Standard Operating Procedures for Geo-scientific Data Management: Louisiana Sand Resources Database (LASARD)

Version 5

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Revision History

Version	Date	Description
1	10/01/2015	Original Issue
2	10/23/2015	Added language on control establishment, navigation and water level corrections
3	06/14/2016	Updated Appendix 4 - File Naming Convention; Changed Appendix 2 - FGDB Templates to Shapefile Templates; Updated Data Submittal Format paragraph on page 27. Removed references to geodatabase throughout.
4	10/5/2022	Revised Data Formatting Standards. Revised QA/QC Standards. Revised Data Formatting Protocols; changed 'points' to 'csv files', removed reference to Appendix and tables. Deleted Oil and Gas Infrastructure. Revised CPRA Geospatial Standards. Revised table 2. Deleted Geoscientific Data Delivery Protocols and Data delivery grid. Revised table 3. SOP has been revised accordingly.
5	01/09/2024	Revised Sediment Samples data formatting protocols; separated core borings from grab samples (shapefile templates, metadata templates, attribute specifications) and updated SedimentSamplesEDD.

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INTRODUCTION

Globally, shorelines are degrading due to increased high energy events and rising sea level and require frequent replacement of sediment. It is well documented that during the past half century, coastal Louisiana has experienced rates of land loss that are considered to be the highest in the nation (Khalil *et al.*, 2010). Since the 1930s, Louisiana has lost over 1,883 square miles of coastal land and is losing land at a rate of 24 square miles/year (Couvillion *et al*., 2011). Land loss, in particular the loss of coastal wetlands, threatens the sustainability of Louisiana's coastal ecosystem.

The success of a Louisiana coastal restoration effort depends on locating sufficient volumes of restoration-quality sediment resources (both sand and marsh-compatible mixed sediment) that are suitable for placement on beaches and dunes, and for creating/nourishing marshes. Thus, locating potential borrow sites with compatible sediment resources that are extractable at acceptable costs is crucial to the success of restoration goals (e.g., Finkl and Khalil, 2005).

Sand and mixed sediment resources in Louisiana are limited but crucial for barrier island and marsh restoration. In addition, knowledge of sediment budget and inventory is essential for regional sediment management (Khalil, 2012). To help facilitate the identification and management of nearshore, offshore and riverine sediment resources, the Coastal Protection and Restoration Authority (CPRA) developed the LouisianA SAnd Resources Database (LASARD). This database is used to manage, archive, and maintain geological, geophysical, geotechnical and other related data pertaining to the exploration of sand/sediment in various environments (Khalil *et al*., 2010). In LASARD, the geoscientific and related data acquired for ecosystem restoration are archived, populated, and maintained on a GIS platform. Once standardized, LASARD data are made available to users through the CPRA publically accessible spatial viewer. The overall objective of LASARD is to centralize relevant data from various sources for better project coordination and to facilitate future planning for delineating and utilizing sediment resources for a sustainable ecosystem restoration in coastal Louisiana (Khalil *et al*, 2010).

Data collected over the course of sand and mixed sediment search investigations were identified for incorporation into the LASARD database. Data collected during these investigations typically includes geophysical (seismic, sidescan sonar, magnetometer, and bathymetric) and geological (vibracore and grab sample) information. Oil and gas infrastructure data are also included in the database since they affect the delineation of borrow areas, quantities of available sand/sediment, and subsequent dredging.

GEOSCIENTIFIC DATA COLLECTION METHODOLOGIES

The identification of sediment resources and final design of borrow areas is achieved through the integration of geophysical surveys and geotechnical investigations. Each data type incorporated into LASARD plays a unique role in delineating sediment resources and finally designing a borrow area. The resulting data are analyzed to identify the most compatible sediment for a specific restoration project while avoiding potential cultural resources, existing infrastructure and environmental impacts. This section describes various geoscientific data collection methodologies, for marine/coastal and riverine geophysical surveys using acoustic remote sensing techniques as well as other remote sensing techniques including Light Detection and Ranging (LiDAR), aerial photography or traditional topographic surveys.

Acoustic Remote Sensing Data – Marine/Coastal/Riverine Surveys[1]

Measurements taken using methods that do not directly contact the object being studied are considered remotely sensed data. To distinguish between LiDAR and other remote sensing applications using electromagnetic waves, remote sensing activities conducted underwater are termed "Acoustic Remote Sensing" as the sensors use acoustic waves. Echo sounders, sidescan sonar, and sub-bottom profilers are three commonly used non-intrusive acoustic remote sensing systems. These systems use electrically powered acoustic devices that propagate acoustic pulses in the water and measure the lapsed time between pulse initiation and return signals that are reflected from features on or beneath the seafloor. They are widely deployed to obtain information that is useful in the interpretation of seafloor geomorphology, for delineation of bottom features (e.g., ripple marks, sand waves, rock outcrops), and for estimating the nature (grain size, composition) of underlying rock and sedimentary units. Acoustic depth sounders are used for bathymetric surveys. Sidescan sonar images show the spatial distribution of bottom sediments, sub-surface bed-forms (e.g., wave or current asymmetrical ripples, low-relief bed-forms, sand waves), and macro-morphological features such as shoals and channels. Sub-bottom profilers show near-surface stratigraphy (sedimentary layering) below the seafloor in a cross sectional manner along with subsurface geomorphology (e.g., buried paleo-channels), and/or subsurface geological structures (e.g., faults). An integrated seafloor (river bottom) mapping for sediment evaluation and characterization uses non-intrusive geophysical surveys followed by intrusive geotechnical investigation to complete a marine/coastal/riverine survey.

Geophysical data populated and archived in LASARD are comprised mainly of bathymetric, seismic, sidescan sonar and magnetometer data. This data is often, but not always, collected during a joint geophysical survey investigation. Normally these data are collected from a survey vessel along pre-defined tracklines. A trackline is a linear feature that represents the path of the vessel that is towing the instrumentation. Trackline spacing varies depending on the objectives of the survey. Data collected during a reconnaissance level investigation covering a large area will be more widely spaced than data collected for a cultural resource investigation that targets a small area. All data that is collected during a geophysical survey should be accurately located for the purpose of analysis (Khalil, 2012). It is necessary to establish positions for seabed features so that they can be mapped and correlated to features from different surveys. During survey operations Differential Global Positioning System (DGPS) navigation provides these accurate positions. DGPS receivers typically have a horizontal positional accuracy of less than 1 m. During a geophysical survey differential corrections are applied that increase the accuracy to about 0.3 m to 1.0 m. The differential corrections are broadcast from U.S. Coast Guard stations and are received by special antennas that are integrated into the GPS receivers. For nearshore geophysical surveys, Real Time Kinematic (RTK) techniques are typically used to further increase the horizontal accuracy to 2–3 cm. The locations of the tracklines typically represent the location of the GPS, not the location of the tow fish. Appropriate correction must be made by using the positioning data that is collected to correct for the layback position of the tow fish, for accurate data analysis and interpretation. A typical geophysical survey is conducted using the instrumentation illustrated in Figure 1.

[1] Initially used for marine/coastal surveys, the same set of equipment and protocols are also used for geophysical surveys conducted in riverine/fluvial environments.

