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GEOPHYSICAL AND HYDROGEOLOGICAL EFFECTS OF ASTORM-WATER RETENTION POND ON THE FLORIDAN AQUIFER, HILLSBOROUGH COUNTY, FLORIDA

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by

Abdullah M. Alamri

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Geology in
the University of South Florida

December, 1985

Major Professor: Mark T. Stewart

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An Abstract

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An integrated geologic, hydrologic, and geophysical investigation was conducted to determine the effect of a storm-water retention pond on the Floridan aquifer. Surface DC resistivity surveys were used to delineate the hydrostratigraphy. There are four distinct geoelectric layers: (1) Layer 1, high resistivity, 3 meters thick, fine to very fine unsaturated sand; (2) Layer 2, moderate resistivity, 1 to 2.5 meters thick, saturated sands and silts; (3) Layer 3, lower resistivity, 4 to 10 meters thick, silt and clay; (4) Layer 4, moderate resistivity, argillaceous limestone. Two fracture zones are defined by resistivity lows and marked by deep, V-shaped depressions in the limestone which formed through solution.

Vertical hydraulic conductivities were combined with head differences between the water table and the Floridan aquifers to determine recharge per unit area to the Floridan at each well. The recharge per unit area at each well was weighted according to the percentage of the total area represented by the well to obtain average recharge per unit area.

A year-long hydrologic budget for the retention pond shows the change in storage to be zero. Surface runoff and precipitation provide 1460 m^3 per day to the pond; evaporation accounts for 282 m^3/day. The remainder (1178 m^3/day) recharges the surficial aquifer. A representative volume with an area twice that of the pond was chosen to evaluate the effect of the retention pond on ground water quality. Multiplying the average recharge rate by this area gives 212 m^3/day. Under-

INTRODUCTION

The purpose of this study is to determine the hydrologic relationship between a large, storm-water-retention pond and the Floridan aquifer, and to estimate the hydrogeologic and geochemical significance of recharge to the ground water system from storm-water-retention ponds in west-central Florida. Data gathered in this study are used to assess the potential effects of storm-water-retention ponds on the water quality of the Floridan aquifer.

The surficial aquifer is recognized as the source of the recharge water for the Floridan aquifer in much of west-central Florida. Local variations in the stratigraphy of the unconsolidated deposits of the surficial aquifer lead to localization of recharge to the underlying limestone aquifer. Hydrogeologic properties of the surficial aquifer of northwest Hillsborough County have been studied by Menke _et al._, (1961), also described by W. C. Sinclair (1973), with emphasis of the role of the surficial aquifer in storage of rain water and movement of water to the Floridan aquifer.

Stewart and Duerr (1973) discuss hydrogeologic factors which influence solid-waste disposal in the Tampa area. Many of the factors discussed can be related to storm-water-retention ponds. Hydrogeologic factors affecting the availability and quality of ground water in the Temple Terrace area was studied by Stewart _et al._, (1978).

The source of water for the city of Temple Terrace is the Floridan aquifer, a thick sequence of Cenozoic limestone and dolomite consisting of several permeable zones that are generally treated as one hydrologic unit. The Floridan is overlain by a sequence of sands, silts and clays of lower permeability. Sinkholes are fairly common throughout the Temple Terrace area; some are potential sources of ground-water degradation because of surface inflow. These sinkholes create zones of preferred recharge from the water table to the limestone (Stewart *et al.*, 1978).

Storm water from urban areas can be a source of contamination, containing heavy metals, pesticides, and other priority pollutants. Recently enacted zoning and building codes encourage or require storm-water-retention ponds for larger projects. A recently completed survey of urban storm water quality provides data on storm-water quality and quantities in the Tampa urban area (Lopes and Giovannelli, 1984).

THE HYDROLOGIC CYCLE

The hydrologic cycle is a continuous process by which water is transported from the ocean, to the atmosphere, to the land and ultimately back to the ocean. The phases of the hydrologic cycle are shown schematically in Figure 1. The difficulty in solving practical problems involving the hydrologic cycle stems from the inability to properly measure or estimate the various factors in the hydrologic budget. Precipitation, wind speed, relative humidity, and other climatological variables are easily measured by placing gauging stations at various locations. Quantities such as runoff, evapotranspiration, and infiltration are not easily quantified, thus reliance on well-known hydrologic equations becomes necessary.

The term infiltration is used to describe the flow of water through the land surface to the unconfined aquifer. It is affected by two factors. The first is whether or not there is any space available below the land surface for the storage of water that may infiltrate. The second factor affecting infiltration is the ability of the water to penetrate through the land surface and upper layers of soil. Certain land uses such as urban development create areas of high runoff and low infiltration due to factors such as paving, buildings and storm sewers. Other land uses have distinct infiltration characteristics. Soil types affect infiltration because of their different permeabilities, soils with high permeabilities allow large

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amounts of infiltration, with the opposite being true of soils with low permeabilities.

The term recharge is used to describe the flow of water from the surficial aquifer through the confining layer to the artesian aquifer (Figure 2). It may occur whenever the water table elevation is higher than the potentiometric surface. The rate of recharge is controlled by two distinct factors. The first is the degree of hydraulic potential or head difference between the water table and potentiometric surface, and the second is the vertical permeability of the confining layer. This permeability is directly related to the percentage of clay in the confining layer and its thickness.

The relative potential for recharge to occur to the aquifer at a given point can be illustrated with the following equation:

$$R/A = K_v \ (HWT-HPOT)/b \qquad (1)$$

where:

R/A = Relative recharge per unit area $\left(\frac{L^3}{L^2\text{-}T}\right)$

K_v = Average vertical hydraulic conductivity of confining layer $\left(\frac{L}{T}\right)$

A = Area represented by conditions at Point (L^2)

HWT = Elevation of water table (L)

$HPOT$ = Elevation of potentiometric surface (L)

b = Thickness of confining layer (L)

This equation is derived from Darcy's Law on the assumption that the recharge is directly proportional to the hydraulic potential or pressure difference (HWT-HPOT) which is forcing flow, and is inversely proportional to the resistance caused by the confining layer (b/K_v). The recharge value (R) may have a positive or negative value depending

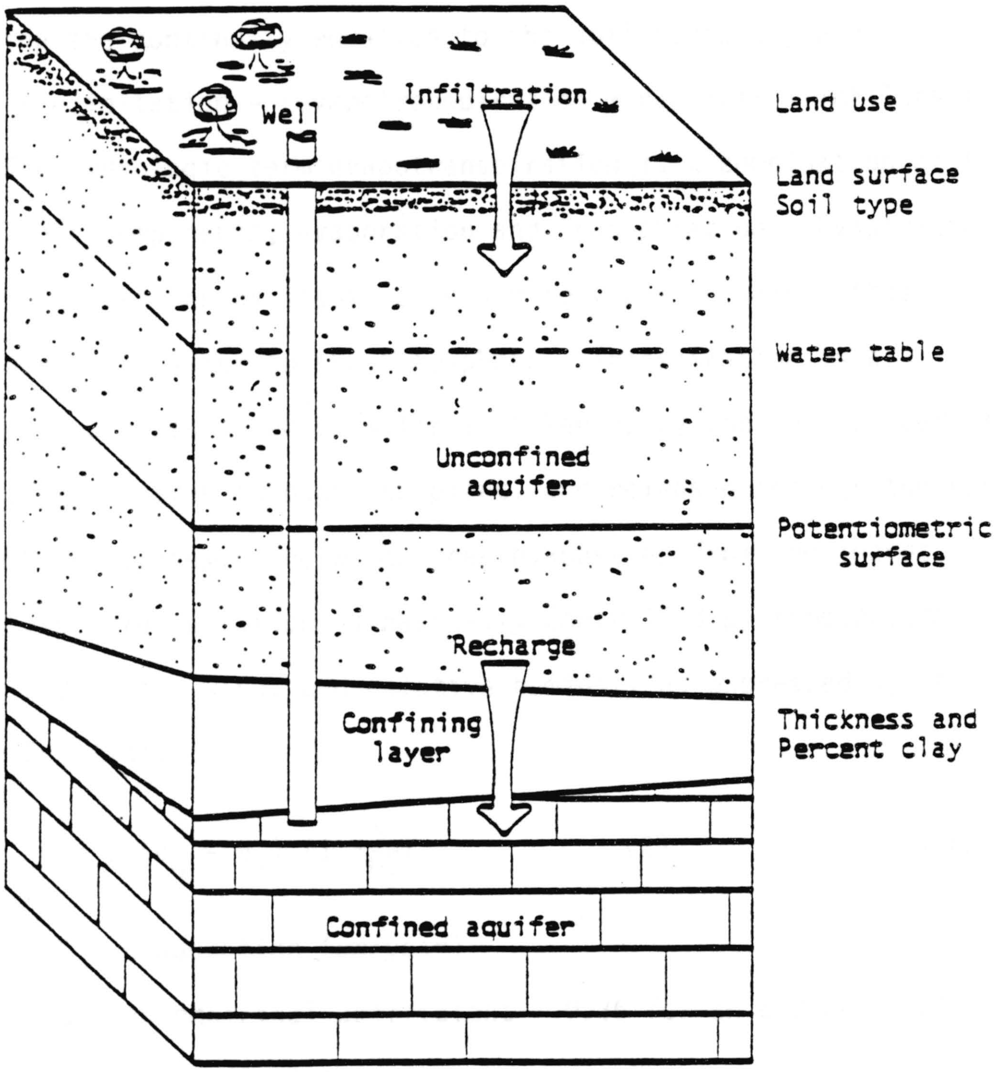


Figure 2. Cross-section of an aquifer system with the parameters relating to infiltration and recharge.

on the level of the water table and potentiometric surface (Giovannelli, 1977).

A hydrologic budget is an accounting technique where recharge - discharge = change in storage is the basic continuity equation. Applying the continuity equation to the soil surface yields

Precipitation - (evapotranspiration + run off) = infiltration.

The hydrologic term evapotranspiration is a combination of two hydrologic components, evaporation and transpiration. Evaporation is based on solar energy input necessary to vaporize water, thus returning this water to the atmosphere. Transpiration is a botanical process by which water is taken up by the root system of a plant, transmitted through the plant, and released through the pores in the leaf system. The water then evaporates from the leaves.

Evapo-transpiration is basically controlled by temperature, solar radiation, wind, and relative humidity as expressed by the Meyer Equation.

$$E = C\,(e_o - e_a)\,\left(1 + \frac{W}{10}\right) \qquad (2)$$

where

E = Evaporation (cm/year)

C = An empirical coefficient = 0.36 for an ordinary lake (dimensionless)

e_o = Saturation vapor pressure at water temperature (mbar)

e_a = Vapor pressure of air (mbar)

W = Wind speed (m/sec) (from Viessman _et al._, 1977)

STUDY AREA

Description of the Study Area

The area of investigation in north-central Hillsborough County (Figures 3 and 4), has undulating topography with elevation ranging from 9.15 to 15 meters above sea level. This topography is the result of three landforms: karst, dunes, and beach ridges. Surficial sands are fine-grained, well-sorted and very permeable, and vary in thickness from 1.2 to over 6.1 m, indicating wind sorting. Beneath the sand is a sequence of clayey sand, sandy clay, and silty sand. Beneath the surficial sand and clay sequence is a dense, plastic clay which is a weathering product of the underlying limestone (Carr and Alverson, 1959; Sinclair, 1973). This is indicated by the presence of distorted and crenulated bedding planes in the clay resulting from slumping and collapse of underlying material, and also by the occurrence of fresh chert. The clay is the most important unit in retarding movement of water from the surficial to the Floridan aquifer because of its extremely low permeability. It varies in thickness from 0.5 to over 6 meters. Beneath the clay is the Tampa Limestone, which has been undergoing karstic erosion for at least several millions of years.

Several sinkholes have occurred within the area since record keeping began in 1960. These result from local subsidence of the land surface due to the sapping of the surficial material into solution openings in the underlying limestone. The sinkholes permit local

hydraulic connection between the surficial water-table aquifer and the Floridan aquifer and are an important avenue of natural recharge to the Floridan aquifer (Sinclair, 1973).

Location

Hillsborough County is located midway down the west coast of Florida. The County encompasses 1660 km^2 of land and 39 km^2 of inland water area for a total area of approximately 1699 km^2. It is bounded by Pasco, Polk, and Manatee Counties to the north, east, and south, respectively (Figure 3).

The study area is located in the north-central portion of the County and includes the western side of the University of South Florida campus and the retention ponds for USF and the University Square Mall (Figure 4). The latitude of the study area is 28°03'35" and longitude is 82°25'14".

Climate

The climate of the Tampa Bay area is characterized by warm, humid summers and mild winters. Temperatures during the summer range from about 21 C° to 32 C° and winter temperatures range from about 0 C° to 21 C°. The mean annual temperature is 22 C°. The normal annual precipitation is about 125 centimeters (Bradley, 1972; Fernald and Donaldson, 1984). Most rainfall occurs from June through September as a result of short duration and high intensity thunderstorms (Lopez and Giovannelli, 1984). August is the wettest month, with about 17% of the annual rainfall. November is the driest month, accounting for slightly less than 4% of the annual total.

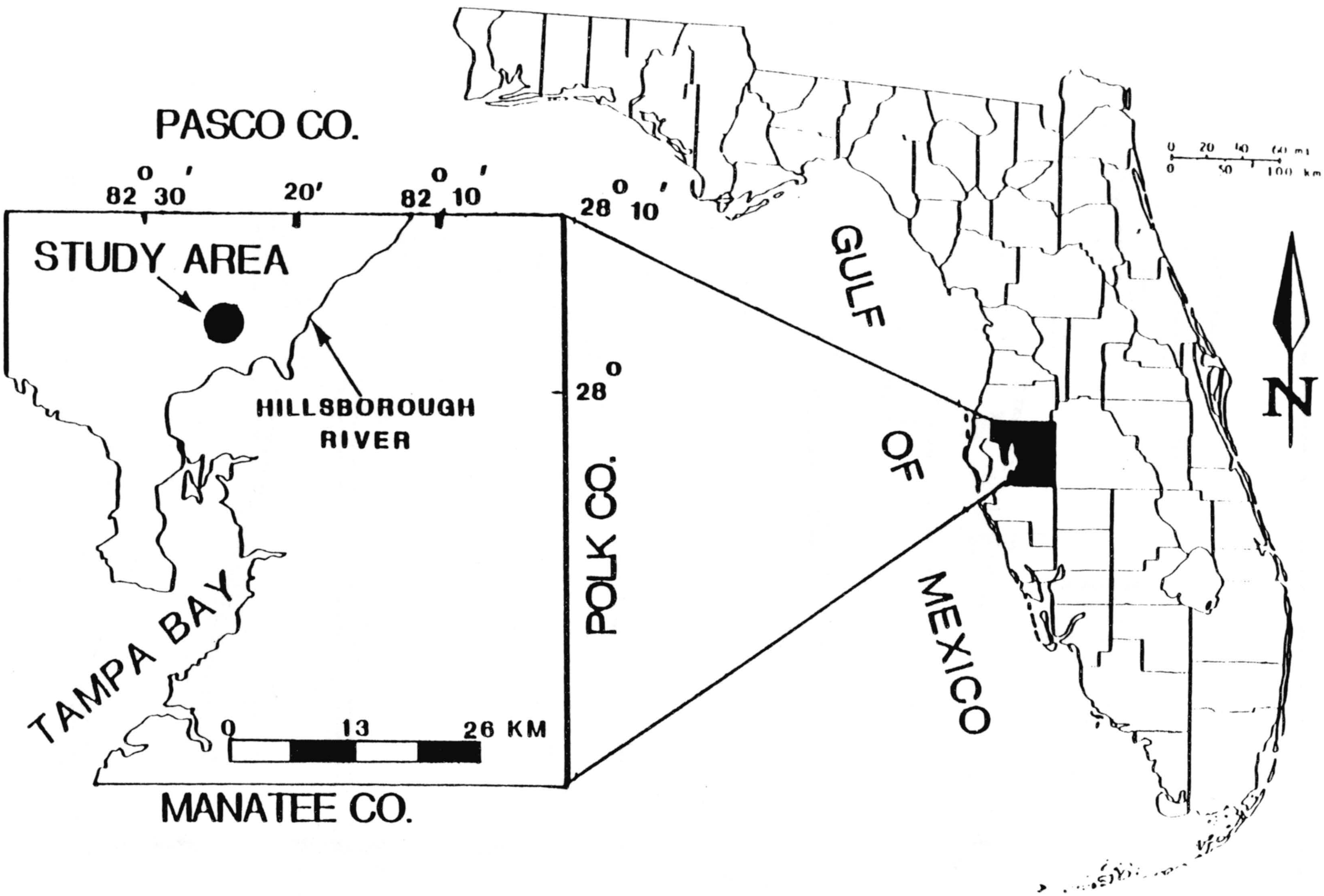


Figure 3. Location of the study area within Hillsborough County, Florida.

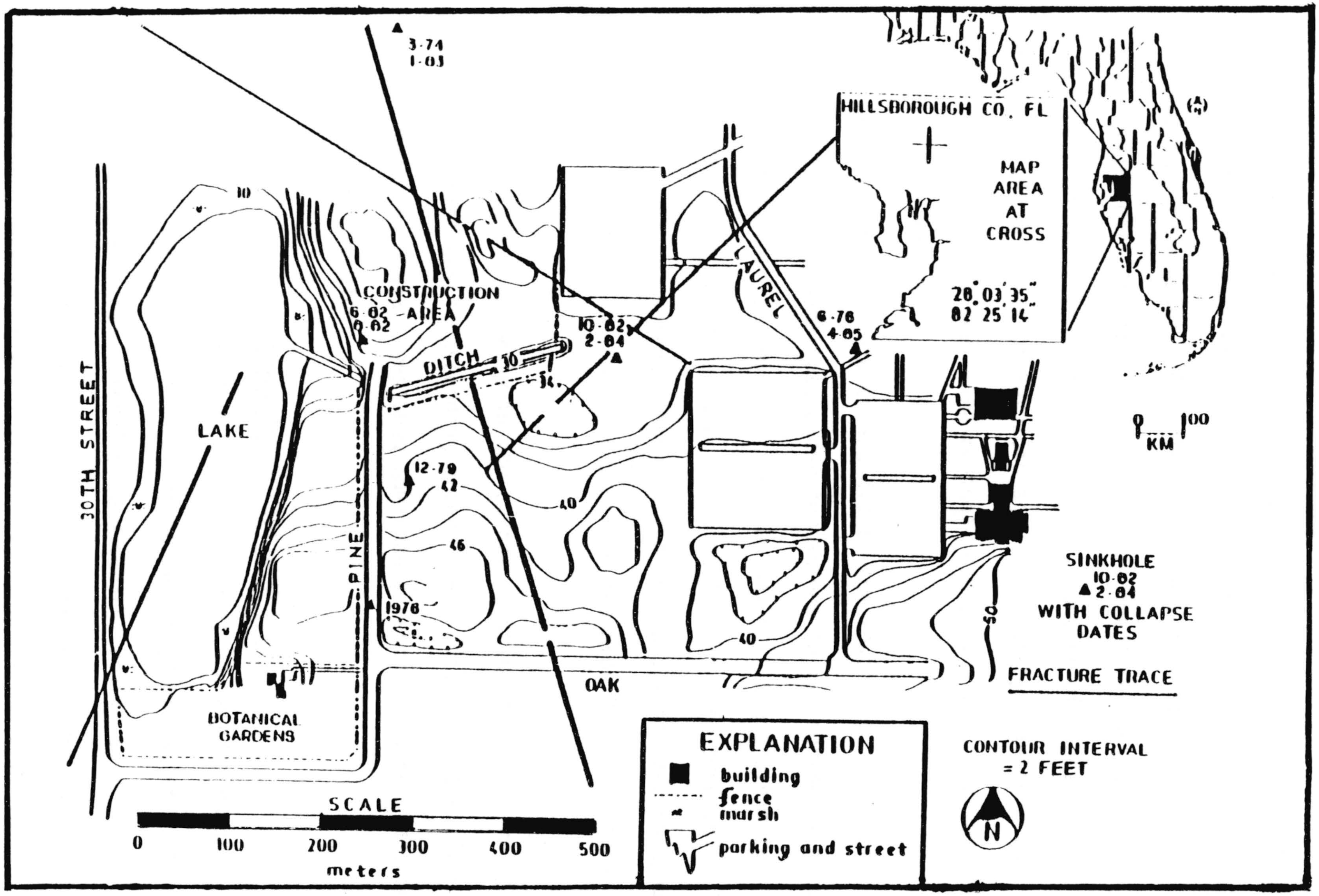


Figure 4. Location and distribution of the retention pond, fracture traces, and sinkholes within the study area.

Geology

The geology of Hillsborough County is described by Menke *et al.*, (1961). The county is underlain by sedimentary rocks ranging in thickness from about 2440 m in the northeast to about 3963 m in the southwest (Applin, 1951). These sedimentary rocks, which rest on Mesozoic crystalline rocks, consist of sandstone, anhydrite and dolomite of Mesozoic age, overlain by limestone and dolomite of Cenozoic age. The regional dip of the Cenozoic rocks is toward the southwest.

Because the beds thicken and dip to the southwest, wells of similar depth will penetrate older formations in the northeast more than in the southwest. Most of the deep wells in the southwestern part of the county produce water principally from the Tampa and Suwannee Limestone, whereas those in the central, east, and northeast parts of the county commonly produce from the Avon Park Limestone (Table 1).

Limestone and dolomite in the county constitute the following Tertiary formations in ascending order: Lake City Limestone, Avon Park Limestone, Ocala Limestone, Suwannee Limestone, Tampa Limestone, and Hawthorn Formation.

Hydrostratigraphic Units

Part of the rain that falls on the earth moves downward through the ground to the zone of saturation to become ground water. The ground water then moves laterally to discharge points such as springs, wells, or the sea. The saturated permeable geologic unit that can transmit significant quantities of water under ordinary

Table 1. Generalized stratigraphy and description of Hillsborough County, Florida (from Menke *et al*., 1961).

SYSTEM	SERIES	FORMATION	THICKNESS (meters)	LITHOLOGY	AQUIFER
Quaternary	Holocene Pleistocene	Undifferentiated	0-45	Sand, clay and marl	water table aquifer
Tertiary	Pliocene				
	Miocene	Hawthorn Fm.	0-70	clay, sand and limestone. Limestone white to gray	shallow artesian
		Tampa Limestone	25-120	Limestone, sandy, white and cream, Pelecypods	Principal Artesian
	Oligocene	Suwannee Limestone		Limestone, white, yellow, dense, chert lenses	
	Eocene	Ocala Group: Crystal River Formation	27-90	Limestone, yellow-gray and brown soft, almost pure limestone. Mostly foraminiferal coquinas in pasty limestone matrix	
		Ocala Group: Williston Formation			
		Ocala Group: Inglis Formation			
		Avon Park Limestone	60+	Limestone, cream to brown, chalky, soft, crystalline dolomite limestone. Locally contains some gypsum.	
		Lake City Limestone	150		
		Oldsmar Limestone	270	Limestone, dolomitic with lenses of chert, some gypsum	

hydraulic gradients is known as an aquifer (Freeze and Cherry, 1979, p. 47).

Water-table conditions exist where the upper surface of an aquifer is subject to atmospheric pressure. The water level in a well that taps a water-table aquifer generally coincides with the upper surface of the zone of saturation. Artesian conditions (for example, the Floridan aquifer) exist where water in an aquifer is confined by distinctly less permeable rock and is under hydrostatic pressure greater than atmospheric. Based on the above criteria, two aquifers exist in Hillsborough County - water-table and Floridan aquifers (Menke _et al._, 1961; Figure 5).

Water-Table Aquifer

The water-table aquifer consists of fine sand, sandy clay, clayey 24 meters. The water in the aquifer is derived from local rainfall, and the water table is only a few meters below the ground surface. The water-table aquifer is thickest in the northwest part of Temple Terrace and is thinnest near the Hillsborough River. The bulk porosity of the surficial aquifer materials ranges from 29 to 46%; the effective porosity averages 28% (Stewart _et al._, 1978). The horizontal hydraulic conductivity of materials constituting the water-table aquifer was estimated to be about 3.96 m/day (Stewart _et al._, 1978). Reported transmissivities ranged from about 19 to 622 m^2/day and storage coefficients range from .05 to .30 (Wilson and Gerhart, 1980). The water table is only a few meters below land surface even in dry periods, and areas that are not well drained are likely to become saturated and have water standing on the surface after a heavy rain. Generally, water is not available in desirable quality or quantity from the

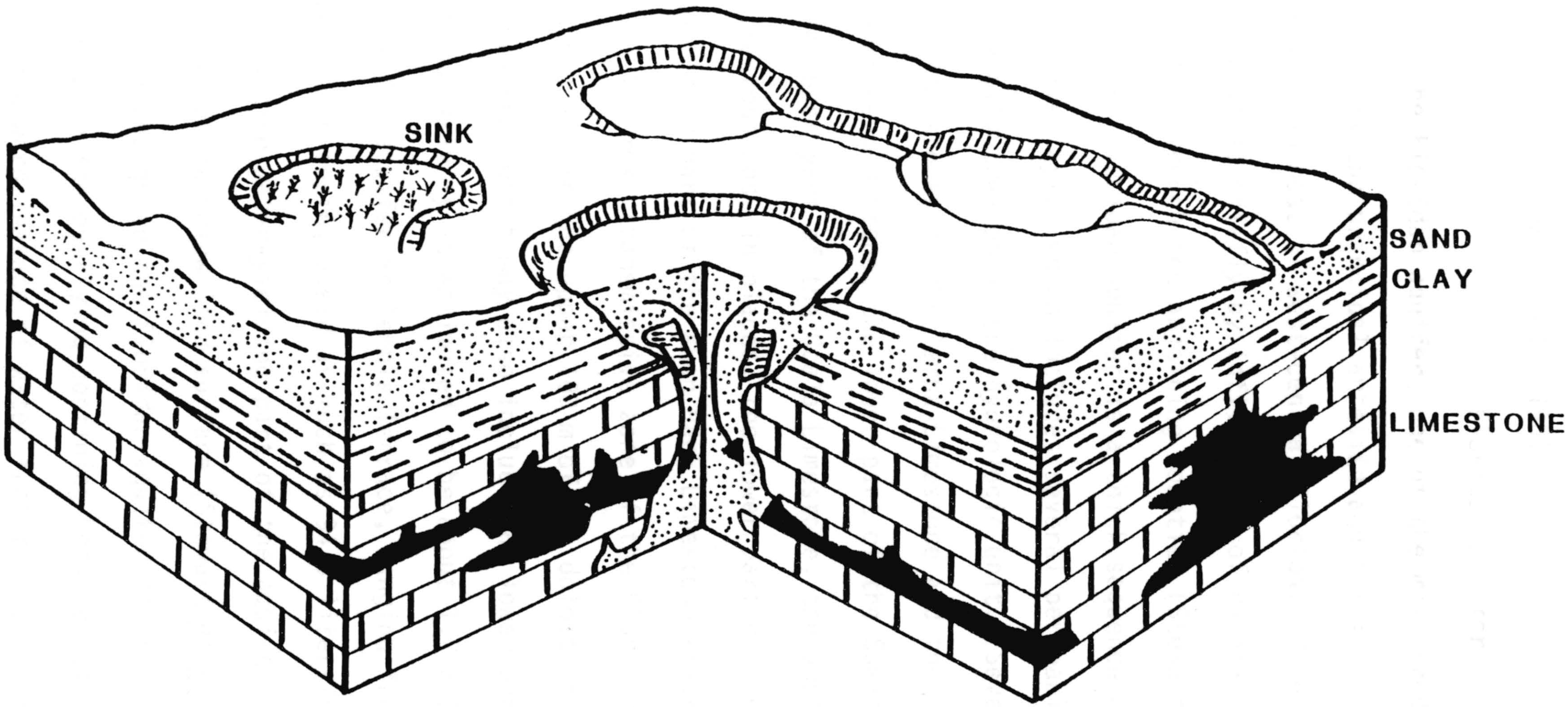


Figure 5. Generalized hydrologic relationship between surficial sand and clay and the upper part of the Floridan aquifer (from Cooper *et al.*, 1953).

water-table aquifer, and it is not a very important source of supply in the county (Menke *et al.*, 1961).

Floridan Aquifer

The Floridan aquifer, one of the most productive aquifers in the world, is the principal artesian aquifer in Hillsborough County, as well as in most of west-central Florida. Water in the aquifer is replenished chiefly by infiltration of rainfall in areas of recharge in Hillsborough and adjoining counties (Stewart, 1980).

The Floridan aquifer is a thick sequence of limestone and dolomite layers which includes several permeable zones that are generally treated as one hydrologic unit. Several of these zones are: the limestones of the Tampa Limestone and the upper part of the Suwannee Limestone, the lower part of the Suwannee Limestone, the upper part of the Ocala Limestone, the upper part of the Avon Park Limestone and, in places, the lower part of the Ocala Limestone and the lower part of the Avon Park Limestone (Hickey, 1982).

The most transmissive zone of the Floridan aquifer generally occurs within the upper 100 m of the dolostone section of the Avon Park Limestone, which may also include the lower part of the Ocala Limestone. Transmissivity is estimated to be about 1.2×10^4 m^2/day. Wells in the Floridan aquifer in Temple Terrace, ranging from about 45 to 150 meters in depth, yield as much as 94.6 liters/second. The most productive water-yielding part of the aquifer is the cavernous zone 36 to 54 meters below land surface (Stewart *et al.*, 1978).

Recharge to the Floridan aquifer is through sinkholes that penetrate the overlying confining beds, by streams and ponds, and by the downward leakage of water from the overlying surficial aquifer in

areas where the water table is above the potentiometric surface of the Floridan aquifer. Water is discharged by pumpage and by upward leakage to the surficial aquifer in areas where the potentiometric surface of the Floridan aquifer is above the water table. The most prominent feature of the potentiometric surface is a large depression in the vicinity of Old Tampa Bay during May, 1979 (Figure 6). The depression in the potentiometric surface is probably caused by the natural discharge of water from the Floridan aquifer to the Bay. The zero contour delineates the approximate boundary of the area of natural, fresh-water discharge from the Floridan aquifer. Bayward from the zero contour line, the aquifer contains saline water. The depression decreased in area by September (Figure 7), suggesting that its development was related to seasonal stresses on the aquifer.

Figures 6 and 7 show the general configuration of the potentiometric surface on the Floridan aquifer for May and September, 1979, respectively. Figure 6 represents conditions near the end of the dry season, when potentials are generally at their lowest (Wolansky et al., 1979). Figure 7 represents conditions near the end of the rainy season when potentials are at their highest (Yobbi et al., 1980).

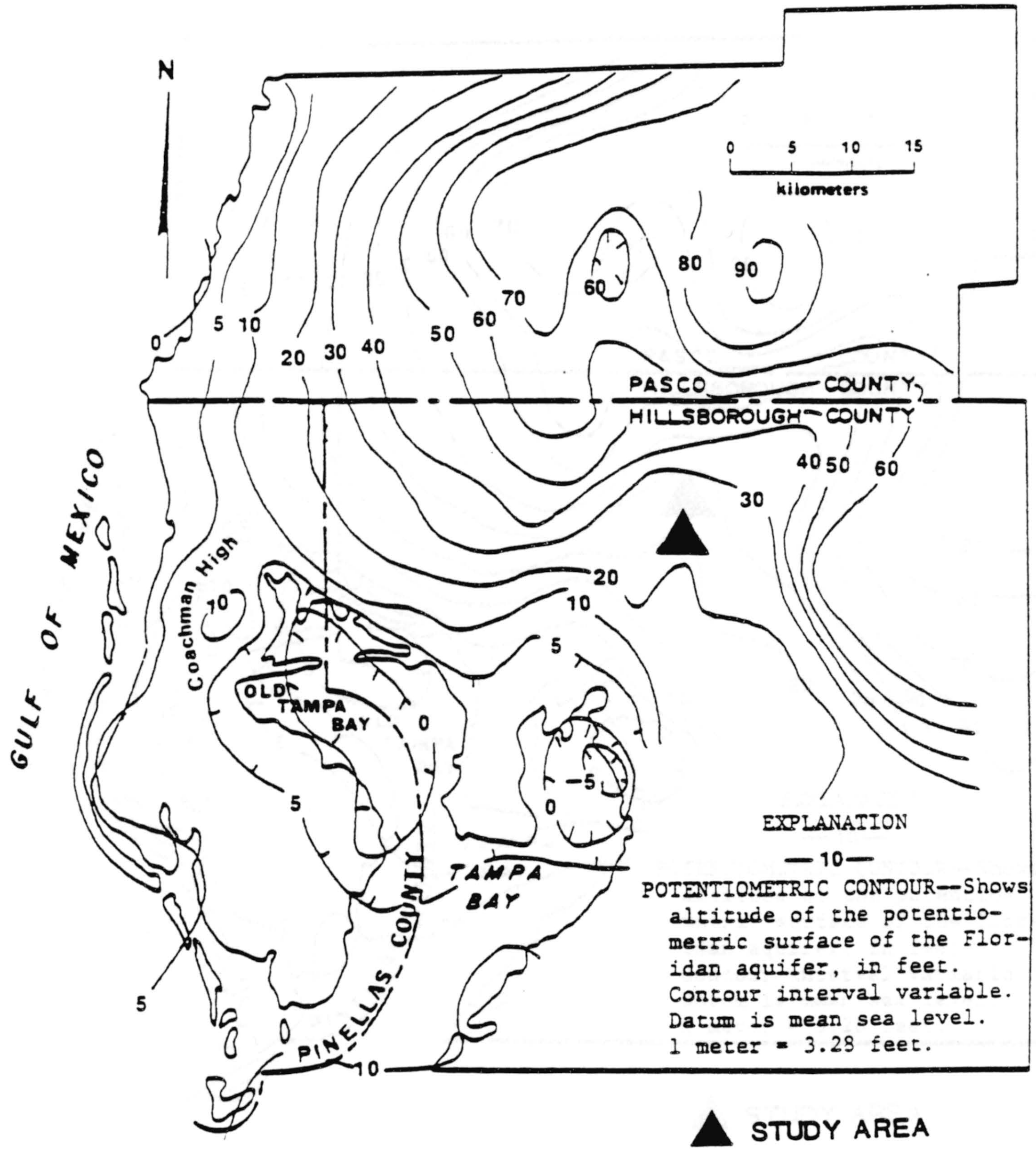


Figure 6. Potentiometric surface of the Floridan aquifer, May, 1979 (from Wolansky et al., 1979).

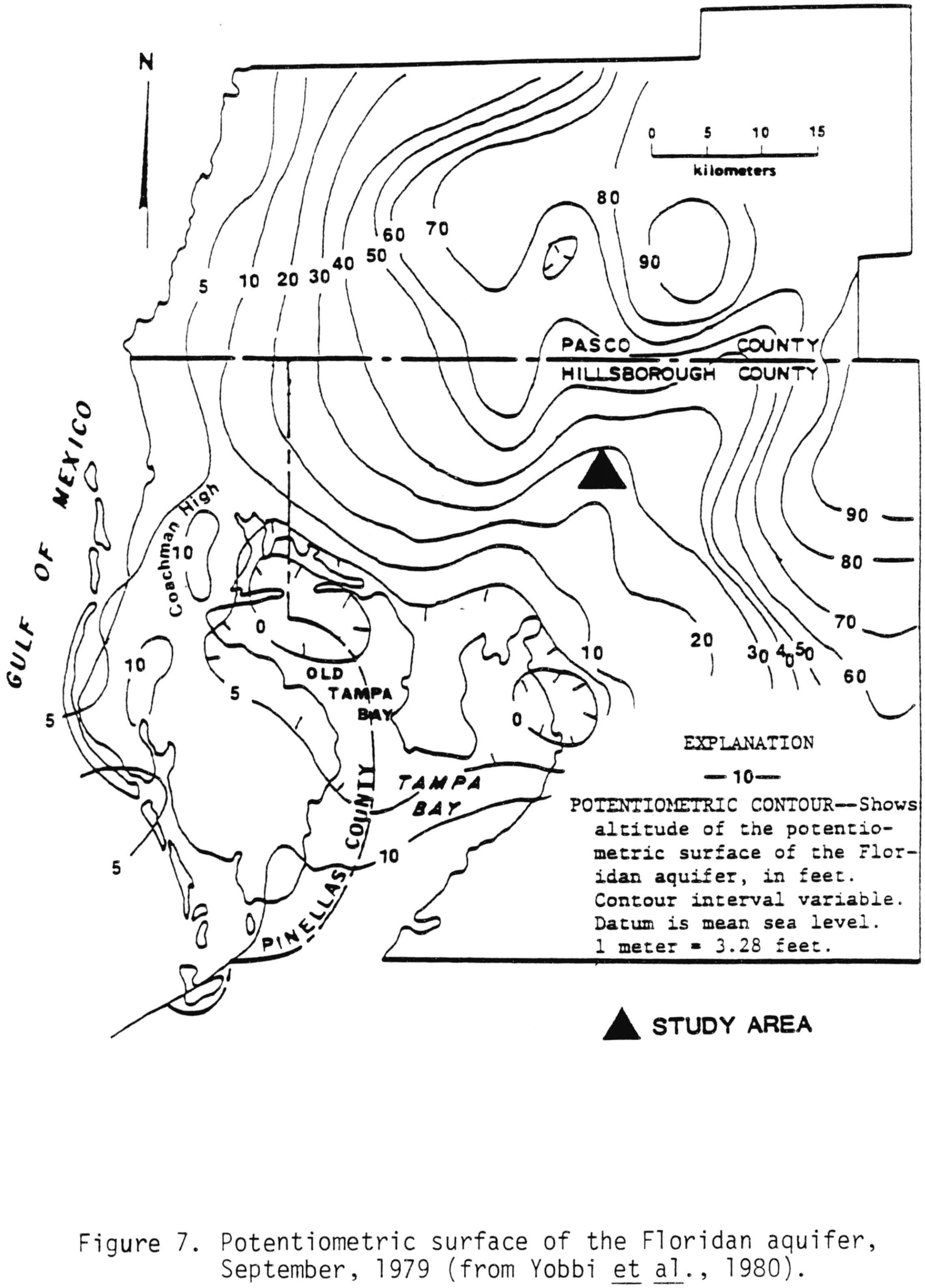


Figure 7. Potentiometric surface of the Floridan aquifer, September, 1979 (from Yobbi et al., 1980).

METHODOLOGY

A study of the water table configuration and the hydrologic budget of the retention pond over a period of time should reveal patterns of infiltration, movement, and storage of water within the surficial aquifer. Recharge to the Floridan Aquifer and the hydrogeology of the retention pond were studied in several ways.

Geologic Methods

Geologic methods were used primarily to determine the hydrostratigraphy of the shallow aquifer. The stratigraphy of the study area was examined using bucket auger and split-spoon sampling methods. Twenty-three auger borings were completed from August through December, 1984. Two of the augered holes extended to depths greater than 7 meters. Sampling unconsolidated material with a bucket auger is superior to sampling by other methods because uncontaminated samples can be obtained at any desired depth in a relatively undisturbed condition. Samples were taken at varying intervals, depending on changes in lithology. However, lithologic variation was recorded for the full depth of the boring. Eleven samples representing different lithologic units recognized from 23 test holes were analyzed in the laboratory using grain size analysis (hydrometer and sieve methods).

The samples were wet-sieved through a 4-phi sieve. The sand-size fraction was sieved using U.S. standard sieves of 6, 40, 60, 100 and 200 mesh. The silt and clay fraction was analyzed using hydrometer analysis.

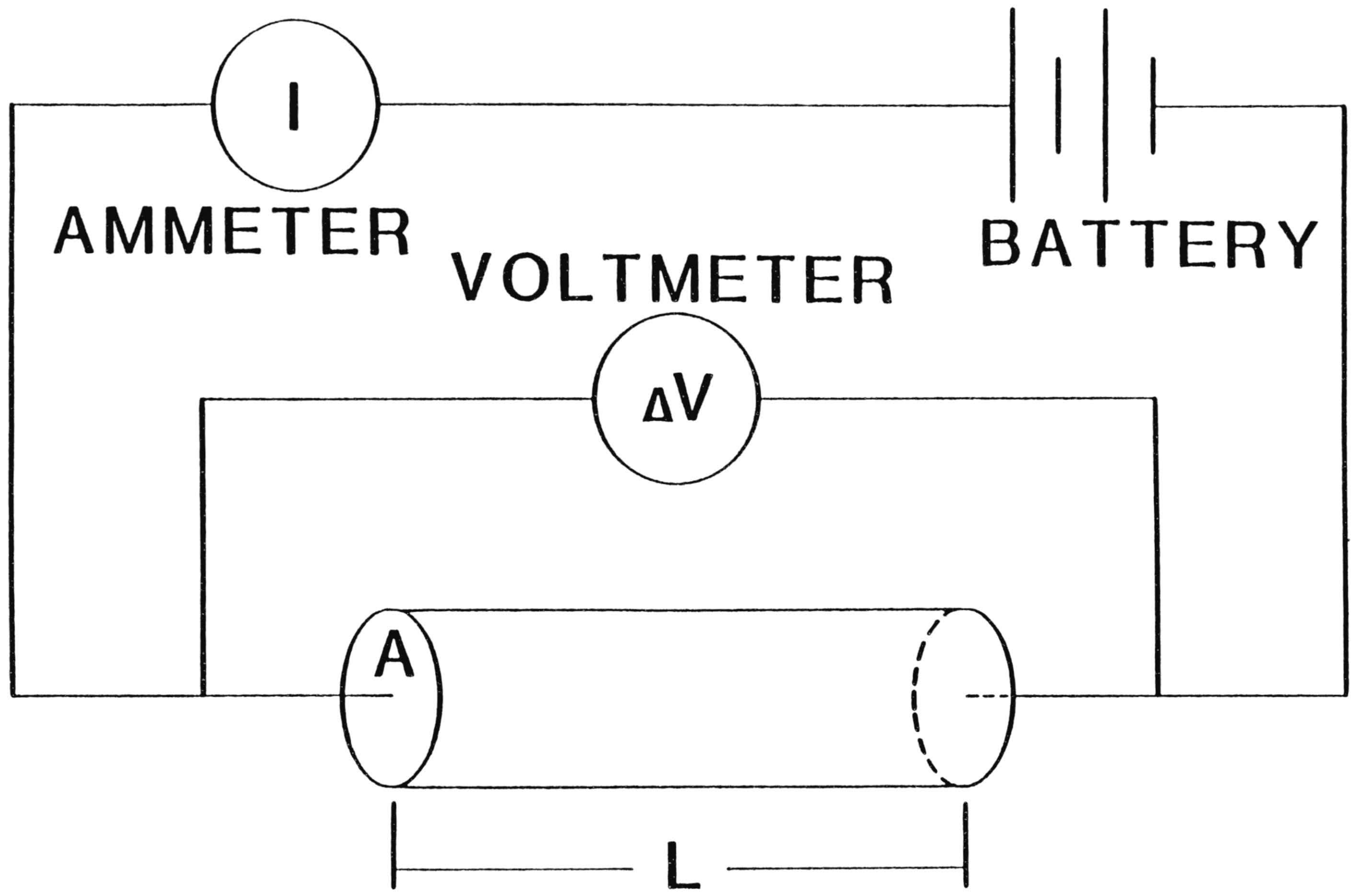
Geophysical Methods

Most geophysical methods require a contrast between the object of investigation and the surrounding material if the object is to be detected. Since the resistivity of earth materials varies over many orders of magnitude, resistivity measurements provide a potential means for determining subsurface lithologies and structures. Resistivity is defined as the ratio of electrical field to current density. In ohmic terms, resistivity is the resistance to electrical current per unit length, proportional to length and inversely proportional to current and cross-sectional area (Sears *et al*., 1982; (Figure 8).

The acquisition of field data involved the use of a soil test model R-50 stratameter direct current resistivity unit and a Geonics EM-16R VLF instrument. All field data were collected from September, 1984 through February, 1985.

Vertical Electric Soundings (VES)

Fourteen VES were completed. The apparent resistivities calculated in the field were reduced using an automatic inversion computer program devised by Zohdy and Bisdorf (1975), which provided depth, thickness, and bulk resistivity values for layers in the geoelectric sections.



$$RESISTIVITY = (A/L)(\Delta V/I)$$

Figure 8. Definition of Resistivity.

Horizontal Electrical Profiling (HEP)

Nineteen HEP were completed. HEP 1-13 are perpendicular to fracture traces, and 14-19 parallel to fracture traces. The calculated apparent resistivity values are plotted on a map at their respective station location and a contour map is drawn connecting points of equal resistivity. Generally, profiling methods determine the lateral variations of apparent resistivity for a given depth of investigation, and detect a vertical (or diagonal) boundary between units if the units vary significantly in resistivity.

EM-16R

A Geonics EM-16R VLF instrument was used to delineate a plume of conductive water migrating from an open drainage ditch to a sinkhole within the study area (personal communication; Parker and McCain, 1984). With the EM-16R instrument, apparent resistivity and phase angle measurements were made at 10 meter intervals along transects parallel to the station direction, extending to the boundaries of the survey area. Transects were spaced at 10 meter intervals measured along the baseline. This field method allows accurate grid coverage of the survey area with a minimum of surveying, provided the base line position is determined accurately.

Hydrogeologic Methods

With the increased awareness of ground-water contamination problems, the need arises for alternative methodologies to determine the hydrologic properties of the aquifer. A high density of data points is necessary to resolve details of the water table configuration. To accomplish this small diameter, steel, driven ground water

samplers were used. The steel samplers were replaced with 1.25 cm PVC wells which fit an 1.8 cm opening left upon removal of the driven sampler. Clusters of monitor wells open to various depths were also also emplaced by the same technique for determination of vertical hydraulic gradients. Samples from the small diameter samplers and wells were collected with a vacuum flask. This technique allows rapid and economical emplacement of wells. Head, specific conductance, and temperature were monitored weekly in the 1.25 cm PVC wells.

RESULTS

Geophysics

Fourteen geoelectric sections were compiled from the reduced data. The location of these sections are shown in Figure 9. Each sounding was plotted with a-spacing on the X-axis and apparent resistivity, ρ_a, on the Y-axis (Figures 10, 11, and Appendix B). The smoothed sounding curves were used for inversion. From the inverted data fourteen geoelectric sections were constructed with apparent resistivity, ρ_a , on the X-axis and depth, Zm, on the Y-axis (Figure 12 and Appendix C).

Boundaries between layers were determined by a graphical procedure referred to here as the midpoint method (Stodghill, 1983). The boundary separating the shallow, high resistivity zone from the shallow, low resistivity zone was determined by finding the midpoint between the maximum value of the first peak and the minimum value of the trough. Except for the lower limit of the deep layer, all other boundaries were determined similarly (Figure 13 and Appendix D).

All of the geoelectric sections exhibit the same general profile As illustrated in Figure 12, these sections are composed of two principal peaks separated by a trough, representing four major geoelectric layers as shown in the two geoelectric cross sections. One is a north-south traverse (Figure 14) and one is an east-west traverse (Figure 15). The resistivity data of the cross-sections

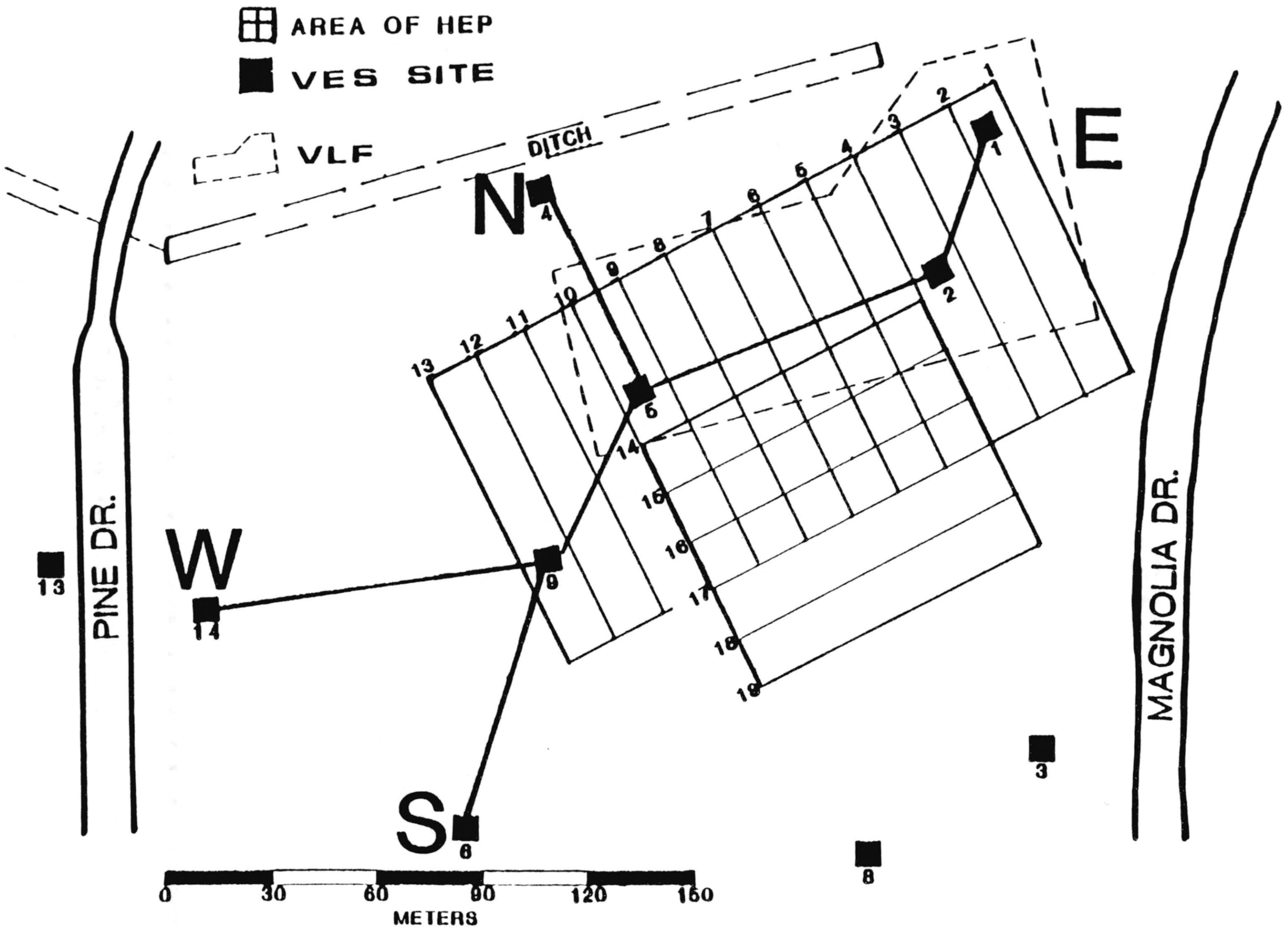


Figure 9. Location and distribution of VES, HEP and VLF stations.

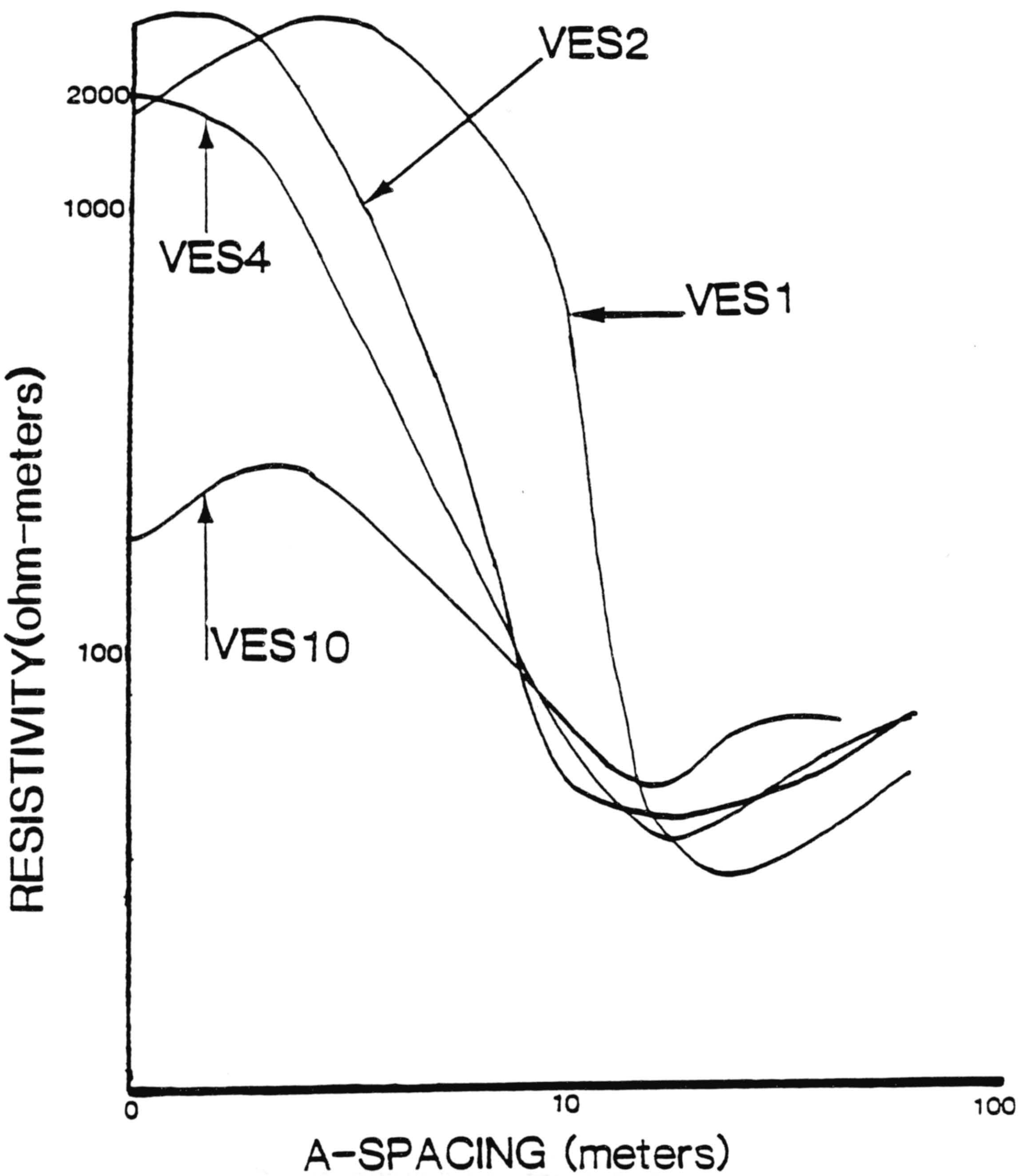


Figure 10. VES curves with a-spacing (meters) versus resistivity (ohm-meters).

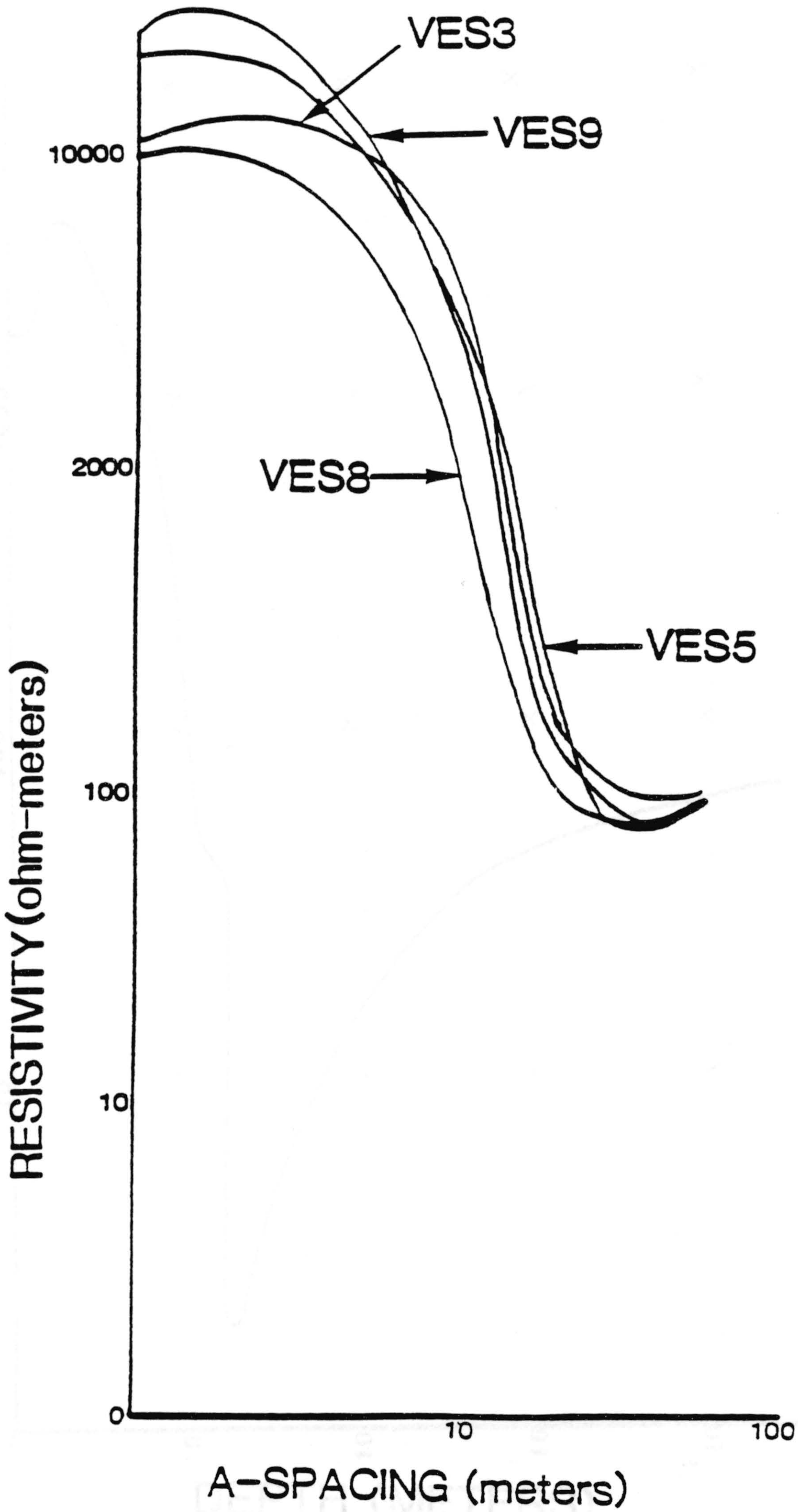


Figure 11. VES curves with a-spacing (meters) versus resistivity (ohm-meters).

