W-159

AQUIFER PERFORMANCE TEST DATA ANALYSIS REPORT AND TECHNICAL APPENDICES - PHASE 1A

PHASE I - REGIONAL INTERCONNECTION

FOR THE

WEST COAST REGIONAL WATER SUPPLY AUTHORITY

DECEMBER 1986

CAMP DRESSER & McKEE INC.
CLEARWATER, FLORIDA

environmental engineers, scientists, planners & management consultants **CDM**

APT Site SWF-153

AQUIFER PERFORMANCE TEST DATA ANALYSIS REPORT AND TECHNICAL APPENDICES - PHASE IA

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PREPARED BY

CAMP DRESSER & McKEE INC.

DECEMBER 1986

WCRWSA5T.1/42

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CAMP DRESSER & McKEE INC.
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813 221-2833

December 12, 1986

Ms. Loretta Holtkamp
West Coast Regional Water Supply Authority
2535 Landmark Drive, Suite 211
Clearwater, FL 33519

RE: Phase IA Draft Report - Phase I Regional Interconnection

Dear Ms. Holtkamp:

Camp Dresser & McKee Inc. is pleased to submit the attached Aquifer Performance Test Data Analysis Report and Technical Appendices - Phase IA. The report was prepared by James H. Jensen and Gerhardt Witt under my direction.

The field investigation and data analysis indicate that the site is suitable for a water supply well producing an average of 3 million gallons per day.

CDM appreciates this opportunity to provide professional engineering and hydrogeologic services to the Authority.

Sincerely,

CAMP DRESSER & McKEE INC.

Edward J. Kent

Edward J. Kent, Ph.D., P.E.

EJK/jra
EJK6T.2/65

cc: T. D. Furman
D. H. Twachtmann
L. R. Tortora
G. H. Witt
J. H. Jensen

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WCRWSA5T.1/41
12/9/86

WEST COAST REGIONAL WATER SUPPLY AUTHORITY
AQUIFER PERFORMANCE TEST ANALYSIS - PHASE IA
EXECUTIVE SUMMARY

PURPOSE

As part of an investigative program examining the water supply potential of the area, the West Coast Regional Water Supply Authority (WCRWSA) authorized Camp Dresser & McKee Inc. (CDM) to design and conduct an aquifer performance test near the intersection of I-75 and State Road 54 in south-central Pasco County. The site is referred to as Phase IA of the Phase I Regional Interconnection.

The purpose of the aquifer performance test was to gain information on the characteristics of the Floridan aquifer in this area and to determine the water quality and potential yield of a test production well at this location. The test program was performed in support of a consumptive use permit application and was conducted according to Southwest Florida Water Management District (SWFWMD) requirements.

APPROACH

Six wells were installed at the Phase 1A site:

- A 24-inch diameter Floridan aquifer test production well,
- Three 8-inch diameter Floridan aquifer monitor wells, and
- Two 4-inch diameter water table monitor wells.

Two separate pump tests were performed:

- A step-drawdown test to determine the performance and efficiency of the test production well, and

- o An aquifer performance test to determine the aquifer properties in the vicinity.

Water quality characteristics of the groundwater were also determined. Details of the well installation and testing procedures are provided in Sections 4 and 5.

RESULTS

Results of the hydrogeologic investigation, step-drawdown test, aquifer performance test, and water quality analyses indicated that the Phase IA site is suitable for a potable water supply well producing an average of 3 million gallons per day (mgd) from the Floridan aquifer. Analysis of the test data indicated the following average aquifer properties:

- o Transmissivity - 423,600 gpd/ft
- o Storage Coefficient - 0.0007
- o Leakance - 6.0×10^{-5} per day

These data indicate that the well is in a productive area, and that the aquifer is semi-confined. Water quality test results indicate that the water from the Floridan aquifer at the test site meets federal and state primary and secondary drinking water standards. Detailed discussions of the test analyses and results are provided in Sections 6 and 7.

1.0 INTRODUCTION

1.1 AUTHORIZATION

West Coast Regional Water Supply Authority (WCRWSA) required that wells be installed and a Floridan aquifer performance test be conducted near the intersection of I-75 and SR 54 in Pasco County (Figure 1-1) as part of an investigative program examining the water supply potential of the area. The objective of the performance test was to gain information on characteristics of the Floridan aquifer and to determine the water quality and water supply capacity of a test production well at this location. The well construction and test program, which is referred to as Phase IA of the planned Phase I Regional Interconnection, was conducted in support of Consumptive Use Permit (CUP) Application No. 208426 filed with the Southwest Florida Water Management District (SWFWMD).

Camp Dresser & McKee Inc. (CDM) was selected to design and conduct the performance test and analyze the results to determine the potential yield at the site.

1.2 SCOPE OF WORK

The approach for the aquifer performance test (APT) at the Phase 1A site in Section 23, Township 26S, Range 19E, consisted of the following three tasks:

- Task I: Development of Specifications
- Task II: Field Investigation
- Task III: Analysis and Report

Task I: Development of Specifications

In order to design the layout, construction and testing of the APT wells, information was collected regarding the hydrogeologic conditions at the proposed APT site. Sources of information included area Development of Regional Impact documents, the U.S. Geological Survey, the Southwest

GENERAL SITE LOCATION

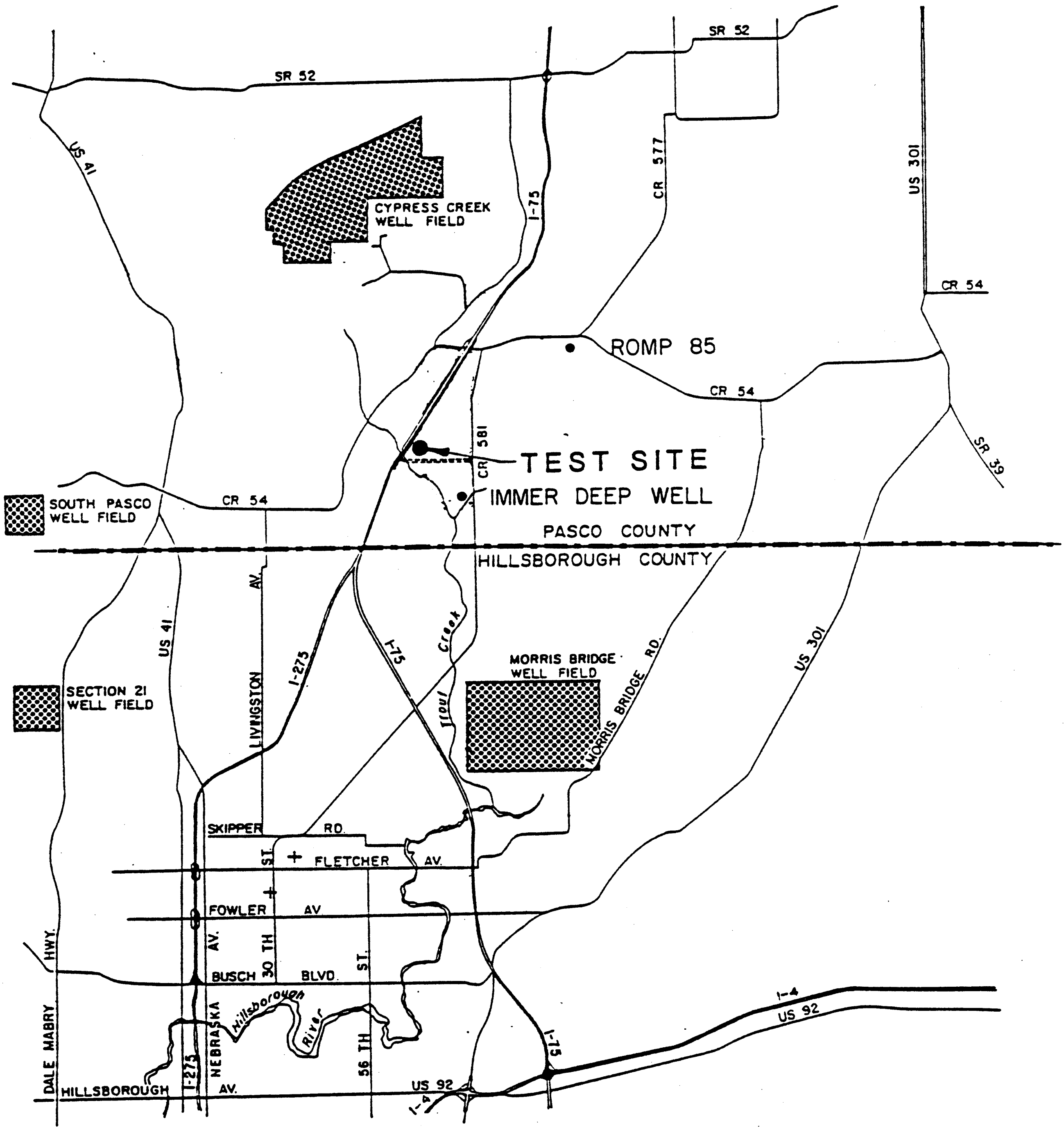

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FIGURE 1-1

General Site Location

Florida Water Management District (SWFWMD), drilling and testing programs reports from wellfields in the region, and Florida Bureau of Geology publications. Based upon the findings of the data collection effort and additional requirements of the SWFWMD, the locations, depths, and construction specifications were developed for:

1. A 24-inch diameter Floridan aquifer test production well;
2. Three 8-inch diameter Floridan aquifer monitor wells; and,
3. Two 4-inch diameter water table monitor wells.

Contract documents and a project manual were prepared. The Authority awarded the drilling contract to Alsay, Incorporated, the lowest qualified bidder.

Task II: Field Investigation

CDM provided resident engineering and hydrogeologic services during drilling, aquifer performance tests, and data collection in accordance with the Project Manual.

Task III: Analysis and Report

The data collected in the field investigations were analyzed to determine the aquifer properties of the site and potential yield of the test production well. This report documents the site hydrogeology, data collection effort, testing procedures, test results, and recommendations.

1.3 SWFWMD REQUIREMENTS

The field investigation included additional activities required by the SWFWMD. WCRWSA submitted a test program on December 13, 1985 and a CUP Application on February 26, 1985. The SWFWMD granted authorization for the APT in a letter dated April 2, 1986 (see Appendix A) with the following additional requirements:

1. Construction of a third deep (Floridan) monitor well at 1,500-2,000 ft. from the test production well.

2. Construction of a second shallow (water table) monitor well.

3. Water samples to be taken at every drilling pipe change (approximately 30 feet) during reverse air drilling and field analyzed for conductivity and temperature.

4. One additional week of pre-APT water level measurements for all wells for a total minimum of two weeks required prior to the start of the APT.

1.4 WELL IDENTIFICATION SYSTEM

A total of six wells were installed at the Phase IA test site. The wells included one test production well, three deep monitor wells, and two shallow monitor wells.

In order to accurately describe the orientation of the various wells at the Phase IA site, an identification coding system was devised. Using this coding system, the test production well at the Phase IA site is designated TPW-IA while the 5 monitor wells are given identification codes based on their depth (shallow or deep) and proximity to the test production well. For example, DMW-IA+500 represents the deep monitor well at the Phase IA site located at 500 feet distance from the test production well.

2.0 PHYSIOGRAPHIC SUMMARY

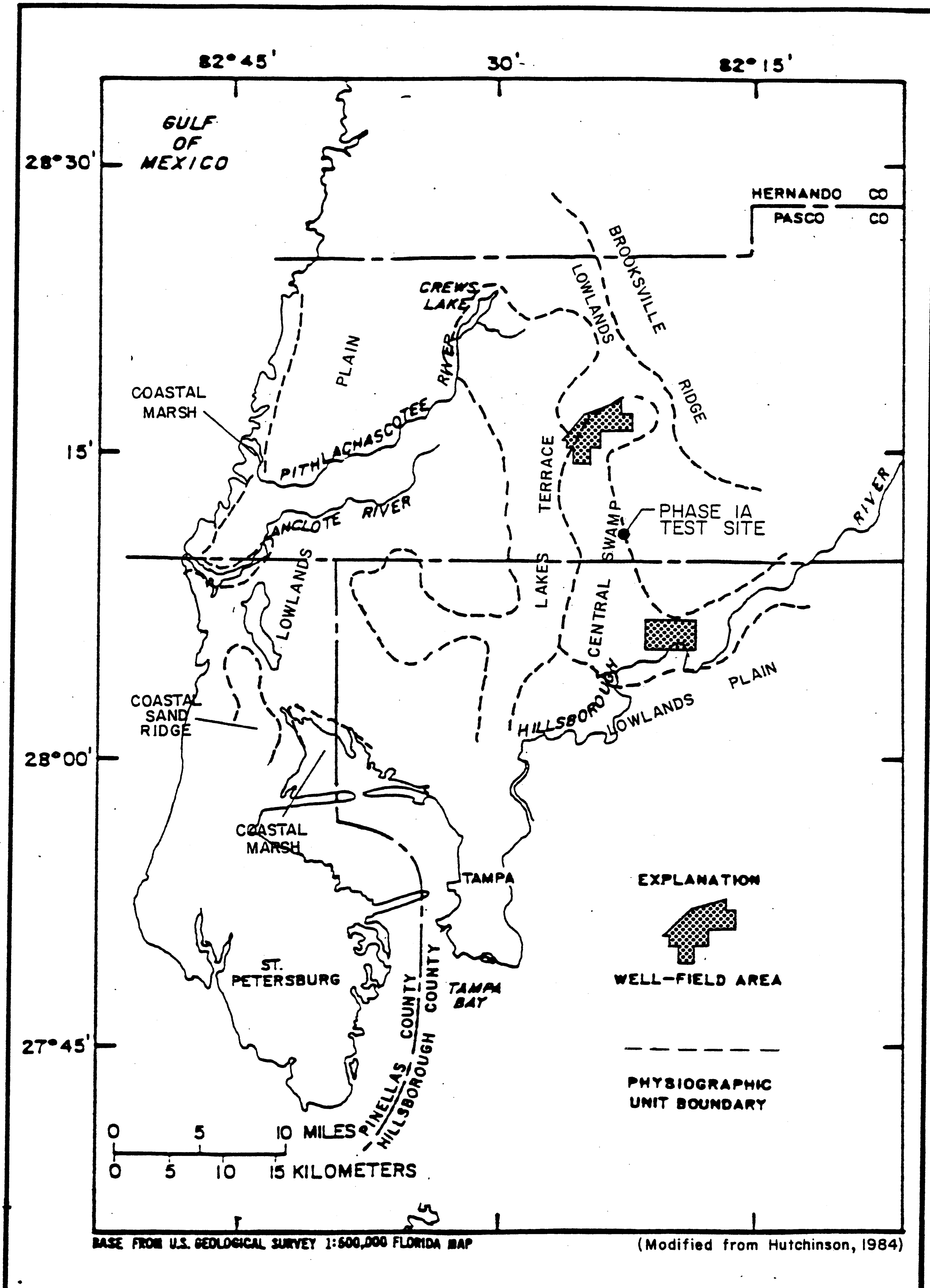
2.1 REGIONAL

The Phase IA site is in southern Pasco County which lies in the Coastal Plain physiographic province. A prominent surface feature located in the central part of the province is the Brooksville Ridge which appears to be composed of old, stabilized sand dunes (White, 1970). The Brooksville Ridge trends in a northwesterly direction and reaches a maximum altitude of 301 feet. The ridge area is flanked by the Withlacoochee River valley on the east, the Hillsborough River valley on the south, and the Terraced Coastal Lowlands on the west. Marine terraces were formed during the Pleistocene Epoch during warm interglacial periods when the seas were higher than present. Relatively sharp breaks in the slope of the land occur at altitudes of about 25 feet and 100 feet above mean sea level (msl) which define the Pamlico and Wicomico terraces, respectively. The Pamlico terrace extends into the Gulf of Mexico to a submerged scarp at about 60 feet below msl. Sinkholes are widely distributed on both the land and the submarine surfaces.

Within the Coastal Plain physiograhic province in the Gulf coast region are a number of physiographic units. Figure 2-1 shows that the Phase IA site is located at the edge of the Central Swamp physiographic unit, characterized by marshy areas and swamps that are maintained by upwelling of artesian water from underlying aquifers (Hutchinson, 1984). However, the Phase IA test site is also near the boundary of the Lowlands Plain physiographic unit which extends to the north and east of the test site and is characterized by few wetlands and the presence of large oak trees and improved pastureland.

2.1.1 CLIMATE

The normal annual rainfall in the region varies from about 51 to 58 inches and is unevenly distributed during the year. Tropical storms in the summer and fall and occasionally in the winter can bring intense rains to the area (Cherry et. al., 1970). The low, flat, coastal area receives about 52



Physiography of the Phase IA Area FIGURE 2-1 inches and the ridge section receives more than 56 inches. Approximately 60 percent of the rain falls during the period of June through September (Sinclair et al., 1985). July, the wettest month, averages more than 9 inches; November, the driest month, averages about 2 inches (Wetterhall, 1965).

Variations in day to day maximum temperatures during the summer range from about 72 degrees Fahrenheit (°F) to 90°F and during the winter from about 55°F to 75°F. During the winter, occasional cold fronts move through the area that drop temperatures into the low and middle 20s. Evapotranspiration in the area is on the order of 35 to 40 inches per year (Guyton and Associates, 1976).

2.1.2 TOPOGRAPHY

Land elevations in the region range from sea level at the shoreline to about 280 feet above msl near Dade City. The areas of highest elevations are a series of eroded sand ridges that trend to the northwest and a ridge of poorly defined sand hills that parallels the Gulf of Mexico. Between the Gulf and the sand hills, and adjacent to Old Tampa Bay are found relatively flat, swampy lowlands. These lowlands form a broad plain with gentle relief in the western parts of southern Pasco, Hillsborough, and northern Pinellas Counties. In eastern Pasco and northeastern Hillsborough Counties the land surface becomes gently rolling with smoothly rounded hills and shallow depressions (Cherry et al., 1970).

2.1.3 SURFACE HYDROLOGY

A large percentage of the water that falls on the surface returns to the atmosphere by evaporation and by transpiration of plants. The remainder drains from the area through the limestone formations that underlie the surface and through a few surface streams. Streams form where the water level in the limestone is near the land surface or where material of low permeability overlies the limestone restricting downward movement of the water (Wetterhall, 1964).

In Citrus, Hernando, and northern Pasco Counties, surface drainage is almost nonexistent. Sand hills and highly permeable land surfaces capture most of the precipitation that falls on them, and sinkholes capture a large part of the surface drainage.

Streams in the northern part of Pasco County generally originate at springs and carry little overland flow; whereas streams in the southern part carry substantial overland flow. Tributaries of the Hillsborough River drain most of the southeast and southcentral parts of Pasco County.

The area contributing water to a stream is usually delineated by topographic divides. However, in the Middle Gulf area, the area contributing water to a stream may better be delineated by groundwater divides than by surface water divides because most of the larger streams are fed by groundwater issuing from springs and seeps during much of the year.

Subsurface drainage is adequate during periods of normal rainfall, but during very wet periods, the closed depressions become flooded and store large volumes of water. Most of this water is released to the groundwater body, raising the water level in the aquifer(s). If the water level is raised sufficiently, some low-lying sinkholes that normally drain off surface waters flow as springs (Cherry et al., 1970).

Some of the sinks in the area known to be hydraulically connected to the Floridan aquifer transmit large quantities of water vertically to recharge the Floridan aquifer. Blue Sink, northeast of Brooksville, is capable of leaking large quantities of water to the Floridan aquifer. This sink has a drainage area of about 30 square miles. Numerous other sinks also occur in the Brooksville area.

The Phase IA site is near the boundary between Sinkhole Zone 2 of Sinclair et al., (1985) which is defined as bare or thinly covered limestone with little recharge and high runoff with rare sinkhole development and Sinkhole Zone 5 where cover is 25 to 150 feet thick with the sand cover underlain by a thick clay layer. In Zone 5, internal drainage is common and both cover-collapse and cover-subsidence sinkholes occur. The cypress heads in the area occupy depressions probably formed by cover-subsidence sinkholes. There have been only 3 small sinkholes reported in the test site vicinity between the years 1968 and 1981. The largest reported sinkhole was 11 feet across and 9 feet deep, located in Section 1, Township 26S, Range 19E about 4 miles north northeast of the site (Sinclair et al., 1985). There have been no reports of recent sinkholes within a mile of the site.

2.2 SITE INFORMATION

The Phase IA site is located just east of I-75 and south of SR 54 at the planned Saddlebrook Village development. The test site may be accessed from SR 581 approximately 2.5 miles south of SR 54 (Figure 2-2). Trout Creek is located about 1,200 feet south of the site.

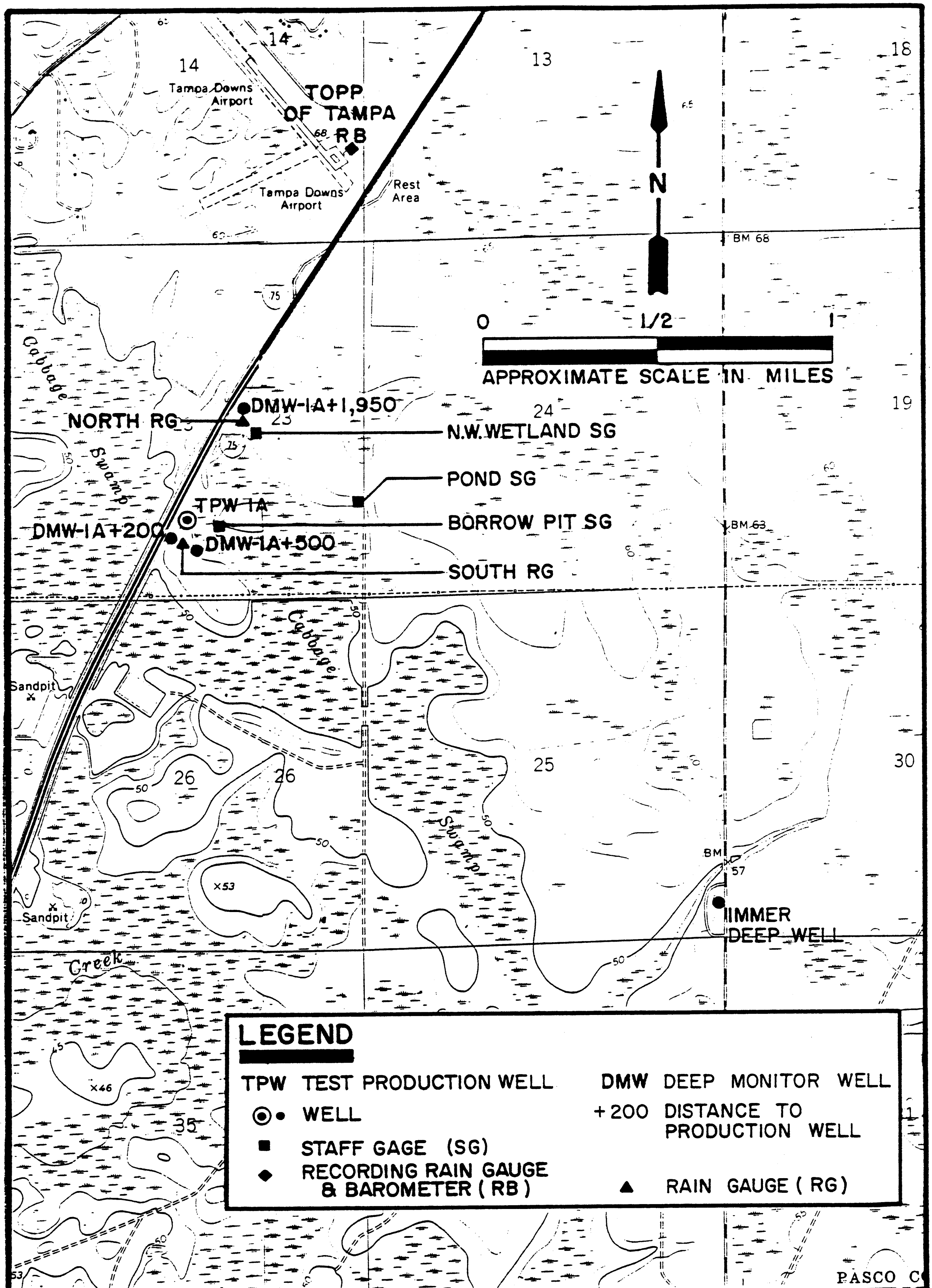
2.2.1 CLIMATE

The average annual rainfall at the site is approximately 55 inches (Wetterhall, 1964). About 70 percent of the rain falls from May through September and approximately 20 percent of the total falls in July alone. November, the driest month, usually accounts for only 3 percent of the annual rainfall.

Rain gages were installed at 3 locations (Figure 2-2) to provide a profile of local rainfall differences at distances from the test production well (TPW-IA). One rain gage (South) was located near TPW-IA. A second (North) was placed near the deep monitor well (DMW-IA+1,950) located about 1,950 feet north of TPW-IA. A recording rain gage and recording barometer were installed at the Topp of Tampa Airport, approximately 1 mile north of the site.

2.2.2 TOPOGRAPHY

In southcentral and southeastern Pasco County, which includes the Phase IA site, the land surface is gently rolling with smoothly rounded hills and shallow, swampy depressions. The site contains a number of small



Base Map for the Phase 1A Test Site

FIGURE 2-2

cypress head and marsh-type wetlands. Most of the drier areas have been cleared for pasture. The average elevation in the vicinity of the site is about 65 feet above msl and the average slope of the land surface is 3 percent. The site is leased for cattle ranching, a common occupation throughout the presently sparsely populated region.

2.2.3 SURFACE HYDROLOGY

The headwaters of Trout Creek are just east of U.S. Highway I-75 and south of State Highway 52. Trout Creek flows under I-75 about 1,200 feet to the south of the site and then generally southward to the Hillsborough River. The channel slope ranges from about 10 feet per mile in the headwaters to less than 5 feet per mile near the mouth of the creek. The streamflow averaged about 20.4 cubic feet per second (cfs) (13.2 million gallons per day (mgd)) between 1975 and 1983 with periods of no flow most years at station 02303350 at the bridge on SR 581 (Mycyk et al., 1985).

The primary surface water features in the vicinity of the test site are wetlands which include swamps and marshes, several borrow pits and Trout Creek. The rather extensive Cabbage swamp is located south and to the west of the test site. These hydrologic features interact with the subsurface hydrogeologic regime in unique ways. For example, in the swamps and marshes, the surface water levels are close to the local water table elevation, although after rainfall events, the swamp and marsh water levels rise in proportion to their drainage area. The surface water level in the borrow pits tend to be a direct reflection of the water table elevation.

Due to the highly permeable nature of the upper zone of the soils at the site, most of the precipitation infiltrates into the ground. Where surface materials are thin and there is a low percentage of clay, drain sinks (ponding) may form in local depressions. Drain sinks may act as principal points of entry for large quantities of water into the aquifer in short periods of time.

3.0 HYDROGEOLOGY

3.1 REGIONAL HYDROGEOLOGY

3.1.1 GEOLOGY

The regional geology is described starting with the most recent deposits at the surface and then descending in depth with increasing age.

Recent and Pleistocene Deposits

At the surface in southcentral Pasco County, undifferentiated deposits of quartz sand, with varying amounts of clay and silt, form a 3 to 40 foot thick veneer. These sediments form the surficial aquifer system which is located above the confining unit and the limestone of the Floridan aquifer (see Table 3-1).

Major low sea-level stands occurred during the glacial stages of the Pleistocene Epoch. During each low stand, the shoreline receded further seaward and erosion, subterranean solution, and widespread sinkhole development in the carbonate (limestone and dolostone) rocks became prevalent. After each period of low sea level, there were associated higher sea stand periods of reworking and/or deposition of sand and clay.

Miocene Epoch Deposits

During the Middle Miocene Epoch, the sea covered most of peninsular Florida, with the exception of the Ocala Uplift area, and deposited clastic (clay and sand) and carbonate sediments along with the abundant phosphate of the Hawthorn Formation. The diverse composition of the Hawthorn sediments reflects depositional environments that include open marine and shallow coastal marine environs (Sinclair et al., 1985). Remnants of the Hawthorn Formation are present in parts of southern Pasco County and northern Hillsborough County as a thin eroded deposit.

Table 3-1 Hydrologeoloic Framework

[Modified from Wilson and Gerhart, 1982, table 1; Miller, in press, table 3]

System	Series	Stratigraphic unit	General lithology	Major lithologic unit	Hydrogeologic unit	Geologic process	Age estimates of boundaries, in million years[1]
Quaternary	Holocene Pleistocene	Surficial sand, terrace sand, phosphorite	Predominantly fine sand; interbedded clay, marl, shell, limestone, phosphorite.	Sand	Surficial aquifer	Fluctuations of sea level with consequent high water tables and deposition in low-lying areas alternating with low water tables and accelerated weathering of soluble rocks.	
Tertiary	Pliocene	Undifferentiated deposits[2]	Clayey and pebbly sand; clay, marl, shell, phosphatic.	Clastic deposits	INTERMEDIATE AQUIFER AND CONFINING UNITS: Confining bed		2
	Miocene	Hawthorn Formation	Dolomite, sand, clay, and limestone; silty, phosphatic.	Carbonate and clastic deposits	INTERMEDIATE AQUIFER AND CONFINING UNITS: Aquifer		5
		Tampa Limestone	Limestone, sandy, phosphatic, fossiliferous; sand and clay in lower part in some areas.	Carbonate and clastic deposits	INTERMEDIATE AQUIFER AND CONFINING UNITS: Aquifer		
	Oligocene	Suwannee Limestone	Limestone, sandy limestone, fossiliferous.	Carbonate deposits	Confining bed	Exposure and weathering Carbonate deposition Exposure and weathering	24 38
	Eocene	Ocala Limestone	Limestone, chalky, foraminiferal, dolomitic near bottom.	Carbonate deposits	Confining bed		
		Avon Park Formation	Limestone and hard brown dolomite; intergranular evaporite in lower part in some areas.	Carbonate deposits	FLORIDAN AQUIFER SYSTEM Upper Floridan aquifer	Carbonate deposition	
		Oldsmar Formation	Dolomite and limestone, containing intergranular gypsum in most areas.	Carbonate and evaporite deposits	Middle confining unit Lower Floridan aquifer		
	Paleocene	Cedar Keys Formation	Dolomite and limestone with beds of anhydrite.	Carbonate and evaporite deposits	Sub-Floridan confining unit	Exposure and weathering Carbonate deposition	55 63

[1] Geologic Times Chart, 1984.

[2] Includes all or parts of Caloosahatchee Marl, Bone Valley Formation, Alachua Formation, and Tamiami Formation.

At an earlier period of the Miocene Epoch, a shallow marine environment covered most, if not all, of western peninsular Florida and resulted in deposition of the Tampa Limestone. The Tampa Limestone consists of cream to yellow limestone with varying amounts of quartz grains and clay embedded in a carbonate matrix.

The formation is differentiated from the overlying Hawthorn Formation based on a decrease in, or absence of, phosphate grains and an increase in quartz grains within the limestone.

Oligocene Epoch Deposits

The Suwannee Limestone is a biogenic limestone composed predominantly of foraminiferal tests. Within the limestone, there are interbeds of quartz sandstone. Dolomite is common in the basal portion of the unit. The upper part of the formation may contain thin chert lenses and be highly fossiliferous.

The Suwanee Limestone is exposed locally in parts of Pasco County, and in the northeast corner of Hillsborough County (Sinclair et al., 1985).

Eocene Epoch Deposits

The Ocala Limestone Formation is a shallow marine limestone composed of large foraminiferal tests, mollusks, and large echinoids. Lithologically, it is a soft-to-hard, highly fossiliferous limestone that contains minor amounts of dolostone. The formation overlies the Avon Park Formation.

The Avon Park Formation is composed of fossiliferous limestone and dolostone. The limestone or dolostone varies from a moderate brown, dark yellow-brown to dusky yellow-brown color, is very-fine to medium-grained, porous to nonporous and may be crystalline or saccharoidal in texture. The formation is very permeable and cavernous where extensive fracturing and dissolution have occurred. The former Lake City Limestone formation is now included as the lower part of the Avon Park Formation (Miller, 1984). The presence of anhydrite or gypsum-filled voids in the lower part of the formation results in a highly mineralized (high sulfate) water and low permeability zone.

3.1.2 AQUIFER SYSTEM

The aquifers in southcentral Pasco County are the surficial (shallow) aquifer and the Floridan aquifer. These aquifers supply almost the entire potable water supply for the Tampa Bay area. The most productive aquifer by far is the Floridan aquifer.

Surficial Aquifer

The groundwater in the surficial deposits is under nonartesian (unconfined) conditions. The upper surface of the groundwater (shallow water table) is free to rise and fall according to input and withdrawal of water from the system. The clay beds generally found at the base of the surficial aquifer are relatively impermeable and, therefore, groundwater flow is primarily lateral toward discharge areas. The water table surface generally follows the contours of the ground surface in a subdued manner, being at a greater depth beneath high areas and may be near or meet the surface in valleys and low lying areas to form seeps or springs. The depth to the water table is usually near the land surface (varying from the surface to more than 10 feet deep). The depth to the water table exhibits seasonal variations with the lowest water levels occurring at the end of the dry season (i.e., April-May) and the highest at the end of the rainy season (September-October). The range of fluctuation in the water table usually averages 3 to 5 feet between dry and wet seasons.

The surficial aquifer is replenished primarily by local precipitation. Some upward leakage from the Floridan aquifer recharges locally whenever the Floridan aquifer potentiometric surface is higher than the water table.

The surficial aquifer discharges by evapotranspiration, leakage to the Floridan aquifer (when the water table is higher than the potentiometric surface of the Floridan aquifer) and/or subsurface flow into surrounding wetlands, ditches, lakes or streams. The surficial aquifer generally yields less than 20 gallons per minute (gpm) to wells and is relatively unused for water supply.

In many areas, the surficial aquifer is slightly acidic and contains an excessive, objectionable amount of iron which can stain clothes, fixtures and utensils. In terms of available potable water supply for Pasco County, an important function of the surficial aquifer is to store water of which a portion recharges the Floridan aquifer.

Floridan Aquifer

The height to which water will rise in an artesian (confined) aquifer is called the artesian pressure head, piezometric surface or potentiometric surface. The potentiometric surface head in the artesian aquifer is controlled in part by the water level in the recharge area.

The artesian Floridan aquifer is the principal water bearing aquifer in the westcentral Gulf area. The Floridan aquifer is confined in many areas by relatively impermeable layers of dolostone with gypsum and anhydrite at the base and by overlying deposits of clay and sandy clay.

The Phase IA site is south of the large potentiometric surface high (recharge area) in the Floridan aquifer in central and east central Pasco County. The potentiometric surface slopes generally southward toward discharge areas in the vicinity of the Hillsborough River. Groundwater flow in the highly transmissive Floridan aquifer is primarily through solution enlarged joints and fractures.

Throughout most of westcentral Florida, the Floridan aquifer system consists of two aquifers; the Upper Floridan aquifer which contains freshwater (except along the coast) and the Lower Floridan aquifer which generally contains connate saltwater. The two units are separated by confining beds that prevent the contamination of the upper Floridan aquifer by upward movement of connate water.

The base of the Upper Floridan aquifer in west-central Florida is generally placed at the first occurrence of vertically persistent, intergranular evaporites in the Avon Park Formation.

In the region, the Upper Floridan aquifer generally has a pronounced vertical anisotropy (Ryder, 1982). Permeabilities are lower in the Ocala Limestone in general as compared to very high permeabilities found in fractured and solution-riddled dolomitic zones within the Avon Park Formation, as substantiated by flow-meter and specific-capacity tests by Wolansky et al., (1980). Despite the large permeability contrasts, aquifer test results indicate that enough vertical interconnection exists between each zone to analyze the Upper Floridan aquifer as a single hydrologic unit on a regional basis (Ryder, 1985).

3.1.3 GROUNDWATER QUALITY

The chemical quality of ground and surface water is generally good throughout the Middle Gulf hydrologic system according to Cherry et al., (1970). Total dissolved solids is generally less than 500 milligrams per liter (mg/l) in the groundwater and 20 mg/l in the surface water. The water within the shallow aquifer has components, such as iron, that can make the water undesirable for use as discussed earlier. Near the coast, the chemical concentrations of sulfates and chlorides in the Floridan aquifer sometimes exceed the Secondary Drinking Water Standards (Chapter 17-3 F.A.C.).

Water quality data from within southcentral Pasco County indicate that the surficial aquifer and upper Floridan aquifer contain calcium bicarbonate type water that meets state water-quality standards for municipal supply (Florida Department of Environmental Regulation, 1982, p. 102). Geophysical logs from deeper zones within the Floridan aquifer show that water quality in the upper Floridan is of a uniform nature (Leggette, Brashears, and Graham, Inc. 1979). At a depth of approximately 900 to 1,000 feet below msl, near the contact with the middle confining unit (bottom of the Upper Floridan aquifer), water may become highly mineralized. The middle confining unit contains highly mineralized sodium chloride to sodium sulfate type water that is associated with intergranular evaporites within the lower part of the Avon Park Formation (Hutchinson, 1985).

3.2 SITE SPECIFIC HYDROGEOLOGY

3.2.1 GEOLOGY

Well completion reports obtained from SWFWMD for the immediate surrounding area, ROMP 85, the Cypress Creek Wellfield, and the Morris Bridge Wellfield were examined in order to plan the construction and anticipate casing depths for the test and observation wells for Phase IA. The well completion reports examined from wells within 1 mile of the Phase IA site indicate that the surficial aquifer lithology is highly variable with surface sands from 2 feet thick (Permit #405867-13) in SW 1/4 Section 14, T26S, R19E, to 31 feet thick (Permit #389807-13) in NW 1/4 Section 11, T26S, R19E. Below the surface sand is generally a sandy clay or clay zone above the limestone. Limestone was encountered at depths from 30 feet to 145 feet below land surface (bls) (Permit #406791) with most wells reporting "lime" or limestone at 30 to 60 feet bls.

Cuttings from the boreholes for all the Phase IA observation wells and the test/production well were closely monitored by CDM personnel during both mud rotary and reverse air drilling operations in order to determine casing depths and total borehole depth. The lithology from the cuttings is described in Appendix C. Dual sample cuttings were collected and saved in sample bags for each 10 feet or change of formation during mud rotary drilling and for each 5 feet during reverse air drilling. One set of samples was sent to SWFWMD and the other one was split between WCRWSA and CDM.

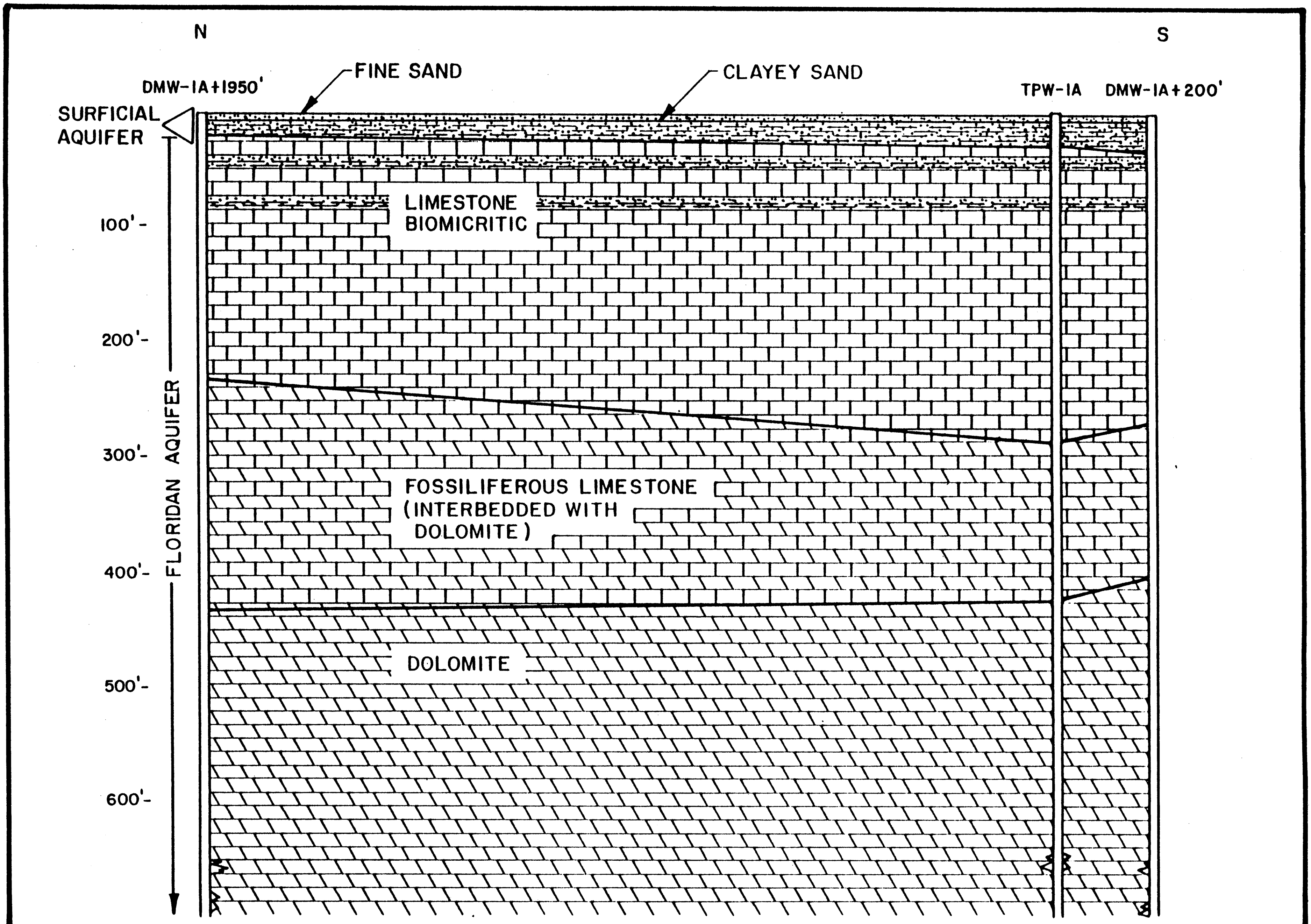


FIGURE 3-1 Lithologic Cross-section of Phase IA Site

Using information from the Phase IA site geologic logs, a lithologic cross section was prepared from DMW-IA+1950 through TPW-IA to DMW-IA+200 as shown in Figure 3-1.

Shallow borings by M.P. Brown and Associates at the Phase IA Site (see Appendix C) confirm the varied horizontal and vertical nature of the surficial sediments. The surficial fine to medium grained sand (2 to 18 feet thick) grades downward into slightly clayey to clayey sand. In most locations, a thin layer (0.5 to 8 feet thick) of a low permeability plastic, cohesive, waxey clay is located immediately above the first limestone which is located at a depth of 20 to 39 feet (M.P. Brown & Associates, August 1986).

3.2.2 AQUIFER SYSTEM

Surficial Aquifer

The water table is generally 2 to 4 feet below land surface except in the low areas where the surficial aquifer intersects the surface to form wetlands. Although the upper portion of the surfical aquifer is a permeable sand, the material quickly grades into a low permeability slightly clayey to clayey sand. Therefore, the surficial aquifer probably has a low storage coefficient and a low vertical permeability.

The surficial aquifer is rapidly recharged by local rainfall. During heavy rains numerous shallow depressions in the nearby pasture flooded to form recharge sinks. After the start of the rainy season (June 1986), a number of seeps or marshy areas were noticed near the base of the slopes, especially adjacent to the wetlands. During the dry period of the investigation (April-May), the water table in the vicinity of the test production well had retreated to 4-5 feet bls into the less permeable, slightly clayey sand.

The base of the surficial aquifer is above the waxey clay and/or the sandy clay found immediately above the first limestone unit. These clays act as the confining unit for the Floridan aquifer. A permeability test conducted on a Shelby tube sample of the plastic, waxy clay found in most areas immediately above the first limestone had a very low permeability estimated to be less than $1x10^{-8}$ cm/sec ($2.8x10^{-5}$ ft/day) (Appendix C, Geologic Logs).

Floridan Aquifer

The Floridan aquifer is located in the thick sequence of limestone and dolostone beginning at a depth of approximately 30 feet bls to below the bottom of the deep wells at 700 feet bls. Wolansky and Garbade (1981) place the total thickness of the Floridan aquifer at approximately 950 feet in the vicinity of the Phase IA site.

During the dry period (April-May) of the investigation, the potentiometric surface of Floridan aquifer was nearly the same elevation or slightly above the water table at the deep monitor well located 200 feet from the test production well. In the low lying wetlands, including Cabbage Swamp, the potentiometric surface is probably above the water table at times during the year, allowing upward leakage (recharge) to the surficial aquifer. At the start of the wet season in June, the water table level in the SMW-IA+500 quickly increased to above the Floridan potentiometric surface. Information on the response of the Floridan aquifer to rainfall recharge of the surficial aquifer is found in Section 6.3.1.

3.2.3 WATER QUALITY

Water quality samples were obtained and evaluated a number of times during the drilling and aquifer performance testing. Field conductivity and temperature of the borehole water were taken at each change of drilling rod (30 feet) during reverse air drilling. There was no significant change in field conductivity readings with depth or between wells. The field readings were consistent with laboratory conductivity readings. Laboratory conductivity results ranged from 120 to 350 micromhos per centimeter (mmhos/cm). Water quality samples were collected by WCRWSA personnel during the APT and analyzed for primary and secondary drinking water standards as established by EPA and Florida Administrative Code, Chapter 17-22. The test results indicate that water from the Floridan aquifer at the test site meets the established drinking water standards. The testing and sampling procedures and analyses are further discussed in Section 4.4. The water quality test results are included as Appendix I.

3.3 BOREHOLE GEOPHYSICS

3.3.1 SITE SPECIFIC

Geophysical well logging (borehole geophysics) involves lowering an electronic sensing device into a borehole to record and/or measure various physical parameters. The information is interpreted as characteristics of the rocks, fluid contained within the rocks, and/or how the well was constructed. Geophysical logs provide the only practical measurement of the undisturbed subsurface sediments and fluids.

Geophysical logs were run in each of the deep observation wells and the test production well for Phase IA. The geophysical logs that were performed in this logging program were:

a. Caliper
b. Spontaneous potential
c. Single point, long and short normal resistivity
d. Temperature
   1. Static
   3. Pumping
e. Flowmeter
   1. Static
   2. Pumping
f. Fluid resistivity
   1. Static
   2. Pumping
g. Gamma Ray

The geophysical logs obtained were compared with other logs from the well site, logs of the other wells, and the lithologic logs to obtain semi-quantitative information on such parameters as permeability (indirectly), porosity, formation resistivity, pore water quality, magnitude and direction of fluid flow, and indication of the source of the groundwater. Although none of these characteristics of the formation and groundwater is measured directly by any particular log, strong inferences are provided which can be interpreted in conjunction with the lithologic logs and knowledge of the local geology. Copies of all the logs are included in Appendix D.

All of the wells showed very similar geophysical logs. The following sections present a summary of the interpretations of the logs emphasizing the similarities and significant differences.

Caliper Log

The caliper log measures the average diameter of the casing or borehole. The diameter of the borehole provides information on the type of lithology and consolidation (induration) of the formations. This tool is useful in the determination of washed-out (increased borehole diameter) zones, cavities, and for locating defects inside the casing. The caliper log can also be used to a limited degree for stratigraphic correlation. Caliper logs were also used to correct for changes in borehole diameter which directly affect some logs, such as short and normal electric and fluid velocity logs.

The caliper logs from all the wells indicated that there was no misalignment of the casings or bad welds within the casings. All of the logs show a typical washed-out area at the end of the casing, which may be either from the overdrilling of the larger diameter hole into which the casing was placed or the comparatively soft limestone material. Thin streaks (peaks) in the log plot indicate softer zones that were washed out.

The caliper logs of all the deep wells show the same general configurations and depths of washed-out areas. The test production well description is representative of the zones in all of the wells although it shows an exaggerated plot due to the larger diameter of the borehole and increased relative diameter in the washed-out zones.

The test production well has washed-out areas to nearly 40 inches in diameter within the sandy textured limestone found at a depth from 180 to 200 feet with a 32-inch diameter at 280 to 322 feet within fossiliferous limestone, and irregular washed out streaks in excess of 40 inches diameter at 322 to 348 feet within a soft foraminiferal coquina zone.

The borehole approaches near bit gage (diameter) in the hard fractured dolostone at 512 feet in DMW-IA+1950, 510 feet in DMW-IA+500, 520 feet in DMW-IA+200, and 518 feet in TPW-IA to the bottom of the boreholes.

The TPW-IA caliper plot shows the largest number of cavities and solution zones including occurences at 546-551, 623-630, and 633-642 foot depths in the hard, fractured dolostone zone. It should be noted that the caliper logs detect only horizontal cavities or fractures, and many vertical fractures are usually found in this dolostone zone.

The observation well at the 200 foot distance from TPW-IA shows a larger number of cavities or fracture zones within the dolostone than does DMW-IA+500. The DMW-IA+1950 plot shows the fewest fractures on the caliper log.

Electric Logs

The electric logs are part of a series of logs divided into two major components, resistivity and spontaneous potential (S.P.). The electric resisitivity of a rock (resistance per unit volume) depends primarily on the amount of fluid it contains and its electric conductivity. The amount of fluid contained within the rock is a function of the porosity of the rock. The three subtypes of resistivity logs are the long (64 inch) and short (16 inch) normal, and single-point. The difference of the logs is the spacing of the electrical current generating device and the receiver, with large spacing allowing the transmission of the signal further into the rock and eliminating drilling fluid interference. The electric logs are sensitive to borehole diameter. The single-point log was not performed on DMW-1A+500, but was performed on the other wells.

The single point resistivity log has a very limited depth of investigation and, furthermore, does not make its measurement on a fixed volume of rock. It can be used for determining formation contacts and for ascertaining qualitatively that resistivities are relatively high or low with respect to one another.

The spontaneous potential (S.P.) logs are records of the potential small electrical current (voltage) generated at the boundaries of dissimilar units of rock, especially between permeable and less permeable units. The movement to the right or left of the "shale line" indicates the permeability of the rocks as well as the salinity of the water. This type of log is also useful in stratigraphic correlation.

Because the well boreholes below the casings were drilled by reverse air, the resistivity of the borehole fluid (water) and the formation water are approximately equal, creating small S.P. deflections with a lack of detail when compared with those from mud rotary drilled wells.

The single point, long and short normal electric logs cannot be run inside the casing, therefore the first 130 to 150 feet of the logged depth are not interpreted. The single point resistivity logs are very similar for TPW-IA, DMW-IA+200 and DMW-IA+1950, although the response is suppressed for TPW-IA because of the greater distance from the probe to the borehole wall. The response is greatly affected by the irregular diameter of the wells. There is a strong decrease in resistance (negative spike) near the contact between the limestone and first dolostone layer in DMW-IA+200 which may reflect a high permeability zone or peat layer. There are similar responses for the other wells within the same zone.

From about 520 feet to the bottom of the wells, the single point log shows a strong cyclic response, typical of the fractured dolostone zone with high resistivity of the low permeability dolostone and much lower resistivity in the water filled cavities and fractures.

The short and normal electric logs show some resistivity from the bottom of the casing to a depth of between 240 feet to 260 feet indicating low porosity zones. From 240 feet to the 360 feet bls depth, the apparent resistivity is low, probably due to the washed out zone and the greater porosity of the foramiferal coquina. From about 360 to 420 feet bls, there are indications of some porous zones in the lithologic unit. From a depth of 420 to approximately 510 feet bls, again the logs indicate low resisitivity and a relatively porous formation.

The S.P. logs from 150 to 500 feet bls show virtually no change, indicating that there are no sharp bedding plane contacts of different electrical potential, which indicates a uniformity in the lithology. Starting at 500 feet bls. the resistivity and the S.P. Logs show a typical dense, fractured dolostone series with little interstitial porosity. This series extends to the bottom of the borehole.

Natural Gamma Ray

The gamma ray log records natural gamma radiation emitted from formations adjacent to the borehole. The gamma radiation detected is primarily from the radioactive decay of naturally occurring isotopes; potassium 40, and daughter products in the uranium and thorium decay series. The gamma radiation is measured in counts per second (cps). Slight changes in the depositional environment or sediment source can greatly influence the amount of radioactive isotope concentration. The gamma ray log can be run through cased holes. The gamma ray log can be used also in regional stratigraphic correlation.

A slightly elevated gamma count at 24 to 28 foot depth at DMW-IA+1950 probably indicates a clay layer. The gamma radiation cps are slightly attenuated at TPW-IA because of the greater distance (radius) from the probe to the borehole wall.

The highest cps peaks for the gamma ray logs were recorded at about the same depth below land surface. The highest peak was at 188 feet for DMW-IA+500, 168 to 173 feet for DMW-IA+200 (over 100 cps), and 177 feet (90 cps) for TPW-IA (soft to medium limestone with shell fragments). A broader peak between 150 and 164 feet depth (50 cps) was recorded at DMW-IA+1950 in a similar limestone.

Each well also has similar depth gamma ray peaks recorded at greater depths. There is a double peak at the 380 and 384 foot depth (30 cps) in DMW-IA+500, a broad peak between 390 and 410 foot depth (30 cps) in DMW-IA+200, two peaks at 378 foot (30 cps) and 385 foot (25 cps) depth at DMW-IA+1950, and a peak between 393 to 409 foot depth (20 cps) in TPW-IA. There is a strong gamma ray peak of 70 cps found at 426 feet depth bls in TPW-IA and 68 cps at a comparable depth of 424 feet in DMW-IA+200, but this peak is not found in the other two wells.

Fluid Conductivity Logs

A fluid conductivity probe measures the conductivity (reciprocal of resistivity) of the borehole fluid passing through electrodes inside the probe. This is the most direct method for measuring water/fluid conductivity. The main purpose is to find zones of major fluid character changes and to eliminate the properties of the rock itself found in the electric resistivity logs.

The conductivity logs for all the wells under static conditions indicate borehole water with conductivity of approximately 250 mmhos/cm within and immediately below the casing. This relatively low value indicates that any drilling fluid in this zone has been flushed out and ionic concentration (e.g., chlorides) are low. There is a very slight increase in conductivity with depth to approximately 275-290 mmhos/cm, below which conductivity stabilizes. Under pumping conditions, essentially a straight line of about 275 mmhos/cm is produced, indicating that most of the water is produced from the lower part of the wells. There appears to be no water quality degradation with depth in any of the wells as measured by fluid conductivity values.

Temperature Log

The temperature log measures the temperature of the fluid in the borehole and/or the casing. The temperature log can be used to detect flow zones and temperature gradients. Thick homogeneous formations exhibit a distinct geothermal gradient that is a function of the formation minerology, porosity, and groundwater circulation.

Under static conditions, the temperature increased with depth below the bottom of the casing. The lowest temperature profile recorded for a well was at DMW-IA+200 where the temperature increased from 73.3°F near the bottom of the casing to 76.0°F at the bottom of the well. The TPW-IA temperature gradient was from 76.1°F to 76.7°F at the bottom of the well, DMW-IA+500 temperature gradient was from 75.4°F to 76.7°F, and DMW-IA+1950 was warmest with a temperature gradient from 76.3°F to 77.0°F. The charts show a slight increase in the temperature gradient within the dolostone below the 500 foot depth.

The temperature logs that were made under pumping conditions all indicate a further increase in water temperature at the bottom of the wells, possibly indicating that warmer water from a greater depth was entering the wells.

Fluid Velocity Logs

Mechanical flowmeters directly measure vertical flow within boreholes. Quantitative results require the borehole to be uniform in diameter or adjustments have to be made to the velocity based on data from the caliper log, using the formula $Q=1/4d^2V$ where:

Q = flow in counts per second (cps)

d = diameter

V = velocity (cps)

The fluid velocity log under pumping conditions was used to infer quantity (percentage) contributed from specific producing zones. The fluid velocity log under static water conditions was used to determine if there was circulation (water flowing in and going out) between different zones.

The "noise" recorded as small jagged peaks on the static and pumping flowmeter logs makes them difficult to interpret. The noise is probably due to the probe scraping along or snagging on the jagged borehole walls.

No large volume flow interchange between different zones in the Floridan aquifer was detected in any of the wells. There may be some flow at DMW-IA+500 between zones below 580 feet and in the vicinity of 400 feet. There may also be limited flow between zones below 640 feet and the 370 feet level in TPW-IA.

Pumping flowmeter logs indicate that over 90 percent of the flow in all of the wells is from the fractured dolostone found below approximately 520 feet and approximately 80 percent of the flow is from fractured and cavernous zones below 600 feet. The strongest flow zones appear to be from near the bottom of the wells (700 feet) to approximately 660 feet except at the TPW-IA where the strongest flow on the log plot is in a cavernous zone between the 614 - 636 foot depth.

Summary of Geophysical Logs

The geophysical logs indicate good well casing and borehole construction. The logs also reflect a typical West Coast Floridan aquifer lithology consisting of approximately 30 feet of unconsolidated surface sand and clay, limestone becoming more dolomitic with depth to approximately 500 feet, and dense, fractured dolostone from that depth to bottom of the boreholes. Approximately 80 percent of the flow is from the fractured dolostone and cavernous zones below 600 feet. The conductivity under pumping conditions was approximately 275 mmhos/cm and the static logs indicated good water quality with no significant change with depth.

4.0 WELL DESIGN AND CONSTRUCTION

Information on each of the wells including identification code, diameter of casing, depth of casing, depth of borehole, drilling method used, development time, as well as start of construction and completion date is listed in Table 4-1. A well location map is shown on Figure 4-1.

4.1 TEST PRODUCTION WELL

A 22-inch diameter borehole was drilled without a pilot hole because there were sufficient data available to indicate that favorable water producing characteristics of the Avon Park are reliably encountered in the area. In addition, the presence of a favorable production zone at the Phase IA site was indicated by the geophysical logging of DMW-IA+500.

In general terms, construction of the test production well consisted of vibrating a 32-inch diameter steel surface casing to the first limestone at an approximate depth of 30 feet bls. Then a 30-inch diameter hole was drilled into competent limestone (a depth of approximately 130 feet) using the conventional mud rotary method. Casing was then installed and the annulus sealed with cement grout. Finally, a 22-inch diameter open borehole was drilled to a depth of 715 feet bls using the reverse air method (see Figure 4-2).

