# Appendix A

# ENGINEERING

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# 1.0 INTRODUCTION

The engineering analysis of the Houma Navigation Channel Deepening Feasibility Study was conducted in accordance with Engineering Regulation (ER) 1110-2-1150, *Engineering and Design for Civil Works Projects*, 31 August 1999. This appendix summarizes the engineering, design, and cost evaluations of the project alternatives. Further details and data are available in Annexes I through VII.

## 1.1 Authorized Project Description

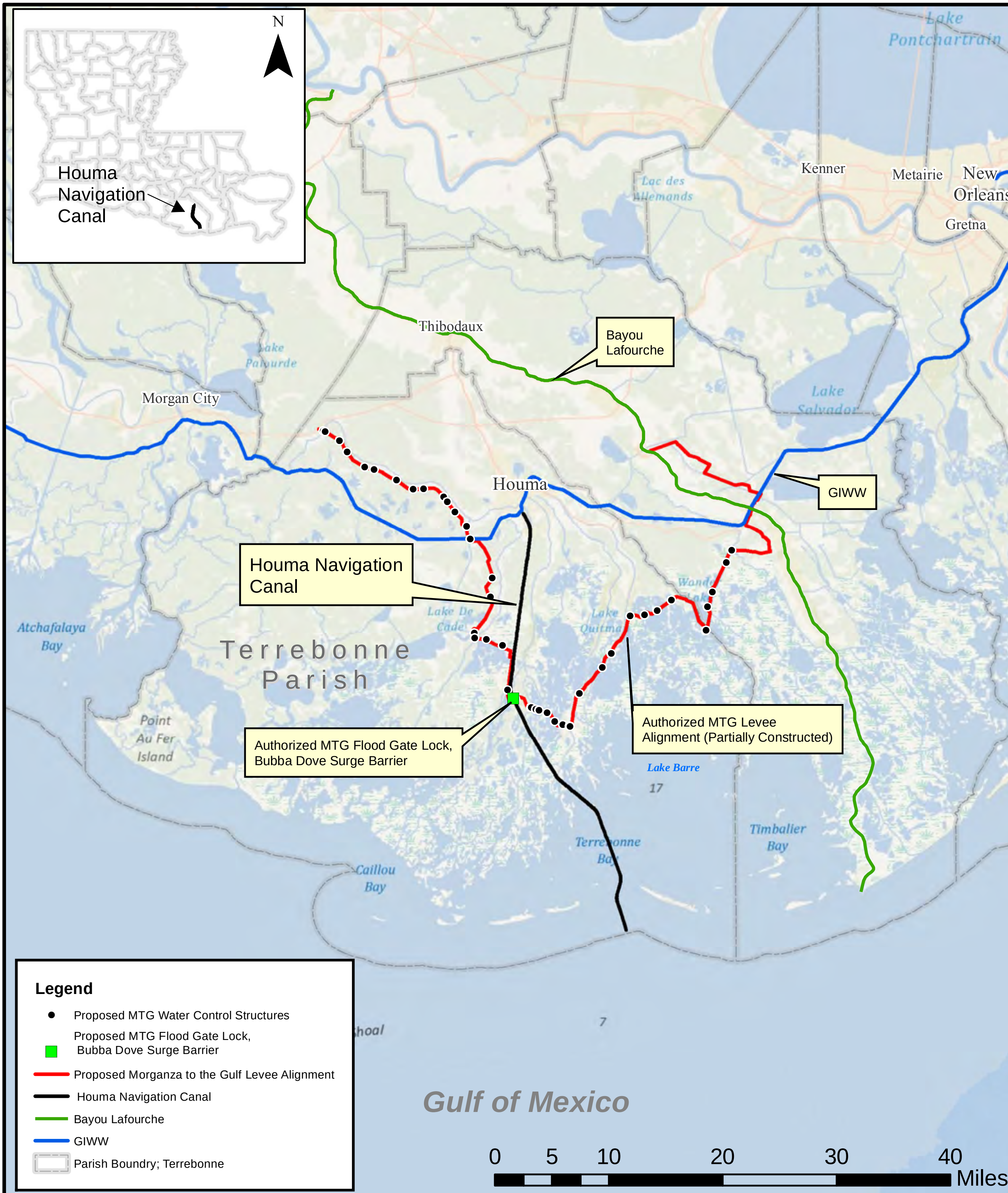
The Houma Navigation Canal (HNC) is located south of Houma, Louisiana in Terrebonne Parish (Figure A-1). It is approximately 39.8 miles long and generally runs north-south, connecting the Gulf Intracoastal Waterway (GIWW) with the Gulf of Mexico (Gulf). The channel is straight with a bank-to-bank width of approximately 920 feet at Mile 35.0 (Houma), opening to approximately 1,250 feet wide at Mile 10.5 (Cocodrie). The channel ends at approximately Mile −3.5, in the Gulf.

The HNC consists of three reaches, Inland Reach (Mile 36.3 to 10.1), Terrebonne Bay Reach (Mile 10.1 to 0.0), and Cat Island Pass Reach (Mile 0.0 to −3.5) (Figure A-2). The HNC is presently authorized to a −15 feet Mean Low Gulf (MLG) depth by 150 foot-wide channel, beginning at Mile 36.3, at the intersection of the HNC with the GIWW in Houma, proceeding southward through Terrebonne Bay Reach to Mile 0.0. The Cat Island Pass Reach is authorized to a depth of −18 feet MLG by 300 feet wide to the −18 feet MLG contour (approximately Mile −3.5).

Elevations in this report are referenced to NAVD88 (2004.65) unless otherwise noted. The relationship between datums NAVD88 (2004.65), NGVD29, and MLG was determined using stream data from CEMVN gage 76315 (Bayou Petit Caillou North of Cocodrie, LA). NAVD88 (2004.65) is 0.96 feet below NGVD29. The elevation of the MLG datum, as established by CEMVN, is 0.78 feet below MLG. The origin of the 0.78 feet is uncertain; however, it likely was based on the tidal range at Biloxi, Mississippi (National Atmospheric and Atmospheric Administration (NOAA) gage 8743735) (USACE 2007). The NAVD88 (2004.65) datum is 0.96 feet below the NGVD29 datum and the MLG datum is 0.78 feet below NGVD29 datum; therefore, the NAVD88 (2004.65) datum is 0.18 feet below the MLG datum. The current authorized elevation of the HNC is −15 feet MLG for the Inland and Terrebonne Bay Reaches and −18 feet MLG for the Cat Island Pass Reach.

## 1.2 Relationship to Other Projects

The Morganza to the Gulf of Mexico, Louisiana Project (MTG) is integral to the planning process for the HNC Deepening Project. MTG was authorized for construction by Section 1001(24) of the Water Resources and Development Act (WRDA) 2007 and is intended to provide a one percent Annual Exceedance Probability (AEP) storm surge risk reduction (100-year storm).




# VICINITY MAP

Houma Navigation Canal Deepening

*ERSI Ocean Map*

GEC

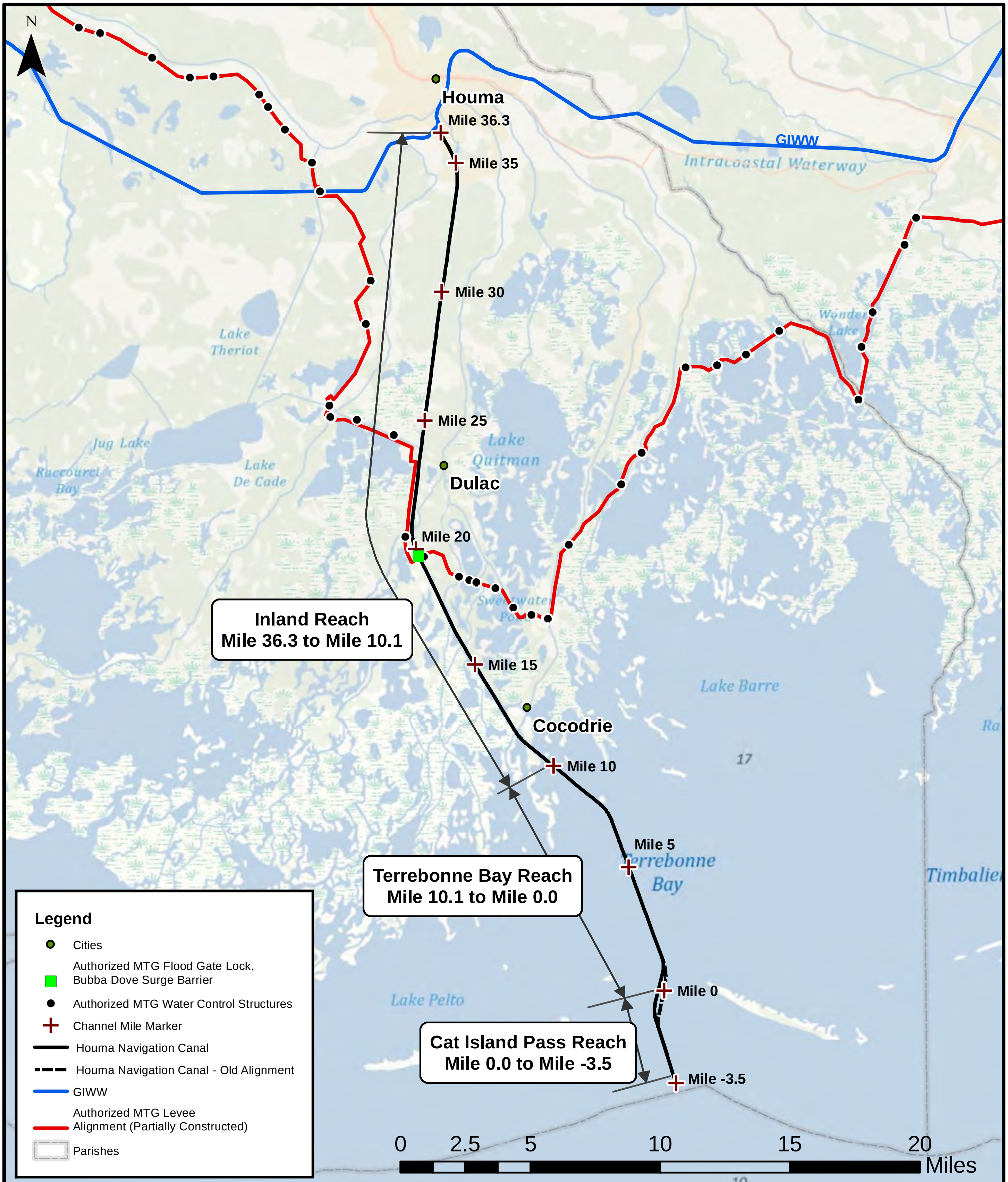
Figure A-1

Date: October 2012

Scale:1:750,000

Source: ESRI/GEC

Map ID: 278500218-3026




# HNC REACHES

Houma Navigation Canal Deepening

*ERSI Ocean Map*

GEC

Figure A-2

Date: September 2012

Scale:1:325,000

Source: ESRI/GEC

Map ID: 278500218-3026

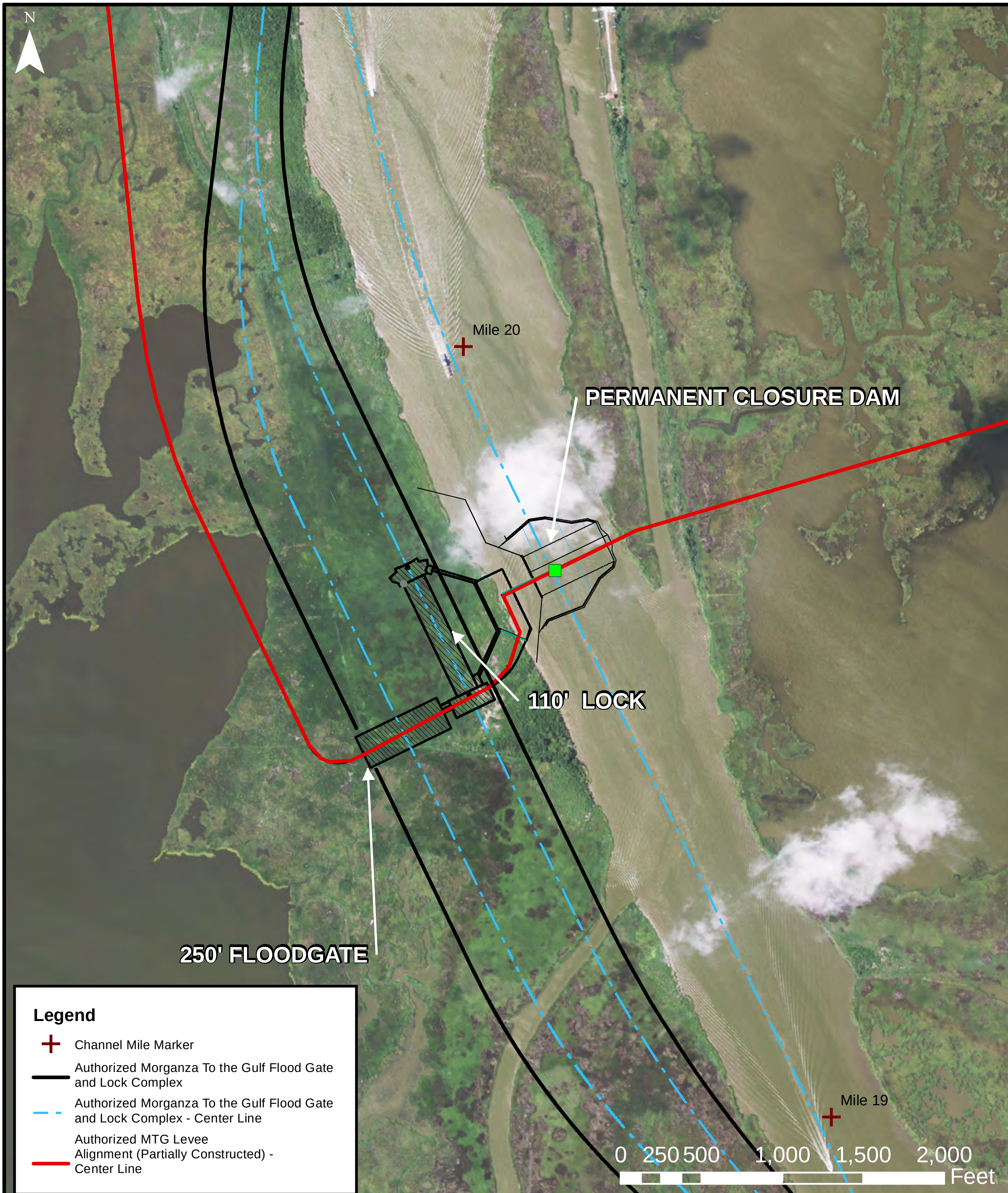
Coastal communities in Lafourche and Terrebonne Parishes are increasingly susceptible to storm surge, which is exacerbated by wetland loss, sea level rise, and subsidence. The MTG Federal Plan would construct 98 miles of levees, 23 environmental water control structures, and 22 navigable structures, including the HNC floodgate and lock complex (Figures A-1 to A-3). The floodgate and lock complex would be located south of Dulac and would consist of a 110-foot by 800-foot lock, an adjacent 250 foot-wide sector gate, and a dam closure tying into adjacent earthen levees to reduce the risk of storm surge traveling up the HNC.

The authorized MTG project estimates were based on pre-Hurricane Katrina standards and costs. As a result of post-Katrina changes in design standards, the authorized project elevations are less than necessary to provide a current (post-Katrina) one percent design level. A Post Authorization Change Report (PAC) was developed to update project designs, costs, and post-Katrina benefits resulting from changes to levee standards to revalidate the Federal interest. The Record of Decision (ROD) for the PAC/RPEIS was signed on December 9, 2013 and the PAC project is included in the WRDA 2013 currently before Congress.

Concurrent with the development of the MTG PAC, the navigation industry and the three non-Federal sponsors of this study [Louisiana Department of Transportation and Development (LADOTD), Terrebonne Parish Consolidated Government (TPCG), and Terrebonne Port Commission (TPC)] have expressed concerns about designing the HNC floodgate and lock complex in order to accommodate future traffic and growth on the HNC. Any changes in the authorized depth of the HNC would affect the HNC lock sill elevation. However, until the HNC Deepening Project (this study) is completed and a Federal navigation channel deepening project is recommended and authorized, there is no Federal interest in deepening the sill. The MTG PAC went to public review before this study could be authorized. A sill constructed at −18 feet (−15 feet MLG authorized depth), could preclude the HNC deepening project and the project would likely not be economically justified.

The MTG PAC included the implementation of a sponsor-funded additional work item to build the lock sill to −23 feet, instead of −18 feet, to accommodate a navigational depth of −20 feet instead of −15 feet MLG. This would alleviate the necessity of reconstructing the lock should this project be authorized and funded. To avoid precluding the future deepening of the HNC, the Louisiana Coastal Protection and Restoration Authority (CPRA) requested that the U.S. Army Corps of Engineers (USACE) proceed with the MTG PAC including the −23 ft NAVD88 sill as an additional sponsor-funded work item. The CPRA had initially agreed to pay for the full incremental cost of the work item above the Federal Plan costs. However, the HNC lock complex is a key component of the MTG Project, Increase Atchafalaya Flow to East Terrebonne Project, and this deepening project. The CPRA is planning to construct the lock complex (TE-113) for flood control, salinity control, freshwater distribution, and navigation. The structure would stay closed except for navigation purposes.

Since 2008, the Terrebonne Levee and Conservation District (TLCD), in cooperation with Terrebonne Parish Government, Lafourche Parish Government and the State of Louisiana, are proceeding with design and construction of the first lift of levee segments, floodgates and the




**Authorized Morganza To the Gulf Flood Gate and Lock Complex**

Houma Navigation Canal Deepening

*ERSI Basemap - Bing Map Hybrid*

GEC

| |
|---|
| Figure A-3 |
| Date: August 2012 |
| Scale:1:10,000 |
| Source: ESRI/GEC |
| Map ID: 278500218-3026 |

HNC lock along the MTG Hurricane Protection Project alignment. One of the floodgates, the HNC Bubba Dove surge barrier south of Dulac was completed in 2013. The floodgate is 42-feet high (including 13-foot flood walls), 273-feet long, and 60-feet wide and will remain open most of the time. The floodgate will be swung shut and filled with water to sink it in place during flooding or major storms. The Bubba Dove floodgate is located in the existing HNC channel along the Morganza to the Gulf Hurricane Protection Project alignment and was designed to provide interim protection until the lock is constructed.

## 2.0 ALTERNATIVES

### 2.1 Management Measures

Management measures included channel depths, dredged material placement locations, dredged material containment features (Figure A-4), and foreshore protection. Measures were designed to make the HNC a more efficient navigation channel. Measures considered were:

**Depth Options:**

- **Measure 1 (M1) –** 18-foot channel, −18 feet NAVD88
- **Measure 2 (M2)** – 20-foot channel, –20 feet NAVD88

**Disposal Options:**

- **Measure 3 (M3) –** Adjacent semi-confined disposal in the Inland Reach for material dredged from Miles 36.3 to 11.0. Existing land features would be used in conjunction with minimal additional earthen and rock retention dikes to reduce the sloughing of dredged material back into the dredged channel.
- **Measure 4 (M4) –** Upland confined disposal (CDF) in uppermost reaches of the Inland Reach where there are no other practicable disposal areas.
- **Measure 5 (M5) –** Foreshore protection (erosion control) along Miles 36.3 to 11.0, as needed. These dikes would protect the existing HNC shoreline to prevent further land loss due to boat wakes.
- **Measure 6 (M6)** – Adjacent Disposal [Single Point Discharge (SPD)]. Unconfined open water discharge into Terrebonne Bay and the HNC Ocean Dredged Material Disposal Site (ODMDS) for dredged material from Miles 11 to −3.7 (Figure A-4).
- **Measure 7 (M7) –** Earthen Containment Cells within Lung. Confined cell with earthen dike constructed of in situ material (Figure A-4). Slurry would be pumped into individual cells for each O&M Cycle (over a 2-year interval). Disposal of dredged material from Miles 11.0 to 1.5 for marsh creation (beneficial use) into lungs with earthen containment dikes. Material from Miles 11.0 to 5.0 would be placed in a lung on the north side of

Terrebonne Bay; material from Miles 5.0 to 1.5 would be placed in a lung on the bay side of East Island.

- **Measure 8 (M8)** – Rock Containment Cells within Lung. Individual cells confined within rock containment (Figure A-4). Slurry would be pumped into individual cells confined with internal cell dikes. Disposal of dredged material from Miles 11.0 to 1.5 into lungs (disposal areas) with rock containment dikes for marsh creation (beneficial use). Material from Miles 11.0 to 5.0 would be placed in a lung on the north side of Terrebonne Bay and material from Miles 5.0 to 1.5 would be placed in a lung on the bay side of East Island.

- **Measure 9 (M9) –** Beach Nourishment. Placement of dredged material from Miles 1.5 to −3.7 (to Mile −3.5 for the 18-foot channel) on the Gulf side of East Island to enable the material to be distributed by currents to nourish the existing beach.

- **Measure 10 (M10)** – Unconfined within Lung. Open water disposal on the bay side of East Island and lung on north side of Terrebonne Bay with no confinement (Figure A-4). This would be for the dredged material from Miles 11 to 1.5.

- **Measure 11 (M11)** – Internal earthen cells within a lung confined with a perimeter rock or earthen dike. Material from Miles 11.0 to 5.0 would be placed in a lung on the north side of Terrebonne Bay; material from Miles 5.0 to 1.5 would be placed in a lung on the bay side of East Island.

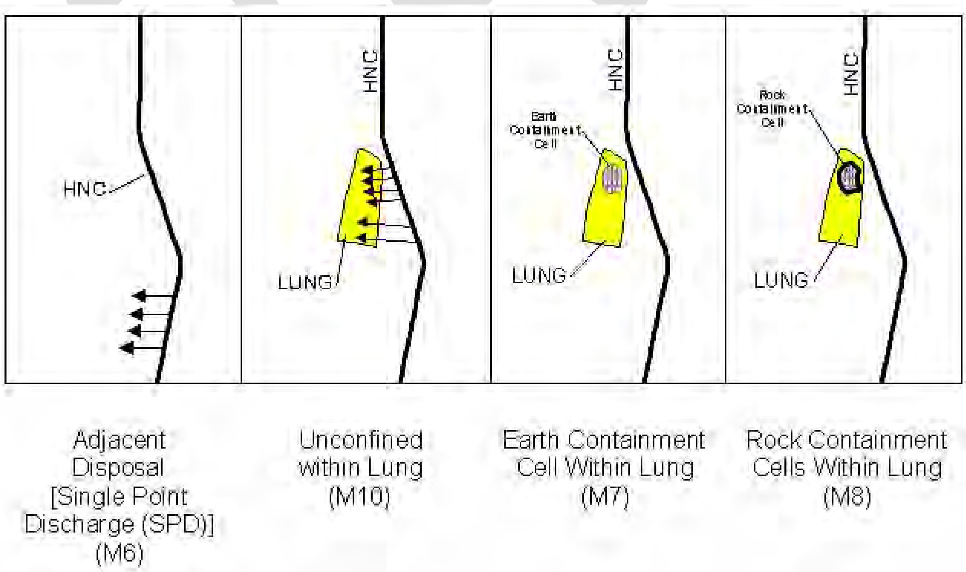



**Figure A-4. Schematic of Terrebonne Bay and Cat Island Pass Disposal Measures**

Measure 10 was eliminated from further consideration because pumping the dredged material to these locations, with no beneficial use of the dredged material, would not be beneficial or cost effective.

Measure 11 was eliminated from further consideration because constructing and maintaining the dikes around the entire lung perimeter for the 50-year period of study could pose a threat to navigation safety (in the case of rock dikes), would require maintenance over the life of the project.

All other measures were retained for alternative formulation.

## 2.2 Alternatives

The No Action Alternative would be continued maintenance dredging of the existing channel. Combinations of the two depths and the seven remaining measures were used to formulate six deepening alternatives for further evaluation (Table A-1). The measures (M3, M4, and M5) for the Inland Reach (Miles 36.3 to 11.0) are the same for all alternatives, including no action; all alternatives would construct 4.0 miles of retention dikes in the inland reach to retain dredged material in disposal areas.

All alternatives, excluding no action, would construct or refurbish foreshore protection and rock retention to reduce bank erosion in locations along both banks from Miles 27.6 to 11.9. A total of 9.9 miles of foreshore protection would be constructed.

The main difference between the deepening alternatives is the disposal options for Miles 11.0 to −3.7 (adjacent disposal, earthen containment, rock containment, and beach nourishment). The No Action Alternative and Alternatives 1A and 2A would use adjacent disposal; Alternatives 1B and 2B would place material beneficially within earthen retention dikes; and Alternatives 1C and 2C would place material beneficially within rock retention dikes.

Beneficial use disposal options (see Section 2.1), would pump material excavated from the Terrebonne Bay Reach (Mile 10.1 to 1.5) into a containment area (Lung) on the north side of Terrebonne Bay (near Mile 10.0) and on the bay side of East Island for marsh creation. Dredged material from Mile 1.5 to 0.0 would be placed at a nearshore disposal location on the Gulf side of East Island. Material excavated within the Cat Island Pass Bar Channel would be placed at a nearshore disposal location on the Gulf side of East Island to serve as a feeder for adjacent barrier island systems.

**Table A-1. Final Array of Alternatives Considered for Detailed Study**

| Alternative | | Channel Depth (ft) | Dredging Depth: All Reaches | | Disposal and Foreshore Protection Measures: Inland Reach, Miles 36.3 to 11.0 | | | Terrebonne Bay and Cat Island Pass, Miles 11.0 to −3.5[2] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10[1] | M11[2] |
| No Action | 15-foot, Adjacent Disposal | 15 | | | √ | √ | | √ | | | | | |
| 1A | 18-foot, Adjacent Disposal | 18 | √ | | √ | √ | √ | √ | | | | | |
| 1B | 18-foot, Earthen Containment | 18 | √ | | √ | √ | √ | | √ | | √ | | √ |
| 1C | 18-foot, Rock Containment | 18 | √ | | √ | √ | √ | | | √ | √ | | √ |
| 2A | 20-foot, Adjacent Disposal | 20 | | √ | √ | √ | √ | √ | | | | | |
| 2B | 20-foot, Earthen Containment | 20 | | √ | √ | √ | √ | | √ | | √ | | √ |
| 2C | 20-foot, Rock Containment | 20 | | √ | √ | √ | √ | | | √ | √ | | √ |

[1]Measures eliminated; [2]−3.7 for 20-foot alternatives

## 2.3 Value Engineering

A Value Engineering study (VE) (Annex IX) was conducted during April 2002, and the VE report was released in May 2002. The speculation phase suggested 84 alternatives. During the analysis phase, 61 alternatives were eliminated because they did not survive critical analysis. Eight of the remaining alternatives were developed as proposals. Additionally, the VE Team commented on the remaining 15 alternatives and identified them as items of interest. The VE study proposed several methods of reducing the cost of the project, but did not suggest any new alternatives. The proposals and follow-up responses are summarized below:

**C1 - Optimize Non-Dredging Rock**. The VE study proposed eliminating the rock dikes for foreshore protection as an alternative. It was questioned as to whether the project would actually exacerbate the current erosion and therefore was a questionable project cost. Study findings indicate major concern from increased in erosion as a result of more frequent boat wakes from increases in traffic expected with the project. Additionally, the HNC project would have to mitigate for any future land loss that could be attributed to the deepening. An analysis indicated that foreshore protection was less expensive than mitigating the land loss (see Section 6.2.4). Foreshore protection using earth dikes is being considered as an alternative in adherence to the Environmental Operating Principles and for consistency with Coast 2050.

**C2 - Consider Geotubes in Lieu of Rock Below Mile 18**. The use of geotubes below Mile 18.0 is an alternative for retention and containment of dredged material. The geotubes can be filled with dredged material and used as breakwaters and/or retention dikes. This design would require overfill of the tubes to allow for consolidation of the pumped fill and the foundation below the tubes. This is a relatively inexpensive option and geotubes are considered to be environmentally friendly. Geotubes were eliminated because they are not permanent due to wave energy in the area, including tropical storms and hurricanes. Other disadvantages to use of the geotubes are discussed in detail in Annex IX.

**C3 - Consider Vinyl Sheetpile Cells in Lieu of Rock below Mile 18**. Below Mile 18.0, retention walls can be constructed with cells of vinyl sheetpile, which are filled with dredged material. Vinyl sheetpile is relatively easy to install and would not corrode in the saltwater environment. Vinyl sheet pile long-term performance when exposed to sunlight is questionable. Vinyl sheetpile also does not create habitat like rock. Other disadvantages to use of vinly sheetpile geotubes are discussed in detail in Annex IX.

**C4 - Consider Revetted PVC Pipe Structures in Lieu of Rock Below Mile 18**. Revetted PVC pipe could be used below Mile 18.0. The revetted PVC pipe would provide for a relatively lightweight structure, thus minimizing settling. The pipe would be easy to install and would not corrode in the saltwater. The mat-sinking unit could potentially be retrofitted to install the PVC pipe. This idea was eliminated because it is an untested structure. Also, failure could release a large quantity of PVC pipes, which could become a navigation hazard. The disadvantages are discussed in more detail in Annex IX.

**C5 - Eliminate Kidney-Shaped Island Work**. The containment structures are kidney-shaped cells built to contain dredged material. These cells were previously discussed as disposal sites for miles 10.1 to 0. The kidney-shaped cells would be built with rock. The backsides of the rock island/cells are designed with the crown one-foot lower than the front sides. This would allow for the dredge effluent to overflow towards the backsides and away from the HNC channel. Over time, the cells would become filled with emergent dredged material; shallow deltas are anticipated to develop along the backsides from the material allowed to overflow the backside of each rock island/cell. Kidney islands were removed from consideration due to the high cost and lack of environmental benefits. Observations at the Bay Channel Island and East Island disposal areas indicate this method of disposal does not show growth of emergent land.

**C6 - Eliminate Advanced Maintenance Dredging**. The VE study also proposed eliminating the advanced maintenance dredging. The Operations Division of CEMVN prefers that the advance maintenance dredging be included for future operations and maintenance purposes. This allows more time between maintenance dredging cycles which in the lower reaches is required every two to three years.

**C7 - Change Kidney-Shaped Island to Circle**. One alternative is to construct round cells in lieu of kidney-shaped cells. The advantage of a round cell is that less rock is used to encompass the same acreage. The kidney shape was proposed to reflect the shape of a natural island. The front part of the island would be a dune, with wetlands in the back part protected by the dune. This would be facilitated more by a kidney-shaped island as opposed to a round island. In any event, use of the kidney-shaped island or round island is not expected to result in emerging marsh habitat.

**C8 - Use Dustpans with Pipeline to Dredge Navigation Channel**. The VE study suggested using a dustpan dredge in lieu of a cutterhead dredge. Dustpan dredges can typically pump dredged material distances of only 800 to 900 feet. Dustpan dredges are also designed for the discharge pipeline to move along with the dredge as the dredge progresses upstream and downstream along the channel. The locations of the disposal sites within the inland reach of the HNC, as well as the disposal sites in Terrebonne Bay and Cat Island Pass, prohibit the use of standard dustpan dredges. Only one dustpan dredge has the capability to pump material farther than the standard 800 to 900 feet. Use of this dredge would result in a sole source contract, which is not in the best interest of the government. Therefore, a cutterhead dredge is recommended.

## 3.0 PHYSICAL ENVIRONMENT

### 3.1 Climate

The climate of the study area is subtropical, humid, with long, hot summers, and brief, mild winters. The climate is influenced largely by the amount of water surface in the immediate area and the proximity to the Gulf. Winds during the summer are generally from the south, bringing warm, moist air from the Gulf and periods of intense rainfall associated with thunderstorms. The growing season lasts 317 days (Muller and Fielding 1987; Sevier 1990). Snowfall is very infrequent in the area.

During the winter, extratropical storms pass through the area about every five days (Stone 2000). These continental fronts pass through the area from the northwest bringing alternating cold and warm air. Extratropical storms may be responsible for most of the variability in wind speed in observed the northern Gulf. Storms were generally characterized by strong southward winds; whereas the fair weather wind direction was primarily westerly (Stone 2000).

Hurricanes and tropical storms can occur in Louisiana from June through November, but are most likely from July to September (Muller and Fielding 1987). On average, since 1871, a tropical storm or hurricane can be expected somewhere within Louisiana every 1.2 years, and a hurricane makes landfall about every 2.8 years (Stone *et al.* 1997). These storms can bring periods of intense rainfall and wind accompanied by storm surges from the Gulf. The hurricane storm surge, a dome of water near the center of the storm, is generally the major component of destruction to coastal areas.

### 3.1.1 Air Temperature

The normal temperature in Houma, LA was 69.0 degrees Fahrenheit (°F) from 1971 to 2000; mean monthly temperatures during this period varied from 82.5°F in July to 53.1°F in January (Table A-2). The Houma station recorded a maximum temperature of 101°F on August 31, 2000 and a minimum of 10°F on December 23, 1989 during that period.

**Table A-2. Monthly Normal Temperatures (°F) from 1971 to 2000 in Houma, Louisiana**

| JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 53.1 | 56.2 | 62.7 | 68.4 | 75.8 | 80.7 | 82.5 | 82.3 | 78.9 | 69.9 | 62.1 | 55.4 |

Source: National Climatic Data Center

### 3.1.2 Precipitation

Houma, Louisiana had an annual average of 63.67 inches of rain from 1971 to 2000; the record monthly rainfall during this period was 20.84 inches in May 1991. July was the wettest month averaging 7.85 inches, and October was the driest month with 3.11 inches (Table A-3).

**Table A-3. Average Precipitation from 1971 to 2000 in Houma, Louisiana**

| JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.4 | 4.6 | 5.0 | 4.5 | 5.45 | 6.0 | 7.8 | 6.7 | 6.3 | 3.1 | 4.6 | 4.4 |

Source: National Climatic Data Center.

### 3.1.3 Wind

The average wind velocity at the Grand Isle, Louisiana C-Man Station (GDIL1) and the New Orleans Airport from 1962 to 2002 was 8.3 miles per hour (mph). Northeast winds were predominant during September through February, while southeast winds prevailed from March to June. Higher winds, which can reach speeds greater than 120 mph, are associated with tropical storms.

### 3.1.4 Visibility

Fog forms near the study area when low water temperatures, warm air temperatures, and high dew points meet. Water temperatures are relatively warm in the fall and early winter and conversely colder in the late winter and spring. The fog potential is higher over land relative to water in the fall and over water surfaces in the spring. Nearly all fog around the HNC is associated with the surrounding water surfaces and wetlands, which generally occurs in late fall and early spring. The area is also vulnerable to sea fog, which occurs occasionally during late fall and early spring.

