SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Hydrogeology of the Caulkins Water Farm Project

Martin County, Florida

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EXECUTIVE SUMMARY

The Caulkins Water Farm Project (CWFP) encompasses a 3,014-acre surface water impoundment adjacent to the C-44 Canal (St. Lucie River) in southern Martin County, Florida. The CWFP includes five cells, separated by earthen berms, that range from approximately 400 to 798 acres in size. Approximately 20,192 acre-feet of water was pumped into the impoundment during the operational period of December 8, 2017 through November 2, 2018. Prior to construction of the CWFP, a pilot project comprising a 414-acre surface water impoundment in the southwestern portion (Cell 1) of the existing CWFP was operational from February 2014 through October 2016.

A total of 19 groundwater monitor wells and 6 surface water stations were installed within and adjacent to the project to characterize site lithology and conduct continuous water level monitoring and water quality sampling. Additional data sources for this report included lithologic logs, geophysical logs, and aquifer performance test data collected prior to construction of the project.

The surficial aquifer system (SAS) is approximately 140 to 150 feet (ft) thick and is divided into three units at the CFWP site. The uppermost unit (Unit 1) was found to consist of predominantly silty sand with irregular interbeds of clayey sand grading to sandy clay and sandy, calcareous clay from surface to approximately 18 ft below land surface (bls). Discontinuous clayey sand or sandy clay layers ranging from 2 to 12 ft in thickness were observed in each of the soil borings within the CWFP footprint at various depths. Slug tests and short-term aquifer performance tests at the CWFP indicated an average horizontal hydraulic conductivity (Kh) of 77 and 8 ft/day, respectively. Laboratory test data at the C-44 Reservoir/STA to the west indicated an average vertical hydraulic conductivity (Kv) of 0.10 ft/day. Unit 2 composes the bulk of the SAS and predominantly consists of poorly graded quartz sand, silty sand, shell, and a few interbeds of sandstone less than 2 ft thick. Locally interbedded units of clayey sand grading to sandy clay and coquina (Unit 3) were found within Unit 2. Twenty-four-hour, multi-well aquifer performance tests within the CWFP and the C-44 Reservoir/STA indicated a range of Kh from 20 to 51 ft/day, and a range of Kv from 0.35 to 1 ft/day. Unit 3 is a less permeable, poorly consolidated granular limestone and coquina with sand, shell and calcareous clay that occurs at the base of the SAS and also is interbedded at relatively shallow depths within Unit 2.

Site hydrogeology is spatially variable, with less permeable sediments observed in the upper and middle portions of the SAS in the eastern half (Cells 4 and 5) and northwestern cell (Cell 3) relative to Cells 1 (pilot project cell) and 2 of the CWFP. These sediments include thicker and potentially more continuous clayey sand in the shallow sand layer; interbedded coquina with shell in Unit 2; and a relatively thick section of clayey sand, grading to sandy clay interbedded in the middle of Unit 2. Well control in Cell 2 was not deep enough to evaluate permeability in Unit 2. Reduced permeability may be responsible for the lower seepage observed during the operational period of the expanded CWFP, approximately 0.022 ft/day, including evapotranspiration, compared to 0.051 ft/day during the pilot project operational period, excluding evapotranspiration. (Evapotranspiration and rain were observed to largely cancel out during the pilot test operational period.) During January 2019, flow between cells was restricted, and seepage from Cells 3, 4, and 5 was approximately 20 to 50 percent of the seepage observed from Cell 1, consistent with the low-permeability sediments observed.

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ACRONYMS AND ABBREVIATIONS

ac-ft	acre-feet
APT	aquifer performance test
bls	below land surface
cm/s	centimeters per second
CWFP	Caulkins Water Farm Project
ET	evapotranspiration
ft	foot
ft/day	feet per day
gpm	gallons per minute
K	hydraulic conductivity
Kh	horizontal hydraulic conductivity
Kv	vertical hydraulic conductivity
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
SPT	standard penetration test
STA	stormwater treatment area
USACE	United States Army Corps of Engineers

1 INTRODUCTION

The Caulkins Water Farm Project (CWFP), implemented as part of the South Florida Water Management District's (SFWMD's) Dispersed Water Management Program, encompasses a 3,014-acre surface water impoundment adjacent to the C-44 Canal (St. Lucie River) in southern Martin County, Florida. Construction of the CWFP was completed in 2017. Pumping commenced on December 8, 2017 and continued intermittently through November 2, 2018. Approximately 20,192 acre-feet (ac-ft) of water was pumped into the impoundment during that period, with a seepage rate of 0.022 feet per day (ft/day), not including evapotranspiration (ET). Prior to construction of the CWFP, a pilot project comprising a 414-acre surface water impoundment in the southwestern cell (Cell 1) of the existing CWFP was constructed between August and December 2013. Pumping into the pilot project impoundment began on February 2, 2014 and continued intermittently through October 26, 2016 (approximately 33 months). In 2014 and 2015, 14 groundwater and 6 surface water stations were installed within and adjacent to the pilot project for continuous water level monitoring and water quality sampling. Previous reports documented station installation and provided analysis of site hydrogeology, water quality, and groundwater seepage at the pilot project site (Janzen et al. 2015, 2017).

2 SITE SETTING AND DESCRIPTION

The CWFP was constructed on former agricultural property. The area is bordered by agricultural land to the north and west and by agricultural and undeveloped land to the east. To the south is undeveloped property, County Highway 726 (Citrus Boulevard), and the C-44 Canal. Prior to construction of the CWFP and pilot project, the property was a citrus grove and leased for farming.

The CWFP includes five cells separated by earthen berms approximately 7 feet (ft) above grade (**Figure 1**). The cells range from approximately 414 to 798 acres in area and are connected to each other by 60-inch diameter gated culverts. Perimeter ditches are adjacent to the exterior of each cell and connected by emergency discharge pipes. A pump station is located approximately 300 ft south of Cell 1 for transferring water from the C-444 Canal (connected to the C-44 Canal) via three electric 35,000-gallon per minute (gpm) pumps.

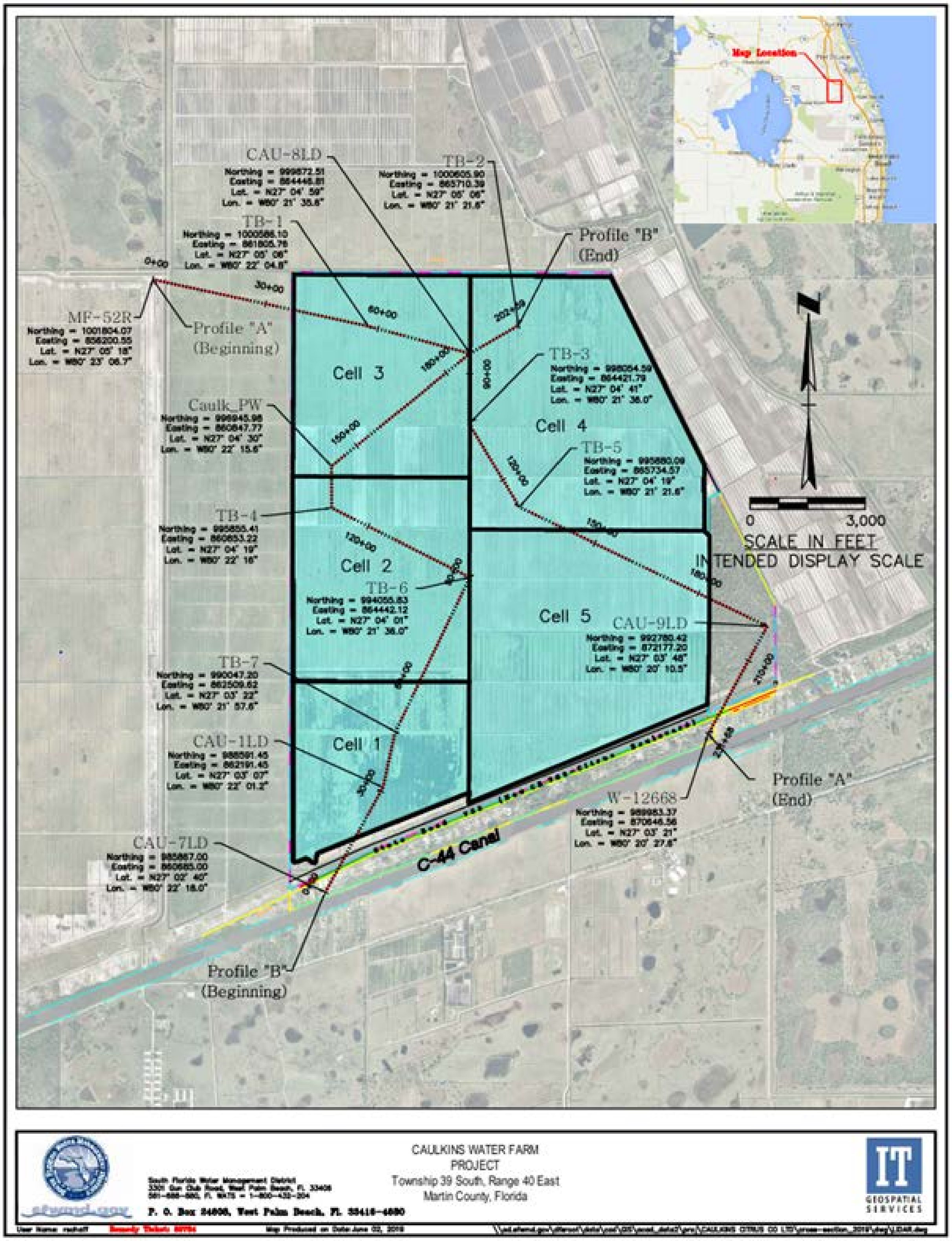

Figure 1. Site map of the Caulkins Water Farm Project in Martin County, Florida.

3 METHODS

Hydrogeologic data collected during previous investigations (prior to construction of the pilot project) and recent investigations conducted by the SFWMD during operation of the pilot project in 2014-2015 and the CWFP in 2018 are summarized below.

Previous investigations within the CWFP footprint and vicinity include the following:

- A groundwater flow model report of the surficial aquifer system (SAS) in Martin County (Adams 1992) and hydrogeologic investigation data report (Lukasiewicz and Adams-Smith 1996) by the SFWMD. These reports provide detailed regional descriptions of the hydrogeology in Martin County, including the CWFP area, and site-specific data from installation and hydraulic testing of SAS monitor well Caulk_PW, installed to a depth of approximately 110 ft below land surface (bls) in Cell 3. Drilling methodology for Caulk_PW was mud-rotary, which does not provide a lithologic sample collection as representative as a standard penetration test (SPT), which was used for the other soil borings within the CWFP footprint.
- Eight SPT soil borings collected in 2006 within the impoundment footprint as part of a geotechnical investigation of the project area (Anderson Andre Consulting Engineers Inc., 2006). The borings, TW-1 through TW-8, were advanced to a depth of approximately 40 ft bls.
- Two aquifer performance tests (APTs) conducted at monitor wells approximately 1 to 6 miles west of the CWFP within the C-44 Reservoir/Stormwater Treatment Area (STA). The wells, W-101 and W-102, were installed to a depth of approximately 135 ft bls (United States Army Corps of Engineers [USACE] 2014).

Lithology and/or geophysical logs were obtained for three wells outside the CWFP footprint: W-12268 (completed 1974), approximately 600 ft south of the CWFP; M-1236, completed in 1988 and geophysically logged in 2017, approximately 1,600 ft east of the CWFP; and MF-52R, completed in 2016, approximately 4,000 ft west of the CWFP.

Recent investigations within the CWFP footprint and vicinity include:

- The SFWMD installed 14 groundwater monitor wells and 6 stilling wells within and adjacent to the impoundment during the pilot project (Janzen et al. 2017). **Table 1** provides details for the monitor well stations, CAU-1 through CAU-7. The monitor wells included three standalone shallow wells (approximately 15 to 20 ft bls) and four SAS well clusters, with well depths from 10 to 140 ft bls. Samples were collected for lithologic description using SPT methods, with plastic-lined cores and drill cuttings. Geophysical logs were run at CAU-1LD in the center of the impoundment. In 2014 and 2015, slug tests and/or short-term APTs were performed on the central and northern well clusters within the pilot project area and shallow perimeter wells and are described in detail in the first and second annual reports (Janzen et al. 2015, Janzen 2017).
- Five groundwater monitor wells were installed in February 2018, shortly after completion of the CWFP. The wells included a deep well at CAU-7 (CAU-7LD), south of the CWFP; a well cluster (CAU-8M and CAU-8LD) in the northern-central portion of the CWFP (on the levee between Cells 3 and 4); and a well cluster (CAU-9M and CAU-9LD) approximately 1,600 ft east of the CWFP (**Figure 1**). During well installation, samples were collected for lithologic description using SPT methods, with plastic-lined cores and drill cuttings. Geophysical logs were run on the two deepest wells at each well cluster. Short-term APTs were performed at CAU-8 and M-1236.

Lithologic descriptions of the four monitor wells installed to the lower-deep screen intervals (CAU-1LD, CAU-7LD, CAU-8LD, CAU-9LD) are included in **Appendix A**. Geophysical logs for those wells and for M-1236 are included in **Appendix B**.

Table 1. Well construction details for the monitor wells at the Caulkins Water Farm Project.

