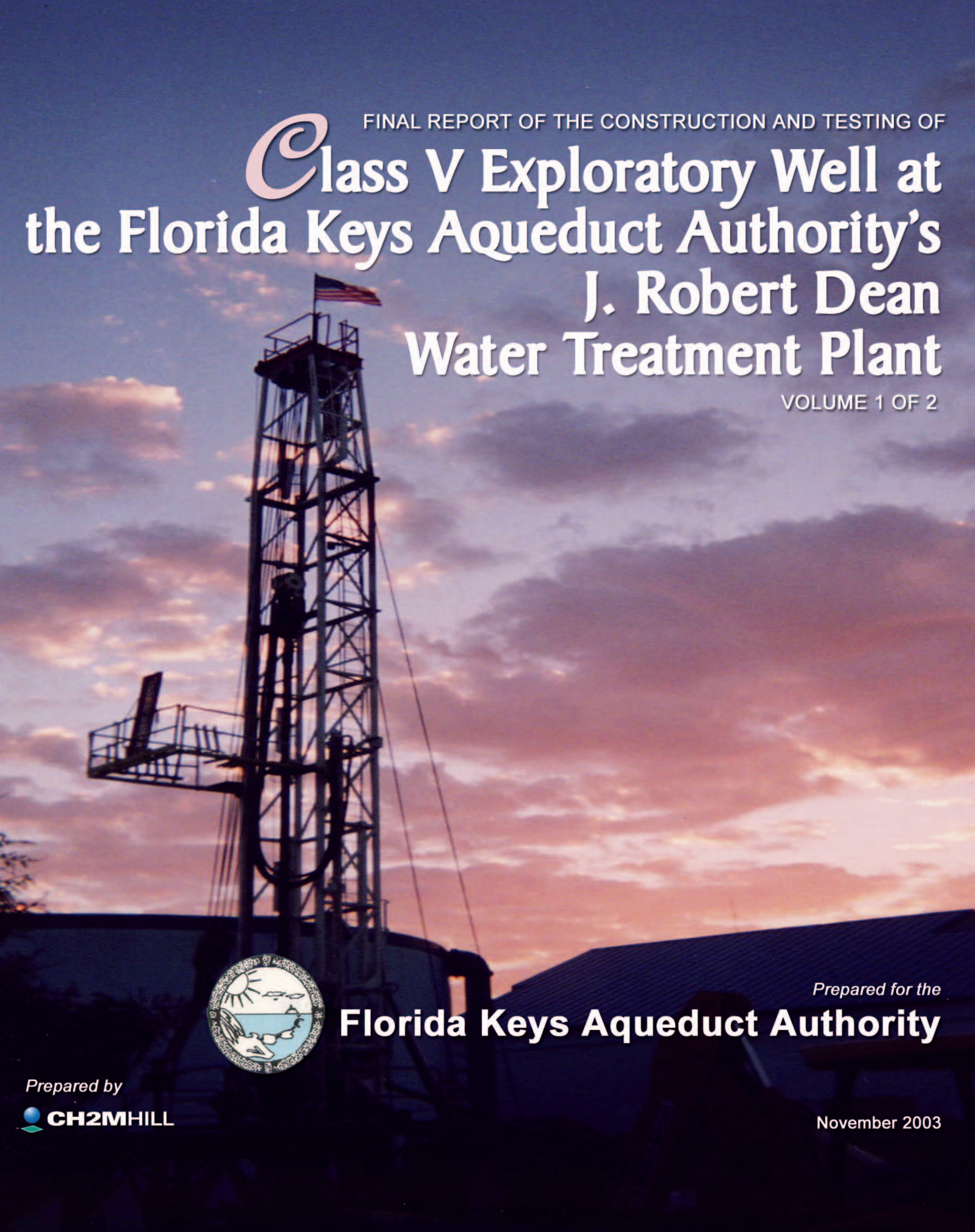

FINAL REPORT OF THE CONSTRUCTION AND TESTING OF

Class V Exploratory Well at the Florida Keys Aqueduct Authority's J. Robert Dean Water Treatment Plant

VOLUME 1 OF 2

Prepared for the

Florida Keys Aqueduct Authority

Prepared by

CH2MHILL

November 2003

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33441
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November 20, 2003

178630.PD.RO

Mr. Len Fishkin, P.G.
Florida Department of Environmental Protection
UIC Group, Southeast District
400 N. Congress Avenue
West Palm Beach, FL 33416

Subject: Final Report for the Class V Exploratory Well at the Florida Keys Aqueduct Authority's J. Robert Dean Water Treatment Plant, Florida City, FL

Dear Mr. Fishkin:

In accordance with the Construction Permit for the Class V Exploratory Well at the Florida Keys Aqueduct Authority's J. Robert Dean Water Treatment Plant in Florida City, Florida, enclosed are two copies of the subject final report for your review and approval. Please note that copies of the application have been forwarded to the Florida Department of Environmental Protection (FDEP), Underground Injection Control (UIC) group Technical Advisory Committee (TAC) members for their review and comment.

Also, in accordance with your letter sent via electronic correspondence on October 30, 2003, regarding FKAA's application to construct and test a Class V, Group 9 ASR well, we will be submitting to you, under separate cover, signed and sealed design drawings for your review.

We hope this report will meet with your approval and that it will expedite your review of the above permit application. Should you have any questions, please call me at 954/426-4008.

Sincerely,

CH2M HILL

Timothy S. Sharp, P.G.
Project Manager
Professional Geologist No. PG743

Enclosures

c: UIC Technical Advisory Committee
Steve Bell/SFWMD
Jim Reynolds/FKAA
Jolynn Cates-Reynolds/FKAA
Jason Parrillo/CH2M HILL

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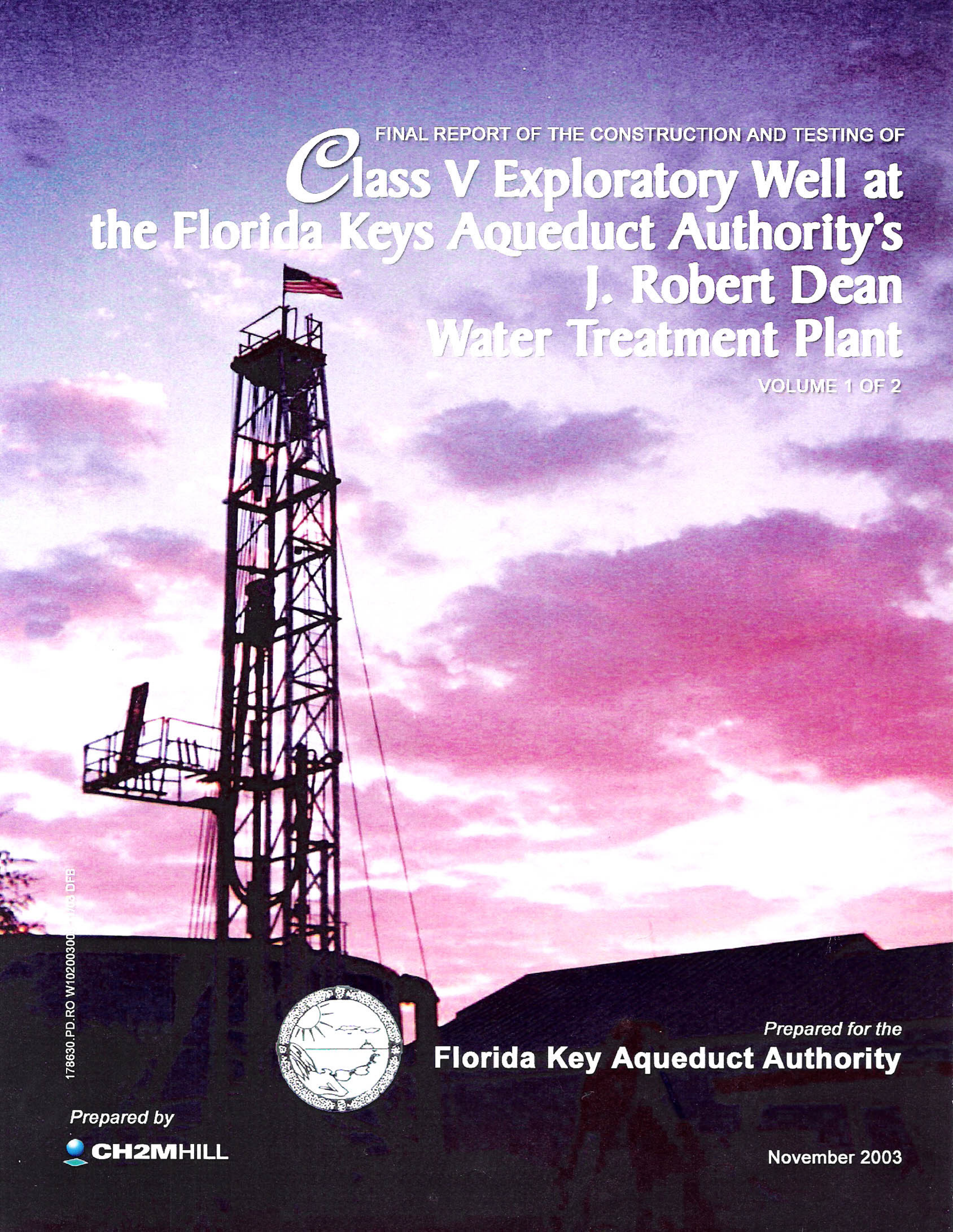

FINAL REPORT OF THE CONSTRUCTION AND TESTING OF

Class V Exploratory Well at the Florida Keys Aqueduct Authority's J. Robert Dean Water Treatment Plant

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CH2MHILL

November 2003

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SECTION 1

Introduction

SECTION 1

Introduction

1.1 Background Information

As part of the Florida Keys Aqueduct Authority's (FKAA's) Water Use Permit with the South Florida Water Management District (SFWMD) issued on October 10, 2002, FKAA had agreed to construct an Aquifer Storage and Recovery (ASR) at the J. Robert Dean Water Treatment Plant, in Florida City, Florida. Exhibit 1-1 depicts the location of the WTP site, and Exhibit 1-2 depicts the location of the exploratory well. The purpose of the ASR well is to manage and offset withdrawals from FKAA's Biscayne Aquifer water supply wellfield during the dry season. However, because of the lack of hydrogeologic information from the Floridan aquifer in this area of Miami-Dade County, FKAA elected to proceed first with the construction of a Class V exploratory well.

An application to construct a Class V, Group 9 Exploratory well was submitted to the Florida Department of Environmental Protection (FDEP) in September 2001. On January 24, 2003, a Construction Permit was issued to FKAA from FDEP for the exploratory well. In accordance with specific condition 4.n, a final report is to be submitted to FDEP, the Underground Injection Control (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 exploratory well. This document serves as that report.

Construction of the Class V exploratory well began in January 2003 and continued through October 2003. After construction and testing of the exploratory well, it was determined that ASR technology was feasible at this location. FKAA is pursuing the permitting, design, and construction an ASR well. In the interim, the exploratory well will be converted to a Floridan aquifer blending well until the ASR well is constructed. The temporary blending well will then be converted to an ASR zone monitoring well.

1.2 Scope

This report summarizes the construction and testing of a Class V exploratory well facility at the J. Robert Dean WTP. Construction and testing of the well were performed in accordance with FDEP Permit number 189862-001-UC and Chapter 62-528 of the Florida Administrative Code (FAC). The well was constructed in accordance with the contract documents provided in *Construction of the Floridan Aquifer Test Well at the J. Robert Dean Water Treatment Plant* (CH2M HILL, October 2002).

