*H*ydrogeologic Investigation of the Floridan Aquifer System, S-65A Site Osceola County, Florida

Prepared by

AECOM Water

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Hydrogeologic Investigation of the Floridan Aquifer System S65-A Site, Osceola County Florida (OSF-104 & OSF-105)

Prepared for:

South Florida Water Management District

November 2008

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Executive Summary

The South Florida Water Management District (SFWMD) Kissimmee Basin Water Supply Plan (2000) and the Regional ASR Study Field Data Collection Plan (USACE & SFWMD, 2006) have identified the Kissimmee Basin as a critical area to tie correlations of the Floridan aquifer between St. Johns River Water Management District (SJRWMD) and Southwest Florida Water Management District (SWFWMD). Factors influencing the location of proposed Floridan aquifer testing and monitoring locations are areas where hydrogeologic information is limited, availability of District-owned property for well construction and testing activities, proximity to large surface water conveyance systems (Kissimmee River) to facilitate discharge of formation water during drilling and testing operations, and the presence of other physical features, which would improve operational efficiency or enhance scientific return. Field-scale hydrogeologic testing was identified as one of the priority tasks in evaluating long-term sustainability of the Floridan aquifer system (FAS) as a water supply source and to determine the hydrogeologic parameters needed to assess aquifer storage and recovery (ASR) potential within the lower portion of the Kissimmee River Basin. The data collected from this site will be instrumental in the refinement of a conceptual hydrogeologic and ground water models, and aid in future regional hydrogeologic and hydro-chemical assessments of the FAS.

The S65A test site is located approximately 9 miles south of State Road 60 on the east side of the Kissimmee River in unincorporated Osceola County, Florida. The FAS tri-zone monitor well (OSF-104) and FAS dual zone production well (OSF-105) were constructed on SFWMD-owned right-of-way, proximal to the S65-A water control structure on the Kissimmee River in the southwest quarter of Section 34 of Township 32 South, Range 32 East (Figure 1).

The scope of the investigation consisted of constructing and testing two FAS wells under the direction of the SFWMD. The first well identified as OSF-104 was drilled to a total depth of 2,513 feet below land surface (bls). Two different Contractors constructed a telescoping-type well in various stages, completing it into three distinct hydrogeologic zones within the FAS. A dual-zone production well identified as OSF-105, located 489 feet south of the FAS tri-zone monitor well, was constructed to facilitate aquifer testing of the upper Floridan aquifer and the Avon Park Permeable zone within the middle portion of the FAS.

SFWMD provided oversight during all well drilling, construction, and testing operations. Rowe Drilling Corporation (Rowe) and All-Webbs Enterprises were responsible for all drilling, well construction, and testing services at the S65A site under SFWMD Contracts CN-050268, CN-060360 and CN060362. This project was completed at a cost of approximately $1,340,000.

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

1. Lithologic information and geophysical logs obtained from OSF-104 and OSF-105 indicates that soft non-indurated detritial clays, silts and quartz sand and poorly indurated mudstones of the Hawthorn Group predominate from 70 to 300 feet bls. These low permeable sediments act as semi-confining units separating the Floridan Aquifer System (FAS) from overlying the Surficial Aquifer System (SAS).
2. The top of the Floridan aquifer system (FAS) as defined by the Southeastern Geological Society AdHoc Committee on Florida Hydrostratigraphic Unit Definition (1986) was identified at a depth of approximately 300 feet below land surface (bls).
3. Lithologic and geophysical logs, specific capacity and Aquifer Performance Test (APT) results indicate moderate production capacity in the upper Floridan aquifer (UFA), and excellent production capacity in the Avon Park Permeable Zone.
4. Water quality data from packer tests and completed monitor zones indicate that chloride and total dissolved solids (TDS) concentration of the produced waters from the UFA and APPZ meet potable drinking water standards.
5. The UFA (330 to 550 feet bls) yielded transmissivity value of 85,450 gpd/ft, storage coefficient of 5.5 x 10^{-3}, a r/B value of 0.64 and a leakance value of 1.58 x 10 gpd/ft^3 based on an APT conducted.
6. A productive horizon in the APPZ from 930 to 1,202 feet bls yielded an estimated transmissivity value of 590,000 gpd/ft. The FAS tri-zone monitor well (OSF-104) was located at a distance where no discernable changes in water levels were observed during the APT.
7. The production type logs (e.g. flow, temperature logs) indicate that below 1,270 feet bls, the productive capacity is limited (as indicated by the fluid-type logs) suggesting lower permeable, semi-confining units near the base of this productive horizon.
8. A permeable interval is present in the Avon Park Formation from 1,490 to 1,635 feet bls that is identified as the first significant permeable zone in the lower Floridan aquifer (LFA).
9. Composite water quality sampling during straddle packer tests and geophysical log data was used in tandem to identify the base of the USDW (those waters having TDS concentrations less than 10,000 mg/L) at approximately 1,850 feet bls.
10. A water quality inversion occurs from 2,020 to 2,100 where brackish (lower TDS concentration) water resides between more saline formation water above and below this interval. This water quality change was indentified using the geophysical log data in tandem with Archie’s equation. The lower monitor interval OSF-104 (2,010 to 2,350 feet bls) was completed through both the

identified brackish and saline water. Waters of different density present within the same monitor interval may affect long-term potentiometric head readings.

11. The groundwater below 2,200 feet to the total depth of borehole at 2,513 feet bls is saline (similar to seawater composition) with TDS concentrations of approximately 36,000 mg/L.

Introduction

Background

The Kissimmee River Basin Water Supply Plan (2000) and the Regional ASR Study Field Data Collection Plan (ACOE & SFWMD, 2006) have identified the Kissimmee River basin as a critical area to tie correlations of the Floridan aquifer between St. Johns River Water Management District (SJRWMD) and Southwest Florida Water Management District (SWFWMD). Factors influencing the location of proposed Floridan aquifer testing and monitoring locations are areas where hydrogeologic information is limited, availability of District-owned property for well construction and testing activities, proximity to large surface water conveyance systems (Kissimmee River) to facilitate discharge of formation water during drilling and testing operations, and the presence of other physical features, which would improve operational efficiency or enhance scientific return. Field scale hydrogeologic testing of the Floridan aquifer system (FAS) was identified as one of the priority tasks in evaluating long-term sustainability of the Floridan aquifer as a water supply source and to determine the hydrogeologic parameters needed to assess aquifer storage and recovery (ASR) potential within the lower portion of the Kissimmee River Basin.

The purpose of this project is to provide site-specific hydrogeologic information on the Floridan aquifer system in support of the Kissimmee River Basin Water Supply Plan (2000) and the Regional ASR Study Field Data Collection Plan. The data collected from this site will be instrumental in the development of a conceptual hydrogeologic and ground water flow model, and aid in future regional hydrogeologic and hydro-chemical assessments of the Floridan aquifer.

Scope

This report primarily describes the drilling, construction, and testing of a FAS tri-zone monitor well identified as (OSF-104) and a FAS dual-zone test-production well identified as (OSF-105) both of which are located at the S65A site. It summaries and presents data obtained during drilling and testing operations and analyses conducted.

Project Description

The S65A test site is located approximately 9 miles south of State Road 60 on the east side of the Kissimmee River in unincorporated Osceola County, Florida. The FAS tri-zone monitor well (OSF-104) and FAS dual zone production well (OSF-105) were constructed on SFWMD-owned right-of-way, proximal to the S65-A water control structure on the Kissimmee River in the southwest quarter of Section 34 of Township 32 South, Range 32 East (**Figure 1**). The geographic coordinates of the tri-zone monitor well identified as OSF-104 are latitude 27° 39′34.8″ N and longitude 81° 07′ 57.8″ W (North American Datum of 1983 – NAD, 83). Land surface of the test monitor well OSF-104 was determined by a closedloop survey at 52.76 feet relative to the North American Vertical Datum of 1988 (NAVD, 88). The geographic coordinates of the test-production well identified as OSF-105 are latitude 27° 39′30.5″ N and longitude 81° 07′ 59.15″ W (NAD, 83). Land surface elevation for the test-production well OSF-105 was not determined because it will not to be used in the SFWMD's long-term groundwater level monitoring program.

The tri-zone monitor well identified as OSF-104 was completed under two separate contracts. The first contract was with Rowe Drilling Company – District Contract CN-050268. Under this contract, the well was advanced to a total depth of 2,000 feet below land surface (bls) with 18-inch diameter steel casing installed to 333 feet bls. The second SFWMD contract CN060360 was awarded to All-Webbs Enterprise, Inc (AWE). AWE advanced the nominal 10-inch diameter borehole from 2,000 to 2,513 feet bls and installed two additional casings including a 12-inch diameter carbon steel and 4-inch diameter fiberglass tubing and cemented them to various depths completing OSF-104 as a telescoping-type FAS tri-zone monitor well. The contract to construct the dual-zone FAS test-production well was awarded to Rowe Drilling Company under SFWMD contract CN060362. The dual-zone production well was constructed using the information gained from the onsite tri-zone monitor well (OSF-104) to allow field-scale aquifer performance tests to be conducted on the upper Floridan and Avon Park Permeable Zone (APPZ) at this site.

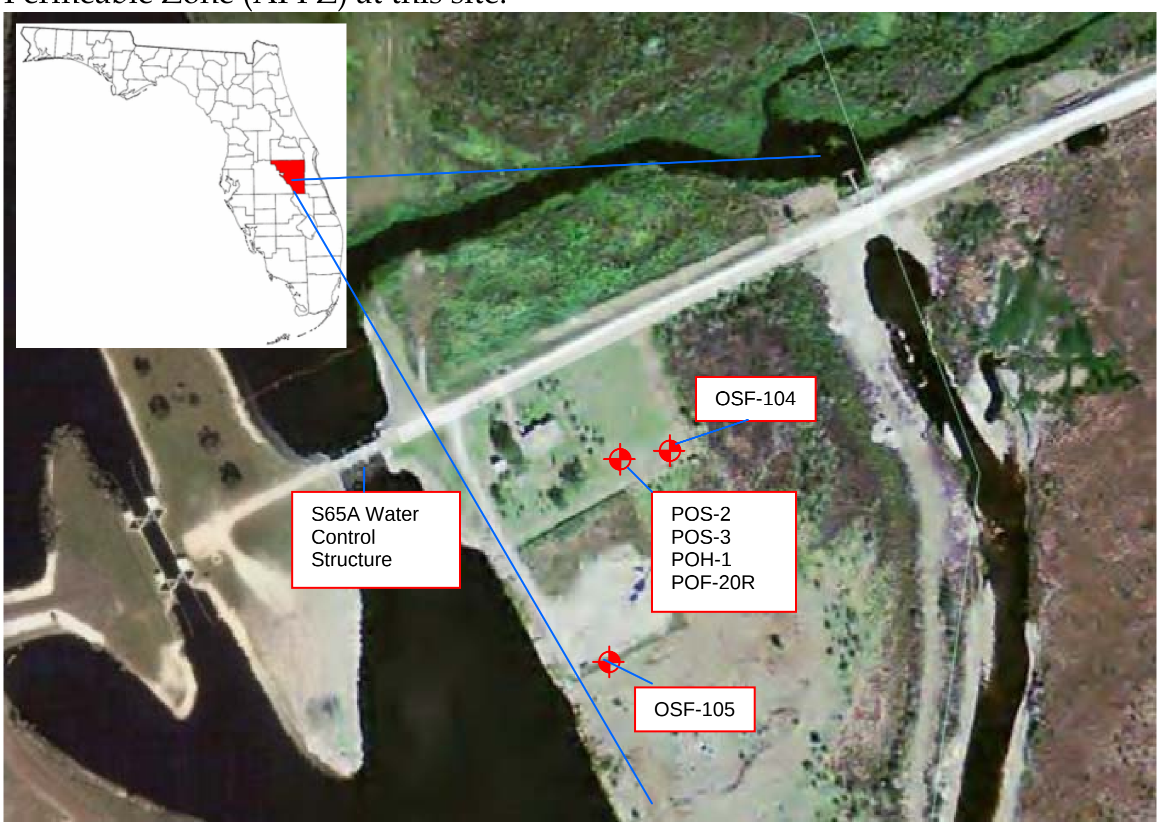

Figure 1. Project Location and Site Map – S65-A

Exploratory Drilling and Well Construction

Test/Monitor Well (OSF-104)

Rowe Drilling Corporation (Rowe) began site preparation for drilling activities April of 2005 and completed the first portion of OSF-104 on October 25, 2005. In the early part of March 2006, All Webbs Enterprises (AWE) began the second phase of the drilling, testing and well construction. The formation samples (well cuttings), packer tests, and borehole geophysical log data obtained during each phase of drilling and testing were used to determine the actual casing setting depths. The nominal 10-inch diameter pilot-hole was enlarged (reamed) to specified diameters and selected diameter casing installed. Three concentric steel casings (24-, 18-, and 12- inch diameter) and 4-inch diameter reinforced fiberglass pipe (FRP) were used in the construction of the Floridan aquifer tri-zone monitor well (OSF-104).

Rowe was responsible for the first phase of the construction for OSF-104, which included: the installation of the 24-inch diameter steel pit casing set to a depth of 42 feet bls; the installation of the 18-inch diameter surface casing to a depth of 333 feet bls; the advancement of the nominal 10-inch diameter pilot-hole via reverse-air method from 333 to 2,000 feet bls and associated geophysical logging services.

The 24-inch diameter pit casing was installed and cemented in place to stabilize the drill rig to allow for continued drilling operations. Once installed a nominal 10-inch diameter pilot-hole was advanced to 360 feet bls. MV Geophysical logged the pilot-hole on August 5, 2005 to a total depth of 364 feet bls, slightly deeper than that measured during drilling operations. Once completed, the pilot-hole was enlarged (reamed) using a nominal 23-inch step bit reaming tool and drilling was completed to a depth of 333 feet bls. A 4-arm caliper and natural gamma logs were conducted in the nominal 23-inch borehole to confirm the depth and borehole dimensions prior to setting the 18-inch diameter steel surface casing. Based on the geophysical log data, the borehole was of specified depth and diameter. Rowe installed the 18-inch diameter steel casing (ASTM A53, Grade B, 0.375 inch wall thickness) to a depth of 333 feet and pressure grouted it in place with cement returns observed at land surface. Once the 18-inch casing was installed and isolated the unconsolidated sediments of the Surficial aquifer and intermediate confining unit, Rowe switched from mud-rotary to reverse-air open circulation drilling operations. The nominal 10-inch diameter pilot-hole was advanced to 1,500 feet bls with intermittent 4-inch full-diameter rock cores obtained between 400 and 1,500 feet bls. On October 5, 2005, Schlumberger Wireline Services conducted specialty formation evaluation logs within the open-hole section of the pilot-hole from 300 to 1,500 feet bls (See Schlumberger Geophysical Log Run No 1). MV Geophysical completed the complementary production-type logs within the same open-hole section the next day. The SFWMD issued a Change Order to Rowe to advance the pilot-hole via the reverse-air method to a depth of 2,000 feet, again taking 4-inch diameter cores during the drilling process. Once the total depth was reached drilling operations ceased and Rowe began to demobilize their equipment and restored the site to satisfactory conditions. Rowe completed site restoration the first half of November 2005.

