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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
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
NGVD	National Geodetic Vertical Datum
psi	Pounds per Square Inch
PtCo	Platinum-Cobalt
PVC	Polyvinyl Chloride
RIDS	Regional Irrigation Distribution System
SAS	Surficial Aquifer System
SFWMD	South Florida Water Management District
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 Hermosa Canal 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. 272886-003 UC/5X for a Class V ASR EXW for the Hermosa Canal 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 Hermosa Canal ASR EXW began on April 17, 2008 and was substantially complete on December 12, 2008. Completion was on December 17, 2008 with final geophysical logging and video survey.

- The ASR EXW was drilled and tested to 1,200 feet below land surface (bls). The well was back plugged to 950 feet bls with neat cement and completed with 6.625 OD PVC set to 880 feet bls.

- The base of the Underground Source of Drinking Water (USDW) was encountered at a depth of approximately 1,075 feet bls and is supported by similar TDS concentrations from packer testing and the log-derived TDS plot.

- Water quality samples were collected at 30-foot intervals in the pilot hole during reverse-air drilling to identify changes in the salinity of groundwater with depth. Water quality of the completed monitoring interval is brackish, and contains chloride and TDS concentrations of approximately 1,110 mg/L and 2,270 mg/L, respectively.

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

- Single packer tests were performed at four selected intervals (672 to 700, 827 to 870, 890 to 940, 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 analysis to determine vertical and horizontal hydraulic conductivity, vertical and horizontal porosity, and specific gravity. Five rock cores were evaluated from the Floridan Aquifer System from the following intervals: 673 to 693, 850 to 870, 900 to 920, 921 to 941 and 1,090 to 1,110 feet bls.

- A constant rate aquifer test was conducted at a rate of 240 gpm on the completed Hermosa Canal ASR EXW on December 15, 2008. The estimated transmissivity is 7,410 gpd/ft calculated using recovery.

- It was concluded that the interval from 880 to 950 feet bls in the Suwannee Limestone is favorable for ASR technology.

1.0 Introduction

This report describes 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. 13 property located proximal to the Hermosa Canal. 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 the casing setting depth for monitoring the potential storage zone
- Identification of hydrogeologic conditions favorable for potential underground storage
- Recommendations on the future well utility and suitability of the site for ASR.

The well was constructed under FDEP Construction Permit No. 272886-003 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 the 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 Hermosa 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 Hermosa Canal site is listed as a permitted ASR well facility (ASR-3) in the City's SFWMD Irrigation Water Use Permit (No. 36-00998-W). The permit, which was 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 Hermosa Canal 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. 272886-003 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, prepare a permit application and provide oversight for 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 February 4, 2008.

1.2 Location

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

A vicinity map of the Hermosa Canal 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 ASR EXW is located approximately 1,460 feet south of the Hermosa Canal and 1,800 feet southwest from the Hermosa Weir 14 in the northeast quarter of Section 7, Township 44 South, Range 23 East, Lee County. The physical address of the well site is 3315 NW 7th Terrace, Cape Coral, Lee County, Florida. The site was selected for the exploratory well because it was the closest available City owned parcel to the SFWMD permitted Hermosa Canal Weir 14 site.

Figure 1-1 Hermosa Canal ASR EXW Vicinity Map

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Figure 1-2 Hermosa Canal ASR EXW Site Map

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1.3 Scope of Services

Diversified Drilling Corporation of Lehigh Acres, FL, as the drilling sub-contractor, conducted the drilling, construction, and testing activities of the Hermosa Canal 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.

Weekly reports documenting the construction and testing of the well were submitted weekly in accordance with Chapter 62-528 F.A.C., to the FDEP, the Technical Advisory Committee (TAC). 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

The study area of northwestern Lee County is underlain by rocks of Cenozoic age to a depth of about 5,000 feet (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 Hermosa ASR Exploratory Well will be discussed from youngest to oldest in age.

2.1 Geology

Sediments encountered during the construction of the Hermosa ASR Exploratory Well range in age from Late Pleistocene to Oligocene. MWH Americas collected geologic formation samples (well cuttings) from the pilot hole during drilling operations and described them based on their dominant lithologic and textural characteristics, and, to a lesser extent, color using the Folk (1959) carbonate rock classification system. A detailed lithologic log 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 during drilling operations 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 with trace amounts of sand and small percentages of marl. This unit was observed at the Hermosa site to a depth of approximately 40 feet.

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. 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) (Scott, 1988 and Cunningham, et al, 2001). Locally, the base of the Peace River Formation contains the Lehigh Acres Sandstone Member. The two formations are separated by a major regional disconformity (Scott, 1988). At the Hermosa ASR site, the Hawthorn Group occurs from approximately 40 to 870 feet bls.

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

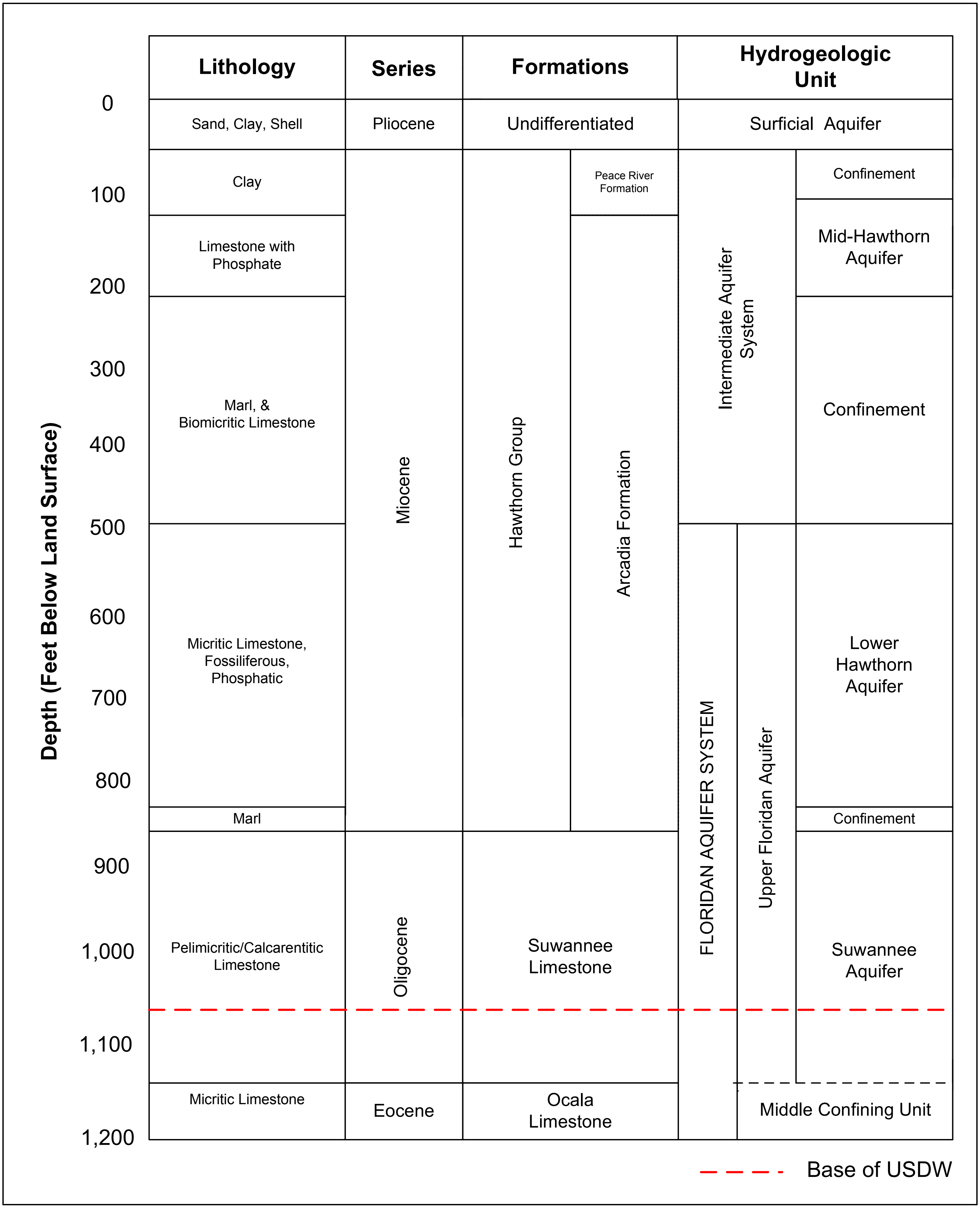

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Figure 2-1 Hermosa Canal Stratigraphic and Hydrostratigraphic Column

Peace River Formation

The Peace River Formation of the Hawthorn Group consists of sandstones, sands, sandy limestones, dolomitic clays or dolosilts, phosphate, and fossilized shell material (Scott, 1988 and Bennett and Rectenwald, 2004). The formation occurs from approximately 40 to 120 feet bls.

At the Hermosa Canal EXW site 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 former unit is predominately a greenish gray to dark greenish gray, soft to moderately soft, semi cohesive clay with trace amounts of silt. The Lehigh Acres Sandstone member does not occur at this site and only intermittently throughout the Peace River Formation within Cape Coral, Florida.

Arcadia Formation

The Arcadia formation, consists predominately of limestone and dolostone containing varying amounts of quartz sand, clay and phosphate grains (Scott, 1988). 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 wells. Several aquifers and confining units occur within the Hawthorn Group (Scott, 1988).

The Arcadia Formation occurs from approximately 120 to 870 feet bls at the Hermosa ASR Site. The formation is lithologically complex, containing beds of varying thickness. The limestones are light to yellowish gray micrites and biomicrites with moderate to good porosity. The formation is interbedded with light gray marl or lime mud and occasional light olive gray dolomitic silty clay. Phosphate granules are present throughout the Arcadia Formation. The base of the Arcadia Formation can be identified by yellowish gray marl, an immediate decrease in phosphate content in lithologic samples, and attenuation of gamma ray activity on geophysical logs. The lithologic log is available in Appendix B and geophysical logs are available in Appendix C.

2.1.3 Oligocene Series

The Oligocene aged Suwannee Limestone occurs from approximately 870 to 1,158 feet bls at the Hermosa site. 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 1,158 feet bls and continued to the total depth of the ASR EXW at 1,200 feet bls. The Ocala Limestone consists of grayish orange, 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.

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 Hermosa ASR 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 system occurs at contact with the Cape Coral Clay Member of the Hawthorn Group at a depth of 40 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 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).

A productive horizon, locally called the Mid-Hawthorn Aquifer, occurs from 120 to 240 feet bls. The Mid-Hawthorn aquifer occurs within limestones in the upper portion of the Arcadia Formation of the Hawthorn Group (Missimer, 1984, Knapp *et al.*, 1986 and 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 system occurs within the lower Arcadia Formation and Suwannee Limestones.

The top of 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 Eocene-aged carbonate sequence. At the study site, the UFA occurs from 440 to 1,158 feet bls and chiefly consists of permeable zones in the lower Hawthorn Group and Suwannee Limestone.

In this investigation, two predominant permeable zones in 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. DIL, BHCS, 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 640 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. This aquifer is currently the major source for public water supply to the residents in Cape Coral, Florida.

The second productive interval within the UFA was identified from 880 to 950 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 120 feet thick and consists of yellowish gray marls. This aquifer is composed of interbedded moderately biomicritic limestones and marls.

The Suwannee Aquifer becomes less permeable with depth due to interbedding and increased lime mud and fine-grained material from 950 to 1,158 feet bls. The base of the Suwannee Limestone is composed predominantly of moderately hard, low porosity limestones, interbedded with lime mud or marl.

