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GLOSSARY

Term	Definition
als	Above Land Surface
APT	Aquifer Performance Test
ASR	Aquifer Storage and Recovery
ASTM	American Society For Testing And Materials
B’	Leakage Parameter
bls	Below Land Surface
°C	Degrees Celsius
cm/sec	Centimeters per Second
DDC	Diversified Drilling Corporation
F.A.C.	Florida Administrative Code
FAS	Floridan Aquifer System
FDEP	Florida Department of Environmental Protection
FRP	Fiberglass Reinforced Plastic
ft	Feet
gpd	Gallons Per Day
gpd/ft	Gallons Per Day Per Foot
gpm	Gallons Per Minute
gpm/ft	Gallons Per Minute Per Foot
HDPE	High Density Polyethylene
IAS	Intermediate Aquifer System
ID	Inside Diameter
LFA	Lower Floridan Aquifer
mgd	Million Gallons Per Day
MWH	MWH Americas, Inc.
lbs	Pounds
mg/L	Milligrams per Liter
NAVD	North American Vertical Datum
psi	Pounds per Square Inch
PtCo	Platinum-Cobalt
PVC	Polyvinyl Chloride
r/B’	Leakage Parameter
r/B”	Leakage Parameter
r(c)	Casing radius
RIDS	Regional Irrigation Distribution System
r(w)	Well radius
S	Storativity
SAS	Surficial Aquifer System
SFWMD	South Florida Water Management District
Sw	Wellbore Skin Factor
T	Transmissivity
TAC	Technical Advisory Committee
TDS	Total Dissolved Solids
EXW	Test Production Well
UFA	Upper Floridan Aquifer
µS/cm	Microsiemens per Centimeter
USEPA	U.S. Environmental Protection Agency
USDW	Underground Source of Drinking Water
WTMW	Water Table Monitor Well

Executive Summary

This report summarizes the construction and testing of the Aquifer Storage and Recovery Exploratory Well (ASR EXW) at the Gator Slough Weir 19 site; one of three ASR EXWs constructed in Northern Cape Coral to test the Upper Floridan Aquifer for the use of ASR technology. The well construction results are summarized below:

On November 30, 2007, the FDEP issued Construction Permit No. 272886-001 UC/5X for a Class V ASR EXW for the Gator Slough ASR EXW site. The well was designed to meet the requirements of the Florida Department of Environmental Protection Class V Injection Well standards and the specific conditions of the Underground Injection Control permit.

Construction of the ASR EXW began on February 27, 2008 and was substantially complete on December 12, 2008.

The ASR EXW was drilled and tested to 1,200 feet below land surface (bls). The well was back plugged to 910 feet bls with neat cement and completed with 6.625 OD PVC set to 770 feet bls.

Water quality of the completed monitoring interval is brackish, and contains chloride and TDS concentrations of approximately 945 mg/L and 2,010 mg/L, respectively.

Geophysical logs were conducted in the pilot hole after each stage of pilot hole drilling, prior to packer testing and before casing installation. The logs provide a continuous record of the physical properties of the subsurface formations and/or their water quality within the borehole.

Single packer tests were performed at four selected intervals (753 to 785, 800 to 853, 867 to 920, and 1,140 to 1,200 feet bls) during drilling within the Upper Floridan Aquifer.

Rock cores were collected during pilot hole drilling. Core samples were sent to Ardaman and Associates for petrophysical analysis to determine vertical and horizontal hydraulic conductivity, vertical and horizontal porosity and specific gravity. Five cores were evaluated from the Floridan Aquifer System from the following intervals; 765 to 785, 823 to 843, 900 to 920, 920 to 937 and 1,100 to 1,120 feet bls.

A constant rate aquifer test was conducted at a constant rate of 300 gpm on the completed Gator ASR EXW on November 4, 2008. The estimated transmissivity is 16,230 gpd/ft and calculated from recovery data using the Moench (1985) Method.

It was concluded that the interval from 770 to 910 feet bls in the Suwannee Limestone is favorable for ASR technology at this location.

1.0 Introduction

This report summarizes the drilling and testing of a Class V Aquifer Storage and Recovery (ASR) Exploratory well constructed at the City of Cape Coral planned Fire Station No 14 property located proximal to the Alligator Slough Canal (Gator Slough) upstream of Weir #19. The following information is included this report:

Well construction methods,
Data collection and testing procedures,
Geological and hydraulic interpretation of data collected,
Documentation of the FDEP approved casing setting depths for monitoring the potential storage zone
Identification of hydrogeologic conditions favorable for potential underground storage, and
Recommendations on the future well utility and suitability of the site for ASR.

The well was constructed under FDEP Construction Permit No. 272886-001 UC/5X and the applicable regulations of Chapter 62-528, Florida Administrative Code (FAC).

1.1 Background

In 2004, the City of Cape Coral selected MWH as the Program Manager at Risk for the expansion of the Water, Wastewater, Irrigation Facilities, and Phase 2 Utility Extension Services. The MWH Facilities Master Plan (2004) estimates the average daily irrigation demands at build-out to be 132 million gallons per day (MGD). The water available from existing and planned sources (approximately 50 MGD of reclaimed water, and 47 MGD from the freshwater canal system during the dry season) is approximately 97 mgd, leaving a potential irrigation water supply deficit of 35 mgd.

Several studies have identified ASR as having a high potential to provide the City with an additional supply of irrigation water (Missimer & Associates, 1989; Dames & Moore, 1998; Camp Dresser & McKee, 2005). Additionally, the City is a stakeholder in a Regional Irrigation Distribution System (RIDS) investigated by the South Florida Water Management District (SFWMD). The RIDS Master Plan for the Lower West Coast area (SFWMD, 2002) and Feasibility Study for the Cape Coral area (SFWMD, 2004) identified significant volumes of surface water and reclaimed water could be available to Cape Coral for ASR wells during the wet season. The Alligator Slough Canal is identified in the latter report as a potential surface water ASR location. The RIDS studies are incorporated into the Lower West Coast Water Supply Plan Update (SFWMD, 2006). As such, construction of the ASR facilities is eligible to receive funding from the SFWMD Alternative Water Supply Program.

The Gator Slough site is listed as a permitted ASR well facility (ASR-1) in the City's SFWMD Irrigation Water Use Permit (No. 36-00998-W). The test well site is located approximately 3-miles east of that listed in the permit, so a letter modification is needed to adjust the reported location of the WUP facility prior to use. The permit issued by the SFWMD Governing Board on March 8, 2006 allows the withdrawal of approximately 720

MG from the freshwater canal system to recharge eight (8) ASR wells. The Irrigation WUP has a duration of 20 years.

An Application to Construct a Class V Injection Well System for the Gator Slough Exploratory Well was prepared and submitted by MWH Americas, Inc. (MWH) to the Florida Department of Environmental Protection (FDEP) on January 12, 2007 under the IRR-2 Work Authorization. The FDEP issued Construction Permit No. 272886-001 UC/5X on November 30, 2007. A copy of the FDEP permit is included as Appendix A.

The Cape Coral City Council authorized MWH Americas to design, permit and supervise the construction and testing of three ASR Exploratory Wells in Northern Cape Coral. Design and construction was conducted under the IRR-6 and IRR-6C.1 Work Authorizations, respectively. Notice to Proceed was issued to the drilling subcontractor on January 28, 2008.

1.2 Location

Several locations in Cape Coral adjacent to freshwater canals having high wet season discharge were identified in the consultant and RIDS reports noted above. The Alligator Slough Canal was cited in several publications as having a high potential for supplying abundant surface water.

A vicinity map of the Gator Slough ASR EXW is shown in Figure 1-1. A map showing the location of the ASR EXW and associated monitor wells is shown in Figure 1-2. The project site is located approximately 500 feet north of Alligator Slough Canal in the southwest quarter of Section 18, Township 43 South, Range 24 East, Lee County. The physical address of the well site is 3918 West Gator Circle, Cape Coral, Lee County, Florida.

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Figure 1-1 Gator Slough ASR EXW Vicinity Map

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Figure 1-2 Gator Slough ASR EXW Site Map

1.3 Scope of Services

Diversified Drilling Corporation of Lehigh Acres, FL acted as the contractor and conducted the drilling, construction, and testing activities of the Gator Slough ASR EXW. MWH Americas, Inc. was the City's onsite representative, providing construction observation and technical services required to comply with the construction permit. Construction management was provided by MWH Constructors, Inc.

Construction and testing of the well was performed and reported weekly in accordance with Chapter 62-528 F.A.C., to the FDEP, the Technical Advisory Committee (TAC), and requirements of the Permit (272886-001 UC/5X). The TAC includes members of local, state, and federal agencies, including state and local representatives of the FDEP, the South Florida Water Management District (SFWMD), and the U.S. Environmental Protection Agency (EPA). Construction and testing activities were reported in accordance with Specific Condition 3 of the Permit. This report was prepared in fulfillment of Specific Condition 5 of the Permit.

2.0 Geology and Hydrogeology

Lee County is underlain by rocks of Cenozoic age to a depth of about 5,000 feet bls (Meyer, 1989). These rocks are composed of carbonates, with minor amounts of evaporates in the lower portion and clastics in the upper portion (Reese, 2000). In this section, the stratigraphy and identified aquifer systems encountered during drilling and testing operations for the Gator Slough ASR EXW are described from youngest to oldest in age. Geologic formations were identified based on interpretations of the lithology, geophysical logs and/or video survey descriptions (Appendices B, C and D).

2.1 Geology

Sediments encountered during the construction of the Gator Slough ASR EXW range in age from Late Pleistocene to Oligocene. MWH collected geologic formation samples (well cuttings) from the pilot hole during drilling operations and described them based on their dominant lithologic and textural characteristics using the Folk (1959) classification system for carbonate rocks. Detailed lithologic logs is provided in Appendix B. A detailed description of the lithostratigraphy and its relationship to the hydrostratigraphy of the study area is provided below. A stratigraphic and hydrostratigraphic column of the site is shown in Figure 2-1.

2.1.1 Pliocene - Pleistocene Series

The undifferentiated deposits encountered include predominately siliciclastic and carbonate deposits of the Pamlico Sand Formation and the Undifferentiated Fort Thompson/Caloosahatchee Formation. Undifferentiated Plio-Pleistocene surficial deposits consisted primarily of unconsolidated sand, marine bivalvia and gastropoda shell. This unit was observed at the Gator Slough ASR EXW site to a depth of approximately 20 feet bls.

2.1.2 Miocene Series

The Hawthorn Group unconformably underlies undifferentiated Pliocene-Pleistocene deposits, and is a lithologically complex sequence of silt, clay, calcareous clay, dolosilt, quartz sand, phosphate, limestone, and dolomite (Scott, 1988). It is a regional stratigraphic unit of early Pliocene to Miocene age that underlies all of South Florida. The Hawthorn Group is comprised of an upper, primarily siliciclastic unit (Cape Coral Clay Member of the Peace River Formation), and a lower, primarily carbonate unit (Arcadia Formation). Locally, the base of the Peace River Formation contains the Lehigh Acres Sandstone Member (Missimer and Associates, 1985). The two formations are separated by a major regional disconformity (Scott, 1988, and Cunningham, et al, 2001). At the Gator Slough ASR EXW site, the Hawthorn Group occurs from approximately 20 to 730 feet bls.