1.3 Project Description

CH2M HILL served as the engineer of record for the design, permitting, and construction activities for the exploratory well. Diversified Drilling Corporation (DDC) was selected as the contractor to construct the exploratory well and following receipt of the Construction Permit from FDEP on January 24, 2003, was issued a Notice to Proceed (NTP) from FKAA

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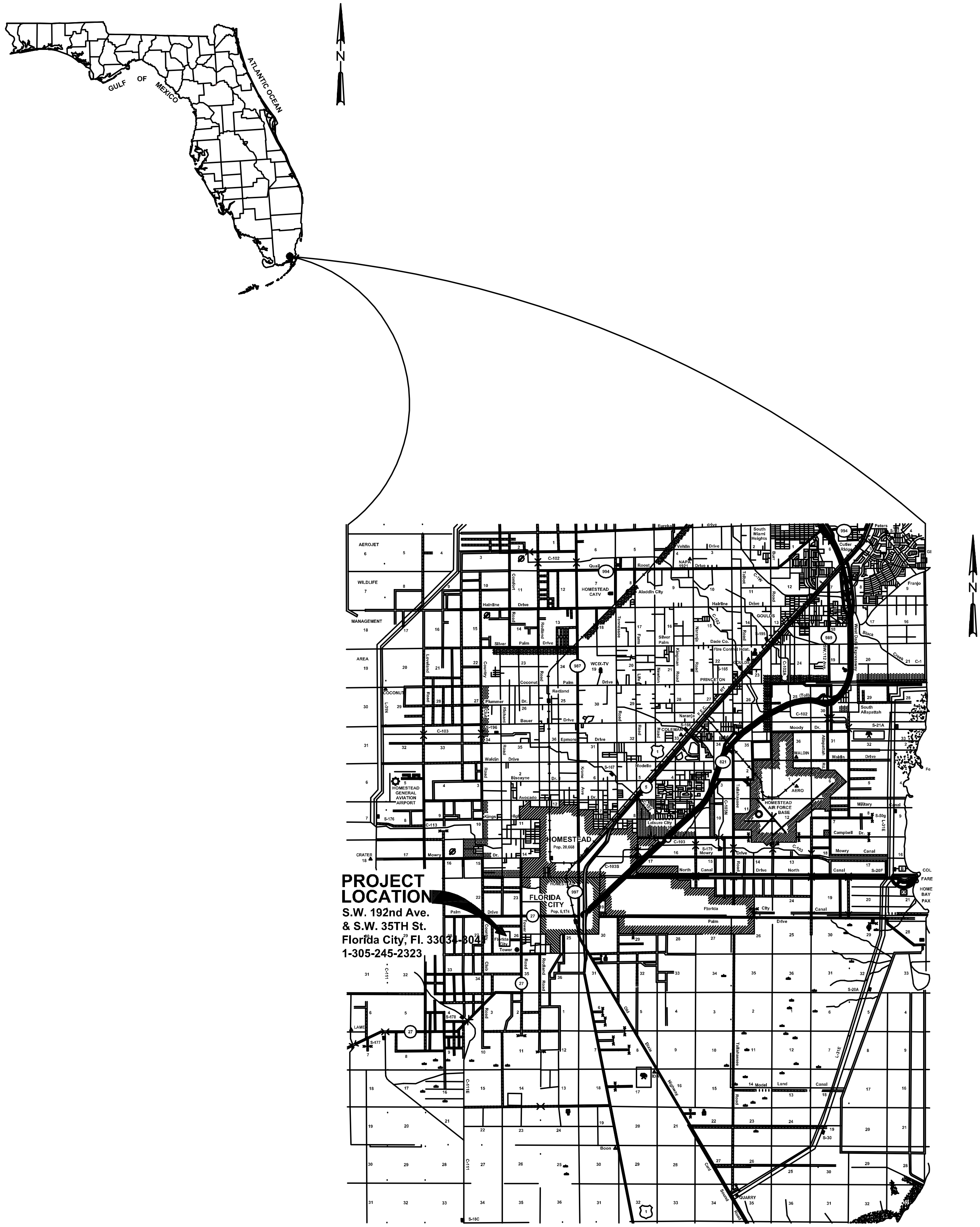

Exhibit 1-1

Project Location Map

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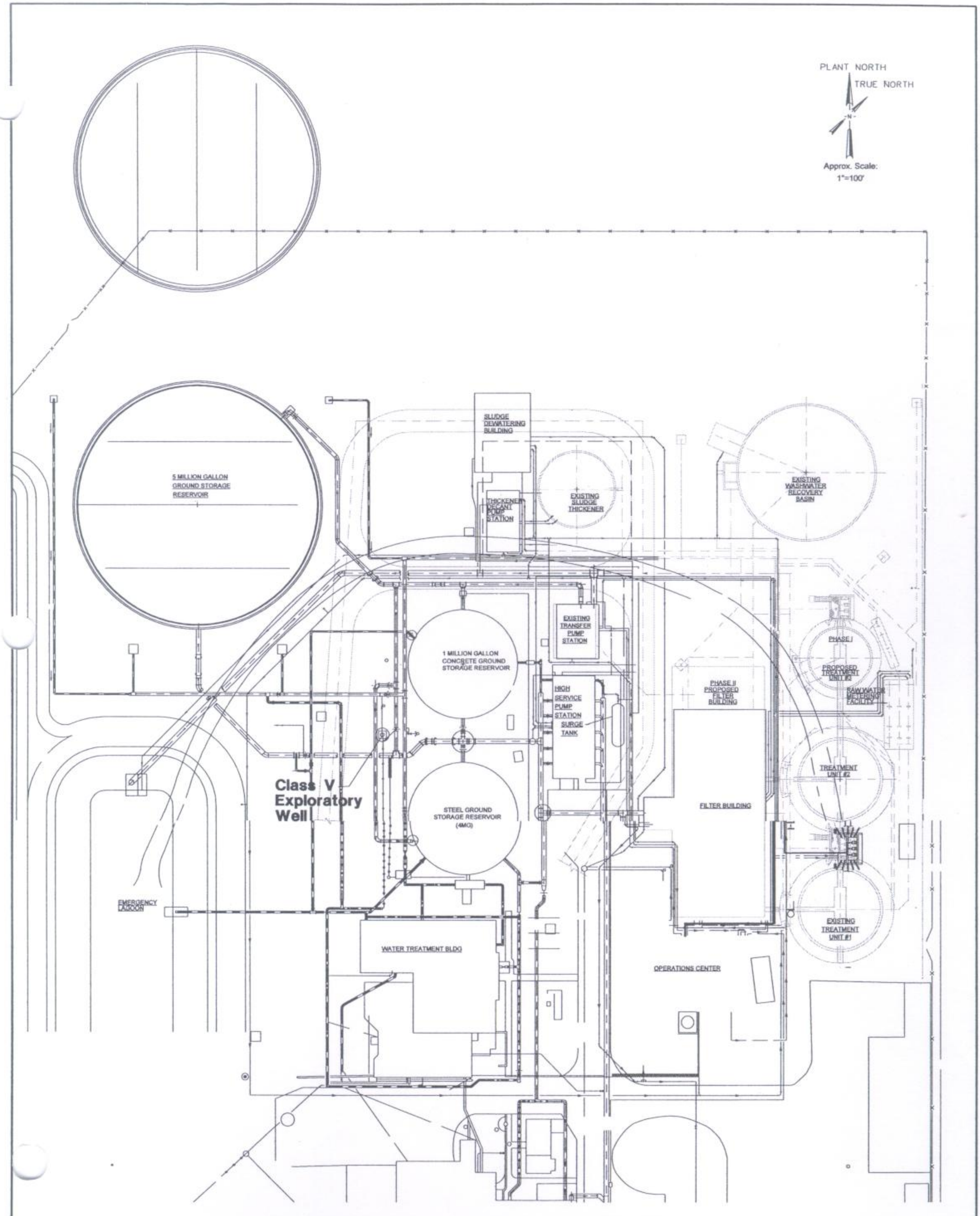

Exhibit 1-2
Site Plan

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on January 25, 2003. Completion of construction was scheduled for July 25, 2003. However, because of difficulties with construction and water quality and permitting issues, construction and testing was not completed until October 2003.

SECTION 2

Exploratory Well Construction

SECTION 2

Exploratory Well Construction

This section describes the drilling and construction activities associated with the Class V exploratory well at the J. Robert Dean WTP. Construction of the exploratory well was completed in November 2003, and included installation of a concrete pad and four surficial (pad) monitor wells.

2.1 Surficial Aquifer Monitor Wells

Prior to constructing the Class V exploratory well, four surficial aquifer monitor wells were installed. A typical surficial aquifer well construction diagram, along with the locations of the wells, is provided as Exhibit 2-1. Before and during construction of the exploratory well, water samples were collected weekly from the four surficial monitor wells. The monitor wells allowed the sampling 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 collected weekly and sent to the FKAA's laboratory at the WTP for analysis of total dissolved solids (TDS), conductivity, chlorides, and temperature. Results from the weekly water quality sampling at the surficial aquifer monitor wells are provided in Appendix A.

2.2 Exploratory Well Construction

Construction of the exploratory well was completed in three steps:

1. Installation of the 30-inch-diameter pit casing
2. Installation of the 18-inch-diameter casing through the Biscayne Aquifer
3. Installation of the 8.5-inch-diameter casing through the confining layers of the Hawthorn Group
4. Completion of the open borehole in the upper Floridan aquifer

The following subsections describe the drilling and installation methods used to complete construction of the exploratory well. Summaries of the construction activities and weekly construction reports are provided in Appendix B and C, respectively. The test well completion diagram is provided in Exhibit 2-2.

2.2.1 Installation of the 30-Inch-Diameter Pit Casing

Construction of the test well began on February 25, 2003, with the drilling of a 35-inch-diameter borehole hole using the mud rotary technique. The hole was drilled in one pass using stacked 12-inch, 23-inch, 29-inch, and 35-inch bits.

The casing is steel with a 0.375-inch wall thickness (29.625-inch inside diameter [ID]/30.00-inch outside diameter [OD]). Copies of the casing mill certificates are provided as Appendix D. Casing sections were welded together as they were lowered into the mud-filled borehole. Casing installation was completed on February 25, 2003. The top of this

