RESTORE ACT CENTER OF EXCELLENCE FOR LOUISIANA FINAL TECHNICAL REPORT

Due within 30 days of the close of the award

Project Title: Improving the Design and Construction Practice of Marsh Creation Projects

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A. TECHNICAL ACTIVITIES

1. Research Summary

The objective of this study is to address the knowledge gaps in the design and construction practices of marsh creation projects. The findings will equip design engineers with essential tools for better estimating the volume of dredged material and the temporal changes in marsh surface elevation. The research approach is centered on integrating field data collection with laboratory testing. The behavior of slurry will be examined through the principles of consolidation theory and by analyzing the sedimentation of relatively dilute suspended sediments—zone settling—to form a soil matrix. The results will yield insights into whether the design elevation will be achieved by the end of a marsh creation project. Such knowledge is particularly crucial for marsh creation projects that require deep filling.

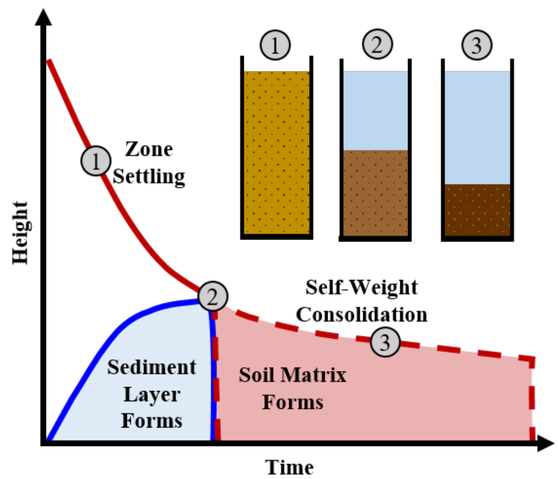

Fig. 1. *Illustrative sketch of consolidation and zone settling. The horizontal axis indicates time and vertical axis indicates the vertical distance from the initial bed elevation. The states of sediment-water mixture in the settling column corresponding to 1, 2 and 3 are shown in the upper right corner with darkening color indicating the concentration.*

Once the soil matrix forms, it undergoes consolidation due to its self-weight. At this stage, the void ratio, or porosity, becomes a crucial parameter, as it reflects the volume of voids that can be filled by the soil under its own weight. This void ratio is also influenced by the zone settling that occurs prior to self-weight consolidation. Thus, it is imperative to more accurately quantify zone settling and then use this data to predict self- weight consolidation. Zone settling is closely related to sediment size, or the content of fine sediments. However, no current relationship allows us to estimate the void ratio as a function of sediment size to predict the consolidation rate over time. Moreover, it is uncertain whether settling column tests can provide accurate void ratio estimates for actual marsh creation projects. Therefore, the focus of this study will be on developing relations for self-weight consolidation informed by zone settling. To accomplish this objective, our methodology was based on

(i) Historical analyses of past marsh creation projects with different borrow material ranging from fine to coarse sediments with different response characteristics to vertical loading (see Table 1),

(ii) On-site field measurements to determine the undrained shear strength of soil —thus the soil stratigraphy— , collect soil samples to determine the sediment size distribution, and the elevation of the soil surface, and

(iii) Perform laboratory tests by using the in sito soil samples collected to determine the grain size distribution, geotechnical indices, such as plasticity index and liquid and plastic limits of the soil.

For the first objective, a historical analysis was conducted on completed marsh creation projects. The sites were selected based on the varying soil mechanics properties of the borrow area soil. Analyses were conducted on selected sites with varying proportions of fine and coarse sediment content in the borrow area soil, considering the availability and compatibility of dredging equipment. In collaboration with Mr. Jacques Boudreaux, who is the project's point of contact at CPRA, we selected three completed marsh creation projects for analysis (see Table 1). The goal is to establish a relationship between various environmental and engineering parameters, such as the fine sediment content of the borrow material, soil plasticity, and the bulking ratio, denoted as P. These parameters have been selected because they represent the range of soil behavior from its initial weak mud deposit state to a fully consolidated soil matrix. Coarse sediments exhibit a solid-like behavior when densely packed, with minimal deformation, whereas fine sediments can plastically deform and consolidate by expelling water from the pores in the soil matrix. The plastic behavior of soil begins after zone settling is complete. During zone settling, the soil remains in a liquid state. Consequently, the fine sediment content, along with the liquid and plastic limits, and the plasticity index of the soil, become the governing parameters for consolidation, thus the bulking ratio. The bulking ratio is the ratio of the soil volume in the designated marsh creation area to that of the dredged borrow material, which is the inverse of the cut-to-fill ratio. The bulking ratio serves as a proxy for efficiency, as it measures the amount of land created per cubic yard of borrow material. Therefore, a higher bulking ratio suggests a more efficient project.

Table 1 *Project parameters for the three marsh creation projects selected for historical analysis.*

Project Code	Project Name	Location	Dredging Equipment Diameter (cm)	Sediment Type
CS-54	Grand Bayou	Lake Calcasieu, Cameron Parish	46	High plasticity clay
TE-100	Caillou Lake	Whiskey Island, Terrebone Parish	76.2	Sand
PO-104	Bonfouca Bayou	Lake Pontchartrain, St. Tammany Parish	76.2	Sandy clay and clayey sand

These projects were chosen due to their significantly different sediment types, geographic locations, and dredging equipment. The primary parameters of interest included grain size, plastic limit, liquid limit, plasticity index, and dredge outfall location and dredge equipment availability or compatibility. Geotechnical characteristics of the soil were particularly selected because they govern the vertical deformation of soil. Parameters such as geographic location were designated as secondary.