The Ocala Limestone was identified from 1,158 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, indicated by a significant decrease in flow identified from the production logs.

2.2.4 Base of Underground Source of Drinking Water and Confinement Analysis

Groundwater containing less than 10,000 mg/L of total dissolved solids (TDS) is designated as a potential Underground Source of Drinking Water (USDW) by the Florida Department of Environmental Protection (FDEP). Log derived TDS and chloride concentration plots were calculated for this well to identify the elevation of the USDW. The plots use the method developed by Callahan, 1996, to calculate TDS from the dual induction resistivity and sonic porosity log values, and empirical relations of water quality (i.e. chloride concentration, TDS and conductivity) in the Floridan aquifer (Reese, 1994) as discussed in Section 4.

The USDW was identified near the base of the Suwannee Limestone at a depth of 1,075 feet bls with calculated TDS concentrations above 10,000 mg/L. Water quality with depth during reverse air drilling and Packer Test #4 supports the base of the USDW occurring above 1,140 feet based on the resulting TDS concentration of 18,900 mg/L obtained from the test. These analyses are discussed in Section 4.

A confinement analysis was conducted in order to evaluate the potential for underlying saline water to affect a potential ASR storage zone. The presence of confinement below the monitoring interval, 880 to 950 feet bls, was evaluated by review of lithology and geophysical logs, primarily the caliper, borehole compensated sonic, and flowmeter logs. An annotated caliper log showing semi-confining intervals based on lithology is provided in Figure 2-2. Three intervals of low permeability sediments are identified, along with lithologic descriptions of each interval. An annotated sonic log is provided in Figure 2-3, which identifies five intervals of lower permeability sediments, based on decreased travel time (Delta T). Correspondence to the FDEP detailing this confinement analysis is provided in Appendix E.

A qualitative description of confinement below the monitoring interval is provided in Table 2-1. The lower permeability confining intervals were identified based on lithologic characteristics and/or Delta Time (in usec/ft). The analysis indicates that approximately 60 feet of confinement is present below the monitoring interval.

Table 2-1 Semi-Confinement Intervals Summary

Depth Interval (ft)	Semi-Confinement Thickness (ft)	Information Source
950-958	8	Lithology
968-978	10	Sonic Log
970-980	10	Sonic Log
1,000-1,010	10	Lithology and Sonic Log
1,045-1,052	7	Sonic Log
1,060-1,075	15	Lithology and Sonic Log

The flow meter log, provided in Appendix C, indicates no flow entering the borehole between depths of 975 to 1,125 feet bls. This apparent non-productive zone corresponds well to the confinement zones in table 2-1.

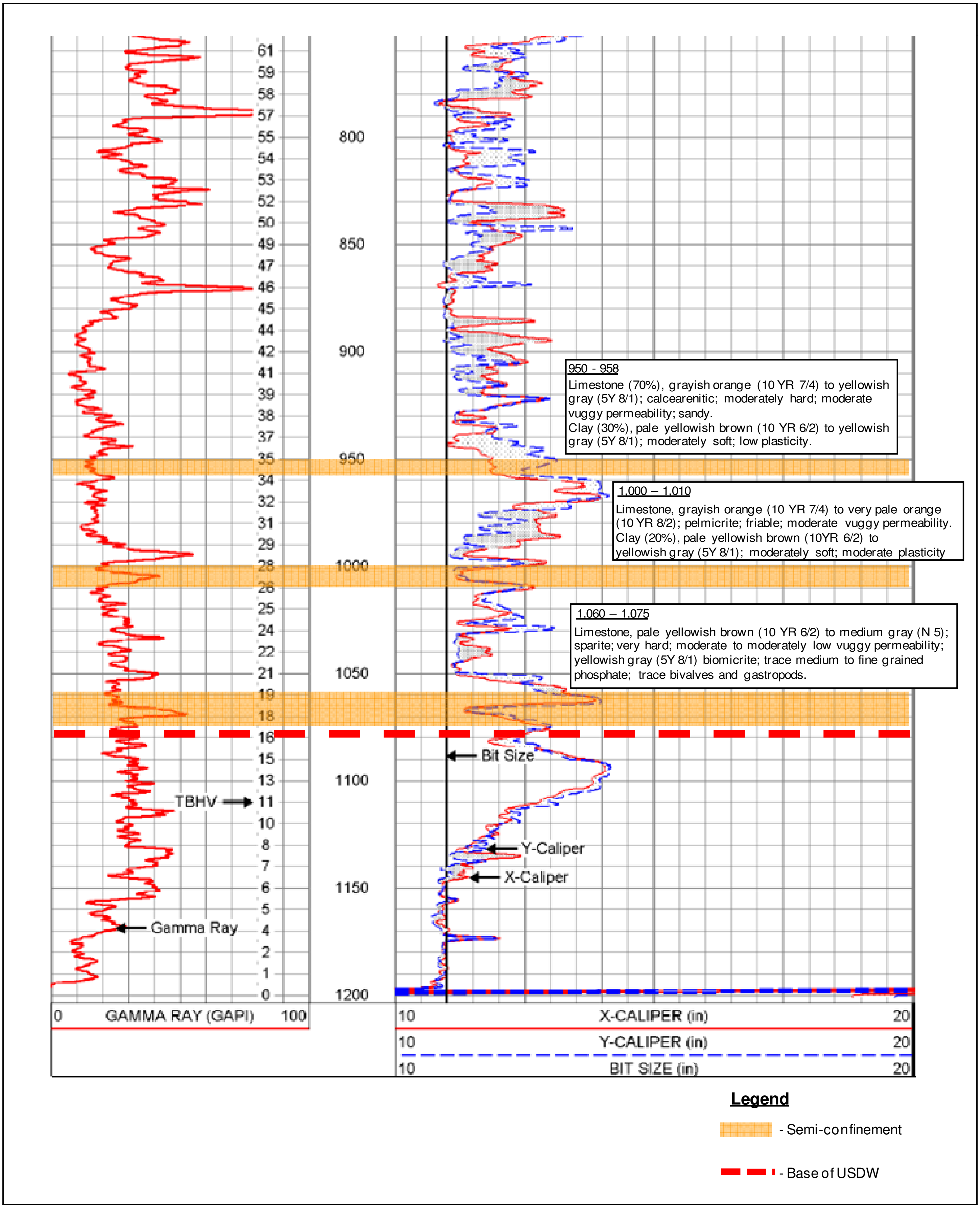

Figure 2-2 Hermosa Canal ASR EXW Caliper Log Showing Intervals of Semi-Confinement with Lithologic Descriptions

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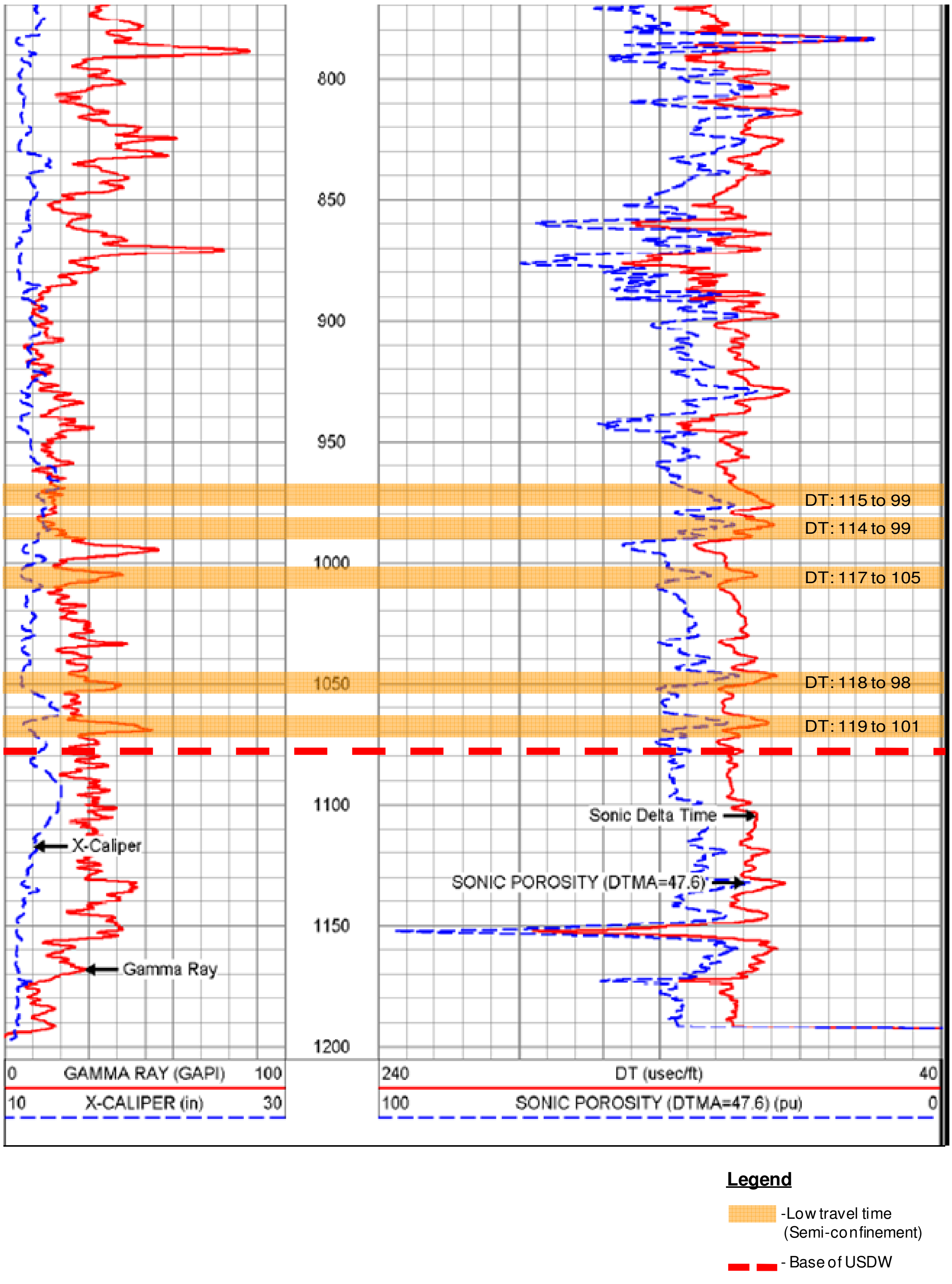

Figure 2-3 Hermosa Canal ASR EXW Sonic Log Showing Intervals of Semi-Confinement

3.0 Well Construction

3.1 Introduction

This section describes the construction activities of the Hermosa ASR Exploratory Well. The site location map is provided as Figure 1-2. Summary reports (Appendix E) of construction and testing activities was prepared and 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 5.8 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 were used to monitor the surficial aquifer water quality during construction and testing of the ASR system. WTMW-1 was located on the northwest portion of lot 49 near Tropicana Parkway and WTMW-2 was located southeast of the ASR EXW near NW 7th Terrace. 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 PVC riser from the top of the screen to land surface. The annulus of the WTMWs 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.

Following their construction the WTMWs were developed. Water samples were collected and tested to measure conductivity, chloride, pH, and temperature were conducted to obtain initial measurements of the parameters. The WTMWs were subsequently developed and sampled once or twice weekly for those water quality parameters and water level measurements were recorded. Figure 3-1 shows a schematic diagram of a typical WTMW.

