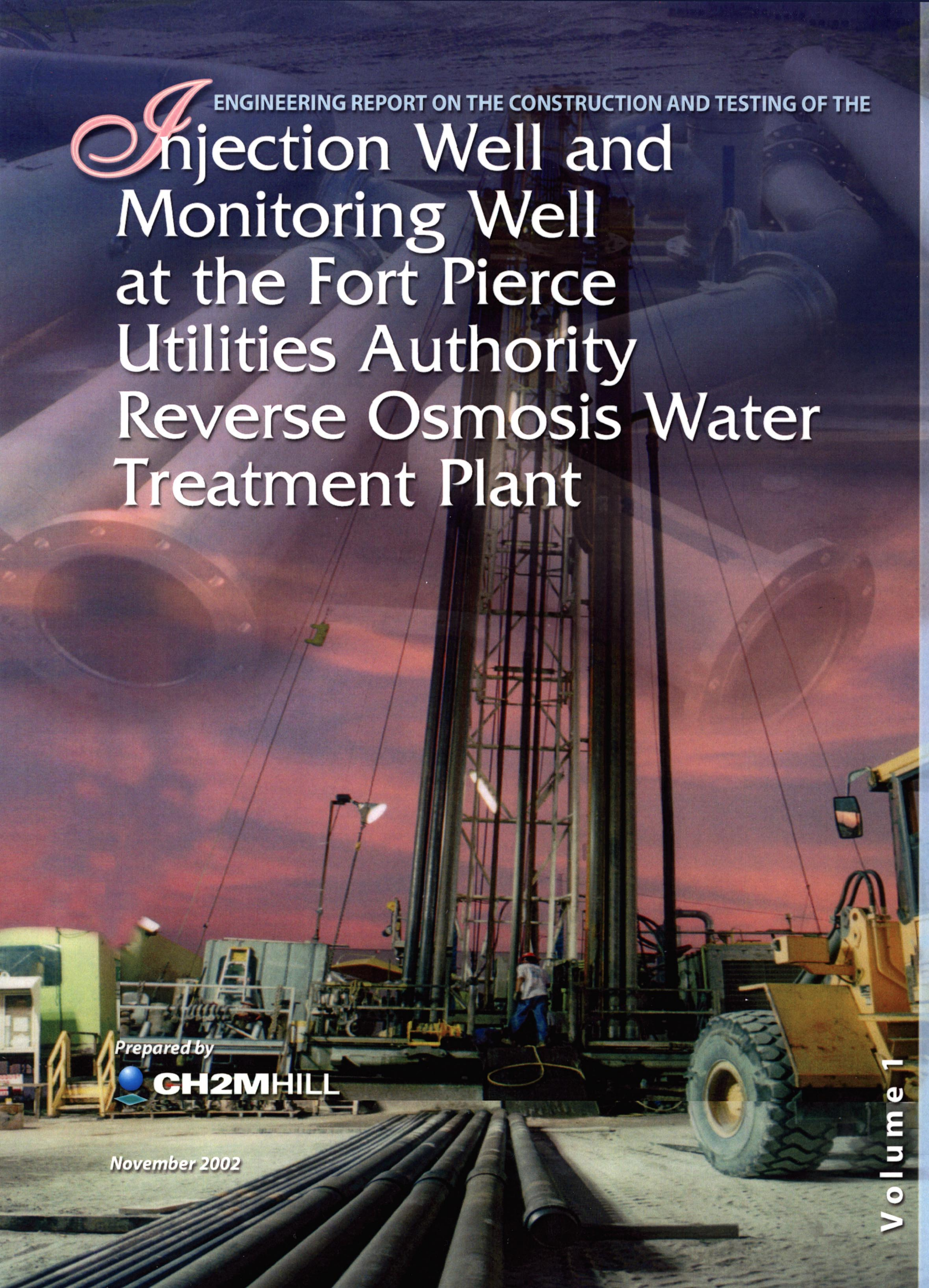

ENGINEERING REPORT ON THE CONSTRUCTION AND TESTING OF THE

Injection Well and Monitoring Well at the Fort Pierce Utilities Authority Reverse Osmosis Water Treatment Plant

Prepared by

CH2MHILL

November 2002

Volume 1

CH2MHILL

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November 4, 2002

169182.IW.CS

Mr. Joe May, P.G.
Florida Department of Environmental Protection
Southeast District
P.O. Box 15425
West Palm Beach, FL 33416

Dear Joe:

Subject: Fort Pierce Utilities Authority WTP RO Injection Well (IW-1)
FDEP Permit No. 171331-001-UC
Transmittal of Final Report

Hereby submitted are two signed and sealed copies of the above-referenced Engineering Report (Volumes 1 and 2). The report includes the data collected during the construction and testing of the injection well at the reverse osmosis water treatment plant for the FPUA. Injection Well IW-1 is now complete and was constructed in accordance with the specific conditions of Construction Pemit No. 171331-001-UC. With the submittal of this report the FPUA would like to request the well be placed into operational testing.

If you have any questions regarding the enclosed material, please call me or Mark Schilling at 954-426-4008.

Sincerely,

CH2M HILL

Sean Skehan

Sean Skehan, P.G.
Project Manager

DFB/DOCUMENT2
c: Dave Mellert/FPUA
Heidi Vandoor/FDEP-WPB
Richard Deuerling/FDEP-Tlh.
Ron Reese/USGS
Nancy Marsh/USEPA/Atl.
Steve Anderson/SFWMD
Mark Schilling/CH2M HILL

Report

Fort Pierce Utilities Authority WTP RO Injection Well (IW-1)

FDEP Permit No. 171331-001-UC

Prepared for
Fort Pierce Utilities Authority

November 2002

Sean Skehan
11/5/02

CH2MHILL

52092
11/5/02

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Exhibit **Page**

Executive Summary

The Fort Pierce Utilities Authority received from the Florida Department of Environmental Protection, a construction permit for the construction and testing of the concentrate disposal system for the reverse osmosis facility on February 8, 2002. This was followed by issuing a notice to proceed to Youngquist Brothers Drilling, Inc. on February 25, 2002. The construction permit contained provisions for both a construction variance to construct the injection well within 500 feet of the onsite production wells and an alternate design to cement in place the final fiberglass liner in lieu of a tubing and packer.

This engineering report describes the construction and testing of the concentrate disposal well and the dual-zone monitor well. Each well was constructed in accordance with applicable section of the Florida Administrative Code (FAC) Chapter 62-528, Construction Permit 171331-001-UC and Contract Documents for the Fort Pierce Utilities Authority Deep Injection Well System at the Henry A. Gahn 25th Street Reverse Osmosis Facility, prepared by CH2M HILL in September 2001. The concentrate disposal system has a total capacity of 2.8 mgd.

Construction of the injection well and monitor wells began on March 15, 2002, with the injection well pilot hole and was completed on September 5, 2002, with the radioactive tracer test, also on the injection well. The final casing of the injection well was set to a depth of 2,676 feet below pad level (bpl) followed by the 10-inch fiberglass tubing being installed to 2,670 feet bpl. The dual-zone monitor well was constructed with two monitor intervals, an upper and lower. The upper interval monitored the depths between 1,508 and 1,557 feet bpl while the lower interval monitored the depths between 1,860 and 1,910 feet bpl. Both wells successfully passed mechanical integrity testing, and appear capable of obtaining a test operating permit.

Acknowledgements

The successful completion of the Fort Pierce Utilities Authority Henry A. Gahn Reverse Osmosis Water Treatment Plant Injection Well System was the result of continuous communication and cooperation between the many organizations and individuals involved in its design, construction, and permitting. These organizations include the Fort Pierce Utilities Authority (FPUA), the Florida Department of Environment Protection (FDEP), the Environmental Protection Agency (EPA), the South Florida Water Management District (SFWMD), the United States Geological Survey (USGS), CH2M HILL, and Youngquist Brothers, Inc.

Individuals who played a key role in this achievement include:

FPUA

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Vaughan Weaver, P.E., Director of Water/Wastewater/Gas Systems
William Thiess, P.E., Supervising Engineer
David Mellert, Project Manager
Richard Stenberg, Superintendent of Water Resources

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Tallahassee Office

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USGS

Ron Reese, P.G.

Youngquist Brothers, Inc.

Tim Youngquist, Vice President
Jim Brantley, President, Drilling Operations
Kevin Greuel, Project Superintendent
Ed McCullers, Contract
Craig Brugger, Assistant Contract Administrator

CH2M HILL

Sean Skehan, P.G., Project Manager
David Schuman, P.E., Project Engineer
Mark Schilling, Project Superintendent
Daniel Jablonski, Resident Inspector
Tracy Levi, P.E., Resident Inspector
John Powers, P.G., Resident Inspector
Curtis Willis, RO Plant Construction Superintendent

Abbreviations and Acronyms

µmhos	micromhos per centimeter
API	American Petroleum Institute
bpl	below pad level
bls	below land surface
btoc	below top of casing
CBL	cement bond log
CCL	casing collar locator
cm	centimeter
DI	dual induction
DIW	deep injection well
EPA	U.S. Environmental Protection Agency
°F	degrees Fahrenheit
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FGS	Florida Geological Survey
fpm	feet per minute
FPUA	Fort Pierce Utilities Authority
FRP	fiberglass reinforced pipe
gpm	gallons per minute
GRB	Bottom Gamma Radiation Detector
GRM	Middle Gamma Radiation Detector
GRT	Top Gamma Radiation Detector
IW-1	injection well
IWSD	Immokalee Water and Sewer District
K	hydraulic conductivity
L	liter
mCi	millicurie
mg	milligrams
mgd	million gallons per day
MI	mechanical integrity
MRIL	Magnetic Resonance Imaging Log

NGR	natural gamma-ray
NGVD	National Geodetic Vertical Datum
PMW	pad monitoring wells
psi	pounds per square inch
PVC	polyvinyl chloride
RO	reverse osmosis
RTS	radioactive tracer surveys
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
SU	standard units
T	transmissivity
TAC	Technical Advisory Committee
TDS	total dissolved solids
TZMW-1	tri-zone monitoring well
UIC	Underground Injection Control
USDW	underground source of drinking water
USGS	U.S. Geologic Survey
WTP	water treatment plant
WWTP	wastewater treatment plant

SECTION 1

Introduction

1.1 Background Information

The Fort Pierce Utilities Authority (FPUA) owns and operates the Henry A. Gahn Water Treatment Plant (WTP) at 715 S. 25th Street, Fort Pierce, Florida. Fort Pierce is situated in northeast St. Lucie County, as shown on the site location map provided in Exhibit 1-1.

The WTP currently includes a lime-softening process and is expanding to include a reverse osmosis (RO) facility. FPUA proposed to construct a 10.75-inch-diameter Class I injection well to dispose of the brine concentrate from the RO facility. The reverse osmosis facility is projected to be completed in October 2002.

Underground Injection Control (UIC) Permit (Construction Permit No. 171331-001-UC) was issued in February 2002 by the Florida Department of Environmental Protection (FDEP). A copy of the construction permit is included in Appendix A. In general, a Class I injection well injects below the base of a formation containing potential future drinking water supplies (or Underground Source of Drinking Water [USDW[1]]). Issuance of the permit allowed the FPUA to proceed with construction and testing of the injection well system.

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[1] An USDW is defined as, among other criteria, aquifers capable of yielding a significant amount of drinking water containing less than 10,000 mg/L of total dissolved solids (TDS).

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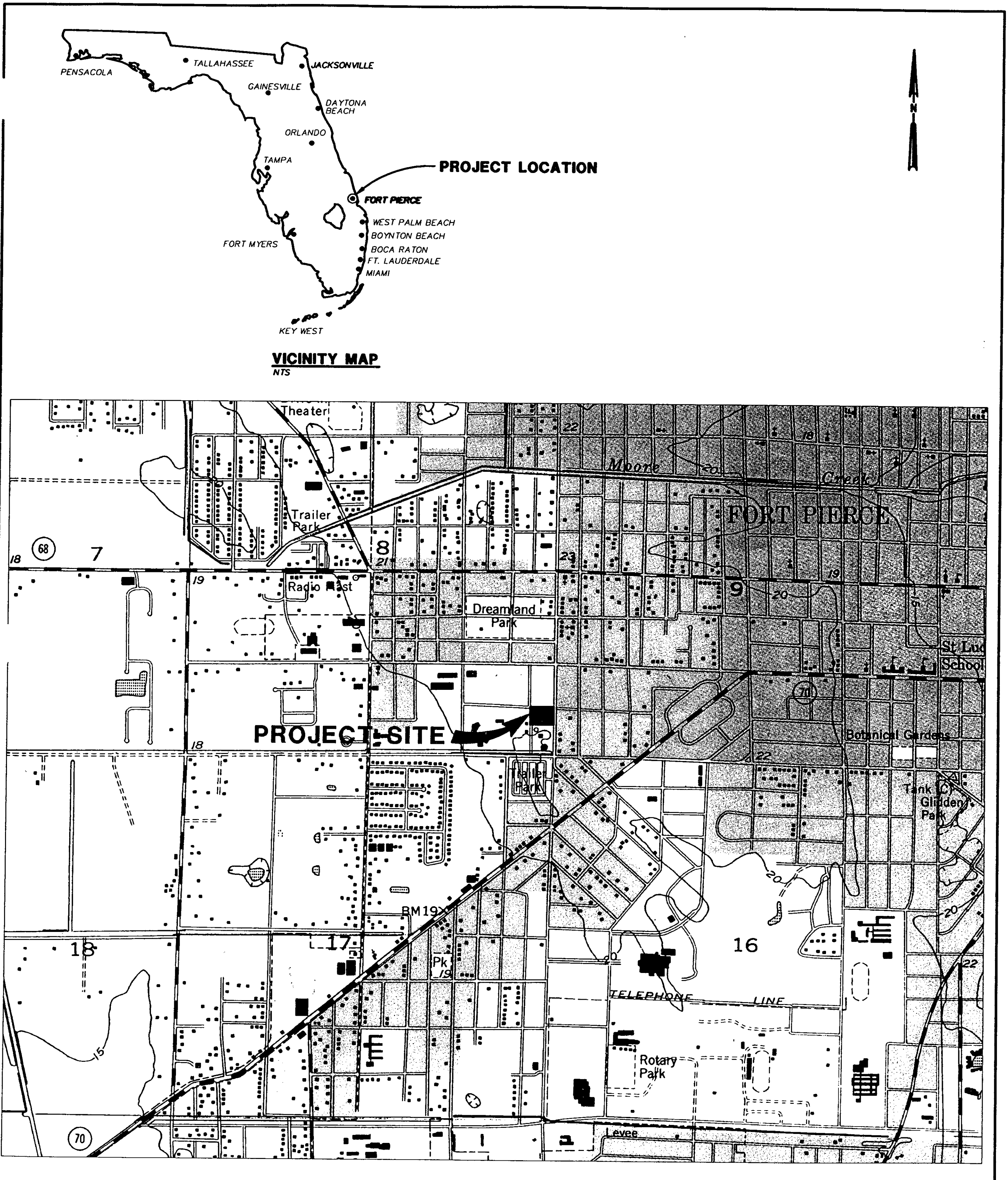

Exhibit 1-1
Location Map

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1.2 Project Description

This report summarizes the construction and testing of the injection well (IW-1) and dual-zone monitoring well (DMW-1) at the FPUA RO WTP. Exhibit 1-2 presents a site map of the WTP, indicating the location of the injection well and monitoring well system. Construction and testing of the injection well system was performed in accordance with Chapter 62-528, Florida Administrative Code (FAC), recommendations from the Technical Advisory Committee (TAC), and provisions of the FDEP Class I injection well Construction Permit No. 171331-001-UC.

CH2M HILL served as the engineer of record for the design, construction, and testing of the injection well system. Youngquist Brothers Inc. (YBI) of Fort Myers, Florida was selected as the drilling subcontractor for construction of the injection well system.

CH2M HILL provided resident observation and technical support services during construction and testing of the injection well system. CH2M HILL and YBI prepared daily and weekly summary reports that were submitted to the TAC on a weekly basis, as required by the well construction permit. Copies of CH2M HILL's weekly summary reports and daily reports are provided in Appendix B.

A comprehensive testing plan was conducted during construction of the injection well and monitoring well system. The testing plan included formation sampling, geophysical logging, reverse-air pilot hole water quality, core sampling, and packer testing. The optimal injection zone identified during construction was located in the Oldsmar Formation. Testing during construction of the injection well emphasized data collection that would identify the injection zone, identify the base of the USDW, and evaluate confining characteristics of the lithology between the injection interval and the base of the USDW from this potential injection zone formation and overlying strata.

A more detailed description of testing activities conducted during well construction can be found in Section 4 of this report.

1.3 Permitting

Regulatory approval is required to install and operate a deep injection well. As a result of the FPUA injection well being a Class I injection well, injection well permitting involves close coordination with the FDEP. The well construction permit issued by the FDEP was obtained prior to construction and testing of the injection well system. As previously mentioned, a copy of the well construction permit is provided in Appendix A. An FDEP Certification of Class I Well Construction Completion form is also provided in Appendix C.

The FDEP UIC division regulates activities in Florida under Chapter 62-528, FAC. The FDEP TAC for this project consists of representatives from the FDEP-West Palm Beach, FDEP-Tallahassee, Region IV (Atlanta) of the U.S. Environmental Protection Agency (EPA), United States Geologic Survey (USGS), and the South Florida Water Management District (SFWMD).