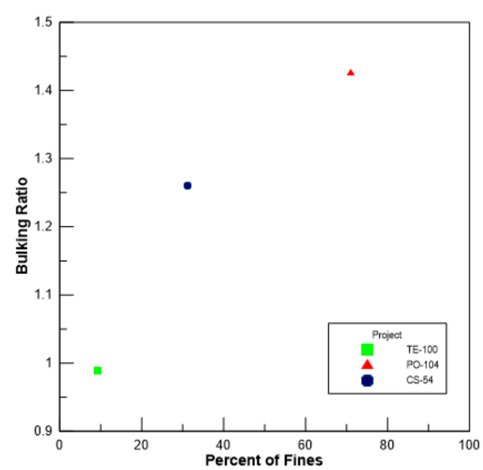

Figure 2 *Bulking ratio with respect to percent fine content in the dredge material inferred from the construction reports of the three projects analyzed.*

The historical analyses suggest that the main factor affecting the bulking ratio is the sediment type, in line with existing literature. As expected, coarser sediments, such as sand, do not undergo a long-term consolidation process, meaning the volume in the borrow area will be similar to the volume once placed in the marsh creation cells. Conversely, finer sediments, such as clays, will have undergone years of consolidation before being dredged. Therefore, when clays are placed in the marsh creation cells, the consolidation process begins anew, resulting in a greater volume post-dredging (see Figure 3). The total values for bulking ratios at each project are presented in both Table 3 and Figure 3. The method through which fill volume data was collected is also conveyed in the table. We suspect that the flat lines towards the end of each curve in Figure 3b is due to lack of continuous data, which probably affects the accuracy of the bulking ratio obtained from grade stake readings.

Table 2 *Bulking ratios for the three projects, calculated from topographic surveys and grade stake readings. The fourth and sixth columns are obtained from grade stake (GS) readings.*

Project	Cut volume (m³)	Fill Volume (m³)	Fill Volume (m³) (GS)	Bulking Ratio	Bulking Ratio (m³) (GS)
CS-54	2,694,000	3,554,000	3,249,000	1.32	1.23
PO-104	2,764,000	3,937,000	N/A	1.42	N/A
TE-100	7,961,000	7,861,000	N/A	0.99	N/A

We closely analyzed whether the dredge outfall location impacts the consolidation process by utilizing construction reports from completed projects. Each analysis converged on a similar conclusion; therefore, we discuss our findings based on the Grand Bayou project (CS-54). The dredge outfall location affects the short-term bulking ratio of the soil, but this impact diminishes as the outfall is moved to subsequent locations. The northern marsh creation area of CS-54 is shown in Figure 3a, divided by areas that exhibited different behaviors according to the grade stake readings. The inset table in Figure 3 presents the days during which the outfall was at each location, while Figure 3b shows the mudline elevation in each area.

Site	Days in Use
A.	1-49
B.	50-68
C.	69-91
D.	92-106
E.	107-119

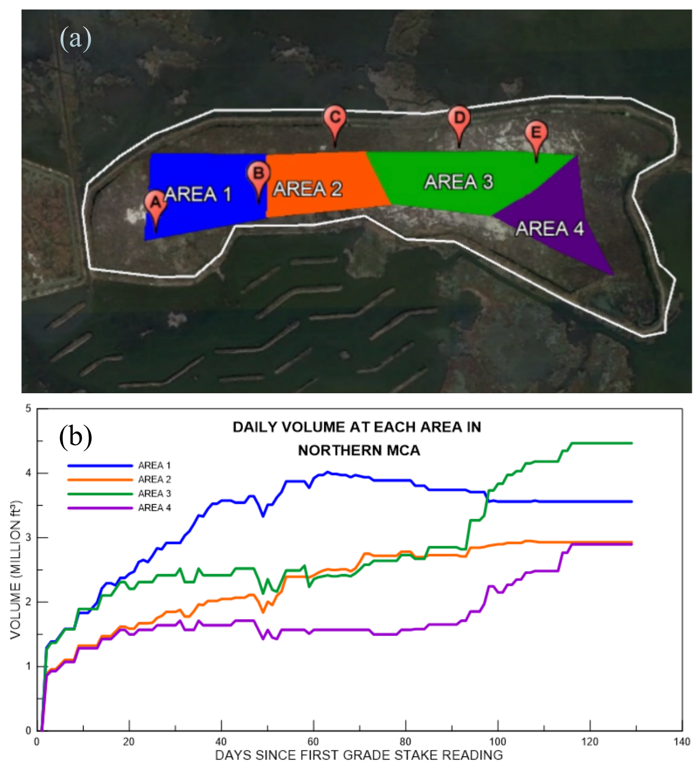

Figure 3 *(a) Northern Marsh Creation Area (MCA) of Project CS-54, divided into four distinct areas exhibiting different mudline behaviors throughout the dredging process. (b) Volume in the Northern MCA of CS-54 plotted as a function of days since the initiation of grade stake monitoring. A, B, C, D, and E in (a) locates the points of dredge outlets, and the days of operation are given on the left.*

The mudline increases rapidly in the vicinity of the dredge outfall. Shortly after the change of the dredge outfall location, sediments start consolidating. It is important to note that data was not collected daily, and the daily reports would present values for previous days' mudline. It must be noted that the volume refers to the soil volume beneath the mudline in Figure 3b. The aim of this analysis is to determine if the elevation gain resulting from infilling correlates with the sand fraction in the dredged soil. It is hypothesized that an increased sand fraction will cause sand deposition closer to the dredge outfall, whereas fine sediments will settle further away, resulting in non-uniform particle size distribution. This is anticipated to result in non-uniform consolidation characteristics.