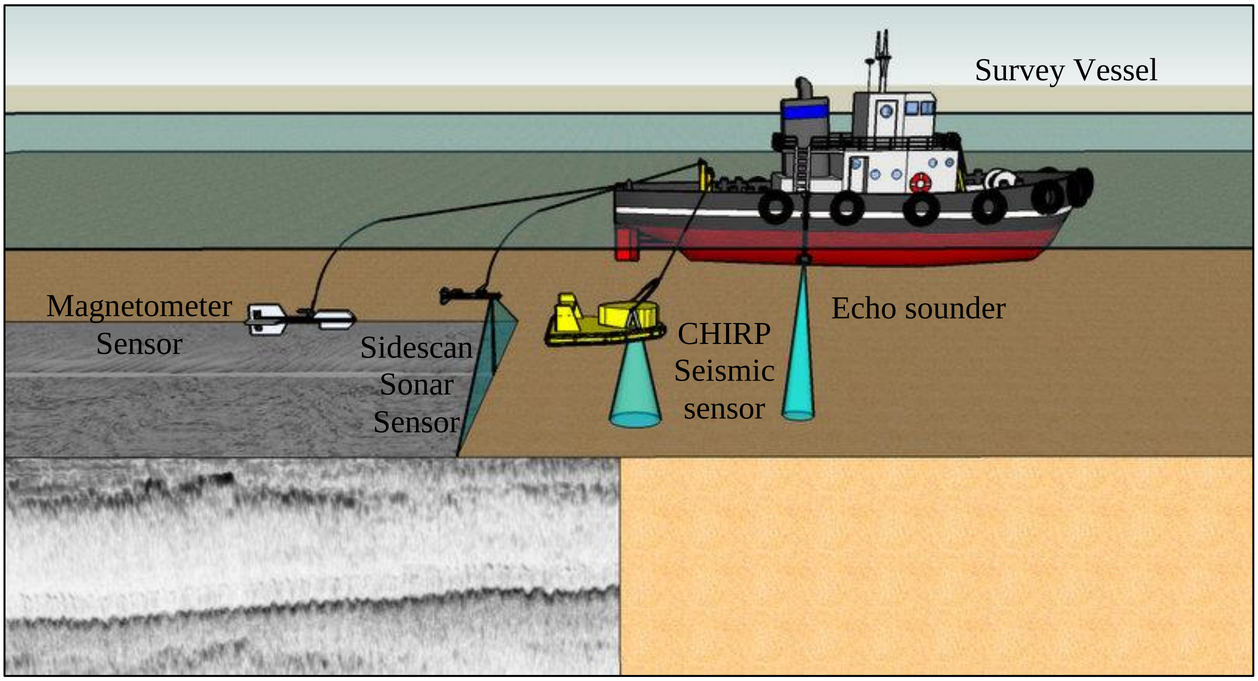

Figure 1. Schematic diagram showing a typical deployment of sensors for a geophysical survey.

The various methods of collecting acoustic remote sensing data are described below.

Control Establishment

A reconnaissance survey of local survey control must be performed prior to geophysical and hydrographic data collection if RTK GPS is used for vessel navigation, positioning, or water level corrections. Local control should be verified using RTK GPS and/or Static GPS methods to ensure the control is stable and relative to the coordinate systems and vertical heights used for the survey. All monuments recovered by Static methods should be processed in accordance with the *CPRA Guide to Minimum standards for performing GPS surveys and Determining GPS derived Orthometric Heights within the Louisiana Coastal Zone.*

Navigation and Water Level Corrections

Appropriate number of tide gauges should be deployed in all survey areas and set relative to local control established or recovered by the static sessions and/or verified local control for the survey in case DGPS is deployed for vessel navigation.

Water level corrections may also be acquired using RTK GPS tide methods in areas under RTK GPS coverage. All GPS derived water levels will be compared to NOAA or locally set tide gauges for comparison and quality control purposes.

Horizontal positioning for areas outside the range of RTK GPS corrections, or in critical areas collected using DGPS, may be supplemented by Post Processed Kinematic (PPK) methods. GPS receivers capable of logging data will be used onboard the survey vessel acquiring data at 1 Hz. Base lines will be post-processed using local NGS CORS stations.

Corrected GPS strings will be input into post processing software to increase the horizontal and vertical accuracies of data collected outside the range of RTK GPS or in critical areas where DGPS was utilized.

Bathymetric Data

Bathymetry is a measurement of the elevation of the seafloor. Bathymetric data can be collected using a variety of methods which result in variable data densities. In single beam systems, an acoustic pulse is emitted from a transducer and propagated in a single, narrow cone of energy directed downward toward the seafloor, providing a single depth measurement for a location directly beneath the survey vessel. The transducer(s) then "listen(s)" for the reflected energy from the seafloor. Water depth is calculated by using the travel time of the emitted pulse. Two-way travel time is multiplied by the speed of sound in the ambient water and divided by two. Data are often collected in straight lines with many measurements recorded along that line. The individual values of depth to the seafloor thus obtained are subsequently contoured to generate bathymetric maps.

Dual frequency bathymetry is similar to single beam bathymetry, but an additional beam is added often at a lower frequency which allows the user to collect two separate returns. This is helpful in areas that have muddy bottoms where the higher frequency captures the surface and the lower frequency measures the mud interface with an underlying layer, assuming the mud is not too deep and the underlying layer (e.g., sand, rock) has a clear signature difference when compared to the mud layer.

A multibeam echo sounder is a device typically used by hydrographic surveyors to determine the depth of water and the water bottom features. Most modern systems work by transmitting a broad acoustic pulse from a specially designed transducer across the full swath across-track then forming a return signal beam that is much narrower (around 1 degree depending on the system) to establish a two-way travel time of the acoustic pulse (e.g. Lurton, 2002). If the speed of sound in water is known for the full water column, the depth and position of the return signal can be determined from the receive angle and the two-way travel time. High-resolution multibeam systems are used to accurately map features on the seafloor/riverbed (e.g., sand waves).

Interferometric bathymetry is also used to determine the depth of water and the water bottom features. It's a sonar system based on the process by which two or more sonar waves of the same frequency combine to reinforce or cancel each other, the amplitude of the resulting wave being equal to the sum of the amplitude of the combining waves. Because the angle of interference can be determined, these sonar systems provide bathymetric information over a wide swath. Interferometric systems typically have a wider swath than multibeam systems. Interferometer, much like multibeam, is used when the project requires 100% coverage of the seafloor and has the ability to map locations of hard bottom or coral reefs, image wrecks or other bottom obstructions or debris, and also provide 100% coverage of borrow areas for highly accurate volume calculations. The XYZ point files produced from interferometer systems are similar to LiDAR data and are extremely large. Although the data is referred to as sidescan, the imagery produced by interferometric sonars is graphically flawed. Because of the interferometry, light and dark banding persists across the record making the depiction of an even seabed reverberation difficult.

Regardless of the collection method, the bathymetric data that is collected is in the form of a series of XYZ data points. In order to better visualize the geomorphology, XYZ data is often interpolated to provide a 3-D representation of the seafloor. Due to the variety of methodologies used to process and interpret these data types, a detailed discussion of data interpolation is presented in the “Data Formatting Protocols” section of this document.

Seismic/Sub-Bottom Profile Data

Seismic data, sometimes called sub-bottom profile or seismic reflection profile data, is used to visualize subsurface settings or subsurface sedimentary stratigraphy and identify potential project compatible sediment resources. The use of seismic data allows common stratigraphic layers to be mapped throughout the study area while determining the thickness and extent of potential project compatible sediment. An example of a seismic cross-section is shown in Figure 2.

Seismic data is obtained using a sub-bottom profiler that produces sound waves to penetrate the seafloor (Khalil, 2012). The basic principles of subbottom seismic profiling and acoustic depth sounding are essentially the same. A lower frequency and higher power signal (to penetrate the seafloor) is employed in subbottom seismic devices. The transmission of the waves through subsurface sediments depends on properties such as density and composition of substrate. The signal is reflected from interfaces between sediment layers of different acoustic impedance (Sheriff and Geldart, 1982). Coarse sand and gravel, glacial till, and highly organic sediments are often difficult to penetrate with conventional sub-bottom profilers, resulting in poor records with data gaps. Digital signal processing of multichannel data can sometimes provide useful data despite poor signal penetration. Seismic reflection profiles are roughly analogous to geological cross sections of sub-bottom sediment because acoustic characteristics are usually related to lithology (Verma, 1986). The two most important parameters of sub-bottom seismic reflection systems are vertical resolution (*e.g.*, the ability to differentiate closely spaced reflectors) and depth of penetration (*e.g.*, Parkes and Hatton, 1986). The dominant frequency of acoustic pulses increases signal attenuation and consequently decreases the effective penetration. In order to carry out operations in different environments, a variety of seismic sources are used viz. Water gun (20-1500 Hz), Air Gun (100-1500 Hz), Sparker (50-4000 Hz), Boomer (300-3000 Hz), and the latest development Chirp systems (500 Hz-12 kHz; 2 - 7 kHz; 4 - 24 kHz; 3.5 kHz and 200 kHz). The Chirp system has an advantage over single-frequency (3.5 kHz) sub-bottom profilers and boomer systems in sediment delineation because the reflectors are more discrete and less susceptible to ringing from both vessel and ambient noise.

