Atchafalaya River
Long Distance Sediment Pipeline

Final Borrow Site Identification Report

moffatt & nichol

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ATCHAFALAYA RIVER LONG DISTANCE SEDIMENT PIPELINE

TERREBONNE PARISH

FINAL BORROW SITE IDENTIFICATION REPORT

Prepared for:

Terrebonne Parish Consolidated Government – Office of Coastal Restoration & Preservation

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Terrebonne Parish Consolidated Government –
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LIST OF ACRONYMS

AAHU	Average Annual Habitat Unit
AEP	Annual Exceedance Probability
ALDSP	Atchafalaya Long Distance Sediment Pipeline
AQCR	Air Quality Control Region
AQI	Air Quality Index
BA	Biological Assessment
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
Cfs	Cubic Feet Per Second
CIAP	Coastal Impact Assistance Program
CPRA	Coastal Protection and Restoration Authority of Louisiana
CRMS	Coastwide Reference Monitoring System
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
CY	Cubic Yard
LDNR	Louisiana Department of Natural Resources
LADOTD	Louisiana Department of Transportation and Development
DPEIS	Draft Programmatic Environmental Impact Statement
E&D	Engineering & Design
EC	Engineering Circular
EO	Executive Order
EFH	Essential Fish Habitat
ER	Engineering Regulation
ESA	Endangered Species Act
ESLR	Eustatic Sea Level Rise
FEMA	Federal Emergency Management Agency
FPEIS	Final Programmatic Environmental Impact Statement
FWCA	Fish and Wildlife Coordination Act
FWOP	Future Without Projects
GIWW	Gulf Intracoastal Waterway
HNC	Houma Navigation Canal
HTRW	Hazardous, Toxic, and Radioactive Waste
HU	Hydrologic Unit
IPCC	Intergovernmental Panel on Climate Change
LACES	Louisiana Applied Coastal Engineering and Science Division
LACPR	Louisiana Coastal Protection and Restoration
LAIS	Louisiana Agriclimatic Information System
LASARD	Louisiana Sand Resource Database
LCA	Louisiana Coastal Area
LCA-ARTM	Louisiana Coastal Area – Atchafalaya River to Northern Terrebonne Marshes
LDEQ	Louisiana Department of Environmental Quality
LDSP	Long Distance Sediment Pipeline
LDWF	Louisiana Department of Wildlife and Fisheries
LiDAR	Light Detection and Ranging
LSU	Louisiana State University
LUMCON	Louisiana Universities Marine Consortium
M&N	Moffatt & Nichol
MLG	Mean Low Gulf
MP	Master Plan
MVN	Mississippi Valley New Orleans District
NAAQS	National Ambient Air Quality Standards
NAVD88	National American Vertical Datum of 1988
NBEM	National Bald Eagle Management

NCDC	National Climatic Data Center
NDBC	National Data Buoy Center
NGO	Non-Governmental Organization
NGVD	National Geodetic Vertical Datum
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Oceanic Service
NRCS	Natural Resources Conservation Service
NWR	National Wildlife Refuge
OMRR&R	Operation, Maintenance, Repair, Rehabilitation and Replacement
PAC	Post Authorization Change report
PDT	Project Delivery Team
PL	Public Law
PPA	Project Partnership Agreement
ppt	Parts-Per-Thousand
RSLR	Relative Sea Level Rise
SAV	Submerged Aquatic Vegetation
SLR	Sea Level Rise
STD	Standard Deviation
TLCD	Terrebonne Levee and Conservation District
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAVCIS	Wave-Current-Surge Information System
WMA	Wildlife Management Area
WRDA	Water Resources Development Act
WVA	Wetland Value Assessment

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1 INTRODUCTION

1.1 Project Background

The Atchafalaya River provides a significant industrial shipping channel for the state of Louisiana. The maintenance of the river as a navigable channel and alternate route to the Mississippi River has been a significant project for the U.S. Army Corps of Engineers for over a century. Thirty percent of the combined flow of the Red River and Mississippi River is diverted by man-made locks and levees down the Atchafalaya River, along with hundreds of millions of cubic yards of sediment. This sediment is building ground near the Gulf of Mexico, while critical marshes in central and eastern Terrebonne Parish have become sediment and nutrient deficient, making them vulnerable to saltwater intrusion. Today, due to human interventions over the past century, there is less natural hydrologic and morphodynamic interaction between the river and the Terrebonne basin. Anthropogenic intervention now aims at restoring this connection by means of mechanically bringing the River's sediment back into the basin.

1.2 Atchafalaya Long Distance Sediment Pipeline Project

1.2.1 Project Objectives

The Terrebonne Parish Consolidated Government, Department of Coastal Restoration & Preservation has received Federal Coastal Impact Assistance Program (CIAP) funds to investigate the feasibility of designing, installing and operating a sediment delivery pipeline extending from the Atchafalaya River south of Morgan City across the central Terrebonne Hydrologic Basin to restore marsh and ridge habitat in that reach. This feasibility study will take the first steps at designing a project to help restore these critical marshes.

The general objective of this study is to find suitable material for marsh restoration within the Lower Atchafalaya River Region, hydraulically dredge the material and transport it by means of a pipeline to the marshes in need. In order to achieve this objective, Terrebonne Parish has divided the study into two separate efforts: the identification of sediment resources within the Lower Atchafalaya River Region (Part 1) and the assessment of transporting the material to the identified areas of need (Part 2). Moffatt and Nichol (M&N) was selected to lead Part 1 while CB&I was selected to analyze Part 2 of the feasibility study. This report will detail the analysis performed, final conclusions, and recommendations developed by Moffatt and Nichol for Part 1 of the study.

1.2.2 Project Assumptions

Though Part 1 and Part 2 of this study are being developed independently, coordination and communication by the two project teams is necessary to ensure that the correct assumptions are being applied to each portion. One of these coordinated assumptions pertains to the pump out location or "approximate point of intake", i.e. the location where the dredged material will enter the pipeline before being transported to the areas in need. For the Atchafalaya Long Distance Sediment Pipeline (LDSP) project, a pump out location has preliminarily been identified to be in the close vicinity of Crew Boat Cut (see Figure 1-1). Existing pipeline corridors, Colombia Gas Pipeline and Tennessee Gas Pipeline, have preliminarily been identified as likely transport routes.

1.3 Study Area

For Part 1 of this feasibility study (the identification of sediment resources executed by Moffatt & Nichol), the Study Area has been defined as the Lower Atchafalaya River region, more specifically; the Lower Atchafalaya River, Bayou Shaffer and parts of Bayou Boeuf, Bayou Black and Bayou Chene (as outlined in Figure 1-1).

1.4 Purpose and Scope

Part 1 of the evaluation of the sediment resources component of the Atchafalaya LDSP project has, in turn, been broken down into two phases.

1.4.1 Phase I: Preliminary Borrow Site Identification

The first phase consisted of a preliminary borrow site identification and preliminary estimation of associated borrow volumes as well as an order-of-magnitude estimation of refill rates for borrow sites. This first phase was completed with the issuance of the *Final Preliminary Borrow Site Identification Report* on December 1st, 2013 (Moffatt and Nichol, 2013).

1.4.2 Phase II: Refill Rate Modeling and Final Borrow Site Identification

The Second Phase of Part 1, addressed within this report, assesses refill rates in more detail through numerical modeling for two identified borrow sites. Whereas Phase I of the ALDSP study focused on determining the location and size of the optimal borrow areas within the Lower Atchafalaya River Region, Phase II examines the performance of the selected areas as a renewable resource for wetland restoration material. Phase II focuses on establishing estimates for refill rates for the two selected borrow sites.

The tasks associated with this phase are focused on conducting numerical model simulations for the two potential borrow areas. Performing hydrodynamic and morphological modeling for the river reach containing the two borrow sites will help inform the anticipated refill rate of the two sites and confirm/deny their feasibility to provide the necessary volume of sediment within the project time scale for marsh restoration.

All findings of the feasibility study will be summarized within this report; it will summarize the conclusions from Phase I, detail the analysis completed for Phase II, and provide a recommendation for the borrow areas location and geometry.

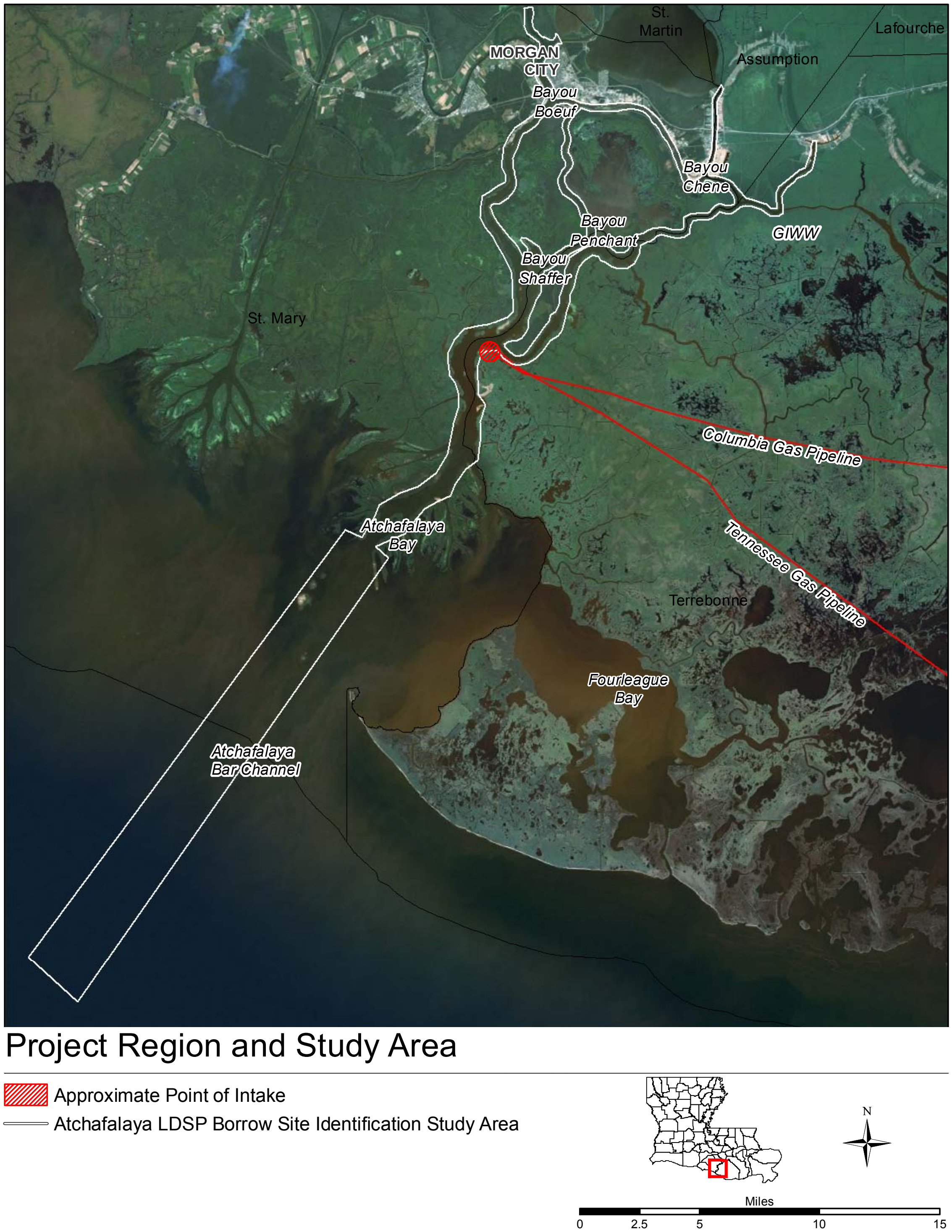


Figure 1-1: Project Region and Study Area for the Atchafalaya LDSP Borrow site identification

1.5 Report Outline – Reader's Guide

This report has been divided into chapters describing the methodology, results, and conclusion of the analysis performed. Chapter 2 discusses in greater detail the borrow sites selected for the numerical modeling analysis. Chapter 3 gives a general description of the modeling procedures, model development and the various input parameters used for model setups utilized throughout the analysis. Chapter 4 details the results of the hydrodynamic and morphological modeling and the conclusions that can be derived from the evaluation of model results. Finally, Chapter 5 provides recommendations for anticipated dredging quantities, dredging frequency as well as refill rates and the total volume of sediment available from the two selected borrow sites.

2 SELECTED BORROW SITES FOR REFILL RATE ESTIMATES

2.1 Chronology – Selected Sites for Refill Rate Estimates

The objective of Phase I of this study was to identify and evaluate all potential Atchafalaya River sediment sources for use in coastal restoration projects. Identification of potential borrow sources was determined by examining the available bathymetry data beginning in the Atchafalaya River just above Morgan City (RM 117) and extending to the end of the Atchafalaya Bar Channel (RM 167). Additionally, Bayou Shaffer and segments of Bayou Boeuf, Bayou Black and Bayou Chene were examined for potential deposits of sediment.

After identification of these areas based on bathymetry and vicinity to the point of intake, they were evaluated more thoroughly against data pertaining to sediment characteristics and proximity to river training works, aids to navigation, or pipeline crossings within the area. Prior to delineation of the borrow areas, dredging limits and offsets were addressed by placing buffers in the vicinity of areas of avoidance. The dredge areas were then outlined and evaluated for available sediment.

Two sites have been identified from the list of potential borrow areas as presented during Phase I and discussed in the Preliminary Assessment Report (Moffatt & Nichol 2013). ATCH-136W is located on the western bank of the Atchafalaya River at River Mile 136 within a reach of the river referred to as Horseshoe Bend. ATCH-137E is located just south of ATCH-136W at River Mile 137 along the Eastern bank in an area called Crew Boat Cut. Both areas are located within 2 miles of the approximate point of intake as shown in the Figure 2-1. Appendix A contains the detailed exhibits of the selected borrow area dimensions as well as multiple cross sections for each.

2.1.1 Sediment Demand Expectations

To determine whether the Lower Atchafalaya River Region contains sufficient volume of sediment to restore the degraded marshes in Terrebonne Parish, it is necessary to determine a volumetric quantity to be dredged and placed within the marsh. On November 26th 2013, a team meeting was held that included Terrebonne Parish, CB&I, and Moffatt and Nichol to discuss the various alternatives and cost methods of project implementation. Since the entire ALDSP project will be divided into cycles governed mainly by sediment availability and funding, an order of magnitude budget and time frame for project completion is required to determine the project feasibility. CB&I has conducted a preliminary study to identify the areas of most need and determine the volume necessary for wetland restoration. Based on this analysis, it was determined that the project requires 50 million cubic yards of dredged material to be available from the identified borrow source.

2.1.2 Project Time Scale

The project time scale, though required to determine project feasibility, is difficult to predict because it is dependent on the re-fill rate of the selected borrow sites. The frequency of dredging cycles is directly related to the rate at which the borrow sources re-fill after river flood events throughout the hydrologic year. As a preliminary assumption, the project time scale is assumed to be bounded by an average annual sediment demand of approximately 5 million cubic yards per year.

It should be noted that at this phase of the study the project does not consider any Beneficial Use of dredge material as a result from routine maintenance dredging performed by USACE. The project time scale can be affected by applying the sump technique discussed in the Preliminary Assessment Report. The sump technique refers to creating a disposal area where the USACE can deposit material dredged for maintenance of the navigation channel. This would expedite the re-fill process and allow for more frequent dredge cycles.

2.1.3 Assumed Budget

Another potential constraint on the feasibility of the ALDSP is budget availability. Though, at this phase, it is unclear what the cost of dredging, transporting, and placing of 50 million cubic yards of material will be, an estimated budget range helped eliminate borrow areas that are too far from the approximate point of intake from further analysis. Per the November 26th team meeting, the budget is assumed to be greater than $100 Million but less than $783 Million.

2.2 Selected Sites for Refill Rate Estimates and Site Conditions

Within the framework of what is mentioned above, Moffatt & Nichol refined the preliminary identified borrow sites (ATCH-136W and ATCH-137E) and investigated the availability of 50 Million cubic yards of borrow material for the project within close proximity. It is furthermore assumed that the material will be borrowed at a rate of approximate 5 Million cubic yards per year. The following sections will summarize the characteristics of each borrow site and the site conditions in the vicinity of the approximate point of intake. Figure 2-1 depicts the delineation of the selected borrow sites with all the identified obstacles within the area.

2.2.1 Site Conditions

As mentioned above, the two sites identified for re-fill modeling are located within an area of the Atchafalaya River referred to as Horseshoe Bend and Crew Boat Cut. The first area under consideration, ATCH-136W is in the outer bend of the Atchafalaya River (the Horseshoe Bend), and covers approximately 140 acres. The natural elevation for the majority of the site is above -20 ft. NAVD88. The proposed cut of this section would result in a bottom width ranging between 400 ft. to 1300 ft. The plan view as well as cross sectional views of this proposed site can be found in Appendix A.

The ATCH- 137E borrow site covers approximately 260 acres of the Atchafalaya River and is located within the Crew Boat Cut reach. The borrow site bottom width ranges from 850 ft. to 1400 ft. Appendix A presents a plan view and cross sections of the borrow area.

2.2.1.1 Borrow Volumes

Based on the most recent bathymetry data, a volume of available sediment to a dredge depth of -70 ft. NAVD88 was estimated for each site. Applying a side slope of 3(H):1(V), the following dimensions and volumes were determined for the two sites, see Table 2-1.

Table 2-1: Selected Borrow Area Dimensions and Volumes

Site Name	Water Body	Reach	Volume [million CYD]	Area [acres]	Length*	Width*
ATCH-136W	Atchafalaya River	Horseshoe Bend	9.80	136.37	6,700	400 - 1300
ATCH-137E	Atchafalaya River	Crew Boat Cut	19.50	260.82	9,900	850 - 1400

*Length is defined as linear feet in flow direction, width as linear feet perpendicular to flow direction

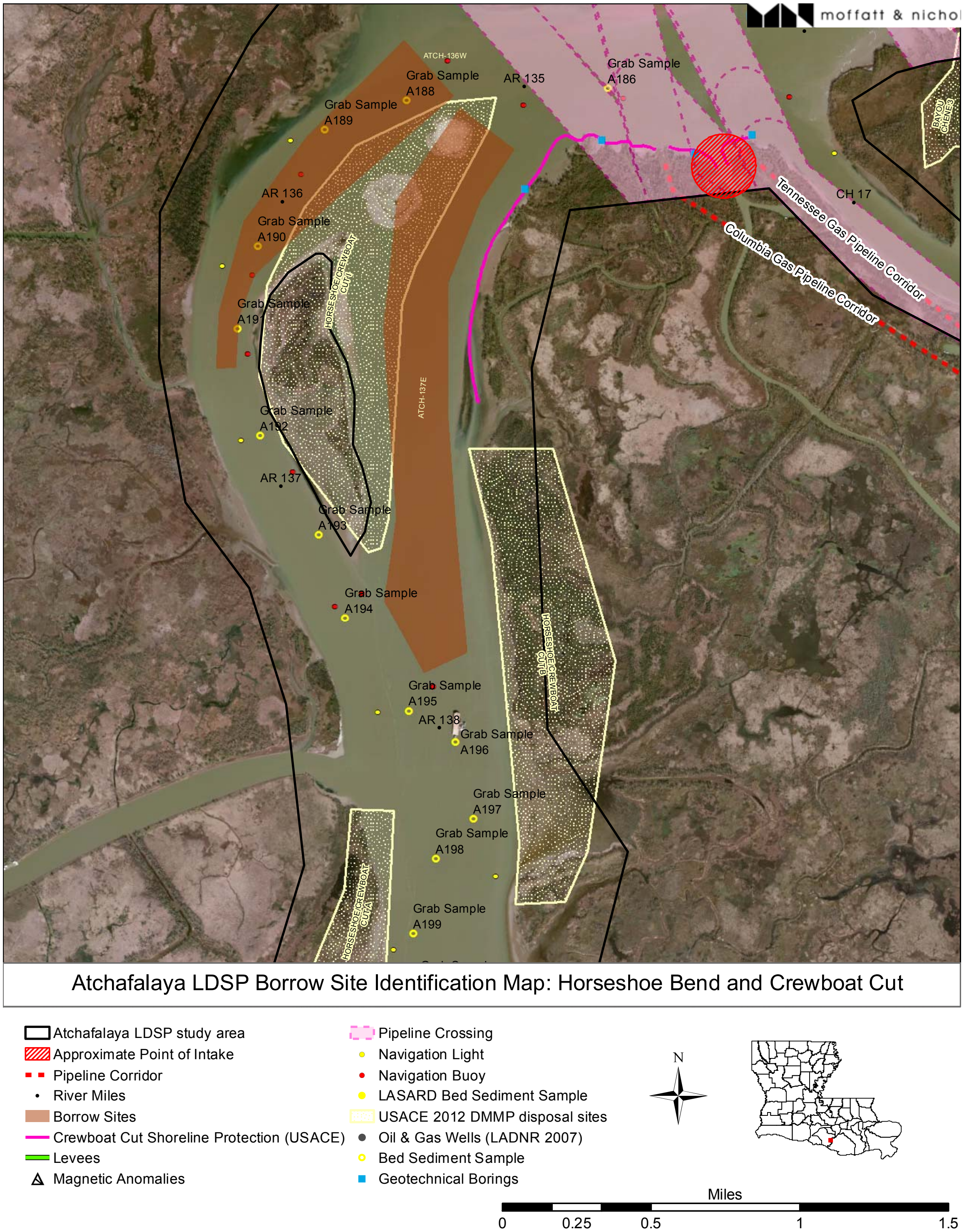


Figure 2-1: Selected Borrow Sites; labeled ATCH-136W and ATCH-137E and vicinity map for the Approximate Point of Intake. The Horseshoe Bend reach is the outer bend of the river (west side), the Crew Boat Cut reach is the straighter flow path in north south direction (east side).

2.2.1.2 Sediment Characteristics

The sediment characteristics can be defined in somewhat greater detail for this reach of the project area due to data that was gathered for the recently completed Crew Boat Cut Revetment Project. During the design phase of this project six borings were taken to a depth of 60 ft. (see also Moffatt & Nichol 2013). Additionally, sediment grab samples along the western portion of Horseshoe Bend are available, as shown in Figure 2-1 and included in Appendix B.

2.2.2 Crew Boat Cut Project

The design and performance of ATCH-136W and -137E could be influenced by the anticipated presence of planned projects that are either approved for construction or currently being constructed. The Crew Boat Cut Realignment and Revetment project is on the immediate horizon (to be completed late 2014) and is briefly addressed here.

2.2.2.1 Navigation Channel Realignment

To potentially decrease the frequency of USACE maintenance dredging events required within Horseshoe Bend, the centerline of the navigation channel will be shifted east into the Crew Boat Cut Reach. Hydrodynamic modeling performed by USACE shows that this alignment will work to 'self-scour' more than the current alignment through Horseshoe Bend, reducing the annual dredging maintenance volume to 250,000 cubic yards from the current annual estimate of 600,000 cubic yards (USACE, 2012). The frequency of dredging is also anticipated to decrease to every three years and the Horseshoe Bend reach will no longer be maintained allowing shoaling to occur.

2.2.2.2 Horseshoe Bend and Crew Boat Cut Dredging Requirements

In the 2012 DMMP prepared by USACE, the Horseshoe Bend reach averages approximately 600,000 cubic yards of dredged material annually when dredged to its authorized depth. However, due to budget constraints, dredging events typically occur every 2-3 years and average over 1.1 million cubic yards (USACE 2012). Presently, Crew Boat Cut is not dredged, but with the re-alignment of the navigation channel out of Horseshoe Bend and through Crew Boat Cut this area will experience an initial dredging event and an estimated maintenance dredging every three years after that, dependent on Federal budget availability.

2.2.2.3 Crew Boat Cut Revetment

In order to provide protection to the river bank with the realignment of the navigation channel, 1.8 miles of rock bank protection has been placed along the eastern bank (see Figure 2-2). In addition to protecting the bank, the rock dike is expected to stabilize the navigation channel. The rock dike has been constructed to a height of 4.5 ft. NAVD88 with a side slope of 2(H):1(V) on the channel side and 3(H):1(V) on the land side. The crown width of this dike is approximately 4 feet. During construction, a floatation channel was dredged approximately 60 feet from the centerline of the rock dike. Though not evaluated in this phase of the study, this project intersects with the assumed location of the point of intake of the ALDSP.

Figure 2-2: Crew Boat Cut Revetment as seen from the air, looking towards the southwest (photo credit: Greg Linscombe)

2.2.3 Workability

Though this study is not specifically intended to address the transport of sediment from the borrow site to the restoration area, the conveyance of the material from the borrow site to the point of intake is an important consideration for determining the site feasibility. Because both sites are located in close proximity to the Navigation Channel, the impacts of construction activities and equipment to navigation should be considered. The following subsections will provide a broad overview of planning-level construction considerations.

2.2.3.1 ATCH-136W Utilization Plan

For planning level purposes, it is assumed that if ATCH-136W is identified as a borrow site for design, the following possibilities exist for transporting the material from the borrow site to the point of intake. The first option would be to dredge the material using a hydraulic (Cutterhead) dredge and passing the material through a pipeline to the point of intake. Since the pipeline will cross the navigation channel, it will need to be sunk and anchored down to the river bottom so as to prevent any obstruction to navigation. Since anchoring a pipeline perpendicular to the direction of strong river currents could be challenging, another option is to bury the pipeline sufficiently deep so as to prevent any opportunity for the pipeline to become dislodged. Because the navigation channel passing near this borrow area will be abandoned for the alternate route through Crew Boat Cut, the use of a hydraulic dredge, which is essentially stationary during dredging, will not create a threat to large navigation vessels.

If passing the pipeline under and across the navigation channel is undesirable, another option is to use a hopper dredge instead of the hydraulic dredge. A trailing suction hopper dredge sails along the borrow area and collects the material within its hopper before traveling to the pump-out site. The hopper dredge will connect to the pipeline at the approximate point of intake and empty its contents before traveling back to the borrow area and reconvening dredging. This option avoids the use of pipelines within the navigation channel.

Double-handling the material is also a technique used to avoid placement of pipelines from the hydraulic dredge to the approximate point of intake. Material can be dredged using a hydraulic dredge and placed in either a scow that can then be transported across the navigation channel to where it will be handled again and conveyed to the approximate point of intake. An alternative method for double-handling will be to dredge the material using a hydraulic dredge and pumping to another location that will also be dredged and pumped to the approximate point of intake. The primary disadvantage to double-handling is that the loss associated with this technique typically results in a higher loss percentage.

2.2.3.2 ATCH-137E Utilization Plan

ATCH-137E has the advantage of being on the same side of the navigation channel as the approximate point of intake, however, its location corresponds directly with the proposed navigation channel realignment, discussed in the next Section. As with the ATCH-136W, a hydraulic dredge can be used to dredge the material and pump it through a pipeline to the approximate point of intake. This will not require the pipeline to cross the navigation channel. However, because the hydraulic dredge is anchored during dredging with swing anchors that extend out to each side of the dredge, a passing navigation vessel will need to maneuver to one side of the channel to avoid coming in contact with either the dredge or its anchors. Restrictions are typically placed on this arrangement that can limit the extent of dredging so as to ensure that no part of the dredge is extending into navigable areas. The option to utilize a hopper dredge which sails during dredging operations and can easily maneuver out of the path of a large vessel may also be considered for this alternative.

3 NUMERICAL MODELING OF HORSESHOE BEND AND CREW BOAT CUT

3.1 Modeling Approach

The hydrodynamic and morphological modeling for the Atchafalaya River containing the two borrow sites will inform the approximation of refill rates for the two sites and confirm their feasibility to provide the necessary volume of sediment to sustain the Atchafalaya Long Distance Sediment Pipeline Project.

Numerical modeling for this study was performed using the Delft3D modeling system. Delft3D is an integrated surface water modeling system developed by Deltares (former WL | Delft Hydraulics) of the Netherlands. The system is based on a flexible framework which simulates two- and three dimensional flows, waves, water quality, ecology, sediment transport and bottom morphology and the interactions between those processes. The package gives direct access to state-of-the-art process knowledge, accumulated and developed at one of the world's oldest and most renowned hydraulic institutes. Delft3D consists of a number of well-tested and validated modules, which are linked and integrated with one-another.