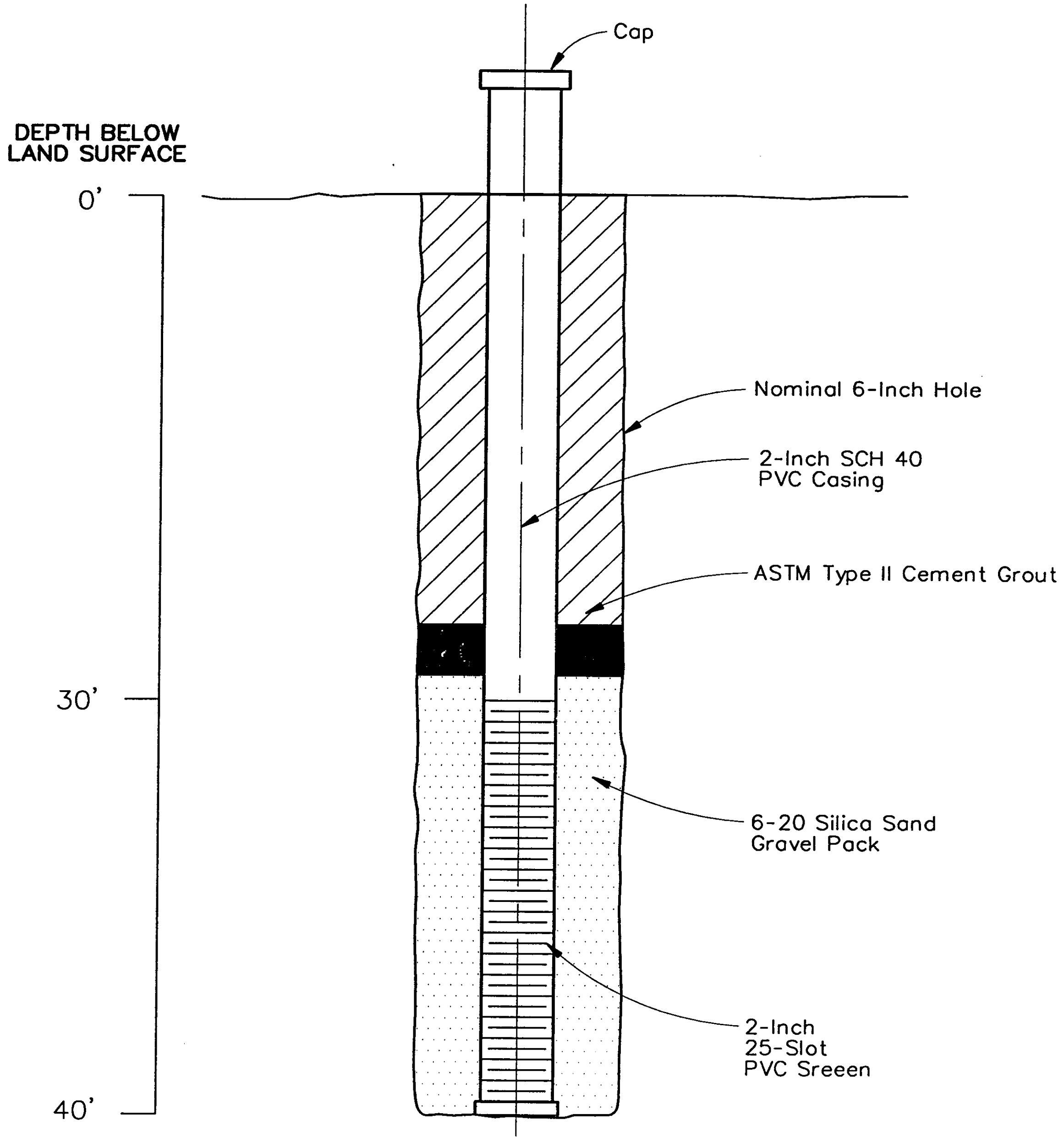

Exhibit 2-1

Surficial Monitoring Well
Completion Diagram

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Permitting for the FPUA RO deep injection well (DIW) allowed for two special provisions, a variance on the location of the well and an alternate design for the design and installation of the final tubing.

The variance allowed for the DIW to be constructed within a 500-foot set back of existing onsite potable water supply wells. The 500-foot setback distance is where groundwater is provided stringent protection measures to protect the raw water source.

The variance request was made because the water plant site is a very congested site with multiple buildings, storage tanks, and extensive underground piping, leaving very little space available for the construction of a deep injection well. In support of the variance request, it was demonstrated that there would be significant vertical separation between the injection well injection zone and the open intervals of the onsite Floridan Aquifer and the surficial aquifer production wells. It was also mentioned that much of the vertical separation was anticipated to be confining in nature. These assumptions were supported by geophysical and hydrologic data collected at the local water reclamation facility injection well.

Protective features of the injection well design include use of staged construction and multiple casings to protect two intervals of underground sources of drinking water at the site. The intervals include the surficial aquifer and the upper Floridan Aquifer. The surficial aquifer will be protected by four cemented casings while the Floridan Aquifer will be protected by three cemented casings. Measures of added protection include corrosion resistant fiberglass reinforced plastic pipe as a final casing for the injection well, stainless steel (316-L) wellhead, and plastic piping from the RO facility to the well.

An additional factor supporting the placement of the injection well within the 500-foot interval is that the water quality of the RO reject (a water treatment by-product) will be a result of concentrating naturally occurring ions and minerals originating from the upper Floridan aquifer. Based on water quality data from the new Floridan Aquifer wells, the total dissolved solids (TDS) of the raw water to the plant is expected to be approximately 1000 mg/L. By comparison, the reject will be approximately 6,600 mg/L and will resemble the native groundwater quality found below a depth of approximately 1,700 feet, thus limiting the potential for density driven movement above this depth.

The alternate design for the well included the use of a fiberglass injection well tubing being cemented in place, and the performance of the mechanical integrity testing on a more frequent basis (every 2.5 years) in lieu of having a tubing and packer assembly and an open annulus.

SECTION 2

Construction Phase

The following section describes the construction, drilling, and testing details associated with the construction of the surficial aquifer system (SAS) monitor wells, IW-1 and DMW-1.

2.1 Surficial Aquifer System Monitor Wells

As required by the injection well construction permit, SAS monitor wells were installed at the northeast, northwest, southeast, and southwest corners of the drilling pad to monitor for groundwater contamination during construction. Each well was constructed to a depth of 40 feet below pad level (bpl) with 2-inch-diameter, schedule 40 polyvinyl chloride (PVC) casing and a 10-foot, 2-inch-diameter 20-slot PVC screen. The SAS monitor wellheads are encased by a stainless-steel cover to protect the wells from damage. Following installation, samples were collected from each well and analyzed to establish background water quality data prior to beginning construction of IW-1. A SAS monitor well construction diagram is presented in Exhibit 2-1. Water quality data from the SAS monitor wells are discussed in Section 4 of this report.

As a result of siting restrictions, the injection well was located near the water plant, next to two SAS production wells (W-1 and W-2), providing raw water to the lime softening plant. Two Floridan Aquifer supply wells (FB-1 and FB-2) were also present nearby. Because of the injection well's proximity to the Floridan Aquifer supply wells, a more aggressive sampling program was required by the construction permit. The water quality data from these wells are also discussed in Section 4 of this report.

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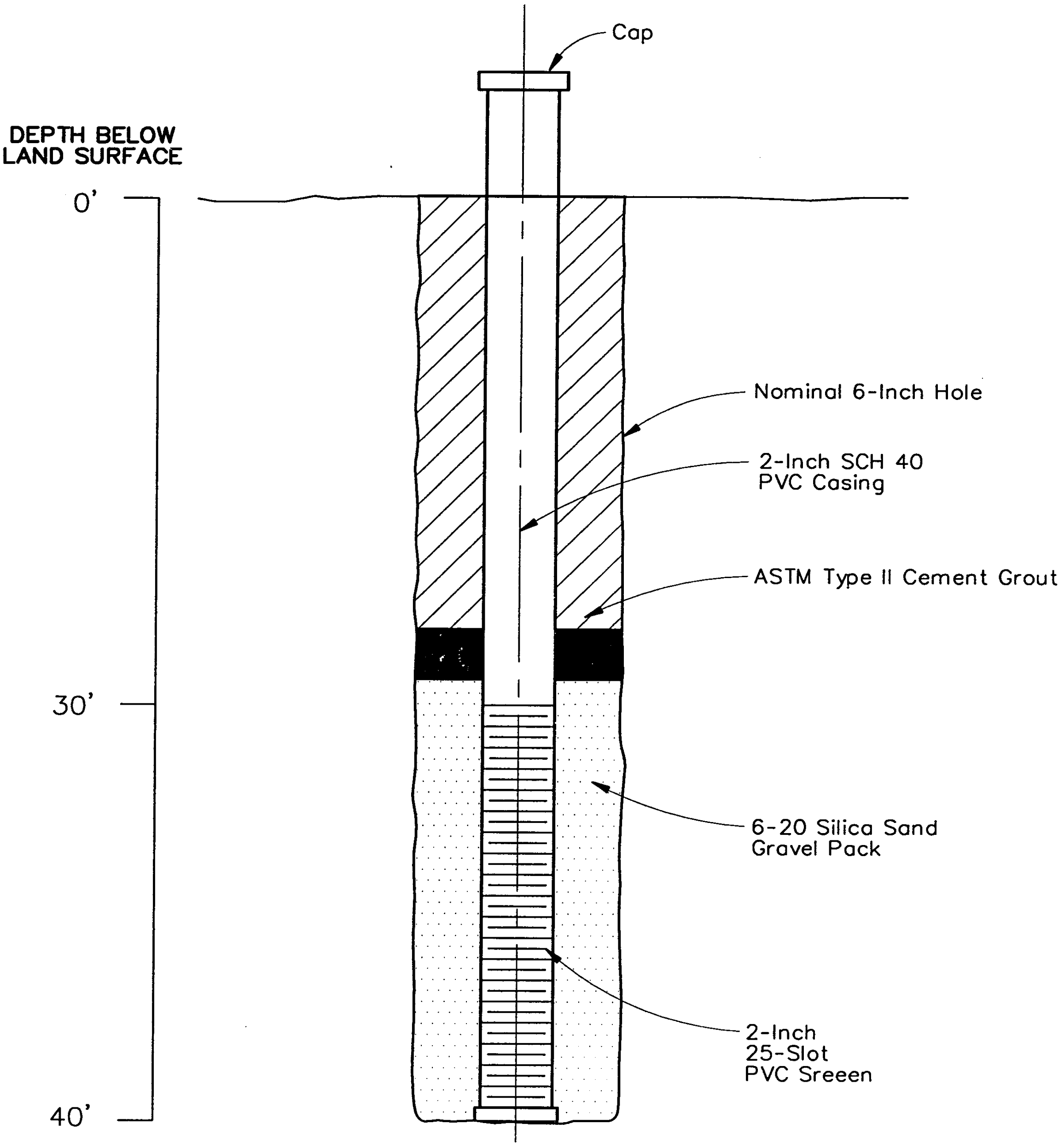

Exhibit 2-1

Surficial Monitoring Well Completion Diagram

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2.2 Injection Well IW-1

Drilling of injection well IW-1 began on March 16, 2002. Mud rotary drilling techniques were used to drill to a depth of 550 feet bpl, followed by closed circulation reverse-air drilling from 550 to 3,200 feet bpl. Water produced while drilling was tankered offsite to an approved disposal site.

The drilling schedule and casing setting depths were designed to conform to the hydrogeological features observed at the site and to regulatory agency requirements. A summary of the well construction schedule is provided in Appendix D. Geologic formation samples were collected and described at 10-foot intervals during the drilling of the pilot hole. Data from the pilot hole interval (formation samples [cuttings], packer tests, and geophysical logs) were evaluated to provide information regarding the geologic formations encountered, to assist in selection of the casing setting depths, and to interpret the site lithology and hydrogeology. The pilot hole was then reamed to the appropriate diameter to prepare for casing installation. FDEP approval of the recommended casing setting depths was obtained prior to installing the intermediate and final casing strings of IW-1.

Construction of IW-1 occurred with four concentric steel casings (44-, 36-, 28-, and 18-inch outside diameters) and a Fiberglass Reinforced Pipe (FRP) tubing (10.75-inch outside diameter) inside the 18-inch steel casing. The cementing program was specifically tailored for each casing installed. Casing depths, the types, and quantities of cement used for the construction of IW-1 are summarized in Appendix E. Copies of casing mill certificates for each casings used during construction are presented in Appendix F. Exhibit 2-2 depicts the completion diagram of IW-1.

Construction of IW-1 began with the installation of a 44-inch-diameter pit casing to 50 feet bpl, using the mud rotary method, and cemented to land surface. A nominal 12.25-inch-diameter pilot hole, centered inside the 44-inch-diameter casing, was then drilled to a depth of 550 feet bpl. The pilot hole was then geophysically logged (caliper, background gamma radiation, spontaneous potential, and dual induction electric logs) and reamed to a nominal 42-inch-diameter to a depth of 515 feet bpl. A caliper log was then performed on the reamed hole, and a 36-inch-diameter casing was installed to a depth of 510 feet bpl and cemented to land surface.

Below the 36-inch-diameter casing, drilling of the 12.25-inch-diameter pilot hole continued to 1,900 feet bpl. The pilot hole was then geophysically logged (caliper, background gamma radiation, spontaneous potential, dual induction electric, sonic, static temperature/fluid conductivity, and static flowmeter logs). Four drill stem packer tests were conducted on the following intervals: 1,501 to 1,554, 1,747 to 1,800, 1,787 to 1,840, and 1,808 to 1,832 feet bpl. The results of drill stem packer testing are discussed in Section 4. Following packer testing, the pilot hole was backplugged with 12 percent bentonite cement from 1,900 to 526 feet bpl, and reamed to a nominal 36-inch diameter to a depth of 1,850 feet bpl. A caliper log was then performed in the reamed hole. The 28-inch-diameter casing was then installed to 1,840 feet bpl and cemented to land surface following FDEP approval of the casing seat recommendation.

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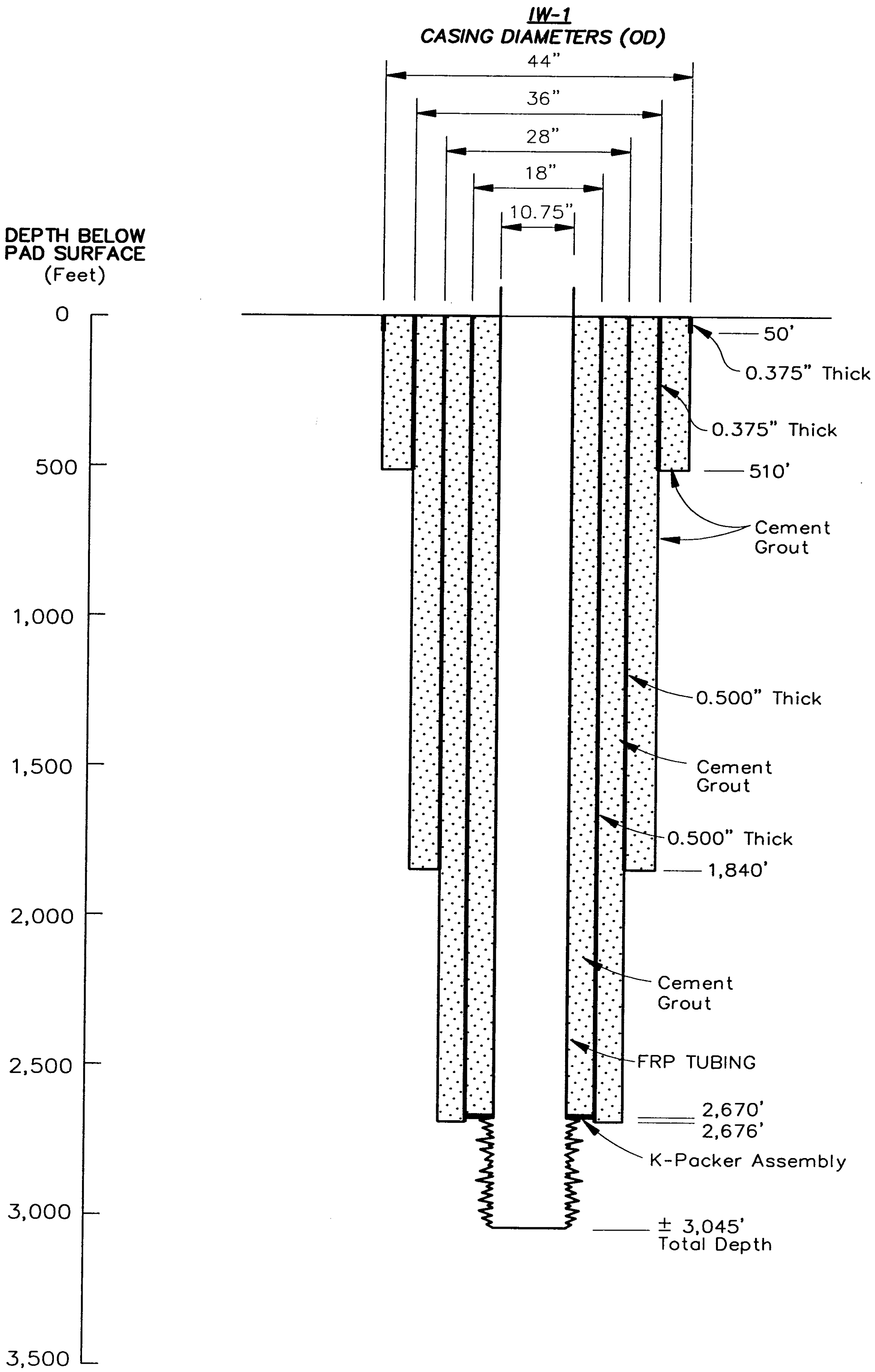

