Miami-Dade County Stormwater Detention Area Hydrogeologic Investigation

Technical Publication WS-56

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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
µS/cm	microsiemens per centimeter
bls	below land surface
DERM	(Miami-Dade County) Department of Environmental Resources Management
District	South Florida Water Management District
ft	foot
HFC	high-frequency cycle
ICU	intermediate confining unit
LECsR	Lower East Coast Sub-Regional (model)
mgd	million gallons per day
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
OBI	optical borehole image
Q	Quaternary
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
SCADA	supervisory control and data acquisition
SDA	stormwater detention area
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WCA	water conservation area

INTRODUCTION

Between September 2006 and April 2007, the South Florida Water Management District (SFWMD or District) installed several monitor wells in the Biscayne aquifer north of Military Canal and west of the L-31E Canal in Miami-Dade County, Florida. The project area and surrounding features are shown in **Figure 1**. The work was conducted to support the Miami-Dade County Department of Environmental Resources Management (DERM), which was constructing a stormwater detention area (SDA) near Military Canal, east of the Homestead Air Reserve Base. The location of the proposed DERM SDA is shown in **Figure 2**. The SFWMD planned to evaluate the hydrogeology of the SDA site and monitor groundwater levels upon completion. The SDA project was never completed, but the hydrogeologic data collected for that effort have advanced understanding of the Biscayne aquifer and supported groundwater modeling activities in the region. **Figure 3** shows the boundaries on the project area, the DERM SDA footprint, monitor well locations, and other pertinent features.

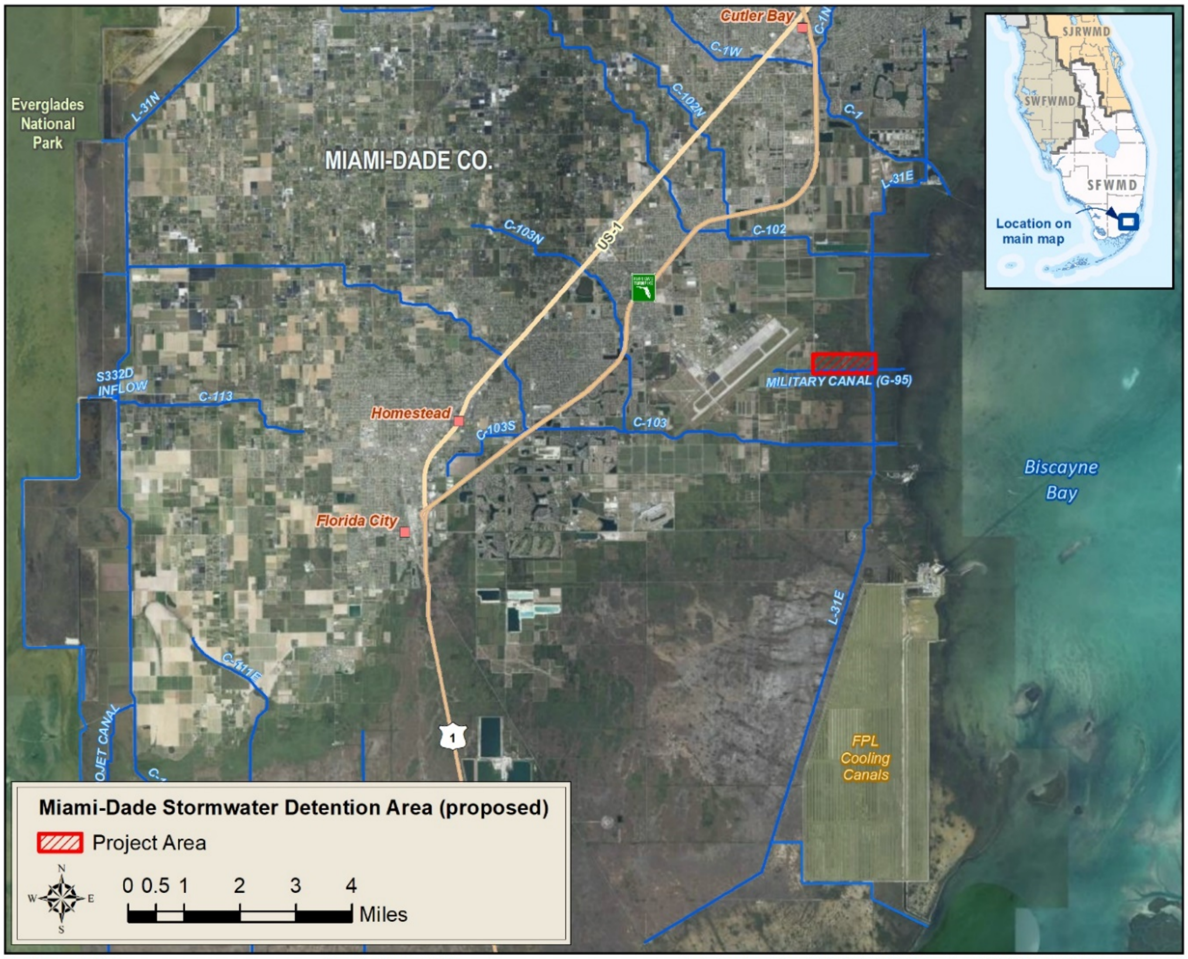

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Figure 1. General location of installed Biscayne aquifer monitor wells.

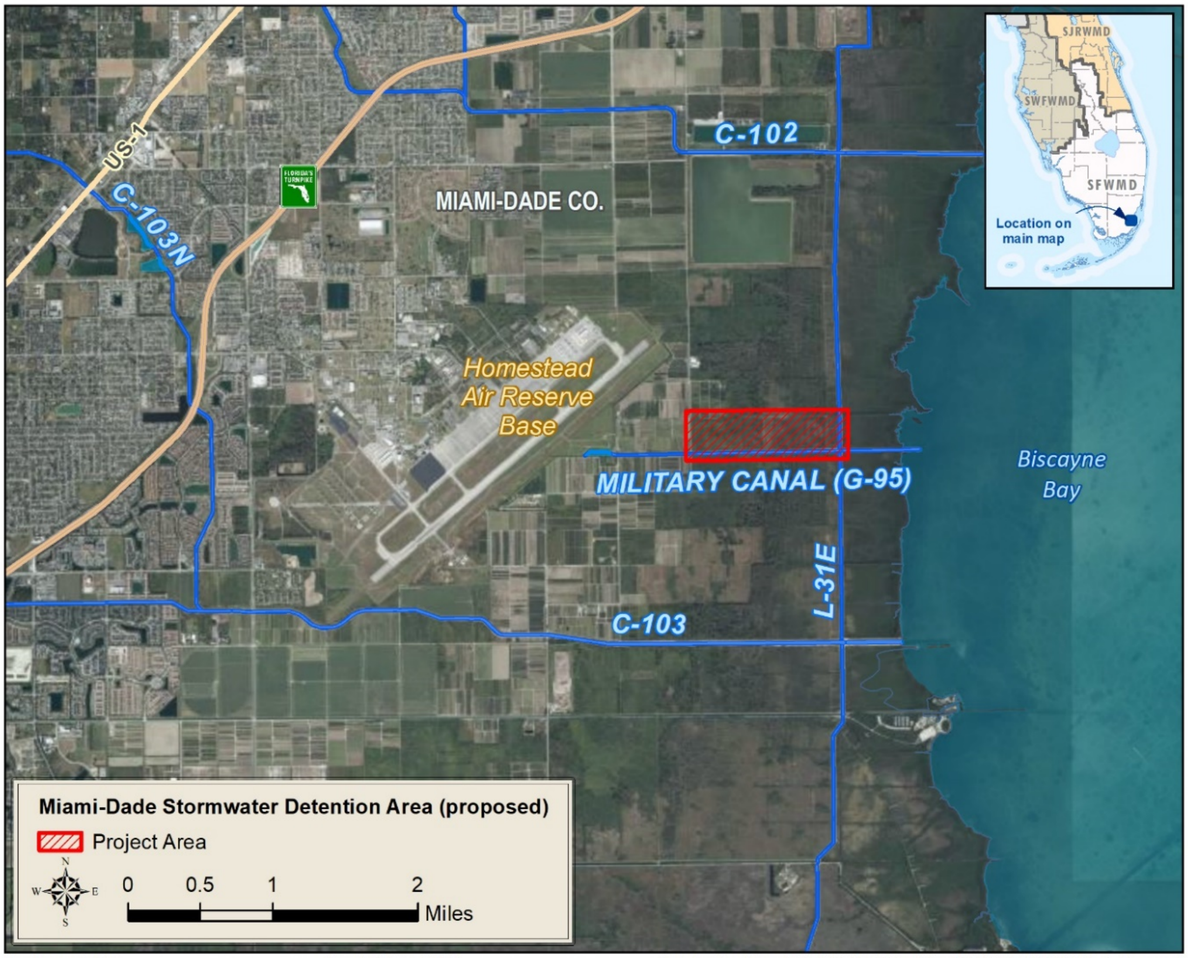

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Figure 2. Location of the proposed stormwater detention area.

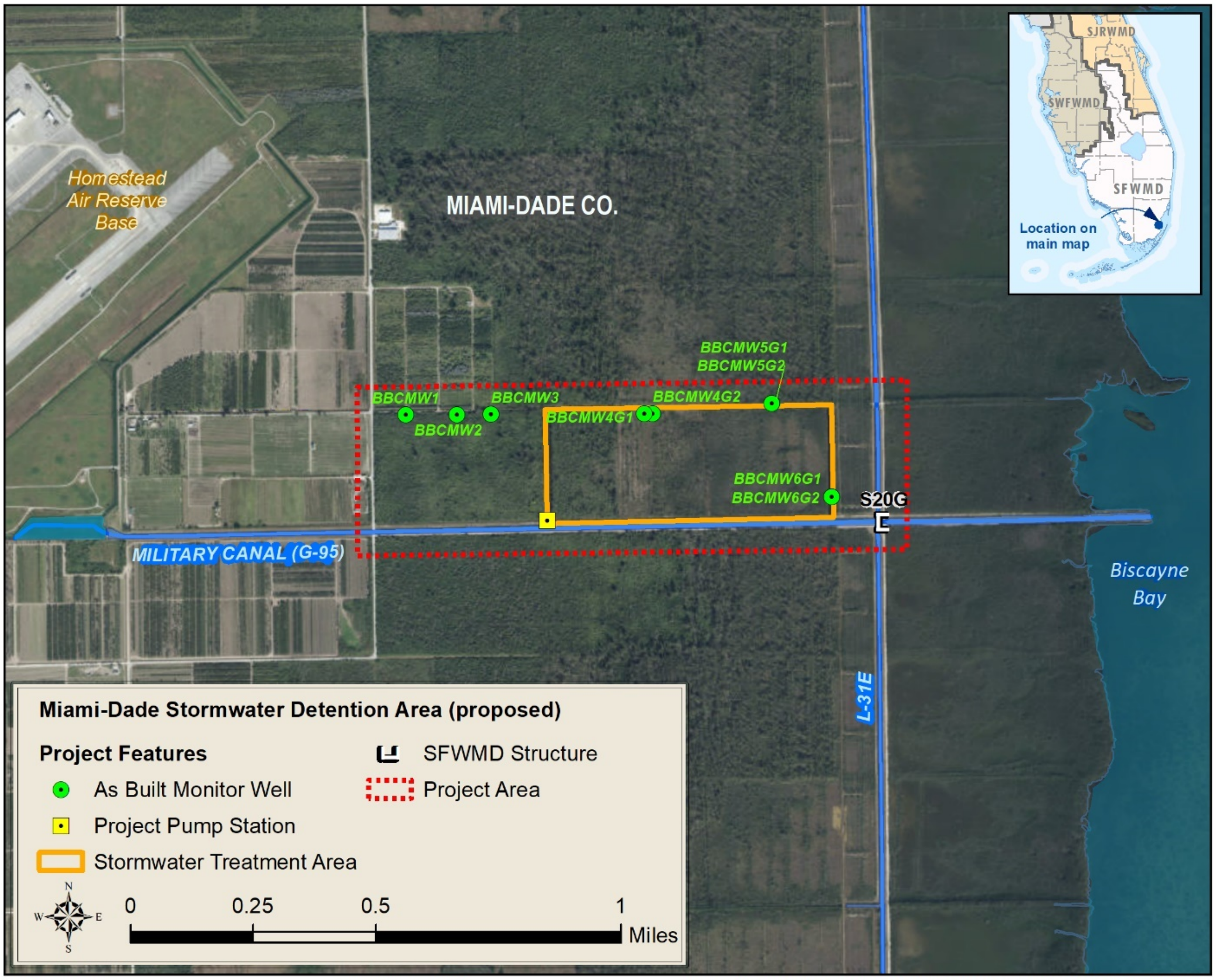

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Figure 3. Project boundaries and features.

The proposed purpose of the monitor wells was to measure seepage rates from the SDA into the underlying aquifer. Data from nine constructed monitor wells were included in this study. Geophysical logs (caliper log and digital borehole image log) in the deep monitor wells were needed to determine the depths of the preferential groundwater flow paths. Acquisition of these logs is discussed in the *Geophysical Logging* section of this report, and interpretation of the logs is provided in the *Hydrogeologic Findings* section. The monitor wells were not consistently named among the data collection efforts. For readability in this report, one naming convention was used and a crosswalk to the name variations is presented in **Table 1**. Three additional wells were constructed as part of a United States Army Corps of Engineers (USACE) study of the Biscayne Bay Coastal Wetlands, is also included in Table 1 and discussed in the Hydrogeologic Findings section of this report.

Table 1. Various naming conventions used for the monitor wells during different data collection efforts.

DBHYDRO				Keith & Schnars	USGS		
Station	Alias Match	Monitor Station Location Map	Fig.7 Geophysical Log Cross-Section	GFA	OBI Header	OBI Column Heading	USGS Well No.
BBCMW1	BBCWSTA-MW1	BBCMW1G1		MW-1			
BBCMW2	BBCWSTA-MW2	BBCMW2G1		MW-2			
BBCMW3	BBCWSTA-MW3	BBCMW3G1		MW-3			
BBCMW4G1	BBCWSTA-MW4B	BBCWMW4G1		MW-4B			
BBCMW4G2	BBCWSTA-MW4A	BBCWMW4G2	BBCW-4new	MW-4A	BBCWSTA-MW-4Anew	STDA-BBCW-4A-New	G-3874
BBCMW5G1	BBCWSTA-MW5B	BBCMW5G1		MW-5B			
BBCMW5G2	BBCWSTA-MW5A	BBCMW5G2	BBCW-5	MW-5A	BBCWSTA-MW-5A	STDA-BBCW-5A	G-3875
BBCMW6G1	BBCWSTA-MW6B	BBCMW6G1		MW-6B			
BBCMW6G2	BBCWSTA-MW6A	BBCMW6G2	BBCW-6	MW-6A	STDA-BBCW-6A	STDA-BBCW-6A	G-3857
BBCW2	CP04-BCBCW-CB-0003						
BBCW3GW1	CP04-BCBCW-CB-0005A						
BBCW9GW1	CP04-BCBCW-CB-0011A						

Note: Blue shaded cells indicate the nomenclature used in this report for stormwater detention area monitor wells, while orange shaded cells indicate the nomenclature used for United States Army Corps of Engineers wells.

HYDROGEOLOGIC FRAMEWORK

The surficial aquifer system (SAS) comprises all rock and sediment from land surface downward to the top of the intermediate confining unit (ICU). The rock and sediment consist primarily of limestones and sandstones, sand, shell, and clayey sand with minor clay or silt components, and range in age from Pliocene to Holocene (Causaras 1987). The base of the SAS is defined hydraulically by a significant change in average permeability. This change separates the underlying section of low permeability (i.e., the ICU) from the overlying higher-permeability sediments of the SAS. The upper part of the ICU typically is green clay or silt. Regionally, green clay or silt indicates the top of the Hawthorn Formation (Southeastern Geological Society Ad Hoc Committee on Hydrostratigraphic Unit Definition 1986).

The SAS in Miami-Dade County typically is referred to as the Biscayne aquifer and considered one of the most productive karst aquifers in the world (Parker et al. 1955). Lithostratigraphic units within the Biscayne aquifer include the upper part of the Tamiami Formation, Anastasia Formation, Key Largo Limestone, Fort Thompson Formation, Miami Limestone, Pamlico Sand, and Lake Flirt Marl (Parker and Cooke 1944, Causaras 1987, Fish and Stewart 1991). Additionally, Fish and Stewart (1991) informally named the Gray Limestone aquifer, which had not previously been identified in the county. Separating the aquifers are less permeable sand, limestone, silt, and clay that generally act as semi-confining units. However, in response to pumping, these semi-confining characteristics typically do not result in hydraulic heads being noticeably different from water table elevations.

Biscayne Aquifer

The Biscayne aquifer is the only formally named SAS component in Miami-Dade County and has been declared a sole source aquifer (Federal Register, 1979). Parker et al. (1955) named the Biscayne aquifer after Biscayne Bay and identified it as the most important water supply source in southeastern Florida. The Biscayne aquifer is a hydrologic unit of water-bearing rocks ranging in age from upper Miocene through Pleistocene. Fish and Stewart (1991) defined the Biscayne aquifer as the part of the SAS in southeastern Florida composed of (from land surface downward) the Pamlico Sand, Miami Oolite, Anastasia Formation, Key Largo Limestone, and Fort Thompson Formation (all of Pleistocene age), and contiguous, highly permeable beds of Tamiami Formation of Pliocene and late Miocene age where at least 10 feet (ft) of the section is highly permeable (i.e., hydraulic conductivity of 1,000 ft/day or more). Sandstones and limestones with well-developed secondary porosity in Miami-Dade and Broward counties have hydraulic conductivities commonly exceeding 10,000 ft/day. The permeability requirement of this definition provides a means of estimating the aquifer boundary where the Fort Thompson Formation, Anastasia Formation, or Key Largo Limestone grades laterally into less permeable facies. If there are contiguous, permeable (i.e., hydraulic conductivity of 100 ft/day or more) limestone or calcareous sandstone beds of the Tamiami Formation, the lower boundary is the transition from these beds to sands or clayey sands. Where the contiguous beds of the Tamiami Formation do not have sufficiently high permeability, the base of the highly permeable limestones or sandstones in the Fort Thompson Formation, Anastasia Formation, or Key Largo Limestone is the base of the Biscayne aquifer.

Gray Limestone Aquifer

Fish (1988) identified a predominantly gray limestone unit in the lower part, and locally the middle part, of the Tamiami Formation. In western Miami-Dade County, the gray limestone occurs between 70 and 160 ft below land surface (bls). The Gray Limestone aquifer consists of predominantly shell and sand and is lightly to moderately cemented. Laterally, the gray limestone grades eastward and southward to less permeable, sandy, clayey limestone and eventually sand and sandstone. Although less permeable than the Biscayne aquifer, the Gray Limestone aquifer is significant and a potential source of water, particularly west of the western limit of the Biscayne aquifer. The Gray Limestone aquifer is defined as the limestone beds (usually gray in color) and contiguous, very coarse, elastic beds in lower to middle part of the Tamiami Formation that are permeable (having a hydraulic conductivity of about 100 ft/day or greater) and at least 10 ft thick. The aquifer may be the source of water for irrigation in southeastern Hendry County and domestic use at the Seminole Tribe of Florida’s Big Cypress Reservation. The Gray Limestone aquifer may extend westward into Collier County but is not believed to extend as far east as the project area.

Sequence Stratigraphy

Sequence stratigraphic relations are described for the Pleistocene carbonate rocks that form the Biscayne aquifer. Critical to defining this sequence stratigraphy was delineation of the lithofacies of the Miami Limestone and Fort Thompson Formation. Sixteen lithofacies compose the upper Fort Thompson Formation and Miami Limestone (Cunningham et al. 2004a). Eleven of these facies form important strata in the Fort Thompson Formation and Miami Limestone. Cunningham et al. (2004a) defined these facies as: 1) peloid grainstone and wackestone; 2) peloid wackestone and packstone; 3) gastropod floatstone and rudstone; 4) mudstone and wackestone; 5) pedogenic limestone (laminated calcrete, massive calcrete, and root-mold limestone); 6) skeletal grainstone and packstone; 7) pelecypod floatstone and rudstone; 8) sandy pelecypod floatstone and rudstone; 9) touching-vug pelecypod floatstone and rudstone; 10) sandy, touching-vug pelecypod floatstone and rudstone; and 11) quartz sandstone and skeletal sandstone.

Two types of high-frequency cycles (HFCs) have been defined for the Pleistocene limestone of the Biscayne aquifer: paralic and subtidal. Subtidal cycles are typical of the Miami Limestone and represented by HFC4 and HFC5, as defined by Cunningham et al. (2004b) will be discussed further in this report.

Perkins (1977) divided the Pleistocene of South Florida into five marine units separated by regional discontinuity surfaces. Marine units are correlated with high sea level stands and discontinuity surface with subaerial exposure during low stands. Criteria for recognizing discontinuity surface include: 1) vadose sediment, 2) land-plant root structures, 3) laminated crusts, 4) diagenetic soilstones, 5) soils and soil breccias, 6) solution surfaces, 7) bored surfaces, and 8) freshwater limestones. Discontinuity surfaces are often found to be intraformational. For example, the Fort Thompson and Anastasia formations contain four such surfaces, the Key Largo Limestone contains two, and the Miami Limestone contains one. From oldest to youngest, the five marine units recognized by Perkins (1977) within the project area are informally termed Q1 through Q5 (Q for Quaternary). **Figure 4** is a generalized scheme showing these geologic units as defined by Perkins (1977) and Cunningham et al. (2009). A more detailed discussion of the stratigraphy and lithology of the project area is found in the *Hydrogeologic Findings* section of this report.

Epoch	Formation	South Florida (Perkins 1977)	Lake Belt (Cunningham et al. 2009)	
		Q unit	Q unit	HFC
Pleistocene	Miami Limestone	-	-	-
		Q5	Q5	HFC5e
		Q4	Q4	HFC4
	Fort Thompson Formation	Q3	Q3	HFC3b
				HFC3a
		Q2	Q2	HFC2h HFC2g3 HFC2g2 HFC2g1 HFC2f HCF2e HFC2d HFC2c HFC2b HFC2a
Pliocene	Tamiami Formation			

Figure 4. Geologic units as defined by Perkins (1977; Q units) and modified from Cunningham et al. (2009).

Hydrogeologic Characteristics of the SAS

The sources of recharge to the SAS in Miami-Dade County are: 1) infiltration of rainfall or irrigation water through surface materials to the water table; 2) infiltration of surface water imported by overland flow from the north in the water conservation areas (WCAs) or by canals; 3) infiltration of urban runoff via drains, wells, or ponds; and 4) groundwater inflow from southwestern Broward County. Soil types have significant control on the rate of recharge. Recharge by rainfall is greatest during the wet season, from June to November, and recharge by canal seepage is greatest during the dry season, from December to May (Fish and Stewart 1991).

Discharge from the SAS is through 1) evapotranspiration; 2) groundwater flow to canals, the ocean, and Monroe County along western Miami-Dade County; and 3) wells pumped for municipal, industrial, domestic, and agricultural supplies. Evapotranspiration and groundwater discharge are greatest during the wet season when water levels, temperature, and plant growth rates are high. Most water that circulates within the SAS is discharged via canals (Fish and Stewart 1991). Public water supply water is the greatest demand in Miami-Dade County and was approximately 400 million gallons per day (mgd) in 2020 and is projected to be approximately 480 mgd by 2040. In comparison, agricultural water use in Miami-Dade County in 2020 was estimated to be 68 mgd with a projected water use of approximately 72 mgd by 2040.

Areas of high groundwater levels in Miami-Dade County are found in WCA-3A and WCA-3B. September average water levels are 10 to 11 ft above mean sea level along the Miami-Dade/Broward County line in WCA-3A, dropping to 7 to 8 ft above mean sea level in WCA-3B and 1 to 2 ft above mean sea level along the coast.

Circulation in the groundwater flow regime (e.g., water levels, discharge areas, recharge patterns) has changed due to development in the area, including construction of drainage canals, irrigation or artificial recharge systems, WCAs, pumping stations, control structures on canals, and wellfields. During heavy rains, canals can quickly remove large amounts of groundwater, as compared to predevelopment conditions. Canals may divide the flow system into independent cells or act as partial penetrating boundaries of flow systems. Drainage canals and pumping from large wellfields have lowered coastal water levels, especially during the wet season, potentially causing saltwater intrusion (Fish and Stewart 1991).

Fish and Stewart (1991) reported that the local variations in transmissivity within Dade County (now Miami-Dade County) are smaller than in Broward County. The transmissivity of the SAS increases from less than 75,000 ft^2/day in westernmost Miami-Dade County to more than 1,000,000 ft^2/day in a large area centered around Krome Avenue in central and southeastern Miami-Dade County. Transmissivities near Homestead may exceed 2,000,000 ft^2/day. Based on contour maps prepared by Fish and Stewart (1991), transmissivity around the project area ranges from 900,000 to 1,000,000 ft^2/day. These high transmissivities cause high seepage rates and hinder the ability to store water, such as in the proposed Miami-Dade County SDA.

FIELD METHODS

Well Drilling

GFA International, Inc. (GFA) installed nine monitor wells between September 2006 and April 2007 (**Figure 3**). A summary of monitor well construction details is provided in **Table 2**. Continuous coring was conducted using a wire-line core barrel before installing the wells. Boreholes were drilled to depths ranging from approximately 43 to 63 ft bls and then backfilled based on geophysical surveying results. All wells were completed using 2-inch polyvinyl chloride (PVC) pipe with 2 ft of slotted screen. Screen intervals were set to meet project objectives. GFA completed each well with a flush-mounted manhole and a 2-ft square cement pad reinforced with rebar.

Table 2. Monitor well construction details.

Station	Install/ Complete Date	Latitude	Longitude	Measuring Point at TOC		Total Depth of Well (ft)	Screen Slot Size (inch)	Elevation at Bottom of Well Screen (ft NGVD29)
				ft NGVD29[a]	ft NAVD88			
BBCMW1	09/06/06	25°29’34.0”	80°21’44.5”	4.30	2.77	10.40	0.01	-6.10
BBCMW2	09/06/06	25°29’34.1”	80°21’39.2”	2.92	1.39	10.45	0.01	-7.53
BBCMW3	09/06/06	25°29’34.3”	80°21’35.6”	4.21	2.68	11.73	0.01	-7.52
BBCMW4G2	04/24/07	25°29’34.4”	80°21’16.4”	5.02	3.50	31.00	0.06	-25.98
BBCMW4G1	04/24/07	25°29’34.5”	80°21’16.6”	4.73	3.21	19.80	0.06	-15.07
BBCMW5G2	04/25/07	25°29’34.5”	80°21’02.1”	4.01	2.49	35.20	0.06	-31.19
BBCMW5G1	04/25/07	25°29’34.5”	80°21’02.6”	4.16	2.64	20.00	0.06	-15.84
BBCMW6G2	04/26/07	25°29’24.7”	80°20’54.6”	4.52	3.00	35.45	0.06	-30.93
BBCMW6G1	04/26/07	25°29’25.0”	80°20’54.5”	4.59	3.07	14.00	0.06	-9.41

TOC = Top of Casing

ft = foot; NAVD88 = North American Vertical Datum of 1988; NGVD29 = National Geodetic Vertical Datum of 1929.

[a] NGVD29 elevations were computed by subtracting the conversion factor of -1.526 ft from the NAVD88 elevation.

In April 2007, each groundwater monitor was developed using compressed air and pumping for approximately 30 to 40 minutes. Temperature, specific conductance, and pH of the groundwater was measured during well development using a calibrated YSI 600XL probe. The wells were considered developed once the parameter readings stabilized to within 5% for three consecutive readings and the on-site geologist observed that the water was free of suspended solids.

Geophysical Logging

To obtain subsurface hydrogeologic (downhole geophysical logs) data, the SFWMD engaged the United States Geological Survey (USGS) to conduct three-arm caliper, borehole fluid temperature and conductance, and OBI-40 Mark III digital optical logging. Caliper logs are used to measure borehole diameter for determination of cavity size and geometry. Digital borehole optical televiewers equipped with a high-resolution camera can create detailed 360° images of borehole walls and simultaneously collect borehole deviation data. The digital borehole images can be used to 1) accurately determine the depths for a well completion interval, 2) position a recovered core to its proper depth, 3) acquire a high-resolution borehole image that serves as a surrogate for intervals having no core recovery, and 4) characterize aquifer pore systems.

