U.S. Army Corps of Engineers
Charleston District

APPENDIX F

CHARLESTON HARBOR POST 45
BENEFICIAL USE OF DREDGED MATERIAL
SUPPLEMENTAL ENVIRIONMENTAL ASSESSMENT
CHARLESTON, SOUTH CAROLINA

Lower Harbor Sediment Sampling in Support of Beneficial Use Analysis

30 September 2016

FINAL REPORT
LOWER HARBOR SEDIMENT SAMPLING AND ANALYSIS
CHARLESTON HARBOR FEDERAL NAVIGATION CHANNEL
CHARLESTON, BERKELEY COUNTY, SOUTH CAROLINA

Submitted to:

U.S. Army Corps of Engineers, Charleston District
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TABLE OF CONTENTS

APPENDICES

**Appendices are provided in electronic format only
and are included on the accompanying disc.**

LIST OF EXHIBITS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

CFR	Code of Federal Regulations
CQAR	Chemical Quality Assurance Report
DCA	Dial Cordy and Associates
DI	de-ionized (water)
DQCR	Daily Quality Control Report
DU	dredging unit
EPA, USEPA	U.S. Environmental Protection Agency
ERL	effects range-low
FDEP	Florida Department of Environmental Protection
GIS	geographic information system
GPS	global positioning system
HSP	Health and Safety Plan
ITM	Inland Testing Manual
MDL	method detection limit
MLLW	mean lower low water
MPRSA	Marine Protection, Research, and Sanctuaries Act
MRL	method reporting limit
NOAA	National Oceanic and Atmospheric Administration
QA	quality assurance
QC	quality control
SAP/QAPP	Sampling and Analysis Plan/Quality Assurance Project Plan
SERIM	Southeastern Regional Implementation Manual (EPA and USACE 2008)
SOP	standard operating procedure
TEL	threshold effects level
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USCS	U.S. Soil Classification Systems

EXECUTIVE SUMMARY

This report details the field sampling, analysis, and analytical results for sediment samples collected from selected sites in the lower harbor of the Charleston Harbor Federal Navigation Channel. Charleston Harbor is a 14-square-mile tidal estuary in Berkeley and Charleston counties, South Carolina, and is formed from the junction of the Ashley, Cooper, and Wando rivers. Field sampling took place from October 13 through October 16, 2014. Vibracore samples were collected in the lower harbor to determine physical and chemical properties of the material and suitability for beneficial use.

Sampling Approach

Vibracore services were provided by Athena Technologies, Inc. An ANAMAR team leader was onboard the sampling vessel at all times to direct operations, record field notes, and containerize and label the samples. The lower harbor sampling consisted of three areas where 20 cores were collected from the *Artemis* (Athena's vessel) between October 13 and October 16, 2014. The lower harbor channel locations include the Rebellion (REBR14) and Bennis (BENR14) Reaches, the Hog Island Reach (HIR14), and the Wando River Lower Reach (WLRW14).

The rationale for the sampling approach is discussed in Section 2.1 and in the Sampling and Analysis Plan (SAP) (Appendix A). All of the cores collected in the lower harbor were obtained using vibracore equipment and were advanced to target depth of 56 feet or refusal. Based on core stratigraphy (as contracted with Athena), core subsamples were collected and submitted for physical analysis only, including total organic carbon (TOC), grain size with hydrometer, and specific gravity. *In situ* measurements including tide cycle, water depth, and weather conditions were documented daily at each sampling station.

Physical Results Stratigraphy Samples

TOC, grain size distribution with hydrometer, and specific gravity were analyzed in stratigraphy subsamples obtained from the lower harbor sampling locations.

Project samples for samples REBR14, BENR1, HIR14, and WLWR14 were composed of varying percentages of fine- to medium-grained sand, silt, and clay. The project samples were classified as high plasticity inorganic clays or fat clays (CH); elastic inorganic silts, or highly elastic inorganic silt (MH); clayey sand, sand-clay mixtures (SC); silty sands, silt-sand mixtures (>12% silt) ((SM)); poorly-graded sands (% fines <5%) ((SP)); poorly graded sand with clay (5%<clay<12%) ((SP-SC)); poorly-graded sand with silt (5%<silt<12%) ((SP-SM)); and well-graded sand (SW).

TOC

TOC was detected above the MRL in all lower harbor stratigraphy samples. TOC concentrations in the lower harbor stratigraphy samples ranged from 0.108% (REBR14-4B) to 3.13% (REBR14-1A). The average percentage of TOC in the lower harbor stratigraphy sediment samples was 0.791%.

