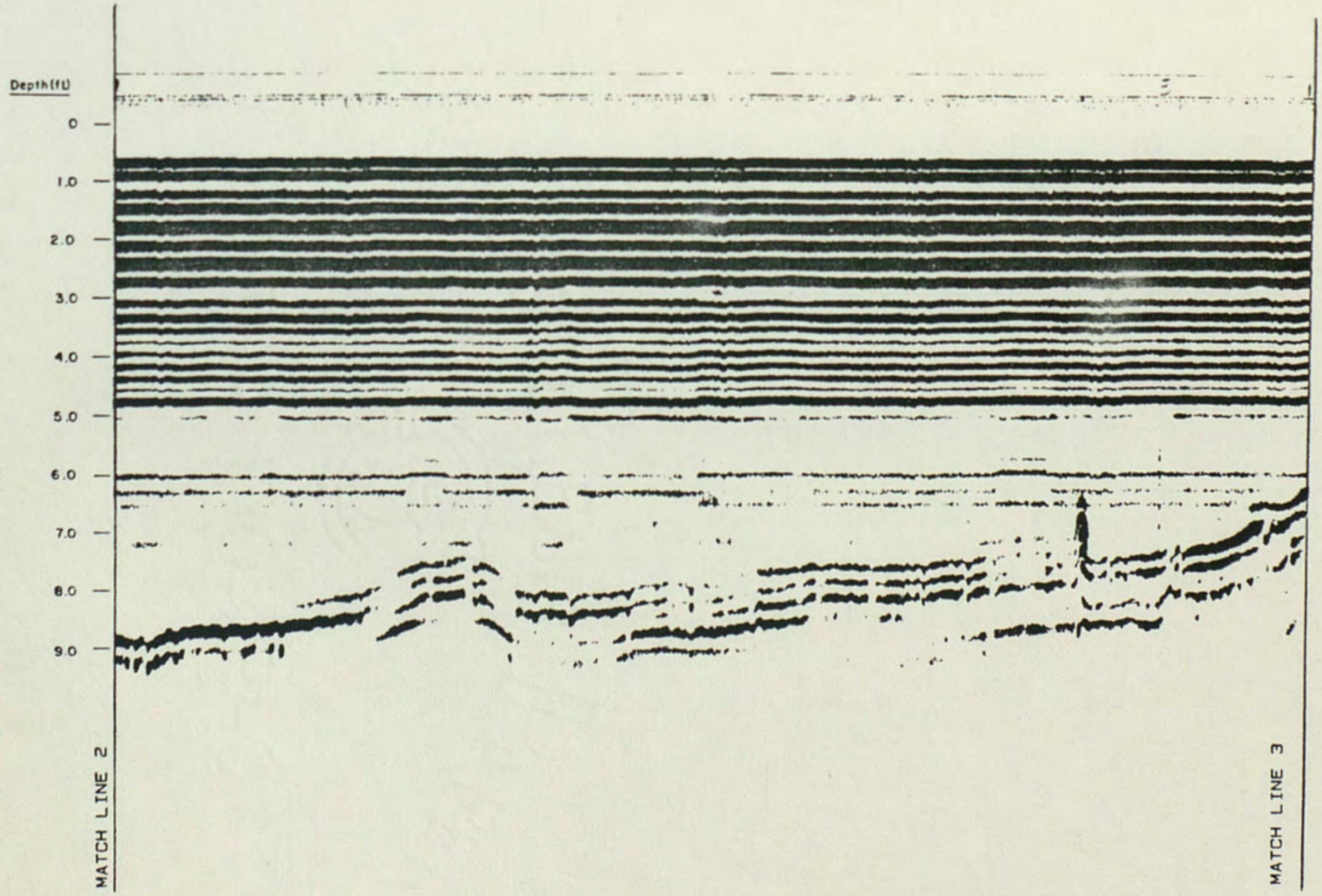


Fig. 71. Radar chart for section 1-1 (continued).