The subsequent phase of the study will concentrate on a specific marsh creation project. However, there were unexpected delays due to challenges in acquiring site access for the field study. The initial project proposed for this study was the New Orleans Land Bridge Marsh Creation Project (PO-169); however, due to over a year of construction delays and issues with site access, the project was suspended. Consequently, we had to select a new project for our study. Given the issues encountered with PO-169, a project that has already completed its construction phase was preferred. The Caminada Backbarrier Marsh Creation Project (BA-171 and BA-194) was chosen. Permits were expedited and obtained approval from the landowners in late October 2023. <u>The first site visit is scheduled for December 7th, 2023. The site visit will fullfill objective (ii), and initiate the task associated with objective (iii) through the samples collected.</u>

The field data collection and laboratory experiment plans are briefly described in the next two sections.

DESCRIPTION OF FIELD DATA COLLECTION ACTIVITIES:

A. **UAV Photogrammetry:** The first site visit will include a reconnaissance survey. We will utilize UAV photogrammetry to collect aerial images of the site. This data will be used to assess the site conditions and elevation, which will then help identify the locations for sampling. Our selection of sampling points will be primarily based on the number of measurement points needed to adequately represent the consolidation process across the entire marsh creation site, as well as the ease of access to these points.

B. **Cone Penetrometer Tests (CPT):** With the points identified from the reconnaissance survey, CPTs will record the tip resistance of the penetrometer. The tip resistance measured by the CPTs will enable the determination of shear strength and pore-water pressure with respect to depth. Depth profiles of shear strength will yield information on the soil stratigraphy, indicating the degree of consolidation following the placement of dredged material.

C. **Russian Peat Cores:** CPT measurments will be complemented by the use of a Russian Peat Corer to obtain soft soil samples. The corer is equipped with a rotating steel blade and a sharpened tip. As the blade turns, it will enclose the sediment within a chamber that is 4 inches in diameter and 6 feet in length.

DESCRIPTION OF LABORATORY EXPERIMENTS:

Once sufficient data samples are collected, the laboratory experiments will be initiated. We will obtain the grain size distribution using a laser particle size analyzer. Moisture content will be measured by oven-drying the sample, and then used to measure the specific gravity of sediment using a pycnometer. Bulk density will be calculated from these measurements.

Standard tests will be employed to measure the Atterberg limits, that is liquid and plastic limits. We will perform settling column and constant rate of strain tests to determine the self-weight consolidation of the soil samples. With the lab analysis, we will obtain the low stress consolidation properties as a function of sediment particle size and index properties.

Completion of the tasks will enable us to draw practical conclusions about the consolidation of the borrow material in the marsh creation area, with special interest in deeper water areas. Typical marsh creation projects infill sediment with mudlines of -1 ft to -2 ft NAVD88. Deeper water areas indicate mudlines closer to -4 ft to – 6 ft NAVD88. Because consolidation is a nonlinear process, adding 2–3 ft could substantially add to the required volume of dredge material. The deeper water also means containment dikes will need to be built higher, which will load very soft organic clays. Analyses are described below to investigate the effect of deeper water in the design process and implications to dredging volumes and containment dikes.

- *Dredge material consolidation:* We will perform consolidation simulations in two scenarios, mudlines of -2 ft NAVD88 and – 5 ft NAVD 88. We will explore building the marsh in one lift and multiple lifts to achieve a target elevation at the end of construction or end of primary consolidation. By conducting a mass balance, we can understand the additional volume of sediment needed to build in deeper areas. We anticipate the self-weight consolidation properties will vary across the site because of sediment heterogeneity in the borrow area and particle size redistribution from the pipe outfall area. We will perform the two scenarios for the range of sediment properties to constrain its impact on the dredged volume.
- *Containment dike stability:* Similar to the consolidation analyses, we will perform slope stability analyses of the containment dike for two mudline elevations. Using our obtained shear strengths, we can evaluate the factor of safety, along with alternatives to improve the design (e.g., build multiple lifts, incorporate a geotextile fabric, etc.). Typical construction involves building the containment dike in multiple lifts and knowing the rate of strength gain can provide a better indication of how quickly they can be built.

Table 2. *Project tasks and timeline for the remainder of the project.*

Task	**Dec**				**Jan**				**Feb**				**Mar**				**Apr**			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site Reconnaissance																				
UAV survey/sampling locations																				
Field Campaign – CPTs & Coring																				
CPT data analysis																				
Core analysis																				
Geotechnical analyses																				
Design recommendations																				

2. **Application of research to implementation of Coastal Master Plan**: The proposed work will help develop and implement consolidation and slope stability engineering practice for marsh creation for these projects. This includes providing CPRA and industry engineers the tools to reduce the volume of dredged material while achieving the marsh surface elevation performance metric. This is especially important given the financial scale of the planned projects because savings from the marsh creation projects can be strategically reinvested for other restoration efforts. Other outcomes of this research are methods related. For example, we will provide methods for performing the field and lab tests, along with generate ideas for future data collection during construction.

   As part of this project, we have developed computer code capable of generating a video sequence of post-construction elevations from grade stake readings. This tool will be instrumental in monitoring the progress of the marsh creation project during the construction phase. It will be shared with CPRA engineers and come with a user guide that will also be made available to the public.

B. DELIVERABLES

*Note – please submit all PDFs of reports, papers, and presentations with the final report **in the portal** (LA-COE Apply). Thank you!*

1. **Deliverables on proposed goals and objectives.** If a goal or activity is not completed, please describe in the “comments” why actual output / deliverable deviated from the proposed.