### 3.1.5 Storms and Floods of Record

The study area has experienced numerous floods from tides, hurricanes, tropical storms, and heavy rainfall. A description of significant storms and floods follows:

a. June 1957. Hurricane Audrey, June 25–28, 1957, caused tidal flooding along the Louisiana coast. A high stage of 8.05 ft NGVD at the Sweet Bay Lake gage in the Atchafalaya area and 3.29 ft NGVD at Grand Isle were recorded.

b. September 1961. Hurricane Carla, September 4–14, 1961, raised tides 3 to 4 feet above normal along the entire Louisiana coastline. A high stage of 4.6 ft NGVD at the Sweet Bay Lake gage and 4.04 ft NGVD at Leeville were recorded. A high stage of 3.15 ft NGVD was observed at the Houma gage on September 14, 1961.

c. October 1964. Hurricane Hilda, during the period of October 3–5, 1964, caused extensive tidal and headwater flooding in the area. Heavy rainfall and several tornadoes were generated by this storm. A high water mark of 5.5 ft NGVD occurred near the Sweet Bay Lake gage. High stages of 5.49 ft NGVD at the Leeville gage and 3.27 ft NGVD at the Houma gage were recorded on 4 October 1964.

d. September 1971. Hurricane Edith, September 5–17, 1971, had a stage of 4.26 ft NGVD at the Cocodrie gage and 3.52 ft NGVD at the Houma gage

e. 1973 Flood. Headwater from rainfall events caused flooding throughout the area during the spring of 1973.

f. September 1974. Hurricane Carmen, September 7–8, 1974, caused tidal and headwater flooding. A questionable high water mark of 11.67 ft NGVD was observed near the Cocodrie gage and high stages of 5.66 ft NGVD at the Leeville gage and 3.81 ft NGVD at the Houma gage were recorded.

g. September 1977. Hurricane Babe, September 3–9, 1977, a Category 1 storm, made landfall just west of the project area producing high stages and rainfall. High stages of 8.68 ft NGVD at the Cocodrie gage and 3.77 ft NGVD at the Houma gage were recorded.

h. August 1985. Hurricane Danny, August 12–20, 1985, was a minimal hurricane that produced high tides in the area. A high stage of 6.70 ft NGVD was recorded at the Eugene Island gage in the Atchafalaya Bay and 5.63 ft NGVD at the Grand Isle gage.

i. October 1985. The prolonged stay of Hurricane Juan during October 26–31, 1985 produced backwater flooding and high water levels throughout the area. A high stage of 5.05 ft MLG was recorded at the Belle Isle gage near the mouth of the Atchafalaya River, 7.39 ft NGVD at the Cocodrie gage, 6.62 ft NGVD at the Leeville gage, and 5.63 ft NGVD at the Grand Isle gage. The storm surge propagated inland and a high stage of 5.17 ft NGVD was recorded at the Houma gage.

j. August 1992. Hurricane Andrew, August 24–27, 1992, caused flooding from high tides and heavy rains in the study area. High stages of 7.65 ft NGVD at the Deer Island gage near the mouth of the Atchafalaya River, 5.61 ft NGVD at the Leeville gage on Bayou Lafourche, and 3.54 ft NGVD at Grand Isle were recorded.

k. July 1997. Hurricane Danny, July 16–27, 1997, a Category 1 storm that originated in the northern Gulf produced a stage of 4 ft NGVD at Barataria Pass.

l. June 2001. Tropical Storm Allison, June 4–12, 2001, produced heavy rains in the study area. Stages above 3 ft persisted for several weeks along the lower Atchafalaya River producing backwater high stages throughout the project area

m. October 2002. Hurricane Lili, October 1–6, 2002, produced high stages of 8.0 ft NGVD at the Cocodrie gage, 6.05 ft at the Golden Meadow gage, 5.01 ft at the USGS gage at Barataria Pass on October 3, 2002, and a stage of 4.09 ft NGVD at the Houma gage on October 4, 2002.

n. September 2005. Hurricane Katrina, August 23–31, 2005, crossed the Mississippi River east of the study area. A high stage of 8.53 ft was recorded at the USGS gage at Barataria Pass. High stages in the study area were considerably lower because winds to the west of the storm were generally offshore.

o. September 2005. Hurricane Rita, September 18–26, 2005, produced very high stages throughout southern Louisiana, particularly in western Louisiana. A peak stage of 10.1 ft

NGVD was recorded at the Eugene Island gage in Atchafalaya Bay and 6.95 ft NAVD88 at the USGS gage at Caillou Lake southwest of Dulac.

p. September 2008. Hurricane Gustav, August 25–September 5, 2008, came ashore east of the project area but still produced high stages of 4.76 ft NGVD at Sweet Bay Lake on the lower Atchafalaya River and 3.57 ft NGVD at Houma.

q. September 2008. Hurricane Ike, September 1–15, 2008, produced high stages throughout coastal Louisiana. High stages of 7.72 ft NGVD at Sweet Bay Lake and 6.33 ft NGVD at Golden Meadow were recorded.

r. August 2012. Hurricane Isaac, August 29–30, 2012, crossed the HNC near Dulac, Louisiana. A high stage of 8.88 feet was recorded at the USGS gage at the Rigolets near Slidell, LA. High stages in the study area were considerably lower. A high stage of 4.08 ft was recorded at the USGS gage Caillou Lake (Sister Lake) southwest of Dulac.

Numerous tropical storms have also passed through or near the project area, raising stages by several feet and producing significant rainfall. Some of these storms include:

- Tropical Storm Bertha in August 1957
- Tropical Storm Esther in September 1957
- Tropical Storm Arlene in May 1959
- Tropical Storm Felice in September 1970
- Tropical Storm Frances and Tropical Storm Hermine in September 1998
- Tropical Storm Bertha in August 2002,
- Tropical Storm Isidore in September 2002
- Tropical Storm Bill in June 2003
- Hurricane Ivan made a second approach to the northern Gulf shoreline as a tropical storm on September 23-24 2004
- Tropical Storm Mathew in October 2004
- Tropical Storm Edouard in August 2008
- Tropical Storm Lee in September 2010

## 3.2 Existing Hydrodynamic Regime

### 3.2.1 Tides and Currents

Tides in the study area are diurnal with mean ranges of about 0.2 feet at the GIWW tidal gauge at Houma and 1.2 feet at Bayou Petit Caillou at Cocodrie. Spring tidal ranges at the Cocodrie station can be more than 2 feet and neap tidal ranges can be less than 0.5 foot. The tidal amplitude decreases inland. Water levels around Wine Island and the adjacent barrier islands are primarily controlled by tides and winds. Wave action, freshwater runoff, and atmospheric pressure also contribute to water levels. Water levels can be affected by natural events such as hurricanes and winter storms. Hurricanes can raise the water level by 12 feet or more; whereas, northerly winter winds can depress nearshore water levels by more than 3 feet.

The Louisiana inner shelf is a low-energy environment where significant hydrodynamic activity is generated almost exclusively by local tropical and extratropical storms. Circulation of coastal waters depends on driving forces such as tides, wind, and atmospheric pressure. Additional circulation mechanisms include high rainfall, large volumes of fresh water from the Mississippi and Atchafalaya Rivers, currents induced by density differences and mixing processes between fresh and saltwater masses, local shoreline and bathymetric features such as the mouth of the Mississippi River, barrier islands, marshes, inlets, and bays. Much of the tidal exchange between the back-barrier areas of Caillou Bay, Terrebonne Bay, and Timbalier Bay and the Gulf of Mexico occurs through broad shallow channels; however, there are several relatively deep (20 to 33-ft) passes maintained by relatively strong tidal currents (3.3 ft/s). Wind and barometric pressure induced circulation is important in the bays, lakes, marshes, and subtidal areas and can result in extreme water level fluctuations.

### 3.2.2 Salinity

Salinities in the HNC grade from predominantly fresh water in the interior to seawater in the Gulf. Daily variations in salinity occur due to tidal flow and at greater intervals due to meteorological and seasonal factors. Winter frontal systems and tropical storms can create wind-driven tides which may substantially change water levels in the shallow estuary. Flows in the Mississippi and Atchafalaya Rivers also vary seasonally, affecting salinities in the area.

Salinity fluctuations due to tidal flow and winter frontal systems at the Cocodrie gage are shown in Figure A-5. The graph is from the hourly record for the USACE gage (76305) at Bayou Petit Caillou at Cocodrie during January 2001. During the first 5 to 7 days, there was a daily salinity fluctuation of about 1 part per thousand (ppt); subsequent fluctuations of 3 to 4 ppt occurred every 3 to 4 days. Although these fluctuations are significantly greater than the fluctuations due to tidal flow, the tidal influence can still be discerned.

Variations in the flow of the Mississippi and Atchafalaya Rivers create salinity changes on a greater time scale and can induce larger changes in salinity levels in the project area. Large river discharges can greatly reduce offshore salinities in the project area. Considerable quantities of fresh water during large discharges from the Atchafalaya River flow eastward into the GIWW from Morgan City to Houma. Salinities can be reduced throughout the project area as waters enter the HNC and proceed toward the Gulf. Conversely, when the flow in these rivers is very low, salinity levels throughout the project area may substantially increase.

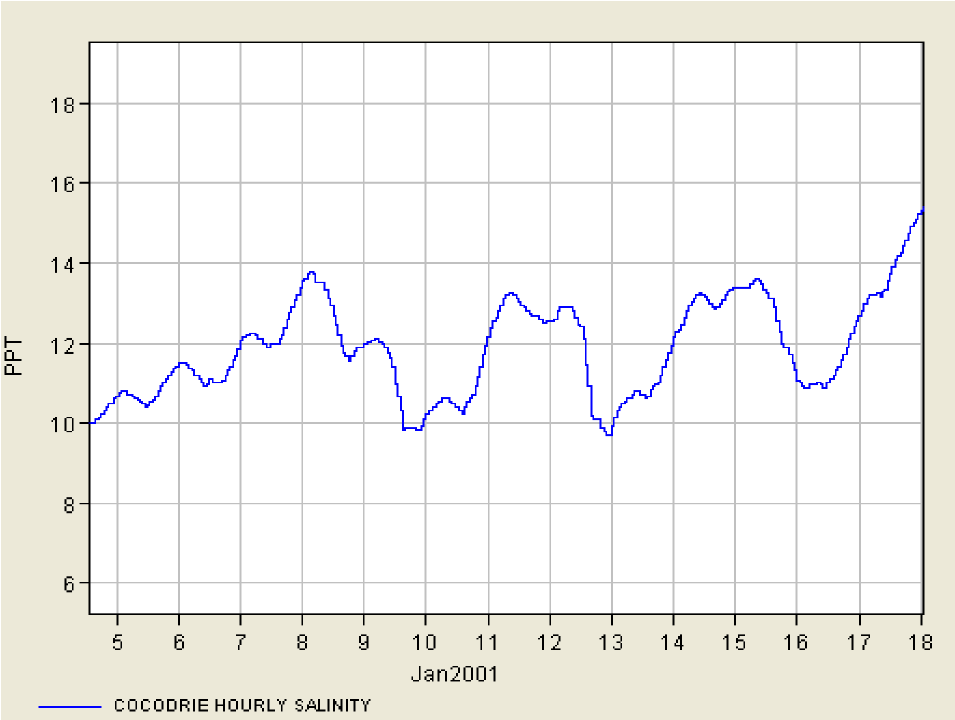



**Figure A-5. Typical Salinity Fluctuations at the Cocodrie Gage**

## 3.3 Hydrodynamic and Salinity Model

### 3.3.1 Purpose

A 3-dimensional (3D) numerical hydrodynamic and salinity model that included the HNC and its major tributaries and distributaries was used to assess the effects of the proposed HNC deepening from −15 ft MLG to −18 feet and −20 feet, respectively, with advanced maintenance. Modeling also evaluated the potential effects of the proposed HNC floodgate and lock complex. The main effects considered were the flow distribution and salinity intrusion. The model domain extended from the mouth of Bayou Lafourche in the east to Caillou Bay in the west. It included Terrebonne Bay, the HNC, the GIWW from the West Minors Canal gage to Grand Bayou, and includes all the major water bodies and channels within the area. The model extends into the Gulf to develop a suitable open-water boundary condition. A detailed description of the model domain, including maps, is contained in the modeling report in Annex I.

### 3.3.2 Model Selection

The USACE CH3D model was selected. CH3D is a time-varying 3D hydrodynamic and transport model based on a boundary-fitted curvilinear numerical grid. The 3D model was used because previous 2D models did not adequately simulate salinity stratification and baroclinic flow in the proposed deeper channel.

Deepening of the channel may allow heavier saltwater to travel up the HNC, thus introducing higher saline waters further inland more frequently than under existing conditions. This effect, if present, could change the ecology of the system. The depth-integrated (2D) model only models the flow field as an average of the depth of each cell. As such, this type of model is good at predicting tidal flows that dominate most of a tidal cycle but does not represent conditions that would include density-driven flow or flow reversals. The 2D model is not appropriate for systems where salinity intrusion may be an important aspect of the flow regime.

### 3.3.3 Grid Development, Boundary Conditions and Input Data

To develop the CH3D model, an existing RMA-2/4 model of the area was used as a starting point for the bathymetry of the grid. The CH3D grid was further refined using available CEMVN Operations Division survey data and NOAA Charts 11356 and 11357 for the offshore areas. Grid development is extensively discussed in Annex I. A *z-grid* version of CH3D, in which fixed vertical layers are defined and the water surface is only allowed to fluctuate in the surface layer, was used in the study. The model was developed using uniform 2-foot vertical layers.

Tide and salinity boundary conditions were imposed on the outer Gulf boundary. Tide information from NOAA and the U.S. Geological Survey (USGS) and salinity data from the Louisiana Universities Marine Consortium (LUMCON) were used.

Riverine flow conditions were provided by the Coastal and Hydraulics Laboratory, Engineer Research and Development Center (ERDC) using USGS data at three locations, the GIWW just west of Minors Canal, the GIWW at Larose just east of Bayou Lafourche, and on Bayou Lafourche at Thibodaux upstream of its confluence with Company Canal. ERDC processed available USGS stream flow gauge data at these locations (Figure A-6). Wind data from the West Bank, Bayou Gauche weather station near Houma and the USGS gauge in Caillou Bay were used.

Stream gage data was available at 10 stations in the project area (Figure A-6; Table A-4). Two stations are the USACE gages GIWW at Houma (7632007) and Bayou Petit Caillou at Cocodrie (7630507). The other gage sites in the immediate project area are the USGS gages Bayou Grand Caillou (BGC) at Dulac (07381324), HNC at Dulac (07381328), GIWW east of HNC at Houma (073813375), Caillou Lake (Sister Lake) SW of Dulac (07381349), Caillou Bay SW of Cocodrie (073813498), Bayou Lafourche at Thibodaux (07381000), GIWW at Minor's Canal (08090302), and GIWW at Larose (07381235).


# GAGE LOCATION MAP

Houma Navigation Canal Deepening

*ERSI Ocean Basemap*

GEC

Figure A-6

Date: August 2012

Scale:1:450,000

Source: ESRI/GEC

Map ID: 278500218-3026

**Table A-4. Summary Gage Data**

| Station | Period of Record | Maximum Stage (Feet NGVD) | Maximum Stage Date | Minimum Stage (Feet NGVD) | Minimum Stage Date |
|---|---|---|---|---|---|
| **USACE Gages** | | | | | |
| GIWW at Houma (7632007) | 1942–2011 | 5.17 | 10/29/85 | −0.8 | 12/24/89 |
| Bayou Petit Caillou at Cocodrie (7630507) | 1969–2011 | 11.67[a] | 1974 | −2.95 | 12/23/89 |
| **USGS Gages** | | | | | |
| Bayou Grand Caillou at Dulac (7381324) | 1987–2011 | 8.89[b] | 10/28/85 | c | c |
| Houma Navigation Canal at Dulac (7381328) | 1972–2011 | 7.17[b] | 09/12/08 | −1.42[b] | 01/08/96 |
| GIWW East of Houma (7381331) | 1999–2011 | 5.58[b] | 09/13/08 | −1.05[b] | 12/15/97 |
| Caillou Lake (Sister Lake) SW of Dulac (7381349) | 1997–2011 | 7.88[b] | 09/12/08 | −2.69[b] | 09/01/08 |
| Caillou Bay SW of Cocodrie (73813498) | 1999–2011 | 9.94[b] | 10/03/02 | −1.99[b] | 01/14/06 |
| Bayou Lafourche at Thibodaux (7381000) | 1996-2011 | 8.76[b] | 05/09/91 | −0.82[b] | 12/02/66 |
| GIWW at Minor's Canal[d] | 1999-2000 | – | – | – | – |
| GIWW West of Larose (7381235) | 2000–2011 | 5.04[b] | 09/13/08 | −0.45[b] | 01/13/11 |

[a]From watermark
[b]Datum of gage is NGVD 1988
[c]From incomplete record
[d]Discharge measurements

### 3.3.4 Model Calibration and Verification

September 13 to October 15, 2004 was selected for model calibration, and February 21, 2005 to March 22, 2005 was selected for model validation. The validation time frame correlated with a very wet period.

The results of the model calibration, verification, and sensitivity demonstrate that a great deal of uncertainty exists with this model formulation. Of greatest concern are model geometry and datum conversions. The team was forced to make assumptions in the geometry to *best fit* results with data. With the uncertainty of the model, the team simulated an entire year to determine whether the model adequately represented system processes except during wet periods.

The model generally matches observed water surface elevations and salinities, and the tidal variability is generally well produced. The model is useful for simulating current conditions (−15 feet MLG) and with project conditions during dry periods (periods with a low volume of freshwater inflow). The *dry* period generally occurs from August through October, when stages on the Mississippi and Atchafalaya Rivers are low. The model overestimates salinities during the *wet* periods. Freshwater inflow is a boundary condition of the model. The freshwater boundary condition may underestimate the volume of freshwater entering the GIWW from the lower Atchafalaya River during wet periods. Therefore, the study focused more on the salinity dynamics associated with *dry* periods rather than *wet* periods.

### 3.3.5 Model Results

The model is designed to assess the effects of a deeper HNC and operation of the HNC lock and floodgate complex on flow distribution and salinities throughout the study area. The model simulated an average year and a low flow month. Four areas of concern were assessed:

1. The effect on the flow distribution at the GIWW–HNC junction (near Houma) during low and high freshwater flow events.

2. The effect on the flow distribution at the BGC–HNC junction during low and high freshwater flow events
3. The effect on saltwater intrusion along the HNC, including its tributaries and distributaries
4. The operation of the HNC lock and floodgate complex on increased flow along BGC during low flow conditions

Alternatives simulated by the model are described in Table A-5. The alternative dredging depths analyzed reflect the currently authorized depth and the −18 and −20 foot scenarios with advanced maintenance depth.

**Table A-5. Alternatives Simulated by the CH3D Model**

| Alternative* | Lock Setup |
|---|---|
| Existing conditions | No Floodgate and Lock |
| Existing conditions | Floodgate Open, Lock Closed |
| Dredge to −20 ft | No Floodgate and Lock |
| Dredge to −20 ft | Floodgate Open, Lock Closed |
| Dredge to −20 ft | Floodgate Closed, Lock Open |
| Dredge to −22 ft | No Floodgate and Lock |
| Dredge to −22 ft | Floodgate Open, Lock Closed |
| Dredge to −22 ft | Floodgate Closed, Lock Open |

* Deepening alternatives include 2 feet of advanced maintenance

Flow distributions were examined at the GIWW–HNC and the HNC–BGC intersections. Each alternative slightly modifies the flow distribution near the City of Houma. The differences between with-project alternatives and existing conditions are presented using exceedance frequency distributions. The maximum increase in the 95 percent flow in the GIWW east of the HNC is 435 cubic feet per second (cfs), or about 18 percent of the existing value. The overall change in the frequency distribution can be calculated from the difference in the area under the frequency curve compared to the existing conditions curve. The maximum cumulative change of 11–14 percent occurs, as one would expect, for with-project alternatives that simulate the floodgate open. The cumulative change for other alternatives is less than 9 percent.

The effect of the various with-project alternatives on flows near the BGC–HNC confluence is more complex. South of the confluence, the effect of an alternative depends on whether the floodgate is open or closed. North of the confluence, in general, as the HNC is deepened, the magnitude of the peak tidal discharges generally also increases. Peak flow differences are as large as 27 percent, and cumulative changes in the frequency distributions may be 18-25 percent for with-project alternatives with the floodgate open. The cumulative change for other alternatives is less than 14 percent. In BGC, east of the confluence, the flows are generally small and the differences modest. In BGC just west of the confluence, maximum flood (positive) flows generally change by less than 8 percent, or up to 173 cfs. However, for the alternatives with the floodgate open, the ebb (negative) flows may increase up to 28 percent, or 636 cfs. For other alternatives, the ebb flows increase by less than 10 percent. Cumulative changes in the frequency distributions may be 18–21 percent for with-project alternatives with the floodgate open and less than 10 percent for other alternatives.

At Houma, near-surface salinities vary little between the alternatives and indicate west to east freshwater flows in the GIWW. However, cumulative changes in the frequency distributions may be large, with absolute changes up to 5 ppt. For channel deepening to −20 feet the maximum reported increase is 3.1 ppt with the floodgate open, but 1.1 ppt with only the lock open. However, channel deepening to −22 feet may increase salinities by 5.1 ppt with the floodgates open and by 3.7 ppt with only the lock open.

On the HNC at Dulac, near-surface and near-bottom salinities can increase up to 8.4 ppt. The major salinity increases are for with-project alternatives with the floodgate open. For these conditions, the cumulative change to the frequency distribution may be 70–90 percent with a maximum reported increase of 8.4 ppt; the difference is less than 25 percent (2.7 ppt) for other alternatives. The minimum change is 3.4 ppt for alternatives with the floodgate open, but only 0.1 ppt for other alternatives.

The salinities at the HNC–BGC confluence increase for the with-project alternatives with the floodgates open since there is a proportional increase in the ebb flow down and an increased flood flow of higher salinity water up the HNC. However, alternatives with the floodgate closed may decrease salinities up to 2.4 ppt (compared to the maximum increase of 8.7 ppt with the floodgates open).

In the Falgout Canal, salinities are very similar for all alternatives (Table A-6). The largest differences (1–1.5 ppt) were observed for the with-project alternatives with the floodgates open and the cumulative change in the frequency distribution may be 19–26 percent. The cumulative frequency change is less than 4 percent for other alternatives. During low flow months, operating the lock complex with the floodgates open will increase ebb flow down BGC. However, leaving the floodgates open will also increase salinities north of the lock complex.

#### 3.3.5.1 Salinity Management

The hydrodynamic and salinity model analysis shows reduced salinities in the HNC at the GIWW when the floodgates are closed and the lock is fully open (operating not as a lock but as an opening). This suggests the lock and floodgate could be operated to mitigate potential salinity increases due to the HNC deepening. The floodgates could be closed and vessel traffic could be routed through the lock during high salinity periods. During periods of prolonged southerly winds and tropical storms that would result in high salinities, the floodgate can be closed and vessel traffic could be routed through the operating lock structure. The lock and floodgate could also be operated in a manner to retain freshwater (e.g., maintain a freshwater head) to reduce saltwater intrusion.

### 3.4 Sea Level Rise

Estimates for RSLR are based on Engineering Circular (EC) 1165-2-212 *Sea-Level Change Considerations for Civil Works Projects, October 1, 2011*. According to the EC guidance, the RSLR is estimated for low (historic), intermediate, and high sea level rise scenarios. The low (historic) rate of RSLR is based on the USACE Gage (82350) Bayou Lafourche at Leeville, Louisiana. Historic RSLR is 7.79 mm/yr and the rate of subsidence is 6.09 mm/yr. The intermediate and high scenarios of RSLR use the eustatic sea level rise derived from the National Research Council equations NRC I (intermediate) and NRC III (high), and the subsidence rate computed from the Leeville gage. The USACE gage Bayou Lafourche at Leeville, Louisiana was used to compute the historic subsidence rate in the study area as approximately 2.0 feet/century. Estimates of low, intermediate, and high rates of RSLR are presented for the year that construction is expected to be completed (2027) and for the 50-year project life (2077) (Table A-7 and Figure A-7).

## Table A-6. Summary of Model Results

| | Exceedence at GIWW and HNC | Exceedence North of BGC and HNC | Exceedence West of BGC and HNC | Salinity at GIWW | Salinity at Dulac | Salinity at BGC | Salinity at Falgout Canal | Salinity at Caillou Lake | Exceedence at BGC and HNC |
|---|---|---|---|---|---|---|---|---|---|
| | Average Flow | Average Flow | Average Flow | Low Flow | Low Flow | Low Flow | Low Flow | Low Flow | Low Flow |
| | ISSUE 1 | ISSUE 2 | ISSUE 3 | | | | | | ISSUE 4 |
| **Existing Bathymetry (No lock)** | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Existing Bathymetry (Floodgate open, Lock closed)** | 8.2% | -7.2% | 20.8% | 8.0% | 71.6% | 74.1% | 19.4% | -4.0% | 21.0% |
| **20-ft Dredge Depth (No lock)** | 1.2% | 13.9% | -1.2% | 10.3% | 7.4% | 7.6% | 0.9% | -0.1% | -1.9% |
| **20-ft Dredge Depth (Floodgate open, lock closed)** | 10.8% | 4.1% | 19.9% | 45.6% | 79.7% | 75.5% | 23.8% | -4.1% | 20.0% |
| **20-ft Dredge Depth (Floodgate closed, lock open)** | 2.2% | 6.2% | 9.4% | 19.2% | 13.3% | 11.0% | 3.4% | -0.9% | 9.3% |
| **22-ft Dredge Depth (No lock)** | 5.0% | 25.2% | -3.1% | 50.0% | 23.7% | 18.0% | 0.3% | -0.3% | -2.1% |
| **22-ft Dredge Depth (Floodgate open, lock closed)** | 14.0% | 13.9% | 17.7% | 174.5% | 89.3% | 77.0% | 26.0% | -4.3% | 18.9% |
| **22-ft Dredge Depth (Floodgate closed, lock open)** | 5.6% | 17.9% | 7.9% | 59.6% | 25.5% | 17.4% | 1.5% | -1.2% | 7.3% |

**Table A-7. Relative Sea Level Rise**

| Scenarios | Construction Completed (2027) RSLR (feet) | Project Life 50 years (2077) RSLR (feet) |
|---|---|---|
| Low (historic) | 0.43 | 1.71 |
| Intermediate | 0.51 | 2.33 |
| High | 0.77 | 4.27 |

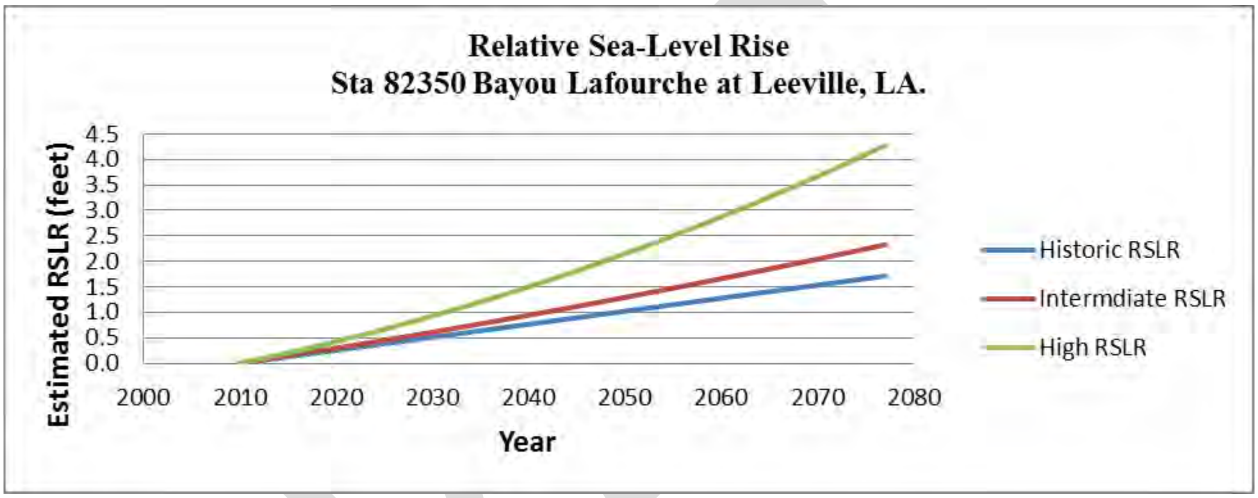



**Figure A-7. Relative Sea Level Rise**

The alternatives under consideration include deepening the channel to either −18 feet or −20 feet. RSLR would not affect future navigation on the HNC because RSLR will increase the channel depth when measured from the water surface. The requirements for safe navigation are based on the draft of the vessel and the depth of the channel. The crest elevations for the rock dikes (6 ft) and foreshore protection (5 ft) dikes will be examined during maintenance cycles.

RSLR will likely increase salinities in the HNC and the GIWW. Many natural and manmade pathways convey saltwater into, and out of, the project area and to the GIWW at Houma. The floodgate and the lock could be operated in a manner that would mitigate saltwater intrusion due to RSLR (see Section 3.3.5.1).

## 3.5 Water Quality

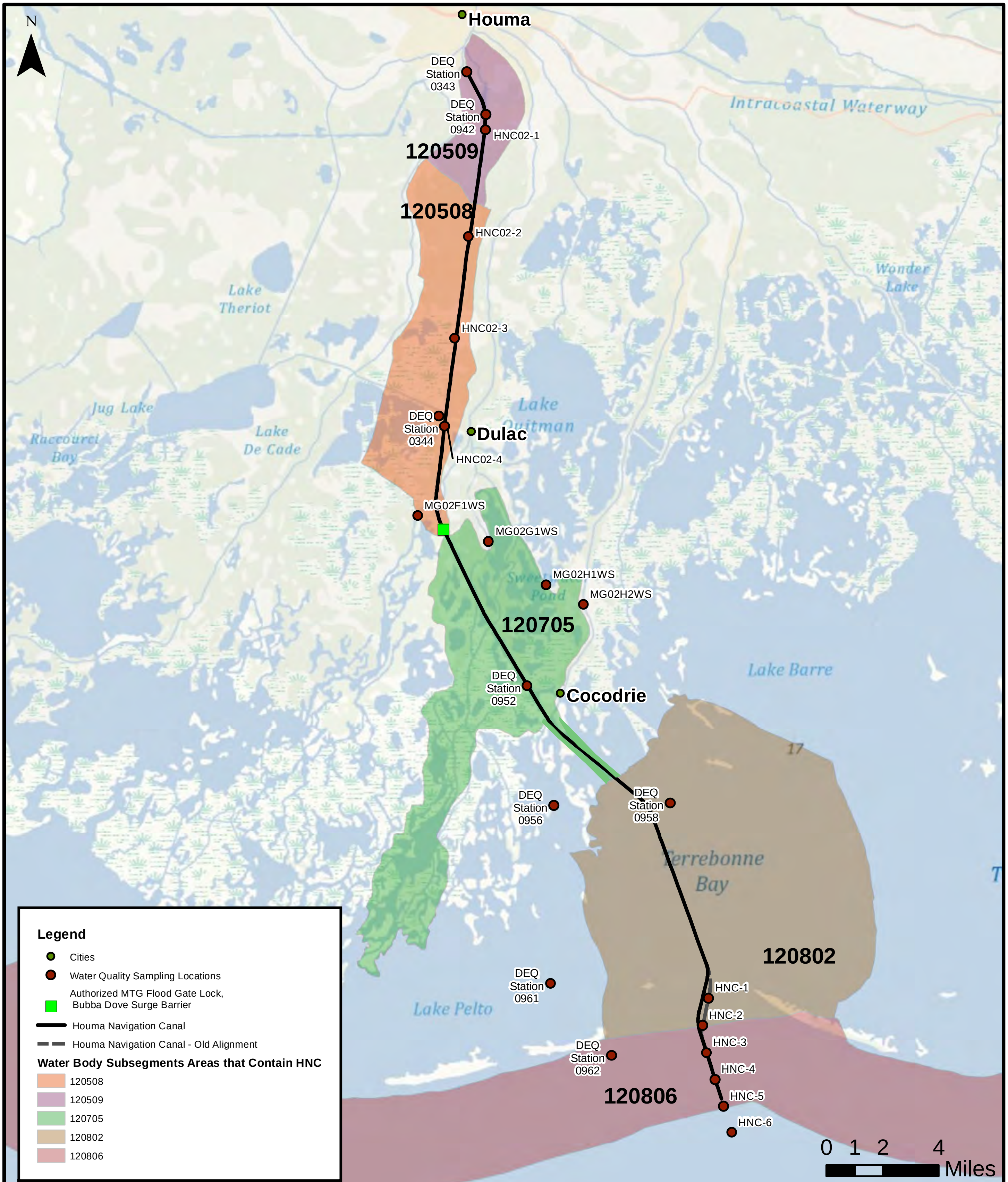
### 3.5.1 Project Water Body Subsegments

The HNC study area includes four water body subsegments of the HNC from Houma to Terrebonne Bay (Table A-8 and Figure A-8). The water body subsegment for Gulf of Mexico is also within the project limits. A total of five water body subsegments are directly affected by the proposed project:

**Table A-8. Water Body Subsegments**

| Water Body Subsegment Number | Water Body Name | Water Body Type |
|---|---|---|
| LA 120509 | Houma Navigation Canal-Houma to Bayou Pelton | River |
| LA 120508 | Houma Navigation Canal-Bayou Pelton to Segments 1205 and 1207 | River |
| LA 120705 | Houma Navigation Canal-Segments 1205 and 1207 to Terrebonne Bay | River |
| LA 120802 | Terrebonne Bay | Estuary |
| LA 120806 | Terrebonne Basin Coastal Bays and Gulf Waters to the State 3 mi limit | Estuary |

A total of 27 water body subsegments, within the Terrebonne Basin were listed as impaired on the 2010 Louisiana Department of Environmental Quality's (LDEQ) Louisiana Water Quality Inventory: Integrated Report (IR). The LDEQ defines a subsegment as a named regulatory water body that is considered representative of the watershed through which it flows and which has numerical criteria assigned to it. All subsegments within the proposed project area are fully support their designated uses except for LA 120806. LA 120806 is listed as impaired for fish and wildlife and oyster propagation. Suspected sources of impairment include upstream sources, marina/boating sanitary on-vessel discharges, petroleum/natural gas activities, and waterfowl.




# WATER QUALITY SAMPLING LOCATIONS AND WATER BODY SUBSEGMENTS

Houma Navigation Canal Deepening

*ERSI Ocean Map*

Figure A-8

Date: August 2012

Scale:1:301,000

Source: ESRI/GEC

Map ID: 278500218-3026

### 3.5.2 Water Quality Evaluation Standards and Criteria

**Water Quality Standards and Criteria**. The LDEQ has established general surface water quality standards (www.deq.state.la.us). The LDEQ standards provide criteria which specify general and numerical limitations for various water quality parameters for designated water uses, except where specifically exempt in the standards. General criteria include: aesthetics, color, floating, suspended and settleable solids, taste and odor, toxic substances, oil and grease, foaming or frothing materials, nutrients, turbidity, flow, radioactive materials, and biological and aquatic community integrity. Numerical criteria include pH; chlorides; sulfates and total dissolved solids; dissolved oxygen; temperature; bacteria; specific toxic substances and metals; and inorganic substances.

The U.S. Environmental Protection Agency (EPA) has established ambient water quality criteria applicable to surface waters in the study area. Numerical criteria have been developed for various physical parameters, nutrients, metals, polychlorinated biphenyls (PCBs), and organic pesticides for uses of freshwater aquatic life, marine and estuarine aquatic life, and public water supply, respectively. EPA's criteria can be obtained at www.epa.gov/OW/index.html.

**Sediment Quality Benchmarks**. There are no sediment quality standards promulgated by the EPA or the State of Louisiana. However, EPA Region IV has recommended the use of Sediment Quality Benchmarks promulgated by National Oceanic and Atmospheric Administration (NOAA) and the Florida Department of Environmental Protection (FDEP). These benchmarks are available at www.epa.gov/OST/cs/guidelines.html.

**Total Maximum Daily Loads (TMDLs)**. The State of Louisiana is working with the EPA to develop Total Maximum Daily Loads (TMDLs) for the water bodies included on the state's 303(d) list (see www.deq.state.la.us). In 2007, EPA developed a TMDL for fecal coliform on Subsegment 120508. The TMDL lists six affected point source dischargers in Subsegment 120508. Evaluation of the water quality in this subsegment has determined that the water quality fully supports its designated uses since the TMDL has been in place. Therefore, Subsegment 120508 is no longer listed on Louisiana's 303(d) list of impaired water bodies. No other TMDLs were listed within the subsegments included within the project area. TMDL development for LA 120806 is listed as a low priority and there is no target date for completion.

**National Pollutant Discharge Elimination System (NPDES/Louisiana Pollutant Discharge Elimination System (LPDES)**. As authorized by the Clean Water Act (CWA), the NPDES permit program, delegated to the LDEQ, controls water pollution by regulating point source discharge into waters of the United States. Through this program, the LDEQ maintains records for point source discharges into waters of the State of Louisiana through the LPDES program. Currently, there are 59 LPDES permitted dischargers on file with LDEQ who discharge either directly into the HNC or into tributaries which ultimately drain into the HNC. Typical discharges are classified as sanitary wastewater, industrial wastewater, and stormwater runoff.

