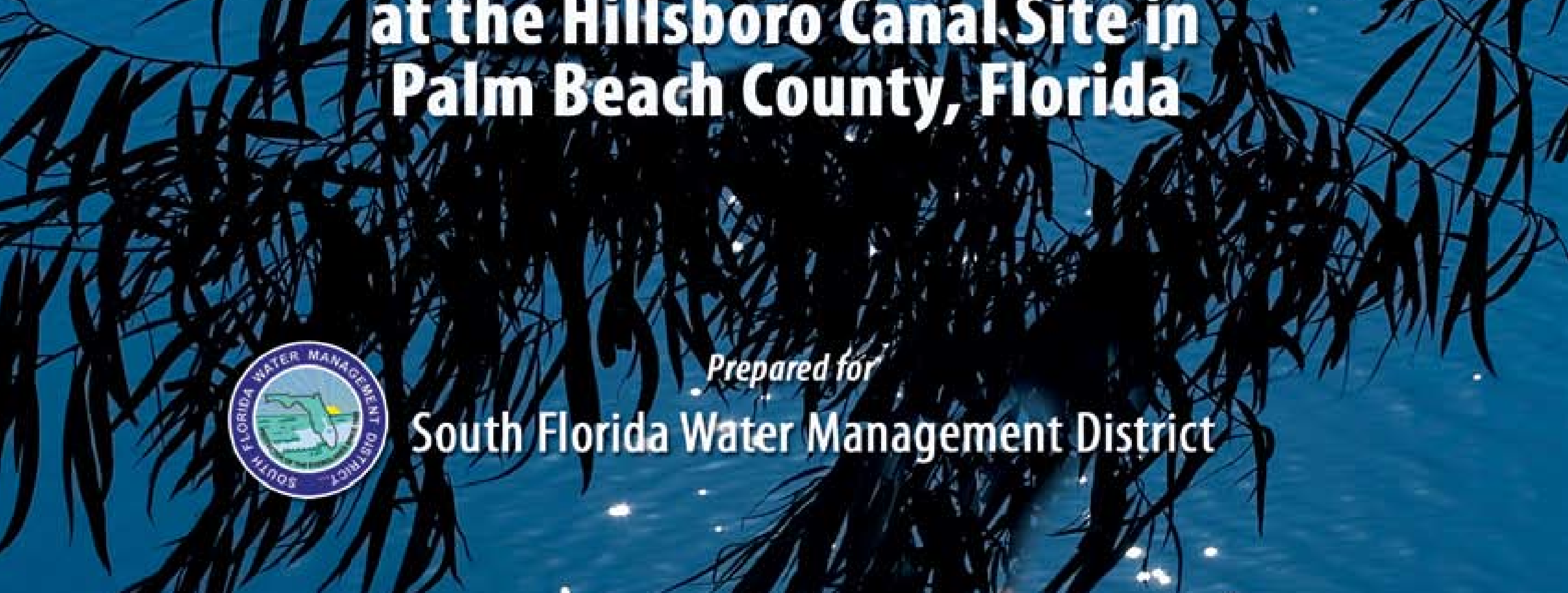
Report on the Construction and Testing of the Hillsboro Aquifer Storage and Recovery Floridan Aquifer System Monitor Well 3 (HASR-FASMW-3) at the Hillsboro Canal Site in Palm Beach County, Florida

Prepared for

South Florida Water Management District



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SECTION 1

Introduction

1.1 Background

A primary focus of the Comprehensive Everglades Restoration Plan (CERP)—jointly being conducted by the U.S. Army Corps of Engineers (USACE) and the South Florida Water Management District (the District)—is storing available water currently lost to tide. Aquifer storage and recovery (ASR) technology has been identified as a potential storage option in the western Hillsboro Canal Basin where available water has been identified. The District received a construction and testing permit (153872-002-UC) from the Florida Department of Environmental Protection (FDEP) Underground Injection Control (UIC) section on June 3, 2005, and a copy is presented in Appendix A. In accordance with Specific Condition 5.e of the permit, a final report is to be submitted to FDEP, the UIC Technical Advisory Committee (TAC), and the Atlanta office of U.S. Environmental Protection Agency (EPA), Region IV, upon completion of construction and testing of the Upper Floridan Aquifer monitor well HASR-FASMW-3. This document serves as that report.

The objective of constructing a single-zone Floridan Aquifer System (FAS) monitor well is to support the implementation of the Hillsboro ASR Pilot Project. This well will augment data from existing FAS monitor wells at the site. Data collected from well testing and long-term monitoring will be instrumental in determining the feasibility of ASR technology at this location.

1.2 Project Description

This report summarizes the construction and testing of a single-zone FAS monitor well that will support the implementation of the Hillsboro ASR Pilot Project. The well is located west of Boca Raton at the west end of Loxahatchee Road in unincorporated Palm Beach County, on the north side of the Hillsboro Canal near the convergence of the L-40, L-39, and L-36 Canals (see Exhibit 1-1).

CH2M HILL served as the onsite engineer during construction activities for the monitor well. Diversified Drilling Corporation (DDC) was selected as the contractor to construct the monitor well. Following receipt of the construction and testing permit from FDEP on June 3, 2005, DDC was issued a Notice to Proceed (NTP) from the District on June 13, 2005. Completion of construction was scheduled for October 7, 2005. However, as a result of construction-related problems, the project was not completed until June 2006.