1 INTRODUCTION

1.1 Project Area Description

Charleston Harbor is a 14-square-mile tidal estuary located in Berkeley and Charleston counties, South Carolina, and is formed from the junction of the Ashley, Cooper, and Wando rivers (U.S. Army Corps of Engineers [USACE] 2012). Morris Island and Sullivan's Island form a protective barrier near the entrance at the southeast portion of the harbor as do two jetties that frame the north and south sides of the inlet. The harbor is part of the Atlantic Intracoastal Waterway and is bordered to the southeast, west, and north by the Atlantic Ocean, Charleston, Mount Pleasant, and James Island, respectively. Mean and spring tidal ranges at the entrance channel are 5.1 and 5.9 feet, respectively (USACE 2012).

This report presents the results of the field sampling and data analysis of 20 vibracore samples collected from selected sites in the lower harbor of the Charleston Harbor Federal Navigation Channel to determine physical properties of the material and its suitability for beneficial use.

The lower harbor sampling effort consisted of four areas where 20 cores were collected from the Athena Technologies, Inc. vessel *Artemis* between October 13 and October 16, 2014. The four lower harbor channel locations are shown in the map below see also Figure 1 included the Rebellion Reach (REBR14), Bennis Reach (BENR14), Hog Island Reach (HIR14), and Wando River Lower Reach (WLWR14).


WLRW14-4
WLRW14-3
WLRW14-2
WLRW14-1
Wando Lower River Reach
HIR14-4
HIR14-3
Hog Island Reach
HIR14-2
HIR14-1
BENR14-5
BENR14-4
BENR14-6
BENR14-2
BENR14-1
BENR14-3
REBR14-5
REBR14-4
REBR14-6
Bennis Reach
REBR14-3
REBR14-2
Rebellion Reach
REBR14-1
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

1.1.1 Objectives and Deliverables

USACE contracted with Dial Cordy and Associates (DCA) (prime contractor) and ANAMAR Environmental Consulting, Inc. to collect vibracore samples for physical sediment analysis based on stratigraphy sediment samples and to conduct physical and chemical analyses (specifically total organic carbon [TOC]) and present the results in a report. The specific objectives of this effort are as follows:

- Provide a detailed Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) for approval before sampling and testing begin.
- Collect sufficient sample volume from each sampling location within the project area. Sample locations were determined by USACE and ANAMAR.
- Conduct sediment testing following the requirements set forth in the SAP/QAPP.
- Provide a report to USACE that describes the field sampling effort and presents the results of the physical/chemical analysis of sediment to provide the basis for a scientific recommendation regarding the management of the project sediment.

Deliverables for this work include:

- Final SAP/QAPP (Appendix A)
- Field paperwork to include the Daily Quality Control Reports (DQCRs) (Appendix B)
- Analytical results and geotechnical report (Appendices C, D, and E)
- Chemical Quality Assurance Report (CQAR) (Appendix D)
- Site-specific Health and Safety Plan/Accident Prevention Plan (HSP)
- Preliminary and final Sediment Evaluation Testing Report

ANAMAR coordinated and directed operations for this project and worked closely with DCA and USACE to develop a sampling and analysis scheme, schedule, and deliverables. ANAMAR also reviewed all data and produced this report summarizing the results of the physical and chemical analysis of the stratigraphy sediment samples collected from the project areas. A list of team members and responsibilities associated with this project is provided in Exhibit 1.1.

Exhibit 1-1. Team Members and Responsibilities Associated with This Project

Company and Contact Information	Area(s) of Responsibility
Prime Contractor: Dial Cordy Project Manager: Steve Dial 201 N. Front Street, Suite 307 Wilmington, NC 28401 Phone: (910) 251-9790	Prime contractor for project
Field Team Lead and Sediment Evaluation Lead: ANAMAR Environmental Consulting, Inc. Project Manager: Christine Smith 2106 NW 67th Place, Suite 5 Gainesville, FL 32653 Phone: (352) 377-5770	Field team lead /sediment evaluation lead for project
Vibracore Services and Geotechnical Report: Athena Technologies, Inc. Project Manager: Neal Wicker P.O. Box 68 McClellanville, SC 29458 Phone: (843) 887-3800	Support for field collection of sediment samples requiring vibracore equipment; geotechnical report
Chemistry Laboratory: ALS Environmental Project Manager: Shar Samy 1317 S. 13th Avenue Kelso, WA 98626 Phone: (360) 501-3293	Laboratory preparation and chemical analysis of sediment (TOC only); sample holding and archiving
Geotechnical Laboratory: AMEC Project Manager: Mark Coleman 6256 Greenland Road Jacksonville, FL 32258 Phone: (904) 396-5173	Laboratory preparation and physical analysis of sediment; sample holding and archiving

2 MATERIALS AND METHODS

2.1 Project Design and Rationale

This sediment evaluation project involved collecting estuarine and marine sediment vibracore samples from the lower harbor area of Charleston Harbor. The lower harbor channel locations included Rebellion and Bennis Reaches, Hog Island Reach, and Wando River Lower Reach. The sediment collected was analyzed for physical and chemical parameters, and the results were reviewed and validated for appropriate data quality objectives.