AWE began the second phase of well construction activities related to OSF-104 on March 10, 2006. The nominal 10-inch diameter pilot-hole was reamed from 333 (base of the 18-inch diameter surface casing) to 927 feet bls using a nominal 17-inch diameter bit assembly. A 4-arm caliper log was conducted and used to verify the true dimensions of the borehole before the 12-inch diameter steel intermediate casing (ASTM A53, Grade B, 0.375 inch wall thickness) was installed to a depth of 925 feet bls. A cement bridge plug was set at a depth of 939 feet bls and the annular space between the 12-inch diameter steel casing and the 17-inch diameter borehole was initially pressure grouted then stage grouted using the tremie method bringing cement levels to a depth of 550 feet bls, which formed the base of the upper monitor interval zone (OSF-104U). On June 1, 2006, a 50-psi hydrostatic pressure test was conducted and successfully completed to verify the internal mechanical integrity of the cemented intermediate 12-inch diameter steel casing. The previously drilled nominal 10-inch diameter pilot-hole was cleared of the temporary backfill material generated by the reaming of the 17-inch diameter borehole. Drilling operations continued by advancing a nominal 10-inch pilot-hole from 2,000 to a total depth of 2,513 feet bls via the reverse-air method. In addition, 4-inch-diameter rock cores were retrieved from specified depth intervals between 2,000 and 2,513 feet bls. Upon completion of pilot-hole drilling to a total depth of 2,513 feet bls, Schlumberger Wireline Services conducted specialty formation evaluation logs and production type geophysical logs in the open-hole section from 925 to 2,513 feet bls (See Schlumberger Log Run No.2 – Appendix D).

Based on the lithologic and geophysical log data, three packer tests were conducted between 1,400 and 2,513 feet bls to obtain depth specific water quality and hydraulic information. On June 8, 2006, the first packer test was completed. This test consisted of setting a single packer at 2,351 feet bls to gain hydraulic and water quality information on the lowermost section of the borehole from 2,351 to 2,513 feet bls. A pre-test was conducted where a minimum of three drill-stem volumes were evacuated. Once the pre-test was completed, a specific capacity test was conducted with the interval stressed under pumped conditions at 30, 60, 90, and 120 gpm at ½ hour intervals. A second packer test was completed on June 14, 2006 using a dual-packer configuration that isolated an interval from 1,907 to 1,957 feet bls with water quality and hydraulic information obtained. The third packer test was completed on June 16, 2006. Again, a dual-packer configuration was used to isolate a portion of the Floridan aquifer from 1,400 to 1,450 feet bls. The results of the packer testing operations are presented in the **Hydrogeologic**

Testing Section of this report. Upon completion of packer testing operations, the bottom of the nominal 10-inch diameter pilot-hole was permanently back-plugged from 2,304 to 2,513 feet bls with ASTM Type II neat cement. Four inch diameter FRP tubing was set to a depth of 2,020 feet bls. Crushed limestone gravel was then installed in the borehole from 2,020 to 2,304 feet bls to temporarily seal-off the open-hole section below the 4-inch diameter FRP tubing during ensuing cement grouting operations. The annular space between the 4-inch casing and the 10-inch diameter borehole was cemented back to 1,222 feet bls in multiple stages using the tremie method. The cement at 1,222 feet bls formed the base of the middle monitor interval (OSF-104M). Once the 4-inch diameter FRP tubing was cemented to 1,222 feet bls, the installed gravel was removed from the borehole leaving a nominal 10-inch diameter open-hole section from 2,020 to 2,304 feet bls. **Table 1 in Appendix A-1** provides a summary of the well construction and testing activities related to OSF-104. **Appendix A** also contains the factory mill certificates for the various steel casing and fiberglass tubing used to construct OSF-104.

In summary, the completed telescoped-style well allows the SFWMD to monitor water levels and water quality from three distinct FAS intervals. The uppermost monitor zone (OSF-104U) is constructed using 18-inch diameter steel casing and completed with an annular zone between 333 to 550 feet bls. The intermediate zone (OSF-104M) is completed with an annular zone from 925 to 1,222 feet bls. The lowermost well (OSF-104L) constructed of 4-inch diameter fiberglass casing was completed with an open-hole of 2,020 to 2,304 feet bls. **Table 1** lists the monitor intervals and completion methods for the tri-zone FAS monitor well.

Table 1. Monitor Intervals for SFWMD Tri-Zone Observation Well OSF-104

Identifier	Monitor Interval (feet bls)	Completion Method
OSF-104U	333 to 550	Annular Zone
OSF-104M	925 to 1,222	Annular Zone
OSF-104L	2,020 to 2,304	Open-Hole

After construction was completed, OSF-104 was surveyed relative to permanent reference points by a Florida registered land surveyor, and located on a site plan map by latitude and longitude. **Figure 2** show a detailed well completion diagram for the tri-zone FAS test/monitor well OSF-104.

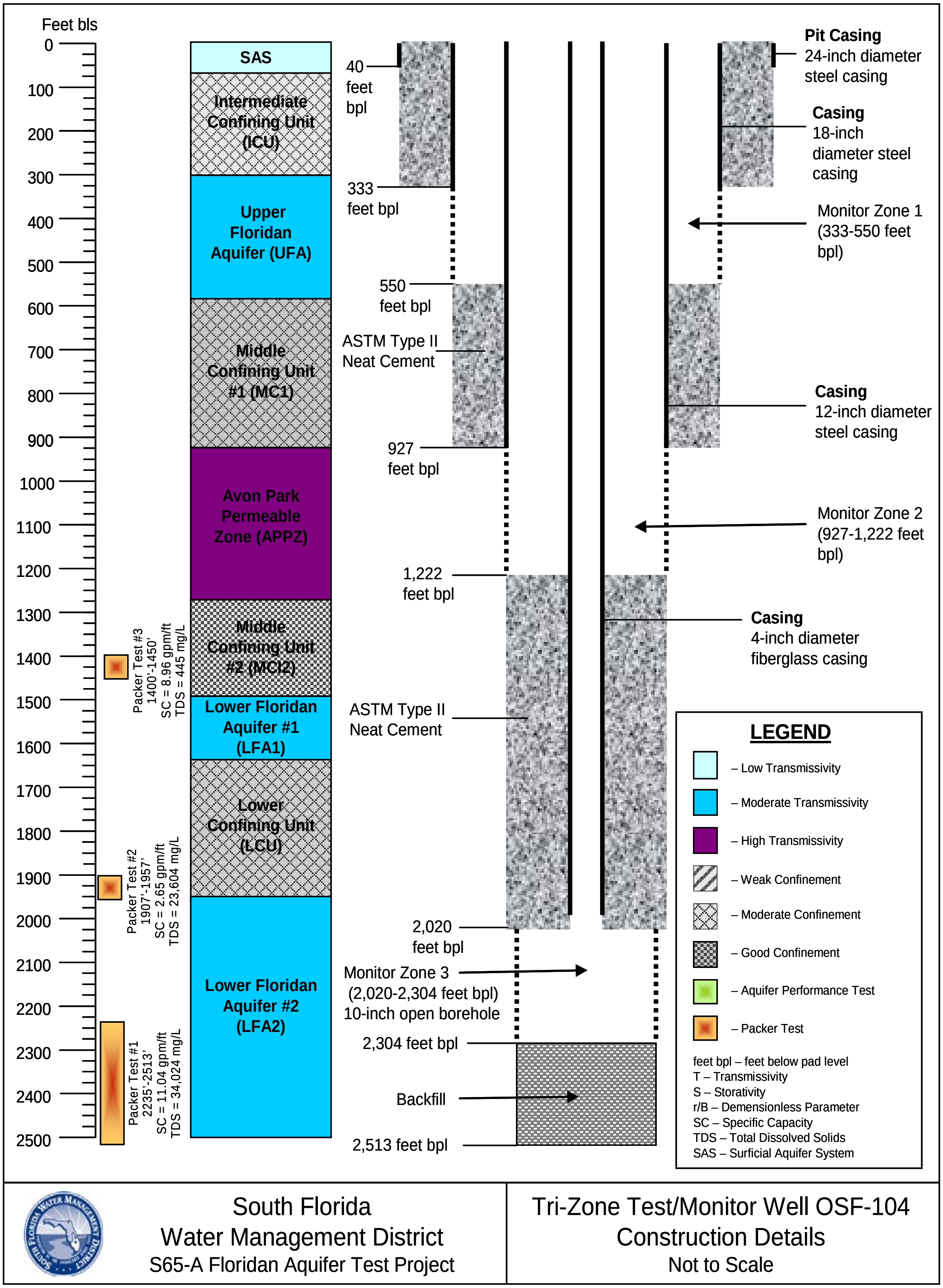

Figure 2. Well Completion Diagram, Test/Monitor Well (OSF-104)

Other Onsite Monitor Wells

In addition, three shallow monitor wells were also installed, to determine the degree of upper confinement and the effects on the Surficial Aquifer System (SAS) as a result of withdrawals from the Upper Floridan Aquifer (UFA). The two SAS wells were constructed by drilling a 10-inch diameter borehole and installing 4-inch diameter schedule 40 PVC casing and slotted well screen (20-slot). The first

SAS monitor well referred to as POS-2 was completed from 20 to30 feet bls. The second monitor well POS-3 was completed in the lower part of the SAS with a screened interval from 75 to 90 feet bls. A 2-inch diameter monitor well referred to as POH-1 was completed in the Intermediate Confining Unit (ICU) from 180 to 200 feet bls.

Previous to this drilling program, a 2-inch monitor well referred to as POF-20R (a continuous core) was completed in the uppermost section of the UFA with a screened interval of 287 to 397 feet bls. **Table 2** lists the monitor intervals and completion methods for the various onsite monitor wells.

Table 2. Other Onsite Monitor Wells, S65A Site

Identifier	Monitor Interval (feet bls)	Aquifer	Completion Method
POS-2	20 to 30	SAS	Screened (20 slot)
POS-3	75 to 90	SAS	Screened (20 slot)
POH-1	180 to 200	ICU	Screened (20 slot)
POF-20R	287 to 397	UFA	Screened (20 slot)

Dual Zone Test/Production Well (OSF-105)

Rowe Drilling Company (Rowe) began site preparations for drilling activities in May 2006. After minor clearing and rough grading of the site, the ground surface beneath the drill rig was lined with an impermeable high-density polyethylene (HDPE) liner. An earthen berm, above pad level, was built that surrounded the perimeter of the rig. This earthen berm was constructed to contain drilling fluids and/or formation waters produced during well drilling, testing, and well construction activities.

Lithologic (well cuttings), packer test, and borehole geophysical log data from well OSF-104 were used to determine the actual casing setting depths for the dual-zone production well identified as OSF-105. The pilot-hole was reamed to specified diameters and depths and casing installed. Three concentric steel casings (24-, 18-, and 12-inch-diameter) were used in the construction of a OSF-105, which was used to facilitate aquifer testing of two distinct productive horizons identified in the FAS between 330 to 1,202 feet bls.

Rowe initiated drilling activities for OSF-105 on June 14, 2006. Drilling operations began by advancing a nominal 12-inch diameter pilot-hole to a depth of 50 feet below land surface (bls) via the mud-rotary drilling method. The nominal 12-inch diameter pilot-hole was reamed to a depth of 43 feet bls using a nominal 29-inch diameter staged reaming bit assembly. On June 15, 2006, Rowe installed 24-inch diameter, steel pit casing, (ASTM A53, Grade B, and 0.375-inch wall thickness) in the nominal 29-inch diameter borehole to a depth of 42 feet bls. The annulus was pressure grouted to land surface using 75 cubic feet (ft^3) of ASTM C-150 Type II, Portland cement (15.6 lbs. /gal).

After installing the 24-inch diameter pit casing, the borehole was advanced via mud-rotary method using a nominal 23-inch diameter bit through the Pleistocene-Pliocene-aged sediments, and the Peace River and Arcadia Formations of the Hawthorn Group and into the Ocala Group to a depth of 335 feet bls. The nominal 23-inch borehole was then geophysically logged (natural gamma ray and 4-arm caliper) to verify its total depth, physical dimensions and to ensure it was completed in the clean (low gamma ray emission) portion of the Ocala Limestone. On June 29, 2006, Rowe installed 18-inch diameter, steel casing (ASTM A53, Grade B, and 0.375-inch wall thickness) in the nominal 23-inch diameter borehole to a depth of 330 feet bls. Once installed, the 18-inch diameter steel pipe was pressure grouted using 216 ft^3 of ASTM Type II cement. An additional 235 ft^3 of ASTM Type II cement, installed in the annulus via the tremie method, was used to bring cement levels in the annulus to surface, completing surface casing installation on July 5, 2006.

On July 7, 2006, Rowe re-configured the drilling operations and bit assembly to advance a nominal 17-inch diameter borehole through the UFA to 550 feet bls using the reverse-air method. Once the borehole was completed it was developed using the reverse-air and over pumping techniques. On July 13, 2006, geophysical logging operations were completed within the nominal 17-inch diameter production interval (See OSF-105 Geophysical Run No.2 – Appendix D-2). SFWMD then conducted an aquifer performance test (APT) on the UFA production interval from 330 to 550 feet bls during the latter part of September 2006. This time lag between drilling completion and testing operation was due to delays in completing the tri-zone monitor well that was concurrently being constructed.

After successfully completing the first APT, Rowe continued to advance the nominal 17-inch diameter borehole via the reverse-air drilling method from 550 to 928 feet bls. It was then geophysically logged (natural gamma ray and 4-arm caliper) and 12-inch diameter, steel production casing (ASTM A53, Grade B) installed and cemented to land surface. On October 3, 2006, Rowe began to advance a nominal 12-inch borehole via the reverse-air method to a total depth of 1,202 feet bls. When drilling operations were completed, Rowe developed the second production interval from 925 to 1,202 feet bls, using reverse-air and over pumping techniques. Once sufficiently developed, SFWMD attempted to conduct an APT on the Avon Park Permeable Zone (APPZ). The pumping capacity of the turbine pump was not sufficient, however, to produce adequate drawdown within the test interval because of several highly transmissive zones. Based on specific capacity results from the first APT attempt on this test interval, Rowe installed the largest capacity turbine pumping bowl that could fit within the 12-inch diameter steel casing. On January 16, 2007, the second APT was completed but drawdown within the production and monitor wells were still insufficient to conduct thorough APT analysis - this will be discussed further in the **Hydrogeologic Testing Section** of this report. At the conclusion of hydraulic testing operations, a 12-inch diameter gate valve and blind flange plate were installed and a 6-foot by 6-foot concrete well pad with a steel enclosure constructed. **Table 2** in **Appendix A-2** provides a summary of the well construction and testing activities related to OSF-105. **Figure 3** show a detailed well completion and testing diagram for the dual-zone FAS test/production well OSF-105.