Exhibit 2-2
Injection Well IW-1 Completion Diagram

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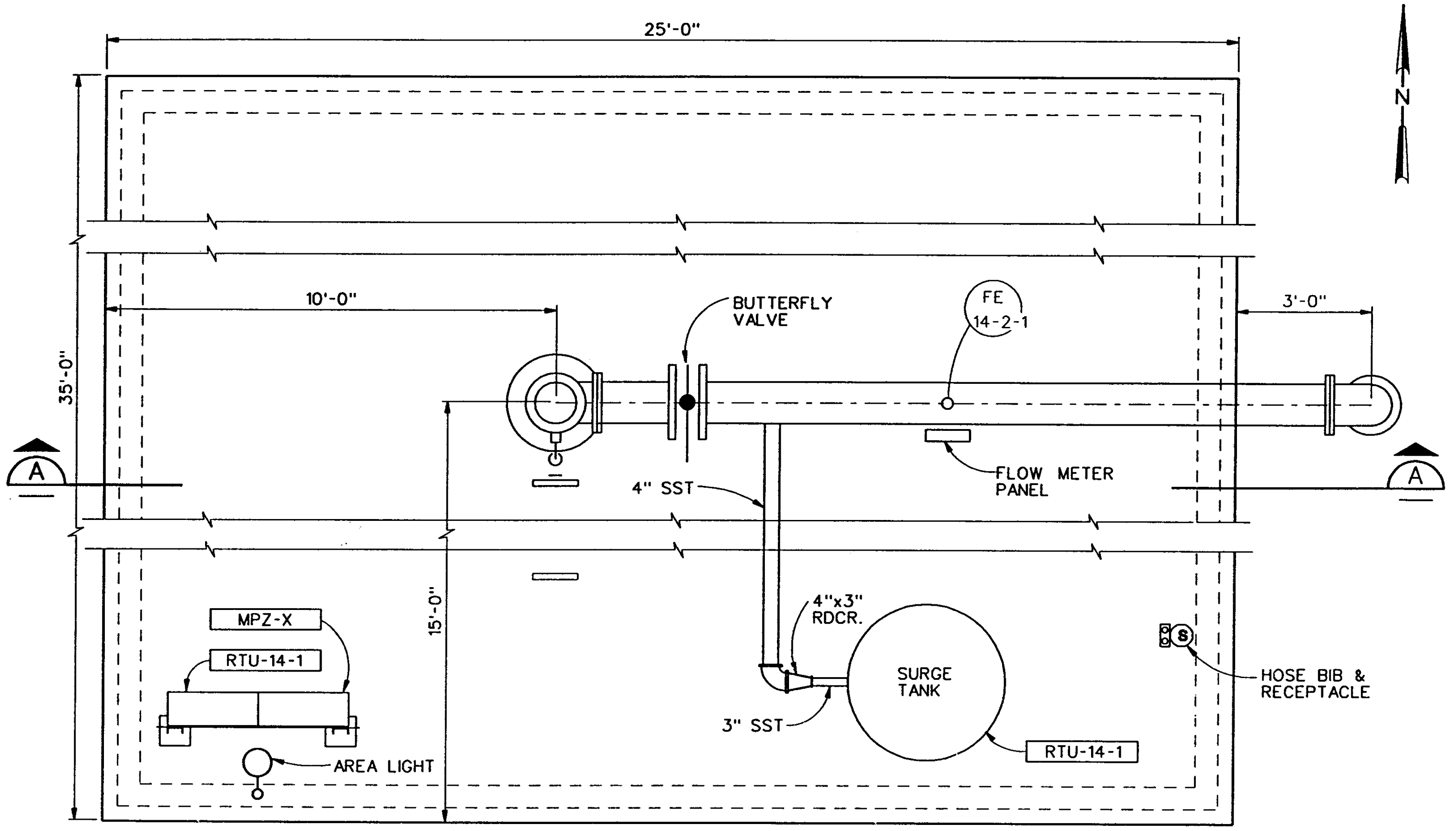
The pilot hole was advanced to a depth of 2,193 feet bpl, where core sampling began. A total of eleven 4-inch-diameter cores were collected to elevate permeability and porosity through the interval of 2,193 to 2,752 feet bpl during this phase of pilot hole drilling. Between the cored intervals, the pilot hole was advanced with the 12.25-inch-diameter drill bit. Core analyses and descriptions are discussed in Section 4. Caliper, gamma radiation, spontaneous potential, static temperature/fluid conductivity, static flowmeter, dual induction electric, and borehole-compensated sonic logs were conducted after pilot hole drilling reached 3,050 feet bpl. Four drill stem packer tests were then conducted on the intervals of 2,181 to 2,199.5, 2,251 to 2,269.5, 2,291 to 2,309.5, and 2,676 to 2,694.5 feet bpl. The results of a second round of drill stem packer tests are discussed in Section 4.

Following completion of the packer test, a video log was conducted in the pilot hole. A drillable bridge plug was set at 2,660 feet bpl, and the pilot hole was backplugged with 12 percent bentonite cement to 1,843 feet bpl, which is just below the base of the 28-inch-diameter casing.

Based on the results of packer testing, coring, geophysical logging, and formation sample analyses, a setting depth of 2,670 feet bpl for the 18-inch diameter casing was recommended and approved by the FDEP and TAC. After drilling a 26.5-inch-diameter hole to 2,670 feet bpl, a nominal 20-inch-diameter hole was drilled to 3,050 feet bpl. A caliper log was performed over the reamed hole interval prior to installing the 18-inch-diameter casing. The 18-inch-diameter casing was then installed with a K-packer assembly attached to its base for cementing purposes, to 2,678 feet bpl and cemented to land surface following FDEP approval of the casing seat recommendation. Upon completion of cementing, a Cement Bond Log (CBL) was conducted to evaluate the quality of the cement bond on the 18-inch-diameter casing.

Following completion of the CBL, the 10.75-inch-diameter FRP casing was seated in a YBI packer assembly at a depth of 2,673 feet bpl and cemented to land surface. An interim casing pressure test was conducted prior to the cementing. A CBL was then conducted on the 10.75-inch diameter casing followed by a final casing pressure test. Geophysical logs were conducted on the completed well to examine the condition of the final casing string and observe the open hole interval. The logs conducted were caliper, static and pumping temperature/fluid conductivity, static and pumping flowmeter, and video logs. Also, an external Radioactive Tracer Survey (RTS) log was conducted to further evaluate the mechanical integrity of the 10.75-inch diameter casing.

The IW-1 wellhead was then installed and wellhead piping was connected to the RO WTP reject disposal piping. Instrumentation (pressure transducer and flowmeter) at the wellhead was wired to the WTP control room to allow remote monitoring and recording of wellhead pressure and flowrate. Exhibit 2-3 provides a completion diagram of the IW-1 wellhead.



INJECTION WELL PLAN
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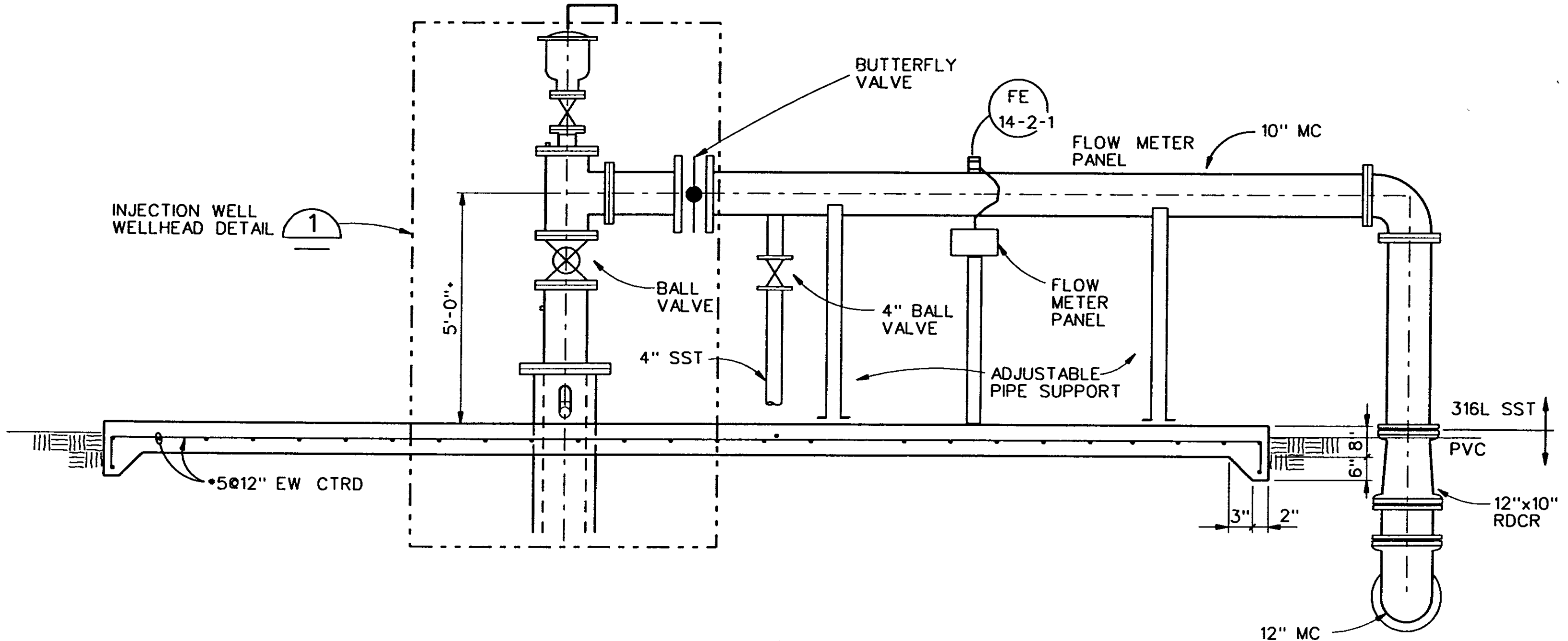

SECTION A
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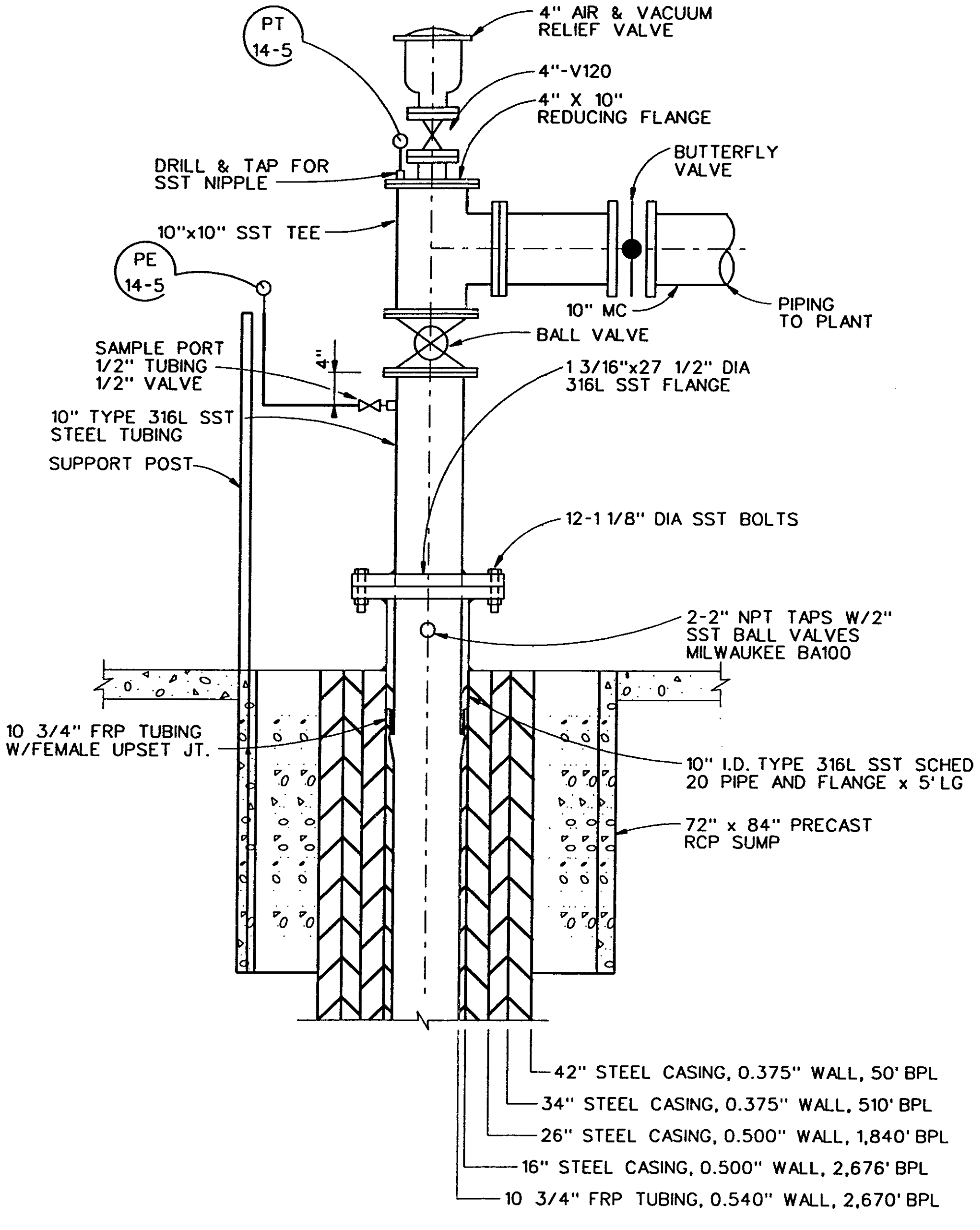

INJECTION WELL WELLHEAD DETAIL 1
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EXHIBIT 2-3

FPUA DEEP WELL INJECTION PLAN, SECTIONS AND DETAIL

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2.3 Dual-Zone Monitor Well

Dual-zone monitor well DMW-1 was constructed to monitor vertical fluid migration in two separate zones above the injection zone. Drilling of DMW-1 began on July 27, 2002. Mud rotary drilling techniques were used to drill to a depth of 550 feet bpl. Reverse-air drilling techniques were used during subsequent drilling to a total depth of 1,850 feet bpl to remove drill cuttings from the borehole and to collect water samples at 30-foot intervals. A closed circulation reverse-air system was used throughout this interval. Water produced while drilling on reverse air was tankered offsite to an approved disposal site.

Lithologic samples were collected and described at 10-foot intervals during the drilling of the pilot hole. Data from the pilot hole interval, cuttings, packer tests, and geophysical logs were evaluated to assist in selection of the casing setting depths, and to interpret the site lithology and hydrogeology. The pilot hole was then reamed to the specified diameter to the selected casing setting depth, as approved by the FDEP.

Construction of DMW-1 took place with three concentric steel casings (34-, 22-, and 12.75-inch outside diameters), and an FRP, 6⅝-inch outside diameter casing. The cementing program was specifically tailored for each casing installed. Casing depths, types, and quantities of cement used in the construction of DMW-1 are summarized in Appendix E. Copies of casing mill certificates for each casings used during construction are presented in Appendix F. Exhibit 2-4 presents the completion diagram of DMW-1.

Construction of DMW-1 began with the drilling of a nominal 40.5-inch-diameter borehole to 50 feet bpl and the installation of 34-inch-diameter casing to 49 feet bpl. Then, a 12.25-inch-diameter pilot hole was advanced to a depth of 550 feet bpl. The pilot hole was geophysically logged (caliper, gamma ray, spontaneous potential, and dual induction electric logs) and reamed to a nominal 30-inch diameter to 510 feet bpl. A caliper log was then performed on the reamed hole, and a 22-inch-diameter casing was installed and cemented through the surficial aquifer to a depth of 510 feet bpl.

Below the 22-inch-diameter casing, drilling of the 12.25-inch-diameter pilot hole continued to a depth of 1,910 feet bpl. The pilot hole was then geophysically logged (caliper, gamma radiation, spontaneous potential, dual induction electric, static and dynamic temperature/ fluid conductivity, static and dynamic flowmeter, and borehole-compensated sonic logs). Upon completion of the logging, a recommendation was made to FDEP for the upper monitor zone to be modified from 1,500 to 1,550 feet bpl. Upon receipt of the recommendation, FDEP expressed concern that the recommended upper monitor zone was not close enough to the 10,000 mg/L TDS interface at 1,800 feet bpl to provide sufficient warning of upward migration of the injection fluid into the productive zones of the Floridan Aquifer. In response to this concern, a packer test on the interval of 1,669 to 1,718 feet bpl was conducted to assist in the selection of the upper monitor zone interval. The results of the packer test revealed this interval was not suitable for a monitoring zone as it was in a confining zone that demonstrated a very low specific capacity (0.13 gallons per minute [gpm/ft]), and was not sufficient for adequate flow for purging. Further, the geophysical logs, specifically the dual-induction and sonic logs, and the lithologic samples indicated that the entire interval from 1,550 to 1,800 feet bpl was consistent in nature.