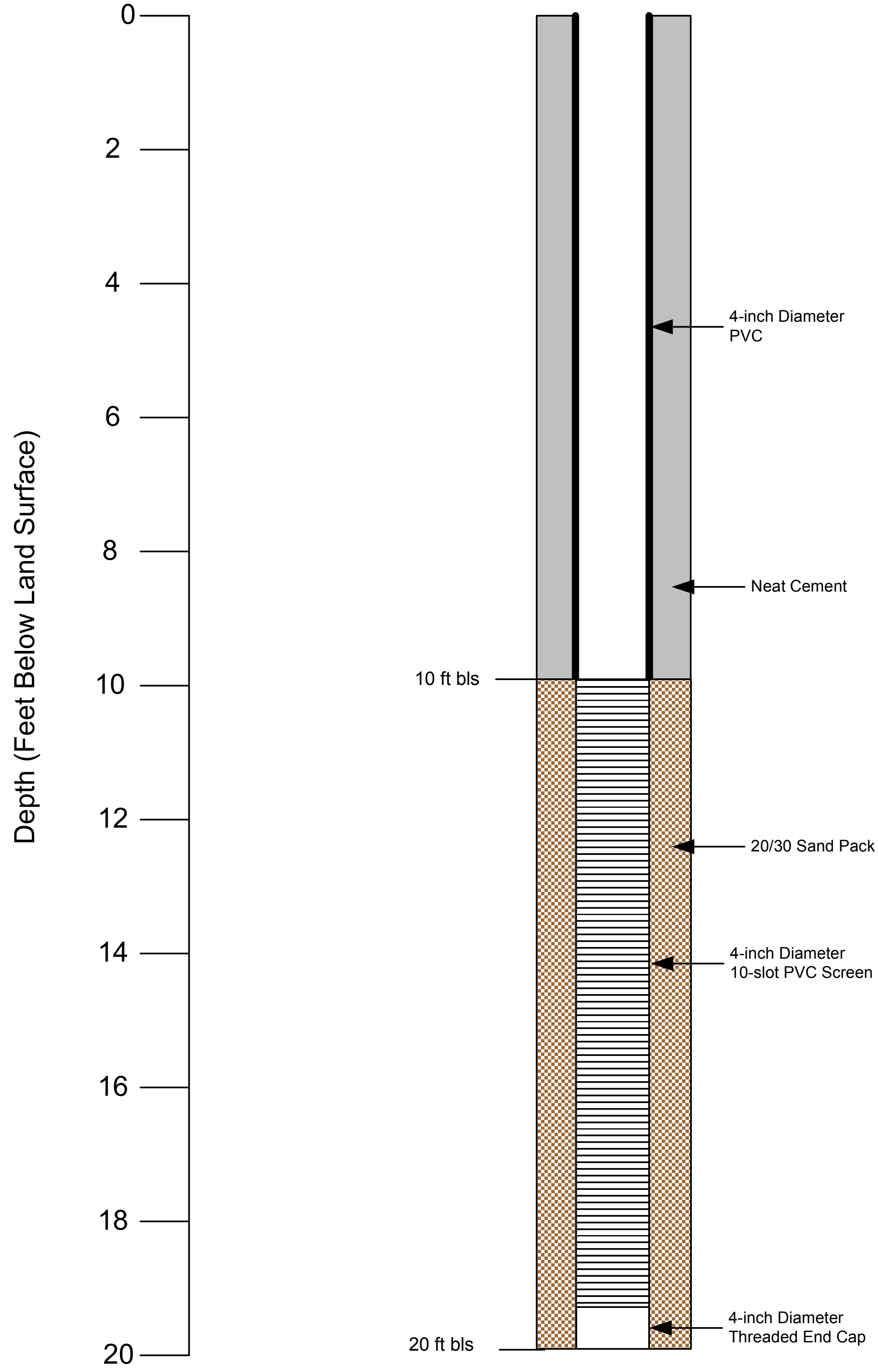

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Figure 3-1 Water Table Monitor Well Schematic

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 drilling fluids produced during construction of the ASR EXW. Following completion of the Hermosa Canal ASR EXW, 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 into the containment pad to remove fluids from the pad to an onsite storage system for removal to the approved off site disposal location.

3.4 Well Construction

The drilling and construction operations for the Hermosa Canal ASR EXW began April 17, 2008 and well construction activities were substantially complete on December 12, 2008. Well construction activities concluded on December 17, 2008 with final geophysical logging and video survey. Drilling operations were normally conducted 10 hours per day, 5 days per week. A schematic diagram of the completed well is available in Figure 3-2. A summary of well construction and testing activities at the ASR EXW is included in Table 3-1.

The surficial sediments and the upper portion of the Hawthorn Group were drilled using the mud rotary drilling method with bentonite based drilling mud to a depth of 530 feet bls. During mud rotary drilling operations, all drilling fluid was contained in a closed system. Intermediate casing was set at 501 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. The reverse air drilling method allowed for the collection of formation water samples while drilling. The well was backplugged with neat cement to 950 feet bls and 6.625-inch OD PVC final casing was installed to 880 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 Date	End Date	Description of Activities
	4/16/2008	Mobilized equipment and prepared site.
4/17/2008	4/17/2008	Drilled nominal 10 inch diameter pilot hole to 50 ft bls.
4/18/2008	4/18/2008	Drilled 25-inch diameter borehole to depth of 41 ft bls.
4/18/2008	4/18/2008	Set and cemented 18-inch outer diameter surface casing to depth of 41 ft bls.
4/25/2008	5/01/2008	Drilled nominal 11-inch diameter pilot hole to 530 ft bls using direct mud rotary drilling methods.
5/01/2008	5/01/2008	Conducted geophysical logging suite to 530 ft bls.
5/02/2008	5/08/2008	Reamed the pilot hole from LS to 503 ft bls using mud rotary drilling with a 17-inch diameter bit.
5/19/2008	5/20/2008	Conducted caliper/gamma ray logs to 503 ft bls.
5/20/2008	5/21/2008	Set and cemented the 12-inch outer diameter steel intermediate casing to 501 ft bls.
6/02/2008	7/22/2008	Drilled nominal 11-inch diameter pilot hole to 1,200 ft bls using reverse-air rotary drilling methods.
6/03/2008	6/03/2008	Generic Discharge Permit Sampling.
6/05/2008	6/06/2008	Cored Interval 673 to 693 ft bls – Core #1.
6/11/2008	6/11/2008	Conducted geophysical logging caliper/gamma ray logs to 700 ft bls.
6/16/2008	6/17/2008	Performed constant-rate single packer pump test from 672 to 700 ft bls – Packer Test #1
6/23/2008	6/23/2008	Cored Interval 850 to 870 ft bls – Core #2.
6/23/2008	6/25/2008	Conducted geophysical logging caliper/gamma ray logs to 870 ft bls.
6/27/2008	6/28/2008	Performed constant-rate straddle packer pump test from 827 to 870 ft bls – Packer Test #2
7/03/2008	7/03/2008	Generic Discharge Permit Sampling
7/05/2008	7/07/2008	Cored Interval 900 to 920 ft bls – Core #3A
7/09/2008	7/09/2008	Cored Interval 921 to 941 ft bls – Core #3B
7/10/2008	7/10/2008	Conducted geophysical logging caliper/gamma ray logs to 941 ft bls.
7/14/2008	7/15/2008	Performed constant-rate straddle packer pump test from 890 to 941 ft bls – Packer Test #3
7/18/2008	7/18/2008	Cored Interval 1090 to 1110 ft bls – Core #4
7/23/2008	7/23/2008	Conducted geophysical logging suite to 1200 ft bls.
7/26/2008	7/27/2008	Performed constant-rate straddle packer pump test from 1140 to 1200 ft bls – Packer Test #4
8/12/2008	8/12/2008	Backplugged pilot hole with grout to 1020 ft bls.
8/13/2008	8/13/2008	Backplugged pilot hole with grout to 931 ft bls.
8/14/2008	8/16/2008	Drill out additional backblug from 931 to 950 feet bls with nominal 11-inch diameter bit
8/20/2008	8/23/2008	Backfilled pilot hole with silica sand to 885 ft bls.
8/24/2008	8/26/2008	Set and cemented the 6.625-inch diameter final PVC casing string to a depth of 880 ft bls.
8/26/2008	8/26/2008	685 feet of tremie pipe lost in the annulus during stage 3 cementing operations.
8/27/2008	8/27/2008	Performed Video Survey of PVC casing.
9/08/2008	11/06/2008	Pipe retrieval and milling PVC casing.
9/16/2008	9/16/2008	Performed Video Survey of PVC casing cut off at 671 ft bls and tremie pipe.
10/11/2008	10/17/2008	Performed Video Surveys of PVC milling and tremie pipe.
10/23/2008	10/27/2008	Back plug with neat cement to 656 ft bls.
10/28/2008	11/06/2008	Milled out cement backplug and casing from 656 to 883 ft bls.
11/10/2008	11/10/2008	Conducted caliper/gamma ray logs to 883 ft bls.
11/11/2008	11/24/2008	Set and cemented the 6.625-inch diameter final PVC casing string to a depth of 880 ft bls.
12/04/2008	12/05/2008	Drilled out cement plug and gravel backfill to 950 ft bls using reverse-air rotary drilling methods.
12/05/2008	12/08/2008	Air developed well for 13 hours.
12/10/2008	12/11/2008	Pump developed well at 240 gpm for 20 hours.
12/15/2008	12/15/2008	Primary and Secondary Water Quality Sampling.
12/15/2008	12/16/2008	Performed step rate drawdown pump test.

Start Date	End Date	Description of Activities
12/17/2008	12/17/2008	Conducted final geophysical logging suite (caliper/gamma ray and video logs) to 950 ft bls.
12/19/2008	12/19/2008	Installed a permanent wellhead assembly.
12/22/2008	12/23/2008	Disinfected well with chlorine at 150 to 200 ppm