### 3.5.3 Water Quality and Sediment Analysis

Data from 23 sampling locations were analyzed to assess existing water quality conditions in the project area (Figure A-8). Chemical analyses of ambient water, sediment, and standard elutriate were conducted for nine of the samples. Chemical analyses of ambient water, sediment, and standard elutriate and solid phase bioassays were conducted for six of the samples. Chemical analysis of ambient water was conducted for three of the samples. These samples were analyzed and compared to the water quality standards and criteria and the sediment quality benchmarks. Details of the analysis for each sampling location can be found in Annex II.

The chemical analyses on the samples indicated no cause for concern. Barium was the only detected compound in the water and elutriate samples. Detected compounds in the sediment were not noticeably different from the reference or background samples and no trends were apparent. No organics were detected in any sediment sample.

Survival of organisms exposed to test sediments in the solid phase bioassays was not significantly different from survival of organisms exposed to the solid phase of the reference control.

## 4.0 NAVIGATION CHANNEL DESIGN

### 4.1 Current (Without-Project) Vessel Dimensions

Vessel dimensions are used to design depth and width of a navigation channel. The HNC is currently used by a variety of vessels: crew and service boats, small oil tankers, tow boats with and without barges, commercial fishing vessels, recreational vessels, and oil rigs (Table A-9). The frequency of travel of these vessels is expected to increase in future years.

All of these vessels can be safely accommodated in the currently authorized channel. The dry cargo barge, with a beam of 78 feet, would have restrictions for use in a one-way condition due to the limited channel width and safety factors required for two passing vessels.

### 4.2 Design Vessel (With-Project)

In order for businesses to be competitive for fabrication contracts, the design vessel is a special offshore petroleum industry barge that is 100 feet wide by 400 feet long, and with a design draft of 20 feet (Table A-10). Movements of this design vessel are constrained to several times per year at approximately two miles per hour (mph) under with-project conditions.

**Table A-9. Maximum Dimensions and Speed of Typical Vessels Using the HNC**

| Vessel Type | Description | Length (Feet) | Beam (Feet) | Draft (Feet) | Speed (Knots) |
|---|---|---|---|---|---|
| Dry Cargo | Crew/Service Boat | 260 | 54 | 18* | 26–35 |
| Tanker | Small Oil Tanker | N/A | N/A | 12 | N/A |
| Tow Boat | Tow Boats without Barges | 140 | 32 | 18* | 20 |
| Dry Cargo | Barges with Tow Boats | 403 | 78+ | 18* | 3-4 |
| Tanker | Barges with Tow Boats | 297 | 54 | 13 | 3-4 |
| Other | Oil Rig | ? | ? | 15 | 3-4 |

* Design draft for this vessel. Currently light loaded to a 13-foot draft due to depth limitation of existing channels.

**Table A-10. Typical Vessels**

| Vessel Type | Description | Maximum (Feet) | Dimensions (Feet) | |
|---|---|---|---|---|
| | | Length | Beam | Draft |
| Dry Cargo | Crew/Service Boat | 325 | 55 | 18 |
| Tanker | Small Oil Tanker | N/A | N/A | 12 |
| Tow Boat | Tow Boats w/o Barges | 250 | 90 | 12 |
| Dry Cargo | Barges w/Tow Boats | 400 | 100 | 20** |
| Tanker | Barges w/Tow Boats | 250 | 75 | 13 |

**Design vessel.

The selection of the channel depths to be considered for the HNC also considered the size of the deepwater fabrication topsides that are expected to be included in future contract solicitations. Topsides are surface hardware installed on an offshore oil platform; can include the oil production plant, accommodation block, and drilling rig. The HNC would need to accommodate topside barges to be competitive. The HNC deepening would make it more efficient and cost effective to build these topsides in Houma for deployment in the north-central Gulf.

The weight of the topside itself is the fabrication weight. However, topside weights on a systematic basis are available only in terms of installed topsides. Installed topside weights (load-out weights) reflect the weights of topsides as they leave the fabrication yards because they include additional components such as heliports and living quarters. Fabricator weight does not include these additional components. In this analysis, the topside fabricator contract weights were assumed to be an average of 6,000, 8,000, and 10,000 tons for Spar, FPSO, and FPS, respectively. The corresponding installed weights were assumed to be 9,000, 12,000, and 15,000 tons. The associated channel depth required to safely move topsides with installed weights of 9,000, 12,000, and 15,000 tons were identified to be 16, 18, and 20 feet, respectively.

Additional efforts were made to establish the weight-draft relationship. A generalized relationship between the weight of topsides and the total draft of the barge used to move the structure to its final destination are shown in Table A-11. The channel depth required to accommodate a given weight class is also presented. Topside weights are arranged in size *categories*. The industry-preferred barge used to move structures weighing in excess of 5,000 tons from port to locations in the deep Gulf waters is 400-feet long, 100-feet wide, and measures 25 feet from the deck to the bottom of the hull. Barges of this type have a maximum draft of about 21 feet.

**Table A-11. Weight-Draft Relationship**

| Topside Installed Weight Category | Topside Tons Divided by Tons per Foot | Topside Draft (feet) | Barge Draft (feet) | Trim Ballast (feet) | Total Draft (feet) | Channel Depth Range (feet) |
|---|---|---|---|---|---|---|
| 5,000 to 6,000 | 5,000–6,000/1,250 | 4–5 | 4 | 2–3 | 10–12 | 11–13 |
| 10,000 to 12,000 | 10,000–12,000/1,250 | 8–10 | 4 | 3–4 | 15–18 | 16–19 |
| 13,000 to 15,000 | 13,000–15,000/1,250 | 10–12 | 4 | 2–3 | 16–19 | 17–20 |
| 16,000 to 18,000 | 16,000–18,000/1,250 | 13–14 | 4 | 0–1 | 17–19 | 18–20 |

*Assuming a 1-foot under-keel clearance.

Source: Based on industry-provided data.

The total draft requirement was computed by adding barge empty draft (*barge draft*) and a trim and ballast estimate to the topside draft. The trim and ballast requirement is an additional emersion requirement for stability and safety reasons. With a greater emersion, the barge rides lower in the water and will be more stable when the load exceeds 12,000 tons (Table A-11). The ballast weight is replaced by the weight of the load. Underkeel clearance, is an additional consideration necessary to determine the required channel depth for each weight class. One foot of underkeel clearance is generally used as the minimum requirement.

Load-Out and Weight-Draft relationship use the same barge draft, ballast and underkeel clearance (Table A-12). The immersion due to topside weight was estimated using the Barge Displacement Calculator published by McDonough Marine. Immersion, expressed as short tons per foot assuming the industry-preferred barge (400 x 100 feet), was determined to be 1,250 tons per foot using the Barge Displacement Calculator. This corresponds to the immersion factors provided by the second referenced industry source.

**Table A-12. Load-Out Weight-Draft Relationship**
(Topside draft estimate from Barge Displacement Calculator; 1,250 tons/ft. Ballast estimates based on industry-provided data.)

| Load-Out Weight (tons) | Topside Draft (feet) | Barge Draft (feet) | Ballast (feet) | Under-Keel Clearance (feet) | Channel Depth (feet) |
|---|---|---|---|---|---|
| 9,000 | 7.2 | 4 | 3 | 1 | 15.2 |
| 12,000 | 9.6 | 4 | 3 | 1 | 17.6 |
| 15,000 | 12 | 4 | 3 | 1 | 20 |

It must be emphasized that the loading relationships are generalized approximations. The variability in physical configuration for topsides of a given weight class, along with variability in operations that exist at the time of transit, make specifications of a precise load to draft relationship impossible. The oil/gas industry interviews suggest that there is limited utility in attempting to generalize among topsides based on size and weight statistics and statistically linking this small sample to reported barge drafts and channel depths. The topsides are viewed as customized pieces of equipment with display considerable variation of weight within each grouping. Moreover, attempts to link topsides *size* to sailing draft requirements were very difficult because of industry preferences for ballasting. The industry interviews suggest that the maximum sailing draft of the barge is preferred for a reduced center of gravity.

However, it is necessary to assume some generalized relationship to facilitate the assignment of specific weight classes to channel depths. The subsequent analysis assumes the initially described relationship, i.e., topside weights of 9,000, 12,000, and 15,000 tons correspond to channel depth requirements of 15, 18, and 20 feet.

## 4.3 Channel Design Requirements

Based on USACE design criteria, the channel depth required to pass the design vessel should include underkeel clearance of about 25 percent of the design draft or about four feet. Currently, the HNC channel is shallow (−15 feet MLG), and the authorized bottom width of the channel is zero feet. These dimensions are smaller than required by the USACE design criteria for the typical vessels in both shallow-draft and deep-draft channels. The channel depths investigated in this study include −18 feet and −20 feet. The channel design considered a traffic analysis obtained from the Traffic Study Forecast for HNC (Annex IV), and design considerations examined in the design of similar channel width requirements at Port of Iberia.

Although the 20-foot channel does not meet USACE design criteria for the large cargo vessel identified as the design vessel, special accommodations can be made, as is done currently to allow usage of restrictive channels with no safety issues. The design vessel does not maneuver under its own power, but is pushed and pulled very slowly downstream by several tugboats. Because the barge moves so slowly, the width dimension can be encroached upon somewhat without surrendering much in terms of safety or bank damage. Additionally, trips along the channel for this vessel are infrequent and can be limited to ideal weather conditions and high tide conditions. Interviews with industry representatives indicate that the 100- by 400-foot barge can be ballasted to a 19-foot draft. Therefore, this report concludes that the maximum channel depth considered in this study, 20 feet will be sufficient for the safe conduct of navigation for the identified design vessel, so long as the actions described above are implemented.

### 4.4 Channel Alignment

The proposed channel alignment would follow the existing alignment.

### 4.5 Channel Width

Channel widths are designed to provide for the safe and efficient movement of vessels along the channel. Standard design criteria for determining bottom width of shallow draft channels are outlined in Engineering Manual (EM) 1110-2-1611. These criteria require that sufficient width be provided in the channel to accommodate the beam width of the design vessel for maneuverability under normal velocity conditions, and include additional width for bank clearance on each side of the vessel. In straight channels the vessel beam width can be used to determine the width of the maneuvering lane. For one-way traffic, 40 feet must be added to each side of the vessel width to provide adequate bank clearance. Thus, for the largest beam in the fleet, 78 feet (Table A-9), the required channel width is (78 feet + 80 feet) 158 feet. However, because the largest beam in the fleet is moving at a slow velocity, the 40 foot required bank clearance has been lessened or relaxed in this case. Therefore, the proposed channel width will provide safe navigation conditions for all vessels in the fleet in a straight channel as stipulated.

Most of the HNC is straight; however, there is a large bend in the channel near the location of the proposed lock. In bends, additional bottom width must be provided in the maneuvering lane to provide adequate clearance for the vessel during turning. Channel width in bendways is determined using the angle of curvature of the bendway. Because the final design for the lock, floodgate, and channel alignment near the lock has not been finalized, the design width of this bendway has not been established.

## 4.6 Channel Depth

Channel depths under consideration are −15 MLG, −18, and −20 feet. Some vessels will not be able to operate without the 20-foot alternative as the new channel. EM 1110-2-1611 states that *Resistance to tow movement and power required to move the tow are increased if the draft is more than 75 percent of the available depth, particularly if the channel has restricted width, such as a canal or lock.* Thus, use of a shallow channel by a too-large vessel will impede the vessel's movement and require additional horsepower and fuel consumption. Additionally, in poor soils, such as those found along coastal Louisiana, the dissipation of the added energy from these too-large vessels may increase the tendency toward bank erosion. The maximum vessel draft is two feet less than the authorized channel depths (Table A-13).

**Table A-13. Maximum Vessel Draft**

| Proposed Channel Depth (feet) | Maximum Vessel Draft (feet) |
|---|---|
| 20 | 18 |
| 18 | 16 |
| 15 | 13 |

## 4.7 Tow Simulation Waiver

For designs where the recommended width of a proposed navigation channel is smaller than the minimum dimensions derived from criteria established in the EMs, the EMs prescribe that a tow simulation model be conducted. ER 1110-2-1403, *Studies by Coastal, Hydraulic and Hydrologic Facilities and Others,* states that hydraulic design studies associated with the planning, design, construction, operation, and maintenance of navigation channels will include a ship-simulation investigation unless omission of such an investigation is approved by the U.S. Army Corps of Engineers Headquarters (HQUSACE). CEMVN requested such a waiver for the proposed HNC Deepening Project. To support HQUSACE with their decision, the ERDC in Vicksburg, Mississippi conducted a desktop study. During the course of this study, ERDC and CEMVN met on-site with representatives from the local navigation industry and manufacturers familiar with the waterway. During this visit and subsequent discussions, ERDC gained an understanding of the size and draft of existing and the design barges, how barges are transported, how much caution and oversight are used during transport, and the number of tows used. ERDC concluded that a tow simulation model was not required for the tug escorted transportation of offshore equipment only as long as the following considerations are included (1) transits of the design barge are scheduled during the times the authorized floodgate and lock will be open; (2) the number of tugs remains at the present level (approximately five) or increases as is deemed necessary for the increase in volume being transported; (3) sufficient tugs are made available as dictated by weather and current conditions; and (4) transits cease during extreme winds and currents. On 24 October 2007, Chief, Engineering and Construction, Directorate of Civil Works, granted the waiver (Annex III).

# 5.0 GEOTECHNICAL INVESTIGATIONS AND DESIGN

## 5.1 Geology

### 5.1.1 Study Area

The study area has low relief with surface elevations ranging from approximately four feet on the natural levees of several distributaries grading to sea level in the adjacent swamps and marshes. The surface and shallow subsurface in the study area is composed of natural levees, marsh, swamp, interdistributary and abandoned distributary deposits (Plates G2 and G3 in Annex V). Natural levee deposits are found adjacent to several distributaries that dissect the study area. Natural levee deposits average approximately eight feet thick and thin away from the channel. These deposits are generally composed of oxidized clays, silts, and silty clays with relatively low water contents and higher compressive strengths than the surrounding environments.

Swamp deposits are found at the surface and interbedded within interdistributary deposits throughout the study area, and are up to 17 feet thick. A laterally extensive layer of swamp deposits are found at approximately −35.0 feet from Mile 19 to 12.5 and from Mile 11.4 to 7.5. This layer of deposits ranges from approximately 5 to 10 feet thick. Swamp deposits consist of soft to medium fat clays with organic material and wood. Swamp deposits are also found at approximately -70.0 feet and extend to the bottom of the soil borings (Section 5.2.1). These deeper swamp deposits are medium to stiff, fat clays with relatively high strengths, organic material and wood. Interdistributary deposits are found at the surface and throughout the study area. Where penetrated, interdistributary deposits extend down to a maximum of −75.0 feet. Interdistributary deposits consist of fat and lean clays with lenses and layers of silt and silty sand.

Abandoned distributary deposits are found in the northern half of the study area at Miles 34.1, 23, 20.7, and 19.4. These deposits are generally found at the surface or near the surface and extend down to approximately −50.0 to −60.0 feet. They are not laterally extensive. Abandoned distributary deposits consist of silty sands, silts, and clay strata. Substratum sands are located beneath interdistributary and swamp deposits and are approximately 100 feet thick.

### 5.1.2 Groundwater

Groundwater is at or near the surface in the study area.

### 5.1.3 Subsidence Rates

The stream gage Bayou Lafourche at Leeville, Louisiana was used to compute the historic subsidence rate in the study area, approximately 2.0 feet/century.

### 5.1.4 Soil Types

Soil types in the study area consist of the Baldwin, and Mhoon Series. Baldwin Series soils are imperfectly or somewhat poorly drained soils that developed on terraces from stratified medium and fine-textured sediments deposited by the Mississippi and Red Rivers. Mhoon Series soils are imperfectly drained soils of the bottom lands developing in slightly acid to moderately alkaline, stratified silt loam, silty clay loam, and silty clay sediments.

## 5.2 Geotechnical Design

### 5.2.1 Field Investigations

Field investigations included soil borings, multi-beam surveys, and surveyed cross sections to beyond top of bank.

a. **Soil Borings**

1. Thirty-five undisturbed soil borings were used to determine the soil conditions along the channel. Five-inch tubes were used to recover samples with the least amount of disturbance. Twenty-one of these borings were taken for the channel deepening study. Six borings were drilled for the lock study. The other eight are historical borings. Borings extend from Mile 35.0 near Houma, Louisiana south to Mile 4.2 in Terrebonne Bay. However, the proposed channel deepening extends to 0.1 of a mile past the 20-foot contour. For this study, it is not economical to take borings for this reach. Instead, it will be the responsibility of the dredging contractor to determine material type and adjust the dredging and proposed cost accordingly.

2. Borings are listed in order from Mile 33.0 at the northern end of the channel proceeding south to Mile 4.2 (Table A-14). Please note that the final four borings listed in Table A-14 are in Terrebonne Bay. The total length of the boring alignment is approximately 28.8 miles utilizing a non-uniform spacing.

b. **Laboratory Tests.** All soil samples were visually classified. Unconfined compression (UC) shear test, unconsolidated-undrained (Q) triaxial shear test, Atterberg limit, water content, and wet density tests were performed on selected samples from the borings. The results of the laboratory tests are shown on the boring log Plates in Annex V.

**Table A-14. Geotechnical Boring Data**

| Boring Number | Ground El. | Depth (Ft) | Latitude | Longitude |
|---|---|---|---|---|
| FF-2 | 2 | 100 | 29º32’48.5715” | 90º42’21.7145” |
| FF-1 | 2 | 100 | 29º32’39.6519” | 90º42’20.3687” |
| HNCL-11U | 4.4 | 62.3 | 29º32’12.7972” | 90º42’15.0128” |
| HNCL-31U | −6.2 | 51.3 | 29º29’30.9961” | 90º42’46.1041” |
| HNCL-32U | −5.4 | 51.2 | 29º28’21.8990” | 90º43’0.0018” |
| HNCL-15U | 4.2 | 62.5 | 29º18’29.2003” | 90º42’59.8920” |
| HNCL-35U | −8.5 | 51.5 | 29º24’43.9989” | 90º43’34.0045” |
| HNCL-18U | 3.4 | 102.3 | 29º23’0.8016” | 90º43’44.9760” |
| MG-6-U | 3.5 | 61.6 | 29º23’0.8990” | 90º43’49.7974” |
| HNCL-16U | 3.6 | 62.5 | 29º24’16.0112” | 90º43’31.4777” |
| HNCL-36U | −2 | 51.5 | 29º22’3.7976” | 90º43’58.0096” |
| HNCL-37U | −3 | 51.3 | 29º21’16.0963” | 90º44’6.1121” |
| HNCL-21U | 3.3 | 62.5 | 29º20’32.8171” | 90º44’0.2618” |
| HNCL-6U | −14 | 119.5 | 29º20’2.6047” | 90º43’54.3018” |
| HNCL-5U | -4 | 151.5 | 29º20’0.0984” | 90º43’55.0983” |
| HNCL-4U | −12 | 119.5 | 29º19’56.7957” | 90º43’56.0870” |
| HNCL-3U | −8 | 119.5 | 29º19’51.5016” | 90º43’47.4902” |
| HNCL-2U | −4 | 119.1 | 29º19’50.1009” | 90º43’52.5989” |
| HNCL-1U | −3 | 151.5 | 29º19’34.6994” | 90º43’45.2106” |
| HNCL-38U | −2.8 | 51.5 | 29º19’5.9015” | 90º43’18.7885” |
| HNCL-22U | 2.6 | 62.4 | 29º18’29.1996” | 90º42’59.9040” |
| HNCL-39U | −2.1 | 51.5 | 29º17’59.5784” | 90º42’43.9343” |
| HNCL-40U | −2 | 51.4 | 29º17’22.4995” | 90º42’33.9917” |
| HNCL-41U | −2.5 | 51.5 | 29º16’51.0306” | 90º42’4.1913” |
| HNCL-42U | −3.1 | 51.5 | 29º16’15.8469” | 90º41’41.7517” |
| HNCL-43U | −2.6 | 51.4 | 29º15’51.3611” | 90º41’34.6106” |
| HNCL-44U | −2.6 | 51.4 | 29º15’18.5326” | 90º41’58.5608” |
| HNCL-45U | −2.8 | 51.3 | 29º14’48.2996” | 90º40’35.6964” |
| HNCL-46U | −1.9 | 51.2 | 29º14’18.7326” | 90º40’30.0110” |
| HNCL-47U | −1.9 | 51.2 | 29º13’59.0465" | 90º40’3.9185” |
| HNCL-48U | −2.9 | 51.4 | 29º13’31.6562” | 90º39’32.4426” |
| H-8.6-U | −2.1 | 59.5 | 29º11’38.2430" | 90º37’49.6930” |
| H-7.5-U | −5.6 | 59.5 | 29º11’26.9988” | 90º36’38.9880” |
| H-5.8-U | −3.1 | 59.1 | 29º10’4.6806” | 90º36’23.2306” |
| H-4.2-U | −3.8 | 59.3 | 29º08’52.8781” | 90º35’54.5563” |

c. **Design Shear Strengths**. Classification and stratification are based on the interpretation of information from individual borings and the geologic profile. Design shear strengths are based on the results of shear tests. The proposed channel has been divided into seven design reaches. The geology of the area is characterized by soft to very soft clay soils interspaced with layers of silt and organic material. This is especially true for the Inland Reach (Mile 36.3 to 10.1). Material types below Mile 10.1 are based on the historical borings and dredging data. The soil in the Terrebonne Bay Reach (Mile 10.1 to 0.0) consists of clay and silt. Based on dredging records, the material in Mile −1.0 to −4.5 consists of fine uniform sand and oyster shells.

d. **Stability of Slopes.**

1. There are three proposed elevations for the channel deepening study: −15 feet MLG (No-Action), −18 feet and -20 feet. The analysis conducted here provides the same results for the 18- and 20-foot alternatives. The 20-foot channel is the only alternative that was actually investigated. Analysis of this dredging alternative provided adequate factors of safety into the channel. The shallower proposed dredge elevations will provide greater factors of safety without having to be individually investigated.

2. Approximately 41 miles of channel has been divided into seven stability reaches based on soils data and top of bank elevations (Table A-15). Factors of safety were computed based on the extent of the existing data. Survey cross sections were obtained by merging multi-beam data of the channel with survey sections to top of bank. The multi-beam data is continuous across the channel bottom up to 15 degrees from the water's surface. Survey sections were taken at approximately 300-foot intervals from the end of the multi-beam to the water's edge with the last shot taken at top of bank. Minimal overbank data exist; therefore, it is assumed that the ground line continues horizontal at the elevation of the last survey point.

**Table A-15. Soil Stability Reaches and Dredge Template Dimensions (All Side Slopes are 1V on 3H)**

| Stability Reach | Mile | Template Depth (ft) | Width (ft) | Advanced Maintenance (ft) | Overdepth (ft) |
|---|---|---|---|---|---|
| 1 | 35.0 to 33.5 | −20 | 150 | 2 | 1 |
| 2[a] | 33.5 to 24.15 | −20 | 150 | 2 | 1 |
| 3 | 24.15 to 20.7 | −20 | 150 | 2 | 1 |
| 4 | 20.7 to 17.25 | −20 | 150 | 2 | 1 |
| 5 | 17.25 to 10.1 | −20 | 150 | 2 | 1 |
| 6 | 10.1 to 0.0 | −20 | 150 | 3 | 2 |
| 7[b] | 0.0 to −4.5 | −20 | 300 | 4 | 2 |

3. The proposed dredge template is narrower than the existing channel along the entire length of the channel. The template is positioned in the channel so that it does not intersect the banks. From Stability Reaches 1 through 5 (Mile 36.5 to 10.1), the dredge template is 150 feet wide to a depth of −20 feet, an additional 2 feet of advanced maintenance and 1 foot of overdepth. For Reach 6 (Mile 10.1 to 0.0), the dredge template is 150 feet wide to a depth of −20 feet, with 3 feet of advanced maintenance and 2 additional feet of overdepth. For Reach 7 (Mile 0.0 to −4.5), the dredge template is 300 feet wide to a depth of −20 feet, with four feet of advanced maintenance and 2 additional feet of overdepth. For Reaches 6 and 7 (Mile 10 to −4.5), the channel is in open water in Terrebonne Bay and out into the Gulf. The centerline of the dredge template is aligned with the current channel centerline. For all reaches the template is configured with 1V on 3H side slopes at depth for the channel section and advanced maintenance portion with the overdepth occurring as a vertical box cut (Plate C16).

4. A digital terrain model was generated from these data. Cross sections were cut through the model every 500 feet and extended to an estimated high top of bank. Ground surfaces were assumed horizontal back from the average high top of bank. Stability analyses were run on composite cross sections for each design reach. Slope stability factors of safety were computed using the wedge method of analysis. A factor of safety (FOS) of 1.3 was required for slope stability into the channel (Table A-16). The results of the stability analysis are shown in Plates G47 to G53 (Annex V). All reaches exceeded the required minimum factor of safety for the 20-foot dredge template.

**Table A-16. Slope Stability Analysis Factors of Safety for Each Design Reach**

| Reach | Minimum FOS Per Reach | Required Minimum FOS |
|---|---|---|
| Mile 35.0–33.5 | 1.62 | 1.3 |
| Mile 35.5–24.15 | 1.33 | 1.3 |
| Mile 24.15–20.7 | 2.07 | 1.3 |
| Mile 20.7–17.25 | 2.18 | 1.3 |
| Mile 17.25–10.0 | 4.52 | 1.3 |
| Mile 10.0–(−5.0) | 4.73 | 1.3 |

e. **Rock Dikes**.

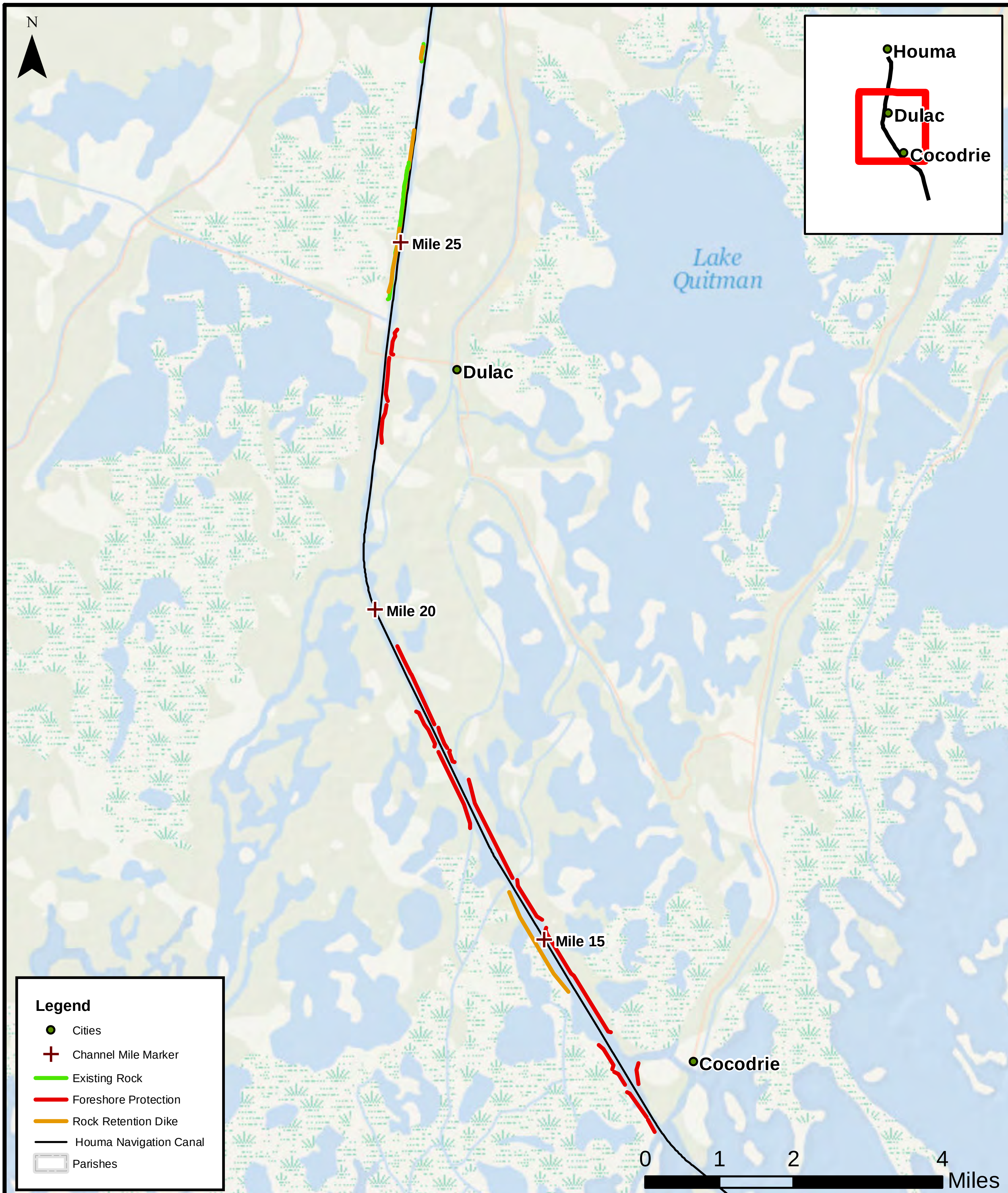
1. **General.** Rock dikes have been proposed for foreshore protection and the retention of dredged material. Foreshore dikes on the Inland Reach will help reduce land loss adjacent to the channel. Retention dikes placed at strategic locations to retain

dredged material would promote the creation of marsh. Proposed dikes are aligned along the historical bank line. The channel is wide enough that the overall channel stability is not affected by the addition of the rock dikes along the channel. Rock dikes currently exist on the west bank between Mile 24.0 and Mile 28.0, north of the bridge at Dulac built in 1995. The location of the existing rock dikes, and proposed locations for rock foreshore protection and retention structures are shown in Section 6.2.3 Figure A-9.

2. **Dike Configuration**. The rock dike cross sections were submitted by the Hydraulics and Hydrologic Branch of the CEMVN in June 2002. Toe elevations of the channel side wave berm range from -1 to -5 foot and the berm top elevations range from 1 to 2 feet. A minimum 3 foot wave berm thickness would be necessary to prevent scour under the toe. Crown elevations for foreshore protection dikes would be five feet. Rock retention dikes would need to be built to an elevation of six feet. All dikes require a geotextile fabric placed under the dike. The fabric tensile strength should be a minimum of 450 psi and hold up to deformation without tearing. Protected side stability berms are required with a minimum width of five feet and thickness of three feet. The protected side berm may be eliminated if the dike is located against an earthen bank of 3.5 feet or higher. A flotation channel may be required if the channel is too far away from the bank line.

3. **Dike Size**. Dike size will be related to geometry of each location selected. To estimate dike size, several values are needed including bottom elevation where the dike is to be built, elevation of the dike crown, and settlement. Dike height and its proximity to the bank line will determine what settlement prediction values should be used.

4. **Dike Settlement Values**. Dredged material has a poor ability to support structures with considerable variability which will relate to significant errors in estimating settlements. Gross settlement values are estimated for the rock dikes along the channel and can only be used as a planning tool. Settlement values are estimated by reach. Long-term settlement values should be based on the location of the dikes and updated during the design phase with geotechnical data collected in a site specific manner. A value of 20 percent settlement was used for cost estimating purposes. The geotechnical data cannot provide an accurate estimate of settlement; therefore, 20 percent seemed reasonable to proceed with the cost estimates. Subsidence values were not added to the calculated dike settlement, since a regional subsidence rate of 2.0 feet in 100 years is not significant when compared to acute construction-related settlement due to increased load within an alignment. Additional geotechnical analysis would be necessary to determine the settlement value.




# FORSHORE PROTECTION AND ROCK RETENTION DIKES

(INLAND REACH)

Houma Navigation Canal Deepening

*ERSI Ocean Map*

GEC

| | |
|---|---|
| Figure A-9 | |
| Date: October 2012 | |
| Scale:1:115,000 | |
| Source: ESRI/GEC | |
| Map ID: 278500218-3026 | |

5. **Flotation Channel**. In some areas, a flotation channel may be necessary to construct the rock dikes. The flotation channel for dike construction should not be dredged any closer than 50 feet to the centerline of the dike. Flotation channels may be dredged up to −7 feet and would not be backfilled. These channels would be allowed to fill in naturally. Material excavated to create the flotation channels would be placed immediately behind/adjacent to the rock structures.

### 5.2.2 Channel Stability (Mile 33 to 24)

The minimum factor of safety is exceeded for all reaches based on the current channel alignment, existing cross section data, and proposed dredge template. Proposed shallower template alternatives will provide greater factors of safety when positioned along the same alignment. Along the channel, there are areas that were previously used for stockpiling dredged material during construction and maintenance. These areas can have an elevation above +10 feet. For these areas, it is recommended that the bank will be cut back on a 1V on 5H slope starting at a height approximately +2 feet above the water surface using a barge mounted long reach backhoe. The high banks between Miles 33.0 and 24.0 should be excavated to meet the factor of safety concerns.

# 6.0 CIVIL DESIGN

## 6.1 Channel Design

### 6.1.1 General

The authorized depth or channel elevation is the minimum depth for safe navigation. Advanced maintenance is the practice of deepening in anticipation of shoaling to allow for reasonable intervals between maintenance dredging events.

### 6.1.2 18-Foot Channel

The project design elevation for this channel alternative would commence at about Mile 36.3 along the HNC, just below the LA 663 Bridge across the HNC, and extend to the −18 foot contour in Cat Island Pass (Mile −3.5, Table A-16). The design width would remain the same as that of the currently authorized project (150 feet between Miles 36.3 and 0.0, and 300 feet between Miles 0.0 and −3.5). The channel would also have design side slopes of 1V to 3H throughout the project limits.

### 6.1.3 20-Foot Channel

The project design elevation for this channel alternative would be 20 feet, commencing at approximately Mile 36.3, just below the LA 663 Bridge, and extending to the −20 foot NAVD88 contour in the Gulf near Cat Island Pass (Table A-17). To accommodate the increased depth requirements, the 20-foot channel would end approximately 1,000 feet further into the Gulf to connect to the 20-food depth contour. The design width would remain the same as that of the currently authorized project (150 feet between Miles 36.3 and 0.0, and 300 feet between Miles 0.0 and −3.7). The channel would also have design side slopes of 3H to 1V throughout the project limits.

**Table A-17. Depth Features for the 18- and 20-Foot Depth Alternatives**

| Depth Alternative | Depth Feature | HNC Reach | | |
|---|---|---|---|---|
| | | Inland | Terrebonne Bay | Cat Island Pass |
| | | (feet) | | |
| 18-foot | Reach Mile | 36.3 to 10.1 | 10.1 and 0.0 | 0.0 to −3.5 |
| | Bottom Width[a] | 150 | 150 | 300 |
| | Total Depth | 21 | 23 | 24 |
| | | | | |
| 20-foot | Reach Mile | 36.3 to 10.1 | 10.1 to 0.0 | 0.0 to −3.7[b] |
| | Bottom Width[a] | 150 | 150 | 300 |
| | Total Depth | 23 | 25 | 26 |

[a] All side slopes would be 3H to 1V.
[b] The 20-foot channel would end approximately 1,000 feet further out into the Gulf to ensure connection to the 20-foot depth contour.

## 6.2 Bank Erosion

### 6.2.1 Bank Erosion Historic Rate

Channel bank erosion is apparent in many locations along the Inland Reach (Mile 36.3 to 10.1). The original canal dimensions were an approximately 250-foot-wide canal. The banks are now as much as 450 to 1,000 feet apart in many reaches of the canal. The historic bank erosion rates were calculated from measurements from the west to the east bank based on aerial photography taken in 1998 and 2005. Bank erosion rates varied from 0.0 to 5.3 feet per year (Table A-18), which equates to approximately 12.9 acres of land loss each year.

