Hydrogeologic Investigation at the S61 Locks for the Central Florida Water Initiative

Osceola County, Florida
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EXECUTIVE SUMMARY

As part of the Central Florida Water Initiative (CFWI; www.cfwiwater.com), the Data Monitoring and Investigations Team (DMIT) identified several areas lacking adequate monitoring and information on the hydraulic properties of the subsurface, particularly in the deeper portions of the Floridan aquifer system (FAS) known as the Lower Floridan aquifer (LFA). Consequently, DMIT developed a work plan for the construction and testing of new data collection sites to meet future data needs within the CFWI Planning Area and increase understanding of the LFA as an alternative water supply source. This report documents one component of that work plan: the exploratory drilling and construction of monitor well OSF-112, located at the S61 Locks site in Osceola County, Florida.

Exploratory drilling at this site reached a maximum depth of 1,400 feet below land surface (ft bls). Work at the S61 Locks site included wire-line coring, geophysical logging, hydraulic testing, and water quality sampling. Data from these activities were used to identify hydrogeologic unit boundaries and evaluate variations in water quality and rock permeability with depth.

Hydrogeologic boundaries for the Avon Park permeable zone (APPZ) and middle confining unit (MCU) were the most affected by the results of this investigation. The base of the APPZ was identified substantially higher (248 ft) than expected based on previous regional hydrogeologic investigations. The MCU was found to be much more confining than anticipated at this location. It included more than 200 ft of very low-permeability evaporites and evaporitic dolostone rock (MCU_II). Interpolation of previously available data predicted the absence of MCU_II at this location. Leakance across MCU_II is one to two orders of magnitude lower than MCU_I, which was anticipated. The S61 Locks site is less than 5 miles from the north end of the Toho Water Authority's (TWA) proposed Cypress Lakes wellfield, which is to be completed in the LFA. Although the TWA did not report the presence of MCU_II in its exploratory boreholes, the extent of its occurrence in OSF-112 makes it likely that some portion of MCU_II extends into the cone of influence for the proposed wellfield.

Water quality samples were obtained with depth via packer testing as the OSF-112 borehole was advanced through the FAS. The samples indicated freshwater existed to a depth of 570 ft bls (base of the APPZ). From 570 ft bls to the top of the LFA (approximately 1,260 ft bls), total dissolved solids (TDS) concentrations increased from less than 200 milligrams per liter (mg/L) to more than 2,300 mg/L, with the salinity derived primarily from sulfate rather than chloride. At the top of the LFA, salinity abruptly dropped and TDS was very close to the drinking water standard (500 mg/L). This deep zone of fresher water was chemically distinct from the waters above 570 ft bls and greatly enriched in multiple ions, particularly sodium and chloride.

The most permeable sections of the FAS are associated with post-depositional fracturing or dissolution of the carbonate rock, which makes permeability within the FAS highly variable. Formation permeability, represented by hydraulic conductivity (k), was estimated from each packer test (30-ft intervals). The major hydrostratigraphic units from shallowest to deepest, yielded the following estimates for k: UFA-upper (k = 10 to 33 ft/day), OCAPlpz (k = 3 to 6 ft/day), APPZ (k = >1,000 ft/day in fractured intervals), MCU_I (k = 2 to 22 ft/day), MCU_II (k = <0.1 ft/day), and LFA-upper (k = 21 to 293 ft/day).

Upon completion of the exploratory coring and testing, the corehole was backplugged to a depth of 595 ft bls and completed as a permanent APPZ monitor well (OSF-112). The adjacent, previously existing but inactive monitor well (OSF-53), originally constructed with a long open-hole interval, was modified to discretely monitor the uppermost permeable zone of the FAS (UFA-upper). The modified monitor well is designated OSF-53R.

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ACRONYMS AND ABBREVIATIONS

µS/cm	microsiemens per centimeter
APhpz	Avon Park high permeability zone
APPZ	Avon Park Permeable Zone
bls	below land surface
CFWI	Central Florida Water Initiative
CTD	conductivity, temperature, and depth
District	South Florida Water Management District
DMIT	Data Monitoring and Investigations Team
DTW	depth-to-water
ECFTX	East Central Florida Transient Expanded (model)
FAS	Floridan aquifer system
ft	foot
g/cm^3	grams per cubic centimeter
gpm	gallons per minute
LFA	Lower Floridan aquifer
MCU	middle confining unit
mg/L	milligrams per liter
NTU	nephelometric turbidity units
OBI	optical borehole imaging
OCAPlpz	Ocala-Avon Park low permeability zone
PVC	polyvinyl chloride
SAS	surficial aquifer system
SCADA	supervisory control and data acquisition
SFWMD	South Florida Water Management District
SPT	standard penetration test
UFA	Upper Floridan aquifer
XRD	x-ray diffraction

INTRODUCTION

The South Florida Water Management District (SFWMD or District) has been working cooperatively with the Southwest Florida and St. Johns River water management districts, Florida Department of Environmental Protection, Florida Department of Agriculture and Consumer Services, and local stakeholders over the last several years to evaluate the status of traditional water supplies and plan for the future of water supply in Central Florida. As part of this Central Florida Water Initiative (CFWI; www.cfwiwater.com), the Data Monitoring and Investigations Team (DMIT) identified several areas lacking adequate monitoring and information on the hydraulic properties of the subsurface, particularly in the deeper portions of the Floridan aquifer system (FAS). Consequently, DMIT developed a work plan for the construction and testing of new data collection sites to meet future data needs within the CFWI Planning Area. This report documents one component of that work plan: the exploratory drilling and monitor well construction at the S61 Locks site (28.139914, -81.351177).

The S61 Locks site is located in Osceola County, on the east bank of the C-35 Canal right-of-way at the southern shore of Lake Tohopekaliga (**Figure 1**). Wells OSF-53, OSF53_GW1, and OSF53_GW2 were present at this location prior to this project. OSF-53 was drilled by the SFWMD in 1982 as part of a hydrogeologic reconnaissance study of the Kissimmee Planning Area (Shaw and Trost 1984). The well was cased to 170 feet below land surface (ft bls), near the top of the FAS, and left open to the total drilled depth of 980 ft bls. From the time of construction until September 2011, water levels in OSF-53 were measured semiannually as part of the United States Geological Survey state-wide potentiometric mapping effort for the Upper Floridan aquifer (UFA). Surficial aquifer system (SAS) wells OSF53_GW1 and OSF53_GW2 were constructed in 2000 as part of the SFWMD Paired Wells project, investigating interconnectivity between the SAS and FAS. These three wells were instrumented with pressure transducers and telemetry connected to a supervisory control and data acquisition (SCADA) system and continuously monitored by the SFWMD from November 2000 to August 2007. In need of repair, the SCADA system was deactivated in 2007.

Project Objectives

Hydrogeologic data collection:

1. Evaluate the lithology, productivity, and water quality of the FAS to a depth of 1,400 ft bls.

2. Identify key hydrogeologic unit boundaries from the top of the Avon Park permeable zone (APPZ) to the top of the Lower Floridan aquifer (LFA).

3. Determine whether and to what extent the evaporitic facies of the middle confining unit (MCU_II) is present at this site.

Monitoring objectives:

1. Backfill the long, open hole of OSF-53 to discretely monitor the UFA above the Ocala-Avon Park low-permeability zone (OCAPlpz).

2. Construct a new well (OSF-112) from the exploratory corehole to discretely monitor the APPZ.

3. Reactivate the on-site SCADA system to resume water level measurements.

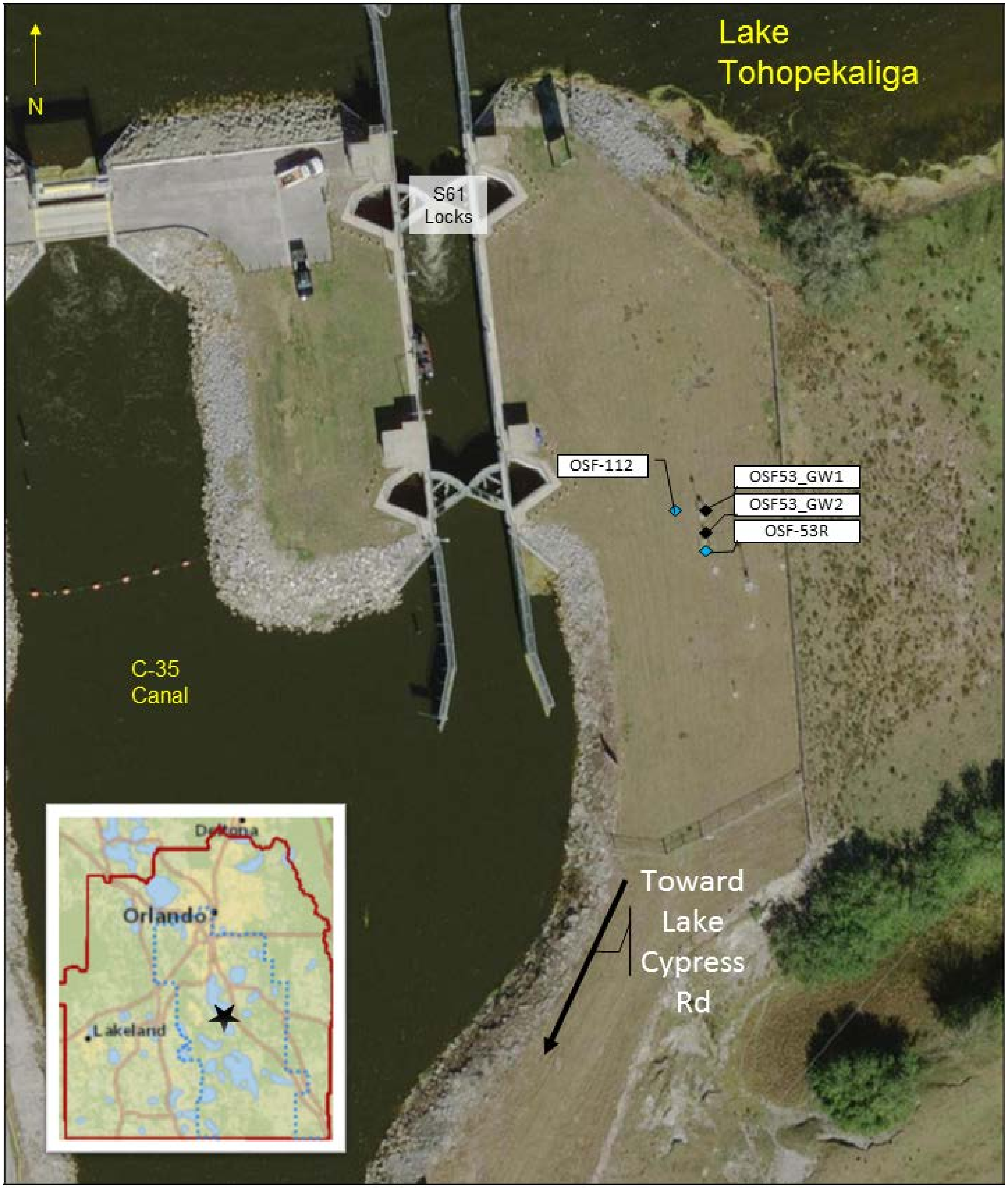

Figure 1. Location of monitor wells and general location (inset) of the S61 Locks site within the Central Florida Water Initiative Planning Area (red boundary).

EXPLORATORY CORING AND WELL CONSTRUCTION

The SFWMD contracted with Huss Drilling, Inc. for exploratory coring, packer testing, and monitor well construction services in August 2017 (CN#4600003686). Huss mobilized a GEFCO 1500 Hole Master drilling rig to the S61 Locks site in October 2017 and commenced construction of exploratory well OSF-112.

The borehole was sampled using the ASTM D-1586-99 continuous split-barrel standard penetration test (SPT) method to a depth of 60 ft bls, where increasing clay content indicated the base of the SAS. At this point, the hole was reamed via mud-rotary drilling to a diameter of 16 inches. Sixty feet of 12-inch diameter polyvinyl chloride (PVC) surface casing was set in the borehole and grouted to land surface.

A nominal 4-inch diameter pilot hole was advanced via mud-rotary drilling from the base of the surface casing to a depth of 169 ft bls. Rock cuttings from the pilot hole were used to identify the top of the FAS and a suitable casing seat for an 8-inch diameter conductor casing to prevent influx of unconsolidated material from the intermediate confining unit during coring operations. The top of the FAS was identified at 155 ft bls. The borehole was reamed to a nominal 12-inch diameter, and geophysical logs (caliper, gamma, normal resistivity, and sonic porosity) were run in the mudded borehole. The 8-inch PVC conductor casing was set at 169 ft bls and grouted to land surface.

From October 23, 2017 to January 5, 2018, a nominal 4-inch hole was advanced using wire-line core drilling in 10-ft increments to a total depth of 1,400 ft bls. The core barrel, equipped with a Boart Longyear HQ series bit, yielded 2.5-inch diameter rock cores. Thirty-eight single (off-bottom) packer tests were conducted during coring operations, at intervals ranging from 20 to 50 ft. Upon achieving final depth, geophysical logs (caliper, gamma, normal resistivity, fluid temperature/conductivity, down-hole video, and optical borehole image [OBI]) were run in the corehole. Based on the log and testing results, the base of the APPZ was identified at 595 ft bls and selected as the final completed depth for the well. The well was backfilled from total depth to 595 ft with a combination of neat cement grout and gravel to bridge productive zones within the upper portion of the LFA. The interval from the top of the conductor casing to the top of the APPZ (430 ft bls) was reamed to a nominal 8 inches via mud-rotary drilling. A 4-inch diameter PVC final casing was hung in the borehole to a depth of 430 ft bls and grouted to land surface using cement baskets. An as-built construction diagram for OSF-112 is provided in **Figure 2**. The completed well was air developed until produced water was visibly free of turbidity, then pumped at 60 gallons per minute (gpm) for 2 hours until turbidity levels were less than 10 nephelometric turbidity units (NTU), and pH was within the pre-backfill range. On January 30, 2018, the rig was moved 14 ft to the original well, OSF-53.

Backfill operations of OSF-53 began on February 1, 2018. Huss performed a hard tag on the bottom of the well at 947 ft bls. The well was backfilled from 947 to 661 ft bls with 8% bentonite grout. To prevent the possibility of grout contamination in the newly constructed OSF-112, no attempt was made to grout through the fractured dolostone of the APPZ. OSF-53 was backfilled with 6.15 cubic yards of pea-gravel from 661 to 422 ft bls. This was capped with an additional 78 ft of 4% bentonite grout to the final depth of 300 ft bls (base of the UFA-upper). An as-built construction diagram for the redesigned well, OSF-53R, is provided in **Figure 3**. The completed well was air-developed for 2 hours until visibly free of turbidity, then pumped at 100 gpm for an additional 6 hours. The pH at the beginning of development was 9.8, showing some impact to the water quality from the curing cement grout. After 8 hours of development, the pH was down to 8.36 and turbidity was less than 5 NTU. A complete timeline of well-construction operations is provided in **Appendix A**. Well construction permits and completion reports are provided in **Appendix B**.

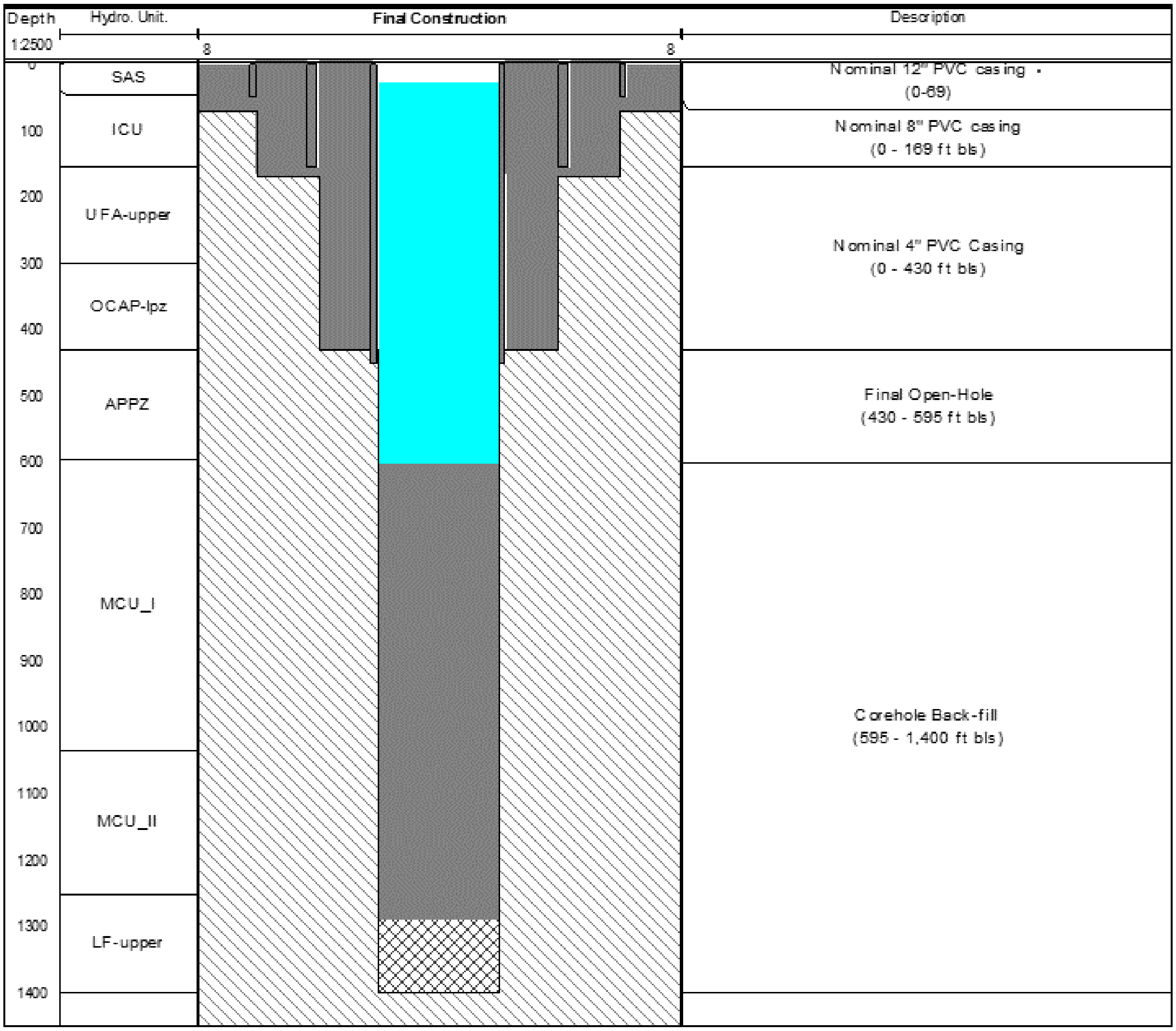

Figure 2. As-built construction diagram for monitor well OSF-112.

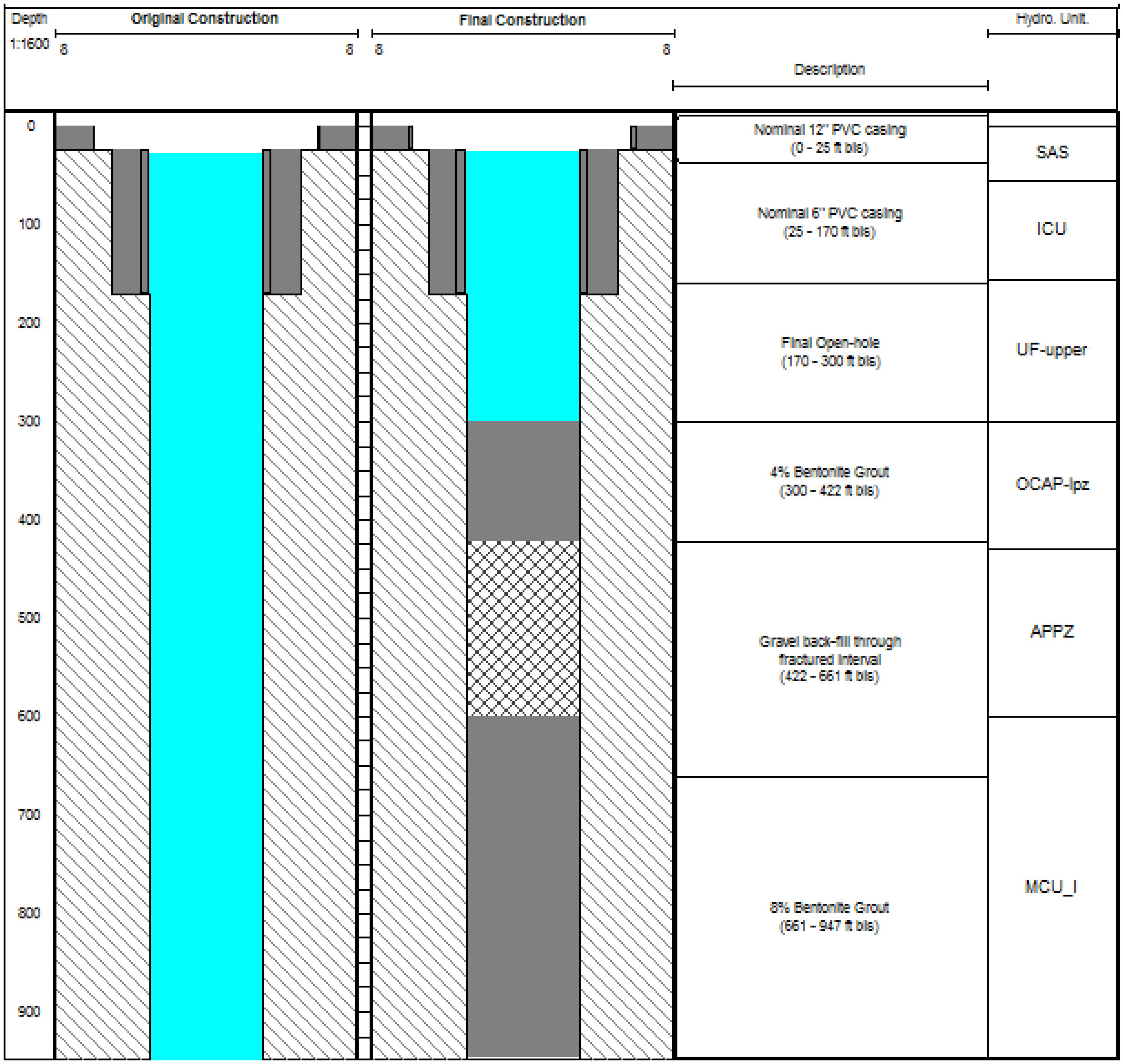

Figure 3. As-built construction diagram for the re-designed OSF-53R well.

The completed wells were surveyed by SFWMD surveyors in April 2018 to provide precise locations and vertical references for depth-to-water (DTW) measuring points. **Figure 4** shows the reference location of surveyed measuring point elevations, and the metadata for the completed monitor wells are summarized in **Table 1**.

Figure 4. Completed wellheads showing measuring point elevations and their reference locations for depth-to-water measurements for wells OSF-112 and OSF-53R.

Table 1. Summary metadata for the completed monitor wells.

Well	Latitude	Longitude	Measuring Point Elevation		Completed Depth	
			Feet (NAVD88)	Feet (NGVD29)	Cased Depth (ft bls)	Total Depth (ft bls)
OSF-53R	28°08’23.677	-81°21’04.235	61.99	63.04	170	300
OSF-112	28°08’23.781	-81°21’04.330	63.10	64.15	430	595

ft bls = feet below land surface; NAVD88 = North American Vertical Datum of 1988; NGVD29 = National Geodetic Vertical Datum of 1929.

STRATIGRAPHIC FRAMEWORK

The SFWMD collected geologic formation samples from pilot holes during the drilling of OSF-112 and described the samples based on the dominant lithologic, textural, and porosity characteristics. Sampling methodologies included continuous SPT samples from surface to 60 ft bls, borehole cuttings from 60 to 169 ft bls, and wire-line core samples from 169 to 1,400 ft bls. SFWMD geologists described the samples (presented in **Appendix C**) using the Expanded Dunham (Embry and Klovan 1971) classification for carbonates. Geophysical logs also helped characterize the geologic formations encountered during drilling.

Holocene, Pleistocene, and Pliocene Series

Undifferentiated sediments of Holocene, Pleistocene, and/or Pliocene age occur from land surface to approximately 58 ft bls. These undifferentiated sediments consist of pale-to-dark yellowish brown, very fine to fine-grained quartz sand with lesser amounts of silt and clay. At approximately 58 ft bls, lithology changes from a dark yellowish-brown clayey sand to an olive-gray clayey sand, showing a higher percentage of clay and the presence of phosphatic sand indicative of the Hawthorn Group.

Miocene Series

The Hawthorn Group is composed of a heterogeneous mixture of silt, clay, calcareous clay, quartz sand, phosphatic sand, shell, silt, limestone, and dolostone. Scott (1988) elevated the Hawthorn Formation to group status in Florida. It consists of two formations: the Peace River Formation, composed of predominantly siliciclastic material; and the underlying Arcadia Formation, composed principally of carbonates.

Peace River and Arcadia Formations

The top of the Hawthorn Group, at approximately 58 ft bls, consists of olive-gray clayey quartz sand with shell fragments, phosphatic wackestone, and up to 10% phosphatic sand. This highly variable lithologic mixture continues to approximately 155 ft bls. Generally, a lithologic change from predominantly siliciclastic to mixed siliciclastic-carbonate sediments differentiates the Arcadia Formation from the overlying Peace River Formation; however, such a change is not observed in these sediments, so the two formations are not differentiated in this description. The Hawthorn Group is approximately 97 ft thick at this site.

Deposition of the Peace River Formation sediments began in the Middle Miocene when siliciclastic sediments overran Florida's carbonate bank environment (Scott 1988). As sea level rose during this period, large amounts of siliciclastic material migrated to southern Florida, restricting carbonate sedimentation. The Arcadia Formation developed during the Lower Miocene in a carbonate bank environment with the deposition of siliciclastics from a southward flowing, long shore current (Scott 1988).

Oligocene Series

Suwannee Limestone

Suwannee Limestone was not present at this location.

Eocene Series

Ocala Limestone

Upper Eocene Ocala Limestone occurs at a depth of 155 ft bls at the S61 Locks site. Lithology of the upper 115 ft of the Ocala Limestone consists of a moderately to poorly indurated, pale yellow-orange to pale yellow-brown, pelletal and fossiliferous packstone to grainstone with moderate intergranular porosity. The first occurrence of the diagnostic microfossil *Lepidocyclina* was observed at 155 ft bls. The unit contains abundant *Lepidocyclina*, *Numulities*, miliolids, unidentified foraminifera, algal fragments, and shell fragments. Below approximately 270 ft bls, the unit consists of interbedded packstone to mudstone with moderate to poor induration and moderate to poor intergranular porosity. Fewer fossils are identifiable and include gastropods, shell fragments, and algal fragments. The base of the Ocala Limestone occurs at a depth of approximately 320 ft bls.

The Ocala Limestone was deposited on a warm, shallow carbonate bank, similar to the modern-day Bahamas (Miller 1986). This low-energy environment probably had low to moderate water circulation (Tucker and Wright 1990).

Avon Park Formation

The top of the Middle Eocene Avon Park Formation is identified from lithologic samples at a depth of 320 ft bls, based on the appearance of the diagnostic fossils *Neolagnum* and *Fallotella*, first identified at a depth of 330 ft bls. The first occurrence of *Neolagnum* and *Fallotella* diagnostic microfossils are used as biostratigraphic indicators for the Avon Park Formation (Bryan et al. 2011). A transition from interbedded packstone to mudstone of the Ocala Limestone to interbedded packstone and wackestone of the Avon Park Formation was observed. The Avon Park Formation continues to the total depth of the corehole (1,400 ft bls).

From approximately 320 to 372 ft bls, lithology consists of interbeds of very pale orange packstone and wackestone with moderate induration and moderate intergranular porosity. From approximately 372 to 408 ft bls, there is a general increase in grain size and associated intergranular porosity. The interval consists mostly of very pale orange, moderately indurated packstone to grainstone with good porosity and a few interbeds of the coarser-grained rudstones and floatstones. Fossils throughout the upper part of the Avon Park Formation include foraminifera, gastropods, and algal fragments. From 408 to 466 ft bls, lithology consists of very pale orange interbeds of wackestone, packstone, and mudstone with low to moderate porosity. An interval of well-indurated calcareous dolostone with moderate vuggy porosity is present from 427 to 431 ft bls. Fractured intervals were identified in the OBI log from 430 to 459 ft bls, consisting of solution-enhanced fractures, open fractures, and fracture swarms. There were 4 ft of core recovery from the 430 to 440 ft bls core interval; this poor core recovery is indicative of the fractured nature of the formation.

The interval from 466 to 601 ft bls consists of alternating beds of limestone, fractured dolostone, and calcareous dolostone as described below:

- From approximately 466 to 485 ft bls, lithology consists of dark yellow-brown to pale yellow-brown, microcrystalline, well-indurated calcareous dolostone with good pinpoint and vuggy porosity. A brecciated zone was identified in the OBI log from 470 to 486 ft bls. From the 480 to 490 ft bls core interval, only 5 ft of core were recovered, the remaining possibly lost due to intense fracturing.
- From approximately 490 to 526 ft bls, lithology comprises very pale orange, poorly to moderately indurated limestone consisting of wackestone, packstone, and grainstone as well as some minor mudstone with predominantly moderate intergranular porosity. One bedding plane fracture was observed in this interval.
- From approximately 526 to 550 ft bls, lithology changes to a dark yellowish-brown and dark gray, well-indurated dolostone with moderate to good moldic and vuggy porosity. Fracture swarms were identified in the OBI log from 526 to 533 ft bls and brecciation from 544 to 550 ft bls.
- From 550 to 561 ft bls, lithology changes again to a very pale orange limestone consisting of poorly indurated packstone, wackestone, and mudstone with moderate interparticle porosity. Fractures were not observed in this interval.
- From approximately 561 to 601 ft bls, lithology changes to a dark yellowish-brown, well-indurated dolostone and calcareous dolostone with moderate to good moldic and vuggy porosity. A fracture swarm and cavity were observed at 593 ft bls in the OBI log.

Lithology changes from approximately 601 to 646 ft bls to very pale orange to moderate yellow-brown dolostone with poor to moderate matrix porosity and few fractures observed. Fourteen feet of this interval were described as poorly indurated with no observable porosity.

From 646 to 1,034 ft bls, lithology is predominantly very pale orange to grayish-orange dolostone and interbedded calcareous dolostone. The dolostone ranges from moderately to well indurated with moderate to good pinpoint, vuggy, moldic, and intergranular porosity to poorly to moderately indurated with little pinpoint or intergranular porosity. There is little visible evidence of recrystallization, such as sucrosic or crystalline texture. Identifiable fossils largely consist of bivalve and gastropod molds and foraminifera. Organic lamination is common within zones of poor induration and little porosity. Calcareous dolostone interbeds up to approximately 20 ft in thickness are present throughout this section. Lithology is microcrystalline in texture with moderate to good induration and moderate pinpoint porosity. Fractured intervals consist almost entirely of bedding plane fractures with few vertical fractures

Lithology from approximately 1,034 to 1,243 ft bls consists of grayish-orange to very pale orange, well-indurated dolostone with large amounts of evaporite minerals (gypsum/anhydrite), ranging from trace amounts up to 80%. The evaporite minerals occur as porosity infill, nodules, chicken-wire, and along bedding planes. There was little matrix porosity and only a few fractures observed within this interval, along with some fossil gastropods and bivalves.

A lithology change at approximately 1,243 ft bls consists of a pale to moderately yellow-brown, well-indurated dolostone with few evaporite minerals present, frequent bedding plane fractures, and moderate vuggy and moldic porosity. The few identifiable fossils consist of gastropods and bivalves. Solution-enhanced fractures and cavities were observed from 1,300 ft bls to the total depth of 1,400 ft bls in both the OBI log and core. Up to 5% evaporite minerals was observed from 1,330 to 1,353 ft bls; however, fractures and porosity within this interval were only partially filled with evaporites. Friable to moderately indurated interbeds up to 3 ft in thickness with up to 20% clay are present from 1,352 to 1,390 ft bls.

HYDROGEOLOGIC FRAMEWORK

Two major aquifer systems underlie this site within the Quaternary/Tertiary sequence, the SAS and FAS. The FAS is the primary focus of this investigation. Aquifers within the FAS are composed of multiple discrete zones of moderate to high permeability, many characterized by karst solution and fracturing. These productive zones are separated by lower permeability units of various degrees of confinement. The sub-units of the FAS are not consistently labeled in the literature. **Figure 5** presents a comparison of commonly used nomenclature.

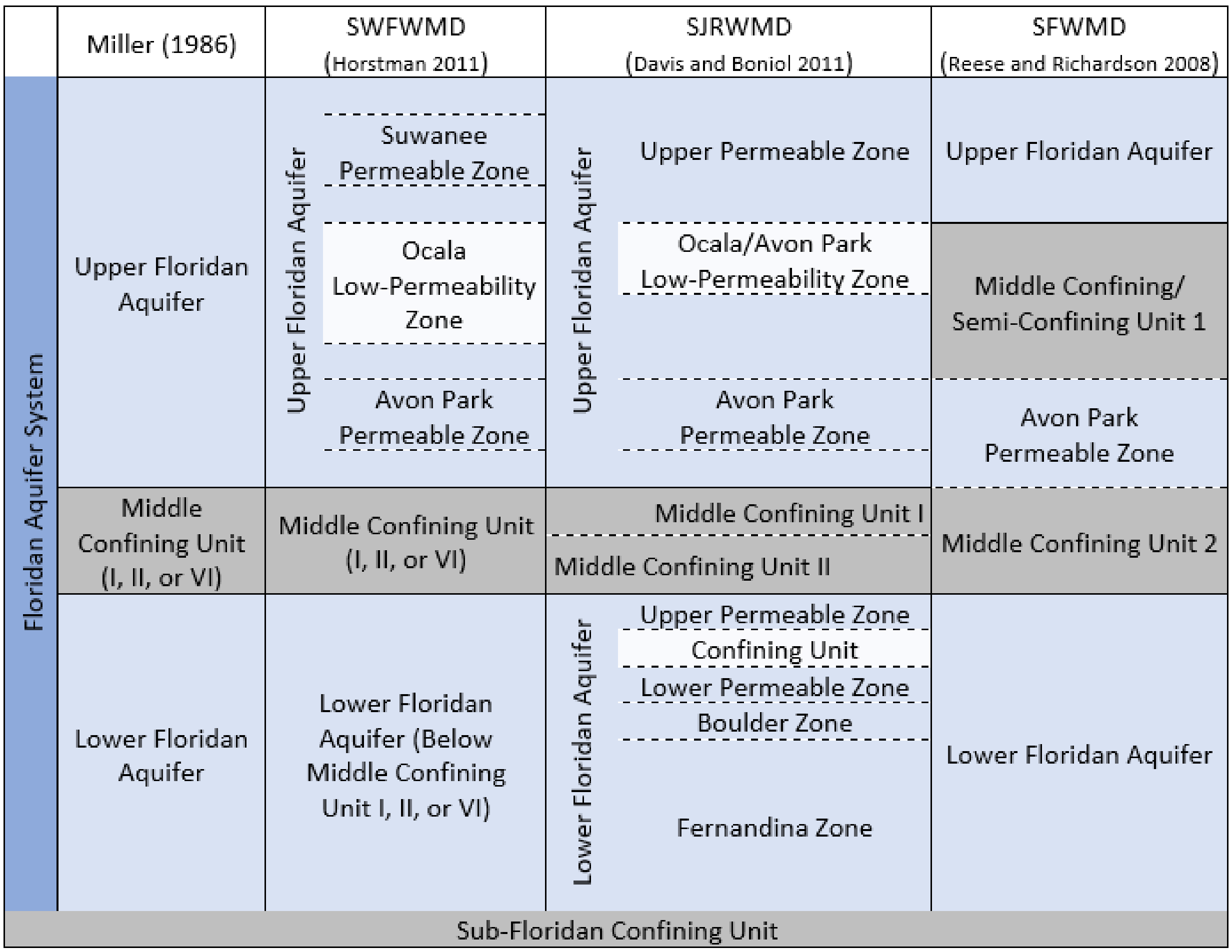

Figure 5. A nomenclature comparison of the hydrogeologic units of within the Floridan aquifer system.

To ensure consistency within the CFWI Planning Area, the cooperating water management districts agreed on a slightly modified hydrogeologic conceptualization (**Figure 6**) as the basis for development of the East Central Florida Transient Expanded (ECFTX) groundwater model, which is being used to evaluate groundwater availability in the region. As a component of the CFWI, this report will follow the same convention for the units intersected by the exploratory drilling. A representative hydrogeologic section, with hydrogeologic units conforming most closely to the S61 Locks site is presented in **Figure 7**.

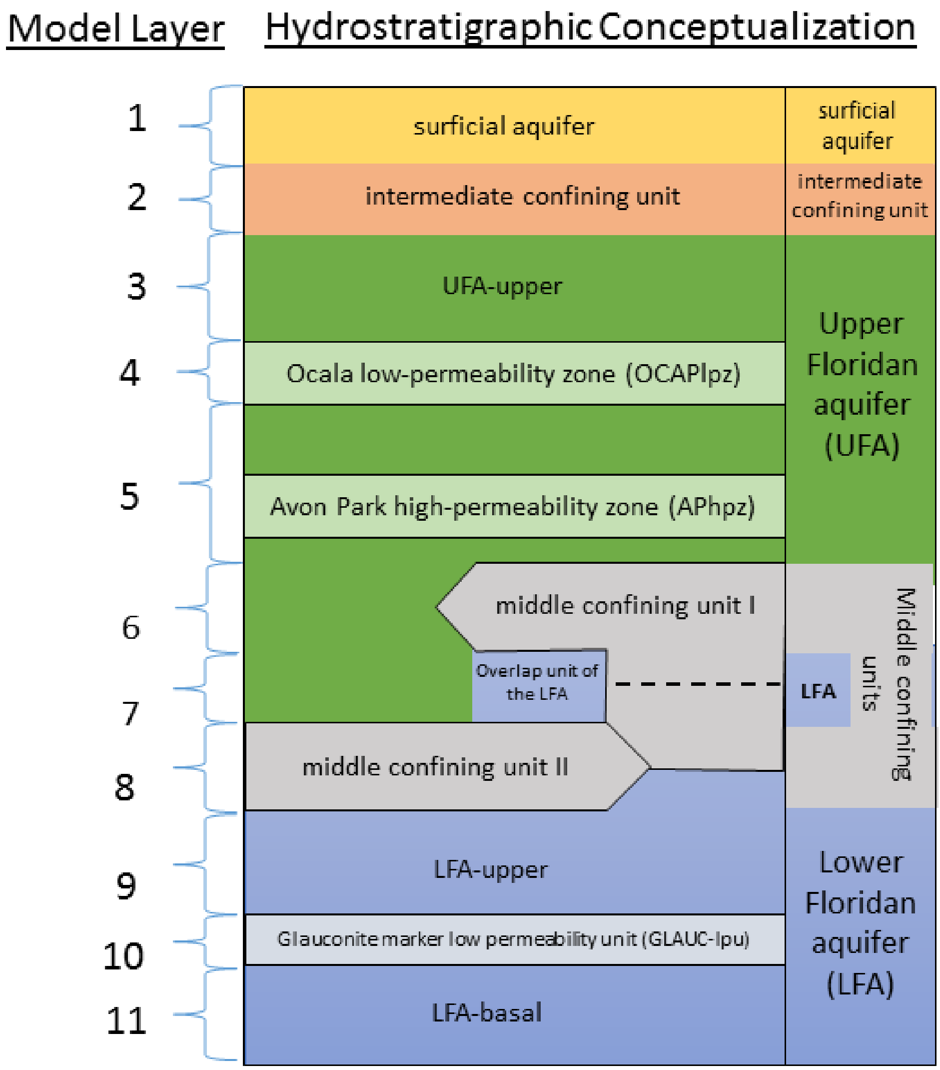

Figure 6. Hydrogeologic conceptualization and vertical discretization of the East Central Florida Transient Expanded model (From: CFWI Hydrologic Assessment Team 2016).

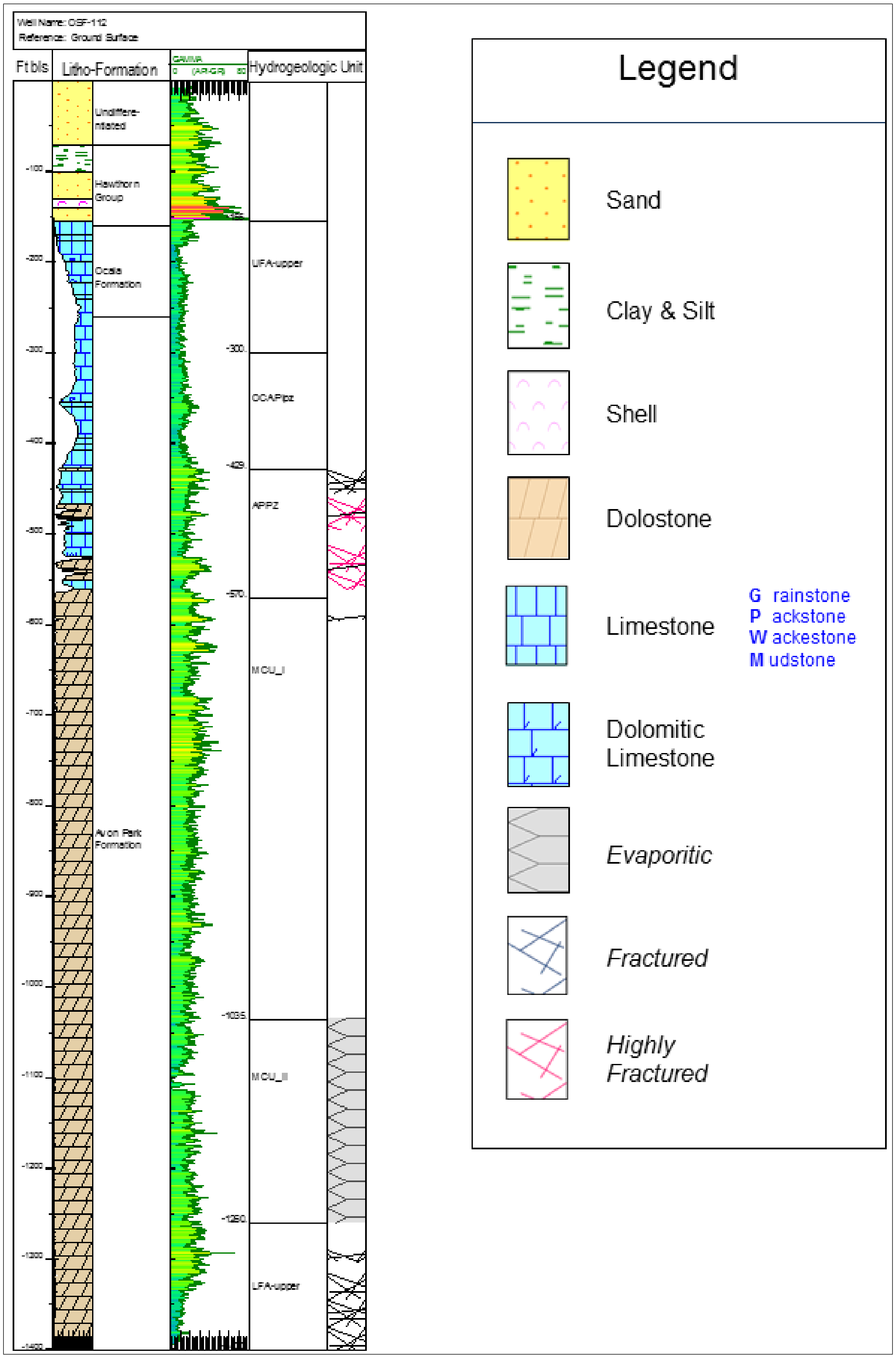

Figure 7. Representative hydrogeologic section for the S61 Locks site. Caliper log deviation from nominal corehole diameter is overlain on the lithologic column.