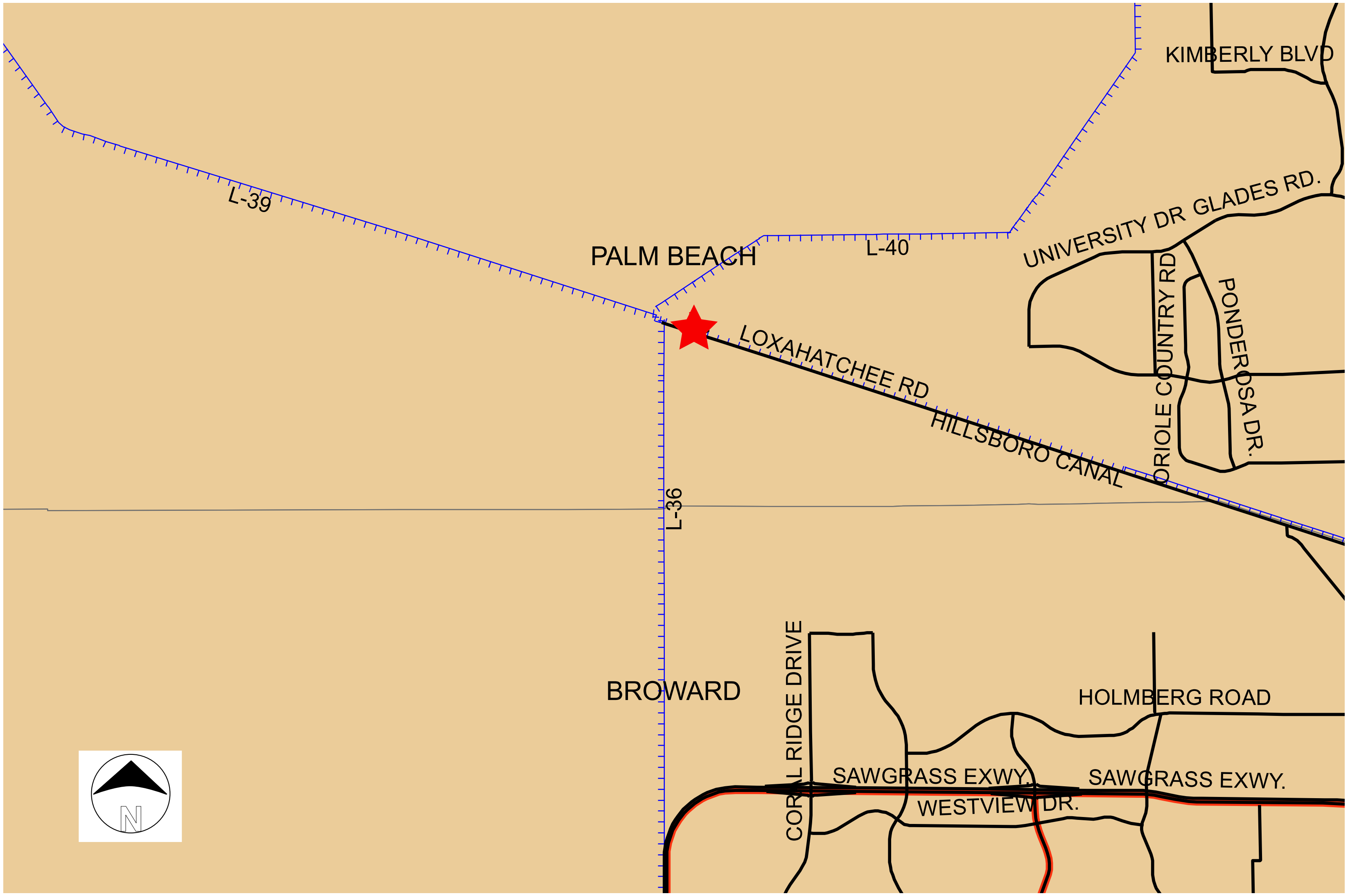

EXHIBIT 1-1
Location Map

SECTION 2

Monitor Well Construction

This section describes the drilling and construction activities associated with the single-zone FAS monitor well, HASR-FASMW-3. Construction of the monitor well was completed in June 2006, and included installation of the Upper Floridan Aquifer (UFA) monitor well, wellhead piping, data logging equipment, a concrete pad, protective bollards, and four shallow Surficial Aquifer System (SAS) monitor wells.

2.1 Monitor Well Construction

Construction of the monitor well was completed as follows:

- Installation of the 20-inch-diameter steel pit casing
- Installation of the 14-inch-diameter steel surface casing through the SAS
- Installation of the nominal 6.625-inch final fiberglass-reinforced pipe (FRP) casing through the confining layers of the Hawthorn Group
- Completion of the open borehole in the UFA

The following subsections describe the drilling and installation methods used to complete construction of the exploratory well. An overall summary of construction activities for the duration of the project is presented in Appendix B. Daily drilling reports (from the engineer) and weekly summaries are presented in Appendix C. Borehole deviation surveys are provided in Appendix D. A completion diagram of HASR-FASMW-3 is provided in Exhibit 2-1.

2.1.1 Installation of the 20-Inch-Diameter Pit Casing

Construction of the monitor well began on June 28, 2005, with the drilling of a 30-inch-diameter borehole hole using the mud rotary technique for surface casing.

The 20-inch (inside diameter [ID]) 0.375-inch thick steel casing was installed and cemented in place on June 28, 2005, to a depth of 37 feet below land surface (bls). A copy of the casing mill certificate is provided in Appendix E. The casing was cemented in place using the pressure grouting method in one stage. A total of 87 cubic feet (ft^3) of neat cement was pumped, and cement returns were visible at land surface. A summary of each casing setting depth and related cementing information is provided in Exhibit 2-2.