3.1.1 Hydrodynamic Formulation

The hydrodynamic module Delft3D-FLOW simulates two-dimensional (2D, depth averaged) or three-dimensional (3D) unsteady flow and transport phenomena resulting from tidal and/or meteorological forcing, including various combinations of inflow/ and water level boundary conditions. The model also includes the effect of density differences due to a non-uniform temperature and salinity distribution (density-driven flows), although this was not used in the present model setup. The model can be used to predict the flow in shallow seas, coastal areas, estuaries, lagoons, rivers and lakes. Using a shallow water approximation it is applied to the flow phenomena with characteristic horizontal scales larger than the vertical scales. When the fluid is regarded as vertically homogeneous with respect to temperature, salinity, and thus, density, a depth-averaged approach is appropriate. Delft3D-FLOW is able to run in two-dimensional mode (one computational vertical layer), which corresponds to solving the depth-averaged equations. This is the approach applied in the present study. The Delft3D-FLOW model is also able to resolve secondary flow effects indirectly in 2D mode by extending these equations to account for the spiral motion intensity and the resulting horizontal shear-stresses from secondary flow. This feature particularly important for the present application and therefore it is used for this study.

Delft3D-FLOW's system of equations consists of the horizontal equations of motion, the continuity equation and the transport equations for conservative constituents. The equations are formulated in orthogonal curvilinear coordinates. In curvilinear coordinates, the free surface level and bathymetry are related to a flat horizontal plane of reference. Flow forcing may include variations of water level, fluxes or velocities at the open boundaries, wind stress at the free surface, with internal pressure gradients calculated from the gradients of free surface elevation (barotropic) or density (baroclinic). Source and sink terms are included in the equations to model the discharge and withdrawal of water. Delft3D-FLOW solves the Navier Stokes equations for an incompressible fluid, under the shallow water and the Boussinesq assumptions. In the vertical momentum equation the vertical accelerations are assumed to be negligible and are neglected; this leads to the hydrostatic pressure equation.

3.1.2 Sediment Transport and Morphology Formulation

Delft3D-FLOW simulates sediment transport and morphologic change through a series of add-ons. Both cohesive (mud) and non-cohesive (sand) sediment fractions can be modeled with Delft3D in suspended and bedload modes. The interaction with the bed is expressed in terms of erosion and deposition rates for mud or reference height and reference concentration for sand. Delft3D allows sediment-specific characteristics and properties to be formulated separately for individual sediment fractions.

Two-dimensional sediment transport is calculated in Delft3D by solving the two-dimensional advection-dispersion equation for the suspended sediment. Computationally, the two-dimensional transport of sediment is computed in the same way as the transport of any other conservative constituent, such as salinity. There are, however, a number of important differences between sediment and other constituents. Sediment comes under the force of gravity and its fall velocity is affected by the sediment characteristics, concentration, and hydrodynamic conditions such as turbulence. Therefore, the exchange of sediment between the bed and the water column is controlled by a set of physical relations between the hydrodynamics and sediment. These additional characteristics of sediment are of critical importance; for example, if a net flux of sediment from the bed to the water column, or vice versa, occurs, then the resulting change in bathymetry can influence subsequent hydrodynamic calculations.

Overall, the system allows for great flexibility in the optimization of total model run times. However, using relatively high spatial resolutions, process based models such as Delft3D, often results in excessively long simulation times. Morphological developments generally take place on a time scale several times longer than typical flow changes. For example, in the river environment bed changes are small and may take days or longer to affect the hydrodynamics. Therefore, river models can be run as a set of steady state simulations associated to a river discharge where each steady state event can be multiplied by a morphological time scale factor to simulate longer time scales of morphological evolution. The “morphological time scale factor” simply multiplies the erosion and deposition fluxes from the bed to the flow and vice versa at each time step.

3.1.3 Cohesive Sediment Formulation

Interaction between cohesive suspended sediment and the bottom is simulated through the well-known Partheniades-Krone formulation that computes erosion and deposition rates based upon critical shear stresses, settling velocity, and local concentration. The mud transport mode does not distinguish between suspended load and bed load. The equations for deposition and erosion are:

$$E = M\left(\frac{\tau}{\tau_{c,e}} - 1\right) \text{ when } \tau > \tau_{c,e}\text{, else } E = 0$$

$$D = w_s c\left(1 - \frac{\tau}{\tau_{c,d}}\right) \text{ when } \tau < \tau_{c,d}\text{, else } D = 0$$

where E and D are the erosion and deposition fluxes respectively (kg/m2/s), M is the erodability parameter (kg/m2/s), ws is the settling velocity (m/s), c is the sediment concentration (kg/m3), and τ, τc,d, and τc,e are the shear stress, critical shear stress for deposition, and critical shear stress for erosion (Pa), respectively (Partheniades, 1965).

3.1.4 Non-cohesive Sediment Formulation

For the transport of sand fractions, the van Rijn (1993) formulation is used. This formulation distinguishes between the two main modes of sand transport - suspended and bed-load - by treating the transport below a reference height as bed-load, and the remaining as suspended load. The critical bed shear stress for initiation of motion of the sand particles is calculated based on the classical Shields parameter, which is modeled as a function of the median grain-size (van Rijn, 1993). The transport rates are assumed to mainly depend on median grain size (D50), depth averaged velocity, and roughness or reference height. The settling velocity of the sand particles in suspension is modeled as a function of the relative density of the sand fraction and the median particle diameter.

3.2 Analysis of Available Data and Assumptions

3.2.1 Discharge Conditions

USGS has several stream flow gages located in the Atchafalaya and Terrebonne basins. The discharge conditions at the borrow site are based on the data collected by USGS at Morgan City. USGS collects discharge, water elevation and suspended sediment concentration at the Morgan City station (Station ID 07381600). Discharge data is available at this site from 1995 to the present, while surface water elevations are available since 1973.

3.2.2 Bathymetry Data

Hydrographic Surveys of the Horseshoe Bend/Crew Boat Cut area are readily available from the USACE New Orleans District from 2006 to 2014. These surveys mainly cover the Federal navigation channel. In addition to bathymetric data, the Southern Lousiana Digital Elevation Model (DEM), covers both the subaqueous as well as the sub-aerial terrain (topography) throughout the project area. Although the coverage of this DEM is excellent, there is a significant difference between elevations from this data set and the hydrographic surveys, possibly as a consequence of the very dynamic nature of this river bend system.

LIDAR data was not available in the project area, since the 2010 LIDAR elevation map of the Atchafalaya Basin does not cover the area of interest, and data from the new USGS LIDAR program was not yet available at the time of this study.

3.2.3 Elevation Data- Water Level Gradient

Two available USGS water level stations with good data coverage closest to the project site are marked in Figure 3-1. These are the USGS station 073816501 at Avoca Island Cutoff and the USGS station 073816501 at Morgan City. The distance between these two stations is approximately 13 miles, and in the present study it is assumed that the water level gradient between these two stations should be the same as in the model extent.

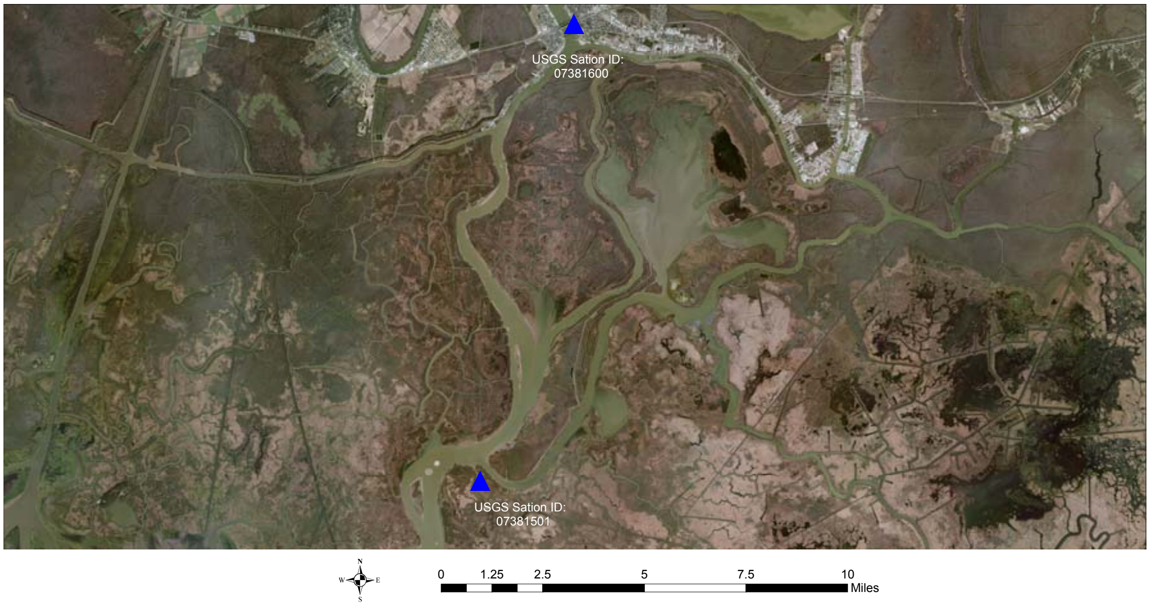


Figure 3-1: USGS stations at Morgan City (Station ID: 07381600) and Avoca Island (Station ID: 07381501)

3.2.4 Suspended Sediment loads

Suspended sediment loads are based on the information collected by USGS at Morgan City. These data have also been analyzed by multiple researchers and several references have been included in this report's reference list.

3.2.4.1 Suspended sediment concentration

Suspended sediment concentration at Morgan City is available from numerous grab samples collected by USGS from 1973 to 2013. Figure 3-2 presents the suspended sediment concentration versus discharge at Morgan City. It can be observed that although there are some outliers in the data showing a very high value of concentration, most of the values are in the range of 150 to 300 mg/l. At low discharges, when practically all the suspended sediment consists of Silts and Clays, concentrations are lower. For medium to high discharge concentrations are almost constant, around a value of 250 mg/l. Previous analysis done by Teeter and Johnson (2005) indicated that the range of values of sediment concentration at Morgan City and Calumet is between 175 to 290 mg/l, comparable to the range of values observed at Morgan City for medium to high flows. Finally for high discharges, sediment concentration slightly decreases although with values very close to the average values.

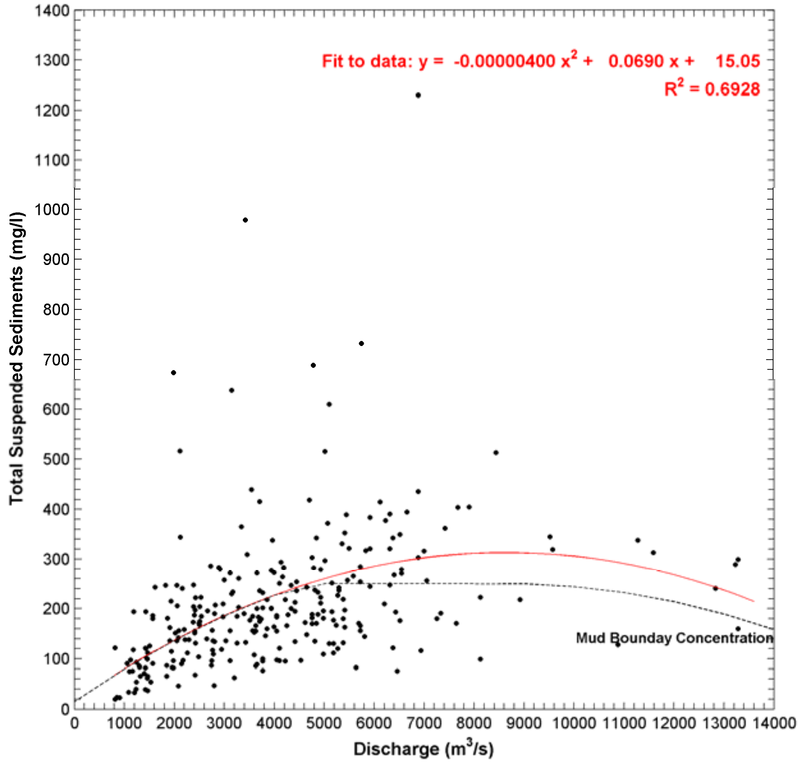


Figure 3-2: Suspended sediment concentration at Morgan City versus Discharge.

3.2.4.2 Sediment load and percent of Sand on Suspended Sediment

Allison (2012) included an analysis of sediment discharge in the Atchafalaya River, in particular at Morgan City, for the water years 2008 through 2010. For these years the total sediment discharge in Million metric Tons per year (MT/y) at Morgan City is estimated at 30.9, 22.7 and 30.1 respectively, while the sand load is 7.4, 3.8 and 5.0 MT/y for the same period. The relation between sand and silt/clay contribution to the total sediment discharge varies from a ratio of 17/83 to 24/76 depending on the year.

Using the information from Figure 4 of Allison et al. (2012), the percentage of suspended sand of the total suspended solid discharge has been calculated. The contribution of sand to the total suspended sediment discharge increases with discharge varying from less than 1% of the total suspended sediment for very low discharges to up to values close to 40% for the high discharges. These approximated values from the aforementioned figure are presented in Table 3-1.

For example, for discharges higher than 6,000 – 7,000 m^3/s at Morgan City, the total solids discharge presented in Allison et al. (2012) is approximately between 200,000 and 300,000 metric tons per day (tons/d), while the sand load is closer to 50,000 to 100,000 tons/d and increasing with discharge. This indicates that for this discharge range, where most of the suspended sediment transport is expected, the percentage of sand could be up to 40% of the total suspended load for the high discharges.

Table 3-1: Variation of percentage of sand of the total suspended sediment discharge at Morgan City, after Allison et al. (2012)

Discharge Range (Morgan City m^3/s)	Percentage of Sand of the total suspended sediment discharge (%)
Larger than 6,000	17 - 40
4,000 – 6,000	8 - 17
3,000 – 4,000	2 - 8
2,000 – 3,000	0.5 - 2

The total sediment discharge at the Horseshoe Bend/Crew Boat Cut site is expected to be less than the one reported for Morgan City, due to the fact that it is downstream from Morgan City and distributaries such as the GIWW and Bayou Chene account for a reduction in flow. It remains a valid assumption that the sand versus silt/clays ratios would be similar.

3.2.5 Sediment Bed Composition

There is very limited information available to define the characteristic of the bed sediments and their spatial distribution in the project area. Similar notions were made in other studies; e.g. Arcadis (2011) identified two data gaps: 1) the information on sediment distribution in the Atchafalaya river and 2) the size distribution of the dredged sediments. In the absence of additional information an approximated sediment distribution was developed based on the Louisiana Sand/Sediment Resource Database LASARD by the Louisiana Department of Natural Resources. This data is based on grab samples taken in the area. No samples from this program are available for the Crew Boat Cut reach. All the samples were taken from the Horseshoe Bend reach.

The average mean diameter from these data samples A186-A196 in the project area (see Appendix B) is in the order of 150 microns, with an average reported standard deviation for these samples of around 75 microns. Because of the uncertainty in this information, the D_{50} of the bed for the whole area was set to 200 microns. In addition, to define the sediment distribution in the project area, the consideration as reported by Arcadis (2011) that the bed approximately contains 20% of fines, has been taken into account. Fines are classified as sediments with a D_{50} smaller than 62.5 microns.

For this modeling effort the bed in the project area has been defined with 5 sediment classes; one cohesive and 4 non cohesive, with the largest content of medium sand, representative of the medium diameter at the site, and 20% of silt and clay content. For the sediment distribution as presented in Table 3-2 the mean diameter of the bed is approximately 200 microns.

Table 3-2: Bed Sediment Classes as defined for this study

Sediment Class	Diameter range (microns)	Percent content (%)
Silts and clays	< 62.5	20
Very Fine Sand	62.5 - 125	25
Fine Sand	125 - 250	30
Medium Sand	250 - 500	20
Coarse Sand	500 - 1000	5

This sediment distribution was spatially kept constant throughout the model domain due to the lack of additional information. Nor was there any correlation derived from the data analysis between the mean diameter and the water depth. In reality this distribution at the bed could change throughout the hydrologic year as water depths and shear stresses change with changing discharge.

3.2.6 Bed Load Sediment transport

Limited information is available about the bed load transport in the Atchafalaya River. Allison et al. (2012) made an estimate of the potential bed load transport in the area. Allison et al. concluded that bed load transport could contribute an approximate additional 10%, or just above, to the total sand transport.

3.3 Model Development

3.3.1 Model Grid

The extent of the numerical model covers 5.2 miles of the Atchafalaya River with the upstream and downstream boundaries located at approximately 2 miles from the project site. The model extent and grid resolution is optimized for simulations of morphological processes within the Horseshoe Bend and Crew Boat Cut reach of the River. The numerical model has been developed using an orthogonal curvilinear grid (see Figure 3-3) with approximately 36,000 grid points. The model will be simulating the depth averaged 2D-equations (see also section 3.1). The smallest grid dimension in the domain is around 10 meters near the project area.

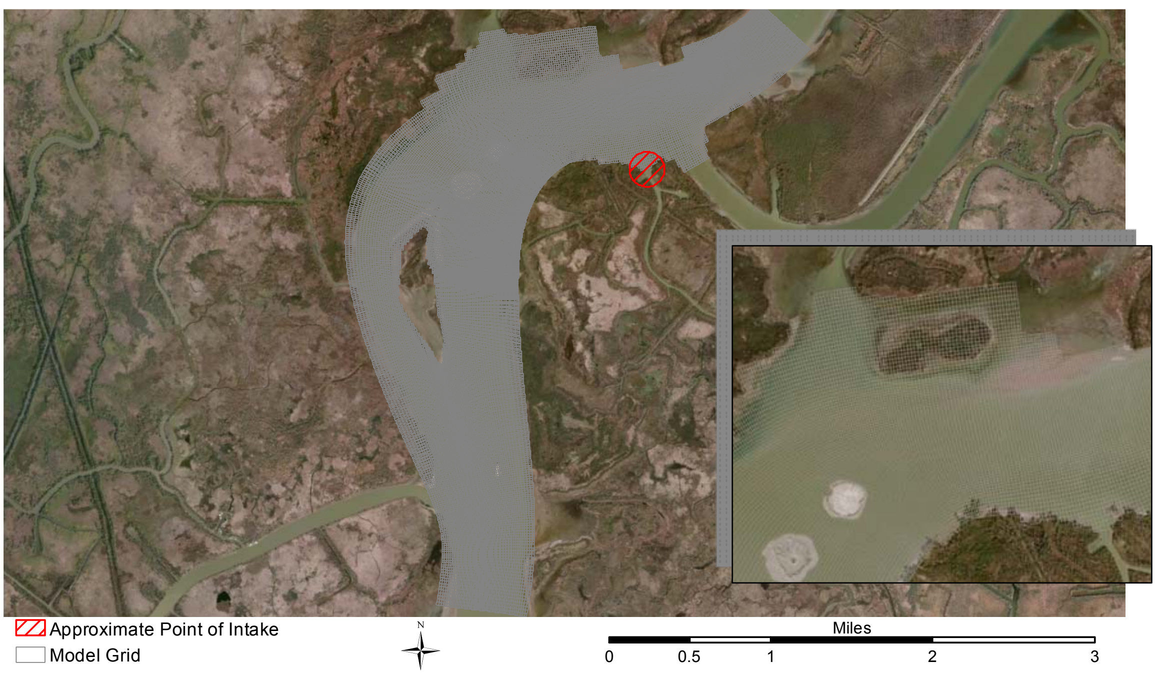


Figure 3-3: Model Extents and Numerical Model Grid of Horseshoe Bend and Crew Boat Cut with the inset displaying the high spatial resolution at the northern end of the model.

3.3.2 Model Bathymetry

The following sources were utilized in order to create the model bathymetry that represents the existing conditions:

1. The Horseshoe Bend/Crew Boat Cut Hydrographic Survey from March 2013 (source USACE MVN, see also Appendix C) was used within the extent of the available data, mainly within the main channel.
2. Other areas outside of the USACE survey domain have been complemented with data from the Louisiana DEM including the definition of the water line from recent satellite photography

The model also includes the recent bank protection project on the east side of the Crew Boat Cut reach. The model bathymetry is presented in Figure 3-4.

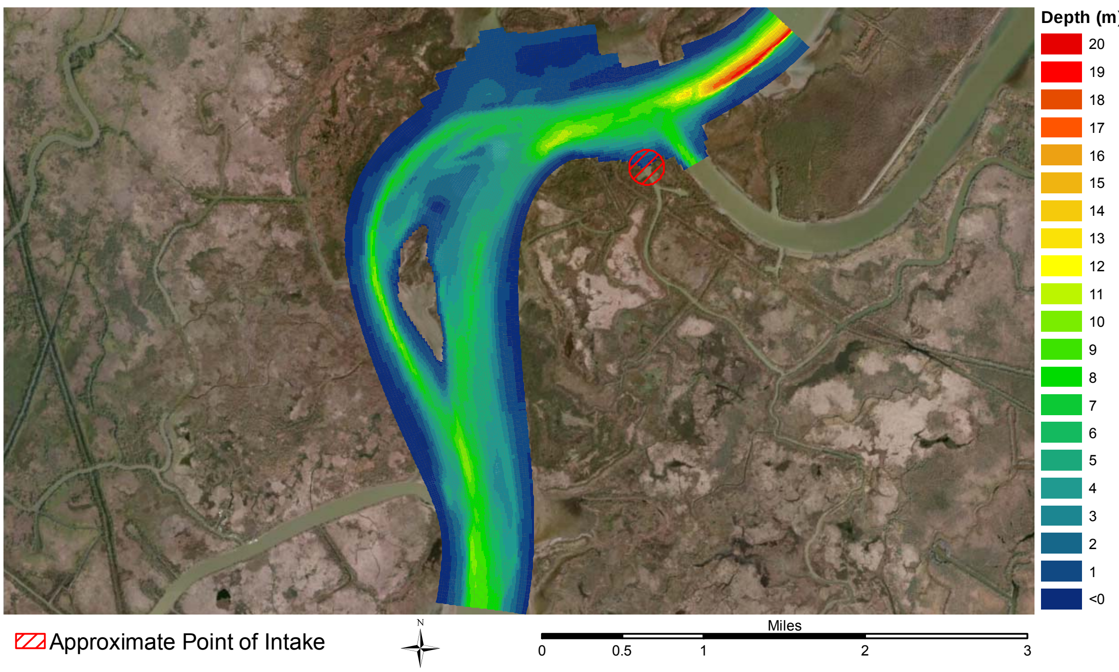


Figure 3-4: Numerical Model Bathymetry (Existing Conditions)

3.3.3 Hydrodynamic Boundary conditions

The model was forced with the river discharge at the upstream boundary, and water-levels at the downstream boundary. In the absence of measured hydrodynamic data to inform the local model, the hydrodynamic boundary conditions were extracted from a modified version of an existing MIKE21 model of the Atchafalaya River. This large scale model is forced by discharge data at Morgan City and neglects the tidal variability downstream. A rating function was developed based on this model to relate the discharge at the upstream boundary of the local model to the discharge at Morgan City (see Figure 3-5). A similar relationship between the Morgan City discharge was developed for the water-levels at the downstream boundary (Figure 3-6). A polynomial fitting function was used in each case, and a strong correlation with the discharge at Morgan City was observed.

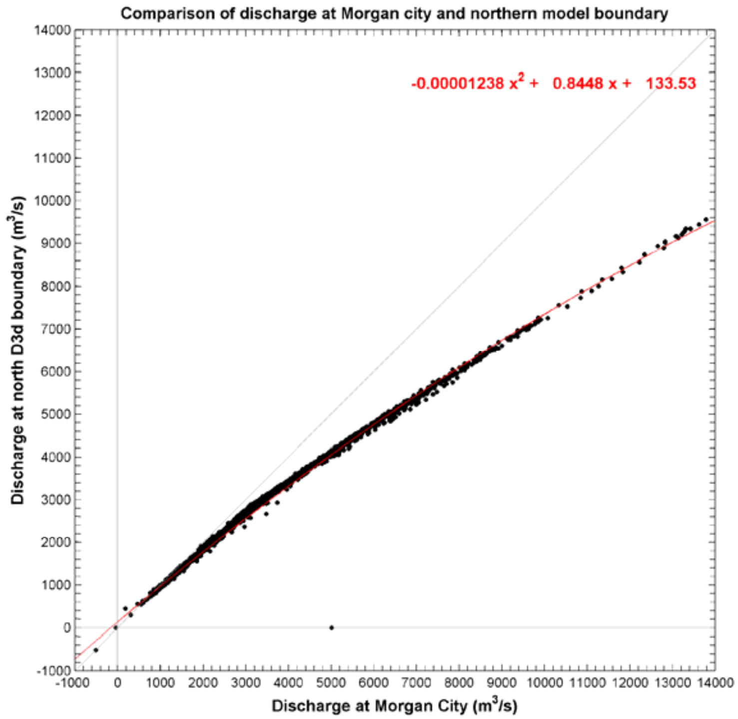


Figure 3-5: Discharge rating function for upstream boundary

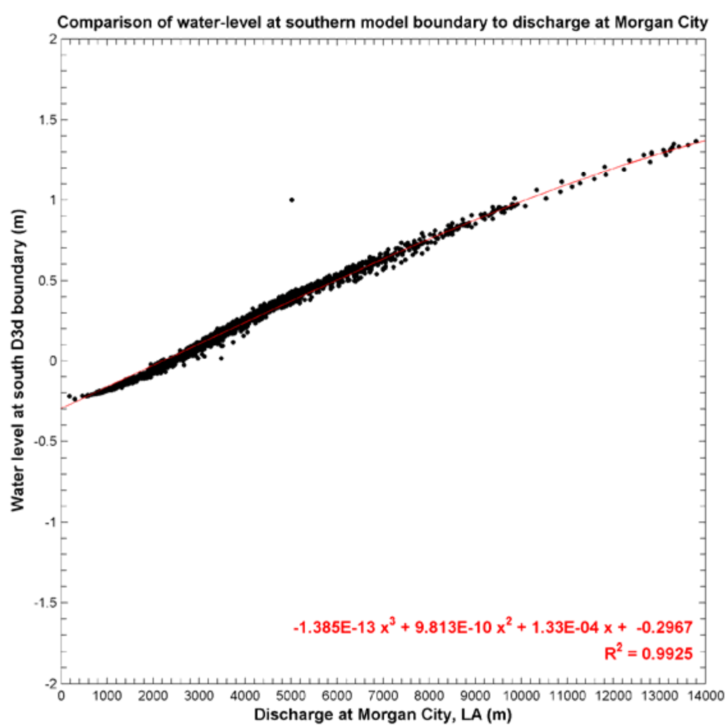


Figure 3-6: Water-level rating function for downstream boundary

3.3.4 Sediment Transport Parameters

3.3.4.1 Unlimited Sediment Supply

The model framework uses the basic assumption of unlimited supply of sediment, while in reality the supply of sediment could be limited. Allison et al. (2012) explains observations from a number of Mississippi stations with continuous data (Belle Chasse, Baton Rouge and RK39) that the sediment loads peak during the raising limb of the hydrograph, and they fall sharply after the peak discharge. This is typically a consequence of a limited amount of sediment available for resuspension within the reach (reaching the maximum sediment load during the raising limb of the hydrograph), and also due to a process referred to as armoring of the bed. As shear stresses increase with the hydrograph raising limb, all the fractions that are erodible could be removed from the bed; what remains are the largest fractions that cannot be eroded. This could generate a layer of coarse material that will armor the bed and protect the underlying layers, reducing further erosion of the bed until the critical shear stresses for erosion for this coarser material are exceeded. As previously mentioned, this process is not included in the present modeling effort, and unlimited supply of sediment during the hydrograph is considered.