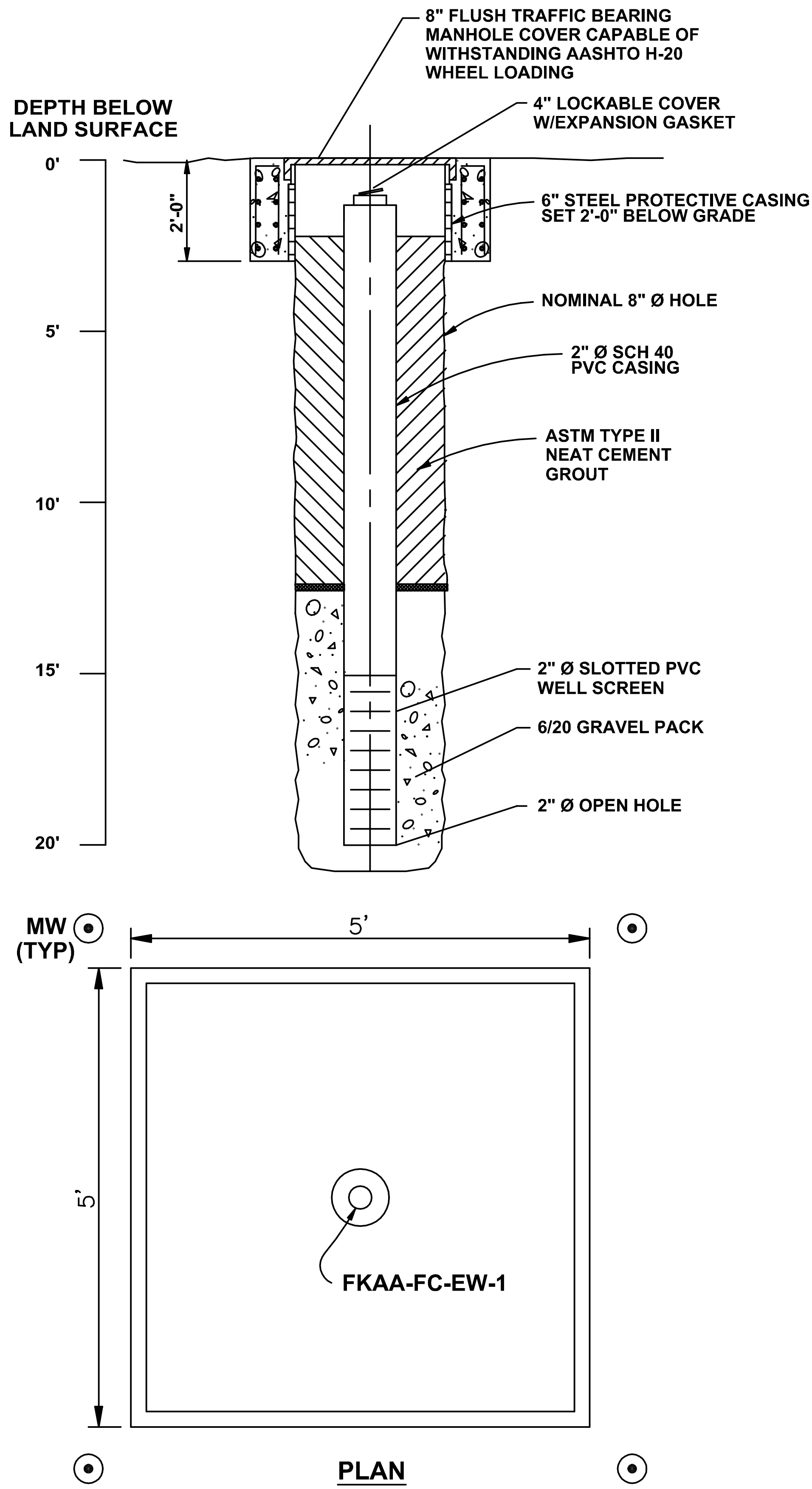

Exhibit 2-1

Typical Surficial Aquifer Monitor Well and Location Diagram

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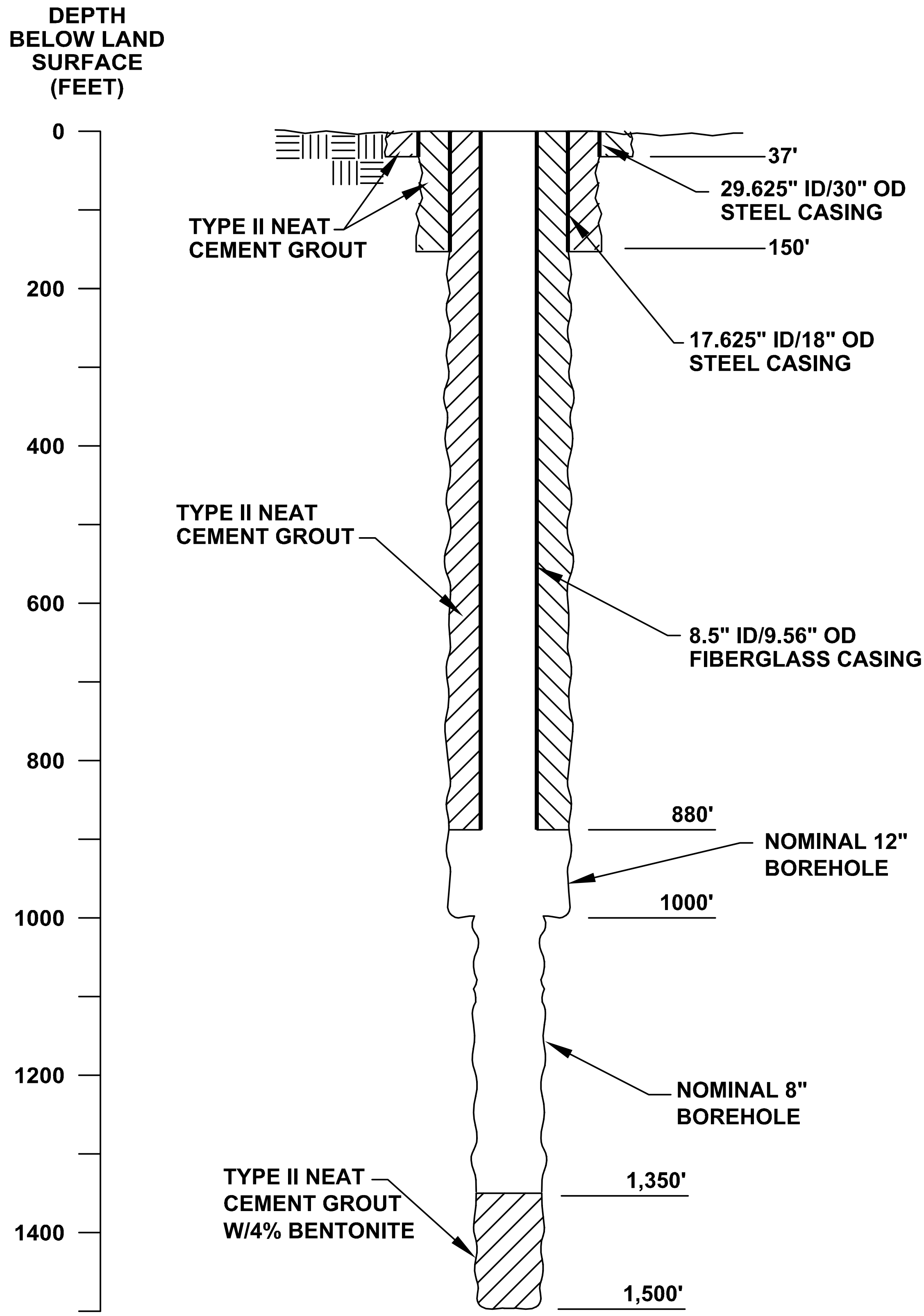

Legend

ID = Inside Diameter

OD = Outside Diameter

Note:

All depths relative to top of casing, approximately 4 ft. above ground surface.

Exhibit 2-2

Exploratory Well
Completion Diagram

CH2MHILL

casing is approximately 4 feet above ground surface, and is 37 feet in length. All subsequent depths are referenced to the top of this casing.

The casing was also cemented into place on February 25, 2003, using the tremie method. A total of 30 42-gallon barrels of neat cement was pumped in the first and only stage. Cementing stopped when cement returns were visible at pad level. A summary of the casing and cementing information is provided in Exhibit 2-3.

EXHIBIT 2-3
Summary of Casings and Cementing

Casing Outside Diameter (inches)	Casing Material	Casing Wall Thickness (inches)	Casing Interval (feet btoc)	Date of Cementing	Stage No.	Cement Type	Cement Quantity (barrels)[1]	Interval Cemented (feet btoc)	Cementing Technique
30	Steel	0.375	0	2-25-03	1	Neat	30	0	Tremie pipe
18	Steel	0.375	0–150	3-5-03	1	Neat 4% Bentonite	43 43	0–150	Pressure grout
8.5	Fiberglass	0.506	0–880	4-9-03 4-10-03	1	Neat	83	468–880	Pressure grout
					2	4% Bentonite	100	0–468	Tremie pipe

Note:
btoc = below top of casing
[1]Barrel = 42 gallons

2.2.2 Installation of the 18-Inch-Diameter Casing

An 18-inch-diameter steel casing was installed to a depth of 150 feet below top of casing (btoc) to isolate the Biscayne Aquifer during the drilling process.

After installation of the 30-inch-diameter pit casing, drilling of the 12-inch-diameter pilot hole using the mud rotary technique resumed February 26, 2003, at a depth of 37 feet btoc. On February 27, 2003, the pilot hole was drilled to 158 feet btoc, where the drill cuttings indicated the end of limestone layers and the beginning of clay layers. Geophysical logging of the hole was conducted on February 28, 2003, and reaming of the pilot hole with a 29-inch bit using the mud rotary technique began on March 3, 2003, and was completed to a depth of 155 feet btoc on March 4, 2003.

On March 5, 2003, CH2M HILL advised FDEP and the UIC-TAC regarding the casing seat depth and received no comments. Therefore, the 18-inch-diameter casing was installed through the Biscayne Aquifer and into the top of the confining units of the Hawthorn Group from 4 feet above pad level to 150 feet btoc. The casing is steel with a 0.375-inch wall thickness (17.625-inch ID/18.00-inch OD). Copies of the casing mill certificates are provided as Appendix D. Casing sections were welded together as they were lowered into the mud-filled borehole. Steel centralizers were welded to the outside of the casing at predetermined intervals to center the casing in the borehole.

The casing was cemented into place on March 5, 2003, using the pressure-grout method. A total of 43 barrels of neat cement and 43 barrels of neat cement with 4 percent bentonite were pumped in the first stage and only stage. Cementing stopped when cement returns were visible at pad level. A summary of the casing and cementing information is provided in Exhibit 2-3. A detailed description of the cementing is provided in Appendix E. Casing installation was completed March 5, 2003. A summary of the casing section lengths and centralizer locations is provided in Appendix F.

2.2.3 Installation of the 8.5-Inch-Diameter Casing

An 8.5-inch-diameter fiberglass casing was installed in the interval from 0 to 880 feet btoc. The purpose of the casing is to extend the well through the confining units and to the top of the test interval.

After installation of the 18-inch-diameter casing, drilling of a 12-inch-diameter pilot hole using the mud rotary technique resumed March 10, 2003, at a depth of 158 feet btoc. By March 18, 2003, the pilot hole had reached 1,000 feet btoc, where a series of geophysical logs were performed.

After geophysical logging was conducted, the pilot hole was reamed with an 17-inch-diameter drill bit beginning March 25, 2003. Reaming was completed April 4, 2003, to a depth of 890 feet btoc (approximately 10 feet below the proposed casing depth). A summary of the borehole deviation surveys during drilling is provided in Appendix G.

On March 27, 2003, CH2M HILL submitted a written request to FDEP and the UIC-TAC for a final casing seat of 880-feet for the 8.5-inch diameter fiberglass casing. FDEP subsequently responded to FKAA on March 31, 2003, with a letter approving the seating depth request.

The 8.5-inch-diameter casing was installed from 0 to 880 feet btoc. The casing is fiberglass with a 0.56-inch wall thickness (8.5-inch ID/9.56-inch OD). Copies of the casing mill certificates are provided as Appendix D. 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. A summary of the casing section lengths and centralizer locations is provided in Appendix F.

The casing was then cemented in place using both the pressure grouting (first stage) and tremie (second stage) methods. For the initial pressure grouting, the top of the casing was sealed, and cement was pumped through the inside of the 8.5-inch-diameter casing. A total of 83 barrels of neat cement with 4 percent bentonite was pumped during the first stage, which filled the annulus to 468 feet btoc. Cementing was completed during the second stage, where a tremie pipe was used to deliver the cement to the top of the cement from the first stage. A total of 100 barrels of neat cement were pumped for the second stage. Cementing stopped when cement returns were visible at pad level. A summary of the casing and cementing information is provided in Exhibit 2-3. A detailed description of the cementing is provided in Appendix E.

2.2.4 Casing Pressure Test

A casing pressure test was conducted April 18, 2003, to verify the mechanical integrity of the 8.5-inch-diameter fiberglass casing. During the 1-hour pressure test, the casing pressure decreased by 2.5 pounds per square inch (psi), which is within the allowable 5.13 psi change. Data from the pressure test are provided as Appendix H.

Prior to the test on April 10, CH2M HILL notified FDEP and the UIC-TAC that a final casing pressure test would be conducted on April 18, 2003. No one from FDEP or the UIC-TAC was present during the pressure testing.

The casing pressure test was conducted on the 8.5-inch-diameter casing after the cementing of the 8.5-inch-diameter casing. The cement plug at the bottom of the 8.5-inch-diameter casing was used to seal the bottom of the well. At the surface, the well was sealed using 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 102.5 pounds per square inch (psi) by adding water under pressure, and was then monitored for 60 minutes while the pressure was recorded. After the 60 minutes, the pressure had decreased by 2.5 psi.

2.2.5 Open Borehole Completion

After installation of the 8.5-inch-diameter fiberglass casing, drilling of the open borehole section of the well resumed on April 22, 2003. Drilling and testing continued to a total depth of 1,504 feet btoc, which was reached on June 6, 2003. Information on the hydrologic testing performed on the open borehole can be found in Section 3.

2.2.6 Borehole Plugback

Based on the results of the hydrogeologic testing performed on the open borehole, it was decided to plug back the borehole to a depth of 1,350 feet btoc. A plugback request was submitted to FDEP/UIC-TAC on August 8, 2003. Exhibit 2-4 summarizes the borehole plugback.

EXHIBIT 2-4
Borehole Plugback

Date of Cementing	Stage No.	Cement Type	Cement Quantity (barrels)[1]	Interval Cemented (feet btoc)	Cementing Technique
8/12/03	1	Neat	5	1,504–1,440	Tremie pipe
8/13/03	2	Neat	9	1,440–1,370	Tremie pipe
8/15/03	3	Neat	2.5	1,370–1,353	Tremie pipe

Note:
[1]Barrel = 42 gallons

A total of 16.5 barrels of neat cement were pumped into the bottom of the well to plug it back to a depth of 1,353 feet btoc.

