Overview of statewide geophysical surveys for ecosystem restoration in Louisiana

By

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ABSTRACT

The System Wide Assessment and Monitoring Program (SWAMP) was implemented by the Louisiana Coastal Protection and Restoration Authority (CPRA) to develop an Adaptive Management Implementation Plan (AMIP). SWAMP ensures that a comprehensive network of coastal data collection/monitoring activities is in place to support the development and implementation of Louisiana's coastal protection and restoration program. Monitoring of physical terrain is an important parameter of SWAMP. For the first time a systematic approach was adopted to undertake a geophysical (bathymetric, side-scan sonar, sub-bottom profile, and magnetometer) survey along more than 5,000 nautical miles (nm) (excluding the 1,559 nm currently being surveyed from west of Terrebonne Bay to Sabine Lake) of track-line in almost all of the bays and lakes from Chandeleur Sound in the east to Terrebonne Bay in the west. This data collection effort complements the regional bathymetric survey undertaken under the Barrier Island Comprehensive Monitoring (BICM) Program in the adjacent offshore areas. This paper describes how a study of this magnitude was conceptualized, planned, and executed along the entire Louisiana coast. It is important to note that the initial intent was to collect bathymetric data only for numerical modelling for ecosystem restoration and storm surge prediction. Geophysical data were added for oyster identification and delineation. These first-order data also help comprehend the regional subsurface geology essential for sediment exploration to support Louisiana's marsh and barrier island restoration projects.

KEYWORDS: Geophysical survey, bathymetric survey, regional monitoring, surficial geology, oyster, side-scan sonar, physical terrain, System Wide Assessment and Monitoring Program (SWAMP).

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Louisiana's dynamic coastal environment lends itself to adaptive management given ongoing landscape changes and the difficulty in predicting the future effects of protection and restoration actions. Adaptive management is critical in coastal Louisiana as most of the strategies adopted are first-of-their-kind, either in scale or scope, and do not have well-established templates to follow (Killebrew and Khalil 2018). An Adaptive Management Implementation Plan (AMIP) was developed to maximize the success of the coastal protection and restoration program by iteratively incorporating new information into each step of the decision-making process to reduce uncertainty in projects and programs. Monitoring is an important adaptive management tool. The state of Louisiana's commitment to monitoring and adaptive management of its coastal zone is evidenced by their monitoring efforts through the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA); the Coast-wide Reference Monitoring System-Wetlands (CRMS-Wetlands); and the Barrier Island Comprehensive Monitoring (BICM) Program.

As the research program in coastal Louisiana expanded, it has become evident there are limited geophysical data in the basins and the lakes along coastal Louisiana. Available data, if any, are sparsely distributed and outdated. Much of the available bathymetric data were collected more than five decades ago. The Louisiana Coastal Protection and Restoration Authority (CPRA) identified a critical need for updated bathymetric, and geophysical data (sub-bottom profiler (seismic), magnetometer and side-scan sonar). Bathymetric data support the hydrodynamic modeling efforts along with quantifying vertical change and providing the basis for future design. Sub-bottom profiler data (Roberts *et al.* 1999) address CPRA's more than 14,000 million cubic yards (mcy) of sediment resource needs for restoring coastal marshes, wetlands and barrier islands in addition to mapping surface and subsurface oyster beds (Khalil *et al.* 2018). Side-scan sonar data support mapping oyster beds as well as infrastructure and hazards on the surface of the seafloor. Poling and oyster dredge tows ground-truth the sub-bottom and side-scan sonar data. Magnetometer data are typically collected to identify potential underwater wrecks, submerged hazards or other features that would affect borrow area delineation and dredging activities. These data are also collected to identify hazards to existing oyster beds (e.g. pipelines).

These data also help in understanding the subsurface geological setting which helps in exploration of restoration quality sediment resources. Exploration for available and accessible sediment is crucial for sustainable ecosystem restoration in Louisiana. Three restoration strategies for ecosystem restoration, which dominate the 2017 Master Plan (viz. river diversions, barrier island restoration, and marsh platform creation), are directly related to land building and are indicative of the importance of sedimentological restoration for maintaining and creating topographic and bathymetric features (Killebrew and Khalil 2018).

The Louisiana Coastal Area Ecosystem Restoration Study Science and Technology Program proposed the System Wide Assessment and Monitoring Program (SWAMP) as an overarching umbrella for both regional monitoring programs viz. CRMS and BICM. For additional details on SWAMP, please see the paper entitled "Statewide monitoring for restoration of coastal Louisiana and data management" by Raynie *et al.* in this Dedicated Issue of Shore & Beach as well as CB&I (2016), APTIM (2018a) and APTIM (2019) which are available on CPRA's Coastal Information Management System website at https://cims.coastal.louisiana.gov/Default.aspx. The purpose of SWAMP is not only to ensure implementation of adaptive management but also to make sure that a comprehensive network of coastal data collection activities is in place to support the development and implementation of the coastal protection and restoration program.