3.3.4.2 Cohesive sediment transport

The river bed could contain a considerable amount of fine particles (silts and clays) that still are not eroded under a high shear stress regime, because these particles are hidden among the largest particles that are resistant to those shear stresses. This hiding process reduces the erosion flux of small particles when the bed contains larger particles. This reduction of the erosion flux of finer particles is not implemented in the numerical model, and therefore under medium to high shear stresses, the erosion flux of fine particles is significantly overpredicted by the model, because the fine sediments are always available to be eroded. The 20% cohesive bed fraction as applied in the model will provide a continued artificial source of this material. On the other hand, it is expected that most of the cohesive material passing by the project site, will do so as wash-load in suspension, which will not be able to deposit in the main channel and areas with moderate to high shear stresses. Because of these limitations, the content of cohesive sediment was reduced to a small number (about 1.2%) with the goal of limiting the source of cohesive material from the bed within the model domain. The concentration of suspended silts/clays defined at the boundaries is still based on the data analysis presented above.

The critical shear stress for erosion of the cohesive sediment was set at 0.4 Pa based on experience with similar sites. For deposition to occur the threshold was set to 1 Pa. A settling speed of 0.25 mm/s was applied, which is within the typical range for cohesive sediments.

3.3.5 Non-cohesive sediment transport

The model uses equilibrium boundary conditions, calculating the suspended and bed load transport for each of the non-cohesive class defined at the bed, based on the model computed shear stresses at the open boundary.

3.4 Model calibration and validation - Existing conditions.

The availability of various comprehensive data sets facilitated the calibration of the sediment transport model. The capability of the model to predict sediment transport in the project area, has been checked against several data sets. The following sections describe the data sets and results of each calibration/validation exercise.

3.4.1 Hydrodynamic model calibration: Water level gradient

Water level observations at Morgan City and Avoca Island from the USGS stations provide approximate information on the longitudinal water level gradient in the project area under different discharge conditions. The hydrodynamic model was calibrated (mainly through alteration of the bottom roughness parameter) to reproduce the expected water level gradients within the model domain for every discharge condition. No additional data, especially current data, was available to calibrate the model to observed currents and flow fields. It is assumed that depth average velocity fields are accurate, as a consequence of the water level gradient calibration.

Table 3-3: Comparison of modeled water-level gradient with ranges computed from 2010 USGS stage data at various discharges

Morgan City Discharge (m^3/s)	Model WL gradient (m/km)	Data WL gradient – Minimum (m/km)	Data WL gradient – Maximum (m/km)
2000	0.014	0.008	0.028
3000	0.025	0.024	0.031
4000	0.036	0.027	0.040
5000	0.048	0.036	0.048
6000	0.059	0.045	0.054

Table 3-3 presents the water level gradient between Morgan City and Avoca Island based on the daily data from the USGS and the water level gradient in the model domain computed from the model. Results indicate that for low flows gradients are very small, and the model simulated gradient is mostly within the range seen in the data. For discharges higher than 6000 m^3/s, the model slightly over predicts the water level gradient (less than 10%). However, considering the inherent assumption of a spatially constant gradient in this analysis and with the variability in gradient observed in the data, the model data comparison is considered satisfactory.

3.4.2 Model Validation to Observed Sediment Loads.

As presented in Section 3.2 sediment load information is available at Morgan City. Total sediment load and distribution of the load between sand and silt/clay has been presented in different analysis, for example Allison et al (2012). The sediment transport model with the set up and parameterization described in the previous sections was used to simulate the sediment loads for the 2008, 2009 and 2010 water years that were reported in Allison et al (2012). Sediment load from the model simulations was computed along a cross section of the Atchafalaya River just upstream of the Horseshoe Bend. Figure 3-7 presents the sediment load as computed from the numerical model for the years 2008, 2009 and 2010, and the cumulative sediment load for each of the year.

The comparison of the model predictions with Allison et al (2012) is presented in Table 3-4. The model as expected, predicts values slightly lower than those observed in Morgan City, since it is expected that the sediment load at the project site will be somewhat smaller than upstream at Morgan City. The model in general is able to predict the expected sediment load for each year and also the variability from year to year. The model somewhat over-predicts the sand load/total load ratio compared to the data at Morgan City.

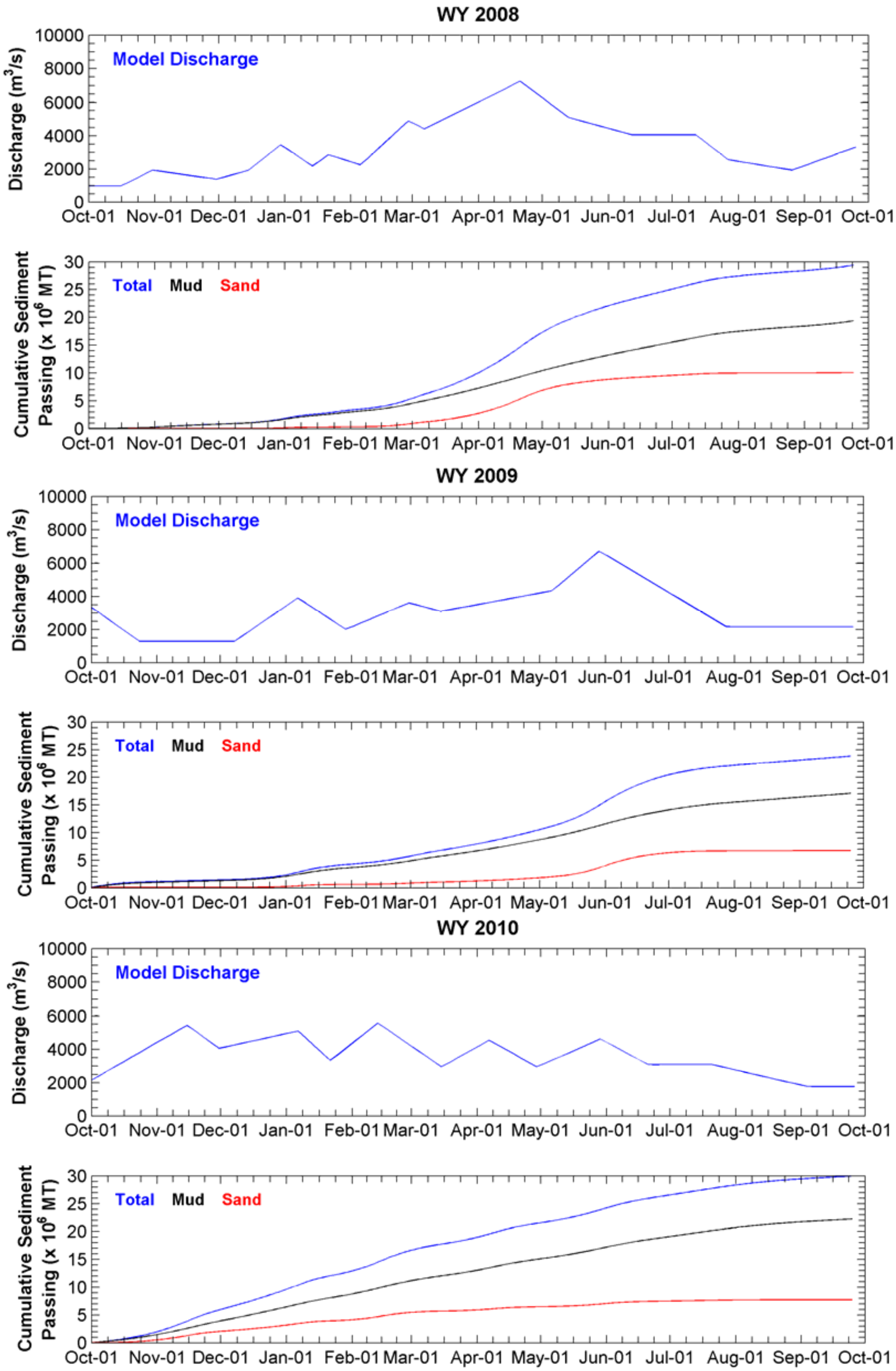


Figure 3-7: Computed Cumulative sediment load (Mud, Sand and Total) for Water Year 2008, 2009 and 2010.

Table 3-4: Sediment Load comparison, Allison et al (2012) versus Sediment Transport Model

Water Year	Allison et al. (2012) Total load at Morgan City (10^6 Tons)	Allison et al. (2012) Sand load at Morgan City (10^6 Tons)	ST model Total Load into Horseshoe Bend (10^6 Tons)	ST model Sand Load into Horseshoe Bend (10^6 Tons)
FY 2008	30.9	7.3	29.40	10.07
FY 2009	22.7	3.8	23.82	6.74
FY 2010	30.1	5.0	29.97	7.73

In addition, the model simulated loads were also validated with USGS data for total sediment loads available at Morgan City from synoptic data collection through the period 1973-2013. The comparison of modeled total loads into the Horseshoe Bend at different steady-state discharge conditions, with the USGS data at Morgan City, is shown in Figure 3-8. The model estimated loads for the simulated discharge conditions are well within the observed range of sediment loads for similar river-discharge.

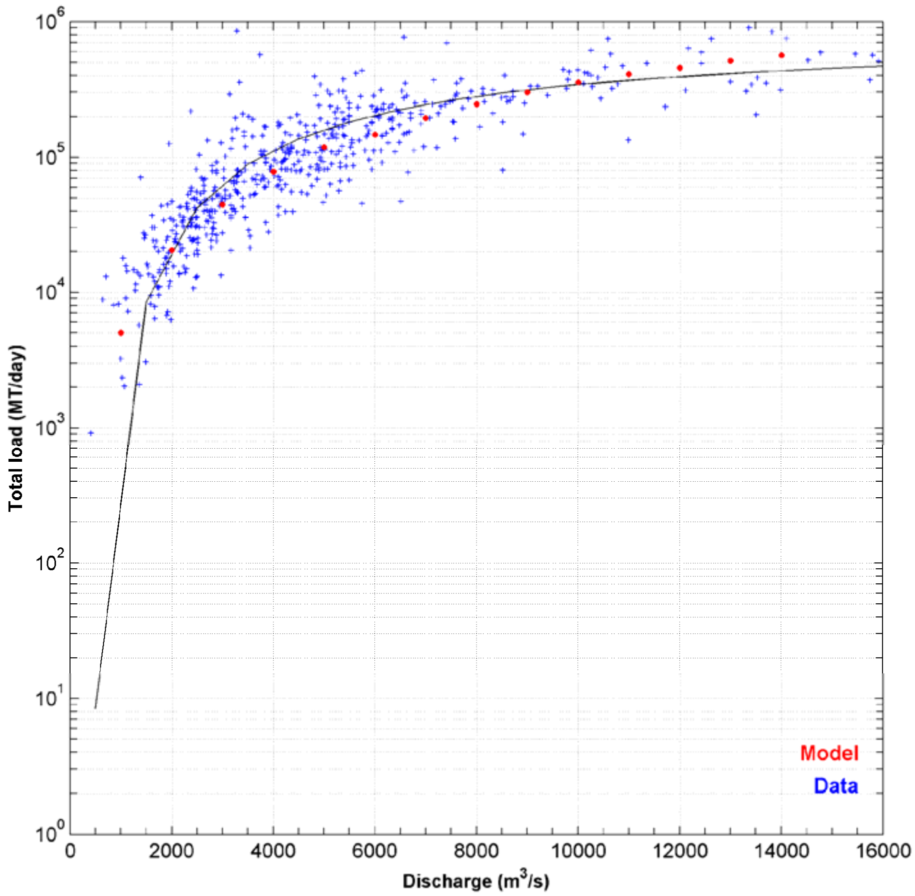


Figure 3-8: Computed Total Sediment Load for Study Area (in red) and observed Total Sediment Load at Morgan City (in blue) vs. Discharge.

These results indicate the reliability of the sediment transport model to predict the sediment loads (sand and silt/clays) expected at the project area and the variability with the discharge conditions.

3.4.3 Validation of the Sediment Transport Model to Bathymetric Changes.

In order to validate the performance of the sediment transport model in the Horseshoe Bend area, the model was run for the time frame November 2010 through August 2011. This time frame was selected because multiple single-beam surveys were conducted in this reach during this period when no maintenance dredging was performed (see Appendix C). The west channel was dredged in October 2010, and the subsequent dredging event occurred after the August 2011 survey. Bathymetric survey data is available for November 2010, and February, June and August 2011. This period includes relatively low flows until March, and a record flood during May through June.

Figure 3-9 shows the comparison of the surveyed and modeled bathymetric changes between November 2010 and August 2011. The model is able to predict the approximate volume of infill in the inner bank of the dredged Horseshoe Bend reach (west channel). However, the model under-predicts the sedimentation in the downstream section of the bend. The model also predicts the infill in the middle of the Crew Boat Cut reasonably well.

During the low flow period of November 2010 to February 2011, the model under-predicts the sedimentation in both the channels. The comparison between model and data of the bathymetric changes during this period is shown in Figure 3-10. The sedimentation and erosion patterns are not as distinctly reproduced by the model as was the case for the flood period. In this context, it must be noted that the sediment loads during low flows are more than an order of magnitude smaller than the loads during flood events. In addition one should note that there significant uncertainty in the single beam data, interpolation of transects and comparison of the two resultant surfaces with those uncertainties leads, in some cases, to uncertainty in the order of 1 to 2 foot.

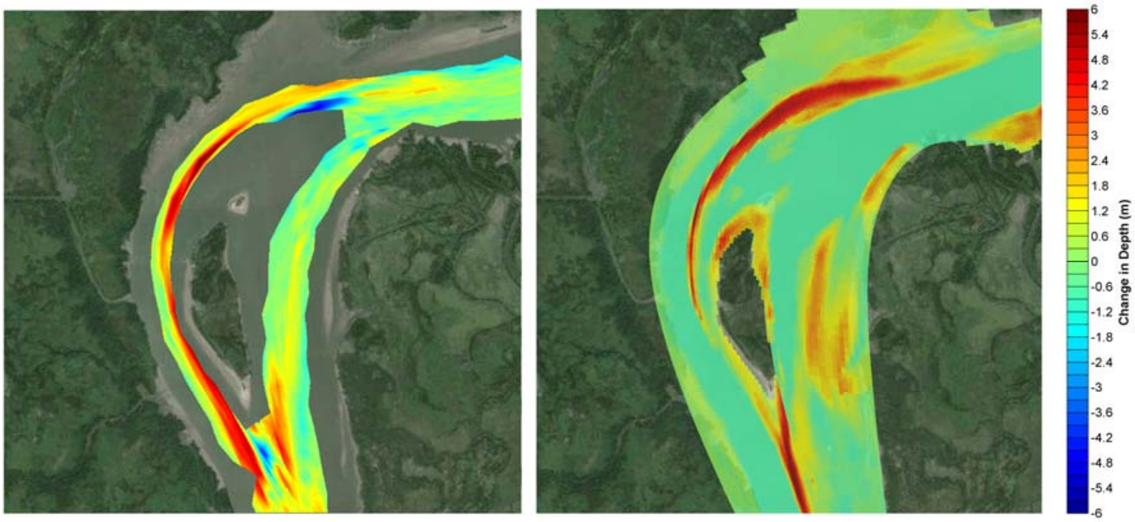


Figure 3-9: Comparison of modeled (right) change in bathymetry from Nov 2010 to Aug 2011 with measured data (left)

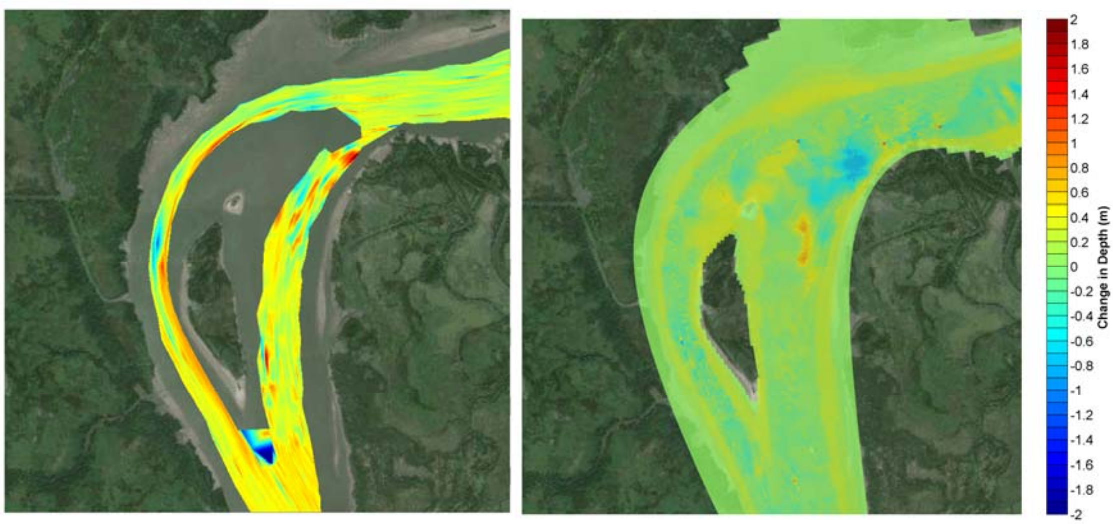


Figure 3-10: Comparison of modeled (right) change in bathymetry from Nov 2010 to Feb 2011 with measured data (left)

3.5 Simulations of the Selected Borrow Sites

After completion of the model simulations for the existing conditions, the two selected borrow site's dimensions as presented in Appendix A were schematized. A synthesized bathymetry was generated to represent the conditions after construction (complete dredging) of each site. Figure 3-11 and Figure 3-12 present the model bathymetry for borrow site ATCH-136W and ATCH-137E respectively. Details of the borrow site simulations as well as the result analysis are discussed in Chapter 4.

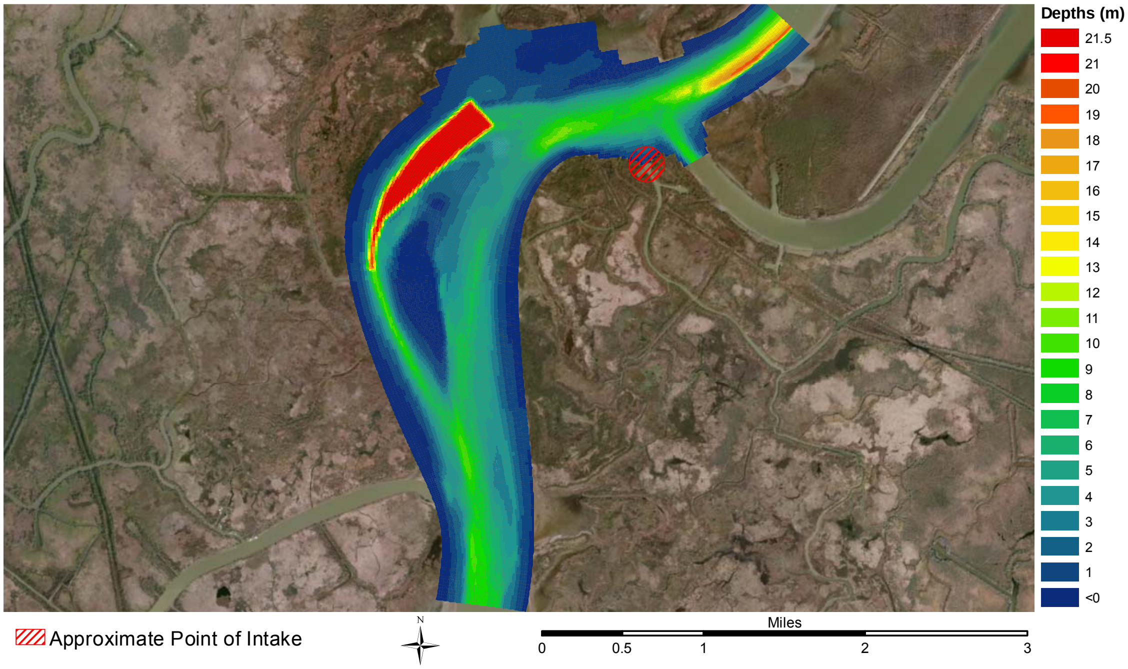


Figure 3-11: Model bathymetry representing the completed/dredged borrow site ATCH-136W

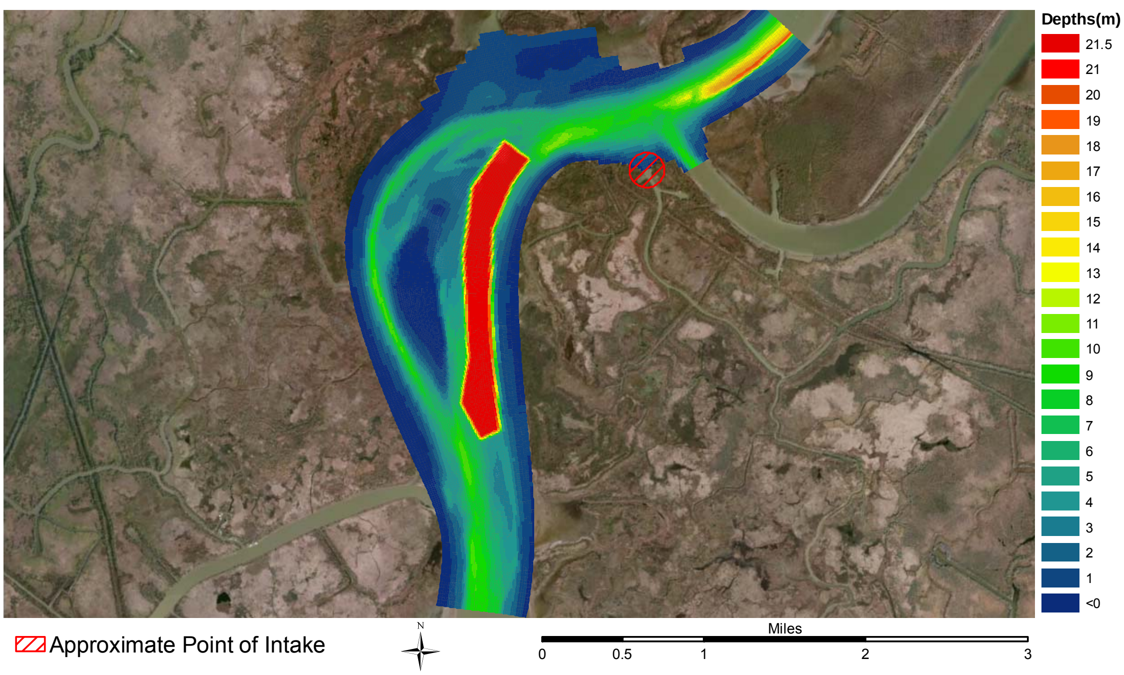


Figure 3-12: Model bathymetry representing the completed/dredged borrow site ATCH-137E

3.6 Final Remarks

One of the most important limitations of the numerical model application is the computational burden associated to the morphological simulations. Simulation times were too long to allow simulations without the application of the morphological acceleration factor, previously described in chapter 3. Sensitivity to different values of this morphological acceleration factor was conducted, indicating that the approach that was followed did not add much uncertainty to the model predictions. However sensitivity to small morphological acceleration factor could not be carried out due to the time required to complete those simulations. The approach followed in this study, combining different approaches to the morphological simulations (steady state runs for constant discharge, water year simulations and multi-year run) and the consistency in the results from these simulations reproducing the reported sediment load data provide reliable estimates of the infill volumes in the borrow sites which was the primary objective of the present study.

4 REFILL RATE ASSESSMENT

4.1 Introduction

As stated within chapter 2 of this study's framework, the objective is to refine the preliminary identified borrow sites (ATCH-136W and ATCH-137E) and investigate the availability of 50 Million cubic yards of borrow material for the project within close proximity to the point of intake. It was furthermore assumed that the material will be borrowed at a rate of approximate 5 Million cubic yards per year. Given these constraints the numerical modeling as detailed in the previous chapter now provides the opportunity to refine the borrow site refill rate estimates and discuss the feasibility of the project.

4.2 Numerical Model Application

The numerical model development and its calibration/validation were discussed in chapter 3 of this report, here the application of the numerical model to estimate the infill rates for annual to decadal time scales is discussed. Three different types of simulations have been performed to calculate the infill rates at the borrow sites:

1. Constant discharge simulations – Simulations of steady state conditions under a constant discharge. These simulations provide an estimate of the sediment load passing by the project site for different discharge conditions.

2. Water year simulations – Simulations representative of one water year were carried out for water year 2006 to water year 2011. Because of the computational burden associated to these simulations, a morphological acceleration factor has been used to represent one year of morphological changes in a much shorter simulation. These one year simulations start with the post dredged bathymetric conditions at the borrow site as presented in Section 3.6, therefore the inherent assumption of the infill rates obtained from these simulations is that the infill rates at the borrow site are not significantly affected by the infill that happened in the preceding years. The results following from these simulations could be considered as a progressive estimate for long term average infill rates of undisturbed borrow sites, meaning that the infill rate in reality could be somewhat slower.

3. Multi-year simulations – A continuous simulation of the borrow–pits with the hydrograph for water year 2006 through 2011. These simulations also use a morphological acceleration factor as described above. The infill rates obtained from these continuous simulations are compared to infill rates computed from the individual water year simulations to evaluate the impact of the partial infill of a pit during a single year on the rate of infill for subsequent years.

The following sections will present the results from the different simulations, discuss the analysis of model results, estimate the annual infill volumes of the two selected borrow sites.

4.3 Discussion of Model Results

4.3.1 Constant discharge simulations

A series of constant river discharges were simulated using steady-state model simulations. These simulations were used to estimate the sand load and mud load associated with each discharge. Figure 4-1 shows the relation between the river discharge at Morgan City and the sand and mud load entering the Horseshoe Bend as simulated by the model. The sand load has a nearly log-linear relationship with river discharge (in cfs), while the mud-load increases much more gradually with discharge until about 8000 m3/s (or 300,000 cfs), beyond which it remains more or less constant. The sand loads predicted by the model can be compared to the sand loads at Morgan City reported by Allison et al (2012). While the Horseshoe Bend is about 13 miles downstream of Morgan City, with the GIWW branching off the river in the intermediate reach, the sediment load data at Morgan City provide a useful reference to ground-truth the loads predicted by the model. Compared to the data at Morgan City, the model predicts much higher sand-loads during low flows up to about 4000 m3/s, and similar sand-loads at the highest observed river flows. Because of the three orders of magnitude variability in the sand load as a function of the river discharge, the contribution of the low-flow periods to the total annual sand load is very small. As a consequence, any potential over-prediction of the loads during low flows has very little impact on the ability of the model to estimate total annual sand loads.

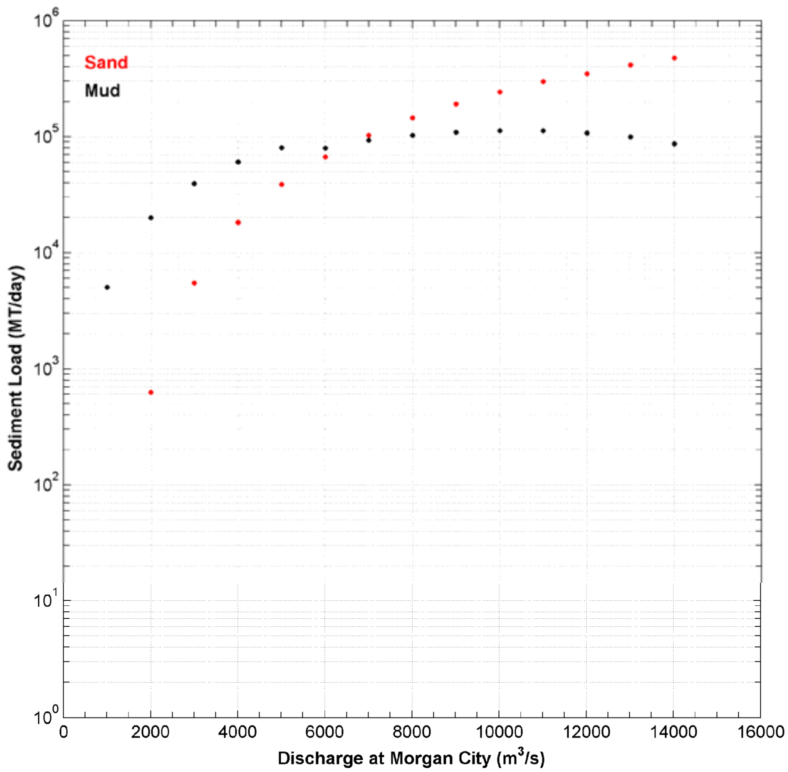


Figure 4-1: Relationship between river discharge at Morgan City and simulated sediment loads entering Horseshoe Bend

4.3.2 Water-year and multi-year simulations

Dredging of the ATCH-136W and ATCH-137E borrow sites have a significant impact on the velocity fields and consequently the shear stresses and sediment transport capacity. The increase in depth and the increase in cross sectional area associated with the borrow site produces a decrease in velocity that leads to a reduced sediment transport capacity over the borrow site. This enhances sedimentation at the upstream end of the borrow site.