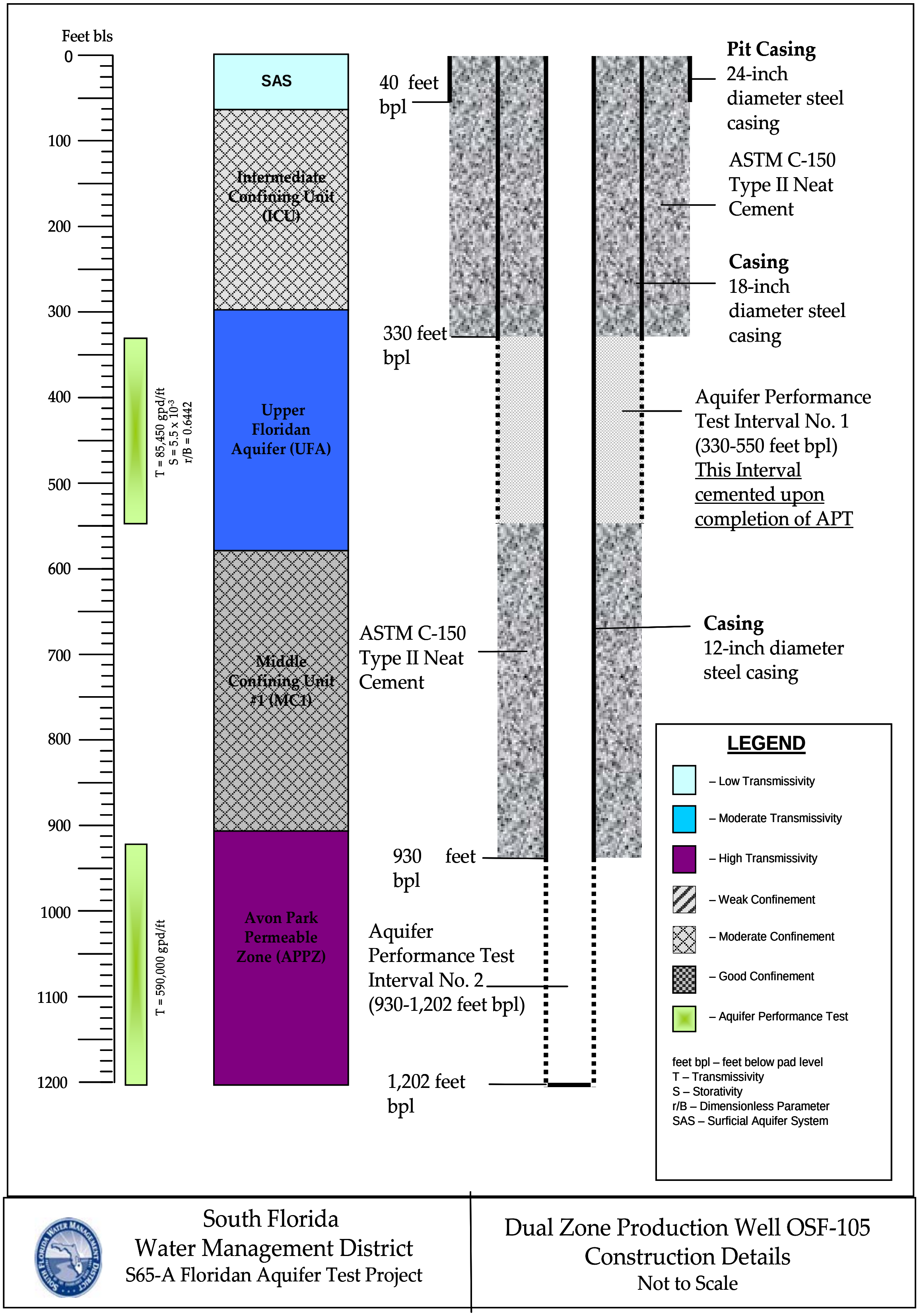

Figure 3. Well Completion Diagram, Dual Zone Production Well (OSF-105)

Hydrostratigraphic Framework

The SFWMD collected geologic formation samples (well cuttings) from the pilot-hole during drilling operations from both the tri-zone FAS monitor (OSF-104) and dual-zone production (OSF-105) wells and separated them based on their dominant lithologic or textural characteristics, and to a lesser extent color. Two major aquifer systems underlie this site - the Surficial Aquifer System (SAS), which is separated by the Intermediate Confining Unit (ICU), from the Floridan Aquifer System (FAS) with the FAS being the focus of this test well program. These aquifer systems are composed of multiple, discrete aquifers separated by low permeable "confining" units that occur throughout this Tertiary/Quaternary-aged sequence. Figure 4 shows a generalized lithostratigraphic and hydrogeologic section underlying the S65A site.

Surficial Aquifer System (SAS)

The SAS extends from land surface (top of the water table) to a depth of 70 feet bls. It consists of Holocene and Pliocene-Pleistocene-aged sediments. The undifferentiated Holocene sediments occur from land surface to a depth of 20 feet bls and consists of unconsolidated yellowish to brownish gray colored, very fine to medium grained quartz sand. Approximately 10% organic material occurs near the top of this interval with varying shell content throughout. The sediments from 40 to 70 feet bls are composed primarily of light olive gray to grayish brown, poorly consolidated, fine grained quartz sand with 2-3% shell content and increased percentage of clay matrix. The increase in clay content within this interval is noted on the natural gamma log by higher natural gamma emissions between 40 to 70 feet bls.

Intermediate Confining Unit (ICU)

Below the SAS lies the Intermediate Confining Unit, and extends from 70 to 300 feet bls at this location. The Peace River and Arcadia Formations of the Miocene-Pliocen-aged Hawthorn Group (Scott, 1988) constitutes the ICU separating the FAS from the SAS and are discussed below.

Peace River Formation

The Peace River Formation is present from 70 to 175 feet bls. Low permeable, unconsolidated, yellowish to medium gray, fine grained quartz sand with phosphatic silts and sands and 30% carbonate mud (calcilutite) occur at 70 feet bls. These sediments form the top of the ICU at this site. The borehole diameter increases significantly from 70 to 85 feet bls and corresponds to unconsolidated fine-grained quartz sand and phosphatic sand and gravel and carbonate mud which was unconsolidated and washed-out during drilling operations. The material from this interval is present in the formation samples to 135 feet bls and shows a higher than expected phosphatic sand content than shown on the natural gamma ray log for this interval. The interval from 90 to 135 feet bls is composed predominately of light to yellowish gray, fine grained quartz sand within a carbonate mud matrix. The light gray, poorly consolidated fine-grained quartz sand intermixed with phosphatic sand and gravel continues from 135 to 175 feet bls; however, the carbonate mud matrix decreases with an increase in poorly to moderately indurated limestone content with depth.

Arcadia Formation

The top of the Acadia Formation is identified at 175 feet based on a change in lithologic character from a fine-grained quartz sand unit intermixed with limestone to a phosphatic, areaneous limestone (wackestone). This phosphatic rich, poorly indurated limestone continues from 175 to 230 feet bls and is marked by an irregular natural gamma log signature due to varying phosphatic sand content. The interval from 230 to 265 feet bls is composed of medium to yellowish gray colored, medium-grained quartz sand with varied phosphatic sand content with 20 to 30 % limestone, which is slightly dolomitic in nature.

The lower part of the Arcadia Formation is present from 265 to 300 feet bls with sediment consisting of yellowish to olive gray, moderately indurated limestone (wackestone) and 5-7% phosphatic sands and silts. This interval is marked by increased formation resistivity and lower sonic transit times, which indicates a moderately competent low porosity limestone unit. The resistivity values increase from 70 to 200 ohm-meters (ohm-m) with a corresponding decrease in porosity and the caliper log shows a relatively gauged borehole (i.e., similar to the diameter of the drill bit) through this competent rock unit. Above and below this interval, the geophysical log data indicates unconsolidated or poorly indurated material. Generally, water producing horizons develop at points of contrasting hardness in rock material; however, production type geophysical logs were not conducted within this interval to evaluate the water production potential. Where present, these water producing horizons are generally hydraulically connected to and considered part of the UFA. Based on their lithologic character, these low permeability sediments form the lower boundary of the Intermediate Confining Unit.

Floridan Aquifer System (FAS)

The FAS consists of a series of Tertiary-age limestone and dolostone units. The system includes permeable sediments of the Ocala Limestone, Avon Park Formation, and the Oldsmar Formation (Chen, C.S., 1965). The Paleocene age Cedar Keys Formation characterized by evaporitic gypsum and anhydrite forms the lower boundary of the FAS (Miller, 1986); however, the Cedar Keys Formation was not encountered at this site.

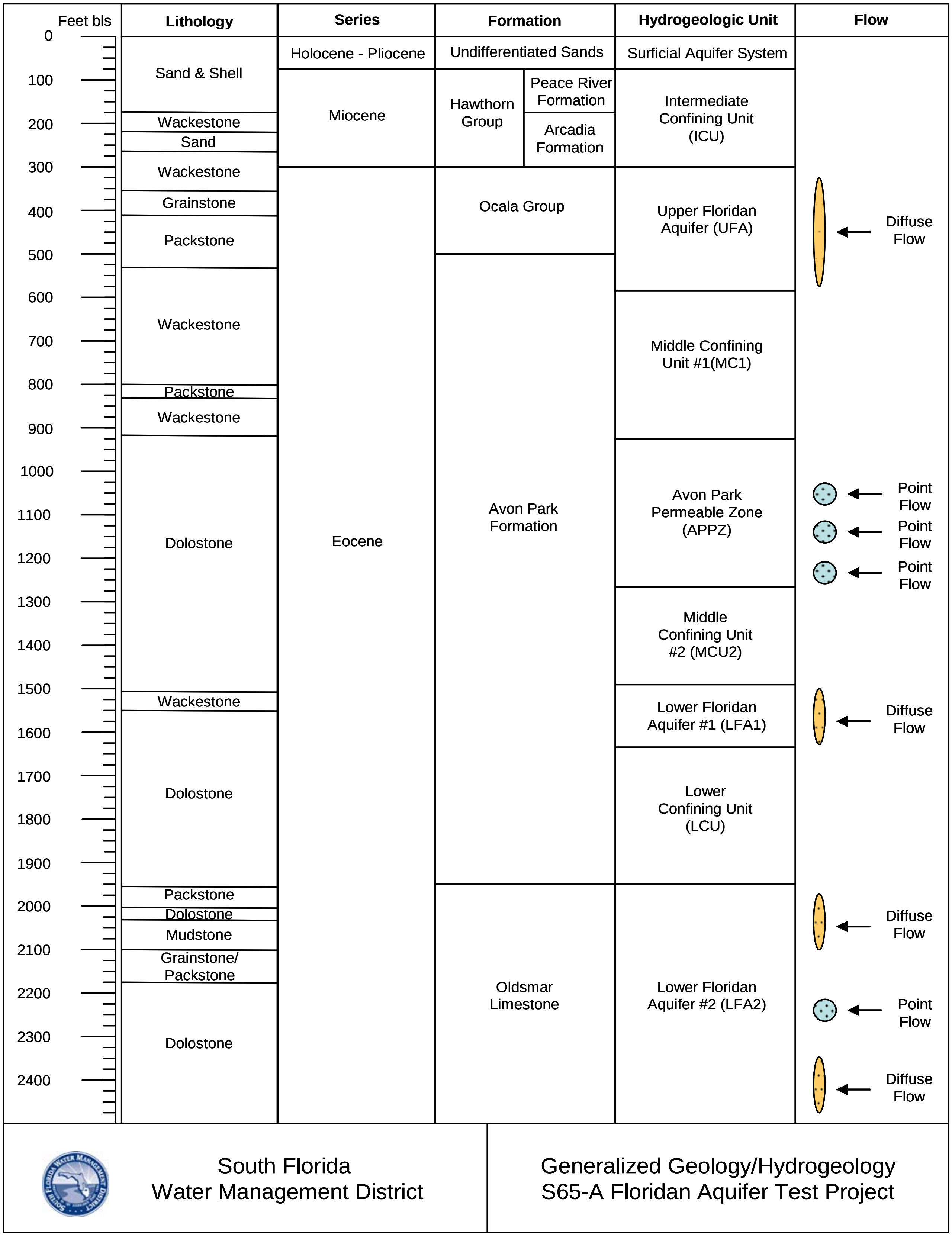

Figure 4. Generalized Lithostratigraphic and Hydrogeologic Section – S65A Site

Upper Floridan Aquifer (UFA)

The top of the FAS, as defined by the Southeastern Geological Society AdHoc Committee on Florida Hydrostratigraphic Unit Definition (1986), coincides with the top of a vertically continuous permeable carbonate sequence. The upper Floridan aquifer (UFA) consists of thin water-bearing horizons with high permeability interspersed within thick units of Early to middle-Eocene age sediments with low permeability, including the Ocala Limestone and the Avon Park Formation. At this site, the top of the FAS occurs at a depth of 300 feet bls, which coincides with the upper portion of the Ocala Limestone.

The formation contact between the Miocene-aged Arcadia Formation (Hawthorn Group) and the underlying Eocene-aged Ocala Limestone at a depth of 300 feet bls is identified by a change in lithology from a yellowish to olive gray, moderately to well indurated limestone (wackestone) with 5-7% phosphatic sands and silts to a poorly indurated, yellowish-gray to white wackestone to packstone with allochems consisting of diagnostic benthic foraminifera (*Lepidocyclina sp*). This discontinuity at 300 feet bls is evidenced on the geophysical logs by a significant attenuation of the natural gamma activity, decrease in the formation resistivity, with a corresponding increase in porosity (based on the log-derived sonic porosity data). The FGS selected the top of the Ocala Limestone at 360 feet based on the absence of quartz and phosphatic sands, characteristic color and texture of the limestone, and noticeable presence of the diagnostic index fossil *Lepidocyclina ocalana*. The formation samples taken during drilling operations from 300 to 360 feet bls, however, may reflect a mix of the strata above the 300 foot interval. Formation samples appear to have been taken at the time the bit penetrated a specified depth based on the length of drill pipe without considering the lag time necessary for the drilling fluid and well cuttings to move up the borehole and back to land surface.

The Ocala Limestone from 300 to 490 feet bls consists of light orange, poorly to moderately indurated packstone to grainstone with moderate to good primary inter-granular porosity and only minor recrystallization and secondary porosity development. The caliper log indicates (see geophysical log run no. 2- Appendix D-1) the borehole diameter exceeds 25-inches and the responses shown related to the formation evaluation logs appear to be affected by the large-diameter borehole through this interval. The interval from 300 to 370 feet appears to be non-productive. During reverse-air drilling operations insufficient formation water was produced so additional water was added to allow drilling operations to continue. A slight change in lithology from a light orange, moderately indurated packstone to a grayish brown, moderately to well indurated slightly dolomitic packstone with diagnostic benthic foraminifera (*Dictyoconus sp*.) identifies the upper boundary of the Avon Park Formation at a depth of 490 feet bls. This formation boundary coincides with a slight increase in natural gamma activity and sonic travel times, and a decrease in the photoelectric factor log trace to 2.5 barnes/electrons (see Schlumberger log run no.2 in Appendix D-1). The lithology is similar in character from 490 to 570 feet only differing in color and percentage of allochems and carbonate mud content (wackestone to packstone). The production logs through this interval also show no definitive flow zones due to the large borehole diameter and large water production capacity of the APPZ that overshadows any smaller production horizons. The static temperature gradient log however shows a steady increase in water temperature indicating small diffuse flow over this interval.