Seismic reflections indicate changes in sediment within the stratigraphic sequence. Seismic images can be used to delineate stratigraphic boundaries, however the quality of the sediment above and below those boundaries must be field verified by obtaining a physical sample. Vibracores are therefore commonly used to ground truth seismic data. The final product of seismic interpretation is a three dimensional representation of the sediment thickness, called an isopach.

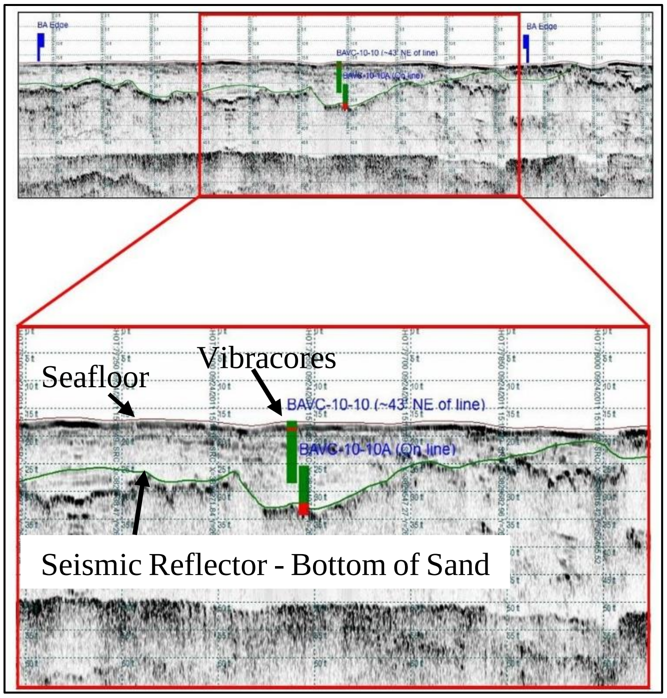

Figure 2. Interpreted sub-bottom profile that correlates seismic-stratigraphy with litho-stratigraphy. Green represents sand and red represents fine grained sediment (most likely clay or silt)

Figure 3. Sidescan sonar image showing a shipwreck and adjacent seafloor, offshore Louisiana in approximately 35 feet of water.

Sidescan Sonar Data

Imaging the seafloor with a sidescan-sonar system is accomplished by towing a sonar "tow-fish" or sensor. The tow-fish is equipped with a linear array of transducers that emit, and later receive, an acoustic energy pulse in a specific frequency range. In general, if all other parameters are constant, a rougher surface will backscatter more energy than a smooth surface and therefore, return higher amplitude signals (Fish and Carr, 1991). Shadows result from areas of no energy return, such as shadows from large boulders or sunken ships. These shadows aid in the interpretation of the sonogram (after Urick, 1983).

Sidescan data provides an acoustically generated image of the seafloor or riverbed as well as to verify the location and extent of unconsolidated sediment and to map water bottom features such as benthic habitats, exposed pipelines, cables, underwater wrecks, potential cultural resources, etc. Sidescan sonar can also be used to confirm or improve interpretation of the sub-bottom seismic records (Khalil, 2012). The sidescan survey is conducted to identify features that may affect borrow area delineation, introduce hazards to dredging, or adversely impact the environment. An example of a sidescan sonar image of a shipwreck is presented in Figure 3 (above).

Sidescan sonar is used to distinguish topographic elements on the seafloor or riverbed. Acoustic signals from a ''fish'' towed below the water surface are directed at a low angle to both sides of a trackline, in contrast to downward-directed echo sounder and seismic reflection signals (Fish, 1990; Mazel, 1985a, 1985b; Sheriff and Geldart, 1982). The resulting image of the bottom is similar in many respects to a continuous aerial photograph. Commonly available sidescan sonar systems operate at 100 kHz frequency and have swath widths of 500 meters or more on either side of the vessel trackline. Depending upon the water depth it is thus possible to image the water bottom/seafloor with 1-kilometer swaths in each pass (Fish, 1990; Morang, Larson, and Gorman, 1997a, 1997b). Advanced digital sidescan sonar systems perform signal processing that corrects for the slant range to seafloor targets and survey vessel speed. A dual-frequency sidescan sonar system (*e.g.*, Klein model 590) can be used simultaneously with a sub-bottom system to map hard-bottom.

Magnetometer Data

A proton or cesium marine magnetometer is typically used for a high-resolution magnetic remote sensing which is needed to identify any metallic objects that could represent a potential cultural resource or hazard to dredging. The purpose of the magnetometer survey is generally to establish the presence and subsequent exclusion zones around any potential underwater wrecks, submerged hazards (debris, pipeline), surface structures or any other features that would affect future sediment/sand borrow area delineation and dredging activities (e.g. Keary *et al*., 2003). The magnetometer provides a measurement of the earth's magnetic field intensity expressed in gammas. Metallic man-made objects and geologic features can create a measurable disturbance in the earth's magnetic field. This data is used to identify potentially significant cultural resources, submerged hazards (pipelines and cables), and modern debris that should be avoided during borrow area design (Khalil, 2012).

Magnetic anomalies can be viewed with seismic and sidescan data to gain additional information about the objects identified. Sidescan sonar may provide images of objects if they are on the surface. Items at depth may be seen in the seismic data. Magnetometer surveys along with sidescan sonar are required for hazard and archaeological assessment survey/cultural resources survey and are conducted on closer line spacing. Normally for such surveys, the specifications and guidelines are provided by the permitting agency. In order to produce a magnetic record of sufficient resolution, the sensor is deployed and maintained in the water column at a depth of approximately +1 to 3 meters below the water surface. A computer record provides a continuous record of magnetic background and target signatures. Positioning data from the navigation system is tied to the magnetometer as it is with any other sensor by regular annotations to facilitate target location and anomaly analyses. When magnetic data is interpreted by a qualified marine archaeologist, avoidance areas are delineated.

ADCP Data

An acoustic Doppler current profiler (ADCP) is similar to sonar. It is used to measure water current velocities over a depth range using the Doppler effect of sound waves scattered back from particles within the water column. ADCP can be used in rivers to continuously measure discharge or sediment flux. ADCP can also be used in the ocean to measure currents, salinity, dissolved oxygen etc. ADCP instrumentation can be mounted on moorings within the water column or can be mounted on a moving vessel.

Other Remote Sensing Data

Other remote sensing techniques are used to obtain information about areas from a distance (*e.g.* using satellites or aircraft). Some of the methods commonly used are described below.

Airborne LiDAR Surveys

Light detection and ranging (LiDAR) measures the elevation of the ground using a scanning laser. LiDAR is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. This method uses ultraviolet, visible or near infrared light to image objects. It can target a wide range of materials including non-metallic objects like rock or sediment. It is an approach commonly used to develop terrain models. Aerial LiDAR collects measurements from an aircraft that has the capability to map large areas in relatively short time intervals. LiDAR can also be attached to a vehicle or mounted on a tripod to measure a localized study area.