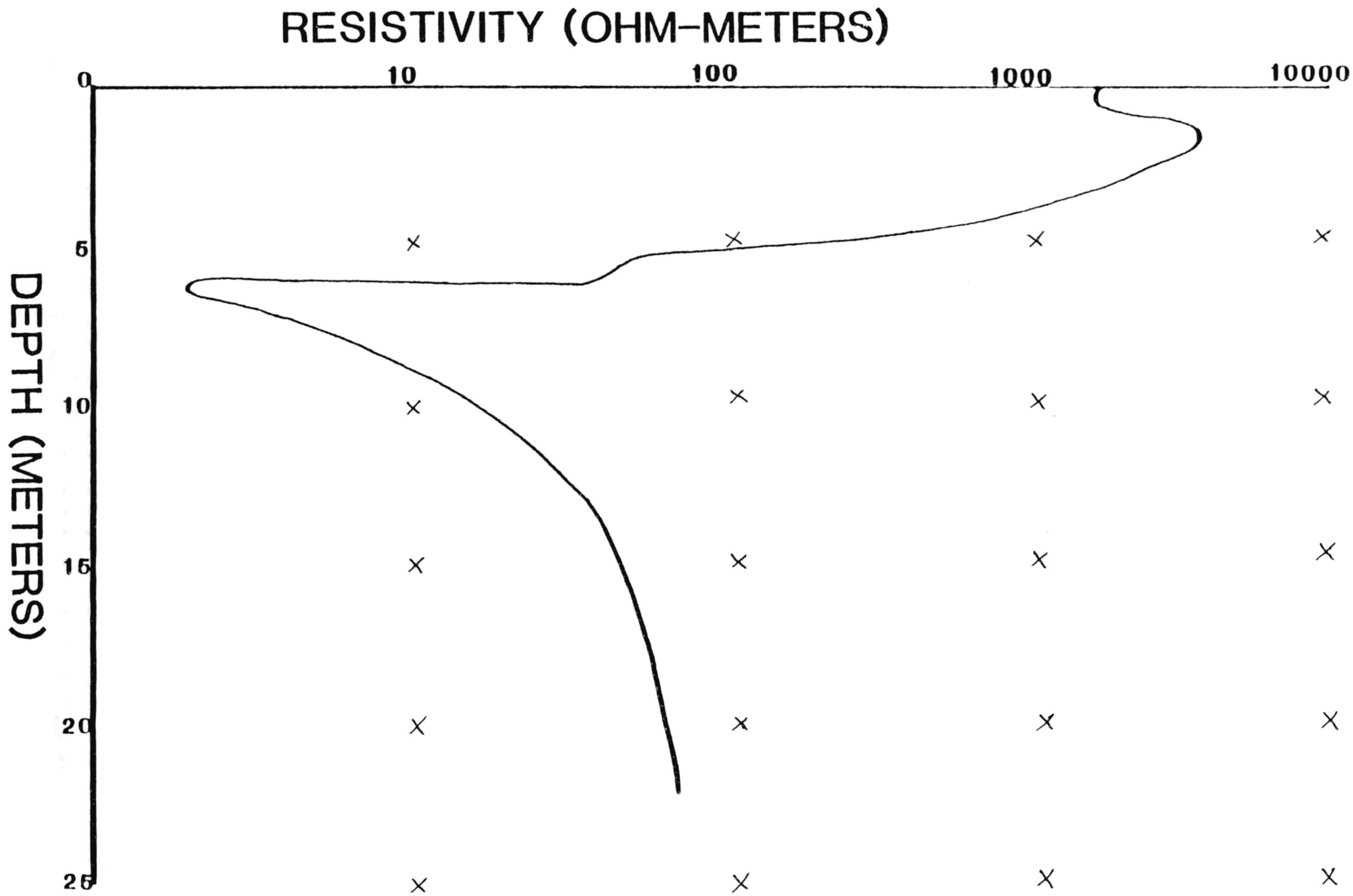


Figure 12. VES curve with resistivity (ohm-meters) versus depth (meters).

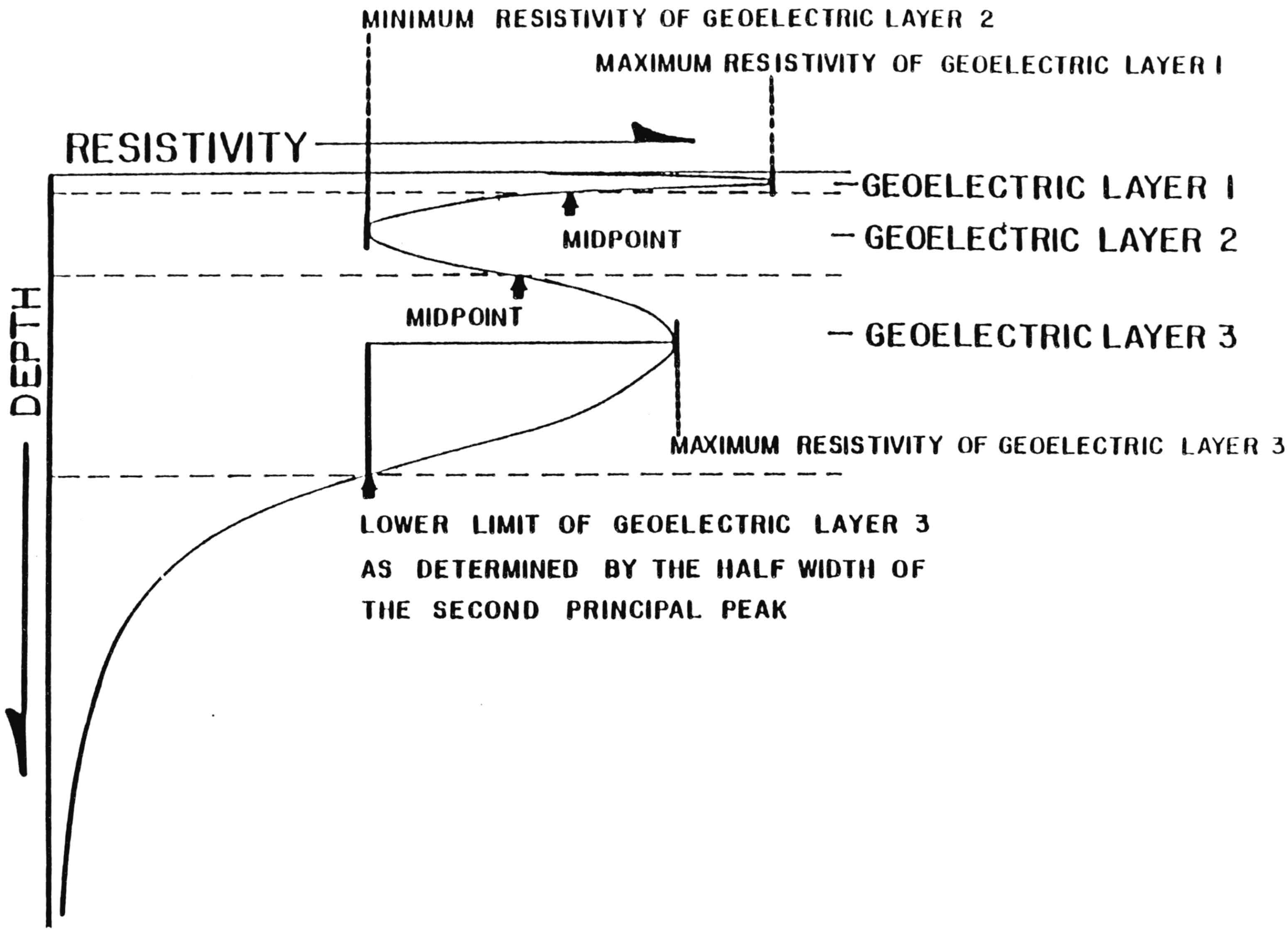


Figure 13. VES curve illustrating the mechanical methods used to determine the limits of each geoelectric layer (from Stodghill, 1983).

are divided into five classes of values ranging from 15 ohm-m to 23,000 ohm-meters.

The results of the VES data inversion by the Zohdy-Bisdorf program indicates the presence of four distinct geoelectric layers. (GEL). These are labeled GEL 1, 2, 3, and 4, counting from the surface downward. Geoelectric layer 1, the uppermost layer, correlates with the first peak. This layer has very high resistivity values, is 3 m thick, and is at or near the surface. It represents the resistive, fine to very fine-grained, unconsolidated and unsaturated sand with clay, silt, and organics grading downward into clean dry sand with trace of fines.

Geoelectric layer 2 is reflected in the profile by the slope of high resistivity. The corresponding geoelectric layer is 1-2.5 m thick. It is interpreted as the top of the shallow water table in the lower part of the dune sand. Elevation of the water ranges from 5.9 m above mean sea level in the dry season and to 9.79 m above mean sea level in the wet season. This fluid contact can be recognized by the much lower resistivities compared to the overlying dry sand.

The third geoelectric layer correlates with the low resistivity trough of the profile (Figure 12). The corresponding geoelectric layer is 4-10 meters thick. The dune sand grades into semi-confining silty and clayey sands and clays. This layer has the lowest resistivity values of all the geoelectric layers. A fourth geoelectric layer is reflected in the profile by the second peak (Figure 12). This peak lies immediately below the trough. This is interpreted as an argillaceous limestone. The resistivity values for the top of the limestone show

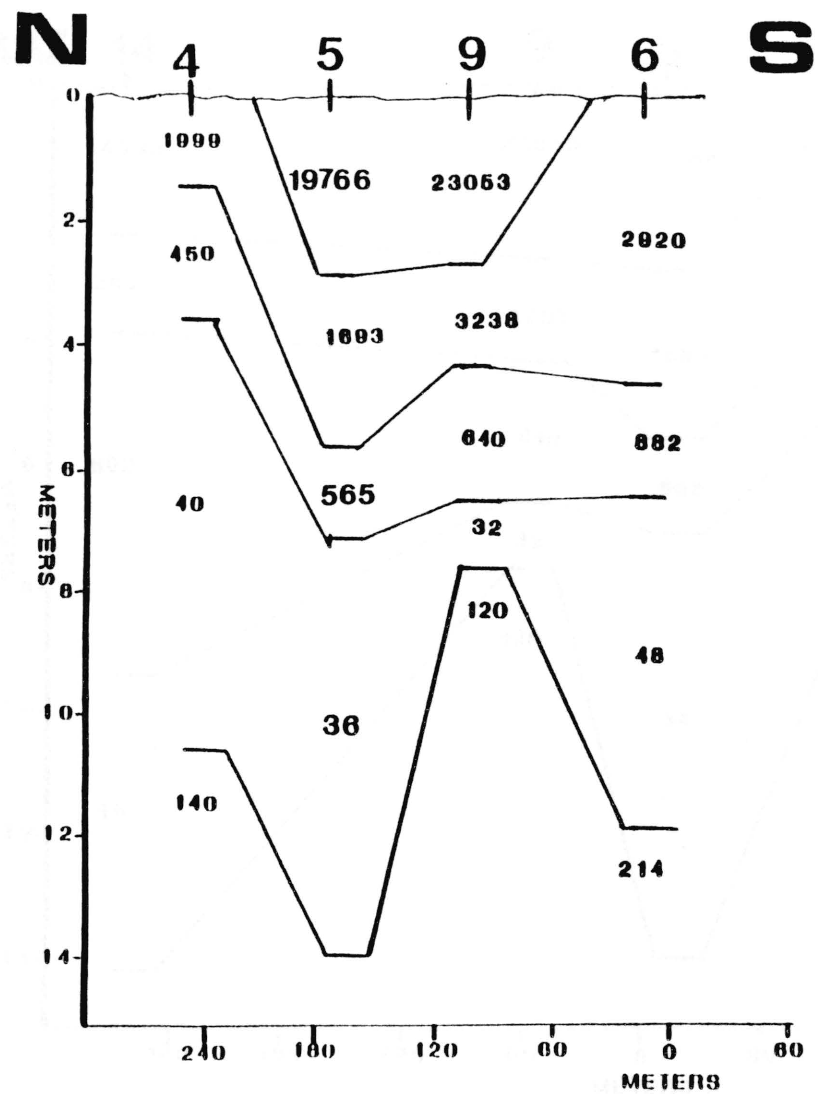


Figure 14. Geoelectric cross-section from VES data (north-south).

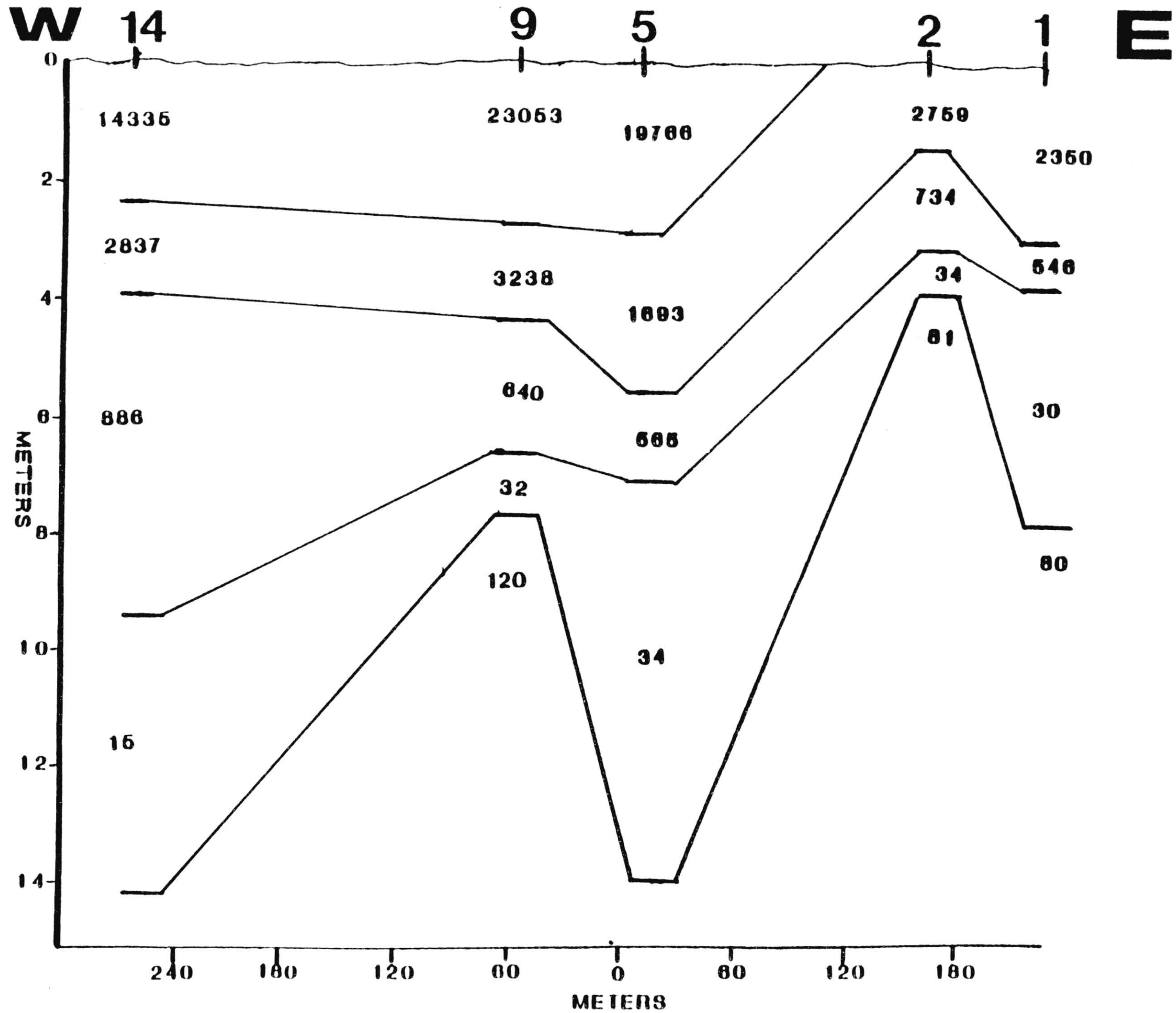


Figure 15. Geoelectric cross-section from VES data (east-west).

an increase when compared with the minimum values of the overlying clay. Depth to the limestone ranges from 7-14 meters.

In all of the resistivity cross-sections, three sets of distinctive features appear. The first set of features is the occurrence of sites of very high-resistivity response near the surface, approximately delineated by the 10,700-23,000 ohm-m range (GEL 1). These areas of very high-resistivity response are discontinuous at VES 1, 2, 4, and 6. However the very high-resistivity response is more continuous and generally thicker in the south-east and west portions of the study area (Figures 14 and 15). The second set of features in the cross sections are sites of high-resistivity response, or GEL 2 (1990-3870 ohm-meters, Figures 14 and 15). These sites of high-resistivity response are continuous, occurring between 3 and 5 m deep.

The third distinctive feature is the occurrence of the lowest resistivity response (15-890 ohm-m) below a depth of 5 meters in both cross sections (GEL 3). GEL 4 gradually increases in thickness toward the north and northwest portions of the cross sections (Figures 14 and 15).

In addition to the two DC resistivity geoelectric cross-sections, nineteen horizontal electrical profiles (HEP) were completed across the study area. A Wenner a-spacing of 15 m was used. HEP 1-12 are perpendicular to the fracture trace, while HEP 13-19 are parallel to the fracture trace and the ditch (Appendix E). The locations of these profiles are shown in Figure 9. These profiles were plotted with distance on the X-axis and apparent resistivity, ρ_a, on the Y-axis (Figures 16 and 17). The apparent resistivity values were also plotted

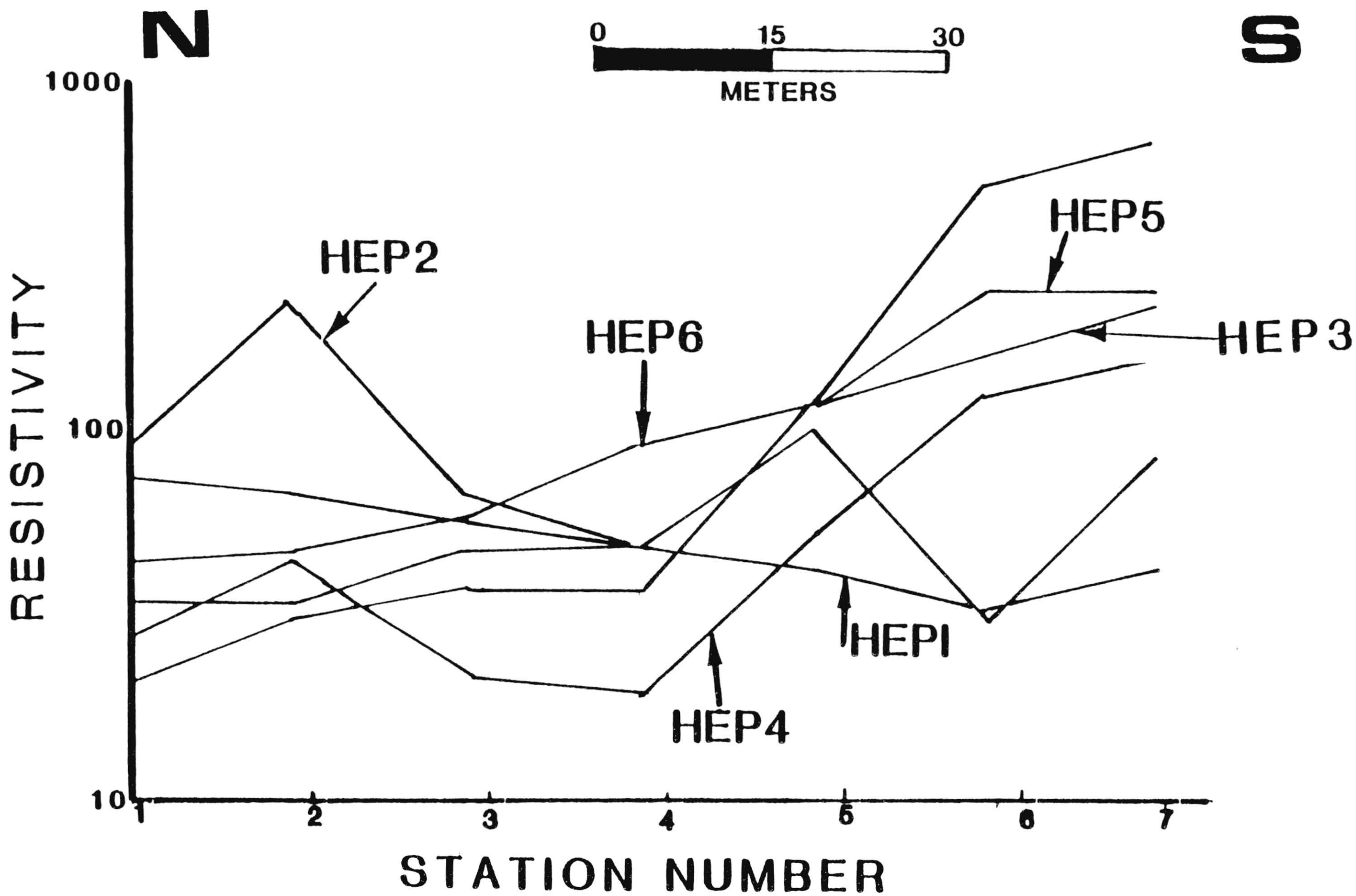


Figure 16. HEP curves with station number versus resistivity (ohm-meters).

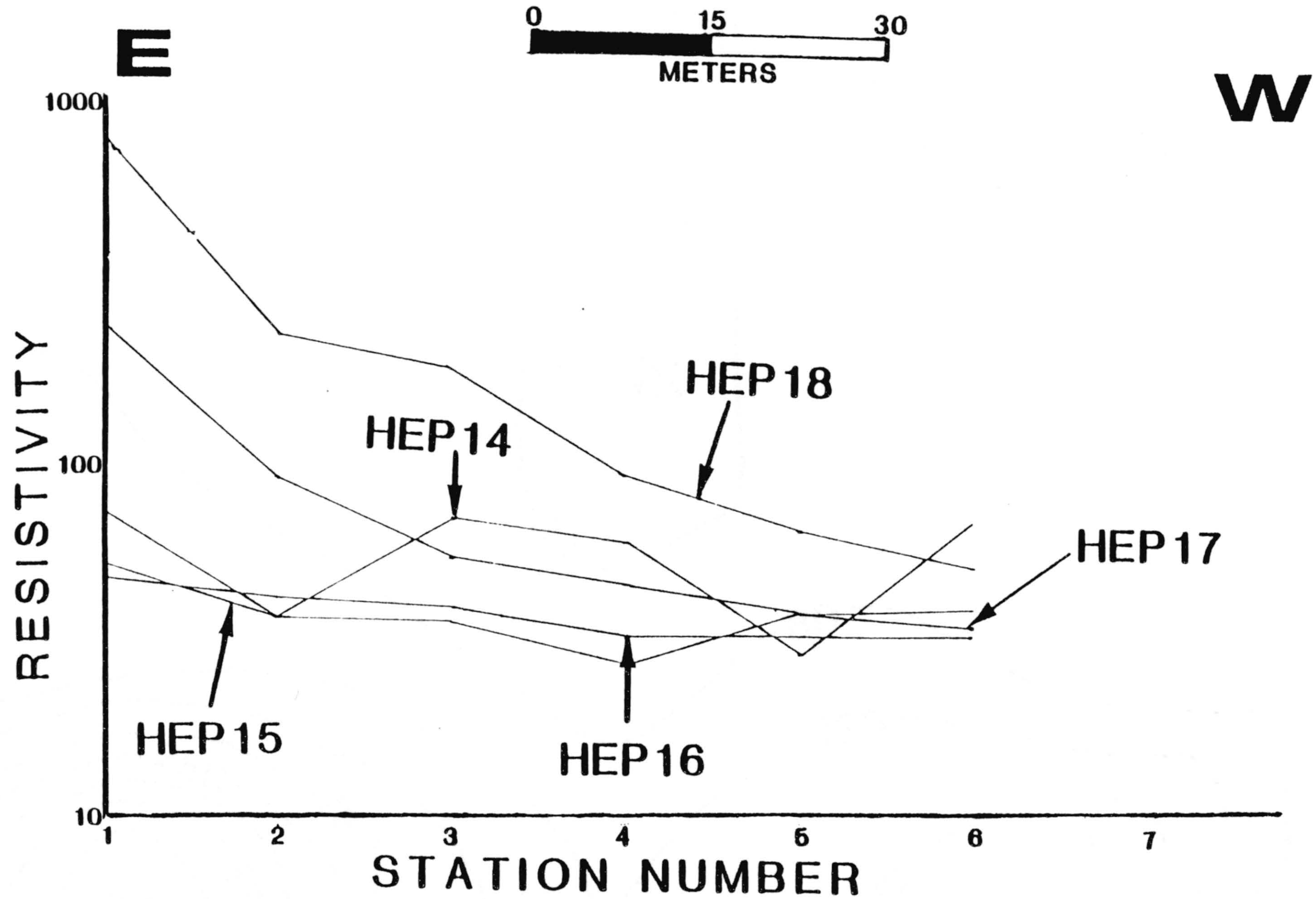


Figure 17. HEP curves with station number versus resistivity (ohm-meters).

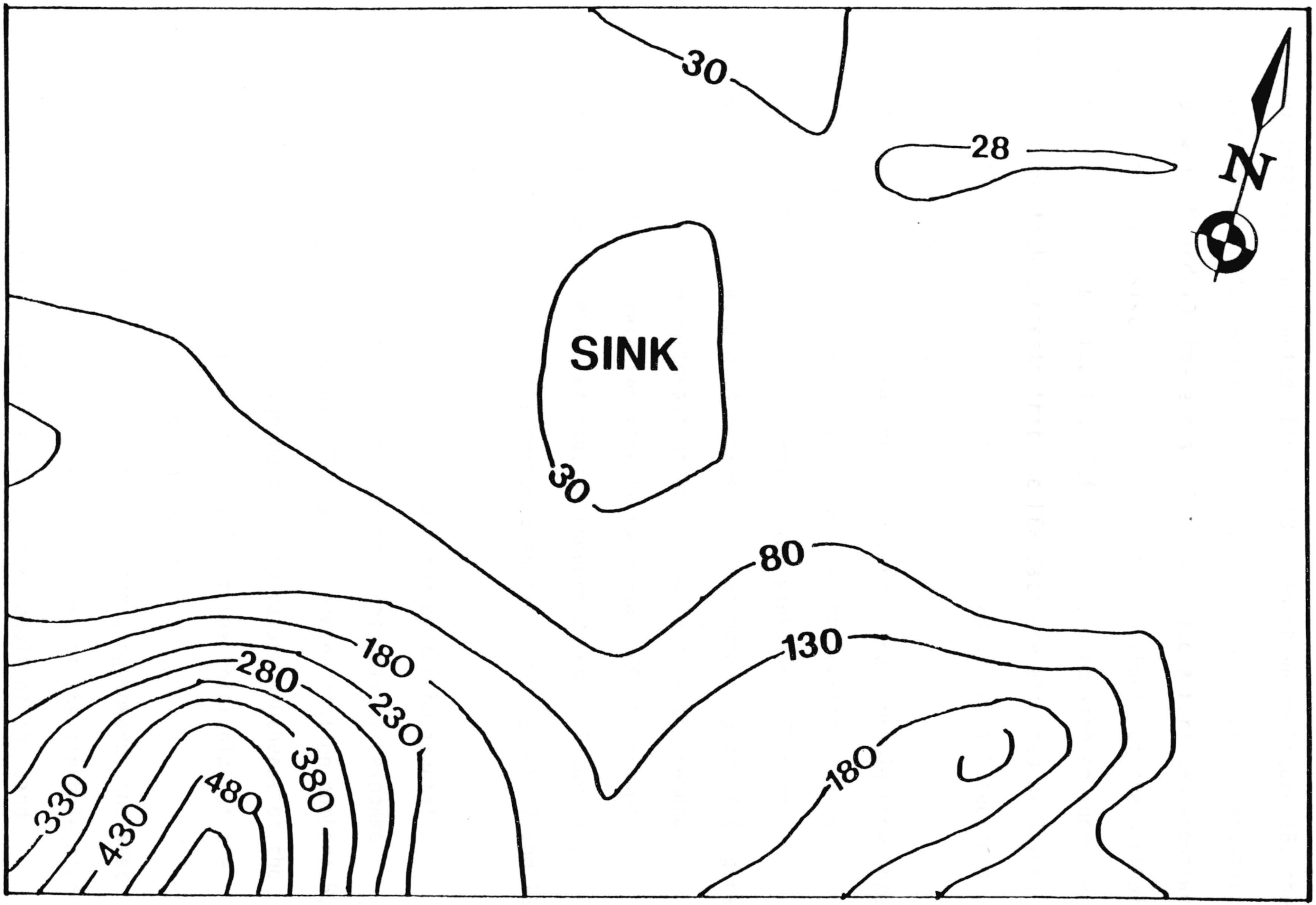


Figure 18. HEP contour map with a 50 ohm-meter contour interval.

at their respective station locations and a contour map with a 50 ohm-m contour interval constructed (Figure 18). As shown in Figure 18, the area between the ditch and sink has relatively low apparent resistivities between 28 and 70 ohm-meters. There is also a northeast-southwest trend of the low resistivity values. To the southwest of the sinkhole resistivity increases markedly. This is associated with an increase in elevation which suggests that the HEP data are affected by layers higher in the geoelectric section, as indicated by the VES sections (Figure 12 and Appendix C).

The horizontal electrical profiles across the sinkhole show three distinctive features. The first feature is the low-resistivity response (<100 ohm-m) in the center of the sinkhole. This is indicated by HEP 2, 4, and 14 between station numbers 3 and 4 (Figure 16). Stations to the northeast of the sinkhole show the second feature which is moderate-resistivity response (100-400 ohm-m). This is indicated by HEP 2 at station numbers 2 and 3 (Figure 16). In Figure 17 moderate-resistivity response is indicated by HEP 17 and 18 between station numbers 1 and 2.

The third distinctive feature indicated by the horizontal electrical profiles is the presence of high-resistivity response (400-1000 ohm-m), indicated by HEP 5 and 6 between station numbers 5, 6, and 7 (Figure 16). The high-resistivity values southeast of the sinkhole are interpreted to be the result of the thickening of the resistive clean sand towards the southeast.

Resistivity values are shown to be decreasing towards the west (Figure 16). The low-resistivity response west of the sinkhole along HEP 16, 17, and 18 is interpreted to be the result of the sand

becoming more saturated and intermixed with silts and clay as one moves toward the fracture trace. Resistivity lows are observed that indicate the zone of fracturing. These resistivity lows are due to an increase in porosity and/or clay content within the fracture zone. The VES data show a thickening of the clay unit over the fracture zone, but it is likely that an increase in porosity due to karstic solution features also contributes to the low resistivity values.

Geology

The stratigraphy to a depth of 7.6 m was determined with a 7.5 cm bucket auger and a driven split-spoon probe. Twenty-three augured wells were completed in the survey area (Appendix F). The locations of these wells are shown in Figure 19.

The interpreted hydrostratigraphy and water-table position is presented in Figure 20. Land surface elevations were corrected to mean sea level. Average elevation of the south portion is 12.5 m, and average elevation in the north portion is 9.2 m above mean sea level. The map shows water level measurements that were taken in November, 1984. Average depth to the water level is 7.2 m above mean sea level in the north portions where the water table is in the silty-sand layer. To the south, the water table level is 7 m above mean sea level and is in the sand layer.

Eleven samples from the augered holes were analyzed in the laboratory using sieve and hydrometer analysis to estimate hydraulic conductivity (K) and percent sand, silt and clay (Figure 21 and Table 2). The value of the hydraulic conductivity is useful in making regional estimates of the infiltration capacity or the rate of

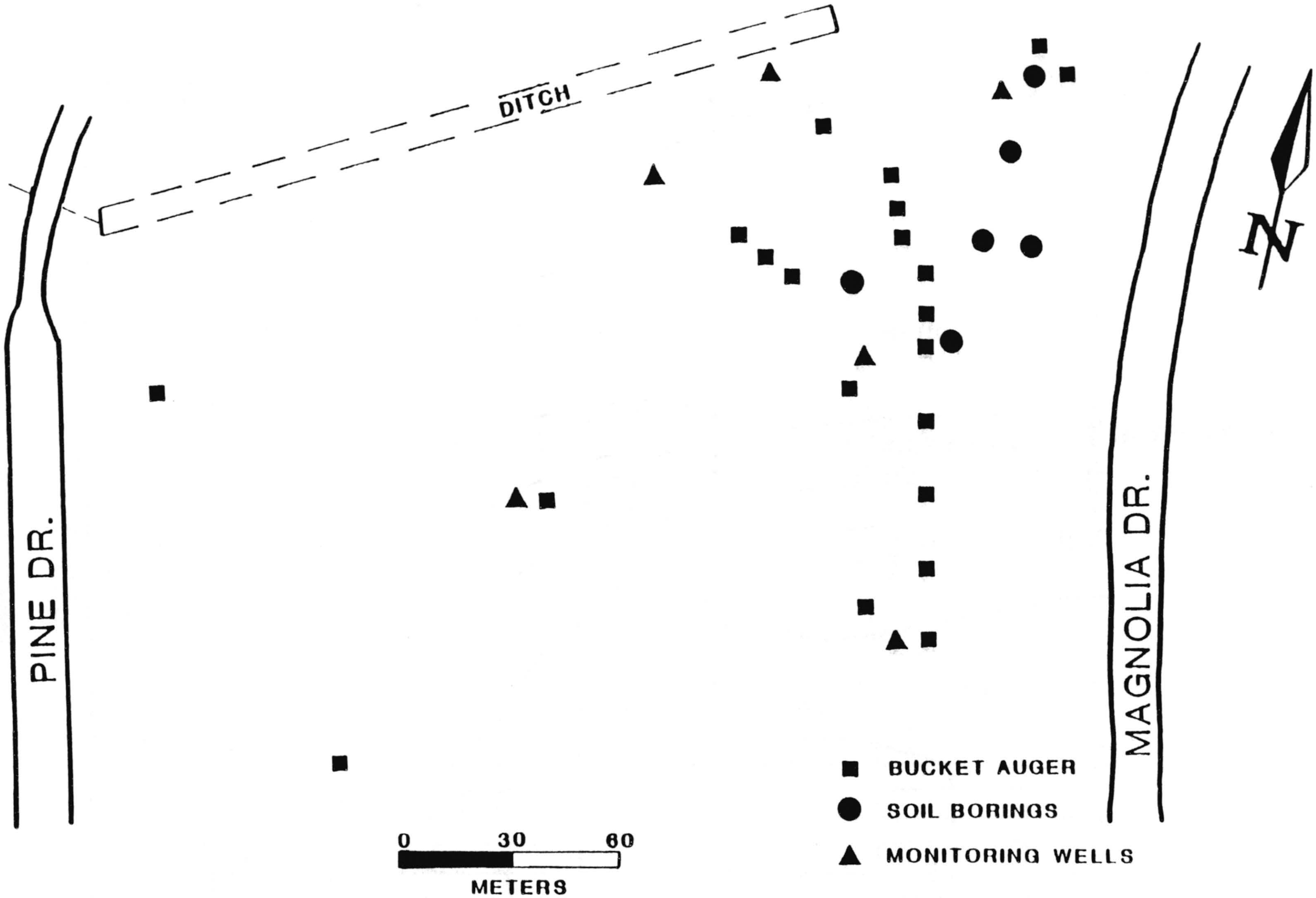


Figure 19. Location and distribution of Bucket Auger, soil borings and monitoring wells within the study area.

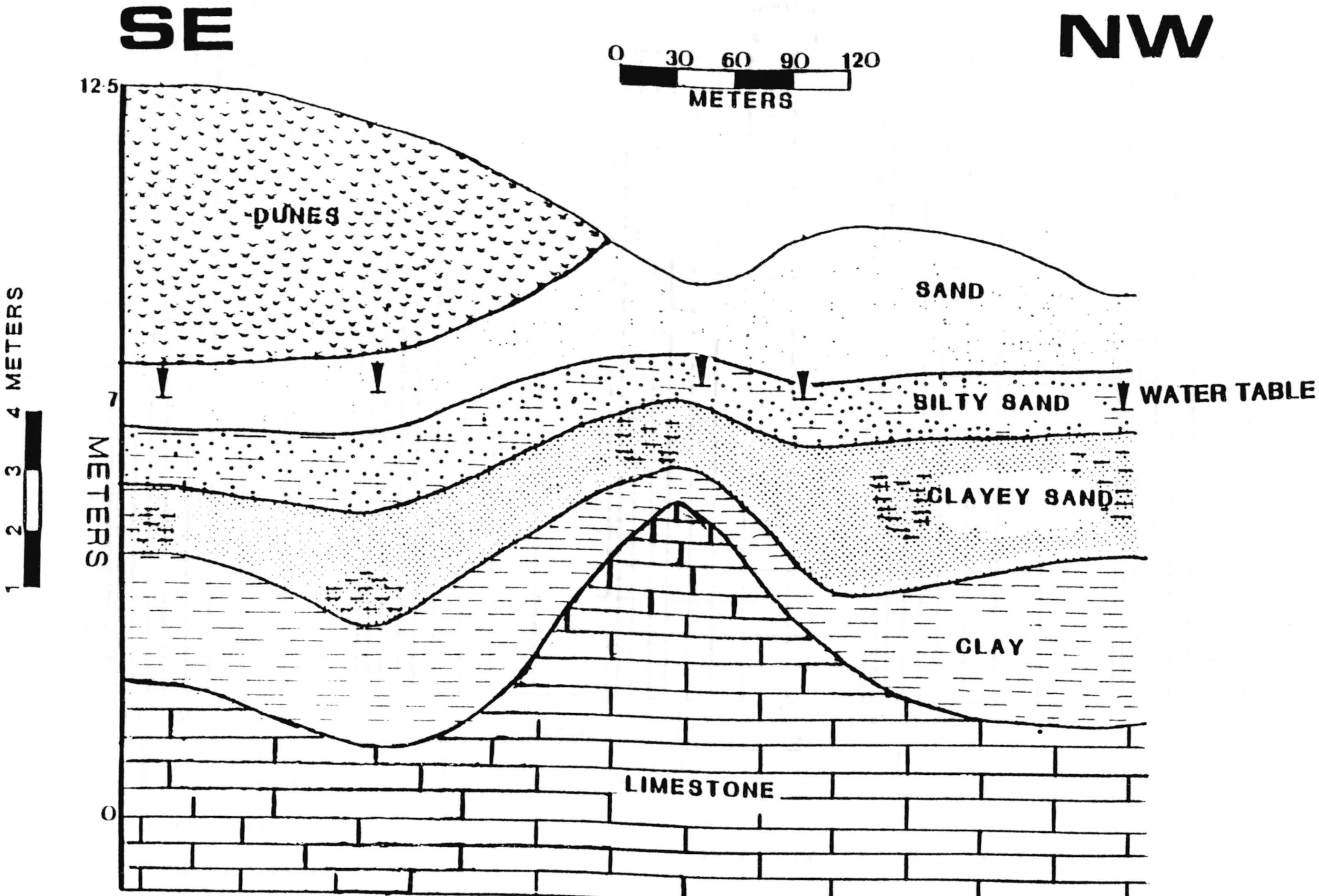
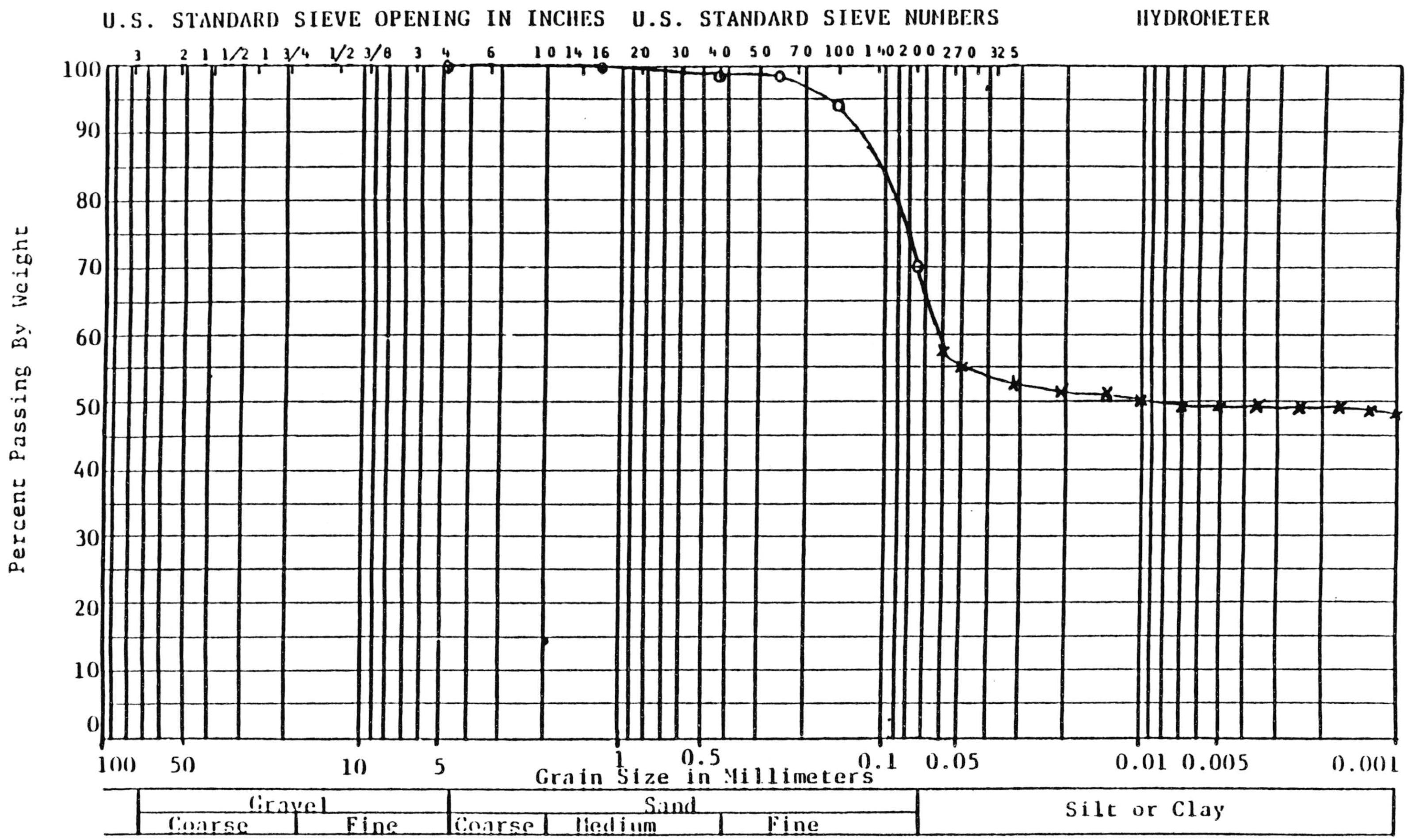


Figure 20. Location of water table in November, 1984 (obtained using augered and monitor wells).



O-by Sieve

X-by Hydrometer

49.7% clay, 43.0% sand, 7.3% silt

Figure 21. Mechanical analysis chart used to determine the percentage of sand, silt and clay.

Table 2. Hydraulic Conductivity (K) Values from Grain Size Analysis.

Sample	Depth cm.	D_{10} (mm)	D_{50} (mm)	D_{60} (mm)	Uniformity Coefficient $\frac{D_{60}}{D_{10}}$	Hydraulic Conductivity (K) cm/sec.
BA-1	177.8 -203.2	0.16	0.18	0.2	1.3	400×10^{-4}
BA-5	35.56-101.6	0.085	0.14	0.15	1.8	180×10^{-4}
BA-2	177.8 -190.5	0.08	0.125	0.15	1.9	130×10^{-4}
BA-6	35.56- 73.66	0.085	0.15	0.175	2.06	170×10^{-4}
BA-7	241.3 -254	0.07	0.22	0.25	3.56	100×10^{-4}
BA-3	127 -139.7	.09	0.2	0.22	2.4	220×10^{-4}
BA-5	152.4 -177.8	0.1	0.20	0.22	2.2	240×10^{-4}
BA-3	165.1 -177.8	0.07	0.22	0.25	3.57	110×10^{-4}

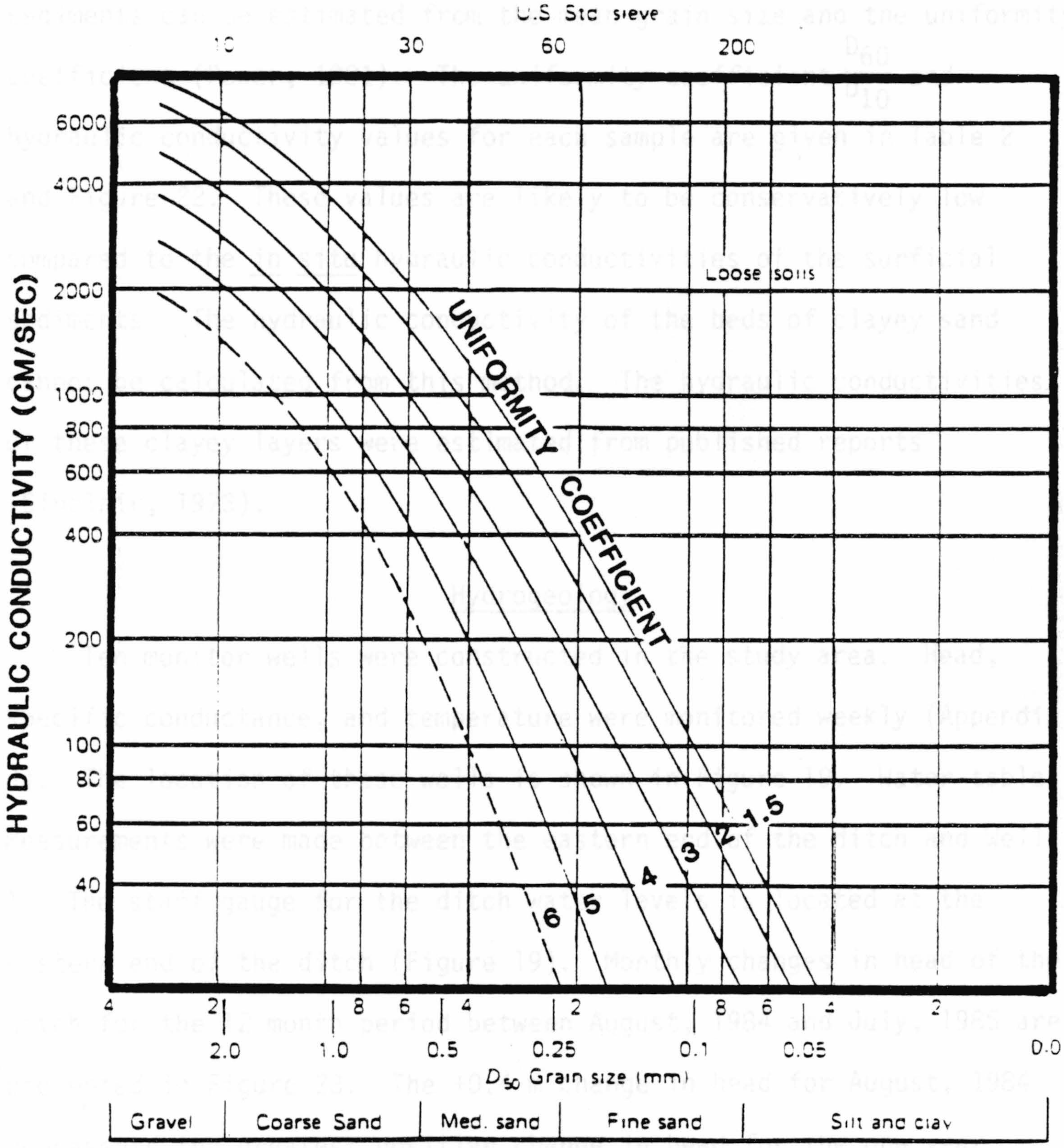


Figure 22. Hydraulic conductivity values for surficial sediments obtained using the mean grain size and the uniformity coefficient (from Powers, 1981).

recharge to the Floridan aquifer from the overlying surficial aquifer. The hydraulic conductivity values were estimated based on grain size and sorting. Hydraulic conductivity values for surficial sediments can be estimated from the mean grain size and the uniformity coefficient (Power, 1981). The uniformity coefficient $\frac{D_{60}}{D_{10}}$ and hydraulic conductivity values for each sample are given in Table 2 and Figure 22. These values are likely to be conservatively low compared to the in situ hydraulic conductivities of the surficial sediments. The hydraulic conductivity of the beds of clayey sand cannot be calculated from this method. The hydraulic conductivities of these clayey layers were estimated from published reports (Sinclair, 1973).

Hydrogeology

Ten monitor wells were constructed in the study area. Head, specific conductance, and temperature were monitored weekly (Appendix J). The location of these wells is shown in Figure 19. Water-table measurements were made between the eastern end of the ditch and Well 1. The staff gauge for the ditch water levels is located at the eastern end of the ditch (Figure 19). Monthly changes in head of the ditch for the 12 month period between August, 1984 and July, 1985 are presented in Figure 23. The +0.4 m change in head for August, 1984 represents the greatest positive change in head for the one year period. The -0.4 m change in head recorded in December, 1984 is the greatest negative change in head recorded. The sum of the monthly values of ΔS indicates that that the annual change in storage (ΔS) for the pond is zero (Table 3).

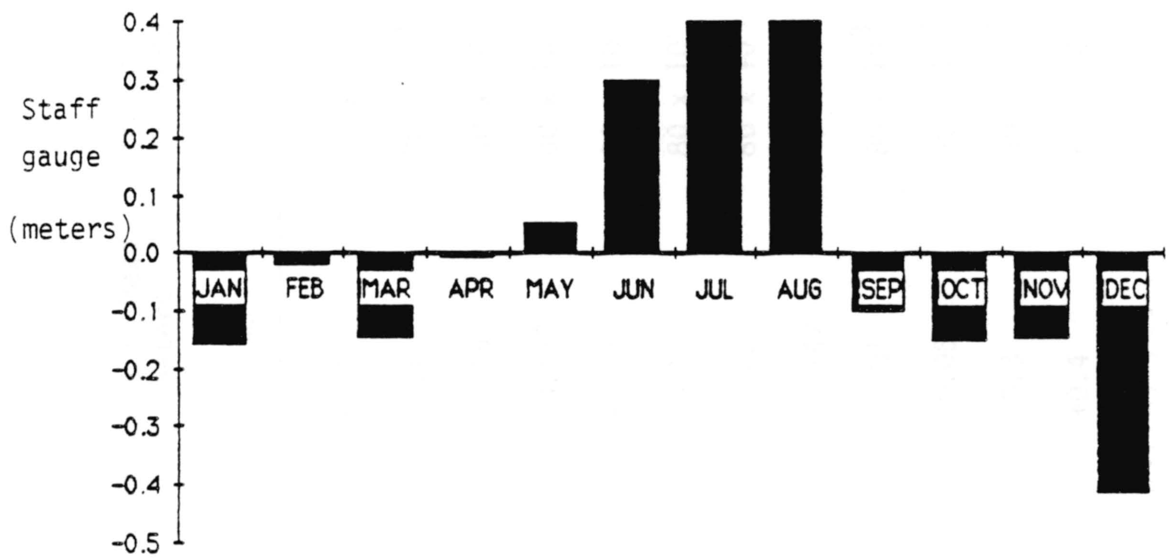


Figure 23. Monthly change in head (meters) in the ditch (August, 1984 through July, 1985).

Table 3. Monthly Change in Storage, Δs, (in m^3) of the pond for 12 Month Period (August, 1984, to July, 1985).

Month	Monthly Beginning (m) Elevation	Monthly Ending (m) Elevation	Difference in Head (ΔH) meters	Area of the Lake (m^2)	Change in Storage (M^3) (Δs)	$\Sigma\Delta s$
Aug. 84	9.10	9.50	+0.4	80×10^3	+ 32,000	+32,000
Sept. 84	9.50	9.4	-0.1	80×10^3	-8000	+24,000
Oct. 84	9.4	9.25	-0.15	80×10^3	-12,000	+12,000
Nov. 84	9.25	9.103	-0.147	80×10^3	-11,760	+ 240
Dec. 84	9.103	8.69	-0.413	80×10^3	-33,280	-33,040
Jan. 85	8.69	8.53	-0.16	80×10^3	-12,800	-45,840
Feb. 85	8.53	8.51	-0.02	80×10^3	- 1,600	-47,440
Mar. 85	8.51	8.363	-0.147	80×10^3	-11,760	-59,200
Apr. 85	8.363	8.353	-0.01	80×10^3	- 800	-60,000
May 85	8.353	8.4	+0.05	80×10^3	+ 4,000	-56,000
June 85	8.4	8.7	0.3	80×10^3	+24,000	-32,000
July 85	8.7	9.1	+0.4	80×10^3	+32,000	0

Head measurements of the ten ground water wells taken during the wet seasons (August through September) indicate that Well 9, near the ditch, has the highest wet season head of 9.79 m above mean sea level. Well 1 during the same time period has the lowest head with a value of 7.24 m above mean sea level. Measurements during the dry seasons (May through June) indicate that Well 9 has the highest dry season head with a value of 7.77 m above mean sea level, and well 1, again had the lowest head with a value of 5.66 meters above mean sea level (Appendix K).

The first observation of the head measurements is that the water table slopes away from the ditch at a rate of 25.5 m/km in August, and at a rate of 24.6 m/km in May. This slope is away from the ditch toward the lowest portion of the study area (sinkhole), indicating that the ditch is recharging the surficial aquifer. The water table also slopes away from the 30th St. pond. This indicates that it is also recharging the surficial aquifer. This head relationship beween the pond and the water table was maintained throughout the year. The second observation is that the flow direction of the water table south of the ditch is from the northeast toward the southwest. This is parallel to the direction of the fracture trace in the study area.

Water conductivities of the ditch, the ten monitoring wells, and the University Square Mall duck pond were taken concurrently with the head measurements (Appendix J). Water conductivities for the ditch of 2180 micromhos/cm in March, 1985 and 65 micromhos/cm in August, 1985 (Figure 24), indicate that the drainage ditch was contaminated by urban runoff during March, but in August increasing amounts of fresh water precipitation dilutes this contamination. Ground water conductivity

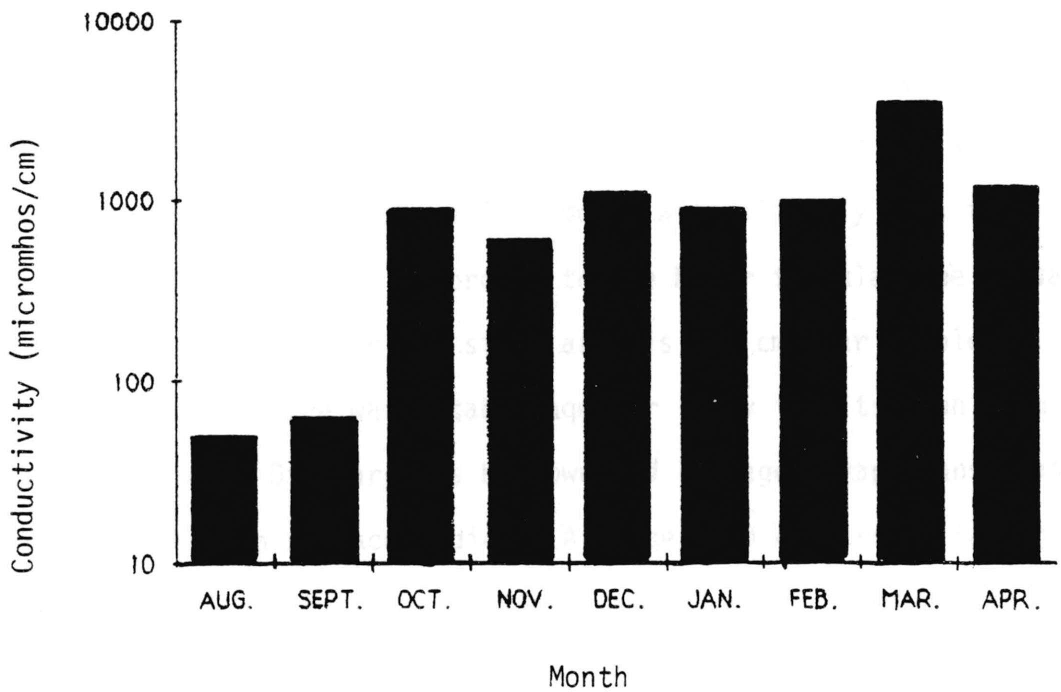


Figure 24. Monthly conductivity values (micromhos/cm) in the ditch (August, 1984 through July, 1985).

measurements, taken at well 3, in the lowest part of the sinkholes were 680 micromhos/cm during March, 1985 and 105 micromhos/cm during August 1985. Average conductivities measured at the University Square Mall duck pond range from 110-300 micromhos/cm.

Water Budget

Average annual runoff from the drainage basin to the pond was estimated to be 125 cm/year. The impermeable area of the drainage basin that discharges to the pond is approximately 0.34 km^2 giving 1178 m^3/day for the average daily runoff to the pond. About 60 percent of precipitation falls during June through early September. August is the wettest month, with about 16 percent of the annual rainfall. November is the driest month with slightly less than 4 percent (Figure 25). According to the Meyer formula, the annual average evaporation for the study area is 129 cm/year (Table 4).

Recharge to the water table aquifer is by infiltration from precipitation. Discharge is by downward leakage, evapotranspiration, and discharge to surface bodies. Average head difference (ΔH) between the surficial and Floridan aquifers was 1.8 and 0.7 meters for August and May, respectively. This represents an average daily recharge of 212 m^3/day for the amount of water that moves from the surficial to the Floridan aquifer. The hydraulic gradient, $\frac{\Delta H}{\Delta L}$, of the Floridan aquifer is relatively low, averaging less than 0.5 m/km. Quantitatively, the total amount of water (Q out) for the study area was calculated to be 2598 m^3/day. This will be discussed in the next chapter.