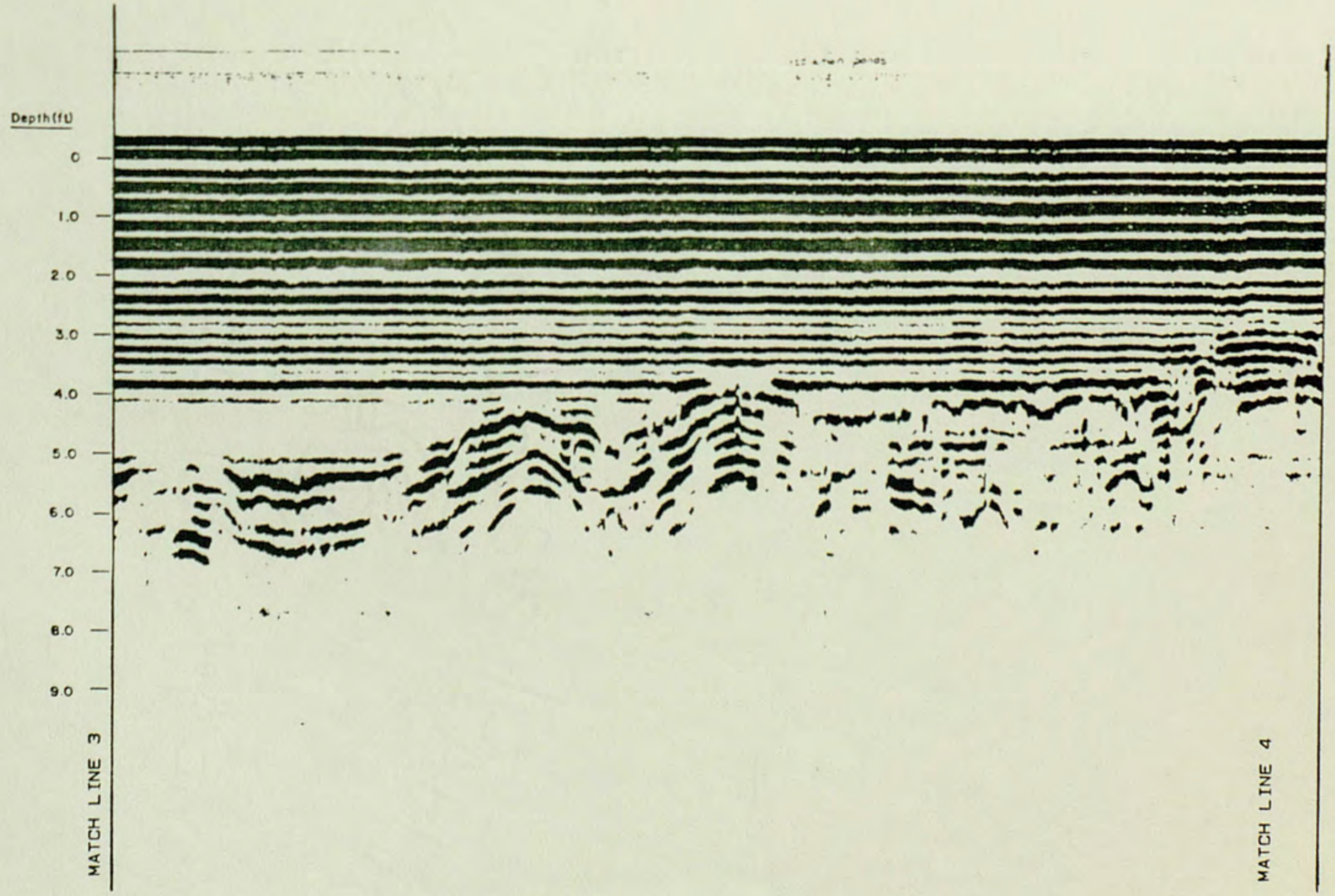


Fig. 72. Radar chart for section 1-1 (continued).