Bathymetric LiDAR measures the elevation of the seafloor using a scanning laser. The systems are almost identical to topographic LiDAR systems, but bathymetric LiDAR utilizes blue-green lasers as opposed to the near-infrared lasers used in topographic systems. Bathymetric LiDAR systems have slower pulse rates and collect relatively smaller density of points when compared to topographic LiDAR due to the larger wavelengths of the blue-green lasers combined with the need to correct for angular distortions when measuring light through air and water. Bathymetric LiDAR collects measurements from an aircraft that has the capability to map large areas in relatively short time intervals. Bathymetric LiDAR is used to determine water depth by measuring the time delay between the transmission of a pulse and its return signal. Bathymetric LiDAR techniques are not effective in the turbid water off Louisiana. However, during periods of the year when the water is less turbid, the USGS has reported successfully using LiDAR to depths of up to 3m in some parts of the Chandeleur Islands.

Aerial Photographs

Aerial photographs are photographs of the ground taken from an elevated position. The camera is typically not supported by a ground-based structure but rather by platforms such as helicopters or airplanes. Aerial photographs are often used to identify land features and often form the basis for topographic maps.

Topographic Survey

Coastal profiles are the backbone to measuring change along the coastline. Conventional beach profiles start at installed monuments and are surveyed seaward of the monument at a defined azimuth. The beach profiles measure both the dune and berm and are often combined with bathymetric data in order to capture the entire active profile. When the same profile is measured repeatedly at different times, a time series can be developed that enables quantification of coastal change and represents the performance of the section of beach over the measured time period. Beach profiles are often measured using RTK GPS and differential leveling techniques. The RTK GPS provides centimeter-accuracy with respect to elevations with real time horizontal positioning provided to the surveyor to ensure on line measurements. Differential leveling techniques are typically used in upland areas that are inaccessible to RTK GPS systems. Elevations are typically taken at fixed intervals along each profile line and at all grade breaks.

Shoreline Position

Shoreline data are influenced by a multitude of geomorphological (exogenic), hydrological (tidal), and anthropogenic processes. Capturing and recording these dynamic data are critical to understanding and assessing coastal erosion. Recording and tracking accurate shoreline positioning is critical to calculating shoreline change rates.

Various techniques are implemented for shoreline mapping including remote sensing, LiDAR, analytical photogrammetry, differential global positioning (DGPS), and more. Shoreline change is often quantified by measuring horizontal differences between Mean High Water (MHW) positions along a transect over time (Figure 4). MHW is a tidal datum that often translates to a legal boundary that represents the land-sea interface. Since the datum is tidal, the elevation of MHW changes spatially depending on local tidal conditions. There are three primary methods for measuring MHW: conventional survey, aerial photography, and LiDAR. Conventional surveys use leveling, total station, and more recently RTK GPS to measure points along the coastline that are approximately 1 foot above and 1 foot below the local MHW level. The position and elevation of the MHW point is then interpolated between the pairs of points. Aerial photography significantly increased the ability to map MHW spatially by digitizing the wet-dry line that is imaged by an orthophotograph mosaic. More recently, MHW has been extracted from LiDAR data by contouring a LiDAR derived digital elevation model (DEM) at the locally determined MHW level.

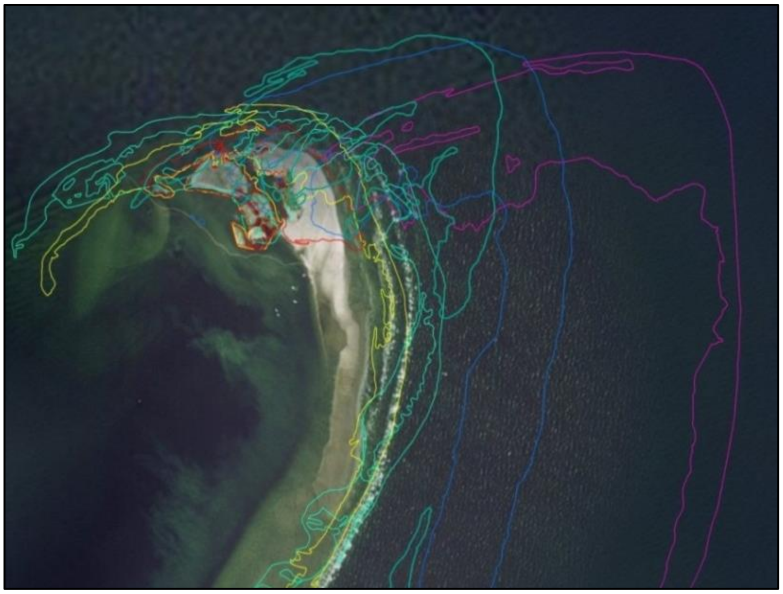

Figure 4. Evolution of shoreline position at Breton Island. Each colored line represents the position of the shoreline at a specific period of time.

Geotechnical Investigation/Sediment Sample Data

Seafloor sediments on the inner continental shelf, especially in deltaic environments, display great spatial and temporal variation. Sediment samples are used to determine sediment quality and to verify the remotely sensed data. The two main types of physical samples are grab samples and core borings.

Surficial Sampling/Grab Samples

The nature of surficial sediment may provide information about the energy of the environment as well as the long-term processes and movement of sediment, such as sediment transport pathways, sources and sinks (Morang *et al*., 1993). Surficial sediments are typically collected using grab samplers. These samplers basically consist of opposing, articulated scoop-shaped jaws that are lowered to the bottom in an open position and are then closed by various trip mechanisms to retrieve a sample (Morang *et al*., 1993) (Figure 5). There are a number of methods also used to collect grab samples including ponar, auger, box core, dredge, Ekman, rotary wash, scoop, Van Veen and Young. The method used depends on the nature of the seafloor and thickness of the sediment sample required. Grab samples are typically used for reconnaissance level investigations to determine surficial sediment characteristics/distribution.

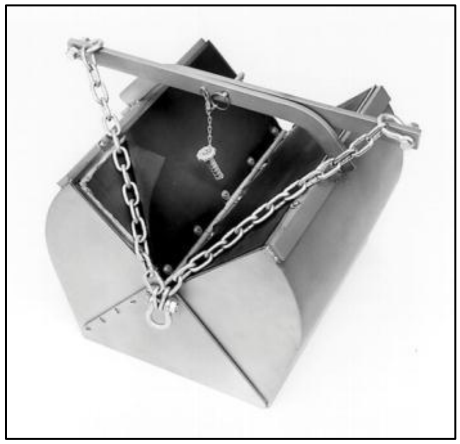

Figure 5. Ponar sampler used to collect grab samples.

Core Borings

Although obtaining surficial samples is helpful for assessing recent processes, it does not provide sufficient details about stratigraphy and sediment thickness. Direct sampling of sub-bottom materials is often essential for stratigraphic studies that extend beyond historic time scales (Morang *et al*., 1993). There are various subaqueous sediment-sampling systems that do not require drill rigs. Exploration for offshore sand and delineation of potential borrow sites mainly involve geotechnical or sediment-sampling programs in addition to geophysical surveys mentioned earlier. The geotechnical operations include surface sampling, jet probes, and vibracores (Finkl and Khalil, 2004). Vibracores, are commonly used for obtaining sand samples in marine and coastal environment and now frequently used in riverine environment too. Core borings provide sediment samples at depth, and are therefore used to characterize sediment in a deposit and correlate sediment types to seismic records in order to map specific deposits. There are several core boring methods, however vibracores are typically used for sediment search investigations, and they are the most prevalent in the LASARD database. Vibracores provide a continuous physical sample. A core barrel is driven into the seafloor through the use of a vibrating head. Once the core barrel has reached maximum penetration, the vibrating head is stopped and the core is extracted. Other core boring methods include Cone Penetrometer (CPT), Gravity Cores, Piston Cores, Push Cores, Standard Penetrometer (SPT) and Air/Wet Rotary.

Cores can be invaluable because they allow a direct, detailed examination of the layering and sequences of the subsurface sediment in the study area. The sequences provide information regarding the history of the depositional environment and the physical processes during the time of sedimentation.

Depending upon the information required, the types of analysis that may be performed on cores include grain size, sedimentary structures, identification of minerals and shells, organic content, micro-faunal identification, x-ray radiographs and other geotechnical studies. Cores are split lengthwise and logged by describing sedimentary properties by layer in terms of layer thickness, color, texture (grain size), composition and presence of clay, silt, gravel, or shell and any other identifying features (Figure 6). Sub samples are generally collected from the cores for laboratory analysis and vibracores may be photographed in sections.