Monitor Well	Total Depth (ft bls)	Cased Depth (ft)	Screen Slot (inches)	Screen Length (ft)	Ground Level Elevation	Top of Casing Elevation	Bottom Screen Elevation	Aquifer Depth	Location
CAU-1S	9.5	7.5	0.02	2	27.1	36.2	17.6	Shallow	CWFP Cell 1
CAU-1M	23	13	0.02	10	26.9	36.3	3.7	Middle	CWFP Cell 1
CAU-1D	72	62	0.02	10	27.0	36.2	-44.9	Deep	CWFP Cell 1
CAU-1LD	130	120	0.02	10	26.3	36.1	-103.4	Lower Deep	CWFP Cell 1
CAU-2S	16	14	0.02	2	32.6	32.2	16.3	Shallow	CWFP between Cells 1 and 5
CAU-3S	16	14	0.02	2	28.6	28.4	12.5	Shallow	CWFP south of Cell 1
CAU-4S	16	14	0.02	2	32.3	31.9	15.8	Shallow	West of Cell 1
CAU-5S	16	14	0.02	2	32.8	32.3	16.5	Shallow	CWFP between Cells 1 and 2
CAU-5M	31	21	0.02	10	32.8	32.4	1.9	Middle	CWFP between Cells 1 and 2
CAU-5D	79	69	0.02	10	32.8	32.5	-46.6	Deep	CWFP between Cells 1 and 2
CAU-6M	33	23	0.02	10	40.1	39.7	6.9	Middle	North of C-44 Canal
CAU-6D	79	69	0.02	10	40.1	39.6	-39.2	Deep	North of C-44 Canal
CAU-7M	32	22	0.02	10	35.6	35.3	3.4	Middle	North of C-44 Canal
CAU-7D	80	70	0.02	10	35.6	35.3	-44.2	Deep	North of C-44 Canal
CAU-7LD	140	130	0.02	10	35.2	35.2	-104.8	Lower Deep	North of C-44 Canal
CAU-8M	28	18	0.02	10	32.5	32.3	4.3	Middle	CWFP between Cells 2 and 3
CAU-8LD	136	126	0.02	10	32.5	32.5	-103.5	Lower Deep	CWFP between Cells 2 and 3
CAU-9M	25	15	0.02	10	17.6	17.0	-8.0	Middle	East of Cell 5
CAU-9LD	116	106	0.02	10	17.6	22.3*	-98.7	Lower Deep	East of Cell 5
M-1236	104	94	ND	10	ND	24.9	-79.1	Lower Deep	East of CWFP

bls = below land surface; ft = foot; ND = no data available.
Notes: Elevations are provided in feet National Geodetic Vertical Datum of 1929. Casing for all wells was polyvinyl chloride (PVC).
* Elevation was measured from the top of 2-inch stick-up casing.

4 SITE HYDROGEOLOGY

4.1 Hydrogeologic Framework

The SAS in Martin County is estimated to be approximately 140 to 150 ft thick in the vicinity of the CWFP and composed of a sequence of sand, silt, shell, and limestone. The SAS is unconfined to semi-confined in Martin County and underlain by the confining sediments of the Hawthorn Group. The Martin County SAS groundwater flow model (Adams 1992) and corresponding data report (Lukasiewicz and Adams-Smith 1996) divided the SAS into three hydrogeologic layers (units), each with lateral and vertical variability and discontinuity:

- The uppermost unit (Unit 1) is described as an unconsolidated sand/soil unit with very fine to course-grained quartz sand and interbedded lenses of shell, sandy clay, and silt. The unit has low to moderate permeability and is estimated to be approximately 20 ft thick in the vicinity of the CWFP.

- The bulk of the SAS is composed of Unit 2, also referred to as the production zone within the SAS in Martin and St. Lucie counties. Unit 2 consists of unconsolidated quartz sand and shell beds with thin beds of sandstone and has the highest permeability in the SAS. It interfingers with the less permeable granular limestone of Unit 3.
- Unit 3 is a less permeable, poorly consolidated, granular limestone with sand and calcareous clay. In the vicinity of the CWFP, Unit 3 is shown as the lowermost unit in the SAS and can be interbedded within Unit 2 as shallow as 15 ft bls.

Based on soil boring data gathered for this report, the hydrogeology of the CWFP is consistent with regional hydrogeology described by Adams (1992) and Lukasiewicz and Adams-Smith (1996). Geologic cross-sections A–A' and B–B', showing site lithology, are presented in **Figures 2** and **3**, respectively. Unit 1 was found to consist of predominantly silty sand, with irregular interbeds of clayey sand grading to sandy clay and sandy calcareous clay from the surface to approximately 18 ft bls. Discontinuous clayey sand or sandy clay layers, ranging from 2 to 13 ft in thickness, were observed in each of the SPT soil borings within the footprint of the CWFP. In geophysically logged wells, the clayey sections were indicated by reductions in induction conductivity to below 20 ohm-meters. As shown in **Figure 2**, these intervals appeared thicker and potentially more continuous in soil borings advanced in Cells 3, 4, and 5 relative to Cells 1 (pilot project cell) and 2. Thicknesses of the clayey sand and sandy clay observed typically were 9 to 13 ft in Cells 3, 4, and 5; compared to approximately 7 ft in Cell 1 and 8 ft in Cell 2 (**Figures 2** and **3**).

Two soil borings at CAU-8 in the northern portion of the CWFP (on the levee between Cells 3 and 4) and CAU-9 (approximately 1,600 ft east of the CWFP) found beds of clayey sand grading to sandy clay within Unit 2, from approximately 59 to 81 ft bls at CAU-8 and 64 to 72 ft bls at CAU-9. The clayey sections were indicated by a reduction in induction conductivity to approximately 20 ohm-meters. The consistent depths of these beds suggest they may be continuous across much of the northeastern and eastern portions of the CWFP (**Figure 2**). Up to 6 ft of sandy silt was encountered at a similar depth (60 to 72 ft bls) at CAU-1 in the center of Cell 1; however, this unit did not appear clayey and a reduction in induction conductivity was not observed.

Soil borings within the CWFP encountered shell beds and coquina representative of Unit 3 interbedded within Unit 2 at depths between 15 and 38 ft bls in the northeastern portion of the CWFP. The unit is described as poorly cemented, sandy coquina, with abundant unconsolidated shell fragments. The unit was between 5 and 10 ft thick in soil borings from CAU-8LD, TB-2, TB-3, and TB-5, all within or adjacent to Cell 4. The consistent depths of these beds suggest they may be continuous across much of the northeastern portion of the CWFP. Unit 3 was identified in lithology logs near the base of the SAS in M-1236 and W-12688 southeast of the impoundment.

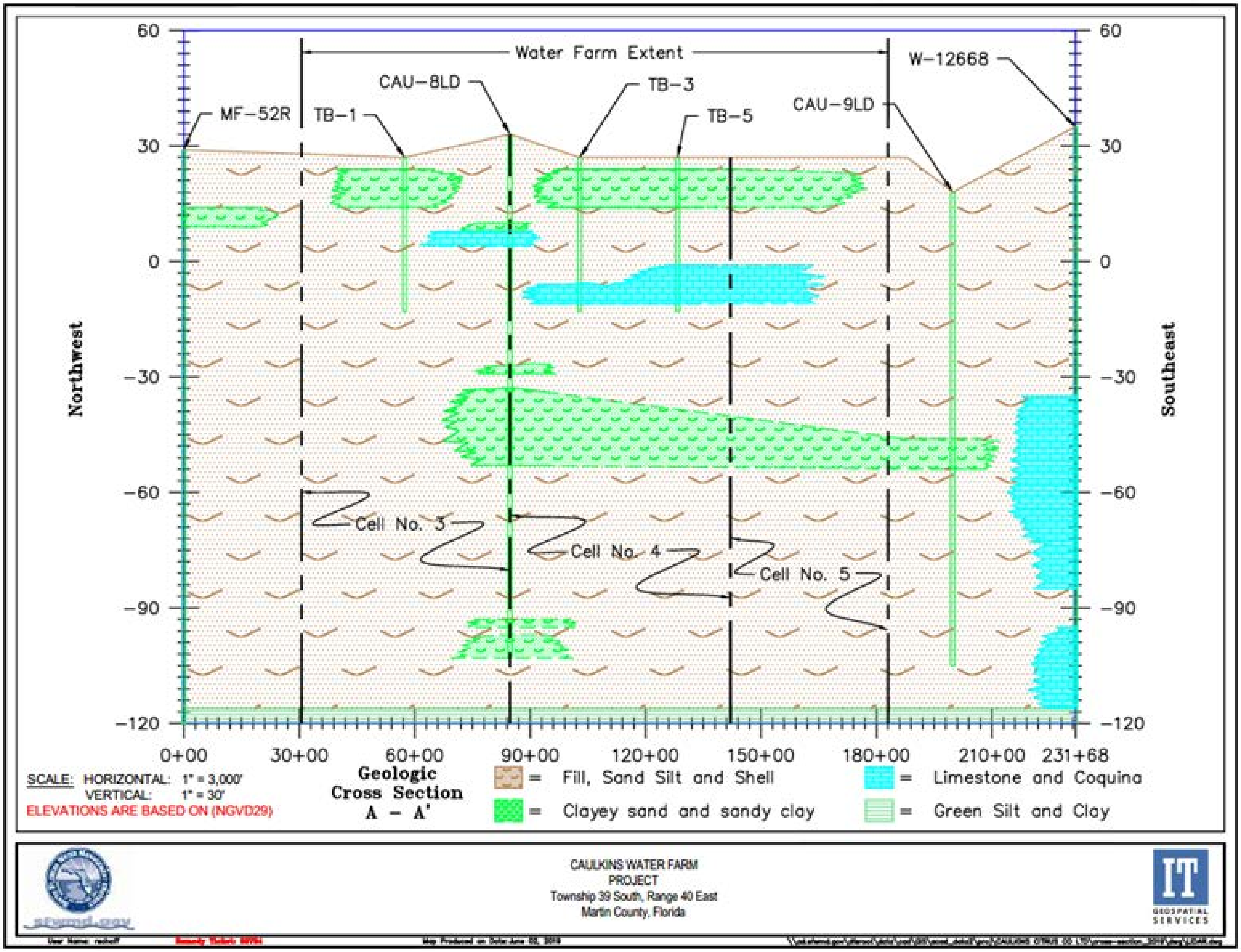

Figure 2. Geologic cross-section A–A'.

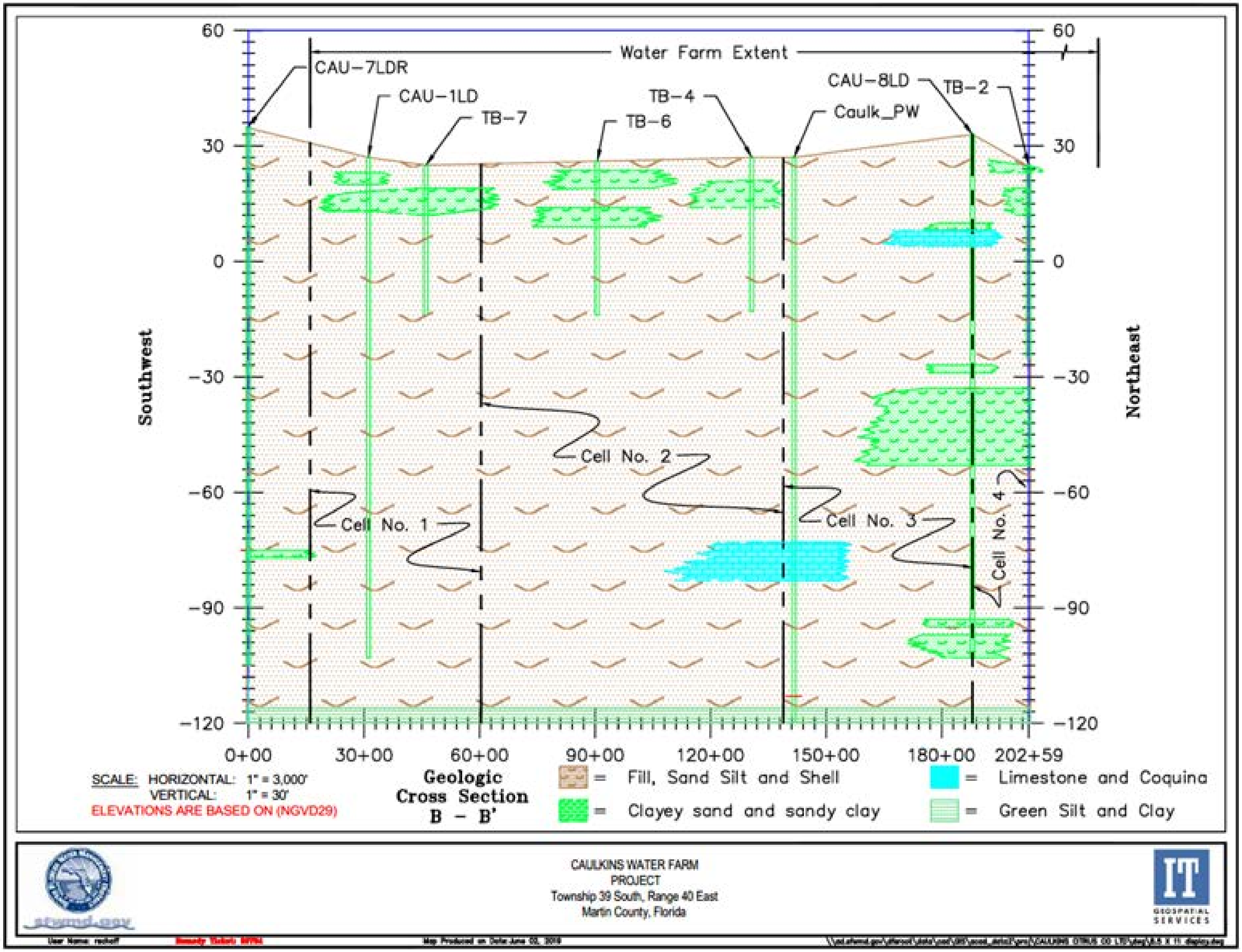

Figure 3. Geologic cross-section B–B'.