Surveying

A State of Florida licensed surveyor determined the elevations of the ground surface and the measuring points for the nine monitoring wells within the SDA. The elevation of a newly constructed benchmark at the site also was obtained. The elevation data are shown in this report with respect to both the North American Vertical Datum of 1988 (NAVD88) and the National Geodetic Vertical Datum of 1929 (NGVD29). A datum shift between the two vertical datums was 1.526 ft. This value agrees with the datum shift computed by the NGS VERTCON algorithm. NGVD29 elevations were computed by subtracting -1.526 ft from the adjusted NAVD88 elevations. The latitudes and longitudes presented in this report were obtained using a handheld global positioning system (GPS) receiver. The surveyor's report can be found in **Appendix A**.

HYDROGEOLOGIC FINDINGS

Stratigraphy and Lithology of the Project Area and Vicinity

Hydrogeologic interpretation of the project area is supplemented by additional wells in the vicinity, including USGS wells, a study by the USACE, and wells constructed as part of the Biscayne Bay Coastal Wetlands, Aquifer Salinity Investigation (Janzen et al. 2008). A literature review was conducted to examine various hydrogeologic interpretations by several SAS investigations in Miami-Dade County.

Fish and Stewart (1991) prepared contour maps delineating the SAS and the aquifers it comprises. Their maps were based on aquifer definitions, aquifer test results, and vertical profiles of hydraulic conductivity determined at hydrogeologic test sites. The base of the SAS occurs at a relatively uniform elevation averaging 160 to 220 ft bls throughout most of Miami-Dade County. The contours maps coincide with Plate 5, cross-section E-E', of the same report, which shows the bottom of the SAS at well G-3321 as approximately 173 ft bls. Well G-3321 is located at the most eastern extent (E') of the cross-section. This cross-section is the southernmost west-to-east transect described by Fish and Stewart (1991), commencing in Everglades National Park, across the L-31W levee, through Florida City, and terminating at the L-31E levee, approximately 5 miles south of the project area. Cross-section D-D', located north of E-E', terminates at well G-3316, approximately 2.25 miles northwest of the project area. Similarly, the base of the Biscayne aquifer at G-3316 is shown to be 160 ft bls, which corresponds to a change in hydraulic conductivity. The lithology of wells G-3321 and G-3316 are included in **Appendix B**.

In 2004, the USACE and SFWMD investigated the SAS in the Biscayne Bay area of Miami-Dade County. The data were documented in a report by Challenge Engineering & Testing, Inc. (2006). Several soil test cores were collected, and monitor wells subsequently were installed. The borings closest to the project area were identified as: CP04-BCBCW-CB-003, CP04-BCBCW-0005A, and CP04-BCBCW-CB-0011A. The location of these borings is shown on **Figure 5**, and the soil boring and well construction logs are included in **Appendix C**. Table 1 provides various naming conventions for these three wells.

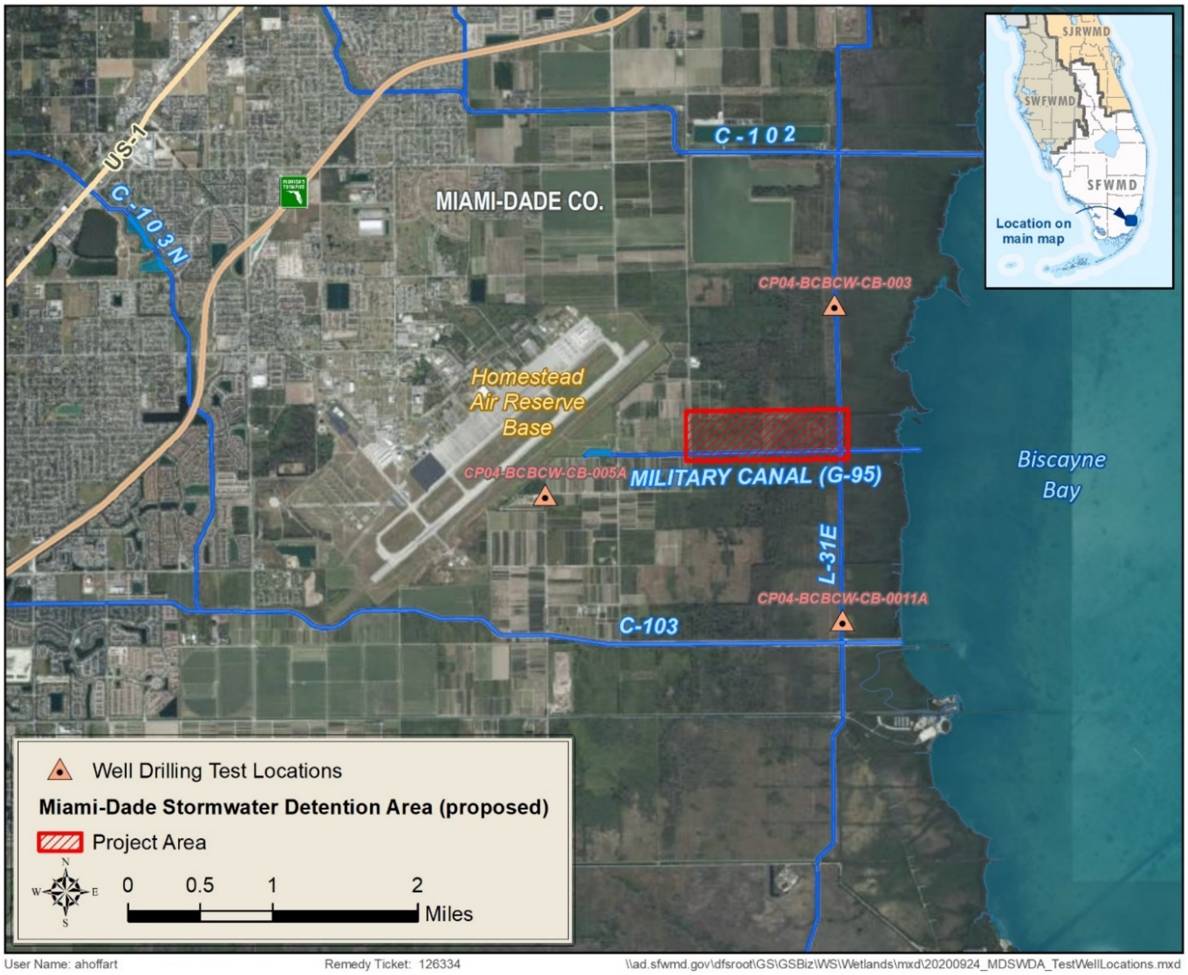


Figure 5. Locations of core borings as part of the surficial aquifer system investigation in the Biscayne Bay area.

Perkins (1977) studied the depositional framework of the Pleistocene sediments in South Florida. Much of the region is underlain by marine sedimentary sequences punctuated by freshwater limestones and subaerial exposure surfaces. This wedge of Pleistocene sediment, with attains a thickness of approximately 200 ft in the lower Florida Keys, pinches out northward against topographically higher Miocene and Pliocene sediments. Perkins (1977) delineated the Pleistocene deposit of South Florida into five marine units, informally termed, from oldest to youngest, Q1 through Q5. This terminology is time-stratigraphic and does not correlate with existing stratigraphic units.

Q1 lithofacies overlies the Tamiami Formation, which is composed primarily of unconsolidated elastics and arenaceous skeletal carbonates. Giddings et al. (2006) describes the Q1 unit as a coralline reef rock of the Key Largo Limestone. Q1 was not believed to be penetrated in the cores collected at the DERM SDA site.

Q2 has similar lithofacies patterns as Q1, except for an increase of mollusk fragments. Giddings et al. (2006) placed the Q2 unit in the Anastasia Formation and described it as coquina, quartz sand, and sandy limestone. For this study, Q2 is placed within the Fort Thompson Formation, as confirmed by J. Giddings (personal communication 2020).

Also within the Fort Thompson Formation is the Q3 unit, which is described as a carbonate sediment of marine origin with the presence of gastropods.

Units Q4 and Q5 are oolitic and bryozoan limestones of the Miami Limestone Formation. Although Giddings et al. (2006) placed Q5 in the Pamlico Sand, the unit is now being included as the top of the Quaternary deposits in the Miami Limestone for modeling purposes.

Figure 4 shows the Q units within the project area. As noted previously, Cunningham et al. (2004a, 2009) further divided the Quaternary sediments into HFCs. Changes in lithofacies can be separated into HFCs, which form the building blocks of the geologic framework (Wacker et al. 2014). These HFCs can be correlated to the Q units, as shown on **Figure 4**. Each HFC contains multiple depositional facies that correspond to groundwater flow classes. Further discussion on Quaternary lithofacies and HFC sub-units can be found in Cunningham et al. (2006).

Site Lithology Using Continuous Core Samples and OBI Logs

Digital, optical, and acoustic borehole imagery uses a televiewer to create images of a borehole wall or casing. The televiewer can be used to reference cores to original depth; detect cavities, faults, and fractures; and characterize pore systems. Optical and acoustic log types can be aligned to magnetic north and exported in NITMAP format. The SFWMD uses WellCAD Reader to display the optical borehole imagery (OBI) log information. WellCAD will import bitmap files (BMP, TIF, JPG, PNG) of core cuttings and thin-sections. Log curves then can be displayed based on measured depth, true vertical depth, elevation, or time. It uses an advanced depth-matching tool to align different types of data. Data can be exported as BMP, EMF, or PDF files, or they can be copied into any Windows application and output to any Windows printer.

Digital OBI can be used with core data to construct stratigraphic sections showing the areal extent of microporous flow zones (Wacker and Cunningham 2008). Cunningham et al. (2004a,c, 2006) used digital OBI to identify lithology, pore type, and zones of concentrated groundwater flow to show the connection between stratigraphy and the development of porosity and permeability within the Biscayne aquifer.

The SFWMD used the services of the USGS to obtain subsurface hydrogeologic data for the DERM SDA project. Data acquisition was via a three-arm caliper tool, borehole fluid temperature, conductance, and an OBI-40 Mark III digital optical log.

Figure 6 shows the results from one of the three wells logged at the SDA site: BBCMW6G2, which was the deepest well logged. A hydrogeologic interpretation of the project area can occur using the OBI log, along with core descriptions and geophysical logs. **Figure 6** shows the depth from land surface in feet, the formation contacts, and the Q units, as described by Perkins (1977) and described in this report. The digital OBI log was generated using the WellCAD program, which shows a 360° view of the borehole. The next column, in blue, is a depiction of the caliper log showing the borehole diameter. The next column shows three vertical lines passing down the borehole. The green line is a measure of fluid conductivity in microsiemens per centimeter (µS/cm). The red line is fluid temperature in degrees Celsius (°C). The orange line is fluid resistivity in ohm-meters (ohm-m) and typically responds inversely to the fluid conductivity. More detailed diagrams of the composite OBI logs for all three wells logged are included in **Appendix D**. Photographs of selected core segments are included in **Appendix E**. **Table 3** identifies the geologic formations at the SDA site and includes data from Challenge Engineering & Testing, Inc. (2006) and Fish and Stewart (1991).

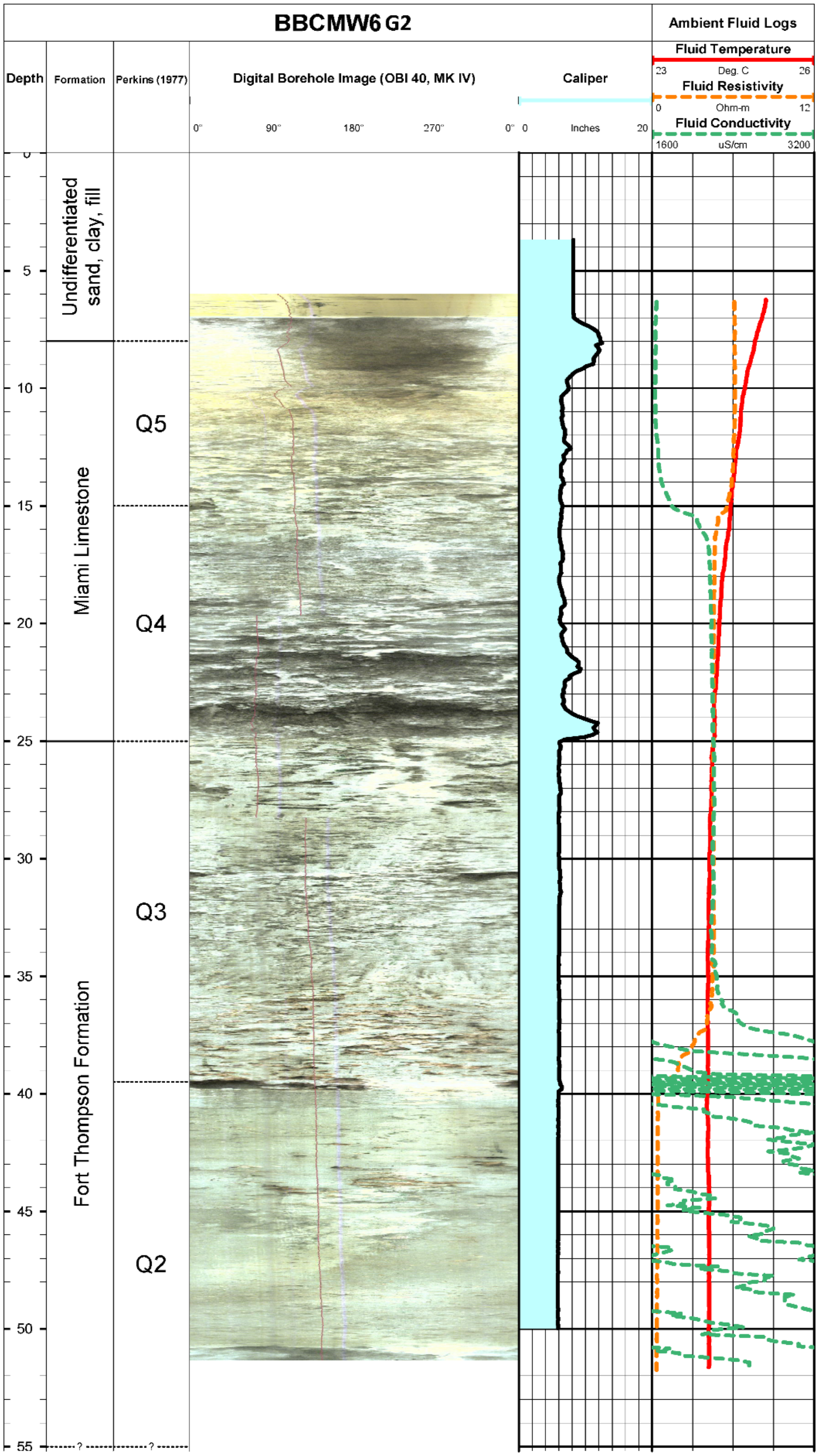


Figure 6. Hydrogeologic interpretation using optical borehole imagery and other geophysical logs.

Table 3. Summary of geologic formations encountered at the project site.

Formation	BBCMW6G2		Perkins (1977)			Challenge[a]	
	From Depth (ft bls)	To Depth (ft bls)	Q Unit	From Depth (ft bls)	To Depth (ft bls)	From Depth (ft bls)	To Depth (ft bls)
Undifferentiated sand, clay, and fill	-	-	-	0	8	-	-
Miami Limestone	8	25	Q5	8	15	5	-
			Q4	15	25	-	27
Fort Thompson	25	106[b]	Q3	25	40	27	40
			Q2	40	-	-	-
			Q1	-	106	-	-
Tamiami	106	170[c]	-	-	-	-	-
Hawthorn	170	-	-	-	-	-	-

- = no data; ft bls = feet below land surface.

[a] Challenge Engineering & Testing, Inc. (2006) average values for CP04-BCBCW-CB-3/5A/11A.

[b] Top of Tamiami Formation from Fish and Stewart (1991).

[c] Bottom of SAS from Fish and Stewart (1991).

Characteristic features of BBCMW6G2 are cavernous zones, visible in the OBI log and shown as a larger-diameter borehole in the caliber log at approximately 22 and 25 ft bls. These cavernous features typically represent high-flow zones within the aquifer. This area of dissolution is the base of the Miami Limestone and refers to the bottom of the Q4 unit. Fish and Stewart (1991) also identified the bottom of the Miami Limestone at 25 ft bls and 32 ft bls for E' and D' on Plates 5 and 4, respectively (**Appendix B**). The core interval for BBCMW6G2 from 17 to 23 ft bls was described as highly solutioned (**Appendix B**). The contact between Q5 and Q4 also is characterized by a shift in the conductivity log.

The base of Q3, which occurs near the top of the Fort Thompson Formation at approximately 38 to 40 ft bls, is evidenced by a slight increase in borehole diameter in **Figure 6**. Brackish or saline water appears to be present at this contact based on a substantial shift in the fluid conductivity. The zone from 38 to 40 ft bls is described as a dense white limestone with horizontal solutioning (**Appendix B**).

Underlying this unit is Q2 within the Fort Thompson Formation. However, it is not believed that the cores penetrate the entire extent of Q2.

WATER LEVEL DATA

Nine monitor wells were constructed as part of the Miami-Dade SDA project. In February 2008, all nine wells were equipped with temporary data loggers, including water level measuring devices. Design and installation of the telemetry equipment was completed by the SFWMD's supervisory control and data acquisition (SCADA) design and installation group. Each well had a measuring point (top of 2-inch casing) and a reference elevation determined by survey. The survey report is included as **Appendix A**. Each well was equipped with a pressure transducer, which was programmed to record water levels at 15-minute intervals, and the site was equipped with the necessary equipment (data logger, radio, antennae, battery, and solar panel) to allow real-time monitoring of water levels.

Table 4 provides the information related to water level data available in DBHYDRO for the nine monitor wells. **Table 4** identifies each recorder at each station by: DBKey, station, frequency, statistic, start date, end date, and strata or well depth. The DBKey number is a unique time series identifier. No two data sets will ever share the same DBKey. For example, a set of instantaneous readings and the mean daily values derived from such readings for the same well (BBCMW3) have two different DBKeys, such as VM887 and VM888 as shown in **Table 4**. DBHYDRO uses the term "breakpoint" synonymously with instantaneous data.

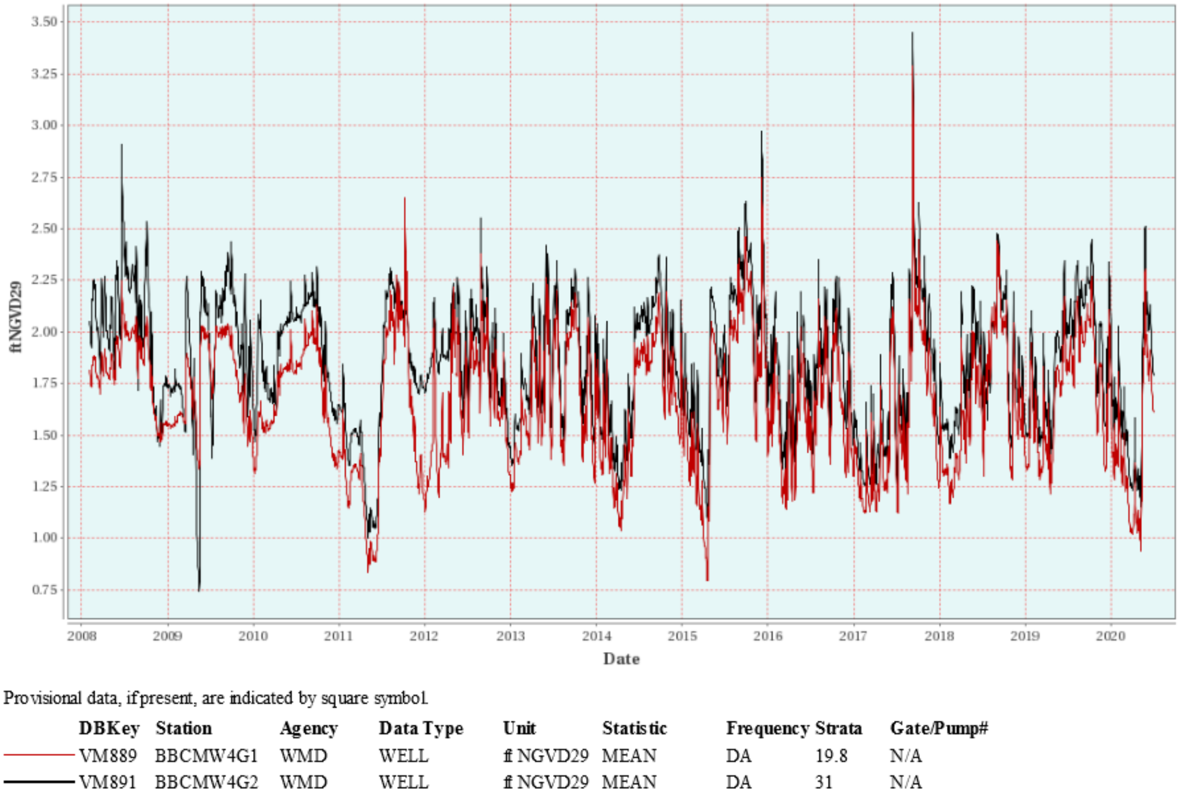
Each well has a brief period of record (February 4 to June 3, 2008) with daily mean values. The next period of record (February 4, 2008 to December 8, 2010) includes instantaneous breakpoint data and daily means for wells BBCMW3, BBCMW5G1/G2, and BBCMW6G1/G2. BBCMW1 and BBCMW2 have instantaneous breakpoint data from February 4, 2008 to December 31, 2012. BBCMW4G1/G2 are the only two monitor wells that continue to collect data at the time of this report and include both instantaneous breakpoint and daily mean values.

Table 4. Available information related to water level data in DBHYDRO.

DBKey	Station	Frequency	Statistic	Start Date	End Date	Strata (Well Depth) ft bls
W3842	BBCMW1	Daily	Mean	2/4/2008	6/3/2008	10.40
W3843	BBCMW2	Daily	Mean	2/4/2008	6/3/2008	10.45
W3844	BBCMW3	Daily	Mean	2/4/2008	6/3/2008	11.73
W3845	BBCMW4G1	Daily	Mean	2/4/2008	6/3/2008	19.80
W3846	BBCMW4G2	Daily	Mean	2/4/2008	6/3/2008	32.00
W3847	BBCMW5G1	Daily	Mean	2/4/2008	6/3/2008	20.00
W3848	BBCMW5G2	Daily	Mean	2/4/2008	6/3/2008	35.20
W3849	BBCMW6G1	Daily	Mean	2/4/2008	6/3/2008	14.00
W3850	BBCMW6G2	Daily	Mean	2/4/2008	6/3/2008	35.45
VM888	BBCMW3	Breakpoint	Instantaneous	2/4/2008	12/8/2010	11.73
VM887	BBCMW3	Daily	Mean	2/4/2008	12/8/2010	11.73
VM894	BBCMW5G1	Breakpoint	Instantaneous	2/4/2008	12/8/2010	20.00
VM893	BBCMW5G1	Daily	Mean	2/4/2008	12/8/2010	20.00
VM896	BBCMW5G2	Breakpoint	Instantaneous	2/4/2008	12/8/2010	35.20
VM895	BBCMW5G2	Daily	Mean	2/4/2008	12/8/2010	35.20
VM898	BBCMW6G1	Breakpoint	Instantaneous	2/4/2008	12/8/2010	14.00
VM897	BBCMW6G1	Daily	Mean	2/4/2008	12/8/2010	14.00
VM900	BBCMW6G2	Breakpoint	Instantaneous	2/4/2008	12/8/2010	35.45
VM899	BBCMW6G2	Daily	Mean	2/4/2008	12/8/2010	35.45
VM884	BBCMW1	Breakpoint	Instantaneous	2/4/2008	12/31/2012	10.40
VM883	BBCMW1	Daily	Mean	2/4/2008	12/31/2012	10.40
VM886	BBCMW2	Breakpoint	Instantaneous	2/4/2008	12/31/2012	10.45
VM885	BBCMW2	Daily	Mean	2/4/2008	12/31/2012	10.45
VM890	BBCMW4G1	Breakpoint	Instantaneous	2/4/2008	8/10/2020	19.80
VM889	BBCMW4G1	Daily	Mean	2/4/2008	8/10/2020	19.80
VM892	BBCMW4G2	Breakpoint	Instantaneous	2/4/2008	8/10/2020	31.00
VM891	BBCMW4G2	Daily	Mean	2/4/2008	8/10/2020	31.00

Time series graphs of the data discussed above can be generated through DBHYDRO. Several such graphs are shown below.

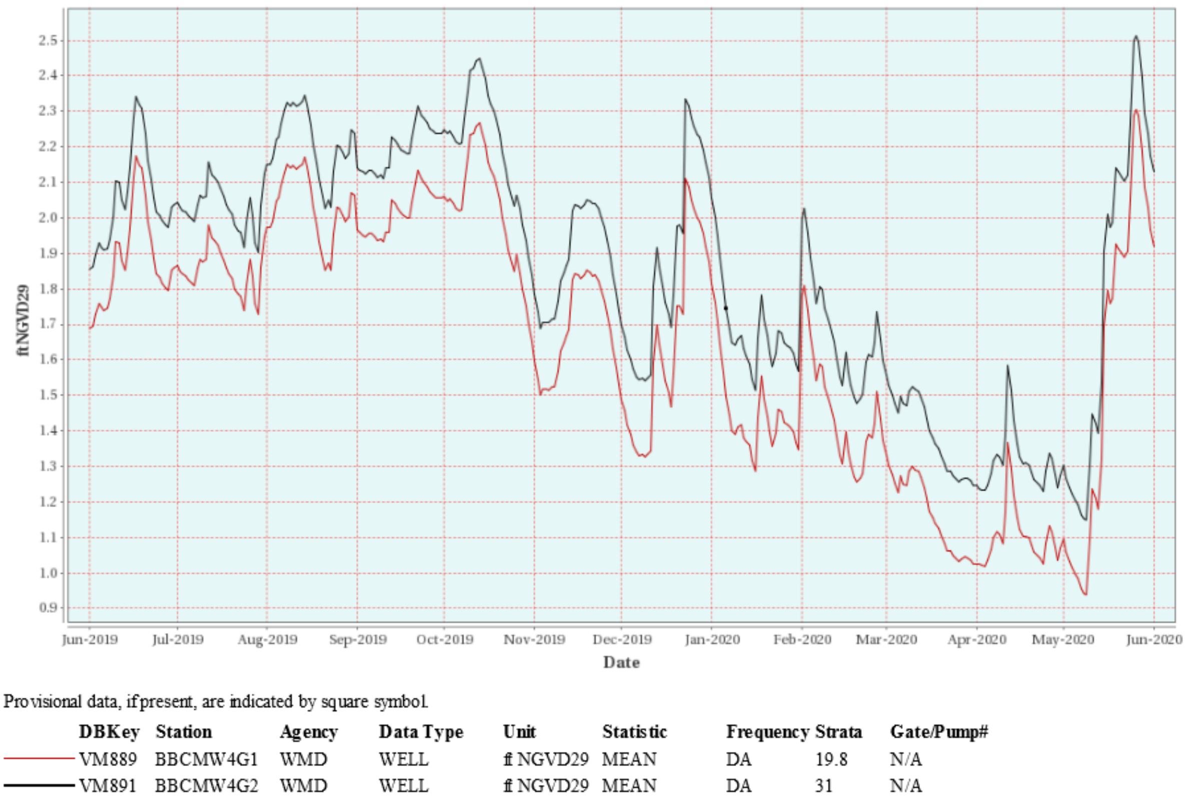
BBCMW4G1 and BBCMW4G2 are the paired well cluster with the longest period of record at the SDA site. BBCMW4G1 is completed to a depth of 19.8 ft bls, while BBCMW4G2 is completed to a depth of 31 ft bls. Hydrographs for these two wells are shown in **Figures 7** and **8**. **Figure 7** shows the full period of record, and the two wells show similar patterns of seasonal fluctuations. For a more detail examination of the two wells and the water levels, **Figure 8** shows a shorter time frame over a 1-year wet-dry season period (June 2019 to June 2020). This shows a continuous separation of the two water levels of approximately 0.20 feet, with the shallower well (BBCMW4G1) having the lower head.