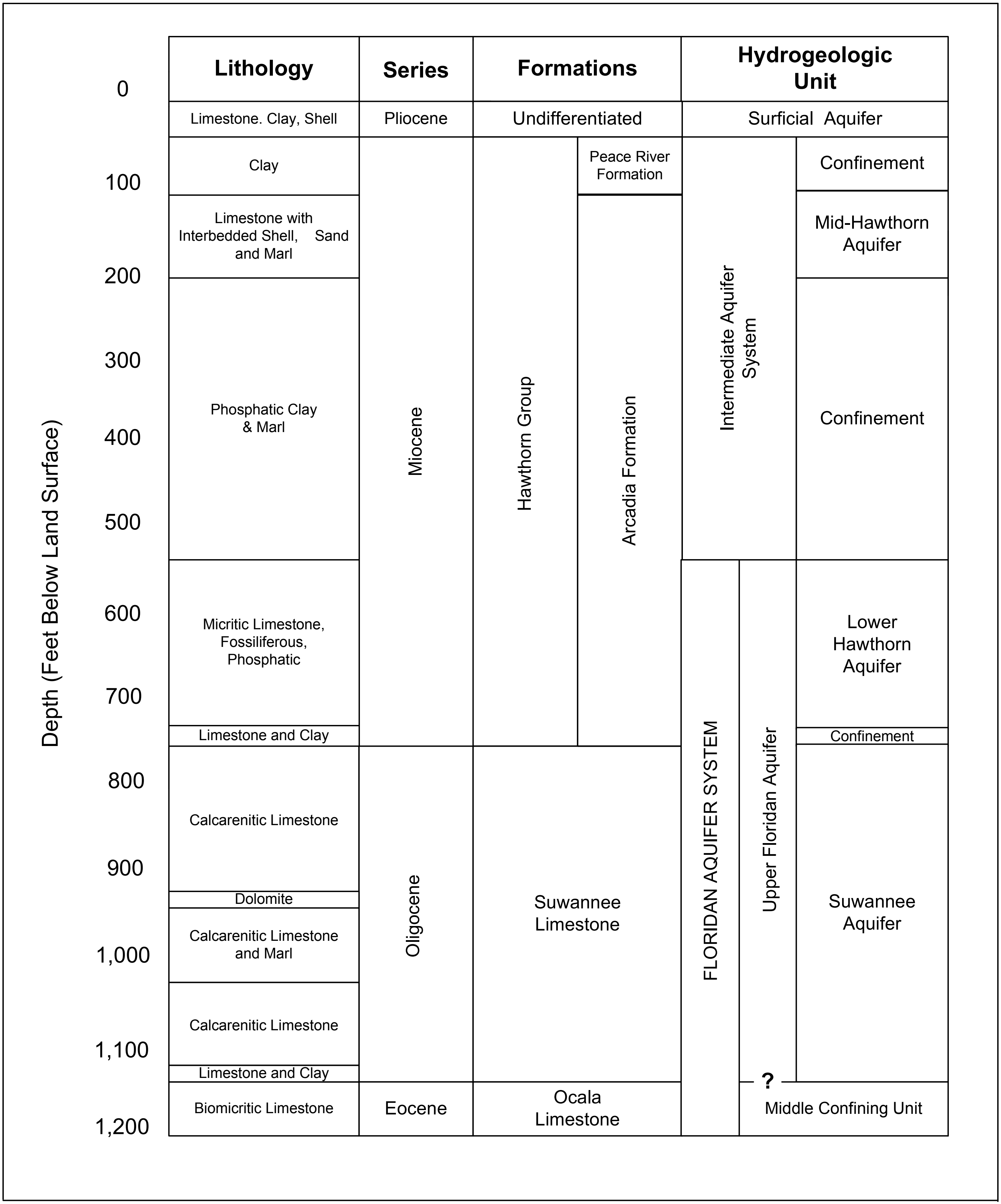

Figure 2-1 Gator Slough Stratigraphic and Hydrostratigraphic Column

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The lower 500 feet of the unit consists of 3 to 4 large scale, transgressive-regressive cycles and each cycle consists of a lower thick limestone unit and an upper mixture of minor carbonate and clastic units (Missimer and Associates, 1985).

Peace River Formation

The Peace River Formation of the Hawthorn Group consists of sandstones, sands, sandy limestones, dolomitic clays or dolosilts, and fossilized shell material (Scott, 1988 and Bennett and Rectenwald, 2004). The formation occurs from approximately 20 to 110 feet bls. In Southwest Florida, the Peace River formation has been subdivided into two named members, the Cape Coral Clay member and the Lehigh Acres Sandstone member (Missimer and Associates, 1985).

The Cape Coral Clay is predominantly a greenish gray to dark greenish gray, moderately hard, semi-cohesive clay with trace amounts of silt. This unit occurs from 20 to 110 feet bls. The Lehigh Acres Sandstone member is not present at the Gator Slough ASR EXW site.

Arcadia Formation

The lower part of the Hawthorn Group, the Arcadia formation, consists predominately of limestone and dolostone containing varying amounts of quartz sand, clay and phosphate grains. The Arcadia Formation is important from a resource viewpoint as a water supply source for the City of Cape Coral domestic and public water supply users. Several aquifers and confining units are identified within the Hawthorn Group.

The Arcadia Formation occurs from approximately 110 to 730 feet bls at the Gator Slough ASR EXW Site. The formation is lithologically complex, containing limestone and dolosilt beds of varying thickness. The limestones are light to yellowish gray micrites and biomicrites with moderate to good porosity. The formation is interbedded with yellowish gray marl or lime mud and occasional light olive gray dolomitic silty clay. Phosphate granules are abundant throughout the Arcadia Formation. The base of the Arcadia Formation can be identified by an immediate decrease in phosphate content in lithologic samples, and attenuation of gamma ray activity on geophysical logs. Lithologic logs are available in Appendix B and geophysical logs are available in Appendix C.

2.1.3 Oligocene Series

The top of the Oligocene age Suwannee Limestone occurs at approximately 730 feet bls and is present to 1,150 feet bls. A disconformity separates the Hawthorn Group from the Suwannee Limestone (Reese, 2000).

The contact between these two formations in the study area is marked by a change in lithology from a micritic limestone to interbedded with lime mud or marl (Appendix B). The Suwannee Limestone is typically a very pale orange biomicrite having a medium-grained calcarenitic texture. The unit is composed of moderately to well-sorted foraminifera, pelloids, and abraded echinoderm and mollusk fragments. In addition, the Suwannee Limestone is characterized an attenuation of the natural gamma activity, primarily due to the decrease in phosphate content and by higher sonic transit times as compared to the basal facies of the Arcadia Formation.

2.1.4 Eocene Series

The Ocala Limestone of late Eocene Age was encountered at 1,150 feet bls and continued to the total depth of the ASR EXW at 1,200 feet bls. The Ocala Limestone consists of white to cream colored, fossiliferous, poorly consolidated, micritic, limestone. Geophysical logs were used to identify the top of the Ocala Limestone. The top of the Ocala Limestone is marked by an attenuation of the natural gamma activity, potential bedding plane feature depicted on the BHC sonic variable density log, and a decrease in flow supported by a decrease in the pumping flow log (Appendix C).

2.2 Hydrogeology

Three major aquifer systems underlie the study area of Cape Coral, Florida: the Surficial Aquifer System (SAS), the Intermediate Aquifer System (IAS), and the Floridan Aquifer System (FAS), with the FAS being the focus of this study. The FAS is composed of multiple, discrete aquifers separated by low permeability "confining" units that occur throughout this Tertiary/Quaternary age sequence.

2.2.1 Surficial Aquifer System

The SAS consists of the water-table aquifer and hydraulically connected units above the top of the first occurrence of laterally extensive and vertically persistent beds of much lower permeability (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986). At the Gator Slough ASR EXW site, the SAS occurs within the undifferentiated Plio-Pleistocene water saturated sediments of the Pamlico Sand Formation, and Undifferentiated Fort Thompson/Caloosahatchee strata. The base of the surficial aquifer at the ASR EXW occurs at contact with the Cape Coral Clay Member of the Hawthorn Group at a depth of 20 feet bls. The aquifer is unconfined and in direct contact with atmospheric pressure. Recharge to the aquifer originates principally from rainfall, with some secondary recharge emanating from leakage from surface water bodies and from lateral movement of groundwater from up gradient sources. Discharge from the surficial aquifer occurs mainly through evapotranspiration, drainage to surface water bodies, downward leakance to deeper aquifers, and lateral groundwater flow.

2.2.2 Intermediate Aquifer System

Aquifers that lie beneath the SAS and above the FAS in southwestern Florida are grouped within the IAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986). The IAS does not outcrop and contains water under confined conditions (Miller, 1986).

One productive horizon was identified during drilling and testing operations. The productive horizon, locally called the Mid-Hawthorn Aquifer, occurs from 110 to 200 feet bls. The Mid-Hawthorn aquifer occurs within limestones in the upper portion of the Arcadia Formation of the Hawthorn Group (Miller, 1986). This aquifer is currently the major source of water supply to residents served by domestic self-supply wells in Cape Coral, Florida.

2.2.3 Floridan Aquifer System

The FAS is defined as a vertically continuous sequence of permeable carbonate rocks of Tertiary age that are hydraulically connected in varying degrees, and whose permeability is generally several orders of magnitude greater than that of the rocks that bound the system above and below (Miller, 1986). The system is subdivided into the upper Floridan Aquifer (UFA), middle confining unit (MCU) and the lower Floridan Aquifer (LFA) based on hydraulic characteristics. The FAS in the study area of the City of Cape Coral, Florida is composed predominately of limestone with dolomitic limestone and dolomite. The FAS occurs within the lower Arcadia Formation, Suwannee Limestone, Ocala Limestone, Avon Park Formation, and Oldsmar Formation.

The FAS, as defined by the Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition (1986) coincides with the top of a vertically continuous permeable early Miocene to Oligocene-aged carbonate sequence. At the study site, the UFA was encountered from 510 to the total depth of the well, 1,200 feet bls, and chiefly consists of permeable zones in the lower Hawthorn Group and Suwannee Limestone.

Two predominant permeable zones, the Lower Hawthorn and Suwannee aquifers, were identified within the UFA. The productive zones in the upper Floridan aquifer were identified using lithology, geophysical logs (i.e. dual induction, fluid resistivity, flowmeter and temperature), borehole video survey (evidence of vuggy porosity), and packer testing.

The first transmissive horizon includes the lower portion of the Basal Hawthorn Unit (Reese, 2000), and occurs from 510 to 730 feet bls. This aquifer is locally named the Lower Hawthorn aquifer. The predominant lithologies present are interbedded yellowish-gray fossiliferous limestones and light gray dolomitic limestones. The limestones are generally moderately hard and have a moderate to high porosity. The Lower Hawthorn aquifer's dolomitic limestones have a microsucrosic texture, are very hard and have variable porosities. The Lower Hawthorn aquifer is the major source of public water supply to the residents in Cape Coral, Florida.

The second productive interval within the UFA was identified from 765 to 1,150 feet bls in the Suwannee Limestone. This aquifer is locally named the Suwannee Aquifer. A semi-confining bed between the Suwannee and Lower Hawthorn Aquifer is approximately 35 feet thick and consists of very pale orange limestone interbedded with clay. This aquifer is composed chiefly of moderately biomicritic limestone. The aquifer becomes less permeable with depth due to interbedding and increased lime mud and fine-grained material.

The Ocala Limestone was identified from 1,150 to 1,200 feet bls and is identified as the top of the MCU of the FAS. This unit is composed of low permeability limestones, as indicated by a significant decrease in flow identified from the production logs.

3.0 Well Construction

3.1 Introduction

This section describes the construction activities of the Gator Slough ASR EXW. The site location map is provided as Figure 1-2. A summary report (Appendix E) of the construction activities were submitted to the Department on a weekly basis as required by Specific Condition 5b of the permit.

3.2 Site Development

The location is essentially flat with elevations varying less than one foot from the average 16.2 feet above the North American Vertical Datum of 1988 (NAVD 88) for the site. The boundary surveys are provided in Appendix F.

Two Water Table Monitoring Wells (WTMWs) were installed prior to the start of drilling activities. The WTMWs monitored the surficial aquifer water quality during construction and testing of the ASR system. Well WTMW-1 was located approximately 40 feet east of the ASR EXW and Well WTMW-2 was located approximately 40 feet northwest of the ASR EXW. The locations of the WTMWs are shown in Figure 1-2 previously presented.

Each WTMW was constructed to a depth of approximately 20 feet bls. The wells were completed with 10 feet of 4-inch diameter 0.010-inch slot Schedule 40 PVC screen at the base and approximately 10 feet of 4-inch diameter Schedule 40 polyvinyl chloride (PVC) riser from the top of the screen to land surface. The annulus of the WTMW's was backfilled with silica sand to approximately one foot above the screen interval with a bentonite seal above the sand and grouted to land surface.

