AECOM

Volume I

December, 2012

Town of Davie

Engineering Report on the Construction & Testing of the Deep Injection Well System Town of Davie, FL Water Treatment and Water Reclamation Facility

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December 3, 2012

Mr. Joseph May, P.G.
UIC/Groundwater Program Manager
Florida Department of Environmental Protection
400 N. Congress Ave, Suite 200
West Palm Beach, FL 33401

RE: Town of Davie Water/Wastewater Facilities
Engineering Report on the Construction of the Deep Injection Well System
FDEP UIC Well Construction Permit Number 0298127-001-UC
AECOM Project No. 60185432

Dear Joe:

Hereby submitted on behalf of The Town of Davie is the Engineering Report on the Construction and Testing of the Deep Injection Well System at the New Water and Wastewater Treatment Facility located at 7351 SW 30th Street, Davie FL 33314. The deep injection well system consists of two (2) deep injection wells (IW-1 and IW-2) and associated dual-zone monitor well (MW-1). The deep injection well system was constructed to serve as the primary disposal method to primarily handle reverse osmosis concentrate and treated effluent generated at this facility. IW-1 and IW-2 were built to Class I (industrial) injection well construction standards in accordance with Rule 62-528, FAC, and the conditions of FDEP issued Class I Injection Well Construction Permit No. 0298127-001-UC.

Should you have any questions regarding the attached engineering report, please contact me at (561) 684-3375.

Sincerely,

Michael W. Bennett
12/3/12

Michael W. Bennett,
Senior Hydrogeologist
Florida Licensed P.G. No-1558
AECOM Technical Services

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Construction and Testing of the Town of Davie Class I Industrial Injection Well System - Engineering Report

Introduction

This report summarizes the construction and testing of an alternate design Class I (Industrial) Injection Well system at the Town of Davie's newly constructed Water Treatment and Water Reclamation Facility (WTF/WRF). The injection well system consists of two Class I industrial type injection wells identified as IW-1 and IW-2, and the associated dual-zone monitor well identified as MW-1. Well construction and testing operations were performed in accordance with Chapter 62-528, of the Florida Administrative Code (FAC), the recommendations of the Florida Dept of Environmental Protection (FDEP), the Technical Advisory Committee (TAC), provisions of FDEP Construction Permit - 0298127-001-UC and the well construction Contract Documents. A copy of the FDEP-issued Construction Permit 0298127-001-UC is provided in **Appendix A.**

Background

The physical address of the Town's new WTF/WRF is 7351 SW 30th Street, Davie, Florida 33314. The Deep Injection Well (DIW) system was constructed at the north end of the site in the northwest quarter of Section 22 of Township 50 South, Range 41 East. A site location map for the DIW system is provided as **Figure 1-1** and a site plan is provided as **Figure 1-2.**

The deep injection well system has a permitted peak flow capacity of 11.4 million gallons per day (mgd) or 7,910 gallons per minute (gpm) with 100% redundancy. The DIW system was constructed to serve as the primary disposal method for concentrate generated by the reverse osmosis plant and as the secondary system to handle treated effluent generated from the WRF. The effluent from the WRF is treated to reuse standards and utilized as part of the Town's reuse program.

Construction of the Class I deep injection well system began on January 21, 2011 and was completed on August 9, 2011 with the performance of a casing pressure test on MW-1. The injection well system was demonstrated to be operational with the performance of an interim injection test on IW-1 completed on October 26, 2011. The Interim injection test was performed at an injection rate of 4.0 mgd.

Figure 1-1: Site Location Map

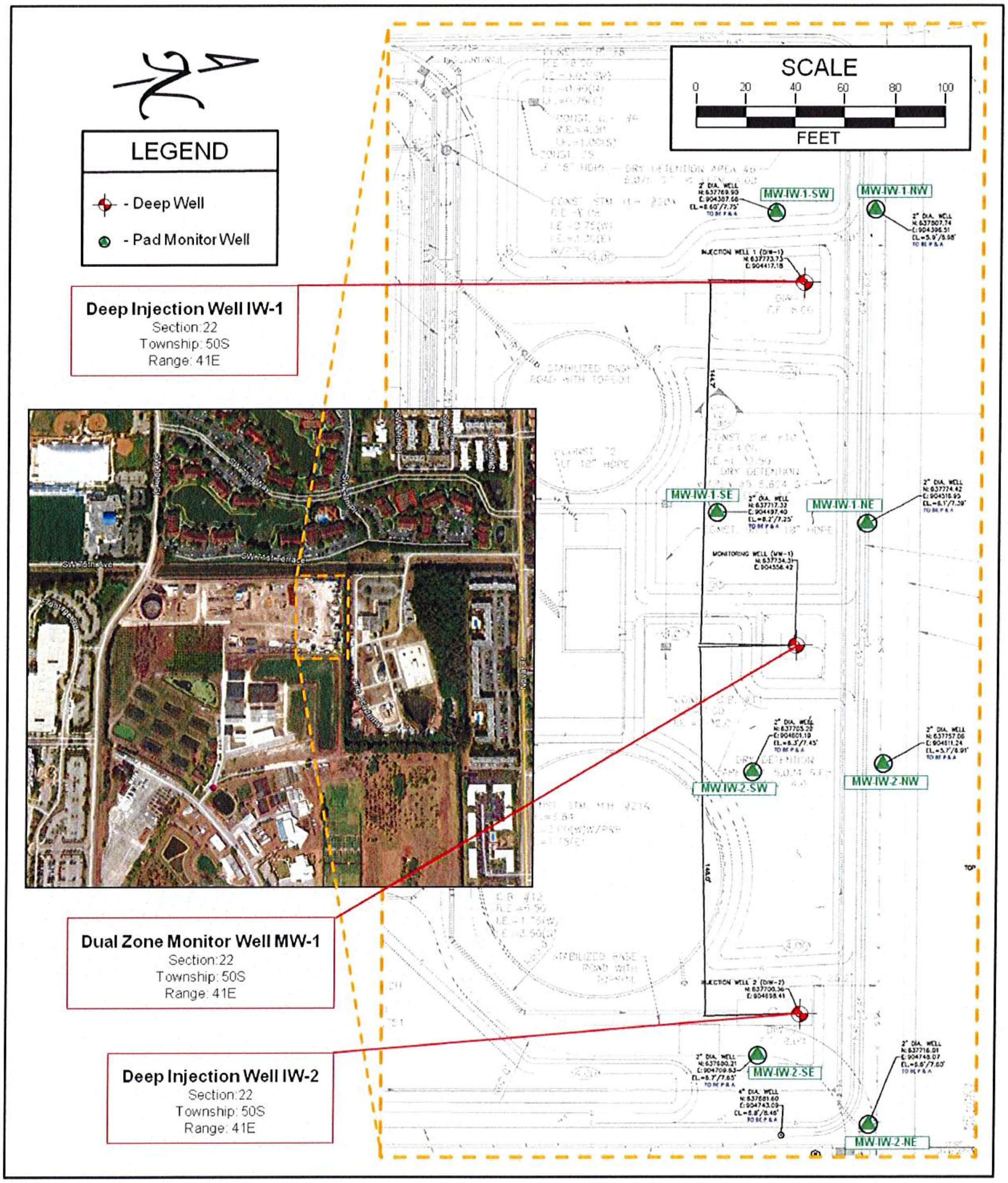


Figure 1-2: Site Plan

Project Description

This project included the design; permitting and construction of two deep injection wells, IW-1 and IW-2, and the associated dual-zone monitor well, MW-1. Well completion diagrams of IW-1, IW-2 and MW-1 are presented as **Figures 1-3, 1-4** and **1-5,** respectively.

The deep injection well identified as IW-1 was completed to a final depth of 3,685 feet below pad level (bpl) with 30-inch diameter steel injection casing installed to a depth of 2,902 feet bpl and a 20 inch outer diameter Fiberglass Reinforced Pipe (FRP) injection tubing installed to a depth of 2,892 feet bpl. The second deep Injection well (IW-2) was constructed to a total depth of 3,800 feet below pad level (bpl) with the 30-inch diameter steel injection casing installed to a depth of 2,925 feet bpl and the 20-inch outer diameter FRP injection tubing installed to a depth of 2,917 feet bpl.

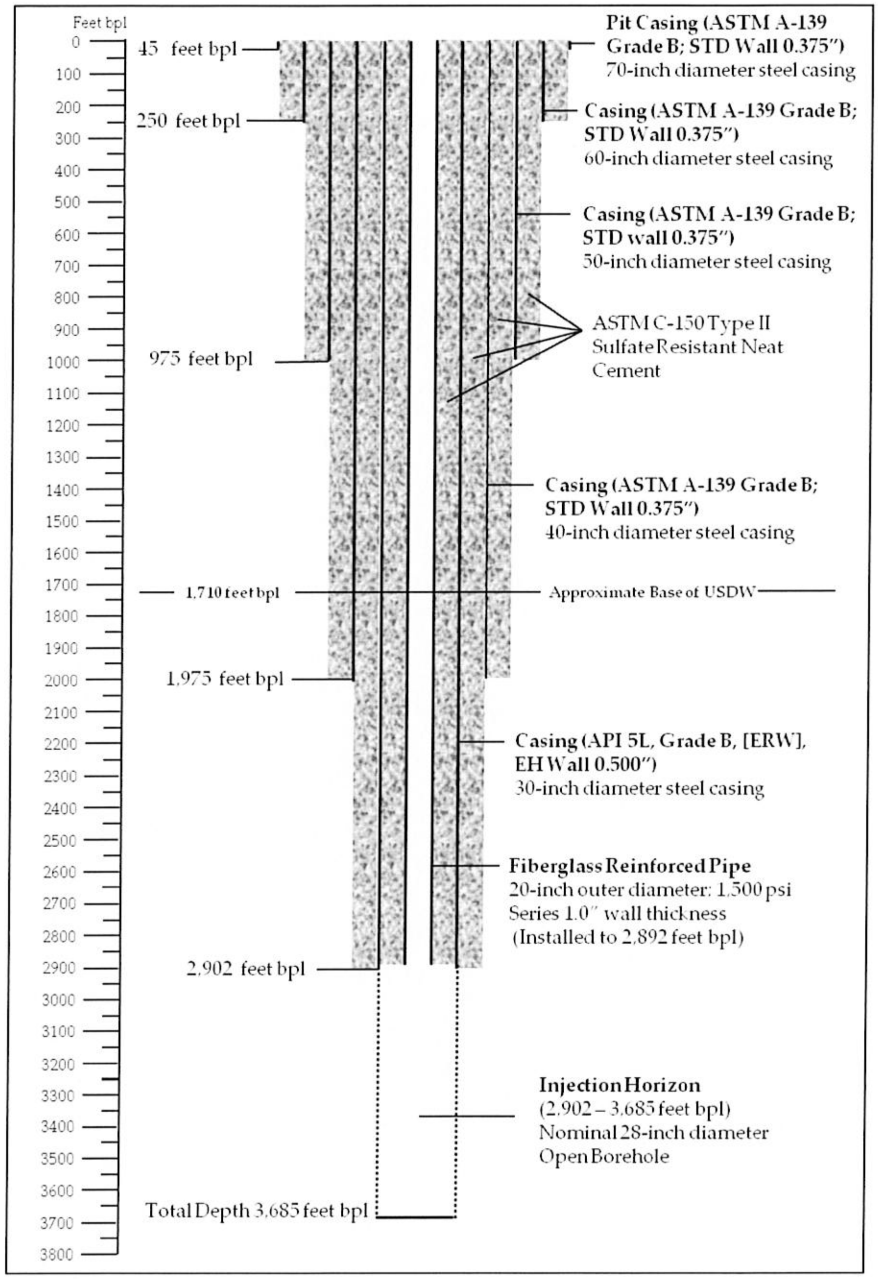


Figure 1-3: IW-1 Well Completion Diagram

This Class I injection well system is monitored by a dual-zone monitor well identified as MW-1 that is located within 150 feet of either of the two injection wells. MW-1 was completed in two distinct zones within the Floridan aquifer to monitor for upward migration of injected fluids during long-term operation of the DIW system. The upper zone (MW-1U) was completed with a monitor interval from 1,630 to 1,660 feet bpl; located above base of the underground source of drinking water (USDW). The lower zone (MW-1L) was completed with a monitor interval from 1,960 to 2,000 feet bpl; located below the base of the USDW.

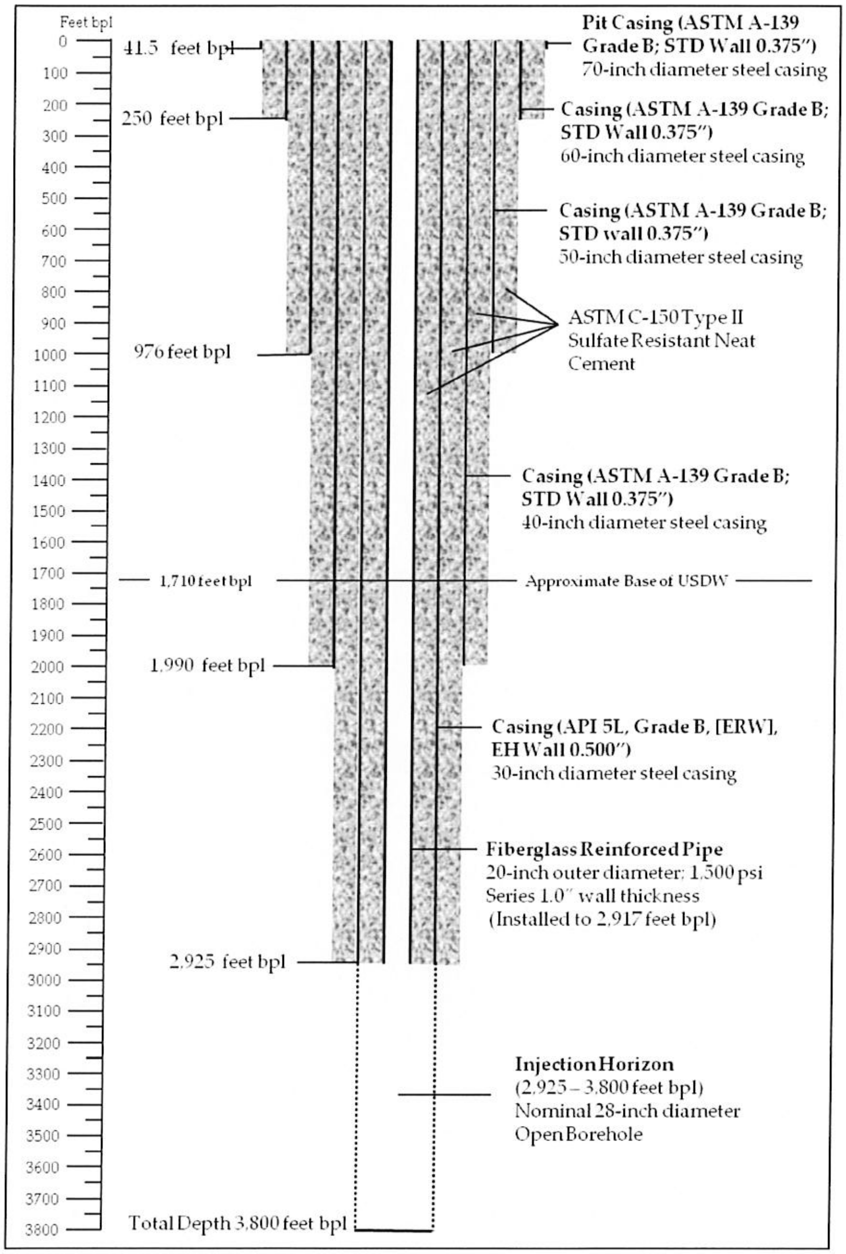


Figure 1-4: IW-2 Well Completion Diagram

Construction activities at the project site also included installation of temporary steel drilling pads, shallow pad monitor wells, the permanent injection well pad, wellhead valves, piping and instrumentation and control facilities.

The deep injection well system was designed by AECOM and constructed by Youngquist Brothers, Inc. AECOM provided resident observation during well construction and testing activities and serves as the Engineer of Record for this project.

The Southeast District office of the FDEP coordinated the review, inspection and approval of various components during the construction of this injection well system. A tabulated summary of well construction activities for IW-1, IW-2 and MW-1 and weekly summary reports documenting the progression of construction and testing activities are presented in **Appendices B-1** and **B-2**, respectively. AECOM's daily activity reports during the construction and testing of IW-1, IW-2 and MW-1 are presented in **Appendices B-3, B-4 and B-5**, respectively.

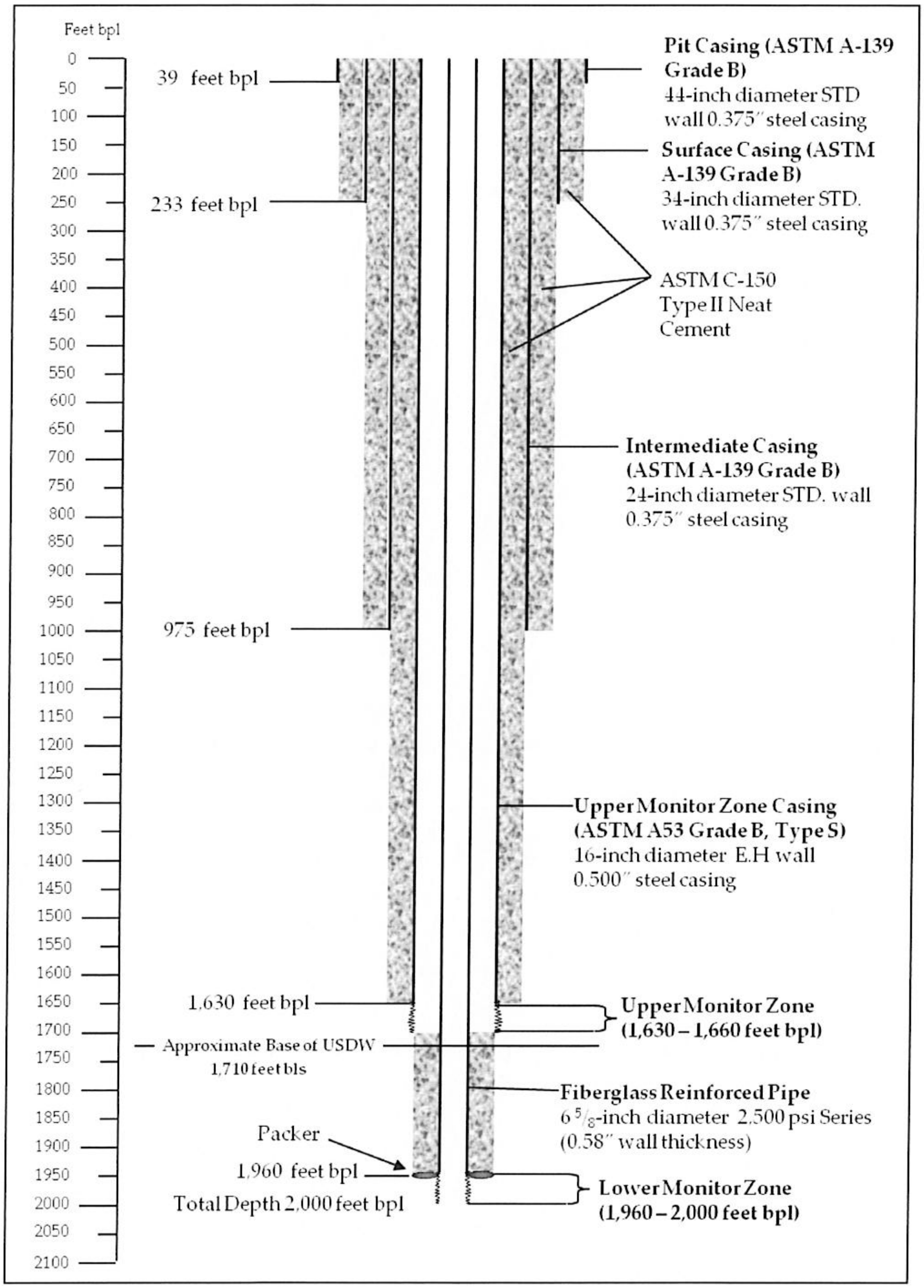


Figure 1-5: MW-1 Well Completion Diagram

SECTION 2

Construction Phase

The following section describes the construction, drilling, and testing details associated with the construction of deep injection wells IW-1 and IW-2, the dual-zone monitor well MW-1 and the associated pad monitor wells at the Town of Davie Water Treatment /Water Reclamation Facility in Davie, Florida.

Pad Monitor Wells

As required by the FDEP Underground Injection Control (UIC) construction permit, pad monitor wells were installed at the NE, SE, SW and NW corners of the drilling pads to monitor for groundwater contamination during construction of IW-1, IW-2 and MW-1. The pad monitor wells were constructed to a depth of 20 feet bpl with 10 feet of 2-inch diameter schedule 40 polyvinyl chloride (PVC) casing and 10-feet of 2-inch diameter 20-slot PVC well screen. Upon completion water samples were collected from each well and analyzed to establish background water quality data prior to the start of construction activities. The location of the pad monitor wells are shown on the site plan presented as **Figure 1-2**. A typical pad monitor well diagram is presented as **Figure 2-1**. Water quality data from the pad monitor wells are discussed in **Section 4** of this report. Once DIW construction and testing activities were

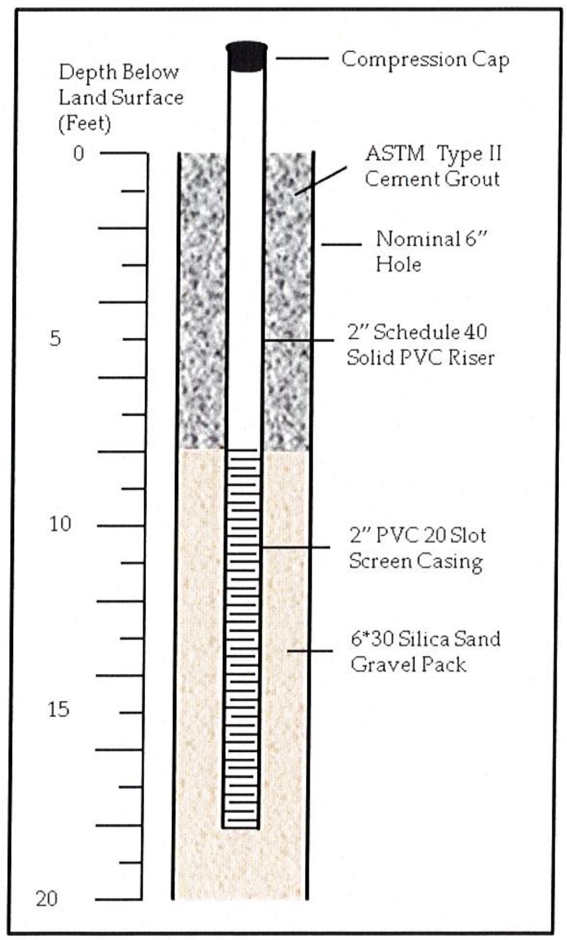


Figure 2-1: Typical Pad Monitor Well Diagram

completed the pad monitor wells were plugged and abandoned. The Well Completion and Well Abandonment Reports for the pad monitor wells are provided in **Appendix C-1 and C-2**, respectively.

Deep Injection Well IW-1

Drilling of deep injection well IW-1 began January 21, 2011. Mud rotary drilling techniques were used to advance the borehole to a depth of 980 feet bpl. Closed circulation reverse-air drilling was used to advance various diameter boreholes from 980 to 3,805 feet bpl that allowed for collection of representative formation water samples. A summary of well construction and testing activities can be found in **Appendix B-1**. Drift indicator surveys were taken every 90 feet while drilling the nominal 12-inch diameter and borehole reaming stages of IW-1 to ensure that the various diameter boreholes were plumb. The result of these deviation surveys for IW-1 are summarized in **Appendix D-1** and graphically shown in **Figure 2-2**.