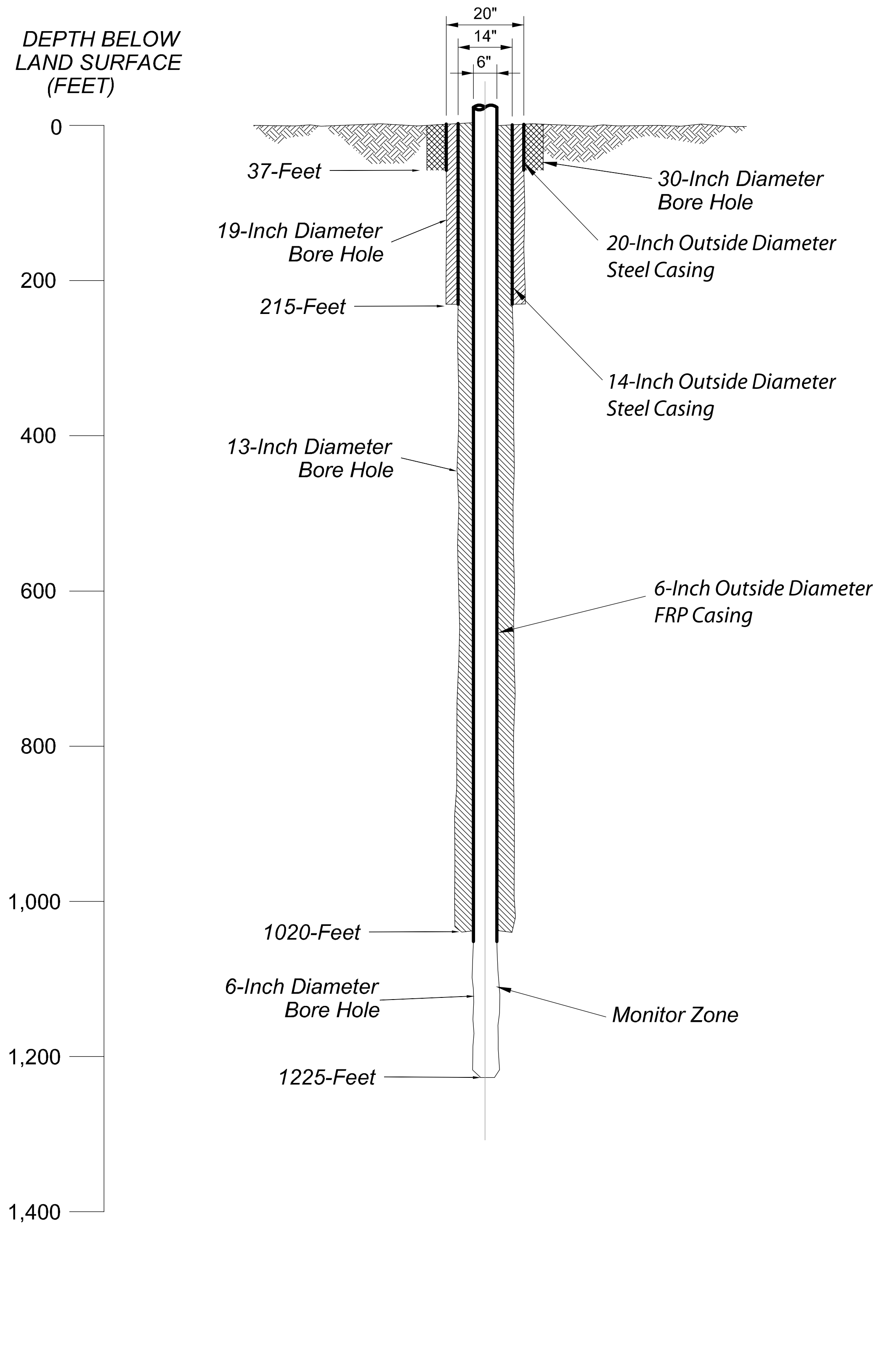

EXHIBIT 2-1
Monitor Well Completion Diagram

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EXHIBIT 2-2
Summary of Casing Setting Depths and Cement Quantities for Well HASR-FASMW-3

Casing	Casing Material	Casing OD (inch)	Casing ID (inch)	Casing Thickness (inch)	Casing Depth (ft bls)	Date	Cement Stage	Type of Cement	Quantity of Cement (ft^3)
Pit	Steel	20.00	19.25	0.375	37	28 June 05	#1	Neat	87.02
					Remarks:	Pressure grout from bottom of casing			
							Total cubic ft:		**87.02**
Surface	Steel	14.00	13.25	0.375	215	29 July 05	#1	Neat	261.03
					Remarks:	Pressure grout from bottom of casing			
							Total cubic ft:		**261.03**
Final	FRP	6.10	5.43	0.34	1020	22 Feb 06	#1	Neat	95.22
								2%	111.78
					Remarks:	Pressure grout from bottom of casing			
						23 Feb 06	#2	2%	227.70
					Remarks:	Tremied into annulus from 605 ft bls			
						24 Feb 06	#3	2%	53.82
					Remarks:	Tremied into annulus from 175 ft bls			
							Total ft^3 Neat:		**95.22**
							Total ft^3 2%:		**393.30**
							ft^3 Neat:		**443.27**
							ft^3 2%:		**393.30**
							Total ft^3:		**836.57**

Notes:
OD=outside diameter
ID=inside diameter
FRP=fiberglass-reinforced pipe

2.1.2 Installation of the 14-Inch-Diameter Surface Casing

Upon completion of the installation of the 20-inch-diameter pit casing, closed circulation mud rotary pilot hole drilling resumed on July 25, 2005, at a depth of 37 feet bls. Drilling advanced through moderately indurated sandstone and limestone to a depth of 225 feet bls, where a transition to clay was observed. This depth was interpreted as the base of the SAS and the top of the Intermediate Confining Unit. On July 27, 2005, geophysical logging of the pilot hole was conducted and was followed by reaming of the pilot hole with a nominal 19-inch bit. Reaming was completed to a depth of 218 feet bls on July 28, 2005.

The 14-inch-diameter casing (0.375-inch wall thickness/13.25-inch ID) was installed on July 29, 2005, through the SAS and into the top of the confining units to 215 feet bls. A copy of the casing mill certificate is provided in Appendix E. The casing was cemented into place immediately upon the completion of the installation using the pressure grout method. A total of 261 ft^3 of neat cement was pumped in a single stage and was stopped when cement returns were observed at land surface. A summary of the casing and cementing information is presented in Exhibit 2-2.

2.1.3 Installation of the Nominal 6.625-Inch Final Casing

Following the installation of the 14-inch-diameter steel surface casing on July 29, 2005, drilling of the 8-inch pilot hole was continued to a depth of 1,230 feet bls. Geophysical logs were then conducted followed by the pilot hole being plugged back with gravel to a depth of 974 feet bls. Reaming of the pilot hole then took place with a nominal 13-inch-diameter drill bit to a depth of 1,025 feet bls.

On September 15, 2005, a written request was submitted to and approval granted by FDEP and the UIC-TAC of a final casing seat of 1,020 feet for the nominal 6.625-inch FRP casing. This setting depth was selected to seal off the overlying clay layers of the Hawthorn Group from the permeable limestone of the storage zone.

Following the approval of the casing seat depth, the nominal 6.625-inch FRP casing was unsuccessfully installed (because of material related issues) on two separate occasions from 0 to 1,020 feet bls. After several unsuccessful attempts to conduct a pressure test, the FRP casing was milled out both times.