2.3 Surface Facilities

The surface facilities consist of a 2-inch PVC tee with a pressure gage and value, on top of an 8-inch-diameter gate. The well is surrounded by a 5-foot by 5-foot concrete pad and collar to protect the fiberglass casing. The wellhead and concrete pad were completed in November 2003. Exhibit 2-5 presents a detail of the wellhead.

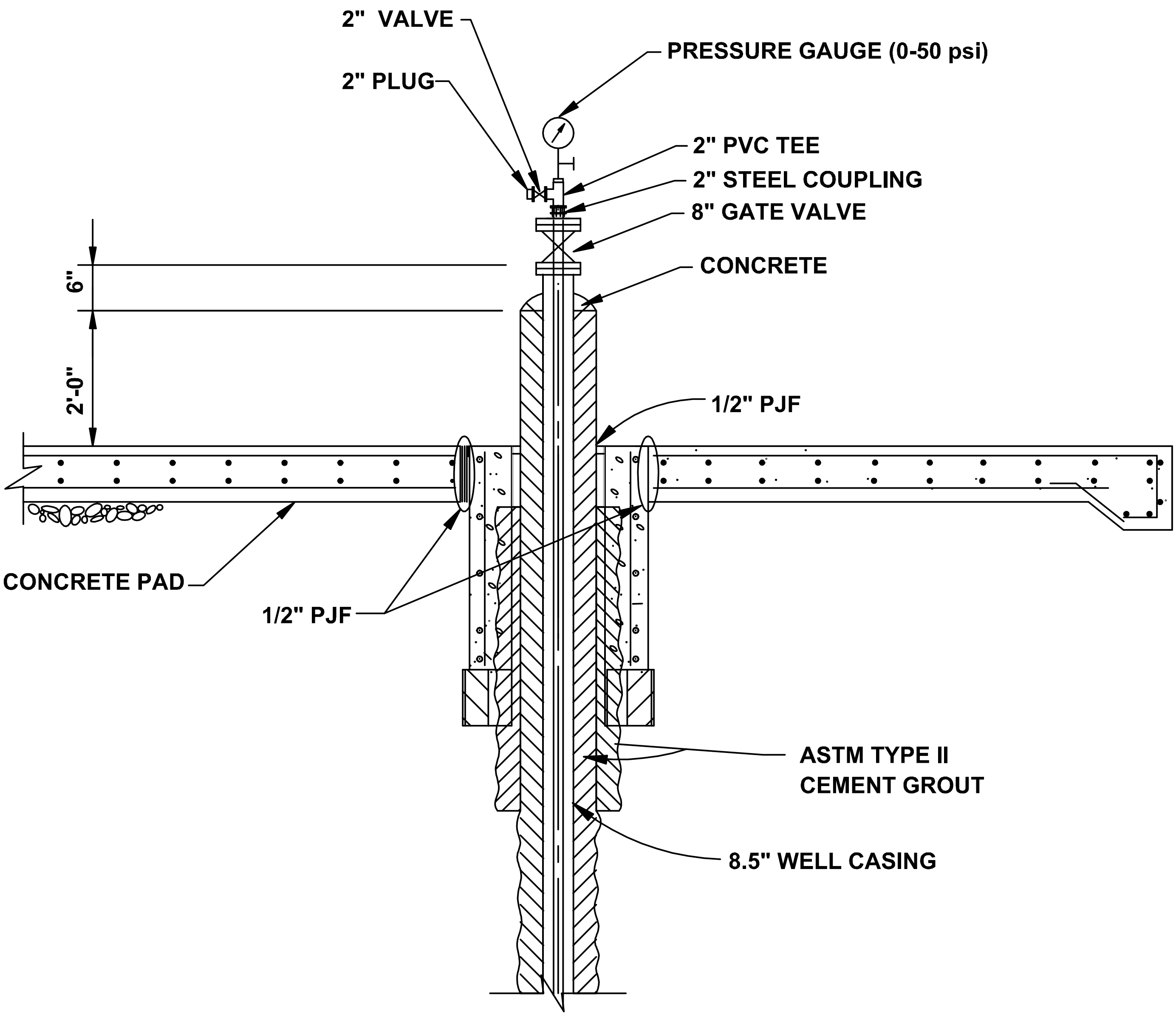

Exhibit 2-5
Exploratory Well
Wellhead Completion Diagram

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SECTION 3

Hydrogeologic Testing

SECTION 3

Hydrogeologic Testing

Several types of hydrogeologic tests were performed during construction of the exploratory well. These tests included collecting drill cuttings, rock cores, geophysical logging, pumping tests, and groundwater quality samples. This section describes the procedures and results of those tests.

3.1 Cutting Samples

Formation cutting samples were collected during drilling at 10-foot intervals from land surface to the total depth of the well (1,500 feet btoc). Cuttings were collected from the drilling mud, or water, as it circulated out of the borehole and into the shale 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. A complete lithologic description of the cuttings is presented in Appendix I.

3.2 Coring Samples

Four core samples were attempted during the construction of the exploratory well. The cores were taken with a 4-inch-diameter core barrel from four intervals between 1,021 to 1,415 feet bpl. The primary purpose of collecting and describing the cores was to obtain additional information about the lithology and hydraulic properties of the aquifer. The core recovery efficiency increased below 1,200 feet btoc. Appendix J provides the descriptions of each core.

3.3 Geophysical Logging

Geophysical logs were performed during the drilling of the exploratory well to identify hydrostratigraphic features and to aid in the construction of the well. The logs used to identify hydrostratigraphic features include caliper, natural gamma ray, long and short normal spontaneous potential (LSN-SP), dual-induction, and borehole compensated sonic logs. 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. A summary of all geophysical logs performed is provided in Exhibit 3-1. Copies of all geophysical logs are presented in Appendix K.

3.4 Pumping Tests

A series of pumping tests were performed during the construction of the exploratory well to evaluate hydraulic, water chemistry, and water-producing characteristics.

EXHIBIT 3-1
Summary of Geophysical Logging

Logging Event No.	Date of Logging Event	Interval Logged (feet btoc)	Nominal Borehole Diameter (inches)	Geophysical Log(s)	Remarks
1	2/28/03	37–153	12.25	Caliper Natural Gamma Ray LSN-SP	Logs performed on 12.25-inch-diameter pilot hole
2	3/5/03	37–153	29	Caliper Natural Gamma Ray	Logs performed to assist in calculating the volume of cement necessary to grout the 18-inch-diameter steel casing
3	3/6/03	0–131	29	Natural Gamma Ray Temperature	Logs performed on 18-inch-diameter steel casing after cementing
4	3/19/03	150–1,004	12.25	Caliper Natural Gamma Ray Dual Induction LSN-SP Borehole Compensated Sonic with Variable Density	Logs performed on 12.25-inch-diameter pilot hole
5	4/7/03	0–885	17	Caliper Natural Gamma Ray	Logs performed to assist in calculating the volume of cement necessary to grout the 8.5-inch-diameter fiberglass casing
6	4/10/03	0–862	17	Natural Gamma Ray Temperature	Logs performed on 8.5-inch-diameter fiberglass casing after 1st and second stages of cementing
7	5/12/03	800–1,087	7.875	Caliper Natural Gamma Ray Fluid Resistivity (Static and Dynamic) Temperature (Static and Dynamic) Flow (Static and Dynamic)	Logs performed to evaluate aquifer characteristics
8	5/22/03	790–1,183	7.875	Caliper Natural Gamma Ray Fluid Resistivity (Static and Dynamic) Temperature (Static and Dynamic) Flow (Static and Dynamic)	Logs performed to evaluate aquifer characteristics

EXHIBIT 3-1
Summary of Geophysical Logging

Logging Event No.	Date of Logging Event	Interval Logged (feet btoc)	Nominal Borehole Diameter (inches)	Geophysical Log(s)	Remarks
9	5/29/03	790–1,284	7.875	Caliper Natural Gamma Ray Fluid Resistivity (Static and Dynamic) Temperature (Static and Dynamic) Flow (Static and Dynamic)	Logs performed to evaluate aquifer characteristics
10	6/4/03	790–1,400	7.875	Caliper Natural Gamma Ray Fluid Resistivity (Static and Dynamic) Temperature (Static and Dynamic) Flow (Static and Dynamic)	Logs performed to evaluate aquifer characteristics
11	6/9/03	790–1,501		Caliper Natural Gamma Ray Fluid Resistivity (Static and Dynamic) Temperature (Static and Dynamic) Flow (Static and Dynamic) Dual Induction LSN-SP Borehole Compensated Sonic with Variable Density	Logs performed to evaluate aquifer characteristics
12	8/21/03	0–1,342	7.875	Caliper Natural Gamma Ray Fluid Resistivity (Static and Dynamic) Temperature (Static and Dynamic) Flow (Static and Dynamic)	Logs performed to evaluate aquifer characteristics
13	11/7/03	0–1,350	7.875	Video Survey	Log performed to provide video record of completed well

Notes:
ft btoc = feet below top of casing
LSN-SP = Long and short normal resistivity and spontaneous potential

The following types of pumping tests were performed:

- Drill Stem Straddle Pumping Tests (3)
- Drill Stem Single-Packer Pumping Test (1)
- Interval Pumping Tests (5)
- Aquifer Performance Test

A summary of testing during construction is provided in Exhibit 3-2.

EXHIBIT 3-2
Summary of Testing During Construction

Date of Test	Type of Pumping Test	Interval Tested (feet btoc)	Pumping Rate (gpm)
5/14/03	Interval #1	88–1090	450
5/23/03	Interval #2	880–1190	450
5/30/03	Interval #3	880–1290	650
6/4/03	Interval #4	880–1405	900
6/9/03	Interval #5	880–1504	950
7/2/03	Packer #1	1050–1150	25
7/9/03	Packer #2	1220–1283	85
7/10/03	Packer #3	1150–1213	82
7/22/03	Packer #4	880–1040	60
10/8/03 – 10/11/03	Final Aquifer Performance Test	880–1350	280
			500
			750
			650
			500

Notes:

btoc = below top of casing

NC = Not calculated

[a]The salt plug in the well was not completely purged prior to the start of the test on 7/2/03, therefore the initial static water level was assumed to be the level to which the water level in the drill stem recovered at the conclusion of the test.

[b]The water level in this interval responded so quickly to the start and stop of the test that the data could not be analyzed since there are no typical pump or recovery curves.

gpm = gallons per minute

ft^2/d = square feet per day

3.4.1 Packer Tests

Three drill-stem straddle packer pumping tests were performed in the interval from 1,050 to 1,283 feet btoc during the drilling of the pilot hole. The tests were used to evaluate the hydraulic and water quality characteristics of the interval and to select the ASR interval. The tests were performed by setting a straddle packer assembly with top and bottom inflatable packers corresponding to the upper and lower boundaries of the interval to be tested. A length of perforated pipe separated the top and bottom packers. Water was pumped through the drill pipe using a submersible pump, and the flow rate was measured at the surface using a calibrated flowmeter.

One single-packer pumping test was conducted on the interval from 880 feet btoc (base of the 8.5-inch-diameter casing) to 1,040 feet btoc. The configuration was identical to that of the straddle packer test, except that only one packer (the bottom) was used.

3.4.2 Interval Tests

Five interval pumping tests were performed during the construction of the evaluation well. The purposes of the interval tests were to assess the change in hydrologic and water quality characteristics of the upper Floridan aquifer as the drilling progressed. The intervals tested were:

- 880 to 1,090 feet (210-foot interval)
- 880 to 1,190 feet (310-foot interval)
- 880 to 1,290 feet (410-foot interval)
- 880 to 1,405 feet (525-foot interval)
- 880 to 1,504 feet (624-foot interval)

The first two tests were conducted using a submersible pump set into the well. No pump was needed for the final three tests because the artesian pressure of the aquifer produced flow in excess of 500 gpm. The purpose of the tests was to evaluate the water yield and quality of the open borehole below the 8.5-inch-diameter casing. Information from these tests was used in the selection of the proposed ASR interval. The flow rate was measured at the surface using a calibrated flowmeter.

3.4.3 Aquifer Performance Test

A 72-hour step pumping and aquifer performance test was performed on the well after completing construction. The test was used to evaluate the water yield and hydrogeological parameters of the ASR interval from 880 to 1,350 ft btoc. The test was performed by pumping water with a submersible pump set into the well. The pumping rate was increased several times during the test. The flow rate was measured at the surface using a calibrated flowmeter.