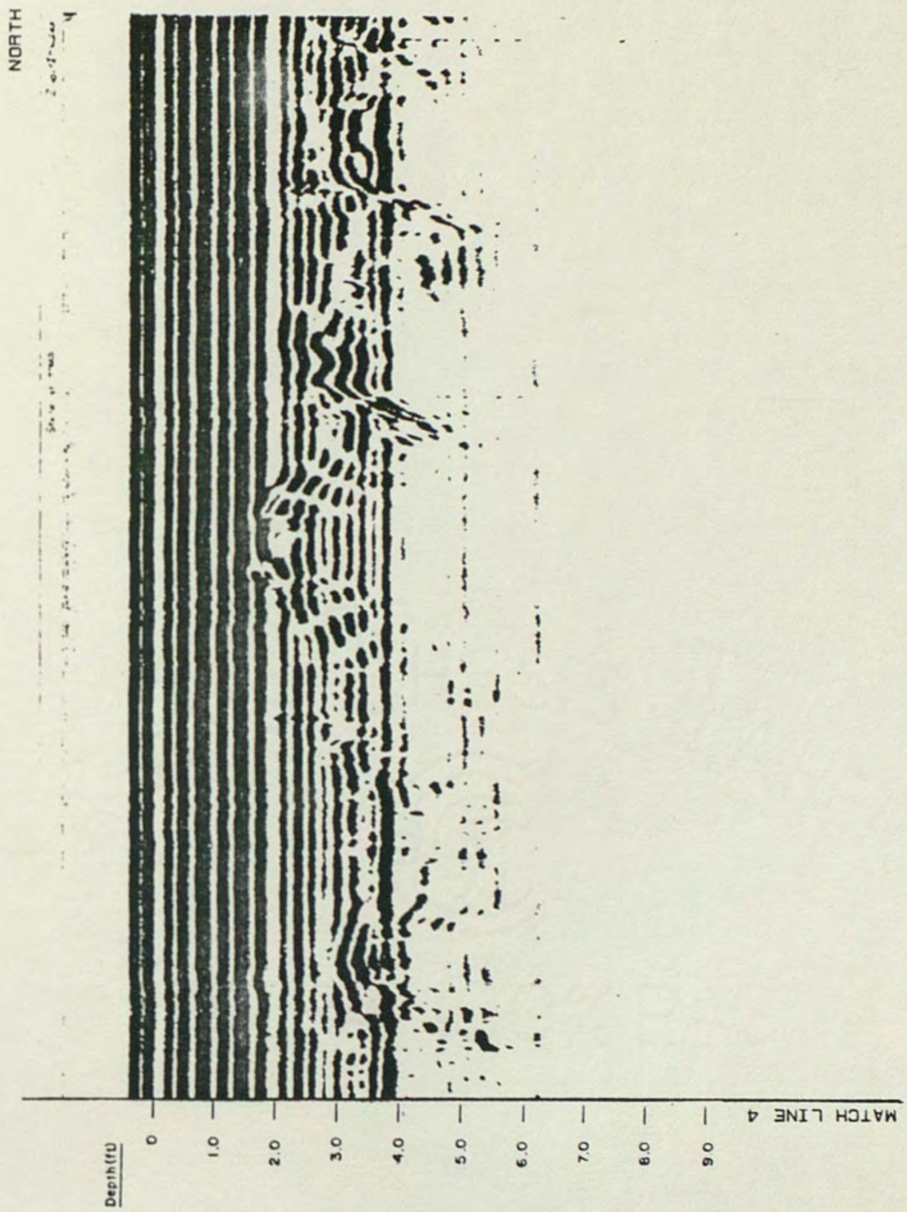


Fig. 73. Radar chart for section 1-1 (continued).

