FLORIDAN AQUIFER SYSTEM
TEST WELL PROGRAM
C-13 CANAL, OAKLAND PARK, FLORIDA
Technical Publication WS-16

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April 2003

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EXECUTIVE SUMMARY

The Lower East Coast (LEC) Planning Area of the South Florida Water Management District (District) includes Miami-Dade, Broward and Palm Beach counties. Water supply plans developed for the LEC (SFWMD, 1993, 2000) have identified the Floridan aquifer system (FAS) as a possible water supply alternative and have recommended it be further explored and characterized. Based on these recommendations, the District initiated a program of exploratory well construction, aquifer testing, and long-term monitoring to provide data needed to assess and model the FAS underlying the area.

This report documents the results of construction and testing of four new FAS wells by the District. The wells were constructed within the City of Oakland Park, Broward County near the District operated salinity control structure S-36 on the C-13 canal's northern right-of- way. This site was selected to augment data available from other wells and to provide broad, spatial coverage within the District's LEC Planning Area. The purpose of the drilling and testing program was to assess the subsurface hydrogeologic and water quality properties and to evaluate the potential of the FAS as a water supply resource at the site.

The scope of the investigation consisted of constructing and testing four FAS wells. The first "pilot" well (BF-1) was drilled to a total depth of 2,280 feet below land surface (bls). This pilot hole was extensively tested and ultimately completed as a deep monitor well into the lower Floridan aquifer. The second well (BF-2) was completed as a larger diameter (14-inch) well to pump a producing zone within the middle Floridan aquifer during an aquifer performance test. Then an upper Floridan aquifer production well (BF-3) was completed followed by a dual zone monitor well, BF-4S and BF-4M, completed into the upper and middle Floridan aquifer, respectively.

The main findings of the exploratory drilling and testing program are as follows:

- Surficial sediments extended from land surface to a depth of approximately 361 feet bls and the Hawthorn Group (upper confining unit) was found to extend to approximately 940 feet bls.

- Limestone comprising the uppermost FAS was identified at a depth of approximately 975 feet bls based on lithologic and hydrogeologic observations.

- An "upper" producing zone was found 25 feet below the top of the FAS between 1,000-1,030 feet bls. The temperature log also indicated the presence of another strong flow zone between 1,145 to 1,155 feet bls. An aquifer performance test (APT) was run across the open-hole interval between 1,000 to 1,200 feet bls. Analysis (using Hantush, 1960) of the time-drawdown data from this (APT) resulted in a transmissivity (T) of 119,600 gallons per day per foot (gpd/ft) and a leakance value of $1.52e^{-3}$ gallons per day per foot. Water sampled from that interval contained a chloride concentration of approximately 4,218 milligrams per liter (mg/L).

- A "middle" producing zone was identified between 1,500 and 1,600 feet bls. This interval had an APT derived transmissivity (Hantush Jacob, 1955) of approximately 70,300 gpd/ft and a leakance value of $2.22e^{-3}$ gallons per day per foot. Water collected from this zone had a chloride concentration of 2,800 mg/L, which was less saline than the zone above it.

- The base of the Underground Source of Drinking Water (USDW) was identified at 1,710 feet bls using water quality analyses from straddle-packer tests and geophysical logs. That base is characterized by a total dissolved solids concentration equal to or greater than 10,000 mg/L.

- Lower zones within the middle confining unit between 1,726 and 1,772 feet bls and 2,078 and 2,088 feet bls exhibited low (corrected) specific capacities of 5.52 and 0.07 gallons per minute per foot (gpm/ft), respectively indicating significant confinement at that depth.

- The cross-well tomography system was used to test its applicability in mapping permeability profiles between two Floridan wells. The results of the pilot were inconclusive. Aquifer permeability mapped using cross-well tomography compared favorably with those from two aquifer performance tests, however those maps also displayed much higher permeability than expected within the middle-confining unit. Aquifer performance test results including estimates of transmissivity and hydraulic conductivity were provided to the contractor for use during their analyses.

- The unadjusted mean water levels in the upper, middle and lower FAS intervals (BF-4S, BF-4M, and BF-1) during the period from April 1993 to March 2001 were approximately +42, +45 and +7 feet above the National Geodetic Vertical Datum of 1929 (NGVD), respectively.

- When corrected to freshwater head equivalent levels, water levels in the upper, middle and lower Floridan aquifer zones calculated as +47, +49 and +59 feet above NGVD, respectively. This agrees with levels used to model the FAS regionally (Fairbank, 1999), (Lukasiewicz, 1992), (Tibbals, 1981).

- When adjusted for density, the gradient between the lower and upper FAS zones was approximately 10 feet. The interpreted direction of ground water movement is upward.

- Water levels in the upper and middle Floridan aquifer fluctuated within a range of approximately three feet above and below the average values during the period of record. Similarly, the lower Floridan aquifer fluctuated within a range of approximately two feet above and below the average values during the period of record. It is interesting to note that water levels in both the upper and lower Floridan aquifers increased over the period of record (7 years).

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ACKNOWLEDGEMENTS

The author would like to give special recognition to three primary contributors to this project: Simon Sunderland, Robert Verrastro and Milton Switanek. Simon was instrumental in researching and plotting the hydrographs in the water levels section of this report and he provided a comprehensive technical review. Mr. Verrastro suggested and developed several of the graphics and also provided a detailed technical review. While with the District, Milton Switanek provided primary assistance as site geologist overseeing much of the drilling, construction and testing associated with this project. Milton now works for the U.S. Army Corp. of Engineers in Jacksonville, Fl. This publication has benefited considerably from the contributions of each of these three individuals, the author sincerely thanks each.

The author would also like to thank those who reviewed this manuscript both internal and external to the District. External reviewers included: Ron Reese of the United States Geological Survey, Jon Arthur and Rick Green of the Florida Geological Survey, Jim Anderson of Stemle, Anderson and Associates, and Jeff Rosenfeld of MacVicar, Federico and Lamb, Inc. Internal (District) reviewers included: Michael Bennett, Keith Smith, Simon Sunderland and Robert Verrastro. In addition, Cindy Bevier organized many of this project's archived files in the early stages of report compilation. The author also thanks Ms. Sorrel Hoover of Orion Consulting for patience, perseverance and technical editing expertise throughout this report compilation process. Thanks are extended to each of these professionals for their unique contributions. This document is a much more useful and organized tool thanks to their contributions.

During the well construction and testing phases, Mr. Robert Tinsely was a source of reliable, invaluable guidance and expertise. At the time Mr. Tinsely owned and operated RST Partnership, Inc (the drilling Contractor). He now works for All-Webb's Enterprises of Ft. Pierce. His expertise in the business of deep well drilling, testing and construction served this project well and the author is grateful to have had the opportunity to benefit and learn from him in the field.

INTRODUCTION

Background

Four wells were constructed under a South Florida Water Management District (District) contract (C-3229) near NW 39th Street in Oakland Park, Broward County, Florida as part of a Floridan aquifer System (FAS) exploratory drilling program. One of the four wells was completed as a dual-zone monitor well (BF-4S and BF-4M). All wells are located along the north bank of the C-13 canal just east of salinity control structure S-36 in Section 20 of Township 49 South, Range 42 East, at Latitude 26 degrees, 10 minutes 23 seconds and Longitude 80 degrees north, 10 degrees 44 seconds. **Figure 1** shows the location of District sponsored exploratory FAS sites drilled south of Lake Okeechobee in the 1990's for water supply planning purposes in south Florida and the reference numbers of the completed reports. The location of the C-13 site is identified on the map with an arrow as "Study Area." The wells were constructed to obtain hydrogeologic and water quality data from the FAS within the District's Lower East Coast (LEC) and Lower West Coast (LWC) planning areas. The District provided oversight during all well drilling, construction, and testing operations. Information from this exploratory drilling program will be used to assist in the conceptual development and calibration of a regional ground water flow model simulating the FAS. Such a model will be developed by the District and U.S. Army Corp of Engineers as part of the Aquifer Storage and Recovery (ASR) Regional Floridan Aquifer Studies project as part of the Comprehensive Everglades Restoration Plan (CERP). Information provided in this report includes a summary of: 1) well drilling and construction details, 2) site geology, 3) hydrogeologic testing, and 4) water quality and levels.

Project Overview

District staff prepared the well designs and technical specifications, and provided construction oversight of the drilling contractor. RST Partnership, Inc. (RST), of Fort Myers, Florida was selected as the contractor to construct and test the wells. District contract C-3229 was executed in September 1992 and a Notice to Proceed was issued November 1992. Construction began in December 1992 and was completed in July 1993. The contract included drilling, testing, construction and installation of associated wellhead piping and appurtenances for wells BF-1, BF-2, BF-3, BF-4M and BF-4S.

Once all wells were constructed, cross-well tomography was performed, under contract to the University of Miami, to map permeability and porosity between wells at the site. The outcome of that work is summarized in a separate report (Yamamoto and Kuru, 1997) and discussed briefly in this report.

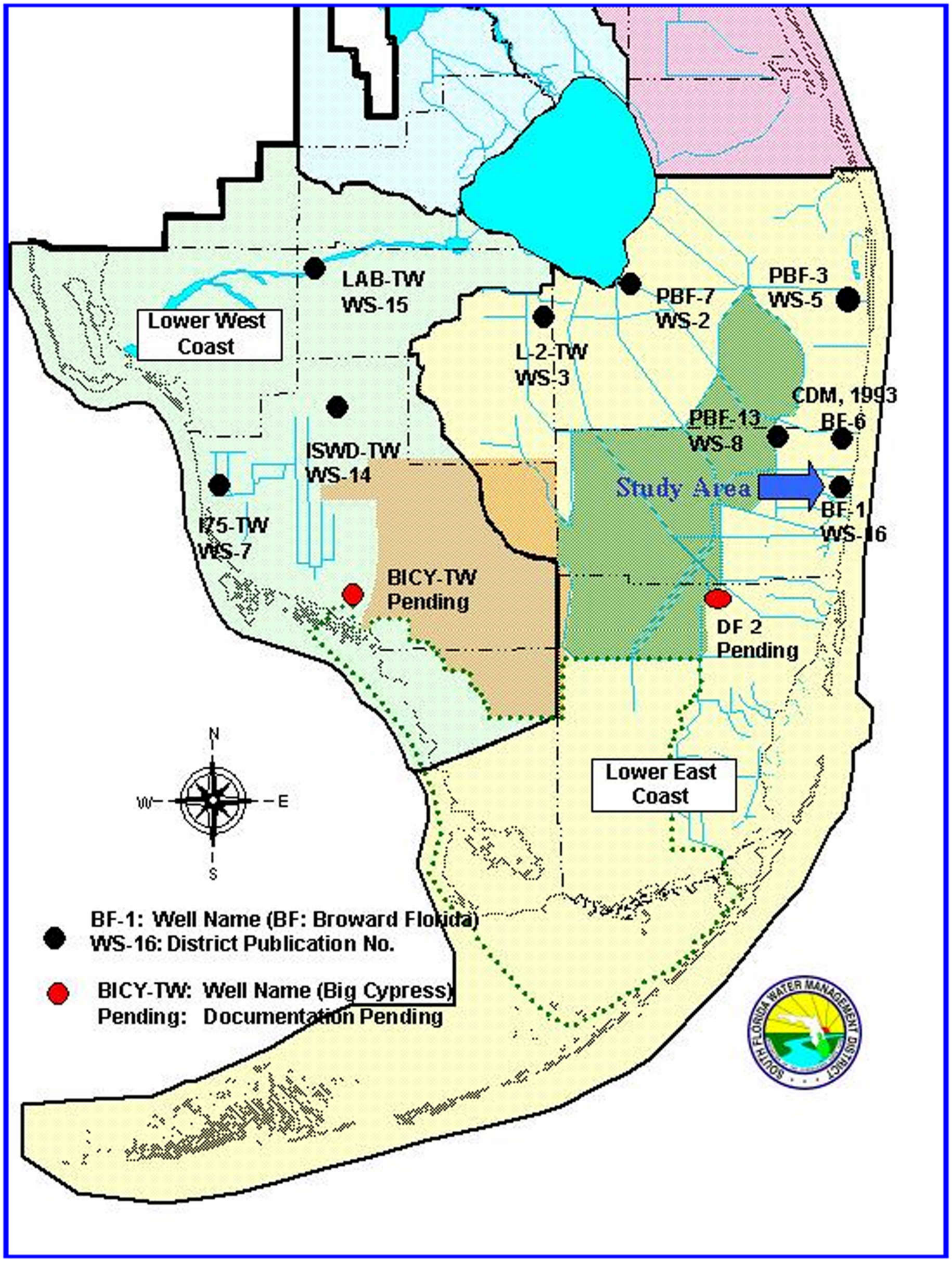


Figure 1. Location of All District Exploratory Floridan Aquifer Wells Constructed and Tested in the 1990's South of Lake Okeechobee.

EXPLORATORY DRILLING AND WELL CONSTRUCTION

Overview

Four FAS wells were constructed on the northern bank of the C-13 canal near the District's S-36 salinity control structure in Oakland Park, Broward County. The locations of the wells are shown in **Figure 2**. The drilling schedule and well casing setting depths for each of the wells were designed to conform to site-specific hydrogeologic features. Data collected during construction and testing of the wells resulted in the interpretation of lithology, geophysical properties, water quality, water levels, transmissivity, and storage and leakance coefficients corresponding to the producing zones within the FAS. The data were obtained from collection and description of drill cuttings, observations during pilot hole drilling, borehole geophysical logs, packer pumping tests, and two aquifer performance tests (APTs).

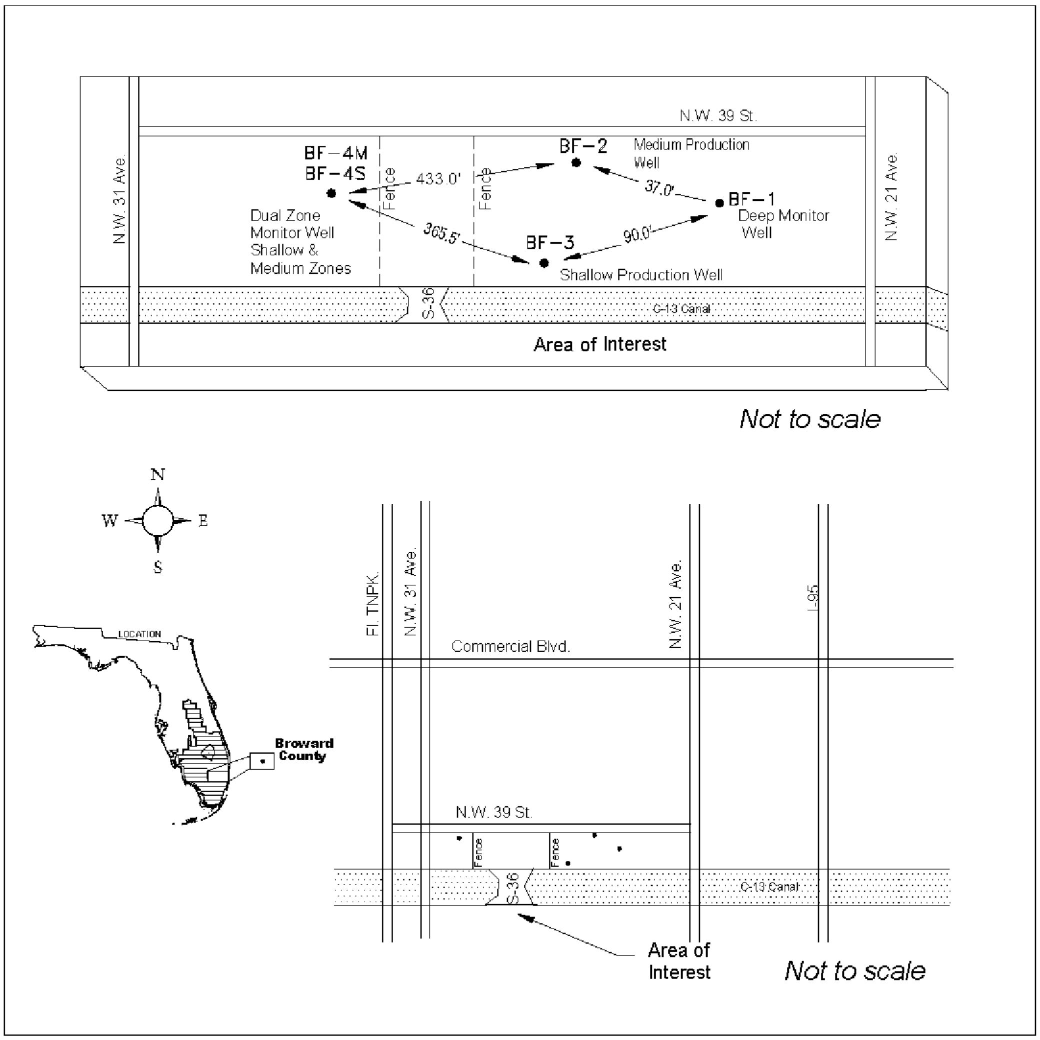


Figure 2. Site Location Map.

RST Partnership, Inc. was issued a notice to proceed by the District in November 1992 and began drilling December 1992 with the rig positioned at well BF-1 (see **Figure 2**). This BF-1 site is located approximately two hundred feet east of salinity control structure S-36 along the northern C-13 right-of-way. BF-1 served as the pilot hole, and ultimately the lower Floridan monitor well having a final total depth of 2,280 feet below land surface (bls). Once complete, the rig moved 37 feet northwest to construct BF-2, a middle Floridan aquifer production well with an open-hole interval between 1,500 to 1,600 feet bls. Once BF-2 was completed, the rig moved 77 feet southwest to drill BF-3, the uppermost Floridan production well. It was completed open-hole between 1,000 feet to 1,200 feet bls. Finally, the contractor move the drill rig 365 feet west (to the west side of S-36) to construct BF-4; a dual zone (upper and middle) Floridan monitor well. **Table 1** lists construction details for each well.

Identifier	Aquifer	MP (feet msl) Elevation	Monitor Interval (feet bls)	Completion Method	Type Well
BF-1	Lower Floridan	12.2	2,080 to 2,280	Open-Hole	Monitor
BF-2	Middle Floridan	n/a	1,500 to 1,600	Open-Hole	Test Production
BF-3	Upper Floridan	n/a	1,000 to 1,200	Open-Hole	Test Production
BF-4S	Upper Floridan	13.4	1,000 to 1,200	Annular Zone	Monitor
BF-4M	Middle Floridan	12.9	1,500 to 1,600	Open-Hole	Monitor

Table 1. Well Construction Summary.

All wells were constructed using conventional closed-circulation mud rotary drilling through the surficial aquifer and the upper confining unit, and reverse-air drilling through the FAS. **Figure 3** illustrates the “as-built” construction of all wells. All installed casings were made of steel and conformed to API 5L or ASTM 53, Grade B standards. Casing centralizers were used for each string of steel casing. All cementing of casings conformed to State of Florida well drilling practices and to American Water Well Association (AWWA) standards for deep wells (AWWA, A100-66).

Well site supervision during drilling operations, casing installation and cementing, packer testing, water quality testing, and aquifer performance testing was conducted by the SFWMD. Other technical support services were provided by Schlumberger (geophysical logging), Consolidated Hydro Technologies (geophysical logging) and Baker Corporation (packer testing).

The information collected during well construction included lithology, water quality, static heads, transmissivity, storage coefficients, and vertical conductivity measurements of the various zones within the FAS. BF-1, BF-4S, and BF-4M were incorporated into a regional monitor well network to obtain temporal water levels.

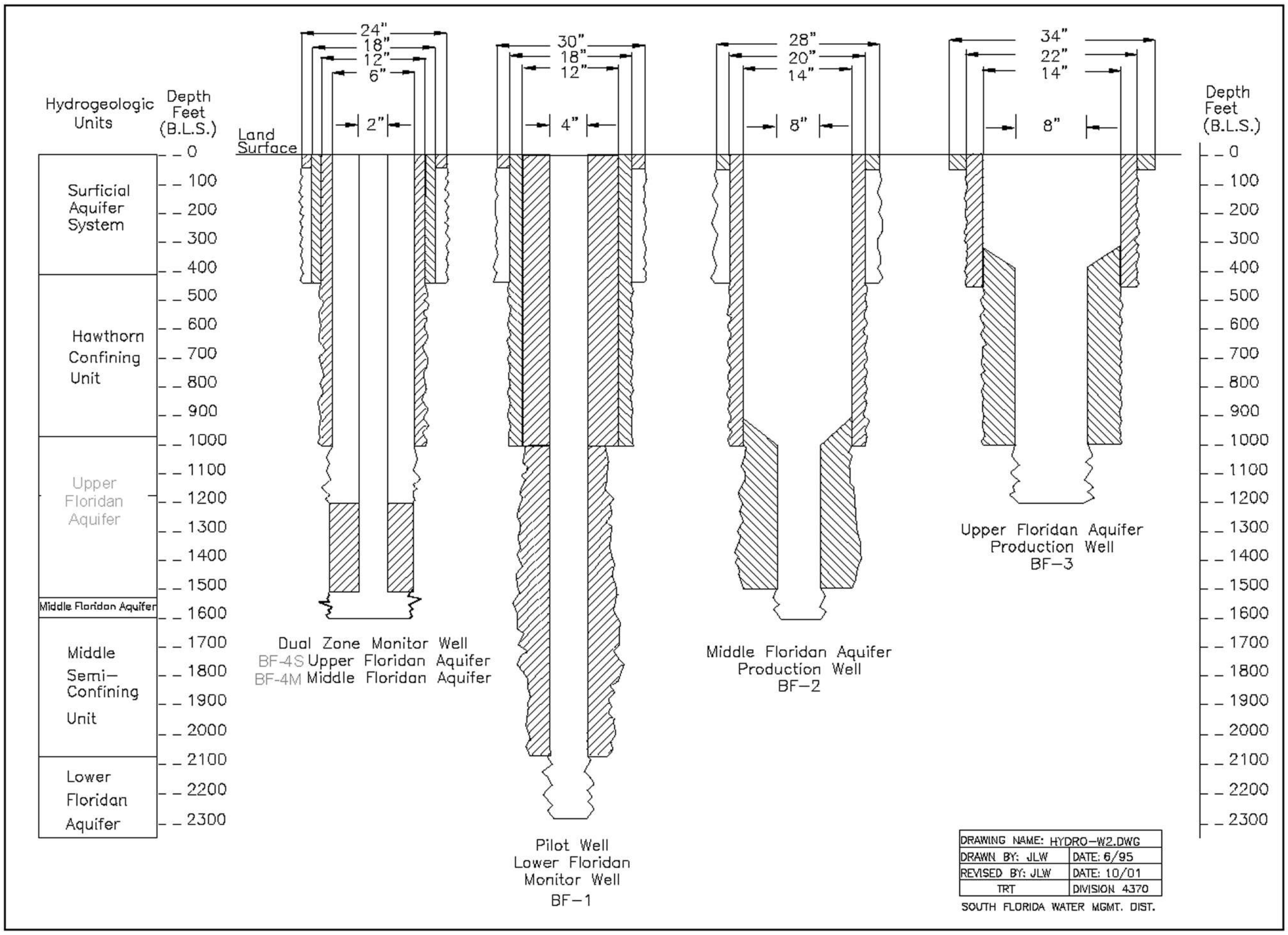


Figure 3. Well Construction Designs.

BF-1: Pilot Hole and Lower Floridan Aquifer Well

Construction of the exploratory FAS well (BF-1) was initiated December 1992 and completed in January 1993. This pilot hole, which was subsequently converted into a lower Floridan aquifer monitor well shown in **Figure 3,** was used to design the three remaining wells on the site. The well was drilled to a total depth of 2,280 feet bls. Geophysical logs, packer tests and lithologic cuttings were used to identify three production zones within the FAS. The reverse-air drilling method (with open circulation) was used to advance the borehole from 1,000 feet bls to the total depth of 2,280 feet bls. Cuttings were collected and described at 10-foot intervals or at any significant change in lithology within the descriptions provided in **Appendix A.** Water samples were collected every 30 feet (end of drill rod) through the Floridan aquifer. A summary of the sequence of drilling, testing and casing runs is provided in the following sections.

Photograph 1: BF-1 (Lower Floridan Aquifer Well)

Steel Pit Casing 30-inch Diameter

A pilot hole was advanced to a depth of 30 feet bls using a nominal 10-inch diameter bit during which time cuttings were collected. This hole was then enlarged (reamed) using a nominal 36-inch diameter bit. Nominal 30-inch diameter steel pit casing was then installed 0 to 30 feet bls. The annulus was pressure grouted to land surface using ASTM Type II neat cement. The purpose of the pit casing was to stabilize the site during drilling operations.

Surface Steel Casing 18-inch Diameter

A nominal 8-inch diameter drill bit then advanced using the mud rotary method through the base of the surficial aquifer system (SAS) and 80 feet into the upper confining unit to a depth of 440 feet bls. This hole was then reamed (enlarged) using a nominal 22-inch diameter bit and caliper logged to calculate the volume of cement/grouting required to fill the annular space. Then an 18-inch diameter steel casing was installed and the annulus pressure grouted to land surface using ASTM Type II neat cement. The purpose of this surface casing was to seal off the SAS and prevent inter-aquifer mixing during drilling operations.

Intermediate Casing 12-inch Diameter

Following installation of the 18-inch diameter surface casing, mud rotary drilling with the nominal 8-inch diameter bit resumed to a depth of 1,000 feet bls (base of the upper confining unit and the top of the upper Floridan aquifer). Upon reaching 1,000 feet bls, drill pipe was removed from the borehole and geophysical logging performed. The interval between 440 to 1,000 feet bls was then reamed using a nominal 18-inch bit. A caliper log was run to verify borehole diameter for annular cement volume calculations prior to installing the 12-inch diameter steel casing to 1,000 feet bls. Once installed, the lowermost 100 feet of the annular space around the casing was pressure grouted using ASTM Type II neat cement. The remaining 900 feet of annular space was filled in stages with ASTM Type II neat cement. There was a minimum of eight hours setting time between each stage lift and then each lift was tagged using a 2-inch diameter steel tremmie pipe to ensure that the cement had risen and set as expected.

Pilot Hole Drilling and Testing

At this point, the drilling method was switched from closed circulation mud rotary to the open-circulation, reverse-air method. All cuttings were air-lifted over a shale shaker screen. Discharge water and the finer-grained cuttings were settled using a three-stage mud tank discharge system.

Once the 12-inch diameter casing was set to 1,000 feet bls, the pilot hole was advanced using a nominal 11-inch diameter bit and the reverse-air drilling method. Cuttings were collected every 10-feet and water samples every 30-feet during reverse-air drilling. Specific conductivity, temperature, and chloride concentration were measured in each of the water samples, the results of which are summarized in **Table 2.** Reverse-air drilling continued to a total depth of 2,280 feet bls, 100 feet below the uppermost portion of the solutioned crystalline dolomites, which marked the top of the lower Floridan aquifer. The borehole was then air-developed until the produced water was clear and free of particulates. The drill tools were then removed from the well and Schlumberger performed geophysical logging to a depth of 2,280 feet bls. The "***Hydrogeologic Testing***" chapter in this document summarizes the results of those geophysical logs. Geophysical and lithologic logs along with the site geologist's observations during drilling were used to select six intervals in the open borehole to packer test. The packer test results are also summarized in the "***Hydrogeologic Testing***" chapter of this report.

Lower Floridan Aquifer 4-inch Steel Casing

Once packer tests were complete, the well was again air-developed until discharge water was clear. Then the bottom 200 feet of the hole was backfilled with pea-sized gravel up to 2,080 feet bls. Once backfilled, 2,080 feet of 4-inch diameter steel casing was installed into the well. The lowermost 200 feet of the annular space around the casing was then pressure grouted using ASTM Type II neat cement. The remaining 1,880 feet of annular space was filled in stages using cement lifts until the entire annular space was filled up to land surface. There was a minimum of 8 hours setting time between each stage lift after which time each lift was tagged using a 2-inch diameter steel tremie pipe to ensure that the cement had risen and set as expected. When cement had adequately set, a nominal 4-inch diameter bit drilled out the basal 200 feet of pea-sized gravel. With gravel removed, the well was then air-developed until discharge water was clear.

Wellhead Installation

After air-developing the well, the upper lip of the 4-inch steel casing was fitted with a gate valve. The area around the wellhead was finished off with a 4-foot by 4-foot by 6-inch reinforced concrete pad surrounded by a locked chain link fence. This well currently serves as a monitoring well for long-term water levels and water quality testing for the lower Floridan aquifer. Between 1993 and 1999, water levels were measured by hand each month. In 1999, an electronic data recorder was installed and programmed to measure and store water levels every 15 minutes. These data are transmitted back to District headquarters via telemetry. Water levels are further discussed under the "***Water Levels***" section in this report.

BF-2: Middle Floridan Aquifer Well

The construction of BF-2 took place between February 1993 and March 1993. This well would facilitate aquifer testing of a single productive horizon in the middle Floridan aquifer between 1,500 to 1,600 feet bls. **Photo 2** shows the final wellhead with pad and gated enclosure. Four concentric steel casings (28-, 20-, 14-, and 8-inch diameter) were used in the construction of this upper Floridan aquifer test-production well. RST installed a 28-inch diameter pit casing to 30 feet bls. Mud rotary drilling advanced a 28-inch diameter. A caliper log was run to calculate cement volumes for grouting operations. Once completed, a 20-inch diameter steel casing was installed to a depth of 440 feet bls. Once installed, the casing was pressure grouted using ASTM Type II neat cement until cement returns were seen at the surface.

Photo 2: BF-2 (Middle Floridan Aquifer Well).

After setting the 20-inch diameter casing, a nominal 20-inch diameter bit advanced the borehole to the top of the upper Floridan aquifer production interval at 1,000 feet bls using the mud rotary method. A caliper log was then run prior to installation of 14-inch diameter casing to 1,000 feet bls. Once the casing was installed, the annular space was filled with ASTM Type II neat cement using both the pressure and tremie grouting methods.

RST then cleared the borehole of mud and advanced the borehole with a nominal 14-inch diameter bit using the reverse-air method to a total depth of 1,600 feet bls. A final 8-inch diameter steel casing was then installed between 900 to 1,500 feet bls. The upper portion of the 8-inch diameter casing was not extended to land surface (but to 900 feet bls) in order to save on casing costs and so the final well design would accommodate a larger diameter, high capacity pump. The drill stem then lowered the 8-inch diameter casing into place between 1,500 to 900 feet bls. At this time, the annular space was pressure grouted using ASTM, Type II neat cement and then allowed to set for 8 hours. Once set, the drill stem was "backed off" or unscrewed from the top of the 8-inch casing and removed it from the well.

RST then drilled an additional 100 feet of hole using a nominal 8-inch diameter bit via the reverse-air method to a total depth of 1,600 feet bls. The well was then air-developed until return waters were clear and free of particulates. In March 1993, RST completed construction of the well by installing a permanent 14-inch diameter gate valve and a portable top head flange consisting of monitoring ports, a cement pad and a security fence.

BF-3: Upper Floridan Aquifer Well

Construction of BF-3 took place between April and May 1993. This well would facilitate aquifer testing of a single productive horizon in the upper Floridan aquifer between 1,000 to 1,200 feet bls. **Photo 3** shows the final wellhead, pad, and gated perimeter. Three concentric steel casings (22-, 14-, and 8-inch diameter) were used in the construction of this upper Floridan aquifer test-production well. RST installed a 22-inch diameter pit casing to 30 feet bls. The annulus was grouted to land surface using ASTM Type II neat cement. Mud rotary drilling advanced a nominal 22-inch diameter borehole into the upper confining unit to 440 feet bls. A caliper log was then run to calculate cement volumes for grouting. Once complete, 14-inch diameter steel casing was installed. The casing annulus was then pressure grouted using ASTM Type II neat from 440 feet bls to land surface.

Photograph 3: BF-3 (Upper Floridan Aquifer Well).

After setting the 14-inch diameter casing, a nominal 14-inch diameter bit advanced the borehole to the top of the upper-most Floridan aquifer production interval at 1,000 feet bls using the mud rotary method. A caliper log was then run prior to installation of 8-inch diameter casing between 300 to 1,000 feet bls. The upper portion of the 8-inch diameter casing was not extended to land surface in order to save on casing costs and so the final well design would accommodate a larger diameter, high capacity pump. The drill stem was used to lower the 8-inch diameter casing into place between 300 to 1,000 feet bls. ASTM Type II neat cement was then pressure grouted into the annular space behind the 8-inch casing from 1,000 to 300 feet bls after which time it was allowed to set for 8 hours. Once set, the drill stem was "backed off" or unscrewed from the top of the 8-inch diameter casing and removed from the well.

RST then drilled the remaining 200 feet of open hole using a nominal 8-inch diameter bit via the reverse-air method to a total depth of 1,200 feet bls. The well was then air-developed until discharge waters were clear and free of particulates. In May 1993, the Contractor completed construction of the well by installing a permanent 14-inch diameter gate valve and a portable top head flange with monitoring ports, a cement pad, and a security fence.

BF-4S and BF-4M: Upper and Middle (Dual-Zone) Floridan Aquifer Well

BF-4S and BF-4M were constructed between June to July 1993 and are shown in **Figure 3**. This dual-zone well would facilitate aquifer testing and monitoring of two productive horizons: the upper Floridan aquifer (BF-4S) between 1,000 to 1,200 bls and the middle Floridan aquifer (BF-4M) between 1,500 and 1,600 feet bls.

Four concentric steel casings (18-, 12-, 6- and 2-inch diameter) were used to construct BF-4. The Contractor installed an 18-inch diameter pit casing to 30 feet bls. The annulus was grouted to land surface using ASTM Type II neat cement. Mud rotary drilling then advanced an 18-inch diameter borehole to the 440 feet bls into the top of the upper confining unit. A caliper log was then run to calculate cement volumes for grouting operations. Once complete, a 12-inch diameter steel casing was installed to a depth of 440 feet bls. Once in, the casing was pressure grouted using ASTM Type II neat cement from 440 feet bls to land surface.

Photograph 4: BF-4S & BF-4M (Upper and Middle (Dual-Zone) Floridan Aquifer Well).

With a 12-inch diameter casing in place, a nominal 12-inch diameter bit advanced the borehole using the mud rotary method to the top of the upper Floridan aquifer production interval at 1,000 feet bls. A caliper log was run prior to installing a 6-inch diameter steel casing from 1,000 feet bls to land surface. ASTM Type II neat cement was then used to pressure and tremie grout the annular space behind the 6-inch casing from 1,000 feet bls to land surface.

With cement set, reverse-air drilling resumed using a 6-inch nominal bit to a depth of 1,600 feet bls. The drill bit was then extracted from the hole and a caliper log was run over the open-hole interval from 1,000 to 1,600 feet bls. The well was then air-developed thoroughly until the discharge water was clear and free of particulates. Then pea-sized gravel was installed using the 6-inch diameter casing to fill the bottom 100 feet of open-hole in the well. At this point, 2-inch diameter steel casing was lowered from land surface to 1,500 feet bls. ASTM Type II neat cement was then pressure grouted into the annular space behind the 2-inch casing and lifted from 1,500 to 1,200 feet bls. With 2-inch casing cemented in place, a 2-inch nominal bit was used to drill out the basal 100 feet of gravel. At this point there was open hole from 1,500 to 1,600 feet bls. The borehole was then air developed until all discharge water flowed clear for several hours. The 2-inch piezometer (BF-4M) was completed in the middle Floridan aquifer.

A second 2-inch diameter stainless steel piezometer was then hung from the top of the 6-inch diameter casing approximately 20 feet into the annulus between the 6-inch and 2-inch diameter casings previously installed. This annular piezometer was secured by filling the upper 10 feet of annular space with ASTM Type II neat cement. Now secure, a 2-inch piezometer (BF-4S) monitors the upper Floridan aquifer between 1,000' to 1,200' bls. The two, 2-inch inner diameter (ID), stainless steel piezometers were equipped with stainless steel ball valves. They facilitate monitoring of water levels and quality within the two aforementioned intervals.