To illustrate how the borrow sites affect the velocity patterns, Figure 4-2 presents the current fields for a 7,000 m^3/s discharge at Morgan City, for existing conditions, with ATCH-136W, with ATCH-137E and with both borrow sites.

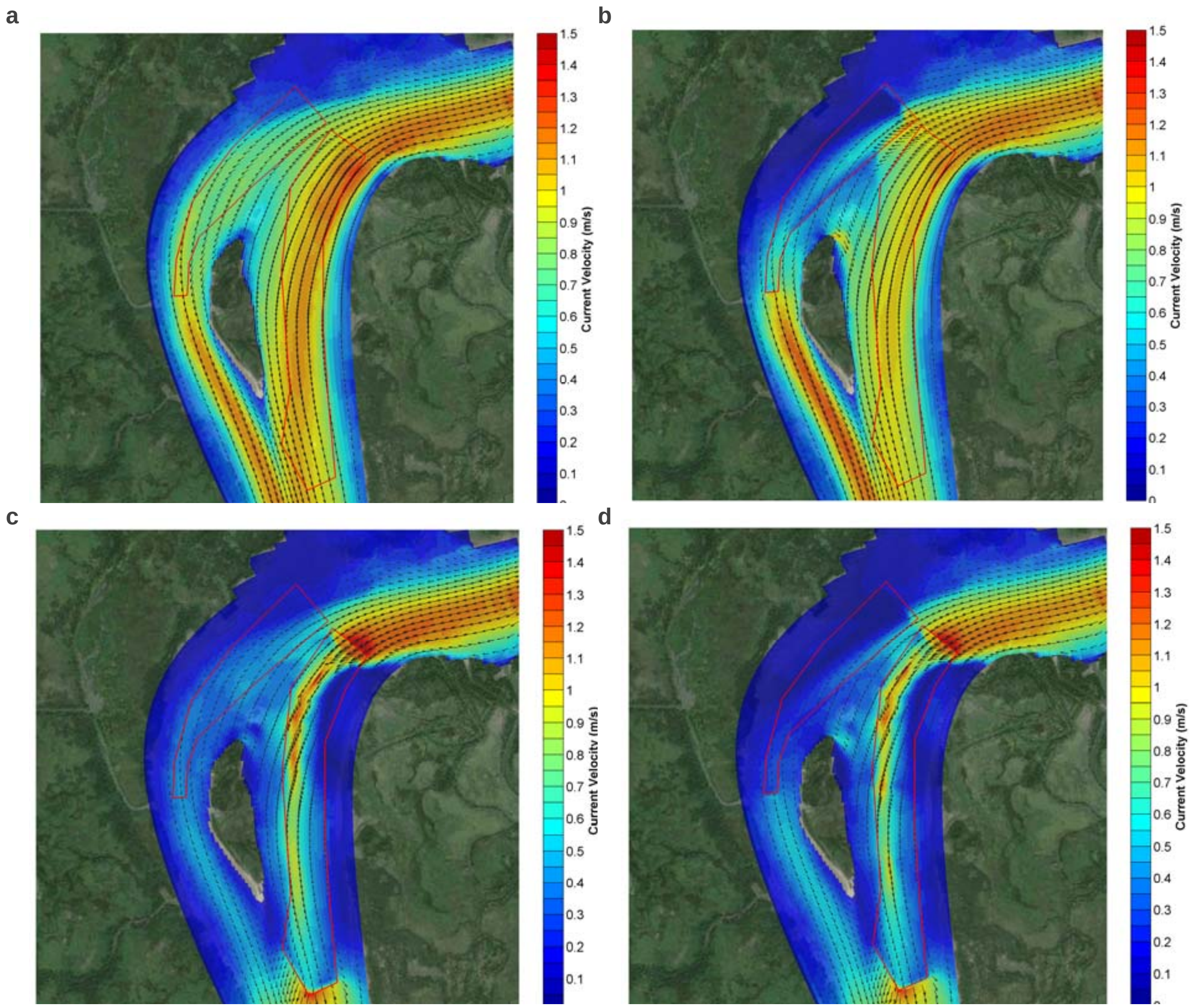


Figure 4-2: Flow Patterns at a Morgan City discharge of 7,000 cms at Morgan City for a) existing conditions, b) with ATCH-136W, c) with ATCH-137E and d) with both borrow sites.

Model results show that velocities decrease significantly inside the borrow site. For the ATCH-136W simulation (top-right panel of Figure 4-2) the velocity is reduced at the upstream edge and throughout the whole length of the borrow site. As velocities increase again downstream of the borrow site, the velocity gradient could potentially lead to erosion at the downstream edge. For the ATCH-137E simulation (bottom-left pane of Figure 4-2) velocity is also significantly reduced at the upstream edge of the borrow site and throughout the whole length of the borrow site. Because the velocity fields were obtained from the simulation of Water Year 2011 during the first peak of the hydrograph (around 7,000 m3/s at Morgan City) the velocity patterns are also affected by the infill of the borrow site that took place between October 2010, and May 2011. This infill is presented in the lower-left panel of Figure 4-3. This infill near the upstream edge of the borrow site implies that the high velocities in that area are maintained. In addition, the infill patterns and the orientation of the borrow site with respect to the flow patterns led to the deflection of the flow patterns towards the east and the creation of a counter-current along the eastern bank. For the combination of ATCH-136W and ATCH-137E simulation (bottom-right pane of Figure 4-2) the observations for the ATCH-137E alone are still valid, while for the ATCH-136W the velocities at the borrow site are reduced even further than when this borrow site is considered alone.

In order to illustrate the infilling of the borrow site as predicted by the model a sequence of model predicted bathymetries during the Water Year 2011 simulation are presented. Note that the spring flood of 2011 was a record flood. From October 2010 to February 2011, very low discharge conditions were observed at Morgan City. Between February 2011 and May 2011 discharges increase and peaked at 7,000 m^3/s. Between May 2011 and August 2011 is when the rising limb, peak and falling limb are observed with a flood-peak discharge of 14,000 m^3/s.

Figure 4-3 presents the morphological infilling sequence at the ATCH-136W borrow site for Water Year 2011 as simulated by the sediment transport model. For this location and geometry infilling of the borrow site occurs from the upstream-east corner in downstream direction, and the largest deposition occurs at the western side of the borrow site. This is also where the largest sediment transport is observed under existing conditions.

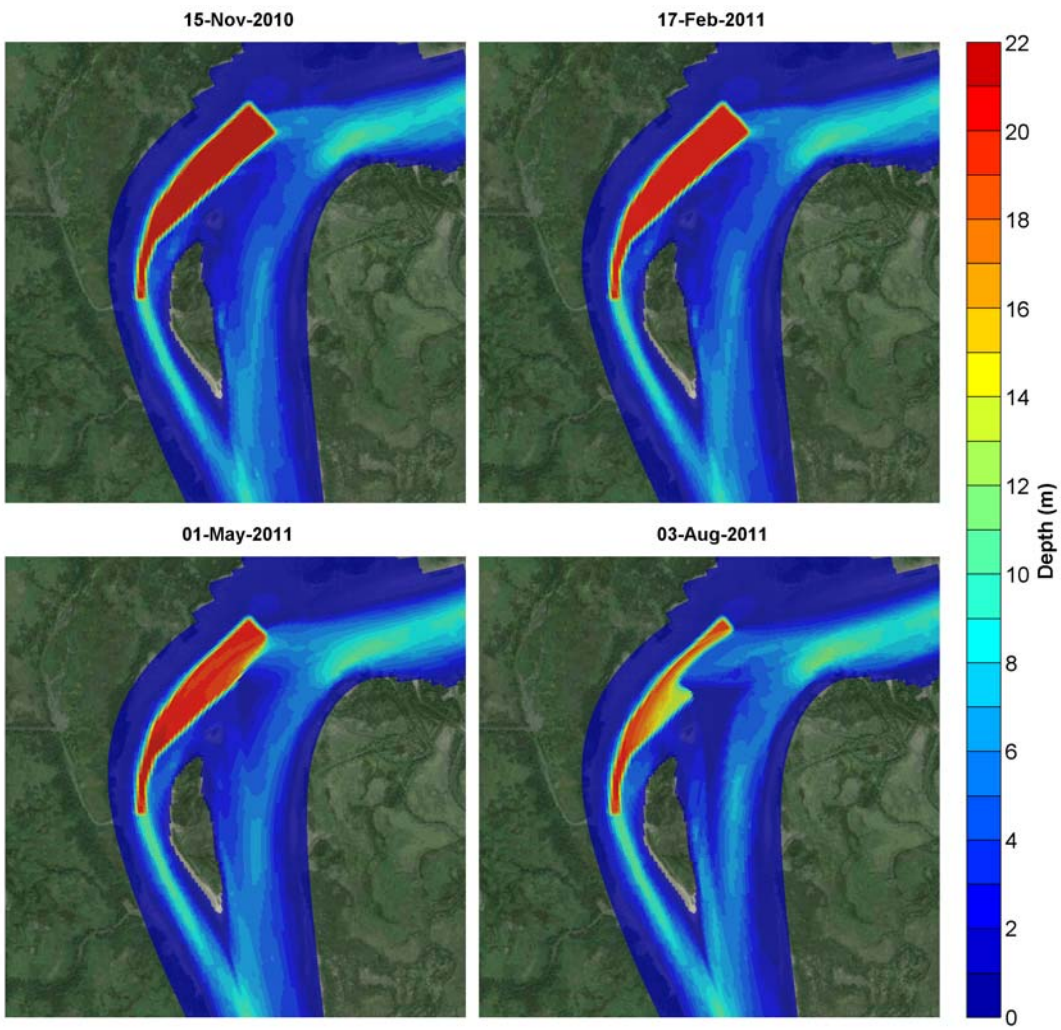


Figure 4-3: Morphological evolution of ATCH-136W during Water Year 2011 as simulated by the numerical model.

Figure 4-4 presents the morphological infilling sequence at the ATCH-137E borrow site for Water Year 2011 as simulated by the numerical model. Infilling of the borrow site occurs from upstream to downstream, and the infill pattern is influenced by the simulated flow patterns. As observed from the final infill patterns, the upstream-east “corner” of the borrow site remains deeper (less infill volume) than the upstream-west corner. This is caused by the change of the flow pattern instigated by the borrow pit geometry. Flows are steered towards the west as a consequence of the counter current moving north near the eastern bank (see bottom-left panel of Figure 4-2).

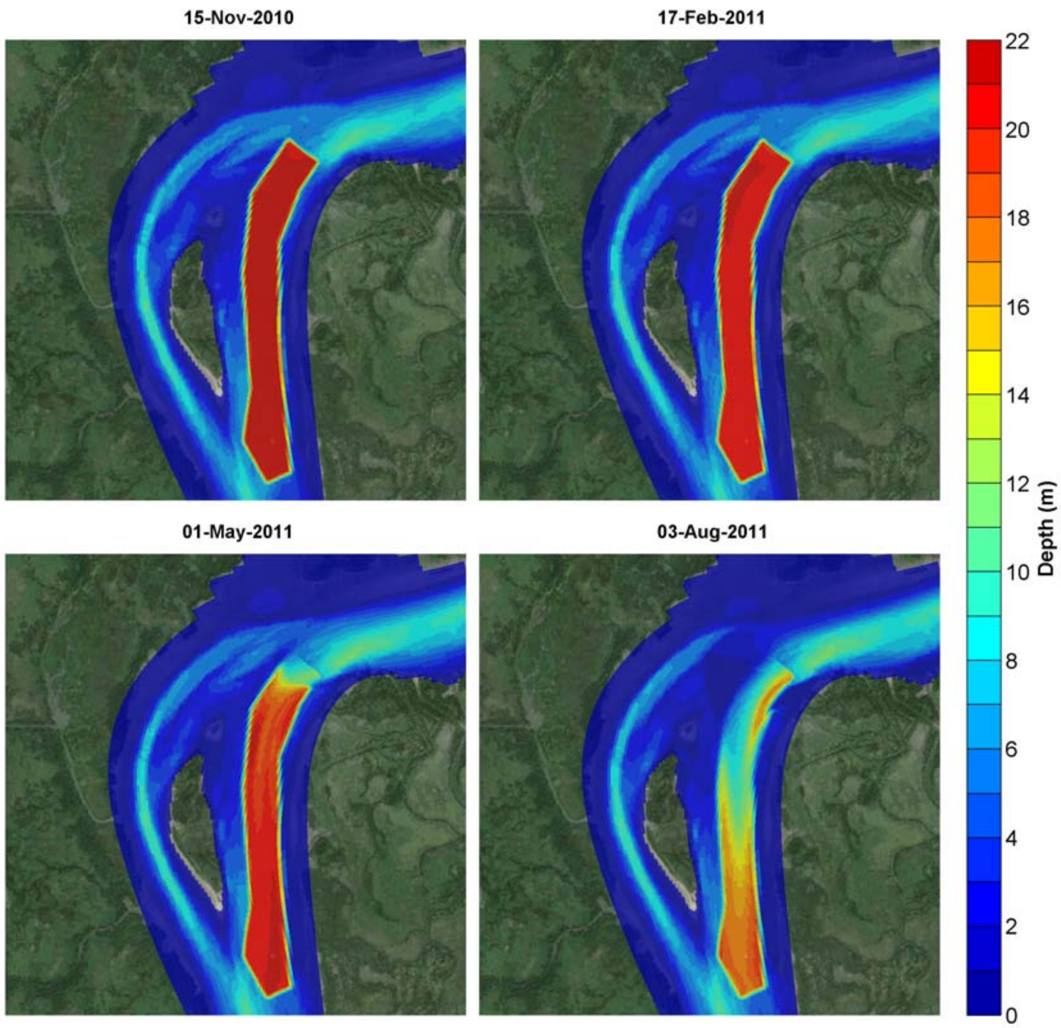


Figure 4-4: Morphological evolution of ATCH-137E during FY2011 as simulated by the numerical model.

The analysis of model results at both borrow sites indicate that more sediment trapping occurs in the areas that are directly in the middle of the main sediment transport pathways. These locations are associated with the higher depth averaged current velocities across the river.

4.4 Infill Volume Assessment

4.4.1 Analysis of Model Results

To analyze how long it would take for the borrow pit to fill up to a certain level a statistical analysis of historical discharge data was completed in lieu of processing and analysis of the model results. It should be noted that the refill rate of any borrow site is dependent on the sediment load carried by the river, which on its turn is dependent on the discharge of the river. The water year (from October through October) can generally be characterized by a high flow (spring flood) and low flow period (autumn) as depicted in Figure 4-5. Throughout the months of the hydrologic year there is still a great amount of variability and hence the total annual flows vary substantially from year to year.

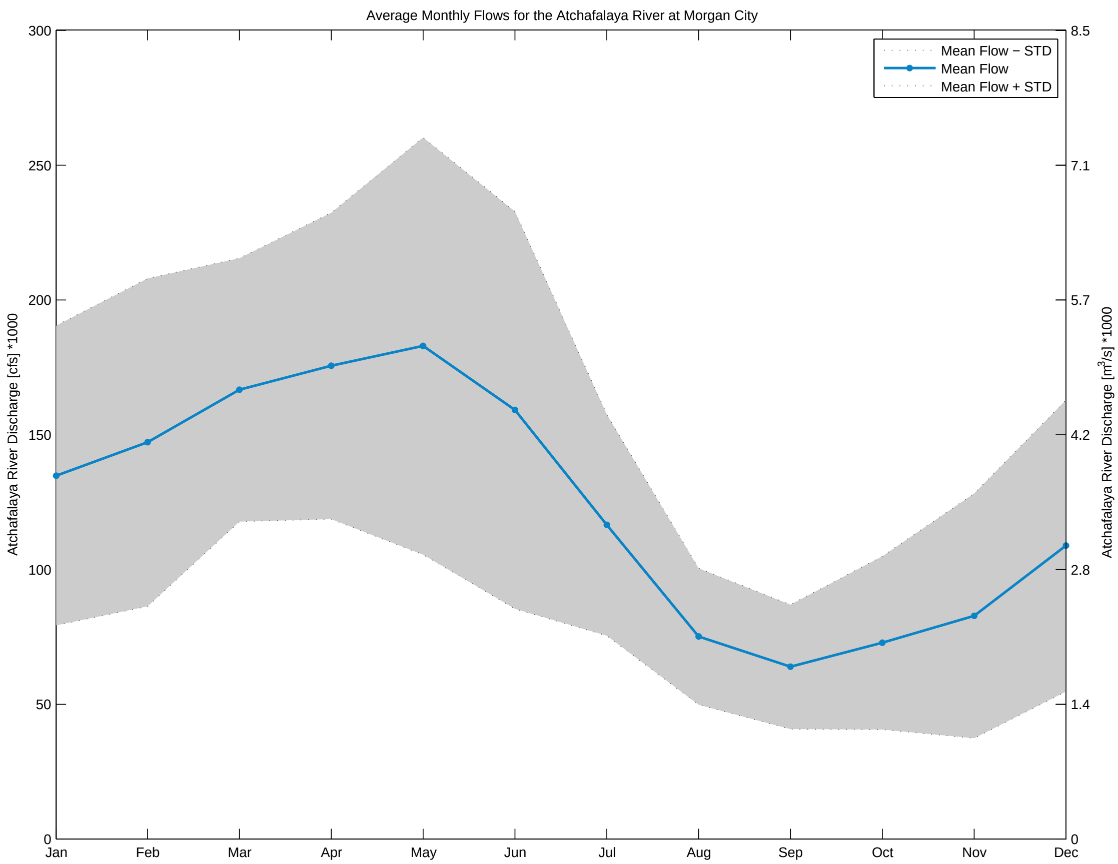


Figure 4-5: Average monthly flows and standard deviation for the Atchafalaya River at Morgan City (USGS Gage ID: 07381600) for the water years 1995-2013.

The variability in river discharge and associate sediment loads complicates the approximation and prediction of infill rates as the infilling of the borrow pit at the proposed dimensions is a process that will take several years. In order to estimate the infill rates for both ATCH-136E and ATCH-137W an analysis consisting out of four (4) steps was completed:

Step 1) First the long term discharge record at Morgan City was analyzed and statistical characteristics were calculated;

Step 2) The established relationships between the discharge at Morgan City and the sediment transport in the project vicinity were used to estimate long-term averages for suspended mud load and sand load;

Step 3) Model results from the water year simulations were used to relate the infill volume to the characteristics of the water years that were simulated;

Step 4) Finally, using the derived relationship, infill volumes were extrapolated to a longer term record, allowing one to determine an estimate for the average infill volume as well as lower and upper confidence bounds to bracket the average infill volume for each borrow site.

The steps are explained in more detail below.

Step 1: The USGS has been recording discharge for the Atchafalaya River at Morgan City since 1995. Unfortunately the data record for the years up to 2001 contain a significant number of gaps. In order to fill in the data gaps and to get a better understanding of the inter-annual discharge variability at Morgan City, a part of the discharge record was synthesized using other observational data. There is a good correlation between the Tarbert landing discharge observations and the Morgan City Discharge observations. Using the established correlation and all existing data a discharge record for 1975 through 2013 was generated (see Appendix D). For all water years within this data record the total volume of river discharge per year was calculated (see Figure 4-6).

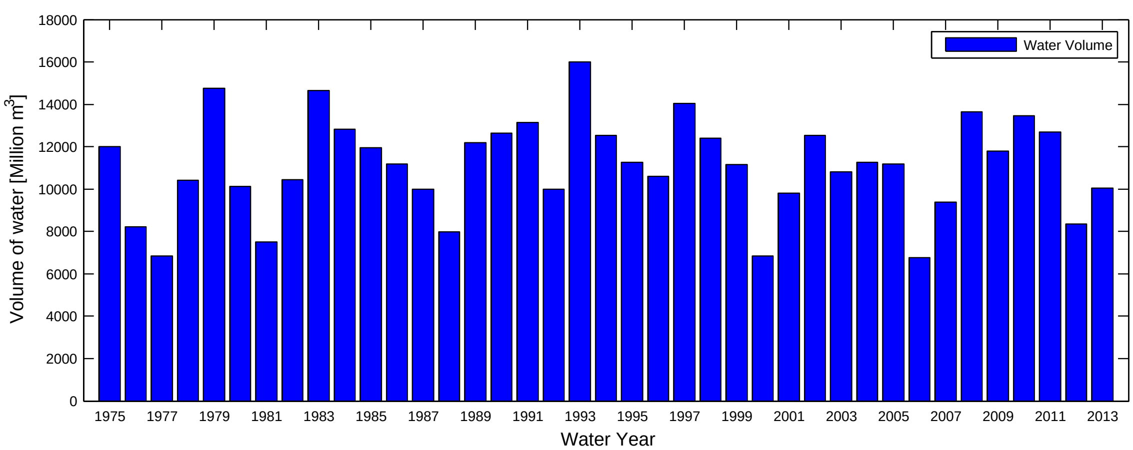


Figure 4-6: Total Volume of discharge for all water years 1975 through 2013

Step 2: With the established relationship between the discharge at Morgan City and the sediment transport in the project vicinity, as detailed in section 4.3, an estimate for the annual suspended mud load, sand load and total load was calculated. These loads are subsequently summed over the course of one water year to estimate the total volume of sediment passing through the Atchafalaya River at the project site (see Figure 4-7). It can be noted that the record flood year of 2011 also carried a record amount of sand.

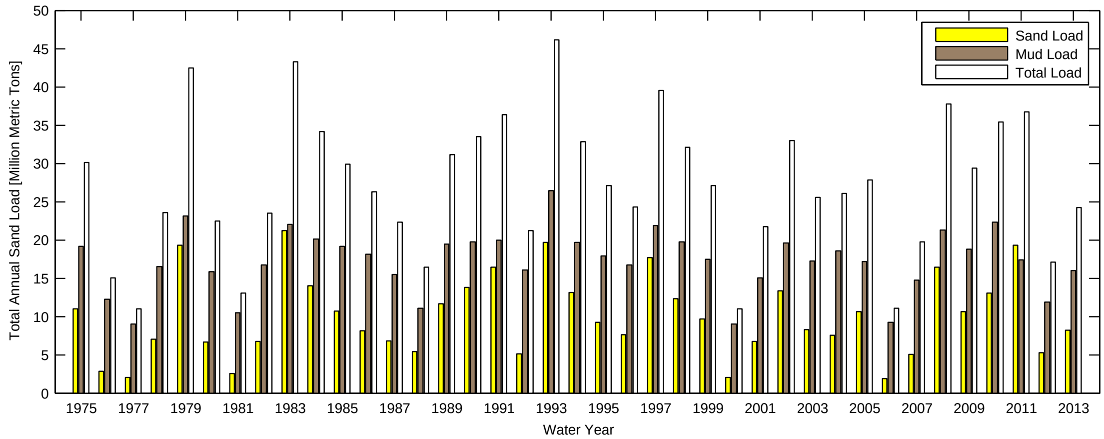


Figure 4-7: Total annual suspended Sand load, Mud load and Total suspended sediment load for water years 1975 through 2013.

Step 3: From the water year simulations that were completed for the years 2006, 2007, 2008, 2009, 2010 and 2011 the total volume of infill was calculated for each borrow site. The total volume of infill for each water year was subsequently plotted against various characteristics of the water year. A strong correlation was observed between the total annual sand load and the volume of infill, see Figure 4-8.

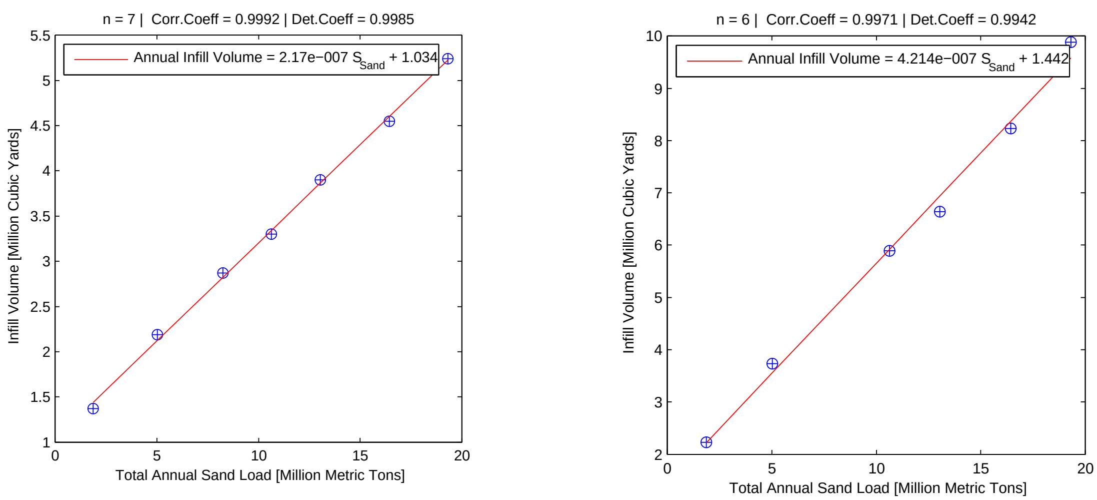


Figure 4-8: Correlation between the total annual sand load and the infill volume within one water year. Correlation is shown for a) Borrow site ATCH-136W and b) Borrow site ATCH137-W. Both display strong correlation with a correlation coefficient of 0.99 and 0.94 for a) and b) respectively.

Step 4: The strong correlation between the infill volume and the total annual sand load allows one to estimate the infill volume for other water years without completion of additional computationally intensive model simulations. Figure 4-9 shows the annual infill volume for all water years between 1975 and 2013. Infill volumes for site ATCH-136W vary from 1.4 million CY to 5.6 million CY, while infill volumes for site ATCH-137E vary from 2.2 million CY to 10.4 million CY. Please note that each infill estimate for each year holds the assumption that at the start of the water year post-dredge borrow pit dimensions are present. The average infill volume equals 3.2 and 5.6 million CY, which is approximately 33% and 29% of the initial volume, for borrow sites ATCH-136W and ATCH-137E respectively.