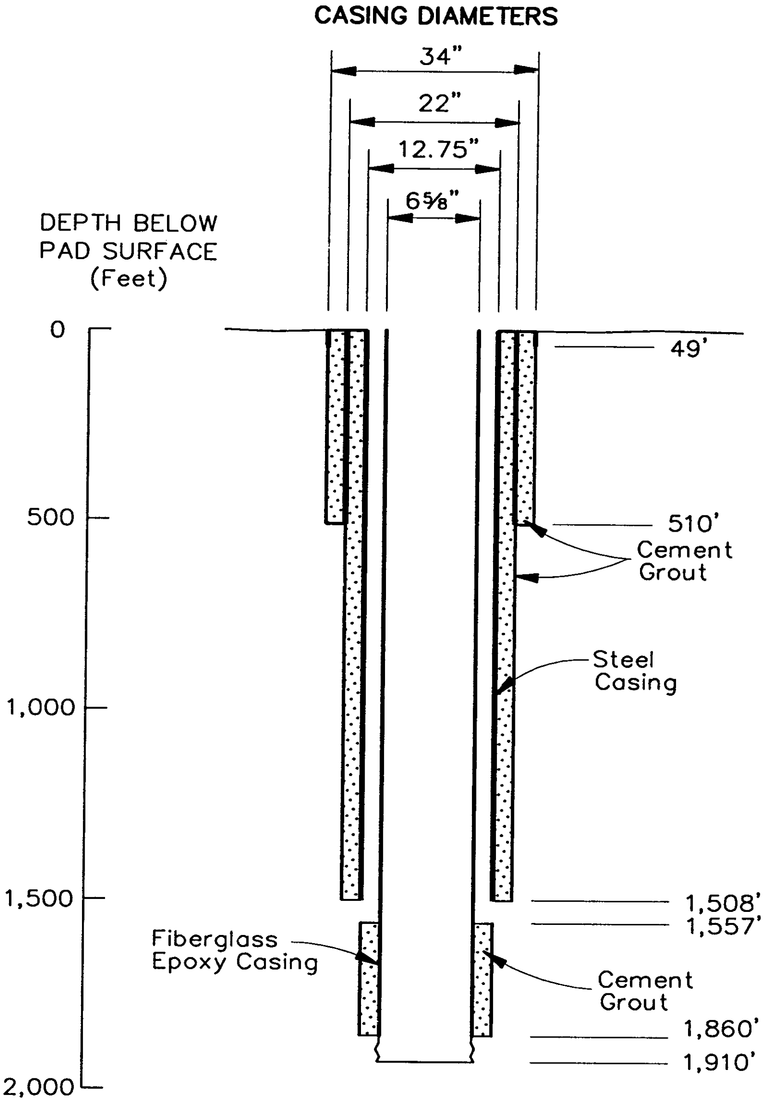

Exhibit 2-4

Dual-Zone
Monitor Well DMW-1
Completion Diagram

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Based on the results of packer testing in both DMW-1 and IW-1, geophysical logging and lithologic sample analysis, the 12.75-inch-diameter casing setting depth of 1,500 feet bpl was approved by FDEP and the TAC. After drilling a nominal 20-inch-diameter borehole to a depth of 1,500 feet bpl, the original nominal 12.25-inch-diameter pilot hole was cleaned out to a depth of 1,910 feet bpl. A caliper log was performed over the entire open hole interval prior to installing the 12.75-inch-diameter casing with a K-packer assembly attached to the base of the casing. After unsuccessful attempts to place a small amount of cement on top of the K-packer assembly to create a plug, the borehole was backfilled with gravel from 1,910 to 1,500 feet bpl This was done to protect the upper monitor zone from any intrusion of cement from the grouting of the casing. The casing was then cemented to the land surface using the tremie method of grouting.

After installing the 12.75-inch-diameter casing to a depth of 1,508 feet bpl, the gravel was removed to a depth of 1,910 feet bpl. Upon completion of the removal of the gravel, a caliper log was conducted prior to the installation of the $6^{5}/_{8}$-inch-diameter FRP casing.

Based on the results of packer testing in IW-1, geophysical logging, and lithologic sample analysis, a $6^{5}/_{8}$-inch-diameter casing setting depth of 1,860 feet bpl was recommended and approved by FDEP and the TAC. This depth was selected to provide adequate separation from the 10,000 mg/L TDS interface at 1,800 feet bpl, as a result of the very low specific capacity (0.01 gpm/ft) determined during packer testing in IW-1 of the interval from 1,808 to 1,832 feet bpl.

A disposable packer was attached to the base of the casing, allowing the casing to be cemented in place and not disturb the open borehole below 1,860 feet bpl. The $6^{5}/_{8}$-inch-diameter FRP was then installed to a depth of 1,860 feet bpl and cemented to a depth of 1,557 feet bpl. The interval from 1,557 feet bpl to land surface was not cemented to establish the upper monitor zone of DMW-1. The open borehole below the $6^{5}/_{8}$-inch-diameter casing was then geophysically logged (CBL, caliper, static temperature, static fluid resistivity, and video logs). A casing pressure test was then conducted on the $6^{5}/_{8}$-inch-diameter casing.

Upon completion of installation of the $6^{5}/_{8}$-inch-diameter FRP casing, the wellhead, sample pumps, and pressure transducers were installed. The upper artesian monitor zone was completed with a pressure transducer mounted at 1.25 feet above pad level (22.85 feet NGVD). The lower nonartesian monitor zone was completed with a pressure transducer set to 74.20 feet bpl (-50.00 feet NGVD). Because of the nonartesian conditions in the lower zone, a sample submersible pump (top of) was set to 97.40 feet bpl (-75.8 feet NGVD). Exhibit 2-5 provides a wellhead completion diagram for DMW-1.

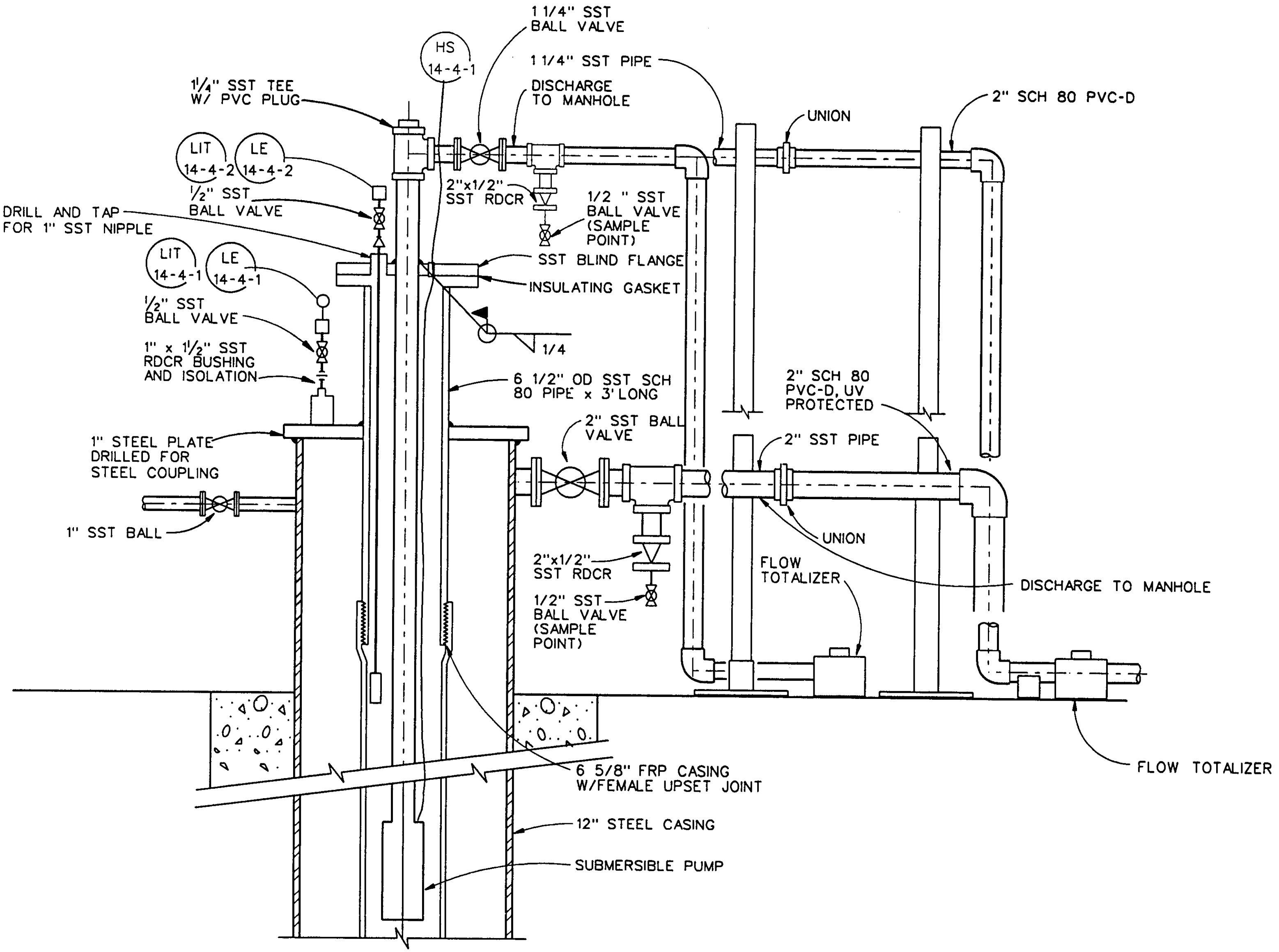

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EXHIBIT 2-5

FPUA DUAL-ZONE MONITOR WELLHEAD (MW-RO) DETAIL

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SECTION 3

Geologic Framework

3.1 Geology

3.1.1 Formation Sampling

Samples of well cuttings from IW-1 and DMW-1 were collected at 10-foot intervals from land surface to total depth, and were characterized for rock type, color, consolidation, porosity, and fossil content. At the completion of construction, one set of samples was sent to the FDEP, as required by the FDEP well construction permit, for analysis. Detailed lithologic descriptions of samples from IW-1 and DMW-1 are provided in Appendix G.

3.2 Geophysical Logging

Geophysical logs were performed in the pilot hole of IW-1 and DMW-1 to correlate lithologic samples collected during drilling, to identify geologic unit boundaries, to aid in the selection of straddle packer testing intervals, and to obtain specific data pertaining to subsurface lithology. These data were then used to assist in the selection of the optimum casing setting depths. Copies of the geophysical logs performed during construction of the wells are presented in Appendix H.

A stratigraphic profile of the site was derived from the correlation of lithologic samples with geophysical logs performed during pilot hole drilling. Strata encountered during construction of the injection well system are as follows in descending order: Undifferentiated Deposits, Peace River Formation, Arcadia Formation, Suwannee Limestone, Ocala Limestone, Avon Park Formation, and Oldsmar Formation. Exhibit 3-1 is a generalized geologic and hydrogeologic interpretation of the lithologic and geophysical log data for IW-1 and DMW-1.

3.3 Lithostratigraphic Descriptions

3.3.1 Undifferentiated Deposits

Undifferentiated deposits that consisted of light gray, very fine grained sand interlayered with black colored peat and shell fragments were encountered from land surface to 80 feet bpl. These loose and unconsolidated, undifferentiated sediments comprise the surficial aquifer system, which also contains the shallow water table.

3.3.2 Peace River Formation

The Peace River Formation consists of interbedded quartz sands, clays, and carbonates. The siliciclastic component dominates and is the distinguishing lithologic feature of the unit (Scott, 1988). Clay beds are quite common in the Peace River Formation. The clays are quartz sandy, silty, calcareous to dolomitic, phosphatic, very fine to medium grained, and poorly

<table>
<tr><th>Lithologic Description</th><th>Geologic Age</th><th>Formation Name</th><th colspan="2">Hydrologic Unit</th><th></th></tr>
<tr><td>Silty, gray; peat, black; shell</td><td>Pleistocene</td><td>Undifferentiated</td><td colspan="2">Surficial Aquifer System</td><td>0</td></tr>
<tr><td>Clay, grayish-olive, olive-gray</td><td>Miocene</td><td>Peace River Formation</td><td colspan="2">Intermediate Confining Unit</td><td>80</td></tr>
<tr><td>Limestone, yellowish-gray</td><td>Oligocene</td><td>Arcadia Formation</td><td rowspan="6">Upper Floridan Aquifer System</td><td rowspan="3">Moderate to High Permeability Artesian Flow</td><td>490</td></tr>
<tr><td>Limestone, yellowish-gray,forams</td><td rowspan="3">Upper Eocene</td><td>Suwannee Limestone/ Ocala Limestone</td><td>600</td></tr>
<tr><td rowspan="3">Limestone, white to yellowish gray, abundant foraminfera; dolomite, yellowish brown</td><td rowspan="4">Avon Park Limestone</td><td>1,000</td></tr>
<tr><td rowspan="3">Middle Confining Unit</td><td>1,530</td></tr>
<tr><td rowspan="2">Middle Eocene</td><td></td></tr>
<tr><td rowspan="2">Dolomite, yellowish gray to yellowish brown, sucrosic, dense</td><td></td></tr>
<tr><td>Lower Eocene</td><td>Oldsmar Formation</td><td>Lower Floridan Aquifer System</td><td>High Permeability (Boulder Zone)</td><td>2,656</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>3,200</td></tr>
</table>

EXHIBIT 3-1
FPUA Generalized Hydrogeologic and Geophysical Data

consolidated. Color ranges from olive gray to yellowish gray. The Peace River Formation is a member of the Hawthorn Group (Scott, 1988) and conformably overlies the Arcadia Formation, also of the Hawthorn Group. The Peace River Formation was encountered to approximately 490 feet bpl. This geologic unit comprises the majority of the intermediate confining unit that separates the surficial aquifer system from the Upper Floridan Aquifer.

3.3.3 Arcadia Formation

The Arcadia Formation underlies the Peace River Formation and was encountered from 490 feet bpl to 600 feet bpl. The Arcadia Formation consists predominantly of limestone and dolomite containing various amounts of quartz sand, clay, and phosphate grains. Thin beds of quartz sand and clay often are present scattered throughout the section. The Arcadia Formation is characterized by moderate to high gamma ray activity, moderate resistivity, and fast sonic travel time.

3.3.4 Suwannee Limestone

It is uncertain if the Suwannee Limestone underlies the Arcadia Formation in the vicinity of Fort Pierce. According to Scott (1988), the Arcadia Formation unconformably overlies the Ocala Limestone because the Suwannee Limestone had been eroded away during a previous seawater low stand. As a result of the depositional and post-depositional history of the Ocala Limestone and Suwannee Limestone being quite similar, the formations can be difficult to distinguish, especially with drill cuttings. Without adequate cores or diagnostic fossil content, delineation of the Suwannee Limestone separate from the Ocala Formation, is problematic. When present, the Suwannee Limestone is characterized by yellowish-gray to very pale orange, fine-sand-grained, and moderately porous limestone. The formation is also characterized by low gamma radiation activity, low but variable resistivity, and relatively short, but highly variable sonic travel time. Permeable sections of the Suwannee Limestone are part of the Upper Floridan Aquifer, and characteristically exhibits high permeability.

3.3.5 Ocala Formation

The Ocala Limestone consists of two separate lithologic subdivisions. The lower subdivision consists of a more granular limestone and is not present everywhere and may be partially to completely dolomitized in some regions (Miller, 1986). The upper subdivision is composed of variably muddy, granular limestone. Often this unit is very soft and contains an abundance of large foraminifera. Chert is a common component of the upper subdivision of the Ocala Limestone. The Ocala Limestone contains one of the most permeable zones within the Upper Floridan Aquifer. Extensive development of secondary porosity by dissolution has greatly enhanced the permeability, especially in those areas where the confining beds are breached or absent (Scott, 1992). The Ocala Limestone was encountered in the IW-1 borehole from approximately 600 feet bpl (assuming the Suwannee Limestone is not present) to approximately 1,000 feet bpl.

3.3.6 Avon Park Formation

The Avon Park Formation is primarily composed of fossiliferous limestone interbedded with vuggy dolostone. The Avon Park Formation occurs throughout the Florida peninsula and the eastern panhandle in a pattern similar to the Oldsmar Formation (Scott, 1992). In contrast, permeable sections of the Avon Park Formation are part of the Upper Floridan Aquifer. The carbonate sediments of the Avon Park Formation form part of the Floridan Aquifer system. Portions of the Avon Park Formation that are fine-grained and of low permeability comprise the middle confining unit, which separates the Lower and Upper Floridan Aquifers. The Avon Park Formation was encountered from approximately 1,000 feet bpl to 2,656 feet bpl.

3.3.7 Oldsmar Formation

The Oldsmar Formation is a sequence of white to gray limestone and interbedded tan to light brown dolomite that lies between the predominantly brown limestone and brown dolomite of the Avon Park Formation and the gray, coarsely crystalline dolomite of the Cedar Keys Formation. Permeable portions of the Oldsmar Formation are included in the Lower Floridan Aquifer. The Oldsmar Formation contains an interval of cavernous porosity locally known as the "Boulder Zone" because of difficult drilling conditions. Because of extremely high transmissivity, the "Boulder Zone" is commonly used to dispose of wastewater. It is this interval that IW-1 was completed into in order to inject and therefore dispose of brine concentrate. The Oldsmar Formation was encountered from approximately 2,656 feet bpl to 3,200 feet bpl (the bottom of the pilot hole). The "Boulder Zone" was encountered from approximately 2,656 feet bpl to 3,200 feet bpl.

SECTION 4

Hydrogeological Testing

Testing during the construction of the injection well system included lithology sampling, reverse-air drilling water sampling, geophysical logging, coring, packer testing, and injection testing. Results were used to determine the lithologic and hydraulic characteristics of the geologic strata intercepted by the borehole, determine the location of the base of the USDW, determine confining strata, and select an adequate injection zone for brine disposal. This section presents the results of testing during construction of the FPUA RO WTP injection system.