A total of 20 vibracore samples were collected from the lower harbor and sectioned based on stratigraphy. The subsamples were tested for physical parameters including grain size with hydrometer and specific gravity. Chemical analyses included TOC only. TOC analysis was not required for four project samples including HIR14-1A, HIR14-1C, WLWR14-1C and WLWR14-4B. All cores were taken to a project depth of -56 feet mean lower low water (MLLW) or to refusal, whichever occurred first.

Coordinates for actual vibracore sample locations are listed in Table 1. A map of the channel sampling areas and sample locations is presented in Figure 1. Maps presenting the sample locations for each of the channel locations are presented in Figures 2 through 4. After geotechnical analysis at the Athena's facility, the sediment samples were properly containerized and shipped to the respective laboratories for physical and chemical analysis. No field splits were collected for this project.

The sampling approach proposed for this project is presented in Exhibit 2-1. The navigational channel areas and sample IDs for the lower harbor substations are listed in Exhibit 2-2. Sediment samples were analyzed for physical and chemical parameters in accordance with the USACE Scope of Work and the QAPP. Prior to sampling, the volume of sediment sufficient for laboratory analyses was calculated. Enough sample volume was collected to ensure adequate volume for all analyses and for archiving in case re-analysis was required.

Exhibit 2-1. Summary of Field Sampling Materials and Methods

Field Sample Collection, Lower Harbor Cores
• 1 core sample was collected via Vibracore at each of 20 sites. • Cores were collected from R/V *Artemis* (30-foot SeaArk pontoon vessel) • Core samples were divided into subsamples based on stratigraphy. • Testing included TOC, grain size with hydrometer, and specific gravity. • *In situ* measurements included tidal cycle, water depth, and weather conditions.

Exhibit 2-2. Lower Harbor Navigational Channel Areas and Sample IDs

Channel Area(s) Represented by Dredging Unit (DU)	Subsample IDs
Rebellion Reach & Bennis Reach	REBR14-1 through 6 BENR14-1 through 6
Wando River Lower Reach	WLRW14-1 through 4
Hog Island Widener	HIR14-1 through 4

2.2 Sample Collection Techniques

2.2.1 Project Field Effort

Field sampling took place between October 13 and October 16, 2014. Field personnel consisted of scientists and crew from ANAMAR and Athena. The sampling vessel R/V *Artemis* (30-foot SeaArk pontoon vessel) departed from Tolers Cove Marina and returned to the marina at the conclusion of daily sampling.

The 20 core samples collected from the lower harbor region between October 13 and October 16 were transported to the Athena Technologies headquarters and sectioned into subsamples for physical analysis based on stratigraphy. Cores were characterized for geotechnical parameters by Athena. Athena used USCS for the initial classification and confirmed the classification using the laboratory results. Physical and chemical samples were then containerized and shipped to AMEC and ALS on October 20, 2015. Physical samples were received by AMEC on October 27, 2014. Chemical analysis samples were received by ALS on October 22, 2014 and logged in for analysis on October 23, 2014. Exhibit 2-3 presents the daily activities that occurred during and following the field effort.

Exhibit 2-3. Daily Activities During and Following the October 2014 Field Effort[1]

Date	General Activity	Samples Collected
12-Oct	• ANAMAR staff mobilized to Charleston	None
13-Oct	• ANAMAR staff collected core samples in lower harbor areas	BENR14-1 HIR14-1, -3, -4, WLRW14-1 to WLRW14-4
14-Oct	• ANAMAR staff collected core samples in lower harbor areas	REBR14-2, -3, -4, BENR14-4 HIR14-2
15-Oct	• ANAMAR staff collected core samples in lower harbor areas. Cores split at Athena's facility for processing.	BENR14-2, -3, -5, -6
16-Oct	• ANAMAR staff collected core samples in lower harbor areas.	REBR14-1, -5, -6
17-Oct	• All remaining cores split at Athena's facility for processing.	None
20-Oct	• Samples sent by Athena to AMEC (received 10/27/14)	None
20-Oct	• Samples sent by Athena to ALS (received 10/22/14, samples logged in on 10/23/14)	None

[1]See Table 1 for more information on core samples.

2.2.2 Site Positioning

Station coordinates for proposed sediment sampling stations were chosen by USACE and are listed in the SAP/QAPP (Appendix A). These coordinates were entered into a GPS receiver capable of 10-meter accuracy. A Trimble GPS (sub-meter accurate) is used on the R/V *Artemis*. A hand-held backup GPS unit (Garmin Oregon 450) was used to confirm the position prior to the coring activities. The GPS antenna on the *Artemis* is located over the coring moon pool to ensure accuracy of the recorded sample location.