GEOLOGIC HISTORY OF MISSISSIPPI RIVER DELTA PLAIN (MRDP)

Developing an understanding of the geologic setting of a region is important because the regional geologic setting defines the seafloor surfaces and the sediments that blanket them. The nature of sedimentary deposits determines sediment type, quality, distribution, and potential use for restoration and habitat creation projects. It is necessary to understand the continental shelf environment because the distribution of sediment on the seabed is not random, but spatially organized (Bentley *et al.* 2016; Penland *et al.* 1988; Kulp *et al.* 2005).

The subsurface geology and surface geomorphology of Louisiana's coastal zone has a complex history of regional plate tectonic events and fluvial, deltaic and marine sedimentary processes affected by numerous large-magnitude sea level variations (Kulp *et al.* 2005). The oldest lobes of the Mississippi delta began to accumulate sediment about 7,000 Years Before Present (YBP), when the rate of sea level rise decelerated and sea level was almost at its present position (Fisk and McFarlan 1955; Roberts 1997). River avulsion (rapid channel switching) and diversion, which often result in delta switching, are responsible for the present complex and diverse geomorphology and stratigraphy of the Mississippi deltaic plain. Delta building occurred at different locations about every 1,000 to 2,000 years (Roberts 1997; Coleman *et al.* 1998). Delta building was initiated when the last of the continental glaciers melted and sea level rose to its present level. This rise in sea level flooded southern Louisiana. Subsequently, the Mississippi River filled the flooded areas with sediment.

The sequence of delta building for Mississippi River Delta Plain as discussed by various workers is summarized below (Coleman 1982: Penland *et al.* 1987; Roberts 1997;). By 7,300 YBP, the main channel of the Mississippi River was located where the present channel of Bayou Maringouin runs. From 7,300 YBP to 6,000 YBP the Mississippi River built the Maringouin Delta Complex where the present-day East and West Cote Blanche Bays and Atchafalaya Bay are located. This delta grew for about 2,500 years until about 5,000 YBP. The Mississippi River then shifted to the west side of the valley, following the course of the Bayou Teche. The Teche Delta Complex developed and partly overlapped the Maringouin Delta Complex. As sedimentation shifted to the east, the Maringouin Delta Complex subsided and open water bays appeared. The Cote Blanche Bays, Atchafalaya Bay, Marsh Island and a few offshore shoals are all that remain of the Maringouin Delta Complex (Penland *et al.* 1988). The Teche Delta Complex grew for approximately 3,500 years, until the Mississippi River shifted toward the east to build the St. Bernard Delta Complex into the area where the city of New Orleans now stands. The St. Bernard Delta Complex grew from 4,600 YBP to 2,000 YBP (Twichell *et al.* 2009). After it was abandoned by the river, waves reworked the front of it. The Chandeleur Islands and an array of marshes in east St. Bernard Parish are remnants of the St. Bernard Delta Complex. About 3,500 YBP, the Mississippi River shifted west again, running south along the course of Bayou Lafourche. The Lafourche Delta Complex grew between 3,500 YBP and 400 YBP. Lake filled marshes in Terrebonne Parish, Terrebonne Bay and Timbalier Bay, Isles Dernieres, Timbalier Island, and East Timbalier Island are remnants of this delta. About 1,000 YBP to 800 YBP, the Mississippi River shifted to its present (Balize) course and began building the modern Birdsfoot delta that we see today.

SURVEY PLANNING

An extensive review of existing geophysical data housed in the LouisianA SAnd Resources Database (LASARD) was conducted. Sub-bottom and bathymetric datasets were reviewed for quality, spatial coverage and timeliness. The review indicated that geophysical (single-beam bathymetry, sub-bottom profiler, side-scan sonar, magnetometer) data inside the bays and nearshore waters of coastal Louisiana are sparsely distributed and/or quite old (CB&I 2016).

Track-line spacing was variable throughout the SWAMP data collection area and was driven by the data type, study area and available budget. The ultimate goal was to provide a regional understanding of the study area and to collect the largest volume of data possible within the allocated budget. Track-line spacing of 3,000 ft was selected for full suite geophysical data collection (bathymetric, sub-bottom profiling, magnetometer and side-scan sonar) to provide the detail necessary to delineate oysters and, if possible, provide some insight into subsurface geology preferably linking it to the surrounding sediment deposits (APTIM 2018a; APTIM 2018b). For areas where only bathymetric data were collected, 6,000 ft line spacing was used due to the relatively featureless survey areas.

MOBILIZATION AND SURVEYING

The bathymetric, side-scan sonar, sub-bottom profiler and magnetometer surveys were conducted concurrently using the setup illustrated in Figure 1. Table 1 provides a summary of the equipment used during these surveys. Table 2 provides a summary of the surveys including details and line miles. In an effort to reduce vessel running time and reduce fuel burn rates, the base of operations was moved as the surveys progressed.

Phase 1: Barataria Bay Pilot Study

Hydrographic and geophysical data were collected within Barataria Basin and within a few selected coastal lakes in southern Louisiana as part of the Barataria Pilot Study (Figure 2) (CB&I 2016). Sub-bottom profiler, magnetometer and bathymetric data were collected within Barataria Bay, Little Lake, Lake Salvador, Lac des Allemands, Lake Cataouatche, The Pen, Bayou Perot, Bayou Rigolets, and other major hydrologic pathways (Baie des Deux Chenes, Bayou Cutler Channel, and GIWW). In addition to sub-bottom profiler, magnetometer and single beam bathymetry, side-scan sonar data were also collected in Little Lake and Barataria Bay. Twenty-three grab samples

Table 1.
Summary of equipment used for each survey type.