Figure 6. Vibracore logging and sub-sample collection.

Other Data Supported by LASARD

In addition to remote sensing data and geotechnical data, LASARD houses the locations of known shipwrecks, oil and gas infrastructure (*e.g.*, pipelines and platforms) and existing deposits/borrow areas. This data is used for borrow area design and is also important in investigation planning.

GEOSCIENTIFIC DATA MANAGEMENT PROCEDURES

Data submitted for incorporation into LASARD must meet all of the guidelines and requirements established by CPRA. To meet these guidelines, procedures have been developed for the standardization of geoscientific data. This section describes the data formatting and quality assurance/quality control procedures and protocols established by CPRA.

Data Formatting Standards

All geoscientific data collected for CPRA must be provided according to their respective data delivery guidelines found in CPRA's Coastal Information Management System (CIMS) document detail site located here. Individual **E**lectronic **D**ata **D**elivery (EDD) guidelines have been developed by CPRA by data type and data deliverables (data packages) are required to follow these structure, formatting, and protocols. EDD's contain detailed instructions, templates (shapefile, metadata), file naming conventions, and data package structure to help facilitate and streamline data deliverables.

Quality Assurance/Quality Control Standards

Quality assurance should be considered during the planning, design, development and production phases of each data collection effort. Each phase of the effort should be designed and modified, where necessary, to produce a high quality end-product. Each phase should be carried out by a surveyor, geoscientist or geologist and overseen by a licensed Professional Geologist and/or Professional Surveyor and Mapper. It is the responsibility of the surveyor to provide accurate and high quality XYZ data.

Prior to data package creation, an independent review should be conducted by a GIS analyst or equivalent. All associated files should be reviewed for data integrity and completeness. This extensive review should include a comparison between the attribute tables and the original document or paper copies (if data were entered manually), accurate projection confirmation, correct file naming convention, and verification of folder structure assembly. Any quality issues identified should be corrected and re-submitted to the original reviewer for an additional review and data package finalization.

Data Formatting Protocols

The data formatting protocols developed by CPRA for each data type are discussed below.

Topographic, Bathymetric and Isopach Data

A major component of LASARD is topographic and bathymetric survey data. Topographic and bathymetric data are collected using multiple platforms and their final products are provided in several formats (Table 1). Some data (e.g., LiDAR) are storage intensive and difficult to manipulate. These larger data sets require a more manageable format that does not sacrifice the resolution necessary to yield meaningful information. This section describes the procedures for processing and storing/archiving topographic and bathymetric data.

Table 1. LASARD topographic and hydrographic data sets

	Type	Approximate Density	Raw Data Format	Approximate Full Resolution File Size	Recommendations	Approximate Recommended File Size
Topographic	Profiles	< 8 meters in Line	ASCII XYZ	10 MB	XYZ Point and Linked Polyline Transect (if available)	10 MB
Topographic	Shoreline Position	< 15 meters in Line	ASCII XYZ	10 MB	XYZ Point and/or Polyline Contour	10 MB
Topographic	LiDAR	0.5-20 Points/Square Meter	LAS and/or ASCII XYZ	> 1 GB	Polyline Contour; 1 m GeoTIFF; link to compressed XYZ	10 MB
Bathymetric	Single Beam; Dual Frequency	< 0.3 meters in Line	ASCII XYZ	100 MB	XYZ Point; Polyline Contour; 10 m GeoTIFF	10 MB
Bathymetric	Multibeam; Interferometer	20 Points/Square Meter	ASCII XYZ	> 1 GB	Polyline Contour; 1 m GeoTIFF; link to compressed XYZ	10 MB
Bathymetric	LiDAR	0.25 Points/Square Meter	ASCII XYZ	> 1 GB	Polyline Contour; 1 m GeoTIFF; link to compressed XYZ	10 MB

Topographic Profiles. Profile data are provided as XYZ points or range and elevation based on monument positions and azimuths. Sometimes profiles are displayed on two-dimensional plots (Figure 7) that show cross sections of the measured environment. Although the along-profile density of points is sufficient to derive localized surfaces, interpolation between transects is often too large to accurately represent the morphology between profiles. Thus, it is not recommended to derive surfaces or contours from the measured profiles. Profile data should be stored as XYZ points within the GIS database, and should profile plots exist, the plots shall be linked in the GIS database to a polyline representing the location and extent of the measured profile.

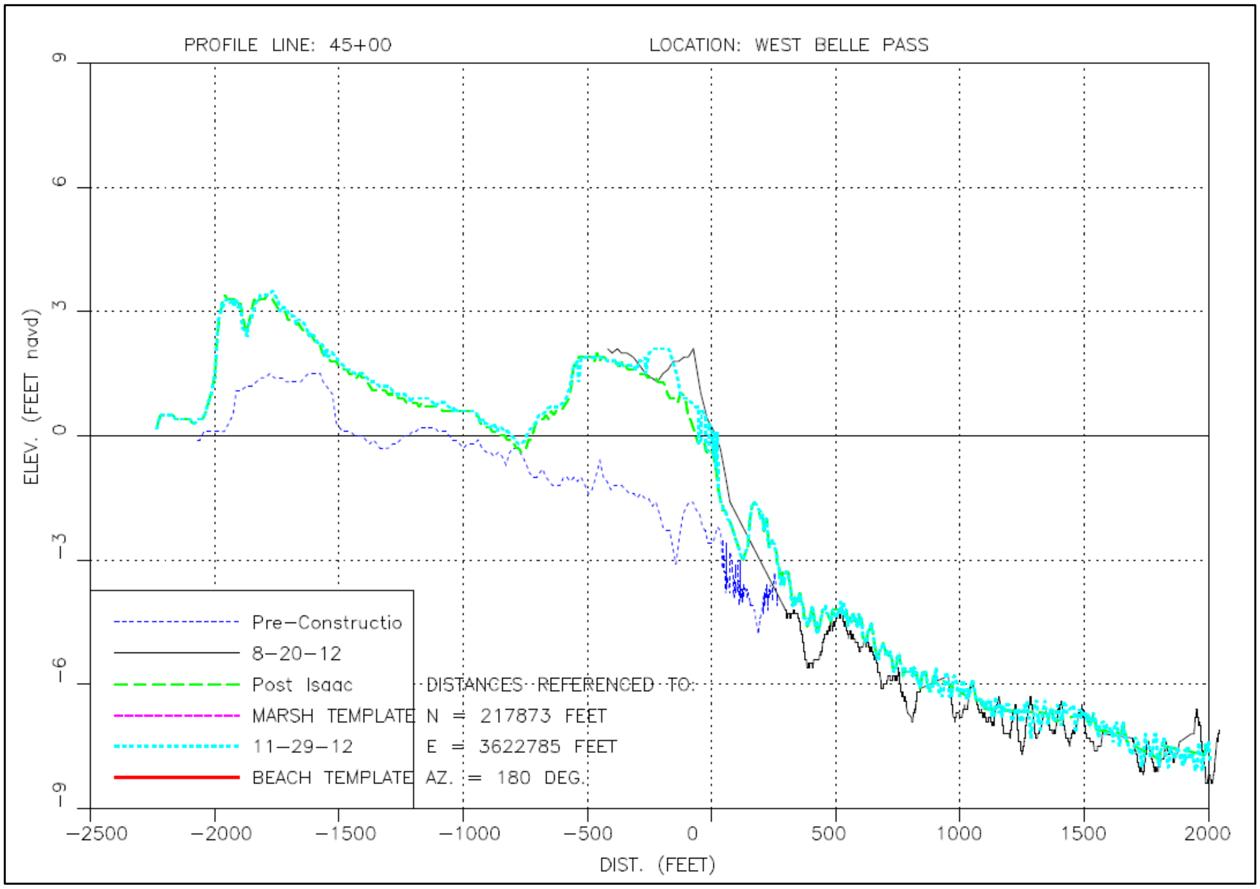

Figure 7. Topographic profiles surveys on West Belle Pass.