**Table A-18. Historic Bank Erosion Estimates**

| Mile | West Bank (feet/year) | East Bank (feet/year) |
|---|---|---|
| 36.6 to 31.6 | 2.5 | 0 |
| 31.1 to 26.6 | 1 | 2.7 |
| 26.1 to 21.6 | 2.6 | 2.9[a] |
| 21.1 to 16.6 | 3.8 | 0.6 |
| 16.1 to 11.6 | 5.3 | 1 |

[a] Erosion rate calculated exclusive of value indicating placement of fill between 1998 and 2005.

### 6.2.2 Bank Erosion Causes

Bank erosion is the result of several factors including sea level rise, subsidence, and wave action. The predominant cause of erosion is wave action created by vessel traffic. This wave action affects the canal banks and newly placed dredged material. A study of boat traffic on the HNC (Annex IV) showed that 31.9 percent of the boat traffic consisted of light tugs, crew boats and offshore supply vessels. These classes of vessels produce the largest wakes.

### 6.2.3 Foreshore Protection Structures

Foreshore protection is recommended to reduce bank erosion, maintenance costs, and environmental impacts. Foreshore protection is a graded stone bank revetment. Rock retention dikes are constructed along the Inland Reach to contain the disposal material. Rock retention dikes will also reduce bank erosion. The location and cost of foreshore protection are shown in Figure A-9.

For all deepening alternatives, approximately 13.1 miles of foreshore protection would be constructed and/or refurbished along the Inland Reach (6.0 miles along the west bank and 7.1 miles along the east bank). In addition to the foreshore protection, approximately 1.6 miles of rock retention dikes would be constructed on the Inland Reach.

Dredging for flotation access within the HNC would likely be required for construction of the rock retention dikes and foreshore protection. Material excavated for flotation access would be placed immediately behind/adjacent the proposed rock structures. In addition to the rock structures, earthen retaining dikes, closures and/or weirs would also be constructed, as needed, to retain the dredged material placed within the disposal sites.

The mean high water level is about one foot in elevation along most of the HNC and the average annual high water level is approximately two feet. Therefore, five feet was selected as a crest elevation for the rock in order to prevent significant wave overtopping during most of the year (Annex V, Plate 17). The crest level for the rock retention structures would be 6.0 ft (NAVD88).

### 6.2.4 Justification for Foreshore Protection

The historic rate of bank erosion along the Inland Reach is approximately 12.9 acres a year. With land loss, the lower reach (Mile 18.0 to 11.0) will become open water and the maintenance volume rate will approach that of the Terrebonne Bay. A graded rock foreshore structure, or bank revetment, is recommended for the Inland Reach to reduce bank erosion, maintenance cost, and environmental impacts. The rock retention feature is a rock dike that would be constructed along portions of the Inland Reach to confine the disposal areas to reduce shoaling, erosion, and maintenance cost. The foreshore protection structure would be built to an elevation of 5 ft and the rock retention structures to an elevation of 6 ft. The rock retention and foreshore protection structures on the Inland Reach are features in all deepening alternatives.

The construction cost of the foreshore protection structures is $35,847,300. The maintenance of rock dikes accounts for settlement, subsidence, and sea level rise. The estimated quantity of rock needed for maintenance is 20 percent of the estimated quantity for construction, with a maintenance cycle every 10 years. The total maintenance cost of the foreshore protection structures is $34,200,000.

The cost justification for the foreshore protection assumes the historic maintenance volume on the Inland Reach will be reduced by 5 percent, the rate of erosion and land loss is reduced to 10 percent of the historic erosion rate, and the beneficial use of the disposal areas is a land gain.

Costs with and without rock for the 18-foot depth and 20-foot depth measures indicate that these rock structures are economically justified (Table A-19). The cost scenario without rock retention and foreshore protection structures assumes there will be an increase in the volume of maintenance dredging and land loss will continue at the historic rate. The additional maintenance and mitigation of land loss would exceed the cost to build and maintain these rock structures. There will be an estimated savings of $15,081,200 for the 15-foot (no action plan), $14,940,000 for the 18-foot channel and $13,366,200 for the 20-foot channel (Table A-19). A detailed description of the assumptions and cost calculations is provided in Appendix K.

**Table A-19. Estimated Cost Comparison Related to Foreshore Protection and Rock Retention for the Inland Reach**

| Depth Option | Cost Without Rock | Cost With Rock |
|---|---|---|
| **15-Foot Channel (No Action Plan)** | | |
| Total Rock Construction Cost | $0 | $38,912,100 |
| Total Rock Maintenance Cost | $0 | $37,188,000 |
| 50-Year Dredging Cost | $80,609,009 | $54,714,540 |
| 50-Year Land Loss Costs | $29,549,394 | $2,954,939 |
| 50-Year Value of Land Created | | $29,549,394 |
| Total Cost (50 years) | $110,158,404 | $104,220,185 |
| **18-Foot Channel** | | |
| Total Rock Construction Cost | $0 | $38,912,100 |
| Total Rock Maintenance Cost | $0 | $37,188,000 |
| 50-Year Dredging Cost | $82,424,807 | $53,104,295 |
| 50-Year Land Loss Costs | $28,610,676 | $2,861,068 |
| 50-Year Value of Land Created | | $28,610,676 |
| Total Cost (50 years) | $111,035,483 | $103,454,786 |
| **20-Foot Channel** | | |
| Total Rock Construction Cost | $0 | $38,912,100 |
| Total Rock Maintenance Cost | $0 | $37,188,000 |
| 50-Year Dredging Cost | $80,282,293 | $54,293,620 |
| 50-Year Land Loss Costs | $27,421,634 | $2,742,163 |

| Depth Option | Cost Without Rock | Cost With Rock |
|---|---|---|
| 50-Year Value of Land Created | | $27,421,634 |
| Total Cost (50 years) | $107,703,926 | $105,714,250 |

### 6.2.5 Rock Design

The rock that comprises the dikes, for both the foreshore protection and rock retention, must be of sufficient weight and thickness to withstand the effects of wave action. The dikes would be constructed using the Standard 36 gradation of rocks placed over a geotextile fabric. This rock size was determined from Hudson's formula using a four-foot wave. The four-foot wave was used from the vessel traffic study and is the wake anticipated from fast-moving vessels using this waterway. Hudson's formula is given below:

$$W_{50} = \frac{w_r H^3}{K_{rr}\left(S_r - 1\right)^3 \cot\Theta}$$

Where:

$W_{50}$ is the weight in lbs. of an individual rock
$w_r$ is the unit weight of rock (155 lbs/ft$^3$)
H is the design wave height at the structure (4 feet)
$K_{rr}$ is the stability coefficient ($K_{rr}$ = 2.2)
$S_r$ is the specific gravity of rock relative to water ($W_r/W_w$) (155/64)
CotΘ is the cotangent of the structure slope (3)

This formula and values for $K_{rr}$ are explained in detail in the Shore Protection Manual, published by the Department of the Army, Waterways Experiment Station, USACE, 1984. Gradations were determined from a set of standard gradations provided by USACE Lower Mississippi Valley Division (CELMV), in a November 1981 letter report. The gradation was selected which most closely fits the rock weight determined from Hudson's formula. Design rock sizes are large enough to ensure that the rock will not be displaced a four foot or lesser wave. Outer rock gradations required for foreshore protection along the HNC are presented in Table A-20. Typical cross sections are shown on Plate C7 in Annex V.

**Table A-20. Foreshore Protection Outer Rock Gradations**

| Percent Lighter by Weight | Limits of Rock Weight (lbs) |
|---|---|
| 100 | 2200 - 900 |
| 50 | 930 - 440 |
| 15 | 460 - 130 |

## 6.3 Earthen Dikes

HNC Operations and Maintenance (O&M) records from the mid 1960s indicate that the dredged material from within the project disposal areas has been suitable for the construction of earthen dikes. Therefore, it is expected that borrow material for earthen dikes, closures, and weirs would primarily come from within the areas to be occupied by the dredged material. A typical cross section of an earthen sacrificial dike is shown in Figure A-10. Although most of the disposal areas are semi-confined or unconfined wetland creation sites, disposal areas confined by earthen dikes will contain spill boxes to allow for drainage.

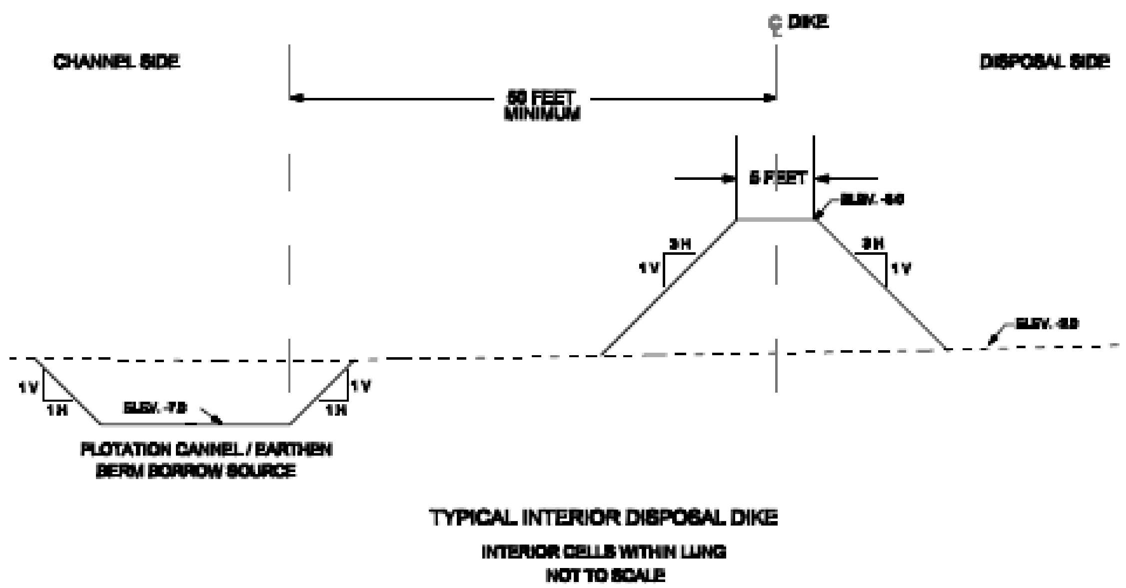



**Figure A-10. Typical Cross Section for Interior Dike**

## 6.4 Construction Schedule

Initial construction of either the −18 or −20 foot alternative is anticipated to be accomplished through eight contracts (three for pipeline relocations and five for channel improvements). Pipeline relocations would begin almost five years before the expected completion of the floodgate and lock complex. Channel improvements would begin soon after completion of both the floodgate and lock and utility relocations. The floodgate and lock construction is an element of the MTG Project; however, the State of Louisiana is planning to construct the lock. For cost estimating purposes, it is estimated that the HNC floodgate and lock complex would be completed in October 2020. It is estimated that initial construction will take over 10 years to complete. This schedule does not include O&M requirements. The estimated construction schedule is presented in Table A-21.

**Table A-21. Estimated Construction Schedule**

| Construction Type | Reach (mile) | Estimated Start Date | Estimated Completion Date |
|---|---|---|---|
| Feasibility Study | | January 2010 | January 2016 |
| Sign PCA | | January 2016 | January 2016 |
| Floodgate and Lock | 18.5 to 20.8 | October 2015 | October 2020 |
| Pipeline Relocation | 34.4 to 26.5 | January 2016 | September 2018 |
| Pipeline Relocation | 23.5 to 11.9 | September 2017 | May 2020 |
| Pipeline Relocation | 11.9 to 6.4 | May 2019 | January 2022 |
| Channel Improvement | 36.3 to 22.0 | January 2021 | March 2023 |
| Channel Improvement | 22.0 to 11.5 | March 2022 | July 2024 |
| Channel Improvement | 11.5 to 6.0 | July 2023 | July 2025 |
| Channel Improvement | 6.0 to 2.0 | July 2024 | September 2026 |
| Channel Improvement | 2.0 to -3.5 | September 2025 | September 2027 |

NOTE: Durations include time required for planning and design phases; Schedule assumes deepening recommended

## 7.0 RELOCATIONS

The information in this section documents potentially affected facilities and presents proposed relocations required by the HNC Deepening Project. Affected facilities would be relocated to facilitate the new design depth and channel cross section. To maintain continuous service for facilities during relocation operations, hot taps and temporary bypasses are assumed, as well as de-energizing submerged electrical cables.

### 7.1 Criteria

The following general criteria are for pipeline and utility line burial in waterways within the CEMVN (05/31/10). The terms *pipeline* and *utility line* include petroleum lines, flow lines, gas lines, chemical lines, water lines, brine lines, power cables, telephone cables, and similar lines. A utility must be relocated when the cover over the utility is less than 4 feet below the authorized channel depth.

### 7.2 Facilities Affected by the Project

Categories of facilities potentially affected by the project include bridges, oil and gas pipelines, electrical and communication lines, and public utilities (water and sewer). The location of potentially affected facilities, depicted on Plates C1 through C12 (Annex V), were obtained from the 1990 Louisiana Parish Pipeline and Industrial Atlas Map of Terrebonne Parish, by researching permits and ownership forms, and site investigations. Potentially affected facilities are referenced to miles along the HNC. Regardless of recommendations for this planning study, all utilities or other facilities identified here or in the design phase would require a physical location, both horizontally and vertically, before design documents are developed and again prior to construction.

### 7.3 Relocation Disposition

Some facilities would be affected by the proposed deepening of the HNC and would require relocation (Table A-22). The elevation of each utility was compared to the maximum dredge depth to determine if the utility would need to be relocated. This relocation information represents utility research that was completed in 2012.

A total of 24 utilities will have to be relocated for the 18-foot channel and 28 utilities for the 20-foot channel (Table A-22). Two utilities have been abandoned; both of these lines would need to be removed (but not relocated) for the 18- and 20-foot channels. Four utilities have unknown depths and are assumed to require relocation.

### 7.4 Facility Descriptions

**Bridge (B-1)** - LADOTD owns the LA Hwy 661 swing bridge across the HNC at Mile 36.3.

**Electrical Submarine Cable (E-1) -** One primary 13.2/7.62 kilovolts (KV) distribution cable owned by South Louisiana Electric Cooperative Association Co. (SLECA) at Mile 36.3 just south of the LA Hwy 661 Swing Bridge. This three-phase buried submarine cable across the HNC provides electric service to residences in five parishes.

**Waterline (W-1)** - One 12-inch waterline owned by Terrebonne Parish Consolidated Waterworks District No. 1. This waterline is made of ductile iron across the HNCs and provides public drinking water.

**Electrical Submarine Cable (E-2)** - One 34.5 KV distribution submarine cable owned by Entergy Louisiana Inc. at Mile 34.5. This cable services businesses and homes along LA Hwy 57.

**Submarine Fiber Optic Cable (C-1) -** One ½-inch diameter submarine fiber optic cable owned by Charter Communications. This fiber optic cable lies within a directional bore 3-inch PVC conduit. This facility provides data, cable television, and internet services.

**Sewer Pipeline (S-1) -** One 10-inch diameter sewer line owned by Terrebonne Parish Consolidated Government Pollution Control Division (TPCGPCD). This sewer force main is within a 14-inch steel diameter casing and crosses the HNC at an unknown elevation, relocation may be required.

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**Table A-22. HNC Facility Potential Relocation Data for the 18- and 20-Foot Channels**

| Facility | | Owner | Mile | Remaining Cover | | Utility Elevation (ft) (NAVD88) | Active | Relocation Required | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 18-ft | 20-ft | | | 18-ft | 20-ft |
| B-1 | HWY 661 Swing Bridge | LADOTD | 36.3 | N/A | N/A | N/A | Yes | No | No |
| E-1 | Electrical Sub Cable | SLECA | 36.3 | 1.0 | −1.0 | −22.0 | Yes | Yes | Yes |
| W-1 | 12-in Waterline | TPCWD#1 | 34.5 | 3.8 | 1.8 | −24.8 | Yes | Yes | Yes |
| E-2 | Electrical Sub Cable | Entergy | 34.5 | 3.1 | 1.1 | −24.1 | Yes | Yes | Yes |
| C-1 | Sub Fiber Optic Cable | Charter | 34.3 | 3.8 | 1.8 | −24.8 | Yes | Yes | Yes |
| S-1 | 10-in Sewer Line (14-in) | TPCGPCD | 34.0 | Unknown* | Unknown* | ? | Yes | TBD | TBD |
| E-3 | Electrical Sub Cable | SLECA | 34.0 | 1.2 | −0.8 | −22.2 | Yes | Yes | Yes |
| P-1 | 20-in NGL | GS | 31.3 | 0.0 | −2.0 | −21.0 | Yes | Yes | Yes |
| P-2 | 16-in NGL | LIG | 31.3 | 5.8 | 3.8 | −26.8 | Yes | No | Yes |
| P-3 | 8-in NGL | Enterprise | 29.8 | 4.8 | 2.8 | −25.8 | Yes | No | Yes |
| P-4 | 10-in NGL | LIG | 31.3 | 1.8 | −0.2 | −22.8 | Yes | Yes | Yes |
| P-5 | 30-in NGL | CGT | 27.8 | 3.8 | 1.8 | −24.8 | Yes | Yes | Yes |
| E-4 | Electrical Sub Cable | SLECA | 27.8 | 5.8 | 3.8 | −26.8 | No | No | No[a] |
| P-6 | 12-in NGL | Koch | 23.5 | 4.8 | 2.8 | −25.8 | Yes | No | Yes |
| B-2 | Bridge | TPCG | 23.5 | N/A | N/A | N/A | Yes | No | No |
| E-5 | Electrical Sub Cable | TPCG | 23.5 | −1.0 | −3.0 | −20.0 | Yes | Yes | Yes |
| E-6 | Electrical Sub Cable | SLECA | 23.3 | 2.8 | 0.8 | −23.8 | Yes | Yes | Yes |
| P-7 | 4-in NGL | GSP | 22.8 | 0.0 | −2.0 | −21.0 | Yes | Yes | Yes |
| P-8 | 6-in NGL | GSP | 23.5 | 0.0 | −2.0 | −21.0 | Yes | Yes | Yes |
| P-9 | 6-in NGL | LAR | 21.8 | 8.0 | 6.0 | −29.0 | Yes | No | No |
| W-2 | Two 4-in Waterlines | Hope | 21.8 | 3.8 | 1.8 | −24.8 | No | No | No[a] |
| P-10 | 6-in NGL | WGPC | 13.5 | 1.8 | −0.2 | −22.8 | Yes | Yes | Yes |
| P-11 | 24-in NGL | TGP | 12.0 | −1.2 | −3.2 | −19.8 | Yes | Yes | Yes |
| P-12 | 26-in NGL | TGP | 12.0 | 2.8 | 0.8 | −23.8 | Yes | Yes | Yes |
| P-13 | 36-in NGL | TGP | 12.0 | 8.8 | 6.8 | −29.8 | Yes | No | No |
| P-14 | 6-in NGL | SNG | 11.8 | 5.8 | 3.8 | −26.8 | Yes | No | Yes |
| P-15 | 2½-in Oil Pipeline | Texaco | 10.5 | 1.8 | −0.2 | −22.8 | Yes | Yes | Yes |
| P-16 | 2 ½-in Gas Pipeline | Texaco | 10.5 | 1.8 | −0.2 | −22.8 | Yes | Yes | Yes |
| P-17 | 3-in NGL | Texaco | 10.5 | 1.8 | −0.2 | −22.8 | Yes | Yes | Yes |
| P-18 | 2½-in NGL | Texaco | 10.5 | 1.8 | −0.2 | −22.8 | Yes | Yes | Yes |
| P-19 | 3-in NGL | Chevron | 10.5 | 1.8 | −0.2 | −22.8 | Yes | Yes | Yes |
| P-20 | 8-in NGL | Comstock | 8.5 | 8.8 | 6.8 | −29.8 | Yes | No | No |
| P-21 | 8-in NGL | Texaco | 10.5 | Unknown* | Unknown* | TBD* | Yes | Yes | Yes |
| P-22 | 16-in NGL | Texaco | 10.5 | Unknown* | Unknown* | TBD* | Yes | Yes | Yes |
| P-23 | 20-in NGL | Texaco | 10.5 | Unknown* | Unknown* | TBD* | Yes | Yes | Yes |
| P-24 | 20-in Pipeline | Shell | −6.0 | 128.8 | 126.8 | −149.8 | Yes | No | No |
| * Utility elevation could not be determined during study phase, so it was assumed that relocation would be necessary. | | | | | | | | | |

[a] Removal required, but not relocation.
NOTE: All utilities fall within the Inland reach except P-24 which is not in the project footprint.

Relocation Not Required, Utility meet 4 ft minimum coverage
Utility may be abandoned in place or removed not relocated
Relocation Required.

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**Electrical Submarine Cable (E-3) -** Two primary 13.2/7.62 KV distribution buried submarine cable owned by SLECA just south of the Hwy 661 Swing Bridge. The two 3-phase submarine buried cable provides electric service to residences in five parishes.

**Natural Gas Pipeline (P-1) -** One 20-inch natural gas pipeline owned by Gulf South Pipeline Co. (GSP). The facility is used to transport high-pressure natural gas.

**Natural Gas Pipeline (P-2)** - One 16-inch natural gas pipeline owned by Louisiana Intrastate Gas Company, LLC (LIG). The facility is used to transport high-pressure natural gas.

**Natural Gas Pipeline (P-3) -** One 8-inch natural gas pipeline owned by Enterprise Products. This pipeline is used to transport high-pressure natural gas.

**Natural Gas Pipeline (P-4) -** One 10-inch natural gas pipeline owned by LIG. The pipeline is used to transport high-pressure natural gas.

**Natural Gas Pipeline (P-5) -** One 30-inch natural gas pipeline owned by Columbia Gulf Transmission (CGT). The pipeline is used to transport high-pressure gas.
**Electrical Submarine Cable (E-4) -** One primary 13.2/7.62 KV submerged distribution cable owned by SLECA. This facility is abandoned in place and relocation is not required; however, may be abandoned in place or removed.

**Natural Gas Pipeline (P-6) -** One 12-inch natural gas pipeline owned by Koch Gateway Pipeline Co. (Koch). The pipeline is used to transport high-pressure natural gas.

**Bridge (B-2) -** The TPCG owns this existing pontoon bridge and no relocation is required.

**Electrical Submarine Cable (E-5) -** One submarine cable owned by TPCG.

**Electrical Submarine Cable (E-6) -** One submarine cable owned by SLECA.

**Natural Gas Pipeline (P-7) -** One 4-inch natural gas pipeline owned by GSP. The pipeline is used to transport high-pressure natural gas.

**Natural Gas Pipeline (P-8) -** One 6-inch natural gas pipeline owned by GSP. The pipeline is used to transport high-pressure natural gas.

**Natural Gas Pipeline (P-9) -** One 6-inch natural gas pipeline formerly owned by Louisiana Resources. No ownership is currently available (Dec 2012). Relocation is not required.

**Water Pipeline (W-2) -** Two 4-inch waterlines previously owned by Hope Services that have been abandoned. Relocation is not required; however, may be abandoned in place or removed.

**Natural Gas Pipeline (P-10) -** One 6-inch natural gas pipeline owned by Williams Gas Pipeline Co. The pipeline is used to transport high-pressure natural gas.

**Natural Gas Pipeline (P-11) -** One 24-inch natural gas pipeline owned by Tennessee Gas Pipeline Co. (TGP). This pipeline is used to transport high-pressure natural gas.

**Natural Gas Pipeline (P-12) -** One 26-inch natural gas pipeline owned by TGP. This pipeline is used to transport high-pressure natural gas.

**Natural Gas Pipeline (P-13) -** One 36-inch natural gas pipeline owned by TGP. This pipeline is used to transport high-pressure natural gas. Relocation is not required.

**Natural Gas Pipeline (P-14)** - One 6-inch natural gas pipeline owned by Southern Natural Gas Pipeline Co. (SNG). The pipeline is used to transport high-pressure natural gas.

**Oil Pipeline (P-15)** – One 2½-inch oil pipeline owned by Texaco Inc. This pipeline is used to transport oil.

**Natural Gas Pipeline (P-16)** – One 2½-inch gas pipeline owned by Texaco Inc. This pipeline is used to transport natural gas.

**Natural Gas Pipeline (P-17)** - One 3-inch gas pipeline owned by Texaco Inc. This pipeline is used to transport natural gas.

**Natural Gas Pipeline (P-18)** – One 2½-inch gas pipeline owned by Texaco Inc. This pipeline is used to transport natural gas.

**Natural Gas Pipeline (P-19)** - One 3-inch gas pipeline owned by Chevron-Texaco Inc. This pipeline is used to transport natural gas.

**Natural Gas Pipeline (P-20)** - One 8-inch gas pipeline owned by Comstock Offshore LLC. This pipeline is used to transport natural gas. Relocation is not required.

**Natural Gas Pipeline (P-21) -** One 8-inch gas pipeline owned by Texaco Pipeline LLC. This pipeline is used to transport natural gas.

**Natural Gas Pipeline (P-22) -** One 16-inch gas pipeline owned by Texaco Pipelines LLC. This pipeline is used to transport natural gas.

**Natural Gas Pipeline (P-23) -** One 20-inch gas pipeline owned by Texaco Pipeline LLC. This pipeline is used to transport natural gas.

**Crude Oil Pipeline (P-24) -** One 20-inch oil pipeline owned by Equilon/Shell Pipeline Company. This pipeline is used to transport oil. This pipeline is located Gulfward of the HNC and relocation is not required.

# 8.0 MAINTENANCE DREDGING

## 8.1 Maintenance Dredging History

The maintenance dredging history (Table A-23) was used to estimate the maintenance volume for the No-action Alternative and the deepening alternatives.

**Table A-23. Maintenance Dredging History (1965-2012)**

| Fiscal Year | Dredging Reaches | Cubic Yards | Disposal Area |
|---|---|---|---|
| 1965 | Inland | 53,000 | CDF |
| 1965 | TB | 2,058,645 | OW |
| 1966 | Inland | 108,300 | CDF |
| 1966 | TB | 1,316,827 | OW |
| 1966 | CIP | 29,866 | ODMDS |
| 1967 | CIP | 252,969 | ODMDS |
| 1968 | CIP | 534,977 | ODMDS |
| 1968 | Inland | 492,586 | CDF |
| 1968 | TB | 1,662,000 | OW |
| 1970 | Inland | 29,299 | CDF |
| 1970 | TB | 523,601 | OW |
| 1970 | CIP | 2,128,246 | ODMDS |
| 1972 | TB | 1,956,000 | OW |
| 1972 | CIP | 106,369 | ODMDS |
| 1973 | Inland | 1,935,805 | CDF |
| 1974 | Inland | 1,482,233 | CDF |
| 1974 | TB | 2,133,841 | OW |
| 1974 | CIP | 627,571 | ODMDS |
| 1976 | CIP | 98,533 | ODMDS |
| 1978 | TB | 1,925,341 | OW |
| 1978 | CIP | 598,318 | ODMDS |
| 1980 | Inland | 1,401,088 | CDF |
| 1981 | TB | 1,180,247 | OW |
| 1981 | CIP | 765,296 | ODMDS |
| 1982 | Inland | 2,450,179 | CDF |
| 1983 | TB | 1,790,720 | OW |
| 1983 | CIP | 625,754 | ODMDS |
| 1984 | TB | 1,174,121 | OW |
| 1984 | CIP | 723,443 | ODMDS |
| 1985 | Inland | 417,848 | CDF |
| 1985 | TB | 1,373,684 | OW |
| 1985 | CIP | 1,118,316 | ODMDS |
| 1987 | TB+CIP | 1,889,000 | WD+OW+ODMDS |
| 1991 | Inland | 186,520 | CDF |
| 1991 | Inland | 447,419 | WD |

| Fiscal Year | Dredging Reaches | Cubic Yards | Disposal Area |
|---|---|---|---|
| 1991 | TB | 88,000 | WD |
| 1991 | TB | 1,499,424 | OW |
| 1991 | CIP | 600,000 | East (Wine) Island |
| 1991 | CIP | 540,000 | ODMDS |
| 1993 | TB | 187,961 | WD |
| 1993 | TB | 150,950 | WD |
| 1993 | TB | 1,431,876 | OW |
| 1993 | CIP | 523,005 | East (Wine) Island |
| 1993 | CIP | 194,273 | ODMDS |
| 1995 | CIP | 1,016,392 | SPD |
| 1995 | TB | 1,265,229 | WD+OW |
| 1995 | Inland | 150,879 | CDF |
| 1998 | CIP | 117,412 | SPD |
| 1998 | TB | 239,884 | OW |
| 1998 | TB | 890,500 | WD |
| 1998 | CIP | 608,810 | SPD |
| 2002 | TB | 1,268,161 | OW |
| 2002 | TB | 607,095 | WD |
| 2002 | TB | 609,505 | OW |
| 2003 | CIP | 1,197,531 | SPD |
| 2005 | TB | 1,123,642 | WD |
| 2005 | CIP | 1,084,156 | SPD |
| 2005 | CIP | 770,741 | SPD |
| 2006 | TB | 1,638,392 | OW |
| 2006 | CIP | 567,045 | SPD |
| 2006 | Inland | 564,225 | CDF |
| 2006 | Inland | 161,065 | WD |
| 2007 | TB | 564,410 | OW |
| 2007 | TB | 442,851 | East (Wine) Island |
| 2008 | TB | 3,464,466 | OW |
| 2009 | TB | 1,345,231 | OW |
| 2011 | TB | 1,264,080 | OW |
| 2011 | TB | 562,148 | OW |
| 2012 | TB | 571,369 | OW |

TB - Terrebonne Bay; CIP - Cat Island Pass; CDF - Upland Confined Disposal Facility
OW = Open Water; ODMDS = Ocean Dredged Material Disposal Site; SPD = Single Point Discharge Site; WD = Bay Chaland

## 8.2 Disposal Areas

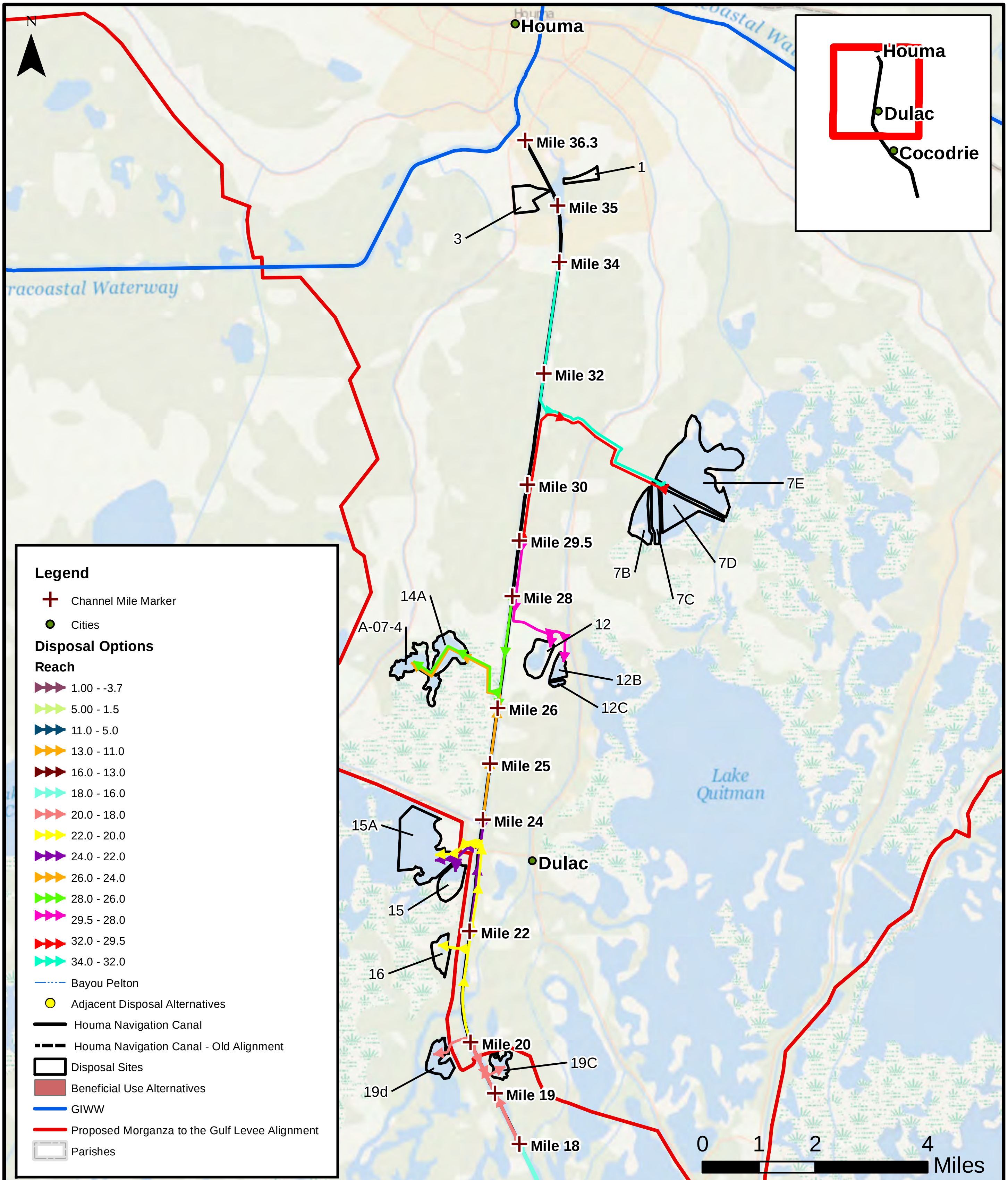
HNC disposal areas range from 50.9 to 2,200 acres (Table A-24, Figures A-11 and A-12).

Material excavated from the Inland Reach would be pumped to numerous disposal sites along the east and west banks of the HNC for upland confined disposal or marsh creation within designated shallow open water areas adjacent to the channel. All placement sites in the inland reach, except for Sites 1 and 3, which have existing dikes around them, will have sacrificial containment dikes built and sized for each event (construction and maintenance).

**Table A-24. Disposal Area Types and Acreage**

| Disposal Site ID | Acres | Disposal Area Type |
|---|---|---|
| 1 | 50.9 | upland |
| 3 | 132.0 | upland |
| 7E | 772.5 | in-water marsh |
| 12 | 130.0 | in-water marsh |
| 12B | 56.5 | in-water marsh |
| A-07-A | 200.7 | in-water marsh |
| 14A | 184.2 | in-water/marsh |
| 15 | 148.3 | in-water/marsh |
| 15A | 578.1 | in-water/marsh |
| 16 | 119.9 | in-water/marsh |
| 19C | 74.9 | in-water/marsh |
| 19D | 131.3 | in-water/marsh |
| 20C | 133.3 | in-water/marsh |
| 21 | 527.2 | in-water/marsh |
| 24 | 71.3 | in-water/marsh |
| Lung | 2,220.0 | in-water/marsh |
| East Island Bay | 1,317.0 | nearshore |
| East Island Nearshore | N/A | beach nourishment |
| Total Acreage | 6,848.1 | |

The material excavated from the Terrebonne Bay Reach (Mile 11.0 to 0.0) and Cat Island Pass Bar Channel will be disposed of by the adjacent disposal option.