The coordinates entered into the GPS unit were double-checked using GIS to ensure they were within the correct sampling areas and within DU boundaries. Using the vessel's GPS, the captain navigated as closely as possible to the target sampling location, which was confirmed with the second GPS unit. GPS coordinates were collected each time the sampler was deployed. Figures 1 through 4 present the sampling locations within the lower harbor channel area. The depth at all stations was recorded using a fathometer. Surface elevations were recorded in MLLW using real-time updated tides from National Oceanic and Atmospheric Administration (NOAA) Tide Station #8665530 at Charleston, South Carolina, or the predicted tides for this project.

Navigation and positioning of the *Artemis* was handled by a U.S. Coast Guard-certified Master Captain under the direction of the ANAMAR project field team leader. All samples were collected within 10 meters of the target station and conformed to Section 2.2.2 of the SAP/QAPP. Waypoints were recorded on sampling field logs (Appendix B). Table 1 contains spatial and temporal data along with field observations taken during sediment core sampling.

2.2.1 Decontamination Procedures

All equipment contacting sediment or water samples were cleaned and decontaminated as described in Florida Department of Environmental Protection (FDEP) SOP-001/01 (FDEP 2008) and a new, pre-cleaned core tube was used at each station. Below is a summarized list of decontamination procedures. Work surfaces on the sampling vessel were cleaned before the sampling day began and before sampling at each new station. Nitrile gloves were changed between sampling stations to prevent cross-contamination.

Decontamination Procedures

- Wash and scrub using site water or tap water to remove gross contamination
- Wash/scrub with Liquinox®
- Rinse with site water
- Rinse with de-ionized (DI) water
- 2X rinse with pesticide-grade (or equivalent) isopropanol
- 3X rinse with DI water
- Air dry
- Store wrapped in new, clean aluminum foil

2.2.2 Sediment Sampling with Vibracore

Subsurface core sediment samples were collected from the R/V *Artemis*, a sampling vessel fitted with a vibratory core sampler (vibracore) and carrying all necessary sediment sampling equipment. Vibracore services were performed by Athena Technologies under the guidance of the ANAMAR field team leader who was present on the sampling vessel at all times to direct operations and record field notes.

The vessel captain navigated to each target using a helms map displayed on a Panasonic Toughbook® computer. Once on-station, the vessel was immobilized using a three-point anchoring system. Vessel coordinates were compared to station coordinates loaded into a second GPS to confirm location accuracy. Depths to the nearest inch were recorded from lead-line readings. RTK was not used. Bottom elevation was calculated in the field using real-time water level in feet MLLW as measured from NOAA Station ID 8665530 at Charleston. The NOAA tide level website was down on October 14, 2014, when core samples were collected at stations HIR14-2, BENR14-4, REBR14-2, REBR14-3, and REBR14-4. The Shem Creek predicted tide heights were used to document the MLLW at these specific stations. Table 1 includes the real time tide heights and water surface elevation data. The vibracore sample locations are shown on Figures 1 through 4.

Athena's vibracore system was deployed from the deck of the vessel and consisted of a generator with a mechanical vibrator attached via cable. This vibrator was attached directly to a 3-inch-diameter galvanized steel core barrel. The sampler was lowered to the substrate through a moon pool in the deck of the sampling platform by attaching lengths of drill stem. The vibracore apparatus was then activated and the core barrel allowed to penetrate the sediment until it reached target depth or refusal, whichever came first. The vibracore apparatus was then deactivated and the core was retrieved using an electric winch. Once the sample was on-deck, the recovered core length was measured. Cores longer than 10 feet were cut into 10-foot lengths, and each end of each section of core was capped and sealed.

The target elevation was 56 feet below the sediment surface (the full length of the core barrel). Thirteen of the cores achieved the target elevation. The remaining seven cores encountered refusal before achieving full penetration. Percent recovery averaged 87.4% (range = 80% to 97%) among the 20 core samples. Table 1 and Appendix C contain more information on vibracoring.

2.2.3 Sample Transport, Processing, and Custody

After returning to shore, the cores were transported to the Athena laboratory in McClellanville, South Carolina, where each core barrel was cut into sections and split lengthwise using a circular saw. Each core was then separated into subsamples based on significant stratigraphic horizons whenever such horizons were clearly evident. If horizons were not clearly observed, cores were separated into two sections as appropriate for adequate characterization of the samples. The geotechnical report drafted by Athena is included in Appendix C, and vibracore sampling station coordinates are presented on Table 1. Photographs of sampling operations are in Appendix F.

Chain-of-custody records for each laboratory (for chemical and physical analyses) were filled out by Athena to reflect the final sample names and to identify the analyses and analytical methods required. These chain-of-custody records accompanied the samples during shipment to the laboratories. The shipping schedule is summarized below (Exhibit 2-4). Copies of final signed chain-of-custody forms are included in Appendix B.