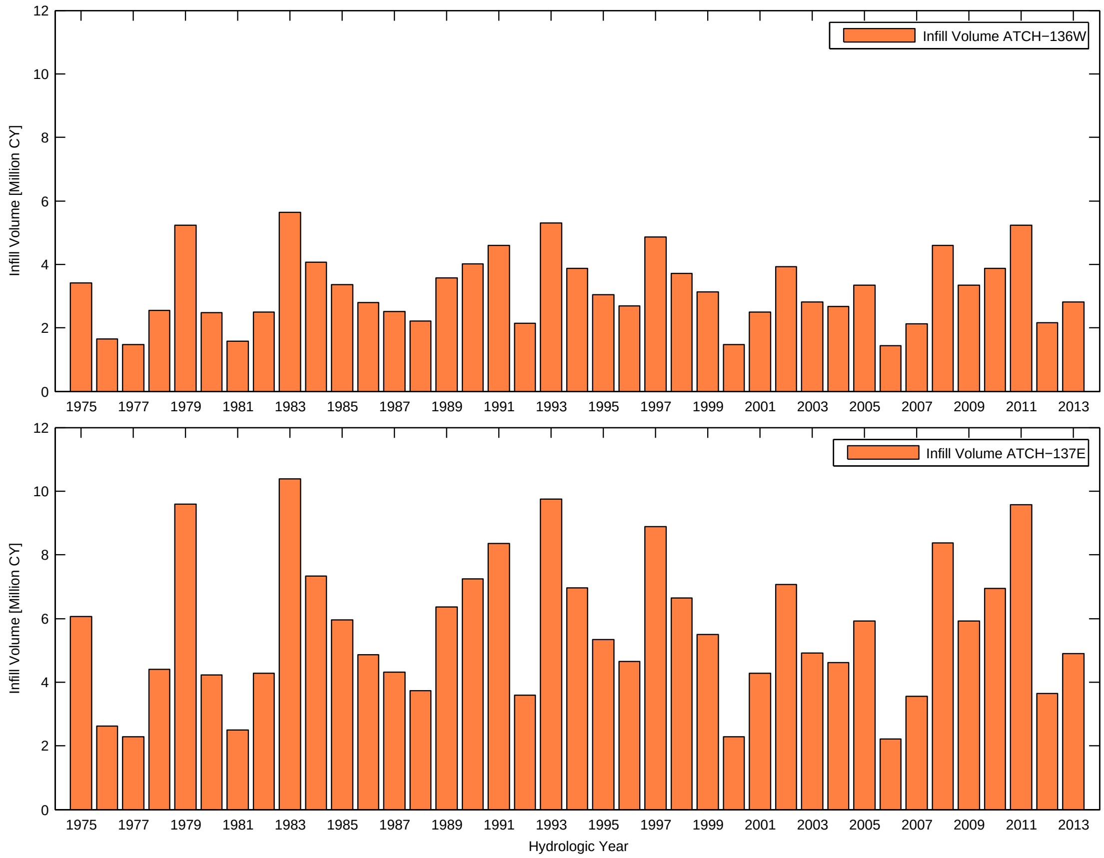


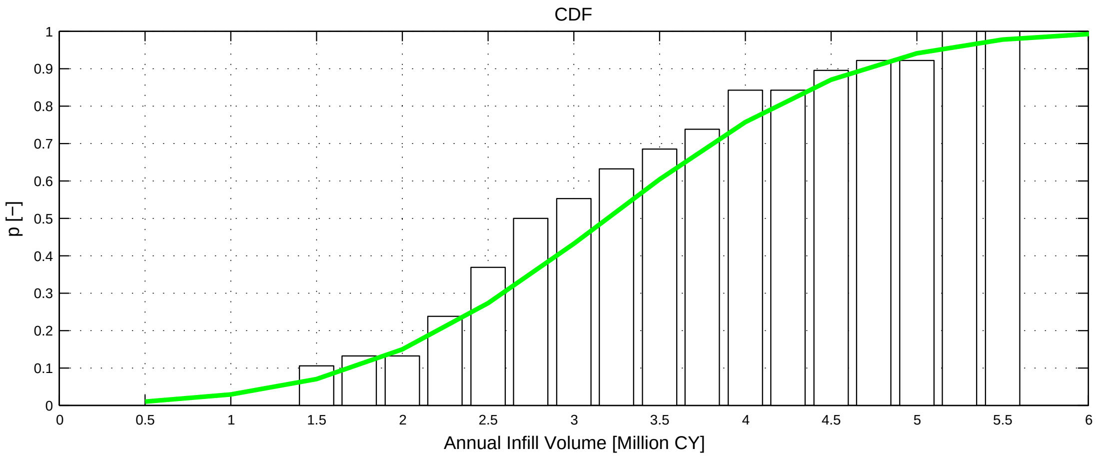
Figure 4-9: Total annual infill volume for water years 1975 through 2013 for Site ATCH-136W (top panel) and ATCH-137E (bottom panel)

4.4.2 Estimates for Annual Infill Volume for ATCH-136E and ATCH-137W

For the 28 years of estimated infill volumes a cumulative probability density function can be calculated using the mean infill volume and standard deviation. The mean infill volume and standard deviation are provided in Table 4-1. Figure 4-10 displays the cumulative distribution function and illustrates the range of possible annual infill volumes for each borrow site.

Table 4-1: Mean annual infill volumes and standard deviation (STD) for borrow sites ATCH-136W and ATCH-137E

Borrow Site	Initial Volume [Million CY]	Estimate for the Mean Annual Infill Volume [Million CY]	STD for the Average Annual Infill Volume [Million CY]
ATCH-136W	9.8	3.2	1.2
ATCH-137E	19.5	5.6	2.2



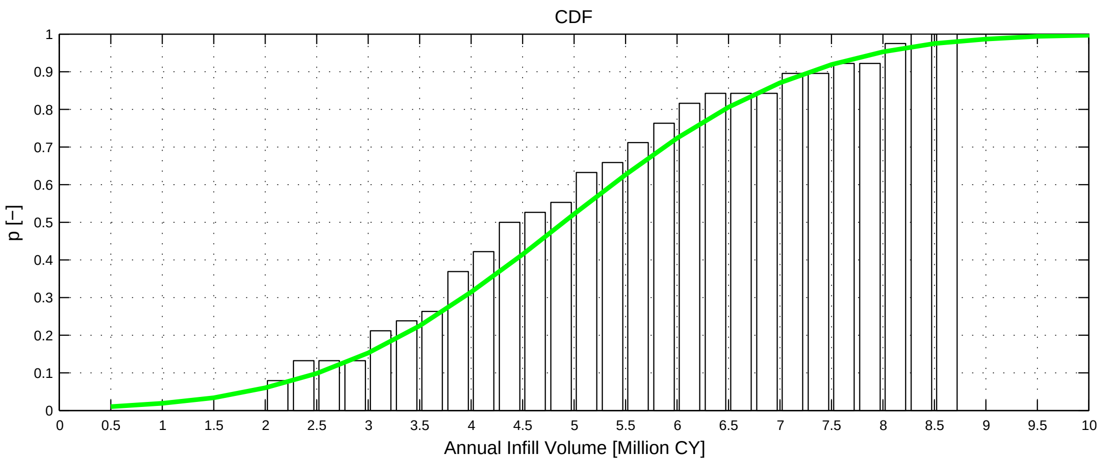


Figure 4-10: Cumulative Distribution Function (CDF) for the annual infill volume for Site ATCH-136W (top panel) and ATCH-137E (bottom panel).

4.5 Dredging Sequence and Project Feasibility

This part of the project's feasibility study has the objective to investigate the availability of 50 Million cubic yards of borrow material within close proximity to the point of intake under the assumption that the material will be borrowed at a rate of approximate 5 Million cubic yards per year.

The estimates for the mean annual infill volume and associated standard deviation (see Table 4-1) can be used to assess the project feasibility and project duration in relation to the total sediment demand. To meet the ALDSP project demand of approximately 50 million CY, the borrow site excavation will provide the initial volume, subsequently any infill volume in following years will be dredged and utilized for the project. The infill volumes will vary from year to year due to the natural variability in river discharge and hence the project duration is dependent on the particular sequence and magnitude of water years following the start of the project.

With a Monte Carlo analysis this year to year variability can be simulated repeatedly (*N* number of times) and help bracket the possible impact on project time line. The Monte Carlo analysis randomly pulls an infill volume from the distribution of infill volumes every year[1]. This represents the uncertainty of having a low flow, medium flow or high flow year. The image below provides an example of one possible simulation for utilization of the ATCH-136W borrow site. The first year a volume of 9.8 Million CY, equal to the capacity of the borrow site, is dredged. After that, each year the volume that fills in is dredged to keep the borrow site at its designed dimensions. Dredge volumes will vary from year to year and are tabulated in **Error! Not a valid bookmark self-reference.**. The blue line indicates the cumulative increase of total dredge material. The total project volume of 50 Million CY is obtained after 13 years.

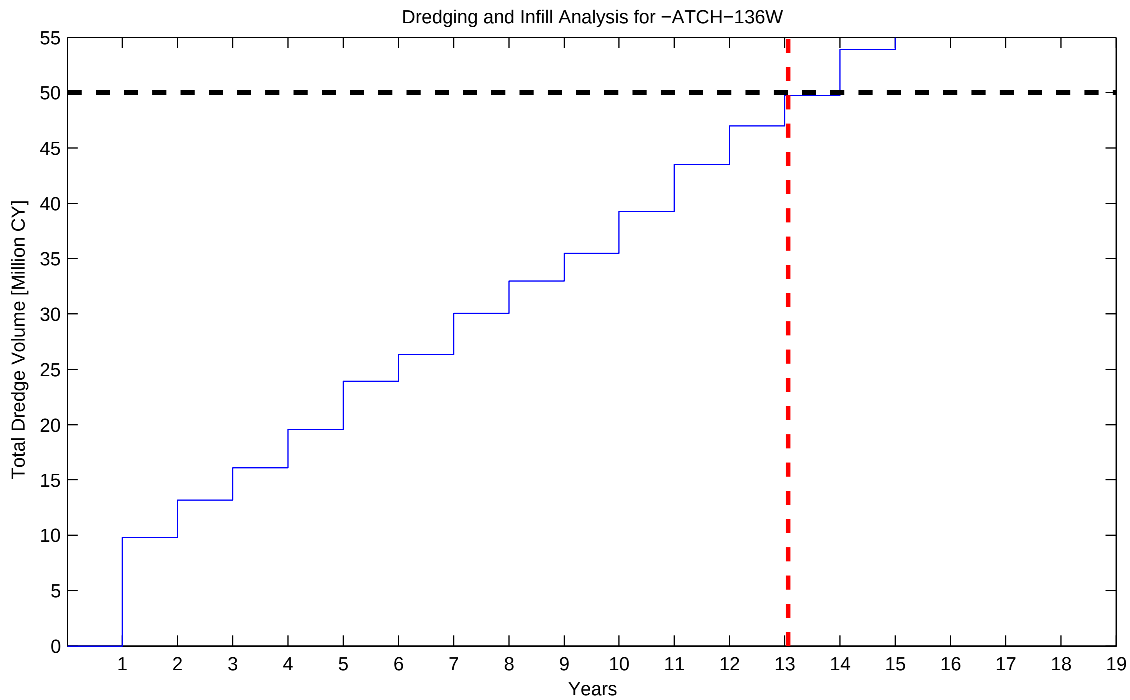


Figure 4-11: One example of dredging and utilization of borrow site 136W as sediment source for the Atchafalaya LDSP project.

Table 4-2: Results of one Monte Carlo simulation for borrow site ATCH-136W as displayed in Figure 4-11 with variable infill volumes per year and the resulting cumulative ALDSP project borrow volume in Million CY.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Initial Dredge volume	9.8													
Infill & Dredge volume	-	3.4	2.9	3.5	4.4	2.4	3.7	2.9	2.5	3.8	4.3	3.5	2.8	4.2
Cumulative volume	9.8	13.2	16.1	19.6	23.9	26.3	30.1	33.0	35.5	39.3	43.5	47.0	49.8	53.9

The Monte Carlo (MC) simulation is repeated one hundred (100) times to account for many possible sequences and magnitudes of water years with associated infill volumes following the start of the project. Figure 4-12 and Figure 4-13 display the results of 100 MC simulations for borrow site ATCH-136W and ATCH-137 respectively. Each colored line is a different simulation; the red dashed line represents the average of all the simulations with a vertical line indicating the intersection of the project demand of 50 Million CY and the average.

[1] The infill volumes are assumed to be normally distributed with a mean and standard deviation as provided in Table 4-1. The assumption is made that if the infill volume is less than 2 Million CY mobilization and dredging is cost prohibitive for the volume available and dredging will wait for a year.

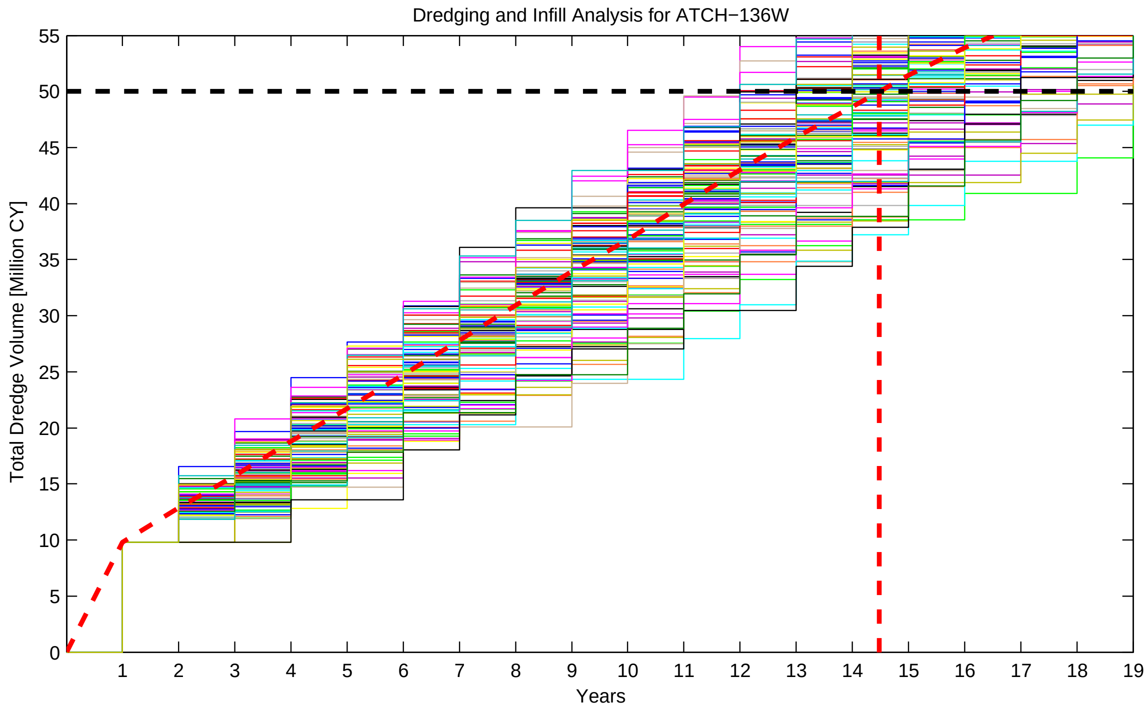


Figure 4-12: Dredging and utilization of borrow site 136W as sediment source for the Atchafalaya LDSP for 100 variations in possible sequenced water years and associated infill volumes

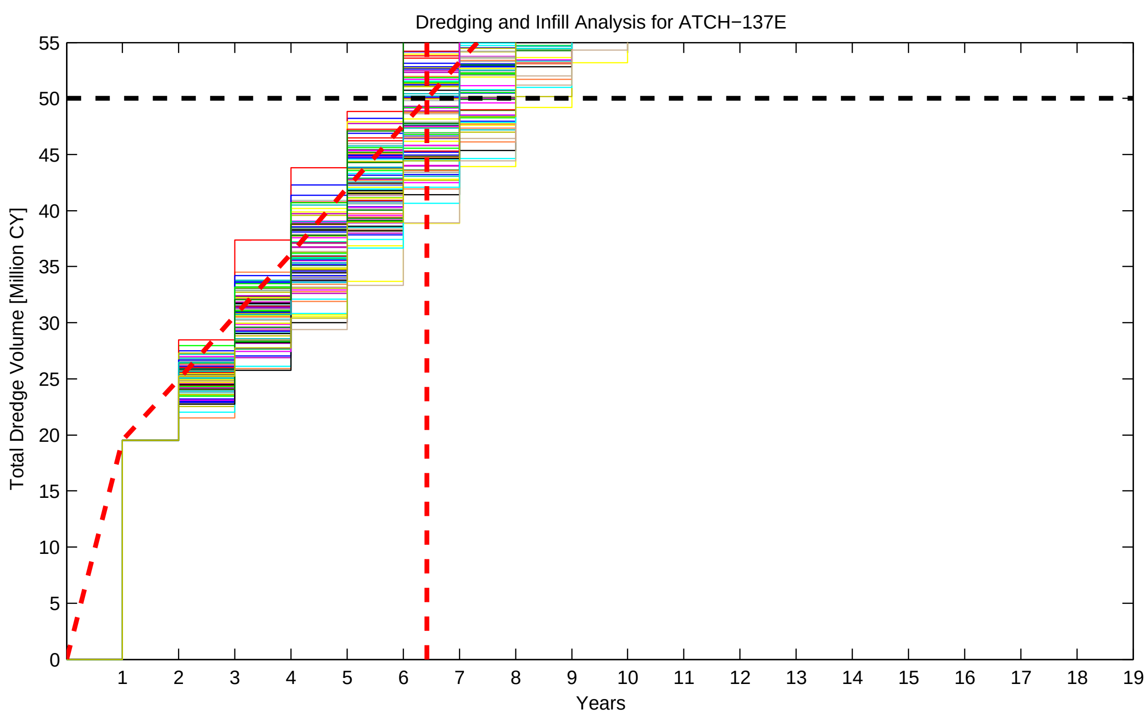


Figure 4-13: Dredging and utilization of borrow site 137E as sediment source for the Atchafalaya LDSP for 100 variations in possible sequenced water years and associated infill volumes

Based on the analysis presented above, the project volume of 50 Million CY can be dredged from ATCH-136W in about 14.5 years. It can take longer (~20 years) it can take shorter (~12 years). For the ATCH-137E site the project duration is significantly shorter, with an estimate average of approximately 6.5 years. Progressive and conservative estimates for a project realization of 50 Million CY utilizing ATCH-137E are approximately 6 and 8 years. All estimates are summarized in Table 4-3.

Table 4-3: Estimate for the project duration for borrow sites ATCH-136W and ATCH-137E based upon a total project volume of 50 Million CY.

Borrow Site	Initial Volume [Million CY]	Estimate for the Project Duration [years]	Progressive Estimate for the Project Duration [years]	Conservative Estimate Project Duration [years]
ATCH-136W	9.8	14.5	12	20
ATCH-137E	19.5	6.5	6	8

4.6 Analysis of Multi-year Simulations

The analysis in the previous section details the availability of sediment within each site by optimally utilizing the annual infill volumes. However after project completion it will take another couple of years before the site will return to pre-dredge conditions. The time it takes for either of the two borrow sites to return to pre-dredge conditions will depend on the sediment loads and therefore the discharge conditions after the borrow site has been dredged. The analysis of the infill rates in the previous section was based on multiple realizations of potential future scenarios. This prediction was based on the infill rates obtained from one year simulations that always start with post-dredged conditions. The computational time required to perform multiple realizations of potential future scenarios using the sediment transport model (i.e. complete model runs for different combinations of sequenced water years on 10 year time scales) was prohibitive for the feasibility study's project schedule. One multi-year simulation from 2006 to 2011 was completed and presented in section 4.2.

The multi-year simulations were carried out starting with a fully dredged borrow-pit in water-year 2006, and allowed to progress through 2011 assuming no subsequent dredging. The infill rates from the continuous multi-year simulation are compared to those from the individual water year simulations to understand how partial sedimentation of the borrow-pit over cumulative years would change the infill rate estimates from 1-year simulations. **Error! Not a valid bookmark self-reference.** and Table 4-5 compares the volume and percent infill of each borrow-pit for each year from 2006 through 2011.

In the continuous simulations both borrow-pits ATCH-136W and ATCH-137E fill in well over 5 million cubic yards by 2008. At that point it is reasonable to assume that the pits would be dredged to borrow sediment. With 2006 being an especially low-flow year, the reduction in the rate of infill for both borrow-pits in the following two years as a result of their partial infilling is about 30%. However, if the borrow-pits are allowed to continue infilling to their capacity, it is reasonable to expect further reduction in infill volumes and hence infill rates in subsequent years. Comparison of the estimates obtained from this simulation to those calculated from the one-year simulations indicates that an overestimation of the infill volume on the order of 30% is possible over a 3 to 4 year time scale.

Table 4-4: Average infill duration for borrow site ATCH-136W, both in single and multi-year simulations for the years 2006 through 2011

	ATCH-136W single water year simulations			ATCH-136W continuous multi-year model simulations		
Initial Volume	9.8 Million CY			9.8 Million CY		
	Volume Infill in year (MCY)	**Percent of initial volume (%)**		**Infill Volume (MCY)**	**Cumulative Infill Volume (MCY)**	**Cumulative Infill Volume (%)**
2006	1.38	15%		1.38	1.38	14%
2007	2.19	23%		1.59	2.97	30%
2008	4.55	48%		3.31	6.28	64%
2009	3.30	35%		2.03	8.31	85%
2010	3.90	41%		1.24	9.55	97%
2011	5.24	55%		1.32	>10.0	>100%

Table 4-5: Average infill duration for borrow site ATCH-137E, both in single and multi-year simulations for the years 2006 through 2011

	ATCH-137E single water year simulations			ATCH-137E continuous multi-year model simulations		
Initial Volume	19.5 Million CY			19.5 Million CY		
	Volume Infill in year (MCY)	**Percent of initial volume (%)**		**Infill Volume (MCY)**	**Cumulative Infill Volume (MCY)**	**Cumulative Infill Volume (%)**
2006	2.23	12%		2.23	2.23	11%
2007	3.73	19%		2.39	4.62	24%
2008	8.23	43%		6.88	11.50	59%
2009	5.89	30%		3.65	15.15	78%
2010	6.64	34%		0.00	15.15	78%
2011	9.88	51%		0.75	15.85	81%

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Research approach

The objective of the study performed by Moffatt & Nichol for the Terrebonne Parish Consolidated Government was to conduct a planning-level search for potential borrow areas in the Lower Atchafalaya River Region which contain sediment suitable for transport with a Long Distance Sediment Pipeline and then utilize the sediment for marsh nourishment. Transport and placement of the sediment was not part of the study discussed in this report. Emphasis was placed on finding suitable material within the Study Area in close proximity to the defined "Approximate Point of Intake" located in the Crew Boat Cut area.

A preliminary set of borrow sites was identified in Phase I of this project (Moffatt & Nichol 2013). Within the study area a substantial amount of borrow material is available if a cut depth of -70 feet is assumed as vertical limit for sites within the River. From the borrow sites delineated in close proximity to the approximate point of intake during Phase I, two larger sites in the Atchafalaya River; ATCH-136W and ATCH-137E; with a volume of 9.8 and 19.5 Million CY respectively, were selected for detailed analysis.

Both the definition of the project volume demand (50 Million CY) as well as the time scale and schedule on which the sediment is likely needed (approximately 5 Million CY per year) allowed for a refined selection procedure for borrow sites in Phase II of the feasibility study. A detailed assessment of refill rates and numerical modeling to establish project feasibility is comprehensively documented within this report. Conclusions and recommendations are provided in the following sections.

5.2 Conclusions for the Atchafalaya LDSP Borrow Sites

5.2.1 Atchafalaya LDSP Project – Sediment Demand Feasibility

The general objective of the study is to find suitable material for marsh restoration within the Lower Atchafalaya River Region, hydraulically dredge the material and transport it by means of a pipeline to the marshes in need.

Within that framework Moffatt & Nichol refined the preliminary identified borrow sites ATCH-136W and ATCH-137E and confirmed the availability of 50 Million cubic yards of borrow material in close proximity to the Approximate Point of Intake. For this feasibility study it was furthermore confirmed that the material can be borrowed at a rate of approximate 5 Million cubic yards per year. From the annual infill volume analysis it followed that the borrow site ATCH-137E could support such a sediment demand (see also Table 5-1). It is recommended that the total volume of sediment needed and the annual demand be better defined through further definition and delineation of placement sites. A more narrow definition would allow for selection and delineation of one dedicated borrow site for the ALDSP Project.

Table 5-1: Average infill duration for borrow sites ATCH-136W and ATCH-137E

Borrow Site	Location	Initial Volume [Million CY]	Estimate for the Mean Annual Infill Volume [Million CY]	Estimate for the Project Duration*	Progressive Estimate for the Project Duration*	Conservative Estimate Project Duration*
ATCH-136W	Horseshoe Bend	9.8	3.2	14.5 years	12 years	20 years
ATCH-137E	Crew Boat Cut	19.5	5.6	6.5 years	6 years	8 years

*Project duration is based on a project need of 50 Million CY

5.2.2 Atchafalaya LDSP Project – Recommendations for Borrow Site Selection

Borrow site ATCH-137E can meet the project demand and is recommended for selection. ATCH-137E has the following characteristics that are beneficial to the objective of the project:

- Borrow Site ATCH-137E has an initial volume of 19.5 Million CY;
- Borrow Site ATCH-137E is estimated to have an annual average infill volume of 5.6 Million CY if the site is utilized on an annual basis;
- Based on the above, borrow Site ATCH-137E is expected to exceed the assumed demand of approximately 5 Million cubic yards per year;
- By utilizing Borrow Site ATCH-137E for the project (with a sediment demand of 50 Million CY) the project duration is estimated to be 6.5 years.

Other aspects and characteristics of the site should be taken into account for final selection and refinement of the borrow site location and geometry. For borrow site ATCH-137E pros and cons are summarized below as detailed throughout this report and earlier phases of the feasibility study. In addition a list of pros and cons is provided for borrow site ATCH-136W for further consideration.

Borrow Site ATCH-137E – Crew Boat Cut

- Borrow Site ATCH-137E is in close proximity to the approximate point of Intake. The dredging pipeline for transport to the point of intake will not affect navigation and will be of shorter length than for the other location.
- The initial volume of sediment for this site is 19.5 Million CY.
- Sediment loads within this reach are larger than for the Horseshoe Bend and could provide the required volume of sediment for the project in the 10 year project lifespan.
- Initial analysis of the model simulations indicate that for the existing borrow sites asymmetric infill occurs as a consequence of the borrow site not being aligned with the flow patterns. As the infill progresses the flow patterns in the borrow site are modified, and flow patterns upstream of the areas that have not filled in yet are very different from the initial flow patterns with post-dredged conditions. If necessary, and in order to improve infill rates for multiple years, the layout of the borrow site can be analyzed and optimized with the aim of maintaining the initial flow patterns and sediment loads as the borrow site fills in from upstream to downstream.

- Borrow Site ATCH-137E is not optimally aligned with the flow and sediment transport patterns in the Crew Boat Cut reach. The cross sectional extent could be modified to capture areas with the largest sediment load.

- Navigation could be disrupted during dredging operations as the site is located within the new authorized federal navigation channel (Crew Boat Cut reach).

- The proposed geometry has an impact on the flow patterns which could have a negative impact on navigation and vessel traffic within the reach, therefore some optimization of the geometry could be considered to reduce this effect.

- Stability of existing shoreline protection structures should be analyzed in coordination with the USACE when this project moves from the feasibility phase into the planning phase.

- The design of the downstream end of the site produces a very large gradient in velocity that could lead to erosion of the downstream edge of the borrow site. It is recommended to investigate the possibility of designing the borrow site with a gradient that will taper upwards at the downstream end to allow for flow conditions to gradually adjust to undisturbed bathymetric conditions.

Borrow Site ATCH-136W – Horseshoe Bend

- In general sediment loads within this reach are smaller than for the Crew Boat Cut reach

- Utilization of borrow site ATCH-136W will not be enough alone to provide the required volume of sediment for the project in the 10 year project life.

- Borrow site ATCH-136W is not aligned with the flow and the upstream section includes an area with very low sediment load leading to an asymmetric infill.

- The initial volume of sediment for this site is 9.8 Million CY.

- The dredging pipeline will have to cross the navigation channel to connect to the point of intake on the east bank of the river.

- ATCH-136W is outside the federal authorized navigation channel (come end of 2014) and hence no significant disruption of navigation during dredging is to be expected. Nor are any special considerations with respect to interference with shoreline protection structures needed for this site.

- No modification of the flow patterns that could affect navigation

- The design of the downstream end of the site produces a very large gradient in velocity that could lead to erosion of the downstream edge of the borrow site. It is recommended to investigate the possibility of designing the borrow site with a gradient that will taper upwards at the downstream end to allow for flow conditions to gradually adjust to undisturbed bathymetric conditions.