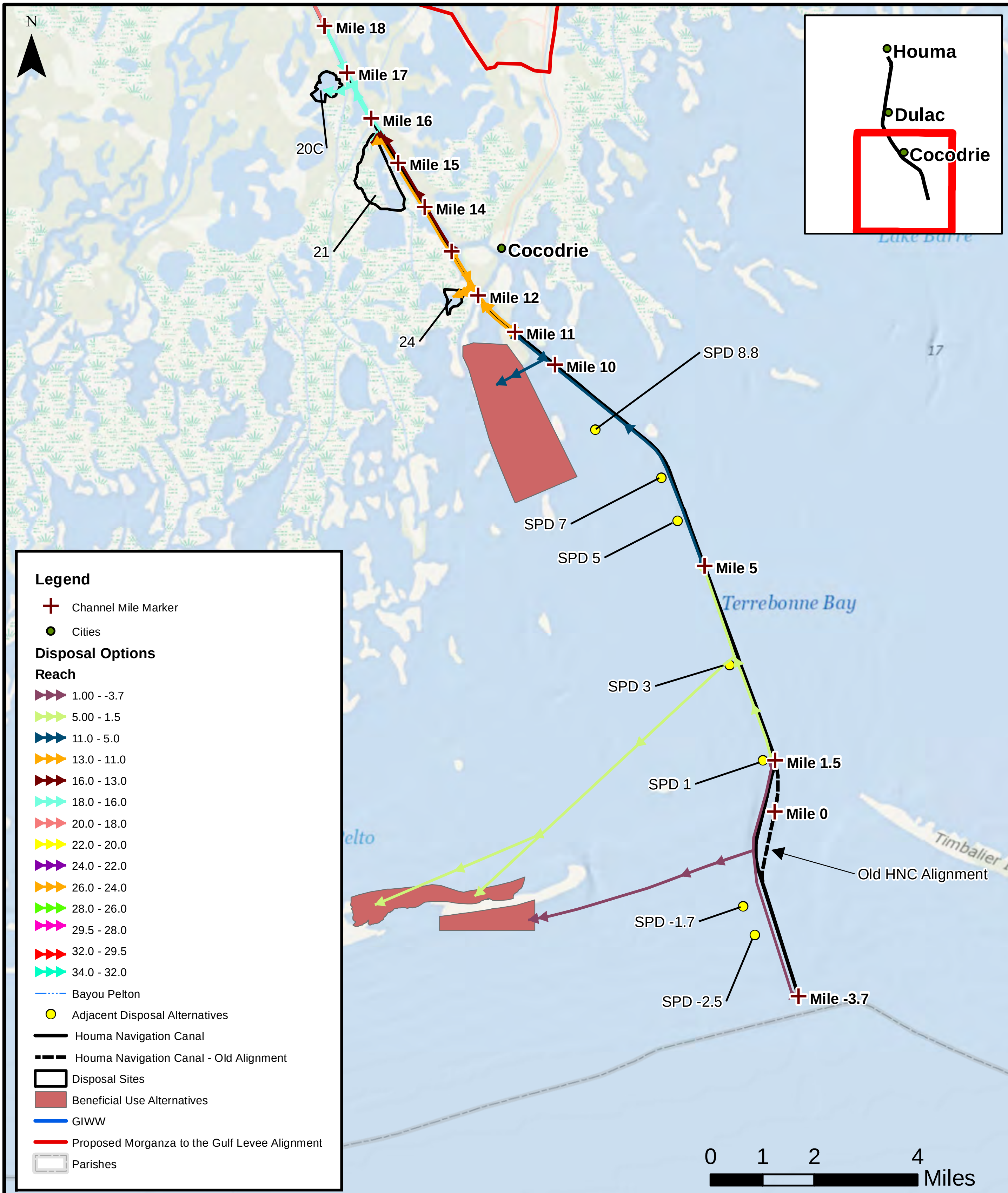



# DISPOSAL AREAS
## North End
Houma Navigation Canal Deepening

*ERSI Ocean Map*

GEC

| |
|---|
| Figure A-11 |
| Date: December 2014 |
| Scale:1:150,000 |
| Source: ESRI/GEC |
| Map ID: 278500218-3026 |




# DISPOSAL AREAS
## South End
Houma Navigation Canal Deepening

*ERSI Ocean Map*

GEC

| |
|---|
| Figure A-12 |
| Date: December 2014 |
| Scale:1:165,000 |
| Source: ESRI/GEC |
| Map ID: 278500218-3026 |

## 8.3 Maintenance Cycle

Each HNC reach is subject to different physical factors affecting the maintenance volumes per cycle and the frequency of the maintenance dredging cycle. Bank erosion is the primary source of sediments on the Inland Reach. The predominant cause of bank erosion is wave action by vessel traffic. In Terrebonne Bay, wind and wave action suspends bottom sediments and contributes to filling the channel. The Cat Island Pass Reach is subject to more external forces. The primary source of the sediment in Cat Island Pass Reach has been from the east, by erosion of the Lafourche headlands and transport along Timbalier Island. It is anticipated that these transport pathways east of the channel will continue. Maintenance dredging will be a non-continuous dredging plan.

The maintenance cycle for the Inland Reach is approximately every 10 years. Some locations (Mile 36.3 to 34.5 and Mile 24.0 to 19.7) occur approximately every 5 years. The maintenance dredging cycle for the Terrebonne Bay and Cat Island Pass Reaches is not expected to deviate from the current maintenance cycle, of approximately every two years. The frequency of required maintenance dredging in the Terrebonne Bay and Cat Island Pass Reaches will be greatly influenced by the proximity, strength, and number of tropical storms.

## 8.4 Maintenance Volume

The estimate of the maintenance volume for the Inland Reach and the Terrebonne Bay Reach is based on the maintenance dredging history. The Cat Island Pass Reach maintenance volume is based on the analysis by the Coastal and Hydraulics Laboratory, ERDC (Annex VII). The currently authorized depth (−15 foot MLG) of HNC will also require maintenance dredging. The maintenance volume estimates for the No-Action plan and the two channel depths are presented in Table A-25.

### 8.4.1 No Action Plan (15-Foot MLG)

The authorized depth for the Inland Reach is −15 feet MLG. The currently authorized plan proposed channels have a 150-foot bottom width and 3H to 1V side slopes. The maintenance volume is based on the maintenance dredging history. The primary source of sediments is bank erosion due to wave action of created by vessel traffic. On the Inland Reach the dredge material for the no-action plan, will utilize the same disposal sites as the proposed alternative plans.

The maintenance volume for the Terrebonne Bay Reach is based on the historical records. The ERDC study estimated the annual maintenance volume for Cat Island Pass as 250,000 cubic yards (Rosati *et al*. 2008, Annex VII).

**Table A-25. Historic and Estimated Maintenance Volumes**

| Reach | Historical (1967–2006) cy | ERDC Study Annex VII cy | Maintenance Volumes | | Volume Used for Alternative Comparison (cy)[f] | Annual Cubic Yards (cy) | Percent Change with Foreshore Rock |
|---|---|---|---|---|---|---|---|
| | | | Volume per Maintenance Cycle (cy) | Maintenance Cycle (Years) | | | |
| **15-Foot Channel (No Action Plan)** | | | | | | | |
| Inland | 243,000 | | 2,430,000 | 10 | 2,430,000 | 243,000 | |
| Terrebonne Bay | 634,500 | | 1,269,000 | 2 | 1,269,000 | 634,500 | |
| Cat Island Pass | 398,000 | 250,000 | 500,000 | 2 | 500,000[e] | 250,000 | |
| **18-Foot Channel** | | | | | | | |
| Inland Reach | 243,000 | | 2,430,000 | 10 | 2,478,600 | 247,860 | 2 |
| Terrebonne Bay | 634,500 | | 1,269,000 | 2 | 1,383,200 | 691,600 | 9 |
| Cat Island Pass | 398,000 | 250,000 | 500,000 | 2 | 500,000[e] | 250,000 | |
| **20-Foot Channel** | | | | | | | |
| Inland Reach | 243,000 | | 2,515,000 | 10 | 2,673,000 | 237,300 | 10 |
| Terrebonne Bay | 634,500 | | 1,269,000 | 2 | 1,434,0000 | 717,000 | 13 |
| Cat Island Pass | 398,000 | 290,000 | 580,000 | 2 | 580,000[e] | 290,000 | |

[a] Terrebonne Bay (Mile 0.0 to 10.1) for the historical record.
[b] Terrebonne Bay (Mile 0.0 to 11.0) for maintenance cost estimate.
[c] ERDC estimate of maintenance volume for Cat Island Pass (Annex VII).
[d] Currently authorized depth for Cat Island Pass is −18 feet MLG.
[e] ERDC value was selected for analysis for Cat Island Pass Reach.
[f] Revised annual maintenance volumes (in lieu of the historical) was used on the Inland Reach for the 18- and 20-foot alternatives because these alternatives would include foreshore protection and rock retention.

### 8.4.2 18-Foot Channel Alternatives

The proposed authorized depth for the Inland Reach is −18 feet NAVD88. This 18-foot channel would be approximately 3 feet deeper than the currently authorized channel (−15 feet MLG). The currently authorized plan and the proposed channels have a 150-foot bottom width and 3H to 1V side slopes. The average top width of the −18 foot channel is 11 feet wider than the existing channel. The 11 foot increase in top width corresponds to a 7 percent increase in top width of the channel at the mud line. It is estimated the rock retention dikes and foreshore protection will decrease the maintenance volume on the inland reach by 5 percent. The revised (in lieu of the historical) volumes were used to estimate the 18-foot annual maintenance volume. The net increase in the maintenance volume for the Inland Reach is 2 percent

The proposed authorized depth for the Terrebonne Bay Reach is −18 feet NAVD88. The −18 feet channel is approximately 3 feet deeper than the currently authorized channel (15 feet MLG). The currently authorized plan and the proposed channels have a 150-foot bottom width and 3H to 1V side slopes. The average top width of the 18-foot channel is 14 feet wider than the existing channel. This 14-foot increase in top width corresponds to a nine percent increase in maintenance volume. The estimated increase in annual maintenance volume for the Terrebonne Reach is 9 percent.

The proposed authorized depth of Cat Island Pass Reach is −18 feet NAVD88, nearly the same as the currently authorized channel (−18 feet MLG). The currently authorized plan and the proposed channel have a 300-foot bottom width and 3H to 1V side slopes. The top width or maintenance volume would not increase. The ERDC study estimated the annual maintenance volume for Cat Island Pass as 250,000 cubic yards. The ERDC study maintenance volume was used for Cat Island Pass.

### 8.4.3 20-Foot Channel Alternatives

The proposed authorized depth for the Inland Reach is −20 feet NAVD88. The 20-foot channel is approximately five feet deeper than the currently authorized channel (−15 feet MLG). The currently authorized plan and the proposed channels have a 150-foot bottom width and 3H to 1V side slopes. The average top width of the 20-foot channel is 23 feet wider than the existing channel. The 23-foot increase in top width corresponds to a 15 percent increase in top width at the mud line. It is estimated the rock retention dikes and foreshore protection will decrease the maintenance volume on the inland reach by 5 percent. The revised (in lieu of the historical) volumes were used to estimate the 18-foot annual maintenance volume. The net increase in the maintenance volume for the Inland Reach is 10 percent.

The proposed authorized depth in the Terrebonne Bay Reach is −20 feet NAVD88. The 20-foot channel is approximately five feet deeper than the currently authorized channel (−15 feet MLG). The currently authorized plan and the proposed channels have a 150-foot bottom width and 3H to 1V side slopes. The average top width of the 20-foot channel is 20 feet wider than the existing channel at the mud line. The 20 feet increase in top width corresponds to a 13 percent increase in maintenance volume. The estimated increase in annual maintenance volume for the Terrebonne Reach is 13 percent.

The proposed authorized depth for the Cat Island Pass Reach is −20 feet NAVD88. The 20-foot channel is approximately 2 feet deeper than the currently authorized channel (−18 feet MLG). The currently authorized plan and the proposed channels have a 300-foot bottom width and 3H to 1V side slopes. The average top width of the 20-foot channel is 21 feet wider than the existing channel. The Cat Island Pass Reach will need to be lengthened approximately 1,000 feet to ensure connection to the 20-foot contour in the Gulf. This depth measure will increase the size [width (at mud line) and length] of the channel by approximately 10 percent. The ERDC study estimated the annual maintenance volume for Cat Island Pass as 290,000 cubic yards. The ERDC study maintenance volume was used for Cat Island Pass.

The construction volumes and maintenance cycle volumes (2, 5, and 10 year cycles) for the No Action Alternative and the proposed channel depths, in approximate 2-mile increments, are presented in Tables A-26 to A-32. No additional maintenance cycles would be necessary for the 18- or 20- foot depths.

**Table A-26. Dredged Material Information for Authorized Channel (15-Foot MLG Channel with Adjacent Disposal)**

| Reach (Mile) | Construction (CY) | Maintenance (CY) | Maintenance Per Cycle (CY) | Cycle (Years) | Construction Disposal Site | Maintenance Disposal Site |
|---|---|---|---|---|---|---|
| 36.3 to 34.0 | NA | 997,000 | 99,700 | 5 | N/A | 1 and 3 |
| 34.0 to 32.0 | NA | 998,000 | 199,600 | 10 | N/A | 7E |
| 32.0 to 29.5 | NA | 753,500 | 150,700 | 10 | N/A | 7E |
| 29.5 to 28.0 | NA | 753,500 | 150,700 | 10 | N/A | 12B and 12 |
| 28.0 to 26.0 | NA | 998,000 | 199,600 | 10 | N/A | A-07-A |
| 26.0 to 24.0 | NA | 998,000 | 199,600 | 10 | N/A | A-07-A and 14A |
| 24.0 to 22.0 | NA | 997,000 | 99,700 | 5 | N/A | 15 |
| 22.0 to 20.0 | NA | 997,000 | 99,700 | 5 | N/A | 16 and 15A |
| 20.0 to 18.0 | NA | 998,000 | 199,600 | 10 | N/A | 19C and 19D |
| 18.0 to 16.0 | NA | 998,000 | 199,600 | 10 | N/A | 20C |
| 16.0 to 13.0 | NA | 1,506,500 | 301,300 | 10 | N/A | 21 |
| 13.0 to 11.0 | | 1,157,000 | 231,400 | 10 | | 24 and 21 |
| 13.0 to 11.5 | NA | | | | 24 | |
| 11.5 to 10.0 | NA | | | | SPD Mile 8.8 | |
| 11.0 to 8.0 | | 8,275,000 | 331,000 | 2 | | SPD Mile 8.8 |
| 10.0 to 8.0 | NA | | | | SPD Mile 8.8 | |
| 8.0 to 6.0 | NA | 5,707,500 | 228,300 | 2 | SPD Mile 7 | SPD Mile 7 |
| 6.0 to 4.0 | NA | 5,915,000 | 236,600 | 2 | SPD Mile 5 | SPD Mile 5 |
| 4.0 to 2.0 | NA | 5,915,000 | 236,600 | 2 | SPD Mile 3 | SPD Mile 3 |
| 2.0 to 0.0 | NA | 5,915,000 | 236,600 | 2 | SPD Mile 1 | SPD Mile 1 |

| Reach (Mile) | Construction (CY) | Maintenance (CY) | Maintenance Per Cycle (CY) | Cycle (Years) | Construction Disposal Site | Maintenance Disposal Site |
|---|---|---|---|---|---|---|
| 0.0 to −3.5 | NA | 12,500,000 | 500,000 | 2 | SPD Mile −1.7 to −2.5 | SPD Mile −1.7 to −2.5 |
| TOTAL | | 56,379,000 | | | | |

**Table A-27. Dredged Material Information for Alternative 1A (18-Foot Channel with Adjacent Disposal)**

| Reach (Mile) | Construction (CY) | Maintenance (CY) | Maintenance Per Cycle (CY) | Cycle (Years) | Construction Disposal Site | Maintenance Disposal Site |
|---|---|---|---|---|---|---|
| 36.3 to 34.0 | 170,000 | 1,016,000 | 101,600 | 5 | 1 | 1 and 3 |
| 34.0 to 32.0 | 77,500 | 1,018,000 | 203,600 | 10 | 7E | 7E |
| 32.0 to 29.5 | 95,500 | 768,500 | 153,700 | 10 | 7E | 7E |
| 29.5 to 28.0 | 88,000 | 768,500 | 153,700 | 10 | 12B | 12B and 12 |
| 28.0 to 26.0 | 117,000 | 1,018,000 | 203,600 | 10 | A-07-A | A-07-A |
| 26.0 to 24.0 | 171,000 | 1,018,000 | 203,600 | 10 | A-07-A | A-07-A and 14A |
| 24.0 to 22.0 | 171,000 | 1,016,000 | 101,600 | 5 | 15 | 15 and 15A |
| 22.0 to 20.0 | 225,000 | 1,016,000 | 101,600 | 5 | 16 | 16 and 15A |
| 20.0 to 18.0 | 21,000 | 1,018,000 | 203,600 | 10 | 19C | 19C and 19D |
| 18.0 to 16.0 | 77,200 | 1,018,000 | 203,600 | 10 | 20C | 20C and 21 |
| 16.0 to 13.0 | 153,000 | 1,536,500 | 307,300 | 10 | 21 | 21 |
| 13.0 to 11.0 | | 1,180,000 | 236,000 | 10 | | 24 and 21 |
| 13.0 to 11.5 | 95,000 | | | | 24 | |
| 11.5 to 10.0 | 125,000 | | | | SPD Mile 8.8 | |
| 11.0 to 8.0 | | 9,020,000 | 360,800 | 2 | | SPD Mile 8.8 |
| 10.0 to 8.0 | 765,800 | | | | SPD Mile 8.8 | |
| 8.0 to 6.0 | 750,800 | 6,220,000 | 248,800 | 2 | SPD Mile 7 | SPD Mile 7 |
| 6.0 to 4.0 | 373,800 | 6,447,500 | 257,900 | 2 | SPD Mile 5 | SPD Mile 5 |
| 4.0 to 2.0 | 373,800 | 6,447,500 | 257,900 | 2 | SPD Mile 3 | SPD Mile 3 |
| 2.0 to 0.0 | 285,800 | 6,447,500 | 257,900 | 2 | SPD Mile 1 | SPD Mile 1 |
| 0.0 to −3.5 | 668,000 | 12,500,000 | 500,000 | 2 | SPD Mile −1.7 to −2.5 | SPD Mile −1.7 to −2.5 |
| TOTAL | 4,804,200 | 59,474,000 | | | | |

**Table A-28. Dredged Material Information for Alternative 1B (18-Foot Channel with Earthen Containment)**

| Reach (Mile) | Construction (CY) | Maintenance (CY) | Maintenance Per Cycle (CY) | Cycle (Years) | Construction Disposal Site | Maintenance Disposal Site |
|---|---|---|---|---|---|---|
| 36.3 to 4.0 | 170,000 | 1,016,000 | 101,600 | 5 | 1 | 1 and 3 |
| 34.0 to 32.0 | 77,500 | 1,018,000 | 203,600 | 10 | 7E | 7E |
| 32.0 to 29.5 | 95,500 | 768,500 | 153,700 | 10 | 7E | 7E |
| 29.5 to 28.0 | 88,000 | 768,500 | 153,700 | 10 | 12B | 12B and 12 |
| 28.0 to 26.0 | 117,000 | 1,018,000 | 203,600 | 10 | A-07-A | A-07-A |
| 26.0 to 24.0 | 171,000 | 1,018,000 | 203,600 | 10 | A-07-A | A-07-A and 14A |
| 24.0 to 22.0 | 171,000 | 1,016,000 | 101,600 | 5 | 15 | 15 |
| 22.0 to 20.0 | 225,000 | 1,016,000 | 101,600 | 5 | 16 | 16 and 15A |
| 20.0 to 18.0 | 21,000 | 1,018,000 | 203,600 | 10 | 19C | 19C and 19D |
| 18.0 to 16.0 | 77,200 | 1,018,000 | 203,600 | 10 | 20C | 20C and 21 |
| 16.0 to 13.0 | 153,000 | 1,536,500 | 307,300 | 10 | 21 | 21 |
| 13.0 to 11.0 | | 1,180,000 | 236,000 | 10 | | 24 and 21 |
| 13.0 to 11.5 | 95,000 | | | | 24 | |
| 11.5 to 10.0 | 125,000 | | | | Lung | |
| 11.0 to 5.0 | | 18,465,000 | 738,600 | 2 | | Lung |
| 10.0 to 5.0 | 1,600,000 | | | | Lung | |
| 5.0 to 1.5 | 760,000 | 11,282,500 | 451,300 | 2 | Bay Side of East Island | Bay Side of East Island |
| 1.5 to 0.0 | 190,000 | 4,835,000 | 193,400 | 2 | Gulf Side of East Island | Gulf Side of East Island |
| 0.0 to −3.5 | 668,000 | 12,500,000 | 500,000 | 2 | Gulf Side of East Island | Gulf Side of East Island |
| TOTAL | 4,804,200 | 59,474,000 | | | | |

## Table A-29. Dredged Material Information for Alternative 1C (18-Foot Channel with Rock Containment)

| Reach (Mile) | Construction (CY) | Maintenance (CY) | Maintenance Per Cycle (CY) | Cycle (Years) | Construction Disposal Site | Maintenance Disposal Site |
|---|---|---|---|---|---|---|
| 36.3 to 34.0 | 170,000 | 1,016,000 | 101,600 | 5 | 1 | 1 and 3 |
| 34.0 to 32.0 | 77,500 | 1,018,000 | 203,600 | 10 | 7E | 7E |
| 32.0 to 29.5 | 95,500 | 768,500 | 153,700 | 10 | 7E | 7E |
| 29.5 to 28.0 | 88,000 | 768,500 | 153,700 | 10 | 12B | 12B and 12 |
| 28.0 to 26.0 | 117,000 | 1,018,000 | 203,600 | 10 | A-07-A | A-07-A |
| 26.0 to 24.0 | 171,000 | 1,018,000 | 203,600 | 10 | A-07-A | A-07-A and 14A |
| 24.0 to 22.0 | 171,000 | 1,016,000 | 101,600 | 5 | 15 | 15 |
| 22.0 to 20.0 | 225,000 | 1,016,000 | 101,600 | 5 | 16 | 16 and 15A |
| 20.0 to 18.0 | 21,000 | 1,018,000 | 203,600 | 10 | 19C | 19C and 19D |
| 18.0 to 16.0 | 77,200 | 1,018,000 | 203,600 | 10 | 20C | 20C and 21 |
| 16.0 to 13.0 | 153,000 | 1,536,500 | 307,300 | 10 | 21 | 21 |
| 13.0 to 11.0 | | 1,180,000 | 236,000 | 10 | | 24 and 21 |
| 13.0 to 11.5 | 95,000 | | | | 24 | |
| 11.5 to 10.0 | 125,000 | | | | Lung | |
| 11.0 to 5.0 | | 18,465,000 | 738,600 | 2 | | Lung |
| 10.0 to 5.0 | 1,600,000 | | | | Lung | |
| 5.0 to 1.5 | 760,000 | 11,282,500 | 451,300 | 2 | Bay Side of East Island | Bay Side of East Island |
| 1.5 to 0.0 | 190,000 | 4,835,000 | 193,400 | 2 | Gulf Side of East Island | Gulf Side of East Island |
| 0.0 to −3.5 | 668,000 | 12,500,000 | 500,000 | 2 | Gulf Side of East Island | Gulf Side of East Island |
| TOTAL | 4,804,200 | 59,474,000 | | | | |

## Table A-30. Dredged Material Information for Alternative 2A (20-Foot Channel with Adjacent Disposal)

| Reach (Mile) | Construction (CY) | Maintenance (CY) | Maintenance Per Cycle (CY) | Cycle (Years) | Construction Disposal Site | Maintenance Disposal Site |
|---|---|---|---|---|---|---|
| 36.3 to 34.0 | 325,000 | 1,096,000 | 109,600 | 5 | 1 | 1 and 3 |
| 34.0 to 32.0 | 175,000 | 1,098,000 | 219,600 | 10 | 7E | 7E |
| 32.0 to 29.5 | 215,000 | 829,000 | 165,800 | 10 | 7E | 7E |
| 29.5 to 28.0 | 185,000 | 829,000 | 165,800 | 10 | 12B | 12B and 12 |
| 28.0 to 26.0 | 250,000 | 1,098,000 | 219,600 | 10 | A-07-A | A-07-A |
| 26.0 to 24.0 | 300,000 | 1,098,000 | 219,600 | 10 | A-07-A | 14A |
| 24.0 to 22.0 | 305,000 | 1,096,000 | 109,600 | 5 | 15 | 15 and 15A |
| 22.0 to 20.0 | 393,000 | 1,096,000 | 109,600 | 5 | 16 | 16 and 15A |
| 20.0 to 18.0 | 92,000 | 1,098,000 | 219,600 | 10 | 19C | 19C and 19D |
| 18.0 to 16.0 | 170,000 | 1,098,000 | 206,600 | 10 | 20C | 20C and 21 |
| 16.0 to 13.0 | 315,000 | 1,657,000 | 331,400 | 10 | 21 | 21 |
| 13.0 to 11.0 | | 1,272,500 | 254,500 | 10 | | 24 and 21 |
| 13.0 to 11.5 | 180,000 | | | | 24 | |
| 11.5 to 10.0 | 230,000 | | | | SPD Mile 8.8 | |
| 11.0 to 8.0 | | 9,350,000 | 374,000 | 2 | | SPD Mile 8.8 |
| 10.0 to 8.0 | 842,000 | | | | SPD Mile 8.8 | |
| 8.0 to 6.0 | 822,500 | 6,447,500 | 257,900 | 2 | SPD Mile 7 | SPD Mile 7 |
| 6.0 to 4.0 | 705,000 | 6,685,000 | 267,400 | 2 | SPD Mile 5 | SPD Mile 5 |
| 4.0 to 2.0 | 665,000 | 6,685,000 | 267,400 | 2 | SPD Mile 3 | SPD Mile 3 |
| 2.0 to 0.0 | 295,000 | 6,685,000 | 267,400 | 2 | SPD Mile 1 | SPD Mile 1 |
| 0.0 to −3.7 | 1,100,000 | 14,500,000 | 580,000 | 2 | SPD Mile −1.7 and Mile −2.5 | SPD Mile −1.7 and Mile −2.5 |
| TOTAL | 7,564,500 | 63,718,000 | | | | |

**Table A-31. Dredged Material Information for Alternative 2B (20-Foot Channel with Earthen Containment)**

| Reach (Mile) | Construction (CY) | Maintenance (CY) | Maintenance Per Cycle (CY) | Cycle (Years) | Construction Disposal Site | Maintenance Disposal Site |
|---|---|---|---|---|---|---|
| 36.3 to 34.0 | 325,000 | 1,096,000 | 109,600 | 5 | 1 | 1 and 3 |
| 34.0 to 32.0 | 175,000 | 1,098,000 | 219,600 | 10 | 7E | 7E |
| 32.0 to 29.5 | 215,000 | 829,000 | 165,800 | 10 | 7E | 7E |
| 29.5 to 28.0 | 185,000 | 829,000 | 165,800 | 10 | 12B | 12 and 12B |
| 28.0 to 26.0 | 250,000 | 1,098,000 | 219,600 | 10 | A-07-A | A-07-A |
| 26.0 to 24.0 | 300,000 | 1,098,000 | 219,600 | 10 | A-07-A | 14A |
| 24.0 to 22.0 | 305,000 | 1,096,000 | 109,600 | 5 | 15 | 15 and 15A |
| 22.0 to 20.0 | 393,000 | 1,096,000 | 109,600 | 5 | 16 | 16 and 15A |
| 20.0 to 18.0 | 92,000 | 1,098,000 | 219,600 | 10 | 19C | 19C and 19D |
| 18.0 to 16.0 | 170,000 | 1,098,000 | 206,600 | 10 | 20C | 20C and 21 |
| 16.0 to 13.0 | 315,000 | 1,657,000 | 331,400 | 10 | 21 | 21 |
| 13.0 to 11.0 | | 1,272,500 | 254,500 | 10 | | 24 and 21 |
| 13.0 to 11.5 | 180,000 | | | | 24 | |
| 11.5 to 10.0 | 230,000 | | | | Lung | |
| 11.0 to 5.0 | | 19,140,000 | 765,600 | 2 | | Lung |
| 10.0 to 5.0 | 2,014,500 | | | | Lung | |
| 5.0 to 1.5 | 1,050,000 | 11,697,500 | 468,000 | 2 | Bay Side of East Island | Bay Side of East Island |
| 1.5 to 0.0 | 265,000 | 5,015,000 | 200,600 | 2 | Gulf Side of East Island | Gulf Side of East Island |
| 0.0 to −3.7 | 1,100,000 | 1,450,000 | 580,000 | 2 | Gulf Side of East Island | Gulf Side of East Island |
| TOTAL | 7,564,500 | 63,718,000 | | | | |

**Table A-32. Dredged Material Information for Alternative 2C (20-Foot Channel with Rock Containment)**

| Reach (Mile) | Construction (CY) | Maintenance (CY) | Maintenance Per Cycle (CY) | Cycle (Years) | Construction Disposal Site | Maintenance Disposal Site |
|---|---|---|---|---|---|---|
| 36.3 to 34.0 | 325,000 | 1,096,000 | 109,600 | 5 | 1 | 1 and 3 |
| 34.0 to 32.0 | 175,000 | 1,098,000 | 219,600 | 10 | 7E | 7E |
| 32.0 to 29.5 | 215,000 | 829,000 | 165,800 | 10 | 7E | 7E |
| 29.5 to 28.0 | 185,000 | 829,000 | 165,800 | 10 | 12B | 12 and 12B |
| 28.0 to 26.0 | 250,000 | 1,098,000 | 219,600 | 10 | A-07-A | A-07-A |
| 26.0 to 24.0 | 300,000 | 1,098,000 | 219,600 | 10 | A-07-A | 14A |
| 24.0 to 22.0 | 305,000 | 1,096,000 | 109,600 | 5 | 15 | 15 and 15A |
| 22.0 to 20.0 | 393,000 | 1,096,000 | 109,600 | 5 | 16 | 16 and 15A |
| 20.0 to 18.0 | 92,000 | 1,098,000 | 219,600 | 10 | 19C | 19C and 19D |
| 18.0 to 16.0 | 170,000 | 1,098,000 | 206,600 | 10 | 20C | 20C and 21 |
| 16.0 to 13.0 | 315,000 | 1,657,000 | 331,400 | 10 | 21 | 21 |
| 13.0 to 11.0 | | 1,272,500 | 254,500 | 10 | | 24 and 21 |
| 13.0 to 11.5 | 180,000 | | | | 24 | |
| 11.5 to 10.0 | 230,000 | | | | Lung | |
| 11.0 to 5.0 | | 19,140,000 | 765,600 | 2 | | Lung |
| 10.0 to 5.0 | 2,014,500 | | | | Lung | |
| 5.0 to 1.5 | 1,050,000 | 11,697,500 | 468,000 | 2 | Bay Side of East Island | Bay Side of East Island |
| 1.5 to 0.0 | 265,000 | 5,015,000 | 200,600 | 2 | Gulf Side of East Island | Gulf Side of East Island |
| 0.0 to −3.7 | 1,100,000 | 1,450,000 | 580,000 | 2 | Gulf Side of East Island | Gulf Side of East Island |
| TOTAL | 7,564,500 | 63,718,000 | | | | |



## 8.5 Maintenance of Rock Dikes

Maintenance of the rock placed along the Inland Reach for foreshore protection and rock retention dikes for containment of disposal sites is expected to be necessary due to settlement, subsidence and sea level rise. The maintenance cycle would be at 10 year intervals. Rock volume for maintenance is estimated at 20 percent of the initial construction volume, per cycle. Additional rock would be added to reaches that have existing rock and this additional rock was estimated at 20 percent.

## 9.0 COST ESTIMATES

Feasibility Level costs were developed to identify the recommended plan (Table A-33; Appendix K). Estimates include the costs associated with hydraulic dredging on a per reach basis, required utility relocations, wetland mitigation, and required real estate costs. The dredging costs for both construction and maintenance were developed using the Coastal Dredge Estimating Program (CEDEP). CEDEP is proprietary software that estimates dredging costs for each cubic yard of material moved, depending on various parameters such as construction equipment, disposal requirements, site characteristics, and slurry composition. The USACE performed the CEDEP calculations.

Mobilization and demobilization, disposal containment, and contract duration were also factored into the development of the dredging costs. Relocation costs were estimated based on the type, size, and location of utility to be moved. Environmental mitigation costs were developed with current mitigation rates for the area. Maintenance quantities were estimated based on historic maintenance records and anticipated shoaling rates.

Additional construction costs, such as Engineering and Design (12 percent) and Supervision and Administration (Variable) were also included for both construction and maintenance costs. Supervision and Administration costs were based on the total construction or maintenance cost and ranged from 5 percent at costs greater the $40 Million to 15 percent for costs less than 1 Million. Based on results derived from an abbreviated risk analysis, contingency costs were applied to both construction and maintenance cost estimates. Real estate costs accounted for easements and acquisitions required for disposal areas. The detailed construction and maintenance costs associated with each reach to be dredged are presented in Appendix K.

Construction and maintenance costs were estimated for the six deepening alternatives plus the No Action Alternative. Once estimated, costs were annualized over the appropriate period of time depending on the contract length. The annualized costs were utilized to develop benefit-to-cost ratios for each alternative. Benefit-to-cost ratios, along with environmental benefits, were evaluated to identify the recommended plan.

## 10.0 FUTURE DESIGN PHASES

### 10.1 Surveying, Mapping, Geospatial Data Requirements

Surveying, mapping, and geospatial data were developed during the course of this study to the level required to support the information presented herein. For future design, Temporary Bench Marks (TBMs) will be established at the site, and detailed cross-section, topographical, and hydrologic surveys of the proposed site and adjacent disposal areas will be taken. Adequate property boundary surveys will also be taken to establish section and title, and to support development of project real estate requirements. Additionally, adequate surveys will be done to develop Geographical Informational System (GIS) information.

## Table A-33. Feasibility Level Cost Estimates for the Alternatives

| | No-Action (-15 MLG) | 1A - 18' Adjacent Disposal | 1B - 18' Earthen Containment | 1C - 18' Rock Containment | 2A - 20' Adjacent Disposal | 2B - 20' Earthen Containment | 2C - 20' Rock Containment |
|---|---|---|---|---|---|---|---|
| Construction Cost | $0 | $87,139,127 | $102,172,982 | $127,255,474 | $90,982,809 | $112,232,813 | $139,329,790 |
| Relocation Costs* | $0 | $0 | $16,513,272 | $16,513,272 | $19,727,658 | $19,727,658 | $19,727,658 |
| **Subtotal** | $0 | $87,139,127 | $118,686,254 | $143,768,746 | $110,710,467 | $131,960,471 | $159,057,448 |
| Planning, Engineering, and Design (12%)** | $0 | $10,456,695 | $14,242,350 | $17,252,249 | $13,285,256 | $15,835,256 | $19,086,894 |
| Supervision & Administration (5% to 15%)*** | $0 | $7,480,547 | $8,688,239 | $10,230,542 | $7,924,447 | $9,851,648 | $11,511,656 |
| Contingency (Variable)**** | $0 | $29,022,672 | $34,419,014 | $41,692,936 | $32,106,035 | $38,268,537 | $46,126,660 |
| Real Estate***** | $0 | $10,628,890 | $10,628,890 | $10,628,890 | $10,628,890 | $10,628,890 | $10,628,890 |
| Mitigation****** | $0 | $428,000 | $428,000 | $428,000 | $917,000 | $917,000 | $917,000 |
| **Total Project Costs** | **$0** | **$145,155,930** | **$187,092,747** | **$224,001,363** | **$175,572,096** | **$207,461,802** | **$247,328,548** |

NOTES:

*Responsible party for relocations will be determined by Determination of Compensability completed by MVN's Real Estate Division

Relocation cost totals are rolled up totals that include 25% contingency, 10% E&D, and 8% S&A

**Planning, Engineering, & Design costs assumed to be a flat 12% of construction costs

***Supervision and Administration costs assumed to be based on the following:≤1$M - 15%$1-5M - 12%$5-25M - 9%$25M - 40M - 7%≥$40M - 5%

**** Contingency calculated by using Crystal Ball Risk Analysis

***** Real Estate Costs provided by USACE. Will be updated as additional information become available

****** Mitigation Costs calculated based on prices for nearby mitigation banks (Bayou Terrebonne Mitigation Bank - Approximately $58,000/AAHU)

## 10.2 Future Design

Approval of this feasibility report will signal completion of this phase of the project. Upon approval of this report, CEMVN would proceed with the Preconstruction, Engineering, and Design (PED) Phase. The PED Phase would consist of finalization of the design, and would include, but not be limited to, development of Plans and Specifications (P&S) and preparation of construction contracts for advertising.