4.2 Summary of Hydraulic Testing

The SFWMD conducted 11 slug tests and 8 short-term APTs within the CWFP at the wells installed in 2015 and 2016 (Janzen et al. 2015, 2017) and in 2018 as part of the current investigation. Additionally, published test data were reviewed, including an on-site APT and APTs conducted at the C-44 Reservoir/STA approximately 1 to 6 miles west of the CWFP.

4.2.1 Recent Short-Term Aquifer Performance Tests

The SFWMD conducted two short-term APTs as part of the current investigation to determine the hydraulic characteristics of the SAS underlying the expanded portions of the CWFP. Two locations were chosen to conduct additional APTs: CAU-8LD, in the northern end of the CWFP footprint between Cells 3 and 5; and M-1236, east of the CFWP (**Figure 4**). Construction information for the tested wells is provided in **Table 1**.

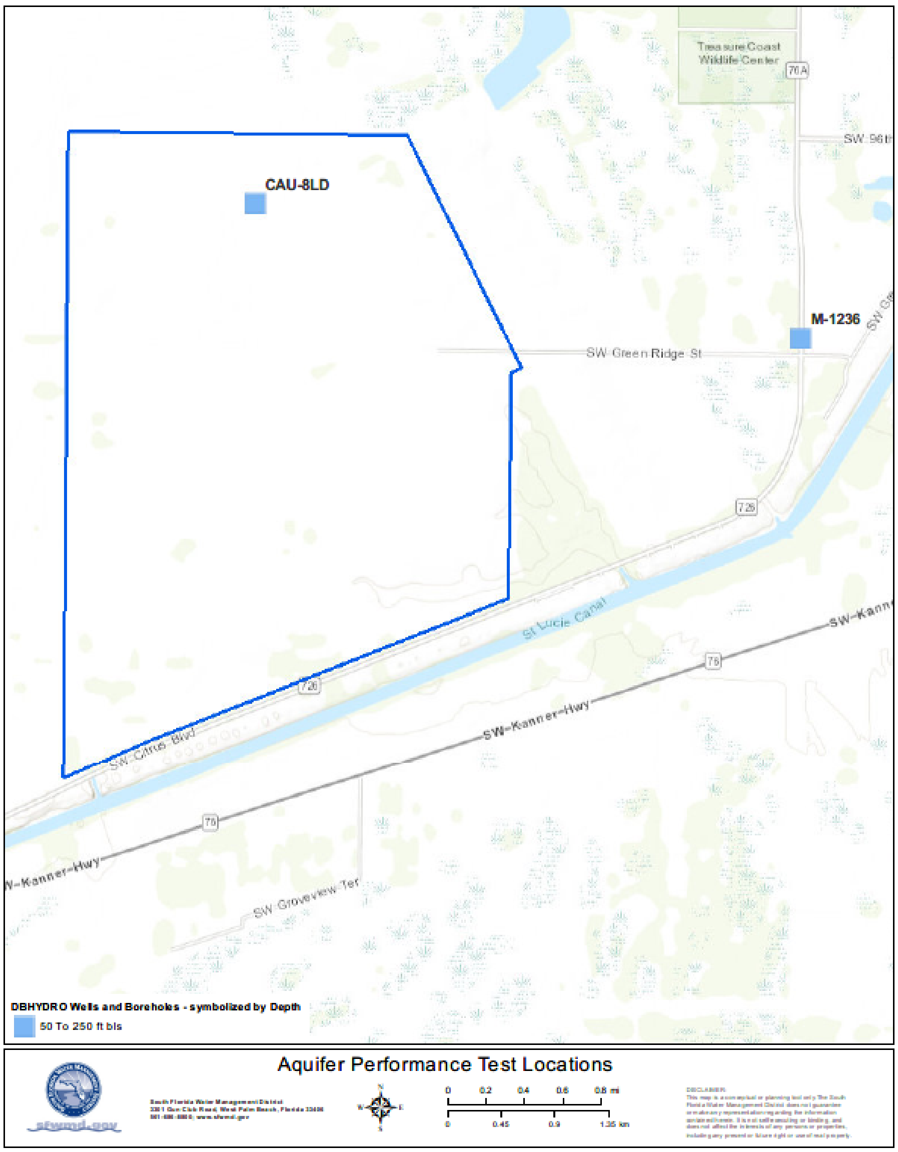

Figure 4. Location of aquifer performance test sites at the Caulkins Water Farm Project site.

Methods

On August 16, 2017, an APT was conducted at M-1236, which is completed in the SAS to a depth of 103 ft bls. A Level Troll® 700 was installed in M-1236 prior to the test in order to record changes in water levels, and the test was configured using Win-situ® (Version 5) software (In-Situ, Inc. 2012). A pumping rate of 6 gpm was initiated, and there was a temporary drop in pumping rate shortly after commencement of the pumping phase. After approximately 1 hour, pumping ceased, and water level data were recorded for an additional 12 minutes. M-1236 groundwater levels returned to background levels during this time. The maximum drawdown observed was 8.29 ft.

Following construction of CAU-8LD, an APT was performed on April 4, 2018. In addition to instrumentation and configuration as described above, a Level Troll® 700 was deployed in CAU-8M as an observation well for the APT. Both wells are completed in the SAS. No changes in water levels were recorded in CAU-8M during the test. CAU-8LD was pumped at a rate of 0.25 gpm, and a maximum drawdown of 34.43 ft was observed approximately 36 minutes into the test. At that time, the well had pumped dry and recovery was initiated. CAU-8LD was left overnight to allow enough time for groundwater levels to return to background conditions.

The results were graphed in Excel and the data sets imported into AQTESOLOV Pro (Version 4.5) software (HydroSOLVE, Inc. 2007) for analysis. The APTs were analyzed using an assumed hydraulic conductivity (K) anisotropy ratio of 0.03. This value is consistent with the previous CAU-1LD analysis (Janzen et al. 2015) and is based on averages of similar field testing (USACE 2014) at the C-44 Reservoir/STA west of the CWFP. Displacement versus time was plotted for each test with associated derivatives. Due to noise in the derivative, the Boudet et al. (1989) curve-smoothing method was applied to each plot. This produces better diagnostic plots that, in turn, assist in determining the best analytical solutions to apply.

Results

Figure 5 shows the drawdown and recovery at M-1236 for the duration of the test. The temporary drop in pumping rate is evident approximately 300 to 600 seconds into the test. Because the initial APT at CAU-8LD did not allow sufficient time for recovery, the test was repeated on April 4, 2018. These results were used for analysis of this well. **Figure 6** shows the drawdown and recovery for the CAU-8LD repeat test. Pumping ceased and recovery was initiated 2,172 seconds into the test, as the well had run dry, and left overnight to return to background conditions.

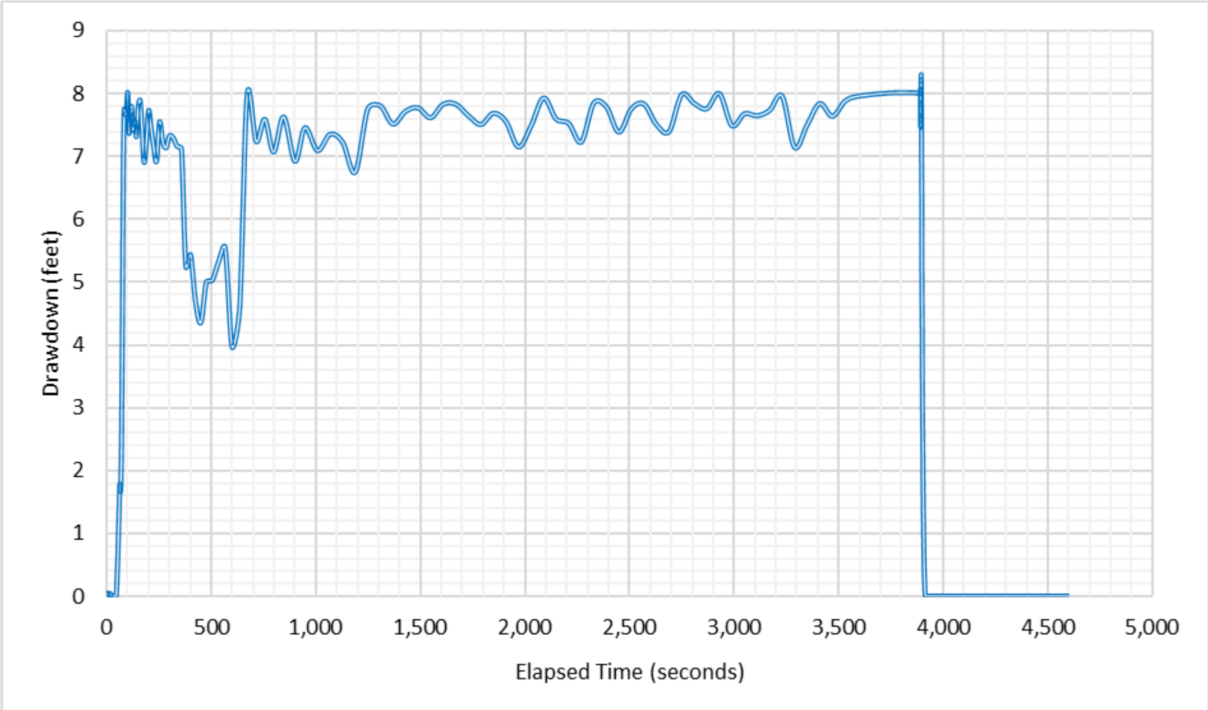

Figure 5. Drawdown and recovery graph of the M-1236 test.

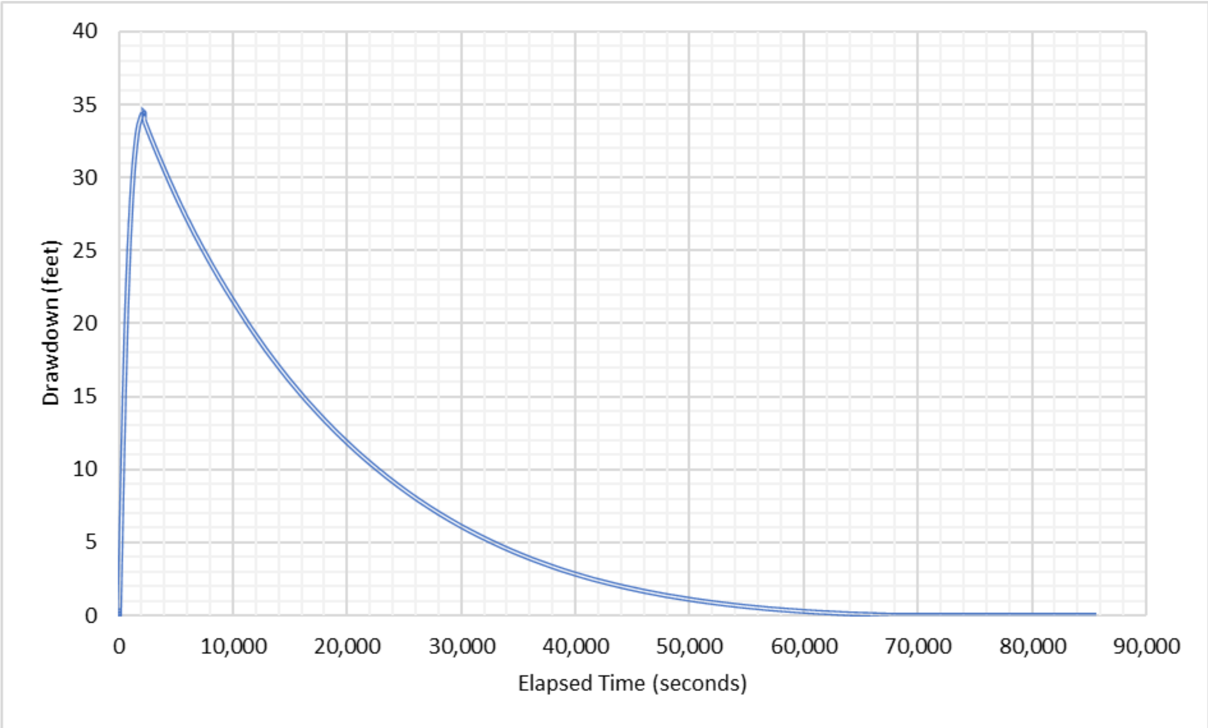

Figure 6. Drawdown and recovery graph of the CAU-8LD repeat test.