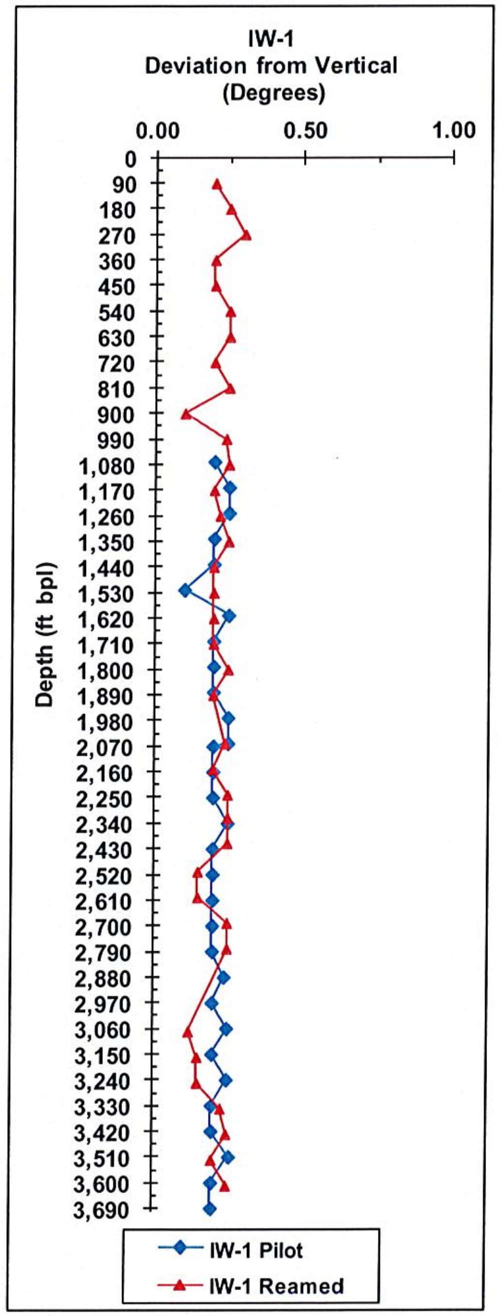


Figure 2-2: Deviation from Vertical Summary for IW-1

The drilling schedule and casing setting depths were designed to conform to the hydrogeological features anticipated at the site and to meet regulatory agency requirements. Geologic formation samples were collected and described at 10-foot intervals during drilling activities. During construction activities data collected included formation samples [cuttings], water samples, packer tests, and geophysical logs. These data 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. Approval from the FDEP of the recommended casing setting depth requests submitted by AECOM were obtained prior to installing the 40-inch diameter steel intermediate and 30-inch diameter steel injection casings of IW-1.

The injection well (IW-1) was constructed using five concentric steel casings (70-, 60-, 50-, 40-, and 30-inch outside diameters) and one fiberglass reinforced pipe (20-inch OD and 17.98-inch ID). The cementing program was specifically tailored for each casing installed. Casing installation summaries including setting depths are presented in **Appendix D-2.** Casing cement summaries including the types and quantities of cement used for the construction of IW-1 are summarized in **Appendix D-3**. Copies of casing mill certificates for each of the casings used during construction of IW-1 are presented in **Appendix D-10.**

Construction of IW-1 began by advancing a nominal 74-inch diameter borehole, via mud-rotary drilling to a depth of 47 feet below pad level (bpl) with 70-inch-diameter steel pit casing installed to a depth of 45 feet bpl. This casing was then fully cemented to surface using ASTM Type II cement. A nominal 68-inch-diameter borehole, centered inside the 70-inch-diameter steel pit casing, was advance to a depth of 254 feet bpl. Geophysical logging (4-arm caliper and natural gamma ray) was conducted in the nominal 68-inch diameter borehole prior to installing the 60-inch diameter steel surface casing (ASTM A-139 Grade B) to a depth of 250 ft bpl. The 60-inch diameter surface casing was pressure grouted in place using 467 barrels of ASTM Type II cement with cement returns observed at land surface.

A nominal 58-inch diameter borehole was advanced from 250 to 980 feet bpl via the mud rotary method. Geophysical logging (4-arm caliper and natural gamma) was conducted, and the 50-inch diameter steel casing (ASTM A-139 Grade B) installed to a depth of 975 feet bpl. The 50-inch diameter steel casing was set through the Hawthorn confining units into the carbonate section of the Floridan aquifer. This casing was initially pressure grouted then tremie grouted in various cement stages back to land surface. After pumping each cement stage, cement levels within the annulus where hard tagged using the steel cement tubing and confirmed using high-resolution temperature logs.

Once the 50-inch diameter steel casing was set through the unconsolidated to poorly consolidated low permeable sediments of the Hawthorn Group, the reverse-air drilling method was employed. This drilling method eliminates lost circulation problem associated with mud rotary drilling operations that generally occurs while though highly permeable zones within the Floridan aquifer. In addition, this drilling method permits water quality monitoring of the reverse-air returns during drilling operations to record change in water quality with depth; helps to identify the base of the underground source of drinking water and assists to determine existing sources of contamination within the drilled interval.

A 12¼-inch diameter pilot-hole was advanced from 975 to 2,100 feet bpl after installing the 50-inch diameter steel casing. A smaller diameter pilot-hole above this depth was not required because a Floridan aquifer production well (total depth of approximately 1,800 feet bpl) was constructed in close proximity to the injection well which provided sufficient information on the Surficial aquifer and Intermediate Confining unit at this location.

The following geophysical logs were conducted on the 12¼-inch diameter pilot-hole between 975 to 2,100 feet bpl: 4-arm caliper, natural gamma ray, dual-induction with shallow resistivity and spontaneous potential (SP), compensated sonic with variable density log (VDL). The production-type logs were conducted under both dynamic and static conditions and included, fluid conductivity, high resolution temperature, and impeller flow meter. A borehole video survey was completed under dynamic (pumped conditions).

The information provided by the lithologic samples and geophysical logs were used to determine intervals for drill stem testing; refer here as packer tests. A total of three (3) packer tests were then conducted between 1,641 and 1,928 feet bpl as follows:

- Packer Test #1 (1,911 to 1,928 feet bpl)
- Packer Test #2 (1,726 to 1,743 feet bpl)
- Packer Test #3 (1,641 to 1,658 feet bpl)

Based on the packer test results, geophysical logs, and analysis of formation samples, the setting depth of 1,975 feet bpl for the 40-inch diameter steel intermediate casing was recommended to and approved by the FDEP. This casing sealed off the overlying sources of drinking water found above a depth of 1,700 feet from the effects of continued drilling operations and adds another level of protection of the USDW during long-term operation of the DIW system

Based on the approved setting depth of 1,975 feet bpl, the nominal 12¼-inch diameter pilot-hole was back-plugged to 1,020 feet bpl (45 feet below the previously installed 50-inch diameter steel casing) using a 12% bentonite/cement grout. This was done to eliminate potential pathways for upward movement of water in close proximity of the 40-inch diameter casing.

Once the pilot-hole was back-plugged, a nominal 48-inch diameter bit was used to advance the borehole via reverse-air closed circulation method from 975 to 1,978 feet bpl. The nominal 48-inch diameter borehole was geophysically logged (4-arm caliper and natural gamma ray log) from 900 to 1,978 feet bpl and the 40-inch steel casing (ASTM A-139 Grade B) was installed to a depth of 1,975 feet bpl.

The 40-inch diameter steel casing was initially pressure grouted then fully cemented back to land surface in multiple stages using the tremie grouting method. After each cement stage, the elevation of the cement within the annulus was determined by a physical tag using the steel cement tubing and confirmed via a high resolution temperature logs.

After the 40-inch diameter steel casing was the fully cemented to surface a hydrostatic pressure test was successfully completed at 156 psi. During the 1-hour pressure test, the internal casing pressure stayed constant at 156 psi – meaning a zero loss in pressure which is well within the +/- 5% limit specified in 62-528 F.A.C.

Drilling operations resumed by advancing a 12¼-inch diameter pilot-hole from 1,975 (base of the 40-inch diameter steel casing) to 3,805 feet bpl. A total of four, 4-inch full-diameter rock cores were collected during this phase of pilot-hole drilling for further laboratory analysis, see **Table 2-1**. The results of the core descriptions and analyses are discussed in greater detail in **Section 4** of this report.

Table 2-1: IW-1 Core Summary

Core ID	Core Interval (feet bls)	Core Footage (feet)	Core Recovered (feet)	Percent Recovery
IW1-1	2,144 - 2,154	10	5.5	55.0
IW1-2	2,372 - 2,389	17	10.0	58.8
IW1-3	2,670 - 2,687	17	12.0	70.6
IW1-4	2,970 - 2,982	12	9.5	79.2

Once the nominal 12-inch diameter pilot-hole was advanced to the total depth of at 3,805 feet bpl, the following geophysical logs were conducted in the open-hole section from 1,975 to 3,505 feet bpl: 4-arm caliper, natural gamma ray, dual-induction with shallow resistivity and SP and compensated sonic with VDL. The production-type logs were conducted under both static and dynamic conditions and included fluid conductivity, high resolution temperature and impeller-type flow meter and a borehole video survey conducted under pumped conditions.

The geophysical and lithologic logs along with the drilling parameter data were reviewed and six (6) additional drill stem type packer tests (test nos. 4 to 9) were conducted within the borehole from 2,081 to 2,688 feet bpl as follows:

- Packer Test #4 (2,671 to 2,688 feet bpl)
- Packer Test #5 (2,546 to 2,563 feet bpl)
- Packer Test #6 (2,366 to 2,383 feet bpl)
- Packer Test #7 (2,181 to 2,197 feet bpl)
- Packer Test #8 (2,269 to 2,286 feet bpl)
- Packer Test #9 (2,081 to 2,097 feet bpl)

Packer tests were conducted to determine hydraulic and water quality data of the overlying confining interval to the proposed injection horizon and are discussed further in **Section 4** of this report.

Based on the results of packer tests, full-diameter cores, geophysical logs, and analysis of formation samples, a casing setting depth of 2,902 feet bpl for the 30-inch diameter steel injection casing was recommended to and approved by the FDEP. A cement bridge plug was installed at 2,968 feet bpl and the 12-¼ inch diameter pilot-hole was back-plugged to the base of the previously installed 40-inch diameter intermediate casing set at 1,975 feet bpl. The pilot-hole was back-plugged to eliminate open pathways along the 30-inch injection casing

Once the injection casing setting depth was approved by the FDEP, a nominal 38-inch diameter borehole was advanced from 1,975 to 2,905 feet bpl. The casing setting depth of 2,902 feet bpl was a selected based on the presence of a component rock unit at this depth which would provide a good annular seal during pressure grouting operations.

The nominal 38-inch diameter borehole was geophysical logged (4-caliper and natural gamma) before installing the 30-inch diameter steel injection casing (API 5L Grade B; 0.5 inch wall thickness) to a depth of 2,902 feet bpl. Once the 30-inch diameter casing was installed, a 4-arm caliper log was completed to ensure all joints were intact and to confirm the correct setting depth of 2,902 feet bpl, before cementing operation began.

The annulus of the 30-inch injection casing was initially pressure grouted from the total depth to 2,640 feet bpl. The remainder of the annulus was tremie grouted back to land surface in multiple cement stages. The elevation of each cement stage was identified by conducting a physical hard tag using the cement tubing and confirmed by conducting a high resolution temperature logs. After cementing operations were completed, a successful hydrostatic pressure test and cement bond log (CBL) were performed on the steel injection casing. In addition, a downhole video survey was conducted to visually inspect the individual welds and inside portion of the 30-inch diameter steel injection casing before the start of drilling a nominal 28-inch diameter borehole through the proposed injection horizon.

The Contractor installed the nominal 28-inch diameter drilling assembly and began to advance a 28-inch diameter borehole from the base of the 30-inch diameter injection casing at 2,902 to a total depth of 3,685 feet bpl. After reaching the specified depth of 3,685 feet bpl, the Contractor conducted a 4-arm caliper and natural gamma log within the completed injection horizon and through the 30-inch injection casing before installing the 20-inch outer diameter FRP injection tubing.

The 20-inch outer diameter Fiberglass Reinforced Pipe (Future Pipe Industry - 1500 psi series) was installed with a mechanical packer connected at its base, set to a depth of 2,895 feet bpl, approximately 7 feet above the base of the 30-inch diameter steel injection casing. Once the Fiberglass Reinforced Pipe (FRP) was landed to the specified depth of 2,895 feet bpl, a nominal 12-inch diameter inflatable packer was installed inside the 20-inch FRP injection tubing at a depth of 2,885 feet bpl which aided in conducting a hydrostatic pressure test before cementing operations began. After successfully completing the initial hydrostatic pressure test (at 108 psi which lost 0.5 psi over the 1-hour test), the Contractor completed the initial CBL log on the un-cement 20-inch diameter FRP injection liner. Once these tests were completed both of which showed good internal mechanical integrity, the FRP injection tubing was cemented back to land surface via the tremie method in multiple stages using up to 6% bentonite/ASTM Type II cement slurry. The elevation of the cement within the annular space after each cement stage was identified by conducting physical hard tags using the cement tubing and confirmed by high resolution temperature logs.

In an effort to allow additional time for the cement surrounding the 20-inch diameter FRP to gain higher compressive strength; the Contractor began pump development in the injection horizon. During pump development, flow rates and volumes were monitored, with a total of five (5) well volume of formation water removed injection horizon. Once the injection well was sufficiently purged, a NELAP certified laboratory obtained water samples for analysis of primary and secondary drinking water constituents. The results of these analyses are provided in **Appendix E-1** and will be discussed further in **Section 4** of this report.

After water quality sampling was complete, additional tests were completed as per the FDEP-issued construction permit associated with the alternate design criteria of this injection well. First, the Contractor conducted a video survey to visually inspect the couplings and inside portion of the 20-inch outer diameter FRP injection tubing. Next, a cement bond log (CBL) was performed on the FRP injection tubing, which overall showed a good cement bond. Finally, a hydrostatic pressure test (conducted at 153 psi) was successfully completed and witnessed by FDEP Staff. During the 1-hour pressure test conducted at 153 psi, the internal casing pressure decreased 3.0 psi to 150 psi, which is within the 5 % testing limits. The results of these tests confirmed the internal mechanical integrity of IW-1. The well construction phase of IW-1 was completed on June 11, 2011 based on the successful completion of all permit related testing requirements.

After well construction was completed the wellhead was installed. On September 9, 2011, Mechanical Integrity Test (MIT) was completed. The MIT consisted of a high-resolution temperature log and radioactive tracer survey (RTS) which successfully completed indicating internal and external mechanical integrity of this alternate design Class I injection well. Testing operations and results of this MIT are discussed further in **Section 5** of this report.

Following the RTS, an interim injection test plan was submitted to and approved by the FDEP. On October 5, 2011, the IW-1 wellhead piping was connected to the onsite Floridan production well identified as PW-4 where uncontaminated brackish formation water from the Upper Floridan aquifer and the Avon Park Permeable Zone was used to conduct a 12-hour injection test at a rate of 4.0 mgd. Temporary piping, pump and instrumentation (pressure transducer and flow meter) were installed to monitor and record wellhead pressure and flow rates during the injection test. The results of the injection test are also discussed further in **Section 5** of this report. The final well head, concrete pad, mechanical components and instrumentation and controls were completed by ENCORE under a separate contract from October 2011 to June 2012. A Well Completion Diagram of IW-1 is presented as **Figure 1-3** in **Section 1**. A wellhead diagram and a well pad design of IW-1 are presented in **Figure 2-3**.

Deep Injection Well IW-2

Drilling of deep injection well IW-2 began January 29, 2011 approximately 2 weeks after the start of constructing IW-1. The Contractor utilized 2 separate drill rigs to complete the injection well and dual-zone monitor wells within the specified 9-month contract period.

Mud rotary drilling techniques were used to advance the borehole to a depth of 980 feet bpl. Closed circulation reverse-air drilling was used to advance various diameter boreholes from 980 to 3,810 feet bpl and to collect representative formation water samples. A summary of well construction and testing activities can be found in **Appendix B-1**. Drift indicator surveys were taken every 90 feet during pilot-hole drilling and borehole reaming of IW-2 to ensure that the various diameter boreholes were plumb. The results of these deviation surveys for IW-2 are summarized in **Appendix D-4** and graphically shown in **Figure 2-4**.

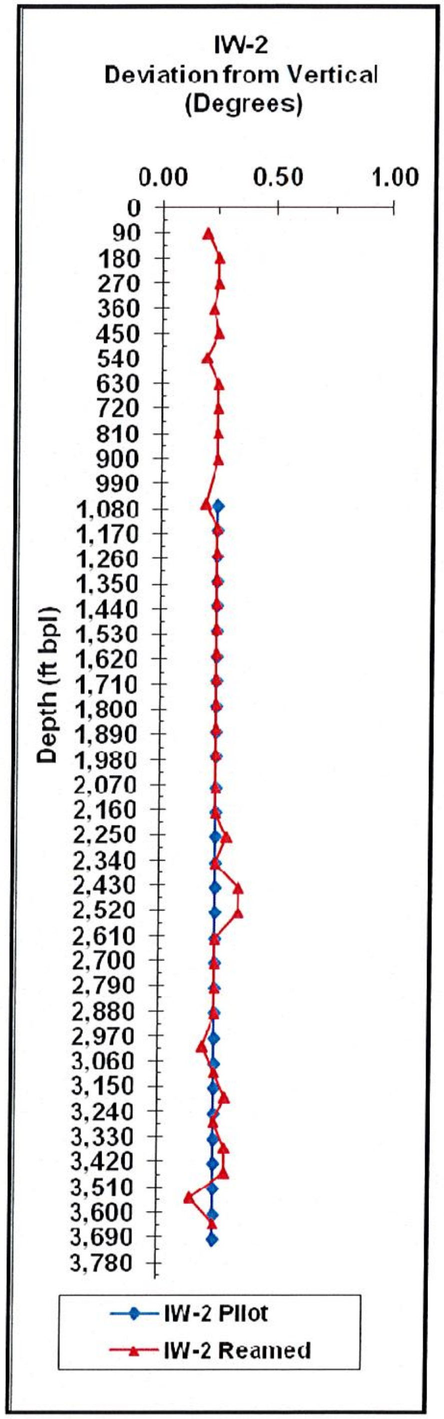


Figure 2-4: Deviation from Vertical Summary for IW-2

As with IW-1, the drilling schedule and casing setting depths were designed to conform to the hydrogeological features observed at the site and to meet regulatory agency requirements. Geologic formation samples were

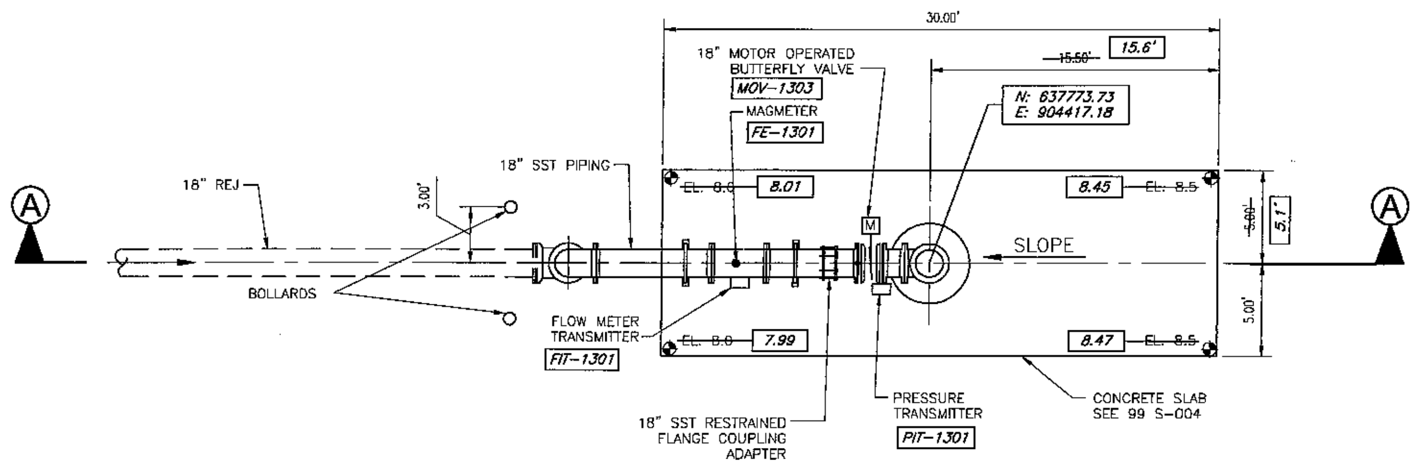
LEGEND:

x 8.0 EXISTING ELEVATION

EL. 9.2 PROPOSED ELEVATION

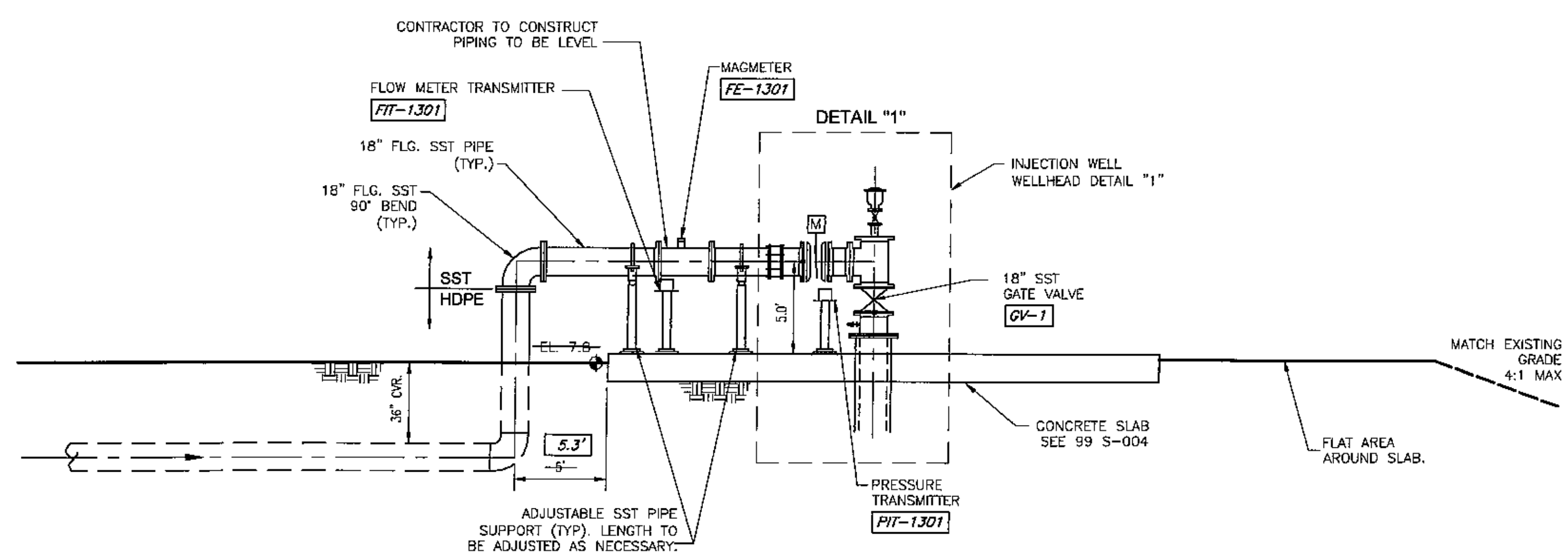
NOTES

1. CONCRETE SHALL SLOPE AWAY FROM INJECTION WELL & TOWARDS THE SOUTHEAST END OF SLAB @ MIN. 1/8" PER FOOT.
2. ALL PIPING AND FITTINGS ABOVE PAD LEVEL SHALL BE TYPE 316L STAINLESS STEEL (SST) FLANGED (FLG). UNDERGROUND DISCHARGE PIPING 4" DIA. & LARGER SHALL BE HDPE.
3. MAINTAIN 7.5' UPSTREAM AND 4.5' DOWNSTREAM OF CLEARANCE INJECTION WELL FLOW METER.
4. ALL BURIED PIPING SHALL BE RESTRAINED JOINT.
5. ALL REINFORCING BARS TO BE #5 UNLESS OTHERWISE NOTED.
6. SST 316 STEEL COMPONENTS SHALL BE SCHEDULE 40.
7. ALL WELL CASING DIAMETERS INDICATED ARE CASING OUTSIDE DIAMETERS (O.D.).
8. ALL CEMENT GROUT SHALL BE ASTM C-150 TYPE II SULFATE RESISTANT CEMENT.
9. *ELEVATIONS ARE RELATIVE TO NATIONAL GEODETIC VERTICAL DATUM OF 1929.*



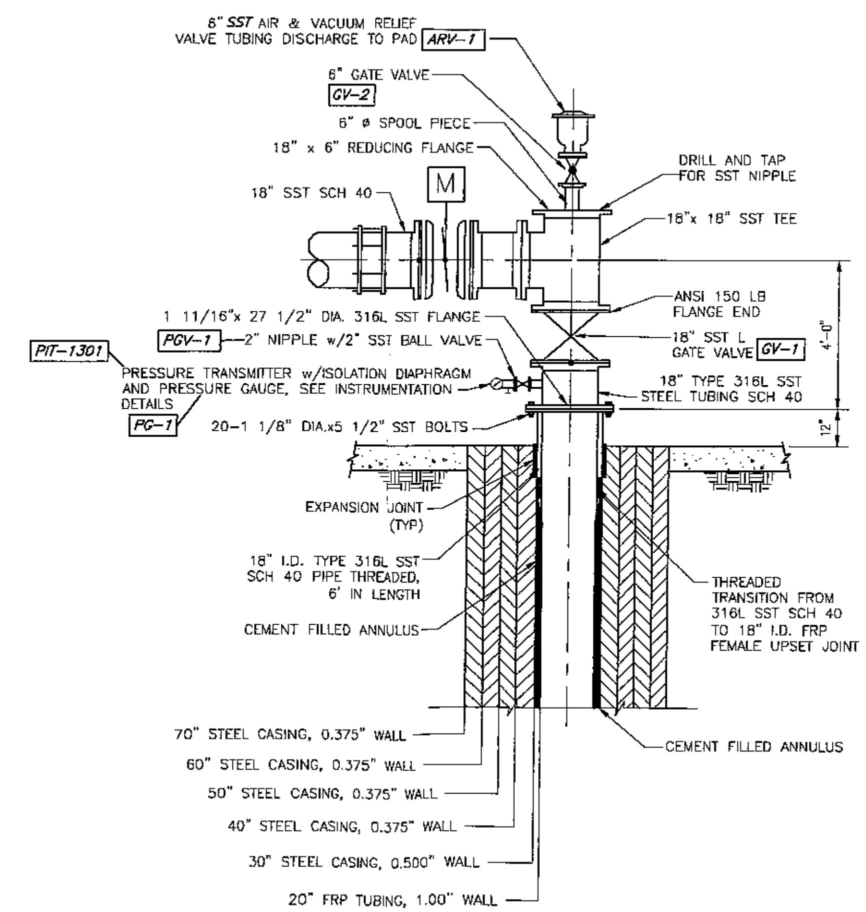
DEEP INJECTION WELL #1 PLAN

N.T.S.