Type of survey	Instrumentation	Specifications
Positioning	Trimble Real Time Kinematic (RTK) Global Positioning System (GPS)	• Sounding data corrected for water level fluctuation relative to NAVD88
Bathymetric	Odom Hydrographic Systems, Inc. "Hydrotac" Hydrographic Echosounder (single beam system)	• Operated at 200 kHz • Calibrated daily for speed of sound using Valeport SWiFT Sound Velocity Profiler • Bar checks performed daily
Magnetometer	Geometrics G-882 Digital Cesium Marine Magnetometer	• ±0.1 gamma resolution • Floated at or just below water surface 50-75 ft behind the survey vessel to avoid recording magnetic signatures from the survey vessel
Sub-bottom profiler	EdgeTech SB-216s Sub-bottom Profiler	• Operated with a pulse frequency sweep of 2.0 kHz-15.0 kHz with a 20 ms pulse length. • System set to ping at a rate of up to 8 Hz run with a 20%-40% pulse power level
Side-scan sonar	EdgeTech 4200	• System operated at 100/400 kHz and 300/600 kHz, with maximum range scales of 1,640 ft at 100 kHz, 754 ft at 300 kHz, 492 ft at 400 kHz and 393 ft at 600 kHz • Utilized for regional, widely-spaced survey lines to maximize coverage
	EdgeTech 4125	• System operated at 400/900 kHz, with max. range scales of 492 ft at 400 kHz or 246 ft at 900 kHz. • Utilized for detailed, closely-spaced survey lines survey lines to maximize imagery resolution
Sediment sampling	Ponar grab sampler	• Spring-loaded dredge designed for shallow samples
Poling	Probe/pole	• Hard pole for bottom probing
Oyster dredge tow	Custom fabricated oyster dredge	• 33"x17"x18" with a 0.5 inch wire mesh lined collection basket

were collected from locations selected based on review of the side-scan sonar data. After initial review of the geophysical data, 21 1-mile square blocks that potentially contain oysters were surveyed at 300- to 400-ft line spacing. These surveys were conducted to obtain information on the presence of oysters and also on the type of acoustic signal that oysters can be expected to produce. This provided guidance when interpreting the sub-bottom and side-scan sonar data.

Phase 2: Lake Borgne, Lake Pontchartrain, Chandeleur Sound, and Mississippi River Gulf Outlet (MRGO)

Geophysical surveys were conducted (bathymetry, side-scan sonar, sub-bottom profiler and magnetometer) within Lake Borgne (Figure 2). Bathymetric data were collected within Lake Pontchartrain, Chef Menteur Pass, and the Rigolets (Figure 2). Within the western section of Chandeleur Sound geophysical data (bathymetry, side-scan sonar and magnetometer) were collected (Figure 2). Only bathymetric data were collected in the eastern portion of Chandeleur Sound (Figure 2). Bathymetric and side-scan sonar data were also collected in the Mississippi River Gulf Outlet (MRGO) (Figure 2). Poling (probing the seafloor with a pole to assess bottom type) was conducted in conjunction with the side-scan sonar survey within Lake Borgne and the western section of Chandeleur Sound. Linear poling samples were taken at approximately 1,000 ft intervals along the survey transects. Up to five poling replicates were conducted at each location to further verify bottom types. To ground-truth the poling and side-scan sonar data, oyster dredge tows were collected using a custom fabricated wire mesh lined collection basket designed to retain small shell hash and bivalve/benthic species. These surveys are summarized in APTIM 2018a and APTIM 2018b.

Phase 3: Terrebonne Basin

This third survey phase included the Terrebonne Basin and select bayous and channels surrounding the basin (Figure 2) (APTIM, 2019). Survey operations included the collection of bathymetric, sub-bottom profiler, side-scan sonar, magnetometer, and poling data within the Terrebonne basin. Oyster dredge tows were collected to ground-truth the side-scan sonar and poling data to determine bottom condition and whether or not oysters were present.

Data processing

All data were processed according to the methods outlined in CB&I (2016), APTIM (2018a), APTIM (2018b) and APTIM (2019).

RESULTS

Bathymetric data and full-suite geophysical (sub-bottom, side-scan sonar, and magnetometer) data were collected during the last four years (2015-2019) in bays and lakes from Chandeleur Sound in the east to Sabine Lake in the west (Table 2). A Topo-Bathy Digital Elevation Model (TBDEM) was created using the methods

Table 2.
Data collection summary for Phases 1 through 3.