3.5 Groundwater Quality Sampling

Samples of native groundwater were collected from the borehole during the interval and packer tests and analyzed by an independent laboratory for a wide range of parameters, including chlorides, temperature-adjusted specific conductance, TDS, major anions and cations, SiO_2, trace metals, and stable isotopes.

A sample of native groundwater was collected from the borehole during the aquifer performance test and analyzed by an independent laboratory for primary and secondary drinking water standards. The purpose of the sampling and analyses was to establish a background water quality baseline.

SECTION 4

Results of Hydrogeologic Testing

SECTION 4

Results of Hydrogeologic Testing

Hydrogeologic data were collected from drill cuttings, cores, geophysical logs, pumping tests, and water quality sampling. This section summarizes the hydrogeology encountered during the construction and testing results from the exploratory well.

4.1 Hydrogeology

Information from the drill cuttings and geophysical logs were used to describe the geologic formations encountered. A geologic log of the well, along with well completion information, is included in Exhibit 4-1. A detailed lithologic description of the drill cuttings is included in Appendix I.

4.1.1 Geologic Framework

Geologic formations found in South Florida, along with the physical and water-bearing characteristics of each formation, are summarized in Exhibit 4-2. Descriptions of formations encountered are provided below in order of geologic age; from the oldest formation to the youngest.

4.1.1.1 Eocene Series

Avon Park Formation. Chen (1965) described the Avon Park Formation of late Middle Eocene age as being light brown-to-brown, porous, finely fragmental limestone, with abundant *Coskinolina sp., Lituonella sp., Dictyoconus sp.,* and other diagnostic forammifers, and brown-to dark brown, rather porous, very fine to medium crystalline, saccharoidal dolostone. A basal unit of dark brown, nonfossiliferous, crystalline dolostone also exists. The Avon Park Formation typically displays low natural radioactivity on natural gamma ray geophysical logs. Neutron logs indicate that the Avon Park Formation exhibits porosities as high as 50 percent, and gradually decreases with depth (Reese, 1994). Miller (1986) observed that portions of the Avon Park Formation are fine-grained and have low permeability, thereby acting as intra-aquifer confining units within the Floridan Aquifer System.

At the FKAA WTP site, the Avon Park Formation was encountered at a depth of approximately 1,190 feet btoc to 1,504 feet btoc. The top of the Avon Park Formation was identified based on its low natural radioactivity on the natural gamma ray geophysical log. Drilling was halted within the Avon Park Formation at a depth of 1,504 feet btoc.

4.1.1.2 Oligocene Series

Suwannee Limestone. The Suwannee Limestone of Oligocene age is described by Johnson (1984) as a “white to tan, pure to slightly argillaceous and arenaceous, coquinoid to chalky limestone, with some dolostone and dolomitic limestone present.” It is regionally extensive and attains a thickness ranging from 120 to 300 feet in the study area (Miller, 1986).

11-20-03

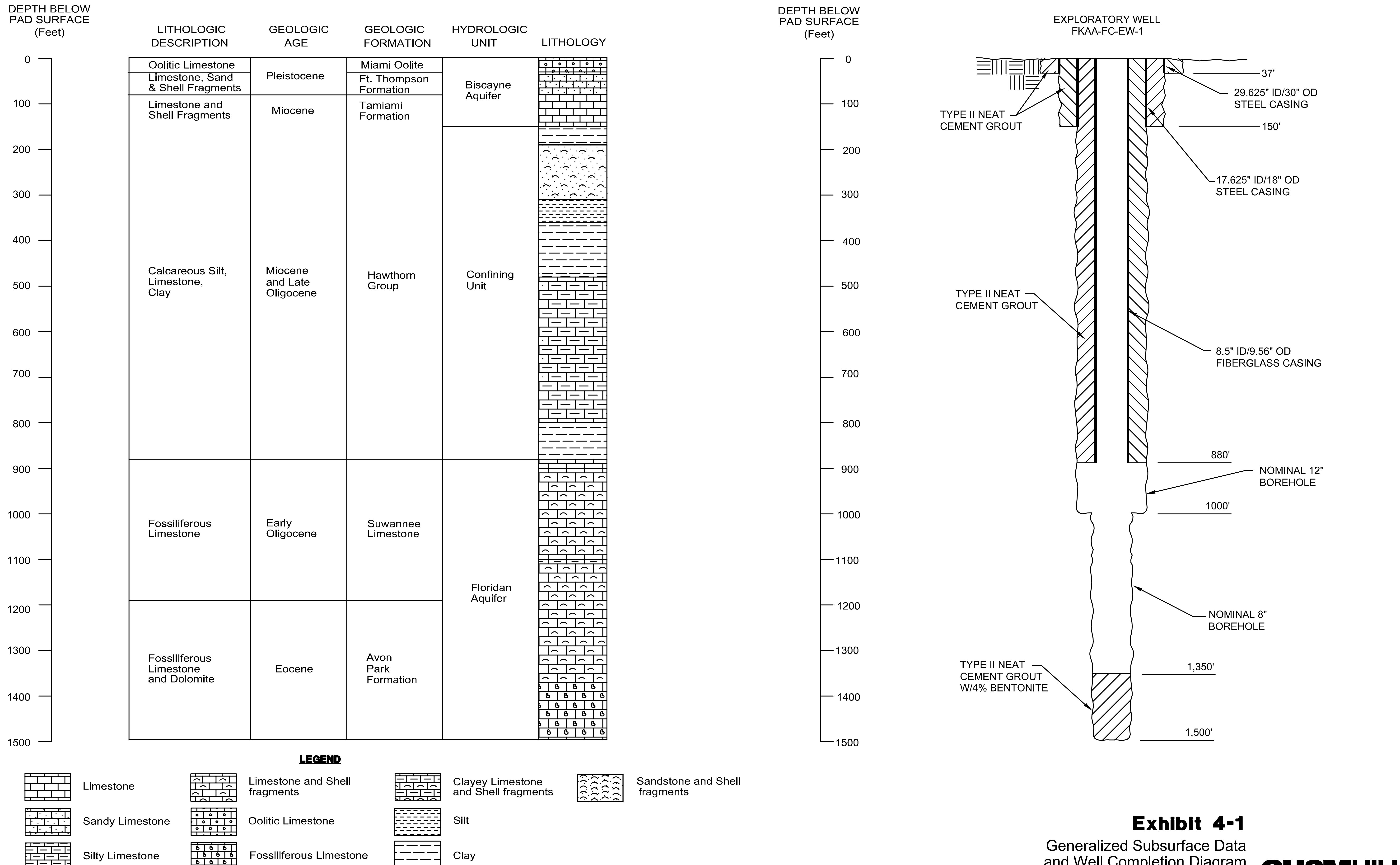

Exhibit 4-1

Generalized Subsurface Data and Well Completion Diagram

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EXHIBIT 4-2
Geologic Formations and Characteristics in South Florida

Formation	Physical Characteristics	Water-Bearing Characteristics
Pamlico Sand	Very fine to coarse, white to black or red quartz sand. Mantles sandy flatlands and coastal ridge.	Small yields to domestic wells. (Fresh)
Key Largo Limestone	Coralline reef rock; highly solution riddled	Important shallow aquifer. Good yields (fresh)
Anastasia Formation	Coquina, sand, calcareous sand stone and shell marl. Some zones contain old mangrove-swamp or salt-marsh deposits composed of fine sand, silt, clay, and organic material.	Important shallow aquifer. Fair to good yields. (Fresh)
Miami Limestone	White to yellow soft limestone. Solution riddled.	Shallow aquifer. Good yields. (Fresh)
Fort Thompson Formation	Alternating marine, brackish and freshwater marls, limestones, and sandstones.	Shallow aquifer. Fair yields. (Fresh)
Caloosahatchee Marl	Sandy marl, clay, silt, sand and shell beds.	Shallow aquifer. Fair yields. (Fresh)
Tamiami Formation	Creamy-white limestone, and greenish-gray clay and marl.	Occasional fair yields in upper few feet. Remainder forms upper part of aquicide. (Fresh)
Hawthorn Group	Sandy, phosphatic marl, interbedded with clay, shell marl, silt, and sand. White to tan, soft to hard limestone.	Major part of aquiclude. Limited artesian water. (Brackish)
Suwannee Limestone	Creamy, soft to hard limestone.	Part of Floridan aquifer. Artesian. (Brackish)
Avon Park Formation	White to cream foraminiferal limestone.	Major formation in Floridan aquifer. Artesian. (Brackish to Saline)
Lake City Limestone	Interbedded dolomite and dense foraminiferal limestone.	Major part of intraquifer low permeability zone. (Saline)
Oldsmar Formation	Highly fractured and cavernous dolomite.	Major formation in Floridan aquifer. High transmissivity. (Saline)

The Suwanee Limestone was encountered at the FKAA WTP site from approximately 870 feet btoc to 1,190 feet btoc.

The base of the Suwanee Limestone was indicated by the presence of high natural radioactivity on the gamma log due to a phosphatic zone in the lower portion of the formation.

4.1.1.3 Miocene Series

Hawthorn Group. The Hawthorn Group is variable in lithology and generally consists of interbedded sand, silt, clay, dolostone, and limestone, with a characteristically high phosphate content (Johnson, 1984). Scott (1988) upgraded the Hawthorn Formation to group status and described the group members throughout Florida.

At the FKAA WTP site, the Hawthorn Group is comprised of the Peace River and Arcadia Formations. The Peace River Formation consists of interbedded quartz sands, clays, and carbonates. The Arcadia Formation lies disconformably below the Peace River Formation, and consists predominantly of limestone and dolostone containing varying amounts of quartz sand, clay, and phosphatic grains.

The top of the Hawthorn Group at the FKAA WTP site was identified at a depth of approximately 130 feet btoc by the presence of olive-green clay. The base of the Hawthorn Group was identified as three progressively increasing natural gamma ray peaks, which occur between 735 and 860 feet btoc.

4.1.1.4 Undifferentiated Pleistocene and Pliocene Series

From land surface to a depth of approximately 130 feet btoc, the lithology at the FKAA site consists of limestone, sand, sandstone, and shell fragments. Formations that make up the Pleistocene to Pliocene series at this site include the Miami Oolite, Fort Thompson Formation, and the Tamiami Formation. The gamma ray response in this interval is relatively low (0 to 50 counts per second [cps]), consistent with the clay-free formations encountered. The Tamiami Formation-Hawthorn Group boundary was selected based on the first occurrence of olive-green clays at a depth of approximately 130 feet bpl. The gamma-ray log shows counts exceeding 50 cps at a depth of approximately 150 feet btoc. The increased gamma-ray counts correspond with the Tamiami Formation. The Hawthorn Group boundary was identified by Carsons (1987) at approximately 150 feet below land surface in this area.

4.2 Hydrogeologic Units

4.2.1 Surficial Aquifer System

The Surficial Aquifer System was identified from pad level (land surface) to approximately 130 feet btoc using drill cuttings and geophysical logs. The upper portion of the aquifer system is the highly transmissive Biscayne Aquifer extending from pad level to approximately 80 feet. At this location, the Biscayne Aquifer consists of oolitic limestone (Miami Oolite) from land surface to a depth of 30 feet btoc and interbedded limestone, sandstone, sand, and shell (Ft. Thompson Formation) from 30 feet btoc to 80 feet btoc. These two highly permeable formations are underlain by the Tamiami Formation (shell fragments and limestone) from approximately 80 feet btoc to 130 feet btoc.

4.2.2 Confining Unit

The Hawthorn Group of the Miocene Age constitutes the primary interval of confinement and low permeability between the Surficial Aquifer System and Floridan Aquifer System (FAS). The Hawthorn Group sediments occur from approximately 130 to 870 feet btoc and consist of dense, phosphatic, olive-colored clay and silt along with limestone and shell fragments. The natural gamma ray levels through this interval are consistently higher than the units above and below it. The base of the Hawthorn Group is marked by a sharp peak in natural gamma ray activity.

4.2.3 Floridan Aquifer System

The FAS consists of Paleocene to Oligocene age formations. Anhydrite beds in the lower Cedar Keys Formation constitute the base of the FAS. At depths ranging from 3,500 to 4,100 feet below land surface (Miller, 1986), these beds were not encountered during the drilling of the Class V exploratory well. Eocene limestone and dolostone formations present throughout the area include the Oldsmar Formation and the Avon Park Formation. The Ocala Limestone was not encountered during the drilling of the Class V exploratory well. The Suwannee Limestone of Oligocene age, which was encountered at the site, typically is the uppermost formation of the FAS.