Surficial Aquifer System

The SAS at the S61 Locks site consists of unconsolidated sediments, predominantly fine to very-fine quartz sand with varying amounts of silt, clay, shell, and heavy minerals. The top of the Hawthorn Group often is selected as the base of the SAS, but lower permeability sediments frequently are found at much shallower depths, so the base of this unit is gradational. A base of 58 ft bls was selected based on persistent high clay content in the SPT samples below that point. An average hydraulic conductivity of 44 ft/day was calculated for this interval from sieve analysis results.

Intermediate Confining Unit

The intermediate confining unit separates the SAS from the FAS. At the S61 Locks site, the intermediate confining unit consists of a highly variable mix of olive-gray clay, quartz sand and silt with shell fragments, phosphatic wackestone, and up to 10% phosphatic sand. This unit was not expressly tested during drilling of OSF-112.

Floridan Aquifer System

The FAS consists of a series of Tertiary-age limestone and dolostone units. At the S61 Locks site, the FAS includes permeable sedimentary strata of the Hawthorn Group, Ocala Limestone, and Avon Park Formation. The base of the FAS occurs in the Paleocene Cedar Keys Formation, not penetrated at the S61 Locks site, which includes massive beds of gypsum and anhydrite (Miller 1986).

The hydrogeologic units within the FAS at the S61 Locks site were delineated based on the exploratory coring, drilling, and geophysical logging of well OSF-112; hydraulic and water quality analyses from 38 off-bottom packer tests conducted during the coring of OSF-112 (**Figure 8**); and previously gathered lithologic and geophysical log data from existing well OSF-53.

Upper Floridan Aquifer

The UFA generally occurs at the base of the Hawthorn Group, though it may include permeable units within the lower Arcadia Formation. It includes the Suwanee Limestone, where present; the Ocala Limestone; and portions of the Avon Park Formation. The UFA generally consists of several thin, highly permeable water-bearing zones interbedded with thicker zones of lower permeability. The CFWI Hydrologic Assessment Team (2016) used three regionally mappable units to represent the vertical heterogeneity of the UFA: UFA-upper, OCAPlpz, and Avon Park high permeability zone (APhpz).

UFA-upper (155 – 300 ft bls)

The UFA-upper is the uppermost permeable zone of the FAS. It is predominantly limestone and characterized by intergranular, vuggy, or moldic porosity and well-developed secondary porosity (Davis and Boniol 2011). The CFWI Hydrologic Assessment Team (2016) identified the top of the UFA-upper in well OSF-53 at a depth of 155 ft bls, the first occurrence of consolidated limestone below the clayey sands of the Hawthorn Group. At the S61 Locks site, the UFA-upper consists of moderately consolidated limestone, predominantly packstone-grainstone. A solutioned flow zone often is observed at its upper boundary, the contact between the Hawthorn Group and Ocala Limestone. This permeable zone presumably exists at the S61 Locks site but could not be confirmed, as the top 15 ft of the unit, being poorly consolidated, lies within the cased interval of both OSF-112 and OSF-53 and, therefore, could not be tested. Three packer tests were conducted within the UFA-upper, yielding hydraulic conductivity values ranging from 10 to 33 ft/day. Water quality from this interval is the freshest in the corehole, with total dissolved solids (TDS) concentrations less than 160 milligrams per liter (mg/L).

The UFA-upper is highly productive in the northern portion of the CFWI Planning Area, but that productivity tends to decline to the south. Reported transmissivity of the UFA-upper ranges from less than 10,000 to more than 100,000 ft^2/day within the greater central Florida area (CFWI Hydrologic Assessment Team 2016). A full aquifer performance test was not conducted on this interval, but based on the packer test results, transmissivity at this site is expected to fall within the low end of the reported regional range.

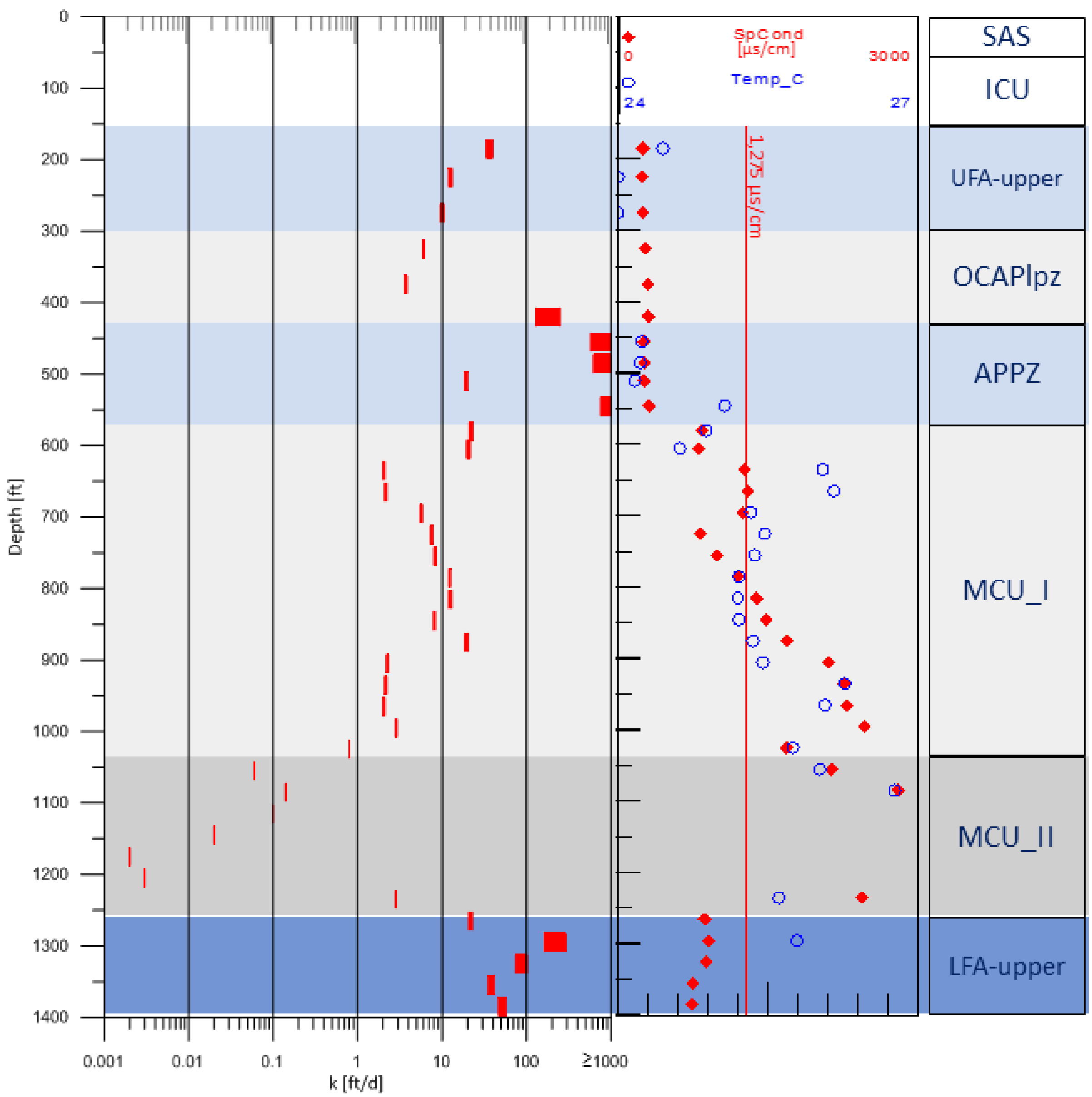

Figure 8. Variation in specific conductance (SpCond) and hydraulic conductivity (k) with depth, from off-bottom packer testing in exploratory corehole OSF-112. (Note: width of bars in the k plot indicates range of uncertainty in the calculated value.)

OCAPlpz (300 – 429 ft bls)

The OCAPlpz is distinguished from the UFA-upper by a reduction in the secondary permeability, which provides most of the productive capacity of that unit. At the S61 Locks site, the OCAPlpz comprises limestone (presented as interbedded mudstone), wackestone, and packstone. It tends to be less well consolidated than the overlying UFA-upper, indicated by large wash-outs on the caliper log (**Figure 7**). Based on packer test results, the OCAPlpz is of persistently lower permeability than the UFA-upper. Only packer tests 4 and 5 fall wholly within the OCAPlpz unit, and these yielded hydraulic conductivity estimates of 3 to 6 ft/day. Packer test water levels and preliminary data from the completed monitor wells (May 1 to July 2, 2018) show a slight decline (0.25 to 0.4 ft) across the OCAPlpz, which indicates it does provide some confinement capacity. Water quality in the OCAPlpz is very similar to the UFA-upper, but slightly more mineralized, reflecting a longer formation residence time.

APhpz (429 – 500 and 520 – 565 ft bls)/APPZ (429 – 570 ft bls)

Reese and Richardson (2008) described the APPZ as a regionally mappable, high-permeability zone within the Avon Park Formation, characterized by dolostone or interbedded dolostone and dolomitic limestone with a high degree of secondary permeability. The permeability primarily is associated with fracturing, but cavernous or karstic, intergranular, and inter-crystalline permeability also can be present. As mapped by Reese and Richardson (2008), the APPZ included all materials from the base of the OCAPlpz to the top of the MCU. The CFWI Hydrologic Assessment Team (2016) adopted the term Avon Park high-permeability zone (APhpz) to distinguish the most productive fractured intervals. Referring to **Figure 6**, the APPZ is equivalent to ECFTX model layer 5, and the APhpz is a subset of that unit.

At the S61 Locks site, the APPZ is composed of hard calcareous dolostone interbedded with less well-indurated limestone mudstone-grainstone. The upper boundary is at 429 ft bls (the first occurrence of fracture flow). Although the OCAPlpz does not constitute a significant confining unit at this location, there are distinctions in the ion chemistry between the APPZ and overlying units that imply limited hydraulic communication between them.

The APhpz consists of two discrete fractured zones at 429 to 500 ft bls and 520 to 565 ft bls, separated by 20 ft of less permeable rock. Estimated hydraulic conductivity within the two fracture sets exceeds 1,000 ft/day. The intervening 20-ft interval, which was discretely evaluated in packer test 9, yielded an estimated hydraulic conductivity of 10 ft/day. The hydraulic continuity of fracture sets within the APPZ has been a subject of some debate within the CFWI Planning Area. South of the S61 Locks site, the APPZ commonly consists of multiple discrete fracture zones separated by much less permeable rock. In most of the region, discrete head and water quality data are not available to assess the hydraulic continuity of these discrete zones. Consequently, some hydrogeologists combine the fracture zones into a single unit, while others split the unit and view the deeper fractured zone as part of the LFA. Such deviations account for some of the variability seen in the literature regarding the mapped thickness of this unit. There is some variation in the water quality results between the upper and lower fracture sets at OSF-112, indicating they probably were not in direct hydraulic communication at the site prior to pilot-hole coring. Water quality from the lower fracture set was somewhat enriched in calcium, magnesium, sulfate, and strontium compared to the upper set. These differences are slight, however, and there was no observable head difference between the upper and lower fracture sets during packer testing at OSF-112 to indicate significant confinement between them.

The base of the APPZ coincides with the top of the MCU, and its position at this site is not entirely clear. Reese and Richardson (2008) identified this boundary at 570 ft bls to coincide with the last influx to the pumped flow log at OSF-53. The CFWI Hydrologic Assessment Team (2016) lowered the position of this boundary to 818 ft bls to include what appeared to be a third fracture set in the caliper and porosity logs of

OSF-53. Although the data set was limited, the deeper depth also placed the base of the APPZ more in line with those in the closest deep wells to the south. Providing sufficient data to resolve this issue was one of the objectives of the exploratory corehole.

Fracturing between 770 and 820 ft bls was poorly developed, with hydraulic conductivity orders of magnitude lower and significantly different chemistry than the fractured rock above 570 ft bls. Packer tests 11 and 12 (570 to 620 ft bls) yielded hydraulic conductivity estimates of approximately 20 ft/day, a minor productive unit. There is, however, a very distinct break in the ion chemistry below 570 ft bls, which suggests waters below that depth are not mixing with the overlying unit. Based on these data, it was determined that the lower fracture set should not be included as part of the APPZ at this location.

Middle Confining Unit

The MCU divides the UFA and LFA. Miller (1986) defined the MCU and subdivided it into eight regional units designated by roman numerals I to VIII. The CFWI Hydrologic Assessment Team (2016) recognized two of these units (MCU_I and MCU_II) as composing the MCU within the ECFTX model domain. MCU_I, which ranges in lithology from dolostone to micritic limestone, is the leakier of the two units. The lithologic composition of MCU_II is more distinct. MCU_II is composed of hard crystalline dolostone to dolomitic limestone, characterized by the occurrence of evaporites as beds or pore in-fillings, which greatly reduces its permeability. MCU_I, the shallower unit, is absent from the western portion of the ECFTX model area, while MCU_II is absent from the eastern portion. Along the western reaches of the Kissimmee River valley and Lake Wales Ridge, the two units overlap each other, greatly increasing the thickness of the MCU in that region.

Prior to construction of OSF-112, regional mapping for the CFWI Hydrologic Assessment Team (2016) estimated the MCU_II would be absent at the S61 Locks site. Evaluating that prediction, which proved erroneous, was one of the objectives of the exploratory corehole.

MCU_I (570 – 1,034 ft bls)

MCU_I is the thickest defined unit at the S61 Locks site and also the most heterogeneous. In an update to Miller (1986), Williams and Kuniansky (2015) noted that many of the numbered MCU subsets were actually semi-confining and might encompass zones with hydraulic conductivity on the same order of magnitude as the aquifers above or below them. For that reason, Williams and Kuniansky (2015) elected to abandon the term “confining unit” for the MCU, replacing it with the term “composite unit” to indicate it could not be defined as either a confining unit or an aquifer across its entire extent. MCU_I clearly is a confining unit at the S61 Locks site, although it shows considerable hydraulic variability (**Figure 9**). In **Figure 9**, the first three columns are borehole geophysical data (caliper, porosity, and electric resistance); column four shows laboratory core permeability results; and column five shows packer test results. These data represent three different scales of investigation and help explain why MCU_I can be difficult to classify. As discussed in the previous section, the base of the APPZ/top of MCU_I was identified at 570 ft bls on the basis of water chemistry and a significant difference in permeability with the overlying fractured flow zone. The base of MCU_I was identified at 1,034 ft bls, where massive evaporites and very low permeability define the top of MCU_II. Fifteen discrete packer tests were conducted entirely within MCU_I. These ranged in horizontal hydraulic conductivity from 2 to 22 ft/day. In general, water levels decrease (see **Figure 21** at the end of this report) and water quality deteriorates with depth in MCU_I. The change in water quality is driven primarily by increasing sulfate content.

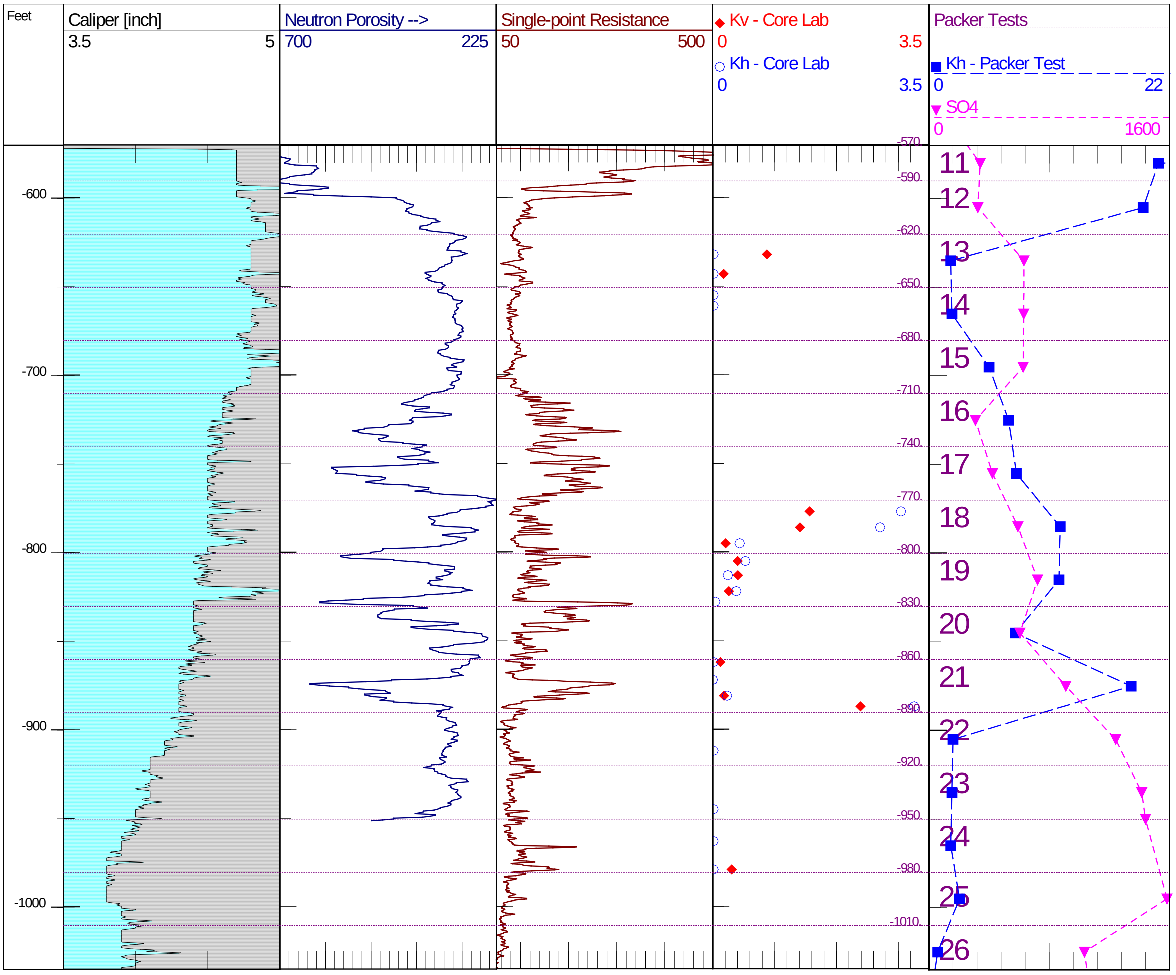

Figure 9. Geophysical log, core, and packer test data illustrating the heterogenous nature of MCU_I at the S61 Locks site.

As seen in **Figure 9**, the upper 50 ft of MCU_I (from 570 to 620 ft bls) are the most permeable based on packer test results. The interval exhibits horizontal hydraulic conductivity similar to the UFA-upper. However, it also contains some of the lowest porosity rock in the corehole, and all of its productive capacity appears to derive from two discrete fractures at 571 and 605 ft bls. There are insufficient data to determine the connectivity of those fractures beyond the corehole. If they are disconnected, vertical permeability across this interval should be the lowest in MCU_I.

The interval from 620 to 714 ft bls represents internal confinement within MCU_I, with packer-derived hydraulic conductivity estimates ranging from 1.2 to 1.3 ft/day. Heads in that zone are approximately 0.5 ft lower than the overlying APPZ and salinity is increased four-fold. The vertical permeability through this interval appears more restrictive than the packer-derived hydraulic conductivity values imply, as there is a brief freshwater inversion from 714 to 770 ft bls, with a distinct increase in static heads back to APPZ levels. Three laboratory core permeability analyses were conducted between 620 and 710 ft bls and yielded vertical permeability values from 0.008 to 0.87 ft/day, which supports the conclusion that good confinement exists within this interval of MCU_1.

The interval from 714 to 890 ft bls is characterized in the geophysical logs by alternating zones of higher electrical resistance coupled with low porosity, and intervals of lower electrical resistance coupled with higher porosity (**Figure 9**). Core lab analysis suggests the high-resistivity/low-porosity zones are confining intervals and resistivity is inversely proportional to matrix permeability within this interval. The two lowest vertical permeability samples at 828 and 872 ft bls were within high-resistivity/low-porosity intervals, with vertical permeabilities of approximately 1×10^{-6} and 6×10^{-6} ft/day, respectively, five orders of magnitude lower than the next nearest sample results. Total porosity results from those samples were 3% and 6%, respectively, while horizontal permeabilities were approximately 0.038 and 1×10^{-6} ft/day, respectively. The three samples with the highest vertical permeabilities were from depths of 777, 786, and 887 ft bls, each of which had relatively low resistivity/high porosity. In these samples, vertical permeability ranged from approximately 0.9 to 1.6 ft/day, total porosity ranged from 31% to 42%, and horizontal permeability ranged from approximately 2.7 to 3.3 ft/day.

This interval includes numerous bedding plane (horizontal) fractures without observable vertical fractures, suggesting fractures do not contribute to vertical transmission of fluid but, in combination with higher matrix porosity and permeability, may contribute to horizontal transmission. Vertical and horizontal transmission throughout this interval appear limited to the low-resistivity/high-porosity zones. The effect of this is a composite unit, a series of chemically and hydraulically isolated aquifer layers within a confining body of rock.

The most persistent zone of low permeability is near the base of the MCU_I. Packer testing from 890 to 1,010 ft bls yielded a permeability of approximately 2 ft/day. Density and x-ray diffraction (XRD) analysis of two core samples within the packer test 24 interval (950 to 980 ft bls) identified celestite, a sulfide mineral often associated with anhydrite and gypsum. Coupled with an increase in sulfates across the interval, this suggests the presence of evaporite minerals in quantities not visible to the naked eye; however, it is not known to what degree this could be contributing to the reduced permeability of this interval.

MCU_II (1,034 – 1,260 ft bls)

Evaporite minerals (e.g., gypsum, anhydrite, celestite), occurring as massive beds or nodules within a hard dolostone matrix, were visible and pervasive in the exploratory corehole from 1,034 to 1,260 ft bls. These minerals are characteristic of MCU_II and result in greatly reduced porosity within the matrix rock. Six discrete packer tests (27 to 32) occur entirely within MCU_II. These yielded hydraulic conductivity estimates of less than 0.1 ft/day, two orders of magnitude lower than the overlying MCU_I. The very low permeability of the rock prevented collection of water samples during packer testing, but specific conductance data from down-hole water quality sensors indicated continuance of the increasing salinity trend observed in MCU_I. Specific conductance of 2,800 microsiemens per centimeter (µS/cm) was measured in this portion of the formation.

As previously noted, regional mapping for the CFWI Hydrologic Assessment Team (2016) estimated MCU_II would be absent at the S61 Locks site. The occurrence of more than 200 ft of this evaporite-rich unit in OSF-112 was an unexpected result, which will necessitate re-mapping the eastern extent of MCU_II.

Lower Floridan Aquifer

LFA-upper (1,260 – Total Depth)

The top of the LFA was identified at 1,260 ft bls in conjunction with notable changes in permeability, water chemistry, and water level. The base of LFA-upper was below the depth of investigation and thus could not be determined from the corehole information. Estimated permeability from packer tests falling entirely within LFA-upper (34 to 38) ranged from 21 to 293 ft/day, three or more orders of magnitude higher than the overlying MCU_II rock. Lithologically, the two units are similar in that both are predominantly dolostone. Like MCU_II, evaporite minerals are present in LFA-upper but at much lower percentages. The permeability in LFA-upper is predominantly secondary, through vugs and fractures. Fracturing is pervasive from 1,260 ft to total depth, though less well developed than in the APPZ.

Water samples collected from LFA-upper (average TDS concentration of 517 mg/L) were much fresher than MCU_I (average TDS concentration of 1,533 mg/L), but ionically and isotopically distinct from UFA waters as well. Formation waters from LFA-upper are particularly enriched in sodium chloride relative to the UFA. Packer test results show an approximate 2-ft increase in static water levels across MCU_II, between MCU_I and LFA-upper, after adjusting for regional trends. Although the absence of discrete on-site monitor wells in UFA-upper and the APPZ during packer testing prevented direct calculation of the head gradient between the UFA and LFA, there appears to be a slight upward gradient at this location. **Figure 10** shows the median head gradient between the UFA and LFA around the S61 Locks site. The site occurs within a zone of transition between downward gradients to the west and upward gradients to the east.

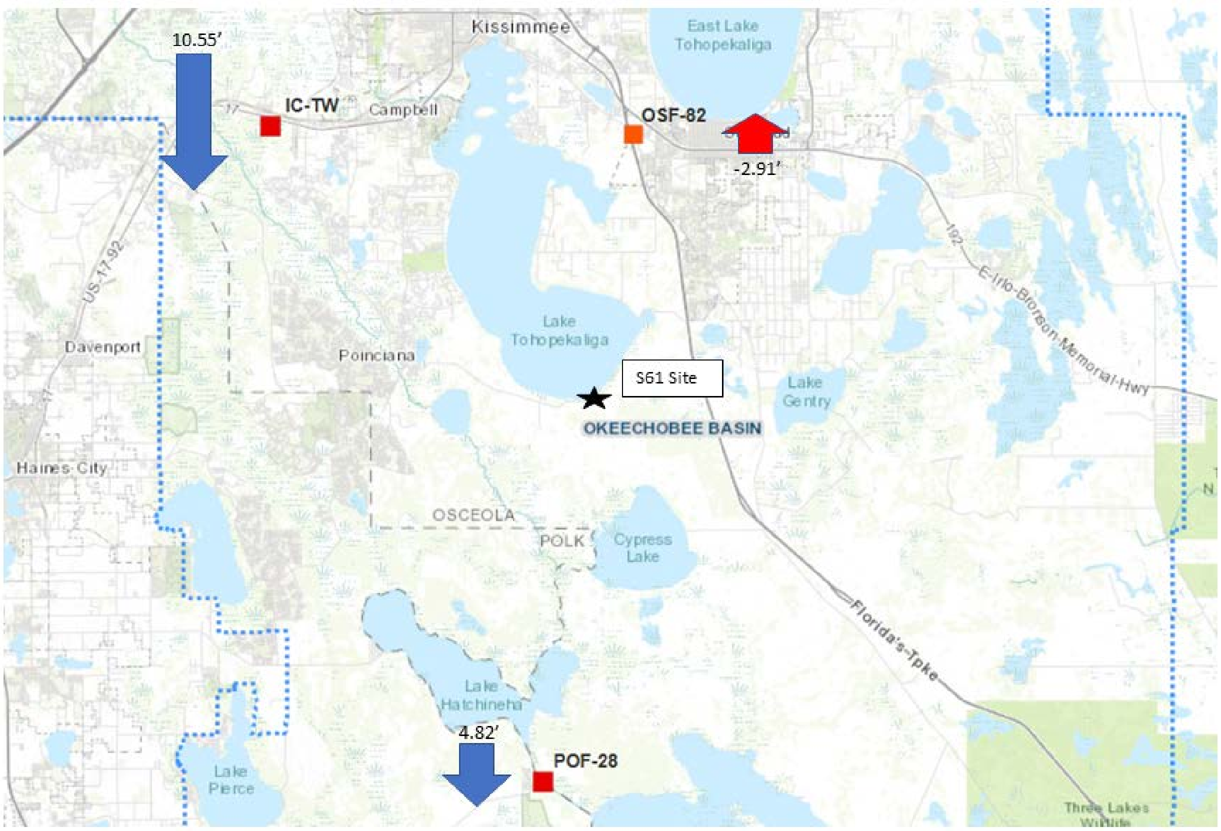

Figure 10. Median head differential between the Upper and Lower Floridan aquifers in the vicinity of the S61 Locks site. Arrows indicate gradient direction upward or downward at the red box location.

DISCUSSION

Exploratory drilling and coring at this site reached a maximum depth of 1,400 ft bls. Work at the S61 Locks site was completed in February 2018 and included:

- Exploratory wire-line coring, geophysical logging, hydraulic testing, and water quality sampling for the purpose of:
  - identifying hydrogeologic unit boundaries, and
  - evaluating variations in water quality and rock permeability with depth;
- Completion of the exploratory corehole as a permanent APPZ monitor well (OSF-112); and
- Modification of a previously existing but inactive monitor well (OSF-53) that originally was constructed with a long open-hole interval, to one that discretely monitors the upper permeable zone of UFA-upper. The modified monitor well is designated OSF-53R.

As a component of the CFWI DMIT project, it is important to review the results from the S61 Locks site in light of their potential impact to the understanding of the hydrogeologic framework as applied in the ECFTX groundwater model. Some findings were as expected, while others were surprising. Differences between interpreted hydrogeologic unit boundaries pre- and post-project are summarized in **Table 2**.

Table 2. Hydrostratigraphic comparison at the S61 Locks site, current report versus ECFTX model layering (From: CFWI Hydrologic Assessment Team 2016).

Hydrogeologic Unit	Current Report			ECFTX Model		
	Top	Base	Thickness (feet)	Top	Base	Thickness (feet)
ICU	52	155	103	41	155	114
UFA-upper	155	300	145	155	250	95
OCAPlpz	300	429	129	360	470	110
APPZ	429	570	141	470	818	348
MCU_I	570	1,035	465	818	1,259*	441
MCU_II	1,035	1,260	225	1,259*	1,259*	0
LFA-upper	1,260	No Data	No Data	1,259*	1,568*	309

APPZ = Avon Park permeable zone; ECFTX = East Central Floridan Transient Expanded; ICU = intermediate confining unit; LFA = Lower Floridan aquifer; MCU = middle confining unit; OCAPlpz = Ocala-Avon Park low-permeability zone; UFA = Upper Floridan aquifer.
Note: Top and Base values are presented in feet below land surface.
* Unit boundary interpolated from surfaces identified in deeper wells located offsite.

When the hydrostratigraphy was developed for the ECFTX model in 2016, the existing 980-ft deep well OSF-53 was the sole source of data for the S61 Locks site. Unit boundaries above 980 ft bls were identified based on the existing OSF-53 data set, while those below (shown with an asterisk in **Table 2**) were interpolated from surfaces identified in deeper wells located offsite. In the before and after comparison, there are minor differences in the boundaries of the shallow units (OCAPlpz and above), but nothing that would be of significance to the regional model.

A larger adjustment was made to the base of the APPZ unit. Packer test results from OSF-112 showed that what appeared to be a deeper fractured interval in the original OSF-53 data set was relatively unproductive with substantially different water chemistry. Based on new data from OSF-112, the base of the APPZ was raised 248 ft, reducing the overall thickness of the unit by 40%.

The top of the LFA derived from the exploratory coring and testing at the S61 Locks site deviated from the previously interpolated value by 1 ft. What was not expected, however, was that the LFA at this location was overlain by more than 200 feet of MCU_II, where previous interpolation of available data predicted the absence of MCU_II. Leakance across MCU_II is one to two orders of magnitude lower than MCU_I, which was anticipated. The S61 Locks site is less than 5 miles from the north end of the Toho Water Authority's (TWA) proposed Cypress Lakes wellfield, which is to be completed in LFA-upper. Although the TWA did not report the presence of MCU_II in its exploratory boreholes, the extent of its occurrence in OSF-112 makes it highly likely that some portion of MCU_II extends into the cone of influence for the proposed wellfield. In the interest of resolving the question of the eastward extent of MCU_II in central Osceola County, an additional site should be cored and tested near the wellfield.

Another unexpected result was the appearance of a slight upward head gradient from the LFA to the UFA. This is not completely surprising as the existing regional monitoring network indicates the S61 Locks site is in an area of transition between a strong downward gradient to the west and a clear upward gradient to the east. However, the gradient was expected to be downward, or close to neutral, at this location. Installation of a discrete monitor well within LFA-upper at the S61 Locks site, planned for a future fiscal year, will allow for more accurate assessment of head gradients between the various hydrogeologic units that make up the FAS at this site.

SITE DATA

Multiple classes of data were collected and analyzed to derive the stratigraphic and hydrogeologic frameworks for the S61 Locks site. Lithologic samples were collected using SPT, mud-rotary, and wire-line coring methods, then described and analyzed. Single (off-bottom) packer testing yielded hydraulic water quality and level information. The following sections summarize the methods and results yielded by each type of data collection and analysis effort.

Standard Penetration Testing

SPT was conducted at 2-ft intervals from land surface to 60 ft bls at OSF-112 to obtain representative sediment samples, determine the penetration resistance, and calculate hydraulic conductivity through mechanical (sieve) analysis.

Methodology

Collection of sediment samples by SPT (1.375 inches inner diameter × 2.0 inches outer diameter) involves dropping a 140-pound enclosed safety hammer 30 inches onto a thick-walled sample tube in order to drive the tube into the ground. Every strike from the hammer is a "blow" and the number of blows it takes to fill the sampler 25% and move the sampler 6 inches deeper is a blow-count (N_1, N_2, N_3, and N_4). Once the sample tube is filled with sediment, it is retrieved and labeled. ATSM Standard D1586-99, Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils, was followed to correlate SPT blow counts (N-value = $N_2 + N_3$) to penetration resistance over depth. The N counts in this investigation have not been corrected or compensated for overburden pressures. The greater the N-value, the greater the resistance.

Samples were transported to the office where the lithology was described. Mechanical sieve analysis was conducted in the laboratory on the interior 12 inches of sediment from every sample. This representative sample was prepared in a drying oven overnight at 100°C and shaken for 15 minutes to optimally separate particles of different sizes through a series of eight graduated sieves. Each sieve was weighed and the tare (i.e., weight of the sieve) was subtracted to give the weight of the sample with that specific grain size. Using the method described in Kasenow (1997), the weight by percent of sediment from each sieve was plotted on a cumulative frequency graph and a curve was fitted to determine the effective grain size.

Sieve data were processed through MVASKF software (Vukovic and Soro 1992). The software uses 10 empirical formulas to calculate hydraulic conductivity, including Hanzen, Slichter, Beyer, Sauerbrei, and Zunker. Some samples did not have the right distribution of weight by percent sediment, or a curve on the cumulative frequency graph to meet the defining assumptions for all formulas. MVASKF flags each formula as either pass or fail, depending on this requirement, and takes an average of the resultant hydraulic conductivity values from the passing formulas to produce a mean hydraulic conductivity for the sample.

Penetration Resistance and Hydraulic Conductivity Results

Results of the SPT and sieve analysis are summarized in **Table 3** and presented graphically in **Figure 11**. The N-values appear to be randomly distributed with depth and do not show any clear relationship to the hydraulic conductivity or Folk classification. Sediment samples from OSF-112 indicate resistance to penetration is fairly uniform from the surface to 60 ft bls. An increase in resistance between 20 and 30 ft bls could be attributed to less clay content. N-values at 22, 24, and 28 ft bls have higher values and approximately 20% clay, while the N-value at 26 ft bls is closer to mean data with 30% clay content.

The change in hydraulic conductivity is more apparent than the penetration resistance with increasing depth. From 6 to 14 ft bls, hydraulic conductivity is trending upward, starting at 42 ft/day and increasing steadily to 53 ft/day. Data are slightly variable but show a steady decrease in hydraulic conductivity at a rate of 0.74 ft/day from the surface to 60 ft bls, excluding the interval from 6 to 14 ft bls.

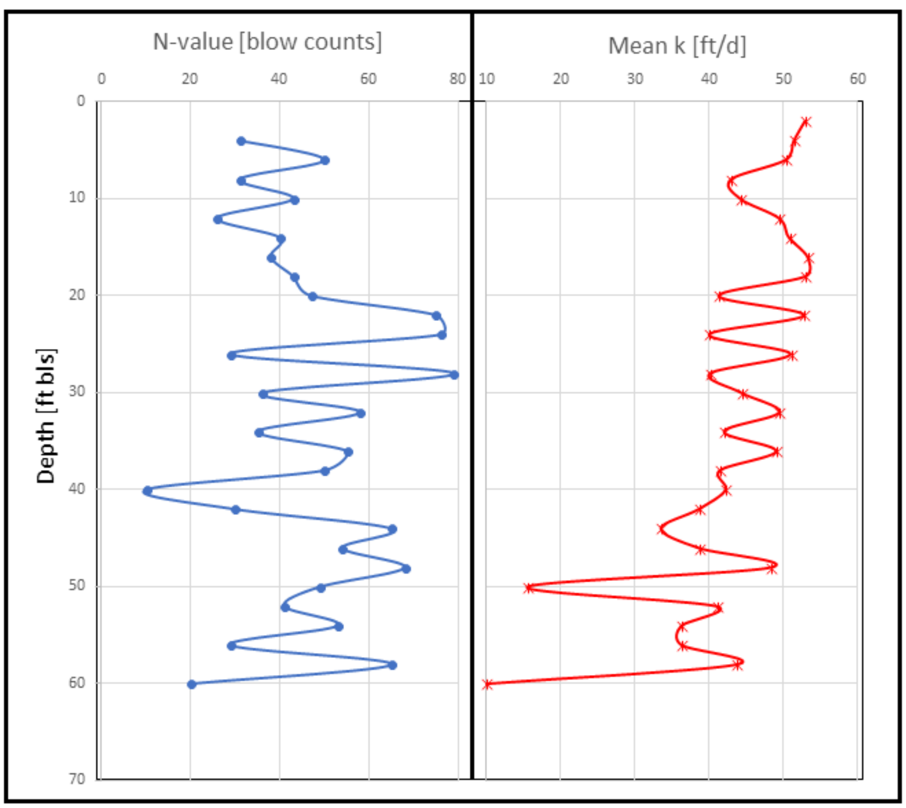

Figure 11. N-value and mean hydraulic conductivity for each 2-foot split-spoon sample.

Table 3. Summary results from standard penetration test and sieve analysis of unconsolidated sediments in the surficial aquifer system.

Depth (feet bls)	N-Value ($N_2 + N_3$)	Mean Hydraulic Conductivity (feet/day)	Folk Classification
2	--	53.0	Moderately well sorted
4	31	51.5	Moderately well sorted
6	50	50.3	Moderately well sorted
8	31	43.0	Extremely poorly sorted
10	43	44.2	Moderately well sorted
12	26	49.5	Well sorted
14	40	50.8	Well sorted
16	38	53.3	Moderately well sorted
18	43	53.0	Moderately well sorted
20	47	41.3	Extremely poorly sorted
22	75	52.8	Well sorted
24	76	40.0	Moderately well sorted
26	29	51.0	Moderately well sorted
28	79	40.1	Extremely poorly sorted
30	36	44.4	Extremely poorly sorted
32	58	49.5	Moderately well sorted
34	35	42.0	Well sorted
36	55	49.1	Moderately well sorted
38	50	41.5	Well sorted
40	10	42.2	Well sorted
42	30	38.6	Well sorted
44	65	33.5	Extremely poorly sorted
46	54	38.7	Extremely poorly sorted
48	68	48.3	Moderately well sorted
50	49	15.5	Extremely poorly sorted
52	41	41.0	Extremely poorly sorted
54	53	36.3	Extremely poorly sorted
56	29	36.3	Extremely poorly sorted
58	65	43.7	Moderately well sorted
60	20	10.0	Extremely poorly sorted

bls = below land surface.

Packer Testing

Thirty-eight packer tests were conducted during continuous coring operations of OSF-112 to determine changes in productive capacity, formation water quality, and water levels with depth. Packer testing methods, analyses, and results are summarized here. **Appendix D** provides additional details.

Methods

Figure 12 illustrates the setup used for OSF-112 packer testing operations. When the corehole had been advanced to a depth selected for testing, the driller pulled up the core casing from total depth to the top of the selected test interval. The test interval was air-developed for a minimum of 1 hour to remove rock detritus and water not native to the selected test interval. After development, the packer assembly was lowered into place, followed by the submersible pump in the annular space above it. Once water levels equilibrated, the packer elements were inflated.

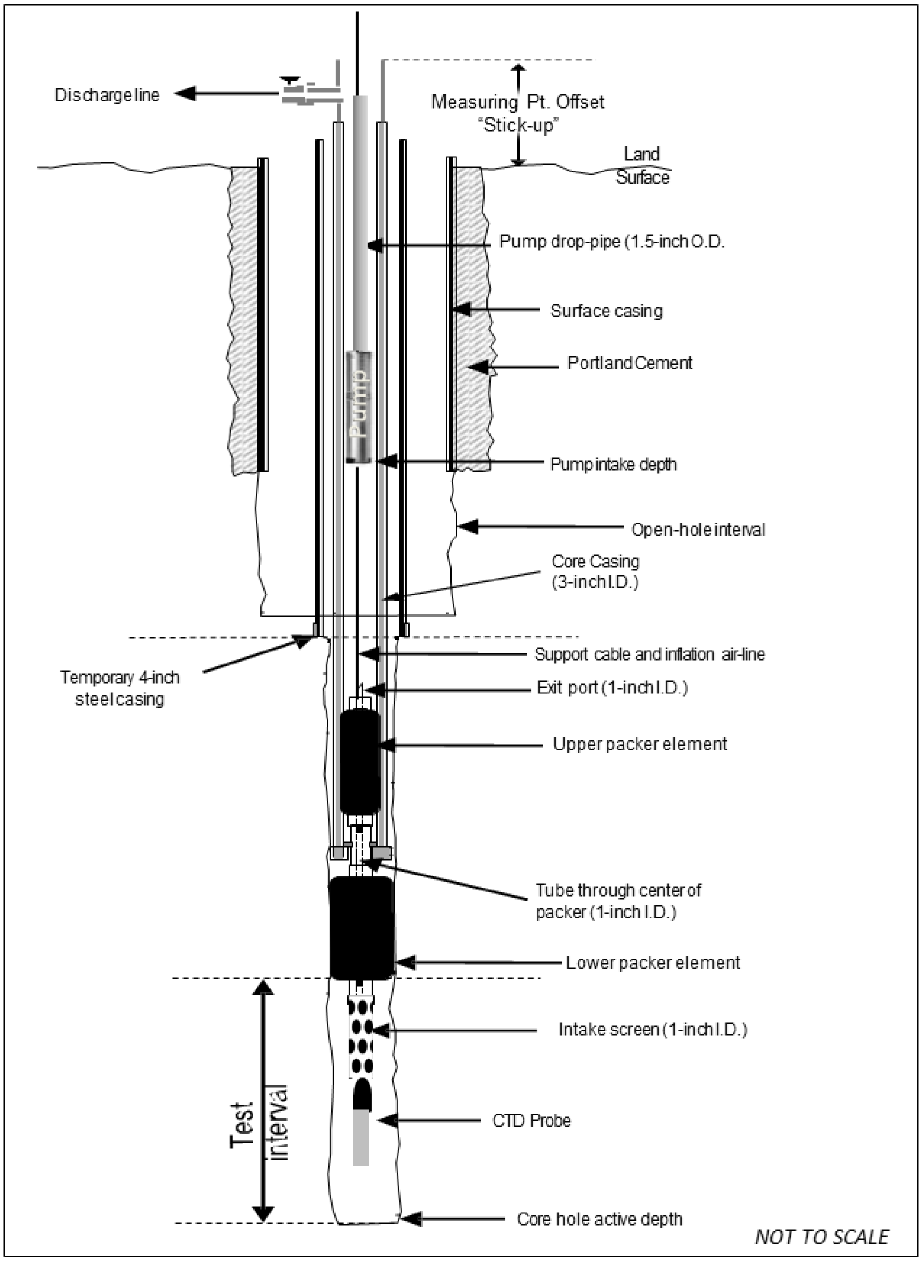

Figure 12. Generalized components of the packer test setup used in OSF-112.