Phase	Survey area	Type of survey	Metrics	Line spacing (ft)	Features identified
1	Barataria Bay, Little Lake	Geophysical (full suite)	782 nm	3,000	Potential oysters, bottom elevation, geologic features, potential hazards
1	Lake Salvador, Lac des Allemands, Lake Cataouatche, The Pen, Bayou Perot & Rigolettes, major hydrologic pathways	Geophysical (full suite excluding side-scan sonar	492 nm	3,000	Bottom elevation. geologic features, potential hazards
1	Barataria Bay detailed survey blocks (21 blocks)	Geophysical (full suite)	331 nm	300-400	Potential oysters, bottom elevation, geologic features, potential hazards
1	Barataria Bay detailed survey blocks (21 blocks)	Sediment sample	23 grab samples	N/A	Potential oysters, bottom type
2	Lake Borgne	Geophysical (full suite)	705 nm	3,000	Potential oysters, bottom elevation, geologic features, potential hazards
2	MRGO, Eastern & Western Chandeleur Sound	Bathymetry only	734 nm	500-6,000	Bottom elevation
2	Lake Pontchartrain, Chef Menteur Pass, Rigolets	Bathymetry only	740 nm	6,000	Bottom elevation
2	MRGO, Eastern & Western Chandeleur Sound	Geophysical (bathymetry, side-scan sonar)	491 nm	500-6,000	Potential oysters, bottom elevation
2	Lake Borgne, MRGO, Eastern & Western Chandeleur Sound	Poling	46,505 sites	N/A	Potential oysters
2	Lake Borgne, Western Chandeleur Sound	Oyster dredge tows	300 tows	N/A	Potential oysters
3	Terrebonne Basin and select bayous and channels	Bathymetry	1,088 nm	6,000	Bottom elevation
3	Terrebonne Basin and select bayous and channels	Geophysical (full suite)	993 nm	3,000	Potential oysters, bottom elevation, geologic features, potential hazards
3	Terrebonne Basin and select bayous and channels	Geophysical (excluding side-scan sonar)	95 nm	3,000	Bottom elevation, geologic features, potential hazards
3	Terrebonne Basin	Poling	3,480 sites	N/A	Potential oysters
3	Terrebonne Basin	Oyster dredge tows	94 tows	N/A	Potential oysters

outline in APTIM (2019) (Figure 3). Elevations throughout the investigation area ranged from approximately -1.0 ft to -11 ft NAVD. Elevations of up to -100 ft were found in channels and in northern Chandeleur Sound. Deeper channels were found within inlets to the Gulf of Mexico as well as channels connecting portions of bayous and adjacent lakes. Several isolated lakes and bayous were uniformly shallow and mostly inaccessible to the survey vessels. These lakes are estimated to have elevations shallower than -4 ft NAVD.

It is important to note that interpretations of the sub-bottom profiler data, are based on experience interpreting similar acoustic sub-bottom profiler data and they were not ground-truthed by geotechnical (vibracore) data. Only data confirmed by geotechnical data can be considered probable. Therefore, all sub-bottom profiler interpretation for this project should be considered potential.

Analysis and interpretation of the sub-bottom profiler data indicates that the shallow sub-surface geology of the survey areas is predominately gas/organic mud, paleochannels, potential channels, potential hard bottom, gas/potential hard bottom and mixed silty sediments (Figure 4). There are also some areas along channels where there are resistant clay layers that occasionally outcrop and become exposed at the seafloor. The varied depositional environments both horizontally and vertically match the geologic models of Frazier (1967) and Penland *et al.* (2002), where the depositional delta of the Mississippi River migrated east and west across the study area over the last 7,000 years (Figure 2). Seaward-dipping reflectors potentially corresponding to Holocene marine, estuarine and tidal shoal sands/silts were identified throughout Little Lake and Barataria Bay and seem to be interbedded with silt (Flocks *et al.* 2006). These deposits were more