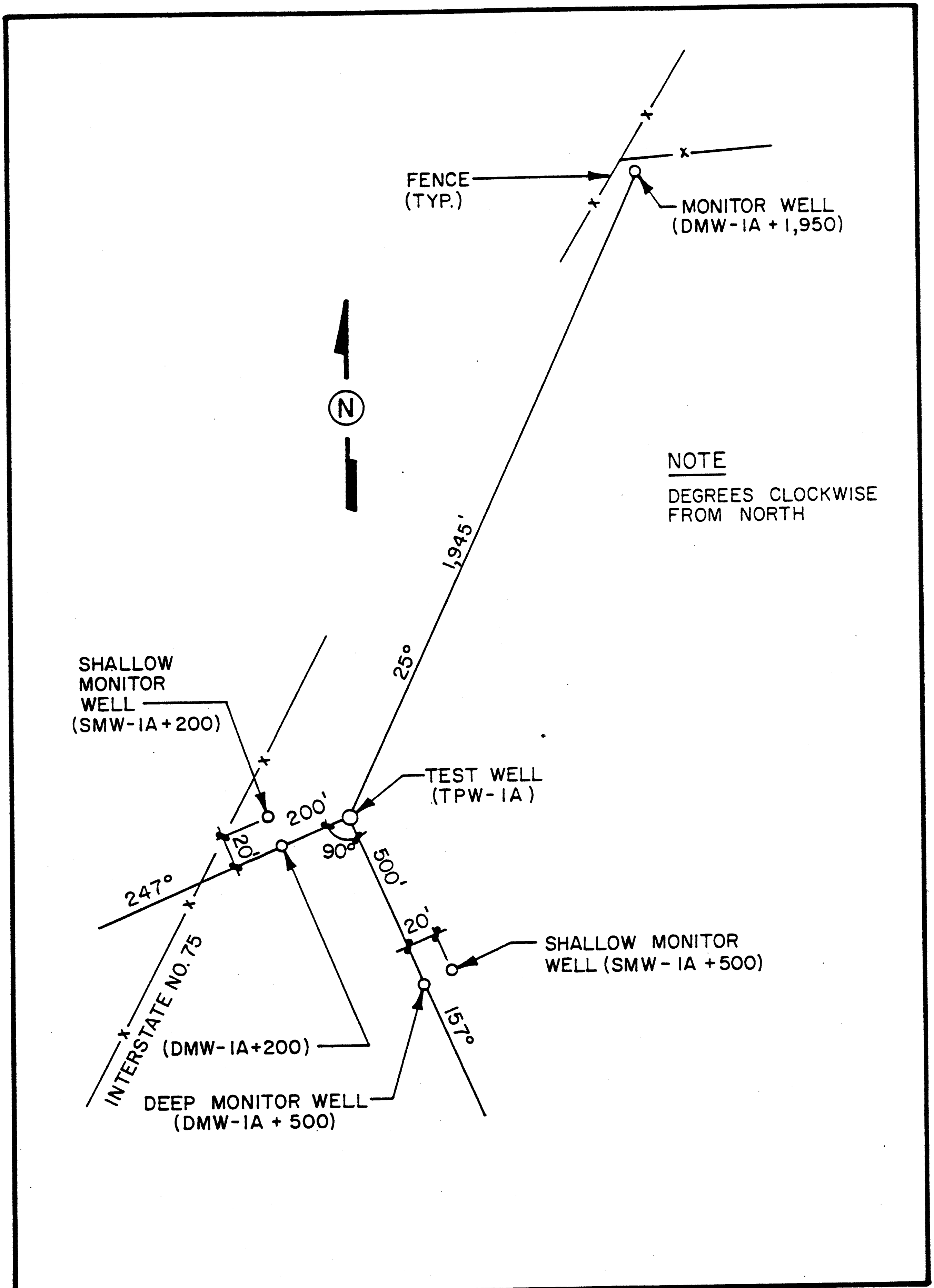
4.2 DEEP MONITOR WELLS

Three deep monitor wells were installed at the Phase IA site in order to monitor water level changes within the Floridan aquifer. The wells are positioned at 500 feet, 200 feet, and approximately 1,950 feet from the test production well. Deep monitor wells DMW-IA+500 and DMW-IA+200 are located to form a right angle to the test production well. The relative locations of the wells are shown in Figure 4-1.

General construction methods for the deep monitor wells involved first setting 16-inch diameter temporary (surface) casing to a depth of approximately 30 feet where limestone was encountered. Then a 15 3/4-inch

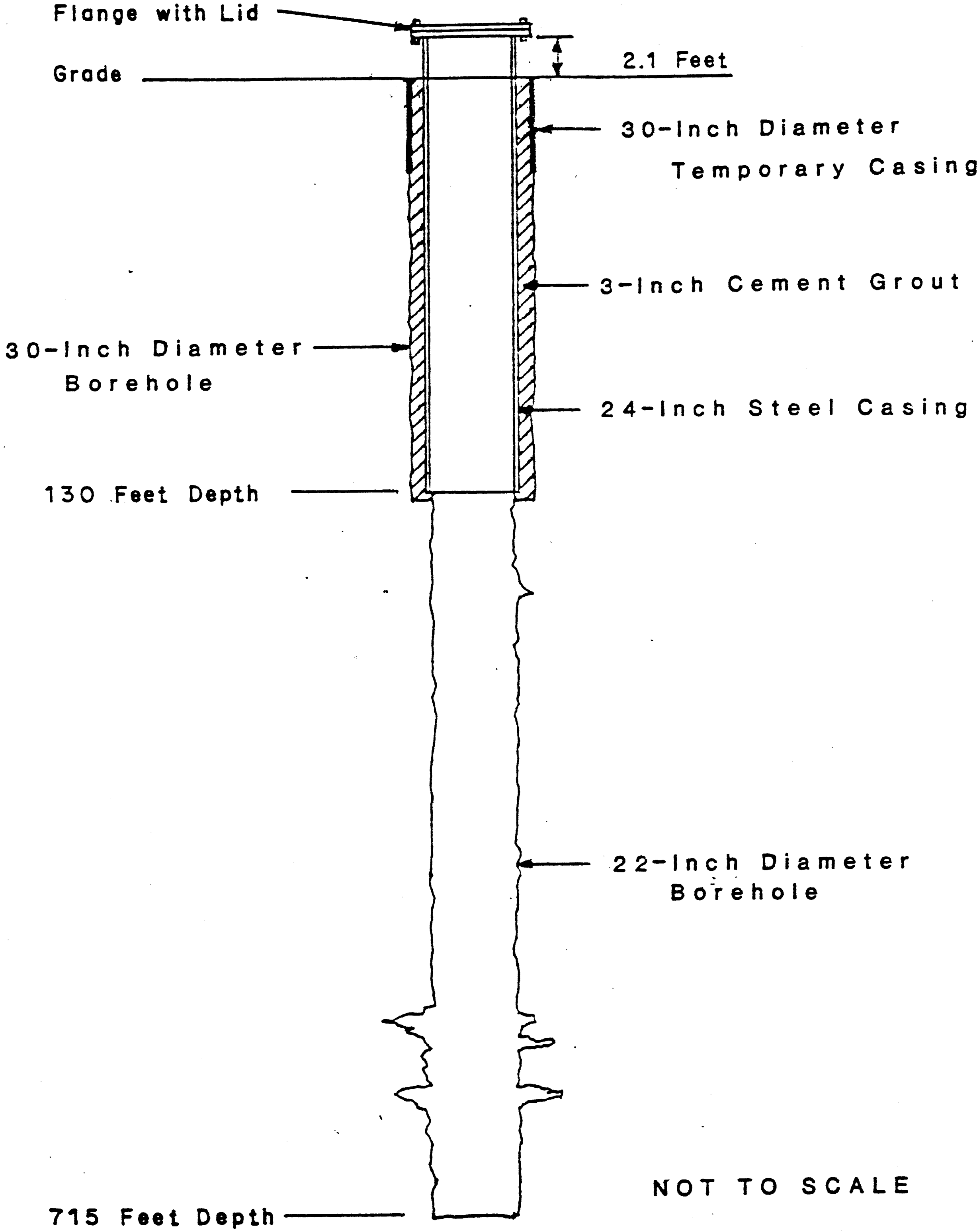
Table 4-1
Well Construction Information

Well No.	Diameter	Depth Casing	Depth Borehole	Drilling Methods	Development Time	Start/Completion Dates
DMW-IA+500	8"	150'	705'	0'-151' - Mud Rotary 151'-705' - Reverse Air	18 hrs.	3-11-86/5-7-86
DMW-IA+200	8"	130'	704'	0'-131' - Mud Rotary 131'-704' - Reverse Air	16 hrs.	4-9-86/4-18-86
TPW-IA	24"	130'	715'	0'-131' - Mud Rotary 131'-715' - Reverse Air	65 hrs.	4-9-86/5-12-86
DMWIA+1950	8"	130'	706'	0-131' - Mud Rotary 131'-706' - Reverse Air	14.5 hrs.	5-19-86/5-26-86
SMW-IA+500	4"	15'	20'	Wash out	2 hrs.	5-9-86/5-13-86
SMW-IA+200	4"	15'	20'	Wash out	3 hrs.	5-9-86/5-10-86



Site 1A Location Map Showing Distances and Directions of Wells FIGURE 4-1

TEST PRODUCTION WELL
AS-BUILT



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Test Production Well Construction

FIGURE 4-2

diameter borehole was drilled to approximately 131 feet bls using the mud rotary method. An 8-inch diameter steel casing was then installed to a depth of 130 feet bls and the annulus surrounding the casing was grouted to the surface with neat cement. Finally, a 7-7/8-inch diameter hole was drilled to approximately 700 feet bls using reverse air methods. The only significant deviation from this procedure is in the case of DMW-IA+500. DMW-IA+500 was the first well drilled and it was cased to a depth of 150 feet bls instead of 130 feet bls. It was decided at this time that the formation was sufficiently stable so that only 130 feet of casing was required for the remaining wells (see Figure 4-3).

Upon completion of each deep monitor well, a Stevens Type F water level recorder was installed. Water level recorders were used to record drawdowns during the step-drawdown test and continuous performance test. In addition, they were used to collect baseline water level information which allowed for corrections to water levels due to regional potentiometric level changes, as well as for significant rainfall events.

4.3 SHALLOW MONITOR WELLS

Shallow monitor wells were installed 20 feet from DMW-IA+200 and DMW-IA+500, respectively, in order to monitor the water level changes in the surficial (water table) aquifer during the APT.

Construction of the shallow monitor wells involved washing out surface material to a depth of approximately 20 feet bls inside of 10-inch temporary surface casings. The surface casings were pulled and 4-inch diameter PVC pipe with 5 feet of .010 slot screen was installed in the hole. A gravel pack was placed around the well screen to a depth of 13 feet bls followed by a sand cap to 11 feet bls. The well annulus was grouted to the surface with neat cement (Figure 4-4) and the monitor wells were developed (Table 4-1).

TYPICAL DEEP OBSERVATION WELL CONSTRUCTION

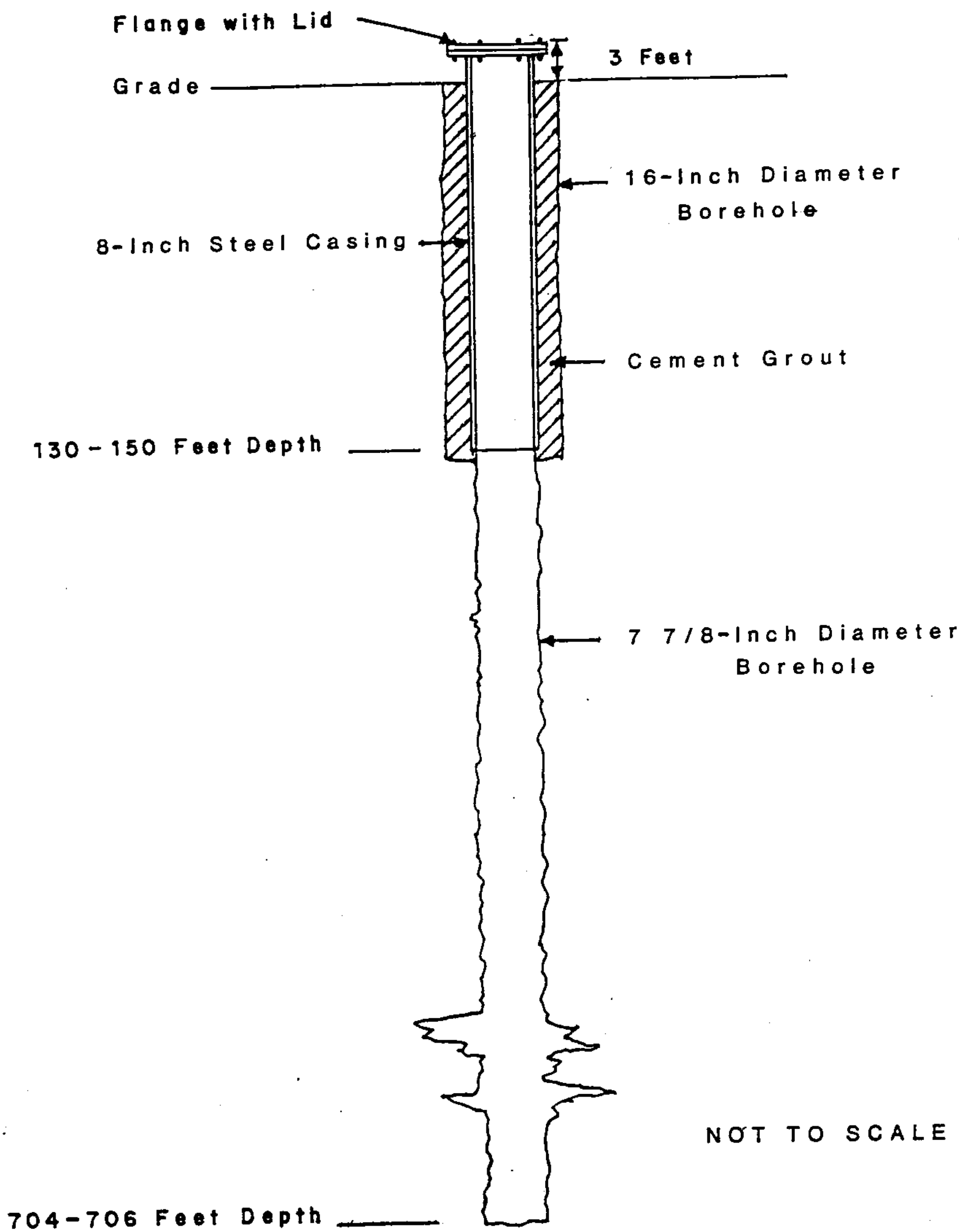

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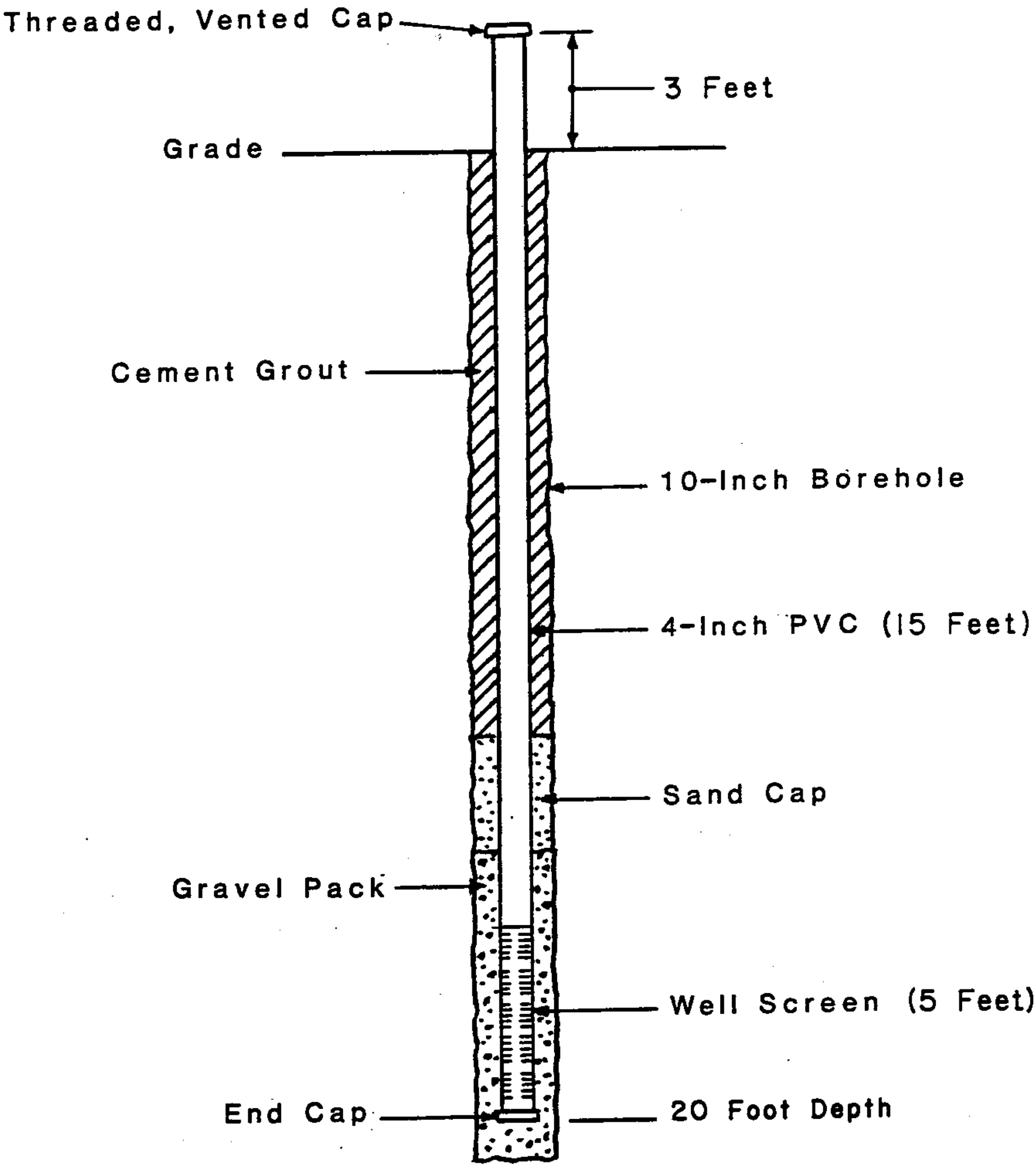
FIGURE 4-3

Typical Deep Monitor Well Construction

TYPICAL SHALLOW MONITOR WELL CONSTRUCTION



NOT TO SCALE

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Typical Shallow Monitor Well Construction FIGURE 4-4

Stevens Type F water level recorders were installed on the shallow monitor wells. Because the 4" PVC casings used for the shallow monitor wells could not accommodate both the float and the counter weight used for the Stevens recorders, 2-inch diameter dry wells were installed adjacent to the shallow monitor wells to a depth of approximately 5 feet bls.

4.4 WELL SAMPLING PROCEDURE

During drilling of the test production well and the deep monitor wells, formation cuttings were examined and described and water quality samples were taken by CDM hydrogeologists. While using the mud rotary method, cuttings were sampled every 10 feet or every formation change (whichever came first). After changing to reverse air drilling, sample cuttings were taken every 5 feet or every formation change.

Water samples were collected only during reverse air drilling. Water samples were collected every 90 feet (every third drill stem change) and taken to the Authority laboratory at Cypress Creek Wellfield for analysis. Temperature and electrical conductivity of the formation waters from the bottom of the borehole were measured at the site every 30 feet (change of drill stem). Water quality samples were not taken during drilling at DMW-IA+500.

Water quality samples were taken by WCRWSA personnel at 73 hours into the APT and at 143 hours, shortly before the end of the APT, and analyzed for primary and secondary drinking water standards in accordance with F.A.C., Chapter 17-22.

4.5 EQUIPMENT USED

Equipment used at the Phase IA site included a Gardner-Denver drilling rig, a Failing 2500 drilling rig, a bulldozer, a backhoe, a low-boy trailer, several pick-up trucks, air compressors and steel mud pits. Steel-lined mud pits were used during all well drilling to prevent bacterial contamination of the groundwater.

5.0 TEST PROCEDURES

Two separate pump tests were performed at the Phase IA Site. The initial test was a step-drawdown test used to determine the well performance (efficiency) of the test production well. An aquifer performance test was used to determine the aquifer properties in the vicinity of the wells. Water quality characteristics of the groundwater were also determined during the APT. Appendix B contains a chronological log of field related events, including the dates when the two tests started and ended, as well as additional project milestones.

5.1 WELL SITE PLAN

The well layout plan was described in Section 4 and Figure 4-1. Stevens Type F recorders were placed on each monitor well (deep and shallow) in order to record changes in water level before, during and after each phase of testing. A nonrecording rain gage was installed in an open area in the vicinity of TPW-IA. One week prior to the APT, a second nonrecording rain gage was placed in the vicinity of the third monitor well located approximately 1,950 feet from the test well. The second rain gage was to observe the local variability in rainfall amount due to convection type thunderstorms.

Also, prior to the APT, 3 staff gages were placed in wetland locations to monitor the water level changes (Figure 2-3). This procedure was intended to give additional insight on leakance from the surficial aquifer to the Floridan aquifer during the APT.

Prior to both the step-drawdown test and the APT, a turbine pump driven by a diesel engine was placed in the test production well. A 12-inch diameter discharge pipe with a 10-inch orifice plate and manometer at the discharge end transported the pumped water approximately 1,100 feet away from the test site to flow into Trout Creek. It was necessary to transport the discharge water away from the pumping well because any significant recharge near the test site could have affected test results.

5.2 STEP-DRAWDOWN TEST

The objective of performing a step-drawdown test is to obtain information about the performance and efficiency of the well being pumped. The result is usually reported in terms of observed drawdown, well yield, well loss and the calculated specific capacity. These data taken under controlled conditions give a measure of the capacity of the completed well and provide data on which the selection of pumping equipment can be based (Johnson UOP, 1975). The step-drawdown test was also used to observe the reactions of the observation wells prior to performing the APT.

The 12-inch discharge pipe was equipped with a recording totalizer gage, a gate valve, and at the discharge end, a 10-inch orifice plate and manometer. Prior to the test, throttle rates for the diesel were selected by setting the gate valve and adjusting the throttle until selected pump rates were obtained as observed at the manometer and totalizer gage.

Three stepped pumping rates were used for the test. Each step or pumping interval was followed by a period of recovery lasting an identical period of time. The initial step was at 1,040 gpm, second step at 1,920 gpm and the third step was at 3,740 gpm. Each step and associated recovery phase lasted 70 minutes. The entire test lasted approximately 6 hours. Results of the test are discussed in 6.1 and Appendix F.

During the test, water levels were taken at the test production well with the aid of an electric sounder (M-Scope). The M-Scope probe was lowered into the test production well through a 1-inch nominal diameter PVC pipe open at the bottom. The pipe was used to minimize the effects of turbulence from the pump so that accurate water level measurements could be obtained.

The time intervals used for M-Scope readings during the step-drawdown test were every 15 seconds for the first minute, every 30 seconds to 5 minutes, every minute to 10 minutes, every 2 minutes to 20 minutes and every 5 minutes to 70 minutes. The same procedure was used for each recovery phase. As an equipment test for the subsequent APT, Steven Type F recorders on the monitor wells were manually marked every 5 seconds for the first minute, every 10 seconds for the second minute every 15 seconds for the third minute, etc. during the test. The recorders were operated manually in order to accurately indicate the short time intervals on the charts.

5.3 AQUIFER PERFORMANCE TESTING

The APT consisted of pumping TPW-IA for a period of 6-days at a rate of 2,150 gpm and recording both the drawdown in that well and the drawdown caused by this pumping in the other monitor wells. The recorded drawdown was used to calculate aquifer properties. Recovery water level data were collected for 9-days after shutdown of the APT on a daily basis and the water level recorders were then adjusted for monthly recording.

Prior to conducting the constant discharge APT, the test pump had to be set at the selected constant rate. This was accomplished in a short period of time by opening the gate valve half way, starting the pump and then simultaneously observing the manometer near the discharge end of the pipe and the totalizing meter installed near the pump. Since a yield of 2,150 gpm was desired and the discharge pipe was 12-inch with a 10-inch orifice plate, a manometer reading of 19 inches of water was required to be maintained during the test. The pumping rate was set with a manometer reading of 19.0-inches and the totalizing meter reading at 2,170 gpm.

Immediately prior to the APT, the Stevens recorder papers were changed and the recorders were again checked for malfunctions. Also, the discharge pipe was checked for leaks. During the hour before beginning the test, the water level was measured with the M-Scope and recorded every 15 minutes in the test production well.

A person was stationed at each water level recorder to manually mark the short time periods during the early part of the APT. Time intervals for recording drawdown data in the monitor wells were every 5 seconds for the first minute, every 10 seconds for the second minute, every 15 seconds for the third minute, etc. The time interval for recording drawdowns eventually increased to 2 hours and remained at this interval for the remainder of the test. Throughout the remainder of the APT, a hydrogeologist checked or recorded information from the recorders, staff gages, test production well, flow meter, and manometer every two hours. Recorders were set so that their pens would move a distance equivalent to the width of chart paper each day. After the chart papers were removed, drawdown data were taken from the charts and tabulated. The tabulated data were then plotted in the field on log-log and semi-log graph paper using the Cooper - Jacob straight line method, distance drawdown method and the Theis curve matching method. Near the end of the APT, each method indicated that the aquifer was stabilizing. Rain gages were also checked daily and barometric pressure data, tide tables and regional rainfall data were obtained from various sources (see Section 6.3). ROMP #85, a deep well near Zephyrhills (Figure 1-1), was used as a source of background data to indicate regional groundwater trends. Also, water samples were collected from the test well after 12 hours, and every 24 hours thereafter to be used for water quality analysis. Water quality parameters checked included chlorides, sulfates and total dissolved solids.

During the aquifer test, all pump test equipment performed properly. The manometer was constant at between 19.0 - 19.5 inches and the totalizer flow meter near the gate valve read between 2,140 and 2,150 gpm for the entire duration of the test. Also, there were no observations of large scale water withdrawals or spray irrigation applications within a 3 mile radius of the site during the test.

6.0 TEST ANALYSIS METHODS AND RESULTS

6.1 STEP-DRAWDOWN TEST

On May 17, 1986 a step-drawdown test was performed on the test production well as discussed in Section 5.3.

Analysis of the data indicated that the test production well is extremely stable, neither experiencing development nor clogging at the tested pumping rates. The well loss was calculated to be less than one foot at the designed pumping rate of 2,100 gpm. The results of the test data analysis are shown in Table 6-1 and the methodology is included in Appendix F.

6.2 FIELD OBSERVATIONS DURING THE APT

The APT was started on June 17, 1986 at 10:30 a.m. The pump was shut down 144 hours later to start the recovery phase of the APT. The drawdown data was extracted and reduced daily from the charts to form time and drawdown test data tables. After sufficient data was available, this uncorrected data was used to determine approximate transmissivity values and the delayed response between the shallow surficial and Floridan aquifers.

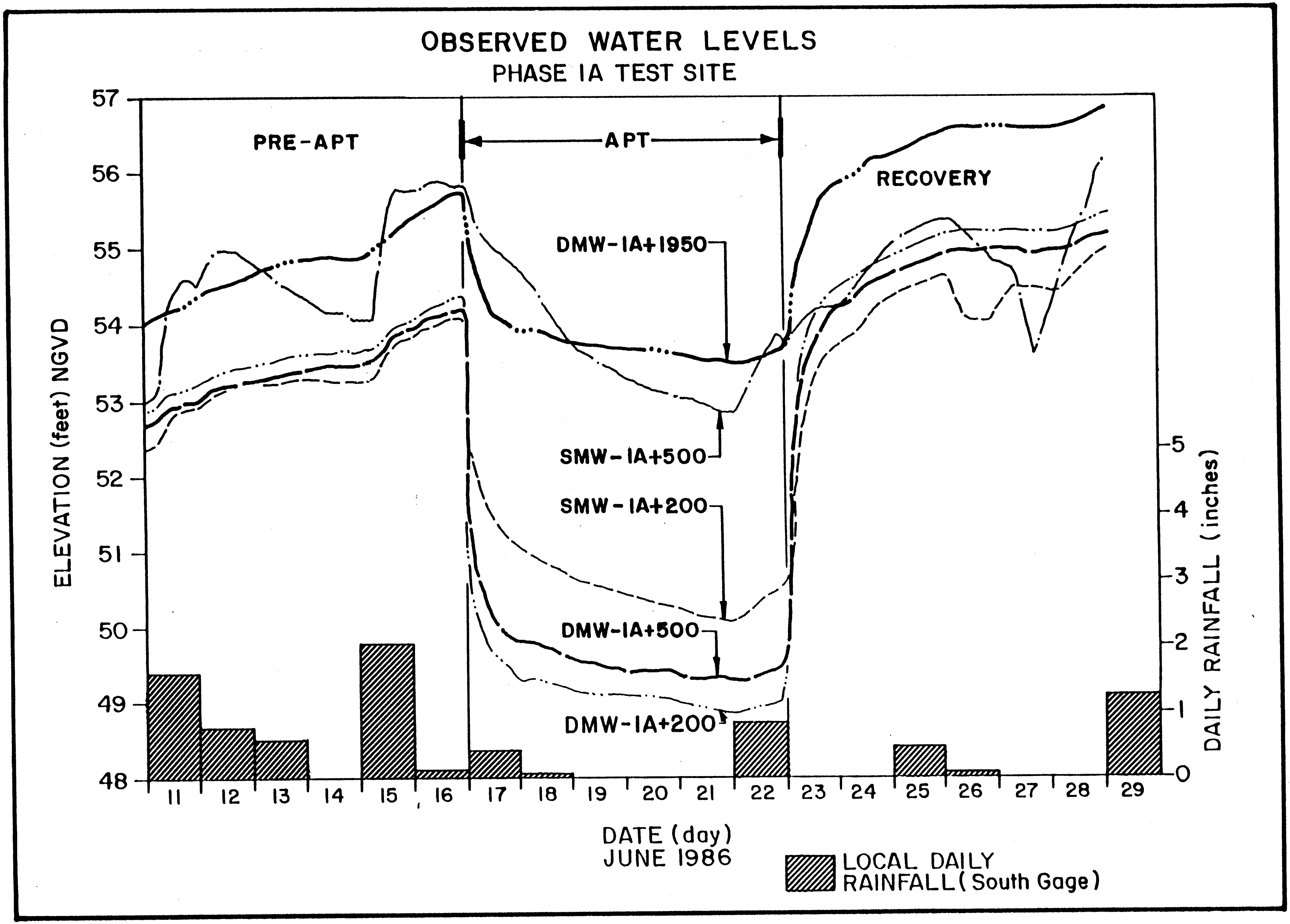
Observed groundwater level data at the Phase IA site wells for the period before, during, and after the APT is shown on Figure 6-1. The two shallow wells responded differently to local rainfall with SMW-IA+500 having a much greater response than SMW-IA+200. The rainfall caused a rapid rise of the water table at SMW-IA+500 above the Floridan aquifer potentiometric surface and the water table also declined rapidly, probably due to lateral drainage toward a depressional area to the north. The SMW-IA+500 also responded more slowly and to a lesser degree to the APT.

The water table at SMW-IA+200 was generally lower than the Floridan aquifer potentiometric surface before and after the APT, even after rain events. The water table closely paralleled the Floridan aquifer with slight declines between rain events that are indicative of evapotranspiration and/or lateral drainage in the surficial aquifer.

Table 6-1
Results of Step-Drawdown Test of TPW-1A

Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Well Loss (ft)
1,020	408	0.25
1,920	375	0.83
3,740	325	3.19

FIGURE 6-1



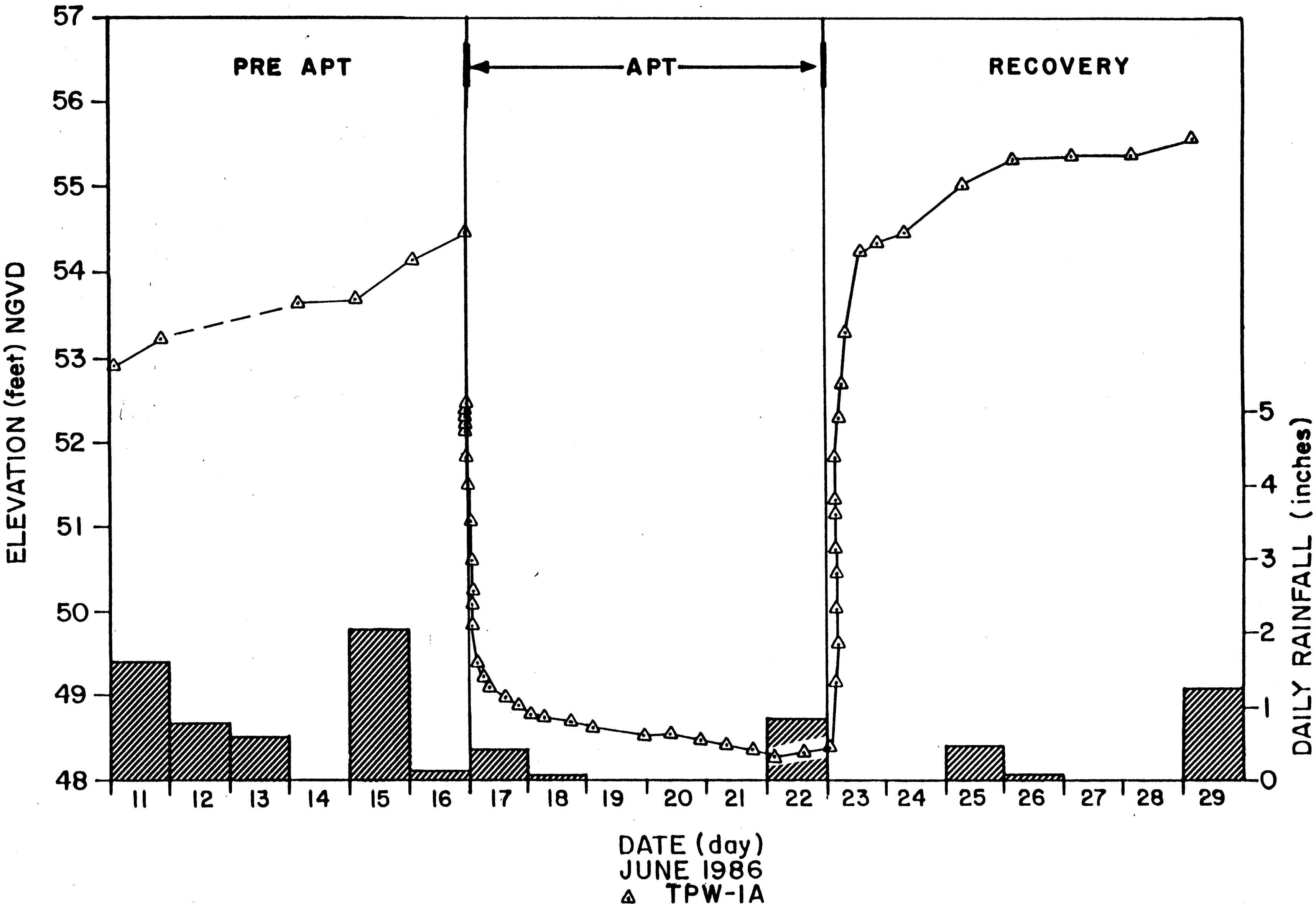
Observed Water Levels of the Aquifers at the Phase IA Site, before, during & after the APT (Aquifer Peformance Test)

The rise in potentiometric levels at the deep observation well sites in response to local rainfall shown on Figure 6-1 is probably due to a rise in the total vertical stress on the moderately confined aquifer. This increased stess is caused by the added weight of rainfall that has fallen and infiltrated into the surficial unit. Increased fluid pressure is a significant compensatory reaction in the underlying aquifer to increased total stress applied from above. As stated by Freeze and Cherry (1979), the total vertical stress at any point is due to the weight of the overlying rock and water; the total stress equals the stress borne by the granular skeleton of the porous medium (i.e., the effective stress) plus the fluid pressure of the water in the pores. The hydrogeologic system responds to the additional stress because of the following attributes: (1) the low permeability and consequent water-retaining nature of the predominately fine-grained surficial sediments, (2) the thinness yet low permeability of the primary confining unit, and (3) the low storativity of the moderately well confined aquifer and the consequent sensitivity of the potentiometric level to increased stress from above.

During the APT, the cone of depression surrounding the pumping well caused drawdowns in the Floridan aquifer ranging from approximately 2 feet at DMW-IA+1,950 to about 5.4 feet at DMW-IA+200. The drawdown at the pumping well (TPW-IA) reached approximately 8 feet during the APT. The water level data for TPW-IA are plotted on Figure 6-2.

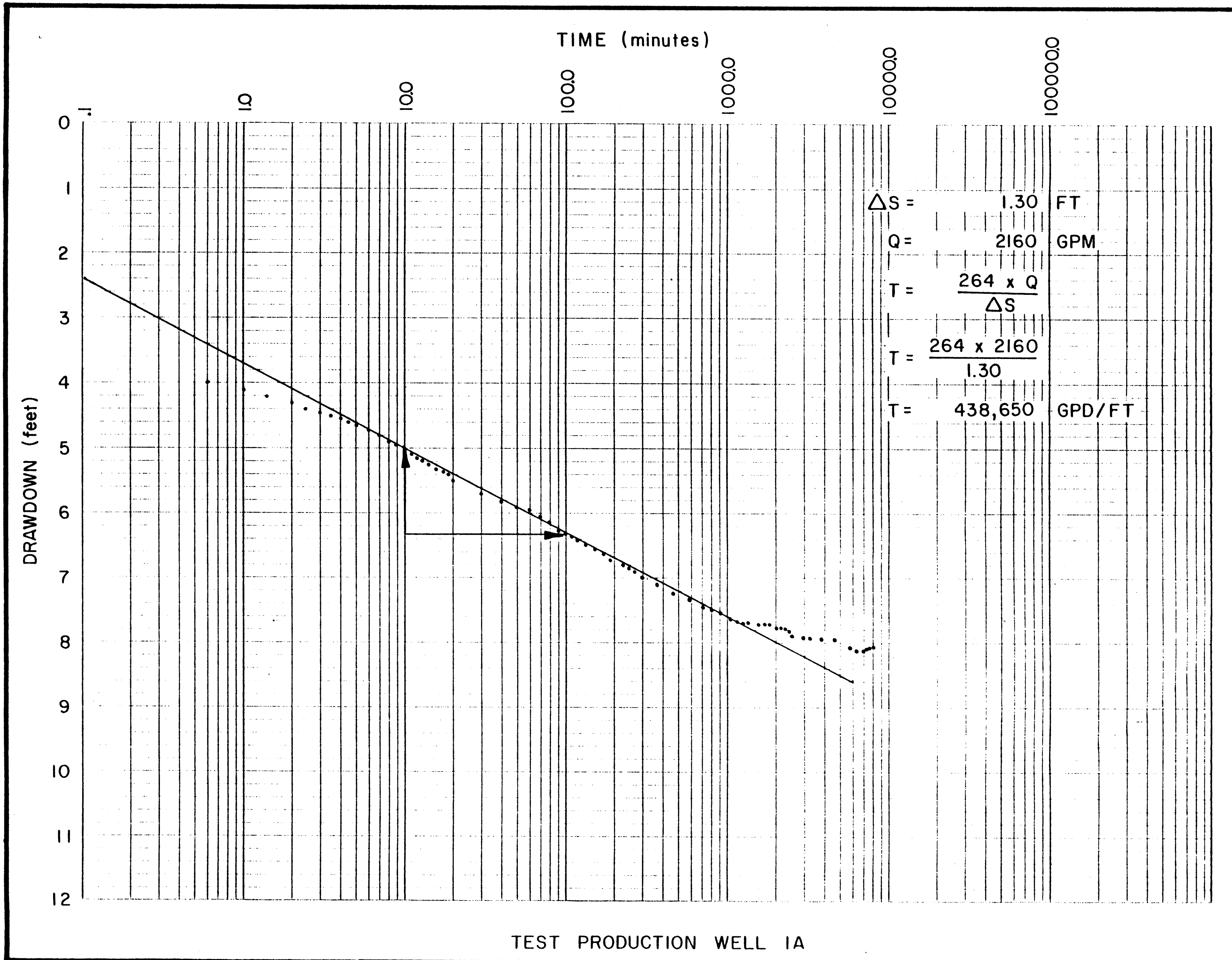
During the APT the maximum drawdowns in the shallow wells ranged from approximately 2.9 feet at SMW-IA+500 to 4.0 feet at SMW-IA+200. The drawdown of the surficial aquifer does not represent a significant overall downward leakance through the semi-confining layer, but occurs because of the low specific yield of the clayey sands of the surficial aquifer. The almost Theis-like response of the deeper aquifer confirms the relatively low leakance.

Using the uncorrected data, and treating the aquifer as being fully confined, the Cooper-Jacob straight-line method (Fetter, 1980) plot gave a transmissivity (T) of 438,650 gpd/ft for TPW-IA (Figure 6-3). Using simultaneous observations at the three deep monitor wells, a modification



Observed Water Levels at TPW-1A
before, during & after the APT (Aquifer Performance Test)

FIGURE 6-2



Approximate Transmissivity of TPW-1A
Using Uncorrected Data

FIGURE 6-3

of the Cooper-Jacob straight-line method referred to as the "distance-drawdown method", was plotted. This effort was not as successful as the plots did not fall on a straight line. A value of transmissivity (T) between 630,000 and 420,000 gpd/ft was obtained.

6.2.1 STABILIZATION

The data plots were also used during the APT to ascertain when the aquifer had essentially stabilized (Figure 6-3), which was one of the criteria imposed by the SWFWMD before the pump test could be terminated. Stabilization of the aquifer was approximated prior to the termination of the APT as demonstrated in Figure 6-3 when the water level began fluctuating up and down a few hundredths of a foot in response to factors other than the pumping of the well.

6.3 TEST DATA EVALUATION

Because the APT was scheduled to last a minimum of 5 days with an equal recovery time, factors that might affect the potentiometric surface during the pump test had to be determined. Proper analysis of the aquifer test data required that corrections be made to the observed water level changes in order to eliminate natural changes caused by barometric and tidal fluctuations, precipitation and regional change (trend) to the potentiometric surface of the Floridan aquifer.

Barometric, tidal, precipitation, and background well (regional trend) information was collected for a minimum of two weeks prior to the test, during the test, and during the well recovery period in order to determine the necessary correction factors.

6.3.1 RAINFALL

Figure 6-4 shows the rainfall at the three rain gage sites. The change in the potentiometric surface level, and the time required for the water level response, were determined for both the surficial and Floridan aquifer for several measured rain events prior to and after the APT. From this data a

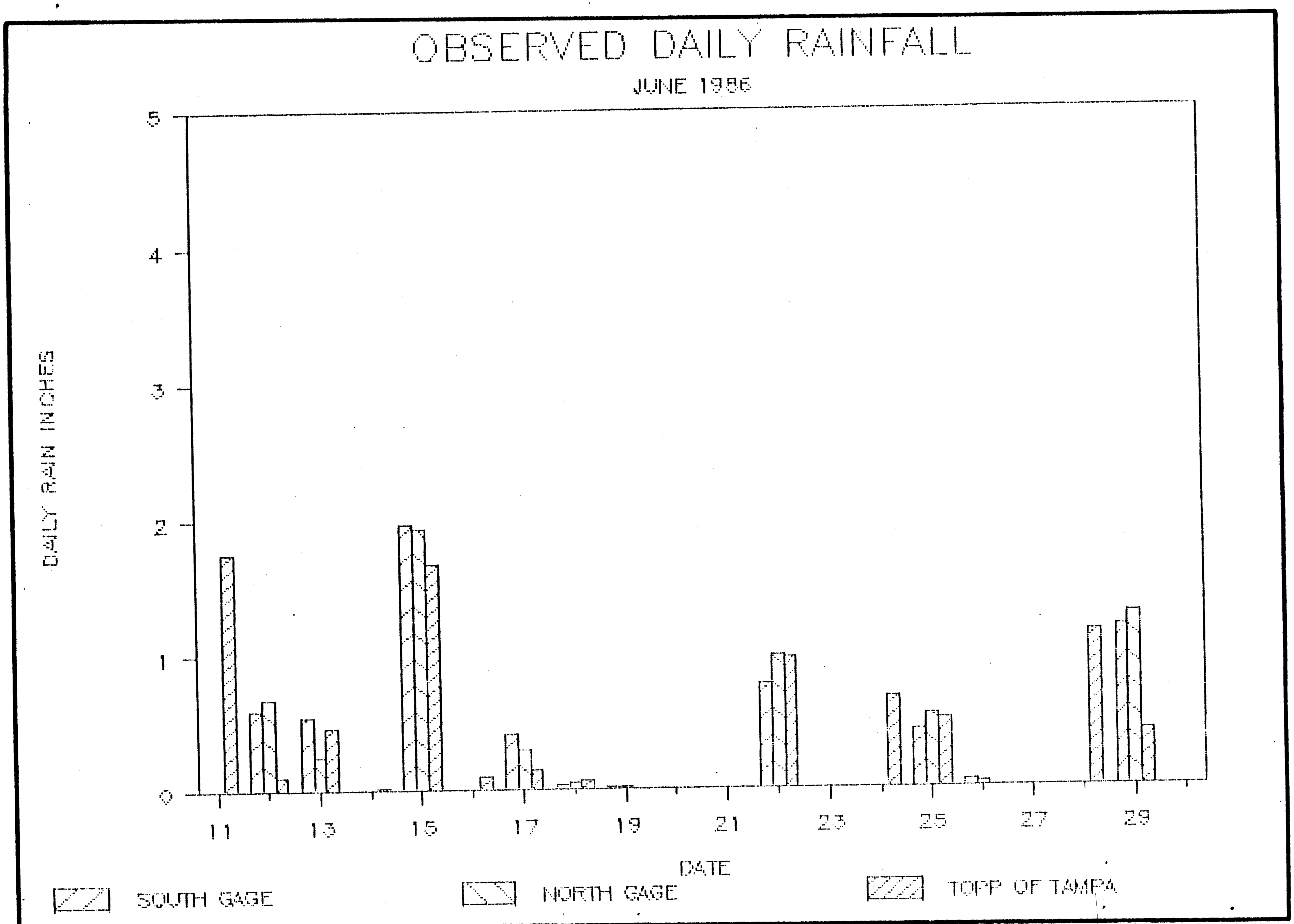


FIGURE 6-4

Observed Daily Rainfall

small drawdown correction factor (change in potentiometric surface per unit time per inch of rainfall) was calculated for the two major rain events that occurred during the pump test. This correction factor was used together with the other correction factors discussed later in this section to produce the corrected computer generated aquifer drawdown curves (Appendix H).

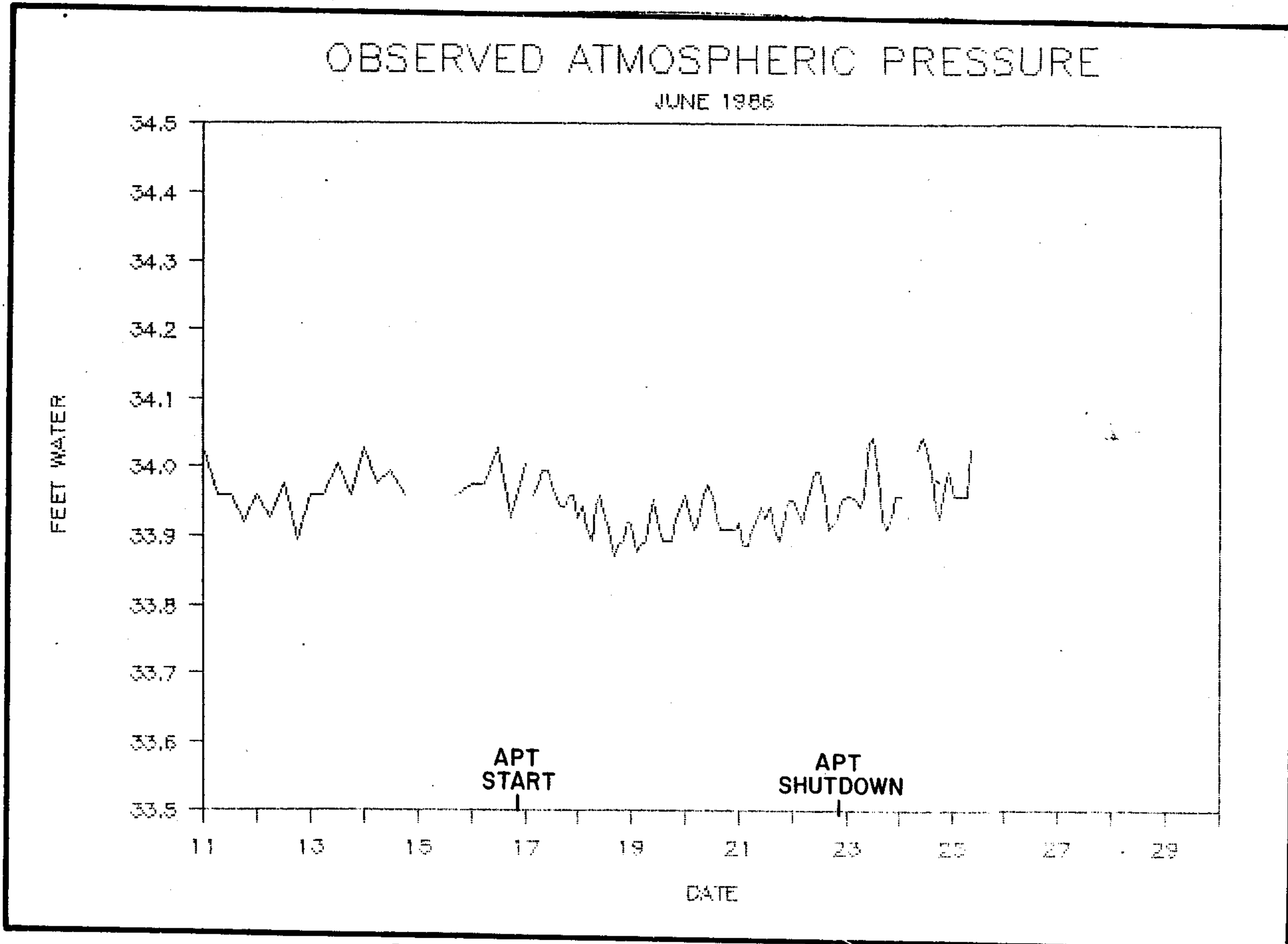
6.3.2 TIDAL/BAROMETRIC EFFECTS

A cyclic variation in the potentiometric surface with a maximum magnitude of 0.03 to 0.04 feet was observed in the deep wells. The cyclic nature of this variation indicated that the fluctuation could be either tidal or barometric in origin. A similar cyclic variation in water level was also observed when the data from ROMP #85 was plotted.

Tidal data for the month of June were obtained from NOAA for Tampa Bay. The cyclic nature of the observed water level changes did not appear to match the lunar progression shown in the tide tables, but appeared to occur about the same time each day. The distance from the aquifer site to the point of contact between the aquifer and tidal waters also appeared to be too great to give the observed response.

Barometric pressure data were obtained from a WCRWSA recording barometer located at the Topp of Tampa Airport. The observed barometric pressure was converted to feet of water head (Figure 6-5). The local barometric pressure experienced diurnal changes as much as 0.10 feet of water with an average of 0.05 feet of water. Todd (1980) states that barometric efficiency for a confined aquifer usually ranges from 0.2 to 0.7. The observed barometric efficiency was approximately 0.6.

The changes in the potentiometric surface caused by the fluctuations of the barometric pressure are negligible when compared with the changes in the potentiometric surface caused by the pumping during the early stage of the



Barometric pressure fluctuations recorded at the Topp of Tampa Airport, June1986

FIGURE 6-5

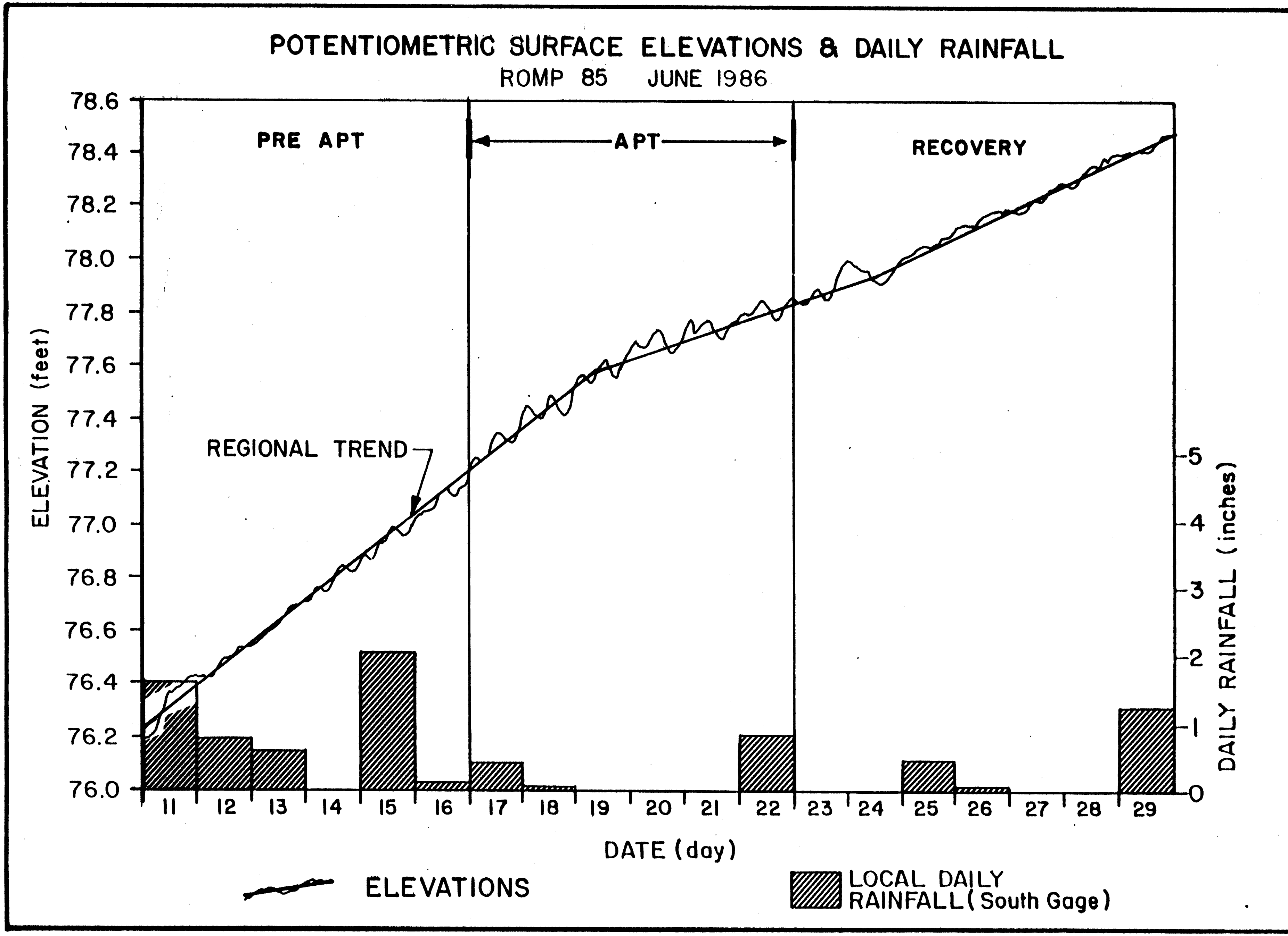
aquifer test. The diurnal high and low pressure changes tend to cancel each other over a period of a day or greater (later stage of APT). Therefore, barometric pressure changes in the potentiometric levels were not considered to be significant in the pump test analysis.

6.3.3 REGIONAL TRENDS

Because of the dynamic nature of the Floridan aquifer, the regional potentiometric surface falls during dry periods (discharge exceeds recharge) and rises during wet periods (high recharge). Initially, two wells were chosen as background or regional trend wells. ROMP #85 well (Lat. 28° 14′ 25", Long. 82° 19′ 25") is a 500-foot deep Floridan well located approximately 4 miles northeast of the site with a permanent recorder installed. The Immer deep well (Lat. 28° 11′ 12", Long. 82° 21′ 13") is measured periodically by USGS as part of a Floridan well network used in preparing potentiometric surface maps for the SWFWMD region. The locations of these wells are shown in Figure 1-1.

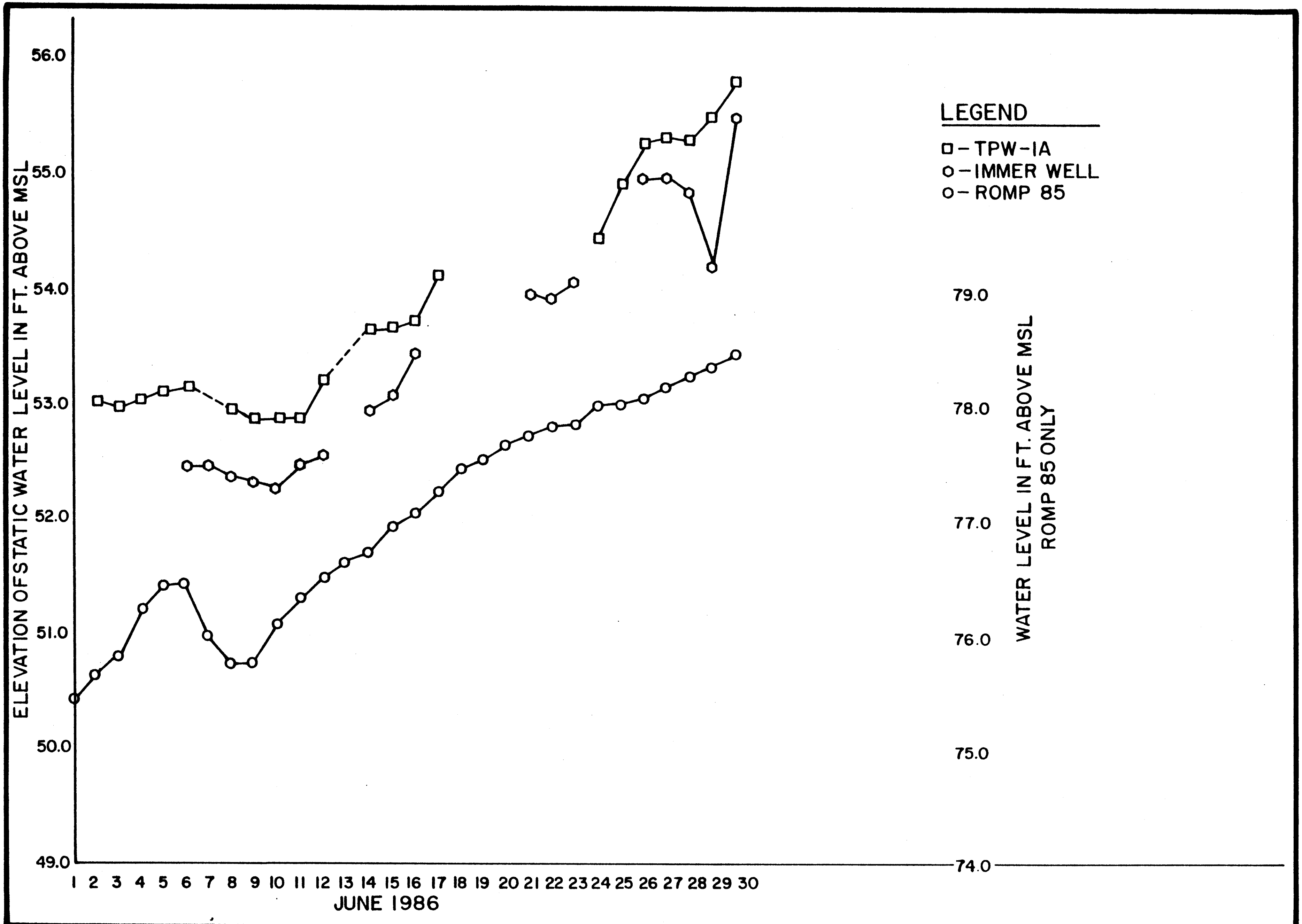
Water level data (provisional data) recorded at 1-hour intervals for the month of June for ROMP #85 was obtained from the Tampa office of USGS. Figure 6-6 shows the upward trend at ROMP #85 during June, 1986.

Daily hand-taped water level measurements were taken by CDM at the Immer deep well. It was soon discovered that after a rain event the water level in the well could not be measured because surface water entered a hole for the electrical cable in the casing, collected around the sanitary collar, and ran into the well when attempts were made to measure the water level through the access plug hole in the sanitary collar. Therefore, water levels could only be measured when the water table was below the opening in the casing. Figure 6-7 shows a comparison of water levels for June 1986 of ROMP #85, the Immer deep well, and TPW-IA. The figure shows that the relative changes in the potentiometric surface are similar.



Regional Trend in the Floridan Aquifer and ROMP 85 and Rainfall at the Phase IA Site

FIGURE 6-6



Regional Aquifer Trends During June 1986

FIGURE 6-7

A correction factor for the regional change in the potentiometric surface was calculated using the average slope of the change in water level at ROMP #85 (Figure 6-6). An average change in head per unit time was calculated and applied to the observed water levels for the APT. This change is reflected in the trend corrected water levels (see Appendix H).

6.4 PARTIAL PENETRATION EFFECTS

One of the causes of departure from the theoretical curve during aquifer pump tests is partial penetration. Wells that do not penetrate the entire thickness of the pumped aquifer create vertical flow gradients near the wells during pumping that makes the analytical methods for fully penetrating wells inaccurate unless data corrections are made. All of the deep wells at the test site are approximately 700 feet deep. Therefore, they penetrate about 670 feet of the Floridan aquifer which is estimated to be 950 feet thick (Wolansky and Garbade, 1981) in the vicinity of the site or about 70 percent of the aquifer thickness.