The WTMWs were developed following their construction. Water quality tests to measure specific conductivity, chloride, pH and temperature were conducted to obtain initial background measurements of the parameters. The WTMWs were developed and sampled on a weekly basis for those water quality parameters. Figure 3-1 shows a schematic diagram of a typical WTMW.

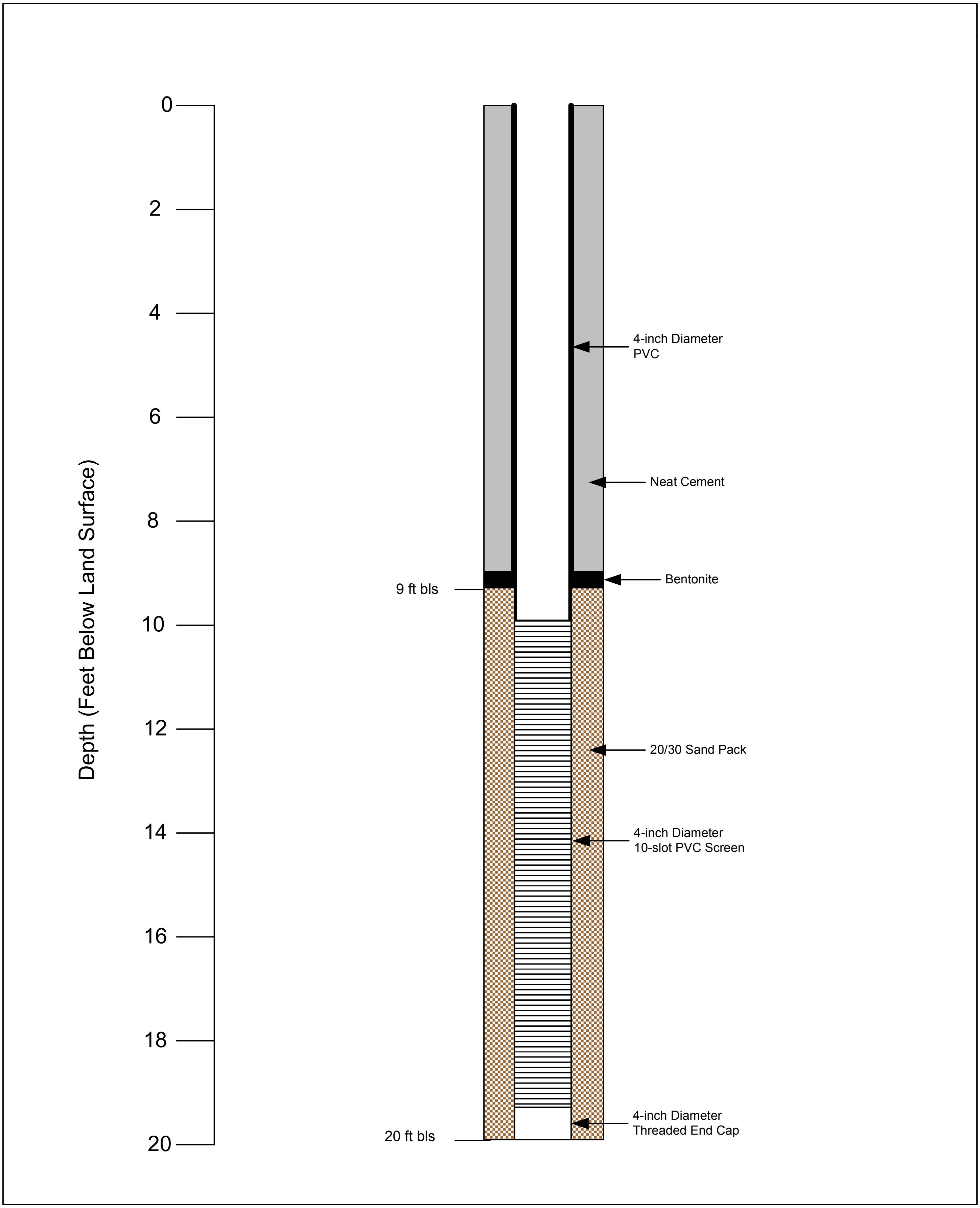

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Figure 3-1 Water Table Monitor Well Schematic

3.3 Containment Pad

A temporary containment pad consisting of a crushed limestone berm approximately 2.5 feet high overlain by high-density polyethylene (HDPE) material was constructed to contain and remove drilling fluids produced during construction activities of the Gator Slough ASR EXW. Following completion, the HDPE material and limestone were removed from the site.

The containment pad was designed to protect the surficial aquifer by containing fluid spills and brackish formation water encountered during drilling operations. A pump was installed in the containment pad to remove fluids from the pad to an onsite storage system for removal to the approved offsite disposal location.

3.4 Well Construction

The Gator Slough ASR EXW drilling and construction operations began February 27, 2008. Well construction activities were substantially complete on December 12, 2008. Well construction activities concluded on October 29, 2008 with final geophysical logging and video survey. Drilling operations were normally conducted 8 hours per day, 5 days per week. A schematic diagram of the completed well is available in Figure 3-2. An As-Built diagram is available in Appendix G. A summary of well construction and testing activities at the ASR EXW is included in Table 3-1.

The surficial aquifer and the upper portion of the Hawthorn Group was drilled using the mud rotary drilling method to a depth of 537 feet bls during the initial drilling phase. During mud rotary drilling operations, all drilling fluid was contained in a closed circulation system. Intermediate casing was set at 523 feet bls. The borehole was drilled through the lower portion of the Hawthorn Group and into the upper portion of the Ocala Limestone to a total depth of 1,200 feet bls using the reverse air drilling method during pilot-hole drilling operations. The reverse air drilling method allowed for the collection of formation water samples while drilling. The well was backplugged with cement from 1,200 to 910 feet bls and 6.625-inch OD Schedule 40 PVC final casing was installed to 770 feet bls.

The diameter of the drill bits used and depths to which the bits penetrated were a function of geology, well design, and regulatory requirements for the project. Extensive sampling and testing was conducted within the borehole to evaluate the potential for aquifer storage and aid in the final design of the well. Specifics of the testing program and data obtained from testing are presented in Section 4.

Table 3-1 Construction Chronology

Start	End	Description of Activities
02-27-2008	02-27-2008	Drilled 25 inch diameter pilot hole to depth of 41 ft bls.
02-27-2008	02-27-2008	Set and cemented 40 feet of 18-inch diameter steel surface casing.
03-03-2008	03-05-2008	Drilled nominal 8½-inch dia. pilot hole to 551 ft bls using direct mud rotary drilling method.
03-06-2008	03-06-2008	Conducted full suite geophysical logging to 551 ft bls.
03-10-2008	03-17-2008	Reamed pilot hole with 17 in dia. bit to 537 ft bls using direct mud rotary drilling method.
03-19-2008	03-19-2008	Conducted caliper/gamma ray logs to 537 ft bls.
03-19-2008	03-20-2008	Set and cemented the 12 inch outer diameter intermediate casing to 523 ft bls.
03-27-2008	05-08-2008	Drilled nominal 11¾-inch diameter pilot hole to 1200 ft bls using reverse air drilling methods.
04-01-2008	04-01-2008	Initial Generic Sampling Permit water quality sample.
04-03-2008	04-03-2008	Cored interval 765 to 785 ft bls – Core #1.
04-07-2008	04-07-2008	Conducted caliper/gamma ray logs to 785 ft bls.
04-11-2008	04-11-2008	Performed constant rate single packer pump test from 753 to 785 ft bls – Packer Test #1.
04-15-2008	04-15-2008	Cored Interval 823 to 843 ft bls – Core #2.
04-16-2008	04-16-2008	Conducted caliper/gamma ray logs to 843 ft bls.
04-18-2008	04-18-2008	Performed constant rate single packer pump test from 800 to 843 ft bls – Packer Test #2.
04-22-2008	04-22-2008	Cored Interval 882 to 900 ft bls – Core #3.
04-23-2008	04-23-2008	Conducted caliper/gamma ray logs to 920 ft bls.
04-30-2008	04-30-2008	Performed constant rate single packer pump test from 867 to 920 ft bls – Packer Test #3.
05-01-2008	05-01-2008	Cored Interval 920 to 937 ft bls – Core #3B.
05-05-2008	05-05-2008	30-day Generic Discharge Permit water quality sample.
05-06-2008	05-06-2008	Cored Interval 1,100 to 1,120 ft bls – Core #4.
05-09-2008	05-09-2008	Conducted caliper/gamma ray logs to 1,200 ft bls.
05-12-2008	05-12-2008	Performed constant rate single packer pump test from 1,140 to 1,200 ft bls – Packer Test #4.
05-29-2008	05-29-2008	Conducted full suite geophysical logging and production logs
06-20-2008	06-26-2008	Backplugged well from 1,200 ft bls to 903 ft bls.
07-02-2008	07-02-2008	Drilled out backplug from 903 ft bls to 910 ft bls.
07-07-2008	07-09-2008	Backfilled pilot hole to 774 ft bls for PVC casing installation.
07-10-2008	07-16-2008	Set and cemented 770 feet of 6-inch diameter PVC casing.
07-17-2008	07-17-2008	Drilled out cement plug from 737 ft bls to 738.5 ft bls. PVC discovered in cuttings return.
07-19-2008	07-19-2008	Conducted video survey to 737 ft bls. No visibility.
07-21-2008	07-21-2008	Conducted video survey to 737 ft bls. Casing blistered at approx. 737 ft bls.
07-22-2008	08-08-2008	Contractor submits repair plan for well.
08-09-2008	09-01-2008	Repair operations suspended pending SFWMD site inspection scheduled for August 26th.
09-02-2008	09-11-2008	Milling PVC casing and cement with nominal 12 inch bit to 605 ft bls with reverse air method. Bit deviated from casing at 585 feet bls.

Start	End	Description of Activities
09-11-2008	09-25-2008	Contractor submits revised repair plan.
09-23-2008	09-23-2008	Conducted video survey to 587 ft bls and verified bit deviated from PVC.
09-24-2008	09-24-2008	Conducted video survey to 580 ft bls to verify tremie was in PVC.
09-25-2008	09-29-2008	FDEP approves new repair plan.
09-30-2008	10-01-2008	Jetted drilling mud from 605 ft bls to 739 ft bls to remove cuttings inside PVC casing.
10-01-2008	10-02-2008	Backplugged PVC casing with cement from 739 to 536 ft bls.
10-03-2008	10-10-2008	Drilled backplug and new borehole with mud rotary method from 605 ft bls to 774 ft bls.
10-14-2008	10-14-2008	Conducted geophysical logging: caliper, gamma ray to 760 ft bls.
10-15-2008	10-15-2008	Conducted geophysical logging: caliper, gamma ray to 773 ft bls.
10-15-2008	10-22-2008	Set and cemented 770 feet of 6-inch diameter PVC casing.
10-24-2008	10-27-2008	Drilled pilot hole with 5¼ inch bit to 910 ft bls using reverse air method.
10-28-2008	10-28-2008	Air developed well for 7 hours.
10-29-2008	10-29-2008	Conducted geophysical logging: caliper, gamma ray, video to 910 ft bls.
10-31-2008	10-31-2008	Pump developed well for 7½ hours.
11-03-2008	11-03-2008	Conduct final water quality sampling for Primary and Secondary parameters.
11-04-2008	11-04-2008	Performed 4 hour Step Rate Test and 4 hour Constant Rate Pump Test.
12-22-2008	12-23-2008	Disinfected well.