Table 4. Average monthly evaporation from the pond obtained using Meyer formula.

Month	Saturation Vapor Pressure at water temperature (e_o)	Vapor Pressure of air (e_a)	(e_o-e_a)	Wind Speed (MPH) (W)	Evaporation cm/month $E= C(e_o-e_a)(1+\frac{W}{10})$
Aug. 84	31.67	29.88	1.79	9	3.05
Sept. 84	33.62	28.85	3.77	8	6.19
Oct. 84	31.64	23.75	7.89	9	13.72
Nov. 84	23.28	18.02	5.26	9	9.14
Dec. 84	25.13	15.2	9.93	9	17.25
Jan. 85	21.96	14.63	7.33	9	12.73
Feb. 85	20.63	15.69	4.94	9	8.58
Mar. 85	23.4	17	6.4	10	11.71
Apr. 85	28.9	19.34	9.56	10	17.47
May 85	32.24	24.39	7.85	9	13.64
June 85	33.6	27.08	6.52	8	10.72
July 85	33.2	29.88	3.32	7	5.16
					129.36 cm/year

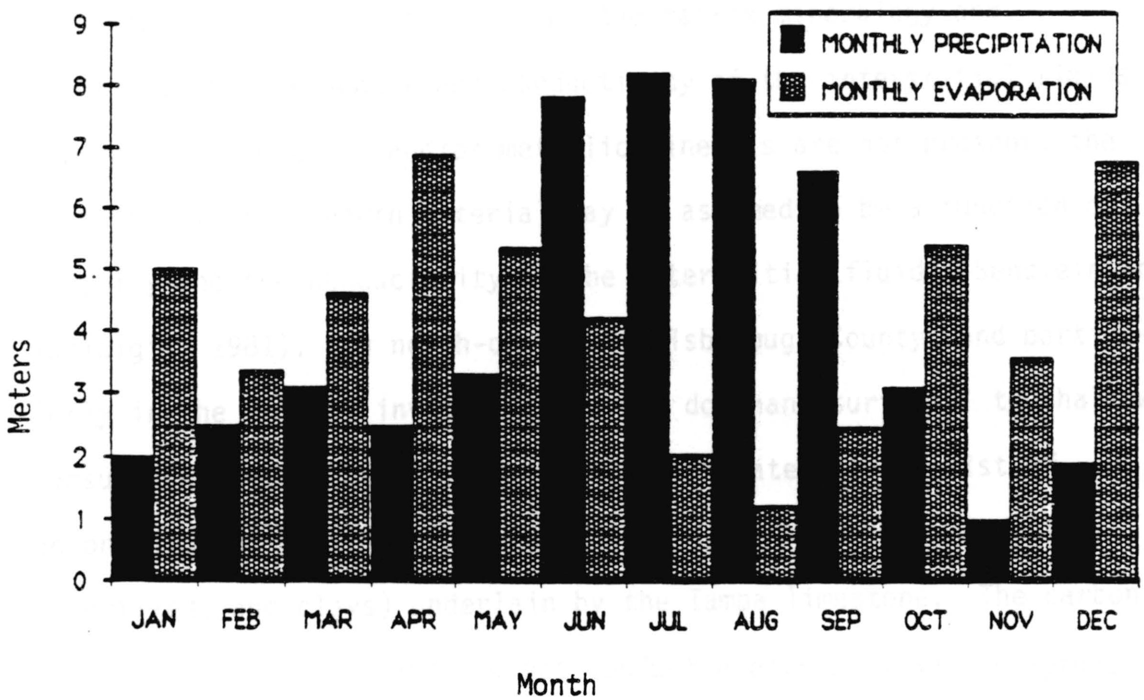


Figure 25. Average evaporation from the pond and monthly precipitation (August, 1984 through July, 1985).

DISCUSSION

Geophysical Investigation

As previously described, the amount of electrical current, measured as conductivity and resistivity, that will flow through an earth material is a function of the matrix mineralogy and porosity, and the amount and conductivity of the interstitial fluids present. Where clays and/or metallic minerals are not present, the resistivity of an earth material may be assumed to be a function of porosity and the conductivity of the interstitial fluids (Sendlein and Yazicigil, 1981). In north-central Hillsborough County, and particularly in the area of investigation, the dominant surficial to shallow subsurface (less than 14 m in depth) earth materials consist of unconsolidated clastics (relict dune sand, sands, silts, and clays intermixed, and clays) underlain by the Tampa limestone. The carbonate materials and quartz sands do not conduct electricity well (Layton, 1982) and are resistive. The clay minerals will have appreciable ionic electrical conduction along clay particle surfaces reducing the bulk resistivity. The interbedding of earth materials of differing high and low bulk resistivities underlain by a carbonate aquifer surface lends itself to mapping by resistivity methods.

The present topography is the result of the three processes: 1) beach ridge formation, 2) dune formation, and 3) karstification of limestone. This topography does affect the results of VES and HEP

data because the resistivity layers are not horizontal planes, but are irregular in thickness and extent. This is reflected in the present local topography (Figure 20).

When interpreting VES curves, the principles of equivalence and suppression must be taken into account. Two layers of different thickness and resistivity such as VES 2 and VES 4 (Figure 10) may produce the same response on a VES curve, demonstrating equivalence. Suppression of a layer (non-detection) occurs when a layer's thickness is less than 10 percent of the depth from the surface to the layer (Bhattacharya and Patra, 1968). The four layers that are indicated by the VES curves in this study can be of varying thicknesses and resistivities (within limits) and still produce an almost identical curve. Several thin layers may also be present.

The major feature of the VES geoelectric cross-sections is the unconformable surface between the Tampa limestone and the semi-confining clay unit overlying it. The geoelectric cross-section (Figure 15) between VES 2 and VES 9, reveals the fracture zone as a V-shaped depression 14 meters deep in the limestone. The thickening of the overlying, unconsolidated deposits over the trace indicates that the fracture zone and associated solution features may have been developing since before deposition of the clay unit (Moore and Stewart, 1983). This should provide enough time for development of the V-shaped depression in the limestone bedrock by weathering and solution created by aggressive groundwaters moving downward through the fractures (Miller, 1977, and Wood, 1985).

Figure 15 also shows that the top of the low resistivity clay layer undulates and varies in depth. This undulation parallels

the underlying unconformity at the top of the Tampa Limestone. Variations in clay thickness may result from local variations in the rate of dissolution of the underlying carbonate unit. The clay may have been subjected to subaerial erosion prior to the deposition of the sand and clay units overlying it. Redeposition of the clay into the paleotopographic lows was the result of this erosion (Sinclair, 1973). In this capacity the residual clay influenced the deposition of the overlying silts and sands. The result is that the high paleokarst features of the Tampa Limestone are surrounded by thick clay infilling with a thinner amount of clay covering the limestone crests.

Cook (1954) has shown that a horizontal electrical profile (HEP) over a filled hemisphirical sink has a distinctive shape for the situation where the sink fill has a resistivity lower than the surrounding material. This distinctive shape is shown in Figure 26. In this figure the general appearance of all curves is the same, and each curve shows a pronounced low-resistivity anomaly over the low resistivity medium and approaches regional resistivity values asymptotically at some distances from the low-resistivity medium. Over the central part of the low-resistivity medium, the slopes of the curves differ somewhat because of the different depths and shapes of the bottoms of the low-resistivity media. This is indicated by HEP 14 and VES 2 which were taken directly over the sink. At close a-spacings over the sink the readings are influenced predominantly by the surficial material, which corresponds to the sandy soil and sands above the clay layer from VES 2 (Figure 15).

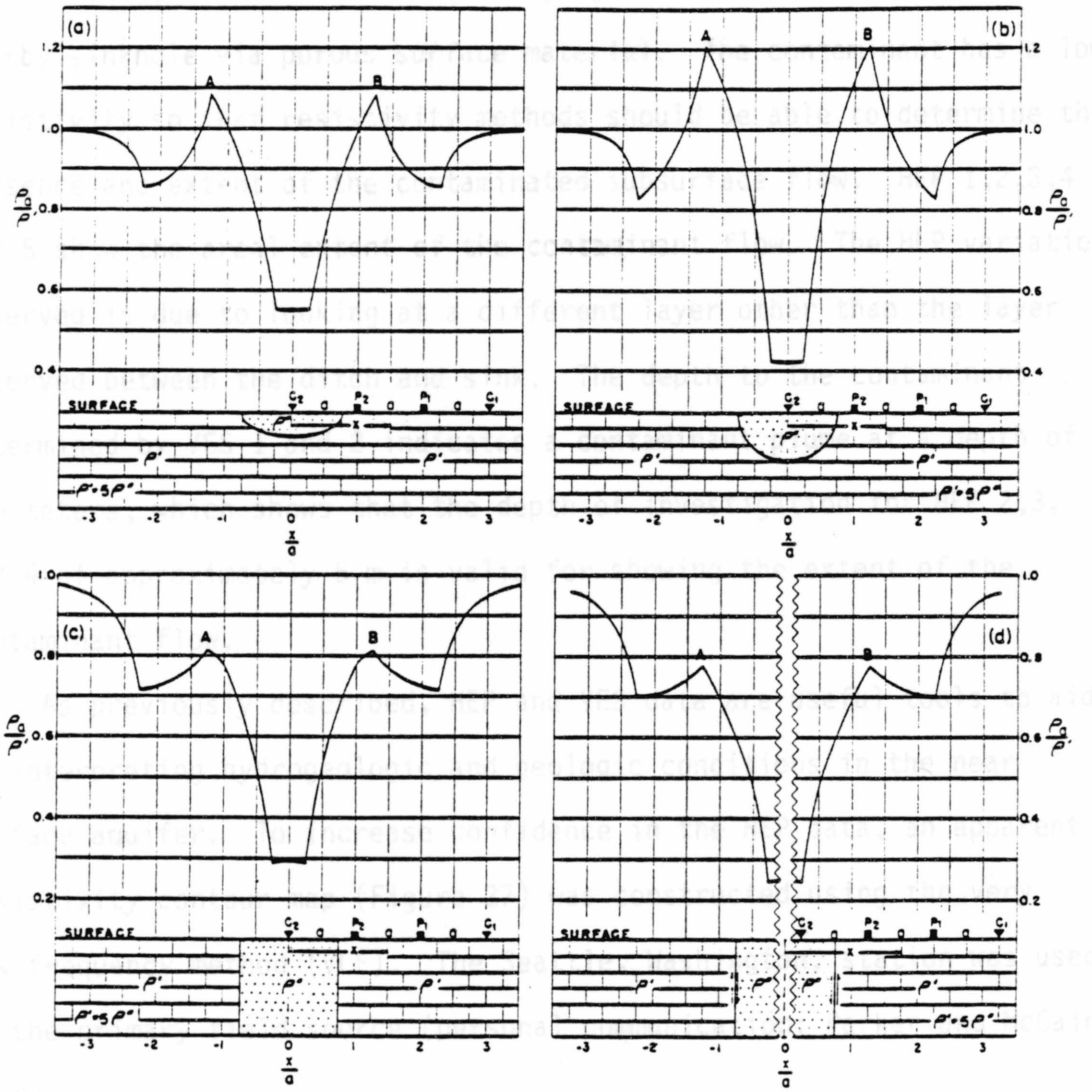


Figure 26. Comparison of theoretical horizontal resistivity profiles over (a) oblate hemispheroid, (b) hemisphere, (c) dike, and (d) pair of faults, Wenner configuration, width at surface $3a/_2$, $\rho''/\rho' = 1/5$ (from Cook, 1954).

It is important to realize that the high conductivity recharge from the ditch is one of the most important features detected by the VES and HEP data. The drainage ditch contaminated by runoff from an urban area is believed to be discharging conductive waters to a nearby sinkhole via porous surface material. The contaminant has a low resistivity so that resistivity methods should be able to determine the presence and extent of the contaminated subsurface flow. HEP 1,2,3,4 and 5 show the areal extent of the contaminant flow. The HEP variation observed is due to looking at a different layer other than the layer observed between the ditch and sink. The depth to the contaminant determined by VES 1 and 2 indicates a contaminant plume at a depth of 5-6 meters, which shows that the depth of investigation for HEP 2,3, and 4 of approximately 5 m is valid for showing the extent of the contaminant flow.

As previously described, HEP and VES data are useful tools to aid in interpreting hydrogeologic and geologic conditions in the near surface aquifer. To increase confidence in the HEP data, an apparent resistivity contour map (Figure 27) was constructed using the very low frequency method (VLF). The Seattle, Washington, station was used as the primary field source (personal communication; Parker and McCain, 1984).

The direction to the Seattle VLF station was determined with the EM-16R instrument and a baseline was established perpendicular to the station direction. As can be seen in Figure 27, the contour interval expands as resistivity increases. The VLF data agree reasonably well with the HEP and VES data. VLF values directly over the center of the sinkhole have resistivities of 11-25 ohm-m. This is represented

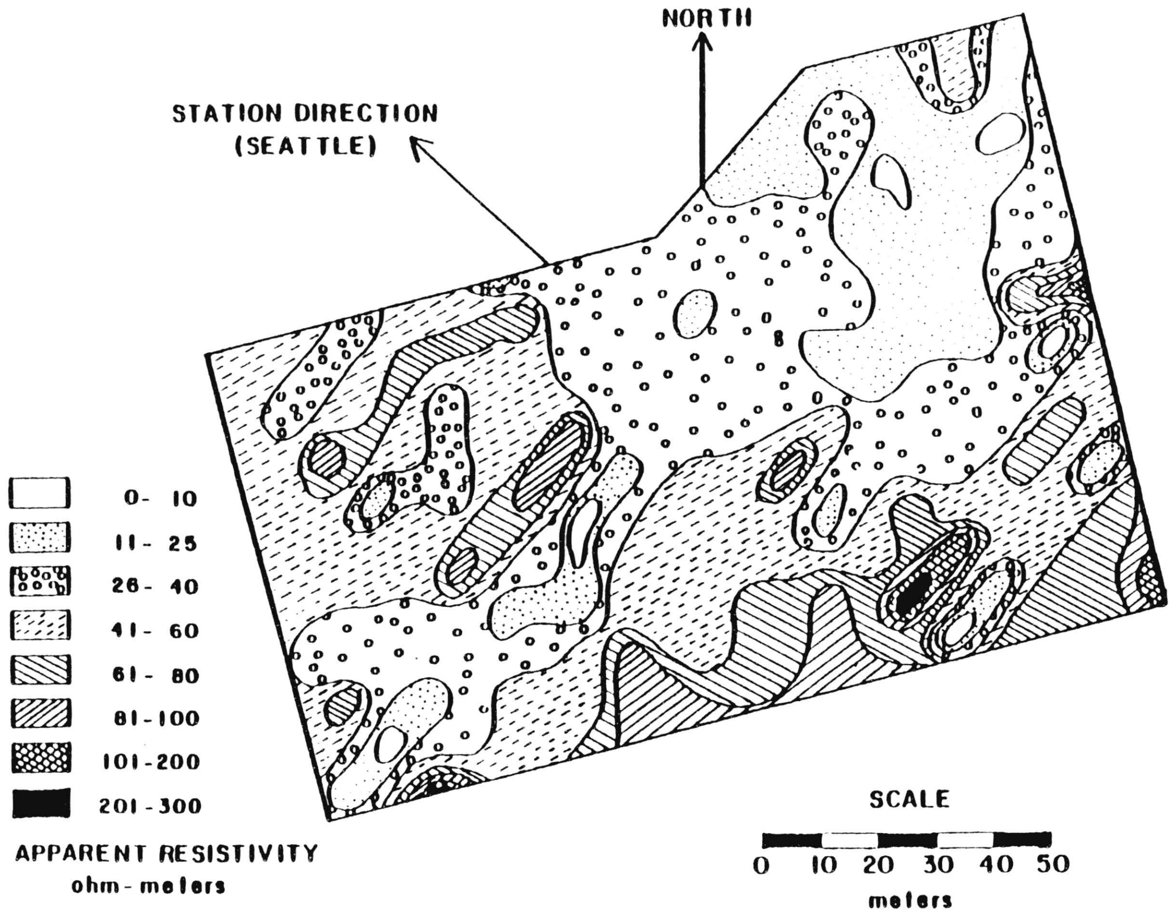


Figure 27. An apparent resistivity contour map obtained using VLF method (from Parker and McCain, 1984).

by the fine stippled pattern. These values are some of the lowest resistivities in the study area. Resistivities of 26-40 ohm-m surround the sinkhole in a roughly circular pattern as seen by an open dot pattern. An interpreted northeast-southwest trending fracture trace that bisects the sinkhole can be seen by the 26-40 ohm-m pattern becoming linear away from the sinkhole location. To the southwest and southeast of the sinkhole and fracture trace resistivity values increase. Northeast of the sinkhole the contaminant plume is indicated by low resistivity values of 11-25 ohm-m. The VLF data tends to confirm the previous interpretation of VES and HEP data that low resistivity values occur over the sinkhole with increasing bulk resistivity away from the sinkhole. The exception to this general relationship is low resistivity values due to a conductive plume of contaminants coming from the ditch northeast of the sinkhole.

Variation of the electrical conductivity of ground water is a function of the electrolyte concentration in the water if the porosity and lithology remain constant. Ground water conductivity measure-measurements for a one year period (Appendix J) for the open drainage ditch and ten monitor wells in the study area show an area of high-conductivity ground water near the drainage ditch, with fluid conductivities of 2180 micromhos/cm in March and 65 micromhos/cm in August. These data suggest contamination of the ground water with a highly conductive fluid for a distance of 120 m to the south and east of the open ditch and extending at least 300 m to the west adjacent to the ditch (personal communication; Kotsoll and Yarborough, 1983). The general flow of the most conductive water is in a south to southwest direction towards the sinkhole.

Geological and Hydrogeological Characteristics

A statigraphic column for the study area was constructed using soil borings in the northeast portion (Figure 19). These indicate a soil column which consists of an upper sand, and intermediate zones of slightly clayey sand to sandy clays underlain by limestone. There is a discontinuous layer within the fine sand layer at a depth of 1.5 to 2 meters. This horizon is characterized by iron-stained clays coating the sand grains and filling some interstitial spaces. This clay forms an argillic horizon, and was transported to the horizon by illuviation (Foth and Turk, 1972). Carr and Alverson (1959) interpreted the argillic horizon as a residuum of the underlying Tampa limestone. Evidence cited for their interpretation is: 1) presence of distorted and crenulated bedding plates in the argillic horizon from slumping and collapse of underlying strata, and 2) occurrence of fresh chert.

The upper Tampa limestone is characterized by zones of silicification. Dissolution of the limestone results in accumulation of insoluble residues. Presence of chert fragments within the clay overlying the Tampa limestone supports the idea that the clay is a residuum which has accumulated as a result of dissolution of the Tampa limestone (Parker, personal communication). The presence of a gleyed (mottled) argillic bed containing chert and limestone fragments recovered from bucket auger 20 at a depth of 5 m (Appendix F) is interpreted to be the residual argillic unit of Sinclair (1973).

The hydraulic conductivity (K) of unconsolidated and granular materials is primarily a function of size and shape of the component grains and their sorting (Sinclair, 1973). Sieve analysis was

performed on eleven samples of the unconsolidated sediments above the Tampa Limestone to determine their hydraulic conductivity.

Eight samples represent lithologic units composed entirely of sand or which contain significant amounts of sand (94% by weight). These eight samples represent the unconsolidated sands of the water-table aquifer. Three samples are predominantly clay and are representative of the semi-confining unit below the sand and above the Tampa limestone. Cumulative grain size curves were plotted for all samples (Appendix H). The steep slopes of the plots for the eight sand samples show that the unconsolidated sands are well-sorted. The well-sorted nature of these fine sands agrees with the interpretation of a shallow marine or beach/dune origin.

An uniformity coefficient value for each sand sample was determined from the graphs in Appendix H. For each sand sample the diameter of the percent finer taken at 60% (D_{60}) and at 10% (D_{10}) were read directly off the graph (Table 2). Hydraulic conductivity (K) of the unconsolidated sands was determined using the ratio $\frac{D_{60}}{D_{10}}$, the grain size (mm) of the percent finer value at 50% (D_{50}), and a hydraulic conductivity nomograph (Figure 22). For each sample, K is determined by plotting the D_{50} value against the appropriate uniformity coefficient curve. The hydraulic conductivity is read directly off on the left side of the nomograph. Hydraulic conductivity values determined for the sands range from 8.6 m/day to 34.5 m/day (Table 5).

Transmissivity for each sand unit was determined by multiplying the hydraulic conductivity by the thickness of each unit. Transmissivity values range from a low of 1.1 m^2/day for the clayey sand to a high of 10.3 m^2/day for the fine sand (Table 5).

Table 5. Hydraulic conductivity (K) and Transmissivity (T) values for unconsolidated surficial sediments obtained from sieve analysis.

Sample No.	Lithologic Unit	Thickness	Hydraulic Conductivity (m/day)	Transmissivity (m^2/day)
BA-1	Fine sand	0.25	34.56	8.64
BA-5	Silty Sand	0.25	20.7	5.2
BA-3	Silty Sand	0.13	19	2.5
BA-5	Fine Sand	0.66	15.6	10.3
BA-6	Fine Sand	0.38	14.7	5.6
BA-2	Very Fine Sand	0.13	11.23	1.5
BA-3	Clayey Sand	0.13	9.5	1.2
BA-7	Clayey Sand	.13	8.6	1.1

Combined sieve and hydrometer analysis was performed on the three samples composed primarily of clay (Appendix G). As stated above these samples are interpreted to be representative of the semi-confining bed below the water-table sands and silts. The maximum value for clay grain size was set at 0.005 mm. The average percentage of the clay component for the three samples is 57%, 34% for the sand component, and 9% for the silt component.

The hydraulic comductivity (K) for the confining clay unit in the study area is taken from previously published data (Sinclair, 1973). This value is an average hydraulic conductivity for the clay and is estimated to be $2x10^{-3}$m/day. The Floridan aquifer hydraulic conductivity is calculated by dividing the transmissivity of the Floridan aquifer, $1.2x10^{4}m^{2}$/day (Stewart _et al_., 1978), by its thickness of 300 m. A hydraulic conductivity value of 39 m/day for the Floridan aquifer is derived by this method.

The difference between the surficial water table head at ten monitor wells in the study area and the Floridan aquifer head (ΔH) was calculated for a twelve month period (Appendix K). The head values for the Floridan aquifer were measured at the three closest wells to the study area (well no. 4, ROMP 66, and ROMP 67). These values are from previously published data (Mycyk _et al_., 1983). For the surficial water table the average thickness of the confining clay units is defined as ΔL. The average thickness determined from soil borings is 6 meters. Recharge per unit area from the surficial aquifer to the Floridan aquifer is equal to the product of hydraulic conductivity and the ratio $\Delta H/\Delta L$. Horizontal flow in the Floridan aquifer is determined by dividing the potentiometric surface contour

interval (ΔH) by the distance between potentiometric contour lines (ΔL). The ratio obtained is the hydraulic gradient, and is defined as the rate of change of head per unit distance (Bates and Jackson, 1980). Two hydraulic gradient values were determined for the study area based on potentiometric contour maps prepared by the U.S. Geological Survey for 1984. For the month of May, 1984 the head loss in the Floridan Aquifer was 6.14 m over a horizontal distance of 4000 meters. Head loss for the month of September, 1984, was 8.54 m over a horizontal distance of 4160 meters. The resulting hydraulic gradients in the Floridan Aquifer for the months of May and September are 0.0016 and 0.002 respectively.

The percentage of the total area represented by geologic conditions at each monitor well was determined by the Theissen polygon method. Six polygon sectors were drawn to divide the study area into representative areas (Figure 28). Each polygon represents a geometrically weighted percentage of the total area. Lithologic percentages for each polygon were determined from soil borings and the geoelectric resistivity sections.

The polygon areas around wells 3 and 4 near the sinkhole represent sand columns with 90% and 85% sand, respectively for the sections above the limestone. Sand content of the surficial aquifer in the polygon areas not over or near the sinkhole is less than half the values of areas 3 and 4 (Table 6).

Retention Pond Effect on Floridan Aquifer

Quantitatively, the relationship between the hydrologic and geologic parameters can be used to assess the potential effect of a

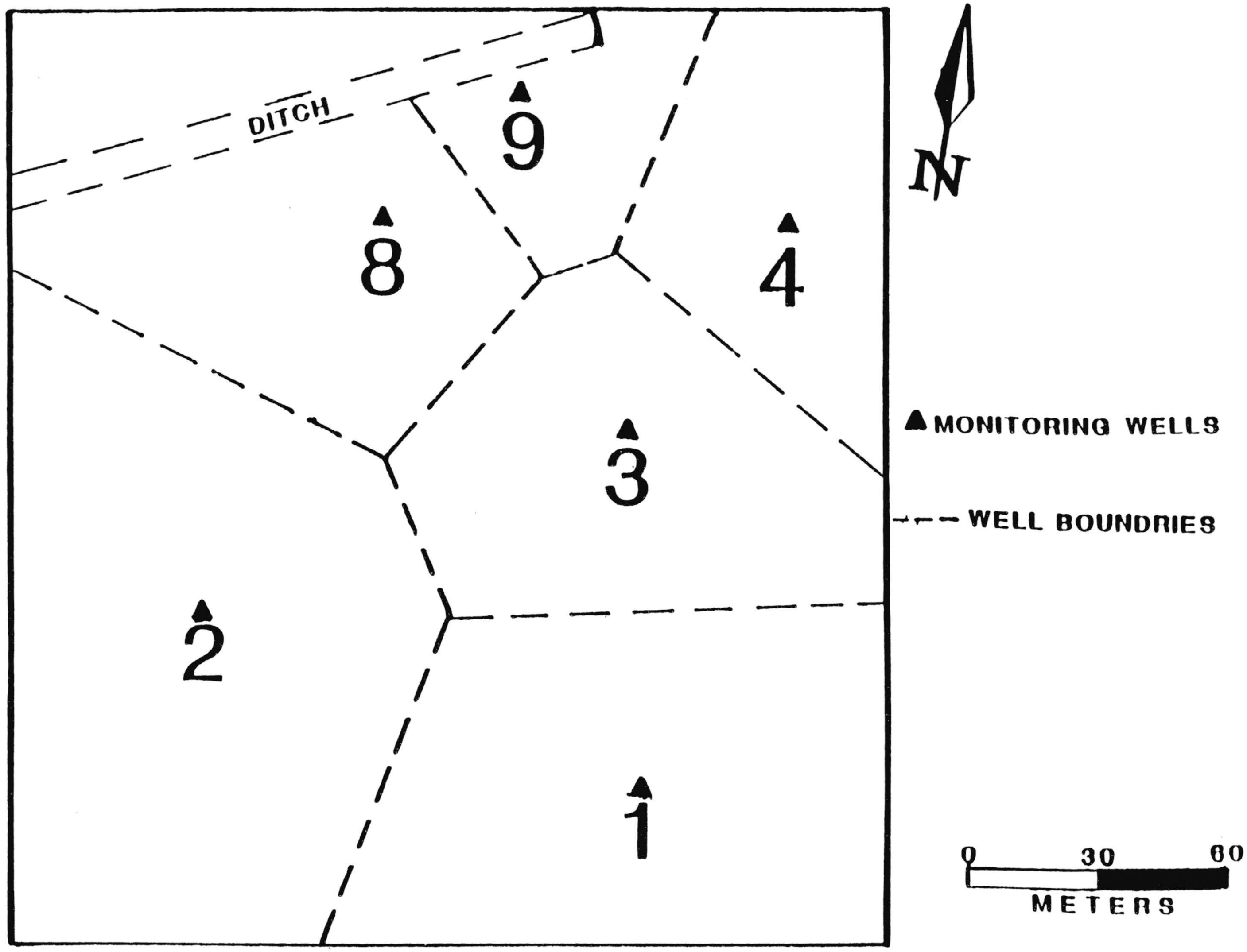


Figure 28. Six polygon sectors represented by geologic conditions at monitoring wells.

Table 6. The percentage of sand, silt and clay from polygon weighted method.

Well No.	Sand %	Silty, clayey %	Clay %	% of total area represented by geologic conditions at well	Weight (W)	Q/A (M/day)	$W(\overline{Q/A})$ (M/day)
1	45	14	41	15	0.15	$3X10^{-5}$	$4.5X10^{-6}$
2	46	15	39	13	0.13	$2X10^{-5}$	$2.6X10^{-6}$
3	90	7	3	26	0.26	$3X10^{-3}$	$780X10^{-6}$
4	85	10	5	25	0.25	$2X10^{-3}$	$500X10^{-6}$
8	40	30	30	11	0.11	$2X10^{-4}$	$22X10^{-6}$
9	35	32	33	10	0.10	$2X10^{-4}$	$20X10^{-6}$

$$\Sigma\ W(\overline{Q/A}) = 1329X10^{-6}\ \text{M/day.}$$

$$Q\ \text{surficial} = \Sigma\ W(\overline{Q/A})\ X\ \text{twice area of the pond} = 1329X10^{-6}X2X8X10^{4}$$

$$= 212\ M^{3}/\text{day.}$$

storm-water retention pond on the water quality in north-central Hillsborough County, Florida, as follows:

1. The effect of storm-water runoff on the retention pond.

   This effect is determined and controlled primarily by evaporation, precipitation and head difference (ΔH) between the retention pond and the water table. The net change in the storage (Δs) for the retention pond for a twelve month period was determined to be zero (Table 3). With Δs being zero the difference between the discharge from the drainage basin (R) and evaporation (E) is the deficit (Q). The deficit value is computed by the following relationship:

$$\Delta s = R - E - Q \qquad (3)$$

   Solving for Q gives the value 1178 m^3/day. This is the amount of water that is recharged per day to the shallow aquifer by the retention pond. Throughout the year, the level of the pond and ditch was above the level of the water table.

2. The relationship between surficial and Floridan Aquifer.

   This relationship is controlled primarily by head difference (ΔH) period between the surficial water table and the Floridan Aquifer for the twelve month period, and by the average hydraulic conductivity (K) and thickness of the confining clay unit. The amount of recharge (Q) per unit area from the surficial aquifer to the Floridan aquifer within each polygon is given by the equation:

$$Q/A_p = K\,\frac{\Delta H}{\Delta L} \qquad (4)$$

where:

K = hydraulic conductivity of clay layer (m/day)

ΔH = average head difference for 12 months between surficial and Floridan (m)

ΔL = clay thickness (m)

A = area of polygon (m^2)

The average recharge per unit area is determined by weighing the polygon recharge rates by their respective areas, expressed decimal fraction of the total area (Table 6). The equation used is

$$(\overline{Q/A}) = \frac{\Sigma\ W_n(Q/A_p)_n}{\Sigma\ W_n} \qquad (5)$$

where

W_n = fractional percent of total area represented by area of nth polygon ($\Sigma W_n=1$)

$(Q/A_p)_n$ = recharge per unit area of nth polygon

$(\overline{Q/A})$ = average recharge per unit area.

For the study area the average recharge per unit area is 212 M^3/day. This amount of water is calculated by the following equation:

$$Q_{surficial} = (\overline{Q/A})A_s \qquad (6)$$

where:

A_s = representative recharge area, taken to be twice the area of the pond.

3. Horizontal flow in the Floridan Aquifer.

This is controlled primarily by the hydraulic gradient ($\frac{\Delta H}{\Delta L}$) and the hydraulic conductivity (K) of the Floridan Aquifer. The calculated hydraulic gradient for the Floridan Aquifer is 0.002. Hydraulic conductivity is estimated to be 39 m/day. The area perpendicular to flow is taken to be the length of 560 m of a representative rectangular basin with an area twice that of the pond times the depth to where flow is essentially horizontal in the Floridan Aquifer (30 m; Figure 29). The amount of horizontal water flow in the Floridan is determined by Darcy's Law. The amount of water that moves horizontally below the pond to a depth of 30 m is 1208 m^3/day.

The total amount of water moving vertically and horizontally within the block of Figure 29 ($Q_{pond} + Q_{surficial} + Q_{Floridan}$) down to 30 meters is computed to be 2598 m^3/day. The dilution factor is used to assess the potential effect of the storm-water retention pond on the water quality in the Floridan aquifer. The dilution factor is the fractional percent of Q_{out} represented by Q_{pond}. The higher the dilution factor the greater the effect of the pond on local ground water quality. This factor is computed using the following formula:

$$\frac{Q_{pond}}{Q_{out}} \frac{(1178)}{(2598)} = 0.45 \qquad (7)$$

This is an average value for the twelve month period. The dilution factor was also computed for May and September, and is 0.37 and 0.57; respectively. This indicates that the pond recharge in the dry season (May) has a dilution factor lower than in the wet season (September).

The result of an increase in the amount of precipitation during the wet season is an increase in both Q_{pond} and Q_{out}. Yet, during the wet season the rate of increase for Q_{pond} is more than the rate of increase for Q_{out}. This results in an increase in the dilution factor during the wet season (Table 7).

SUMMARY AND CONCLUSIONS

Geoelectric profiles reveal the occurrence of four distinct geoelectric layers within the study area. Very high resistivity response, usually exceeding 10,000 ohm-m at the surface, is due to clean, unsaturated sands. This geoelectric layer is usually 3 m thick. High resistivity response characterizes the second geoelectric layer. Within this zone, sediments are saturated sand intermixed with silts and clays. Beneath the second geoelectric layer is a third geoelectric layer, which commonly has the lowest resistivity response (15-65 ohm-m). This layer is primarily composed of clay. A fourth geoelectric layer is represented by a moderate resistivity unit (74-214 ohm-m). This layer represents the upper portion of the Tampa limestone. Resistivity response becomes variable and resistivities are lower throughout the measured section in the north and northeast sections of the study area. Higher and more consistent resistivity values occur in the southeast and west regions of the study area.

Closely-spaced, vertical electric soundings yield the most information on the lithology and thickness of the geologic units. The horizontal electric profiles are sensitive to lateral changes in resistivity and locate a resistivity low associated with the contaminant plume between the ditch and the sinkhole. The flow of the most conductive water is toward an area of low surface and low water table elevations.

Lithologic data have shown that there is a large difference in particle size distribution among the analyzed samples. This difference explains the extremes in vertical hydraulic conductivity. The variability in the values of hydraulic conductivity determined from sieve and hydrometer analysis (8.6 m/day for the clayey sand to 34.56 m/day for fine sand) makes the sieve and hydrometer analysis a questionable methodology for accurately determining hydrologic properties. The values of vertical hydraulic conductivity thus calculated vary widely but are useful in calculating the rate of recharge to the Floridan aquifer from the overlying surficial aquifer.

The purpose of this study is to determine the relationship between a storm-water retention pond and the Floridan Aquifer. To better understand this effect a block diagram is shown in Figure 29 and generalized data is given in Table 7. This relationship is as follows: when rainfall infiltrates into the surficial aquifer and recharges the water table, it moves horizontally through the aquifer from areas of higher water table elevations near the ditch (Well 9) to lower areas (Wells 1 and 2). In general, ground water in the study area slopes away from the ditch at a rate of 25.2 m/km. This slope is toward the lowest portion of the study area (sinkhole) indicating that the ditch is recharging the surficial aquifer. The flow direction of the water table south of the ditch is from the north-east toward the southwest. This is parallel to the direction of an interpreted fracture trace in the study area.

Recharge to the Floridan Aquifer ceases below 30 meters depth and becomes horizontal flow. Recharge from the water-table aquifer is downward into the Floridan Aquifer through sinkholes that have

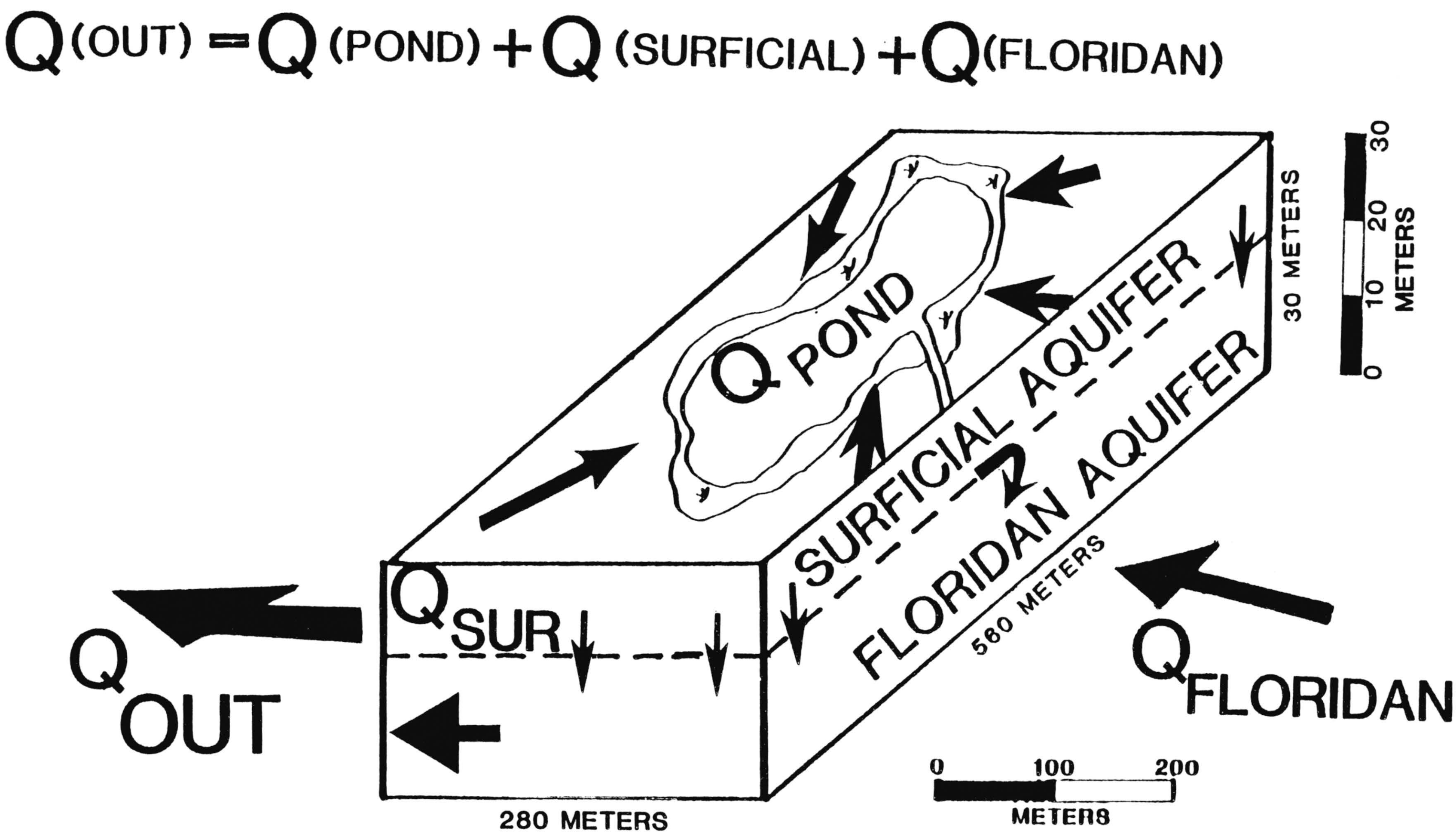


Figure 29. Diagram of the pond, surficial, and Floridan aquifers within the representative volume used for Q calculations. The area of the block is twice the area of the pond.

Table 7. Generalized Effect of the Storm Water Retention Pond on the Surficial and Floridan Aquifers.

Month	Q Pond m^3/day	Q Surficial m^3/day	Q Floridan m^3/day	Q Out m^3/day	Dilution $\frac{Q\ Pond}{Q\ Out}$
May	745	156	1074	1975	0.37
September	2230	340	1342	3912	0.57
Average of the 12 Months	1178	212	1208	2598	0.45

direct hydraulic connection with the aquifer. Quantitatively, the potential effect of the storm water retention pond on the water quality is indicated by the dilution factor. The dilution factor indicates the fractional percent contributed by the retention pond to the total ground-water outflow from the block. This factor was computed for May and September and was found to be 0.37 and 0.57 respectively. This indicates that the retention pond in the dry season (May) has a dilution factor lower than in the wet season (September). This is due to the increase in the amount of water in the pond in the wet season.

Further investigation by other geophysical methods of the effect of water-table recharge to the semi-confined Floridan aquifer is warranted in order to map the subsurface topography of the Tampa limestone and thickness of the overlying clay. The relation ships between sinkhole development, depth to the top of the Tampa limestone, and recharge of the Floridan Aquifer through sinkholes are complex and relatively little is known. Yet, these are vital relationships that must be thoroughly understood in order that ground water quality not be adversely affected by storm water management.

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APPENDIXES

APPENDIX A: VERTICAL ELECTRICAL SOUNDING REDUCED FIELD DATA FROM AN AUTOMATIC INVERSION PROGRAM BY ZHODY AND BISDORF (1975).

VES #1 N260 at Well #4

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	1863.000
1.500	2400.000
2.000	2800.000
3.000	3000.000
4.000	2500.000
6.000	1600.000
8.000	1120.000
10.000	492.000
15.000	44.000
20.000	33.000
30.000	35.000
40.000	42.000
60.000	56.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	1867.3936
0.0468	0.1468	1872.2009
0.0687	0.2154	1850.2007
0.1008	0.3162	1807.5850
0.1479	0.4641	1796.6724
0.2167	0.6806	1976.9617
0.3069	0.9877	2617.8813
0.4489	1.4366	3685.9053
0.4639	1.9005	3904.1638
0.9995	2.9000	2884.6687
0.9334	3.8334	1612.2769
1.3154	5.1487	546.8833
0.3062	5.4549	52.6667
0.6911	6.1460	51.3244
0.2933	6.4393	2.1110
1.4535	7.8928	4.1164
9.9955	17.8883	40.2549
8.3055	26.1938	80.2606

VES #2 N280 at Well #3

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	2951.000
1.500	2945.000
2.000	2771.000
3.000	1390.000
4.000	743.000
6.000	239.000
8.000	80.000
10.000	48.000
15.000	43.000
20.000	43.500
30.000	50.000
40.000	56.000
60.000	75.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	2855.9485
0.0467	0.1467	2846.7742
0.0687	0.2154	2837.4548
0.1008	0.3162	2832.3098
0.1479	0.4641	2868.2244
0.2170	0.6811	2957.8384
0.3184	0.9996	3031.6929
0.4993	1.4989	2733.8198
0.4799	1.9788	1876.4873
0.7407	2.7195	734.2781
0.2088	2.9283	85.0111
0.3953	3.3236	19.7780
1.0414	4.3650	11.0749
0.7938	5.1587	5.2529
4.8597	10.0184	49.7424
4.9993	15.0177	41.6578
9.3791	24.3968	63.7425
6.6355	31.0323	139.8762

VES #3 N313 at Well No. 1

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	11870.000
1.500	14090.000
2.000	16440.000
3.000	15920.000
5.000	13120.000
7.000	9160.000
10.000	3970.000
15.000	800.000
20.000	233.000
30.000	99.000
40.000	84.000
60.000	125.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	11872.9219
0.0468	0.1468	11938.7266
0.0687	0.2154	11905.9727
0.1008	0.3162	11736.0195
0.1479	0.4641	11537.3594
0.2171	0.6813	11833.3125
0.3159	0.9971	13846.3984
0.4752	1.4723	18334.0391
0.4715	1.9438	20939.2382
0.9929	2.9367	17927.3555
1.9109	4.8477	9827.5977
1.4473	6.2949	3743.1086
0.8908	7.1857	656.6208
1.3226	8.5083	148.2077
2.3937	10.9020	49.4420
0.2959	11.1979	0.7946
7.3993	18.5972	174.2605

VES #4 N256

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	2000.000
1.500	1760.000
2.000	1530.000
3.000	780.000
5.000	280.000
7.000	130.000
10.000	60.000
15.000	40.000
20.000	40.000
30.000	52.000
40.000	60.000
60.000	75.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	2079.2346
0.0468	0.1468	2080.8840
0.0686	0.2153	2069.0190
0.1008	0.3161	2061.1545
0.1479	0.4641	2077.7720
0.2171	0.6811	2129.8730
0.3183	0.9994	2225.6479
0.4995	1.4989	2005.0110
0.4721	1.9710	1267.3889
0.7224	2.6934	497.6963
0.9454	3.6387	139.2777
1.4826	5.1214	159.8680
1.6156	6.7369	62.1961
0.8849	7.6218	4.0716
3.0158	10.6376	11.9976
8.2373	18.8749	84.1727
6.7778	25.6527	140.7888

VES #5 N45E at Well #2

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	21590.000
1.500	21850.000
2.000	21370.000
3.000	17870.000
5.000	10770.000
7.000	6060.000
10.000	3200.000
15.000	710.000
20.000	158.000
30.000	69.000
40.000	75.000
60.000	100.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	21047.5312
0.0467	0.1467	20964.6875
0.0687	0.2154	20862.4414
0.1008	0.3162	20704.5117
0.1479	0.4641	20747.4648
0.2171	0.6812	21412.1445
0.3178	0.9990	23049.3164
0.4976	1.4966	24417.6094
0.5000	1.9966	22401.0078
0.9728	2.9694	15586.6914
1.5819	4.5512	6238.8945
1.1179	5.6691	2201.4636
1.5483	7.2174	1185.8345
2.3131	9.5305	565.8430
2.4903	12.0208	95.2589
2.1600	14.1807	2.9422
5.7920	19.9727	7.1668

VES #6 N280

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	3170.000
1.500	3770.000
2.000	3450.000
3.000	2440.000
5.000	2700.000
7.000	2170.000
10.000	1800.000
15.000	410.000
20.000	150.000
30.000	120.000
40.000	130.000
60.000	190.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	3173.5359
0.0468	0.1468	3167.8213
0.0687	0.2154	3151.4468
0.1008	0.3162	3143.5959
0.1479	0.4641	3192.8401
0.2169	0.6810	3369.4719
0.3169	0.9979	3673.1174
0.4996	1.4975	3534.8479
0.4957	1.9932	2817.4543
0.9667	2.9599	2167.3376
1.9535	4.9134	1978.3921
1.9427	6.8561	1696.0498
2.5310	9.3871	883.4851
1.4741	10.8612	111.4699
1.3028	12.1640	29.7819
1.0317	13.1957	6.2790
9.1709	22.3666	214.0513

VES #7 N300 at The Botanical Garden

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	2420.000
1.500	3080.000
2.000	3340.000
3.000	3390.000
5.000	2650.000
7.000	2040.000
10.000	1170.000
15.000	315.000
20.000	120.000
30.000	88.000
40.000	92.000
60.000	100.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	2423.5439
0.0467	0.1467	2414.9861
0.0687	0.2154	2393.2141
0.1008	0.3162	2355.9146
0.1479	0.4641	2353.0081
0.2169	0.6810	2503.3225
0.3136	0.9946	3007.9316
0.4746	1.4693	3851.7244
0.4773	1.9466	4194.4570
0.9959	2.9425	3586.6301
1.9210	4.8635	2087.2292
1.5503	6.4139	905.9089
1.3312	7.7451	244.4079
2.2074	9.9525	79.2225
1.3745	11.3270	16.7719
4.8974	16.2243	23.0388
9.8874	26.1117	107.7365

VES #8 N270 at Well No. 22

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	10520.000
1.500	10840.000
2.000	10220.000
3.000	8800.000
5.000	5170.000
7.000	2770.000
10.000	1016.000
15.000	188.000
20.000	98.000
30.000	80.000
40.000	80.000
60.000	94.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	10155.7344
0.0468	0.1468	10170.4844
0.0686	0.2153	10100.8164
0.1008	0.3161	10017.4258
0.1479	0.4640	10005.3086
0.2171	0.6811	10415.7539
0.3166	0.9976	11725.9805
0.4926	1.4902	13156.7930
0.4985	1.9887	12505.3437
0.9888	2.9775	9233.0312
1.6602	4.6377	3868.3193
0.8193	5.4570	792.8672
1.2228	6.6798	267.7803
2.8059	9.4857	64.9952
2.8497	12.3354	17.1685
9.1559	21.4913	47.6626
9.9987	31.4900	74.9940

VES #9 N353 at Well No. 2

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	24670.000
1.500	28030.000
2.000	24240.000
3.000	19600.000
5.000	11910.000
7.000	5770.000
10.000	2350.000
15.000	440.000
20.000	126.000
30.000	94.000
40.000	75.000
60.000	90.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	22339.7930
0.0467	0.1467	22273.3906
0.0687	0.2154	22004.1094
0.1008	0.3162	21753.2773
0.1479	0.4641	22225.7266
0.2160	0.6801	25063.7852
0.3084	0.9885	31415.2305
0.4863	1.4748	33885.3086
0.4998	1.9746	27019.5469
0.9562	2.9308	17339.9727
1.6477	4.5785	8273.2344
1.2379	5.8164	3238.3203
0.8200	6.6365	640.2434
0.6597	7.2961	63.1312
1.4398	8.7359	15.4402
4.2110	12.9469	20.6973
9.8223	22.7692	120.7934

VES #10 N275 at the University Square Mall Lake

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	190.000
1.500	250.000
2.000	250.000
3.000	190.000
5.000	150.000
7.000	110.000
10.000	60.000
15.000	50.000
20.000	60.000
30.000	70.000
40.000	75.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	107.0208
0.0467	0.1467	203.0252
0.0686	0.2153	99.4113
0.1007	0.3161	107.6590
0.1408	0.4569	153.5780
0.1686	0.6254	282.9800
0.2340	0.8594	396.7805
0.4533	1.3127	336.7122
0.4949	1.8077	273.6384
0.9977	2.8054	220.8650
1.8690	4.6744	126.8338
1.3285	6.0028	43.6168
1.3581	7.3610	15.3280
4.3203	11.6813	28.8366
4.5211	16.2024	85.3183
8.7049	24.9073	109.5764

VES #11 N2

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	680.000
1.500	620.000
2.000	600.000
3.000	470.000
5.000	230.000
7.000	120.000
10.000	40.000
15.000	16.000
20.000	13.000
30.000	17.000
40.000	22.000
60.000	30.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.1000	0.1000	704.5005
0.0468	0.1468	704.9817
0.0687	0.2154	705.5803
0.1008	0.3162	705.2292
0.1478	0.4640	702.9187
0.2171	0.6812	698.8579
0.3186	0.9998	681.6223
0.4997	1.4995	663.8730
0.4988	1.9983	627.8406
0.9767	2.9749	477.1206
1.5561	4.5310	180.0820
0.4978	5.0288	21.6051
0.6684	5.6972	5.1867
2.8773	8.5745	2.6646
4.6940	13.2685	7.1316
6.9646	20.2330	30.4269
5.8034	26.0364	49.8722

VES #12 N33E at The Botanical Gardens

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	10440.000
1.500	12440.000
2.000	15330.000
3.000	16120.000
5.000	12520.000
7.000	9690.000
10.000	6110.000
15.000	2650.000
20.000	770.000
30.000	140.000
40.000	125.000
60.000	175.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.0900	0.0900	8356.1133
0.0421	0.1321	8399.0742
0.0618	0.1939	8548.2422
0.0907	0.2846	8507.2266
0.1330	0.4176	7924.6016
0.1950	0.6126	7593.3750
0.2797	0.8922	10579.7187
0.3279	1.2201	23654.0625
0.2806	1.5007	37389.6328
0.8108	2.3115	25484.8477
1.7598	4.0713	12210.8164
1.5347	5.6060	6281.3594
2.1222	7.7283	3902.3228
3.1433	10.8715	2094.1963
1.4686	12.3402	453.5381
3.3250	15.6651	41.4858
3.4931	19.1582	7.1679

VES #13 N7 at Botanical Gardens

A-Spacing (meters)	Observed Response (ohm-meters)
1.000	2620.000
1.500	2430.000
2.000	2280.000
3.000	1890.000
5.000	1120.000
7.000	519.000
10.000	280.000
15.000	160.000
20.000	150.000
30.000	110.000
40.000	92.000
60.000	75.000
80.000	100.000

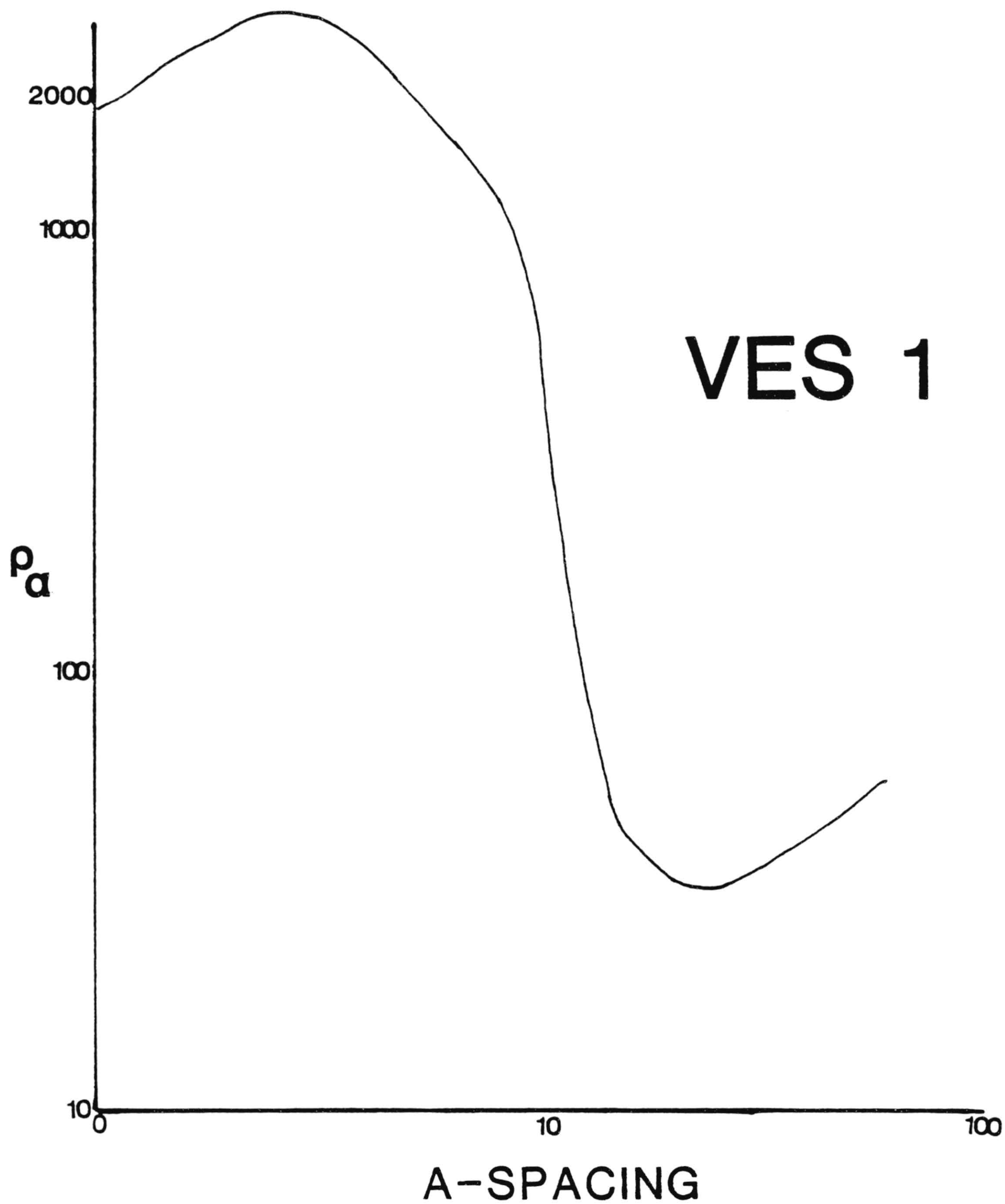
Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.0800	0.0800	2751.0762
0.0374	0.1174	2737.2742
0.0549	0.1723	2733.3154
0.0806	0.2529	2759.4707
0.1183	0.3712	2806.8352
0.1737	0.5449	2754.0349
0.2544	0.7933	2523.3577
0.3987	1.1980	2509.5896
0.3999	1.5980	2535.3967
0.7996	2.3975	2466.7275
1.4705	3.8680	1277.8701
0.5496	4.4176	168.8457
0.6946	5.1125	41.0331
2.6692	7.7817	83.0771
1.8962	9.6779	1002.0933
7.3075	16.9854	144.6107
3.2127	20.1981	16.1709
0.9830	21.1811	1.1896