Differences in the drawdowns produced by partially penetrating wells diminish with increasing distance from the pumping wells. The partial penetration effect is not significant <u>if</u> the monitor wells are farther than $1.5b(K_h/K_v)^{1/2}$ distance units where b = aquifer thickness, K_h = horizontal hydraulic conductivity, and K_v = vertical hydraulic conductivity (Fetter, 1980). However, the monitor wells at the Phase IA site, were calculated to be close enough to the test well to have partial penetration effects on all of the monitor well data.

The partial penetration correction equation by Hantush (1964) was used in a computer program to provide a partial penetration correction factor for each monitor well (Appendix H) in order that the analytical solutions for fully penetrating wells could be used.

6.5 APT ANALYSIS METHODS

Using computerized data management procedures developed by CDM, the aquifer test data, tidal, barometric, rainfall, and regional data were tabulated.

As discussed in Section 6.3.2, it was determined that barometric and tidal effects were insignificant. However, the regional potentiometric surface trends projected from ROMP #85 were significant (Section 6.3.3). In addition, two local rain events affected the observed data (Section 6.3.1). Corrections for partial penetration (Section 6.4) for the deep observation wells and for well loss for TPW-IA (Section 6.1) were also made to the drawdown data. The correction factors and corrected drawdown data are shown in Appendix G.

After corrections for partial penetration, well loss, regional trend, and rain events were made to the drawdown data files, semilog and log-log plots of the data were generated to be used with the various analysis methods.

As previously stated, observations during drilling operations and shallow borings performed by M.P. Brown & Associates (August 1986) indicated that the confining beds are relatively thin and may not cover the entire site. Conversely, a Shelby tube soil sample analysis (Appendix C) showed that a waxy clay layer identified over much of the area immediately above the first limestone unit had a very low permeability of less than $1x10^{-8}$ cm/sec.

As there was a concern as to how well the Floridan aquifer was connected with the water table aquifer, several methods of analysis were selected and performed. Early time-drawdown data from tests of aquifers that are not anisotropic can generally be analyzed by the nonequilibrium or modified nonequilibrium nonleaky-aquifer methods, particularly if the leakance is not large and the monitor wells are not too distant. The assumption is that leakage has not affected drawdown or has not affected it enough to make the nonleaky-aquifer methods inapplicable.

Late time-drawdown data can generally be analyzed by the nonsteady-state, leaky-aquifer method. This method does not take into account confining bed storage; however, in much of west-central Florida, the confining bed is thin or discontinuous. It is therefore assumed that confining bed storage has a minimal effect on most aquifer tests. The APT was also analyzed by steady-state, leaky-aquifer methods. The latter method assumes that steady state had been attained. However, the method is applicable for verification of the nonsteady-state analysis because a quasi-steady-state had been reached.

The plots and solutions for the various methods are in Appendix H. The results of the analyses are discussed in Section 7.

6.5.1 THEIS NONEQUILIBRIUM METHOD

The nonequilibrium, nonleaky formula was derived by C.V. Theis in 1935 from the analogy between the hydraulic conditions in an aquifer and the thermal conditions in an analogous thermal system. The formula is based upon the following assumptions:

(1) the aquifer is homogeneous and isotropic,
(2) the aquifer has infinite areal extent,
(3) the aqufier is bounded above and below by impervious layers,
(4) the flow to the well is in an unsteady state, i.e., the drawdown differences with time are not negligible nor is the hydraulic gradient constant with time,
(5) the discharge well penetrates and receives water from the entire thickness of the aquifer and pumps water at a constant rate,
(6) the well has a reasonably small diameter so that well-bore storage can be ignored, and
(7) water removed from storage is discharged instantaneously with decline in head.

The above assumptions appear to be restrictive, and in fact, the first four are never fully met and seldom closely approached. Nevertheless, the Theis nonequilibrium formula has been applied successfully to many groundwater flow problems.

In applying the Theis method, values of drawdown(s) are plotted against a time per radius squared (t/r^2) on logarithmic paper. The data curve is superimposed on a nonleaky type curve and a match point selected and the coordinates of this common point recorded and used to solve for Transmissivity (T) and Storage Coefficient (S).

In American practical hydrologic units (Fetter, 1980):

$$h_o - h = \frac{114.6QW(u)}{T}$$

$$S = \frac{Ttu}{2693r^2}$$

where:

$h_o - h$ = Drawdown (feet)
Q = Well discharge (gallons per minute)
T = Transmissivity (gallons per day per foot)
r = Distance to the monitor well (feet)
S = Storativity (dimensionless)
t = Time since pumping began (minutes)

6.5.2 COOPER-JACOB METHOD

The Cooper-Jacob staight-line modified nonequilibrium method was derived for values of the function u of less than 0.02 for a confined, areally extensive aquifer. In this graphical method, a straight line is drawn through the field data points (drawdown versus log of time) and extended backward to the zero-drawdown axis. The change of drawdown per log cycle is obtained from the slope of the graph.

In American practical units (listed below), these equations are expressed as (Fetter, 1980):

$$T = \frac{264Q}{(h_o - h)}$$

$$S = \frac{Tt_o}{4{,}790r^2}$$

where

Q = Constant rate of pumpage (gallons per minute)

$(h_o - h)$ = Drawdown per log cycle of time (feet)

t = Time since pumping began (minutes)

T = Transmissivity (gallons per day per foot)

r = Distance to the pumped well (feet)

t_o = Value of time at the intercept with the zero-drawdown axis.

$t > (5r^2)(S/T)$, limiting condition

The Theis and Cooper-Jacob methods may be used if the leakance is not large and the monitor wells are not too distant. The assumption is that leakage has not affected drawdown or has not affected it enough to make the nonleaky aquifer method inapplicable (Wolansky and Corral, 1985).

6.5.3 WALTON METHOD

Walton derived a graphical method for a leaky artesian aquifer (semiconfined) with negligible storage in the confining layer. Instead of one type curve, there is a type curve for each value of r/L, where L is a leakage factor. The s versus t/r^2 plot is superimposed and adjusted on the family of type curves until most of the plotted points fall on one of the type curves and a match point is selected (Kruseman and de Ridder, 1979). The assumptions listed for the Theis equation should be satisfied except that the aquifer is semiconfined.

The equation for the Walton Method may be stated as follows:

$$T = \frac{Q}{4\Pi s} W(u, r/L)$$

$$S = \frac{4Tt}{r^2} u$$

where:

s = Drawdown (meters)

T = Transmissivity (m^2/day)

Q = Rate of discharge (m^3/day)

W(u,r/L) = Well function

r = Distance from observation well to discharge well (meters)

L = Leakage factor of water bearing layer.

S = Storage Coefficient

t = Time (days)

6.5.4 HANTUSH I METHOD

Hantush (1956) developed a method of analyzing the data from pumping tests in semi-confined aquifers, using the inflection point of the time-drawdown curve on single logarithmic paper. However, to determine the inflection point, the steady state drawdown should be (approximately) known from direct observation or from extrapolation. Explanation of this rather complex straight line method is in Appendix H and Kruseman and de Ridder (1979). The equations are:

$$T = \frac{2.3Qe^{-r/L}}{4\Pi\Delta s_p} \qquad S = \frac{r4Tt}{2Lr^2}$$

Definition of terms are as for the Walton Method with:

s_p = Drawdown at inflection point

Δs_p = Slope of the curve at inflection point

L = Leakage factor of water bearing layer through semi-confining unit

6.5.5 HANTUSH II METHOD

This method is based on the same assumptions as the Hantush I method and Walton method but is graphically solved in a different manner. Observations from at least two wells are required. A description of the method and solutions is located in Appendix H and Kruseman and de Ridder (1979). The equations are:

$$T = \frac{2.30Q}{4\Pi\,(\Delta s)_o} \qquad S = \frac{2Tt_p}{Lr}$$

The definition of terms are as for the Hantush I with:

$(\Delta s)_o$ = Δs axis

where:

r = o
t_p = time at the inflection point.

6.5.6 HANTUSH - JACOB METHOD

Hantush and Jacob (1955) found that, in addition to the transmissivity and coefficient of storage of a leaky artesian aquifer, the leakance can be determined by superimposing a plot of time versus drawdown on a family of type curves. The above method incorporates the assumptions of the Theis method except that assumption 3 is deleted and the following four assumptions are added:

(8) flow in the aquifer is augmented by vertical leakage through the confining beds,
(9) the flow lines are assumed to be refracted at a full right angle as they cross the confining bed and aquifer interface,
(10) the confining beds are assumed to be incompressible so that water released from storage therein is negligible, and

(11) the heads above an overlying confining bed and below an underlying confining bed are influenced by the pumping (Wolansky and Corral, 1985).

The equations may be written:

$$T = \frac{Q}{4\Pi s} L(u,v)$$

$$S = \frac{4T\ t/r^2}{1/u}$$

Leakance (K'/b') is determined from the following equation:

$$\frac{K'}{b'} = 4T \frac{v^2}{r^2}$$

where:

L (u,v) = L function of u,v.

K' = Vertical hydraulic conductivity of the confining bed (feet per day)
b' = Thickness of the confining bed (feet).

6.5.7 JACOB LEAKY ARTESIAN METHOD

Jacob (1946) described a method where the final or essentially steady-state (latest) drawdown observation in each well is plotted on logarithmic paper against the distance of the monitor well from the pumped well. The data are then matched to the Bessel function logarithmic type curve of $K_o(x)$ versus x and a common match point is chosen.

The formula may be written as:

$$T = \frac{0.16QK_o(x)}{s}$$

$$\frac{K'}{b'} = T\,(x/r)^2$$

where:

T = Transmissivity (ft^2/day)
K'/b' = Leakance (/day)
Q = Pumping rate (ft^3/day)
s = Drawdown (ft)
r = Distance from monitor well to pumping well

6.5.8 ANISOTROPIC METHOD

In conventional methods of aquifer test analysis, homogeneous and isotropic aquifers are assumed. In many instances, however, the aquifers tested are anisotropic. The SWFWMD required that a third deep monitor well(DMW-IA+1,950) be installed so that the amount of anisotropy at the Phase IA site could be determined. Hantush (1966) developed a method for determining hydraulic properties and the principal directions of anisotropy. It requires data from at least three wells if the principal directions of anisotropy are not known. Solutions are based on either the Theis formula or Hantush-Jacob formula.

7.0 TEST RESULTS

The application of the several analytical techniques discussed in Section 6 indicated that the Floridan aquifer in the vicinity of the Phase IA site is semi-confined and exhibits a low leakance that is consistent with other APT results in the area. The leakance value is also consistent with measured permeabilities of the clay semi-confining unit at the site.

Hydraulic properties determined from the aquifer test analysis methods described in Section 6.5 and presented in Appendix H are summarized in Table 7-1.

7.1 TRANSMISSIVITY

The transmissivities (T) for the different analytical methods fell within a range from 378,000 gpd/ft. to a high of 471,000 gpd/ft.

The greatest variation in transmissivity for any well using the eight methods was 17 percent. The average of the eight different methods is 423,600 gpd/ft. with a ±7 percent variation for all methods except for the Hantush I method which is -11 percent. There is no apparent pattern to the variation in transmissivity between the monitor wells for the different methods. The Cooper-Jacob method yielded a slightly lower T value for TPW-IA than for the monitor wells. The Hantush anisotropic method shows a negligible anisotropy in transmissivity at the site with the major axis at 112.2°. The transmissivities are comparable to the values of 51,800 to 57,000 ft^2/d (387,000 to 426,000 gpd/ft) used by Robertson and Mallory (1977) for Pasco County. Transmissivities from 51,000 to 71,000 ft^2/d (381,000 to 531,000 gpd/ft) were reported for the South Pasco Wellfield to the west of the Phase IA site.

7.2 STORAGE COEFFICIENT

The storage coefficient is fairly consistent as determined by the different methods with an average of 0.0007. The highest storage coefficient was in the vicinity of DMW-IA+1,950 which had a range of 0.0009 to 0.0015. The

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Table 7-1
Results of APT Analysis Methods

Analysis Method	Well(s)	T (gpd/ft)	S (dimensionless)	Leakance k'/b' (day^{-1})	Leakance Factor L(ft)
Theis	DMW-IA+1,950	404,515	0.0015		
	DMW-IA+500	416,692	0.0002		
	TPW-IA+200	404,249	0.0005		
	TPW-IA	433,750			
	average	414,801	0.0007		
Cooper-Jacob	DMW-IA+1,950	461,500	0.0010		
	DMW-IA+500	426,770	0.0005		
	DMW-IA+200	417,350	0.0008		
	TPW-IA	403,100			
	average	427,180	0.0008		
Walton	DMW-IA+1,950	406,553	0.0015		
	DMW-IA+500	455,658	0.0002		
	DMW-IA+200	471,390	0.0005		
	average	444,534	0.0007		
Hantush I	DMW-IA+500	377,649	0.0005	$3.90X10^{-5}$	44,763
Hantush II	DMW-IA+1,950		0.0009		
	DMW-IA+500		0.0003		
	DMW-IA+200		0.0009		
	average	408,304	0.0007		12,268
Hantush-Jacob	DMW-IA+1,950	451,976	0.0014	$2.54x10^{-5}$	
	DMW-IA+500	450,488	0.0005	$2.41x10^{-5}$	
	DMW-IA+200	451,976	0.0002	$2.42x10^{-5}$	
	average	451,480	0.0007	$2.46x10^{-5}$	
Jacob Leaky Artesian	average	412,800		$1.16x10^{-4}$	
Hantush Anisotropic	x axis (112.2°)	462,324	0.0007		
	y axis (22.2°)	440,939	0.0007		
	average (T_e)	451,505			

lowest storage coefficient was for DMW-1A+500 with 0.0002 to 0.0005 being calculated by the various methods. The values for S are generally lower than those obtained for the South Pasco Wellfield of 0.001 to 0.006 (Wolansky and Corral, 1985).

7.3 LEAKANCE

Leakance as calculated from the APT data (see Table 7-1) ranged from 2.46×10^{-5} to 1.16×10^{-4} per day (day^{-1}). This range of relatively low leakance is in agreement with values reported for the Cypress Creek Wellfield, permeability testing results on the semi-confining unit at the Phase IA site and groundwater modeling calibration results in the area. The table below summarizes some of the leakance data from the Phase IA site and other nearby areas.

Data Source	Leakance (day^{-1})
Phase IA APT results (CDM, 1986)	2.46×10^{-5} to 1.16×10^{-4}
Phase IA site laboratory permeability testing (M.P. Brown & Associates, 1986)	1.9×10^{-5}
C-2 test well at Cypress Creek Wellfield (Leggette, Brashears & Graham, 1975)	4.01×10^{-4}
Cypress Creek Wellfield ground-water model calibration (Ryder, 1978)	1.34×10^{-5} to 1.34×10^{-4}
South Pasco Wellfield testing (Wolansky and Corral, 1985)	5.0×10^{-5}

The above table lists a leakance value ($1.9x10^{-5}$ day^{-1}) calculated from laboratory permeability testing of a Shelby tube from the Phase IA site. Leakance is actually another method of expressing the vertical permeability (K′) of the semi-confining bed and is expressed by the following equation:

$$L = \frac{K'}{b'}$$

where:

L = Leakance (day^{-1})
K′ = Vertical hydraulic conductivity of the semi-confining bed (ft/day)
b′ = Thickness of the semi-confining bed

A Shelby tube laboratory permeability of $1x10^{-8}$ cm/sec ($2.83x10^{-5}$ ft/day) was measured for the semi-confining unit at the Phase IA site (M.P. Brown & Associates, August, 1986). The semi-confining unit ranged from 0.5 feet to 8 feet thick, but averaged approximately 1.5 feet. Applying the above equation to the Phase IA laboratory permeability value yields:

$$L = \frac{2.83x10^{-5} \text{ ft/day}}{1.5 \text{ ft}} = 1.9x10^{-5} \text{ day}^{-1}$$

The above leakance is slightly lower than the $2.46x10^{-5}$ day^{-1} value obtained by the Hantush-Jacob method, but is in agreement with the magnitude of leakance values obtained by the APT anlysis.

The comparatively low leakance values calculated for the confining unit are also supported by the fact that the drawdown curves generated from the test data are close in shape to the Theis non-leaky aquifer curve.

7.4 TEST SUMMARY

Analysis of the Phase IA aquifer performance test data by several applicable techniques resulted in the following average aquifer properties at the site:

Transmissivity = 423,600 gpd/ft
Leakance = 6.0×10^{-5} per day
Storage Coefficient = .0007

The analyses were based upon an exceptionally complete set of on-site monitor well water level data and should be considered as highly reliable. The Floridan aquifer at the Phase IA site is hydraulically suitable for installation of a 3 mgd water supply well.

8.0 CONCLUSIONS

Results of the hydrogeologic investigation, step-drawdown test, aquifer performance test and water quality analyses indicate that the test site is suitable for a potable water production well producing an average of 3 million gallons per day (mgd) from the Floridan aquifer. Drawdown at the test production well was 8 feet or less during the aquifer performance test at a pumping rate of 2,150 gallons per minute (3.1 mgd). The aquifer performance test results indicate that the test/production well is in a productive area with a transmissivity of approximately 423,600 gpd/ft. Although the confining bed above the Floridan aquifer is relatively thin, the Floridan aquifer acts as a semi- confined aquifer (storage coefficient approximately 0.0007) with a slightly leaky confining unit (leakance between 1.16×10^{-4} and 2.46×10^{-5} per day).

Estimation of long term pumping effects on the water table and vegetation are beyond the scope of this investigation. Impact of large scale water withdrawals on both wells of local residents and nearby wellfields will need to be addressed by further testing at other sites and by a regional groundwater modeling analysis.

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APPENDICES

AQUIFER PERFORMANCE TEST - PHASE IA

PHASE I - REGIONAL INTERCONNECTION

FOR THE
WEST COAST REGIONAL WATER
SUPPLY AUTHORITY

DECEMBER 1986

CAMP DRESSER & McKEE INC.
CLEARWATER, FLORIDA

EJK6T.3/12
12/10/86

APPENDICES

CONTENTS

APPENDIX A

SWFWMD AQUIFER PERFORMANCE TEST AUTHORIZATION

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

2379 BROAD STREET, BROOKSVILLE, FLORIDA 33512-9712
PHONE (904) 796-7211 SUNCOM 684-0111

COPY
ORIGINAL SENT TO FILE
cc - Cypress [illegible]
Water Supply Develop.

RECEIVED
APR - 9 1986
WCRWSA

April 2, 1986

Mrs. Loretta Holtkamp
West Coast Regional Water Supply Authority
2535 Landmark Drive, Suite 211
Clearwater, Florida 33519

Re: Authorization For Proposed Test Program, CUP No. 208426

Dear Mrs. Holtkamp:

The District has reviewed your request to construct and test wells in order to develop specific hydrogeologic information in support of Consumptive Use Permit Application No. 208426.

In accordance with this request, the District hereby grants permission to proceed with the test program as represented in the attached memorandum. Your well construction permit will be released accordingly.

Please continue to keep the District staff appraised of your progress. Should you have any questions or comments regarding this information, please call.

Sincerely,

Richard V. McLean

RICHARD V. MCLEAN
Director, Resource
Regulation Department

MT

Attachments

RECEIVED
APR 16 1986
WCRWSA
CLEARWATER OFFICE

April 2, 1986

MEMORANDUM

TO: RICHARD V. MCLEAN, Director, Resource Regulation Department

FROM: MT MARK THAGGARD, Hydrogeologist, Consumptive Use Permitting Section

RE: Authorization For Proposed Test Program, West Coast Regional Water Supply Authority, CUP No. 208426

I. BACKGROUND

A.	Entity Proposing Test:	West Coast Regional Water Supply Authority
B.	Hydrogeologic Consultant:	Camp Dresser & McKee
C.	Location:	Pittway Real Estate, Inc. property in southern Pasco County; Township 26 South, Range 19 East, Section 23.
D.	Date of Request:	Test program submitted December 13, 1985; CUP application received on February 26, 1986.
E.	Purpose:	Hydrologic investigation in support of a consumptive use permit for 24 MGD from 16 wells. Data obtained will provide information used to estimate the effects of the groundwater withdrawals.

II. TEST PROGRAM

A. The test-production well casing will be 24-inches in diameter and will extend to an estimated depth of 150 feet (or below the upper confining unit). The total well depth will be roughly 700 feet.

Three 8-inch diameter production zone monitor wells will be drilled at a distance of 200, 500, and 1500-2000 feet from the test-production well. The monitor wells will each have 150 feet of casing and a total depth of 700 feet.

At two of the two production zone monitor sites (the two closest to the test-production well}, a 4-inch diameter water table monitor well will be drilled to a total depth of 25 feet. The well will be fitted with PVC pipe with the bottom 5 feet screened.

All monitor wells will be properly developed following construction.

B. Formation cuttings will be collected every 10 feet while drilling by mud rotary and every 5 feet or change of formation while drilling by reverse air. These cuttings will be collected while drilling the test-production well and both production zone observation wells.

C. Water samples will be taken at every rod change (approximately 30 feet) and field analyzed for conductivity and temperature on the test-production wells and the three production zone observation wells.

D. Upon completion of the test-production well, the following geophysical logs will be performed on the well and the first monitor well completed:

1. Caliper
2. Electric
3. Temperature (static and sustained stress)
4. Flow meter (static and sustained stress)
5. Fluid resistivity
6. Gamma ray

E. A step drawdown specific capacity test will be performed on the test-production well.

F. Prior to the start of the aquifer pumping test, water levels will be measured in all wells for a minimum of two weeks.

G. A rain gage and recording barometer will be installed on the site after the completion of well drilling but prior to the aquifer pumping test.

H. An aquifer pumping test consisting of drawdown and recovery will be performed for a period long enough so that all aquifer parameters can be determined (i.e. transmissivity, storage, and leakance). The production well will be pumped at least five days and longer if equilibrium conditions are not established.

1. During the test, water level will be measured in the test-production well by using an electric sounder (M-SCOPE or equivalent). Each monitor well will be equipped with a continuously recording water level instrument (Stevens Type F or equivalent).

2. The estimated pump rate of the test-production well is 2,100 gpm. The production rate will be monitored by use of an in-line flow meter and an orifice-manometer.

3. Discharge water will be routed 1000-1500 feet to the east away from the test and into Trout Creek.

I. Water samples will be collected at 12 hours into the test and everyday thereafter and analyzed for chlorides, sulfates, total dissolved solids, and conductivity using standard testing procedures.

J. Water levels will be monitored before, during, and after the test in nearby monitor wells to account for regional affects of pumpage within the area. Additionally, a visual reconnaissance will be maintained of the area to determine when pumpage is taking place in the area.

III. <u>SPECIAL CONDITIONS</u>

Staff recommends approval of the testing as outlined above, subject to the following conditions.

A. If it is determined that the production well cannot be used for water supply development, all wells will be properly abandoned (i.e. plugged) in accordance with 17-21, FAC. One of the deep zone well and one of the water table monitor well may be converted to regional monitor wells.

B. A report on the results of the hydrologic testing will be completed and a copy submitted to the District. Additionally, a copy of all raw and analyzed data and calculations will be submitted to the District.

A meeting will be be arranged between District staff and West Coast representatives to discuss the test results and determine additional testing needs.

C. District staff shall be notified at least 48 hours prior to commencement of any testing.

D. District staff shall be notified prior to termination of pumpage during the test.

E. District staff shall be allowed on the property with proper prior verbal notification.

F. WCRWSA will have to obtain a consumptive use permit from the District prior to putting any wells into production.

G. The location of the third deep zone monitor well will be at a site mutually agreed upon by District and West Coast staff.

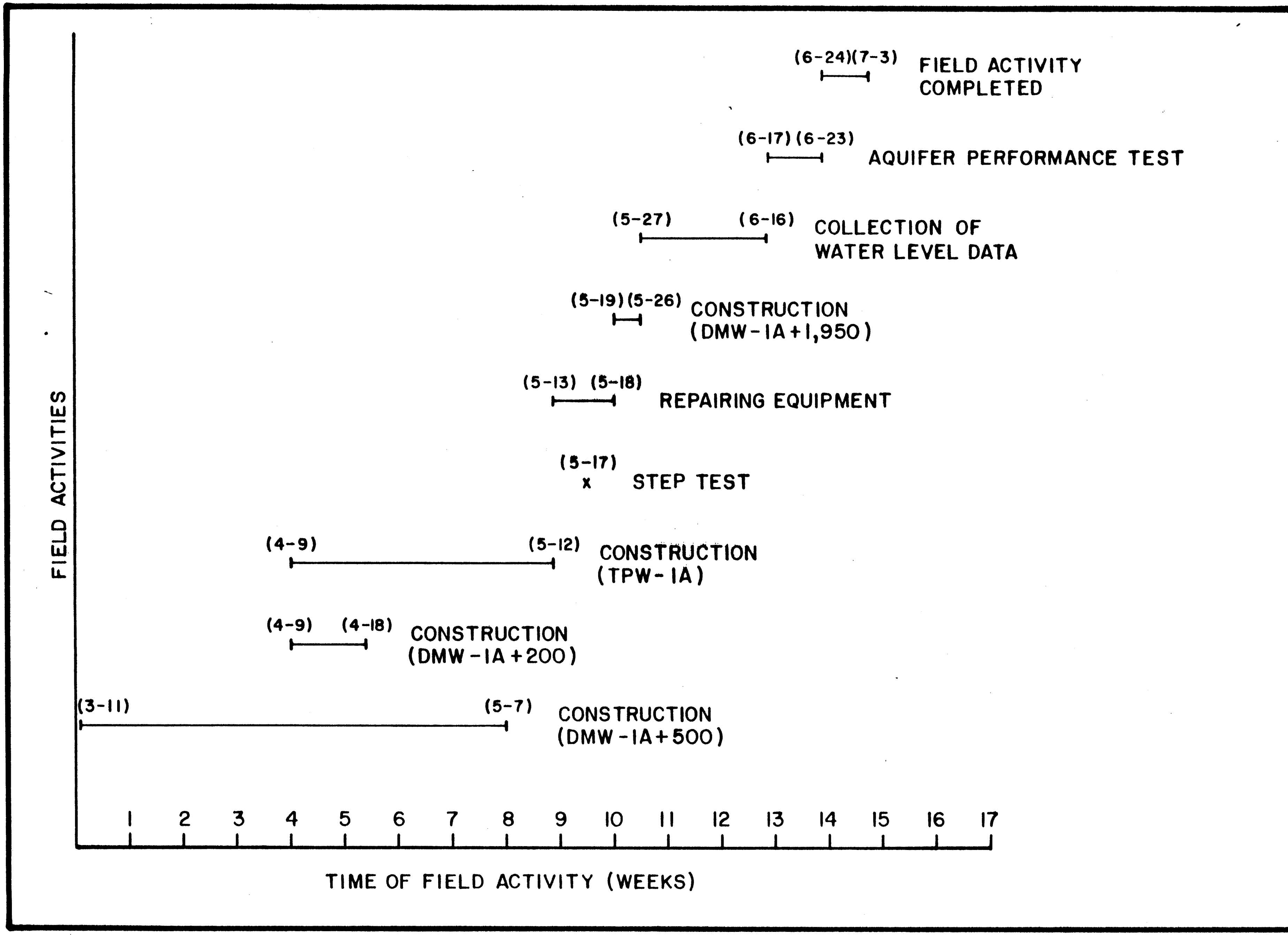
H. The results of this test will determine the necessity for further testing in the area.

I. West Coast shall investigate withdrawal related complaints from nearby property owners. West Coast shall either satisfactorily establish that its withdrawals are not causing the problem or take action to mitigate the problem. Either action shall be subject to review and approval by the District.

MT:eab

APPENDIX B

ACTIVITY CHRONOLOGY



Chronological Log of Field Activities

APPENDIX C

GEOLOGIC LOGS

TEST PRODUCTION WELL IA

CAMP DRESSER & McKEE INC.

TPW-1A

GEOLOGIC LOG OF WELL Phase 1A (Test Production Well)

Project Name WCRWSA Phase IA
Project Number 6006-43
Hole Size 30"

Date 4/8/86
Drilling Method rotary mud
Sampling Method cuttings

Depth Interval Ft.	Geologic Description
0'-5'	Fine Sand
5'-13'	Fine Sand and clay
13'-20'	claey sand - light gray to white
20'-25'	Sandy clay - light gray, very fine
25'-30'	Sandy clay - light gray, very fine
	Limestone - white, hard, fine grained, contact is around 28'

TPW-1A

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Phase 1A (Test Production Well)

Project Name WCRWSA - Phase 1A

Date 4/9/86

Project Number 6006-43

Drilling Method rotary mud

Hole Size 30"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
30'-35'	Limestone - white to tan, hard, fine to medium grained, biomicritic
35'-40'	Limestone - white to tan, hard, fine to medium grained, biomicritic
40'-45'	Limestone - white to tan, hard, medium grained, biomicritic with green clay dispersed throughout.
45'-50'	Limestone - white to tan, hard, medium grained, biomicritic, with small nodular bits of green clay dispersed throughout
50'-55' st circulation	Limestone - white to tan, hard, medium grained, biomicritic with green clay.
55'-60'	Limestone - white to tan, fine to medium grained, very little clay, hard, biomicritic.
60'-65' st culation	Limestone - white to gray, hard, fine to medium grained, biomicritic, very little clay, shell fragments.

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Test production well

Project Name WCRWSA Phase IA

Date 4/10/86

Project Number 6006-43

Drilling Method Rotary Mud

Hole Size 30"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
65-70'	Limestone, medium hardness, tan to gray, biomicritic
70'-75'	Limestone - hard to medium hardness, white to gray, biomicritic with some clay
75-80'	Limestone - tan to gray, hard, biomicritic
80'-85'	Limestone - tan to Lt. gray, medium hardness, fine grained, biomicritic
85'-90'	Limestone - tan to gray, medium hardness, fine grained, biomicritic, shell fragments
90'-95'	Limestone - tan to gray, coarser grained, medium hardness, biomicritic, shell fragments
95'-100'	Limestone - same as above
100'-105'	Limestone - tan to gray, medium grained, medium hardness, biomicritic and a small amount of shell fragments
105'-110'	Limestone - Tan to Lt. gray, medium grained, medium hardness, biomicritic, shell fragments

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Test Production Well

Project Name WCRWSA Phase IA

Date 4/10/86

Project Number 6006 - 43

Drilling Method Mud Rotary

Hole Size 30"

Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
110'-115'	Limestone, gray to tan, fine to med. grain, medium hardness - biomicritic shell fragments, microfossils.
115'-120'	Same as above
120'-125	Same as above, with black specks (salt and pepper) occasional hard strata, medium hard
125'-132	Same as above -

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Test Production well

Project Name	WCRWSA Phase IA	Date	4/18/86
Project Number	6006-43	Drilling Method	Reverse Air
Hole Size	22"	Sampling Method	Cuttings

Depth Interval Ft.	Geologic Description
132' - 150'	Limestone - Tan to Lt. gray, fine grained, hard with hard dark gray clay and some recrystalized material
150' - 155'	Limestone - Tan to gray, fine grained, hard with two different textures. One is biomicritic and the other is sucrosic
155' - 160'	Limestone - gray, fine grained, hard to medium hardness, biomicritic
160' - 165'	Limestone - gray, fine grained, hard to medium hardness, biomicritic with some shell fragments
165- 170'	Limestone - tan to gray, fine grained, hard biomicritic, shell fragments.
170'- 175'	Limestone - tan to gray, fine grained, hard, biomicritic, shell fragments with some hard dark gray clay
175' - 180'	Limestone - tan to gray, fine grained, hard, biomicritic, shell fragments with a greater percentage of hard gray clay

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL TEST WELL 1A

Project Name WCRWSA Phase 1A
Date 4-22-86
Project Number 6006-45
Drilling Method Reverse Air
Hole Size 22"
Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
180 – 185	Limestone grayish tan, biomicritic fine sandy grained, black specks, gastropod & shell casts and molds. Made up of fossil fragments, medium to well indurated.
185 - 190	Same as above, more echinoid spines and plates, pyrite crystals inside some fossil molds
0 -203	Limestone, tan, biomicritic, fine sandy grained black specks (iron minerals), made up of fossil fragments, medium to well indurated
203- 210	Same as above, gray, with thin carbonate mud layers, tan, at 304-305.
210 - 215	Same as above, no carbonate mud, oyster shells, barnacles (?)
215 - 217	Same as above, medium hardness
217 - 219	Limestone, gray with black specks, fine grained, medium to hard layers, shells, gastropod molds, green to dark gray chert, black shark teeth.
219 - 225'	Limestone, gray to tan as above, fair to well indurated, echinoid spines & plates, gastropods, shells
225' - 230'	Limestone, gray, hard, medium grained some shell fragments

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Test Well 1A

Project Name WCRWSA Phase IA

Date 4-22-86

Project Number 6006-45

Drilling Method Reverse Air

Hole Size 22"

Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
230'-235'	Limestone - tan to gray, hard, fine grained, biomicritic, echinoid plates and spines, shell fragments
235'-240'	Limestone - tan to gray, soft to medium hardness, fine grained, very few shell fragments
240'-245'	Limestone - tan to gray, soft to hard, fine grained, shell fragments with a large amount of soft, tan to gray clay.
245'-250'	Limestone - tan to gray, soft to hard, fine grained, shell fragments with a large amount of soft green clay
250'-255'	Limestone - tan to gray, soft to hard, fine grained, shell fragments
255'-260'	Limestone - tan, hard, fine grained, very fossiliferous (echinoid spines and plates), biomicritic
260'-265'	Limestone, tan to gray, soft to hard, fine grained, biomicritic and sucrosic, shell fragments (bivalves, gastropods, echinoderms)

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Test Well 1A

Project Name WCRWSA Phase 1A
Date 4/22/86
Project Number 6604-45
Drilling Method Reverse Air
Hole Size 22"
Sampling Method cuttings

Depth Interval Ft.	Geologic Description
265'-270'	Limestone - gray, soft, fine grained, shell fragments (echinoderms)
270'-275'	Limestone - gray, very soft, fine grained with some shell fragments
275'-280	same as above
280'-285'	Limestone - (limey mudstone?) gray very soft, fine grained
285'-290'	Limestone - gray, hard, fine grained, very fossiliferous (echinoid plates and stems) - primarily
290'-295'	Extremely fossiliferous, especially forams. No rock matrix
295'-300'	Forams and shell fragments
300'-305'	Limestone - gray, hard, fine grained, very fossiliferous (forams and shell fragments)
305'-310'	Limestone - gray, soft to hard, fine grained, a lesser percentage of forams and shell fragments
310'-315'	Limestone - tan, soft to medium hardness, fine grained, shell fragments
315'-320'	Limestone - tan, soft to medium hardness, fine grained, shell fragments
320'-325'	Same as above except Limestone is weathered to a greater degree

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Test Well 1A

Project Name WCRWSA Phase 1A

Date 4/23/86

Project Number 6006-45

Drilling Method Reverse Air

Hole Size 22"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
325-350	Coquina, limestone with over 50% forams Camerinidae (Operculinoides ocalanus) and Lepidocylina ocalana predominant, very soft.
350-355	Same as above with more limestone matrix, soft to medium hardness
355-369.5	Limestone, light tan, biomicritic fine sandy grained, shell and gastropod fragments and molds, Lepidocyclina ocalana, medium hardness, well cemented.
369.5-372	Same as above but poorly to fairly indurated.
372-183	Limestone, light tan, biomicritic fine sandy grained, shell, gastropod, echinoid, & foram fragments, fairly soft to medium hardness.
383-387	Same as above, but harder, well indurated.
387	Same as above, fairly soft, fair induration
387'-395	Limestone, light tan, biomicritic, fine grained shell fragments
395-400	Limestone, light tan, hard, biomicritic, fine grained, shell fragments
4 -405	Limestone, light tan, hard to soft, biomicritic, fine grained, shell fragments. The soft limestone is sucrosic

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL TEST WELL 1A

Project Name WCRWSA Phase 1A

Date 4/23/86

Project Number 6006-45

Drilling Method Reverse Air

Hole Size 22"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
405-410	Limestone; tan to light brown, hard to soft fine grained, biomicritic with a large percentage of forams
410-420	Limestone, tan to brown, hard to medium hardness, fine grained, biomicritic with a large percentage of forams and shell fragments
..20-425	Dolomite, gray to dark brown, hard to medium hardness, fine grained, shell fragments
425-430	Dolomite, gray to brown, hard to medium hardness, fine grained, shell fragments. Also quite a bit of peat (dark black, medium hardness, thin bedded) Peat began to occur at 428'
430-435	Dolomite, tan to light brown, hard to medium hardness, fine grained, shell fragments and a great deal of peat until 433'
435-440	(Dolomitic) Limestone, tan, soft to medium hardness, fine grained, shell fragments with a small percentage of peat
44 -445	~~Dolomite~~ Limestone tan, hard, fine grained, shell fragments including echinoids, soft brown clay
445-450	Limestone, tan, medium hardness, fine grained shell fragments including forams and echinoid plates,

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GEOLOGIC LOG OF WELL Test Well 1A

Project Name WCRWSA Phase 1A

Date 4-24-86

Project Number 6006-45

Drilling Method Reverse air

Hole Size 22

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
450-457	Dolomite, gray, fine to medium grained, some fossil zones, peat flecks, soft, interlayered with dolomite mud and occasional thin peat bed.
457-462	Dolomite, tannish gray, fine to medium grained, some microfossils, peat flecks, medium soft toward top and medium hardness thereafter.
2 - 468	Dolomite, light grayish brown, biomicritic fine to medium grained, many forams, Dictyoconus cookei below 465.
468-471	Dolomite, foram coquina, unconsolidated to fair consolidation, Dictyoconus cookei
471-480	Same as above, better consolidated, medium to soft hardness.
480-484	Dolomitic Limestone, medium brown, fossiliferous moldaic porosity, medium hardness
484-486	Dolomitic limestone, foram coquina, poorly consolidated Dictyoconus cookei.
486-504	As above with harder layers, light brown, ~~very~~ hard layer at 489-490, thin layers peat and occasional thin layer barely consolidated carbonate mud.

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Test Well 1A

Project Name WCRWSA Phase 1A

Date 4-24-86

Project Number 6006-45

Drilling Method Reverse air

Hole Size 22"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
504 - 509	Limestone, light gray, very fine grained, fossil molds and impressions, hard; interlayered with Dolomitic limestone, coquinoid, largely forams, very soft to medium hard, occasional thin peat bed.
509 - 512.5	Limestone, light gray, fine to medium grained, medium to hard, fossiliferous zones
12.5 - 520	Dolomite, brown to gray brown, fine grained to medium sucrosic, vugy, medium hardness to hard. Some solutioning along joints & fractures
520 - 525	Dolomite, light brown to dark brown, hard, fine grained to medium sucrosic, some solutioning along joints and fractures
525 - 530	Dolomite, light brown to dark brown very hard, fine grained with quite a bit of solutioning in some areas.
530 - 535	Dolomite, light brown to brown, medium hardness to very hard, fine grained without much solutioning, vugy, more solutioning at 534'.
535 - 536	Cavity, solution riddled dolomite, orange-brown mud

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Test Well 1A

Project Name WCKWSA Phase 1A

Date 4-25-86

Project Number 6006-45

Drilling Method Reverse air

Hole Size 22"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
536-540	Dolomite, ~~dark~~ gray to brown, dense, fine grained to medium grained sucrosic, very hard, solution zones, ~~et~~ thin layers peat and dark brown mud.
540-550	Dolomite, gray to brown, fine to medium grained, honeycombed solution zones, with brown muddy water, Very hard to fairly soft in solution zones

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL Test Well 1A

Project Name WCRWSA 1A

Date 4-28-86

Project Number 6006-45

Drilling Method Reverse Air

Hole Size

Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
550-565	Dolomite, brown, fine to medium grained sucrosic, solution in some zones, medium hard
565-570	Dolomite, medium brown, medium grained sucrosic, vugy zones, occasional echinoid, hard to very hard.
570-573.5	Dolomite, brown, alternating fine grained and medium sucrosic, hard to very hard, very dense to vugy, some solutioning. small echinoid fossils
573.5-575	Dolomite, brown, medium grained sucrosic, solution riddled (honeycombed), brown muddy water
575-585	Dolomite, brown, fine grained dense very hard, interlayered with medium grained sucrosic, vugy to solution riddled, some layers with mud in voids, medium hardness. Soft zone (honeycombed) 583-584'
585-597	Dolomite, brown, fine grained, vugy, very hard to hard, some thin zones softer sucrosic dolomite
597-598	Dolomite, brown to dark brown, medium grained sucrosic, honeycombed, brown mud
598-599	Dolomite, brown fine grained, vugy, hard to very hard
599-608	Dolomite, gray to brown, fine grained dense, extremely hard, shows thin bedding and banding
608-609	Same as above, some vugy zones, more solutioning

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL TEST WELL 1A

Project Name WCRWSA Phase IA
Date 4/28/86
Project Number 6006-45
Drilling Method Reverse Air
Hole Size
Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
608'-615	Dolomite, Light brown to dark brown, hard, fine grained, a few recrystalized zones and very little solutioning
615'-620	same as above except they hit soft zone at 617'. The zone produced redish brown water
620'-625'	Dolomite, brown, hard, fine grained, little solutioning
25'-630'	Dolomite, brown to gray brown, hard, fine grained, sucrosic, some solutioning with redish water
630'-635'	Dolomite, light brown to ~~brown~~, hard to medium hardness, fine grained, hard gray clay
635'-640'	Dolomite, brown, very hard, fine grained
640'-645'	Dolomite, light brown to brown, very hard, fine grained
645'-650'	Dolomite, brown to dark brown, medium hardness to very hard, fine grained, recrystalized in places
650'-655'	Dolomite, Light brown to brown, very hard fine grained with very little solutioning
655'-660'	Dolomite, Light brown to dark brown, very hard to hard, fine grained

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL TEST WELL 1A

Project Name WCRWSA Phase 1A

Date 4/29/86

Project Number 6066-43

Drilling Method Reverse Air

Hole Size

Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
660'-664	Dolomite, medium brown to dark brown, very hard, fine grained with banding
664-667	Same as above
667-670	Dolomite, light gray and tan, very fine grained dense, very hard
670-670.5	Clay, dark gray, hard carbonat clay
70.5-674	Dolomite, Tan, fine grained, dense, little solutioning,
674-675	Dolomite, gray, fine grained, some vugs. and solutining, hard
675-677	Dolomite, gray to dark gray, fine grained, fossil molds of pelecypods and gastropods, moldic, hard to very hard.
677-682	Dolomite, gray, fine grained, moldic porosity, some solutioning along fractures. Very hard.
682-683	Dolomite, mottled dark brown and tan, fine grained, vugy, thin zones of honeycomb solutioning
683-690	Dolomite, tan to brown, fine grained, vugy, very hard.
690-693	Dolomite, Dark Brown to tan banded, fine grained, considerable solutioning along banding and fractures, hard to very hard.
693-700	Dolomite, gray to tan, fine grained to medium grained sucrosic with solution zones, hard to very hard.

DEEP MONITOR WELL IA+200

CAMP DRESSER & McKEE INC.

DMW-1A + 200

GEOLOGIC LOG OF WELL Phase 1A

Project Name WCRWSA Phase 1A

Date 4/9/86

Project Number 6006-43

Drilling Method Rotary mud

Hole Size 16"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
0-5'	Fine sand lt. gray
5-10'	Fine sand, lt gray with clay
10-15'	clayey sand, very fine grained, gray
15-20'	sandy clay, very fine, gray
20'-25'	sandy clay, gray, fine, almost plastic
25'-30'	sandy gray clay and green nodular pieces of clay with bits of biomicritic limestone

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GEOLOGIC LOG OF WELL DMW-1A+200'

Project Name WCRWSA Phase IA

Date 4/10/86

Project Number 6006-43

Drilling Method Rotary Mud

Hole Size ~~5"~~ 16"

Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
30'-35'	Limestone - medium hardness, white to Lt brown, fine grained with some green clay - Biomicritic limestone
35'-40'	Limestone - medium hardness white to tan, fine to medium grained with some green clay - Biomicritic limestone
40'-45'	Limestone - hard, tan, fine to medium grained, biomicritic with a great deal of green hydrated clay.
45'-50'	Limestone - medium hardness, ~~tan~~ white to Lt. brown, medium grained, biomicritic with less green clay.
50'-55'	limestone - hard to medium hardness, white to tan, fine grained, biomicritic, green clay is increasing again.
55'-60'	limestone - medium hardness, white to tan, fine grained, biomicritic with some green clay
60'-65'	Limestone, hard, white to tan with quite a bit of green clay (Limestone is biomicritic)
65'-70'	same as above only there is more green clay

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GEOLOGIC LOG OF WELL DMW+2001

Project Name WCRWSA Phase IA | Date 4/10/86

Project Number 6006-43 | Drilling Method Rotary Mud

Hole Size 16" | Sampling Method cuttings

Depth Interval Ft.	Geologic Description
70'-75'	Sandy Limestone, medium grained, medium hardness, some green clay, shell
75'-80'	sandy Limestone, medium grained, medium hardness, ~~gray~~ tan to gray with a large amount of green hydrated clay, shell
80'-88'	Sandy limestone, medium grained, soft to medium hardness, tan to gray with some clay (biomicritic limestone)
88'-90'	Limestone, tan to Lt. gray, medium hardness, biomicritic, shell fragments (primarily bivalves) (begin to notice salt & pepper)
90'-95'	Limestone, tan to Lt. gray, medium hardness, biomicritic, shell fragments
95'-100'	same as above only more green clay
100'-105'	Limestone, tan to Lt. gray, medium grained soft to medium hardness, biomicritic and increasing shell fragments
105'-110'	same as above accept less shell fragment
110'-115'	Limestone, tan to Lt. gray, medium hardness, fine grained, biomicritic, shell fragments

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GEOLOGIC LOG OF WELL DMW+200'

Project Name WCRWSA Phase IA

Date 4/10/86

Project Number 6006-43

Drilling Method Rotary Mud

Hole Size 16"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
115-121	Limestone; tan to Lt. gray medium hardness. fine grained, biomicritic, very little shell fragments
121-131	Limestone, same as above, many microfossils

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GEOLOGIC LOG OF WELL DW 1A + 200

Project Name WCRWSA Phase 1A
Date 4-14-86
Project Number 6006-43
Drilling Method Reverse Air
Hole Size 8"
Sampling Method cuttings

Depth Interval Ft.	Geologic Description
131-135	Limestone, light tan to gray, fine grained biomicritic, shell and microfossil fragments and casts, some secondary calcite deposition in voids. Considerable grout.
135-145	Same as above, medium hardness
145-150	Same as above, more shell, echinoid (?) fragments.
150-155	Same as above, medium hardness, some layers (thin) of microcrystalline limestone, gray, with shell and gastropod casts.
155-170	Limestone, light tan to occasional gray layer, fine grained biomicritic, shell, echinoid spines + plates, micro fossils, secondary calcite, medium hardness.
170-180'	Limestone, light tan - gray, biomicritic, shell, micro fossils, medium hardness
180'-190'	Limestone, light tan - gray, biomicritic, shell, micro fossils, medium hardness
190-195	Sandy limestone, tan-gray, soft shell fragments with hard thin layers of gray clay
195'-200'	Sandy limestone, tan-gray; soft, shell fragments with hard thin layers of dark gray clay

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GEOLOGIC LOG OF WELL DMW +200'

Project Name: WCRWSA Phase IA
Date: 4/14/86 - 4/15/86
Project Number: 6006-43
Drilling Method: ~~Roto~~ Reverse Air
Hole Size: $7\frac{7}{8}$"
Sampling Method: cuttings

Depth Interval Ft.	Geologic Description
200'-205	Sandy Limestone - Tan to gray, soft, medium grained, shell fragments with hard thin layers of dark gray clay
205'-210'	~~same as above~~ cavity
210'-215'	Sandy limestone - tan to gray, soft, medium grained, shell fragments, hard thin layers of dark gray clay
215'-220	sandy limestone - tan to gray, soft, medium grained, shell fragments. Limestone, white to tan, hard biomicritic, fine grained. Also thin hard layers of dark gray clay
220'-225'	Sandy Limestone - Lt gray, harder, medium grained, very few shell fragments and a very small amount of clay.
225'-230'	Sandy Limestone - Lt gray, soft, medium grained with a greater percentage of hard gray clay as well as shell fragments
230'-240'	Sandy Limestone - Lt gray, soft, medium grained with hard gray clay and shell fragments
240'-250'	Sandy Limestone - tan - Lt. gray, medium hardness, medium grained. Hard dark gray clay

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GEOLOGIC LOG OF WELL PMW+200'

Project Name WCRWSA Phase IA

Date 4/15/85

Project Number 6006-43

Drilling Method reverse air

Hole Size 7 7/8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
250'-255	Limestone - Lt gray, hard, fine grained slightly fossiliferous
255'-265'	Limestone - Lt gray, soft, fine grained slightly fossiliferous with a small amount of hard clay
265'-270	Limestone - Lt. gray, hard, medium grained
270'-275'	Limestone - tan to gray, hard, fine grained highly fossiliferous.
275'-290'	shell fragments, extremely fossiliferous zone (drilled very quickly)
290'-295'	same as above
295'-300'	Limestone - tan-gray, fine grained, medium hardness, very fossiliferous
300'-315	Limestone; tan to gray, fine grained, medium hardness, very fossiliferous with a little hard dark gray clay
315-320'	entirley shell fragments
320'-330'	same as above
330'-340'	shell fragments
340'-350'	Sandy Limestone - tan fine grained, soft

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GEOLOGIC LOG OF WELL DMW +2 rol

Project Name	WCRWSA Phase IA	Date	4/5/84
Project Number	6006-43	Drilling Method	Reverse Air
Hole Size	7 7/8"	Sampling Method	cuttings

Depth Interval Ft.	Geologic Description
	with shell fragments
350'-360	Limestone, white to tan, hard, fine grained with some shell fragments
360'-370'	Limestone, white to tan medium hardness, fine grained with a good deal of shell
370'-380	Sandy Limestone - tan, soft, medium grained with a lesser percentage of shell
380'-390'	Sandy Limestone with a good deal of shell. Limestone is tan, soft and medium grained
390'-395'	Limestone, tan, hard, fine grained with a moderate amount of shell fragments
395'-400'	Limestone, light brown, soft, fine to medium grained, shell fragments
400'-410'	Dolomite - tan to light brown, hard, medium grained with shell fragments
410-420	Dolomite - tan to dark brown, fairly hard to hard, interlayered, medium to fine grained, lighter colored fossil fragments (calcium carbonate?)

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GEOLOGIC LOG OF WELL DW 1A+200

Project Name WCRWSA Phase 1A
Date 4-15-86
Project Number 6006-43
Drilling Method reverse air
Hole Size 8"
Sampling Method cuttings

Depth Interval Ft.	Geologic Description
420-425	~~420-42~~ Dolomite, brown, fine grained sucrosic, flat black impressions (leaves?), medium hardness.
425-426	Limestone, tan, fossiliferrous (forams, shell) medium hardness
426-427	Peat, black, soft
427-435	Limestone, tan to medium brown, forams, gastropods, shell fragments, medium soft to medium hardness, with thin harder layers.
435-440	Dolomite, ~~Limestone~~ " brown to tan, fine grained, small carbonaceous inclusions, fairly soft
440-445	Limestone, tan, fine grained, biomicritic, with some brown lime mud,
445-467	Limestone, tan, fine grained biomicritic, forams, echinoid spines, medium hardness, some tan lime mud and peat (minor amount)
467-475	Coquina, foram & echinoid fragments, interlayered with lime mud and thin layers of limestone, tan fine grained biomicritic.
475-491	Coquina, foram, great many Dictyoconus cookei; more limestone layers, fossiliferrous, with depth, poorly to moderately consolidated

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL DW 1A + 200

Project Name WCRWSA Phase 1A

Date 4-15-86

Project Number 6006-43

Drilling Method Reverse air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
491 - 492.5	Limestone, tannish gray, very fine grained biomicritic, hard
492.5 - 501	Limestone, tan, and coquina, Dictyoconus cookei and other forams, Peronella dalli echinoids, poor to fairly good induration (soft to medium hardness).
501 - 503	Limestone, grayish tan, fine grained biomicritic hard
503 - 510	Limestone, tan, fine to medium grained biomicritic, forams, fairly soft to medium hardness
510 - 511	Limestone, gray and tan, very fine grained
511 - 512	Limestone, tan, fine to medium grained biomicritic with forams
512 - 515	Dolomite, Brown medium grained sucrosic, and brownish gray fine grained, interbedded
515 - 522	Dolomite, Brown, fine grained, some vugs (pores) fairly hard to hard.
522 - 535	Dolomite, as above, very hard, some fossil molds
535 - 536	Dolomite, brown, soft sucrosic, medium size grains (sandy)

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GEOLOGIC LOG OF WELL DW 1A + 200

Project Name WCRWSA Phase 1A

Date 4-15-86

Project Number 6006-43

Drilling Method Reverse Air

Hole Size 8"

Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
536-548	Dolomite, gray to brown, fine grained, hard with softer zones of brown medium grained sucrosic dolomite.
548'-555'	Dolomite, dark brown, fine grained, hard with shell fragments, Dolomite sand bottom 2 ft.
Lost circulation 555'-560'	Dolomite, light brown to dark brown, fine grained, hard with shell fragments
560'-565'	Dolomite, gray to dark brown, medium grained, hard with softer zones of brown medium grained sucrosic dolomite, shell fragments (echinoderms)
565'-570'	Dolomite, brown, medium grained, hard with softer zones of brown medium to coarse grained sucrosic dolomite, shell fragments.
570'-575'	Dolomite, brown, medium to coarse grained, hard with a small amount of peat, shell fragments
575-578	Dolomite, brown, fine grained, very hard, low porosity
578-583	Dolomite, brown, medium grained sucrosic, honeycombed (good porosity) alternating with Dolomite, brown, fine grained, very hard, low porosity.

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GEOLOGIC LOG OF WELL DW 1A + 200

Project Name WCRWSA Phase 1A
Date 4-16-86
Project Number 6006-43
Drilling Method Reverse air
Hole Size 8"
Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
583-593.5	Dolomite, fine to medium grained, very hard, solution pitting in some places, occasional fossil mold.
593.5-595.5	Dolomite, dark brown, medium grained, solution pitting (honeycombed) in some places, may have larger cavities as it drilled fast.
595.5-600	Dolomite, brown, fine grained, very hard, solution along fractures in a few cuttings, otherwise dense.
600-601	Dolomite, dark gray, lavender & brown banding, fine grained, very dense & hard (Note Interval may be off 5ft.)
602-603	Dolomite, brown to light brown, fine grained, dense and very hard.
603-606	Dolomite, dark brown, completely honeycombed and dolomite sand, medium grained, water turned dark brown, plugged bit temporarily.
606-610	Dolomite, gray to brown, fine grained dense, very hard
610-619	Dolomite, brown, fine grained dense, solutioning along and in vicinity of fractures, very hard.
619-621	Dolomite, reddish brown, completely honeycombed, medium grained

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GEOLOGIC LOG OF WELL DW 1A + 200

Project Name WCRWSA Phase 1A
Date 4-16-86
Project Number 6006-43
Drilling Method Reverse Air
Hole Size 8"
Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
621 - 626	Dolomite, brown, fine grained dense and very hard, some solution, very small amount of gray chert.
626 - 630.5	Dolomite, brown, medium grained sucrosic, friable, honeycombed in places, drills easy
630.5 - 631	Void, mud and organics causes water to turn brown.
631 - 638	Dolomite, gray brown + dark brown, fine to medium grained, highly variable solutioning, medium hard to extremely hard
638 - 640.5	Dolomite, brown, medium grained sucrosic, honeycombed fairly soft to soft, brown colored water
640.5 - 645	Dolomite, brown, fine grained hard to medium grained sucrosic with solutioning, brown colored water in the areas with solutioning (fine mud & organic accumulation?)
645' - 650'	Dolomite, gray brown + dark brown, fine to medium grained, very hard to medium hardness, sucrosic texture with some solutioning
650' - 655'	Dolomite, brown, fine grained, hard, some solutioning

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GEOLOGIC LOG OF WELL DMW +200'

Project Name WCRWSA Phase IA

Date 4/14/86

Project Number 6006-43

Drilling Method Reverse Air

Hole Size 8"

Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
655'-660'	Dolomite, Lt brown to dark brown, fine to medium grained, hard, some solutioning.
660'-665'	Dolomite, brown, fine to medium grained, hard, some solutioning. A pasty limey gray clay layer around 663'
665'-671'	Dolomite, gray to light brown, fine to medium grained, hard, a very small degree of solutioning
671'-675	Dolomite, brown, fine grained, hard, very little solutioning
675-681	Dolomite, gray to brown, fine grained to medium grained, hard, very little solutioning except in vicinity of fractures.
681-682	Dolomite, dark brown, medium grained, considerable solutioning
682-686	Dolomite, tan, fine grained, hard to very hard with solution zones. Thin zones of darker, coarser grained dolomite
686-697	Dolomite, gray, very fine grained, hard, fossil molds and casts (pores), forams, gastropods, & shell, variable solutioning inter bedded with darker, coarser grained dolomite

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GEOLOGIC LOG OF WELL DMW +2001

Project Name WCR WSA Phase IA

Date 4/17/86

Project Number 6006-43

Drilling Method Reverse air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
697-698	Void, dark brown dolomite silt and organics, solution riddled dolomite
698-704	Dolomite, gray to dark gray, very fine grained, hard, very little solutioning

DEEP MONITOR WELL IA+500

CAMP DRESSER & McKEE INC.

GEOLOGIC LOG OF WELL DMW 1A+500

Project Name WCRWSA Phase 1A +500 Date 3-11-86

Project Number 6006-43 Drilling Method Rotary Mud

Hole Size 15 3/4" Sampling Method mud cuttings

Depth Interval Ft.	Geologic Description
0 - 7'	sand, white, fine to medium clear grained moderately rounded, slight amount of heavy minerals
7-10'	sand, fine to medium grain, light gray clayey
10-25'	sand mostly fine to medium grain, light bluish gray clayey, soft and sticky
25-28'	clay, bluish gray and tan, translucent (waxy) slightly sandy, fairly firm and sticky, cracks as it dries
28-30	limestone, hard tan micritic fine grained

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GEOLOGIC LOG OF WELL DW-1A+500

Project Name WCRWSA

Project Number Test well Phase IA +500 6006-43

Hole Size 16"

Date 3-11-86

Drilling Method Rotary Mud

Sampling Method Mud Cuttings

Depth Interval Ft.	Geologic Description
30-32'	Limestone - Fine grained, sandy white - Lt brown
32-34'	Limestone - Fine grained, sandy white - tan
34-40'	Limestone - fine-grained, sandy white - tan
40'-45'	Limestone - soft Fine grained chalky white
45-50'	Limestone - soft fine grained sandy white, very small amount of greenish clay
50'-55'	Limestone - hard fine grained sandy, white, small amount of greenish clay
55-60'	Limestone - hard fine grained sandy white, lenses of green clay
60-65'	Limestone - hard fine grained tan interbedded with green clay
65'-70'	Limestone - hard fine grained tan interbedded with green clay
70-75'	Limestone - hard fine grained tan interbedded with green clay

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GEOLOGIC LOG OF WELL DW-1A+500

Project Name WCRWSA Phase 1A+500

Date 3-13-86

Project Number 6096-43

Drilling Method rotary mud

Hole Size 15 3/4"

Sampling Method mud cuttings

Depth Interval Ft.	Geologic Description
75-80	limestone, light gray to tannish, medium hardness, fine grained biomicritic, with a little soft gray clay
80-90	limestone, light gray, medium hardness, fine grained biomicritic, with shell fragments
90-92	Same
92-95	limestone, light tan to gray, hard, biomicritic fine grained with shell fragments
95-100	same as above with some soft gray clay
100-110	limestone, light tan, fairly hard, biomicritic fine grained with shell fragments, slight amount gray soft clay
110-112	same as above, no clay
112-117	same as above, very hard, fine black specks
117-135	limestone, gray, firm to hard, biomicritic, fine grained, shell fragments
135-145	limestone, gray to light tan, medium hardness biomicritic, fine grained, shell fragments & small shells
Lost Circulation 145-151	Same as above

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GEOLOGIC LOG OF WELL DW 1A + 500

Project Name: WCRWSA

Date: 3-18-86

Project Number: Test Well Phase IA 6026-13

Drilling Method: mud rotary

Hole Size: 8

Sampling Method: mud cutting

Depth Interval Ft.	Geologic Description
151-60	same as above
160-70	Limestone - gray to light tan, medium hardness, fine grained - a small amount of green hard clay
170-82	Lost circulation

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GEOLOGIC LOG OF WELL DW 1A+500

Project Name WCRWSA Phase 1A
Date 3-19-86
Project Number 6006-43
Drilling Method Reverse Air
Hole Size 8"
Sampling Method cuttings

Depth Interval Ft.	Geologic Description
172-174	Limestone, gray to tan, fine grained biomicritic, medium Hard fossil fragments, spary calcite matrix
175-176	clay, green translucent, soft
176-180	Limestone, tan, fine grained biomicritic, medium hard, fossil fragments
180-185	Sand, Calcium carbonate, fine to medium grain a little clay, green translucent, soft - zone producing water
185-186.5	Limestone, tannish gray, fine grained biomicritic, medium hardness, shell fragments
186.5-190	Limestone, gray, only fair cementation of small to medium size sand like grains. Becoming more indurated with depth to medium hard. More tan in color.
190-195	Limestone as above, interlayered with clayey lime sand, tan, fine grained, firm, slightly sticky. Also few chunks dark gray grout falling in.
195-200	Limestone, fairly indurated, tan, fine to med. sand size grains, orange recrystalized oyster shells, very small amount brown and white clay (thin layers)
200-218	Limestone, tan, friable, fine to medium sand size grains, shell fragments, some thin harder layers

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GEOLOGIC LOG OF WELL DW 1A+500

Project Name

Project Number

Hole Size

Date

Drilling Method

Sampling Method

Depth Interval Ft.	Geologic Description
218-223	Limestone, tan, well indurated, biomicritic, intergrain spaces filled with clear calcite
223-228	Limestone, light brown, poorly indurated medium to course sand size grains, ground up shell. better indurated (fair) thin layers. a few thin layers of clayey carbonate sand.
228-228.5	marl, white calcium carbonate mud
228.5-230	Limestone, light brown to light gray, biomicritic well indurated, very little primary porosity.
230-235	Limestone, light brown, poorly to well indurated layers, grainy, oyster fragments

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GEOLOGIC LOG OF WELL DW 1A +500 / +500 deep observ.