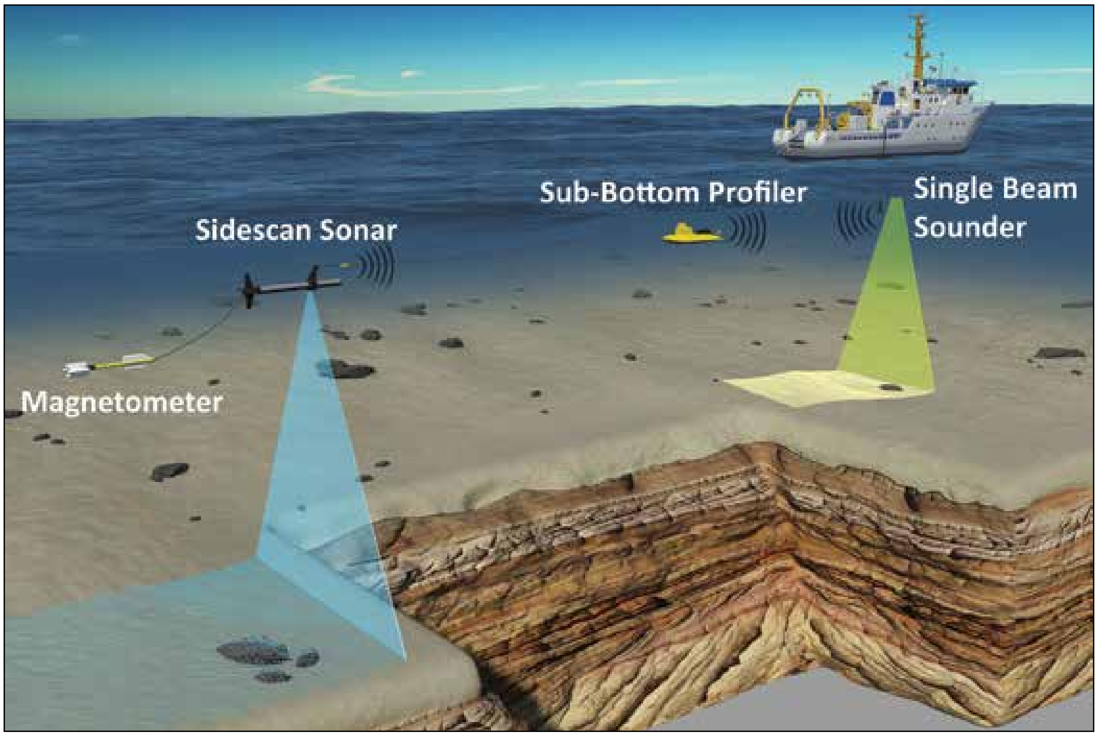

Figure 1 Schematic diagram showing the typical deployment of sensors for a joint bathymetric, sub-bottom profiler, sidescan sonar and magnetometer survey.

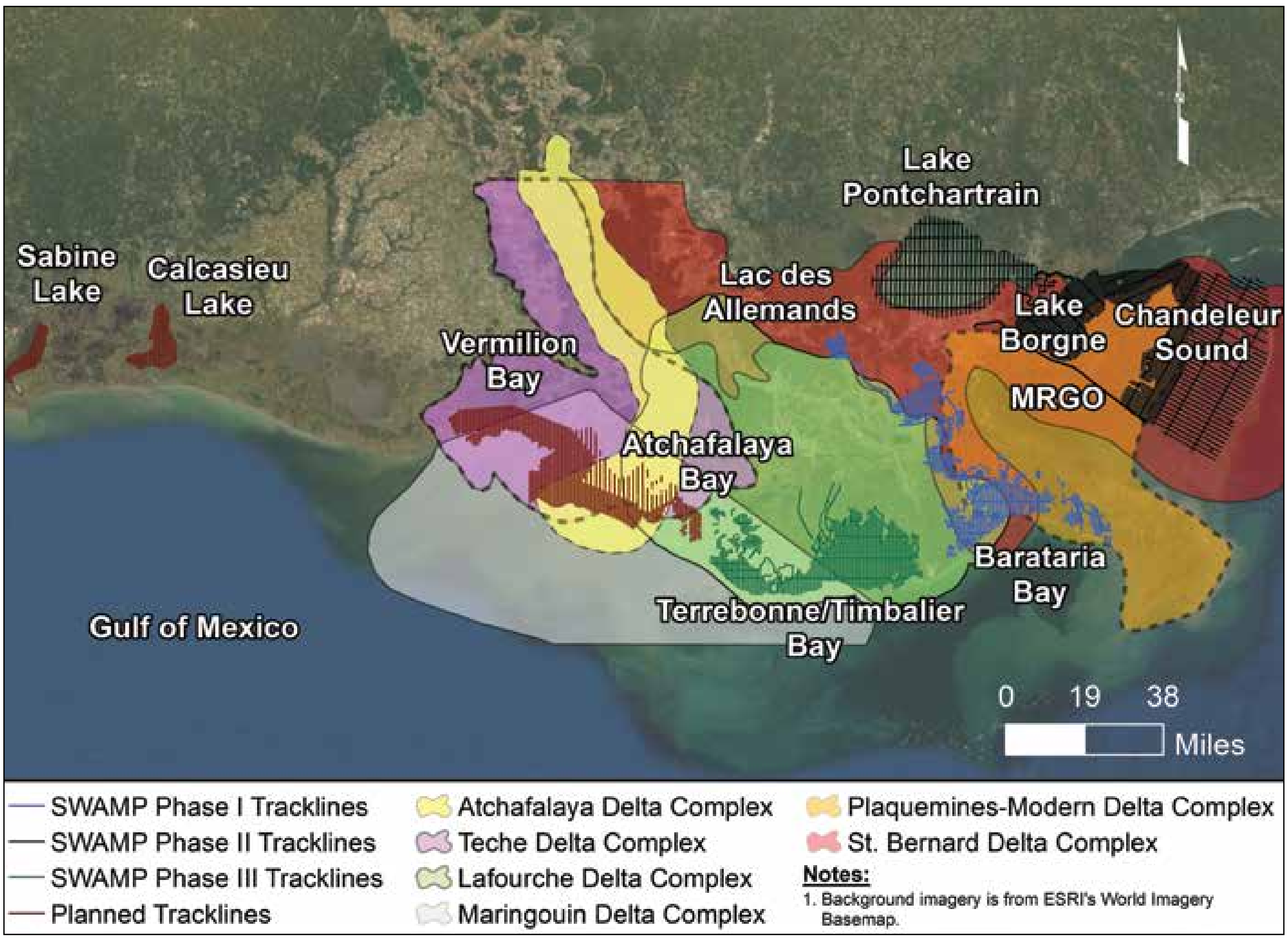

Figure 2. As run survey tracklines. Surveys are currently being conducted to the west of the Terrebonne Basin along the lines designated as "Planned Tracklines." The tracklines have been superimposed on the Mississippi delta complexes defined by Frazier (1967) and Penland *et al.* (2002).

prevalent on the west side of Barataria Bay and were observed to have boundaries at depths of 5 to 30 ft beneath the seafloor (Figure 5).