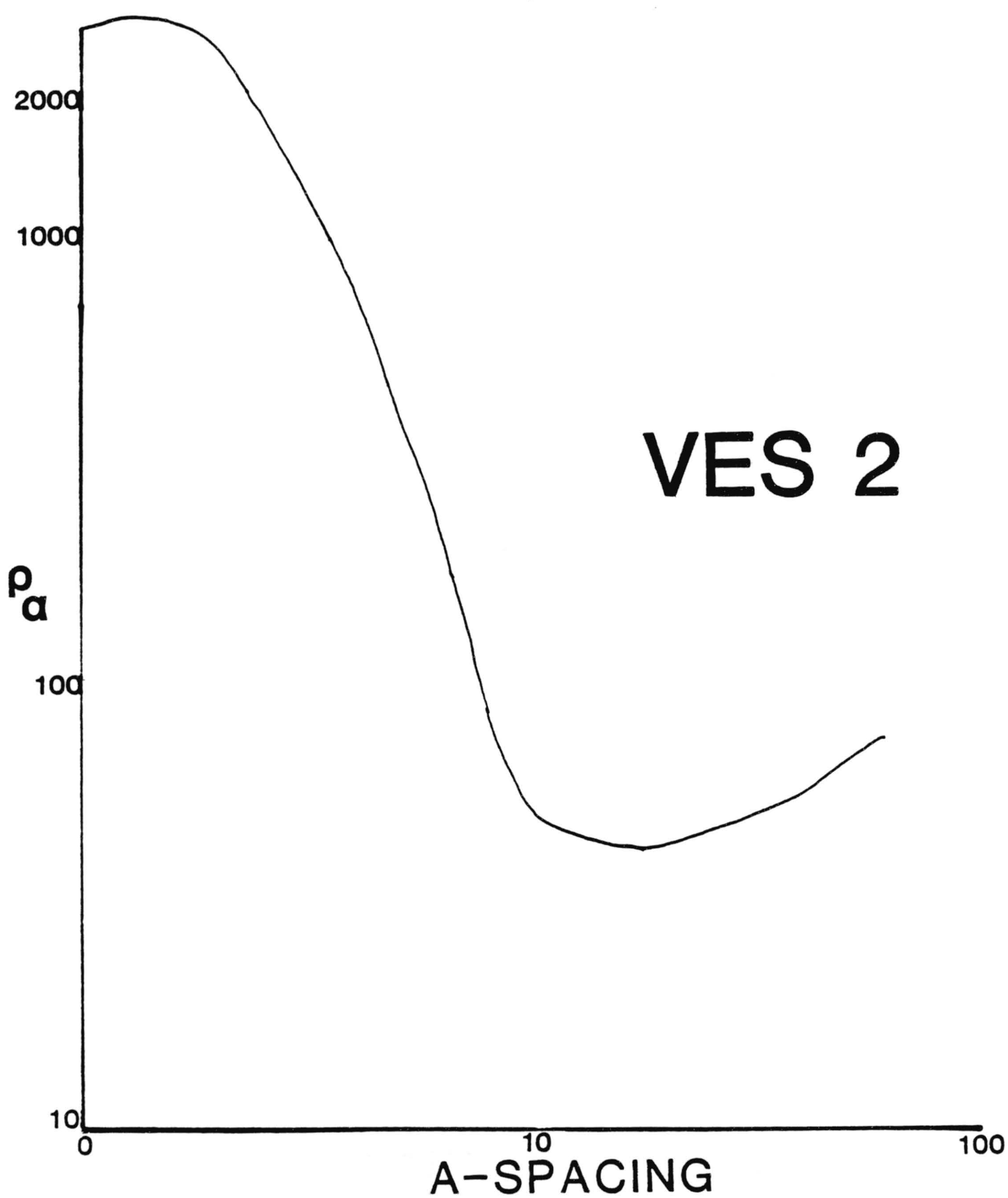
VES #14 N8

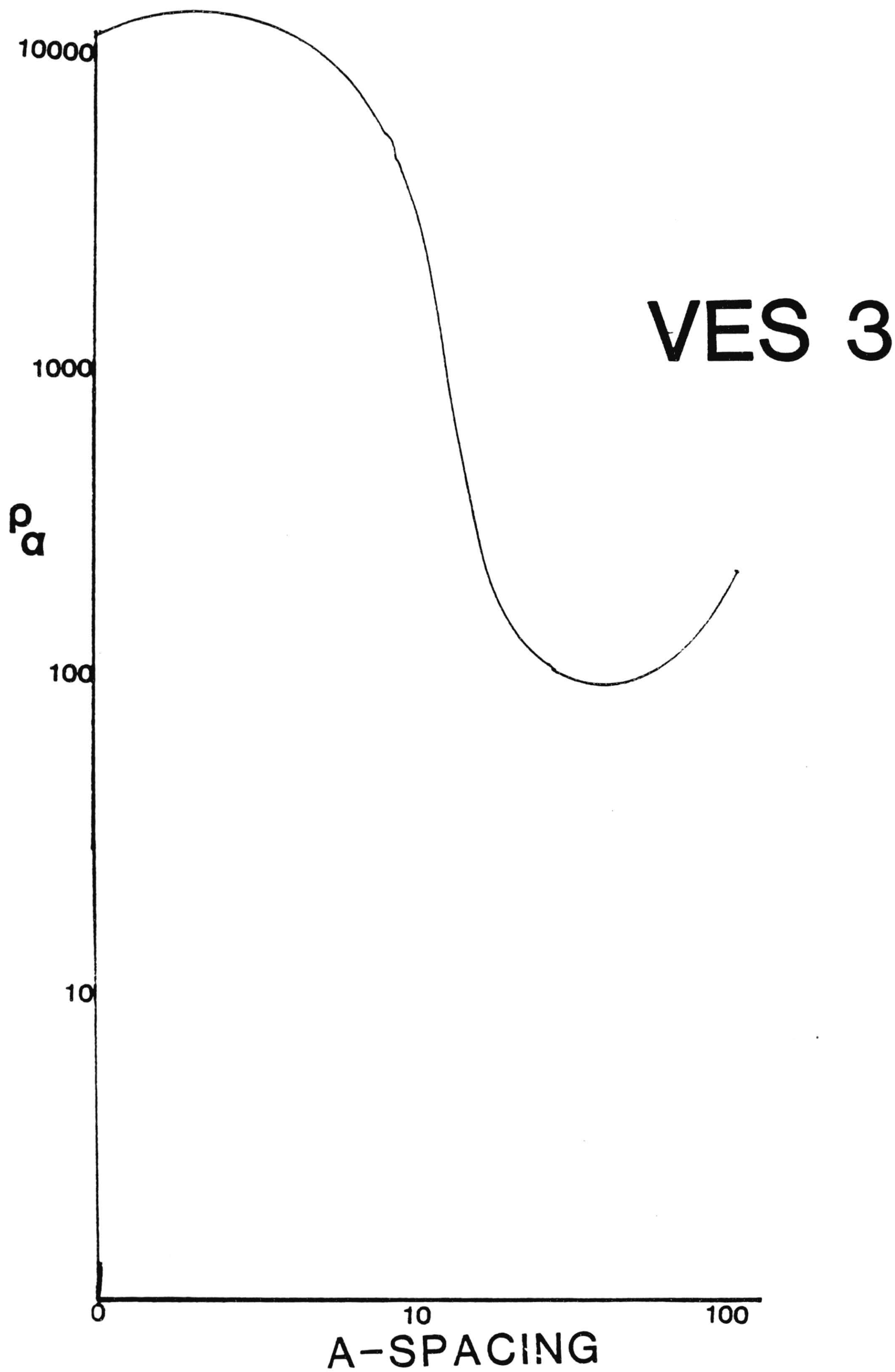
A-Spacing (meters)	Observed Response (ohm-meters)
1.000	13030.000
1.500	14200.000
2.000	15360.000
3.000	14300.000
5.000	9500.000
7.000	5000.000
10.000	2550.000
15.000	710.000
20.000	170.000
30.000	120.000
40.000	100.000
60.000	140.000

Thickness (meters)	Depth (meters)	Resistivity (ohm-meters)
0.0900	0.0900	11839.1719
0.0421	0.1321	11940.0547
0.0618	0.1939	12026.5039
0.0907	0.2846	11898.9102
0.1331	0.4176	11446.6133
0.1953	0.6129	11190.4219
0.2854	0.8983	13097.1484
0.4161	1.3144	19579.3789
0.3960	1.7104	25359.1875
0.8818	2.5922	20659.4219
1.6473	4.2395	8658.3838
1.1314	5.3709	2837.9480
1.3314	6.7024	1222.0281
3.0147	9.7171	1145.0862
1.5933	11.3104	292.0691
3.3167	14.6271	24.2263
2.5404	17.1675	7.8583

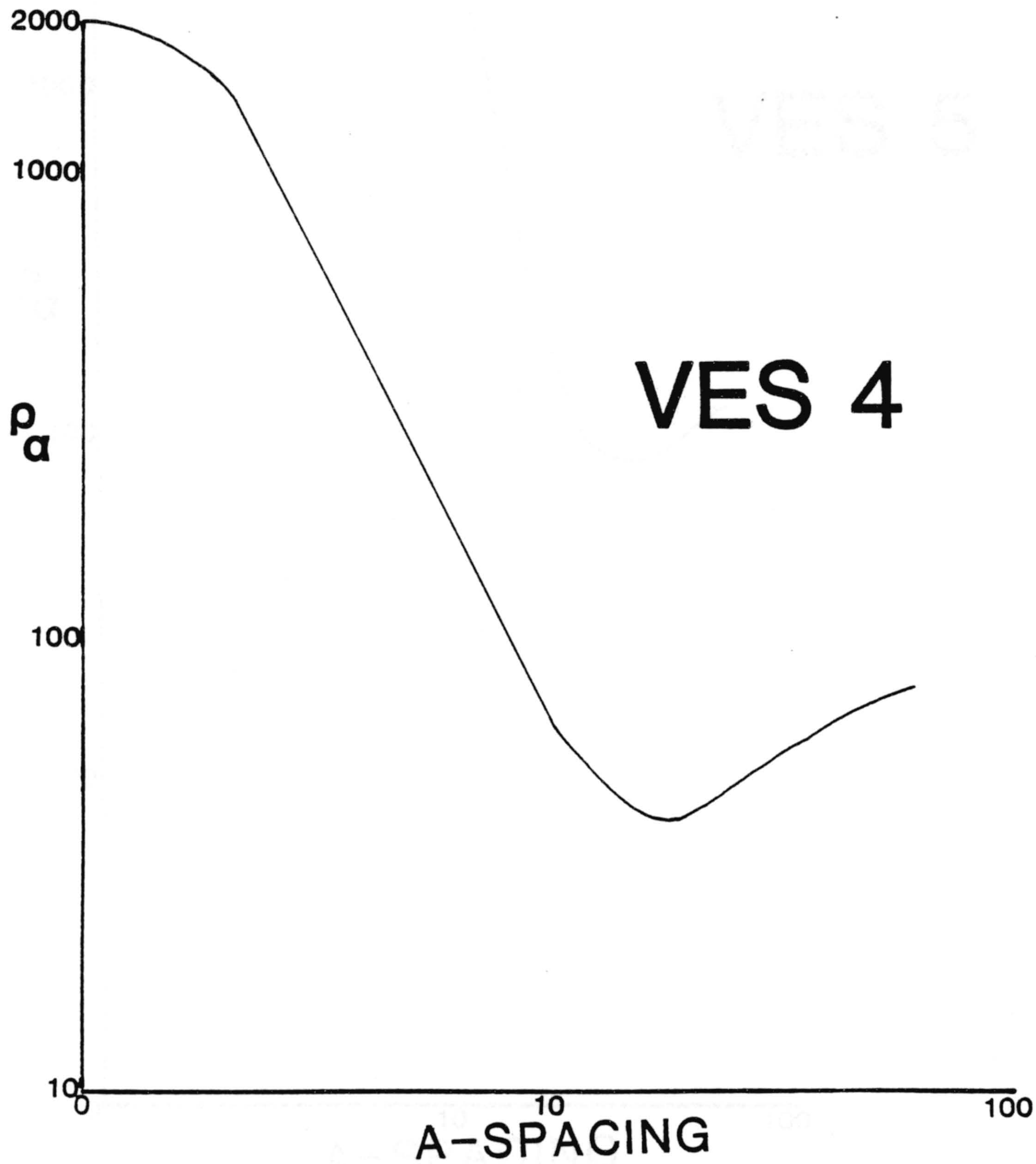
APPENDIX B: FOURTEEN VERTICAL ELECTRIC SOUNDING CURVES PLOTTED AS RESISTIVITY (OHM-METERS) VERSUS A-SPACING.

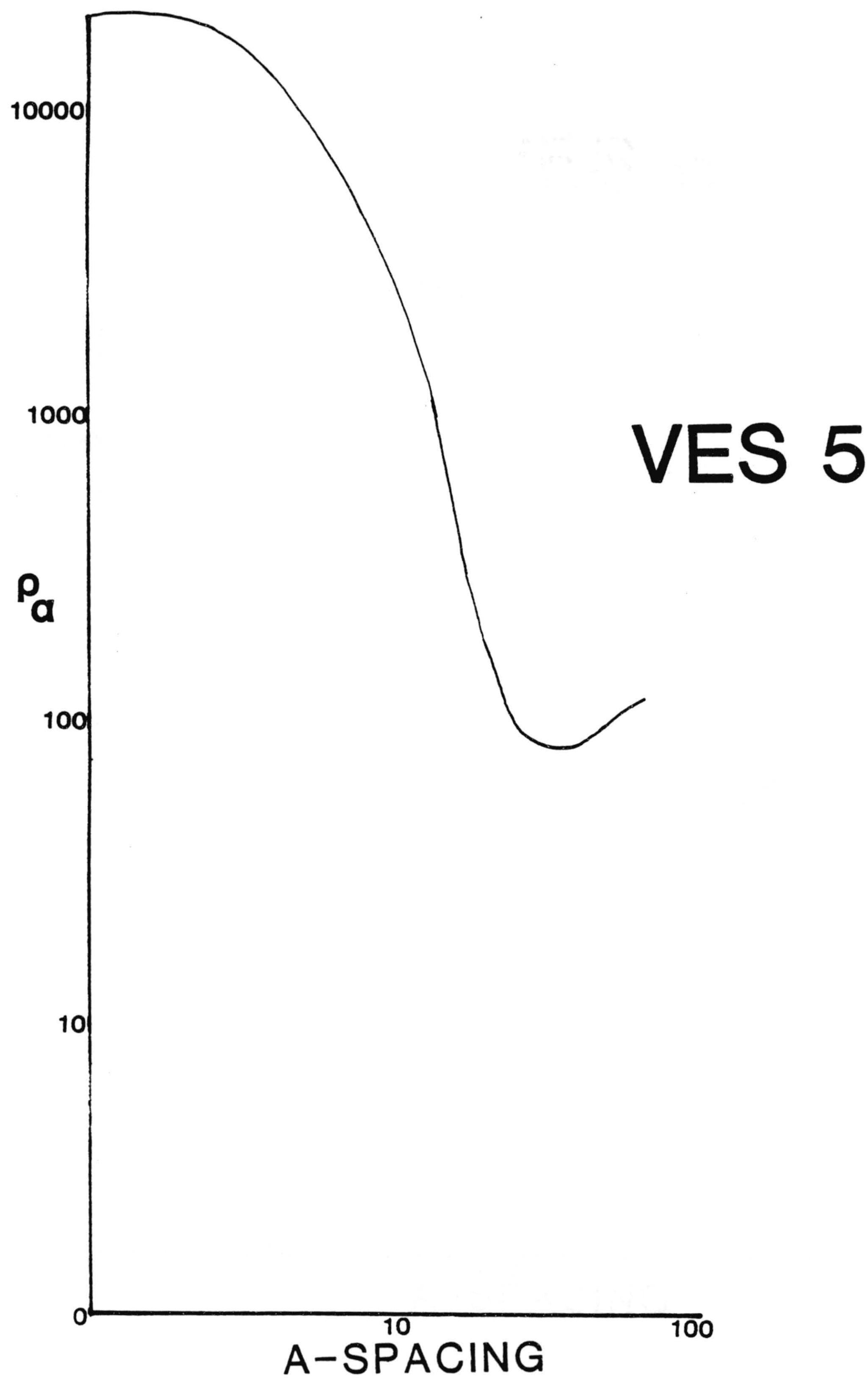



VES 2
2000
1000
100
10
ρ_a
0
10
100
A-SPACING

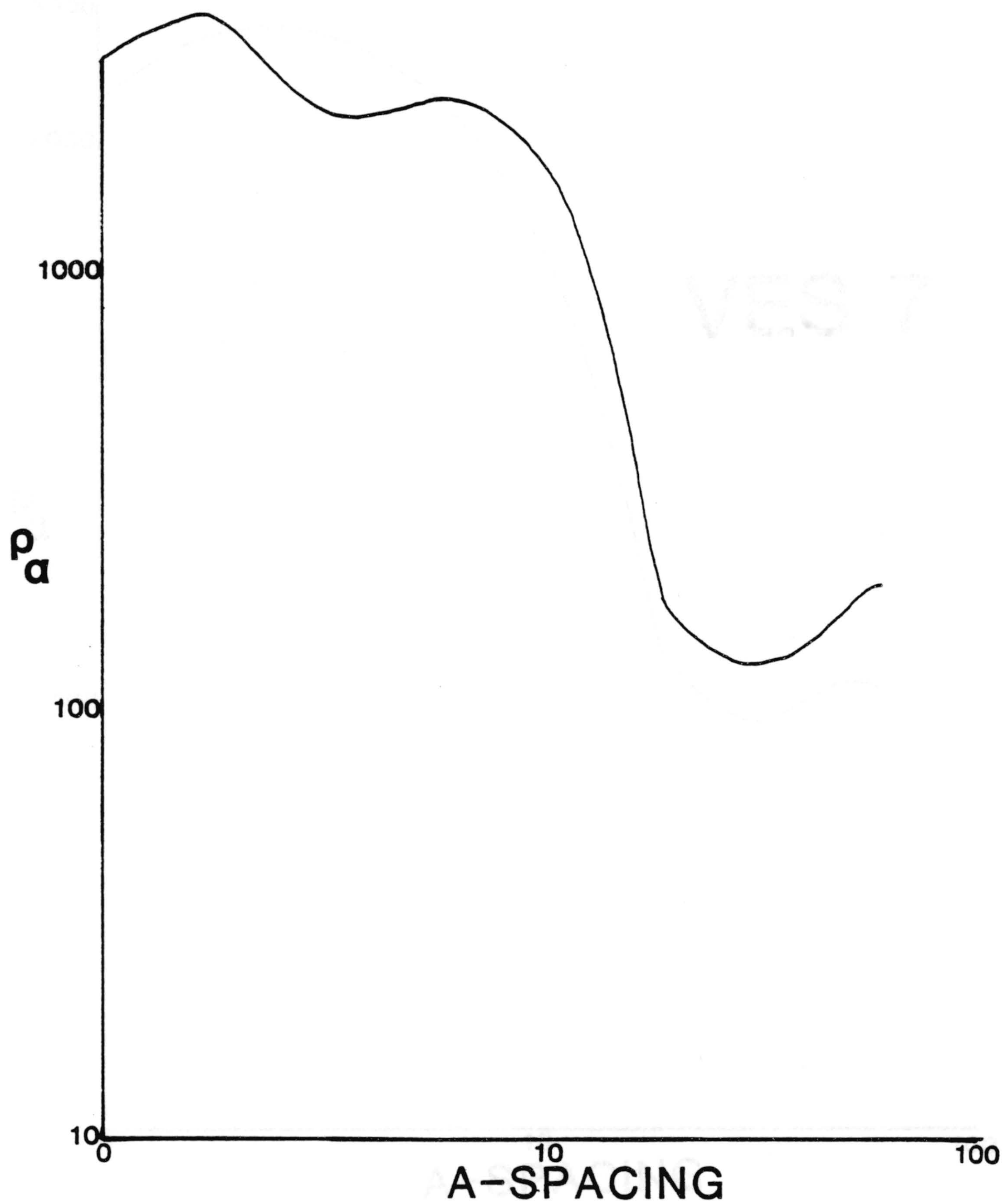


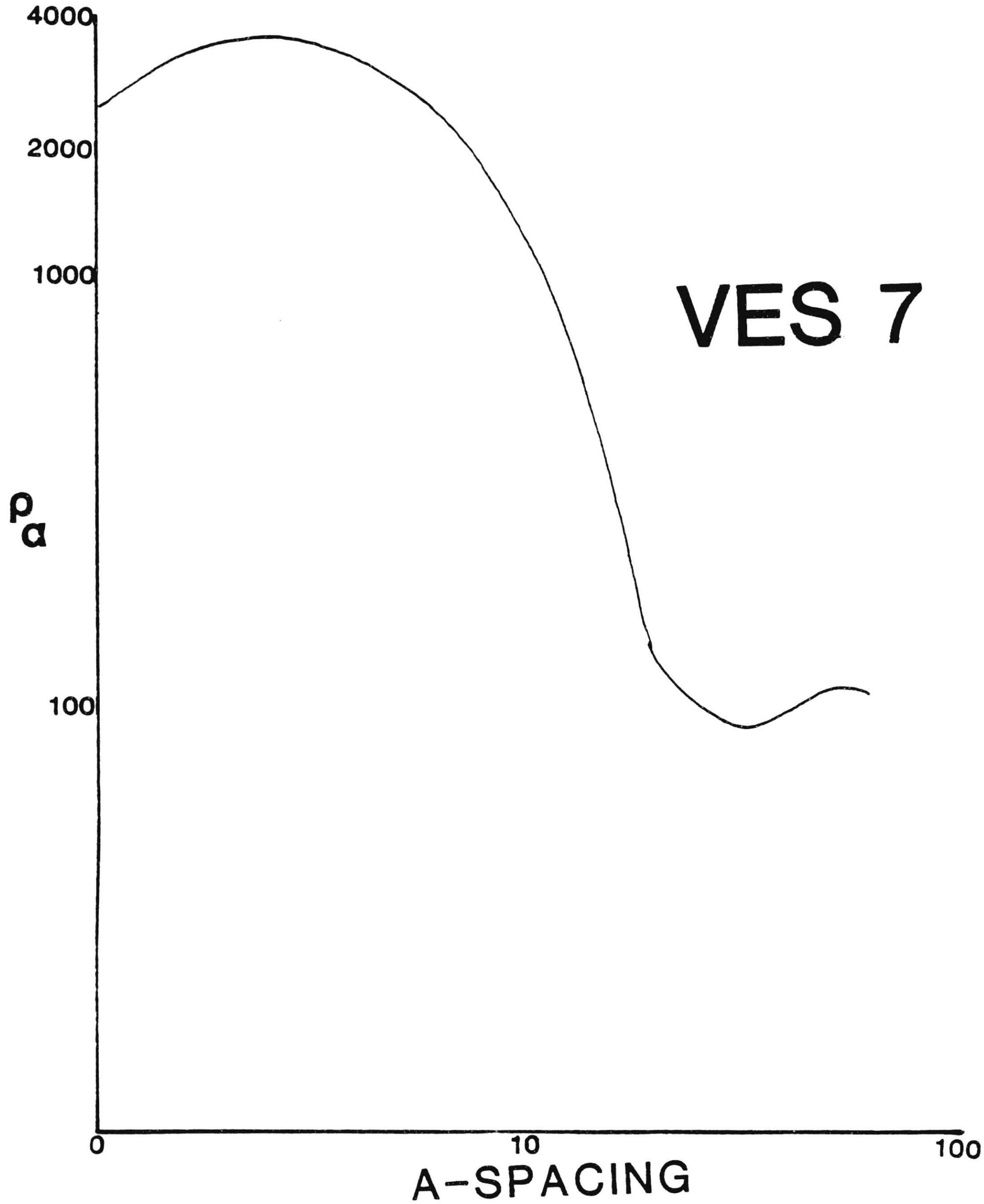
VES 3
10000
1000
100
10
ρa
0
10
100
A-SPACING

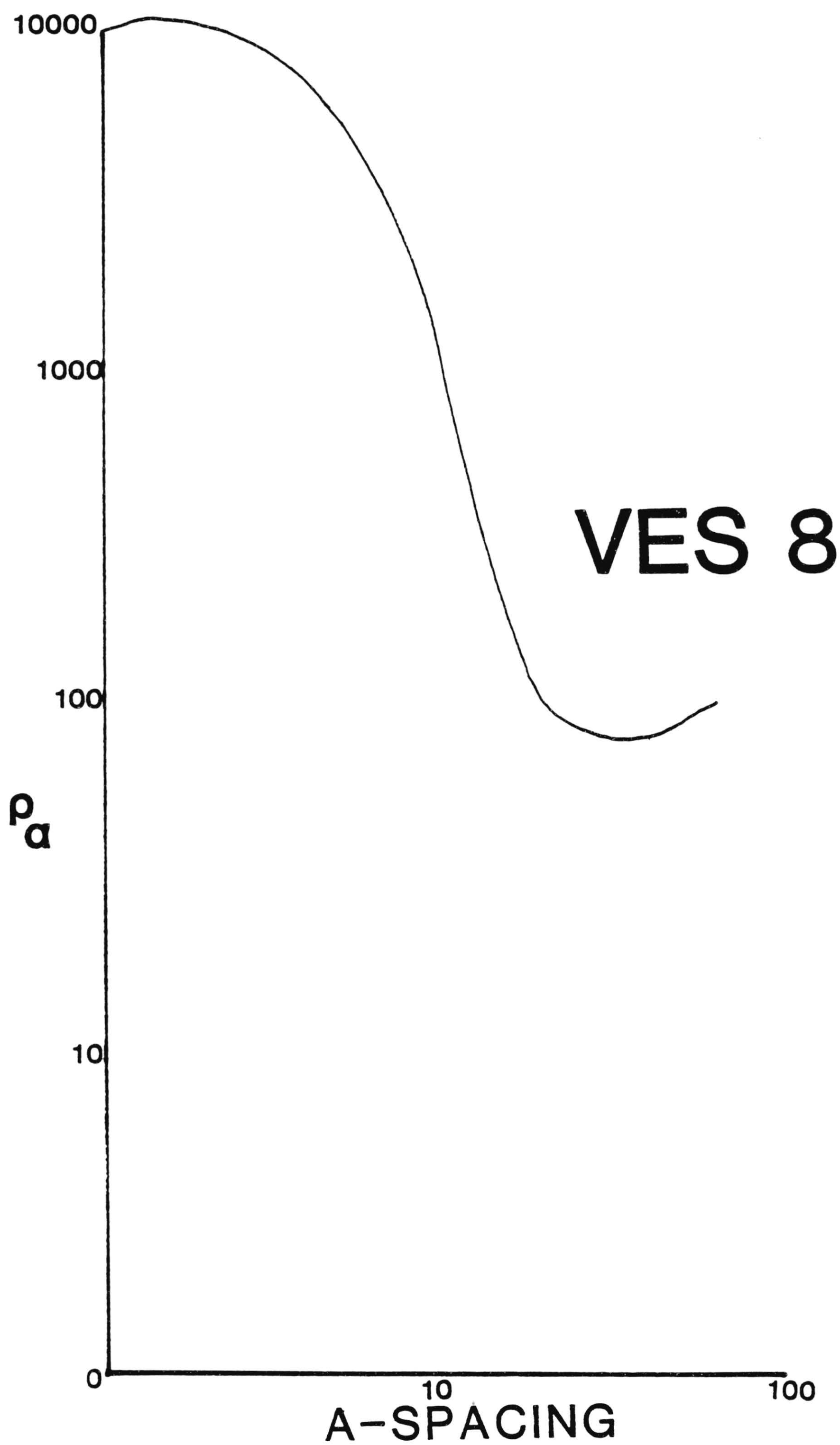

2000
1000
100
10
ρ_a
VES 4
0
10
100
A-SPACING

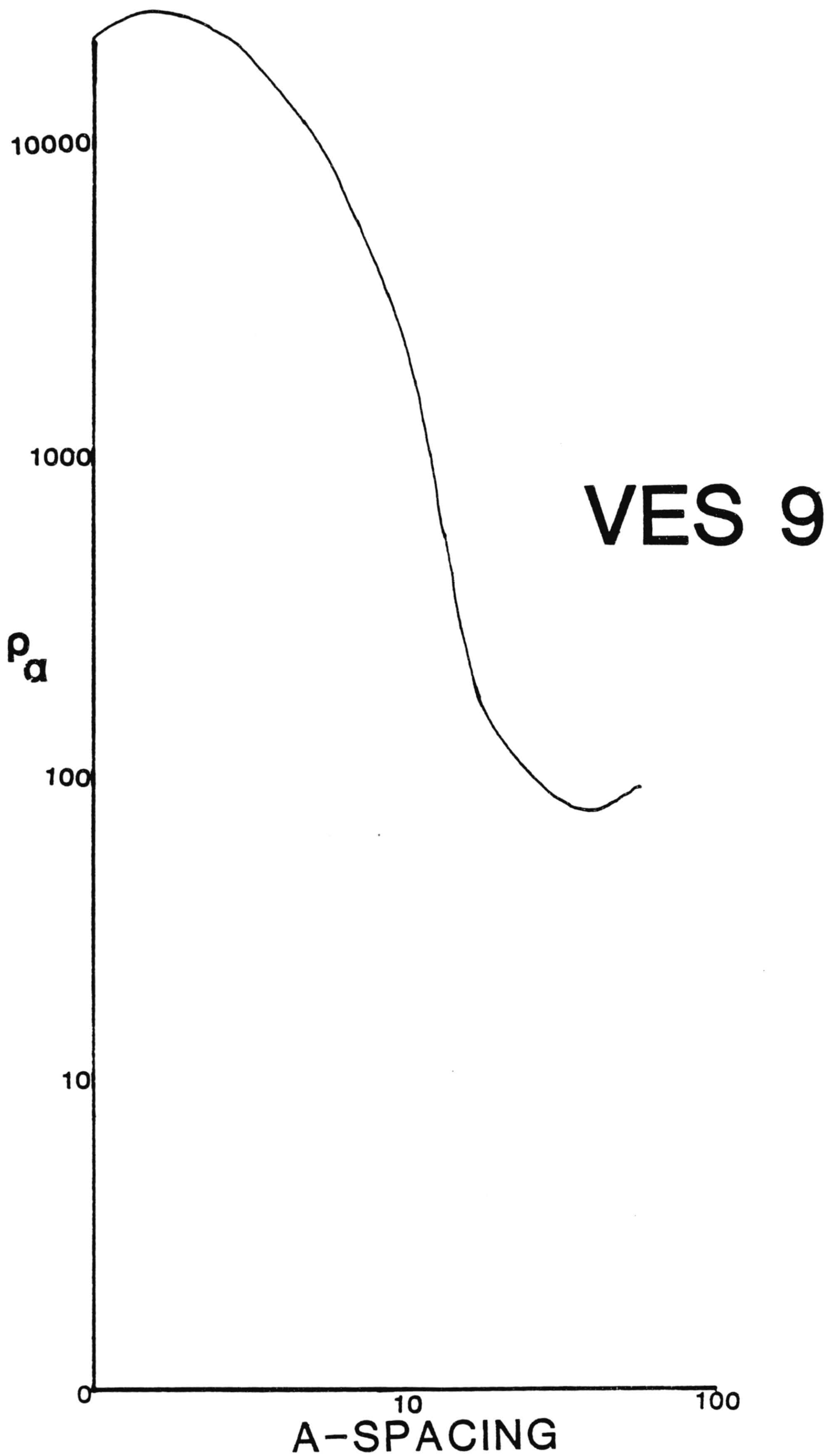

10000
1000
100
10
0
ρ_a
VES 5
10
100
A-SPACING

VES 6



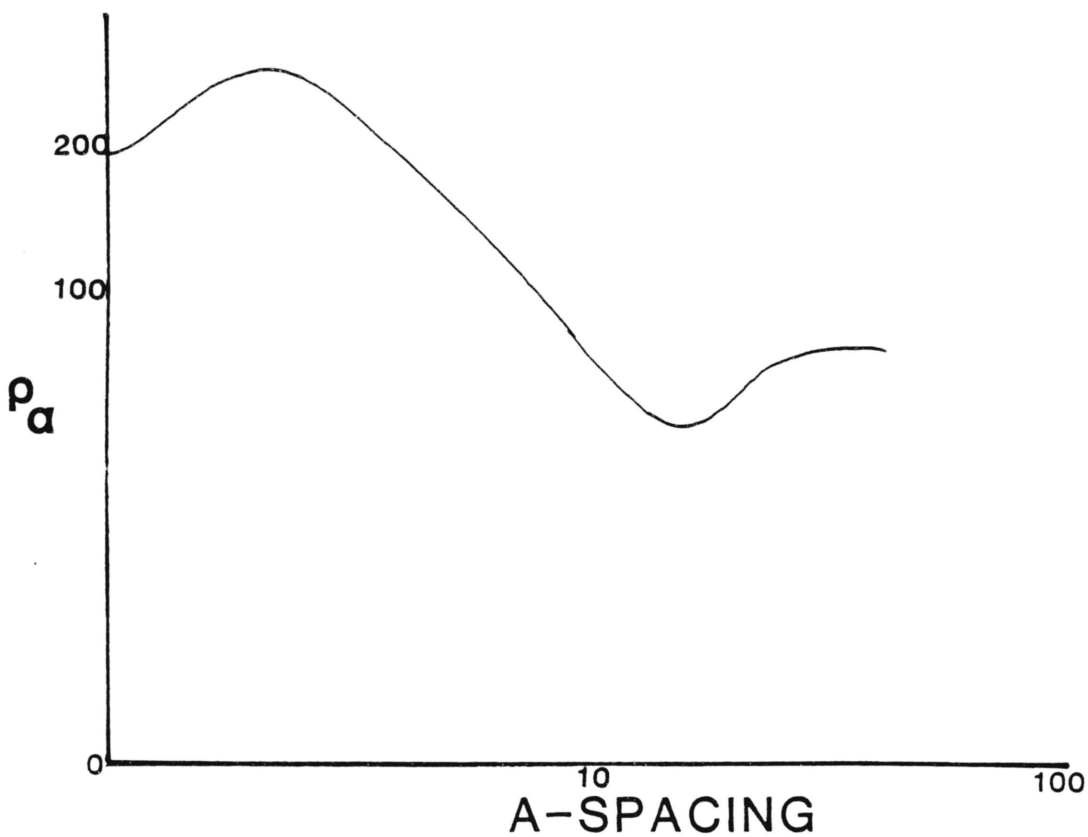

4000
2000
1000
100
ρa
VES 7
0
10
100
A-SPACING

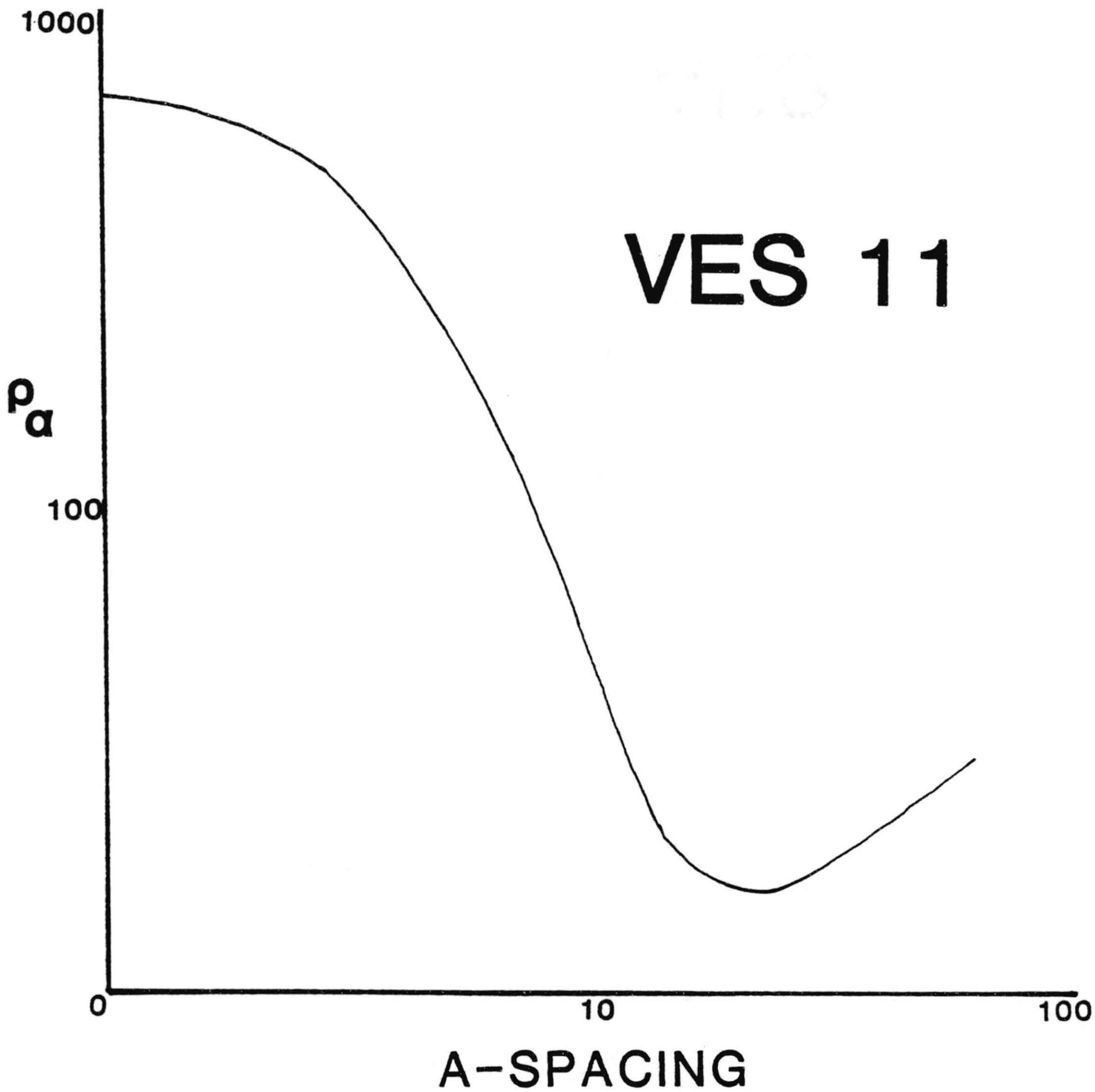

10000
1000
100
10
0
ρ_a
VES 8
10
100
A-SPACING

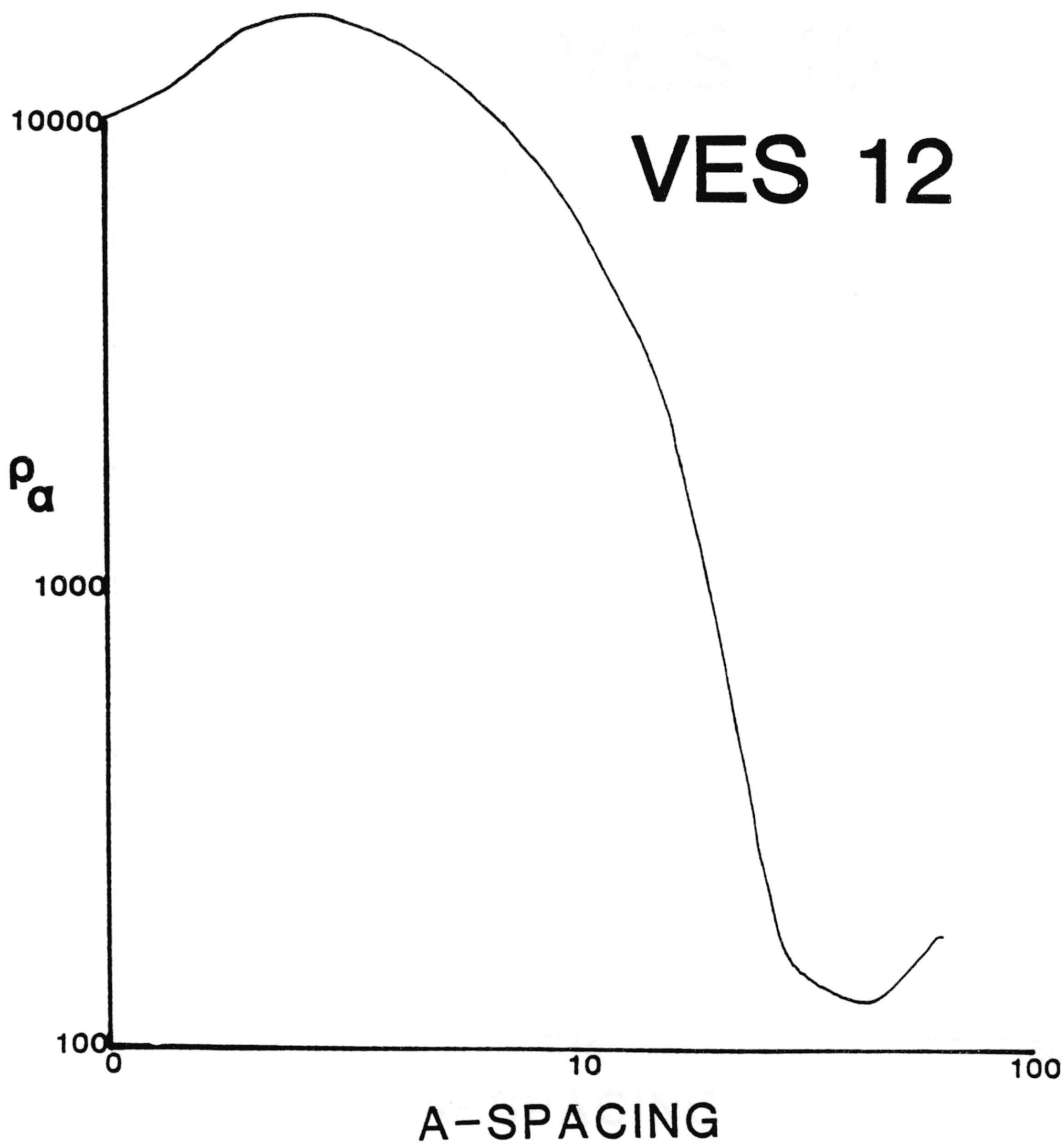


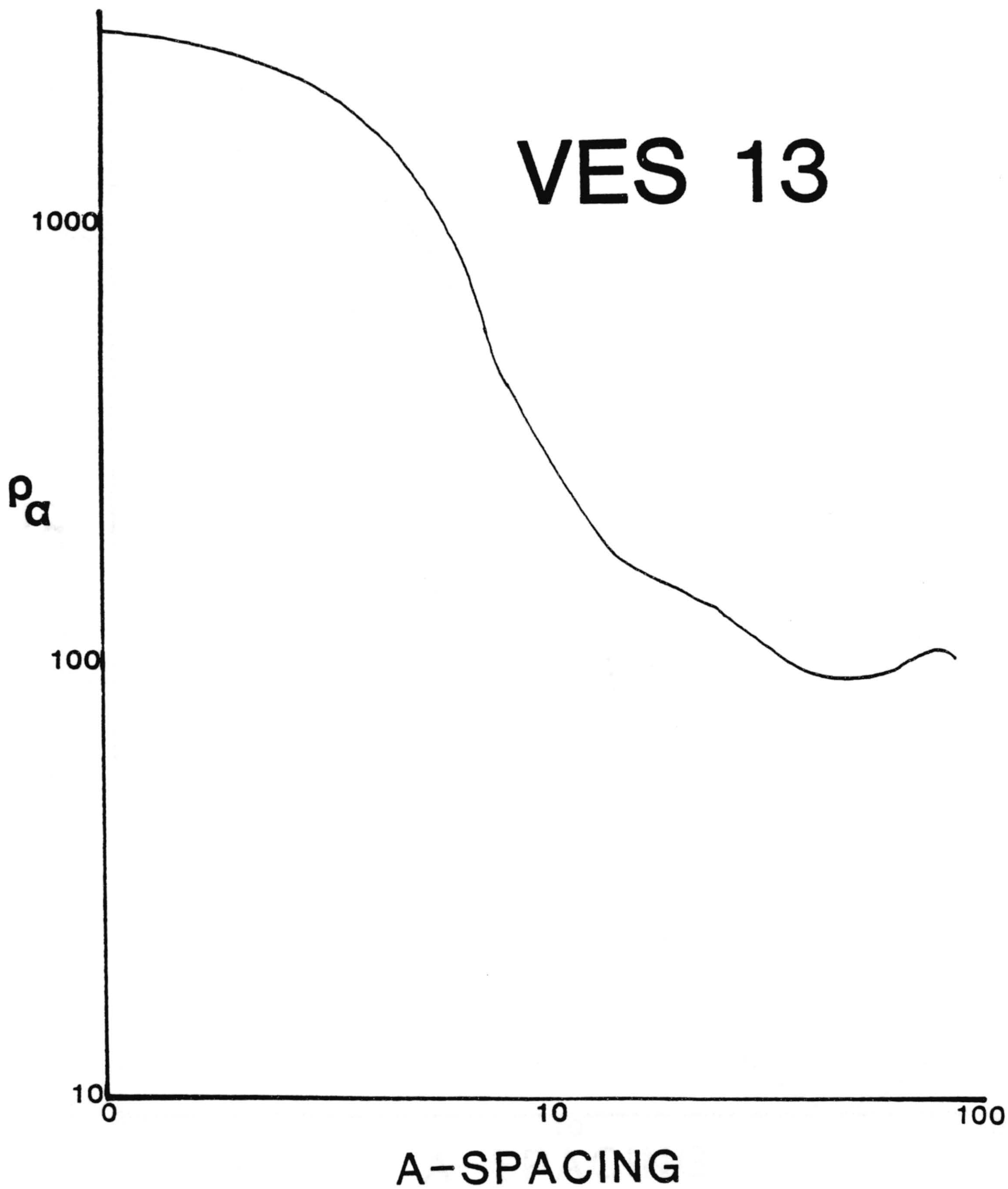
VES 9
10000
1000
100
10
0
ρ_a
10
100
A-SPACING

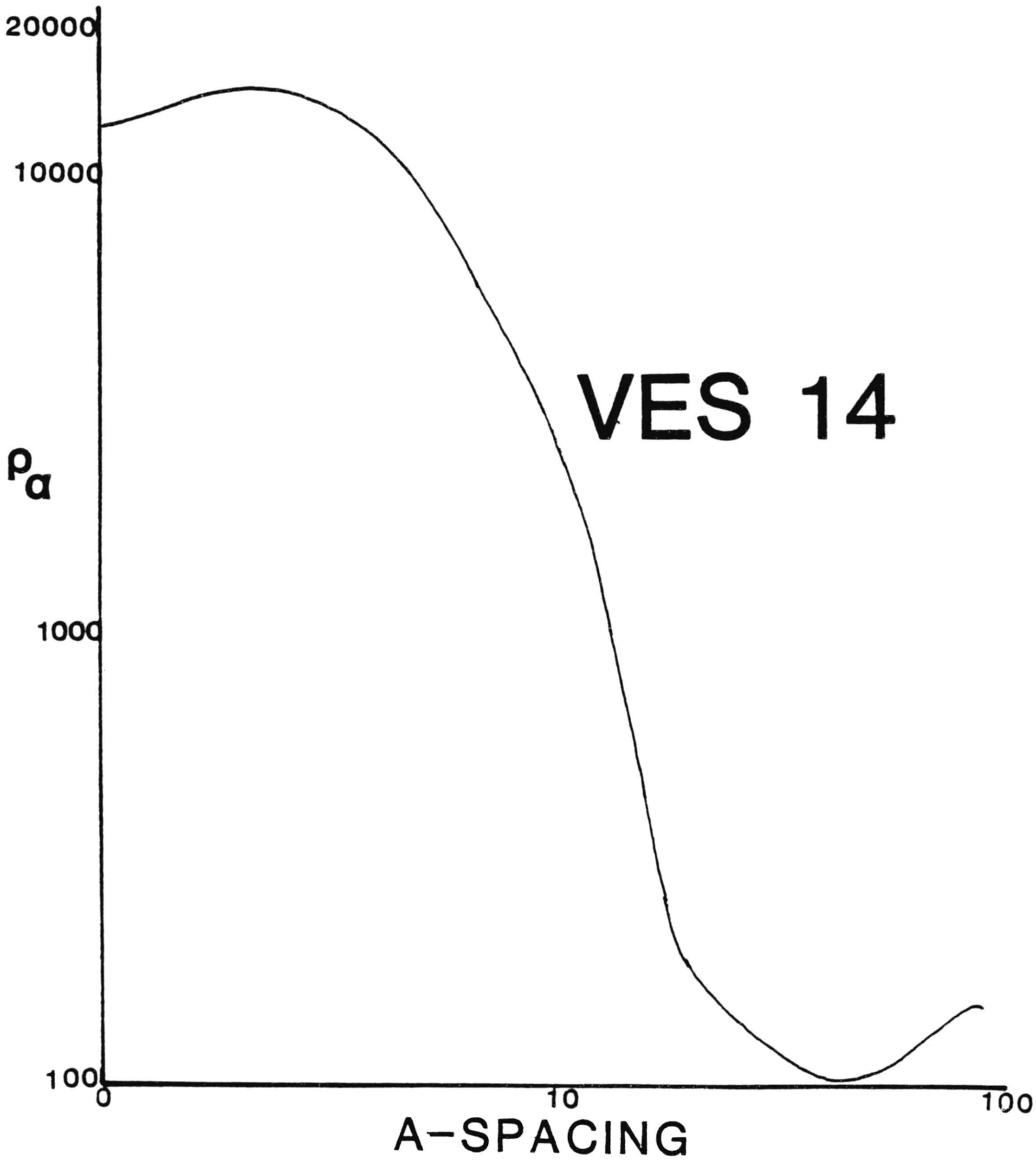
VES 10



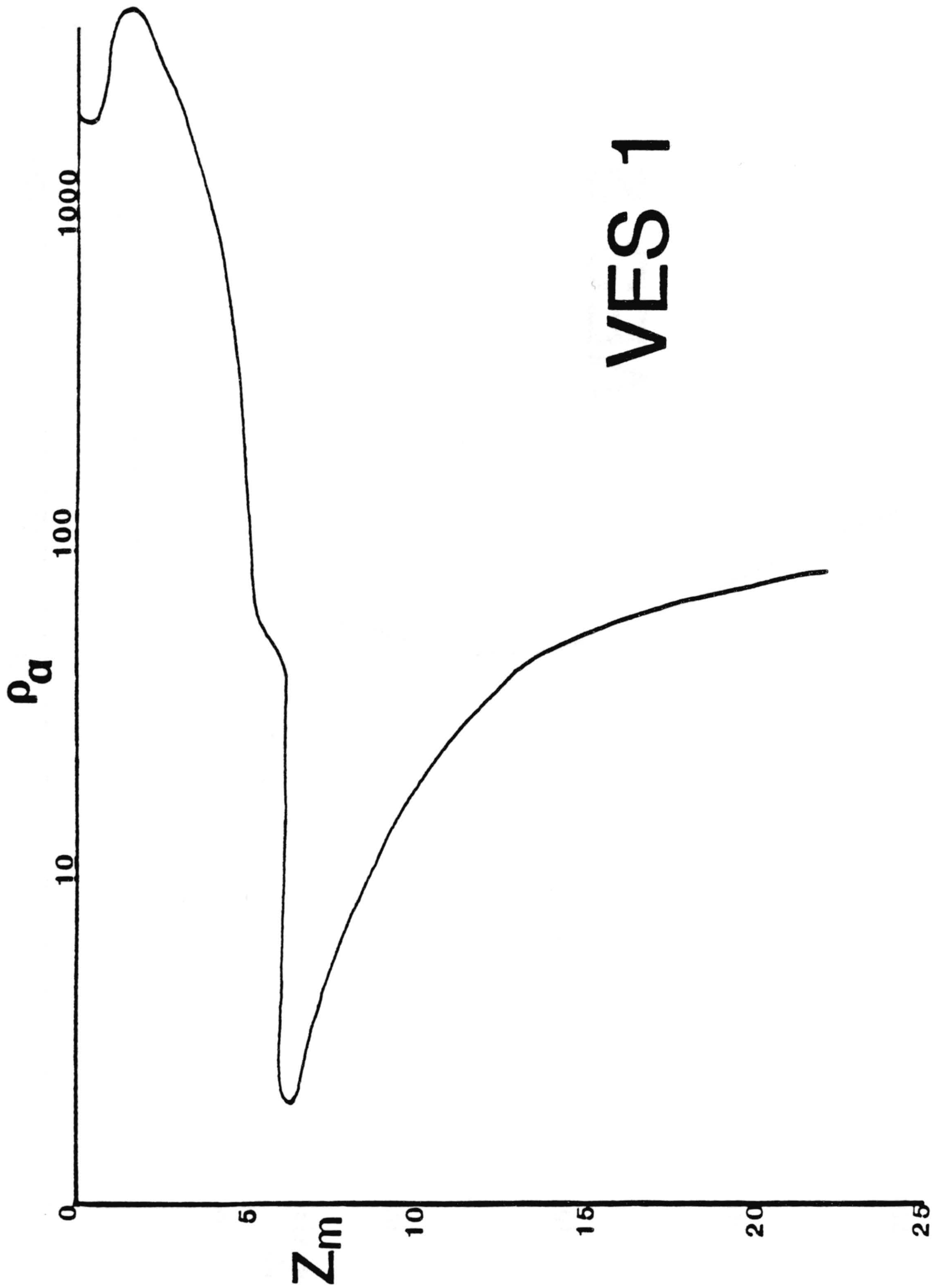

1000
100
ρ_a
VES 11
0
10
100
A-SPACING

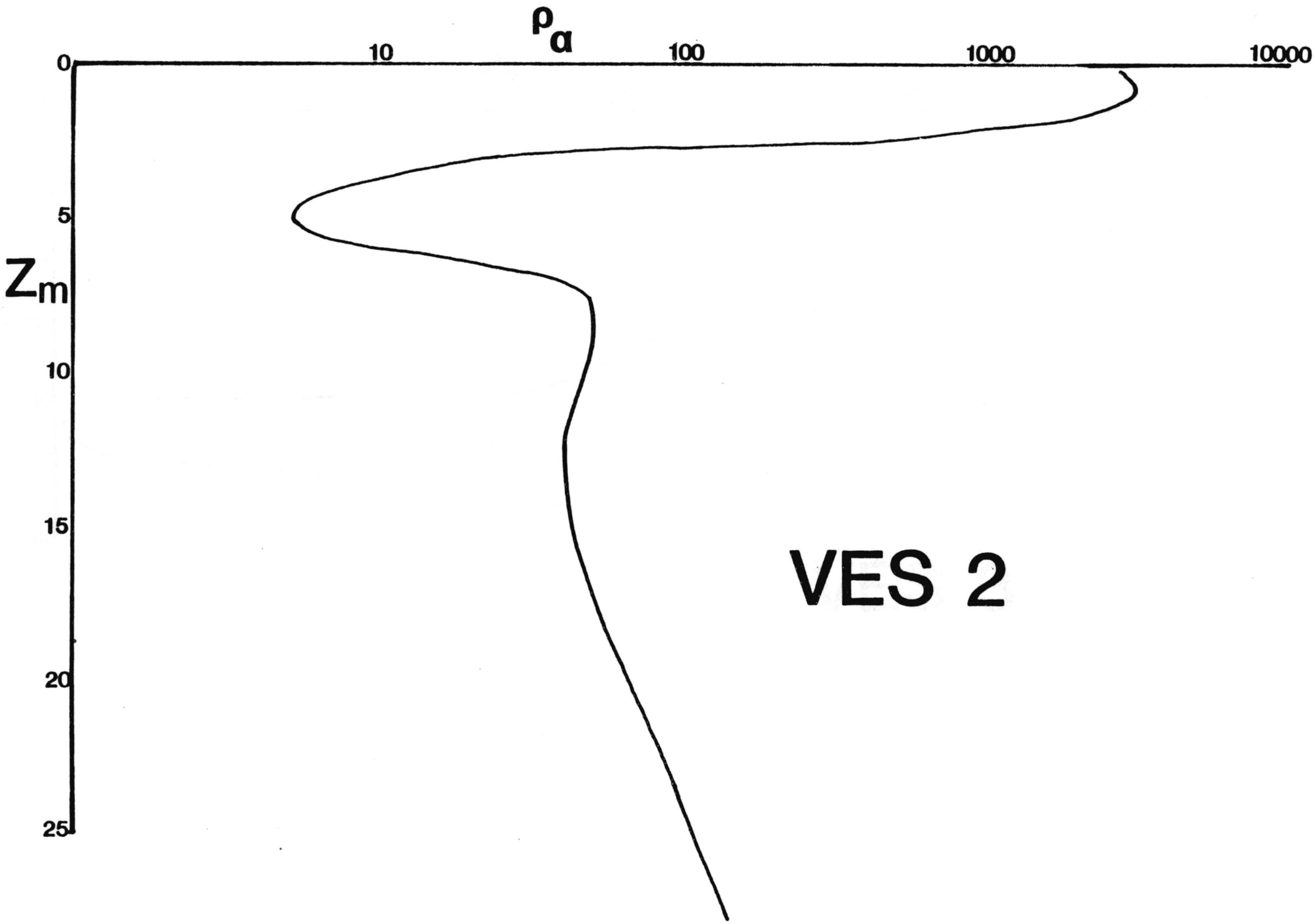

VES 12
10000
1000
100
ρa
0
10
100
A-SPACING


VES 13
1000
100
10
ρ_a
0
10
100
A-SPACING

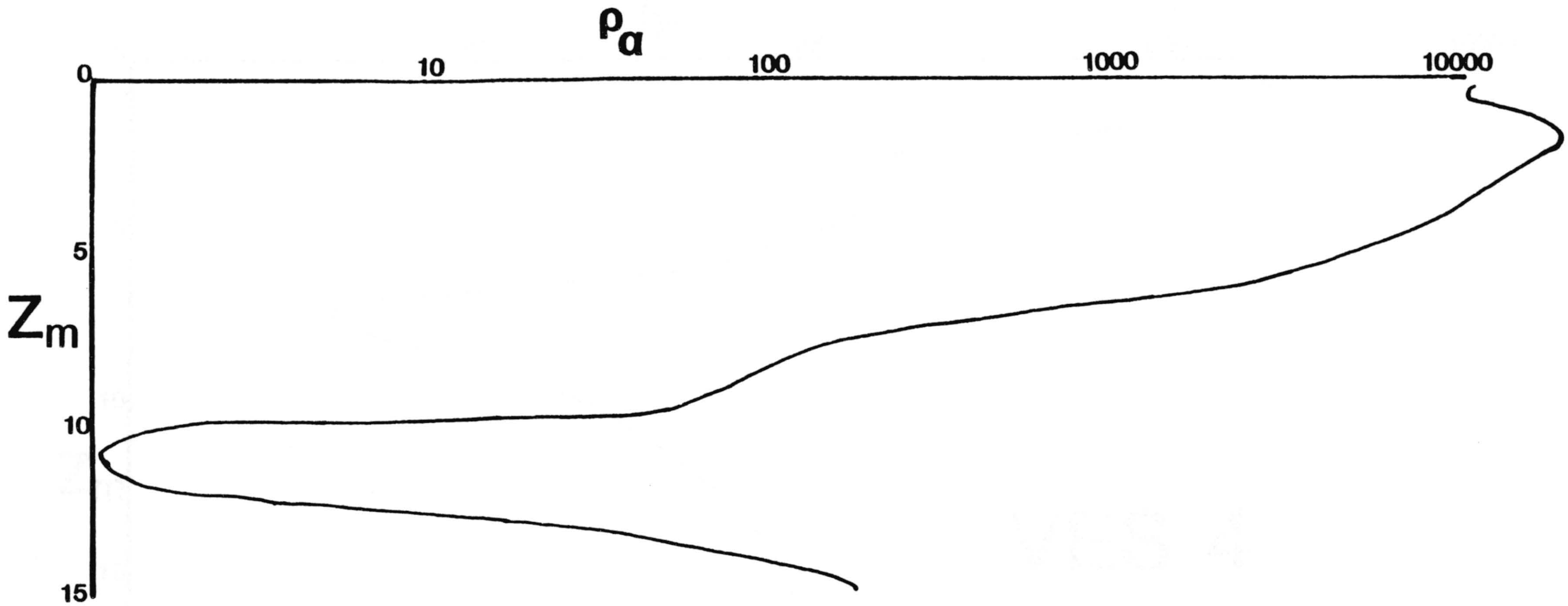

20000
10000
1000
100
ρa
VES 14
0
10
100
A-SPACING

APPENDIX C: FOURTEEN VERTICAL ELECTRIC SOUNDING CURVES PLOTTED AS RESISTIVITY (OHM-METERS) VERSUS DEPTH (METERS).