SECTION "A"

N.T.S.



DEEP INJECTION WELL #1 WELLHEAD DETAIL "1"

N.T.S.

MARK	DATE	MADE BY	CHECKED	DESCRIPTION

REVISIONS

AECOM

AECOM USA, INC.
3550 S.W. CORPORATE PARKWAY
PALM CITY, FL 34990
(772) 286-3883
CERTIFICATE NO. 38

TOWN OF DAVIE FLORIDA
WATER TREATMENT AND WATER RECLAMATION FACILITY

DEEP INJECTION WELL NO.1 PLAN SECTIONS & DETAILS

MECHANICAL PROCESS

PROJECT NO:	60096581
CAD DWG FILE:	_13 D-101
DESIGNED BY:	NWB
DRAWN BY:	DLP
DEPT CHECK:	LAL
PROJ CHECK:	B. DALY
DATE:	NOVEMBER 2010
SCALE:	AS NOTED

FIGURE 2-3

ANSI D - 4-Dec-12

collected and described at 10-foot intervals during drilling activities. Data collected during construction activities formation samples [cuttings], water samples, 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. Approval from the FDEP of the recommended casing setting depths was obtained prior to installing the 40-inch diameter steel intermediate and 30-inch diameter steel injection casings for IW-2.

Similar to IW-1, the second injection well (IW-2) was constructed using five concentric steel casings (70-, 60-, 50-, 40-, and 30-inch outside diameters) and one fiberglass reinforced pipe (20-inch OD and 17.98-inch ID). The cementing program was specifically tailored for each casing installed. Casing installation summaries including setting depths are presented in **Appendix D-5.** Casing cement summaries including the types and quantities of cement used for the construction of IW-2 are summarized in **Appendix D-6**. Copies of casing mill certificates for each casing used in the construction of IW-2 are presented in **Appendix D-10.**

Construction of IW-2 began by advancing a nominal 74-inch diameter borehole, via mud-rotary drilling, to a depth of 47 feet below pad level (bpl). The 70-inch diameter steel pit casing was installed to a depth of 45 feet bpl and fully cemented to surface using ASTM Type II cement. A nominal 68-inch diameter borehole, centered inside the 70-inch diameter steel pit casing, was drilled to a depth of 254 feet bpl. Geophysical logging (4-arm caliper and natural gamma ray) was conducted in the nominal 68-inch diameter borehole prior to installing the 60-inch diameter steel surface casing (ASTM A-139 Grade B) to a depth of 250 ft bpl. The 60-inch diameter surface casing was pressure grouted using 441 barrels of ASTM Type II cement with cement returns observed at land surface.

A nominal 58-inch diameter borehole was then advanced from base of the 60-inch diameter casing set at 250 feet bpl to 980 feet bpl via the mud rotary method. Geophysical logging (4-arm caliper and natural gamma) was then conducted, and the 50-inch diameter steel casing (ASTM A-139 Grade B) installed to a depth of 975 feet bpl. The 50-inch diameter casing was set into the carbonate section of the Floridan aquifer and initially pressure grouted then tremie grouted in various cement stages back to land surface. After pumping each cement stage, cement levels within the annulus where hard tagged using the steel cement tubing and confirmed using high-resolution temperature logs.

Once the 50-inch diameter casing was set through the unconsolidated to poorly consolidated sediments of the Hawthorn Group, the reverse-air drilling circulation method was used to avoid drilling problems related to lost circulation associated with mud rotary drilling operations though permeable carbonate sections within the Floridan aquifer. In addition, the reverse-air method allowed for the monitoring water quality with depth during drilling operations to the total depth of the injection well and to assist in identifying the base of the underground source of drinking water and to determine if sources of contamination exist.

A 12¼-inch diameter pilot-hole was advanced from 975 to 2,100 feet bpl. Once the pilot-hole was completed to 2,100, the following geophysical logs were conducted: a 4-arm caliper, natural gamma ray, dual-induction with shallow resistivity and spontaneous potential (SP), compensated sonic with variable density log (VDL). The production-type logs were conducted under both dynamic and static conditions and included, fluid conductivity, high resolution temperature, and impeller-type flow meter. A borehole video survey was completed under dynamic (pumped) conditions.

The information provided by the lithologic samples and geophysical logs were used to determine test interval for packer tests. A total of four (4) pack tests were then conducted between 1,661 and 2,003 feet bpl as follows:

- Packer Test No.1 (1,986 to 2,003 feet bpl)
- Packer Test No.2 (1,711 to 1,728 feet bpl)
- Packer Test No.3 (1,661 to 1,678 feet bpl)
- Packer Test No.4 (1,821 to 1,838 feet bpl)

Based on the results of the packer tests and geophysical logs, and analysis of formation samples, the setting depth for the 40-inch diameter steel intermediate casing of 1,990 feet bpl was recommended to and approved by the FDEP.

Based on the approved setting depth of 1,990 feet bpl, the nominal 12¼-inch diameter pilot-hole was back-plugged to 1,019 feet bpl (44 feet below the previously installed 50-inch diameter steel casing) using a 12% bentonite/cement grout. This was done to eliminate potential pathways for fluid migration near the intermediate casing if the reamed borehole was offset from the original pilot-hole.

Once the pilot-hole was back-plugged, a nominal 48-inch diameter bit was used to advance the borehole via reverse-air closed circulation method from 975 to 1,994 feet bpl. The nominal 48-inch diameter borehole was geophysically logged (4-arm caliper and natural gamma ray log) from 975 to 1,994 feet bpl after which the 40-inch diameter steel casing (ASTM A-139 Grade B) was installed to a depth of 1,990 feet bpl, 15 deeper than in IW-1.

The 40-inch diameter steel casing was initially pressure grouted then fully cemented to land surface in multiple stages using the tremie grouting method. After each cement stage, the elevation of the cement within the annular space was determined by a physical tag using steel cement tubing and confirmed via a high resolution temperature log

A hydrostatic pressure test conducted at 154 psi was successfully completed on the fully cemented 40-inch diameter steel casing. During the 1-hour pressure test, the internal casing pressure declined 5.5 psi to 148.5 psi. The 5.5 psi reduction in pressure during the test represents a 3.5% decline from the initial test pressure of 154 psi and within the 5% limit specified in the construction permit.

Drilling operations resumed by advancing a 12¼-inch diameter pilot-hole from 1,990 (base of the 40-inch diameter casing) to 3,810 feet bpl. A total of five, 4-inch full-diameter rock cores were collected during this phase of pilot-hole drilling, see **Table 2-2**. Between cored intervals, the pilot-hole was advanced with a 12¼-inch diameter tri-cone drill bit. The results of the core analyses and descriptions are discussed in greater detail in **Section 4** of this report.

Table 2-2: IW-2 Core Summary

Core ID	Core Interval (feet bls)	Core Footage (feet)	Core Recovered (feet)	Percent Recovery
IW2-1	2,353 - 2,370	17	16.20	95.3
IW2-2	2,414 - 2,429	15	14.70	98.0
IW2-3	2,477 - 2,492	15	11.25	75.0
IW2-4	2,710 - 2,722	12	8.75	72.9
IW2-5	2,890 - 2,905	15	13.25	88.3

Once the nominal 12-inch diameter pilot-hole was advanced to its total depth, geophysical logs were conducted in the open-hole section from 1,990 to 3,810 feet bpl. The suite of geophysical logs completed within this interval consisted of a 4-arm caliper, natural gamma ray, dual-induction with shallow resistivity and SP and compensated sonic with VDL. The production-type logs were conducted under both static and dynamic conditions and included fluid conductivity, high resolution temperature and impeller-type flow meter and a borehole video survey, which was conducted under pumped conditions.

The geophysical and lithologic logs along with the drilling parameter data (e.g. weight on bit, rotary speed, etc) were reviewed and six (6) additional drill stem type packer tests (test nos. 5 to 10) were conducted within the borehole from 2,007 to 2,916 feet bpl as follows:

- Packer Test No.5 (2,007 to 2,023 feet bpl)
- Packer Test No.6 (2,196 to 2,213 feet bpl)
- Packer Test No.7 (2,296 to 2,313 feet bpl)
- Packer Test No.8 (2,409 to 2,425 feet bpl)
- Packer Test No.9 (2,621 to 2,638 feet bpl)
- Packer Test No.10 (2,899 to 2,916 feet bpl)

Packer testing operations were conducted to determine hydraulic and water quality data of the overlying confining interval to the proposed injection horizon and are discussed further in **Section 4** of this report.

Upon completion of packer test no. 10, a cement bridge plug was installed at 2,946 feet bpl and the 12-¼ inch diameter pilot-hole was back-plugged to a depth of 2,146 feet bpl. Cementing the pilot-hole was discontinued at this depth because the interval from 2,100 to 2,150 feet in depth was being considered as the completion interval for the lower monitor of the dual-zone monitor well - MW-1.

Based on the results of packer tests, full-diameter cores, geophysical logs, and analysis of formation samples, a casing setting depth of 2,925 feet bpl for the 30-inch diameter API 5L steel injection casing was recommended to and approved by the FDEP.

During the FDEP review and approval process of the casing setting depth recommendation, of 30-inch injection casing, the Contractor continued to advance the nominal 38-inch diameter borehole from a depth of 1,990 feet. Upon FDEP approval, the nominal 38-inch borehole was advanced to the recommend setting depth of 2,925 feet bpl. The casing setting depth of 2,925 feet bpl was a selected based on a component rock unit located at this depth which would provide a good seal for cementing purposes.

The nominal 38-inch diameter borehole was geophysically logged (4-caliper and natural gamma) before installing the 30-inch diameter steel injection casing (API 5L Grade B; 0.5

inch wall thickness) to a depth of 2,925 feet bpl. Once the 30-inch diameter casing was installed, a 4-arm caliper log was completed to ensure all joints were intact and to confirm the correct setting depth of 2,925 feet bpl.

The annulus of the 30-inch diameter injection casing was pressure grouted then a hard tagged completed, which identified the elevation of cement at a depth of 2,703 feet. The Contractor then completed a cement bond log of the pressure grouted and un-cemented portion of the 30-inch diameter steel injection casing. Next, a hydrostatic casing pressure test was successfully completed at 100 psi. These efforts were part of a preliminary verification process to ensure a proper seal at the base was obtained and that the alternate design material consisting of 30-inch diameter steel (API 5L – non seamless) injection casing had internal mechanical integrity before fully cementing it to surface.

Once the verification process was completed, the Contractor began to tremie grout the 30-inch diameter injection casing to surface. The elevation of each cement stage was identified by conducting a physical hard tag and confirmed by high resolution temperature logs. After cementing the casing to a depth of 400 feet bpl and allowing the cement to cure for 40 hours a cement bond log (CBL) was completed on the 30-inch diameter steel injection casing.

The Contractor continued to flush the 30-inch diameter casing with water to cool the casing as result of cementing and to ensure a consistent fluid temperature within the casing before conducting the hydrostatic pressure test. Once the fluids were circulated; a pressure test was successfully completed at conducted at 164 psi. Over the 1-hour test period, pressure within the 30-inch casing declined 4.5 psi to a final pressure reading of 159.5 psi. The 4.5 psi decrease in hydrostatic pressure equates to 2.8 % which is within the 5% test limit. The remaining 400 feet of the annulus was then tremie grouted to land surface during Cement Stage No. 12.

The Contractor waited the required 24-hour after cementing the annulus of the 30-inch diameter injection casing to land surface, then began to install the drilling assembly to advance a 28-inch diameter borehole from the base of the 30-inch diameter injection casing at 2,925 feet bpl. After 23 days of continuous drilling operations, the Contractor completed the nominal 28-inch diameter borehole through the injection horizon to a total depth of 3,800 feet bpl.

After reaching the specified total depth of 3,800 feet bpl, the Contractor conducted a video survey to visually inspect the individual welds and inside portion of the 30-inch diameter steel injection casing with no anomalies observed. Next a 4-arm caliper and natural gamma log was conducted within the completed injection horizon and through the 30-inch injection casing before the 20-inch FRP injection tubing was installed.

The 20-inch outer diameter Fiberglass Reinforced Pipe (Future Pipe Industry - 1500 psi series) injection tubing was installed with a mechanical packer connected at its base, set to a depth of 2,917 feet bpl, approximately 8 feet above the base of the 30-inch diameter steel injection casing. Once the 20-inch outer diameter FRP injection tubing was landed, an inflatable packer was installed inside the FRP at 2,985 feet bpl to conduct a hydrostatic casing pressure test before the FRP injection tubing was cemented. The initial hydrostatic pressure test was successfully completed at 157 psi with no loss in pressure over the 1-hour test period along with the initial CBL log on the un-cemented 20-inch FRP injection tubing. Once these tests were completed both of which showed good internal mechanical integrity, the 20-inch FRP injection tubing was cemented to land surface via the tremie method in multiple stages using up to 8% bentonite/ASTM Type II cement slurry. The elevation of the cement within the annulus, after each cement stage, was identified by conducting a physical hard tag and confirmed by a high resolution temperature log. In an effort to allow additional time for the cement surrounding the 20-inch diameter FRP injection tubing to gain higher compressive strength; the Contractor did no further work due to the July 4th holiday

After the July 4th holiday, a cement bond log (CBL) was performed on the FRP injection tubing, which overall showed a good cement bond. The Contractor began to flush the 20-inch FRP injection tubing with water to ensure a consistent fluid temperature within the casing before conducting the hydrostatic pressure test. Once the fluids were circulated, an inflatable packer was installed inside the 20-inch FRP injection tubing at a depth of 2,892 feet bpl. A final hydrostatic pressure test was successfully completed at 152 psi which was witnessed by FDEP Staff. During the 1-hour pressure test, the internal hydrostatic pressure of the 20-inch FRP injection tubing decreased 5.0 psi to 147 psi, which is within the 5 percent testing limits. The results of these tests confirmed the internal mechanical integrity of IW-2.

Following these tests, the remaining section of the annulus of the 20-inch outer diameter FRP injection tubing was cemented to land surface. After fully cementing the 20-inch outer diameter injection tubing to surface, the IW-2 was pumped developed to obtain water samples for analysis. During pump development flow rates and volumes were monitored, with a total of 5 well volume of formation water removed. Once the injection well was sufficiently purged, staff from a NELAP certified laboratory obtained water samples from the completed injection horizon for analysis of primary and secondary drinking water constituents. The results of these analyses are provided in **Appendix E-2** and discussed further in **Section 4** of this report.

After sampling the injection well to determine the background water quality of the injection horizon, the Contractor conducted a final video survey to visually inspect the joints and inside portion of the 20-inch diameter FRP injection tubing and the nominal 28-inch diameter injection horizon. The well construction phase of IW-2 was completed on July 7, 2011

After the well construction component of IW-2 was completed the wellhead was installed. On September 13, 2011 a Mechanical Integrity Test was conducted that consisted of a temperature log and radioactive tracer survey (RTS). The results of these surveys indicated external mechanical integrity of this alternate design Class I injection well. Testing operations and results of the RTS are discussed further in **Section 5** of this report.

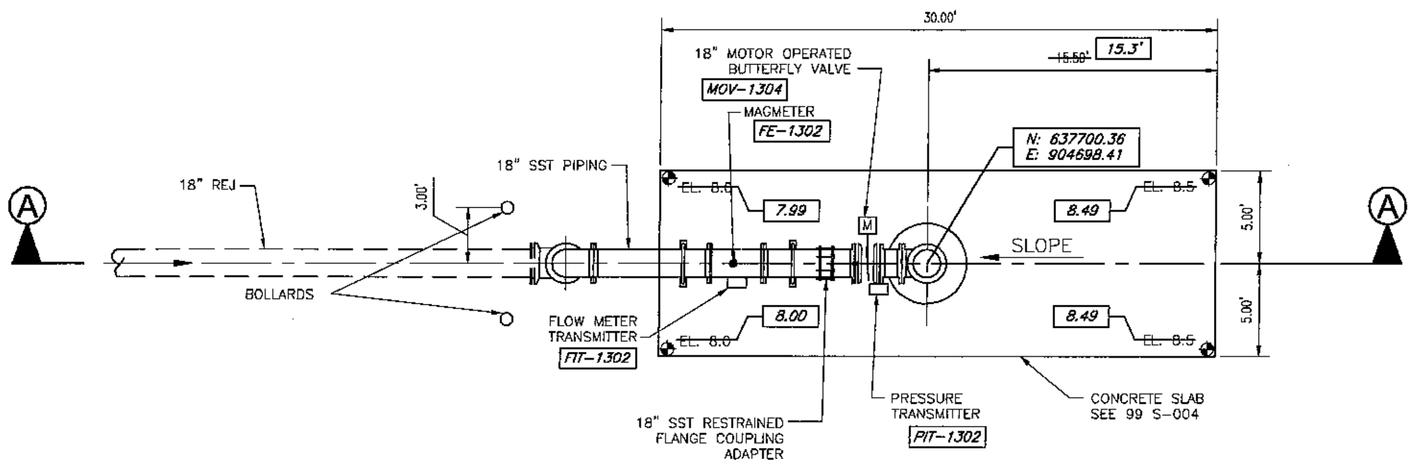
The final well head, concrete pad, mechanical components and instrumentation and controls were completed by ENCORE under a separate contract from October 2011 to September 2012. A Well Completion Diagram of IW-2 is presented as **Figure 1-4** in **Section 1**. A wellhead diagram and a well pad design of IW-2 are presented in **Figure 2-5**.

NOTES

1. CONCRETE SHALL SLOPE AWAY FROM INJECTION WELL & TOWARDS THE SOUTHEAST END OF SLAB @ MIN. 1/8" PER FOOT.
2. ALL PIPING AND FITTINGS ABOVE PAD LEVEL SHALL BE TYPE 316L STAINLESS STEEL (SST) FLANGED (FLG). UNDERGROUND DISCHARGE PIPING 4" DIA. & LARGER SHALL BE HDPE.
3. MAINTAIN 7.5' UPSTREAM AND 4.5' DOWNSTREAM OF CLEARANCE INJECTION WELL FLOW METER.
4. ALL BURIED PIPING SHALL BE RESTRAINED JOINT.
5. ALL REINFORCING BARS TO BE #5 UNLESS OTHERWISE NOTED.
6. SST 316 STEEL COMPONENTS SHALL BE SCHEDULE 40.
7. ALL WELL CASING DIAMETERS INDICATED ARE CASING OUTSIDE DIAMETERS (O.D.).
8. ALL CEMENT GROUT SHALL BE ASTM C-150 TYPE II SULFATE RESISTANT CEMENT.
9. *ELEVATIONS ARE RELATIVE TO NATIONAL GEODETIC VERTICAL DATUM OF 1929.*

LEGEND:

x 8.0	EXISTING ELEVATION
EL. 9.2	PROPOSED ELEVATION



DEEP INJECTION WELL #2 PLAN

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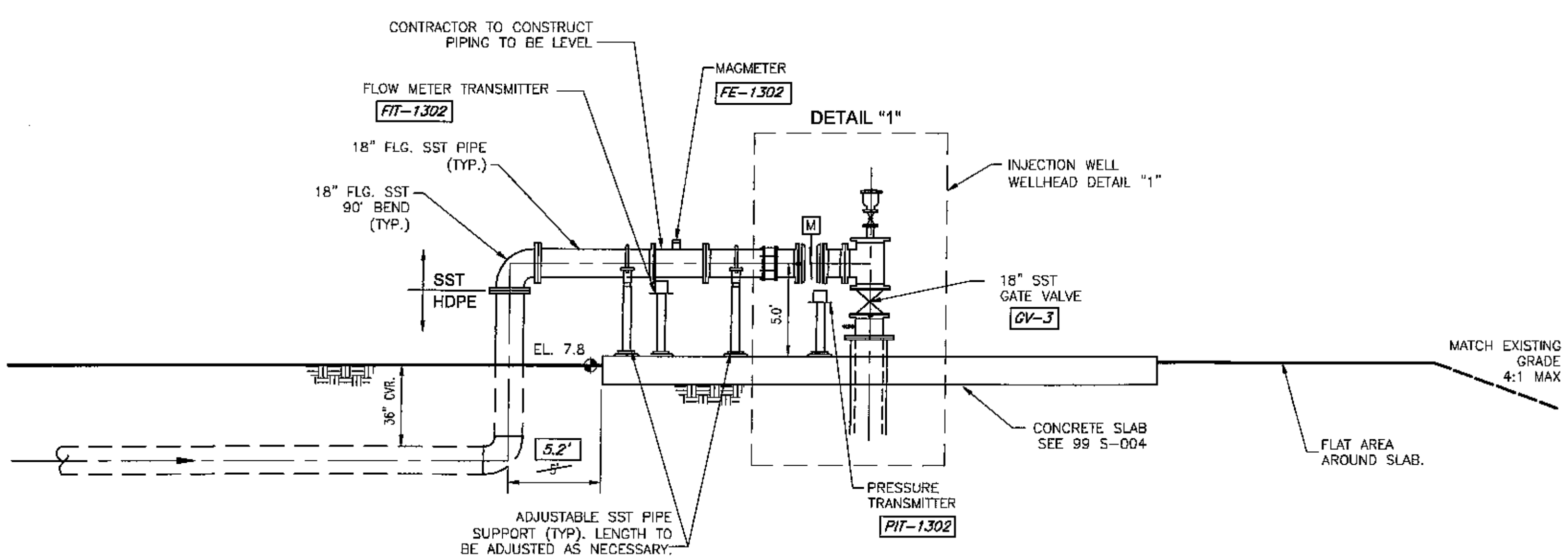

SECTION "A"

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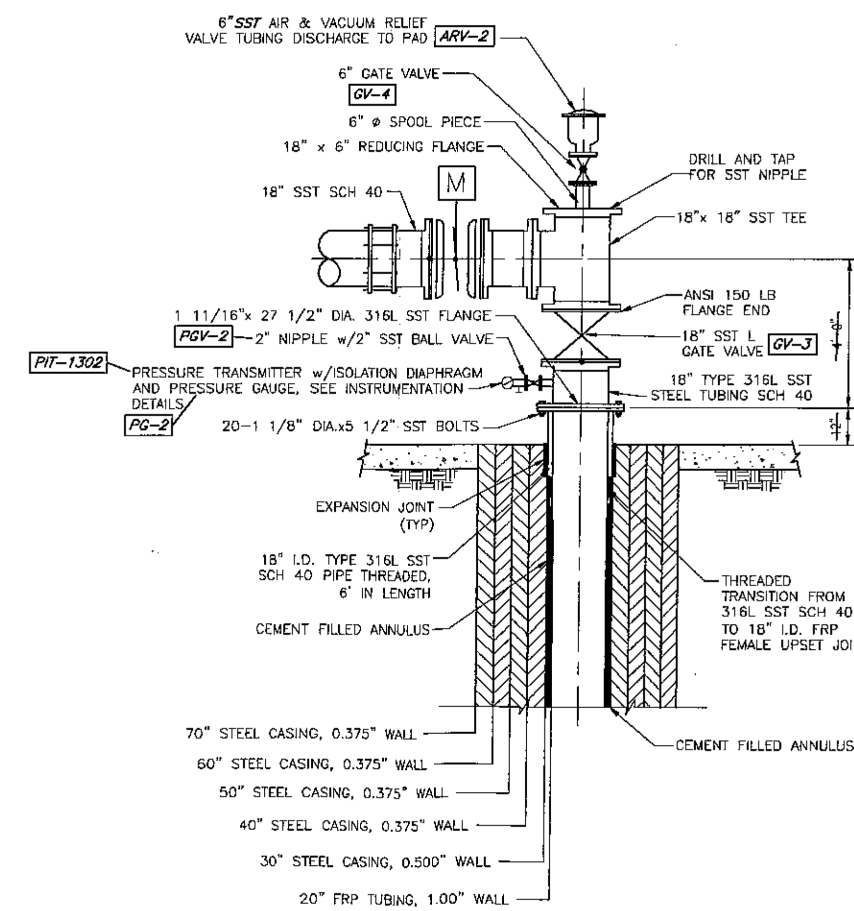


DEEP INJECTION WELL #2 WELLHEAD DETAIL "1"

N.T.S.