Following the second milling of the casing, the borehole was reamed for the third time to a depth of 1,027 feet bls on February 16, 2006. A caliper and gamma log of the reamed hole was conducted on February 22, 2006, and installation of the final 6.625-inch FRP casing was successfully completed through the confining units of the Hawthorn Group to a depth of 1,020 feet bls. The fiberglass casing has a 0.34-inch wall thickness (5.43-inch ID/6.10-inch OD). Casing sections were threaded together with Teflon pipe dope and Teflon tape as they were lowered into the mud-filled borehole. Stainless-steel centralizers were fastened to the outside of the casing at predetermined intervals to center the casing in the borehole. Following installation, the casing was cemented to land surface using the pressure and tremie grout methods. Additionally, temperature logs were conducted after the first stage of cementing. Exhibit 2-2 presents a summary of the casing and cementing information.

2.1.4 Mechanical Integrity Testing

A casing pressure test was conducted March 13, 2006, to verify the mechanical integrity of this casing. To conduct the pressure test, the well was sealed using the cement plug at the base of the casing and a blind flange on top of the temporary wellhead. A calibrated pressure gauge was used at the surface to measure the pressure during the test. The pressure inside of the well was raised to 50 pounds per square inch (psi) by injecting water, and was then monitored for 60 minutes while the pressure was recorded. After 60 minutes, the pressure had decreased by 1 psi, a decrease of less than of 5 percent. A volume of 0.5 gallons was bled off when the pressure was released and returned to 0 psi. Data from the pressure test are provided in Appendix F.

2.1.5 Open Borehole Completion

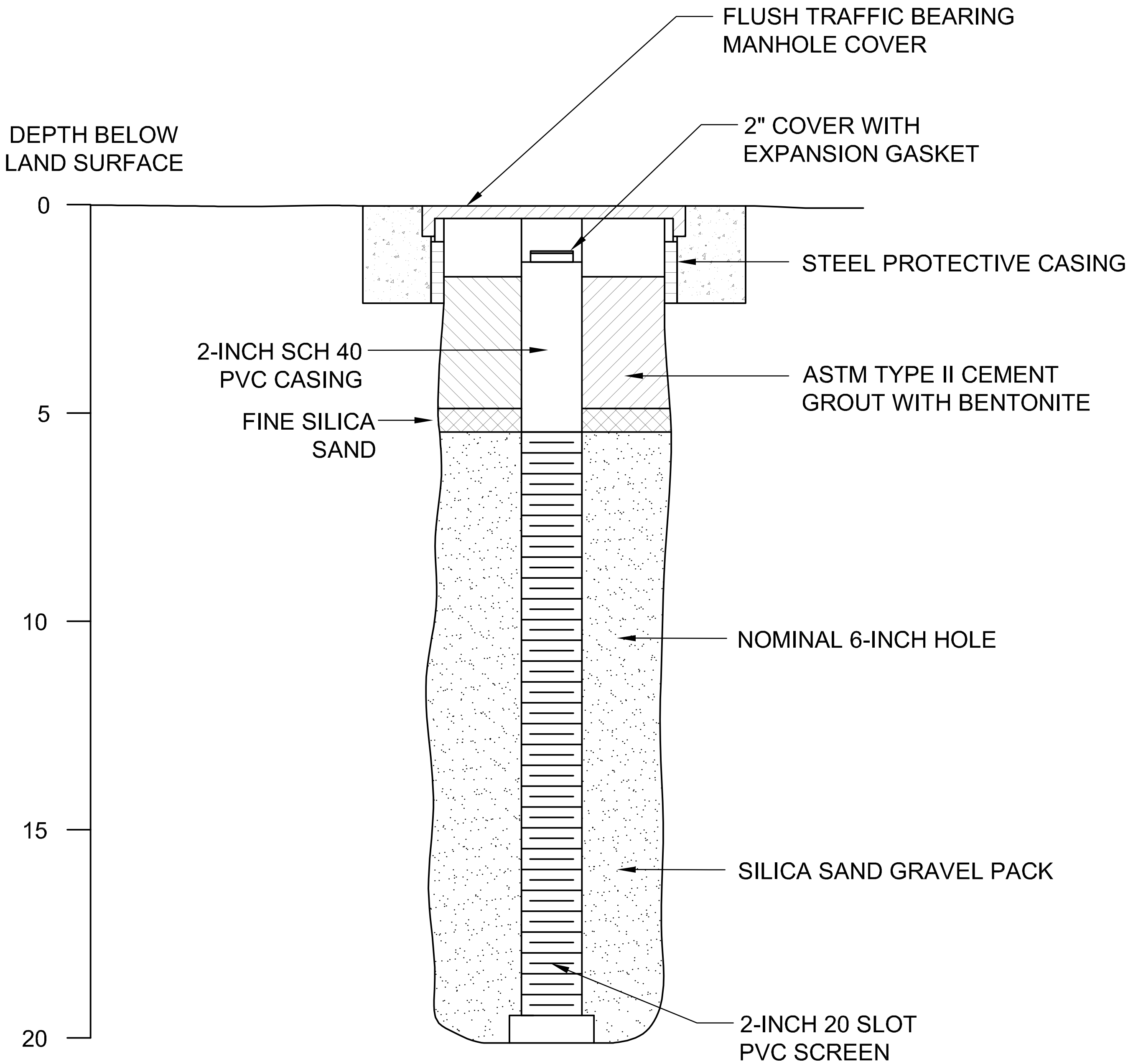
The removal of the gravel used for plugging back the borehole prior to installation of the 6.625-inch FRP casing began on March 15, 2006, and the total depth of 1,225 feet bls was reached on the same day. Information on the hydrologic testing performed on the open borehole is provided in Section 3.