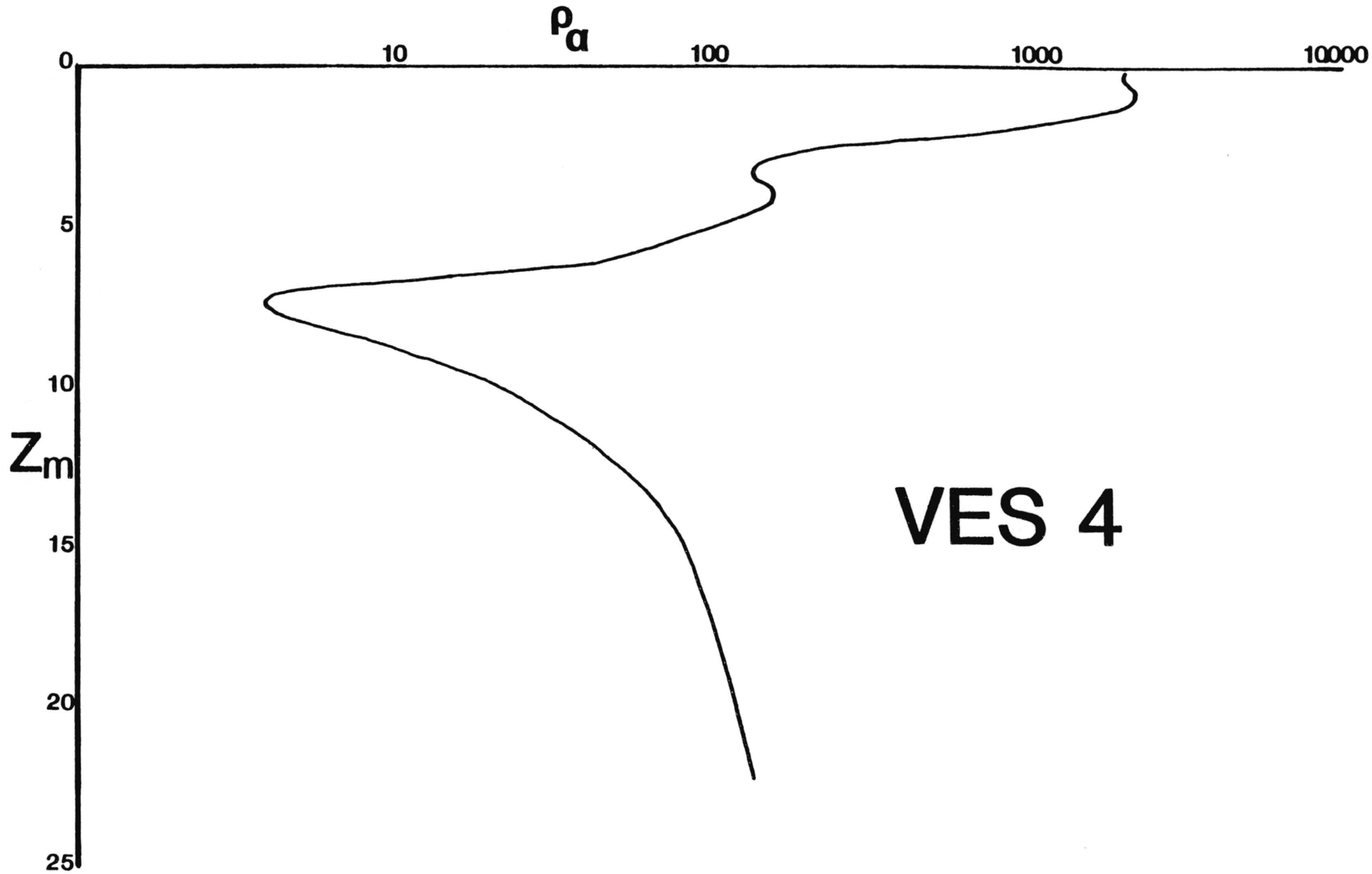


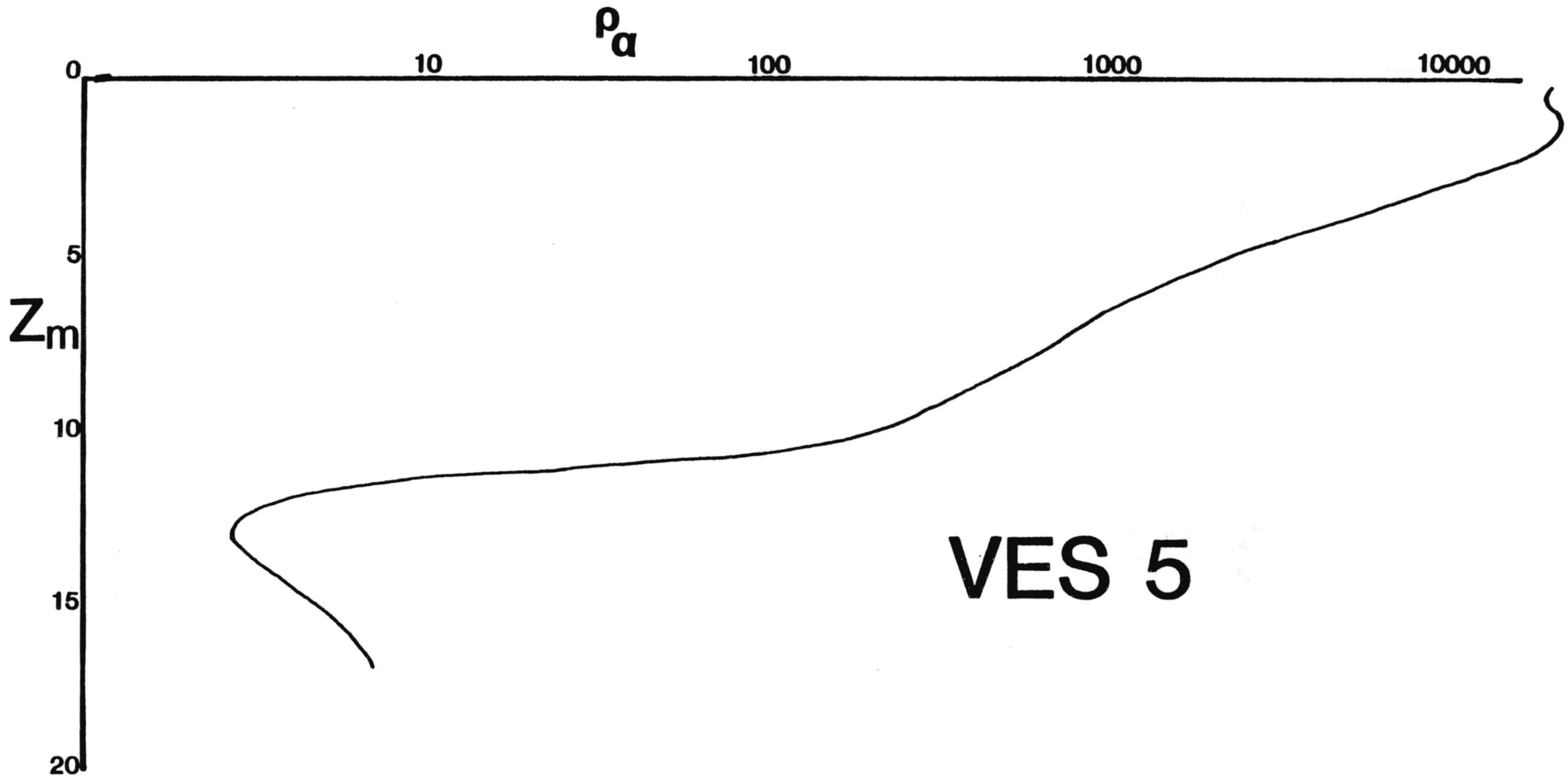


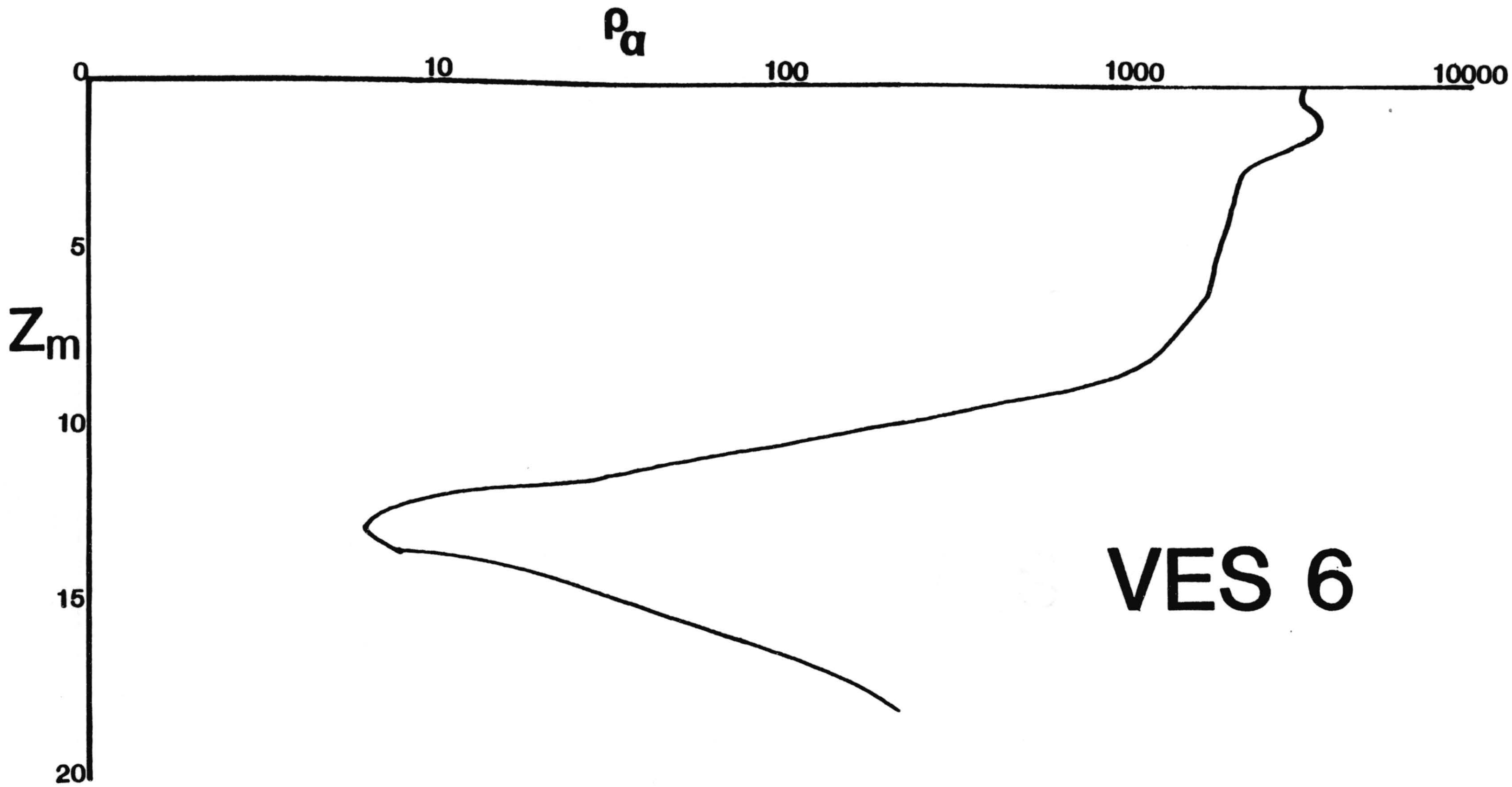
ρ_a
0
10
100
1000
10000
5
10
15
20
25
Z_m
VES 2

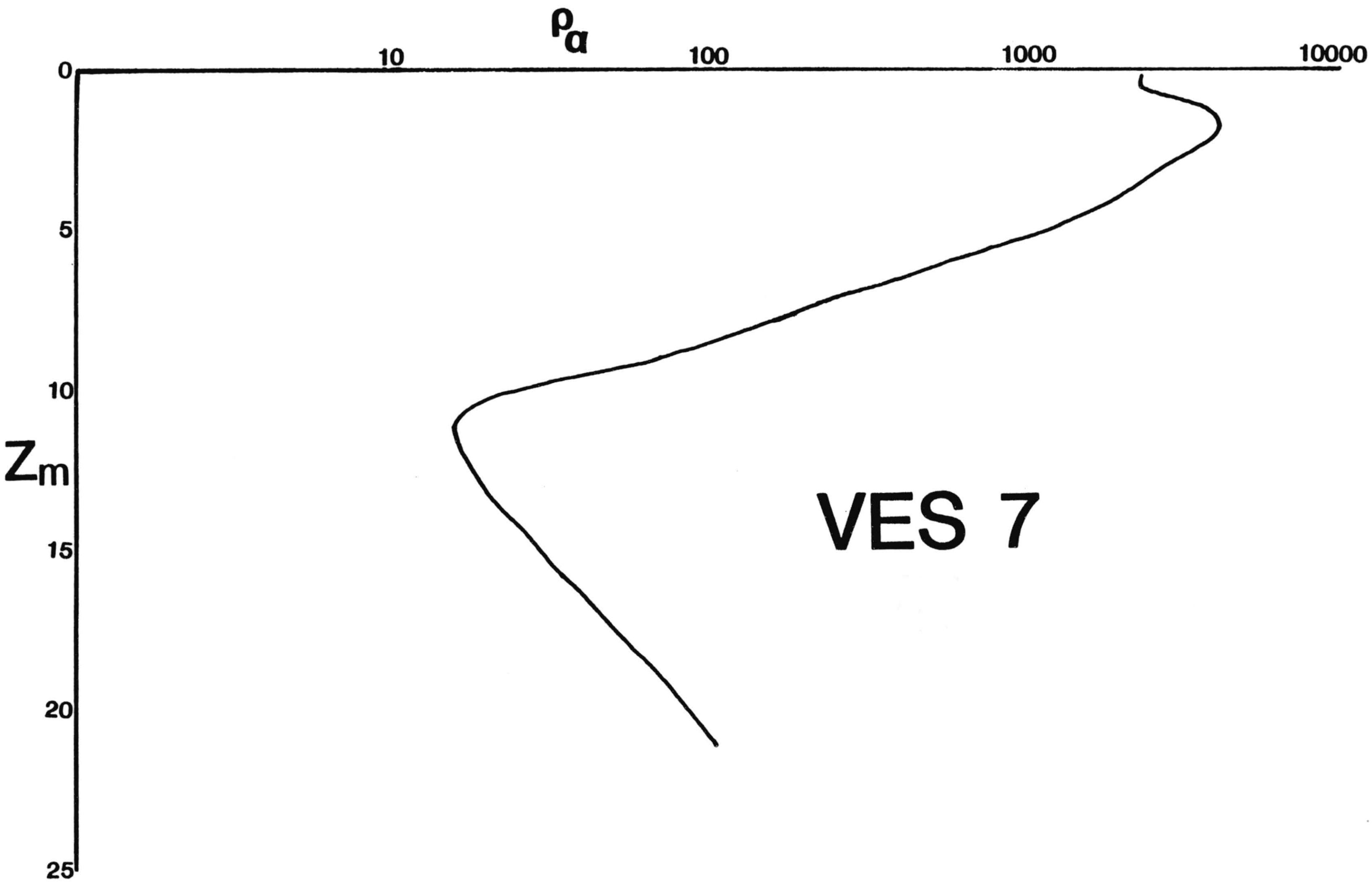


VES 3

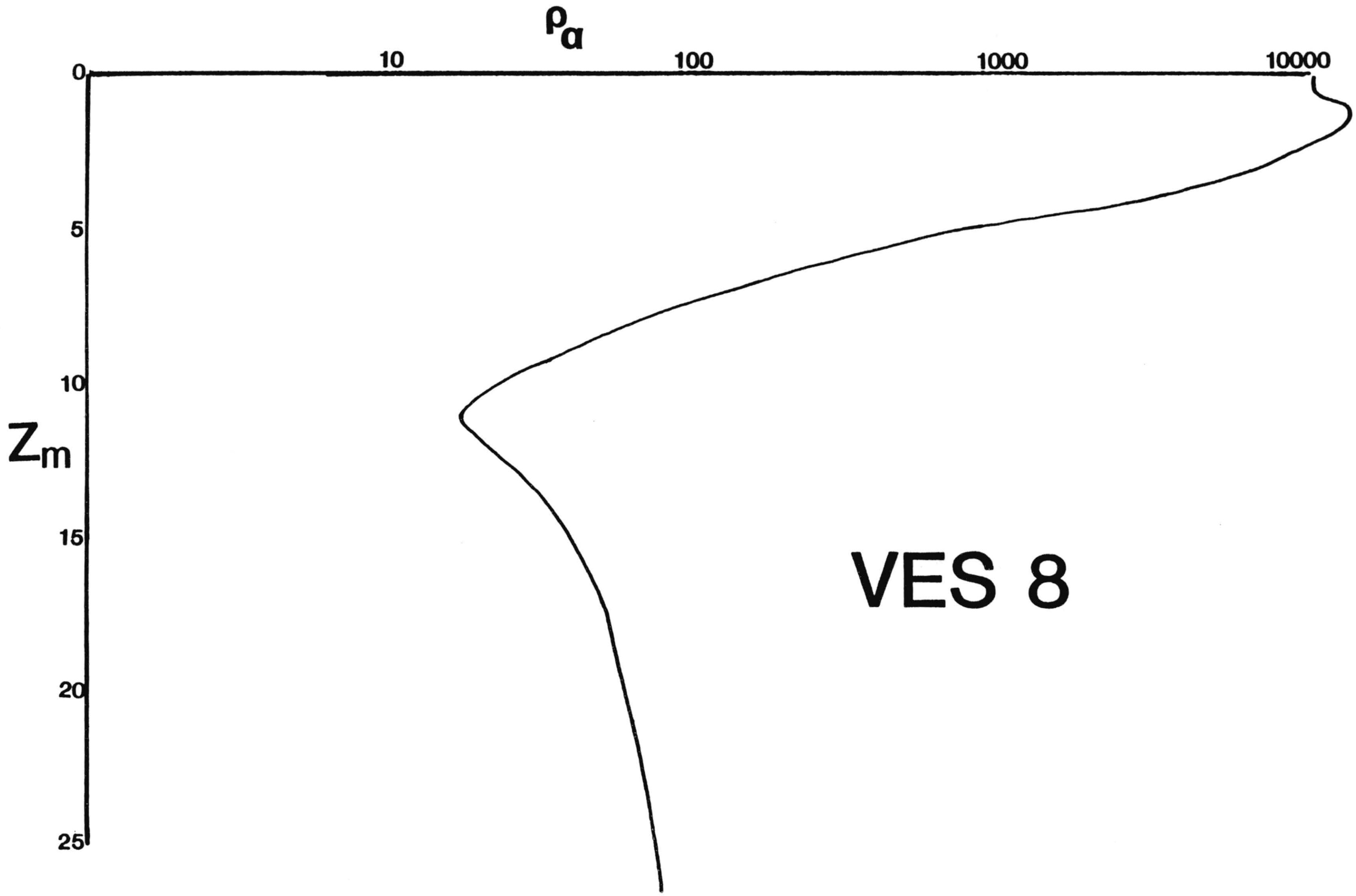

ρa
0
10
100
1000
10000
5
10
15
20
25
Zm
VES 4

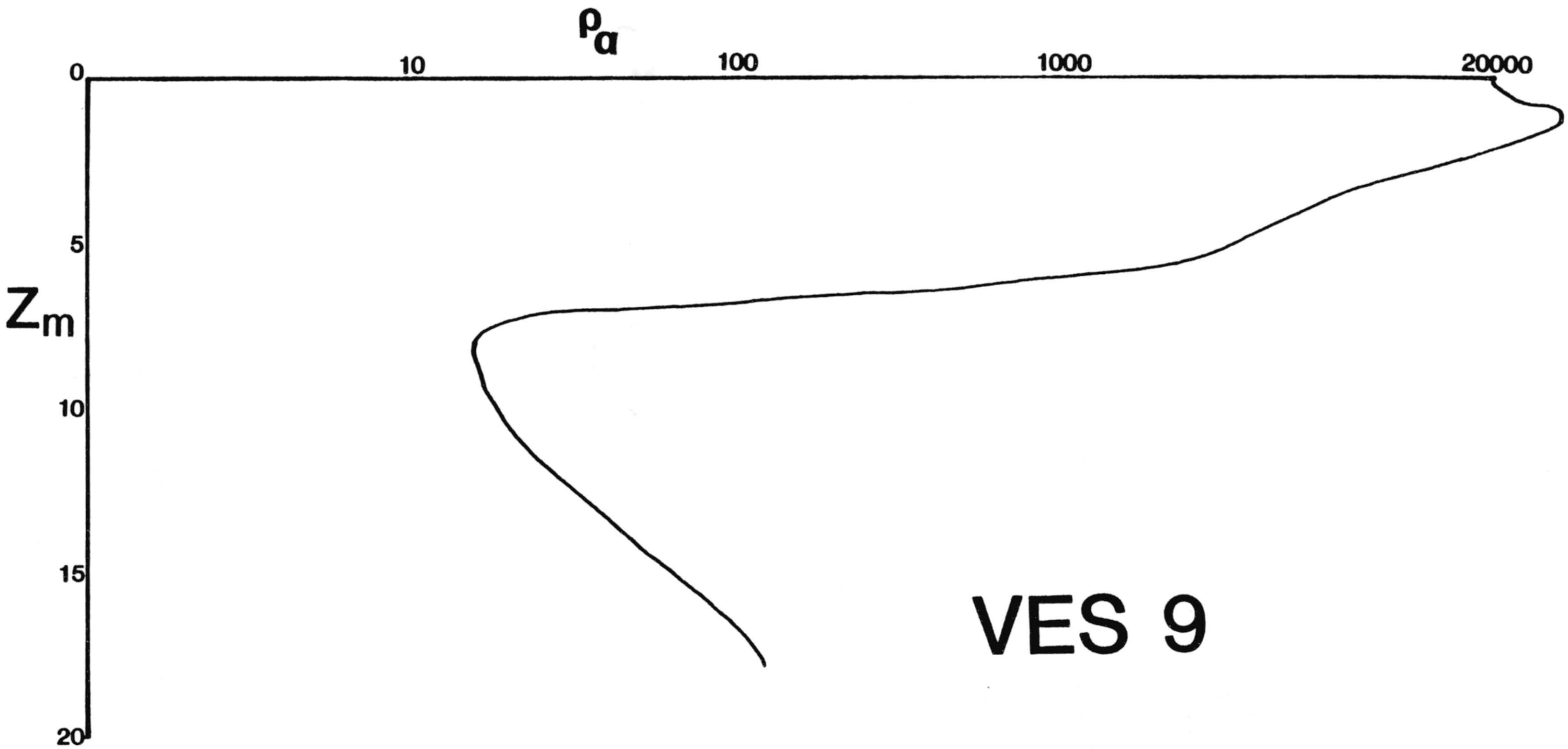

ρa
0
10
100
1000
10000
Zm
5
10
15
20
VES 5


ρ_a
0
10
100
1000
10000
Z_m
5
10
15
20
VES 6



ρa
10
100
1000
10000
0
5
10
15
20
25
Zm
VES 7


ρ_a
10
100
1000
10000
0
5
10
15
20
25
Z_m
VES 8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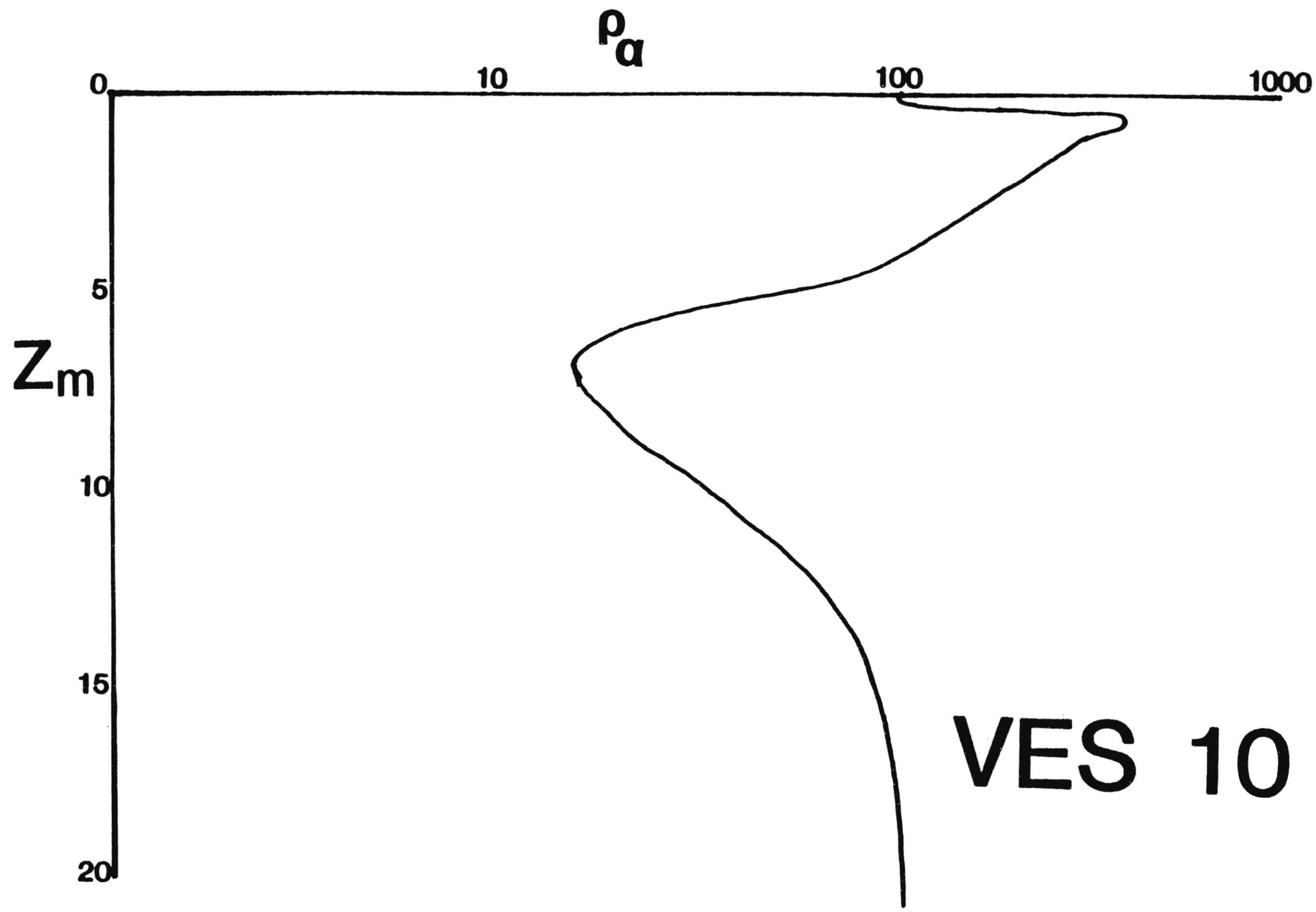

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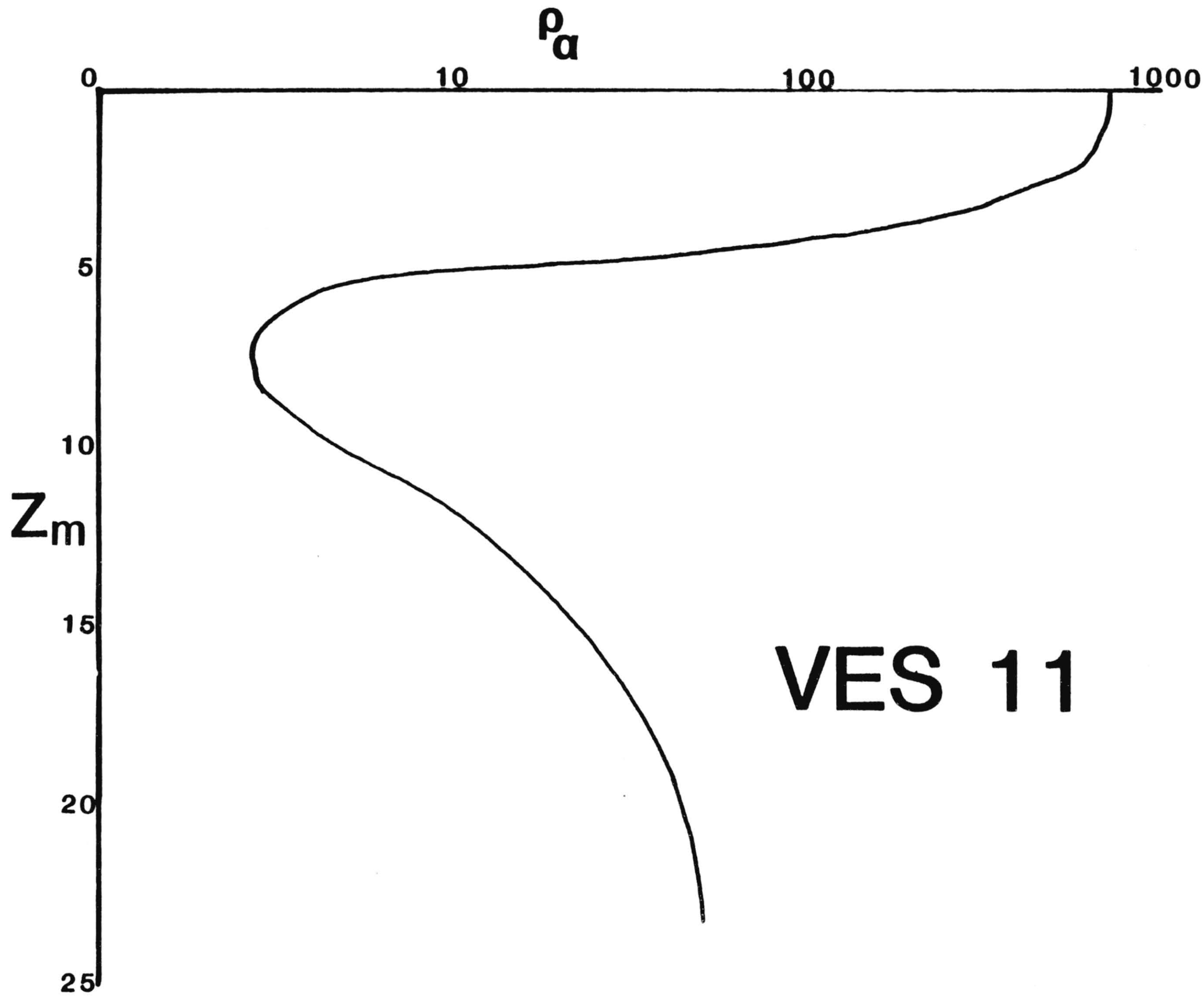
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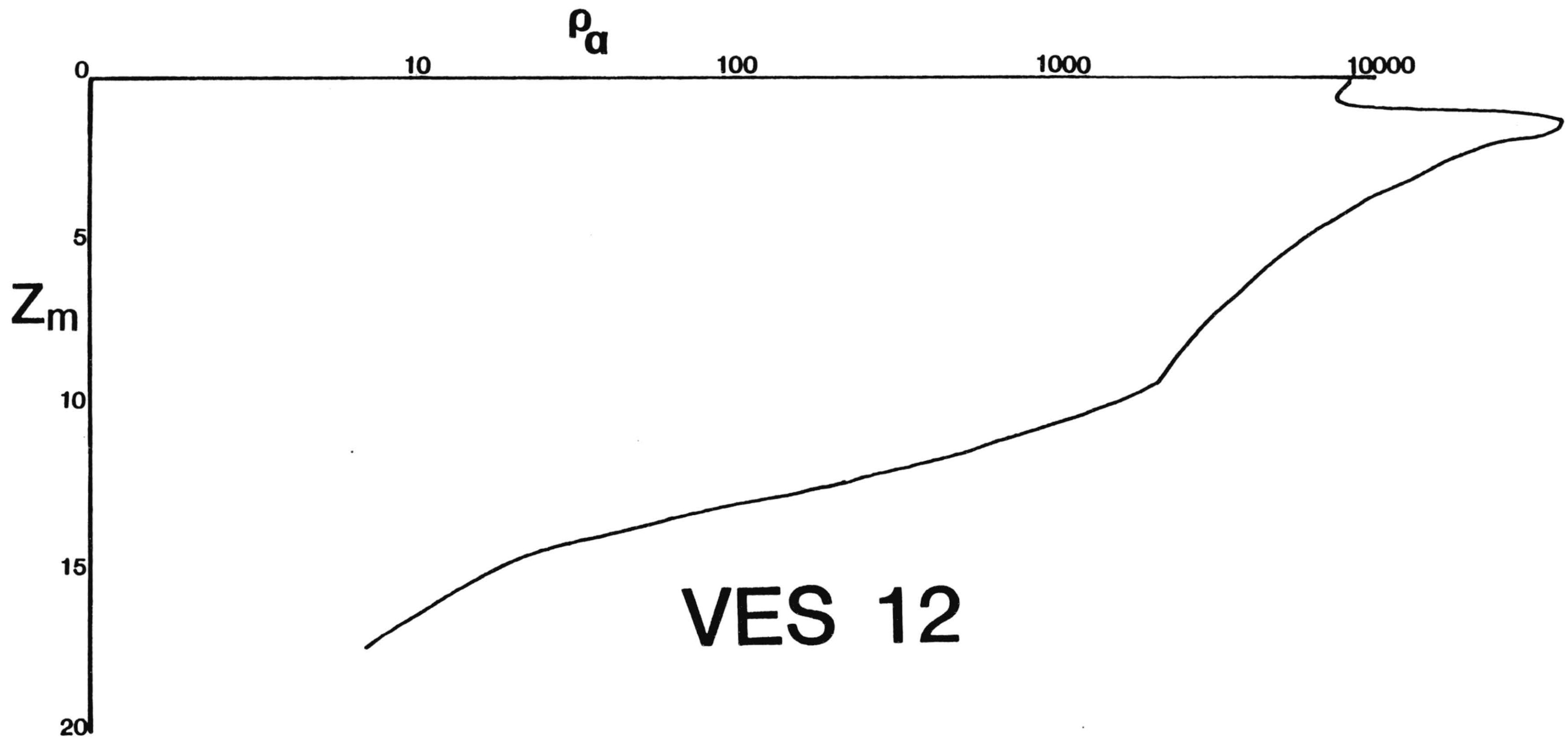

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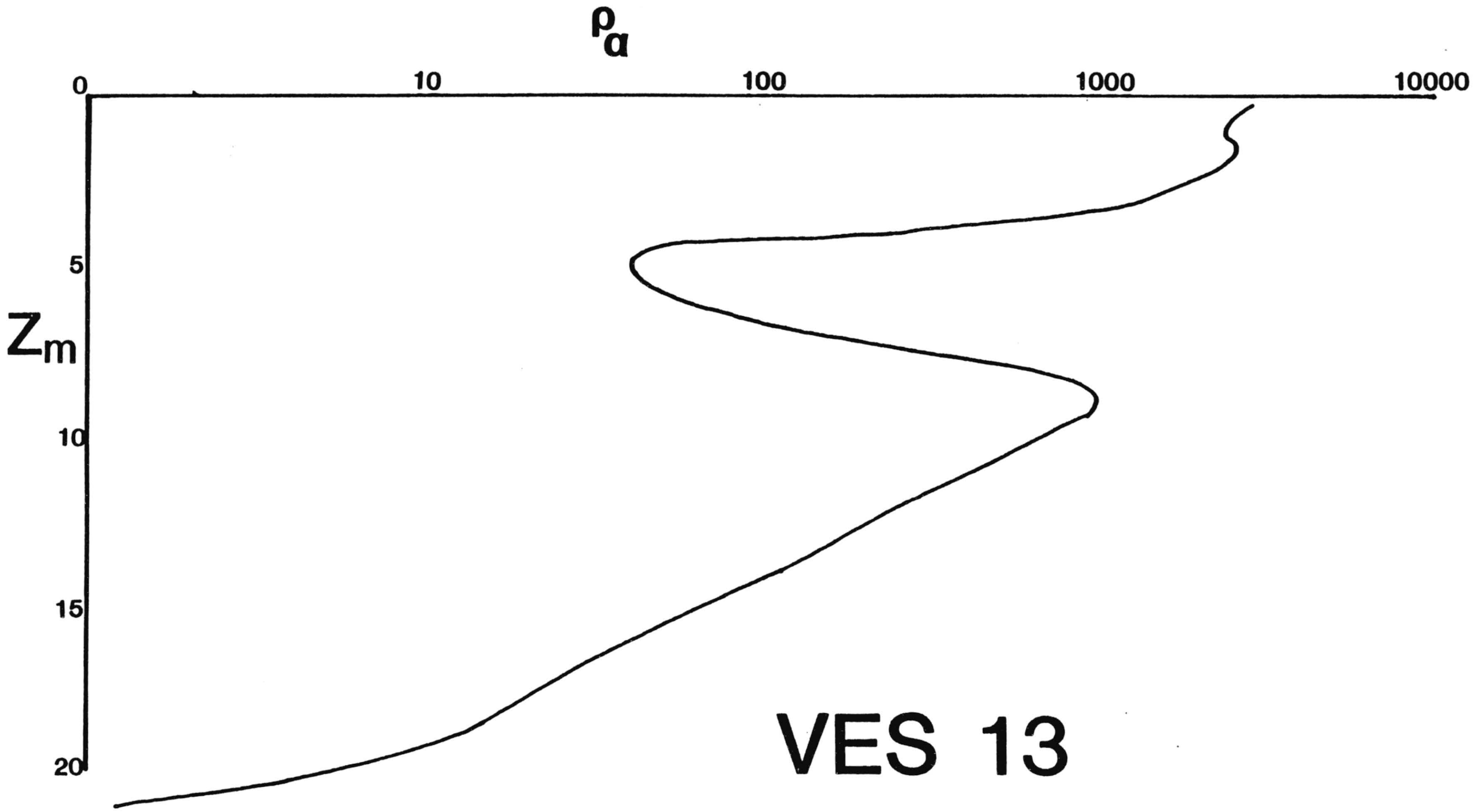
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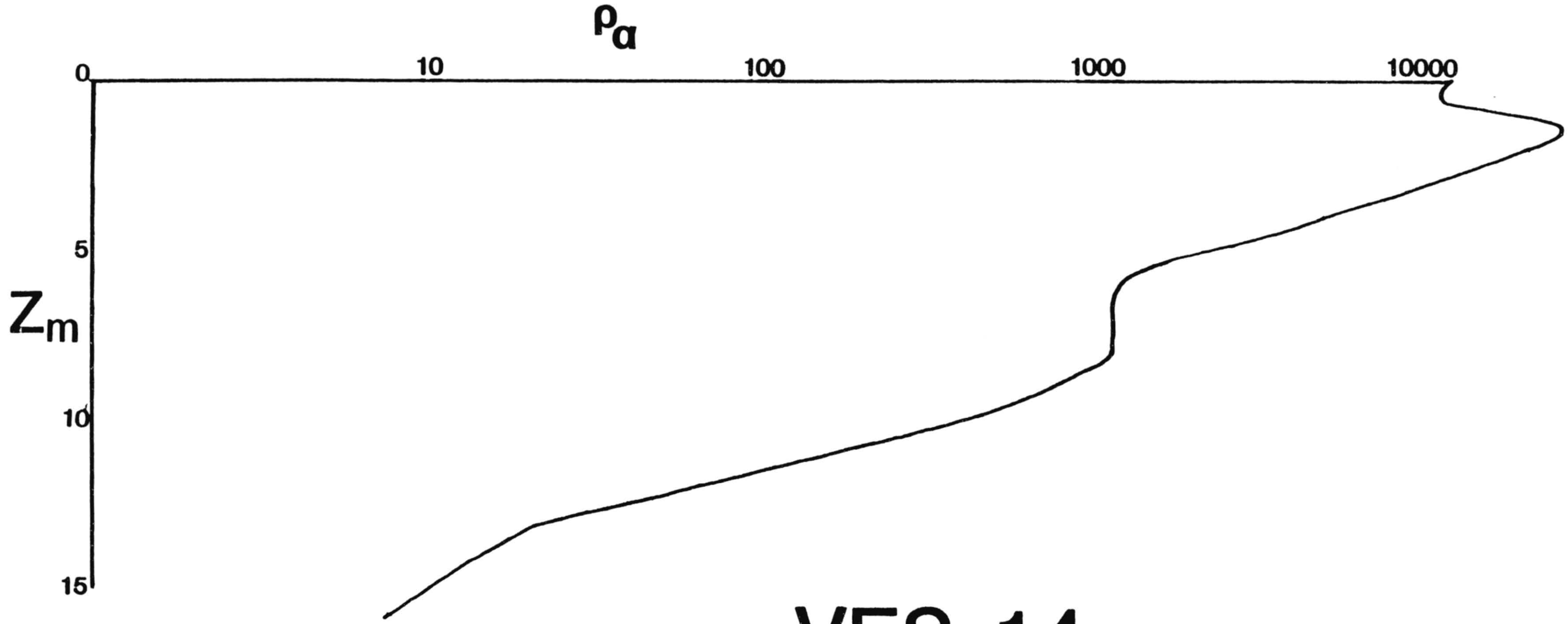
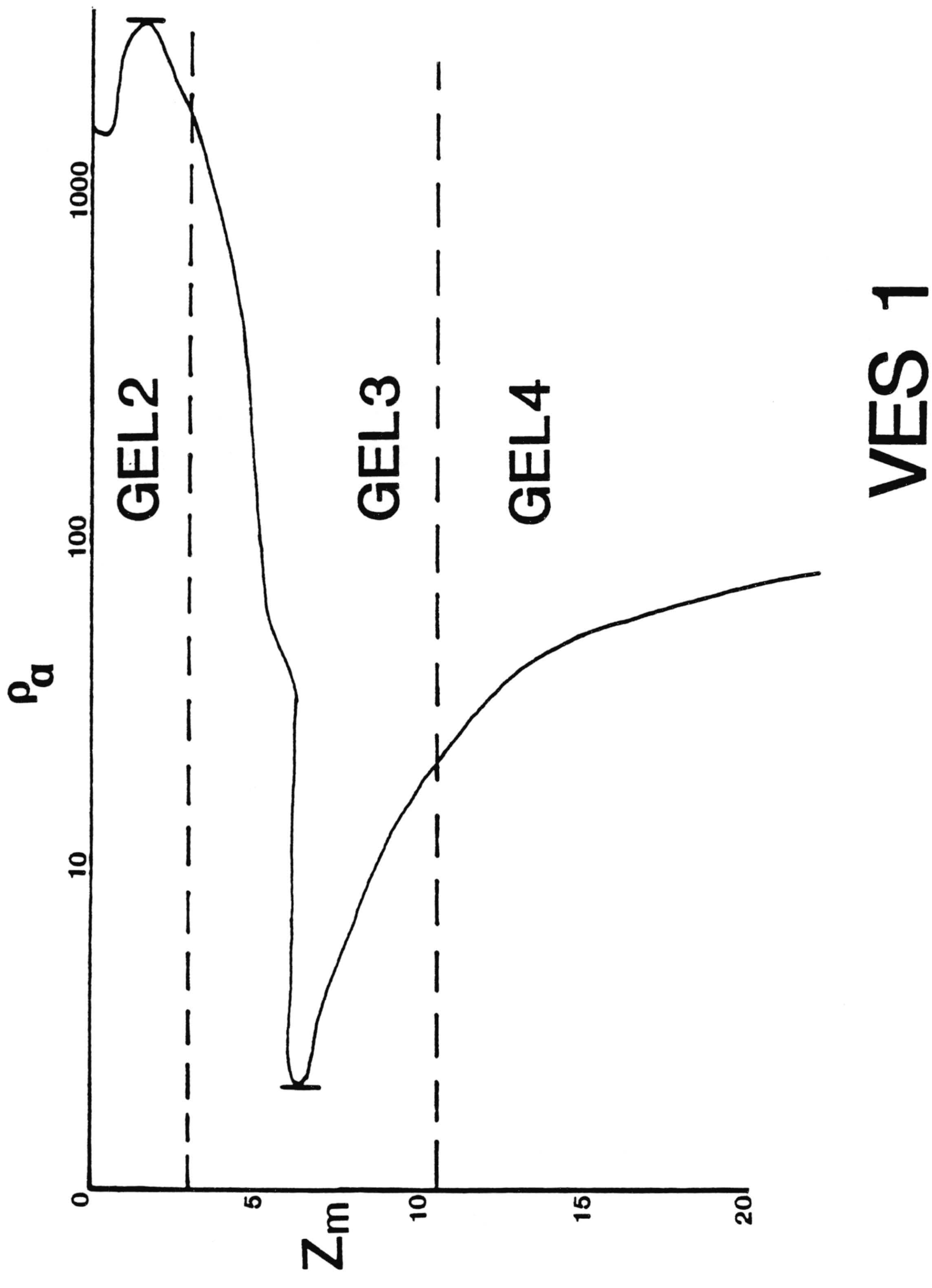
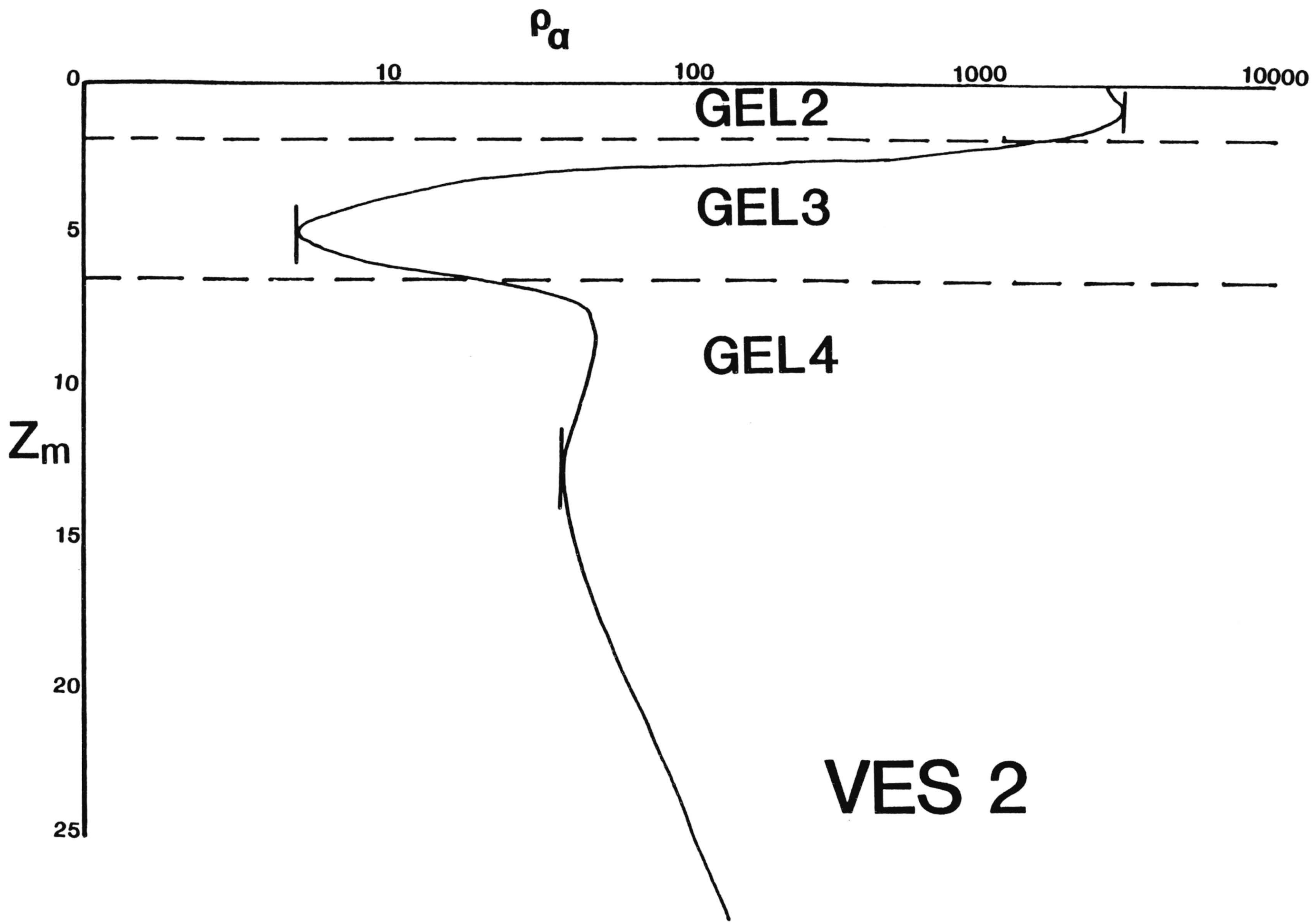


VES 14

APPENDIX D: VERTICAL ELECTRIC SOUNDING CURVES ILLUSTRATING THE MECHANICAL METHODS USED TO DETERMINE THE LIMITS OF EACH GEOELECTRIC LAYER.





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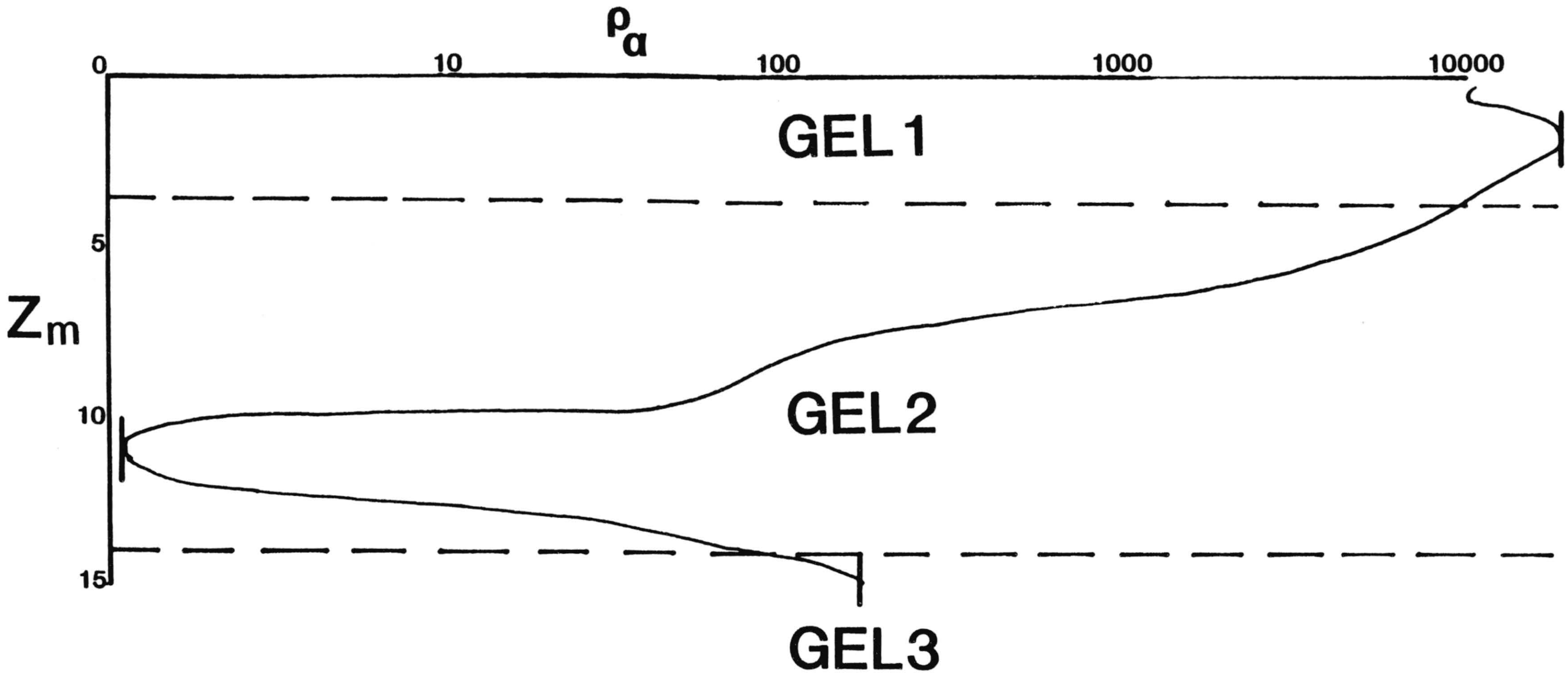