AECOM

AECOM USA, INC.
3550 S.W. CORPORATE PARKWAY
PALM CITY, FL 34990
(772) 286-3883
CERTIFICATE NO. 38

TOWN OF DAVIE FLORIDA
WATER TREATMENT AND WATER RECLAMATION FACILITY

DEEP INJECTION WELL NO. 2 - PLAN SECTIONS & DETAILS

MECHANICAL PROCESS

PROJECT NO:	60096591
CAD DWG FILE:	_13 D-102
DESIGNED BY:	MWB
DRAWN BY:	DLP
DEPT CHECK:	LAL
PROJ CHECK:	B. DALY
DATE:	NOVEMBER 2010
SCALE:	AS NOTED

FIGURE 2-5

Dual-Zone Monitor Well MW-1

The dual-zone monitor well identified as MW-1 was constructed in accordance with the FDEP-issued construction permit to monitor water levels and quality long-term to determine the occurrence of vertical migration of injected fluids into units above the injection horizon at its potential effects on the USDW.

Drilling operation related to MW-1 began June 11, 2011. Mud rotary drilling techniques were used to advance the borehole from land surface to a depth of 975 feet bpl. Closed & open circulation reverse-air drilling was used to advance the borehole from 975 to 2,000 feet bpl to collect representative formation water samples and to negate loss circulation horizons. A summary of well construction and testing activities for MW-1 can be found in **Appendix B-1**. Drift indicator surveys were taken every 90 feet during pilot-hole drilling and borehole reaming of MW-1 to ensure that the individual boreholes were relatively plumb. The results of these deviation surveys for MW-1 are summarized in **Appendix D-7** and illustrated in **Figure 2-6**.

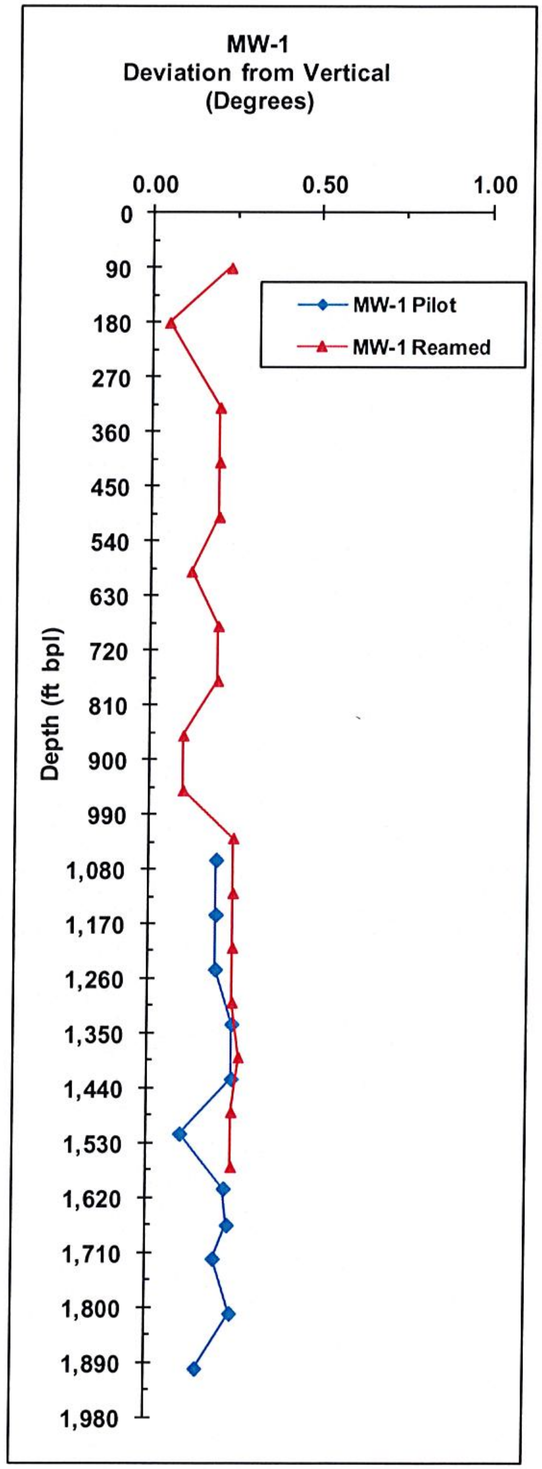


Figure 2-6: Deviation from Vertical Summary for MW-1

The drilling sequence and casing setting depths were designed to conform to the hydrogeological conditions observed at the site and to meet regulatory agency requirements. Geologic formation samples were collected and described at 10-foot intervals during drilling operations. Data collected during construction activities included formation samples [cuttings], water samples, packer tests, and geophysical logs were evaluated to provide information regarding the geologic formations encountered and to assist in selection of the casing setting depths. The recommended casing setting depths by AECOM were provide to and approved by FDEP prior to installing the upper and lower monitor casings of MW-1.

The dual-zone monitor well identified as MW-1 was constructed using four concentric steel casings (44-, 34-, 24-, and 16-inch outside diameters) and one fiberglass reinforced pipe ($6^5/_8$-inch OD and 6-inch ID) of various lengths. The cementing program was specifically tailored for each casing installed. Casing installation summaries including setting depths are presented in **Appendix D-8.** Casing cement summaries including the types and quantities of cement used for the construction of MW-1 are summarized in **Appendix D-9**. Copies of casing mill certificates for each casings used during to construct MW-1 are presented in **Appendix D-10**.

Construction of MW-1 began by advancing a nominal 48-inch diameter borehole via closed circulation mud-rotary drilling to a depth of 40 feet below pad level (bpl), installing the 44-inch diameter steel pit casing(ASTM A-139 Grade B) to a depth of 38 feet bpl and cementing it to land surface by the pressure grouting method.

A nominal 42-inch diameter borehole, centered inside the 44-inch diameter casing was drilled to a depth of 235 feet bpl. Geophysical logging (4-arm caliper and natural gamma ray) was conducted prior to installing the 34-inch diameter steel surface casing (ASTM A-139 Grade B) to a depth of 230 ft bpl. The 34-inch diameter steel surface casing was pressure grouted to surface using ASTM Type II neat cement.

After waiting 24-hours for the annular cement to cure and gain sufficient compressive strength, the Contractor installed a nominal 32-inch diameter drilling assembly and began to advance the borehole from 230 feet bpl. Once the nominal 32-inch borehole was completed to a total to 979 feet bpl, a 4-arm caliper and natural gamma ray logs were conducted with the 24-inch diameter steel casing (ASTM A-139 Grade B) installed to a depth of 975 feet bpl. The 24-inch diameter casing was pressure grouted to land surface in single stage using 475 barrels of 4% bentonite | Type II cement slurry.

Drilling operations resumed by advancing a 12¼-inch diameter pilot-hole from 975 feet bpl via the open circulation reverse-air drilling method. Once the nominal 12-inch pilot-hole was completed to a depth of 1,700 feet bpl, the following geophysical logs were conducted: a 4-arm caliper, natural gamma ray, dual-induction with shallow resistivity and SP, and compensated sonic with VDL. The production-type logs were conducted under both static and dynamic conditions and included fluid resistivity, high-resolution temperature and impeller-type flow meter. The borehole video survey of the open-hole section was conducted under pumped conditions.

Drill stem packer testing (packer tests nos. 1 to 3) were then conducted within the nominal 12-inch diameter pilot-hole between 1,410 feet bpl and 1,672 feet bpl as follows:

- Packer Test No.1 (1,655 to 1,672 feet bpl)
- Packer Test No.2 (1,580 to 1,597 feet bpl)
- Packer Test No.3 (1,410 to 1,427 feet bpl)

Based on the results of the packer tests, geophysical logging, and analysis of formation samples, a casing setting depth for the 16-inch diameter steel casing of 1,630 feet bpl was recommended to and approved by the FDEP. The results of these packer tests are discussed further in **Section 4** of this report.

Once the 16-inch diameter casing setting depth was approved by the FDEP, the lower portion the nominal 12-inch diameter pilot hole was back-filled with gravel from 1,580 to 1,700 feet bpl as a portion of this interval will serve as part of the upper monitor zone for MW-1. After the pilot-hole was back-plugged from 1,580 feet bpl to the base of the previously installed 24-inch diameter casing, a nominal 22-inch diameter borehole was advanced from 975 feet bpl to the top of the upper monitor interval at 1,633 feet bpl. A 4-arm caliper and natural gamma log was conducted to verify that the depth and geometry of the drilled section were accurate.

The 16-inch diameter (API - 5L Grade B; 0.5-inch wall thickness) seamless steel casing was installed to the FDEP-approved casing setting depth of 1,630 feet bpl and cemented in place to 276 feet bpl. The Contractor waited 24 hours before conducting a cement bond log to allow the cement grout to gain sufficient compressive strength. Several issues were encountered while conducting the CBL using two separate types of logging tools. While these issues were being resolved, a hydrostatic pressure test was conduct on the 16-inch diameter steel casing at 108 psi. During the 1-hour test period, pressure decreased 3.5 psi or 3.24% from the initial test pressure, which is within the 5 % test limit. Following the hydrostatic pressure test, the Contactor successfully completed the CBL. The successful completion of the casing pressure test and CBL helped to verify the internal and external mechanical integrity of the installed 16-inch diameter steel casing.

Following the installation and testing components of the 16-inch steel casing, a nominal 12-inch diameter pilot-hole was advanced from 1,630 to 2,002 feet bpl and geophysically logged upon completion. The geophysical logs conducted within this interval included: a 4-arm caliper/natural gamma ray, dual-induction, compensated sonic, fluid resistivity, temperature, flow meter, and a video survey.

After geophysical logging was completed to 2,000 feet bpl, two (2) additional packer tests (packer tests no. 4 & 5) were completed between 1,741 and 2,000 feet bpl as follows:

- Packer Test No.4 (1,952 to 2,000 feet bpl)
- Packer Test No.5 (1,741 to 1,758 feet bpl)

Based on the lithologic, geophysical and water quality data, the proposed lower monitor zone interval of 1,960 to 2,000 feet bpl was submitted to and approved by the FDEP. Upon gaining concurrence from FDEP relate to the proposed lower monitor interval of 1,960 to 2,002 feet bpl, the 6 5/8-inch outer diameter fiberglass reinforced pipe (Future Pipe 2,500 Series Red Box) with cement packer was installed to depth of 1,960 feet and cemented in place to a depth of 1,660 feet bpl. The top of the cement at 1,660 feet bpl serves as the base of the upper monitor zone. A cement bond log on the 6 5/8-inch diameter fiberglass reinforced pipe and successful casing pressure test (at 105 psi with 0.5 psi decrease) were completed. The CBL and casing pressure test verified the internal and external mechanical integrity of the 6 5/8-inch outer diameter FRP. Once these tests were completed, a 4-arm caliper, fluid resistivity and temperature logs, and a video survey were conducted thru the lower monitor zone and 6-inch FRP monitor tubing.

The two monitor intervals were pump developed displacing a minimum of five (5) well volumes before background water quality samples were collected for analysis of primary and secondary drinking water constituents. The results of these water quality analyses are presented in **Appendix E-3** and discussed further in **Section 4.**

The dual-zone monitor well was completed in two distinct zones within the Floridan aquifer system one above and one below the base of the USDW. The upper zone (MW-1U) monitors an interval from 1,630 to 1,660 feet bpl within a uniformly porous interval. The specific conductance reading and laboratory-determined total dissolved solids concentration for MW-1U were 10,900 micro-Siemens and 6,588 mg/L, respectively. The lower zone (MW-1L) monitors an interval from 1,960 to 2,000 feet bpl, located within the first transmissive zone below the base of the USDW in accordance 62-528, FAC. The specific conductance and laboratory-determined total dissolved solids concentration for MW-1L were 51,200 micro-Siemens and 38,933 mg/L, respectively.

The final well head, concrete pad, mechanical and instrumentation and controls were completed by YBI and Encore Construction Co. from August, 2011 to March 2012, under separate contracts. The upper monitor zone was completed with a centrifugal sample pump and submersible transducer set 30 feet below top of flange. A 1-horsepower submersible pump was installed 90 feet below the flange in the lower monitor zone with a submersible pressure transducer set to a depth of 60 feet bpl.

A Well Completion Diagram of MW-1 is presented as **Figure 5** in **Section 1**. A wellhead diagram and a well pad design of MW-1 are presented in **Figure 2-7**.

Final Site Survey

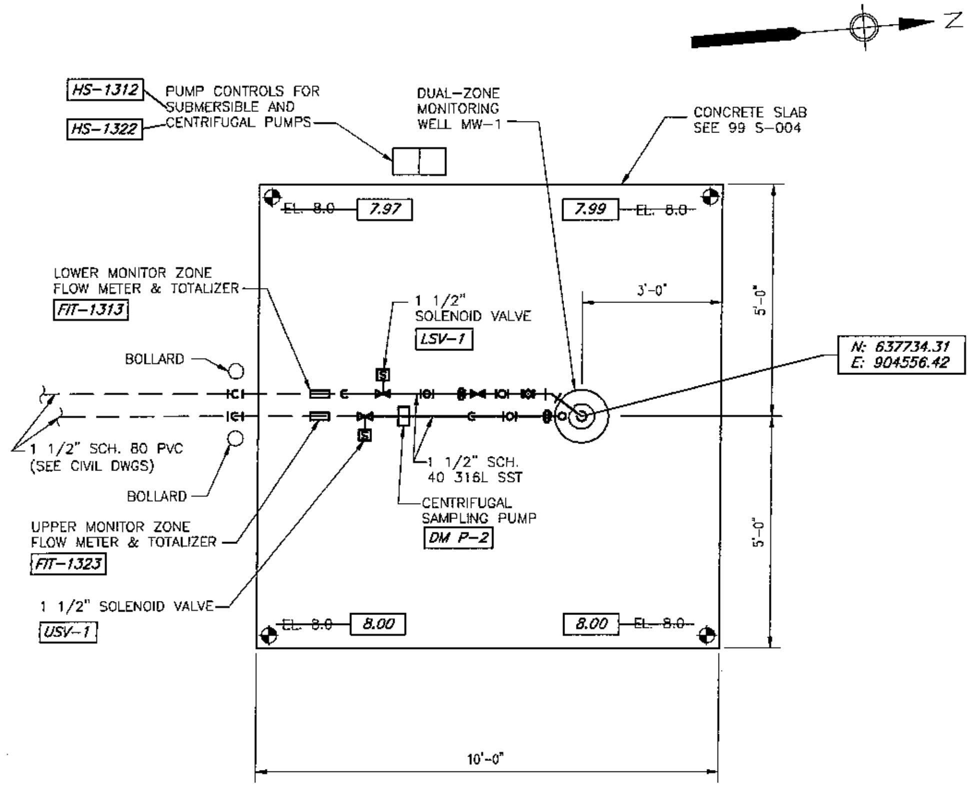
A final site survey was performed at the completion of construction to confirm that injection wells IW-1 and IW-2 and the monitor well were located in accordance with the original site plans. A copy of the specific purpose survey depicting the well head locations and elevations is provided in **Appendix F-1**. Signed and sealed well completion certifications of the Injection Wells IW-1 and IW-2 and the Dual-Zone Monitor Well MW-1 are presented in **Appendix F-2**.

NOTES:

1. ALL PIPING AND FITTINGS ABOVE PAD LEVEL TO BE 316L SST. UNDERGROUND DISCHARGE PIPING 4" DIA. & LARGER SHALL BE C-900 PVC AND BELOW 4" DIA. SHALL BE SCHEDULE 80 PVC.
2. SUBMERSIBLE PUMP SHALL BE 316 SST GRUNDFLOS REDI-FLO SERIES. APPROXIMATE SIZE 0.5 TO 1 HP, 460 V AC, THREE PHASE. FINAL SIZE TO BE DETERMINED BASED ON FIELD CONDITIONS. ASSUME PUMP SET TO APPROXIMATELY 100' BPL.
3. CENTRIFUGAL SAMPLING PUMP SHALL BE GORMAN-RUPP T-SERIES SELF PRIMING HORIZONTAL END SUCTION TYPE BRONZE CONSTRUCTION WITH 316 SST SHAFT. APPROXIMATE SIZE 0.5 TO 1.5 HP, 460 V AC, THREE PHASE. FINAL SIZE TO BE DETERMINED BASED ON FIELD CONDITIONS. PUMP SHALL BE TOTALLY ENCLOSED FAN COOLED (TEFC).
4. ALL WELL CASING DIAMETERS INDICATED ARE CASING OUTSIDE DIAMETERS (O.D.).
5. SST 316 STEEL COMPONENTS SHALL BE SCHEDULE 40.
6. ALL CEMENT GROUT SHALL BE ASTM C-150 TYPE II SULFATE RESISTANT CEMENT.
7. *UNLESS OTHERWISE NOTED, ELEVATIONS ARE RELATIVE TO NATIONAL GEODETIC VERTICAL DATUM OF 1929.*

LEGEND:

x 8.0	EXISTING ELEVATION
EL. 9.2	PROPOSED ELEVATION



DUAL ZONE MONITOR WELL MW-1 PAD PLAN

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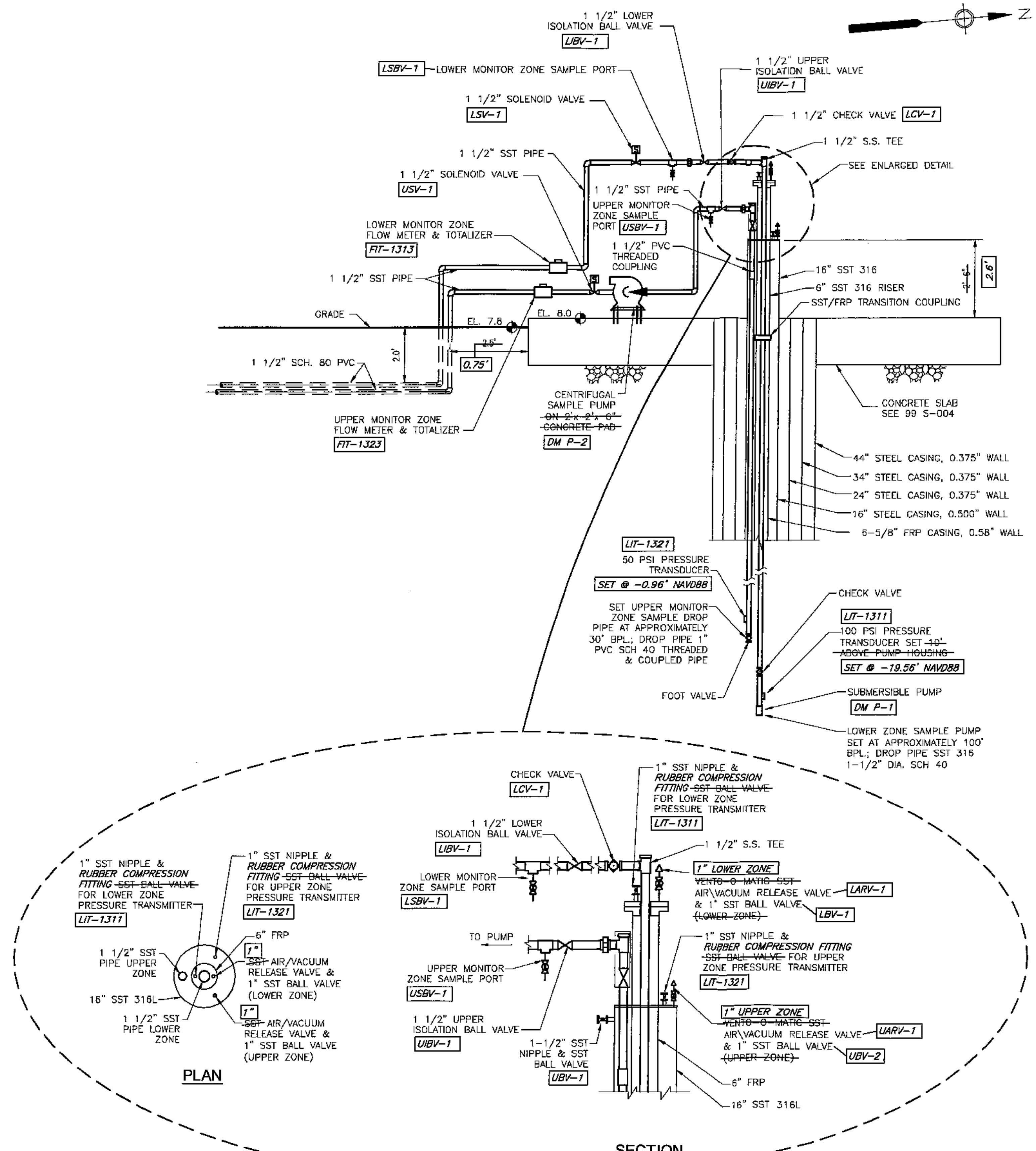

DUAL-ZONE MW-1 MONITOR WELLHEAD DIAGRAM

N.T.S.