The FAS can generally be subdivided into several permeable zones, separated by low-permeability limestones. It is composed of limestone and dolostone beds generally dipping to the east and south, and contains brackish to saline water. The permeable zones within the aquifer system are regionally grouped into upper and lower units, separated by a middle confining unit. These units are informally designated “upper Floridan aquifer”, “middle confining unit”, and “lower Floridan aquifer”. Only the upper Floridan aquifer was encountered during the drilling of the Class V exploratory well.

The upper Floridan aquifer consists of Oligocene to Middle Eocene formations, including the Suwannee and Ocala Limestones (where present) and the Avon Park Formation. Two predominant permeable zones exist within the upper Floridan aquifer. The most transmissive part of this upper permeable zone usually occurs near the top, coincident with an unconformity at the top of Eocene formations. A second permeable interval has been documented within the Avon Park Formation, and the base is also located within the Avon Park Formation.

At this site, the Suwannee Limestone of Oligocene Age marks the top of the FAS and occurs from a depth of approximately 870 to 1,190 feet btoc. The Suwannee Limestone is characterized by a light-colored fossiliferous limestone and exhibits high permeability and artesian pressure. Reese (1994) estimated the Suwanee Limestone-Avon Park Formation boundary to be at a depth of 1,100 to 1,200 feet below sea level in a well located approximately 8 miles east of the FKAA WTP.

The Avon Park Limestone of Eocene Age occurs from a depth of approximately 1,190 feet btoc to below the total depth of the well (1,504 feet btoc). It is characterized by limestone and dolomite and also exhibits high permeability and artesian pressure.

4.3 Hydrogeological Characteristics of the Upper Floridan Aquifer

A series of interval and packer pumping tests were conducted during the drilling of the Class V exploratory well to estimate the hydrogeologic properties of the upper Floridan aquifer. Information on the test procedures and configuration can be found in Section 3. Exhibit 4-3 shows the intervals tested and the associated lithologic log. Exhibit 4-4 summarizes the test results. Additional information on the testing results is provided in the following sections.

4.3.1 Results of Interval Pumping Tests

Interval tests were conducted at intervals of approximately 100 feet as drilling progressed starting at the base of the final 8-inch-diameter casing string (880 feet btoc) and concluding at the base of the exploratory borehole (1,504 feet btoc). The data from these tests are presented in Exhibit 4-4 and indicate that the specific capacity and transmissivity increase with depth, from 4 gallons per minute per foot (gpm/ft) to 40 gpm/ft and from 866 square feet per day (ft^2/d) to 37,000 ft^2/d, respectively. Detailed information on each interval test, including pumping rates, a plot of water levels, and water quality results, can be found in Appendix L.

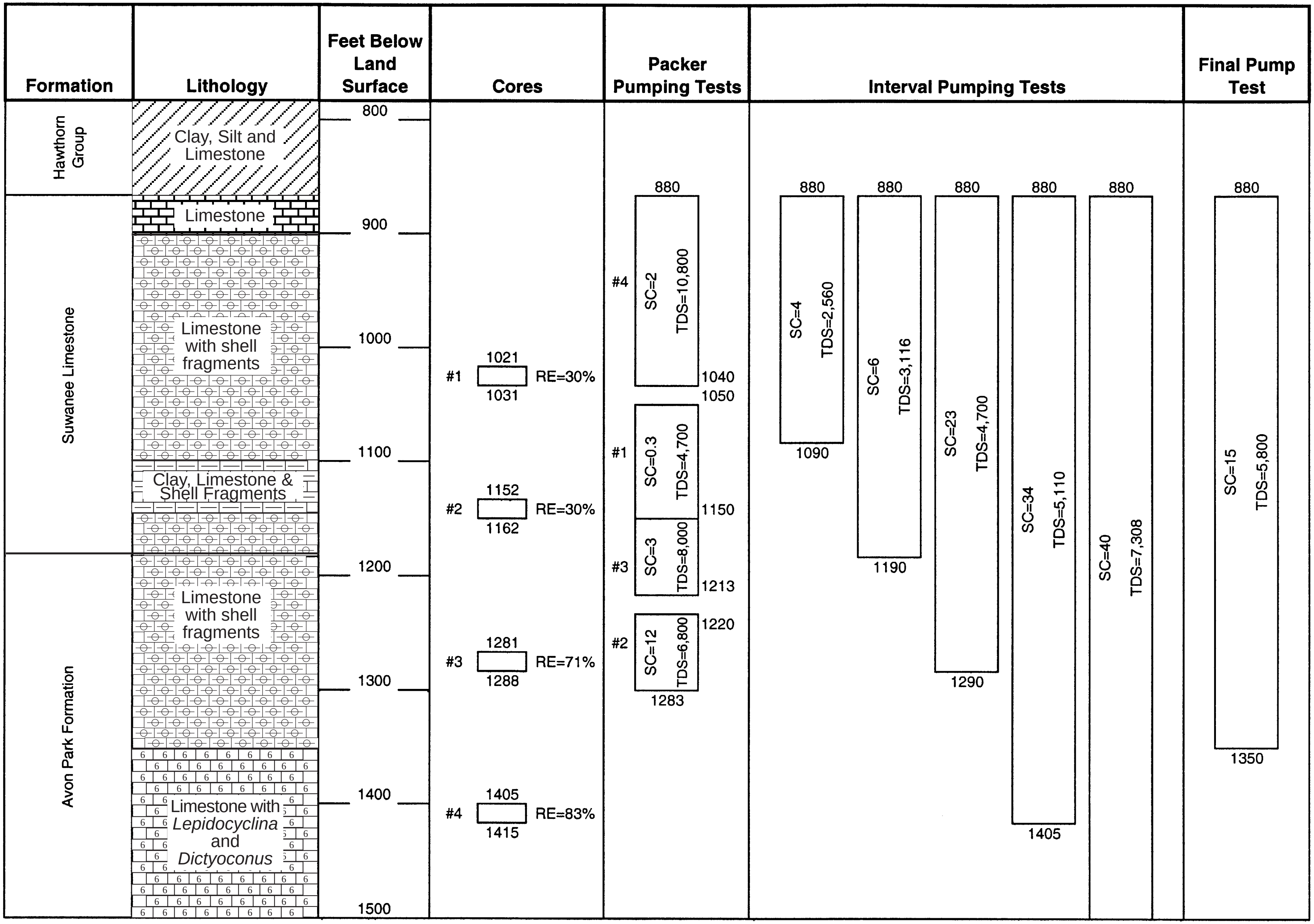
4.3.2 Packer Pumping Tests

Straddle- and single-packer pumping tests were performed after the drilling had reached its final depth of 1,504 feet btoc to isolate and further assess the hydrogeologic and water quality properties of potential ASR or confining zones. Detailed information on each packer pumping test, including pumping rates, a plot of water levels, and water quality results, can be found in Appendix M.

The single-packer test between 880 and 1,040 feet btoc was conducted to assess the properties of the uppermost portion of the Suwanee Limestone. The specific capacity of this interval was approximately 3 gpm/ft, which correlated with the 4 gpm/ft specific capacity observed during the interval test from 880 to 1,090 feet btoc.

A straddle-packer pumping test was conducted on the interval from 1,050 and 1,150 feet btoc. This interval had a specific capacity of 0.3, which likely results from the presence of clay observed in the drill cuttings between 1,100 and 1,150 feet btoc. A straddle-packer pumping test was conducted on the interval from 1,150 feet btoc to 1,213 feet btoc to evaluate the hydrogeologic properties of the aquifer immediately below this clay layer; the specific capacity was 3 gpm/ft, one order of magnitude higher than the interval from 1,050 to 1,150 feet btoc.

A straddle-packer pumping test was conducted on the interval between 1,220 and 1,283 feet btoc to evaluate the hydrogeologic properties of the Avon Park Formation. The specific capacity was 12 gpm/ft.



RE = Recovery Efficiency
SC = Specific Capacity (gpm/ft)
TDS = Total Dissolved Solids (mg/L)

Exhibit 4-3
Summary of Hydrogeologic Testing

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EXHIBIT 4-4
Results of Hydrogeologic Testing

Date of Test	Type of Pumping Test	Interval Tested (feet btoc)	Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Calculated Transmissivity (ft^2/d)
5/14/03	Interval #1	88–1090	45	4	866
5/23/03	Interval #2	880–1190	450	6	1276
5/30/03	Interval #3	880–1290	650	23	36,629
6/4/03	Interval #4	880–1405	900	34	82,803
6/9/03	Interval #5	880–1504	950	40	37,000
7/2/03	Packer #1	1050–1150	25	<1[a]	29[a]
7/9/03	Packer #2	1220–1283	85	12	NC[b]
7/10/03	Packer #3	1150–1213	82	3	2,200
7/22/03	Packer #4	880–1040	60	2	492
10/8/03 – 10/11/03	Final Pump Test	880–1350	280	16	10,790
			500	16	
			750	15	
			650	15	
			500	15	

Notes:

btoc=below top of casing
NC=Not calculated
[a]The salt plug in the well was not completely purged prior to the start of the test on 7/2/03; therefore, the initial static water level was assumed to be the level to which the water level in the drill stem recovered at the conclusion of the test.
[b]The water level in this interval responded so quickly to the start and stop of the test that the data could not be analyzed because there are no typical pump or recovery curves.
gpm=gallons per minute
ft^2/d=square feet per day

4.3.3 Aquifer Performance Test

Following the completion of the exploratory borehole and after receiving verbal approval from FDEP, the borehole was plugged back to a depth of 1,353 feet btoc, and preparations were made for a 72-hour aquifer performance test.

During previous interval and packer testing, the length of the tests were relatively short (i.e., less than 4 hours) and, thus water could be discharged to the local sanitary sewer system. However, because of capacity limitations, the sanitary sewer system was not able to sustain a constant flow rate from the well for the proposed 72-hour period. Therefore, FKAA elected to blend the water from the final pumping test with the raw water from their existing Biscayne Aquifer wellfield. To accommodate this blending of the two water supplies, FKAA had to be sure that water quality standards in the finished water from the WTP would not violate drinking water standards. Thus, FKAA conducted extensive blending analyses and determined that a maximum blend of 6 to 8 percent would be feasible.

Since blended water entering the WTP must eventually be distributed to FKAA customers, the water quality has little room for error. Therefore, the aquifer performance test would be initiated as a step test, beginning at a flow rate of approximately 280 gpm, with water quality being analyzed for TDS, chlorides, conductivity, and pH at four locations:

- Floridan aquifer raw water
- Floridan aquifer and Biscayne Aquifer blended raw water
- Treated water after the transfer pumps to the onsite storage tanks
- Following distribution

A 72-hour aquifer performance test was conducted on the final interval from 880 feet to 1,353 feet from October 8 to October 11, 2003. Once the water quality data indicated that the blended water had passed through the WTP transfer pump, and no drinking water violations of the above parameters were realized, the flow rate was stepped up to 500 gpm, and then finally to 750 gpm. After approximately 24 hours of pumping, the TDS concentration (a secondary standard) began to increase above the standard of 500 mg/L. Therefore, the flow rate was eventually reduced to a rate of 600 gpm and continued for the remainder of the test. Exhibits 4-5a through 4-5d depict the water quality data from the above four sampling locations during the 72-hour test and the subsequent 48-hour recovery period.

Throughout the 72-hour test, the specific capacity was approximately 15 gpm/ft over the entire range of flow rates. Water level data from the recovery portion of the test were used to estimate an aquifer transmissivity of 10,790 ft^2/d. Detailed information from the test, including a plot of water levels and water quality data, is presented in Appendix N.