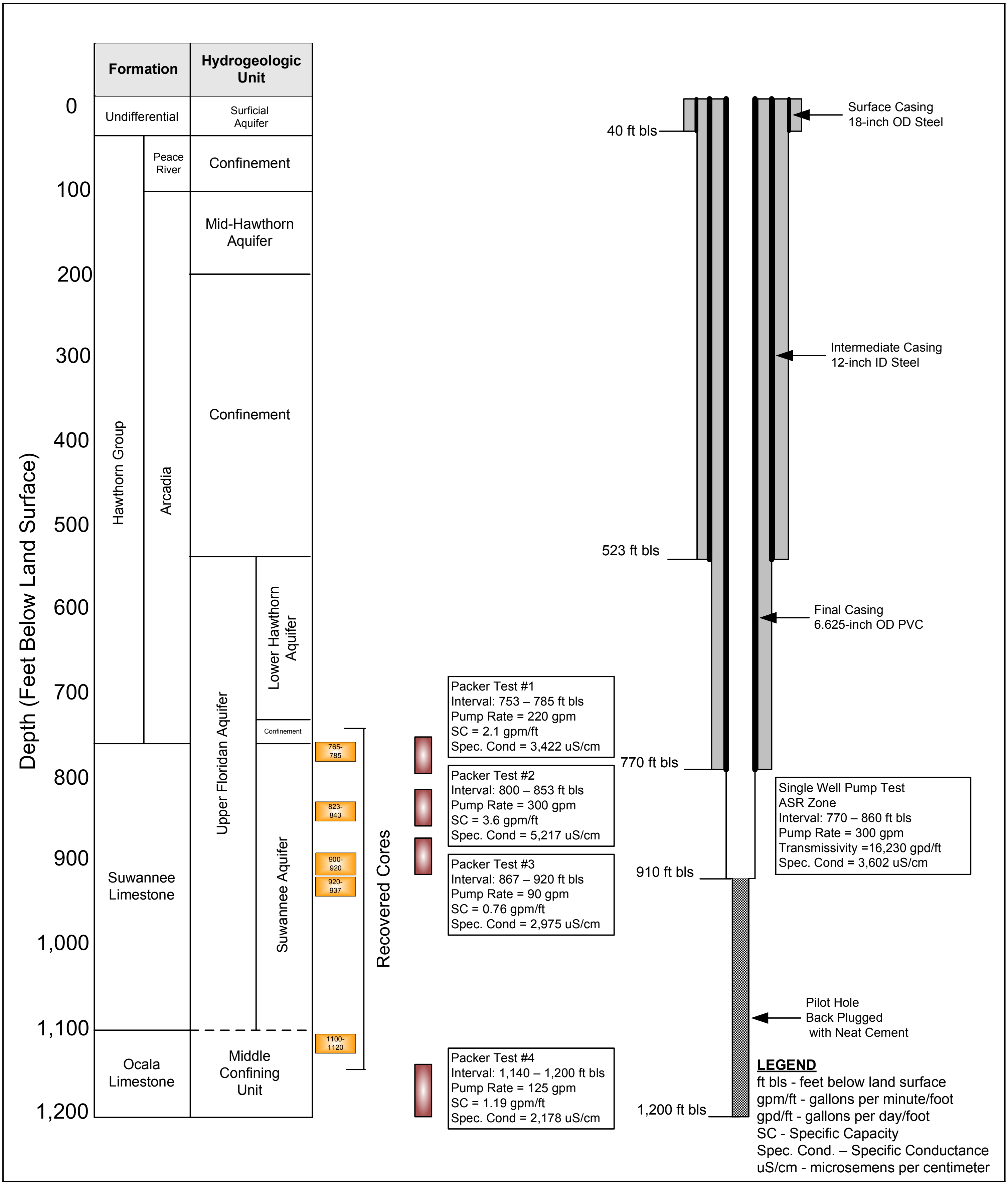

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Figure 3-2 Gator Slough ASR EXW Schematic and Hydrogeologic Summary

3.4.1 Surface Casing

A 25-inch diameter borehole was drilled to a depth of 41 feet bls. Forty feet of 18-inch diameter steel casing was then installed and pressure grouted in place. The purpose of the surface casing was to prevent surficial material from collapsing into the borehole during drilling operations, maintain the strength and integrity of the surficial material from the weight and vibration of the drill rig, and to isolate the surficial aquifer from drilling materials and fluids used in the construction of the well.

3.4.2 Pilot Hole Drilling and Reaming Operations

A 12.25-inch diameter pilot hole was drilled using the mud rotary method to determine an intermediate casing depth. The construction of a pilot hole allows better identification of target zones without drilling the final borehole, minimizes attenuation effects of large diameter boreholes on geophysical logs and maintains the vertical alignment of the borehole during reaming activities. Inclination surveys were conducted in both pilot and reamed borehole every 60 feet and are described in more detail in Section 4.

Lithologic samples were collected at 10-foot intervals and at changes in the lithology during pilot hole drilling operations (Appendix B). Lithologic samples were used to help determine formation changes and the hydrologic and physical properties of the aquifers. Geophysical logging consisted of XY caliper, gamma ray, dual induction, spontaneous potential, borehole compensated sonic and video surveys. Lithologic sampling and geophysical logging are described in Section 4, Data Collection and Analysis. Geophysical logs and video survey descriptions are available in Appendices C and D.

A pilot hole was drilled to a depth of 551 feet bls. It was determined, from the lithology and geophysical logs, that this depth had penetrated the lower Hawthorn aquifer, the formation was sufficient to support the weight of the intermediate casing, and provide a good grout seal. Geophysical logs and video descriptions are available in Appendices C and D. The pilot hole was subsequently reamed with a 17-inch diameter two-stage reaming bit to a depth of 537 feet bls using mud rotary techniques. Twelve inch diameter intermediate steel casing was set at 523 feet bls as approved by the FDEP on March 18, 2008. Mill certificates for the steel casing are provided in Appendix I. Prior to placement of the intermediate casing, geophysical logging was performed consisting of an XY caliper and gamma ray log. The XY caliper log was used to determine the physical properties of the borehole and provide annular volume information for cementing operations. Intermediate casing grouting operations are summarized in Table 3-2.

Table 3-2 Intermediate Casing Grout Summary

Date	Stage	Cement Type	Density (lbs/gal)	Total Volume (Barrels)	Total Volume (cuft)	Theoretical Tag (ft bls)	Actual Tag (ft bls)
03-19-2008	1A	4% gel	13.7	33	185	-	-
03-19-2008	1B	Neat	14.4	39	219	0	52
03-20-2008	2	4% gel	14.2	12	67	0	0

3.4.3 Open Hole Drilling Operations

Following intermediate casing installation pilot hole drilling resumed using reverse air drilling techniques. The reverse air drilling method allowed samples to be collected for water quality analyses at approximately 30-foot intervals. Reverse air water quality results are provided in Section 4.4. Excess water during reverse air drilling was filtered through a settling tank before being discharged into the Alligator Canal. In addition, a silt curtain was installed in the canal to provide an additional measure of containment.

Prior to reverse air drilling and discharging into the Alligator Canal, Sanders Laboratory of Nokomis, Florida collected groundwater samples from the ASR EXW on April 1, 2008 to fulfill the requirements of the Generic Discharge Permit as required by the FDEP. The water produced from the ASR EXW was analyzed by Sanders Laboratory at initial discharge into the Alligator Canal and 30 days after the initial sampling. The results met acceptable limits of the Generic Discharge Permit and are presented in Appendix J.

During pilot hole drilling operations, five rock cores measuring 4-inches in diameter were recovered from various depths. The samples from the cores were sent to Ardaman and Associates of Orlando, Florida for additional analyses. Coring operations and results of the analyses are discussed in Section 4.

3.4.4 Back Plugging

The pilot-hole was backplugged from 1,200 to 903 feet bls in five stages, with a total of 58 barrels of neat cement as shown in Table 3-3. Seven feet of cement backplug overshot was drilled out to 910 ft bls.

Table 3-3 Backplug Summary

Date	Stage	Cement Type	Density (lbs/gal)	Total Volume (Barrels)	Total Volume (cuft)	Theoretical Tag (ft bls)	Actual Tag (ft bls)
06-20-2008	1	Neat	14.4	33	185.1	1,080	1,049
06-23-2008	2	Neat	14.5	16	89.8	960	972
06-24-2008	3	Neat	14.2	7	39.3	930	923
06-25-2008	4	Neat	14.6	1	5.6	910	917
06-25-2008	5	Neat	14.1	1	5.6	910	903

3.4.5 Final Casing

On June 17, 2008, the FDEP approved a final casing seat at 770 feet bls. The final casing was installed on July 10, 2008. The 6.625-inch OD PVC, was installed to 770 feet bls. The casing was grouted in place in seven stages with the summary of cement volumes provided in Appendix E. Following casing installation, it was suspected during drill out that the PVC casing was damaged at 737 feet bls likely due to the heat of the cement during grouting operations. Video surveys conducted on July 19 and 21, 2008 confirmed that the casing was damaged. Repair operations were suspended pending a SFWMD site inspection conducted on August 26, 2008.

Beginning on September 2, 2008, the PVC casing was removed by milling operations from land surface to 605 ft bls. During the milling operations, the bit deviated at 585 feet bls which ceased any further removal of the casing. As approved by the FDEP on September 29, 2008, the PVC casing and borehole were backplugged and abandoned with 13 barrels of neat cement from 536 ft bls to 770 ft bls. The borehole was then re-drilled using the mud rotary method with an 11.875-inch bit to 774 ft bls.

On October 15, 2008, the second string of casing, consisting of 6.625-inch OD PVC, was reinstalled to 770 feet bls as approved by the FDEP. The casing was grouted in place in seven stages as summarized in Table 3-4. Following casing installation, the open hole portion of the well was drilled to 910 ft bls with a 5.25-inch bit using the reverse air method.

Table 3-4 Final Casing Grout Summary

Date	Stage	Cement Type	Density (lbs/gal)	Total Volume (Barrels)	Total Volume (cuft)	Theoretical Tag (ft bls)	Actual Tag (ft bls)
10-15-2008	1	Neat	14.9	4	22.4	734	741
10-16-2008	2	Neat	14.8	6	33.7	679	610
10-17-2008	3	6% gel	13.5	16	89.8	445	455
10-18-2008	4	6% gel	13.5	14	78.5	311	291
10-19-2008	5	6% gel	13.8	10	56.1	188	187
10-20-2008	6	6% gel	13.6	10	56.1	84	83
10-21-2008	7	6% gel	13.4	9.5	53.3	0	0

3.4.6 Well Development

After drilling operations were complete, the well was developed using reverse air, and a submersible pump. Water quality samples were collected periodically during development and tested for specific conductivity, dissolved oxygen, pH, and temperature. Well development water quality measurements are discussed in Section 4.5.

4.0 Hydrogeological Testing / Data Collection

Data collected during the drilling and construction of the Gator Slough ASR EXW included inclination surveys, lithologic samples, geophysical logging and water quality sampling. Analysis of collected data was used to characterize the lithology, water quality and relative permeability of the sediments encountered. Cores were collected during drilling operations at selected depths to determine discrete hydraulic properties of the aquifer and to aid in identification of potential storage zones.

4.1 Inclination Surveys

Inclination surveys were conducted on the borehole during both pilot hole and reamed hole operations to ensure the borehole did not deviate significantly from plum and prevent, hinder, or interfere with casing and cement grout placement. Surveys were performed every 60 feet during drilling operations. In accordance with vertical drift specifications for the well, each inclination measurement was less than one degree and consecutive survey measurements differed no more than 0.5 degrees. The survey results were recorded with a Sure-Shot tool. The average inclination during construction was 0.64 degrees for the pilot hole and 0.39 degrees for the reamed hole. Results of the inclination surveys are provided in Appendix H.

4.2 Lithologic Sampling and Coring

Formation samples were collected during drilling operations every 10 feet from surface to the total depth of the pilot hole. Samples were characterized for rock type, color, consolidation, texture, cementation, hardness/induration, fossil type and visible porosity/permeability. Lithologic sampling aided in identifying the contacts between formations, selection of core intervals, selection of packer test intervals and understanding the overall physical characteristics of formations penetrated by the borehole. Detailed descriptions of the lithology encountered during pilot hole drilling of the Gator Slough ASR EXW are presented in Appendix B.

During drilling of the Gator Slough ASR EXW, conventional cores were collected using a 4-inch diameter, 20-foot, core barrel with a diamond bit. A total of five rock cores were retrieved from the Arcadia Formation and Suwannee Limestone between 665 and 1,120 feet bls. The core recoveries ranged between 19 to 96 percent. A summary of the full-diameter coring program conducted at this site is presented in Table 4-1.