4.1 Surficial Aquifer System and Upper Floridan Aquifer Monitor Well Water Quality

Throughout construction, water samples were collected on a weekly basis from the four SAS monitoring wells (NE, NW, SE, and SW) surrounding the well construction area to demonstrate that the SAS was not impacted by construction activities. Water samples were also collected on a weekly basis from FPUA's production wells W-1, W-2, FB-1, and FB-2, which are located within or near a 500-foot radial distance from the injection well system. W-1 and W-2 are completed into the SAS and FB-1 and FB-2 are completed into the Upper Floridan Aquifer. Water samples were field-analyzed for chloride, total dissolved solids, conductivity, and temperature. The water level at each well was recorded weekly during construction activities. Water quality and water level data recorded during the construction period is presented in Appendix I.

Prior to construction of the injection well, a water sample was collected from each monitor well to establish background groundwater conditions. The background chloride concentrations for NE, NW, SE, and SW were 35 milligrams per liter (mg/L), 96 mg/L, 20 mg/L, and 45 mg/L, respectively. W-1, W-2, FB-1, and FB-2 had background chloride concentrations of 50 mg/L, 75 mg/L, 315 mg/L, and 330 mg/L, respectively. Throughout the construction period, water quality and water levels at each monitor well indicated some minor variability as a result of seasonal rain. Wells NE, NW, SE, and SW had an average chloride concentration near 35 mg/L. The average chloride concentration at W-1 and W-2 were near 68 mg/L. Wells FB-1 and FB-2 had an average chloride concentration of approximately 330 mg/L. Based on these data, no adverse impacts to the SAS or Upper Floridan Aquifer were observed during the well construction activities.

4.2 Lithologic Samples

Lithologic samples from IW-1 and DMW-1 were collected every 10 feet from land surface to the total depth of each well and were characterized for rock type, color, consolidation, texture, porosity, and fossil content. As required in the FDEP well construction permit, duplicate samples for IW-1 were submitted to the Florida Geological Survey (FGS) of Tallahassee, Florida . Exhibit 4-1 provides a generalized description of the lithology encountered during construction of the wells as well as geological interpretation of formations and ages. Detailed lithologic descriptions of samples from IW-1 and DMW-1 are provided in Appendix F.

EXHIBIT 4-1
Summary Description and Interpretation of Lithologic Samples
Samples collected from Well Cuttings of Injection Well IW-1

Depth (feet bls)	Dominant Lithology	Geologic Unit (Age)
0-80	Silt, Peat, Clay	Undifferentiated
80-490	Clay	Peace River Formation (Lower Pliocene – Upper Miocene)
490-600	Limestone, Dolomite, Clay	Arcadia Formation (Middle Miocene – Upper Oligocene)
600-1,000	Limestone	Suwannee Limestone/Ocala Limestone (Lower Oligocene – Upper Eocene)
1,000-2,860	Limestone, Dolomite	Avon Park Formation (Middle Eocene)
2,860-3,200	Dolomite	Oldsmar Formation (Lower Eocene)
3,200		End of Pilot Hole

4.3 Pilot-Hole Water Quality

Water samples were collected at approximately 30-foot intervals during reverse-air drilling of IW-1 and DMW-1 and field-analyzed for conductivity, chloride concentration, and pH to provide a generalized profile of water quality change with depth. Closed circulation reverse-air drilling techniques were used during pilot hole drilling below a depth of approximately 560 feet bpl in the injection well and below a depth of 510 feet bpl in DMW-1. In all closed circulation systems, pilot hole water quality reflects a mixture of formation fluids for the entire open borehole interval including any fresh water, which may have been used to begin reverse-air drilling. The mixing of pilot hole water from multiple zones results in diluted changes in water quality with depth, and may not accurately represent the water quality near the bottom of the borehole. However, this analysis is useful for identifying broad changes in water quality with depth.

Analytical results from the water quality testing of IW-1 and DMW-1 showed an overall increase in concentration with depth for most parameters. Conductivity and chloride data for IW-1 are presented in Exhibits 4-2 and 4-3, respectively. Pilot hole water quality data for IW-1 and DMW-1 are included in Appendix J. Chloride concentration and conductivity show nearly identical trends. Both parameters gradually increased from approximately 500 to 2,250 feet bpl. From 2,250 feet bpl to approximately 2,400 feet bpl, both parameters increased sharply. From 2,380 to 2,450 feet bpl, concentrations decreased. At 2,480 feet bpl, concentrations increased followed by a very sharp increase at 2,510 feet bpl. Concentrations then declined followed by a sharp increase at 2,720 feet bpl. Below this depth, concentrations essentially stabilized and demonstrated little change.

4.4 Coring

Core samples were collected at selected intervals while drilling the injection well pilot hole to correlate with drill cuttings and geophysical logs, and to more thoroughly determine the hydrogeological properties of the formation. Core samples are typically collected in geological zones of suspected low permeability. Samples were obtained by a 4-inch-diameter, 20-foot core barrel. A total of 11 cores were attempted between 2,193 feet bpl and 2,752 feet bpl. A description of each core is presented in Exhibit 4-4.

The cores were first examined and described onsite. Selected cores were then shipped to a testing laboratory for a detailed geotechnical and hydrogeological analysis. The testing laboratory, Ardaman & Associates, Inc. of Orlando, Florida (Ardaman), analyzed the selected cores for hydrogeological parameters. Eight representative core samples over the interval from 2,283 to 2,750 feet bpl were analyzed to determine the specific gravity, total porosity, and vertical and horizontal permeability. Two representative core samples over the interval from 2,662 to 2,752 feet bpl were analyzed to determine unconfined compressive strength.

Results of the laboratory hydraulic conductivity and porosity analyses conducted by Ardaman are summarized in Exhibit 4-5. The analysis reports are provided in Appendix K. All of the core samples sent to the laboratory exhibited low permeability. The reports contain a detailed description of the cores and laboratory methods used for hydraulic conductivity and porosity determinations, along with the laboratory results. Results of hydraulic conductivity laboratory analyses demonstrate varying degrees of confining characteristics throughout the intervals tested. Vertical hydraulic conductivity varied from 6.7 X 10^{-4} centimeters per second (cm/sec) at 2,361 feet bpl to 3.8 X 10^{-10} cm/sec at 2,682 feet bpl. Horizontal conductivity ranged from 1.2 X 10^{-3} cm/sec at 2,361 feet bpl to 3.4 X 10^{-10} cm/sec at 2,682 feet bpl. Note that the highest vertical and horizontal conductivities were measured from the same core sample (2,361 feet bpl). In the same manner, the lowest vertical and horizontal hydraulic conductivities were measured from the same core sample (2,682 feet bpl). Specific gravity for all samples ranged from 2.72 to 2.85. Total porosity ranged from 0.04 to 0.34 and correspond with the samples that yielded the lowest and highest hydraulic conductivities, respectively.

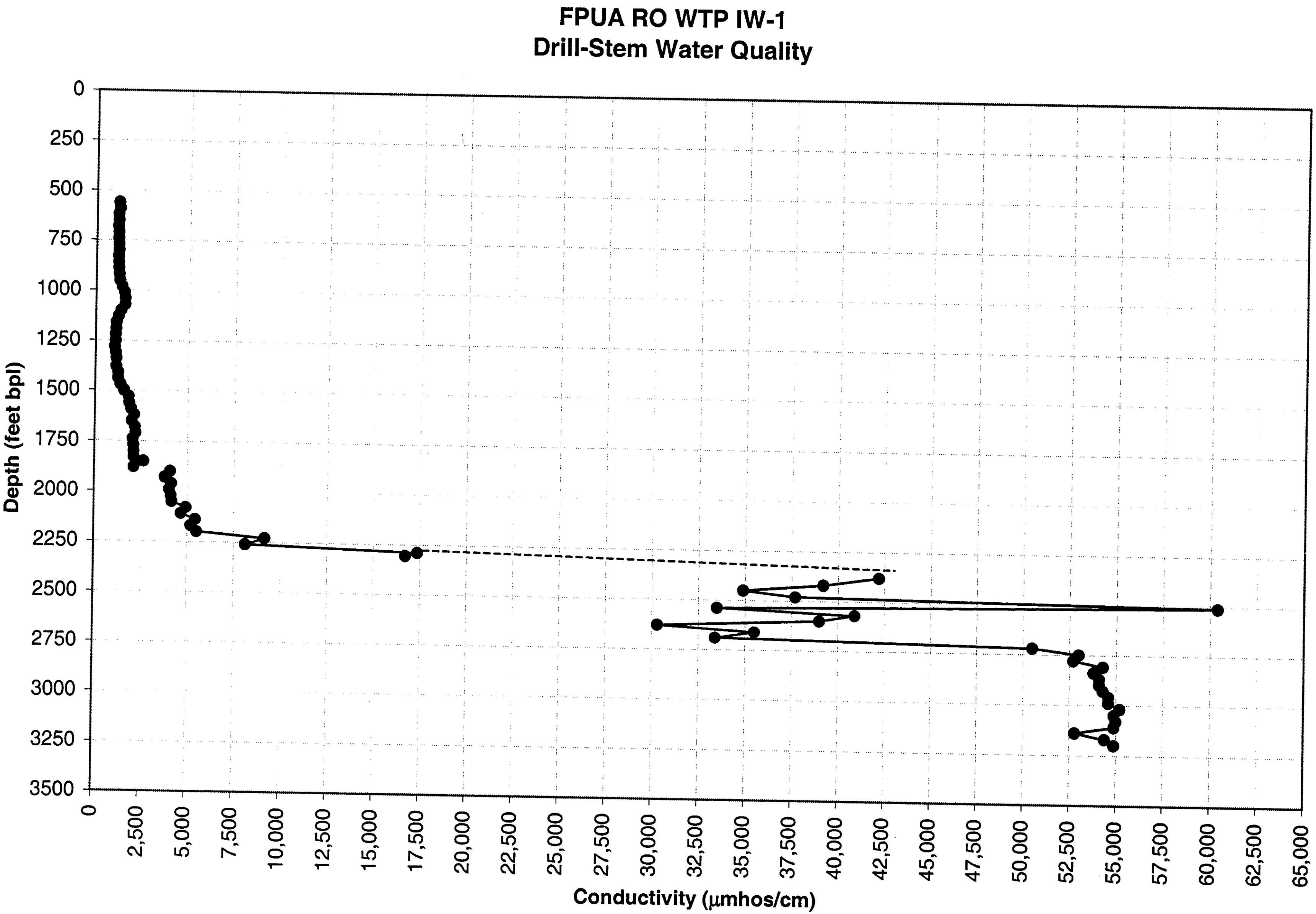

Exhibit 4-2
FPUA RO WTP
IW-1 Pilot Hole Conductivity Data

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FPUA RO WTP IW-1
Drill-Stem Water Quality

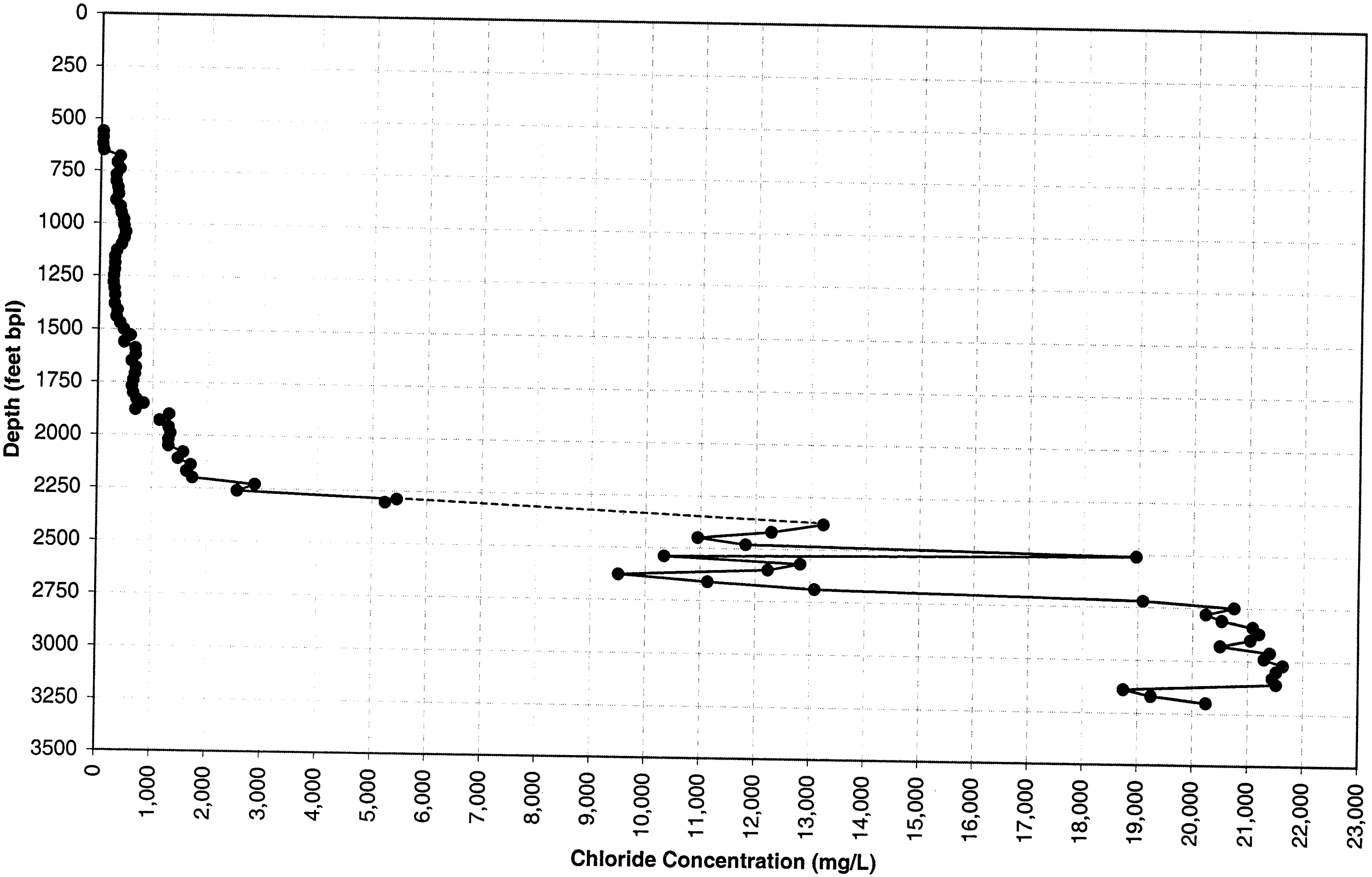

Exhibit 4-3
FPUA RO WTP
IW-1 Pilot Hole Chloride Data

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EXHIBIT 4-4
Core Descriptions Below Intermediate Casing Depth of 1,840 feet

Interval (feet bpl)	Percent Recovery	Generalized Description
2,193-2,278	1%	Limestone, very pale orange, fine to coarse grained, poorly to well consolidated, low porosity, some chert
2,281-2,293	29%	Limestone, very pale orange, coarse grained, well consolidated, moderate porosity
2,325-2,336.5	55%	Limestone, very pale orange, fine to medium grained, well consolidated, low to high porosity
2,338-2,352	54%	Limestone, very pale orange, very fine to medium grained, moderately to well consolidated, moderate porosity
2,355-2,369	86%	Limestone, very pale orange, calcilutitic, fossiliferous, interbedded hard and soft intervals
2,413-2,425	56%	Limestone, very pale orange with white mottling, microfossilan, medium hard to friable
2,482-2,494	42%	Limestone, very pale orange with white mottling, microfossilan, medium hard to friable
2,582-2,594	38%	Limestone, grayish orange to very pale orange, fossiliferous, moderately hard to friable
2,660-2,673	35%	Dolomite, pale yellowish brown to medium yellowish brown, very hard, vuggy, microcrystalline
2,675-2,685	78%	Dolomite, pale yellowish brown to dark yellowish brown with gray mottling, very hard, vuggy with fracturing
2,749-2,752	100%	Dolomite, pale yellowish brown, very hard, microcrystalline

Notes:
Lithologic color designations are based on the *Rock-Color Chart*, distributed by the Geological Society of America, 1984.

EXHIBIT 4-5
Injection Well Generalized Core Laboratory Analyses

Core Depth (feet bpl)	Test Specimen Orientation	Specific Gravity	Total Porosity	Hydraulic Conductivity (cm/sec)
2,283	Vertical	2.73	0.16	3.1×10^{-4}
2,325	Vertical Horizontal	2.72	0.10 0.10	2.4×10^{-6} 6.1×10^{-8}
2,361	Vertical Horizontal	2.72	0.34 0.34	6.7×10^{-4} 1.2×10^{-3}
2,485-2,486	Vertical Horizontal	2.72	0.31 0.31	6.3×10^{-5} 1.0×10^{-4}
2,663	Vertical Horizontal	2.84	0.10 0.09	1.9×10^{-6} 1.2×10^{-6}
2,680-2,681	Vertical	2.83	0.06	1.5×10^{-8}
2,682-2,683	Vertical Horizontal	2.85	0.04 0.04	3.8×10^{-10} 3.4×10^{-10}
2,749-2,750	Vertical Horizontal	2.84	0.04 0.03	1.3×10^{-9} 1.5×10^{-9}

4.5 Packer Tests

4.5.1 Injection Well

After the completion of the injection well pilot hole, eight straddle packer tests were conducted at IW-1 to determine water quality and hydraulic characteristics of the open borehole. Testing was conducted on the intervals from 1,501 to 1,554 feet bpl, 1,747 to 1,800 feet bpl, 1,787 to 1,840 feet bpl, 1,808 to 1,832 feet bpl, 2,181 to 2,199.5 feet bpl, 2,251 to 2,269.5 feet bpl, 2,291 to 2,309.5 feet bpl, and 2,676 to 2,694.5 feet bpl. Two additional packer tests were attempted from 2,746 to 2,764.5 feet bpl and 2,851 to 2869.5 feet bpl, but were discontinued due to their lack of confinement.