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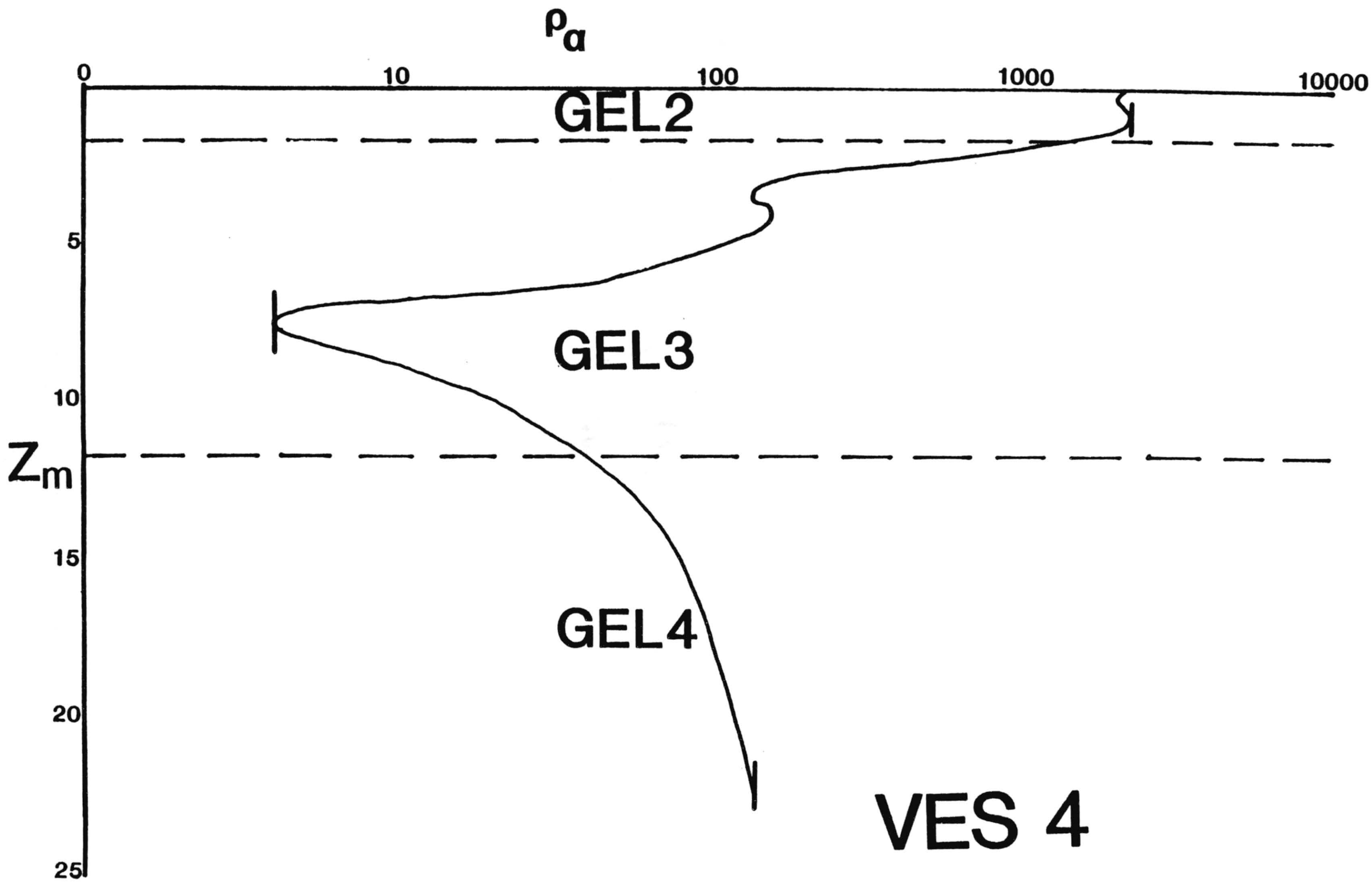
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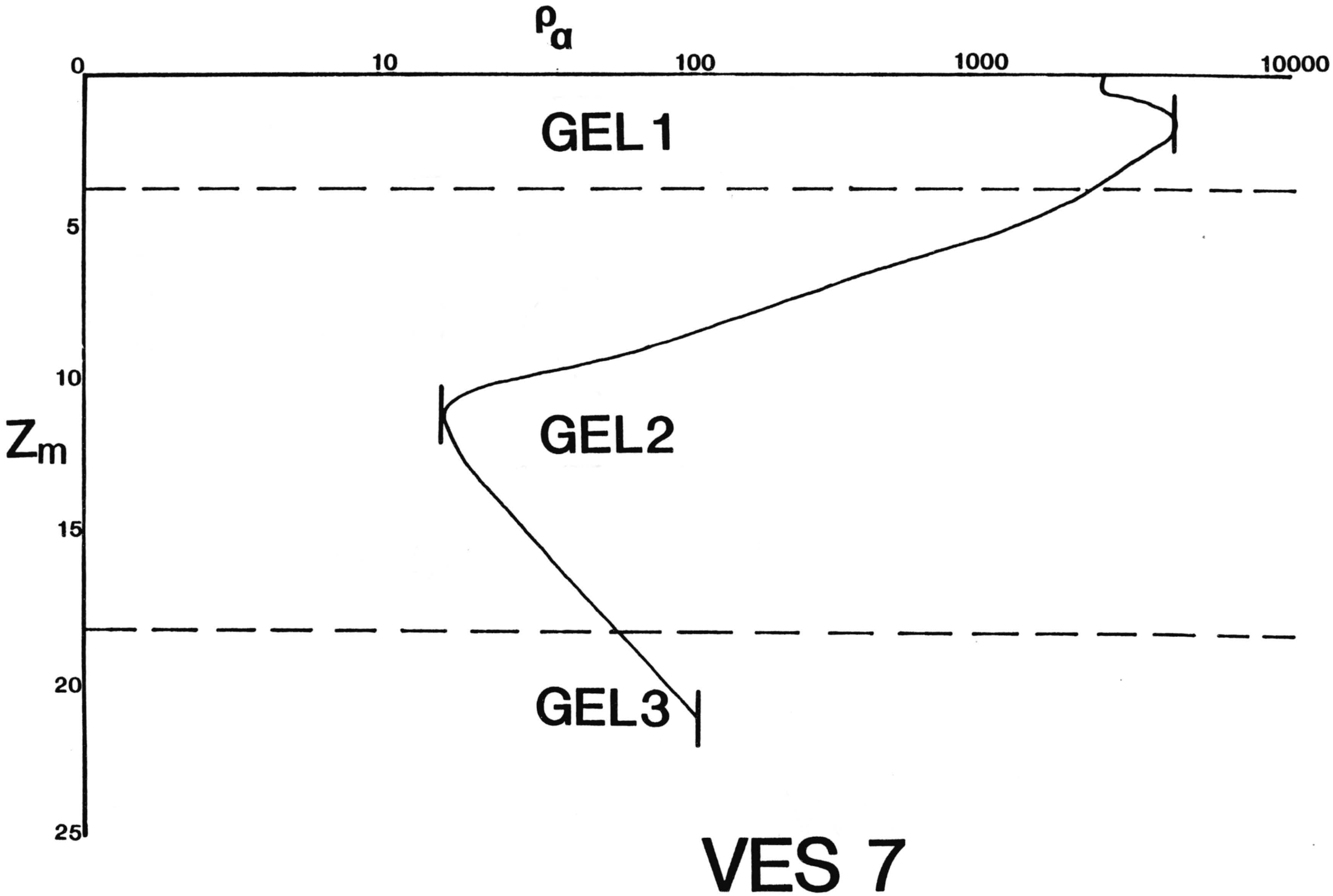
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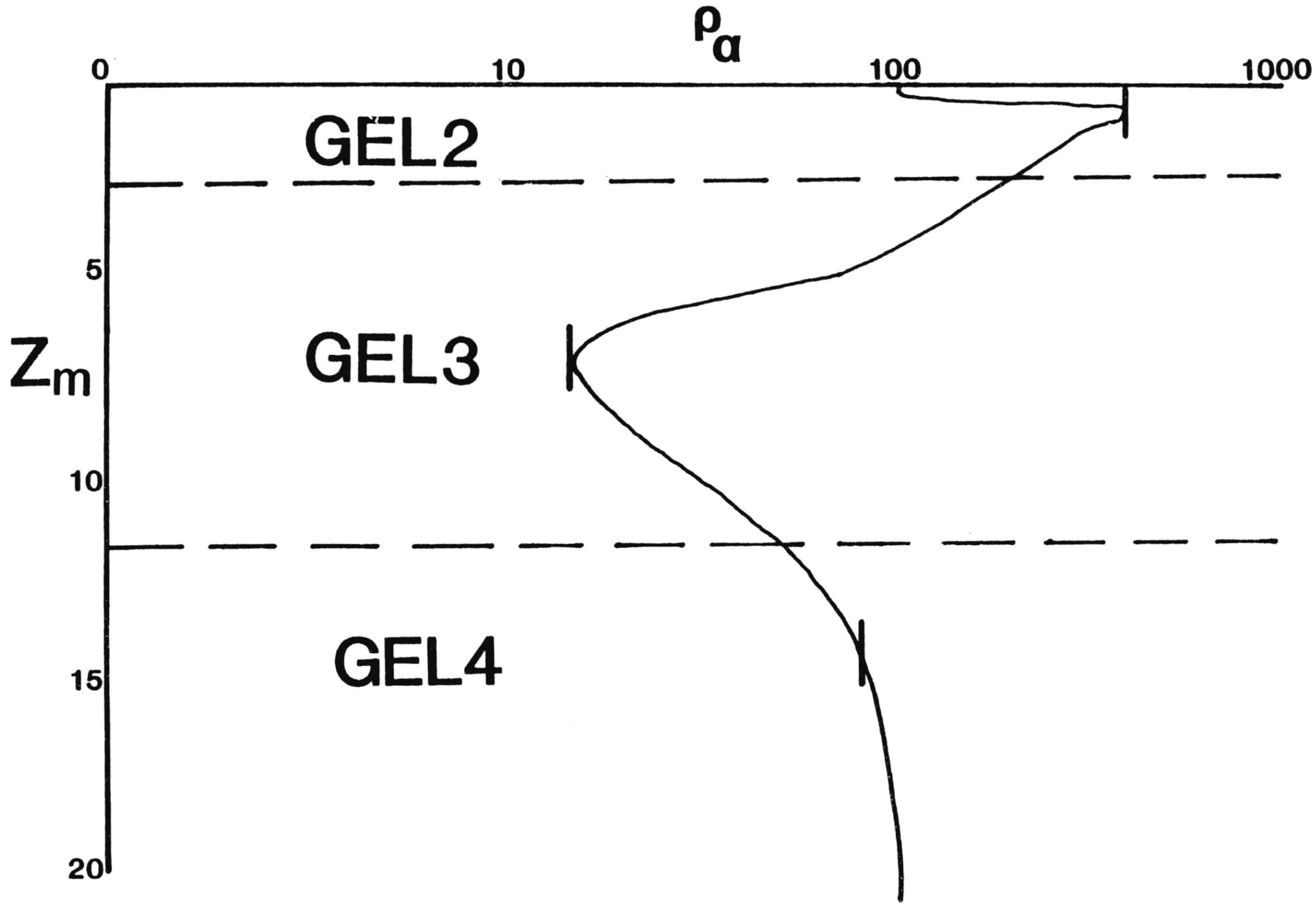
VES 7



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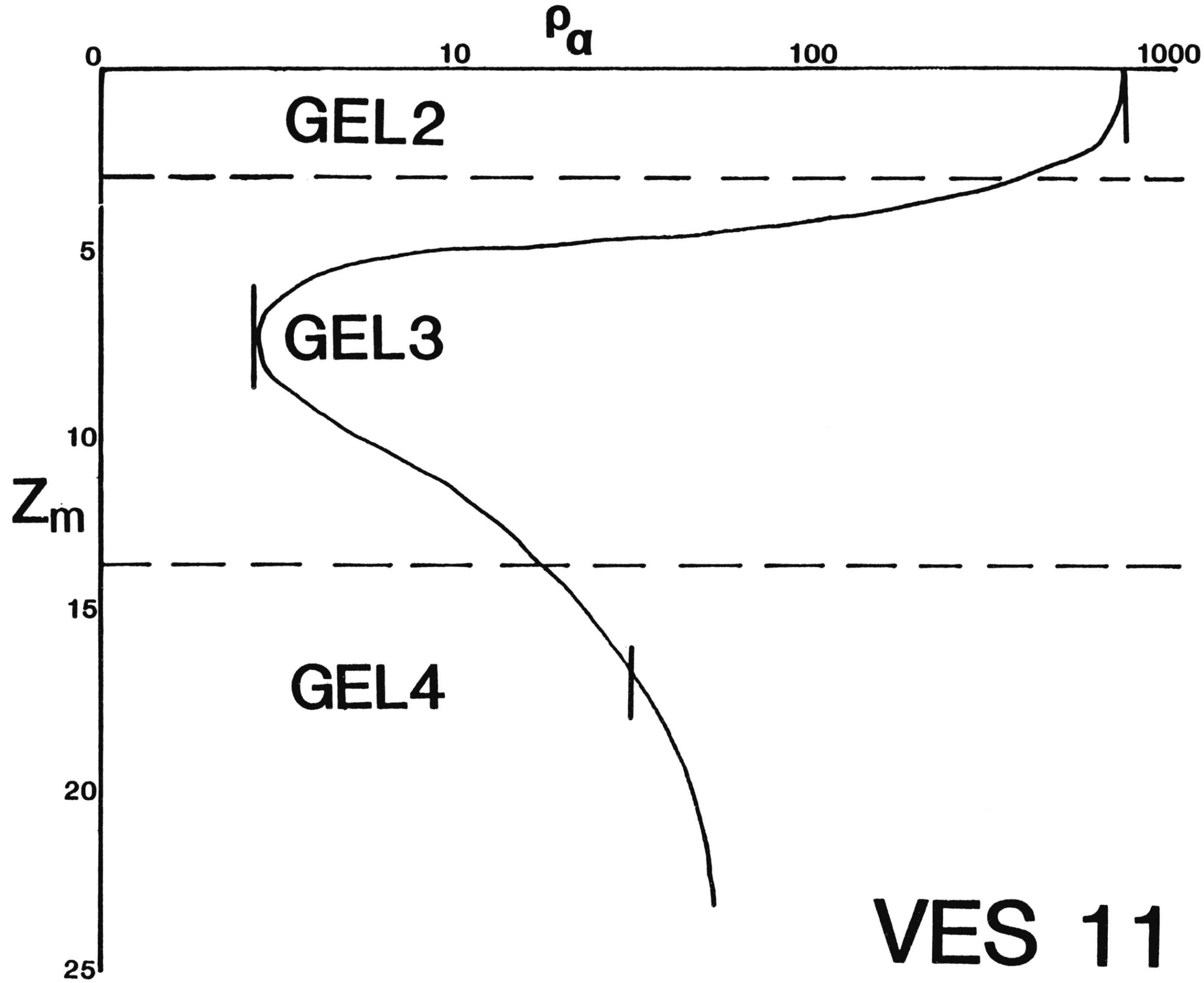
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GEL4
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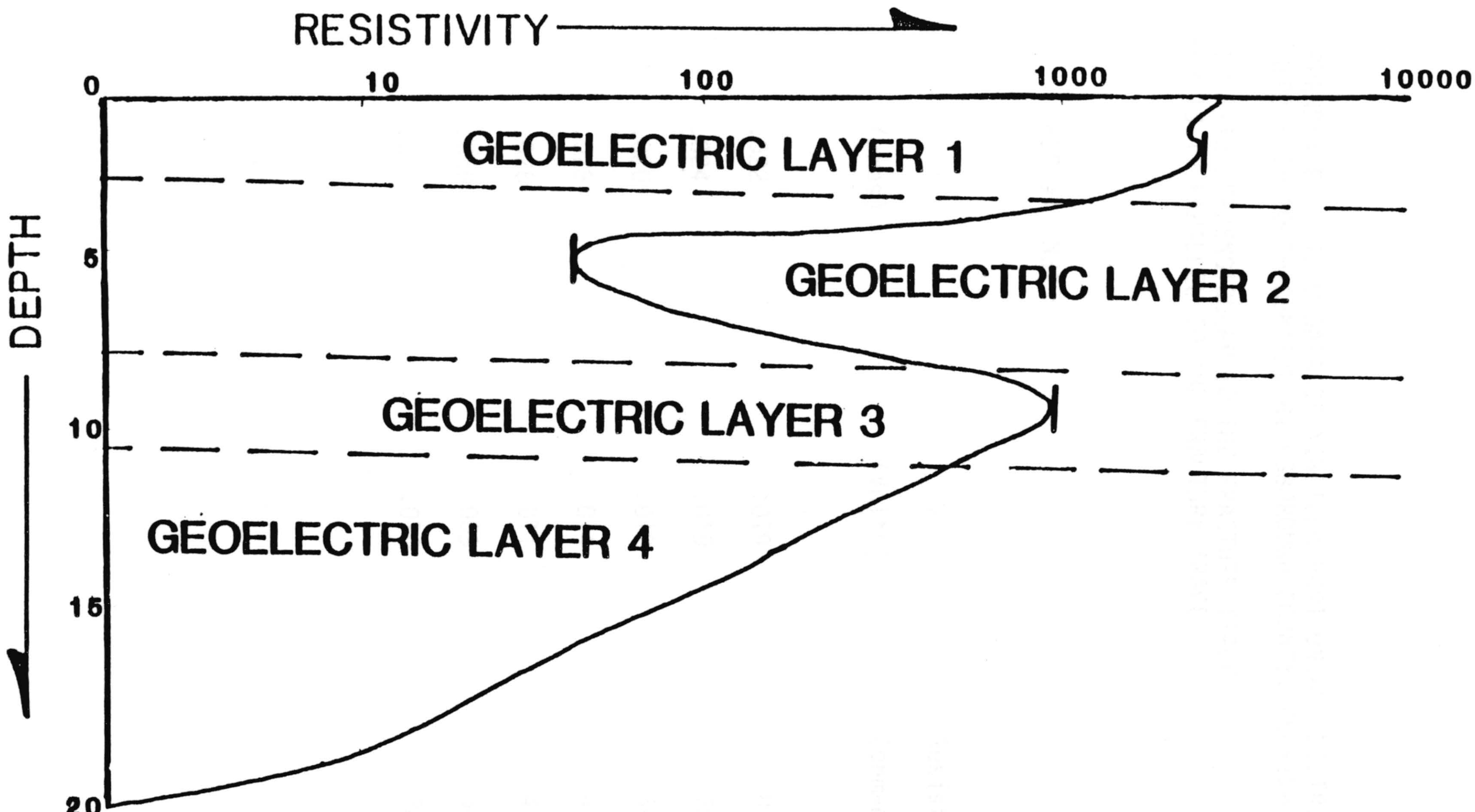
Zm
VES 11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DEPTH
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GEOELECTRIC LAYER 1
GEOELECTRIC LAYER 2
GEOELECTRIC LAYER 3
GEOELECTRIC LAYER 4

VES 13

APPENDIX E: FIELD DATA OF NINETEEN HORIZONTAL ELECTRICAL PROFILES (HEP) FROM NORTH-CENTRAL HILLSBOROUGH COUNTY, FLORIDA.

HEP 1-12 PERPENDICULAR TO THE FRACTURE TRACE
HEP 13-19 PARALLEL TO THE FRACTURE TRACE

HEP #1 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.022	.019	81
.024	.019	70
.020	.012	56
.028	.014	47
.026	.011	40
.030	.009	30
.025	.010	38

HEP #2 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.025A	.025	94
.015	.038	239
.018	.013	68
.022	.011	47
.030	.031	97
.020	.006	28
.030	.0245	77
.030	.01	30

HEP #3 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.016	.0036	21
.015	.005	31
.018	.007	37
.016	.006	35
.015	.018	113
.012	.020	157
.013	.028	203

HEP #4 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.020	.006	28
.035	.0173	46
.027	.006	21
.024	.0053	19
.025	.0133	50
.012	.0153	120
.015	.0236	148

HEP #5 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.013	.005	36
.020	.0073	34
.014	.007	47
.011	.013	111
.012	.0293	230
.010	.023	217

HEP #6 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.020	.010	47
.020	.010	47
.016	.01	59
.013	.0126	91
.014	.016	108
.014	.067	451
.017	.104	576

HEP #7 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.025	.013	49
.020	.0113	53
.016	.013	76
.012	.017	134
.012	.012	94
.010	.026	245
.009	.032	335

HEP #8 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.010	.009	80
.010	.011	100
.011	.011	94
.011	.027	230
.009	.05	520
.008	.090	1060
.013	.133	964

HEP #9 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.012	.017	134
.009	.017	178
.013	.018	131
.010	.017	160
.012	.041	322
.012	.057	447
.013	.077	558

HEP #10 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.014	.037	249
.006	.008	126
.018	.037	194
.014	.037	249
.006	.019	298
.013	.056	406
.014	.100	673

HEP #11 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.012	.1261	990
.011	.080	685
.008	.097	1143
.014	.102	687
.012	.105	825
.013	.066	478
.014	.064	431

HEP #12 N313

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.010	.075	707
.012	.113	887
.012	.077	605
.009	.087	911
.014	.104	700
.007	.054	727
.012	.054	424

HEP #13 N256

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.040	0.012	2827
.028	.007	2356
.036	.01	2880
.036	.012	3140
.045	.015	3140
.027	.009	3140
.025	.009	3400

HEP #14 N256

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.065	.052	75.4
.040	.016	37.7
.035	.025	70.1
.060	.039	61.26
.032	.01	29.4
.035	.029	78

HEP #15 N256

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.021	.012	53.86
.017	.007	38.8
.025	.01	37.7
.020	.006	28.27
.017	.007	38.8
.028	.012	40.39

HEP #16 N256

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.03	.016	50.26
.03	.014	43.98
.014	.006	40.39
.028	.01	33.66
.033	.012	33.26
.012	.004	33.77

HEP #17 N256

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.015	.04	251.33
.02	.02	94.25
.02	.012	56.35
.03	.015	47.125
.021	.008	37.25
.022	.008	34.27

HEP #18 N256

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.013	.115	833.7
.017	.043	238.4
.019	.038	188.5
.012	.012	94.25
.024	.017	66.8
.018	.01	52.36

HEP #19 N256

I (amps)	ΔV (Volts)	Resistivity (ohm-meter)
.011	.046	394.13
.008	.043	510.12
.013	.07	530.05
.013	.05	362.5
.016	.075	441.8
.014	.016	107.7

APPENDIX F: LITHOLOGIC DATA FROM TWENTY THREE WELLS OBTAINED USING HAND-AUGER IN NORTH-CENTRAL HILLSBOROUGH COUNTY, FLORIDA.

Augered Well #BA-1

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-6	0-15.24	Sand, grayish brown, coarsely mottled
6-10	15.24-25.4	Sand, light yellow brown, coarsely mottled
10-17	25.4-43.18	Sand, light yellowish brown to grayish brown , coarsely mottled
17-45	43.18-114.3	Sand, very pale brown, coarsely mottled
45-70	114.3-177.8	Sand, white, coarsely mottled
70-80	177.8-203.2	Sand, white, coarsely mottled
80-130	203.2-330.2	Sand, white sand, pink to reddish yellow, coarsely mottled
130-170	330.2-431.8	Sand, pink to reddish yellow
170-175	431.8-444.5	Sand, silty, reddish brown
170-200	444.5-508	Sand, silty, pink
200-250	508-635	Sand, silty, white, 250 inches to water table

Augered Well #BA-2

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-5	0-12.7	Sand, black, organic matter
5-10	17.7-25.4	Sand, very dark gray
10-13	25.4-33.02	Sand, pinkish gray, fine-grained
13-20	33.02-50.8	Sand, pinkish gray, fine-grained
20-25	50.8-63.5	Sand, pinkish gray, fine-grained
25-70	63.5-177.8	Sand, pinkish gray, fine-grained
70-75	177.8-190.5	Sand, light brown, fine to coarse grained
75-85	190.5-215.9	Water table
85-105	215.9-266.7	Sand, pink, fine-grained
105-120	266,7-304.8	Sand, strong brown, fine-grained

Augered Well #BA-3

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-7	0-17.78	Sand, gray, fine-grained
7-10	17.78-25.4	Sand, light brownish gray, fine-grained
10-20	25.4-50.0	Sand, light gray, fine-grained
35-40	50.8-101.6	Sand, light gray, fine-grained
40-45	101.6-114.3	Sand, pink, fine-grained
45-50	114.3-127	Sand, yellowish red to pinkish gray, fine-grained
50-55	127-139.7	Sand, silty, red to white, argillic
55-65	139.7-165.1	Sand, silty, white, argillic
65-70	165.1-177.8	Sand, clayey, dark red to light gray, lots of shell
70-80	177.8-203.2	Sand, light gray sand and minor of strong brown sand, root debris
80-95	203.2-241.3	Clay, light gray, hard

Augered Well #BA-4

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-5	0-12.7	Sand, argillic, red, fills,
5-12	12.7-30.48	Sand, dark grayish brown, fine-grained
15-20	30.48-50.8	Sand, light brownish gray, fine-grained
20-40	50.8-101.6	Sand, light gray and traces of yellowish brown
40-70	101.6-177.8	Sand, white, fine-grained
70-80	177.8-203.2	Sand, very pale brown, fine-grained
80-95	203.2-241.3	Sand, pale brown, fine-grained, capillary fringe
95-102	203.2-241.3	Sand, pale yellow, 95 inches to water table

Augered Well #BA-5

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-7	0-17.78	Sand, dark gray, fine-grained
7-14	17.78-35.56	Sand, light brownish gray, fine-grained
14-40	35.56-101.6	Sand, light gray, fine-grained
40-60	101.6-152.4	Sand, silty, argillic, yellowish to pinkish white
60-70	152.4-177.8	Sand, silty, very pale brown, slightly mottled
70-95	177.8-241.3	Sand, clayey, light gray,
95-125	241.3-317.5	Sand, yellow, fine-grained
125-139	317.5-353.06	Clay, silty, white to red, mottled
139-143	353.06-363.22	Clay, silty, white to yellow, mottled

Augered Well #BA-6

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-7	0-17.78	Sand, dark gray, fine-grained
7-14	17.78-35.56	Sand, light brownish gray, fine-grained
14-29	35.56-73.66	Sand, light gray, fine-grained
29-40	73.66-101.6	Sand, mottled, very pale brown, argillic
40-50	101.6-127	Sand, argillic, reddish yellow,
50-60	127-152.4	Sand, red, gleyed or mottled
60-65	152.4-165.1	Sand, sandy, white with reddish stains

Augered Well #BA-7

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-7	0-17.78	Sand, dark gray, fine-grained
7-14	17.78-35.56	Sand, grayish brown, fine-grained
14-50	35.56-127	Sand, white, fine-grained
50-58	127-147.32	Sand, very pale brown, fine-grained
58-70	147.32-177.8	Clay, sandy, yellow, hard
70-95	177.8-241.3	Clay, argillic, red, mottled
95-100	241.3-254	Clay, white, gleyed, wetter
110-125	254-317.5	Clay, silty, white, some shell fragments

Augered Well #BA-8

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-80	0-203.2	Sand, altering to very pale brown with increasing depth, fine-grained
80-90	203.2-228.6	Clay, silty, yellow, wet

Augered Well #BA-9

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-98	0-248.92	Sand, dark gray, fine-grained
98-102	248.92-259.08	Clay, silty, yellow,

Augered Well #BA-10

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-7	0-17.78	Sand, gray, fine-grained
7-120	17.78-304.8	Sand, very pale brown, fine-grained
120-125	304.8-317.5	Sand, yellow, fine-grained
125-130	317.5-330.2	Clay, sandy, light gray, mottled, hard

Augered Well #BA-11

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-7	0-17.78	Sand, light brownish gray, fine-grained
7-172	17.78-436.88	Sand, white, fine-grained
172-176	436.88-447.04	Sand, reddish yellow, fine-grained
176-190	447.04-482.6	Sand, clayey, light gray,
190-220	482.6-558.8	Sand, clayey, pinkish white,
220-225	558.8-571.5	Sand, clayey, light red, fine-grained
225-230	571.5-584.2	Sand, clayey, white, mottled, 225 inches to water table
230-250	609.6-635	Clay, silty, red, mottled,
250-260	635-660	Sand, yellow, slightly mottled and fine-grained
260-275	660-698.5	Sand, clayey, red, fine-grained
275-280	698.5-711.5	Clay, white to red mottling, hard
280-290	711.2-736.6	Clay, light gray to white reddish yellow mottling
290-300	736.6-762	Clay, brownish yellow, mottling, white, marly grains

Augered Well #BA-12

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-7	0-17.78	Sand, light brownish gray, fine-grained
7-40	17.78-101.6	Sand, very pale brown, fine-grained
40-110	101.6-279.4	Sand, white, fine-grained, capillary fringe at 105 inches
110-150	279.4-391	Sand, clayey, very pale brown to yellowish red,
150-160	381-406.4	Clay, sandy, red to white, mottled,
160-180	406.4-457.2	Clay, sandy, white,
180-185	457.2-469.9	Sand, clayey, reddish yellow, 185 inches to water table
185-205	469.9-520.7	Clay, white, limestone bits smaller than 5mm
205-210	520.7-533.4	Limestone, weathered, yellow,
210-230	533.4-584.2	Clay, silty, white, hard

Augered Well #BA-13

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-60	0-152.4	Sand, silty, dark gray to very pale brown, fine-grained,, clay with iron stain. Mottled and mixed due to ravelling action
60-120	152.4-304.8	Sand, gray, fine-grained and very soft, 65 inches to water table
120-125	304.8-317.5	Sand, silty, light gray, very fine-grained
125-130	317.5-330.2	Sand, silty, dark gray, fine-grained

Augered Well #BA-14

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-7	0-17.78	Sand, silty, clayey, very pale brown, fine-grained, some iron stains
7-15	17.78-38.1	Sand, dark gray, fine-grained
15-55	38.1-139.7	Sand, white, fine-grained
55-60	139.7-152.4	Sand, white, fine-grained
60-65	152.4-165.1	Sand, silty, pale yellow,
65-75	165.1-190.5	Sand, silty, reddish yellow,
75-100	190.5-254	Sand, silty, 60% light gray, 40% yellowish red,
100-140	254-355.6	Clay, pale yellow, hard
140-150	355.6-381	Sand, white to yellowish red, gleyed, poorly-sorted, 145 inches to water table
150-160	381-406.4	Clay, sandy, pale yellow to reddish brown,
160-170	406.4-431.8	Clay, silty, lime yellow to white, poorly-sorted, hard

Augered Well #15

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-5	0-12.7	Fill, gray, organic matter
5-30	12.7-76.2	Sand, 85% pale yellow, 15% light gray, fine-grained, well sorted
30-60	76.2-152.4	Sand, pale yellow, fine-grained, well-sorted
60-130	152.4-330.2	Sand, pale yellow to grayish brown, fine-grained, well-sorted.
130-150	330.2-381	Sand, pale yellow to grayish brown, fine-grained
150-160	381-406.4	Sand, pale yellow, fine-grained, 155 inches to water table
160-180	406.4-457.2	Sand, light gray to pale yellow, fine-grained

Augered Well #16

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-15	0-38.1	Sand, dark gray, fine-grained, organic matter
15-30	38.1-76.2	Sand, very dark gray, fine-grained
30-40	76.2-101.6	Sand, dark yellowish brown, fine-grained
40-70	101.6-177.8	Sand, light brownish gray, fine-grained
70-80	177.8-203.2	Sand, light brownish gray, fine-grained
80-130	203.2-330.2	Sand, white, fine-grained
130-140	330.2-355.6	Sand, light gray, fine-grained, wet
140-150	355.6-381	Sand, pale yellow, fine-grained
155-165	381-419.1	Sand, dark yellowish brown, fine-grained
165-175	419.1-444.4	Sand, dark yellowish brown, fine-grained, 170 inches to water table
175-210	444.5-533.4	Sand, light yellowish brown, fine-grained, dark gray, gleyed, wet

Augered Well #BA-17

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-5	0-12.7	Fills, white
5-65	12.7-165.1	Sand, white, fine-grained, well-sorted, wet (close to lake), 65 inches to water table
65-120	165.1-304.8	Sand, fine-grained, well-sorted, saturated with water

Augered Well #BA-18

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-5	0-12.7	Sand, fills, very dark gray, fine- to medium-grained, organic
5-15	12.7-32.25	Sand, gray, fine-grained
15-60	32.25-152.4	Sand, very pale brown, fine-grained
60-70	152.4-177.8	Sand, brownish yellow, fine-grained, well-sorted, capillary fringe
70-75	177.8-190.5	Sand, brownish yellow, fine-grained, well-sorted, saturated with water, 70 inches to water table
75-120	190.5-304.8	Sand, brownish yellow, very pale brown, fine-grained

Augered Well #19

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-5	0-12.7	Sand, grayish brown, fine-grained
5-100	12.7-254	Sand, pale yellow, fine-grained
100-135	254-342.9	Sand, pale yellow, reddish yellow, fine-grained
135-145	342.9-368.3	Sand, silty, strong brown,
145-150	368.3-381	Sand, silty, dark brown, strong brown, gleyed
150-160	381-406.4	Sand, silty, reddish yellow,
160-165	406.4-419.1	Clay, silty, white, strong brown, gleyed
165-170	419.1-431.8	Clay, silty, white, red, gleyed, with root debris
170-195	431.8-495.3	Clay, silty, white,
195-200	495.3-508	Clay, silty, white, yellowish red, gleyed
200-210	508-533.4	Clay, silty, white,
210-227	533.4-576.58	Silt, clayey, white, yellowish red, gleyed
227-232	576.58-589.28	Sand, silty, white, yellow, gleyed
232-240	589.28-609.6	Clay, silty, white, yellowish red, gleyed
240-245	609.6-622.3	Clay, silty, limestone fragments
245-255	622.3-647.7	Silt, white, clayey
255-288	647.7-731.52	Silt, white, yellow, clayey, gleyed, 270 inches to water table
288-295	731.52-749.3	Clay with limestone fragments, white, well-lithified

Augered Well #BA-20

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-5	0-12.7	Sand, light brownish gray, with fill
5-40	12.7-101.6	Sand, light yellowish brown
40-75	101.6-190.5	Sand, pale yellow, fine-grained, well-sorted
75-95	190.5-241.3	Sand, pale yellow, reddish brown, gleyed, well-sorted
95-105	241.3-266.7	Sand, white to reddish brown, gleyed
105-111	266.7-279.4	Sand, silty, strong brown,
110-115	279.4-279.1	Silt, clayey, strong brown, white, gleyed
115-120	292.1-304.8	Clay, silty, white, strong brown, gleyed, well-lithified
120-125	304.8-317.5	Clay, yellowish to dark brown, gleyed, well-lithified
125-130	317.5-330.2	Clay, white, well-lithified
130-135	330.2-342.9	Clay, silty, white to yellowish red, gleyed
135-150	342.9-381	Clay, clayey, white, red brown, gleyed
150-160	381-406.4	Silt, clayey, dark brown,
160-183	406.4-464.82	Clay, silty, white, well-lithified
183-200	464.82-508	Silt, clayey, white to brownish yellow, limestone fragments, gleyed, well-lithified

Augered Well #BA-21

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-5	0-12.7	Fill, light brownish gray
5-10	12.7-25.4	Sand, light yellowish brown, fine-grained, well-sorted
10-90	25.4-228.6	Sand, pale yellow, fine-grained
90-100	228.6-245	Sand, pale yellow, fine-grained
100-125	245-317.5	Sand, pale yellow, fine-grained
125-140	317.5-355.6	Sand, pale yellow to reddish brown, fine-grained
140-185	355.6-469.9	Sand, pale yellow, fine-grained
185-195	469.9-495.3	Sand, silty, reddish yellow,
195-205	495.3-520.7	Silt, sandy, reddish brown,
205-210	520.7-533.4	Silt, sandy, reddish brown,
210-240	533.4-60916	Silt, clayey, reddish brown, white, gleyed
240-245	609.6-622.3	Clay, silty, dark brown, yellowish red, gleyed
245-260	622.3-660.4	Clay, dark brown, yellowish red, gleyed, well-lithified

Augered Well #BA-22

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-10	0-25.4	Fills, light brown gray
10-30	25.4-76.2	Sand, pale yellow, fine-grained
30-40	76.2-101.6	Sand, pale yellow fine-grained
40-60	101.6-152.4	Sand, pale yellow, fine-grained
60-80	152.4-203.2	Sand, silty, pale yellow, fine-grained
80-145	203.2-368.3	Sand, white, fine-grained, clean, well-sorted
145-155	368.3-393.7	Sand, white, fine-grained, clean, saturated with water
155-160	393.7-406.4	Silt, sandy, strong brown,
160-170	406.4-431.8	Silt, clayey, white, reddish yellow, gleyed
170-180	431.8-457.2	Clay, silty, white,
180-190	457.2-482.6	Clay, white to dark brown, gleyed, well-lithified
190-200	482.6-508	Sand, clayey, pink to reddish yellow, gleyed
200-210	508-533.4	Silt, clayey, red,
210-240	533.4-609.6	Silt, sandy, red,
240-250	609.6-635	Clay, silty, pale yellow, dense, with white weathered limestone fragments
250-260	635-660.4	Clay, silty, pale yellow, dense, with white weathered limestone fragments
260-270	660.4-685.8	Clay, silty, pale yellow, dense, white limestone fragments ranging in size from 2mm-11mm in maximum diameter

Augered Well #BA-23

Depth Below Land Surface		Lithologic Description
Inches	Centimeters	
0-6	0-15.24	Sand, light brown gray, fine-grained
6-10	15.24-25.4	Sand, pale yellow, fine-grained
10-20	25.4-50.8	Sand, pale yellow fine-grained
20-50	50.8-127	Sand, pale yellow, fine-grained
50-55	127-139.7	Sand, yellow, fine-grained
55-70	139.7-177.8	Sand, yellow, fine-grained, mottling increases with depth
70-115	177.8-292.1	Sand, yellow, fine-grained
115-135	292.1-342.9	Sand, white, very fine-grained, well-sorted, no mottling
135-148	342.9-375.9	Sand, white, very fine-grained, well-sorted, saturated with water
148-164	375.9-416.56	Sand, silty, clayey, reddish yellow, % clay increases with depth
164-180	416.56-457.2	Sand, silty, clayey, reddish yellow, mottling
180-200	457.2-508	Clay, silty, very pale brown, dense, 190 inches to water table
200-212	508-538.48	Silty, clayey, very pale brown, mottling

APPENDIX G: LITHOLOGIC DATA FOR ELEVEN SAMPLES ANALYZED USING SIEVE AND HYDROMETER ANALYSIS.

SIEVE ANALYSIS DATA

Job No. 1 Date 7/29/85

Sample No. BA-1 Location U.S.F.

Depth of Sample. 177.8-203.2 cm

Sample Preparation: Air Dried ____ Oven Dried X

Sieve Method: Washed ____ Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
16	0.00	0.0	100
40	00.5	0.57	99.43
60	6.7	8.17	91.83
100	76.8	95.3	4.7
200	3.2	99	1
Pan	0.9	100	0
Total	88.1		

Water Content Data

Container No. 100
Wt. Tare & Wet Soil 541.5
Wt. Tare & Dry Soil 531.8
Wt. Water 9.7
Wt. Tare 195.4
Wt. Dry Soil 336.4
Water Content (%) 2.9

SIEVE ANALYSIS DATA

Job No. 2 Date 7/29/85

Sample No. BA-5 Location U.S.F.

Depth of Sample 35.56-101.6 cm

Sample Preparation: Air Dried ______ Oven Dried X

Sieve Method: Washed ______ Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
16	0.5	0.2	99.8
40	1.3	0.78	99.22
60	8.6	4.5	95.5
100	94	45.2	54.8
200	120.9	97.5	2.5
Pan	5.7	100	0
Total	231		

Water Content Data

Container No. 2
Wt. Tare & Wet Soil 351.5
Wt. Tare & Dry Soil 348.8
Wt. Water 2.7
Wt. Tare 117.8
Wt. Dry Soil 231
Water Content (%) 1.17

SIEVE ANALYSIS DATA

Job No. 3 Date 7/30/85

Sample No. BA-2 Location U.S.F.

Depth of Sample 177.8-190.5 cm

Sample Preparation: Air Dried ____ Oven Dried X

Sieve Method: Washed ____ Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
16	0.1	0.05	99.95
40	1.5	0.84	99.16
60	9.9	6	94
100	69.3	42.2	57.8
200	105.6	97.3	2.7
Pan	5.2	100	0
Total	191.6		

Water Content Data

Container No. 4
Wt. Tare & Wet Soil 339.6
Wt. Tare & Dry Soil 309.6
Wt. Water 30
Wt. Tare 117.6
Wt. Dry Soil 192
Water Content (%) 15.6

SIEVE ANALYSIS DATA

Job No. 4 Date 7/30/85

Sample No. BA-6 Location

Depth of Sample 35.56-73.66 cm

Sample Preparation: Air Dried ____ Oven Dried X

Sieve Method: Washed ____ Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
16	0.2	0.1	99.9
40	1.3	0.8	99.2
60	8.1	5	95
100	82.8	47.9	52.1
200	96.2	97.7	2.3
Pan	4.4	100	0
Total	193		

Water Content Data

Container No. 3
Wt. Tare & Wet Soil 319.6
Wt. Tare & Dry Soil 312.9
Wt. Water 6.7
Wt. Tare 119.9
Wt. Dry Soil 193
Water Content (%) 3.5

SIEVE ANALYSIS DATA

Job No. 5 Date 7/30/85

Sample No. BA-2 Location U.S.F.

Depth of Sample 241.3-254 cm

Sample Preparation: Air Dried ______ Oven Dried X

Sieve Method: Washed ______ Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
16	0.9	0.8	99.2
40	17.8	16.7	83.3
60	24.6	38.6	61.4
100	38.6	73	27
200	17.6	88.7	11.3
Pan	12.7	100	0
Total	112.2		

Water Content Data

Container No. 3
Wt. Tare & Wet Soil 272.9
Wt. Tare & Dry Soil 236.3
Wt. Water 36.6
Wt. Tare 120
Wt. Dry Soil 116.3
Water Content (%) 3.15

SIEVE ANALYSIS DATA

Job No. 6 Date 7/30/85

Sample No. BA-3 Location U.S.F.

Depth of Sample 127-139.7 cm

Sample Preparation: Air Dried ______ Oven Dried X

Sieve Method: Washed ______ Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
16	0.2	0.1	99.9
40	1.9	1.4	98.6
60	24.1	17.6	82.4
100	89.2	77.4	22.6
200	24.7	94	6
Pan	8.9	100	0
Total	149		

Water Content Data

Container No. 4
Wt. Tare & Wet Soil 287
Wt. Tare & Dry Soil 269.7
Wt. Water 17.3
Wt. Tare 117.7
Wt. Dry Soil 152
Water Content (%) 11.4

SIEVE ANALYSIS DATA

Job No. 7 Date 7/30/85

Sample No. BA-5 Location U.S.F.

Depth of Sample 152.4-177.8 cm

Sample Preparation: Air Dried ____ Oven Dried X

Sieve Method: Washed ____ Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
16	0	0	100
40	2.7	1.9	98.1
60	34	26.3	73.7
100	86.5	88.2	11.8
200	6.5	92.8	7.2
Pan	10	100	0
Total	139.7		

Water Content Data

Container No. 5
Wt. Tare & Wet Soil 304.1
Wt. Tare & Dry Soil 291.8
Wt. Water 12.3
Wt. Tare 124.1
Wt. Dry Soil 167.7
Water Content (%) 7.3

SIEVE ANALYSIS DATA

Job No. 8 Date 7/30/85

Sample No. BA-3 Location

Depth of Sample 165.1-177.8 cm.

Sample Preparation: Air Dried ____ Oven Dried X

Sieve Method: Washed ____ Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
16	0.1	0.1	99.99
40	2	1.8	98.2
60	32.4	29.5	70.5
100	48.9	71.3	28.7
200	19.1	87.6	12.4
Pan	14.5	100	0
Total	117		

Water Content Data

Container No. 2
Wt. Tare & Wet Soil 274.6
Wt. Tare & Dry Soil 249.2
Wt. Water 25.4
Wt. Tare 117.9
Wt. Dry Soil 131.3
Water Content (%) 19

SIEVE ANALYSIS DATA

Job No. 9 Date 8/5/85

Sample No. BA-5 Location U.S.F.

Depth of Sample 350-357 cm.

Sample Preparation: Air Dried ______ Oven Dried X

Sieve Method: Washed X Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
4	0	0	100
16	0	0	100
40	0	0	100
60	0	0	100
100	.7	.4	98.6
200	9.3	19.9	80.1
Pan			
Total			

Water Content Data

Container No. ______
Wt. Tare & Wet Soil 155
Wt. Tare & Dry Soil 142.6
Wt. Water 12.4
Wt. Tare 120
Wt. Dry Soil 22.6
Water Content (%) 54.9
Wt. Soil 50.3 gm.

SIEVE ANALYSIS DATA

Job No. 10 Date 8/5/85

Sample No. BA-11 Location U.S.F.

Depth of Sample 750-762 cm.

Sample Preparation: Air Dried ____ Oven Dried X

Sieve Method: Washed X Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
4	0.5	0.4	99.6
16	.3	0.74	99.26
40	.9	1.6	98.4
60	.4	1.94	98.06
100	4.5	6.1	93.9
200	25.8	30	70
Pan			
Total			

Water Content Data

Container No. ____
Wt. Tare & Wet Soil 199.8
Wt. Tare & Dry Soil 174.4
Wt. Water 25.4
Wt. Tare 124.1
Wt. Dry Soil 50.3
Water Content (%) 50.5
Wt. Soil 108 gm.

SIEVE ANALYSIS DATA

Job No. 11 Date 8/5/85

Sample No. BA-19 Location U.S.F.

Depth of Sample 731.5-749.3

Sample Preparation: Air Dried ______ Oven Dried X

Sieve Method: Washed X Dry X

Sieve Analysis

Sieve Size	Weight Retained	Cumulative & Retained	Percent Passing
4	1.6	2	98
16	1.1	3.4	96.6
40	1.2	4.8	95.2
60	1.1	6.3	93.7
100	3.4	8.4	90.5
200	14.9	29.2	70.8
Pan			
Total			

Water Content Data

Container No. ______
Wt. Tare & Wet Soil 97.5
Wt. Tare & Dry Soil 87.3
Wt. Water 10.2
Wt. Tare 68.9
Wt. Dry Soil 18.4
Water Content (%) 55.4
Wt. Soil 79.9 gm.

HYDROMETER ANALYSIS DATA

Date of Testing 8/1/85 Job No. 9

Location of Project U.S.F. Sample No. BA-5

Description of Soil Clay, silty, mottled Depth of Sample 350-357

Hydrometer analysis

Hydrometer no. 151 H G_s of solids = 2.74

Dispersing Agent Sodium silicate Amount 1 ml Wt. of soil, W_s 50.3

Meniscus correction 0

Date	Time	Elapsed Time	Susp. Hydr. Reading	Susp. Hydr. Reading	Correc. Hydr. Reading	Z R	D,mm	% Finer
8/1/85	10:00	15 sec.	24.5	1.0245	1.0245	9.85	.08	76.7
		30 sec.	23.5	1.0235	1.0235	10.1	.055	73.6
		1 min.	23	1.023	1.023	10.2	.04	72
		2 min.	22.75	1.02275	1.02275	10.3	.028	71.2
		5 min.	22.5	1.0225	1.0225	10.35	.018	70.4
		10 min.	22.25	1.02225	1.02225	10.4	.013	69.7
		20 min.	22	1.022	1.022	10.5	.009	68.9
		40 min.	21.75	1.02175	1.02175	10.6	.0065	68.1
		80 min.	21.75	1.02175	1.02175	10.6	.0045	68.1
	13:00	3 hrs.	21.5	1.0215	1.0215	10.65	.003	67.3
	16:00	6 hrs.	21.25	1.02125	1.02125	10.7	.0022	66.5
	22:00	12 hrs.	21	1.021	1.021	10.7	.0015	65.7
8/2/85	10:00	24 hrs.	20.9	1.0209	1.0209	10.7	.0011	65.4
8/3/85	10:00	48 hrs.	20.75	1.02075	1.02075	10.85	.0008	64.96
8/5/85	10:00	96 hrs.	20.5	1.0205	1.0205	10.9	.0006	64.2

HYDROMETER ANALYSIS DATA

Date of Testing 8/1/85 Job No. 10

Location of Project U.S.F. Sample No. BA-11

Description of Soil Clay, white, marly grains Depth of Sample 750-762

Hydrometer analysis

Hydrometer no. 151 H G_s of solids = 2.74

Dispersing Agent Sodium silicate Amount 1 ml Wt. of soil, W_s 108

Meniscus correction 0

Date	Time	Elapsed Time	Susp. Hydr. Reading	Susp. Hydr. Reading	Correc. Hydr. Reading	Z R	D,mm	% Finer
8/1/85	9:00	15 sec.	39	1.039	1.039	6	.06	57
		30 sec.	38	1.038	1.038	6.2	.05	55.4
		1 min.	36.5	1.0365	1.0365	6.65	.032	53.2
		2 min.	36	1.036	1.036	6.8	.023	53.5
		5 min.	35	1.035	1.035	7	.015	51
		10 min.	34.5	1.0345	1.0345	7.15	.011	50.3
		20 min.	34.25	1.03425	1.03425	7.2	.0075	49.9
		40 min.	34.10	1.0341	1.0341	7.2	.0052	49.7
		80 min.	34	1.034	1.034	7.3	.0037	49.6
	12:00	3 hrs.	33.9	1.0339	1.0339	7.3	.0025	49.4
	15:00	6 hrs.	33.75	1.03375	1.03375	7.4	.0017	49.2
	21:00	12 hrs.	33.5	1.0335	1.0335	7.45	.0012	48.8
8/2/85	9:00	24 hrs.	32	1.032	1.032	7.8	.0009	46.-
8/3/85	9:00	48 hrs.	31	1.031	1.031	8.1	.00065	45
8/5/85	9:00	96 hrs.	30.5	1.0305	1.0305	8.25	.0005	44.5

HYDROMETER ANALYSIS DATA

Date of Testing 7/31/85 Job No. 11

Location of Project U.S.F. Sample No. BA-19

Description of Soil Clay, Depth of Sample 731.5-749.3 cm.

Hydrometer analysis

Hydrometer no. 151 H G_s of solids = 2.74

Dispersing Agent Sodium silicate Amount 1 ml. Wt. of soil, W_s 79.9 gm

Meniscus correction 0

Date	Time	Elapsed Time	Susp. Hydr. Reading	Susp. Hydr. Reading	Correc. Hydr. Reading	Z R	D,mm	% Finer
7/31/85	10:48	15 sec.	33	1.033	1.033	7.6	.07	65
		30 sec.	32	1.032	1.032	7.8	.05	63.1
		1 min.	30.7	1.0307	1.0307	8.3	.036	60.5
		2 min.	29.5	1.0295	1.0295	8.5	.026	58.1
		5 min.	28.5	1.0285	1.0285	8.75	.017	56.2
	10:58	10 min.	28.3	1.0283	1.0283	8.8	.012	55.8
	11:08	20 min.	28.2	1.0282	1.0282	8.85	.0085	55.6
		40 min.	28	1.028	1.028	8.9	.006	55.1
		80 min.	27.9	1.0279	1.0279	8.9	.006	55
		3 hrs.	27.75	1.02775	1.02775	9	.0028	54.7
	18:00	6 hrs.	27.25	1.02725	1.02725	9.1	.002	53.7
	24:00	12 hrs.	26.5	1.0265	1.0265	9.3	.0014	52.5
8/1/85	11:00	24 hrs.	24.5	1.0245	1.0245	9.85	.001	48.3
8/2/85	11:00	48 hrs.	21.5	1.0215	1.0215	10.6	.00075	42.4
8/4/85	11:00	96 hrs.	21.25	1.02125	1.02125	10.7	.00055	41.9

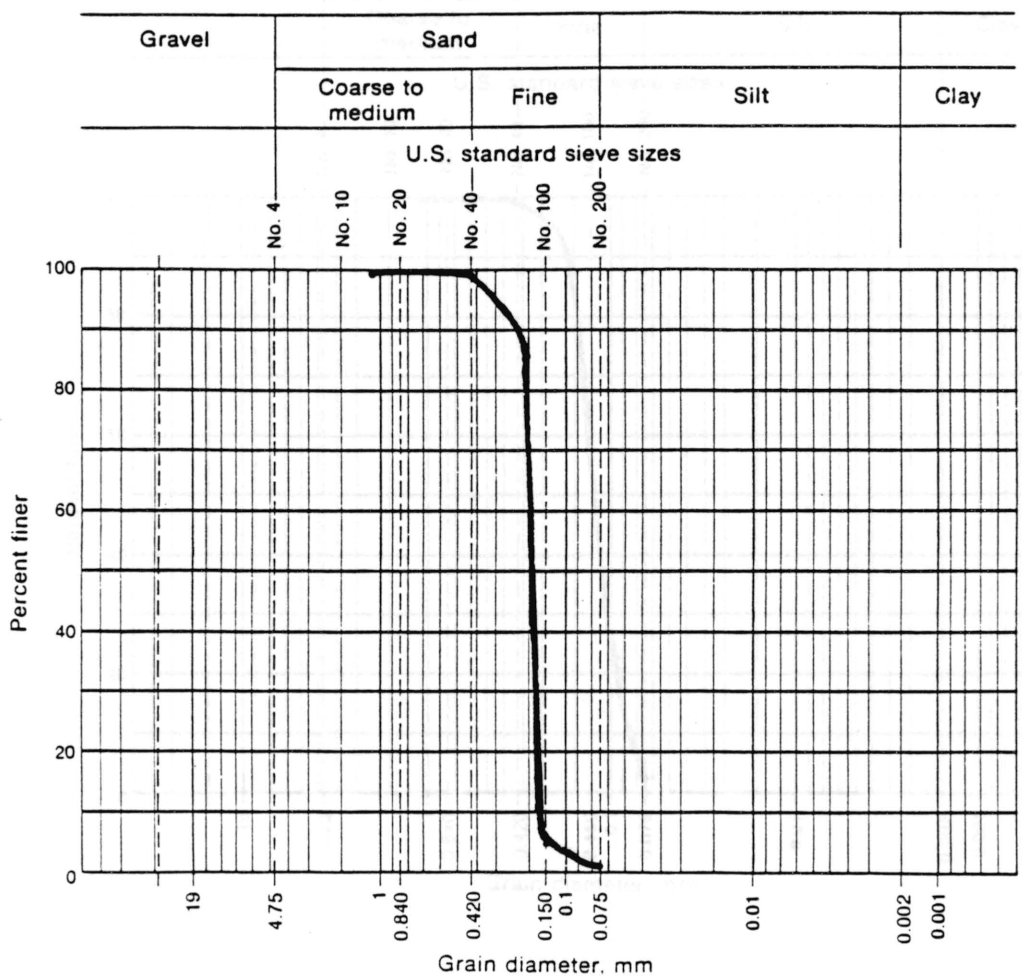
APPENDIX H: ELEVEN LITHOLOGIC SAMPLES PLOTTED AS GRAIN SIZE DIAMETER (MM) VERSUS PERCENT FINER.

Project Sieve Analysis Job. No. 1

Location of Project U.S.F. Boring No. ~ Sample No. BA-1

Description of Soil Sand, white Depth of Sample 177.8-203.2 cm.

Tested By. Alamri Date of Testing 7/29/85

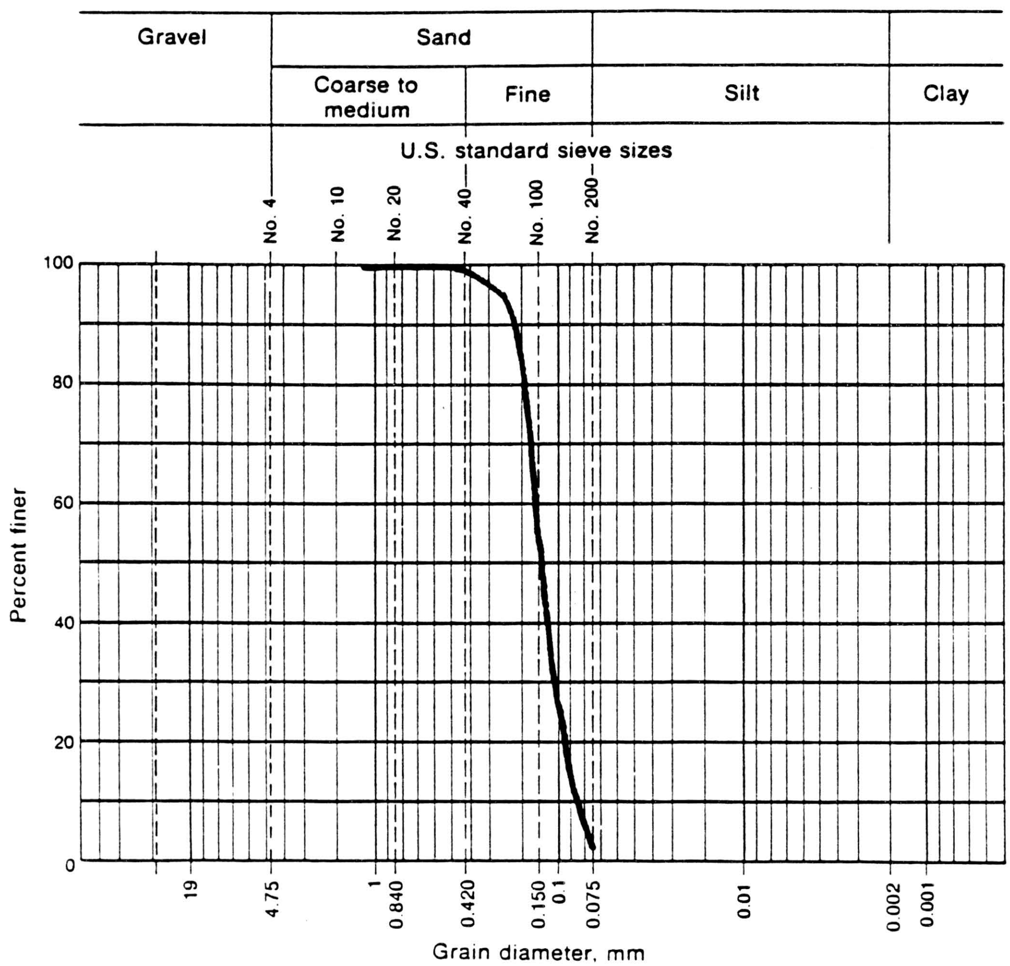


Project Sieve Analysis Job. No. 2

Location of Project U.S.F. Boring No. ~ Sample No. BA-1

Description of Soil sand, light gray Depth of Sample 35.56-101.6 cm.

Tested By. Alamri Date of Testing 7/29/85

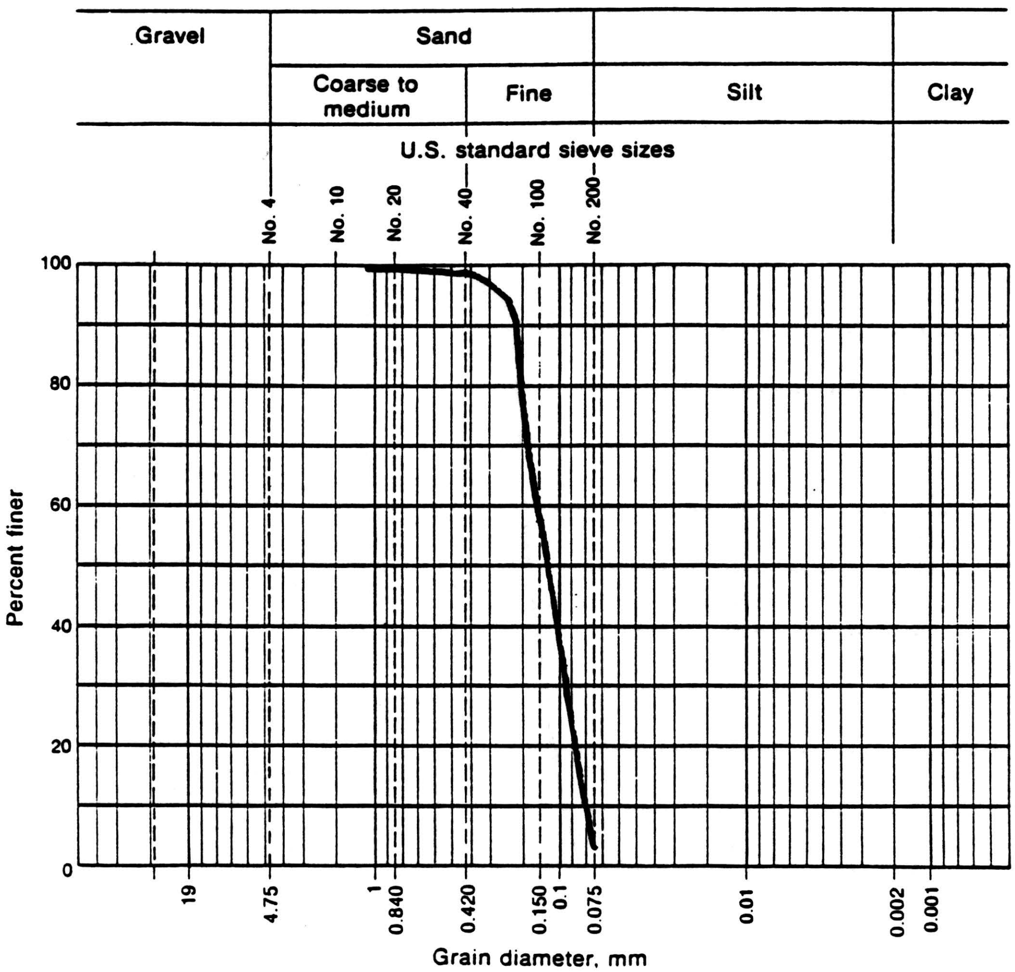


Project Sieve Analysis Job. No. 3

Location of Project U.S.F. Boring No. ~ Sample No. BA-2

Description of Soil sand, light brown Depth of Sample 177.8-190.5 cm.