## 11.0 REFERENCES

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# Annex I

# 3-D Hydraulic Model Report

U.S. Army Corps of Engineers
New Orleans District

# Assessment of Houma Navigation Canal Deepening on Flow Distribution and Salinity Intrusion on its Major Tributaries and Distributaries

February 2008

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# 1 General

## 1.1 Introduction

The Houma Navigation Canal (HNC) is a 36.6-mile navigation channel that begins at the Gulf Intracoastal Waterway (GIWW) in Houma, Louisiana, and extends southward to Terrebonne Bay and the Gulf of Mexico (Figure 1). Terrebonne Parish constructed the canal in 1962 to provide direct access to the nearby resources of the Gulf of Mexico. The channel was originally constructed with a usable dimension of 15 feet by 150 feet from the GIWW to mile 0.0 of the HNC and an 18-foot contour to the Gulf of Mexico. The River and Harbor Act of October 23, 1962, provided for the maintenance of the HNC by the Federal government. Maintenance by the United States was initiated on November 27, 1964.

**Figure 1. Project Location Map**

In accordance with Section 5 of the River and Harbor Act, approved March 4, 1915, authority was granted on August 23, 1973, to increase the HNC project dimensions to Elevation -18 feet Mean Low Gulf (MLG) by 300 feet in bottom width, between mile 0 and the Gulf of Mexico. This enlargement of the HNC was completed in July 1974.

The U.S. Army Corps of Engineers, Chief of Engineers' report dated August 23, 2002, recommends the construction of a flood protection project known as the Morganza, Louisiana to the Gulf of Mexico Hurricane Protection Project. One feature of the Morganza Project is a multipurpose lock located in the HNC, south of the town of Dulac, Louisiana. The lock sill elevation was proposed to be -18 feet North American Vertical Datum (NAVD88) based on the currently authorized channel elevation of -15 feet MLG and based on navigation safety and maintenance concerns. Current plans for the lock include a -23 NAVD88 sill, which will accommodate the proposed deepened Houma Navigation Canal.

The Morganza Project has received Congressional Authorization for construction through the Water Resources Development Act of 2007, and is continuing Pre-

Construction Engineering and Design of the lock complex and associated features.

## 1.2 Study Purpose

The objective of this study is to develop a 3-D numerical hydrodynamic and salinity model that will include the HNC and its major tributaries and distributaries. The model is used assess the effects of the HNC being deepened from -14 ft NAVD88 (-15 ft MLG) to -18 ft and -20 ft NAVD88, respectively, with 2 feet of overdredging. The main effects considered are the flow distribution and salinity intrusion. The numerical model addresses:

1. The impact on the flow distribution at the junction of the GIWW and HNC during low and high freshwater flow events.
2. The impact on the flow distribution at the Bayou Grand Caillou (BGC) and HNC junction during low and high freshwater flow events.
3. The impact on salt water intrusion along the HNC and HNC's tributaries and distributaries.
4. The operation of the HNC Lock Complex to increase flow along the BGC during low flows.

## 1.3 Study Area and Model Summary

The study area is located in Terrebonne Parish and includes the city of Houma, which is approximately 50 miles southwest of New Orleans, Louisiana. Houma is located at the northern end of the HNC and is home to commerce and industry that relies on the HNC.

This report discusses the development and application of a 3-D hydrodynamic and salinity model, using the Corps' model CH3D, that extends from where Bayou Lafourche discharges to the Gulf of Mexico (Gulf) to the east, and includes Caillou Bay to the west. The model includes Terrebone Bay, and the following tributaries and distributaries: the HNC; the GIWW from the "West Minors Canal" gauge to where it meets the Grand Bayou Canal; the lower part of the Grand Bayou canal; Falgout Canal; Minors Canal; and Caillou Lake, Lake de Cade and Lake Mechant (Figure 2). The model extends into the Gulf to develop a suitable open-water boundary condition. The model does not include hydraulic connections to either Barataria Bay or to Atchafalaya Bay, or other small conveyances or lakes in the system. The model is calibrated to data during March 2004 – March 2005, and is used to simulate and evaluate project impacts for a low-flow month and an average-flow year.

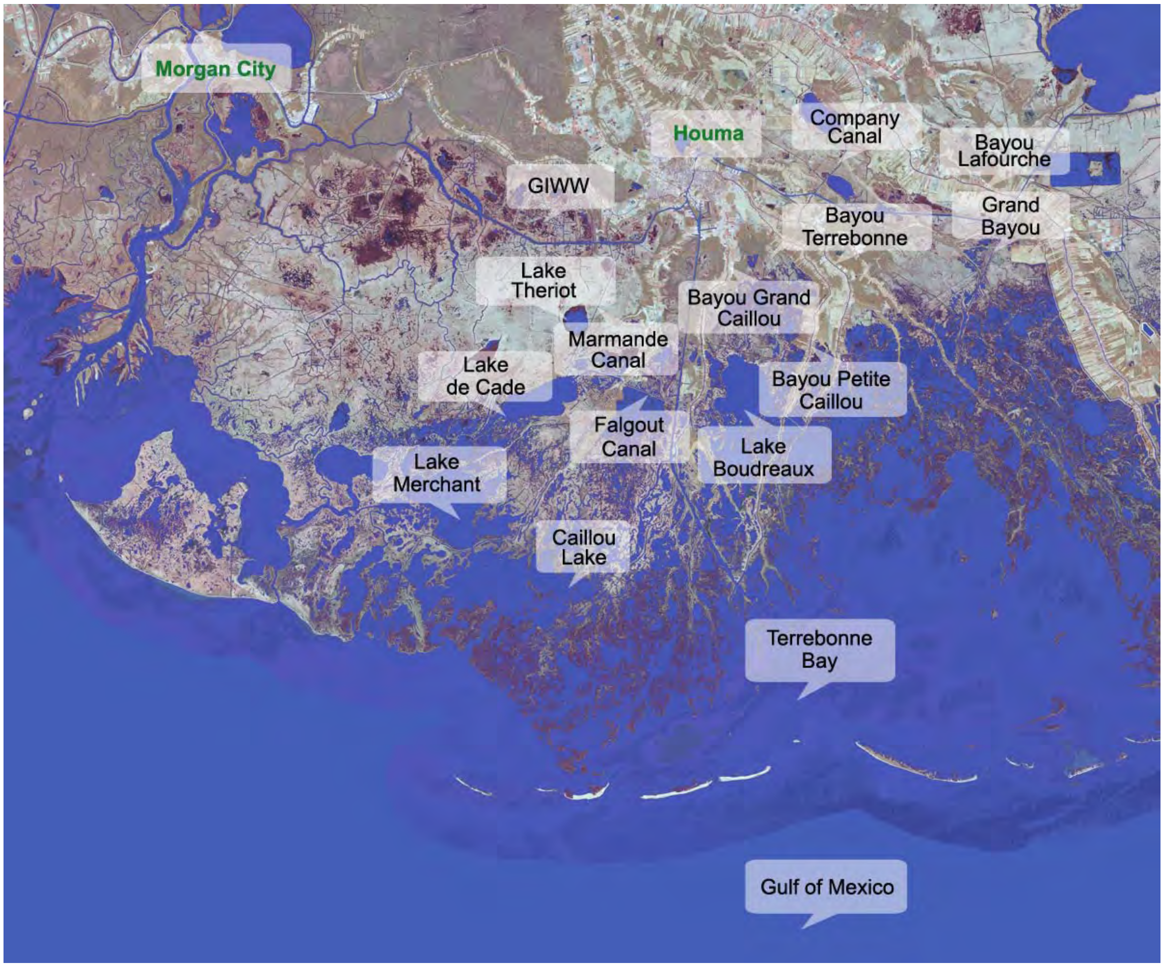

**Figure 2. Area Map Showing Waterbodies Modeled**

## 1.4 Authorization and Acknowledgement

The New Orleans District, Corps of Engineers (CEMVN), contracted with WEST Consultants, Inc. (WEST) under ID/IQ Contract Number W912P8-07-D-0013, Task Order Number 001.

For the WEST Consultants study team, Mr. Martin Teal was the ID/IQ contract manager, Dr. Raymond Walton was the project manager and lead modeler, and Dr. Henry Hu and Mr. J.T. Sanford were team hydraulic modelers. The technical manager for the New Orleans District was Ms. Cherie Price. Dr. Sung-Chan Kim of the Corps of Engineers' Engineering Research and Development Center (ERDC) provided the Independent Technical Review (ITR).

Many thanks to Nancy Rabalais and Adam Sapp of the Louisiana Universities Marine Consortium (LUMCON) for providing salinity transect data offshore from Terrebonne Bay.

# 2 Model Selection and Data Availability

To simulate the hydrodynamics of Terrebonne Bay and the Houma Navigation Canal (HNC), a 3-dimensional model is needed that can simulate tides, freshwater inflows, salinity stratification, and perhaps wind shear. This section discusses the model selection and available data for model calibration.

## 2.1 Model Selection and General Approach

CH3D is a time-varying 3-dimensional hydrodynamic and transport model based on a boundary-fitted curvilinear numerical grid. CH3D numerically solves the shallow water Navier Stokes equations on each numerical grid cell. The boundary-fitted coordinates feature allows the modeler to fit an irregular shoreline and natural or man-made deep channels that often exist in estuaries, bays and harbors. Physical processes governing the circulation and vertical mixing include tides, wind, density effects (salinity and temperature) freshwater inflows, turbulence and the effect of the earth's rotation (Coriolis effect). Water surface elevation and water velocities (u,v,w) in the water column at each grid cell are output from the model. The turbulence module used in CH3D-WES simulates vertical mixing in the water column and, therefore, CH3D-WES simulates strafication/destratification processes that often constitute important mechanisms for biological and water quality dynamics.

CH3D was selected for this study because (1) the study needs a 3-dimensional model, (2) CH3D is a Corps-supported model being used for a Corps' study, and (3) because CH3D is widely used. The most commonly used version of CH3D is the "sigma-stretch" version, in which the same number of layers are prescribed in each cell. However, experience in Chesapeake Bay with its deep channel and very shallow overbanks, led to concern about how the baroclinic gradients are handled in adjacent cells with very different depths. This concern led to the development of a "z-grid" version of CH3D for Chesapeake Bay, in which fixed vertical layers are defined, and the water surface is only allowed to fluctuate in the surface layer. Because it is required to simulate physical processes in a very shallow bay with a relatively deep ship canal dredged through it, it was decided to use the "z-grid" version of CH3D for the Houma Navigation Canal study.

## 2.2 Bathymetry

Bathymetry data are relatively sparse in the study area. Fortunately, CEMVN had used the available bathymetric data to develop a 2-dimensional, depth-averaged RMA-2 hydrodynamic model extending from Bayou Lafourche in the east to Atchafalaya Bay in the west. CH3D uses a boundary-fitted curvilinear grid of quadrilaterals. The RMA-2 model (Figure 3) was constructed mainly of quadrilateral elements, and was used as a basis for both the grid development and model bathymetry for the CH3D model. The CH3D grid was further refined using available CEMVN – Operations Division survey data (red points in Figure 3) and NOAA charts 11356 and 11357 of the offshore areas.

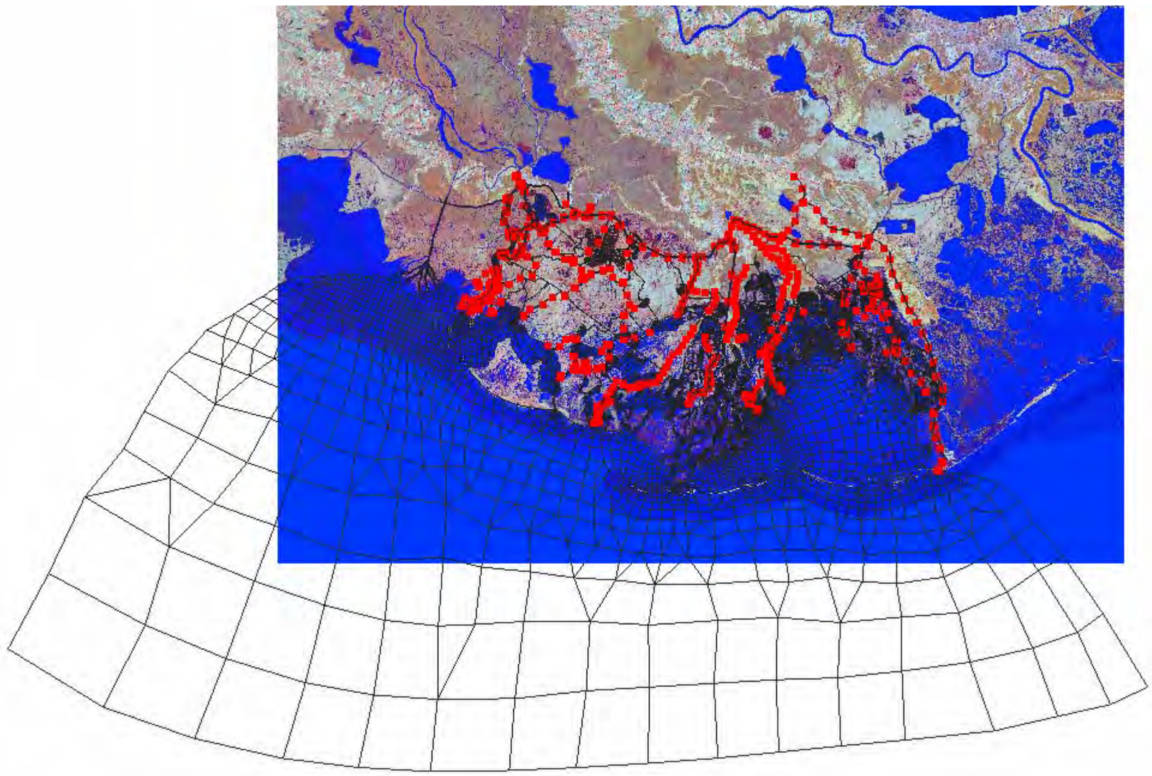

**Figure 3. RMA-2 Grid of Bayou Lafourche to Atchafalaya Bay**

## 2.3 Gulf Tides and Salinity

NOAA maintains a tide gauge at Port Fourchon, Louisiana. The gauge is located in the port facility a short distance up Bayou Lafourche from the Gulf. It is not known to what extent offshore tides are modified by the entrance geometry at this location. 6-minute data from this gauge were obtained for thirteen months from March 2004 through March 2005, in feet referenced to Mean Lower Low Water (MLLW). The 6-minute data were corrected to NAVD, and re-sampled every half hour for model input, and input as cm NAVD to the model. The correction from MLLW to Mean Sea Level (MSL) was estimated to be -0.65 feet. However, the exact correction is not precisely known.

Later in the study, it was discovered that the USGS maintains a tide gauge in Caillou Bay. The USGS provided us with one-hour data at this gauge for the period March 2004 through March 2005. Again, the precise correction from the tidal datum to NAVD was not known. However, as this gauge is in an open-water location, and not too distant from another USGS stage recording gauge in Caillou Lake, which is precisely referenced to NAVD, the model was run and the datum conversion adjusted at the Caillou Bay gauge until a good agreement with high tide elevations at the Caillou Lake gauge was achieved.

There was much difficulty in locating salinity profiles in the Gulf of Mexico, offshore of Terrebonne Bay in approximately 25 meters (80 feet of water), where the model tidal boundary was to be located (Figure 6). Murray (1988) reports salinity profiles on the Terrebonne Bay shelf for 1992 and 1993. These profiles were initially used to define the salinity distribution at the tidal boundary in the Gulf of Mexico, and the effect of specifying this boundary was explored during initial sensitivity analyses. Later in the study, it was discovered that the Louisiana Universities Marine Consortium (LUMCON) surveyed a transect about monthly from the HNC, through Terrebonne Bay, and through the barrier islands to the Gulf of Mexico (Figure 4). Station C8 is the closest to the location of the offshore boundary in the numerical model. Figure 5 shows the vertical salinity profiles at Station C8 from March 2004 through March 2005.

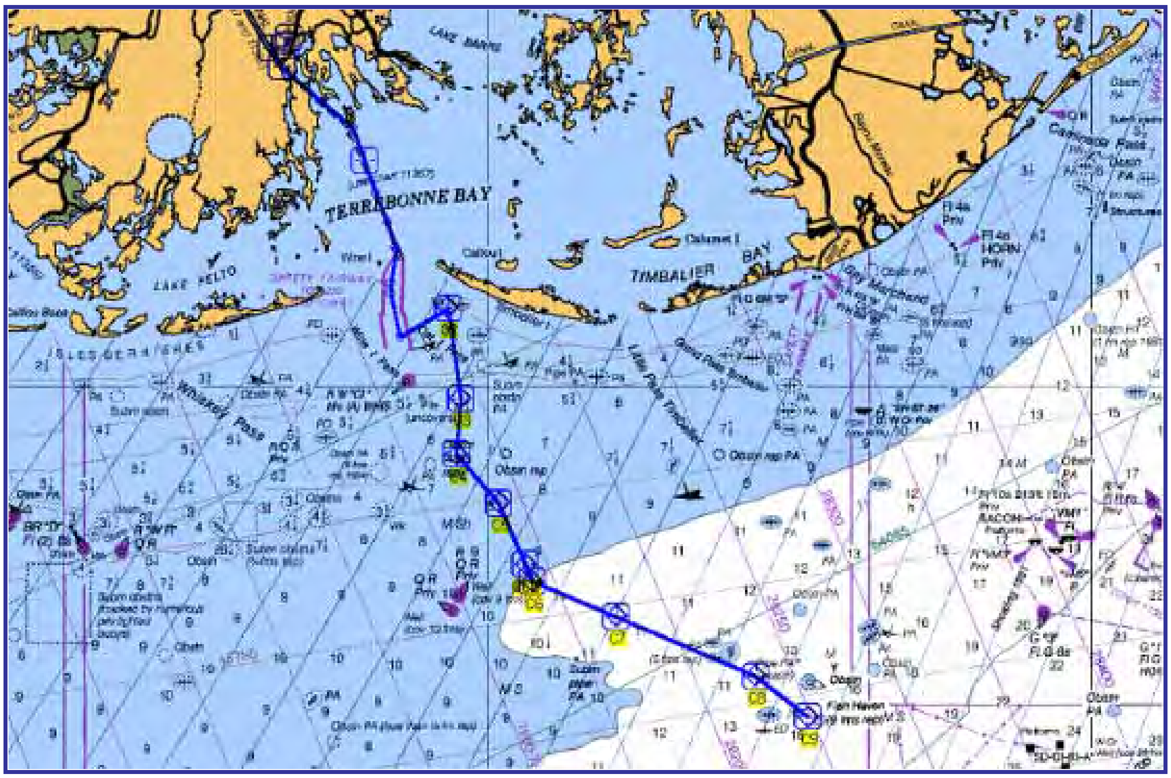


**Figure 4. Salinity Transect Surveyed by LUMCON**

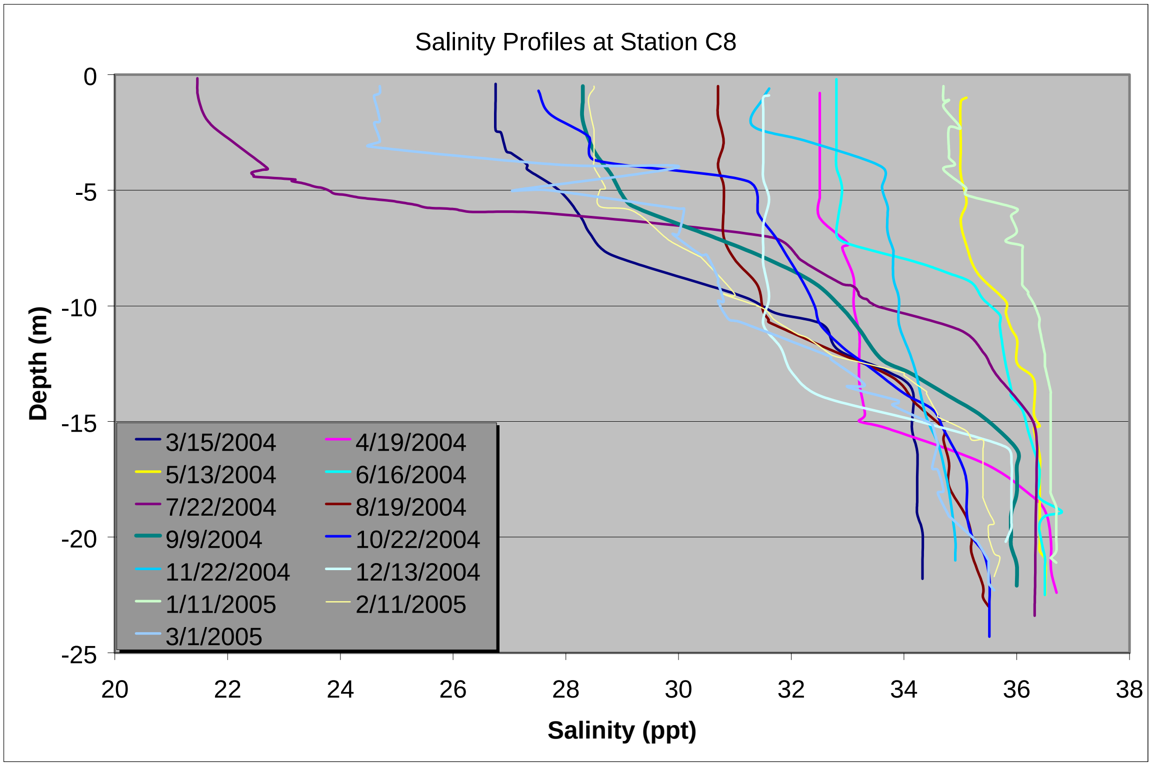


**Figure 5. Salinity Profiles from LUMCON Station C8**

## 2.4 River Inflows and Salinity

The model of the HNC and its major tributaries and distributaries has three inflow locations. The Corps of Engineers Engineer Research and Development Center (ERDC) processed available USGS streamflow gauge data at these locations, and provided the modeling team time histories of flows and salinities from March 22, 2005 to March 23, 2005. The three gauge locations used are (Figure 6):

1. On the GIWW just to the west of the West Minors Canal (Corps Gauge No. 76307).

2. On the GIWW, at Larose (USGS Gauge No. 07381235), just to the northeast of its confluence with Bayou Lafourche, and

3. On Bayou Lafourche at Thibodaux (USGS Gauge No. 07381000) upstream of its confluence with Company Canal.

The data were processed, and flows in cfs and salinities in parts per thousand (ppt) developed for the model.

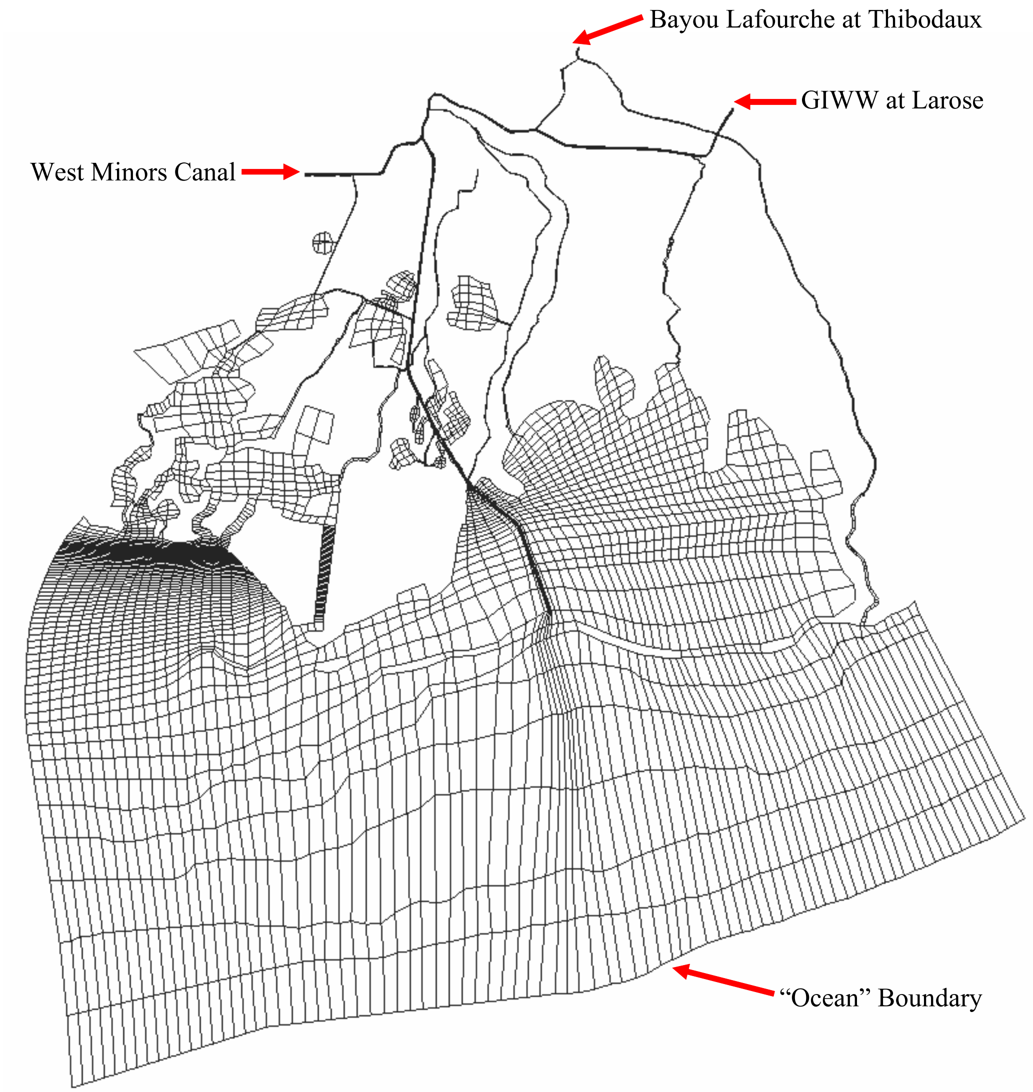


**Figure 6. Location of Inflows to HNC 3-D Model**

## 2.5 Wind Shear

Wind speed (in m/s) and direction data are available from a weather station at "West Bank, Bayou Gauche, LA", near Houma. Data for March 2004 through March 2005 were processed by ERDC to develop x- and y-components of wind speed, and were used in initial model simulations. Later, it was discovered that wind speed and direction data were also available at the USGS gauge in Caillou Bay. As these data more closely sample open-water conditions, they were obtained from the USGS, processed, and used in later model simulations.

## 2.6 Interior Data

During the period March 2004 to March 2005, a number of gauges were operating within the study area that provided a range of data for model calibration (Figure 7). Data included water surface elevation, salinity, current speed, and total flow. Table 1 shows the variables measured at each of the gauging stations, and their periods of data recovery.

**Table 1. Internal Stations with Calibration Data**

| Gauge Name/ Location | Variable Measured | Coverage |
|---|---|---|
| Grand B.C. South of Bayou L'Eau Bleu | Stage | 5/4/04-3/22/05 |
| | Salinity | 5/4/04-3/22/05 |
| GIWW at Houma | Stage | 3/23/04-2/5/05 |
| | Salinity | 3/23/04-2/6/05 |
| | Flow | 3/23/04-2/5/05 |
| HNC at Dulac | Stage | 3/23/04-7/8/04; 9/21/04-12/2/04 |
| | Salinity | 3/23/04-3/22/05 |
| | Flow | 3/23/04-3/22/05 |
| HNC South of Bayou Grand Caillou | Stage | 3/23/04-9/21/04 |
| | Velocity | 10/26/04-12/1/04 |
| Bayou Dularge South of Falgout Canal | Stage | 3/23/04-4/2/04; 5/20/04-11/5/04; 1/6/05-3/22/05 |
| | Salinity | 3/23/04-4/2/04; 5/20/04-11/5/04; 1/6/05-3/22/05 |
| | Velocity | 6/17/04-2/4/05 |
| Bayou Grand Caillou, West of HNC | Stage | 10/12/04-11/15/04; 12/1/04-12/5/04 |
| | Salinity | 10/26/04-11/9/04 |
| Bayou Petite Caillou | Stage | 3/23/04-6/15/04; 8/4/04-9/27/04; 10/4/04-12/7/04; 1/2/05-3/8/05 |
| | Salinity | 3/23/04-6/15/04; 8/4/04-9/27/04; 10/4/04-12/7/04; 1/2/05-3/8/05 |
| Bayou Point Aux Chenes | Stage | 3/23/04-4/20/04; 4/22/04/8/9/04; 10/12/04-3/8/05 |
| | Salinity | 4/22/04/8/9/04; 10/12/04-3/8/05 |
| Falgout Canal West of Bayou Dularge | Stage | 9/21/-4-1/3/05 |
| | Salinity | 9/21/-4-1/3/05 |
| Caillou Lake | Salinity | 3/23/04-3/22/05 |

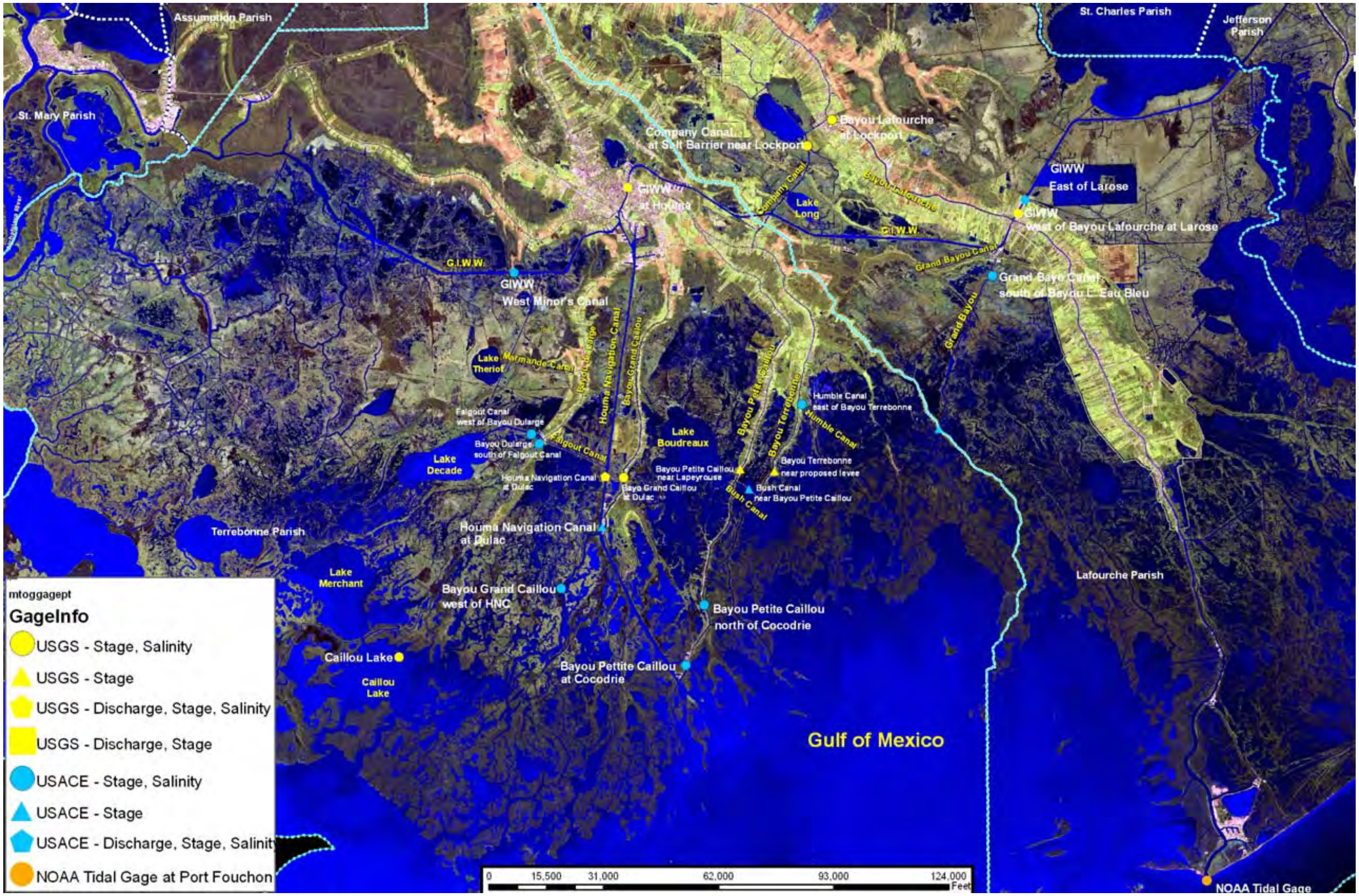


**Figure 7. Area Map Showing Gauge Locations**

# 3 Model Development and Calibration

## 3.1 Development of Grid and Bathymetry

As bathymetry data are relatively sparse in the study area, and CEMVN had used the available bathymetric data to develop a 2-dimensional, depth-averaged RMA-2 hydrodynamic model extending from Bayou Lafourche in the east to Atchafalaya Bay in the west (Figure 3), the RMA-2 grid was used as the starting point to develop the CH3D model grid. CH3D uses a boundary-fitted curvilinear grid of quadrilaterals, and the District's RMA-2 model was constructed mainly of quadrilateral elements.

The RMA-2 model was run first to determine a flow-line to the west that would allow us to separate the model of Terrebonne Bay to the east from the portion of the RMA-2 grid covering Atchafalaya Bay to the west (Figure 8). A new grid was then developed consisting only of quadrilaterals that overlaid the clipped RMA-2 grid, and the mesh cells were adjusted in order to capture the parts of the system to be included in the model. This included reducing the lateral resolution of some of the more minor channels in the model to be only one cell width (Figure 9). The interior geometry was then refined using the available surveyed sections (red squares in Figure 3), and some of the offshore geometry was refined using NOAA charts 11356 and 11357. Once the LUMCON salinity data was discovered, the maximum depths were compared from the survey with model depths at the same locations (Figure 5), and it was found that they were consistent. The CH3D model includes Terrebonne Bay, the HNC (modeled with 5 cells laterally), and the GIWW (modeled with 3 cells laterally), and a number of smaller canals and lakes, including (Figure 2):

- Marmande Canal
- Falgout Canal
- Bayou Grand Caillou
- Bayou Petite Caillou
- Bayou Terrebonne
- Company Canal
- Grand Bayou
- Bayou Lafourche
- Lake Theriot
- Lake de Cade
- Lake Mechant
- Caillou Lake
- Lake Boudreaux

Figure 9 also shows the CH3D convention for flows and velocities as being positive to the east along rows and positive to the north along columns.