A straddle packer test consists of two inflatable packers with the tested zone of the borehole between the packers. Each packer test consisted of pumping the tested interval at a predetermined rate and recording water level changes (drawdown) over time. Preliminary pumping tests were conducted to determine the optimal pumping rate for each interval. Because these zones were selected as a result of their low permeability the pumping rates are relatively low. The testing periods were long enough to observe the drawdown achieve near steady state (small water level changes) or, at a minimum, long enough to evacuate three well volumes.

Data from the pumping portion of each packer test was used to determine the specific capacity, transmissivity, and storativity of the test interval. Water level recovery measurements were taken immediately following the pumping period to provide data for transmissivity. Water levels during the packer tests and recovery periods were measured using a submersible pressure transducer and recorded by an In-Situ Hermit 3000 series data logger. Water levels were also monitored in the annular space between the well casing and the pump drop pipe to determine if the upper packers were leaking, indicated by a water level change in the annular space above the packers. Exhibit 4-6 summarizes packer test flow rates, drawdown, calculated specific capacity, transmissivity, and storativity. Cooper Jacob and Theis recovery curves used to estimate aquifer parameters are presented in Appendix L. The packer test water level data for the test interval and annular zones are also presented in Appendix L.

It is evident from the data presented in Exhibit 4-6 that of the eight packer tests, six were conducted in intervals that would be considered confinement. The tests that would be considered nonconfining are the upper most (1,501 to 1,554 feet bpl) and lower most (2,676 to 2,694.5 feet bpl) intervals while the interval in between, demonstrates confining type characteristics. The specific capacities of the intervals with confining characteristics range from a low of 0.01 gpm/ft to 0.6 gpm/ft. On the other hand, the nonconfining intervals demonstrate specific capacities that range from 4.7 gpm/ft to 46.9 gpm/ft. Extensive drawdowns and low discharge rates also correlate to the intervals that have shown low specific capacity and low porosity and permeability data seen in the core data and geophysical logs.

EXHIBIT 4-6
Summary of Packer Test Results

Packer Test Interval	Test Duration (hours)	Discharge Rate (gpm)	Drawdown (feet)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)	Transmissivity (ft^2/d)	Storativity	Analysis Method
1,501 to 1,554 feet	10.3	56	12	4.7	ND	ND	ND	---
					ND	ND		---
1,747 to 1,800 feet	23.8	60	84	0.7	ND	ND	ND	---
					ND	ND		---
1,787 to 1,840 feet	18.1	26	121	0.2	79	11	0.21	CJ
					384	51		R
1,808 to 1,832 feet	12.5	1.3	102	0.01	7	1	0.16	CJ
					4	0.5		R
2,181 to 2,199.5 feet	4.3	1.6	87	0.02	8	1.1	0.23	CJ
					8	1		R
2,251 to 2,269.5 feet	4.5	45	125	0.4	128	17	0.20	CJ
					111	15		R
2,291 to 2,309.5 feet	4	65	106	0.6	228	30	0.22	CJ
					298	40		R
2,676 to 2,694.5 feet	2	75	1.6	46.9	ND	ND	ND	---
					ND	ND		---

CJ Cooper-Jacob Method (straight line method)
R Theis Recovery Method
ND Not Determined
gpm gallons per minute
ft^2/d square feet per day
gpd/ft gallons per day per foot

Water samples were collected throughout the pumping portion of each packer test and analyzed for conductivity and chloride concentrations to demonstrate that water quality had stabilized before collecting a final water sample for laboratory analysis. Final water samples were then collected at the end of each pumping period to evaluate water quality within the test interval to identify the base of the USDW. Samples were analyzed for specific conductance, TDS, chloride, sulfate, ammonia, and total kjeldahl nitrogen concentrations. Water quality data, in particular chloride and TDS concentrations, from the straddle packer tests indicate that the base of the USDW is located within the interval from 1,790 to 1,800 feet bpl. Below this interval, TDS concentrations increase rapidly to 30,000 mg/L. The water quality data obtained from the packer test closely correlate to the geophysical log interpretations. Exhibit 4-7 summarizes water quality data for packer tests conducted at the injection well. The packer test water quality laboratory analytical reports are provided in Appendix L.

EXHIBIT 4-7
IW-1 Packer Test Water Quality Results

Packer Test Interval (feet bpl)	Specific Conductance (µmhos/cm)	Total Dissolved Solids (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)
1,501-1,554	3,100	1,700	800	220	0.36	0.52
1,747-1,800	6,770	---	---	---	---	---
1,787-1,840	14,000	7,900	4,500	170	0.74	1.1
1,808-1,832	28,000	18,000	10,000	340	0.67	1.1
2,181-2,199.5	49,000	34,000	19,000	2,100	0.17	0.59
2,251-2,269.5	48,000	33,000	18,000	2,000	0.20	0.64
2,291-2,309.5	48,000	33,000	20,000	2,300	0.27	1.1
2,676-2,694.5	52,000	36,000	21,000	2,700	<0.009	0.23

Notes:
--- Information not available

4.5.2 Dual-Zone Monitor Well

After completion of the DMW-1 pilot hole, one straddle packer test was conducted over the interval from 1,669 feet bpl and 1,718 feet bpl to provide assurance to the FDEP that there is an adequate layer of confinement between the upper monitor zone and the base of the USDW. Packer test water level data for the test interval and annular zone is presented in Appendix L. As shown in the figure, a drawdown of 166 feet was reported at a flow rate of 22 gpm, yielding a specific capacity of 0.13 gpm/ft. The aquifer transmissivity of the interval tested ranges from 45 gpd/ft to 67 gpd/ft (6 ft^2/day to 9 ft^2/day) with a storativity of 0.02. Cooper Jacob and Theis recovery curves used to estimate DMW-1 aquifer parameters are presented in Appendix L. Exhibit 4-8 presents water quality results for a water sample collected near the end of the packer test. The TDS concentration of the tested interval was 1,760 mg/L, indicating that the interval is located above the USDW.

EXHIBIT 4-8
DMW-1 Packer Test Water Quality Results

Packer Test Interval (feet bpl)	Specific Conductance (µmhos/cm)	Total Dissolved Solids (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)
1,669–1,718	3,970	1,760	1,060	250	0.45	0.647

4.6 Geophysical Logs

Geophysical logs were performed in the pilot holes of IW-1 and DMW-1 to correlate data obtained by different mechanisms and to provide additional geologic water quality information. The geophysical logs were compared to the drill cuttings samples taken during drilling to identify lithologic boundaries, as well as to obtain specific geologic and hydrogeologic data pertaining to the geologic units. This geophysical data was then utilized in the evaluation of cores and packer testing intervals, identification of specific water-producing geologic zones, and the optimum casing setting depths for each well. Reamed borehole caliper logs were also performed prior to casing installation to confirm borehole size and appropriate casing setting depths. The geophysical logs are provided in Appendix H.

4.6.1 Injection Well

Geophysical logging took place in three stages. The first interval was from 50 feet bpl to 556 feet bpl and was conducted on March 21, 2002. The interval from 556 feet bpl to 1,900 feet bpl underwent geophysical logging on April 6, 2002. The interval from 1,900 feet bpl to 3,050 feet bpl underwent geophysical logging on May 30, 2002. No geophysical logging was conducted prior to the installation of the 44-inch-diameter surface casing to 50 feet bpl. The geophysical logging included caliper, static natural gamma radiation, spontaneous potential, and dual induction on the first interval. For the remaining intervals, borehole compensated sonic/variable density, flowmeter, fluid conductivity, and temperature logs were added to previously mentioned logs. Borehole video logs on the pilot hole and completed well were conducted on June 6, 2002, and July 22, 2002, respectively. A video log summary is provided as Appendix M.

In general, the geophysical logs correlate well to each other and to the drill cuttings, cores, and packer test data. Evaluation of the geophysical logs suggests that the interval below the surface casing to the total depth of the injection well of 3,050 feet bpl can be divided into 10 distinct zones. Exhibit 4-9 presents a hydrogeological interpretation of these zones.

4.6.2 Dual-Zone Monitoring Well

In general, the geophysical logs correlate well to the injection well logs and to the drill cuttings to a depth of 1,910 feet bpl. The geophysical logs are provided in Appendix H. A video log summary is provided in Appendix M.

EXHIBIT 4-9
Hydrogeological Interpretation of Lithology Encountered

Interval (feet bpl)	Comments
50-122	The borehole diameter ranged from 12 to 14 inches in diameter with a gamma radiation response from 20 to 50 API, and a medium resistivity response on the induction log. This interval is considered nonconfining.
122-500	The borehole diameter was consistent from 12 to 13 inches in diameter with a high gamma radiation response from 40 to 90 API with some higher kicks below 450 feet bpl. The induction log showed a fairly consistent resistivity response. This interval is considered to be confining.
500-900	The borehole ranged from 14 to 20 inches in diameter with a gamma radiation response from 10 to 20 API, a fairly consistent resistivity response on the induction log with some minor interbedding and high sonic porosity, as shown on the BCS transmissive. This interval is considered nonconfining.
920-1,200	The borehole diameter ranged from 13 to 16 inches through a fairly competent fractured interval with a gamma radiation response ranging from 15 to 50 API, high resistivity with interbedding evident, and moderate porosity. This interval is considered a non-confining producing zone.
1,200-1,480	The borehole diameter ranged from 14 to 19 inches through a soft to moderately consolidated interval with a gamma radiation response generally ranging from 15 to 20 API. This interval also demonstrated a moderate resistivity with a change of water quality at 1,470 feet bpl, and a moderate porosity. This interval is considered a nonconfining producing zone.
1,480-1,900	A borehole that is generally between 15 and 18 inches in diameter with a gamma radiation count near 10 API through most of the interval and low resistivity demonstrating a gradual water quality transition from 1,480 to 1,750 feet bpl. Below 1,750 feet bpl, TDS concentrations rapidly increase to greater than 10,000 mg/L (or the base of the USDW), which is also demonstrated on the TDS derived log. Packer testing confirmed the base of the USDW exists between 1,790 and 1,800 feet bpl. The interval has a low porosity as demonstrated on the sonic porosity log and represents a consistent confining unit.
1,900-2,150	A nonuniform borehole ranging from 14 to 30 inches in diameter, a low gamma radiation response of less than 10 API, a consistent resistivity response on the induction log but decrease in spontaneous potential (between 2,000 and 2,150 feet bpl), and low sonic porosity of approximately 35 percent as shown on the sonci log. This interval is considered to be confining.
2,150-2,330	A relatively gauged borehole ranging from 12 to 18 inches in diameter through a moderately competent interval with a low gamma radiation response of less than 10 API. The formation resistivity was relatively consistent with only minor fluctuations. A slight increase in resistivity was noted between 2,290 and 2,330 feet bpl. Porosity of this interval is generally low; however, a slight increase in porosity was observed between 2,170 and 2,220 feet bpl where the porosity reached 50 percent but then decreased to 15 percent near 2,330 feet bpl. This interval is considered to be confining.
2,330-2,650	A nonuniform borehole ranging from 16 to 24 inches in diameter, a low gamma radiation response of less than 10 API, a consistent formation resistivity response with only minor fluctuations, sonic porosity ranging from 20 to 50 percent. This interval is considered to be confining.
2,650-3,050	A highly fractured and cavernous borehole ranging from 12 inches to greater than 40 inches in diameter, a slight increase in gamma radiation counts near the bottom portion of the borehole, large divergences between long and short normal resistivity, high sonic porosity (up to 100 percent). This interval is highly transmissive and is considered to be the injection zone.

4.7 Definition of the USDW

The results of the reverse-air water quality samples, packer test water quality samples and the resistivity and dual induction geophysical logs were used to determine the depth of the base of the USDW. Waters with concentrations less than 10,000 mg/L TDS are defined as a USDW by state and federal regulations, and are provided protection for their potential as a future source of drinking water.

Analysis of the reverse-air water samples identified a noticeable deterioration of water quality near 1,880 feet bpl and deeper, suggesting that the base of the USDW is located near this depth. An evaluation of packer test water quality data suggested that the base of the USDW exists between 1,790 and 1,800 feet bpl. Finally, while the borehole was static for a period of time, allowing for natural water quality stratification, a combination of the resistivity and dual induction geophysical logs were utilized to locate the USDW at a more precise depth of approximately 1,800 feet bpl. A plot of this combination log is provided with all the logs in Appendix H.

4.8 Selection of Injection and Monitoring Zones

Data collected were used to determine the final casing setting depths of both the injection and dual-zone monitor wells. As required by the construction permit, certain casing setting depths had to be approved by the FDEP before proceeding. Those casing seats included the final casing, the injection zone, and the upper and lower monitoring zones.

4.8.1 Injection Zone of IW-1

The drill cutting samples, geophysical logs, and packer test data show that a distinct change in hydrogeology occurs at a depth of approximately 2,650 feet bpl. The zone below 2,650 feet bpl consists of hard, vuggy dolomite with extensive fracturing and large cavernous zones. This zone also shows a rapid deterioration of water quality and increase in production capacity. The zone immediately above 2,650 feet bpl consists of soft, low porosity limestone with confining characteristics, capable of preventing vertical fluid migration from the injection zone. The highly fractured and transmissive zone between 2,650 and 3,050 feet bpl was determined to be the injection zone. After the review of available data, it was decided to set the final casing to 2,678 feet bpl. This placed the final casing approximately 28 feet into the dolomitic interval immediately above extensive fracturing present at 2,700 feet bpl.

4.8.2 Upper Monitoring Zone of DMW-1

The FDEP construction permit requires that for the upper monitoring zone be completed into the lowermost permeable zone above the base of the USDW. After identifying the USDW, approximately 1,800 feet bpl, the lowermost permeable zone within the USDW, was located at approximately 1,500 feet bpl. As a result of the significant separation between the permeable interval at 1,500 feet and the base of the USDW at 1,800 feet, additional evaluation was conducted (at FDEP's request) to verify the conditions of this interval. Further evaluation (using logs and packer test data) confirmed the lack of a viable zone for monitoring close to the base of the USDW and was ultimately agreed to by the FDEP. Therefore, the upper monitoring zone was completed with an open interval between 1,508 feet bpl to a depth of 1,557 feet bpl. The water quality within this interval fluctuates between approximately 1,000 and 1,500 mg/L TDS.

4.8.3 Lower Monitoring Zone of DMW-1

The FDEP construction permit requires that the lower monitoring zone be completed into the first permeable zone below the base of the USDW. Since the base of the USDW was determined to be at 1,800 feet bpl, the first permeable zone was located at approximately 1,860 feet bpl. Well DMW-1 was completed with an open interval between 1,860 feet bpl to 1,910 feet bpl.

4.9 Background Water Sampling

Background water quality sampling was conducted at the injection well and dual-zone monitoring well after construction activities were completed. Appendix N contains the certified laboratory results final report for each well.

4.9.1 Injection Well

IW-1 was sampled for background water quality on July 22, 2002. The water sample was analyzed for primary and secondary drinking water standards and FDEP's minimum criteria list. The background sample had a TDS concentration of 36,000 mg/L, which demonstrates that the injection zone is located below the base of the USDW. Exhibit 4-10 summarizes ambient water quality data for IW-1.