The narrow (3-inch) diameter of the core casing did not allow sufficient space to accommodate a pressure transducer after the pump, drop-pipe, and associated electrical cabling were in place. Therefore, DTW readings were collected manually using an electric DTW tape. Readings were collected at 1-minute intervals for the first 5 minutes of both the drawdown and recovery portions of the test, and at 5-minute intervals thereafter. The packer assembly was configured so a conductivity, temperature, and depth (CTD) probe could be attached below the bottom packer, providing those parameters from directly within the tested interval for select tests.

Standard procedure for each test was to pump three complete corehole volumes at a maximum producible rate (typically 4 to 30 gpm), collect a sample for water quality analysis, then shut down the pump and monitor until water levels re-stabilized. For test intervals in which low-permeability rock did not allow removal of three corehole volumes of water, pumping would continue until both drawdown and water quality (temperature, pH, and specific conductance) were stabilized, or until water levels declined below pumpable levels. Configuration specifics for each test are summarized in **Table 4**, with deviations from standard procedure noted in the comments.

Table 4. Packer test configuration summary.

Test #	Date	Water Quality Sample ID	Test Interval (ft bls)		Q (gpm)	Pumping Duration (hh:mm)	Stick-up* (ft)	Comments
			From Depth	To Depth				
1	20-Oct-17	P90746-2	170	200	27	0:45	2.15	
2	24-Oct-17	P91174-2	200	250	30	0:55	2.37	
3	24-Oct-17	P91174-3	250	300	28	0:30	2.19	
4	25-Oct-17	P91560-2	300	350	30	0:35	2.48	
5	26-Oct-17	P91561-2	350	400	24	0:39	2.24	
6	31-Oct-17	P91692-2	400	440	28	0:33	2.28	
7**	31-Oct-17	P91692-3	440	470	28	0:35	2.30	
8**	1-Nov-17	P91684-2	470	500	28	0:37	2.04	
9**	1-Nov-17	P91684-3	500	520	22	0:47	2.14	
10	6-Nov-17	P91685-2	520	570	22	1:00	2.14	
11	7-Nov-17	P91686-2	570	590	22	1:00	2.03	
12	7-Nov-17	P91686-3	590	620	28	0:45	2.09	
13	8-Nov-17	P91563-2	620	650	8.5	1:15	2.01	½ standard purge volume
14	9-Nov-17	P91687-2	650	680	8.5	1:20	2.02	½ standard purge volume
15	10-Nov-17	P91688-2	680	710	16	1:30	2.17	
16	13-Nov-17	P91689-2	710	740	18	1:10	2.18	
17	14-Nov-17	P91690-2	740	770	18	1:06	2.05	
18	15-Nov-17	P91700-2	770	800	30	0:55	2.08	
19	16-Nov-17	P91701-2	800	830	19	1:29	2.11	
20	16-Nov-17	P91701-3	830	860	23	1:00	2.00	
21	27-Nov-17	P91702-2	860	890	27	1:05	2.20	
22	28-Nov-17	P91703-2	890	920	8	1:40	2.06	½ standard purge volume
23	29-Nov-17	P91704-2	920	950	8	1:45	2.00	½ standard purge volume
24	30-Nov-17	P91705-2	950	980	8	1:57	2.44	½ standard purge volume
25	1-Dec-17	P91706-2	980	1010	10	1:40	2.22	½ standard purge volume
26	4-Dec-17	P91707-2	1010	1040	4	1:25	2.16	$^1/_6$ standard purge volume
27**	5-Dec-17	--	1040	1070	4	0:04	1.99	No sample, pumped dry
28**	6-Dec-17	--	1070	1100	4	0:05	1.95	No sample, pumped dry
29	7-Dec-17	--	1100	1130	4	0:05	2.16	No sample, pumped dry
30	12-Dec-17	--	1130	1160	4	0:04	2.13	No sample, pumped dry
31	13-Dec-17	--	1160	1190	4	0:04	2.08	No sample, pumped dry
32	15-Dec-17	--	1190	1220	4	0:04	2.19	No sample, pumped dry
33**	19-Dec-17	P91709-2	1220	1250	12	1:55	1.99	½ standard purge volume
34**	20-Dec-17	P91710-2	1250	1280	30	1:30	2.14	
35	21-Dec-17	P91711-2	1280	1310	30	1:25	2.03	
36	3-Jan-18	P91712-2	1310	1340	30	1:40	2.03	
37	4-Jan-18	P91713-2	1340	1370	30	1:30	2.15	
38	5-Jan-18	P91714-2	1370	1400	30	1:38	2.19	

ft = feet; ft bls = feet below land surface; gpm = gallons per minute; hh:mm = hours:minutes; Q = rate of discharge.
* Stick-up is the offset distance (in feet) of the depth-to-water measuring point from land surface.
** Conductivity, temperature, and depth data are available for the test.

Hydraulic Analysis

To estimate the hydraulic properties of the geologic formation from the packer tests, well loss components of the measured drawdown, such as those caused by turbulent flow into the packer intake screen or friction losses in the packer pipe (1-inch diameter) and core casing (3-inch diameter), needed to be eliminated. The Hazen-Williams equation (Finnemore and Franzini 2002) was used to calculate the pressure loss due to friction in the pipes (**Table 5**). A conversion factor of 2.31 ft of water per pound per square inch of pressure was used to convert to consistent drawdown units.

$$P_d = L \, \frac{4.52Q^{1.85}}{C^{1.85} \, d^{4.865}}$$

Where:

P_d = pressure drop due to friction loss over the length of pipe (pounds per square inch)
L = length of pipe (ft)
Q = discharge rate (gpm)
C = pipe roughness coefficient
d = inside pipe diameter (inches)

Table 5. Pipe information for well-loss calculations using the Hazen-Williams equation.

Pipe Section	Inner Diameter (inches)	Length (feet)	Roughness Coefficient*
Core Casing	3.00	Top of Test Interval - DTW	140
Packer Assembly	1.00	9.0	150

* Hazen-Williams coefficients for unlined steel 140-150 sourced from Engineering ToolBox (retrieved June 6, 2018).

The intake screen below the packer assembly was fabricated by the driller to facilitate use of the CTD probe. Because this test assembly was configured in the field from various components, head losses due to changes in the flow into this custom-designed device were most easily estimated empirically. Thus, packer test 18 was run as a step-drawdown test at four rates, ranging from 3 to 30 gpm. Upon completion of this test, the packer assembly was removed from the borehole and the intake screen was removed from the packer assembly. The packers were then reset, and the test was run again at the same step rates. A third-order polynomial trendline was fitted to the resultant points of head difference (with and without screen) versus pumping rate for the two tests (**Figure 13**). The equation of that line was used to estimate head losses due to the intake screen for other pumping rates.

Total well losses were estimated as the sum of the friction losses across the packer assembly, core casing, and intake screen (see **Appendix D** for example calculation). For tests in which data were available from the CTD probe, drawdown calculated from the measured pressure change was used as a backcheck on the well-loss estimates. The CTD probe was situated directly within the open formation, so its measurements were not subject to the effects of well losses across the testing assembly. Because of this position, the CTD data best represent the actual formation drawdown but have some limitations.

The CTD probe was outfitted with a highly sensitive pressure sensor with an accuracy of 0.01% and a precision of up to 0.002% of its full pressure range. To operate across the complete depth of the FAS, a large pressure range is required. The CTD probe was outfitted with a 100-bar (1,450.38 pounds per square inch) pressure transducer. Given the water density encountered in OSF-112, this equates to a rated accuracy of ±0.335 ft and a precision of 0.067 ft. The manual DTW readings, by contrast, have an expected accuracy of at least 0.1 ft and a precision of 0.01 ft.

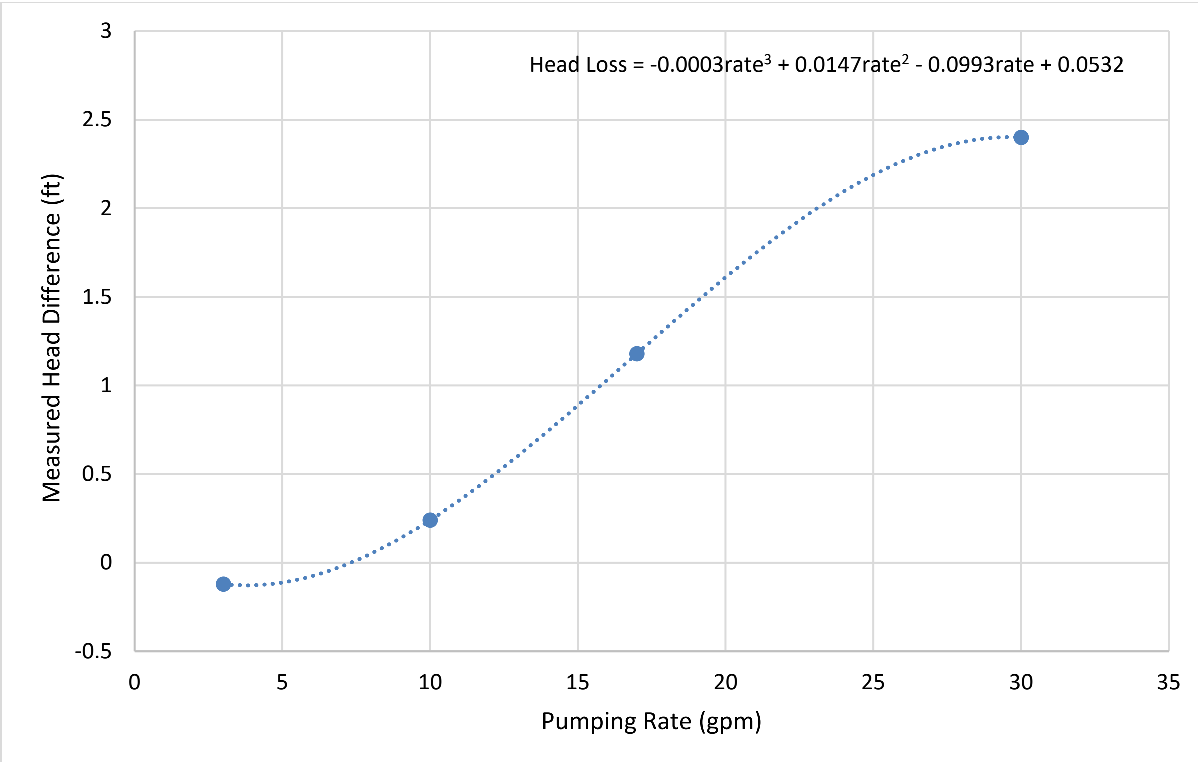

Figure 13. Measured head loss due to the intake screen at different rates of pumping.

Calculated well losses for the 38 packer tests ranged from 0.18 to 11.14 ft, depending on the pumping rate and depth of the tested interval. If the CTD data represent the true formation drawdown, the error in the estimated well losses in five tests, for which comparison is available, ranged from -0.30 ft (within the CTD error range) to 1.32 ft. The reasons for this range of discrepancy are not certain. Given that the differences were highest in the more productive units, it could be related to well losses due to turbulent flow, which are not compensated for with the Hazen-Williams correction. Negative values are overestimates and positive values are underestimates, with the tendency towards underestimation. For the most part, this range of error does not have a strong impact on the subsequent hydraulic conductivity calculations; however, when the measured drawdowns are small (i.e., in the most productive intervals), the hydraulic conductivity could be significantly underestimated.

After head-loss corrections were made, hydraulic properties were estimated from the drawdown data using an empirical formula presented by Driscoll (1986). This formula estimates transmissivity in a confined aquifer based on specific capacity as:

$$T = \frac{Q}{s} * 2000$$

Where:

T = transmissivity (gallons/day/ft)
Q = pumping rate (gpm)
s = drawdown (ft)

After converting transmissivity to square-feet per day units, the hydraulic conductivity was calculated as:

$$k = \left(\frac{T}{b}\right)$$

Where:

k = hydraulic conductivity (ft/day)
b = thickness of the tested interval (ft)

For six tests (27 to 32), the water levels dropped to the pump intake level after less than 5 minutes of withdrawal at a pumping rate of 4 gpm. The drawdown data from these tests are not valid for analysis, as the results are more a reflection of the depth of the pump than the permeability of the formation. This is illustrated in **Figure 14**, which shows the rate of water level recovery for each test after cessation of pumping. The drawdown for all tests was the same, but after 30 minutes, water level recovery varied from 6% to 65%. Because the drawdown was near instantaneous relative to recovery rate, these tests can be treated as slug-out or bail tests. Consequently, recovery data from these tests were analyzed in AQTESOLV Pro (v.4.5) software (Duffield 2007) using a slug test analytical method developed by the Kansas Geological Survey (Hyder et al. 1994).

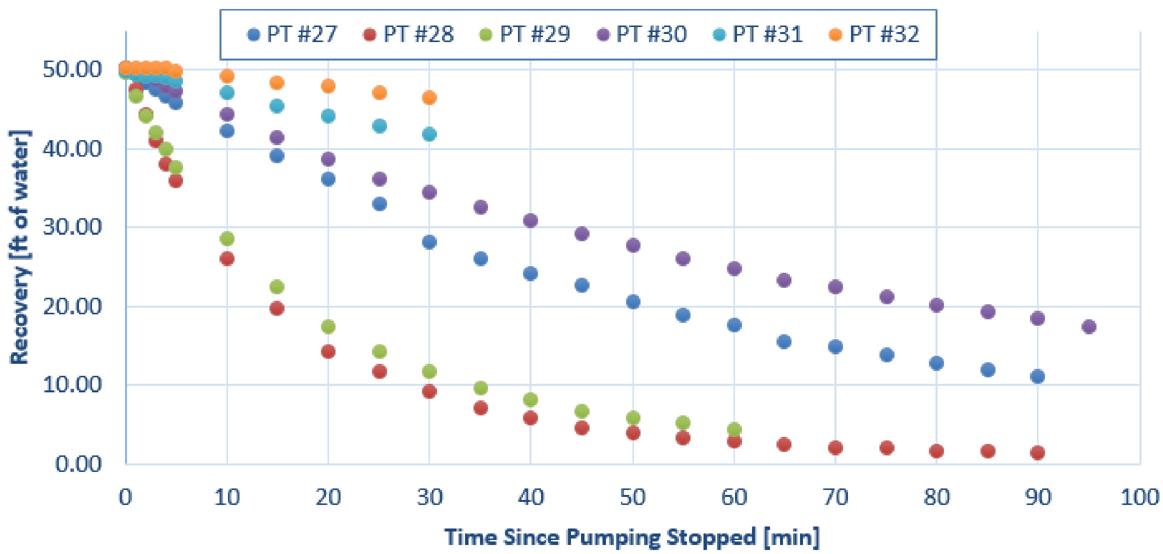

Figure 14. Rates of water level recovery from tests that rapidly pumped dry.

Hydraulic Analysis Results and Discussion

Results from the hydraulic analysis are summarized in **Table 6**. The table shows the maximum drawdown from the manual DTW data for each test after correction for estimated head losses not related to the formation, the measured drawdown from the CTD probe for tests in which CTD data were available, and the resultant hydraulic conductivity. Estimated hydraulic conductivity varies by six orders of magnitude in OSF-112, from as little as 0.001 ft/day in the evaporitic MCU_II to more than 1,000 ft/day in the fractured dolostones of the APPZ. Where both DTW and CTD data are available, they are not always in close agreement, due to uncertainty in the estimated head losses and, to a lesser extent, the drawdown measurements themselves. **Table 6** specifies the tests for which uncertainty in the drawdown could have a notable effect on the resultant hydraulic conductivity.

The smaller the actual drawdown, the greater the impact of any error in the drawdown measurement. This is illustrated in **Table 7**, which examines the range in hydraulic conductivity estimates due to the accuracy of the pressure readings from the CTD probe. The CTD drawdown measurements have a measurement uncertainty range of 0.67 ft (measurement accuracy of ±0.335 ft). This possible drawdown measurement error is a fixed value and a function of the probe sensitivity, but the significance of this error to the estimated hydraulic conductivity varies. For large drawdowns (e.g., tests 9, 34, and 35), a measurement uncertainty range of 0.67 ft yields uncertainty in hydraulic conductivity ranging from 0.5 to 1.29 ft/day, an insignificant variation. Where the measured drawdown is close to the minimum measurable value of the probe (e.g., tests 7 and 8), the resulting range in hydraulic conductivity varied by almost an order of magnitude, a significant variation.

As noted in the previous section, the largest source of uncertainty is the error associated with correcting the measured drawdown for well losses. Unlike error related to instrumentation accuracy, error in the well loss estimate can vary from test to test. Driscoll (1986) listed numerous factors that lead to well losses, including roughness of the pipe wall, pipe diameter, flow velocity, density and viscosity of the water, directional changes in the flow path, obstructions in the flow path, and any change in the cross-sectional area or slope of the flow path. The Hazen-Williams analysis accounts for losses due to the diameter and roughness of the pipe, which generally are the largest percentage of the loss in piping systems (Driscoll 1986). The other factors, though smaller, can be difficult to quantify. A comparison between drawdown estimated from the corrected DTW data with that from the CTD data indicates the range of uncertainty that might be expected in these estimates (-0.3 to 1.3 ft). What makes a drawdown error significant is not the absolute value, but the effect it would have on the resulting hydraulic conductivity estimate. With that in mind, the following approach is offered as a tool for evaluating the reliability of the packer test results.

The percent error in a hydraulic conductivity estimate for well loss errors ranging from 0.3 to 1.3 ft was calculated for a total test drawdown ranging from 1.31 (to avoid negative numbers) to 50 ft (**Figure 15**). The figure shows that if the drawdown is 15 ft or greater, the estimated error for hydraulic conductivity should never exceed 10%. Between 5 and 15 ft of drawdown, there is greater uncertainty, with potential errors up to 25%. Tests with maximum drawdown of less than 5 ft yield highly uncertain results. These low-drawdown tests are from the most productive units: the APPZ and LFA-upper. This illustrates the difficulty of properly assessing productive units within small-diameter boreholes. The CTD probe and below-packer measurement method offer some improvement in limiting the percent error in hydraulic conductivity estimates due to uncertainty in the formation drawdown to 25% or less.

Table 6. Summary of results from the hydraulic analysis.

Test #	Hydrogeologic Unit	Drawdown (ft)		Head Loss Correction Error (ft)	Hydraulic Conductivity (ft/day)		Solution Method
		DTW	CTD		DTW	CTD	
1	UFA-upper	7.25			33.5		Driscoll (1986)
2	UFA-upper	13.45			11.9		
3	UFA-upper	15.53			9.6		
4	OCAPlpz	27.13			5.9		
5	OCAPlpz	35.34			3.6		
6*	APPZ	1.43			130		
7*	APPZ	1.17	0.10	1.07	213	2,481	
8*	APPZ	1.39	0.07	1.32	180	3,722	
9	APPZ	15.92	15.59	0.33	18.5	18.9	
10*	APPZ	0.16			750		
11	MCU_I	14.00			21.0		
12	MCU_I	12.72			19.6		
13	MCU_I	37.03			2.0		
14	MCU_I	35.67			2.1		
15	MCU_I	25.90			5.5		
16	MCU_I	22.03			7.3		
17	MCU_I	19.99			8.0		
18	MCU_I	22.37			12.0		
19	MCU_I	14.28			11.9		
20	MCU_I	25.93			7.9		
21	MCU_I	13.02			18.5		
22	MCU_I	32.32			2.2		
23	MCU_I	33.78			2.1		
24	MCU_I	35.28			2.0		
25	MCU_I	31.83			2.8		
26	MCU_I	45.13			0.8		
27	MCU_II	50.06			0.06		Hyder et al. (1994)
28	MCU_II	49.94			0.14		
29	MCU_II	49.49			0.1		
30	MCU_II	50.09			0.02		
31	MCU_II	49.60			0.003		
32	MCU_II	50.01			0.002		
33	MCU_II to LFA-upper	38.80	39.10	-0.30	2.8	2.7	Driscoll (1986)
34	LFA-upper	12.98	11.79	1.19	20.6	22.7	
35*	LFA-upper	1.64			163		
36*	LFA-upper	3.60			74.3		
37	LFA-upper	7.57			35.3		
38	LFA-upper	5.76			46.4		

* Uncertainty in the drawdown could result in a significant underestimate of hydraulic conductivity.

Table 7. Variation in estimated hydraulic conductivity from CTD probe data as a function of the measurement accuracy (±0.335 feet) of the CTD pressure sensor.

Packer Test #	CTD Drawdown Range (feet)			Hydraulic Conductivity (feet/day)			
	Measured	(+) 0.335	(-) 0.335	Measured Drawdown	Drawdown (+) 0.335	Drawdown (-) 0.335	Range
7	0.10	0.44	<0*	2,481	573	3,722	3,149
8	0.07	0.40	<0*	3,722	621	3,722	3,101
9	15.59	15.93	15.26	18.87	18.47	19.28	0.81
34	39.10	39.44	38.77	2.74	2.71	2.76	0.05
35	11.79	12.13	11.46	22.68	22.05	23.34	1.29

CTD = conductivity, temperature, and depth.
* Low end of the error yields negative drawdown, so an assumed drawdown of 0.067 feet, the minimum measurable value, is used for resulting hydraulic conductivity estimate.

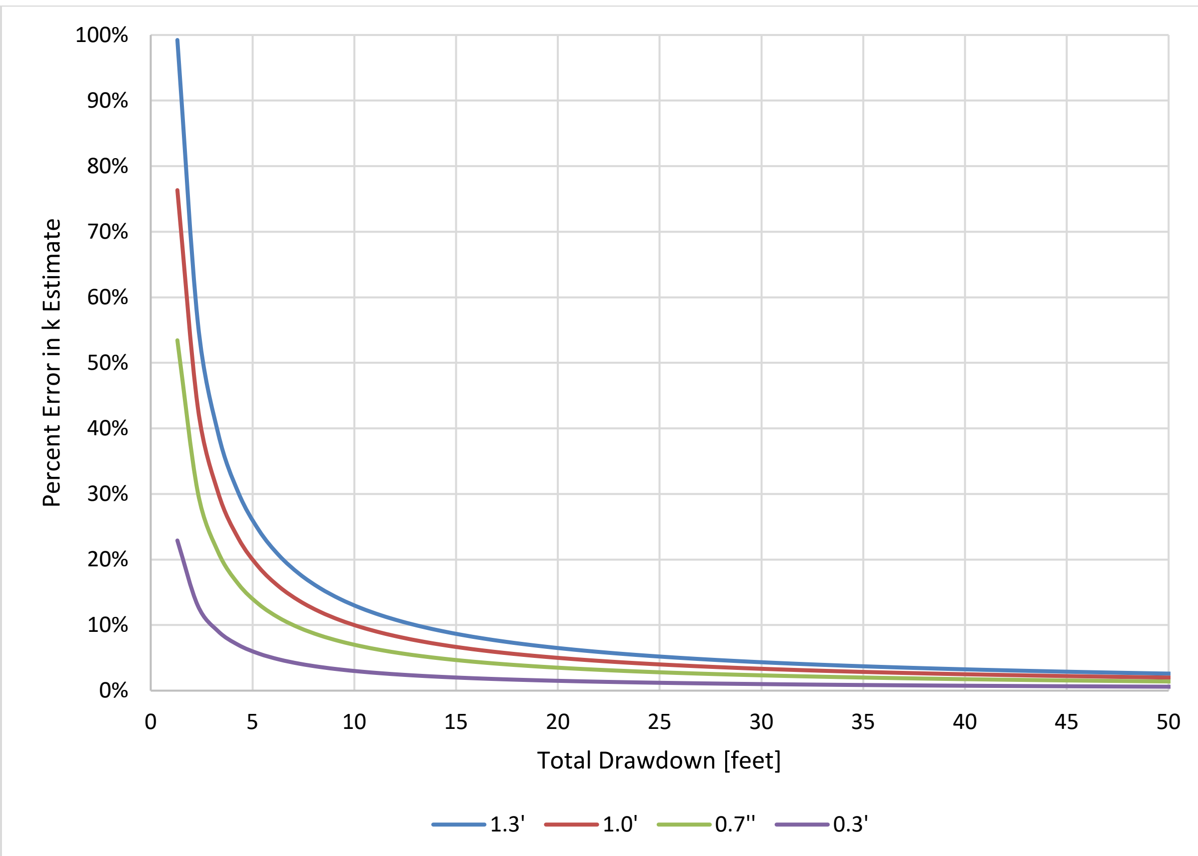

Figure 15. Error of hydraulic conductivity estimates as a function of total test drawdown for observed range of error in well loss estimate.

Water Quality and Inorganic Chemistry

Thirty-two discrete water samples were collected during packer testing at OSF-112 to characterize the water chemistry variation in the FAS at the S61 Locks site. Field parameters (temperature, pH, and specific conductance) were recorded on site with a YSI 600XL multiprobe, and each sample was collected and submitted for laboratory analysis in accordance with the project's Water Quality Monitoring Plan (SFWMD 2017). Major cations and anions, silica, dissolved iron and strontium, and stable isotopes of oxygen and hydrogen (^{18}O and ^{2}H) were analyzed in each packer test sample. A summary of the results is provided here; complete results from the testing program are available for download from the District's DBHYDRO database (www.sfwmd.gov/dbhydro). Field parameters and quality assurance data from individual samples are summarized in **Table 8**, and major ion chemistry is provided in **Table 9**. The discrete samples are organized from shallowest to deepest to allow differences between hydrogeologic units to be more easily distinguished.

Table 8. Field and quality assessment sample summary. (Note: Bolded values exceed the secondary drinking water standard.)

Sampled Depth (ft bls)	Field Parameters			Sample Ion Balance			TDS (mg/L)	TDS to Specific Conductivity Ratio
	pH	Temp. (°C)	Specific Cond. (µS/cm)	Sum of Anions (meq/L)	Sum of Cations (meq/L)	Balance %		
170-200	7.7	24.5	251	2.60	2.60	-0.16%	155	0.62
200-250	7.8	24.0	244	2.54	2.48	1.16%	157	0.64
250-300	7.9	--	250	2.57	2.48	1.63%	152	0.61
300-350	7.7	--	279	2.66	2.72	-1.23%	161	0.58
350-400	8.3	24.4	303	2.83	2.98	-2.78%	184	0.61
400-440	7.6	23.8	305	2.59	2.61	-0.55%	162	0.53
440-470	7.7	24.8	304	2.79	2.57	4.02%	162	0.53
470-500	7.5	24.5	305	2.71	2.60	1.84%	168	0.55
500-520	7.4	24.5	303	2.76	2.67	1.72%	182	0.60
520-570	7.6	25.1	302	3.26	3.14	1.79%	192	0.64
570-590	7.8	24.9	840	9.80	9.37	2.07%	**652**	0.78
590-620	7.3	24.7	811	9.02	9.18	-1.01%	**655**	0.81
620-650	7.7	26.1	1,265	15.67	15.42	0.60%	**1,099**	0.87
650-680	7.6	26.2	1,305	15.52	15.42	2.12%	**1,139**	0.87
680-710	7.5	25.3	1,249	15.94	15.38	1.59%	**1,108**	0.89
710-740	7.7	25.5	823	8.94	8.98	-0.42%	**628**	0.76
740-770[a]	7.6	25.4	989	12.72	11.16	6.37%	**751**	0.76
770-800	7.5	25.2	1,203	14.37	14.59	-0.76%	**1,008**	0.84
800-830	7.8	25.2	1,389	16.58	17.27	-2.25%	**1,197**	0.86
830-860[a]	7.7	24.9	1,482	18.18	14.78	10.09%	**1,316**	0.89
860-890	8.3	25.4	1,694	20.12	21.27	-2.96%	**1,483**	0.88
890-920	7.4	25.5	2,107	27.81	28.01	-0.55%	**2,000**	0.95
920-950	7.4	26.3	2,263	31.11	31.77	-1.34%	**2,297**	1.02
950-950	7.2	26.1	2,292	32.99	32.21	0.87%	**2,345**	1.02
980-1,010	7.1	27.6	2,467	33.87	35.24	-2.18%	**2,533**	1.03
1,010-1,040[b]	8.0	25.8	1,688	24.79	23.83	1.54%	**1,766**	1.05
1,220-1,250	7.4	25.6	2,445	33.83	32.74	1.35%	**2,332**	0.95
1,250-1,280	7.6	22.9	867	8.13	7.95	1.56%	**528**	0.61
1,280-1,310	8.1	25.8	906	8.22	8.24	0.51%	**531**	0.59
1,310-1,340	8.0	23.0	882	8.16	8.04	0.78%	**563**	0.64
1,340-1,370[a]	7.8	23.2	746	8.63	7.17	9.00%	495	0.66
1,370-1,400	7.7	21.8	743	7.40	7.09	1.79%	471	0.63

°C = degrees Celsius; µS/cm = microsiemens per centimeter; ft bls = feet below land surface; meq/L = milliequivalents per liter; mg/L = milligrams per liter; TDS = total dissolved solids.

[a] Potentially unreliable: ion-balance error is above the threshold for acceptance.

[b] Potentially unreliable: very low purge volume, could result in mix of formation and drilling fluids.

Table 9. Major ion composition with depth. (Note: Bolded values exceed the secondary drinking water standard.)

Sampled Depth (ft bls)	Anions (mg/L)			Cations (mg/L)					
	Chloride	Bicarbonate	Sulfate	Sodium	Magnesium	Calcium	Potassium	Strontium*	Iron
170-200	7.5	138	6.4	6.1	5.4	37.2	< 1	< 1	< 0.3
200-250	7.4	129	7.1	7.2	5.3	35.2	< 1	< 1	< 0.3
250-300	7.5	130	5.9	6.3	5.3	36.4	< 1	< 1	< 0.3
300-350	8.2	141	8.0	5.8	6.6	36.6	< 1	< 1	< 0.3
350-400	9.0	151	12.1	6.3	8.0	37.2	< 1	< 1	< 0.3
400-440	6.9	123	18.9	4.7	7.2	35.1	< 1	< 1	< 0.3
440-470	6.6	122	18.6	4.8	7.9	37.9	< 1	< 1	< 0.3
470-500	6.4	122	20.4	4.8	7.6	36.7	< 1	< 1	< 0.3
500-520	6.8	124	21.2	4.9	7.6	37.8	< 1	< 1	< 0.3
520-570	6.7	127	41.4	5.5	9.1	44.3	< 1	1.1	< 0.3
570-590	6.0	128	**341**	4.8	31.1	136	1.1	7.9	**0.5**
590-620	6.0	137	**325**	7.0	28.8	123	1.0	8.0	**0.3**
620-650	5.5	128	**632**	4.7	49.6	219	1.4	15.4	**0.9**
650-680	5.4	129	**631**	4.4	49.8	216	1.4	16.2	**0.8**
680-710	5.5	132	**627**	4.6	51.1	222	1.3	15.6	**0.8**
710-740	6.3	144	**309**	4.6	27.7	124	1.3	9.1	**0.5**
740-770	5.7	134	**423**	4.0	44.1	172	1.3	10.6	**0.4**
770-800	5.3	129	**592**	3.6	48.4	195	1.3	19.9	**0.7**
800-830	5.1	125	**723**	3.7	56.4	225	1.3	18.8	**1.0**
830-860	4.9	125	**605**	4.1	62.1	248	1.3	17.4	**1.0**
860-890	11.0	121	**911**	3.9	68.4	278	1.4	15.7	**0.9**
890-920	4.4	122	**1,242**	4.1	91.0	394	1.7	13.7	**1.5**
920-950	7.9	124	**1,416**	4.6	102	441	1.8	12.8	**2.1**
950-950	5.8	124	**1,441**	4.4	113	460	2.0	12.9	**2.3**
980-1010	6.8	124	**1,584**	4.4	120	467	2.3	12.4	**2.4**
1010-1040	5.1	130	**1,034**	8.1	74	356	1.6	13.9	**3.5**
1220-1250	50	134	**1,399**	30.9	106	464	4.3	12.8	**2.9**
1250-1280	111.0	105	149	59.7	21.4	73.8	2.7	4.3	**0.8**
1280-1310	138	99	131	75.7	22.2	61.4	3.1	2.7	**0.8**
1310-1340	133	101	126	73.6	21.8	60.7	3.0	2.6	**0.9**
1340-1370	102	100	127	59.3	25.7	75.4	2.6	2.6	**0.7**
1370-1400	99.3	101	126	56.9	20.5	61.4	2.5	2.4	**0.8**

* Values shaded in blue indicate the analyte is not currently regulated but exceeds the United States Environmental Protection Agency’s proposed health reference level for strontium of 1.5 mg/L.

Two major breaks are apparent in this data set: the first at 570 ft bls and the second at 1,250 ft bls. Above 570 feet bls, water is very fresh, meeting all drinking water standards for naturally occurring ions. Bicarbonate is the dominant anion, and calcium the dominant cation. Below 570 ft bls, there is a gradual increase in salinity with depth, but the salinity derives primarily from sulfate rather than chloride. A maximum specific conductance of 2,467 µS/cm was recorded from the collected water samples. This value, which came from the 980- to 1,010-ft bls interval, is somewhat misleading as the very low permeability of the rock from 1,040 to 1,220 ft bls prevented any water quality samples from being collected at those depths.

CTD data from the 1,070- to 1,100-ft bls interval yielded a specific conductance of 2,800 µS/cm and continued to trend upward when the probe was removed. This indicates that overall salinity continued to rise across the sampling gap (i.e., higher salinity exists within the very low-permeability MCU_II unit). Below the 1,220- to 1,250-ft bls packer test interval, a freshwater inversion occurs. Salinity drops abruptly, reflected by a 77% decrease in total dissolved solids between the adjacent packer tests. There is a decrease in multiple ions across this depth, but an increase in sodium and chloride concentrations. TDS concentrations continued to decline slightly from 1,250 ft bls to the total drilled depth of 1,400 ft bls. This deep fresher water zone is chemically distinct from the waters above 570 ft bls. It is greatly enriched in multiple ions, particularly sodium and chloride. **Figure 16** illustrates the variations in major ion concentrations with depth.

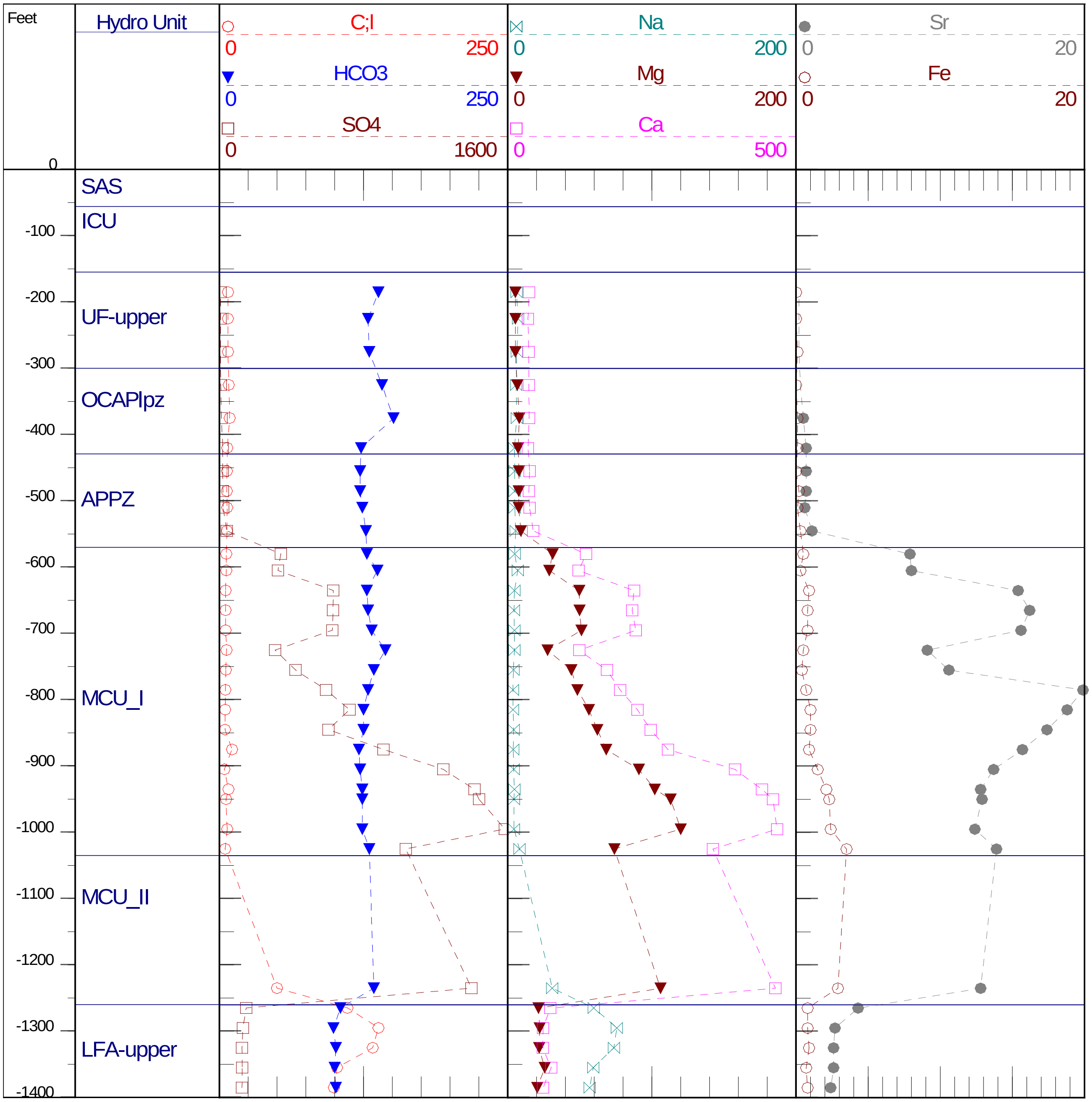

Figure 16. Variation in ion concentration (mg/L) with depth. Points are positioned at the middle of the tested interval.

Samples were further examined using the geochemical pattern analysis method developed for the FAS by Frazee (1982) to relate the chemical signature to recharge source, residence time, and saltwater intrusion. The Frazee water types are defined in **Table 10**. **Figure 17** shows how the packer test samples conform to the water types on Frazee's pattern overlay.

Above 570 ft bls, the formation water falls into the FW-I and FW-II types of Frazee (1982). These are the purest and youngest forms of limestone water, having a definite calcium bicarbonate dominance. From 570 to 1,250 ft bls, the formation water becomes increasingly enriched in calcium, magnesium, and sulfate through prolonged contact with the formation rock. These waters, which plot into Frazee type FW-IV, are an older form of the FW-I and FW-II types and developed due to limited vertical circulation and insufficient lateral influx of fresh recharge water. Below 1,250 ft bls, water samples fall into the TCW water type. The term "transitional" is used to indicate waters that are evolving through chemical reaction with the host rock or mixing with other chemically distinct water masses. Higher chloride content in these waters is assumed to be derived from inadequate flushing after deposition rather than active lateral intrusion.

Table 10. Description of Frazee (1982) water types.

Abbreviation	Description	Characteristics
FW-I	Fresh Recharge Water Type I	Rapid infiltration through sands, high calcium bicarbonate ($CaHCO_3$).
FW-II	Fresh Recharge Water Type II	Infiltration through sands and clay lenses, $CaHCO_3$ with sodium (Na), sulfate (SO_4), and chloride (Cl). Marginal type II waters are beginning to transition toward FW-IV.
FW-III	Fresh Recharge Water Type III	Infiltration through clay-silt estuarine depositional environment, high sodium bicarbonate ($NaHCO_3$).
FW-IV	Fresh Formation Water Type IV	Fresh water, low calcium (Ca), magnesium (Mg), SO_4, and Cl. Vertical infiltration insignificant. Older form of FW-II or FW-III.
TW-I	Transitional Water Type I	Seawater begins to dominate source water; Cl begins to dominate bicarbonate (HCO_3) with increasing sodium chloride (NaCl) percentage.
TW-II	Transitional Water Type II	Transitional water with source water still dominant, $HCO_3 – SO_4$ mixing zone with increasing Cl.
TCW	Transitional Connate Water	Connate water dominates source water, SO_4 begins to dominate HCO_3 with increasing Cl.
TRSW	Transitional Seawater	Transitional water with seawater dominating source water.
CW	Connate Water	Highly mineralized fresh water with high total dissolved solids and calcium sulfate ($CaSO_4$) dominance. Presence of highly soluble minerals; hydrogen sulfide (H_2S) gas prevalent.
*RSW	Relict Seawater	Unflushed seawater with NaCl.

* Strongly NaCl-dominant waters may plot in this category even if the overall salinity is substantially less than seawater.

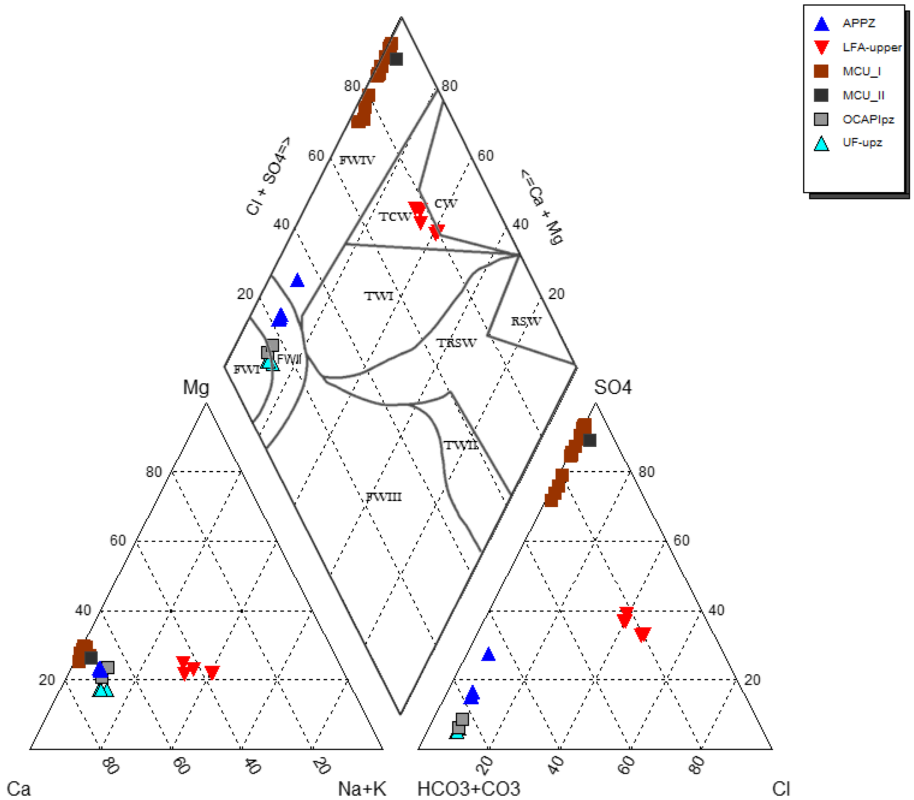

Figure 17. Water-type classification of packer test sample data, illustrating distinctions between hydrogeologic units (Modified from: Frazee 1982).