#	Proposed goal / objective / activity	Target output / deliverable	Completed (Y/N)	Comments	Topical area (s) and research need(s) addressed (as described in the proposal)
1	Historical analyses of past marsh creation projects with different borrow material ranging from fine to coarse sediments with different response characterics to vertical loading	Initial assessment of important soil properties on cut-to-fill ratio was made. Fine sediment content was found to be the governing parameter.	Y		Develop standardized geotechnical laboratory testing procedures for hydraulically dredged slurry for marsh fill material
2	On-site field measurements to determine the undrained shear strength of soil —thus the soil stratigraphy— , collect soil samples to determine the sediment size distribution, and the elevation of the soil surface	.	N	Reconnaissance survey in Caminada Headland has been conducted on December 7^{th}. The collected samples will be analyzed within the time frame given in Table 2.	Develop standardized geotechnical laboratory testing procedures for hydraulically dredged slurry for marsh fill material
3	Perform laboratory tests by using the in sito soil samples collected to determine the grain size distribution, geotechnical indices, such as plasticity index and liquid and plastic limits of the soil.	Standardized geotechnical laboratory testing procedure for hydraulically dredged slurry for marsh fill material	N	The standardization of laboratory testing will be made after completion of the laboratory testing, which are ongoing and will be finished as outlined in Table 2.	Develop standardized geotechnical laboratory testing procedures for hydraulically dredged slurry for marsh fill material

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2. Peer-reviewed publications. Please provide .pdf copies of all publications.

Authors	List author names of graduate students/postdocs	Title	Journal	DOI (or other identifier)	Published; submitted; in prep; planned?	Date
Daniel Gellagos, Navid H. Jafari, Celalettin E. Ozdemir	Daniel Gellagos	Geotechnical Aspects of Marsh Creation Efficiency Assessment	Journal of Waterway Port Coastal and Ocean Engineering	N/A	Planned	TBD

3. Oral presentations and posters. (See the pdf attached at the end)

Presenter	Co-authors	List author names of graduate students/Postdocs	Title	Oral or poster?	Conference or meeting name	Date	Proceedings published? (Y/N)
Daniel Gallegos	Jafari, N. H., Ozdemir, C. E. & Boudreaux, J.	Daniel Gallegos	EMPIRICAL MODEL OF SEDIMENT TRANSPORT AND CONSOLIDATION IN MARSH CREATION PROJECTS	Poster	Coastal Sediments 2023	04/12/2023	Y
Daniel Gallegos	Jafari, N. H., Ozdemir, C. E. & Boudreaux, J.	Daniel Gallegos	COMPARISON OF EFFICIENCY IN MARSH CREATION PROJECTS	Poster	State of the Coast 2023	06/01/2023	N

4. **List other products or deliverables**. These can include white papers, patent applications, workshops, outreach activities/products. Describe and provide .pdf copies, as applicable.

5. **Data.** Making data publicly accessible in a timely manner is a key goal of the data management policy of RESTORE Act Center of Excellence. All projects must ensure that data and ISO metadata are collected, archived, digitized, and made available using methods that allow current and future investigators to address new questions as they arise. Per the U.S. Department of the Treasury's Office of Gulf Coast Restoration Data Accessibility and Management Best Practices[1] *"Data are generally expected to be made publicly available at the time of publication of a peer- reviewed article relying on the data or two years after the data are collected."* All information products resulting from funded projects must be associated with detailed, machine-readable metadata (ISO format) and shared in a regional or national digital repository or data center (e.g., National Centers for Environmental Information, Gulf of Mexico Research Initiative Information & Data Cooperative, Inter-university Consortium for Political and Social Research, DataOne Dash) for discovery and long-term preservation. Metadata, a brief description of the data, and location of the data (e.g., repository, DOI) must be provided to the LA-COE to enable tracking of all data and information products.

#	Data Title	Data Description	Repository or Data Center	Date by when it will be publicly available (1 year after final report)	DOI link (if already available)
1	TBD	Geotechnical characteristics of soil from three marsh creation projects	TBD	11/1/2024	TBD
2	TBD	Bulking ratios and timeline from three marsh creation projects	TBD	11/1/2024	TBD
3	TBD	UAC Photogrammetry data	TBD	11/1/2024	TBD
4	TBD	Cone Penetrometer Tests	TBD	11/1/2024	TBD
5	TBD	Russian Peat Core CPT measurements	TBD	11/1/2024	TBD
6	TBD	Project monitoring computer program for marsh creation projects, including the surce code and user guide	TBD	11/1/2024	TBD
7					

[1] https://www.fio.usf.edu/documents/flracep/program-documents/Treasury%20RESTORE%20COE%20data%20management%20best%20practices%20Jan%202018.pdf

6. **Mentoring and Training.** Please list post-doctoral and graduate and undergraduate student participants (provide .pdf copies of thesis/dissertation).

First Name	Last Name	BS/MS/PhD/Postdoc	# Years involved	Institution	Thesis/Dissertation Title/Research Topic or Tasks	Did the student graduate? (Y/N)	If they graduated, current position/location?
Daniel	Gellagos	MS	2	Louisiana State University A&M		N	

C. CERTIFICATION

Certification: I certify to the best of my knowledge and belief that this report is correct and complete for performance of activities for the purposes set forth in the award documents.

Principal Investigator: Celalettin Emre Ozdemir

Signature: Celalettin Ozdemir

Name: Celalettin Emre Ozdemir

Date Signed: 12/4/2023

Approval: I have evaluated the final report and associated invoice and confirm that the project is finished.

LA-COE Technical Point of Contact:

Signature: Jason Curole

Name: Jason P. Curole

Date Signed: 12/8/2023

Approval: I have reviewed the final report and approve for payment.