Analysis

Displacement versus time and the derivatives for the M-1236 and CAU-8LD APTs are shown in **Figure 7**. The shape of the M-1236 displacement versus time curve is consistent with that of an unconfined aquifer (Renard et al. 2009). Several analytical solutions were applied to the test data, including Theis (1935), Cooper and Jacob (1946), Neuman (1974), Moench (1997), and Tartakovsky and Neuman (2007). While no solution fit the data well for M-1236, Moench (1997) was selected as the best fit available. **Figure 8** shows the calculated aquifer parameters using this solution.

The CAU-8LD well had more than 30 ft of drawdown and took several hours to return to background conditions. Given the lower K of the sediments in this well, several analytical solutions for unconfined, leaky confined, and confined aquifers were applied to the test data, including Theis (1935), Cooper and Jacob (1946), Hantush (1960), Cooley and Case (1973), Neuman (1974), Moench (1997), and Tartakovsky and Neuman (2007). None of the solutions gave a fair fit for the data in drawdown or recovery. No solutions fit the data satisfactorily, so the recovery data were analyzed as a slug test using the Hvorslev (1951) and Bouwer and Rice (1976) solutions. There was very little difference in calculated parameters, so the Hvorslev (1951) results are reported for consistency with previous publications. **Figure 9** shows the result of this analysis and the calculated aquifer parameters.

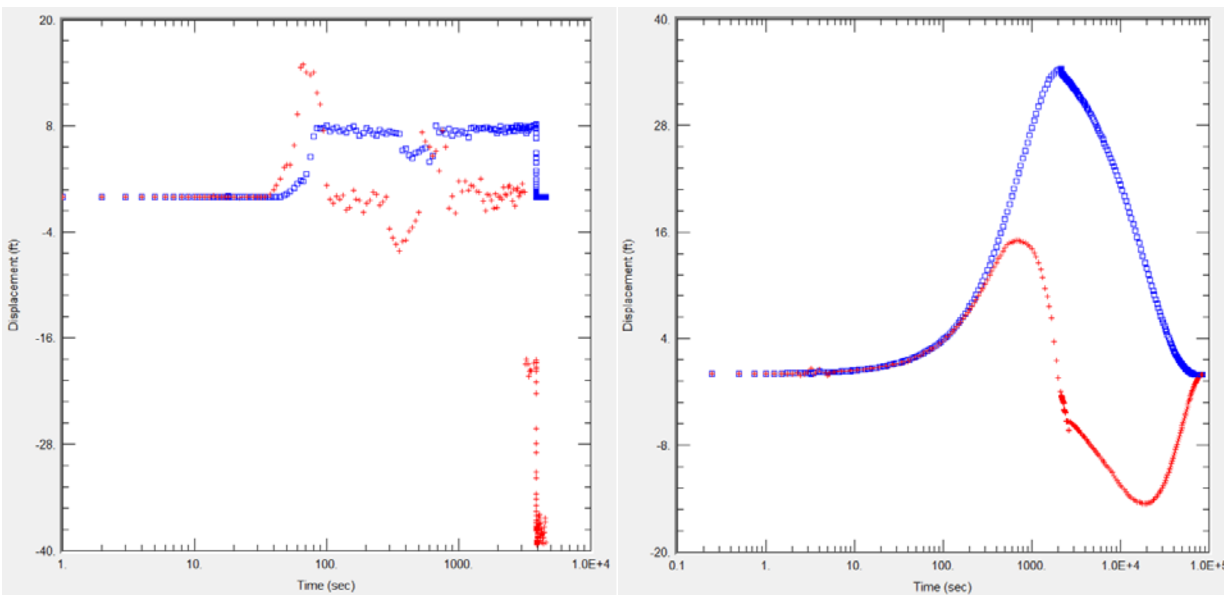

Figure 7. Displacement (blue) versus time with derivative (red) for M-1236 (left) and CAU-8LD repeat test (right).

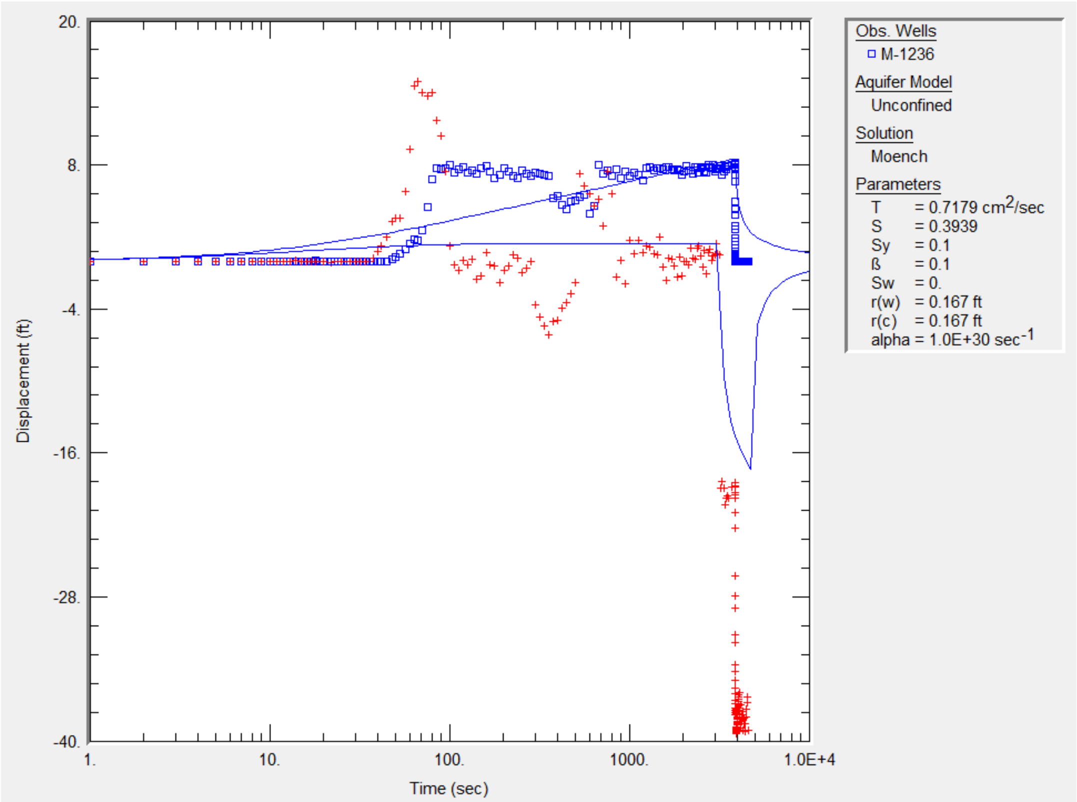

Figure 8. Analysis of M-1236 test data using the Moench (1997) solution.

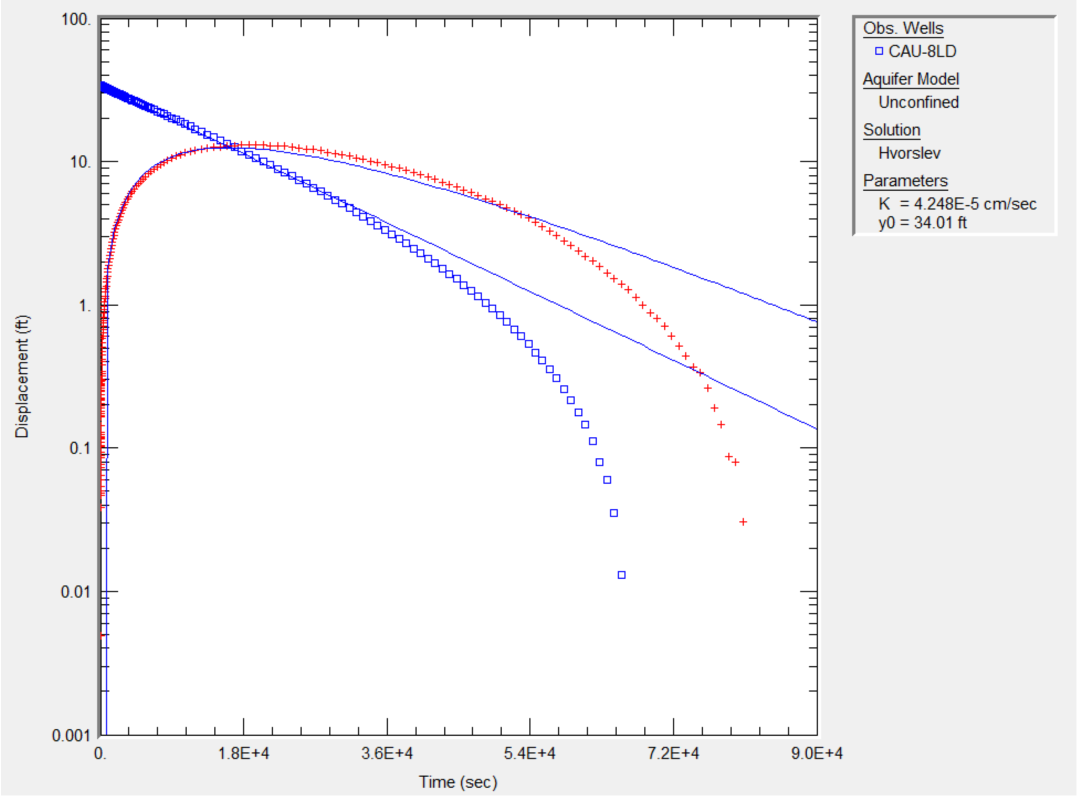

Figure 9. Analysis of CAU-8LD repeat test data using the Hvorslev (1951) solution.

Discussion

Based on the aquifer test analysis, the K of the sediments in M-1236 is in the middle of the range for silty sands and fine sands (10^{-5} to 10^{-3} centimeters per second [cm/s]) at 2×10^{-4} cm/s (0.5 ft/day), as described by Fetter (2001). The screened interval at M-1236 consisted of shell beds and poorly indurated limestone, and most likely is representative of Unit 3. However, the low Kh result is inconsistent with lithology, and M-1236 is an older well and the condition of the well screen is unknown. Therefore, the results from M-1236 are not considered reliable and are not included in the hydrologic summary. CAU-8LD had a lengthier recovery interval and the K of this well is in the range for silt, sandy silts, and clayey sands (10^{-6} to 10^{-4} cm/s) at 4×10^{-5} cm/s (0.1 ft/day) as described by Fetter (2001). Based on lithology, the screened interval at CAU-8LD intercepts a clayey sand and is not considered representative of Unit 2; therefore, it is not included in this summary.

4.2.2 Previous Slug Tests

SFWMD staff conducted 11 slug tests on 5 newly installed wells within the Caulkins pilot project in 2014 and 2015. Four of the tests were in Unit 1 and seven were in Unit 2. Average Kh was 77 ft/day for Unit 1 and 23 ft/day for Unit 2. Slug tests provide reasonable order-of-magnitude estimates for K values (Thompson, 1987).

4.2.3 Previous Aquifer Performance Tests

The following published K values were reviewed:

- Six short-term APTs were conducted in 2014 and 2015 and are described further in Janzen et al. (2015, 2017). Those tests included two APTs at CAU-1S, screened in Unit 1, and four APTs at CAU-1M, CAU-1D, or CAU-1LD, screened within Unit 2. Average Kh was 8 ft/day for Unit 1 and 4 ft/day for Unit 2.
- The USACE (2014) conducted two APTs in the footprint of the planned C-44 Reservoir/STA. The wells, W-101 and W-102, were approximately 1 and 6 miles west of the CWFP, respectively. The wells were installed to a depth of approximately 135 ft bls, and each test included a pumping well and an observation well. The tests were run for a minimum of 24 hours. Based on lithologic descriptions, the test wells were screened within Unit 2. The tests yielded horizontal hydraulic conductivity (Kh) results of 28 and 20 ft/day and vertical hydraulic conductivity (Kv) of 0.35 and 1 ft/day, respectively. The USACE also conducted laboratory tests on the shallow sand layer (Unit 1) and derived an average Kv of 0.10 ft/day.
- The SFWMD conducted an APT in the footprint of Cell 3 as part of data acquisition for the Martin County SAS groundwater flow model (Lukasiewicz and Adams-Smith 1996). The pumped well was screened from 30 to 110 ft bls, within Unit 2. The test was run for 19 hours and included one observation well. The test yielded a Kh of 51 ft/day.

4.2.4 Summary of Hydraulic Conductivity Test Results

Average Kh for Unit 1, the upper clayey unit, ranged from 77 ft/day in slug tests to 8 ft/day in short-term APTs. Due to the high variability of clay content in the upper unit, this range of values is considered reasonable. Average Kh for Unit 2, the production unit, were 23 ft/day in slug tests, 12 ft/day in short-term APTs, and 33 ft/day in 24-hour APTs. The 24-hour APTs included longer screened intervals and a paired monitor well and are considered a more reliable testing method. Results for Kh are summarized in **Table 2**.

Table 2. Average horizontal hydraulic conductivity (Kh) derived from aquifer performance tests at the Caulkins Water Farm Project and C-44 Reservoir/Stormwater Treatment Area.