MARK	DATE	MADE BY	CHECKED	REVISIONS DESCRIPTION

AECOM

AECOM USA INC.
3550 S.W. CORPORATE PARKWAY
PALM CITY, FL 34990
(772) 286-3883
CERTIFICATE NO. 38

TOWN OF DAVIE FLORIDA
WATER TREATMENT AND WATER RECLAMATION FACILITY

DUAL ZONE MONITORING WELL NO.1 PLAN SECTIONS & DETAILS

MECHANICAL PROCESS

PROJECT NO:	60096591
CAD DWG FILE:	_13 D-103
DESIGNED BY:	MWB
DRAWN BY:	DLP
DEPT CHECK:	LAL
PROJ CHECK:	B. DALY
DATE:	NOVEMBER 2010
SCALE:	AS NOTED

FIGURE 2-7

ANSI D - 4-Dec-12

SECTION 3

Geologic and Hydrogeologic Framework

Data Collection

Formation Sampling

Formation Samples from IW-1, IW-2 and MW-1 were collected at 10-foot intervals from land surface to the total depth of the wells during drilling operations. The formation samples were described to develop a detailed lithologic log for each well. Formation samples were described based on rock type, color, consolidation, porosity, and fossil content. Once these wells were completed, one set of formation samples were sent to the Florida Geological Survey in Tallahassee, Florida, as per the specific conditions of FDEP-issued construction permit. Detailed lithologic descriptions of formation samples from IW-1, IW-2 and MW-1 are provided in **Appendix G-1 to G-3.**

Rock Cores

During pilot-hole drilling of IW-1 and IW-2, full diameter cores were collected to allow a more detail description of the intact rock samples and to obtain hydraulic and geo-mechanical properties from representative rock samples from the overlying confining units to the proposed injection horizon. The full-diameter rock cores were obtained using a 4-inch diameter core bit on a 17-foot-long core barrel.

A description of each core, including rock type, color, grain size, consolidation and porosity was prepared after the recovered footage of each core was measured. During the construction of IW-1 and IW-2, a total of eight (8) cores were obtained from the overlying confining units between 2,144 and 2,905 feet below pad level (bpl) and one (1) core obtained within the injection horizon between 2,970 and 2,982 feet bpl. In general, the core descriptions were consistent with the lithologic log developed from the drill cuttings.

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Detailed descriptions and results of the laboratory analyses for the individual rock cores are provided in **Appendix H**. Results of the laboratory analyses of the core samples are discussed in **Section 4** of this report.

Geophysical Logging

Geophysical logs were performed over selected intervals of the boreholes during the drilling of the pilot holes and reamed intervals in IW-1, IW-2 and MW-1. The data from the geophysical logs were used to correlate formation samples collected during drilling, to identify formation boundaries, to aid in the selection of straddle packer test intervals and to obtain specific rock properties and water quality data on the subsurface rock formations encountered. These data were also used in the selection of casing setting depths for the injection wells and dual-zone monitor well. A summary of the geophysical logging program and paper and electronic copies of each of the geophysical logs performed during construction of these wells are provided in **Appendix N** of Volume II and III of this report.

Regional Geology and Hydrogeology

The regional geology of southeastern Florida consists primarily of inter-layered sands, clay, and limestone formations that were deposited primarily in a shallow sea environment. The upper 100 to 200 feet consists of inter-layered sand, sandstone, sandy limestone, limestone, and porous coquina. Beneath these sediments is the Hawthorn Group, which consists of approximately 750 feet of varying lithology and includes shell beds, quartz sand, silt and calcareous clay with abundant phosphate grains. A few zones within this sequence may be minor aquifers, but in general, the sediments are relatively impermeable. Underlying the Hawthorn Group is several thousand feet of carbonates (limestone and dolomite) including the Ocala Limestone, and Avon Park, Oldsmar and Cedar Keys Formations.

The regional hydrogeology consists of the Surficial and Floridan aquifer systems. The Surficial aquifer (or Biscayne aquifer) is highly transmissive and used extensively for private and municipal water supply. The base of the aquifer system commonly is defined where sediments grade from sand to low permeable clayey sand or clay units.

The Surficial and Floridan aquifer systems are separated by an intermediate confining unit (Hawthorn Group), which contains sediments of low permeability. The intermediate confining unit extends from the base of the Surficial aquifer system to the top of the Floridan aquifer system (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986). In southeast Florida, the upper contact in the intermediate confining unit is commonly equivalent to the upper Peace River Formation but can extend into the overlying Tamiami Formation.

The Floridan aquifer system has two major water-bearing zones, the upper and lower Floridan aquifers, which are separated by less permeable carbonate sediments of the middle confining unit. The upper Floridan aquifer generally consists of several thin water-bearing zones of high permeability (flow zones) interlayered with thicker zones of substantially lower permeability. Commonly, one or two major flow zones provide the bulk of the productive capacity. Both the upper and lower Floridan aquifers are highly productive; however, the upper Floridan contains significantly higher quality of water than the lower Floridan. The lower Floridan aquifer contains multiple intervals of highly permeable rock units within the lower part of the Avon Pak and Oldsmar formations that are cavernous and fractured in nature. These highly permeable intervals are generally referred to as the "Boulder Zone" and the target horizon for this injection well project. The base of the Floridan aquifer system is marked by a sub-confining unit composed of low to impermeable limestone and inter-bedded anhydrite beds of the lower part of the Oldsmar Formation or Cedar Keys Formation.

Site Geology and Hydrogeology

A site specific stratigraphic profile was derived from the correlation of formation samples and geophysical logs. The major stratigraphic and corresponding hydrogeological units encountered at the site are presented in **Figure 3-1**. Strata encountered during construction of deep injection well IW-1, IW-2 and dual-zone monitor well MW-1 ranged in age from Eocene to Pleistocene-aged deposits. The stratigraphic units and their respective ages from land surface to the total depth are as follows: the Palimco Sand and Fort Thompson Formation of Pleistocene epoch; the Tamiami Formation of Pliocene age; the Hawthorn Group of late Oligocene and Pliocene ages; the Ocala Limestone of Eocene age; and the

Avon Park and Oldsmar Formations of Eocene age. The Surficial aquifer system, intermediate confining unit, upper Floridan aquifer, middle confining unit and lower Floridan aquifer were encountered during well construction activities at this site.

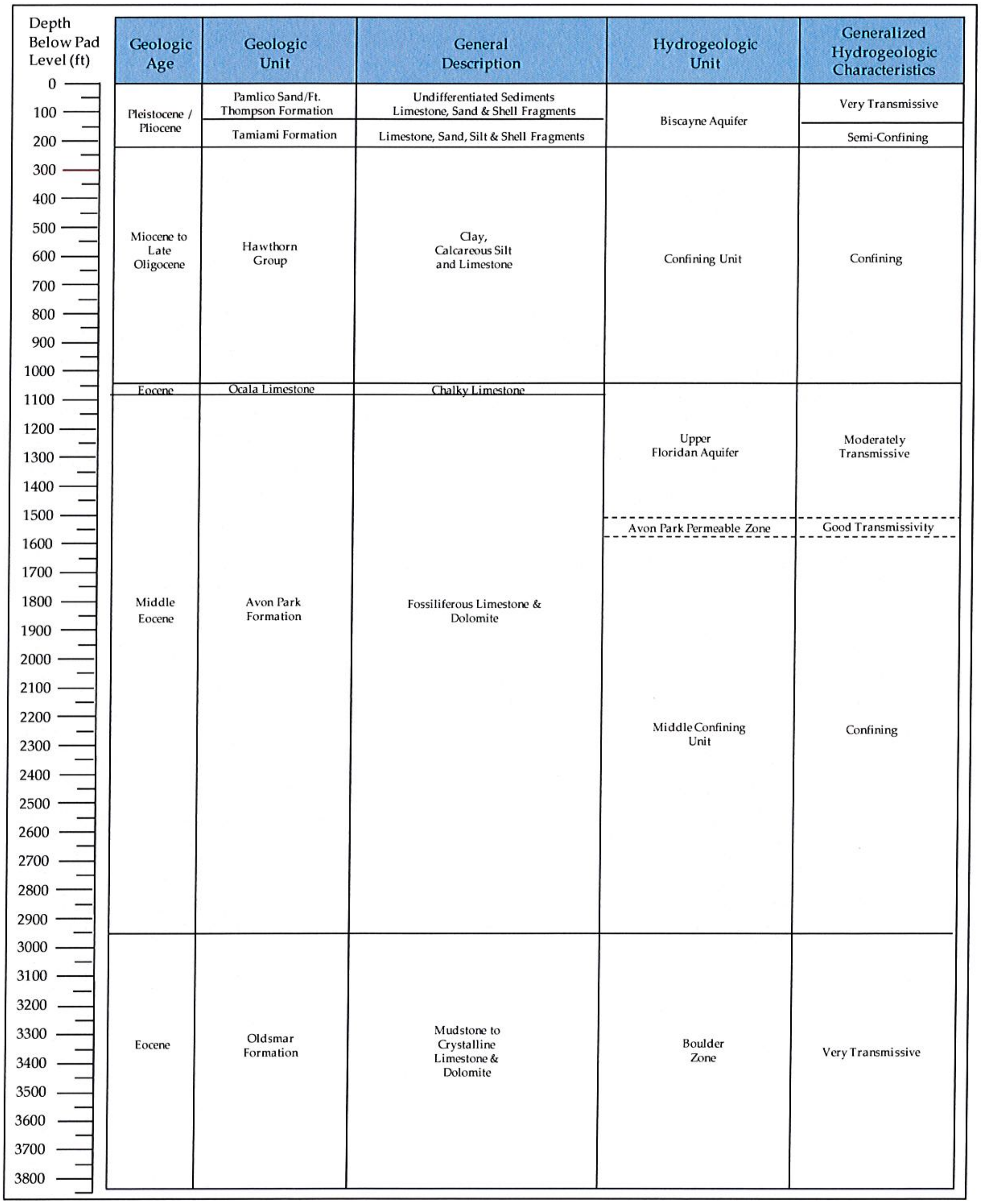

Figure 3-1: Site Specific Stratigraphic Profile

Pamlico Sand

The Pamlico Sand is late Pleistocene in age and represents beach sand deposits composed of medium to fine grained quartz and carbonate grains. These terrace sands were deposited during a +25-foot stand of sea level during the Pleistocene. At the project site, the Pamlico Sand deposits occur at land surface to a depth of approximately 10 to 15 feet bpl.

Fort Thompson Formation

The Fort Thompson Formation is a Pleistocene marine limestone. It consists primarily of white to orangish gray, poorly consolidated limestone composed of ooliths, pelecypod and molds of peloiods. Ooliths are small rounded grains that are formed by the deposition of layers of calcite around tiny particles, such as sand grains or shell fragments. The Fort Thompson Formation also consists of white to cream colored sandy limestone, calcareous sandstone, sand, marl, and shell, and thin beds of limestone of fresh-water and marine origin. The limestone and calcareous sandstone units are riddled with solution feature that significantly increase its overall permeability. The Fort Thompson Formation is the major producing horizon within the Surficial aquifer generally referred to as the "Biscayne Aquifer" and occur just from 15 to approximately 120 feet bpl at the project site.

Tamiami Formation

The Tamiami Formation is a Pliocene marine unit comprising a wide range of rock types, including: light gray to tan fossiliferous sands, light gray to green fossiliferous sandy clays to clayey sands, and white to light gray colored, poorly consolidated, sandy, fossiliferous limestone. Fossils present in the Tamiami Formation include barnacles, mollusks, corals, echinoids, foraminifers and calcareous nannoplankton. The lower portion of the Tamiami Formation consists primarily of light brown to light olive gray sand and silt with varying shell and shell fragments. The Tamiami Formation is present from 120 to 220 feet in depth.

Hawthorn Group

The Hawthorn Group of the Oligocene-Pliocene age occurs at a depth of 220 to 1,045 feet bpl. The Hawthorn Group consists of the Peace River and Arcadia formations which forms the primary confining interval that separates the Surficial and the Floridan aquifer systems. The top of the confining unit is commonly equivalent to the top Peace River Formation but can extend into the overlying Tamiami Formation. The Hawthorn Group sediments consist primarily of olive-gray and dark greenish-gray, slightly sandy, phosphatic, calcareous clay, inter-bedded with thin layers of quartz sand and silt. The lower portion of the Hawthorn Group corresponds to the Arcadia Formation which is generally composed of fine-grained micritic limestone and marl or clay. The Hawthorn Group is identified on geophysical logs by high natural gamma ray activity and low apparent formation resistivity. The high natural gamma ray activity within the Hawthorn Group is a result of high clay content (primarily potassium bearing minerals) and phosphate content with the low apparent resistivity attributed to the high porosity and poorly or unconsolidated nature of the sediments.

Suwannee Limestone

In southeast Florida, there are opposing interpretations concerning the presence of the Suwannee Limestone. The Suwannee Limestone has been interpreted by some investigators to be absent in southeast Florida (Mooney, 1980, Shaw and Trost, 1984, Miller, 1986). Based on the lack of index fossils within the formation samples and the interpretation of the geophysical logs conducted during this project, the Suwannee Limestone is absent at this site.

Ocala Limestone

The Ocala Limestone of late Eocene age was encountered between 1,045 and 1,080 feet bpl. It consists primarily of yellowish gray to tan colored, chalky to fossiliferous limestone. Inter-bedded throughout the Ocala Limestone are minor layers of chert and clay units. This formation is generally characterized by abundant foraminifera, such as *Operculinoides sp.*, *Camerina sp.*, and *Lepidocyclina sp.* (Peacock, 1983). The presences of Lepidocyclina sp within the sediment samples help to distinguish the Ocala Limestone from the underlying Avon Park Formation. The Ocala Limestone is part of the upper Floridan aquifer that is under artesian pressure and is frequently the source of brackish raw water for RO treatment facilities in southeast Florida.

Avon Park Formation

The Avon Park Formation of Eocene Age occurs at a depth of 1,080 to 2,950 feet bpl. The upper portion of the Avon Park Formation consists primarily of yellowish gray to very pale orange, fine-to-medium grained, fossiliferous limestone with low-to-moderately porosity. The lower section of the formation consists of very pale orange, fine-to-medium grained, moderate porosity limestone inter-bedded with low porosity and permeability, re-crystallized limestone that is generally confining in nature. The upper portion of the Avon Park Formation is characterized by low natural gamma ray activity, low and fairly stable resistivity, and somewhat variable and moderately high sonic travel times. The lower portion of the formation is characterized by low natural gamma ray activity, low to moderate and less stable resistivity, and similar but slightly more stable sonic transit times when compared to the upper portion of the formation. Corresponding fluctuations in gamma ray emissions and dual-induction values in the Avon Park Formation represent alternating sections of softer limestone and harder dolomitic limestone and dolostone units. The cone-shaped benthic foraminifer index fossil *Dictyoconus sp* characteristic of the Avon Park Formation (Duncan and others, 1994) are present throughout this interval.

Oldsmar Formation

The Oldsmar Formation at the project site consists primarily of massively bedded, dense, re-crystallized dolomite of low permeability with fractured and cavernous intervals known as the "Boulder Zone". The top of the Oldsmar Formation is often difficult to identify because of a lack of diagnostic microfossils. The top of the Oldsmar in South Florida is often identified based on the presence of a hard, crystalline dolomite unit and on geophysical logs by increased natural gamma ray counts and higher formation resistivity values, both characteristics of dolomite (dolostone).

The top of the Oldsmar Formation at this site has been identified at approximately 2,950 feet bpl. This corresponds to the occurrence of a well-indurated, crystalline dolomite and elevated natural gamma activity and higher resistivity readings on the geophysical logs. The upper part of the Oldsmar Formation makes up the lower portion of the middle Floridan confining unit while the lower section contains highly transmissive, fractured, and cavernous intervals known as the "Boulder Zone", which makes up a portion of the lower

Floridan aquifer. The formation water within the Boulder Zone is similar in composition to sea water with total dissolved solids concentration in excess of 35,000 mg/L. The injected reverse osmosis concentrate and reuse quality effluent will exit the borehole in the "Boulder Zone" after IW-1 and IW-2 is placed into service.

SECTION 4

Hydrogeologic Testing

Pad Monitor Wells

The pad monitor wells are required by the FDEP-issued construction permit to help ensure that ground water quality within the upper portion of the Surficial aquifer system is not adversely impacted during the construction and testing operations related to the deep injection well system.

Groundwater samples were collected from the pad monitor wells before the start of constructing IW-1 to establish background water quality conditions of the upper part of the Surficial aquifer system. The samples were collected and field parameters determined that included specific conductance, pH and temperature. Laboratory determined results for chloride, sulfate and total dissolved solids (TDS) concentrations were provided by Florida Spectrum Environmental Services, Inc. The pad monitor wells were then sampled on a weekly basis throughout the construction period. Static water level measurements were also taken prior to each sample collection event to determine time-dependent and the long-term ground water gradient and flow direction.

Tabulated and graphical summaries of the weekly analytical data from each of the pad monitor wells are presented in **Appendix C-3**. Based on the results of the field and laboratory determined water quality data and integrating the ground water level data to determine flow directions, the Surficial aquifer system was not adversely impacted by drilling and testing activities related to this Class I injection well system.

Formation Sampling During Drilling of Injection Well System

Drill cutting samples were collected at 10-foot intervals from land surface to the total depth of the wells during drilling of IW-1, IW-2 and MW-1. Each formation 10 foot sample was described in detail to develop a lithologic log, relative to depth. Formation samples from IW-1, IW-2 and MW-1 were characterized for rock type, color, consolidation, porosity, and fossil content. At the completion of construction, one set of formation samples were sent to the Florida Geological Survey in Tallahassee, Florida. Detailed lithologic descriptions of the formation samples from IW-1, IW-2 and MW-1, developed by AECOM, are provided in **Appendix G.**

Coring and Analyses

During drilling operations of IW-1 and IW-2, core samples were collected to obtain hydraulic and geo-mechanical properties from representative rock samples. The full-diameter rock cores were obtained using a 4-inch-diameter core bit on a 17-foot-long core barrel. A description of each core, including rock type, color, grain size, consolidation and porosity was prepared after the recovered footage of each core was measured. Four (4) cores between 2,144 and 2,982 feet bpl were collected during the construction of IW-1 and five (5) cores between 2,353 and 2,905 feet bpl were collected from IW-2. The detailed descriptions for the individual rock cores are provided in **Appendix H**.

After being described onsite, selected samples from individual rock cores were labeled and sent to Core Laboratories in Houston, Texas to be analyzed for various hydraulic and geo-mechanical rock properties. The full laboratory analysis reports compiled by Core Laboratories are provided in **Appendix H**.

Full Diameter Analysis

The Midland, Texas Core Laboratories received twenty-four (24) core samples from IW-1 and IW-2 for petrophysical evaluation. The cores were marked with lines and oriented relative to each other that indicated top and bottom of each core sample. These core samples were tested at 400 pounds per square inch (psi) net confining stress while determining permeability and porosity values. The net confining pressure technique was used during testing to obtain representative value by simulating overburden pressure. Full-diameter porosity was determined by direct grain volume measurement using Boyle's law helium expansion. Steady state air permeability was measured in two horizontal directions and vertically. The horizontal core permeability measurements were determined at two angles with 90 degrees of separation to determine anisotropy. The measured horizontal and vertical core permeability and porosity measurements are summarized in **Table 4-1.**

Table 4-1: Petrophysical Summary of Cores from IW-1 and IW-2

Well	Sample Number	Sample Interval Depth (feet bpl)	Permeability				Porosity %
			Horizontal Maximum (md)	Horizontal 90 Degree (md)	Vertical (md)	Variability between Horizontal Max and Vertical Permeability	
IW-1	1	2,148.1 - 2,148.7	2804	137	<.01	280400	9.3
IW-1	2	2,150.8 - 2,151.4	1.28	0.95	0.25	5	4.6
IW-1	3	2,153.1 - 2,153.8	4365	665	<.01	436500	2.5
IW-2	16	2,362.8 - 2,363.4	444	431	343	1.3	32.6
IW-2	14	2,364.6 - 2,365.3	208	208	117	1.8	31.6
IW-2	15	2,368.9 - 2,369.7	11.5	10.9	8.61	1.3	24.2
IW-1	4	2,383.6 - 2,384.1	33.5	32.5	26.2	1.3	24.6
IW-1	5	2,387.5 - 2,388.3	408	8.5	2.31	177	10.5
IW-1	6	2,388.3 - 2,389.0	2.36	0.72	0.16	15	7.8
IW-2	17	2,418 - 2,418.8	18.2	17.4	9.35	1.9	23.1
IW-2	18	2,421.8 - 2,422.5	32.9	31.7	21	1.6	24.2
IW-2	19	2,422.7 - 2,423.6	26.7	23	5.55	4.8	24.2
IW-2	20	2,486.1 - 2,486.8	308	308	206	1.5	26.4
IW-1	7	2,677.6 - 2,678.2	206	205	117	1.8	37.7
IW-1	8	2,678.2 - 2,678.9	123	117	75.8	1.6	36.7
IW-1	9	2,683.4 - 2,684.3	1016	959	317	3.2	33
IW-1	10	2,684.3 - 2,685.1	430	401	166	2.6	35.3
IW-2	21	2,715.9 - 2,716.7	568	553	403	1.4	40.5
IW-2	22	2,891.8 - 2,892.4	957	923	822	1.2	38
IW-2	23	2,893.3 - 2,894.3	346	339	199	1.7	37.2
IW-2	24	2,897.9 - 2,898.8	344	332	286	1.2	36.8
IW-1	11	2,980.8 - 2,981.4	8.87	7.04	<.01	887	6
IW-1	12	2,978.2 - 2,978.9	22.1	0.05	<.01	2210	5
IW-1	13	2,975.2 - 2,975.8	1362	714	<.01	136200	5.7
Minimum Value			1.28	0.05	<.01	1.2	2.5
Maximum Value			4365	959	822	436500	41
Mean Value			650	302	208	42188	24

These laboratory determined data show that the maximum horizontal permeability ranged from 1.28 to 4,365 millidarcies (md). Minimum horizontal permeability ranged from 0.046 to 959 millidarcies. Vertical permeability ranged from 0.001 to 822 millidarcies. Porosity values ranged from 2.5 to 40.5 percent of pore volume. Grain densities for the samples ranged from 2.70 to 2.83 gram per cubic centimeter (g/cm3), indicative of a mix of limestone and dolomite mineralogy. The basic core analysis results are provided in **Appendix H**

A comparison between the horizontal maximum and vertical permeability data for representative samples of rock units overlying the injection horizon indicate higher horizontal permeability valves. These data suggest that there would be a greater tendency for injected fluids to travel laterally as opposed to vertical migration under a given hydrostatic pressure gradient limiting the potential for upward movement of injected fluids.

Once the permeability and porosity measurements were complete, the core samples were shipped to the Advanced Technology Center of Core Laboratories in Houston, Texas where they were slabbed and photographed under white light. The photographs of the cores completed by Core Labs are provided in **Appendix H.**

Geomechanical Analysis - Acoustic Velocity

The Houston facility of Core Laboratories tested twenty-three (23) full-diameter samples from the IW1 and IW-2. These samples were taken from a depth range of 2,148.10 to 2,981.40 feet, and tested at 800 psi net confining stress. The pulse transmission technique of velocity measurements was used with 1MHz frequency for P-waves and S-waves. The accuracy of velocity measurements is about 1%. Dynamic elastic parameters (bulk modulus, Young's modulus, shear modulus, and Poisson's ratio) were calculated using compressional-wave and shear-wave velocities, respectively and the bulk density of the sample based on the linear elastic theory.

The acoustic velocities of the core samples from IW-1 and IW-2 ranged from 8,431 to 18,800 feet per second (ft. /sec) for the compressional waves and 5,027 to 11,638 ft. /sec for the shear waves. The range in compressional and shear velocities is a function of porosity and consolidation of the individual carbonate rock units. The low range of acoustic velocities for compressional waves is associated with high porosity, high carbonate mud content, and poorly cemented carbonate sediments. In comparison, the highest compressional wave velocities were determined on the well-indurated, low porosity, crystalline limestone and dolomite units.