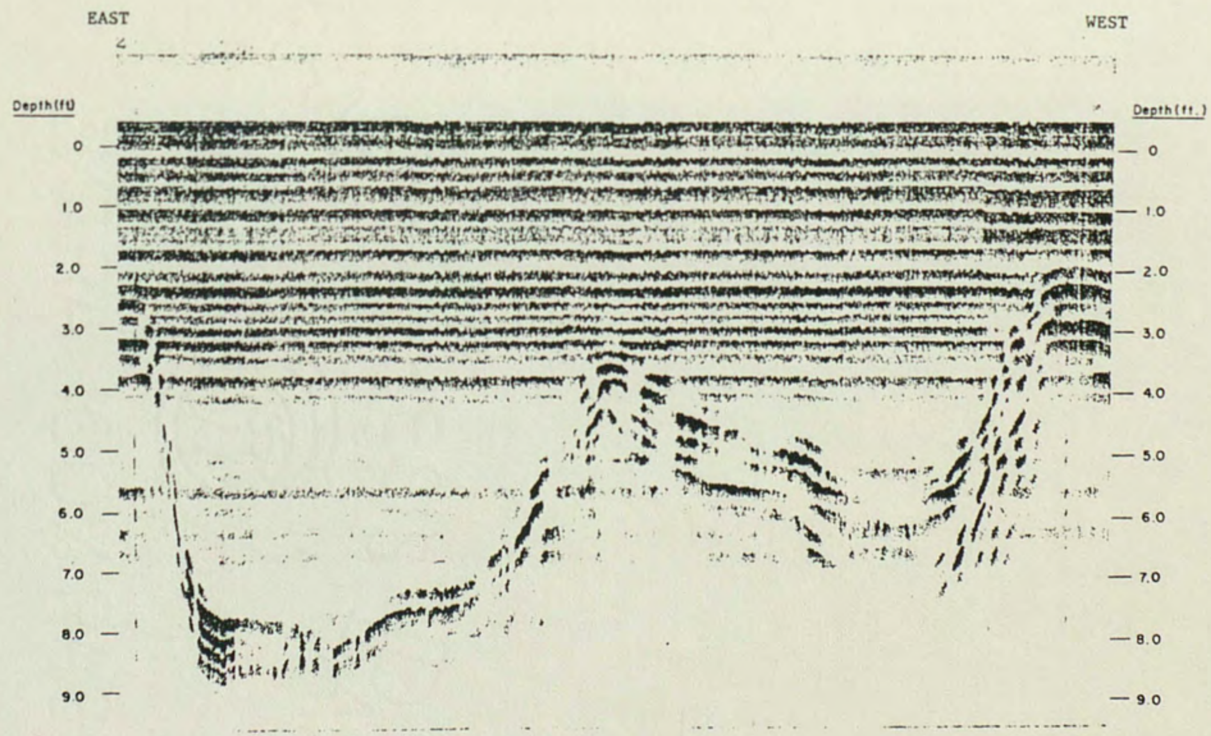


Fig. 74. Radar chart for section 2-2.

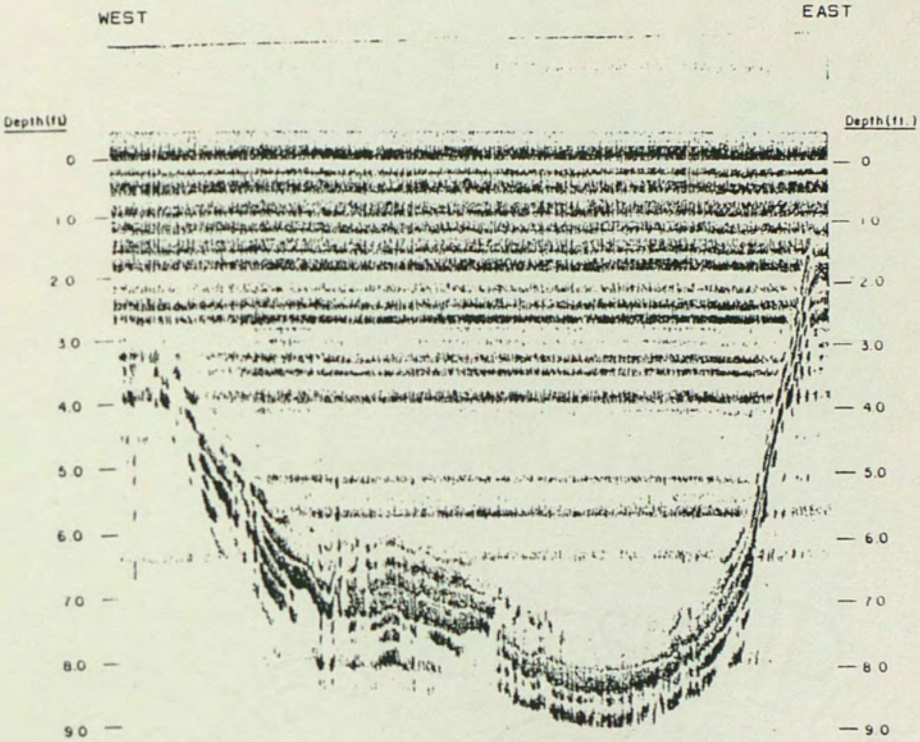


Fig. 75. Radar chart for section 3-3.