Tested By. Alamri Date of Testing 7/30/85

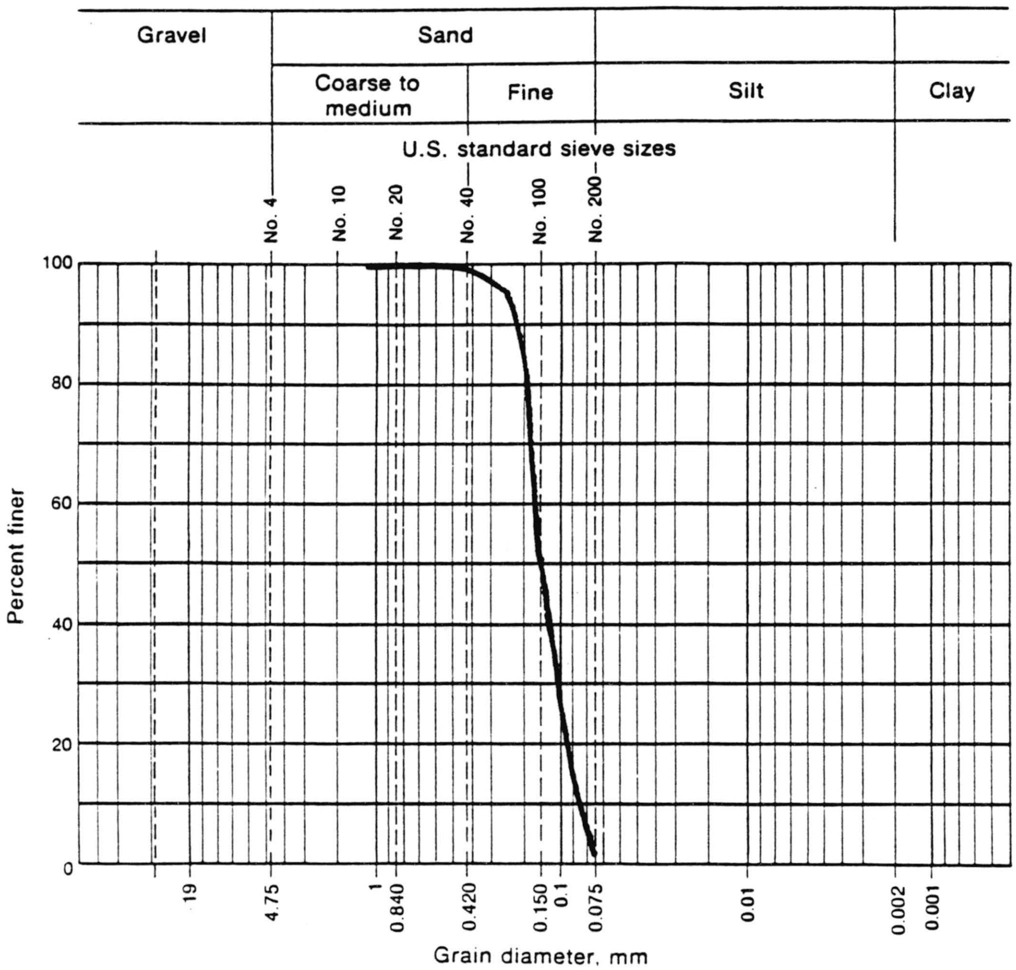


Project Sieve Analysis Job. No. 4

Location of Project U.S.F. Boring No. ~ Sample No. BA-6

Description of Soil sand, light gray Depth of Sample 35.56-73.66 cm.

Tested By. Alamri Date of Testing 7/30/85

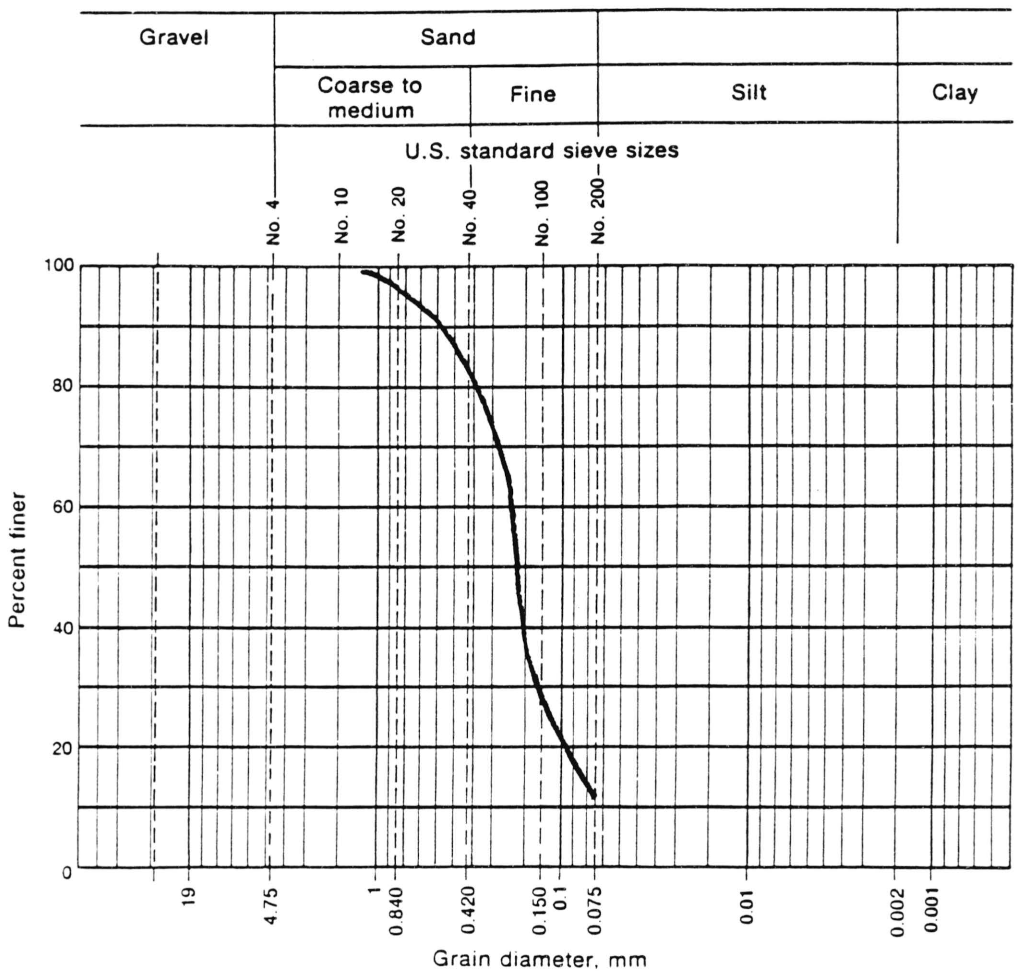


Project Sieve Analysis Job. No. 5

Location of Project U.S.F. Boring No. ~ Sample No. BA-7

Description of Soil sand, clayey, gleyed Depth of Sample 241.3-254 cm.

Tested By. Alamri Date of Testing 7/30/85

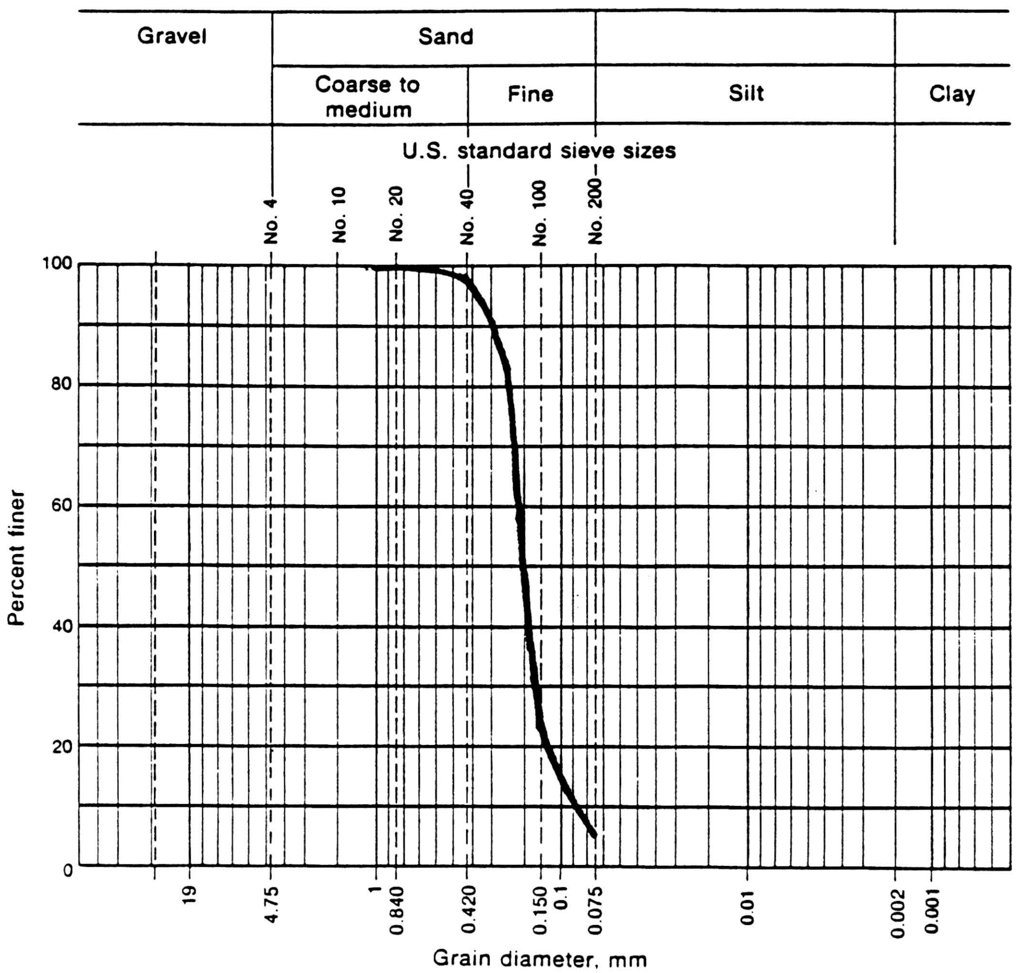


Project Sieve Analysis Job. No. 6

Location of Project U.S.F. Boring No. ~ Sample No. BA-3

Description of Soil sand, silty, argillic Depth of Sample 127-139.7 cm.

Tested By. Alamri Date of Testing 7/30/85

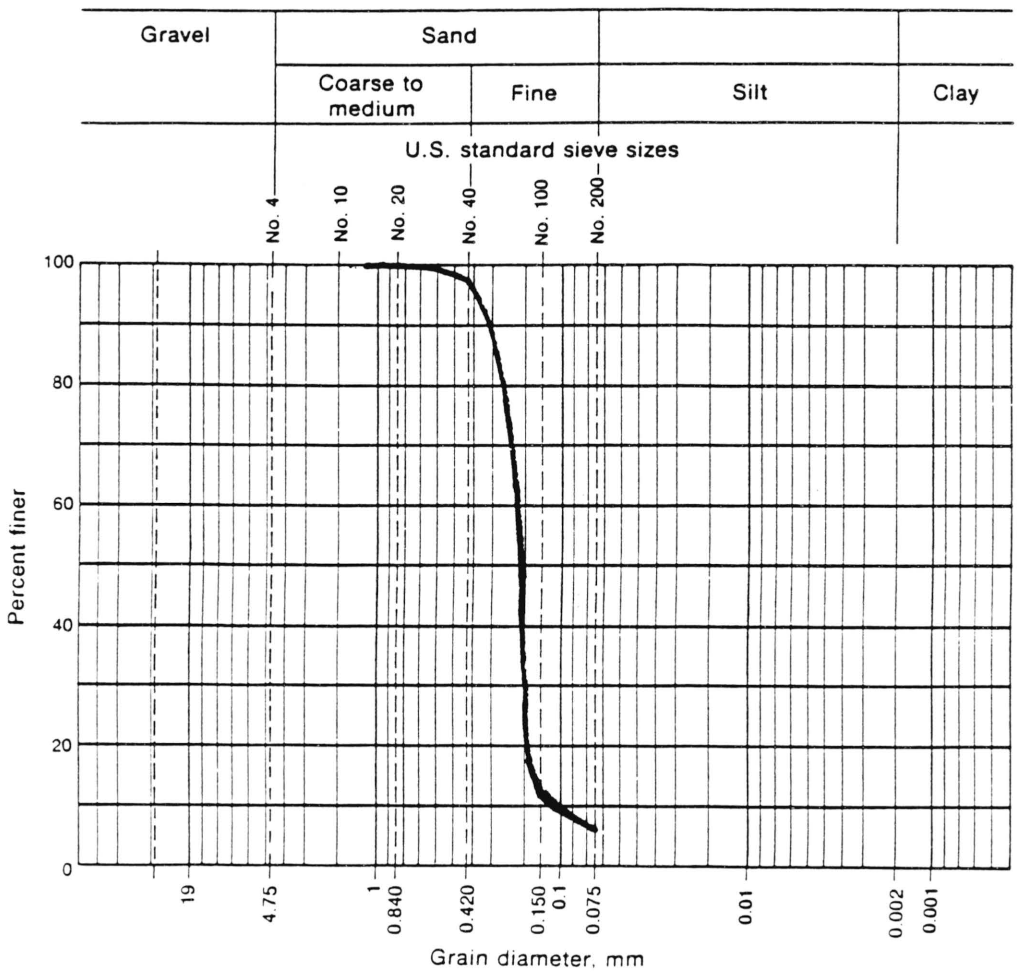


Project Sieve Analysis Job. No. 7

Location of Project U.S.F. Boring No. ~ Sample No. BA-5

Description of Soil Sand, silty, mottled Depth of Sample 152.4-177.8 cm.

Tested By. Alamri Date of Testing 7/30/85

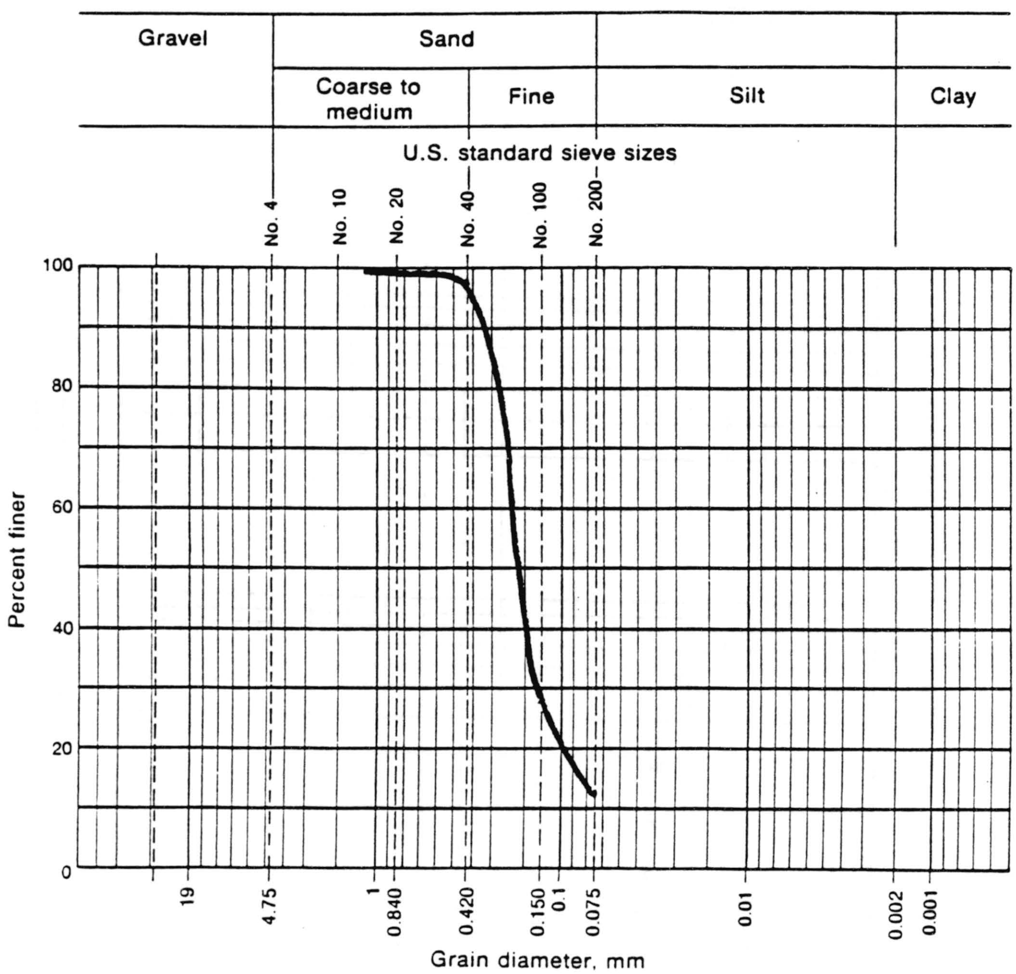


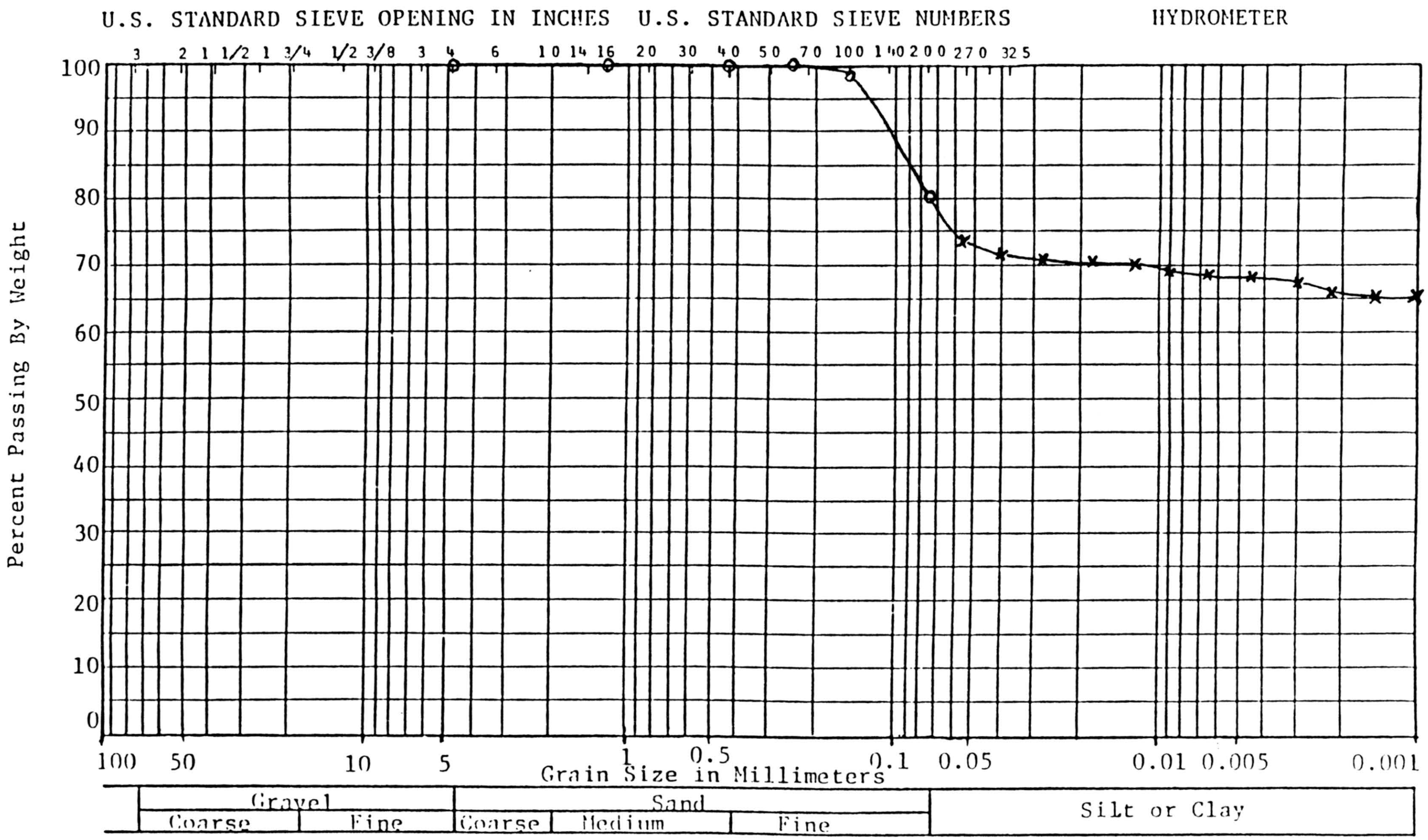
Project Sieve Analysis Job. No. 8

Location of Project U.S.F. Boring No. ______ Sample No. BA-3

Description of Soil Sand, clayey, red Depth of Sample 165.1-177.8 cm.

Tested By. Alamri Date of Testing 7/30/85

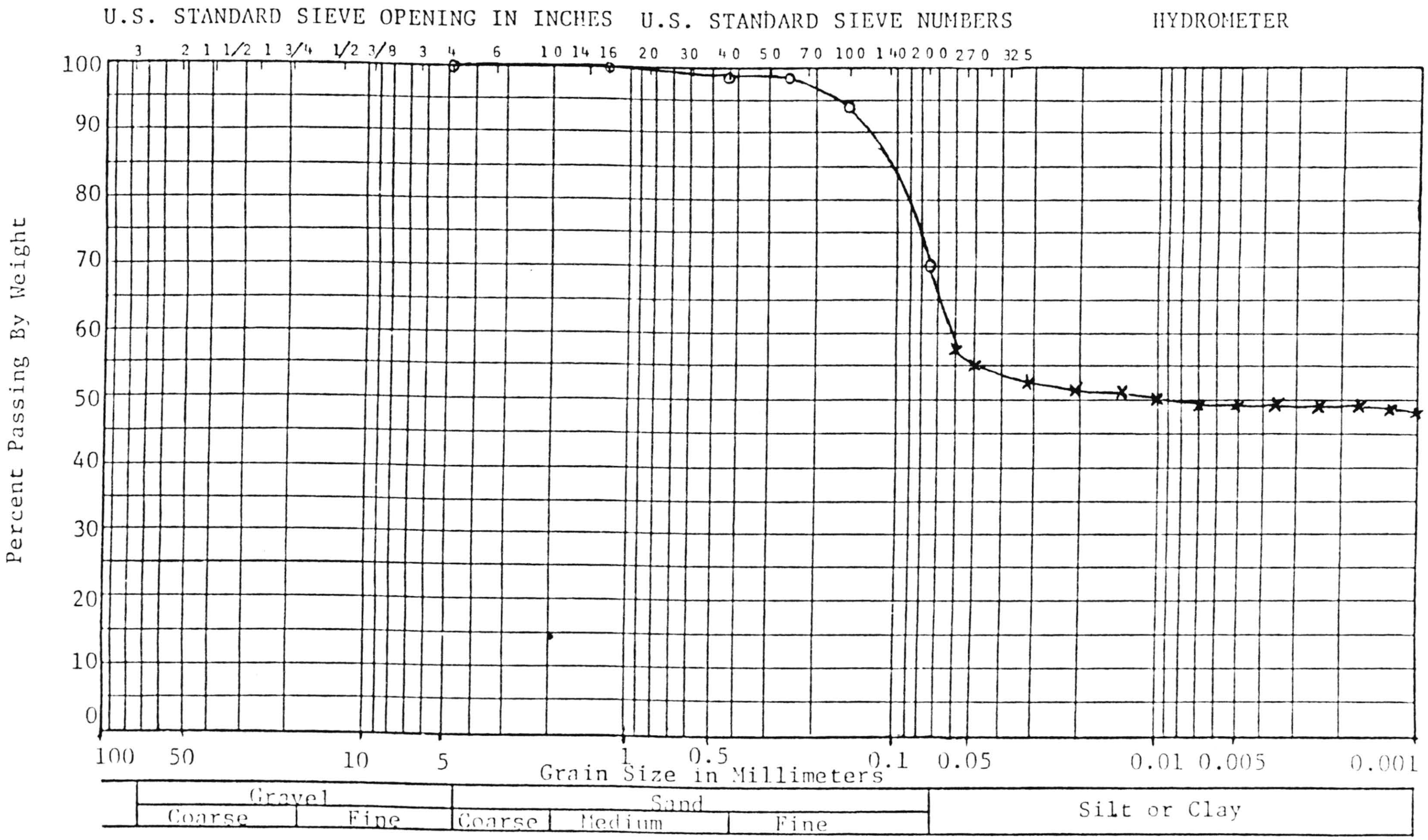




O- by Sieve

X- by Hydrometer

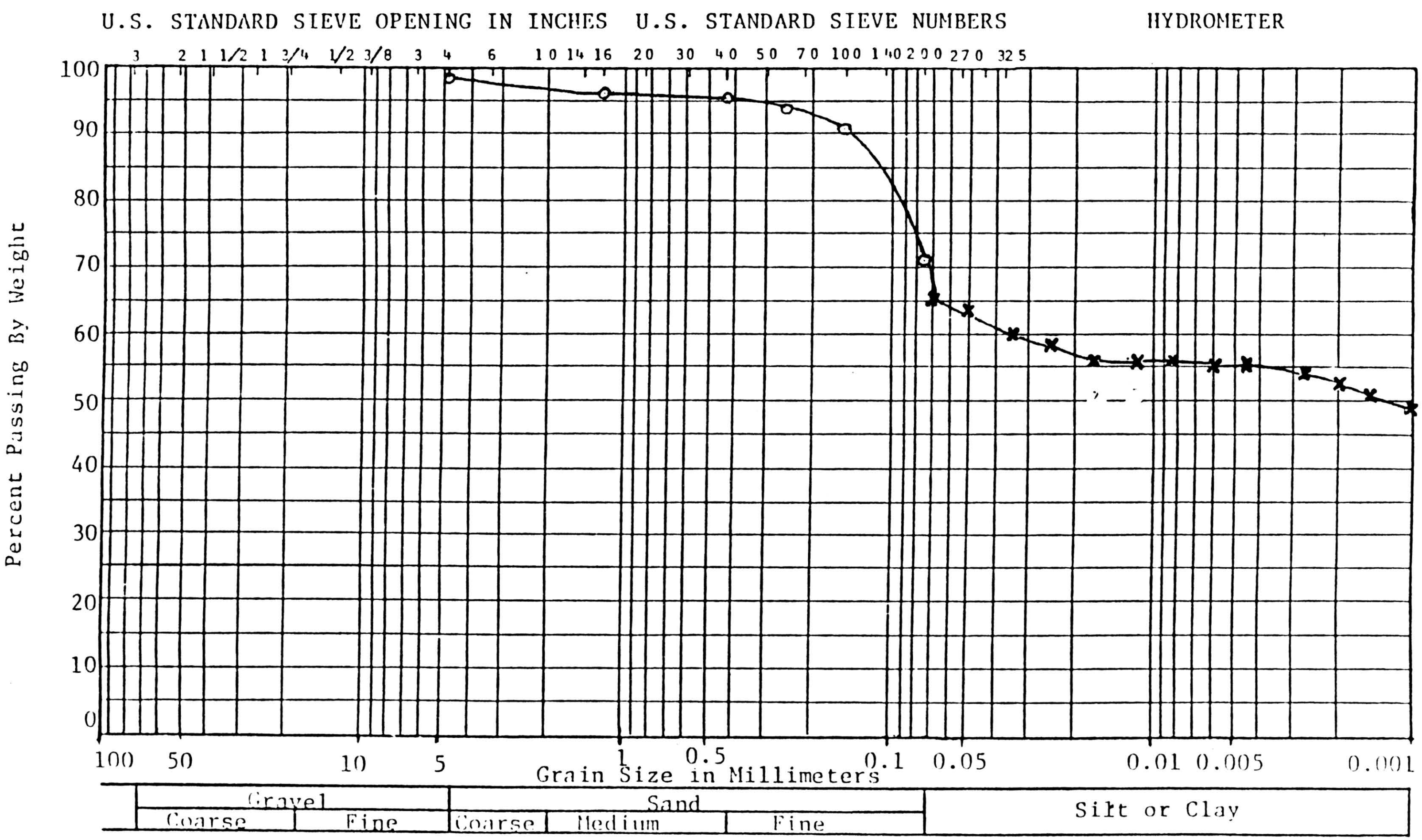
68.1% clay, 23.3% sand, 8.6% silt



0-by Sieve

X-by Hydrometer

49.7% clay, 43.0% sand, 7.3% silt

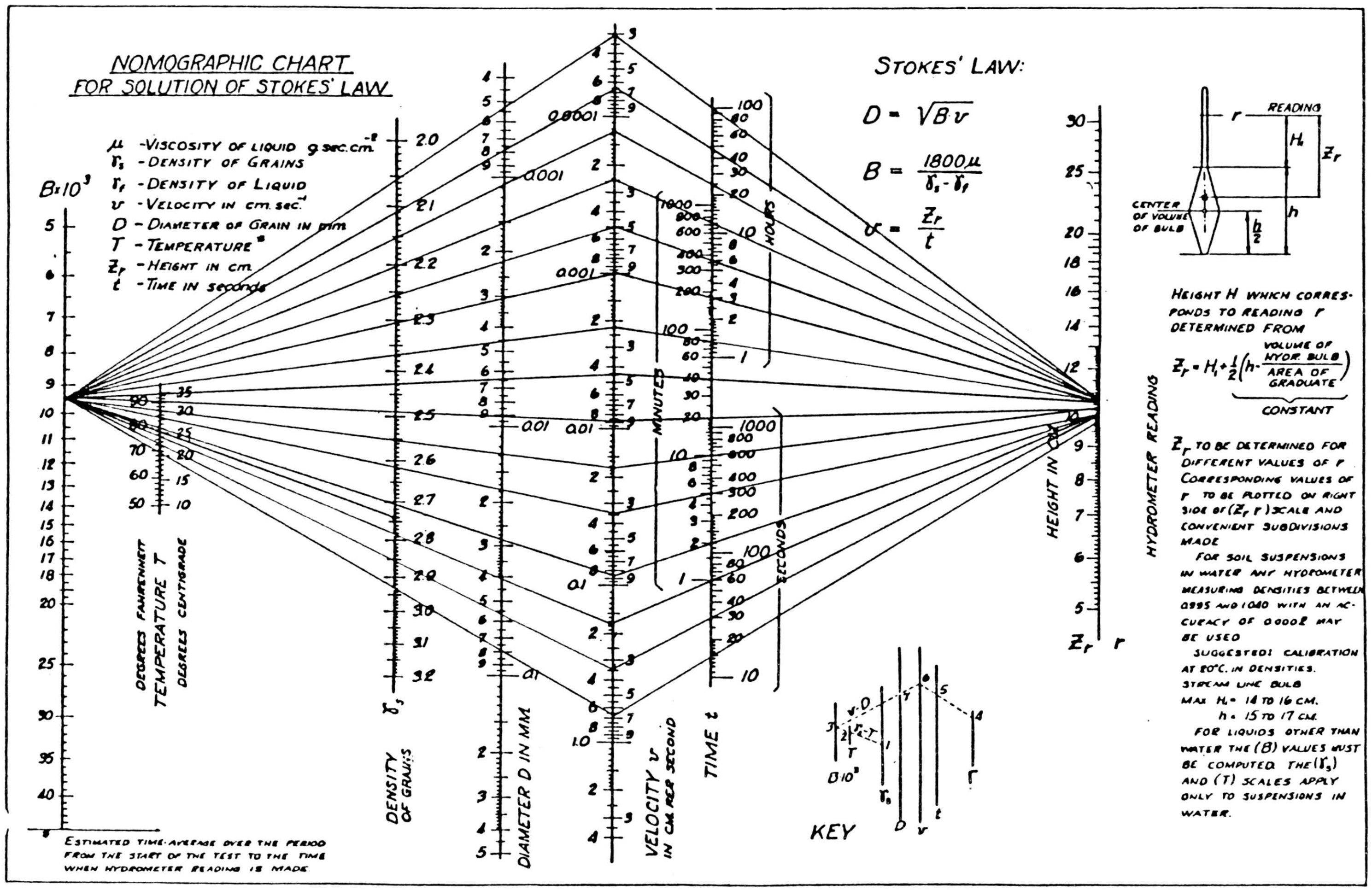


0- by Sieve

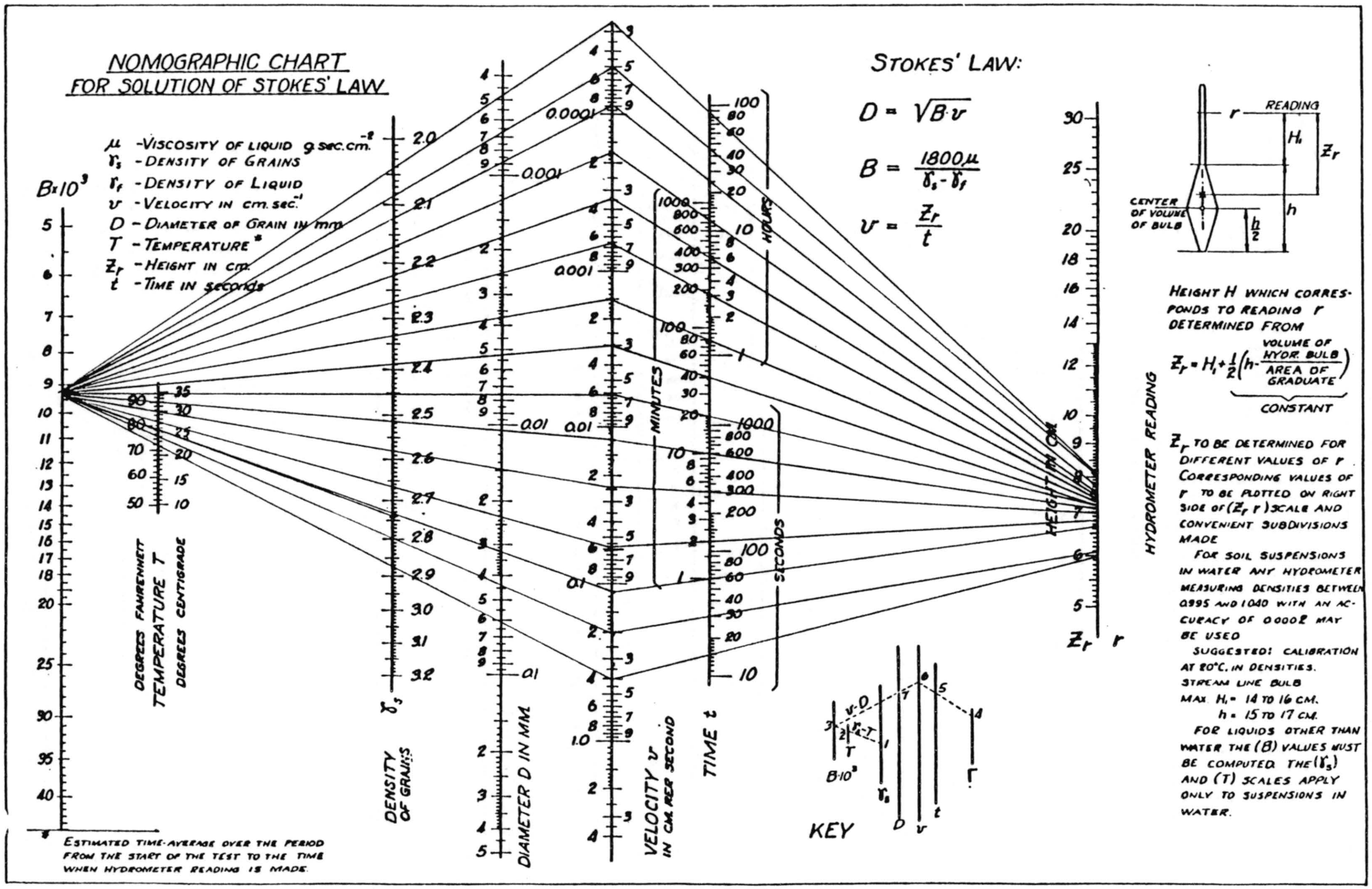
X- by Hydrometer

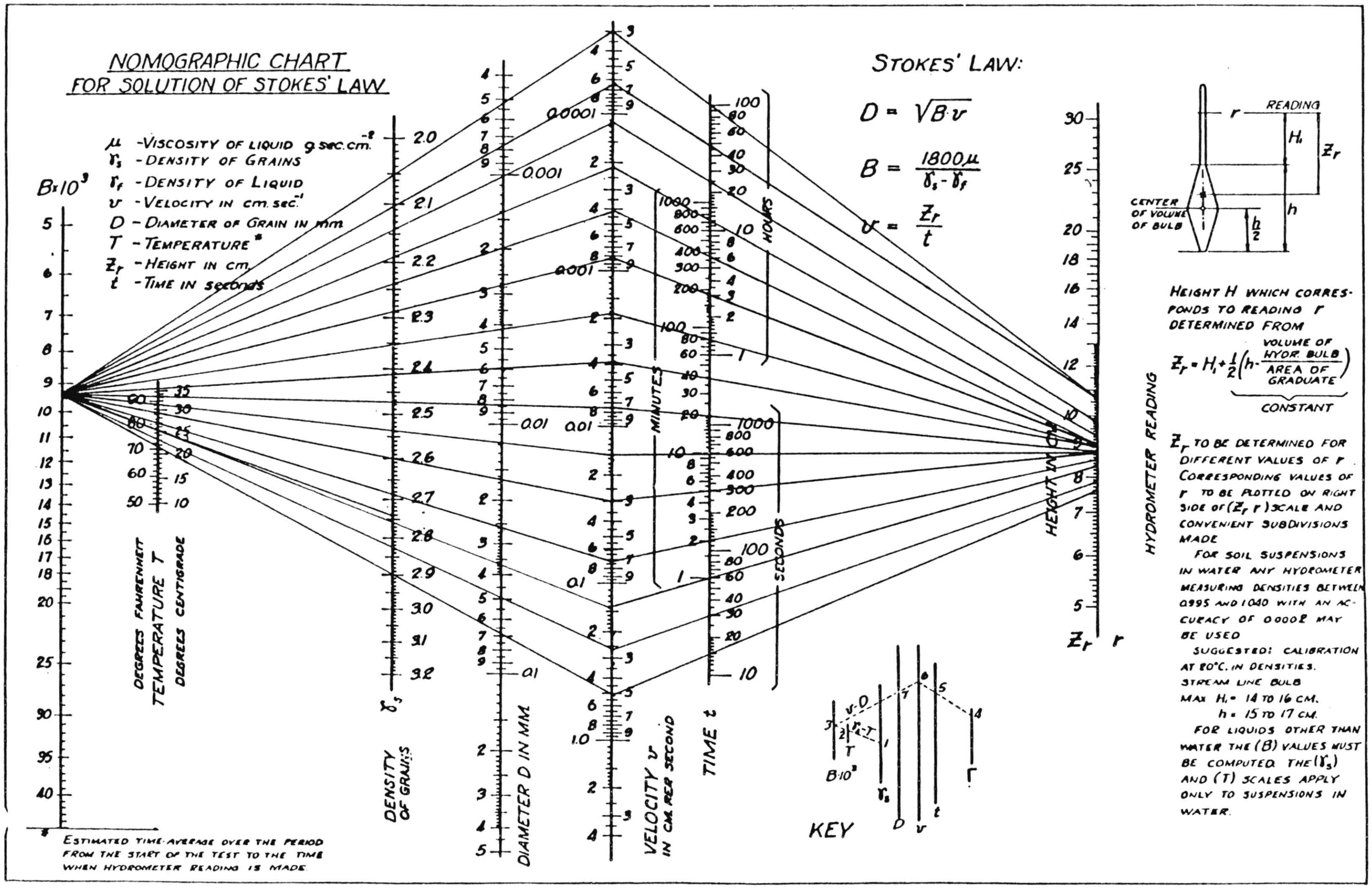
55% clay, 35% sand, 10% silt

BA-5



APPENDIX I: THREE CLAY SAMPLES ANALYZED QUANTITATIVELY USING NOMOGRAPHIC CHART FOR SOLUTION OF STOCKS' LAW.


NOMOGRAPHIC CHART
FOR SOLUTION OF STOKES' LAW
μ - Viscosity of liquid g.sec.cm.⁻²
γs - Density of Grains
γf - Density of Liquid
v - Velocity in cm.sec.⁻¹
D - Diameter of Grain in mm
T - Temperature*
Zr - Height in cm.
t - Time in seconds
B×10³
Degrees Fahrenheit
Temperature T
Degrees Centigrade
Density of Grains γs
Diameter D in MM.
Velocity v in cm. per second
Time t
Hours
Minutes
Seconds
STOKES' LAW:
D = √(B·v)
B = 1800μ / (γs - γf)
v = Zr / t
Height in cm.
Hydrometer Reading
Zr
r
Reading
H1
h
h/2
Center of volume of bulb
Height H which corresponds to reading r determined from
Zr = H1 + ½(h - Volume of hydr. bulb / Area of graduate)
Constant
Zr to be determined for different values of r. Corresponding values of r to be plotted on right side of (Zr r) scale and convenient subdivisions made
For soil suspensions in water any hydrometer measuring densities between 0.995 and 1.040 with an accuracy of 0.0002 may be used
Suggested: calibration at 20°C, in densities. Stream line bulb
Max H1 = 14 to 16 cm.
h = 15 to 17 cm.
For liquids other than water the (B) values must be computed. The (γs) and (T) scales apply only to suspensions in water.
KEY
* Estimated time-average over the period from the start of the test to the time when hydrometer reading is made.


NOMOGRAPHIC CHART
FOR SOLUTION OF STOKES' LAW
μ - Viscosity of liquid g.sec.cm.^-2
γs - Density of Grains
γf - Density of Liquid
v - Velocity in cm.sec.^-1
D - Diameter of Grain in mm
T - Temperature*
Zr - Height in cm.
t - Time in seconds
B×10^3
Degrees Fahrenheit
Temperature T
Degrees Centigrade
γs
Density of Grains
Diameter D in mm
Velocity v in cm. per second
Minutes
Time t
Hours
Seconds
Height in cm
Zr
r
Hydrometer Reading
STOKES' LAW:
D = √(B·v)
B = 1800μ / (γs - γf)
v = Zr / t
Reading
Center of volume of bulb
Height H which corresponds to reading r determined from
Zr = H1 + 1/2 (h - Volume of hydr. bulb / Area of graduate)
Constant
Zr to be determined for different values of r. Corresponding values of r to be plotted on right side of (Zr r) scale and convenient subdivisions made
For soil suspensions in water any hydrometer measuring densities between 0.995 and 1.040 with an accuracy of 0.0002 may be used
Suggested: calibration at 20°C. in densities. Stream line bulb
Max H1 = 14 to 16 cm.
h = 15 to 17 cm.
For liquids other than water the (B) values must be computed. The (γs) and (T) scales apply only to suspensions in water.
KEY
* Estimated time-average over the period from the start of the test to the time when hydrometer reading is made

APPENDIX J: HYDROGEOLOGIC DATA FROM TEN MONITOR WELLS IN NORTH-CENTRAL HILLSBOROUGH COUNTY, FLORIDA.

WELL NO. 1

LOCATION The Dune GRADE ELEV. 12.500m

TOP ELEV.

INSTALLATION NOTES (in BA-11

DATE 8/84 MATERIAL 2" galvanized steel

TOTAL STRING 8m TOP HEIGHT ABOVE GRADE 0.35m

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
8/28				7.239					
10/2				7.154	28.5	0	143		3 liters drawn slightly turbid
10/11	5.80	.075		7.124			123		3 liters drawn slightly turbid Hydro Labs
10/16	5.81	.050	.012	7.077			104		3 liters drawn
10/23				6.991					
10/29	5.90	.068	.012	7.005					significant rainfall 10/28
10/30	5.90	.080	.012	7.017					
11/9	5.80	.035	.012	7.072	25.1	0.1	85		3 liters
					24.5	0.1	85		4 liters, well drawn, dry, very turbid
11/16	5.80	.002	.012	7.039	28	0	88		2 liters
11/25	5.90	.036	.012	6.973	27.5	0	120		2 liters
					27.5		95		4 liters
					25.5	0	97		5 liters well drawn dry
11/30	6.00	.034	.012	6.871	25	0	115		2 liters
							93		4 liters thermistor malfunction
12/7	6.10	.043	.012	6.780			117		2 liters
							93		4 liters
							100		5 liters well drawn dry

WELL NO. 1

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
12/15	6.20	.050	.012	6.687	24.5	0	130		2 liters Strom's YSI-SCT
					24.5	0	100		4 liters
12/23	6.30	.045	.012	6.582	23.9	0	130		2 liters
1/1	6.40	.040	.012	6.477	25.5	0	130		2 liters
					25.5	0	105		4 liters well dry
1/14	6.40	.056	.012	6.493	22.5	0	157		1 liter turbid
					24.0	0	48		3 liters slightly turbid
					23.5	0	98		4 liters turbid - well dry
1/18	6.40	.054	.012	6.491					
1/22	6.40	.062	.012	6.499	24	0	120		2 liters slightly turbid
							105		4 liters clear - well dry
2/1	6.40	.095	.012	6.532	25.5	0	135		2 liters
					25	0	115		4 liters slightly turbid
2/11	6.30	.052	.012	6.589					
2/12	6.30	.076	.012	6.613					
2/15	6.30	.100	.012	6.637	21.2	0	118		2 liters SBU's YSI-SCT slightly turbid
					21.5	0	115		4 liters slightly turbid
3/13	6.50	.025	.012	6.362					
3/20	5.60	.047	.012	6.284	24.5	0	122		2 liters slightly turbid
					23.5	0	120		3.4 liters , slightly turbid, well dry
3/29	6.60	.086	.012	6.323	26	0	155		2.0 liters
					25	0	134		3.6 liters slightly turbid
4/6	6.60	.060	.012	6.297					
4/20	6.60	.059	.012	6.296	24.5	0.0	120		3.5 liters
4/29	6.70	.029	.012	6.166	26.8	0.1	138		3.2 liters

WELL NO. 1

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
5/7	6.90	.076	.012	6.013	26.5	0.1	155		3.0 liters
5/18	7.10	.036	.012	5.773	26.2	0.1	135		2.0 liters
					26.8	0.1	135		2.6 liters
5/25	7.30	.092	.012	5.629	23.5	0.2	130		2.0 liters
6/3	7.50	.074	.012	5.411	19.0	0.2	155		1.9 liters
6/7	7.60	.090	.012	5.327					right after 2" rain
6/13	7.40	.037	.012	5.474	26.0	0.1	118		1.8 liters
6/15	7.30	.024	.012	5.561	26.2	0.0	100		2.0 liters
6/21	6.90	.018	.012	5.955	27.2	0.1	87		2.0 liters
					27.2	0.1	77		3.0 liters
7/2	6.50	.001	.012	6.338	26.5	0.1	88		3.9 liters
7/9	6.50	.054	.012	6.392	26.8	0.0	95		4.0 liters
7/16	6.40	.099	.012	6.536					
7/22	6.00	.043	.012	6.880	26.5	0.1	95		2.0 liters
7/27	5.90	.068	.012	7.005					
7/29	5.60	.066	.012	7.303					
8/3	5.30	.003	.012	7.540	26.5	0.1	78		4.0 liters
8/13	5.20	.025	.011	7.662					
8/16	5.20	.069	.011	7.707	27.5	0.0	78		4.0 liters
					29.5	0.1	80		7.2 liters well dry
8/26	5.00	.070	.011	7.91					
8/30	4.90	.017	.011	7.95					
9/4	4.80	.035	.011	8.07					
9/6	4.70	.032	.011	8.19	27.0	0.0	70		2.0 liters
9/11	4.80	.062	.011	8.1					

WELL NO. 2

LOCATION On the trace - SW of doline GRADE ELEV. 11.816m

TOP ELEV. 12.251m

INSTALLATION NOTES (BA - 12)

DATE 8/28/84 MATERIAL 2" galvanized steel

TOTAL STRING 6.280m TOP HEIGHT ABOVE GRADE 0.433m

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
8/30				7.28					
10/2				7.17	25	0.2	270		3 liters drawn slightly turbid
10/11	5.15	.08		7.18			301		3 liters drawn slightly turbid Hydro Lab
10/16	5.20	.037	.012	7.07			328		3 liters drawn slightly turbid
10/23				6.97					
10/29	5.30	.05	.012	6.99					significant rainfall 10/18/84
10/30	5.30	.058	.012	6.997					
11/9	5.20	.030	.012	7.069	24	0.5	245		first liters very turbid due to contaminated
									sampling tube
					24	0.5	255		third liter - very little degassing
					24	0.5	260		fifth liter
11/16	5.30	.085	.012	7.02	25.5	0.2	278		little degassing third liter
11/25	5.30	.029	.012	8.97	24.5	0.2	263		3 liters
					24.5	0.2	265		5 liters & 7 liters
11/30	5.40	.030	.012	6.86	25.5	0.2	268		2 liters & 4 liters
12/7	5.50	.025	.012	6.76		0.2	264		2.3 liters
12/15	5.60	.031	.012	6.67	23.8	0.2	295		1.5 liters
					23.5	0.2	330		3 liters - very turbid gray-green

WELL NO. 2

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
12/23	5.70	.020	.012	6.56	23	0.2	315		1.5 liters turbid
1/1	5.80	.008	.012	6.44	25.5	0.2	335		1 liter drawn green turbid
1/14	5.80	0.25	.012	6.46	21.5	0.2	280		1 liter green turbid
				6.46	21.5	0.2	305		1.5 liters slightly turbid
1/18	5.80	.025	.012	6.46					
1/22	5.80	.030	.012	6.47	20	0.2	270		1 liter, green-turbid, well drawn dry
2/1	5.80	.066	.012	6.5	24.5	0.2	275		1 liter, green-turbid, well drawn dry
2/11	5.70	.022	.012	6.56					
2/12	5.70	.050	.012	6.59					
2/15	5.70	.076	.012	6.6	20.5	0.2	203		1.3 liters, green-turbid, well drawn dry
3/13	6.00	.095	.012	6.33					
3/20	6.00	.024	.012	6.26	25.5	0.2	230		0.4 liters very turbid (opaque)
									well drawn dry
3/29	6.00	.060	.012	6.3	25.0	0.1	198		0.4 liters
4/6	6.00	.037	.012	6.3					
4/20	6.00	.031	.012	6.27	24.5	0.2	160		0.5 liters
4/29	6.09	.000	.012	6.15	30.0	0.2	190		0.3 liters, opaque greenish black
5/7	6.09	-.130	.012	5.02	31.0	0.2	205		30ml opaque greenish black
7/2	6.09	-.022	.012	6.13	28.5	0.3	225		0.3 liters
7/9	6.09	.073	.012	6.22	26.5	0.2	218		0.6 liters
7/16	5.90	.002	.012	6.34					
7/23	5.40	.020	.012	6.86	26.2	0.3	340		1.7 liters
7/27	5.30	.035	.012	6.97					
7/29	5.00	.012	.012	7.25					
8/3	4.80	.094	.012	7.53	27.5	0.1	115		3.3 liters dry

WELL NO. 2

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
8/13	4.70	.080	.011	7.62					
8/16	4.60	.022	.011	7.661	29	0.0	90		3.4 liters dry
8/26	4.40	.026	.011	7.86					
8/30	4.40	.095	.011	7.93					
9/4	4.30	.038	.011	7.97					
9/6	4.20	.025	.011	8.06	26.7	0.0	85		2.0 liters
9/11	4.10	.017	.011	8.15					

WELL NO. 3A

LOCATION Bottom of Doline GRADE ELEV. 9.277m

TOP ELEV. 9.665m

INSTALLATION NOTES

DATE 10/11/84 MATERIAL 1/2" CPVC

TOTAL STRING 3.28m TOP HEIGHT ABOVE GRADE 0.39m

Open 2.59-2.84m below grade

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
10/11	2.30	0	.011	7.35			320		draws well, air bubbles, pulling air or degassing
10/16	2.40	.074	.011	7.33			280		Hydro Lab 3 volumes purged
10/23	2.50	.090	.011	7.24					
10/29	2.00	.065	.011	7.72					significant rainfall 10/28
10/30	2.10	.090	.011	7.64					water puddled to .30m at well
11/8	2.20	.005	.011	7.46	24.5	0.3	275		great degassing 2 liters drawn
11/16	2.40	.090	.011	7.34	25	0.2	365		degassing; H_2S_0 odor 2 liters drawn
11/25	2.50	.090	.011	7.24	25	0.4	430		1.5 liters drawn
11/30	2.50	.025	.011	7.18	23	0.3	420		mild H_2S_0 odor 1.5 liters drawn
12/7	2.60	.041	.011	7.09		0.2	345		2 liters drawn
12/15	2.72	.060	.011	6.99	22.5	0.2	405		1.5 liters drawn
12/23	2.80	.040	.011	6.89	21.5	0.3	410		1.5 liters drawn
1/1	2.90	.060	.011	6.8	23.5	0.3	430		2.0 liters drawn
1/14	2.84	.000	.000	6.825	22	0.3	420		2.0 liters drawn
1/18	2.84	.000	.000	6.825					puddling on 1/17 to 5 cm depth
1/25	2.84			6.82	19.5	0.3	460		1.6 liters drawn
2/1	2.84			6.8	23.5	0.3	500		sucking air 0.5 liters drawn
2/11	2.84			6.8					no sample

WELL NO. 3A

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
2/12	2.84			6.825	16.5	0.3	328		2 liters drawn
2/15	2.84			6.825	18.3	0.3	455		2 liters drawn
3/19					22.0	0.4	405		3.5 liters drawn
3/20					30.0	0.4	625		3.5 liters drawn
3/25					24.8	0.3	480		1.4 liters clear
3/29					31	0.4	680		2.0 liters clear
4/20					23.5	0.4	550		2.0 liters
4/29					25.5	0.4	445		2.0 liters clear
5/7		dry			31	0.4	650		0.4 liters drawing air
7/16	1.90	.032	.011	7.79					
7/22	2.20	.028	.011	7.482	30.5	0.1	132		2.0 liters
7/27	2.20	.089	.011	7.55					
7/28	-.250								
7/31	0.80	.078	.011						
8/3	1.10	.066	.011	8.64	29.7	0.0	90		2.0 liters
8/13	1.20	.014	.011	8.47					
8/15	1.30	.067	.011	8.43					at 8:30 a.m.
8/15	1.30	.055	.011	8.4					at 12:30 p.m.
8/15	1.30	.049	.011	8.41	30	0.2	105		at 2:10 p.m.
8/26	1.30	.077	.011	8.431					
8/30	1.40	.076	.011	8.33					
9/4	1.10	.037	.011	8.59					
9/5					31.5	0.0	84		2.0 liters
9/11	1.30	.059	.011	8.41	29.5	0.0	72		1.5 liters

WELL NO. 38

LOCATION Doling bottom　　GRADE ELEV. 9.281m

TOP ELEV. 9.674m

INSTALLATION NOTES

DATE 3/19/85　MATERIAL 1/2" CPVC

TOTAL STRING 4/19m　TOP HEIGHT ABOVE GRADE .4m

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
3/20	3.20	.053	.011	6.52	27.5	0.4	610		2.3 liters drawn slowly slightly turbid
3/22				6.52	22.0	0.4	440		1.5 liters slightly turbid
3/25	3.20	.038	.011	6.5					
					29	0.3	500		0.5 liters slightly turbid
3/29	3.20	.022	.011	6.49	33	0.4	680		0.8 liters - very slow slightly turbid
4/6	3.30	.098	.011	6.46					1.50 PM after light rain at 1:00
4/20	3.30	.082	.011	6.45	26.5	0.3	415		0.5 liters - very slowly slightly turbid
4/29	3.30	.015	.011	6.38	31	0.4	455		1.5 liters - clear
5/7	3.40	.009	.011	6.320	31	0.3	600		0.6 liters
5/17	3.60	.045	.022	6.120	25.5	0.5	650		0.4 liters
5/24	3.68	.039	.011	6.02	24.5	0.5	720		1.7 liters
6/3	dry				27	0.5	700		
6/15	dry				27.6	0.3	346		1.2 liters
6/21	3.40	.007	.011	6.27	26.5	0.3	325		1.6 liters
7/2	3.30	.011	.011	6.37	36.5	0.4	435		2.0 liters
7/9	3.30	.074	.011	6.44	31	0.4	400		2.0 liters
7/16	2.00	.041	.011	7.7					
7/22	2.30	.078	.011	7.44	30	0.3	250		

WELL NO. 3B

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
7/27	2.20	.038	.011	7.5					
7/31	0.90	.068	.011	8.83					
8/3	1.20	.083	.011	8.54	33	0.1	198		2.0 liters
8/13	1.30	.056	.011	8.42					
8/15	1.30	.009	.011	8.372	30	0.2	200		2.0 liters
8/26	1.30	.042	.011	8.4					
8/30	1.40	.050	.011	8.31					
9/4	1.10	.001	.011	8.56					
9/5					33.5	0.1	125		2.0 liters
9/11	1.30	.029	.011	8.39	30.5	0.1	105		1.5 liters

WELL NO. 4A

LOCATION Ravelling Sinkhole GRADE ELEV. 10.02m

TOP ELEV. 10.34m

INSTALLATION NOTES

DATE 10/15/84 MATERIAL 1/2" PVC

TOTAL STRING 4.47m TOP HEIGHT ABOVE GRADE 0.314m

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
10/16	3.1	.056	.011	7.29			345		3 liters drawn
10/18				7.29	25	0.8	335		3 liters drawn
10/23				7.29					
10/29	3.1	.022	.011	7.25					significant rainfall
10/30	3.1	.030	.011	7.26					
11/8	3.1	.093	.011	7.32	24	0.1	322		3 liters drawn
11/16	3.1	.038	.011	7.27	25.5	0.1	343		2 liters drawn
11/25	3.2	.081	.011	7.21	25.5	0.2	340		2 liters drawn
11/30	3.3	.076	.011	7.11	24	0.2	328		2 liters drawn
12/7	3.4	.076	.011	7.01		0.2	315		2 liters drawn
12/15	3.5	.085	.011	6.91	24	0.2	385		2 liters drawn
12/23	3.6	.082	.011	6.8	23.2	0.3	380		2 liters drawn
1/1	3.7	.06	.011	6.69	24.5	0.3	390		2 liters drawn
1/14	3.7	.026	.011	6.66	21.7	0.3	370		2 liters drawn
1/18	3.7	.028	.011	6.66	22	0.3	375		4 liters drawn
1/25	3.7	.028	.011	6.66	22	0.3	375		2 liters drawn
2/1	3.7	.034	.011	6.7	26.5	0.25	405		2 liters drawn
	3.7	.08	.011	6.71	22.3	0.2	280		2 liters drawn

WELL NO. 4A

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
2/11	3.70	.080	.011	6.709	22.3	0.2	390		2 liters drawn
2/12	3.60	.024	.011	6.753					
2/15	3.60	.030	.011	6.759	20	0.3	340		4 liters drawn
3/13	3.90	.071	.011	6.5					
3/20	3.95	.015	.011	6.395	23	0.3	315		4 liters drawn
3/25	3.90	.065	.011	6.494					rain on 3/21/85
3/29	3.90	.022	.011	6.451	23.2	0.3	310		4 liters drawn
4/6	3.95	.043	.011	6.422					2:00 P.M. after 1:00 PM rain
4/20	3.95	.036	.011	6.415	23.0	0.3	305		4 liters
4/29	3.95	-.070	.011	6.449	25.0	0.3	295		3.0 liters
7/2	3.89	.065	.011	6.504	26	0.2	190		2.0 liters drawn
7/9	3.80	.020	.011	6.549	26.5	0.3	300		2.0 liters
7/16	3.60	.071	.011	6.8					
7/22	3.30	.019	.011	7.048	25.5	0.3	240		2.0 liters
7/27	3.20	.082	.011	7.211					
7/29	2.50	.005	.011	7.835					
8/3	2.60	.090	.011	7.819	27	0.2	145		2.0 liters
8/13	2.40	.068	.011	7.997					
8/15					28.5	0.2	140		2.0 liters
8/26	2.40	.061	.011	8.19					
8/30	2.20	.061	.011	8.19					
9/4	2.00	.051	.011	8.38					
					28.3	0.1	125		2.0 liters
9/11	2.10	.085	.011	8.314	31	0.1	123		2.0 liters