Table 4-1 Coring Program Summary

Core #	Date Cored	Cored Interval (ft bls)	Recovered (ft)	Recovered (%)
1	04-03-2008	765-785	12.2	61
2	04-15-2008	823-843	5.2	26
3	04-22-2008	900-920	3.8	19
3B	05-01-2008	920-937	16.4	96
4	05-06-2008	1,100-1,120	5	25

Six sections of the cores obtained during drilling were sent to Ardaman and Associates, Inc., located in Orlando, Florida to determine the following parameters: vertical and horizontal hydraulic conductivity, vertical and horizontal porosity and specific gravity. Five of the six samples were tested. Hydraulic conductivity and porosity were measured in general accordance with American Society for Testing and Materials (ASTM) Standard D 5084 "Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter" using constant head (Method A). Specific gravity measurements were made in general accordance with ASTM Standard D 854 "Specific Gravity of Soil Solids by Water Pycnometer" using approximately 50 gram specimens ground top pass the U.S. Standard No. 40 sieve. Unconfined compression tests were performed in general accordance with ASTM Standard D 7012 "Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures" using the unconfined test method (Method C). The results are summarized in Table 4-2. Full laboratory reports from Ardaman and Associates, Inc are available in Appendix K.

Table 4-2 Core Sample Petrophysical Analyses Summary

Core No.	Sample Depth (ft)	Vertical Hydraulic Conductivity (cm/sec)	Horizontal Hydraulic Conductivity (cm/sec)	Vertical Porosity (%)	Horizontal Porosity (%)	Specific Gravity
1	770.7	8.1×10^{-5}	1.2×10^{-4}	41.4	41.5	2.72
2	823.1	2.5×10^{-4}	4.6×10^{-4}	39.6	39.7	2.71
2	826.6	7.3×10^{-4}	7.8×10^{-4}	41.0	41.2	2.71
3B	931.7	1.2×10^{-7}	1.3×10^{-7}	25.1	24.5	2.83
4	1,101.6	1.7×10^{-3}	1.6×10^{-3}	41.1	41.1	2.73

4.3 Geophysical Logging and Analysis

Geophysical logging was conducted in the pilot hole after each stage of pilot hole drilling and before casing installation. The geophysical logging runs conducted during drilling are summarized in Table 4-3. The logs provide a continuous record of the geophysical properties of the subsurface formations and/or their formation fluids adjacent to the borehole. Analysis of the logs were used to assist in the interpretation of lithology, to provide estimates of permeability, porosity, bulk density, resistivity, and to estimate the total dissolved solids of the groundwater (Archie, 1942, Reese, 1994). Geophysical logs in PDF and LAS format and are presented in Appendix C.

The geophysical logs were compared to lithologic logs to aid in identifying geologic contacts and were used to obtain specific hydrogeologic data pertaining to the formations. The geophysical data, in conjunction with water quality results, specific capacity testing, and lithologic descriptions, were utilized to determine aquifer properties, casing depths, packer-test intervals and the potential storage zone interval.

Table 4-3 Geophysical Logging Summary

Date	Logged Interval (ft bls)	XY Caliper	Gamma Ray	Spontaneous Potential	Dual Induction	Temperature	Fluid Resistivity	Flow	Sonic Porosity	Comments
03-06-2008	0-551	X	X	X	X				X	12.25-inch pilot hole
03-19-2008	0-537	X	X							17-inch reamed hole
04-07-2008	0-785	X	X							Select depth for Packer Test 1
04-16-2008	0-843	X	X							Select depth for Packer Test 2
04-23-2008	0-920	X	X							Select depth for Packer Test 3
05-09-2008	0-1,200	X	X							Select depth for Packer Test 4
05-29-2008	0-1,200	X	X	X	X	X	X	X	X	12.25-inch borehole
10-14-2008	0-760	X	X							Post milling operations for installation of replacement casing – encountered heavy drilling fluid.
10-15-2008	0-773	X	X							In preparation for replacement casing
10-29-2008	0-910	X	X							Final logging of completed well

4.4 Video Surveys

Video surveys were conducted within borehole and casing inspections. The video surveys provide a continuous record of the visual characteristics of the subsurface formations. A list of video surveys conducted on the well is summarized in Table 4-4. Analysis of the videos were used to assist in the interpretation of casing and borehole conditions. Video surveys and descriptions are presented in Appendix D. Video surveys were run in the pilot hole, final open borehole and to view damaged PVC casing of the Gator Slough ASR EXW.

Table 4-4 Video Survey Summary

Date	Interval (ft bls)	Comments
05-29-2008	0-1,200	Video to total depth of borehole
07-19-2008	0-737	No visibility. Obstruction encountered at 737 feet bls.
07-21-2008	0-737	Identify 6.625 inch OD PVC final casing is blistered at 737 feet bls.
09-23-2008	0-587	Video of milling operations and verified bit deviated from PVC
09-24-2008	0-580	Video verified tremie pipe inside PVC for back plugging operations
10-29-2008	0-910	Final video inspection of completed well

4.5 Water Quality Sampling and Analysis

4.5.1 Water Quality during Drilling Operations

Water quality samples were collected at approximately 30-foot intervals in the pilot hole during reverse-air drilling. Sampling started at a depth of 580 feet bls and continued to the total depth of 1,200 feet bls. Samples were collected from the discharge point of the fluid circulation system. The samples were analyzed on site for specific conductivity, dissolved oxygen, pH, temperature and chloride. This data indicated fluctuations in salinity of groundwater with depth.

The water samples from reverse-air drilling provide an indication of relative water quality trends versus depth. Pilot hole water quality results are presented in Table 4-5. The salinity increased from approximately 590 to 882 feet bls and decreased slightly from 882 to 1,200 feet bls.

Table 4-5 Reverse Air Drilling Water Quality with Depth

Date	Depth (ft bls)	Specific Conductivity (µS/cm)	Dissolved Oxygen (%)	pH	Temp. (°C)	Chloride (mg/L)
03-31-2008	580	2,716	35.8	7.57	27.5	650
03-31-2008	609	2,885	38.9	7.40	25.5	688
04-01-2008	640	2,842	30.1	7.03	25.7	662
04-01-2008	671	3,032	35.9	7.90	25.5	688
04-01-2008	702	3,055	36.7	7.55	25.8	688
04-01-2008	735	3,051	40.1	7.69	26.1	662
04-01-2008	765	3,110	38.9	7.61	26.0	700
04-14-2008	794	3,490	45.0	7.35	28.0	825
04-15-2008	823	3,495	57.6	7.02	26.3	862
04-22-2008	882	3,555	57.1	7.15	27.5	888
05-02-2008	940	3,186	50.8	7.60	18.5	1,270
05-02-2008	970	3,180	63.1	7.20	25.4	1,120
05-02-2008	1000	3,217	51.5	7.20	22.8	1,180
05-05-2008	1032	3,113	48.4	7.29	22.4	950
05-05-2008	1084	2,987	47.1	7.90	21.3	925
05-05-2008	1094	3,037	47.7	7.85	22.6	913
05-07-2008	1126	3,209	46.9	6.84	23.2	913
05-07-2008	1157	3,037	55.8	6.82	29.5	888
05-08-2008	1188	2,872	44.7	6.89	22.1	888
05-08-2008	1200	2,871	47.1	6.68	22.2	900

4.5.2 Well Development

After drilling operations were complete, the well was developed with reverse air at a depth of 910 feet bls on October 28, 2008 for approximately three hours. Water quality samples were collected during development for field parameters approximately every 30 minutes. Water quality results during well development are provided in Table 4-6.

Table 4-6 Air Development Water Quality

Time	Specific Conductivity (µS/cm)	D.O. (%)	pH	Temp. (°C)
1115	3,681	21.3	7.33	24.4
1135	3,672	18.6	7.82	23.7
1210	3,668	17.4	8.23	23.9
1240	3,625	18.8	8.38	24.3
1315	3,652	18.4	8.09	23.6
1345	3,6,71	19.1	7.94	23.8
1400	3,657	17.9	8.28	24.3

The well was pump developed for four hours on October 31, 2008 at a rate of 300 gpm. Water samples were obtained and tested for specific conductivity, dissolved oxygen, pH, temperature, and chloride. Well development water quality measurements are shown in Table 4-7.

Table 4-7 Pump Development Water Quality

Time	Specific Conductivity (µS/cm)	D.O. (%)	pH	Temp. (°C)	Chloride (mg/L)
1400	3,588	15.5	7.44	25.5	900
1430	3,561	16.5	7.85	25.8	1,050
1500	3,598	12.0	7.87	25.1	962
1515	3,574	14.9	7.79	25.1	-
1530	3,561	12.5	7.89	25.4	1,025
1545	3,538	15.5	7.98	25.5	-
1600	3,594	13.4	7.90	25.3	888
1615	3,552	15.9	8.04	25.5	-
1630	3,584	12.3	7.81	25.6	912
1645	3,580	12.2	7.88	25.2	-
1700	3,558	13.1	7.96	25.5	925
1715	3,554	13.5	8.01	25.5	-
1730	3,564	13.3	8.01	25.6	950
1745	3,556	13.8	8.03	25.8	-
1800	3,602	12.7	7.82	25.5	962

4.5.3 Total Dissolved Solids Analysis with Depth

The Sonic porosity log and Dual Induction log resistivity were used to calculate a log-derived Total Dissolved Solids (TDS) plot for the ASR EXW based on the method developed by Callahan (1996) using empirical data from South Florida compiled by Reese (1994).

The calculated TDS ranged between approximately 200 and 2,000 mg/L with increased mineralization from 550 to 750 feet bls; water quality is stabilized to 1,100 feet bls; and slightly decreases in TDS to 1,200 feet bls (Figure 4-1). The base of the USDW was not encountered at this site to a depth of 1,200 feet bls and is supported by water quality packer tests and the log-derived TDS plot.

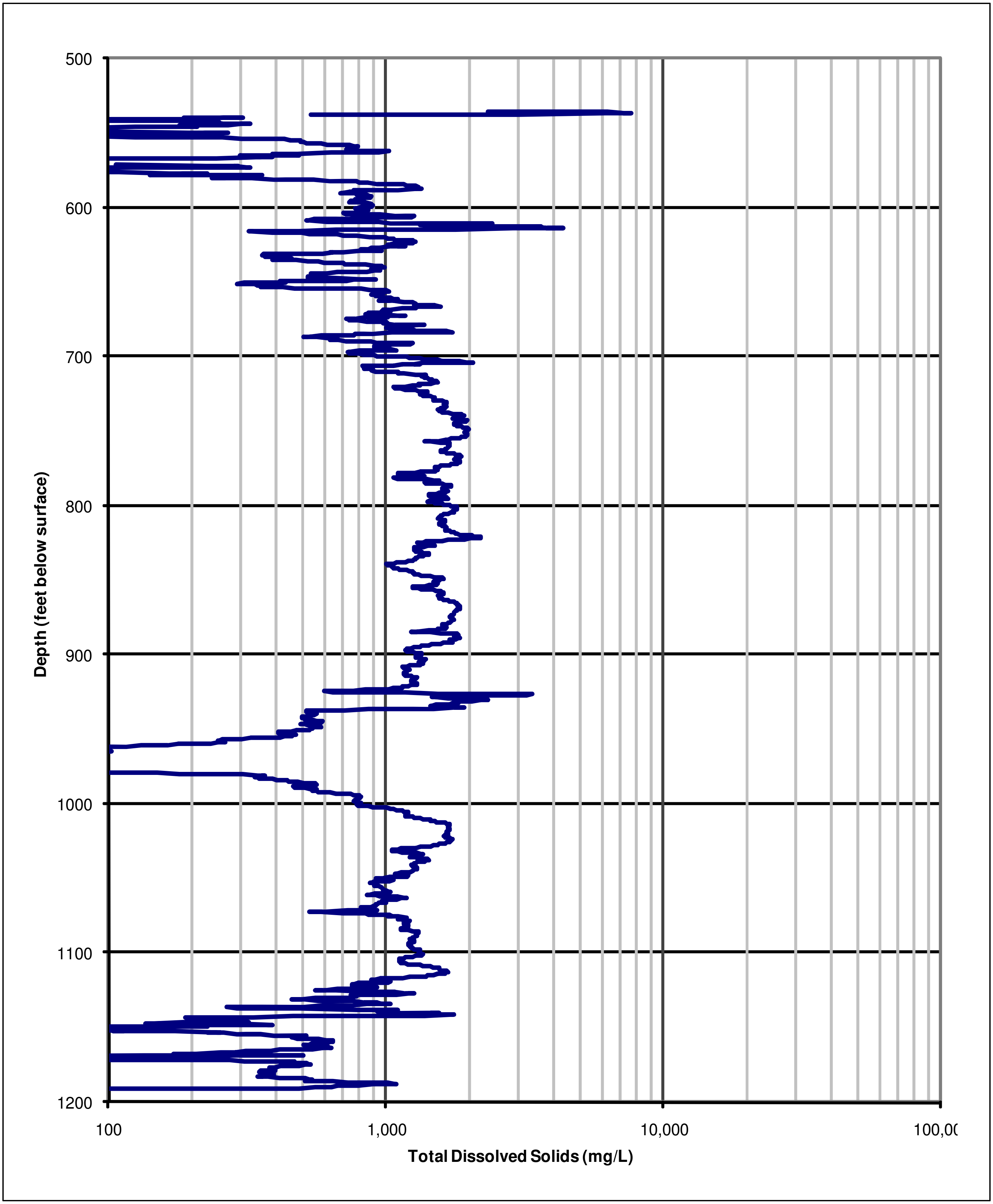

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Figure 4-1 Log Derived Total Dissolved Solids Plot for the Gator Slough ASR EXW