The first aquifer performance test was conducted on the interval between 330 and 550 bls. Analysis of the data yielded a transmissivity value of 85,450 gallons per day per foot (gpd/ft), a dimensionless storage coefficient of 5.5×10^{-3}, and an r/B value of 0.64 with a calculated leakance of 1.58 gallon per day per cubic foot (gpd/ft^3) (Walton, 1960).

Middle Confining Unit (MC1)

The middle semi-confining unit separates the UFA and Avon Park permeable zone (APPZ). It is composed of moderately to poorly indurated limestone (wackestone to packstone) units with well indurated dolomitic limestone and dolostone units at 595 to 630 feet bls and 770 to 780 feet bls, respectively. The dolomitic limestone and dolostone units are identified on the geophysical logs by increased natural gamma ray emissions; a smaller diameter borehole, lower sonic transit time and corresponding porosity readings and higher formation resistivity. Formation samples from this interval do not show evidence of large-scale secondary porosity development (e.g., good pinhole, or moldic porosity). In addition, the production type geophysical logs traces indicate no significant productive horizons, as seen by smooth log traces in both the temperature and flow meter logs, which support the confining nature of this interval. The top of the middle semi-confining unit is located at approximately 580 feet bls and is approximately 350 feet thick, which effectively isolates the UFA and APPZ.

Avon Park Permeable Zone (APPZ)

The Avon Park Permeable Zone (APPZ), previously reported as the middle Floridan aquifer or the Upper Floridan Zone B in some previous SFWMD and consultant publications, underlies the middle semi-confining unit (MC1) (Reese & Richardson, 2006). The top of the APPZ at this site was identified at 925 feet bls corresponding to a well-indurated dolostone unit having high production capacity. The dolostone units are cryptocrystalline to sucrosic in nature with the limestone units showing evidence of varying degrees of pinhole, vuggy and moldic porosity development. The majority of the APPZ exhibits good fracture and secondary porosity development and is marked by increased formation resistivity and decreased sonic transit time indicative of a well indurated rock unit. Through the APPZ, however, the formation resistivity, sonic transit times and caliper sondes produce an irregular (spiked) log signature indicative of fractures and solution features. The production-type logs indicate three primary flow zones (1,060, 1,140, 1,230 feet bls) from 925 to 1,230 feet bls as shown on the pumped flow meter log (see geophysical log run no.3 – Appendix D-1). During drilling, a solution feature was encountered at a depth 1,140 feet bls where a significant volume of sucrosic dolomite was "dredged" removed and is shown on the caliper log by an enlarged borehole that exceeds 20 inches in diameter. The static temperature gradient log shows cooler formation water present from 900 to 1,270 feet bls. In addition, a noticeable change in water quality near the base of the APPZ is noted by both the static and dynamic fluid resistivity logs and by the dual-induction log.

An aquifer performance test was conducted on the interval from 930 to 1,202 feet bls and analysis of the test data yielded an estimated transmissivity value of 590,000 gpd/ft, however, storage or leakance values could not be determined. These hydraulic results indicate that the APPZ is highly productive but semi-confined to confined in nature as seen by fairly small changes in water levels in monitor zones above (OSF-104U) or below (OSF-104L) this interval and small changes in water quality of produced formation water during the APT. Results of laboratory analyses conducted on water samples from the APPZ indicate that inorganic constituents meet potable drinking water standards. Low permeability dolostones of the middle Avon Park Formation mark the base of the APPZ at approximately 1,270 feet bls.

Middle Confining Unit (MCU2)

The Avon Park Formation from 1,270 to 1,490 feet bls, consists of dark yellowish to grayish brown, low permeability, well indurated, dense microcrystalline dolostone that constitues the middle confining unit 2 (MCU2). The bulk density values are 2.6 gm/cc and porosity derived values average 15 porosity units (p.u) and are fairly consistent, the caliper log is gauged without any enlarged section of the borehole noted. Based on the geophysical log data from Schlumberger log run no.1 (see Appendix D-1), the photoelectric factor (PEFZ) log signature indicates that this interval is consistent throughout and is composed of dolomite with log values of approximately 3 barnes/electrons. The dual induction log signature shows decreasing formation resistiviy in the deep induction curve (AHT90) without changes in the bulk density values (RHOZ curve), which indicates a water quality transition occurs through this inteval The water quality of the reverse-air water returns remained consistent (see Figure 5); the formation samples did not show evidence of large-scale secondary porosity development, and the temperature and flowmeter log traces indicated limited water production, which supports the overall confining nature of this interval.

Lower Floridan Aquifer (LFA1)

A permable interval is present in the Avon Park Formation from 1,490 to 1,635 feet bls that is identified as the first significant permeable zone in the lower

Floridan aquifer (LFA). The top of this interval is composed of light orange to white, moderately indurated dolomitic limestone (wackestone) with sparry calcite cement interbeded with crystalline dolostone. The lower portion (1,550 to 1,635 feet bls) is composed of grayish brown, dolostone with moderate secondary porosity development with pin-hole and vugs noted in the FGS lithologic description. The graph of water quality of the reverse-air water returns versus depth (Figure 5) indicates a noticable change in all parameters (chloride, sulfate and specific conductance) at approximately 1,500 feet bls. The water quality in the overlying confining interval is fairly consistent but as the top of the LFA is encountered, there is suffiecient water production to cause a change in the water quality of the reverse-air returns. Production type logs (e.g. flowmeter and tempeature logs) were conducted but the pump rate during logging operations was not sufficient to overcome the production of the APPZ to stress the intervals lying below and no packer tests were conducted, so that further analysis of the production capacity of this interval could not be assessed.

Lower Confining Unit (LC1)

The lower Avon Park Formation from 1,635 to 1,950 feet bls consists of dark yellowish to grayish brown, low permeability, well indurated, dense microcrystalline dolostone with minor productive zones present which is identified as the lower confining unit 1(LC1). The photoelectric factor (PEFZ) log trace through this interval is 3 barnes/electron which indicates a dolostone and corresponds well with the lithologic descriptions of the formation samples. The geophyscial log data from 1,635 to 1,690 indicate a moderatly dense dolostone. The bulk density and porosity-derived values average 2.6 gm/cc and 12 porosity units, respectively with sonic transit times of 64 micosecond per foot, all which indicate a confining unit. The physical characteristics of the dolostone changes slighty from 1,690 to 1,800 feet bls. The natural gamma log shows a change in natural gamma emissions at 1,690 feet bls and continues to 1,960 feet bls. The formation resistivity and bulk density values decrease with an increase in porosity through this interval. A productive interval was noted between 1,800 and 1,860 feet bls. The caliper log trace show a slight increase in borehole diameter with a decrease in resisitivity and bulk density with increased sonic transit times and log-derived porosity values. The water quality of the reverse-air returns (see Figure 5) changes significantly after a depth of 1,800 feet. A permeable zone that produces significant water would be necessary to cause this change. An intervening confining unit is present from 1,860 to 1,948 feet bls as indicated by increased bulk density, consistent resistivity and porosity values and lower sonic transit times. These low moderately indurated, low porosity dolostones form the base of this confining interval.

Lower Floridan Aquifer (LFA2)

The Florida Geological Survy identified the top of the Oldsmar Formation at a depth of 1,948 feet based on a change in lithologic character from a dolostone unit to a dolomitic limestone with moderate secondary porosity development and the presence of diagnostic benthic foraminifera. The top of the Oldsmar Formation is noted on the geophysical logs by a slight increase in natural gamma ray emissions and borehole diameter and an increase in the PEFZ values from 3 (dolomite) to 4.5 (limestone) barnes per electron. The interval from 1,948 to 2,000 feet is marked by variable resisitivity, bulk density and sonic transit times. At a depth of 2,000 feet there is a marked shift in resistivity and sonic transit times. The PEFZ log trace indicates a change from a dolostone to moderately indurated dolomitic limestone with good secondary porosity development as noted by the increase in sonic transit times and derived porosity values. This well developed secondary porosity zone is present from 2,000 to 2,020 feet bls. The interval from 2,020 to 2,100 feet is composed of moderately indurated mudstone with good primary porosity development as indicated by a high sonic, density and neutron porosity values. This interval exhibits higher formation resisitivty with corresponding lower density and higher porosity readings. The log-derived apparent resistivity and total dissolved solid concentration indicate slightly fresher (lower TDS concentration) formation water within the mudstone unit that was not completely flushed by the invading salt water. The fresh water used in the reverse-air drilling process may have invaded this interval during drilling operations causing a shift to higher resistivity values causing the logs to indicate fresher water (See Figure 5 in the Hydrogeologic Testing Section). The limestone units from 2,100 to 2,200 feet are composed of packstones and grainstones that are not as recrystallized and posess a higher degree of intergranular versus intercystalline porosity. Based on the geophysical log data, the limestones from a depth of 2,200 to 2,240 feet become progressively more dolomitic, better indurated and less porous with depth. This change in lithlogy and porosity is seen in the formation samples and by the PEFZ log values decreasing from 4 to 3 barnes/electrons and lower log-derived porosity values. A potential flow zone is present from 2,240 to 2,250 feet bls near the contact between the dolomitc limestone and the dense, low permeablilty dolostone that occurs below this depth. This lowermost interval was identified for long-term water level and quality monitoring (OSF-104L; 2,020 to 2,304 feet bls). The water quality within this interval is similar to seawater composition with TDS concentrations of 36,350 mg/L. The saline formation water may be derived predominately from productive horizons in the lower portion of the open-hole section.

The dense, low permeablilty dolostone contines from 2,250 to 2,420 feet bls and forms a substanital confining unit in the lower part of the FAS. The induction and sonic logs show relatively high formation resistivity and lower sonic transit times, which are indicative of dense well-indurated dolostones The bulk density over this interval average 2.6 gram/cc with average log-derived porosity values of six (6) porosity units. The lithologic logs indicate only minor secondary porosity development through this interval.

The lithlogic and geophysical log data shows the lower portion of the borehole from 2,420 to 2,530 feet to be a well indurated dolostone but both indicate intervals of good secondary porosity development. The lithologic logs indicate secondary porosity to include pin-point, vugs, moldic and caverneous porosity types with euhedrel dolomite crystal growth that generally are present in large voids. The lithogy and geophsycial log signatures are similar to those found in the "Boulder Zone" a highly permeable horizon within the Oldsmar Formation underlying central and south Florida (Duncan, et al., 1994).

Hydrogeologic Testing

Specific information was collected during the drilling program to determine the lithologic, hydraulic and water quality characteristics of the FAS at the S65-A site. These data were used in the preliminary design of the tri-zone monitor well identified as OSF-104 and the test-production well OSF-105. In addition, these data will be incorporated into the SFWMD long-term FAS water level and quality monitoring program.

Formation Sampling

Geologic formation samples (well cuttings) were collected by the contractor during drilling operations of the test/monitor well OSF-104. The formation samples were sent to the Florida Geological Survey (FGS) for detail analysis and permanent archival. **Appendix B1 and B-2** contain copies of the Florida Geological Survey's detailed lithologic descriptions for OSF-104 and OSF-105 using the FGS reference numbers identified as W-18725 and W-18784, respectively. An electronic version of the lithologic descriptions for both wells can be downloaded directly from Florida Geological Survey's internet site.

During drilling of the test/monitor well OSF-104, Rowe and AWE obtained conventional cores using a 4-inch diameter core barrel. Fourteen rock cores of various lengths were recovered from the FAS between 400 and 2,513 feet bls with core recoveries of 12 to 100 percent (**see Table 3**). Five (5) of the fourteen cores were sent to the FGS to determine specific geochemical and petrophysical characteristics of specified cored intervals. A summary of the geochemical and petro physical data from the FGS study is provided in **Appendix C.**

Table 3 . Summary of Full-Diameter Coring Activity – OSF-104

OSF-104 Core No.	Core Interval (feet bls)	Send to Florida Geological Survey	Core Footage (feet)	Core Recovered (feet)	Percent Recovery
1	410-420	x	10	1.2	12.0
2	610-620	x	10	4.5	45.0
3	620-630	x	10	5.0	50.0
4	910-920	x	10	5.0	50.0
5	980-990	x	10	8.2	82.0
6	1200-1210	x	10	7.6	76.0
7	1400-1410		10	6.0	60.0
8	1506-1516	x	10	8.0	80.0
9	1675-1687	x	12	12.0	100.0
10	1946-1966	x	20	12.0	60.0
11	2020-2035		15		0.0
12	2170-2187		17		0.0
13	2320-2335		15		0.0
14	2500-2513		13		0.0
Totals:			**172**	**69.5**	**40.4**

Formation Fluid Sampling

During reverse-air drilling of the pilot-hole, samples were taken from circulated return fluids (composite formation water) at 30-foot intervals (average length of drill rod) from 340 feet bls to 2,513 feet bls. These samples were then sent to the SFWMD water quality analysis for laboratory-determined chloride and sulfate concentrations and specific conductance values. Figure 5 shows laboratory determined chloride (Cl) and sulfate (SO4) concentrations and specific conductance (SpCond) values plus calculated total dissolved solids (TDS) concentrations with respect to depth using the following equation: TDS = Specific Conductance * 0.60 (Hem, 1994).

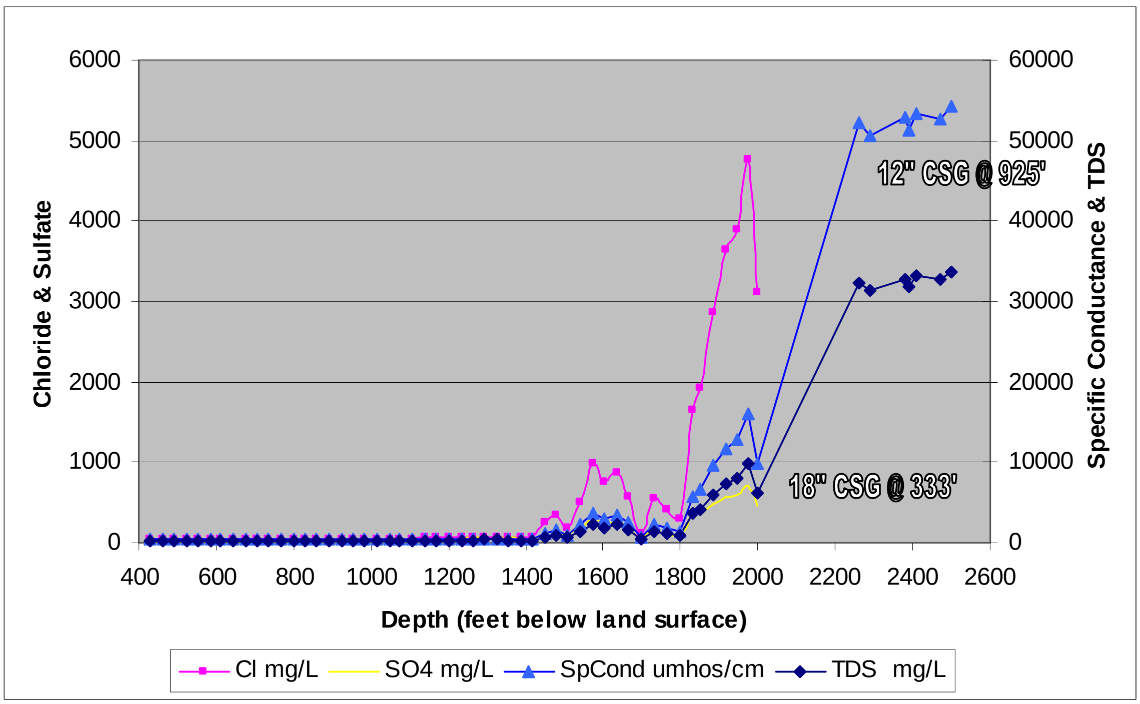

Figure 5. Reverse-air Return Water Quality with Depth from OSF-104

Geophysical Logging

Geophysical logging was conducted in the pilot-hole after each stage of drilling and before reaming the borehole for casing installations. The resulting logs provide a continuous record of the geometry of the borehole and physical properties of the subsurface formations and their respective fluids. These logs were later used to assist in the interpretation of lithology, and provide estimates of permeability, porosity, bulk density, and resistivity of the aquifer and formation water. In addition, the extent of confinement of discrete intervals can be discerned qualitatively from the individual logs.