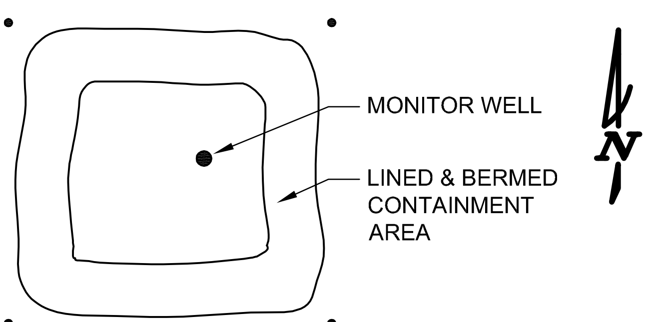
2.2 Shallow Surficial Aquifer System Monitor Wells

The four shallow SAS monitor wells were installed on June 30 and July 1, 2005. Exhibit 2-3 provides a typical SAS well construction diagram, along with the locations of the wells. During construction of HASR-FASMW-3, water samples were collected weekly from the four surficial monitor wells. The monitor wells allowed for the collection of samples and analysis of shallow groundwater during drilling. The location of each monitor well corresponded approximately with the corners of the temporary concrete drilling pad. Water samples were analyzed for conductivity, pH, temperature, and total dissolved solids (TDS). Results from the weekly water quality sampling at the shallow monitor wells are provided in Appendix G.

2.3 Surface Facilities

The surface facilities consist of a 6-inch stainless steel tee equipped with a pressure transmitter connected to a solar panel powered data logger. A 6-inch butterfly valve on the tee connects the wellhead to a PVC discharge line, which may be used to flow the artesian well during instrument installation, maintenance, or sampling. Water is discharged to the Hillsboro Canal. The wellhead, a 3.5-foot by 3.5-foot concrete pad, and four concrete bollards were completed in June 2006. Exhibit 2-4 presents a detail of the wellhead.





SHALLOW MONITOR WELL ORIENTATION

EXHIBIT 2-3
Shallow SAS Monitor Well Diagram

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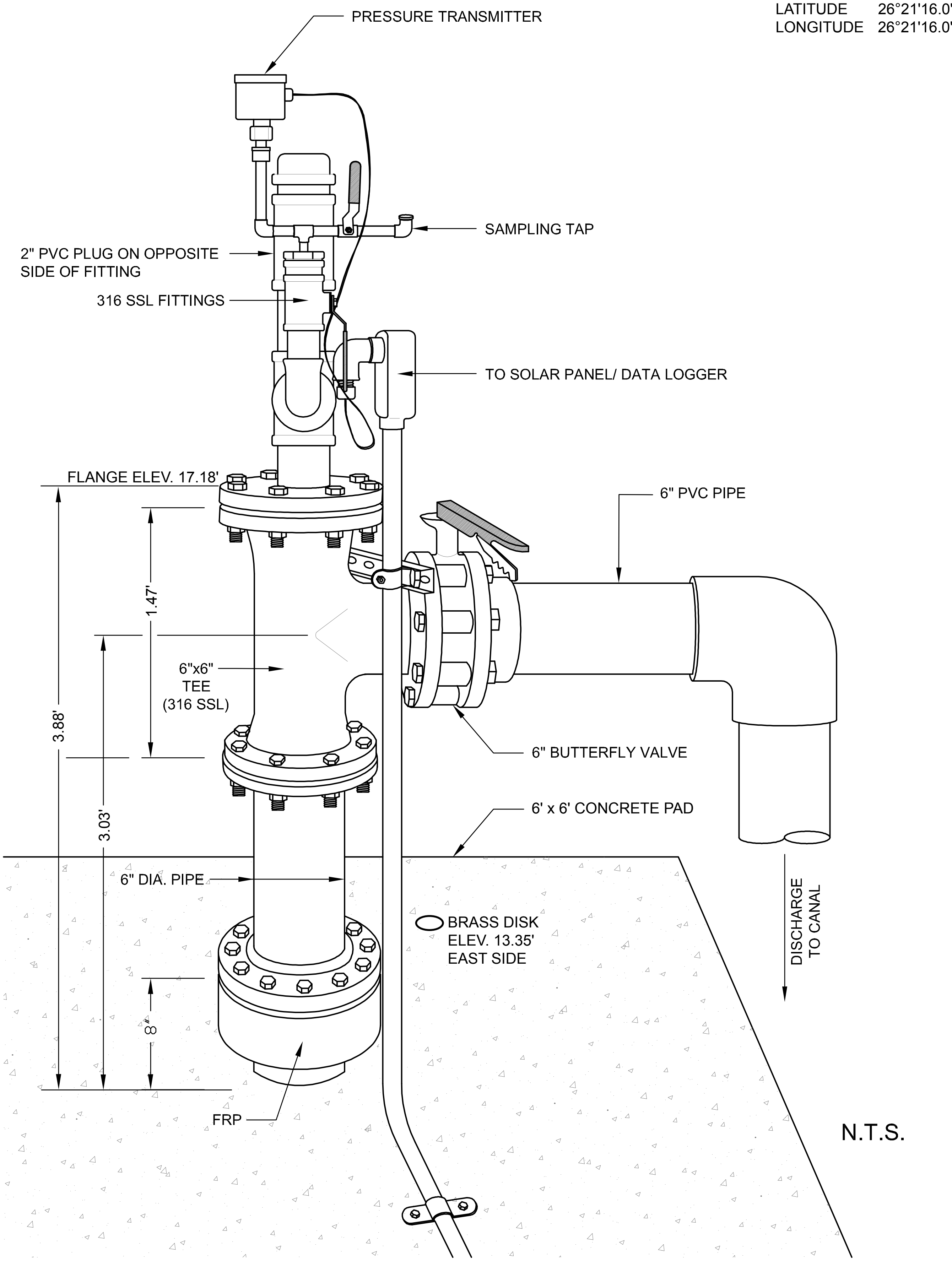

EXHIBIT 2-4
Wellhead Completion Diagram

SECTION 3

Hydrogeologic Testing

Several types of hydrogeologic tests were performed during construction of the exploratory well. These tests included the collection of drill cuttings, geophysical logging, a packer test, and groundwater quality sampling. This section describes the procedures and results of those tests.

3.1 Cutting Samples

Formation cutting samples were collected during drilling at 5-foot intervals from land surface to the total depth of the well (1,225 feet bls). Cuttings were collected from the drilling mud, or water, as it circulated out of the borehole and onto the shell shakers (a screened area used to separate the mud/water from the cuttings). The cuttings were collected in cloth bags, labeled, and characterized for rock type, color, consolidation, hardness, and fossils. Appendix H provides detailed lithologic descriptions of the cuttings.