Stable isotopes of oxygen and hydrogen (^{18}O and ^{2}H) were analyzed to identify distinctions between source waters and the hydrogeologic units penetrated during coring and packer testing operations (**Figure 18**). Craig (1961) first noted a linear relationship between ^{18}O and ^{2}H isotope values measured in precipitation from all over the world. This relationship $^{2}H = 8\ ^{18}O + 10$ parts per thousand (‰) has become known as the global meteoric water line. All OSF-112 water quality samples plot close to the global meteoric water line, implying that none of the source waters experienced a prolonged period of evaporation prior to recharge. Compared to the wide range of ^{18}O and ^{2}H observed in modern rainfall around the world, the samples from OSF-112 are very similar, ^{18}O ranging from -3 to -2‰, and ^{2}H from -15 to -6.5‰. Despite this relatively narrow range of absolute values, the stable isotope results clearly cluster by hydrogeologic unit, indicating conditions during recharge to each unit were not identical. With the exception of the two tests immediately underlying the APPZ, samples collected from the MCU clustered in the upper right quadrant of the plot, possibly indicating that environmental conditions were slightly warmer when those waters initially were recharged into the aquifer.

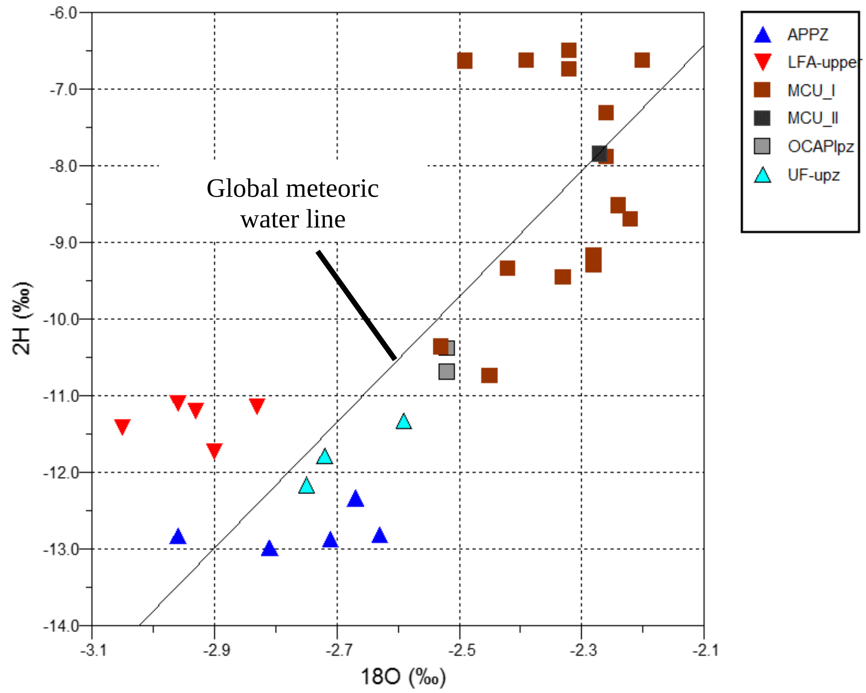

Figure 18. Stable isotopic ratios of ^{2}H and ^{18}O from OSF-112 packer test water quality samples, shown relative to the global meteoric water line.

Geophysical Logging

Borehole geophysical logs collected during the construction of OSF-112 and earlier construction of OSF-53 are listed in **Table 11**.

Table 11. Geophysical log inventory for the S61 Locks site.

	OSF-53			OSF-112			
Date	9-Sep-82	3-Dec-15	5-Jan-15	17-Oct-17	9-Jan-18	16-Jan-18	17-Jan-18
Logging Company	SFWMD	Baker	Baker	ABS	ABS	ABS	USGS
Logged Interval (ft bls)	0-955	165-979	0-532	0-165	570-1,400	0-547	350-1,335
Caliper	✓		✓	✓	✓	✓	
Natural Gamma	✓	✓	✓	✓	✓	✓	
Normal Resistivity	✓	✓		✓	✓	✓	
Dual Induction/ Spontaneous Potential	✓		✓				
Neutron Porosity	✓						
Sonic Porosity				✓			
Flow Meter	✓						
Temperature	✓		✓		✓	✓	
Fluid Resistivity	✓		✓		✓	✓	
Downhole Video			✓			✓	
Optical Borehole Imaging							✓

ABS = Advanced Borehole Services; Baker = RMBaker LLC; ft bls = feet below land surface; SFWMD = South Florida Water Management District; USGS = United States Geological Survey.
✓ Collected under pumped flow conditions.
✓ Collected under static flow conditions.

The January 9, 2018 logging run from 570 ft bls to total depth had to be conducted through the core casing to protect the logging tools from loose rocks above 570 ft bls. This placed diameter restrictions on the logging suite; therefore, down-hole video, porosity, and flow logs could not be conducted, and the OBI log had to be run uncentralized, which reduced image quality. Geophysical logs collected as part of this project are provided in **Appendix E**.

Laboratory Core Analysis

Nineteen core samples from lower-permeability sections of the corehole were shipped to Core Lab in Houston, Texas for more extensive analysis. Samples were selected based on the following objectives: 1) assess the heterogeneity and anisotropy of permeability within a packer test interval; 2) evaluate the reliability of visual assessments of apparent permeability; and 3) evaluate the presence of clay and evaporite minerals at scales not visible to the naked eye. Vertical and horizontal permeability calculated from conventional plug analysis were used to address objectives one and two, while objective three was addressed via thin-section petrographic and bulk XRD analyses. Sample depths and analyses run relative to the packer test interval and visual assessment of apparent permeability are summarized in **Table 12**.

Table 12. Summary of samples selected for laboratory core analysis. Samples from adjacent rows of the same color (blue or white) were collected from the same 10-foot core run.

Approximate Sample Depth (ft bls)	Horizontal Permeability	Vertical Permeability/ Porosity	Thin Section Petrography	XRD	Apparent Permeability (Visual)	Packer Test #
632	--	Yes	--	--	Low	13
643	--	Yes	--	--	Low	13
655	--	Yes	--	--	Low	14
661	--	Yes	--	--	Low	14
777	Yes	Yes	--	--	High	18
786	Yes	Yes	--	--	Medium	18
795	Yes	Yes	--	--	Low	18
805	Yes	Yes	--	--	High	19
813	Yes	Yes	--	--	High	19
822	Yes	Yes	--	--	Medium	19
828	Yes	Yes	--	--	Low	19
862	--	Yes	--	--	High	21
872	Yes	Yes	--	--	Low	21
881	Yes	Yes	--	--	Medium	21
887	Yes	Yes	--	--	High	21
912	--	Yes	Yes	Yes	Low	22
945	--	Yes	Yes	Yes	Low	23
963	--	Yes	Yes	Yes	Low	24
979	--	Yes	Yes	Yes	Low	24

ft bls = feet below land surface; XRD = x-ray diffraction.

The Core Lab report of the conventional plug analysis is provided in **Appendix F**. **Table 13** contains a summary of the results, with permeability units converted from milli-Darcy to ft/day to facilitate ease of comparison with the packer test results. As expected from the scale of the plug analyses, the laboratory permeability is considerably lower than that derived from packer testing within the cored interval. The sole exception to this occurred in the sample from 945 ft bls. That sample was found to have Klinkenberg permeability of 11.9 ft/day (4,409 milli-Darcy), more than an order of magnitude higher than results for the other samples collected from this low-permeability zone. Based on conversation with the laboratory (Joel Henderson, Core Laboratories, personal communication), if the core sample has been broken or otherwise lacked integrity, it would not have been tested, and the result was more likely to be a statistical anomaly. The tested sample is small relative to the entire core, about an inch, so that an anomaly such as a fossil mold or burrow could lead to an unrepresentative permeability result. Because of this, and the extreme discontinuity between the apparent and measured permeability, the measured value in this plug is believed to represent a statistical anomaly. It is not representative of the core as a whole and was consequently omitted from further analyses.

Table 13. Summary results of conventional plug analysis.

Approximate Depth (feet bls)	Horizontal Hydraulic Conductivity (feet/day)	Vertical Hydraulic Conductivity (feet/day)	Porosity	Grain Density (g/cm^3)
632		0.876	48%	2.79
643		0.175	35%[a]	2.81
655		0.051	46%	2.79
661		0.008	49%	2.79
777	3.044	1.565	42%[a]	2.82
786	2.705	1.411	31%	2.82
795	0.435	0.208	24%	2.84
805	0.526	0.403	37%	2.83
813	0.243	0.404	26%	2.81
822	0.379	0.260	36%	2.83
828	0.038	1.044×10^{-6}	3%	2.78
862	--[b]	0.122	33%	2.80
872	4.188×10^{-6}	6.286×10^{-6}	6%	2.71
881	0.230	0.182	19%	2.81
887	3.257	2.387	35%	2.82
912		0.262	43%	2.81
945		11.904[c]	42%	2.82
963		6.554×10^{-5}	10%	3.16
979		0.305	29%	2.84

bls = below land surface; g/cm^3 = grams per cubic centimeter.
[a] Short sample, porosity may be optimistic due to lack of conformation of boot material to plug surface.
[b] Horizontal sample unsuitable for measurement at stress.
[c] Anomalously high hydraulic conductivity, unrepresentative of core as a whole.

Measured porosity from the laboratory analyses ranged from 3% to 48% in the plugs. Permeability varied more widely, more than seven orders of magnitude, from 1×10^{-6} to 2.4 ft/day (discounting the anomalous value at 945 ft bls). It is clear from **Figure 19** that there is a correlation between measured porosity and vertical permeability at the core scale. Variations in porosity could account for approximately 54% of the variation in vertical permeability. Porosity data are much more widely available than permeability data due to the availability of geophysical log-derived porosity. Therefore, it often is tempting to assume high porosity must equate to high permeability in carbonate aquifers. That this correlation is not stronger helps illuminate the danger of that assumption. Both horizontal and vertical permeability were measured in 10 core samples from OSF-112 to evaluate anisotropy within MCU_I (**Figure 20**). In isotropic media, a plot of horizontal versus vertical permeability would have a slope of one. As seen in **Table 13**, the horizontal to vertical hydraulic conductivity ratio is far from consistent; however, based on that limited sample population, linear regression indicates 60% of the horizontal permeability value would be a reasonable prediction for vertical permeability. Additional samples are required to assess the reliability of this ratio as a general rule for MCU_I.

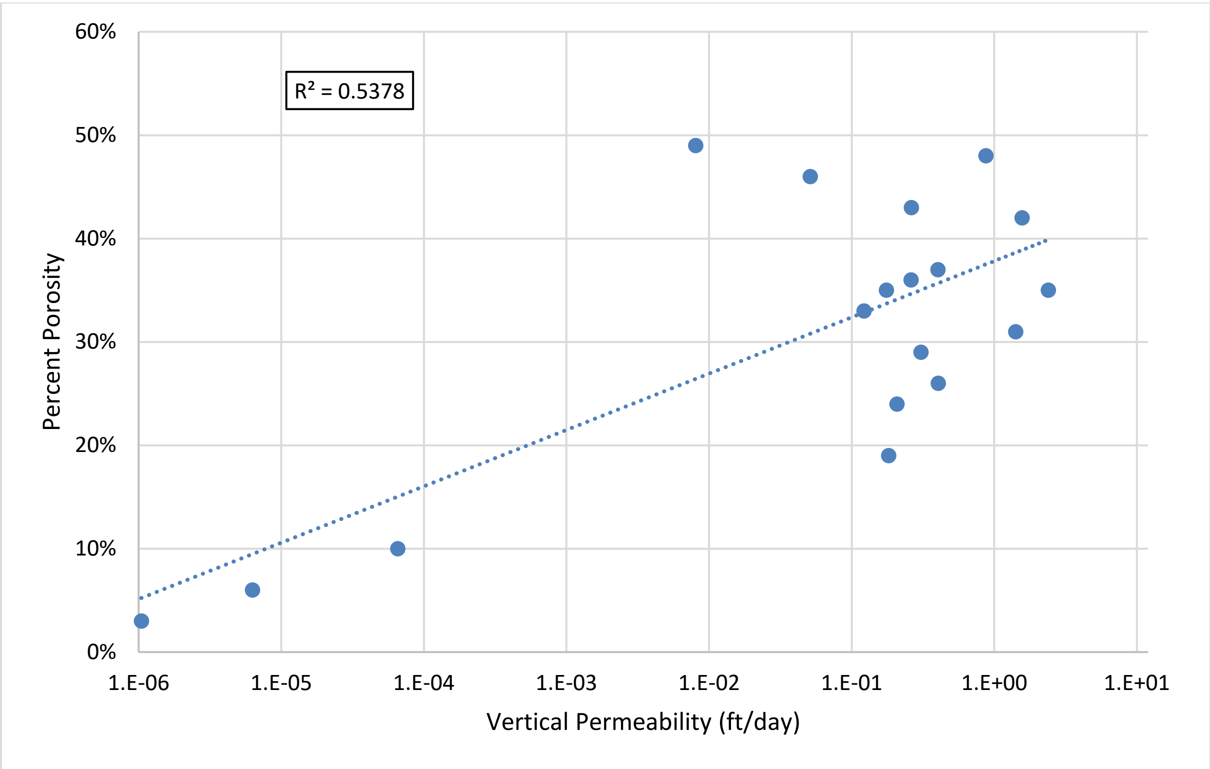

Figure 19. Relationship between porosity and permeability in the core samples.

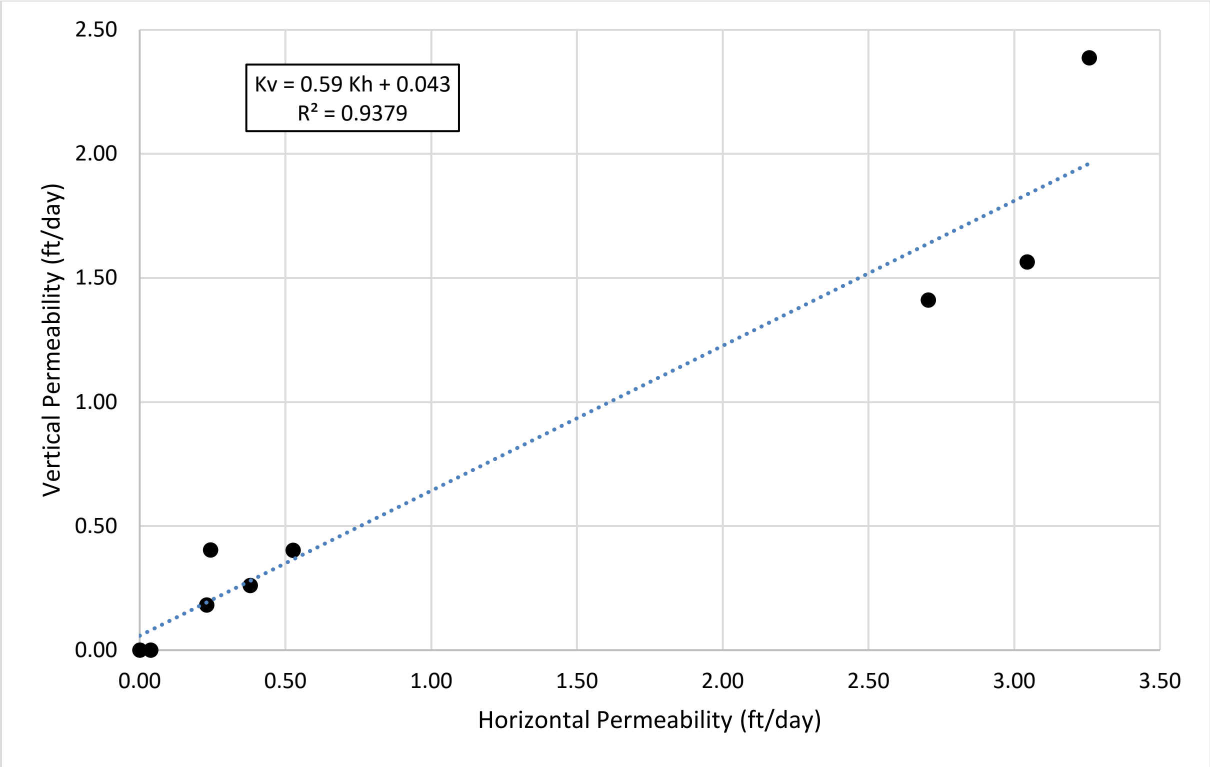

Figure 20. Relationship between horizontal and vertical core permeability from the OSF-112 samples.

Thin-section petrographic and bulk XRD analyses were conducted on four core samples from near the base of MCU_I (**Appendix F**). The packer tests in this region of the corehole yielded hydraulic conductivity of approximately 2 ft/day. The samples were selected based on low apparent permeability, with the objective of the XRD analysis to assess the presence of clay or evaporite minerals in-filling matrix porosity at scales not visible to the naked eye. Three of the four samples (912, 945, and 962 ft bls) were almost entirely dolomite. The deepest sample (979 ft bls) was predominantly limestone; however, a substantial percentage was replaced with evaporite mineral celestite.

The major weakness of core permeability analysis is that it samples only a small percentage of the total rock material. XRD analysis uses the trim ends of the core permeability sample, which is an even smaller percentage of the total rock. The grain density results help to scale XRD up to the whole core level. In the 979 ft bls sample, XRD reported 39.7% celestite, but grain density was only 2.84 grams per cubic centimeter (g/cm^3). Given the density of the individual minerals (**Table 14**), 2.84 g/cm^3 is too low for a rock composed of nearly 40% celestite. The whole plug could be no more than 11% celestite by weight. In contrast, XRD analysis yielded only 0.3% by weight of celestite in the core sample at 962 ft bls, but from the grain density of the plug (3.16 g/cm^3), it can be safely assumed that a larger amount is present in the sample as a whole. Assuming the plug was composed entirely of dolomite and celestite, almost 30% celestite would be required to yield that grain density given the density of the pure minerals (**Table 13**). None of the other plugs sampled exhibited grain densities clearly indicative of anything but limestone, dolostone, or some combination of the two; but as celestite is the most likely source of strontium in the packer water chemistry results (**Figure 16**), it may be present as a minor constituent throughout the MCU.

Table 14. Grain density for primary minerals within OSF-112 (Adapted from: Mason and Berry 1968).

Mineral	Formula	Grain Density
Gypsum	$CaSO_4 \cdot H_2O$	2.32
Calcite (Limestone)	$CaCO_3$	2.71
Dolomite (Dolostone)	$CaMg(CO_3)_2$	2.85
Anhydrite	$CaSO_4$	3.00
Celestite	$SrSO_4$	3.90

Water Levels

Changes in water level with depth are the most reliable indication that there has been a breach of confinement during drilling. DTW recorded at the end of recovery during packer testing operations most accurately reflects static water level within the geologic formation. Referenced water levels calculated from DTW at end of recovery during packer testing are presented in **Figure 21**. The blue points show the absolute water level at the end of recovery from OSF-112 packer testing. Because these measurements were recorded over approximately 3 months (October 20, 2017 to January 5, 2018), it is necessary to differentiate between regional changes in water level over this time and those related to changes in depth. To this end, the orange points show the background water level from the nearest off-site FAS monitor well, OSF-64, at the same date and time of each packer test reading. The difference between these two water levels (black squares) best reflects depth-related change.

OSF-64, located 6.4 miles southeast of OSF-112, is open to UFA-upper. This is the same hydrogeologic unit to which OSF-112 was open at the beginning of coring operations. While OSF-112 is within UFA-upper, static water levels are approximately 0.5 ft lower than OSF-64. This difference increases slightly across the OCAPlpz to a difference of approximately 0.75 ft. Levels in OSF-112 decline another 0.4 ft from 570 to 620 ft bls, then remain stable to a depth of 710 ft bls. Below 710 ft bls, there is an abrupt

0.5-ft rise in water level back to APPZ levels. These levels hold to a depth 770 ft bls. Below that point to 1,010 ft bls, water levels steadily decline relative to those in OSF-64 to a maximum difference of 2.25 ft below the OSF-64 baseline. From 1,010 to 1,250 ft bls, the tightness of the geologic formation made the time required for complete water level recovery prohibitive, so absolute water levels within that portion of the geologic formation could not be recorded. From 1,250 ft bls to total depth, there is a noticeable reversal. Water levels in this interval are 2.5 ft higher than the last recorded values, indicating good confinement between 1,202 and 1,250 ft bls. Where heads in the upper portion of the corehole are 0.5 ft lower than those in OSF-64, the heads at the bottom are 0.5 ft higher, indicating an upward head gradient from the lower to the upper FAS at this location.

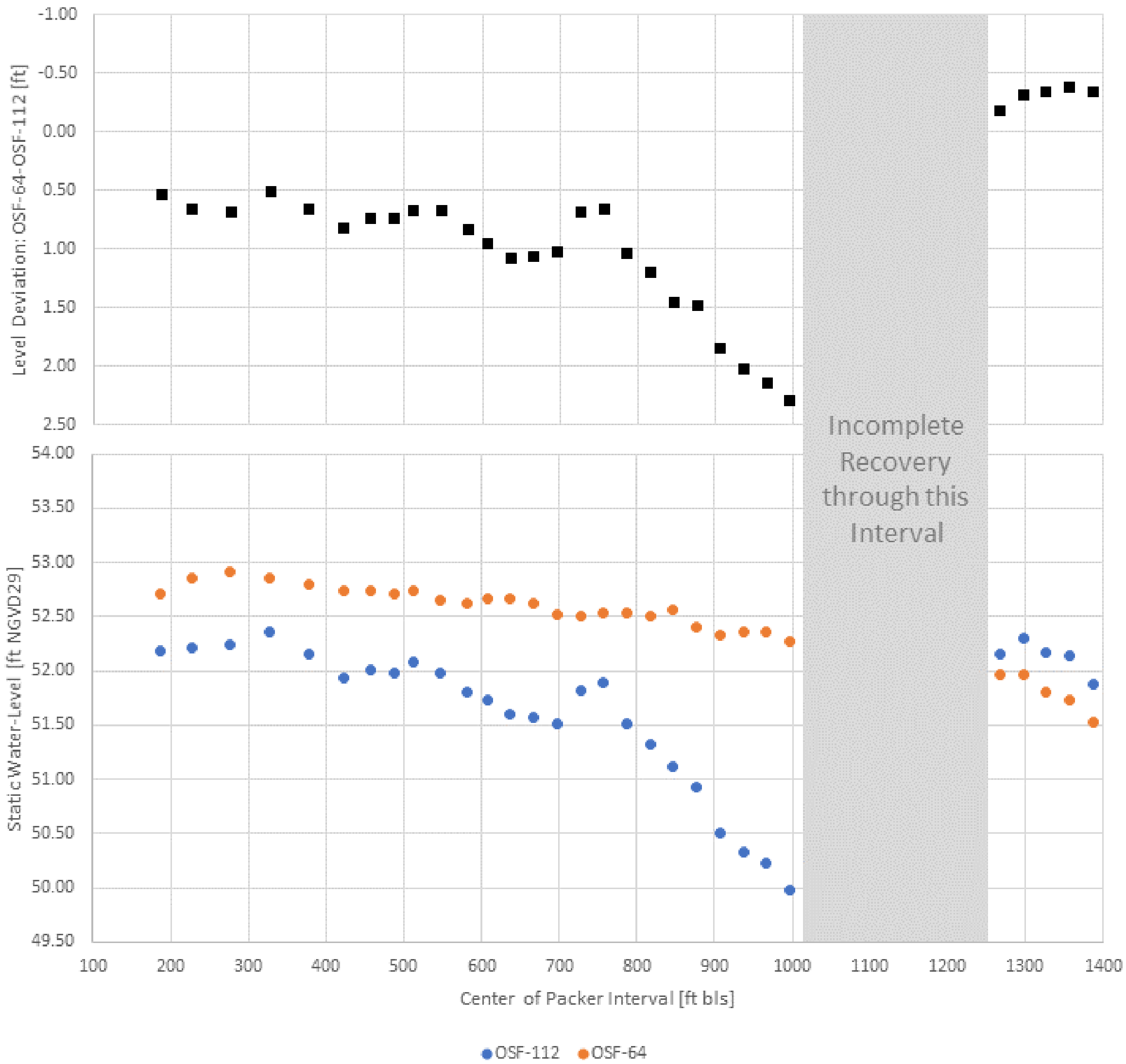

Figure 21. Recovered water levels from packer testing in OSF-112, relative to time-variant changes in water-level from off-site monitor well OSF-64.

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APPENDICES

APPENDIX A:
WELL CONSTRUCTION SUMMARY

Start Date	End Date	Activity	Site Geologist
9-Oct-17	13-Oct-17	Huss Drilling rig mobilization, SPT to 60' bls, Ream 16" mud rotary and Set 60' of 12-inch PVC surface casing, Drill 4-inch mud rotary pilot hole from 60' to 169' bls	E. Richardson
16-Oct-17	20-Oct-17	Ream 12" mud rotary, Log mudded hole 0 -169 (ABS Geophysical), Install 169' 8-inch PVC conductor casing, Core 170 - 230 ft bls, Conduct packer test #1 (170 - 200 ft bls)	B. Collins
23-Oct-17	27-Oct-17	Core 230- 415 ft bls, Conduct packer tests: #2 (200 - 250 ft bls), #3 (250 - 300 ft bls), #4 (300 - 350 ft bls), #5 (350 - 400 ft bls)	L. Lindstrom
30-Oct-17	2-Nov-17	Core 415 -550 ft bls, Conduct packer tests: #6 (400-440 ft bls), #7 (440-470 ft bls), #8 (470-500 ft bls), #9 (500-520 ft bls)	E. Geddes
6-Nov-17	10-Nov-17	Core 550 -728 ft bls, Conduct packer tests: #10 (520-570 ft bls), #11 (570-590 ft bls), #12 (590-620 ft bls), #13 (620-650 ft bls), #14 (650-580 ft bls), #15 (680-710 ft bls)	B. Collins
13-Nov-17	17-Nov-17	Core 728 -879 ft bls, Conduct packer tests: #16 (710-740 ft bls), #17 (740-770 ft bls), #18 (770-800 ft bls) [step], #19 (800-830 ft bls), #20 (830-860 ft bls). *Note: Temporary 4-inch casing fell 50' down-hole 17-nov-17, after some effort, Kevin was able to hook back into it with additional temporary casing.*	E. Richardson
18-Nov-17	26-Nov-17	NO WORK - THANKSGIVING HOLIDAY	
27-Nov-17	1-Dec-17	Core 880-1,010 ft bls, Conduct packer tests: #21 (860-890 ft bls), #22 (890-920 ft bls), #23 (920-950 ft bls), #24 (950-980 ft bls), #25 (980-1010 ft bls)	B. Collins
4-Dec-17	8-Dec-17	Core 1,010-1,130 ft bls, Conduct packer tests: #26 (1010-1040 ft bls), #27 (1040-1070 ft bls), #28 (1070-1100 ft bls), #29 (1100-1130 ft bls). *Note: Air-line broke while retrieving packer #29, and packer became stuck in core casing. The cable had to be cut, and all core casing broken out of the hole to retrieve it.*	E. Richardson
11-Dec-17	15-Dec-17	Core 1,130-1,230 ft bls, Conduct packer tests: #30 (1130-1160 ft bls), #31 (1160-1190 ft bls), #32 (1190-1220 ft bls)	B. Collins
18-Dec-17	21-Dec-17	Core 1,230-1,340 ft bls, Conduct packer tests: #33 (1220-1250 ft bls), #34 (1250-1280 ft bls), #35 (1280-1310 ft bls)	L. Lindstrom
25-Dec-17	29-Dec-17	NO WORK - CHRISTMAS HOLIDAY	
2-Jan-18	5-Jan-18	Core 1,340-1,400 ft bls [Total Depth], Conduct packer tests: #36 (1310-1340 ft bls), #37 (1340-1370 ft bls), #38 (1370-1400 ft bls). *Note: Air-line broke 1/2/17 during 1st attempt at PT#36, but packer and line were retrieved without having to break-out, causing only one day delay.*	J. Janzen
8-Jan-18	19-Jan-18	8 hours of well development in preparation for geophysical logging: ABS partial base logs 570-1400 ft bls, USGS OBI tool stuck in hole at 1,395 ft bls, were able to dislodge and retrieve, but could not collect data. *Note: ABS unable to run camera, flow or porosity through 2.5" core bit. Logs to be completed following week.*	E. Richardson
15-Jan-18	19-Jan-18	ABS Log 0 - 540 ft bls (*Rock blocking corehole @540 ft bls prevented overlap with previous log-run*). USGS OBI log through core casing (no centralizers). Begin borehole backfill: gravel 1,400 - 1,290, 1,290 - 1,247 with neat cement grout.	S. Krupa
22-Jan-18	26-Jan-18	Complete grout backfill of OSF-112 from 1,247 to final depth of 595 feet bls. Ream nominal 8" borehole to 430 feet bls and set final 4" PVC casing with cement baskets. Grout casing to land-surface.	K. Smith

Start Date	End Date	Activity	Site Geologist
29-Jan-18	2-Feb-18	Ream corehole to 595 feet. Complete final development of OSF-112. Remove rig from OSF-112 to OSF-53, hard-tag bottom of the well @ 947 feet bls. Begin borehole backfill operations. Grout backfill from 947 to 661 feet bls, then gravel backfill from 661 to 481 feet bls.	L. Lindstrom
5-Feb-18	7-Feb-18	Complete backfill operations at OSF-53; gravel from 481 to 422 feet bls followed by grout to OSF-53R final depth of 300 feet bls. Complete final development of OSF-53R, and well-head and well-pad installations. Huss Drilling de-mobilized from the site.	E. Richardson

APPENDIX B:
WELL COMPLETION REPORTS

49WP 1793155

STATE OF FLORIDA PERMIT APPLICATION TO CONSTRUCT, REPAIR, MODIFY, OR ABANDON A WELL

☐ Southwest
☐ Northwest
☐ St. Johns River
☐ South Florida
☐ Suwannee River
☐ DEP
☒ Delegated Authority (If Applicable) Osceola

PLEASE FILL OUT ALL APPLICABLE FIELDS (*Denotes Required Fields Where Applicable)

The water well contractor is responsible for completing this form and forwarding the permit application to the appropriate delegated authority where applicable.

Permit No.
Florida Unique ID
Permit Stipulations Required (See Attached)
62-524 Quad No. Delineation No.
CUP/WUP Application No.
ABOVE THIS LINE FOR OFFICIAL USE ONLY

1. SFWMD PO Box 24680 W. Palm Beach, FL. 33416
*Owner, Legal Name if Corporation *Address *City *State *ZIP Telephone Number
2. E Southport Rd. Kissimmee, FL. 34759
*Well Location - Address, Road Name or Number, City
3. 182730000000400000
*Parcel ID No. ☒ (PIN) or ☐ Alternate Key Lot Block Unit
4. 18 Osceola Check if 62-524: ☐ Yes ☐ No
*Section or Land Grant *Township *Range *County Subdivision
5. Stephanie Stallsmith 9342 352-567-9500 stephanie@hessdrilling.com
*Water Well Contractor *License Number *Telephone Number E-mail Address
6. 35920 State Road 52 Dade City FL 33525
*Water Well Contractor's Address City State ZIP
7. *Type of Work: ☒ Construction ☐ Repair ☐ Modification ☐ Abandonment
*Reason for Repair, Modification, or Abandonment
8. *Number of Proposed Wells 1
9. *Specify Intended Use(s) of Well(s):
☐ Domestic ☐ Landscape Irrigation ☐ Agricultural Irrigation ☐ Site Investigations
☐ Bottled Water Supply ☐ Recreation Area Irrigation ☐ Livestock ☒ Monitoring
☐ Public Water Supply (Limited Use/DOH) ☐ Nursery Irrigation ☐ Test
☐ Public Water Supply (Community or Non-Community/DEP) ☐ Commercial/Industrial ☐ Earth-Coupled Geothermal
☐ Class I Injection ☐ Golf Course Irrigation ☐ HVAC Supply
☐ HVAC Return
Class V Injection: ☐ Recharge ☐ Commercial/Industrial Disposal ☐ Aquifer Storage and Recovery ☐ Drainage
Remediation: ☐ Recovery ☐ Air Sparge ☐ Other (Describe)
☐ Other (Describe)

Date Stamp

Official Use Only

10. *Distance from Septic System if ≤ 200 ft. 11. Facility Description 12. Estimated Start Date 10/9/17
13. *Estimated Well Depth 600 ft. *Estimated Casing Depth 450 ft. Primary Casing Diameter 4 in. Open Hole: From to ft.
14. Estimated Screen Interval: From 450 To 600 ft.
15. *Primary Casing Material: ☐ Black Steel ☐ Galvanized ☒ PVC ☐ Stainless Steel
☐ Not Cased ☐ Other
16. Secondary Casing: ☐ Telescope Casing ☐ Liner ☐ Surface Casing Diameter in.
17. Secondary Casing Material: ☐ Black Steel ☐ Galvanized ☐ PVC ☐ Stainless Steel ☐ Other
18. *Method of Construction, Repair, or Abandonment: ☐ Auger ☐ Cable Tool Jetted ☒ Rotary ☐ Sonic
☐ Combination (Two or More Methods) ☐ Hand Driven (Well Point, Sand Point) ☐ Hydraulic Point (Direct Push)
☐ Horizontal Drilling ☐ Plugged by Approved Method ☐ Other (Describe)
19. Proposed Grouting Interval for the Primary, Secondary, and Additional Casing:
From 0 To 450 Seal Material (☐ Bentonite ☒ Neat Cement ☐ Other)
From To Seal Material (☐ Bentonite ☐ Neat Cement ☐ Other)
From To Seal Material (☐ Bentonite ☐ Neat Cement ☐ Other)
From To Seal Material (☐ Bentonite ☐ Neat Cement ☐ Other)
20. Indicate total number of existing wells on site List number of existing unused wells on site Ø
21. *Is this well or any existing well or water withdrawal on the owner's contiguous property covered under a Consumptive/Water Use Permit (CUP/WUP) or CUP/WUP Application? Yes No If yes, complete the following: CUP/WUP No. District Well ID No.
22. Latitude Longitude
23. Data Obtained From: ☐ GPS ☐ Map ☐ Survey Datum: NAD 27 NAD 83 WGS 84

I hereby certify that I will comply with the applicable rules of Title 40, Florida Administrative Code, and that a water use permit or artificial recharge permit, if needed, has been or will be obtained prior to commencement of well construction. I further certify that all information provided is accurate and that I will obtain necessary approval from other federal, state, or local governments, if applicable. I agree to provide a well completion report to the District within 30 days after completion of the construction, repair, modification, or abandonment authorized by this permit, or the permit expiration, whichever occurs first.

I certify that I am the owner of the property, that the information provided is accurate, and that I am aware of my responsibilities under Chapter 373, Florida Statutes, to maintain or properly abandon this well; or, I certify that I am the agent for the owner, that the information provided is accurate, and that I have informed the owner of their responsibilities as stated above. Owner consents to allowing personnel of the WMD or Delegated Authority access to the well site during the construction, repair, modification, or abandonment authorized by this permit.

*Signature of Contractor 9342 *License No. *Signature of Owner or Agent 10/3/17 *Date

Approval Granted By Issue Date 10-9-17 Expiration Date 1-9-18 Hydrologist Approval Initials
Fee Received $ 75.— Receipt No. Check No.

THIS PERMIT IS NOT VALID UNTIL PROPERLY SIGNED BY AN AUTHORIZED OFFICER OR REPRESENTATIVE OF THE WMD OR DELEGATED AUTHORITY. THE PERMIT SHALL BE AVAILABLE AT THE WELL SITE DURING ALL CONSTRUCTION, REPAIR, MODIFICATION, OR ABANDONMENT ACTIVITIES.

STATE OF FLORIDA WELL COMPLETION REPORT

Date Stamp

Official Use Only

☐ Southwest
☐ Northwest
☐ St. Johns River
☐ South Florida
☐ Suwannee River
☐ DEP
☒ Delegated Authority (If Applicable) Osceola

PLEASE, FILL OUT ALL APPLICABLE FIELDS
(*Denotes Required Fields Where Applicable)

1.*Permit Number 49WPM93155 *CUP/WUP Number ______ *DID Number ______ 62-524 Delineation No. ______

2.*Number of permitted wells constructed, repaired, or abandoned 1 *Number of permitted wells not constructed, repaired, or abandoned Ø

3.*Owner's Name SFWMD 4.*Completion Date 2/7/18 5. Florida Unique ID ______

6. E Southport Rd. Kissimmee, Fl. 34759
*Well Location - Address, Road Name or Number, City, ZIP

7. *County Osceola *Section 18 Land Grant ______ *Township ______ *Range ______

8. Latitude ______ Longitude ______

9. Data Obtained From: ___GPS ___Map ___Survey Datum: ___NAD 27 ___NAD 83 ___WGS 84

10.*Type of Work: X Construction ___Repair ___Modification ___Abandonment

11.*Specify Intended Use(s) of Well(s):
___Domestic ___Landscape Irrigation ___Agricultural Irrigation ___Site Investigation
___Bottled Water Supply ___Recreation Area Irrigation ___Livestock X Monitoring
___Public Water Supply (Limited Use/DOH) ___Nursery Irrigation ___Test
___Public Water Supply (Community or Non-Community/DEP) ___Commercial/Industrial ___Earth-Coupled Geothermal
___Class I Injection ___Golf Course Irrigation ___HVAC Supply ___HVAC Return
Class V Injection: ___Recharge ___Commercial/Industrial Disposal ___Aquifer Storage and Recovery ___Drainage
Remediation: ___Recovery ___Air Sparge ___Other (Describe) ______
___Other (Describe) ______

12.*Drill Method: ___Auger ___Cable Tool X Rotary ___Combination (Two or More Methods) ___Jetted ___Sonic ___Horizontal Drilling ___Hydraulic Point (Direct Push) ___Other ______

13.*Measured Static Water Level ______ ft. Measured Pumping Water Level ______ ft. After ______ Hours at ______ GPM

14.*Measuring Point (Describe) ______ Which is ___ ft. ___Above ___Below Land Surface *Flowing: ___Yes ___No

15.*Casing Material: ___Black Steel ___Galvanized X PVC ___Stainless Steel ___Not Cased ___Other ______

16.*Total Well Depth 590 ft. Cased Depth 430 ft. *Open Hole: From 430 To 590 ft. *Screen: From ___ To ___ ft. Slot Size ___

17.*Abandonment: ___Other (Explain) ______
From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___

18.*Surface Casing Diameter and Depth:
Dia 12 in. From 0 ft. To 60 ft. No. of Bags 42 Seal Material (Check One): X Neat Cement ___Bentonite ___Other ___
Dia 8 in. From 0 ft. To 260 ft. No. of Bags 44 Seal Material (Check One): X Neat Cement ___Bentonite ___Other ___

19.*Primary Casing Diameter and Depth:
Dia 4 in. From 0 ft. To 430 ft. No. of Bags 82 Seal Material (Check One): X Neat Cement ___Bentonite ___Other ___
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___

20.*Liner Casing Diameter and Depth:
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___

21.*Telescope Casing Diameter and Depth:
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___
Dia ___ in. From ___ ft. To ___ ft. No. of Bags ___ Seal Material (Check One): ___Neat Cement ___Bentonite ___Other ___

22. Pump Type (If Known):
___Centrifugal ___Jet ___Submersible ___Turbine
Horsepower ______ Pump Capacity (GPM) ______
Pump Depth ___ ft. Intake Depth ___ ft.

23. Chemical Analysis (When Required):
Iron ___ ppm Sulfate ___ ppm Chloride ___ ppm
___Laboratory Test ___Field Test Kit

24. Water Well Contractor:
*Contractor Name Stephanie Stallsmith *License Number 9342 E-mail Address Stephanie@husedrilling.com
*Contractor's Signature ______ *Driller's Name (Print or Type) Kevin Reffuse
(I certify that the information provided in this report is accurate and true.)

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
2379 BROAD STREET, BROOKSVILLE, FL 34604-6899
PHONE: (352) 796-7211 or (800) 423-1476
WWW.SWFWMD.STATE.FL.US

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
4049 REID STREET, PALATKA, FL 32178-1429
PHONE: (386) 329-4500
WWW.SJRWMD.COM

NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT
152 WATER MANAGEMENT DR., HAVANA, FL 32333-4712
(U.S. Highway 90, 10 miles west of Tallahassee)
PHONE: (850) 539-5999
WWW.NWFWMD.STATE.FL.US

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
P.O. BOX 24680
3301 GUN CLUB ROAD
WEST PALM BEACH, FL 33416-4680
PHONE: (561) 686-8800
WWW.SFWMD.GOV

SUWANNEE RIVER WATER MANAGEMENT DISTRICT
9225 CR 49
LIVE OAK, FL 32060
PHONE: (386) 362-1001 or (800) 226-1066 (Florida only)
WWW.MYSUWANNEERIVER.COM

***DRILL CUTTINGS LOG** (Examine cuttings every 20 ft. or at formation changes. Note cavities and depth to producing zone. Grain Size: F=Fine, M=Medium, and C=Coarse)

From (ft.)	To (ft.)	Color	Grain Size (F, M, C)	Material
0	60	Brown	F	Sand
60	100	Green	M	Sandy clay, shell
100	120	green	M	Shell & clay
120	140	green	M	Shell & sandy
				clay w/ rock fragments
140	160	green	M	Shell & clay
160	590	white	F-S	limestone

Comments:

Figure 5. Site layout showing general dimensions of the project area, position of existing wells at the site and proposed well OSF-112.

Give distances from all n … thin 500 ft. of well.

Oct. 3. 2017 11:38AM No. 1463 P. 3

WGWCP1193152

SCL 1962 8800

STATE OF FLORIDA PERMIT APPLICATION TO CONSTRUCT, REPAIR, MODIFY, OR ABANDON A WELL

☐ Southwest
☐ Northwest
☐ St. Johns River
☐ South Florida
☐ Suwannee River
☐ DEP
☒ Delegated Authority (If Applicable) Osceola

PLEASE FILL OUT ALL APPLICABLE FIELDS
(*Denotes Required Fields Where Applicable)

The water well contractor is responsible for completing this form and forwarding the permit application to the appropriate delegated authority where applicable.

Permit No.
Florida Unique Id
Permit Stipulations Required (See Attached)
62-524 Quad No. ____ Delineation No. ____
CUP/WUP Application No. ____
ABOVE THIS LINE FOR OFFICIAL USE ONLY

1. SFWMD PO Box 24680 W. Palm Beach, FL 33416
*Owner, Legal Name if Corporation *Address *City *State *ZIP Telephone Number

2. E Southport Rd. Kissimmee, FL 34759
*Well Location - Address, Road Name or Number, City

3. 182730000000400000
*Parcel ID No. ☒ (PIN) or ☐ Alternate Key Lot Block Unit

4. 18 ___ Osceola ___ Check if 62-524: ☐ Yes ☐ No
*Section or Land Grant *Township *Range *County Subdivision

5. Stephanie Stallsmith 9342 352-567-9500 stephanie@hessdrilling.com
*Water Well Contractor *License Number *Telephone Number E-mail Address

6. 35920 State Road 52 Dade City FL 33525
*Water Well Contractor's Address City State ZIP

7. *Type of Work: ☐ Construction ☐ Repair ☒ Modification ☐ Abandonment ____
*Reason for Repair, Modification, or Abandonment

8. *Number of Proposed Wells ____

9. *Specify Intended Use(s) of Well(s):
☐ Domestic ☐ Landscape Irrigation ☐ Agricultural Irrigation ☐ Site Investigations
☐ Bottled Water Supply ☐ Recreation Area Irrigation ☐ Livestock ☒ Monitoring
☐ Public Water Supply (Limited Use/DOH) ☐ Nursery Irrigation ☐ Test
☐ Public Water Supply (Community or Non-Community/DEP) ☐ Commercial/Industrial ☐ Earth-Coupled Geothermal
☐ Class I Injection ☐ Golf Course Irrigation ☐ HVAC Supply
☐ HVAC Return

Class V Injection: ☐ Recharge ☐ Commercial/Industrial Disposal ☐ Aquifer Storage and Recovery ☐ Drainage
Remediation: ☐ Recovery ☐ Air Sparge ☐ Other (Describe) ____
☐ Other (Describe)

Date Stamp

Official Use Only

10. *Distance from Septic System if ≤ 200 ft. ____ 11. Facility Description ____ 12. Estimated Start Date 10/9/17

13. *Estimated Well Depth 950 ft. *Estimated Casing Depth 160 ft. Primary Casing Diameter 6 in. Open Hole: From ____ To ____ ft.