Delineation of potential oysters was achieved by looking for areas of high return/high intensity backscatter in the side-scan sonar data. Such signals can be caused by any object, debris and/or hard bottom features and without sampling or physical observation of the bottom, it is difficult to accurately determine or confirm oyster beds. While geologists utilized the backscatter intensity, distribution and texture to make educated interpretations as to the location of potential oyster beds, these interpretations are solely based on the acoustic response and required additional ground-truthing to confirm the acoustic interpretation.

Nearshore coastal Louisiana has a long history of maritime commerce, which contributes to its high potential for anthropogenic items and debris. Over 17,000 magnetic anomalies were identified. Some were classified as "Potential Pipelines" due their close proximity (within 200 ft) to known pipelines (locations available through databases like the National Pipeline Mapping System). All other anomalies were classified as "Unidentified Anomalies." Despite their apparent association with existing pipelines, some of the Unidentified Anomalies appear to represent elongated objects. Many of the magnetic anomalies appear to represent active and abandoned infrastructure. Areas like Terrebonne Bay have a high concentration of oil and gas infrastructure (flow lines, pipelines, platforms, wellheads, etc.), sometimes located in dense concentrations. Most magnetic anomalies found around the infrastructure indicate the potential for subsurface pipelines and cables. Other magnetic anomalies may represent lost or discarded dredge pipe, lost equipment, tools, shipwrecks and/or cultural resources. It is also important to note that a large number of these anomalies were located within heavily traveled canals. However, without an associated acoustic feature, it is difficult to confidently identify many of these anomalies without ground-truthing the area. In addition, a large number of crab pots were located throughout the survey sites which, due to their ferrous nature, give off a magnetic signature. The wide line spacing of this survey does not support eliminating any magnetic anomalies from consideration as potential hazards, pipelines or cultural resources.

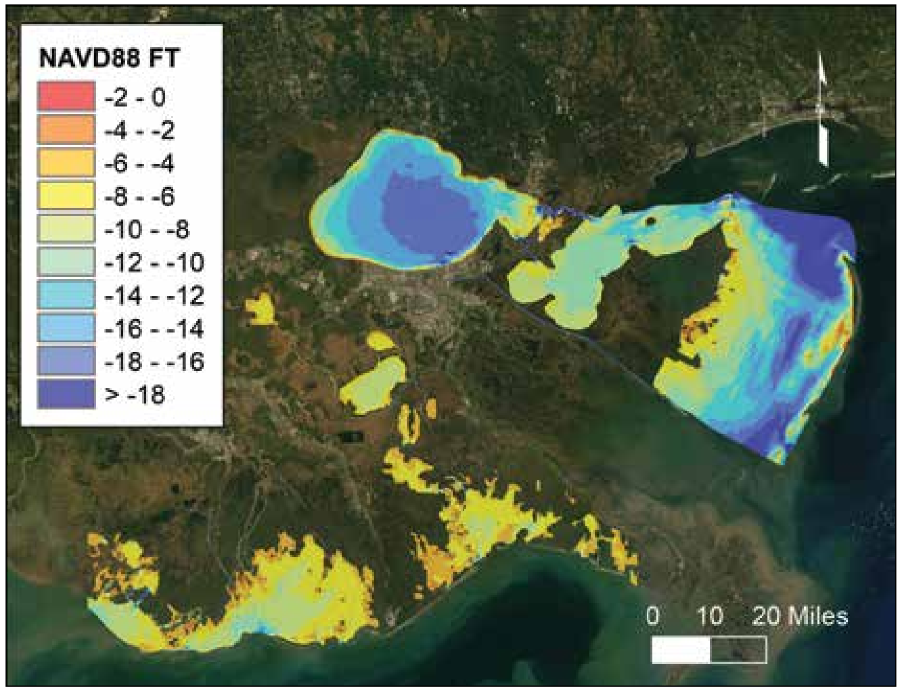

Figure 3. TBDEM developed based on regional topographic (Lidar) and bathymetric data collected for the SWAMP project through 2018.

DISCUSSION

As mentioned above, ecosystem restoration in Louisiana is unique in many ways and there is no single design template to follow. Various design templates evolved and developed wherein adaptive management played and still plays a critical role (e.g. Khalil *et al.* 2013). For this reason, a dedicated funding source was recognized to develop and implement an AMIP. It was also realized that SWAMP should be funded appropriately as a regional monitoring program to implement the AMIP. Under the overarching umbrella of SWAMP, regional-scale baseline data are being collected for various parameters, most of which are not monitored programmatically. Depending upon the restoration need, the return-frequency for repeat data collection will be determined. Understandably, it will depend upon the parameter as well. Physical terrain is one of the important parameters recommended to be monitored. Monitoring this parameter requires the collection of both topographic and bathymetric data. LiDAR surveys have been undertaken for the entire state. Offshore bathymetric data are collected under the BICM program. Bathymetric data within the nearshore regions including bays and lakes were missing. Funds from Deepwater Horizon oil spill penalties helped fill this gap. These data were incorporated into the development of a TBDEM on a statewide scale which will aid in the development of the 2023 Coastal Master Plan. These geophysical surveys are also extremely helpful for exploration of sediment which in turn aids the sedimentological restoration component of ecosystem restoration in Louisiana.