The geophysical logging contractor(s) downloaded the data directly from the onsite logging processor onto CD or DVD using log ASCII standard (LAS) version 1.2 or 2.0 format. Appendix D-1 and D-2 contains the geophysical log traces from the various log runs for OSF-104 and OSF-105, respectively. The original geophysical logs and video surveys from the S65A site are archived and available for review at the SFWMD headquarters in West Palm Beach, Florida.

Composites of the geophysical log traces from log runs no. 1 through 6 for well OSF-104 are presented in Appendix D-1 through D-6. **Table 4** provides a summary of the conventional geophysical logging operations conducted at this site.

Table 4. Summary of the Conventional Geophysical Logs Program for OSF-104

Summary of Geophysical Logging Program -- OSF-104												
Run #	Date	Logging Company	Logged Interval (ft. bls)	Caliper	Natural Gamma	SP	DIL	Sonic	Flow-Meter	Temp	Fluid Res.	Video
1	08/15/05	MV-Geophysical	0-366	x	x	x	x	x				
2	08/19/05	MV-Geophysical	0-332	x	x							
4	10/06/05	MV-Geophysical	90-1507	x	x				x	x	x	x
5	05/17/06	MV-Geophysical	90-1000	x	x							
6	05/08/06	Schlumberger	940-2512						x	x	x	x

Specialty and conventional geophysical logs were conducted in the pilot-hole of OSF-104 from 330 to 2,512 feet bls. The geophysical logging suites included the following logs; 4-arm caliper, spontaneous potential, natural gamma ray, natural gamma ray spectrometry (NGS), dual-induction (DIL), high resolution array induction (AIT), compensated sonic (BHC), dipole sonic imager (DSI), compensated density with photoelectric factor (PEF), compensated neutron, and full-bore formation micro-imager (FMI). The neutron and density porosity values provided as part of Schlumberger's specialty logging suite were derived using a limestone matrix with a density of 2.71 grams per cubic centimeter (gm/cm^3).

Specialty logging operations conducted by Schlumberger Wireline Services are summarized in **Table 5**.

Table 5. Summary of the Specialty Geophysical Logs Program for OSF-104

	Summary of Specialty Geophysical Logging Program -- OSF-104									
Run #	Date	Logging Company	Logged Interval (ft.) bls	Natural Gamma Ray Spectral (NGS)	Array Induction Imager (AIT)	Comp. Density PEFZ	Comp. Neutron	Dipole Sonic Imager (DSI)	Formation Micro-Imager (FMI)
3	10/04/05	Schlumberger	0-1506	x	x	x	x	x	x
6	05/08/06	Schlumberger	800-2530	x	x	x	x	x	x

Table 6 summarizes physical characteristics, specific log type, and properties measured by the specialty geophyscial logs conducted at the S65A site.

Log	Log Type	Principal Application	Max. Hole Size	Benefit to GW Study
4-arm Caliper	Mechanical	Determines borehole diameter and rugosity in two horizontal planes and used to correct other logs	22-inches	Used to correct flow meter logs and aids in identifying suitable inflatable packer and casing placement
Gamma Ray (GR)	Passive Nuclear	Correlation, stratigraphic boundaries	24-inches	Correlation, used to estimate shale content
Spectralog® (SL)	Nuclear –Natural Gamma Emissions of the 256 Mineral spectrum	Correlation, mineral identification – U, Th, and K and clay content	22-inches	Correlation, defines clay content, aids in mineral identification and fracture detection
Array Induction-Imaginer Tool (AIT)	Resistivity – Bedding resolution to 3 feet in smooth borehole	Provides invasion profile and accurate R_w determination	20 inches	Water Quality - through R_w used in Archie Equation and provides estimates of permeability from invasion profile
Compensated Z-Density (ZDL) w/ Photoelectric absorption (PEF)	Nuclear – Induced Radioactive – Pad mounted	Porosity analysis, bulk density and lithologic and fluid determination	14 inches effected by rugged borehole	Porosity estimates and lithologic indicator – porosity may be used in Archie Equation.
Compensated Neutron (CN)	Nuclear – Induced Radioactive	Porosity analysis, and lithologic determination	14 inches good in rough or washed out borehole	Porosity estimates and porosity may be used in Archie Equation.
Multipole Array Acoustilog[SM] (MAC)	Acoustic Sonic - Full wave form records the Primary, Secondary and Tube Wave	Porosity and permeability analysis, dynamic and mechanical properties	15-inches sensitive to washouts	Evaluates porosity and permeability plus rock mechanical properties aids in fracture and lithology estimates
Fullbore Formation MicroImager	Resistivity – Pad mounted	Structural and sedimentary features and rock textures	14-inches – sensitive to washout and rugged borehole	Detection & evaluation of sedimentary dip, factures, fault and secondary porosity

A method used to determine formation water quality characteristics using geophysical log data is the Archie equation (Hallenburg, J.K., 1998). SFWMD used the geophysical log data to identify water quality changes (as related to TDS concentration) within the Floridan aquifer system, which assisted in identifying the depth of the base of the USDW (ground water with TDS concentrations greater than 10,000 mg/L). Archie (1942) discovered that the resistivity of a water-saturated rock (R_o) varies by a constant value as the resistivity of the formation water (R_w) changes. He qualified the relationship as:

$$R_o = F * R_w \qquad \textit{(Equation 1)}$$

Where:
R_o = the resistivity in ohm-meters of the formation 100% water saturated
F = the formation factor, a proportionality constant.
R_w = the resistivity in ohm-metes of the water saturating the formation.

Archie derived the above equation by saturating core samples of different porosity (10 to 50%) with water of various salinity (1,000 to 20,000mg/L) then measured R_o. He found that the equation was valid for the entire range of porosity and salinity. Archie also observed that R_o, and consequently F, decreased as porosity increased and inferred that F was a function of porosity and derived an empirical relationship between the two as;

$$F = 1/\phi^m \qquad \textit{(Equation 2)}$$

A subsequent investigation by Winsauer et al., (1952) led to the addition of the variable "a" in the numerator:

$$F = a/\phi^m \qquad \textit{(Equation 3)}$$

Where:
F = Formation factor
A = Tortuosity factor
ϕ = Porosity in decimal form
m = cementation factor

Chombart (1960) noted that "m" generally had values of 1.8 to 2.0 for chalky limestone, and 2.1 to 2.6 for vugular carbonates while "a" ranged between 0.85 and 1.3 for carbonates.

Therefore, to determine the resistivity of the formation water, Archie equation can be rearranged as R_w = Ro/F. The temperature corrected (to 77^0 F) deep induction (RILD) resistivity log values were substituted for Ro and the formation factor (F) determined using the empirical relationship of F = a/ϕm (with a = 1, m = 2 and ϕ = density porosity values). The resulting resistivity values (R_w in ohm-m) were converted to specific conductance by taking the inverse of R_o ($1/R_o$) then multiplying it by 10,000 to produce values in micromhos per centimeters. The SFWMD translated the calculated specific conductance values to TDS using a two step approach described in Reese (1994). **Figure 6** shows the calculated formation water TDS log compared to measured TDS concentrations of water samples taken during packer tests and from completed monitor zones (OSF-104).

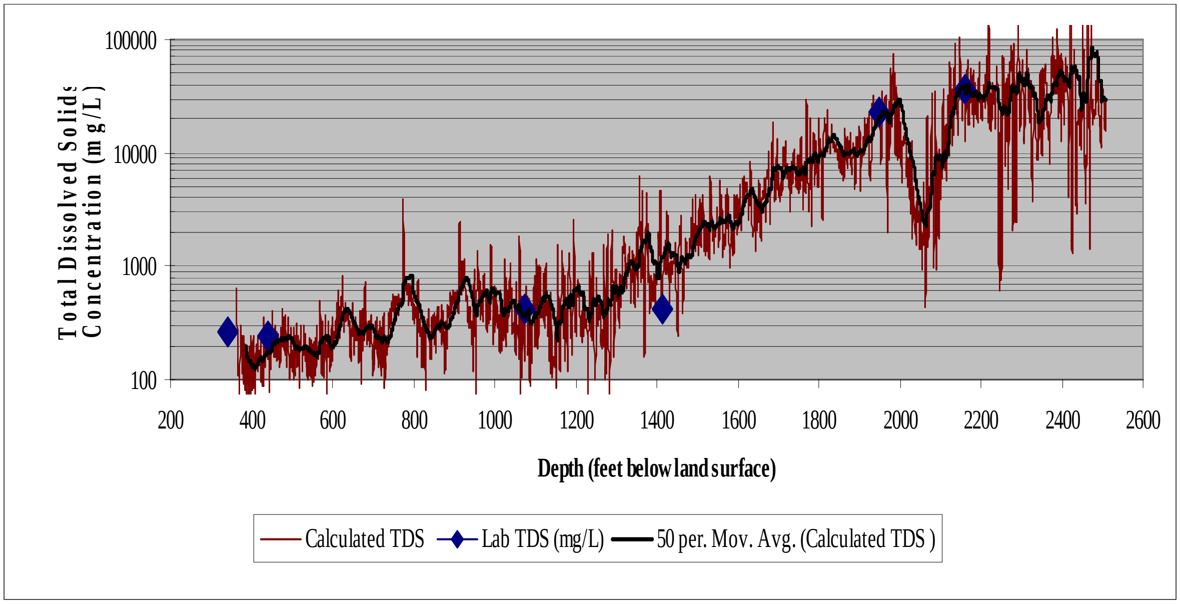

Figure 6. Calculated TDS Concentration vs. Depth for OSF-104.

From a water resource perspective, intervals having total dissolved solids (TDS) concentration greater than 10,000 mg/L were not considered for further aquifer hydraulic characterization because they are not considered potential sources of drinking water as defined in Chapter 62-520 of the Florida Administrative Code. An "Underground Source of Drinking Water" (USDW) is defined as an aquifer containing water with a TDS concentration of less than 10,000 milligrams per liter (mg/L).

The calculated versus laboratory-determined TDS are in close agreement as shown in Figure 6. TDS concentrations of the groundwater within the FAS are fairly consistent to 1,250 feet bls. Below 1,250 bls, the TDS concentration of the groundwater steadily increases to approximately 2,000 feet bls. The TDS concentration based on the field-determined specific conductance value obtained during packer testing of the 1,400 to 1,430 foot interval is not in close agreement with the log-derived TDS concentration. This may be due to an incomplete seal on the upper inflatable packer, which allowed fresher water from above to enter the test interval. The pump rate and specific capacity results from this interval were higher than expected based on the lithology that suggested low permeable sediments.

The base of the USDW is identified at a depth of approximately 1,850 feet bls. The interval between 2,020 and 2,100 feet appears to contain groundwater with lower TDS concentrations than above or below this depth. A poorly to moderately indurated, low permeable mudstone (limestone) with good primary porosity (as noted in all the porosity logs) is present within this depth interval. The lower TDS concentrations may represent fresher groundwater that was not completely displaced by the more saline water from above and below. The reverse-air return samples (**see Figure 4**) also show a drop in the specific conductance and chloride concentration at the top of this interval. The resistivity log profile within this interval does not show significant invasion of fresher water into the formation that may have developed during drilling operations. The chlorine values from the geochemical logs that were conducted by Schlumberger also show a slight decrease in chlorine content within this interval. The groundwater below 2,200 feet to the total depth of borehole at 2,513 feet bls is saline (similar to seawater composition) with TDS concentrations of approximately 36,000 mg/L.

Packer Tests

Packer test intervals were selected using the information provided by analysis of the geophysical logs and lithologic data. The purpose of these tests was to characterize the water quality and production capacities of specific intervals within the larger open-hole interval.

AWE completed packer testing operations on June 16, 2006. The water quality data obtained from the straddle-packer tests were used in tandem with the log-derived total dissolved solids concentrations to identify the base of the USDW at approximately 1,850 feet bls. The production and water quality results for the various packer tests are presented in the next section.

Three straddle-packer tests were conducted in the Floridan Aquifer System from 1,400 feet to 2,513 feet bls at this site. The purpose of these tests was to gain water quality and production capacity data on discrete intervals (approximately 30 feet in length) and to establish the depth of the 10,000-mg/L TDS interface.

The procedures listed below were used to conduct individual-packer tests in well OSF-104 at the S65A site:

1) Lower packer assembly to the interval selected for testing based on geophysical logs and lithologic data.
2) Set and inflate packers and open the ports between the packers to the test interval.
3) Install an appropriate capacity submersible pump to depth of 60 to 120 feet below the drill floor.
4) Install a 100-psig-pressure transducer inside the drill pipe and one 30-psig transducer in the annulus connected to a Hermit 3000 ™ Data Logger to measure and record water-level changes during testing operations.
5) Purge a minimum of three drill-stem volumes.

6) Monitor pressure transducer readings and field parameters (e.g., temperature, specific conductance, and pH) from the purged formation water until stable. These parameters were used to determine the quality of isolation of the packed-off interval.
7) Once the interval was effectively isolated, perform step-drawdown test.
8) Record recovery data until water levels return to static conditions.