SITE GEOLOGY

Strata encountered during drilling of the pilot-hole (BF-1) range in age from Holocene (most recent) to early Eocene (oldest). These lithostratigraphic units generally followed those recognized by Reese (1994), Fish (1988) and Reese and Cunningham (1999). The units, in descending order, are as follows: the Undifferentiated Pleistocene series, the Ochoppee Limestone (Pliocene), the Peace River and Arcadia Formations (Miocene), the Avon Park (middle Eocene) and the Oldsmar Formation of early Eocene age. **Figure 4** presents a hydrostratigraphic summary of the site, including depths, lithostratigraphic unit, geologic age, and lithology. The stratigraphic interpretation was derived primarily from formation samples and geophysical logs collected in pilot hole BF-1. Cuttings were described twice, once by the District site geologist, then again by the Florida Geologic Survey (FGS), both sets are provided in **Appendix A**. An electronic FGS version can be downloaded directly from FGS's Internet site at http://www.dep.state.fl.us/geology/gisdatamaps/litholog.htm.

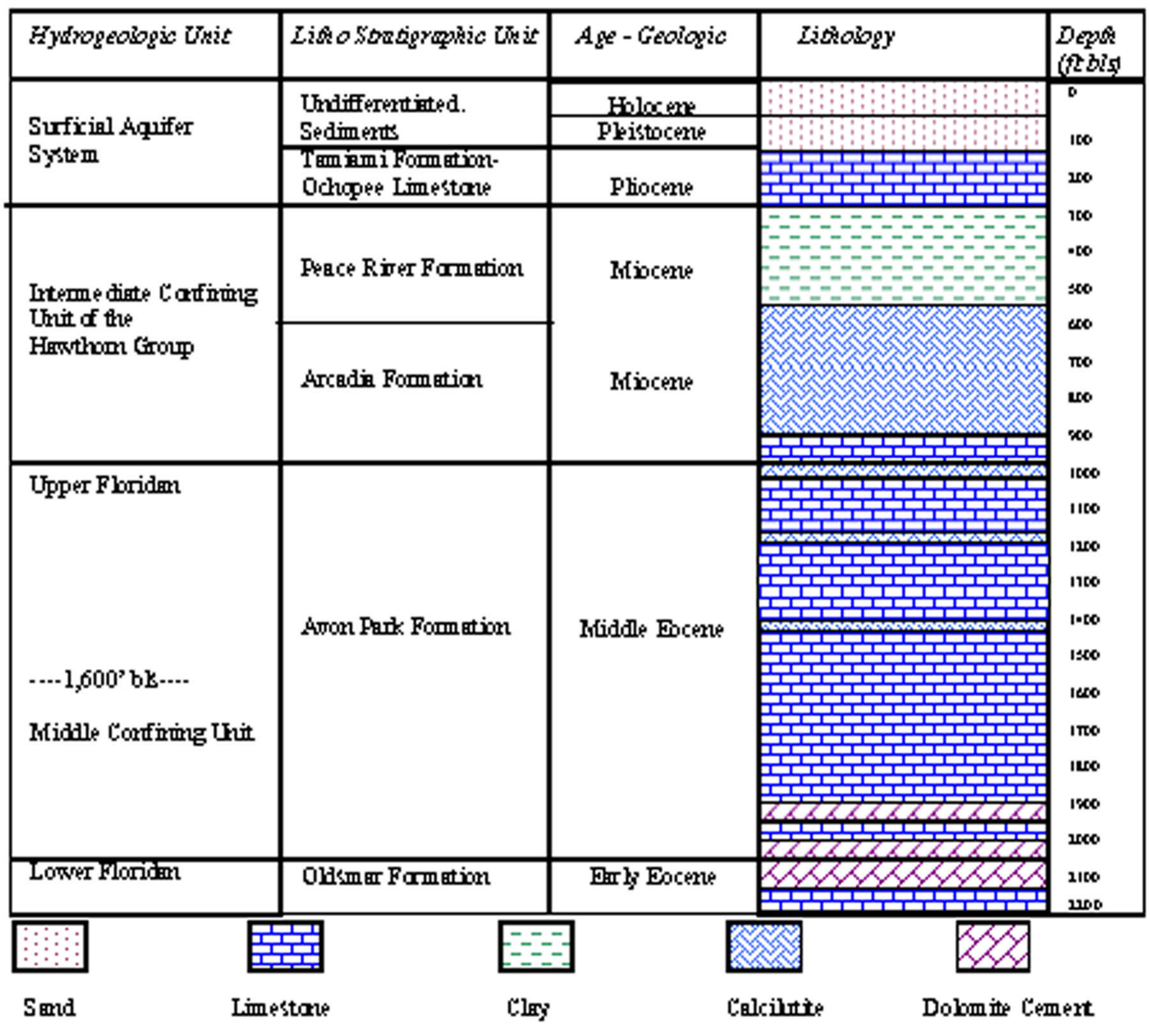


Figure 4. Hydrostratigraphic Summary Diagram.

Undifferentiated Pleistocene Series

From land surface to a depth of approximately 153 feet bls, the lithology consists primarily of white to tan and light orange oolitic limestone and sand of the undifferentiated Pleistocene series. This Pleistocene series consists of the Pamlico sand, Miami Limestone the Anastasia and the Key Largo Formations (Fish, 1988). At 153 feet bls, there was a noticeable change in lithology as the drill bit began to chatter and its penetration slowed. The lithology changed from a sandy, oolitic texture to a well indurated, harder limestone. From 153 to 361 feet bls, the lithology was primarily a mixed marine limestone, quartz sand and sandy limestone. These deposits were identified as equivalents of the Ochopee Limestone, member of the Tamiami Formation of Pliocene age.

Miocene

Hawthorn Group (Peace River and Arcadia Formations)

The Hawthorn Group, as defined by Scott (1988), is divided into two lithostratigraphic units. In descending order, they are the Peace River and Arcadia Formations. The Peace River Formation was defined as having a predominance of siliclastic material (Scott, 1988). At the C-13 site, the Peace River Formation is a light olive gray, clay rich quartz sand, sandstone, and mudstone found between 361 feet to 570 feet bls. The lower Arcadia Formation was distinguishable at this site as a yellowish gray, low permeability calcilutite between 570 and 975 feet bls. The base of the Arcadia Formation is marked by a significant increase of natural gamma emissions as evidenced on the gamma ray log in **Appendix B.**

Oligocene

Suwannee Limestone

The Suwannee Limestone (early Oligocene age) was not definitively identified at the site. It is generally described as white, tan, light brown, yellowish gray and green limestone (calcilutite and carbonaceous mud), with benthic forams, crinoid stems, and mollusks as well as shell and phosphatic sand. The FGS cutting descriptions **(Appendix A)** make no mention of an occurrence of a Suwannee Limestone. This notable absence is probably based on an interpretation made using Scott's (1988) definition. Scott places the base of the Hawthorn Group at the base of the last occurrence of a sandy, variably phosphatic carbonate. Reese (review comments, March 2003) also places the phosphatic zone in the Hawthorn Group.

Upper Eocene

Ocala Limestone

The Ocala Limestone is not present in most of Miami-Dade and Broward counties (Miller, 1986) and was not present at the C-13 site. However, this geologic unit is present in western Broward, northernmost Monroe, northwestern Dade and Collier counties and reaches thickness of 150 to 200 feet (Reese, 1994).

Middle Eocene

Avon Park Formation

The top of the Avon Park Formation was identified at 975 feet bls. The first occurrence of the benthic foraminifera *Dictyoconus sp*. was found at 1,034 feet bls. This along with faster drilling rates, color change from grey to pale orange, and abundant marine fossils provided evidence of an unconformity. The top of the rocks of Eocene age may represent an unconformity in the study area. Generally this top can be readily determined using gamma ray geophysical logs and is closely associated with the top of the Floridan aquifer (Reese, 1994).

The Avon Park Formation is approximately 1,100 to 1,200 feet thick in the study area and is composed predominantly of micritic or chalky to fine-grained limestone with low permeability. This geologic unit is characterized as having relatively low natural radioactivity, generally less than 20 to 30 American Petroleum Institute (API) standard units on the gamma ray log. Total porosity can be as high as 50 percent at or near the top of the formation and gradually decreases with depth (Reese, 1994). The base of the Avon Park was identified in BF-1 as 2,074 feet bls.

Lower Eocene

Oldsmar Formation

The top of the Oldsmar Formation is often difficult to identify because of a lack of diagnostic microfossils. It is predominantly comprised of micritic limestone in Broward County (Reese, 1994). The top of the Oldsmar in south Florida is often identified based on the presence of a hard, crystalline dolostone unit that generally occurs below a depth of 2,000 feet bls in southeast Florida. This unit is identified on geophysical logs by increased gamma ray counts and resistivity values characteristic of dolomite. If these criteria are used, the Oldsmar could be identified at 2,074 feet bls at the site corresponding to the occurrence of a well indurated, crystalline dolostone.

SITE HYDROGEOLOGY

Two major aquifer systems underlie most of southeast Florida, the SAS and FAS. The latter is the primary focus of this report and the field testing program. These aquifer systems are composed of multiple, discrete aquifers separated by low permeability "confining" units. **Figure 4** shows a generalized lithologic and hydrogeologic section underlying the C-13 site. **Figure 5** shows the location of the C-13 site relative to nearby offset well sites in the area as well as the cross-sectional line A-A'. The third dimensional subsurface display of that cross sectional line is illustrated in **Figure 6** which shows the top of the FAS to be flat with the Plantation Injection well and the Ft. Lauderdale Fiveash ASR well.

Surficial Aquifer System

The SAS extends from land surface to a depth of 361 feet bls at the site. It comprises all materials from the water table to the top of the intermediate confining unit. These materials are primarily sandstone, sand, shell, clayey sand and cavity-riddled limestone ranging in age from Miocene to Holocene (Fish, 1988). The top of the system may be considered to be land surface because virtually all of Broward County formerly was seasonally flooded (Fish, 1988). Sediments of the SAS have a wide range of permeability, and locally may be divided into one or more aquifers separated by less permeable or semi-confining units. The Biscayne aquifer is the best known and contains the most permeable materials of the SAS. Another permeable unit, the grey limestone aquifer, is approximately 100 feet thick in western Broward County but thins to the east and ultimately pinches out near the Florida Turnpike. It is not present at the site. Since the focus of this exploratory drilling was the Floridan aquifer, the individual permeable portions of the SAS were not identified or tested.

Intermediate Confining Unit

The intermediate confining unit varies in thickness from about 600 to 1,050 feet in Broward and Miami Dade counties (Reese, 1994). It was identified between 361 to 975 feet bls, and is 614 feet thick at the site. The geologic units in the intermediate confining unit generally include the Hawthorn Group and Suwannee Limestone, but locally the uppermost sediments of the unit can be part of the Miocene-Pliocene Tamiami Formation (Fish and Stewart, 1991). The lithology of the intermediate confining unit is variable and includes clay, silt, fine sand, sandstone, siltstone, and limestone.

Floridan Aquifer System

The FAS is defined as a vertically continuous sequence of permeable carbonate rocks of Tertiary age that are hydraulically connected in varying degrees (Miller, 1986). It ranges in thickness from 2,500 to 3,000 feet in southeastern Florida. Its top varies from 900 to more than 1,100 feet bls in Broward county (Miller, 1986, pls. 26 and 27). The top was identified in the pilot hole as 975 feet bls based on the breakout from a transition from clays to limestones and the first occurrence of flow into the borehole while drilling. The portion of the FAS drilled, tested, and described at the C-13 site includes permeable units of the Avon Park and the Oldsmar Formations.

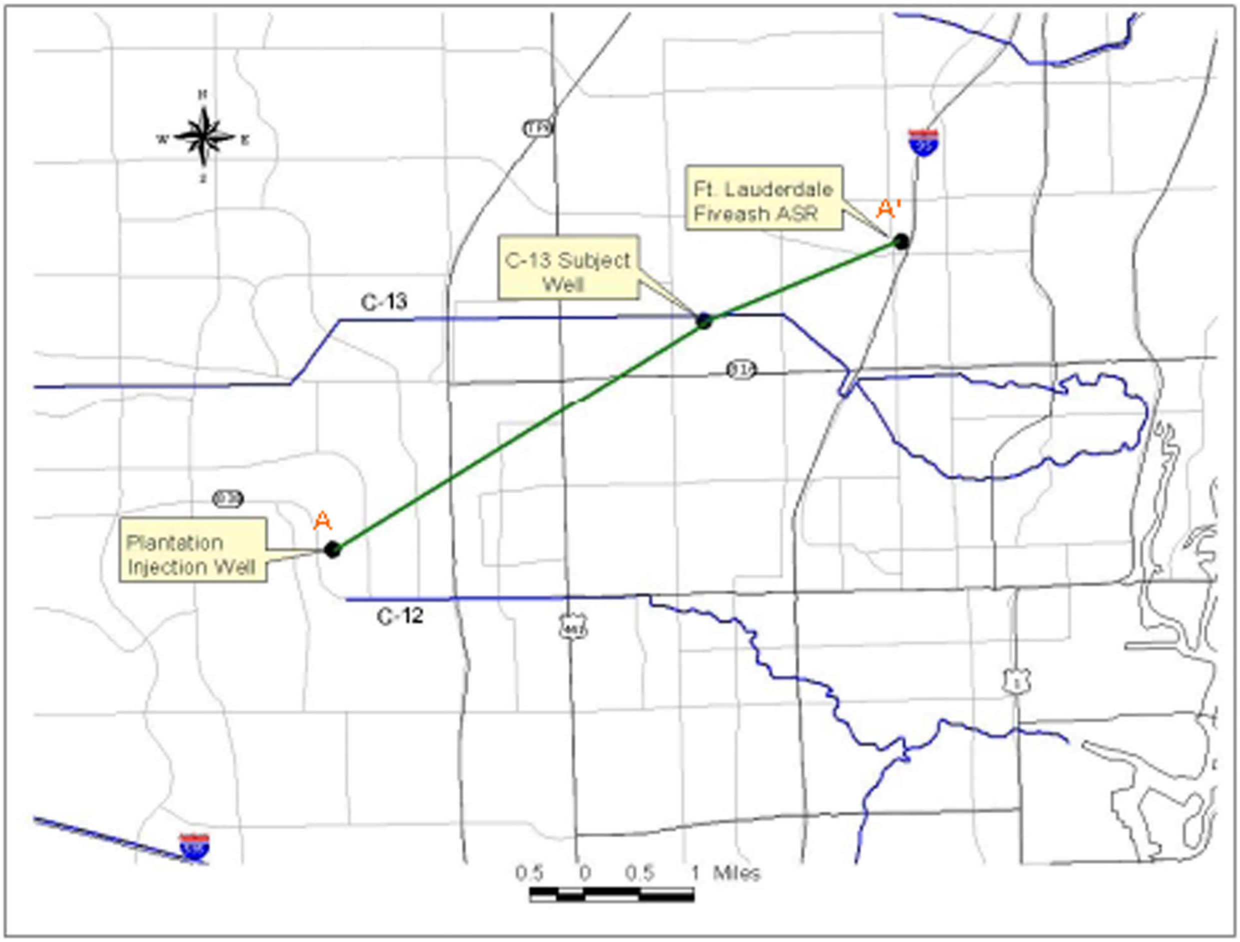


Figure 5. Location of C-13 Study Area Relative to Other Nearby Wells and Cross Sectional Line A-A'.

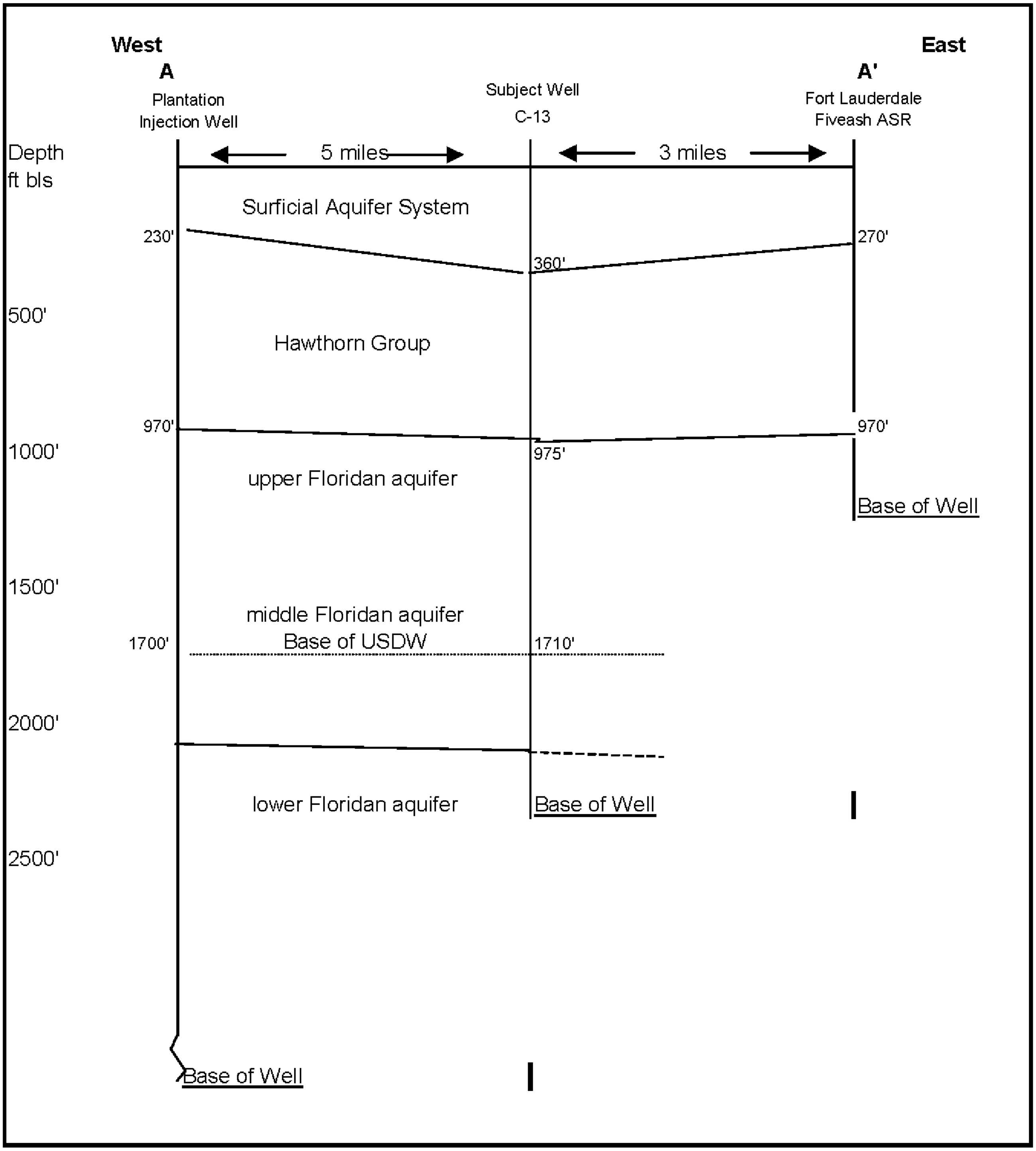


Figure 6. Hydrogeologic Cross Section.

The FAS can be divided into three hydrogeologic units: the upper Floridan aquifer, the middle semi-confining unit, and the lower Floridan aquifer (Reese, 1994). Discrete flow zones at the site were identified using information garnered from drilling characteristics, cuttings descriptions, geophysical logs (primarily flow meter, temperature, caliper, resistivity, and downhole video logs), packer tests, aquifer performance tests, and water quality variations with depth. This combined information painted a comprehensive picture of the system described below.

Upper Floridan Aquifer

The top of the Floridan aquifer system was defined as 975 feet bls, however the first flow zone penetrated at the site was identified in the upper Floridan aquifer between 1,000 to 1,034 feet bls. The flow zone is within the unconformity between the base of the Suwannee Limestone and the top of the Avon Park Formation. This interval was tested with a packer assembly (Packer Test No. 6) at a rate of 65 gpm resulting in a specific capacity of 18.57 gallons per minute per foot (gpm/ft). Other evidence observed for a flow zone included:

- flow log showed evidence of flow;
- a small temperature increase (0.1 degree F) on the temperature log;
- a sudden increase in borehole size (1,024-1,026 feet bls) on the caliper log;
- drill bit penetration increased notably; and;
- artesian formation water flowed from the well directly after drilling out from under casing set at 1,000 feet bls.

The predominant flow zone found in the pilot hole within the upper Floridan aquifer was between 1,146 to 1,150 feet bls (depth from geophysical logs). This thin interval is 112 feet below the top of the Avon Park Formation in the section. It was not packer tested, but was included in the open-hole portion of the well pumped in Aquifer Performance Test Number 2 (APT-2). Analyses of time-drawdown data from APT-2 resulted in a transmissivity of 120,000 gallons per day/foot (gpd/ft) across the open-hole interval between 1,000 to 1,200 feet bls. This thin flow zone appears to be a solution feature as evidenced by the following pieces of information:

- flow log showed evidence of flow;
- temperature of water rose abruptly from 65 to 66.5 degrees Fahrenheit;
- caliper probe opened significantly when pulled across it;
- density pad lost contact with the borehole wall; and,
- drill rate increased notably through it.

A second (middle) flow zone was identified between 1,500 and 1,600 feet bls at the base of the upper Floridan aquifer. Flow was not particularly strong across this interval and was not detected on geophysical logs or by drilling characteristics. Here, permeability was identified in on a packer test where the interval was pumped at a flow rate of 64 gpm. This confirmed water enters the borehole across this interval. Specific capacity was calculated to be 13.4 gpm/ft. Transmissivity was also derived from APT-1 as 70,260 gallons per day per foot (gpd/ft). Water quality in this interval, sampled during APT-1 and APT-2, was less saline than in the upper Floridan aquifer (chloride concentration of 2,800 milligrams per liter (mg/L) versus 4,218 mg/L, respectively). A video log across this interval provided no visible evidence of a large solution feature or of flow. It appears to originate from intergranular porosity rather than point-specific sources seen in solution features. The base of the upper Floridan aquifer was identified 1,600 feet bls at the site based on the flow logs that indicate flow stopped entering the borehole below this point.

Middle Semi-Confining Unit

The middle semi-confining unit was identified between 1,600 and approximately 2,074 feet bls at this site. This interval is composed primarily of low permeability packstones and grainstones. No other flow zones were identified within the semi-confining unit. The base of the Underground Source of Drinking Water (USDW) (10,000 mg/L total dissolved solids (TDS)) was found 1,710 feet bls as seen on the dual-induction log (drop from 5 to 3 Ohm-meters). This was collaborated by packer tests 3 and 4 (see ***Hydrogeologic Testing*** section) where TDS concentrations were measured as 31,300 and 8,920 mg/l, respectively on either side of the boundary.

Lower Floridan Aquifer

Reese (1994) interpreted the occurrence of a crystalline dolomite as a marker for the top of the lower Floridan aquifer, which is placed in the Oldsmar Formation. This dolomite and the top of the lower Floridan aquifer were identified at 2,074 feet bls in the pilot hole. Between 2,074 and 2,170 feet bls, the bit penetrated alternating layers of crystalline dolomite and limestone (packstone). The dolomite was hard and had little signs of permeability until 2,124 feet bls, when dolomitic cavities and associated flow zones were encountered as evidenced by:

- the bit dropped suddenly through at least two, 2-foot high cavities;
- the caliper log indicted a sudden and large increase in borehole size between 2,124-2,126 feet bls, 2,136-2,141 feet bls and between 2,146-2,147 feet bls;
- conductivity of recovered reverse-air water quality samples increased from 4,640 to 8,250 mmhos somewhere between 2,121-2,148 feet bls; and,
- a packer test pumped at a rate of 110 gpm between 2,120 and 2,142 feet bls resulted in a specific capacity of 550 gal/min/ft, the highest tested in the entire pilot hole.

Below 2,170 feet bls was limestone (packstone) which persisted to the total depth of the well (2,280 feet bls). No additional flow zones were detected below the base of the dolomite. Although the well terminated at 2,280 feet bls, the Oldsmar Formation probably extends down another 900 to 1,000 feet (Reese, 1994). At the base of Oldsmar Formation is the Boulder Zone (local name), which is predominantly dolomite and contains massively bedded cavernous or fractured dolomite of high permeability and dense, recrystallized dolomite of low permeability. The Boulder Zone was not penetrated at this site.

HYDROGEOLOGIC TESTING

Information was collected during the drilling and testing program to determine the lithologic, hydraulic, and water quality characteristics of the FAS at the site. The formation testing program at the site included lithologic examination, observations while drilling, geophysical surveys, packer pumping tests, APTs, water quality sampling, and water level measurements. Raw data is contained in the appendices of this report.

Formation Fluid Sampling

Water quality samples were collected while reverse-air drilling BF-1 through the FAS at approximately 30-foot intervals from 1,008 feet bls to the total depth of the pilot hole at 2,280 feet bls. A Hydrolab multi-parameter probe measured field parameters on each sample, which included temperature, specific conductance, and pH. A field titration method (Hach® Kit) measured chloride concentrations. District staff collected filtered and unfiltered water directly from the discharge point into a Teflon bailer. Samples were then preserved and immediately placed on ice in a closed container and transported to the District's water quality laboratory. The samples were then analyzed for major ions using Environmental Protection Agency (EPA) and/or Standard Method procedures (SFWMD, Comprehensive Quality Assurance Plan, 1995).

A graph of chloride concentrations and specific conductivity as a function of depth is presented in **Figure 7**. Results of water quality analyses are listed in **Table 2**. Chloride concentrations remained relatively consistent (approximately 4,000 mg/L) from 1,008 to 1,813 feet bls. At a depth of approximately 1,845 feet bls, chloride concentration increased to approximately 6,100 mg/l, then jumped to 9,500 mg/l at 1,970 feet bls.

The chloride concentration then decreased noticeably from 2,090 feet bls (4,640 mg/L) only to increase again to 17,250 mg/l at approximately 2,154 feet bls, which is where it remained to the last sample collected at 2,218 feet bls.

Geophysical Logging

Geophysical logging was conducted in the pilot holes after each stage of drilling and prior to casing installations. Schlumberger was contracted to run the primary set of geophysical logs across the entire open-hole section of the FAS in BF-1. These were run directly after reverse-air drilling in a water filled borehole and included: caliper, natural gamma ray, spontaneous potential, dual induction, sonic, compensated neutron and density, flow meter, temperature, fluid resistivity and video logs. The resulting logs provide a continuous record of the physical properties of the subsurface formations and their contained fluids. These logs assisted in the interpretation of lithology, provided estimates of permeability, porosity, bulk density, and resistivity of the formations. In addition, the extent of confinement of discreet intervals and identification of permeable zones can be discerned from the logs. Geophysical log traces for several of the logging runs were digitized and are included as **Appendix B**. Original geophysical logs are archived at the District while the digital traces are available through the District's on-line corporate database (DBHydro) Browser at the following Internet address:

http://sonar.sfwmd.gov:7777/pls/dbhydro_pro_plsql/show_dbkey_info.main_page.

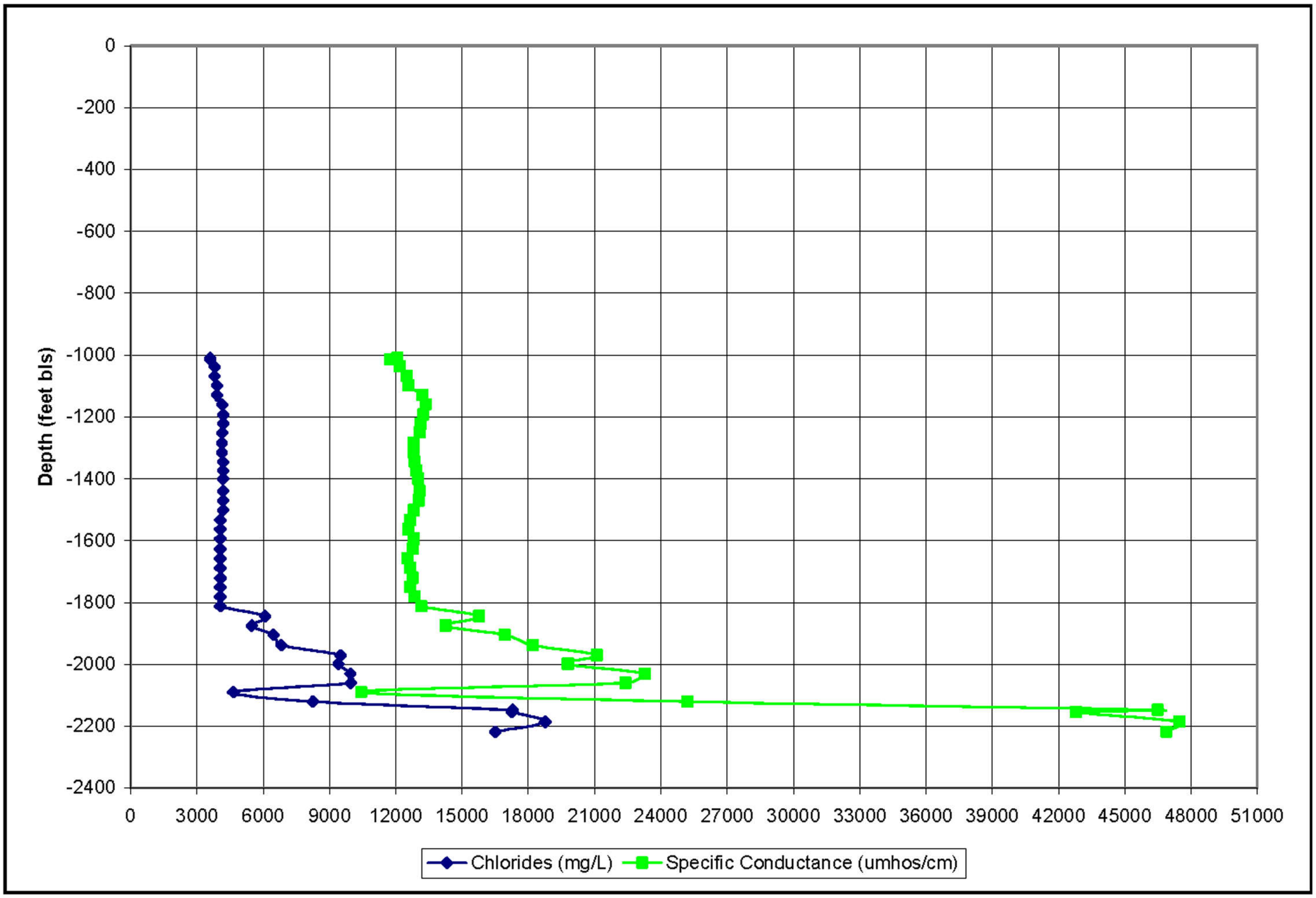


Figure 7. Reverse-Air Water Quality Profile BF-1.

Depth Kelly Down (feet bls)	Chloride* (mg/L)	Conductivity (umhos/cm)	Temp (C)	pH	Other: Color, etc.
1008	**3600**	4760	24.4	7.4	Lt. Brown
1010	**3600**	12090	23	7.6	
1014	3600	11760	24.6	7.3	Before Drilling Started
1038	3799	12190	22.4	7.5	Brown Stained
1068	**3800**	12500	22	7.6	Brown Stained
1100	3900	12580	21.9	7.7	
1130	3900	13210	21.6	7.7	
1160	4150	13340	21.2	8.1	Slightly Milky
1193	4200	13250	21.2	7.8	Last sample of the day
1221	**4200**	13130	21.2	8	Cloudy Sample
1251	4140	13080	21.8	8.3	
1285	**4130**	12820	21.9	7.5	
1315	**4130**	12790	22	8	Water Milky
1345	4180	12860	21.7	7.9	Water Milky
1375	**4180**	12930	21.5	7.7	
1401	**4180**	13020	21.4	7.9	
1440	**4180**	13080	21.3	7.7	
1471	**4180**	13030	21	8.6	Very Cloudy
1502	**4180**	12830	21.7	6.8	
1534	4050	12680	21.6	6.8	
1564	**4050**	12570	21.3	7.5	
1594	4050	12830	21.4	7.7	
1627	**4050**	12760	20.9	7.8	
1659	**4050**	12550	20.4	7.9	
1689	**4050**	12670	22.1	7.8	Sat for 30 min
1721	**4050**	12770	21.4	7.7	
1751	**4050**	12650	21.6	7.9	
1782	**4050**	12870	21.2	8	
1813	**4050**	13150	21.2	7.8	
1845	6092	15770	21.7	7.4	
1875	5480	14250	21.6	7.1	
1905	6470	16940	21.4	7.7	
1938	6815	18210	20.8	7.4	
1970	9500	21100	20.5	7.4	
1999	**9400**	19800	20.1	7.7	
2031	9950	23300	20.6	7.2	
2061	**9960**	22400	20.6	7.4	
2090	4640	10440	21.2	7.7	
2121	8250	25200	20.3	7.8	
2148	**17280**	46500	21.1	7.9	
2154	17250	42800	21.7	8.3	
2186	18780	47500	19.8	8.2	
2218	16500	46900	20.2	8.2	

Table 2. Reverse-Air Drilling Field Water Quality Results BF-1.

Packer Tests

Methods

The following methods were used to conduct individual packer tests in well BF-1 and are standard operating procedures at the District.

- Using a 4.5" inner diameter (O.D.) drill stem, lowered packer assembly to the interval selected for testing based on geophysical and lithologic log data.
- Set and inflated packers and opened the ports between the packers to the test interval.
- Installed a submersible pump from a depth of 60 feet to 120 feet below the drill floor with a pumping capacity of 200 gallons per minute (gpm).
- Installed two 50-psig pressure transducers inside the drill pipe and one 10-psig transducer in the annulus.
- Purged a minimum of three drill-stem volumes.
- Monitored pressure transducer readings and field water quality parameters (e.g., temperature, specific conductance, and pH) from the purged formation water until stable. The water quality parameters and transducer readings were used to determine the quality of isolation of the packed-off interval.
- Performed constant rate drawdown test once the interval was effectively isolated and recorded water levels.
- Collected formation water samples for laboratory water quality analyses per SFWMD's Quality Assurance, Quality Control (QA/QC) protocol.
- Reconfigured recorders to recovery in logarithmic time.
- Turned off pump.
- Recorded recovery data until water levels returned to static conditions.

A hydrolab multi-parameter probe measured field parameters including temperature, specific conductance, and pH on each sample. Chloride concentrations were determined using a field titration method (Hach® Kit).

Results - Packer Tests

Packer pumping tests were conducted during drilling operations to isolate six selected FAS zones in pilot well BF-1. The purpose of these tests was to gain water quality and production capacity data on discrete intervals and to establish the depth of the 10,000 mg/L TDS interface to determine the base of the USDW. **Table 3** lists static water levels, total pumping time, and hydraulic results for each of the packer tests. **Table 4** lists the water quality parameters determined from analyses of samples taken during packer tests. **Appendix C** provides tables summarizing field results for each of the six packer tests. Friction was calculated using a 4.5-inch inside diameter (I.D.) steel drill pipe.

Packer Test Number	Interval (ft. bls)	Thickness (feet)	Pumping Rate (gpm)	Actual/*Corrected Drawdown (feet)	Static Water Level (feet above land surface)	Total Pumping Time (min)	Corrected Specific Capacity (gal/min/ft)
1	2120-2142	22	110	14.2 / 0.2	-1.6	200	550.00
2	2078-2088	10	4.5	64 / 64.0	-0.4	1046	0.07
3	1726-1772	46	74	22 / 13.4	3.0	145	5.52
4	1644-1690	46	63	33 / 27.2	29.0	200	2.31
5	1494-1540	46	64	10 / 4.7	29.0	200	13.42
6	1000-1031	31	65	7 / 3.5	31.0	210	18.57

*Note: Drawdowns corrected for friction losses within drill pipe

Table 3. Packer Pumping Test - Hydraulic Results.