LA-COE Director:

Signature: Jessica R. Henkel

Name: Jessica Renee Henkel

Date Signed: 12/28/2023

EMPIRICAL MODEL OF SEDIMENT TRANSPORT AND CONSOLIDATION IN MARSH CREATION PROJECTS

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Abstract: Louisiana's land loss problem is a well-studied phenomenon. In order to mitigate the effects of this phenomenon, Louisiana Coastal Protection and Restoration Authority has set in place the Coastal Master Plan, with marsh creation projects as a cornerstone. Marsh creation projects are costly, mainly due to dredging costs. A better understanding of the dredging process and its driving factors can help reduce the costs. In this paper these factors are analyzed setting the basis for the future development of an empirical model. Three different projects, that had different locations, dredge fill material and equipment used were analyzed. It was possible to conclude that there is a correlation between sediment type and the bulking factor in the finished projects.

Background

Wetlands provide flood protection against hurricane storm surge and waves (Barbier et al. 2013; Gedan et al. 2011). Several studies have showed that coastal marsh vegetation helps increase wave attenuation by reducing the wave height per unit distance across the wetlands (Koch et al. 2009; Shepard et al. 2011). Severe levels of deterioration have been observed in the Louisiana coastline, this can be attributed to marsh edge erosion, saltwater intrusion, sediment deprivation, and channel construction (Harris et al. 2020).

The economic value the wetlands provide in the form of property protection is considerable, even a small increase in the solid wetland to water ratio could yield significant monetary savings (Barbier 2013). Conversely, the lack of action restoring and protecting the wetlands has a negative economic impact. Not solely as a result of the loss of protection against storm surge, but also due to the effects on industries such as fisheries which has been reported to perceive reductions in the range of tens of millions of dollars as a result of the land loss (Craig et al. 1979).

The Louisiana Coastal Protection and Restoration Authority (LACPRA) has recognized that the Louisiana coasts bring between $12 and $47 billion dollars to the nation in benefits (LACPRA 2017). In order to protect these coasts and the benefits they provide, LACPRA has set in place the Coastal Master Plan. This initiative has set future steps in order to protect the existing coastline and restore the land that has been lost (LACPRA 2017). Restoration projects are one of the cornerstones of this plan. Dredged sediment has been used for the last several decades, and the projections suggest they will be more frequently used in the future (Edwards and Proffitt 2003).

The main factor driving the cost of marsh creation projects is dredging, which accounts for around 60% of the cost of the project, this means that even a slight reduction in the cost of dredging will result in a massive amount of savings given the amount of cubic yards each project includes and the amount of projects that LACPRA has approved for the upcoming years (LACPRA 2017). The cost of dredging is directly related to the energy required, dredges almost solely use diesel fuel, hence the price of diesel plays a weighty role in the total cost of dredging (Hollinberger 2010; Murphy 2012). A greater understanding of how hydraulically dredged sediment will move, settle, and consolidate will reduce the uncertainty and therefore improve volume predictions and fuel efficiency.

This paper aims to set the parameters for the future development of an empirical model. To set these parameters, it is necessary to identify the different factors that affect the efficiency of marsh creation projects. The cut-to-fill and bulking ratios will be used as an indicator of efficiency. The effects of the location, grain size, percent of fines and diameter of the dredge were analyzed so as to determine their impacts on a project's efficiency. The importance of the location of the dredge outfall will also be analyzed in order to better comprehend the behavior of the dredge fill sediment. The conclusions drawn will aid in the future development of a model that will predict the behavior of the dredged material in marsh creation areas (MCAs).

Methods

The increase in elevation throughout the development of the marsh creation projects is key to identify the volume of the fill material. Two different methods for monitoring the change in elevation were employed in the analyzed projects: grade stakes (GS) and surveying. GS are driven into the ground and allow for easily accessible daily readings. Surveys cannot be performed as frequently, although they offer higher accuracy. Because borrow areas are in open water (lakes or oceans) the change in elevation is measured solely by surveys.

Because the GS location is known and daily readings were available, it was possible to calculate a fill volume from the elevations. MCAs were divided into different areas according to GS proximity and similarity in daily readings. The GS are not usually placed towards the earthen containment dikes of the marsh creation cells; therefore, the volume was not accounting for the entire MCA. Linear extrapolations were performed in order to account for the remaining area. Using the GS readings, it was possible to observe the daily behavior in MCAs that used this method. A MATLAB code was written to create daily contour maps based on the GS readings. A correlation between the dredge outfall location and the change in elevation was observed.

Surveys of complete MCAs are usually performed only in pre-construction and after finalizing the project. The lack of frequency in measurements makes it impossible to create a time-dependent analysis for projects monitored through surveys. The pre-construction and 30 days post-construction surveys were inputted in AutoCAD Civil 3D. This program has the capability of calculating the difference in volume between the pre-construction survey and the completed project.

Cut-to-fill and bulking ratios were utilized to determine the efficiency of the projects. The cut and fill volumes were estimated through GS readings or surface comparison the ratios were calculated using Equations 1 and 2:

$$Cut - to - Fill\ ratio = \frac{Cut\ Volume}{Fill\ Volume} \tag{1}$$

$$Bulking\ ratio = \frac{1}{Cut{-}to{-}Fill\ ratio} \tag{2}$$

Results

As previously mentioned, the state of Louisiana has prioritized marsh, barrier islands, and headland restoration projects in the 2017 Coastal Master Plan. Almost a third of the total projects that LACPRA has identified in their 2017 Coastal Master Plan are classified as either marsh creation or barrier island/ headland restoration. In order to obtain the broadest dataset possible, three very different projects were selected. Differences in sediment grain size, dredging equipment, and monitoring procedures can be observed among these projects.

Three marsh creation projects were analyzed, Table 1 presents the project name, location, and type of sediment. Figure 1 presents the general location of the three projects.