Local Hydrogeologic Unit	Slug Test Average Results – (Number of Tests)	Short-Term Aquifer Test Average Results – (Number of Tests)	C-44 Aquifer Test Average Results – (Number of Tests)	Caulk_APT Aquifer Test Results / (Number of Tests)
Unit 1	77 – (2)	8 – (2)	N/A	N/A
Unit 2	23 – (7)	12 – (4)	24 – (2)	51/1
Unit 3	N/A	N/A	N/A	N/A

All values are presented in feet per day.
N/A = not applicable, no tests were run.

4.3 Groundwater Flow and Seepage

Based on relative water levels during operation of the pilot project (Cell 1), surface water from the impoundment flowed downward into deeper portions of the SAS and outward into perimeter canals. The hydraulic gradient between the shallow and intermediate wells, compared to intermediate to deep and deep to lower-deep wells, suggests semi-confinement in Unit 1 consistent with the clay constituents observed. Downward gradients from the shallow to deep wells (CAU-1) suggest predominantly downward flow, at least to the screened interval of the deep well at approximately 72 ft bls. The lowest gradient was between the deep and lower-deep wells (screened approximately 135 ft bls), likely due to a change in flow direction from vertical to horizontal towards the C-44 Canal to the south. The underlying Hawthorn Group, a confining unit, acts as the lower boundary for vertical flow.

During the pilot project, a seepage rate of 0.092 ft/day was observed (Janzen et al. 2017). During the 2018 operational period of the expanded CWFP, a much lower seepage rate of 0.022 ft/day was observed, not including effects of ET and rain, which largely cancel each other out (B. Gunsalus, pers. comm.). To evaluate seepage from individual cells, flow between cells was restricted via gated culverts from November 20, 2018 through January 31, 2019. During this period, seepage from Cell 1 was approximately 0.05 ft/day, compared to seepages from Cells 2, 3, and 5 of 0.01, 0.01, and 0.02 ft/day, respectively, roughly 20 to 40 percent of Cell 1. Measurements for Cell 4 were not provided. Subsurface lithology indicates spatial discontinuity of low-permeability units within the SAS, with less permeable sediments inferred in Cells 3, 4, and 5, representing most of the northern and eastern portions of the CWFP.

5 SUMMARY

The CWFP encompasses a 3,014-acre surface water impoundment adjacent to the C-44 Canal (St. Lucie River) in southern Martin County, Florida. The impoundment includes five cells, separated by earthen berms, that range from approximately 414 to 798 acres in area. Approximately 20,192 ac-ft of water was pumped into the impoundment during the operational period of December 8, 2017 through November 2, 2018. Prior to construction of the CWFP, a pilot project comprising a 414-acre surface water impoundment in the southwestern portion of the existing CWFP (Cell 1) was operational from February 2014 through October 2016. Since 2014, a total of 19 groundwater monitor wells and 6 surface water stations have been installed within and adjacent to the CWFP to assess lithology and facilitate continuous water level monitoring and water quality sampling. Additional data sources reviewed for this report included lithologic logs and APT data obtained prior to construction of the CWFP.

Site hydrogeology was found to be consistent with that described in the Martin County SAS groundwater flow model and data report (Adams 1992, Lukasiewicz and Adams-Smith 1996). Regionally, the SAS is unconfined to semi-confined and composed of three hydrogeologic units: the shallow, unconsolidated sand/soil unit (Unit 1); more permeable sandy shell with interbedded sandstone, which together compose the production unit (Unit 2); and the less permeable granular limestone (Unit 3), which inter-fingers with and underlies the production unit.

Within the CWFP footprint, the uppermost unit (Unit 1) was found to consist of predominantly silty sand with irregular interbeds of clayey sand grading to sandy clay and sandy, calcareous clay from the surface to approximately 18 ft bls. Discontinuous clayey sand or sandy clay layers ranging from 2 to 12 ft in thickness were observed in each of the soil borings within the CWFP footprint at various depths. Average Kh values from slug tests (77 ft/day) and short-term APTs (8 ft/day) were estimated at the CWFP. Laboratory test data at the C-44 Reservoir/STA to the west indicated an average Kv of 0.10 ft/day. Unit 2 composes the bulk of the SAS. At the CWFP, Unit 2 consists of predominantly poorly graded quartz sand, silty sand, shell, and a few interbeds of sandstone less than 2 ft thick. Locally interbedded units of clayey sand grading to sandy clay, and coquina (Unit 3), were found within Unit 2. Twenty-four-hour, multi-well APTs within the CWFP and the C-44 Reservoir/STA to the west indicated a range of Kh from 20 to 51 ft/day, and a range of Kv from 0.35 to 1 ft/day. Unit 3 is a less permeable, poorly consolidated granular limestone and coquina with sand, shell and calcareous clay that occurs at the base of the SAS and also interbedded at relatively shallow depths within Unit 2.

Site hydrogeology is spatially variable, with lower-permeability sediments inferred in the eastern half (Cells 4 and 5) and in the northwestern cell (Cell 3), relative to the pilot project cell (Cell 1). Low-permeability sediments include thicker and potentially more continuous clayey sediments in the shallow sand layer, a poorly consolidated coquina from approximately 15 to 38 ft bls, and clayey sand grading to sandy clay from approximately 59 to 81 ft bls. Well control in Cell 2 was not deep enough to evaluate below approximately 40 ft bls. The lower permeability sediments in Cells 3, 4, and 5 may be responsible for the lower seepage observed in the operational period for the expanded CWFP (approximately 0.022 ft/day, including ET) compared to approximately 0.051 ft/day during the pilot project operational period (Cell 1), excluding ET and rain, which were observed to largely cancel out during the pilot project operational period. During a short test period in January 2019, cells were isolated and seepage from Cells 3, 4, and 5 was approximately 20 to 40 percent of the seepage observed from Cell 1, consistent with the low-permeability sediments observed beneath the cells.

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APPENDIX A: LITHOLOGIC DESCRIPTIONS

Date: 2/5/15	Page 1 of 4	Mud Weights and Viscosity			Drilling Parameters		
		Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Well Name	CAU-ILD						
Contractor/Driller	GFA/Brian McCormack						
Site Geologist	J. Janzen						
Starting Depth	0						
Ending Depth	130						

Drilling Notes: bit size/fluid additives/mud type, etc.

Continuous split spoon with liner to 130' bls. Rotary drilling with 3" bit every 2nd split spoon (every 4 feet).

	Time	Depth (5 ft int.)	Blow count ~~Sampling Time~~	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
2/5/15		0-2	1/2/2/5	Soil, dk gy to yellow orange, 60% organics & 40% fine qtz sd, dry
		2-4	4/3/2/3	Poorly graded Sand (SP) yellowish orange, v. fine qtz sand, 5% phosphate, non-calc. - moist
	☆	4-6	4/3/6/8	Sandy Lean Clay (CL) lt brn to brn, w very fine qtz sd, moist, medium plasticity, non-calc.
		6-8	9/12/11/10	Silty Sand (SM) lt gy brn-brn, v. fine qtz sd, 40% fines, non-coh, non-calc, moist
	☆	8-10	9/9/8/9	8-9 - a/a 9-10 - calcareous clay, lt gy, 40% fine qtz, 10% LS fragments, Low Plastic
2/6/15		10-12	6/7/5/6	calcareous clay, pale orange brown, 30% fine qtz sd, mod plasticity, wet
		12-14	5/2/3/3	a/a
	☆	14-16	3/4/6/6	Silty Sd (SM) - pale orange brn, 30% fines, 5% phosphate, 5% shell, non-coh, calcareous
		16-18	3/4/4/3	a/a
	☆	18-20	2/3/2/3	Silty Sand (SM) grey, 10% phosphate, 10% shell, calc. v. fine qtz sd, ?
		20-22	1/2/3/5	a/a
		22-24	2/9/11/10	Poorly Graded Sd, gy brn, v.f. qtz sd, 20% f-med shell, 10% fines, 10% phosphate, calc.
		24-26	7/13/16/14	a/a w 30% f-med. shell
		26-28	16/18/26/29	Poorly graded sd (SP), lt gy brn, non-coh., calcareous, 70% fine qtz sd, 20% fine to med shell sd, 5% fines, 5% phosphate
		28-30	15/18/23/27	a/a
		30-32	17/18/30/38	Silty Sand (SM), lt gy brn, fine to coarse shell 50%, fine qtz sd, 30%, 15% fines, 5% phosphate, non-coh, calc.
		32-34	18/20/10/16	Poorly graded Sd (SP), lt gy, non-coh., 50% med. grained shell, 30% fine qtz sd, 15% fines, 5% phosphate, calc.
		34-36	21/26/30/30	a/a

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	
	☆ - litho change									

Date: 2/6/15	Page 2 of 4	Mud Weights and Viscosity			Drilling Parameters		
		Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Well Name	CAU-ILD						
Contractor/Driller	GFA - Brian						
Site Geologist	J. Janzen						
Starting Depth	0						
Ending Depth	130						

Drilling Notes: bit size/fluid additives/mud type, etc.

a/a

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
	36-38	13/30/30/31	Poorly graded Sd (SP) lt gy brn, non-coh, calc, 50% fine to med shell, 30% fine qtz sd, <5% fines, 5% phosphate
	38-40	18/23/24/23	Silty Sand (SM), lt gy brn, v. fine qtz sd, 15% fines, 5% fine shell, 5% phosphate, calc, non-coh.
	40-42	6/9/16/23	a/a
	42-44	16/23/24/19	a/a
	44-46	5/12/19/27	a/a
	46-48	17/23/19/17	Silty Sand (SM) gy green, very fine qtz sd, 15% fines, 10% fine shell, 5% phosphate, calcareous, non-coh.
	48-50	4/17/10/21	Silty Sd (SM) gy green, very fine qtz sd, 30% fines, calcareous 5% phosphate, non-C.
	50-52	7/7/8/9	Sandy Silt ( ) gy green, 40% v. fine qtz sd, 5% phosphate
	52-54	6/7/13/12	a/a
	54-56	7/11/12/6	Silty Sand (SM), gy green, 40% v. fine qtz sd, 35% very fine to coarse shell fragments, 40% fines, 5% phosphate, calcareous
	56-58	6/8/9/11	Silty Sand (SM) gy green, fine qtz sd, 5% fine to coarse shell fragments, 40% fines, 5% phosphate, calcareous
	58-60	8/8/10/8	Sandy Silt gy gn, 40% v fine qtz sand, trace shell fragments 5% phosphate - calcareous
	60-62	2/5/7/7	Sandy Silt a/a - with 10% limestone - gy gn, very sandy (qtz) with 20% shell fragments
	62-64	1/1/2/2	Silty Sand (SM) - gy green, v. fine qtz sd, 20% cylindrical shells ?, 40% silt, 5% phosphate, calcareous.
	64-66		Missed This Interval (overdrilled)
	66-68	6/12/14/17	Poorly graded Sd (SP) - gy gn, very fine qtz sd, 10% fine shell fragments, calcareous, non-C
	68-70	2/3/7/4	Silty Sd (SM) v. fine qtz sd, 10% fine shell, 15% fines 5% phosphate, gy gn, calcareous, - non-C
	70-72	5/2/3/3	Silty Sand (SM), 40% v. f to med. shell, 25% f. qtz sd, 30% fines, 5% coarse shell, calcareous phosphate

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

Date: 2/6/15	Page 3 of 4
Well Name	CAU-ILD
Contractor/Driller	GFA - Brian
Site Geologist	J. Janzen
Starting Depth	0
Ending Depth	130

Mud Weights and Viscosity

Time	Weight (lbs/gal)	Viscosity (sec/qt)

Drilling Parameters

Time	Wt on Bit (1,000 lbs)	Discharge (gpm)

Drilling Notes: bit size/fluid additives/mud type, etc.

o/a

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
	72-74	12/10/9/12	Silty sd (SM) 60% fine-med shell, 20% fine qtz sd, 15% fines, 5% phosp, gygn, calc.
	74-76	9/11/10/11	o/a
	76-78	0/4/9/10	Silty sd (SM) - gygn to pale brn, 70% fine to med shell, 20% fine qtz sd, 5% gravel sized shell, 5% phosphate, calcareous
	78-80	10/11/15/14	o/a with 50% fine qtz sd.
	80-82	11/12/11/14	o/a
	82-84	11/10/8/10	Silty sd w Gravel (SM), gy green, fine sand to gravel sized shell, 10% fine qtz sd, 15% fines, 5% phosphate, calc.
★	84-86	11/12/15/18	o/a with 20% coquina - shell + qtz sd o/a
	86-88	26/26/23/24	Silty Sand - fine to med shell + fine qtz sd (50/50), >15% fines, gygreen 10% phosphate, calc,
	88-90	14/15/15/11	o/a
	90-92	0/8/10/11	Poorly Graded sd (SP) - gygn, fine shell + qtz sand (70/30); <5% fines, calc.
	92-94	8/0/7/6	o/a w. fine to med. shell sd, 10% phosphate
	94-96	7/9/9/7	o/a w 5% phosphate
	96-98	2/5/5/5	Silty sd (SM) gygn, fine-med shell sd, 20% fine qtz, 5% phospho calc.
	98-100	5/6/4/5	Poorly graded sd (SP) - pale brn to gygn, vf to f shell + sd, 5% med to coarse shell, 5% phosphate, <5% fines, calc.
	100-102	8/8/8/8	Silty sd (SM) - pale brn to gygn, f to coarse shell sd, 20% fine qtz sd, >15% fines, 5% phosphate, calc
	102-104	8/16/21/15	o/a with fine shell + qtz sd (50/50)
	104-106	7/9/9/7	o/a
	106-108	9/4/10/8	Silty sd (SM) - greenish gy, fine to medium shell sd and qtz sd (70/30) 15% phosphate, calc, 15% fines

2/6/15

2/9/15

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

Date: 2/9/15	Page 4 of 4
Well Name	CAU-16D
Contractor/Driller	GPA-Brian
Site Geologist	J. Janzen
Starting Depth	0
Ending Depth	130

Mud Weights and Viscosity

Time	Weight (lbs/gal)	Viscosity (sec/qt)

Drilling Parameters

Time	Wt on Bit (1,000 lbs)	Discharge (gpm)

Drilling Notes: bit size/fluid additives/mud type, etc.

o/a

Time	Depth (5 ft int.)	~~Sampling Time~~ Blowcounts	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
	108-110	4/5/5/5	Silty Sd (SM) greenish gy, f-med shell + qtz sd (70/30), 15% phosphate, calc. 15% fines
	110-112	5/7/5/5	o/a with 30% fines
	112-114	4/5/7/8	o/a
	114-116	6/8/7/9	Silty Sand (SM) greenish gy, fine to med shell sd, 25% fines, 10% phosphate calcareous
	116-118	5/6/7/6	o/a
	118-120	7/9/7/5	Silty Sand (SM) - greenish gy, fine to coarse shell sd, 10% fine qtz sd, ~15% fines, 10% phosphate, calcareous,
	120-122	3/4/3/3	o/a
	122-124	5/6/7/9	Silty Sd (SM) - greenish gy, fine to med. shell sd, 10% fine qtz sd, 10% phosphate, ~15% fines, calc
	124-126	8/9/8/8	o/a
	126-128	8/7/8/9	Silty Sd (SM) ~~gy green~~ greenish gy, fine shell sd, ~15% fines, 5% phosphate, calcareous
	128-130	9/7/7/7	Silty Sd (SM) greenish gy, fine to med shell, ~15% fines, 5% phosphate, calc.