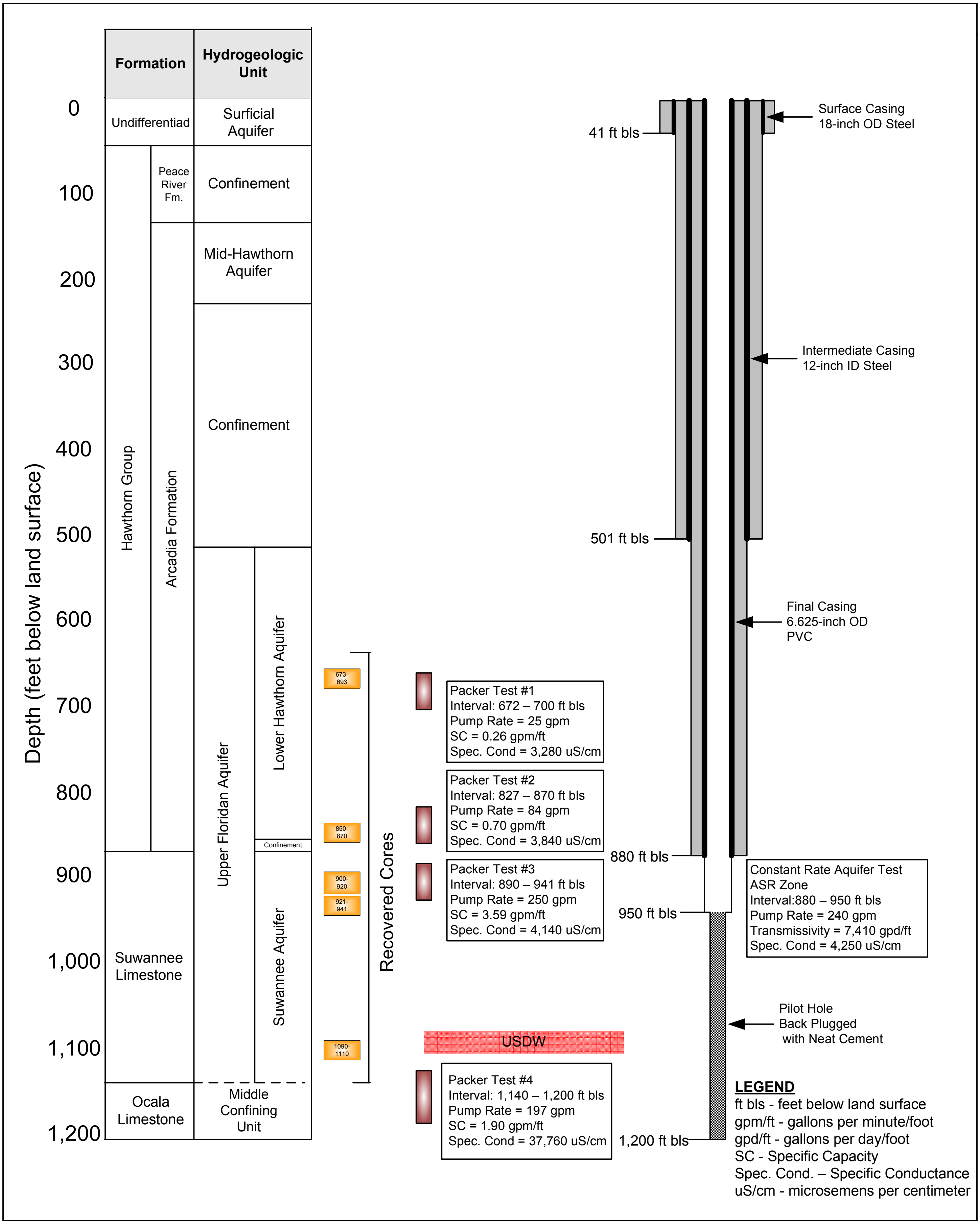


Figure 3-2 Hermosa Canal ASR EXW Schematic and Hydrogeologic Summary

3.4.1 Surface Casing

A 25-inch diameter borehole was initially drilled to a depth of 41 feet bls and 41 feet of 18-inch diameter steel casing was installed and grouted in place. The purpose of the surface casing was to prevent surficial material from falling 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 protect the surficial aquifer from drilling materials and fluids used in the construction of the well.

3.4.2 Pilot Hole Drilling Operations

A nominal 11-inch diameter pilot hole was drilled 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 survey. Lithologic sampling and geophysical logging are described in Section 4, Data Collection and Analysis. Geophysical logs and video survey descriptions and DVD's are available in Appendices C and D.

The pilot hole was drilled to a depth of 530 feet. 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. The pilot hole was subsequently reamed with a 17-inch diameter two-stage bit to the depth of 503 feet bls and 12-inch diameter intermediate steel casing was installed to 501 feet bls as approved by the FDEP on May 12, 2008. A Mill certificate for the steel casing are provided in Appendix I. Prior to placement of the intermediate casing, geophysical logging was performed 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 12-inch Steel Intermediate Casing Grout Summary

Date	Stage	Cement Type	Density (lbs/gal)	Total Barrels	Total cuft	Theoretical Tag (ft bls)	Actual Tag (ft bls)
5/20/2008	1A	4% gel	14.1	50	280	-	-
5/20/2008	1B	Neat	15.6	21	118	50	46
5/21/2008	2	4% gel	14.1	36	202	0	0

3.4.3 Open Hole Drilling Operations

Following intermediate casing installation pilot hole drilling resumed using reverse air drilling techniques using a nominal 11-inch diameter bit. 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 generated during reverse air drilling was filtered through a settling tank before being discharged into the Caravan Canal. A silt curtain was installed in the canal to provide containment.

On June 3, 2008, Sanders Laboratory of Nokomis, Florida collected groundwater samples from the drilling fluid discharge to fulfill the requirements of the Generic Discharge Permit as required by the FDEP when discharging groundwater into surface water bodies. At the time of sampling, the open hole depth was 520 feet bls or 19 feet below the intermediate casing depth. The water produced from the ASR EXW, was sampled and analyzed by Sanders Laboratory at initial discharge into Hermosa Canal, 30 days after initial sampling, and 6 months after the initial sampling. The results from the Generic Discharge Permit sampling are presented in Appendix J.

During pilot hole drilling operations, five conventional rock cores measuring 4-inches in diameter were obtained at various depth. Samples of the rock 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. Packer tests were performed within the open hole over four intervals. Analyses of the packer tests are provided in Section 4.

3.4.4 Back Plug

Upon approval of the proposed storage zone for the well of 880 to 950 ft bls by the FDEP, the borehole was back plugged in two stages from 1200 to 931 feet bls, with a total of 45 barrels of neat cement as shown in Table 3-4. The borehole was air drilled with a 11-inch diameter bit through the 19 feet cement plug overage, 931 to 950 feet bls. The open hole was then backfilled with 64 cubic feet of silica sand followed by 9 cubic feet of pea gravel from 950 to 885 feet bls. Eight gallons of neat cement was placed on top of the gravel to act as a cap and protect the integrity of the storage zone while setting the final casing.

Table 3-3 Back Plug Summary

Date	Stage	Cement Type	Density (lbs/gal)	Total Volume (barrels)	Total Volume (cuft)	Theoretical Tag (ft bls)	Actual Tag (ft bls)
8/12/2008	1	Neat	14.9	35	196	950	1,020
8/13/2008	2	Neat	14.5	10	56	950	931

3.4.5 Final Casing

On August 11, 2008, the FDEP approved installation of the final casing string to 880 feet bls. The Final Casing was installed on August 24, 2008, consisting of 6.625-inch OD PVC, was set at 880 feet bls. The pumping of two stages of grouting consisting of 8 barrels of neat and 9 barrels of 8% gel was completed by August 26, 2008. During Stage 3 cementing operations on the afternoon of August 26, 2008, 685 feet of 1.5-inch diameter hydril cementing pipe was accidentally dropped down into the annular space between the casing and borehole wall. From August 27 to September 7, 2008, the drilling contractor made unsuccessful attempts to “fish” the hydril from the annular space. Fishing operations were unsuccessful because the hydril pipe became embedded in the annular cement.

On September 8, 2008, the 6.625-inch OD PVC casing from land surface to 671 feet bls was removed by cutting the pipe using a sand jetting method. Milling operations removed the casing from 671 to 800 feet bls and 500 feet of hydril was retrieved from of the borehole. After several unsuccessful attempts, milling operations were discontinued at 800 feet bls due to the bit binding up on the PVC and hydril pipe. As approved by the FDEP on October 22, 2008 (Appendix A), the 80 feet of PVC, 185 feet of hydril, and borehole was backplugged to 661 feet bls with 13 barrels of neat cement. The borehole was then drilled out with an 11 7/8-inch diameter bit employing mud rotary method from 661 to 883 feet bls.

On November 11, 2008, the final casing, consisting of 6.625-inch OD PVC, was reinstalled to 880 feet bls as approved by the FDEP. The casing was grouted in place in ten stages as summarized in Table 3-4. Following casing installation, the open hole portion of the well was drilled to 950 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)
11/12/2008	1	Neat	14.6	2	11	860	867
11/13/2008	2	Neat	14.9	7	39	750	805
11/14/2008	3	Neat/12% gel	15.0/12.7	7	39	730	741
11/15/2008	4	12% gel	12.9	10	56	670	678
11/17/2008	5	12% gel	13.0	11	62	620	637
11/18/2008	6	12% gel	12.7	13	73	580	586
11/19/2008	7	12% gel	12.7	13	73	540	540
11/20/2008	8	12% gel	13.0	13	73	450	448
11/21/2008	9	12% gel	12.7	20	112	250	234
11/22/2008	10	12%	12.2	22	123	Land Surface	7

3.4.6 Well Development

After drilling operations were complete, the well was developed using reverse air, and a submersible pump. Water 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 Hermosa ASR EXW included inclination surveys, lithologic samples, geophysical logging, water quality sampling, and specific capacity testing. 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 of the ASR EXW was 0.33 degrees for the pilot hole and 0.24 degrees for the reamed hole. Results of the inclination surveys conducted during drilling operations are provided in Appendix H.

4.2 Lithologic Sampling and Coring

Formation samples were collected during drilling operations every 10 feet from land 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. Descriptions of the lithology encountered during pilot hole drilling of the ASR EXW are presented in Appendix B.

During drilling of the ASR EXW, conventional cores were collected using a 4-inch diameter, 20-foot long, diamond-tipped core barrel with a diamond bit. Five rock cores were retrieved from the Hawthorn Group and Suwannee Limestone between 673 and 1,110 feet bls with core recoveries ranging from 19 to 100 percent. A summary of the coring program conducted at this site is presented in Table 4-1.

Table 4-1 Coring Program Summary

Core No.	Core Interval (ft bls)	Core Footage (ft)	Core Recovered (ft)	Percent Recovery (%)
1	673-693	20	3.8	19
2	850-870	20	20.0	100
3A	900-920	20	4.5	22
3B	921-941	20	8.5	42
4	1090-1110	20	13.4	67

Five sections of the cores obtained during drilling were sent to Ardaman and Associates, Inc., located in Orlando, Florida to be tested for the following parameters: vertical and horizontal hydraulic conductivity, vertical and horizontal porosity and specific gravity. Hydraulic conductivity and porosity were measured in general accordance with 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	674	1.2×10^{-6}	1.8×10^{-6}	33.5	33.1	2.78
2	864	1.5×10^{-5}	-	38.5	-	2.74
3A	901	2.7×10^{-3}	4.6×10^{-3}	39.3	38.0	2.70
3B	925	5.5×10^{-5}	4.4×10^{-5}	37.1	36.1	2.70
4	1093	1.2×10^{-5}	4.5×10^{-5}	38.8	38.4	2.75

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 formation fluids. Analyses of the logs were used to assist in the interpretation of lithology, 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 correlated with the 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 results, and lithologic descriptions, were used to determine aquifer properties, casing depths, packer-test intervals and the 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
5-01-2008	0-530	X	X	X	X				X	12.25-inch pilot hole
5-20-2008	0-503	X	X							17-inch reamed hole
6-11-2008	501-700	X	X							Select depth for Packer Test 1
6-25-2008	501-870	X	X							Select depth for Packer Test 2
7-10-2008	501-941	X	X							Select depth for Packer Test 3
7-23-2008	501-1,200	X	X	X	X	X	X	X	X	Select depth for Packer Test 4
11-10-2008	0-883	X	X							12-inch reamed hole
12-17-2008	0-950	X	X							Final logging of completed well

4.4 Video Surveys

Video surveys were conducted within the borehole and casing inspections. The video surveys provide a continuous record of the visual characteristics of the subsurface formations. 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. The video surveys were run in the pilot hole to view well repair conditions, and in the final open borehole of the Hermosa Canal ASR EXW. A list of video surveys conducted on the well is summarized in Table 4-4.

Table 4-4 Video Survey Summary

Date	Interval (ft bls)	Comments
7-23-2008	501-1,200	Pilot Hole Logging
8-27-2008	0-880	Inspect casing for damage
9-04-2008	0-128	Locate hydril pipe
9-16-2008	0-671	View depth where casing was cut off for hydril pipe removal
10-11-2008	0-640	Locate hydril pipe at 344 ft
10-14-2008	0-716	Locate hydril pipe at 375 ft
10-17-2008	0-778	Locate hydril pipe at 670 ft
12-17-2008	0-950	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 30-foot intervals in the pilot hole during reverse-air drilling. Sampling started at a depth of 530 feet bls and continued to the total depth of the well at 1,200 feet bls. Samples were collected from the discharge point of the fluid circulation system. The samples were analyzed on-site for dissolved oxygen, temperature, pH, conductivity, and chloride. These data indicated an increased 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. Both specific conductivity and chloride measurements generally increase with depth and increased abruptly at 1,150 feet bls.