Project Name WCRWSA Phase 1A

Date 3-20-86

Project Number 6506-43

Drilling Method reverse air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
235-245	Limestone lt. brown to gray, small to medium grainy, numerous shell fragments, medium induration, biomicritic
245-275	Limestone mostly tan to gray, biomicritic fine to medium grained, fair to medium induration, shell (large flat discoid forams?) gastropod fragments
275-277	Limestone, tan to lt brown, biomicritic grain, fair induration, large percent large discoid forams, thicker
277-280	Coquina, large discoid forams and shell fragment, unconsolidated sand to gravel.
280-286	Limestone, tan, biomicritic grainy, over 50% discoid forams & shell, poor to fair induration
286-300	Limestone, as above better induration (fair to medium)
300-315	Limestone, tan biomicritic, grainy, poor to medium indurated, less forams and shell than above, large flat bent forams abundant below 308
315-335	Coquina, large discoid forams and shell, orangish tan
335-340	Same as above with layers of limestone, biomicritic poorly to fairly well indurated. Still many forams.
340-360	Limestone, tan, biomicritic, small to to medium grained many forams and shell fragments, mostly well indurated occasional thin layer white carbonate mud, softer at 350'

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GEOLOGIC LOG OF WELL DW 1A+500

Project Name WCRWSA Phase IA
Date 3-24-86
Project Number 6006-43
Drilling Method Reverse Air
Hole Size 8"
Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
360-380	Limestone, tan, biomicritic, grainy, fairly well indurated, Camerinidae forams
380-384	Limestone, light brown to gray, biomicritic with sparry matrix, well indurated, Camerinidae
384-391	Limestone, dark to light brown, biomicritic with sparry calcite, fossiliferous, Hard to medium layers about 6 inches thick, Cone shaped forams (Dictyoconus cookei). Camerinidae & Some Lepidocylina may have washed down from above.
391-399.5	Limestone, light to dark brown, biomicritic fossiferous, Dictyoconus cookei, echinoid spines fragments
399.5-400	Cavity Black silt (organic?) in bottom.
400-425	Limestone, brown, and dolomite, hard, fewer Dictyoconus below 405' Some black staining.
425-429	Dolomite, dark brown, fine textured, fractured, minor calcite, some small vugs, hard drilling but only moderately cemented, sucrosic.
429-439	Limestone, tan to brown, biomicritic fine grained, fossilferous, with thin layers of lime mud, Camerinidae type forams mostly fairly soft; minor peat
439-444	Dolomite, dark brown, fine grained, moderately cemented, friable

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GEOLOGIC LOG OF WELL DW 1A+500

Project Name WCRWSA Phase IA

Date 3-24-86

Project Number 6006-43

Drilling Method Reverse Air

Hole Size 8"

Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
444-455	Limestone, tan, soft biomicritic, Dictyoconus cookie?, small amount lime mud and peat
455-457	Dolomite, Dark brown, sucrosic fine grained, moderately cemented
457-460	Clay, light brown, calcareous (Lime mud), slight peat
460-469	Limestone, tan, fine grained, slightly indurated (very soft)
469-485	Coquina, tan foram (Dictyoconus cookei and Camerinidae type) with some clay layers, Periarchus dalli (small echinoid) slightly to moderately consolidated
485-510	Limestone, tan biomicritic fine grained, fair to good induration (soft to accasional hard drilling)
510-515	Dolomite, Brown, fine grained sucrosic, moderate porosity, hard to very hard
515-523	Dolomite, as above, very fine grained, very hard

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GEOLOGIC LOG OF WELL DW 1A+500 Phase 1A

Project Name WCA WSA Phase 1A

Date 3/25/86

Project Number 6006-43

Drilling Method Reverse Air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
520'-530'	Dolomite - dark brown, fine grained with light green hydrated clay
530'-535'	~~Sandstone~~ - tan to brown, fine grained with light green hydrated clay.
533'-535'	Dolomite - dark brown, fine grained
535'-540'	same as above
40'-545'	Dolomite - dark brown coarser grained interbedded with sandstone which is tan to light brown, fine grained. There is a small amount of hydrated clay in the sandstone.
545'-550'	Dolomite - dark brown fine grained with sandstone - tan with calcitic cement and a small amount of hydrated clay
550'-560'	same as above (except for an increase in fossils in the dolomite. Perhaps its Lepidocylina Ocalana).
560-570	Dolomite - coarse grained, dark brown fossiliferous, interbedded with

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GEOLOGIC LOG OF WELL DW 1A+500 Phase 1A

Project Name WCRWSA Phase IA

Date 3/25/86

Project Number 6006-47

Drilling Method Reverse Air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
	– a small sandstone lense fine grained tan poorly cemented with calcite occuring at 567'
570'–575'	Dolomite – fossiliferous, dark brown coarse grained
575–580'	Dolomite – dark brown, fossiliferous, coarse grained with black thin bedded peat near 580'
580'–585'	Dolomite – dark brown fossiliferous coarse grained with a small lense of tan limestone near 585'
585'–590'	Dolomite – medium brown to dark brown, coarse grained, fossiliferous with another thin black peat layer occuring at 590'
590–595	Dolomite – medium brown to dark brown with black lenses of organic material in places, coarse grained fossiliferous
595–600	Dolomite – medium brown to

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GEOLOGIC LOG OF WELL DW 1A+500 Phase 1A

Project Name WCR WSA Phase 1A

Date 3/25/86

Project Number 6006-43

Drilling Method Reverse Air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
	dark brown, very weathered in places. fossiliferous, coarse grained
600'-605'	Dolomite - medium brown to dark brown fossiliferous, coarse grained Recrystalized in some areas
600'-610'	Dolomite - medium to dark brown, fossiliferous, coarse grained. Some areas are recrystalized
610'-615	Dolomite medium to dark brown fossiliferous (echinoderms) coarse grained
615'-620'	sam as above
620'-625'	Dolomite - medium to dark brown very fossiliferous to non-fossiliferous coarse grained. Distinct zones of solutioning and recrystalization
625' 630'	Dolomite - medium to dark brown fossiliferous coarse grained
630'-635	Truck gave out at 631

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GEOLOGIC LOG OF WELL DW 1A+500 Phase 1A

Project Name WCRWSA Regional Intercon. Date 4/2/86
Project Number Test Well Phase 1A 6006-13 Drilling Method Reverse Air
Hole Size 8" Sampling Method cuttings

Depth Interval Ft.	Geologic Description
631 - 640'	Dolomite - Dark brown to light brown coarse grained, fossiliferous (moderately). Two distinct textures of dolomite present. One is weathered (experienced solutioning) and the other is dense and unaltered. There is a greater percentage of dense unaltered dolomite than weathered dolomite
640' - 645'	Dolomite - Dark brown to tan, coarse grained, slightly fossiliferous. Two textures present; a thin bed of hard gray to green clay at 643'. Some recrystalized areas.
645' - 650'	Dolomite - very Dark brown to light brown, coarse grained, moderately fossiliferous. A greater percentage of unweathered rock than weathered rock
650' - 655'	Dolomite - Dark brown to tan, coarse grained moderately to highly fossiliferous. Quite a bit of recrystalized material

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DW 1A+500

GEOLOGIC LOG OF WELL Phase 1A

Project Name WCRWSA

Project Number Test Well Phase 1A 6006-43

Hole Size 8"

Date April 2 1986

Drilling Method reverse air

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
	at 652'. The recrystalized layer was followed by a thin peat layer. At 653' the dark black peat changed to a tan dolomite.
655'-660'	Dolomite - Dark brown to tan, coarse grained, slightly fossiliferous. A small amount of muck and recrystalized material. Two distinc textures still present
660'	Engine over heated. stopped drilling 11:45
660'-665'	Dolomite - Light brown to tan, coarse grained, slightly fossiliferous. Hardly any solutioning of the formation.
665'-670'	same as above
670'-680'	Dolomite Dark brown to light brown medium to coarse grained, moderately fossiliferous. Very little solutioning
680'-690'	Dolomite, Dark brown to light brown, coarse grained, moderately to highly fossilferous. A greater degree of solutioning

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GEOLOGIC LOG OF WELL DW 1A+500 Phase 1A

Project Name WCRWSA

Date April 2 1986

Project Number Test Well Phase 1A 6006-43

Drilling Method reverse Air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
690'-700'	-Dolomite medium brown to light brown, coarse grained, Very fossiliferous to non-fossiliferous.
	-Dolomite light green to gray, coarse grained, moderately fossiliferous.
	-Very little solutioning in either Dolomite.
700'-704'	-Dolomite - Light green to gray, coarse grained slightly fossiliferous.
	-Peat bed preceded by a layer of muck.
	-Dolomite - tan, coarse grained, slightly fossiliferous

DEEP MONITOR WELL IA+1950

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GEOLOGIC LOG OF WELL DMW + 19501

Project Name WCRWSA Phase-1A

Date 5/17/86

Project Number 6006-45

Drilling Method Mud rotary

Hole Size 16"

Sampling Method Mud cuttings

Depth Interval Ft.	Geologic Description
0-5'	Sand, fine to very fine, light gray to brown, organic matter
5'-20'	Sand, slightly clayey to clayey, fine grain quartz, light gray to white.

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GEOLOGIC LOG OF WELL DWW + 1950'

Project Name WCR WSA - Phase IA
Date 5/19/86
Project Number 6006-45
Drilling Method Mud Rotary
Hole Size 16"
Sampling Method Mud cuttings

Depth Interval Ft.	Geologic Description
20'-35'	Limestone, very fine grained, buff to white, hard interlayered with clay, white, soft, also some green to yellow sandy clay
35'-42'	Limestone - tan to white, fine grained, very hard, some thin layers of clay, white, soft.
42'-50'	clay, gray, soft with stringers of limestone as above
50'-55'	Limestone, fine grainy, buff, medium soft
55'-62'	Coquina, shell fragments, lightly cemented with some solutioning and secondary calcite
62'-65'	same as above, some soft peat and mud, loosing circulation
65-70'	Limestone - tan to white, fine grained, very hard, shell fragments, secondary calcite
70'-80'	same as above
80'-85'	Limestone - tan to gray, fine grained, medium hardness shell fragments with small amounts of gray clay
85'-90'	Limestone - tan to gray, fine grained, medium hardness, shell fragments (it is difficult to tell what the returns are because of poor circulation)

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GEOLOGIC LOG OF WELL DMW + 1950'

Project Name WCRWSA - Phase IA

Date 5/20/86

Project Number 6006-45

Drilling Method Rotary Mud

Hole Size 16"

Sampling Method mud cuttings

Depth Interval Ft.	Geologic Description
90' - 130'	Loss of circulation, Limestone, hard from 109 to 118, medium in hardness otherwise
130' - 150'	no samples.

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GEOLOGIC LOG OF WELL DMW+1950'

Project Name WCRWSA Phase IA

Date 5/21/86

Project Number 6606-46

Drilling Method Reverse Air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
150'-160'	Limestone, tan to gray, fine grained, medium hardness
160'-165'	Limestone, tan to light gray, fine grained medium hardness with a small percentage of hard dark gray clay
165'-170'	Limestone, tan to light gray, fine grained, medium hardness to soft, echinoid plates and stems with a greater percentage of hard dark gray clay.
170'-175'	Limestone - light gray, fine grained, medium hardness, a small amount of shell with even a greater percentage of hard dark gray clay
175'-180	Limestone - buff to tan, fine grained, medium hardness to very hard with a small amount of hard dark gray clay.
180-185	Limestone - buff to tan, fine grained, medium hardness with thin layers of hard dark gray clay and peat
185-190	Limestone - buff to tan, fine grained; hard to medium hardness with the zones of soft light gray clay and hard dark gray clay
190'-195'	same as above

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GEOLOGIC LOG OF WELL DMW 1A+1950

Project Name WCRWSA - Phase-1A Date 5/21/86

Project Number 6006-46 Drilling Method Reverse Air

Hole Size 8" Sampling Method cuttings

Depth Interval Ft.	Geologic Description
195' - 200'	Limestone - Tan to buff, fine grained, medium hardness to hard, shell fragments with a small amount of hard dark gray clay
200' - 205'	Limestone - Tan to light gray, fine grained, medium hardness to hard with hard dark gray clay
205' - 213'	Same as above
213' - 220	Limestone - tan, fine grained, medium hardness and a small percentage of shell fragments
220' - 230	Limestone - tan to light gray, fine grained, medium hardness to soft
230 - 235	same as above
235 - 243	Limestone - tan to light gray, fine grained, loosely cemented, soft
243 - 255	Same as above
255 - 283	All forams, 100% shell, drilling very fast
283 - 303	Limestone - tan, fine grained, soft, loosely cemented, a very large percentage of shell fragments (forams, echinoids etc...)
303 - 310	Limestone tan, fine grained, soft, loosely cemented, fossiliferous

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GEOLOGIC LOG OF WELL DMW 1A+1950

Project Name WCRWSA

Date 5-22-86

Project Number 6006-46

Drilling Method reverse air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
310'-320'	Primarily forams and echinoderms, drilling quickly
320'-333'	same as above only a smaller percentage of echinoderms
333'-345'	Limestone, tan, fine grained, soft to medium hardness, very fossiliferous
345'-355	Limestone, tan, fine grained, soft to medium hardness, some shell fragments
355'-366'	same as above
366'-380'	Limestone, tan, fine to medium grained, medium hardness, some shell fragments (penetration rate slowing down)
380'-385'	Limestone, tan, fine to medium grained, medium hardness, very fossiliferous
385'-390'	Limestone, light brown to tan, fine to medium grained, hard to medium hardness, fossiliferous
~~396'-410~~	~~Limestone, light gray to tan, fine to medium grained~~, medium hardness interlayered with ~~coquina, foram, very soft, Camerinidae type.~~
~~410'-420~~	~~Same as above~~, occasional gray ~~chert(?), echinoid spine~~

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GEOLOGIC LOG OF WELL DMW 1A + 1950

Project Name WCRWSA Phase 1A

Date 5-22-86

Project Number 6006-46

Drilling Method reverse air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
390' - 394'	Limestone, tan biomicritic cemented foram and shell fragments, solutioning (molds) and secondary calcite cement, medium hardness, interlayered with coquina Dictyoconus cookei and Camerinidae type forams.
394' - 400'	Limestone, tan biomicritic, fine grained as well as forams and shell fragments, secondary calcite cement and Camerinidae type forams
400' - 405'	Limestone, tan biomicritic, fine grained, also containing cemented forams and shell fragments, forams of Camerinidae type and a small amount of hard gray clay, some solutioning
405' - 410'	Limestone, tan biomicritic (same as above
410' - 415'	Limestone, tan to light gray, fine grained with forams and shell fragments cemented together, medium hardness, solutioning (molds).
415' - 433'	Same as above
433' - 440'	Dolomite, fine grained, tan to light brown, medium hardness to hard, many forams

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GEOLOGIC LOG OF WELL DMW-1A + 1950'

Project Name	WCRWSA - Phase-1A
Date	5/22/86
Project Number	6006-46
Drilling Method	Reverse Air
Hole Size	8"
Sampling Method	cuttings

Depth Interval Ft.	Geologic Description
~~470'~~ 440' - ~~475'~~ 445'	Dolomite, tan, fine grained, medium hardness to hard, loosely cemented in some zones, shell fragments, Hard dark gray clay
~~475'~~ 445' - ~~480'~~ 450'	Same as above
~~480'~~ 450' - ~~485'~~ 455'	Dolomite, tan to brown, fine grained, medium hardness to soft, shell fragments, very little solutioning
~~485'~~ 455' - ~~493'~~ 463'	Dolomite, buff to tan, fine grained, medium hardness to soft, shell fragments
~~493'~~ 463' - ~~505'~~ 475'	Dolomite, light brown, sucrosic, hard with solutioning
~~505~~ 475 - ~~515~~ 485	Dolomite, tan, fine grained, medium hardness to hard, very little solutioning
~~515~~ 485 - ~~523'~~ 493'	Dolomite, tan, fine grained, medium hardness to hard.
~~523'~~ 493' - ~~535'~~ 505'	Dolomite, tan, fine grained, medium hardness, very little solutioning
~~535'~~ 505' - ~~545~~ 515	Dolomite, tan, fine grained, hard, very little solutioning, shell fragments incorporated into rock.
~~545~~ 515 - ~~553'~~ 523'	Dolomite, dark brown, fine grained, very hard, little solutioning, a small amount of shell

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GEOLOGIC LOG OF WELL DMW 1A+1950

Project Name WCRWSA - Phase-1A
Project Number 6006-46
Hole Size 8"

Date 5/23/86
Drilling Method Reverse Air
Sampling Method Cuttings

Depth Interval Ft.	Geologic Description
523 - 535	Dolomite, tan to brown, fine grained, medium hardness to hard, some solutioning
535 - 540	Dolomite, tan to dark brown, fine grained, medium hardness, solutioning, zones of thin bedded dolomite
540 - 550	Dolomite, brown to dark brown, fine grained to sucrosic, medium hardness, a little solutioning, dolomite is thin bedded in zones
550 - 555	Dolomite, brown, fine grained, hard, more solutioning interbedded with gray chert?
555 - 561	Limestone, gray, medium, grainy, biomicritic medium hardness
561 - 570	Dolomite, brown, fine grained to medium sucrosic vugy, some solutioning, medium hard.
570 - 573	Limestone, gray, medium grained, recrystallized biomicritic, medium hardness.
573- 490	Dolomite, brown, fine grained to medium sucrosic, vugy, occasional small echinoid, medium to hard
490 - 595	Dolomite, tan, fine grained, hard to very hard
595- 600	Dolomite, brown, fine grained, hard to very hard

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GEOLOGIC LOG OF WELL DMW 1A+1950

Project Name WCRWSA Phase 1A

Date 5-23-86

Project Number 6006-46

Drilling Method reverse air

Hole Size 8"

Sampling Method cuttings

Depth Interval Ft.	Geologic Description
600 - 611	Dolomite, brown to gray, dense fine grained, very hard, a few small vugs.
611 - 612	Cavity filled with brown mud, solution pitting adjacent to cavity
612 - 615	Dolomite, brown, fine to medium grained sucrosic, medium hard in solution zones to very hard
5 - 647	Dolomite, brown, dense fine grained to medium grained sucrosic with solution zones, very hard except in solution riddled zones.
647 - 648.5	Dolomite, brown to tan, banded, dense very fine grained, very hard
648.5 - 649.5	Dolomite, brown to dark brown, fine to medium grained, honeycombed (solution), medium hardness
649.5 - 657	Dolomite, tan to dark brown to dark gray, very fine grained, solution in vicinity of fractures, extremely hard
657 - 660	Dolomite, fine grained tan brechia (fractured dolostone) surrounded by dark brown vuggy matrix, very hard
660 - 670	Dolomite, gray to tan, fine grained, dense, very hard, solutioning along fractures.

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GEOLOGIC LOG OF WELL DMW + 19501

Project Name: WCRWSA Phase IA
Date: 5/23/86
Project Number: 6006-46
Drilling Method: Reverse Air
Hole Size: 8"
Sampling Method: cuttings

Depth Interval Ft.	Geologic Description
670' 675'	Dolomite, grayish brown, fine grained, very hard, solutioning along fractures
675 - 685	same as above accept for an increase in tan breccia surrounded by dark vugy matrix
685' - 690'	Dolomite, grayish brown, fine grained, very hard, solutioning along fractures
690' - 695'	Dolomite, brown, fine grained, very hard, solutioning along fractures
695 - 705'	Dolomite, brown to light brown, fine grained, very hard, solutioning along fractures

LITHOLOGIC LOGS OF SHALLOW BORINGS

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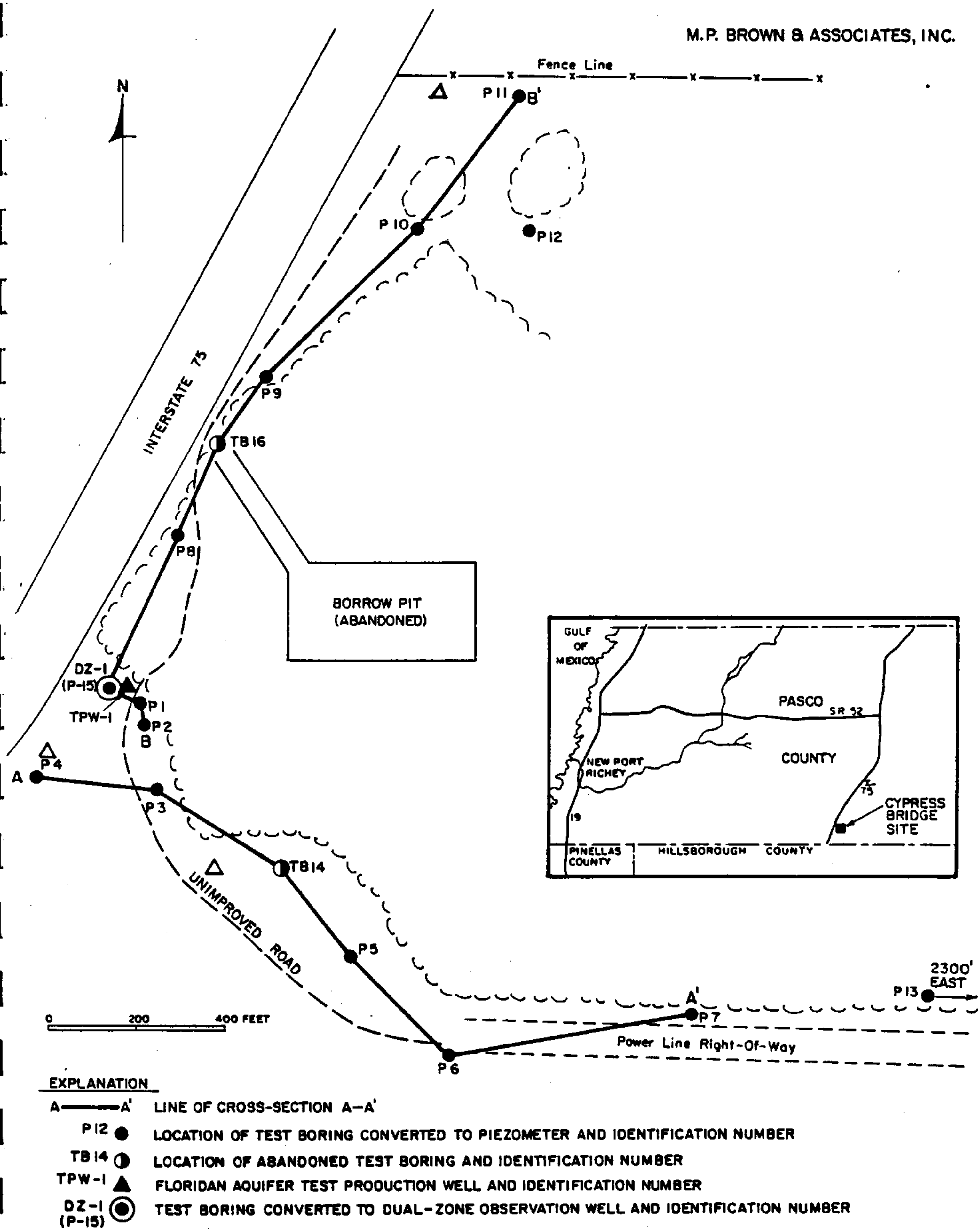

FIGURE 1. Location of Study Area, Dual-Zone Observation Wells, Piezometers, Borings, and Lines of Cross Sections,

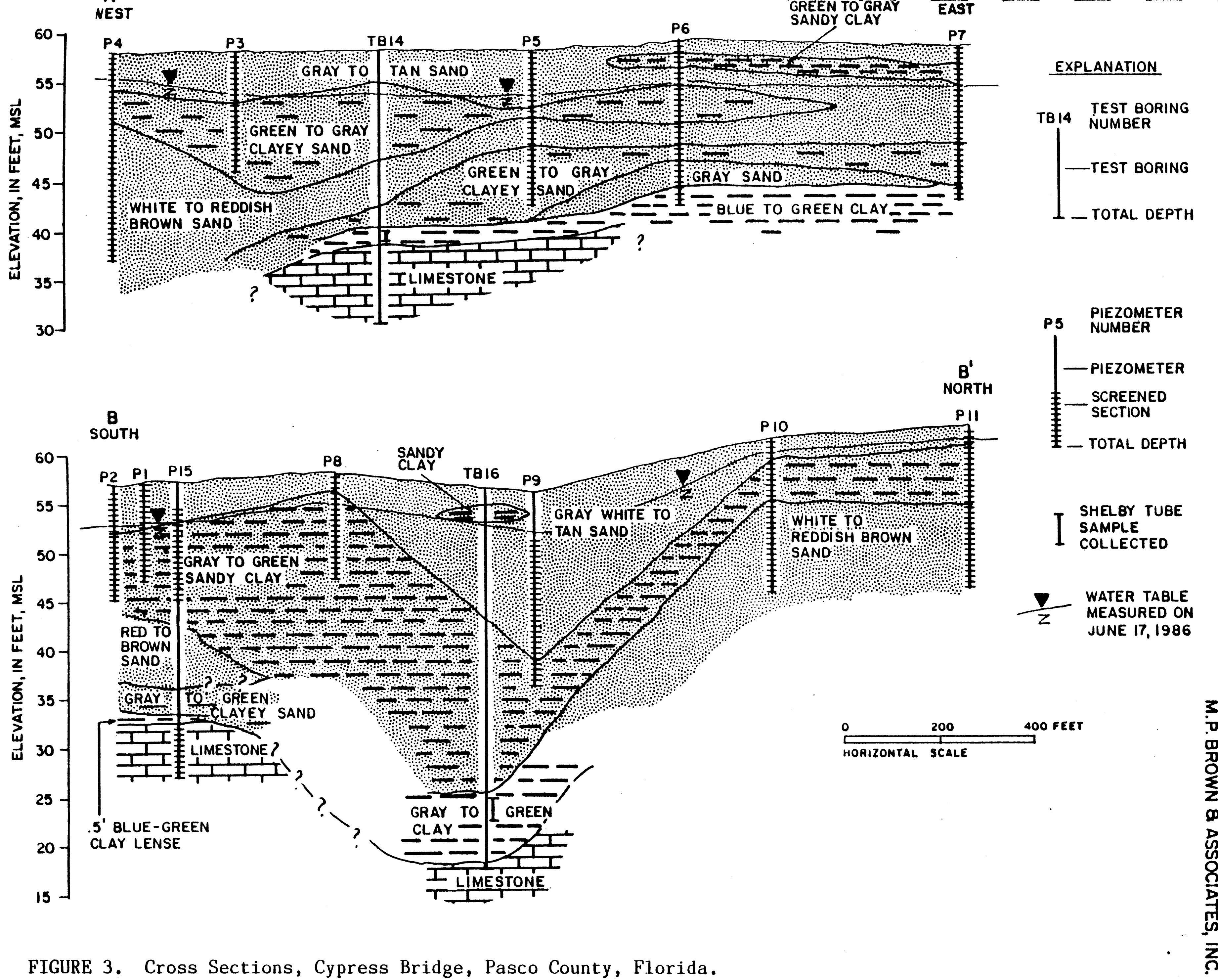

FIGURE 3. Cross Sections, Cypress Bridge, Pasco County, Florida.

Lithologic Log of Piezometer P-1

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 1.0	Sand, quartz, dark gray to black, very fine grained, angular, well sorted, silty, organics.	1.0
1.0 - 2.5	Sand, quartz, light gray with dark brown inclusions, fine grained, angular, well sorted.	1.5
2.5 - 3.5	Sand, quartz, red to brown, fine grained, angular, well sorted.	1.0
3.5 - 4.0	Sandy clay, red to brown, iron stained, cohesive, somewhat plastic, ductile.	0.5
4.0 - 5.0	Sandy clay, light gray, iron stained, cohesive, ductile, plastic; Limestone, light green, sand included, pebble sized.	1.0
5.0 - 8.5	Clayey sand, quartz, light gray, fine grained, angular to subangular, slightly cohesive.	3.5
8.5 - 10.0	Sandy clay, light gray, cohesive, ductile, plastic, stiff.	1.5

Lithologic Log of Piezometer P-2

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 2.0	Sand, quartz, light gray, fine grained, angular, organics.	2.0
2.0 - 3.0	Sand, quartz, dark brown to black, very fine grained, angular, silty.	1.0
3.0 - 5.0	Sand, quartz, tan, fine to medium grained, angular, silty.	2.0
5.0 - 8.5	Sandy clay, gray to green, cohesive, ductile, plastic, micaeous.	3.5
8.5 - 10.0	Clayey sand, quartz, light gray to green, fine grained, angular.	1.5
10.0 - 12.0	Sandy clay, gray to green, cohesive, ductile, plastic, mottled.	2.0

Lithologic Log of Piezometer P-3

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 0.5	Root zone, sand, quartz, dark gray to black, very fine grained, angular, silty, organics.	0.5
0.5 - 2.0	Sand, quartz, light gray, fine grained, angular, well sorted.	1.5
2.0 - 3.0	Sand, quartz, dark brown to black, very fine grained, angular, silty, organics.	1.0
3.0 - 5.0	Sand, quartz, tan, fine to medium grained, subangular, well sorted.	2.0
5.0 - 6.5	Sandy clay, gray, iron stained, cohesive, ductile, plastic.	1.5
6.5 - 10.0	Clayey sand, quartz, light green to white, fine grained, subangular.	3.5
10.0 - 12.0	Sandy clay, gray to green, cohesive, ductile, plastic, micaeous.	2.0

Lithologic Log of Piezometer P-4

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 0.5	Root zone, sand, quartz, very fine grained, angular, silty, organics.	0.5
0.5 - 3.0	Sand, quartz, light gray, fine grained, angular, well sorted.	2.5
3.0 - 4.0	Sand, quartz, light brown to tan, fine grained, angular to subangular, well sorted.	1.0
4.0 - 4.5	Clayey sand, quartz, red to brown, fine grained, angular, slightly cohesive.	0.5
4.5 - 6.0	Sandy clay, light gray, cohesive, ductile, plastic, iron stained.	1.5
6.0 - 12.5	Sand, quartz, white, fine grained, angular to subangular, well sorted.	6.5
12.5 - 21.0	Sand, quartz, red to brown, fine grained, angular, silty.	8.5

Lithologic Log of Piezometer P-5

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 0.5	Root zone, sand, quartz, very fine grained, angular, silty, organics.	0.5
0.5 - 5.0	Sand, quartz, dark brown to black, very fine grained, angular, silty, organics.	4.5
5.0 - 6.5	Sand, quartz, tan, fine to medium grained, subangular, well sorted.	1.5
6.5 - 7.0	Clayey sand, quartz, light gray, fine grained, subangular.	0.5
7.0 - 10.0	Sand, quartz, white, fine to medium grained, subangular to subrounded.	3.0
10.0 - 16.0	Sandy clay, light green to gray, cohesive, ductile, plastic.	6.0

Lithologic Log of Piezometer P-6

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 0.5	Root zone, sand, quartz, very fine grained, angular, silty, organics.	0.5
0.5 - 1.0	Sand, quartz, dark reddish brown, very fine grained, angular, well sorted.	0.5
1.0 - 1.5	Sand, quartz, biege, fine grained, angular, well sorted.	0.5
1.5 - 2.0	Clayey sand, quartz, red to brown to gray, iron stained, cohesive, dry.	0.5
2.0 - 3.0	Sandy clay, light green to gray, cohesive, plastic, ductile, dry, iron stained, organic material imbedded; Limestone, light green, sand included, nonfossiliferous.	1.0
3.0 - 5.0	Sand, quartz, white, iron stained, fine to medium grained, angular to subangular, well sorted.	2.0
5.0 - 7.0	Clayey sand, quartz, light green to gray, dark brown inclusions, fine grained, angular, organic material interbedded, cohesive.	2.0
7.0 - 9.0	Clayey sand, quartz, light green to gray, fine grained, angular, organic material interbedded, cohesive.	2.0
7.0 - 11.5	Sand, quartz, light green to gray, dark gray laminae, fine to medium grained, subangular to subrounded, well sorted.	4.5
11.5 - 12.5	Clayey sand, quartz, light gray to green, fine to medium grained, subangular to subrounded, cohesive, dry.	1.0
12.5 - 15.0	Sand, quartz, light green to gray, fine to medium grained, subangular to subrounded, well sorted.	2.5
15.0 - 17.0	Clay, blue green, cohesive, ductile, plastic, micaeous, carbonaceous material imbedded.	2.0

Lithologic Log of Piezometer P-7

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 0.5	Root zone, sand, quartz, dark gray, very fine grained, angular, silty, organic.	0.5
0.5 - 2.0	Sand, quartz, dark brown to red, fine grained, angular, organics.	1.5
2.0 - 4.0	Sandy clay, gray to green, iron stained, cohesive, ductile, plastic, dry.	2.0
4.0 - 10.0	Sand, quartz, white to light green, fine to medium grained, subangular, well sorted.	6.0
10.0 - 14.5	Clayey sand, quartz, light green to gray, fine grained, subangular, cohesive.	4.5
14.5 - 16.0	Clay, blue to green, cohesive, ductile, plastic, micaeous, stiff.	1.5

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Lithologic Log of Piezometer P-8

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 0.3	Root zone, sand, quartz, dark gray to black, very fine grained, angular, silty, organics.	0.3
0.3 - 2.0	Sand, quartz, light gray, fine grained, angular, well sorted.	1.7
2.0 - 6.0	Clay, gray to green, cohesive, ductile, plastic, iron stained; Limestone, light green, sand included, nonfossiliferous.	4.0
6.0 - 11.0	Sandy clay, light gray to green, cohesive, ductile, plastic.	5.0

Lithologic Log of Piezometer P-9

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 2.0	Sand, quartz, light gray, fine grained, angular, silty.	2.0
2.0 - 3.0	Sand, quartz, dark brown to black, very fine grained, angular, silty, organics.	1.0
3.0 - 4.0	Sand, quartz, light brown to tan, fine grained, angular to subangular, well sorted.	1.0
4.0 - 7.0	Sandy clay, light gray, iron stained, cohesive, ductile, plastic.	3.0
7.0 - 13.0	Sand, quartz, white, fine grained, angular, well sorted.	6.0
13.0 - 18.0	Sand, quartz, red to brown, fine grained, angular, well sorted.	5.0
18.0 - 19.5	Clayey sand, quartz, red to brown, fine grained, angular.	1.5
19.5 - 20.0	Sandy clay, light gray, cohesive, ductile, plastic, micaeous.	0.5

Lithologic Log of Piezometer P-10

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 2.0	Sand, quartz, light gray, fine grained, angular, silty, organics.	2.0
2.0 - 6.0	Sandy clay, gray, iron stained, cohesive, ductile, plastic, micaeous.	4.0
6.0 - 12.0	Sand, quartz, white, fine grained, subangular to subrounded, well sorted.	6.0
12.0 - 16.0	Sand, quartz, pale red to brown, fine grained, subangular to subrounded, well sorted.	4.0

Lithologic Log of Piezometer P-11

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 2.0	Sand, quartz, light gray, fine grained, angular, silty, organics.	2.0
2.0 - 6.0	Sandy clay, quartz, iron stained, cohesive, ductile, plastic; Limestone, light green, sand included, nonfossiliferous.	4.0
6.0 - 8.0	Clayey sand, quartz, light green, fine grained, angular, cohesive.	2.0
8.0 - 13.0	Sand, quartz, white, fine grained, angular, cohesive.	5.0
13.0 - 17.0	Sand, quartz, pale red to brown, fine grained, angular, well sorted.	4.0

Lithologic Log of Piezometer P-12

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 2.0	Sand, quartz, light gray, very fine grained, angular, silty, organics.	2.0
2.0 - 3.0	Clayey sand, quartz, pale red to brown, dark brown inclusions, fine grained, angular.	1.0
3.0 - 7.0	Sand, quartz, white with gray inclusions, fine to medium grained, subangular to subrounded, well sorted.	4.0
7.0 - 8.0	Sand, quartz, dark brown to black, fine grained, angular, silty, organics.	1.0
8.0 - 9.5	Sand, quartz, pale red to brown, medium to coarse grained, subangular to subrounded, iron stained.	1.5
9.5 - 13.0	Clayey sand, light gray to brown, fine grained, angular.	3.5
13.0 - 18.0	Sand, quartz, pale red to brown, fine to medium grained, subangular.	5.0

Lithologic Log of Piezometer P-13

Depth Below Land Surface (Ft)	Description	Thickness Feet
0.0 - 0.5	Root zone, sand, quartz, dark gray to black, very fine grained, angular, silty, organics.	0.5
0.5 - 3.5	Sand, quartz, light gray, fine grained, angular, well sorted.	3.0
3.5 - 4.0	Sand, quartz, dark brown to black, very fine grained, angular, silty, organics.	0.5
4.0 - 6.0	Sand, quartz, tan, fine to medium grained, subangular, well sorted.	2.0
6.0 - 7.0	Sand, quartz, red to brown, fine grained, subangular, well sorted.	1.0
7.0 - 9.0	Sand, quartz, black, very fine grained, angular, silty, organics.	2.0
9.0 - 19.0	Sand, quartz, white, fine to medium grained, subangular to subrounded, well sorted.	10.0

Lithologic Log of Test Boring TB-14.

Depth Below Land Surface (Ft)	Description	Thickness Feet
.0 - 1.5	Sand, quartz, gray, fine grained, silty, organics.	1.5
1.5 - 2.0	Sand, quartz, black, fine grained, angular, silty.	0.5
2.0 - 3.5	Sand, quartz, light brown, fine grained, angular, well sorted.	1.5
3.5 - 7.0	Clayey sand, quartz, light gray, fine grained, angular, cohesive.	3.5
7.0 - 11.0	Sandy clay, light gray, cohesive, ductile, plastic.	4.0
11.0 - 16.0	Sand, quartz, light gray, fine grained, angular to subangular, well sorted.	5.0
16.0 - 18.0	Clayey sand, quartz, light green to gray, fine grained, angular, cohesive.	2.0
18.0 - 19.5	Clay, blue-green, cohesive, ductile, plastic, waxy, mottled.	1.5
19.5 - 22.0	Limestone, white to light green, sand included, friable, few macrofossils; clay, calcareous, white, cohesive. Lost drilling circulation at 22 ft. bls.	2.5
22.0 - 24.5	Cavity.	2.5
24.5 - 26.0	Limestone, white, sand included, partially recrystallized, friable; Clay, calcareous, white, dry, stiff.	1.5
26.0 - 29.0	Limestone, white to pale brown, recrystallized, hard, few gastropod molds, calcite inclusions.	3.0

Lithologic Log of Dual Zone Well DZ1 (P15)

Depth Below Land Surface (Ft)	Description	Thickness Feet
.0 - 2.0	Sand, quartz, gray, very fine grained, angular, silty, organics.	2.0
2.0 - 2.5	Sand, quartz, black, very fine grained, angular, silty.	0.5
2.5 - 7.0	Sandy clay, gray to green, iron stained, cohesive, ductile, plastic.	4.5
7.0 - 11.0	Clayey sand, quartz, gray to green, fine grained, angular, cohesive.	4.0
11.0 - 14.0	Sandy clay, gray to green, cohesive, ductile, plastic.	3.0
14.0 - 21.0	Clayey sand to sand, quartz, red to brown, fine grained, angular to subangular.	7.0
21.0 - 23.5	Clayey sand, quartz, gray to green, fine grained, angular, cohesive.	2.5
23.5 - 24.0	Clay, blue-green, cohesive, ductile, plastic, micaceous.	0.5
24.0 - 30.0	Limestone, white, sand included, friable, generally recrystallized, few macrofossiliferous. Lost drilling circulation at 25 ft. bls.	6.0

Lithologic Log of Test Boring 16.

Depth Below Land Surface (Ft)	Description	Thickness Feet
.0 - 2.0	Sand, quartz, light gray, fine grained, angular, silty, organics.	2.0
2.0 - 4.0	Clay, orange to brown, cohesive, ductile, plastic; Limestone, white to pale yellow, sand included, nonfossiliferous.	2.0
4.0 - 9.5	Sand, quartz, pale gray to brown, fine grained, angular to subangular, well sorted.	5.5
9.5 - 13.0	Sand, quartz, white, fine grained, angular to subangular, well sorted.	3.5
13.0 - 14.0	Sandy clay, dark gray, cohesive, ductile, plastic.	1.0
14.0 - 18.0	Clayey sand to sand, quartz, green to gray, fine grained, angular.	4.0
18.0 - 31.0	Clayey sand to sand, light green, quartz, fine grained, angular.	13.0
31.0 - 39.0	Clay, gray to green, cohesive, ductile, plastic, stiff; limestone, white, friable, sand included, shell included.	8.0
39.0 - 39.5	Limestone, white, sand included, friable, partly recrystallized, few macrofossils.	0.5

SOIL TESTS

PTL-INSPECTORATE INC.
NATIONWIDE AND INTERNATIONAL SERVICES

TAMPA DISTRICT

Sept. 18, 1986

PTL Ref: TAM-2584

West Coast Regional Water Supply Authority
2535 Landmark Drive
Suite 211
Clearwater, Fla. 33519

RECEIVED SEP 19 1986 WEST COAST REGIONAL SUPPLY AUTHORITY

Attn: Loretta Holtkamp

Ref: Soil Mechanics Tests
Undisturbed Samples
Cypress Bridge - Site A
Pasco County, Fla.

Dear Ms. Holtkamp:

As per your request received from your Mr. Douglas Crowson, this is to document the results of our testing of samples submitted to us. Both permeability and grain size analysis tests were performed on two Shelby Tube samples submitted to us by Mr. Crowson. These tubes were identified as P-14 18.5'- 20.0' and PL-15 32.0' - 34.0'. The following permeability test results were obtained for these samples.

P-14 $k= 1.56 \times 10^{-2}$ cm/sec.

PL-15 k= less than 1×10^{-8} cm/sec.

The rapid permeability rate of P-14 is probably due to the fissures within the weathered limestone sample contained in this tube. Thus, this permeability coefficient represents the matrix permeability rather than the permeability through the stone or calcareous clay.

The permeability of PL-15 was estimated on the length of time that this sample has been saturating. As of this date, complete saturation has not occurred. We attribute this to the amount of clay present in this sample (80% to 90%) and to its lack of free water.

The results of the grain size analyses are summarized by the distribution curves attached to this letter. Should you have any questions regarding this information, please contact the writer at your convenience.

Respectfully submitted,

Joseph A. Eduardo

Joseph A. Eduardo, P.E.
Fla. Reg. 33318
District Engineer

JAE/lt

09-18-86

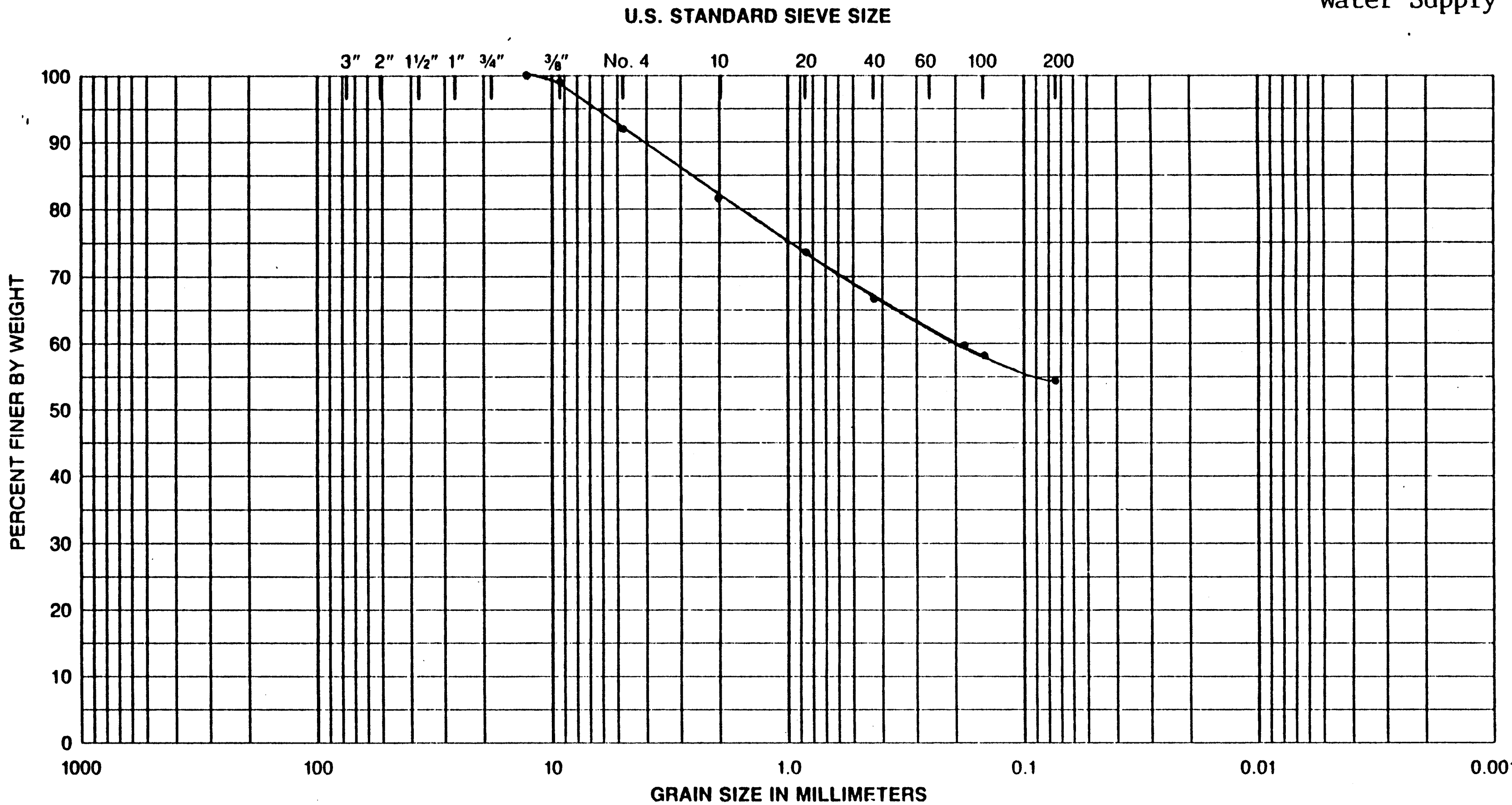
Form N[illegible]435, Rev. 1/83

Pittsburgh Testing Laboratory

GRAIN SIZE DISTRIBUTION CURVE

ORDER NO. TAM-2584

CLIENT: West Coast Regional Water Supply



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

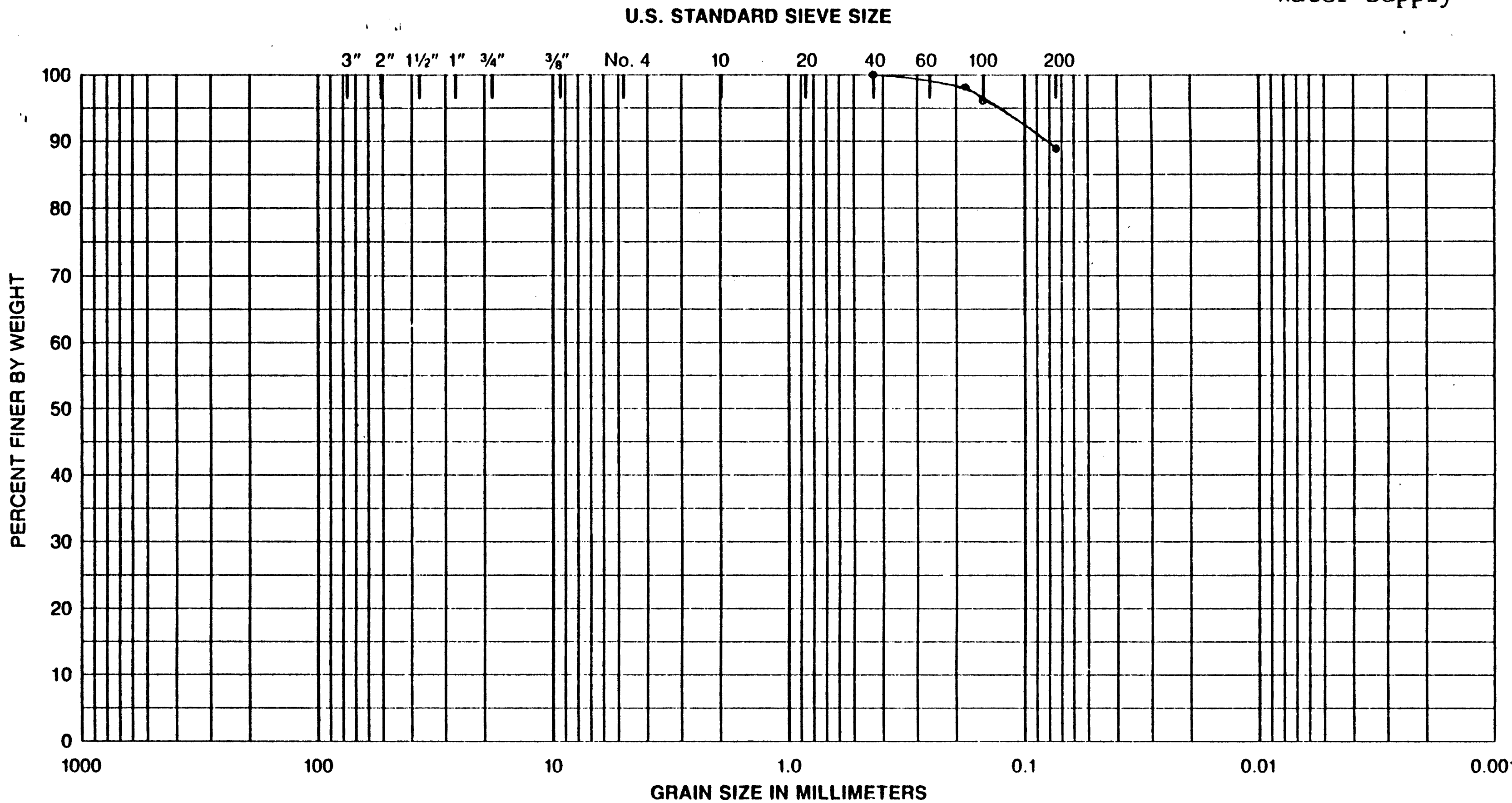
TEST BORING NO.	SAMPLE NO.	DEPTH FT.	LINE	GROUP SYM.	CLASSIFICATION	IN-SITU WC	LL	PL	PI	Gs	REMARKS	PLOTTED BY:
P-14		18.5'-20'	——	CL	Gravelly CLAY							JFE
			— —									
			—·—									
			—··—									

Form ' '435, Rev. 1/83

Pittsburgh Testing Laboratory
GRAIN SIZE DISTRIBUTION CURVE

ORDER NO. TAM-2584

CLIENT: West Coast Regional Water Supply



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

TEST BORING NO.	SAMPLE NO.	DEPTH FT.	LINE	GROUP SYM.	CLASSIFICATION	IN-SITU WC	LL	PL	PI	Gs	REMARKS	PLOTTED BY:
P-15		32'-34'	——	CL	CLAY							JFE
			— —									
			—·—									
			—··—									

APPENDIX D

GEOPHYSICAL LOGS

APPENDIX E

WELL COMPLETION REPORTS

WELL COMPLETION REPORT

Date 4-9-86

Consultant CDM

Owner West Coast Regional

Location: Pasco County

Complete Job Description: (Include full pump info) - Drilled 14 3/4" hole to 151' + set 8' casing + cemented up to surface. Drilled 7 7/8"-hole to 703'. pulled up to 300' and developed well till water was clean. pulled out + logged.

Casing (and Screen) Used:
153'-8"

Rig Used: Garder Denver

Days on Location: 23-days

Mud Used: - 15-gel

Gravel (size):

Additives: (Drispak, salt, etc) - 1/2 Soda. ash

Bits Used Up: - 14 3/4 - tooth, 7 7/8 - button

Cement: - 130 - bags

List All Logs and Surveys Run By Type and Company: Southern Resources
Caliper; Spontaneous potential; Single point (long + short normal resistivity)
Temperature log (Began pumping); Flow meter, (Satitic, pumping)
Fluid resistivity (Begam pumping)
Gamma Ray

T.D. 4-2-86 - 6:45 pm

Driller(s): J. Denchfield

Remarks:

PW 1A + 500
6006-43

ALSAY – PIPPIN CORPORATION

Date: 4-9-86

WELL LOG

. Owner West Coast Regional   2. Location Pasco Co

3. Type Const. Water Well   4. Casing 153' - 8"

. Screen, Gravel, Etc.