At the end of the drawdown phase of the packer test, field parameters were measured on the samples collected. The field parameters measured for the samples obtaining during the three packer tests are reported in **Table 7.**

Table 7. Packer Test Field-Determined Water Quality Parameters – OSF-104

Identifer	Depth Interval (ft. bls)	Sample Date	Specific Conduct. umhos/cm	Temp °C	pH s.u.	Calculated TDS Conc. (mg/l)
OSF-104 PT3	1400-1450	6/16/2006	684	26.55	6.84	445
OSF-104 PT2	1907-1957	6/14/2006	36,314	27.97	7.22	23,604
OSF-104 PT1	2350-2513	6/8/2006	52,345	28.87	7.12	34,024

Friction loss coefficients were obtained from Appendix 17.A *Ground Water and Wells*, Driscoll, 1989) according to the pipe diameters used during testing operations. This coefficient was then multiplied by the length of pipe to calculate the friction (head) losses as a result of induced flow up the drill pipe. These head losses were then used to correct the drawdown data for specific capacity determinations. The specific capacity (SC) was calculated using the following method:

$$SC = Q / s \qquad \textit{(Equation 4)}$$

Where; Q = pumping rate in gpm as measured by an in-line flow meter,
s = aquifer head loss in feet: Measured drawdown minus the pipe friction loss component.

Curve-matching techniques were not used to determine transmissivity values from the drawdown or recovery data collected from straddle packer tests because they generally involve partial penetration, significant friction loss in small diameter pipe, and short pumping period, which violate the basic assumptions of various analytical methods. In additional, the productive nature of several of the tested intervals enabled them to respond almost instantaneously to the limited applied pumping stress, which induced a pressure wave into the formation. The response to this pressure wave masks their true drawdown and recovery responses. The drawdown and recovery semi-log plots from the individual-packer tests are provided in **Appendix E**. The production and static water level data from the individual-packer tests are summarized in **Table 8.**

Table 8. Packer Test Specific Capacity Data – OSF-104

Test Name	Depth Interval (ft bls.)	Surveyed Elev. (ft.)	Potentio. Head (ft-NGVD)	Q (gpm)	Total Drawdown (ft/H2O)	Total Friction Loss (ft.)	Corrected Drawdown (ft.)	Specific Capacity (gpm/ft)
OSF-104-PT3	1400-1450	59.76	26.00	120.00	26.00	12.60	13.40	8.96
OSF-104-PT2	1907-1957	59.76	15.57	120.00	61.98	16.65	45.33	2.65
OSF-104-PT1	2350-2513	59.76	0.03	120.00	32.02	21.15	10.87	11.04

Stable Isotope and ^{14}Carbon Data

Stable isotope data complements inorganic geochemistry and physical hydrogeology investigations. SFWMD plans to use the isotopic data collected at this site as part of a regional investigation to better understand ground water circulation patterns of the Floridan aquifer system and to identify recharge and discharge areas. If an interval has a particular isotopic signature, it may be used to identify and map the lateral extent of an aquifer storage and recovery (ASR) or raw water supply zones within the FAS. Radiocarbon data often complements stable isotope and inorganic data. These data have been used to estimate regional flow velocities within the FAS (Hanshaw et al., 1964).

Water samples collected during packer tests from well OSF-104 were sent to the University of California Santa Barbara Environmental Isotope Laboratory (EIL) for stable isotope determinations. The analytical services included the determination of the stable isotope compositions for the following parameters: $\delta^{18}O$, $\delta^{2}H$ or δD (deuterium), and $\delta^{13}C$.

$\delta^{18}O$ values were determined by CO_2 equilibration using standard procedures outlined by Epstein and Mayeda (1953), and Drimmie and Heemskerk (1993). Hydrogen isotope compositions were determined using the methods of Coleman et al. (1982) and Drimmie et al. (1991). The results are presented as per mil (‰) deviations from a water standard using the ∂-notation (delta):

$$\delta_x = \delta_{x-std} = \left(\frac{Rx}{R_{Standard}} - 1\right) x\ 1000 \qquad (Equation\ 5)$$

Where:

Rx = the isotope ratio of the sample (e.g., $^{2}H/^{1}H$)

$R_{Standard}$ = the isotopic standard.

The standard related to deuterium and ^{18}O is Standard Mean Ocean Water (SMOW). The precision for $\delta^{18}O$ and δD were ± 0.05‰ and ±0.5‰, respectively.

Water samples received by EIL for $\delta^{13}C$ determinations were acidified under vacuum with phosphoric acid. The released CO_2, which is produced from dissolved inorganic carbon (DIC) in the sample, is then purified using cold distillation and analyzed by a mass spectrometry (Drimmie et al., 1990). These results are then compared to a carbon standard. The standard is the carbon isotope ratio derived from the CO_2 liberated from belemnites of the Cretaceous-aged Pee Dee Formation of South Carolina. The results are presented as per mil (‰) deviations with respect to the standard using the δ-notation:

$$\delta^{13}C(‰, PDB) = \left(\frac{^{13}C/^{12}C_{sample}}{^{13}C/^{12}C_{standard}} - 1 \right) \times 1000 \qquad (\textit{Equation 6})$$

An accelerator mass spectrometer (AMS) was used to determine percent modern carbon (pmC). The pmC values are absolute percent of modern carbon, relative to the National Bureau of Standards (NBS) oxalic acid standard (HOxI) corrected for decay since 1950. The activity of "modern carbon" is 95 % of the ^{14}C in the 1950 NBS oxalic acid standard. The stable isotope and ^{14}C data obtained from OSF-104 are provided in Table 9.

Table 9. Stable isotope results for well OSF-104 at the S65A site.

Identifier	Aquifer	Sample Interval ft. bls	Sample Date	d ^{18}O $^0/_{00}$ SMOW	d ^{2}H $^0/_{00}$ SMOW	d ^{13}C $^0/_{00}$ PDB	^{14}C pmC
OSF-104 PT3	MC1	1,400-1,450	6/16/2006	-1.39	-6.80	-6.40	36.30
OSF-104 PT2	LC1	1,900-1,937	6/14/2006	-0.60	-3.10	-5.40	12.30
OSF-104 PT1	LF2	2,351-2,513	6/8/2006	0.19	2.80	-3.00	10.60
OSF-104U	UFA	330 - 550	12/18/07	-1.75	-5.80	-8.30	4.40
OSF-104M	APPZ	927-1,222	12/18/07	-1.74	-5.10	-8.30	29.70
Rainfall				-3.90	-18.00		
SMOW				0.00	0.00		

ft. bpl - feet below land surface
$^0/_{00}$ - per mil
SMOW - Standard Mean Ocean Water Standard
SMOC - Standard Mean Ocean Chloride Standard
PDB - Pee Dee Belemnitella Standard
Rain data from Candell (2000) collected in St Lucie County

PT = Packer Test
UFA = upper Floridan aquifer
MC = middle confining unit
APPZ = Avon Park Permeable Zone
LC = Lower confining unit
LFA = lower Floridan aquifer

The plot of $\delta^{18}O$ versus δD in **Figure 7** indicates depletion of the heavy isotopes among the UFA samples with respect to ocean water standard (SMOW), suggesting the role of meteoric precipitation in aquifer recharge. Samples are from the UFA and APPZ lie on Global Meteoric Water Line (GMWL as defined by Craig, 1961) but is offset for the mean isotopic composition of recent rainfall in St Lucie County (Candell, 2000). The samples collected between 1,400 and 1,450 feet bls (below the APPZ) are offset from the GMWL, possibly due to precipation during the last glacial period (Plummer, 1993) or the sample was a mix of water from above this zone as mentioned in the packer testing section. The occurrence of $\delta^{18}O$ and δD values near the GWML indicate that these waters are likely meteoric in origin.

Stable isotope results deep within the LFA are also depleted in both ^{18}O and deuterium as compared to SMOW but plot closer to SMOW than the UFA and APPZ samples. The inorganic water quality results from the first packer tests indicate the water is brackish to saline in composition. The stable isotope and inorganic data from the 1,907 to 1,957 foot interval suggests a mixing of ground water and seawater and is slightly depleted in ^{18}O and deuterium (plots slightly below SMOW – see Figure 7). The inorganic and stable isotope data for a sample taken from a depth of 2,351 to 2,513 feet indicate the water is saline (similar to seawater compostion) and is slightly enriched in ^{18}O and deuterium (plots slightly above SMOW). The fractured dolostone (zone of high permeability) unit may provide the mechanism (conduit) for the seawater inflow.

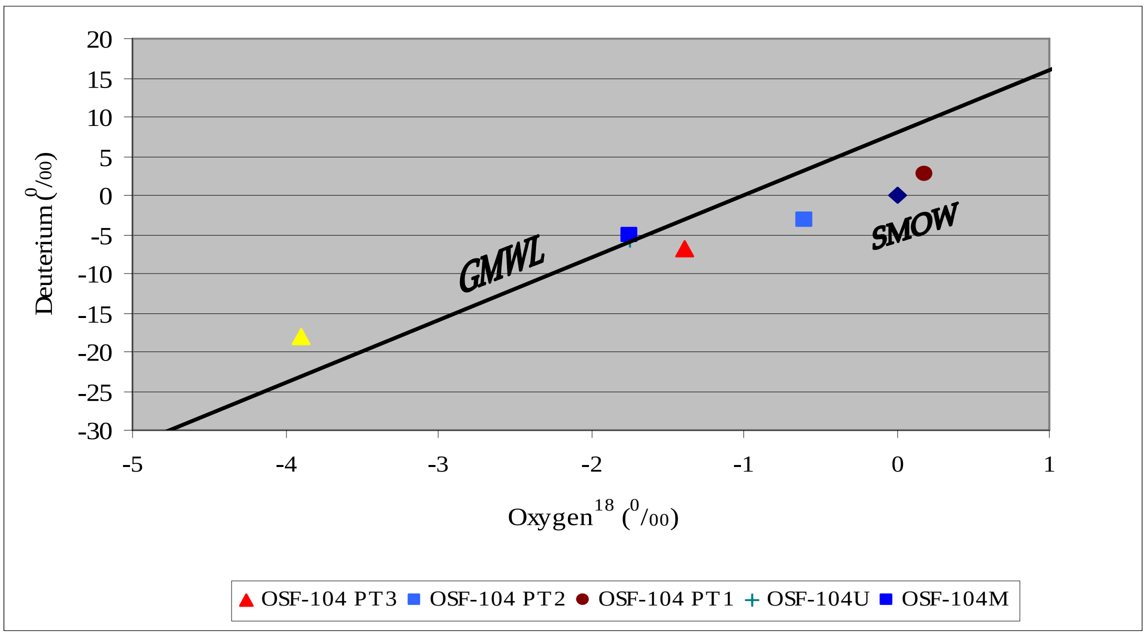

Figure 7. Cross-Plot of Stable Isotopes of Deuterium and ^{18}Oxygen

Aquifer Performance Testing

Aquifer Performance Test No. 1

The SFWMD conducted the first of two aquifer performance tests (APTs) to determine the hydraulic performance of an interval from 330 to 550 feet bls within the upper Floridan aquifer. The principal factors of aquifer performance such as transmissivity and storage coefficients can be calculated from the drawdown and/or recovery data obtained from the proximal monitor well completed in the same interval (POF-20R). If the aquifer tested is semi-confined, the hydraulic parameter of leakance of the semi-pervious layer(s) can also be determined.

The drawdown phase began September 28, 2006. The test-production well (OSF-105) was pumped at a constant-rate of 1,950-gpm for 69.25 hours while recording water level changes in the proximal tri-zone FAS monitor (OSF-104U, OSF-104M, and OSF-104L); a separate 4-inch diameter UFA well identified as POF-20R; a 2-inch diameter monitor well completed in the overlying intermediate confining unit identified as POH-1; and two 4-inch diameter monitor wells completed in the upper and lower part of the Surficial aquifer system referred to as POS-2 and POS-3, respectively. The 69.25-hour drawdown phase was followed by a 21.1 -hour recovery period, where pumping stopped and water levels were allowed to return to background conditions. Figure 1 shows the location of the various wells monitored during the aquifer performance test.

Rowe initially installed a 60 hp (6-inch diameter) submersible pump in the test-production well (OSF-105) then removed and it was replaced with an 75 hp, 8-inch diameter submersible pump. In both instances, the pump capacity of 700 and 1,250 gpm did not produce sufficient drawdown in the proximal monitor wells completed in the pumped horizon. Rowe then installed a 12-inch diameter vertical turbine pump into OSF-105 to begin testing operation for the aquifer performance test (APT1B) at 1,950 gpm.

The pumping bowl on the vertical turbine pump was set at 226 feet bls. SFWMD chose this depth based on initial water levels (approx. 15 feet bls) and preliminary data that indicated moderate drawdown would occur. A 12-inch diameter circular orifice weir with a 10-inch diameter orifice plate was used to measure discharge rates during pumping, verified by an in-line flowmeter. SFWMD personnel installed a pressure transducer on the orifice weir to record discharge rates during the APT at specific time intervals. In addition, pressure transducers were installed in all monitor wells and the test-production well (OSF-105), which were connected to a Hermit® 2000 or Hermit 3000® (Insitu, Inc) data loggers via electronic cables. The transducers and data loggers were used to measure and record water-level and barometric pressure changes at pre-determined time intervals during testing operations.

On September 28, 2006, the drawdown phase of the APT started by initiating pumping of the test-production well (OSF-105) at 1,950 gpm -- located 373 feet south of POF-20R and 489 feet south of OSF-104. SFWMD maintained the installed electronic devices, which continuously measured and recorded water levels, and pump rates during the drawdown phase. Rowe operated the pump uninterrupted for the next 69.25 hours, completing the drawdown phase on October 1, 2006.

Semi-log plots of the drawdown data for both the pumped well (OSF-105) and corresponding UFA monitor well (POF-20R) are shown in Figure 8. Maximum drawdowns in OSF-105, and POF-20R were 191.6 feet, 3.47 feet, respectively.

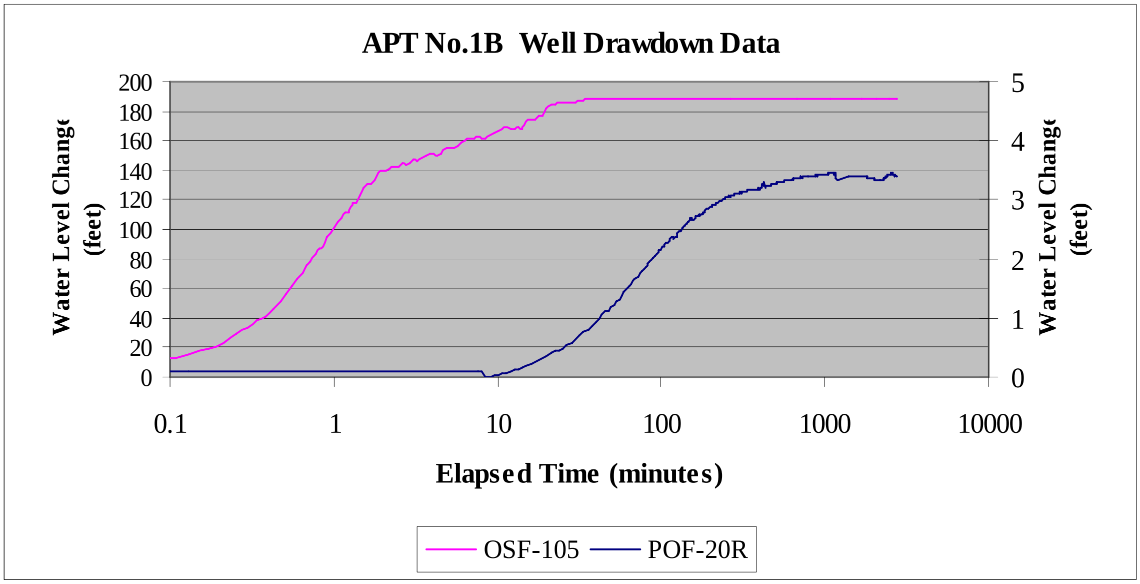

Figure 8. Drawdown data for OSF-105 and POF-20R

Figure 9 show a time-series plot of the drawdown within OSF-105 and manometer (pump rate) data collected from the 12-inch diameter, circular orifice weir during the pumping phase of APT No.1B. This figure shows minor fluctuations in pump rates during the course of the APT. These fluctuations were small enough (less than +/- 3%) to be inconsequential to the overall test results. The average manometer reading during the 69.25-hour test period was 1.286 feet (15.43 inches).