Table 4-5 Reverse Air Drilling Water Quality with Depth

Date	**Depth** (ft bls)	**Specific Conductivity** (µS/cm)	**pH**	**Temperature** (°C)	**Chloride** (mg/L)
6/2/2008	530	2,290	11.08	24.5	338
6/3/2008	561	2,260	8.94	27.6	513
6/3/2008	592	2,010	8.66	28.2	425
6/3/2008	621	3,160	8.22	26.7	750
6/4/2008	654	3,190	7.91	25.5	725
6/10/2008	683	3,260	8.10	27.8	750
6/17/2008	715	3,140	8.48	28.4	725
6/18/2008	715	3,210	8.85	29.5	770
6/18/2008	746	3,350	8.02	30.4	835
6/18/2008	775	3,310	8.11	28.0	875
6/18/2008	806	3,450	8.20	28.2	975
6/19/2008	837	3,660	8.06	27.5	1,175
6/30/2008	870	3,680	7.89	26.3	1,013
7/1/2008	900	2,728	7.45	25.82	1,150
7/10/2008	930	2,950	7.40	27.0	1,032
7/16/2008	961	4,333	7.88	28.98	1,030
7/16/2008	992	4,509	7.80	28.91	1,118
7/16/2008	1,022	4,610	7.63	25.36	1,127
7/17/2008	1,054	4,770	7.68	26.43	1,237
7/17/2008	1,087	6,210	7.70	28.04	1,567
7/21/2008	1,118	5,170	7.96	27.07	1,550
7/22/2008	1,150	32,970	7.88	26.70	9,750
7/22/2008	1,190	34,070	7.38	28.04	10,050

4.5.2 Well Development

After drilling operations were complete, the well was developed with reverse air at a depth of 950 feet bls on December 5 and 8, 2008 for approximately thirteen hours. Water quality samples were collected during development for field parameters approximately every hour. Water quality results during well development are provided in Table 4-6.

Table 4-6 Air Development Water Quality

Date	Time	Specific Conductivity (µS/cm)	pH	Temperature (°C)	Chloride (mg/L)
12-5-2008	1030	8,378	7.20	25.4	2,200
12-5-2008	1130	7,574	7.72	25.7	2,038
12-5-2008	1400	7,720	8.03	26.9	1,925
12-5-2008	1430	7,521	7.88	25.9	1,888
12-5-2008	1500	7,302	7.99	25.6	1,838
12-5-2008	1530	7,064	7.99	25.5	1,775
12-5-2008	1600	6,910	7.97	25.6	1,738
12-5-2008	1630	6,787	8.04	24.8	1,688
12-8-2008	1030	6,417	7.81	24.5	1,663
12-8-2008	1100	6,389	7.52	24.9	1,700
12-8-2008	1200	6,188	7.66	25.0	1,638
12-8-2008	1300	5,779	7.55	25.8	1,562
12-8-2008	1400	5,764	7.74	25.8	1,438
12-8-2008	1500	5,589	7.64	24.8	1,462
12-8-2008	1600	5,491	7.78	25.3	1,388
12-8-2008	1700	5,406	8.01	25.4	1,388

The well was pump developed with a submersible pump for approximately 13.5 hours on December 10 and 11, 2008 at a rate of 240 gpm. Water samples were obtained approximately every hour and tested for specific conductivity, dissolved oxygen, pH, temperature, and chloride. Pump development water quality measurements are shown in Table 4-7.

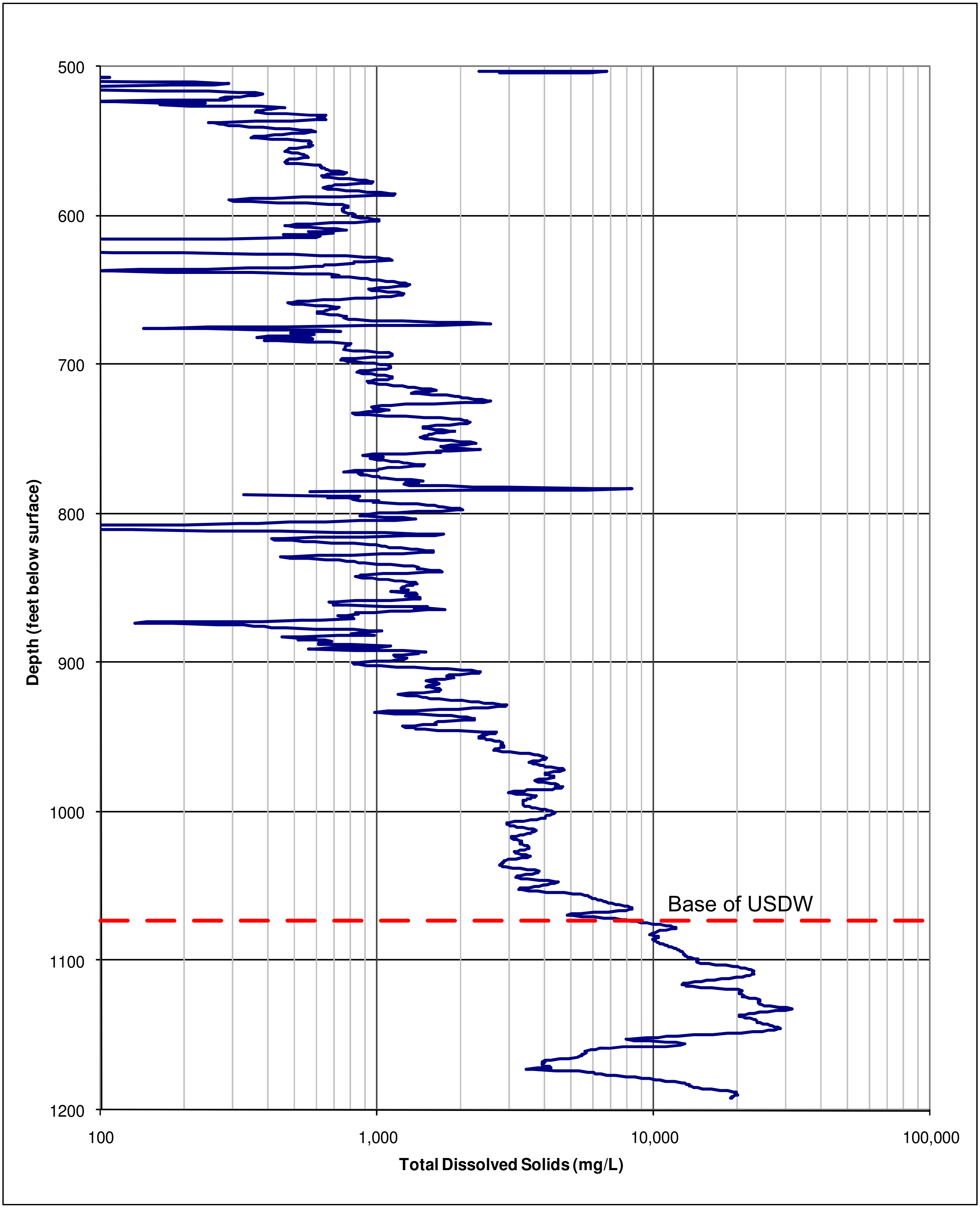
Table 4-7 Pump Development Water Quality

Date	Time	Specific Conductivity (µS/cm)	pH	Temperature (°C)	Chloride (mg/L)	D.O. (%)
12/10/2008	0900	4,914	7.55	24.49	1650	19.7
12/10/2008	1000	4,790	NR	NR	1530	NR
12/10/2008	1100	4,728	7.40	26.73	1550	7.8
12/10/2008	1200	4,673	7.41	26.72	1560	19.4
12/10/2008	1300	4,716	7.43	29.57	1420	39.5
12/10/2008	1400	4,507	7.52	29.14	1420	32.2
12/10/2008	1500	4,531	7.48	29.42	1420	29.4
12/10/2008	1600	4,399	7.48	27.63	1400	45.7
12/10/2008	1700	4,340	7.30	22.92	1390	22.5
12/11/2008	1000	4,340	7.39	25.88	1400	31.9
12/11/2008	1100	4,393	7.34	23.93	1300	20.6
12/11/2008	1200	4,350	NR	NR	1330	NR
12/11/2008	1300	4,297	7.41	24.07	1290	22.1
12/11/2008	1400	4,330	7.34	27.22	1280	20.6
12/11/2008	1500	4,313	7.38	29.24	1310	20.8
12/11/2008	1600	4,288	7.36	28.83	1300	20.0
12/11/2008	1700	4,264	7.36	29.13	1220	20.0

4.5.3 Total Dissolved Solids Analysis with Depth

The Sonic porosity 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) to solve the Archie Equation (Archie, 1942).

The calculated TDS plot shows generally increasing total dissolved solids with depth in the ASR EXW (Figure 4-1) with a maximum calculated TDS of 31,512 mg/L. The base of the USDW was identified at a depth of approximately 1,075 feet bls based on the log-derived TDS plot and supported by TDS results obtained from Packer Test #4, conducted in the interval from 1,140 to 1,200 feet bls. The decrease in calculated TDS concentrations at approximately 1,150 feet bls are unreliable values calculated from anomalously high sonic porosities at that depth.



MWH BUILDING A BETTER WORLD

Figure 4-1 Log Derived Total Dissolved Solids Plot for Hermosa Canal 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 confirm 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 Sanders Laboratories, Inc. during each packer test and results are presented in Table 4-8. The full laboratory report of the water quality analyses are available in Appendix L.

Table 4-8 Packer Test Water Quality

	Parameter	**Packer Test 1** 672–700 ft bls	**Packer Test 2** 827–870 ft bls	**Packer Test 3** 890–941 ft bls	**Packer Test 4** 1140–1200 ft bls
Primary Inorganics	Arsenic (mg/L)	BDL	BDL	BDL	BDL
	Barium (mg/L)	0.026	0.025	0.041	0.066
	Fluoride (mg/L)	1.7	1.6	1.2	1.7
	Nitrate (mg/L)	0.02*	BDL*	0.01	BDL
	Sodium (mg/L)	437	476	547	6420
Secondary Inorganics	Aluminum (mg/L)	BDL	BDL	BDL	BDL
	Chloride (mg/L)	786	1030	966	11,800
	Iron (mg/L)	0.472	0.044	BDL	0.090
	Manganese (mg/L)	0.040	0.004	0.002	0.008
	Sulfate (mg/L)	208	291	261	1410
	Color (PtCo Color Units)	10*	5*	5	10
	Total Dissolved Solids (mg/L)	1,790	1,500	2,140	18,900
Additional Parameters	Ammonium (mg/L)	0.34	0.05	0.21	0.33
	Bicarbonate Alkalinity (mg/L)	141	132	128	128
	Calcium (mg/L)	84.8	108	122	439
	Carbon Dioxide (mg/L)	125	116	112	113
	Carbonate Alkalinity (mg/L)	0.62	0.43	0.35	0.25
	Dissolved Oxygen (mg/L)	NR	NR	NR	NR
	Hydrogen Sulfide (mg/L)	0.35	BDL	0.072	0.026
	Magnesium (mg/L)	97.4	103	108	675
	Potassium (mg/L)	25.6	19.9	27.8	265
	Silica (mg/L)	11.4	11.7	6.8	15.0

*Analyzed past holding time

Water samples from the ASR EXW were collected from the completed open hole, 880 to 950 feet bls, during the step drawdown test and during the constant rate pump test conducted on December 15, 2008. During the pumping 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)
60	4,146	13.0	7.29	28.3	1,180
125	4,132	12.6	7.27	28.5	1,170
185	4,410	12.5	7.29	27.1	1,180
240	4,330	12.4	7.25	27.7	1,200

4.5.5 Background Water Quality

After construction activities were finished for the Hermosa Canal ASR EXW, the completed well was developed until at least three well volumes of water had been evacuated from the well and the chloride concentration, temperature, pH and specific conductivity measurements stabilized. Water samples were collected by Sanders Laboratories, Inc. on April 3, 2008. The samples were analyzed for primary and secondary drinking water standards and minimum criteria parameters using EPA and/or Standard Method procedures. Results of primary and secondary water quality parameters are listed in Table 4-10. Complete laboratory results are available in Appendix M.