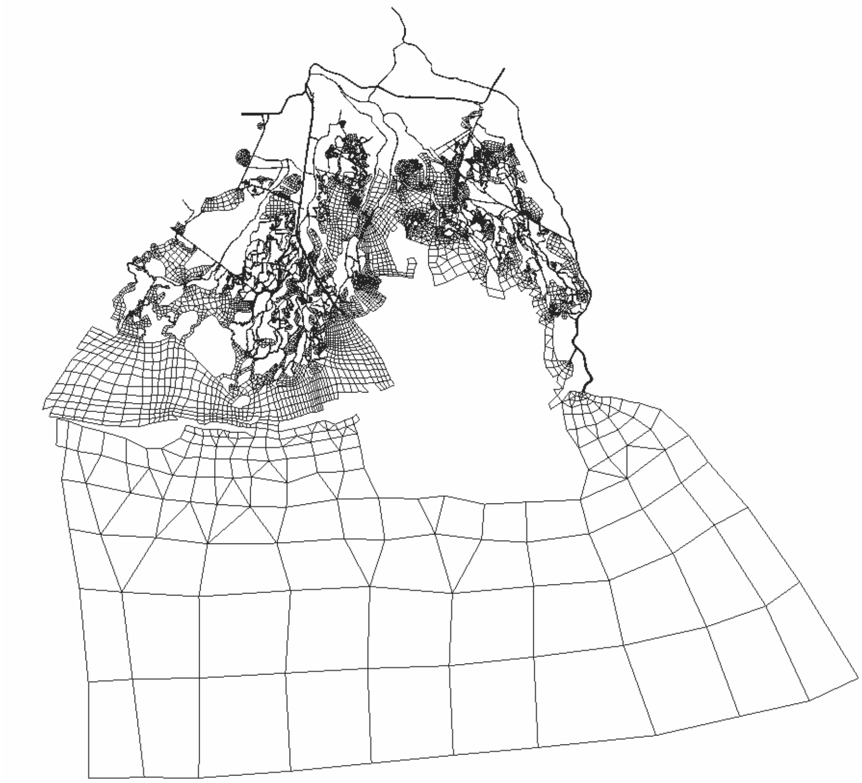

**Figure 8. Clipped RMA-2 Grid of Terrebonne Bay**

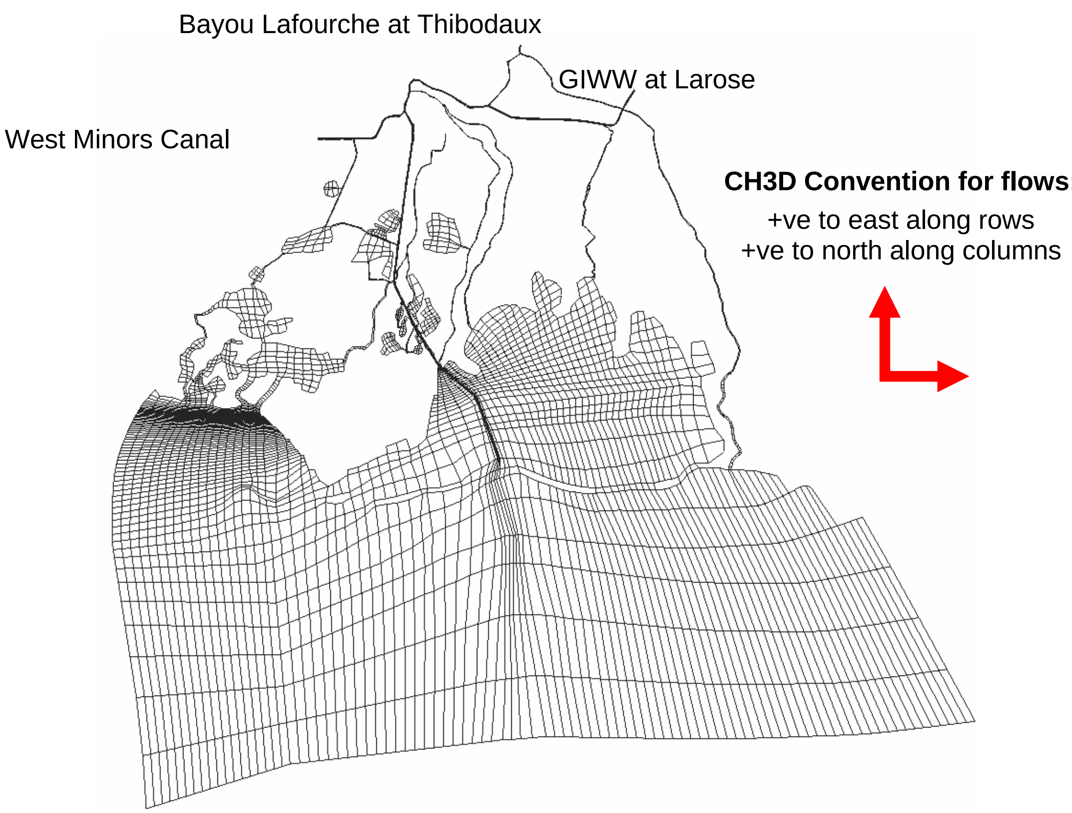


**Figure 9. CH3D Grid of Terrebonne Bay**

The bathymetry was developed in two stages. First, the main body of Terrebonne Bay was interpolated using the depths at the RMA-2 nodes as "mass points". Next, the individual canals in the system were cut out of the RMA-2 grid, processes individually to preserve their cross section distributions of depths, and pasted back into the CH3D grid, using the editing tools in SMS. Finally, the grid was processed to output the appropriate CH3D grid files (FORT.15 and FORT.50), and checked to ensure that the CH3D (I,J) indices were consistent. Figure 10 shows the resulting CH3D grid bathymetry and Figure 11 shows some of the detail in the NHC. The model was developed using uniform 2-ft layers in the vertical.

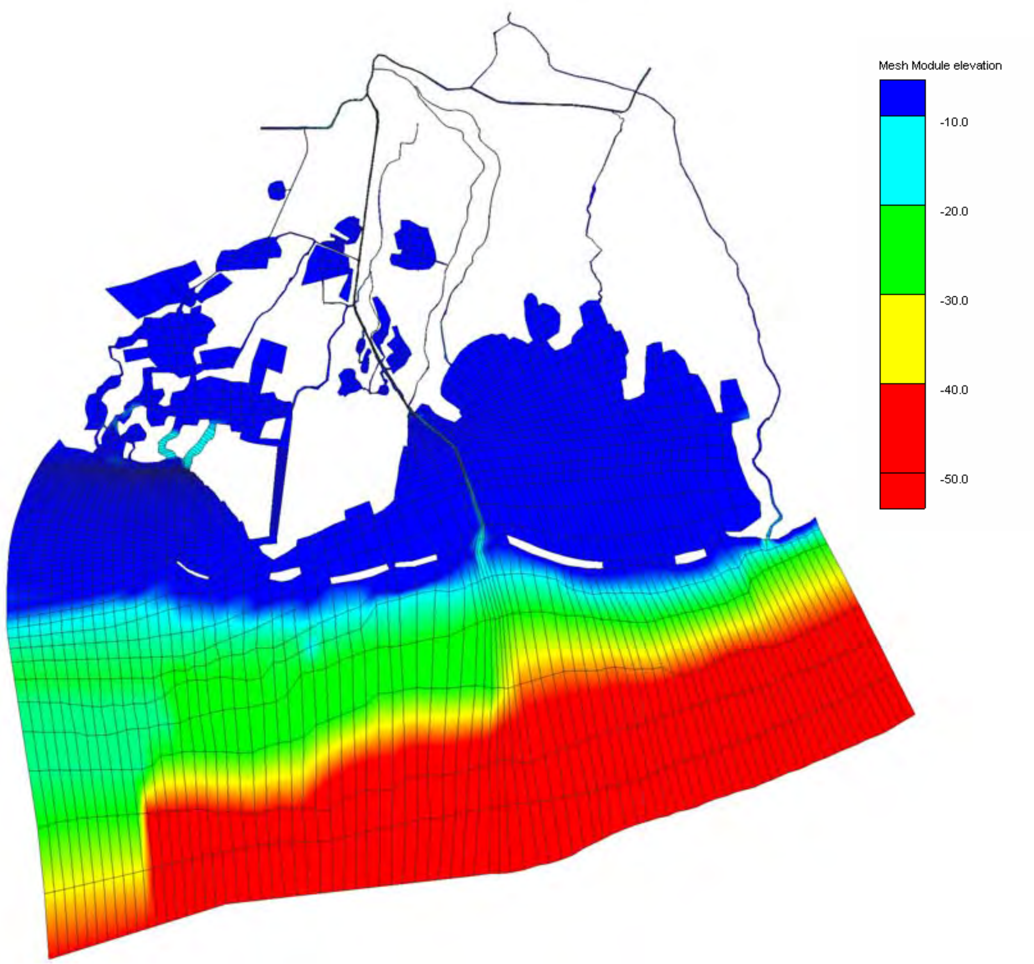


**Figure 10. Bathymetry of CH3D Model of Terrebonne Bay**

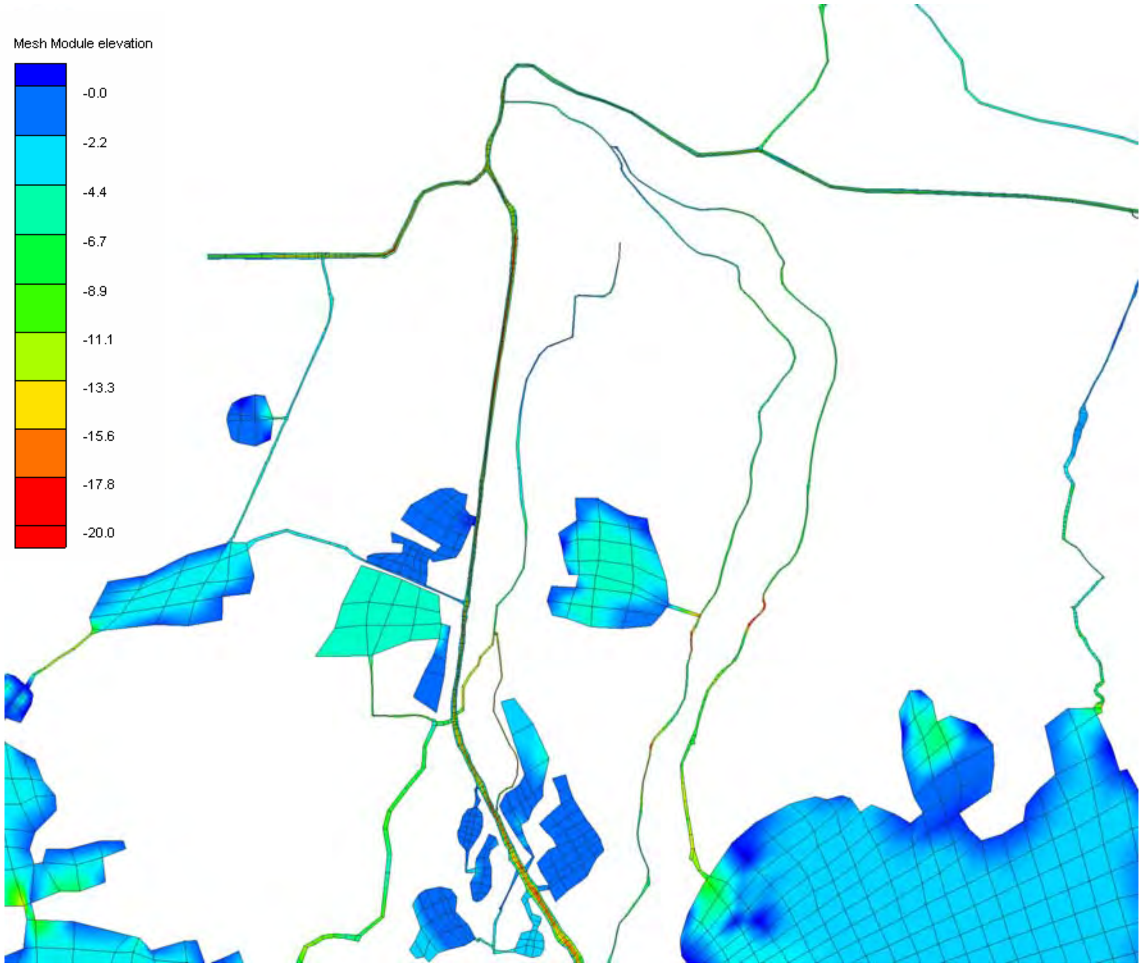

**Figure 11. Bathymetry Detail in NHC**

## 3.2 Selection of Calibration Periods

After reviewing the availability and coverage of data for model calibration (see Table 1), the following two periods were initially selected for model calibration and validation:

1. September 13, 2004 -to- October 15, 2004
2. February 21, 2005 -to- March 25, 2005

The period September 13, 2004 -to- October 15, 2004 was selected for model calibration, and the period February 21, 2005 -to- March 22, 2005 was selected was model validation.

## 3.3 Model Sensitivity

Using the model calibration period of February September 13, 2004 -to- October 15, and following a number of initial simulations to produce a model that generally matched observations, a number of initial simulations were performed to determine the most sensitive model parameters. The analysis included:

- Running the model with and without the wind stress
- Running the model with (1) the observed salinity profiles, (2) a uniform vertical profile of 35 ppt, and (3) a profile with 25 ppt near the surface and 35 ppt near the bed, imposed at the tidal boundary.
- Varying the bottom roughness height, $z_0$, 3, 5, and 7 cm.
- Simulating 75%, 100% and 125% of the inflows.
- Running the model with time steps of 60 and 30 seconds.

The results are shown in Appendix A and summary statistics are presented in Table 2. The locations selected for comparison include sites of interior gauges with data during the calibration period of September 13, 2004 -to- October 15, including the key location at Dulac in the NHC.

**Wind Stress:** Figures A1-A5 show the effect of including or not including the wind stress terms on water surface elevations and salinity. Only at the “Bayou Dularge South of Falgout Canal” gauge location was there a significant difference in salinity; and only then of about 1 ppt. Generally, the inclusion of the wind stress terms had little effect of model results throughout the system, during this period of relatively light-to-moderate winds. However, wind data are readily available and it requires little additional computational effort to include these terms. Therefore, they were included in the model calibration and sensitivity runs, but without any additional review of their effect.

**“Ocean” Salinity:** Figures A6-A10 show the effect of defining a salinity distribution at the model boundary on water surface elevations and salinity. The observed profiles were compared to a uniform profile of 35 ppt and a 25/35 ppt (top/bottom) profile. The results indicate that the uniform profile causes the water surface elevations upstream to increase by a small amount (perhaps 0.1 feet), as greater head is needed to push the fresh water out the system to the Gulf of Mexico against the larger density at the boundary. Generally, the time histories are similar, simply offset in elevation by up to 0.1 feet at Houma. Small differences were seen in the salinity distributions, but generally only 1-2 ppt.

**Roughness:** In CH3D, bottom roughness can be parameterized using both a roughness height, $z_0$, and the bottom drag coefficient, $c_b$. To test the model sensitivity, the roughness height was varied, $z_0$=3, 5, and 7 cm. The results, shown in Figures A11-A15, show that bed roughness parameters do have a small influence on water surface elevations and salinity. Increasing roughness height, $z_0$, tends to decrease the tidal amplitude with distance upstream and decrease the range of salinity variations. Figure A15 shows that as the roughness height increases, the simulated tidal range more closely matches the observed tidal range.

**River Inflows:** Inflows in a tidal regime are subject to a great deal of uncertainty. To test the effect on water surface and salinities, 75%, 100% and 125% of the gauged inflows were specified at the three inflow boundaries. The results (Figures A16-A20), show little effect on water surface elevations, but a significant effect on salinities for interior areas with non-zero salinities, especially at Dulac along the HNC.

**Model Time Step:** The model runs stably with a time step of 60 seconds. To test the sensitivity to the time step, the model was also run with a time step of 30 seconds, and the results shown in Figures A21-A25. As expected, the model is generally insensitive to the time step once it runs stably.

**Summary:** The sensitivity analysis indicated that the model is most sensitive to inflows, and next to the bottom friction parameters. The model is somewhat sensitive to the salinity distribution at the open "ocean" boundary, and is least sensitive to wind shear (which did not include extreme wind events) and the model time step. Practically, however, most of the inflows are reported values, and while somewhat uncertain, there is no clear systematic way to adjust them. And while wind shear had a small effect on model results, it is included in the model calibration and validation runs because the data are readily available and there is little additional computational effort.

The data with the highest uncertainty is elevation data – both bathymetry and datums. While Figure 3 seems to show numerous surveyed cross sections, in fact the data are quite sparse. Along the HNC, for example, there are several sections at the upstream end (near Houma) and near the downstream end (near Terrebonne Bay), but none along the majority of its length, and none through Terrebonne Bay and into the Gulf. Also, the datum corrections at both tide gauge locations (Port Fourchon and Caillou Bay) are not precise. In fact, data from the USGS gauge in Caillou Bay were used and the datum conversion was adjusted to best match observations at the USGS gauge in Caillou Lake, which was accurately surveyed to the NAVD datum.

Therefore, aside from ensuring that the geometry is as accurately portrayed as possible, bottom friction is the only real calibration parameter for the CH3D model of Terrebonne Bay and the HNC.

**Table 2. Summary Statistics for Sensitivity Analyses**

Water Surface Elevation

| Location | Mean Obs | Mean Model | SD Obs | SD Mod | Mean Error | Mean Absolute Error | RMS Error |
|---|---|---|---|---|---|---|---|
| GBC South of Bayou L'Eau Blue | 0.804 | 1.3391 | 0.602 | 0.4421 | 0.5351 | 0.6746 | 0.9232 |
| GIWW at Houma | 1.6869 | 1.3707 | 0.4005 | 0.4098 | -0.3163 | 0.3455 | 0.3972 |
| HNC at Dulac | 0.9203 | 1.1289 | 0.4657 | 0.4629 | 0.2085 | 0.2584 | 0.3541 |
| Bayou Petite Caillou North of Cocodrie | 1.1416 | 1.1578 | 0.5832 | 0.4173 | 0.0162 | 0.2935 | 0.3813 |
| Falgout Canal West of Bayou Dularge | 1.3508 | 1.1456 | 0.5014 | 0.4603 | -0.2053 | 0.2286 | 0.2728 |
| Caillou Lake | 1.1446 | 0.9623 | 0.632 | 0.6372 | -0.1823 | 0.2547 | 0.3072 |

Salinity

| Location | Mean Obs | Mean Model | SD Obs | SD Mod | Mean Error | Mean Absolute Error | RMS Error |
|---|---|---|---|---|---|---|---|
| GBC South of Bayou L'Eau Blue | 0.3168 | 0.2655 | 0.8035 | 0.2857 | -0.0513 | 0.3057 | 0.8579 |
| GIWW at Houma | 0.1999 | 0.3377 | 0.3063 | 0.6086 | 0.1378 | 0.259 | 0.6966 |
| HNC at Dulac | 2.1445 | 0.9726 | 4.5641 | 2.5262 | -1.1719 | 2.086 | 4.7475 |
| Bayou Petite Caillou North of Cocodrie | 9.0158 | 8.4917 | 2.3155 | 6.4996 | -0.5241 | 4.5695 | 5.5255 |
| Falgout Canal West of Bayou Dularge | 3.1435 | 0.4359 | 3.545 | 0.2055 | -2.7076 | 2.7184 | 4.3902 |
| Caillou Lake | 9.409 | 6.3276 | 5.2062 | 3.46 | -3.0814 | 4.2151 | 5.2956 |

## 3.4 September 2004 Calibration

The period September 13, 2004 -to- October 12, 2004 was selected for model calibration, and the model was run with a three-month "warm-up" period from an initial "hot start" file to remove transients from the initial conditions in this slowly varying system. The results (Appendix B) are reported after the "warm-up" period. The boundary conditions included the tide in Caillou Bay (Figure 12), "ocean" salinity from LUMCON Station C8 (see Figure 5), inflows at West Minors Canal, GIWW at Larose and Bayou Lafourche at Thibodaux (Figure 13), and wind shear from the USGS gauge in Caillou Bay.

During the calibration effort, it became clear that the data with the most uncertainty was the bathymetry, especially of the middle reach of the HNC, and the HNC through Terrebonne Bay to the Gulf. Initially, observed salinities at either the Dulac or Caillou Lake gauges were not able to be matched. Therefore, considerable effort was spent modifying the bathymetry in these areas of uncertainty until we were able to reproduce the range of observed salinities at Dulac and in Caillou Lake. At this point, the sensitivity analysis (see Appendix A) was redone and the results with the observed wind stress, with the observed tides, inflows and observed salinities at Station C8, and with the roughness height, $z_0$, set to 7 cm is believed to best produce a calibrated model. Appendix B shows the results for the model calibration.

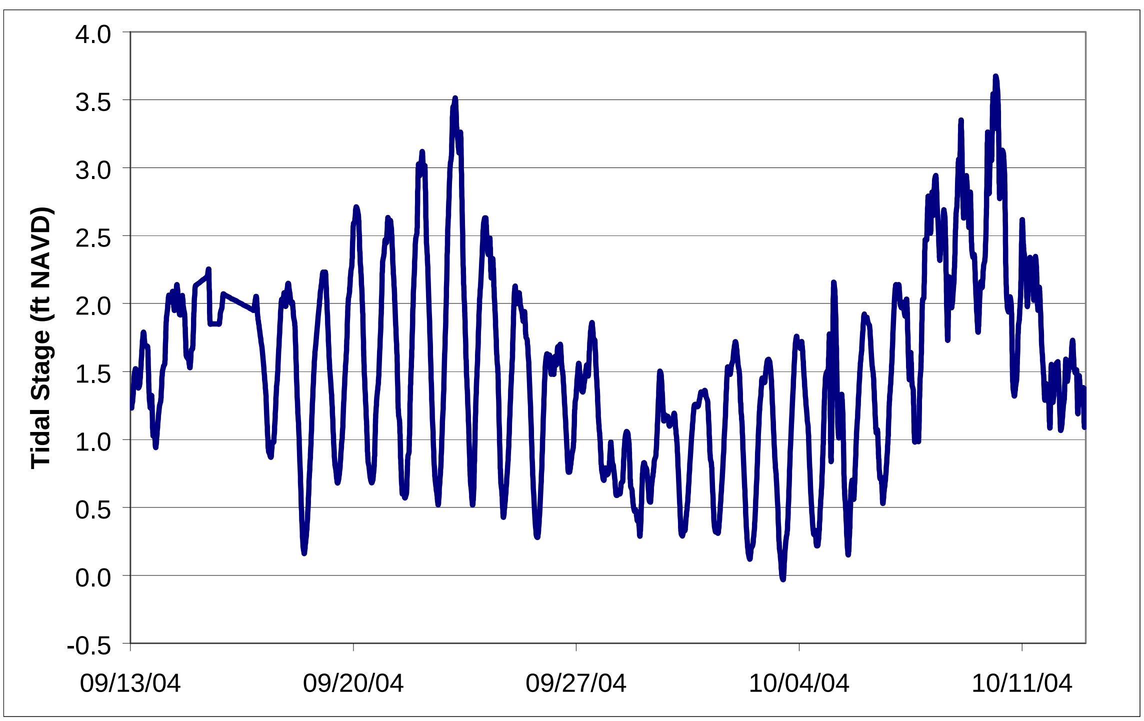


**Figure 12. Tide in Caillou Bay for Calibration Period**

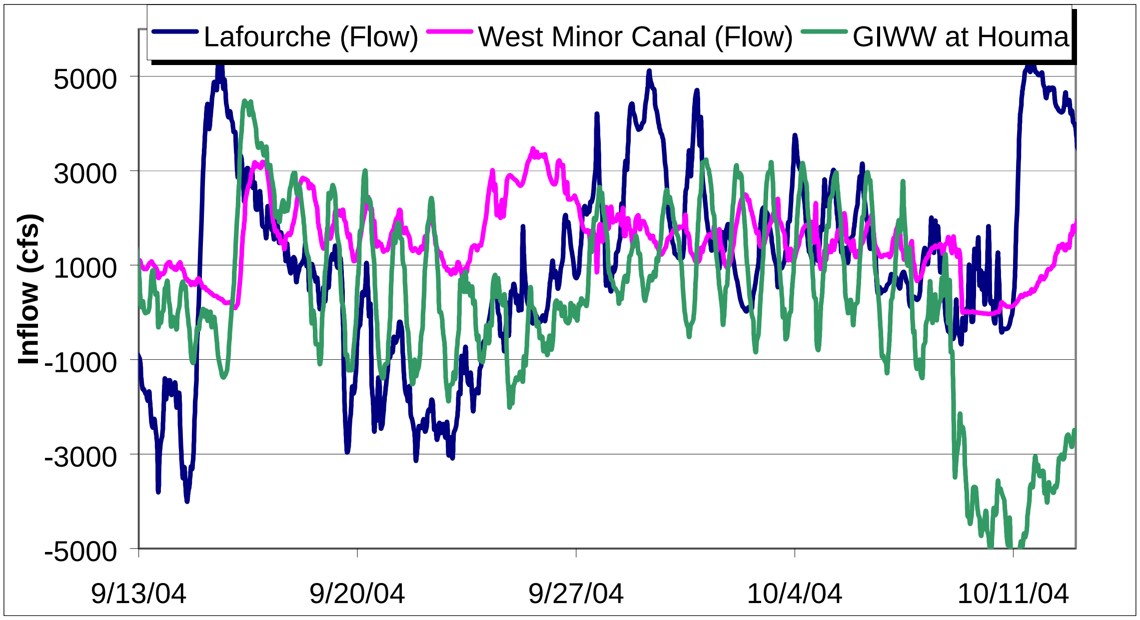


**Figure 13. Inflows for Validation Period**

## 3.5 February 2005 Validation

The period February 21, 2005 -to- March 22, 2005 was selected for model validation, and the model was run with a three-month "warm-up" period from an initial "hot start" file. The results are evaluated after the "warm-up" period. The boundary conditions included the tide in Caillou Bay (Figure 14), "ocean" salinity from LUMCON Station C8 (see Figure 5), inflows at West Minors Canal, GIWW at Larose and Bayou Lafourche at Thibodaux (Figure 15), and wind shear from the USGS gauge in Caillou Bay.

This was supposed to represent a "wet" period with high freshwater inflows and low salinities throughout the system. The interior gauges do show very low salinities during this period. And the USGS gauge in Caillou Bay also shows relatively lower salinities. However, if the net freshwater inflow to the system is calculated as the inflows in the GIWW at West Minors Canal plus the inflows in Bayou Lafourche at Thibodeaux minus the outflows in the GIWW at Larose (see Figure 6) the net inflow is actually negative – representing a net outflow. Consequently, the model results show more salt in the system than during the September/October 2004 calibration period, which supposedly represents a "dry" period.

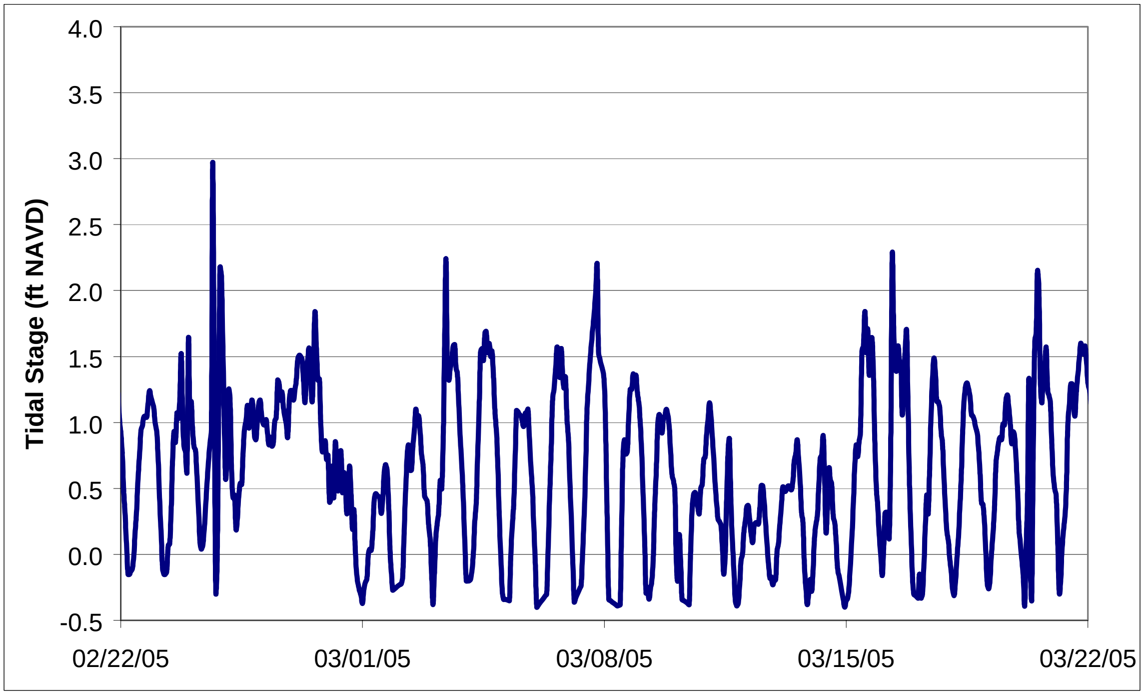


**Figure 14. Tide in Caillou Bay for Validation Period**

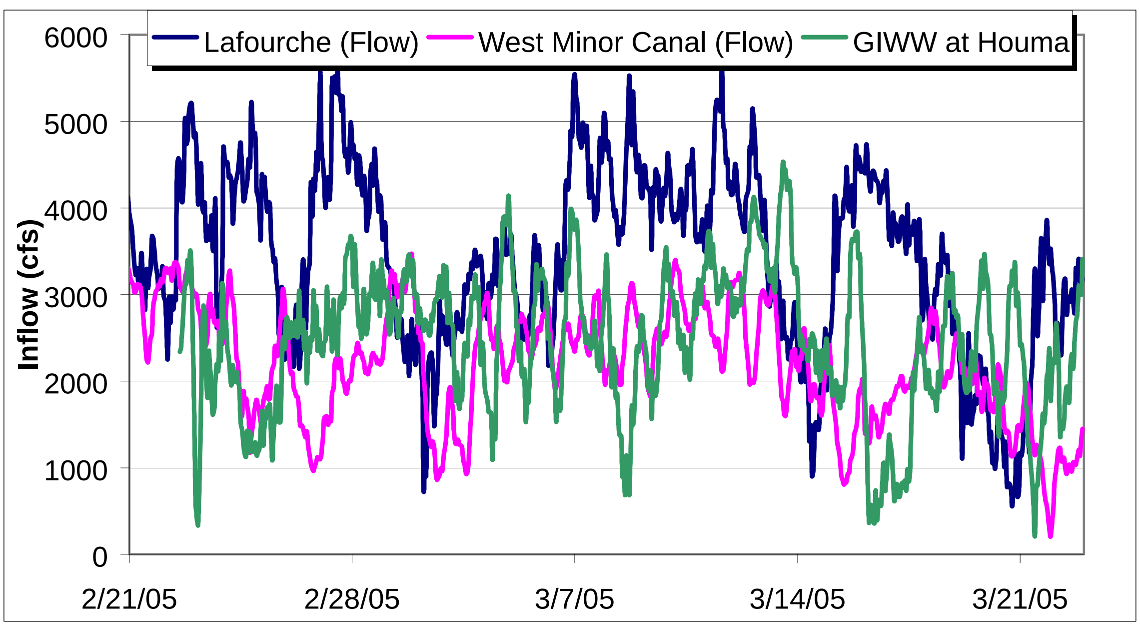


**Figure 15. Inflows for Calibration Period**

Swarzenski (2003) examined flows in the GIWW and the lower Atchafalaya River, and noted a relationship between flows in the GIWW at (1) Bay Wallace (to the west of our study area but east of Morgan City and the Atchafalaya River) and (2) just to the west of Houma, as a function of daily-average stage in the lower Atchafalaya River at Morgan City. During the validation period, February

21, 2005 -to- March 22, 2005, the daily-average stage in the lower Atchafalaya River often exceeded 5 ft (NGVD or NAVD). At 5 ft, the regression equations in Swarzenski (2003) give flows of 9,400 cfs at Bay Wallace and 8,600 cfs near Houma. However, Figure 15 shows that measured flows in the GIWW at West Minors Canal barely exceeded 3,000 cfs. And on February 8, 2005, the daily-average stage in the lower Atchafalaya River was nearly 7 feet, which should have resulted in flows exceeding 10,000 cfs in the GIWW (using the regression equations of Swarzenski [2003]), However, the observed flows at West Minors Canal did not exceed 5,000 cfs. Clearly, high stages in the lower Atchafalaya River result in significant amounts of fresh water moving east into the study area. But with flows of about 3,000 cfs being observed in the GIWW, it is clear that significant (but unknown) amounts of freshwater, not accounted for as boundary inflows, are causing the system to become very “fresh”. As the quantity and spatial distribution of these additional sources of freshwater inflows are not known, it was decided not to proceed further with model validation for this period. Rather, the project team decided to simulate the entire year of record to evaluate how well the model performed over this period.

## 3.6 Simulation of Year-Long Record

The Corps had provided data for March 22, 2004 through March 23, 2005. Given the uncertainty of freshwater inflows during “wet” periods, it was decided to simulate this entire period and examine the results to determine whether the model adequately represented system processes, except during these wet periods. The model results are compared to observations at a number of interior points in Appendix C and summary statistics are presented in Table 3.

The results show good agreement for stage. While the mean stage in the GIWW at Houma is a little underestimated, the tidal and inflow-induced variations are generally reproduced. As expected, the comparison with observed salinity is only fair. At Houma, the model confirms the generally freshwater system. At Dulac and in Caillou Lake, the model approximates the tidal fluctuations in salinity, but struggles to reproduce the long-term variations due to wet and dry events. This is especially true in Caillou Lake. At Dulac in the HNC, the model does simulate some of the long-term variability of salinity, but misses a number of short-term “episodes”.

**Table 3. Statistics for Year-Long Simulation**

**Salinity**

| Location | ID | 95% | 90% | 75% | 50% | 25% | 10% | 5% |
|---|---|---|---|---|---|---|---|---|
| GIWW at Houma | Observed | 0.345 | 0.215 | 0.166 | 0.142 | 0.117 | 0.106 | 0.103 |
| | Model | 0.574 | 0.313 | 0.193 | 0.131 | 0.085 | 0.067 | 0.058 |
| HNC at Dulac | Observed | 14.362 | 7.703 | 1.051 | 0.238 | 0.154 | 0.132 | 0.122 |
| | Model | 10.919 | 7.961 | 4.690 | 1.856 | 0.409 | 0.109 | 0.076 |
| Bayou Petite Caillou North of Cocodrie | Observed | 12.917 | 12.148 | 10.631 | 8.911 | 7.484 | 6.234 | 5.102 |
| | Model | 27.689 | 27.035 | 22.594 | 16.998 | 13.027 | 9.799 | 9.231 |
| Falgout Canal West of Bayou Dularge | Observed | 11.790 | 8.155 | 3.754 | 1.873 | 0.832 | 0.379 | 0.271 |
| | Model | 1.365 | 1.160 | 0.811 | 0.535 | 0.357 | 0.288 | 0.269 |
| Caillou Lake | Observed | 17.927 | 16.438 | 13.220 | 9.380 | 5.113 | 2.333 | 1.222 |
| | Model | 14.780 | 14.203 | 12.716 | 11.411 | 9.942 | 8.618 | 8.001 |

**Water Surface Elevation**

| Location | ID | 95% | 90% | 75% | 50% | 25% | 10% | 5% |
|---|---|---|---|---|---|---|---|---|
| GIWW at Houma | Observed | 2.350 | 2.170 | 1.930 | 1.670 | 1.400 | 1.190 | 1.090 |
| | Model | 2.013 | 1.792 | 1.407 | 1.019 | 0.689 | 0.407 | 0.256 |
| HNC at Dulac | Observed | 1.640 | 1.460 | 1.210 | 0.920 | 0.630 | 0.350 | 0.160 |
| | Model | 1.963 | 1.713 | 1.347 | 0.990 | 0.684 | 0.403 | 0.246 |
| Bayou Petite Caillou North of Cocodrie | Observed | 2.120 | 1.840 | 1.500 | 1.120 | 0.760 | 0.420 | 0.230 |
| | Model | 1.881 | 1.682 | 1.365 | 1.023 | 0.754 | 0.531 | 0.405 |
| Falgout Canal West of Bayou Dularge | Observed | 2.220 | 1.940 | 1.630 | 1.340 | 1.020 | 0.702 | 0.570 |
| | Model | 2.024 | 1.721 | 1.378 | 1.059 | 0.758 | 0.441 | 0.258 |
| Caillou Lake | Observed | 2.140 | 1.910 | 1.580 | 1.190 | 0.710 | 0.320 | 0.080 |
| | Model | 2.014 | 1.766 | 1.353 | 0.936 | 0.493 | 0.104 | -0.123 |

## 3.7 Discussion of Calibration and Uncertainty

The purpose of the study is to develop a model capable of simulating flows and salinities in the HNC its major tributaries and distributaries with sufficient accuracy that comparisons can be made between existing and "with project" conditions. It is clear from the model development, sensitivity analyses and calibration, that a great deal of uncertainty exists in the model. Perhaps the data with the greatest uncertainty is the model geometry – both bathymetry and datum conversions. The next area of data uncertainty is the quantification of freshwater inflows to the system. While flows in the GIWW at Larose and in Bayou Lafourche at Thibodaux are generally observed, most of the flow record in the GIWW at West Minors Canal is synthetic, and developed as a combination of observations (about 2 of the 12 months) and the results of a neural network "training" program developed by Corps of Engineers' Engineer Research and Development Center (ERDC).