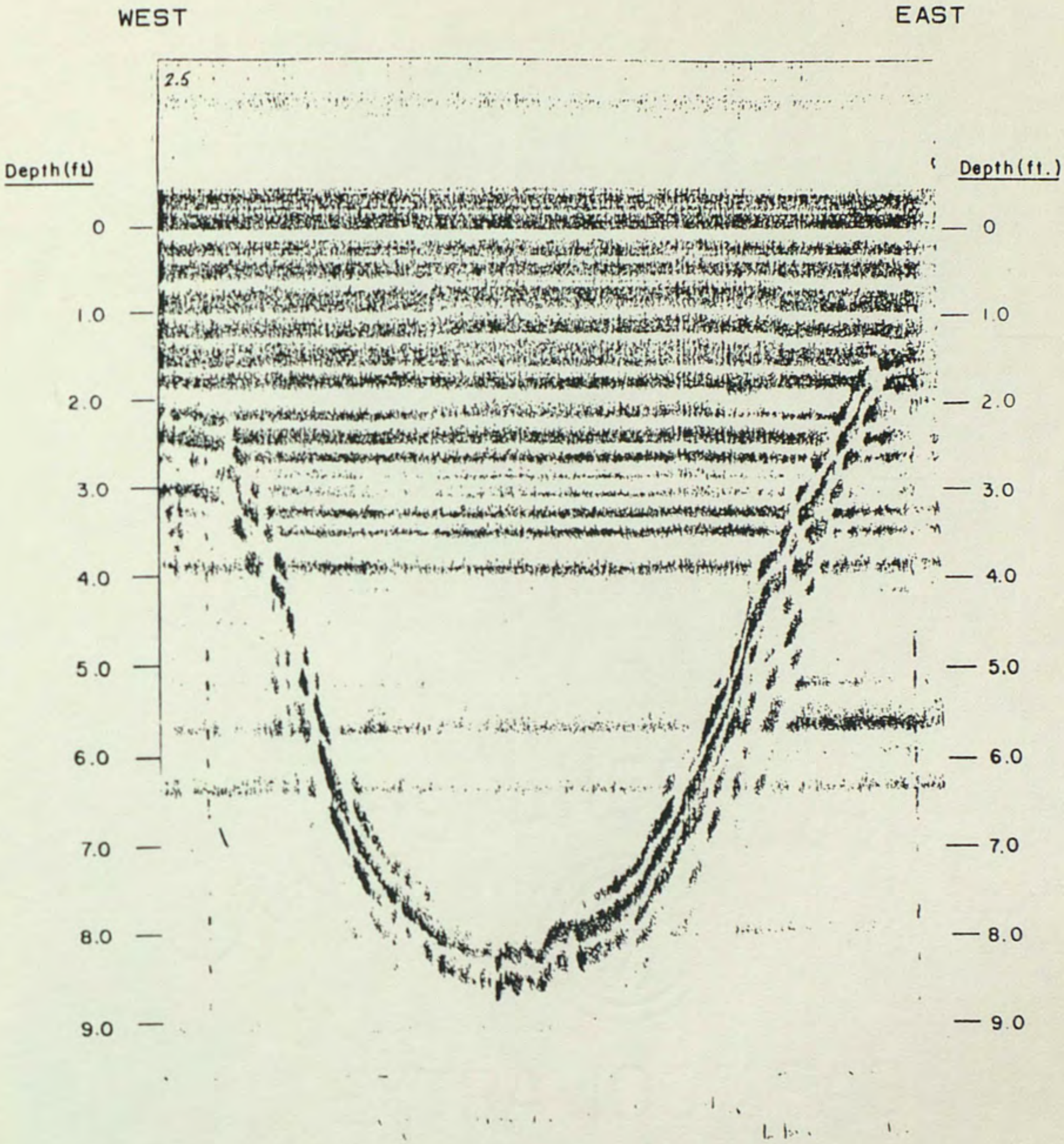


Fig. 76. Radar chart for section mid-distance between section 3-3 and section 4-4.