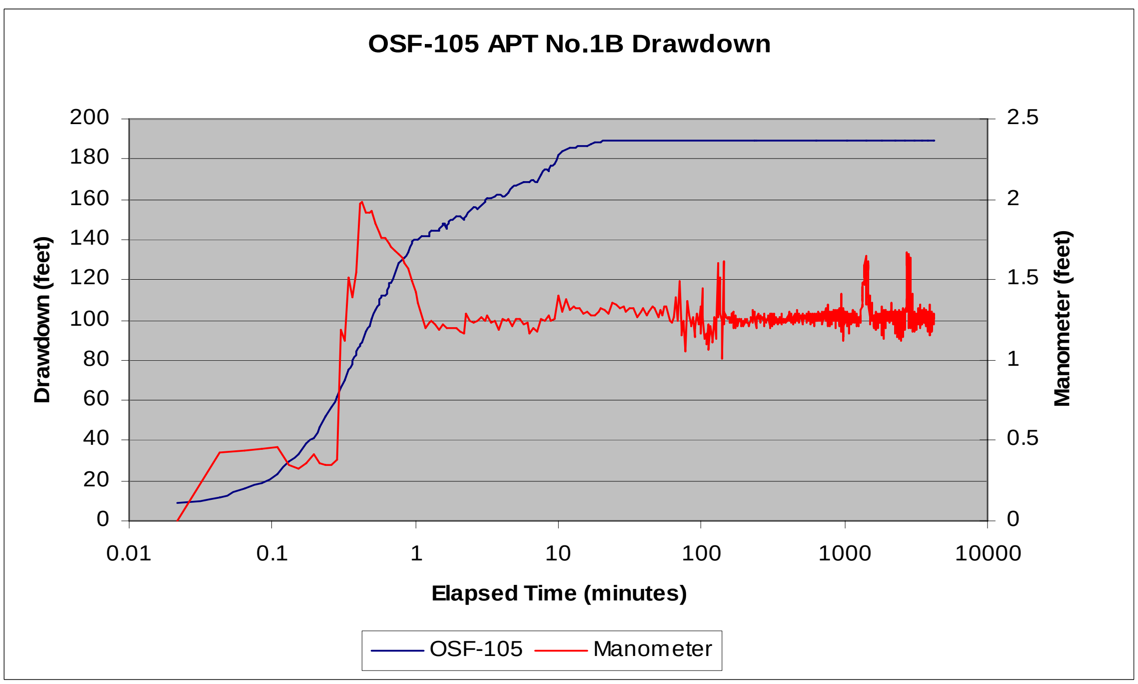

Figure 9. Semilog plot of Drawdown from OSF-105 and Manometer readings.

Before pumping stopped, SFWMD reconfigured the various data loggers to record the recovery data. Rowe manually stopped the pump and water levels slowly recovered to static conditions. The recovery phase of the APT continued for 21.1 hours, ending on October 2, 2006. **Figure 10** is a semi-log plot of the recovery data for the production well (OSF-105). Electronic copies of the original drawdown, recovery and orifice weir (pump rate) time series data for the APT are archived and available for review at the SFWMD headquarters in West Palm Beach, Florida.

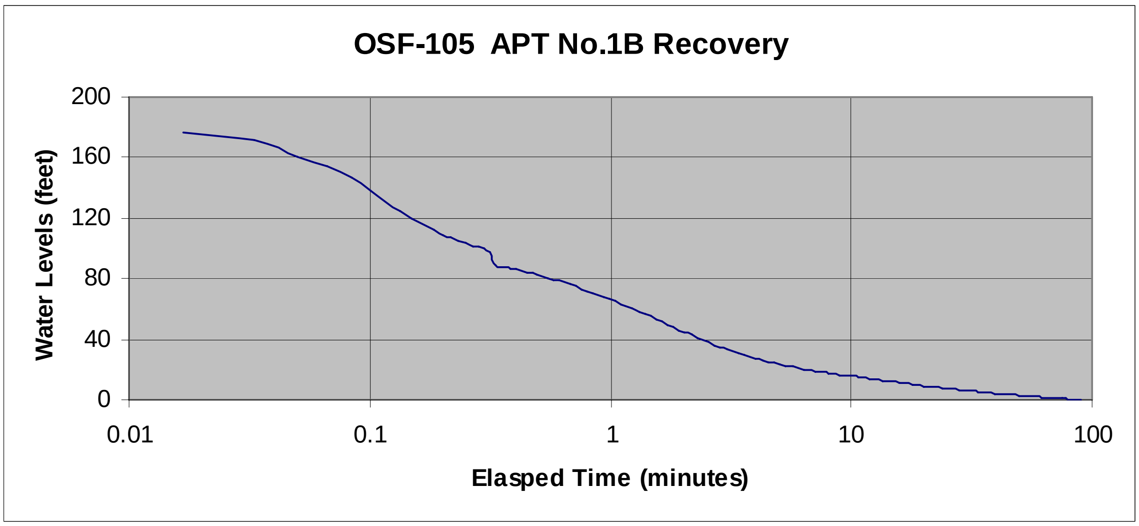

Figure 10. Semi-log plot of recovery data from OSF-105.

SFWMD applied various analytical models to the drawdown data collected during the APT to determine the hydraulic properties of the aquifer and aquitard(s) at this site. The analytical methods employed were for semi-confined "leaky" solutions. The semi-confined "leaky" analytical models include the Hantush-Jacob (1955), Hantush (1960), and Moench (1985). The methods referenced are based on various assumptions and interested readers should refer to the original articles for further details. Data analyses of the recovery produced similar hydraulic results. In general, drawdown data from a single observation well only provides an estimate of aquifer and aquitard properties because many of the type curves are similar in shape to one another and do not necessarily provide a unique match to a given data set.

Figure 11 is a log/log plot of drawdown versus time for the pumped monitor zones POF-20R. The shape of the drawdown curves for POF-20R and the declining water levels in the intermediate confining unit and surficial aquifer plus middle zone (OSF-104M) during pumping indicate a leaky-type aquifer. A leaky (semi-confined) aquifer is one that loses or gains water (depending on the pressure gradients) through a semi-confining unit (aquitard). If a semi-confining unit(s) is composed of a thick layer of poorly indurated, high porosity sediments, it may provide water to the pumping well. The lithologic data indicates that the overlying and underlying units are composed of porous (25% to 45% porosity) sediments, which have the potential to transmit water through them, and to supply additional water released from storage to the pumping well.

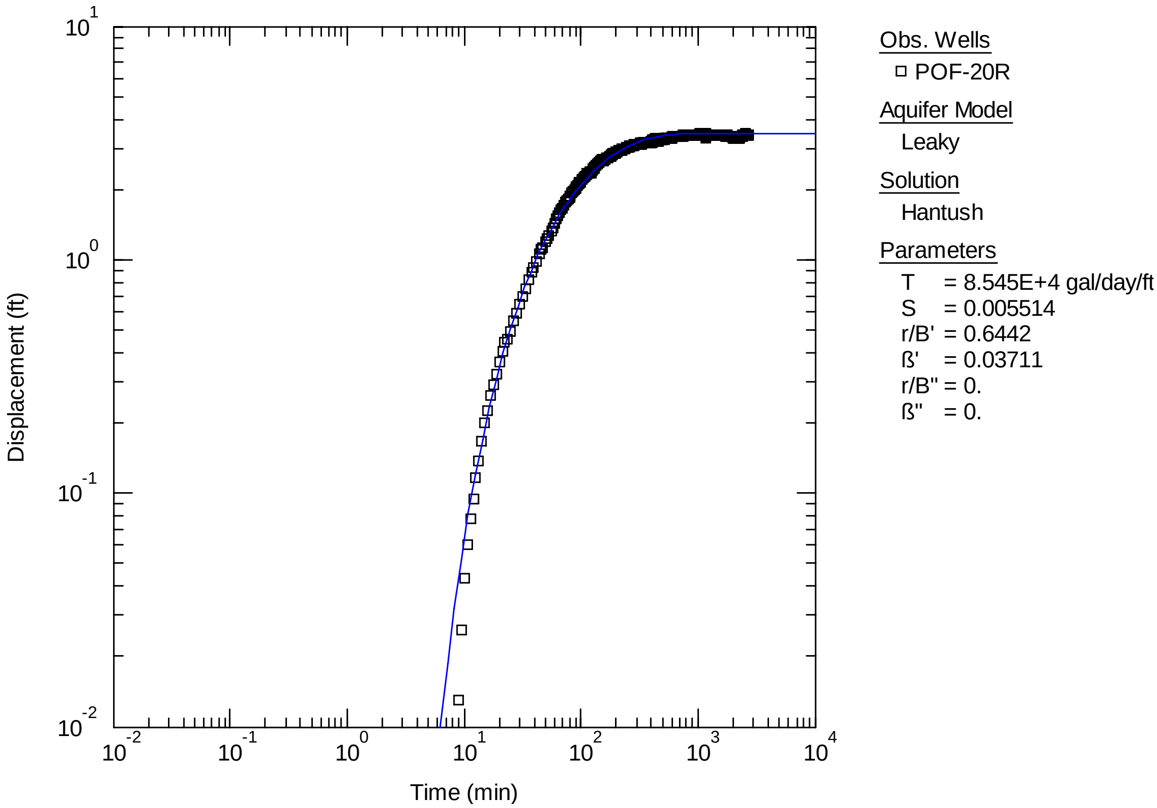

Figure 10 Log-log plot of drawdown versus time for POF-20R.

Hantush (1960), derived an analytical solution for predicting water-level displacements in response to a pumping well with aquitard storage. Based on these considerations and the site-specific hydrogeologic data collected during drilling and aquifer testing, the Hantush analytical model appears to best represent the conditions present at this site. The results of this solution yielded a transmissivity value of 85,450 gpd/ft, a storage coefficient of 5.5 x 10^{-3}, and an (r/B) value of 0.64. The dimensionless parameter r/B characterizes the leakage across the aquitard(s) to the pumped aquifer, from this value a leakance value of 1.58 gpd/ft^3 was calculated (Walton, 1960).

Aquifer Performance Test No. 2

After Rowe completed the second phase of construction on the dual-zone test-production well (OSF-105), SFWMD conducted a second APT to determine in-situ hydraulic characteristics of the APPZ from 930 to 1,202 feet bls. The drawdown phase consisted of pumping this interval at a constant-rate of 2,795 gpm for 95-hours. **Figure 1** shows the well locations of the tri-zone monitor well (OSF-104U,M,L) and test-production well (OSF-105) and other onsite monitor wells used in the aquifer performance test. The 95-hour drawdown phase was followed by a 23.5-hour recovery period, where water levels were allowed to return to background conditions.

Rowe installed a vertical turbine pump in the test-production well with the 12-inch pumping bowl set at 226 feet bls. The wellhead was re-installed with appurtenances consisting of a shut-off valve, discharge pressure gauge, and wellhead pressure transducer. A 12-inch diameter circular orifice weir with a 10-inch diameter orifice plate was used to measure discharge rates during pumping, verified by an in-line flowmeter. SFWMD personnel installed a pressure transducer on the orifice weir to record discharge rates during the APT at 2-minute intervals. Additional pressure transducers were installed in the test-production well and the various onsite monitor wells including; the tri-zone FAS monitor OSF-104, POF-20R, POH-1 and POS-2 and POS-3 and the test-production well (OSF-105). Each of these monitor wells were connected to Hermit® 3000 or Hermit® 2000 (Insitu, Inc) data loggers via electronic cables. The transducers and data loggers were used to measure and record water level and barometric pressure changes at pre-determined time intervals during testing operations.

On January 22, 2007, SFWMD started the drawdown phase of the second APT by initiating pumping of OSF-105 at 2,795 gpm. SFWMD maintained the installed electronic devices, which continuously measured and recorded water levels, and pump rates during the drawdown phase. Rowe operated the pump uninterrupted for the next 95-hours, completing the drawdown phase on January 26, 2007.

Figure 12 is a semi-log plot of the drawdown data from both the pumping well (OSF-105) and corresponding pumped monitor well (OSF-104M). Maximum drawdown in OSF-105 and OSF-104M were 9.5 feet and 0.128 feet, respectively.

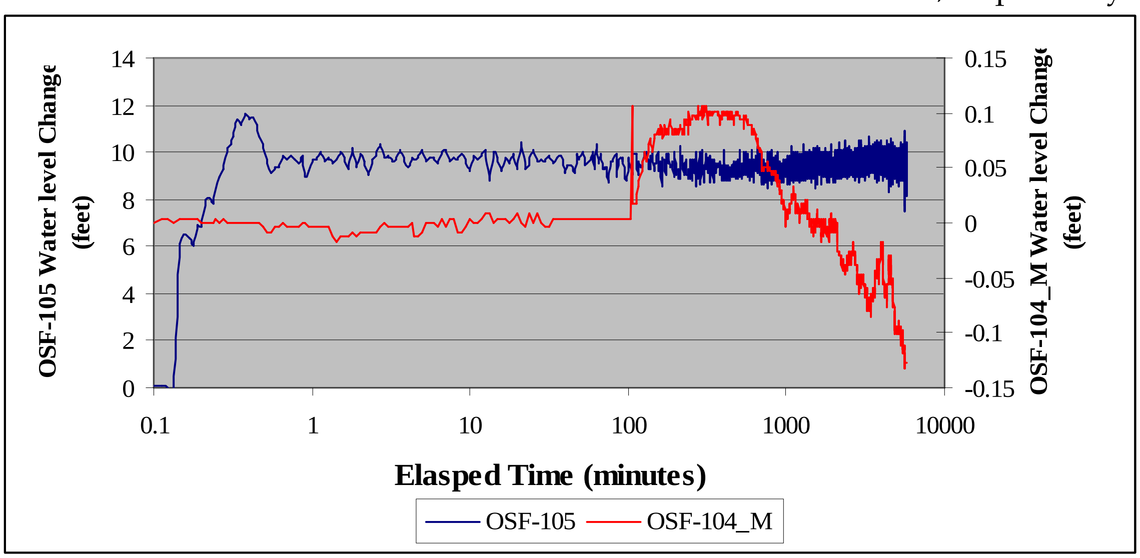

Figure 12. Semi-log plot of drawdown from OSF-105 and OSF-104_M

Figure 13 is a time-series plot of water-level changes during the drawdown phase for the UFA monitor zone OSF-104U (330 to 550 feet bls) and LFA monitor zone OSF-104L (2,020 to 2,305 feet bls), each located at the same radial distance from the test-production well as OSF-104M. There is minimal water-level change in the the over-and under-lying monitor zones during pumping. Water levels in the upper (OSF-104U) and lower Floridan aquifer monitor zones (OSF-104L) separated by 375 and 820 feet of low permeability carbonates-responded primarly to barometric pressure variations during the pumping phase of this APT.