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

SFWMD Daily Drilling Form

Date: 2/15/18 2/16/18	Page 1 of 2
Well Name	CAU-7LD
Contractor/Driller	Drill pro Jerrod
Site Geologist	J. Janzen
Starting Depth	80'
Ending Depth	140'

Mud Weights and Viscosity			Drilling Parameters		
Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)

Drilling Notes: bit size/fluid additives/mud type, etc.

2" split spoon followed by reaming with 4" bit.
split spoon 2 to 6 feet before reaming.

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
17/10/23/28	80-82	/	Sandstone - medium lt gy, v.f. to fine qtz sd + shell, calcareous cement, soft to mod Ind, <5% phosphate
13/26/22/40	82-84	/	Poorly Graded Sand, lt gy, v.f. to fine qtz sd + shell, <5% phosphate, with SS a/a
21/42/37/33	84-86	/	Poorly graded Sand lt gy, v.f. to fine qtz sand w shell <5% phosphate
20/20/17/17	86-88	/	a/a with Sandstone, vf to fine, rare qtz + shell calcareous.
17/25/34/23	88-90	/	Sandstone medium lt gy, vf to fine qtz sd + shell, calcareous, mod Ind, <5% phosphate, with poorly graded Sand
14/24/20/18	90-92	/	Poorly graded Sand - lt gy, vf to fine qtz + shell sand, <5% phosphate, calc cement, with some Sandstone a/a
16/10/15/13	92-94	/	a/a with gravel sized shell fragments
0/9/9/12	94-96	/	Silty Sand with Gravel - v fine to fine qtz + shell sand with gravel sized shell fragments.
13/15/20/18	96-98	/	a/a
10/20/23/21	98-100	/	Poorly ~~well~~ graded Sand - medium gy, ~~fine to coarse qtz + shell sand~~, v-fine to fine qtz sd, fine to coarse shell sd. <5% phosphate
0/6/6/10	100-102		a/a
21/20/30/17	102-104		a/a
17/13/9/9	104-106		a/a
13/16/9/6	106-108		a/a
16/11/7/6	108-110		Silty Sd, yellowish gy, vf to fine qtz + shell sand, calcareous, <5% phosphate
5/6/7/6	110-112		Clayey Sand, yellowish gy v-fine to f qtz sand + shell, calcareous clay, <5% phosphate
11/16/15/16	112-114	/	Silty Sand with gravel, yellowish gy, v fine to med. qtz + shell sand, some gravel sized shell fragments, <5% phosphate
16/21/21/20	114-116		Poorly graded Sand - medium gy, fine to qtz sd w fine to coarse shell fragments, <5% phosphate.

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

SFWMD Daily Drilling Form

Date: 2/16/10	Page 2 of 2	Mud Weights and Viscosity			Drilling Parameters		
Well Name	CAU-7LD	Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Contractor/Driller	Drillpro - Jerrod						
Site Geologist	J. Janzen						
Starting Depth	0						
Ending Depth	140						

Drilling Notes: bit size/fluid additives/mud type, etc.

see 1st page

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
14/22/25/30	116-118		Poorly graded sand w Gravel - lt olive gy, vf to fine qtz sd and fine to coarse sd shell fragments + gravel sized shell fragments
21/24/22/15	118-120	/	Poorly graded sand - lt olive gy, vf to f. qtz sd w/ fine to coarse shell sand, <5 % phosphate
15/12/15/13	120-122		Poorly graded sd w gravel - lt gy, vf to fine qtz sand and fine + gravel sized shell fragments, <5% phosphate
14/15/25/24	122-124		Silty sand with gravel lt olive gy, vf to fine qtz sand, fine to gravel ~~coarse~~ shell fragments, <5% phosphate
16/23/21/26	124-126	/	Poorly graded sd w gravel, lt gy, vfine to f. qtz sd + fine to gravel shell, <5% phosphate
26/21/24/24	126-128		Silty sd, lt gy, vfine to fine qtz sd + fine to coarse shell fragments, <5% phosphate
13/31/22/16	128-130		Coquina - fine to coarse shell fragments + qtz sand, calcareous
6/8/11/27	130-132		Silty sd - lt olive gy, vf to f qtz sd w f. to coarse shell fragments, <5% phosphate
21/12/10/10	132-134	/	Poorly Graded sd - lt gy, vf to fine qtz sd + f to ~~med~~ coarse shell, <5% phosphate
13/13/16/21	134-136	/	a/a
15/16/19/16	136-138	/	a/a
12/13/16/12	138-140		Poorly Silty Sand lt olive gy, vf to fine qtz sd + fine to med shell frag, <5 % phosphate

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (μS/cm)	Temp. (deg C)	

SFWMD Daily Drilling Form

Date: 2/5/18	Page 1 of 4
Well Name	CAU-BL10
Contractor/Driller	Drill Pro - Jerred
Site Geologist	J. Janzen
Starting Depth	0
Ending Depth	136

Mud Weights and Viscosity			Drilling Parameters		
Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)

Drilling Notes: bit size/fluid additives/mud type, etc.

4" - Pilot hole with mud rotary, split spoon 1st then ream
Samples collected in 2" SPT with acrylic liner.
(R) = refusal
samples described later after sleeves cut.

~~Time~~ Blowcounts	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
	0-2		Hand Auger - no sample
7/13/10/9	2-4		Poorly graded sand w silt, very fine to fine qtz sand; brownish black - levee fill
13/14/14/10	4-6		as above
4/4/7/10	6-8		Silty sand brownish black, v. fine to fine qtz sand
7/13/14/21	8-10		a/a
6/14/12/12	10-12		a/a
13/19/20/16	12-14		~~Silt~~ Silty sand - brownish grey, fine to med qtz sand
17/20/19/21	14-16		No Sample
14/13/11/8	16-18		Silty sand - brownish grey, fine to med qtz sand
8/6/6/5	18-20		a/a
1/1/1/4	20-22		~~Poorly Graded~~ Clayey silt ~~w clay~~, fine to med qtz sand
29/+50 (R)	22-24		Coquina and shell beds - olive grey, coarse to gravel sized shell fragments
+5 (R)	24-26		a/a
29/39/+50 (R)	26-28		mostly poorly graded sand - medium grey, fine to med qtz sand and coarse shell fragments, some coquina, some phosphate
20/43/50 (R)	28-30		a/a - lt grey.
9/24/29/4	30-32		mostly poorly graded sand, medium gy, fine to med qtz sand, and coarse shell fragments, some 5% phosphate
9/25/32/34	32-34		Poorly graded sand, medium gy, very fine to fine qtz sd, some phosphate
20/50+ (R)	34-36		a/a

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

SFWMD Daily Drilling Form

Date: 2/5/18 10/6/18	Page 2 of 4	Mud Weights and Viscosity			Drilling Parameters		
		Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Well Name	CAU-8LD						
Contractor/Driller	Drill Pro - Tassel						
Site Geologist	T. Janzen						
Starting Depth	0						
Ending Depth	136						

Drilling Notes: bit size/fluid additives/mud type, etc.

see previous sheet

Reamed 4" hole every 4', every other split spoon.

Blow Counts Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
29/10/21/21	36-38		Shell fragments, yellowish gray coarse sand to Gravel, some (5%) qtz sand, no phosphate
1/15/17/20	38-40		Poorly graded sand, fine to v.f. qtz, some phosphate, yellowish gy
7/12/13/6	40-42		calcareous ss, medium lt gy, very fine sand w shell fragments
2/16/20/41	42-44		Silty Sand, yellowish gy, with very fine to fine qtz sd, <5% phosphate
14/12/26/24	44-46	/	Silty Sand, greenish gy, with very fine to fine qtz sd, some shell fragments, <5% phosphate
17/17/20/21	46-48	/	as above
8/13/13/14	48-50	/	Poorly graded sand yellowish gy, v.fine to fine qtz sand, with coarse sand to gravel shell fragments, some phosphate
13/23/21/26	50-52	/	as above
1/9/16/20	52-54	/	Poorly graded sand medium lt gy, fine to medium qtz sand and shell fragments, 10% phosphate
7/18/25/21	54-56	/	Silty sand, lt. olive gy, v.fine to fine qtz sand, some shell fragments
5/7/12/12	56-58	/	a/a
17/15/18/20	58-60	/	Poorly graded sd lt olive gy, fine to coarse sand, medium grained sized shell fragments
10/15/13/15	60-62	/	Sandy clay lt. olive gy, with qtz sand + shell fragments, cohesive, med. plasticity, calcareous
3/25/50 (R)	62-64	/	Silty Sand lt olive gy, fine to v.fine qtz sand, shell fragments
0/24/50 (R)	64-66	/	o/a
5/13/7/10	66-68	/	Sandy clay, lt olive gy, with qtz sand + shell fragments, cohesive, Med. plasticity, calcareous
4/7/6/5	68-70	/	o/a
4/5/10/10	70-72	/	Sandy clay lt olive grey, with shell fragments, cohesive high plasticity, calcareous

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

SFWMD Daily Drilling Form

Date: 2/6/18	Page 3 of 4	Mud Weights and Viscosity			Drilling Parameters		
		Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Well Name CAU-8LO							
Contractor/Driller DrillPro - Tesnord							
Site Geologist J. Tinzen							
Starting Depth 0							
Ending Depth 136							

Drilling Notes: bit size/fluid additives/mud type, etc.

see 1st page

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
8/8/9/11	72-74		Sandy clay - lt olive gy, w shell fragments, cohesive, high plasticity, calcareous
6/7/8/9	74-76		o/a
4/5/6/8	76-78		Sandy clay - lt olive gy, with qtz sd & shell fragments, cohesive low plasticity, calcareous
4/4/5/8	78-80		o/a
5/5/6/5	80-82		o/a
4/11/15/18	82-84		Clayey sand - medium lt gy, with v.f. + fine qtz sand and sand to gravel sized shell fragments.
4/6/6/7	84-86		Sandy clay - lt olive gy, with qtz sd & shell fragments, cohesive, low plasticity, calcareous
1/15/150 (R)	86-88	/	Sandy clay - lt olive gy, with qtz sd & shell fragments, cohesive high plasticity, calcareous
30/13/14-10	88-90	/	Poorly graded sand - lt olive gy, fine to v.f. qtz sand + f to coarse shell fragments
5/21/24/27	90-92		o/a
11/12/15/20	92-94		o/a
5/17/22/17	94-96		o/a
9/21/26/21	96-98		o/a
13/11/20/17	98-100		o/a
(R)	100-102	/	~~No~~ o/a Sandstone, medium gy, mostly shell + qtz sand, calcareous cement.
	102-104		No Sample
	104-106		Poorly graded sd, yellowish gy, fine to medium qtz sd w shell fragments
	106-108		Poorly graded sd, med lt gy, fine to med qtz sd w shell fragments

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

SFWMD Daily Drilling Form

Date: 2/6/18	Page 4 of 4	Mud Weights and Viscosity			Drilling Parameters		
Well Name	CAU-8LD	Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Contractor/Driller	Drill Pro-Jerrard						
Site Geologist	J. Tanzer						
Starting Depth	0						
Ending Depth	136						

Drilling Notes: bit size/fluid additives/mud type, etc.

see 1st page

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
	108-110		Poorly graded sand, medium lt gy, fine to med qtz with shell fragments
6/4/18	110-112		a/a
	112-114		a/a
	114-116		a/a
	116-118		a/a
	118-120		a/a
	120-122		Poorly graded sand ~~with silt~~ medium lt gy, fine to med qtz & shell fragments
	122-124		~~a/a~~ Poorly Graded sand w silt - a/a
	124-126		a/a
	126-128		Clayey sand - medium lt gy, fine to med qtz & shell fragments, calcareous clay
	128-130		Poorly graded sand with silt - medium lt gy, fine to med qtz sand and sand to gravel sized shell fragments
	130-132		Clayey sand - ~~med~~ lt greenish grey, fine to v fine qtz sand with shell fragments, calcareous
	132-134		a/a
	134-136		a/a

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

SFWMD Daily Drilling Form

Date: 2/12/18	Page 1 of 4	Mud Weights and Viscosity			Drilling Parameters		
Well Name	CAU-91D	Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Contractor/Driller	Drill Pro - Ferrell						
Site Geologist	L.E. Geddes						
Starting Depth	0						
Ending Depth	126						

Drilling Notes: bit size/fluid additives/mud type, etc.