Provisional data, if present, are indicated by square symbol.

	DBKey	Station	Agency	Data Type	Unit	Statistic	Frequency	Strata	Gate/Pump#
—	VM889	BBCMW4G1	WMD	WELL	ft NGVD29	MEAN	DA	19.8	N/A
—	VM891	BBCMW4G2	WMD	WELL	ft NGVD29	MEAN	DA	31	N/A

Figure 7. Period of record water levels for cluster wells BBCMW4G1 and BBCMW4G2.

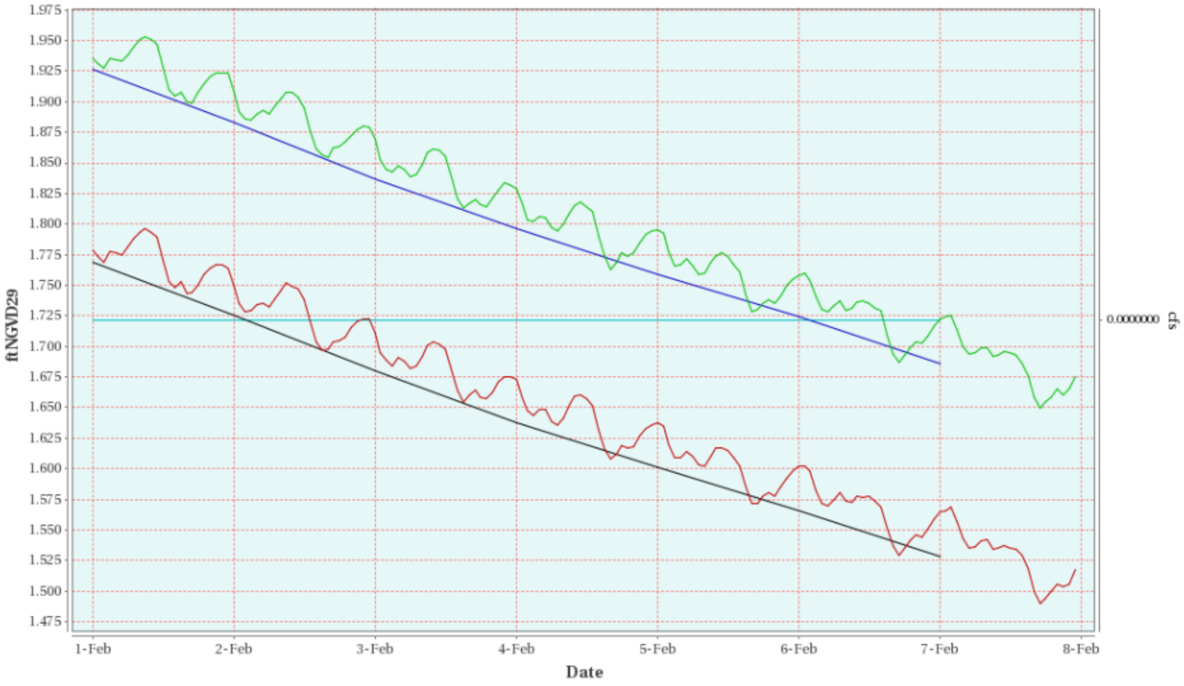


Provisional data, if present, are indicated by square symbol.

	DBKey	Station	Agency	Data Type	Unit	Statistic	Frequency	Strata	Gate/Pump#
—	VM889	BBCMW4G1	WMD	WELL	ft NGVD29	MEAN	DA	19.8	N/A
—	VM891	BBCMW4G2	WMD	WELL	ft NGVD29	MEAN	DA	31	N/A

Figure 8. Water levels for cluster wells BBCMW4G1 and BBCMW4G2 between June 2019 and June 2020.

Semidiurnal tidal fluctuations can be observed in BBCMW4G1/G2, as shown in **Figure 9**. During a period of no discharge through the S20G structure located on Military Canal (turquoise line = 0 cubic feet per second), tidal fluctuations can be observed over a 1-week period using the breakpoint data for the paired monitor wells, BBCMW4G1/G2 (red and green lines). While Biscayne Bay had a semidiurnal tidal fluctuation of approximately 2 ft in early February 2019, the semidiurnal fluctuation in the groundwater monitor wells is approximately 0.05 ft. **Figure 9** also shows that these daily fluctuations are only apparent by using the instantaneous data sets from DBHYDRO as the daily mean data obscure these subtle fluctuations.

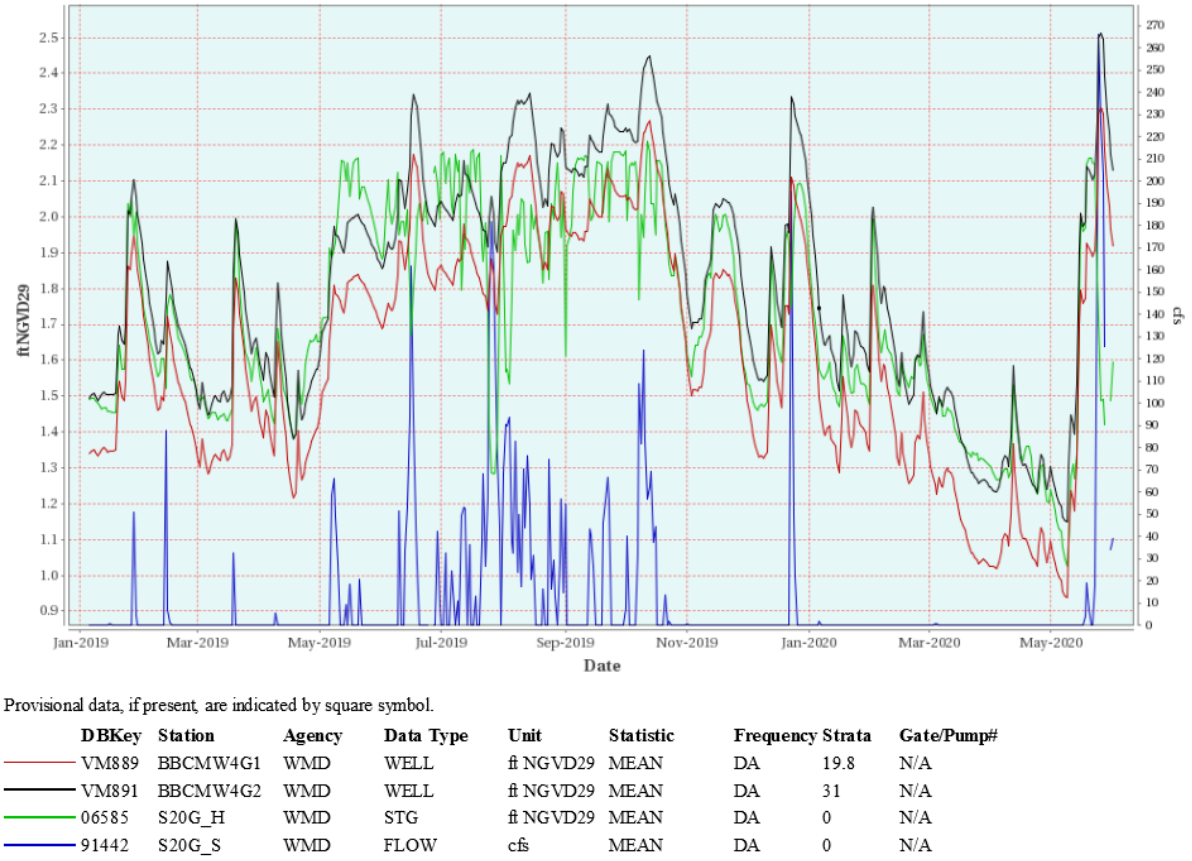


Provisional data, if present, are indicated by square symbol.

	DBKey	Station	Agency	Data Type	Unit	Statistic	Frequency	Strata	Gate/Pump#
—	VM890	BBCMW4G1	WMD	WELL	ft NGVD29	INST	BK	19.8	N/A
—	VM889	BBCMW4G1	WMD	WELL	ft NGVD29	MEAN	DA	19.8	N/A
—	VM892	BBCMW4G2	WMD	WELL	ft NGVD29	INST	BK	31	N/A
—	VM891	BBCMW4G2	WMD	WELL	ft NGVD29	MEAN	DA	31	N/A
—	91442	S20G_S	WMD	FLOW	cfs	MEAN	DA	0	N/A

Figure 9. Short-term semidiurnal tidal influence in BBCMW4G1/G2 during a no-flow period at the S20G structure.

Groundwater levels in BBCMW4G1/G2 were compared to the upstream stage elevation and discharge of the S20G structure (S20G_H and S20G_S, respectively; **Figure 10**). During periods without discharge, Military Canal stages closely reflect groundwater levels. Canal stages more closely track the deeper monitor well (BBCMW4G2), likely due to the canal depth. This may explain why the groundwater elevation of the deeper well is above the shallower well elevation. When discharge occurs through the S20G structure, canal stage elevation typically falls below the groundwater elevation by as much as 0.5 ft.

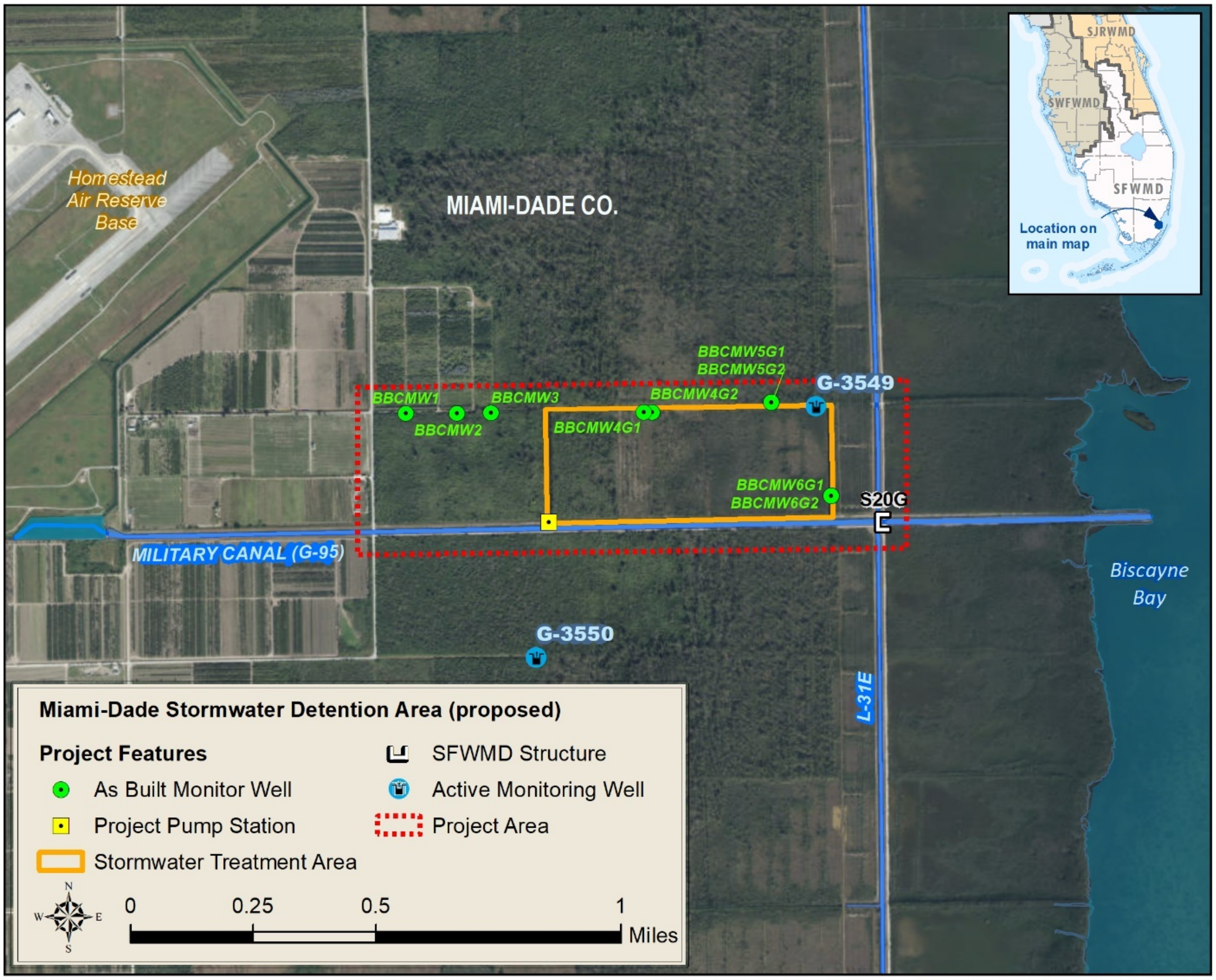


Provisional data, if present, are indicated by square symbol.

	DBKey	Station	Agency	Data Type	Unit	Statistic	Frequency	Strata	Gate/Pump#
—	VM889	BBCMW4G1	WMD	WELL	ft NGVD29	MEAN	DA	19.8	N/A
—	VM891	BBCMW4G2	WMD	WELL	ft NGVD29	MEAN	DA	31	N/A
—	06585	S20G_H	WMD	STG	ft NGVD29	MEAN	DA	0	N/A
—	91442	S20G_S	WMD	FLOW	cfs	MEAN	DA	0	N/A

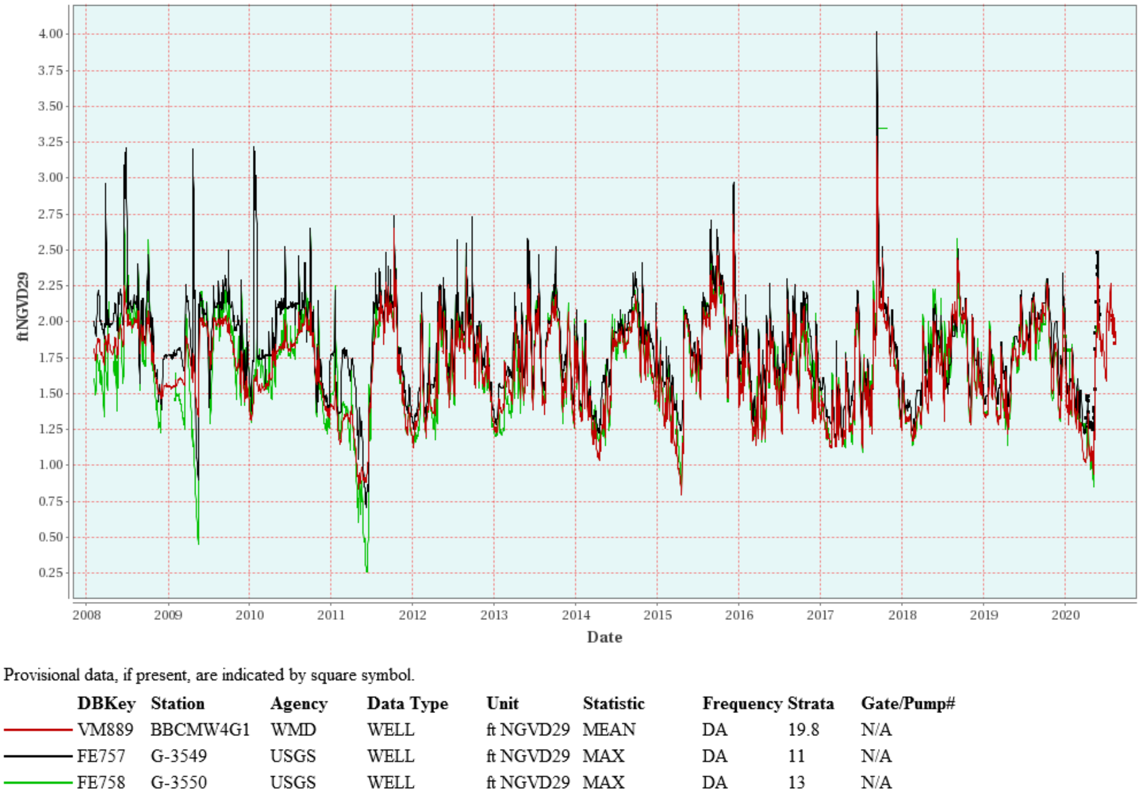
Figure 10. Groundwater level fluctuations in BBCMW4G1/G2 and canal stage during periods of discharge through the S20G structure.

For a more regional perspective, two USGS monitor wells with water level data were compared to monitor well BBCMW4G1. Wells G-3349 and G-3350 are within 1 mile of the SDA site and both monitor the same portion of the aquifer (**Figure 11**). The USGS wells follow the same general fluctuations and typically are within 0.01 ft of each other. **Figure 12** shows water levels over the period of record for all three wells, and **Figure 13** shows a closer examination of a 1-year wet-dry season period (June 2019 to June 2020). In general, groundwater level in BBCMW4G1 falls between the groundwater levels for the two USGS wells.



User Name: ahoffart Remedy Ticket: 126334 \\ad.sfwmd.gov\dfsroot\GS\GSBiz\WS\Wetlands\mxd\20201027_MDSWDA_WellSitesDBHydro.mxd

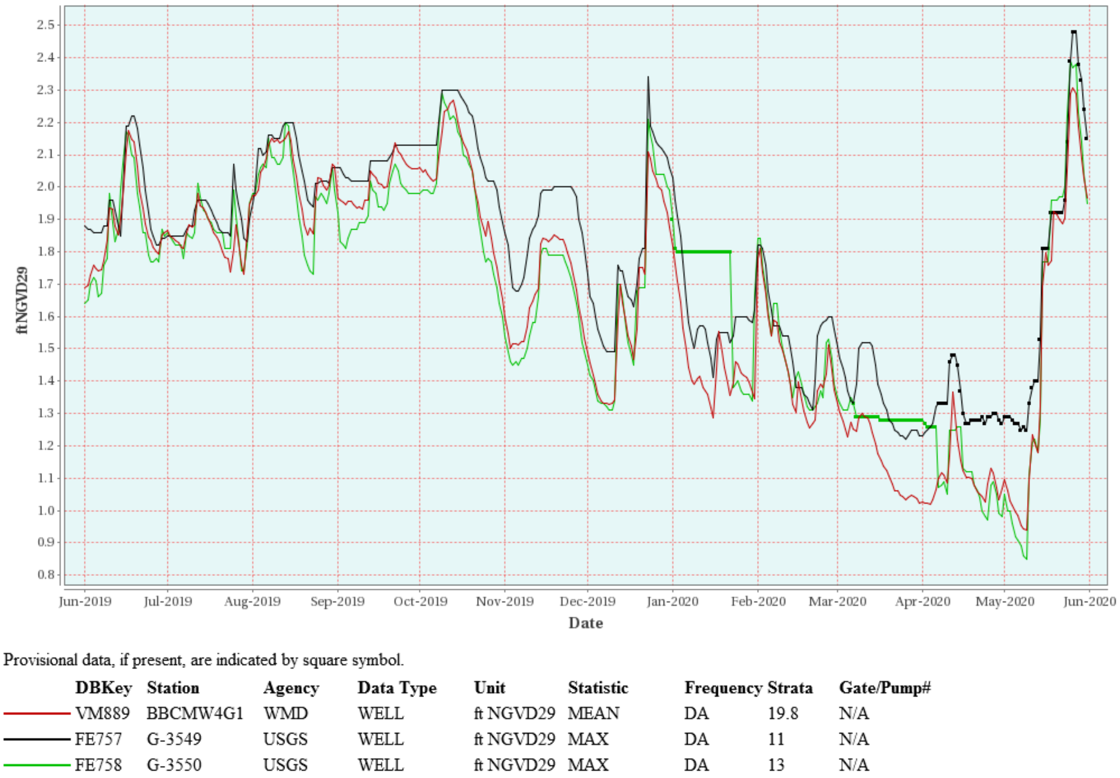
Figure 11. Location of active United States Geological Survey monitor wells near the proposed stormwater detention area.



Provisional data, if present, are indicated by square symbol.

	DBKey	Station	Agency	Data Type	Unit	Statistic	Frequency	Strata	Gate/Pump#
🟥	VM889	BBCMW4G1	WMD	WELL	ft NGVD29	MEAN	DA	19.8	N/A
⬛	FE757	G-3549	USGS	WELL	ft NGVD29	MAX	DA	11	N/A
🟩	FE758	G-3550	USGS	WELL	ft NGVD29	MAX	DA	13	N/A

Figure 12. Period of record water levels for wells BBCMW4G1, G-3549, and G-3550.



Provisional data, if present, are indicated by square symbol.

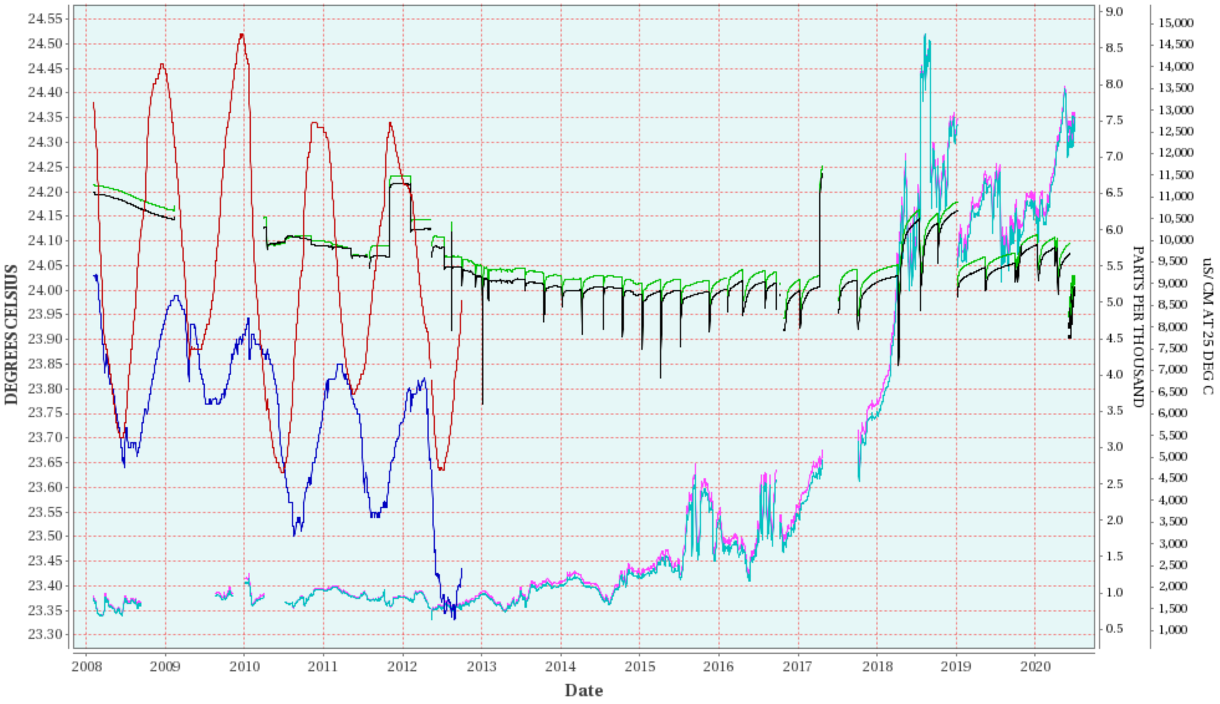
	DBKey	Station	Agency	Data Type	Unit	Statistic	Frequency	Strata	Gate/Pump#
🟥	VM889	BBCMW4G1	WMD	WELL	ft NGVD29	MEAN	DA	19.8	N/A
⬛	FE757	G-3549	USGS	WELL	ft NGVD29	MAX	DA	11	N/A
🟩	FE758	G-3550	USGS	WELL	ft NGVD29	MAX	DA	13	N/A

Figure 13. Water levels for wells BBCMW4G1, G-3549, and G-3550 between June 2019 and June 2020.

WATER QUALITY DATA

Water quality data are available for wells within the SDA. Temperature, salinity, and conductivity were collected on a continuous basis for BBCMW3, BBCMW6G1, BBCMW5G1, BBCMW5G2, and BBCMW6G2 from startup through December 2010. Wells BBCMW1 and BBCMW2 have continuous water quality data from startup through December 2012. Wells BBCMW4G1 and BBCMW4G2 have data available from startup to the time of this report.

Water quality data for the longest period of record are from BBCMW4G1/G2, shown in **Figure 14**. There was a significant increase in salinity and conductivity in BBCMW4G2 in mid-2017. Although conductivity in BBCMW4G1 was elevated (approximately 4,000 µS/cm) throughout the period of record, BBCMW4G2 had a relatively low conductivity (1,000 to 4,000 µS/cm) from 2008 to mid-2017 before it increased to almost 15,000 µS/cm in 2018. Groundwater temperature fluctuates seasonally, ranging from 23.6°C to 24.5°C in BBCMW4G1, and 23.3°C to 24°C in BBCMW4G2. Temperature data using breakpoint frequency are available through the time of this report; however, there were too many errors to represent the data on the graph.



Provisional data, if present, are indicated by square symbol.

	DBKey	Station	Agency	Data Type	Unit	Statistic	Frequency	Strata	Gate/Pump#
—	VM919	BBCMW4G1	WMD	H2OT	DEGREES CELSIUS	MEAN	DA	19.8	N/A
—	87453	BBCMW4G1	WMD	SALIN	PARTS PER THOUSAND	MEAN	DA	19.8	N/A
—	87452	BBCMW4G1	WMD	SCOND	uS/CM AT 25 DEG C	MEAN	DA	19.8	N/A
—	VM923	BBCMW4G2	WMD	H2OT	DEGREES CELSIUS	MEAN	DA	31	N/A
—	87455	BBCMW4G2	WMD	SALIN	PARTS PER THOUSAND	MEAN	DA	31	N/A
—	87454	BBCMW4G2	WMD	SCOND	uS/CM AT 25 DEG C	MEAN	DA	31	N/A

Figure 14. Water quality parameters for wells BBCMW4G1 and BBCMW4G2.

DISCUSSION AND CONCLUSIONS

DERM proposed to construct an SDA near Military Canal, east of the Homestead Air Reserve Base in Miami-Dade County. Working with DERM, the SFWMD planned to evaluate the hydrogeology and monitor water levels and seepage at the site. The proposed SDA was constructed but never became operational. However, the SFWMD collected data from the nine monitor wells constructed at the site.

Using geologic nomenclature for the Biscayne aquifer proposed by Perkins (1977) and supported by numerous subsequent investigations, data collected for this study are intended to support the Lower East Coast Sub-Regional (LECsR) MODFLOW model. Core samples and geophysical logs (e.g., OBI, caliper, fluid conductivity, temperature) were used to define marine units referred to by Perkins (1977) as Q (Quaternary) units.

Q1 through Q3 are within the Fort Thompson Formation, and Q4 and Q5 are within the Miami Limestone. Unit contacts are described from the OBI and accompanying and confirmed by core descriptions. Cavernous high-flow zones were identified at the base of Q4 (22 to 25 ft bls), representing the bottom of the Miami Limestone. The base of Q3 was identified at 39 to 40 ft bls within the Fort Thompson Formation. Underlying this unit is Q2 within the Fort Thompson Formation. However, it is not believed that the cores penetrated the entire extent of Q2.

Historical and current water level data are maintained in the District's DBHYDRO database. Water level data for BBCMW4G1/G2 continue to be collected. A separation of approximately 0.20 ft is observed, with the shallower well (BBCMW4G1) having the lower head. Nearby USGS wells that straddle the site north-to-south also straddle the groundwater level of BBCMW4G1. Semidiurnal fluctuations in the groundwater monitor wells of approximately 0.05 ft may be due to the influence of Biscayne Bay. During periods without discharge, Military Canal stages closely reflect groundwater levels. Canal stages more closely track the deeper monitor well (BBCMW4G2), likely due to the canal depth, and may explain why the groundwater elevation of the deeper well is above the shallower well elevation.

Water quality data, including temperature, salinity, and conductivity, are archived in the District's DBHYDRO database. Well BBCMW4G2 showed a significant increase in salinity and conductivity from 1,000 to 4,000 µS/cm between 2008 and mid-2017 to almost 15,000 µS/cm in 2018.