Packer Test Number	Interval (ft. bls)	Na Mg/L	K Mg/L	Ca Mg/L	Mg Mg/L	Cl Mg/L	SO4 Mg/L	Alka MEQ/L	SiO2 Mg/L	T Diss Fe Mg/L	TDS Mg/L	Sp. Cond umhos/cm
1	2120-2142	9,880	437	578	1,286	17,103	2,659	348	5.5	.97	33,900	41,400
2	2078-2088	10,600	390	700	1,200	18,972	2,487	312	4.9	2.29	34,300	47,200
3	1726-1772	9,460	340	620	1,062	17,268	2,307	6	5.8	.95	31,300	43,900
4	1644-1690	2,640	92	380	214	4,695	750	193	11.8	.65	8,920	13,950
5	1494-1540	2,460	86	380	190	4,167	844	201	11.6	.38	8,340	11,330
6	1000-1031	2,340	98	220	318	3,915	882	3	12.7	.82	7,730	10,860

Table 4. Packer Pumping Tests - Water Quality Summary.

Base of Underground Source of Drinking Water (USDW)

The base of the USDW is defined by the Florida Department of Environmental Protection as the depth to which water containing a TDS concentration of less than 10,000 mg/L extends. The concentration of TDS in water sampled between 1,726 feet and 1,772 feet bls during Packer Test No. 3 was 31,300 mg/L, while Packer Test No. 4, sampled between 1,644 and 1,690 feet bls, had water with TDS concentration of 8,920 mg/L. This places the USDW between these two intervals or at approximately 1,710 feet bls.

Packer Test No.1 (2,120 to 2,142 feet bls):

The purpose of this packer test was to determine the hydraulic properties and water quality characteristics of a productive interval within the lower Floridan aquifer. It was conducted on February 17, 1993, when a dual packer assembly isolated an interval between 2,120 and 2,142 feet bls in pilot well BF-1. This interval was pumped for 200 minutes at an average discharge rate of 110 gpm. The static water level prior to pumping was measured as –1.6 feet relative to ground level. The maximum measured drawdown while pumping was approximately 18 feet, approximately 14 feet of that is estimated friction loss. A friction loss corrected specific capacity of 550 gpm/ft was estimated. **Figure 8** is a semi-log plot of the time versus residual drawdown (t/t') data collected during the recovery phase of the test. At the end of the recovery phase, the static water level rose to the initial height of –1.6 feet (ground level). Shortly before the end of the drawdown phase, a composite water sample was taken from the discharge point and field water quality parameters measured. Chlorides and TDS concentrations in water sampled from the zone were 17,103 mg/L and 33,900 mg/L, respectively.

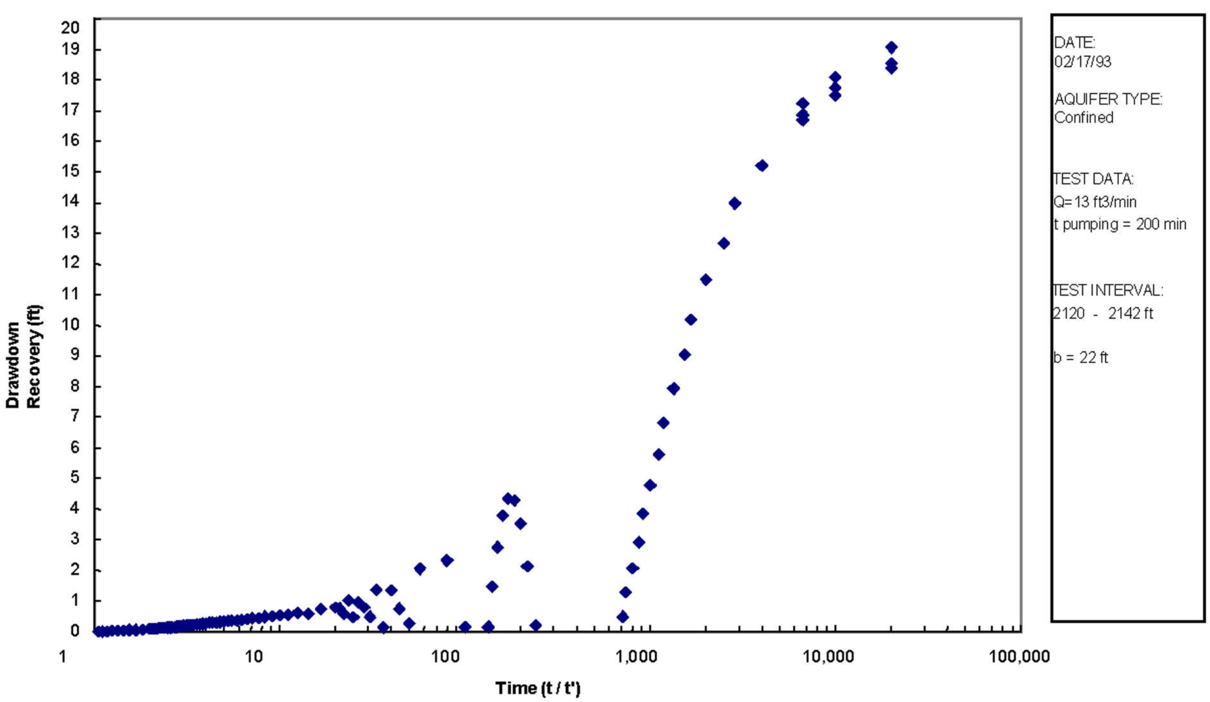


Figure 8: Packer Test 1, Recovery Data (2,120-2,142 feet bls).

Packer Test No. 2 (2,078 – 2,088 feet bls):

Packer Test No. 2 was conducted on February 19, 1993 and isolated an interval between 2,078 and 2,088 feet bls in BF-1. The test was conducted by lowering a dual-packer assembly to isolate an interval between 2,078 and 2,088 feet bls in pilot well BF-1. This interval was pumped for 1,046 minutes at an average discharge rate of 4.5 gpm. The static water level prior to pumping was measured as –0.4 feet relative to ground level. The maximum measured drawdown while pumping was approximately 64 feet, zero feet of that was friction loss because of the very low flow rate. A friction loss corrected specific capacity of 0.07 gpm/ft was calculated. **Figure 9** is a semi-log plot of the time versus residual drawdown data collected during the recovery phase of the test. Chloride and TDS concentrations in water sampled from the zone were 18,972 mg/L and 34,300 mg/L, respectively.

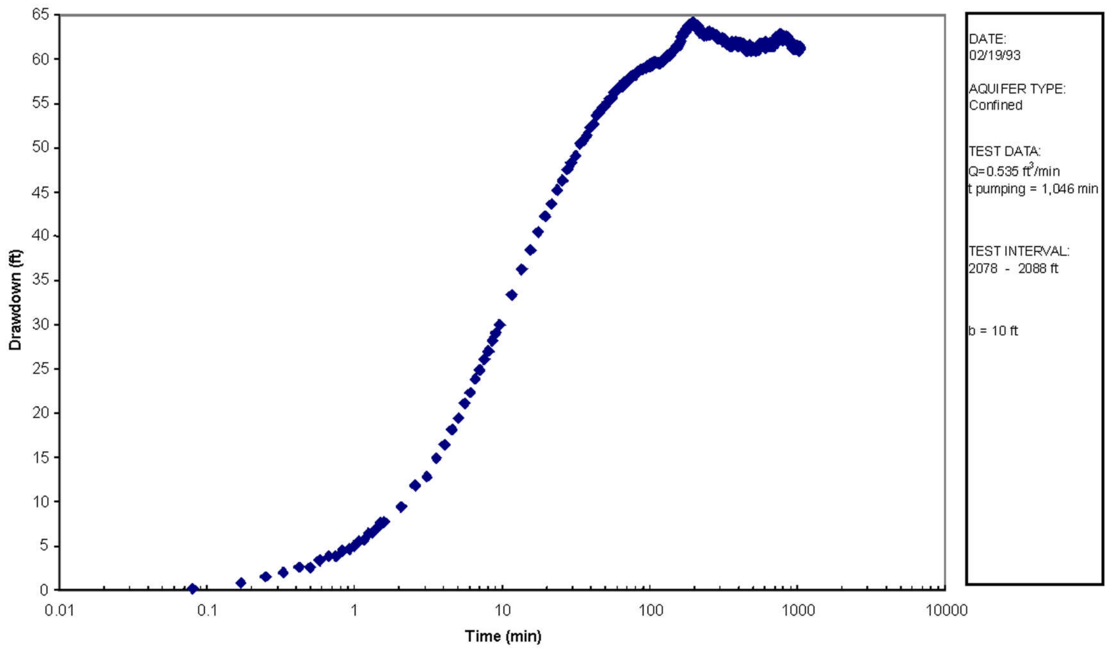


Figure 9. Packer Test Number 2, Recovery Data (2,078-2,088 feet bls).

Packer Test No. 3 (1,726 – 1,772 feet bls):

Packer Test No. 3 was conducted on February 23, 1993 and isolated the interval between 1,726 and 1,772 feet bls in well BF-1. The test was conducted by pumping this interval for 145 minutes at a rate of 74 gpm. The static water level was measured at 3.0 feet above ground level at the site. The maximum drawdown was 22 feet and the friction loss corrected specific capacity calculated as 5.52 gpm/ft. **Figure 10** is a semi-log plot of the time versus residual drawdown data collected during the recovery phase of the test. Chlorides and TDS concentrations in water sampled from the zone were 17,268 mg/L and 31,300 mg/L, respectively.

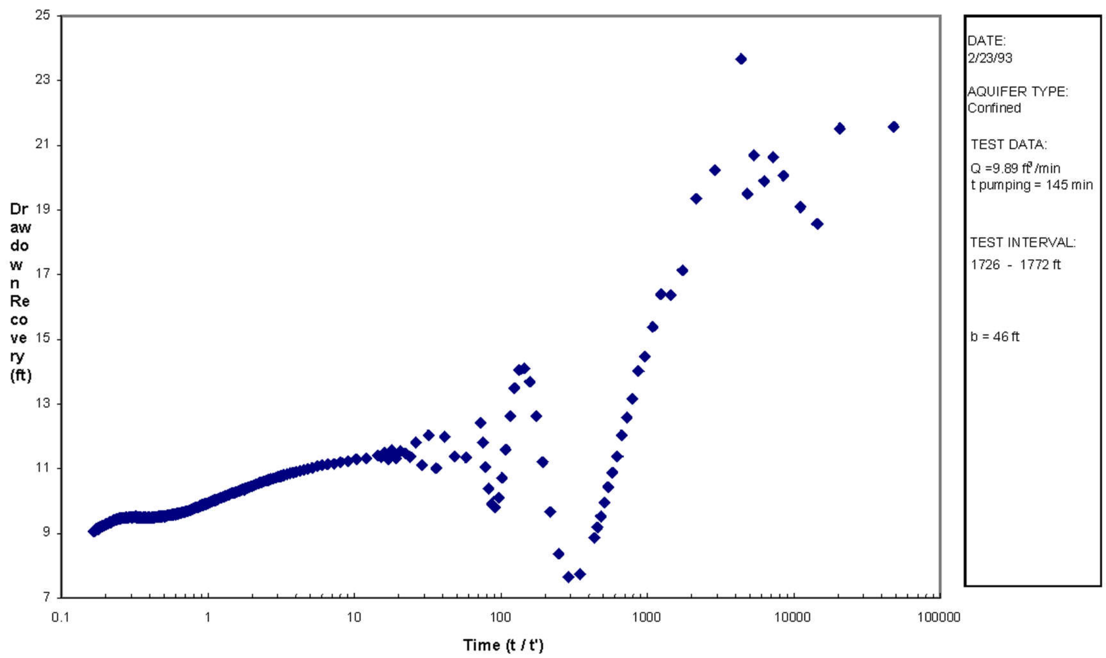
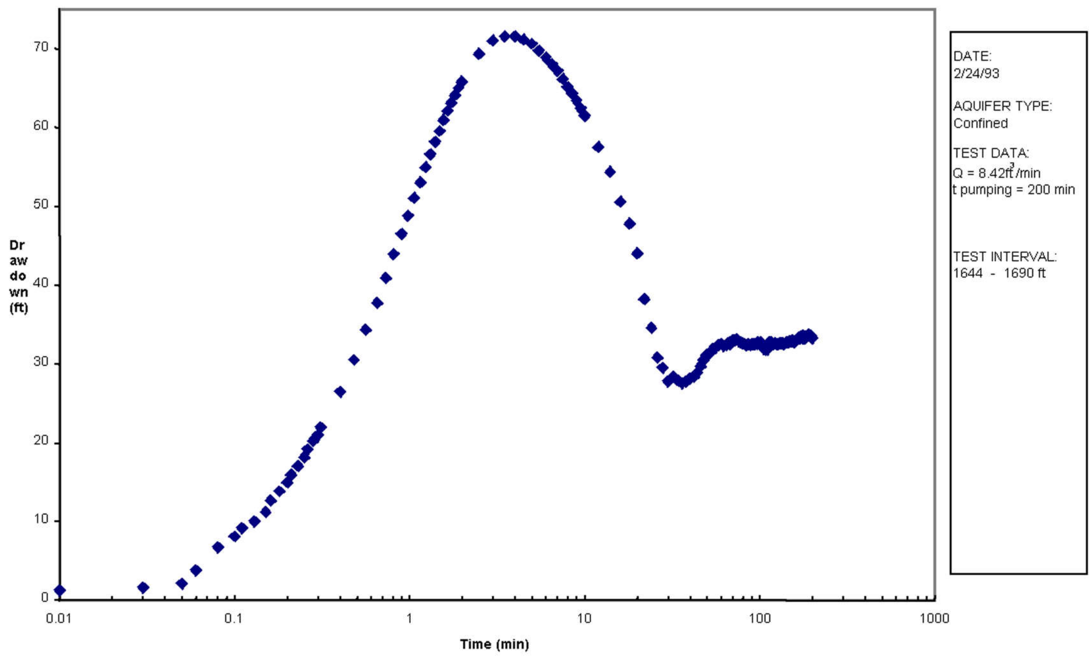


Figure 10. Packer Test Number 3, Recovery Data (1,726-1,772 feet bls).

Packer Test No. 4 (1,644 – 1,690 feet bls):

Packer Test No. 4 conducted on February 24, 1993, and isolated an interval between 1,644 and 1,690 feet bls in well BF-1 using a dual-packer assembly. The test was conducted by pumping this interval for 200 minutes at an average rate of 63 gpm. Static water level measured 29.0 feet above ground level. The maximum measured drawdown was 33 feet and the friction loss corrected specific capacity calculated as 2.31 gpm/ft. **Figure 11** is a semi-log plot of the time versus residual drawdown data collected during the recovery phase of the test. Chlorides and TDS concentrations in water sampled from the zone were 4,695 mg/L and 8,920 mg/L,



respectively.

Figure 11. Packer Test Number 4, Recovery Data (1,644-1,690 feet bls).

Packer Test No. 5 (1,494 – 1,540 feet bls):

Packer Test No. 5 conducted on February 26, 1993 and isolated an interval between 1,494 and 1,540 feet bls in BF-1. The test was conducted by pumping this interval for 200 minutes at an average rate of 64 gpm. The static water level was measured as 29 feet above ground level. The maximum measured drawdown was 10 feet and the friction loss corrected specific capacity calculated as 13.42 gpm/ft using a friction loss of 5.23 feet. **Figure 12** is a semi-log plot of the time versus residual data collected during the recovery phase of the test. Chlorides and TDS concentrations in water sampled from the zone were 4,167 mg/L and 8,340 mg/L, respectively.

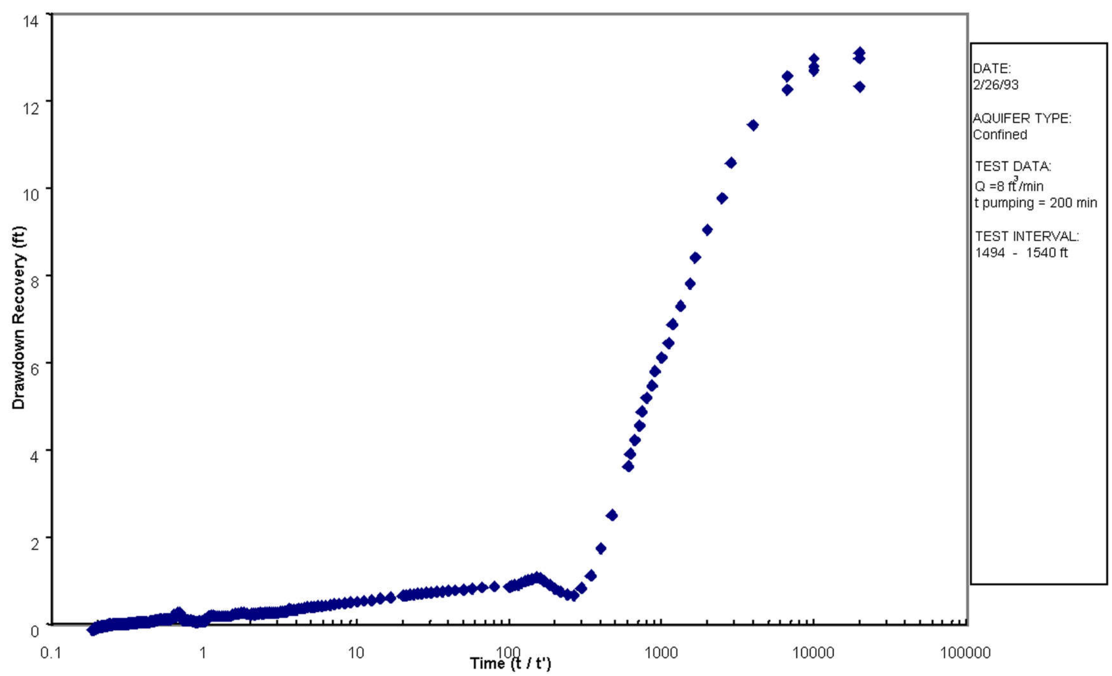


Figure 12. Packer Test Number 5, Recovery Data (1,494-1,540 feet bls).

Packer Test No. 6 (1,000 – 1,031 feet bls):

Packer Test No. 6 was conducted on March 31, 1993 and isolated an interval between 1,000 and 1,031 feet bls in BF-1 with a dual packer assembly. The test was conducted by pumping this interval for 210 minutes at an average rate of 65 gpm. The static water level was measured as 31 feet above ground level. The maximum measured drawdown was 7 feet and the friction loss corrected specific capacity calculated as 18.57 gpm/ft. **Figure 13** is a semi-log plot of the time versus residual drawdown data collected during the recovery phase of the test. Chlorides and TDS concentrations in water sampled from the zone were 3,915 mg/L and 7,730 mg/L, respectively.

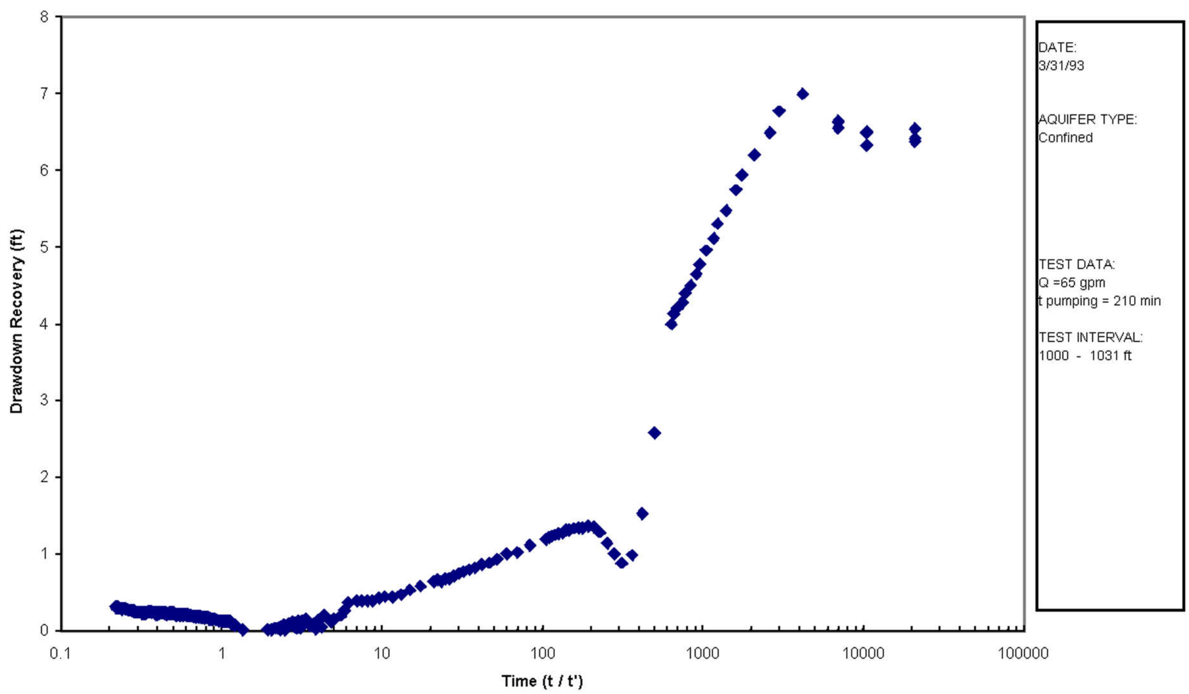


Figure 13. Packer Test Number 6, Recovery Data (1,000-1,031 feet bls).

Aquifer Performance Testing

Two APTs were conducted at the site to evaluate subsurface hydraulics and water quality characteristics within the FAS. The results of these tests, including interval tested, static water level, maximum drawdown, discharge rate (Q), transmissivity, storage coefficient, and analytical methods are listed in **Table 5**. It should be noted that both APTs were attempted directly after well construction was completed in 1993, but only APT-1 was successful at that time. District staff finally returned to the site in June 1997 to test the upper-most Floridan flow zone (APT-2) again, this time successfully. A 10-inch diameter submersible pump was installed in the test-production well with the pumping bowl set approximately 100 feet bls. A 12-inch circular orifice weir with a 6-inch orifice plate was used to measure the discharge rate during pumping, verified by an in-line flowmeter. Pressure transducers were installed on/in the test-production well and all monitor wells at the site and were connected to a datalogger during the drawdown recovery periods of the aquifer performance tests. Further details on both tests are summarized below.

APT	Interval (ft bls)	Transmissivity (gal/day/ft)	Storativity	Leakance (Gal/ day Per ft^3)	Q avg (gpm)	Maximum Drawdown (feet)	Cl (mg/L)	TDS (mg/L)
1	1,500-1,600	70,259	5.89E-05	2.22 E-03	1,070	9.5	2,800	5,000
2	1,000-1,200	119,600	3.70E-04	1.52 E-03	990	6.1	4,218	8,360

Table 5. Aquifer Performance Test Results

APT-1: Middle Floridan aquifer:

On October 17, 1993, APT-1 was conducted in the open-hole interval between 1,500 to 1,600 feet bls. This APT consisted of pumping well BF-2 for 72 hours at a relatively constant discharge rate of 1,070 gpm, while monitoring water levels in all other wells. The static water level in BF-2 was 32.9 feet above ground level prior to the initiation of pumping. Aquifer parameters were computed from time-drawdown data collected during pumping and recovery from monitoring well BF-4M completed in the same zone as BF-2. BF-4M is located 433 feet from the pumping well. The Hantush (1960) leaky solution provided the "best fit" to the time-drawdown data. **Figure 14** is a log/log plot of drawdown versus time for the tested interval and the Hantush (1960) solution.

Figure 15 illustrates water level responses in the upper and lower FAS flow zones (BF-4S and BF-1, respectively) in response to pumping the middle Floridan aquifer (BF-4M). Water levels in the upper flow zone (BF-4S) decreased approximately 0.25 feet after 4,000 minutes of pumping while those in the lower flow zone had no discernable decline over the same period. The changing levels in this lower Floridan zone is attributed to tidal rather than pumping responses based on findings from the second APT (discussed later). These results indicated that the interval between the upper and middle zones was "leaky-confining" whereas the interval between the middle and lower zones exhibited more substantial confinement.

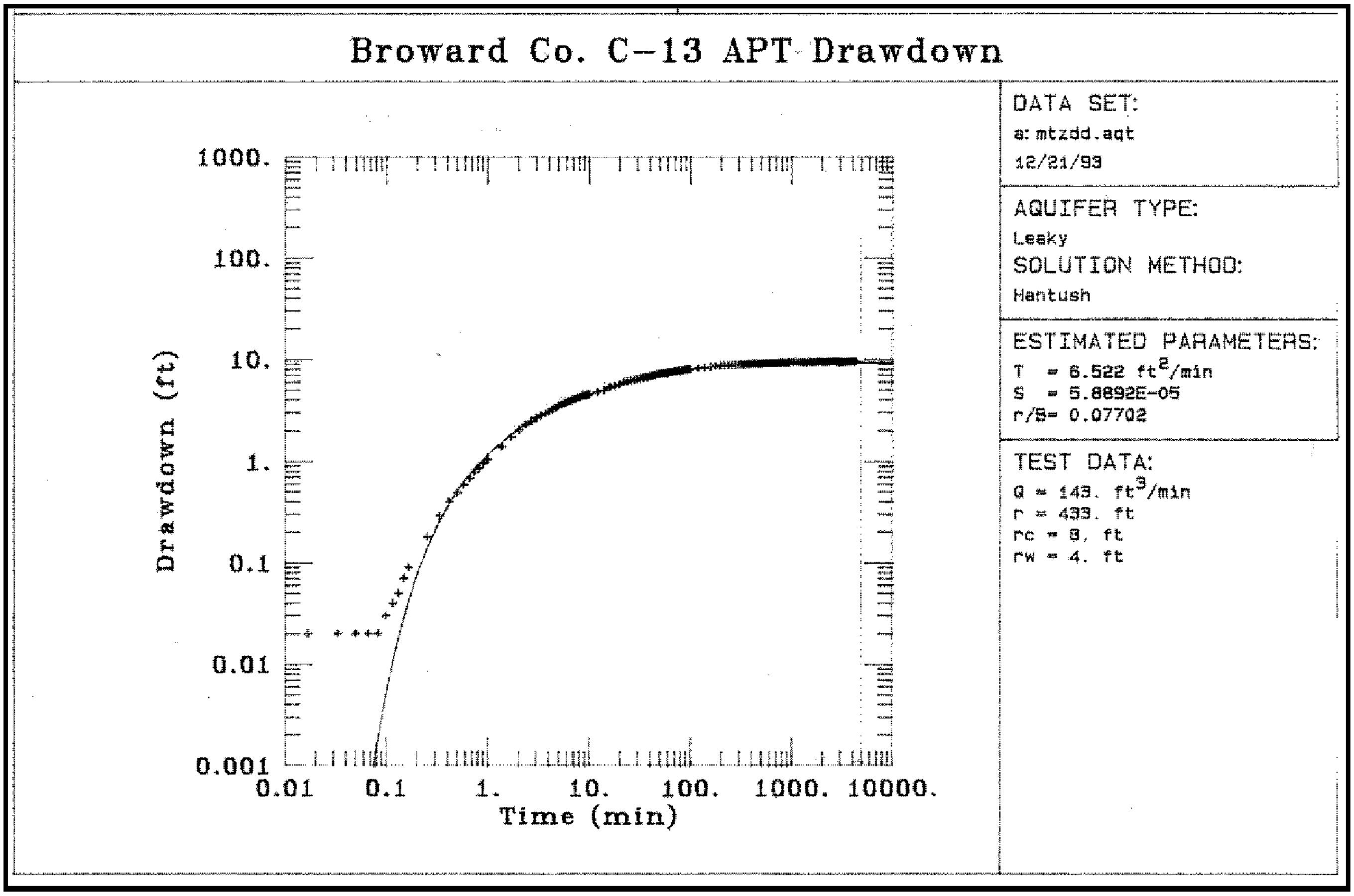


Figure 14. APT-1, Log/Log Plot of Drawdown vs. Time for Monitor Well BF-4M (Middle Flow Zone).

Before pumping stopped, District staff reconfigured the dataloggers to record the recovery data. The submersible pump was then shut off and water levels allowed to recover to static condition. The recovery phase of the APT continued for 72 hours, ending October 21, 1993. The recovery time-drawdown data and Theis straight-line recovery analysis are shown in **Figure 16.** Analyses of the recovery data from this APT produced similar hydraulic results when compared to the drawdown analysis. Electronic copies of the original drawdown and recovery data for the APT are archived and available for review at the District's headquarters in West Palm Beach, Florida.

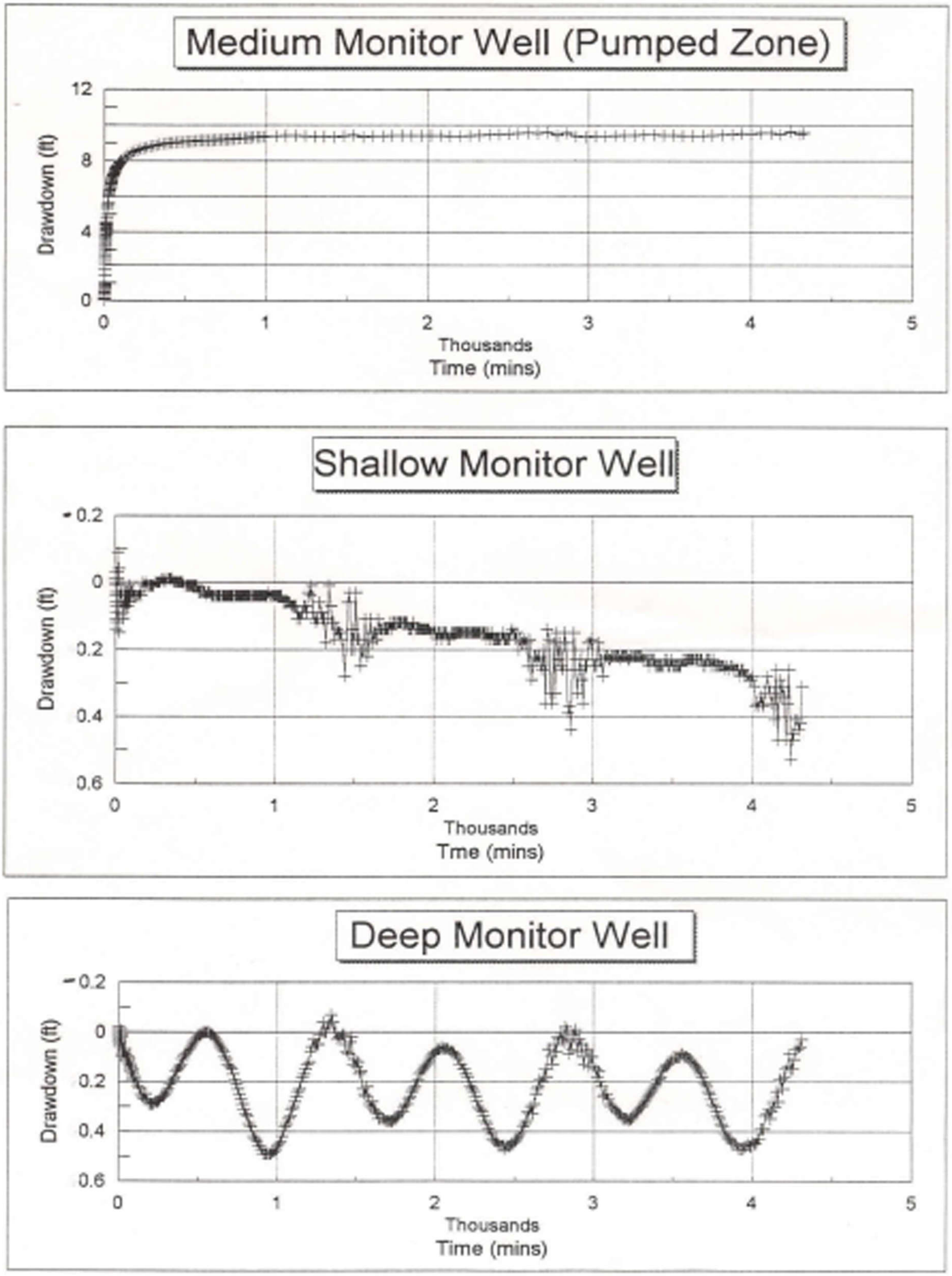


Figure 15. Water Level Responses in all Monitor Wells to Pumping BF-2 (Middle Flow Zone).

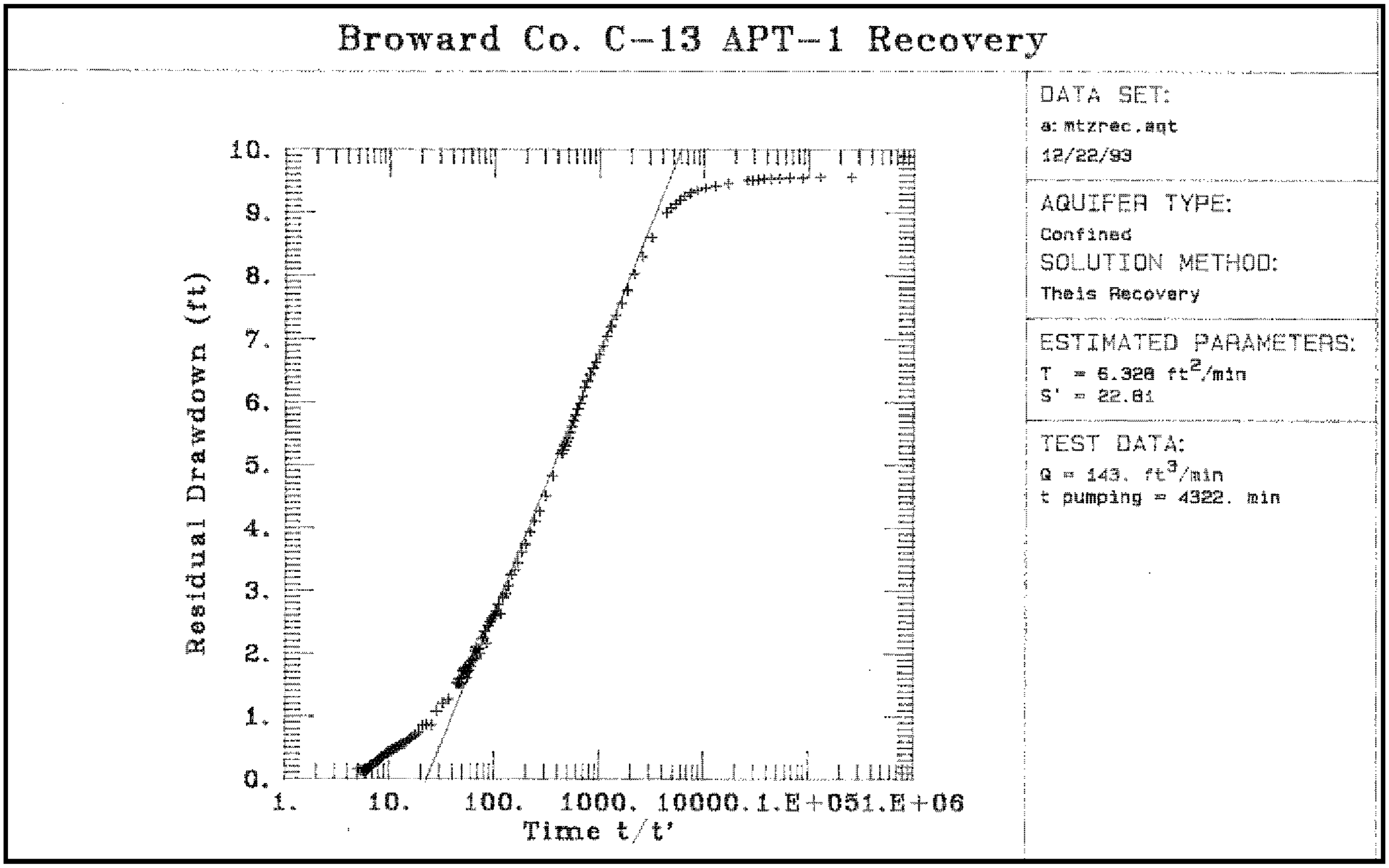


Figure 16. **APT-1, Semi-Log Plot of Time Drawdown During Recovery Phase (Middle Flow Zone).**

APT-1 Water Quality Results

BF-2 was sampled every eight hours during the pumping phase of APT-1 to determine if any temporal changes in water quality resulted from pumping the aquifer. Those samples were submitted to the District's Laboratory for cation/anion analyses. **Table 6** summarizes the analytical results. No significant water quality trends/changes over time can be seen in this data.