14. Estimated Screen Interval: From ____ To ____ ft.

15. *Primary Casing Material: ☐ Black Steel ☐ Galvanized ☒ PVC ☐ Stainless Steel
☐ Not Cased ☐ Other ____

16. Secondary Casing: ☐ Telescope Casing ☐ Liner ☐ Surface Casing Diameter ____ in.

17. Secondary Casing Material: ☐ Black Steel ☐ Galvanized ☐ PVC ☐ Stainless Steel ☐ Other ____

18. *Method of Construction, Repair, or Abandonment: ☐ Auger ☐ Cable Tool Jetted ☐ Rotary ☐ Sonic
☐ Combination (Two or More Methods) ☐ Hand Driven (Well Point, Sand Point) ☐ Hydraulic Point (Direct Push)
☐ Horizontal Drilling ☐ Plugged by Approved Method ☐ Other (Describe) ____

19. Proposed Grouting Interval for the Primary, Secondary, and Additional Casing:
From 950 To 600 Seal Material (☒ Bentonite ☒ Neat Cement ☐ Other ____)
From 600 To 950 Seal Material (☒ Bentonite ☒ Neat Cement ☐ Other Gravel)
From 950 To 300 Seal Material (☐ Bentonite ☐ Neat Cement ☐ Other ____)
From ____ To ____ Seal Material (☐ Bentonite ☐ Neat Cement ☐ Other ____)

20. Indicate total number of existing wells on site ____ List number of existing unused wells on site ____

21. *Is this well or any existing well or water withdrawal on the owner's contiguous property covered under a Consumptive/Water Use Permit (CUP/WUP) or CUP/WUP Application? Yes No If yes, complete the following: CUP/WUP No. ____ District Well ID No. ____

22. Latitude ____ Longitude ____

23. Data Obtained From: ☐ GPS ☐ Map ☐ Survey Datum: ____ NAD 27 ____ NAD 83 ____ WGS 84

I hereby certify that I will comply with the applicable rules of Title 62, Florida Administrative Code, and that a water use permit or artificial recharge permit, if needed, has been or will be obtained prior to the commencement of well construction. I further certify that all information provided is accurate and that I will obtain necessary approval from other federal, state, or local governments, if applicable. I agree to provide a well completion report to the District within 30 days after completion of the construction, repair, modification, or abandonment authorized by this permit, or the permit expiration, whichever comes first.

I certify that I am the owner of the property, that the information provided is accurate, and that I am aware of my responsibilities under Chapter 373, Florida Statutes, to maintain or properly abandon this well; or, I certify that I am the agent for the owner, that the information provided is accurate and that I have informed the owner of their responsibilities as stated above. Owner consents to allowing personnel of the WMD or Delegated Authority access to the well site during the construction, repair, modification or abandonment authorized by this permit.

*Signature of Contractor 9342 *License No. Signature of Owner or Agent 10/3/17 *Date

Approval Granted By Jeffrey Smith Issue Date 10-4-17 Expiration Date 4-4-18 Hydrologist Approval ____ Initials
Fee Received $ 7500 Receipt No. ____ Check No. ____

THIS PERMIT IS NOT VALID UNTIL PROPERLY SIGNED BY AN AUTHORIZED OFFICER OR REPRESENTATIVE OF THE WMD OR DELEGATED AUTHORITY. THE PERMIT SHALL BE AVAILABLE AT THE WELL SITE DURING ALL CONSTRUCTION, REPAIR, MODIFICATION, OR ABANDONMENT ACTIVITIES.

STATE OF FLORIDA WELL COMPLETION REPORT

☐ Southwest
☐ Northwest
☐ St. Johns River
☐ South Florida
☐ Suwannee River
☐ DEP
☒ Delegated Authority (If Applicable) Osceola

PLEASE, FILL OUT ALL APPLICABLE FIELDS
(*Denotes Required Fields Where Applicable)

Date Stamp

Official Use Only

1.*Permit Number 49WP179152 CUP/WUP Number ______ *DID Number ______ 62-524 Delineation No. ______

2.*Number of permitted wells constructed, repaired, or abandoned 1 *Number of permitted wells not constructed, repaired, or abandoned Ø

3.*Owner's Name SFWMD 4.*Completion Date 2/7/18 5. Florida Unique ID ______

6. E Southport Rd. Kissimmee, Fl. 34759
*Well Location - Address, Road Name or Number, City, ZIP

7. *County Osceola *Section 18 Land Grant ______ *Township ______ *Range ______

8. Latitude ______ Longitude ______

9. Data Obtained From: ____GPS ____Map ____Survey Datum: ____NAD 27 ____NAD 83 ____WGS 84

10.*Type of Work: ____Construction ____Repair X Modification ____Abandonment

11.*Specify Intended Use(s) of Well(s):
____Domestic ____Landscape Irrigation ____Agricultural Irrigation ____Site Investigation
____Livestock X Monitoring
____Bottled Water Supply ____Recreation Area Irrigation ____Nursery Irrigation ____Test
____Public Water Supply (Limited Use/DOH) ____Commercial/Industrial ____Earth-Coupled Geothermal
____Public Water Supply (Community or Non-Community/DEP) ____Golf Course Irrigation ____HVAC Supply
____Class I Injection ____HVAC Return
Class V Injection: ____Recharge ____Commercial/Industrial Disposal ____Aquifer Storage and Recovery ____Drainage
Remediation: ____Recovery ____Air Sparge ____Other (Describe) ______
____Other (Describe) ______

12.*Drill Method: ____Auger ____Cable Tool ____Rotary ____Combination (Two or More Methods) ____Jetted ____Sonic
____Horizontal Drilling ____Hydraulic Point (Direct Push) X Other Backplugging

13.*Measured Static Water Level ______ ft. Measured Pumping Water Level ______ ft. After ______ Hours at ______ GPM

14.*Measuring Point (Describe) ______ Which is ____ft. ____Above ____Below Land Surface *Flowing: ____Yes ____No

15.*Casing Material: ____Black Steel ____Galvanized X PVC ____Stainless Steel ____Not Cased ____Other ______

16.*Total Well Depth 950 ft. Cased Depth 160 ft. *Open Hole: From ____ To ____ ft. *Screen: From ____ To ____ ft. Slot Size ____

17.*Abandonment: ____Other (Explain) Back Plugged 6" Well

From	To	No. of Bags	Seal Material (Check One)
From 298 ft.	To 422 ft.	51	X Neat Cement ____Bentonite ____Other
From 422 ft.	To 661 ft.	332	____Neat Cement ____Bentonite X Other gravel
From 661 ft.	To 861 ft.	62/3	X 62 Neat Cement ____Bentonite X 3 Other gravel
From 861 ft.	To 960 ft.	54/2	X 54 Neat Cement ____Bentonite X 2 Other gravel
From ____ ft.	To ____ ft.	____	____Neat Cement ____Bentonite ____Other

18.*Surface Casing Diameter and Depth:
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____

19.*Primary Casing Diameter and Depth:
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____

20.*Liner Casing Diameter and Depth:
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____

21.*Telescope Casing Diameter and Depth:
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____
Dia____in. From____ft. To____ft. No. of Bags____ Seal Material (Check One): ____Neat Cement ____Bentonite ____Other____

22. Pump Type (If Known):
____Centrifugal ____Jet ____Submersible ____Turbine
Horsepower ______ Pump Capacity (GPM) ______
Pump Depth ____ft. Intake Depth ____ft.

23. Chemical Analysis (When Required):
Iron ____ppm Sulfate ____ppm Chloride ____ppm
____Laboratory Test ____Field Test Kit

24. Water Well Contractor:
*Contractor Name Stephanie Stallsmith *License Number 9342 E-mail Address Stephanie@hussdrilling.com

*Contractor's Signature [signature] *Driller's Name (Print or Type) Kevin Reffuse
(I certify that the information provided in this report is accurate and true.)

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
2379 BROAD STREET, BROOKSVILLE, FL 34604-6899
PHONE: (352) 796-7211 or (800) 423-1476
WWW.SWFWMD.STATE.FL.US

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
4049 REID STREET, PALATKA, FL 32178-1429
PHONE: (386) 329-4500
WWW.SJRWMD.COM

NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT
152 WATER MANAGEMENT DR., HAVANA, FL 32333-4712
(U.S. Highway 90, 10 miles west of Tallahassee)
PHONE: (850) 539-5999
WWW.NWFWMD.STATE.FL.US

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
P.O. BOX 24680
3301 GUN CLUB ROAD
WEST PALM BEACH, FL 33416-4680
PHONE: (561) 686-8800
WWW.SFWMD.GOV

SUWANNEE RIVER WATER MANAGEMENT DISTRICT
9225 CR 49
LIVE OAK, FL 32060
PHONE: (386) 362-1001 or (800) 226-1066 (Florida only)
WWW.MYSUWANNEERIVER.COM

***DRILL CUTTINGS LOG** (Examine cuttings every 20 ft. or at formation changes. Note cavities and depth to producing zone. Grain Size: F=Fine, M=Medium, and C=Coarse)

From_____ ft. To_____ ft. Color__________ Grain Size (F, M, C)_____ Material__________
From_____ ft. To_____ ft. Color__________ Grain Size (F, M, C)_____ Material__________
From_____ ft. To_____ ft. Color__________ Grain Size (F, M, C)_____ Material__________
From_____ ft. To_____ ft. Color__________ Grain Size (F, M, C)_____ Material__________
From_____ ft. To_____ ft. Color__________ Grain Size (F, M, C)_____ Material__________
From_____ ft. To_____ ft. Color__________ Grain Size (F, M, C)_____ Material__________
From_____ ft. To_____ ft. Color__________ Grain Size (F, M, C)_____ Material__________
From_____ ft. To___
From_____ ft. To___
From_____ ft. To___
From_____ ft. To___
From_____ ft. To___
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From_____ ft. To___
From_____ ft. To___
From_____ ft. To___
From_____ ft. To___
From_____ ft. To___
From_____ ft. To___

Comments:

Figure 5. Site layout showing general dimensions of the project area, position of existing wells at the site and proposed well OSF-112.

Give distances from a ... 10 ft. of well.

APPENDIX C:
LITHOLOGIC DESCRIPTION

From Depth (ft bls)	To Depth (ft bls)	Material Description
0.0	2.0	Fine to very fine quartz sand, pinkish gray(5yr8/1); sub-anglar, non-cohesive, dry
2.0	8.0	Fine to very fine quartz sand, pale brown(5yr5/2); 10 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive; damp
8.0	10.0	Fine to very fine quartz sand, grayish orange (10yr7/4); 10 percent clay; 5 percent dark minerals, sub-anglar, non-cohesive
10.0	12.0	Fine to very fine quartz sand, pale brown(5yr5/2); 5 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive
12.0	14.0	Fine to very fine quartz sand, dark yellow brown(5yr4/2); 20 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive
14.0	16.0	Fine to very fine quartz sand, pale yellow brown(5yr6/2); 20 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive
16.0	20.0	Clayey sand; pale yellow brown(5yr6/2); fine to very fine quartz sand, 30 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive;
20.0	24.0	Fine to very fine quartz sand, pale yellow brown(5yr6/2); 20 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive
24.0	26.0	Clayey sand; dark yellow brown (5yr4/2); fine to very fine quartz sand, 30 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive
26.0	30.0	Fine to very fine quartz sand, dark yellow brown(5yr4/2); 20 percent silt; sub-anglar; non-cohesive
30.0	34.0	Silty sand; dark yellow brown (5yr4/2): very fine quartz sand, 30 percent silt; subangular; non-cohesive
34.0	38.0	Fine to very fine quartz sand, pale brown (5yr5/2); 5 percent dark minerals; sub-anglar; non-cohesive
38.0	40.0	Silty sand; dark yellow brown (5yr4/2): very fine quartz sand, 20 percent silt; subangular; non-cohesive
40.0	42.0	Clayey sand; dark yellow brown (5yr4/2); fine to very fine quartz sand, 20 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive
42.0	52.0	Silty sand; dark yellow brown (5yr4/2): very fine quartz sand, 30 percent silt; subangular; non-cohesive
52.0	54.0	Clayey sand; dark yellow brown (5yr4/2); fine to very fine quartz sand, 20 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive
54.0	56.0	Silty sand; dark yellow brown (5yr4/2): very fine quartz sand, 30 percent silt; subangular; non-cohesive
56.0	58.0	Clayey sand; dark yellow brown (5yr4/2); fine to very fine quartz sand, 20 percent clay; 5 percent dark minerals; sub-anglar; non-cohesive
58.0	60.0	Clayey sand; olive gray (5y 4/1); fine grained quartz sand, calcareous, 30 percent clay, 10 percent phosphate; sub-anglar; non-cohesive
60.0	70.0	Clayey sand; olive gray (5y 4/1); fine grained quartz sand, 20 precent light gray phosphatic wackestone, 20 percent clay, 10 percent phosphate; sub-anglar; non-cohesive
70.0	75.0	Shelly, sandy clay; olive gray (5y 4/1); 30 percent shell fragments, 20 percent fine grained quartz sand,10 precent light gray phosphatic wackestone, 10 percent phosphate; sub-anglar; non-cohesive
75.0	100.0	Shelly, sandy clay; olive gray (5y 4/1); 30 percent shell fragments, 20 percent fine grained quartz sand, 10 percent phosphate; sub-anglar; non-cohesive
100.0	120.0	Fine quartz sand and limestone; olive gray (5y 4/1); fine grained quartz sand, 30 percent sandy, phosphatic wackestone, 20 percent shell fragments, 10 phosphate sand; non-cohesive
120.0	130.0	Fine quartz sand; olive gray (5y 4/1); fine grained quartz sand, 20 percent shell fragments, 10 phosphate sand, 10 percent phosphatic wackestone; non-cohesive
130.0	140.0	Shell (5y 4/1); 20 percent fine to coarse grained quartz sand, 20 percent clay, 10 percent phosphatic wackestone, 10 phosphate sand; non-cohesive

From Depth (ft bls)	To Depth (ft bls)	Material Description
140.0	155.0	Clayey sand; olive gray (5y 4/1); fine to coarse grained quartz sand, 30 percent clay; 20 percent shell fragments; 20 percent phosphate; sub-anglar; non-cohesive
155.0	170.0	Limestone (wackestone); very pale orange(10yr 8/2); 30 intergranular porosity; mod induration; highly fossiliferous, foraminifera, lepicyclina
170.0	176.5	Limestone (grainstone); very pale orange(10yr 8/2); 30 percent intergranular porosity; mod induration; highly fossiliferous, foraminifera, lepicyclina, miliolids, bivalves.
176.5	180.0	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; highly fossiliferous, foraminifer, lepicyclina, miliolids, bivalves.
180.0	198.0	Limestone (packstone); very pale orange(10yr 8/2); 30 percent interparticle porosity; mod induration; highly fossiliferous, foraminifera, lepicyclina, miliolids, bivalves, numulites, pellets.
198.0	200.0	No sample
200.0	222.5	Limestone (grainstone); very pale orange(10yr 8/2); 30 percent interparticle porosity; mod to poor induration; highly fossiliferous, foraminifera, pellets, miliolids, bivalves, shell fragments.
222.5	224.5	Limestone (wackestone); greyish orange(10yr 7/4); 20 percent interparticle porosity; poor induration to unconsolidated; pellets, shell fragments.
224.5	235.0	No sample
235.0	240.0	Limestone (grainstone); greyish orange(10yr 7/4); 30 percent interparticle porosity; poor induration to unconsolidated; highly fossiliferous, foraminifera, pellets, miliolids, algae, numulites, shell fragments.
240.0	241.5	Limestone (packstone); greyish orange(10yr 7/4); 20 percent interparticle porosity; poor induration; pellets, miliolids, algae, shell fragments.
241.5	258.0	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; poor induration; highly fossiliferous, pellets, lepidocyclina, miliolids, numulites, shell fragments.
258.0	260.0	No sample
260.0	270.3	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; poor induration; highly fossiliferous, foraminifera, pellets, miliolids, neolagnum molds, numulites, shell fragments.
270.3	277.9	Limestone (packstone) grading to (wackestone); very pale orange(10yr 8/2); 20 percent interparticle porosity; poor induration; pellets, algea, shell fragments.
277.9	278.8	Limestone (mudstone); very pale orange (10yr 7/2); poorly indurated; no observable porosity
278.8	285.8	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; poor induration; pellets.
285.8	286.8	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent interparticle porosity; poor induration; pellets.
286.8	288.0	Limestone (mudstone); very pale orange (10yr 7/2); mod indurated; no observable porosity
288.0	288.3	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets.
288.3	290.0	Limestone (mudstone); very pale orange (10yr 7/2); poorly indurated; no observable porosity
290.0	290.4	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent interparticle porosity; mod induration; pellets.
290.4	292.0	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets, gastropods.
292.0	294.0	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent interparticle porosity; mod induration; pellets; trace organics.
294.0	295.6	Limestone (mudstone); very pale orange (10yr 7/2); poorly indurated; no observable porosity

From Depth (ft bls)	To Depth (ft bls)	Material Description
295.6	301.0	Limestone (wackestone); very pale orange(10yr 8/2); no visible porosity; mod induration; pellets; bivalves, gastropods.
301.0	304.8	Limestone (packstone); very pale orange(10yr 8/2); 10 percent interparticle porosity; mod induration; pellets, foram. Fragments
304.8	305.4	Limestone (mudstone); very pale orange (10yr 7/2); poorly indurated; no observable porosity
305.4	306.9	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets.
306.9	308.2	Limestone (mudstone); very pale orange (10yr 7/2); poorly indurated; no observable porosity
308.2	309.4	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; no visible porosity; mod induration; pellets; sm lamination.
309.4	313.0	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets; sm lamination.
313.0	314.2	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; no visible porosity; mod induration; pellets.
314.2	314.6	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets.
314.6	315.0	Limestone (mudstone); very pale orange (10yr 7/2); mod indurated; no observable porosity
315.0	320.8	Limestone (packstone grading to wackestone); very pale orange(10yr 8/2); 10 percent interparticle porosity; mod induration; pellets.
320.8	322.5	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; no visible porosity; mod induration; many gastropods, neolagnum, bivalves, pellets.
322.5	323.3	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets.
323.3	328.5	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; no visible porosity; mod induration; pellets; laminated.
328.5	329.3	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets.
329.3	330.0	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; no visible porosity; mod induration; pellets.
330.0	331.8	Limestone (grainstone); very pale orange(10yr 8/2); 30 percent interparticle porosity; mod to poor induration; highly fossiliferous, foraminifera, pellets, fallotella, algal, shell fragments.
331.8	338.0	Limestone (wackestone); very pale orange(10yr 8/2); 20 to 10 percent intergranular porosity; no visible porosity; mod induration; pellets, bivalve.
338.0	338.5	Limestone (mudstone); very pale orange (10yr 7/2); mod indurated; no observable porosity
338.5	344.0	Limestone (wackestone); very pale orange(10yr 8/2); 20 to 10 percent intergranular porosity; no visible porosity; mod induration; pellets, neolagnum.
344.0	354.0	Limestone (packstone grading to wackestone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets.
354.0	355.0	Limestone (wackestone); greyish orange(10yr 7/4); 20 to 10 percent intergranular porosity; no visible porosity; mod induration; pellets.
355.0	359.5	Dolomitic limestone; moderate yellow brown (10yr5/4); 30 to 40 percent vuggy porosity
359.5	371.6	Limestone (packstone); very pale orange(10yr 8/2); 10 percent interparticle porosity; mod induration to unconsolidated; pellets, foraminifera,algae, bivalve; sm lamination.
371.6	373.0	Limestone (grainstone); very pale orange(10yr 8/2); 30 percent interparticle porosity; mod induration; peletal, foraminifera, bivalves.
373.0	375.0	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; no visible porosity; mod induration; pellets; sm lamination.
375.0	377.7	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets, foraminifera,algae, bivalve; sm lamination.

From Depth (ft bls)	To Depth (ft bls)	Material Description
377.7	378.0	Limestone (rudstone); very pale orange(10yr 8/2); 30 percent interparticle porosity; mod induration; intraclasts, pelets, foraminifera, neolagnum, shell fragments.
378.0	383.9	Limestone (wackestone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets, foraminifera, neolagnum.
383.9	392.5	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets, foraminifera, neolagnum.
392.5	393.5	Limestone (floatstone); very pale orange(10yr 8/2); 30 percent interparticle porosity; mod to poor induration; pelets, foraminifera, neolagnum, fallotella, shell fragments.
393.5	394.0	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod to poor induration; pellets, foraminifera, fallotella, neolagnum, shell fragments.
394.0	399.3	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; no visible porosity; mod to poor induration; pellets.
399.3	400.0	Limestone (floatstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod to poor induration; pelets, foraminifera, fallotella, shell fragments.
400.0	402.2	Limestone (packstone grading to grainstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets, foraminifera, shell fragments.
402.2	402.8	Limestone (packstone grading to grainstone); very pale orange(10yr 8/2); 30 percent interparticle and vuggy porosity; mod induration; pellets, foraminifera, fallotella, gasrtropods, shell fragments.
402.8	404.5	Limestone (packstone grading to grainstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets, foraminifera, shell fragments.
404.5	406.3	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; no visible porosity; mod to poor induration; pellets, cushmania, fallotella.
406.3	408.0	Limestone (packstone grading to grainstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets, foraminifera, fallotella, neolagnum, fabularia, shell fragments.
408.0	410.0	Limestone (wackestone); very pale orange(10yr 8/2); no visible intergranular porosity; intergranular porosity; poor induration; pellets.
410.0	412.6	Limestone (wackestone); very pale orange(10yr 8/2); 10 to 20 percent intergranular porosity; intergranular porosity; good induration; pellets.
412.0	412.6	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets.
412.6	427.0	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; good induration; pellets.
427.0	430.8	Calcareous dolostone; dark yellow brown (10yr4/2); microcrystalline; 20 percent pin-point and vugular porosity; well indurated
430.8	436.0	Limestone (mudstone); very pale orange (10yr 7/2); cryptpcrystalline; mod indurated; no observable porosity
436.0	440.0	No sample
440.0	442.3	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets.
442.3	446.1	Limestone (floatstone); very pale orange(10yr 8/2); 30 percent interparticle porosity; mod induration; pelets, foraminifera, shell fragments, algae.
446.1	447.8	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intercrystalline porosity; microcrystalline; moderate induration; pellets.
447.8	449.7	Limestone (wackestone); dark yellow orange(10yr 6/6); 10 percent intercrystalline porosity; microcrystalline; good induration; pellets.
449.7	450.2	Limestone (mudstone); very pale orange (10yr 7/2); cryptpcrystalline; mod indurated; no observable porosity
450.2	451.0	Limestone (packstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; mod induration; pellets.
451.0	453.0	Limestone (mudstone); very pale orange (10yr 7/2); mod indurated; no observable porosity

From Depth (ft bls)	To Depth (ft bls)	Material Description
453.0	454.3	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; poor induration; pellets.
454.3	457.5	Limestone (packstone grading to grainstone); very pale orange(10yr 8/2); 20 percent interparticle porosity; poor induration; pellets, foraminifera, shell fragments.
457.5	457.7	Limestone (mudstone); very pale orange (10yr 7/2); poor indurated; no observable porosity
457.7	459.0	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; poor induration; pellets.
459.0	460.0	No sample
460.0	466.4	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; poor induration; pellets, shell fragments.
466.4	469.5	Calcareous dolostone; dark yellow brown (10yr4/2); 10 percent pin-point porosity; well indurated
469.5	470.0	No sample
470.0	471.2	Calcareous dolostone; pale yellow brown (5yr6/2); 20 percent pin-point porosity; well indurated; moderately fractured
471.2	475.2	Calcareous dolostone; pale yellow brown (5yr6/2); 20 percent pin-point and moldic porosity; well indurated; moderately fractured
475.2	476.0	Calcareous dolostone; moderate yellow brown (10yr5/4); 10 percent pin-point porosity; well indurated
476.0	480.0	No sample
480.0	482.3	Calcareous dolostone; moderate yellow brown (10yr5/4); 10 to 20 percent pin-point and moldic porosity; bivalves; well indurated; microcrystalline
482.3	485.3	Limestone (packstone); mod yellow brown (10yr5/4); 20 percent intergranular porosity; poor induration; pellets; some laminated.
485.3	490.0	No sample
490.0	490.8	Limestone (wackestone); very light gray(n8); 20 percent intergranular porosity; good induration; pellets; fractured.
490.8	491.9	Limestone (packstone); very pale orange(10yr8/2); 20 percent intergranular porosity; poor induration.
491.9	492.8	Limestone (wackestone); very pale orange(10yr8/2); 10 percent intergranular porosity; moderate induration.
492.8	493.5	Limestone (wackestone); very pale orange(10yr8/2); 30 percent fracture and intergranular porosity; poor induration.
493.5	496.0	Limestone (packstone grading to grainstone); very pale orange(10yr8/2); 30 percent intergranular porosity; poor induration; pellets, bivlalves, echnoids.
496.0	497.6	Limestone (wackestone); very pale orange(10yr8/2); 20 percent intergranular porosity; poor induration; pellets; laminated.
497.6	499.0	Limestone (grainstone); very pale orange(10yr8/2); 30 percent intergranular porosity; poor induration; pellets, echnoids.
499.0	500.0	No sample
500.0	505.0	Limestone (mudstone); very pale orange(10yr8/2); 10 percent pin point porosity; good induration.
500.5	504.8	Limestone (packstone); very pale orange(10yr8/2); 20 percent intergranular porosity; poor induration; pellets, intraclasts, algae, foraminifera.
504.8	506.0	Limestone (packstone); grayish orange(10yr7/4); 20 percent intergranular porosity; mod induration; pellets, intraclasts, algae, foraminifera.
506.0	506.4	Limestone (grainstone); grayish orange(10yr7/4); 30 percent intergranular porosity; mod induration; pellets, intraclasts, algae, foraminifera.
506.4	510.0	No sample
510.0	510.8	Limestone (grainstone); very pale orange(10yr8/2); 30 percent intergranular porosity; poor induration; pellets, intraclasts, algae, foraminifera, fallotella.

From Depth (ft bls)	To Depth (ft bls)	Material Description
510.8	511.8	Limestone (mudstone); very pale orange(10yr8/2); no observable porosity; poor induration.
511.8	518.4	Limestone (wackestone); very pale orange(10yr8/2); 10 percent intergranular porosity; poor induration; some lamination.
518.4	520.0	No sample
520.0	520.5	Limestone (mudstone); very pale orange(10yr8/2); no observable porosity; poor induration.
520.5	522.0	Limestone (wackestone); very pale orange(10yr8/2); 10 percent intergranular porosity; poor induration.
522.0	524.6	Limestone (mudstone); very pale orange(10yr8/2); no observable porosity; poor induration; some lamination.
524.6	526.0	Dolomitic limestone; dark yellow brown (10yr4/2); 30 percent fracture porosity; microcrystalline; well indurated.
526.0	528.7	Dolostone; dark yellow brown (10yr4/2); microcrystalline; 10 percent intercrystalline porosity; well indurated.
528.7	530.0	Dolostone; pale yellow brown (10yr6/2); microcrystalline; 30 percent fracture porosity; well indurated.
530.0	534.6	Dolostone; mod yellow brown (10yr5/4); microcrystalline; 20 percent fracture, vuggy and moldic porosity; well indurated.
534.6	535.4	Dolostone; dark yellow brown (10yr4/2); microcrystalline; 10 percent intercrystalline and moldic porosity; well indurated.
535.4	537.0	Dolostone; dark yellow brown (10yr4/2); microcrystalline; 30 percent intercrystalline and moldic porosity; well indurated.
537.0	540.0	Dolostone; dark yellow brown (10yr4/2); microcrystalline; 20 percent intercrystalline and moldic porosity; well indurated.
540.0	540.4	Dolostone; very pale orange (10yr8/2); microcrystalline; 10 percent intercrystalline porosity; well indurated.
540.2	540.8	Dolostone; mod dark gray (n4); microcrystalline; 20 percent vuggy and pin point porosity; well indurated.
540.8	541.7	Dolostone; mod dark gray (n4); microcrystalline; no observable porosity; well indurated.
541.7	546.1	Dolostone; mod dark gray (n4); microcrystalline; 30 percent fracture and vuggy porosity; well indurated.
546.1	548.5	Dolostone; mod dark gray (n4); microcrystalline; 10 percent intercrystalline porosity; well indurated.
548.5	550.0	No sample
550.0	550.6	Dolomitic limestone; very pale 0range (10yr 8/2); microcrystalline; 10 percent intercrystalline porosity; mod indurated.
550.6	551.6	Limestone (packstone); very pale 0range (10yr 8/2); 20 percent intergranular porosity; poorly indurated.
551.6	556.3	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; poor induration
556.3	556.5	Limestone (mudstone); very pale orange(10yr8/2); no observable porosity; laminated; poor induration.
556.5	560.0	No sample
560.0	561.0	Limestone (packstone); very pale 0range (10yr 8/2); 20 percent intergranular porosity; pellets, algae; poorly indurated.
561.0	566.7	Calcareous dolostone; dark yellow brown (10yr 4/2); 20 percent pin-point porosity; microcrystalline; well indurated
566.7	567.0	Calcareous dolostone; dusky yellow brown (10yr 2/2); 20 percent pin-point porosity; carbonatious lamination; mod induration
567.0	568.0	Calcareous dolostone; dark yellow brown (10yr 4/2); 20 percent pin-point porosity; microcrystalline; good induration

From Depth (ft bls)	To Depth (ft bls)	Material Description
568.0	570.0	No sample
570.0	570.5	Limestone (wackestone); very pale orange(10yr 8/2); 10 percent intergranular porosity; mod induration
570.5	574.6	Dolostone; dark yellow brown (10yr 4/2); 20 percent pin-point porosity; good induration
574.6	578.4	Dolostone; dark yellow brown (10yr 4/2); 10 percent pin-point porosity; good induration
578.4	579.6	Dolostone; dark yellow brown (10yr 4/2); 20 percent pin-point porosity; organic vug filling; good induration
579.6	580.0	Dolostone; very pale orange (10yr 8/2); 20 percent pin-point porosity; good induration
580.0	588.0	Dolostone; grayish orange (10yr 7/4); 10 percent pin-point porosity; good induration
588.0	589.4	Dolostone; dusky yellow brown (10yr 2/2); 10 percent pin-point porosity; good induration
589.4	590.0	Dolostone; dusky yellow brown (10yr 2/2); 20 percent fractured, pin-point and moldic porosity; good induration
590.0	594.8	Dolostone; dark yellow brown (10yr 4/2); 30 percent fractured, pin-point and moldic porosity; microcrystalline; good induration
594.8	596.4	Dolostone; dark yellow brown (10yr 4/2); 10 percent intergranular porosity; good induration
596.4	600.0	Dolostone; very pale orange (10yr 8/2); 10 percent intergranular porosity; good induration
600.0	600.6	Dolostone; dark yellow brown (10yr 4/2); 30 percent fractured and pin-point porosity; good induration
600.6	603.6	Dolostone; mod yellow brown (10yr5/4); 10 pinpoint porosity; mod indurated; organic lamination
603.6	607.8	Dolostone; mod yellow brown (10yr5/4); 20 percent vuggy and pinpoint porosity; mod indurated; some organic lamination
607.8	610.0	Dolostone; grayish orange (10yr 7/4); 10 percent pin-point porosity; mod induration
610.0	602.2	Dolostone; very pale orange (10yr 8/2); 20 percent intergranular porosity; mod induration
602.2	619.1	Dolostone; very pale orange (10yr 8/2); 10 percent intergranular porosity; mod induration
619.1	620.0	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy and pinpoint porosity; mod induration; some organic lamination
620.0	624.0	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy and pinpoint porosity; poor induration; some lamination
624.0	630.0	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy and pinpoint porosity; poor induration; some lamination
630.0	630.4	Dolostone; grayish orange (10yr 7/4); 20 percent pinpoint porosity; some organic material, fallotella, poor induration
630.4	632.3	Dolostone; grayish orange (10yr 7/4); 20 percent pinpoint porosity; poor induration
632.3	634.1	Dolostone; grayish orange (10yr 7/4); 10 percent intergranular porosity; mod induration
634.1	640.0	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; moderate induration
640.0	640.7	Dolostone (packstone); dark yellow brown (10yr 4/2); 20 percent intergranular and pin-point porosity; pellets and intraclasts; high organics; very poor induration
640.7	646.4	Dolostone; very pale orange (10yr 8/2); no observable pinpoint porosity; mod induration; some organic lamination
646.4	650.0	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; poor induration; lamination
650.0	650.8	Dolostone; grayish orange (10yr 7/4); 30 percent fracture and pinpoint porosity; mod induration
650.8	651.5	Dolostone; grayish orange (10yr 7/4); 10 pinpoint porosity; organic vug filling; mod induration
651.5	652.2	Dolostone; grayish orange (10yr 7/4); 30 pinpoint and vuggy porosity; poor induration
652.2	657.2	Dolostone; grayish orange (10yr 7/4); 10 pinpoint porosity; poor induration

From Depth (ft bls)	To Depth (ft bls)	Material Description
657.2	658.1	Dolostone; grayish orange (10yr 7/4); 20 percent pinpoint and vuggy porosity; poor induration
658.1	660.0	No sample
660.0	660.7	Calcareous dolostone; grayish orange (10yr 7/4); 10 intergranular; some lamination; poor induration
660.7	662.4	Calcareous dolostone; grayish orange (10yr 7/4); no visible porosity; some lamination; poor induration
662.4	670.0	Calcareous dolostone; grayish orange (10yr 7/4); 10 intergranular; poor induration
670.0	677.0	Calcareous dolostone; pale yellow brown (5yr 6/2); 20 percent vuggy and pin-point porosity; mod indurated
677.0	678.0	Calcareous dolostone; pale yellow brown (5yr 6/2); 30 percent fracture, vuggy and pin-point porosity; mod indurated
678.0	680.0	Calcareous dolostone; pale yellow brown (5yr 6/2); 30 percent vuggy and moldic porosity; bivalve and gastropod molds; mod indurated
680.0	681.4	Dolostone; pale yellow brown (5yr 6/2); 20 percent intergranular porosity; mod indurated
681.4	683.0	Dolostone; pale yellow brown (5yr 6/2); 30 percent fractured, vuggy, and intergranular porosity; poorly indurated
683.0	687.0	Dolostone; pale yellow brown (5yr 6/2); 20 percent fractured, vuggy, and intergranular porosity; poorly indurated
687.0	690.0	No sample
690.0	696.7	Dolostone; grayish orange (10yr 7/4); 10 intergranular; poor induration
696.7	697.0	Dolostone; pale yellow brown (5yr 6/2); 10 percent intergranular porosity; clayey; poor induration
697.0	698.2	Dolostone; grayish orange (10yr 7/4); 10 percent intergranular porosity; poor induration; some lamination
698.2	700.0	No sample
700.0	709.0	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; some lamination; poor induration
709.0	710.0	No sample
710.0	726.0	Dolostone; moderate yellow brown (5yr 5/4); 30 percent fracture, vuggy and pin-point porosity; microcrystalline; poorly to well indurated
726.0	727.4	Dolostone; moderate yellow brown (5yr 5/4); 20 percent vuggy and pin-point porosity; moderately indurated
727.4	729.0	Dolostone; pale yellow brown (5yr 6/2); 10 percent intergranular porosity; mod indurated
729.0	730.0	Dolostone; pale yellow brown (5yr 6/2); 20 percent vuggy and pin point porosity; mod indurated
730.0	736.0	Dolostone; pale yellow brown (5yr 6/2); 30 percent fracture, vuggy and pin-point porosity; microcrystalline; well indurated
736.0	740.0	Dolostone; pale yellow brown (5yr 6/2); 20 percent fracture and intercrystalline porosity; microcrystalline; moderately indurated
740.0	749.0	Dolostone; dark yellow brown (10yr 4/2); 30 percent fracture, vuggy and pin point porosity; microcrystalline; some lamination; well indurated
749.0	750.0	Dolostone; pale yellow brown (5yr 6/2); 30 percent fracture vugs and pin point porosity; microcrystalline; laminated; well indurated
750.0	754.6	Dolostone; moderate yellow brown (5yr 5/4); 30 percent fracture, vuggy and pin-point porosity; microcrystalline; well indurated
754.6	756.4	Calcareous dolostone; moderate yellow brown (10yr 5/4); 30 percent fracture, vuggy and pin point porosity; well indurated
756.4	759.4	Calcareous dolostone; moderate yellow brown (10yr 5/4); 20 percent vuggy and pin point porosity; well indurated

From Depth (ft bls)	To Depth (ft bls)	Material Description
759.4	760.0	Calcareous dolostone; very pale orange (10yr 8/2); 20 percent vuggy and pin point porosity; moderate induration
760.0	766.5	Dolostone; moderate yellow brown (5yr 5/4); 30 percent fracture, pin-point, vuggy and fossil moldic (bivalves) porosity; microcrystalline; some organic lamenation; well indurated
766.5	770.0	Dolostone; grayish orange (10yr 7/4); 30 vuggy, pin point, and moldic porosity; microcrystalline; moderate induration
770.0	778.4	Dolostone; grayish orange (10yr 7/4); 30 fracture, vuggy, fossil moldic (bivalves) , and pin pointporosity; microcrystalline; good induration
778.4	778.8	Dolostone; grayish orange (10yr 7/4); 10 percent intergranular porosity; clayey; organic lamenae; poor induration
778.8	780.0	Dolostone; grayish orange (10yr 7/4); 30 fracture, vuggy and pin pointporosity; microcrystalline; moderate induration
780.0	786.0	Dolostone; pale yellow brown (5yr 6/2); 30 percent fracture, moldic, pin point and vuggy porosity; microcrystalline; moderately indurated
786.0	786.4	Dolostone; pale yellow brown (5yr 6/2); 10 percent pin point porosity; clayey; poor induration
786.4	786.7	Dolostone; pale yellow brown (5yr 6/2); 10 percent pin point porosity; clayey; organic lamenae; poor induration
786.7	788.1	Dolostone; pale yellow brown (5yr 6/2); 20 percent pin point porosity; microcrystalline; well indurated
788.1	790.0	No sample
790.0	791.9	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; poor induration
791.9	794.4	Dolostone; grayish orange (10yr 7/4); 10 pinpoint; good induration
794.4	795.6	Dolostone; grayish orange (10yr 7/4); 10 pinpoint; poor induration
795.6	796.2	Dolostone; grayish orange (10yr 7/4); no observable porosity; laminated; moderate induration
796.2	798.2	Dolostone; grayish orange (10yr 7/4); 10 pinpoint; poor induration
798.2	799.4	Calcareous dolostone; dark yellow brown (10yr 4/2); 30 fracture porosity; microcrystalline; good induration
799.4	805.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture and pinpoint porosity; microcrystalline; good induration
805.0	806.0	Dolostone; very pale orange (10yr 8/2); 30 percent moldic and pinpoint porosity; microcrystalline; good induration
806.0	808.5	Dolostone; very pale orange (10yr 8/2); 30 percent fracture and pinpoint porosity; microcrystalline; moderate induration
808.5	809.4	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy, and pinpoint porosity; microcrystalline; good induration
809.4	810.1	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; microcrystalline; poor induration
810.0	811.2	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; microcrystalline; good induration
811.2	811.9	Dolostone; very pale orange (10yr 8/2); no observable porosity; poor induration
811.9	812.2	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; poor induration
812.2	813.3	Dolostone; very pale orange (10yr 8/2); 30 percent moldic, vuggy and pinpoint porosity; moderate induration
813.3	814.2	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy and pinpoint porosity; moderate induration
814.2	814.8	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy and pinpoint porosity; poor induration
814.8	817.0	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; moderate induration, some lamination

From Depth (ft bls)	To Depth (ft bls)	Material Description
817.0	817.2	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; moderate induration, laminated; organics
817.2	817.8	Dolostone; very pale orange (10yr 8/2); 30 percent fracture and pinpoint porosity; mod induration
817.8	819.0	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy and pinpoint porosity; poor induration
819.0	819.9	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; some organic lamination; poor induration
819.9	820.3	Dolostone; very pale orange (10yr 8/2); 30 percent fracture and pinpoint porosity; poor induration
820.3	822.1	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; poor induration
822.1	822.7	Dolostone; grayish orange (10yr 7/4); 20 percent pinpoint porosity; moderate induration
822.7	823.2	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; moderate induration
823.2	824.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture and pinpoint porosity; moderate induration
824.0	827.3	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; microcrystalline; some lamination; good induration
827.0	828.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture and pinpoint porosity; microcrystalline; good induration
828.0	829.1	Dolostone; grayish orange (10yr 7/4); 20 percent pinpoint and intercrystalline porosity; moderate induration
829.1	830.0	No sample
830.0	830.7	Calcareous dolostone; grayish orange (10yr 7/4); no observable porosity; poor induration
830.7	832.0	Calcareous dolostone; grayish orange (10yr 7/4); 20 percent pin point porosity; moderate induration
832.0	832.7	Calcareous dolostone; grayish orange (10yr 7/4); 30 percent vuggy and moldic porosity; microcrystalline; some lamination; moderate induration
832.7	833.2	Dolostone; grayish orange (10yr 7/4); no observable porosity; microcrystalline; moderate induration
833.2	836.0	Dolostone; grayish orange (10yr 7/4); 30 percent vuggy and pin point porosity; microcrystalline; good induration
836.0	837.0	Dolostone; grayish orange (10yr 7/4); 30 percent vuggy, moldic and pin point porosity; microcrystalline; bivalve molds; good induration
837.0	837.7	Dolostone; grayish orange (10yr 7/4); 10 percent pin point porosity; microcrystalline; good induration
837.7	839.2	Dolostone; grayish orange (10yr 7/4); no observable porosity; organic lamination; poor induration
839.2	840.0	Dolostone; grayish orange (10yr 7/4); 20 percent pin point porosity; microcrystalline; good induration
840.0	841.6	Dolomitic silt; grayish orange (10yr 7/4); no observable porosity; non-cohesive
841.6	844.0	Dolostone; grayish orange (10yr 7/4); 10 percent pin point and vuggy porosity; good induration
844.0	850.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy and pinpoint porosity; poor induration
850.0	850.7	Dolomitic silt; grayish orange (10yr 7/4); no observable porosity; non-cohesive
850.7	853.1	Dolostone; grayish orange (10yr 7/4); 10 percent pin point porosity; poor to moderate induration
853.1	856.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture and pinpoint porosity; microcrystalline; good induration
856.0	857.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy, moldic, and pinpoint porosity; microcrystalline; good induration