Topographic Shoreline Position. Shoreline change is often quantified by measuring horizontal differences between Mean High Water (MHW) positions along a transect over time. As previously discussed, there are three primary methods for measuring MHW: conventional survey, aerial photography, and LiDAR. The display and storage of MHW data within a GIS involves both XYZ points and lines. Both data formats have relatively small file sizes, thus, all XYZ and line data is stored as points or polylines with their associated attributes.

Topographic LiDAR. The high pulse rate of LiDAR systems combined with an aerial platform translates to a significant amount of data that measures large areas. These data are often processed by the data provider and provided to the client as XYZ or LAS points. The point cloud data produced by LiDAR are often provided as sets of very dense (XYZ) points or in a more complex, public file binary format called LAS that may include multiple returns as well as intensities. A typical file size of a single LiDAR project in point format often exceeds 1 GB. Despite Esri's ability to load and display the LAS format, it is both time and storage prohibitive to work with LiDAR data at the point level. A sample of processed LiDAR data is provided in Figure 8.

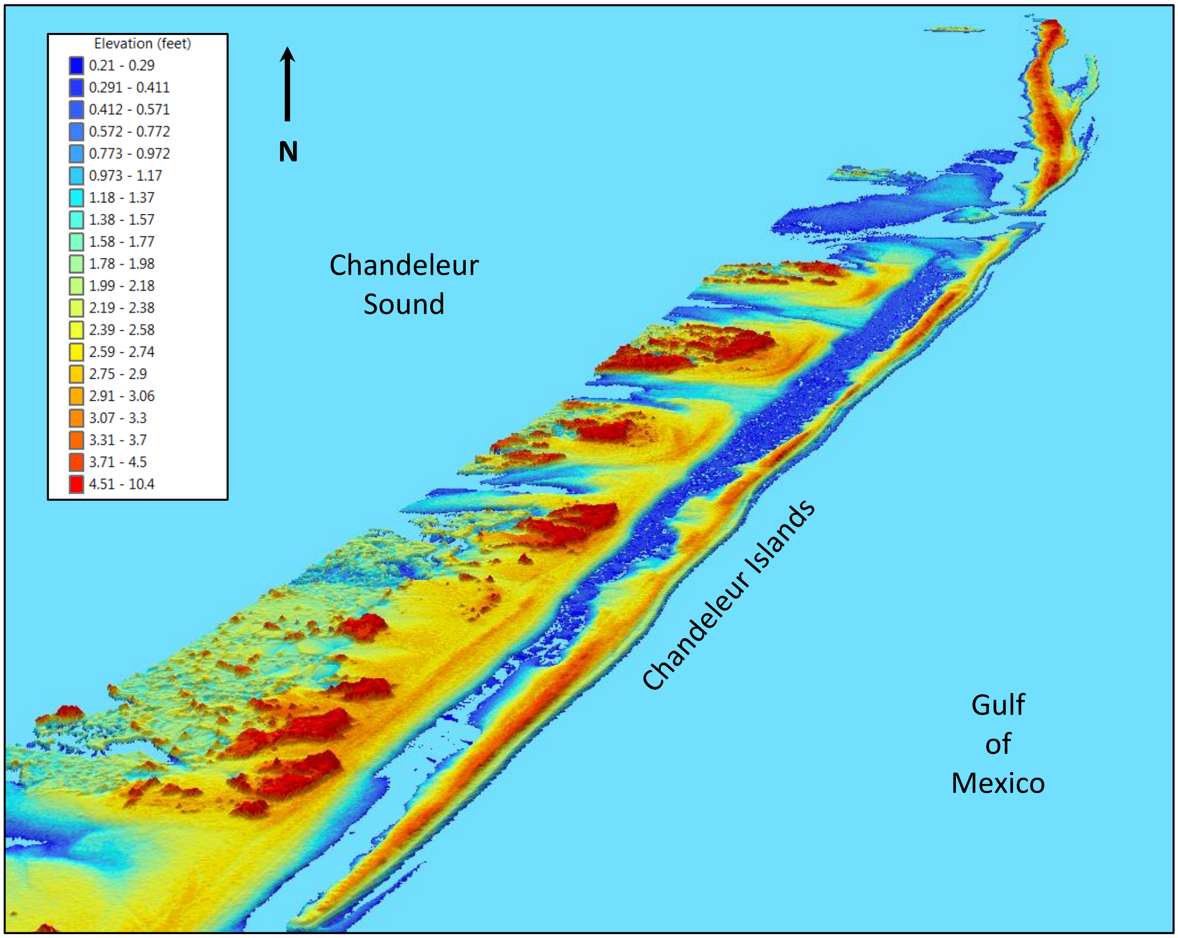

Figure 8. Three-dimensional oblique view of the Chandeleur Islands using topographic LiDAR elevation data.

Given the scientific and management standard of working with LiDAR data at the surface level, LASARD stores LiDAR data as surfaces and contours. Both the surface and contour formats require significantly smaller disk space and quantifications from surfaces and contours are easier when working in a GIS environment. Interpolated surfaces are regularly spaced and the equal area properties of the UTM datum assure accurate area and volume calculations.

The final LiDAR surface can be saved in GeoTIFF format at 1 meter resolution. The final contours should be in polyline format with attributes that indicate elevation in 1 foot intervals. Although data are formatted into contours, raw XYZ data are also being maintained. A link to the raw XYZ data is provided in the attributes.

Single Beam and Dual Frequency Bathymetry. In LASARD, all XYZ single beam bathymetry data is stored as CSV files with their associated attributes. A sample of spot elevations derived from single beam data is provided in Figure 9.

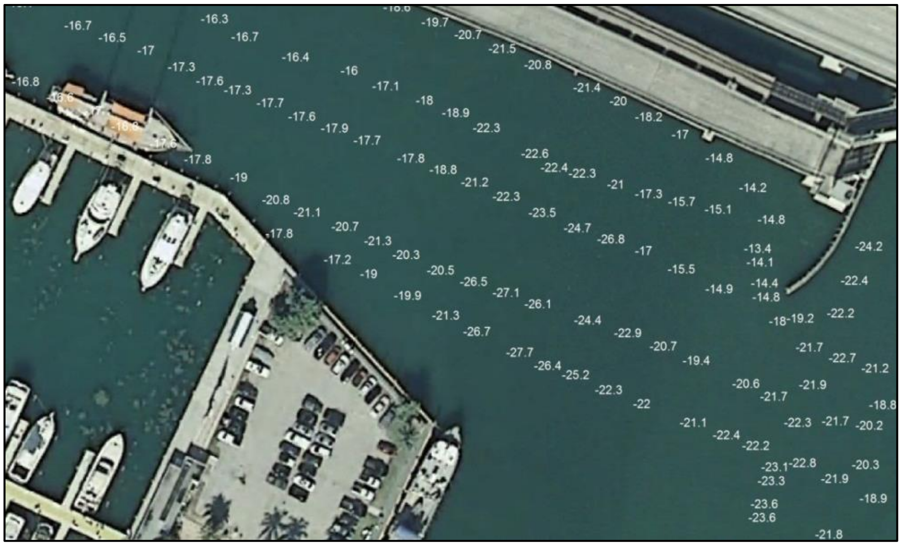

Figure 9. Spot elevations derived from single beam data overlain on an aerial photograph.

Dual frequency data should be stored the same as single beam data, but the points must represent the seafloor. Should the single beam or dual frequency datum be interpolated into surfaces and contoured, the data should be stored as a 10 meter GeoTIFF along with the attributed polyline contours.

Multibeam and Interferometer Bathymetry. The XYZ point files produced from these systems are similar to LiDAR data and are extremely large due to the potentially large areas of swath bathymetry that multibeam systems are able to collect. Figure 10 is an example of processed multibeam bathymetry collected in the Wax Lake Outlet area.