The rapid channel switching and diversion within Mississippi's depositional lobes, as previously described, resulted in the complex and diverse geomorphology and stratigraphy that was imaged by the sub-bottom profiler data (Figure 4). Potential sand has been mapped throughout Barataria Bay and represents paleochannel features that suggest sand filled or sand-capped deposits (Figure 5). Paleochannels or buried incised former river/stream channels (Figure 4) were seen throughout the survey area (Figure 5). The identified paleochannels have varying amounts of overburden, with a majority being at or near the seafloor. Few of the identified channels exhibit characteristics indicative of a complex or sequential infill, normally associated with paleochannels. The sequential infill of paleochannels suggest the potential for a higher content of sandy sediment that may be suitable for beach emplacement but would require vibracores to confirm and quantify sediment characteristics.

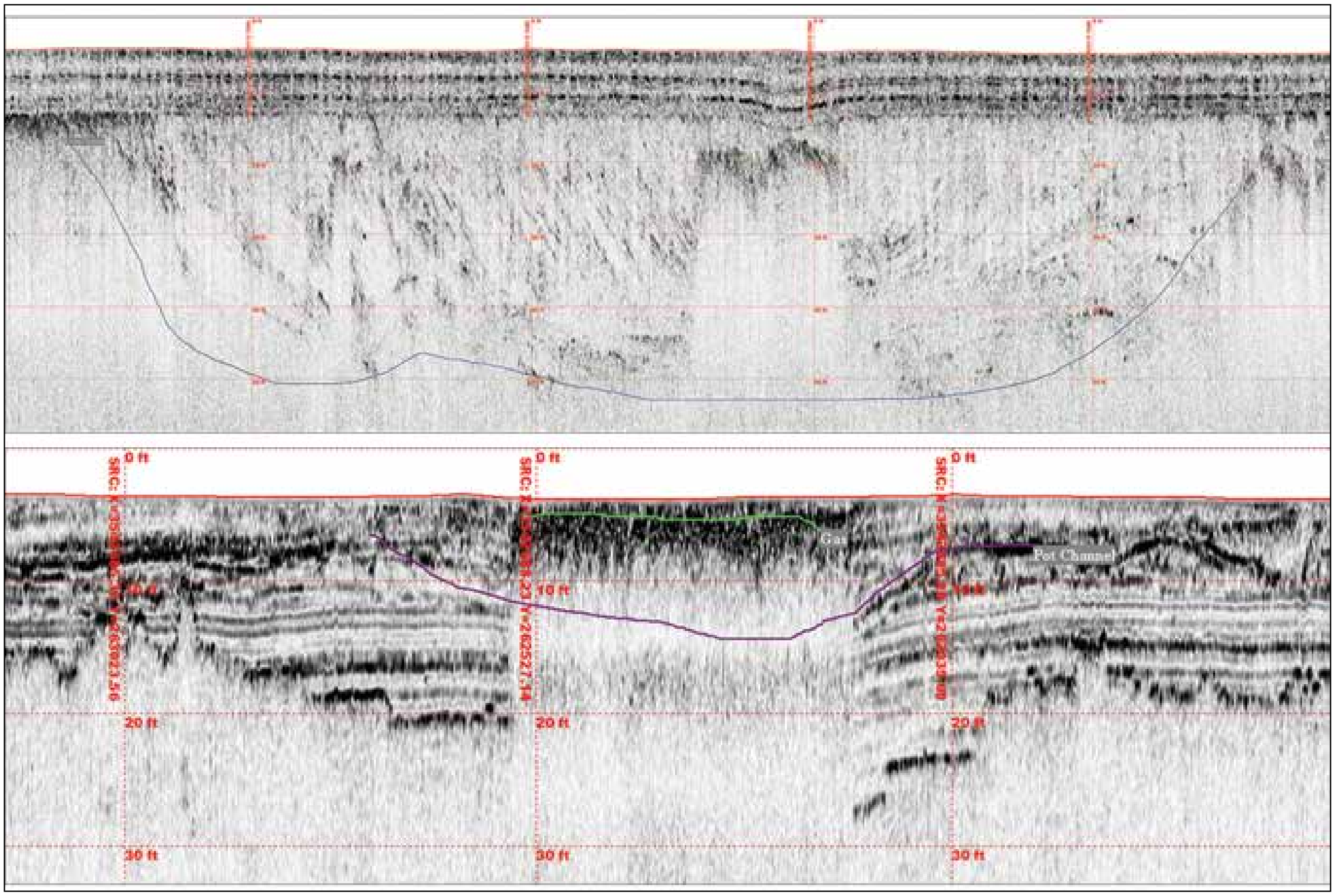

Figure 4. Digitized deep paleochannel (blue line) along a sub-bottom profiler line collected in Lake Pelto (top image). Digitized potential paleochannel (purple) with gas (green) along a subbottom profiler line collected in Terrebonne Bay (bottom image). Note: The distance between vertical dotted lines is 500 ft.