From Depth (ft bls)	To Depth (ft bls)	Material Description
857.0	858.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture and pinpoint porosity; microcrystalline; good induration
858.0	860.0	No sample
860.0	860.4	Dolostone; very pale orange (10yr 8/2); 30 percent moldic, vuggy and pinpoint porosity; good induration
860.4	861.1	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy and pinpoint porosity; microcrystalline; good induration
861.1	864.8	Dolostone; very pale orange (10yr 8/2); 30 percent fracture, vuggy and pinpoint porosity; some lamination; good induration
864.8	865.7	Dolostone; greyish orange (10yr 8/2); 30 percent fracture, vuggy and pinpoint porosity; good induration
865.7	868.2	Dolostone; very pale orange (10yr 8/2); 30 percent fracture, vuggy, and pinpoint porosity; moderate induration
868.2	868.9	Calcareous dolostone; dark yellow brown (10yr 4/2); 20 percent pinpoint porosity; microcrystalline; moderate induration
868.9	870.0	No sample
870.0	870.8	Calcareous dolostone; pale yellow brown; 20 percent intercrystalline and pin point porosity; microcrystalline; good induration
870.8	873.0	Calcareous dolostone; pale yellow brown; 10 percent pin point porosity; microcrystalline; good induration
873.0	874.0	Dolostone; grayish orange (10yr 7/4); 10 percent pin point porosity; microcrystalline; good induration
874.0	874.7	Dolostone; grayish orange (10yr 7/4); 30 percent moldic, vuggy and pin point porosity; gastropods and foraminifera; microcrystalline; good induration
874.7	879.0	Dolostone; grayish orange (10yr 7/4); 20 percent vuggy and pin point porosity; good induration
879.0	879.5	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; poor induration
879.5	880.0	No sample
880.0	884.5	Dolostone; grayish orange (10yr 7/4);20 percent pin point porosity; good induration
884.5	884.9	Dolostone; grayish orange (10yr 7/4); 30 percent moldic, vuggy, and pin point porosity; foraminifera and gastropods; good induration
884.9	886.4	Dolostone; grayish orange (10yr 7/4); 20 percent vuggy and pin point porosity; poor induration
886.4	888.9	Dolostone; grayish orange (10yr 7/4); 30 percent vuggy, fossil moldic, and pin point porosity; moderate induration
888.9	890.0	Calcareous dolostone; very pale orange (10yr 8/2); 10 intergranular porosity; moderate induration
890.0	893.4	Dolostone; very pale orange (10yr 8/2); 20 percent pinpoint porosity; some lamination; bivalves; poor induration
893.4	898.6	Dolostone; very pale orange (10yr 8/2); 30 percent fracture, vuggy and pinpoint porosity; moderate induration
898.6	900.0	No sample
900.0	909.0	No sample
909.0	912.0	Dolostone; grayish orange (10yr 7/4); 10 percent pin point porosity; some lamination; moderate induration
912.0	913.5	Dolostone; grayish orange (10yr 7/4); 10 percent pin point porosity; some lamination; good induration
913.5	914.3	Dolostone; grayish orange (10yr 7/4); 10 percent pin point porosity; poor induration
914.3	914.9	Calcareous dolostone; dark yellow brown (10yr 4/2); 20 vuggy porosity; microcrystalline; good induration
914.9	917.2	Dolostone; grayish orange (10yr 7/4); 10 percent vuggy point porosity; poor induration

From Depth (ft bls)	To Depth (ft bls)	Material Description
917.2	920.6	Dolostone; grayish orange (10yr 7/4); 10 percent pin point porosity; microcrystalline; some lamination and organics; poor induration
920.6	921.7	Dolostone; dark yellow orange (10yr 6/6); 30 percent fracture and pin point porosity; good induration
921.7	926.8	Dolostone; very pale orange (10yr 8/2); 20 percent pinpoint and vuggy porosity; moderate induration
926.8	929.4	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; organic lamination; moderate induration
929.4	930.7	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; poor induration
930.7	937.0	Dolostone; very pale orange (10yr 8/2); no observable porosity; poor induration
937.0	938.8	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; poor induration
938.8	942.8	Dolostone; very pale orange (10yr 8/2); no observable porosity; poor induration
942.8	943.7	Calcareous dolostone; dark yellow brown (10yr 4/2); 10 percent vuggy porosity; microcrystalline; good induration
943.7	947.1	Dolostone; very pale orange (10yr 8/2); no observable porosity; poor induration
947.1	947.7	Dark yellow brown (10yr 4/2); 10 percent vuggy porosity; moderate induration
947.7	948.7	Dolostone; very pale orange (10yr 8/2); no observable porosity; poor induration
948.7	949.2	Dark yellow brown (10yr 4/2); 10 percent vuggy porosity; moderate induration
949.2	950.0	Dolostone; greyish orange (10yr 7/4); no observable porosity; poor induration
950.0	951.1	Greyish orange (10yr 7/4); 10 percent pin point porosity; moderate induration
951.2	952.2	Dolostone; grayish orange (10yr 7/4); 20 percent vuggy, moldic, and pin point porosity; microcrystalline; good induration
952.2	958.6	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; some lamination; poor induration
958.6	960.0	Dolostone; grayish orange (10yr 7/4); no observable porosity; some lamination; poor induration
960.0	962.2	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; poor induration
962.2	963.4	Calcareous dolostone; dark yellow brown (10yr 4/2); 20 percent vuggy porosity; microcrystalline; moderate induration
963.4	966.8	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; some lamination; poor induration
966.8	967.3	Dolostone; very pale orange (10yr 8/2); no observable porosity; poor induration
967.3	968.5	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; poor induration
968.5	969.0	Dolostone; dark yellow brown (10yr 4/2); 30 percent vuggy porosity; fenestrate vugs; microcrystalline; good induration
969.0	969.6	Dolostone; very pale orange (10yr 8/2); 10 percent intergranular porosity; some lamination; poor induration
969.6	972.3	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; microcrystalline; moderate induration
972.3	974.2	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; moderate induration
974.2	976.1	Dolostone; very pale orange (10yr 8/2); 10 percent intercrystalline porosity; microcrystalline; interclasts and organic lamination; moderate induration
976.1	976.7	Dolostone; dark yellow brown (10yr 4/2); 30 percent fracture, vuggy, and pin point porosity; microcrystalline; good induration
976.1	980.0	Dolostone; very pale orange (10yr 8/2); 10 percent pin point porosity; moderate induration
980.0	986.7	Dolostone (packstone); very pale orange (10yr 8/2); 20 percent pin point and intergranular porosity; pellets; moderate induration
986.7	989.2	Dolostone; very pale orange (10yr 8/2); 10 percent pin point and intergranular porosity; poor induration
989.2	990.5	Dolostone; very pale orange (10yr 8/2); no observable porosity; good induration

From Depth (ft bls)	To Depth (ft bls)	Material Description
990.5	991.3	Dolostone; very pale orange (10yr 8/2); 10 percent intergranular porosity; moderate induration
991.3	991.7	Dolostone; very pale orange (10yr 8/2); 20 percent intergranular porosity; moderate induration
991.7	993.5	Dolostone (packstone); very pale orange (10yr 8/2); 10 percent intergranular porosity; pellets; moderate induration
993.5	994.0	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy and pin point porosity; poor induration
994.0	1000.0	Dolostone; very pale orange (10yr 8/2); 10 percent intergranular porosity; poor induration
1000.0	1000.3	Calcareous dolostone; dark yellow brown (10yr 4/2); 20 percent vuggy porosity; microcrystalline; moderate induration
1000.3	1001.8	Dolostone; very pale orange (10yr 8/2); 10 percent intergranular porosity; moderate induration
1001.8	1002.0	Calcareous dolostone; dark yellow brown (10yr 4/2); 30 percent fractured porosity; microcrystalline; moderate induration
1002.0	1005.0	Dolostone; very pale orange (10yr 8/2); no observable porosity; poor induration
1005.0	1005.3	Calcareous dolostone; dark yellow brown (10yr 4/2); 30 percent fractured porosity; microcrystalline; moderate induration
1005.3	1008.0	Dolostone; very pale orange (10yr 8/2); no observable porosity; moderate induration
1008.0	1010.0	No sample
1010.0	1011.1	Dolostone (packstone); grayish orange (10yr 7/4); 20 percent pinpoint porosity; organic lamination; moderate induration
1011.1	1012.3	Dolostone (packstone); very pale orange (10yr 8/2); 30 percent vuggy, moldic and pin point porosity; organic lamination; moderate induration
1112.3	1013.0	Dolostone; grayish orange (10yr 7/4); no observable porosity; organic lamination; moderate induration
1013.0	1015.6	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; moderate induration
1015.6	1016.3	Dolostone; grayish orange (10yr 7/4); 30 percent vuggy and pinpoint porosity; moderate induration
1016.3	1016.8	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; organic lamination; moderate induration
1016.8	1017.4	Dolostone; grayish orange (10yr 7/4); 20 percent pinpoint porosity; moderate induration
1017.4	1018.0	Dolostone; grayish orange (10yr 7/4); 30 percent vuggy, moldic and pinpoint porosity; moderate induration
1018.0	1019.8	Dolostone; grayish orange (10yr 7/4); 20 percent vuggy, fossil moldic, and pinpoint porosity; moderate induration
1019.8	1021.0	Dolostone; very pale orange (10yr 8/2); 30 percent fracture, vuggy and pinpoint porosity; poor induration
1021.0	1022.5	Dolostone; very pale orange (10yr 8/2); 10 percent vuggy and moldic porosity; poor induration
1022.5	1026.3	Dolostone; very light gray (n8); no observable porosity; 20 percent clay; 10 percent organics; poor induration
1026.3	1027.4	Dolostone; pale yellow brown (5yr 6/2); 10 percent intergranular porosity; poor induration
1027.4	1030.0	No sample
1030.0	1031.4	Dolostone; pale yellow brown (5yr 6/2); no observable porosity; laminated; moderate induration
1031.4	1032.8	Dolostone; pale yellow brown (5yr 6/2); 10 percent intergranular porosity; poor induration
1032.8	1034.0	Dolostone; pale yellow brown (5yr 6/2); no observable porosity; moderate induration
1034.0	1034.7	Evaporite; light gray (n7); microcrystalline; no observable porosity; well indurated
1034.7	1038.8	Dolostone; very pale orange (10yr 8/2); 10 percent intergranular porosity; moderate induration

From Depth (ft bls)	To Depth (ft bls)	Material Description
1038.8	1039.3	Evaporite; light gray (n7); no observable porosity; well indurated
1039.3	1041.1	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; 20 percent evaporite nodules; moderate induration
1041.1	1041.6	Evaporite; light gray (n7); microcrystalline; no observable porosity; well indurated
1041.6	1043.2	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; 20 percent evaporite nodules; highly laminated; good induration
1043.2	1050.7	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; 20 percent evaporite nodules; good induration
1050.7	1051.0	Evaporite; light gray (n7); microcrystalline; no observable porosity; well indurated
1051.0	1054.9	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; some organic lamination; good induration
1054.9	1056.3	Dolostone; pale yellow brown (5yr 6/2); 10 percent pinpoint porosity; intraclasts; good induration
156.3	1058.8	Dolostone; very pale orange (10yr 8/2); no observable porosity; some evaporite nodules; good induration
1058.8	1059.0	Evaporite; light gray (n7); microcrystalline; no observable porosity; well indurated
1059.0	1060.0	Dolostone; very pale orange (10yr 8/2); no observable porosity; good induration
1060.0	1060.7	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; good induration
1060.7	1061.6	Evaporite; light gray (n7); microcrystalline; no observable porosity; well indurated
1061.6	1063.6	Dolostone; grayish orange (10yr 7/4); no observable porosity; moderate induration
1063.6	1064.4	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; good induration
1064.4	1065.1	Evaporite; light gray (n7); microcrystalline; no observable porosity; well indurated
1065.1	1067.0	Dolostone; grayish orange (10yr 7/4); 20 percent vuggy, moldic, and pinpoint porosity; microcrystalline; good induration
1067.0	1068.2	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; 20 percent evaporite nodules; good induration
1068.2	1070.3	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; 5 percent evaporite nodules; good induration
1070.3	1071.4	Dolostone; grayish orange (10yr 7/4); 20 percent vuggy, moldic, and pinpoint porosity; microcrystalline; good induration
1071.4	1071.8	Dolostone; grayish orange (10yr 7/4); no observable porosity; microcrystalline; 30 percent evaporite nodules; good induration
1071.8	1072.6	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; microcrystalline; organic lamination; mod induration
1072.6	1074.1	Dolostone; grayish orange (10yr 7/4); 20 percent moldic and pinpoint porosity; microcrystalline; good induration
1074.1	1077.9	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; microcrystalline; good induration
1077.9	1079.8	Dolostone; grayish orange (10yr 7/4); 20 percent moldic, vuggy, and pinpoint porosity; microcrystalline; bivalve molds; good induration
1079.8	1080.4	Evaporite; light gray (n7); microcrystalline; no observable porosity; well indurated
1080.4	1082.6	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; microcrystalline; good induration
1082.6	1085.8	Dolostone; grayish orange (10yr 7/4); no observable porosity; microcrystalline; 30 percent evaporite nodules; good induration
1085.8	1088.0	Evaporite; white (n9); no observable porosity; well indurated
1088.0	1089.0	Evaporite; very pale orange (10yr 8/2); no observable porosity; 40 percent dolomite; well indurated
1089.0	1090.0	Dolostone; very pale orange (10yr 8/2); no observable porosity; 40 percent evaporite nodules; well indurated

From Depth (ft bls)	To Depth (ft bls)	Material Description
1090.0	1094.6	Dolostone; very pale orange (10yr 8/2); no observable porosity; 10 percent evaporite nodules; well indurated
1094.6	1096.8	Dolostone; very pale orange (10yr 8/2); no observable porosity; 40 percent evaporite nodules; well indurated
1096.8	1103.7	Evaporite; very light gray (n8); microcrystalline; no observable porosity; 40 percent dolomite; well indurated
1103.7	1106.8	Dolostone; very pale orange (10yr 8/2); no observable porosity; 40 percent evaporite nodules and fill of pinpoint porosity; some lamination; well indurated
1106.8	1111.4	Evaporite; light gray (n7); microcrystalline; no observable porosity; 40 percent dolostone; well indurated
1111.4	1112.8	Dolostone; very pale orange (10yr 8/2); microcrystalline; no observable porosity; 20 percent evaporite nodules; well indurated
1112.8	1120.0	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; 10 percent evaporite nodules; well indurated
1120.0	1122.7	Dolostone; very pale orange (10yr 8/2); no observable porosity; 20 percent evaporite nodules and intergranular; well indurated
1122.7	1126.4	Dolostone; grayish orange (10yr 7/4); microcrystalline; 10 percent pinpoint and vuggy porosity; 5 percent evaporite nodules; well indurated
1126.4	1129.1	Dolostone; very pale orange (10yr 8/2); no observable porosity; 20 percent evaporite nodules; moderately indurated
1199.1	1130.0	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint porosity; 5 percent evaporite nodules; moderate induration
1130.0	1131.4	Dolostone; grayish orange (10yr 7/4); microcrystalline; 10 percent pinpoint and vuggy porosity; 30 percent evaporite nodules; well indurated
1131.4	1131.6	Dolostone; dark yellow brown (10yr 4/2); 10 percent intergranular porosity; highly organic; poor induration
1131.6	1133.8	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint and vuggy porosity; 20 percent evaporite nodules; well indurated
1133.8	1134.8	Dolostone; grayish orange (10yr 7/4); no observable porosity; well indurated
1134.8	1137.7	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint and vuggy porosity; microcrystalline; 10 percent evaporite nodules; gastropod molds; well indurated
1137.7	1138.6	Dolostone; very pale orange (10yr 8/2); no observable porosity; moderatly indurated
1138.6	1140.0	No sample
1140.0	1141.5	Dolostone; grayish orange (10yr 7/4); 10 percent pinpoint and vuggy porosity; microcrystalline; 30 percent evaporite nodules; well indurated
1141.5	1143.4	Dolostone; very pale orange (10yr 8/2); microcrystalline; 10 percent pinpoint porosity; 10 percent evaporite nodules; well indurated
1143.4	1147.3	Dolostone; very pale orange (10yr 8/2); microcrystalline; 10 percent pinpoint porosity; 20 percent evaporite nodules and intersitial fill; well indurated
1147.3	1148.0	Dolostone; very pale orange (10yr 8/2); no observable porosity; poor induration
1148.0	1151.2	Dolostone; very pale orange (10yr 8/2); microcrystalline; 10 percent pinpoint porosity; 20 percent evaporite nodules and intersitial fill; well indurated
1151.2	1151.7	Dolostone; very pale orange (10yr 8/2); no observable porosity; poor induration
1151.7	1156.0	Dolostone; ver pale orange (10yr 8/2); no observable porosity; microcrystalline; 20 percent evaporite nodules and interstial, some birdseye; well indurated
1156.0	1157.5	Dolostone; very pale orange (10yr 8/2); 10 percent pinpoint porosity; moderate induration
1157.5	1160.5	Dolostone; very pale orange (10yr 8/2); no observable porosity; 30 percent evaporite nodules and interstitial; well indurated
1160.5	1162.0	Dolostone; grayish orange (10yr 7/4); 10 percent pin point porosity; moderatly indurated; some lamination
1162.0	1162.4	Dolostone; very pale orange (10yr 8/2); microcrystalline; no observable porosity; 40 percent evaporite nodules and interstitial; well indurated

From Depth (ft bls)	To Depth (ft bls)	Material Description
1162.4	1163.9	Dolostone; grayish orange (10yr 7/4); 10 percent pin point porosity; moderatly indurated
1163.9	1164.4	Evaporite; very light gray (n8); microcrystalline; no observable porosity; 40 percent dolomite; well indurated
1164.4	1170.9	Dolostone; very pale orange (10yr 8/2); no observable porosity; chalky; up to 20 percent evaporite nodules and interstitial fill; well indurated
1170.9	1172.0	Evaporite; light gray (n8); microcrystalline; no observable porosity; mod indurated; trace organics
1172.0	1179.5	Dolostone; very pale orange (10yr 8/2); no observable porosity; chalky; 30 percent evaporite nodules and interstitial fill; mod indurated
1179.5	1180.0	No sample
1180.0	1181.9	Dolostone; very pale orange (10yr 8/2); no observable porosity; chalky; 20 percent evaporite nodules and interstitial fill; mod indurated
1181.9	1182.8	Evaporite; very light gray (n8); microcrystalline; no observable porosity; 20 percent dolomite; well indurated
1182.8	1189.5	Dolostone; very pale orange (10yr 8/2); no observable porosity; chalky; 20 percent evaporite nodules and interstitial fill; mod indurated
1189.5	1190.0	No sample
1190.0	1192.0	Dolostone; very pale orange (10yr 8/2); no observable porosity; chalky; 20 percent evaporite nodules and interstitial fill; mod indurated
1192.0	1195.0	Dolostone; grayish orange (10yr 7/4); no observable porosity; 20 percent evaporite nodules and interstitial fill, some crystalline; well indurated; mollusks
1195.0	1199.5	Dolostone; grayish orange (10yr 7/4); no observable porosity; 20 percent evaporite nodules and interstitial fill, some crystalline; mod indurated; mollusks
1199.5	1200.0	No sample
1200.0	1209.5	Dolostone; very pale orange (10yr 8/2); no observable porosity; 30 percent evaporite nodules and interstitial fill; well indurated; few mollusks
1209.5	1210.0	No sample
1210.0	1212.1	Dolostone; very pale orange (10yr 8/2); no observable porosity; 20 percent evaporite nodules and interstitial fill; well indurated; trace organics
1212.1	1212.8	Evaporite; very light gray (n8); microcrystalline; no observable porosity; 20 percent dolomite; well indurated
1212.8	1215.7	Dolostone; very pale orange (10yr 8/2); no observable porosity; 20 percent evaporite nodules and interstitial fill; well indurated
1215.7	1216.2	Dolostone; very pale orange (10yr 8/2); 10 percent vuggy porosity; 10 percent evaporite nodules and interstitial fill; well indurated
1216.2	1216.8	Dolostone; very pale orange (10yr 8/2); no observable porosity; 20 percent evaporite nodules and interstitial fill; well indurated; organic lamination
1216.8	1217.1	Evaporite; light gray (n7); microcrystalline; no observable porosity; well indurated
1217.1	1218.2	Dolostone; mod yellow brown (10yr 5/4); no observable porosity; well indurated
1218.2	1218.8	Evaporite; light gray (n7); microcrystalline; no observable porosity; well indurated
1218.8	1219.5	Dolostone; mod yellow brown (10yr 5/4); no observable porosity; 20 percent evaporite nodules and interstitial fill; well indurated; organic lamination
1219.5	1220.0	No sample
1220.0	1221.1	Dolostone; very pale orange (10yr 8/2); no observable porosity; 40 percent evaporite nodules and interstitial fill; chalky; moderately indurated
1221.1	1222.0	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy porosity; chalky; well indurated; some residual evaporite in vugs
1222.0	1223.5	Dolostone; grayish orange (10yr 7/4); no observable porosity; 20 percent evaporite nodules and interstitial fill; well indurated
1223.5	1228.5	Dolostone; grayish orange (10yr 7/4); 10 percent vuggy porosity; well indurated; residual evaporite in vugs

From Depth (ft bls)	To Depth (ft bls)	Material Description
1228.5	1229.5	Dolostone; grayish orange (10yr 7/4); no observable porosity; well indurated
1229.5	1230.0	No sample
1230.0	1230.8	Dolostone; dark yellow orange (10yr 6/6); 10 percent vuggy porosity; well indurated; organic lamination at at base
1230.8	1235.3	Dolostone; very pale orange (10yr 8/2); no observable porosity; 40 percent evaporite nodules and interstitial fill; chalky; moderately indurated
1235.3	1236.1	Dolostone; very pale orange (10yr 8/2); no observable porosity; organic lamination; well indurated; gastropod
1236.1	1237.3	Dolostone; pale yellowish brown (5yr 6/2); 10 percent vuggy porosity; 20 percent evaporite nodules and interstitial fill; bivalve; well indurated
1237.3	1238.2	Dolostone; pale yellowish brown (5yr 6/2); no observable porosity; 20 percent evaporite nodules and interstitial fill; well indurated
1238.2	1239.4	Dolostone; very pale orange (10yr 8/2); 10 percent vuggy porosity; 20 percent evaporite nodules and interstitial fill; bivalve; well indurated
1239.4	1240.7	Dolostone; very pale orange (10yr 8/2); no observable porosity; 20 percent evaporite nodules and interstitial fill; gastropod; well indurated
1240.7	1241.8	Dolostone; moderate gray (n5); no observable porosity; 40 percent evaporite nodules and interstitial fill; organic lamination at base; well indurated
1241.8	1242.8	Dolostone; pale yellowish brown (5yr 6/2); no observable porosity; well indurated
1242.8	1243.3	Dolostone; very pale orange (10yr 8/2); 10 percent vuggy porosity; well indurated; trace residual evaporite in vugs
1243.3	1244.8	Dolostone; very pale orange (10yr 8/2); no observable porosity; chalky; 20 percent evaporite nodules and interstitial fill; well indurated
1244.8	1245.7	Dolostone; very pale orange (10yr 8/2); 10 percent vuggy porosity; poorly indurated; apparent evaporite nodule dissolution
1245.7	1248.5	Dolostone; very pale orange (10yr 8/2); no observable porosity; well indurated
1248.5	1249.5	Dolostone; very pale orange (10yr 8/2); 10 percent pin point porosity; well indurated
1249.5	1250.0	No sample
1250.0	1260.0	Dolostone; very pale orange (10yr 8/2); 10 percent vuggy and moldic porosity; bivalves; some residual evaporite vug filling; well indurated
1260.0	1262.8	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy porosity; well indurated
1262.8	1266.7	Dolostone; very pale orange (10yr 8/2); no observable porosity; some organic lamination; well indurated
1266.7	1267.2	Dolostone; very pale orange (10yr 8/2); 10 percent vuggy porosity; well indurated
1267.2	1269.0	Dolostone; very pale orange (10yr 8/2); no observable porosity; well indurated
1269.0	1270.9	Dolostone; very pale orange (10yr 8/2); no observable porosity; 10 percent evaporite nodules and interstitial fill; organic lamination; well indurated
1270.9	1274.4	Dolostone; very pale orange (10yr 8/2); 10 percent vuggy porosity; some lamination; partial evaportie vug fill; well indurated
1274.4	1275.0	Dolostone; very pale orange (10yr 8/2); 10 percent vuggy porosity; well indurated
1275.0	1275.6	Dolostone; very pale orange (10yr 8/2); no observable porosity; well indurated
1275.6	1276.7	Dolostone; very pale orange (10yr 8/2); 20 percent vuggy and moldic porosity; gastropods; well indurated
1276.7	1277.8	Dolostone; pale yellow brown (5yr 6/2); no observable porosity; 20 percent evaporite nodules and interstitial fill; partial evaporite vug fill; well indurated
1277.8	1287.0	Dolostone; pale yellow brown (5yr 6/2); 20 percent vuggy and moldic porosity; partial evaporite vug fill; well indurated
1287.0	1289.5	Dolostone; pale yellow brown (5yr 6/2); 10 percent vuggy and moldic porosity; gastropod mold; well indurated
1289.5	1290.0	No sample

From Depth (ft bls)	To Depth (ft bls)	Material Description
1290.0	1294.0	Dolostone; pale yellow brown 5yr 6/2); 10 percent vuggy porosity; organic lamination and streaks; well indurated;
1294.0	1294.5	Dolostone; mod yellow brown (10yr 5/4); sucrosic; 20 percent fracture and pin point porosity; well indurated; organic lamination
1294.5	1295.7	Dolostone; mod yellow brown (10yr 5/4); sucrosic; no observable porosity; well indurated
1295.7	1296.3	Dolostone; mod yellow brown (10yr 5/4); sucrosic; 10 percent pin point porosity; well indurated
1296.3	1298.2	Dolostone; mod yellow brown (10yr 5/4); sucrosic; no observable porosity; well indurated
1298.2	1299.0	Dolostone; mod yellow brown (10yr 5/4); sucrosic; 20 percent fracture and vuggy porosity; well indurated;
1299.0	1300.0	No sample
1300.0	1301.0	Dolostone; mod yellow brown (10yr 5/4); 20 percent fracture and vuggy porosity; well indurated;
1301.0	1303.4	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point vugs; well indurated
1303.4	1303.5	Clay; very pale orange (19yr 8/2); silty; low plasticity; no observable porosity
1303.5	1304.2	Dolostone; mod yellow brown (10yr 5/4); sucrosic; no observable porosity; well indurated
1304.2	1305.0	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy porosity; well indurated;
1305.0	1308.1	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point vugs; some lamination; well indurated
1308.1	1309.1	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy and moldic porosity; well indurated
1309.1	1311.7	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point vugs; some lamination; well indurated
1311.7	1313.8	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture and vuggy porosity; residual evaporites in vugs; well indurated;
1313.8	1313.9	Clay; very pale orange (19yr 8/2); silty; low plasticity; no observable porosity
1313.9	1315.6	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy porosity; well indurated;
1315.6	1315.7	Clay; very pale orange (19yr 8/2); silty; low plasticity; no observable porosity
1315.7	1317.3	Dolostone; pale yellow brown (5yr 6/2); 10 percent vuggy porosity; well indurated
1317.3	1318.4	Dolostone; pale yellow brown (5yr 6/2); 20 percent vuggy and moldic porosity; well indurated
1318.4	1319.0	Dolostone; pale yellow brown (5yr 6/2); 30 percent fracture, vuggy and moldic porosity; well indurated
1319.0	1320.0	No sample
1320.0	1321.2	Dolostone; pale yellow brown (5yr 6/2); 30 percent vuggy and moldic porosity; well indurated
1321.2	1322.9	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy porosity; well indurated;
1322.9	1324.3	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy, and moldic porosity; well indurated
1324.3	1324.4	Clay; very pale orange (19yr 8/2); silty; low plasticity; no observable porosity
1324.4	1325.7	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; mod indurated
1325.7	1326.0	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; 10 percent clay; mod indurated
1326.0	1326.4	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture porosity; well indurated
1326.4	1328.8	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; mod indurated
1328.8	1330.0	No sample
1330.0	1330.4	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture porosity; 5 percent evaporite vug filling; poorly indurated
1330.4	1331.5	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; 5 percent evaporite vug filling; well indurated

From Depth (ft bls)	To Depth (ft bls)	Material Description
1331.5	1331.6	Clay; very pale orange (19yr 8/2); silty; low plasticity; no observable porosity
1331.6	1333.3	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture porosity; 5 percent evaporite vug filling; well indurated
1333.3	1334.5	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; 5 percent evaporite vug filling; well indurated
1334.5	1334.9	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; 5 percent evaporite vug filling; clay lamination; well indurated
1334.9	1335.4	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; 5 percent evaporite vug filling; well indurated
1335.4	1340.0	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture and vuggy porosity; some organic lamination; 5 percent evaporite vug filling; well indurated
1340.0	1340.7	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy and moldic porosity; slightly friable; trace organics; mod indurated
1340.7	1343.3	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy and moldic porosity; trace evaporite; well indurated
1343.3	1344.6	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy and moldic porosity; slightly friable; mod indurated
1344.6	1345.5	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy and moldic porosity; well indurated
1345.5	1349.0	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy and moldic porosity; well indurated
1349.0	1350.0	No sample
1350.0	1351.3	Dolostone; mod yellow brown (10yr 5/4); 30 percent vuggy and moldic porosity; residual evaporite in vugs; well indurated
1351.3	1352.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy and moldic porosity; slightly friable; mod indurated
1352.0	1353.0	Dolostone; mod yellow brown (10yr 5/4); 30 percent vuggy and moldic porosity; residual evaporite in vugs; well indurated
1353.0	1353.4	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy and moldic porosity; slightly friable; mod indurated
1353.4	1354.8	Dolostone; mod yellow brown (10yr 5/4); 30 percent vuggy and moldic porosity; well indurated
1354.8	1355.6	Dolostone; mod yellow brown (10yr 5/4); 30 percent vuggy and moldic porosity; 20 percent clay; well indurated
1355.6	1358.0	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy and moldic porosity; well indurated
1358.0	1359.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy and moldic porosity; slightly friable; mod indurated
1359.0	1360.0	No sample
1360.0	1362.1	Dolostone; mod yellow brown (10yr 5/4); 30 percent vuggy and moldic porosity; well indurated
1362.1	1363.1	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy and moldic porosity; 20 percent clay; slightly friable; mod indurated
1363.1	1365.1	Dolostone; mod yellow brown (10yr 5/4); 30 percent vuggy and moldic porosity; well indurated
1365.1	1365.8	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy and moldic porosity; 20 percent clay; slightly friable; mod indurated
1365.8	1368.5	Dolostone; mod yellow brown (10yr 5/4); 30 percent vuggy and moldic porosity; well indurated
1368.5	1370.0	No sample
1370.0	1370.3	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy porosity; well indurated

From Depth (ft bls)	To Depth (ft bls)	Material Description
1370.3	1371.0	Dolostone; grayish orange (10yr 7/4); 30 percent fracture, vuggy and moldic porosity; 10 percent clay; slightly friable; mod indurated
1371.0	1372.2	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy and moldic porosity; well indurated
1372.2	1374.7	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point and moldic porosity; well indurated
1374.7	1376.6	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy and moldic porosity; well indurated
1376.6	1377.1	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy and moldic porosity; 10 percent clay; mod indurated
1377.1	1377.6	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy and moldic porosity; well indurated
1377.6	1378.0	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy and moldic porosity; 10 percent clay; mod indurated
1378.0	1379.5	Dolostone; mod yellow brown (10yr 5/4); 30 percent vuggy and moldic porosity; well indurated
1379.5	1381.3	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy and moldic porosity; 10 percent clay; mod indurated
1381.3	1382.2	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture, vuggy and moldic porosity; well indurated
1382.2	1383.3	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; well indurated
1383.3	1383.8	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy and moldic porosity; well indurated
1383.8	1387.3	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture and vuggy porosity; trace clay in fractured zones; well indurated
1387.3	1388.2	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; well indurated
1388.2	1389.5	Dolostone; mod yellow brown (10yr 5/4); 20 percent pin point porosity; well indurated
1389.5	1390.0	No sample
1390.0	1395.0	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture and vuggy porosity; residual evaporite in vugs; well indurated
1395.0	1396.0	Dolostone; mod yellow brown (10yr 5/4); 20 percent vuggy porosity; residual evaporite in vugs; well indurated
1396.0	1396.8	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture and vuggy porosity; mod indurated
1396.8	1398.7	Dolostone; mod yellow brown (10yr 5/4); 10 percent pin point porosity; well indurated
1398.7	1400.0	Dolostone; mod yellow brown (10yr 5/4); 30 percent fracture and vuggy porosity; residual evaporite in vugs; mod indurated

APPENDIX D:
SUPPORTING INFORMATION FOR PACKER TEST ANALYSIS

CTD Probe Make & Model: Idronaut - Ocean Seven 304

Parameter	Range	Accuracy
Pressure	0 to 1,000 dbar	0.01% Full Range
Temperature	-5 to 35°C	0.005°C
Conductivity – Saltwater	0 to 70 mS/cm	0.007 mS/cm
Conductivity – Freshwater	0 to 7,000 µS/cm	5 µS/cm

°C = degrees Celsius; µS/cm = microsiemens per centimeter; dbar = decibar; mS/cm = millisiemens per centimeter.

Core casing inner diameter	3.0 inches
Submersible pump make and model	Grundfos 1HP 3"
Flow-meter make and model	Sensus 1" PPM Series
Pump drop pipe material	Galvanized steel
Pump drop pipe diameter	1.25 inches inner / 1.5 inches outer
Packer center pipe material	Carbon steel
Packer center pipe inner diameter × length	1 inch × 9 feet
Packer screen intake area	16 square inches

Example Head Loss Calculation: Packer Test #2

$$P_d = L\,\frac{4.52Q^{1.85}}{C^{1.85}\,d^{4.865}}$$

Where:

P_d = pressure drop due to friction loss over the length of pipe in psig
L = length of pipe (feet)
Q = discharge rate (gpm)
C = pipe roughness coefficient
d = inside pipe diameter (inches)

1) Pressure drop in Core Casing

   a) $P_d = 191.32ft\,\frac{4.52(30gpm)^{1.85}}{(140)^{1.85}\,(3")^{4.865}}$ = 0.24 psi

   b) Convert pressure in psi to feet of water = 0.24 $psi\,\frac{2.31 \text{ ft H20}}{psi}$ = *0.55 ft*

2) Pressure drop in Packer Assembly

   a) $P_d = 9\,ft\,\frac{4.52(30gpm)^{1.85}}{(150)^{1.85}\,(1")^{4.865}}$ = 2.07 psi

   b) Convert pressure in psi to feet of water= 2.07 $psi\,\frac{2.31 \text{ ft H20}}{psi}$ = *4.78 ft*

3) Calculate head loss across screen

   a) **Head Loss** = -0.0003**rate**^{3} + 0.0147**rate**^{2} - 0.0993**rate** + 0.0532
   = -0.0003**(30)**^{3} + 0.0147**(30)**^{2} - 0.0993**(30)** + 0.0532 = *2.204 ft*

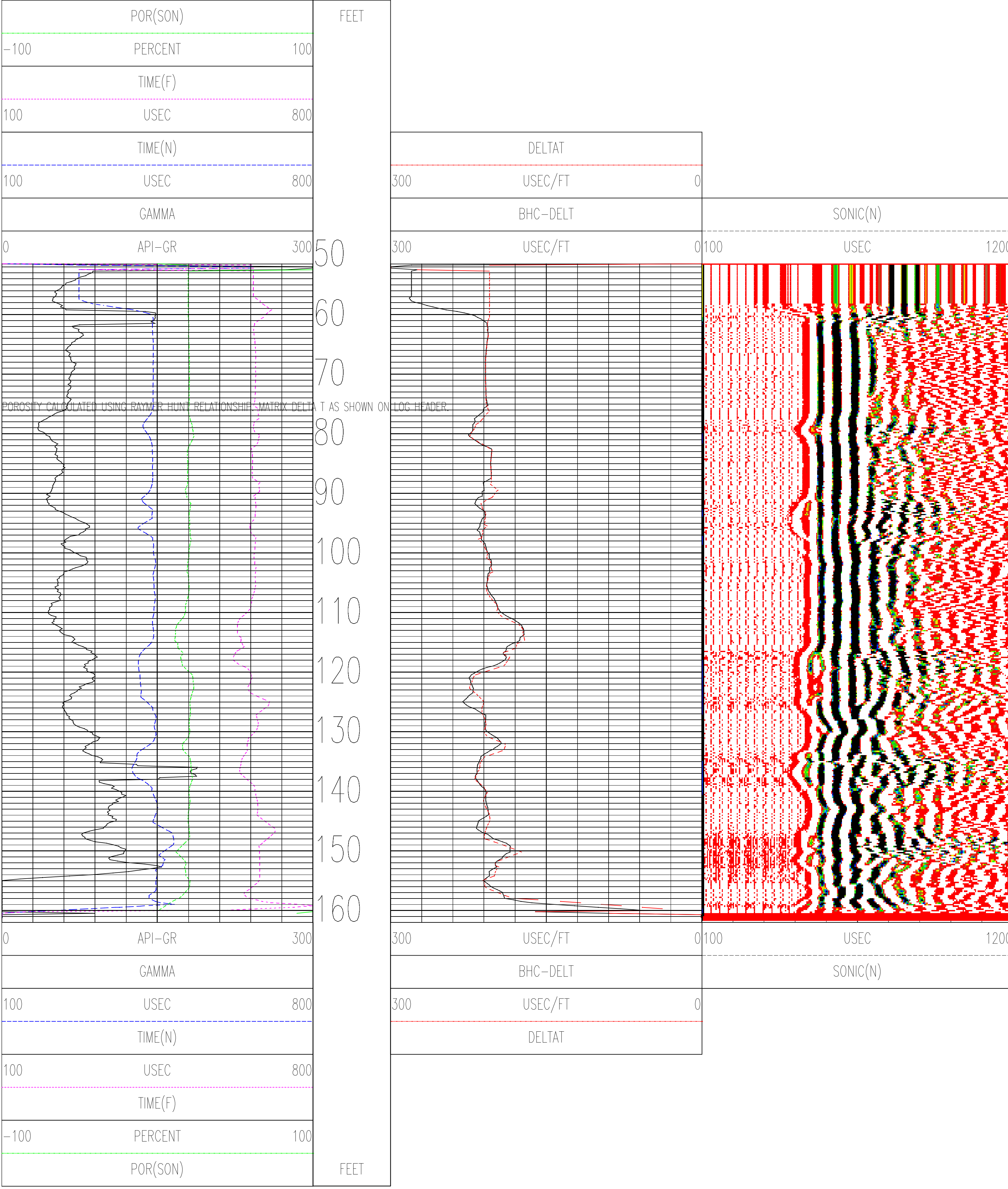
4) **Total head loss for packer test #2** = *0.55 ft* + *4.78 ft* + *2.204 ft* = **7.53 ft**

APPENDIX E:
GEOPHYSICAL LOGS

FULL WAVE BHC ACOUSTIC-VDL

OSF-112-

COMPANY	: HUSS DRILLING	OTHER SERVICES:	
WELL	: OSF-112-	8044	
FIELD	: TOHO	.9320	
COUNTY	: OSCEOLA		
STATE	: FLORIDA		
LOCATION	:		
SECTION	: None		
TOWNSHIP	: None		
RANGE	: None		
API NO.	:		
UNIQUE WELL ID.	:		
PERMANENT DATUM	: MSL	ELEVATION KB:	None
LOG MEASURED FROM:	GS	ELEVATION DF:	NA
DRL MEASURED FROM:	NA	ELEVATION GL:	NA
DATE	: 10/17/17		
DEPTH DRILLER	: 169		
BIT SIZE	: 6		
LOG TOP	: 51.50		
LOG BOTTOM	: 161.75		
CASING OD	:		
CASING BOTTOM	: 60		
CASING TYPE	: STEEL		
BOREHOLE FLUID	: MUD		
RM TEMPERATURE	: 0		
MUD RES	: 0		
MUD WEIGHT	:		
WITNESSED BY	:		
RECORDED BY	: AFB		
REMARKS 1	: MUDDED PILOT		
REMARKS 2	:		


POR(SON)
-100 PERCENT 100
TIME(F)
100 USEC 800
TIME(N)
100 USEC 800
GAMMA
0 API-GR 300
FEET
DELTAT
300 USEC/FT 0
BHC-DELT
300 USEC/FT 0
SONIC(N)
100 USEC 1200
50
60
70
POROSITY CALCULATED USING RAYMER HUNT RELATIONSHIP, MATRIX DELTA T AS SHOWN ON LOG HEADER.
80
90
100
110
120
130
140
150
160
0 API-GR 300
GAMMA
100 USEC 800
TIME(N)
100 USEC 800
TIME(F)
-100 PERCENT 100
POR(SON)
FEET
300 USEC/FT 0
BHC-DELT
300 USEC/FT 0
DELTAT
100 USEC 1200
SONIC(N)

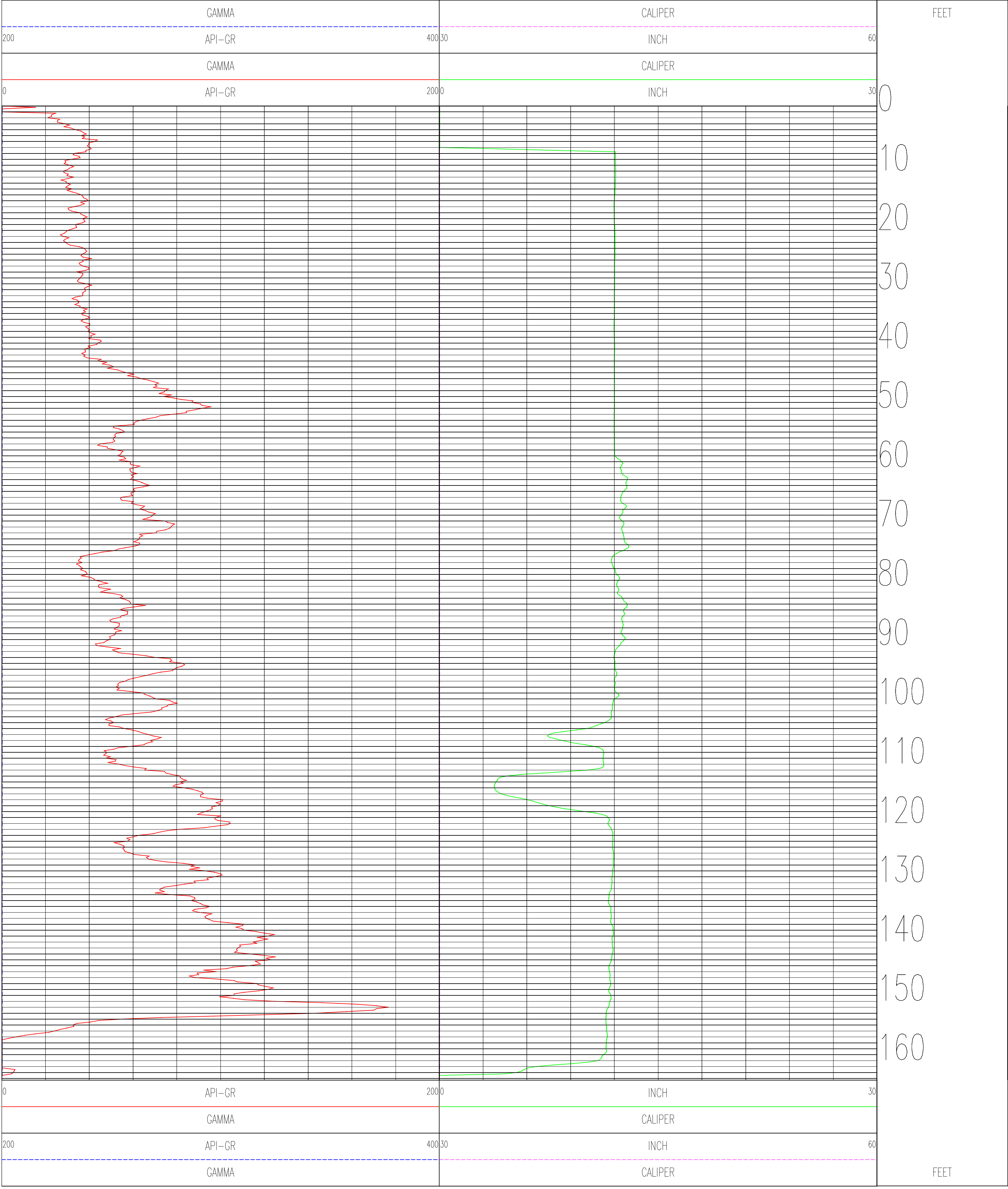
TOOL CALIBRATION OSF-112- 10/17/17 11:12
TOOL 9320A2 TM VERSION 0
SERIAL NUMBER 667