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APPENDIX A

SURVEYOR'S REPORT – SPECIFIC PURPOSE SURVEY OF THE WELLS AND OTHER FEATURES

SURVEYOR'S REPORT

Specific Purpose Survey of Wells and Other Features
Military Canal Wells
Miami-Dade County, Florida

South Florida Water Management District's
Purchase Order number 4500010364

Keith and Schnars project number 16434.00,
Task 22185
Report Date: July 2, 2007
Submittal: First

Prepared for:

South Florida Water Management District

Prepared by:

KEITH and SCHNARS, P.A.
ENGINEERS, PLANNERS, SURVEYORS

6500 N. Andrews Avenue
Ft. Lauderdale, Florida 33309-2132
Ph. (954) 776-1616 Fax (954) 351-7643
Licensed Business (L.B.) 1337

Surveyor's Report
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SURVEYOR’S CERTIFICATION

I hereby certify that this Specific Purpose Survey meets applicable portions of the Minimum Technical Standards set forth by the Florida Board of Professional Surveyors and Mappers in Chapter 61-G17, Florida Administrative Code. This report is prepared for the sole and specific use of the South Florida Water Management District and is not assignable.

KEITH and SCHNARS, PA.
L.B. number 1337

By:

Date of Survey
May 29, 2007

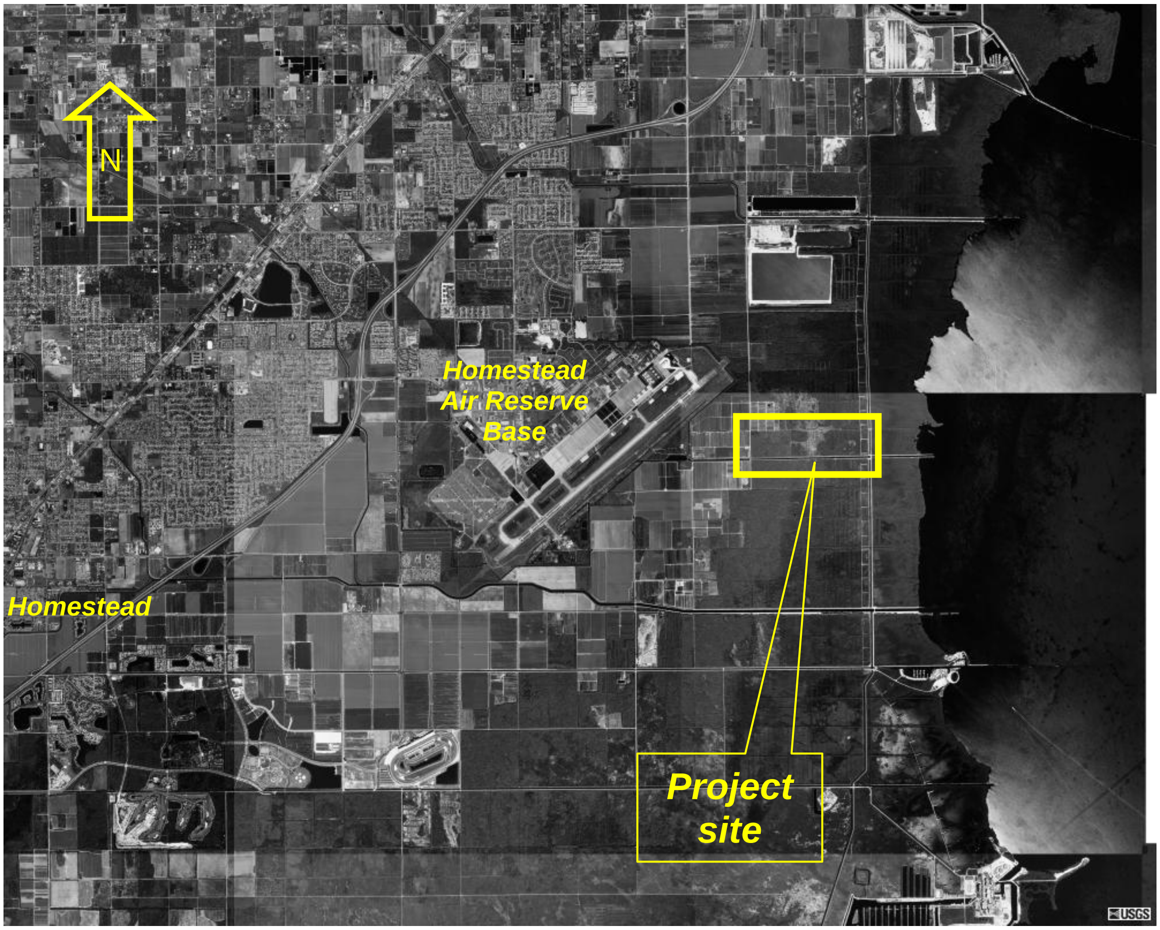
Loren J. Gibson, PSM
Professional Surveyor and Mapper
State of Florida
License No. 6510

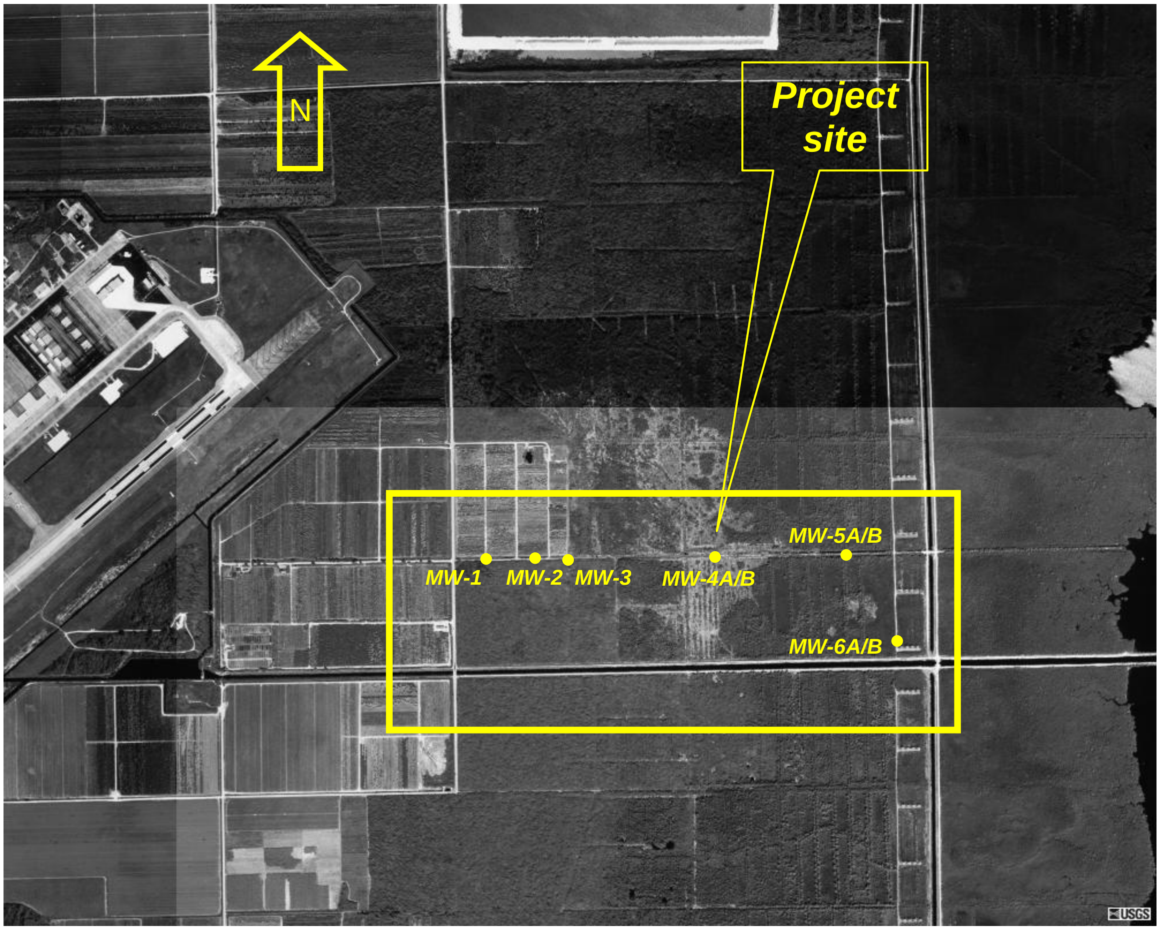
PURPOSE

This survey was done in order to determine the elevations of nine monitoring wells and of the ground adjacent to those wells. The elevation of a newly constructed bench mark at the site was also obtained. The well designations are MW-1, MW-2, MW-3, MW-4A, MW-4B, MW-5A, MW-5B, MW-6A, and MW-6B. The bench mark designation is MW4A, named similarly to one of the wells due to their proximity to each other.

LOCATION OF PROJECT

The approximate center of the project is located in Miami-Dade County, Florida, about 8 miles east-northeast of Homestead, approximately 1 mile southeast of the northeast end of the runway at the Homestead Air Reserve Base, and approximately 1 mile inland (west) of the Atlantic Ocean coast.





ITEMS DELIVERED TO THE DISTRICT

1. This Surveyor’s Report.
2. Microsoft® Office PowerPoint® file of the wells.
3. PDF file of all field notes.
4. CORPSMET-generated metadata files.
5. SFWMD bench mark data sheet (computer file)
6. Computer files for all office computations.

DATUMS FOR THE PROJECT

The elevation data is shown in this report with respect to both the North American Vertical Datum of 1988 (NAVD 88) and the National Geodetic Vertical Datum of 1929 (NGVD 29). NAVD 88 elevations were determined by differential leveling (see **LEVELING METHODS**, below) from bench mark R 724 (NGS PID AC1181), with a published elevation of 1.624 meters (5.328 feet). It also has a published NGVD 29 elevation of 2.089 meters (6.854 feet), which implies a datum shift between the two vertical datums of -0.465 meters (-1.526 feet). This value agrees with the datum shift computed by the NGS VERTCON algorithm and software (version 2.0, available at *http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html*, accessed for this survey

6/28/07), so the value of -1.526 feet was adopted for this survey. NGVD 29 elevations were computed by subtracting -1.526 feet from (*i.e.*, by adding 1.526 feet to) the adjusted NAVD 88 elevations.

The horizontal datum used for this survey is the North American Datum of 1983 (NAD 83), and positions expressed as geodetic latitude and longitude with respect to that datum.

The conversion between meters and feet for this project was governed by the definition of the U.S. Survey Foot: 1200 meters = 3937 U.S. Survey Feet, exactly.

LEVELING METHODS

Three-wire leveling observations were done using a Wild NA2 automatic optical level between bench mark R 724 (noted above), NGS bench mark R 725 (NGS PID AC1180), a newly placed site bench mark MW4A, and several temporary bench marks established on site (designated as "TP's" in the field notes and data files). The elevations of the wells were determined by subsequent single-wire differential leveling observations with the NA2 using the on-site temporary bench marks and MW4A. The maximum allowable misclosures (in units of feet) for the leveling observations were computed as $\pm 0.03\sqrt{M}$, where M is the length of the loop or section in miles.

Three-wire leveling was done from bench mark R 725 to R 724, and from R 724 back to R 725. The magnitude of the section misclosure for the forward and backward runs was 0.010 feet, less than the maximum allowable misclosure of 0.0347 feet. The mean difference in elevation obtained from the forward and backward runs (-0.090 feet from R 724 to R 725) differs from the difference in elevation implied by the published elevation (-0.069 feet) by 0.021 feet, which is also less than the allowable misclosure. Based on these results, there is no basis to conclude that these two bench marks and their published elevations are bad.

A closed three-wire leveling loop beginning at R 724, proceeding through several temporary bench marks and newly constructed site bench mark MW4A, and closing back on R 724 provided elevations on points in the immediate vicinity of the nine wells in this project. The magnitude of the loop misclosure was 0.0088 feet, which was less than the maximum allowable misclosure of 0.0462 feet. The differences in elevation in this loop were adjusted, and the adjusted elevations were subsequently used in the reduction of the single-wire leveling to determine the elevations of the wells and adjacent ground.

The datum point for the elevation on each of the nine wells is on the north edge of the PVC pipe, accessible through the bolted-down circular cover. Each has been so marked by ink.

HORIZONTAL POSITIONS

The latitudes and longitudes set out in this report were obtained by means of a hand-held GPS receiver.

RESULTS: ELEVATIONS, LATITUDES, AND LONGITUDES

Well designation	*Feature*	*NAVD 88 elevation (feet)*	*NGVD 29 elevation (feet)*	*NAD 83 Latitude*	*NAD 83 Longitude*
MW-1	Well	2.77	4.30	25°29'34"N	80°21'45"W
	Ground	2.68	4.21		
MW-2	Well	1.39	2.92	25°29'34"N	80°21'39"W
	Ground	1.71	3.24		
MW-3	Well	2.68	4.21	25°29'34"N	80°21'35"W
	Ground	2.44	3.97		
MW-4A	Well	3.50	5.02	25°29'34"N	80°21'16"W
	Ground	3.36	4.88		
	Site bench mark MW4A	3.66	5.18		
MW-4B	Well	3.21	4.73	25°29'34"N	80°21'17"W
	Ground	3.59	5.11		
MW-5A	Well	2.49	4.01	25°29'35"N	80°21'02"W
	Ground	2.87	4.39		
MW-5B	Well	2.64	4.16	25°29'35"N	80°21'02"W
	Ground	2.98	4.50		
MW-6A	Well	3.00	4.52	25°29'25"N	80°20'55"W
	Ground	3.33	4.85		
MW-6B	Well	3.07	4.59	25°29'25"N	80°20'55"W
	Ground	3.38	4.90		

APPENDIX A: ABBREVIATIONS

K&S: Keith and Schnars
L.B.: Licensed surveying and mapping business
NAD 83: North American Datum of 1983
NAVD 88: North American Vertical Datum of 1988
NGS: National Geodetic Survey
NGVD 29: National Geodetic Vertical Datum of 1929
PVC: Polyvinyl chloride
SFWMD: South Florida Water Management District

APPENDIX B: WELL PHOTOGRAPHS

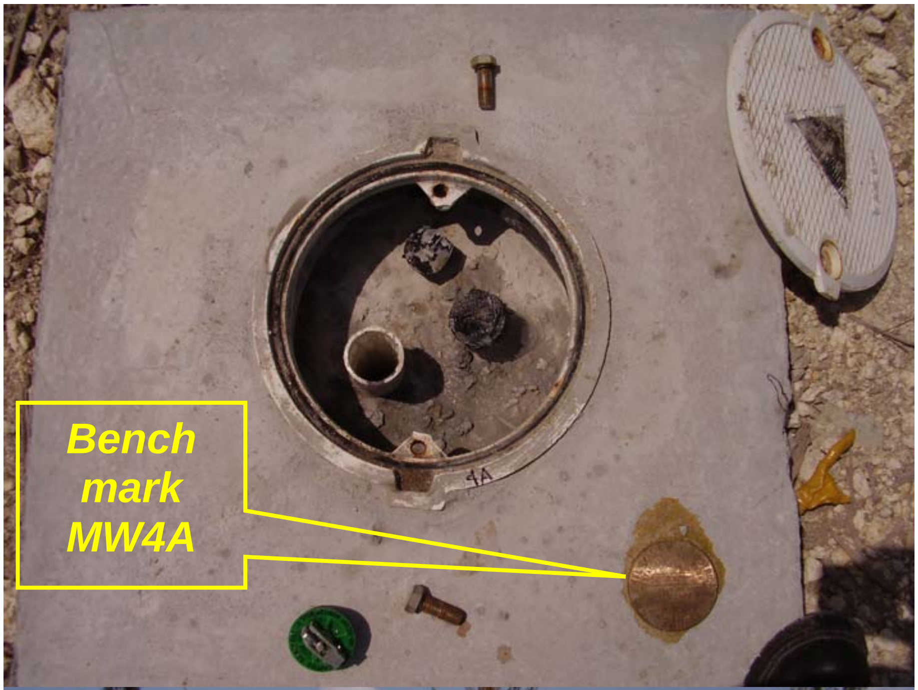
For all wells except MW-6A and MW-6B, the views shown in the following photographs are those seen by looking south at each site. For MW-6A and MW-6B, the views shown are those seen looking east.

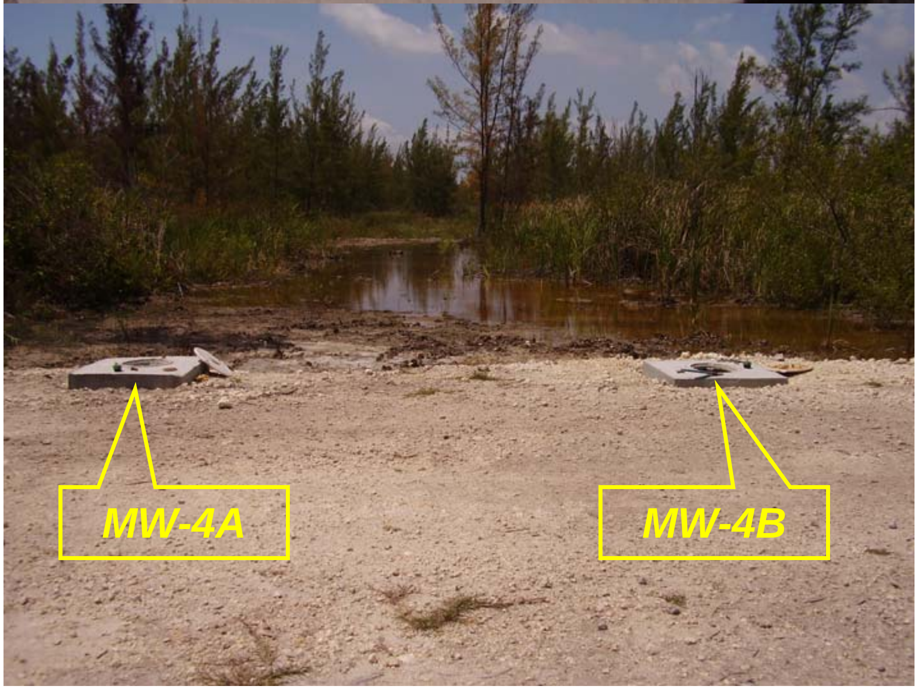
Well MW-1

Well MW-2

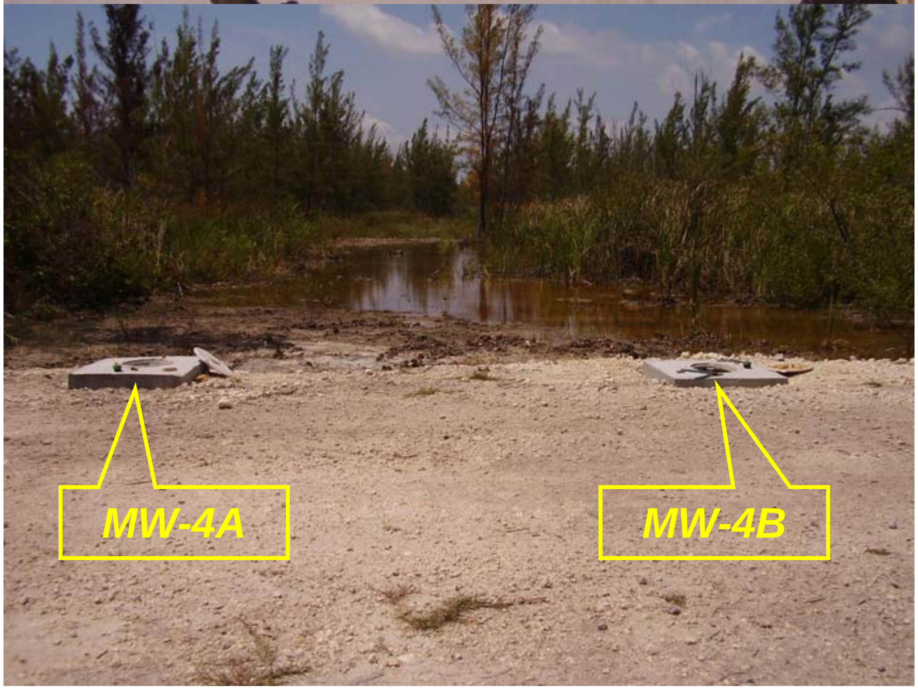
Well MW-3

Well MW-4A

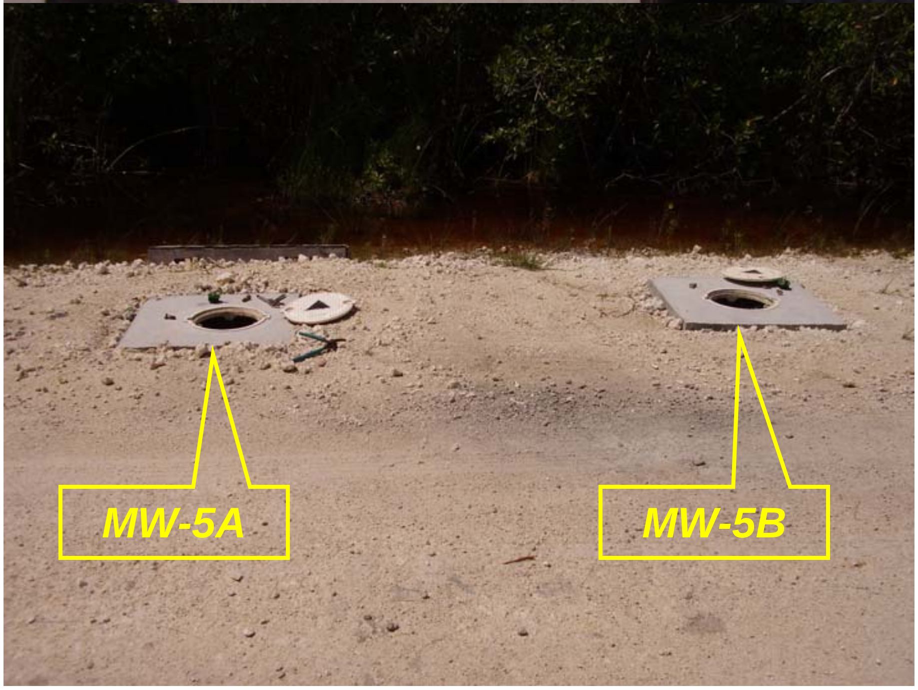




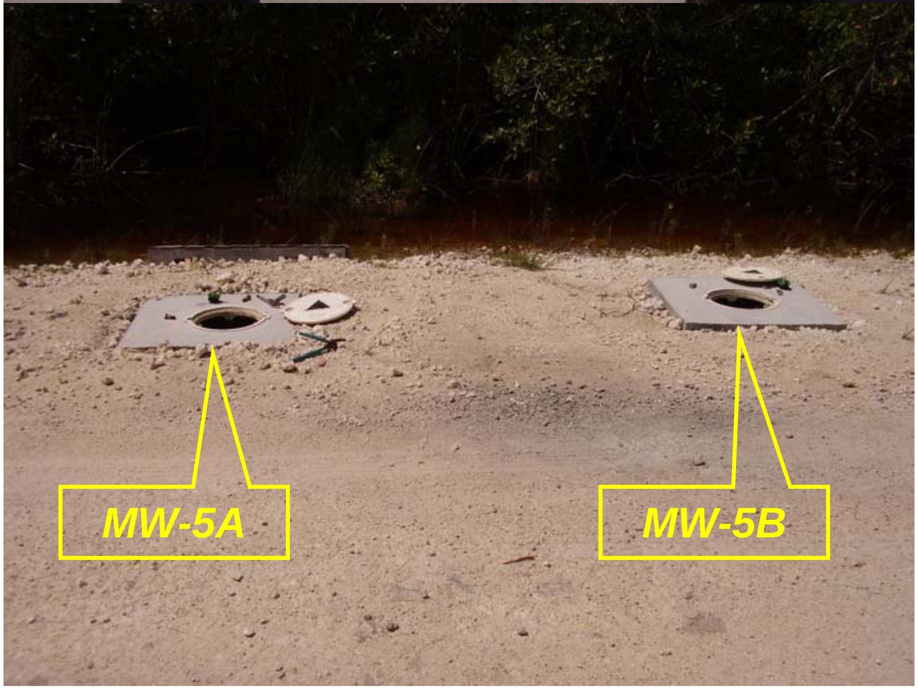
Well MW-4B



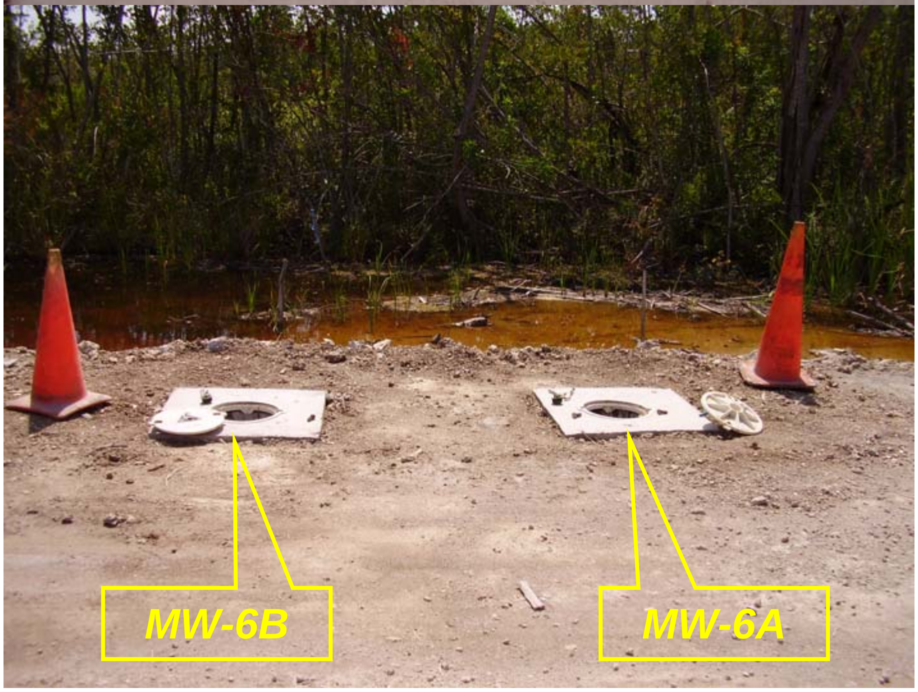
Well MW-5A



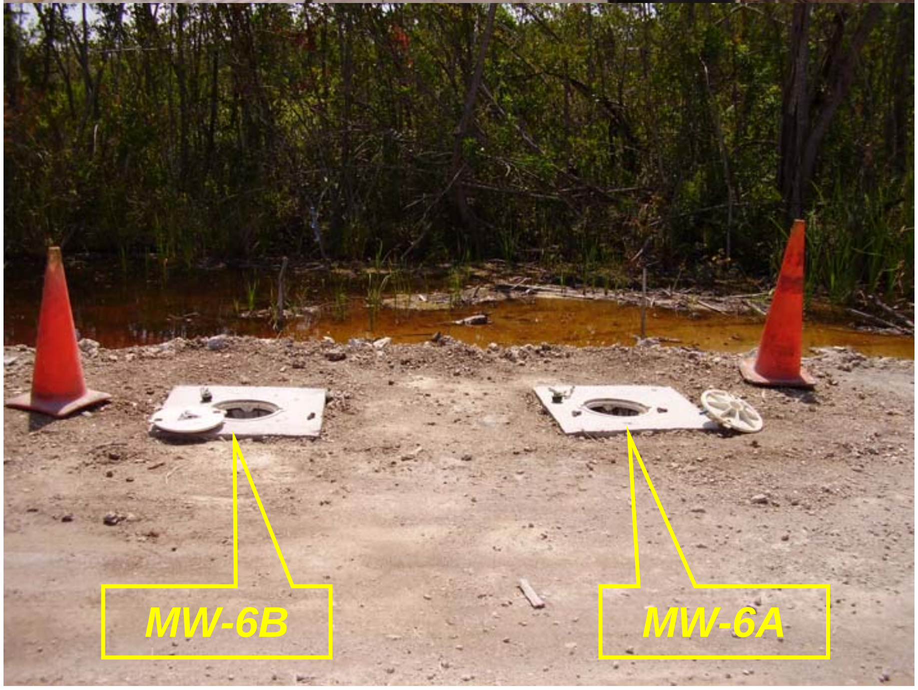
Well MW-5B



Well MW-6A

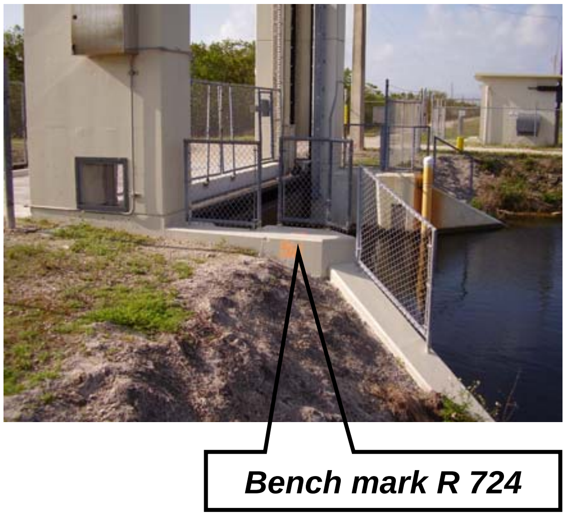


Well MW-6B



APPENDIX B: EXISTING CONTROL BENCH MARKS

The following data was extracted from the NGS data sheets, supplemented from on-site photographs.