Laboratory determined dynamic Young's modulus values ranged from 1.31×10^6 to 11.75×10^6 psi, which indicates that the overlying confining units can withstand a wide range of induced pressures related to injection activities at this site. The dynamic Poisson's ratio obtained from the core samples ranged from 0.11 to 0.26, which is in close agreement to other carbonate rock material. This range in laboratory determined Poisson's ratios imply a low fracture potential within the overlying confining unit. A summary of the geomechanical results are provided in **Appendix H**

Petrophysical Properties - Permeability to Brine

After geomechanical testing was completed permeability measurements were determined using a brine solution similar in composition to the formation water to better determine flow characteristics of the confining units overlying the injection horizon. These tests were completed using synthetic formation brine filtered to 0.45 microns and degassed. Fluid parameters including viscosity and density were measured at ambient temperature.

Each sample was then loaded into a hydrostatic core holder and 800 psi net confining stress was applied. The samples were flushed with synthetic formation brine using 500 psi backpressure to ensure saturation. Permeability to liquid data was calculated from the experimental data and measured sample and fluid parameters using Darcy's law. The brine permeability measurements were completed at ambient temperature and at 800 psi net confining stress. The specific permeability to brine completed on the core plugs ranged from 0.00191 to 668.599 millidarcies which equates to 5.16 x 10-6 to 1.8 ft. /day. A summary of the laboratory-determined brine permeability results are provided in **Appendix H**

Pilot-Hole Water Quality Data

During reverse-air drilling of the nominal 12-inch diameter pilot-hole drilling, formation water samples were collected below the base of the 50-inch diameter intermediate casing set at 975 feet bpl to the total depths of IW-1 and IW-2. In addition reverse-air returns were obtained from MW-1 below the base of the 24-inch diameter steel casing (975 feet bpl) to its total depth of 2,000 feet bpl.

Samples were collected at 30-foot intervals during reverse-air drilling to monitor water quality changes with respect to depth. Field parameters were determined, which included specific conductance, pH and temperature with the water samples sent to Florida Spectrum Environmental Services, Inc. and tested for TDS, specific conductance, chloride, ammonia, total Kjeldahl nitrogen (TKN) and sulfate. Tables summarizing the field and laboratory results of the reverse-air return samples obtained from IW-1, IW-2 and MW-1 are provided in **Appendix I-1**. **Figures I-1, I-4 and I-7** in **Appendix I-1** provide water quality profiles relative to depth based on laboratory determined specific conductance, TDS and chloride data for IW-1, IW-2 and MW-1, respectively,. **Figures I-2, I-5 and I-8** in **Appendix I-1** provide water quality profiles of laboratory determined ammonia and TKN data for IW-1, IW-2 and MW-1, respectively. **Figures I-3, I-6 and I-9** in **Appendix I-1** provide compiled graphs of field determined parameters including specific conductance, TDS and chloride data for IW-1, IW-2 and MW-1, respectively. The laboratory analytical reports for reverse-air return samples from IW-1, IW-2 and MW-1 are provided in **Appendix I-2**.

As illustrated in **Figure I-1 and I-3** for IW-1 and **Figures I-4 and I-6** for IW-2, specific conductance, TDS and chloride values are steady from 980 to 1,700 feet bpl then gradually increase from 1,700 to a depth of 2,100 feet bpl. The significant increase in all measured values at 2,100 feet bpl is the result of advancing the first stage of the pilot-hole drilling from around 980 to 2,100 feet bpl then this interval was sealed off with the installation of the 40-inch diameter casing before the second stage of pilot-hole drilling was advanced below 2,000 feet bpl to the total depth of the injection wells. During each stage of pilot-hole drilling, a closed loop reverse-air circulation system was used where the formation water is brought to surface and re-circulated into the well. The pilot-hole water samples therefore do not provide a true representation of the formation water quality at depth of collection, but instead represent a composite of the formation water as the borehole is advanced along with fluids from the open-hole interval that is continuously circulated during drilling operations through the closed loop reverse-air drilling system.

For comparative purposes, **Figures I-10 and I-11** in **Appendix I-1** illustrate the conductivity readings, and TDS and chloride concentrations from samples collected during both pilot-hole drilling and packer testing of IW-1 and IW-2, respectively. The results from the water quality samples collected during packer testing clearly display a gradual decrease in water quality from 1,700 to 2,200 feet bpl. These plots demonstrate the effect of the closed loop circulation system on water quality samples collected during pilot-hole drilling.

Reverse-air returns were collected and analyzed for ammonia and total Kjeldahl nitrogen (TKN) values and nitrogen (typical wastewater indicators) to determine if this site was impacted by other permitted and operational injection well facilities in the vicinity. As illustrated in **Figures I-2 and I-5**, ammonia and TKN values obtained while drilling IW-1 and IW-2, display a decreasing trend with depth. The TKN concentrations are highest (0.6 - 1.0 mg/L) for the interval from 1,000 feet bpl to approximately 1,950 feet bpl. The slightly higher TKN concentrations may be the result of higher concentrations of organic material present within the borehole or within the closed circulation reverse-air system. The TKN concentrations display a gradual decreasing trend (0.2 - 0.6 mg/L) from 2,000 to 2,700 feet bpl. Below 2,700 feet bpl, the TKN concentrations generally range from below the laboratory detection limit of 0.07 mg/L to 0.2 mg/L.

Laboratory ammonia results from IW-1 were only slightly different than those from IW-2. Accept for a small interval from 2,130 to 2,280 feet bpl where concentrations range from 0.1 to 0.5 mg/L, the ammonia concentrations in IW-1 were below the laboratory detection limit of 0.01 mg/L to 0.1 mg/L. Concentrations below 2,400 feet bpl did not exceed the laboratory method detection limit of 0.01 mg/L. From 1,070 to 2,400 feet bpl, the ammonia concentrations of samples obtained from IW-2 ranged between 0.1 mg/L and 0.4 mg/L. Between 2,400 and 3,100 feet bpl, the results range from below detection limit of 0.01 mg/L to 0.1 mg/L.

The slightly higher TKN and ammonia concentrations in the upper portion of the pilot-hole may be the result of residual drilling mud and high concentration of organic material present within the rock formations. The ammonia and TKN results within the overlying confining units however do not indicate that this site has been impacted by other proximal subsurface injection well systems.

Geophysical Logging

Geophysical logs were conducted within the various diameter boreholes to correlate formation samples taken during drilling, identify formation boundaries, obtain specific data pertaining to the underground formations, and assist in establishing the base of the Underground Source of Drinking Water (USDW). The geophysical logs also provided data for determining optimum casing setting depths for the injection wells and associated dual-zone monitor well.

Geophysical logging suites conducted at this site include: 4-arm caliper, natural gamma ray, spontaneous potential, dual-induction, and borehole compensated sonic, fluid conductivity, temperature, flowmeter, and downhole video surveys. A tabulated summary of the geophysical logs performed during the construction of the Class I injection well system along with paper and electronic copies of each of log performed are provided in **Appendix M-1** of **Volume II** for IW-1 and **Appendix M-2** and **M-3** in **Volume III** for IW-2 and MW-1, respectively. Based on the close inspection of the geophysical log data, there is good geologic and hydrogeologic correlation between IW-1, IW-2 and MW-1.

Caliper Log

The caliper log records the borehole or casing diameter versus depth. Caliper logs indicate borehole enlargements (subsurface cavities), provide the data needed to calculate cement volumes to provide an annular seal for the various casings and are necessary for quantitative interpretation of flow meter logs to determine changes in fluid velocity as a function of borehole diameter.

Natural Gamma Log

Natural gamma logs measures the natural gamma ray emissions from certain very low level radioactive elements which includes potassium, thorium and uranium that occur in varying amounts in different subsurface units. Certain strata, such as clay minerals, dolomite, and phosphate can be identified by its higher natural gamma ray emissions.

Dual Induction Log

The dual induction log is a record of the apparent resistivity which includes the sediment and formation water fluids plotted against depth. Dual induction logging induces a magnetic field which creates an electrical current that passes through the rock formation and surrounding fluids. The relative ease of the flow of the electrical current gives an indication of water quality and/or formation porosity. Higher resistivity values suggest harder strata, which is a function of lower porosity, or better water quality (lower total dissolved solids content).

Temperature Log

The temperature log record water temperature within the borehole versus depth. Temperature logs may be used to locate zones of water entry into the borehole. This can be accomplished by identifying changes in the thermal gradient within the wellbore. Significant differences between the static temperature log values versus the dynamic temperature log values can also be useful in determining productive and non-productive water horizons which is relative indication of permeability.

Fluid Conductivity/Resistivity Log

The fluid conductivity/resistivity log is also used to identify zones of water entry into the borehole. Similar to the temperature log, production zones frequently possess different water quality, primarily in total dissolved solids concentration, which causes changes in the fluids electrical resistance and subsequently detected by the fluid resistivity log. Significant changes in the static and dynamic fluid resistivity log values versus depth can also be useful in determining water bearing zones and to identify poor water quality intervals.

Flowmeter – Fluid Velocity Log

Flowmeter or fluid velocity logs measure upward vertical flow of water in the wellbore. Flows at various depths are measured by means of a propeller flow meter that is lowered into the well at a known, constant line speed. Fluid velocity logs are used to determine areas of high water production or flow zones but also varies as a function of the borehole diameter, therefore, a caliper log must be conducted to properly evaluate a flowmeter log. Fluid velocity logs are normally conducted under both static and dynamic conditions. Areas of greater separation between the static and dynamic flowmeter plots indicate zones of greater water production.

Video Survey

Video surveys are digital video recordings of the well as a sealed camera is slowly lowered down the casing and borehole. Video surveys are used to inspect the integrity of the casings and joints, visually confirm of formation changes, determine the extent of well development based on particulate matter as a function of visibility (particulate matter refracts the light from the camera) within the fluid column and visually confirm specific flow zones that were identified by the other geophysical logs.

Interpretation of Geophysical Logs

IW-1, IW-2 and MW-1 can be divided into several differing intervals based on the lithologic and geophysical log data information. Although there may be slight variations between the logs for each well, the following interpretations are a general summary of the combined geophysical logging program and subsurface conditions.

The interval from ground surface to 220 feet is characterized by an irregular shaped borehole with moderate to low natural gamma ray emission indicative of a clean, moderate to well-indurated limestone unit with intervening poorly consolidated calcareous sandstone to unconsolidated quartz sands and silts. Between 220 and 975 feet bpl; the 4-arm caliper records a fairly gauge (similar to diameter of the drill bit) borehole and the natural gamma log is characterized by elevated gamma ray emissions indicative of increased clay and/or phosphate content within the Peace River and Arcadia Formations of the Hawthorn Group. The interval from 220 to 950 feet bpl forms the intermediate confining unit that separates the Surficial and Floridan aquifer systems.

Upper Floridan Aquifer

At this site, the Upper Floridan aquifer extends from approximately 950 to 1,440 feet bpl. The interval from 950 to 1,040 feet bpl forms the upper most carbonate section of the Floridan aquifer system. This interval is characterized by an average borehole diameter of approximately 14-inches with intervals of very high natural gamma ray counts, dual-induction readings that range between 15 and 30 ohm-m, and high acoustic travel times. The log-derived TDS log indicates that this interval contains water with TDS concentrations of between 2,000 and 3,000 mg/L. Fluid conductivity and temperature are stable through this interval but the flowmeter and temperature gradient logs indicate a significant fluid producing zone at a depth of 1,042 feet bpl at IW-1and 1,044 feet bpl at IW-2.

The interval from 1,040 to 1,100 feet is characterized by an enlarged borehole with diameter of approximately 16 to 17 inches with low natural gamma ray counts, dual-induction readings that average 9 ohm-m and average acoustic travel times of 130 usec/ft. The washed-out nature of the borehole, as indicated by the caliper log, suggests this interval is composed of poorly cemented limestone units. The log-derived TDS log indicates that this interval contains water with total dissolve solids (TDS) concentrations of between 4,500 and 6,000 mg/L.

The interval between 1,100 and 1,335 feet bpl is a moderately porous interval with intermittent gamma ray peaks. The dual-induction readings are fairly consistent over this interval that average 7.5 to 8 ohm-m and average acoustic travel times of 120 usec/ft. The computed TDS log indicates that this interval contains water with an average TDS concentration of 6,000 mg/L.

The interval between 1,335 to 1,440 feet bpl composed of moderately indurated limestone (wackestone to packstone). The sonic log shows lower porosity and sonic travel times (110 usec/ft) with average dual-induction readings of 6.5ohm-m indicating lower water quality as compared to the overlying interval. The computed TDS logs indicate that this interval contains formation water with an average TDS concentration of 7,500 to 8,000 mg/L.

Avon Park Permeable Zone

The interval from 1,440 to 1,570 feet is known as the Avon Park Permeable Zone and is characterized by a borehole diameter of approximately 15 inches with natural gamma ray counts of 22 API units, dual-induction readings that average 15 ohm-m and average acoustic travel times of 110 to 120 usec/ft. The variable porosity and sonic travel time readings combined with higher dual-induction readings indicated better water quality than the overlying interval with a computed TDS concentration of 3,000 mg/L. The signature of the flow meter and temperature logs indicate significant flow zones with good secondary porosity development is present at a depth of 1,560 feet bpl at IW-1and 1,565 feet bpl at IW-2.

Middle Confining Unit

At this site, the Middle Confining Unit extends from approximately to 1,570 to 1,810 feet bpl. This interval is composed of poorly to moderately indurated grayish orange limestone (wackestone to packstone) inter-bedded with greenish gray packstone that is much better indurated than the grayish orange limestone. This interval is interpreted to be confining in nature due to the lack of evidence of fluid production and its fine-grained nature and high carbonate mud content. The dual-induction and log-derived TDS plot indicate a steady increase in TDS concentrations of the formation water ranging from brackish to near saline over this interval. The dual-induction readings decrease significantly but the sonic transit time readings average 115 to 120 usec/ft below 1,570 feet bpl. The decrease in dual-induction readings through this interval are not due to increase in porosity but a function of changes in formation water quality. The decreasing trend in the dual-induction (deep resistivity curve) suggests the transition zone from the USDW to non-USDW fluids is located within this interval. The log-derived TDS plot indicates a transition in water quality with increased TDS concentrations from 3,000 mg/L at around 1,570 feet bpl to approximately 10,000 mg/L at 1,710 feet bpl at IW-1 and 1,695 feet bpl at IW-2. The dual- induction and log-derived TDS plot indicate that TDS concentrations of the formation waters exceed 10,000 mg/L below 1,710 feet bpl at IW-1 and below 1,695 feet bpl at IW-2. Based on the geophysical log data, the base of the USDW at IW-1 is estimated at a depth of approximately 1,710 to 1,715 feet bpl and the base of the USDW at IW-2 is estimated at a depth of approximately 1,695 to 1,705 feet bpl.

Over the depth of the interval from 1,810 to 1,895 feet bpl, the dual-induction and log-derived TDS plot shows water quality degrades slowly and steadily with TDS concentrations of the formation water increasing from to 20,000 to 30,000 mg/L. The dual-induction log produces fairly consistent readings of 2 ohm-m with variable porosity readings over this interval. The consistent resistivity readings in combination with the variable porosity readings through this interval indicate formation water quality continues to degrade to near seawater composition. The dynamic temperature and fluid conductivity logs also note the change in water quality over this same interval with slight but steady changes in measured values.

The lithologic character of the interval from 1,895 to 1,970 feet bpl is composed of very pale orange to white colored, moderately to well indurated limestone with evidence of secondary porosity development. The sonic derived porosity value average 45 porosity units with sonic travel times of 120 usec/ft. The deep and medium induction curves are similar in value through this interval indicating moderate degree of porosity development. The TDS concentrations of the formation water from 1,895 to 1,970 feet bpl are similar to sea water composition based on the log-derived TDS values.

The lowermost interval of the pilot-hole from 1,970 to 2,090 feet bpl is better indurated than the interval above based on a greater amount of weight placed on the bit (WOB) while drilling through this interval. This interval is also characterized by harder, lower porosity limestone and dolomitic limestone units. These better indurated low porosity rock units below 1,970 feet bpl were identified for casing points for the 40-inch diameter intermediate casings for both IW-1 and IW-2.

The sonic transit time generally decrease from 1,970 to 2,090 feet bpl with dual-induction readings based on the deep resistivity curve average about 1.5 to 1.7 ohm-m. The log-derived TDS concentrations of the formation water from 1,970 to 2,090 feet bpl are similar to sea water composition.

The diameter of the pilot-hole from 2,090 to 2,140 continues to decrease in diameter due to better cementation of the rock units. The natural gamma ray count through this interval is low averaging 5 to 7 API units indicating a clean limestone unit. The deep resistivity readings average 1.5 ohm-m and the sonic log produces average travel times and porosity readings of 110 to 130 usec/ft and 40 porosity units, respectively. The calculated TDS concentration in this interval using the sonic and dual-induction log data is approximately 35,000 mg/L. Fluid conductivity and temperature readings are stable through this interval and no large inflows of water are indicated by the flowmeter log.

Lower Floridan Aquifer – Upper Productive Horizon

The interval from 2,140 to 2,185 feet bpl is characterized by a gauge borehole, high natural gamma ray counts and dual-induction readings that average 7 ohm-m with variable acoustic travel times. Fluid conductivity and dynamic temperature readings are stable through this interval. A minor flow zone present near the base of this interval is indicated by a shift in the flowmeter, static temperature and static fluid conductivity log traces. The video surveys show good secondary porosity development and water flow interspersed within the hard crystalline dolomite units.

Lower Floridan Confining Unit

The Lower Floridan Confining Unit extends from 2,185 to approximately 2,925 feet bpl. Although there is a little more variation between the logs run at IW-1 and those run at IW-2 from 2,185 to 2,430 feet bpl, the log-derived porosity readings and fairly stable production type log traces at both wells indicate low water production within this interval. The dual-induction log from 2,180 and 2,350 feet bpl at IW-1 is fairly consistent. The sonic log readings average 2.5 ohm-m and the acoustic travel times average 95 usec/ft. The natural gamma readings were around 8 API units with an average computed sonic porosity reading of 32 porosity units. These data indicate a moderately indurated limestone unit. The interval between 2,350 to 2,430 feet bpl at IW-1 is composed of moderately to well indurate limestone (wackestone to packstone) inter-bedded with very well indurated low porosity crystalline dolomite. The log traces reflect the inter-bedded nature with a variable sonic and resistivity log readings through this interval. The sonic travel times and dual-induction readings through this interval at IW-1 average 85 micro sec/ft and 3.0 ohm-m, respectively. The dual-induction and sonic log readings from 2,190 to 2,290 feet bpl at IW-2 decrease slowly over this interval that average 2.5 ohm-m and average acoustic travel times of 95 usec/ft. The natural gamma readings were around 8 API units with an average computed sonic porosity reading of 32 porosity units. The sonic transit times and porosity reading decrease and the deep induction reading increase. These data indicate a moderately indurated limestone unit that becomes harder and less porous with depth. The interval between 2,290 to 2,430 feet bpl at IW-2 is composed of moderately to well-indurated limestone (wackestone to packstone) inter-bedded with very well indurated low porosity crystalline dolomite. The log traces reflect the inter-bedded nature with a variable sonic and resistivity log readings through this interval. The sonic travel times and dual-induction readings through this interval average 92 micro-sec/ft and 3 ohm-m, respectively.

The interval from 2,430 to 2,545 feet bpl is characterized by consistent natural gamma ray counts of 10 API units, dual-induction readings that average 2.5 to 2.6 ohm-m and average acoustic travel time of 90 usec/ft. The production log traces also show fairly consistent data through this interval indicating low water production potential.

The interval from 2,545 to 2,600 is composed of moderately indurated, wackestone to packstone, with stringer of very well indurated crystalline dolomite. The presence of well indurated crystalline dolomite is reflected by higher and more variability in the sonic and dual-induction readings. The deep and medium induction readings average 3 to 4 ohm-m, the diameter of the pilot-hole decreases slightly to 15-inches and sonic log readings decrease to approximately 85 usec/ft. The temperature, fluid conductivity and flowmeter log readings are consistent, indicating little water production from this interval. This interval is interpreted to be confining in nature due to the lack of evidence of fluid production and it fine-grained nature and higher carbonate mud content.

The interval from 2,600 to 2,730 feet bpl is composed of moderately indurated, wackestone to packstone with low to moderate inter-granular porosity inter-bedded with low porosity, well-indurated mudstone units. The natural gamma log readings increase below 2,675 feet bpl to 2,725 feet bpl. These higher natural gamma readings indicate that the formation becomes more dolomitic in nature with depth. The borehole diameter also decreases over this interval as shown by the caliper indicating the lower portion of this interval is better indurated. This interval is characterized by fairly consistent log readings in the upper portion of the interval becoming more variable with increasing depth. Both the formation and production log traces indicate a minor high porosity unit having higher water production capacity from 2,720 to 2,730 feet bpl. The borehole video surveys also show an enlarged water-filled borehole at this depth.

The interval from 2,730 to 2,900 feet bpl is composed of poorly to moderately indurated mudstone to packstone with low to moderate inter-granular porosity. It also contains white limestone units which are more micritic in nature with very poor primary porosity. The caliper log shows an enlarged borehole with an average diameter of 20 to 22 inches. The enlarged borehole causes the sonic travel times to increase and the dual-induction readings to decrease through this interval as compared to the overlying rock intervals.

The interval from 2,900 to 2,925 feet bpl is characterized by harder, lower porosity limestone units. The diameter of the borehole decreases, the dual-induction readings increase based on the deep resistivity curve is about 2.5 ohm-m and the sonic log indicates average transit times of 95 microseconds and porosity readings of 32 porosity units through this interval. This harder, low porosity unit was identified as an effective confining unit to the underlying injection horizon and selected as a casing point for the 30-inch diameter injection casing.

Lower Floridan Aquifer – "Boulder Zone Injection Horizon"

Below a depth of 2,925 feet bpl through the injection horizon the secondary porosity development increases significantly, the borehole diameter intermittently increases associated with larger voids, the resistivity readings and the sonic travel times become highly variable indicating good secondary porosity/permeability features throughout this interval. The highly permeable zones are also noted by a shift in the temperature log data. The video survey's also shows the presence of cavities/cavernous zones throughout the injection horizon at this site.

In IW-1, fractured and cavernous intervals extend from 2,925 to 3,650 feet bpl and will provide good injection capacity. Below 3,680 feet bpl, the lithology change from crystalline limestone and dolomite to a moderately indurated wackestone to packstone and the degree of secondary permeability development decreases significantly. Limited injection capacity occurs from 3,680 to 3,800 feet bpl.

In IW-2, there are no significant fractured or cavernous intervals in the upper portion of the "Boulder Zone" as compared to IW-1. However there are moderate secondary to good secondary permeability units interspersed throughout the completed injection zone from 2,925 to 3,800 feet bpl that will provide good injection capacity.

Packer Tests

Packer tests were conducted during the construction of IW-1, IW-2 and MW-1 to determine water quality and hydrogeologic characteristics of the tested intervals and to establish the base of the Underground Source of Drinking Water (USDW) at this site. A total of nineteen packer tests were conducted during the construction of IW-1 and IW-2, and an additional five packer tests were conducted during the construction of MW-1. A summary of the packer testing program is provided in **Table 4-2**.