Exhibit 2-4. Sample Shipping Schedule

Laboratory	Sample Type(s)	Shipping Method	Shipping Date	Arrival Date
AMEC	• Physicals • Chemical (TOC)	FedEx	10/20/14	10/27/14
ALS Environmental	• Physical • Chemical (TOC)	FedEx	10/20/14	10/22/14 (logged in on 10/23/14)

2.3 Physical and Chemical Analytical Procedures

2.3.1 Physical Procedures

AMEC performed physical analysis of all sediment samples. ANAMAR performed quality assurance/quality control (QA/QC) and summarized the data.

2.3.1.1 Grain Size Distribution

Gradation tests were performed by AMEC in accordance with methods ASTM D-422 and ASTM D-1140. The representative sample was air-dried and dry-prepped in accordance with method ASTM D-421, and results of sieve analysis of material larger than a #10 sieve (2.00-mm mesh size) were determined. The minus #10 sieve material was then soaked in a dispersing agent. Following the soaking period, the sample was placed in a mechanical stirring apparatus and then in a sedimentation cylinder where hydrometer readings were taken over a 24-hour period. After the final hydrometer reading was taken, the sample was washed over a #200 sieve (0.075-mm mesh size), placed in an oven, and dried to a constant weight. After drying, the sample was sieved over a nest of sieves to determine the gradation of the material greater than #200 sieve size. Cumulative frequency percentages were graphed and presented by AMEC on USACE Form 2087 (Appendix C).

2.3.1.2 Moisture Content

Moisture content was determined in accordance with method ASTM D-2216-80 and Plumb (1981). The sample weight was recorded and the sample was placed in an oven and dried to a constant mass at 110°C (383.2 Kelvin). Once a constant dry mass was obtained, the percent moisture was determined by subtracting the dry mass from the wet mass, then dividing the loss in mass due to drying (the mass of just moisture) by the wet mass. The percent total solids were reported on a 100% wet weight basis.

2.3.1.3 Specific Gravity

Specific gravity was determined for sediment samples in accordance with method ASTM D-854. Each sample was placed in a mechanical stirring device and de-ionized water was added to form a slurry. The slurry was then transferred to a pycnometer and de-aired by applying a vacuum. After vacuuming, the pycnometer with sample was allowed to reach thermal equilibrium. The water level was adjusted to a calibration mark and the pycnometer with sample was weighed. After the pycnometer with sample weight was recorded, the sample was emptied into a drying container and placed in an oven until a constant dry mass of sediment solids was obtained.

2.3.2 Chemical Analytical Procedures

ALS performed TOC analysis on the sediment samples. ANAMAR performed QA/QC and summarized data and results. Brief descriptions of the analytical methods and instrumentation used to analyze sediments is provided in Exhibit 2-5.

Exhibit 2-5. Analytes, Methods, Target Detection Limits and Laboratory Reporting Limits: Sediment Chemistry

Test Parameter	Prep Method	Recommended Test Method	Target Detection Limit* (dry weight)	Laboratory Reporting Limit** (dry weight)
TOC	ASTM D4129-05	ASTM D4129-05	24 mg/kg = 0.024%	0.05% (0.02 MDL)

2.4 Data Reduction and Applicable Technical Quality Standards

Raw field and laboratory data were summarized and compiled into tables. Sampling locations can be found in Figures 1 through 4.

2.4.1 Sediment Chemistry

There are no published screening criteria applicable to TOC (USEPA and USACE 1991 [Green Book], Buchman 2008, USEPA and USACE 2008 [SERIM]).

2.5 Reporting Limits

The sediment chemical concentration, method detection limit (MDL), and method reporting limit (MRL) were reported on a dry weight basis. The MDL refers to the minimum concentration of a given analyte that can be measured and reported with a 99% confidence level that the analyte concentration is greater than zero. The procedures for determining MDLs is defined in 40 CFR Part 136 Appendix B for most chemical analyses.

3 RESULTS AND DISCUSSION

3.1 Field Data and In Situ Measurements

3.1.1 Weather Conditions

Field sampling took place from October 13 through October 16, 2014. Weather conditions during the field sampling effort were clear and sunny. Weather conditions did not delay or suspend any sampling operations, and the overall project schedule was maintained. Details on daily weather, wind, and tidal conditions are provided on the field sheets (Appendix B).

3.1.2 Vibracore Sampling Data

Refusal was encountered at some of the lower harbor core stations due to the presence of Cooper Marl, consolidated clay (especially calcareous clay), and/or coarse sand. "Cooper Marl" as originally described by Toumey (1848), is a term used to describe soft, very fine rained impure carbonate material along the Cooper and Ashley River's in South Carolina. The target depth of -56 feet was reached at all stations except WLWR14-3, WLWR14-4, HIR14-1, HIR14-2, HIR14-3, BENR14-6, and REBR14-1. The core barrel over-penetrated 0.2 to 11.4 feet below target elevation at 12 stations (WLRW14-1, WLWR14-2, HIR14-4, BENR14-1, BENR14-2, BENR14-3, BENR14-4, REBR14-2, REBR14-3, REBR14-4, REBR14-5, and REBR14-6). Over-penetration was measured at the Athena facility and the material collected below project depth was discarded. No material was discarded in the field.