<table>
<tr><td>R 724</td><td>Elevation:</td><td>NAVD 1988</td><td>5.328'</td><td>NGVD 1929</td><td>6.854'</td></tr>
<tr><td>PID AC1181</td><td>Latitude</td><td>25°29'21"
(Scaled)</td><td></td><td></td><td></td></tr>
<tr><td>State/County
FL/Miami-Dade</td><td>Longitude</td><td>80°20'48"
(Scaled)</td><td></td><td></td><td></td></tr>
<tr><td>USGS QUAD
Arsenicker Keys (1997)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Vertical Order Second
Class 0</td><td></td><td colspan="4" rowspan="2">Described by National Geodetic Survey 1970. 7.4 mi SE from Princeton, about 4.0 miles east along Coconut Palm Drive from the intersection of U.S. Highway 1 at Princeton, thence 3.4 miles south along a graveled road set on the top of the north abutment for the flood control gate across Military Canal, 26 feet south of the northwest corner of the hurricane fence around the flood control gate, 2.4 feet east of the west end of the abutment, 1.8 feet west of the west fence line around the gate and level with the ground.</td></tr>
<tr><td colspan="2">  </td></tr>
</table>

R 725	Elevation:	**NAVD 1988**	**5.259'**	**NGVD 1929**	**6.785'**
PID AC1180	Latitude	25°28'13" (Scaled)			
State/County FL/Miami-Dade	Longitude	80°20'49" (Scaled)			
USGS QUAD Arsenicker Keys (1997)					
Vertical Order Second Class 0		Described by National Geodetic Survey 1970. 8.7 mi SE from Princeton, about 4.0 miles East along Coconut Palm Drive from the intersection of U.S. Highway 1 at Princeton, thence 4.7 miles south along a graveled road, set on the top of the west end of the south concrete abutment for the flood control gates over Mowry Canal, 2.3 feet northwest of the southwest corner of the hurricane fence around the gates, 2.3 feet east of the west end of the abutment, 18 1/2 feet west of the center line of a road at south entrance to gates for flood control gates and level with the ground.			
  **_Bench mark R 725_**					

APPENDIX B
GEOLOGIC DESCRIPTIONS

Geologic Description – BBCWMW6G2

Recorded by Steven Krupa on April 10, 2007

Depth (ft bls)	Description (Field Notes)
8-13	Highly weathered Miami Limestone. First solid sample at 13 ft bls. Core is highly weathered with vertical solution features evident. Milky white.
13-14	Limestone, weathered with secondary deposits on outside, shelly.
14-15	First competent core with no weathering, vertical solution present.
15-17	Partial coral skeletons with vertical solution/shrimp burrows.
17-23	Highly solutioned with lots of lose rounded limestone chips.
23-28	Upper 10 inches loose limestone fragments remain. Core competent down to 29 ft bls.
28-29	Very dense white limestone. Vertical solutioning. Very high tortuosity. Broken at twist.
29-31.5	Very dense limestone, white.
31.5-33	Limestone slightly weathered or solutioned. More horizontal solutioning.
33-38	Incredible solutions vertical and horizontal. Very competent sample over 2.5 ft long. Lot of calcite crystals.
38-40	Limestone, white, very dense more horizontal than vertical solutioning. Lots of calcite.
40-43	At 40 ft bls spectacular calcite deposit with dense limestone large white calcite crystals.
43-44	At 43 ft bls dense white limestone. At 44 ft bls horizontal solution feature.
44-48	Very dense white limestone with mollusk casts cut in half.
48-49.5	White limestone, dense.
49.5-53	White limestone, dense, shells, vuggy with some shell casts.
53-58	Limestone parts/fragments. One small 4-inch core segment with shell casts. Horizontal solution feature in core.
58-63	Broken white limestone pieces, shell fragments 4-inch solid core.
63-65	No recovery. Sand or unconsolidated limestone.

ft bls = feet below land surface.

Geologic description of well G-3317 (From: Fish and Stewart 1991; Plate 4 D-D').

Unit	Depth (ft bls)	Depth (ft bls)	Hydraulic Conductivity (ft/day)	Description
	0-10			Fill
Qm	10-32		>1,000	Miami Oolite-oolitic limestone grading to a shelly limestone
Qf	32-71			Fort Thompson limestone
		32-50		Sandy shelly limestone
		50-64	10-100	Sandy limestone
Qk	71-95		>1,000	Key Largo Limestone-limestone with sand and shell
Tt	95-176		0.1-10	Tamiami Formation
		95-100		Shelly limestone
		100-130		Silt and claystone
		130-149		Sandy limestone
		149-155		Sandstone
		155-160	10-100	Silt and claystone BASE OF BISCAYNE AQUIFER
		160-164	≤0.10	Silty clayey limestone

ft bls = feet below land surface.

Geologic description of well G-3321 (From: Fish and Stewart 1991; Plate 5 E-E’).

Unit	Depth (ft bls)	Depth (ft bls)	Hydraulic Conductivity (ft/day)	Description
Ql	0-10			Fill
Qm	10-35			Miami Oolite
		10-29		
		29-32		Oolitic limestone grading to a shelly limestone
		32-35		Sandy shelly limestone
Qf	35-62			Fort Thompson limestone
		35-45		Sandy shelly limestone
		45-52		Shelly limestone
		52-62	10-100	Sandy limestone
Tt	62-179			Tamiami Formation
		62-70		Sandy shelly limestone
		70-80	100-1,000	Shelly limestone
		80-110		Sandy shelly limestone
		110-116		Sandstone with shell
		116-120	10-100	Sandstone with shell and concretions
		120-122	100-1,000	Sandstone with shell
		122-128	0.1-10	
		128-135	100-1,000	
		135-140	0.1-10	
		140-158	10-100	
		158-167	0.1-10	
		167-173	10-100	Base of Biscayne aquifer
		173-179	0.1-10	

ft bls = feet below land surface.

APPENDIX C
SOIL BORING AND WELL CONSTRUCTION LOGS FROM CHALLENGE ENGINEERING & TESTING, NOVEMBER 2006

SOILS TEST CORE
BORING NUMBER
CP04-BCBCW-CB-0003

Core Boring Log
Well Construction Logs
Reference Sample Photographs

Boring Designation CP04-BCBCW-CB-0003

DRILLING LOG

DIVISION South Atlantic

INSTALLATION Jacksonville District

SHEET 1 OF 3 SHEETS

1. PROJECT CERP Biscayne Bay Coastal Wetlands Model Validation Wells
2. BORING DESIGNATION CP04-BCBCW-CB-0003 LOCATION COORDINATES X = 871,342 Y = 426,013
3. DRILLING AGENCY Challenge Engineering & Testing, Inc. CONTRACTOR FILE NO.
4. NAME OF DRILLER Adam Benson
5. DIRECTION OF BORING ☒ VERTICAL ☐ INCLINED DEG. FROM VERTICAL BEARING
6. THICKNESS OF OVERBURDEN N/A
7. DEPTH DRILLED INTO ROCK N/A
8. TOTAL DEPTH OF BORING 45.0 Ft.
9. SIZE AND TYPE OF BIT See Remarks
10. COORDINATE SYSTEM/DATUM State Plane, FLE (U.S. Ft.) HORIZONTAL NAD83 VERTICAL NGVD29
11. MANUFACTURER'S DESIGNATION OF DRILL CME-55 ☐ AUTO HAMMER ☒ MANUAL HAMMER
12. TOTAL SAMPLES DISTURBED 19 UNDISTURBED (UD) 0
13. TOTAL NUMBER CORE BOXES 3
14. ELEVATION GROUND WATER 1.5 Ft.
15. DATE BORING STARTED 08-05-04 COMPLETED 08-05-04
16. ELEVATION TOP OF BORING 2.4 Ft.
17. TOTAL RECOVERY FOR BORING 70 %
18. SIGNATURE AND TITLE OF INSPECTOR Bob Momberger, Geologist

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE
2.4	0.0						2.4		
			LIMESTONE, fossiliferous, moderately hard, aphanitic, porous, sand filled pores, Levee Roadway Fill, cream ▼	50	1		SPT Sampler 0.9	28 9 10	19
				50	2		SPT Sampler -0.6	9 9 13	22
-1.9	4.3			60	3		SPT Sampler -2.1	15 18 12	30
-2.1	4.5	Moderately Weathered	PEAT, nonplastic, some wood debris, some silt, strong reaction with HCl, wet, brown (PT) LIMESTONE, oolitic, soft, moderately weathered, aphanitic, vuggy, sand filled vugs, Miami Oolitic Formation, cream - light gray	93	4		SPT Sampler -3.6	28 27 17	44
				75	1	RQD 33	4 x 5-1/2" Diamond Impregnated Bit DT = 1 mins HP = 400 psi DFR = 50 % -7.6		
				45	BOX 1 2	RQD 0	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 25 % -12.6		

SAJ FORM 1836
JUN 02

(Continued)

Boring Designation CP04-BCBCW-CB-0003

DRILLING LOG (Cont. Sheet)

INSTALLATION: Jacksonville District

SHEET 2 OF 3 SHEETS

PROJECT: CERP Biscayne Bay Coastal Wetlands

COORDINATE SYSTEM/DATUM: State Plane, FLE (U.S. Ft.)

HORIZONTAL: NAD83

VERTICAL: NGVD29

LOCATION COORDINATES: X = 871,342 Y = 426,013

ELEVATION TOP OF BORING: 2.4 Ft.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE	
		Moderately Weathered		67	5		SPT Sampler -14.1	29 18 5	23	15
				50	6		SPT Sampler -15.6	12 13 5	18	
				47	7		SPT Sampler -17.1	5 3 1	4	
-18.6	21.0			60	8		SPT Sampler -18.6	2 1 1	2	20
-19.6	22.0		SAND, poorly-graded, mostly fine-grained sand-sized quartz, some fine-grained sand-sized carbonate, strong reaction with HCl, wet, cream white (SP) LIMESTONE, oolitic, soft, aphanitic, vuggy, sand filled vugs, light gray	47	9		SPT Sampler -20.1	12 1 1	2	
				53	10		SPT Sampler -21.6	3 5 10	15	
				53	11		SPT Sampler -23.1	4 5 10	15	25
-23.6 -24.6	26.0 27.0		SAND, poorly-graded, mostly fine-grained sand-sized quartz, some fine-grained sand-sized carbonate, strong reaction with HCl, wet, light gray (SP)	87	12		SPT Sampler -24.6	13 8 13	21	
		Moderately Weathered	LIMESTONE, fossiliferous, moderately hard, moderately weathered, aphanitic, thick bedding, vuggy, sand filled vugs, Ft. Thompson Formation, white	1400	13		-24.7 SPT Sampler	50/0.1'		
				60	BOX 1 3	RQD 33	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 % -27.6			30
				100	BOX 2 4	RQD 50	4 x 5-1/2" Diamond Impregnated Bit DT = 3 mins HP = 400 psi DFR = 0 % -32.6			35

Boring Designation CP04-BCBCW-CB-0003

DRILLING LOG (Cont. Sheet)	INSTALLATION Jacksonville District	SHEET 3 OF 3 SHEETS

PROJECT CERP Biscayne Bay Coastal Wetlands	COORDINATE SYSTEM/DATUM State Plane, FLE (U.S. Ft.)	HORIZONTAL NAD83	VERTICAL NGVD29
LOCATION COORDINATES X = 871,342 Y = 426,013	ELEVATION TOP OF BORING 2.4 Ft.		

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE
-39.6	42.0	Moderately Weathered	At El. -32.6 Ft., light gray-whitte	100	BOX 2 5	RQD 67	4 x 5-1/2" Diamond Impregnated Bit DT = 3 mins HP = 400 psi DFR = 0 % -37.6		
-42.6	45.0		SAND, poorly-graded, mostly medium-grained sand-sized quartz, some fine-grained sand-sized carbonate, strong reaction with HCl, wet, light gray (SP)	46	BOX 3 6	RQD 25	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 % -42.6		
			NOTES: 1. Soils are field visually classified in accordance with the Unified Soils Classification System. 2. Monitoring Well Designated CP04-BCBCW-CB-0003 Installed In This Boring: Top of 2" Well Casing @ 2.36 Ft.				140# hammer w/30" drop used with 2.0' split spoon (1-3/8" I.D. x 2" O.D.). Abbreviations: DT = Drill Time. HP = Hydraulic Pressure. DFR = Drill Fluid Return.		

35 40 45 50 55

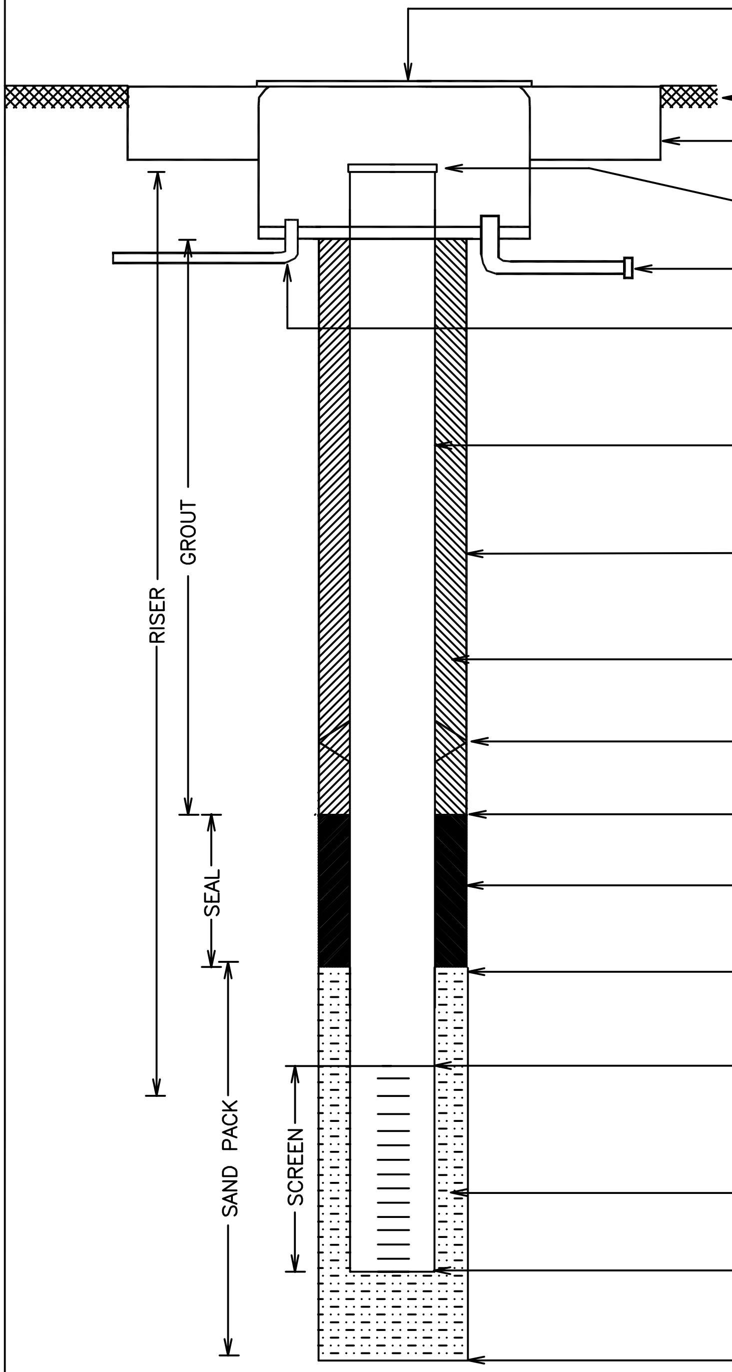
SAJ FORM 1836-A
JUN 02

CHALLENGE
ENGINEERING & TESTING, INC.
4234 HALLS MILL ROAD, MOBILE, ALABAMA 36693 (251) 666-1435

MONITORING WELL CONSTRUCTION LOG

PROJECT: **BISCAYNE BAY COASTAL WETLANDS SEEPAGE STUDY**
LOCATION: **BISCAYNE BAY-MIAMI DADE COUNTY, FL**
BORING: **CP04-BCBCW-CB-0003**
CHALLENGE JOB NO.: **2004D21**
DATE: **SEPTEMBER 2004**

DRILLER: **ADAM BENSON**
DRILLING METHOD: **4" WIRELINE CORING SYSTEM**
DEVELOPMENT METHOD: **PUMPING**
GROUND ELEVATION: **2.40 FT NGVD29**
FIELD GEOLOGIST: **BOB MOMBERGER, P.G.**



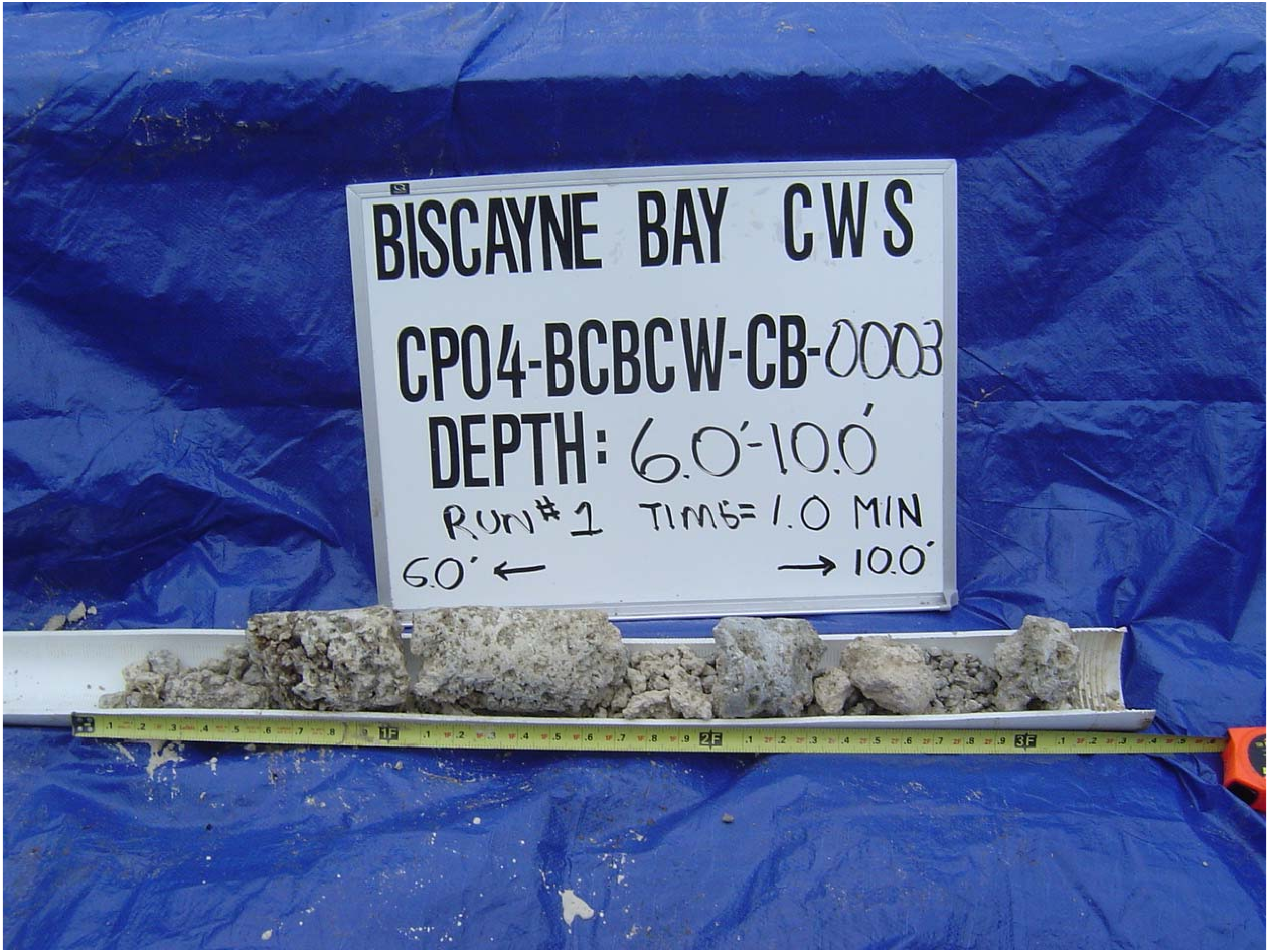
BOLT DOWN COVER: **MANHOLE COVER 12" DIAMETER PAINTED RED**
GROUND SURFACE: **2.40 FT**
3' X 3' X 6" CONCRETE PAD
LOCKING TOP CAP WITH MASTER LOCK
TOP OF CASING = 2.36 FT.
1" CONDUIT PIPING
3/4" DRAIN PIPE
RISER PIPE: **2" TRILOC PVC THREADED PIPE**
BOREHOLE DIAMETER: **5 3/4"**
TYPE OF BACKFILL: **GROUT/BENTONITE**
CENTRALIZERS: **STAINLESS STEEL**
ELEVATION/DEPTH TOP OF SEAL: **-35.31 FT**
TYPE OF SEAL: **BENTONITE 3/8" PELLETS**
ELEVATION TOP OF SAND PACK: **-37.31 FT**
ELEVATION/DEPTH TOP OF SCREEN: **-38.31 FT**
SCREEN: **2" x 0.020" x 2.5 FT THREADED (2 FT SCREEN / .5 FT JOINT)**
SAND PACK: **16/10 GRADED SAND**
ELEVATION/DEPTH BOTTOM OF SCREEN: **-40.81 FT**
ELEVATION BOTTOM OF HOLE: **-42.60 FT**


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 0.0-1.5'


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 1.5-3.0'
2F
1F


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 3.0-4.5'


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 4.5-6.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 6.0'-10.0'
RUN# 1 TIME=1.0 MIN
6.0' ←
→ 10.0'
1F
2F
3F


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 10.0'-15.0'
RUN# 2 TIME=2.0 MIN
10.0' ←
→ 15.0'
1F
2F