Minutes After Pumping	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Alka/50 meq/L	Cl- mg/L	SO4 mg/L	mg/LACO CACO	SIO2 mg/L	TDS mg/L	Sp Cond umhos/cm	TEMP °C	pH units
0	156.0	215.7	1540.0	58.7	2.3	2798.9	545.3	1280.0	10.2	4930.0	9070.0	21.8	7.2
8	159.0	215.1	1502.0	54.3	2.3	2766.0	541.6	1280.0	10.3	5430.0	9510.0	20.7	7.6
14	159.5	217.4	1480.0	55.2	2.3	2783.3	546.7	1290.0	10.3	5520.0	9360.0	21.2	7.4
20	159.5	219.4	1448.0	55.4	2.4	2737.2	103.7	1300.0	10.3	5420.0	8980.0	21.8	7.3
25	160.5	212.7	1432.0	53.5	2.4	2800.0	108.1	1280.0	10.4	5280.0	8860.0	21.9	7.3
31	162.5	195.2	1520.0	52.6	2.3	2861.7	499.4	1210.0	10.3	4990.0	9030.0	21.1	7.5
37	160.0	195.0	1550.0	51.4	2.3	2863.7	504.5	1200.0	10.3	4950.0	9070.0	21.1	7.2
46	163.5	194.1	1560.0	51.4		2873.4	498.5	1210.0	10.3	5270.0	8990.0	21.9	7.2
55	163.0	193.0	1445.0	51.0	2.3	2828.2	491.6	1200.0	10.2	4920.0	8240.0	20.9	7.7
61	163.5	197.5	1555.0	52.3	2.3	2827.0	489.2	1220.0	10.3	5310.0	8340.0	20.9	7.4
67	151.0	195.9	1540.0	51.1	2.3	2833.5	491.9	1180.0	10.3	5190.0	8790.0	21.6	7.5
70	162.5	193.9	1540.0	52.1	2.3	2836.5	490.8	1200.0	10.5	5380.0	8490.0	21.6	7.5

Table 6. Water Quality Data from APT-1 (1,500' to 1,600' bls).

APT-2: Upper Floridan- Attempt 1

An APT-2 was performed in BF-3 and failed on October 25, 1993. It pumped the uppermost flow zone in the FAS open hole completed between 1,000 to 1,200 feet bls. The submersible pump failed 10 hours into the test, probably due to the large suspended load of silts and sands being lifted through the pump. Drawdown data collected during the first 10 hours of the test were not suitable for analysis because the pumping rate during that time was not constant. The following is an account of the failed APT documented by the on-site geologist. It is presented here to provide additional insight into the character of this upper-most flow zone.

The APT began at 14:22 hours on October 25, 1993. During the first 30 minutes of the pump test, the production well was pumping at 1,100 gpm, with slightly milky water being discharged. Then at 16:40 hours (2.2 hours into the test) the production well started to produce very turbid water containing considerable amounts of phosphatic silt and fine quartz sand. Once this happened, the pumping rate dropped to approximately 980 gpm. The well continued to discharge turbid water until approximately 19:00 hours at which time the submersible pump stopped due to a circuit overload causing the breaker to be tripped. The pump could not be restarted. The source of the fine phosphatic sand may have been due to sinkhole development or karstification in the Avon Park Formation and the infilling of the sinkhole with overlying sediment of the Suwannee Formation.

APT-2: Upper Floridan- Attempt 2:

The District attempted a second APT in BF-3 on June 9, 1997. This time it was completed successfully over the open hole interval from 1,000 to 1,200 feet bls. The well was developed prior to the APT for several hours until discharge water was clear. This APT consisted of pumping well BF-3 for 70 hours at a constant discharge rate of 990 gpm while monitoring water levels in all other wells. Aquifer parameters were computed from time-drawdown data collected in monitoring well BF-4S in the same zone as BF-3 and located 365 feet from the pumping well. Various analytical solutions were applied to the drawdown data to determine the hydraulic properties of the aquifer and aquitard(s) at this site. The Hantush Jacob (1955) leaky solution provided the "best fit" to the time-drawdown data. **Figure 17** is a log/log plot of drawdown versus time for the pumped interval and the Hantush Jacob solution.

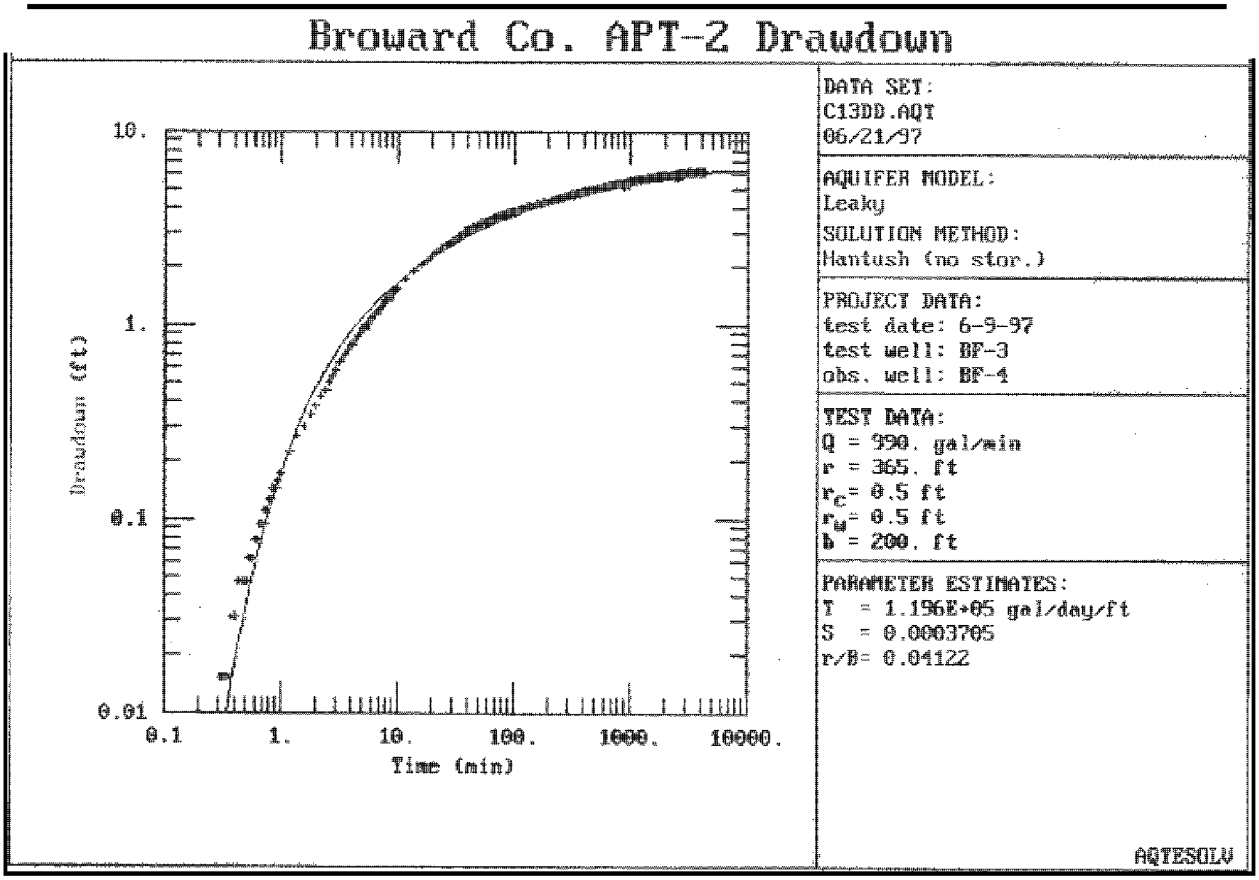


Figure 17. APT-2, Log/log Plot of Drawdown vs. Time for Monitor Well BF-4S (Upper Flow Zone).

A plot of water levels measured in each of the three flow zones of the Floridan (Deep: BF-1, Shallow: BF-4S, and Middle: BF-4M) in response to pumping the upper flow zone at a rate of 990 gpm is given in **Figure 18**. This figure shows the interaction of water levels between zones. Water levels in the upper flow zone (BF-4S) decreased approximately 6.0 feet, those in the middle flow zone (BF-4M) decreased approximately 0.25 feet while the lower zone increased approximately 0.4 feet over the same period after 4,000 minutes of pumping. This increase in the lower flow zone is attributed to tidal rather than pumping responses.

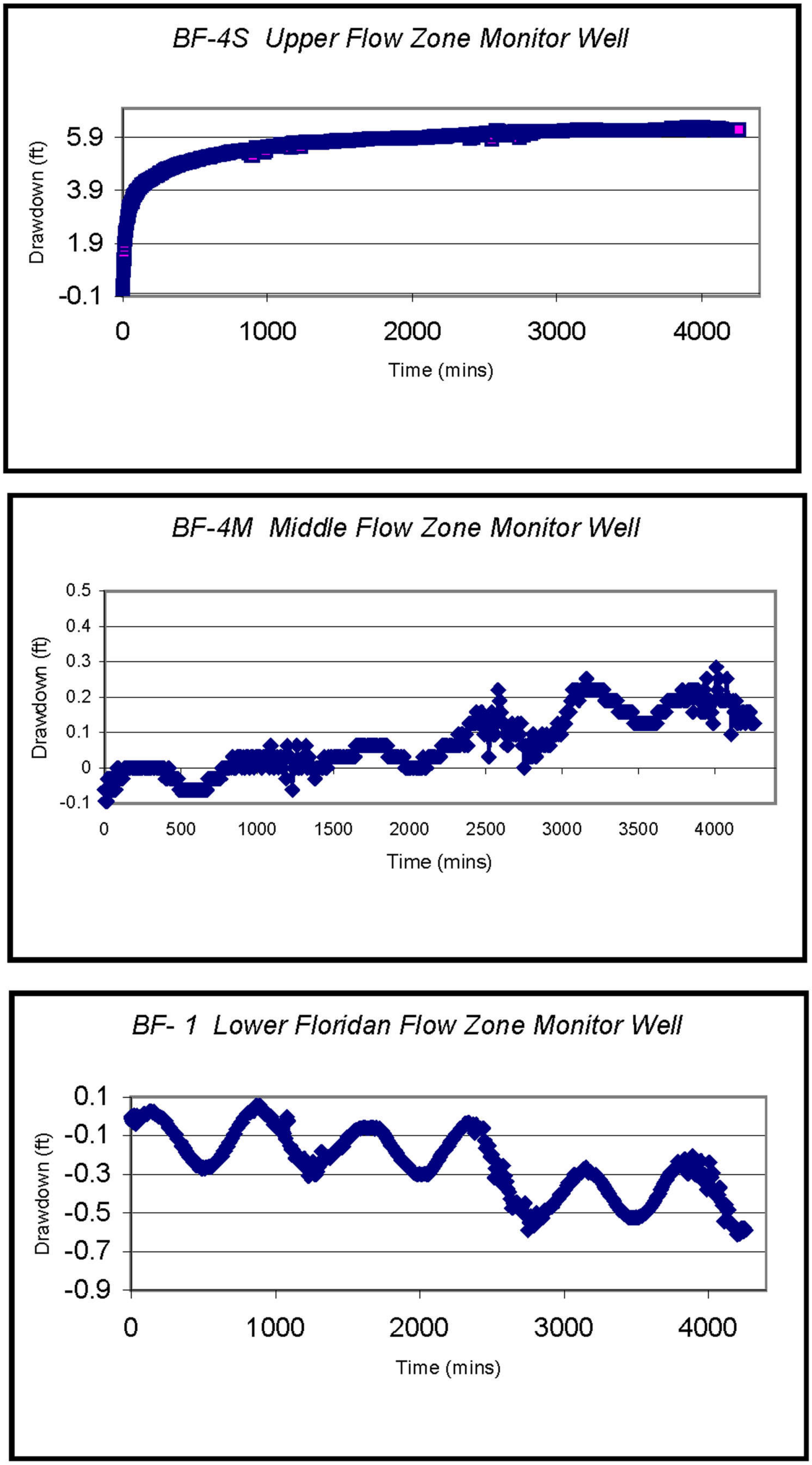


Figure 18. **Water Level Responses in All Monitor Wells to Pumping BF-3 (Upper Flow Zone).**

Before pumping stopped, District staff reconfigured the dataloggers to record the recovery data. The Contractor stopped the submersible pump and water levels recovered to static conditions. The recovery phase of the APT continued for 72 hours, ending June 12, 1997. The recovery time-drawdown data and Cooper-Jacob (1946) analysis are shown in **Figure 19.** Analyses of the recovery data from this APT produced similar hydraulic results as compared to the drawdown analysis. The analysis of the recovery data yielded a transmissivity of 159,600 gpd/ft. These results compare favorably with the analysis of the equivalent zones at the City of Ft. Lauderdale Five-ash water treatment plant ASR system (located 3 miles east), with a transmissivity value of 146,000 gpd/ft (Montgomery Watson, 1998). Electronic copies of the original drawdown and recovery data for the APT are archived and available for review at the District's headquarters in West Palm Beach, Florida.

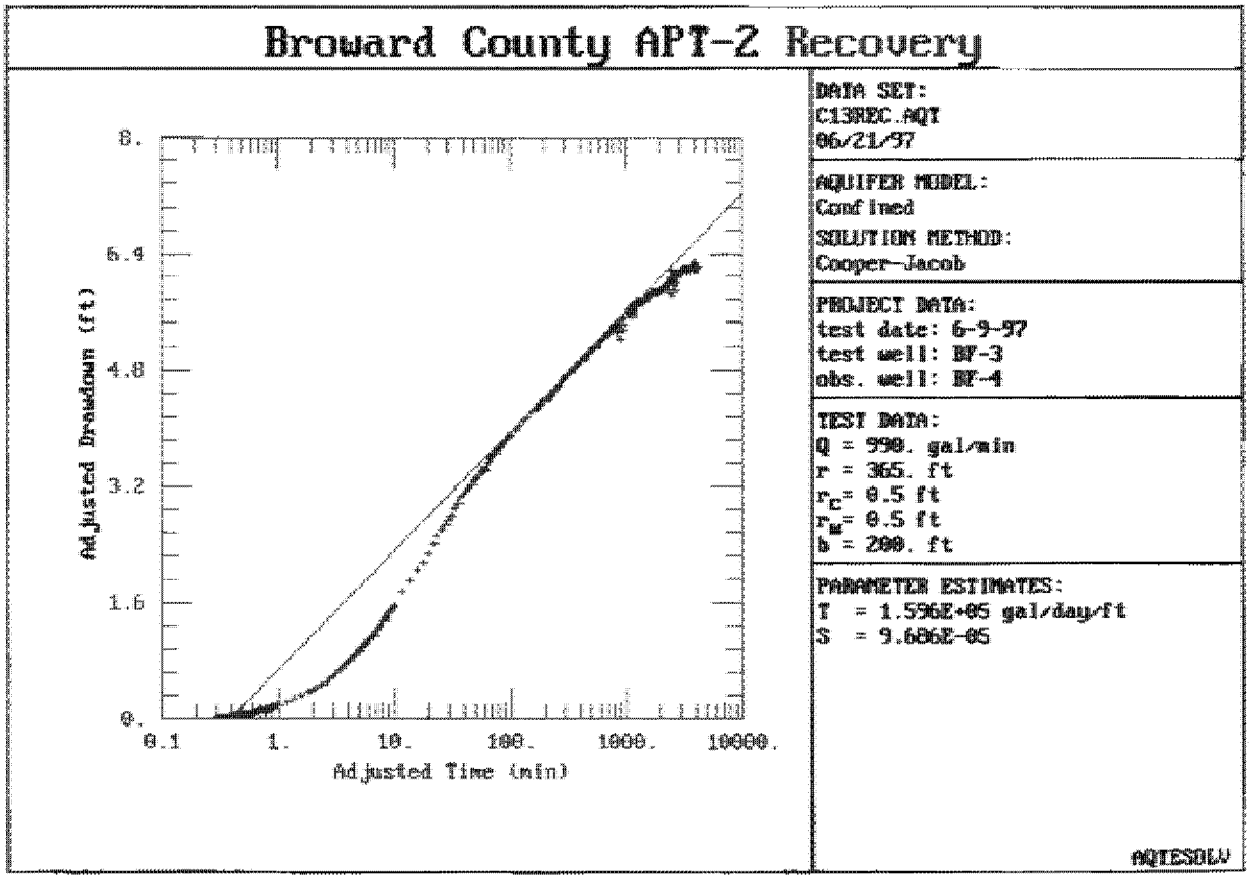


Figure 19. APT-2, Semi-Log Plot of Time Drawdown During Recovery Phase.

APT-2 Water Quality Results

BF-3 was sampled once after 25 hours of pumping during the drawdown phase of APT-2. Those samples were submitted to the District's laboratory for cation/anion analyses. **Table 7** summarizes the analytical results.

Date	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Alka/50 meq/L	Cl-(Lab) mg/L	SO4 mg/L	Hardness mg/L CACO	SIO2 mg/L	TDS mg/L	pH Units
06/12/97	200.0	286.0	9880.0	436.8	7.0	4218.0	883.0	1680.0	13.8	8360.0	7.0

Table 7. Water Quality Data from APT-2 (1,000' to 1,200' bls).

Figure 20 summarizes most of the pertinent hydraulic characteristics of the FAS at the site including: depths to flow zones, packer test depths and results, APT depths, final monitor intervals, water quality characteristics, etc.

Cross-Well Tomography

The District contracted with the University of Miami to conduct a pilot experiment of the Super Cross-Well Tomography (SCWT) system at the C-13 canal site. A summary of this pilot project was documented by Yamamoto and Kuru (1997) and is available in the District's reference center. The field data collection effort took place between March 3 through March 12, 1997. The District served as the coordinator and facilitator in the field, providing a 40-foot high standpipe over the well and mechanical devices, cranes and staff to lower probes into the stand pipe. An acoustic source was placed in well BF-2 while an 8-channel hydrophone array with a constant inter-element distance of 26 feet was placed in well BF-1. These two wells are 37 feet apart. The velocity and attenuation within the limestone formations were measured by transmitting pseudo-random binary sequence pulses. The measured velocity and attenuation data were inverted for the permeability and porosity images. Theoretically, these images provide an uninterrupted vertical map (between 150 to 1,600 feet bls) of permeability and porosity, both in open hole and through casing. **Figure 21** and **Figure 22** are example strip logs showing permeability in the section between 1,000 and 1,220 feet bls and 1,320 and 1,560 feet bls. **Figure 23** is a permeability bar graph summarizing the interpretations of the cross-well tomography results.

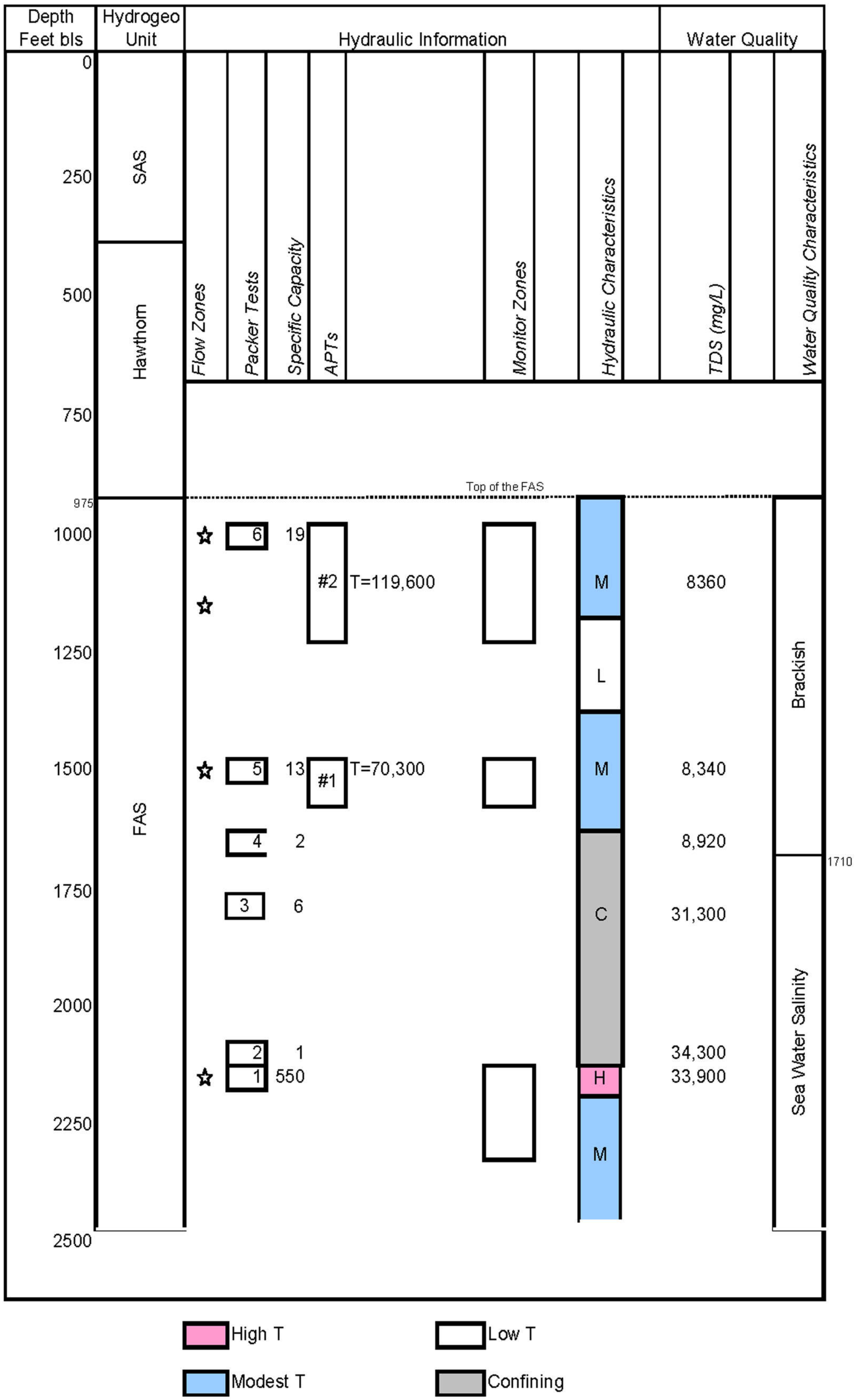


Figure 20. Hydraulic Summary of C-13 Site.

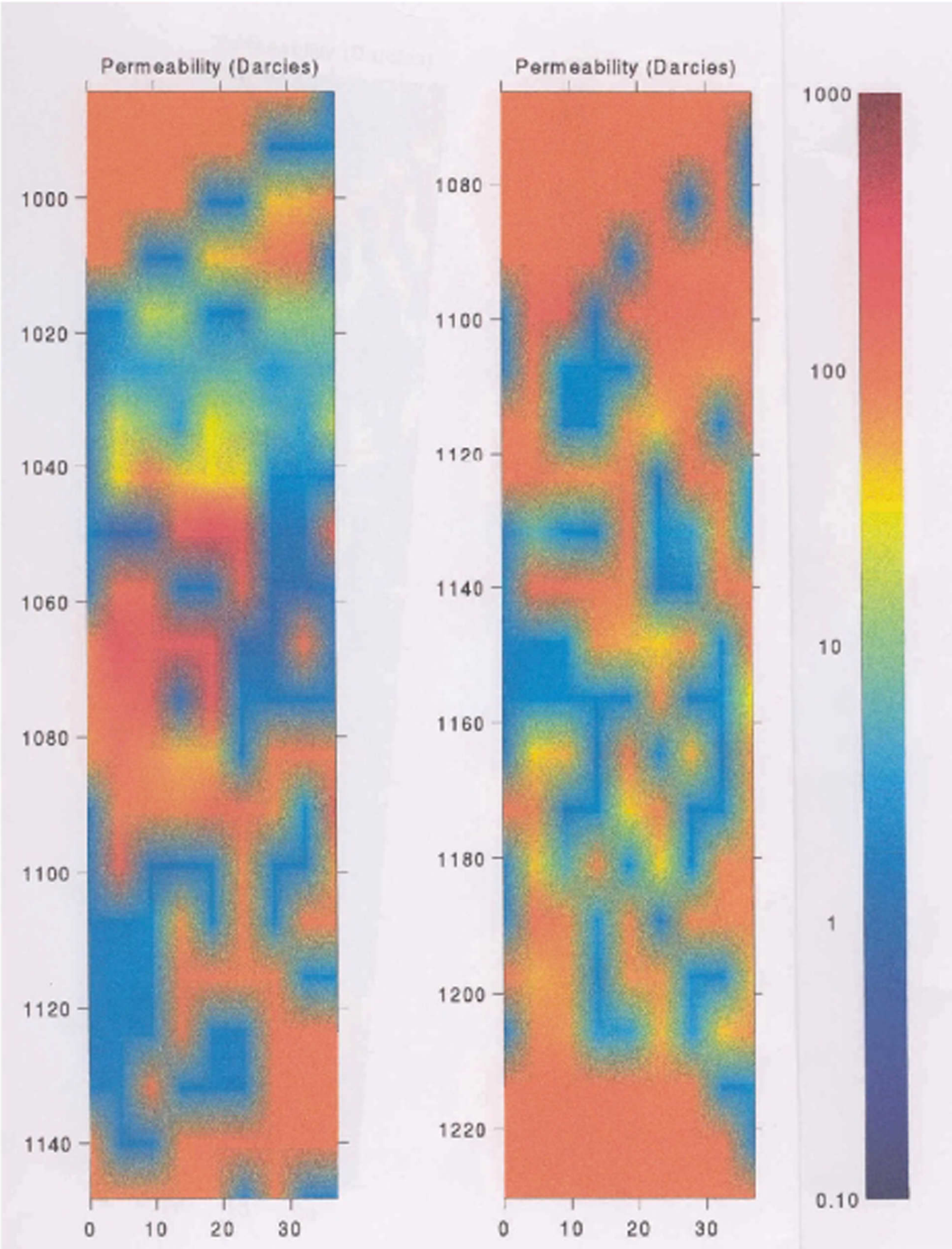


Figure 21. Permeability Trace Between 1,000 and 1,220 feet bls (Yamamoto, 1997)

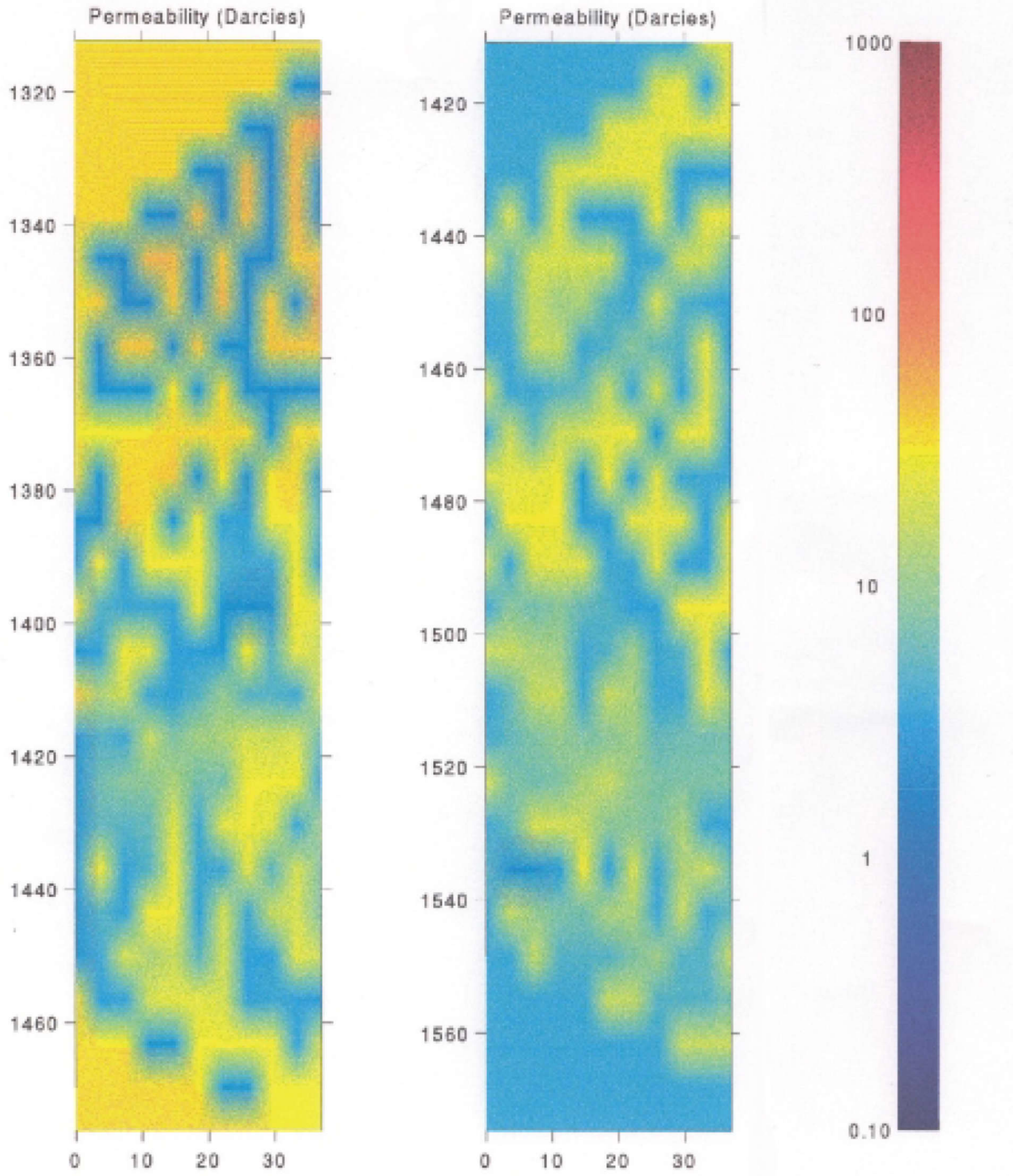


Figure 22. Permeability Trace Between 1,320 to 1,560 feet bls (Yamamoto, 1997)

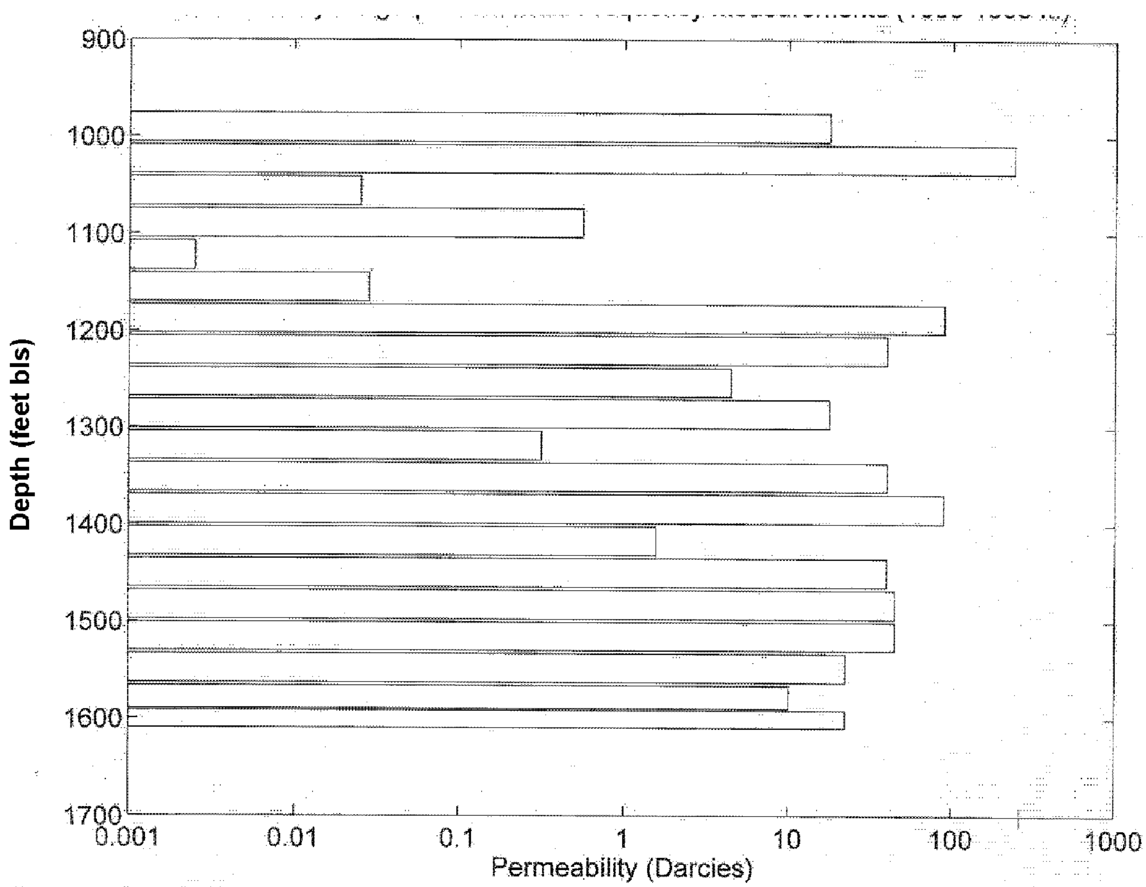


Figure 23. Permeability Bargraph from Multi Frequency Measurements (1,000 – 1,600 feet), (Yamamoto, 1997) .

WATER LEVELS

District staff collected monthly water levels from wells BF-1, BF-4M, and BF-4S manually from January 1994 to June 2001. In November 2001, a Campbell Scientific CR10 data recorder was installed on the wells with a pressure transducer. This recorder measures and records water levels every 15 minutes. Water levels are referenced to NGVD, 1929. Both monthly and average daily water levels from wells BF-4M, BF-4S, and BF-1 were used to develop **Figures 24 and 25**. These hydrographs illustrate how temporal water levels (unadjusted for density) in BF-4M are approximately 2-3 feet higher than those in BF-4S, both of which are approximately 35 feet higher than those in BF-1, as shown in **Figure 25**. Water in the lower Floridan aquifer is more saline than in the upper and middle Floridan aquifers and thus denser and heavier. This heavy water suppresses the height that the column of water can rise in the well.

The mean water level for the period of record (January 1994 to June 2002) for the upper, middle and lower Floridan aquifer zones (BF-4S, BF-4M, BF-1, respectively) at the site were approximately +42, +45 and +7 feet NGVD, respectively. Since the wells' measuring points are approximately +12 feet NGVD, water in the upper and middle Floridan aquifer wells stands approximately 30 feet above land surface, while water in the lower Floridan aquifer stands approximately 5 feet bls.

Water levels in the upper and middle Floridan aquifer fluctuated within a range of approximately 3 feet above and below the average values during the period of record. Similarly, water levels in the lower Floridan aquifer fluctuated within a range of approximately 2 feet above and below the average values during the period of record. It is interesting to note that water levels in both the upper and lower Floridan aquifers increased over the period of record (7 years).

Equivalent Freshwater Head Correction

The "raw" water levels recorded at the wellhead were converted to "equivalent freshwater heads" using the Ghyben-Herzberg method. To perform the correction, the specific gravity of the water collected from each monitor zone was computed, the results of which are presented in **Table 8**. Mean freshwater equivalent heads for the upper, middle, and lower Floridan flow zones are shown in **Table 9**.

Examination of the density-corrected water levels indicates that the lower Floridan aquifer actually exhibits higher water levels than the upper Floridan aquifer. This infers that ground water flow at the site is upward from the lower Floridan aquifer to the upper Floridan aquifer.

Monitor Zone	Total Dissolved Solids (mg/L)	Specific Gravity (g/cm^3)
BF-4S (upper)	8,360	1.0045
BF-4M (middle)	5,000	1.0026
BF-1 (lower)	31,900	1.0237

Table 8. Specific Gravity of Water in Wells BF-4S, BF-4M, and BF-1.