A minimum of five drill stem volumes (including the tested interval) were purged during packer testing operations to ensure that the formation water produced had stabilized based on measured field parameter (conductivity, temperature and pH) and was representative of the interval tested prior to sample collection. Water samples were collected near the end of the pumping phase of each packer test within IW-1, IW-2 and MW-1 and sent to Florida Spectrum Environmental Services, Inc. for turbidity, total dissolved solids (TDS), major ions, ammonia, and TKN analyses. The water samples were also field analyzed for temperature, pH, and specific conductance. The laboratory analytical reports for water samples collected during the individual packer tests for IW-1, IW-2 and MW-1 can be found in **Appendix J-2.**

Table 4-2: Summary of Packer Testing Program with Specific Capacity Results

Well	ID	Depth (ft bpl)	Lab TDS (mg/L)	Specific Capacity (gpm/ft)	Specific Capacity per ft of Tested Interval (gpm/ft/ft)
IW-1	Packer Test #1	1,911 - 1,928	33,900	0.800	0.050
IW-1	Packer Test #2	1,726 - 1,743	15,380	0.411	0.026
IW-1	Packer Test #3	1,641 - 1,658	6,796	0.938	0.059
IW-1	Packer Test #4	2,671 - 2,688	36,250	0.085	0.005
IW-1	Packer Test #5	2,546 - 2,563	35,200	0.278	0.017
IW-1	Packer Test #6	2,366 - 2,383	37,850	0.132	0.008
IW-1	Packer Test #7	2,181 - 2,197	37,250	0.059	0.004
IW-1	Packer Test #8	2,269 - 2,286	35,300	0.385	0.024
IW-1	Packer Test #9	2,081 - 2,097	35,300	0.370	0.023
IW-2	Packer Test #1	1,986 - 2,003	35,633	1.080	0.067
IW-2	Packer Test #2	1,711 - 1,728	14,840	0.290	0.018
IW-2	Packer Test #3	1,661 - 1,678	8,090	0.240	0.015
IW-2	Packer Test #4	1,821 - 1,838	27,833	1.140	0.071
IW-2	Packer Test #5	2,007 - 2,023	37,000	1.010	0.063
IW-2	Packer Test #6	2,196 - 2,213	38,600	0.010	0.001
IW-2	Packer Test #7	2,296 - 2,313	39,200	0.320	0.021
IW-2	Packer Test #8	2,409 - 2,425	38,267	0.060	0.004
IW-2	Packer Test #9	2,621 - 2,638	38,850	0.160	0.010
IW-2	Packer Test #10	2,899 - 2,916	39,100	0.330	0.021
MW-1	Packer Test #1	1,655 - 1,672	8,960	0.800	0.050
MW-1	Packer Test #2	1,580 - 1,597	4,900	2.250	0.140
MW-1	Packer Test #3	1,410 - 1,427	6,468	0.480	0.030
MW-1	Packer Test #4	1,952 - 2,000	37,367	1.880	0.040
MW-1	Packer Test #5	1,741 - 1,758	17,440	1.100	0.065

Based on the results of the laboratory determine water quality analysis from the packer tests, the base of the USDW was identified at a depth between 1,695 and of 1,705 feet bpl. The laboratory TDS data for the packer tests, see **Table 4-2**, are in good agreement with the log-derived TDS concentrations using a modified Archie equation (1944) as provided in Geophysical Log Run No.3 for both IW-I and IW-2. In addition, the packer test water quality data also helped to confirm that the native ground water below the intermediate casings (set at 1,975 and 1,990 feet bpl) is saline in composition. **Table J-1** in **Appendix J** provides a summary of laboratory determined water quality results from the packer tests conducted within the confining units above proposed injection horizon.

Table 4-2 and **Table J-1** in **Appendix J** provides a summary of packer test's pumping rate and water level drawdown data and calculated specific capacity to show relative production capacity/permeability of the tested intervals within the confining unit overlying the injection horizon. The normalized specific capacity data based on length of tested interval range from 0.001 to 0.071 gpm/foot for the overlying confining unit below the base of the USDW.

The horizontal maximum and vertical permeability data for representative samples of rock units overlying the injection horizon indicate higher horizontal permeability valves. These data suggest that there would be a greater tendency for injected fluids to travel laterally as opposed to vertical migration under a given hydrostatic pressure gradient limiting the potential for upward movement of injected fluids. In addition, the dynamic Poisson's ratio obtained from the core samples implies a low fracture potential within the overlying confining unit.

These data suggest that the overlying confining unit (1,700 to 2,925 feet bpl) should serve as an effective seal to the underlying injection horizon at this site.

SECTION 5

Mechanical Integrity Testing

Mechanical Integrity Testing

Mechanical integrity tests (MIT) were conducted on the completed injection wells identified as IW-1 and IW-2 to evaluate their internal and external integrity in accordance with standards set forth in Chapter 62-528, FAC. The components of each test included a hydrostatic casing pressure test, video survey on the fully cemented 20-inch diameter FRP injection liner, a high-resolution temperature log and a radioactive tracer survey.

AECOM coordinated and scheduled all testing activity with FDEP staff. Youngquist Brothers, Inc. (YBI) provided all testing services related to MIT operations at this site with AECOM staff onsite during all testing operations to document testing activities and results and to provide technical oversight. Daily activity reports summarizing work conducted during the MIT's are included in **Appendix A**.

The results of the tests demonstrate that IW-1 and IW-2 meet the requirements for mechanical integrity as set forth in Rule 62-528.300(6), FAC.

Injection Well IW-1

Video Survey (IW-1)

A color video survey of IW-1 was conducted on June 6, 2011, by Youngquist Brothers, Inc. (YBI). The camera assembly was equipped with centralizers to keep it centered in the well casing. Depth readings on the video are relative to feet below pad level. The video survey was conducted to an approximate depth of 3,684 feet below pad level (bpl).

During the video survey, the FRP injection liner and threaded and coupled connections appeared to be in excellent condition based on fully seated connections and no evidence of galling or damage to the interior surface. The base of the 30-inch diameter (0.5-inch wall) steel injection casing was observed at a depth of 2,902 feet bpl. The bottom of the 20-inch

FRP injection liner was noted at 2,894 feet bpl which is slightly different than the depth observed on other geophysical logs. The cement seal around the base of the 30-inch injection casing and 20-inch FRP injection liner both appeared to be in good condition based no apparent cracks and seal was observed around the full circumference of the pipe. Below the base of the 30-inch steel injection casing; the open-hole interval was gauge over the majority of its length with intermittent voids and cavernous areas observed to the total depth of the injection zone at 3,684 feet bpl.

The video survey showed no inconsistencies within the logged interval and the nominal 20-inch diameter FRP injection liner of IW-1 appears to be in excellent condition. A DVD reproduction of the video survey along with a written summary of observations noted during this video survey is presented in **Appendix K-1**.

Hydrostatic Pressure Test (IW-1)

On June 8, 2011, a hydrostatic pressure test was successfully conducted within the nominal 20-inch diameter FRP injection liner of IW-1. This test was designed to detect the presence of leaks within the fully cemented FRP injection tubing. Mr. Gardner Strasser (FDEP) and Sheldon Barnes (AECOM) were onsite to record data and witness the performance of the hydrostatic pressure test.

The hydrostatic pressure test was completed using an inflatable packer set at a depth of 2,875 feet bpl (located below the first threaded coupling) of the 20-inch FRP injection liner. Before starting the 60-minute hydrostatic pressure test; precaution were taken to remove entrapped air from the inside FRP injection liner. Then water was added to the FRP injection liner using a high-pressure water pump to achieve an internal pressure of 153.0 psi. During the 60-minute test, pressure readings were taken at 5-minute intervals from a calibrated pressure gauge. A copy of the calibration certificate for the pressure gauge used during this test is included in **Appendix K-2**. At the conclusion of the test, the hydrostatic pressure within the FRP liner was 150.0 psi. The 3.0 psi loss in pressure is within the 5 percent limit (7.65 psi) from the initial test pressure as specified in Rule 62-528.300(6)(e), FAC. After the test was completed, a total of 32 gallons of water used to pressurize to FRP liner during the test was discharged. A summary of the hydrostatic pressure test results is included in **Appendix K-2**.

High-Resolution Temperature Logging (IW-1)

A high-resolution temperature log was performed on IW-1 on September 7, 2011, by YBI. Copies of the temperature logs are provided in **Appendix K-3.**

The temperature log for IW-1 was performed from pad level to the total depth of the well to evaluate the nominal 20-inch diameter FRP injection liner for potential leaks. The temperature log recorded a temperature of 91.0 °F at pad level, which decreased to 77.7 °F at depth of 25 feet bpl. The higher temperatures in the uppermost section of the injection tubing are due to solar heating of the stainless steel wellhead that transferred the heat to the water within the well column. Based on the results of the hydrostatic pressure test, this slight change in temperature at the surface does not appear to suggest a deviation in the internal mechanical integrity of the well.

From a depth of 25 to 2,800 feet bpl the recorded temperature values steadily decrease from 77.7 to 60.7 °F then increases gradually to 62.6 °F at the base of the 30-inch injection casing at 2,902 feet bpl. Directly below the base of the 30-inch steel injection casing the temperature increased from 62.6 to 66.2 °F. This increase in temperature is most likely due to the presence of a highly permeable zone where a significant volume of warmer water which was circulated downhole during drilling operations mixes with cooler ambient ground water that was transmitted laterally through the formation. The recorded temperatures within the injection horizon steadily decrease to a depth of 3,395 feet bpl where there is a noted change in the temperature differential log and the temperature begins to steadily increase to the total depth of the well. This temperature change noted at a depth of 3,395 feet bpl mostly likely represents a transition to the less permeable section of the injection horizon where either warmer water circulated during drilling operations remain or there is limited influx of cooler native groundwater.

The temperature log conducted gives no indication of a lack of internal mechanical integrity of the injection casing or liner of IW-1.

Radioactive Tracer Survey (IW-1)

On September 9, 2011, a Radioactive Tracer Survey (RTS) was performed on IW-1. The purpose of the RTS was to verify the integrity of the grout seal around the base of the 30-

inch diameter steel injection casing and cemented annuls of the 20-inch FRP injection liner. The survey was conducted by YBI and witnessed by Mr. Len Fishkin, P.G of the FDEP and Mr. Shamus English of AECOM.

The area surrounding each of the injection wells was monitored using a Geiger counter before and after the Radioactive Trace Survey (RTS) to confirm that no tracer material (Iodine 131) impacted the site. A Copy of the Geiger Counter Survey conducted at IW-1 is included in **Appendix K-4**.

The RTS tool used to perform testing operations was equipped with a tracer ejector port (TREJCT-A) located 13.5 feet above the base of the tool, an upper gamma ray detector (GRT) located 10.5 feet above the tracer ejector port, a middle gamma ray detector (GRM) located 3.0 feet below the ejector port, a lower gamma ray detector (GRB) located 12.3 feet below the ejector port and a Casing Collar Locator (CCL) located 9.5 feet above the base of the tool. **Figure 5-1** provides a schematic of the YBI's logging tool that was used to conduct the radioactive tracer survey (RTS).

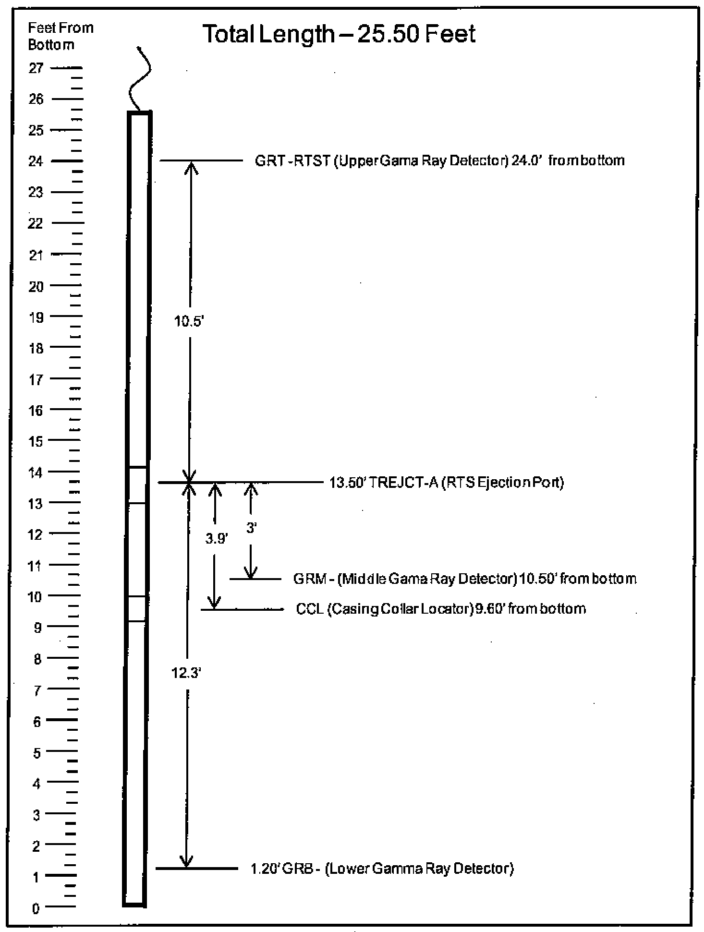

Figure 5-1: RTS Tool Schematic

A background gamma ray log was conducted from pad level to a depth of 3,628 feet bpl to record background readings within IW-1. The initial background gamma log is identified at the bottom of the RTS log sheet as "Background Gamma Ray".

Using the casing collar locator (CCL), the base of the nominal 20-inch diameter FRP injection liner was verified at approximately 2,892 feet bpl. The base of the 30-inch diameter steel injection casing could not be verified by the CCL, so the 4-arm caliper log conducted on September 7, 2011 was used to establish the reference depth for the base of the 30-inch steel injection casing at 2,902 feet bpl.

The casing tie-in log sheet shows four data fields across the page from left to right, as follows:

- GRT (top detector, 10.5 feet above ejector) – left data field
- CCL (casing collar locator, 3.9 feet below ejector) – left data field
- GRB (bottom detector, 12.3 feet below ejector) – center data field
- GRM (middle detector, 3.0 feet below ejector) – right data field

Two (2) low-flow dynamic tests were performed on IW-1. Each of the low flow tests are labeled on the RTS log sheet as "Dynamic Test" followed by the designated test number and the water injection rate. The dynamic test log sheets show three data fields across the page and are set up identical to the casing tie-in log sheet except that the vertical scale represents time, rather than depth, and there is no CCL data. The horizontal scale for the time-drive logs are similar to the tie-in pass which represents the gamma ray count on the log output. Reading the log upwards, each inch of the vertical scale represents 100 seconds of time.

A total of 4 mCi of tracer fluid (Iodine 131) was placed in the RTS tool at the start of logging operation. A copy of the Iodine 131 Assay is included in **Appendix K-4**. Prior to the release of the tracer, the RTS tool was positioned with the ejector port approximately 5 feet above the base of the 30-inch steel diameter injection casing at 2,897 ft bpl. To ensure the detectors were functioning properly prior to the test, the RTS tool was held stationary while collecting gamma ray data for 1 minute, before ejecting the tracer. Keeping the RTS tool stationary while collecting gamma ray data is referred to as "time drive" in this report. Following the 1 minute detector test, 1 mCi of Iodine 131 tracer was ejected during each dynamic test. Gamma ray activity was then monitored for 60 minutes after the release of the tracer during Dynamic Tests Nos. 1 and 2.

Following each of the monitoring periods, a "log out of position" (LOP) was performed to determine if tracer had migrated above the ejection point. The LOP was conducted to about 200 feet above the tracer ejection point. This was followed by injecting water to flush the tracer fluid and any associated tracer stains from the casings. After completion of dynamic testing and water flush, the tool was lowered and a final gamma ray log or "log after flush" was conducted.

Dynamic Test #1 (IW-1)

Upon completion of background gamma ray logging and performance of the casing tie-in log, the RTS tool was positioned with the ejector port located 5 feet above the base of the 30-inch steel diameter injection casing (ejector port at 2,897 feet bpl). Based on FDEP guidance for injection wells designed with a cement-filled annulus, the flow velocity during the dynamic RTS' was determined based on the inner diameter of the 20-inch outer diameter (17.98-inch I.D.) injection tubing. Based on the nominal 18-inch I.D. of the FRP injection tubing, a water injection rate of 61 gpm yields an approximate downhole flow velocity of 4.5 feet per minute. A copy of the calibration certificate for the flow meter used to measure flow rates during testing operations is included in **Appendix K-4**.

Approximately 1 minute after beginning the time-drive gamma ray log, 1 mCi of tracer was released from the RTS tool ejector port. Increased gamma readings were recorded by the middle gamma ray detector 75 seconds after release of the tracer and peaked after about 110 seconds following the release of the tracer. Gamma ray readings remained between 2,200 and 2,500 gAPI (total gamma ray emissions in American Petroleum Institute units) for more than 11 minutes as the slug of tracer passed by the middle detector before beginning to decrease. Gamma ray activity recorded by the middle detector was close to background levels within approximately 38 minutes after the release of the tracer.

An initial increase in gamma ray activity were recorded by the bottom detector 270 seconds following the release of tracer and began to decrease as the slug of tracer passed by approximately 16 minutes after release. Gamma ray activity at the bottom detector was close to background levels 46 minutes after the release of the tracer. No increase in gamma ray activity was detected by the upper detector during the 60-minute monitoring period for Dynamic Test #1. The result of this survey is labeled on the RTS log sheet as "Dynamic Test #1 (61 GPM)"

After the first dynamic test was completed, the tool was logged out of position while continuing to inject water at 61 gpm. The log out of position was performed while raising the tool to a depth of 2,675 feet bpl. While moving the tool upward, the middle and bottom detectors showed elevated gamma ray activity from 2,898 to 2,892 feet bpl as they passed the depth where the ejector port released the radioactive tracer at the start of the dynamic test. These elevated gamma ray readings are most likely caused by staining of the injection tubing when the tracer fluid was released from the RTS tool. Gamma ray activity at the upper detector was not detected during the log out of position run. The output of the three gamma detectors and the CCL during the log out of position is displayed in the RTS log sheet as LOP #1.

The injection well was then flushed using brackish ground water before lowering the radioactive tracer tool to the base of the injection tubing to perform a Log after Flush (LAF). The LAF is run in a similar manner to the LOP. During the LAF, elevated gamma ray activity was recorded by the middle and bottom detectors from 2,898 to 2,892 feet bpl as they passed the stained area as previously described. Elevated gamma ray activity was not recorded by the upper detector during the log after flush run. The output of the three gamma detectors and the CCL during the Log after Flush is displayed in the on the RTS log sheet as LAF #1.

After completing the test components related to Dynamic Test #1, the radioactive tracer tool was then lowered to the base of the casing to begin Dynamic Test #2.

Dynamic Test #2 (IW-1)

For dynamic test 2, the RTS tool was again positioned with the ejector port located 5 feet above the base of the 30-inch steel diameter injection casing at a depth of 2,897 feet bpl. The second test was conducted using an injection rate of 59 gpm which yields an approximate down-hole flow velocity of 4.3 feet per minute. Similar injection rates were used during the two dynamic tests to determine how closely the results correlated between the two radioactive tracer surveys. However, the test duration for this RTS was limited to 30 minutes as compared to 60 minutes for the first dynamic test.

Approximately 1 minute after beginning the time-drive gamma ray log, 1 mCi of tracer was released from the RTS tool ejector port. The initial increase in gamma ray activity was evident at the middle detectors approximately 30 seconds following the release of radioactive tracer. Elevated gamma ray activity decreased quickly after the tracer slug passed by the middle detector and neared background levels within 15 minutes after the release of the tracer.

Increased gamma ray activity was recorded by the bottom detector within 220 seconds after the tracer was released. The recorded gamma ray activity peaked quickly and stayed between 2,300 - 2,400 gAPI for approximately 7.5 minutes as the tracer passed before beginning to decrease. Gamma ray activity at the bottom detector decreased to around 150-200 gAPI but never fully returned to background levels. Elevated gamma responses were not detected at the upper detector during the 30-minute test period. The results from Dynamic Test #2 are labeled on the RTS log sheet as "Dynamic Test #2 (59 GPM)"

Following completion of Dynamic Test #2, the tool was logged out of position while continuing to inject water at 59 gpm. The log out of position was performed upward to a depth of 2,765 feet bpl to monitor for movement of tracer on the outside of the injection casing. Elevated gamma ray activity, above background levels, was recorded by the bottom gamma detector below the base of the 30-inch steel injection casing where the tracer fluid had traveled into the permeable rock formation at 2,907 feet bpl. Again, both the middle and bottom detectors as logged upward showed elevated gamma ray activity from 2,898 to 2,892 feet bpl where the tracer fluid had been released from the RTS tool during the two dynamic tests. Gamma ray activity was not detected in the upper detector during the second log out of position. The output of the three gamma detectors and the CCL during the log out of position is displayed in the RTS log sheet as LOP #2.

The tool was lowered to 3,050 feet bpl and the injection well was flushed with brackish ground water while the remaining tracer fluid from the RTS tool was released.

After ejecting the remaining tracer and the flushing the injection well, the tool was lowered to 3,685 feet bpl and a final gamma log conducted for comparative purposes with the background gamma log. The gamma ray response from each detector is shown on the RTS log sheet as FINAL GAMMA RAY. As expected, the upper, middle and bottom gamma ray detectors peaked at 3,050 feet bpl where the remaining tracer fluid was released and then gamma ray activity gradually decreased to within background levels at around 3,000 feet bpl. All three detectors also displayed increased gamma ray activity just below the base of the 30-inch diameter steel casing at 2,902 feet bpl. It is evident that most of the tracer material ejected during Dynamic Test #1 and #2 was entering into permeable section of the injection zone immediately below the 30-inch steel injection casing. However, above a depth of 2,892 feet bpl; the base of the 20-inch OD FRP injection liner there was no indication of elevated gamma ray activity.

Although the results of the second dynamic test are not the same as those for the first dynamic test, there is no indication of upward migration of radioactive tracer outside the 30-inch steel injection casing or the 20-inch FRP injection liner during either of these two tests. A comparison between the "Final" and "Background" Gamma Ray logs show no elevated gamma ray activity above the 20-inch FRP injection liner. The results of the Radioactive Tracer Survey completed within IW-1 demonstrate the external mechanical integrity of this injection well. Copies of the radioactive tracer survey logs are presented in **Appendix K-3.**

Injection Well IW-2

Video Survey (IW-2)

A color video survey of IW-2 was conducted on July 7, 2011, by Youngquist Brothers, Inc. (YBI). The camera assembly was equipped with centralizers to keep it centered in the well casing. Depth readings on the video are relative to feet below pad level. The video survey was conducted to an approximate depth of 3,808 feet bpl.

During the video survey, the FRP injection liner and threaded and coupled connections appeared to be in excellent condition based on fully seated connections and no evidence of galling or damage to its interior surface. The base of the 20-inch FRP injection liner was observed at a depth of 2,916 feet bpl during the video survey. The base of the 30-inch diameter steel injection casing was observed at a depth of 2,925 feet bpl. The cement seal around the base of the 30-inch injection casing appeared to be in good condition as there were no significant evidence of cracking or voids and good contact around the full circumference of the injection casing. Below the base of the casing; the open-hole interval was gauge with intermittent voids and minor cavernous areas to the total depth of the well at 3,808 feet bpl.

A DVD reproduction of the video survey along with a written summary of observations noted during this video survey is presented in **Appendix K-5**.

Hydrostatic Pressure Test (IW-2)

On July 6, 2011, a casing pressure test was successfully conducted on the nominal 20-inch diameter FRP injection liner of IW-2. Mr. Len Fishken (FDEP) and Shamus English (AECOM) were onsite to record data and witness the performance of the hydrostatic pressure test.

The hydrostatic pressure test was conducted by pressurizing the FRP injection liner using a high-pressure water pump to the top of an inflatable packer set inside the injection tubing at a depth of 2,892 feet bpl (located below the first FRP coupling). Precautions were taken to bleed the injection liner to ensure no air was trapped inside the FRP before the start of the 60-minute hydrostatic pressure test. At the start of the casing pressure test the internal pressure was 152.5 psi. Pressure readings were taken at 5-minute intervals over the 60-minute period using a calibrated pressure gauge. A copy of the calibration certificate for the pressure gauge used during this test is included in **Appendix K-6**. At the conclusion of the test, the hydrostatic pressure was 147.0 psi. The 5.5 psi loss in pressure from within the injection tubing was less than the 5 percent limit (7.65 psi) as specified in Rule 62-528.300(6)(e), FAC with reduction in pressure due to cooling of the fluids within the injection tubing. A total of 36 gallons of water used to pressurize the injection tubing was discharged after the test was completed. A summary of the hydrostatic pressure test results is included in **Appendix K-6.**

High-Resolution Temperature Logging (IW-2)

A high-resolution temperature log was performed on IW-2 on September 7, 2011, by YBI. Copies of the temperature logs from IW-2 are provided in **Appendix K-7.**

The temperature log for IW-2 was performed from pad level to its total depth (3,686 feet bpl) to evaluate the nominal 20-inch diameter FRP injection liner for potential leaks. The temperature log recorded a temperature of 74.8 °F at pad level, with a small increase to 75.3 °F at depth of 25 feet bpl. The temperature variation is likely due to solar heating of the well head that transferred the heat for the stainless steel wellhead to the water within the well column. Based on the results of the casing pressure test, this slight change in temperature at the surface does not appear to suggest a deviation in the internal mechanical integrity of the well.