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 15.0'-16.5'
S-5


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 16.5-18.0'
S-6

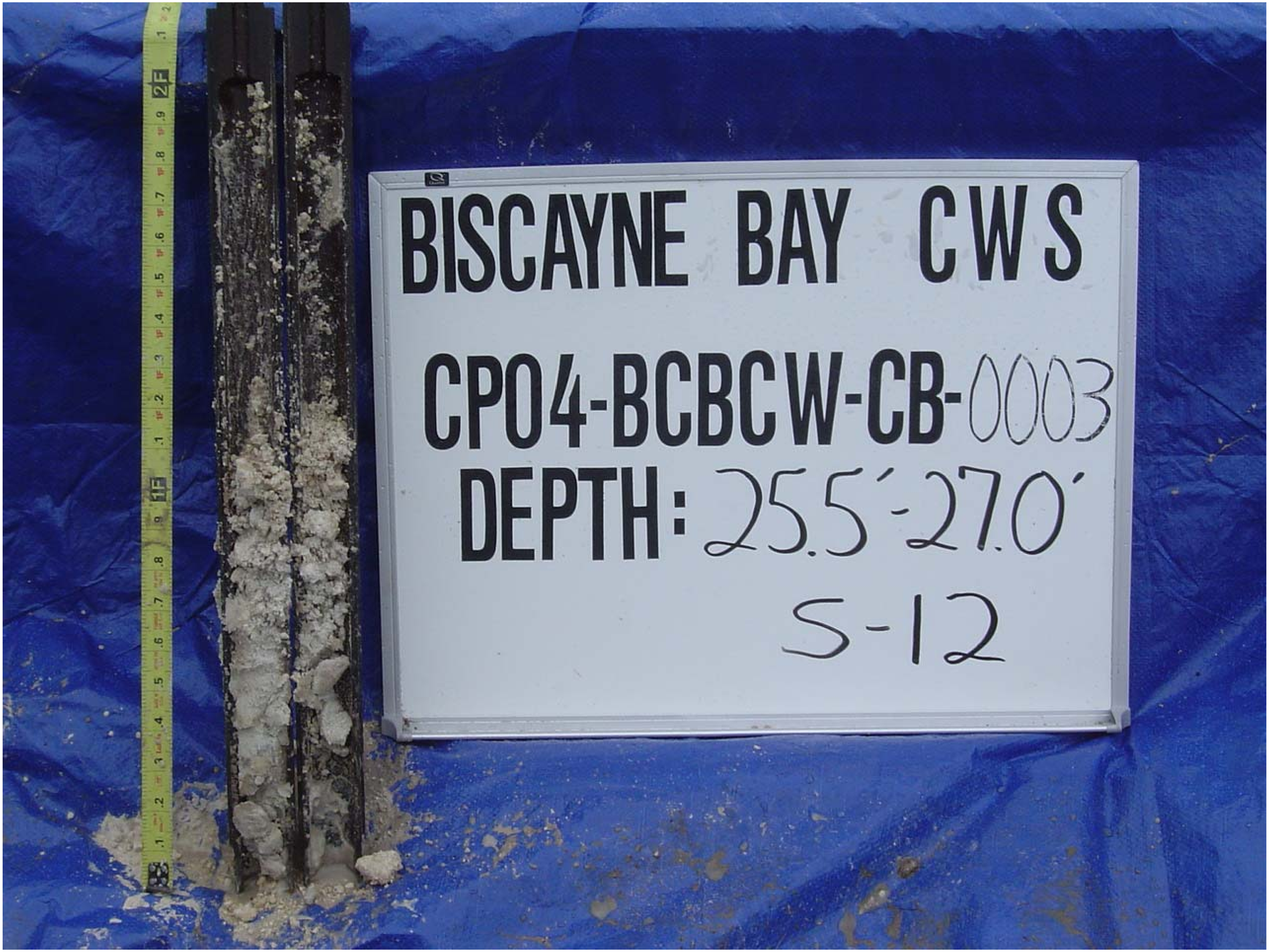

BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 18.0-19.5'
S-7

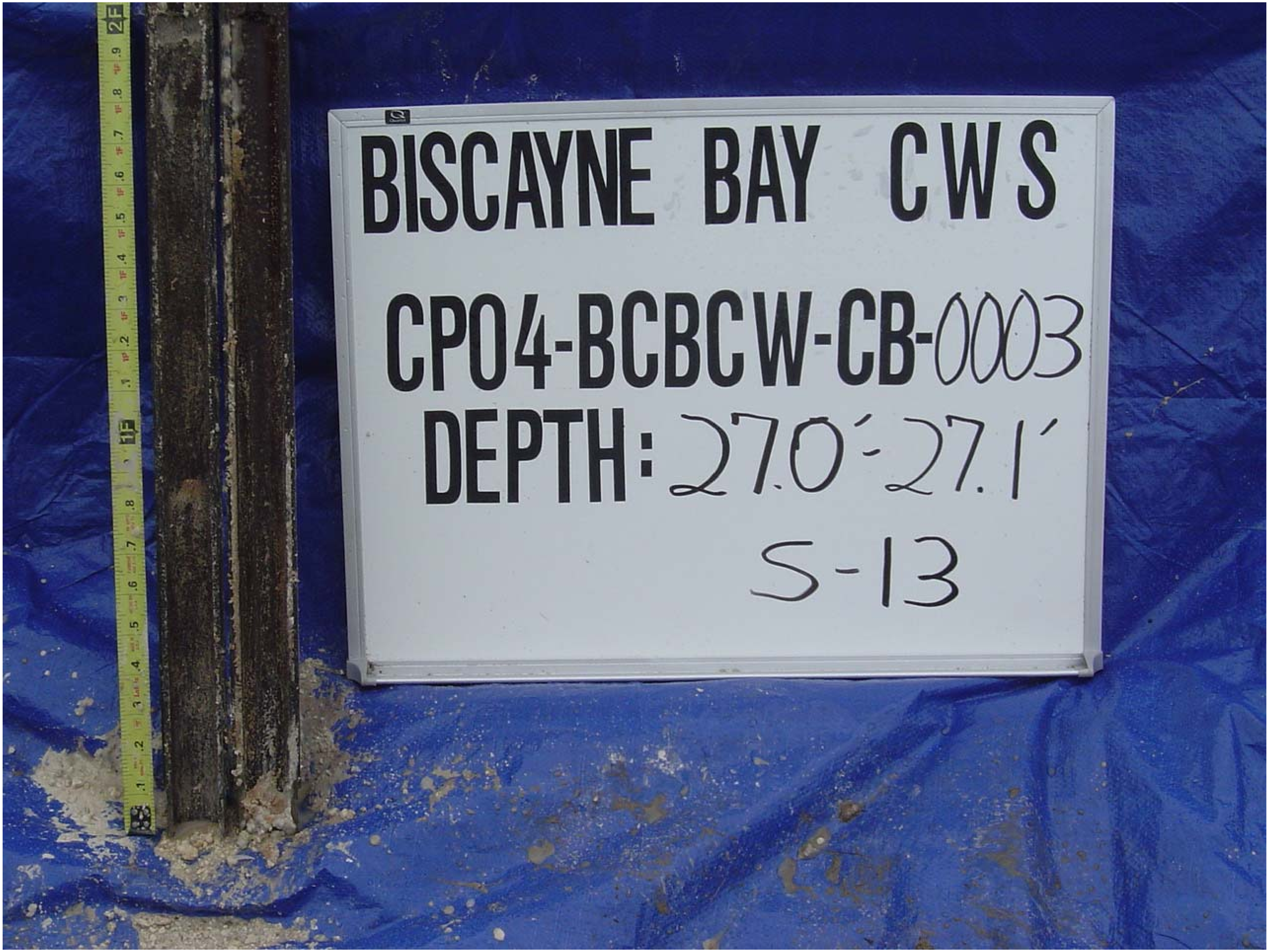

BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 19.5'-21.0'
S-8

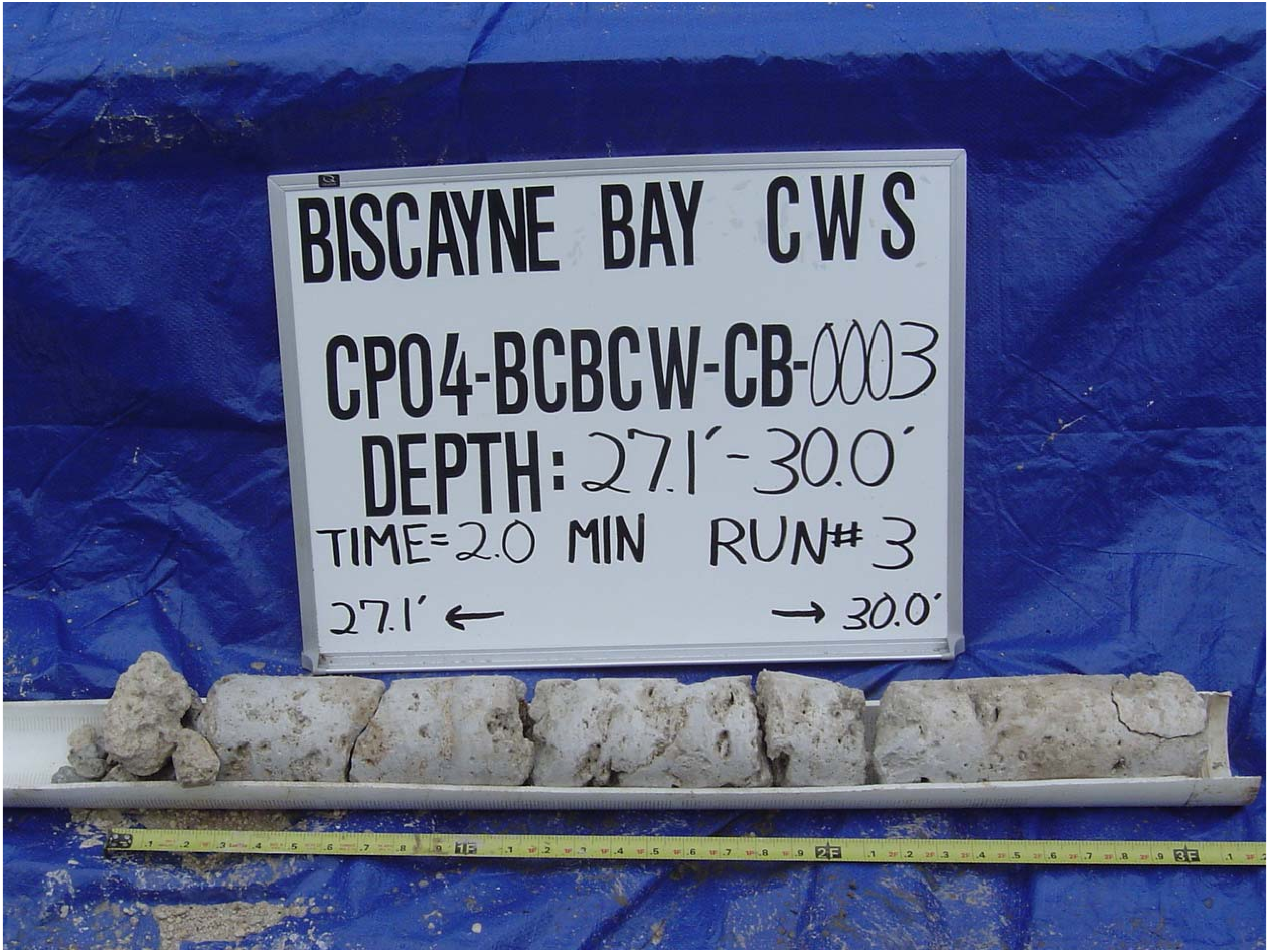

BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 21.0'-22.5'
S-9
2F
1F


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 22.5'-24.0'
S-10
2F
1F


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 24.0'-25.5'
S-11


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 25.5'-27.0'
S-12


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 27.0'-27.1'
S-13
2F
1F


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 27.1´-30.0´
TIME=2.0 MIN RUN# 3
27.1´ ←
→ 30.0´
1F
2F
3F


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 30.0´-35.0´
TIME=2.85 MIN RUN#4
30.0´ ←
→ 35.0´

BISCAYNE BAY CWS

CP04-BCBCW-CB-0003

DEPTH: 35.0'-40.0'

TIME=2.66 MIN RUN# 5

35.0' ← → 40.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-0003
DEPTH: 40.0'-45.0'
TIME= 1.2 MIN RUN# 6
40.0' ←
→ 45.0'
1F
2F

SOILS TEST CORE
BORING NUMBER
CP04-BCBCW-CB-0005A

Core Boring Log
Well Construction Logs
Reference Sample Photographs

Boring Designation CP04-BCBCW-CB-0005A

DRILLING LOG	DIVISION South Atlantic	INSTALLATION Jacksonville District	SHEET 1 OF 3 SHEETS

1. PROJECT
CERP Biscayne Bay Coastal Wetlands
Model Validation Wells
2. BORING DESIGNATION: CP04-BCBCW-CB-0005A
LOCATION COORDINATES: X = 860,821 Y = 419,086
3. DRILLING AGENCY: Challenge Engineering & Testing, Inc.
CONTRACTOR FILE NO.:
4. NAME OF DRILLER: Adam Benson
5. DIRECTION OF BORING: ☒ VERTICAL ☐ INCLINED
DEG. FROM VERTICAL:
BEARING:
6. THICKNESS OF OVERBURDEN: N/A
7. DEPTH DRILLED INTO ROCK: N/A
8. TOTAL DEPTH OF BORING: 45.0 Ft.
9. SIZE AND TYPE OF BIT: See Remarks
10. COORDINATE SYSTEM/DATUM: State Plane, FLE (U.S. Ft.) HORIZONTAL: NAD83 VERTICAL: NGVD29
11. MANUFACTURER'S DESIGNATION OF DRILL: CME-55 ☐ AUTO HAMMER ☒ MANUAL HAMMER
12. TOTAL SAMPLES: DISTURBED 13 UNDISTURBED (UD) 0
13. TOTAL NUMBER CORE BOXES: 4
14. ELEVATION GROUND WATER: 1.8 Ft.
15. DATE BORING: STARTED 08-06-04 COMPLETED 08-06-04
16. ELEVATION TOP OF BORING: 4.1 Ft.
17. TOTAL RECOVERY FOR BORING: 66 %
18. SIGNATURE AND TITLE OF INSPECTOR: Bob Momberger, Geologist

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE
4.1	0.0						4.1		
3.6	0.5	Moderately Weathered	SAND, silty, mostly fine-grained sand-sized quartz, some silt, strong reaction with HCl, moist, gray - brown (SM) LIMESTONE, oolitic, soft, moderately weathered, aphanitic, vuggy, sand filled vugs, Miami Oolitic Formation, cream - white	100	1		SPT Sampler 2.6	15 23 23	46
			▼	100	2		SPT Sampler 1.1	36 30 28	58
				50	1	RQD 90	4 x 5-1/2" Diamond Impregnated Bit DT = 0 mins HP = 400 psi DFR = 50 % -0.9		
				40	BOX 1 2	RQD 0	4 x 5-1/2" Diamond Impregnated Bit DT = 1 mins HP = 400 psi DFR = 50 % -5.9		
				50	3		SPT Sampler -7.4	4 5 11	16
				100	4 BOX 1		-7.8 SPT Sampler	50/0.4'	
				97	3 BOX 2	RQD 60	4 x 5-1/2" Diamond Impregnated Bit DT = 1 mins HP = 400 psi DFR = 0 % -10.9		

0
5
10
15

(Continued)

Boring Designation CP04-BCBCW-CB-0005A

DRILLING LOG (Cont. Sheet)	INSTALLATION Jacksonville District	SHEET 2 OF 3 SHEETS

PROJECT CERP Biscayne Bay Coastal Wetlands	COORDINATE SYSTEM/DATUM State Plane, FLE (U.S. Ft.)	HORIZONTAL NAD83	VERTICAL NGVD29
LOCATION COORDINATES X = 860,821 Y = 419,086	ELEVATION TOP OF BORING 4.1 Ft.		

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE	
										15
				70	4	RQD 30	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 %			
					BOX		-15.9			
			At El. -15.9 Ft., cavity		2					20
-17.9	22.0		LIMESTONE, fossiliferous, moderately hard, aphanitic, thick bedding, sand filled cavity, Ft. Thompson Formation, white - light yellow	60	5	RQD 30	4 x 5-1/2" Diamond Impregnated Bit DT = 1 mins HP = 400 psi DFR = 0 %			
							-20.9			25
		Moderately Weathered		45	6	RQD 0	4 x 5-1/2" Diamond Set Bit DT = 2 mins HP = 400 psi DFR = 0 %			
					BOX		-25.9			
					3					30
				45	7	RQD 0	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 %			
			At El. -29.9 Ft., fossiliferous, white - light yellow - tan							
							-30.9			35

Boring Designation CP04-BCBCW-CB-0005A

DRILLING LOG (Cont. Sheet)	INSTALLATION Jacksonville District			SHEET 3 OF 3 SHEETS
PROJECT CERP Biscayne Bay Coastal Wetlands	COORDINATE SYSTEM/DATUM State Plane, FLE (U.S. Ft.)	HORIZONTAL NAD83	VERTICAL NGVD29	
LOCATION COORDINATES X = 860,821 Y = 419,086	ELEVATION TOP OF BORING 4.1 Ft.			

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE
	Moderately Weathered			70	BOX 8 3	RQD 50	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 % -35.9		
			At El. -35.9 Ft., vuggy, sand filled vugs	100	BOX 9 4	RQD 90	4 x 5-1/2" Diamond Impregnated Bit DT = 1 mins HP = 400 psi DFR = 0 %		
-40.9	45.0						-40.9		

NOTES:

1. Soils are field visually classified in accordance with the Unified Soils Classification System.

2. Monitoring Well Designated CP04-BCBCW-CB-0005A Installed In This Boring:
Top of 2" Well Casing @ 7.12 Ft.

140# hammer w/30" drop used with 2.0' split spoon (1-3/8" I.D. x 2" O.D.).

Abbreviations:
DT = Drill Time.
HP = Hydraulic Pressure.
DFR = Drill Fluid Return.

35
40
45
50
55

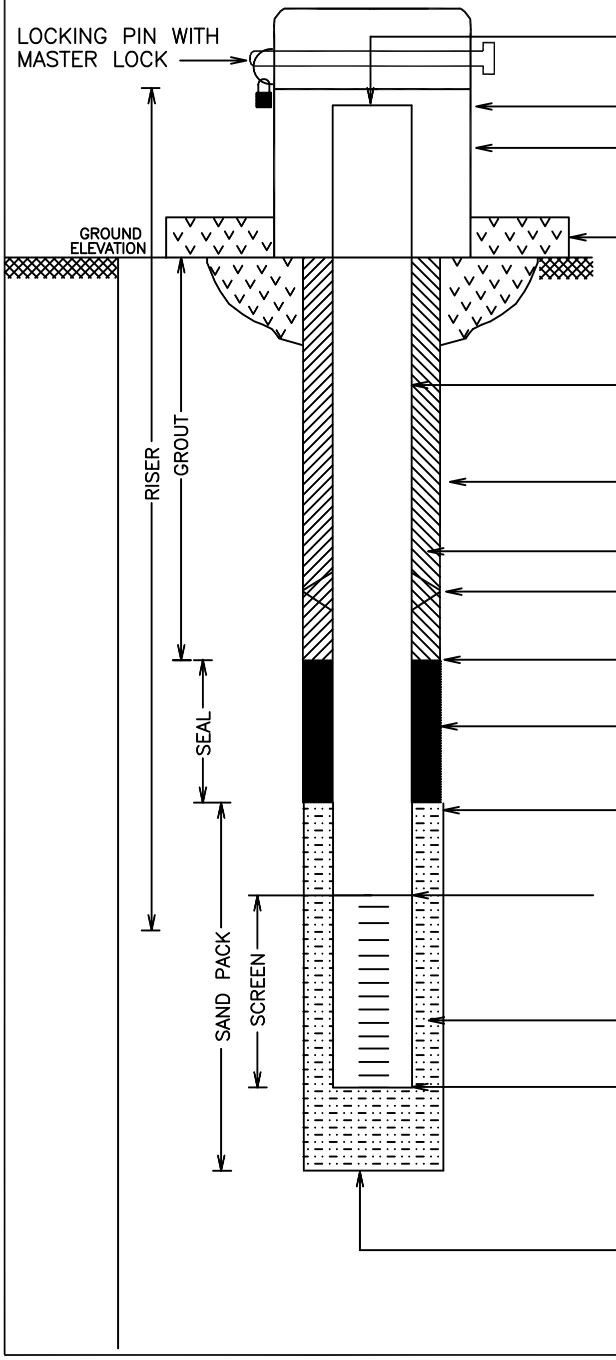
SAJ FORM 1836-A
JUN 02

CHALLENGE
ENGINEERING & TESTING, INC.
4234 HALLS MILL ROAD, MOBILE, ALABAMA 36693 (251) 666-1435

MONITORING WELL CONSTRUCTION LOG

PROJECT: **BISCAYNE BAY COASTAL WETLANDS SEEPAGE STUDY**
LOCATION: **BISCAYNE BAY-MIAMI DADE COUNTY, FL**
BORING: **CP04-BCBCW-CB-0005A**
CHALLENGE JOB NO.: **2004D21**
DATE: **SEPTEMBER 2004**

DRILLER: **ADAM BENSON**
DRILLING METHOD: **4" WIRELINE CORING SYSTEM**
DEVELOPMENT METHOD: **PUMPING**
GROUND ELEVATION: **4.10 NGVD29**
FIELD GEOLOGIST: **BOB MOMBERGER, P.G.**



LOCKING PIN WITH MASTER LOCK

TOP CAP WITH VENT HOLE

ELEVATION OF TOP OF CASING PIPE: **7.12 FT**

STICK-UP TOP OF SECURITY CASING: **6" SCHEDULE 80 PVC**

TYPE OF SURFACE SEAL: **3' X 3' X 6" CONCRETE PAD WITH 4 STEEL PROTECTIVE BOLLARDS**

RISER PIPE: **2" TRILOC PVC THREADED PIPE**

BOREHOLE DIAMETER: **5 3/4"**

TYPE OF BACKFILL: **GROUT/BENTONITE**

CENTRALIZERS: **STAINLESS STEEL**

ELEVATION/DEPTH TOP OF SEAL: **-34.45 FT**

TYPE OF SEAL: **BENTONITE 3/8" PELLETS**

DEPTH TOP OF SAND PACK: **-36.45 FT**

ELEVATION/DEPTH TOP OF SCREEN: **-37.45 FT**
SCREEN: **2" x 0.020" x 2.5 FT THREADED**
(2 FT SCREEN / .5 FT JOINT)

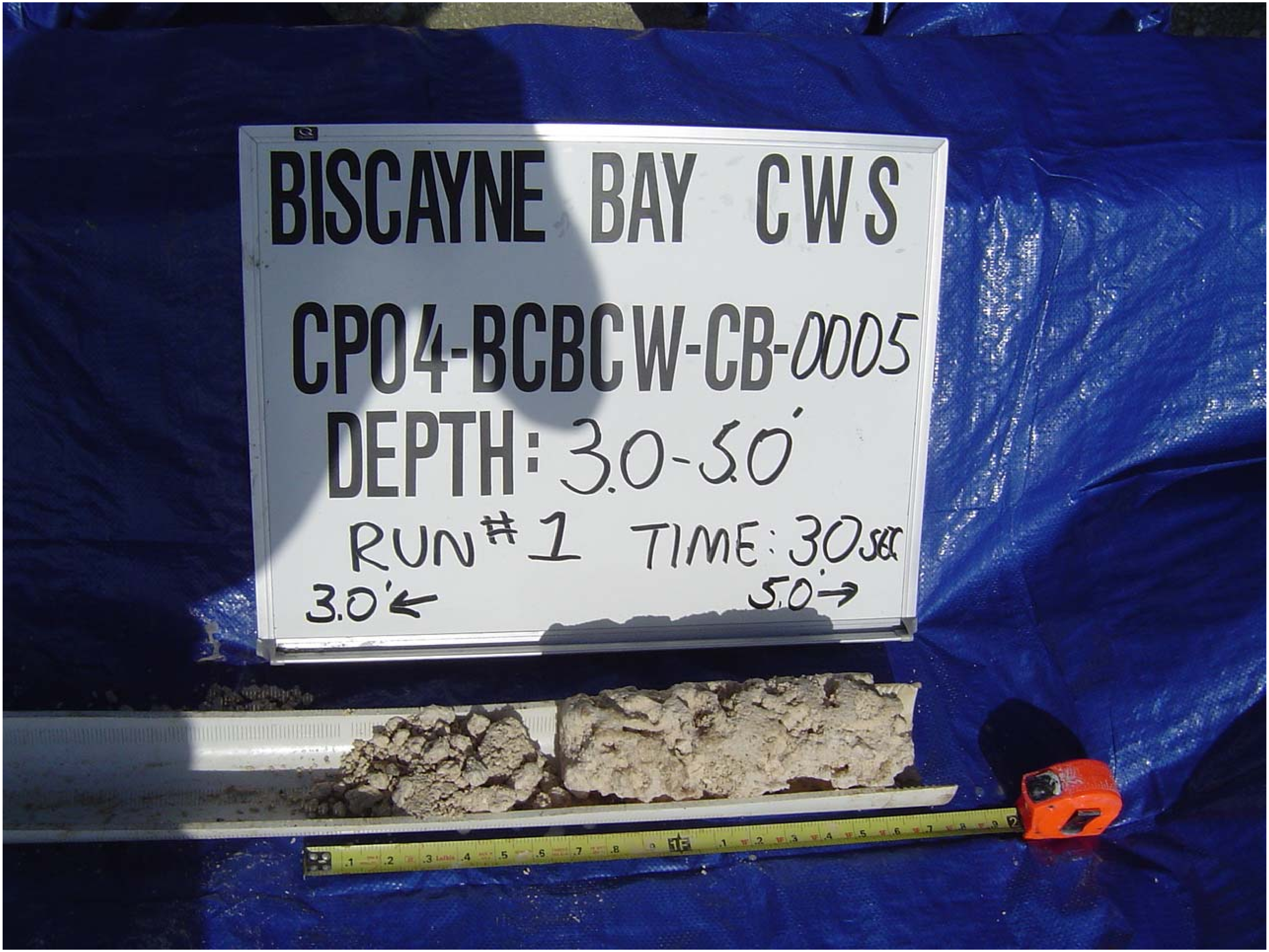
SAND PACK: **16/10 GRADED SAND**

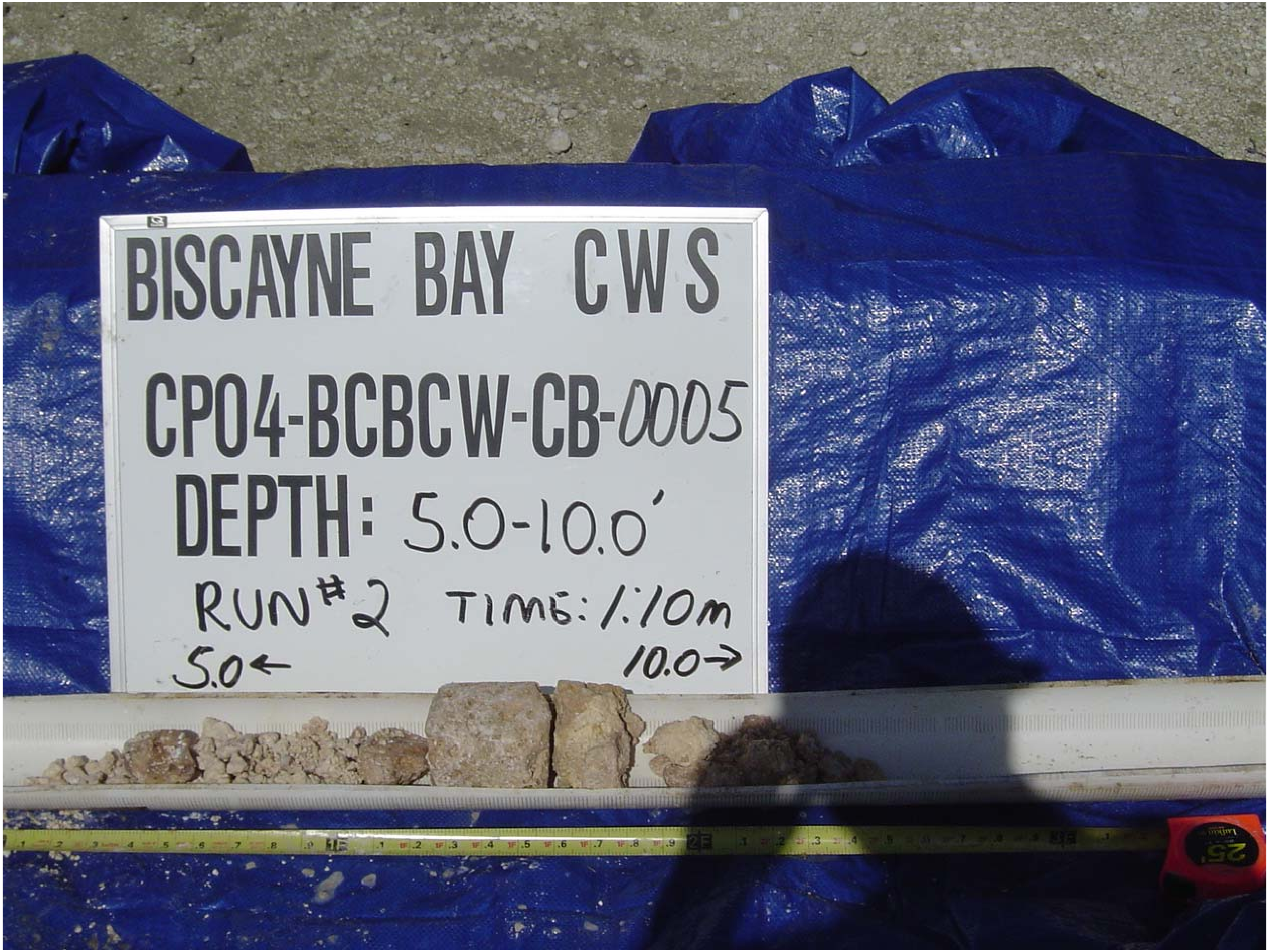
ELEVATION/DEPTH BOTTOM OF SCREEN: **-39.95 FT**

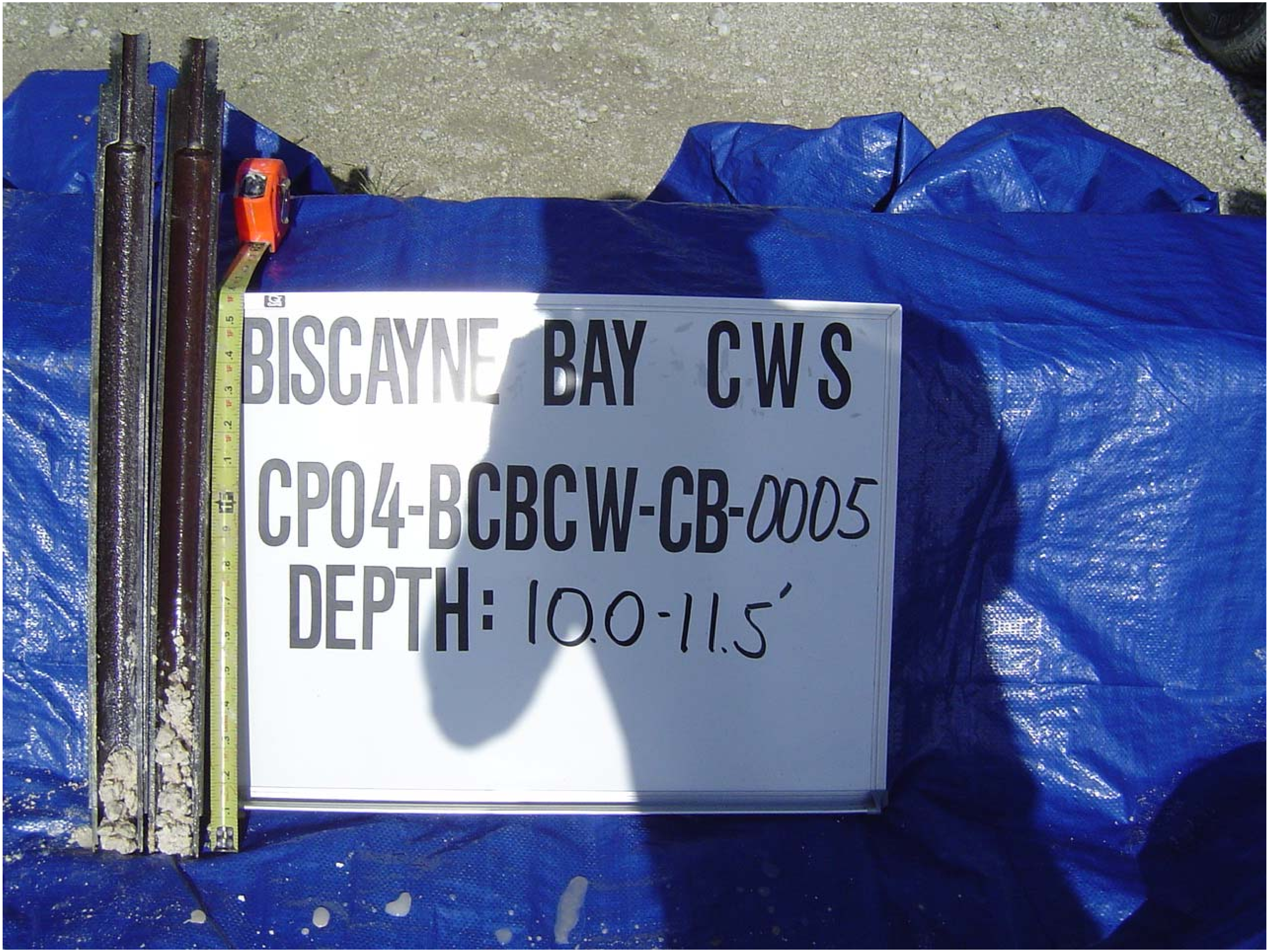
ELEVATION BOTTOM OF HOLE: **-40.90 FT**


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 0.0-1.5'