Monitor Well	Depth Interval (feet, bls)	Measuring Point Elevation (feet NGVD)	Uncorrected Water Level (feet, NGVD)	Corrected Water Level (feet, NGVD)
BF-4S (upper)	1,000 - 1,200	13.72	42	47
BF-4M (middle)	1,550 - 1,600	13.01	45	49
BF-1 (lower)	2,100 - 2,250	12.44	7	59

Table 9. Mean Water Levels and Equivalent Freshwater Heads (mean levels over POR).

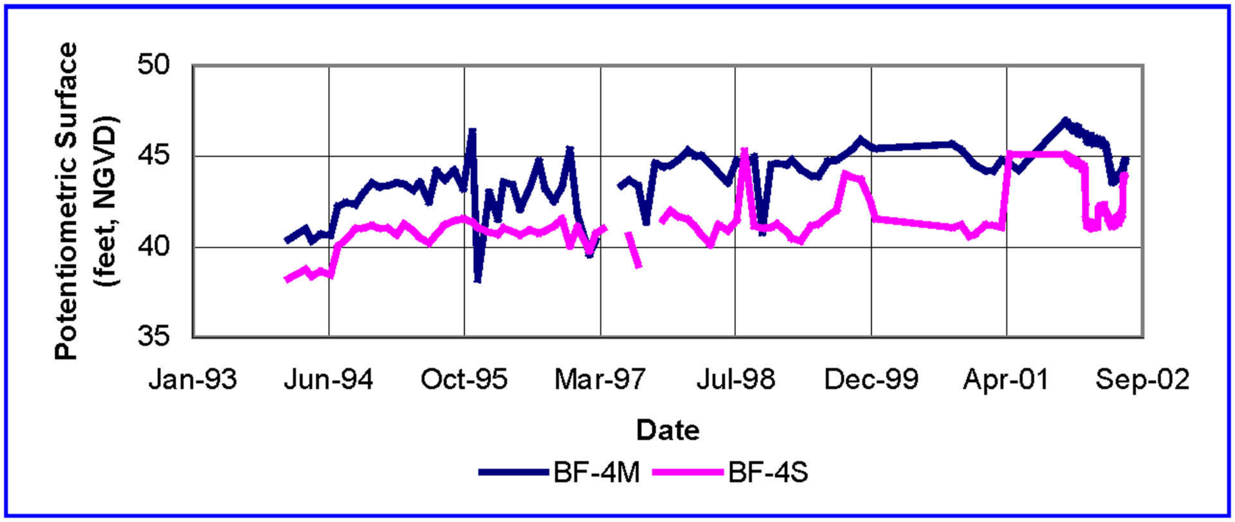


Figure 24. Hydrographs for BF-4M and BF-4S.

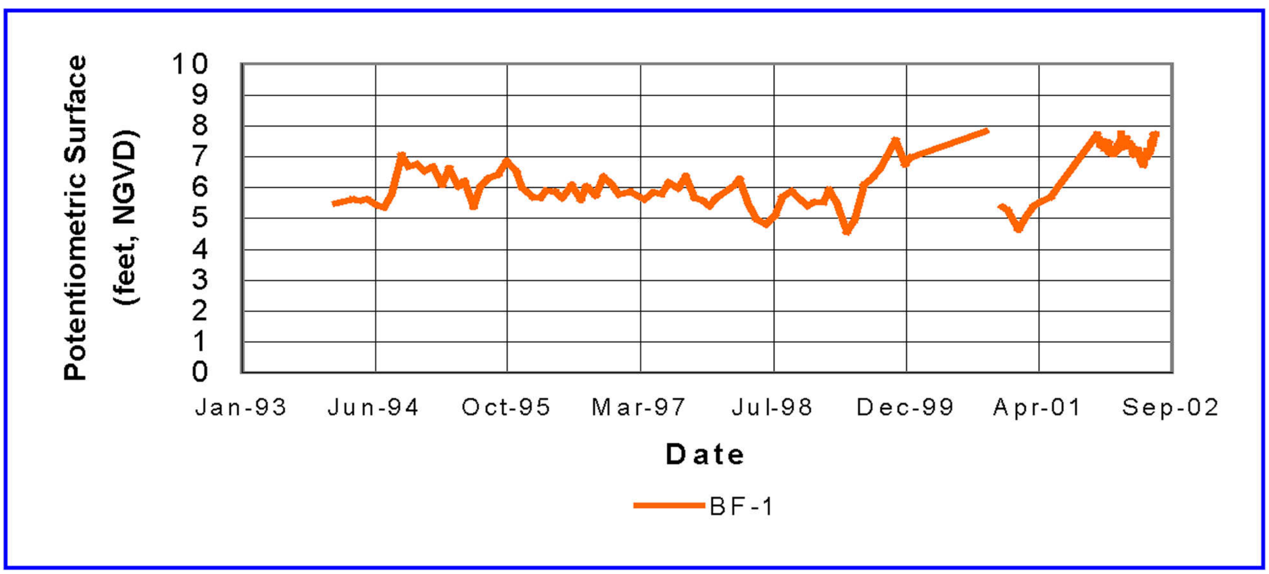


Figure 25. Hydrograph for BF-1.

SUMMARY

Four new wells were constructed in east-central Broward County at the S-36 salinity control structure on the northern right-of-way of the District's C-13 canal. These wells were constructed to obtain hydrogeologic and water quality data from the FAS. The pilot hole (BF-1) was drilled deepest and was the most extensively tested among the four wells. It was drilled to a total depth of 2,280 feet bls.

The principal findings of the exploratory drilling and testing program are as follows:

- The SAS extends from land surface to a depth of approximately 361 feet bls.
- The Hawthorn group (upper confining unit) was found to extend to approximately 975 feet bls.
- The top of the FAS was identified at a depth of approximately 975 feet bls.
- Significant flow was found coming from an "upper" producing zone 60 feet below the top of the FAS between 1,000-1,030 feet bls. The temperature log recorded a strong flow zone between 1,145 to 1,155 feet bls. An APT performed on the open-hole interval between 1,000 – 1,200 feet bls yielded a transmissivity of 119,600 gpd/ft, leakance was $1.52e^{-3}$ gallons per day per foot and chloride concentration was 4,218 mg/L.
- A significant flow zone was found between 1,500 and 1,600 feet bls. Transmissivity across this interval was approximately 70,300 gpd/ft, leakance was $2.22e^{-3}$ gallons per day per foot and the chloride concentration was 2,800 mg/L.
- The base of the USDW was found at approximately 1,710 feet bls.
- The middle confining units were tested using packers. They were found to have low permeability overall. Two intervals were packer tested between 1,726-1,772 feet bls and 2,078-2,088 feet bls and found to have specific capacities of 5.52 and 0.07 gpm/ft, respectively.
- The cross-well tomography system was used in a pilot to test its applicability in mapping permeability profiles between two Floridan wells. The results of the pilot were inconclusive in the author's opinion. Aquifer permeability mapped using cross-well tomography compared favorably with those from two aquifer pump tests, however, those maps also displayed much higher permeability than expected within the middle-confining unit.

- Mean water levels (uncorrected for salinity) in the upper, middle and lower FAS intervals (BF4S, BF-4M, and BF-1) over a 7-year period of record were approximately +42, +45 and +7 feet above the National Geodetic Vertical Datum of 1929 (NGVD), respectively. Water levels fluctuated 3-5 feet in the upper and middle flow zones and between 1-3 feet in the lower Floridan aquifer.

- Equivalent freshwater heads in those same aquifers (upper, middle and lower Floridan) were +47, +49 and +59 feet NGVD, respectively, inferring groundwater moves from the lower to the upper Floridan at the site.

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APPENDICES

APPENDIX A-1
FLORIDA GEOLOGIC SURVEY DESCRIPTIONS

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LITHOLOGIC WELL LOG PRINTOUT                     SOURCE - FGS

WELL NUMBER:   W-17013                           COUNTY -   BROWARD
TOTAL DEPTH:     2218  FT.                       LOCATION:  T.49S R.42E S.20
332 SAMPLES FROM 0 TO 2218 FT.                              LAT = 26D 10M 23S
                                                            LON = 80D 10M 44S
COMPLETION DATE: 02/00/93                        ELEVATION: 20 FT
OTHER TYPES OF LOGS AVAILABLE - OTHER

OWNER/DRILLER:SOUTH FLORIDA WATER MANAGEMENT DISTRICT/HENRY BLAIR

WORKED BY:__LI LI (10/15/93)
SFWMD ID# FOR CUTTINGS IS 011-18 (HOLE #HWTW-1), BROWARD COUNTY.
SFWMD GEOPHYSICAL LOG # 011000009.
LOCATED IN THE SW 1/4, SW 1/4, NE 1/4, SEC.20, T49S, R42E.
FLORIDA POLYCONIC EAST ZONE IN FEET; PLANAR X=769323; PLANAR Y=669411.
SFWMD GEOLOGIST LOGS FOR THIS MONITOR WELL.
WELL IS LOCATED IN THE FORT LAUDERDALE NORTH 7.5 MINUTE QUADRANGLE.
THE OKEECHOBEE FORMATION IS PROPOSED FOR THE PLIO-PLEISTOCENE INTERVAL
(SCOTT, 1992, P. 23, FLORIDA GEOLOGICAL SURVEY SPECIAL PUBLICATION 36).

    0.    -   30.   000NOSM   NO SAMPLES
   30.    -   70.   112MIMI   MIAMI LIMESTONE
   70.    -  361.   121PCPC   PLIOCENE-PLEISTOCENE
  361.    - 1035.   122HTRN   HAWTHORN GROUP
 1035.    - 2218.   124AVPK   AVON PARK FM.
    0.    -   30.   000NOSM   NO SAMPLES
   55.    -   60.   000NOSM   NO SAMPLES
   90.    -  100.   000NOSM   NO SAMPLES
  160.    -  165.   000NOSM   NO SAMPLES
  225.    -  230.   000NOSM   NO SAMPLES
  315.    -  325.   000NOSM   NO SAMPLES
  394.    -  395.   000NOSM   NO SAMPLES
  515.    -  520.   000NOSM   NO SAMPLES
  860.    -  870.   000NOSM   NO SAMPLES
 1000.    - 1015.   000NOSM   NO SAMPLES
 1590.    - 1593.   000NOSM   NO SAMPLES
 1595.    - 1597.   000NOSM   NO SAMPLES

    0  -   30   NO SAMPLES

   30  -   55   LIMESTONE; VERY LIGHT ORANGE TO VERY LIGHT GRAY
                20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
                GRAIN TYPE: OOLITE, CRYSTALS, CALCILUTITE
                80% ALLOCHEMICAL CONSTITUENTS
                GRAIN SIZE: FINE; RANGE: MICROCRYSTALLINE TO COARSE
                MODERATE INDURATION
                CEMENT TYPE(S): SPARRY CALCITE CEMENT, CALCILUTITE MATRIX
                ACCESSORY MINERALS: QUARTZ SAND-10%, SHELL-05%
                FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

   55  -   60   NO SAMPLES

   60  -   70   LIMESTONE; VERY LIGHT ORANGE TO VERY LIGHT GRAY
                25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
                GRAIN TYPE: OOLITE, CRYSTALS, CALCILUTITE
                80% ALLOCHEMICAL CONSTITUENTS
                GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
                MODERATE INDURATION
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		CEMENT TYPE(S): SPARRY CALCITE CEMENT, CALCILUTITE MATRIX ACCESSORY MINERALS: QUARTZ SAND-20%, SHELL-10% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
70	- 90	LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX, SPARRY CALCITE CEMENT ACCESSORY MINERALS: QUARTZ SAND-30%, SHELL-05% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
90	- 100	NO SAMPLES
100	- 115	LIMESTONE; VERY LIGHT ORANGE 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT, CALCILUTITE MATRIX ACCESSORY MINERALS: QUARTZ SAND-20%, SHELL-20% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
115	- 120	LIMESTONE; YELLOWISH GRAY TO LIGHT GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC 85% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT, CALCILUTITE MATRIX ACCESSORY MINERALS: QUARTZ SAND-30%, SHELL-10% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
120	- 140	LIMESTONE; YELLOWISH GRAY TO LIGHT GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS; 90% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT ACCESSORY MINERALS: QUARTZ SAND-20%, SHELL-10% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
140	- 160	LIMESTONE; YELLOWISH GRAY 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC 90% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT ACCESSORY MINERALS: QUARTZ SAND-20%, SHELL-15% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

160 - 165	NO SAMPLES
165 - 175	LIMESTONE; VERY LIGHT GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC 85% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT ACCESSORY MINERALS: QUARTZ SAND-20%, SHELL-15% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
175 - 178	LIMESTONE; LIGHT GRAY 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC 85% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO COARSE GOOD INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT ACCESSORY MINERALS: SHELL-20%, QUARTZ SAND-10% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
178 - 185	LIMESTONE; VERY LIGHT ORANGE 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT, CALCILUTITE MATRIX ACCESSORY MINERALS: SHELL-15%, QUARTZ SAND-05% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
185 - 195	LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC 85% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRAVEL MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT ACCESSORY MINERALS: SHELL-30%, QUARTZ SAND-20% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
195 - 200	LIMESTONE; PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT ACCESSORY MINERALS: QUARTZ SAND-10%, SHELL-10% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
200 - 208	LIMESTONE; YELLOWISH GRAY TO PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY

	GRAIN TYPE: CRYSTALS, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX, SPARRY CALCITE CEMENT ACCESSORY MINERALS: QUARTZ SAND-10%, SHELL-05% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, SPICULES
208 - 225	LIMESTONE; YELLOWISH GRAY TO PINKISH GRAY 30% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CRYSTALS 90% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: COARSE; RANGE: FINE TO GRAVEL; POOR INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT ACCESSORY MINERALS: SHELL-30%, QUARTZ SAND-05% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, SPICULES
225 - 230	NO SAMPLES
230 - 240	LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CRYSTALS 90% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MEDIUM; RANGE: FINE TO GRAVEL; POOR INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT ACCESSORY MINERALS: SHELL-25%, QUARTZ SAND-05% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
240 - 260	LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MEDIUM; RANGE: FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX, SPARRY CALCITE CEMENT ACCESSORY MINERALS: SHELL-10%, QUARTZ SAND-05% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA
260 - 268	LIMESTONE; LIGHT OLIVE GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE POOR INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: SHELL-10%, QUARTZ SAND-10% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
268 - 285	LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, BIOGENIC 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE POOR INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX, SPARRY CALCITE CEMENT ACCESSORY MINERALS: SHELL-20%, QUARTZ SAND-20%

		PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA AMMONIA SP.
285 - 298		LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CRYSTALS, CALCILUTITE 70% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE POOR INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: SHELL-30%, QUARTZ SAND-15% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, SPICULES, BENTHIC FORAMINIFERA
298 - 315		LIMESTONE; YELLOWISH GRAY 30% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CRYSTALS, CALCILUTITE 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: COARSE; RANGE: FINE TO GRAVEL; POOR INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: SHELL-30%, QUARTZ SAND-20% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, SPICULES
315 - 325		NO SAMPLES
325 - 332		LIMESTONE; YELLOWISH GRAY 30% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CRYSTALS, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: COARSE; RANGE: FINE TO GRAVEL; POOR INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: SHELL-40%, QUARTZ SAND-10% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, SPICULES
332 - 361		LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CRYSTALS, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO VERY COARSE POOR INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX, SPARRY CALCITE CEMENT ACCESSORY MINERALS: QUARTZ SAND-10%, SHELL-05% PHOSPHATIC SAND-01% FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS
361 - 394		SANDSTONE; LIGHT OLIVE GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN SIZE: FINE; RANGE: VERY FINE TO MEDIUM MEDIUM SPHERICITY; POOR INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: CALCILUTITE-25%, PHOSPHATIC SAND-02% FOSSILS: MOLLUSKS, BENTHIC FORAMINIFERA ARCHAIAS SP., GYPSINA GLOBULA
394 - 395		NO SAMPLES

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395  -  400   SHELL BED; WHITE TO YELLOWISH GRAY
              35% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
              UNCONSOLIDATED
              ACCESSORY MINERALS: CALCITE-30%, QUARTZ SAND-10%
              PHOSPHATIC SAND-01%
              FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, SPICULES
              OOLITE FRAGMENTS 10%; PROBABLY FROM CAVING.

400  -  410   LIMESTONE; VERY LIGHT ORANGE TO YELLOWISH GRAY
              30% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
              GRAIN TYPE: BIOGENIC, CRYSTALS
              90% ALLOCHEMICAL CONSTITUENTS
              GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRAVEL
              POOR INDURATION
              CEMENT TYPE(S): SPARRY CALCITE CEMENT, CALCILUTITE MATRIX
              ACCESSORY MINERALS: SHELL-40%, QUARTZ SAND-10%
              FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

410  -  415   LIMESTONE; YELLOWISH GRAY
              30% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
              GRAIN TYPE: CRYSTALS, BIOGENIC
              90% ALLOCHEMICAL CONSTITUENTS
              GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRAVEL
              POOR INDURATION
              CEMENT TYPE(S): SPARRY CALCITE CEMENT, CALCILUTITE MATRIX
              ACCESSORY MINERALS: SHELL-25%, QUARTZ SAND-20%
              FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA

415  -  423   LIMESTONE; YELLOWISH GRAY TO LIGHT OLIVE GRAY
              25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
              GRAIN TYPE: CRYSTALS, BIOGENIC, CALCILUTITE
              75% ALLOCHEMICAL CONSTITUENTS
              GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
              POOR INDURATION
              CEMENT TYPE(S): CALCILUTITE MATRIX
              ACCESSORY MINERALS: QUARTZ SAND-25%, SHELL-10%
              PHOSPHATIC SAND-01%
              FOSSILS: MOLLUSKS, BENTHIC FORAMINIFERA

423  -  445   SILT; LIGHT OLIVE GRAY
              25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
              POOR INDURATION
              CEMENT TYPE(S): CALCILUTITE MATRIX
              ACCESSORY MINERALS: CALCILUTITE-20%, QUARTZ SAND-05%
              SHELL-05%, PHOSPHATIC SAND-01%
              FOSSILS: MOLLUSKS, BENTHIC FORAMINIFERA
              ARCHAIAS SP.;  OOLITE FRAGMENTS MAY COME FROM CAVING.

445  -  450   SILT; LIGHT OLIVE GRAY TO YELLOWISH GRAY
              25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
              POOR INDURATION
              CEMENT TYPE(S): CALCILUTITE MATRIX
              ACCESSORY MINERALS: CALCILUTITE-20%, QUARTZ SAND-05%
              SHELL-05%, PHOSPHATIC SAND-01%
              FOSSILS: MOLLUSKS, BENTHIC FORAMINIFERA
              OOLITE FRAGMENTS MAY COME FROM CAVING.

450  -  456   SILT; LIGHT OLIVE GRAY
              20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
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POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX, CLAY MATRIX
ACCESSORY MINERALS: CALCILUTITE-25%, QUARTZ SAND-03%
SHELL-02%, PHOSPHATIC SAND-02%
FOSSILS: MOLLUSKS, BENTHIC FORAMINIFERA
OOLITE FRAGMENTS MAY COME FROM CAVING.

456 - 470 LIMESTONE; YELLOWISH GRAY TO LIGHT OLIVE GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: CRYSTALS, BIOGENIC, CALCILUTITE
70% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: QUARTZ SAND-30%, SHELL-15%
PHOSPHATIC SAND-02%
FOSSILS: MOLLUSKS, BENTHIC FORAMINIFERA
ARCHAIAS SP.

470 - 480 LIMESTONE; YELLOWISH GRAY TO LIGHT OLIVE GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: CRYSTALS, BIOGENIC, CALCILUTITE
75% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRANULE
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX, SPARRY CALCITE CEMENT
ACCESSORY MINERALS: QUARTZ SAND-25%, SHELL-10%
PHOSPHATIC SAND-02%
FOSSILS: MOLLUSKS

480 - 515 LIMESTONE; YELLOWISH GRAY TO LIGHT OLIVE GRAY
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CRYSTALS, BIOGENIC, CALCILUTITE
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MEDIUM; RANGE: FINE TO COARSE; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX, SPARRY CALCITE CEMENT
ACCESSORY MINERALS: QUARTZ SAND-40%, SHELL-05%
PHOSPHATIC SAND-03%
FOSSILS: MOLLUSKS, BENTHIC FORAMINIFERA

515 - 520 NO SAMPLES

520 - 540 SILT; LIGHT OLIVE GRAY
20% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX, CLAY MATRIX
ACCESSORY MINERALS: CALCILUTITE-25%, PHOSPHATIC SAND-01%
FOSSILS: MOLLUSKS, BENTHIC FORAMINIFERA

540 - 550 LIMESTONE; YELLOWISH GRAY TO LIGHT OLIVE GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: CRYSTALS, BIOGENIC, CALCILUTITE
75% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX, SPARRY CALCITE CEMENT
ACCESSORY MINERALS: QUARTZ SAND-25%, SHELL-20%
PHOSPHATIC SAND-01%
FOSSILS: MOLLUSKS, BENTHIC FORAMINIFERA

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550  -  570   LIMESTONE; YELLOWISH GRAY
              20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
              GRAIN TYPE: BIOGENIC, CALCILUTITE
              60% ALLOCHEMICAL CONSTITUENTS
              GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
              POOR INDURATION
              CEMENT TYPE(S): CALCILUTITE MATRIX
              ACCESSORY MINERALS: SHELL-20%, QUARTZ SAND-10%
              PHOSPHATIC SAND-03%
              FOSSILS: MOLLUSKS

570  -  600   CALCILUTITE; YELLOWISH GRAY
              15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
              GRAIN TYPE: CALCILUTITE, CRYSTALS
              30% ALLOCHEMICAL CONSTITUENTS
              GRAIN SIZE: MICROCRYSTALLINE
              RANGE: MICROCRYSTALLINE TO COARSE; POOR INDURATION
              CEMENT TYPE(S): CALCILUTITE MATRIX
              ACCESSORY MINERALS: SHELL-10%, PHOSPHATIC SAND-02%
              FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

600  -  640   CALCILUTITE; YELLOWISH GRAY
              15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
              GRAIN TYPE: CALCILUTITE, CRYSTALS
              30% ALLOCHEMICAL CONSTITUENTS
              GRAIN SIZE: MICROCRYSTALLINE
              RANGE: MICROCRYSTALLINE TO MEDIUM; POOR INDURATION
              CEMENT TYPE(S): CALCILUTITE MATRIX
              ACCESSORY MINERALS: SHELL-05%, PHOSPHATIC SAND-01%
              FOSSILS: FOSSIL FRAGMENTS

640  -  700   CALCILUTITE; YELLOWISH GRAY
              15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
              GRAIN TYPE: CALCILUTITE, CRYSTALS
              25% ALLOCHEMICAL CONSTITUENTS
              GRAIN SIZE: MICROCRYSTALLINE; POOR INDURATION
              CEMENT TYPE(S): CALCILUTITE MATRIX
              ACCESSORY MINERALS: SHELL-02%, PHOSPHATIC SAND-02%
              FOSSILS: FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA

700  -  725   CALCILUTITE; YELLOWISH GRAY
              15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
              GRAIN TYPE: CALCILUTITE, BIOGENIC
              40% ALLOCHEMICAL CONSTITUENTS
              GRAIN SIZE: MICROCRYSTALLINE
              RANGE: MICROCRYSTALLINE TO GRANULE; POOR INDURATION
              CEMENT TYPE(S): CALCILUTITE MATRIX
              ACCESSORY MINERALS: SHELL-10%, PHOSPHATIC SAND-02%
              FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, SPICULES

725  -  755   CALCILUTITE; YELLOWISH GRAY
              20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
              GRAIN TYPE: CALCILUTITE, BIOGENIC
              40% ALLOCHEMICAL CONSTITUENTS
              GRAIN SIZE: MICROCRYSTALLINE
              RANGE: MICROCRYSTALLINE TO VERY COARSE; POOR INDURATION
              CEMENT TYPE(S): CALCILUTITE MATRIX
              ACCESSORY MINERALS: SHELL-25%, PHOSPHATIC SAND-02%
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FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

755 - 770 CALCILUTITE; YELLOWISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO GRANULE; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-10%, PHOSPHATIC SAND-01%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

770 - 795 CALCILUTITE; YELLOWISH GRAY
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO GRANULE; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-20%, PHOSPHATIC SAND-02%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

795 - 820 CALCILUTITE; YELLOWISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 25% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO COARSE; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-05%, PHOSPHATIC SAND-05%
DOLOMITE-01%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

820 - 824 CALCILUTITE; YELLOWISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 20% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO COARSE; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: DOLOMITE-10%, SHELL-05%
PHOSPHATIC SAND-02%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

824 - 860 CALCILUTITE; YELLOWISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 20% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO COARSE; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-05%, PHOSPHATIC SAND-03%
DOLOMITE-01%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

860 - 870 NO SAMPLES

870 - 890 CALCILUTITE; YELLOWISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO COARSE; POOR INDURATION

CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-05%, PHOSPHATIC SAND-03%
DOLOMITE-02%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS

890 - 920 CALCILUTITE; YELLOWISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO COARSE; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-03%, PHOSPHATIC SAND-02%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA

920 - 930 CALCILUTITE; YELLOWISH GRAY
10% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 20% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE; MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: PHOSPHATIC SAND-02%
FOSSILS: FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA

930 - 945 CALCILUTITE; YELLOWISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO GRANULE; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-10%, QUARTZ SAND-05%
PHOSPHATIC SAND-02%, DOLOMITE-01%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA

945 - 950 LIMESTONE; YELLOWISH GRAY
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: VERY FINE TO GRANULE
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-10%, PHOSPHATIC SAND-08%
QUARTZ SAND-05%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA

950 - 965 CALCILUTITE; YELLOWISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO GRANULE; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-05%, PHOSPHATIC SAND-01%
QUARTZ SAND-01%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA

965 - 980 LIMESTONE; YELLOWISH GRAY
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE

POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: PHOSPHATIC SAND-10%, SHELL-05%
QUARTZ SAND-02%
FOSSILS: MOLLUSKS, FOSSIL FRAGMENTS, BENTHIC FORAMINIFERA

980 - 990 CALCILUTITE; YELLOWISH GRAY
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO COARSE
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-05%, PHOSPHATIC SAND-03%
QUARTZ SAND-02%
FOSSILS: MOLLUSKS, SHARKS TEETH, BENTHIC FORAMINIFERA

990 - 1000 LIMESTONE; YELLOWISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CRYSTALS
75% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-20%, PHOSPHATIC SAND-02%
QUARTZ SAND-01%
FOSSILS: MOLLUSKS, SPICULES, BENTHIC FORAMINIFERA

1000 - 1015 NO SAMPLES

1015 - 1025 LIMESTONE; VERY LIGHT GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: CRYPTOCRYSTALLINE TO GRANULE; GOOD INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-10%
FOSSILS: MOLLUSKS

1025 - 1030 LIMESTONE; VERY LIGHT GRAY
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC, CRYSTALS
40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: CRYPTOCRYSTALLINE TO GRANULE; GOOD INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: SHELL-10%, QUARTZ SAND-10%
FOSSILS: MOLLUSKS

1030 - 1035 LIMESTONE; VERY LIGHT GRAY TO LIGHT OLIVE GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CRYSTALS, CALCILUTITE
75% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: VERY FINE TO GRAVEL
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: QUARTZ SAND-15%, SHELL-10%
PHOSPHATIC SAND-05%
FOSSILS: MOLLUSKS

BOTTOM OF THE HAWTHORN FORMATION.

1035 - 1060 LIMESTONE; PINKISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
85% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRAVEL
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MOLLUSKS, ECHINOID, MILIOLIDS
BENTHIC FORAMINIFERA
DICTYOCONUS COOKEI, DICTYOCONUS AMERICANUS, GYPSINA
GLOBULA, CRIBROBULIMINA SP., LITUONELLA SP.

1060 - 1090 LIMESTONE; PINKISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CRYSTALS, CALCILUTITE
90% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRAVEL
MODERATE INDURATION
CEMENT TYPE(S): SPARRY CALCITE CEMENT, CALCILUTITE MATRIX
FOSSILS: CORAL, ECHINOID, MILIOLIDS, BENTHIC FORAMINIFERA

1090 - 1125 LIMESTONE; VERY LIGHT ORANGE
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
75% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: VERY FINE TO VERY COARSE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: SPICULES, ECHINOID, MILIOLIDS
BENTHIC FORAMINIFERA
POOR SAMPLES FROM 1110' TO 1125'; GRAY CALCILUTITE APPEARS
DUE TO CAVING.

1125 - 1130 LIMESTONE; PINKISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
70% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: SPICULES, MILIOLIDS, BENTHIC FORAMINIFERA
DICTYOCONUS COOKEI, DICTYOCONUS AMERICANUS, SPIROLINA SP.
CRIBROBULIMINA SP.

1130 - 1160 LIMESTONE; WHITE
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: ECHINOID, MILIOLIDS, BENTHIC FORAMINIFERA

1160 - 1175 LIMESTONE; PINKISH GRAY
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
75% ALLOCHEMICAL CONSTITUENTS

	GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: ECHINOID, MILIOLIDS, BENTHIC FORAMINIFERA
1175 - 1200	LIMESTONE; WHITE 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 50% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO COARSE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: ECHINOID, MILIOLIDS, BENTHIC FORAMINIFERA
1200 - 1221	CALCILUTITE; VERY LIGHT ORANGE 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY GRAIN TYPE: CALCILUTITE, BIOGENIC 40% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: ECHINOID, MILIOLIDS, BENTHIC FORAMINIFERA
1221 - 1250	LIMESTONE; VERY LIGHT ORANGE 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: DOLOMITE-05% FOSSILS: MOLLUSKS, ECHINOID, MILIOLIDS BENTHIC FORAMINIFERA
1250 - 1280	LIMESTONE; VERY LIGHT ORANGE 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE POOR INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: ECHINOID, MILIOLIDS, BENTHIC FORAMINIFERA
1280 - 1290	LIMESTONE; PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC; 90% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT ACCESSORY MINERALS: DOLOMITE-05% FOSSILS: ECHINOID, MILIOLIDS, BENTHIC FORAMINIFERA
1290 - 1305	LIMESTONE; VERY LIGHT ORANGE 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CRYSTALS 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO VERY COARSE MODERATE INDURATION CEMENT TYPE(S): SPARRY CALCITE CEMENT

	ACCESSORY MINERALS: DOLOMITE-05% FOSSILS: ECHINOID, MILIOLIDS, BENTHIC FORAMINIFERA
1305 - 1335	LIMESTONE; PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: DOLOMITE-02% FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA DICTYOCONUS AMERICANUS, DICTYOCONUS COOKEI, SPIROLINA SP. CRIBROBULIMINA SP., LITUONELLA SP.
1335 - 1355	LIMESTONE; WHITE TO PINKISH GRAY 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY GRAIN TYPE: CALCILUTITE, BIOGENIC 50% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO COARSE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MOLLUSKS, MILIOLIDS, BENTHIC FORAMINIFERA
1355 - 1375	LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1375 - 1380	LIMESTONE; PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 70% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: DOLOMITE-02% FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1380 - 1385	LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: DOLOMITE-02% FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1385 - 1405	LIMESTONE; PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION

CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: DOLOMITE-02%
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1405 - 1420 LIMESTONE; PINKISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO COARSE; MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: BENTHIC FORAMINIFERA

1420 - 1430 LIMESTONE; YELLOWISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CRYSTALS
90% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX, SPARRY CALCITE CEMENT
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1430 - 1440 CALCILUTITE; PINKISH GRAY
10% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 20% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: CRYPTOCRYSTALLINE TO VERY FINE; GOOD INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1440 - 1470 LIMESTONE; PINKISH GRAY
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1470 - 1490 LIMESTONE; VERY LIGHT ORANGE
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
80% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRAVEL
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1490 - 1520 LIMESTONE; WHITE
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
50% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO FINE
GOOD INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: DOLOMITE-03%
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1520 - 1530 LIMESTONE; YELLOWISH GRAY

15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: CRYPTOCRYSTALLINE TO FINE; GOOD INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1530 - 1534	LIMESTONE; VERY LIGHT ORANGE 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 60% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1534 - 1565	LIMESTONE; WHITE 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY GRAIN TYPE: CALCILUTITE, BIOGENIC 40% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO COARSE GOOD INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1565 - 1570	LIMESTONE; PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 70% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE GOOD INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1570 - 1580	LIMESTONE; PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: CALCILUTITE, BIOGENIC 40% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO COARSE GOOD INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1580 - 1590	LIMESTONE; WHITE 15% POROSITY: INTERGRANULAR, LOW PERMEABILITY GRAIN TYPE: CALCILUTITE; 20% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MICROCRYSTALLINE RANGE: CRYPTOCRYSTALLINE TO VERY FINE; GOOD INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1590 - 1593	NO SAMPLES
1593 - 1595	LIMESTONE; VERY LIGHT ORANGE 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 75% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRAVEL MODERATE INDURATION

CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: ECHINOID, MILIOLIDS, BENTHIC FORAMINIFERA
DICTYOCONUS AMERICANUS, DICTYOCONUS COOKEI, CRIBROBULIMINA SP.

1595 - 1597	NO SAMPLES
1597 - 1605	LIMESTONE; VERY LIGHT ORANGE 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 80% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: COARSE; RANGE: FINE TO GRAVEL MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1605 - 1610	LIMESTONE; WHITE 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 60% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRAVEL MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1610 - 1615	LIMESTONE; VERY LIGHT ORANGE 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC; 90% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO VERY COARSE UNCONSOLIDATED FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA DICTYOCONUS AMERICANUS, DICTYOCONUS COOKEI, CRIBROBULIMINA SP., LITUONELLA SP., SPIROLINA SP.
1615 - 1620	LIMESTONE; YELLOWISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC; 90% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE UNCONSOLIDATED FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1620 - 1665	LIMESTONE; PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 70% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
1665 - 1700	LIMESTONE; PINKISH GRAY 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY GRAIN TYPE: BIOGENIC, CALCILUTITE 85% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE MODERATE INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

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1700  - 1703   LIMESTONE; VERY LIGHT GRAY
               15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
               GRAIN TYPE: CALCILUTITE; 20% ALLOCHEMICAL CONSTITUENTS
               GRAIN SIZE: MICROCRYSTALLINE
               RANGE: CRYPTOCRYSTALLINE TO MEDIUM; GOOD INDURATION
               CEMENT TYPE(S): CALCILUTITE MATRIX
               FOSSILS: BENTHIC FORAMINIFERA

1703  - 1708   LIMESTONE; YELLOWISH GRAY
               20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
               GRAIN TYPE: BIOGENIC, CALCILUTITE
               60% ALLOCHEMICAL CONSTITUENTS
               GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO COARSE
               MODERATE INDURATION
               CEMENT TYPE(S): CALCILUTITE MATRIX
               FOSSILS: BENTHIC FORAMINIFERA

1708  - 1730   LIMESTONE; PINKISH GRAY
               20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
               GRAIN TYPE: CALCILUTITE, BIOGENIC
               40% ALLOCHEMICAL CONSTITUENTS
               GRAIN SIZE: MICROCRYSTALLINE
               RANGE: MICROCRYSTALLINE TO MEDIUM; GOOD INDURATION
               CEMENT TYPE(S): CALCILUTITE MATRIX
               FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1730  - 1735   LIMESTONE; VERY LIGHT ORANGE
               25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
               GRAIN TYPE: BIOGENIC, CALCILUTITE
               80% ALLOCHEMICAL CONSTITUENTS
               GRAIN SIZE: COARSE; RANGE: FINE TO GRAVEL; POOR INDURATION
               CEMENT TYPE(S): CALCILUTITE MATRIX
               FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1735  - 1740   LIMESTONE; WHITE TO PINKISH GRAY
               25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
               GRAIN TYPE: BIOGENIC, CALCILUTITE
               80% ALLOCHEMICAL CONSTITUENTS
               GRAIN SIZE: FINE; RANGE: VERY FINE TO COARSE
               MODERATE INDURATION
               CEMENT TYPE(S): CALCILUTITE MATRIX
               FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1740  - 1745   LIMESTONE; WHITE TO VERY LIGHT ORANGE
               25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
               GRAIN TYPE: BIOGENIC, CALCILUTITE
               75% ALLOCHEMICAL CONSTITUENTS
               GRAIN SIZE: VERY FINE; RANGE: VERY FINE TO GRANULE
               POOR INDURATION
               CEMENT TYPE(S): CALCILUTITE MATRIX
               FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1745  - 1750   LIMESTONE; WHITE
               25% POROSITY: INTERGRANULAR, PIN POINT VUGS
               POSSIBLY HIGH PERMEABILITY
               GRAIN TYPE: CALCILUTITE, BIOGENIC
               40% ALLOCHEMICAL CONSTITUENTS
               GRAIN SIZE: VERY FINE; RANGE: VERY FINE TO COARSE
               MODERATE INDURATION
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CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1750 - 1760 LIMESTONE; YELLOWISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
80% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRAVEL
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1760 - 1770 LIMESTONE; VERY LIGHT ORANGE
15% POROSITY: INTERGRANULAR, PIN POINT VUGS
LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO COARSE; GOOD INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1770 - 1800 LIMESTONE; VERY LIGHT ORANGE
30% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC; 90% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: COARSE; RANGE: FINE TO GRAVEL; POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1800 - 1805 LIMESTONE; YELLOWISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC; 85% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
DICTYOCONUS AMERICANUS, DICTYOCONUS COOKEI, COSKINOLINA SP.