Table 1 Site description for each project

Project Code	Project Name	Location	Dredging Equipment Diameter (cm)	Sediment Type
CS-54	Grand Bayou	Lake Calcasieu, Cameron Parish	46	High plasticity clay
TE-100	Caillou Lake	Whiskey Island, Terrebone Parish	76.2	Sand
PO-104	Bonfouca Bayou	Lake Pontchartrain, St. Tammany Parish	76.2	Sandy clay and clayey sand

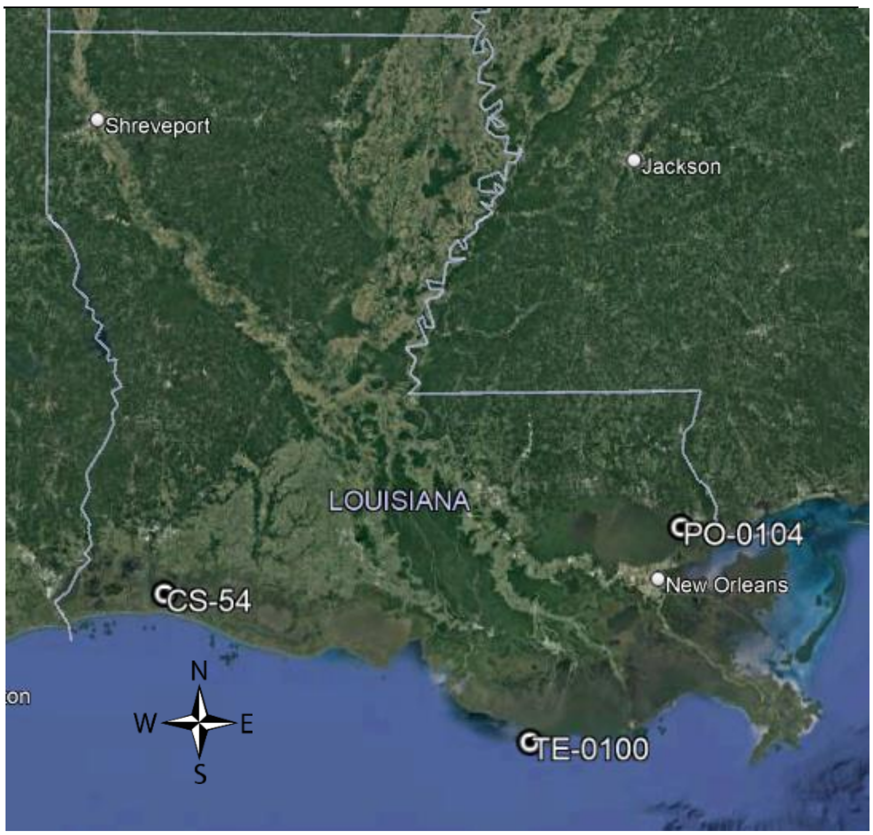


Figure 1. Location of CS-54, TE-100, and PO-104 in Louisiana.

CS-54 Analysis

Project CS-54 consists of three MCAs and one Marsh Nourishment Area (MNA) as shown in Figure 2. The MCAs are known as Northern, Southern and Louisiana Department of Natural Resources (LDNR) MCAs. This project was monitored through both GS and surveying. Contractor daily reports were used to obtain GS readings, dredging rates, and dredge outfall locations. GS located in the northern and southern MCAs allowed for the monitoring to be continuous during the dredging of the fill material, these readings were used to create contours for the dredged material elevation. Example contours for the southern MCA are presented in Figure 3. The dredge outfall location and direction of the flow are also shown in the figure.

Figure 2. Location of MCAs and MNA in project CS-54.