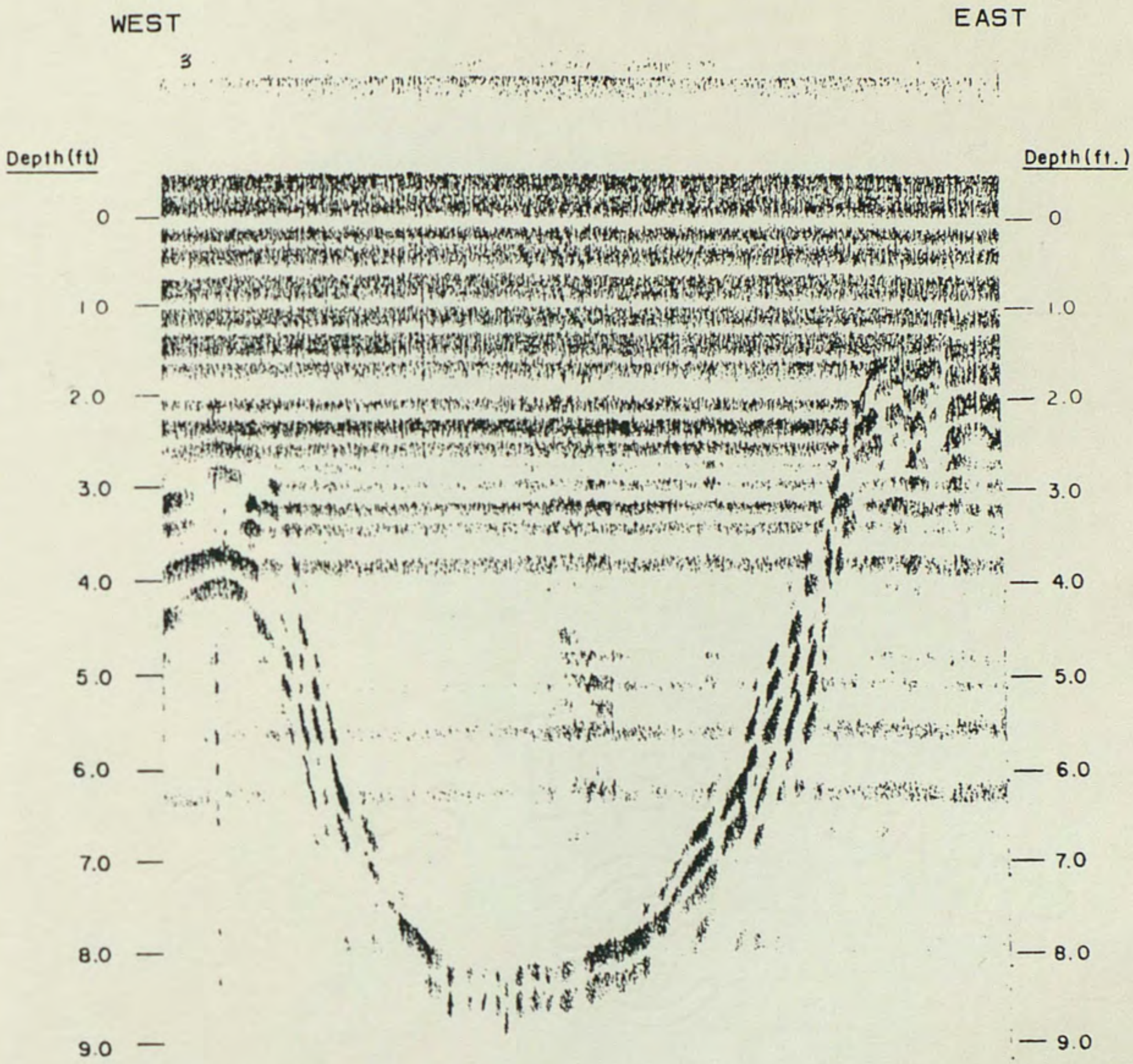


Fig. 77. Radar chart for section 4-4.