From a depth of 25 feet bpl; the recorded temperature values steadily decrease from 75.3 to 59.3 °F at the base of the 30-inch steel injection casing at 2,925 feet bpl. A steeper decrease in the temperature gradient was observed from 2,000 to 2,170 feet bpl with a small deviation on the temperature differential log noted at 2,095 feet bpl. These minor variations are believed to be caused by the transition from a triple-casing to a double casing configuration at a depth of 1,990 feet bpl and the presence of a permeable horizon at a depth of 2,150 feet with greater ground water circulating proximal to the outer injection casing.

Directly below the base of the 30-inch steel injection casing at 2,925 feet bpl to 2,950 feet bpl; the temperature continues to decrease from 59.3 to 55.6 °F. This continued decrease in temperature is most likely due to the presence of a permeable zone reflects the cooler ambient ground water that was transmitted laterally through the formation, typical of the Boulder Zone in southeast Florida. The recorded temperatures within the injection horizon steadily decrease to a depth of 3,375 feet bpl where there is noted change in the temperature differential log and the temperature begins to steadily increase to the base of the injection horizon. This temperature change noted at a depth of 3,375 feet bpl mostly likely represents a less permeable section whereby the natural positive geothermal gradient returns in combination with either warmer water circulated from drilling operations remain or there is limited influx of cooler groundwater as found above.

Results of the temperature log provide no indication of a lack of internal mechanical integrity of the injection casing or liner of IW-2. Copies of the high-resolution temperature are provided in **Appendix K-7.**

Radioactive Tracer Survey (IW-2)

On September 13, 2011, a Radioactive Tracer Survey (RTS) was performed on IW-2. The purpose of the RTS was to verify the integrity of the grout seal around the base of the 30-inch diameter steel injection casing and cemented annuls of the 20-inch FRP injection liner. The survey was conducted by YBI and witnessed by Mr. Len Fishkin, P.G of the FDEP and Mr. Shamus English of AECOM.

The area surrounding each of the injection wells was monitored using a Geiger counter before and after the Radioactive Trace Survey (RTS) to confirm that no tracer material (Iodine 131) impacted this site. A Copy of the Geiger Counter Survey conducted at IW-2 is included in **Appendix K-8**.

The RTS tool used to perform testing operations was the same tool used for IW-1 and was described previously in this report. A background gamma ray log was conducted from pad level to a depth of 3,610 feet bpl to record background gamma ray levels within IW-2. The initial background gamma log is identified at the bottom of the RTS log sheet as "Background Gamma Ray".

Based on the casing collar locator (CCL), the bottom of the nominal 20-inch diameter FRP injection liner was noted at 2,917 feet bpl which is slightly different then the video survey and casing tally. The base of the 30-inch diameter steel injection casing could not be verified with the CCL, so the 4-arm caliper log conducted on September 6, 2011 was used as reference depth to confirm the depth of the 30-inch diameter steel injection casing at 2,925 feet bpl.

The casing tie-in log sheet shows four data fields across the page from left to right, as previously described.

Two (2) low-flow dynamic tests were performed at IW-2. Each of the low flow tests are labeled on the RTS log sheet as "Dynamic Test" followed by the designated test number and the water injection rate. The dynamic test log sheets show three data fields across the page and are set up identical to the casing tie-in log sheet except that the vertical scale represents time, rather than depth, and there is no CCL data. The horizontal scale for the time-drive logs are similar to the tie-in pass which represents the gamma ray count on the log output. Reading the log upwards, each inch of the vertical scale represents 100 seconds of time.

A total of 5 mCi of tracer fluid (Iodine 131) was placed into the RTS tool. A copy of the Iodine 131 Assay is included in **Appendix K-8**. Prior to the release of the tracer, the RTS tool was positioned with the ejector port approximately 6 feet above the base of the 30-inch diameter steel injection casing at 2,919 ft bpl. To ensure the detectors were functioning properly prior to the test, the RTS tool was held stationary while collecting gamma ray data for 1 minute, before ejecting the tracer. Following the 1 minute detector test, 1 mCi of Iodine 131 tracer was ejected during each dynamic test. Gamma ray activity was then monitored for 60 minutes after the release of the tracer during Dynamic Tests Nos. 1 and 2.

Following each of the monitoring periods, a "log out of position" (LOP) was performed to determine if tracer had migrated above the ejection point. The LOP was conducted to about 200 feet above the tracer ejection point. This was followed by injecting brackish ground water to flush the tracer fluid and any associated tracer stains from the casings. After completion of dynamic testing and water flush, the tool was lowered and a final gamma ray log or "log after flush" was conducted.

Dynamic Test #1 (IW-2)

Upon completion of background gamma ray logging and performance of the casing tie-in log, the RTS tool was positioned with the ejector port located 6 feet above the base of the 30-inch diameter steel injection casing (ejector port at 2,919 feet bpl). Based on FDEP's guidance for injection wells designed with a cement-filled annulus, the flow velocity during the dynamic RTS was determined based on the inner diameter of the 20-inch outer diameter (17.98-inch inner diameter [I.D.]) injection liner. Using the nominal 18-inch I.D. FRP injection tubing combined with a water injection rate of 59 gpm yielded an approximate downhole flow velocity of 4.5 feet per minute. A copy of the calibration certificate for the meter used to measure flow rates used during testing operations included in **Appendix K-8.**

One (1) mCi of tracer was released from the RTS tool ejector port at the start of the time-drive gamma ray log. Increased gamma readings were recorded by the middle gamma ray detector 80 seconds after release of the tracer and peaked after about 150 seconds following the release of the tracer. Gamma ray readings remained between 2,000 and 2,300 gAPI (total gamma ray emissions in American Petroleum Institute units) for approximately 10 minutes as the slug of tracer passed by the middle detector before readings began to decrease. Gamma ray activity recorded by the middle detector was close to background levels within approximately 41 minutes after the release of the tracer.

An initial increase in gamma ray activity were recorded by the bottom detector 240 seconds following the release of tracer and began to decrease as the slug of tracer passed by approximately 14.5 minutes after release. Gamma ray activity at the bottom detector was close to background levels 55 minutes after the release of the tracer. No increase in gamma ray activity was detected by the upper detector during the 60 minute monitoring period for Dynamic Test #1. The result of this survey is labeled on the RTS log sheet as "Dynamic Test #1 (59 GPM)"

After the first dynamic test was completed, the tool was logged out of position while continuing to inject water at 59 gpm. The log out of position was performed while raising the tool to a depth of 2,697 feet bpl. While moving the tool upward, the middle and bottom detectors showed elevated gamma ray activity from 2,916 to 2,920 feet bpl as they passed the depth where the ejector port released the radioactive tracer at the start of the dynamic test. These elevated gamma ray readings are most likely caused by staining of casing when the tracer fluid was released from the RTS tool. Gamma ray activity at the upper detector was not detected during the log out of position run. The output of the three gamma detectors and the CCL during the log out of position is displayed in the RTS log sheet as LOP #1.

The injection well was then flushed with brackish groundwater before lowering the radioactive tracer tool to the base of the injection tubing to perform a Log after Flush (LAF). The LAF is run in a similar manner to the LOP. During the LAF, elevated gamma ray activity was recorded by the middle and bottom detectors from 2,916 to 2,920 feet bpl as they passed the stained area as previously described. Elevated gamma ray activity was not recorded by the upper detector during the log after flush run. The output of the three gamma detectors and the CCL during the Log after Flush is displayed in the on the RTS log sheet as LAF #1.

After completing the test components related to Dynamic Test #1, the radioactive tracer tool was then lowered to the base of the injection casing to begin Dynamic Test #2.

Dynamic Test #2 (IW-2)

For dynamic test #2, the RTS tool was again positioned with the ejector port located 6 feet above the base of the 30-inch diameter steel injection casing at a depth of 2,919 feet bpl. The second test was conducted using an injection rate of 52 gpm which yields an approximate down-hole flow velocity of 3.9 feet per minute. Similar water injection rates were used during the two dynamic tests to determine how the closely the test results compare. However, the test duration for the second test was limited to 30 minutes as compared to 60 minutes for the first dynamic test.

At the beginning the time-drive gamma ray log, 1 mCi of tracer was released from the RTS tool ejector port. The initial increase in gamma ray activity was evident at the middle detectors approximately 90 seconds following the release of radioactive tracer. Elevated gamma ray activity decreased quickly after the tracer slug passed by the middle detector and neared background levels within 18 minutes after the release of the tracer.

Increased gamma ray activity was recorded by the bottom detector within 400 seconds after the tracer was released. The recorded gamma ray activity peaked quickly and stayed between 2,200 - 2,300 gAPI for approximately 6 minutes as the tracer passed before beginning to decrease. Gamma ray activity at the bottom detector decreased to around 350-400 gAPI but never fully returned to background levels. Elevated gamma responses were not detected at the upper detector during the 30-minute test period. The results from Dynamic Test #2 are labeled on the RTS log sheet as "Dynamic Test #2 (52 GPM)"

Following completion of Dynamic Test #2, the tool was logged out of position while continuing to inject water at 52 gpm. The log out of position was performed upward to a depth of 2,696 feet bpl to monitor for movement of tracer on the outside of the injection casing. Elevated gamma ray activity, above background levels, was recorded by the bottom gamma detector below the base of the 30-inch steel injection casing where the tracer fluid had traveled into the permeable rock formation at 2,930 feet bpl. Again, both the middle and bottom detectors showed elevated gamma ray activity from 2,916 to 2,920 feet bpl where the tracer fluid had been released from the RTS tool during the two dynamic tests. Gamma ray activity was not detected in the upper detector during the second log out of position. The output of the three gamma detectors and the CCL during the log out of position is displayed in the RTS log sheet as LOP #2.

The tool was lowered to 3,055 feet bpl and the injection well was then flushed with brackish groundwater while the remaining tracer fluid from the RTS tool was released.

After releasing the remaining tracer and the flushing the injection well, the tool was lowered to 3,610 feet bpl and a final gamma log was conducted for comparative purposes with the background gamma log. The gamma ray response from each detector is shown on the RTS log sheet as FINAL GAMMA RAY. As expected, the upper, middle and bottom gamma ray detectors peaked at 3,055 feet bpl where the remaining tracer fluid was released and then gradually decreased to within the background levels at around 3,010 feet bpl. All three detectors also displayed increased gamma ray activity just below the base of the 30-inch diameter steel injection casing at 2,925 feet bpl. It is evident that most of the tracer material ejected during Dynamic Test #1 and #2 was entering into permeable section of the injection zone immediately below the 30-inch steel casing. However, above a depth of 2,916 feet bpl (the base of the 20-inch OD FRP injection liner) there was no indication of elevated gamma ray activity.

The results of the two RTS' provide no indication of upward migration of radioactive tracer outside the 30-inch steel injection casing or the 20-inch FRP injection liner during either of these two tests. A comparison between the "Final" and "Background" Gamma Ray logs show no elevated gamma ray activity above the 20-inch FRP injection liner. The results of the Radioactive Tracer Survey completed within IW-2 demonstrate the external mechanical integrity of this injection well. Copies of the radioactive tracer surveys for IW-2 are presented in **Appendix K-7.**

As described above, the results of the hydrostatic pressure tests, temperature logs and video and radioactive tracer surveys conducted on IW-1 and IW-2 at this site demonstrate that both injection wells meet the requirements for internal and external mechanical integrity as set forth in Rule 62-528.300(6), FAC.

SECTION 6

Injection and Extended Testing Operations

Interim Injection Testing – Injection Well IW-1 (2011)

An interim injection test was performed on IW-1 to initially demonstrate that the system was able to accept flows of up to 4.0 million gallons per day (MGD). The results of the 12-hour injection test show no significant pressure build-up at IW-1 or induced pressure changes in the dual-zone monitor well during this test. After the interim injection test was completed, extended testing operations of the injection well system was completed by continuing flows of produced ground water from the Floridan aquifer generated during the construction of the Town's brackish water supply wells to ensure that the DIW system could meet long-term injection requirements.

The interim injection test was conducted on October 1, 2011 through October 6, 2011 and included: 72 hours of background data collection, a 3-hour preliminary test, 12 hours of injection at a rate of 2,761 gallons per minute (gpm), and 13 hours of recovery data collection. Wellhead pressure at IW-1, IW-2 and both zones of dual-zone monitor well MW-1 were recorded using a Hermit 3000 data logger. Flow rates throughout the injection test were measured using a calibrated flowmeter that was recorded manually. Water used for injection test of IW-1 was brackish ground water pumped from a previously constructed Floridan aquifer production well (PW-4) located approximately 600 feet south of the DIW system.

Hydrostatic pressure data recorded at IW-1, IW-2, MW-1U and MW-1L during the injection test are represented in **Figures L-1** through **L-5** in **Appendix L-1**. **Figure L-1** illustrates the static water levels recorded as background data prior to the injection test. **Figure L-2** represents the results of the 3-hour preliminary injection test conducted to insure that all equipment and instrumentation was functioning properly before the start of the 12 hour injection test. **Figure L-3** shows the 19 hours of recovery data recorded after completing the 3-hour preliminary injection test. **Figure L-4** illustrates the data recorded during the 12-

hour interim injection test and **Figure L-5** represents 13 hours of recovery data recorded following the 4.0 MGD injection test.

The shut in pressure for IW-1 during the background phase stabilized between 26.6 and 27.0 psi. The 12-hour injection test was conducted at an average injection rate of 2,761 gpm with a corresponding wellhead pressure of 28.4 to 29.6 psi. The wellhead pressure at IW-1 during the recovery period stabilized near the background pressure of 26.9 psi.

The pressure recorded in the upper monitor zone of MW-1 designated as MW-1U (completed 1,630 to 1,660 feet bpl) during background was approximately 9.3 psi and decreased to approximately 8.7 psi shortly after the 12-hour injection test began. After the injection test was completed, the pressure in MW-1U returned to around 9.3 psi.

The source of water for the interim injection test was brackish ground water pumped from a Floridan aquifer production well (PW-4) located approximately 600 feet from MW-1. This production well was completed to a depth of 1,582 feet bpl as compared to the top of the upper monitor zone of MW-1 completed at a depth of 1,630 feet bpl. The influence of the withdrawals from PW-4 on MW-1U during the injection test is seen by a minor decline in pressure due to the semi-confined nature of carbonate unit that separates these two intervals.

The lower zone of MW-1 (MW-1L) was not affected by the withdrawals from PW-4 or the injection into IW-1 and remained around 7.1 psi throughout the testing period. The lower zone did not exhibit noticeable pressure changes during testing operation because of adequate confinement above the injection zone and sufficient confinement from the pumped interval.

The results of the injection test demonstrate that IW-1 is capable of operating at a rate of up 4.0 mgd safely without impacts to the USDW as inferred by pressure data from the dual-zone monitor well.

Extended Testing & Monitoring

An operational testing request was submitted to the FDEP in late 2011. However, since the Water/Wastewater Treatment facilities were not fully constructed, the operational testing request was deferred until the W/WW facilities were completed. During this interim period, flows of produced ground water, generated during the drilling and testing of the Town's brackish production wells, to IW-1 would be allowed under the construction permit as additional testing to ensure the DIW system was functional before being placed into long-term operational testing mode. The extended injection period of the DIW system began on December 22, 2011 after FDEP completed a site inspection and continued until the long term operational testing request was approved by the Department. The "Request for Operational Testing Deep Injection Well System Town of Davie, Fl Water Treatment and Water Reclamation Facility" was submitted to the Department on October 12, 2012.

The flows of brackish groundwater produced from the Floridan aquifer during the construction and testing of the Town's production wells to IW-1 was performed in accordance with the specific conditions of the FDEP-issued construction permit and information provided as part of the Interim O&M manual submitted to the Department in November of 2011.

During this interim period where flows of produced ground water from the Floridan aquifer production wells were conveyed to IW-1; flow, pressure and water quality data from IW-1 and MW-1 were collected to provide a record of the DIW systems performance. These operating and monitoring data from IW-1 and MW-1 were compiled in Monthly Operating Report's (MOR) and submitted to the FDEP for review.

Operational data from the DIW system recorded during the extended testing period has demonstrated that the DIW functions properly and will operate as designed.

Final Injection Testing (2012)

Variable Rate Injection Testing

Prior to performing 12-hour injection tests at design capacity, a 3-hour variable rate preliminary test was performed at IW-1 and IW-2. The test was conducted at IW-1 on September 27, 2012 at injection rates of 3,944, 6,324, and 8,127 gallons per minute (gpm). IW-2 was tested on September 28, 2012 at injection rates of 4,324, 6,253, and 8,152 gpm. Data collected as part of the 3-hour preliminary tests will be used as baseline performance for future evaluation of the DIW system injectivity. The results of the step rate injection tests are summarized in **Table 6-1** and illustrated in **Figures L-6 and L-7** in **Appendix L.**

Table 6-1: Variable Rate Injection Test Summary

IW-1 Step Test			IW-2 Step Test		
Flow rate (gpm)	Pressure at well head (psi)	Average injection capacity (gpm/psi)	Flow rate (gpm)	Pressure at well head (psi)	Average injection capacity (gpm/psi)
Static*	26.7		Static	26.4	
3,944	31.4	839	4,324	33.3	627
6,324	36.6	639	6,253	38.7	508
8,127	42.5	514	8,152	45.4	429

* Static water level at IW-1 was obtained from recovery data.

Injection Testing at Design Capacity

A short term (12-hour) injection test was performed on IW-1 and IW-2 to demonstrate that each injection well is able to accept flows at the design capacity of 11.4 million gallons per day (MGD). The results of the 12-hour injection test show no significant pressure build-up at the injection wells IW-1 and IW-2 or induced pressure changes in the dual-zone monitor well during the tests.

The 12-hour injection testing was conducted at IW-1 and IW-2 from September 29, 2012 through October 5, 2012 and included the following at each well: 48 hours of background data collection, 12 hours of injection at an average injection rate of 7,987 gallons per minute (gpm) at IW-1 and an average injection rate of 7,991 gpm at IW-2, and 24 hours of recovery data collection. Flow rates throughout the injection tests were recorded manually using calibrated flow meters. Wellhead pressure at IW-1 and IW-2 were recorded using Hermit 3000 data loggers. Wellhead pressure at both zones of dual-zone monitor well MW-1 were recorded using In-Situ Inc. Level Troll 700 Transducers capable of storing data internally. Calibration certification for the flow meters and pressure sensors is provided in **Appendix L-2.**

Water used for injection testing was brackish ground water pumped from Floridan aquifer production wells PW-3, PW-4 and PW-5. Production wells PW-3, PW-4 and PW-5 are located approximately 600, 900 and 2,250 feet from MW-1, respectively. PW-3 was completed to a depth of 1,570 feet bpl, PW-4 was completed to a depth of 1,582 feet bpl and PW-5 was completed to a depth of 1,400 feet bpl as compared to the top of the upper monitor zone of MW-1 completed at a depth of 1,630 feet bpl. The influence of the withdrawals from PW-3, PW-4 and PW-5 on MW-1U during the injection tests is seen by a minor decline in pressure due to the semi-confined nature of the carbonate unit that separates these two intervals.

Figure L-8 (Appendix L) provides tidal data, barometric pressure data and the hydrostatic pressure data recorded at IW-1, IW-2, MW-1U and MW-1L during the entire injection testing period from September 29, 2012 through October 5, 2012. Specific Data collected during the injection test at IW-1 is provided in **Figures L-9 through L-12 (Appendix L)** and data collected during the injection test at IW-2 is provided in **Figures L-13 through L-16.**

12-Hour Injection Test – Injection Well IW-1

Figure L-9 provides tidal data, barometric pressure data and the hydrostatic pressure data recorded at IW-1, IW-2, MW-1U and MW-1L during the entire injection testing period of IW-1 (background, injection and recovery phases). The shut in pressure for IW-1 during the background phase stabilized between 26.17 and 26.27 psi. **Figure L-10** illustrates the static water levels recorded during 48 hours of background data collected prior to the 12-hour injection test at IW-1. The 12-hour injection test was successfully completed at IW-1 on Monday, October 1, 2012 from 7:00 am to 7:00 pm. The test was conducted at an average injection rate of 7,987 gpm with minimum, maximum and average wellhead pressures of 41.8, 44.6 and 43.2 psi, respectively. **Figure L-11** illustrates the data recorded during the 12-hour injection test. The wellhead pressure at IW-1 during the recovery period stabilized at 27.1 psi, slightly higher than the background pressure. **Figure L-12** represents 24 hours of recovery data recorded immediately following the 12-hour injection test at IW-1. The average injection capacity at IW-1, calculated from this test data, is 470 gpm/psi.

The pressure recorded in the upper monitor zone of MW-1 designated as MW-1U (completed 1,630 to 1,660 feet bpl) during background was approximately 15.6 psi. The pressure steadily decreased during the 12-hour injection test to approximately 14.7 psi at the end of the injection test. After the injection test was completed, the pressure in MW-1U gradually increased to background levels, see **Figure L-9**. Hydrostatic pressure data recorded at MW-1U is illustrated in **Figures L-9 through L-12.** As previously discussed, the minor decline in pressure at MW-1U during the injection test is due to the withdrawals from the local Floridan Aquifer production wells.

The lower zone of MW-1 (MW-1L) was not affected by the withdrawals from the production wells or the injection into IW-1 and remained around 7.1 psi throughout the testing period. Hydrostatic pressure data recorded at MW-1L is illustrated in **Figures L-9 through L-12**. The lower zone did not exhibit noticeable pressure changes during testing operation because of adequate confinement above the injection zone and sufficient confinement from the pumped interval in the UFA.

12-Hour Injection Test – Injection Well IW-2

Figure L-13 provides tidal data, barometric pressure data and the hydrostatic pressure data recorded at IW-1, IW-2, MW-1U and MW-1L during the entire injection testing period of IW-2 (background, injection and recovery phases). The shut in pressure for IW-2 during the background phase stabilized between 26.69 and 26.82 psi. **Figure L-14** illustrates the static water levels recorded during 48 hours of background data collected prior to the 12-hour injection test at IW-2. The 12-hour injection test was successfully completed at IW-2 on Thursday, October 4, 2012 from 7:00 am to 7:00 pm. The test was conducted at an average injection rate of 7,991 gpm with minimum, maximum and average wellhead pressures of 44.0, 46.2 and 45.1 psi, respectively. **Figure L-15** illustrates the data recorded during the 12-hour injection test. The wellhead pressure at IW-2 during the recovery period stabilized at 27.0 psi, slightly higher than the background pressure. **Figure L-16** represents 24 hours of recovery data recorded immediately following the 12-hour injection test at IW-2. The average injection capacity at IW-2, calculated from this test data, is 434 gpm/psi.

The pressure recorded in the upper monitor zone of MW-1 designated as MW-1U (completed 1,630 to 1,660 feet bpl) during background was approximately 15.4 psi. The pressure steadily decreased during the 12-hour injection test to approximately 14.5 psi at the end of the injection test. After the injection test was completed, the pressure in MW-1U gradually increased to background levels, see **Figure L-13**. Hydrostatic pressure data recorded at MW-1U is illustrated in Figures **Figures L-13 through L-16**. As previously discussed, the minor decline in pressure at MW-1U during the injection test is due to the withdrawals from the local Floridan aquifer production wells.

The lower zone of MW-1 (MW-1L) was not affected by the withdrawals from the production wells or the injection into IW-2 and remained around 7.0 psi throughout the testing period. Hydrostatic pressure data recorded at MW-1L is illustrated in **Figures L-13 through L-16**. The lower zone did not exhibit noticeable pressure changes during testing operation because of adequate confinement above the injection zone and sufficient confinement from the pumped interval.

The results of the injection tests demonstrate that IW-1 and IW-2 are capable of operating at a rate of up 11.4 mgd safely without impacts to the USDW as inferred by pressure data from the dual-zone monitor well.