Table 4-10 Completed Well Background Water Quality Results

Parameter		ASR EXW (880 – 950 ft bls)
Primary Inorganics	Aluminum (mg/L)	BDL
	Antimony (mg/L)	0.006
	Arsenic (mg/L)	BDL
	Barium (mg/L)	0.038
	Berylium (mg/L)	BDL
	Cadmium (mg/L)	BDL
	Chromium (mg/L)	BDL
	Fluoride (mg/L)	1.2
	Mercury (mg/L)	BDL
	Nickel (mg/L)	BDL
	Nitrate (mg/L)	BDL
	Nitrite (mg/L)	BDL
	Selenium (mg/L)	BDL
	Sodium (mg/L)	0.40
	Thallium (mg/L)	0.002
Secondary Inorganics	Color (PtCo Color Units)	BDL
	Copper (mg/L)	BDL
	Chloride (mg/L)	1,110
	Iron (mg/L)	BDL
	Manganese (mg/L)	BDL
	Silver (mg/L)	BDL
	Specific Conductance (umhos/cm)	4,250
	Sulfate (mg/L)	291
	Total Dissolved Solids (mg/L)	2,270
	Zinc (mg/L)	0.009
Bacteriological	Total Coliform (CFU/100ml)	BDL
Radionuclides	Gross Alpha (pCi/l)	43
	Radium-226 (pCi/l)	8.0
	Radium-228 (pCi/l)	BDL
Additional Parameters	Dissolved Oxygen (mg/L)	2.78
	Turbidity (NTU)	2.2
	Sand (ppm)	BDL
	SDI	BDL

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)
530	19.7	0.0	19.7	13	0.7
561	14.5	0.0	14.5	9	0.6
592	14.5	2.0	12.5	12.5	1.0
621	26.1	2.0	24.1	164	6.8
654	24.3	2.0	22.3	692	31.0
683	25.1	2.0	23.3	450	19.3
715	27.3	2.0	25.3	510	20.2
746	27.3	2.0	25.3	470	18.6
775	26.8	2.0	24.8	556	22.4
806	27.2	2.0	25.2	600	24
837	27.2	2.0	25.2	794	31.5
870	25.7	2.0	23.7	720	30.4
900	26.7	2.0	24.7	843	34.2
930	27.6	2.0	25.6	900	35.2
961	26.9	2.0	24.9	900	36.1
992	27.1	2.0	25.1	900	34.5
1,020	26.9	2.0	24.9	900	36.1
1,050	28.3	2.0	26.3	1000	38.0
1,087	28.0	2.0	26.0	938	36.0

4.6.2 Packer Testing

Packer testing was conducted within the nominal 11-inch pilot hole over discreet intervals in the 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 Hermosa Canal ASR EXW Well. All packer 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 in the annulus 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 120 feet bls to monitor water pressure/levels in the isolated tested interval. In-Situ Mini-Troll pressure transducers were used to record and store water pressure/level measurements and were used in conjunction 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. The solutions are provided in Appendix N.

2) A submersible pump was set into the drill pipe to a depth of approximately 130 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 were monitored and recorded and water samples were collected and analyzed. Each packer test pumping phase was conducted for 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 188, 376, 2,289, and 814 gpd/ft, respectively.

Table 4-12 Packer Testing Summary

Packer Number	**Interval** (ft bls)	**Pump Rate** (gpm)	**Drawdown** (ft)	**Specific Capacity** (gpm/ft)
1	672-700	25	96.2	0.3
2	827-870	84	120.0	0.7
3	890-941	250	69.6	3.6
4	1,140-1,200	197	103.7	1.9

4.6.3 Step Drawdown Testing

A step drawdown test was conducted on December 15, 2008. The well was pumped at increasing rates of 60, 125, 185 and 240 gpm for one hour at each rate using a submersible pump. During the test, water samples were collected and tested for specific conductivity, dissolved oxygen, pH, temperature, and chloride. The step drawdown test yielded an average specific capacity of 4.4 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 set to 90 feet bls to record water level measurements electronically. Results for the Step Drawdown Test are presented in Table 4-13.

Table 4-13 Step Drawdown Test

Step	**Pump Rate** (gpm)	**Drawdown** (ft)	**Specific Capacity** (gpm/ft)
1	60	10.5	4.9
2	125	27.8	4.5
3	185	41.6	4.4
4	240	65.6	3.7

4.6.4 Constant Rate Aquifer Testing

A constant rate aquifer test was conducted on December 15, 2008 following the step drawdown test (Step #4) at a rate of 240 gpm for three hours to determine the hydraulic performance of the well in the completed open interval, 880-950 feet bls. 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 electronically collected in feet and psi using an In-Situ pressure transducer set at 90 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 pumping 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.

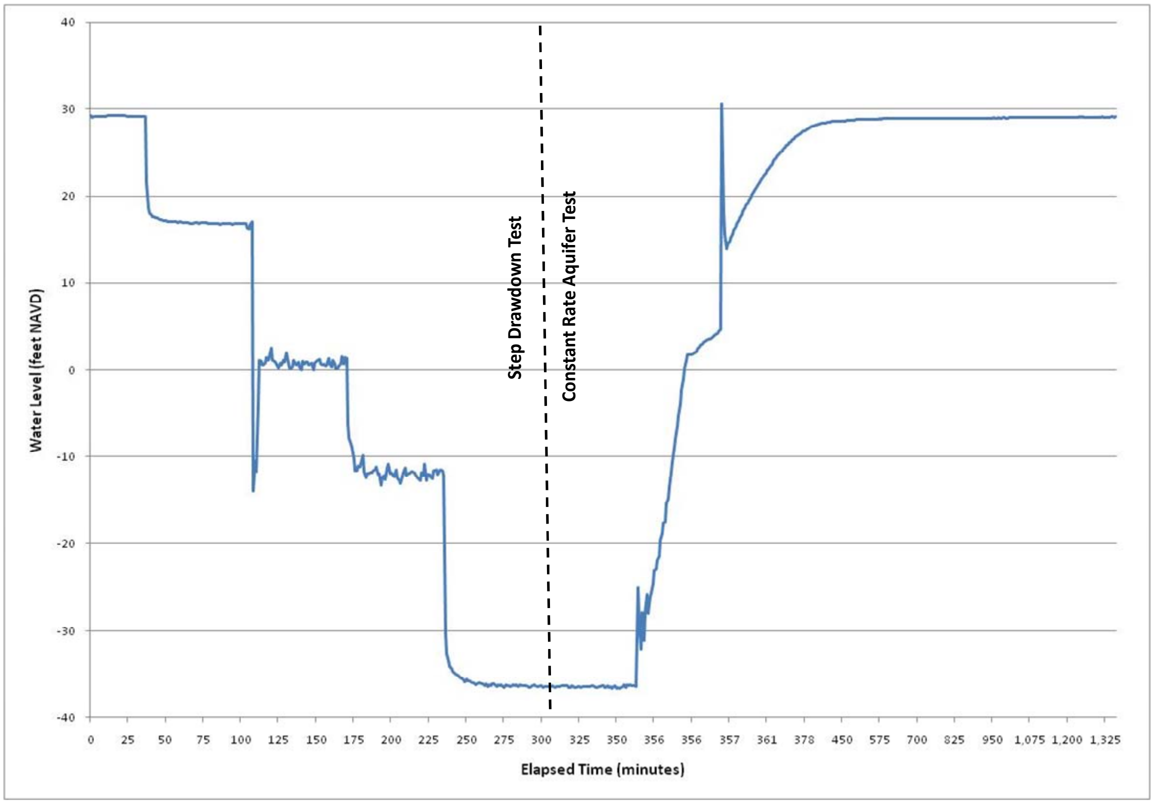


Figure 4-2 Step Drawdown and Constant Rate Aquifer Test

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 and consisted of pumping the well at a constant rate of 240 gpm for three hours while recording water level changes in the well. The average specific capacity during the test was 3.7 gpm/ft. The drawdown phase was followed by an 18-hour recovery period after pumping stopped.

Recovery data from the ASR EXW was used to calculate transmissivity of the aquifer using three solution methods. These three methods were the Cooper-Jacob (1946) method for confined aquifers, the Hantush-Jacob (1955) method for leaky confined aquifers, and the Moench (1985) method for leaky confined aquifers. A summary of the transmissivity results are presented in Table 4-14.

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

Parameter	**Cooper-Jacob** (1946)	**Hantush-Jacob** (1955)	**Moench** (1985)
Transmissivity (gpd/ft)	7,121	7,319	7,410
Storativity	3.24×10^{-5}	1.0×10^{-8}	2.69×10^{-4}

The transmissivity measured with the Moench analysis is comparable to the estimated transmissivity, 7,400 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 7,410 gpd/ft, a storage coefficient of 2.69×10^{-4}. The log/log plots of recovery versus time for the Cooper-Jacob and the Hantush-Jacob solutions are provided in Appendix O.

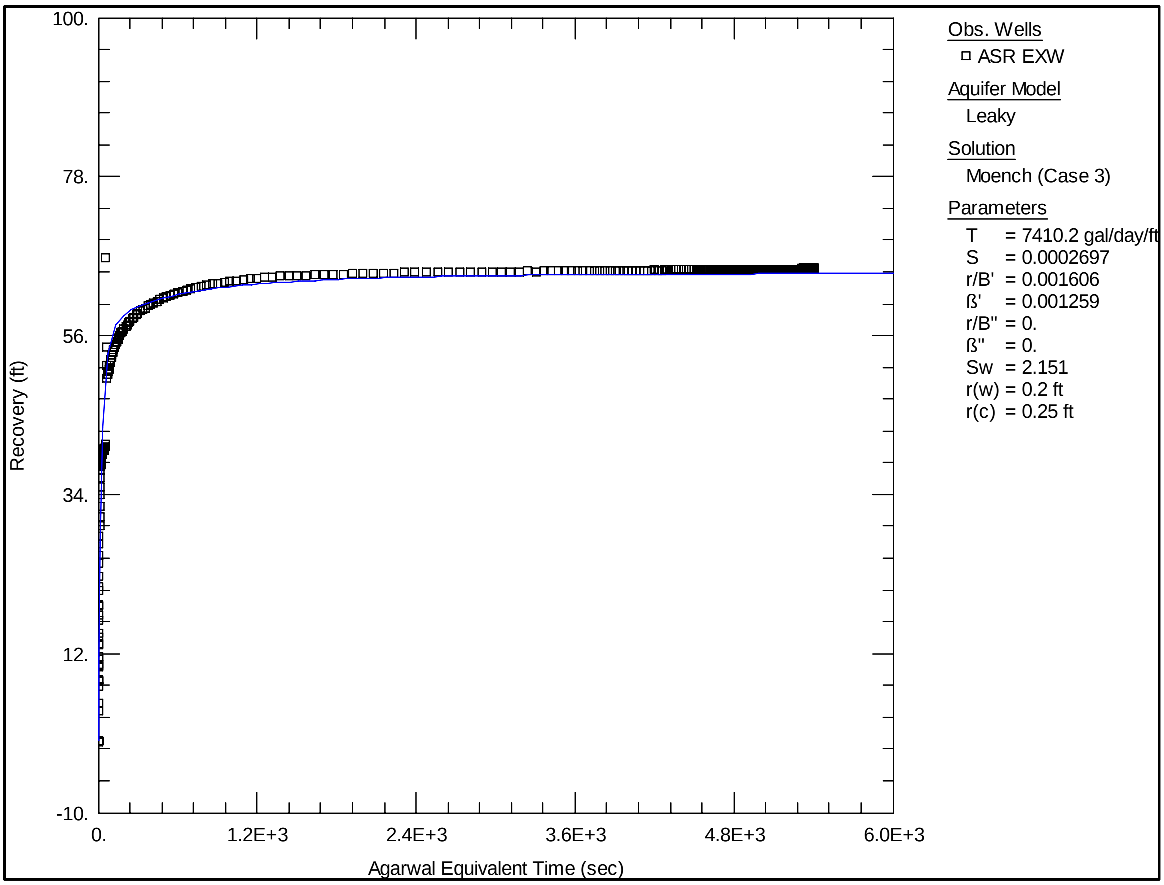


Figure 4-3 Hermosa Canal ASR TPW Constant rate Aquifer Test Plot of Recovery vs. Time