1805 - 1810 LIMESTONE; WHITE
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1810 - 1820 LIMESTONE; VERY LIGHT ORANGE
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC; 90% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: COARSE; RANGE: FINE TO GRAVEL
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1820 - 1830 LIMESTONE; WHITE TO VERY LIGHT ORANGE
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
75% ALLOCHEMICAL CONSTITUENTS

GRAIN SIZE: COARSE; RANGE: FINE TO GRAVEL
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1830 - 1835 LIMESTONE; PINKISH GRAY
20% POROSITY: INTERGRANULAR, PIN POINT VUGS
LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC, CRYSTALS
40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE
RANGE: MICROCRYSTALLINE TO VERY COARSE; GOOD INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1835 - 1845 LIMESTONE; VERY LIGHT ORANGE
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
75% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1845 - 1855 LIMESTONE; WHITE TO YELLOWISH GRAY
20% POROSITY: INTERGRANULAR, PIN POINT VUGS
LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: MICROCRYSTALLINE TO VERY COARSE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1855 - 1870 LIMESTONE; VERY LIGHT ORANGE
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
70% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: VERY FINE TO COARSE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1870 - 1880 LIMESTONE; YELLOWISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO COARSE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1880 - 1885 LIMESTONE; VERY LIGHT ORANGE
20% POROSITY: INTERGRANULAR, PIN POINT VUGS
LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO GRANULE; MODERATE INDURATION

CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: BENTHIC FORAMINIFERA

1885 - 1890 LIMESTONE; WHITE TO YELLOWISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
75% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRAVEL
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1890 - 1900 LIMESTONE; WHITE TO VERY LIGHT GRAY
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: BENTHIC FORAMINIFERA

1900 - 1910 LIMESTONE; WHITE TO VERY LIGHT GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1910 - 1920 CALCILUTITE; WHITE
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
25% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO GRANULE; MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: BENTHIC FORAMINIFERA

1920 - 1938 LIMESTONE; WHITE TO PINKISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
80% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRAVEL
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1938 - 1940 LIMESTONE; WHITE
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO GRANULE; MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: BENTHIC FORAMINIFERA

1940 - 1945 LIMESTONE; VERY LIGHT GRAY
20% POROSITY: INTERGRANULAR, PIN POINT VUGS

LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO GRANULE; MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: BENTHIC FORAMINIFERA

1945 - 1970 LIMESTONE; WHITE TO PINKISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1970 - 1975 LIMESTONE; WHITE
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
60% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: BENTHIC FORAMINIFERA

1975 - 1977 LIMESTONE; PINKISH GRAY
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
80% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: COARSE; RANGE: VERY FINE TO GRAVEL
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: DOLOMITE-03%
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

1977 - 1980 DOLOSTONE; LIGHT GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
50-90% ALTERED; ANHEDRAL
GRAIN SIZE: MICROCRYSTALLINE
RANGE: CRYPTOCRYSTALLINE TO FINE; GOOD INDURATION
CEMENT TYPE(S): DOLOMITE CEMENT
ACCESSORY MINERALS: CALCITE-10%
FOSSILS: BENTHIC FORAMINIFERA

1980 - 1999 LIMESTONE; WHITE
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE; 40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
FOSSILS: BENTHIC FORAMINIFERA

1999 - 2010 LIMESTONE; VERY LIGHT ORANGE
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
70% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
POOR INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX

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                FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2010 - 2025     LIMESTONE; WHITE TO PINKISH GRAY
                25% POROSITY: INTERGRANULAR, PIN POINT VUGS
                POSSIBLY HIGH PERMEABILITY
                GRAIN TYPE: BIOGENIC, CALCILUTITE
                85% ALLOCHEMICAL CONSTITUENTS
                GRAIN SIZE: MEDIUM; RANGE: VERY FINE TO GRAVEL
                POOR INDURATION
                CEMENT TYPE(S): CALCILUTITE MATRIX
                ACCESSORY MINERALS: DOLOMITE-02%
                FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2025 - 2028     DOLOSTONE; WHITE TO LIGHT GRAY
                25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
                50-90% ALTERED; EUHEDRAL
                GRAIN SIZE: FINE; RANGE: VERY FINE TO MEDIUM
                GOOD INDURATION
                CEMENT TYPE(S): CALCILUTITE MATRIX, DOLOMITE CEMENT
                ACCESSORY MINERALS: CALCITE-40%

2028 - 2040     DOLOSTONE; VERY LIGHT ORANGE TO GRAYISH BROWN
                20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
                50-90% ALTERED; SUBHEDRAL
                GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO FINE
                GOOD INDURATION
                CEMENT TYPE(S): DOLOMITE CEMENT
                ACCESSORY MINERALS: CALCITE-20%
                FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2040 - 2045     LIMESTONE; VERY LIGHT ORANGE
                25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
                GRAIN TYPE: BIOGENIC, CALCILUTITE
                85% ALLOCHEMICAL CONSTITUENTS
                GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
                POOR INDURATION
                CEMENT TYPE(S): CALCILUTITE MATRIX
                ACCESSORY MINERALS: DOLOMITE-05%
                FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
                DICTYOCONUS AMERICANUS, DICTYOCONUS COOKEI, COSKINOLINA
                SP., CRIBROBULIMINA SP.

2045 - 2050     DOLOSTONE; LIGHT GRAY TO VERY LIGHT ORANGE
                25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
                10-50% ALTERED; SUBHEDRAL
                GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO FINE
                GOOD INDURATION
                CEMENT TYPE(S): DOLOMITE CEMENT
                ACCESSORY MINERALS: CALCITE-40%
                FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2050 - 2060     LIMESTONE; VERY LIGHT ORANGE
                25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
                GRAIN TYPE: BIOGENIC, CALCILUTITE
                70% ALLOCHEMICAL CONSTITUENTS
                GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
                MODERATE INDURATION
                CEMENT TYPE(S): CALCILUTITE MATRIX
                ACCESSORY MINERALS: DOLOMITE-30%
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FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2060 - 2080 LIMESTONE; VERY LIGHT ORANGE
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
GRAIN TYPE: BIOGENIC, CALCILUTITE
70% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: DOLOMITE-03%
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2080 - 2082 DOLOSTONE; VERY LIGHT ORANGE TO GRAYISH BROWN
25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
50-90% ALTERED; SUBHEDRAL
GRAIN SIZE: FINE; RANGE: MICROCRYSTALLINE TO FINE
GOOD INDURATION
CEMENT TYPE(S): DOLOMITE CEMENT, CALCILUTITE MATRIX
ACCESSORY MINERALS: CALCITE-40%
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2082 - 2085 LIMESTONE; YELLOWISH GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC, CRYSTALS
30% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: MICROCRYSTALLINE
RANGE: CRYPTOCRYSTALLINE TO MEDIUM; GOOD INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: DOLOMITE-10%
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2085 - 2087 DOLOSTONE; LIGHT GRAY TO MODERATE GRAY
15% POROSITY: INTERGRANULAR, LOW PERMEABILITY
50-90% ALTERED; ANHEDRAL
GRAIN SIZE: MICROCRYSTALLINE
RANGE: MICROCRYSTALLINE TO FINE; GOOD INDURATION
CEMENT TYPE(S): DOLOMITE CEMENT
ACCESSORY MINERALS: CALCITE-40%
FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2087 - 2089 DOLOSTONE; GRAYISH BROWN
15% POROSITY: INTERGRANULAR, PIN POINT VUGS
LOW PERMEABILITY; 50-90% ALTERED; EUHEDRAL
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO FINE
GOOD INDURATION
CEMENT TYPE(S): DOLOMITE CEMENT
ACCESSORY MINERALS: CALCITE-10%
FOSSILS: BENTHIC FORAMINIFERA

2089 - 2091 LIMESTONE; WHITE TO GRAYISH ORANGE PINK
20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
GRAIN TYPE: CALCILUTITE, BIOGENIC
40% ALLOCHEMICAL CONSTITUENTS
GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE
MODERATE INDURATION
CEMENT TYPE(S): CALCILUTITE MATRIX
ACCESSORY MINERALS: DOLOMITE-20%
FOSSILS: BENTHIC FORAMINIFERA

2091 - 2095	DOLOSTONE; WHITE TO GRAYISH BROWN 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY 10-50% ALTERED; SUBHEDRAL GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO FINE GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT ACCESSORY MINERALS: CALCITE-50% FOSSILS: BENTHIC FORAMINIFERA
2095 - 2100	DOLOSTONE; GRAYISH BROWN TO GRAYISH ORANGE 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY 90-100% ALTERED; SUBHEDRAL GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO FINE GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT ACCESSORY MINERALS: CALCITE-10% FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
2100 - 2105	LIMESTONE; LIGHT GRAY 15% POROSITY: INTERGRANULAR, LOW PERMEABILITY GRAIN TYPE: CALCILUTITE, BIOGENIC 25% ALLOCHEMICAL CONSTITUENTS GRAIN SIZE: MICROCRYSTALLINE RANGE: CRYPTOCRYSTALLINE TO MEDIUM; GOOD INDURATION CEMENT TYPE(S): CALCILUTITE MATRIX ACCESSORY MINERALS: DOLOMITE-10% FOSSILS: BENTHIC FORAMINIFERA
2105 - 2115	DOLOSTONE; LIGHT GRAYISH BROWN 15% POROSITY: INTERGRANULAR, LOW PERMEABILITY 90-100% ALTERED; ANHEDRAL GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO FINE GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT ACCESSORY MINERALS: CALCITE-05%
2115 - 2120	DOLOSTONE; LIGHT GRAY 15% POROSITY: INTERGRANULAR, LOW PERMEABILITY 50-90% ALTERED; ANHEDRAL GRAIN SIZE: MICROCRYSTALLINE RANGE: MICROCRYSTALLINE TO FINE; GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT ACCESSORY MINERALS: CALCITE-15% FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA
2120 - 2130	DOLOSTONE; MODERATE YELLOWISH BROWN 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY 50-90% ALTERED; EUHEDRAL GRAIN SIZE: VERY FINE; RANGE: VERY FINE TO FINE GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT ACCESSORY MINERALS: CALCITE-10%
2130 - 2137	DOLOSTONE; DARK YELLOWISH BROWN TO MODERATE YELLOWISH BROWN 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY 90-100% ALTERED; EUHEDRAL GRAIN SIZE: FINE; RANGE: VERY FINE TO FINE GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT

2137	- 2148	DOLOSTONE; GRAYISH BROWN 15% POROSITY: INTERGRANULAR, LOW PERMEABILITY 90-100% ALTERED; ANHEDRAL GRAIN SIZE: MICROCRYSTALLINE RANGE: MICROCRYSTALLINE TO VERY FINE; GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT ACCESSORY MINERALS: CALCITE-02%
2148	- 2150	DOLOSTONE; LIGHT GRAY TO DARK GRAY 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY 50-90% ALTERED; EUHEDRAL GRAIN SIZE: FINE; RANGE: MICROCRYSTALLINE TO FINE GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT ACCESSORY MINERALS: CALCITE-20%
2150	- 2154	DOLOSTONE; MODERATE YELLOWISH BROWN 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY 90-100% ALTERED; SUBHEDRAL GRAIN SIZE: VERY FINE; RANGE: VERY FINE TO FINE GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT
2154	- 2159	DOLOSTONE; LIGHT GRAY TO DARK GRAY 15% POROSITY: INTERGRANULAR, LOW PERMEABILITY 50-90% ALTERED; ANHEDRAL GRAIN SIZE: MICROCRYSTALLINE RANGE: MICROCRYSTALLINE TO FINE; GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT ACCESSORY MINERALS: CALCITE-10% FOSSILS: BENTHIC FORAMINIFERA
2159	- 2160	DOLOSTONE; DARK YELLOWISH BROWN TO DARK YELLOWISH BROWN 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY 90-100% ALTERED; SUBHEDRAL GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO FINE GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT
2160	- 2166	DOLOSTONE; GRAYISH BROWN 15% POROSITY: INTERGRANULAR, LOW PERMEABILITY 50-90% ALTERED; ANHEDRAL GRAIN SIZE: MICROCRYSTALLINE RANGE: CRYPTOCRYSTALLINE TO VERY FINE; GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT ACCESSORY MINERALS: CALCITE-10%
2166	- 2170	DOLOSTONE; GRAYISH BROWN 25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY 90-100% ALTERED; EUHEDRAL GRAIN SIZE: FINE; RANGE: VERY FINE TO MEDIUM GOOD INDURATION CEMENT TYPE(S): DOLOMITE CEMENT
2170	- 2180	DOLOSTONE; LIGHT GRAY TO GRAYISH BROWN 20% POROSITY: INTERGRANULAR, LOW PERMEABILITY 50-90% ALTERED; SUBHEDRAL GRAIN SIZE: MICROCRYSTALLINE

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                RANGE: MICROCRYSTALLINE TO FINE; GOOD INDURATION
                CEMENT TYPE(S): DOLOMITE CEMENT
                ACCESSORY MINERALS: CALCITE-25%
                FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2180  - 2195    LIMESTONE; VERY LIGHT ORANGE TO LIGHT GRAY
                25% POROSITY: INTERGRANULAR, POSSIBLY HIGH PERMEABILITY
                GRAIN TYPE: BIOGENIC, CALCILUTITE
                80% ALLOCHEMICAL CONSTITUENTS
                GRAIN SIZE: FINE; RANGE: VERY FINE TO GRANULE
                MODERATE INDURATION
                CEMENT TYPE(S): CALCILUTITE MATRIX
                ACCESSORY MINERALS: DOLOMITE-25%
                FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2195  - 2218    LIMESTONE; WHITE
                20% POROSITY: INTERGRANULAR, LOW PERMEABILITY
                GRAIN TYPE: BIOGENIC, CALCILUTITE
                60% ALLOCHEMICAL CONSTITUENTS
                GRAIN SIZE: VERY FINE; RANGE: MICROCRYSTALLINE TO GRANULE
                MODERATE INDURATION
                CEMENT TYPE(S): CALCILUTITE MATRIX
                ACCESSORY MINERALS: DOLOMITE-05%
                FOSSILS: MILIOLIDS, BENTHIC FORAMINIFERA

2218  TOTAL DEPTH
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APPENDIX A-2
SITE GEOLOGIST'S DESCRIPTIONS

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
LITHOLOGIC
PROJECT: C-13 WELL NO: D-1 DATE: 12/14/92

TIME STARTED: 11:00 A.M.

DEPTH (FT)	GEOLOGIC DESCRIPTION
GL (Note)	0-30' Drilled W/Auger, Set 27' of 30" Steel Pit Casing.
0-30	No samples
30-35	Sand, white-tan, med. grained(mg), oolitic, fairly well indurated; carbonate cement shell frags: minor, wht. 10% silty clay.
35-40	Sand, wht, oolitic, shells, minor (more shells than above),less clay fraction.
40-45	As above.
45-50	As above, shells, tr.calcite, more grey silstone.
50-55	As above, increasing grey siltstone 15%.
55-60	Decreasing siltstone 10%.
60-63	As above, chunks of grey siltstone as above.
63-65	Sand, 65% wht-tan as above. 30% silt, grey chunks, mod.indurated. 5% shell & wht chalk.
65-70	Sand, 70% wht-tan to calcite grey silt, as above tr. chalk, shells.
70-75	Sand, as above, less silt.
75-80	Sand and calcite, silt as above.
80-90	Sand 80%, calcite, phosphate nodules and grains.
90-100	No sample.
100-105	Sand and limestone, wht-tan, grey silt, calcite and shell to phosphate, chalk.
105-110	Sand and limestone, tan-grey, well indurated small chunks.

110-115	Oolitic,grey sand: oolitic, tr. chalk.
115-117	Sand and limestone, grey & tan as above, shells, phosphate as above.
117-120	Sand and limestone, tan-grey, tr. phosphate.
120-125	Sand and Limestone, as above.
125-150	Sand and limestone, as above, tr. phosphate, some shells, tr. calcite, chalk. Good amount of chalk and phosphate.
150-153	No sample.
153-155	Limestone and sandy limestone: tan-grey-dk.grey grainy, tr. phosphate, chalk, v.minor trace small shells.
155-160	Limestone and sandstone, as above, more shell, chalk.
160-165	As above, more limstone, chalky.
165-178	Limestone, grey, hard, well indurated, less-no chalk.
178-180	Limestone, dk.grey with fine gr. sandy white limestone, oolitic with some chalk.
180-185	Sandy limestone, dk.grey: tan sandy limestone with traces of phosp. quartz present with small small shell frags.
185-190	As above with more shell frags, also larger shell. Dark grey limestone present. V.hard limestone.
190-195	Sandy limestone, tan to white, with some dark limestone; less frags of shell. Quartz sand present, well rounded grain size.
195-200	As above with specks of phosphate.
200-208	As above.
208-210	Sandy limestone, tan and grey, with calcite. Contains small specks of phosp., grain size, very small with shell frags.
210-215	As above.

215-220	As above, with small frags of cone-shaped shell increase. limestone appears harder.
220-225	As above.
225-230	As above.
230-237	As above.
237-240	Clay, plastic, tan to lt.brown. Sandstone, tan to white. 20% shell, 20% clay, 60% sand and limestone. No phosph.
240-245	As above.
245-250	Sand and limestone, as above 85%, with trace of clay as above.
250-255	Sandy limestone, 90%, dark green with tan lime-stone.(Sand: mg, carbonate cmt. aggregates) small shell frags.
255-268	Sand, 90%, lt.green-dk.green with tan limstone as above, shell frags as above.
268-270	Sand, 90%, caco3 cmt., fine-m.grained, lt.green-grey, tr. phosphate. Shell 10%.
270-298	As above.
298-300	Shell, 60%, green-grey, and tan limestone.
300-305	As above.
305-310	As above, containing green silty clay. Sand and shell; sand: lt.green, caco3 cmt.,f-m gr.,vf-f grn.,grn-hgrn & silt. Some phosphate, tr. clay.
310-332	As above. Grn-dk.grn silty clay.

332-335	Sand and shell;sand with lt.gr. caco3 limestone.
335-340	As above, with tr. phos., tr. clay
340-361	As above.
361-392	Sandy limestone, caco3 cmt., dark green with tan limestone. Tr. phos.
392-395	Clay, silty green,with dark green and tan lime-stone frags. Small specks of phos.
395-400	Shell frags, 90%, with sandy gray limestone, with trace of phosphate and some calcite.
400-405	As above.
405-410	As above, with increased silty green clay.
410-415	Shell frags, 60%, and sandy gray limestone, frags of quartz and tan fine grain limestone with phos. 40% clay: olive silty clay.
415-420	As above, 60% clay, 30% shell, 10% dk.and tan limestone.
420-423	As above, 70% clay, 20% shell, 10% dk.and tan limestone.
423-425	As above, 85% clay, 10% shell, 5% dk.and tan limestone.
425-430	95% silty plastic green clay, with 3% tan lime-stone, and 2% shell.
430-435	As above.
435-440	95% clay, with 5% frags of tan limestone and shell.
440-445	98% clay, with frags of shell and limestone.

445-450	95% clay, with 3% tan and dk.limestone, 2% shell frags.
450-456	99% clay, with tan and dk.limestone.
450-460	Clay: 60%, dk.green, plastic (mod), silty, tr. phosph. Limestone: 30%, sandy, md-cs grained, wht,tan & grey. Shell: 9%, small frags, wht-tan, some whole small clamshells,(buttercup lucines).
460-475	Clay and limestone as above.
475-483	Clay: 80%, more plastic than above. Sandy limestone as above.
483-485	60% silty green clay, 30% intergranular limestone nodules and sandstone, with 5% shell fragments ranging 2 to 4mm in length, 1% whole "buttercup lucine" shells; 4% trace phosphorites.
485-490	As above.
490-500	As above.
500-510	Sandstone, limestone and quartzitic grains , size increase ranging 4 to 6mm in width/length, all contained into a green silty clay matix.
510-515	As above, with increase of grain components 40%, with 50% being silty green hawthorn clay.
515-530	65% silty green phosphoritic clay matrix with 25 to 30% sandy limestone as above.
530-540	As above.
540-545	65% silty, green phosphoritic clay, +/- 30 gray

	to tan limestone as above; chalky, also introducing black angular limestone, platy cleavage.
545-550	55% silty, green phosphatic clay matrix, 30% chalky gray limestone, size 3mm, trace shell fragments along with trace of dark angular limestone.
550-560	As above however, lesser amount of phosphatic specs inside clay matrix. 60% clay green matrix, 25% gray, chalky, limestone, 10% tan to gray oolitic limestone, trace of coquina limestone and dark, angular limestone.
560-565	Increasing amount of soft green silty clay 75 to 80%. 5% oolitic limestone, tan to light gray. Tr. limestone nuggets ranging in size from 3mm to 5mm in length.
565-570	As above.
570-575	As above with an increase in plasticity.
575-580	Clay: light green to milky white, chalky yet less plastic. "Shark tooth".
580-600	Clay: 80%, lt. to med.gray, mod. plasticity. 20% limestone and sandy limestone as above.
600-605	Clay: 95%, as above, more plastic, nodules of adhesive clay. 5% limestone as above.
605-610	Clay: 95%, globular plastic, light green to milky white. 5% limestone grains.
610-615	As above.
615-620	As above.
620-630	As above with lesser degree of limestone chips.

630-640	Clay: 95%, globular plastic, somewhat soupier.
640-650	98% chunky, milky clay with trace of limestone chips.
650-660	As above.
660-670	As above, increase of limestone chips, make up 4%.
670-680	Clay: 97%, light green to milky, decreasing in plasticity, silty.
680-690	As above.
690-700	As above, yet clay comprised of larger size limestone chips, no additional limestone content.
700-710	Clay: gray-green as above, mod. plasticity, little to no limestone of rock.
710-725	Clay: as above, increase slightly in limestone as above, less plastic.
725-730	Clay; 40% gray-green and silt as above, 60% limestone; white-tan, grainy, tr. shell, tr. phosphate.
730-755	Clay: 50%, as above, plastic. Limestone; 45%, white, med. grain, chalky, some subangular, tr. oolitic, mod. well indurated, carb. cmt. Shark tooth, tr. phosphorite.
755-763	As above, increasing limestone, tr. chert or siltstone; olive green, subangular, translucive, 4-6mm, no reaction with acid, hard.
763-770	Clay: comprised of 50% matrix of light green to gray, 40% limestone grains ranging in size from 2mm to 4mm, trace chert fragments, little to no HCL reaction.

770-780	Clay: as above,50%, limestone; white to tan, fine to med. grain, some platy, oolitic trace of phosphate.
780-790	As above, trace chert(platy cleavage).
790-795	Clay: 70%, limestone; 30% as above.
795-824	Clay and limestone as above.
824-830	80% light green plastic clay, 5% fragmented light colored shells, 5% limestone chips, oblong to round, coarse grained, 2% chert chips.
830-840	As above.
840-850	80% light green plastic clay, 10% limesone chips, 5% dark limestone chips, trace chert fragments.
850-855	As above, increase of chert fragements.
855-860	90% clay, green plastic, 10% oolitic limestone nodules, trace of chert.
860-870	As above.
870-875	90% clay, light green, 10% limestone.
875-880	80% clay, light green, plastic. Combination of anthracite; black to brown, semiangular, well indurated. Oolitic limestone; white, med. grain, poorly indurated. siltstone; olive green, mod. indurated, platy, coquina rock.
880-885	90% clay as above, 10% limestone as above, some dark olive limestone, well indurated, cryptocrystalline, hard, angular.
885-890	80% clay light green, plastic. 15% limestone, olive green to light gray, moderately indurated, fine to med. grained, shell molds, tr. shell frag-

	ments, tr. phosphate nodules.
890-900	As above, slight increase in phosphate nodules.
900-905	As above, trace crinoidal stems.
905-915	90% clay as above, 5% siltstone, fragments.
915-920	80% clay, light green, plastic. 5% limestone, light green to tan, moduratelу indurated, med. grain, shell molds, trace of crinoid stems, siltstones; d.brown to black.
920-940	As above.
940-945	80% limestone, light tan-green, med. grain, mod. indurated. 15% clay, light green, less plastic, tr. shell fragments.
945-955	90% limestone, tan to light brown, phosphatic specs, poorly indurated, fine to med. grain. 10% micritic mud, trace snail molds.
955-965	50% carbonaceous mud, slightly plastic, tan to green. 50% limestone as above.
965-970	80% limestone, tan to light olive green, fine grain, poorly indurated. 20% carbonaceous mud as above, tr. phosphate, tr. shell.
970-975	80% limestone, as above, abundant phosphate specs, 20% mud as above.
975-985	90% limestone, tan-lt.green, med. grain, poorly indurated, tr. phosphate, 9% clay as above, tr. shell frags, tiny disk-shaped leps, crinoid stems, shark tooth.
985-990	90% limestone, as above, shell molds, increasing tiny disk leps, tr. crinoids as above.
990-995	100% limestone, as above, 10% white limestone; fairly well indurated, fine grain, tr. tiny leps as above, tr. shell frags.
995-1000	100% limestone, 60% white, 1/2 fine grained, mod. indurated, 1/2 cryptocrystalline, angular, hard, tr. wishbone coral, 20% tan-lt.green as above, 10% coral and crinoids.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
LITHOLOGIC
PROJECT: C-13 WELL NO: D-1 DATE:1/25/93

DEPTH (FT)	GEOLOGIC DECRIPTION
1000-1005	Limestone: 100% Mixed, olive green-green; hard micro crystalline, some conchoidal fractures, angular, subangular, hard, no porosity black:hard, sub-rounded and dense. White, hard-mod.hard, shell molds, biogenic, no chalk or silt. Tr. clay:from above, tr. cement:from grouting.
1005-1008	Limestone: 90% wht-lt.gray, biogenic, abundant crinoid, shell molds. Med-coarse grained, friable, no visible leps or cones, tr. silt, wht.
1008-1018	Limestone: 100% wht to lt.gray med grained, mod. friable shell molds, shark teeth, criniods, small shells(misc), possible tr. leps.
1018-1025	Limestone: 100% med.-dk.gray, hard, slow drlg., crystalline, some solution vugs and moldic porosity, tr.shell molds, tr. calcite,tr. snail.
1025-1030	Limestone as above 80%, limestone: 20%; m.-dk.gray dense, hard, tr. shell molds, calcite a.a., tr. crinoids.
1030-1035	Limestone: 85% dk.gray: sucrosic, hard; black specks, indicative of carbonaceous reducing environment, blk.specks resemble phosphate specks, tr. crinoids, tr. shells.
1035-1038	Limestone: 10% m-dk.gray as above, 5% wht.silty clay, carbonaceous.
1038-1040	As above.
1040	Limestone: lt.orange "Avon Park" dictyoconus, crinoids, sand dollars, etc.
1040-1050	Limestone: 100% pale orange, med. grained, mod. friable, numerous buttons up to 3/4" dia., dictyoconus numerous, crinoids, shell molds moderate-high silt fraction; good intergan porosity.
1050-1060	As above, becoming slightly finer grained, more silty, trace fossils as above.

1060-1065	Limestone; lt.tan-pale orange(lees orange than above), finer grained, lots of small cones.
1065-1068	As above, 85%, 10% limestone: dk.gray-blk.; microcrystaline, platy, hard.
1068-1080	Limestone: wht-tan-pale orange, oolitic, grainy, fairly well indurated, oolitic silty-sand component washing through screen, low perm, buttons and cones.
1080-1090	Limestone: pale orange, oolitic, fairly well indurated, intergran porosity, low perm component, much more indurated, cones.
1090-1100	Limestone: wht-tan, vf.g, silty-chalky, low perm, buttons and cones a.a.
1100-1103	Limestone: tan-light shade of pale orange; f.g., silty, oolitic, mod. indurated, low perm.
1103-1105	Limestone: lt.shade pale orange-tan; well indurated m.g., less silt, large button, pin-point, and moldic porosity.
1105-1110	50% limestone as above; 50% limestone; dk.gray-blk, microcrystalline, hard platy cleavage.
1110-1115	Limestone: lt.gray, v.hard, cryptocrystalline, angular, large fragments, some pin-point porosity, low-no silt. 10% black-gray limestone as above increased porosity here.
1115-1120	Limestone: tan-lt.gray, well indurated, vuggy, pin pt. porosity, prob. low perm due to silty component.,tr. snails, sanddollar buttons, shell frags.
1120-1125	Limestone: 80% tan-lt.orange, f-med. grained,mod-well indurated, siltstone: 20%, dk.gray-blk. platy cleavage, well indurated, tr. crinoid stems, buttons.
1125-1130	Limestone: tan-pale orange, f-m. grained, very gritty almost sandy, lots of silt and fines, low perm, well cemented rounded aggregates with v.fine caco3 cement.
1130-1140	Limestone: as above, v.silty, low perm.
1140-1150	Limestone: white-lt.tan, mostly granular, f-med. grained, partly(10%) crystalline, tr. small cones.

1150-1160	Limestone: bright white, v.well indurated,to crystalline, shell molds present, discharge milky white and silty, increase to abundant small-med. cones in last few feet. Cones and buttons.(Wht-tan silt f-vf.g. to calcareous ooze in pit).
1160-1170	Limestone: tan-lt.brown, well indurated, m. grained tr. cones.
1170-1175	Limestone: tan-pale orange, well indurated, pin-point porosity, cones, hard.
1175-1180	Limestone: lt.tan-white, semi-platy, well indurated some portion(40%) crystalline, chalky silt in water, low-no perm
1180-1193	Limestone: wht. 80%, well indurated as above, and siltstone (20%), blk.-dk.gray, no fizz HCL, hard, platy.
1193-1200	Limestone: 80%, light shade of pale orange-tan, well cemented, v.fine grain, powder like matrix (not crystalline), mod. hardness, tr. shell molds and worm burrows, no perm or appreciable porosity. Limestone: 20%, white, semi-crystalline to mod. indurated, m.grained full of white silt and f.g. sandy carbonate mud. Tr. cones, tr. calcite. Lt. orange silt and carbonate ooze(mud)in discharge.
1200-1215	Limestone: tan-pale orange and white limestone as above.
1215-1221	Limestone: 98%, tan-v.pale orange as above, 2% wht. limestone as above, a lot of silt and cloudiness in discharge a.a.
1221-1230	Limestone: tan-lt.brown, poorly mod. indurated, vf. f.grn., tr. shell molds, partial snail molds, no visible cones, abundant silt and calc. ooze, v.low-no perm.
1230-1251	Limestone: as above.
1251-1270	Limestone: as above. All could be called calcare-nite, mg indurated-silty calcareous grains, low-no perm.
1270-1285	Limestone: 90% as above, siltstone: 5%, blk.dk. gray, fissile, platy, lt.wt. not v. dense, lots of calcareous mud with silt as above. Low-no perm.

1285-1290	Limestone: 100%, tan-pale orange, calcarenite as above, mod. indurated, small cuttings, abundant cones, lots of silt and calc. mud in discharge.
1290-1295	Limestone: tan as above, less orange, 5% trace siltstone; blk. as above, buttons.
1295-1305	Limestone: 30%,as above, 70% siltstone: v.light, low density, like gravel, black when wet, gray gravel bed. Blk.-gray silt and fines in discharge.
1305-1315	Limestone: 100%, tan-pale orange as above, v.silty. cones, buttons,tr. white chalk, prob. low perm due to silt in discharge.
1315-1325	Limestone: 80%, tan-calcarenite, small cuttings, abundant cones, tr. buttons, silty and low perm. Limestone: 20%, coal blk.-dk.gray, crystalline, well indurated, low-no porosity, milky silt in discharge.
1325-1330	Limestone: 95%, tan-lt. orange calcarenite as above 5% blk. limestone a.a., milky silt in discharge, cones.
1330-1335	Limestone: 85%, tan-lt. orange as above, 30% of the 85% is well indurated-crystalline, harder, trace of white chalk, milky silt in discharge. 15% dk.gray clay, plastic, in clumps, abundant cones.
1335-1345	Limestone: 95%, tan-lt. orange as above, mostly calcarenite, some crystalline ext. well indurated nodules, 5% wht. chalk-clay, tr. cones.
1345-1355	Limestone: as above.
1355-1365	Limestone: 30% as above, 70% black-dk.gray poorly indurated limestone with some well indurated gray and black, evidently organic in deposition, grain size range from med.-v.fine, mostly fines. Dk.gray sand and silty calcareous mud, v.fine grains, proceeded by long discharge of silt and clay size carbonate mud, and sand. No siliceous sand, all carbonate. V. low perm., organic deposit.
1365-1375	Limestone: 95%, tan-pale orange calcarenite, abundant cones, mod. well indurated, 5% limestone dk.gray-black as above, silty fraction in discharge.

1375-1380	Limestone: tan-pale orange as above, mostly silt, fine grains, low perm.
1380-1385	Limestone: 90%, coal blk., micrite, appears organic in origin, well cemented, mod. well indurated, abundance of blk. silt in discharge. Low perm. 10% tan limestone as above.
1385-1390	Limestone: 50%, tan-pale orange as above, buttons. Limestone: 45%, gray, mod. indurated, f.-m. grained low perm., calcarenite. 5% white chalk, tr. cones.
1390-1400	Limestone: lt.gray-tan, calcarenite, f-m. grained, poor mod. indurated, some shell molds, silty with tr. of chalk. Low-no perm. 5% dk.gray-black limestone as above, tr. cones.
1400-1405	Limestone: 40%, lt.gray-tan as above. Limestone: 60%, m.gray, hard, cryptocrystalline, pin holes, tr. calcite, poss. healed fractures or solutioning.
1405-1410	Limestone: calcarenite, tan-cream, v. silty, gritty low perm.
1410-1420	Limestone: as above with 25% blk.gray limestone calcarenite.
1420-1430	Limestone: 70%, med.dk.gray with some black, hard, fissile and granular, mod. indurated, low perm. 30% limestone: tan-cream calcarenite as above.
1430-1435	Limestone: tan-cream, v. hard cryptocrystalline, platy cuttings resulting from slow drilling, no visible porosity, no calcite, no cones.
1435-1440	Limestone: tan-cream, calcarenite, gritty, f-m. grained, mod. indurated cutting pieces, abundance of silt and carbonate mud. Low perm.
1440-1445	Limestone: Lenses of tan-cream limestone as above and lt-med.gray limestone, mod. well indurated, f-vf. grain calcarenite, some well cemented, mostly silt and sand size. Low perm.
1445-1450	Limestone: 85%-95%, tan-cream as above, +/- 10% gray clay, mod. plastic, abundant silt, snails.
1450-1460	Limestone: as above, no clay, 15% gray limestone. Cream and gray calcarenite mix, v. gritty, silty limestone, tr.(5%) of hard gray limestone, fissile and platy, hard.