4.5.4 Water Quality During Packer and Step Drawdown Testing

During the pumping phase of packer testing, groundwater samples were collected and analyzed to determine discreet water quality properties of the sampled intervals. Water samples collected during packer tests showed higher conductivity, and chloride, at shallower depths than reverse air water quality samples. This variance in water quality is likely due to drilling fluid water samples being partially diluted with fresher water of overlying flow zones. Water samples were collected by MWH and analyzed by Sanders Laboratories, Inc. during each packer test. Water quality results from the packer tests are presented in Table 4-8. The full laboratory analyses of the water quality samples are available in Appendix L.

Table 4-8 Packer Test Water Quality

	Parameter	**Packer Test 1** 753–785 ft bls	**Packer Test 2** 800–853 ft bls	**Packer Test 3** 867–920 ft bls	**Packer Test 4** 1140–1200 ft bls
Primary Inorganics	Arsenic (mg/L)	0.003*	BDL	BDL	BDL
	Barium (mg/L)	0.045	0.042	0.042	0.025
	Fluoride (mg/L)	1.8	0.9	1.1	1.2
	Nitrate (mg/L)	BDL**	0.02**	0.01	0.01**
	Sodium (mg/L)	365	461	403	308
Secondary Inorganics	Aluminum (mg/L)	0.072	BDL	BDL	0.27
	Chloride (mg/L)	740	975	851	531
	Iron (mg/L)	7.07	0.082	0.045	0.107
	Manganese (mg/L)	0.092	0.004	0.007	0.011
	Sulfate (mg/L)	177	303	321	332
	Color (PtCo Color Units)	10**	5**	5	5**
	Total Dissolved Solids (mg/L)	1,500	2,060	1,890	1,450
Additional Parameters	Ammonium (mg/L)	0.40	0.36	0.35	0.27
	Bicarbonate Alkalinity (mg/L)	170	125	128	129
	Calcium (mg/L)	97.3	131	121	77.3
	Carbon Dioxide (mg/L)	151	111	112	114
	Carbonate Alkalinity (mg/L)	1.57	0.78	0.44	0.57
	Hydrogen Sulfide (mg/L)	BDL	0.20	0.46	0.50
	Magnesium (mg/L)	97.6	88.3	90.9	63.3
	Potassium (mg/L)	25.3	18.8	21.0	20.4
	Silica (mg/L)	11.8	17.9	18.2	15.6

* sample not properly preserved
**sample analyzed beyond holding time

Water samples from the ASR EXW was collected during the step drawdown test and during the constant rate pump test conducted on November 4, 2008 of the completed open interval, 770-910 feet bls. During the drawdown phase, the water samples were obtained approximately every hour and measurements of specific conductivity, dissolved oxygen, pH, temperature and chloride were obtained. Results of the water quality measurements for the pump test are shown in Table 4-9.

Table 4-9 Step Drawdown/Constant Rate Pump Test Water Quality

Pump Rate (gpm)	**Specific Conductivity** (µS/cm)	**D.O.** (%)	**pH**	**Temp.** (°C)	**Chloride** (mg/L)
75	3,574	16.3	7.94	24.2	938
150	3,564	18.2	7.91	24.5	912
225	3,600	19.0	7.94	25.1	900
300	3,584	12.3	7.81	25.6	912

4.5.5 Background Water Quality

After construction activities were completed, the well was developed until at least three well volumes of water had been evacuated and specific conductivity, pH, temperature and chloride concentration measurements stabilized. Water samples were collected by Sanders Laboratories, Inc. on November 3, 2008. Results of primary, secondary, bacteriological and radionuclide water quality parameters are listed in Table 4-10. Complete results are available in Appendix M.

Table 4-10 Completed Well Background Water Quality Results

Parameter		ASR EXW (770 – 910 ft bls)
Primary Inorganic	Aluminum (mg/L)	BDL
	Antimony (mg/L)	BDL
	Arsenic (mg/L)	BDL
	Barium (mg/L)	0.047
	Beryllium (mg/L)	BDL
	Cadmium (mg/L)	BDL
	Chromium (mg/L)	BDL
	Fluoride (mg/L)	0.9
	Mercury (mg/L)	BDL
	Nickel (mg/L)	BDL
	Nitrate (mg/L)	BDL
	Nitrite (mg/L)	BDL
	Selenium (mg/L)	BDL
	Sodium (mg/L)	500
	Thallium (mg/L)	BDL
Secondary Inorganic	Color (PtCo Color Units)	BDL
	Copper (mg/L)	BDL
	Chloride (mg/L)	945
	Iron (mg/L)	0.076
	Manganese (mg/L)	BDL
	Silver (mg/L)	BDL
	Specific Conductance (μmhos/cm)	3,640
	Sulfate (mg/L)	284
	Total Dissolved Solids (mg/L)	2,010
	Zinc (mg/L)	0.012
Bacteriological	Total Coliform (CFU/100ml)	BDL
Radionuclide	Gross Alpha (pCi/l)	20
	Radium-226 (pCi/l)	4.9
	Radium-228 (pCi/l)	0.3
Additional Parameters	Dissolved Oxygen (mg/L)	2.43
	Turbidity (NTU)	2.4

4.6 Well Testing and Analysis

4.6.1 Specific Capacity Testing while Drilling

Specific capacity testing was conducted at each rod change (30-foot intervals) during reverse-air drilling operations. These tests were conducted by determining the static water level in the pilot hole and the flow rate developed during airlifting. The resultant specific capacity measurement is an indication of the flow in that section of the pilot hole, relative to the rest of the pilot hole. Specific Capacity measurements from the ASR EXW during drilling operations are provided in Table 4-11.

Table 4-11 Specific Capacity During Drilling Operations

Depth (ft bls)	**Static Water Level** (ft als)	**Flow Water Level** (ft als)	**Drawdown** (ft)	**Flow Rate** (gpm)	**Specific Capacity** (gpm/ft)
580	26.0	1.0	25.0	60	2.4
609	25.8	1.0	24.8	75	3.0
640	26.5	1.0	25.5	100	3.9
671	25.2	1.0	24.2	109	4.5
702	25.6	1.0	24.6	300	12.2
735	25.7	1.0	24.7	300	12.1
765	25.5	1.0	24.5	310	12.6
794	27.5	1.0	26.5	525	19.8
853	27.6	1.0	26.6	750	28.2
882	27.4	1.0	26.4	782	29.6
940	22.6	1.0	21.6	643	29.8
970	22.3	1.0	21.3	655	30.7
1000	22.8	1.0	21.8	405	18.6
1032	23.0	1.0	22.0	429	19.5
1063	25.3	1.0	24.3	720	29.6
1100	25.4	1.0	24.4	766	31.4
1126	23.1	1.0	22.1	800	36.2
1157	23.5	1.0	22.5	818	36.2
1188	24.0	1.0	23.0	818	35.6
1200	24.2	1.0	23.2	818	35.2

4.6.2 Packer Testing

Packer testing was conducted while drilling the nominal 11-inch pilot hole to test discreet intervals in FAS to determine water quality and formation hydraulic parameters. Depth intervals were selected for packer testing based on the potential to produce water as determined from specific capacity testing, geophysical logging, and lithologic characteristics. Four packer tests were performed at the Gator Slough ASR EXW Well. All packers tests were single packer tests performed during drilling operations. The results from each tested interval are provided below in Table 4-12.

The following procedures were used to perform the packer tests:

1) To test each isolated depth interval, a packer assembly, attached to drill pipe, was lowered into the borehole. The packer was then inflated to seal off the selected depth interval. A pressure transducer was set above the top packer to measure water pressure/levels above the packer to verify that the packer seal was not leaking. A second pressure transducer was set in the drill pipe to approximately 130 feet bls, to monitor water levels in the isolated tested interval. In-Situ Mini-Troll pressure transducers were used to record and store water level measurements and were used in junction with Rugged Readers to monitor the measurements during the packer tests. Data from each packer test was analyzed using Aqtesolv Pro software for calculating transmissivities and the solutions are provided in Appendix N.

2) A submersible pump was set into the drill pipe to a depth of approximately 140 feet bls. A pre-test was conducted prior to establish a maximum pumping rate and to stabilize water quality parameters to ambient conditions. After water quality stabilized and pump rates were selected, the pump was turned off and the water level was allowed to return to static conditions prior to the pumping portion of the packer test.

3) During the pumping phase of packer testing, water levels and pumping rates were monitored and recorded and water samples were collected and analyzed. Each packer test was conducted from approximately 4 - 5 hours, which was dependent on pumping rate and/or drawdown stabilization.

4) Following the pumping phase of the test, water level recovery was monitored and recorded until the water level had stabilized to pre-pumping, ambient conditions. Upon completion of the test, the packer assembly was deflated and removed from the borehole. Water level data was downloaded from the data logger on site after each packer test.

Packer test recovery data were used to calculate hydraulic parameters of each packer test interval. Water level data from the top transducer was also reviewed to confirm the integrity of the top packer seal. Water levels above the packer assembly showed no effect resulting from pumping. The calculated transmissivities for Packer Test 1 through 4 are 605, 2,313, 443, and 182 gpd/ft, respectively.

Table 4-12 Packer Test Results

Packer Number	**Interval** (ft bls)	**Pump Rate** (gpm)	**Specific Capacity** (gpm/ft)
1	753 – 785	220	2.1
2	800 – 853	300	3.6
3	867 – 920	90	0.8
4	1,140 – 1,200	125	1.2

4.6.3 Step Drawdown Testing

A step drawdown test was completed on November 4, 2008. The well was pumped at increasing rates of 75, 150, 225 and 300 gpm for one hour at each rate. During the test, water samples were taken and tested for specific conductivity, dissolved oxygen, pH, temperature, and chloride. The step drawdown test yielded an average specific capacity of 9.4 gpm/ft. Water level measurements were obtained both manually, with a manometer for above land surface measurements, and with an electric water level tape for below land surface measurements. A transducer was used to record water level measurements electronically. A transducer was set to 120 feet bls to record water level measurements electronically. Results for the Step Drawdown Test are shown in Table 4-13.

Table 4-13 Step Drawdown Test

Step	Pump Rate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)
1	75	7.2	10.4
2	150	15.0	10.0
3	225	25.1	9.0
4	300	36.9	8.1

4.6.4 Constant Rate Aquifer Testing

A constant rate aquifer test was conducted on November 4, 2008 following the step drawdown test (Step #4) at a rate of 300 gpm for four hours to determine the hydraulic performance of the well in the completed open interval, 770-910 feet bls. Transmissivity was calculated from the drawdown and/or recovery data obtained during the test. Water level measurements were obtained both manually with a manometer, for above land surface measurements, and with a water level tape for below land surface measurements. Water level data was collected in feet and PSI using an In-Situ pressure transducer set at 190 feet bls.