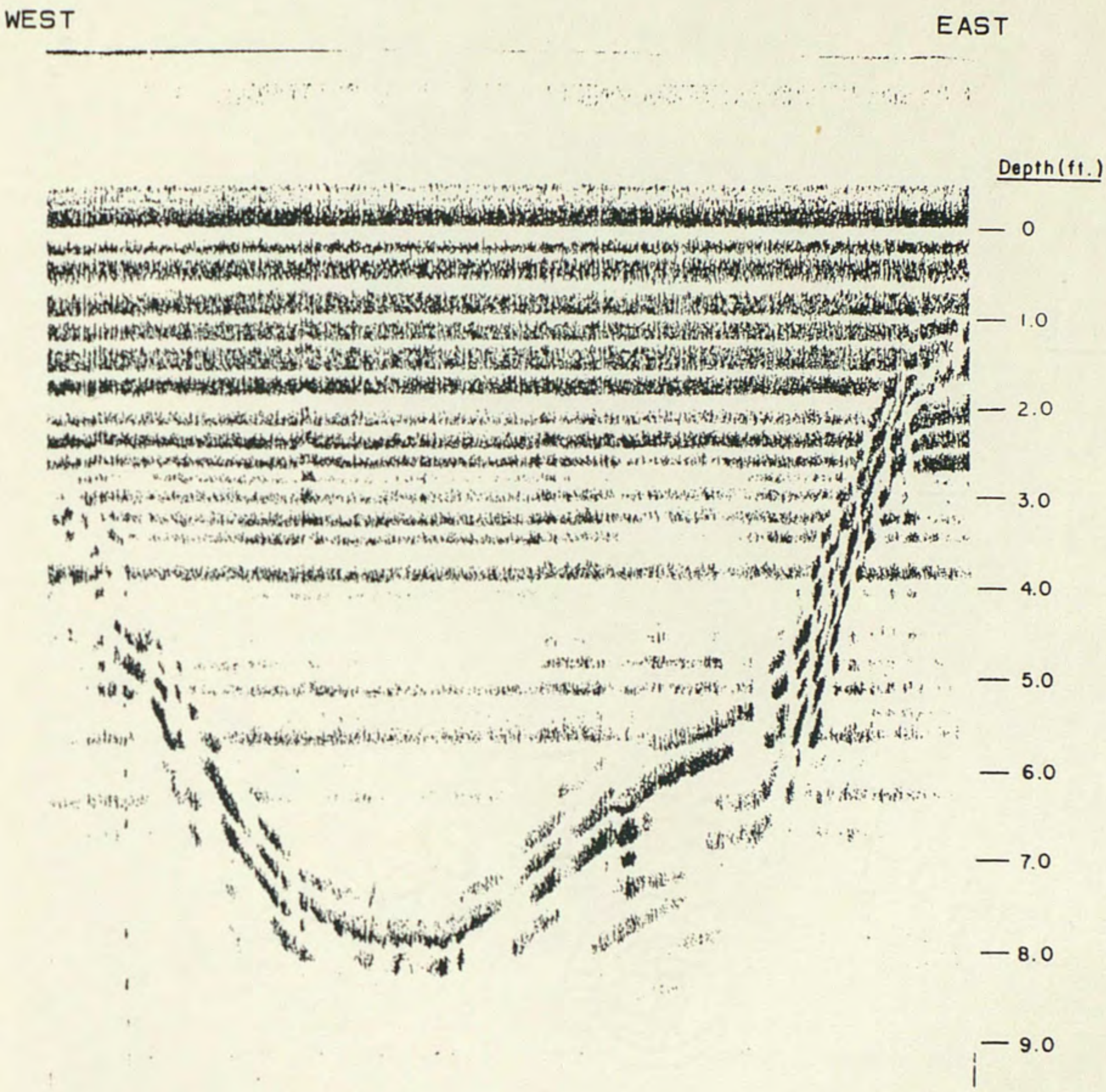


Fig. 78. Radar chart for section 5-5.