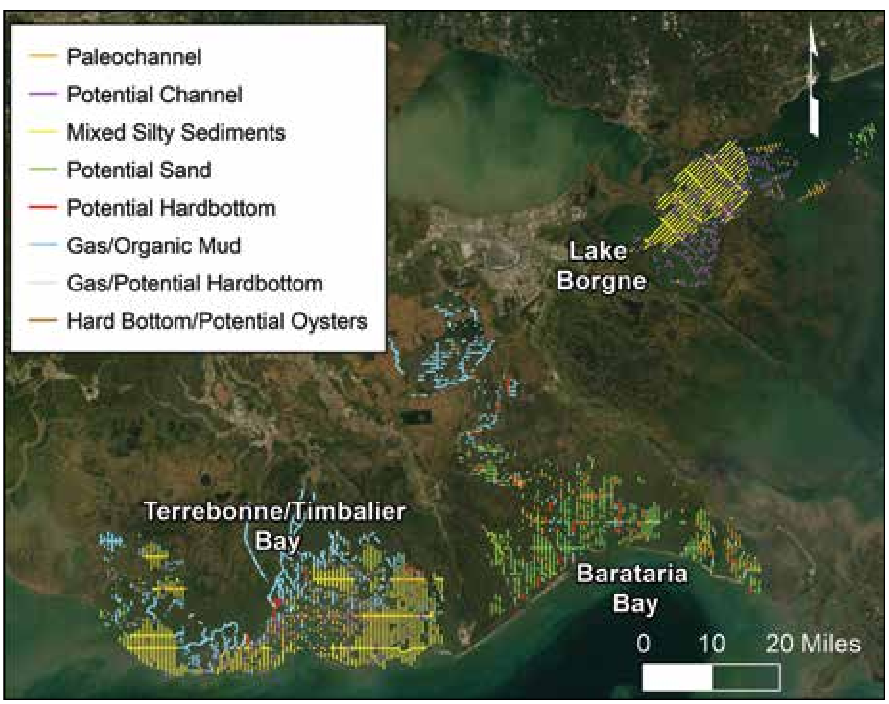

Figure 5. Sub-surface geology based on analysis and interpretation of sub-bottom profiler data along the survey tracklines.

Other paleochannels appear to have infill indicative of degassing episodes where the infill of these channels could potentially be organic in nature. Potential channels (Figure 4) are areas where the sub-surface stratigraphy appears to be "chaotic/disorganized", similar to what is seen in paleochannels. However, there aren't any abrupt boundaries like those seen in a paleochannel. Paleochannels and potential paleochannels are primarily located in Lake Borgne, Lake Pelto, Terrebonne Bay and portions of Timbalier Bay (Figure 5).

Mixed sediments (<70% sand), which are more suited for marsh restoration, have been mapped throughout Lake Borgne, Calliou Bay, Lake Pelto and Timbalier Bay (Figure 5). Acoustically, these units show characteristics of being sandy within a mud matrix and separate from the mud layers spread throughout the surveyed area. Thickness of the layers vary throughout, and layer boundaries are sometimes blocked by gas/organic mud or incised by paleochannels or potential paleochannels. Thicker mixed sediment deposits appear to be on the southern portion of the survey area (5-7 ft) and along some areas on the eastern side (4-6 ft). A thin (2-4 ft) layer of mixed sediments was also present in Lake Mechant and Caillou Lake.

CONCLUSIONS

As stated earlier, this is a first attempt to develop a bathymetric as well as a geophysical map of entire coastal Louisiana. Bathymetric and geophysical data collection has been completed and currently being processed. These data will fill a void which existed for long time. Such data, if collected in the past, were of very limited extent and scope. There was a need to collect these data to support ecosystem restoration especially sedimentological restoration. Initially, due to limited funds, the decision was made to collect only bathymetric data. It was realized that adding three more sensors to collect side-scan sonar, sub-bottom profiler, and magnetometer data could be done in the same mobilization and would be cost effective.

Analysis and interpretation of the sub-bottom profiler data indicates that the subsurface geology of the study area consists of gas/organic mud, paleochannels, potential channels, potential hardbottom, gas/potential hardbottom and mixed silty sediments. The varied depositional environments, both horizontally and vertically, match the geologic models of Frazier (1967) and Penland *et al.* (1988) where the depositional delta of the Mississippi River migrated east and west between 3,500 and 400 YBP (Figure 2). In order to support the more than 14,000 mcy of sediment resource needs for the state of Louisiana to maintain their barrier island and marshes (Khalil *et al.* 2018, CPRA 2017), potential sediment sources are likely located in potential sand, paleochannels, potential paleochannels and mixed sediment areas. The intersection between the sandy areas (potential sand, paleochannel, potential paleochannel) and mixed sediment are the best opportunity for projects that require both barrier island and marsh habitat restoration.

The regional surficial and subsurface geology is a first order interpretation based on a reconnaissance level geophysical surveys with geophysical data collected along tracklines spaced 3,000 ft apart. Additional future work by adding/inserting tracklines between existing survey lines and collecting additional ground-truthing data, including vibracores, would support a higher degree of confidence in the interpretation of surficial and subsurface geology. The wider line spacing of these surveys does not support eliminating any magnetic anomalies from consideration as potential hazards, pipelines or cultural resources. It also does not eliminate the presence of any features between survey lines.

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