Strong currents sometimes affected the core barrel during sampling by reducing the angle at which the barrel entered the sediment. A tag line was tied to the core barrel and operated from the bow of the vessel to correct for the effects of current.

Percent effective recovery averaged 87% (range = 80% to 97%) among the core samples retained for analysis (Table 1) and within the acceptance criteria for percent recovery (75%) as discussed in Section 2.2.5 of the QAPP (Appendix A).

One core sample was discarded from station HIR14-2 due to sample loss from the bottom of the core (possibly sand). The second core obtained from this station met acceptable recovery criteria.

3.2 Physical Testing Data

<u>Lower Harbor Core Stratigraphy Samples</u>

Grain size distribution was analyzed in core stratigraphy samples. Complete results of physical testing for grain size distribution, percent total solids, percent moisture, Unified Soil Classification System (USCS), specific gravity, and hydrometer readings are presented in Table 2. Laboratory reports of sediment physical analysis results using USACE Form 2087 are provided in Appendix C.

Project samples (core stratigraphy samples) for REBR14 (1A, 2A, 2B, 3A, 4A, 4B, 4C, 5A, 5B, 5C, 5D, 6A, 6B); BENR14 (1A, 1B, 1C, 2A, 2B, 3A, 3B, 3C, 4A, 4B, 5A, 6A and 6B); HIR14 (1A, 1B, 1C, 2A, 2B, 2C, 2D, 3A, 4A); and WLWR14 (1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B, 4A, 4B) were composed of varying percentages of fine to medium-grained sand, silt, and clay. Subsample IDs, respective depth interval, and grain size results are summarized in Exhibit 3-1.

Exhibit 3-1. Grain Size Distribution for Core Stratigraphy Samples

Sample ID and Depth in Feet Below MLLW	Grain Size Distribution[1] (percent by weight)				
	Gravel	Sand	Silt	Clay	USCS
REBR14-1A, (0.5'-2.0') Marl	0.0	30.5	23.6	25.9	MH
REBR14-2A, (0.0'-3.2')	1.4	52.7	26.0	18.4	SM
REBR14-2B, (3.2'-5.8')	0.1	84.6	6.4	8.9	SC
REBR14-3A, (0.0'-4.8')	13.8	81.8	3.9	0.5	SP
REBR14-4A, (0.0'-4.5')	5.3	27.1	31.6	36.0	CH
REBR14-4B, (4.5'-9.3')	1.8	95.6	0.9	1.7	SP
REBR14-4C, (9.3'-19.6')	0.3	86.6	5.7	7.4	SC
REBR14-5A, (0.0'-3.0')	0.4	89.6	5.7	4.3	SP-SM
REBR14-5B, (3.0'-6.0')	4.3	90.7	2.9	2.1	SP-SM
REBR14-5C, (6.0'-12.0')	0.8	79.9	9.4	9.9	SC
REBR14-5D, (12.0'-12.5') Marl	0.0	35.0	33.0	32.0	MH
REBR14-6A, (0.0'-3.5')	10.8	81.9	4.8	2.5	SP-SM
REBR14-6B, (3.5'-11.0')	5.9	87.8	4.5	1.8	SP-SM
BENR14-1A, (0.0'-3.3')	0.3	84.1	10.6	5.0	SM
BENR14-1B, (3.3'-6.9')	0.0	98.2	0.6	1.2	SP
BENR14-1C, (6.9'-11.3')	4.1	93.8	0.6	1.5	SP
BENR14-2A, (0.0'-6.0')	2.5	94.1	2.5	0.9	SM
BENR14-2B, (6.0'-12.6')	0.0	63.1	24.9	12.0	SM
BENR14-3A, (0.0'-7.0')	0.5	92.7	4.6	2.2	SP-SC
BENR14-3B, (7.0'-11.0')	23.7	72.8	3.5	0.0	SW
BENR14-3C, (11.0'-11.5') Marl	0.0	54.2	31.1	23.7	MH
BENR14-4A, (0.0'-5.0')	4.8	89.7	1.6	3.9	SP-SC
BENR14-4B, (6.5'-7.0') Marl	1.8	40.8	25.4	32.0	CH
BENR14-5A, (0.5'-1.0') Marl	0.0	36.6	25.8	34.9	CH
BENR14-6A, (0.0'-1.9')	0.0	32.3	32.6	35.1	CH
BENR14-6B, (3.0'-3.5') Marl	0.0	92.0	6.0	2.0	SP-SC
HIR14-1A, (0.0-3.3')	0.5	39.4	16.1	44.0	CH
HIR14-1B, (3.3'-7.0')	0.0	77.5	10.9	11.6	SC
HIR14-1C, (7.5'-8.0') Marl	0.0	76.8	7.3	15.9	SC
HIR14-2A, (0.0'-3.1')	1.1	93.0	3.2	2.7	SP-SM
HIR14-2B, (3.1'-5.8')	0.0	78.1	14.2	7.7	SM
HIR14-2C, (5.8'-8.3')	0.0	93.7	1.5	1.2	SP
HIR14-2D, (8.3'-8.8') Marl	0.0	34.7	36.2	27.9	MH
HIR14-3A, (0.0'-7.6')	5.9	80.2	6.1	7.8	SC
HIR14-4A, (0.0'-10.4')	1.4	76.0	5.9	4.2	SM
WLWR14-1A, (0.0'-7.3')	0.4	75.9	9.6	14.1	SC
WLWR14-1B, (7.3'-13.3')	3.5	89.9	3.1	3.5	SP-SC
WLWR14-1C, (13.5'-14.0') Marl	2.9	40.6	31.7	24.8	MH
WLWR14-2A, (0.0'-4.9')	1.5	67.7	19.0	11.8	SM
WLWR14-2B, (4.9'-10.3')	0.0	94.0	4.2	1.8	SP-SM
WLWR14-2C, (10.3'-13.3')	4.1	83.5	6.1	6.3	SP-SM
WLWR14-3A, (0.0'-2.9')	0.3	88.9	8.0	2.8	SP-SM
WLWR14-3B, (2.9'-9.0')	11.0	85.6	1.4	2.0	SW
WLWR14-4A, (0.0'-4.9')	2.2	62.7	20.5	14.6	SM
WLWR14-4B (5.5'-6.0') Marl	0.0	22.1	44.8	33.1	MH