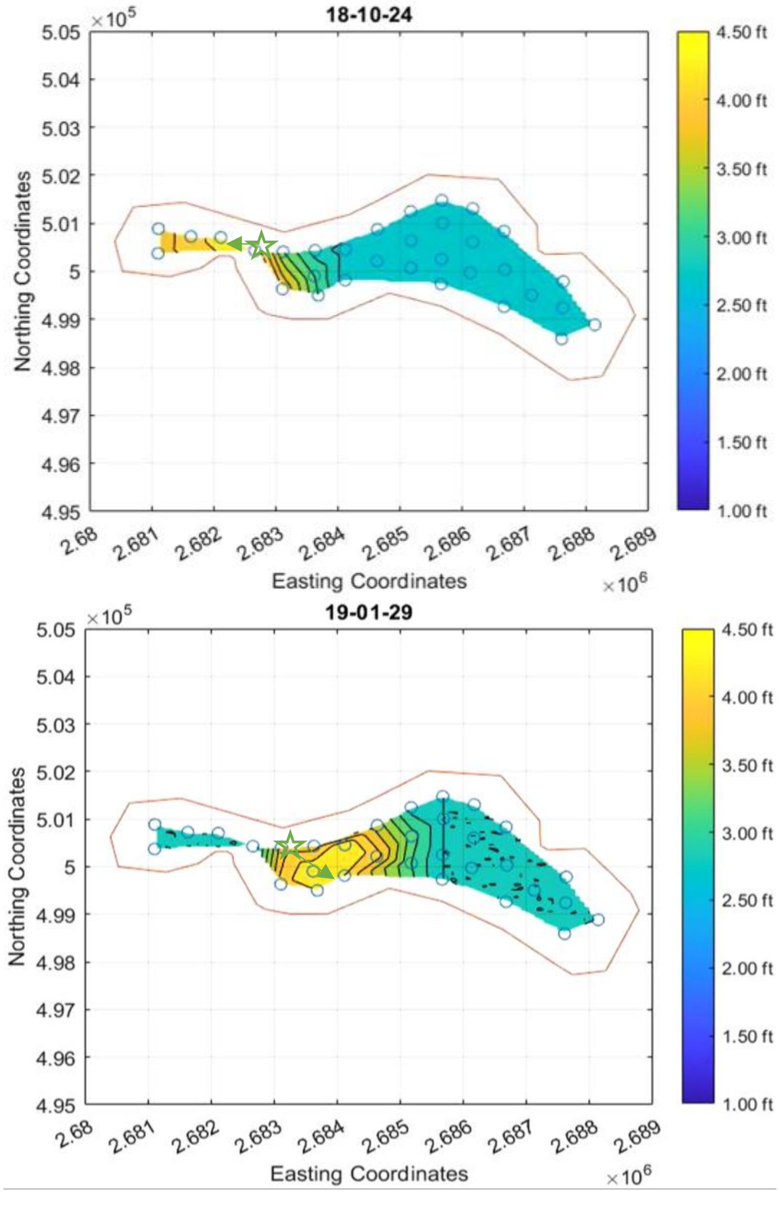


Figure 3. Contours for the southern MCA of project CS-54 for days 118 (top) and 153 (bottom) after the first GS reading. The purple line represents the Earthen Containment Dike (ECD), the blue circles represent the GS locations, the star and the arrow represent the dredge outfall locations and directions, respectively.

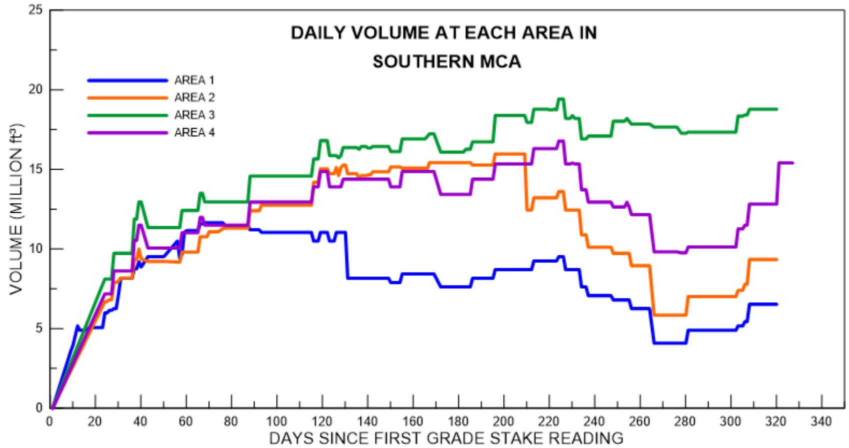
It is possible to observe that the GS are not covering the whole area of the MCAs. Therefore, to calculate the volumes extrapolations were performed. The northern and southern MCAs were divided into four areas based on the time in which they were receiving dredged material. The extrapolated volumes for the southern and northern MCAs are presented in Figure 4.

GS readings are consistent with the location of the dredge outfall. GS that are closer to the outfall show higher increases in elevation. In the days following the outfall being relocated, consolidation begins to occur and noticeable decreases in elevation occur. A clear example occurs on day 45 in the Northern MCA. The outfall was moved from Area 1 to Area 2. Area 1 shows a decrease in volume while Area 2 shows an increase. It is important to note that there are instances in which the same value is presented for several days in a row before presenting a sudden change. This is likely due to inability to take a GS reading.

All three MCAs, the MNA, and the borrow area for the source materials were surveyed pre-construction and 30 days post-acceptance of the project. The two surfaces were compared using the software Civil 3D. Cut-to-Fill ratios were calculated for the project. The results of this analyses are presented in Table 2.Table 2 Cut and fill calculations for project CS-54

MCA	SMCA	NMCA	LDNR	MNA	Total
Total Fill from GS (yd³)	1,852,000	1,287,000			4,249,000
Total Fill from surveys (yd³)	2,358,000	1,181,000	255,000	855,000	4,649,000
Cut volume yd³					3,523,000
Cut-to-Fill Ratio (GS)					0.83
Cut-to-Fill Ratio (Surveys)					0.76

There is a difference of approximately 11% in the total cut volumes when calculated from the GS readings and the surveys. Cut-to-fill ratios were 0.83 and 0.76 for the GS and surveys, respectively. The average cut-to-fill ratio is 0.80 (bulking factor of 1.26). The information from the surveys from LDNR MCA and the MNA were used in the calculation for the cut-to fill ratio from the GS.



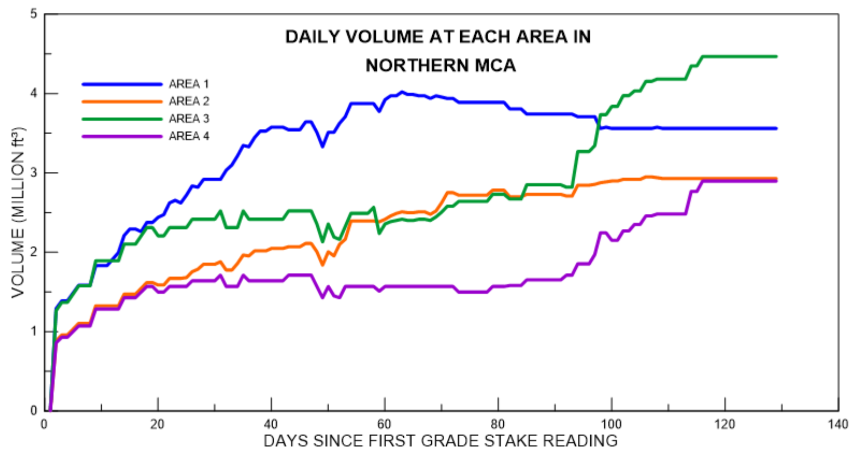


Figure 4 Extrapolated volumes for each of the areas in the southern (top) and northern (bottom) MCAs

TE-100 Analysis

Project TE-100 is a barrier island restoration located in the Caillou Headlands, south of Calliou Lake, as shown in Figure 5. This project consists of only one cell, and one borrow area. Therefore, the dredged sediment is mainly sand. Since the sandy sediment will settle within a short distance from the dredge outfall, the use of GS was not possible, therefore the only means of monitoring the progress throughout the project is by comparing the surfaces generated from the topographic surveys.