2" split spoon in acrylic sleeve followed by reaming with 4" BIT.
Described by J. Janzen

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
~~5/7/9/11~~ WD	2-4		Poorly graded sand - greyish orange, v. fine to fine qTZ sand
5/7/6/8	4-6		a/a
3/4/6/5	6-8		a/a
5/7/9/11	8-10		a/a
14/16/36	10-12		Shell fragments - fine sand to gravel sized. greyish brown
10/15/23/2	12-14		a/a
Refusal	14-16		NO SAMPLE
4/21/23/26	16-18		Shell Fragments and qTZ sand, brownish grey, fine to coarse grained
14/20/33	18-20		a/a
(R)	20-22		No Sample
10/11/26/10	22-24		Silty Sand - 14%, v. fine to fine qTZ sand, shell fragments, <5% phosphate, some sand, trace
9/32	24-26		Silty sand - 14%, v fine to fine qTZ sand, some shell fragments, <5% phosphate
10/20/21	26-28		Poorly graded sand - medium (79%), fine to medium qTZ sand and shell fragments, <5% phosphate
8/22/33/33	28-30		a/a
10/20/30/30	30-32		a/a
12/22/29/40	32-34		a/a
18/21/38/25	34-36		Poorly graded sand - greyish orange, v. fine to fine qTZ sand, few shell fragments <5% phosphate
8/15/50 (R)	36-38		a/a

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

SFWMD Daily Drilling Form

Date: 2/12/18 2/13/18	Page 2 of 4	Mud Weights and Viscosity			Drilling Parameters		
		Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Well Name	CM-910						
Contractor/Driller	Drill Pro-Jerrod						
Site Geologist	Geddes						
Starting Depth	0						
Ending Depth	126						

Drilling Notes: bit size/fluid additives/mud type, etc.

as previous page

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
7/26/36/34	38-40	/	Poorly Graded Sand - v fine to fine qtz sand, few shell fragments, <5% phosphate - greyish orange
12/10/26/31	40-42	/	Poorly graded sand - a/a
19/26/31/45	42-44	/	a/a
15/20/18/12	44-46	/	a/a
15/21/20/18	46-48	/	Poorly graded sand, greyish orange, v. fine to fine qtz sand with shell fragments, <5% phosphate.
11/13/11/8	48-50	/	a/a
11/12/11/12	50-52	/	Silty sand - lt olive gy, v fine to fine qtz sand with medium to gravel sized shell fragments, <5% phosphate
15/21/36/48	52-54	/	a/a
16/21/20/32	54-56	/	a/a
10/20/28/30	56-58	/	Poorly Graded Sand, v. Gravel, medium lt gy, v fine to fine qtz sand with medium to gravel sized shell fragments, <5% phosphate
14/21/12/8	58-60	/	a/a
12/12/11/8	60-62	/	a/a
3/5/4/5	62-64	/	Shell & Sand, light brownish gy, Gravel sized shell fragments with v fine to fine qtz sand.
4/4/5/4	64-66	/	Sandy Clay, olive grey, with qtz salt shell fragments, also cohesive, med plasticity, calcareous
4/4/4/4	66-68	/	a/a w high plasticity
6/7/10/12	68-70	/	a/a
9/8/8/15	70-72	/	Sandstone with clayey sand, olive gy, fine qtz & shell sand & more calcareous, with phosphate, and clayey fine qtz sand.
10/11/19/18	72-74	/	Silty sand, olive gy, v fine to fine qtz sand with gravel sized shell fragments, calcareous

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

SFWMD Daily Drilling Form

Date: 2/13/18	Page 3 of 4	Mud Weights and Viscosity			Drilling Parameters		
		Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Well Name	CAU-9LD						
Contractor/Driller	Drill pro - Jerrod						
Site Geologist	Liz Geddes						
Starting Depth	0						
Ending Depth	136						

Drilling Notes: bit size/fluid additives/mud type, etc.

As page 1

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
4/20/12/27	74-76	/	Shell fragments with silty sand - lt brownish grey, gravel sized shell fragments with silty qtz sand.
23/36/10/10	76-78	/	Sandstone, shell fragments, silty sand, lt brownish gy, fine qtz + shell sandstone, calcareous, with gravel sized shell fragments
31/19/11/10	78-80	/	Shell fragments with silty sand, lt brown gy, gravel sized shell fragments with silty qtz sand
4/7/10/11	80-82	with	Silty sand light olive gray, v.fine to fine sd with fine sd to gravel sized shell fragments
10/9/9/8	82-84	/	Poorly graded sand - medium l gy, fine to medium qtz sd + shell fragments, <5% phosphate
6/4/11/14	84-86	/	a/a
13/12/12/14	86-88	/	Sandstone - medium grey, fine to medium sd + shell, calcareous cement
18/19/21/15	88-90	/	a/a
20/23/20/17	90-92	/	Silty sand with gravel - yellowish gy, v. fine to medium coarse sd + shell fragments, some gravel sized shell fragments, <5% ph.
19/30/32/31	92-94	/	Silty sand and sandstone - yellowish gy, as above with calcareous qtz sandstone,
21/19/21/15	94-96	/	Silty sand - yellowish gy, v. fine to medium qtz sand + shell few gravel sized shell fragments, & <5% ph.
21/14/11/13	96-98	/	Silty sand with gravel - yellowish gy - v. fine to medium qtz sd + shell with gravel sized shell fragments <5% phosphate
7/11/10/12	98-100	/	a/a
1/-/10/11	100-102	/	Silty sand and sandstone yellowish grey, v.fine to medium qtz sand + shell with calcareous qtz SS. <5% ph.
8/11/10/7	102-104	/	a/a
9/11/11/8	104-106	/	Silty sand w gravel - yellowish gy, v.fine to medium qtz sd + shell with gravel sized ~~qtz~~ shell fragments, <5% ph.
6/15/12/15	106-108	/	Silty sand with gravel - a/a
11/12/14/10	108-110	/	a/a

Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

Date: 2/13/18	Page 4 of 4	Mud Weights and Viscosity			Drilling Parameters		
		Time	Weight (lbs/gal)	Viscosity (sec/qt)	Time	Wt on Bit (1,000 lbs)	Discharge (gpm)
Well Name	CM-960						
Contractor/Driller	Drillpro - Jerrod						
Site Geologist	Liz Geddes						
Starting Depth	0						
Ending Depth	126						

Drilling Notes: bit size/fluid additives/mud type, etc.

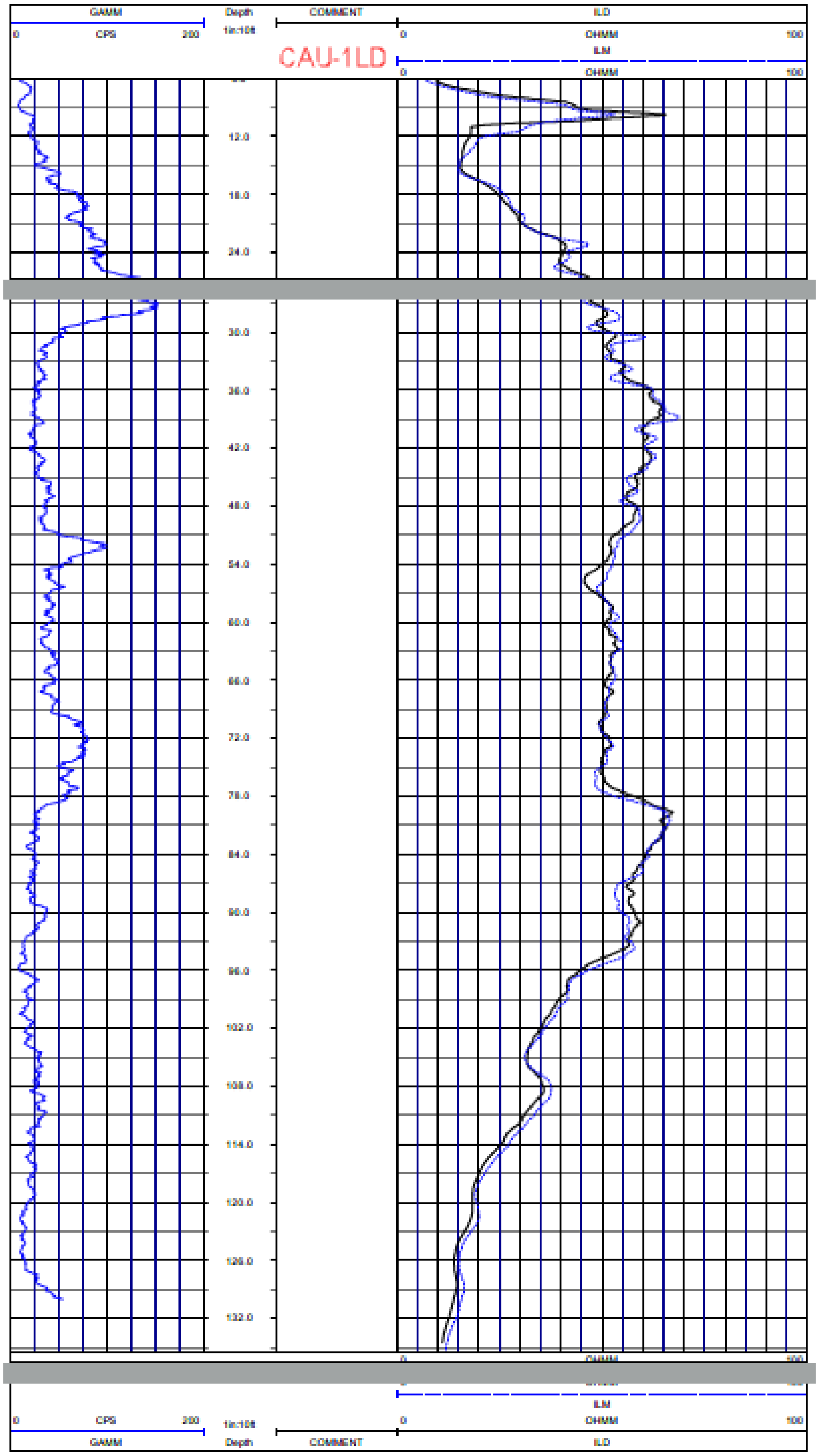
As Page 1

Time	Depth (5 ft int.)	Sampling Time	Lithology and Formation Notes (lost circulation zones, chatter, rate changes, etc.)
9/15/19/8	110-112	✓	Silty Sand w Gravel - yellowish gy, v. fine to med, qtz sd & shell with gravel sized shell fragments, <5% phosphate
6/10/10/13	112-114	✓	a/a
9/13/14/39	114-116	✓	Poorly graded Sand - medium lt gy, v fine to med qtz sd & shell, <5% phosphate
16/16/32/42	116-118	✓	Poorly graded Sand with Gravel - medium lt gy, a/a with gravel sized shell fragments
9/16/9/6	118-120	✓	Poorly graded Sand - medium lt gy, v fine to med qtz & shell sand, few gravel shell fragments <5% phosphate
19/9/9/3	120-122	✓	Silty Sd - yellowish gy, v fine to fine qtz sd, few shell fragments, <5% phosphate
25 total	122-124		a/a
6/6 3+ (R)	124-126		a/a