3.2 Geophysical Logging

Geophysical logs were performed during the drilling of the monitor well to identify hydrostratigraphic features and to aid in the construction of the well. The logs used to identify hydrostratigraphic features included caliper, gamma ray, dual induction, and borehole compensated sonic. In addition, caliper logs, temperature, and cement bond logs were used to evaluate cement placement around the casings. During and after completion of the well, fluid resistivity, fluid flow, and video survey logs were performed. Exhibit 3-1 lists the geophysical logs performed. Copies of the geophysical logs are provided in Appendix I, and the video survey log is included in Appendix J. The logs conducted by Schlumberger were at the request of the SFWMD, and copies of these logs were collected directly by the SFWMD representative and are not included as part of this report.

EXHIBIT 3-1
Geophysical Logging

Logging Event No.	Date of Logging Event	Interval Logged (feet bls)	Nominal Borehole Diameter (inches)	Geophysical Log(s)	Remarks
1	07/27/05	0–226	7.875	Caliper Natural Gamma Ray Dual Induction Borehole Compensated Sonic	Logs performed on 7.875-inch-diameter pilot hole
2	07/29/05	0–218	19	Caliper Natural Gamma Ray	Logs performed to assist in calculating the volume of cement necessary to grout the 14-inch-diameter steel casing

EXHIBIT 3-1
Geophysical Logging

Logging Event No.	Date of Logging Event	Interval Logged (feet bls)	Nominal Borehole Diameter (inches)	Geophysical Log(s)	Remarks
4	09/08/05 & 09/09/05	0–1,227	7.875	Dipole Shear Sonic Imager (DSI) Formation Micro Imaging Gamma Ray Compensated Neutron Elemental Capture Spectroscopy Compensated Density Photoelectric Effect Array Induction Spontaneous Potential	Logs performed on 7.875-inch-diameter pilot hole
5	10/4/05	0–1,003	13	Caliper Natural Gamma Ray	Logs performed to evaluate hole for 7.5-inch-diameter FRP casing installation.
6	10/7/05	0–1,024	13	Caliper Natural Gamma Ray	Logs rerun to evaluate hole for 7.5-inch-diameter FRP casing installation.
7	10/8/05	0–757	6	Temperature Natural Gamma Ray	Temperature log performed to identify top of cement.
8	11/16/07	0–1,019	13	Caliper Natural Gamma Ray	Logs performed to evaluate hole for 7.5-inch-diameter FRP casing installation.
9	11/17/07	0–1,026	13	Caliper Natural Gamma Ray	Logs rerun to evaluate hole for 7.5-inch-diameter FRP casing installation.
10	11/18/07	0–995	6	Temperature Natural Gamma Ray	Temperature log performed to identify top of cement.
11	2/22/06	0–1,038	13	Caliper Natural Gamma Ray	Logs performed to assist in calculating the volume of cement necessary to grout the 6.625-inch-diameter FRP casing
12	2/23/06	0–964	13	Natural Gamma Ray Temperature	Logs performed on 6.625-inch-diameter fiberglass casing after 1st stage of cementing
7	4/21/06	964–1,225	5.25	Video survey Caliper Natural Gamma Ray Flowmeter Fluid Conductivity Temperature Cement Bond with Variable Density	Logs performed to evaluate aquifer characteristics
13	5/23/06	975–1,227	5.25	Video survey Caliper	Logs performed to evaluate aquifer characteristics
14	6/19/06	0–1,221	5.25	Final video survey	Logs performed to provide video record of completed well

3.3 Groundwater Quality Sampling

On May 31, 2006, a single packer assembly was installed at a depth of 1,074 feet bls to isolate the interval from 1,020 feet bls to 1,074 feet bls. This interval was isolated to meet the requirements of the Water Quality Criteria Exemption (WQCE) for testing the "uppermost permeable zone with the best water quality with regard to Total Dissolved Solids of the upper Floridan aquifer system" (FDEP Specific Condition 4l). Water was allowed to flow under artesian pressure at approximately 113 gallons per minute (gpm) from the well to the canal adjacent to the project site.

Samples of native groundwater were collected from the borehole after the water quality stabilized, as measured by field instruments. These samples were analyzed by an independent laboratory for primary and secondary drinking water standards including chlorides, temperature-adjusted specific conductance, TDS, major anions and cations, and organics. In addition to meeting WQCE requirements, this sampling was used to establish a background water quality baseline. Results are discussed in Section 4.2 of this document.

SECTION 4

Hydrogeology

This section summarizes the hydrogeology encountered during the construction and testing of the exploratory well. As described in Section 3, hydrogeologic data were collected during the drilling and testing of the well from drill cuttings, geophysical logs, and water quality sampling. Exhibit 4-1 presents a summary of the hydrogeology, along with selected information from the geophysical logs.

4.1 Hydrogeologic Framework

The SAS and the FAS comprise the two major aquifer systems typical of this region of South Florida. The aquifer systems are composed of multiple, discrete aquifers separated by a thick clay and silt confining unit (see Exhibit 4-1).

4.1.1 Surficial Aquifer System

The SAS extends from land surface to approximately 220 feet bls, and is made up of both undifferentiated Tertiary-Quaternary sediments and Pleistocene Series sediments. The unconsolidated sands from land surface to approximately 20 feet bls are categorized as undifferentiated Tertiary-Quaternary sediments (Scott, 2001). Below this depth to 220 feet bls, light-gray to pale yellowish brown fossiliferous limestone, with interbedded shell horizons are interpreted as the Pleistocene Series Miami Limestone. This interpretation is consistent with the Geologic Map of Florida (Scott, 2001), which states that the Miami Formation occurs at or near the surface in Palm Beach County and extends south and west beneath the Everglades. To the north, the Miami Limestone grades into the Anastasia Formation (Scott, 2001). At 220 feet bls, a significant increase in the natural gamma ray activity, with values at approximately 150 GAPI *(*Gamma-ray American Petroleum Institute*)* units, correlates to an increase in clay content , and marks the top of the Hawthorn Group Peace River Formation.