[1]Particle sizes: gravel ≥4.750 mm, sand = 0.075–4.749 mm, silt & clay <0.075 mm.

CH = High plasticity inorganic clay or fat clay, MH = elastic inorganic silts, , or highly elastic inorganic silt, SC = Clayey sands, sand-clay mixtures, SM = Silty sands, silt-sand mixtures (>12% silt), SP = Poorly-graded sands (% fines <5%), SP-SC = Poorly-graded sand with clay (5%<Clay<12%), SP-SM = Poorly-graded sand with silt (5%<silt<12%), SW = Well-graded sand

3.2.1 Grain Size Distribution Summary

Gravel was identified in 28 of the 41 project samples, with the highest percentage being 23.7% in BENR14-3B and the lowest percentage being 0.3% in BENR14-1A, REBR14-4C, and WLWR14-3A. Percent sand ranged from 98.2% in project sample BENR14-1B to 27.1% in project sample REBR14-4A. Percent silt ranged from 36.2% in project sample HIR14-2D to 0.6% in project samples BENR14-1B and BENR14-1C. Percent clay ranged from 44.0% in project sample HIR14-1A to 0.0% in project sample BENR14-3B.

3.2.2 USCS Symbol Summary

CH

Project samples with USCS symbol CH include REBR14-4A, BENR14-4B, BENR14-5, and BENR14-6A.

MH

Project samples with USCS symbol MH include REBR4-1A, REBR14-5D, BENR14-3C, and HIR14-2D.

SC

Project samples with USCS symbol SC include REBR14-2B, REBR14-4C, REBR14-5C, HIR14-1B, HIR14-3A, and WLWR14-1A.

SM

Project samples with USCS symbol SM include REBR14-2A, BENR14-1A, BENR14-2A, BENR14-2B, HIR14-2B, HIR14-4A, WLWR14-2A and WLWR14-4A.

SP

Project samples with USCS symbol SP include REBR14-3A, REBR14-4B, BENR14-1B, BENR14-1C, and HIR14-2C.

SP-SC

Project samples with USCS symbol SP-SC include BENR14-3A, BENR14-4A, BENR14-6B, and WLWR14-1B.

SP-SM

Project samples with USCS symbol SP-SM include REBR-5A, REBR14-5B, REBR14-6A, REBR14-6B, HIR14-2A, WLWR14-2B, WLWR14-2C, and WLWR14-3A.

SW

Project samples with USCS symbol SW include BERN14-3B and WLWR14-3B.

3.3 Sediment Chemistry

Sediment chemistry was performed on all lower harbor stratigraphy samples. Analytical results for sediment chemistry (TOC results) are presented in Exhibit 3.2.