EXHIBIT 4-10
Ambient Water Quality Data[1]

State Primary Drinking Water Standards: Inorganic				
Parameter	MCL[2] (mg/L)	IW-1	DMW-1 (Upper)	DMW-1 (Lower)
Antimony	0.006	<0.005	<0.006	<0.006
Arsenic	0.05	<0.01	0.015	<0.01
Barium	2	0.033	26	0.039
Beryllium	0.004	<0.0001	<0.004	<0.004
Cadmium	0.005	<0.005	<0.005	<0.005
Chromium	0.1	<0.005	0.013	<0.005
Cyanide	0.2	<0.005	<0.005	<0.005
Fluoride	4	<4	0.66	<2
Lead	0.015	<0.005	0.013	<0.005
Mercury	0.002	<0.0002	<0.0002	<0.0002
Nickel	0.1	0.011	0.013	<0.005
Nitrate (as N)	10	<1	<0.5	<0.5
Nitrite (as N)	1	<1	<0.5	<0.5
Selenium	0.05	0.012	<0.001	<0.001
Sodium	160	110	390	<0.5
Thallium	0.002	<0.002	<0.001	<0.001
State Primary Drinking Water Standards: Volatile Organics				
Parameter	MCL[2] (µg/L)	IW-1	DMW-1 (Upper)	DMW-1 (Lower)
1,1-Dichloroethene	7	<0.5		
1,1,1-Trichloroethane	200	<0.5	<0.5	<0.5
1,1,2-Trichloroethane	5	<0.5	<0.5	<0.5
1,2-Dichloroethane	3	<0.5	<0.5	<0.5
1,2-Dichloropropane	5	<0.5	<0.5	<0.5
1,2,4-Trichlorobenzene	70	<0.5	<0.5	<0.5
Benzene	1	<0.5	<0.5	<0.5
Carbon Tetrachloride	3	<0.5	<0.5	<0.5
Cis-1,2-Dichloroethylene	70	<0.5	<0.5	<0.5

EXHIBIT 4-10
Ambient Water Quality Data[1]

Dichloromethane (Methylene Chloride)	5	<0.5	<0.5	5.8
Ethylbenzene	700	<0.5	<0.5	<0.5
Monochlorobenzene (Chlorobenzene)	100	<0.5	<0.5	<0.5
o-Dichlorobenzene (1,2-Dichlorobenzene)	600	<0.5	<0.5	<0.5
p-Dichlorobenzene (1,4-Dichlorobenzene)	75	<0.5	<0.5	<0.5
Styrene	100	<0.5	<0.5	<0.5
Tetrachloroethylene	3	<0.5	<0.5	<0.5
Toluene	1,000	<0.5	<0.5	66
Trans-1,2-Dichloroethylene	100	<0.5	<0.5	<0.5
Trichloroethylene	3	<0.5	<0.5	<0.5
Vinyl Chloride	1	<0.5	<0.5	<0.5
Xylenes (Total)	10,000	<0.5	<0.5	<0.5

State Primary Drinking Water Standards: Pesticides and PCB's

Parameter	MCL[2] (μg/L)	IW-1	DMW-1 (Upper)	DMW-1 (Lower)
2,4,5-TP (Silvex)	50	<0.005	<0.005	<0.005
2,4-D	70	<0.01	<0.01	<0.01
Alachlor	2	<0.01	<0.01	<0.01
Atrazine	3	<0.01	<0.01	<0.01
Benzo(a)pyrene	0.2	<0.01	<0.01	<0.01
Carbofuran	40	<1	<1	<1
Chlordane	2	<0.1	<0.1	<0.1
Dalapon	200	<0.01	<0.01	<0.01
Di(2-ethylhexyl)adipate (bis(2-ethylhexyl)adipate)	400	<0.1	<0.1	<0.1
Di(2-ethylhexyl)phthalate (bis(2-ethylhexyl)phthalate)	6	<0.1	<0.1	<0.1
Dibromochloropropane	0.2	<0.02	<0.02	<0.02
Dinoseb	7	<0.1	<0.1	<0.1
Dioxin (2,3,7,8-TCDD)	30	<0. 01	<0.01	<0.1
Diquat	20	<0.44	<0.44	<0.44
Endothall	100	<10	<10	<10
Endrin	2	<0.01	<0.01	<0.01
1,2-Dibromoethane (Ethylene Dibromide – EDB)	0.02	<0.02	<0.02	<0.02

Parameter	MCL[2] (μg/L)	IW-1	DMW-1 (Upper)	DMW-1 (Lower)
Glyphosate (Roundup)	700	<10	<10	<10
Heptachlor	0.4	<0.005	<0.005	<0.005
Heptachlor Epoxide	0.2	<0.005	<0.005	<0.005
Hexachlorobenzene	1	<0.01	<0.01	<0.01
Hexachlorocyclopentadiene	50	<0.1	<0.1	<0.1
Lindane (G-BHC)	0.2	<0.001	<0.001	<0.001
Methyoxychlor	40	<0.01	<0.01	<0.01
Oxamyl (Vydate)	200	<1	<1	<1
Pentachlorophenol	1	<0.01	<0.01	<0.01
Picloram	500	<0.01	<0.01	<0.01
Polychlorinated Biphenyl (PCB)	0.5	<0.1	<0.1	<0.1
Simazine	4	<0.01	<0.01	<0.01
Toxaphene	3	<0.1	<0.1	<0.1

State Primary Drinking Water Standards: Radionuclides

Parameter	MCL[2] (pCi/L)	IW-1	DMW-1 (Upper)	DMW-1 (Lower)
Radium 226	3 pCi/L[3]	15.9±0.7	0.80±0.2	0.40±0.1
Radium 228	3 pCi/L[3]	1.1±0.6	<1.0±0.7	<1.0±0.7
Gross Alpha	5 pCi/L	23.5±44.8	12.1±7.7	12.1±21.8

State Secondary Drinking Water Standards

Parameter	MCL[2] (mg/L)	IW-1	DMW-1 (Upper)	DMW-1 (Lower)
Aluminum	0.2	<0.05	3.2	<0.05
Chloride	250	27,000	720	17000
Copper	1	<0.01	0.022	<0.01
Fluoride	4	<4	0.66	<2
Iron	0.3	0.51	5	0.87
Manganese	0.05	0.017	0.24	0.29
Silver	0.1	<0.01	<0.01	0.05
Sulfate	250	2,900	190	1400
Zinc	5	0.024	0.068	0.034
Color	15 PCU	40	10	60

EXHIBIT 4-10
Ambient Water Quality Data[1]

Odor	3 TON	<1	1	1
pH	6.5-8.5	7.5	7.97	7.12
Total Dissolved Solids (TDS)	500	36,000	1700	26000
Foaming Agents (MBAS)	0.5	0.43	<0.1	0.10

Microbiological

Parameter	MCL[2] (CFU)	IW-1	DMW-1 (Upper)	DMW-1 (Lower)
Total Coliform	4	<1	C	TNTC
Fecal Coliform	1	--	--	--

Notes:
1. Concentrations expressed in milligrams/liter (mg/L) or micrograms/liter (μg/L) unless otherwise indicated.
2. Maximum Contaminant Level (MCL) per Rules 62-550.310, FAC.
3. The MCL for Radium 226 and Radium 228 combined is 5 pCi/L

Abbreviations:

pCi/L:	Picocurries/liter
MDL:	Minimum Detection Limit
MFL:	Million Fibers/Liter > 10 um.
μg/L:	Micrograms/Liter
TON:	Threshold Odor Number
PCU:	Platinum Cobal Units
CFU:	Colony Forming Units/100 mL
ND:	Non Detect

Both monitoring zones of DMW-1 were sampled for background water quality analyses on September 23, 2002. Before sampling, both zones were fully developed. The samples were analyzed for primary and secondary drinking water standards and FDEP's minimum criteria. The background sample for the upper monitoring zone had a TDS concentration of 1,700 mg/L, demonstrating that the monitoring zone is located above the base of the USDW. The TDS concentration of the lower monitoring zone sample was 26,000 mg/L, demonstrating that the lower monitoring zone is located below the base of the USDW. Exhibit 4-10 also summarizes water quality data for the upper and lower zones of DMW-1.

4.10 Injection Testing

Upon completion of the injection wellhead, an injection test was conducted on October 23, 2002, to evaluate the hydraulic characteristics of the injection well and verify the integrity of the confining units between the injection zone and the specific monitoring intervals of DMW-1. The flow rate was measured using the permanent 12-inch diameter injection well piping and a magnetic flowmeter throughout the 14-hour test. The injection pressure at IW-1 and water levels in the monitoring well zones were monitored and recorded for a 2-day background period, 14-hour injection test, and 12-hour recovery period. The pressure data was measured using an In-Situ pressure transducer attached to the wellheads and recorded using In-Situ Hermit 3000 data recorders.

The injectate water used for this test was the raw water pumped from the existing RO production wells. The injection test was conducted at flow rates of 1,570 and 1,935 gpm. The flow rate was regulated by use of the in-line gate valve in the pipeline from the RO plant. The first step was maintained for a 2-hour period and wellhead pressure was measured in a logrithmic scale with 1-minute intervals being the final interval during the injection test. The second step was maintained for a 12-hour period with the data collected in the same manner as the first step. The test was stopped after 14 hours due to mechanical problems with the RO production wells. Following the stoppage of the test, 12 hours of recovery data was collected using the logrithmic method previously discussed. The raw and graphic data with wellhead pressure of the injection well and monitoring wells are presented in Appendix Q.

Wellhead pressure at IW-1 was approximately 18 pounds per square inch (psi) before the test, and ranged from approximately 38 psi (1st step) to 49 psi (2nd step) during the injection test. Wellhead pressure returned to approximately 18psi almost immediately following completion of the testing.

Data collected at the dual-zone monitoring well during the test indicate stable readings throughout the test and the expected variations as a result of diurnal conditions and earth tide.

SECTION 5

Mechanical Integrity Testing

5.1 External Mechanical Integrity Testing

5.1.1 Controlling Regulations

The FDEP is responsible for regulating injection wells in Florida. Chapter 62-528, Florida Administrative Code (FAC), contains regulations for constructing and operating an injection well system. These regulations require that injection wells undergo mechanical integrity (MI) testing every 5 years. Furthermore, Section 62-528.300(6), FAC, defines the MI of injection wells, while Section 62-528.425(1) lists the monitoring requirements for injection wells related to MI. Exhibit 5-1 presents these sections of the FAC.

As noted above, MI testing has internal and external components. Demonstration of internal MI investigates the integrity of the well casing, while external MI investigates the integrity of the grout seal to restrict fluid movement adjacent to the casing. The approved method for external MI demonstration includes the Radioactive Tracer Survey (RTS) methodology, temperature logging, and review/interpretation of water quality data from monitoring wells.

5.1.2 MI Demonstration Test Program

The test program includes temperature logging and RTS testing for the demonstration of external MI. The radioactive isotope Iodine-131 (^{131}I) was utilized as a tracer for the RTS because it has a short half-life of 8.05 days and is an excellent emitter of gamma radiation. ^{131}I is a manufactured isotope of naturally occurring Iodine-126 that primarily emits beta particles but also emits gamma radiation. The end product of ^{131}I radioactive decay is Xenon-131, which is an inert noble gas. The tracer is contained within a solution of sodium iodide (NaI^{131}). The assay date of the tracer used during testing at the IWSD was less than its half-life, as required by FDEP. Additionally, the tracer has a specific gravity of approximately 1.0, which is similar to that of the potable water injected at the site. Additional isotope information including assay dates and quantity is contained in Appendix O.

RTS testing was conducted by the Geophysical Logging Division of YBI. YBI has completed similar MI work at many wastewater facilities and is licensed in Florida to handle radioactive materials and has an ongoing health and safety program, providing a safe working environment at the site.

A schematic diagram of the RTS tool configuration used during the external MI demonstration is shown on the RTS log in Appendix H. The tool has three gamma radiation detectors with the following designations:

- Top Gamma Radiation Detector (GRT)
- Middle Gamma Radiation Detector (GRM)
- Bottom Gamma Radiation Detector (GRB)

EXHIBIT 5-1

FAC Sections Pertaining to Mechanical Integrity

Mechanical Integrity Definition (Section 62-528.300(6))

(a) An injection well has mechanical integrity if:

(1) There is no leak in the casing, tubing or packer; and

(2) There is no fluid movement into an underground source of drinking water through channels adjacent to the injection well bore.

(b) One of the following tests shall be used to evaluate the absence of leaks under Subsection (a)1. of this subsection.

(1) Monitoring of tubing-casing annulus pressure with sufficient frequency to be representative, as determined by the Department, while maintaining an annulus pressure different from atmospheric pressure measured at the surface, after an initial pressure test pursuant to subparagraph 2. And paragraph (e) of this subsection; or

(2) Pressure test of inner casing or tubing.

(c) The following methods shall be used to determine the absence of fluid movement under Subparagraph (a)2. A temperature or noise log, and a radioactive tracer survey.

(d) The Department shall allow the use of a test to demonstrate mechanical integrity, other than those listed in paragraphs (b) and (c) above, with the written approval of the United States Environmental Protection Agency. If the Environmental Protection Agency has approved an alternative mechanical integrity test method, only written Department approval shall be required before conducting alternative mechanical integrity tests to those specified in (b) and (c) above.

(e) A pressure test required under paragraph (b) above shall be conducted with a liquid at a minimum pressure of 1.5 times the maximum pressure at which the well is to be permitted, or 50 psi, whichever is higher, for at least one hour. Internal mechanical integrity under subparagraph (a)1. above is demonstrated if there is no more than a five-percent pressure change over the one-hour test period. The pressure used to test wells constructed using tubing and packer shall not exceed the design specifications of the tubing or packer.

(f) In conducting and evaluating the tests enumerated in this rule or others to be allowed by the Department, the permittee and the Department shall apply methods and standards generally accepted in the industry. When the permittee reports the results of mechanical integrity tests to the Department, a description of the test(s), method(s) used, and interpretation of the results shall be included. In making the evaluation, the Department shall review monitoring and other test data submitted since the previous evaluation.

(g) The Department shall require additional or alternative mechanical integrity tests unless the results presented by the permittee under (b) and (c) above provide reasonable assurance that there is no fluid movement into or between underground sources of drinking water resulting from the injection activity.

(h) A permit for any Class I or III well or injection project which lacks mechanical integrity shall include, and for any Class V well may include, a condition prohibiting injection operations until the permittee affirmatively demonstrates under Rule 62-528.300(6)(a)-(c), F.A.C., that the well has mechanical integrity, unless the permittee affirmatively demonstrates that there is no movement of fluid into or between underground sources of drinking water.

Class I Injection Well Monitoring Requirements (Section 62-528.425(1), F.A.C.)

(d) A demonstration of mechanical integrity pursuant to Rule 62-528.300(6), F.A.C., at least once every five years during the life of the well; and

(1) As part of the baseline monitoring information, a video survey from the surface to the bottom of the injection zone shall be run prior to injection but after completion of testing, except for those wells that inject through tubing or where it is physically impossible to do so, and every five years thereafter, or more frequently if impairment of the integrity of the casing, tubing, or formation is suspected based on physical or geochemical data such as water quality, pressure changes, or mechanical integrity results.

(2) The video survey may be either black and white or color.

(3) Adequate provisions must be made to centralize the camera in the borehole.

(4) Before running the survey, adequate provisions shall be made to assure that fluid in both the casing and open borehole is of sufficient clarity to provide a baseline survey of a quality acceptable to the Department.

The gamma radiation detectors are spaced at 1.20 feet (GRB), 10.50 feet (GRM), and 24.00 feet (GRT) from the bottom of the tool. The tool is equipped with one tracer ejector port, located 13.50 feet from the bottom of the tool, spaced between the GRT and GRM detectors. A casing collar locator (CCL) is located 9.60 feet from the tool bottom. The RTS tool was field-calibrated upon mobilization to the site.

The three detectors on the tool register gamma radiation in American Petroleum Institute (API) units. The API unit is a standard industry measure of gamma radiation and relates to two test wells maintained by the University of Texas at Houston. One of the test wells is completed into a geologic formation with no sources of gamma radiation. The second well is completed into a formation that naturally emits a consistent level of gamma radiation arbitrarily set to 200 API units. To utilize a new tool for a RTS, the contractor must log both test wells with the new tool and calibrate to the 200 API units and 0 API units standards. Instead of measuring the radiation in units of energy, arbitrary API units are used to account for differences in electronics inherent in different logging tools. The logging tool used by YBI has been calibrated to these test wells. Field calibration is intended as a supplement to the baseline calibration.

A representative from CH2M HILL, John Powers, was onsite to observe all RTS testing activities. A representative from FDEP, Heidi Vandor, was also present during testing. Notes taken by the CH2M HILL representative during testing are contained in Appendix O. A 2-inch-diameter flexible hose and a totaling flowmeter were installed at the injection well to provide the accurate flow measurements necessary to complete the RTS work. The flowmeter was used to measure the relatively low flows (approximately 10 to 175 gpm) utilized during the external MI demonstration. A copy of the flowmeter calibration certificate is included in Appendix O. Potable water from the WTP was used to achieve the desired flow rate in the well. During flushing of the well between tests, the maximum flow rate was limited to approximately 175 gpm. Typically, the injection well was flushed at this rate for about 30 minutes (approximately 5,000 gallons) to remove the tracer between tests. Much lower rates (20 to 25 gpm) were used during actual testing.

5.1.3 External RTS Test Methodology

Exhibit 5-2 summarizes the FDEP-approved external MI testing procedures. Background gamma radiation logs were conducted under static well conditions before releasing any radioactive material in each well. The background gamma radiation log provides a baseline of comparison for establishing MI. A static temperature log was also run to determine the static temperature gradient. The static temperature log is useful in identifying areas where internal or external MI may be suspect and is a standard procedure during external MI testing. A CCL log was also performed before the RTS testing to locate the bottom of the injection casing. As approved by the FDEP, static external MI testing was not performed.

Three dynamic tests were conducted by ejecting 1 or 2 mCi of energy 10 above the base of the final injection casing for each test. This put the ejection point 2 feet above the bottom of the tubing, which is 8 feet less than that for the casing. During the first and second tests, a fluid velocity of not to exceed 5 feet per minute (fpm) was established in the well before ejecting the tracer. However, the third test was completed using a higher fluid velocity, approximately 23 fpm or 175 gpm, which is the highest rate possible at the site with existing equipment. The equation $Q=V*A$ was used to determine either the volumetric rate (Q) or the fluid velocity (V). The inner area of the tubing was determined to be 0.42 ft^2 (inner diameter 8.75 inches).

EXHIBIT 5-2
FDEP-Approved External Radioactive Tracer Survey Procedures

Static External RTS Procedures

1. Notify FDEP 72 hours in advance of testing.
2. Run static temperature, CCL, and background gamma radiation logs of the entire well.
3. Flush well with at least 3,000 gallons of potable water.
4. Position the RTS logging probe ejector port approximately 1 foot below the bottom of the casing, and eject a measured tracer volume (1 mCi ^{131}I).
5. With the tool stationary, monitor the tracer plume for at least 60 minutes under static conditions for upward fluid movement.
6. Log profile of tracer plume to verify positioning. Log up out of position to at least 100 feet above the top of the radioactive plume.
7. Flush tracer material down hole until tracer material is flushed sufficiently below the base of the casing to perform additional testing.
8. Log through area affected by static radioactive plume to verify that plume has been properly flushed and to identify areas that may have become stained by the ^{131}I.

Dynamic External RTS Procedures

1. Position RTS logging probe ejector port 5 feet above the base of the well casing, and eject 1 mCi of 131I while pumping into the well at a downhole velocity, not to exceed 5 feet per minute.
2. With the tool stationary, monitor for upward migration of the plume external to the well casing for at least 30 minutes under dynamic conditions.
3. Conduct steps 6 through 8 above.
4. Repeat dynamic external test by repeating steps 9 through 11 above.
5. Run a final gamma radiation log from approximately 100 feet below the base of the casing to land surface.