. Total Depth 703'   7. Jet Head   8. Static Level – 1'7"

rom	To	Formation
5'	5	White sand
5	10	White clay
)	20	White sandy clay
0	25	White + brown slightly sandy clay
5	28	White + brown clay - w/some lime
28	40	hard white limestone
40	50	White limestone chalky (w/some white + green clay)
)	60	White limestone chalky (w/some green + gray clay)
60	70	Clay w/some white limestone
70	80	Medium hard white limestone (w/some clay)
80	90	Medium hard white limestone
90	100	Medium hard white limestone (w/some clay)
110	170	Medium hard white limestone
'70	180	Medium hard white limestone (w/some clay)
'80	185	Fine tan limestone w/sand
85	195	Coarse tan limestone (w/some grey clay)

From	To	Formation
195	205	Coarse tan limestone
205	215	Coarse + fine tan limestone
215	220	Coarse tan limestone (w/some shell fragments)
220	230	Coarse to fine tan limestone (w/some lime mud)
230	240	Coarse to medium tan limestone shell fragments
240	260	Coarse to fine tan limestone (w/shell fragments)
260	290	Coarse to fine tan limestone (w/some shell fragments)
290	320	Coarse to fine tan + grey limestone (w/shell fragments)
320	330	Medium to fine tan limestone
330	340	Medium to fine tan limestone (w/more consolidation)
340	360	Medium to fine tan limestone (w/shell fragments)
360	370	Coarse to fine tan limestone white lime mud - shell fragments

. Total Chlorides (ppm)   10. Iron   11. Ph   12. Hardness

ks: Driller (s):

ALSAY – PIPPIN CORPORATION

Date:

WELL LOG

1. Owner *West Coast Regional* 2. Location *Pasco Co.*

3. Type Const. *Water Well* 4. Casing *53'-8"*

5. Screen, Gravel, Etc.

6. Total Depth *703'* 7. Jet Head 8. Static Level *1'7"*

From	To	Formation
370	399.5	Coarse to fine tan + brown limestone (w/shell fragments)
399.5	400	Cavity - black sediment
400	410	Coarse to fine Tan + brown limestone, shell fragments + Lime mud
410	420	Fine to medium tan limestone w/shell fragments
420	430	Fine + coarse tan limestone w/shell fragments + Dolomite - brown + black
30	440	Fine to coarse tan limestone
440	450	Fine to Coarse Brown dolomite + fine to medium limestone w/black peat
450	460	Fine to coarse brown dolomite fine to medium limestone w/tan clay
460	480	Fine to medium tan limestone w/some tan clay + shell fragments
480	490	Fine to coarse tan + grey limestone + tan clay
490	510	Fine to coarse tan limestone
510	530	Fine to coarse brown dolomite + fine tan limestone

From	To	Formation
530	533	Sandstone tan + brown fine grained w/light green c
533	535	Dark brown Dolomite + limest fine grained
535	540	Dark brown Dolomite finegra
540	550	Brown dolomite - fine to coars Tan sandstone - fine to coarse
550	560	Brown dolomite - fine to coa Tan sandstone - fine to coars Fine tan limestone
570	590	Brown + dark brown dolomite fine to coarse w/fine tan limestone + fossils
590	610	Brown + dark brown dolomit fine to coarse w/fine tan limestone + honey comb dola
610	703	Brown, dark brown + grey dolomite - fine to coarse w/fine tan limestone

9. Total Chlorides (ppm) 10. Iron 11. Ph 12. Hardness

marks: Driller (s):

WELL COMPLETION REPORT

Date 4/21/86

Consultant C D M

Owner WEST COAST REGIONAL

Location:
CYPRESS BRIDGE
PASCO COUNTY

Complete Job Description:
(Include full pump info)

Casing (and Screen) Used:
133' x 8"

Rig Used: GARDNER DENVER 1500

Days on Location:

Mud Used: 8 BAGS

Gravel (size):

Bits Used Up:
7 7/8 BUTTON 14 3/4 TOOTH

Additives:
(Drispak, salt, etc)
1/2 BAG SODA ASH

Cement:
87 BAGS

List All Logs and Surveys Run By Type and Company:

T.D. 704 FEET

Driller(s):
KEITH CAMPBELL
JEFF DENCHFIELD

Static Water Level:

Specific Yield:

Remarks:
PW 1A + 200
6006-45

ALSAY – PIPPIN CORPORATION

Date:

WELL LOG

1. Owner WEST COAST REGIONAL 2. Location PASCO COUNTY

3. Type Const. ROTARY 4. Casing 133' x 8"

5. Screen, Gravel, Etc. ________

6. Total Depth 704' 7. Jet Head ________ 8. Static Level ________

From	To	Formation	From	To	Formation
350'	370'	white & tan lime, some shell	510'	512'	tan & gray lime
370'	380'	tan lime	512'	536'	brown dolomite
380'	395'	tan lime, shell	536	548'	gray dolomite
395'	400'	light brown lime, shell	548'	560	brown dolomite
400'	410'	tan dolomite	560	565'	gray & brown dolomite
410'	420'	tan dolomite, dark brown dolomite	565'	583'	brown dolomite
420'	425'	brown dolomite	583'	600'	brown dolomite
425'	426'	tan lime	600'	601'	gray dolomite
426'	427'	black Peat	602'	603'	brown dolomite
427'	435'	tan & brown lime	603	606'	dark brown dolomite
435'	440'	brown dolomite	606'	610'	gray & brown dolomite
440'	467'	tan lime	610'	630'	brown dolomite
467'	491'	tan lime, coquina	630'	655'	brown dolomite
491'	501'	tan lime	655	671'	brown dolomite
501'	503'	gray lime	671	675'	brown dolomite
503'	510'	tan lime	675'	681'	gray & brown dolomite
			681'	682'	dark brown dolomite
			682'	686'	~~tan~~ dolomite
			686	697'	gray dolomite
			697	698'	dark brown dolomite
			698'	704'	gray dolomite

9. Total Chlorides (ppm) ________ 10. Iron ________ 11. Ph ________ 12. Hardness ________

arks:

Driller (s):

ALSAY – PIPPIN CORPORATION

Date:

WELL LOG

1. Owner WEST COAST REGIONAL 2. Location PASCO COUNTY

3. Type Const. ROTARY 4. Casing 133' × 8"

5. Screen, Gravel, Etc. 8 BAGS AQUA GEL, 87 BAGS CEMENT

6. Total Depth 704'. 7. Jet Head ______ 8. Static Level ______

From	To	Formation	From	To	Formation
0'	5'	light gray sand	190'	200'	tan & gray lime, dark grey clay
5'	15'	light gray sand & clay	200'	215'	gray & tan sandy lime dark grey clay
15'	30'	gray sandy clay	215'	220'	tan & gray lime (soft hard white lime some grey clay
30'	40'	tan lime, green clay	220'	225'	gray lime
40'	50'	white lime, tan lime, green clay	225'	240'	grey lime, grey clay
50'	70'	tan & white lime, varied amounts of green clay	240'	250'	tan & gray lime, dark gray clay
70'	80'	sandy lime, green clay shell	250'	265'	light gray lime
80'	88'	tan & gray lime, gray clay	265	270	light gray lime
88'	100'	tan & gray lime	270'	275'	tan & gray lime
100'	115'	tan & gray lime, shell	275'	295'	shell
115'	131'	tan & gray lime	295'	315'	tan & gray lime
131'	155'	tan & gray lime shell	315'	340'	shell
155'	170'	tan lime	340'	350'	tan lime, shell
170'	190'	tan & gray lime			

9. Total Chlorides (ppm)______ 10. Iron______ 11. Ph______ 12. Hardness______

Remarks: Driller (s):

WELL COMPLETION REPORT

Date 5/15/86

Consultant C D M

Owner WEST COAST REGIONAL WMD

Location: PASCO COUNTY

Complete Job Description:
(Include full pump info)
700' PRODUCTION WELL
[redacted]
TPW-1A

Casing (and Screen) Used:
24" × 133'

Rig Used: FAILING 2500

Days on Location: 21

Mud Used: 40 BAGS

Gravel (size): ______

Additives:
(Drispak, salt, etc)
3 BAGS SODA ASH

Bits Used Up: 30" (2) TOOTH
(1) .2" TOOTH, (1) 22" BUTTON (1) 14 3/4 BUTTON

Cement:
280 SACKS

List All Logs and Surveys Run By Type and Company:

T.D. 700'

Driller(s):
BARRIE CHENEA
KEITH CAMPBELL

Static Water Level: 3'

Specific Yield: ______

Remarks: RAN FOLLOWING LOGS:
CALIPER, SPONTANEOUS POTENTIAL, SINGLE POINT (LONG & SHORT NORMAL RESISTIVITY), TEMPERATURE LOG (STATIC AND PUMPING) FLOW METER (STATIC AND PUMPING), FLUID RESISTIVITY (STATIC AND PUMPING), GAMMA RAY

ALSAY – PIPPIN CORPORATION

Date: 5/13/86

TEST PRODUCTION WELL

WELL LOG

1. Owner WCRWSA
2. Location PASCO COUNTY
3. Type Const. ROTARY
4. Casing 24" x
5. Screen, Gravel, Etc.
6. Total Depth 700'
7. Jet Head
8. Static Level 3'

From	To	Formation
0	5'	SAND
5	20'	SAND & CLAY
20	30'	SANDY CLAY (light gray)
30	35'	WHITE LIMESTONE
35	60'	WHITE & TAN LIME
60	65'	WHITE & GRAY LIME
(	70'	TAN & GRAY LIME
70	75'	WHITE & GRAY LIME
75	155'	TAN & GRAY LIME, SHELL
155	170'	GRAY LIME
170	180'	GRAY & TAN LIME, GRAY CLAY
180	190'	GRAY & TAN LIME
190	217'	TAN LIME
217	219'	GRAY LIME
219	225'	GRAY & TAN LIME
225	230'	HARD GRAY LIME
230	255'	TAN & GRAY LIME
255	260'	TAN LIME
260	265'	TAN & GRAY LIME
265	295'	SOFT GRAY LIME
295	300'	SHELL
300	310'	GRAY LIME
310	410'	TAN LIME, SHELL
410	420'	BROWN LIME
420	430'	GRAY & BROWN DOLOMIT
430	435'	TAN DOLOMITE
435	450'	TAN LIME
450	480'	GRAY DOLOMITE
480	513'	GRAY LIME
513	535'	BROWN DOLOMITE
535	550'	GRAY & BROWN DOLOMIT
550	665'	BROWN DOLOMITE
666	670'	GRAY & TAN DOLOMITE
670	671'	DARK GRAY CLAY
671	674'	TAN DOLOMITE
674	682'	GRAY DOLOMITE
682	693'	BROWN & TAN DOLOMITE
693	700'	GRAY & TAN DOLOMITE

9. Total Chlorides (ppm)
10. Iron
11. Ph
12. Hardness

R. rks:

Driller (s): BARRIE CHENEA
KEITH CAMPBELL

Pg______of______

WELL COMPLETION REPORT

Date 5/26/86

Consultant CDM

Owner WEST COAST REGIONAL

Location: PASCO COUNTY

Complete Job Description:
(Include full pump info)

700' MONITOR WELL
DMW #3
(DMW 1A+1950)

Casing (and Screen) Used:
130' x 8"

Rig Used: FAILING 2500

Days on Location: 7

Mud Used: 55 BAGS AQUA GEL

Gravel (size): ______

Additives:
(Drispak, salt, etc)
1½ BAGS SODA ASH
25 LBS DRISPAK

Bits Used Up: 14 3/4 TOOTH
7 7/8 BUTTON

Cement: 87 SACKS

List All Logs and Surveys Run By Type and Company:

T.D. 700'

Driller(s): BARRIE CHENEA
KEITH CAMPBELL

Static Water Level: 3'

Specific Yield: ______

Remarks: RAN FOLLOWING LOGS
CALIPER, SPONTANEOUS POTENTIAL, SINGLE POINT (LONG AND SHORT NORMAL RESISTIVITY), TEMPERATURE LOG (STATIC & PUMPIN
FLOW METER (STATIC & PUMPING), GAMMA RAY
FLUID RESISTIVITY (STATIC & PUMPING)

ALSAY – PIPPIN CORPORATION

Date:

WELL LOG

1. Owner WEST COAST REGIONAL 2. Location PASCO COUNTY

3. Type Const. ROTARY 4. Casing 130' x 8"

5. Screen, Gravel, Etc.

6. Total Depth 700' 7. Jet Head 8. Static Level 3'

From	To	Formation	From	To	Formation
0	5'	FINE SAND			
10	25'	SANDY CLAY			
25	30'	GREEN CLAY			
30	250'	WHITE & GRAY LIMESTONE, MEDIUM HARDNESS WITH ZONES OF CLAY & PEAT			
250	300'	TAN & GRAY LIMESTONE RANGED FROM VERY SOFT TO MEDIUM HARDNESS			
300	500'	MEDIUM HARD LIMESTONE TAN & GRAY			
500	700'	LIGHT BROWN & DARK BROWN DOLOMITE. MEDIUM HARDNESS TO VERY HARD			

9. Total Chlorides (ppm) 10. Iron 11. Ph 12. Hardness

marks:

Driller (s): BARRIE CHENEA
KEITH CAMPBELL

APPENDIX F

STEP-DRAWDOWN TEST DATA

CDM
environmental engineers, scientists, planners, & management consultants

CAMP DRESSER & McKEE INC.

One Tampa City Center, Suite 1750
Tampa, Florida 33602
813 221-2833

May 28, 1986

Ms. Loretta H. Holtkamp
West Coast Regional Water Supply Authority
2535 Landmark Drive, Suite 211
Clearwater, FL 33519

Re: Analysis of Step Drawdown Test from Test Well IA

Dear Ms. Holtkamp:

I am forwarding to you the results of the step drawdown test performed on May 17, 1986, on Test Well IA. The analysis of the data indicates that the well is extremely stable, neither experiencing further development nor clogging at the tested pumping rates. The well is fully developed and should not experience excessive deterioration through clogging adjacent to the borehole during the expected life of the well. The well meets the design pumping rate of 2,100 gpm with a minimal well loss of less than one foot.

The results of the step drawdown test will be included in the final report on Phase IA. Based on the above results, the pumping rate for the 5 day aquifer performance test and recovery will be at the rate of 2,100 gpm as specified in the Project Manual.

If you have any questions concerning the above analysis, please give me a call.

Sincerely,

CAMP DRESSER & McKEE INC.

James H. Jensen

JHJ/cj

JHJ5T.1/4
PN: 6006-46-TW
Enclosure

cc: Ed Kent
Larry Roesner
Gary Witt
Tod Monks
E. L. Adams

MEMORANDUM

TO: Jim Jensen
Tod Monks

FROM: Gary Witt

DATE: May 22, 1986

RE: Analysis of Step Drawdown Test from
West Coast Regional Water Supply Authority
Test Production Well #1 (revised)

The analysis methods used to analyze pumping test data from the stop drawdown phase of the TPW-A1 are described below. The drawdown (well loss) in the test/production well due to the turbulent flow of water through the borehole and inside the casing to the pump intake may be computed with the following equation (Jacob, 1946):

$$s_{WL} = CQ^2$$

where

s_{WL} = well loss, ft

C = well loss constant, sec^2/ft^5

Q = production well discharge, cubic feet per second (cfs).

The value of C may be computed from step-drawdown pumping test data using the following equation (Jacob, 1946):

$$C = \frac{\Delta s_i/\Delta Q_i - \Delta s_{i-1}/\Delta Q_{i-1}}{\Delta Q_{i-1} + \Delta Q_i}$$

The Δs terms in Equation 1a represent increments of drawdown produced by each increase, ΔQ, in the rate of pumping. The dimensions of Δs and ΔQ are feet and cfs, respectively.

The method described above was used to analyze the data from the step drawdown test of the above-referenced well.

Data obtained is as follows:

Q_1 = 1,020 gpm = 2.27 cfs S_1 2.49
Q_2 = 1,920 gpm = 4.28 cfs S_2 5.11
Q_3 = 3,740 gpm = 8.33 cfs S_3 11.5

C_1 = .048

C_2 = .045

$C_{1,\ 2\&3}$ = .047

$C_{1\&2,\ 3}$ = .046

Based on this, the well losses are as follows for the three rates:

1,020 gpm =	2.27 cfs	.25 feet
1,920 gpm =	4.28 cfs	.83 feet
3,740 gpm =	8.33 cfs	3.19 feet

The analysis indicates the following about the well:

The well is extremely stable and capable of producing large quantities of water. The well loss at the design rate of 2,100 gpm will be approximately one foot. The high rate of 3,740 gpm shows that at higher rates the well is less efficient. However, the rate tested exceeds the design capacity by factor of 1.80. The velocity in the well casing is approximately 4 feet per second which is more than acceptable. Therefore, most of the turbulent flow is from friction losses in the borehole.

Specific capacities of the wells are as follows:

Step 1 - 408 gpm/ft of drawdown
Step 2 - 375 gpm/ft of drawdown
Step 3 - 325 gpm/ft of drawdown

If you have any questions concerning this analysis, please give me a call.

GMW/jra
EJK6T.3/13

cc: E.L. Adams
E.J. Kent

APPENDIX G

AQUIFER PERFORMANCE TEST DATA

CDM

Sheet 1 of
Date 6/17/8

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. TPW - 1A
Elevation of Measuring Point 56.46
Reference Point TOC
Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 53.98 (2.48)
Distance from Pumping well in feet 0
Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
10:30	✓0				2.48		Pump started at gpm
	0.08						
	0.17						
	0.25						
	0.33						
	0.42						
	✓0.50	4.0			6.48		
	0.58						
	0.67	4.03			6.51		
	0.75	4.045			6.525		
	0.83	4.06			6.54		
	0.92	4.075			6.555		
	✓1.00	4.09			6.57		
	1.17	4.13			6.61		
	1.33	4.17			6.65		
	✓1.50	4.22			6.70		
	1.67	4.25			6.73		
	1.83	4.28			6.76		
	✓2.00	4.31			6.79		
	2.25	4.355			6.825		
	2.50	4.40			6.88		
	2.75	4.42			6.90		
	3.00	4.44			6.92		
	3.50	4.51			6.99		
	4.00	4.54			7.02		
	4.50	4.58			7.06		
	5.00	4.63			7.11		
	6.00	4.70			7.18		
	7.00	4.77			7.25		
	8.00	4.82			7.30		
	9.00	4.88			7.36		
	10.00	4.93			7.41		
	12.00	5.00			7.48		
	14.00	5.08			7.56		
	16.00	5.17			7.65		
	18.00	5.21			7.69		
	20.00	5.27			7.75		

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. TPW-1A Elevation of Measuring Point 56.46

Reference Point TOC Elevation of Ground Level

Pre-test Water Level (Ref. Measuring Point) 53.98 (2.48)

Distance from Pumping well in feet 0 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
	22.00	5.32			7.80		
	24.00	5.37			7.85		
	26.00	5.41			7.89		
	28.00	5.46			7.94		
	30.00	5.48			7.96		.5 hr
	35.00	5.62			8.10		
	40.00	5.67			8.16		
	45.00	5.73			8.21		
	50.00	5.81			8.29		
	55.00	5.86			8.34		
	60.00	5.91			8.39		1 hr.
	70.00	6.03			8.51		
	80.00	6.11			8.59		
	90.00	6.22			8.70		
	100.00	6.30			8.78		
	110.00	6.35			8.83		
	120.00	6.42			8.90		2 hr.
	135.00	6.52			9.00		
	150.00	6.56			9.04		
	165.00	6.63			9.11		
	180.00	6.72			9.20		3 hr.
	200.00	6.76			9.24		
	220.00	6.80			9.28		
	240.00	6.86			9.34		4 hr. 0.37" Rain
	270.00	6.93			9.41		13:47 to 1425
15:30	300.00	6.99			9.47		5 hr. orifice 19.0"
16:30	360.00	7.07			9.55		6 hr. 16:15 - Total
17:30	420.00	7.165			9.645		7 hr. Rain 0.42
18:30	480.00	7.25			9.73		8 hr.
20:30	600.00	7.355			9.835		10 hr.
22:30	720.00	7.462			9.942		12 hr.
24:30	840.00	7.51			9.99		14 hr.
2:30	960.00	7.54			10.02		16 hr.
4:30	1080.00	7.59			10.07		18 hr.
6:30	1200.00	7.63			10.11		20 hr.
8:30	1320.00	7.69			10.17		22 hr.
10:30	1440.00	7.71			10.19		24 hr.
[illegible]	1560.00	7.71			10.19		26 hr.

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CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. TPW -1A Elevation of Measuring Point 56.46

Reference Point TOC Elevation of Ground Level

Pre-test Water Level (Ref. Measuring Point) 53.98 (2.48)

Distance from Pumping well in feet Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
14:30	1680.00	7.71			10.19		28 hr.
16:30	1800.00	7.695			10.175		30 hr.
18:30	1920.00	7.72			10.20		32 hr.
20:30	2040.00	2.26			10.24		34 hr.
22:30	2160.00	7.785			10.265		36 hr.
24:30	2280.00	7.79			10.27		38 hr.
2:30	2400.00	7.78			10.26		40 hr.
4:30	2520.00	7.805			10.285		42 hr.
6:30	2640.00	7.833			10.313		44 hr.
8:30	2760.00	7.835			10.335		46 hr.
10:30	2880.00	7.84			10.36		48 hr.
12:30	3000.00	7.895			10.375		50 hr.
14:30	3120.00	2.866			10.346		52 hr.
16:30	3240.00	2.87			10.35		54 hr.
18:30	3360.00	2.88			10.36		56 hr.
20:30	3480.00	2.925			10.405		58 hr.
22:30	3600.00	7.945			10.425		60 hr.
24:30	3720.00	7.96			10.44		62 hr.
2:30	3840.00	7.95			10.43		64 hr.
4:30	3960.00	7.925			10.405		66 hr.
6:30	4080.00	7.95			10.43		68 hr.
8:30	4200.00	7.98			10.46		70 hr.
10:30	4320.00	7.98			10.46		72 hr.
12:30	4440.00	7.955			10.435		74 hr.
14:30	4560.00	7.935			10.415		76 hr.
16:30	4680.00	7.92			10.40		78 hr.
18:30	4800.00	7.947			10.427'		80 hr.
20:30	4920.00	7.97			10.45		82 hr.
22:30	5040.00	7.99			10.47		84 hr.
24:30	5160.00	7.99			10.47		86 hr.
2:30	5280.00	7.99			10.47		88 hr.
4:30	5400.00	8.002			10.482		90 hr.
6:30	5520.00	8.02			10.50		92 hr.
8:30	5640.00	8.062			10.542		94 hr.
10:30	5760.00	8.055			10.535		96 hr.
12:30	5880.00	8.08			10.56		98 hr.
14:30	6000.00	8.09			10.57		100 hr.
[illegible]	6120.00	[illegible]			10.55		102 hr.

Sheet 4 of
Date 6/21/8

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. TPN-1A Elevation of Measuring Point 56.46

Reference Point TOC Elevation of Ground Level

Pre-test Water Level (Ref. Measuring Point) 53.98 (2.48)

Distance from Pumping well in feet Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
1830	6240.00	8.08			10.56		104 hr.
20:30	6360.00	8.13			10.61		106 hr.
22:30	6480.00	8.13			10.61		108 hr.
24:30	6600.00	8.13			10.61		110 hr.
2:30	6720.00	8.12			10.60		112 hr.
4:30	6840.00	8.13			10.61		114 hr.
6:30	6960.00	8.145			10.625		116 hr.
8:30	7080.00	8.145			10.625		118 hr.
10:30	7200.00	8.155			10.635		120 hr.
12:30	7320	8.17			10.65		122
14:30	7440	8.16			10.64		124
16:30	7560	8.15			10.63		226
18:30	7680	8.14			10.62		128
20:30	7800	8.13			10.61		130
22:30	7920	8.095			10.575		132
24:30	8040	8.075			10.558		134
6/23 2:30	8160	8.035			10.515		136
4:30	8280	8.03			10.51		138
6:30	8400	8.02			10.50		140
8:30	8520	7.997			10.477		142
10:00	8580	7.98			10.46		144

Sheet 1 of 4
Date 6-17-8

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AQUIFER TEST RECORD
WEST COAST REGIONAL

Well No. DMW 1A + 200 Elevation of Measuring Point 59.02
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.59
Distance from Pumping well in feet 200 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
10:30	0				4.59	5443	Pump started at gpm
	0.08	0.01			[illegible]	54.42	
	0.17	0.26			[illegible]	54.17	
	0.25	0.60			5.19	53.83	
	0.33	0.86			5.45	53.57	
	0.42	1.02			5.61	53.41	
	0.50	1.07			5.66	53.36	
	0.58	1.10			5.69	[illegible]	
	0.67	1.13			5.72	53.30	
	0.75	1.18			5.77	53.25	
	0.83	1.195			[illegible]	[illegible]	
	0.92	1.21			5.80	53.22	
	1.00	1.23			5.82	[illegible]	
	[illegible]	1.29			[illegible]	53.14	
	1.33	1.35			5.94	53.08	
	1.50	1.39			5.98	[illegible]	
	1.67	1.44			6.03	[illegible]	
	1.83	1.48			6.07	52.95	
	2.00	1.52			6.11	[illegible]	
	2.25	1.57			6.16	[illegible]	
	2.50	1.61			6.20	52.82	
	2.75				6.		Missed Mark
	3.00	1.645			6.235	52.78	
	3.50	1.65			6.24	52.78	
	4.00	1.83			6.42	52.60	
	4.50	1.88			6.47	52.55	
	5.00	1.93			6.52	52.50	
	6.00	2.02			6.61	52.41	
	7.00	2.10			6.69	52.33	
	8.00	2.17			6.76	[illegible]	
	9.00	2.23			6.82	52.20	
	10.00	2.28			6.87	52.15	
	12.00	2.37			6.96	52.06	
	14.00	2.44			7.03	51.99	
	16.00	2.51			7.10	51.92	
	18.00	2.56			7.15	51.87	
	20.00	[illegible]			[illegible]	[illegible]	

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. DMW 1A+200 Elevation of Measuring Point 59.02
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.59
Distance from Pumping well in feet 200 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
	22.00	2.655			7.245	51.775	
	24.00	2.705			7.295	51.725	
	26.00	2.74			[illegible]	51.69	
	28.00	2.79			[illegible]	51.64	
	30.00	2.83			[illegible]	51.60	.5 hr
	35.00	2.93			[illegible]	51.50	
	40.00	3.00			7.59	51.43	
	45.00	3.07			7.66	51.36	
	50.00	3.14			7.73	51.29	
	55.00	3.20			7.79	51.23	
	60.00	3.255			7.845	51.175	1 hr.
	70.00	3.36			7.95	51.07	
	80.00	3.44			8.03	50.99	
	90.00	3.515			8.105		
	100.00	3.59			8.18	50.84	
	110.00	3.645			8.225		
	120.00	3.71			8.30	50.72	2 hr.
	135.00	3.79			8.37		
	150.00	3.84			8.43	50.59	
	165.00	3.91			8.50		
	180.00	3.975			8.565	50.455	3 hr.
	200.00	4.06			8.65	50.37	
	220.00	4.09			8.68	50.34	
	240.00	4.135			8.725	50.295	4 hr.
	270.00	4.22			8.81	50.21	
	300.00	4.275			8.865	50.155	5 hr.
	360.00	4.365			8.955		6 hr.
	420.00	4.46			9.05	49.97	7 hr.
	480.00	4.54			9.135		8 hr.
	600.00	4.685			9.28	49.74	10 hr.
	720.00	4.78			9.375		12 hr.
	840.00	4.82			9.41	49.61	14 hr.
	960.00	4.86			9.45		16 hr.
	1080.00	4.89			9.48	49.54	18 hr.
	1200.00	4.955			9.545		20 hr.
	1320.00	5.02			9.61	49.41	22 hr.
	1440.00	5.08			9.67		24 hr.
	1560.00	5.085			9.675	49.295	26 hr.

CDM

Date 6/18/86

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. DMW 1A +200 Elevation of Measuring Point 59.02

Reference Point TOC Elevation of Ground Level

Pre-test Water Level (Ref. Measuring Point) 4.59

Distance from Pumping well in feet 200 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
	1680.00	5.075			9.665		28 hr
	1800.00	5.07			9.66	49.30	30 hr
	1920.00	5.085			9.675	[illegible]	32 hr
	2040.00	5.125			9.715	[illegible]	34 hr
	2160.00	5.16			9.75	49.27	36 hr
20:30	2280.00	5.165			9.755		38 hr.
6/19 24:30	2400.00	5.155			9.745		40 hr.
4:30	2520.00	5.16			9.75	49.27	42 hr.
6:30	2640.00	5.19			9.78	49.24	44 hr.
8:30	2760.00	5.215			9.805		46 hr.
	2880.00	5.235			9.825		48 hr.
	3000.00	5.247			9.837		50 hr.
	3120.00	5.24			9.83		52 hr.
	3240.00	5.22			9.81		54 hr.
	3360.00	5.223			9.813		56 hr.
	3480.00	5.247			9.837		58 hr.
	3600.00	5.275			9.865		60 hr.
6/20	3720.00	5.295			9.885		62 hr.
	3840.00	5.28			9.87		64 hr.
	3960.00	5.268			9.858		66 hr.
	4080.00	5.273			9.863		68 hr.
	4200.00	5.31			9.90		70 hr.
	4320.00	5.345			9.935		72 hr.
	4440.00	5.355			9.945		74 hr.
	4560.00	5.32			9.91		76 hr.
	4680.00	5.30			9.89		78 hr.
	4800.00	5.295			9.885		80 hr.
	4920.00	5.318			9.905		82 hr.
	5040.00	5.341			9.928		84 hr.
6/21	5160.00	5.363			9.95		86 hr.
2:30	5280.00	5.356			9.943		88 hr.
4:30	5400.00	5.348			9.935		90 hr.
	5520.00	5.36			9.947		92 hr.
	5640.00	5.391			9.978		94 hr.
	5760.00	5.42			10.007		96 hr.
	5880.00	5.436			10.023		98 hr.
[illegible]:30	6000.00	5.453			10.04		100 hr.
	6120.00	5.428			10.015		102 hr.

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. DMW 1A +200 Elevation of Measuring Point 59.02
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.59
Distance from Pumping well in feet 200 Pumping Rate (gpm) 2150 gpm

	Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6/21	16:30	6240.02	5.41			10.0		104 hr.
	[illegible]	6360.00	5.445			10.035		106 hr.
	[illegible]	6480.00	5.465			10.055		108 hr.
6/22	[illegible]	6600.00	5.48			10.07		110 hr.
	[illegible]	6720.00	5.48			10.07		112 hr.
	[illegible]	6840.00	5.465			10.055		114 hr.
	[illegible]	6960.00	5.47			10.06		116 hr.
	[illegible]	7080.00	5.495			10.095		118 hr.
	12:30	7200.00	5.525			10.115		120 hr.
	[illegible]	7320.00	5.547			10.137		
	[illegible]	7440.00	5.535			10.125	48.90	
	[illegible]	7560.00	5.515			10.105		
	[illegible]	7680.00	5.52			10.11		
	[illegible]	7800.00	5.465			10.055		
	[illegible]	7920.00	5.46			10.05		
6/23	24:30	8040.00	5.455			10.045		
	2:30	8160.00	5.435			10.025		
	4:30	8280.00	5.405			9.995		
	[illegible]	8400.00	5.383			9.975		
	[illegible]	8520.00	—			—		
	10:30	8640.00	5.42			10.01	49.01	

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Sheet 1 of
Date 6/17/8

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. DMW-1A-500
Elevation of Measuring Point 59.86
Reference Point TOC
Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 5.665
Distance from Pumping well in feet 500
Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
	0				5.665	54.195	Pump started at
	0.08	0.015			5.68	54.18	gpm
	0.17	0.085			5.75	54.11	
	0.25	0.210			5.875		
	0.33	0.305			5.97		
	0.42	0.355			6.02		
	0.50	0.395			6.06	53.80	
	0.58	0.425			6.09		
	0.67	0.465			6.13		
	0.75	0.505			6.17		
	0.83	0.535			6.20		
	0.92	0.570			6.235		
	1.00	0.625			6.29	53.57	
	1.17	0.685			6.35		
	1.33	0.725			6.39		
	1.50				—		Missed [illegible]
	1.67	0.795			6.46		
	1.83	0.815			6.48		
	2.00	0.835			6.50	53.36	
	2.25	0.890			6.555		
	2.50	0.940			6.605		
	2.75	0.975			6.64		
	3.00	1.015			6.68	53.18	
	3.50	1.075			6.74		
	4.00	1.125			6.79		
	4.50	1.175			6.84		
	5.00	1.215			6.88		
	6.00	1.295			6.96	52.90	
	7.00	1.360			7.025		
	8.00	1.415			7.08		
	9.00	1.475			7.14		
	10.00	1.525			7.19	52.67	
	12.00	1.620			7.285		
	14.00	1.705			7.37		
	16.00	1.760			7.425		
	18.00	1.820			7.455		
	20.00	[illegible]			7.555	52.305	

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AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. DMW-1A-500 Elevation of Measuring Point 59.86
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 5.665
Distance from Pumping well in feet 500 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
	22.00	1.935			7.60		
	24.00	1.985			7.65		
	26.00	2.035			7.70		
	28.00	2.075			7.74		
	30.00	2.105			7.77	52.09	.5 hr
	35.00	2.205			7.87		
	40.00	2.265			7.93		
	45.00	2.335			8.00		
	50.00	2.395			8.06	51.80	
	55.00	2.455			8.12		
	60.00	2.505			8.17		1 hr.
	70.00	2.610			8.275		
	80.00	2.710			8.375		
	90.00	2.785			8.45		
	100.00	2.87			8.535	51.325	
	110.00	2.94			8.605		
	120.00	3.00			8.665		2 hr.
	135.00	3.085			8.75		
	150.00	3.115			8.78		
	165.00	3.17			8.835		
	180.00	3.235			8.90		3 hr.
	200.00	3.315			8.98	50.88	
	220.00	3.345			9.01		
	240.00	3.40			9.065		4 hr.
	270.00	3.47			9.135		
	300.00	3.535			9.20	50.66	5 hr.
	360.00	3.65			9.315		6 hr.
	420.00	3.745			9.41		7 hr.
	480.00	3.825			9.49		8 hr.
	600.00	3.97			9.635	50.225	10 hr.
	720.00	4.065			9.73		12 hr.
	840.00	4.105			9.77		14 hr.
	960.00	4.145			9.81	50.05	16 hr.
	1080.00	4.175			9.84		18 hr.
	1200.00	4.245			9.91		20 hr.
	1320.00	4.305			9.97		22 hr.
	1440.00	4.365			10.03		24 hr.
	1560.00	4.375			10.04		26 hr.

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. DMW-1A - +500　　Elevation of Measuring Point 59.86
Reference Point TOC　　Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 5.665
Distance from Pumping well in feet 500　　Pumping Rate (gpm) 2150 gpm

	Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
		1680.00	4.365			10.03		28 hr
		1800.00	4.37			10.025		30 hr
		1920.00	4.355			10.02	49.84	32 hr
		2040.00	4.40			10.065		34 hr
		2160.00	4.435			10.10		36 hr
6/19	24:30	2280.00	4.46			10.125		38 hr.
	[illegible]	2400.00	4.45			10.115		40 hr.
	[illegible]	2520.00	4.445			10.11		42 hr.
	[illegible]	2640.00	4.465			10.13	49.73	44 hr.
	[illegible]	2760.00	4.515			10.18		46 hr.
	[illegible]	2880.00	4.545			10.21		48 hr.
	[illegible]	3000.00	4.547			10.212		50 hr.
	[illegible]	3120.00	4.635			10.20		52 hr.
	[illegible]	3240.00	4.615			10.18		54 hr.
	[illegible]	3360.00	4.62			10.185		56 hr.
	[illegible]	3480.00	4.647			10.212		58 hr.
		3600.00	4.66			10.245		60 hr.
6/20		3720.00	[illegible]			10.263		62 hr.
		3840.00	[illegible]			10.25		64 hr.
	[illegible]	3960.00	[illegible]			10.24	[illegible]	66 hr.
	6:30	4080.00	4.685			10.25		68 hr.
	[illegible]	4200.00	4.73			10.295		70 hr.
	[illegible]	4320.00	4.76			10.325		72 hr.
	[illegible]	4440.00	4.768			10.333		74 hr.
	[illegible]	4560.00	4.735			10.30		76 hr.
	16:30	4680.00	4.72			10.285		78 hr.
	[illegible]	4800.00	4.71			10.275		80 hr.
	[illegible]	4920.00	4.725			10.29	49.57	82 hr.
	22:30	5040.00	4.745			10.31		84 hr.
6/21	24:30	5160.00	4.77			10.335		86 hr.
	2:30	5280.00	4.77			10.335		88 hr.
	4:30	5400.00	4.76			10.325		90 hr.
	[illegible]	5520.00	4.765			10.33		92 hr.
	[illegible]	5640.00	4.795			10.36		94 hr.
	10:30	5760.00	4.825			10.39		96 hr.
	[illegible]	5880.00	4.85			10.415		98 hr.
	[illegible]	6000.00	4.858			10.423	49.437	100 hr.
	[illegible]	6120.00	[illegible]			10.41		102 hr.

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. DMW 1A +500 Elevation of Measuring Point 59.86

Reference Point ______ Elevation of Ground Level ______

Pre-test Water Level (Ref. Measuring Point) 5.665

Distance from Pumping well in feet 500 Pumping Rate (gpm) 2150 gpm

Date	Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
		6240.00	4.725			10.39		104 hr.
		6360.00	4.74			10.405		106 hr.
		6480.00	4.775			10.44	49.42	108 hr.
		6600.00	4.788			[illegible]		110 hr.
		6720.00	4.79			10.455		112 hr.
		6840.00	4.775			10.44		114 hr.
		6960.00	4.785			10.447		116 hr.
		7080.00	4.808			10.473		118 hr.
6/22	10:30	7200.00	4.838			10.503		120 hr.
	12:30	7320.00	4.862			10.527		
	14:30	7440.00	4.855			10.52		
	16:30	7560.00	4.832			10.497		
	18:22	7680.00	4.835			10.50	49.36	
	20:30	7800.00	4.785			10.45		
	22:30	7920.00	4.775			10.44		
6/23	24:30	8040.00	4.72			10.435		
	2:30	8160.00	4.75			10.415		
	4:30	8280.00	4.715			10.38		
	6:30	8400.00	4.695			10.36		
	[illegible]	8520.00	4.695			10.36		
	10:30	8640.00	4.71			10.375		
		8860.00	4.715			10.38	49.48	

Sheet 1 of [illegible]
Date 6/17/8[illegible]

CDM

AQUIFER TEST RECORD
WEST COAST REGIONAL

Well No. [illegible] 1A + 1950   Elevation of Measuring Point 63.22
Reference Point TOC   Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 7.45
Distance from Pumping well in feet 1950'   Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
10:30	0				7.45		Pump started at
	0.08	-0.005			7.445		gpm
	0.17	0			7.45		
	0.25	0			7.45		
	0.33	0			7.45		
	0.42	0			7.45		
	0.50	0			7.45		
	0.58	0			7.45		
	0.67	0			7.45		
	0.75	0			7.45		
	0.83	0			7.45		
	0.92	0			7.45		
	1.00	0			7.45		
	1.17	0			7.45		
	1.33	0			7.45		
	1.50	0			7.45		
	1.67	0			7.45		
	1.83	0			7.45		
	2.00	0.005			7.455		
	2.25	0.005			7.455		
	2.50	0.005			7.455		
	2.75	0.005			7.455		
	3.00	0.005			7.455		
	3.50	0.01			7.46		
	4.00	0.01			7.46		
	4.50	0.01			7.46		
	5.00	0.012			7.462		
	6.00	0.015			7.465		
	7.00	0.02			7.47		
	8.00	0.025			7.475		
	9.00	0.03			7.48		
	10.00	0.035			7.485		
	12.00	0.04			7.49		
	14.00	0.05			7.50		
	16.00	0.065			7.515		
	18.00	0.07			7.52		
	20.00	[illegible]			[illegible]		

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. SWC-1A+1950 Elevation of Measuring Point 63.22
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 7.45
Distance from Pumping well in feet 1950 Pumping Rate (gpm) 2150

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
	22.00	0.045			7.545		
	24.00	0.105			7.555		
	26.00	0.12			7.57		
	28.00	0.125			7.575		
	30.00	0.135			7.585		.5 hr
	35.00	0.165			7.615		
	40.00	0.19			7.64		
	45.00	0.22			7.67		
	50.00	0.245			7.695		
	55.00	0.27			7.72		
	60.00	0.30			7.75		1 hr.
	70.00	0.35			7.80		
	80.00	0.40			7.85		
	90.00	0.45			7.90		
	100.00	0.50			7.95		
	110.00	0.545			7.995		
	120.00	0.59			8.04		2 hr.
	135.00	0.655			8.105		
	150.00	0.715			8.165		
	165.00	0.77			8.22		
	180.00	0.86			8.31		3 hr.
	200.00	0.95			8.40		
	220.00	1.01			8.46		
	240.00	1.05			8.50		4 hr.
	270.00	1.10			8.55		
	300.00	1.22			8.67		5 hr.
	360.00	1.31			8.76		6 hr.
	420.00	1.39			8.84		7 hr.
	480.00	1.44			8.89		8 hr.
	600.00	1.53			8.98		10 hr.
	720.00	1.57			9.02		12 hr.
	840.00	1.60			9.05		14 hr.
	960.00	1.64			9.09		16 hr.
	1080.00	1.71			9.16		18 hr.
	1200.00	1.755			9.205		20 hr.
	1320.00				—		22 hr.
	1440.00	1.805			9.255		24 hr.
	15[illegible]0.00	1.805			9.255		26 hr.

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. DMW-1A-+ 1950 Elevation of Measuring Point 63.22
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 7.45
Distance from Pumping well in feet 1950 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
	1680.00	1.79			9.24		28 hr.
	1800.00	1.78			9.23		30 hr.
	1920.00	1.805			9.255		32 hr.
	2040.00	1.84			9.29		34 hr.
	2160.00	1.86			9.31		36 hr.
	2280.00	1.87			9.32		38 hr.
	2400.00	1.85			9.30		40 hr.
	2520.00	1.86			9.31		42 hr.
	2640.00	1.89			9.34		44 hr.
[illegible]	2760.00	1.925			9.375		46 hr.
[illegible]	2880.00	1.96			9.41		48 hr.
[illegible]	3000.00	1.96			9.41		50 hr.
[illegible]	3120.00	1.94			9.39		52 hr.
[illegible]	3240.00	1.92			9.37		54 hr.
[illegible]	3360.00	1.92			9.37		56 hr.
[illegible]	3480.00	1.947			9.397		58 hr.
[illegible]	3600.00	1.97			9.42		60 hr.
[illegible]	3720.00	1.985			9.435		62 hr.
[illegible]	3840.00	1.97			9.42		64 hr.
[illegible]	3960.00	1.955			9.405		66 hr.
[illegible]	4080.00	1.965			9.415		68 hr.
[illegible]	4200.00	2.02			9.46		70 hr.
10:30	4320.00	2.05			9.49		72 hr.
12:30	4440.00	2.06			9.50		74 hr.
14:30	4560.00	2.035			9.475		76 hr.
16:30	4680.00	2.01			9.45		78 hr.
[illegible]	4800.00	2.007			9.447		80 hr.
[illegible]	4920.00	2.02			9.46		82 hr.
[illegible]	5040.00	2.04			9.48		84 hr.
[illegible]	5160.00	2.065			9.505		86 hr.
2:30	5280.00	2.057			9.497		88 hr.
4:30	5400.00	2.05			9.49		90 hr.
6:30	5520.00	2.06			9.50		92 hr.
8:30	5640.00	2.095			9.535		94 hr.
10:30	5760.00	2.12			9.57		96 hr.
12:30	5880.00	2.159			9.599		98 hr.
14:30	6000.00	2.158			9.598		100 hr.
[illegible]	6120.00	[illegible]			9.565		102 hr.

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. DMW-1A + 1950   Elevation of Measuring Point 63.22
Reference Point TOC   Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 7.45
Distance from Pumping well in feet 1950   Pumping Rate (gpm) 2150

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
[illegible]	6240.00	2.095			[illegible]	53.69	104 hr.
20:30	6360.00	2.095			9.595		106 hr.
[illegible]	6480.00	2.125			9.565		108 hr.
[illegible]	6600.00	2.148			[illegible]		110 hr.
[illegible]	6720.00	2.15			9.59		112 hr.
[illegible]	6840.00	2.13			9.58		114 hr.
[illegible]	6960.00	2.14			9.59		116 hr.
[illegible]	7080.00	2.165			9.615		118 hr.
[illegible]	7200.00	2.20			9.65	53.57	120 hr.
12:30	[illegible]	2.225			9.675		
14:30	[illegible]	2.225			9.675		
16:30	[illegible]	2.20			9.65		
18:30	[illegible]	2.20			9.65		
[illegible]	[illegible]	2.155			9.605		
[illegible]	[illegible]	2.145			9.595		
[illegible]	[illegible]	2.14			9.59		
[illegible]	[illegible]	2.11			9.56		
[illegible]	[illegible]	2.075			9.525		
[illegible]	[illegible]	2.05			9.50		
[illegible]	8520.00	2.04			9.49		
[illegible]	[illegible]	2.055			9.505		
11:30	8860.00	2.06			9.51	53.71	

Sheet 1 of
Date 6/17

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. SMW-1A+200 Elevation of Measuring Point 59.08
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.93
Distance from Pumping well in feet 200 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6/17 12:30	0	–			4.93		Pump started at gpm
	0.08						
	0.17						
	0.25						
	0.33						
	0.42						
	0.50						
	0.58						
	0.67						
	0.75						
	0.83						
	0.92						
	1.00	0			4.93		
	1.17						
	1.33						
	1.50						
	1.67						
	1.83						
	2.00	0			4.93		
	2.25						
	2.50						
	2.75						
	3.00	0			4.93		
	3.50						
	4.00						
	4.50						
	5.00	0.01			4.93		
	6.00	0.01			4.94		
	7.00	0.01			4.94		
	8.00						
	9.00						
	10.00	0.01			4.94		
	12.00	0.02			4.95		
	14.00	0.03			4.96		
	16.00	0.04			4.97		
	18.00	0.05			4.98		
12:50	20.00	0.06			4.99		

Sheet 2 of
Date 6/17

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. SMW 1A + 200   Elevation of Measuring Point 59.08
Reference Point TOC   Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.93
Distance from Pumping well in feet 200   Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6/17	22.00	0.07			5.00		
	24.00	0.09			5.02		
	26.00	0.10			5.03		
	28.00	0.12			5.05		
11:00	30.00	0.13			5.06		.5 hr
	35.00	0.17			5.10		
	40.00	0.22			5.15		
	45.00	0.27			5.20		
	50.00	0.32			5.25		
	55.00	0.37			5.30		
11:30	60.00	0.42			5.35		1 hr.
	70.00	0.53			5.46		
	80.00	0.64			5.57		
12:00	90.00	0.75			5.68		
	100.00	0.87			5.80		
	110.00	0.97			5.90		
12:30	120.00	1.07			6.00		2 hr.
12:45	135.00	1.21			6.14		
13:00	150.00	1.37			6.30		
13:15	165.00						
13:30	180.00	1.62			6.55		3 hr.
13:50	200.00						
14:10	220.00	1.89			6.82		
14:30	240.00	1.99			6.92		4 hr.
15:00	270.00	2.13			7.06		
15:30	300.00	2.21			7.14		5 hr.
16:30	360.00	2.33			7.26		6 hr.
17:30	420.00	2.43			7.36		7 hr.
18:30	480.00	2.52			7.45		8 hr.
20:30	600.00	2.69			7.62		10 hr.
22:30	720.00	2.82			7.75		12 hr.
24:30	840.00	2.89			7.82		14 hr.
2:30	960.00	2.95			7.88		16 hr.
4:30	1080.00	3.00			7.93		18 hr.
6:30	1200.00	3.05			7.98		20 hr.
8:30	1320.00	3.10			8.03		22 hr.
10:30	1440.00	3.16			8.09		24 hr.
12:30	1560.00	3.20			8.13		26 hr.

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. SMW 1A+200 Elevation of Measuring Point 59.08
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.93
Distance from Pumping well in feet 200 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
14:30	1680.00	3.24			8.17		28 hr.
16:30	1800.00	3.265			8.195		30 hr.
18:30	1920.00	3.26			8.19		32 hr.
20:30	2040.00	3.30			8.23		34 hr.
22:30	2160.00	3.36			8.29		36 hr.
6/19 24:30	2280.00	3.40			8.33		38 hr.
2:30	2400.00	3.41			8.34		40 hr.
4:30	2520.00	3.44			8.37		42 hr.
6:30	2640.00	3.48			8.41		44 hr.
8:30	2760.00	3.525			8.455		46 hr.
10:30	2880.00	3.56			8.49		48 hr.
12:30	3000.00	3.587			8.517		50 hr.
14:30	3120.00	3.602			8.532		52 hr.
16:30	3240.00	3.610			8.53		54 hr.
18:30	3360.00	3.627			8.547		56 hr.
20:30	3480.00	3.658			8.578		58 hr.
22:30	3600.00	3.70			8.62		60 hr.
6/20 24:30	3720.00	3.73			8.65		62 hr.
2:30	3840.00	3.74			8.66		64 hr.
4:30	3960.00	3.74			8.66		66 hr.
6:30	4080.00	3.75			8.67		68 hr.
8:30	4200.00	3.785			8.705		70 hr.
10:30	4320.00	3.81			8.735		72 hr.
12:30	4440.00	3.83			8.755		74 hr.
14:30	4560.00	3.84			8.765		76 hr.
16:30	4680.00	3.845			8.77		78 hr.
18:30	4800.00	3.855			8.78		80 hr.
20:30	4920.00	3.89			8.795		82 hr.
22:30	5040.00	3.89			8.815		84 hr.
6/21 24:30	5160.00	3.915			8.84		86 hr.
2:30	5280.00	3.93			8.855		88 hr.
4:30	5400.00	3.94			8.865		90 hr.
6:30	5520.00	3.945			8.87		92 hr.
8:30	5640.00	3.965			8.89		94 hr.
10:30	5760.00	3.985			8.91		96 hr.
12:30	5880.00	4.015			8.94		98 hr.
14:30	6000.00	4.025			8.95		100 hr.
16:30	6120.00	4.035			8.96		102 hr.

CDM

Sheet 4 of 5
Date 6/21/

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. SMW 1A ± 200 Elevation of Measuring Point 59.08
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.93
Distance from Pumping well in feet 200 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6/21 18:30	6240.00	4.04			[illegible]		104 hr.
20:30	6360.00	4.045			8.97		106 hr.
22:30	6480.00	4.062			8.987		108 hr.
6/22 24:30	6600.00	4.085			9.01		110 hr.
2:30	6720.00	4.095			9.02		112 hr.
4:30	6840.00	4.10			9.025		114 hr.
6:30	6960.00	4.165			9.03		116 hr.
8:30	7080.00	4.125			9.05		118 hr.
10:30	7200.00	4.14			9.065		120 hr.
12:30	7320.00	4.16			9.085		
14:30	7440.00	4.175			9.10	49.98	
16:30	7560.00	4.175			9.10		
18:30	7680.00	4.18			9.11		
20:30	7800.00	4.065			8.995		
22:30	7920.00	3.85			8.78		
6/23 24:30	8040.00	3.77			8.70		
2:30	8160.00	3.73			8.66		
4:30	8280.00	3.71			8.64		
6:30	8400.00	3.70			8.63		
8:30	8520.00	3.72			8.65		
10:30	8640.00	3.73			8.66		
11:30	8700.00	3.73			8.66	50.42	

Sheet 1 of [illegible]
Date 6/17/8[illegible]

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. SMW-1A +500 Elevation of Measuring Point 60.07
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.225
Distance from Pumping well in feet 500' Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6/17 10:30	0				4.225	55.85	Pump started at gpm
	0.08				4.225		
	0.17				4.225		
	0.25				4.225		
	0.33				4.225		
	0.42				4.225		
	0.50				4.225		
	0.58				4.225		
	0.67				4.225		
	0.75				4.225		
	0.83				4.225		
	0.92				4.225		
	1.00				4.225		
	1.17				4.225		
	1.33				4.225		
	1.50				4.23		
	1.67				4.225		
	1.83				4.225		
	2.00				4.225		
	2.25				4.225		
	2.50				4.225		
	2.75				4.225		
	3.00				4.225		
	3.50				4.225		
	4.00				4.225		
	4.50				4.225		
	5.00				4.225		
	6.00				4.225		
	7.00				4.225		
	8.00				4.225		
	9.00				4.225		
	10.00	0			4.225		
	12.00	0.005			4.23		
	14.00	0.005			4.23		
	16.00	0.005			4.23		
	18.00	0.005			4.23		
	20.00	0.01			4.235		

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. SMW-1A-+500 Elevation of Measuring Point 60.07
Reference Point TOC Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.225
Distance from Pumping well in feet 500 Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6/17	22.00	0.01			4.235		
	24.00	0.01			4.235		
	26.00	0.012			4.237		
	28.00	0.015			4.24		
11:00	30.00	0.015			4.24	55.83	.5 hr
	35.00	0.02			4.245		
	40.00	0.022			4.247		
	45.00	0.027			4.252		
	50.00	0.04			4.265		
	55.00	0.05			4.275		
	60.00	0.055			4.28	55.79	1 hr.
	70.00	0.08			4.305		
	80.00	0.105			4.33		
	90.00	0.127			4.352		
	100.00	0.15			4.375	55.695	
	110.00	0.18			4.405		
	120.00	0.21			4.435	55.635	2 hr.
	135.00	0.245			4.47		
	150.00	0.28			4.505		
	165.00	0.39			4.615		
	180.00	0.43			4.655		3 hr.
	200.00	—			—		
	220.00	0.51			4.735		
	240.00	0.525			4.75		4 hr.
	270.00	0.525			4.75		
	300.00	0.53			4.755	55.315	5 hr.
	360.00	0.545			4.77		6 hr.
	420.00	0.585			4.81		7 hr.
	480.00	0.615			4.84		8 hr.
	600.00	0.695			4.92	55.15	10 hr.
	720.00	0.775			5.0		12 hr.
	840.00	0.835			5.06		14 hr.
	960.00	0.895			5.12	54.95	16 hr.
	1080.00	0.955			5.18		18 hr.
	1200.00	1.025			5.25		20 hr.
	1320.00	—			—		22 hr.
	1440.00	1.095			5.32		24 hr.
	1560.00	1.165			5.39		26 hr.

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. SMW 1A + 500
Elevation of Measuring Point 60.07
Reference Point TOC
Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 4.225
Distance from Pumping well in feet 500
Pumping Rate (gpm) 2150 gpm

	Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
		1680.00	1.245			5.47		28 hr
		1800.00	1.32			5.545		30 hr
		1920.00	1.355			5.58	54.49	32 hr
		2040.00	1.445			5.67		34 hr
		2160.00	1.555			5.78		36 hr
4/19	24:30	2280.00	1.665			5.89		38 hr.
	2:30	2400.00	1.755			5.98		40 hr.
	4:30	2520.00	1.845			6.07		42 hr.
	6:30	2640.00	1.935			6.16	53.91	44 hr.
	8:30	2760.00	2.02			6.245		46 hr.
	10:30	2880.00	2.08			6.305		48 hr.
	12:30	3000.00	2.135			6.36		50 hr.
	14:30	3120.00	2.155			6.38		52 hr.
	16:30	3240.00	2.17			6.395		54 hr.
	18:30	3360.00	2.22			6.445		56 hr.
	20:30	3480.00	2.275			6.50		58 hr.
	22:30	3600.00	2.345			6.57		60 hr.
4/20	24:30	3720.00	2.395			6.62		62 hr.
	2:30	3840.00	2.425			[illegible]		64 hr.
	4:30	3960.00	2.445			[illegible]	53.40	66 hr.
	6:30	4080.00	2.475			6.70	53.37	68 hr.
	8:30	4200.00	2.505			6.73		70 hr.
	10:30	4320.00	2.535			6.76		72 hr.
	12:30	4440.00	2.555			6.78		74 hr.
	14:30	4560.00	2.575			6.80		76 hr.
	16:30	4680.00	2.60			6.825		78 hr.
	18:30	4800.00	2.63			6.855		80 hr.
	20:30	4920.00	2.665			6.89	53.18	82 hr.
	22:30	5040.00	2.685			6.91		84 hr.
4/21	24:30	5160.00	2.71			6.935		86 hr.
	2:30	5280.00	2.73			6.955		88 hr.
	4:30	5400.00	2.75			6.975		90 hr.
	6:30	5520.00	2.765			6.99		92 hr.
	8:30	5640.00	2.785			7.01		94 hr.
	10:30	5760.00	2.805			7.03		96 hr.
	12:30	5880.00	2.825			7.05		98 hr.
	14:30	6000.00	2.845			7.07		100 hr.
	16:30	6120.00	2.855			7.08		102 hr.