WELL NO. 4D

LOCATION Ravelling Sinkhole GRADE ELEV. 10.022m

Filled by Physical Plant 8/31/84 TOP ELEV. 10.327m

INSTALLATION NOTES

DATE 10/19/84 MATERIAL 1/2" CPVD

TOTAL STRING 12.40m TOP HEIGHT ABOVE GRADE 0.302

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
10/19					sun 29	0.4	650		5 liters drawn, 5th tested slightly turbid
10/23				8.845					apparently not equilibrating
10/29	2.60	.074	.011	7.79					
10/30	3.20	.060							
11/8	3.10	.003	.011	7.219	21.5	0.5	580		1 liter drawn
					21.5	1.0	580		2 liters deawn
11/16	3.20	.074	.011	7.19	sun 28	0.4	650		2.5 liters drawn
11/25	3.30	.085	.011	7.101	22	0.4	495		2.3 liters drawn
11/26	3.30	.076	.011	7.092					
11/30	3.30	.009	.011	7.025	sun 24.5	0.5	590		1 liter drawn
					sun 24	0.5	570		2 liters drawn
12/7	3.40	.013	.011	6.929		0.5	455		1 liter drawn
						0.3	425		2 liters drawn
12/15	3.50	.027	.011	6.843	26.5	0.4	650		Strom's YSI-33 1 liter drawn
					24	0.4	630		1 liters drawn
12/23	3.60	.017	.011	6.733	21	0.4	600		1.4 liters drawn
					19.5	0.4	600		2.2 liters drawn
1/1	3.70	.018	.011	6.634	sun 25.0	0.4	650		real fast 2.0 liters drawn

WELL NO. 4D

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
					sun 28.0	0.4	690		very slow 2.0 liters drawn
1/14	3.80	.088	.011	6.604	22	0.4	650		2.0 liters drawn
1/18	3.80	.094	.011	6.61					
1/25	3.70	.007	.011	6.623	20.5	0.4	590		2.0
					18	0.4	550		2.7 liters drawn
2/1	3.70	.011	.011	6.627	sun 29.5	0.4	700		2.0 liters drawn
2/11	3.70	.056	.011	6.672					
2/12	3,70	.099	.011	6.715					
2/15	3.60	.003	.011	6.719	15.5	0.3	465		2.0 liters drawn Sam's YSI
3/13	3.90	.038	.011	6.454					
3/20	4.00	.045	.011	6.361	33	0.4	725		3.2 liters drawn
3/25	3.90	.027	.011	6.443					
3/29	4.00	.092	.011	6.408	28	0.4	600		drawing fairly fast 2 liters drawn
					31.5	0.4	675		3.4 liters
4/6	4.00	.076	.011	6.392					
4/20	4.00	.070	.011	6.386	25.2	0.4	470		3.6 liters
4/29	4.10	.045	.011	6.261	35.5	0.4	680		2.0 liters
					34	0.4	670		3.1 liters
5/7	4.20	.000	.011	6.116	36	0.4	760		1.1 liters
					32	0.4	700		1.7 liters
5/17	4.50	.084	.011	5.9	27	0.5	600		1.1 liters
5/24	4.60	.007	.011	5.723					
5/25					25.5	0.5	580		2.0 liters
6/3	4.80	.014	.011	5.53	27.5	0.3	530		2.0 liters
6/7	4.90	.011	.011	5.438					right after 2" rain

WELL NO. 4D

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
6/13	4.80	.087	.011	5.603					
6/15	4.70	.095	.011	5.721	26.5	0.2	270		
6/21	4.20	.002	.011	6.118	27.2	0.3	290		1.1 liters
7/2	3.90	.029	.011	6.445	30.5	0.3	305		2.0 liters
7/9	3.90	.074	.011	6.49	30.5	0.4	355		2.0 liters
7/16	3.70	.073	.011	6.54					
7/22	3.40	.051	.011	6.963	33	0.4	335		2.0 liters fast
7/27	3.20	.002	.011	7.118					
7/29	2.90	.053	.011	7.469					
8/3	2.70	.044	.011	7.66	25.5	0.3	355		Strong H_2S_0 odor 2.0 liters fast
8/13	2.50	.001	.011	7.817					
8/25					27	0.4	410		2.0 liters
8/26	2.30	.042	.011	8.058					
8/30	2.30	.082	.011	8.098					
9/4	2.10	.030	.011	8.246					
9/5					27.2	0.2	270		2.0 liters fast
9/11	2.10	.016	.011	8.232	30	0.3	335		2.0 liters

WELL NO. 8

LOCATION ________ GRADE ELEV. ________

TOP ELEV. 10.174m

INSTALLATION NOTES

DATE 3/22/85 MATERIAL 1/2" CPVC

TOTAL STRING 4.42m TOP HEIGHT ABOVE GRADE -4m

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
3/22					20.9	0.5	940		4 liters drawn quickly
3/25	3.30	.011	.011	6.87	24.8	0.5	980		2 liters drawn
3/29	3.40	.054	.011	6.81	24	0.5	830		4 liters drawn clear
4/6	3.50	.094	.011	6.75					
4/20	3.50	.080	.011	6.74	24	0.5	750		3.5 liters drawn quickly clear
4/29	3.50	.015	.011	6.67	23.2	0.7	950		4.0 liters
5/7	3.60	.016	.011	6.57	23.5	0.9	1320		2.0 liters
5/17	3.80	.069	.011	6.43	23.5	0.8	1150		3.5 liters
5/24	3.88	.034	.011	6.31					
5/25					23.3	1.0	1330		2.0 liters
6/3	dry				24	0.8	1020		1.7 liters
6/13	dry				25	0.6	810		2.0 liters
6/15	3.88	.093	.011	6.19	25.2	0.4	700		2.0 liters
6/21	3.50	.038	.011	6.69	24.7	0.5	725		2.0 liters
7/2	3.20	.041	.011	7	28.5	0.4	380		2.0 liters
7/9	3.10	.028	.011	7.08	27	0.6	850		2.0 liters
7/16	2.80	.053	.011	7.416					

WELL NO. 8

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
7/22	2.30	.011	.011	7.874	27.5	0.5	470		2.0 liters
7/27	2.10	.016	.011	8.07					
7/29	1.00	.055	.011	9.2					
8/3	1.50	.075	.011	8.73	26.5	0.5	700		2.0 liters
8/13	1.50	.027	.011	8.69					
8/15	1.60	.049	.011	8.61	27	0.4	438		2.0 liters
8/26	1.60	.065	.011	8.62					
8/30	1.70	.062	.011	8.52					
9/4	1.50	.092	.011	8.75					
9/5					26.3	0.3	298		2.0 liters
9/11	1.60	.003	.011	8.56	30	0.1	323		2.0 liters

WELL NO. 9

LOCATION Beside Ditch - SE End GRADE ELEV. 10.564m

TOP ELEV. 10.961m

INSTALLATION NOTES

DATE 3/27/85 MATERIAL 1/2" CPVC

TOTAL STRING 4.25m TOP HEIGHT ABOVE GRADE .4m

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
3/29	3.20	.091	.011	7.84	24.5	0.8	1300		4.0 liters drawn - clear pumps fast
4/6	3.20	.073	.011	8.82					1:30 PM rain at 1:00 PM
4/20	3.20	.042	.011	7.79	23.5	0.7	1050		4.0 liters drawn strong H_2S odor
4/29	3.20	.043	.011	7.79	25.0	1.4	2200		4.0 liters strong H_2S odor
5/7	3.20	.045	.011	7.79	26.0	2.5	4050		4.0 liters very strong H_2S odor & black stain
5/17	3.20	.011	.011	7.76	26.0	2.2	3175		2.0 strong H_2S odor
5/24	3.20	.006	.011	7.76					
5/25					27.5	1.9	3200		2.0 strong H_2S odor
6/3	3.30	.092	.011	7.74	27	3.0	3700		2.0 strong H_2S odor
6/7	3.10	.041	.011	7.89					7:00 PM after rain 5:45-6:30 PM
6/13	3.00	.007	.011	7.96	29.5	1.0	1650		4.0 liters drawn
6/15	2.90	.073	.011	8.12	28.5	0.6	1130		2.0 liters
6/21	2.80	.041	.011	8.19	25	0.5	405		2.0 liters
7/2	2.90	.057	.011	8.11	28.4	0.4	380		
7/9	2.90	.049	.011	8.1	29	0.5	480		2.0 liters
7/16	2.00	.061	.011	9.01					
7/18	1.90	.005	.011	9.05	29	0.2	175		2.0 liters
7/22	2.00	.083	.011	9.033	27.7	0.3	265		2.0 liters

WELL NO. 9

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
7/27	1.70	.066	.011	9.32					
7/29	1.20	.055	.011	9.8					
8/3	2.00	.010	.011	8.96	29	0.2	162		2.0 liters H_2S odor
8/13	1.90	.016	.011	9.066					
8/15					28	0.3	318		2.0 liters H_2S odor
8/26	2.00	.021	.011	8.97					
8/30	2.10	.028	.011	8.88					
9/4	2.00	.081	.011	9.03					
9/5					27.8	0.2	215		2.0 liters
9/11	2.10	.000	.011	8.85	36.5	0.1	248		2.0 liters

WELL NO. Ditch - East End

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
9/19	-.102			9.146					
9/28	+.152			9.4			65	55	at ~24"; after heavy rain of ISODOR
10/2	+.056			9.304	26°	0.5	395		at ~24"
10/5	+.004			9.256	25	0.5	680		at ~24"
10/11	-.094			9.154			1220		at ~48" Hydro lab
10/16	-.168			9.08	27.5		710		at ~6" Hydro lab
							1070		at ~24" Hydro lab
							1090		at ~48" Hydro lab
10/18	-.210			9.038	29	0.5	940		at ~6"
					28	0.5	1050		at ~24"
					27.5	1.3	2220		at ~48" Significant rain on 10/28
10/29	-.029			9.219	28.0	0.3	900		at ~6"
					26.5	0.3	350		at ~24"
					25.5	0.3	400		at ~48"
10/30	-.045			9.203					
11/8					24.5	1.0	850		at ~6"
					22.5	0.5	650		at ~24"
					21.5				
11/9	+.057			9.305					
11/16	-.072			9.176	24	0.5	720		at ~6"
					21	0.4	620		at ~24"
					21	0.4	650		at ~48"
11/25	-.120			9.128	20.5	0.4	620		at ~6"
					19	0.3	333		at ~24"
					19	0.3	348		at ~48"

WELL NO. Ditch - East End

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
11/30	-.190			9.058	21.5	0.5	710		~6"
					20	0.4	640		~24"
					20	0.4	660		~48"
12/7	-.289			8.959	19.5	0.5	800		at all depths
12/15	-.400			8.893	23.0	0.7	1070		at ~6"
					22.8	0.7	1020		at ~24"
					22.8	0.7	1020		at ~48"
12/23	-.495			8.848	26.5	0.8	1350		very calm and clear
					25	0.8	1300		very calm and clear
					24.5	0.8	1300		at ~40"
1/1	-.600			8.648	24.5	0.8	1250		at ~6"
					24.0	0.8	1280		at ~24"
1/14	-.680			8.568	22	0.9	1400		at all levels
1/18	-.615			8.633	15	0.7	920		at ~36"
					16	0.8	950		at ~6"
1/25	-.680			8.568	21	0.4	235		at ~36" after series of light rains
					21	0.4	260		at ~6"
					19.5	0.6	900		in northern outlet from hospital site
2/1	-.755			8.493	24.5	1.0	1650		~36" nile perch
					24.5	1.0	1500		~6"
					24.5	0.5	850		N. outlet
2/11	-.770			8.478	20.5	0.5	900		all levels
					19	0.4	550		N. outlet
2/12	-.630			8.618	20	1.5	2480		~36" Rain on 2/11 P.M.
					18	0	278		~6"

WELL NO. Ditch - East End

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
					19	1.0	1500		~24"
					17.5	0.2	150		N. outlet
2/15	-.670			8.578	19.7	0.6	780		~36"
					20.5	0.5	680		~6"
					17.5	0.7	1000		N. outlet
3/13	-.900			8.348					
3/19	-.900			8.348					
3/20	-.900			8.348	25.5	1.2	2050		~20" ½ ~6"
3/22	-.835			8.413	23	0.3	780		~20" Rain on 3/21/85
					23.4	0.3	750		~6"
3/25	-.875			8.373	25.5	2.0	4100		~20" nile perch kill
					25.5	0.7	1150		~6"
3/29	-.93			8.318	27.5	2.8	4950		~20" minnows returning
					28	0.8	1500		~6"
4/6	-.78			8.468					at 1:30 p.m. after shower at 1:00 p.m.
4/19	-.94			8.308	27.5	1.9	3225		~18"
					28.2	0.8	1300		~6"
4/29	-.94			8.308	31.0	1.6	3050		~18"
					30.0	0.7	1200		~6"
5/7	-.92			8.328	30.0	3.0	5700		~18"
					29	0.9	1780		~6"
5/17	-.91			8.338	30	2.0	3850		~18"
					28	0.6	1000		~6"
5/24	-.92				29	1.4	2500		~18" small fish and 22" gator
					29.5	0.5	900		~6" 10:00 A.M.

WELL NO. Ditch - East End

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
									after 0.54 rain 4:00 p.m.
5/24	-.92				29	1.7	3400		~18"
					29	0.9	1500		~6"
5/25					30	4.3	8000		~18" rain
					30	0.9	1500		~6" .05" on 5/24
6/3	-.895			8.353	32	1.9	3430		~18"
					31	0.8	1180		~6"
6/7	-.81			8.438					7:30 P.M. 2" rain 5:45-6:30 P.M.
6/13	-.83			8.418	28.7	0.2	186		~20"
					29.5	0.3	280		~6"
6/15	-.67			8.578	23.2	0.0	105		~30"
					26	0.2	295		~6"
6/21	-.70			8.548	30	0.2	325		~30"
					31	0.3	370		~6"
6/22	-.70			8.548	30.5	0.4	490		~30"
					31.5	0.3	425		~6"
7/2	-.75			8.498	30	0.5	830		~30"
					30.5	0.5	800		~6"
7/9	-.755			8.493	31.5	0.8	1475		~30"
					33	0.6	1180		~6"
7/15	+.100			9.348					Heavy rain 7/13 & 7/14
7/16	+.070			9.318					
7/18	+.055			9.303	28.5	0.3	415		~60"
					30.5	0.2	250		~6"
7/22	-.005			9.243	29	0.6	975		~60"

WELL NO. Ditch - East End

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
					33	0.4	650		~6"
7/26	+.180			9.428					
7/27	+.303			9.551					
7/28	+.79			10.038	27.7	0.1	215		bottom
8/3	-.15			9.098	27.7	0.1	215		bottom
					30	0.1	150		top
8/8	+.020			8.268					
8/13	-.205			9.043	29.5	0.5	860		bottom
					32.0	0.4	600		top
8/16	-.220			9.028	28.5	1.2	2200		bottom
					31.5	0.4	830		top
8/26	-.220			9.028					
8/30	-.280			8.968					
9/4	-.200			9.048					
9/5					28.2	0.6	870		bottom
					28.7	0.2	228		top
9/11	-.325			8.923	32	1.1	2100		bottom
					32	0.6	1210		top

WELL NO. ____________

LOCATION Ditch at Pine St. GRADE ELEV. ____________

TOP ELEV. ____________

INSTALLATION NOTES

DATE ____________ MATERIAL ____________

TOTAL STRING ____________ TOP HEIGHT ABOVE GRADE ____________

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
1/22				8.641	11	0.4	375		at ~36"
2/1				8.538	20.5	0.8	920		at ~36"
					27.5	0.4	1030		at ~6"
2/12				8.663	15	0	120		at ~36"
					15.5		105		at ~6"
3/19	-0.99			8.218					
3/20	-1.0			8.208	19	0.8	1050		~30"
3/22	-.75			8.42	20	0.2	235		~36"
3/25	-.79			8.418	22.8	0.6	570		~36"
					23.5	0.4	570		~6"
3/29	-0.86			8.32	23.8	0.6	1080		~30"
					26	0.6	1230		~6"
4/6	-.96			8.21					
4/14	-1.05			8.158	24.5	0.7	1030		~24"
4/29	-1.17			8.01	29	0.7	1110		~20"
					31	0.7	1210		~6"

WELL NO. Ditch at Pine St.

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
5/7	-1.25			7.93	27	0.4	1530		~20"
					32	0.4	1620		~6"
5/17	-1.37			7.81	27	0.8	1280		~20"
					27	0.8	1280		~6"
5/24	-1.45			7.73	27.5	0.7	1000		~6"
6/7	-1.42			7.76	27.5	0.7	1700		steaming
6/13	-1.12			8.05	27.2	0.1	120		~24"
					32.5	0.2	255		~6"
6/15	-.54			8.58	23.2	0	60		~50"
					25.5	0.2	245		~6"
6/22	-0.615			8.56	29	0.2	190		~6"
					27.5	0.3	240		~50"
7.2	-.67			8.51	29.2	0.3	355		~50"
					31	0.3	2S5		~6"
7/9	-.685			8.49	32.5	0.5	800		~50"
					33.5	0.6	975		~6"

WELL NO. ____________

LOCATION Lake at Botanical Garden GRADE ELEV. ____________

TOP ELEV. ____________

INSTALLATION NOTES

DATE ____________ MATERIAL ____________

TOTAL STRING ____________ TOP HEIGHT ABOVE GRADE ____________

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
10/5					24.5	0.1	265		~24"
11/30					19.5	0.2	240		~24"
12/7					19.5	0.2	235		~12"
1/22					12	0.3	300		~12"
2/1/85					19.5	0.5	365		~12"

WELL NO. ____________

LOCATION Staff guage on lake GRADE ELEV. ____________

TOP ELEV. 8.144

INSTALLATION NOTES

DATE 6/7/85 MATERIAL 2" PVC

TOTAL STRING ____________ TOP HEIGHT ABOVE GRADE ____________

MONITORING RECORD (HEAD = TOP ELEV. - HELD + WET - DISP. CORR.)

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
6/7/85	-.61			7.534					followed by 2" rain
6/7/85	-.45			7.694					rain stopped
6/7/85	-.42			7.724					6 P.M.
6/10/85	-.215			7.929					
6/13/85	-0.085			8.059	29.5	0.3	270		~12" depth
7/2/85	submerged				32	0.2	285		~12" depth
7/19/85	submerged				33.3	0.3	375		~12"

WELL NO. Duck Pond

DATE	HELD	WET	DISP. CORR.	HEAD	TEMP. °C	SAL. ‰	S. C. µmhos	Corr. S.C. µmhos	NOTES
9/25					30	0.1	250		sunny, breezy
9/28					25.5	0.1	104		cloudy, before raining
10/28					29	0.1	132		sunny, after raining
12/7					24	0.2	155		sunny, clear
12/7					17	0.1	137		sunny
12/7					17.5	0.1	108		sunny
12/15					18	0.1	110		sunny
1/11/85					20	0.1	130		cloudy
1/16					14	0.1	125		cloudy
1/16					14	0.1	120		cloudy
1/25					9.5	0.4	145		
1/25					11.5	0.4	165		
1/31					18	0	145		
2/7					18	0	150		
2/14					20	0.1	155		
2/26					21.5	0.5	160		
3/10					22	0.1	190		
3/20					20	0.1	200		
4/7					22	0.1	190		
4/19					21	0.0	220		
5/10					23	0.1	240		
5/26					21	0.5	230		
6/30					22	0.5	270		
7/10					24	0.1	190		
8/9					23	0.5	150		

APPENDIX K: MONTHLY HEAD DIFFERENCES (METERS) BETWEEN THE SURFICIAL AND FLORIDAN AQUIFERS FOR SIX WELLS IN NORTH-CENTRAL HILLSBOROUGH COUNTY, FLORIDA.

Well No. 1

Month	Surficial Aquifer Elevation (meter)	Floridan Aquifer Elevation (meter)	ΔH (meter)	Q m^3/month
Aug. 84	7.24	6.43	+0.81	80.35
Sept.	7.20	6.31	+0.89	85.44
Oct.	7.06	6.87	+0.19	18.84
Nov.	6.99	6.64	+0.35	33.6
Dec.	6.68	6.59	+0.09	8.93
Jan. 85	6.49	6.28	+0.21	20.83
Feb.	6.59	6.19	+0.4	35.83
Mar.	6.32	5.80	+0.52	51.58
Apr.	6.25	5.67	+0.58	55.68
May	5.81	5.64	+0.17	16.86
June	5.66	5.66	0.00	0.00
July	6.74	6.04	+0.69	68.45

Well No. 2

Month	Surficial Aquifer Elevation (meter)	Floridan Aquifer Elevation (meter)	ΔH (meter)	Q m^3/month
Aug. 84	7.28	6.43	+0.85	74.4
Sept.	7.25	6.31	+0.94	79.62
Oct.	7.07	6.87	+0.2	17.50
Nov.	6.98	6.64	+0.34	28.8
Dec.	6.66	6.59	+0.07	6.12
Jan. 85	6.46	6.28	+0.18	15.75
Feb.	6.57	6.19	+0.38	30.05
Mar.	6.29	5.80	+0.49	42.88
Apr.	6.23	5.67	+0.56	47.43
May	6.01	5.64	+0.37	32.38
June	5.85	5.66	+0.19	16.1
July	6.63	6.05	+0.58	50.76

Well No. 3

Month	Surficial Aquifer Elevation (meter)	Floridan Aquifer Elevation (meter)	ΔH (meter)	Q m^3/month
Aug. 84	8.47	6.43	2.04	97.7
Sept.	8.02	6.31	1.71	79.3
Oct.	7.48	6.87	0.61	29.2
Nov.	7.33	6.64	0.69	32.7
Dec.	7.01	6.59	0.42	20.12
Jan. 85	6.84	6.28	0.56	26.8
Feb.	6.83	6.19	0.64	27.7
Mar.	6.5	5.80	0.7	33.5
Apr.	6.44	5.67	0.77	35.7
May	6.15	5.64	0.51	24.4
June	6.27	5.66	0.61	28.3
July	7.6	6.05	1.55	74.2

Well No. 4

Month	Surficial Aquifer Elevation (meter)	Floridan Aquifer Elevation (meter)	ΔH (meter)	Q m^3/month
Aug. 84	7.9	6.43	1.47	84.1
Sept.	7.59	6.31	1.28	70.9
Oct.	7.28	6.87	0.41	23.5
Nov.	7.23	6.64	0.59	32.7
Dec.	6.9	6.59	0.31	17.7
Jan. 85	6.7	6.28	0.42	24
Feb.	6.73	6.19	0.54	27.9
Mar.	6.46	5.80	0.66	37.7
Apr.	6.42	5.67	0.75	41.55
May	5.92	5.64	0.28	16.01
June	5.68	5.-6	0.02	1.1
July	6.99	6.05	0.94	53.8

Well No. 8

Month	Surficial Aquifer Elevation (meter)	Floridan Aquifer Elevation (meter)	ΔH (meter)	Q m^3/month
Aug. 84	8.66	6.43	2.23	207.39
Sept.	8.30	6.31	1.99	179.1
Oct.	7.99	6.87	1.12	104.16
Nov.	7 9	6.64	1.26	113.4
Dec.	7.57	6.59	0.98	91.14
Jan. 85	7.30	6.28	1.02	94.9
Feb.	7.11	6.19	0.92	77.3
Mar.	6.84	5.80	1.04	96.7
Apr.	6.72	5.67	1.05	94.5
May	6.4	5.64	0.76	70.7
June	6.5	5.66	0.84	75.6
July	7.77	6.05	1.72	159.7

Well No. 9

Month	Surficial Aquifer Elevation (meter)	Floridan Aquifer Elevation (meter)	ΔH (meter)	Q m^3/month
Aug. 84	9.79	6.43	3.36	89.57
Sept.	9.4	6.31	3.09	79.7
Oct.	9.1	6.87	2.23	59.5
Nov.	9.00	6.64	2.36	60.8
Dec.	8.5	6.59	1.91	50.9
Jan. 85	8.2	6.28	1.92	51.2
Feb.	7.50	6.19	1.31	31.3
Mar.	7.84	5.80	2.04	54.4
Apr.	7.8	5.67	2.13	54.9
May	7.77	5.64	2.13	56.78
June	7.97	5.66	2.31	59.6
July	8.9	6.05	2.85	75.98

APPENDIX L: SLUG TEST DATA OBTAINED FROM SIX MONITOR WELLS IN NORTH-CENTRAL HILLSBOROUGH COUNTY, FLORIDA.

Well No. 3B

8/15/85

Initial Head (H_o) = 1.291 m

Time	Residual Head (H) meters	Residual Head (H) over initial Head (H_o) meters $\frac{H}{H_o}$
2 min.	0.067	0.05
3 min.	0.112	0.98
4 min.	0.137	0.11
5 min.	0.167	0.13
6 min.	0.201	0.16
7 min.	0.221	0.17
8 min.	0.252	0.19
9 min.	0.28	0.22
10 min.	0.304	0.24
15 min.	0.43	0.34
20 min.	0.537	0.42
25 min.	0.632	0.49
30 min.	0.704	0.54
35 min.	0.78	0.6
40 min.	0.84	0.65
45 min.	0.917	0.7
60 min.	1.022	0.79
75 min.	1.102	0.85
90 min.	1.164	0.9
105 min.	1.217	0.94
120 min.	1.242	0.96
135 min.	1.256	0.97
150 min.	1.277	0.99
165 min.	1.287	1

Well No. 4B　　　　Initial Head (H_o) = 2.395 m.

8/16/85

Time	Residual Head (H) meters	Residual Head (H) over initial Head (H_o) meters $\frac{H}{H_o}$
30 sec.	.03	0.01
45	.1	0.04
1 min.	.16	0.07
1:15	.22	0.09
1:30	.275	0.11
1:45	.335	0.14
2 min.	.39	0.16
2:15	.45	0.19
2:30	.49	0.2
2:45	.545	0.22
3 min.	.6	0.25
3:15	.645	0.27
3:30	.695	0.29
3:45	.74	0.31
4 min.	.785	0.33
4:15	.83	0.35
4:30	.87	0.36
4:45	.905	0.38
5 min.	.945	0.39
5:30	1.01	0.42
6 min.	1.08	0.45
6:30	1.155	0.48
7 min.	1.215	0.5
7:30	1.275	0.53
8 min.	1.33	0.55
8:30	1.38	0.58
9:30	1.48	0.62
10 min.	1.515	0.63
11 min.	1.6	0.67
12 min.	1.66	0.7
13 min.	1.72	0.72
14 min.	1.775	0.74
15 min.	1.825	0.76
16 min.	1.865	0.78
18 min.	1.93	0.81
19 min.	1.96	0.82
20 min.	1.98	0.83
25 min.	2.08	0.87
30 min.	2.135	0.89
35 min.	2.175	0.91
40 min.	2.21	0.92

Well No. 4B, Continued Initial Head (H_o) = 2.395 m.

8/16/85

Time	Residual Head (H) meters	Residual Head (H) over initial Head (H_o) meters $\frac{H}{H_o}$
50 min.	2.26	0.94
60 min.	2.29	0.96
70 min.	2.305	0.96
90 min.	2.335	0.97
110 min.	2.34	0.98

Well No. 4C

Initial Head (H_o) = 2.29 m

8/16/85

Time	Residual Head (H) meters	Residual Head (H) over initial Head (H_o) meters $\frac{H}{H_o}$
30 sec.	.25	0.11
45	.45	0.19
1 min.	.71	0.31
1:15	.88	0.38
1:30	1.05	0.46
1:45	1.22	0.53
2 min.	1.33	0.58
2:30	1.54	0.67
3 min.	1.69	0.74
3:30	1.84	0.8
4 min.	1.935	0.84
4:30	2.01	0.88
5 min.	2.07	0.9
6 min.	2.51	0.93
7 min.	2.195	0.96
8 min.	2.23	0.97
10 min.	2.265	0.99
12 min.	2.28	0.99
14 min.	2.29	1

Well No. 3A

8/15/85

Initial Head (H_o) = 1.245 m.

Time	Residual Head (H) meters	Residual Head (H) over initial Head (H_o) meters $\frac{H}{H_o}$
15 sec.	.025	0.02
30	.05	0.04
45	.075	0.06
1 min.	.103	0.08
1:30	.148	0.12
2 min.	.196	0.16
2:30	.244	0.20
3 min.	.309	0.25
3:30	.36	0.29
4 min.	.404	0.32
4:30	.444	0.36
5 min.	.487	0.39
5:30	.525	0.42
6 min.	.567	0.45
6:30	.597	0.48
7 min.	.618	0.5
7:30	.655	0.53
8 min	.684	0.55
8:30	.714	0.57
9 min.	.736	0.59
9:30	.764	0.6
10 min.	.785	0.63
11 min.	.836	0.67
12 min.	.875	.7
13 min.	.91	0.73
14 min.	.941	0.76
15 min.	.973	.078
16 min.	1.004	0.82
17 min.	1.02	0.82
18 min.	1.048	0.84
19 min.	1.065	0.86
20 min.	1.083	0.87
22 min.	1.114	0.89
24 min.	1.126	0.9
26 min.	1.144	0.92
28 min.	1.158	0.93
30 min.	1.171	0.94
35 min.	1.199	0.96
45 min.	1.217	0.98
55 min.	1.226	0.98
60 min.	1.245	1

Well No. 4D

Initial Head (H_o) = 2.425 m.

8/16/85

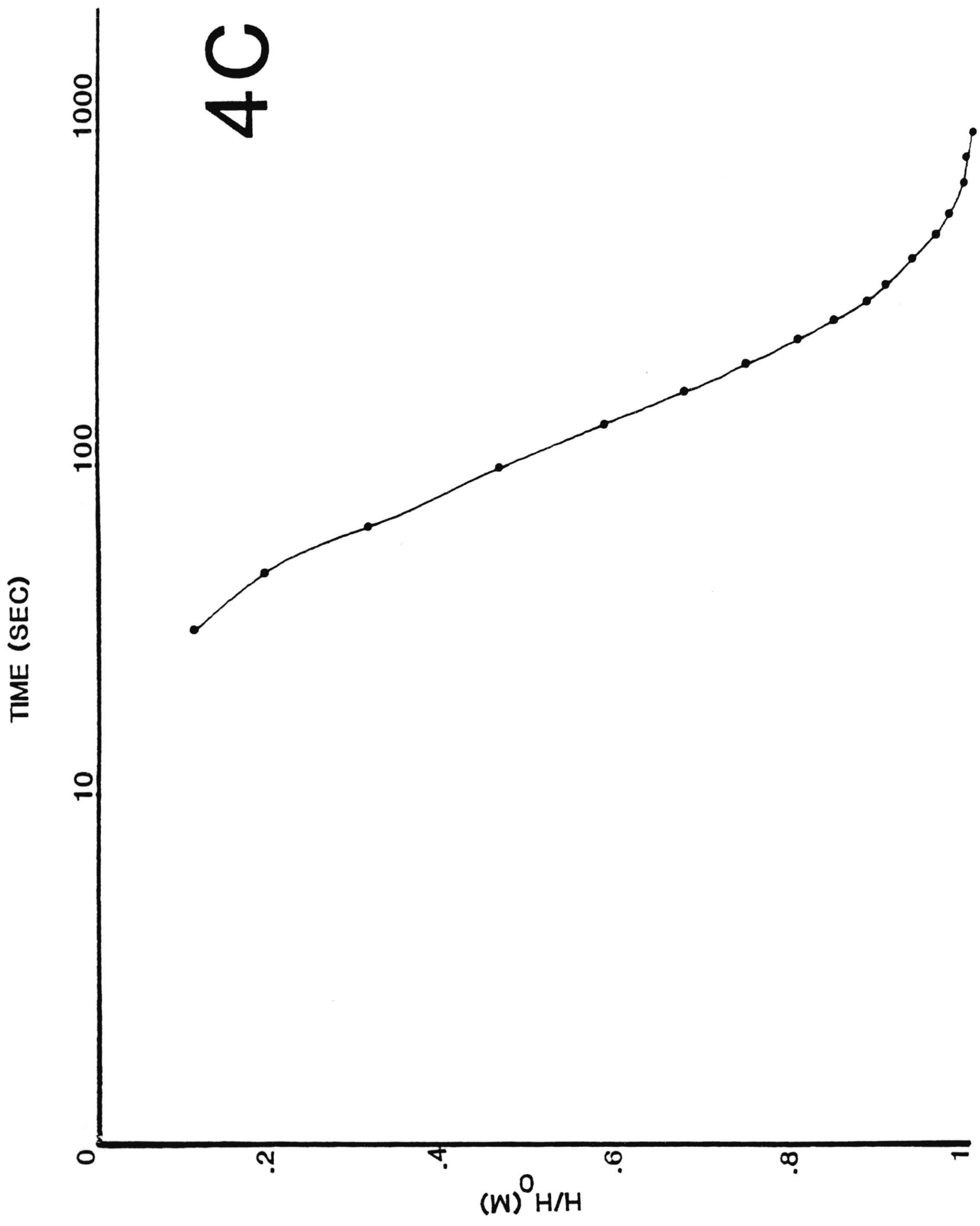
Time	Residual Head (H) meters	Residual Head (H) over initial Head (H_o) meters $\frac{H}{H_o}$
45 sec.	1.4	0.58
1 min.	2.1	0.87
1:30	2.35	0.97
2 min.	2.4	0.99
2:30	2.415	0.995
3 min.	2.42	0.997
4 min.	2.425	1

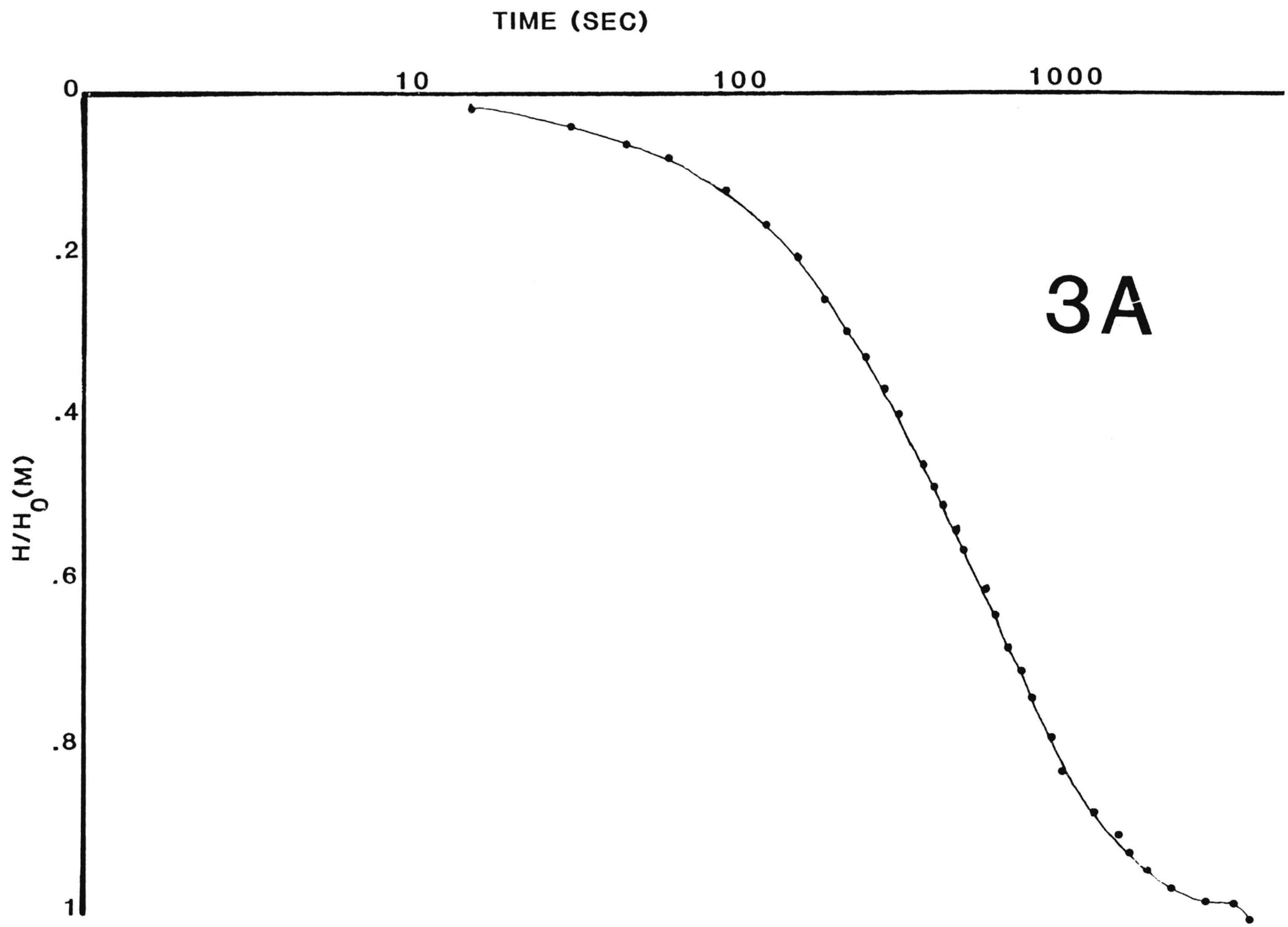
Well No. 8 Initial Head (H_o) = 1.551 m

8/16/85

Time	Residual Head (H) meters	Residual Head (H) over initial Head (H_o) meters $\frac{H}{H_o}$
15 sec.	.07	0.05
30	0.13	0.08
45	0.24	0.15
1 min.	0.3	0.19
1:15	0.4	0.26
1:30	.48	0.31
1:45	0.54	0.35
2 min.	0.61	0.39
2:15	0.675	0.44
2:30	0.74	0.48
2:45	0.795	0.51
3 min.	0.85	0.55
3:15	0.9	0.58
3:30	0.945	0.6
3:45	0.99	0.64
4 min.	1.03	0.66
4:15	1.08	0.69
4:30	1.105	0.71
4:45	1.145	0.74
5 min.	1.175	0.76
5:30	1.23	0.79
6 min.	1.28	0.82
6:30	1.315	0.85
7 min.	1.345	0.87
7:30	1.375	0.89
8 min.	1.4	0.9
8:30	1.42	0.92
9 min.	1.435	0.93
9:30	1.45	0.935
10 min.	1.46	0.94
10:30	1.49	0.96
12 min.	1.495	0.963
12:30	1.508	0.97
13 min.	1.513	0.979
13:30	1.518	0.979
14 min.	1.52	0.98

APPENDIX M: SLUG TEST DATA PLOTTED AS TIME (SECONDS) VERSUS RESIDUAL HEAD (H) OVER INITIAL HEAD (H_0) METERS.

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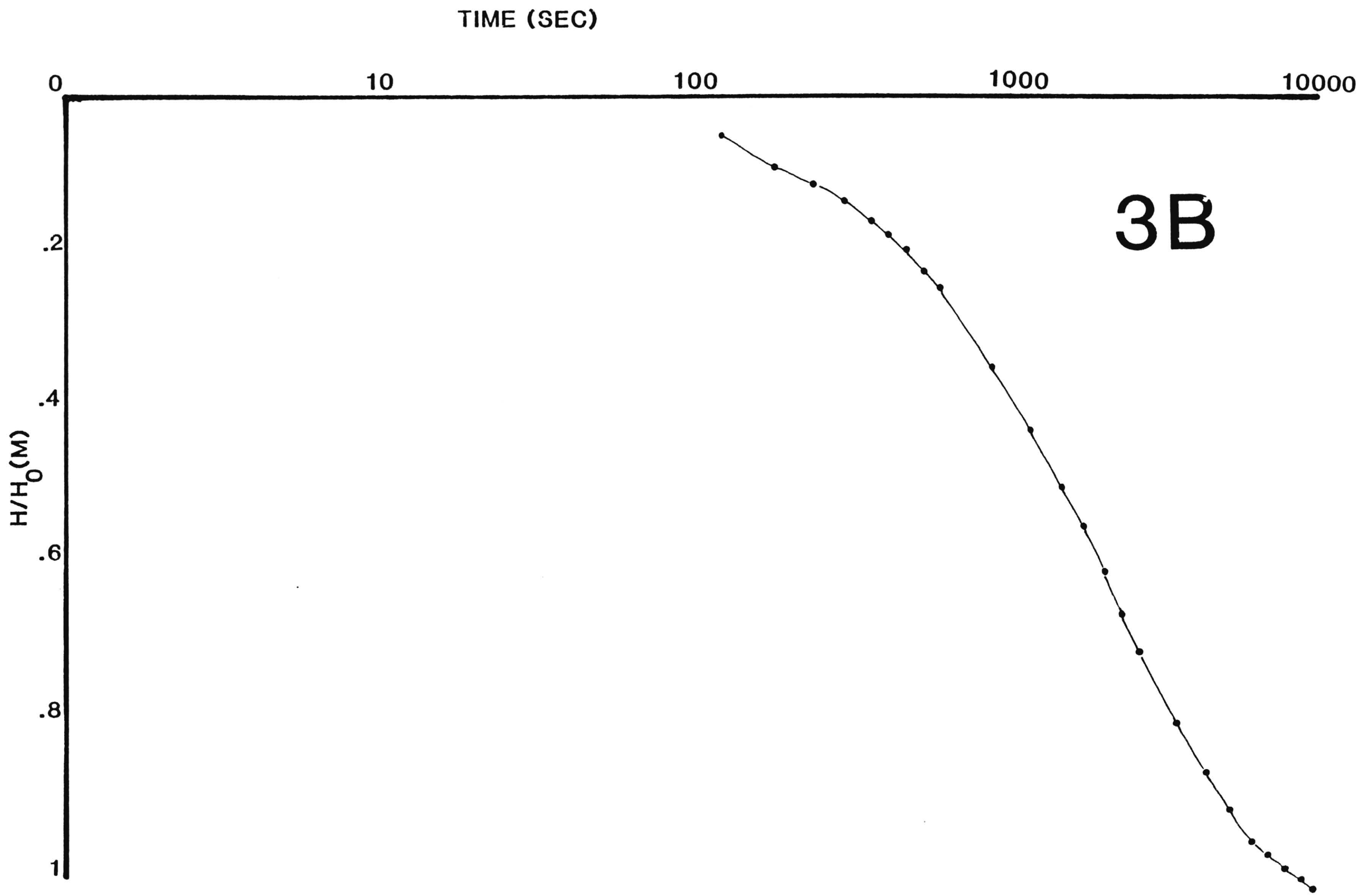
100
1000
.2
.4
.6
.8
1
H/H0(M)
3A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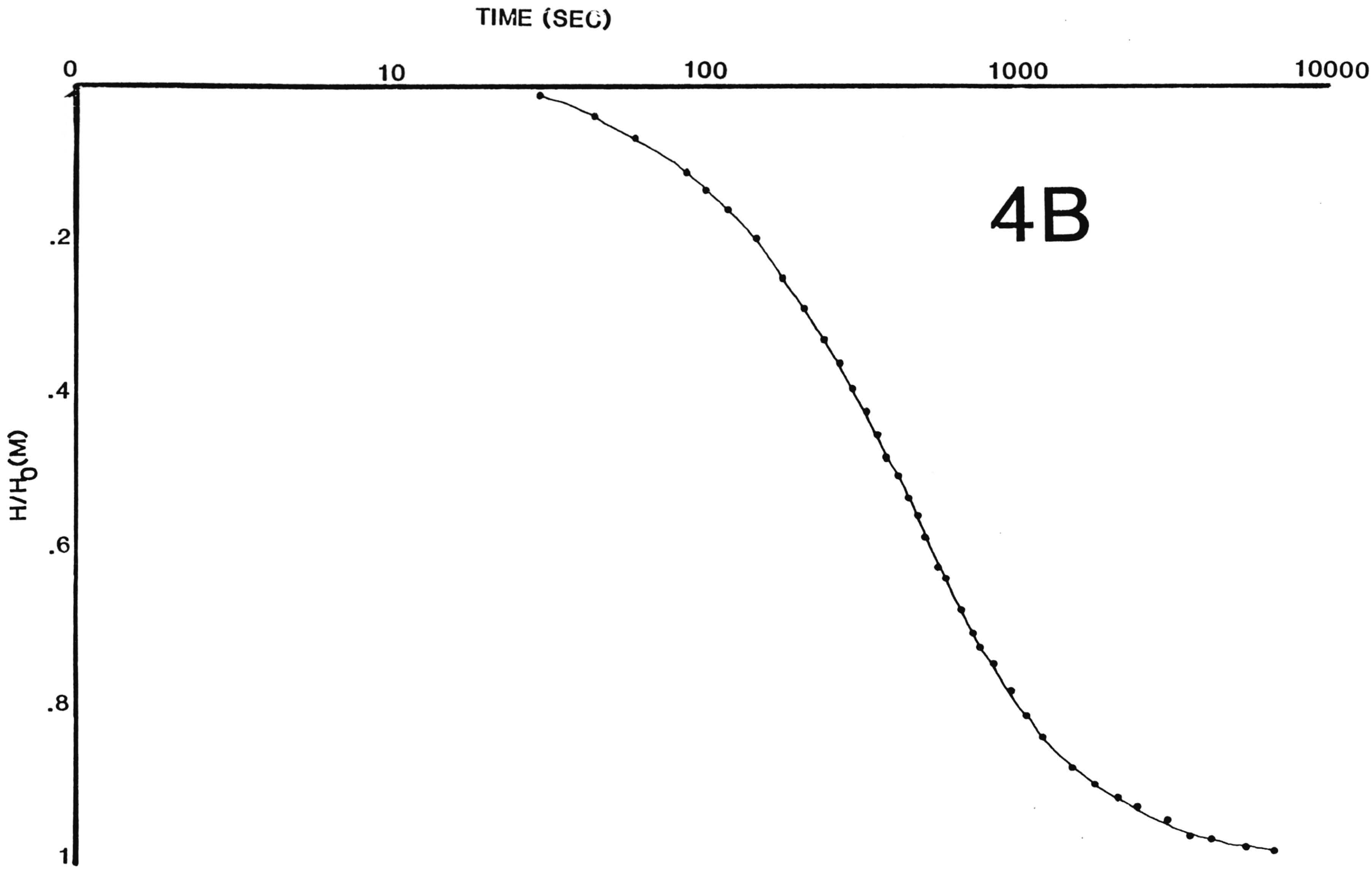
10
100
1000
10000
.2
.4
.6
.8
1
H/H0(M)
3B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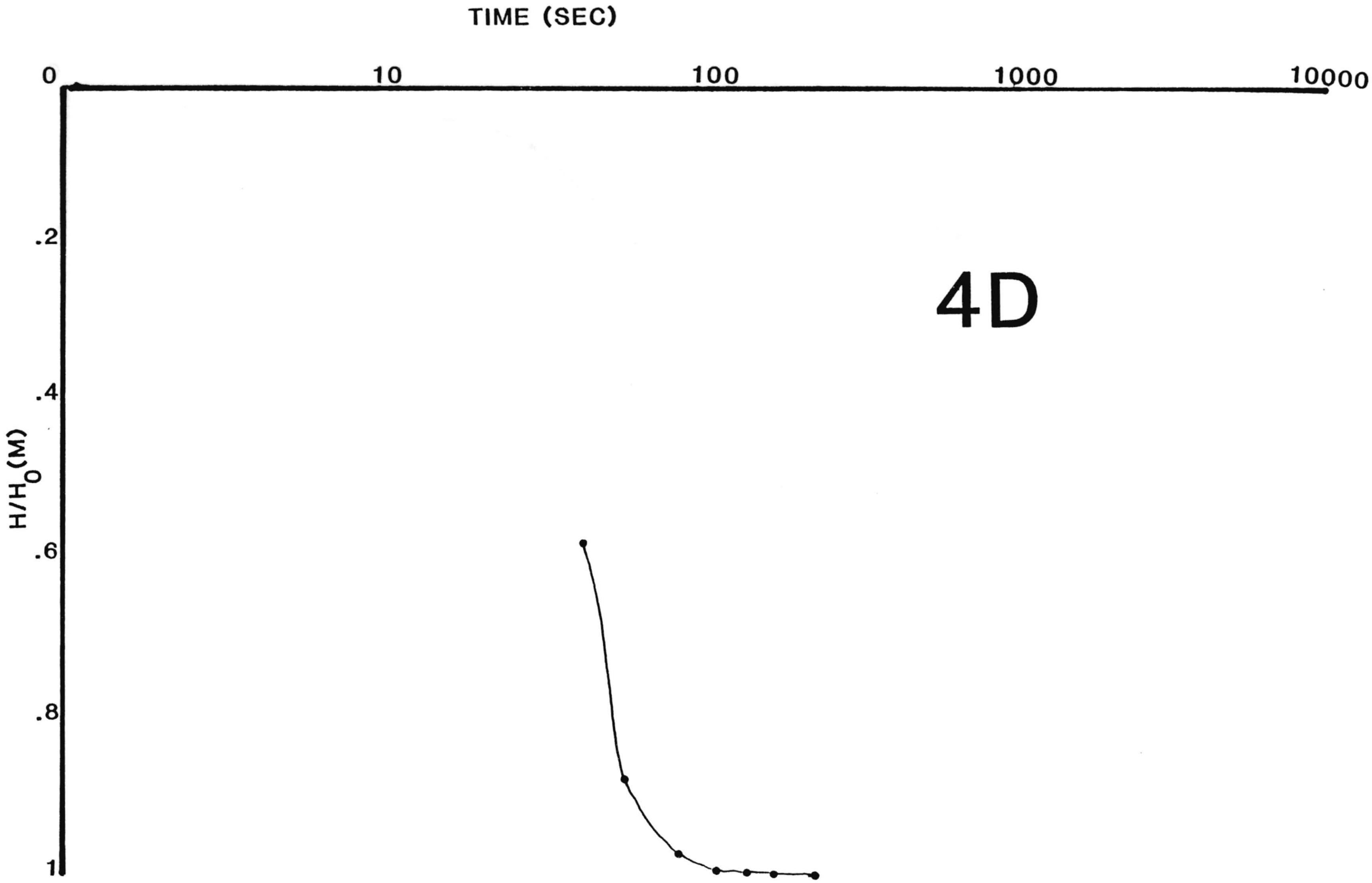
100
1000
10000
4B
.2
.4
.6
.8
1
$H/H_0(M)$



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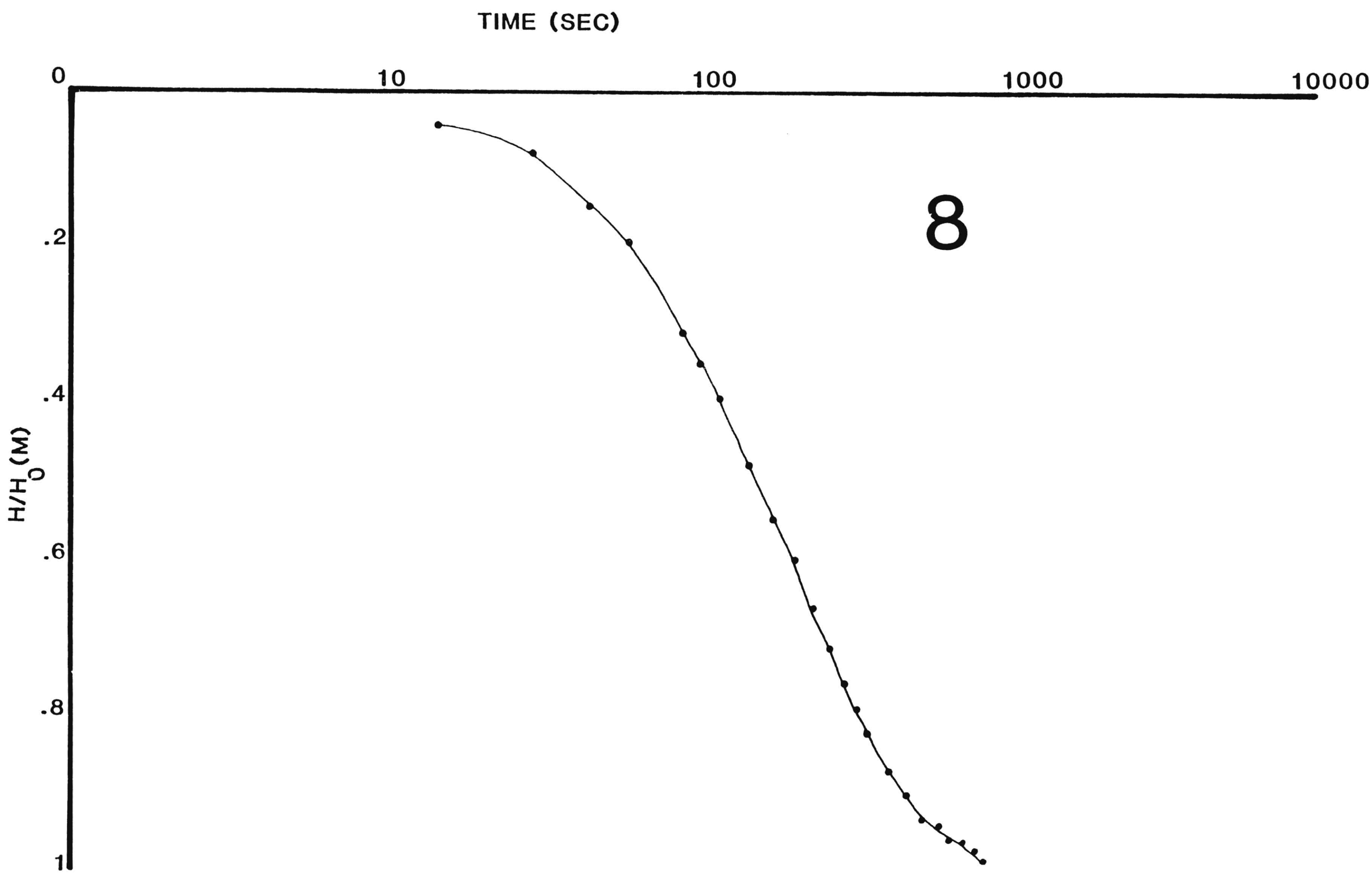
100
1000
10000
.2
.4
.6
.8
1
H/H0(M)
4D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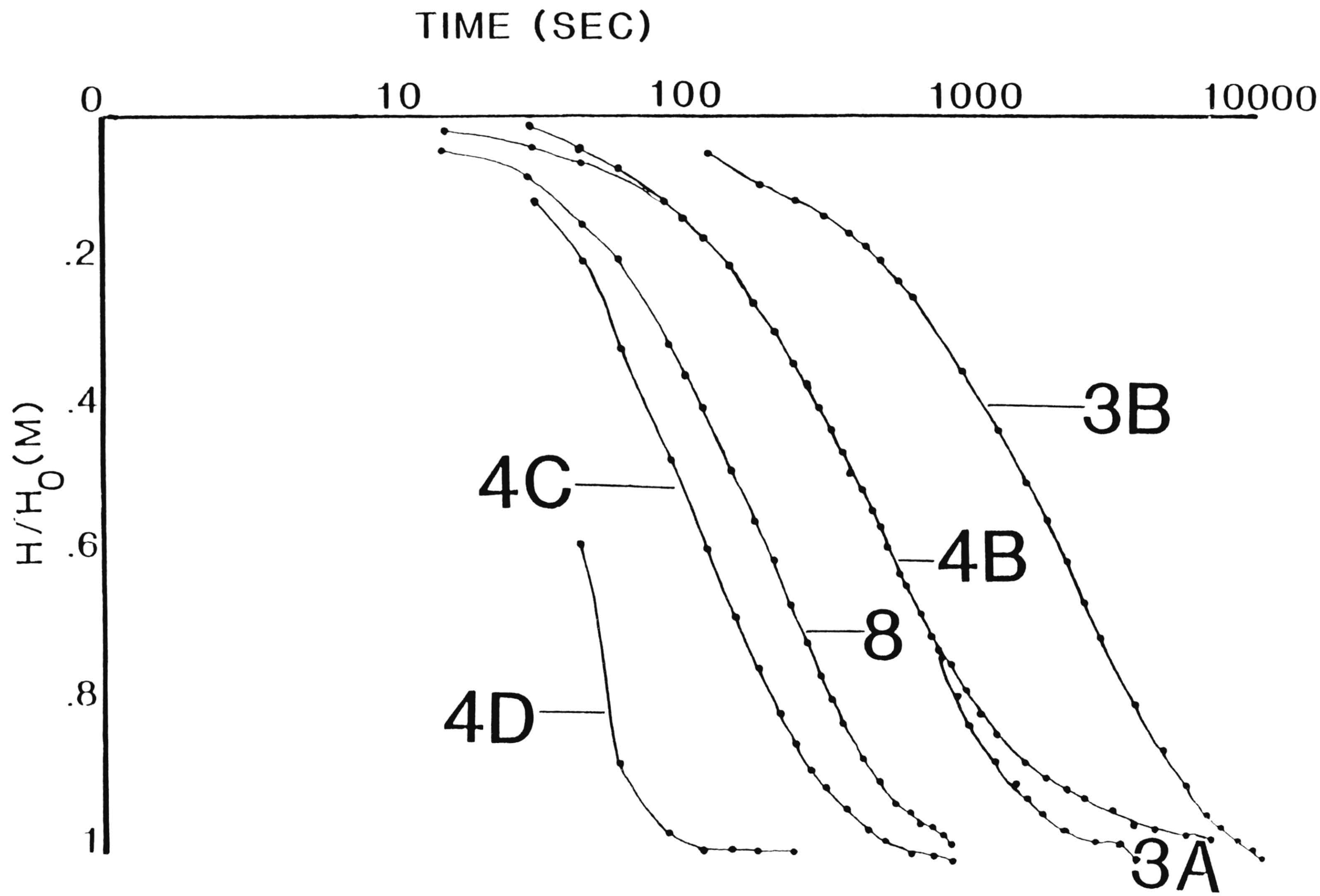
100
1000
10000
.2
.4
.6
.8
1
H/H0(M)
8



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100
1000
10000
.2
.4
.6
.8
1
H/H$_0$(M)
3B
4C
4B
8
4D
3A