4.3.4 Core Sampling

During drilling of the pilot hole, core samples were recovered to correlate with drill cuttings and geophysical logs. Samples were recovered using a 4-inch-diameter, 10-foot core barrel. A total of four core samples were recovered during pilot-hole drilling. The estimated coring intervals and respective geologic units for these samples are as follows:

- Core Sample No. 1: 1,021 to 1,031 feet btoc (Suwannee Limestone)
- Core Sample No. 2: 1,152 to 1,162 feet btoc (Suwannee Limestone)
- Core Sample No. 3: 1,281 to 1288 feet btoc (Avon Park Formation)
- Core Sample No. 4: 1,405 to 1,415 feet btoc (Avon Park Formation)

A section of cores from the interval 1,021 to 1,031 feet btoc was submitted to Core Lab, Inc., of Houston, Texas, for porosity, grain density, and vertical and horizontal permeability testing. The samples were found to have a mean porosity of 0.38, a mean grain density of 2.695 gm/cm^3, a mean horizontal air permeability of 1,196 millidarcies (mD) (3.4 feet per day [ft/d]), and a mean vertical air permeability of 367 mD (1.0 ft/d). These estimates of permeability compare favorably to the hydraulic conductivity values estimated from the interval and packer tests within this cored interval. A description of each core can be found in Appendix J.

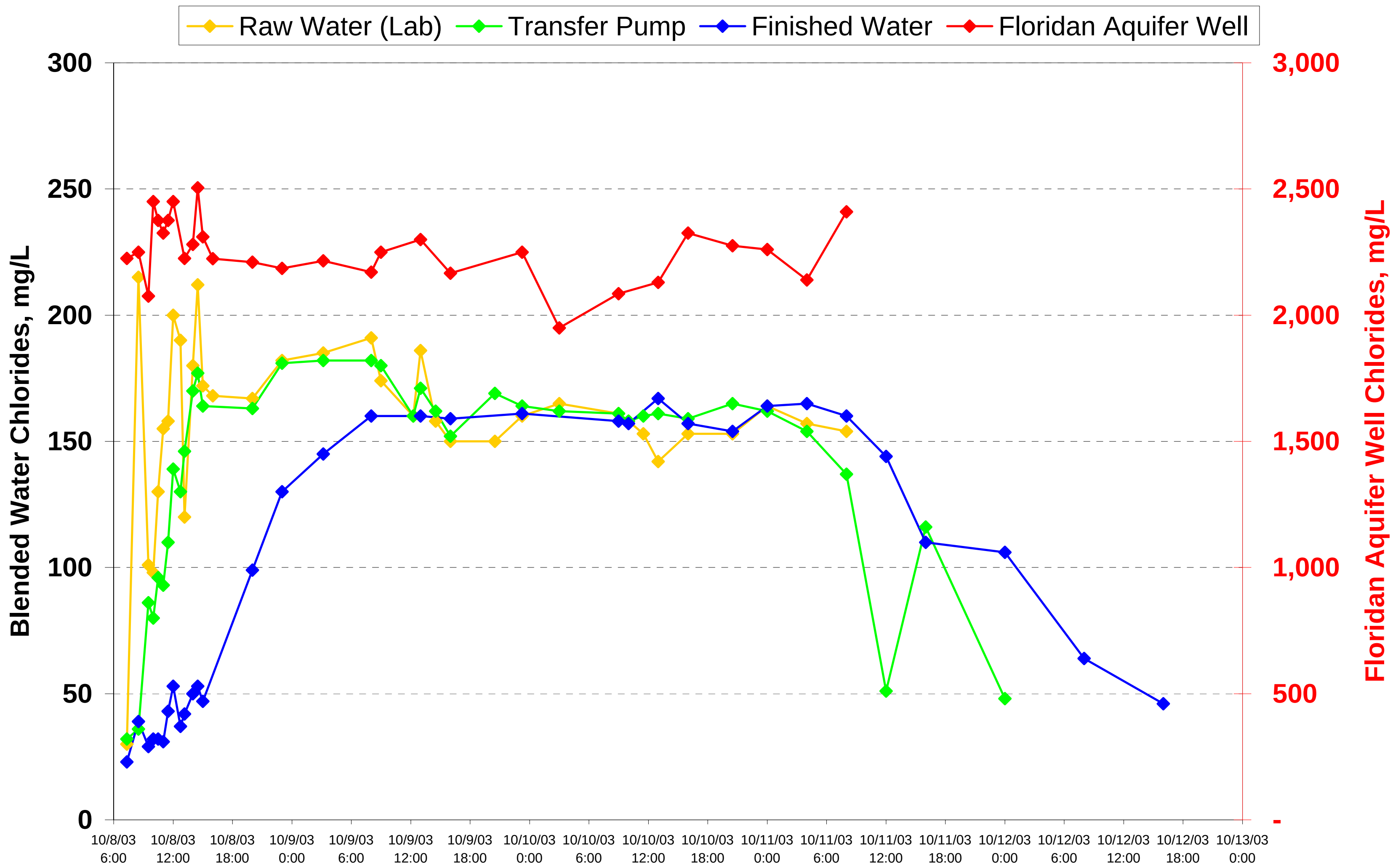

Exhibit 4-5a
Floridan Aquifer Full Scale Blending and Pumping Test - Chlorides (mg/L)

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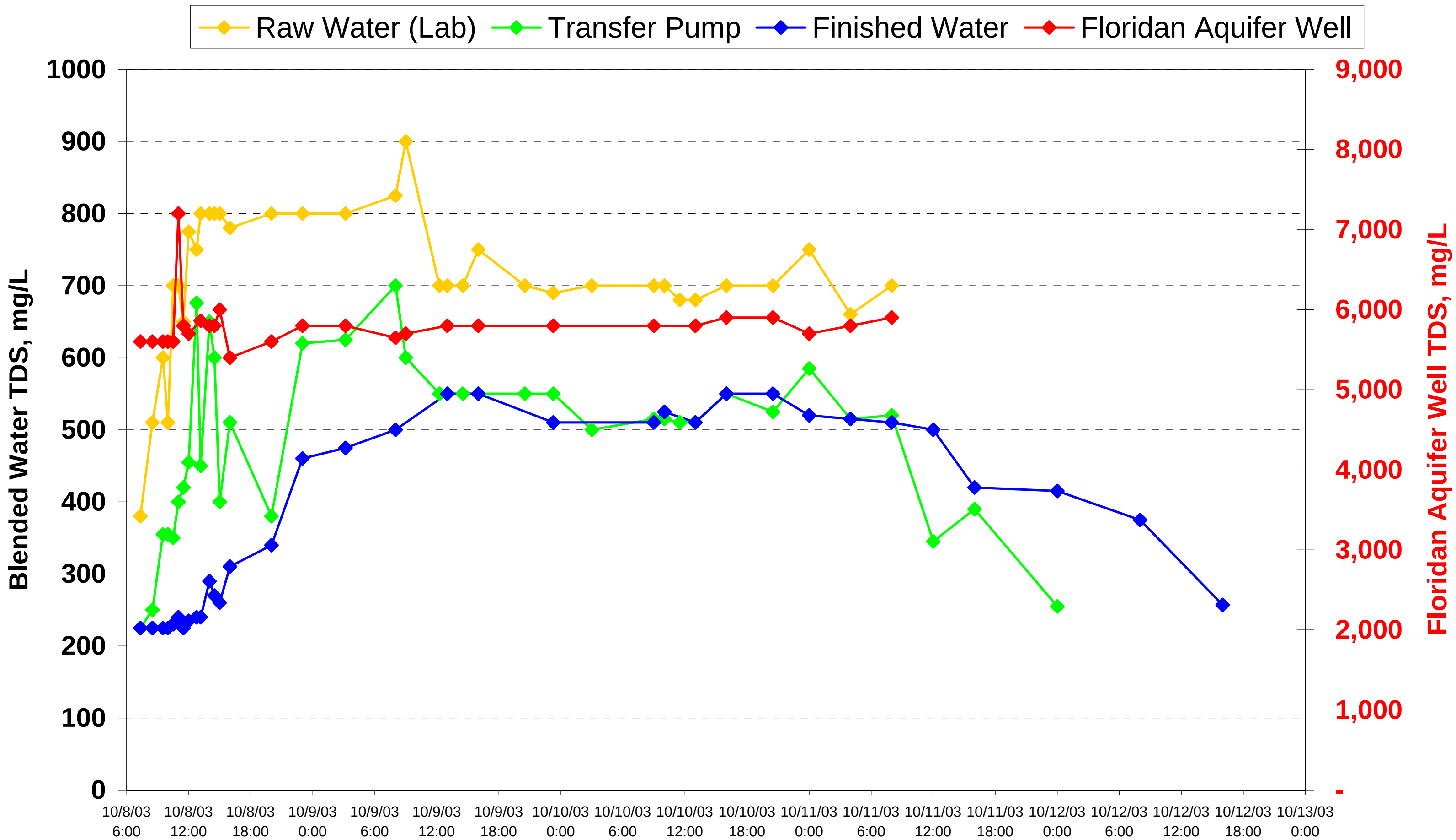

Exhibit 4-5b

Floridan Aquifer Full Scale Blending and Pumping Test - Total Dissolved Solids (mg/L)

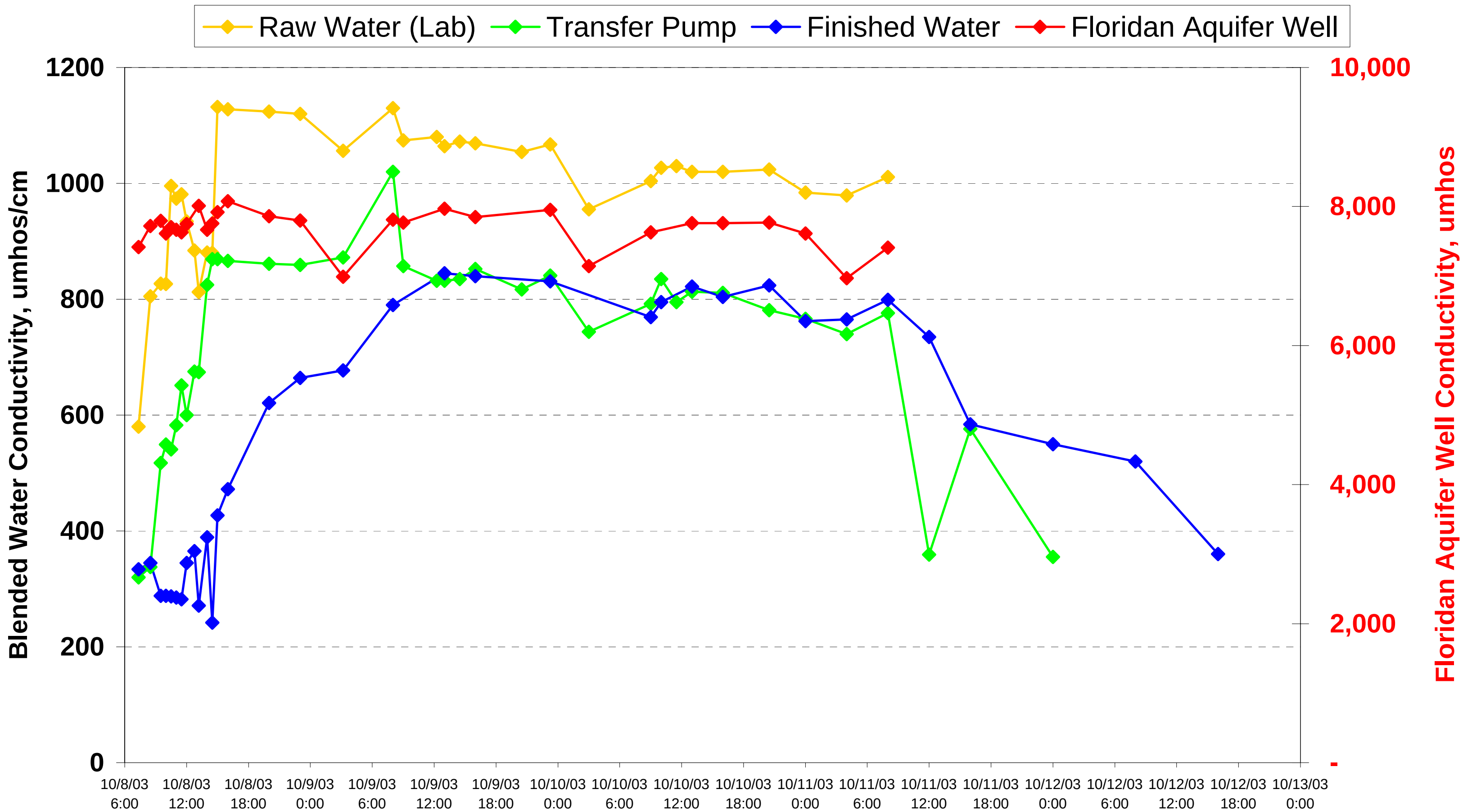

Exhibit 4-5c

Floridan Aquifer Full Scale Blending and Pumping Test - Conductivity (µmhos/cm)