CDM

AQUIFER TEST RECORD

WEST COAST REGIONAL

Well No. SMW 1A +500
Elevation of Measuring Point 60.07
Reference Point TOC
Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 41.225
Distance from Pumping well in feet 500
Pumping Rate (gpm) 2150 gpm

	Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
	18:30	6240.00	2.875			7.10	52.97	104 hr.
	20:31	6360.00	2.875			7.10		106 hr.
	22:30	6480.00	2.895			7.12		108 hr.
6/22	24:30	6600.00	2.91			7.135		110 hr.
	2:30	6720.00	2.93			7.148		112 hr.
	4:30	6840.00	2.932			7.157		114 hr.
	6:30	6960.00	2.945			7.17		116 hr.
	8:30	7080.00	2.96			7.185		118 hr.
	10:30	7200.00	2.975			7.20		120 hr.
	12:30	7320.00	2.98			7.205		
	14:30	7440.00	2.99			7.215		
	16:30	7560.00	2.995			7.22	52.85	
	18:30	7680.00	3.02			7.245		
	20:30	7800.00	2.755			6.98		
	22:30	7920.00	2.34			6.565		
6/23	24:30	8040.00	2.06			6.285		
	2:30	8160.00	1.935			6.16		
	4:30	8280.00	1.90			6.125		
	6:30	8400.00	1.905			6.13		
	8:30	8520.00	1.945			6.17		
	10:30	8640.00	2.01			6.235		
	11:30	8860.00	2.035			6.26	53.81	

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Sheet 1 of 2
Date 6/17/86

AQUIFER TEST RECORD

PROJECT 6006-46-PT

Well No. Orifice Readings — Elevation of Measuring Point ______
Reference Point ______ — Elevation of Ground Level ______
Pre-test Water Level (Ref. Measuring Point) ______
Distance from Pumping well in feet ______ — Pumping Rate (gpm) ______

Time	t in min.	s Engine rpm ~~in feet~~	Tape Reading at — Meas. Point	Tape Reading at — Water Level	Depth to water below m.p.	Elev. of water level	Remarks Totalizer meter
15:00		800				19.0	
16:00						19.0	
17:00		800				19.0	2120 gpm
18:15						18 15/16	2140 gpm
19:18		820				19.0	2150 gpm
20:56		800				19.0	2150 gpm
23:02		800				19.0	2150 gpm
6/18 1:00		800				19.0	2150 gpm
3:03		800				19.0	2150 gpm
5:04		800				19.0	2150 gpm
7:32		800				19.0	2150 gpm
8:55		800				19.0	
11:27		800				19.0	2150 gpm
13:02		800				19.0	2150 gpm
15:10		800				19.0	2150 gpm
17:03		800				19.0	
19:00		800				19.0	2150 gpm
21:10		800				19.0	2150 gpm
22:05		800				19.0	2140 gpm
6/19 1:03		800				19.0	2150 gpm
3:04		800				19.0	2150 gpm
5:01		800				19.0	2150 gpm
7:01		800				19.0	2150 gpm
8:53		800				19.0	2140 gpm
11:00		800				19.0	2130 gpm
11:50		800	opened	valve 1/5	turn 9:15	19.0	2140 gpm
12:55		800				19 1/16	2150 gpm
14:59		800				19 1/8	2150 gpm
16:55		800				19 1/8	2150 gpm
18:41		800				19 1/8	2140 gpm
20:56		800				19.0	2150 gpm
23:00		800				19 1/8	2150 gpm
1:00		800				19 1/8	2150 gpm
3:06		800				19 1/8	2150 gpm
5:06		800				19 1/8	2150 gpm
7:02		800				19 1/8	2150 gpm
9:00		800				19 1/8	2150 gpm

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Sheet ___ of ___
Date 6/20/86

AQUIFER TEST RECORD

PROJECT 6006-46-PT

Well No. Orifice Reading
Elevation of Measuring Point ___
Reference Point ___
Elevation of Ground Level ___
Pre-test Water Level (Ref. Measuring Point) ___
Distance from Pumping well in feet ___
Pumping Rate (gpm) ___

Time	t in min.	s Engine RPMs in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks Totalizer meter
11:00		800			19 1/8		2140 gpm
12:55		800			19.0		2150 gpm
15:00		800			19 1/8		2150 gpm
17:00		800			19.0		2150 gpm
19:00		800			19 1/8		2140 gpm
21:00		800			19 1/8		2150 gpm
23:00		800			19 1/8		2150 gpm
6/21 1:00		800			19 1/8		2150 gpm
3:00		800			19 1/8		2150 gpm
5:00		800			19 1/8		2150 gpm
7:00		800			19 1/8		2150 gpm
8:55		800			19.0		2140 gpm
10:56		800			19 1/8		2140 gpm
13:02		800			19 1/8		2150 gpm
14:56		800			19 1/8		2150 gpm
16:56		800			19 1/8		2140 gpm
18:50		800			19 1/8		2150 gpm
21:00		800			19 1/8		2150 gpm
23:00		800			19 1/8		2150 gpm
6/22 1:00		800			19 1/8		2150 gpm
4:00		800			19 1/8		2150 gpm
5:00		800			19 1/8		2140 gpm
7:00		800			19 1/8		2150 gpm
9:00		800			19 1/8		2150 gpm
10:58		800			19 1/16		2150
13:00		800			19 1/16		2150
14:55		800			19 1/16		2140
19:00		800			19 1/4		2150
21:00		800			19 1/4		2150
23:00		800			19 1/4		2150
6/23 1:00		800			19 1/4		2150
3:00		800			19 1/4		2150
5:00		800			19 1/4		2150
7:00		800			19 1/4		2150
9:00		800			19 1/4		2150
10:00		800			19 1/4		2150

CDM

Sheet 1 of 5
Date 6/17

AQUIFER TEST RECORD

PROJECT 6086-46-PT
TPW-1A APT

Well No. STAFF Guage Pond - east
Elevation of Measuring Point ______
Reference Point ______
Elevation of Ground Level ______
Pre-test Water Level (Ref. Measuring Point) ______
Distance from Pumping well in feet ______
Pumping Rate (gpm) 2150 gpm

	Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6/17	9:50					3 7/8		
	5:40					2 9/16		
	21:17					[illegible]		
	24:00					2 9/16		
	1:26					2 9/16		
	3:31					2 9/16		
	6:05					2 9/16		
	8:15					2 9/16		
	10:06					2 9/16		
	11:45					2 9/16		
	2:54					2 5/8		
	17:31					2 9/16		
	19:25					2 9/16		
	21:30					2 9/16		
	23:31					2 9/16		
	1:26					2 9/16		
	3:44					2 5/8		
	5:23					2 5/8		
	8:00					2 5/8		
	9:20					2 5/8		
	11:18					2 5/8		
	13:07					2 5/8		
	15:17					2 5/8		
	17:14					2 5/8		
	18:58					2 5/8		
	22:01					2 5/8		
	23:23					2 5/8		
	1:16					2 5/8		
	3:25					2 5/8		
	5:22					2 5/8		
	7:16					2 7/8		
	9:17					2 3/4		
	11:22					2 5/8		
	13:14					2 5/8		
	15:10					2 3/4		
	17:22					2 7/8		
	19:23					2 7/8		
	21:16					2 7/8		

CDM

Sheet 2 of 2
Date 6/21/8

AQUIFER TEST RECORD

PROJECT TPW-1A
TPW-1A APT

Well No. Staff gauge pond-east Elevation of Measuring Point
Reference Point Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point)
Distance from Pumping well in feet Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
23:24					2 7/8"		
1:28					3"		
3:32					3"		
5:15					3"		
7:17					3"		
9:20					3 1/16"		
11:41					3 1/16		
13:15					3 1/16		
15:43					3 1/8		
17:15					3 1/8		
21:16					3 1/8		
23:15					3 1/8		
6/22 1:20					3 1/8		
4:19					3 1/8		
5:12					3 1/8		
7:15					3 3/8		
9:16					3 5/16		
11:12					3 3/8		
13:16					3 3/8		
15:16					3 3/8		
17:17					3 3/8		Just started raining
21:19					2 7/8		after .99" rain
23:13					2 7/8		at north rain
/23 1:12					2 7/8		gauge
3:21					2 7/8		
5:13					2 1/4		
7:13					1 7/8		
9:28					1 1/2		
10:36					1 1/2		
15:00					1 9/16		
3:47					1 9/16		
7:36					1 9/16		

CDM

Sheet 1 of 2
Date 6/17

AQUIFER TEST RECORD

PROJECT 6006-46-PT
TPW-1A APT

Well No. STAFF guage - northwest Elevation of Measuring Point ____
Reference Point ____ Elevation of Ground Level ____
Pre-test Water Level (Ref. Measuring Point) ____
Distance from Pumping well in feet ≈1450- Pumping Rate (gpm) 2150 gpm

Date	Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6/17	10:13					28 1/4		
	11:18					28 1/4		
	12:12					28 5/16		
	15:05					28 3/16		0.30 rain
	17:50					28 1/8		+0.02 rain
	19:35					28 1/8		
	21:30					28 1/8		
	23:58					28 1/8		
6/18	1:36					28 1/4		
	3:47					28 1/4		
	6:20					28 1/2		
	8:25					28 1/2		
	10:18					28 9/16		
	11:52					28 5/8		
	13:37					28 11/16		0.0 rain
	15:02					28 3/4		0.0 rain
	17:23					28 3/4		0.05 Rain
	19:34					28 3/4		
	21:39					28 7/8		
	23:37					28 7/8		
	1:35					28 7/8		
	3:56					28 7/8		
	5:30					28 7/8		
	9:21					28 7/8		
	9:26					29.0		
	11:23					29		
	13:13					29 1/8		0.025 rain but stopped
	15:22					29 1/4		Starting to Rain Again
	17:20					29 1/4		Light Rain
	19:03					29 1/4		
	22:17					29 1/4		
	23:28					29 1/4		
	1:21					29 1/4		
	3:32					29 1/4		
	5:29					29 1/4		
	7:22					29 1/4		
	9:24					29 1/4		
	11:28					29 1/4		

Sheet 1 of 1
Date 6/17

AQUIFER TEST RECORD

PROJECT TPW-1A APT

Well No. Borrow pit staff gauge
Elevation of Measuring Point
Reference Point
Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point)
Distance from Pumping well in feet northeast of Test well
Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6:50						11 3/16	
6/18 8:02						11 1/8	
10:10						11 1/8	
11:56						11 1/8	
13:45						11 1/4	
15:05						11 1/4	light rain at 15:10
17:19						11 1/4	0.04" rain stopped at 16:30
19:40						11 1/4	
9:30						11 1/4	
11:22						11 3/8	
13:15						11 3/8	Light Rain 0.03" Rain
15:25						11 1/4	
17:22						11 1/4	
19:06						11 1/2	Light Rain Between 5 & 6 0.01"
9:27						11 5/8	
11:30						11 5/8	
13:29						11 7/8	
15:15						11 3/4	
17:35						11 13/16	
19:35						11 7/8	
9:32						12	
11:51						12 1/8	
13:30						12 1/4	0.01 rain
15:55						12 1/4	
17:22						12 1/4	
19:46						12 1/4	
6/22 9:27						12 3/16	
11:22						12 3/16	
13:32						12 3/16	
15:26						12 3/4	
6/ 17:26						12 3/4	started raining
9:24						11 1/2	
10:30						11 1/2	
13:55						11 5/8	
15:49						11 5/8	

CDM

Sheet 2 of 2
Date 6/20

AQUIFER TEST RECORD

PROJECT 6006-46-PT TPW-1A APT

Well No. Staff Gauge - Northwest Elevation of Measuring Point ______
Reference Point ______ Elevation of Ground Level ______
Pre-test Water Level (Ref. Measuring Point) ______
Distance from Pumping well in feet ≈ 1950' Pumping Rate (gpm) 2150 gpm

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
13:20					29 1/2		
15:13					29 1/2		
17:30					29 3/4		
19:30					29 13/14		
21:23					29 3/4		
23:30					29 3/4		
6/21 1:35					29 7/8		
3:38					29 7/8		
5:21					29 7/8		
7:23					30		
9:29					30		
11:45					30 1/16		
13:29					30 1/8		0.01 rain
15:50					30 1/8		
17:21					30 1/4		
19:42					30 1/4		
21:22					30 1/4		
23:22					30 1/4		
6/22 1:24					30 1/4		
4:20					30 1/4		
5:18					30 1/4		
7:26					30 1/2		
9:24					30 1/2		
11:17					30 9/16		
13:22					30 5/8		
15:22					30 3/4		
17:23					30 3/4		Just started rain in
21:32					28 7/8		after .99" of
23:20					28 7/8		rain at north
1:20					28 5/8		raingage
3:29					28 1/8		
5:18					28 1/8		
7:18					29		
9:31					29		
10:41					29		
6/23 1:45					29 1/8		
16:10					29 1/8		
18:05					29 1/4		
3:55					29 1/4		

CDM

Date 6/16/86

AQUIFER TEST RECORD

PROJECT 6006-416

Well No. IMMER WELL Elevation of Measuring Point 55.71 1.54 from Sanitary to TOC

Reference Point Sanitary Collar Elevation of Ground Level

Pre-test Water Level (Ref. Measuring Point)

Distance from Pumping well in feet Pumping Rate (gpm)

~~Time~~ DATE	t ~~in min.~~ TIME	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
6-6-86	7:00p				4.77	52.48	
6-7	8:00p				4.80	52.45	
6-8	7:15p				4.86	52.39	
6-9	5:30				4.93	52.32	
6-10					4.96	52.29	
6-11	6:00p				4.79	52.46	
6-12	1:30p				4.71	52.54	
6-13	—				—	—	
6-14	12:15p				4.26	52.99	
6-15	11:20				4.18	53.07	
6-16	1:45p				3.77	53.48	
6-17	—				9.01	48.24	Surface water is Flowing into the WELL
6-18	—				—	—	
6-19	—				—	—	
6-20	—				—	—	
6-21	6:45				3.30	53.95	
6-21	11:28				3.325	53.925	
6-21	15:30				3.30	53.95	
6-22	6:50				3.35	53.90	
6-22	10:34				3.36	53.89	
6-23	—				3.14	54.11	Surface water is Flowing into WELL
6-24	—				—	—	
6-25	—				—	—	
6-26	14:50				2.28	54.97	
6-27	15:20				2.26	54.99	
6-28	11:36				2.36	54.89	
6-29	11:15				3.01	54.24	
6-30	15:30				1.72	55.53	WATER Flowing into well

CDM

Date 6-1-86

AQUIFER TEST RECORD

PROJECT 6006-46

Well No. Rainfall

Elevation of Measuring Point

Reference Point

Elevation of Ground Level

Pre-test Water Level (Ref. Measuring Point)

Distance from Pumping well in feet

Pumping Rate (gpm)

~~Time~~ DATE	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	~~Depth to water below m.p.~~ Rainfall	Elev. of water level	Remarks
6-1					0.0		
6-2					0.09		
6-3					0.29		
6-4					0.12		
6-5					0.16		All south gauge (6-1 to 6-10)
6-6					0.0		
6-7					0.0		
6-8					0.0		
6-9					0.55		
6-10					—		
6-11					4.53 (?)		
6-12					0.60		South
					0.67		North
6-13					0.55		S
					0.25		N
6-14					0.00		S
					0.00		N
6-15					1.96		S
					—		N
6-16					—		S
					1.93		N Includes 6-15
6-17					0.42		S
					0.30		N
6-18					0.04		S
					0.05		N
6-19					0.03		S
					0.03		N
6-20					0.0		S
					0.0		N
6-21					0.01		S
					0.01		N
6-22					0.77		S
					0.99		N
6-23					0.0		S
					0.0		N
6-24					0.0		S Started Raining
					0.0		N Shortly Afterward

CDM

2.2
Date 6/25/86

AQUIFER TEST RECORD

PROJECT 6006-46

Well No. Rainfall
Reference Point
Pre-test Water Level (Ref. Measuring Point)
Distance from Pumping well in feet
Elevation of Measuring Point
Elevation of Ground Level
Pumping Rate (gpm)

~~Time~~ DATE	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	~~Depth to water below m.p.~~ RAINFALL	Elev. of water level	Remarks
6-25					0.43		S
					0.55		N
6-26					0.05		S
					0.04		N
6-27					0.0		S
					0.0		N
6-28					0.0		S
					0.0		N
6-29					1.19		S
					1.29		N

APPENDIX H

AQUIFER PERFORMANCE TEST ANALYSES

APT DRAWDOWN DATA SUMMARY

West Coast Regional Water Supply Authority
Phase IA Aquifer Performance Test
Drawdown Data Summary

TPW-1A Q = 2150 gpm

TIME		DRAWDOWN (ft.)				
			Corrected			
Log	Minutes	Uncorrected	Well Loss (a)	Well Loss & Regional Trend (b)	Well Loss, Regional Trend, & Rain (c)	Log(c) (d)
	0.00	0.000	0.000			
-1.097	0.08	0.670	-0.130			
-0.770	0.17	1.340	0.540	0.540	0.540	-0.268
-0.602	0.25	2.010	1.210	1.210	1.210	0.083
-0.481	0.33	2.680	1.880	1.880	1.880	0.274
-0.377	0.42	3.350	2.550	2.550	2.550	0.407
-0.301	0.50	4.000	3.200	3.200	3.200	0.505
-0.237	0.58	4.015	3.215	3.215	3.215	0.507
-0.174	0.67	4.030	3.230	3.230	3.230	0.509
-0.125	0.75	4.045	3.245	3.245	3.245	0.511
-0.081	0.83	4.060	3.260	3.260	3.260	0.513
036	0.92	4.075	3.275	3.275	3.275	0.515
0.000	1.00	4.090	3.290	3.290	3.290	0.517
0.124	1.33	4.170	3.370	3.370	3.370	0.528
0.176	1.50	4.220	3.420	3.420	3.420	0.534
0.262	1.83	4.280	3.480	3.480	3.480	0.542
0.699	5.00	4.630	3.830	3.831	3.831	0.583
1.000	10.00	4.930	4.130	4.131	4.131	0.616
1.415	26.00	5.410	4.610	4.614	4.614	0.664
1.699	50.00	5.810	5.010	5.017	5.017	0.700
1.903	80.00	6.110	5.310	5.321	5.321	0.726
2.000	100.00	6.300	5.500	5.514	5.514	0.741
2.217	165.00	6.630	5.830	5.853	5.853	0.767
2.477	300.00	6.990	6.190	6.232	6.232	0.795
2.623	420.00	7.165	6.365	6.423	6.431	0.808
2.778	600.00	7.355	6.555	6.638	6.657	0.823
2.982	960.00	7.540	6.740	6.873	6.914	0.840
3.079	1200.00	7.630	6.830	6.997	7.052	0.848
3.158	1440.00	7.710	6.910	7.110	7.180	0.856
3.255	1800.00	7.695	6.895	7.145	7.237	0.860
3.380	2400.00	7.780	6.980	7.313	7.442	0.872
3.477	3000.00	7.895	7.095	7.512	7.607	0.881
3.623	4200.00	7.980	7.180	7.763	7.785	0.891
3.681	4800.00	7.947	7.147	7.814	7.814	0.893
3.742	5520.00	8.020	7.220	7.912	7.912	0.898
3.787	6120.00	8.070	7.270	7.983	7.983	0.902
827	6720.00	8.120	7.320	8.053	8.053	0.906
.865	7320.00	8.170	7.370	8.124	8.124	0.910
3.899	7920.00	8.095	7.295	8.070	8.104	0.909
3.930	8520.00	7.997	7.197	7.993	8.118	0.909
3.947	8860.00					

West Coast Regional Water Supply Authority
Phase IA Aquifer Performance Test
Drawdown Data Summary

DMW-1A+1950 Q = 2150 gpm

TIME		DRAWDOWN (ft.)				
			Corrected			
Log	Minutes	Uncorrected	Partial Penetration (-0.04) (a)	Partial Penetration & Regional Trend (b)	Partial Penetration, Regional Trend, & Rain (c)	Log(c) (d)
	0.00	0.000				
-1.097	0.08	0.000	-0.040			
-0.770	0.17	0.000	-0.040			
-0.602	0.25	0.000	-0.040			
-0.481	0.33	0.000	-0.040			
-0.377	0.42	0.000	-0.040			
-0.301	0.50	0.000	-0.040			
-0.237	0.58	0.000	-0.040			
-0.174	0.67	0.000	-0.040			
-0.125	0.75	0.000	-0.040			
-0.081	0.83	0.000	-0.040			
036	0.92	0.000	-0.040			
0.000	1.00	0.000	-0.040			
0.124	1.33	0.000	-0.040			
0.176	1.50	0.000	-0.040			
0.262	1.83	0.000	-0.040			
0.699	5.00	0.012	-0.028			
1.000	10.00	0.035	-0.005			
1.415	26.00	0.120	0.080	0.084	0.084	-1.078
1.699	50.00	0.245	0.205	0.212	0.212	-0.674
1.903	80.00	0.400	0.360	0.371	0.371	-0.430
2.000	100.00	0.500	0.460	0.474	0.474	-0.324
2.217	165.00	0.770	0.730	0.753	0.753	-0.123
2.477	300.00	1.220	1.180	1.222	1.222	0.087
2.623	420.00	1.390	1.350	1.408	1.416	0.149
2.778	600.00	1.530	1.490	1.573	1.592	0.197
2.982	960.00	1.640	1.600	1.733	1.774	0.239
3.079	1200.00	1.755	1.715	1.882	1.937	0.275
3.158	1440.00	1.805	1.765	1.965	2.035	0.293
3.255	1800.00	1.780	1.740	1.990	2.082	0.299
3.380	2400.00	1.850	1.810	2.143	2.272	0.331
3.477	3000.00	1.960	1.920	2.337	2.432	0.369
3.623	4200.00	2.020	1.980	2.563	2.585	0.409
3.681	4800.00	2.007	1.967	2.634	2.634	0.421
3.742	5520.00	2.060	2.020	2.712	2.712	0.433
3.787	6120.00	2.128	2.088	2.801	2.801	0.447
827	6720.00	2.150	2.110	2.843	2.843	0.454
.865	7320.00	2.225	2.185	2.939	2.939	0.468
3.899	7920.00	2.145	2.105	2.880	2.914	0.459
3.930	8520.00	2.040	2.000	2.796	2.921	0.447
3.947	8860.00	2.060	2.020	2.828	3.005	0.451

West Coast Regional Water Supply Authority
Phase IA Aquifer Performance Test
Drawdown Data Summary

DMW-1A+500 Q = 2150 gpm

TIME		DRAWDOWN (ft.)				
			Corrected			
Log	Minutes	Uncorrected	Partial Penetration (-0.14) (a)	Partial Penetration & Regional Trend (b)	Partial Penetration, Regional Trend, & Rain (c)	Log(c) (d)
	0.00	0.000				
-1.097	0.08	0.015	-0.125			
-0.770	0.17	0.085	-0.055			
-0.602	0.25	0.210	0.070	0.070	0.070	-1.155
-0.481	0.33	0.305	0.165	0.165	0.165	-0.782
-0.377	0.42	0.335	0.195	0.195	0.195	-0.710
-0.301	0.50	0.395	0.255	0.255	0.255	-0.593
-0.237	0.58	0.425	0.285	0.285	0.285	-0.545
-0.174	0.67	0.465	0.325	0.325	0.325	-0.488
-0.125	0.75	0.505	0.365	0.365	0.365	-0.438
081	0.83	0.535	0.395	0.395	0.395	-0.403
-0.036	0.92	0.570	0.430	0.430	0.430	-0.366
0.000	1.00	0.625	0.485	0.485	0.485	-0.314
0.124	1.33	0.725	0.585	0.585	0.585	-0.233
0.176	1.50					
0.262	1.83	0.815	0.675	0.675	0.675	-0.171
0.699	5.00	1.215	1.075	1.076	1.076	0.032
1.000	10.00	1.525	1.385	1.386	1.386	0.142
1.415	26.00	2.035	1.895	1.899	1.899	0.278
1.699	50.00	2.395	2.255	2.262	2.262	0.354
1.903	80.00	2.710	2.570	2.581	2.581	0.412
2.000	100.00	2.870	2.730	2.744	2.744	0.438
2.217	165.00	3.170	3.030	3.053	3.053	0.485
2.477	300.00	3.535	3.395	3.437	3.437	0.536
2.623	420.00	3.745	3.605	3.663	3.671	0.565
2.778	600.00	3.970	3.830	3.913	3.932	0.595
2.982	960.00	4.145	4.005	4.138	4.179	0.621
3.079	1200.00	4.245	4.105	4.272	4.327	0.636
3.158	1440.00	4.365	4.225	4.425	4.495	0.653
3.255	1800.00	4.370	4.230	4.480	4.572	0.660
3.380	2400.00	4.450	4.310	4.643	4.772	0.679
3.477	3000.00	4.547	4.407	4.824	4.919	0.692
3.623	4200.00	4.730	4.590	5.173	5.195	0.716
3.681	4800.00	4.710	4.570	5.237	5.237	0.719
3.742	5520.00	4.765	4.625	5.317	5.317	0.726
787	6120.00	4.845	4.705	5.418	5.418	0.734
.827	6720.00	4.790	4.650	5.383	5.383	0.731
3.865	7320.00	4.862	4.722	5.476	5.476	0.738
3.899	7920.00	4.775	4.635	5.410	5.444	0.736
3.930	8520.00	4.695	4.555	5.351	5.476	0.738
3.947	8860.00	4.715	4.575	5.383	5.560	0.745

West Coast Regional Water Supply Authority
Phase IA Aquifer Performance Test
Drawdown Data Summary

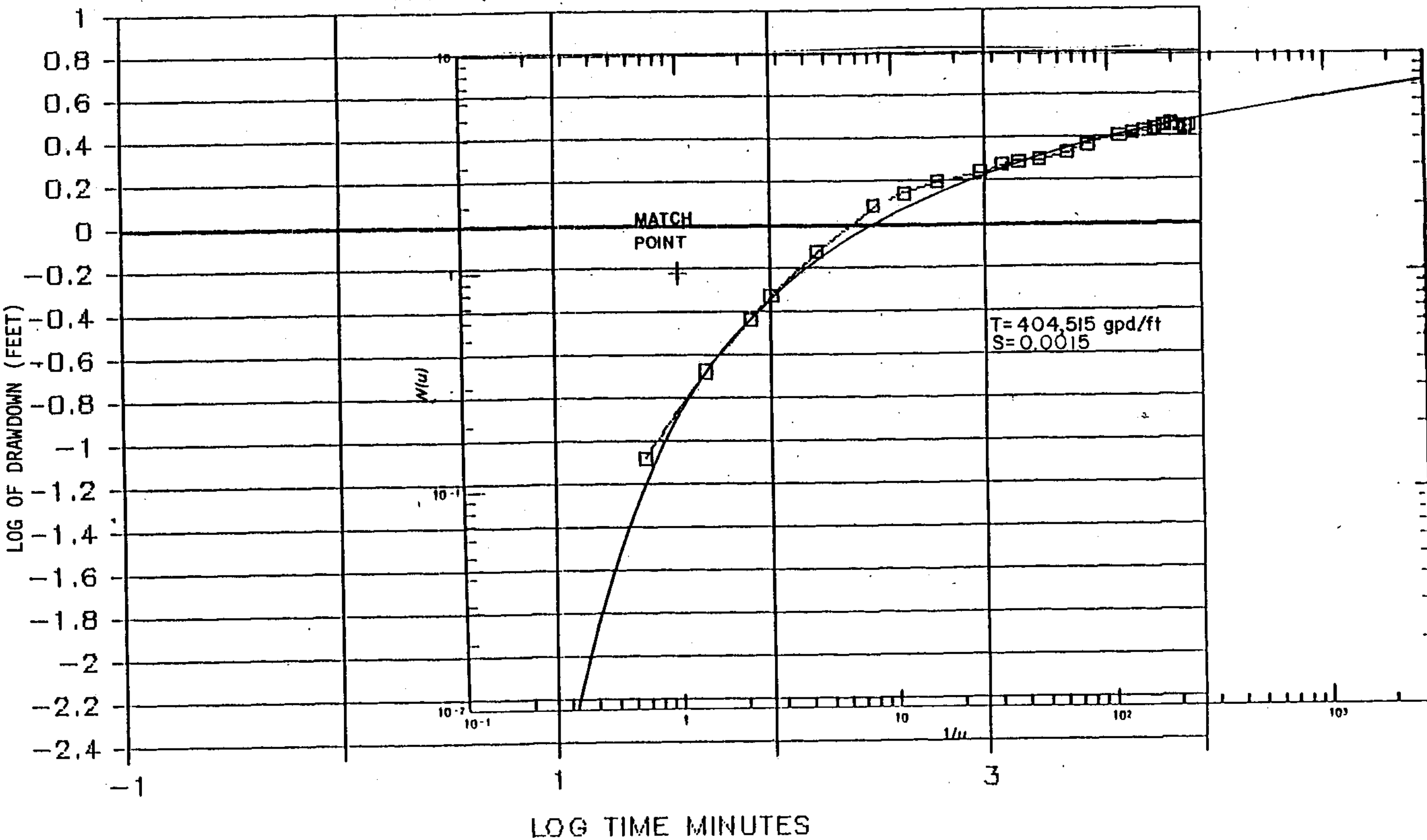
DMW-1A+200 Q = 2150 gpm

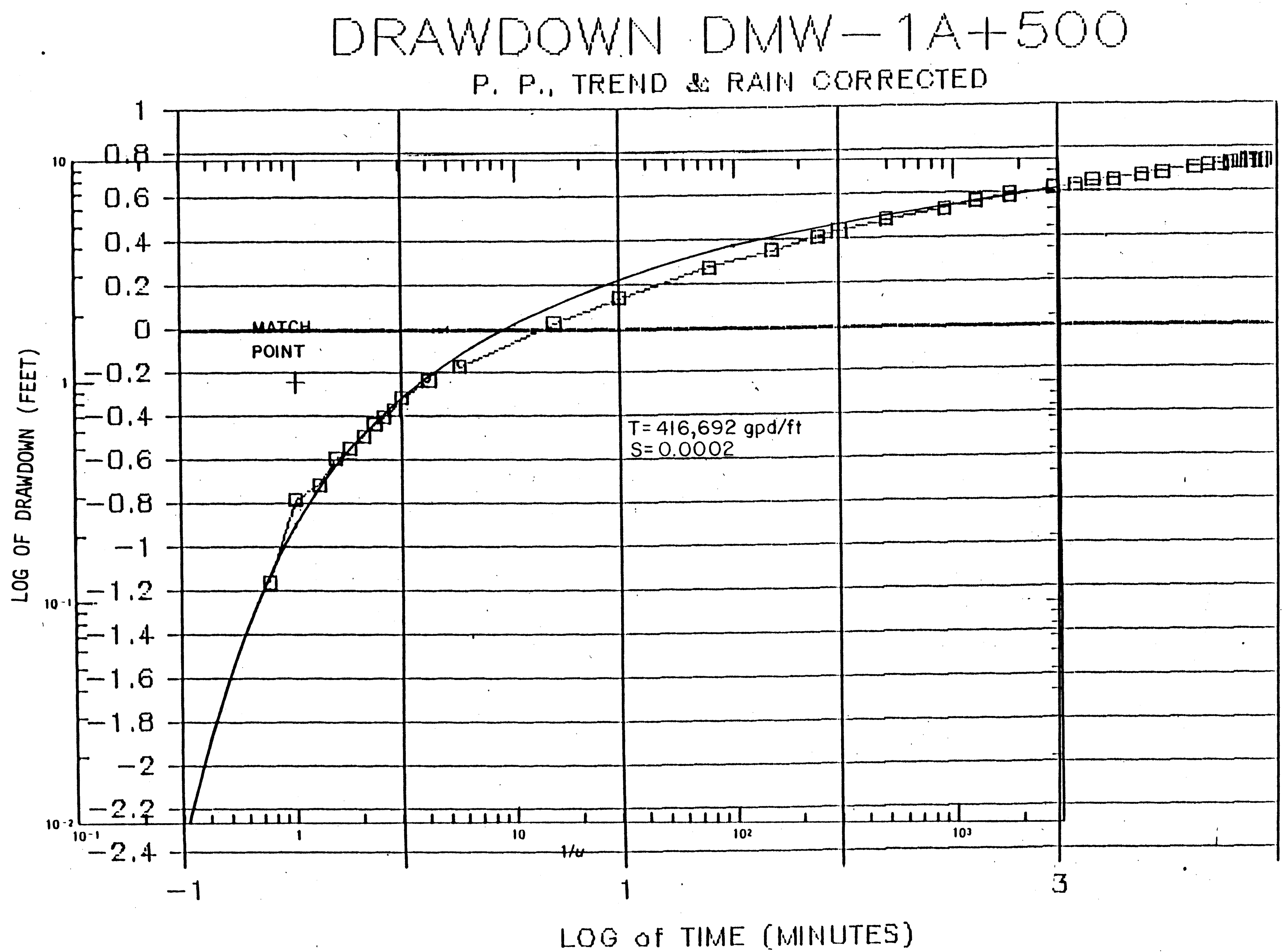
TIME		DRAWDOWN (ft.)				
			Corrected			
Log	Minutes	Uncorrected	Partial Penetration (-0.35) (a)	Partial Penetration & Regional Trend (b)	Partial Penetration, Regional Trend, & Rain (c)	Log(c) (d)
	0.00	0.000				
-1.097	0.08	0.010	-0.340			
-0.770	0.17	0.260	-0.090			
-0.602	0.25	0.600	0.250	0.250	0.250	-0.602
-0.481	0.33	0.860	0.510	0.510	0.510	-0.292
-0.377	0.42	1.020	0.670	0.670	0.670	-0.174
-0.301	0.50	1.070	0.720	0.720	0.720	-0.143
-0.237	0.58	1.100	0.750	0.750	0.750	-0.125
-0.174	0.67	1.130	0.780	0.780	0.780	-0.108
-0.125	0.75	1.180	0.830	0.830	0.830	-0.081
-0.081	0.83	1.195	0.845	0.845	0.845	-0.073
036	0.92	1.210	0.860	0.860	0.860	-0.065
0.000	1.00	1.230	0.880	0.880	0.880	-0.055
0.124	1.33	1.350	1.000	1.000	1.000	.000
0.176	1.50	1.390	1.040	1.040	1.040	0.017
0.262	1.83	1.480	1.130	1.130	1.130	0.053
0.699	5.00	1.930	1.580	1.581	1.581	0.199
1.000	10.00	2.280	1.930	1.931	1.931	0.286
1.415	26.00	2.740	2.390	2.394	2.394	0.379
1.699	50.00	3.140	2.790	2.797	2.797	0.447
1.903	80.00	3.440	3.090	3.101	3.101	0.492
2.000	100.00	3.590	3.240	3.254	3.254	0.512
2.217	165.00	3.910	3.560	3.583	3.583	0.554
2.477	300.00	4.275	3.925	3.967	3.967	0.598
2.623	420.00	4.460	4.110	4.168	4.176	0.621
2.778	600.00	4.685	4.335	4.418	4.437	0.647
2.982	960.00	4.860	4.510	4.643	4.684	0.671
3.079	1200.00	4.955	4.605	4.772	4.827	0.684
3.158	1440.00	5.080	4.730	4.930	5.000	0.699
3.255	1800.00	5.070	4.720	4.970	5.062	0.704
3.380	2400.00	5.155	4.805	5.138	5.267	0.722
3.477	3000.00	5.247	4.897	5.314	5.409	0.733
3.623	4200.00	5.310	4.960	5.543	5.565	0.745
3.681	4800.00	5.295	4.945	5.612	5.612	0.749
3.742	5520.00	5.360	5.010	5.702	5.702	0.756
3.787	6120.00	5.428	5.078	5.791	5.791	0.763
827	6720.00	5.480	5.130	5.863	5.863	0.768
.865	7320.00	5.547	5.197	5.951	5.951	0.775
3.899	7920.00	5.460	5.110	5.885	5.919	0.772
3.930	8520.00	5.400	5.050	5.846	5.971	0.776
3.947	8860.00					

THEIS NONEQUILIBRIUM METHOD

DRAWDOWN DM\.-1A+1950

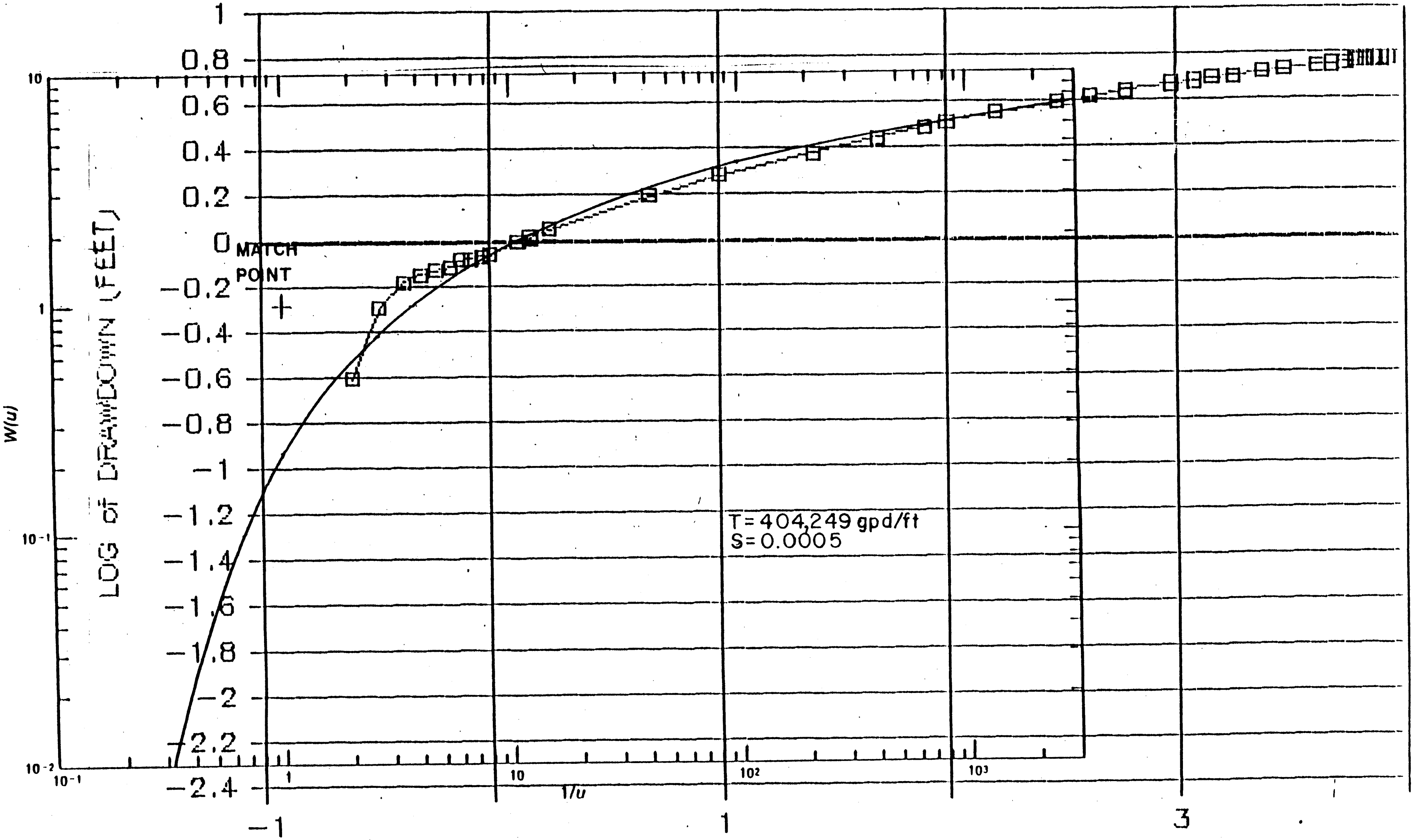
P. P., TREND & RAIN CORRECTED

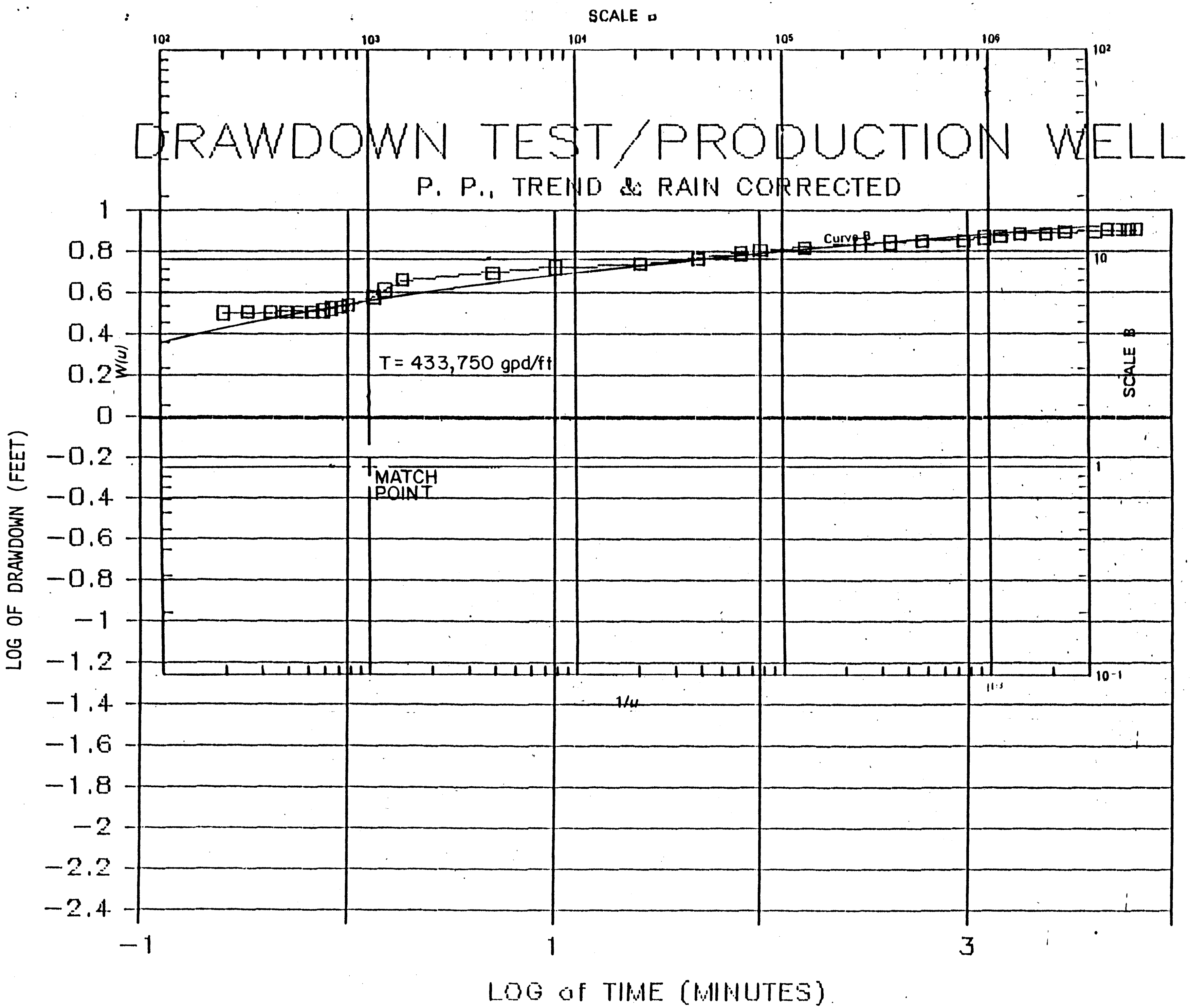



DRAWDOWN DMW—1A+500
P. P., TREND & RAIN CORRECTED
LOG OF DRAWDOWN (FEET)
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6
−1.8
−2
−2.2
−2.4
10
1
10^{-1}
10^{-2}
MATCH POINT
T= 416,692 gpd/ft
S= 0.0002
10^{-1}
1
10
10^2
10^3
1/u
−1
1
3
LOG of TIME (MINUTES)

DRAWDOWN DMW-1A+200

P. P., TREND & RAIN CORRECTED



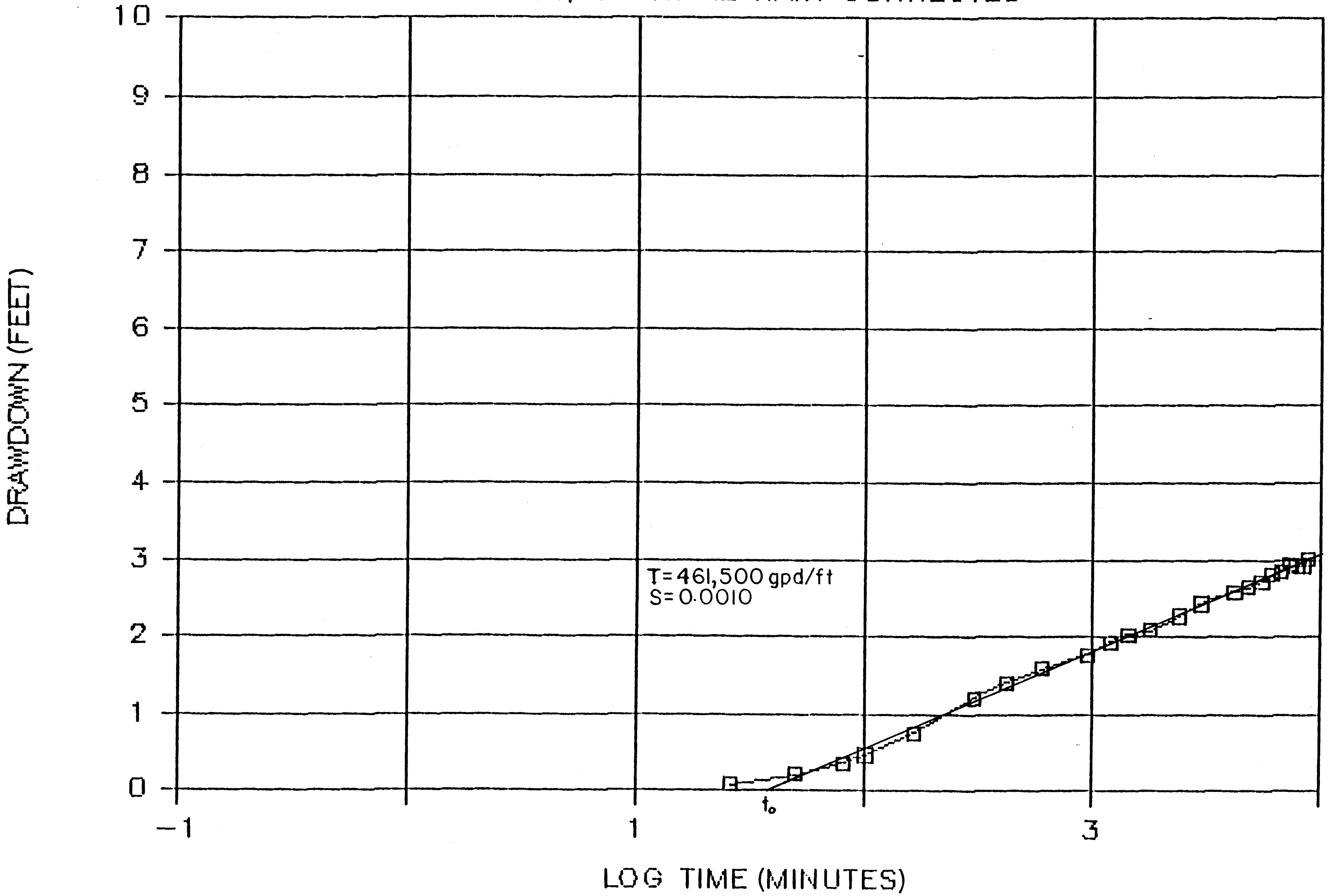


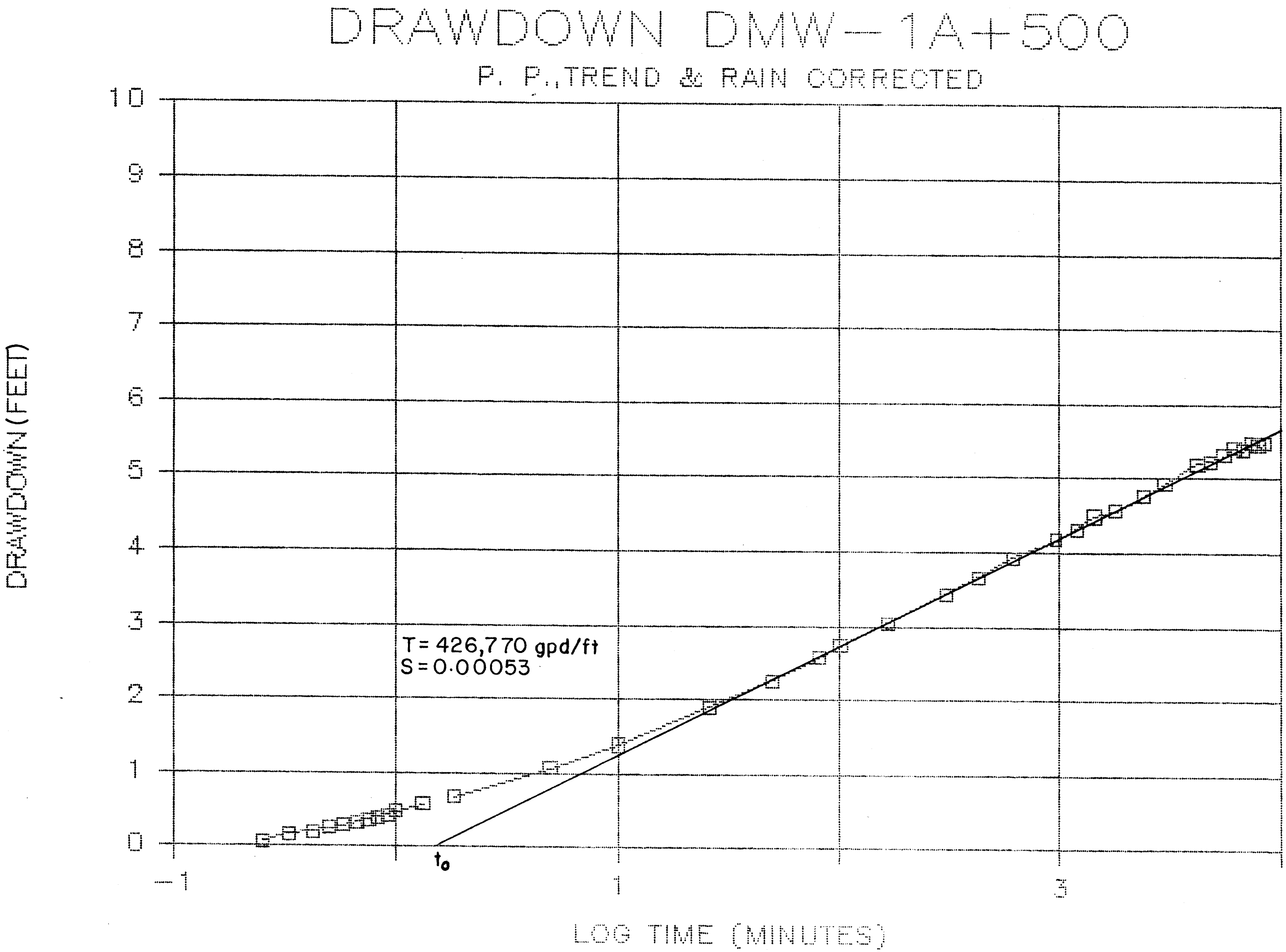
DRAWDOWN TEST/PRODUCTION WELL
P. P., TREND & RAIN CORRECTED
SCALE B
T= 433,750 gpd/ft
MATCH POINT
Curve B
W(u)
1/u
LOG OF DRAWDOWN (FEET)
LOG of TIME (MINUTES)

COOPER - JACOB METHOD

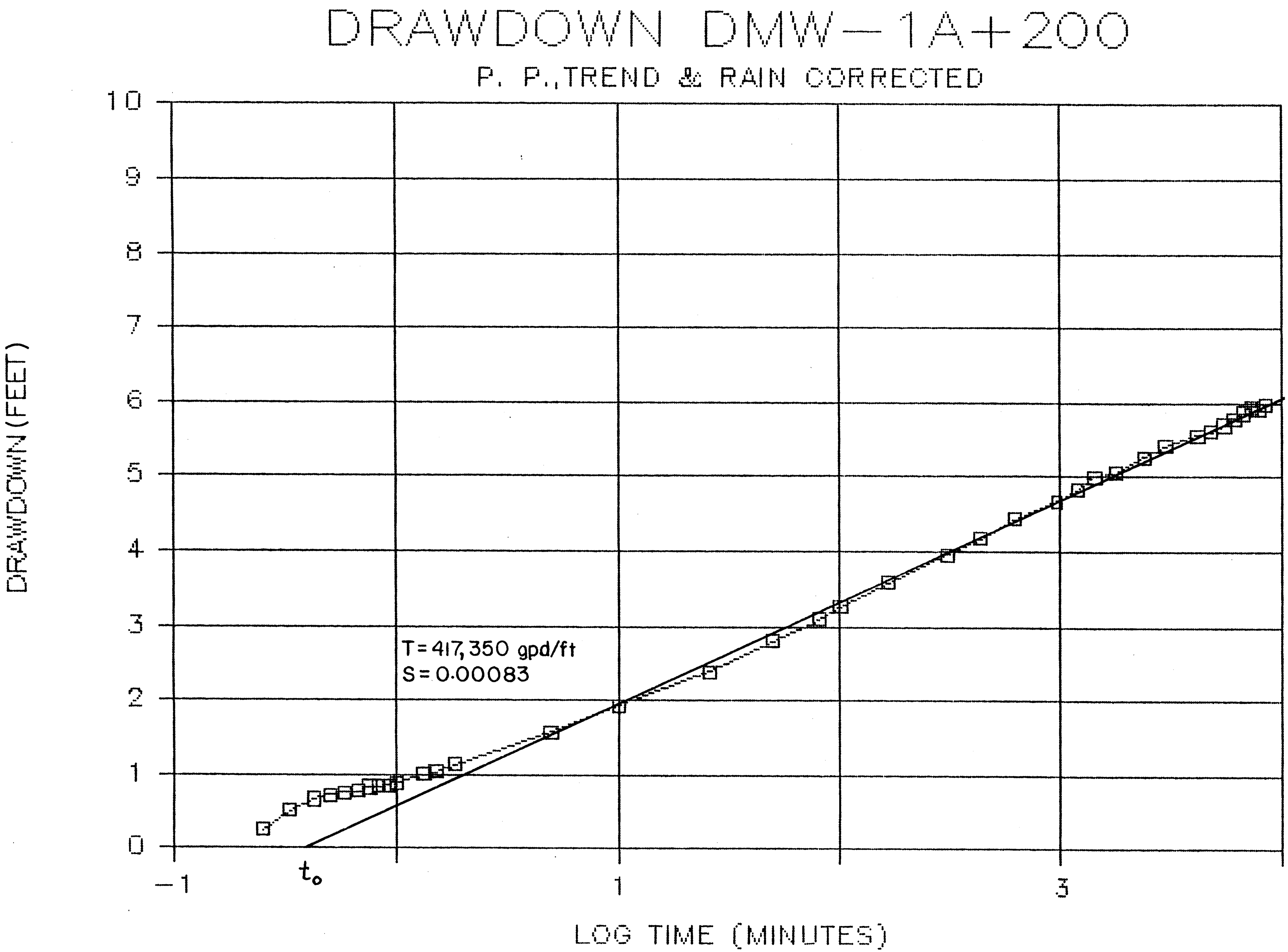
DRAWDOWN DMW-1A+1950

P. P., TREND & RAIN CORRECTED

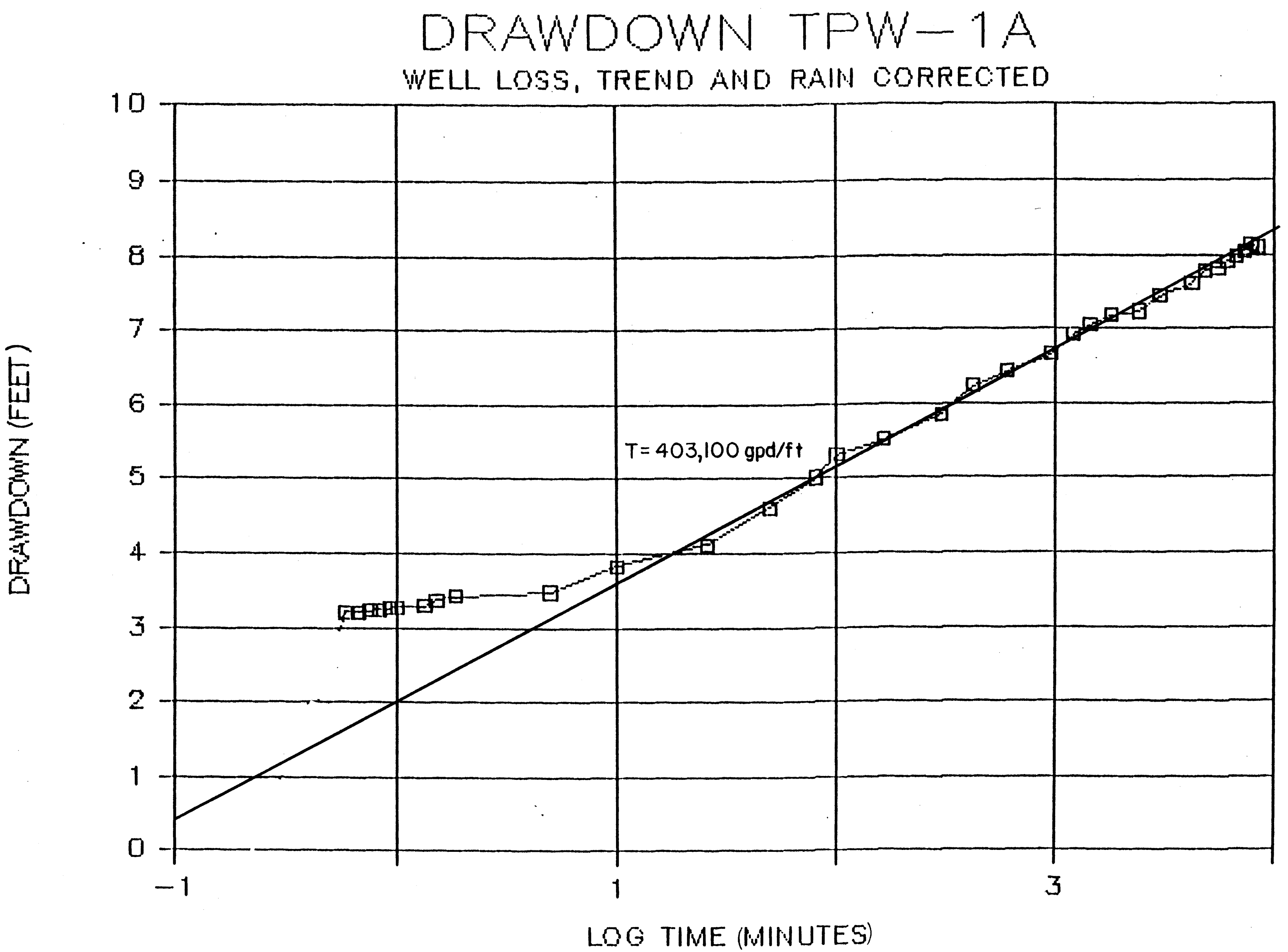




DRAWDOWN DMW-1A+500
P. P., TREND & RAIN CORRECTED
DRAWDOWN (FEET)
10
9
8
7
6
5
4
3
2
1
0
T= 426,770 gpd/ft
S=0.00053
t_0
-1
1
3
LOG TIME (MINUTES)



DRAWDOWN DMW-1A+200
P. P., TREND & RAIN CORRECTED
DRAWDOWN (FEET)
10
9
8
7
6
5
4
3
2
1
0
-1
1
3
t_o
T = 417,350 gpd/ft
S = 0.00083
LOG TIME (MINUTES)

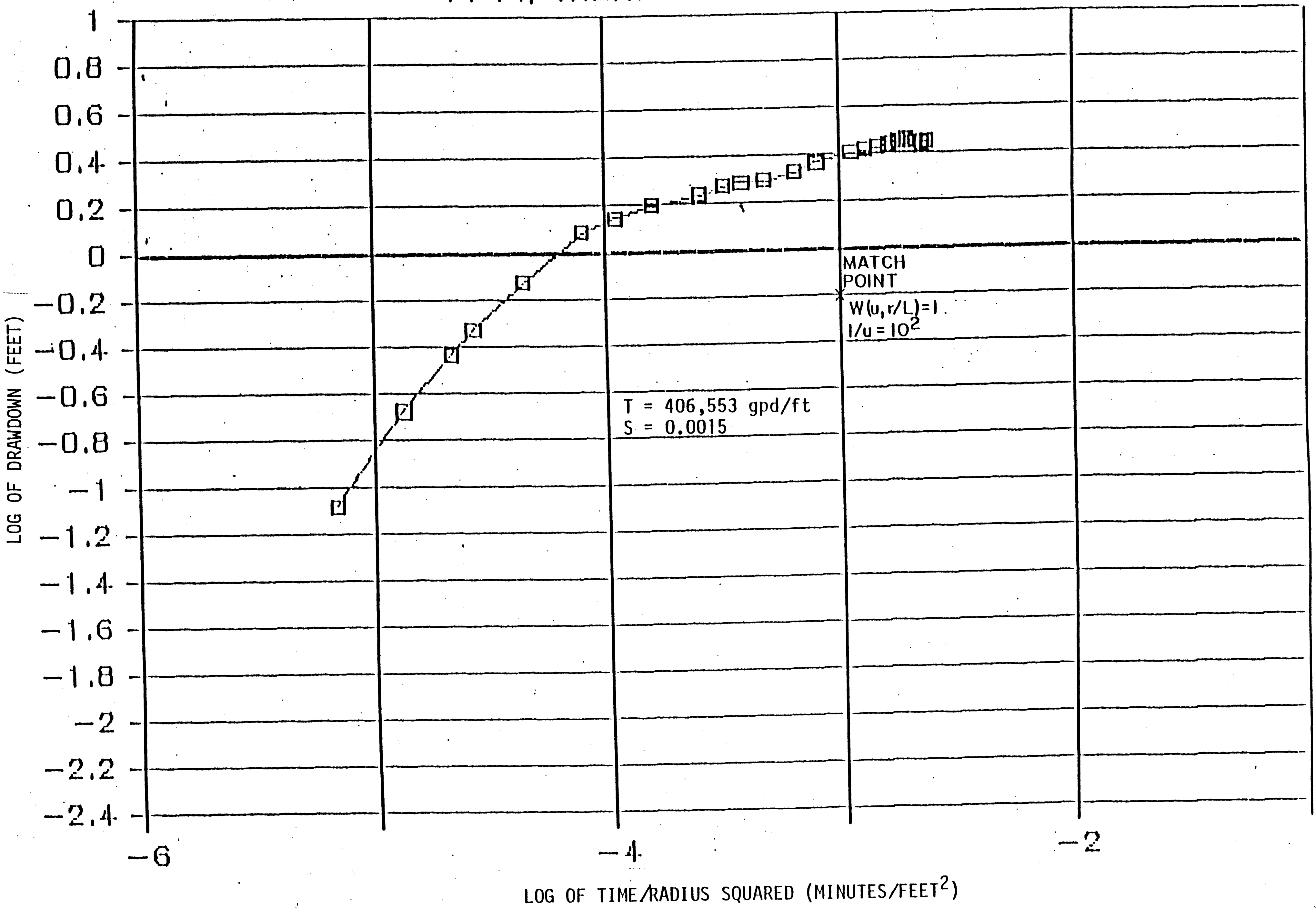


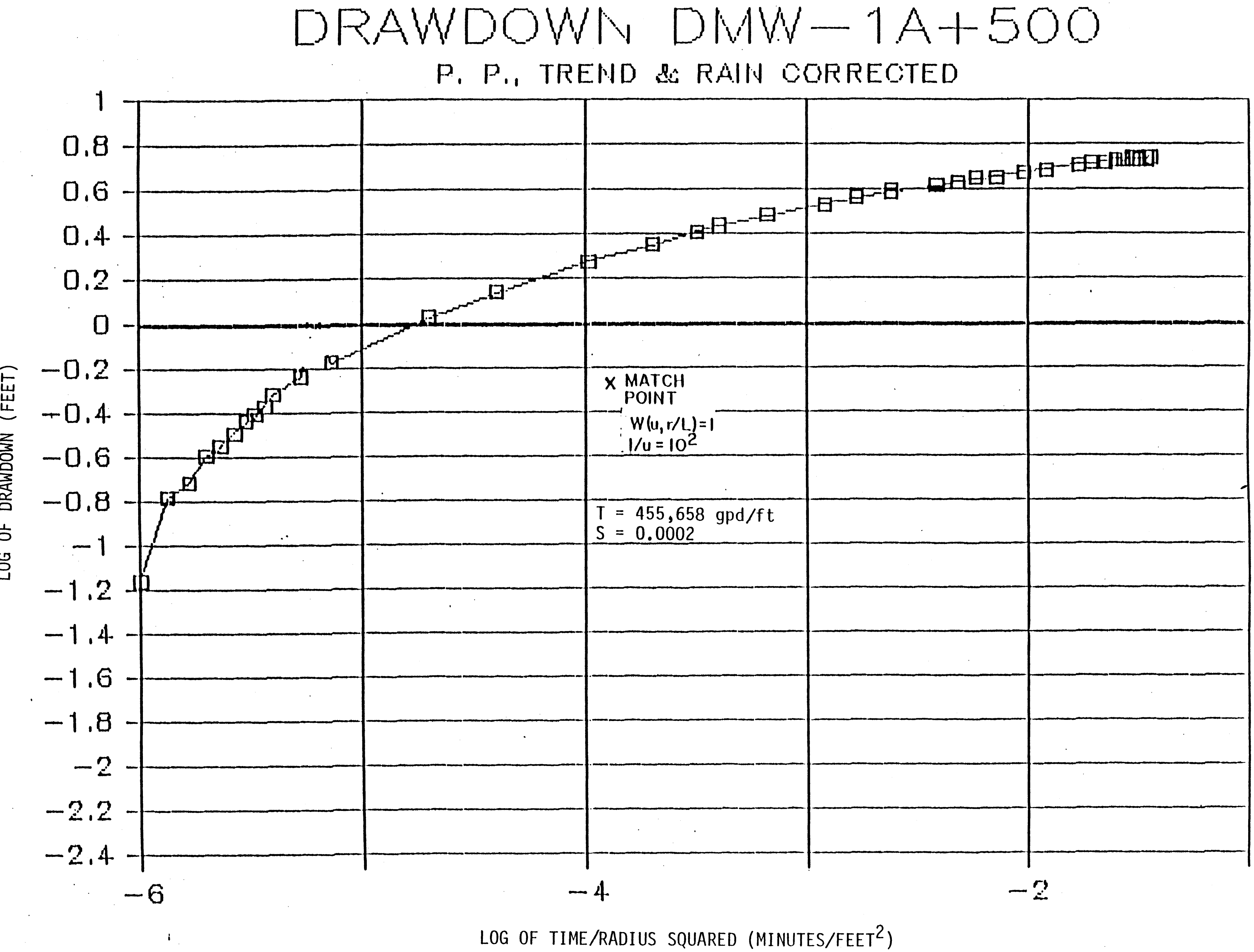
DRAWDOWN TPW-1A
WELL LOSS, TREND AND RAIN CORRECTED
DRAWDOWN (FEET)
LOG TIME (MINUTES)
T= 403,100 gpd/ft
10
9
8
7
6
5
4
3
2
1
0
−1
1
3

WALTON METHOD

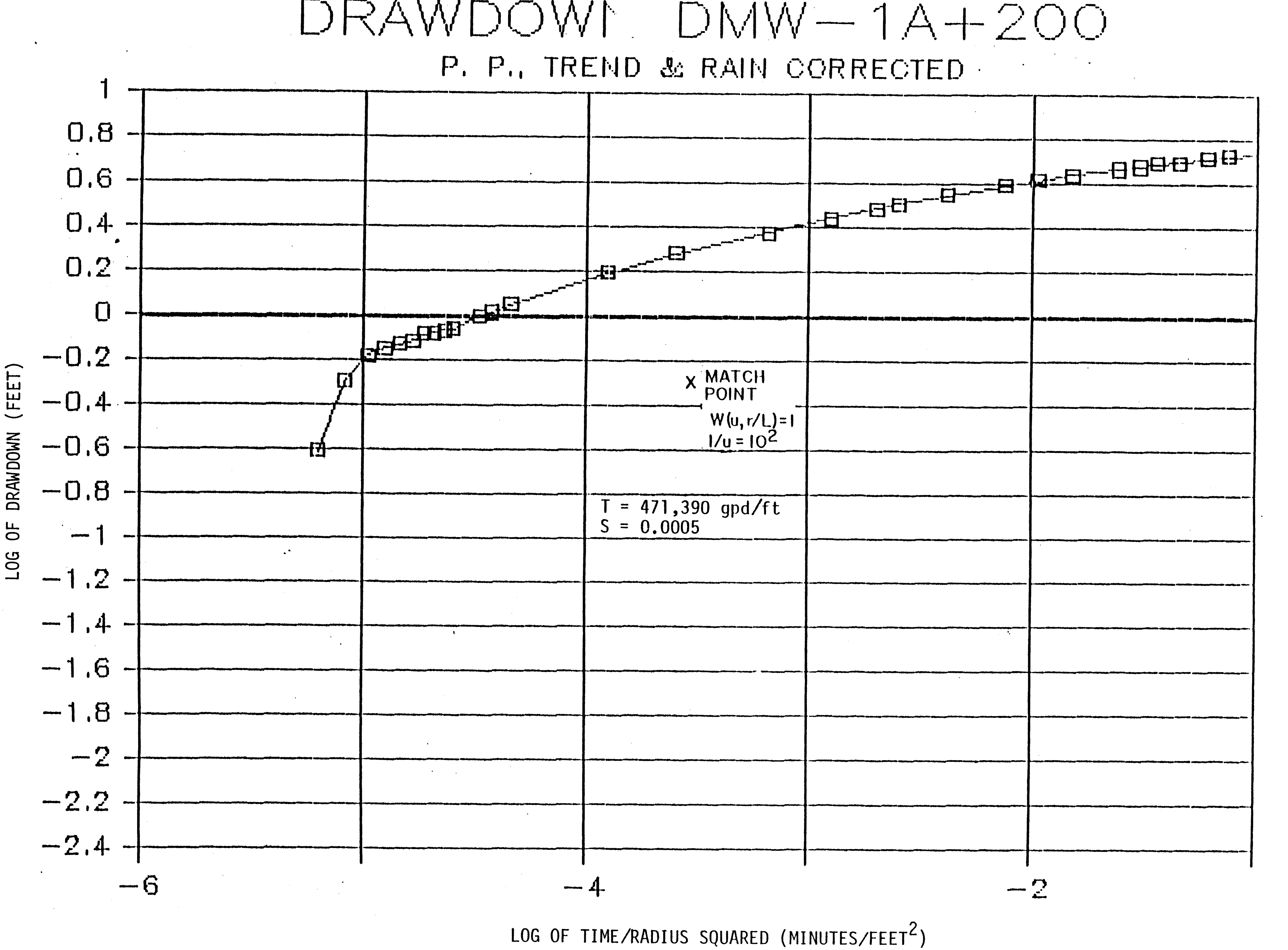
DRAWDOWN DMW-1A+195C

P. P., TREND & RAIN CORRECTED

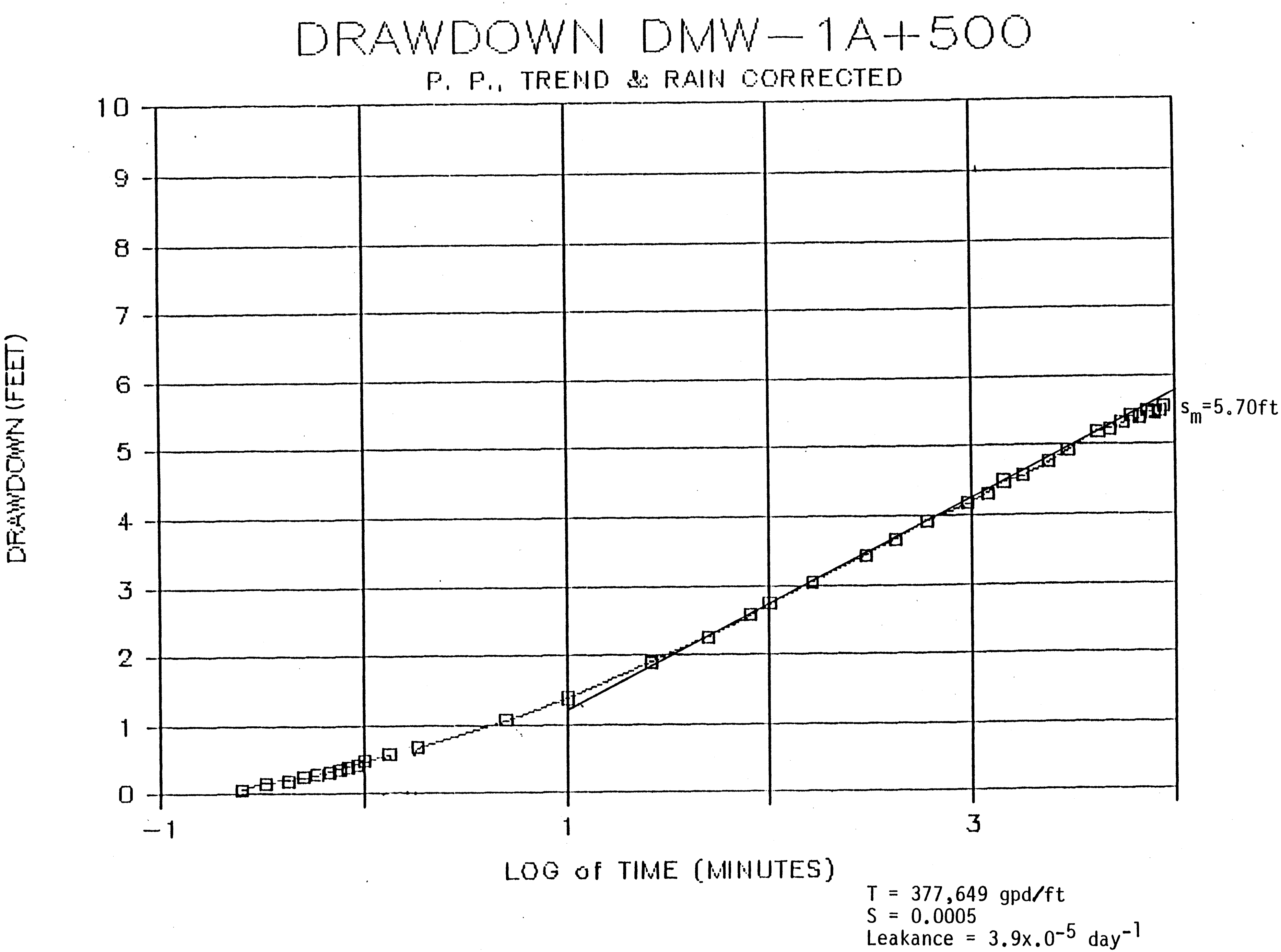




DRAWDOWN DMW-1A+500
P. P., TREND & RAIN CORRECTED
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-2.2
-2.4
-6
-4
-2
LOG OF DRAWDOWN (FEET)
LOG OF TIME/RADIUS SQUARED (MINUTES/FEET2)
X MATCH POINT
W(u, r/L) = 1
1/u = 10^2
T = 455,658 gpd/ft
S = 0.0002


DRAWDOWN DMW-1A+200
P. P., TREND & RAIN CORRECTED
LOG OF DRAWDOWN (FEET)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-2.2
-2.4
-6
-4
-2
X MATCH POINT
W(u, r/L) = 1
1/u = 10^2
T = 471,390 gpd/ft
S = 0.0005
LOG OF TIME/RADIUS SQUARED (MINUTES/FEET^2)

HANTUSH I METHOD



DRAWDOWN DMW—1A+500
P. P., TREND & RAIN CORRECTED
DRAWDOWN (FEET)
10
9
8
7
6
5
4
3
2
1
0
−1
1
3
LOG of TIME (MINUTES)
s_m=5.70ft
T = 377,649 gpd/ft
S = 0.0005
Leakance = 3.9x.0^{-5} day^{-1}

HANTUSH, M. S., 1964.
HYDRAULICS OF WELLS. ADVANCES IN HYDROSCIENCES

The point where $W(u, r/L) = 1$ and $1/u = 10^2$ is chosen as match point A_{90}. On the observed data sheet this point has the coordinates $s = 0.035$ m ant $t = 0.22$ day. Introduction of the appropriate numerical values into Eqs. (27) and (28) yields

$$kD = \frac{Q}{4\pi s} W(u,r/L) = \frac{761}{4 \times 3.14 \times 0.035} \times 1 = 1729 \text{ m}^2/\text{day}$$

and

$$S = \frac{4kDt}{r^2} u = \frac{4 \times 1729 \times 0.22}{90^2} \times \frac{1}{10^2} = 1.9 \times 10^{-3}$$

Furthermore, because $r = 90$ m and $r/L = 0.1$ it follows that $L = 900$ m and hence $c = L^2/kD = (900)^2/1729 = 468$ days.