5.0 Conclusions and Recommendations

Construction of the Hermosa ASR Exploratory Well at the City of Cape Coral's planned Fire Station No. 13 property has been completed successfully. One 6.625-inch OD ASR exploratory well with PVC casing installed to 880 feet bls and an open hole extending from 880 to 950 feet bls is now ready for installation of the monitoring equipment. The well was constructed to the requirements specified under FDEP permit No. 272886-003 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 Hermosa Canal. The Hermosa Canal in the vicinity of Burnt Store Road 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 within the Suwannee Limestone of the Upper Floridan aquifer and is confined beneath 120 feet of low permeability marl and clays. The ASR EXW has a specific capacity of 3.7 gpm/ft and an a transmissivity of 7,410 gpd/ft at a pump rate 240 gpm. The ambient water within the monitoring interval is brackish, and contains a chloride and TDS concentration of approximately 1,110 mg/L and 2,270 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 the Hermosa Canal is on the low end of the range for a successful ASR system and acidization of the storage zone would be recommended upon completion of an ASR test production well in the vicinity of this site.

Based on the information obtained from this well and its proximity to the Hermosa Canal, we would recommend the City acquire property along the Hermosa 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 Hermosa ASR Exploratory Well

WELL NUMBER	L1042
PERMIT NUMBER	272886-003-UC/5X
JOB NUMBER	3220194.363702
OWNER	City of Cape Coral

Depth (ft bls)	**Description**
0-20	Sandy Shell Fragments: greenish gray 5GY 6/1 to yellowish gray 5Y 8/1; friable; moderate induration; predominantly bivalves.
20-30	Clay: grayish olive 10Y 4/2; stiff; moderate plasticity; shell fragments predominantly bivalves (25%); trace coarse grained phosphate.
30-40	Clay: grayish olive 10Y 4/2; soft; moderately high plasticity; trace very fine grained sand and phosphate.
40-50	Clay: greenish gray 5Y 6/1; moderately soft; moderate plasticity; trace very fine grained phosphate.
50-70	Clay: greenish gray 5Y 6/1; moderately soft; moderate plasticity; occasional very fine grained phosphate.
70-90	Clay: dusky yellow green 5GY 5/2; moderately soft; moderately plastic.
90-100	Clay (50%): dusky yellow green 5GY 5/2; moderately soft; moderately plastic; 3-4% very fine phosphate. Limestone (50%): yellowish gray 5Y 8/1; biomicrite; moderate porosity; friable.
100-120	Clay: light olive gray 5Y 5/2; very soft; silty; 2-3% very fine phosphate.
120-130	Limestone: yellowish gray 5Y 8/1; micrite; moderate porosity; friable; trace of shell fragments.
130-150	Limestone: light gray N7 to very light gray N8; sandy, pelmicrite; high intergranular porosity; friable; 10-15% very fine grained quartz and phosphate.
150-160	Limestone: light olive gray 5Y 6/1 and very light gray N8; micrite; high intergranular porosity; friable; 5% very fine phosphate.
160-180	Limestone: light olive gray 5Y 6/1 – 5/2; micrite; high intergranular porosity; friable; quartz silt and 5% very fine phosphate.
180-190	Limestone: yellowish gray 5Y 8/1 to light olive gray 5Y 6/1; micrite; high intergranular porosity; silty; friable; 5% very fine phosphate.
190-200	Limestone: light olive gray 5Y 6/1 – 5/2; micrite; high intergranular porosity; silty; friable; 5% very fine phosphate.

Depth (ft bls)	Description
200-210	Limestone: light olive gray 5Y 6/1; micrite; marly; moderate to low intergranular porosity; slightly friable; 3-4% very fine phosphate.
210-240	Limestone: yellowish gray 5Y 8/1 and light gray N7; biomicrite and sparite; moderately high porosity; moderately friable; 3-4% very fine phosphate; trace of marl; trace of shell fragments.
240-250	Clay: Olive gray 5Y 4/1; soft; silty; 2-3% very fine phosphate.
250-260	Limestone: light gray N7 and light greenish gray 5GY 8/1; biomicrite; high porosity; friable; 10% very fine phosphate; trace of shell fragments.
260-270	Marl (70%): very light gray N8; soft; 3-4% very fine phosphate. Limestone (30%): yellowish gray 5Y 8/1; biomicrite; moderately high porosity; friable.
270-280	Limestone: yellowish gray 5Y 8/1 and light gray N7; biomicrite and sparite; moderately high porosity; moderately friable; trace of marl; trace of shell fragments.
280-290	Marl (80%): very light gray N8; soft; 5% very fine phosphate. Limestone (20%): very light gray N8; micrite; moderately low porosity; friable.
290-330	Limestone (80%): yellowish gray 5Y 8/1; biomicrite; moderately high intergranular and moldic porosity; friable; 2-3% fine phosphate. Marl (20%): light gray N7 to yellowish gray 5Y 8/1; soft.
330-340	Limestone (50%): yellowish gray 5Y 8/1; biomicrite; moderately high intergranular and moldic porosity; friable; 2-3% fine phosphate. Marl (50%): light gray N7 to yellowish gray 5Y 8/1; soft.
340-360	Marl: very light gray N8; soft; 5% very fine phosphate.
360-370	Marl: very light gray N8 to greenish gray 5GY 6/1; soft; 5% very fine phosphate.
370-390	Marl (70%): light gray N7 to yellowish gray 5Y 8/1; soft. Limestone (30%): yellowish gray 5Y 8/1; biomicrite; moderately high intergranular and moldic porosity; friable; 2-3% fine phosphate.
390-400	Limestone: greenish gray 5GY 6/1; biomicrite; high intergranular porosity; moderately friable; 3-4% fine phosphate.
400-410	Marl: very light gray N8; soft; 5% very fine phosphate.
410-430	Limestone: greenish gray 5GY 6/1 and yellowish gray 5Y 8/1; micrite; high intergranular porosity; moderately hard; trace of shell fragments.
430-440	Limestone (90%): very light gray N8; biomicrite; moderately high porosity; moderately friable; 1-2% very fine phosphate. Marl (10%): very light gray N8; soft.
440-470	Limestone: very light gray N8; biomicrite; high intergranular, moldic, and vuggy porosity; moderately friable.

Depth (ft bls)	Description
470-480	Clay/Marl: very light gray N8; moderately stiff; plastic.
480-490	Limestone (70%): very light gray N8 and yellowish gray 5Y 8/1; biomicrite; marly; moderate porosity; slightly friable. Marl (40%): very light gray N8; moderately soft; plastic.
490-500	Limestone (90%): very light gray N8 and yellowish gray 5Y 8/1; biomicrite; marly, moderately high moldic porosity; slightly friable. Marl (10%): very light gray N8; moderately soft.
500-510	Marl: very light gray N8; moderately soft; plastic.
510-530	Limestone (50%): very light gray N8 and yellowish gray 5GY 8/1; biomicrite; marley; moderately high moldic porosity; slightly friable; 2-3% very fine phosphate. Marl (50%): very light gray N8; moderately soft.
530-543	Limestone: yellowish gray 5Y 8/1; pel-micrite; hard; moderate vuggy porosity; very fine to medium grained phosphate (12%); trace sparite; trace fossils; thin lenses of interbedded clay.
543-550	Marl: yellowish gray 5 Y 7/2; soft to moderately stiff; moderately high plasticity; trace limestone.
550-570	Limestone: yellowish gray 5Y 8/1; biomicrite; moderately hard to friable; moderately high vuggy and moldic porosity; pelitic; very fine to medium grained phosphate (4%).
570-586	Limestone: yellowish gray 5Y 8/1 to medium gray N5; biomicrite; moderately hard; high vuggy and moldic porosity; trace dolomite; trace sparite.
586-587	Marl: yellowish gray 5Y 8/1; soft to very stiff; moderately high plasticity.
587-599	Limestone: yellowish gray 5Y 8/1 to medium gray N5; biomicrite; moderately hard; high vuggy and moldic porosity; trace dolomite; very fine to medium grained phosphate (10%).
599-600	Marl: yellowish gray 5Y 8/1; very stiff; moderate plasticity.
600-610	Limestone: yellowish gray 5Y 8/1 to medium light gray N6; biomicrite; moderately hard; high vuggy and moldic porosity; very fine to medium grained phosphate (7%).
610-627	Limestone: yellowish gray 5Y 8/1 to medium light gray N6; biosparite; hard; high moldic porosity; very fine to medium grained phosphate (5%).
627-651	Limestone: yellowish gray 5Y 8/1; biomicrite; moderately hard to friable; high vuggy and moldic porosity; trace sparite; very fine grained phosphate (13%).
651-655	Limestone: yellowish gray 5Y 8/1 to light gray N7; biomicrite; friable; moderate vuggy and moldic porosity; pelitic; clay (20%); very fine grained phosphate (12%).
655-671	Limestone: yellowish gray 5Y 8/1 to medium light gray N6; biomicrite; friable; moderately high moldic porosity; abundant gastropod shell fragments and intraclastic sparite.