5.2.3 Long Term Infill Volumes

It is the expectation that after completion of the ALDSP Project the utilized borrow pit will take additional years to fill back in and return to pre-dredge conditions. One multi-year simulation from 2006 to 2011 was presented in chapter 4. Comparison of the estimates obtained from this simulation to those calculated from the one-year simulations indicates that an overestimation of the infill volume on the order of 30% is possible over a 3 to 4 year time scale.

5.3 Recommendations for the advancement of the ALDSP Project

5.3.1 General Recommendations

Borrow area delineations at this phase of the study should be considered preliminary and serve as an estimate of total potential sediment available. More recent bathymetric data, magnetometer and numerical model studies, as well as coordination with USACE, USCG and MNSA are required to further refine the borrow area delineations, volumes and re-fill rates when this project moves from feasibility into planning phase.

Borrow area delineations were appropriate for a feasibility level study and did not consider detailed geotechnical or bathymetric analysis and all analyses were completed utilizing the latest readily available data. Final detailed design of the borrow area will need to adhere to all required offsets and buffer zones.

Apart from the dedicated dredging to identify sediment sources for the Atchafalaya River LDSP a second concept was considered. Sediment dredged from maintenance dredging works in the Lower Atchafalaya River, Bayou Boeuf, Bayou Black and Bayou Chene, could potentially serve as a source for the sediment pipeline project. This topic was extensively addressed in Phase I (Moffatt & Nichol, 2013). It should be noted that the USACE disposal areas partially overlap and are in close proximity to the potential borrow sites ATCH-136E and ATCH-137W. Disposal of maintenance dredge material could potentially be done within the designated borrow pit. This creates a scenario in which the sump technique could be beneficial. Sediment would be dredged from the borrow site to the depth as determined in this report, creating a large open pit in the river bed. The USACE would then place Beneficial Use (BU) sediment in the pit during dredging cycles in the Horseshoe Bend / Crew Boat Cut reach. This, in addition to infill due to natural sedimentation from the river, provides two sources of refilling of the borrow site. Maintenance dredging works in the Crew Boat Cut reach are estimated by the USACE to yield 750,000 CY per three (3) year dredging cycle. Theoretically, this would provide the Atchafalaya LDSP with a faster-filling borrow site which could be mined more often for sediment and at the same time beneficially use maintenance dredge material.

5.3.2 Recommendations for Data Collection

It is recommended that more detailed geotechnical and bathymetric data be collected as the level of detail progresses for this project. In addition more empirical data via repeated bathymetric surveys could help to validate modeling results. Borrow area delineations were appropriate for a feasibility level study but did not consider detailed geotechnical or bathymetric analysis.

Borrow site delineation will benefit from additional information on velocities and flow patterns at the project area. This information could be used to better calibrate the numerical model developed for this project and to reproduce the local flow patterns under different discharge conditions, and consequently provide a more accurate prediction of the sediment loads. As a result, it is recommended that a hydraulic data collection campaign would be initiated in order to provide insight in the local current and flow fields and depth average currents in the project vicinity.

5.3.3 Numerical Modeling Considerations

The hydrodynamic and sediment transport model developed as part of this study and presented in chapter 3 has been used to estimate sediment loads and infill rates for the ATCH-136W and ATCH-137E borrow site. All readily available data, data obtained from publications and data derived from additional analysis has been used to calibrate and validate the numerical model. Additional data, especially velocity patterns and suspended sediment concentration data at the project site could be used to improve the model predictions. However, model simulations and predictions for existing conditions match reasonably well with the information available and provide confidence in the model's ability to forecast morphological behavior for the project area with the borrow areas present.

The availability of the model provides the opportunity to analyze the performance of the existing layout for ATCH-136W and ATCH-137E, and provide alternatives to optimize the trapping capacity of the borrow sites. Model results indicate that the existing layouts do not optimally benefit from the predicted flow/sediment transport patterns, i.e. the upstream edge of the borrow sites are not perpendicular to the currents. As a consequence of promoting an asymmetric infill the flow patterns inside the borrow site change as the site fills in and subsequently reduce the sediment trapping efficiency. In addition, based on the existing model results, the ATCH-136W upstream edge covers an area of low velocities and low sediment transport, where very limited infill takes place. From the analysis of the model results we could conclude that alignment of the borrow site with the existing flow patterns, and areas of significant sediment load, will maximize the infill volumes and hence optimize the design.

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Appendix A

Preliminary Borrow Sites Plans and Sections

APPENDIX A

PRELIMINARY BORROW SITES - PLANS AND SECTIONS

REPORT FIGURE
ISSUED: 2014-04-24
NOT TO BE USED FOR CONSTRUCTION

5000' 0' 5000' 10000'
SCALE: 1"=5000'

OFFICE OF COASTAL RESTORATION AND PRESERVATION

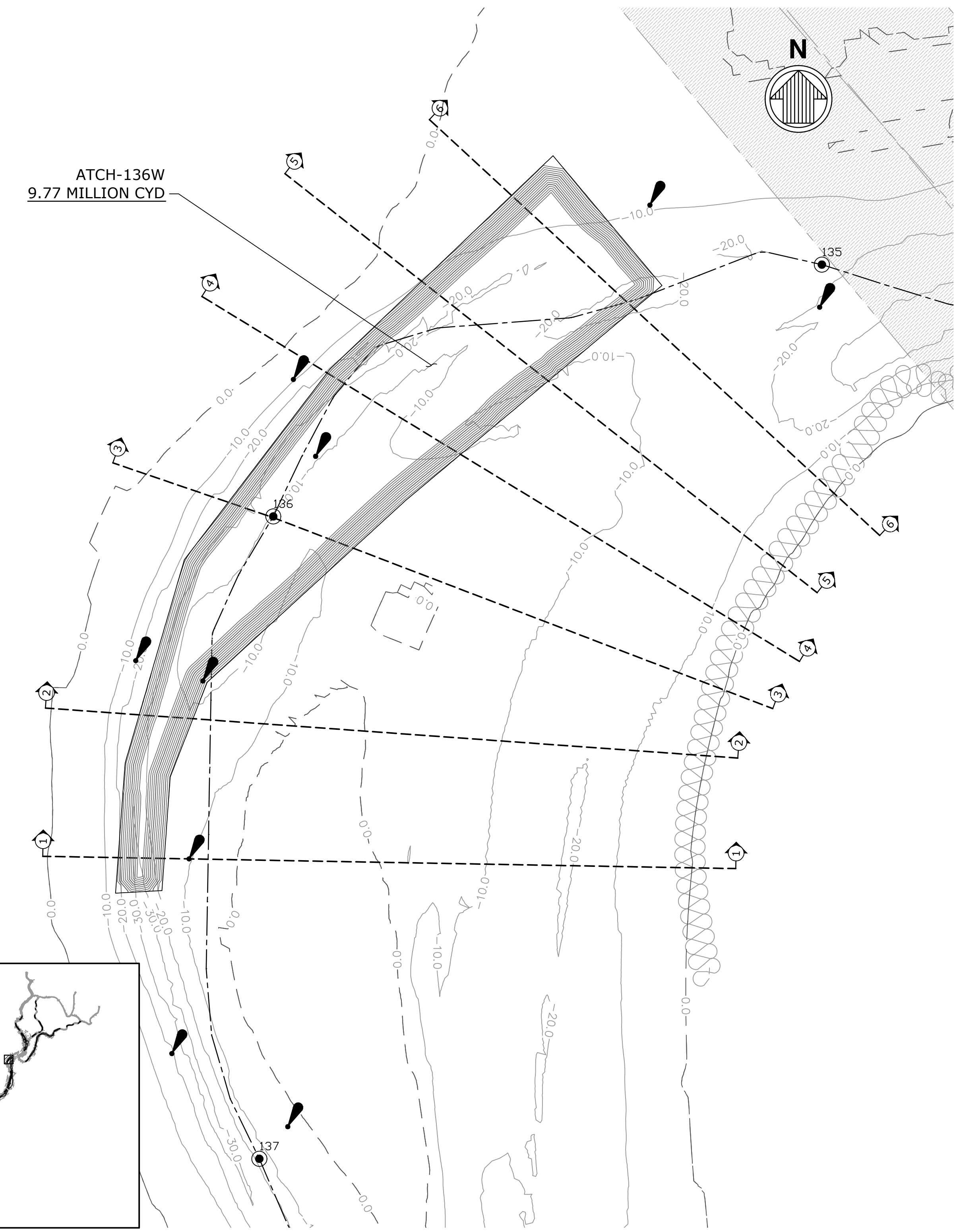
TERREBONNE PARISH

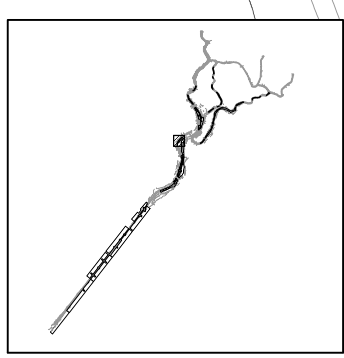
ATCHAFALAYA RIVER LONG DISTANCE SEDIMENT PIPELINE

PRELIMINARY BORROW SITE IDENTIFICATION AND ESTIMATION OF BORROW VOLUMES

FIG-01 - BORROW SITES LOCATION PLAN

moffatt & nichol





KEY PLAN

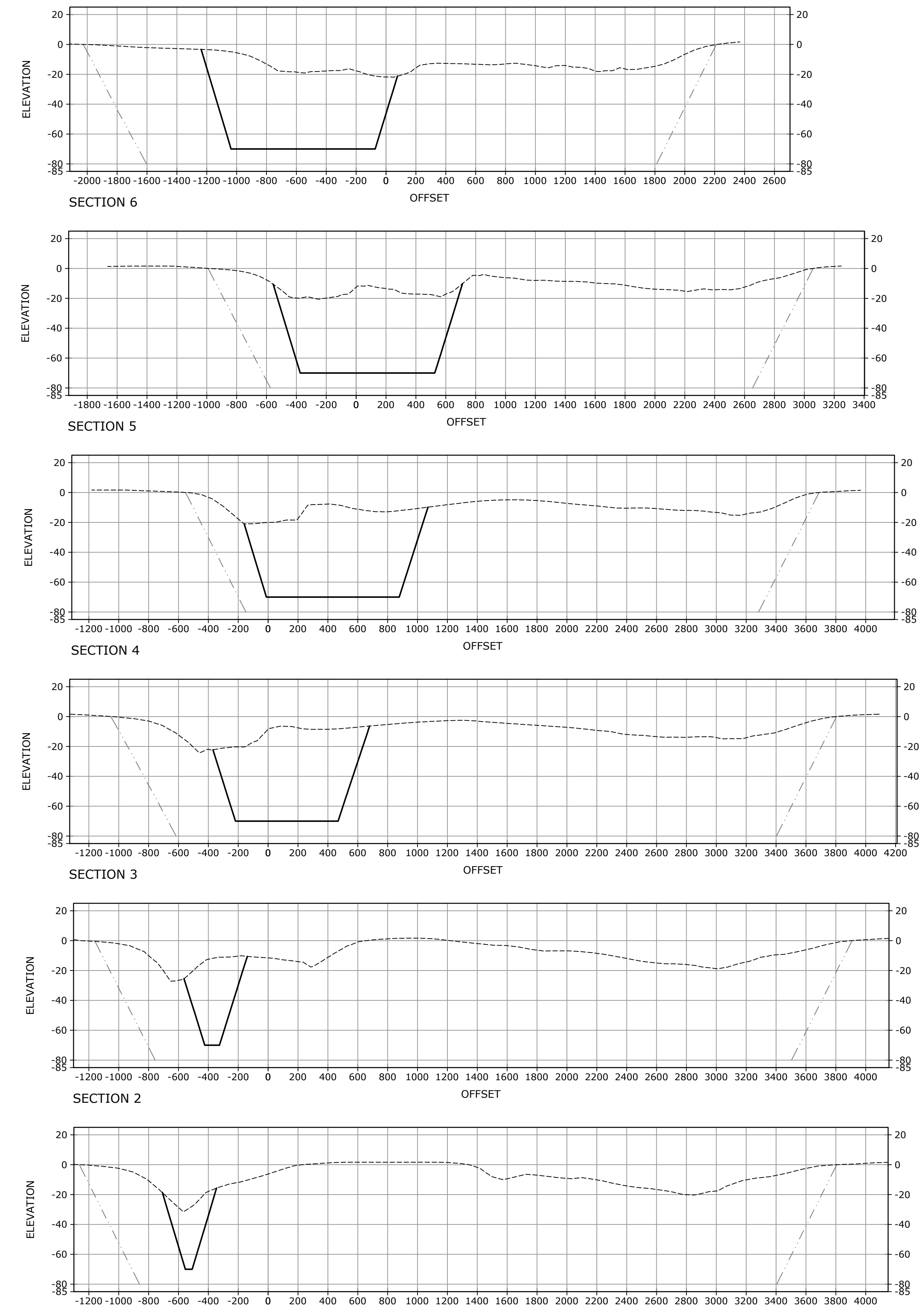
LEGEND & SYMBOLS:

- NAVIGATION AIDS
- RIVER MILES
- MAGNETIC ANOMALIES
- BAYOU CENTERLINE
- CONTOUR LINE
- CONTOUR LINE (EL 0.0)
- CREWBOAT CUT SHORELINE PROTECTION
- DCAS STRUCTURE
- LEVEES
- ELECTRICAL CROSSINGS
- PIPELINES WITH BUFFERS
- PIPELINE CORRIDORS

1200' 0' 1200' 2400'

SCALE: 1''=1200'

REPORT FIGURE
ISSUED: 2014-04-24
NOT TO BE USED FOR CONSTRUCTION



SECTIONS LEGEND

- BATHYMETRY
- EXISTING GRADE 5 TO 1
- PROPOSED BORROW SITE

100' 0' 100' 200'

V.SCALE: 1''=100'

1000' 0' 1000' 2000'

H.SCALE: 1''=1000'

OFFICE OF COASTAL RESTORATION AND PRESERVATION

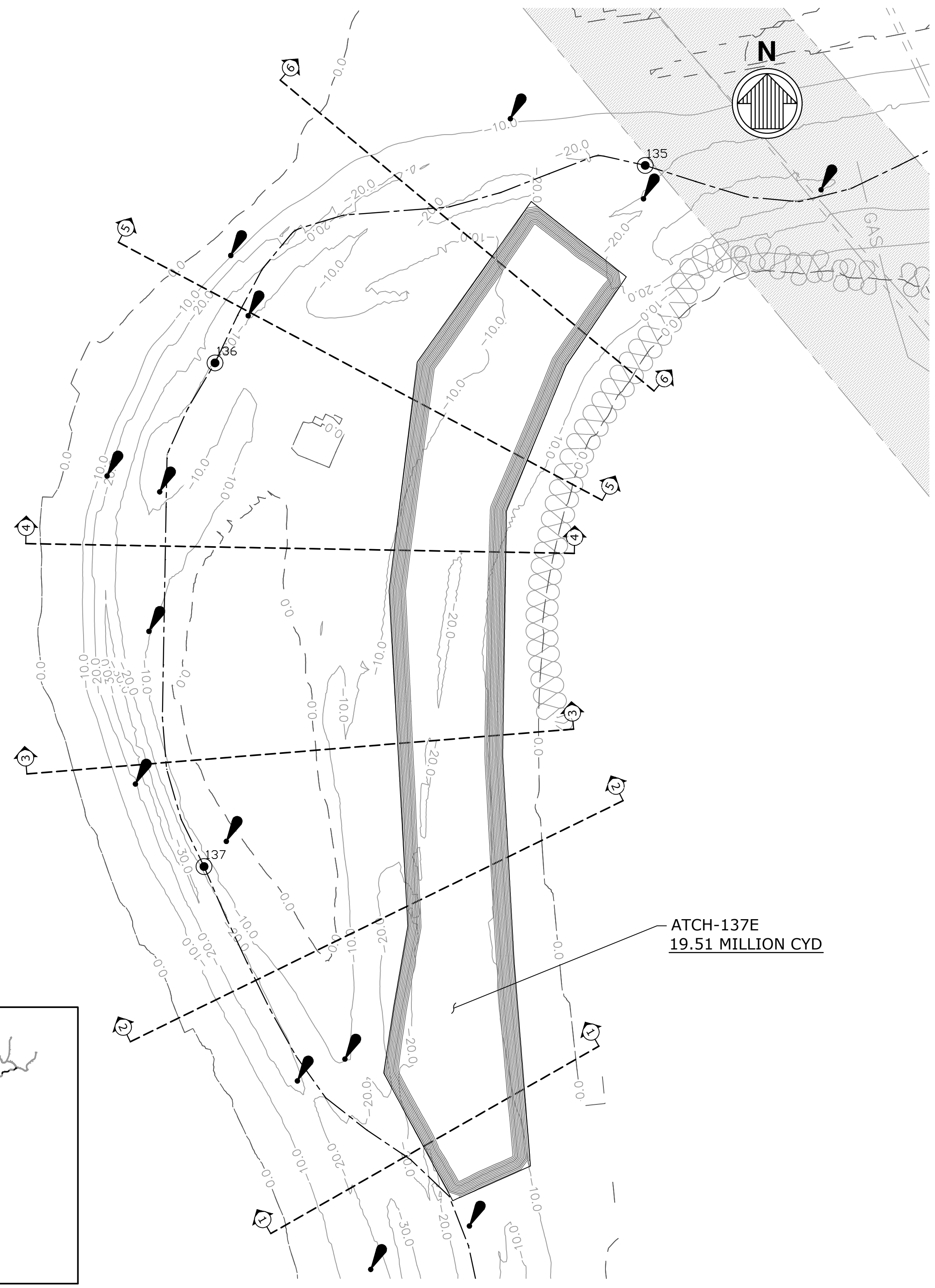
TERREBONNE PARISH

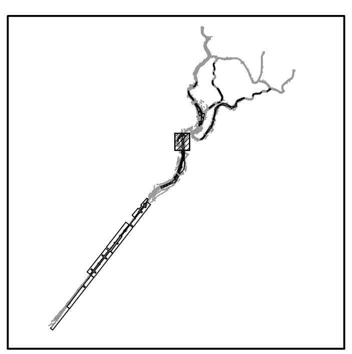
ATCHAFALAYA RIVER LONG DISTANCE SEDIMENT PIPELINE

PRELIMINARY BORROW SITE IDENTIFICATION AND ESTIMATION OF BORROW VOLUMES

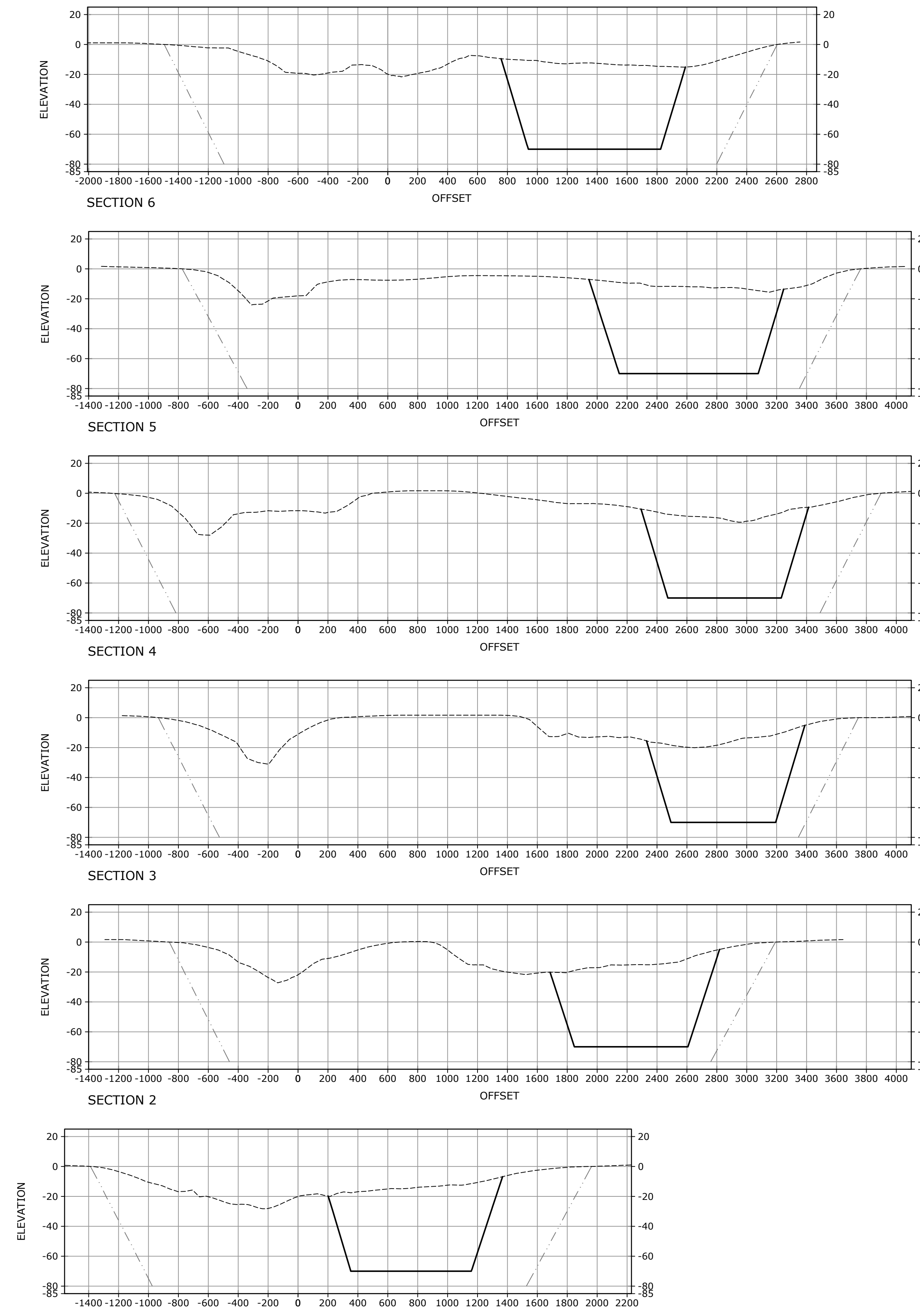
FIG-02: ATCH-136W - PLAN & SECTIONS

moffatt & nichol





KEY PLAN



LEGEND & SYMBOLS:

- NAVIGATION AIDS
- RIVER MILES
- MAGNETIC ANOMALIES
- BAYOU CENTERLINE
- CONTOUR LINE
- CONTOUR LINE (EL 0.0)
- CREWBOAT CUT SHORELINE PROTECTION
- DCAS STRUCTURE
- LEVEES
- ELECTRICAL CROSSINGS
- PIPELINES WITH BUFFERS
- PIPELINE CORRIDORS

1600' 0' 1600' 3200'

SCALE: 1''=1600'

REPORT FIGURE
ISSUED: 2014-04-24
NOT TO BE USED FOR CONSTRUCTION

SECTIONS LEGEND

- BATHYMETRY
- EXISTING GRADE 5 TO 1
- PROPOSED BORROW SITE

100' 0' 100' 200'

V.SCALE: 1''=100'

1000' 0' 1000' 2000'

H.SCALE: 1''=1000'

OFFICE OF COASTAL RESTORATION AND PRESERVATION

TERREBONNE PARISH

ATCHAFALAYA RIVER LONG DISTANCE SEDIMENT PIPELINE

PRELIMINARY BORROW SITE IDENTIFICATION AND ESTIMATION OF BORROW VOLUMES

FIG-03: ATCH-137E - PLAN & SECTIONS

moffatt & nichol

Appendix B

Grab Sample Data Atchafalaya River

APPENDIX B

GRAB SAMPLE DATA – HORSESHOE BEND AND CREW BOAT CUT

Grab Samples: **Lower Atchafalaya River**

Collected for the Study "Assessing Quantity and Quality of Sand Available in the Lower Atchafalaya River Channel for Coastal Marsh and Barrier Island Restoration in Louisiana" in 2006

GRAB	MEAN microns	MEAN phi	SKEWNESS	STD_DEV microns	KURTOSIS	WATER DEPTH m	LAT	LONG
A178	184.59	2.4376	1.6551	116.82	5.5252	4.27	29.57693	-91.231
A180	188.65	2.4062	1.4822	71.5	14.105	9.14	29.56753	-91.2306
A181	174.68	2.5172	1.6749	72.09	17.064	16.46	29.56317	-91.2311
A182	93.53	3.4185	-1.0941	62.47	3.96	12.8	29.55728	-91.2322
A183	89.68	3.4791	-1.2157	49.84	4.7364	6.1	29.55115	-91.239
A184	106.68	3.2286	-0.9733	98.77	3.6766	17.68	29.54862	-91.2403
A185	81.14	3.6235	-5.8045	42.37	57.209	8.23	29.54595	-91.2469
A186	208.22	2.2638	2.4678	71.46	19.563	9.14	29.54187	-91.2584
A188	144.13	2.7946	-0.1516	90.98	7.9894	5.79	29.54143	-91.2696
A189	103.85	3.2674	-0.5862	51.61	7.9966	7.62	29.54005	-91.2743
A190	140.61	2.8302	0.206	68.52	4.7932	3.66	29.53442	-91.2781
A191	177.33	2.4955	0.9731	109.46	11.386	7.62	29.5304	-91.2793
A192	171.88	2.5405	0.638	73	20.61	7.01	29.52518	-91.2781
A193	118.42	3.078	-1.2182	69.02	10.968	5.18	29.5203	-91.2749
A194	180.38	2.4709	2.6952	57.12	26.531	6.71	29.5162	-91.2735
A195	113.36	3.141	-1.0609	84.47	7.0754	9.14	29.51163	-91.27
A196	153.17	2.7068	1.0271	77.93	6.8942	6.4	29.51008	-91.2674
A197	126.09	2.9875	-1.5673	73.86	14.011	5.18	29.50632	-91.2665
A198	165.29	2.5969	1.7444	68.51	8.0578	8.53	29.50442	-91.2687
A199	132.68	2.914	-0.5502	68.44	11.523	7.32	29.50075	-91.27
A200	172	2.5395	2.436	52.78	15.674	7.62	29.49798	-91.2696

Appendix C

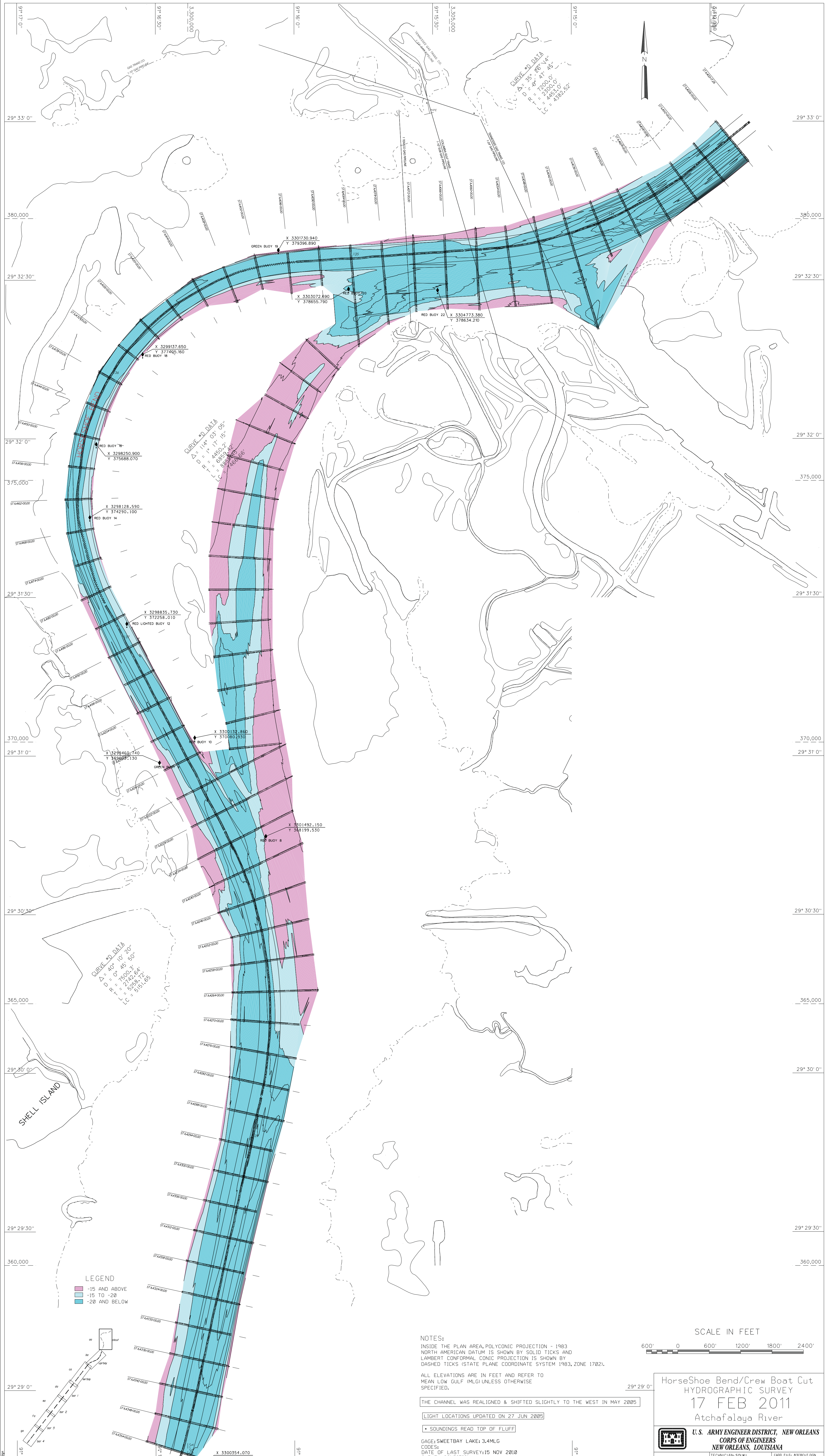
Hydrographic Surveys USACE

APPENDIX C

HORSESHOE BEND / CREW BOAT CUT – HYDROGRAPHIC SURVEYS USACE

Collected from the USACE MVN Survey Section

http://www.mvn.usace.army.mil/Missions/Navigation/ChannelSurveys.aspx



NOTES:

INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).