General Requirements

1. Calibrate all geophysical tools within 1 week of testing.
2. The tracer (131I) must be dated less than one-half-life at time of actual use during testing.
3. All mechanical and digital gauges used for flow and pressure measurements must be calibrated within 60 days of actual testing.
4. Gamma radiation detectors shall be field calibrated by the geophysical logging crew upon mob to injection well.
5. The RTS probe shall be emptied of all tracer material prior to removal from the well.

The dynamic external RTS began with the geophysical logging probe held stationary. The travel time of the plume was monitored by the GRM and GRB detectors to confirm the flow velocity in the well. With the tool stationary, the gamma counts were monitored for arrival of the source at the GRT detector for 30 minutes to 1 hour. Arrival of the plume at the GRT detector would indicate inadequate external MI at the base of the well as a result of vertically upward tracer movement outside the injection well casing.

Following the monitoring period, the contractor logged out of position up to at least 100 feet above the ejection point in the well. The injection well was then flushed at a high rate, and logging through this interval was repeated. The absence of any elevated gamma counts near the base of the injection casing demonstrated that adequate external MI existed at the base of the injection well.

The testing procedure for the dynamic external RTS was repeated twice, ejecting the tracer at 10 feet above the base of the injection casing. However, for the second and third tests, the monitoring period was reduced to 30 minutes. After all three tests were conclusive in demonstrating external MI, a final gamma-radiation log was completed to well bottom and compared to the background log for further external MI verification. Appendix H contains copies of all geophysical logs. The format of each gamma radiation log is as follows:

1. The top detector (GRT) trace is on the far left of each log. The CCL, which provides depth control, is also shown on the left side.
2. The bottom detector (GRB) trace is located in the center.
3. The middle detector (GRM) trace is located on the far right.

The background temperature logs have been formatted at 20 degrees/inch with a scale ranging from 50°F to 150°F. The differential temperature is also shown on the log, with a range from -1.0 to 1.0 over 5 inches.

5.1.4 External MI Test Results

Exhibit 5-3 summarizes the geophysical logging conducted during the external MI testing of the FPUA injection well. The logs consist of 14 datasets: TEMP and RTS1 through RTS14. Each logging run completed is a separate electronic dataset. Except for the temperature log and initial background gamma radiation log, which were completed on September 4, 2002, all logs were completed on September 5, 2002. The background temperature log (dataset TEMP) shows the water temperature in the casing gradually increased from 78.6°F at approximately 30 feet bpl to 79.9°F at 240 feet bpl. From 240 to 280 feet bpl, the fluid temperature decreased over 1°F. From 280 to 550 feet bls, the fluid temperature fluctuated gradually. From 550 feet bpl to 2,616 feet bpl, the fluid temperature gradually increased. The fluid temperature then decreased gradually from 2,616 to 2,674 feet bpl. Over the next 8 feet (2,674 to 2,682 feet bpl), the fluid temperature increased sharply. This interval coincided with the bottom of casing (2,678 feet bpl). Fluid temperature then decreased gradually to 2,950 feet bpl. Below 2,950 feet bpl, the fluid temperature was unchanged. No anomalous intervals within the casing are indicated by the del-T log, which measures water temperature difference, not temperature value. The depth to bottom of casing at 2,678 feet bpl was detected by the del-T log, as indicated by the sharp decrease in temperature.

5.1.5 Dynamic Testing

5.1.5.1 First Dynamic Test

The initial dynamic test began by ejecting tracer with an activity of 1 mCi 2,668 feet bpl (10 feet above bottom of casing) under dynamic conditions and monitoring in time-drive mode for 60 minutes. A flow rate of approximately 11 to 12 gpm (3.50 to 3.82 feet /minute) was maintained at the wellhead during the logging event. The ^{131}I plume was observed in less than 20 seconds at the GRM detector, but was not detected by GRB detector during the entire test. Because the GRB detector was positioned 2 feet below the bottom of the casing, it is likely the plume exited the flow zone immediately below the bottom of the casing. The low fluid velocity within the casing was likely overpowered by the flow zone, thus preventing the plume from reaching the GRB detector. No increase was observed at the GRT during the entire monitoring time with gamma radiation averaging about 34 to 36 API units.

EXHIBIT 5-3

Summary of Geophysical Logs

	Dataset	Interval Logged (1)	Logging Performed (2)	Injection Rate gpm	Comments
Background Logs	TEMP	0-3,045	T, del-T	STATIC	Fluid temperature
	RTS1	3,045-0	GR	STATIC	Background gamma radiation
	RTS3	2,596-2,705	CCL	STATIC	Casing tie in
	RTS4	Time Drive	GR	12 (3.82 fpm)	Eject 1 mCi at 2,668 ft bls (10 ft above casing bottom)
	RTS5	2,684-2,448	GR	11 (3.50 fpm)	Log Out of Position (LOP) No. 1
Dynamic Tests	RTS7	2,450-2,682	GR	STATIC	Log After Flush (LAF) No. 1
	RTS8	Time Drive	GR	10 (3.18 fpm)	Eject 2 mCi at 2,668 ft bls (10 ft above casing bottom)
	RTS9	2,682-2,448	GR	10 (3.18 fpm)	LOP No. 2
	RTS10	2,446-2,704	GR	STATIC	LAF No. 2
	RTS11	Time Drive	GR	175 (23.39 fpm)	Eject 2 mCi at 2,668 ft bls (10 ft above casing bottom)
	RTS12	2,682-2,446	GR	175 (23.39 fpm)	LOP No. 3
	RTS13	Time Drive	GR	175 (23.39 fpm)	Dumped remaining tracer at 2,845 ft bls and 2,870 ft bls
	RTS14	2,805-2,495	GR	STATIC	Final gamma radiation background up
	RTS14	0-3,050	GR	STATIC	Final gamma radiation background down

Injection Well Specifications

	Casing Inner Diameter (in.)	Casing Depth (ft bls)	Tubing Inner Diameter (in.)	Tubing Depth (ft bls)
IW-1	18.00	2,676	8.75	2,670

(1) Depths shown are referenced to land surface
(2) CCL: Casing Collar Locator; GR: Gamma Radiation; T: Temperature; del-T: Differential Temperature; fpm: feet per minute; gpm: gallons per minute
(3) Casing depth was determined with the CCL
(4) Time Drive: stationary tool
(5) Datasets RTS2 and RTS6 were failed logging runs

Q gpm	Q ft^3pm	V fpm	A ft^2
10	1.34	3.18	0.42
11	1.47	3.50	0.42
12	1.60	3.82	0.42
175	23.39	55.70	0.42

The log out of position (LOP) after 60 minutes of monitoring showed no increased radioactivity inside the casing with any of the detectors (dataset RTS5), indicating that the plume was dispersed into the open borehole below the casing. Correlation between background gamma radiation (RTS1) and LOP No.1 (RTS5) was excellent, especially with the GRT detector. After flushing the well at a rate of 158 gpm for approximately 30 minutes, a very good correlation (RTS7) with background (RTS1) was present above 2,676 feet bls (with the GRB detector) and above 2,656 feet bls with the GRT detector.

5.1.5.2 Second Dynamic Test

The second dynamic test was completed (RTS8-RTS10) under similar conditions as the first test except that tracer with an activity of 2 mCi was used and the monitoring time was reduced to 30 minutes. The established flow rate was approximately 10 gpm (3.18 fpm). The ^{131}I plume was observed in less than 20 seconds at the GRM detector, but was not detected by the GRB detector during the test. Like the first test, because the GRB detector was positioned 2 feet below the bottom of casing it is likely the plume exited the flow zone immediately below the bottom of the casing. No increase was observed at the GRT during the entire monitoring time with gamma radiation ranging between 30 and 40 API units

The second LOP showed no increased radioactivity inside the casing with any of the detectors (dataset RTS9), indicating that the plume was dispersed into the open borehole below the casing. Correlation between background gamma radiation (RTS1) and LOP No. 2 (RTS9) was excellent. After flushing the well at a rate of 170 to 172 gpm for approximately 30 minutes, a very good correlation (RTS10) with background (RTS1) was present above 2,666 feet bls.

5.1.5.3 Third Dynamic Test

The third dynamic test was completed using a higher flow rate in order to better simulate actual injection conditions. The established flow rate was increased to 175 gpm (23.39 fpm), the highest achievable rate at the time. Tracer with an activity of 2 mCi was released 10 feet above the bottom of the final casing. The ^{131}I plume was recorded almost instantaneously by the GRM detector, but unlike the first two tests the plume was detected by the GRB detector in less than 20 seconds. The tool had been positioned at the same depth as the first two tests. Because of the higher flow rate (175 gpm) the plume was flushed past the flow zone immediately below the casing bottom and subsequently detected by the GRB detector. No increase was observed at the GRT detector during the entire monitoring time with gamma radiation ranging between 30 and 40 API units

LOP No. 3 showed no increased radioactivity inside the casing with any of the detectors (dataset RTS12), indicating that the plume was dispersed into the open borehole below the casing. Correlation between background gamma radiation (RTS1) and LOP No. 3 (RTS12) was excellent. The ejector was then positioned at 2,870 feet bls while flushing at 175 gpm and the remaining tracer was released into the open borehole (RTS13). The tool was then repositioned 25 feet higher in the borehole at 2,845 feet bls and the remaining tracer released a second time. After flushing of the tracer was completed, the tool was moved up to measure residual gamma radiation (RTS14). An increase in gamma radiation was detected at 2,704 feet bls within the open borehole, 26 feet below the bottom of casing (2,678 feet bls). The increased gamma radiation at this point may indicate the location of a flow zone where the released tracer from the third test exited the borehole. This feature was not present during the initial background gamma radiation log (RTS1).

Above the casing the residual gamma radiation log (RTS14) correlated closely with background conditions (RTS1) except at the tracer release point of 2,668 feet bls where the casing is stained with tracer. After flushing the well for approximately 30 minutes at 172 gpm, a final background gamma radiation log (also designated as RTS14) was completed under static conditions from land surface to the bottom of the well. An excellent correlation with initial background conditions was recorded for all three detectors within the entire length of casing. The increase in gamma radiation previously detected at 2,668 feet bls (ejection point), 2,704 feet bls (flow zone), 2,845 feet bls (tracer dump) and 2,870 feet bls (tracer dump) were also detected, as expected, during this final background log.

5.1.6 Summary of Results

The results of the two low flow rate and one high flow rate dynamic external RTS tests were conclusive in successfully demonstrating the external MI of the Fort Pierce Utilities Authority injection well located at the Henry A. Gahn 25th Street Reverse Osmosis Water Treatment Plant. No external MI problems were noted during testing.

5.2 Internal Mechanical Integrity Testing

5.2.1 IW-1

5.2.1.1 Tubing Pressure Test

On August 8, 2002, a tubing pressure test was successfully conducted on the final 10.75-inch-diameter FRP tubing of IW-1. The pressure test was conducted after cementing the casing in place. The casing was pressurized with water to 150 psi and monitored for 2 hours with a 200-psi calibrated pressure gauge. A copy of the calibration certificate for the pressure gauge is provided in Appendix P. Pressure readings were manually recorded every 5 minutes during the 2-hour test. Exhibit 5-4 summarizes the casing pressure test data. During the test, the pressure decreased slightly from 150.0 psi to 149.25 psi. The 0.75 psi decrease was within the 5 percent pressure differential limit (7.5 psi) specified by the FDEP for a 2-hour pressure test. The casing pressure test was observed by Mark Schilling (CH2M HILL) and Heidi Vandor (FDEP).

EXHIBIT 5-4
Tubing Pressure Test Data for IW-1

Elapsed Time (minutes)	Pressure(psi)	Elapsed Time (minutes)	Pressure (psi)
0	150.0	65	149.5
5	150.0	70	149.5
10	150.0	75	149.5
15	150.0	80	149.5
20	150.0	85	149.5
25	150.0	90	149.5
30	150.0	95	149.25
35	150.0	100	149.25
40	150.0	105	149.25
45	149.5	110	149.25
50	149.5	115	149.25
55	149.5	120	149.25
60	149.5		

5.2.1.2 Video Survey

A video survey was conducted under static conditions at IW-1 on July 22, 2002, by Florida Geophysical, Inc., after purging the well for over 72 hours. The quality of the video survey, in terms of visibility, was excellent. The final 18-inch steel casing setting depth was confirmed at 2,676 feet bpl with the 10.75-inch FRP tubing setting depth at 2,669 feet bpl. Several native fractures in the injection zone interval were evident from the base of the casing to the total depth of 3,045 feet bpl. These fractures are indicative of the highly transmissive "Boulder Zone".

In summary, the geophysical logs of the completed well indicate no inconsistencies and that the casing is in good condition. Below the base of the casing, the most productive intervals of the open borehole exist between approximately 3,050 and 3,165 feet bpl and between approximately 3,220 and 3,260 feet bpl. A copy of the video survey report is provided in Appendix M.

5.2.1.3 Geophysical Logging

Per the FDEP construction permit, a cement bond log (CBL) was performed on the steel 18-inch-diameter casing prior to installation of the 10.75-inch FRP tubing. The logs were performed by Florida Geophysical Surveys, Inc., on July 9, 2002, and August 9, 2002, respectively. Copies of the logs are provided in Appendix H.

The CBL was conducted to assess the quality of the cement-to-casing bond of the final casing of IW-1. The log was performed before cementing the upper 290 feet of the 18-inch-diameter final well casing to allow a comparative calibration of the tool to non-cemented casing (above 290 feet bpl) and cemented casing (below 290 feet bpl). The CBL demonstrated that a good cement bond exists around the final casing from 2,678 feet bpl to 290 feet bpl. Above 290 feet bpl, the CBL confirms that the casing was non-cemented at the time of the logging event. The interval from pad level to 290 feet bpl was cemented after completion of the CBL.

The CBL on the 10.75-inch-diameter FRP tubing was conducted to access the quality of the cement-to-tubing bond of the liner inside the final casing. The log was performed before cementing the upper 285 feet of the 10.75-inch-diameter FRP tubing to allow the tool to be calibrated to non-cemented tubing (above 285 feet bpl) and cemented tubing (below 285 feet bpl). The CBL demonstrated that a good cement bond exists around the FRP tubing from 2,670 to 285 feet bpl. Above 285 feet bpl, the CBL confirms that the tubing was non-cemented at the time of the logging event. The interval from pad level to 285 feet bpl was cemented after completion of the CBL.

5.2.2 Dual-Zone Monitor Well

5.2.2.1 Casing Pressure Test

On September 5, 2002, a casing pressure test was successfully conducted on the final 6.625-inch-diameter FRP casing of DMW-1. The pressure test was conducted after cementing the casing in place. The casing was pressurized with water to 100 psi. The wellhead pressure was monitored for 2 hours with a 200-psi calibrated pressure gauge. A copy of the calibration certificate for the pressure gauge is provided in Appendix P. Pressure readings were manually recorded every 10 minutes during the 2-hour test. Exhibit 5-5 summarizes the casing pressure test data. During the test, the pressure increased slightly from 150.0 psi to 150.5 psi. The 0.5 psi increase was within the 5 percent pressure differential limit (7.5 psi) specified by the FDEP for a 2-hour pressure test. The casing pressure test was observed by John Powers (CH2M HILL) and Heidi Vandor (FDEP).

EXHIBIT 5-5
Casing Pressure Test Data for DMW-1

Elapsed Time (minutes)	Pressure (psi)	Elapsed Time (minutes)	Pressure (psi)
0	100.0	70	100.25
10	100.0	80	100.25
20	100.0	90	100.5
30	100.0	100	100.5
40	100.0	110	100.5
50	100.0	120	100.5
60	100.25		

5.2.2.2 Video Survey

Several attempts were made to conduct a video survey of the monitor well after approximately 30 days of continuous development. The poor quality of the video is a result of the milky color of the water coming from the formation. When conducting video surveys on injection wells, the test results are generally attained after injecting potable water for some period of time. However, injecting freshwater into the monitor well was not considered desirable because of the impact on water quality in the lower zone.

5.2.2.3 Geophysical Logging

A CBL was performed on the 6.625-inch-diameter FRP casing by YBI on September 3, 2002. Copies of the log are provided in Appendix H.

The CBL was conducted to access the quality of the cement-to-casing bond of the final casing of DMW-1. The log was performed after the casing had been cemented from the total depth of 1,860 feet bpl to 1,557 feet bpl allowing the tool to be calibrated to non-cemented casing (above 1,557 feet bpl) and cemented casing (below 1,557 feet bpl). The CBL demonstrated that a good cement bond exists around the final casing from 1,860 feet bpl to 1,557 feet bpl. Above 1,557 feet bpl, the CBL confirms that the casing was non-cemented at the time of the logging event. The interval from pad level to 1,557 feet bpl will remain uncemented for use as the upper monitor zone.

5.3 MI Testing

Testing of IW-1 and DMW-1 was performed to evaluate the MI of the wells in accordance with standards set forth in FAC 62-528. Testing of the injection well included a video survey of the casing and wellbore, cement bond logs, a casing pressure test, and radioactive tracer testing (external). Testing of the dual-zone monitor well included a video survey of the casing and wellbore, cement bond log, and a casing pressure test. Results of testing demonstrated that the wells meets the requirements for both internal and external mechanical integrity testing, as set forth in FAC 62-528.300(6). It should be noted that an internal RTS was to be conducted at the injection well but as a result of time restrictions it has not been completed prior to the preparation and submittal of this report. Once this test has been completed, a separate submittal will be prepared and submitted to the FDEP, addressing this matter.

SECTION 6

References

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