3.3.1 Total Organic Carbon (TOC)

TOC was detected above the MRL in all lower harbor stratigraphy subsamples. TOC concentrations in the lower harbor samples ranged from 0.108% (REBR14-4B) to 3.13% (REBR14-1A). The average percentage of TOC in the lower harbor stratigraphy samples is 0.791%. TOC analysis was not required for four project samples including HIR14-1A, HIR14-1C, WLWR14-1C and WLWR14-4B. Exhibit 3-2 provides the lower harbor sample TOC concentrations compared to the MRL. There are no published sediment screening criteria (i.e., TEL, ERL) for TOC.

Exhibit 3-2. TOC Results for Lower Harbor Core Stratigraphy Samples

	Total Organic Carbon			
Sample ID	**Result %**	**Qualifier**	**MDL**	**MRL**
REBR14-1A	3.13	-	0.020	0.050
REBR14-2A	0.841	-	0.020	0.050
REBR14-2B	0.318	-	0.020	0.050
REBR14-3A	0.459	-	0.020	0.050
REBR14-4A	0.828	-	0.020	0.050
REBR14-4B	0.108	-	0.020	0.050
REBR14-4C	0.214	-	0.020	0.050
REBR14-5A	0.447	-	0.020	0.050
REBR14-5B	1.83	-	0.020	0.050
REBR14-5C	0.347	-	0.020	0.050
REBR14-5D	1.54	-	0.020	0.050
REBR14-6A	0.533	-	0.020	0.050
REBR14-6B	0.421	-	0.020	0.050
BENR14-1A	0.317	-	0.020	0.050
BENR14-1B	0.082	-	0.020	0.050
BENR14-1C	0.074	-	0.020	0.050
BENR14-2A	0.224	-	0.020	0.050
BENR14-2B	0.203	-	0.020	0.050
BENR14-3A	1.12	-	0.020	0.050
BENR14-3B	1.79	-	0.020	0.050
BENR14-3C	1.12	-	0.020	0.050
BENR14-4A	0.263	-	0.020	0.050
BENR14-4B	2.07	-	0.020	0.050
BENR14-5A	2.07	-	0.020	0.050
BENR14-6A	0.248	-	0.020	0.050
BENR14-6B	1.88	-	0.020	0.050
HIR14-1A	Not Analyzed for TOC			
HIR14-1B	0.355	-	0.020	0.050
HIR14-1C	Not Analyzed for TOC			
HIR14-2A	0.157	-	0.020	0.050
HIR14-2B	2.35	-	0.020	0.050
HIR14-2C	0.178	-	0.020	0.050
HIR14-2D	1.32	-	0.020	0.050
HIR14-3A	0.459	-	0.020	0.050
HIR14-4A	0.509	-	0.020	0.050
WLWR14-1A	1.15	-	0.020	0.050
WLWR14-1B	0.206	-	0.020	0.050
WLWR14-1C	Not Analyzed for TOC			
WLWR14-2A	0.536	-	0.020	0.050
WLWR14-2B	0.404	-	0.020	0.050
WLWR14-2C	0.174	-	0.020	0.050
WLWR14-3A	0.287	-	0.020	0.050
WLWR14-3B	0.165	-	0.020	0.050
WLWR14-4A	0.945	-	0.020	0.050
WLWR14-4B	Not Analyzed for TOC			

– = no qualifier needed

4 QUALITY ASSURANCE/QUALITY CONTROL

4.1 Field Sampling

Field sampling took place October 13 through 16, 2014. Core processing took place October 15 and October 17, 2014, at Athena's facility in McClellanville, SC. Sampling and processing conformed to methods outlined in the QAPP, except for some differing core stratigraphy samples. See Appendix C and Table 2 for geotechnical report and physical subsample data.

The total range of core recoveries across all locations was 80% to 96%. At HIR14-2, the first core was discarded due to low recovery; the second core recovery was 85%.

The NOAA water level station at Charleston was down on October 14, 2014, when core samples were collected at stations HIR14-2, BENR14-4, REBR14-2, REBR14-3, and REBR14-4. The Shem Creek predicted tide heights were used to measure water elevation during this period (see Table 1).

4.2 Sample Receipt

4.2.1 AMEC

Sediment samples were received at AMEC on October 27, 2014, in good condition.

4.2.2 ALS Environmental

Sediment samples were received at ALS Environmental on October 22, 2014 and logged in on October 23, 2014, in good condition. The samples were stored at 4°C, and an aliquot of the sediment was frozen at -20°C upon receipt at the laboratory.

All analyses were performed consistent with ALS Environmental's QA program. This report contains analytical results for samples designated for Tier IV validation, including summary forms and all associated raw data for each analysis. When appropriate to the method, method blank results have been reported for each analytical test.

4.3 Physical Analysis

All physical analyses were performed by AMEC, and the results met the quality control criteria specified in the QAPP. One triplicate was analyzed for grain size for the core samples.

4.4 Total Organic Carbon

Sample triplicates were not analyzed; however, three sample duplicates were analyzed and all quality control met the acceptance limits stated in the QAPP.

5 REFERENCES

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