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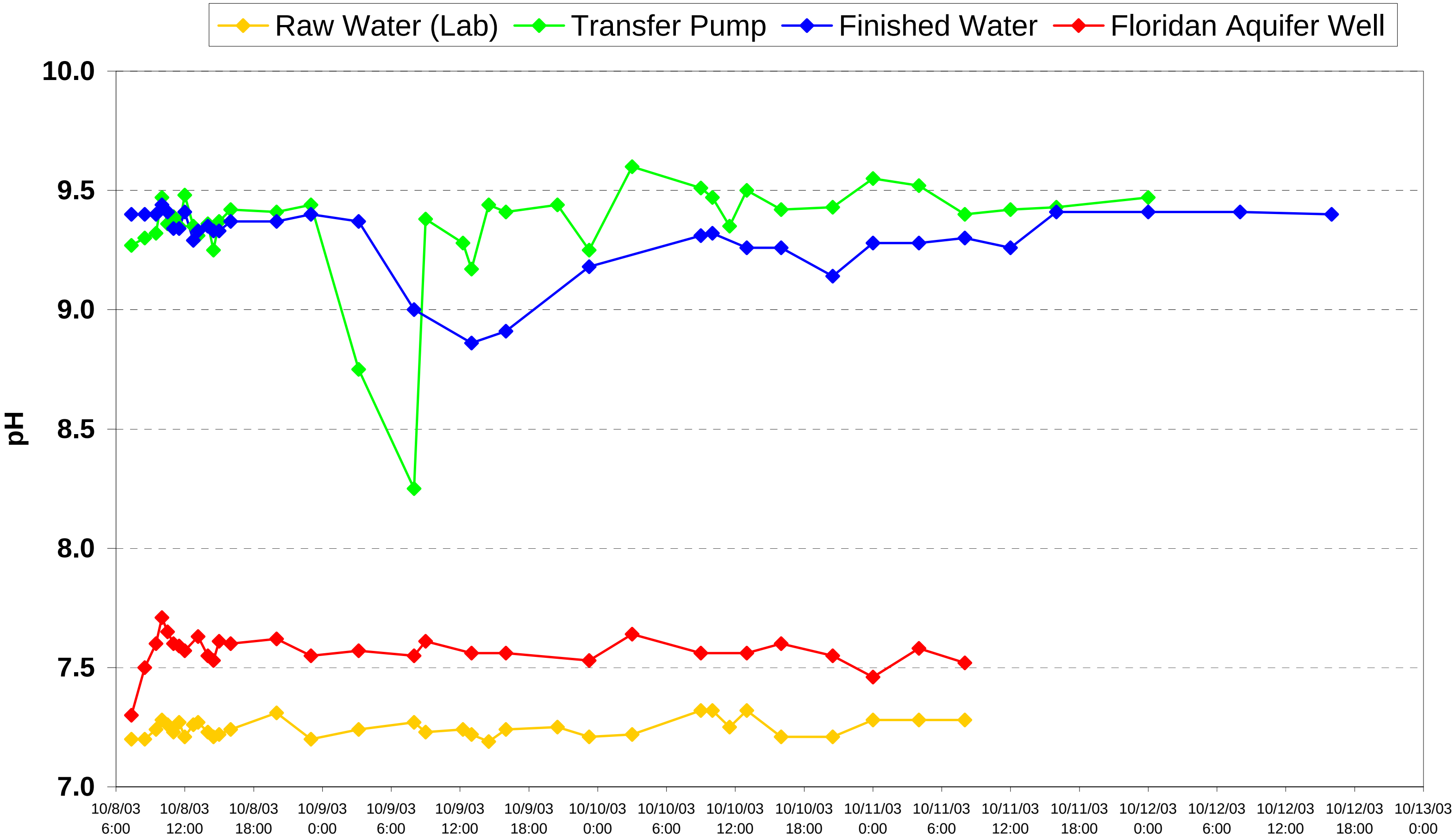

Exhibit 4-5d

Floridan Aquifer Full Scale Blending and Pumping Test - pH

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4.4 Groundwater Quality

4.4.1 Water Quality During Construction

Water samples were collected during each interval test in accordance with the requirements of the well construction permit from FDEP. The samples were analyzed by Severn Trent Laboratories (STL) of Miami, Florida. Exhibit 4-6 presents a summary of the water quality from the interval testing.

EXHIBIT 4-6
FKAA-FC-EW-1 Interval Testing Water Quality Summary

Date	Test Interval (ft btoc)	Chlorides (mg/L)	Conductivity (µmhos/cm)	Total Dissolved Solids (mg/L)
5/14/03	880–1,090	670	3,420	2,560
5/23/03	880–1,190	1,550	4,470	3,116
5/30/03	880–1,290	2,233	7,620	4,700
6/4/03	880–1,405	2,254	8,210	5,110
6/9/03	880–1,504	3,927	9,220	7,308

Chlorides, conductivity and total dissolved solids concentrations were observed to increase with depth, consistent with the findings of Meyer (1989) and others.

Water samples were also collected during each packer test and were analyzed for chlorides, specific conductance (conductivity), and TDS by the FKAA WTP laboratory. Exhibit 4-7 presents a summary of the packer testing water quality data.

EXHIBIT 4-7
FKAA-FC-EW-1 Packer Testing Water Quality Summary

Date	Test Interval (bpl)	Chlorides (mg/L)	Conductivity (µmhos/cm)	Total Dissolved Solids (mg/L)
7/22/03	880–1,040	4,789	12,970	10,800
7/2/03	1,050–1,150	1,990	5,900	4,700
7/10/03	1,150–1,213	2,700	6,000	8,000
7/9/03	1,220–1,283	3,400	8,020	6,800

The water quality results from the packer test conducted on the interval from 880 to 1,040 feet btoc appear to be anomalous. The chlorides are approximately 4,000 mg/L higher than observed during the interval test from 880 to 1,090 feet btoc. Specific conductivity and TDS are approximately four times higher in the packer test than in the comparable interval test. Prior to conducting the test, the well was pumped and allowed to flow for approximately 40 hours to ensure that the salt kill plug had been removed. Water quality samples were collected during this pumping period, and showed no improvement with continued pumping once the salt plug had been pumped out of the well.

4.4.2 Final Pumping Test

Water quality samples were collected near the conclusion of the 72-hour aquifer performance test and analyzed for a range of parameters, including primary and secondary drinking water standards. Exhibit 4-8 summarizes the water quality results.

Results from the analyses show that the native groundwater is brackish (TDS concentration of approximately 4,550 mg/L). This TDS value is consistent with data collected during the interval and packer testing, with the exception of the single-packer pumping test conducted on July 22, 2003. It is believed that the high TDS value (10,800 mg/L) observed during this packer test is the result of an incomplete purging of salt water used to "kill" the well during packer placement. The full laboratory report is included in Appendix O.

EXHIBIT 4-8
Background Water Quality Results

Parameter	Concentration
Volatile organic contaminants	Pending
Trihalomethanes	Pending
Purgeable organics	Pending
Pesticides	Pending
Herbicides	Pending
Barium	BDL
Sodium	1,900 mg/L
Fluoride	7.5 mg/L
Iron	Pending
Zinc	0.010 mg/L
Chloride	2,185 mg/L
Total dissolved solids	4,550 mg/L
Turbidity	Pending
Odor	50 TON
Color	2.5 CU
Sulfate	485 mg/L
Coliform	Pending

Notes:
1. Water samples were collected on October 10, 2003, during the aquifer performance test, and analyzed for primary and secondary drinking water standards.
2. All other parameters analyzed, but not listed, were below the method detection limits.
3. Refer to Appendix O for a complete report of results.
At the date of this report, some analyses results were still pending.

BDL=below detection limits
mg/L=milligrams per liter
TON=threshold odor number
CU=color units

SECTION 5

Summary and Conclusions

SECTION 5

Summary and Conclusions

This report has been prepared to document the drilling and testing activities during the construction of the Class V Exploratory well at the J. Robert Dean WTP. The exploratory well facilities consist of the exploratory well, surface equipment, and a concrete pad.

The exploratory well was constructed with a 30-inch-diameter pit casing set from pad level to a depth of 37 feet btoc. Inside that casing, an 18-inch-diameter steel casing was set from pad level to a depth of 150 feet btoc. Inside the 18-inch-diameter steel casing, an 8.5-inch-diameter fiberglass casing was set from pad level to 880 feet btoc. The open borehole is from 880 to 1,350 feet btoc. A pressure test was performed on the casing to demonstrate mechanical integrity.

Hydrogeologic testing was conducted on the intervals encountered during construction of the exploratory well. The testing included lithologic sampling, cores, geophysical logging, and several types of pumping tests. An aquifer performance test was conducted after completion of construction. The hydrogeologic testing focused on identifying intervals of relative low permeability (confining units) above and below an interval of relative high permeability (proposed ASR zone) and determining the water quality of the proposed ASR zone.

The hydrogeology at the site consists of the Biscayne Aquifer from land surface to approximately 130 feet btoc. Below that are the clays and silts of the Intermediate Confining Unit, which separates the Biscayne Aquifer from the Floridan aquifer below it. The confining units are from approximately 130 to 870 feet btoc. The ASR interval consists of limestone layers within the upper Floridan aquifer. The top of the Floridan Aquifer System is at approximately 870 feet btoc and continues to the total depth of the well. The water quality of the upper Floridan aquifer water is brackish, with a TDS concentration of approximately 5,800 mg/L.

Based on the water quality and hydrogeologic data collected during the exploratory drilling and testing, the recommended ASR interval is the upper portion of the Avon Park Formation from the base of the Suwannee Limestone at 1,190 feet btoc to a depth of approximately 1,350 feet btoc. This interval takes advantage of a highly fractured zone with solution channels at a depth range from approximately 1,250 to 1,280 feet btoc. Based on the cuttings, cores, geophysical logs, interval, and packer tests, the Suwannee Limestone appears to have very low permeability and hydraulic conductivity and, thus, should provide semi-confinement above the proposed ASR zone. In addition, the lower portion of the Avon Park Formation (below 1,300 feet) appears to contribute little to no flow until a depth of approximately 1,400 feet is reached.

The water quality data collected during the drilling of the exploratory well and during the interval testing indicate that above 1,350 feet btoc, water quality is relatively good. The chloride concentrations in the proposed ASR interval are on the order of 1,200 to 2,500 mg/L; specific conductance is on the order of 5,400 to 7,300 µmhos/cm; and TDS is on the order of 5,000 mg/L. Below a depth of 1,350 feet btoc, all three of these parameters begin to increase.

The aquifer properties estimated from the 880 to 1,405 feet btoc interval test indicate a specific capacity of 34 gpd/ft and a transmissivity of 82,800 ft^2/d. The estimates of specific capacity and hydraulic conductivity from the interval and packer tests indicate an apparent flow zone just below the base of the Suwannee Limestone. These aquifer properties indicate that the injection or recovery of water from this zone should not result in significant changes in potentiometric head.

Clay was observed in the drill cuttings beginning at a depth of 1,040 feet btoc. However, clay did not constitute a substantial portion of the cuttings until the depth of 1,110 feet btoc. The markedly different water quality above this depth (chlorides on the order of 500 mg/L; specific conductance on the order of 3,500 μmhos/cm; and TDS on the order of 2,500 mg/L) suggests that the clay may act as a semi-confining bed above the proposed ASR interval.

Core samples collected below the proposed ASR interval show thinly laminated chalky limestone without any fractures. The sonic porosity log also confirms a decrease in fractures below 1,300 feet. The dynamic flowmeter log showed that the flow in the interval below 1,300 feet btoc was close to static, and did not increase until approximately 1,280 feet btoc. It is expected that this competent, low-permeability interval from 1,300 feet btoc to 1,504 feet btoc will provide confinement below the proposed ASR interval.

One discrepancy noted was the difference between the observed specific capacity test on the interval from 880 to 1,290 feet btoc (23 gpm/ft) and the specific capacity observed during the final pumping test from 880 to 1,350 feet btoc (15 gpm/ft). Both the interval test and the final pumping test had similar flow rates (approximately 600 gpm). It is theorized that cement migration during plug-back of the borehole may be responsible for the diminished specific capacity.

SECTION 6

Works Cited

SECTION 6

Works Cited

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