3.4.2. HANTUSH'S METHOD I

HANTUSH (1956) developed several methods of analyzing the data from pumping tests in semi-confined aquifers, using the inflection point of the time-drawdown curve on single logarithmic paper. However, to determine the inflection point the steady-state drawdown should be known from direct observation or from extrapolation.
The following assumptions and conditions should be satisfied:

- *The assumptions and limiting conditions as listed for the Walton method* (*Section* 4.1).
- *The steady-state drawdown should be* (*approximately*) *known.*

In the Hantush method I, which is based on Eq. (27), the drawdown measurements of a single piezometer are used.
The curve of s versus t on single logarithmic paper has an inflection point p, discussed further below (Fig. 26) where the following relations hold

a. $$s_p = \tfrac{1}{2} s_m = \frac{Q}{4\pi kD} K_0\left(\frac{r}{L}\right) \qquad (29)$$

where K_0 is the modified Bessel function of the second kind and zero order.

b. $$u_p = \frac{r^2 S}{4kDt_p} = \frac{r}{2L} \qquad (30)$$

c. the slope of the curve at the inflection point, Δs_p, is given by

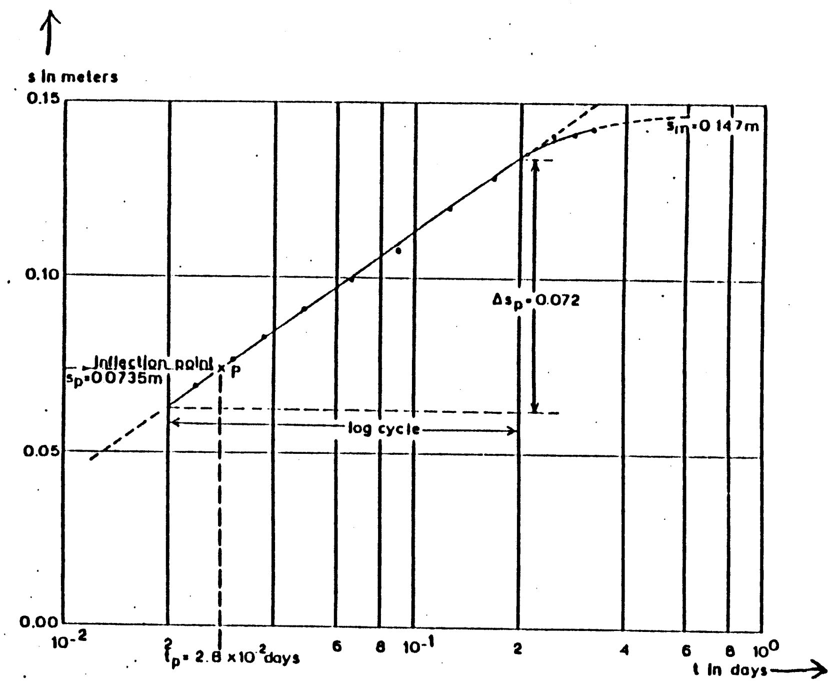


Fig. 26. Analysis of data from pumping test 'Dalem' ($r = 90$ m) the Hantush method I

$$\Delta s_p = \frac{2.30Q}{4\pi kD} e^{-r/L} \qquad (31)$$

or

$$r = 2{,}30L \left(\log \frac{2.30Q}{4\pi kD} - \log \Delta s_p\right) \qquad (32)$$

d. at the inflection point the relation between the drawdown and the slope of the curve is given by

$$2.30 \frac{s_p}{\Delta s_p} = e^{r/L} K_0 (r/L) \qquad (33)$$

In Eqs. (29) to (33) the index p means 'at the inflection point'. Further Δs stands for the slope of a straight line, i.e. the drawdown difference per log cycle of time.

Procedure
- Plot on single logarithmic paper the drawdown s versus the corresponding time t (t on logarithmic scale) and draw the curve that best fits through the plotted points (time-drawdown curve, Fig. 26).
- Determine the value of the maximum drawdown s_m by extrapolation. It will be noticed that this is only possible if the period of the test was long enough.
- Calculate s_p by using Eq. (29): $s_p = (\frac{1}{2})\, s_m$. The value of s_p on the curve locates the inflection point P.
- Read the value of t_p at the inflection point from the time-axis (absciss).
- Determine the slope Δs_p of the curve at the inflection point. This can be closely approximated by reading the drawdown difference per log cycle of time over the straight portion of the curve on which the inflection point lies, or over the tangent to the curve at the inflection point.
- Substitute the values of s_p and Δs_p into Eq. (33) and find r/L by interpolation from the table of the function $e^x K_0(x)$ given in Annex III.
- Knowing r/L and r, calculate L.
- Knowing Q, s_p, Δs_p and r/L, calculate kD from Eq. (31) using the table of the function e^{-x} (Annex III), or from Eq. (29) using the table of the function $K_0(x)$, (Annex III).
- Knowing kD, t_p, r and r/L, calculate S from Eq. (30).
- Knowing kD and L, calculate c from the relation $c = L^2/kD$.

Remarks
- The accuracy of the calculated formation constants depends on the accuracy of the extrapolation of the value of s_m. The calculation should therefore be checked by substituting the values of S, L and kD into Eqs. (28) and (27).
For different values of t, s should be calculated. The values of s should – in any case if the values of t are not too small – fall on the observed data curve. If the calculated data deviate from the observed data, the extrapolation of s_m should be adjusted. Sometimes the observed data curve may be drawn somewhat steeper or flatter through the plotted points and so Δs_p can be adjusted too. With the new values of s_m and/or Δs_p the calculation is repeated.
- If there is more than one piezometer this method can be applied to the data of each piezometer separately, or the Hantush method III for the analysis of unsteady-state flow in leaky aquifers with more than one piezometer should be applied.

Example
From the pumping test 'Dalem' the data from the piezometer at 90 m (Table 10) are used for a numerical example.
The drawdown data from this well are plotted versus t on single logarithmic paper (Fig. 26) and the maximum (or steady-state) drawdown is found by extrapolation ($s_m = 0.147$ m). According to Eq. (29) the drawdown at the inflection point

$s_p = \frac{1}{2}\, s_m = 0.0735$ m. Plotting this point on the time-drawdown curve gives $t_p = 2.8 \times 10^{-2}$ day.
Through the inflection point of the curve a tangent line to the curve is drawn which matches here with the straight portion of the curve itself. The slope of this tangent line $\Delta s_p = 0.072$ m.
Introducing these values into Eq. (33) gives

$$2.30\,\frac{s_p}{\Delta s_p} = 2.30 \times \frac{0.0735}{0.072} = 2.34 = e^{r/L} K_0(r/L)$$

Using Annex III gives $r/L = 0.15$ and because $r = 90$ m it follows that $L = 90/0.15 = 600$ m.
Furthermore $Q = 761$ m³/day is given, and the value of $e^{-r/L} = e^{-0.15} = 0.86$ is found from Annex III. Substitution of these numerical values into Eq. (31) yields

$$kD = \frac{2.30Q}{4\pi\Delta s_p}\, e^{-r/L} = \frac{2.30 \times 761}{4 \times 3.14 \times 0.072} \times 0.86 = 1665 \text{ m}^2/\text{day}$$

and consequently

$$c = \frac{L^2}{kD} = \frac{600^2}{1665} = 216 \text{ days}$$

Introduction of the appropriate numerical values into Eq. (30) gives

$$S = \frac{r4kDt}{2Lr^2} = \frac{90}{2 \times 600} \times \frac{4 \times 1665 \times 2.8 \times 10^{-2}}{90^2} = 1.7 \times 10^{-3}$$

To verify the extrapolated steady-state drawdown, the drawdown at a chosen moment is calculated using Eqs. (27) add (28). If $t = 0.1$ days is chosen, then

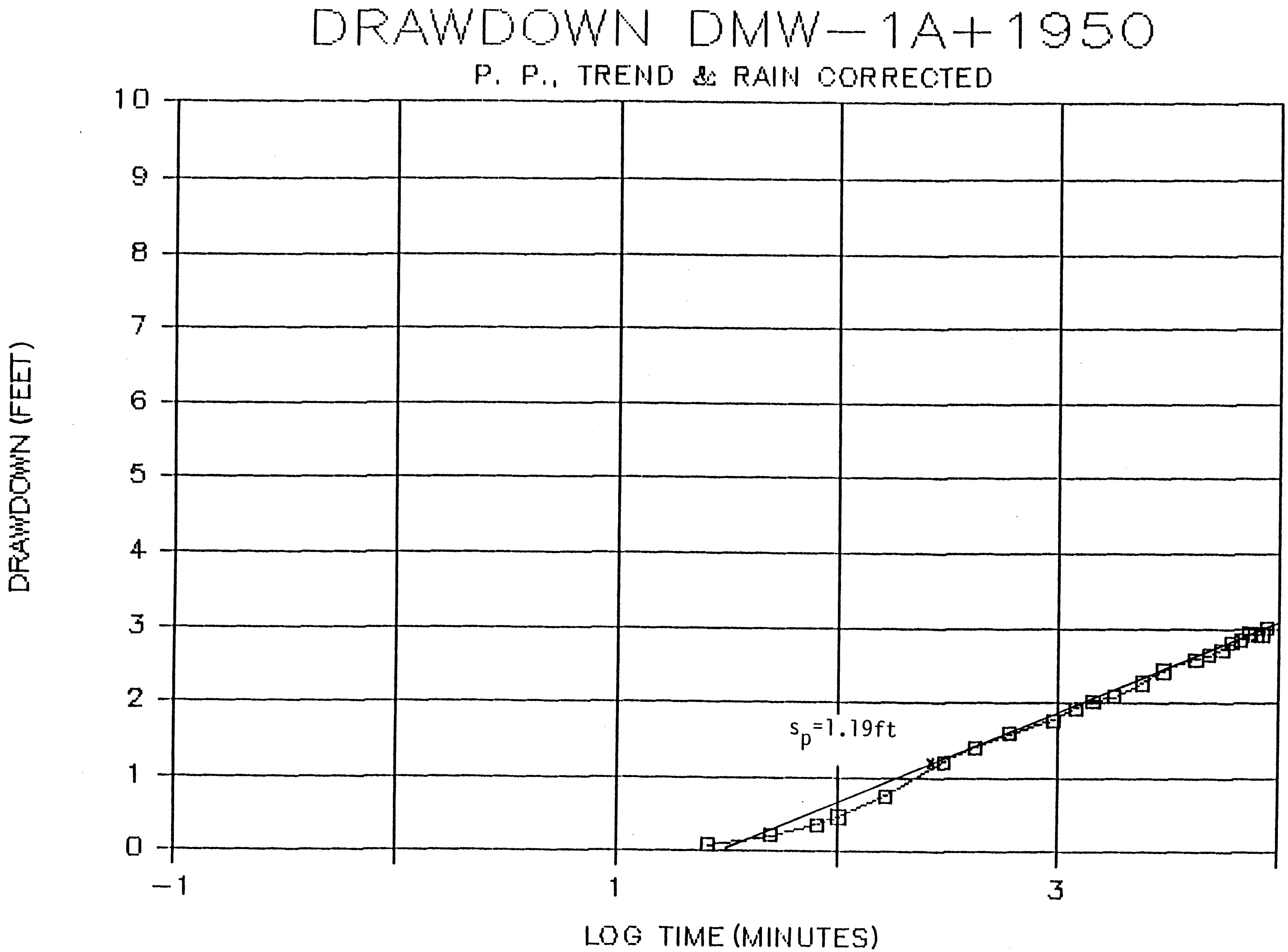
$$u = \frac{r^2 S}{4kDt} = \frac{90^2 \times 1.7 \times 10^{-3}}{4 \times 1665 \times 10^{-1}} = 0.02$$

According to Annex IV, $W(u, r/L) = 3.11$ (for $u = 0.02$ and $r/L = 0.15$). Thus

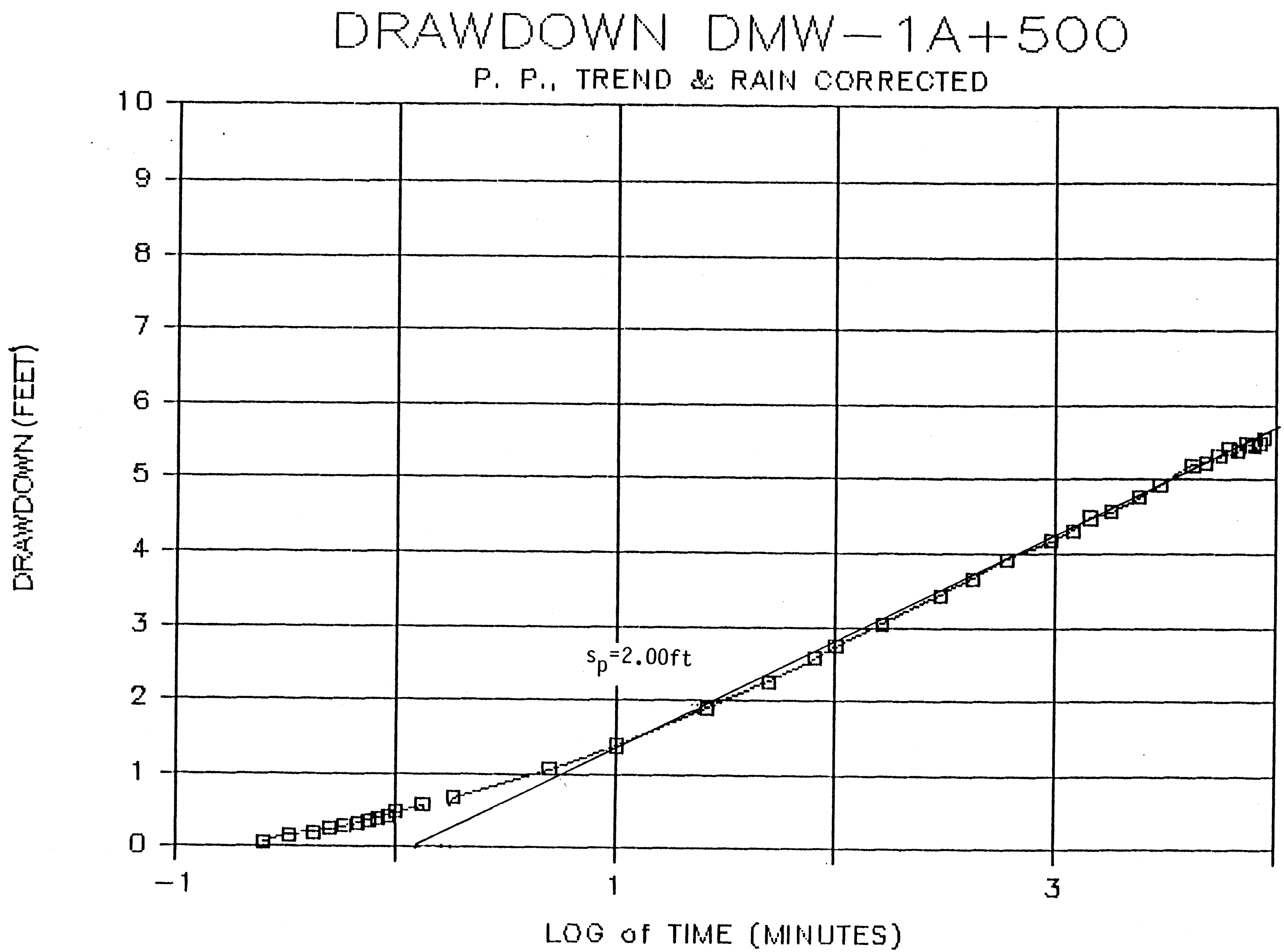
$$s_{(t=0.1)} = \frac{Q}{4\pi kD}\, W(u,r/L) = \frac{761}{4 \times 3.14 \times 1665} \times 3.11 = 0.113 \text{ m}$$

The point $t = 0.1$, $s = 0.113$ falls on the time-drawdown curve and justifies the extrapolated value of s_m.
In practice several points should be tried out.

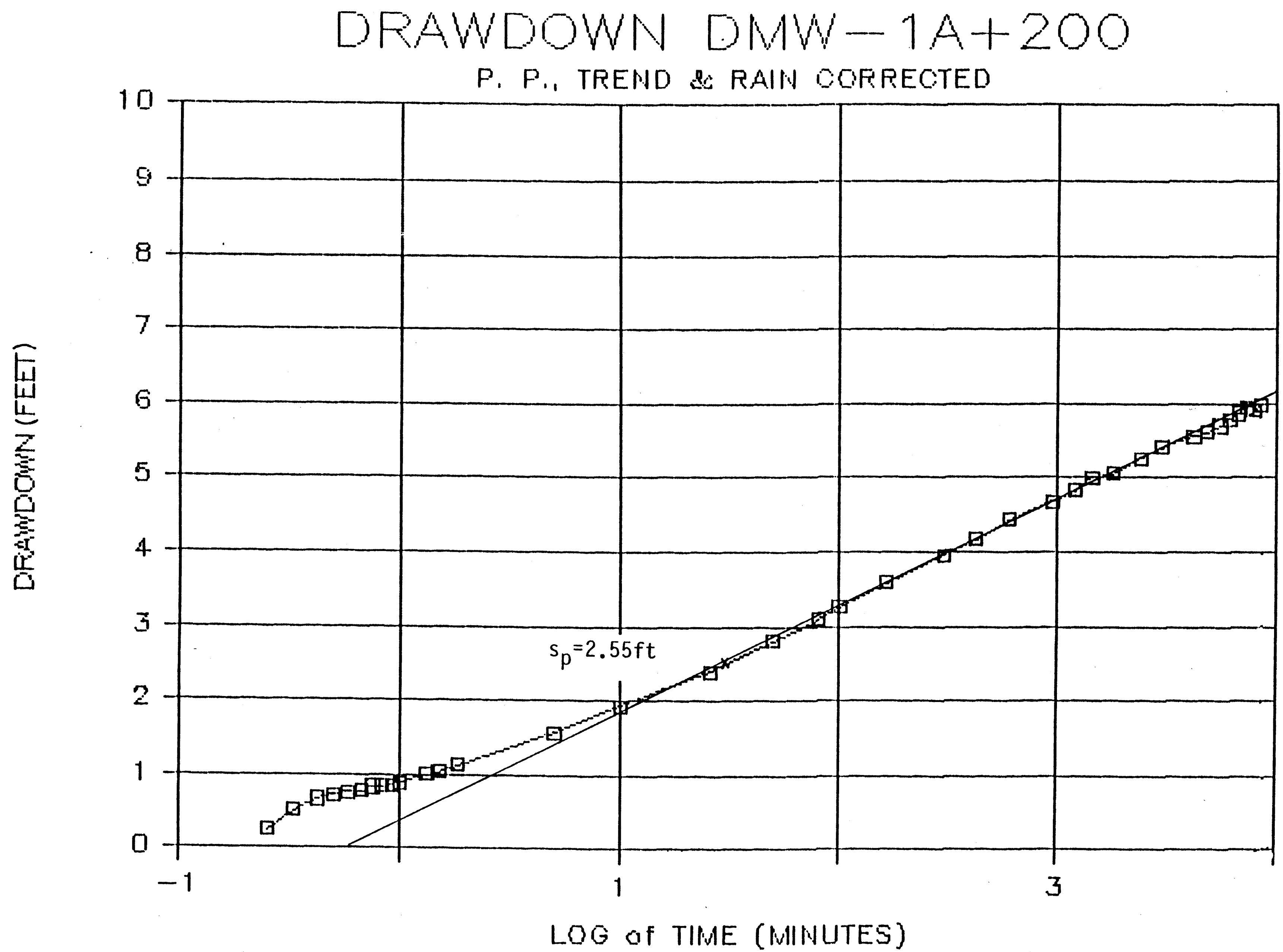
HANTUSH II METHOD



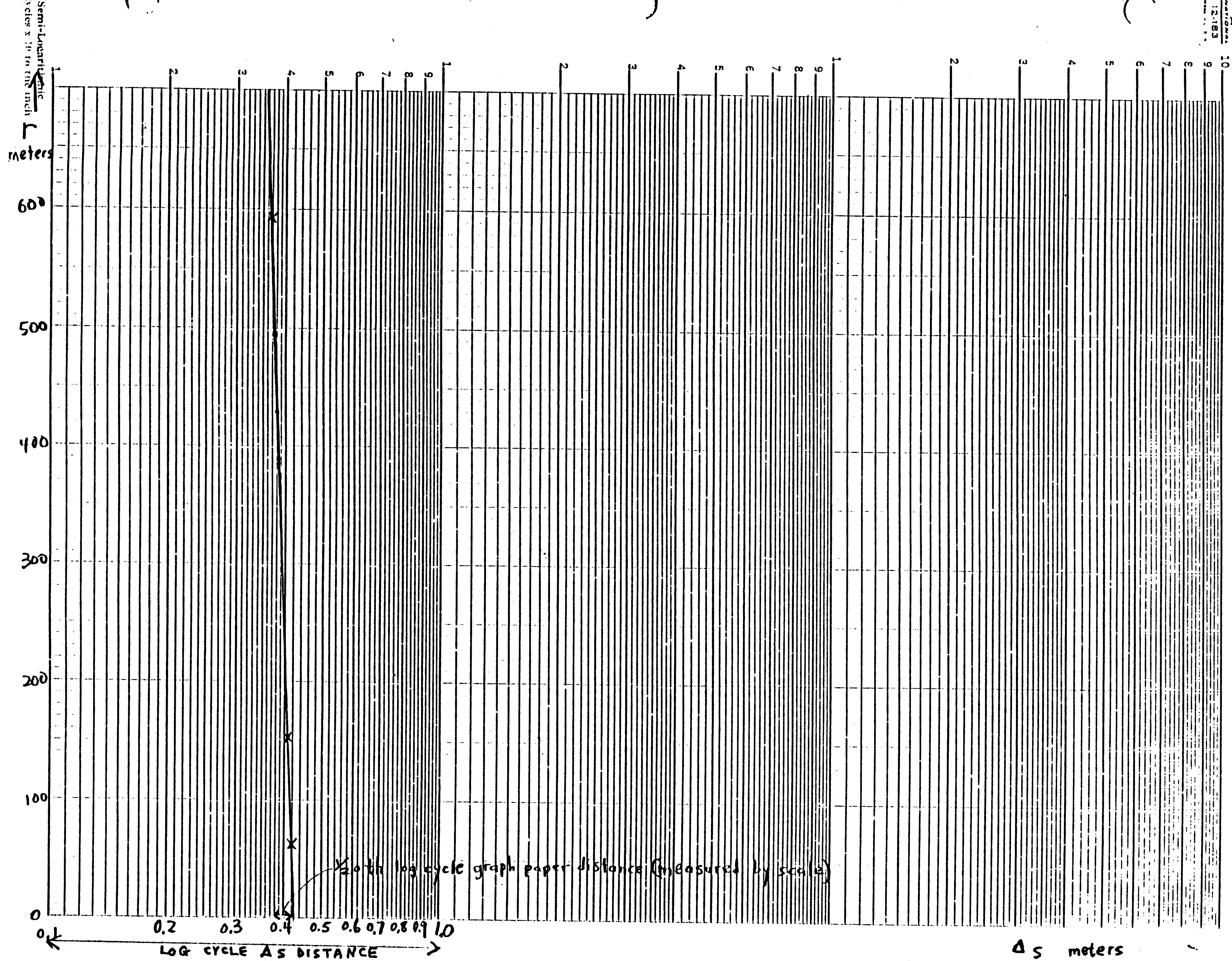
DRAWDOWN DMW-1A+1950
P. P., TREND & RAIN CORRECTED
DRAWDOWN (FEET)
10
9
8
7
6
5
4
3
2
1
0
-1
1
3
LOG TIME (MINUTES)
sp=1.19ft



DRAWDOWN DMW-1A+500
P. P., TREND & RAIN CORRECTED
DRAWDOWN (FEET)
10
9
8
7
6
5
4
3
2
1
0
-1
1
3
s_p=2.00ft
LOG of TIME (MINUTES)



DRAWDOWN DMW-1A+200
P. P., TREND & RAIN CORRECTED
DRAWDOWN (FEET)
LOG of TIME (MINUTES)
s_p=2.55ft
0
1
2
3
4
5
6
7
8
9
10
-1
1
3



Semi-Logarithmic
r
meters
600
500
400
300
200
100
0
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
LOG CYCLE Δ s DISTANCE
1/20 th log cycle graph paper distance (measured by scale)
Δ s meters

HANTUSH, M.S., 1964.
HYDRAULICS OF WELLS. ADVANCES IN HYDROSCIENCES

3.4.3. HANTUSH'S METHOD II

This method, which is also based on Eq. (27), can be used to analyse the data from pumping tests for which the *assumptions and limiting conditions as described in Section 4.1 (Walton method) are satisfied. However, it should be noted that data from at least two piezometers should be available and that the maximum drawdown can be extrapolated for each of these wells.*

Procedure

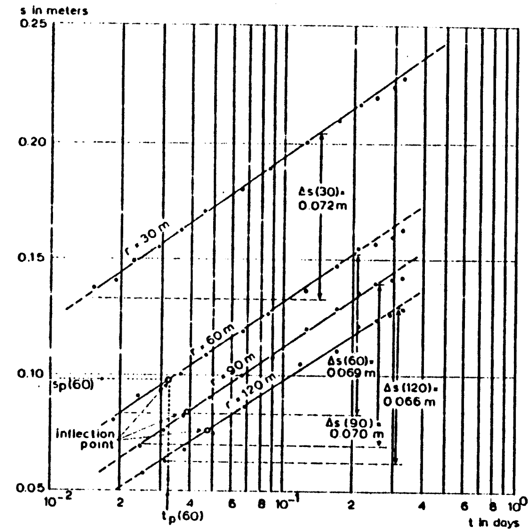
- Plot on single logarithmic paper the drawdown s versus the corresponding time t for all piezometers (t on logarithmic scale, Fig. 27).
- Determine the slope of the straight portion of each curve; these are the values Δs (the drawdown difference per log cycle of time).
- Plot on single logarithmic paper distance r versus slope Δs (Δs on logarithmic scale), and draw the best-fit straight line through the plotted points. This line is the graphic representation of Eq. (32).
- Determine the slope of this line Δr: the difference of r per log cycle of Δs (Fig. 28).
- Extend the straight line till it intercepts the absciss where $r = 0$ and $\Delta s = (\Delta s)_0$. Read the value of $(\Delta s)_0$.
- Knowing the values of Δr and $(\Delta s)_0$, calculate L from Eq. (34)

$$L = \frac{1}{2.30}\Delta r \qquad (34)$$

and kD from Eq. (35)

$$kD = 2.30\frac{Q}{4\pi(\Delta s)_0} \qquad (35)$$

- Knowing kD and L, calculate c from the relation $c = L^2/kD$.
- With the known values of Q, r, kD and L, calculate s_p for each observation well, using Eq. (29): $s_p = (Q/4\pi kD)K_0(r/L)$ and the table for the function $K_0(x)$, given in Annex III.



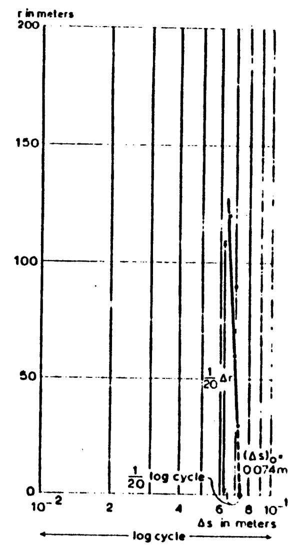


Fig. 27. Analysis of data from pumping test 'Dalem' with the Hantush method II: Determination of values of Δs for different values of r

Fig. 28. Idem, Determination of the value of Δr

- Plot each s_p value on its corresponding drawdown-time curve and read t_p on the absciss.
- Knowing the values of kD, r, r/L and t_p, calculate S from Eq. (30): $(r^2S)/(4kDt_p) = \frac{1}{2}(r/L)$.

Example

From the pumping test 'Dalem' (Table 10), data from the piezometers at 30, 60, 90 and 120 m are used in working out a numerical example.

In Fig. 27 a time-drawdown curve has been drawn for each of the piezometers on single logarithmic paper. The slope of the straight portion of each curve was determined, resulting in

$$\Delta s\ (30\ \text{m}) = 0.072\ \text{m}$$
$$\Delta s\ (60\ \text{m}) = 0.069\ \text{m}$$
$$\Delta s\ (90\ \text{m}) = 0.070\ \text{m}$$
$$\Delta s(120\ \text{m}) = 0.066\ \text{m}$$

In Fig. 28 the values of Δs were plotted versus r on single logarithmic paper and a straight line was fitted through the plotted points. Because of its steepness, the slope was measured as the difference of r over 1/20 log cycle of Δs (if 1 log cycle measures 10 cm, 1/20 log cycle measures 0.5 cm). The difference of r per 1/20 log cycle of Δs equals 120 m or the difference of r per log cycle of Δs, i.e. Δr, equals 2400 m. The straight line intersects the Δs axis where $r = 0$ in the point $(\Delta s)_0 = 0.074$ m. Substitution of these values into Eqs. (34) and (35) gives

$$L = \frac{1}{2.30}\Delta r = \frac{1}{2.30} \times 2400 = 1044 \text{ m}$$

and since $Q = 761$ m³/day

$$kD = \frac{2.30Q}{4\pi(\Delta s)_0} = \frac{2.30 \times 761}{4 \times 3.14 \times 0.074} = 1883 \text{ m}^2\text{/day}$$

finally

$$c = \frac{L^2}{kD} = \frac{(1044)^2}{1883} = 550 \text{ days}$$

For each piezometer the value of r/L is calculated and the corresponding values of $K_0(r/L)$ are found in Annex III. The results are listed in Table 11.

TABLE 11
Data to be substituted into Eqs. (29) and (30)

r (m)	r/L	$K_0(r/L)$	s_p (m)	t_p (day)	s_m (m)
30	0.0287	3.668	0.1200	outside figure	0.240
60	0.0575	2.984	0.0982	3.25×10^{-2}	0.196
90	0.0860	2.576	0.0841	3.85×10^{-2}	0.168
120	0.1148	2.290	0.0748	4.70×10^{-2}	0.150

The drawdown, s_p, in the inflection point of the curve through the observed data, as plotted in Fig. 27 for the piezometer at 60 m, is calculated from Eq. (29)

$$s_p(60) = \frac{Q}{4\pi kD} K_0(r/L) = \frac{761}{4 \times 3.14 \times 1883} \times 2.984 = 0.0982 \text{ m}$$

The point on this curve for which $s = 0.0982$ m is determined; this is the inflection point. On the abscissa the value of t_p at the inflection point is $t_p(60) = 3.25 \times 10^{-2}$ days. While from Eq. (29) it follows that $s_m(60) = 2\,s_p(60) = 0.196$ m.

This calculation is also made for the other piezometers. The results are listed Table 11.

Substitution of the values of t_p into Eq. (30) yields values of S.
For example for $r = 60$ m

$$S = \frac{r}{2L}\,\frac{4kDt_p}{r^2} = \frac{60}{2 \times 1044} \times \frac{4 \times 1880 \times 3.25 \times 10^{-2}}{60^2} = 2.0 \times 10^{-3}$$

In the same way for $r = 90$ m and for $r = 120$ m, the values $S = 1.6 \times 10^{-3}$ a $S = 1.5 \times 10^{-3}$ are calculated. The average value of $S = 1.7 \times 10^{-3}$.
It will be noticed that the calculated values for the steady-state drawdown are so what higher than the extrapolated values from Table 8.

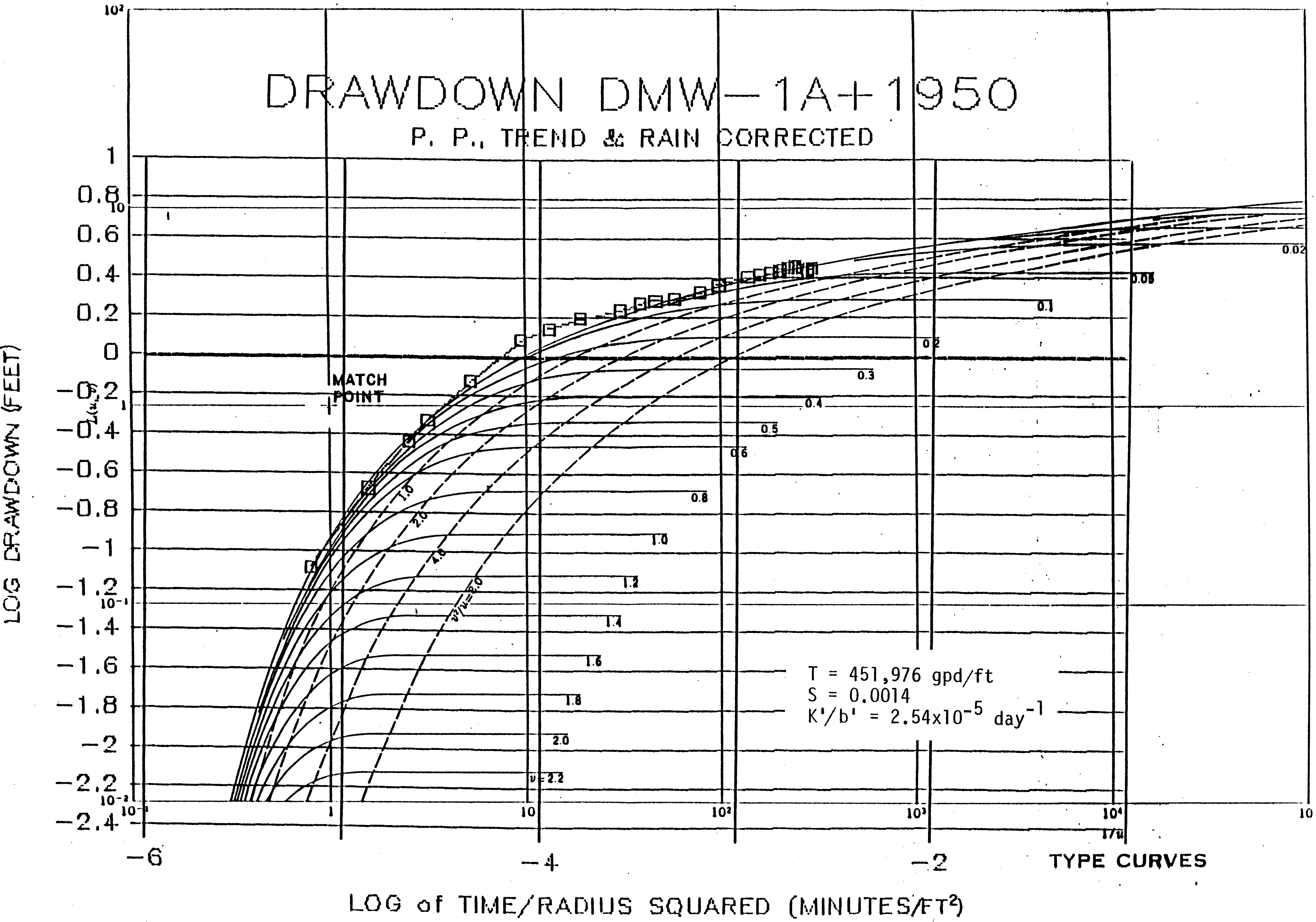
ANNEX III. Table of the functions e^x, e^{-x}, $K_0(x)$ and $e^xK_0(x)$; after HANTUSH (1956)

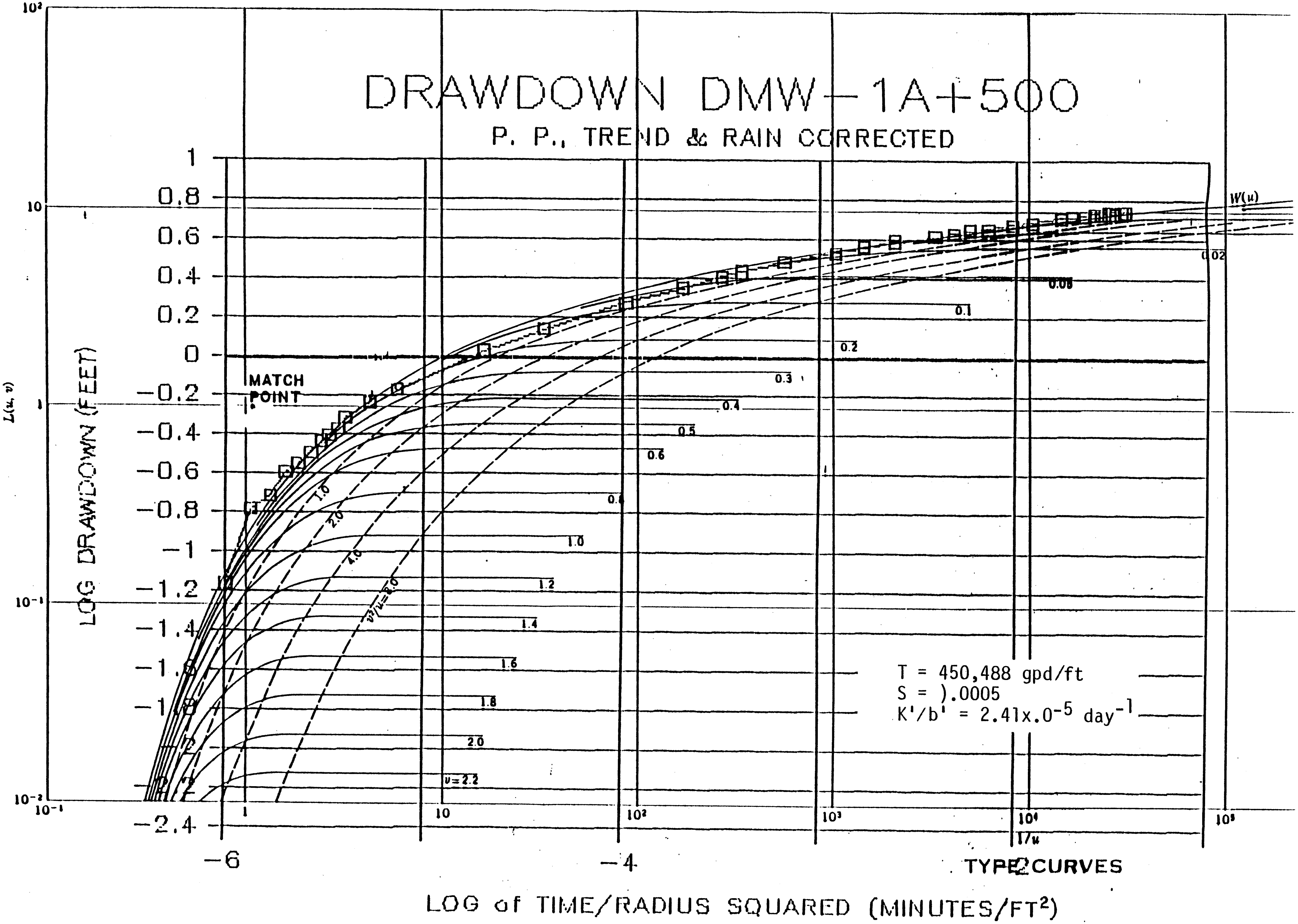
x	e^x	e^{-x}	$K_0(x)$	$e^xK_0(x)$
0.010	1.010	0.990	4.721	4.769
11	1.011	0.989	4.626	4.677
12	1.012	0.988	4.539	4.594
13	1.013	0.987	4.459	4.517
14	1.014	0.986	4.385	4.447
15	1.015	0.985	4.316	4.381
16	1.016	0.984	4.251	4.320
17	1.017	0.983	4.191	4.263
18	1.018	0.982	4.134	4.209
19	1.019	0.981	4.080	4.158
0.020	1.020	0.980	4.028	4.110
21	1.021	0.979	3.980	4.064
22	1.022	0.978	3.933	4.021
23	1.023	0.977	3.889	3.979
24	1.024	0.976	3.846	3.940
25	1.025	0.975	3.806	3.902
26	1.026	0.974	3.766	3.866
27	1.027	0.973	3.729	3.831
28	1.028	0.972	3.692	3.797
29	1.029	0.971	3.657	3.765
0.030	1.030	0.970	3.623	3.734
31	1.031	0.969	3.591	3.704
32	1.032	0.968	3.559	3.675
33	1.034	0.967	3.528	3.647
34	1.035	0.967	3.499	3.620
35	1.036	0.966	3.470	3.593
36	1.037	0.965	3.442	3.568
37	1.038	0.964	3.414	3.543
38	1.039	0.963	3.388	3.519
39	1.040	0.962	3.362	3.495
0.040	1.041	0.961	3.336	3.473
.041	1.042	0.960	3.312	3.450
.042	1.043	0.959	3.288	3.429
.043	1.044	0.958	3.264	3.408
.044	1.045	0.957	3.241	3.387
.045	1.046	0.956	3.219	3.367
.046	1.047	0.955	3.197	3.348
.047	1.048	0.954	3.176	3.329
.048	1.049	0.953	3.155	3.310
.049	1.050	0.952	3.134	3.292
0.050	1.051	0.951	3.114	3.274
.051	1.052	0.950	3.094	3.256
.052	1.053	0.949	3.075	3.239
.053	1.054	0.948	3.056	3.223
.054	1.055	0.947	3.038	3.206
.055	1.056	0.946	3.019	3.190
.056	1.058	0.945	3.001	3.174
.057	1.059	0.945	2.984	3.159
.058	1.060	0.944	2.967	3.144
.059	1.061	0.943	2.950	3.129
0.060	1.062	0.942	2.933	3.114
.061	1.063	0.941	2.916	3.100
.062	1.064	0.940	2.900	3.086
.063	1.065	0.939	2.884	3.072
.064	1.066	0.938	2.869	3.058
.065	1.067	0.937	2.853	3.045
.066	1.068	0.936	2.838	3.032
.067	1.069	0.935	2.823	3.019
.068	1.070	0.934	2.809	3.006
.069	1.071	0.933	2.794	2.994
0.070	1.072	0.932	2.780	2.981
71	1.074	0.931	2.766	2.969
72	1.075	0.930	2.752	2.957
73	1.076	0.930	2.738	2.945
74	1.077	0.929	2.725	2.934
75	1.078	0.928	2.711	2.923
76	1.079	0.927	2.698	2.911
77	1.080	0.926	2.685	2.900
78	1.081	0.925	2.673	2.889
79	1.082	0.924	2.660	2.879
0.080	1.083	0.923	2.647	2.868
81	1.084	0.922	2.635	2.857
82	1.085	0.921	2.623	2.847
83	1.086	0.920	2.611	2.837
84	1.088	0.919	2.599	2.827
85	1.089	0.918	2.587	2.817
86	1.090	0.918	2.576	2.807
87	1.091	0.917	2.564	2.798
88	1.092	0.916	2.553	2.788
89	1.093	0.915	2.542	2.779
0.090	1.094	0.914	2.531	2.769
91	1.095	0.913	2.520	2.760
92	1.096	0.912	2.509	2.751
93	1.097	0.911	2.499	2.742
94	1.099	0.910	2.488	2.733
95	1.100	0.909	2.478	2.725
96	1.101	0.908	2.467	2.716
97	1.102	0.908	2.457	2.707
98	1.103	0.907	2.447	2.699
99	1.104	0.906	2.437	2.691

x	e^x	e^{-x}	$K_0(x)$	$e^xK_0(x)$
0.10	1.105	0.905	2.427	2.682
11	1.116	0.896	2.333	2.605
12	1.127	0.887	2.248	2.534
13	1.139	0.878	2.169	2.471
14	1.150	0.869	2.097	2.412
15	1.162	0.861	2.030	2.358
16	1.173	0.852	1.967	2.309
17	1.185	0.844	1.909	2.262
18	1.197	0.835	1.854	2.219
19	1.209	0.827	1.802	2.179
0.20	1.221	0.819	1.753	2.141
21	1.234	0.811	1.706	2.105
22	1.246	0.802	1.662	2.071
23	1.259	0.794	1.620	2.039
24	1.271	0.787	1.580	2.008
25	1.284	0.779	1.541	1.979
26	1.297	0.771	1.505	1.952
27	1.310	0.763	1.470	1.925
28	1.323	0.756	1.436	1.900
29	1.336	0.748	1.404	1.876
0.30	1.350	0.741	1.372	1.853
31	1.363	0.733	1.342	1.830
32	1.377	0.726	1.314	1.809
33	1.391	0.719	1.286	1.788
34	1.405	0.712	1.259	1.768
35	1.419	0.705	1.233	1.749
36	1.433	0.698	1.207	1.731
37	1.448	0.691	1.183	1.713
38	1.462	0.684	1.160	1.696
39	1.477	0.677	1.137	1.679
0.40	1.492	0.670	1.114	1.663
.41	1.507	0.664	1.093	1.647
.42	1.522	0.657	1.072	1.632
.43	1.537	0.650	1.052	1.617
.44	1.553	0.644	1.032	1.602
.45	1.568	0.638	1.013	1.589
.46	1.584	0.631	0.994	1.575
.47	1.600	0.625	0.976	1.562
.48	1.616	0.619	0.958	1.549
.49	1.632	0.613	0.941	1.536
0.50	1.649	0.606	0.924	1.524
.51	1.665	0.600	0.908	1.512
.52	1.682	0.594	0.892	1.501
.53	1.699	0.589	0.877	1.489
.54	1.716	0.583	0.861	1.478
.55	1.733	0.577	0.847	1.467
.56	1.751	0.571	0.832	1.457
.57	1.768	0.565	0.818	1.446
.58	1.786	0.560	0.804	1.436
.59	1.804	0.554	0.791	1.426
0.60	1.822	0.549	0.777	1.417
.61	1.840	0.543	0.765	1.407
.62	1.859	0.538	0.752	1.398
.63	1.878	0.533	0.740	1.389
.64	1.896	0.527	0.728	1.380
.65	1.915	0.522	0.716	1.371
.66	1.935	0.517	0.704	1.363
.67	1.954	0.512	0.693	1.354
.68	1.974	0.507	0.682	1.346
.69	1.994	0.502	0.671	1.338
0.70	2.014	0.497	0.660	1.330
71	2.034	0.492	0.650	1.322
72	2.054	0.487	0.640	1.315
73	2.075	0.482	0.630	1.307
74	2.096	0.477	0.620	1.300
75	2.117	0.472	0.611	1.293
76	2.138	0.468	0.601	1.285
77	2.160	0.463	0.592	1.278
78	2.181	0.458	0.583	1.272
79	2.203	0.454	0.574	1.265
0.80	2.225	0.449	0.565	1.258
81	2.248	0.445	0.557	1.252
82	2.270	0.440	0.548	1.245
83	2.293	0.436	0.540	1.239
84	2.316	0.432	0.532	1.233
85	2.340	0.427	0.524	1.226
86	2.363	0.423	0.516	1.220
87	2.387	0.419	0.509	1.214
88	2.411	0.415	0.501	1.209
89	2.435	0.411	0.494	1.203
0.90	2.460	0.407	0.487	1.197
91	2.484	0.402	0.480	1.192
92	2.509	0.398	0.473	1.186
93	2.534	0.395	0.466	1.181
94	2.560	0.391	0.459	1.175
95	2.586	0.387	0.452	1.170
96	2.612	0.383	0.446	1.165
97	2.638	0.379	0.440	1.159
98	2.664	0.375	0.433	1.154
99	2.691	0.372	0.427	1.14[illegible]

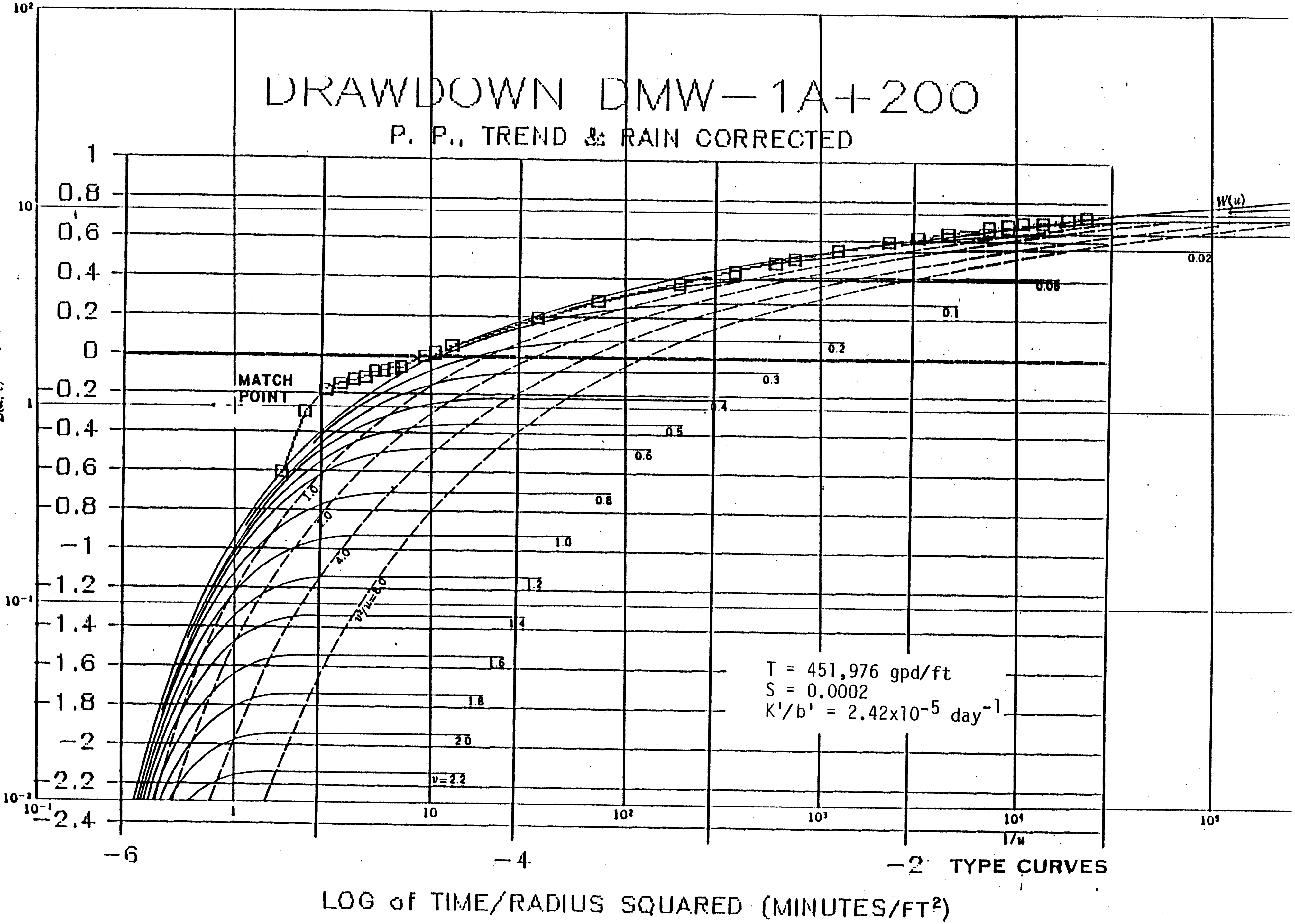
x	e^x	e^{-x}	$K_0(x)$	$e^xK_0(x)$
1.0	2.718	0.368	0.421	1.144
1.1	3.004	0.333	0.366	1.098
1.2	3.320	0.301	0.318	1.057
1.3	3.669	0.272	0.278	1.021
1.4	4.055	0.247	0.244	0.988
1.5	4.482	0.223	0.214	0.958
1.6	4.953	0.202	0.188	0.931
1.7	5.474	0.183	0.165	0.906
1.8	6.050	0.165	0.146	0.883
1.9	6.686	0.150	0.129	0.861
2.0	7.389	0.135	0.114	0.842
2.1	8.166	0.122	0.101	0.823
2.2	9.025	0.111	8.93 (-2)	0.806
2.3	9.974	0.100	7.91 (-2)	0.789
2.4	1.102(1)	9.07 (-2)	7.02 (-2)	0.774
2.5	1.218(1)	8.21 (-2)	6.23 (-2)	0.760
2.6	1.346(1)	7.43 (-2)	5.54 (-2)	0.746
2.7	1.488(1)	6.72 (-2)	4.93 (-2)	0.733
2.8	1.644(1)	6.08 (-2)	4.38 (-2)	0.721
2.9	1.817(1)	5.50 (-2)	3.90 (-2)	0.709
3.0	2.009(1)	4.98 (-2)	3.47 (-2)	0.698
3.1	2.220(1)	4.50 (-2)	3.10 (-2)	0.687
3.2	2.453(1)	4.08 (-2)	2.76 (-2)	0.677
3.3	2.711(1)	3.69 (-2)	2.46 (-2)	0.667
3.4	2.996(1)	3.34 (-2)	2.20 (-2)	0.658
3.5	3.312(1)	3.02 (-2)	1.96 (-2)	0.649
3.6	3.660(1)	2.73 (-2)	1.75 (-2)	0.640
3.7	4.045(1)	2.47 (-2)	1.56 (-2)	0.632
3.8	4.470(1)	2.24 (-2)	1.40 (-2)	0.624
3.9	4.940(1)	2.02 (-2)	1.25 (-2)	0.617
4.0	5.460(1)	1.83(-2)	1.12(-2)	0.609
4.1	6.034(1)	1.00(-2)	1.00(-2)	0.602
4.2	6.669(1)		8.9 (-3)	0.595
4.3	7.370(1)		8.0 (-3)	0.589
4.4	8.145(1)		7.1 (-3)	0.582
4.5	9.002(1)		6.4 (-3)	0.576
4.6	9.948(1)		5.7 (-3)	0.570
4.7	1.099(2)		5.1 (-3)	0.564
4.8	1.215(2)		4.6 (-3)	0.559
4.9	1.343(2)		4.1 (-3)	0.553
5.0	1.484(2)		3.7 (-3)	0.548

HANTUSH - JACOB METHOD


DRAWDOWN DMW-1A+1950
P. P., TREND & RAIN CORRECTED
MATCH POINT
T = 451,976 gpd/ft
S = 0.0014
K'/b' = 2.54x10^-5 day^-1
LOG DRAWDOWN (FEET)
LOG of TIME/RADIUS SQUARED (MINUTES/FT²)
TYPE CURVES
1/u
0.02
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
v=2.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-2.2
-2.4
-6
-4
-2

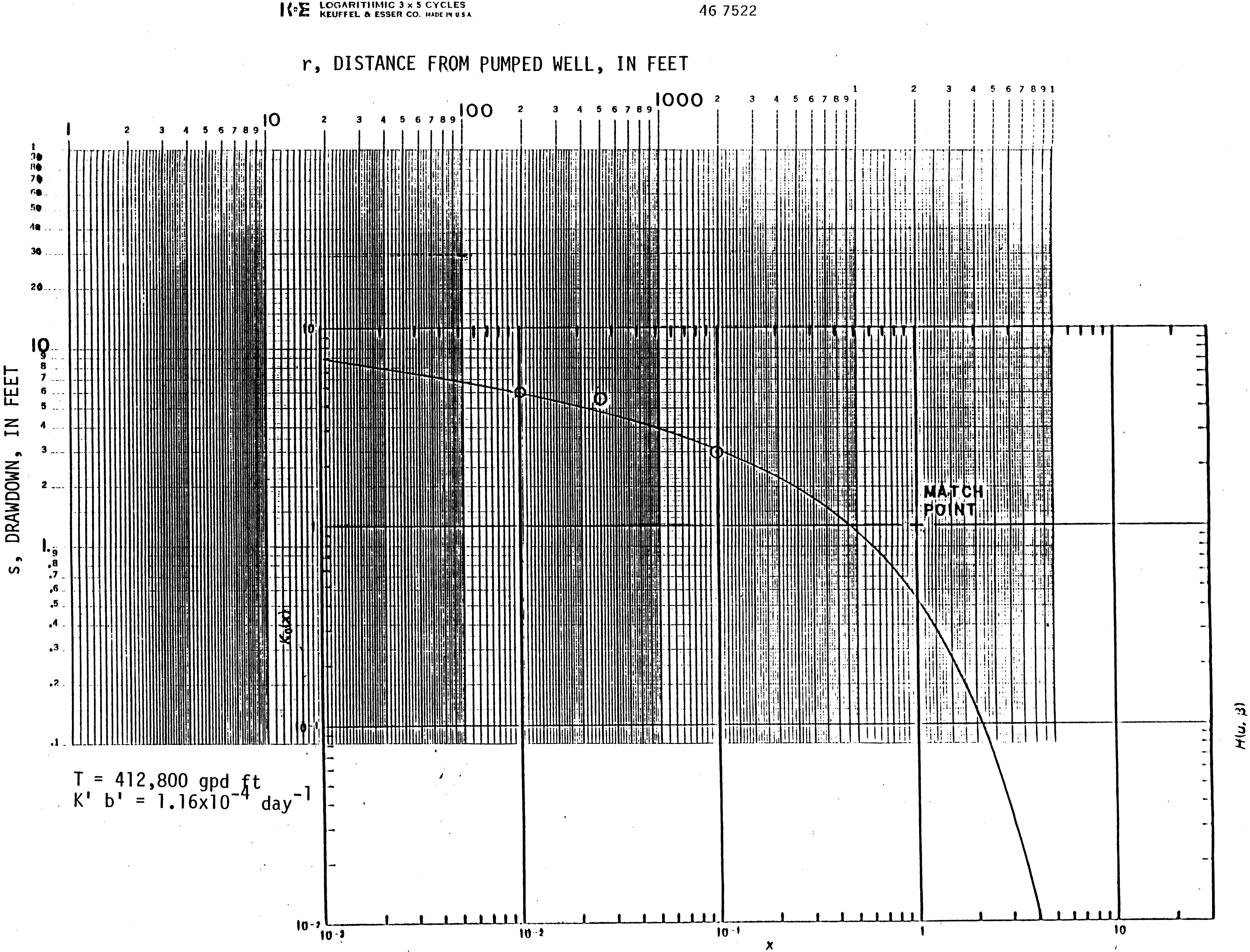


DRAWDOWN DMW-1A+500
P. P., TREND & RAIN CORRECTED
MATCH POINT
LOG DRAWDOWN (FEET)
LOG of TIME/RADIUS SQUARED (MINUTES/FT²)
T = 450,488 gpd/ft
S =).0005
K'/b' = 2.41x.0-5 day-1
TYPE CURVES
W(u)
L(u, v)
v=2.2



DRAWDOWN DMW-1A+200
P. P., TREND & RAIN CORRECTED
MATCH POINT
T = 451,976 gpd/ft
S = 0.0002
K'/b' = 2.42x10^-5 day^-1
W(u)
0.02
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
v=2.2
v²/u=6.0
4.0
2.0
1.0
1/u
TYPE CURVES
LOG DRAWDOWN (FEET)
LOG of TIME/RADIUS SQUARED (MINUTES/FT²)

JACOB LEAKY ARTESIAN METHOD



—Type curve of the Bessel function $K_0(x)$ versus x.