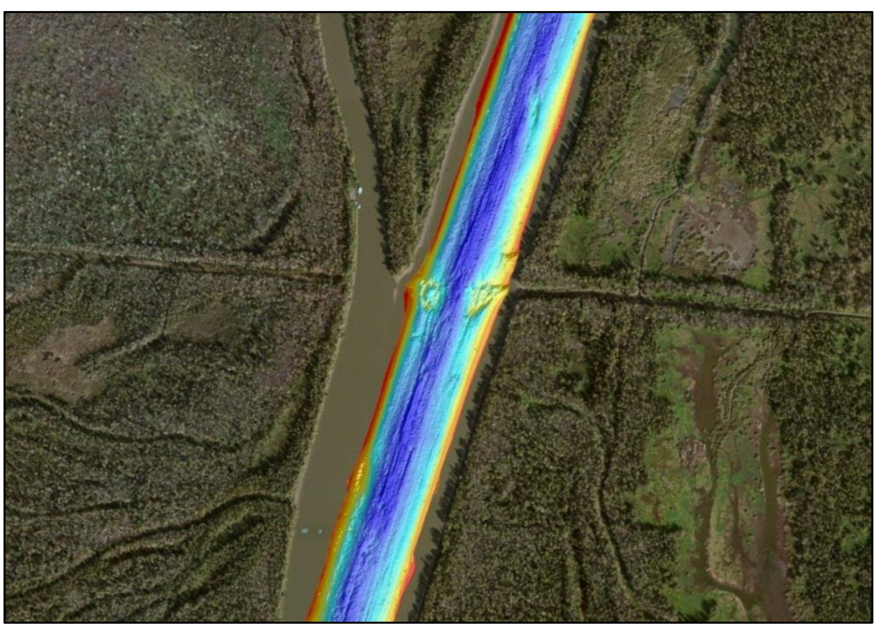

Figure 10. Color-shaded relief image of multibeam data collected in the Wax Lake Outlet area of the Atchafalaya River combined with an aerial photograph to provide orientation.

a. Given the scientific and management standard of working with multibeam or interferometer data at the surface level, it is stored as surfaces and contours. Both the surface and contour formats require significantly smaller disk space and quantifications from surfaces and contours are easier when working in a GIS environment. Interpolated surfaces are regularly spaced and the equal area properties of the UTM datum assure accurate area and volume calculations. The final multibeam or interferometer surface can be saved in GeoTIFF format at 1 meter resolution. The final contours should be in polyline format with attributes that indicate elevation in 1 foot intervals. It is important to note that although data is being formatted into contours, a link to the raw satellite navigation system data files (e.g., RINEX, etc.) and XYZ data is included in the attributes.

Bathymetric LiDAR. These data are often processed by the data provider and produced to the client as XYZ or LAS points. A typical file size of a single bathymetric LiDAR project in point format often exceeds 1 GB. Even with Esri's ability to load and display the LAS format, it is both time and storage prohibitive to work with bathymetric LiDAR data at the point level. Figure 11 shows an example of bathymetric and topographic LiDAR data collected in Florida.

Given the scientific and management standard of working with bathymetric LiDAR data at the surface level, bathymetric LiDAR data are stored as surfaces and contours. Both the surface and contour formats require significantly smaller disk space and quantifications from surfaces and contours are easier when working in a GIS environment. Interpolated surfaces are regularly spaced and the equal area properties of the UTM datum assure accurate area and volume calculations. It is recommended that the final bathymetric LiDAR surface be saved in GeoTIFF format at 1 meter resolution. The final contours should be in polyline format with attributes that indicate elevation in 1 foot intervals. As previously indicated, although data is being formatted into contours, a link to the raw XYZ data is included in the attributes.

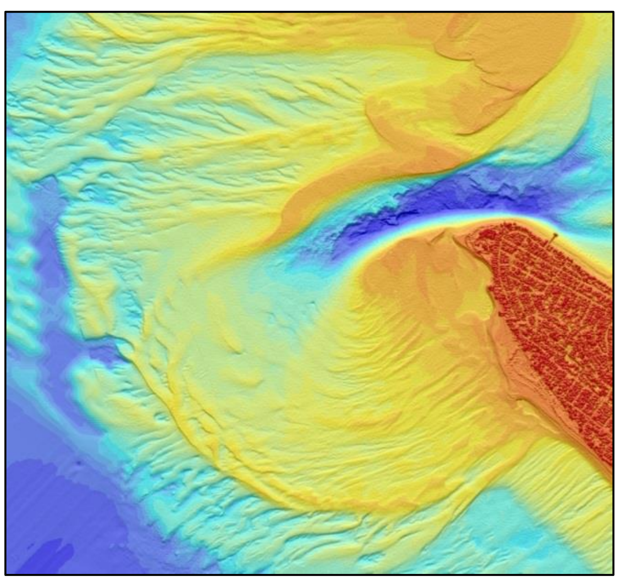

Figure 11. Bathymetric and topographic LiDAR data collected on the west coast of Florida.

Special care must be taken when interpolating topographic and bathymetric data to surfaces (DEMs) and deriving contours. It is not appropriate to apply a single interpolation technique to all data types and environments. Open flat areas with several hills should be interpolated differently than river channels. Although the high density of LiDAR points minimizes the need to interpolate over large distances, the final surface shall represent the measured ground or seafloor and every effort should be taken to minimize artifacts. For example, single beam measurements along profiles that map the Mississippi River have large gaps to be interpolated between transects, and these data should use different methods for generating DEMs. Typical interpolation algorithms include kriging or a triangulated irregular network (TIN), as long as the TIN surface does not result in unrealistic angular surfaces. Kriging tends to work best for high density measurements like multibeam and LiDAR. TIN tends to perform best when interpolating between transects, assuming the elevations between transects trends perpendicular to the transect direction like the Mississippi River or any featureless water bottom. Contours/isobaths should not contain angular deviations that do not exist on the measured surface. Finally, interpolations outside the measured area should be removed to ensure the user is working with measured areas and not misleading interpolation. The final surface derived from high-density data should be provided in GeoTIFF format at 1 meter resolution. Other formats like Esri Grid or ER Mapper have limited portability due to their multiple linked files and directories.

Isopach Data. Using the seafloor and the reflector representing non project-compatible material (*e.g.* high rock content), the thickness of the sediment deposit can be calculated and exported in order to develop an isopach (sediment thickness) map of each potential resource area. The maps that are created may be verified by importing and gridding the thickness data in Golden Software Inc's Surfer 8®. After gridding the data, contour maps showing sediment thickness are produced. The contour maps should be checked for discrepancies in the data. Once the data has been verified, final thicknesses can be exported and used in the borrow area design process. Isopach data are stored in LASARD as XYZ-CSV files using the attribute formats provided in the Bathy-Topo EDD document.

Magnetic Anomaly Data

Upon completion of a general magnetometer survey, the data are examined/analyzed by a marine geologist and also by a qualified marine archaeologist (as required by state/federal agencies), who provides the locations of magnetic anomalies, indicates whether they are significant or not and provides recommendations regarding avoidance buffers. Magnetic anomaly data are stored in LASARD as XY points, using the attribute formats provided in the Magnetometer Data EDD document.

Survey Tracklines/Transects

As previously discussed, geophysical data including seismic, sidescan sonar, magnetometer and bathymetric data as well as some Acoustic Doppler Current Profiler (ADCP) data are collected along pre-defined tracklines. Topographic data is also collected along transect lines. Due to the linear nature of these features, trackline and transect data are stored as polylines, using the attribute formats provided in the SurveyTrackline EDD document. . Links to associated sidescan sonar images, seismic profiles and ADCP survey data are also provided.