The constant rate aquifer test consisted of three phases as shown in Figure 4-2: a background phase to determine ambient static water conditions, a drawdown phase, which immediately followed the step drawdown test to determine water levels changes associated with pumping, and a recovery phase to determine the return to static water level conditions. Water quality samples were obtained approximately every fifteen minutes and measurements of specific conductivity, dissolved oxygen, pH, temperature and chloride were made.

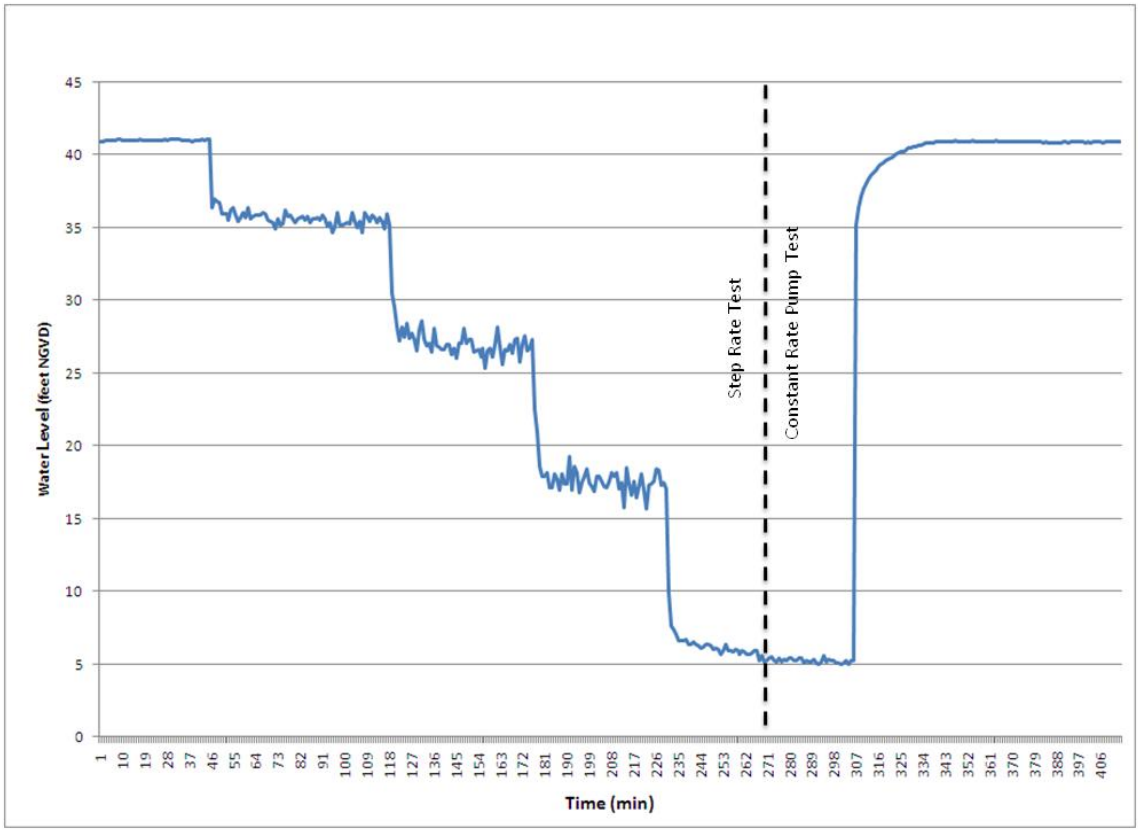

Figure 4-2 Step Drawdown Test/Constant Rate Aquifer Test

The background phase consisted of recording water level measurements in the well for a period of 24 hours. The constant rate pumping phase immediately followed the step drawdown test. This consisted of pumping the well at a constant rate of 300 gpm for four hours while recording water level changes in the well. An average specific capacity during the test was 8.1 gpm/ft. The drawdown phase was followed by a 16-hour recovery period after pumping stopped and water levels were allowed to return to background conditions.

Recovery data from the ASR EXW was used to calculate transmissivity of the aquifer using three solution methods. These three methods were: the Theis (1935) method for confined aquifers with residual drawdown/recovery, the Hantush (1960) method for leaky aquifers with aquitard storage, and the Hantush-Jacob (1955)/Hantush (1964) method for leaky aquifers without aquitard storage. A summary of the transmissivity results are presented in Table 4-14.

Table 4-14 Aquifer Parameter Values from Constant Rate Aquifer Test

Parameter	Theis (1935)	Hantush-Jacob / Hantush (1955)	Moench (1985)
Transmissivity (gpd/ft)	16,130	16,010	16,230
Storativity	-	1.27×10^{-6}	3.18×10^{-3}

The transmissivity measured with the Moench analysis is comparable to the estimated transmissivity, 16,200 gpd/ft calculated using the standard multiplier of 2,000 times the specific capacity. A log/log plot of drawdown versus time, utilizing the Moench solution, for the pumped interval is provided in Figure 4-3. The results of this solution yielded a transmissivity value of 16,230 gpd/ft, a storage coefficient of 3.18×10^{-3}. The log/log plots of drawdown versus time for the Theis and the Hantush-Jacob/Hantush solutions are provided in Appendix O.

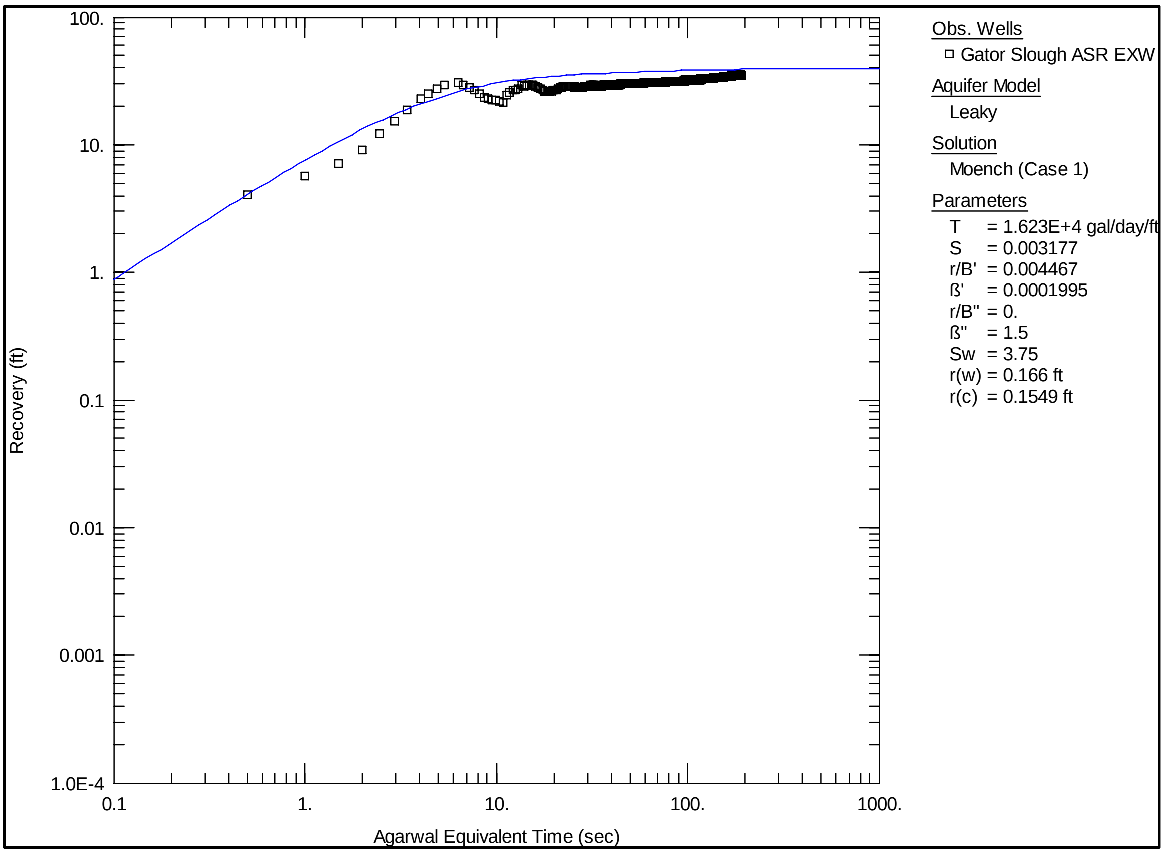

Figure 4-3 Gator Slough ASR TPW Constant rate Aquifer Test Plot of Recovery vs. Time

5.0 Conclusions and Recommendations

Construction of the Gator Slough ASR EXW for the City of Cape Coral was substantially completed on December 12, 2009. One 6.625-inch OD ASR exploratory well with PVC casing installed to 880 feet bls and an open hole extending from 770 to 910 feet bls is now ready for installation of the monitoring equipment. The well was constructed to the requirements specified under FDEP permit No. 272886-001 UC/5X.

The well was completed as a monitor well, with future potential utility as a Storage Zone Monitor Well (SZMW) for an ASR System to capture excess wet season flows from the Alligator Canal. The Gator Slough in Northeast Cape Coral was identified in the RIDS Feasibility Study (SFWMD, 2002) as a preferred location for an ASR System to capture excess flows during the wet season and provide irrigation water to the Cape Coral Irrigation System in the dry season.

The monitoring interval of the ASR EXW is completed primarily within the Suwannee Limestone of the Upper Floridan aquifer and is confined beneath 30 feet of low permeability marl and clays. The ASR EXW has a specific capacity of 8.1 gpm/ft and a transmissivity of 16,230 gpd/ft at a pump rate 300 gpm. The ambient water within the proposed storage zone is brackish, and contains a chloride and TDS concentration of approximately 945 mg/L and 2,010 mg/L, respectively.

The range of transmissivity values for a successful ASR System in southern Florida is approximately 6,000 to less than 224,400 gpd/ft (Reese and Alvarez-Zarikian, 2006). The transmissivity at Gator Slough is near the low end of the range for a successful ASR system and acidization of the storage zone is recommended upon completion of an ASR TPW in the vicinity of the site.

Based on the information obtained from this well and its proximity to the Alligator Slough watershed, we would recommend the City acquire property along the Alligator Slough Canal, and begin monitoring the ASR EXW by recording monthly water levels. Permitting and construction of an ASR System should be conducted at such time as warranted by City irrigation demands. The lead-time to permit and develop a fully operational ASR system is approximately 5-years so this should be taken into consideration in facilities planning.

6.0 References

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Report Supplement

Lithologic Logs

MWH

LITHOLOGY

IRR-6C.1 ASR Exploratory Well
Gator Slough

Well Number	001 (L-1040)
Permit Number	272886-001-UC/5X
Job Number	3220289.864702
Owner	City of Cape Coral

Depth (ft bls)	**Description**
0-10	Shell Fragments (90%): medium light gray N6 and light gray N7; predominantly bi-valves. Sandstone (10%): light brown 5YR 5/6; carbonate; weathered; high porosity.
10-20	Shell Fragments: medium light gray N6 and light gray N7; predominantly bi-valves.
20-30	Clay: dark greenish gray 5GY 4/1; moderately soft; trace of silt.
30-40	Clay: greenish gray 5GY 6/1; soft; trace of silt.
40-70	Clay: greenish gray 5GY 6/1; moderate hard; trace of silt.
70-90	Clay (90%): greenish gray 5GY 6/1; moderately soft; 2-3% fine sand. Limestone (10%): yellowish gray 5Y 7/2; micrite; friable; high porosity.
90-110	Clay (90%): greenish gray 5GY 6/1 to light greenish gray 5GY 8/1; soft; 2-3% fine sand; 5-6% coarse phosphate. Limestone (10%): yellowish gray 5Y 7/2; micrite; friable; high porosity.
110-120	Limestone (80%): light gray N7 to very light gray N8; biomicrite; friable; high porosity; 10-15% very fine phosphate; trace of shell fragments. Marl (20%); light olive gray 5Y 6/1; soft.
120-130	Limestone: white N9 and very light gray N8; biomicrite; friable; high porosity; 10-15% very fine phosphate.
130-140	Limestone (90%): light gray N7 to very light gray N8; biomicrite; friable; high porosity; 10-15% very fine phosphate; trace of shell fragments. Marl (10%); light olive gray 5Y 6/1; soft.
140-150	Marl (60%): pale olive 10Y 6/2; soft; 10-15% very fine phosphate. Limestone (40%): very light gray N8; micrite; friable; high porosity.
150-160	Limestone (60%): very light gray N8; micrite; friable; high porosity. Marl (40%): pale olive 10Y 6/2; soft; 10-15% very fine phosphate.
160-170	Clay (70%): light olive gray 5Y 5/2; soft; 5-6% very fine phosphate. Limestone (30%): white N9 and very light gray N8; biomicrite; friable; high porosity.