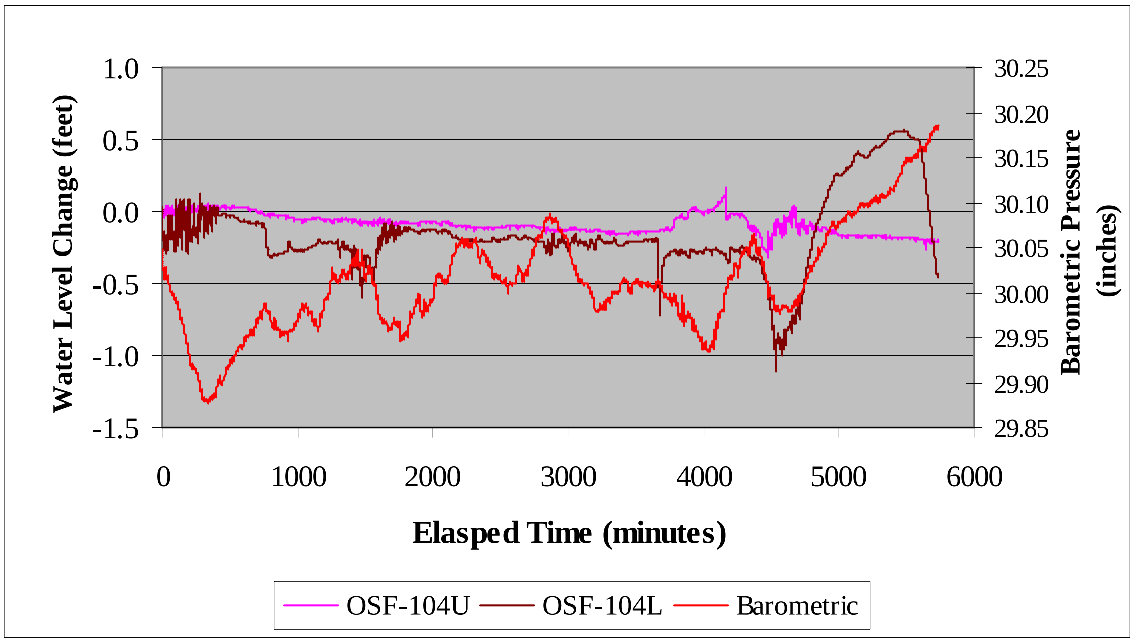

Figure 13. Time series plot of water levels OSF-104U & OSF-104L with barometic pressure

Figure 14 show a time-series plot of the manometer reading collected from the 12-inch diameter, circular orifice weir and water level change from OSF-105 during the pumping phase of the APT No.2. This figure shows minor fluctuations in pump rates during the course of the APT. These fluctuations were small enough (less than +/- 3%) to be inconsequential to the overall water change in the production well.

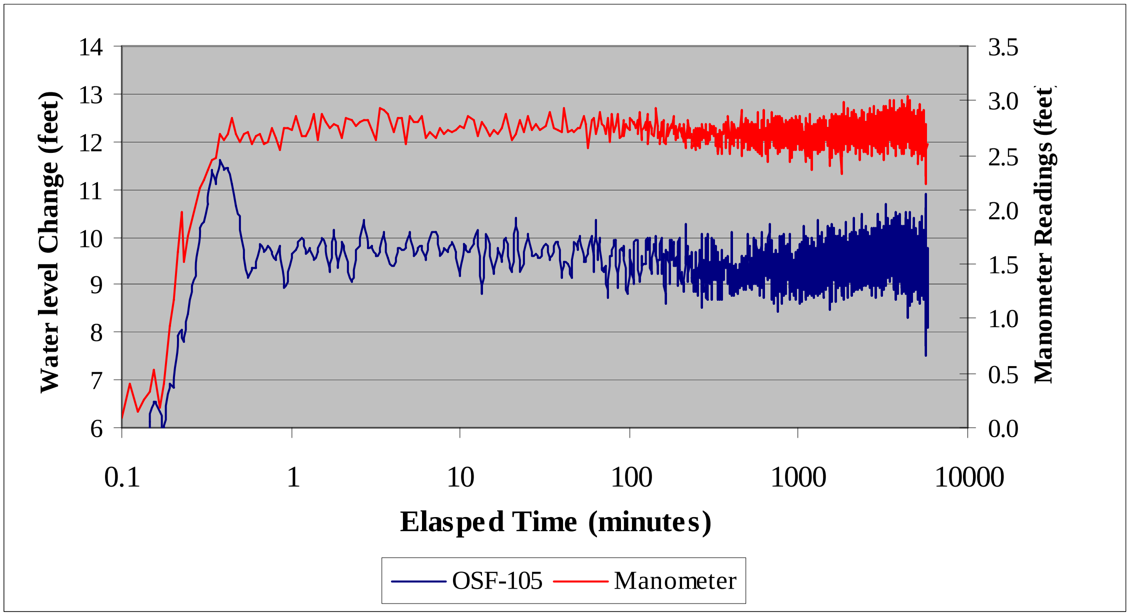

Figure 14 Time-series plot of manometer readings and drawdown from OSF-105

Before pumping stopped, SFWMD reconfigured the various data loggers to record the recovery data. Rowe manually stopped the pump and water levels slowly recovered to static conditions. The recovery phase of the APT continued for 24 hours, ending on January 27, 2007. **Figure 15** is a time series plot of the recovery data for the pumped monitor zone (OSF-104M) within the APPZ and the other two monitor intervals (OSF-104U and POF-20) that are completed in the UFA. The data shows that water levels respond primarily to barometric changes over time and were not directly affected by the withdrawals from OSF-105. The water levels in OSF-104L were erratic and had no correlation to the recovery phase, barometric pressure change or tidal variations. Electronic copies of the original drawdown, recovery and orifice weir (pump rate) data for the APT are archived and available for review at the SFWMD headquarters in West Palm Beach, Florida.

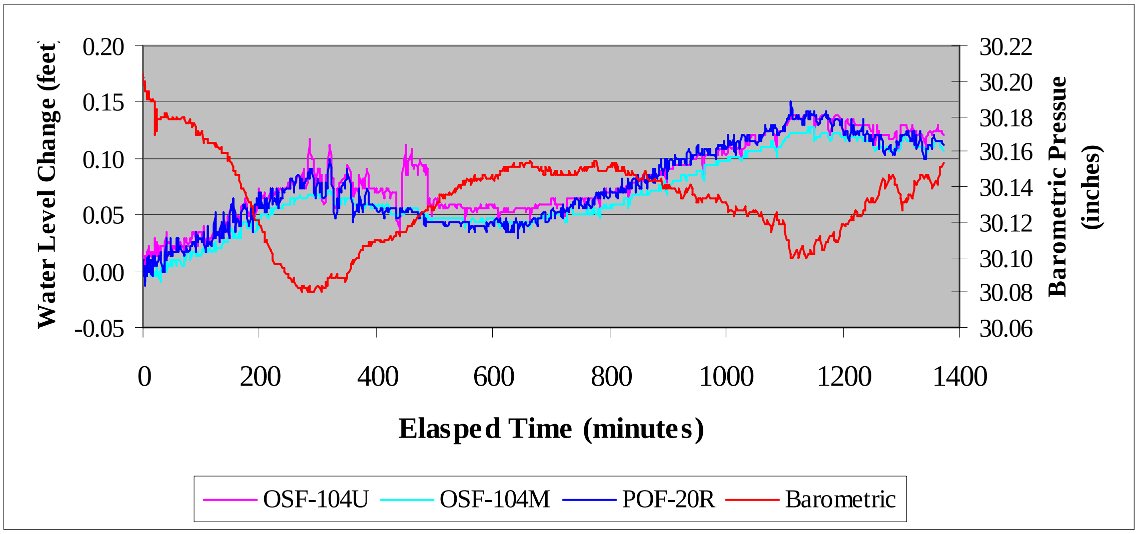

Figure 15 Time series plot of the recovery data from the onsite monitor wells

Figure 16 is a semi-log plot of the recovery data versus time for the pumped well (OSF-105). The shape of the drawdown (Figure 14) and recovery curves from OSF-105 show that water levels respond and stablize quickly after the start and stop of the pump. This is indicative of a of highly transmissive interval which stabilizes quickly with miminal change and generates an oscillatory response in water levels. The lithologic data shows that the pumped interval is composed of fractured dolostone and cavernous limestones, which can transmit water through them rapidly with minimal drawndown. The proximal FAS monitor well within the pumped interval (OSF-104M) showed only slight discernable negative trends with a water level decline of 0.128 feet. The UFA monitor well OSF-104U (completed from 330 to 550 feet bls) declined 0.25 feet. Water levels in OSF-104L (completed from 2,020 to 2,303 feet bls) were erratic during testing operations with no discernable response to pumping or changes in barometric pressure or tidal influences.

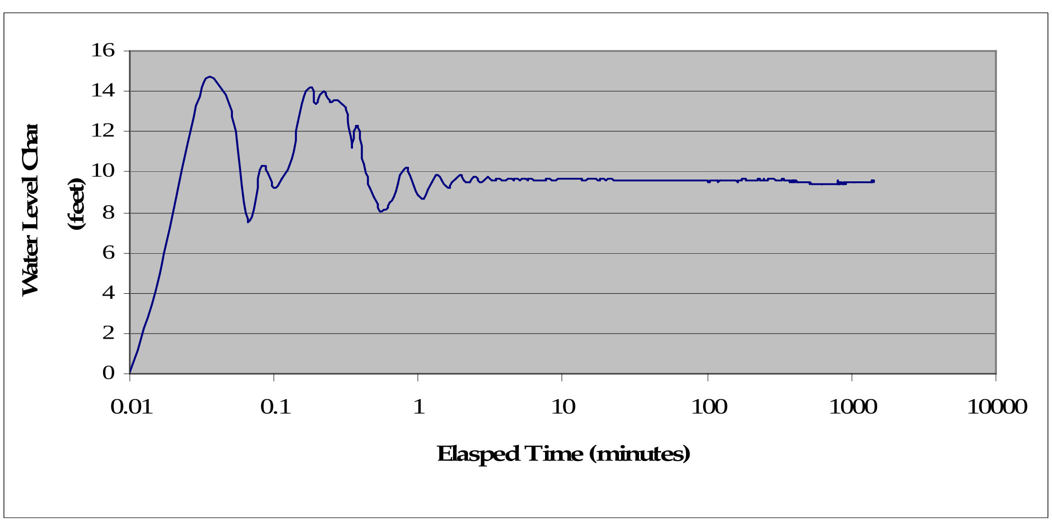

Figure 16 Semi-log plot of the recovery data for OSF-105

Based on water level responses in the pumping well (OSF-105) and the pumped interval monitor well (OSF-104M), analytical solutions could not be properly applied to the data collected. However, an empirical formula can be used to calculate the approximate transmissivity value for a confined aquifer based on the specific capacity data. The specific capacity of the production well was 295 gpm per foot of drawdown. Based on Discoll (1989), the specific capacity of 295 gpm/ft is multiplied by 2,000 to generate a estimated transmissivity of 590,000 gpd for the APPZ. The storage coefficient and leakance coefficient can not be detemined using this method.

Summary

1. Lithologic information and geophysical logs obtained from OSF-104 and OSF-105 indicates that soft non-indurated detritial clays, silts and quartz sand and poorly indurated mudstones of the Hawthorn Group predominate from 70 to 300 feet bls. These low permeable sediments act as semi-confining units separating the Floridan Aquifer System (FAS) from the overlying Surficial Aquifer System (SAS).
2. The top of the Floridan aquifer system (FAS) as defined by the Southeastern Geological Society AdHoc Committee on Florida Hydrostratigraphic Unit Definition (1986) was identified at a depth of approximately 300 feet below land surface (bls).
3. Lithologic and geophysical logs, specific capacity and APT results indicate moderate production capacity in the UFA, and excellent production capacity in the Avon Park Permeable Zone (APPZ).
4. Water quality data from packer tests and completed monitor zones indicate that chloride and total dissolved solids concentrations of the produced waters from the upper and middle Floridan aquifer meet potable drinking water standards.
5. The UFA (330 to 550 feet bls) yielded a transmissivity value of 85,450 gpd/ft or 11,423 ft^2/day, storage coefficient of 5.5 x 10^{-3}, a r/B dimensionless value of 0.64 and a leakance value of 1.58 x 10 gpd/ft^3.
6. A productive horizon in the APPZ from 930 to 1,202 feet bls yielded an estimated transmissivity value of 590,000 gpd/ft or 78,877 ft^2/d. The FAS tri-zone monitor well (OSF-104) was located at a distance where no discernable changes in water levels were observed during the APT.
7. The production type logs (e.g. flow, temperature logs) indicate that below 1,270 feet bls, the productive capacity is limited (as indicated by the fluid-type logs) suggesting lower permeability – semi-confining units near the base of this productive horizon.
8. A permeable interval is present in the Avon Park Formation from 1,490 to 1,635 feet bls. It is identified as the first significant permeable zone in the lower Floridan aquifer (LFA).
9. Composite water quality sampling during packer tests and geophysical log data was used in tandem to identify the base of the USDW (those waters having TDS concentrations less than 10,000 mg/L) at approximately 1,850 feet bls.
10. A brackish water zone was identified from 2,020 to 2,100 using the geophysical log data in tandem with Archie's equation. The water quality of the above and below this zone was near sea water composition.
11. The groundwater below 2,200 feet to the total depth of borehole at 2,513 feet bls is saline (similar to seawater composition) with TDS concentrations of approximately 36,000 mg/L.

Recommendations

1. A 16 or 18-inch diameter test/production well could be properly located and constructed to produce meaningful water responses in both the tri-zone monitor well (OSF-104) and the current test/production well (OSF-105). The data derived would allow analysis of field-scale hydraulic parameters and determination of anisotropy within the APPZ and leakance from the semi-confining intervals

2. The three monitor zones associated with OSF-104 should be acidized and developed sufficiently by air-lift or over pumping methods until total suspended solids content is below 5 mg/L or turbidity levels are below three (3) N.T.U's.

3. All onsite monitor wells including POF-20R, POH-1 and POS-2 and POS-3, should be properly developed to ensure water quality and water level data is representative of the monitor interval.

4. Additional production-type geophysical logging (i.e., temperature, and fluid resistivity) should be conducted in the open-hole section of the lower monitor zone (2,020 to 2,304 feet bls) of OSF-104 to verify if a brackish water zone is present between 2,020 and 2,100 feet bls. This will confirm the log-derived TDS concentrations and assist in qualifying water levels changes that occur due to varying water density present with the lower monitor interval.

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