ALL ELEVATIONS ARE IN FEET AND REFER TO MEAN LOW GULF (MLG) UNLESS OTHERWISE SPECIFIED.

THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005

LIGHT LOCATIONS UPDATED ON 27 JUN 2005

* SOUNDINGS READ TOP OF FLUFF

GAGE: SWEETBAY LAKE: 3.4MLG
CODES:
DATE OF LAST SURVEY: 15 NOV 2010
SURVEY CONDITION: CALM

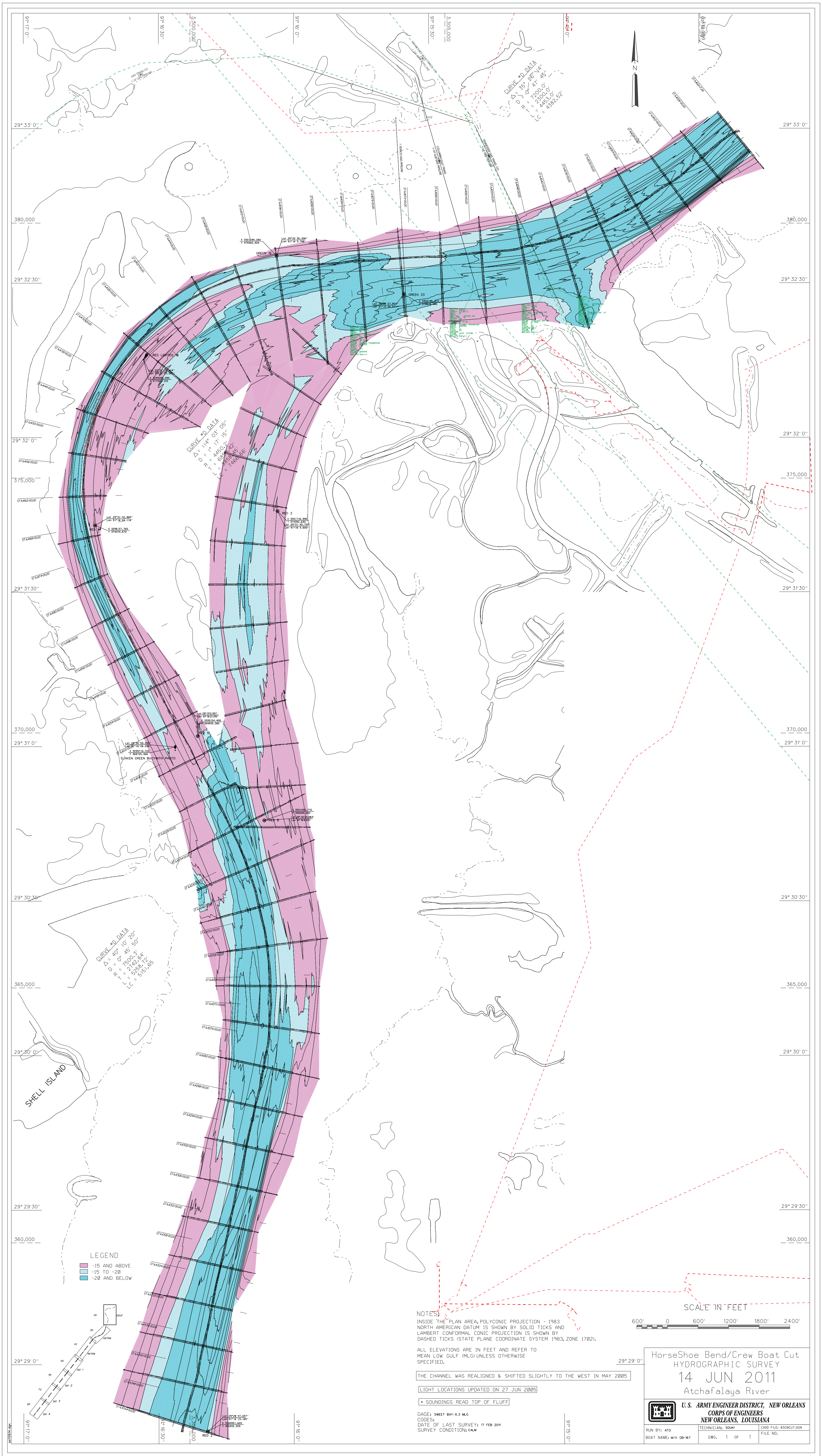
SCALE IN FEET

600' 0 600' 1200' 1800' 2400'

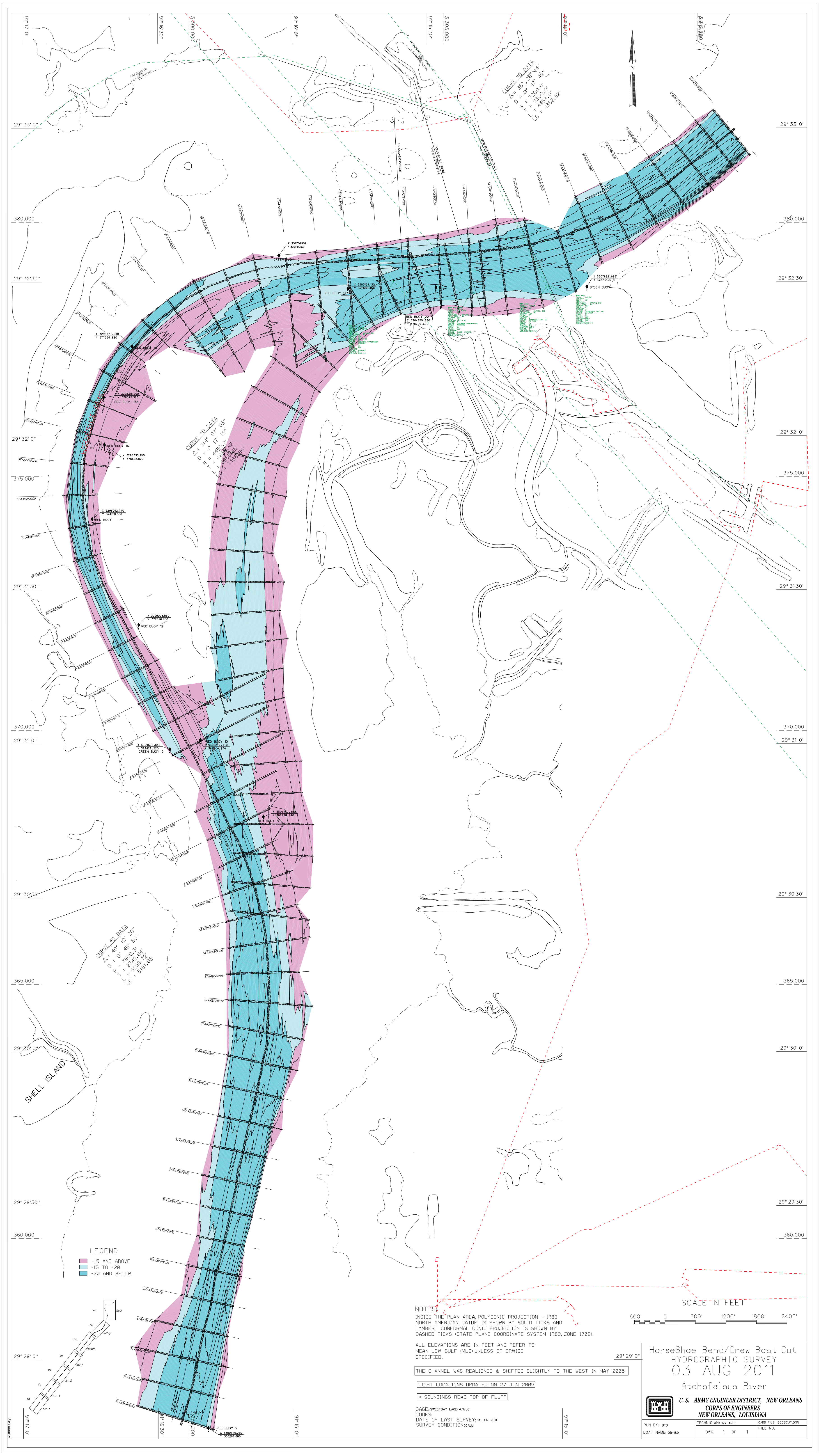
HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
17 FEB 2011
Atchafalaya River

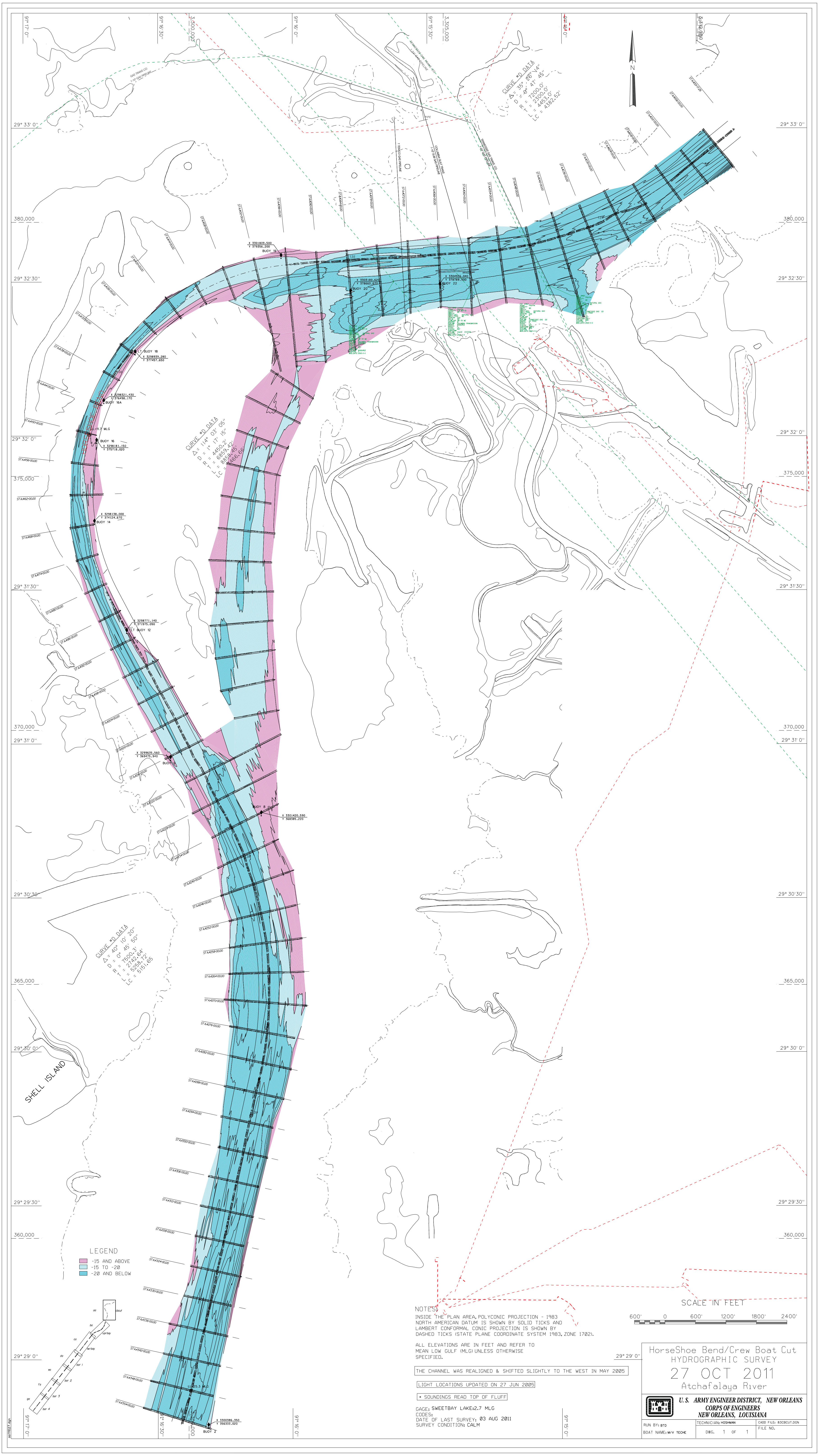
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA

RUN BY: BTD	TECHNICIAN: SOUKI	CADD FILE: 83CBCUT.DGN
BOAT NAME: M/V TECHE	DWG. 1 OF 1	FILE NO.

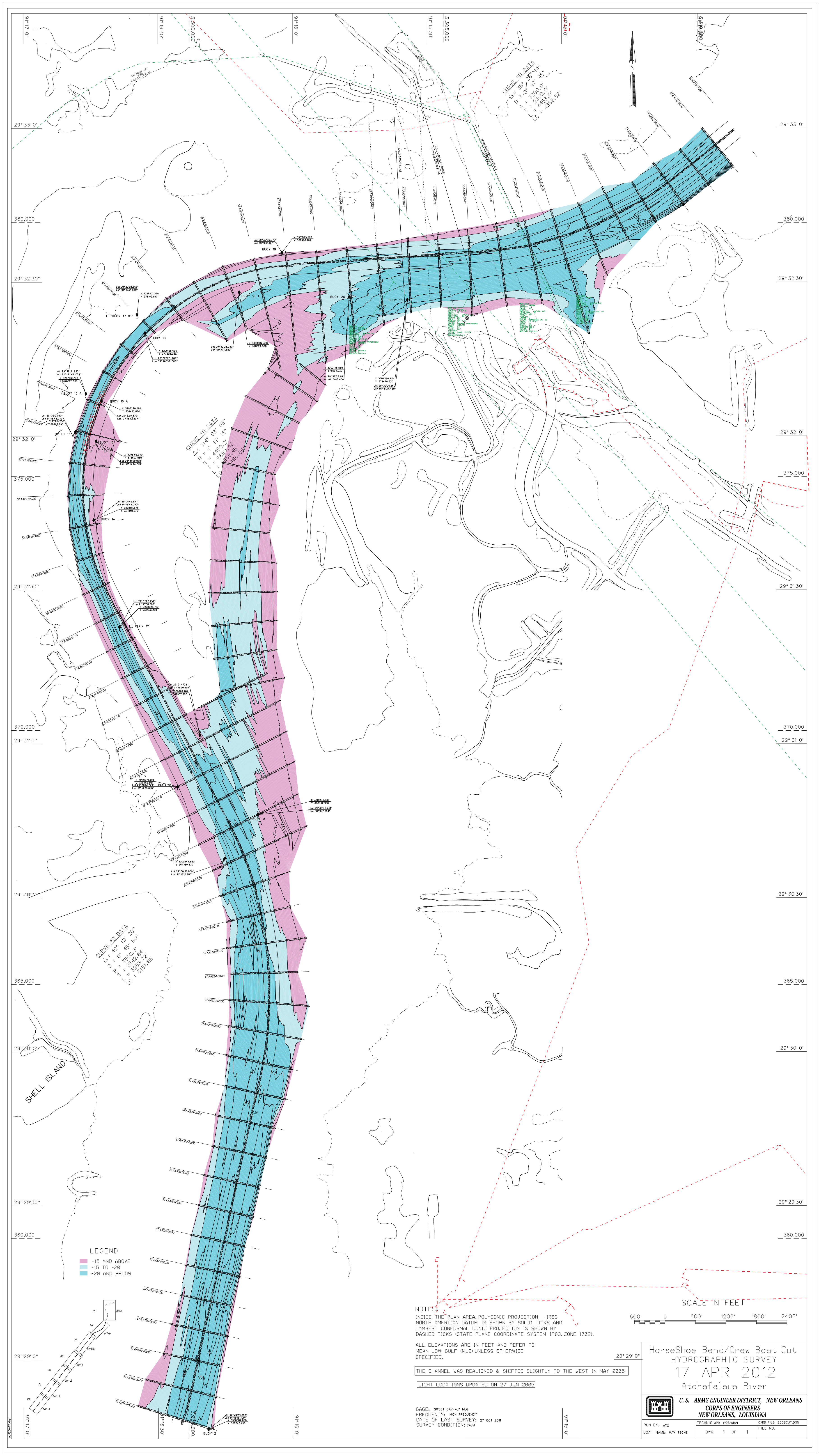


HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
14 JUN 2011
Atchafalaya River
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
RUN BY: ATO
BOAT NAME: M/V OB-167
TECHNICIAN: SOUKI
DWG. 1 OF 1
CADD FILE: 83CBCUT.DGN
FILE NO.
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).
ALL ELEVATIONS ARE IN FEET AND REFER TO MEAN LOW GULF (MLG) UNLESS OTHERWISE SPECIFIED.
THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005
LIGHT LOCATIONS UPDATED ON 27 JUN 2005
* SOUNDINGS READ TOP OF FLUFF
GAGE: SWEET BAY: 6.3 MLG
CODES:
DATE OF LAST SURVEY: 17 FEB 2011
SURVEY CONDITION: CALM
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'
LEGEND
-15 AND ABOVE
-15 TO -20
-20 AND BELOW
SHELL ISLAND
29° 33' 0"
29° 32' 30"
29° 32' 0"
29° 31' 30"
29° 31' 0"
29° 30' 30"
29° 30' 0"
29° 29' 30"
29° 29' 0"
380,000
375,000
370,000
365,000
360,000

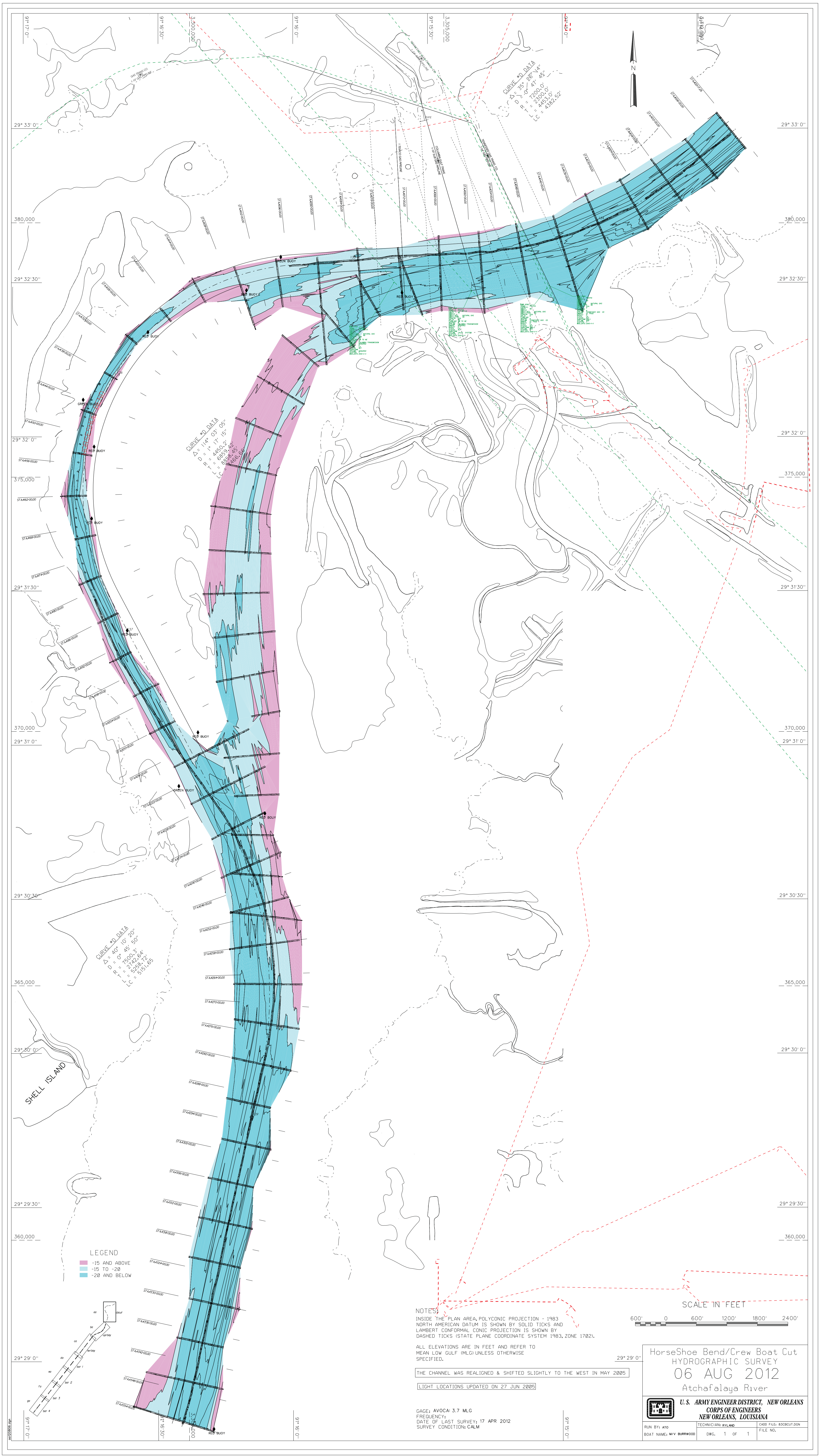

HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
03 AUG 2011
Atchafalaya River
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
RUN BY: BTD
BOAT NAME: OB-189
TECHNICIAN: RYLAND
DWG. 1 OF 1
CADD FILE: 83CBCUT.DGN
FILE NO.
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983
NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND
LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY
DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).
ALL ELEVATIONS ARE IN FEET AND REFER TO
MEAN LOW GULF (MLG) UNLESS OTHERWISE
SPECIFIED.
THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005
LIGHT LOCATIONS UPDATED ON 27 JUN 2005
* SOUNDINGS READ TOP OF FLUFF
GAGE: SWEETBAY LAKE: 4.1MLG
CODES:
DATE OF LAST SURVEY: 14 JUN 2011
SURVEY CONDITION: CALM
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'
LEGEND
-15 AND ABOVE
-15 TO -20
-20 AND BELOW
SHELL ISLAND
N
29° 33' 0"
29° 32' 30"
29° 32' 0"
29° 31' 30"
29° 31' 0"
29° 30' 30"
29° 30' 0"
29° 29' 30"
29° 29' 0"
380,000
375,000
370,000
365,000
360,000
91° 17' 0"
91° 16' 30"
91° 16' 0"
91° 15' 30"
91° 15' 0"
3,300,000
3,305,000
RED BUOY 2
RED BUOY 8
GREEN BUOY 9
RED BUOY 10
RED BUOY 12
RED BUOY 16
RED BUOY 16A
RED BUOY 22
GREEN BUOY

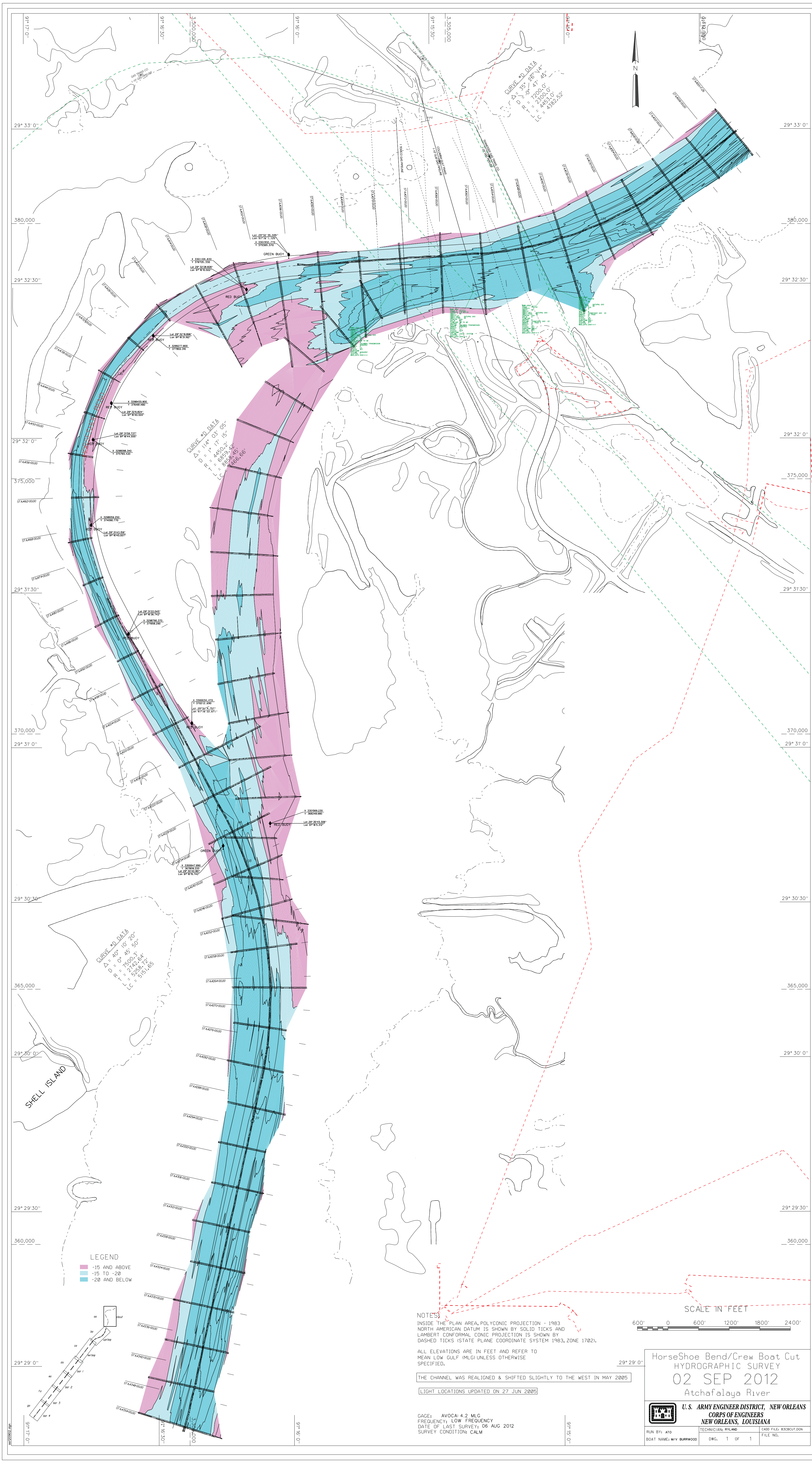


N
CURVE "D DATA"
SHELL ISLAND
LEGEND
-15 AND ABOVE
-15 TO -20
-20 AND BELOW
29° 33' 0"
29° 32' 30"
29° 32' 0"
29° 31' 30"
29° 31' 0"
29° 30' 30"
29° 30' 0"
29° 29' 30"
29° 29' 0"
380,000
375,000
370,000
365,000
360,000
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).
ALL ELEVATIONS ARE IN FEET AND REFER TO MEAN LOW GULF (MLG) UNLESS OTHERWISE SPECIFIED.
THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005
LIGHT LOCATIONS UPDATED ON 27 JUN 2005
* SOUNDINGS READ TOP OF FLUFF
GAGE: SWEETBAY LAKE:2.7 MLG
CODES:
DATE OF LAST SURVEY: 03 AUG 2011
SURVEY CONDITION: CALM
HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
27 OCT 2011
Atchafalaya River
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
RUN BY: BTD
BOAT NAME: M/V TECHE
TECHNICIAN: HOSHMAN
DWG. 1 OF 1
CADD FILE: 83CBCUT.DGN
FILE NO.