Depth (ft bls)	Description
170-180	Marl (60%): yellowish gray 5Y 7/2; soft; 10-15% very fine phosphate. Limestone (40%): very light gray N8; micrite; friable; high porosity.
180-190	Limestone (80%): white N9 and very light gray N8; biomicrite; friable; high porosity; 5-10% fine phosphate; trace of coarse phosphate; trace of shell fragments. Marl (20%): very light gray N8; soft.
190-200	Limestone (90%): light gray N7 to very light gray N8; biomicrite; friable; high porosity; 10-15% very fine phosphate; trace of shell fragments. Marl (10%); light olive gray 5Y 6/1; soft.
200-220	Marl (60%): light olive gray 5Y 6/; very soft. Limestone (40%): yellowish gray 5Y 8/1; biomicrite; friable; high porosity; 4-5% fine phosphate; trace of shell fragments.
220-230	Clay (80%): greenish gray 5GY 6/1 to dark greenish gray 5GY 4/1; moderately soft. Limestone (20%): yellowish gray 5Y 8/1and very light gray N8; biomicrite; friable; high porosity; 4-5% fine phosphate.
230-240	Clay (60%): greenish gray 5GY 6/1 to dark greenish gray 5GY 4/1; moderately soft. Limestone (40%): yellowish gray 5Y 8/1and very light gray N8; biomicrite; friable; high porosity; 3-4% fine phosphate; trace of shell fragments.
240-270	Limestone (90%): yellowish gray 5Y 8/1; biomicrite; moderate porosity; friable; 4-5% fine phosphate; trace of shell fragments. Marl (10%): greenish gray 5GY 6/1; soft.
270-280	Limestone (90%): very light gray N8; biomicrite; moderate porosity; friable; 4-5% fine phosphate; trace of shell fragments. Marl (10%): light greenish gray 5GY 8/1; soft.
280-290	Limestone (90%): yellowish gray 5Y 8/1; biomicrite; moderate porosity; friable; 4-5% fine phosphate; trace of shell fragments. Marl (10%): greenish gray 5GY 6/1; soft.
290-300	Marl: very light gray N8 to yellowish gray 5Y 8/1; soft.
300-320	Marl (60%): light greenish gray 5GY 8/1; soft. Limestone (40%): very light gray N8 to yellowish gray 5Y 8/1; biomicrite; moderate porosity; moderately hard; 2-3% fine phosphate.
320-330	Marl (70%): light greenish gray 5GY 8/1; soft. Limestone (30%): very light gray N8; biomicrite; moderate porosity; moderately hard; 4-5% fine phosphate.
330-340	Marl (70%): light gray N7 to light olive gray 5Y 5/2; soft. Limestone (30%): very light gray N8; biomicrite; moderately high porosity; moderately hard; 3-4% fine phosphate.
340-360	Marl (70%): light greenish gray 5GY 8/1; soft. Limestone (30%): very light gray N8; biomicrite; moderate porosity; moderately hard; 4-5%

Depth (ft bls)	Description
	fine phosphate.
360-370	Marl (70%): light gray N7 to light olive gray 5Y 5/2; soft. Limestone (30%): very light gray N8; biomicrite; moderately high porosity; moderately hard; 3-4% fine phosphate.
370-380	Marl (60%): light greenish gray 5GY 8/1; soft. Limestone (40%): very light gray N8 to yellowish gray 5Y 8/1; biomicrite; friable; moderate porosity; 2-3% fine phosphate.
380-410	Marl (80%): light greenish gray 5GY 8/1; very soft; 2-3% fine phosphate. Limestone (20%): very light gray N8 to yellowish gray 5Y 8/1; biomicrite; moderate porosity; moderately friable; 2-3% fine phosphate.
410-440	Marl (90%): light greenish gray 5GY 8/1; very soft. Limestone (10%): yellowish gray 5Y 7/2; micrite; moderate porosity; friable.
440-460	Limestone: yellowish gray 5Y 7/2; micrite; very friable, high porosity.
460-470	Marl: yellowish gray 5Y 7/2; soft; 1-2% fine phosphate.
470-490	Marl (90%): light greenish gray 5GY 8/1; very soft. Limestone (10%): yellowish gray 5Y 7/2; micrite; friable; moderate porosity.
490-500	Marl (50%): light greenish gray 5GY 8/1; very soft. Limestone (50%): yellowish gray 5Y 7/2; micrite; friable; moderate porosity.
500-510	Clay: greenish gray 5GY 6/1 to dark greenish gray 5GY 4/1; moderately soft.
510-520	Limestone (70%): yellowish gray 5Y 7/2; biomicrite; moderately hard; moderately high porosity; 4-5% fine phosphate. Marl (30%): light greenish gray 5GY 8/1; soft.
520-550	Limestone (90%): yellowish gray 5Y 7/2; biomicrite; hard; vuggy; moderately high porosity; 4-5% fine phosphate. Marl (10%): light greenish gray 5GY 8/1; soft.
550-580	Limestone: white N9 to very light gray N8; biomicrite; hard; vuggy; high porosity; 1-2% fine phosphate.
580-590	Limestone; yellowish gray 5Y 8/1; biomicrite; moderately high intergranular and moldic porosity; moderately soft; 2-3% very fine phosphate.
590-600	Limestone; yellowish gray 5Y 8/1; biomicrite; moderately high intergranular and moldic porosity; hard; 2-3% very fine phosphate.
600-640	Limestone: yellowish gray 5Y 8/1; biomicrite; high vugular and moldic porosity; hard; fossiliferous; 1-2% very fine phosphate.
640-670	Limestone: very light gray N8; micrite; high intergranular porosity; friable.

Depth (ft bls)	Description
670-680	Limestone: very pale orange 10 YR 8/2; micrite; high intergranular porosity; friable; trace of marl.
680-710	Limestone: very pale orange 10 YR 8/2; biomicrite; high intergranular porosity; moderately friable; fossiliferous.
710-730	Limestone: very pale orange 10 YR 8/2 and very light gray N8; micrite; calcarenitic; high intergranular porosity; moderately friable.
730-740	Limestone (90%): very pale orange 10 YR 8/2; micrite; calcarenitic; high intergranular porosity; moderately friable. Clay (10%): pale yellowish brown 10YR 6/2; moderately hard; moderately plastic.
740-755	Limestone: very pale orange 10YR 8/2 and yellowish gray 5Y 8/1; biomicrite; high intergranular and moldic porosity; moderately hard; fossiliferous.
755-760	Limestone (70%): very pale orange 10YR 8/2; biomicrite; moderate moldic and intergranular porosity; friable; fossiliferous. Clay (30%): very pale orange 10YR 8/2; moderately hard; moderately plastic; silty.
760-765	Limestone (90%): very pale orange 10YR 8/2; biomicrite; moderate moldic and intergranular porosity; friable; fossiliferous. Clay (10%): very pale orange 10YR 8/2; moderately hard; moderately plastic; silty.
765-790	Limestone: very pale orange 10YR 8/2; biomicrite; moderately high moldic and intergranular porosity; friable; fossiliferous.
790-800	Limestone: very pale orange 10YR 8/2; biomicrite; calcarenitic; high intergranular and moldic porosity; friable; fossiliferous; trace of marl.
800-820	Limestone: very pale orange 10YR 8/2; biomicrite; calcarenitic; high intergranular and moldic porosity; friable; fossiliferous; gunteri.
820-840	Limestone: very pale orange 10YR 8/2; biomicrite; calcarenitic; high intergranular, moldic and vuggy porosity; moderately hard; fossiliferous.
840-860	Limestone: very pale orange 10YR 8/2; biomicrite; calcarenitic; very high intergranular, moldic and vuggy porosity; hard; fossiliferous.
860-890	Limestone: very pale orange 10YR 8/2; biomicrite; calcarenitic; very high intergranular, moldic and vuggy porosity; moderately hard; fossiliferous.
890-900	Limestone: very pale orange 10YR 8/2 to yellowish gray 5Y 8/1; biomicrite; calcarenitic; very high intergranular and moldic porosity; moderately hard; fossiliferous.
900-910	Limestone: white N9; micrite; calcarenitic; high intergranular porosity; moderately hard.
910-920	Limestone: yellowish gray 5Y 7/2; micrite; calcarenitic; high intergranular porosity; moderately friable.
920-930	Dolomite: pale yellowish brown 10YR 6/2; low moldic porosity; hard to very hard.

Depth (ft bls)	Description
930-940	Dolomite (40%): pale yellowish brown 10YR 6/2; low moldic porosity; hard to very hard. Limestone (30%): yellowish gray 5Y 7/2; biomicrite; calcarenitic; moderately high moldic and intergranular porosity; friable. Marl (30%): yellowish gray 5Y 8/1; soft.
940-950	Limestone (70%): yellowish gray 5Y 7/2; biomicrite; calcarenitic; moderately high moldic and intergranular porosity; friable. Marl (30%): yellowish gray 5Y 8/1; soft.
950-960	Limestone (50%): yellowish gray 5Y 8/1 and very light gray N8; biomicrite; calcarenitic; moderately high moldic and intergranular porosity; friable. Marl (50%): yellowish gray 5Y 8/1 and very light gray N8; soft.
960-990	Marl (90%): very light gray N8; soft. Limestone (10%): very light gray N8; biomicrite; calcarenitic; high moldic and intergranular porosity; very friable.
990-1,020	Limestone (60%): very light gray N8; biomicrite; calcarenitic; high moldic and intergranular porosity; very friable. Marl (40%): very light gray N8; soft.
1,020-1,050	Limestone: very pale orange 10 YR 8/2, micrite, soft, low macroporosity (intergranular), friable, calcarenetic, chalky.
1,050-1,060	Limestone: very pale orange 10 YR 8/2 to white N9, biomicrite, moderately hard to soft, low macroporosity (intergranular), fossiliferous.
1,060-1,080	Limestone: very pale orange 10 YR 8/2, micrite, soft, low macroporosity (intergranular), friable, calcarenetic, chalky, fossil fragments evident.
1,080-1,100	Limestone: very pale orange 10 YR 8/2 to white, biomicrite, moderately hard to soft, low macroporosity, slightly friable, chalky, trace fossil fragments.
1,100-1,110	Limestone: very pale orange 10 YR 8/2, micrite, soft, low macroporosity (intergranular), friable, calcarenetic, chalky.
1,110-1,120	Limestone (80%): very pale orange 10 YR 8/2 to pale yellowish brown 10YR 6/2, biomicrite, soft, moderate macroporosity (vuggy), friable, calcarenetic, chalky Clay (20%): pale yellowish brown 10YR 6/2; moderately cohesive; silty.
1,120-1,130	Limestone: very pale orange 10 YR 8/2, micrite, soft, low macroporosity (intergranular), friable, calcarenetic, chalky.
1,130-1,140	Limestone (80%): very pale orange 10 YR 8/2, micrite, soft, low macroporosity (intergranular), friable, calcarenetic, chalky. Clay (20%): very pale orange 10 YR 8/2 to pale yellowish brown 10YR 6/2; moderately cohesive; silty.
1,140-1,150	Limestone (60%): very pale orange 10 YR 8/2, micrite, soft, low macroporosity (intergranular), friable, calcarenetic, chalky. Clay (40%): very pale orange 10 YR 8/2 to pale yellowish brown 10YR 6/2; moderately cohesive; silty.

Depth (ft bls)	Description
1,150-1,180	Limestone: very pale orange 10 YR 8/2, biomicrite, soft, low macroporosity (intergranular to vuggy), friable, fossil fragments evident.
1,180-1,200	Limestone: very pale orange 10 YR 8/2, micrite, moderately hard to soft, very low macroporosity, fine grained, chalky, trace fossil fragments.