Depth (ft bls)	Description
671-673	Clay: yellowish gray 5Y 8/1; moderately soft; moderately high plasticity; trace very fine grained phosphate.
673-675	Limestone: yellowish gray 5Y 8/1 to medium gray N5; micrite; fine grained; low porosity; low permeability; dolomitic intraclasts (10%) thin clay laminations (8%).
675-676	Marl: yellowish grey 5Y 7/2; soft to moderately stiff; moderate plasticity; very low porosity; very low permeability; very fine to medium grained phosphate (4%).
676-677	Limestone: light gray N7 to medium gray N5; biomicrite; moderately hard; moldic and vuggy porosity; moderately low permeability; predominantly bivalves; trace sparite; very fine to medium grained phosphate (2%).
677-678	Marl: yellowish grey 5Y 7/2; soft; moderate plasticity; very low porosity; very low permeability; very fine grained phosphate (1%).
678-691	Limestone: yellowish gray 5Y 8/1 to medium gray N5; micrite; fine grained; low vuggy porosity; low permeability; dolomitic (30%).
691-700	Clay: white N9; soft to moderately stiff; high plasticity.
700-701	Limestone: biomicrite; friable; moldic porosity; predominantly bivalves; trace sparite; very fine to medium grained phosphate.
701–703	Marl: very light gray (N8), soft, trace silt phosphate, very poor apparent porosity and permeability.
703–710	Limestone, medium light gray (N6), micrite, high induration, minor fine-grained quartz, trace coarse grained quartz, moderate apparent porosity and permeability.
710–711	Marl: very light gray (N8), soft, trace silt phosphate, very poor apparent porosity and permeability.
711–713	Limestone, light gray (N7), sparse biomicrite, high induration, abundant coral and some shell fragments, common carbonate and quartz sand, good apparent porosity and permeability.
713–716	Limestone, light gray (N7), biomicrite, moderate induration, abundant coarse grained carbonate sand, common coarse to medium grained quartz sand, some shell fragments, minor casts and molds, good apparent porosity and permeability.
716–720	Marl, yellowish gray (5Y 8/1), soft, mostly clean, trace coarse grained sub-rounded carbonate sand, poor apparent porosity and permeability
720–735	Limestone, very pale orange (10YR 8/2), micrite, moderate induration, clean, no allochems, moderate apparent porosity and permeability
735 – 740	Limestone, yellowish gray (5Y 8/1), sparse biomicrite, poor induration, abundant medium to coarse grained sub-rounded/rounded carbonate sand, trace fine grained sand/silt phosphate, trace pin point vugs, trace shell fragments, good apparent porosity and permeability

Depth (ft bls)	Description
740–748	Limestone, yellowish gray (5Y 8/1), biomicrite, moderate induration, abundant medium to coarse grained sub-rounded carbonate sand, common casts and molds, minor pin point vugs, very good apparent porosity and permeability
748–748	Limestone, moderate yellowish brown (10YR 5/4), firm but moderate induration, abundant pin point vugs, good apparent porosity and permeability
748–752	Limestone, very light gray (N8) to yellowish gray (5Y 8/1), biomicrite, moderate induration, common coral, common coarse grained sub-rounded carbonate sand, minor casts and molds, trace shell fragments, trace coarse grained quartz sand in matrix, good apparent porosity and permeability
752–760	Limestone, yellowish gray (5Y 8/1), sparse biomicrite, moderate induration, minor casts and molds, minor coarse grained sub-rounded carbonate sand, trace shell fragments, trace vugs, good apparent porosity and permeability
760–765	Marl, very light gray (N8), chalky, clean, dense, minor/trace amounts of medium grained rounded yellowish gray carbonate sand, very poor apparent porosity and permeability
765–767	Clay, very light gray (N8), marly, thick, minor/trace amounts of medium grained rounded yellowish gray carbonate sand, trace phosphatic silt, very poor apparent porosity and permeability
767–775	Limestone, yellowish gray (5Y 8/1), packed biomicrite, moderate to high induration with depth, abundant casts and molds, corals, shell fragments, common vugs, minor medium sub-rounded carbonate sand, very good apparent porosity and permeability
775–781	Limestone, yellowish gray (5Y 8/1), packed biomicrite, firm but moderate induration, common casts and molds, common shell fragments, common vugs, good apparent porosity and permeability
781–783	Limestone, yellowish gray (5Y 8/1), micrite, high induration, trace casts and molds, trace shell fragments, trace vugs, good apparent porosity and permeability
783–790	Dolostone, light olive gray (5Y 6/1), very high induration, overall clean, microcrystalline, trace phosphatic silt, poor apparent porosity and permeability
790-810	Limestone, yellowish gray (5Y 8/1), biomicrite; moderately hard; high moldic porosity; moderately high permeability; shell fragments (20%), predominately bivalves; fine grained phosphate (3%).
810-830	Limestone, medium gray (N6); biomicrite; friable to moderately hard; moderately high moldic porosity; corals and shell fragments (25%), trace hard dolomite (15%).
830-840	Limestone, light gray (N7) to white (N9); micrite; moderately hard; moderately high vuggy porosity; hard dolomite (18%); shell fragments (7%); thin high plasticity clay lamination.
840-850	Limestone, light gray (N7) to white (N9); micrite; moderately hard; moderately high vuggy porosity; hard dolomite (17%); trace sparite; trace fossils.

Depth (ft bls)	Description
850-855	Limestone, very pale orange (10 YR 8/2); micrite; moderately hard to friable; moderately low intergranular permeability; pelitic; dolomitic intraclasts; gastropods; trace fine grained phosphate.
855-857	Limestone, white (N9) to light gray (N7); biomicrite; hard; moderately high moldic and vuggy permeability; gastropods and bivalves; pelitic; trace fine to medium grained phosphate.
857-872	Limestone, yellowish gray (5Y 8/1) to medium gray (N5); biomicrite; moderately hard to friable; moderately low moldic and vuggy permeability; pelitic; dolomitic intraclasts; trace drusey sparite; trace very fine to medium grained phosphate.
872-873	As above grading to 15% marl.
873-880	Marl, white (N9); moderately soft; high plasticity; very low permeability.
880-890	Limestone, very pale orange (10YR 8/2) to yellowish gray (5Y 8/1); calcarenitic; hard; high vuggy permeability; sandy to pelitic; dolomitic intraclasts; trace marl.
890-900	Limestone, very pale orange (10YR 8/2); pelmicritic to calcarenitic; moderately hard; high vuggy permeability; sandy.
900-901	Limestone, yellowish gray (5Y 8/1) to light olive gray (5Y 6/1); pelmicritic to calcarenitic; very hard to friable; high vuggy permeability; dolomitic intraclasts; sandy pelitic; drusey sparite; trace molds and casts of bivalves and gastropods.
901-903	Limestone, grayish orange (10 YR 7/4); pelmicritic to calcarenitic; moderately hard; high to moderate vuggy permeability; sandy, intraclasts of light olive gray (5Y 6/1) biomicrite.
903-905	Limestone (50%), white(N9); pelmicritic to calcarenitic; moderately hard to friable; moderate to low vuggy permeability; sandy. Marl (50%), white (N9);moderately soft; high plasticity, low permeability.
905-912	Limestone, yellowish gray (5Y 8/1) to light olive gray (5Y 6/1); calcarenitic; moderately hard to friable; moderately high vuggy permeability; dolomitic/ glauconitic intraclasts; sandy; drusey sparite.
912-923	Limestone, very pale orange (10YR 8/2) to pale yellowish brown (10YR 6/2); pelmicrite; moderately hard; high to moderate vuggy permeability; sandy, intraclasts of light olive gray (5Y 6/1) biomicrite; gastropods.
923-928	Limestone, white(N9); pelmicrite; moderately hard to friable; low intergranular permeability; sandy; high induration; drusey sparite; trace small vugs.
928-931	Limestone, yellowish gray (5Y 8/1); calcarenitic; moderately soft to friable; low intergranular permeability; marly; sandy.
931-933	Limestone, yellowish gray (5Y 8/1) to white (N9); pelmicrite; moderately hard to friable; low intergranular permeability; sandy; high induration; trace small vugs.
933-945	Limestone, pale yellowish orange (5Y 8/1) to yellowish gray (5Y 8/1); pelmicrite; moderately hard; moderate vuggy permeability; sandy, intraclasts of light gray (N7) biomicrite.

Depth (ft bls)	Description
945-950	Limestone, grayish orange (10 YR 7/4) to yellowish gray (5Y 8/1); pelmicrite; moderately hard; moderate vuggy permeability; trace sparite; gastropods.
950-958	Limestone (70%), grayish orange (10 YR 7/4) to yellowish gray (5Y 8/1); calcarenitic; moderately hard; moderate vuggy permeability; sandy. Clay (30%), pale yellowish brown (10 YR 6/2) to yellowish gray (5Y 8/1); moderately soft; low plasticity.
958-970	Limestone, grayish orange (10 YR 7/4) to yellowish gray (5Y 8/1); biomicrite; moderately hard; moderate moldic and vuggy permeability; sandy, intraclasts of light gray (N7) micrite; trace fine grained phosphate.
970-980	Limestone, yellowish gray (5Y 8/1); micrite; friable; moderate vuggy permeability; drusey sparite; gastropods; trace marl.
980-1000	Limestone, grayish orange (10 YR 7/4) to yellowish gray (5Y 8/1); calcarenitic; moderately hard; moderate moldic and vuggy permeability; sandy to pelitic, trace intraclasts of light gray (N7) micrite.
1000-1010	Limestone, grayish orange (10 YR 7/4) to very pale orange (10 YR 8/2); pelmicrite; friable; moderate vuggy permeability. Clay (20%), pale yellowish brown (10YR 6/2) to yellowish gray (5Y 8/1); moderately soft; moderate plasticity
1010-1030	Limestone, very pale orange (10 YR 8/2); pelmicrite; moderately hard to friable; moderate vuggy permeability.
1030-1038	Limestone, yellowish gray (5Y 8/1); pelmicrite; moderately hard; moderate vuggy permeability; intraclasts of light gray (N7) micrite; trace sparite; gastropods.
1038-1050	Limestone, yellowish gray (5Y 8/1) to medium light gray (N 6); sparite; very hard; high moldic and vuggy permeability; trace bivalves and gastropods.
1050-1060	Limestone, very pale orange (10 YR 8/2); pelmicrite; moderately hard to friable; moderate vuggy permeability; sandy; trace very fine grained phosphate.
1060-1075	Limestone, pale yellowish brown (10 YR 6/2) to medium gray (N 5); sparite; very hard; moderate to moderately low vuggy permeability; yellowish gray (5Y 8/1) biomicrite; trace medium to fine grained phosphate; trace bivalves and gastropods.
1075-1090	Limestone, very pale orange (10 YR 8/2); calcarenitic; moderately hard to friable; moderate vuggy permeability; sandy; trace sparite; trace gastropods.
1090-1099	Limestone, very pale orange (10 YR 8/2); pelmicrite; moderately hard to friable; low intergranular permeability; sandy; high induration; trace vugs; trace fine grained phosphate; thin clay laminations; intraclasts of medium gray (N 5) biomicrite.
1099-1101	Limestone, very pale orange (10 YR 8/2); pelmicrite; moderately hard; high to moderate vuggy permeability; sandy; intraclasts of medium gray (N 5) biomicrite; gastropods and bivalves.

Depth (ft bls)	**Description**
1101-1118	Limestone, very pale orange (10 YR 8/2); calcarenitic; moderately soft to friable; moderately low intergranular permeability; marly; sandy.
1118-1119	Clay, white (N 9); moderately soft; moderately high plasticity; trace sand; trace limestone.
1119-1132	Limestone, very pale orange (10 YR 8/2); pelmicrite; moderately hard; high to moderate moldic and vuggy permeability; sandy; intraclasts of medium gray (N 5) biomicrite; gastropods and bivalves.
1132-1134	Clay, white (N 9); moderately soft; moderately high plasticity; trace sand; trace limestone.
1134-1155	Limestone, very pale orange (10 YR 8/2); calcarenitic; moderately hard; high to moderate moldic and vuggy permeability; sandy; intraclasts of medium gray (N 5) biosparite; bivalves.
1155-1160	Marl, yellowish gray (5Y 8/1); very soft; low intergranular permeability.
1160-1187	Limestone, grayish orange (10 YR 7/4); micrite; moderately hard to friable; moderate vuggy permeability; poor induration; sandy to pelitic, trace drusey sparite.
1187-1200	Limestone, grayish orange (10 YR 7/4) to yellowish gray (5Y 8/1); micrite; moderately soft; moderate moldic and vuggy permeability; very poor induration, sandy to pelitic, trace drusey sparite.