ANISOTROPIC METHOD

(Requires Hantush - Jacob Method)

Ref. - Analysis of Data from Pumping
Test in Anisotropic Aquifers
by Mandi Hantush, Journal of
Geophysical Research, Vol. 71 (1966)

Analysis of Data from Pumping Tests in Anisotropic Aquifers

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Abstract. In conventional methods of aquifer tests homogeneous and isotropic aquifers are assumed. In many instances, however, the aquifers tested are anisotropic. Procedures are outlined for determining the principal directions of anisotropy and the hydraulic properties of homogeneous anisotropic aquifers. Data from pumping tests in leaky or nonleaky aquifers are used. The aquifers are uniform in thickness, and the flow therein during the period of the test behaves as if it were in an infinite aquifer. The collected data are from at least two groups of wells if the principal directions of anisotropy are known and from at least three groups of wells if these directions are not known. Each group of wells is located on a different radial line. When the pumped well partially penetrates the aquifer, the observation wells should either be completely screened throughout the aquifer or be located at distances from the pumped well of at least $1.5b(K_z/K_r)^{1/2}$, where b is the uniform thickness of the aquifer, K_z is the vertical conductivity, and K_r is the directional conductivity in the horizontal planes of the aquifer. The procedures are illustrated by an example of computation.

Introduction

The methods for analyzing data from pumping tests, in which the pumped well completely penetrates and steadily discharges from infinite nonleaky and leaky artesian aquifers, are based on either the Theis formula or on the Hantush-Jacob formula [see for example *Schoeller*, 1959, 1962; *Todd*, 1959; *Hantush*, 1964; *De Wiest*, 1965]. The Theis formula, describing the flow in nonleaky aquifers, is given by

$$s = (Q/4\pi T)\,W(u) \qquad (1)$$

and the Hantusch-Jacob formula for the flow in leaky aquifers can be expressed by either

$$s = (Q/4\pi T)\,W(u, r/B) \qquad (2)$$

or

$$s = (Q/4\pi T)\,W^*(q, r/B) \qquad (3)$$

with the ultimate steady-state drawdown s_s given by

$$s_s = (Q/2\pi T)\,K_0(r/B) \qquad (4)$$

where

$$u = r^2/4\nu t \qquad \nu = T/S \qquad B^2 = T/(K'/b')$$
$$q = (K'/b')t/S$$

and s denotes the induced drawdown at any time t since pumping started and at any point r distant from the pumped well; Q is the constant discharge of the completely penetrating well; T and S are, respectively, the transmissivity and the storativity (storage coefficient) of the homogeneous and isotropic aquifer; (K'/b') is the leakage coefficient, K' and b' being the hydraulic conductivity and the thickness of the semipervious layer, respectively; $W(u)$ and $W(u, r/B)$ are the well functions for nonleaky and leaky aquifers, respectively; they are extensively tabulated [see for example *Hantush*, 1956, 1964; *Walton*, 1962; *De Wiest*, 1965]; and K_0 is the zero-order modified Bessel function of the second kind, tabular values of which are available [see for example *Dwight*, 1961; *Hantush*, 1956; *Walton*, 1962; *De Wiest*, 1965]. The function $W^*(q, r/B)$ is the second form of the well function for leaky aquifers and is defined by

$$W^*(\alpha, \beta) = 2K_0(\beta) - W(\alpha, \beta)$$
$$= W(0, \beta) - W(\alpha, \beta)$$

where $W(\alpha, \beta)$ is the well function for leaky aquifers. Obviously, $W^*(\alpha, \beta)$ can be obtained from the available tables of $W(\alpha, \beta)$.

The methods of analyzing data from pumping tests in leaky and nonleaky homogeneous isotropic aquifers, henceforth referred to as the *isotropic methods of analysis*, are well known [see for example *Jacob*, 1950; *Butler*, 1957;

Todd, 1959; *Schoeller*, 1959, 1962; *Walton*, 1962; *Hantush*, 1964; *De Wiest*, 1965]. All these methods first determine T and one or both of the constant parameters ν and B. The two remaining unknowns S and (K'/b') follow from the relations $\nu = T/S$ and $B^2 = T/(K'/b')$, since T has already been obtained. Obviously, S and (K'/b') could not have been computed if the value of T, appearing in the expressions for ν and B, were not the same as that involved in the factor $(Q/4\pi T)$.

In many instances, aquifers may be considered homogeneous but not isotropic. In such aquifers, the hydraulic conductivity varies from direction to direction. In two-dimensional flow (or what may be considered as two-dimensional flow), the transmissivity in the flow direction, usually referred to as the directional transmissivity, can be shown [see for example *Maasland*, 1957] to be given by

$$T_r = T_x/[\cos^2\theta + (T_x/T_y)\sin^2\theta] \quad (5)$$

where T_x, T_y, and T_r are the transmissivities in the x, y, and r directions, respectively, the r direction making the angle θ with the x axis, and where the coordinate axes x and y are parallel to the principal directions of anisotropy.

The counterparts of (1), (2), (3), and (4) for homogeneous anisotropic aquifers [*Hantush*, 1965] are

$$s = (Q/4\pi T_e) W(u') \quad (6)$$

$$s = (Q/4\pi T_e) W(u', r/B') \quad (7)$$

$$s = (Q/4\pi T_e) W^*(q, r/B') \quad (8)$$

$$s = (Q/2\pi T_e) K_0(r/B') \quad (9)$$

where

$$u' = r^2/4\nu' t \qquad q = (K'/b')t/S$$

$$T_e = (T_x T_y)^{1/2} \qquad \nu' = T_r/S \quad (10)$$

$$B' = [T_r/(K'/b')]^{1/2}$$

It should be observed that, although T_e is a constant for the anisotropic aquifer, the quantities ν' and B' are not constant but are functions of direction, since they depend on T_r, which varies with the polar angle θ.

Equations 6, 7, 8, and 9 are analogous to (1), (2), (3), and (4), respectively, the difference being in the meaning of the parameters involved. This analogy suggests the possibility of making use of the *isotropic methods of analysis* in attempting to develop procedures for analyzing similar data from anisotropic aquifers.

Analysis

The isotropic methods of analysis are based on one or the other of (1) through (4). The parameters T, ν, and B in these equations are constants. In general, this is not true in the corresponding equations for the flow in anisotropic aquifers. Although T_e herein is constant regardless of the location of the observed point, the quantities ν' and B' vary from direction to direction. They are constants for any given direction, however. Thus the drawdown variation in observation wells finished in anisotropic aquifers and located on any radial line will be given by (6), (7), (8), or (9), with constant values for T_e, ν', and B'. Consequently, the isotropic methods of analysis when used in conjunction with data from observation wells located on a radial line in an anisotropic aquifer will yield values for T_e and either one or both of the parameters ν' and B' for that given direction.

The determination of T_e, ν' and B' in only one direction provides three equations with four or five unknowns, depending on whether the principal directions of anisotropy are known. These equations are

$$T_e = (T_x T_y)^{1/2} \qquad \nu' = T_r/S \quad (11)$$

$$B' = [T_r/(K'/b')]^{1/2}$$

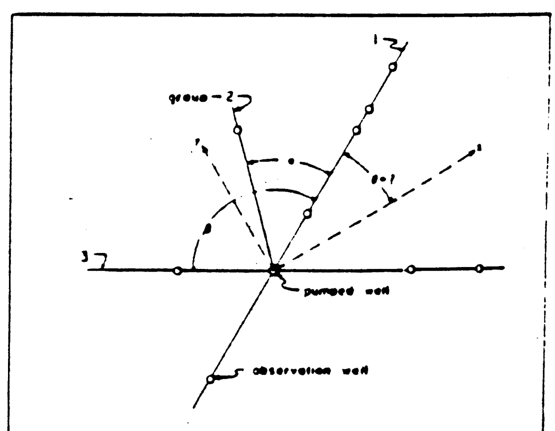

Fig. 1. Location of three rays of observation wells in anisotropic aquifer of unknown principal directions of anisotropy.

where the unknowns are T_x, T_y, S, (K'/b'), and the principal directions of anisotropy are as defined by θ in the expression of T_r [see (5)]. Consequently, more information is needed to complete the solution of the problem. Such information can be provided if observations in one or two (depending on whether θ is known) other groups of observation wells are available.

Figure 1 shows three groups of wells (one well can constitute a group), each on a different radial line. Let α and β be the angles which the second and third line make, respectively, with the first. Let the x and y axes be parallel to the directions of anisotropy, the first line making the angle θ with the x axis. Consequently, the first, second, and third lines of observation wells are making the angles θ, $\theta + \alpha$, and $\theta + \beta$ with the x axis, respectively, the x axis being one of the principal directions of anisotropy. Let the values of the parameters (ν', T_r, B') for the first, second, and third groups of observation wells be denoted by (ν_1', T_{r1}, B_1'), $(\nu_2' T_{r2}, B_2')$, and $(\nu_3' T_{r3}, B_3')$, respectively. From (5), T_{r1}, T_{r2} and T_{r3} are given by

$$T_{r1} = T_x/[\cos^2\theta + n\sin^2\theta] \qquad (12)$$

$$T_{r2} = T_x/[\cos^2(\theta+\alpha) + n\sin^2(\theta+\alpha)] \qquad (13)$$

$$T_{r3} = T_x/[\cos^2(\theta+\beta) + n\sin^2(\theta+\beta)] \qquad (14)$$

from which the following two relations can be obtained

$$a = \frac{\cos^2(\theta+\alpha) + n\sin^2(\theta+\alpha)}{\cos^2\theta + n\sin^2\theta} \qquad (15)$$

$$b = \frac{\cos^2(\theta+\beta) + n\sin^2(\theta+\beta)}{\cos^2\theta + n\sin^2\theta} \qquad (16)$$

where

$$a = (\nu_1'/\nu_2') = (B_1'/B_2')^2 \qquad (17)$$

$$b = (\nu_1'/\nu_3') = (B_1'/B_3')^2 \qquad (18)$$

$$n = T_x/T_y = (T_x/T_y)^2 \qquad (19)$$

Known principal directions of anisotropy. If the principal directions of anisotrophy are known, the information required to solve for the four unknown quantities can be provided from observations in two groups of wells, each being on a different radial line. Let these two groups be those of the first and second lines (Figure 1). From (15) and (19), one obtains

$$T_y = T_x\left(\frac{\sin^2(\theta+\alpha) - a\sin^2\theta}{a\cos^2\theta - \cos^2(\theta+\alpha)}\right)^{0.5} \qquad (20)$$

Since θ, α, T_x, ν_1', ν_2' B_1' B_2', and, consequently, a are known from observation, the successive solutions of (20), (19), (12), (13), $S = (T_{r1}/\nu_1')$ or $= (T_{r2}/\nu_2')$, and $(K'/b') = (T_{r1}/B_1'^2)$ or $= (T_{r2}/B_2'^2)$ will produce values for T_y, T_x, T_{r1}, T_{r2}, S, and (K'/b'), respectively.

Unknown principal directions of anisotropy. If the principal directions of anisotropy are unknown, the information required to solve for the five unknown quantities can be provided from observations in three groups of wells lying on different radial lines. Let these groups be those of Figure 1.

Solving (15) and (16) for θ and n yields

$$\tan 2\theta = -2\,\frac{(b-1)\sin^2\alpha - (a-1)\sin^2\beta}{(b-1)\sin 2\alpha - (a-1)\sin 2\beta} \qquad (21)$$

$$n = \frac{\cos^2(\theta+\alpha) - a\cos^2\theta}{a\sin^2\theta - \sin^2(\theta+\alpha)} \qquad (22)$$

or

$$n = \frac{\cos^2(\theta+\beta) - b\cos^2\theta}{b\sin^2\theta - \sin^2(\theta+\beta)} \qquad (23)$$

It should be noted that a negative value of θ indicates that the positive x axis lies to the left of the first line of observation wells.

Equation 21 has two roots for the angle (2θ) in the range 0 and 2π of the xy plane. If one of the roots is δ, the other will be $\pi + \delta$. Consequently, θ has the two values $\delta/2$, and $\pi/2 + \delta/2$. One of the values of θ yields $n > 1$ and the other $n < 1$. This is to be expected because these two values leave (15) and (16) invariant except for reciprocating the value of n. Since the x axis is assumed to be along the major axis of anisotropy, $n = T_x/T_y > 1$. Thus [redacted] $n > 1$ locates the major axis of anisotropy; the other value locates the minor axis of anisotropy, the y axis.

The quantities α, β, T_x, ν_1', ν_2', ν_3', B_1', B_2', B_3', and, consequently, a and b are known from observation. Successive solutions of (21), (22) or (23), (19), (12), (13), (14), $S = T_{r1}/\nu_1'$ or $= T_{r2}/\nu_2'$ or $= T_{r3}/\nu_3'$, and $(K'/b') = T_{r1}/B_1'^2$

or $= T_{r2}/B_2''$ or $= T_{r3}/B_3''$ will produce values for θ, n, T_y, and then T_x, T_{r1}, T_{r2}, T_{r3}, S, and (K'/b'), respectively.

PROCEDURES OF ANALYSIS

The procedures presented herein are for analyzing data from pumping tests in leaky aquifers. They are applicable step by step for tests in nonleaky aquifers after the steps involving the use of the leakage factor B' are dropped out.

The application of the isotropic methods on each group of wells on a radial line will determine values of the parameters T_e, ν', and B'. Let (T_{e1}, ν_1', B_1'), (T_{e2}, ν_2', B_2'), and (T_{e3}, ν_3', B_3') be the values of these parameters obtained from applying the isotropic method on the first, second, and third group of wells, respectively. Theoretically, the relations $T_{e1} = T_{e2} = T_{e3}$, $(\nu_1'/\nu_2') = (B_1'/B_2')^2$, $(\nu_1'/\nu_3') = (B_1'/B_3')^2$, and $(\nu_1'/B_1''' = \nu_2'/B_2''' = \nu_3'/B_3''')$ should hold. These equalities should be used as a guide when applying the isotropic methods of analysis. If these equalities are not at least approximately satisfied, field conditions are not in agreement with that assumed by theory and other vitiating conditions must be present. If they are reasonably satisfied, the procedures of analysis are as follows.

Known directions of anisotropy. Data from two groups of wells, each being on a different radial line, and the isotropic method of analysis produce the values (T_{e1}, ν_1', B_1') and (T_{e2}, ν_2', B_2'). The angles α and θ are known from observation (Figure 1). These values and successive computations in the following equations produce average values of the formation constants, namely, T_x, T_y, S, and, in case of leaky aquifers, K'/b', the leakage coefficient.

$$a = 0.5[(\nu_1'/\nu_2') + (B_1'/B_2')^2] \quad \text{for leaky aquifers}$$

$$a = \nu_1'/\nu_2' \quad \text{for nonleaky aquifers} \qquad (24)$$

$$T_e = 0.5(T_{e1} + T_{e2}) \qquad (25)$$

$$T_x = T_e^2/T_y \qquad (26)$$

Equation 20 is used for T_y, and equation 12 and 13 are used for T_{r1} and T_{r2}.

$$S = 0.5[(T_{r1}/\nu_1') + (T_{r2}/\nu_2')]$$

$$K'/b' = 0.5S[(\nu_1'/B_1'^2) + \nu_2'/B_2'^2] \qquad (27)$$

Unknown direction of anisotropy. The use of the isotropic method in conjunction with data from three groups of wells, each being on a different radial line (Figure 1) will yield the values (T_{e1}, ν_1', B_1'), (T_{e2}, ν_2', B_2'), and (T_{e3}, ν_3', B_3'). The angles α and β are known from observation. The unknown principal directions of anisotropy, as well as the unknown formation constants, are obtained from successive computations in the following relations:

Equation 24 is valid for a.

$$b = 0.5[(\nu_1'/\nu_3') + (B_1'/B_3')^2] \quad \text{for leaky aquifers}$$

$$b = \nu_1'/\nu_3' \quad \text{for nonleaky aquifers} \qquad (28)$$

Equations 26, 12, 13, and 14 are valid for T_x, R_{r1}, T_{r2}, and T_{r3}.

$$T_e = (1/3)(T_{e1} + T_{e2} + T_{e3})$$

$$T_y = T_e n^{1/2}$$

Equations 26, 12, 13, and 14 are valid for T_x, T_{r1}, T_{r2}, and T_{r3}.

$$S = (1/3)[(T_{r1}/\nu_1') + (T_{r2}/\nu_2') + (T_{r3}/\nu_3')] \qquad (29)$$

$$K'/b' = (1/3)S[(\nu_1'/B_1'^2) + (\nu_2'/B_2'^2) + (\nu_3'/B_3'^2)] \qquad (30)$$

When more than three groups of wells are available for observation, the application of the preceding analysis to each combination of three will produce a set of values for each of the formation constants and directions of anisotropy. The average of each set of values of a constant will be considered as the average value of the corresponding formation constant. For example, if four groups of wells are available, there will be four combinations of three. The application of the preceding analysis to these combinations produces four values for the direction of anisotropy and four values for each of the constants. Theoretically, the four values of each of the unknowns, thus deter-

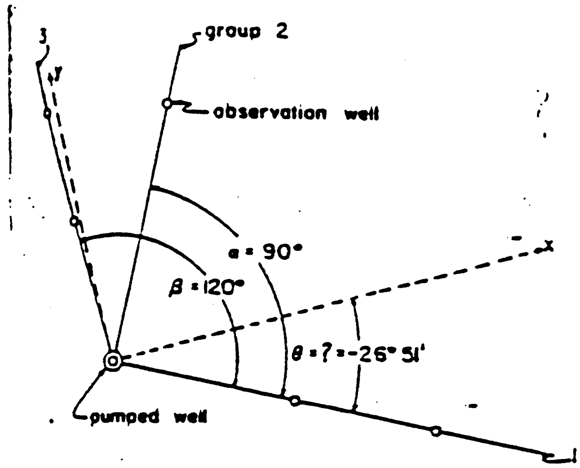

Fig. 2. Location of three rays of observation wells used in a pumping test in an anisotropic leaky aquifer.

mined, should be the same. In practice, four different values of each unknown may be obtained; they should not differ greatly, however, if field conditions approximate those called for by theory. The average of the four determined values for each constant will be taken as the average value of the constant in question.

Example of computation. Figure 2 illustrates the location of three rays of observation wells in a leaky anisotropic aquifer. The principal directions of anisotropy are not known. The isotropic methods of analysis in leaky aquifers produced the following values: $T_{e1} = 0.12$ ft^2/sec, $\nu_1' = 1150$ ft^2/sec, $B_1' = 4800$ ft, $T_{e2} = 0.10$ ft^2/sec, $\nu_2' = 615$ ft^2/sec, $B_2' = 3450$ ft, $T_{e3} = 0.09$ ft^2/sec, $\nu_3' = 510$ ft^2/sec, and $B_3' = 3260$ ft.

The ratios $\nu_1'/\nu_2' = 1.87$ and $(B_1'/B_2')^2 = 1.94$ are approximately equal; so are the ratios $\nu_1'/\nu_3' = 2.26$ and $(B_1'/B_3')^2 = 2.16$, and the ratios $(\nu_1'/B_1'^2) = 5 \times 10^{-5}$, $(\nu_2'/B_2'^2) = 5.17 \times 10^{-5}$, and $(\nu_3'/B_3'^2) = 4.81 \times 10^{-5}$. Also the values of T_{em} are approximately the same. Such magnitudes of deviation may be due to observational errors as well as mechanical errors in applying the isotropic method of analysis. Consequently, average values of these ratios, as shown in (24), (28), (22 or 23), (29), and (30), will be used in the analysis. Successive slide rule computations yield the following values: $a = 1.9$, $b = 2.21$, $\theta \approx -26°51'$ (locating the major axis of anisotropy, since it gives $n \approx 3.22 > 1$), $T_x \approx 0.103$ ft^2/sec, $T_y \approx 0.0575$ ft^2/sec, $T_e \approx 0.185$ ft^2/sec, $T_{r1} \approx 0.127$ ft^2/sec, $T_{r2} \approx 0.0665$ ft^2/sec, $T_{r3} \approx 0.0575$ ft^2/sec, $S = 1.1 \times 10^{-4}$, and $K'/b' = 5.5 \times 10^{-8}$ sec^{-1}. The transmissivity in any direction is then given by (5).

Concluding Remarks

Information that is obtained from applying the *isotropic methods of analysis* is used in the above procedures. To bring these procedures to completion, the information supplied by the isotropic methods should include values of T_e and ν' from tests in nonleaky aquifers and values of T_e and ν' and/or B' from tests in leaky aquifers. Not all isotropic methods furnish such information, however. For example, the Thiem method, the Theis recovery method, the Skibitzke bailer method, and the Ferris slug method furnish values [see for example *Jacob*, 1950; *Todd*, 1959, *Hantush*, 1964; *De Wiest*, 1965] for $T_e = (T_x T_y)^{1/2}$ only. Consequently, such methods do not supply enough information for the procedures presented above to be of use in solving even for T_x and T_y. A procedure in which data from tests in anisotropic aquifers are used and in which the number of observation wells is large enough to delineate the expected elliptical shape of an equal drawdown (or residual drawdown) curve is reserved for a subsequent paper. This procedure can be used where the present procedure fails to produce a solution for T_x and T_y.

References

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APPENDIX I

WATER QUALITY ANALYSES

GEO TEC inc. 1602 CLARE AVENUE • WEST PALM BEACH, FL 33401 • 305/833-7280

PRFORM PRIMARY ANALYSIS REPORT

ALSAY INCORPORATED	CLIENT NAME AND ADDRESS
P O BOX 6650	
LAKE WORTH, FLORIDA 33460	
19777	SAMPLE NUMBER
02-11-86 CLIENT	DATE/TIME COLLECTED /BY
02-11-86 1520	DATE/TIME RECEIVED
WEST COAST WATER SUPPLY	LOCATION

PARAMETER	STORET NO.	DATE	BY	NBR	RESULT, mg/L
ARSENIC	01002	03-03	MD	57-318	0.007
BARIUM	01007	02-27	MD	57-316	0.148
CADMIUM	01027	02-27	MD	57-317	<0.001
CHROMIUM	01034	03-05	MD	57-319	<0.005
LEAD	01051	03-01	MD	57-317	0.006
MERCURY	71900	03-04	MD	57-318	<0.0002
SELENIUM	01147	03-03	MD	57-318	0.004
SILVER	01077	02-27	MD	57-316	0.002
FLUORIDE	00951	02-15	MD	57-311	<0.20
NITRATE-N	00630	02-20	BM	50-451	0.005
SODIUM	00929	03-07	MD	57-320	13.8

DATE 04-08-86 BY [signature]

ID 86122

GEO TEC

GEO TEC inc. 1602 CLARE AVENUE • WEST PALM BEACH, FL 33401 • 305/833-7280

SFORM SECONDARY ANALYSIS REPORT

ALSAY INCORPORATED	CLIENT NAME AND ADDRESS
P O BOX 6650	
LAKE WORTH, FLORIDA 33460	
19777	SAMPLE NUMBER
02-11-86 CLIENT 02-11-86 1520	DATE TIME COLLECTED BY; RECEIVED
WEST COAST WATER SUPPLY	LOCATION

PARAMETER	STORET NO.	DATE	BY	NBR	RESULT mg/L
ALKALINITY	00410	02-12	MD	57-309	210.0
CALCIUM	00916	03-07	MD	57-320	86.8
CHLORIDE	00940	02-13	BM	62-99	10.4
COLOR	00081	02-11	CM	43-249	15
COPPER	01042	03-10	MD	57-322	<0.005
CORROSIVITY					.31
FOAMING AGENTS	38260	02-12	TM	64-13	46
IRON	01045	03-10	MD	57-321	0.158
MAGNESIUM	00927	03-07	MD	57-321	6.78
MANGANESE	01055	03-10	MD	57-321	0.009
ODOR	00085	02-11	CM	43-249	1
pH	00400	02-12	MD	57-314	7.48
SODIUM	00929	03-07	MD	57-320	13.8
SULFATE	00945	02-19	MD	57-314	<5.0
FILTERABLE RESIDUE	70300	02-21	CM	43-254	252
TOTAL HARDNESS	00900				244.7
ZINC	01092	03-06	MD	57-320	<0.10

DATE 04-08-86 BY [signature]

LAB ID 86122

GEO TEC inc. 1602 CLARE AVENUE • WEST PALM BEACH, FL 33401 • 305/833-7280

OFORM

PRIMARY ORGANICS

ALSAY INCORPORATED P O BOX 6650 LAKE WORTH, FLORIDA 33460	CLIENT NAME AND ADDRESS
19777	SAMPLE NUMBER
02-11-86 CLIENT	DATE/TIME COLLECTED BY
02-11-86 1520	DATE/TIME RECEIVED BY
WEST COAST WATER SUPPLY	LOCATION

PARAMETER	STORET NO.	RESULTS, mg/L
ENDRIN	39390	<0.00005
LINDANE	39782	<0.00005
METHOXYCHLOR	39480	<0.0001
TOXAPHENE	39400	<0.0005
2,4-D		<0.0001
2,4,5-TP	39760	<0.00001

METHOD FOR ORGANOCHLORINE PESTICIDES IN INDUSTRIAL EFFLUENTS. EPA 1973
METHOD FOR CHLORINATED PHENOXY ACID HERBICIDES IN INDUSTRIAL EFFLUENTS, EPA 1973

DATE 04-08-86 BY [signature]

LAB ID 86109

WEST COAST REGIONAL WATER SUPPLY AUTHORITY

2535 LANDMARK DRIVE, SUITE 211 CLEARWATER, FL. 33519
Clearwater (813) 796-2355 · Tampa (813) 223-9343

SUMMARY OF WATER QUALITY ANALYSES
PERFORMED ON WATER SAMPLES
COLLECTED DURING THE
DRILLING OF THE DEEP MONITOR WELL
LOCATED 500 FEET FROM CYPRESS BRIDGE
TEST PRODUCTION WELL 1A

DATE	DEPTH	Cl	SO4	TDS	CONDUCTIVITY
4/02/86	660'	10.4	<1	213	300
4/03/86	660'	10.4	<1	210	300

WP:C/BRIDGE/ANALYSES/2

WEST COAST REGIONAL WATER SUPPLY AUTHORITY

2535 LANDMARK DRIVE, SUITE 211 CLEARWATER, FL. 33519
Clearwater (813) 796-2355 · Tampa (813) 223-9343

SUMMARY OF WATER QUALITY ANALYSES PERFORMED ON WATER SAMPLES COLLECTED DURING THE DRILLING OF THE DEEP MONITOR WELL LOCATED 200 FEET FROM CYPRESS BRIDGE TEST PRODUCTION WELL 1A

DATE	DEPTH	C1	S04	TDS	CONDUCTIVITY	ALKALINITY	TOTAL HARDNESS	CALCIUM HARDNESS
4/14/86	168'	12.0	<1	193	310			
4/15/86	260'	10.4	<1	167	250			
4/15/86	350'	11.4	<1	185	300			
4/15/86	420'	9.9	<1	203	320			
4/15/86	514'	11.4	<1	202	310			
4/16/86	609'	6.2	<1	214	300			
4/17/86	700'	9.9	<1	218	300			
4/18/86	700' After 16 hours	9.9	12	211	300	173	161	157

WP:C/BRIDGE/ANALYSES

WEST COAST REGIONAL WATER SUPPLY AUTHORITY

2535 LANDMARK DRIVE, SUITE 211 CLEARWATER, FL. 33519
Clearwater (813) 796-2355 · Tampa (813) 223-9343

SUMMARY OF WATER QUALITY ANALYSES
PERFORMED ON WATER SAMPLES
COLLECTED DURING THE
DRILLING OF CYPRESS BRIDGE TEST
PRODUCTION WELL 1A

DATE	DEPTH	Cl	SO4	TDS	FE	CONDUCTIVITY
4/18/86	145'	10.9	17	497	-	1900
4/22/86	176'	12.0	<1	157	-	200
4/23/86	268'	10.9	<1	217	-	200
4/23/86	356'	9.4	<1	207	0.01	300
4/24/86	450'	10.9	<1	207	0.01	300
4/25/86	540'	10.9	10	205	0.03	300
4/29/86	635'	9.4	<1	202	0.02	300
4/29/86	696'	10.4	<1	203	<0.01	300

WP:C/BRIDGE/ANALYSES/4

WEST COAST REGIONAL WATER SUPPLY AUTHORITY

2535 LANDMARK DRIVE, SUITE 211 CLEARWATER, FL. 33519
Clearwater (813) 796-2355 · Tampa (813) 223-9343

SUMMARY OF WATER QUALITY ANALYSES
PERFORMED ON WATER SAMPLES
COLLECTED DURING THE
DRILLING OF THE DEEP MONITOR WELL
LOCATED 1950 FEET FROM CYPRESS BRIDGE
TEST PRODUCTION WELL 1A

DATE	DEPTH	C1	SO4	TDS	FE	CONDUCTIVITY
5/21/86	183'	10.7	<1	162	<0.01	220
5/22/86	273'	10.2	<1	94	<0.01	120
5/22/86	366'	10.7	<1	105	<0.01	150
5/22/86	424'	15.3	<1	187	<0.01	250
5/22/86	463'	10.2	<1	116	<0.01	122
5/23/86	553'	10.2	<1	209	<0.01	325
5/23/86	616'	10.2	<1	133	<0.01	220
5/23/86	705'	11.7	<1	164	<0.01	290

WP:C/BRIDGE/ANALYSES/3

WEST COAST REGIONAL WATER SUPPLY AUTHORITY

2535 LANDMARK DRIVE, SUITE 211 CLEARWATER, FL. 33519
Clearwater (813) 796-2355 · Tampa (813) 223-9343

SUMMARY OF WATER QUALITY ANALYSES
ON PUMP TEST SAMPLES FROM THE
CYPRESS BRIDGE TEST PRODUCTION WELL 1A

DATE	HOURS PUMPED	Cl	SO4	TDS	H_2S	CONDUCTIVITY
6/17/86	12 hr	11.4	<1	224	0.02	330
6/18/86	36 hr	10.9	<1	216	0.02	330
6/19/86	60 hr	10.9	<1	220	0.01	340
6/20/86	84 hr	10.9	1	202	0.02	340
6/21/86	108 hr	10.9	1	212	0.01	330
6/22/86	132 hr	10.4	1	220	0.02	330

WP:C/BRIDGE/ANALYSES/5

WEST COAST REGIONAL WATER SUPPLY AUTHORITY LABORATORY DHRS #54043

RESULTS OF ANALYSIS OF INORGANIC CHEMICAL CONSTITUENTS OF CYPRESS BRIDGE TEST PRODUCTION WELL 1A

ALL RESULTS ARE LISTED IN (mg/l) UNLESS OTHERWISE STATED

DATE OF THIS REPORT:	8-DEC-86	#1	#2	#3	#4	#5
	SAMPLE NAME:	CYPT1A 072 HRS	CYPT1A 0143 HRS			
	DATE SAMPLED:	20-JUN-86	23-JUN-86			
	TIME SAMPLED:	1130	0900			
	COLLECTED BY:	SBR/KKL	SBR/KKL			
	DATE ANALYZED:	20-JUN-86	23-JUN-86			
	ANALYZED BY:	KJC	KJC			

PRIMARY INORGANIC CHEMICALS:	STORET#	EPA METHOD#	MCL	#1	#2	#3	#4	#5
ARSENIC	1002	206.2	0.05					
BARIUM	1007	208.2	1		0.07			
CADMIUM	1027	213.2	0.01					
CHROMIUM	1034	218.1	0.05					
LEAD	1051	239.2	0.05					
MERCURY	71900	245.1	0.002					
NITRATE	620	352.1	10		0.08			
SELENIUM	1147	270.2	0.01					
SILVER	1077	272.2	0.05	0.006	<0.002			
FLUORIDE	951	340.2	1.4-2.4	<0.2	<0.2			
TURBIDITY (NTU)	76	N/A	5.0	0.22	0.21			

SECONDARY INORGANIC CHEMICALS:	STORET#	EPA METHOD#	MCL	#1	#2	#3	#4	#5
TOTAL ALKALINITY	410	S.M.403		169	178			
CALCIUM	916	CALCULATED		69.60	73.60			
CALCIUM	916	215.2			135			
CHLORIDE	940	S.M.407-A	250.0	10.9	11.4			
COLOR (P.C.U.)	80	S.M.204-A	15.0	5.0	5.0			
COPPER	1042	220.2	1.0	<0.002	<0.001			

MCL: MAXIMUM CONTAMINANT LEVEL

WEST COAST REGIONAL WATER SUPPLY AUTHORITY LABORATORY DHRS #54043

RESULTS OF ANALYSIS OF INORGANIC CHEMICAL CONSTITUENTS OF CYPRESS BRIDGE TEST PRODUCTION WELL 1A

ALL RESULTS ARE LISTED IN (mg/l) UNLESS OTHERWISE STATED

DATE OF THIS REPORT:	8-DEC-86		#1	#2	#3	#4	#5
	SAMPLE NAME:		CYPT1A 973 HRS	CYPT1A 9143 HRS			
	DATE SAMPLED:		20-JUN-86	23-JUN-86			
	TIME SAMPLED:		1130	0900			
	COLLECTED BY:		SBR/KKL	SBR/KKL			
	DATE ANALYZED:		20-JUN-86	23-JUN-86			
	ANALYZED BY:		KJC	KJC			

CORROSIVITY (LANGELIER)	99413	NONE	(0.19)	(0.12)
	CALCULATED			
FOAMING AGENTS (MBA)	38260	0.5		
	S.M.512-A			
HYDROGEN SULFIDE			1.00	1.00
	S.M.427-C			
IRON	1045	0.3	0.13	0.04
	236.2			
MAGNESIUM			0.49	1.22
	CALCULATED			
MAGNESIUM				7.5
	242.1			
MANGANESE	1055	0.05	0.003	0.006
	243.2			
ODOR (THRESHOLD)	85	3.0		
	140.1			
pH	403	>6.5	7.50	7.52
	150.1			
SODIUM	929	160.0		3.4
	273.2			
SULFATE	945	250.0	1	<1
	375.4			
T.D.S.	70300	500.0	211	207
	S.M.209-C			
TOTAL HARDNESS			176	189
	S.M.314-B			
ZINC	1092	5.0	<0.003	0.011
	289.2			
CARBONATE ALKALINITY	CALCULATED			
BICARBONATE ALKALINITY	CALCULATED		169	178
CARBONATE HARDNESS	CALCULATED		169	178
NON-CARBONATE HARDNESS	CALCULATED		7.00	11.00
CALCIUM HARDNESS	CALCULATED		174	184
MAGNESIUM HARDNESS	CALCULATED		2.00	5.00
CONDUCTIVITY (umhos/cm)			330	330

MCL: MAXIMUM CONTAMINANT LEVEL

WEST COAST REGIONAL WATER SUPPLY AUTHORITY LABORATORY DHRS #54043

RESULTS OF ANALYSIS OF ORGANIC CONSTITUENTS OF CYPRESS BRIDGE TEST PRODUCTION WELL 1A

ALL RESULTS ARE LISTED IN (ug/l) UNLESS OTHERWISE STATED

DATE OF THIS REPORT:	08-AUG-86		#1	#2	#3	#4
	SAMPLE NAME:		CYPT1A @73 HRS	CYPT1A @143 HRS		
	DATE SAMPLED:		20-JUN-86	23-JUN-86		
	TIME SAMPLED:		1130	0900		
	COLLECTED BY:		SBR/KKL	SBR/KKL		
	DATE ANALYZED:		20-JUN-86	23-JUN-86		
	ANALYZED BY:		KJC	KJC		
P U R G E A B L E S :	STORET# EPA METHOD#	MCL				
BROMODICHLOROMETHANE	32101 601		<0.3	<0.3		
BROMOFORM	32104 601		<0.6	<0.6		
CHLOROFORM	32106 601		<0.6	<0.6		
DIBROMOCHLOROMETHANE	32105 601		<0.4	<0.4		
METHYLENE CHLORIDE	34423 601		<1.0	<1.0		

DATE OF THIS REPORT:	08-AUG-86		#1	#2	#3	#4
	SAMPLE NAME:		CYPT1A @73 HRS	CYPT1A @143 HRS		
	DATE SAMPLED:		20-JUN-86	23-JUN-86		
	TIME SAMPLED:		1130	0900		
	COLLECTED BY:		SBR/KKL	SBR/KKL		
	DATE ANALYZED:		26-JUN-86	26-JUN-86		
	ANALYZED BY:		KJC	KJC		
P U R G E A B L E S :	STORET# EPA METHOD#	MCL				
ETHYLBENZENE	34371 602		<1.9	<1.9		
TOLUENE	34010 602		<1.2	<1.2		
CHLOROBENZENE	34301 602		<1.6	<1.6		
1,4-DICHLOROBENZENE	34571 602		<0.5	<0.5		
1,3-DICHLOROBENZENE	34566 602		<0.8	<0.8		
1,2-DICHLOROBENZENE	34536 602		<0.3	<0.3		

WEST COAST REGIONAL WATER SUPPLY AUTHORITY LABORATORY DHRS #54042

RESULTS OF ANALYSIS OF ORGANIC CONSTITUENTS OF CYPRESS BRIDGE TEST PRODUCTION WELL 1A

ALL RESULTS ARE LISTED IN (ug/l) UNLESS OTHERWISE STATED

DATE OF THIS REPORT:	08-AUG-86		#1	#2	#3	#4
	SAMPLE NAME:		CYPT1A 073 HRS	CYPT1A 0143 HRS		
	DATE SAMPLED:		20-JUN-86	23-JUN-86		
	TIME SAMPLED:		1130	0900		
	COLLECTED BY:		SBR/KKL	SBR/KKL		
	DATE ANALYZED:		20-JUN-86	23-JUN-86		
	ANALYZED BY:		KJC	KJC		
P U R G E A B L E S :	STORET# EPA METHOD#	MCL				
TRICHLOROETHYLENE	39180 601	3	<0.2	<0.2		
TETRACHLOROETHYLENE	34475 601	3	<0.2	<0.2		
CARBON TETRACHLORIDE	32102 601	3	<0.3	<0.3		
VINYL CHLORIDE	39175 601	1	<1.0	<1.0		
1,1,1-TRICHLOROETHANE	34506 601	200	<1.3	<1.3		
1,2-DICHLOROETHANE	34531 601	3	<0.5	<0.5		
ETHYLENE DIBROMIDE	77651 DHRS	0.02	<0.02	<0.02		

DATE OF THIS REPORT:	08-AUG-86		#1	#2	#3	#4
	SAMPLE NAME:		CYPT1A 073 HRS	CYPT1A 0143 HRS		
	DATE SAMPLED:		20-JUN-86	23-JUN-86		
	TIME SAMPLED:		1130	0900		
	COLLECTED BY:		SBR/KKL	SBR/KKL		
	DATE ANALYZED:		26-JUN-86	26-JUN-86		
	ANALYZED BY:		KJC	KJC		
P U R G E A B L E S :	STORET# EPA METHOD#	MCL				
BENZENE	34030 602	1	<0.2	<0.2		

WEST COAST REGIONAL WATER SUPPLY AUTHORITY LABORATORY DHRS #54043

r TS OF ANALYSIS OF ORGANIC CONSTITUENTS OF CYPRESS BRIDGE TEST PRODUCTION WELL 1A

ALL RESULTS ARE LISTED IN (ug/l) UNLESS OTHERWISE STATED

DATE OF THIS REPORT:	08-AUG-86		#1	#2	#3	#4	#5
	SAMPLE NAME:		CYPT1A @73 HRS	CYPT1A @143 HRS			
	DATE SAMPLED:		20-JUN-86	23-JUN-86			
	TIME SAMPLED:		1130	0900			
	COLLECTED BY:		SBR/KKL	SBR/KKL			
	DATE EXTRACTED:		24-JUN-86	24-JUN-86			
	DATE ANALYZED:		07-JUL-86	01-JUL-86			
	ANALYZED BY:		KJC	KJC			
BASE NEUTRAL EXTRACTABLES:	STORET# EPA METHOD#	MCL					
HEXACHLOROBUTADIENE	34391 612		<5.0	<5.0			
HEXACHLOROETHANE	34396 612		<5.0	<5.0			
HEXACHLOROCYCLOPENTADIENE	34386 612		<200.0	<200.0			
1,2,4-TRICHLOROBENZENE	34551 612		<20.0	<20.0			

MCL: MAXIMUM CONTAMINANT LEVEL

WEST COAST REGIONAL WATER SUPPLY AUTHORITY LABORATORY DHRS #54043

RF S OF ANALYSIS OF ORGANIC CONSTITUENTS OF CYPRESS BRIDGE TEST PRODUCTION WELL 1A

ALL RESULTS ARE LISTED IN (ug/l) UNLESS OTHERWISE STATED

DATE OF THIS REPORT:	08-AUG-86		#1	#2	#3	#4	#5
	SAMPLE NAME:		CYPT1A @73 HRS	CYPT1A @143 HRS			
	DATE SAMPLED:		20-JUN-86	23-JUN-86			
	TIME SAMPLED:		1130	0900			
	COLLECTED BY:		SBR/KKL	SBR/KKL			
	DATE EXTRACTED:		24-JUN-86	24-JUN-86			
	DATE ANALYZED:		06-AUG-86	31-JUL-86			
	ANALYZED BY:		KJC	KJC			
P E S T I C I D E S :	STORET# / EPA METHOD#	MCL					
ALDRIN	39330 / 608		<0.7	<0.7			
A-BHC	39337 / 608		<0.6	<0.6			
B-BHC	39338 / 608		<1.3	<1.3			
G-BHC	39340 / 608		<0.5	<0.5			
D	39259 / 608		<0.5	<0.5			
CHLORDANE	39350 / 608		<1.0	<1.0			
4,4-DDD	39310 / 608		<3.1	<3.1			
4,4-DDE	39320 / 608		<1.3	<1.3			
4,4-DDT	39300 / 608		<0.2	<0.2			
DIELDRIN	39380 / 608		<1.5	<1.5			
ENDOSULFAN I	34361 / 608		<0.2	<0.2			
ENDOSULFAN II	34356 / 608		<3.1	<3.1			
ENDOSULFAN SULFATE	34351 / 608		<2.0	<2.0			
ENDRIN ALDEHYDE	34366 / 608		<3.1	<3.1			
HEPTACHLOR	39410 / 608		<0.7	<0.7			
HEPTACHLOR EPOXIDE	39420 / 608		<0.2	<0.2			

MCL: MAXIMUM CONTAMINANT LEVEL

WEST COAST REGIONAL WATER SUPPLY AUTHORITY

2535 LANDMARK DRIVE, SUITE 211 CLEARWATER, FL. 33519
Clearwater (813) 796-2355 · Tampa (813) 223-9343

Sample: Cypress Bridge Test Production Well 1A
After 143 Hours Pumping
Collected June 23, 1986
At 0930 by Susan B. Reinhardt

Gross Alpha (pCi/l)	Gross Beta (pCi/l)
3.7±3.2	<4.0

This analysis was performed by Environmental Science and Engineering FDHRS ID#82138.

WP:C/BRIDGE/ANALYSES/6

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC. DATE:07/17/86
PROJECT MANAGER: JOSEPH J. VONDRICK

WEST COAST REG'L UTILITIES

FLD.GRP.	#	SAMPLE ID	DATE	TIME	ALPHA, GROSS PC/L	ALPHA, GR, CT. ERROR PC/L	BETA, GROSS PC/L	BETA, GR, CT. ERROR PC/L
WCRU-3	1	CYPT1	06/23/86	09:30	4.50	2.90	<4.0	NA
WCRU-3	2	CYPT1	06/23/86	09:30	5.40	3.50	<4.0	NA
WCRU-3	3	CC	06/23/86	09:30	<3.00	NA	<4.0	NA

CYPT1 - CYPRESS BRIDGE
PRODUCTION TEST #1

TWX 810 876-9134
THORNT LAB TPA

THORNTON LABORATORIES, INC.
1145 EAST CASS STREET
TAMPA, FLORIDA 33601 - 2880
MARINE, ANALYTICAL AND ENVIRONMENTAL SERVICES

TELEPHONE (813) 223-9702
P.O. BOX 2880

July 22, 1986

Laboratory Number 640611

For West Coast Regional Water Supply Authority
2535 Landmark Dr. Suite 211
Clearwater, FL 33519

Attn: S. Reinhardt

System Name CYPTI
Date & Time Received 6-23-86/09:30 am
Date & Time Collected 6-23-86/10:30
Collector SBR/KKL

DRINKING WATER CHEMICAL ANALYSIS
Laboratory ID #84147
PRIMARY STANDARDS

PARAMETER	MCL (a)	RESULT (b)	PARAMETER	MCL (a)	RESULT (b)
INORGANICS			**ORGANICS**		
Arsenic (As)	0.05	<0.005	Endrin	0.0002	< 0.0001
Barium (Ba)	1.0	<0.03	Lindane	0.004	< 0.0001
Cadmium (Cd)	0.01	0.002	Methoxychlor	0.1	< 0.005
Chromium (Cr)	0.05	<0.005	Toxaphene	0.005	< 0.001
Lead (Pb)	0.05	0.02	2,4-D	0.1	< 0.02
Mercury (Hg)	0.002	<0.0002	2,4,5-TP	0.01	< 0.002
Nitrate (N)	10	0.02			
Selenium (Se)	0.01	<0.005			
Silver (Ag)	0.05	<0.005			
Sodium (Na)	160	4.1			
Fluoride (F)	1.6	0.13			
Turbidity (NTU)	1	0.14			

Analysis according to approved methods listed in Chapter 17-22.
(a) Quality Standards, Chapter 17-22.104 F.A.C.
(b) All results are expressed as mg/L except as noted

THORNTON LABORATORIES, INC.

Fred R. Hartley Jr.

THORNTON LABORATORIES, INC.
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July 22, 1986

Laboratory Number 640611

For West Coast Regional Water Supply Authority
2535 Landmark Dr. Suite 211
Clearwater, FL 33519

Attn: S. Reinhardt

System Name CYPTI
Date & Time Received 6-23-86/09:30 am
Date & Time Colledted 6-23-86/10:30
Collector SBR/KKL

DRINKING WATER CHEMICAL ANALYSIS
Laboratory ID #84147
SECONDARY STANDARDS

PARAMETER	MCL(a)	RESULT(b)	PARAMETER	MCL(a)	RESULT(b)
Calcium (Ca)	—	68	**CORROSIVITY**		
Chloride (Cl)	250	8.1	Total Hardness(c)	—	181
Color (Pt-Co Units)	15	5	Total Alkalinity(c)	—	172
Copper (Cu)	1	<0.005	N.C.H.(c)	—	9
Foaming Agents	0.5	<0.02	Bicarbonate (HCO_3)	—	210
Hydrogen Sulfide	—	<0.04	Carbon Dioxide (CO_2)	—	5.0
Iron (Fe)	0.3	0.17	Bicarbonate (c)	—	172
Magnesium (Mg)	—	2.9	Carbonate(c)	—	-0-
Manganese (Mn)	0.05	0.005	Hydroxide(c)	—	-0-
Odor (Threshold Units)	3	-0-	pHs Value	—	7.3
pH Value	6.5 Min.	7.8	Saturation Index	>-0.2	
Sulfate (SO_4)	250	<1		<+0.2	0.5
Total Dissolved Solids	500	212	Stability Index	—	6.8
Zinc (Zn)	5	0.012	Interpretation:		Scale Forming

Analysis according to approved methods listed in Chapter 17-22.
(a) Quality Standards, Chapter 17-22.104 F.A.C.
(b) All results are expressed as mg/L except as noted
(c) Results expressed as mg/L $CaCO_3$

THORNTON LABORATORIES, INC.

Fred R. Hartley

APPENDIX J

GLOSSARY OF TERMS

EJK6T.3/11
12/4/86

GLOSSARY OF TERMS

Anhydrite. An evaporite mineral, $CaSO_4$, found in sedimentary rocks associated with gypsum.

Anisotropy. The condition under which one or more of the hydraulic properties of an aquifer vary according to the direction of flow.

Annular Space (Annulus). The space between casing or well screen and the wall of the drilled hole or between drill pipe and casing.

Aquifer. Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer, artesian. An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer. Also called a confined aquifer.

Bore Hole. An uncased drilled hole

Confining Unit. A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. It may lie above or below the aquifer. Also called a confining bed.

Connate Water. Water that was deposited simultaneously with the geologic formation in which it is contained.

Cone of Depression. The depression, approximately conical in shape, that is formed in a water-table or potentiometric surface when water is removed from an aquifer at a well.

Coquina Zone. A zone within the subsurface in which sand and small shell fragments are the dominant constituents.

Consumptive Use. That part of the water withdrawn that is no longer available because it has been either evaporated, transpired, incorporated into products and crops, or otherwise removed from the immediate water environment.

Cuttings. Subsurface material which has been returned to the surface during drilling operations as grains or fragments.

Diffusivity. A property of an aquifer or confining bed defined as the ratio of the transmissivity to the storativity.

Discharge Pipe. Pipe which transports cuttings, drilling mud or water away from the bore hole during drilling operations or during testing phases.

Drawdown. A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of groundwater from wells.

Dry Well. A bore hole or well that does not extend into the zone of saturation.

Evapotranspiration. The sum of evaporation plus transpiration by plants.

Foram (foraminifera). A benthonic or planktonic form of Protazoa usually with a calcareous test in which there is considerable morphologic variation.

Gravel Pack. Graded material placed directly around a well screen in order to prohibit the clogging of the screen by formation material to insure an adequate hydraulic connection between the water producing formation and the well.

Groundwater. The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer. The water that enters wells and issues from springs.

Grout. Cement which is placed between the well casing and the wall of the drilled bore hole for sealing purposes. A small percentage of bentonite is often added to reduce shrinkage and cracking upon drying.

Gypsum. An evaporite mineral, $CaSO_4.2H_2O$, found in clays and limestones; sometimes associated with sulphur.

Heterogeneous. Pertaining to a substance having different characteristics in different locations. A synonym is nonuniform.

Homogeneous. Pertaining to a substance having identical characteristics everywhere. A synonym is uniform.

Hydraulic Conductivity. A coefficient of proportionality describing the rate at which water can move through a permeable medium.

Isotropy. The condition in which hydraulic properties of the aquifer are equal in all directions.

Leakance Coefficient. The rate of flow that crosses a unit area of the interface between the main aquiifer and its semiconfining bed if the difference between the head in the main aquifer and the source supplying leakage is unity.

Manometer. A narrow, vertical tube located near the orifice on the discharge pipe. The manometer measures the hydraulic head of water in the discharge pipe as a function of pumping rate and size of the orifice.

Monitor(ing) Well. A well used to observe the elevation of the water table or the potentiometric surface. An observation well is generally of larger diameter than a piezometer and typically is screened or slotted throughout the thickness of the aquifer. Water quality samples may also be obtained.

Mud Pit. A steel-lined pit used to contain the mixture of drilling mud, water and cuttings which are brought to the surface during drilling operations. Mud pits are used to guard against bacterial contamination of the well during drilling processes.

Mud Rotary Drilling Methods. A method of drilling in which bentonite or other additives is used to create a drilling fluid of a viscosity to circulate cuttings to the surface at the same time it lubricates the drill bit and seals (coats) the bore hole.

Orifice. A machined plate of an exact diameter size which is attached to the open end of a discharge pipe. The diameter of the orifice and the discharge pipe in combination with a specific manometer reading can be used to measure the discharge from a well.

Permeability (k). A property of a rock or medium which describes ease with which water is transported.

Potable Water Supply. Water of a quality which is fit for human consumption. Potable water quality standards are dictated by government regulations.

Potentiometric Surface. A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Production Well. A well which is constructed with the intent of providing specific quantities of water for water supply purposes.

Reverse Air Drilling Method. A drilling method in which compressed air and formation waters are used to circulate cuttings to the surface through the drill stem. This method does not require the use of clay additives to the bore hole water.

Shelby Tube. A thin wall tube sampler secured to a head containing a ball check valve. The head is threaded to receive standard drill rods. The Shelby tube is used to obtain an undisturbed formation sample immediately below the bottom of the bore hole.

Solution Zone. A zone within carbonate rock which has been dissolved leaving voids capable of supplying significant quantities of groundwater.

Specific Capacity. An expression of the productivity of a well, obtained by dividing the rate of discharge of water from the well by the drawdown of the water level in the well. Specific capacity should be described on the basis of the number of hours of pumping prior to the time the drawdown measurement is made. It will generally decrease with time as the drawdown increases.

Staff Gage. A measuring stick similar to a yard stick used to monitor the change in surface water level.

Storage Coefficient (S), dimensionless. The volume of water an aquifer released from or takes into storage per unit surface area of the aquifer per unit change in head.

Totalizing Flow Meter. A meter which measures the accumulated discharge of water through a pipe.

Transmissivity (T). The rate at which water is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.

Vibrated Casing. A method of installing casing in which the casing is actually vibrated into the substratum instead of first drilling a hole and inserting the casing.

Well Loss. A loss in water head during pumping which is related to the presence or the design of the well.