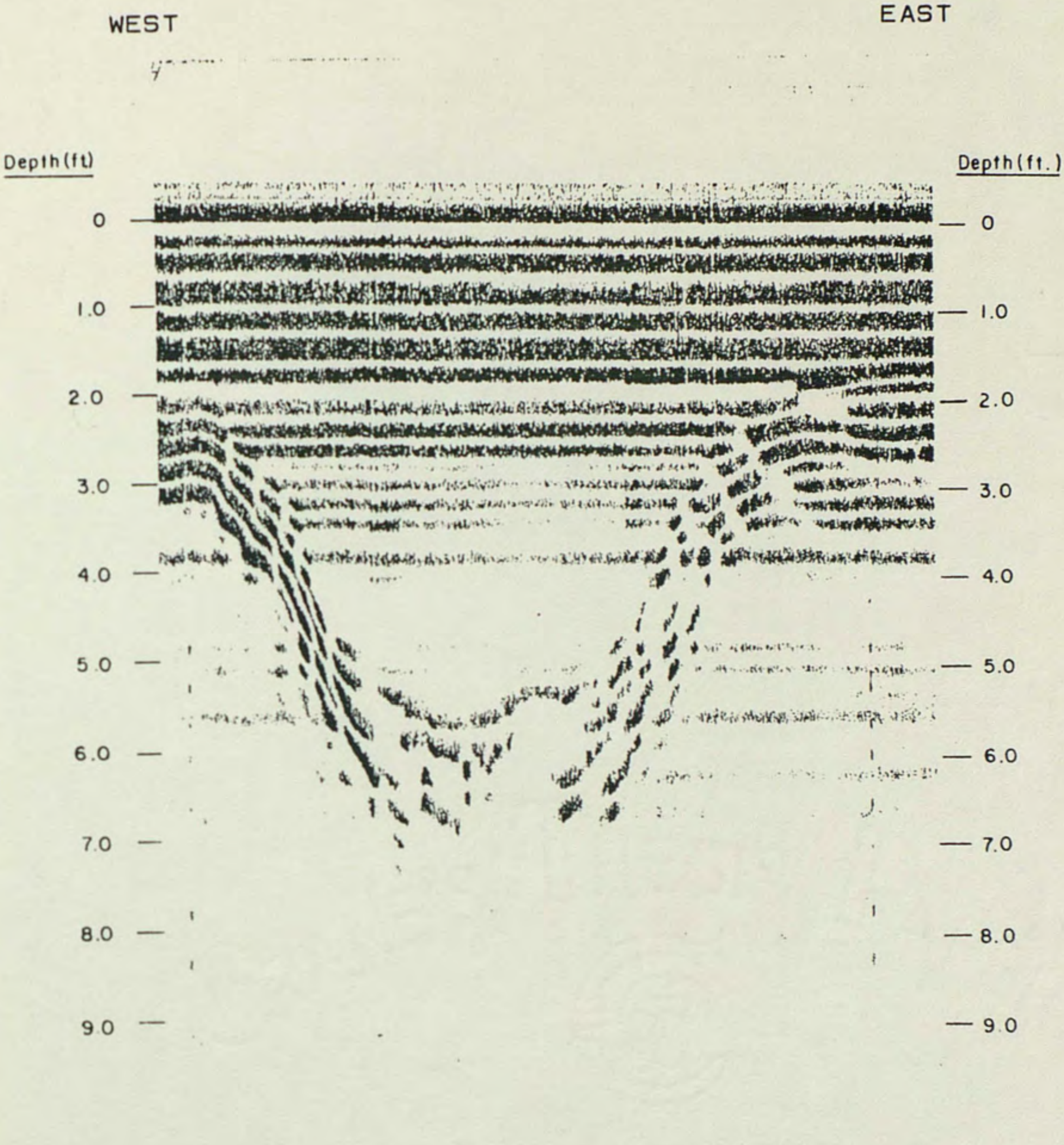


Fig. 79. Radar chart for section 6-6.

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