1460-1470	As above.
1470-1475	Limestone: gray, f-m. grained calcarenite, gray silt in discharge, seem impermeable, intergran porosity, poor-mod. indurated, tr. shell frags, tr. cones, extremely silty.
1475-1485	Limestone: 50%, gray as above. 40% limestone, tan, 1/2 is f-m. grained calcarenite, soft, 1/2 is well indurated, hard, fossiliferous limestone, buttons and cones abundant. Mod. silty. 10% hard, well indurated, limestone, gray, moldic and pin-point porosity.
1485-1490	Calcarenite 80%, tan, f-m. grained, poorly-mod. indurated, 20% gray calcarenite as above, mod. silty.
1490-1500	Limestone: 95%, white,pale tan calcarenite f-m. grained, chalky, extremely silty, 10% gray shale, hard, fissile.
1500-1505	Limestone: white-pale tan, harder than above, cryptocrystalline, pin hole porosity, some vugs and solutioning, good porosity, platy, dense.
1505-1520	Limestone: white tan, interbeded hard, fissile, platy limestone and f-m. grained calcarenite, abundance of silt in discharge, no fossils, mostly calcarenite.
1520-1530	Limestone: dark tan-light brown(coffee color), hard, cryptocrystalline, platy, no apparent porosity, no calcite, prob. dense.
1530-1534	Limestone: white tan, v. silty, soft, poorly indurated calcilutite and calcarenite, chalky, low-no perm., tr. buttons.
1534-1545	Limestone: white, interbeded 50/50 of 50% f-m. grained calcarenite with tr. of chalk, abundance of silt in discharge, low perm., intergran porosity, 50% well indurated, cryptocrystalline, hard, no visible porosity, tr. cones.
1545-1550	Limestone: 80%, tan-cream, hard, platy, crypto-crystalline, no visible porosity, tr. chalk. Lime-stone 20%: f-m. grain calcarenite as above.
1550-1555	Limestone: 70%, f-vf. grained, f.g. calcarenite, poorly-mod. indurated, intergranular porosity, poss. perm., cones and forams abundant. Siltstone: 30%, dk.gray, platy, no perm.

1555-1560	Limestone: 90%, white f.g. calcarenite, 10% chalk and silt, low-no perm. as above. 10% siltstone, gray as above, tr. forams as above.
1560-1565	Limestone: tan-white, f-med. grain calcarenite, slightly more indurated than above, some tan-pale orange, button frags., not as grainy, less silt than above. Tr. buttons.
1565-1570	Limestone: tan, moderately to well indurated,v.f.-fine grained, some intergranular porosity, hard, tr. white and greenish blue chalk and clay.
1570-1575	Limestone: tan-gray as above, tr. chalk, cones and forams as above.
1575-1580	Limestone: as above, more tan-cream, increasing siltyness and chalk.
1580-1585	Limestone: bright white,pinhole porosity,worm burrows, v. hard, platy, angular, crypto-crystalline, fair porosity, tr. forams.
1585-1590	Limestone: 90%, white as above. 10% siltstone, gray, mod. well indurated, less silt than above, tr. forams as above.
1590-1593	Limestone: wht. to tan, v.f.-fine grained, calci-lutite, poorly indurated, chalky and silty. 5% siltstone dk.gray as above, tr. forams, disks.
1593-1595	Limestone: tan-brown(mocha), v.f.-fine grained, poorly indurated, silty. 10% buttons and forams.
1595-1605	Limestone: tan, f.-v.fine grained calcarenite , poorly indurated, poss. intergran porosity, tr. chalk, tr. buttons.
1605-1610	Limestone: white-tan as above.
1610-1615	Calcareous sand and silt, tan-lt.brown, unconsoli-dated, v.f.-fine and med. grained, poorly sorted, tr. chalk, abundance of small buttons, poor perm., soft.
1615-1620	Calcareous sand and mud, med.-dk.gray, finer grained than above, v.f.-fine grained, poorly sorted, organic deposit, black coal-like nodules, low-no perm., soft.

1620-1623	Calcareous sand, gray-tan and black, poorly sorted, silty, coarser grained than above.
1623-1627	Limestone: 90%, mostly tan, some gray, blk. and white, poor mod. indurated, f.-med. grained calcarenite, abundance of disks and cones.
1627-1635	Limestone: 90%, tan, some dark and light colored, mod. indurated, fine to med. grained. +/- 5% siltstone, gray to dark, fine grained.
1635-1640	As above, tan, tr. forams.
1640-1645	Limestone: 90%, tan to white, medium grained, mod. induration. Tr. forams.
1645-1650	Limestone: 90%, tan to white, moderately indurated, calcilutite, calcarenite,+/- 5% forams, disk shape, tr. chalk, tr. silt.
1650-1653	Limestone: 90%, tan to brown, mod. to well indurated, silty, chalky, light colored, tr. forams.
1653-1658	Limestone: 90%, tan, moderately indurated, calcarenite with some calcilutite, +/- 5% siltstone, gray, poorly indurated, fine grained, tr. forams.
1658-1665	Limestone: dark gray and black organic deposit, tr. chalk, v.f.-fine grained calcarenite, low perm, abundance of silt.
1665-1670	Limestone: tan-cream, calcilutite 50%, calcareous sand and silt 50%, abundant forams and cones.
1670-1690	Limestone: 50% gray, 50% tan as above.
1690-1700	Limestone: tan-cream, v.f.-fine grained calcilutite poorly indurated, abundance of silt, low perm., abundant forams,cones, snails, disks and buttons, 5 to 10% gray limestone as above.
1700-1703	Limestone: blk.-dk.grey, fissile, hard, platy, cryptocrystalline, no apparent porosity, small tan disks, forams.
1703-1708	Limestone: 70%, blk.-dk.gray as above, 30% tan-gray calcilutite, abundance of silt.
1708-1715	Limestone: tan-cream, hard, platy angular, dense, no visible porosity, low silt and sand content, potential perm., no calcite.

1715-1721	Limestone: lt-med.gray, f. grained calcarenite, poorly indurated, sandy calcareous mud, low perm., tr. forams.
1721-1725	Limestone: dk.gray, mod-well indurated, f-med. grained calcarenite, angular subrounded. 5% tan calcarenite as above with cones and forams, low silt content.
1725-1730	Limestone: beige-lt.tan, poorly-mod. indurated f.-v.f. grained calcarenite and calcilutite, low silt and chalk component.
1730-1735	Limestone: tan-cream to pale orange v.f.-f. grained calcarenite, abundant cones, silty.
1735-1740	Limestone: mostly gray with 20% black and 20% tan limestone as above, gray limestone 60%, floor rock-v.f. grain calcilutite black limestone, more well indurated.
1740-1745	Limestone: 90%, gray, poorly indurated, fine to med. grained calcarenite and calcilutite nodules, siltstone +/- 5% dark, poor-mod. indurated, tr. tan forams.
1745-1750	Limestone: 90%, gray, poorly indurated, fine to med. grain, calcilutite, tr. light gray chalk.
1750-1755	Limestone: 95%, tan to slightly gray, calcarenite with some moldic porosity of darker colors.
1755-1760	Limestone: 90%, tan to slightly gray, fine to med. grained, moldic porosity, +/- 5% white to tan forams.
1760-1765	As above with increase of forams.
1765-1770	Limestone: tan, as above, siltier.
1770-1775	Limestone: 90%, tan, silty, poorly indurated calcilutite, intergranular with some darker calcarenite limestone. 5% tan forams with tr. of conus species.
1775-1780	Limestone: 90%, tan to white, chalky, moldic, calcarenite/calcilutite, moderately indurated with dark colored limestone chips. 10% forams.
1780-1785	Limestone: 95%, large, moldic, floury, poorly indurated, light gray. Siltstone 5%, dark, large, platy.

1785-1790	Limestone: 90%, tan to light gray, moldic fine grain, floury, poorly indurated with some chalk.
1790-1795	As above.
1795-1800	Limestone: 80%, dark, well indurated, crystalline, dark forams in with lighter color limestone and chalk.
1800-1805	Limestone: 90%, light gray to tan, intergranular and moldic, calcarenite, calcilutite in a fine grain soupy/chalky matrix.
1805-1810	Limestone: 95%, light tan to brown, intergranular, moderately indurated calcilutite. 5% tan to brown forams with conus speciation.
1810-1815	Limestone: 95%, light tan to brown, intergranular porosity, poorly indurated, fine to v.fine grain. 5% tan forams, tr. siltstone.
1815-1820	Limestone: 90%, yellow-brown to gray, poorly cemented to moderate fine grain. 5% forams, tan, cylindrical, disc shaped.
1820-1825	Limestone: 80%, yellow-brown to gray, poorly cemented to moderate fine grain, calcilutite. Dolomite; 20%, gray cryptocrystalline, well indurated, calcarenite.
1825-1830	Limestone: 95%, yellow-brown, poorly cemented to moderate, fine grains, calcilutite. Tr. dolomite chips and forams.
1830-1835	Limestone: 90%, tan to light gray, poorly to moderately cemented. Tr. of dolomite and forams. Dolomite chips, crypto. to finely crystalline, gray, well indurated.
1835-1840	Limestone: 85%, yellowish brown to light gray, poorly cemented calcilutite. Some gray silty clay. 5% dolomite, gray, cryptocrystalline, well indurated, some forams.
1840-1845	As above.
1845-1850	Limestone: 100%, light gray to gray, calcarenite, well indurated, fine to moderate grain, some chalk.
1850-1855	Limestone: 90%, light gray to gray, calcilutite, calcarenite, fine graining. Siltstone; 10%, dark, ultra-fine grain, uncemented, poorly indurated.

1855-1860	Sandy limestone: 95%, tan to brown, v. poorly indurated, intergranular, nodule and platy. Limestone: 5%, white chips, moderately indurated, calcarenite.
1860-1865	Sandy limestone: 95%, tan to brown as above in a silty, tan-like matrix soup.
1865-1870	Sandy limestone: 95%, tan to brown as above mixed with white and dark limestone chips.
1870-1875	Sandy limestone: 80%, tan, limestone well cemented, as above. 10% gray chalk, gritty, clayey. 10% limestone chips, gray, calcarenite, moderately indurated.
1875-1880	Limestone: 90%, brown, calcilutite, moldic, mod. indurated, fine to medium grain. 10% coal; soft, black, oily, ultra-fine grain.
1880-1883	Limestone: 100%, tan to lt.brown, moldic, vuggy, uniform grain size, calcilutite, moderately to well indurated.
1883-1885	Limestone: 90%, fossilized, black, fossiliferous, coal-like, ultra-fine to fine grain, poorly indurated. 5% limestone; tan calcilutite, vuggy, well indurated. Tr. tan and black forams.
1885-1888	Limestone: 100%, white, to tan to gray, to dark, calcilutite, moldic, fossiliferous, poorly to well indurated, with the dark black limestone being sucrosic in texture.
1888-1890	Limestone: 100%, light gray to gray, moldic, vuggy, moderately indurated, calcilutite.
1890-1892	Limestone: 100%, gray to dark gray, moldic porosity vuggy, por to moderately indurated, calcilutite.
1892-1894	Limestone: 100%, as above with some calcarenite chips.
1894-1900	Limestone: 90%, gray, calcilutite, moldic porosity, sucrosic. 10% dolomite; dark, crypto-crystalline, well indurated, fine grain.
1900-1905	Limestone: white to very light gray, chalky, sucrosic, fine grained, silty chalk. Silty clay, gray, ultra-fine grain.

1905-1910	Limestone: 70%, white-lt.gray, as above. 20% tan limestone; carcarenite, vf.-f. grained, poorly-mod. indurated. 10% siltstone; dark grey,fissile, poorly mod indurated, tr. cones and forams.
1910-1920	Limestone: 100%, lt.gray calcilutite, vf.-f. grain, poorly-mod. indurated, no tr. cones or forams, poss. intergran. porosity, abundance of silt and clay particles, low-no perm.
1920-1930	Limestone: lt.tan, vf. grained calcilutite, abundant cones, disks and forams.
1930-1934	Limestone: lt.gray-tan calcilutite, vf. grain, v. silty and fine, murky discharge, low perm., abundant gray-tan cones.
1934-1938	Limestone: harder, med.-dk.gray, poorly sorted "rubble" character, assorted small and large(3/4") aggregates, moderately indurated calcarenite, f.g. vuggy, moldic. Some light tan v. well indurated limestone with abundant pinhole porosity and vugs, poss. worm burrows, tr. disk forams and chalk, low silt,cones.
1938-1940	Limestone: 100%, light gray, moderately indurarated vuggy, med. grain.
1940-1945	Limestone: 95%, light to dark gray, moderately to well indurated, light gray limestone; vuggy cal-cilutite, dark gray limestone; well indurated, fine grain, chalky gray clay 5%.
1945-1950	Limestone: 100%, light gray to tan as above.
1950-1955	Limestone: 100%, tan to light brown, vuggy, mod. to well indurated, calcilutite with tr. of gray calcarenite limestone chips.
1955-1970	As above.
1970-1975	Limestone: light gray, poorly indurated, sucrosic, ultra-fine to fine grain, calcilutite.
1975-1977	Limestone: tan, hard, well indurated, intergranular with some dark limestone chips, fine grain, well indurated.
1977-1980	Limestone: light gray to dark gray; 100%, angular, platy, well indurated, fine grain, hard.

1980-1990	Limestone: white to lt.tan calcilutite 90%, v.f.g., poorly indurated, chalky, silty, no perm, tr. cones, disks forams. 10% gray limestone as above.
1990-1999	As above.
1999-2005	Limestone: 90%, tan to lt.gray, poorly indurated, calcilutite, fine grain, sandy residue. Sandy limestone; 5%, tan, platy, sucrosic to gritty.
2005-2010	Limestone: 90%, gray to lt.gray, poorly indurated, fine grain, confining texture qualities, calcilutite.,with some calcarenites.
2010-2015	Limestone: 95%, light gray to tan, poorly indurated sandy grain(sucrosic), no permeablity.
2015-2025	As above.
2025-2028	Limestone: 80%, gray to dark gray, mottled, angular dolomitic, well indurated. Dolomite; dk.tan, hard, platy, cryptocrystalline, tr. brown, tr. pinhole porosity and calcite inclusions, low porosity.
2028-2032	Dolomite: 95%, brown, angular, well indurated. Limestone; 5%, light gray as above, no visible porosity, iron color stain on flat side of cuttings, platy, hard.
2032-2040	Limestone and dolomite: dolomite; as above 50%. Limesand; 50%, lt.tan unconsolidated v.f.-f.g. calcareous sand, silty, low-no perm., abundant cones.
2040-2045	Limesand and limestone: light tan limesand and stone as above, poorly indurated, abundant cones and disks, tr. of browngray dolomite as above.
2045-2050	Limestone: 80%, tan, poorly indurated, fine grained calcilutite. Dolomite; 20%, brown, platy, no porosity, some calcite inclusions, angular, hard.
2050-2060	Limestone: 90%, tant poorly indurated, fine grain, calcilutite. Limestone; 10%, light gray, poorly indurated, ultra-fine grain.
2060-2082	Limestone: as above.
2082-2085	Dolomite: dark brown, hard, mostly platy, some angular , no visible porosity, cryptocrystalline.
2085-2087	Dolomite: 100%, dark gray, hard, platy, no visibly porosity, cryptocrystalline and angular.

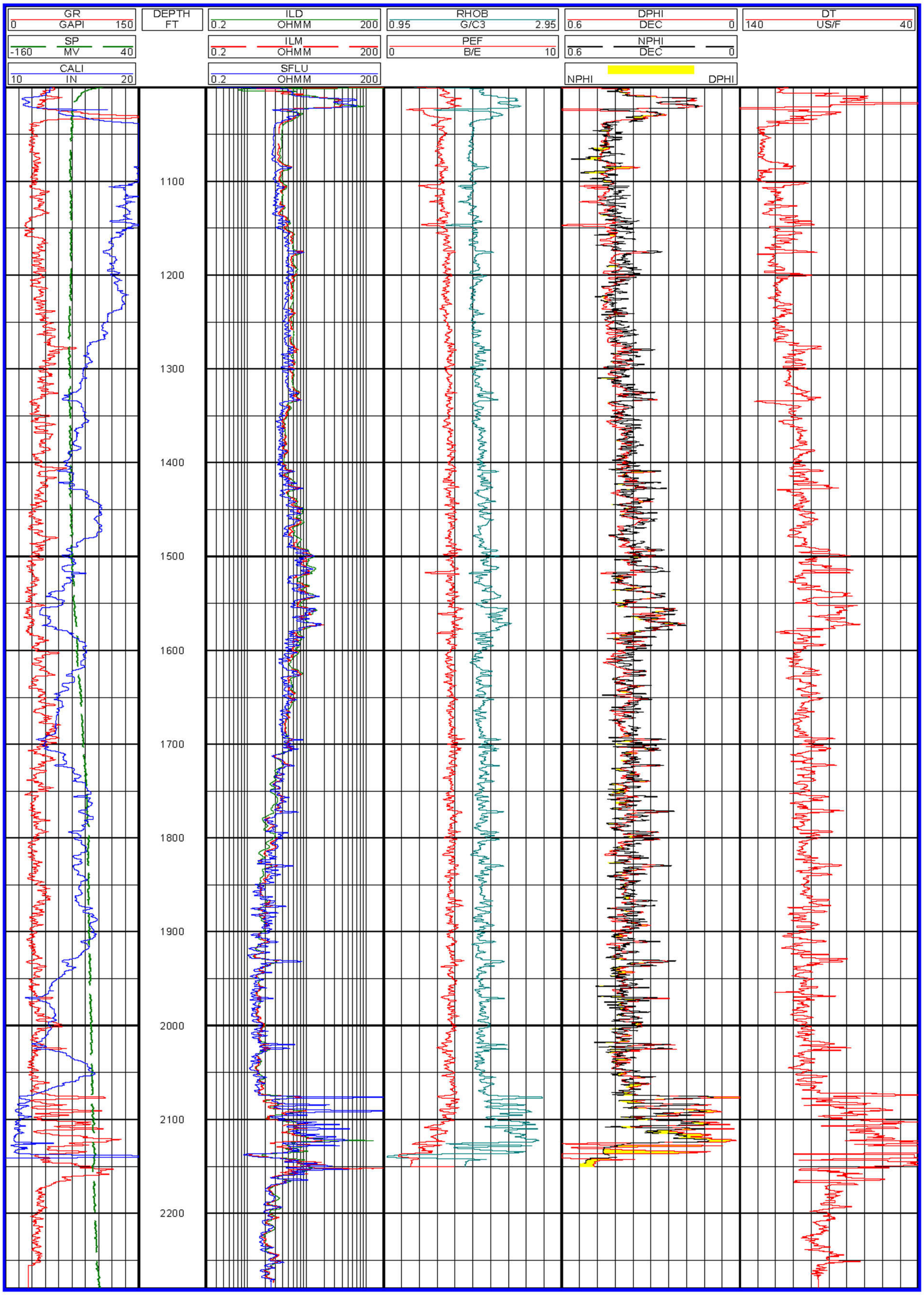
2087-2088	Dolomite: 100%, dark gray to brown, angular, no visible porosity, cryptocrystalline, angular.
2088-2090	Limestone: 100%, poorly to moderately indurated, ultra-fine to fine grain, white to tan.
2090-2095	Limestone: white lt.-tan, poorly indurated, v.f.-f.grain, 10% dolomite as above.
2095-2100	Dolomite: lt.brown, platy, hard, cryptocrystalline, some dark brown, some pinhole porosity, low porosity, well indurated.
2100-2105	Dolomite: med. dark gray, platy, fissile, hard, tr. concoidal fractures, tr. vugs, low visible porosity.
2105-2110	Dolomite: dark brown, hard, platy-angular, low-no porosity.
2110-2115	Dolomite: dark gray, platy, hard, cuttings v. small with no visible porosity, however one large +/- 2" long piece had obvious sucrosic pinhole porosity (vesicular), v. porous and permeable. Also tr. dark brown dolomite, v. porous, v. perm., friable.
2116-2117	Note: 1 foot void between v. hard rock. Drill rod fell abruptly(cavity).
2115-2120	Dolomite: 50%, dk.gray-blk. to dark tan, sucrosic, extremely porous, angular-subangular, sponge-like. Also same color dolomite 50%, platy, fissile, hard, no porisity, 1 to 2' stringer of limestone, white-lt. tan, calcilutite, fairly indurated, low perm. and porosity.
2120-2130	Dolomite: brown, hard, alternating platy and subangular, sucrosic, porous, vuggy.
2130-2137	Dolomite: black and brown, brown; sucrosic and porous. Black; dolomite, low porosity, hard platy.
2137-2148	Dolomite: 80%, lt.brown-dark tan, alternating hard, fissile, platy, cryptocrystalline. Dolomite; brown to dark gray, sucrosic, poorly to mod. indurated, sponge-like porosity, color grades from med.lt. brown to gray.
2148-2150	Dolomite: 50%, med.dk.gray, hard, platy-subangular, dense, no visible porosity, cryptocrystalline. Dolomite; 50%, black, sucrosic, slightly vuggy, crystalline, hard, well indurated.

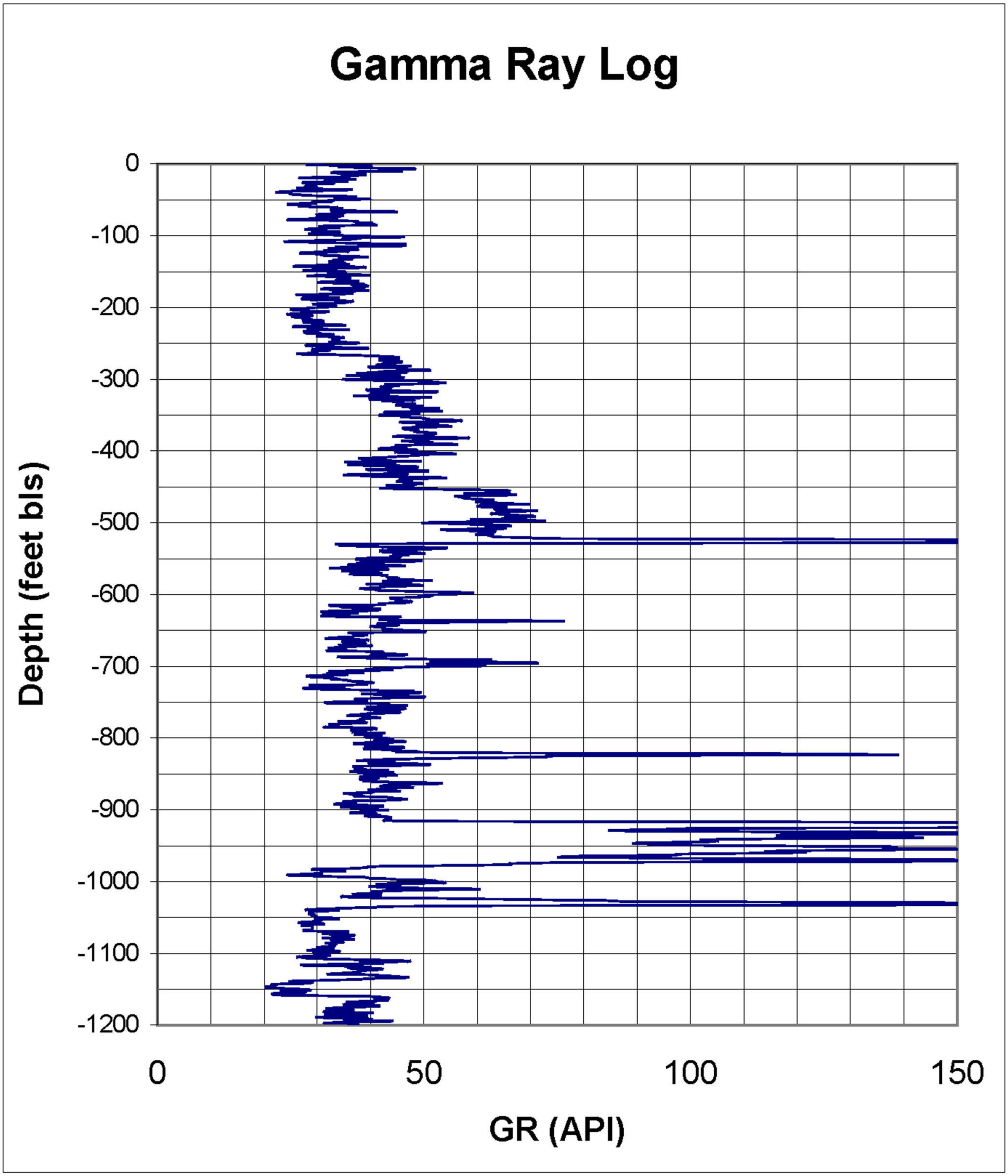
2150-2154	Dolomite: tan-lt.brown, sucrosic, mod.-well indurated, sponge-like porosity, v. porous, as above tan dolomite.
2154-2157	Dolomite: 100%, brown to lt.gray to gray, cryptocrystalline, platy, with some sucrosic specimens, salty taste, well indurated, sponge-like, hard.
2157-2159	Dolomite: 95%, black and gray to dk.gray, finely crystalline, platy, pinhole porosity, hard, well indurated, mottled. Dolomite 5%, tan, lustery.
2159-2160	Dolomite: 50%, tan-lt.brown, sucrosic, lustery, v. fine grained, mod. indurated, pinhole porosity, very porous and some hard, crystalline, no visible porosity. 50% dk.gray-black, mottled dolomite, crystalline, pinhole porosity.
2160-2162	Dolomite: lt.brown-tan and gray with some black and white, hard, platy, cryptocrystalline, pinhole porosity, tan-gray dolomite has calcite filled vugs and inclusions.
2162-2175	Dolomite: lt.orange-brown, 1/2 no visible porosity, platy, angular, cryptocrystalline, 1/2 brown dolomite is sucrosic, high porosity, mod. indurated. 10% gray dolomite, 5% black coal, friable, black residue.
2175-2180	Dolomite: 70%, lt.orange to brown, some pinhole porosity, well indurated, sponge-like. 20% white limestone calcilutite, poorly indurated, fine grain. 10% black coal, soft, oily residue.
2180-2185	Limestone: 60%, white, poorly indurated, ultra to fine grain, oolitic, tr. cones, echinoderms. 40% dolomite; brown to gray, hard, no visibly porosity, platy.
2185-2218	Limestone: pale-white to white-tan, v. chalky and f.g., poorly indurated, low-no perm., tr. cones, abundant echinoderms(sea biscuits) from 1/4" to 3/4" in diameter, oval, round.
2218 T.D.	

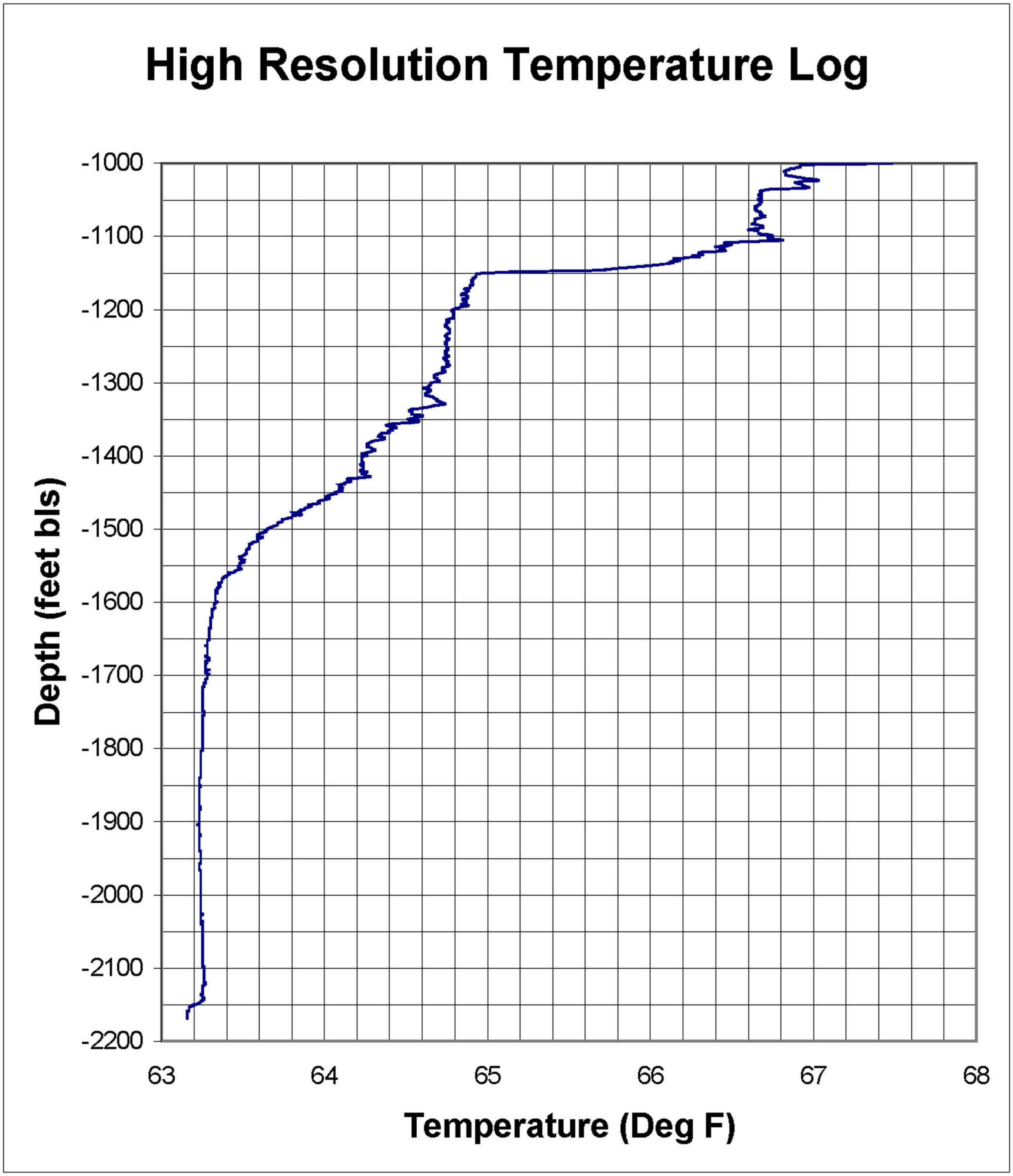
APPENDIX B- GEOPHYSICAL LOGS

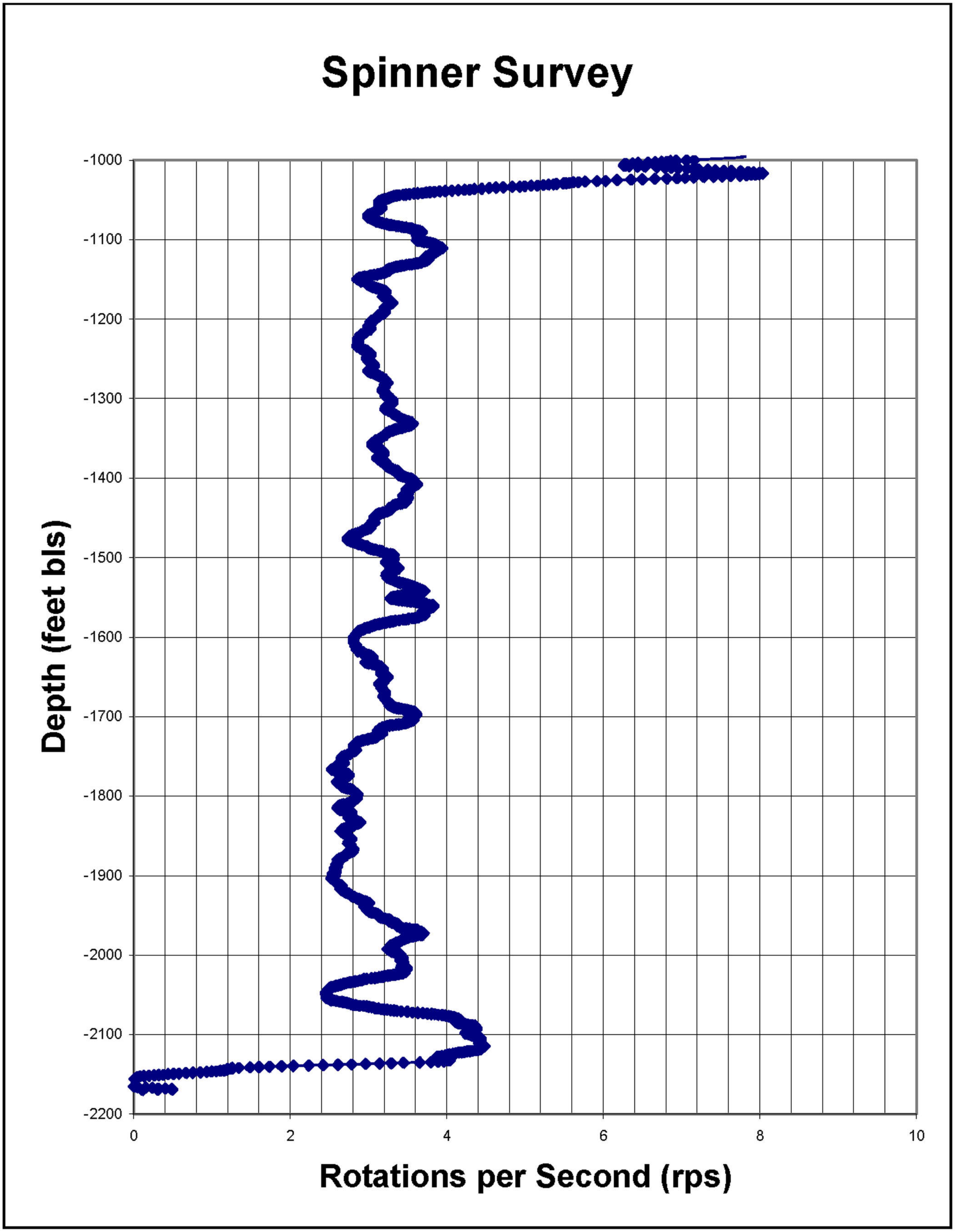
Legend for Geophysical Log Traces

CALI	caliper
cps	counts per second
dec	decimal fraction
DegF	degrees Fahrenheit
DT	delta transient time
FLOWD	flowmeter dynamic
FT	feet
API	gamma American Petroleum Institute
GR	gamma ray
RILD	deep induction log
RILM	medium induction log
in	inches
LAT6	lateral – 6-foot resistivity
NPHI	neutron porosity
OHMM	ohm-meters
RES16	normal resistivity (16-inch)
RES64	normal resistivity (64-inch)
RLL3	shallow focused resistivity
TEMPG	temperature gradient
USEC	microseconds per foot
XCAL	x-caliper
YCAL	y-caliper


GR
0 GAPI 150
SP
-160 MV 40
CALI
10 IN 20
DEPTH
FT
ILD
0.2 OHMM 200
ILM
0.2 OHMM 200
SFLU
0.2 OHMM 200
RHOB
0.95 G/C3 2.95
PEF
0 B/E 10
DPHI
0.6 DEC 0
NPHI
0.6 DEC 0
NPHI DPHI
DT
140 US/F 40
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200


Gamma Ray Log
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-1100
-1200
Depth (feet bls)
0
50
100
150
GR (API)


High Resolution Temperature Log
Depth (feet bls)
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-1900
-2000
-2100
-2200
63
64
65
66
67
68
Temperature (Deg F)


Spinner Survey
Depth (feet bls)
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-1900
-2000
-2100
-2200
0
2
4
6
8
10
Rotations per Second (rps)

APPENDIX C – PACKER TEST DATA SHEETS AND ANALYSES

PACKER TEST NO. 1 (2,120 – 2,142' BLS)

Background Data		
Packer Test No.: 1	Date:02/17/93	Interval Tested: 2120 - 2142 ft
Static Water Level (G.L.) before pumping: -1.6 ft		After Recovery: -1.6 ft
Measuring Point Distance to Kelly Bushing: +2.1 ft TOC		
Distance from G.L. to Rig's Kelly Bushing: 10.0 ft		
Maximum Drawdown During Pumping: 14 ft with pipe loss, 0.2 ft aquifer loss		
Total Pumping Time: 120 minutes		Average Pumping Rate: 110 gpm
Min. Pumping Rate: 100 gpm		Max. Pumping Rate: 120 gpm
Pump Type: 4" submersible, 3 hp		
Depth to Pump Intake from Kelly Bushing: 100 ft		
I.D. Drill Pipe: 3.5 in	Tester: Baker	Driller: R.S.T. Inc.
Hermit #		
Input #1 Transducer #: 3047	Range: 30 psi	Depth: 70 ft below W.L.
Input #2 Transducer #: 137	Range: 10 psi	Depth: 20 ft below W.L.
Time Pumping Started: 1510	Time Pumping Ended: 1710	Total Pumping Time: 120 min
Aquifer Analysis		
Transmissivity:	Hydraulic Conductivity:	
Method of Analysis:		
Software Used: AQTESOLV		
Specific Capacity: 550 gpm/ft		
Friction Loss (Observed): approx. 13.8 ft		
Static Head:-1.6 ft G.L.		
Water Quality		
Field Parameters	***Major Ion Concentrations***	
Cond.: 47,200	Cations (mg/L)	Anions (mg/L)
TDS: 32	Ca = 578	Alka = 348
Temp: 20.3°C	Mg = 1286	Cl = 17,103
pH: 6.9	Na = 9880	SO_4 = 2659
D.O.: 7.5	K = 437	SiO_2 = 5.5
	Tot Fe = 0.971	
Definitions		
G.L. = ground level	I.D. = inner diameter	W.L. = water level
TOC = top of casing	hp = horsepower	

Comments:
Test 0: Background before pump started (time: 1320 to 1500)
Test 1: Drawdown data - head decreased as well was pumped due to increased water density
Test 2: Recovery data, used for analysis
Initial static head of +3.8 ft G.L. not correct due to lighter hydrostatic pressure in pipe from low salt water (mix).