Sediment Samples/Grain Size

Vibracores and grab samples are typically analyzed for physical parameters of the sediment (e.g., color, texture/grain size, composition and presence of clay, silt, gravel or shell). The products of these analyses may include core logs, photographs, granularmetric reports and grain size distribution curves. Sediment sample locations are stored as XY points, using the attribute formats provided in the Sediment Samples Data EDD document. Any available elevation information is stored within the attribute table. Links to any associated sediment analysis products (*e.g.* core logs, photographs etc.) are also provided.

Deposit/Borrow Areas

Sediment resource data are stored as polygons, using the attribute formats provided in the DepositBorrowArea EDD document and are classified as potential deposits, borrow areas, offshore disposal sites, re-handling areas or staging areas based on their use.

Cultural Resources

Cultural resources typically include cemeteries, mounds, plantations, shell middens and shipwrecks. Since these are discrete locations, cultural resource data are stored as XY points, using the attribute formats provided in the CulturalResources EDD document.

Shoreline Position

As previously discussed, shoreline position is based on measuring Mean High Water (MHW) positions along a transect over time. The display and storage of MHW data within a GIS involves both XYZ points and lines. Both data formats have relatively small file sizes, however, shoreline position is stored as polylines with their associated attributes. Although shoreline position is used to analyze shoreline change (Figure 12), shoreline change data is not being stored in LASARD.

Sidescan Sonar Contacts

Sidescan sonar contacts are stored as XY points using the attribute formats provided in the SideScanSonarContact EDD document. Information provided for each contact includes the dimensions of the target, the location of the target, the type of feature represented by the target (if known) and the frequency of the sonar system used to detect the target. Links to sidescan sonar contact images such as that shown in Figure 3 (if available), are also provided. The contact images are typically provided in pdf, jpeg or tiff format.

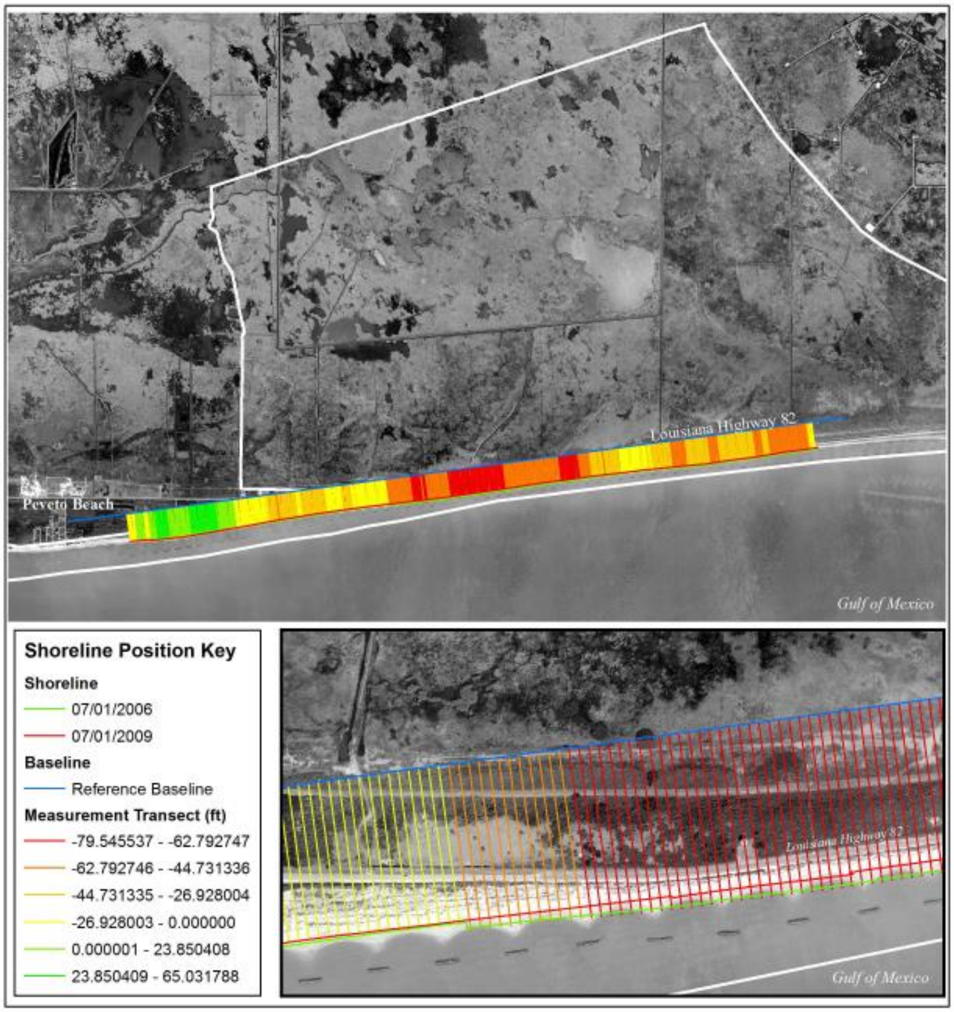

Figure 12. Shoreline-change map used for CWPPRA project analysis Holly Beach Sand Management (CS-31)

CPRA Geospatial Standards (Excludes BathyTopo XYZ Deliverables)
All geospatial data must meet the requirements outlined below and as referenced in the individual EDD. The required projection is NAD 83 UTM Zone 15N Meters GRS 1980 as shown in the table below.

Table 2. Projection Requirements.

Horizontal Datum	Units: Units of XY data (meters) Coordinate System: Universal Transverse Mercator (UTM) Zone 15 N Datum: North American Datum 1983 (NAD 83)

Vertical Datum	Z_Unit: feet or meters are acceptable Datum: NAVD 88
Geodetics	GEOID12A/GEOID12B : Geodetic Reference System 1980 (GRS 80)

Vector Data
All vector data should be provided in Esri shapefile format.

Raster Data
All raster data should be provided in GeoTIFF or ERDAS Imagine (.img) format. Data may also be provided as a compressed FGDB or ArcGIS raster (mosaic, catalog, dataset). If provided as a raster, compression must be lossless.

Tabular Data (Includes BathyTopo XYZ data)
All xyz survey data should be provided in csv format along with the raw satellite navigation system data files (e.g., RINEX, etc.).

Map Documents
Map documents should be provided in either MXD (ArcMap) or APRX (ArcPro) format. All data should be packaged and provided with the MXD. Data within the MXD (shapefiles, rasters, tables, etc.) should be linked to the correct source file.

Map Elements
All map documents must include the following elements: title, legend, map date, citation for background imagery, scale bar, scale text (absolute scale) and north arrow. Map documents should also include a logo and an inset map that shows location.

All data must be provided with Federal Geographic Data Committee (FGDC) compliant metadata in both XML and HTML format. All data must be reviewed prior to submittal to ensure that the data is topologically correct, accurate and complete.

File Naming Convention
CPRA has also established a file naming convention that all data deliverables must comply with. This nomenclature is designed to describe the data files, with or without the presence of a sub-folder structure, through the use of naming elements which are summarized in the table below. In the naming convention, each of the elements summarized in Table 3 is separated by an underscore. A detailed description of the naming convention and its use is provided here.

Table 3. Summary of File Naming Convention Elements

Element	Description	Maximum Characters	Example
1	Identifies the specific project for which the data collection was completed. If known, this should be a CPRA assigned project ID.	20	LA-0026
2	Identifies the type of data being delivered within the file.	5	ELMBB
3	This element is for internal use only. Please leave this element as '0' for all deliverables. CPRA identifies the location of the data within the data package based on a defined data delivery grid.	10	0
4	Identifies the collection date or range of the data within the file.	16	2011051420110514
5	Provides a sequence element to distinguish data packages that might otherwise have the same name. The first character in this sequence indicates whether the data is processed, raw or an analysis product. The remaining sequence is typically the ID of the dataset.	7	PBF0003
6	Required for Sediment Samples, optional for other data types and may be used to capture any additional information that might be useful to help identify the data.	10	CHANDELEUR

Note: based on the examples provided in the table above, the data package containing the processed data would be named "LA-0026_ELMBB_0_2011051420110514_PBF0003_CHANDELEUR.zip"

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