4.1.2 Intermediate Confining Unit

The Peace River and Arcadia Formations of the Miocene-Oligocene Series Hawthorn Group constitute the primary interval of confinement between the SAS and the FAS (Scott, 1988). The Hawthorn Group sediments occur from approximately 220 to 925 feet bls. The natural gamma ray levels through this interval are consistently higher than the units above and below it. Greenish-gray clay and fossiliferous limestone representing the Peace River Formation are found between 220 and 485 feet bls, underlain by phosphate-rich intervals of clay, and sandy, poorly indurated limestone, interpreted as the Arcadia Formation. The Arcadia Formation is characteristically comprised of carbonate sediments with thin siliciclastic beds (Scott, 2001). Geophysical logging at HASR-FASMW-3 revealed thin, intermittent, moderate peaks on both the gamma ray and electrical resistivity logs, suggesting an increase in clay and phosphate content.

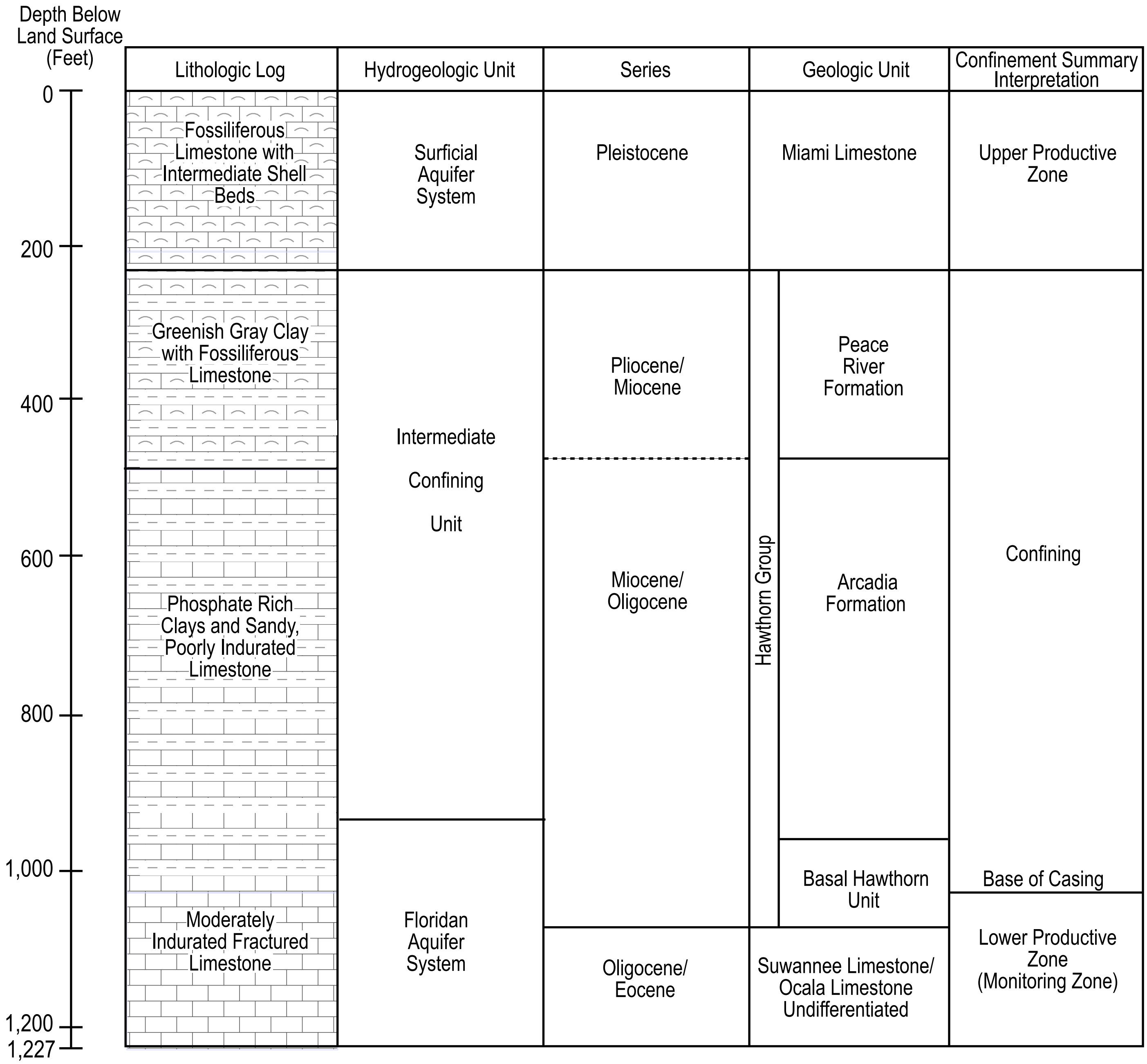

EXHIBIT 4-1
Summary Interpretation of the Hydrogeology at the Hillsboro ASR Site

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Exhibit 4-2 provides these and other selected geophysical profiles. The Intermediate Confining Unit grades into the UFAS near the top of the basal Hawthorn unit, as described below.

4.1.3 Floridan Aquifer System

The FAS consists of Tertiary Period limestones and dolostone beds generally dipping to the east and south, and contains brackish to saline water. Sediments at this site are made up of the lower Arcadia Formation, the basal Hawthorn unit, and the Suwannee and Ocala Limestones (undifferentiated).

At the Hillsboro ASR site, the top of the FAS may occur as high as 925 feet bls, in the lower Arcadia Formation. This interpretation is supported by the fairly abrupt increase in resistivity in a thick interval of wackestone at this depth. The top of the basal Hawthorn unit, which is commonly associated with the top of the FAS (Reese and Memberg, 2000), is identified by a spike in natural gamma-ray activity to over 300 GAPI units at 950 feet bls. This gamma-ray stratigraphic signature is likely related to laterally extensive highly phosphatic sand and limestone horizons correlated throughout southeastern Florida (Reese and Memberg, 2000; Reese and Alvarez-Zarikian, 2007). The lithologic transition from a wackestone to packestone/wackestone with interbedded shell and sand lenses corresponds to a spike in resistivity and neutron porosity at 1,020 feet bls, immediately below the highest levels of gamma-ray activity. This more competent limestone at 1,020 feet bls is interpreted as the first productive zone in the UFA and is the start of the open borehole in HASR-FASMW-3. The contact between the basal Hawthorn unit and the underlying Suwannee and Ocala Limestones at a depth of 1,070 feet bls is indicated by a significant attenuation of the natural gamma activity from approximately 180 GAPI units to approximately 75 GAPI units. This decrease in gamma-ray activity is associated with the gradational decrease in phosphatic sand content. Below this depth, limestone is fractured and yellowish-gray to white, compatible with the Eocene Period Suwannee and Ocala Limestones.