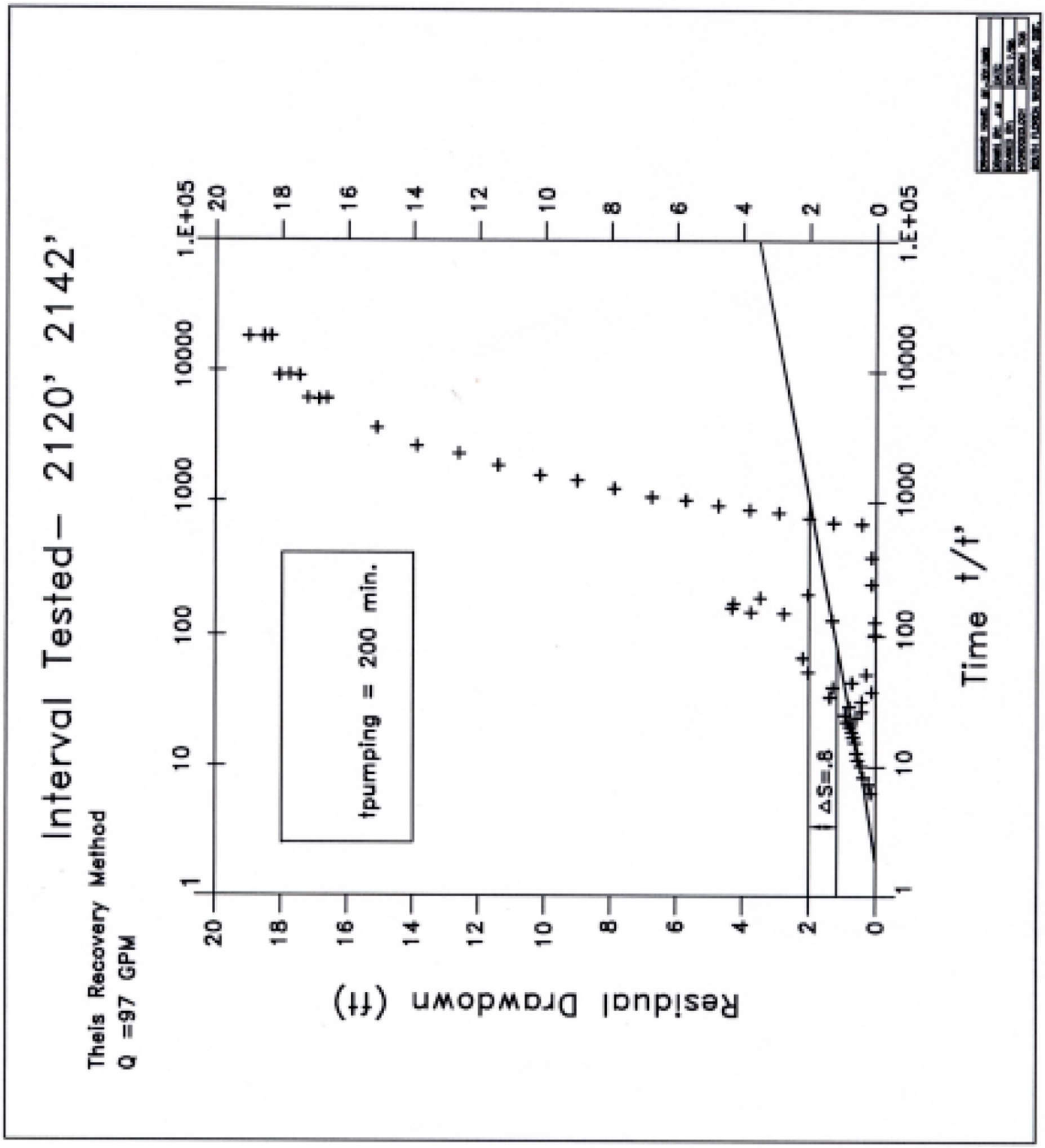


Figure C.1 - Straddle-Packer Test No. 1 (2,120-2,142' bls)

PACKER TEST NO. 2 (2,078 – 2,088' BLS)

Background Data		
Packer Test No.: 2	Date:02/19/93	Interval Tested: 2078 - 2088 ft
Static Water Level (G.L.) before pumping: +3.8 ft		After Recovery: -0.4 ft
Measuring Point Distance to Kelly Bushing: +2.2 ft TOC		
Distance from G.L. to Rig's Kelly Bushing: 10.0 ft		
Maximum Drawdown During Pumping: 63.95 ft		
Total Pumping Time: 1046 minutes		Average Pumping Rate: 4.5 gpm
Min. Pumping Rate: 4 gpm		Max. Pumping Rate: 5 gpm
Pump Type: 4" submersible, 3 hp		
Depth to Pump Intake from Kelly Bushing: 100 ft		
I.D. Drill Pipe: 3.5 in	Tester: Baker	Driller: R.S.T. Inc.
Hermit # 2		
Input #1 Transducer #: 3047	Range: 30 psi	Depth: 20 ft
Input #2 Transducer #: none	Range:	Depth:
Time Pumping Started: 1530	Time Pumping Ended: 0900	Total Pumping Time: 1046 min
Aquifer Analysis		
Transmissivity:	Hydraulic Conductivity:	
Method of Analysis:		
Software Used: AQTESOLV		
Specific Capacity: 0.7 gpm/ft		
Friction Loss (Observed): 0		
Static Head:-0.4 ft G.L.		
Water Quality		
Field Parameters	***Major Ion Concentrations***	
Cond.: 47,200	*Cations (mg/L)*	*Anions (mg/L)*
TDS: 34,300	Ca = 700	Alka = 312.9
Temp: 24.8 °C	Mg = 1200	Cl = 18,972
pH: 6.6	Na = 10,600	SO_4 = 2847
D.O.: 2.0	K = 390	SiO_2 = 4.9
Sulfides: 2	Tot Fe = 5.58	TDSFe = 2.29
		Hardness = 6690
Definitions		
G.L. = ground level	I.D. = inner diameter	W.L. = water level
TOC = top of casing	hp = horsepower	

Comments:
Yield was so low pump was left on overnight. Initial static head level suspect due to different water quality in borehole over it, before zone was developed.

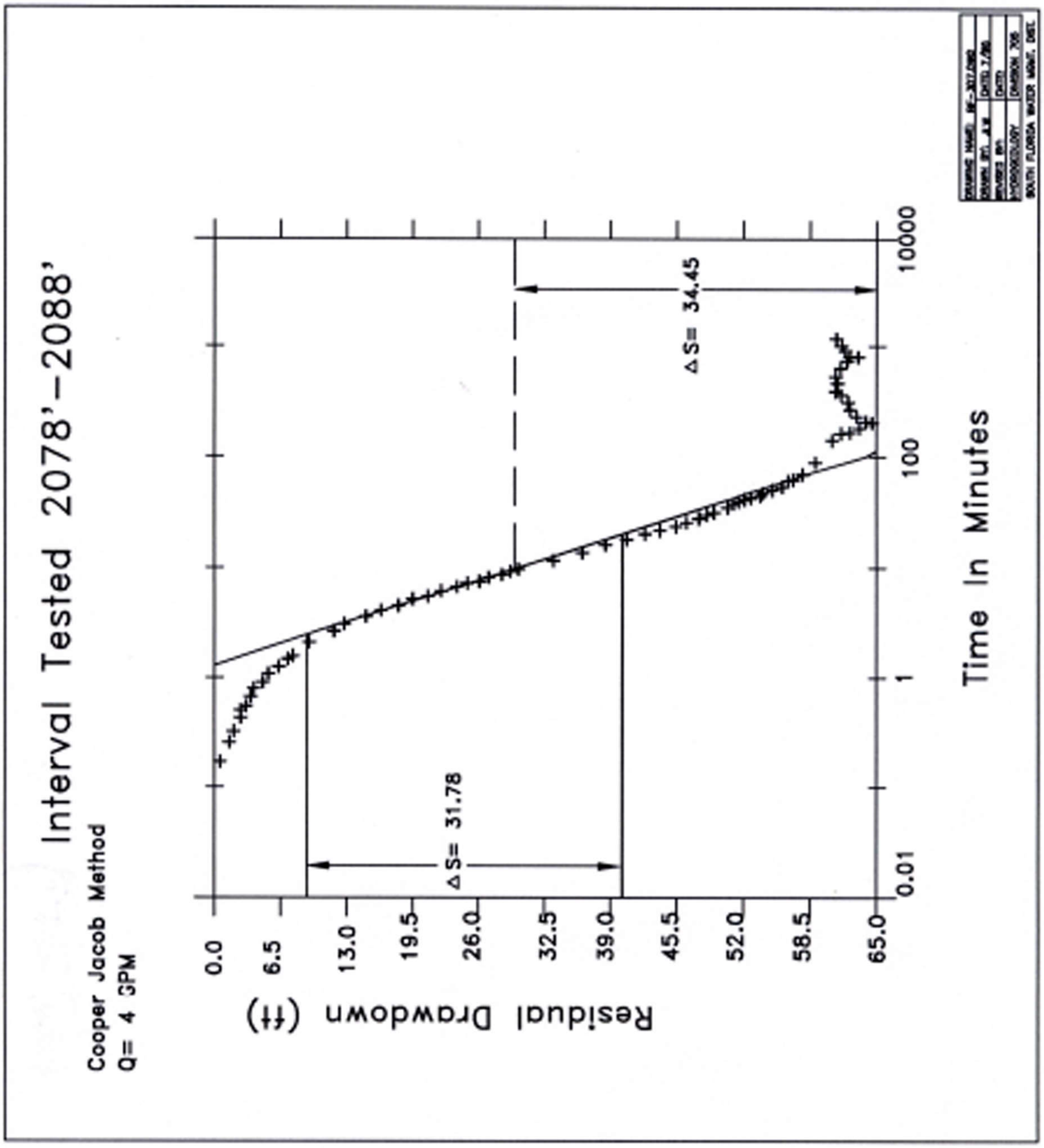


Figure C.2 – Straddle-Packer Test No. 2 (2,078-2,088' bls)

PACKER TEST NO. 3 (1,726 – 1,726' BLS)

Background Data		
Packer Test No.: 3	Date:02/23/93	Interval Tested: 1726 - 1772 ft
Static Water Level (G.L.) before pumping: +26 ft		After Recovery: +3 ft (real head)
Measuring Point Distance to Kelly Bushing: 29.35 ft (TOC-KB)		
Distance from G.L. to Rig's Kelly Bushing: 10.0 ft		
Maximum Drawdown During Pumping: 22.0 ft		
Total Pumping Time: 145 minutes		Average Pumping Rate: 74 gpm
Min. Pumping Rate: 73 gpm		Max. Pumping Rate: 98 gpm
Pump Type: 4" submersible, 3 hp		
Depth to Pump Intake from Kelly Bushing: 93 ft		
I.D. Drill Pipe: 3.5 in	Tester: Baker	Driller: R.S.T. Inc.
Hermit # 1		
Input #1 Transducer #: 3047	Range: 30 psi	Depth: 90 ft below TOC
Input #2 Transducer #: none	Range:	Depth:
Time Pumping Started: 1425	Time Pumping Ended: 1650	Total Pumping Time: 145 min
Aquifer Analysis		
Transmissivity:	Hydraulic Conductivity:	
Method of Analysis:		
Software Used: AQTESOLV		
Specific Capacity: 37 gpm/ft (corrected)		
Friction Loss (Observed): approx. 11 ft		
Static Head: +3 ft G.L.		
Water Quality		
Field Parameters	***Major Ion Concentrations***	
Cond.: 43,900	Cations (mg/L)	Anions (mg/L)
TDS: 31,300	Ca = 620	Alka = 6.37
Temp: 20.2 °C	Mg = 1062	Cl = 17,268
pH: 7.0	Na = 9460	SO_4 = 2307
D.O.: 3.6	K = 340	SiO_2 = 5.8
	Tot Fe = 1.67	Turbidity = 12.8 ntu
	TDSFe = 0.957	Hardness = 5920
Definitions		
G.L. = ground level	I.D. = inner diameter	W.L. = water level
TOC = top of casing	hp = horsepower	

Comments:
Head decreased after zone was pumped due to increased water density in pipe. Test lower portion saltwater interface.

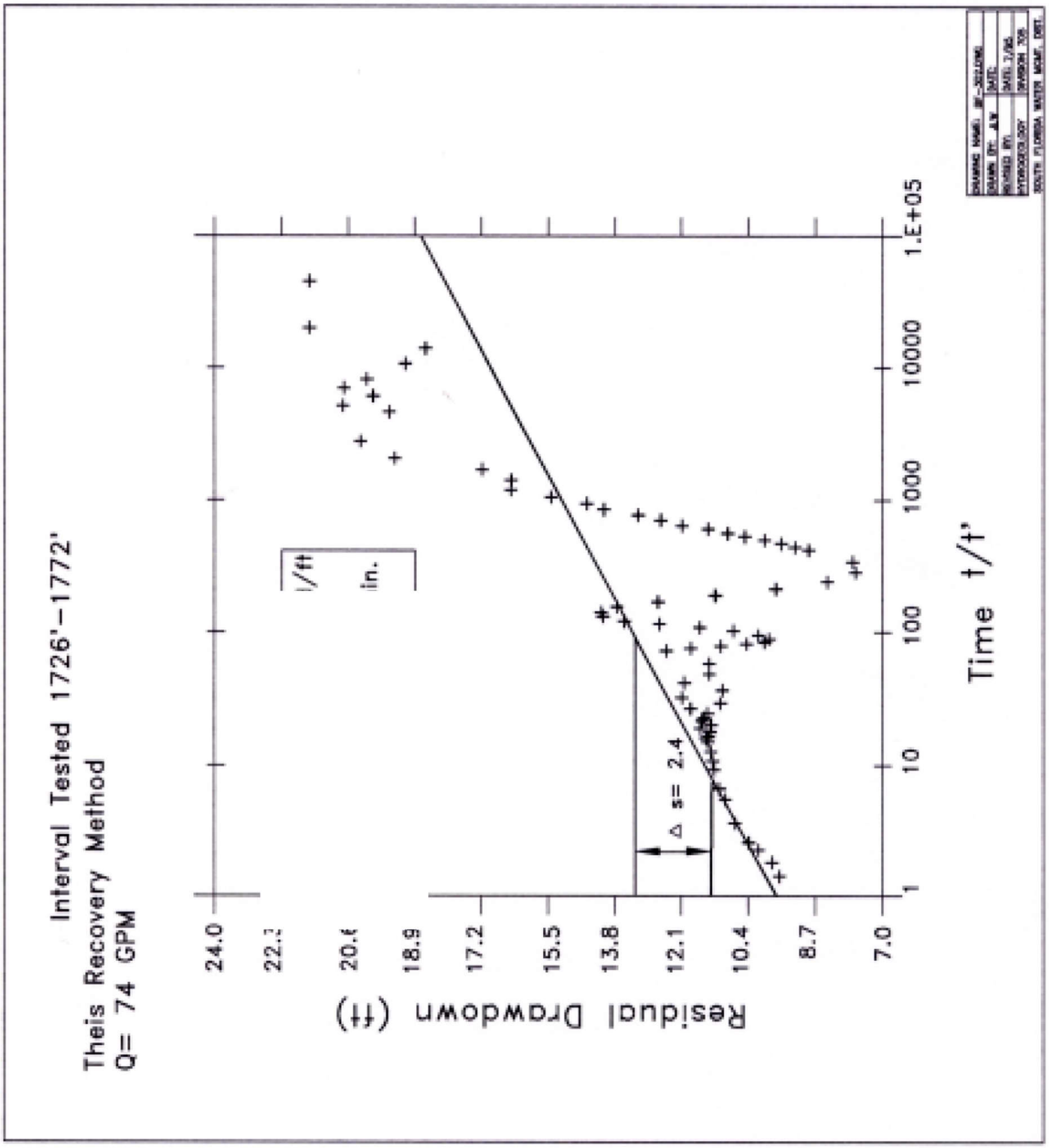


Figure C.3 – Straddle-Packer Test No. 3 – (1,726-1,772' bls)

PACKER TEST NO. 4 (1,644 – 1,690' BLS)

Background Data		
Packer Test No.: 4	Date:02/24/93	Interval Tested: 1644 - 1690 ft
Static Water Level (G.L.) before pumping: +5.7 ft		After Recovery: +29 ft
Measuring Point Distance to Kelly Bushing: +30 ft TOC		
Distance from G.L. to Rig's Kelly Bushing: 10.0 ft		
Maximum Drawdown During Pumping: 33.3 ft		
Total Pumping Time: 200 minutes		Average Pumping Rate: 63 gpm
Min. Pumping Rate: 54 gpm		Max. Pumping Rate: 84 gpm
Pump Type: 4" submersible, 3 hp		
Depth to Pump Intake from Kelly Bushing: 60 ft		
I.D. Drill Pipe: 3.5 in	Tester: Baker	Driller: R.S.T. Inc.
Hermit # 2		
Input #1 Transducer #: 3047	Range: 30 psi	Depth: 85 ft (dd) / 35 ft (rc)
Input #2 Transducer #: 137	Range: 10 psi	Depth: 85 ft (dd) / 35 ft (rc)
Time Pumping Started: 1431	Time Pumping Ended: 1820	Total Pumping Time: 200 min
Aquifer Analysis		
Transmissivity:	Hydraulic Conductivity:	
Method of Analysis:		
Software Used: AQTESOLV		
Specific Capacity: 63 gpm/ft		
Friction Loss (Observed):		
Static Head: 29 ft G.L.		
Water Quality		
Field Parameters	***Major Ion Concentrations***	
Cond.: 13,950	*Cations (mg/L)*	*Anions (mg/L)*
TDS: 8920	Ca = 380	Alka = 193
Temp: 21.6 °C	Mg = 214	Cl = 4695
pH: 7.4	Na = 2640	SO_4 = 750
D.O.: 4.5	K = 92	SiO_2 = 11.8
	TDS Fe = 0.651	Tubidity = 8.1 ntu
	TotFe = 0.9	
	Color = 22	Hardness = 1830
Definitions		
G.L. = ground level	I.D. = inner diameter	W.L. = water level
TOC = top of casing	hp = horsepower	dd = drawdown
		rc = recovery

Comments:
Head initially fell 70 ft, then rebounded in response to fresher water occupying drill stem. Transducers moved up pipe for recovery. Test 1 not useful, water level over TOC in recovery. Recovery data questionable because well was pumped 200 min, shut down for recovery, W.L. rose above TOC, pumped again w/ standpipe connected for extension, then recovery resumed.

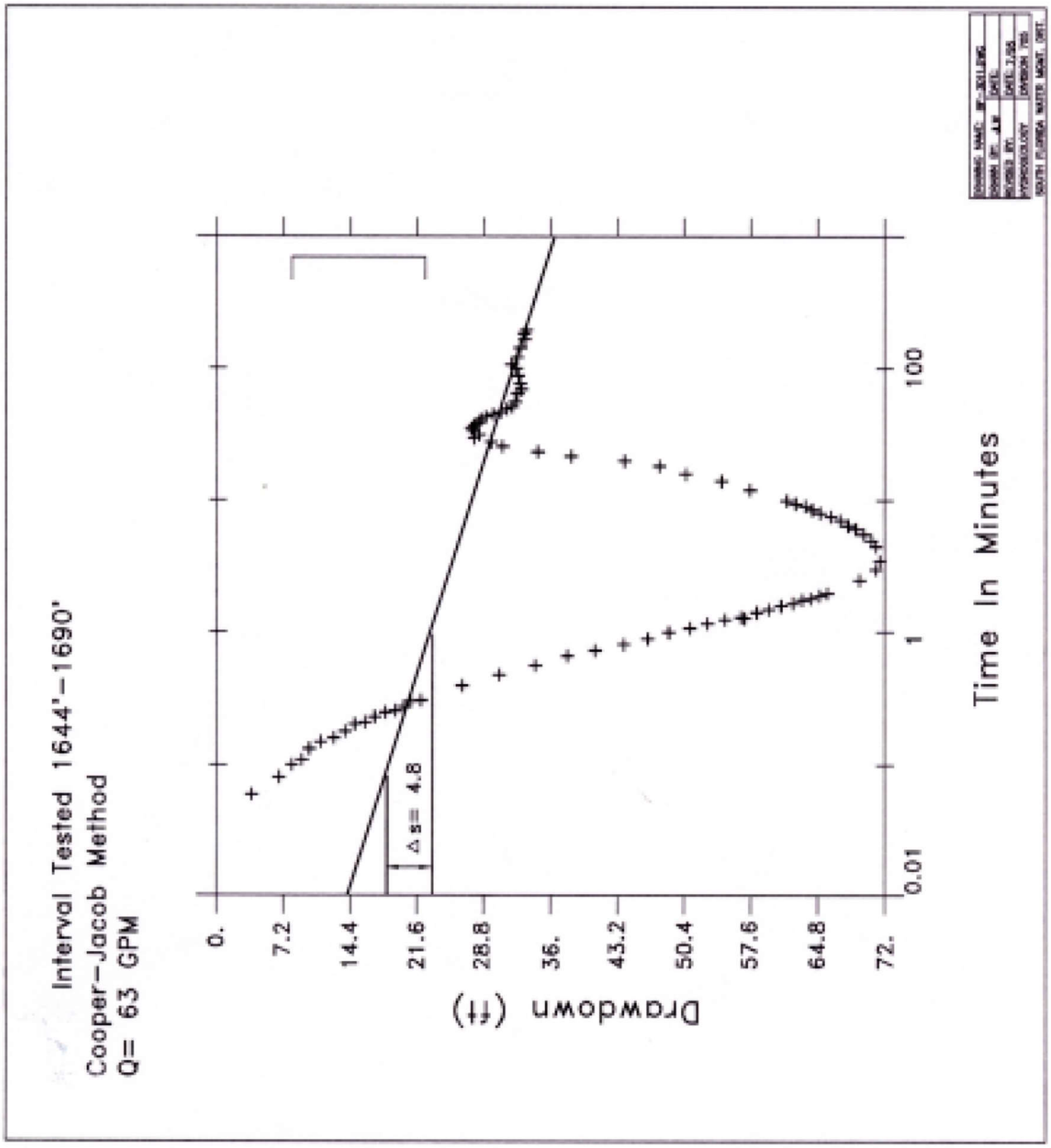


Figure C.4 – Straddle-Packer Test No. 4 – (1,644-1,690' bls)

PACKER TEST NO. 5 (1,494 – 1,540' BLS)

Background Data		
Packer Test No.: 5	Date:02/26/93	Interval Tested: 1494 - 1540 ft
Static Water Level (G.L.) before pumping: +29 ft		After Recovery: +28.76 ft
Measuring Point Distance to Kelly Bushing: 30ft TOC to KB		
Distance from G.L. to Rig's Kelly Bushing: 10.0 ft		
Maximum Drawdown During Pumping: 9.7 ft aquifer loss		
Total Pumping Time: 230 minutes		Average Pumping Rate: 64 gpm
Min. Pumping Rate: 60 gpm		Max. Pumping Rate: 90 gpm
Pump Type: 4" submersible, 3 hp		
Depth to Pump Intake from Kelly Bushing: 70 ft		
I.D. Drill Pipe: 3.5 in	Tester: Baker	Driller: R.S.T. Inc.
Hermit # 1		
Input #1 Transducer #: 3047	Range: 30 psi	Depth: 120 ft TOC (dd)/45 ft (rc)
Input #2 Transducer #: 137	Range: 10 psi	Depth: 70 ft TOC (dd)/60 ft (rc)
Time Pumping Started: 0857	Time Pumping Ended: 1248	Total Pumping Time: 230 min
Aquifer Analysis		
Transmissivity:	Hydraulic Conductivity:	
Method of Analysis: Theis Recovery		
Software Used: AQTESOLV		
Specific Capacity: 45.7 gpm/ft		
Friction Loss (Observed): 8.3 ft		
Static Head: +29 ft G.L.		
Water Quality		
Field Parameters	***Major Ion Concentrations***	
Cond.: 11,330	*Cations (mg/L)*	*Anions (mg/L)*
TDS: 8340	Ca = 380	Alka = 201
Temp: 22 °C	Mg = 190	Cl = 4167
pH: 7.2	Na = 2460	SO_4 = 844
D.O.: 5.0	K = 86	SiO_2 = 11.6
	Tot Fe = 1.1	Turbidity = 55 ntu
	TDSFe = 0.375	Color = 14
Definitions		
G.L. = ground level	I.D. = inner diameter	W.L. = water level
TOC = top of casing	hp = horsepower	dd = drawdown
		rc = recovery

Comments:
Set new reference for Hermit before starting recovery test. Discharge rate was not consistent during pumping (fluttered). Head during pumping fluctuated 3 - 6 inches over 2 min intervals.

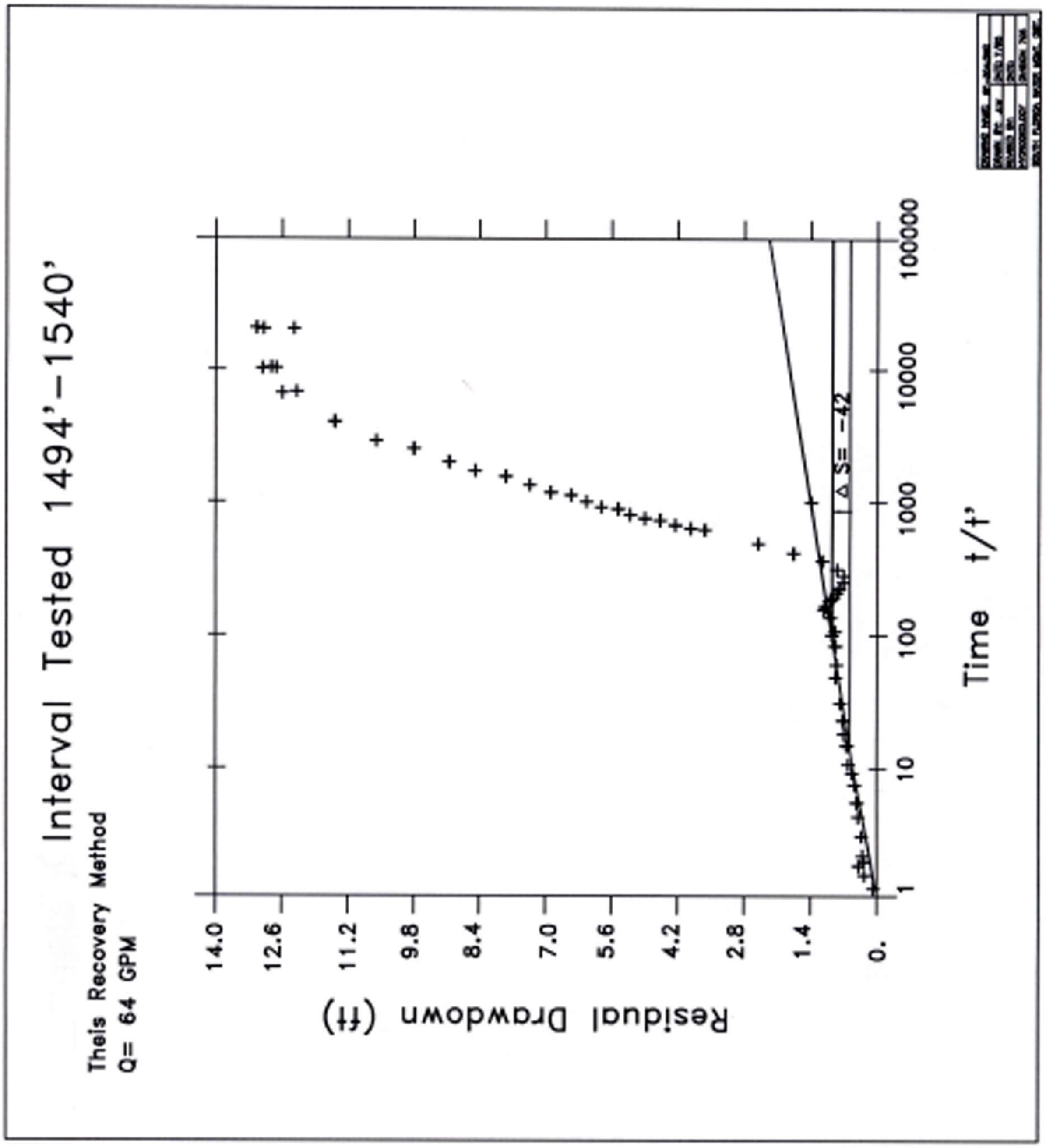


Figure C.5 – Straddle-Packer Test No. 5 – (1,494-1,540' bls)

PACKER TEST NO. 6 (1,000 – 1,031' BLS)

Background Data		
Packer Test No.: 6	Date:03/01/93	Interval Tested: 1000 - 1031 ft
Static Water Level (G.L.) before pumping: +30 ft		After Recovery: +30.7 ft
Measuring Point Distance to Kelly Bushing: 33.7 ft KB to TOC		
Distance from G.L. to Rig's Kelly Bushing: 10.0 ft		
Maximum Drawdown During Pumping: 7 ft total, 1.4 ft aquifer loss		
Total Pumping Time: 210 minutes		Average Pumping Rate: 65 gpm
Min. Pumping Rate: 50 gpm		Max. Pumping Rate: 92 gpm
Pump Type: 4" submersible, 3 hp		
Depth to Pump Intake from Kelly Bushing: 100 ft		
I.D. Drill Pipe: 3.5 in	Tester: Baker	Driller: R.S.T. Inc.
Hermit #		
Input #1 Transducer #: 3047	Range: 30 psi	Depth: 70 ft below W.L.
Input #2 Transducer #: 137	Range: 10 psi	Depth: 20 ft below W.L.
Time Pumping Started: 1510	Time Pumping Ended: 1710	Total Pumping Time: 120 min
Aquifer Analysis		
Transmissivity:	Hydraulic Conductivity:	
Method of Analysis:		
Software Used: AQTESOLV		
Specific Capacity: 46.4 gpm/ft		
Friction Loss (Observed): 5.6 ft		
Static Head: 30.7 ft G.L.		
Water Quality		
Field Parameters	***Major Ion Concentrations***	
Cond.: 10,730	*Cations (mg/L)*	*Anions (mg/L)*
TDS: 7730	Ca = 220	Alka = 348
Temp: 22.4 °C	Mg = 318	Cl = 17,103
pH: 7.2	Na = 2340	SO_4 = 2659
D.O.: 3.3	K = 98	SiO_2 = 5.5
	Tot Fe = 0.8	Turbidity = 57 ntu
	TDSFe = 0.1	Color = 29
Definitions		
G.L. = ground level	I.D. = inner diameter	W.L. = water level
TOC = top of casing	hp = horsepower	

Comments:
Pumping rate decreased throughout test.

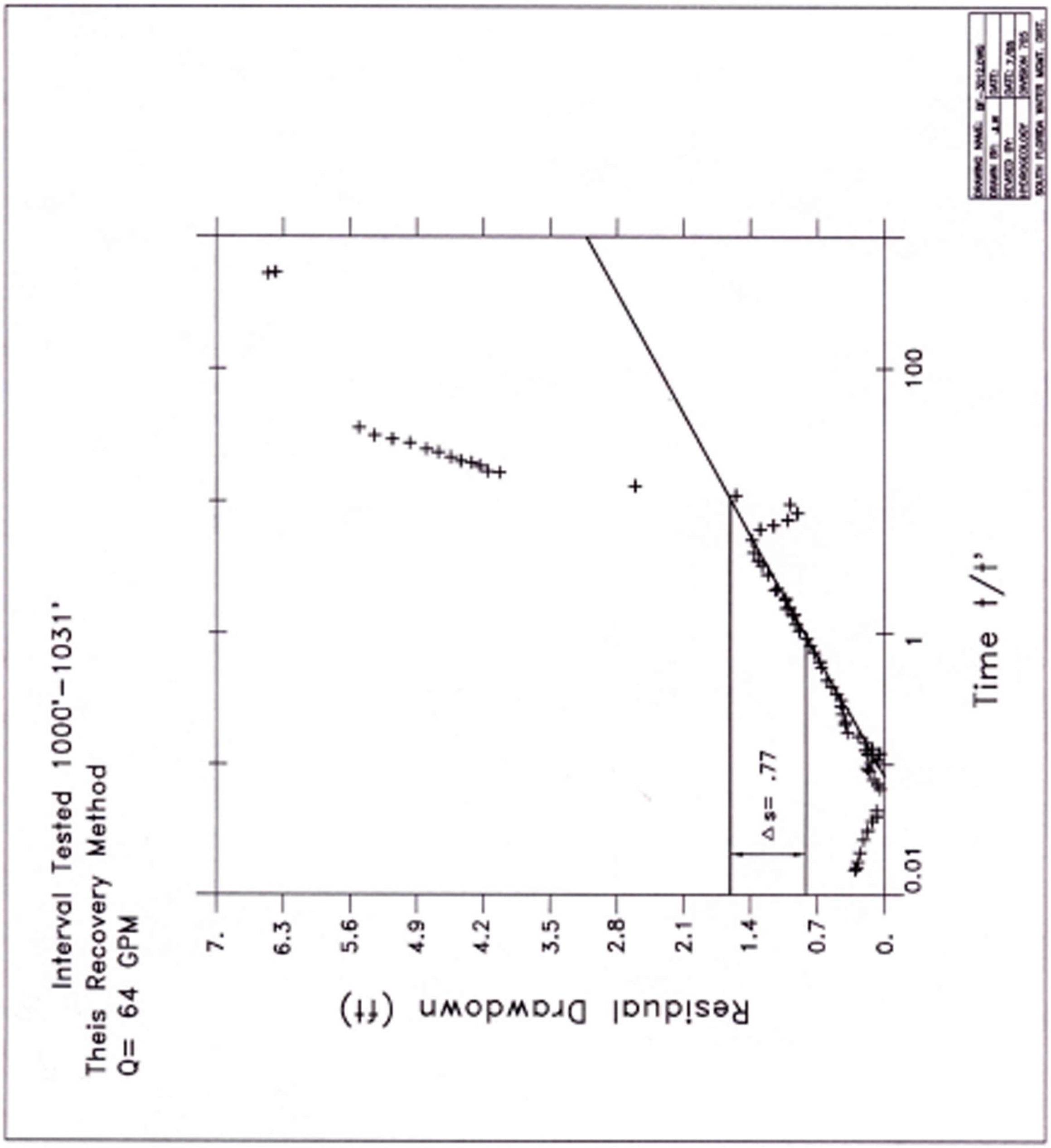


Figure C.6 – Straddle-Packer Test No. 6 – (1,000-1,031' bls)