	DATE	TIME	SENSOR	STANDARD		RESPONSE	
1	Apr12,99	23:12:30	GAMMA	Default	[CPS]	Default	[CPS]
	Apr12,99	20:12:30	GAMMA	Default	[CPS]	Default	[CPS]

GAMMA RAY (API)-CALIPER

OSF-112-

COMPANY	: HUSS DRILLING	OTHER SERVICES:	
WELL	: OSF-112-	8044	
FIELD	: TOHO	.9320	
COUNTY	: OSCEOLA		
STATE	: FLORIDA		
LOCATION	:		
SECTION	: None		
TOWNSHIP	: None		
RANGE	: None		
API NO.	:		
UNIQUE WELL ID.	:		
PERMANENT DATUM	: MSL	ELEVATION KB:	None
LOG MEASURED FROM:	GS	ELEVATION DF:	NA
DRL MEASURED FROM:	NA	ELEVATION GL:	NA
DATE	: 10/17/17		
DEPTH DRILLER	: 169		
BIT SIZE	: 6		
LOG TOP	: 1.00		
LOG BOTTOM	: 165.00		
CASING OD	:		
CASING BOTTOM	: 60		
CASING TYPE	: STEEL		
BOREHOLE FLUID	: MUD		
RM TEMPERATURE	: 0		
MUD RES	: 0		
MUD WEIGHT	:		
WITNESSED BY	:		
RECORDED BY	: AFB		
REMARKS 1	: MUDDED PILOT		
REMARKS 2	:		


GAMMA
API-GR
200
400
CALIPER
INCH
30
60
FEET
GAMMA
API-GR
0
200
CALIPER
INCH
0
30
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

TOOL CALIBRATION OSF-112- 10/17/17 10:11
TOOL 9074A1 TM VERSION 0
SERIAL NUMBER 857

	DATE	TIME	SENSOR	STANDARD		RESPONSE	
1	Jan12,03	07:10:06	GAMMA	Default	[CPS]	Default	[CPS]
	Jan12,03	04:10:06	GAMMA	180.000	[API-GR]	205.00	[CPS]
2	May11,17	21:01:04	CALIPER	3.000	[INCH]	156245.00	[CPS]
	May11,17	21:01:04	CALIPER	5.000	[INCH]	150790.00	[CPS]
3	Oct16,17	15:53:00	CALIPERL	4.000	[INCH]	156269.00	[CPS]
	Oct16,17	15:53:00	CALIPERL	35.500	[INCH]	86954.00	[CPS]
4	Dec13,00	22:19:45	CALIPERX	Default	[CPS]	Default	[CPS]
	Dec13,00	22:19:45	CALIPERX	Default	[CPS]	Default	[CPS]

GAMMA RAY-RESISTIVITY (16-64)

OSF-112-

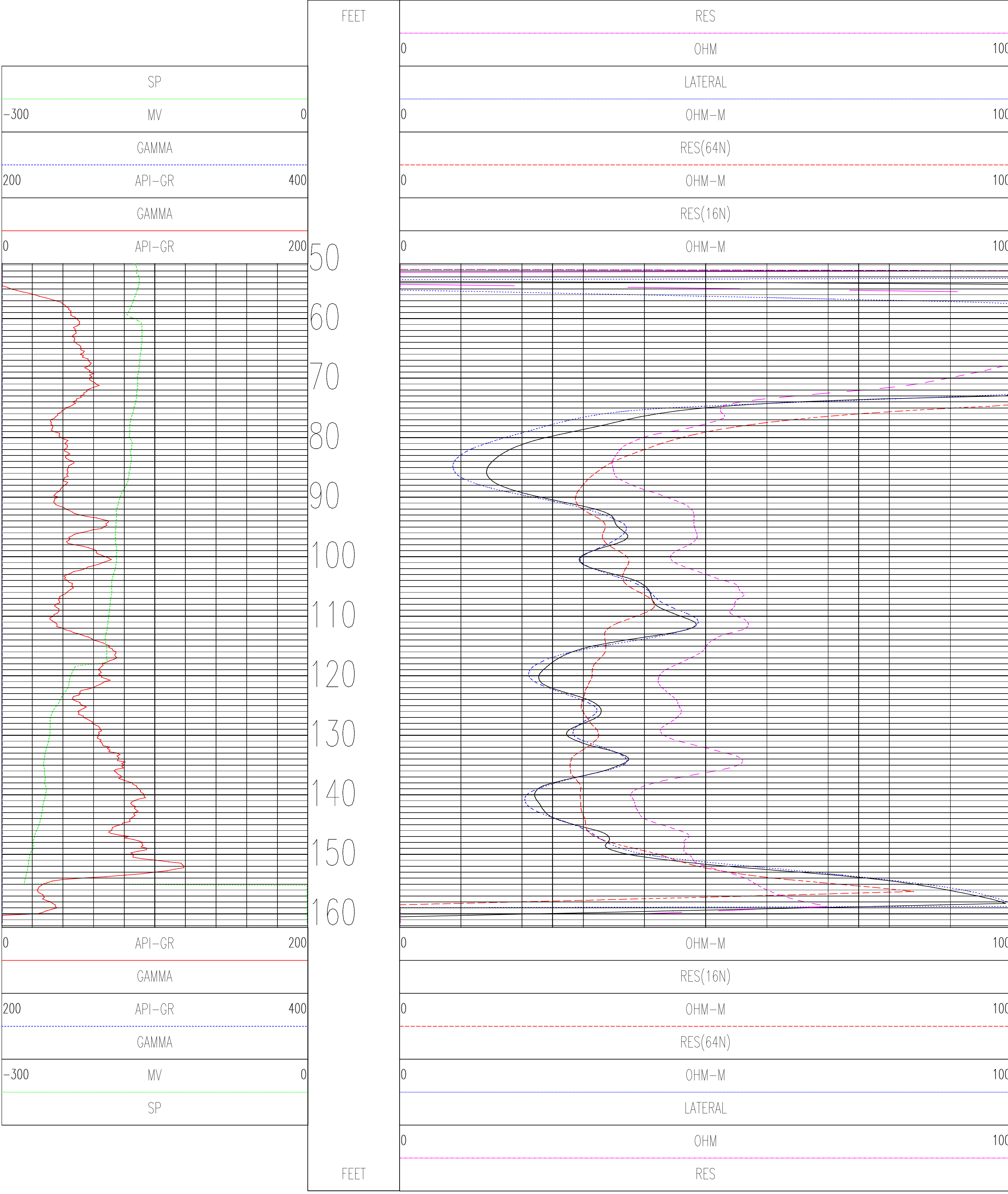
COMPANY	:	HUSS DRILLING
WELL	:	OSF-112-
FIELD	:	TOHO
COUNTY	:	OSCEOLA
STATE	:	FLORIDA

OTHER SERVICES:
8044
.9320

LOCATION	:	
SECTION	:	None
TOWNSHIP	:	None
RANGE	:	None
API NO.	:	
UNIQUE WELL ID.	:	

PERMANENT DATUM	: MSL	ELEVATION KB:	None
LOG MEASURED FROM:	GS	ELEVATION DF:	NA
DRL MEASURED FROM:	NA	ELEVATION GL:	NA

DATE	:	10/17/17
DEPTH DRILLER	:	169
BIT SIZE	:	6
LOG TOP	:	50.75
LOG BOTTOM	:	162.00
CASING OD	:	
CASING BOTTOM	:	60
CASING TYPE	:	STEEL
BOREHOLE FLUID	:	MUD
RM TEMPERATURE	:	0
MUD RES	:	0
MUD WEIGHT	:	
WITNESSED BY	:	
RECORDED BY	:	AFB
REMARKS 1	:	MUDDED PILOT
REMARKS 2	:	


FEET
RES
0 OHM 100
SP
-300 MV 0
LATERAL
0 OHM-M 100
GAMMA
200 API-GR 400
RES(64N)
0 OHM-M 100
GAMMA
0 API-GR 200
RES(16N)
0 OHM-M 100
50
60
70
80
90
100
110
120
130
140
150
160
0 API-GR 200
GAMMA
200 API-GR 400
GAMMA
-300 MV 0
SP
0 OHM-M 100
RES(16N)
0 OHM-M 100
RES(64N)
0 OHM-M 100
LATERAL
0 OHM 100
RES
FEET

TOOL CALIBRATION OSF-112- 10/17/17 10:52
TOOL 8044A TM VERSION 0
SERIAL NUMBER 938

	DATE	TIME	SENSOR	STANDARD		RESPONSE	
1	Jan03,03	10:49:05	GAMMA	0.001	[API-GR]	0.00	[CPS]
	Jan03,03	07:49:05	GAMMA	180.000	[API-GR]	169.00	[CPS]
2	May16,17	19:08:20	RES(FL)	41.600	[OHM-M]	54104.00	[CPS]
	May16,17	19:08:20	RES(FL)	0.100	[OHM-M]	11978.00	[CPS]
3	Aug17,14	17:00:23	SP	0.000	[MV]	59670.00	[CPS]
	Aug17,14	17:00:23	SP	395.000	[MV]	23612.00	[CPS]
4	Jul25,17	06:42:26	RES(16N)	0.000	[OHM-M]	4284.00	[CPS]
	Jul25,17	06:42:26	RES(16N)	1996.000	[OHM-M]	138447.00	[CPS]
5	Jul25,17	06:42:50	RES(64N)	0.000	[OHM-M]	4160.00	[CPS]
	Jul25,17	06:42:50	RES(64N)	1990.000	[OHM-M]	176008.00	[CPS]
6	Aug17,14	17:19:05	TEMP	71.700	[DEG F]	63355.00	[CPS]
	Aug17,14	17:19:05	TEMP	81.500	[DEG F]	58740.00	[CPS]
7	Aug17,14	15:39:11	RES	0.000	[OHM]	9855.00	[CPS]
	Aug17,14	15:39:11	RES	988.000	[OHM]	58788.00	[CPS]

ABS
Advanced Borehole Services

GAMMA RAY (API)-CALIPER

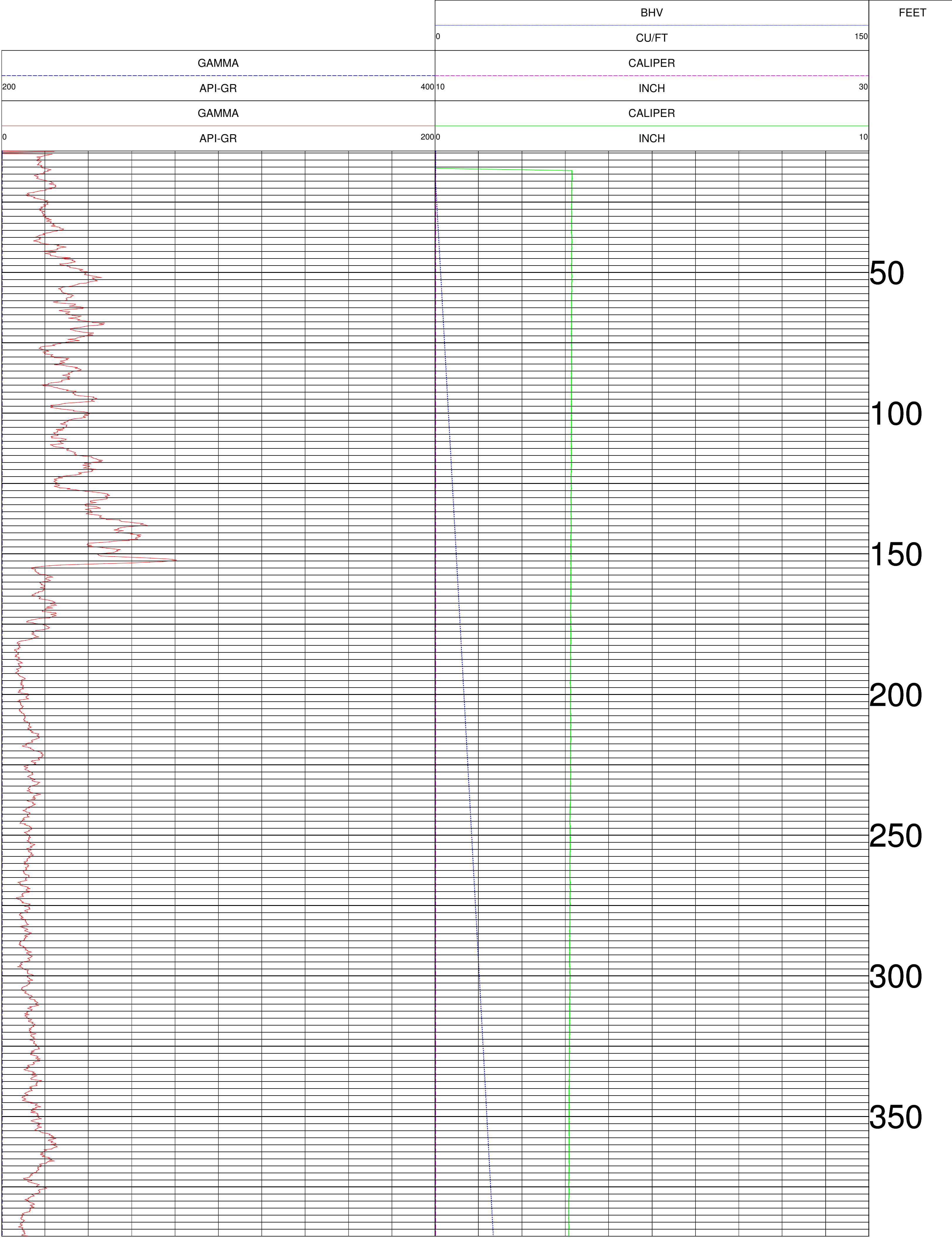
TOHO WELL OSF-112

COMPANY	: HUSS DRILLING	OTHER SERVICES: LOWER S
WELL	: TOHO WELL OSF-112	
FIELD	: ST CLOUD	
COUNTY	: OSCEOLA	
STATE	: FLORIDA	

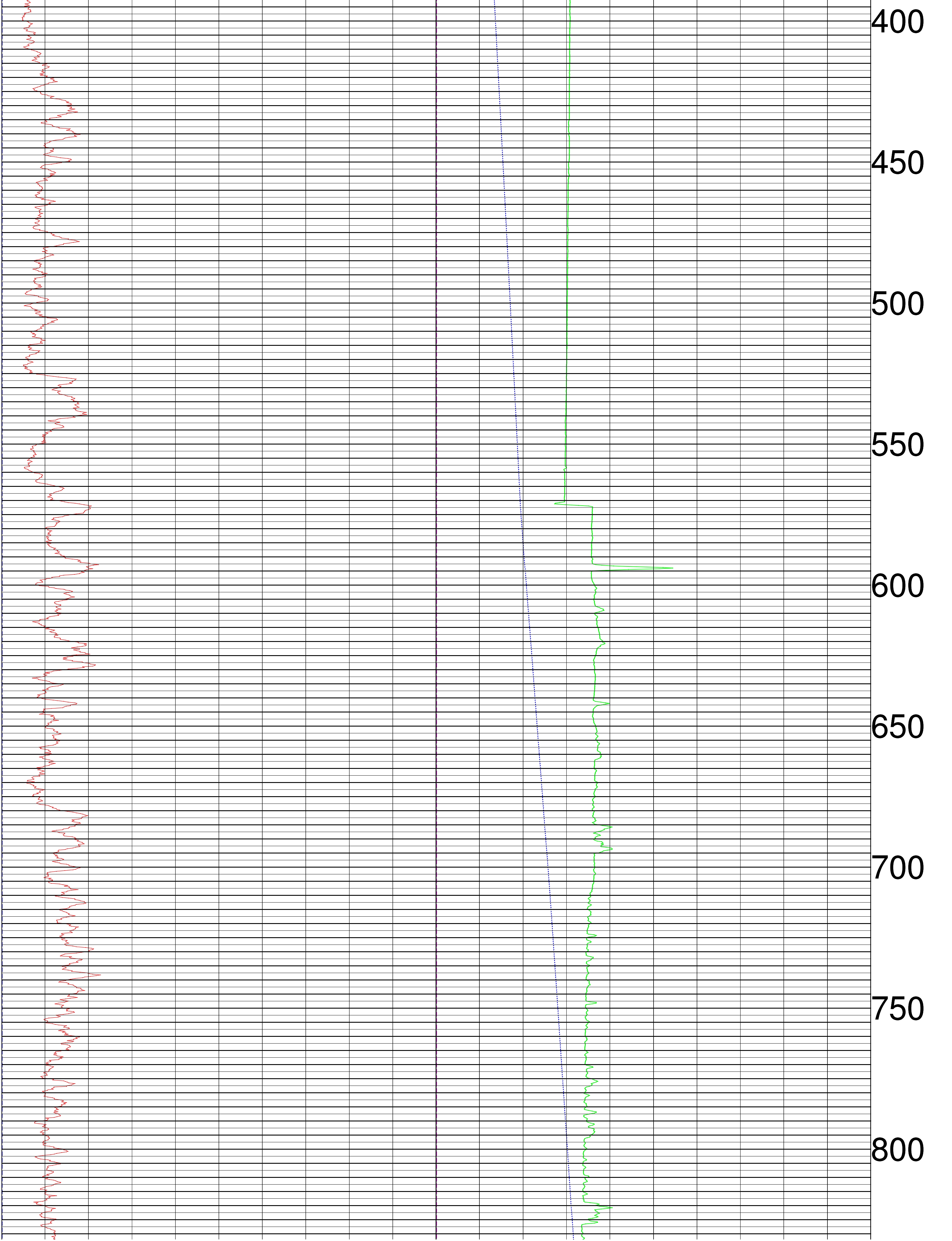
LOCATION	:
SECTION	: None
TOWNSHIP	: None
RANGE	: None
API NO.	:
UNIQUE WELL ID.	:

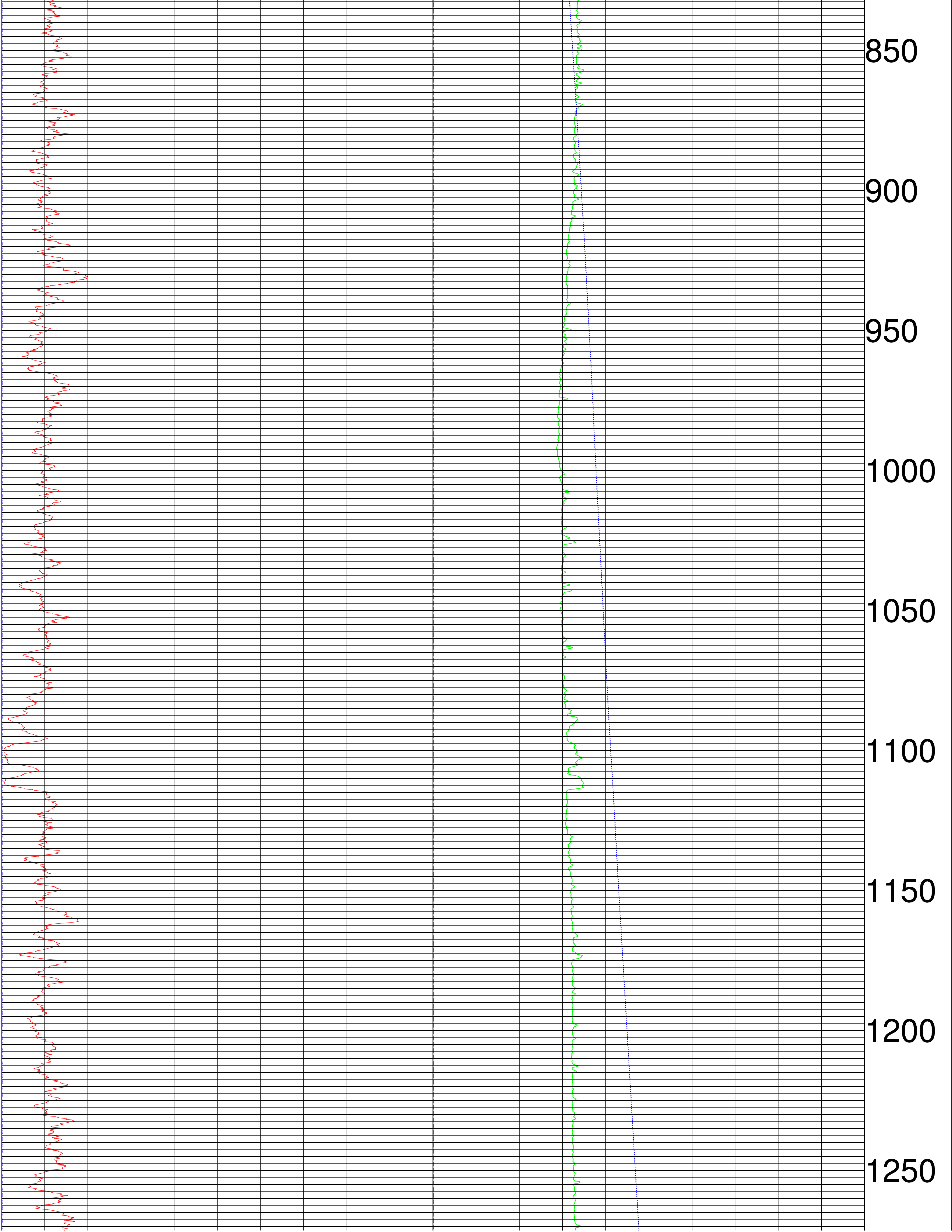
PERMANENT DATUM	: MSL	ELEVATION KB:	None
LOG MEASURED FROM:	GS	ELEVATION DF:	NA
DRL MEASURED FROM:	NA	ELEVATION GL:	NA

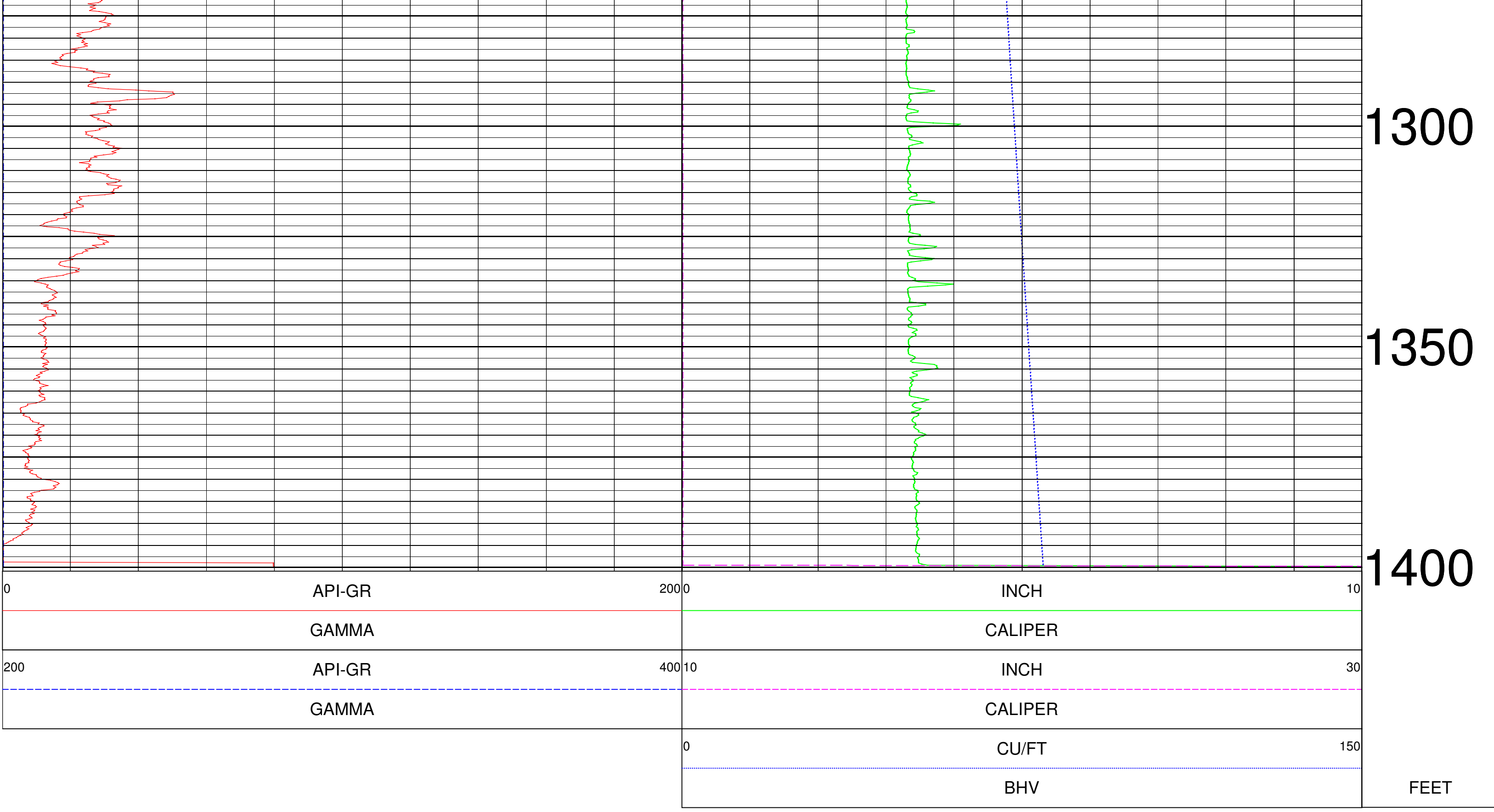
DATE	: 01/09/18
DEPTH DRILLER	: 1400
BIT SIZE	: 6
LOG TOP	: 6.75
LOG BOTTOM	: 1400.50
CASING OD	:
CASING BOTTOM	: 570
CASING TYPE	: STEEL
BOREHOLE FLUID	: FOR
RM TEMPERATURE	: 0
MUD RES	: 0
MUD WEIGHT	:
WITNESSED BY	:
RECORDED BY	: AFB
REMARKS 1	: .
REMARKS 2	:



BHV
0 CU/FT 150
FEET
GAMMA
200 API-GR 400
CALIPER
10 INCH 30
GAMMA
0 API-GR 200
CALIPER
0 INCH 10
50
100
150
200
250
300
350


400
450
500
550
600
650
700
750
800


850
900
950
1000
1050
1100
1150
1200
1250


1300
1350
1400
0 API-GR 200
GAMMA
200 API-GR 400
GAMMA
0 INCH 10
CALIPER
10 INCH 30
CALIPER
0 CU/FT 150
BHV
FEET

TOOL CALIBRATION TOHO WELL OSF-112 01/09/18 10:08
TOOL 9074A   TM VERSION 0
SERIAL NUMBER   857

	DATE	TIME	SENSOR	STANDARD		RESPONSE	
1	Jan12,03	07:10:06	GAMMA	Default	[CPS]	Default	[CPS]
	Jan12,03	04:10:06	GAMMA	180.000	[API-GR]	205.00	[CPS]
2	Jan09,18	14:50:00	CALIPER	3.000	[INCH]	157313.00	[CPS]
	Jan09,18	14:50:00	CALIPER	5.000	[INCH]	150790.00	[CPS]
3	Dec27,17	20:57:41	CALIPERL	6.000	[INCH]	153523.00	[CPS]
	Dec27,17	20:57:41	CALIPERL	35.500	[INCH]	86954.00	[CPS]
4	Dec13,00	22:19:45	CALIPERX	Default	[CPS]	Default	[CPS]
	Dec13,00	22:19:45	CALIPERX	Default	[CPS]	Default	[CPS]

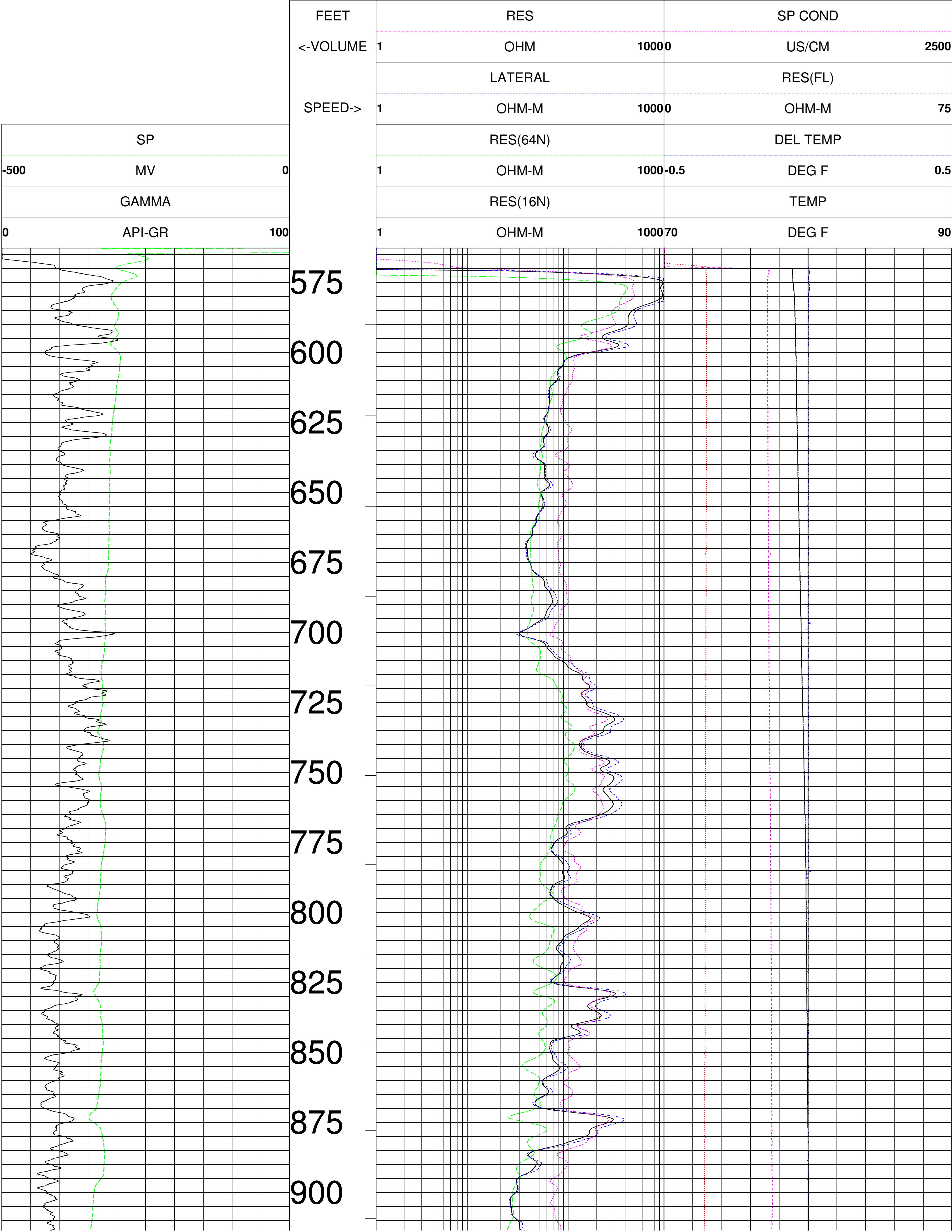
COMBINATION LOG
STATIC WATER QUAL.
TOHO WELL OSF-112

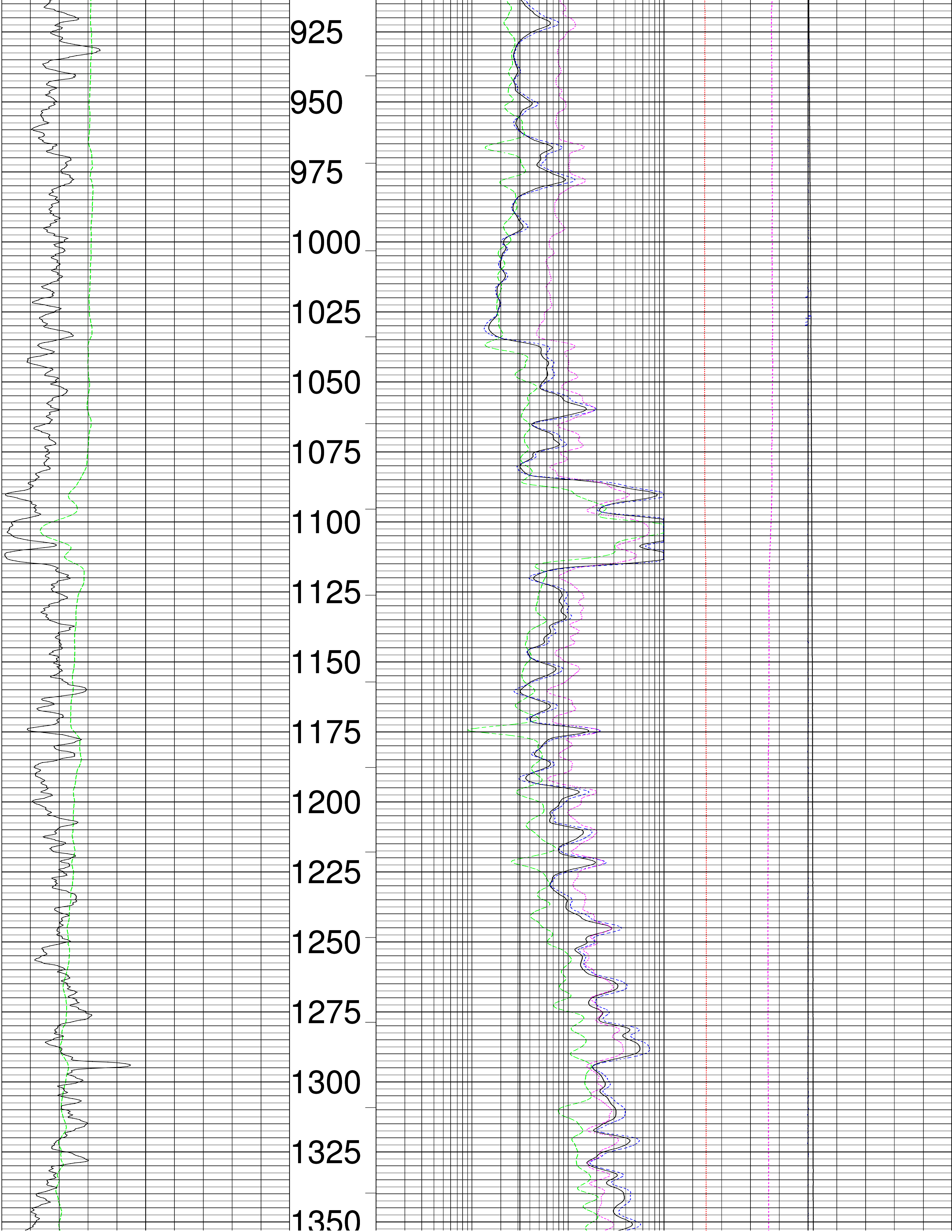
COMPANY	: HUSS DRILLING	OTHER SERVICES: LOWER S
WELL	: TOHO WELL OSF-112	
FIELD	: ST CLOUD	
COUNTY	: OSCEOLA	
STATE	: FLORIDA	

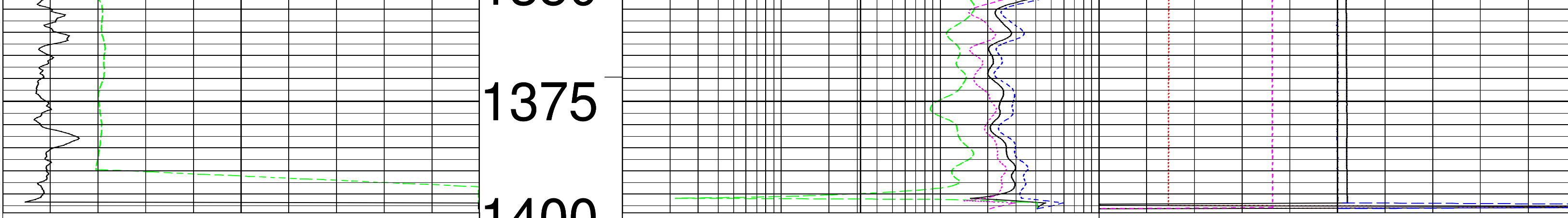
LOCATION	:
SECTION	: None
TOWNSHIP	: None
RANGE	: None
API NO.	:
UNIQUE WELL ID.	:

PERMANENT DATUM	: MSL	ELEVATION KB:	None
LOG MEASURED FROM:	GS	ELEVATION DF:	NA
DRL MEASURED FROM:	NA	ELEVATION GL:	NA

DATE	: 01/09/18
DEPTH DRILLER	: 1400
BIT SIZE	: 6
LOG TOP	: 562.75
LOG BOTTOM	: 1398.75
CASING OD	:
CASING BOTTOM	: 570
CASING TYPE	: STEEL
BOREHOLE FLUID	: FOR
RM TEMPERATURE	: 0
MUD RES	: 0
MUD WEIGHT	:
WITNESSED BY	:
RECORDED BY	: AFB
REMARKS 1	: .
REMARKS 2	:


FEET
<-VOLUME
SPEED->
RES
1 OHM 1000
LATERAL
1 OHM-M 1000
RES(64N)
1 OHM-M 1000
RES(16N)
1 OHM-M 1000
SP COND
0 US/CM 2500
RES(FL)
0 OHM-M 75
DEL TEMP
-0.5 DEG F 0.5
TEMP
70 DEG F 90
SP
-500 MV 0
GAMMA
0 API-GR 100
575
600
625
650
675
700
725
750
775
800
825
850
875
900


925
950
975
1000
1025
1050
1075
1100
1125
1150
1175
1200
1225
1250
1275
1300
1325
1350



0 API-GR 100		1 OHM-M 1000	70 DEG F 90
GAMMA		RES(16N)	TEMP
-500 MV 0		1 OHM-M 1000	-0.5 DEG F 0.5
SP	SPEED->	RES(64N)	DEL TEMP
		1 OHM-M 1000	0 OHM-M 75
	<-VOLUME	LATERAL	RES(FL)
		1 OHM 1000	0 US/CM 2500
	FEET	RES	SP COND

TOOL CALIBRATION TOHO WELL OSF-112 01/09/18 08:38
TOOL 8044A   TM VERSION 0
SERIAL NUMBER   938

	DATE	TIME	SENSOR	STANDARD		RESPONSE	
1	Jan03,03	10:49:05	GAMMA	0.001	[API-GR]	0.00	[CPS]
	Jan03,03	07:49:05	GAMMA	180.000	[API-GR]	169.00	[CPS]
2	May16,17	19:08:20	RES(FL)	41.600	[OHM-M]	54104.00	[CPS]
	May16,17	19:08:20	RES(FL)	0.100	[OHM-M]	11978.00	[CPS]
3	Aug17,14	17:00:23	SP	0.000	[MV]	59670.00	[CPS]
	Aug17,14	17:00:23	SP	395.000	[MV]	23612.00	[CPS]
4	Jul25,17	06:42:26	RES(16N)	0.000	[OHM-M]	4284.00	[CPS]
	Jul25,17	06:42:26	RES(16N)	1996.000	[OHM-M]	138447.00	[CPS]
5	Jul25,17	06:42:50	RES(64N)	0.000	[OHM-M]	4160.00	[CPS]
	Jul25,17	06:42:50	RES(64N)	1990.000	[OHM-M]	176008.00	[CPS]
6	Aug17,14	17:19:05	TEMP	71.700	[DEG F]	63355.00	[CPS]
	Aug17,14	17:19:05	TEMP	81.500	[DEG F]	58740.00	[CPS]
7	Aug17,14	15:39:11	RES	0.000	[OHM]	9855.00	[CPS]
	Aug17,14	15:39:11	RES	988.000	[OHM]	58788.00	[CPS]

COMBINATION LOG
STATIC WATER QUAL.
TOHO WELL OSF-112

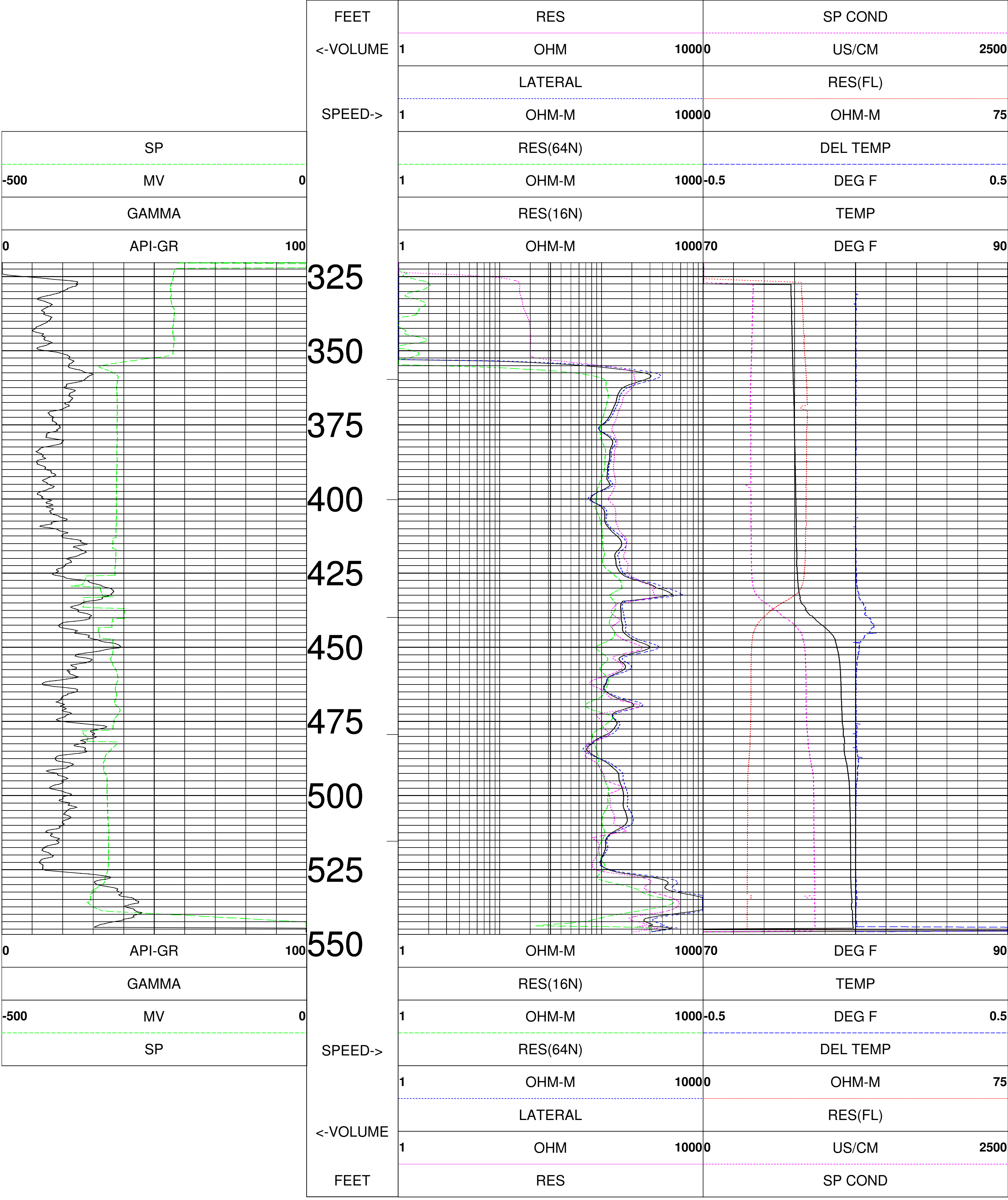
COMPANY	:	HUSS DRILLING
WELL	:	TOHO WELL OSF-112
FIELD	:	ST CLOUD
COUNTY	:	OSCEOLA
STATE	:	FLORIDA