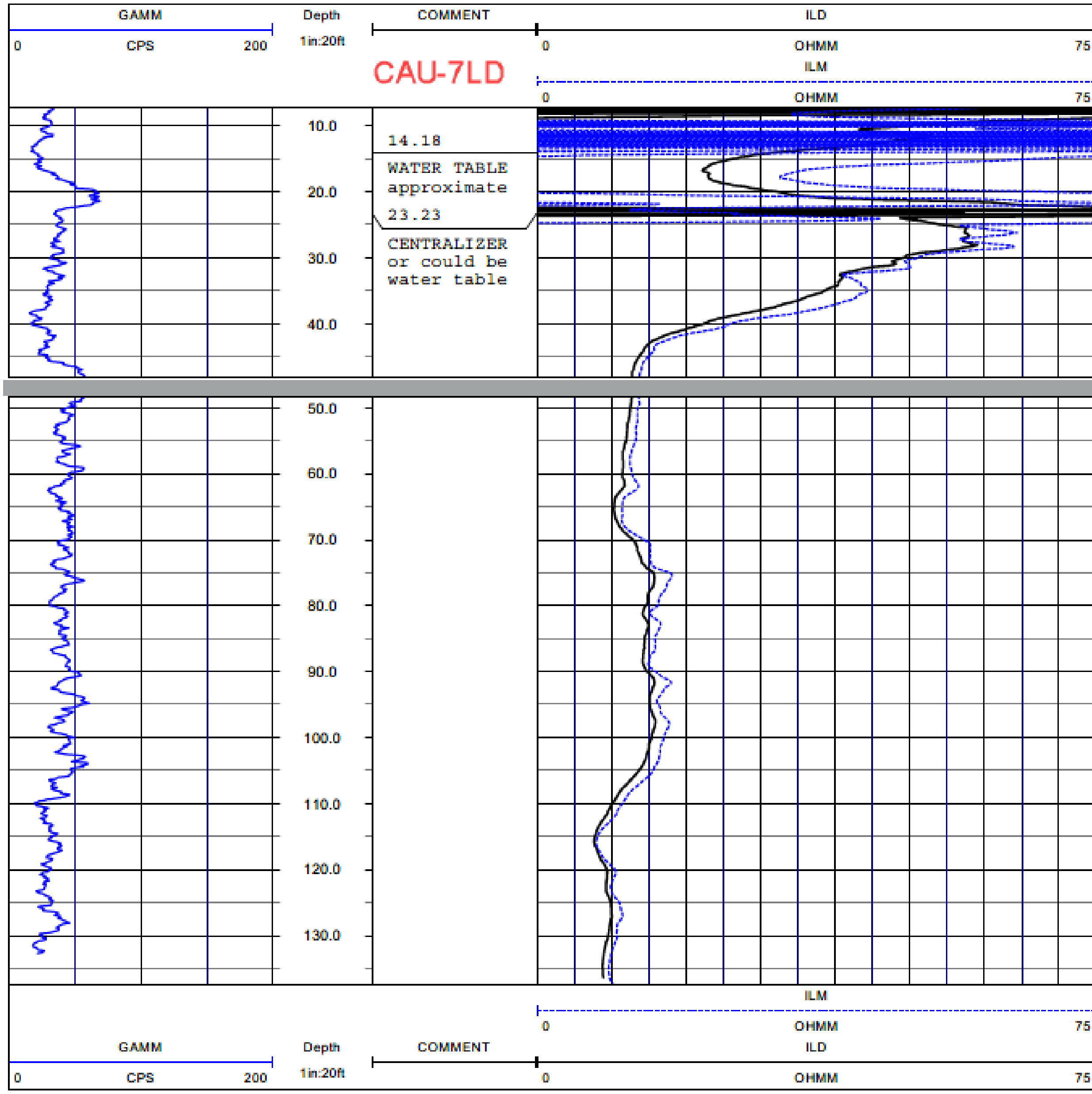
Time	Depth (feet)	New Rod Meas. (feet)	Dev. Survey (deg)	Depth to Water (reverse air only)			Water Quality Measurements (reverse air only)			Laboratory Sample ID
				Ref	Drill Pipe	Annulus	pH	Sp. Cond. (µS/cm)	Temp. (deg C)	

APPENDIX B: GEOPHYSICAL LOGS

LOG CODES					
3-arm caliper	CAL	long normal resistivity	RLN	deep induction conductivity	IDC
natural gamma (CPS)	GAMM	8 inch resistivity	R8	shallow induction conductivity	ISC
spontaneous potential	ESP	32 inch resistivity	R32	sonic interval velocity	DT
single point resistance	RES	deep induction resistivity	ILD	sonic porosity (RHG method)	SPHI
short normal resistivity	RSN	shallow induction resistivity	ILM	repeat designation	R



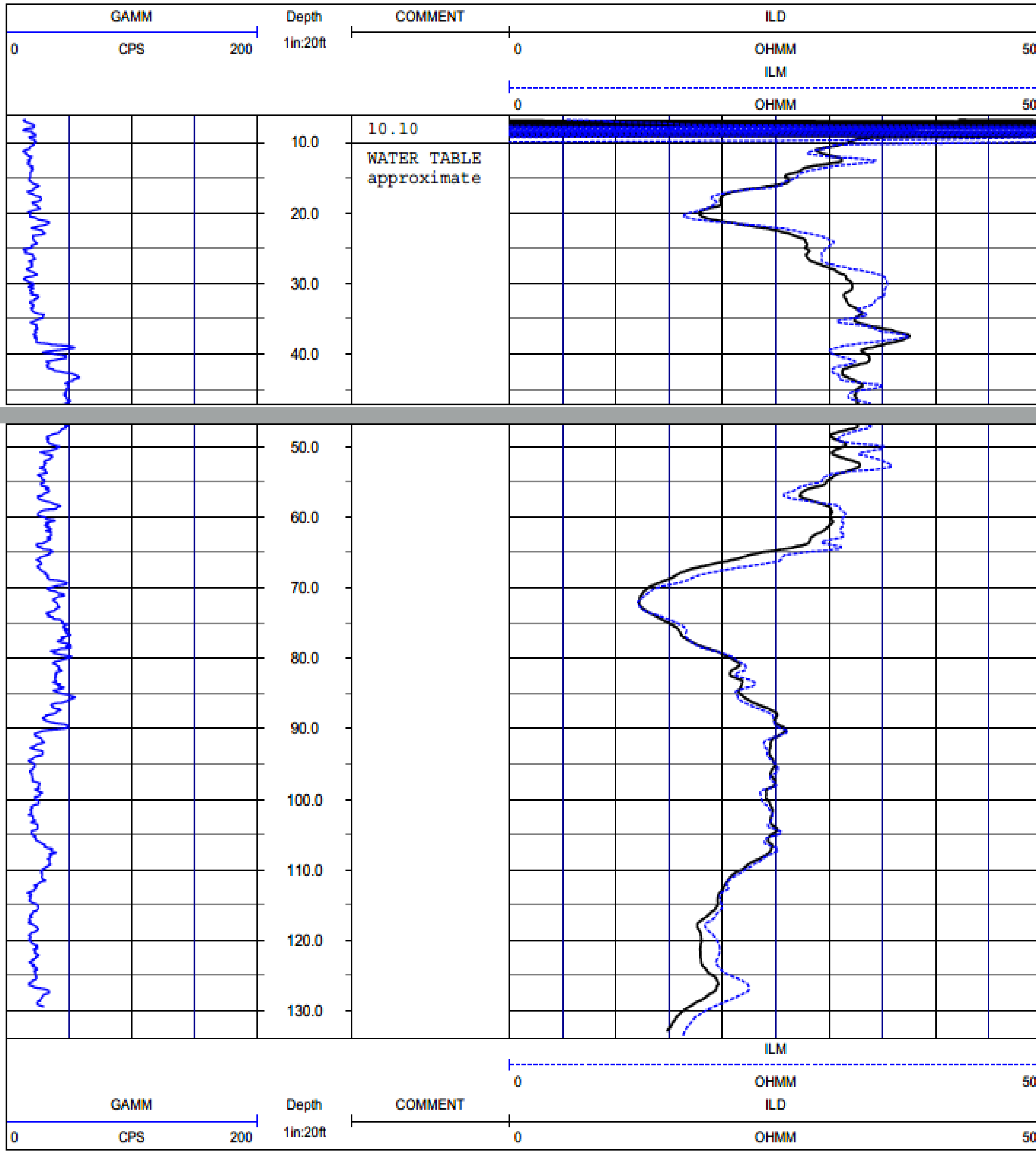
LOG CODES					
3-arm caliper	CAL	long normal resistivity	RLN	deep induction conductivity	IDC
natural gamma (CPS)	GAMM	8 inch resistivity	R8	shallow induction conductivity	ISC
spontaneous potential	ESP	32 inch resistivity	R32	sonic interval velocity	DT
single point resistance	RES	deep induction resistivity	ILD	sonic porosity (RHG method)	SPHI
short normal resistivity	RSN	shallow induction resistivity	ILM	repeat designation	R



CAU-8LD

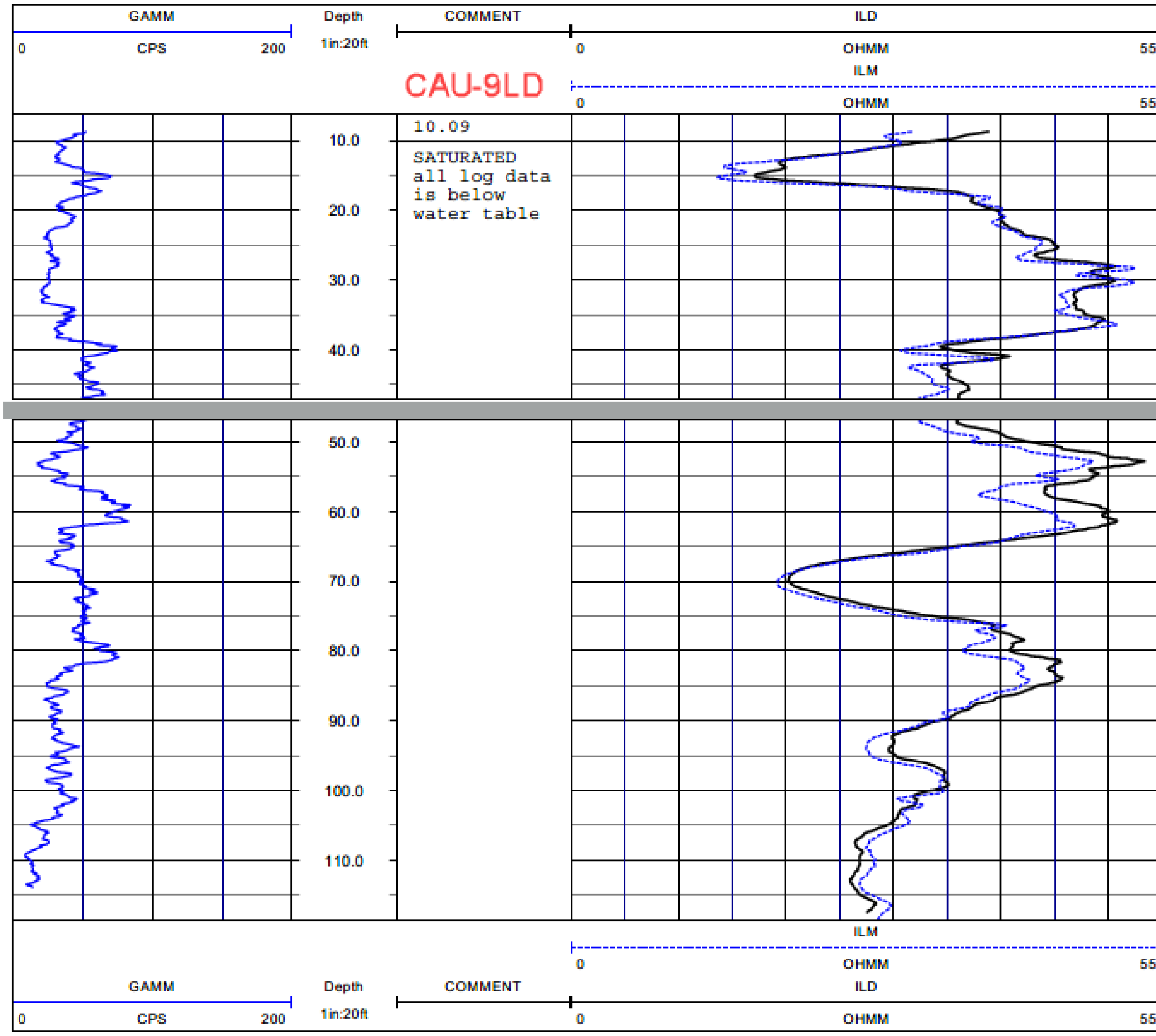
LOG CODES

3-arm caliper	**CAL**	long normal resistivity	**RLN**	deep induction conductivity	**IDC**
natural gamma (CPS)	**GAMM**	8 inch resistivity	**R8**	shallow induction conductivity	**ISC**
spontaneous potential	**ESP**	32 inch resistivity	**R32**	sonic interval velocity	**DT**
single point resistance	**RES**	deep induction resistivity	**ILD**	sonic porosity (RHG method)	**SPHI**
short normal resistivity	**RSN**	shallow induction resistivity	**ILM**	repeat designation	**R**



LOG CODES

3-arm caliper	**CAL**	long normal resistivity	**RLN**	deep induction conductivity	**IDC**
natural gamma (CPS)	**GAMM**	8 inch resistivity	**R8**	shallow induction conductivity	**ISC**
spontaneous potential	**ESP**	32 inch resistivity	**R32**	sonic interval velocity	**DT**
single point resistance	**RES**	deep induction resistivity	**ILD**	sonic porosity (RHG method)	**SPHI**
short normal resistivity	**RSN**	shallow induction resistivity	**ILM**	repeat designation	**R**



M-1236

LOG CODES

3-arm caliper	**CAL**	long normal resistivity	**RLN**	deep induction conductivity	**IDC**
natural gamma (CPS)	**GAMM**	8 inch resistivity	**R8**	shallow induction conductivity	**ISC**
spontaneous potential	**ESP**	32 inch resistivity	**R32**	sonic interval velocity	**DT**
single point resistance	**RES**	deep induction resistivity	**ILD**	sonic porosity (RHG method)	**SPHI**
short normal resistivity	**RSN**	shallow induction resistivity	**ILM**	repeat designation	**R**