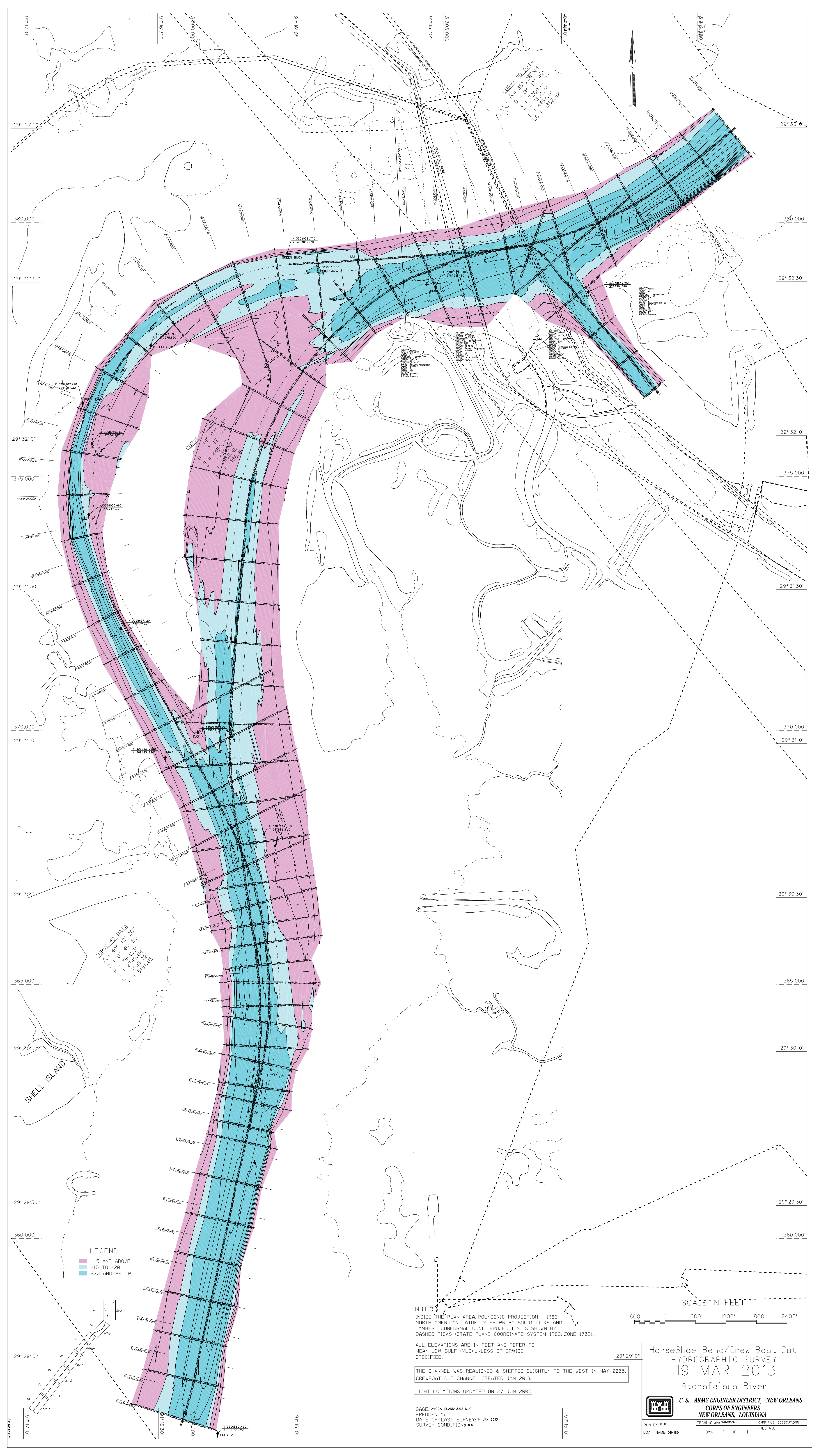


CURVE "D DATA
Δ = 114° 03' 05"
D = 1° 17' 15"
CURVE "D DATA
Δ = 35° 26' 44"
D = 0° 47' 45"
R = 7200.0'
T = 2300.0'
L = 4453.0'
LC = 4382.52'
CURVE "D DATA
Δ = 40° 10' 20"
D = 0° 45' 50"
R = 7500.3'
T = 2742.64'
L = 5258.72'
LC = 5151.65
SHELL ISLAND
LEGEND
-15 AND ABOVE
-15 TO -20
-20 AND BELOW
29° 33' 0"
29° 32' 30"
29° 32' 0"
29° 31' 30"
29° 31' 0"
29° 30' 30"
29° 30' 0"
29° 29' 30"
29° 29' 0"
380,000
375,000
370,000
365,000
360,000
91° 17' 0"
91° 16' 30"
91° 16' 0"
91° 15' 30"
91° 15' 0"
3,300,000
3,305,000
BUOY 19
BUOY 18 A
BUOY 20
BUOY 22
LT BUOY 17 WR
BUOY 18
BUOY 15 A
BUOY 16 A
LT 15
BUOY 16
BUOY 14
LT BUOY 12
BUOY 9
BUOY 8
BUOY 2
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983
NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND
LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY
DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).
ALL ELEVATIONS ARE IN FEET AND REFER TO
MEAN LOW GULF (MLG) UNLESS OTHERWISE
SPECIFIED.
THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005
LIGHT LOCATIONS UPDATED ON 27 JUN 2005
GAGE: SWEET BAY: 4.7 MLG
FREQUENCY: HIGH FREQUENCY
DATE OF LAST SURVEY: 27 OCT 2011
SURVEY CONDITION: CALM
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'
HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
17 APR 2012
Atchafalaya River
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
RUN BY: ATO
BOAT NAME: M/V TECHE
TECHNICIAN: HOSHMAN
DWG. 1 OF 1
CADD FILE: 83CBCUT.DGN
FILE NO.


SHELL ISLAND
LEGEND
-15 AND ABOVE
-15 TO -20
-20 AND BELOW
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).
ALL ELEVATIONS ARE IN FEET AND REFER TO MEAN LOW GULF (MLG) UNLESS OTHERWISE SPECIFIED.
THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005
LIGHT LOCATIONS UPDATED ON 27 JUN 2005
GAGE: AVOCA: 3.7 MLG
FREQUENCY:
DATE OF LAST SURVEY: 17 APR 2012
SURVEY CONDITION: CALM
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'
HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
06 AUG 2012
Atchafalaya River
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
RUN BY: ATO
BOAT NAME: M/V BURRWOOD
TECHNICIAN: RYLAND
DWG. 1 OF 1
CADD FILE: 83CBCUT.DGN
FILE NO.


SHELL ISLAND
GREEN BUOY
RED BUOY
LEGEND
-15 AND ABOVE
-15 TO -20
-20 AND BELOW
29° 33' 0''
29° 32' 30''
29° 32' 0''
29° 31' 30''
29° 31' 0''
29° 30' 30''
29° 30' 0''
29° 29' 30''
29° 29' 0''
380,000
375,000
370,000
365,000
360,000
3,300,000
3,305,000
91° 17' 0''
91° 16' 30''
91° 16' 0''
91° 15' 30''
91° 15' 0''
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).
ALL ELEVATIONS ARE IN FEET AND REFER TO MEAN LOW GULF (MLG) UNLESS OTHERWISE SPECIFIED.
THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005
LIGHT LOCATIONS UPDATED ON 27 JUN 2005
GAGE: AVOCA: 4.2 MLG
FREQUENCY: LOW FREQUENCY
DATE OF LAST SURVEY: 06 AUG 2012
SURVEY CONDITION: CALM
HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
02 SEP 2012
Atchafalaya River
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
RUN BY: ATO
BOAT NAME: M/V BURRWOOD
TECHNICIAN: RYLAND
DWG. 1 OF 1
CADD FILE: 83CBCUT.DGN
FILE NO.


CURVE "D DATA
CURVE "D DATA
CURVE "D DATA
SHELL ISLAND
GREEN BUOY
RED BUOY
LEGEND
-15 AND ABOVE
-15 TO -20
-20 AND BELOW
29° 33' 0"
29° 32' 30"
29° 32' 0"
29° 31' 30"
29° 31' 0"
29° 30' 30"
29° 30' 0"
29° 29' 30"
29° 29' 0"
380,000
375,000
370,000
365,000
360,000
91° 17' 0"
91° 16' 30"
91° 16' 0"
91° 15' 30"
91° 15' 0"
3,305,000
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983
NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND
LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY
DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).
ALL ELEVATIONS ARE IN FEET AND REFER TO
MEAN LOW GULF (MLG) UNLESS OTHERWISE
SPECIFIED.
THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005
LIGHT LOCATIONS UPDATED ON 27 JUN 2005
GAGE: SWEETBAY LAKE: 4.3MLG
FREQUENCY:
DATE OF LAST SURVEY: 02 SEP 2012
SURVEY CONDITION: CALM
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'
HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
14 JAN 2013
Atchafalaya River
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
RUN BY: BTD
BOAT NAME: OB-189
TECHNICIAN: RYLAND
DWG. 1 OF 1
CADD FILE: 83CBCUT.DGN
FILE NO.


SHELL ISLAND
CURVE "D" DATA
LEGEND
-15 AND ABOVE
-15 TO -20
-20 AND BELOW
29° 33' 0"
29° 32' 30"
29° 32' 0"
29° 31' 30"
29° 31' 0"
29° 30' 30"
29° 30' 0"
29° 29' 30"
29° 29' 0"
380,000
375,000
370,000
365,000
360,000
GREEN BUOY
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983
NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND
LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY
DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).
ALL ELEVATIONS ARE IN FEET AND REFER TO
MEAN LOW GULF (MLG) UNLESS OTHERWISE
SPECIFIED.
THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005.
CREWBOAT CUT CHANNEL CREATED JAN 2013.
LIGHT LOCATIONS UPDATED ON 27 JUN 2005
GAGE: AVOCA ISLAND: 3.92 MLG
FREQUENCY:
DATE OF LAST SURVEY: 14 JAN 2013
SURVEY CONDITION: CALM
HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
19 MAR 2013
Atchafalaya River
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
RUN BY: BTD
BOAT NAME: OB-189
TECHNICIAN: HOSHMAN
DWG. 1 OF 1
CADD FILE: 83CBCUT.DGN
FILE NO.

CAUTION
SUBMARINE PIPELINES AND CABLES

Plotted submarine pipelines, submarine cables and submarine pipeline and cable areas are shown as:

Pipeline or Cable from As-built	Unconfirmed Pipeline or Cable	Pipeline or Cable Area Approximated from NOAA Charts

Additional unplotted submarine pipelines and submarine cables may exist within the area of this chart. Not all submarine pipelines and submarine cables are required to be buried, and those that were originally buried may have become exposed. Mariners should use extreme caution when operating vessels in depths of water comparable to their draft in areas where pipelines and cables may exist, and when anchoring, dragging, trawling, or dredging. The submarine pipelines and submarine cables plotted on this sheet are intended for U. S. Army Corps of Engineers' internal use. This agency accepts no responsibility for errors or omissions contained in this data. The accuracy of this data is, therefore, not guaranteed. Prudent mariners should not rely solely upon it.

NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).

ALL ELEVATIONS ARE IN FEET AND REFER TO MEAN LOW GULF (MLG) UNLESS OTHERWISE SPECIFIED.

THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005.
CREWBOAT CUT CHANNEL CREATED JAN 2013.

LIGHT LOCATIONS UPDATED ON 27 JUN 2005

GAGE: AVOCA ISLAND: 5.5 MLG
FREQUENCY:
DATE OF LAST SURVEY: 19 MAR 2013
SURVEY CONDITION: CALM

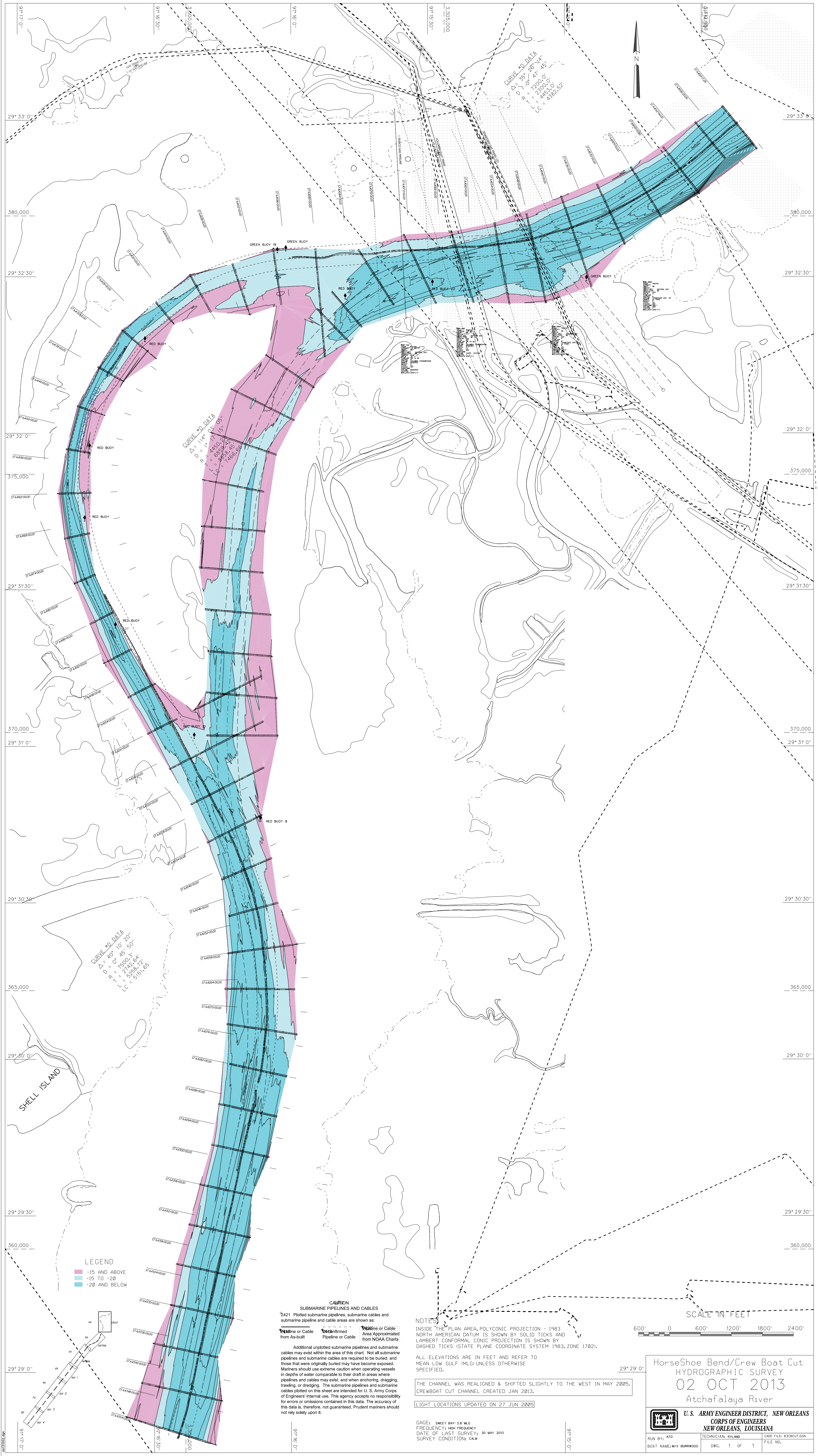
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'

29° 29' 0"
91° 16' 0"
91° 15' 0"

HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
30 MAY 2013
Atchafalaya River

U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA

RUN BY: BTD	TECHNICIAN: RYLAND	CADD FILE: 83CBCUT.DGN
BOAT NAME: M/V BURRWOOD	DWG. 1 OF 1	FILE NO.


CURVE #D DATA
Δ = 35° 26' 44"
D = 0° 47' 45"
R = 7200.0'
T = 2300.0'
L = 4453.0'
LC = 4382.52'
GREEN BUOY 19
GREEN BUOY
GREEN BUOY 1
RED BUOY
RED BUOY 8
TENNESSEE GAS TRANS. CO.
CURVE #D DATA
Δ = 114° 03' 05"
D = 1° 17' 15"
R = 4450.2'
T = 6859.42
L = 8858.45'
LC = 7466.66'
CURVE #D DATA
Δ = 40° 10' 20"
D = 0° 45' 50"
R = 7500.3'
T = 2742.64'
L = 5258.72'
LC = 5151.65
SHELL ISLAND
29° 33' 0"
29° 32' 30"
29° 32' 0"
29° 31' 30"
29° 31' 0"
29° 30' 30"
29° 30' 0"
29° 29' 30"
29° 29' 0"
380,000
375,000
370,000
365,000
360,000
3,300,000
3,305,000
91° 17' 0"
91° 16' 30"
91° 16' 0"
91° 15' 30"
91° 15' 0"
91° 14' 30"
N
LEGEND
-15 AND ABOVE
-15 TO -20
-20 AND BELOW
CAUTION
SUBMARINE PIPELINES AND CABLES
2421 Plotted submarine pipelines, submarine cables and submarine pipeline and cable areas are shown as:
Pipeline or Cable from As-built
Unconfirmed Pipeline or Cable
Pipeline or Cable Area Approximated from NOAA Charts
Additional unplotted submarine pipelines and submarine cables may exist within the area of this chart. Not all submarine pipelines and submarine cables are required to be buried, and those that were originally buried may have become exposed. Mariners should use extreme caution when operating vessels in depths of water comparable to their draft in areas where pipelines and cables may exist, and when anchoring, dragging, trawling, or dredging. The submarine pipelines and submarine cables plotted on this sheet are intended for U. S. Army Corps of Engineers' internal use. This agency accepts no responsibility for errors or omissions contained in this data. The accuracy of this data is, therefore, not guaranteed. Prudent mariners should not rely solely upon it.
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION - 1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS AND LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS (STATE PLANE COORDINATE SYSTEM 1983, ZONE 1702).
ALL ELEVATIONS ARE IN FEET AND REFER TO MEAN LOW GULF (MLG) UNLESS OTHERWISE SPECIFIED.
THE CHANNEL WAS REALIGNED & SHIFTED SLIGHTLY TO THE WEST IN MAY 2005.
CREWBOAT CUT CHANNEL CREATED JAN 2013.
LIGHT LOCATIONS UPDATED ON 27 JUN 2005
GAGE: SWEET BAY: 3.8 MLG
FREQUENCY: HIGH FREQUENCY
DATE OF LAST SURVEY: 30 MAY 2013
SURVEY CONDITION: CALM
SCALE IN FEET
600' 0 600' 1200' 1800' 2400'
HorseShoe Bend/Crew Boat Cut
HYDROGRAPHIC SURVEY
02 OCT 2013
Atchafalaya River
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
RUN BY: ATO
BOAT NAME: M/V BURRWOOD
TECHNICIAN: RYLAND
DWG. 1 OF 1
CADD FILE: 83CBCUT.DGN
FILE NO.

Appendix D

Atchafalaya Discharge Records

APPENDIX D

ATCHAFALAYA RIVER - DISCHARGE RECORDS AT MORGAN CITY

Atchafalaya River - Discharge Record At Morgan City
and synthesized Discharge Record At Morgan City

Morgan City Discharge

A rating curve was developed for the Atchafalaya River at Morgan City (USGS 07831600) and the Mississippi River at Tarbert Landing (USACE 01100) (see Figure D-1). A synthetic 50-year daily discharge dataset was generated for the Atchafalaya River at Morgan City. Using this hydrograph and the rating curve, the historical hydrograph for the Atchafalaya River at Morgan City was synthesized. Figure D-1 shows the observed data in the top panel and the synthetic hydrograph overlaid on the observed hydrograph in the lower panel of Figure D-2.

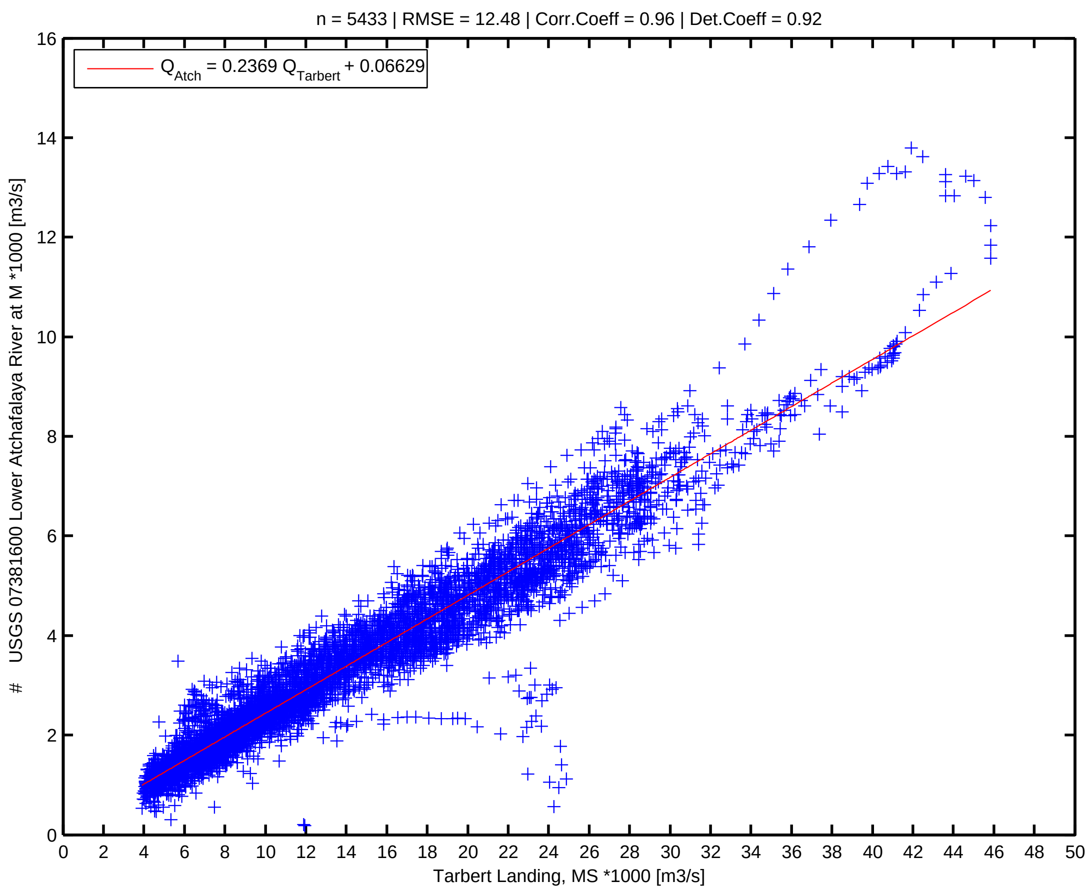


Figure D-1: Atchafalaya River at Morgan City and Mississippi River at Tarbert Landing rating curve

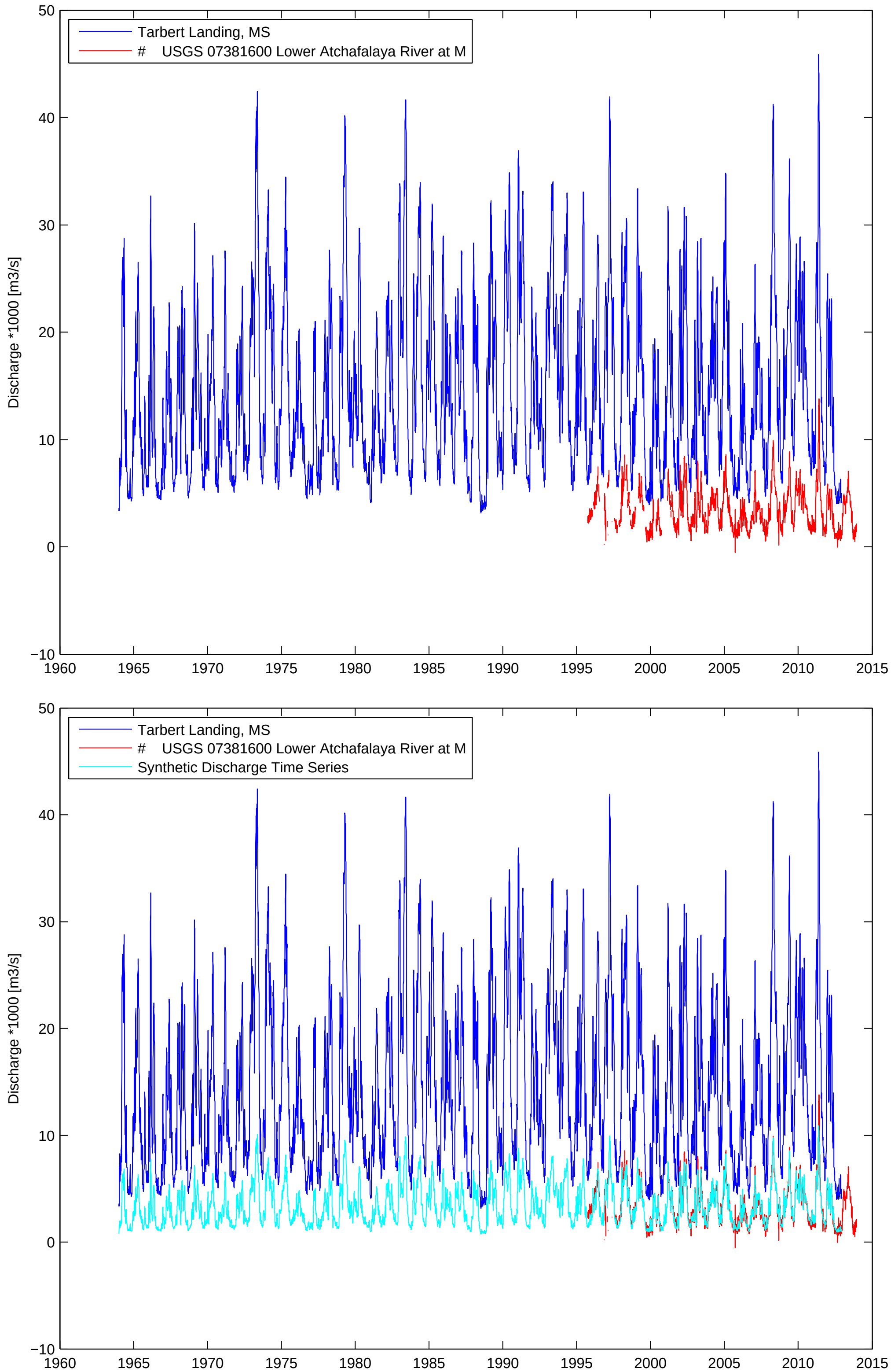


Figure D-2: Atchafalaya River at Morgan City (in red) and Mississippi River at Tarbert Landing discharge (in blue) in the top panel. Bottom panel shows the Synthesized record for the Atchafalaya River at Morgan City in cyan.

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