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 1.5 - 3.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 3.0-5.0'
RUN #1 TIME: 3.0sec
3.0'←
5.0'→


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 5.0-10.0'
RUN#2 TIME: 1:10m
5.0←
10.0→


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 10.0-11.5'


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 11.5-12.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 12.0-15.0'
RUN# 3 TIME:
12.0←
15.0→
25'

BISCAYNE BAY CWS

CP04-BCBCW-CB-0005

DEPTH: 15.0´-20.0´

RUN#4 TIME: 1:30m

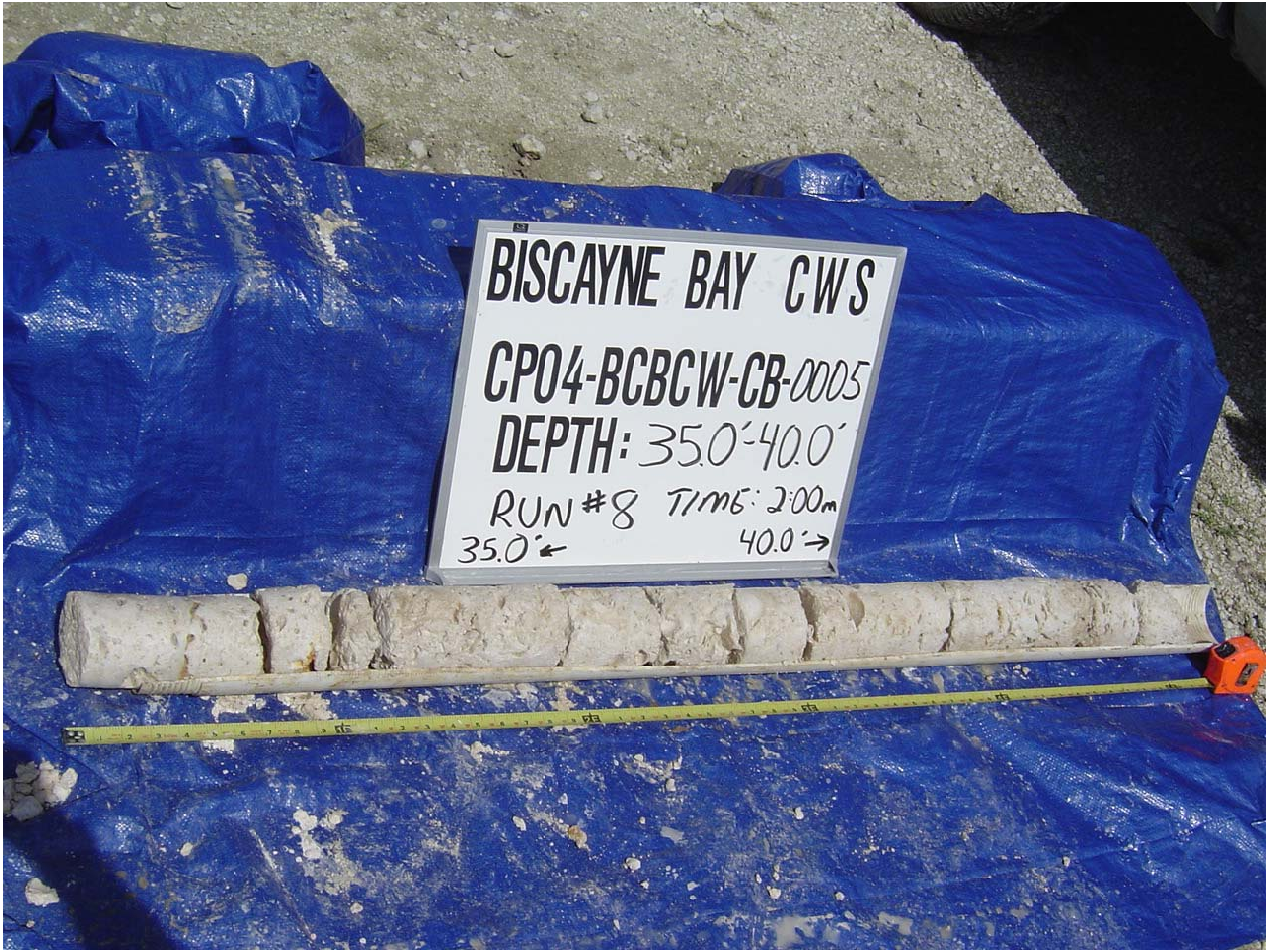
15.0´←

20.0´→


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 20.0'-25.0'
RUN#5
TIME=1:10m
20.0'←
25.0'→


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 25.0-30.0'
RUN #6
TIME: 2:00pm
30.0'→
25.0'←


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 30.0'-35.0'
RUN #7 TIME: 2:30m
30.0' ←
35.0' →
1F
2F
3F


BISCAYNE BAY CWS
CP04-BCBCW-CB-0005
DEPTH: 35.0'-40.0'
RUN #8 TIME: 2:00m
35.0' ←
40.0' →

BISCAYNE BAY CWS

CP04-BCBCW-CB-0005

DEPTH: 40.0'-45.0'

RUN #9 TIME: 1:15m

40.0' ←

45.0' →

SOILS TEST CORE
BORING NUMBER
CP04-BCBCW-CB-0011A

Core Boring Log
Well Construction Logs
Reference Sample Photographs

Boring Designation CP04-BCBCW-CB-0011A

DRILLING LOG

DIVISION: South Atlantic

INSTALLATION: Jacksonville District

SHEET 1 OF 5 SHEETS

1. PROJECT: CERP Biscayne Bay Coastal Wetlands Seepage Wells
2. BORING DESIGNATION: CP04-BCBCW-CB-0011A — LOCATION COORDINATES: X = 871,638 Y = 414,526
3. DRILLING AGENCY: Challenge Engineering & Testing, Inc. — CONTRACTOR FILE NO.:
4. NAME OF DRILLER: Adam Benson
5. DIRECTION OF BORING: ☒ VERTICAL ☐ INCLINED — DEG. FROM VERTICAL: — BEARING:
6. THICKNESS OF OVERBURDEN: N/A
7. DEPTH DRILLED INTO ROCK: N/A
8. TOTAL DEPTH OF BORING: 71.5 Ft.
9. SIZE AND TYPE OF BIT: See Remarks
10. COORDINATE SYSTEM/DATUM: State Plane, FLE (U.S. Ft.) — HORIZONTAL: NAD83 — VERTICAL: NGVD29
11. MANUFACTURER'S DESIGNATION OF DRILL: CME-55 — ☐ AUTO HAMMER ☒ MANUAL HAMMER
12. TOTAL SAMPLES: DISTURBED 19 — UNDISTURBED (UD) 0
13. TOTAL NUMBER CORE BOXES: 9
14. ELEVATION GROUND WATER: 1.7 Ft.
15. DATE BORING: STARTED 08-04-04 — COMPLETED 08-04-04
16. ELEVATION TOP OF BORING: 4.0 Ft.
17. TOTAL RECOVERY FOR BORING: 52 %
18. SIGNATURE AND TITLE OF INSPECTOR: Bob Momberger, Geologist

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE
4.0	0.0						4.0		
			LIMESTONE, oolitic, soft, aphanitic, porous, sand filled pores, Levee Fill Material, light grayish - white	40	1		SPT Sampler 2.5	15 13 10	23
			▼	40	2		SPT Sampler 1.0	10 6 10	16
				40	3		SPT Sampler -0.5	3 5 9	14
-1.8	5.8			70	4		SPT Sampler -2.0	3 2 1	3
-2.0	6.0		SAND, silty, little fine-grained sand-sized organic matter, little fine-grained sand-sized carbonate, few clay, strong reaction with HCl, moist, brown (SM) LIMESTONE, oolitic, very soft, moderately weathered, aphanitic, Miami Oolitic Formation, creamy white	100	5		SPT Sampler -3.5	5 6 23	29
		Moderately Weathered		25	1	RQD 0	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 25 % -6.0		
-8.0	12.0				BOX 1				
			SAND, poorly-graded, mostly fine-grained sand-sized quartz, some fine-grained sand-sized carbonate, strong reaction with HCl, wet, light gray (SP)	0	2	RQD 0	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 %		
-11.0	15.0						-11.0		

(Continued)

SAJ FORM 1836
JUN 02

Boring Designation CP04-BCBCW-CB-0011A

DRILLING LOG (Cont. Sheet)	INSTALLATION Jacksonville District	SHEET 2 OF 5 SHEETS

PROJECT CERP Biscayne Bay Coastal Wetlands	COORDINATE SYSTEM/DATUM State Plane, FLE (U.S. Ft.)	HORIZONTAL NAD83	VERTICAL NGVD29
LOCATION COORDINATES X = 871,638 Y = 414,526	ELEVATION TOP OF BORING 4.0 Ft.		

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE
	Moderately Weathered		LIMESTONE, oolitic, soft, moderately weathered, fine-grained, medium bedding, vuggy, sand filled vugs, cream to light yellow	55	BOX 1 3	RQD 25	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 % -16.0		
				85	BOX 2 4	RQD 60	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 % -21.0		
				55	BOX 3 5	RQD 8	4 x 5-1/2" Diamond Impregnated Bit DT = 3 mins HP = 400 psi DFR = 0 % -26.0		
-31.0	35.0			55	BOX 4 6	RQD 35	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 % -31.0		

15
20
25
30
35

Boring Designation CP04-BCBCW-CB-0011A

DRILLING LOG (Cont. Sheet)	INSTALLATION Jacksonville District		SHEET 3 OF 5 SHEETS
PROJECT CERP Biscayne Bay Coastal Wetlands	COORDINATE SYSTEM/DATUM State Plane, FLE (U.S. Ft.)	HORIZONTAL NAD83	VERTICAL NGVD29
LOCATION COORDINATES X = 871,638 Y = 414,526	ELEVATION TOP OF BORING 4.0 Ft.		

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE
-36.0	Moderately Weathered 40.0		SANDSTONE, calcrete, moderately hard, aphanitic, vuggy, sand filled vugs, Ft. Thompson Formation, - light greenish gray	20	7 BOX 5	RQD 0	4 x 5-1/2" Diamond Impregnated Bit DT = 1 mins HP = 400 psi DFR = 0 % -36.0		
-39.0	43.0		SAND, poorly-graded, mostly fine-grained sand-sized carbonate, some fine-grained sand-sized quartz, light gray (SP)	60	8	RQD 12	4 x 5-1/2" Diamond Impregnated Bit DT = 3 mins HP = 400 psi DFR = 0 % -41.0		
			LIMESTONE, fossiliferous, moderately hard, aphanitic, medium bedding, vuggy, sand filled vugs, white	60	BOX 6 9	RQD 12	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 % -46.0		
				70	BOX 10 7	RQD 50	4 x 5-1/2" Diamond Impregnated Bit DT = 3 mins HP = 400 psi DFR = 0 % -51.0		

35
40
45
50
55

Boring Designation CP04-BCBCW-CB-0011A

DRILLING LOG (Cont. Sheet)	INSTALLATION Jacksonville District		SHEET 4 OF 5 SHEETS
PROJECT CERP Biscayne Bay Coastal Wetlands	COORDINATE SYSTEM/DATUM State Plane, FLE (U.S. Ft.)	HORIZONTAL NAD83	VERTICAL NGVD29
LOCATION COORDINATES X = 871,638 Y = 414,526	ELEVATION TOP OF BORING 4.0 Ft.		

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE	
				80	BOX 11 8	RQD 30	4 x 5-1/2" Diamond Impregnated Bit DT = 3 mins HP = 400 psi DFR = 0 % -56.0			55 60
-61.0	65.0			20	12	RQD 0	4 x 5-1/2" Diamond Impregnated Bit DT = 3 mins HP = 400 psi DFR = 0 % -61.0			65
-66.0	70.0		SAND, poorly-graded, mostly medium-grained sand-sized quartz, some fine-grained sand-sized carbonate, strong reaction with HCl, wet, light gray (SP)	0	BOX 9 13	RQD 0	4 x 5-1/2" Diamond Impregnated Bit DT = 2 mins HP = 400 psi DFR = 0 % -66.0			70
-67.0	71.0		SAND, silty, mostly fine-grained sand-sized carbonate, few silt, light gray (SM)	283	6		SPT Sampler	21 38 36	74	
-67.5	71.5		SAND, poorly-graded, mostly medium-grained sand-sized quartz, some fine-grained sand-sized carbonate, light gray (SP)				-67.5			
			NOTES: 1. Soils are field visually classified in accordance with the Unified Soils Classification System. 2. Monitoring Well Designated CP04-BCBCW-CB-0011A				140# hammer w/30" drop used with 2.0' split spoon (1-3/8" I.D. x 2" O.D.). Abbreviations: DT = Drill Time. HP = Hydraulic Pressure. DFR = Drill Fluid Return.			75

SAJ FORM 1836-A
JUN 02

Boring Designation CP04-BCBCW-CB-0011A

DRILLING LOG (Cont. Sheet)	INSTALLATION Jacksonville District			SHEET 5 OF 5 SHEETS
PROJECT CERP Biscayne Bay Coastal Wetlands	COORDINATE SYSTEM/DATUM State Plane, FLE (U.S. Ft.)	HORIZONTAL NAD83	VERTICAL NGVD29	
LOCATION COORDINATES X = 871,638 Y = 414,526	ELEVATION TOP OF BORING 4.0 Ft.			

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% REC.	BOX OR SAMPLE	RQD OR UD	REMARKS	BLOWS/ 0.5 FT.	N-VALUE
			Installed In This Boring: Top of 2" Well Casing @ 3.87 Ft.						

75

80

85

90

95

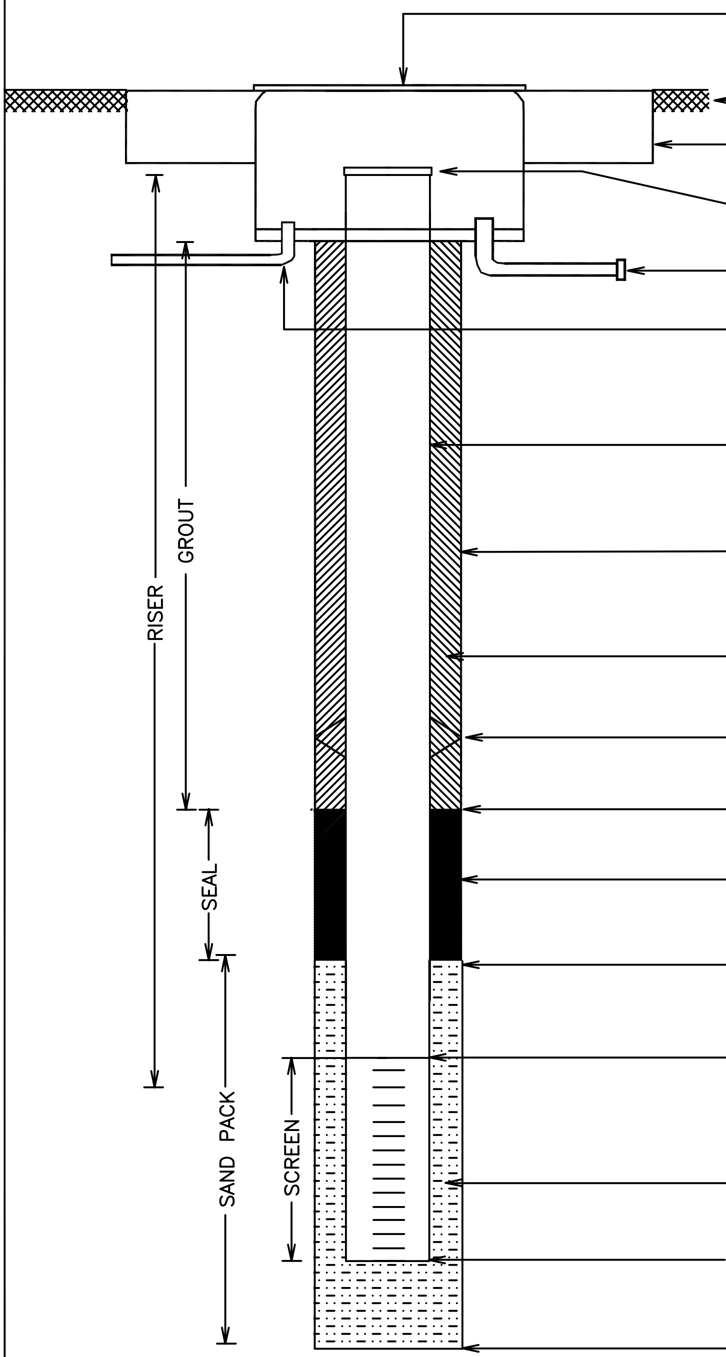
SAJ FORM 1836-A
JUN 02

CHALLENGE
ENGINEERING & TESTING, INC.
4234 HALLS MILL ROAD, MOBILE, ALABAMA 36693 (251) 666-1435

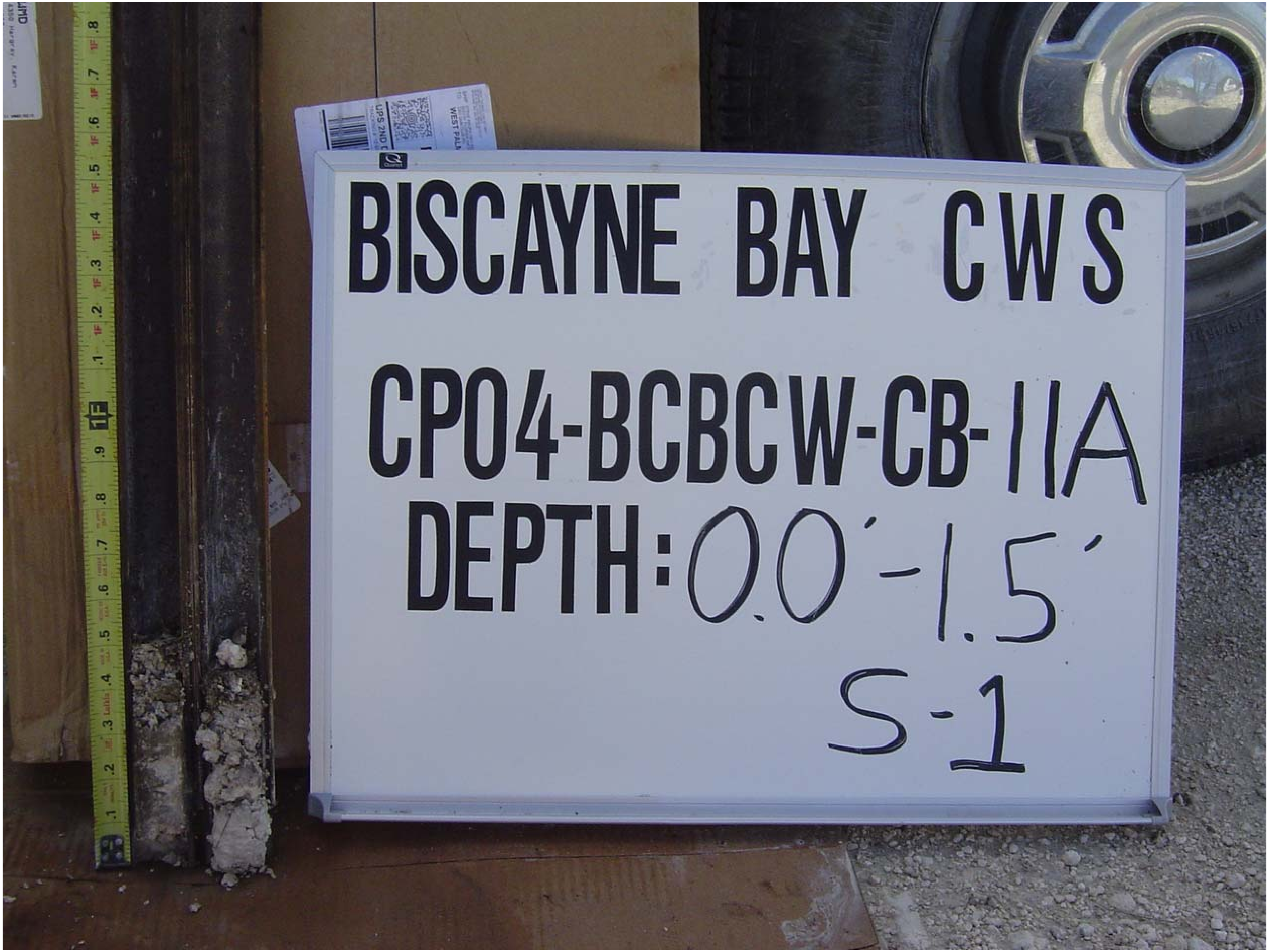
MONITORING WELL CONSTRUCTION LOG

PROJECT: **BISCAYNE BAY COASTAL WETLANDS SEEPAGE STUDY**
LOCATION: **BISCAYNE BAY-MIAMI DADE COUNTY, FL**
BORING: **CP04-BCBCW-CB-0011A**
CHALLENGE JOB NO.: **2004D21**
DATE: **SEPTEMBER 2004**

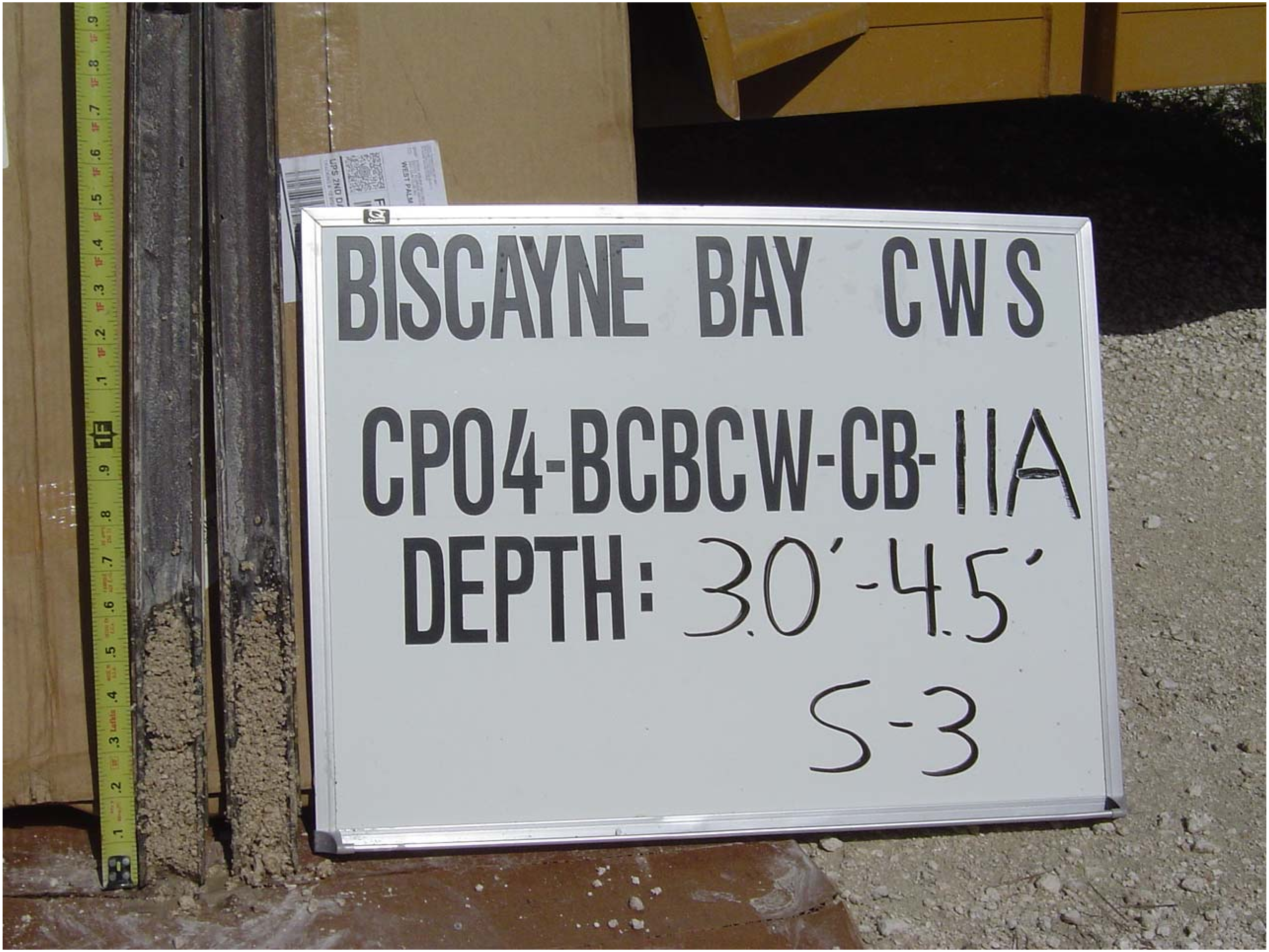
DRILLER: **ADAM BENSON**
DRILLING METHOD: **4" WIRELINE CORING SYSTEM**
DEVELOPMENT METHOD: **PUMPING**
GROUND ELEVATION: **4.00 FT NGVD29**
FIELD GEOLOGIST: **BOB MOMBERGER, P.G.**



BOLT DOWN COVER: **MANHOLE COVER 12" DIAMETER PAINTED RED**
GROUND SURFACE: **4.00 FT**
3' X 3' X 6" CONCRETE PAD
LOCKING TOP CAP WITH MASTER LOCK
TOP OF CASING = 3.87 FT.
1" CONDUIT PIPING
3/4" DRAIN PIPE
RISER PIPE: **2" TRILOC PVC THREADED PIPE**
BOREHOLE DIAMETER: **5 3/4"**
TYPE OF BACKFILL: **GROUT/BENTONITE**
CENTRALIZERS: **STAINLESS STEEL**
ELEVATION/DEPTH TOP OF SEAL: **-19.95**
TYPE OF SEAL: **BENTONITE 3/8" PELLETS**
ELEVATION TOP OF SAND PACK: **-21.95 FT**
ELEVATION/DEPTH TOP OF SCREEN: **-22.95 FT**
SCREEN: **2" x 0.060" x 2.5 FT THREADED**
(2 FT SCREEN / .5 FT JOINT)
SAND PACK: **PEA GRAVEL**
ELEVATION/DEPTH BOTTOM OF SCREEN: **-25.45 FT**
ELEVATION BOTTOM OF HOLE: **-67.50 FT**