OTHER SERVICES:
VIDEO

LOCATION	:	
SECTION	:	None
TOWNSHIP	:	None
RANGE	:	None
API NO.	:	
UNIQUE WELL ID.	:	

PERMANENT DATUM	:	MSL	ELEVATION KB:	None
LOG MEASURED FROM	:	GS	ELEVATION DF:	NA
DRL MEASURED FROM	:	NA	ELEVATION GL:	NA

DATE	:	01/16/18
DEPTH DRILLER	:	1400
BIT SIZE	:	6
LOG TOP	:	320.25
LOG BOTTOM	:	546.50
CASING OD	:	
CASING BOTTOM	:	570
CASING TYPE	:	STEEL
BOREHOLE FLUID	:	FOR
RM TEMPERATURE	:	0
MUD RES	:	0
MUD WEIGHT	:	
WITNESSED BY	:	
RECORDED BY	:	AFB
REMARKS 1	:	UPPER SEC
REMARKS 2	:	



FEET
<-VOLUME
SPEED->
RES
1 OHM 1000
LATERAL
1 OHM-M 1000
RES(64N)
1 OHM-M 1000
RES(16N)
1 OHM-M 1000
SP COND
0 US/CM 2500
RES(FL)
0 OHM-M 75
DEL TEMP
-0.5 DEG F 0.5
TEMP
70 DEG F 90
SP
-500 MV 0
GAMMA
0 API-GR 100
325
350
375
400
425
450
475
500
525
550

TOOL CALIBRATION TOHO WELL OSF-112 01/16/18 10:51
TOOL 8044A TM VERSION 0
SERIAL NUMBER 938

	DATE	TIME	SENSOR	STANDARD		RESPONSE	
1	Jan03,03	07:49:05	GAMMA	0.001	[API-GR]	0.00	[CPS]
	Jan03,03	07:49:05	GAMMA	180.000	[API-GR]	169.00	[CPS]
2	May16,17	19:08:20	RES(FL)	41.600	[OHM-M]	54104.00	[CPS]
	May16,17	19:08:20	RES(FL)	0.100	[OHM-M]	11978.00	[CPS]
3	Aug17,14	17:00:23	SP	0.000	[MV]	59670.00	[CPS]
	Aug17,14	17:00:23	SP	395.000	[MV]	23612.00	[CPS]
4	Jul25,17	06:42:26	RES(16N)	0.000	[OHM-M]	4284.00	[CPS]
	Jul25,17	06:42:26	RES(16N)	1996.000	[OHM-M]	138447.00	[CPS]
5	Jul25,17	06:42:50	RES(64N)	0.000	[OHM-M]	4160.00	[CPS]
	Jul25,17	06:42:50	RES(64N)	1990.000	[OHM-M]	176008.00	[CPS]
6	Aug17,14	17:19:05	TEMP	71.700	[DEG F]	63355.00	[CPS]
	Aug17,14	17:19:05	TEMP	81.500	[DEG F]	58740.00	[CPS]
7	Aug17,14	15:39:11	RES	0.000	[OHM]	9855.00	[CPS]
	Aug17,14	15:39:11	RES	988.000	[OHM]	58788.00	[CPS]

OSF-112 (Depth below LS)

Depth 1ft:4ft	Optical Borehole Image (QL40-OBI-2G 0° 90° 180° 270° 0°

350

355

360

365


370
375
380


385
390
395
400

405

410

415

420


425
430
435
440


445
450
455
460


465
470
475
480


485
490
495
500


505
510
515

520

525

530

535


540
545
550
555

560

565

570

575


580
585
590
595

600

605

610

615


620
625
630
635


640
645
650


655
660
665
670


675
680
685
690

695

700

705

710

715

720

725

730

735

740

745

750

755

760

765

770

775

780

785

790

795

800

805

810

815

820

825


830
835
840
845


850
855
860
865

870

875

880

885


890
895
900

905

910

915

920

925

930

935

940


945
950
955
960

965

970

975

980


985
990
995
1000


1005
1010
1015
1020


1025
1030
1035


1040
1045
1050
1055

1060

1065

1070

1075


1080
1085
1090
1095


1100
1105
1110
1115

1120

1125

1130

1135


1140
1145
1150
1155


1160
1165
1170


1175
1180
1185
1190


1195
1200
1205
1210


1215
1220
1225
1230

1235

1240

1245

1250


1255
1260
1265
1270

1275

1280

1285

1290


1295
1300
1305

1310

1315

1320

1325

1330

1335

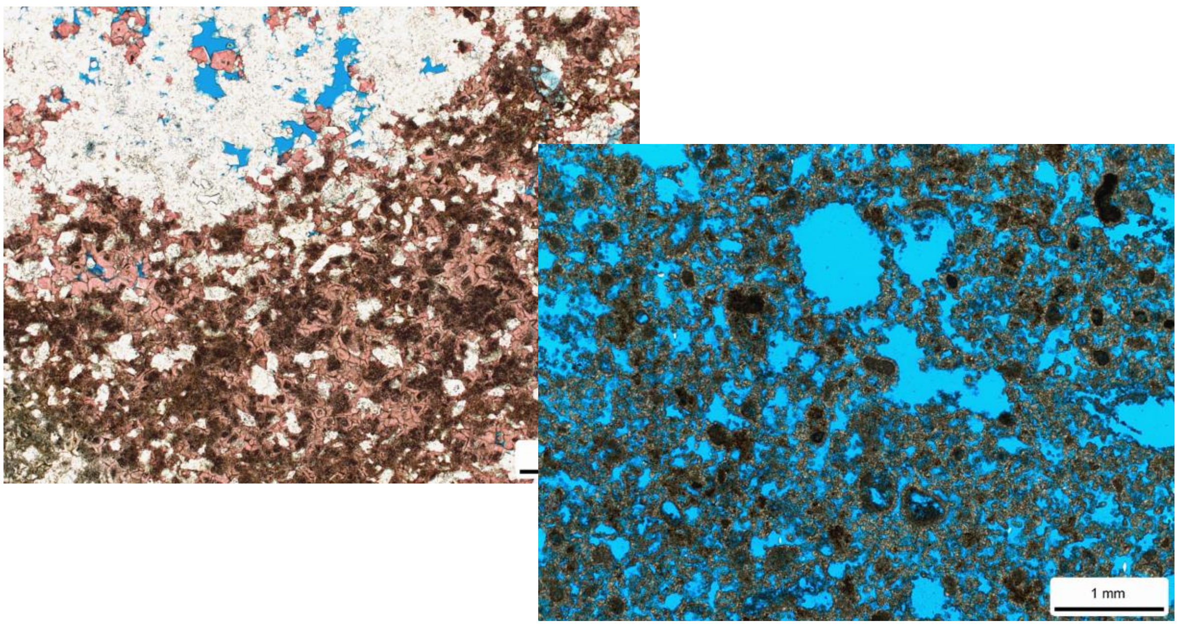
APPENDIX F:
CORE LABORATORY REPORTS

PETROLEUM SERVICES

Thin Section and X-ray Diffraction Analyses of Core Samples

South Florida Water Management

OSF-112 Well



October 2018

Core Laboratories, Inc.
Houston Advanced Technology Center
6316 Windfern Road
Houston, Texas 77040

Houston ATC Job File No.: 1802883G

PETROGRAPHIC SUMMARY

Four (4) core samples from OSF-112 Well were selected for thin section and X-ray diffraction (XRD) analyses (Table 1).

- Thin section samples were impregnated with blue-dyed epoxy, and subsequently ground and polished to a thickness of 30 microns. The samples were stained for calcite, ferroan calcite (Fe-calcite) and ferroan dolomite (Fe-dolomite). Thin section photomicrographs and descriptions are provided in Plates 1-4.

- Based on thin section and XRD analyses, the analyzed samples consist of dolostone (Plates 1, 2, 3) and limestone (Plate 4).

- Visible pores are generally abundant and well interconnected in all the dolostone samples. They are mostly vugs and intercrystal pores, others such as intraskeletal and moldic pores are less common.

- Visible pores (mainly vug and intercrystal pores) are rare and poorly interconnected in the limestone sample. The limestone sample is locally replaced by celestine, which is unevenly distributed.

Thank you for choosing Core Laboratories to perform this study. Please feel free to contact us if you have any questions or comments concerning this report.

Sincerely,

Yongqiang Wu

Yong Q. Wu PhD
Senior Project Geologist
Reservoir Geology
Core Laboratories - Houston
Phone: 713-328-2554
E-mail: Yong.Wu@corelab.com

ANALYTICAL PROCEDURES

THIN SECTION PETROGRAPHY

Thin sections were prepared by first impregnating the samples with epoxy to augment cohesion and to prevent loss of material during grinding. Blue dye was added to the epoxy. Each thinly sliced sample was mounted on a frosted glass slide and then cut and ground to an approximate thickness of 30 microns. The thin sections were stained with the following: Alizarin Red-S to differentiate calcite (stains red) from clear dolomite (does not stain); potassium ferricyanide to identify ferroan dolomite (stains dark blue) and ferroan calcite (stains purple to dark blue depending on acid concentration and iron content of the sample). The thin sections were analyzed using standard petrographic techniques.

XRD ANALYSIS (XRD)

Samples submitted for whole-rock mineral analysis are first cleaned of obvious drilling contaminants and then disaggregated in a mortar and pestle. Approximately five grams of each sample are transferred to isopropyl alcohol and pulverized using a McCrone micronizing mill. The resultant powders are dried, disaggregated, and packed into aluminum sample holders to produce random whole-rock mounts. The whole rock samples are analyzed over an angular range of 2-60 degrees 2-theta at a scan rate of one degree/minute.

Semi-quantitative determinations of whole-rock mineral amounts are done utilizing integrated peak areas (derived from peak-decomposition / profile-fitting methods) and empirical reference intensity ratio (RIR) factors determined specifically for the diffractometer used in data collection.

TABLE 1

South Florida Water Management , OSF-112 Well

ANALYTICAL PROGRAM AND SAMPLE SUMMARY

Sample ID	Depth (ft)	TS	XRD	Lithology	Plate No.
16V	912.30-912.50	**X**	**X**	Dolostone	1
17V	945.40-945.60	**X**	**X**	Dolostone	2
18V	962.70-962.90	**X**	**X**	Dolostone	3
19V	978.70-978.90	**X**	**X**	Limestone	4

TABLE 2

South Florida Water Management , OSF-112 Well

Mineralogy Determined by X-ray Diffraction

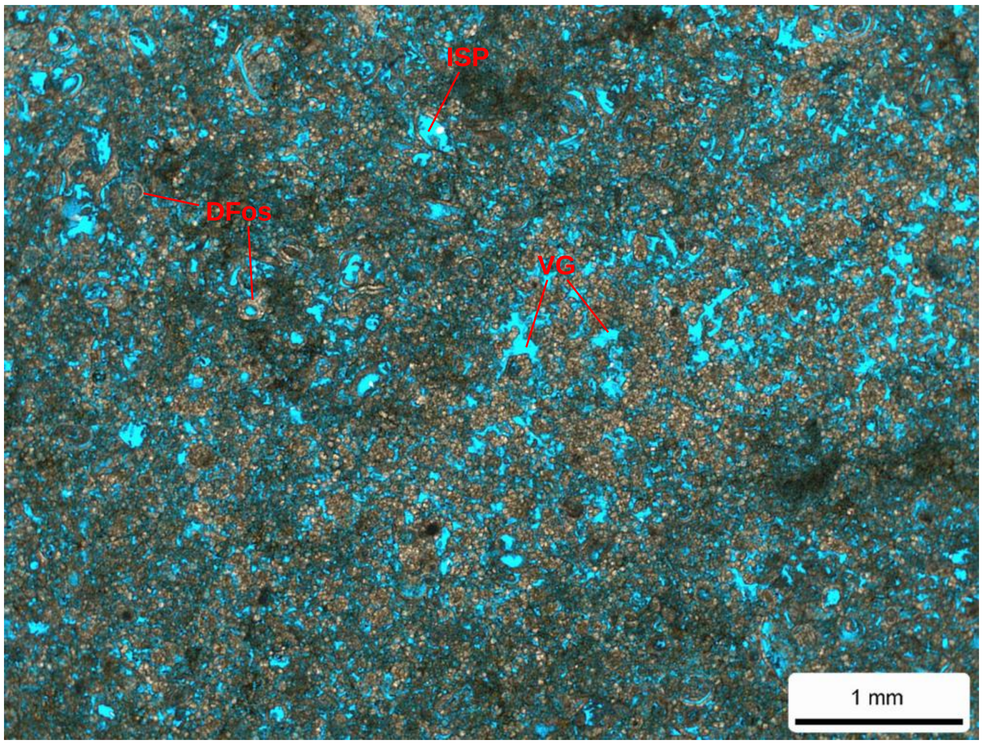
Sample ID	Depth (ft):	Whole Rock Mineralogy (Weight %)			
		Quartz	Calcite	Dolomite	Celestine
16V	912.30-912.50	0.5	0.0	99.5	0.0
17V	945.40-945.60	0.7	0.0	99.3	0.0
18V	962.70-962.90	0.2	2.2	97.3	0.3
19V	978.70-978.90	0.4	57.5	2.4	39.7

PLATE 1

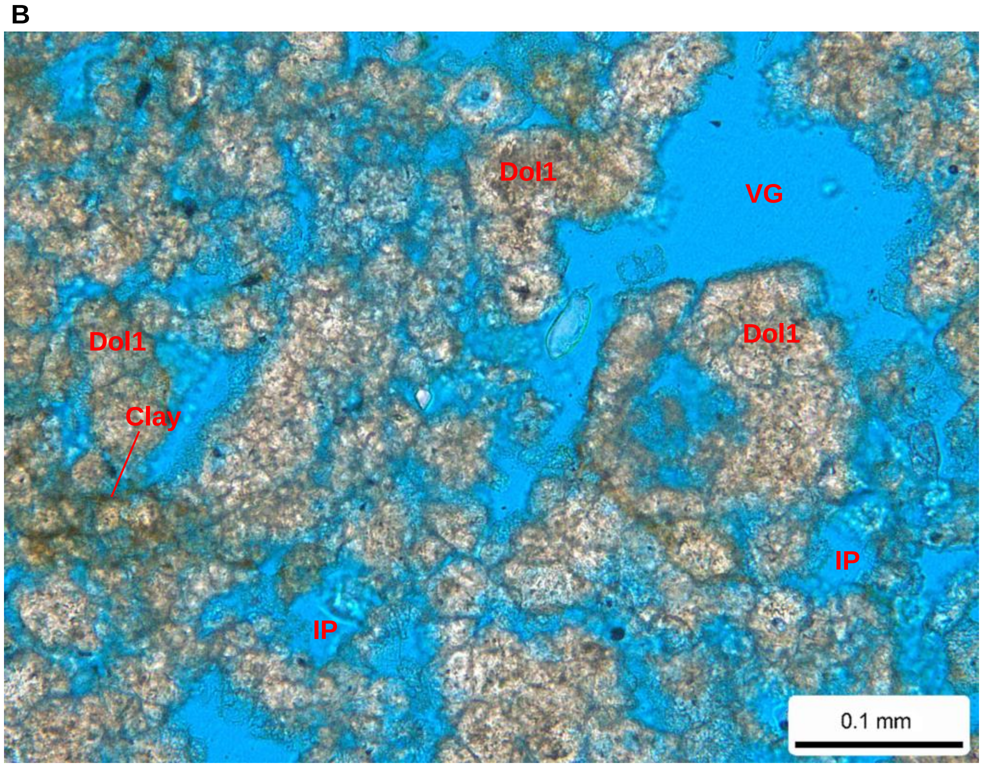
Thin Section Petrography

Company: South Florida Water Management
Well: OSF-112
Location: na
Core Type: Conventional Core
Depth (ft): 912.30-912.50
Sample ID: 16V

A



B



Relative Abundances:

Trace	<1%
Minor	1-5%
Moderate	5-10%
Common	10-20%
Abundant	>20%

Sample Description

Lithology: Dolostone

Classification (mod. Dunham 1962)
Finely crystalline dolostone

Texture and Structures:
Massive

Allochemical Grains:
Moderate dolomitized fossil fragments

Other Grains:
na

Matrix:
na

Cement and Replacement:
Abundant dolomite; trace to minor clays

Pore Types:
Common to abundant vugs and intercrystal pores; minor to moderate intraskeletal and moldic pores

XRD-Whole Rock Mineralogy (weight %)

Quartz	0.5	Dolomite	99.5
Calcite	0.0	Celestine	0.0

Photo Caption:

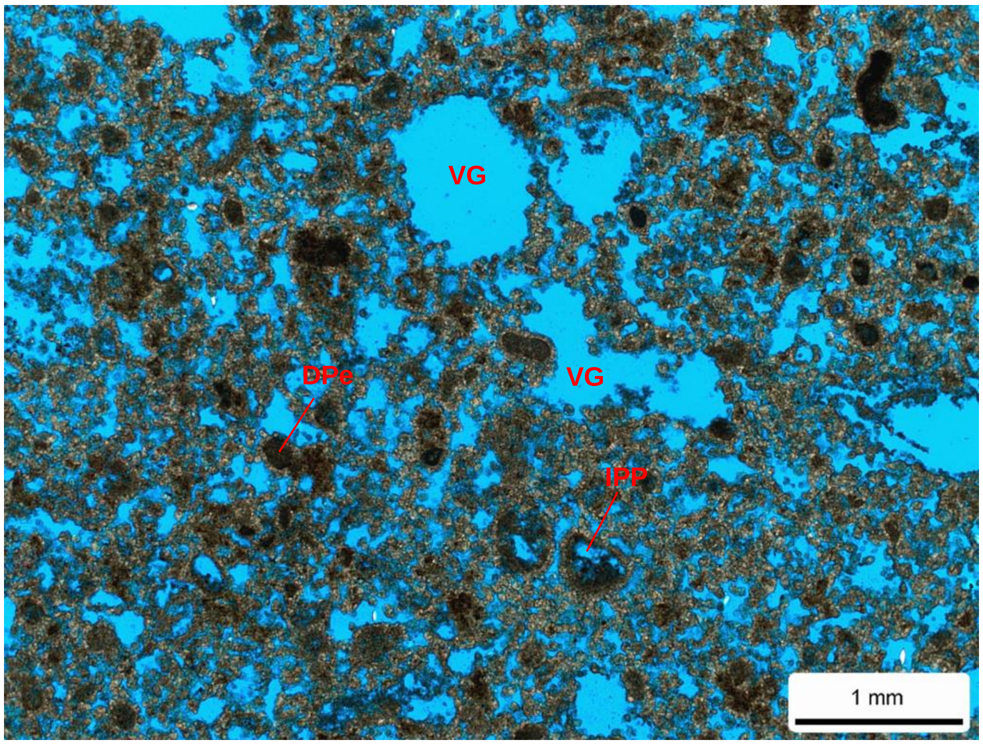
Visible pores (blue) are abundant in this dolostone, and consist of vugs (VG), intercrystal pores (IP), intraskeletal pores (ISP) and moldic pores. Dolomite crystals (Dol1) are mostly turbid in appearance; however, the dolomite crystals associated with the dolomitized fossil fragments (DFos) are relatively clear in appearance. Trace amounts of clays (Clay) are locally observed. The original limestone was possibly a wackestone or packstone and has been extensively dolomitized.

PLATE 2

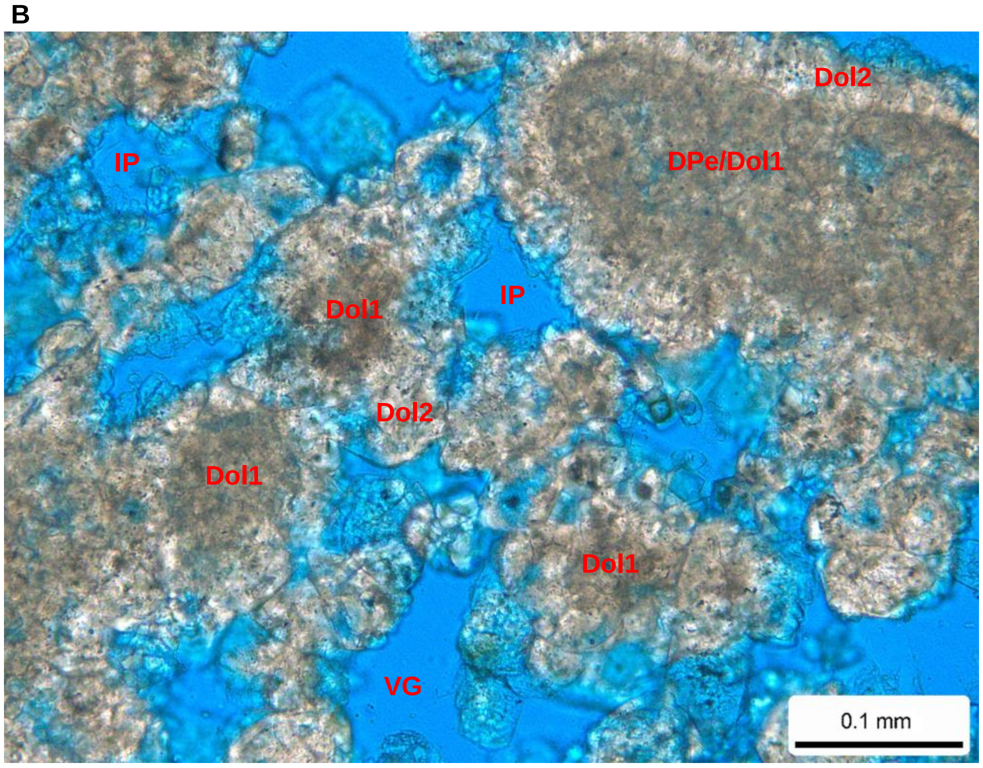
Thin Section Petrography

Company: South Florida Water Management
Well: OSF-112
Location: na
Core Type: Conventional Core
Depth (ft): 945.40-945.60
Sample ID: 17V

A



B



Relative Abundances:

Trace	<1%
Minor	1-5%
Moderate	5-10%
Common	10-20%
Abundant	>20%

Sample Description

Lithology: Dolostone

Classification (mod. Dunham 1962)
Finely crystalline dolostone

Texture and Structures:
Massive

Allochemical Grains:
Moderate dolomitized peloids

Other Grains:
na

Matrix:
na

Cement and Replacement:
Abundant dolomite

Pore Types:
Abundant vugs and intercrystal pores; minor intraparticle and moldic pores

XRD-Whole Rock Mineralogy (weight %)

Quartz	0.7	Dolomite	99.3
Calcite	0.0	Celestine	0.0

Photo Caption:

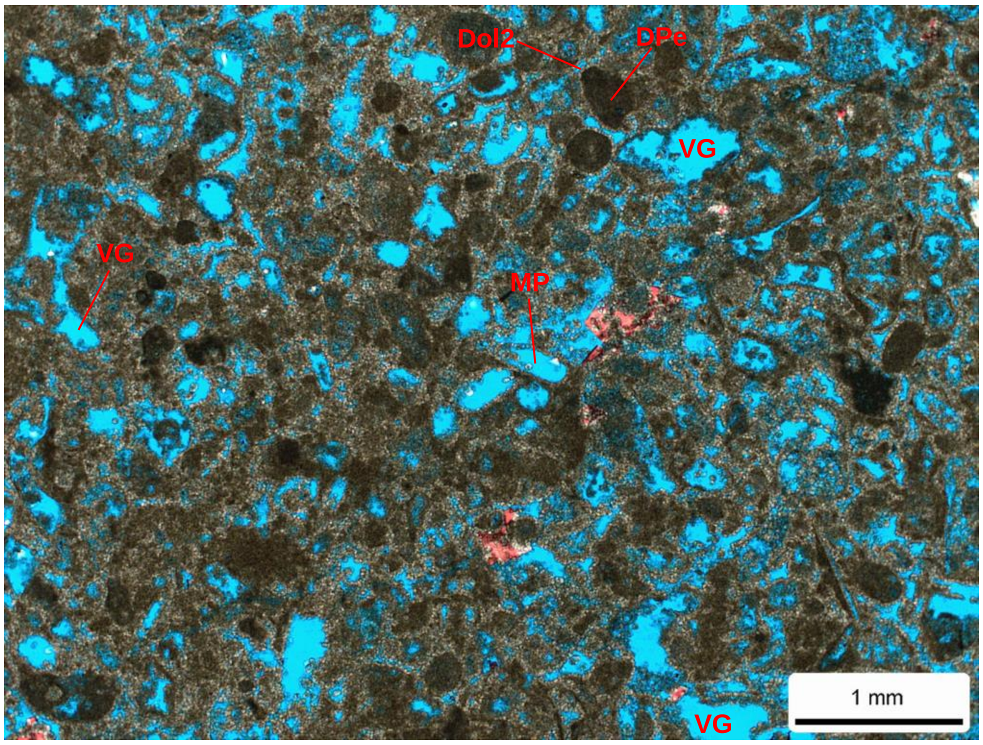
Visible pores (blue) are abundant in this dolostone, and consist of vugs (VG), intercrystal pores (IP), intraparticle pores (IPP) and moldic pores. The dolomite crystals (Dol1) associated with the dolomitized peloids (DPe) are turbid in appearance; however, some dolomite crystals (Dol2) are relatively clear in appearance, locally forming rims around the peloids. The original limestone was possibly a wackestone or packstone and has been extensively dolomitized.

PLATE 3

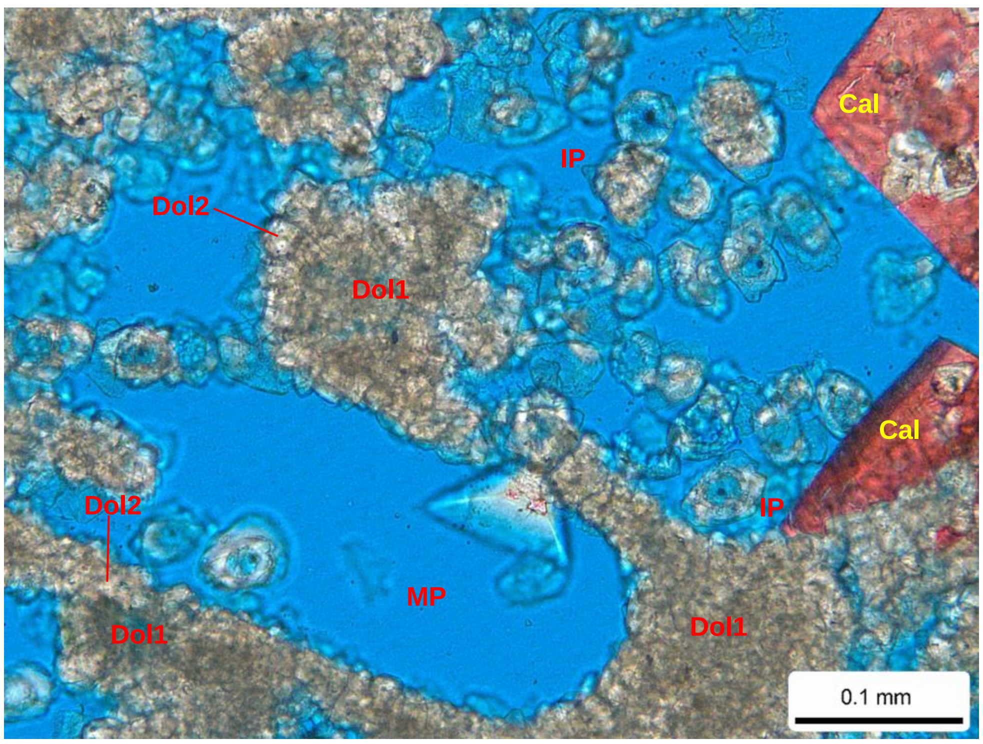
Thin Section Petrography

Company: South Florida Water Management
Well: OSF-112
Location: na
Core Type: Conventional Core
Depth (ft): 962.70-962.90
Sample ID: 18V

A



B



Relative Abundances:

Trace	<1%
Minor	1-5%
Moderate	5-10%
Common	10-20%
Abundant	>20%

Sample Description

Lithology: Dolostone

Classification (mod. Dunham 1962)
Finely crystalline dolostone

Texture and Structures:
Massive

Allochemical Grains:
Moderate dolomitized peloids

Other Grains:
na

Matrix:
na

Cement and Replacement:
Abundant dolomite; trace to minor calcite

Pore Types:
Abundant vugs and intercrystal pores; minor intraparticle and moldic pores

XRD-Whole Rock Mineralogy (weight %)

Quartz	0.2	Dolomite	97.3
Calcite	2.2	Celestine	0.3

Photo Caption:

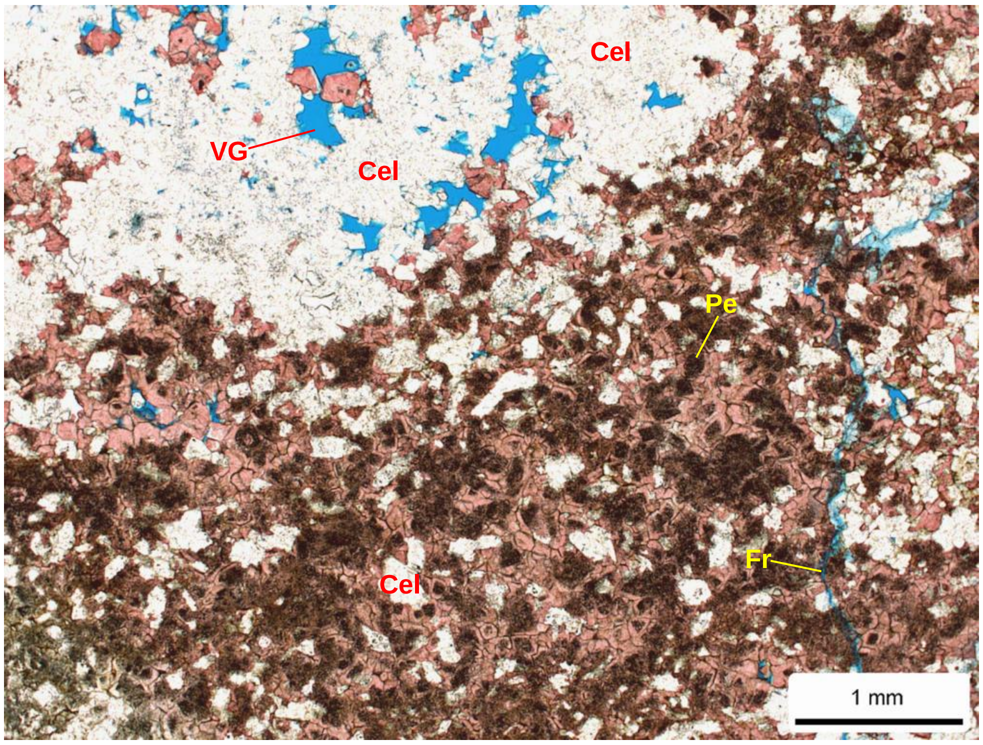
Visible pores (blue) are abundant in this dolostone, and consist of vugs (VG), intercrystal pores (IP), intraparticle pores and moldic pores (MP). The dolomite crystals (Dol1) associated with the dolomitized peloids (DPe) are turbid in appearance; however, some dolomite crystals (Dol2) are relatively clear in appearance, locally forming rims around the peloids. Trace amounts of calcite cement (Cal; stained reddish) are locally observed. The original limestone was possibly a wackestone or packstone and has been extensively dolomitized.

PLATE 4

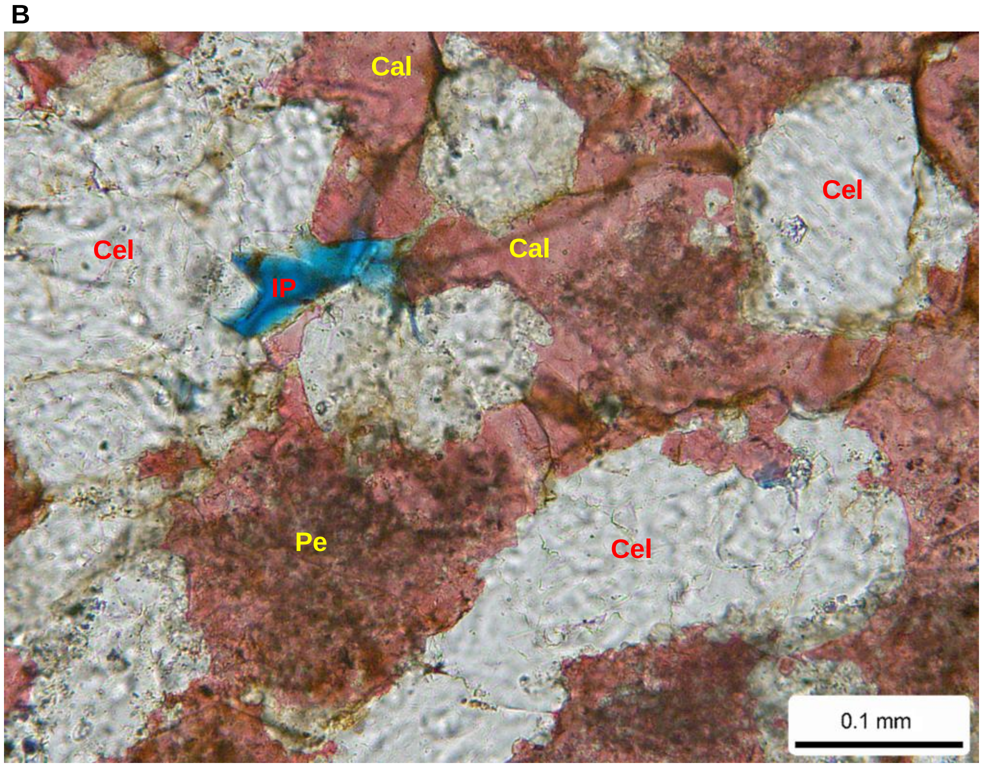
Thin Section Petrography

Company: South Florida Water Management
Well: OSF-112
Location: na
Core Type: Conventional Core
Depth (ft): 978.70-978.90
Sample ID: 19V

A



B



Relative Abundances:

Trace	<1%
Minor	1-5%
Moderate	5-10%
Common	10-20%
Abundant	>20%

Sample Description

Lithology: Limestone

Classification (mod. Dunham 1962)
Grainstone / Packstone

Texture and Structures:
Massive

Allochemical Grains:
Abundant peloids; trace fossil fragments

Other Grains:
na

Matrix:
na

Cement and Replacement:
Moderate to common celestine and calcite cement; trace dolomite

Pore Types:
Trace to minor intercrystal pores and vugs

XRD-Whole Rock Mineralogy (weight %)

Quartz	0.4	Dolomite	2.4
Calcite	57.5	Celestine	39.7

Photo Caption:

This limestone sample is locally replaced by celestine (Cel), which is unevenly distributed as shown in Image A. Visible pores (blue) are trace to minor in this sample, consisting of vugs (VG) and intercrystal pores (IP). Fractures (Fr) are probably unnatural and induced artificially. Peloids (Pe) are the principal allochem grains; calcite cement (Cal; stained reddish) mostly occurs between the allochem grains. In addition, the XRD sample may contain much more celestine than thin section sample.

CMS-300 CONVENTIONAL PLUG ANALYSIS

South Florida Water Management District

OSF-112

Florida

CL File Number: 201802883

Date: 9/11/18

South Florida Water Management District
OSF-112
Florida

CL File No.: 201802883
Date: 9/11/18
Analyst(s): JDH-TW-IM

CMS-300 CONVENTIONAL PLUG ANALYSIS

Sample Number	Depth (ft)	Net Confining Stress (psig)	Porosity (%)	Permeability Klinkenberg (md)	Permeability Kair (md)	b(air) psi	Beta ft(-1)	Alpha (microns)	Grain Density (g/cm3)	Footnote
1V	632.40	800	48.01	324	359	1.71	5.49E+06	5.75E+00	2.796	
2V	642.60	800	35.21	64.8	76.2	3.04	5.60E+07	1.17E+01	2.812	(3)
3V	655.20	800	45.86	19.0	25.8	6.58	8.53E+07	5.22E+00	2.799	
4V	661.00	800	49.09	2.98	4.78	12.35	1.51E+10	1.45E+02	2.799	
5V	776.55	800	42.38	580	931	9.53	5.76E+06	1.08E+01	2.826	(3)
5H	776.80	800	40.78	1127	1342	2.92	7.55E+06	2.75E+01	2.834	(3)
6V	785.75	800	30.63	523	582	1.80	2.01E+07	3.39E+01	2.826	
6H	786.00	800	31.79	1002	1274	4.20	5.33E+06	1.72E+01	2.833	
7H	794.65	800	20.77	161	184	2.33	1.90E+08	9.87E+01	2.823	
7V	794.70	800	23.97	77.0	86.2	2.06	3.82E+08	9.48E+01	2.841	
8V	805.30	800	36.50	149	180	3.44	6.18E+07	2.98E+01	2.836	
8H	805.65	800	27.73	195	243	4.05	4.54E+07	2.85E+01	2.829	
9V	812.75	800	25.53	150	165	1.68	9.63E+07	4.65E+01	2.819	
9H	813.00	800	20.41	90.2	101	1.96	4.27E+08	1.24E+02	2.817	
10V	822.30	800	35.72	96.4	116	3.37	1.45E+08	4.50E+01	2.831	
10H	822.50	800	20.68	140	167	3.21	4.97E+08	2.25E+02	2.767	
11V	828.15	800	3.02	.0004	.002	188.70	7.03E+16	8.81E+04	2.786	
11H	828.35	800	4.16	13.9	14.2	0.34	3.80E+12	1.71E+05	2.739	(3)
12V	862.30	800	32.70	45.3	53.3	3.12	6.45E+08	9.43E+01	2.819	
12H	862.60	Ambient	41.50	NA	NA	NA	NA	NA	2.809	(5)
13V	871.60	800	6.41	.002	.009	100.68	1.67E+15	1.30E+04	2.718	
13H	871.61	800	5.22	.002	.007	113.40	3.31E+15	1.83E+04	2.711	
14H	880.50	800	17.28	85.0	106	4.12	7.50E+08	2.06E+02	2.817	
14V	880.55	800	19.18	67.3	74.9	1.93	8.70E+08	1.90E+02	2.816	

South Florida Water Management District
OSF-112
Florida

CL File No.: 201802883
Date: 9/11/18
Analyst(s): JDH-TW-IM

CMS-300 CONVENTIONAL PLUG ANALYSIS

Sample Number	Depth (ft)	Net Confining Stress (psig)	Porosity (%)	Permeability Klinkenberg (md)	Permeability Kair (md)	b(air) psi	Beta ft(-1)	Alpha (microns)	Grain Density (g/cm3)	Footnote
1V	632.40	800	48.01	324	359	1.71	5.49E+06	5.75E+00	2.796	
15H	887.00	800	36.92	1206	1346	1.77	9.44E+06	3.69E+01	2.823	
15V	887.05	800	34.98	884	988	1.83	1.55E+07	4.44E+01	2.818	
16V	912.30	800	43.02	96.9	111	2.41	1.73E+07	5.43E+00	2.819	
17V	945.40	800	42.09	4409	4562	0.52	6.26E+05	8.93E+00	2.822	
18V	962.70	800	9.96	.024	.044	22.62	2.24E+13	1.77E+03	3.168	
19V	978.70	800	28.95	113	157	6.50	1.23E+08	4.49E+01	2.842	

Footnotes :

(3) : Denotes very short sample, porosity may be optimistic due to lack of conformation of boot material to plug surface.

(5) : Denotes sample unsuitable for measurement at stress. Porosity determined using Archimedes bulk volume at ambient conditions.

Permeability greater than 0.1 mD measured using helium gas. Permeability less than 0.1 mD measured using nitrogen gas. All b values converted to b (air)

South Florida Water Management District
OSF-112
Florida

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APPENDIX A: EXPLANATION OF CMS-300 TERMS "b", "Beta, and "Alpha"

K_∞	=	Equivalent non-reactive liquid permeability, corrected for gas slippage, mD
K_{air}	=	Permeability to Air, calculated using K_∞ and b, mD
b	=	Klinkenberg slip factor, psi
β (Beta)	=	Forcheimer inertial resistance factor, ft^{-1}
α (Alpha)	=	A factor equal to the product of Beta and K_∞. This factor is employed in determining the pore level heterogeneity index, H_i.
H_i	=	$\log_{10}(\alpha ø/RQI)$ α, microns = $3.238E^{-9}\ \beta K_\infty$
Ø	=	Porosity, fraction
RQI	=	Reservoir Quality Index, microns
RQI	=	$0.0314(K/ø)^{0.5}$

For further information please refer to:

Jones, S.C.: "Two-Point Determination of Permeability and PV vs. Net Confining Stress" SPE Formation Evaluation (March 1988) 235-241.

Jones S.C.: "A Rapid Accurate Unsteady-State Klinkenberg Permeameter," Soc. Pet. Eng. J. (Oct. 1972) 383-397.

Jones, S.C.: "Using the Inertial Coefficient, β, To Characterize Heterogeneity in Reservoir Rock: SPE 16949 (September 1987).

Amaefule, J.O.; Kersey, D.G.; Marschall, D.M.; Powell, J.D.; Valencia, L.E.; Keelan, D.K.: "Reservoir Description: A Practical Synergistic Engineering and Geological Approach Based on Analysis of Core Data,: SPE Technical Conference (Oct. 1988) SPE 18167.

South Florida Water Management District
OSF-112
Florida

CL File No.: 201802883
Date: 9/11/18
Analyst(s): JDH-TW-IM

CMS-300 CONVENTIONAL PLUG ANALYSIS PROTOCOL

1.0" diameter plugs were drilled with water and trimmed into right cylinders with a diamond-blade trim saw.
All sample trims were archived.

Sample Drying

Samples were oven dried at 240° F to weight equilibrium (+/- 0.001 g).

Porosity

Porosity was determined using Boyle's Law technique by measuring grain volume at ambient conditions & pore volume at indicated net confining stresses (NCS)

Grain Density

Grain density values were calculated by direct measurement of grain volume and weight on dried plug samples.
Grain volume was measured by Boyle's Law technique.

Permeability

Permeability to air was measured on each sample using unsteady-state method at indicated NCS.