4.2 Background Water Quality

Samples of the native groundwater from the open interval (1,020 to 1,074 feet bls) were collected and analyzed by an independent laboratory. The water quality is brackish, with a TDS concentration of 6,670 milligrams per liter (mg/L), a conductivity of 9,880 micromhos per centimeter (µmhos /cm), and a chloride concentration of 2,400 mg/L. At 3.3 parts per billion (ppb), arsenic (As) content is well below the national primary drinking water standard MCL of 10 ppb. The complete laboratory report is provided as Appendix K.

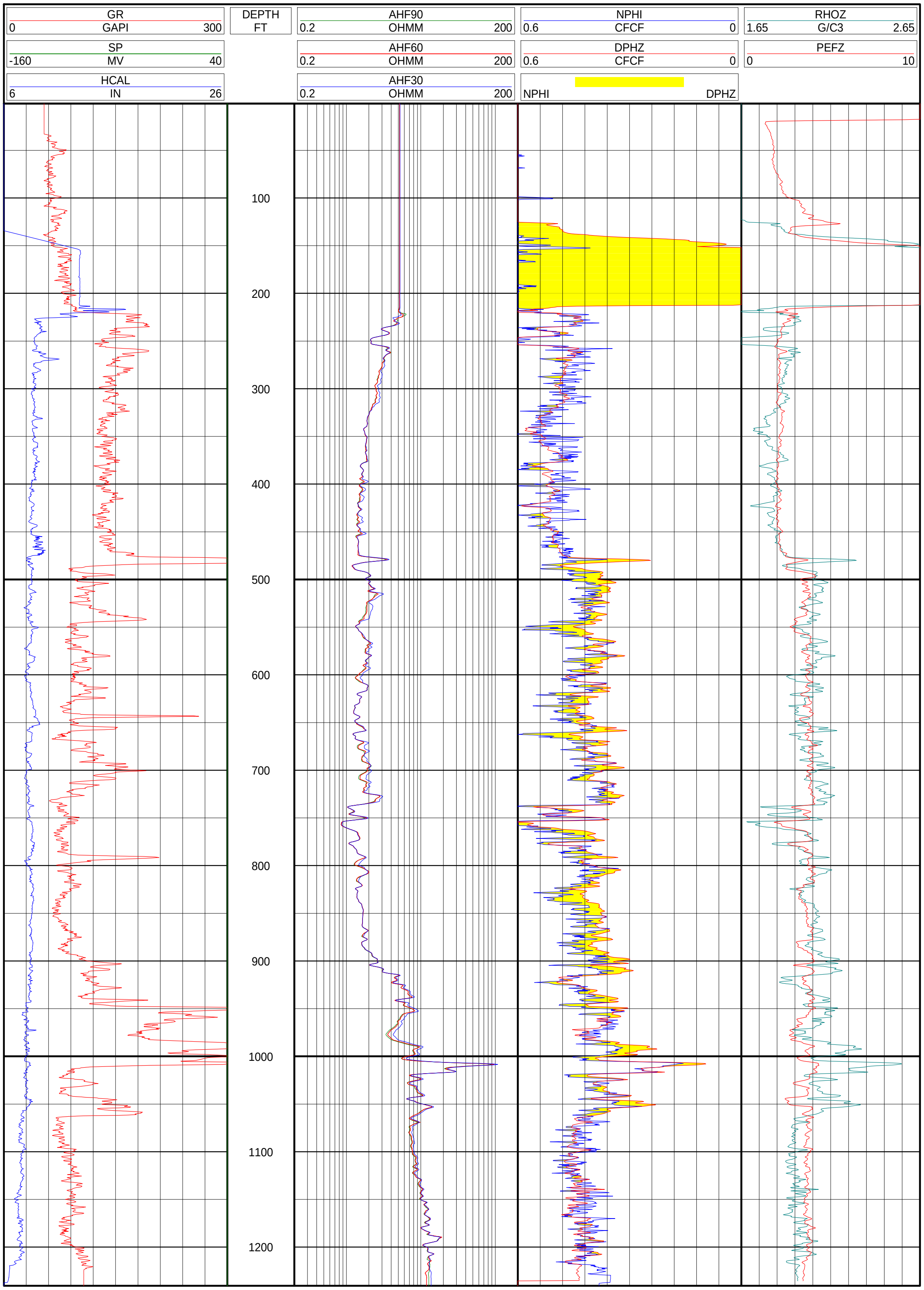

EXHIBIT 4-2

Selected Geophysical Profiles of HASR-FASMW-3

The logs presented here include natural gamma ray, caliper, array induction, density, and porosity. Data were recorded in the open borehole between 220 and 1,227 feet bls.

SECTION 5

Summary and Conclusions

This report summarizes the construction and testing of HASR-FASMW-3. The monitor well facilities consist of the monitor well, surface equipment, and a concrete pad.

The well was constructed with a 20-inch-diameter pit casing set from pad level to a depth of 37 feet bls. Inside that casing, a 14-inch-diameter steel casing was set from pad level to a depth of 215 feet bls. Inside the 14-inch-diameter steel casing, a nominal 6.625-inch fiberglass casing was set from pad level to 1,020 feet bls. The open borehole is from 1,020 to 1,225 feet bls. A pressure test performed on the casing successfully demonstrated the mechanical integrity of the well.

Hydrogeologic testing included lithologic sampling, geophysical logging, and packer testing.

The hydrogeology at the site consists of the SAS from land surface to approximately 220 feet bls. The SAS is underlain by the clays and silts of the Intermediate Confining Unit, which separates the SAS from the underlying UFA. The confining units are present from approximately 220 to 925 feet bls. The UFA starts at approximately 925 feet bls in the lower Arcadia Formation and continues to the total depth of the well. The water quality of the UFA is brackish, with a TDS concentration of approximately 6,670 mg/L. The open interval between 1,020 and 1,225 feet bls is characterized by permeable, low phosphate Suwannee/Ocala Limestone within the UFA.

SECTION 6

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