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 0.0'-1.5'
S-1

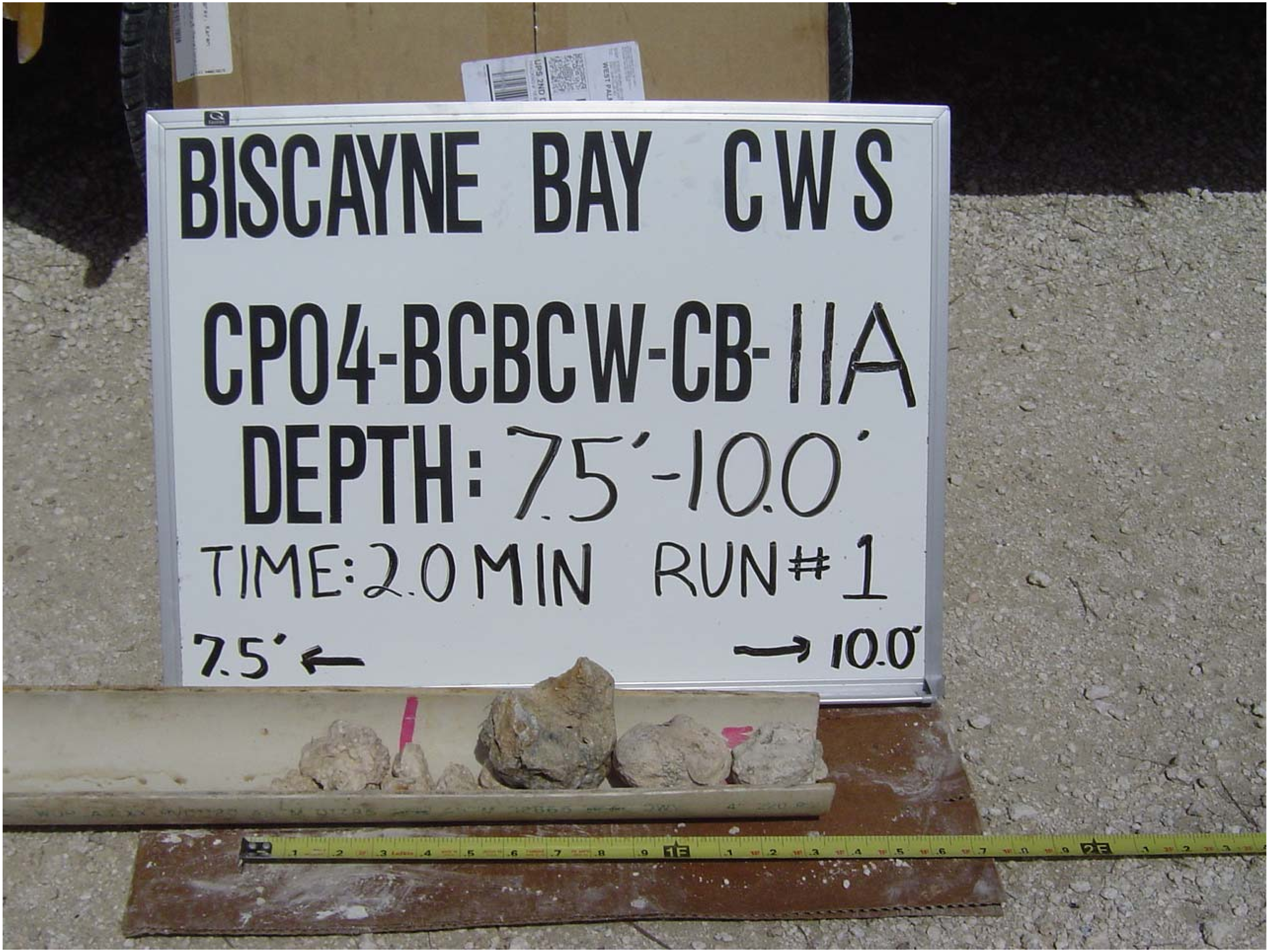

BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 1.5'-3.0'
S-2



BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 3.0'-4.5'
S-3

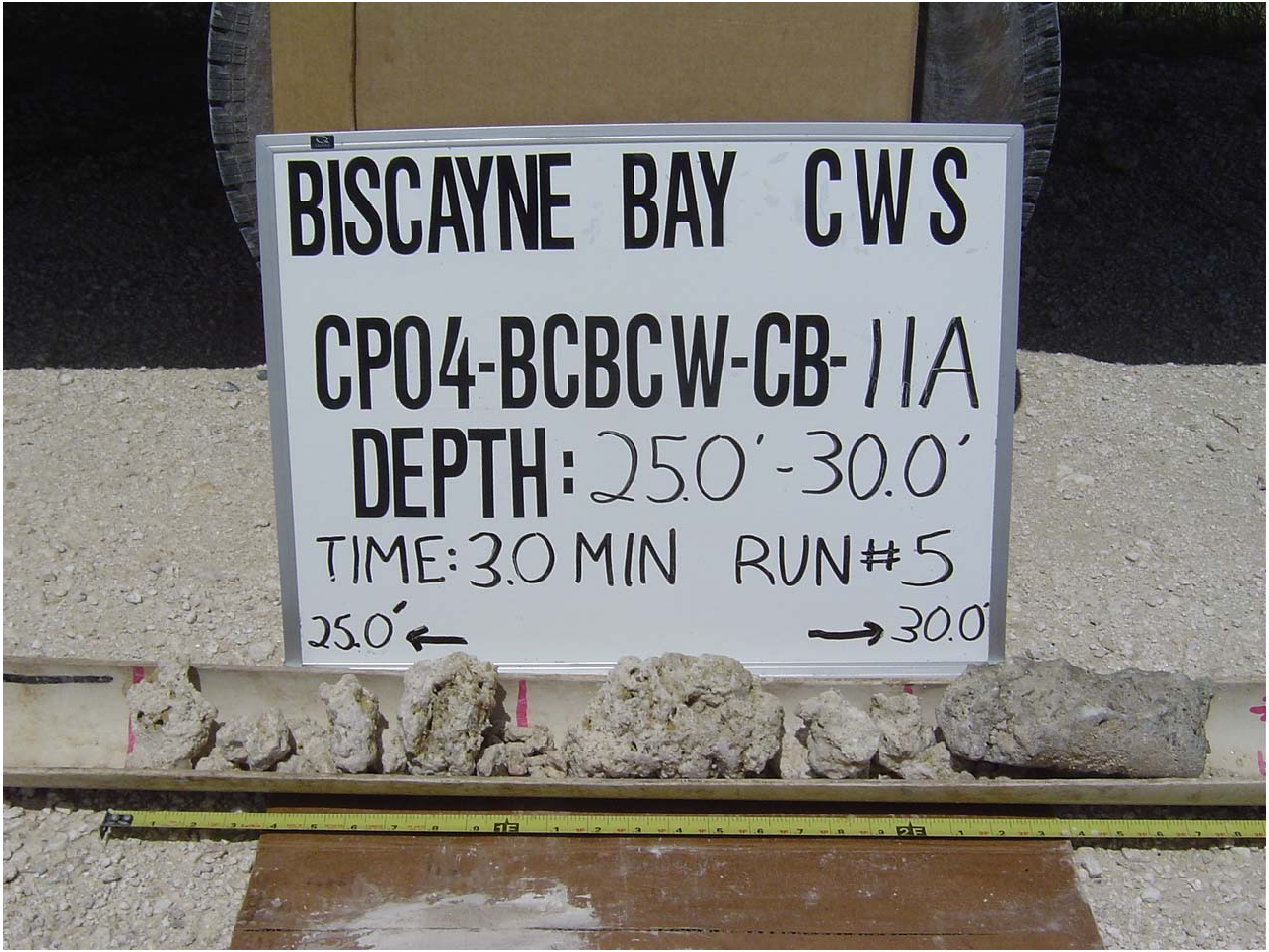

BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 4.5'-6.0'
S-4


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 6.0'-7.5'
S-5


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 7.5'-10.0'
TIME: 2.0 MIN RUN #1
7.5' ←
→ 10.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 15.0'-20.0'
TIME: 2.0 MIN RUN#3
15.0' ←
→ 20.0'

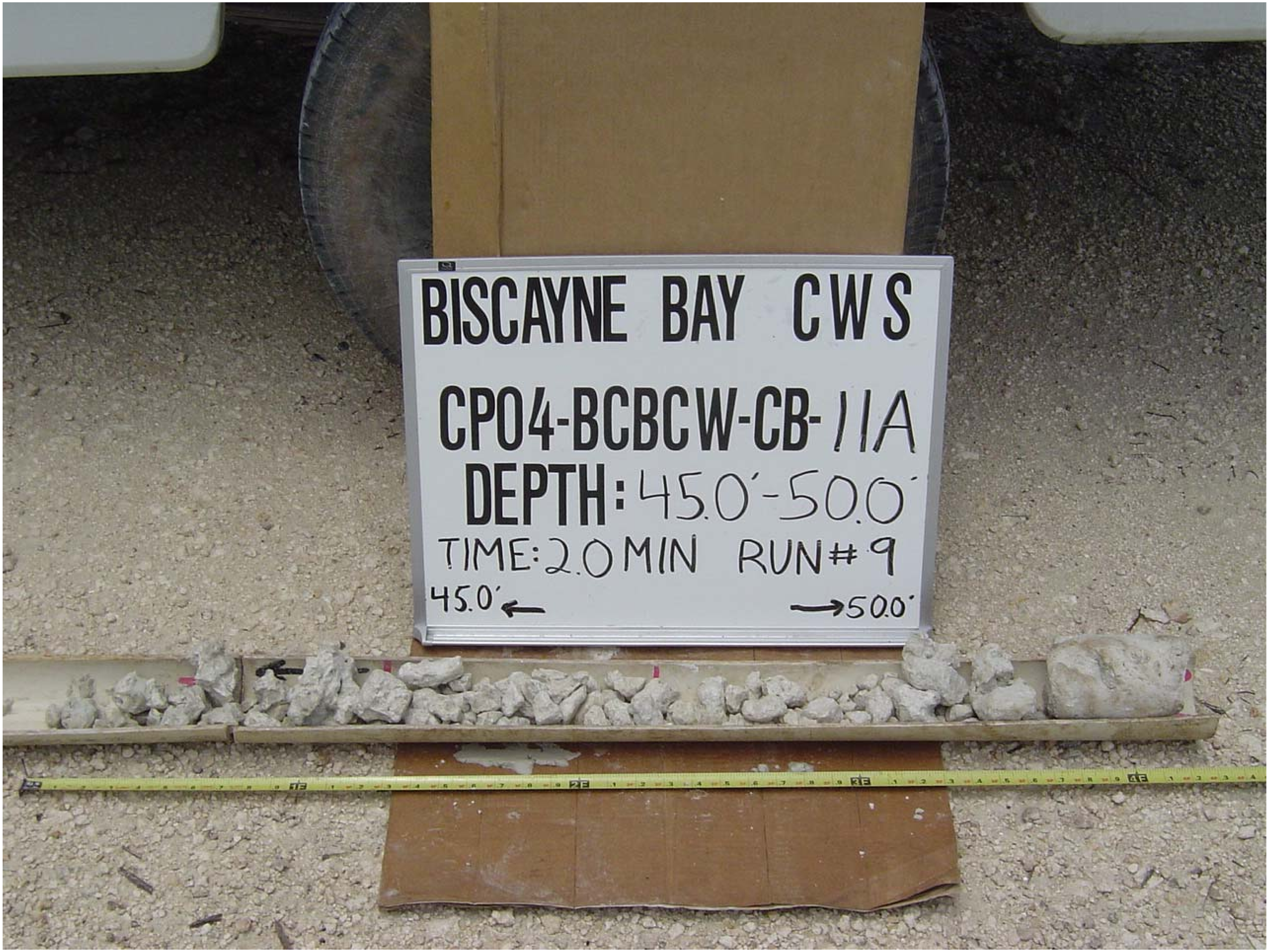

BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 20.0'-25.0'
TIME: 2.0 MIN RUN#4
20.0' ←
→ 25.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 25.0'-30.0'
TIME: 3.0 MIN RUN #5
25.0' ←
→ 30.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 30.0-35.0'
TIME: 2.0 MIN RUN #6
30.0' ←
→ 35.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 35.0'-40.0'
TIME: 1.0 MIN RUN# 7
35.0' ←
→ 40.0'

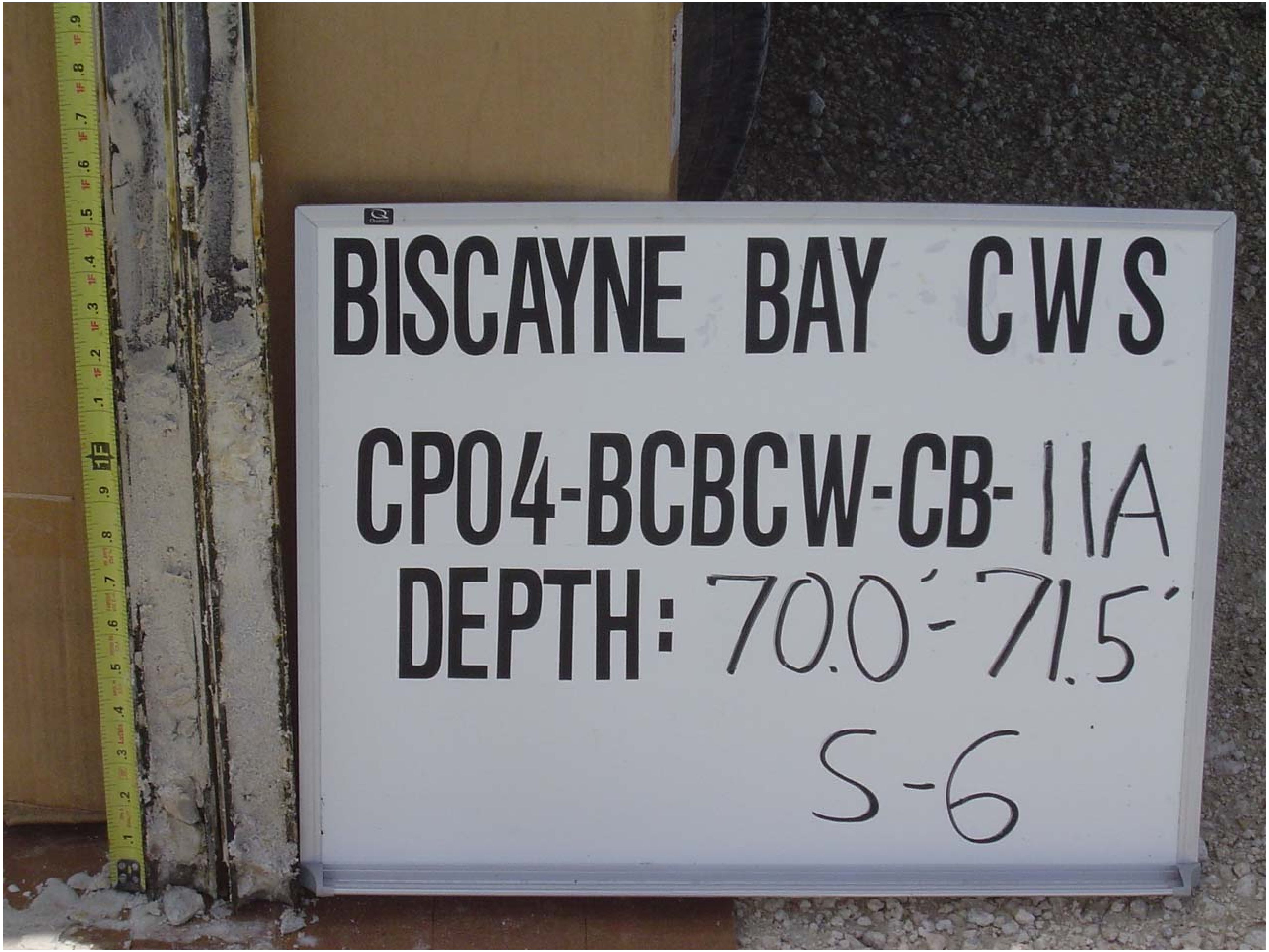

BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 40.0'-45.0'
TIME: 3.0 MIN RUN# 8
40.0' ←
→ 45.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 45.0'-50.0'
TIME: 2.0 MIN RUN# 9
45.0' ←
→ 50.0'


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 50.0'-55.0'
TIME: 3.0 MIN RUN #10
50.0' ←
→ 55.0'
1F
2F
3F


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 55.0'-60.0'
TIME: 2.5 MIN RUN #11
55.0' ←
→ 60.0'
1F
2F
3F
4F


BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 60.0'-65.0'
TIME: 3.0 MIN
RUN #12
60.0' ←
→ 65.0'

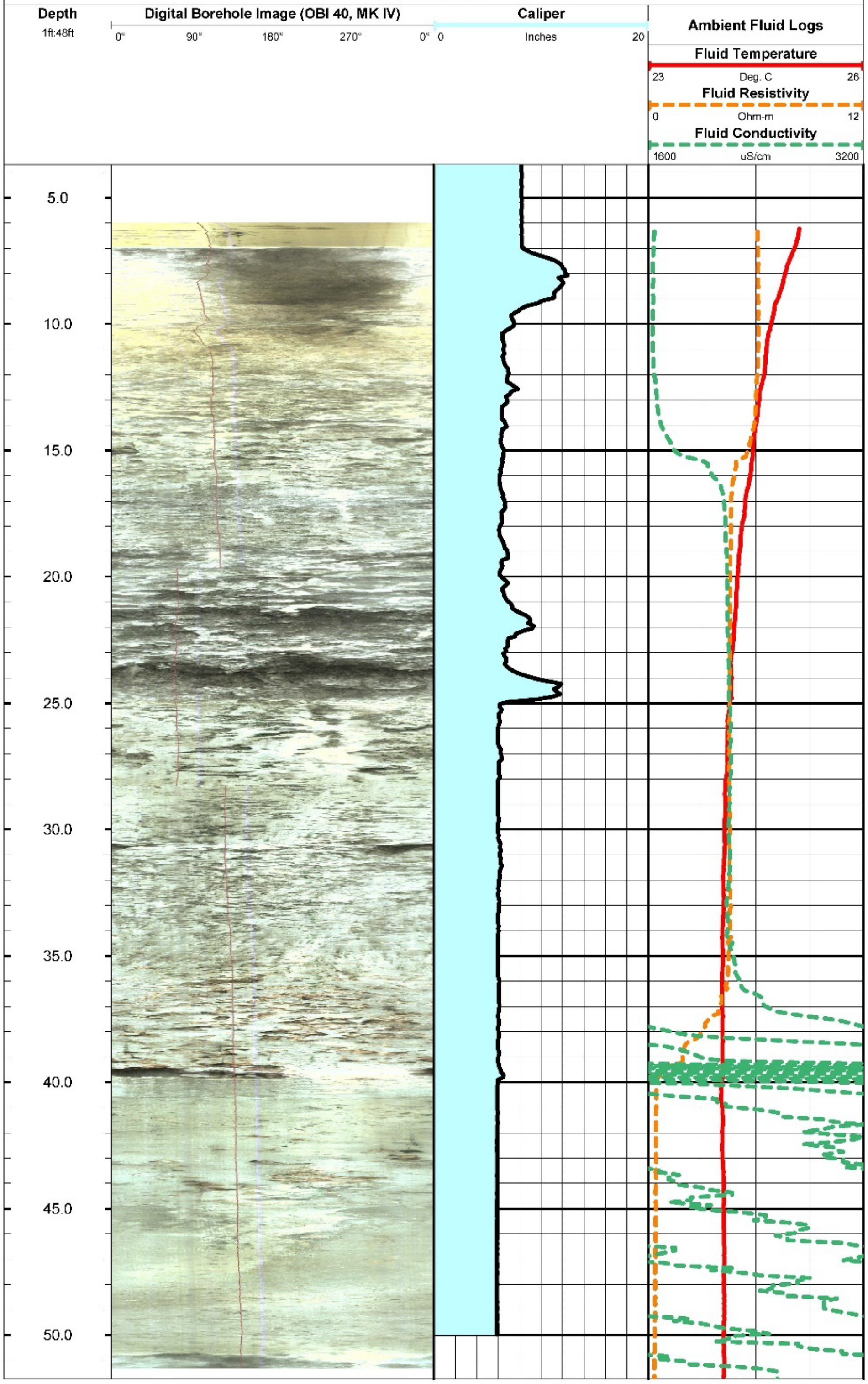

BISCAYNE BAY CWS
CP04-BCBCW-CB-11A
DEPTH: 70.0'-71.5'
S-6

APPENDIX D
GEOPHYSICAL LOGS

USGS-Florida Water Science Center

WELL	*G-3857 (STDA-BBCW-6A)*	**PROJECT**	*DERM STDA Project*	**DATE OF COMPLETION**	*April 2007*
LOCATION	*25-29-25 N (Survey, NAD 83)*	**ELEVATION**	*4.85 Feet (Survey, NGVD 29)*	**WELL DEPTH**	*65 Feet TD*
	080-20-55 W	**DATE OF INITIAL LOGGING**	*14 April 2007*		

G-3857

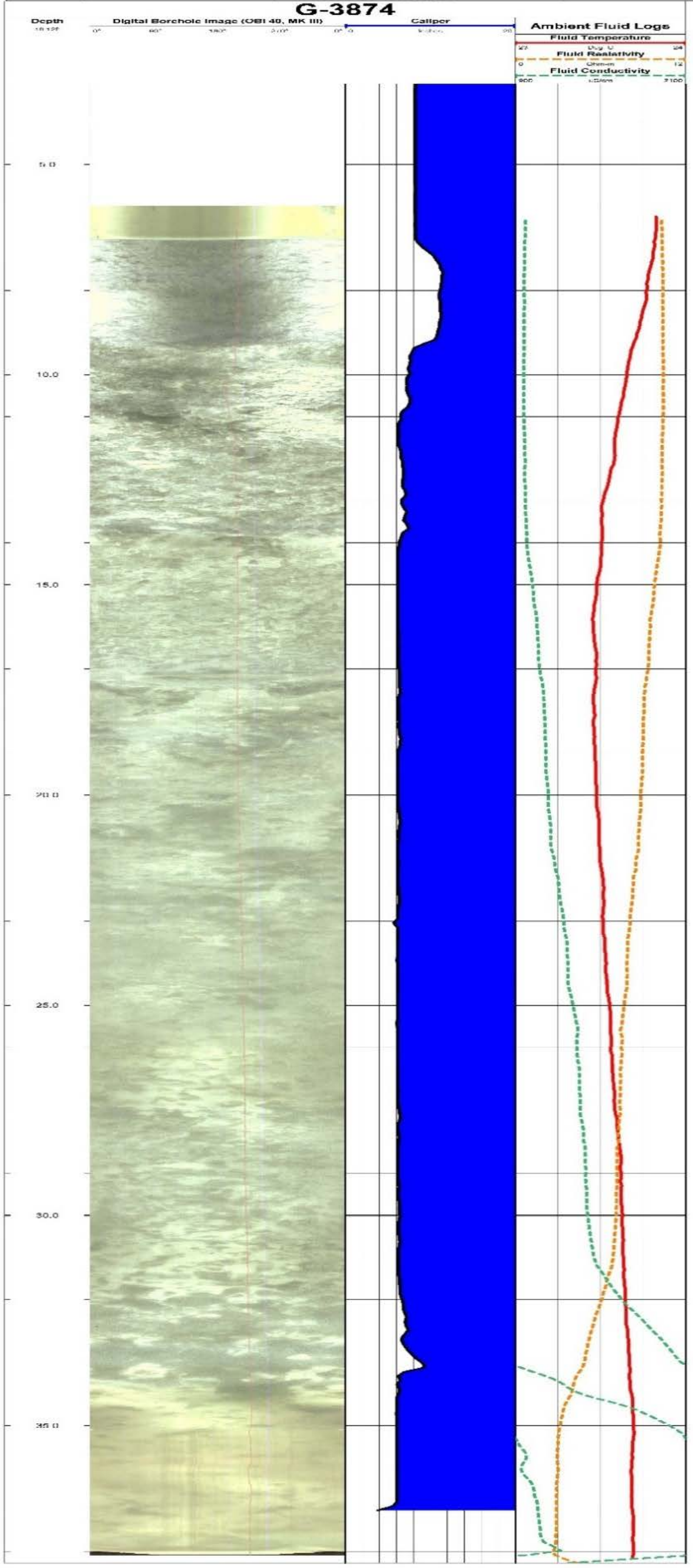


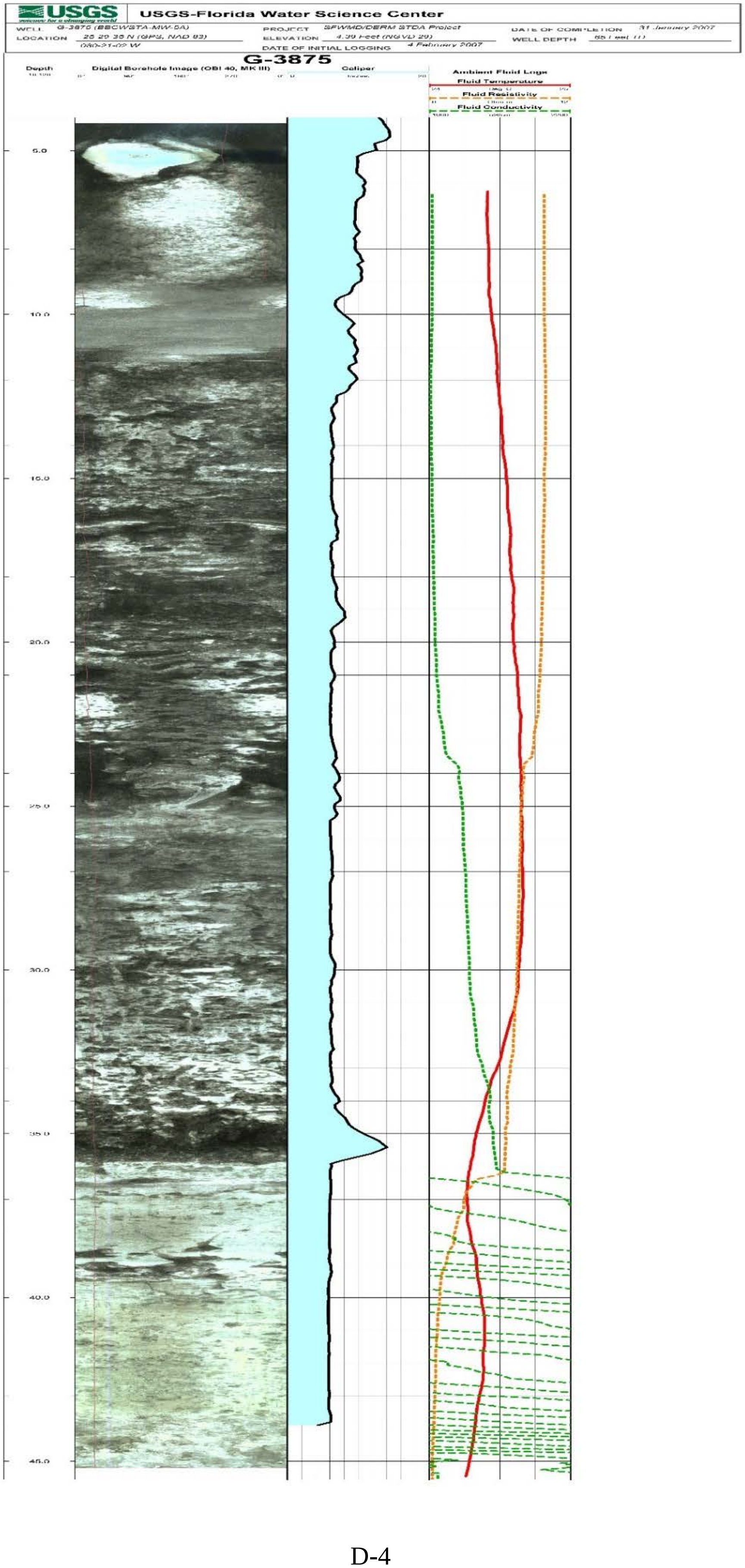
USGS-FISC Fort Lauderdale, Florida

WELL G 3874 (DDCWSTA MW 4A New)
LOCATION 25-29-34 N (GPS, NAD 83)
080-21-16 W

PROJECT SFWMD/DERM STDA Project
ELEVATION 5.07 Feet (NGVD 29)
DATE OF INITIAL LOGGING 14 April 2007

DATE OF COMPLETION April 2007
WELL DEPTH 65 Feet TD





USGS-Florida Water Science Center

WELL G-3875 (BBCWSTA-MW-5A)
LOCATION 25 29 35 N (GPS, NAD 83)
080-21-02 W

PROJECT SFWMD/DERM STDA Project
ELEVATION 4.39 Feet (NGVD 29)
DATE OF INITIAL LOGGING 4 February 2007

DATE OF COMPLETION 31 January 2007
WELL DEPTH 65 Feet (?)

APPENDIX E
PHOTOGRAPHIC LOG