Given that the surveys were not performed as often as the GS readings, this analysis focuses on the pre-construction and 30-day post-construction surveys. From the surface comparison in Civil 3D, the cut and fill volumes were calculated. The cut volume comes out to be 10,412,000 yd^3 (7,961,000 m^3), and the fill volume is 10,282,000 yd^3 (7,861,000 m^3). The resulting cut-to-fill ratio for this project was 1.01 (bulking factor of 0.99).

Figure 5 Location of project TE-100

PO-104 Analysis

Project PO-104 is in the northeastern bank of Lake Pontchartrain. It consists of four MCAS and three MNAs as shown in Figure 6. The dredged fill sediment in this project was predominantly high plasticity clay, which formed clay balls. Two borrow areas were used for the completion of this project, identified as northern and southern borrow areas.

The volume calculations were performed using the change in elevation found during the pre-construction and 30-day post-completion surveys. The results of the cut and fill volumes are presented in Table 3. Because of the dredge fill material conditions, GS were not used in this project. Therefore, it is impossible to obtain a daily result. The volume approximation was established from the surveys. The cut-to-fill ratio for this project is 0.70 (bulking factor of 1.43).

Figure 6 Location of project PO-104

Table 3 Cut and fill volumes in PO-104

Area	Fill Volume, yd³ (m³)	Cut Volume, yd³ (m³)
MCA 1	1,630,000 (1,246,000)	
MCA 2	625,000 (478,000)	
MCA 3	103,000 (79,000)	
MCA 4	351,000 (268,000)	
MNA 1	1,342,000 (1,026,000)	
MNA 2	382,000 (292,000)	
MNA 3	716,000 (547,000)	
Northern Borrow Area		1,549,000 (1,184,000)
Southern Borrow Area		2,066,000 (1,580,000)
Total	5,149,000 (3,937,000)	3,615,000 (2,764,000)

Discussion

The three projects had significantly different conditions, based on their location dredge fill sediment type, and equipment used. These differences have an impact in the amount of material required to complete the project.

The dredged sediment type is the main factor driving the cut-to-fill ratios, the content of fines has a direct impact on the sediment transport of the material. Coarse materials will deposit close to the dredge outfall, while fine grained materials will float prior to flocculation and posterior deposition. Finer materials will also bulk once they are excavated and dredged into the MCAs.

The percent of fines in each project were obtained from the geotechnical reports. Figure 6 presents the relationship between the percent of fines and the bulking factor.

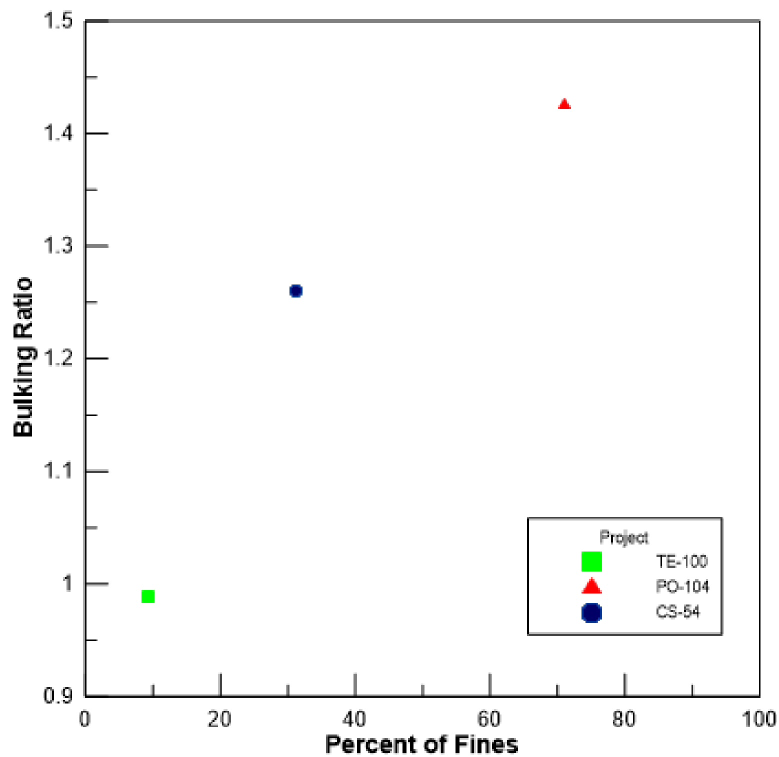


Figure 7 Relationship between percent of fines in the three projects

It is possible to observe the direct relationship that exists between the content of fines and the bulking ratio. This relationship is most likely due to the consolidation clays have undergone through time in the borrow area. Once they are excavated and dredged, the soil structure is broken and the self-weight consolidation in the MCAs will occur over a long period of time.

Conclusions

Three different projects were analyzed through GS and survey data. GS data has proved to be valuable. In order for the data to be properly analyzed obtaining reliable, frequently collected data is key for further analyses.

The three different projects that were analyzed showed that there is a correlation between the grain size of the dredge fill material and the cut-to-fill (or bulking) ratio. The material used in each project depends on site availability, as well as the type of restoration project. Barrier island restoration projects tend to use coarser materials, whereas marsh restoration projects use finer sediments.

The development of a model will use the data presented in this paper, as well as integrating other projects developed by CPRA to obtain a broader data set that provides more accurate results.

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