In calibrating the model, particularly to observed salinities at Dulac, it was required that the bathymetry of the HNC be adjusted in its middle reach and also through Terrebonne Bay and through the barrier islands to the Gulf of Mexico. These adjustments were made by widening the navigation channel, rather than deepening it to introduce more salt into the HNC, in order to not lower the elevations below those of the "with project" geometry. This conservative assumption allows for the "with project" bathymetry to have an influence on the hydrodynamics and salt transport compared to existing conditions.

The model does a fair job of matching observed and model salinities in the system during "dry" periods. However, the model does a poor job during "wet" periods as there appears to be significant amounts of additional fresh water entering the system from the lower Atchafalaya River that are not captured by observations of flows in the GIWW at West Minors Canal. Due to these unknown quantities of additional freshwater inflows and their spatial distribution, the model could not be adjusted to simulate these wet periods.

The year-long simulation shows that the model generally captures water surface elevations and salinities in the system except for these "wet" periods. And the tidal variability is generally well produced. Therefore, the model is useful for simulating flows and salinities in the HNC system, except during "wet" events, and is capable of comparing "existing" and "with project" conditions for these not-wet periods, which are generally of more interest in terms of potentially higher salinities at Houma.

# 4 Model Application

## 4.1 Alternatives Simulated

The purpose of the study is to evaluate the potential impact on salinity, tidal elevations, and flows that might be caused by deepening the Houma Navigation Canal (HNC) from the confluence with the GIWW to the Gulf of Mexico. The Corps is also considering the construction of a lock near Dulac.

Currently, the channel invert of the HNC is -14.1 ft NAVD. Including two feet of overdredging, the Corps is considering dredging the HNC to -20 or -22 ft NAVD. The proposed dredging template (Figure 16) would deepen the HNC to the project depth with a bottom width of 150 feet in the HNC increasing to 300 feet to the Gulf.

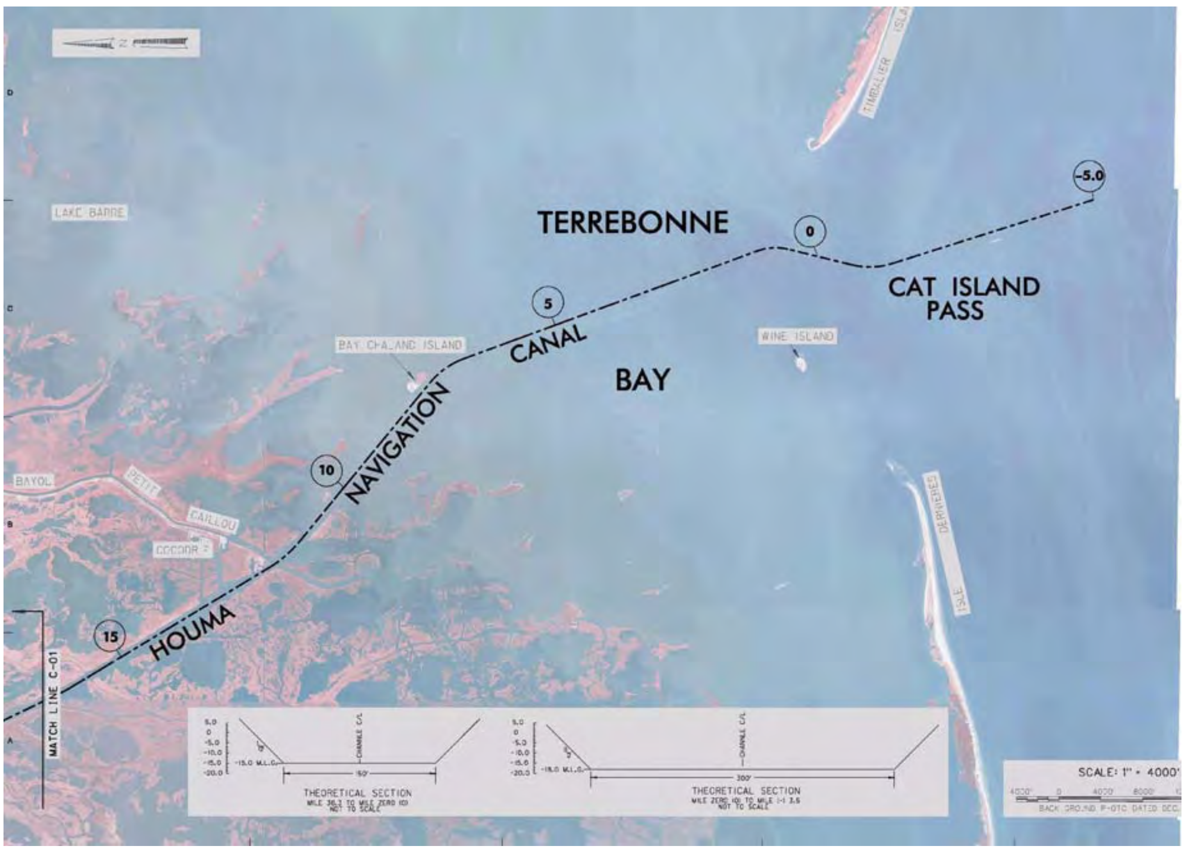

**Figure 16. Proposed Dredging Template**

In addition, the Corps is considering the construction of a lock near Dulac. The proposed structure (Figure 17) would include a permanent closure dam on the HNC, a bypass channel dredged to -20 or -22 feet, a lock structure, and a flood gate and channel that bypasses the lock. The strategy is that during hurricane surges from the Gulf of Mexico, the flood gate could be closed and vessel traffic would be locked to the lower system.

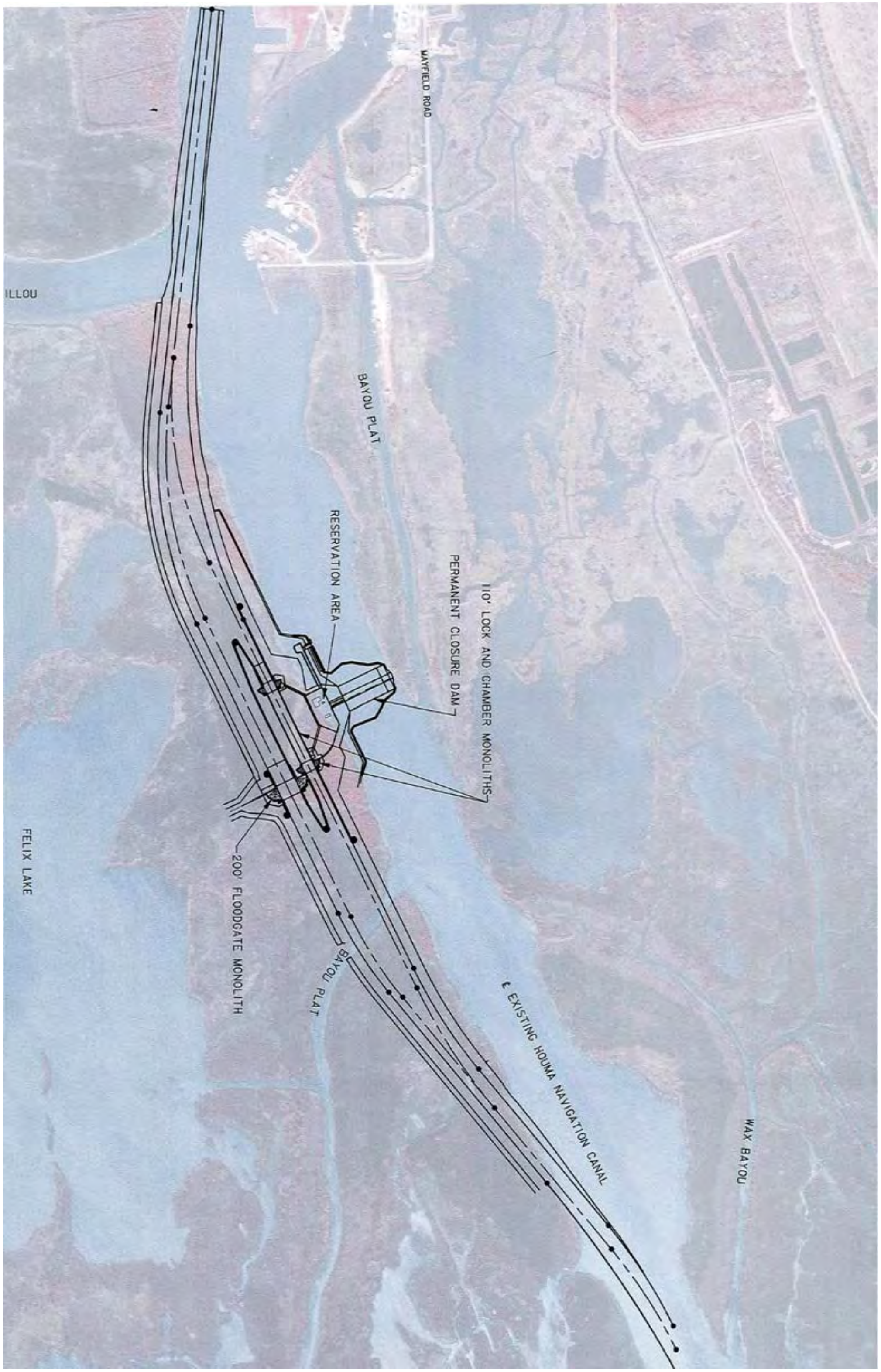


**Figure 17. Proposed Lock Structure**

To evaluate the channel deepening and the lock facility, the Corps developed a range of scenarios (Table 4).

**Table 4. Alternatives Simulated**

| Alternative | Lock Setup |
|---|---|
| Existing Conditions | none |
| Existing Conditions | Flood Gate Open, Lock closed |
| Dredge to -20 ft | none |
| Dredge to -20 ft | Flood Gate Open, Lock closed |
| Dredge to -20 ft | Flood Gate closed, Lock open |
| Dredge to -22 ft | none |
| Dredge to -22 ft | Flood Gate Open, Lock closed |
| Dredge to -22 ft | Flood Gate closed, Lock open |

## 4.2 Periods Simulated

A main concern of the project is whether the channel deepening, the lock structure, or both, might permit high-salinity water to intrude further up the HNC, perhaps as far as Houma, and threaten the City's freshwater intake. As this is more of a concern during periods of low freshwater inflows to the GIWW, two periods were selected to simulate each of the alternatives shown in Table 4. They represent (1) a low-flow month, and (2) and an average-flow year. These periods were identified by staff at ERDC.

The "low-flow" month was chosen to be September 2006, and the "average-flow" year was chosen to be 2003. Data for these periods provided to the modeling team included flows in the GIWW at West Minors Canal and Larose, and flows in Bayou Lafourche at Thibodaux. In addition, tidal elevations and wind speed and direction were obtained from the USGS for their gauge in Caillou Bay, and the tides were adjusted to the estimated NAVD datum. The observed salinity profiles for March 2004 through April 2005, obtained from LUMCON, were used for the appropriate month of each simulation.

## 4.3 Discussion of Results

The "low-flow" month and the "average-flow" year periods were simulated for each of the alternatives listed in Table 4. For each alternative, the CH3D grid was modified to reflect the physical changes due to deepening and to the addition of a lock structure as appropriate. The results were processed to compare (1) salinities, (2) water surface elevations and (3) flows for each alternative, and the results are presented at a number of "key" locations:

- On the HNC approximately 100 feet upstream and downstream of the confluence with Bayou Grand Caillou (BGC)

- On Bayou Grand Caillou (BGC) approximately 100 feet upstream and downstream of the confluence with the HNC

- HNC at Dulac
- In Caillou Bay
- In the Falgout Canal
- GIWW at Houma, and
- Approximately 100 feet to the east, west, and south, of the confluence of the GIWW and the HNC.

A compact way to present the differences between “with project” alternatives and “existing” conditions is to use exceedance frequency distributions. For the “low-flow” month simulation (September 2006), the frequency distributions of salinity are shown in Appendix D, of water surface elevation in Appendix E, and of flow in Appendix F. For the “average-flow” year, the frequency distributions of salinity are shown in Appendix G, of water surface elevation in Appendix H, and of flow in Appendix I. In Appendix D and Appendix G, the salinity results are also plotted for near-surface and near-bottom elevations to examine the influence of stratification. In Appendix J, the near-surface and near-bottom salinity profiles along the HNC are plotted for all the project alternatives for seven exceedance frequencies from 5% to 95%, for the “low-flow” month simulations. Appendix K is the same as Appendix J, except the exceedance frequency distributions are plotted for the “average-flow” year simulations. For all locations, the data are plotted over the same ranges for ease of comparison.

The model results showed only very small changes in water surface elevations, with maximum differences on the order of 0.1 feet. While changes in flow compared to existing conditions are generally small, several “with project” alternatives would cause more significant changes in the flow distribution. The changes in salinity would be the most noticeable, as channel deepening allows higher salinity water to intrude further up the HNC. In general, the salinities for the “low-flow” month simulations were higher than for the “average-flow” year simulations, except at higher return intervals. This means that while the “low-flow” month generally has smaller inflows resulting in higher salinity intrusion throughout the system, the “average-flow” year may have shorter periods (perhaps on the order of one week) with even smaller inflows, and these show up as higher salinity at the high frequencies. Similar patterns are seen for canal flows (even smaller flows at low frequencies) and for water surface elevations (larger tides during the “average-flow” year compared to September 2006).

In assessing the model results, the Corps’ project team is interested in understanding how “with project” conditions might differ from “existing” conditions throughout the study area. Specifically, they wish to examine four issues:

**Issue 1: Impact on the flow distribution at GIWW and HNC junction during low and high freshwater flow events.**

Figure 18 (also Figure I5) and Table 5 compare the exceedance distributions of average-year flows for existing conditions with flows for the various “with project” alternatives just to the east of the confluence of the GIWW and the HNC. The figure shows that each of the project alternatives has a relatively small effect on modifying the flow distribution near the City of Houma. The maximum increase in the 95%-discharge is 435 cfs to the east, or about 18 percent of the existing value. The minimum change, the 5%-discharge, is -88 cfs, or an increase of 88 cfs flowing to the west, and then down the HNC. If we compare the change in the overall frequency distribution by calculating the change in area compared to existing conditions under the frequency curve (“percent change” column in Table 5), the maximum cumulative change of 11-14 percent occurs for “with project” alternatives that simulate the lock closed and flood gate open. The cumulative change for other alternatives is less than nine percent.

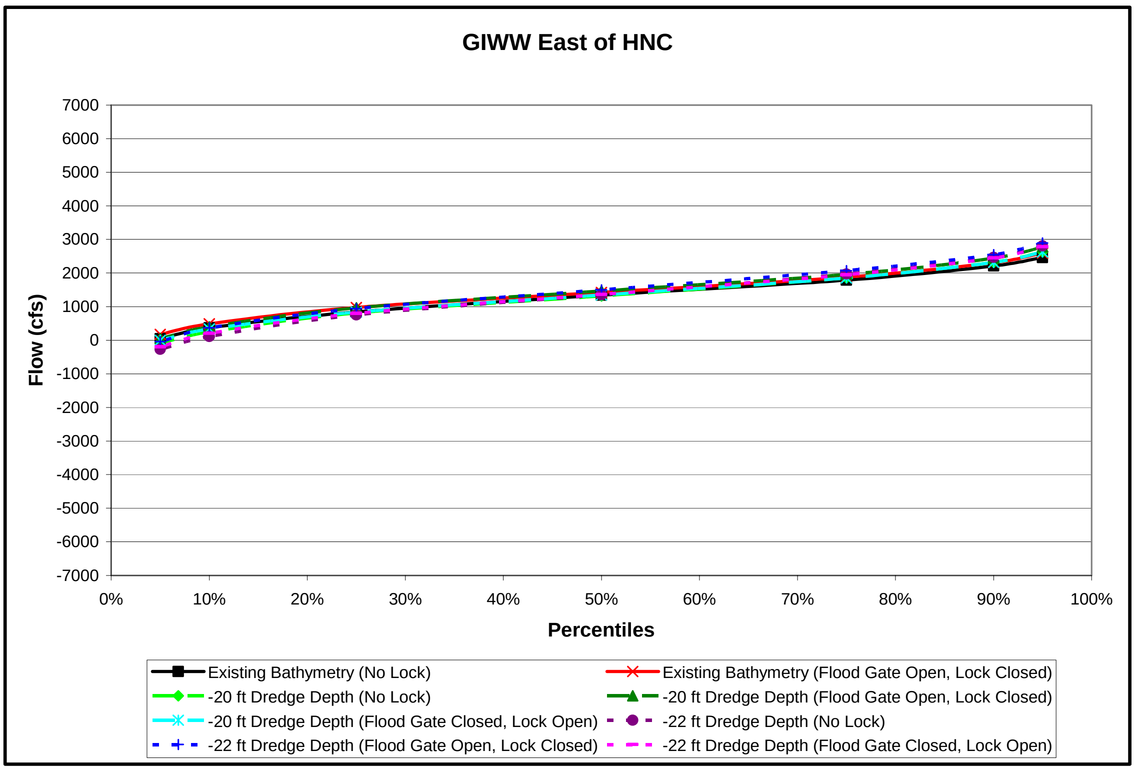


**Figure 18. Average-Year Flows Near Confluence of GIWW and HNC**

**Table 5. Exceedance for Average-Year Flows Near Confluence of GIWW and HNC**

| Alternative | 95% | 90% | 75% | 50% | 25% | 10% | 5% | Percent Change |
|---|---|---|---|---|---|---|---|---|
| Existing Bathymetry (No Lock) | 2462 | 2212 | 1788 | 1342 | 843 | 369 | 47 | - |
| Existing Bathymetry (Flood Gate Open, Lock Closed) | 2599 | 2305 | 1877 | 1426 | 977 | 490 | 178 | 8.2% |
| -20 ft Dredge Depth (No Lock) | 2633 | 2319 | 1854 | 1320 | 810 | 247 | -80 | 1.2% |
| -20 ft Dredge Depth (Flood Gate Open, Lock Closed) | 2781 | 2444 | 1961 | 1463 | 965 | 403 | 55 | 10.8% |
| -20 ft Dredge Depth (Flood Gate Closed, Lock Open) | 2624 | 2317 | 1854 | 1346 | 839 | 333 | 2 | 2.2% |
| -22 ft Dredge Depth (No Lock) | 2809 | 2469 | 1971 | 1354 | 756 | 111 | -272 | 5.0% |
| -22 ft Dredge Depth (Flood Gate Open, Lock Closed) | 2897 | 2552 | 2070 | 1499 | 944 | 372 | -41 | 14.0% |
| -22 ft Dredge Depth (Flood Gate Closed, Lock Open) | 2785 | 2447 | 1951 | 1367 | 801 | 205 | -197 | 5.6% |

**Issue 2: Impact on the flow distribution at Bayou Grand Caillou (BGC) and HNC junction during low and high freshwater flow events.**

The impact of the various “with project” alternatives on flows near the confluence of the BGC and HNC is more complex. To the south of the confluence, the effect depends on whether the lock system is included in the alternative (Figure I1). To the north of the confluence, Figure 19 (also Figure I2) and Table 6 show that, in general, as the HNC in deepened, the magnitude of the peak tidal discharges also increases (see results in Figure 19 and Table 6 for the 5% and 95 percent exceedance). Peak flow differences are as large as 27 percent, and cumulative changes in the frequency distributions may by 18-25 percent for “with project” alternatives with the lock closed and flood gate open. The cumulative change for other alternatives is less than 14 percent.

In the BGC to the east of the confluence, the flows are generally small and the differences modest (Figure I4). In the BGC just the west of the confluence, Figure 20 (also Figure I3) and Table 7 show similar maximum flood (positive) flows, generally changing by less than eight percent, or up to 173 cfs. However, for the alternatives with the lock closed but the flood gate open, the ebb (negative) flows may increase up to 28 percent, or 636 cfs. For other alternatives, the ebb flows increase by less than ten percent. Cumulative changes in the frequency distributions may by 18-21 percent for “with project” alternatives with the lock closed and flood gate open and less than ten percent for other alternatives.

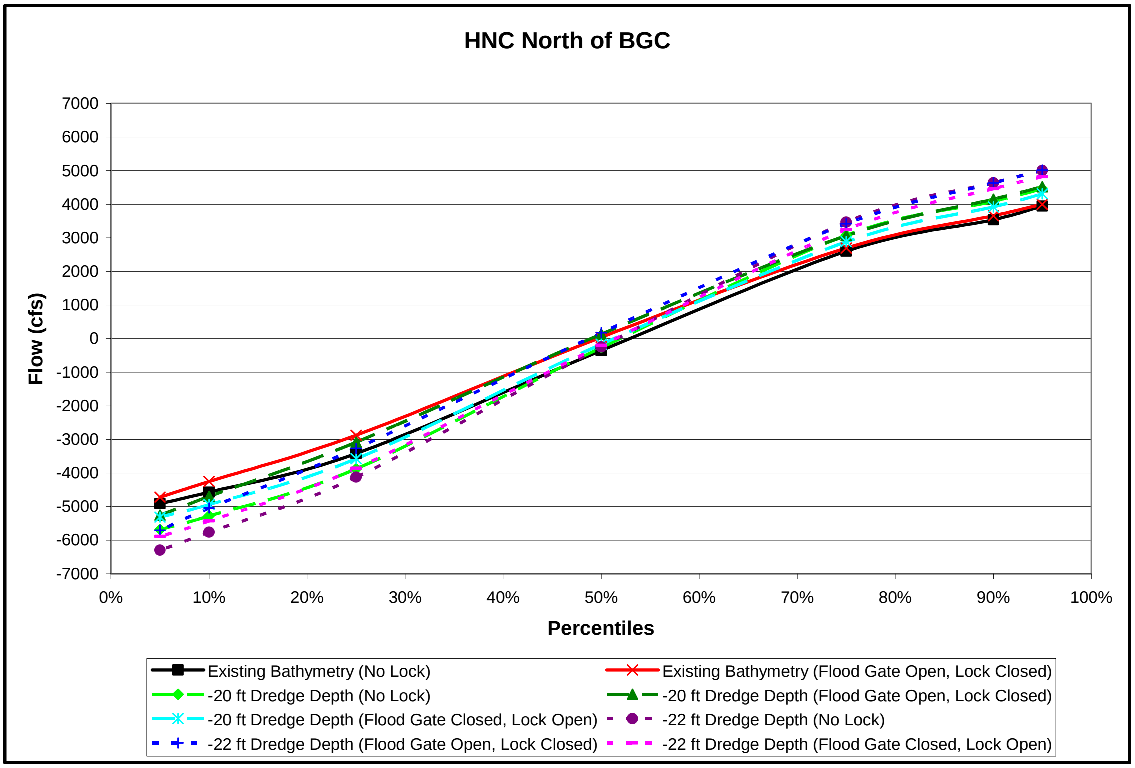


**Figure 19. Average-Year Flows Just North of the Confluence of BGC and HNC**

**Table 6. Exceedance for Average-Year Flows Just North of the Confluence of BGC and HNC**

| Alternative | 95% | 90% | 75% | 50% | 25% | 10% | 5% | Percent Change |
|---|---|---|---|---|---|---|---|---|
| Existing Bathymetry (No Lock) | 3945 | 3537 | 2605 | -354 | -3421 | -4569 | -4908 | - |
| Existing Bathymetry (Flood Gate Open, Lock Closed) | 3996 | 3657 | 2695 | 43 | -2875 | -4253 | -4716 | -7.2% |
| -20 ft Dredge Depth (No Lock) | 4462 | 4089 | 3077 | -263 | -3876 | -5277 | -5680 | 13.9% |
| -20 ft Dredge Depth (Flood Gate Open, Lock Closed) | 4520 | 4153 | 3070 | 138 | -3076 | -4694 | -5249 | 4.1% |
| -20 ft Dredge Depth (Flood Gate Closed, Lock Open) | 4311 | 3922 | 2882 | -163 | -3571 | -4934 | -5312 | 6.2% |
| -22 ft Dredge Depth (No Lock) | 5004 | 4639 | 3469 | -246 | -4123 | -5755 | -6292 | 25.2% |
| -22 ft Dredge Depth (Flood Gate Open, Lock Closed) | 5016 | 4636 | 3418 | 178 | -3269 | -5042 | -5704 | 13.9% |
| -22 ft Dredge Depth (Flood Gate Closed, Lock Open) | 4824 | 4464 | 3250 | -200 | -3857 | -5423 | -5888 | 17.9% |

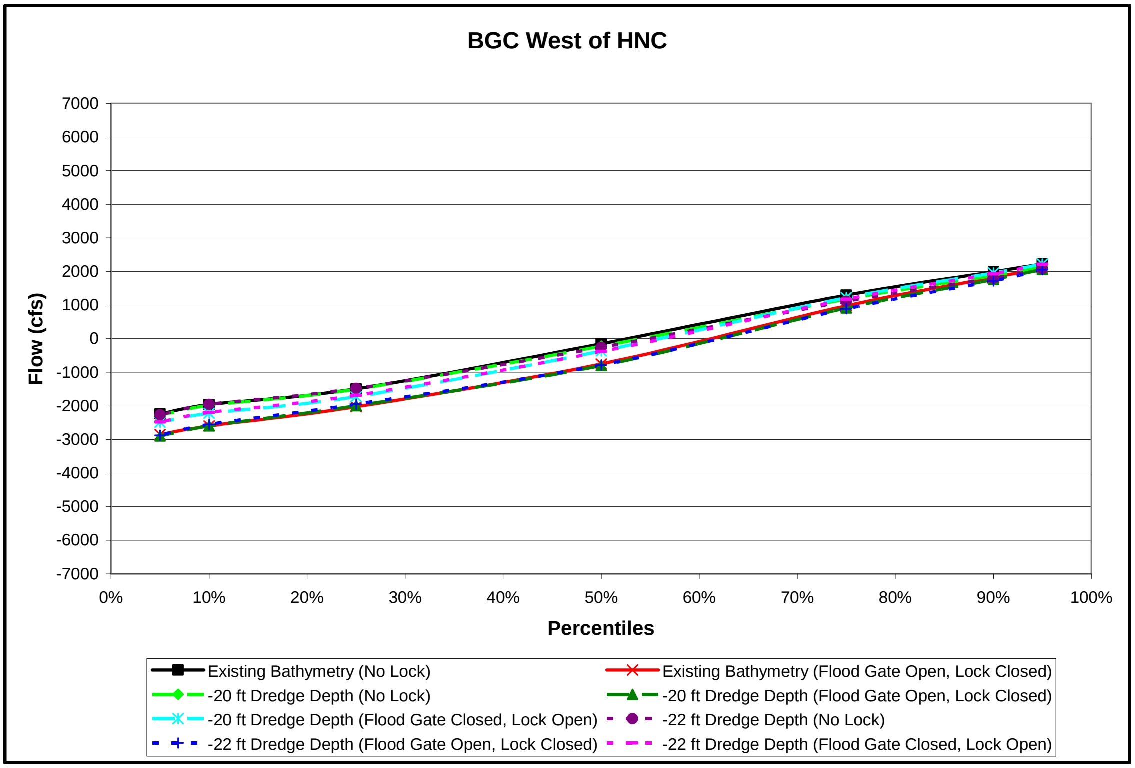


**Figure 20. Average-Year Flows Just West of the Confluence of BGC and HNC**

**Table 7. Exceedance for Average-Year Flows Just West of the Confluence of BGC and HNC**

| Alternative | 95% | 90% | 75% | 50% | 25% | 10% | 5% | Percent Change |
|---|---|---|---|---|---|---|---|---|
| Existing Bathymetry (No Lock) | 2227 | 1989 | 1293 | -154 | -1494 | -1958 | -2238 | - |
| Existing Bathymetry (Flood Gate Open, Lock Closed) | 2096 | 1819 | 979 | -753 | -2027 | -2595 | -2848 | 20.8% |
| -20 ft Dredge Depth (No Lock) | 2146 | 1878 | 1180 | -221 | -1503 | -1982 | -2278 | -1.2% |
| -20 ft Dredge Depth (Flood Gate Open, Lock Closed) | 2059 | 1758 | 911 | -801 | -1998 | -2596 | -2894 | 19.9% |
| -20 ft Dredge Depth (Flood Gate Closed, Lock Open) | 2218 | 1957 | 1218 | -365 | -1724 | -2221 | -2484 | 9.4% |
| -22 ft Dredge Depth (No Lock) | 2085 | 1801 | 1112 | -256 | -1480 | -1955 | -2266 | -3.1% |
| -22 ft Dredge Depth (Flood Gate Open, Lock Closed) | 2054 | 1719 | 887 | -782 | -1950 | -2550 | -2874 | 17.7% |
| -22 ft Dredge Depth (Flood Gate Closed, Lock Open) | 2211 | 1933 | 1173 | -380 | -1682 | -2195 | -2481 | 7.9% |

**Issue 3: Impact on salt water intrusion along the HNC and HNC's tributaries and distributaries.**

To evaluate the impacts of the various "with project" alternatives, we focus on the results of the low-month simulations (see Appendix D). This is because of the uncertainty in the salinity results at high flows due to the unknown inflows to the system from the Atchafalaya River.

At **Houma**, near-surface salinities change very little between the alternatives and show fresh water from west-to-east flows in the GIWW. However, Figure 21 (also Figure D10) and Table 8 show that the cumulative change in the frequency distributions may be large, exceeding 100 percent, with absolute changes up to 5 ppt. For channel deepening to -20 ft NAVD, the maximum increase is 3.1 ppt with the flood gate open, but 1.1 ppt with only the lock open. However, channel deepening to -22 ft NAVD may increase salinities by 5.1 ppt with the flood gates open, and by 3.7 ppt with only the lock open.

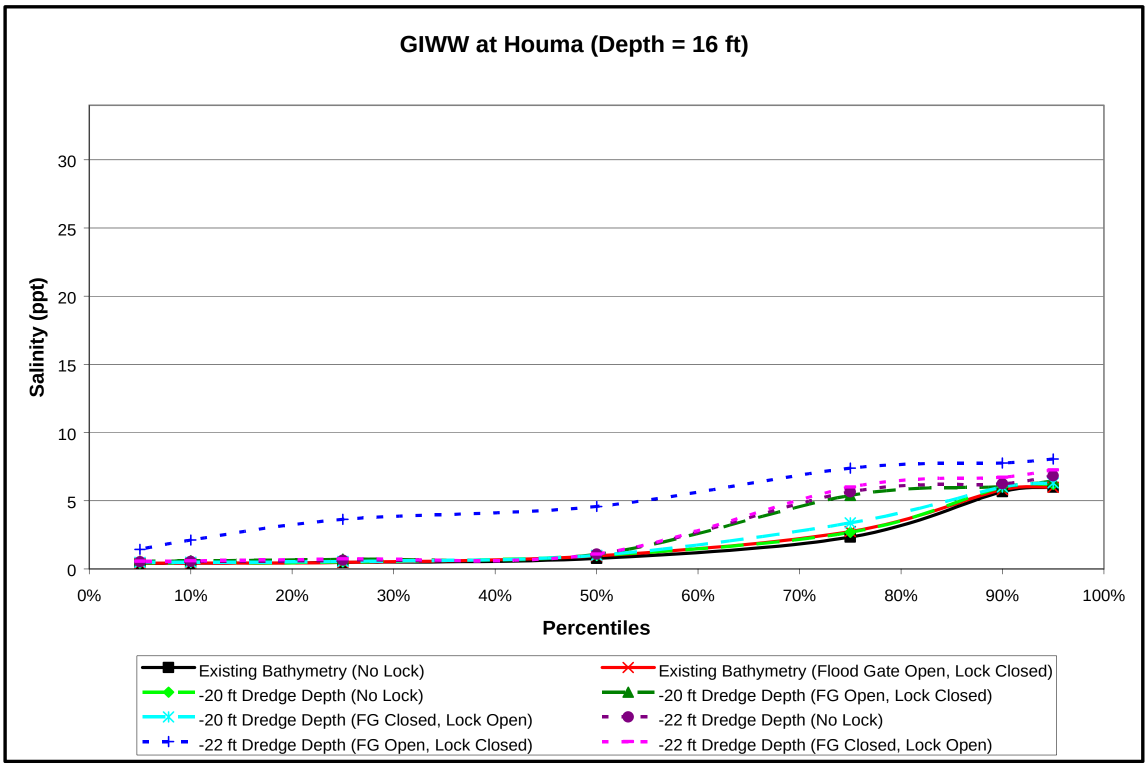


**Figure 21. Salinities at 16-ft Depth in GIWW at Houma for Low-Flow Month**

**Table 8. Salinities at 16-ft Depth in GIWW at Houma for Low-Flow Month**

| Alternative | 95% | 90% | 75% | 50% | 25% | 10% | 5% | Percent Change |
|---|---|---|---|---|---|---|---|---|
| Existing Bathymetry (No Lock) | 6.0 | 5.7 | 2.3 | 0.8 | 0.5 | 0.4 | 0.4 | - |
| Existing Bathymetry (Flood Gate Open, Lock Closed) | 6.0 | 5.8 | 2.7 | 0.9 | 0.5 | 0.4 | 0.4 | 8.0% |
| -20 ft Dredge Depth (No Lock) | 6.2 | 6.0 | 2.7 | 1.0 | 0.5 | 0.5 | 0.4 | 10.3% |
| -20 ft Dredge Depth (FG Open, Lock Closed) | 6.4 | 6.1 | 5.4 | 1.1 | 0.7 | 0.6 | 0.6 | 45.6% |
| -20 ft Dredge Depth (FG Closed, Lock Open) | 6.3 | 6.0 | 3.4 | 1.0 | 0.5 | 0.5 | 0.5 | 19.2% |
| -22 ft Dredge Depth (No Lock) | 6.8 | 6.3 | 5.7 | 1.1 | 0.6 | 0.5 | 0.5 | 50.0% |
| -22 ft Dredge Depth (FG Open, Lock Closed) | 8.1 | 7.8 | 7.4 | 4.6 | 3.6 | 2.1 | 1.4 | 174.5% |
| -22 ft Dredge Depth (FG Closed, Lock Open) | 7.3 | 6.7 | 6.0 | 1.1 | 0.7 | 0.6 | 0.6 | 59.6% |

On the **HNC at Dulac**, near-surface and near-bottom salinities can increase up to 8.4 ppt. The near-bottom results in Figure 22 (also Figure D7) and Table 9 show that the major increases are for “with project” alternatives with the lock closed and flood gate open. For these conditions, the cumulative change to the frequency distribution may be 70-90 percent with a maximum increase of 8.4 ppt, while the difference is less than 25 percent (2.7 ppt) for other alternatives. The minimum change is 3.4 ppt for alternatives with the flood gate open, but only 0.1 ppt for other alternatives. We note that these same “flood gate open” alternatives also result in increased ebb flow down the BGC. Upstream of the confluence of the HNC and BGC, the magnitude of both the flood and ebb flows increase, as discussed in “Issue 2” above. However, during the ebb tide, proportionally more of this increase in flood-tide flow ebbs down the BGC rather than the HNC. During the flood tide, more salinity intrudes into the HNC due to the deepening (including the lock structure). However, during the ebb tide, not as much of it is “pushed” back down the HNC. The net effect is that the salinity intrudes further up the HNC for “with project” alternatives with the flood gate open due to the increased ebb flows down the BGC.

The salinities at the confluence of the **HNC and BGC** increase for the “with project” alternatives with the flood gates open for the reasons discussed for the salinities at Dulac. Figure 23 and Table 10 show the same relative distributions of salinities. However, alternatives with the flood gate closed and the lock open may results in a decrease in salinities of up to 2.4 ppt (compared to the maximum increase of 8.7 ppt with the flood gates open), as the narrower lock channel blocks the upstream movement of the salt wedge.

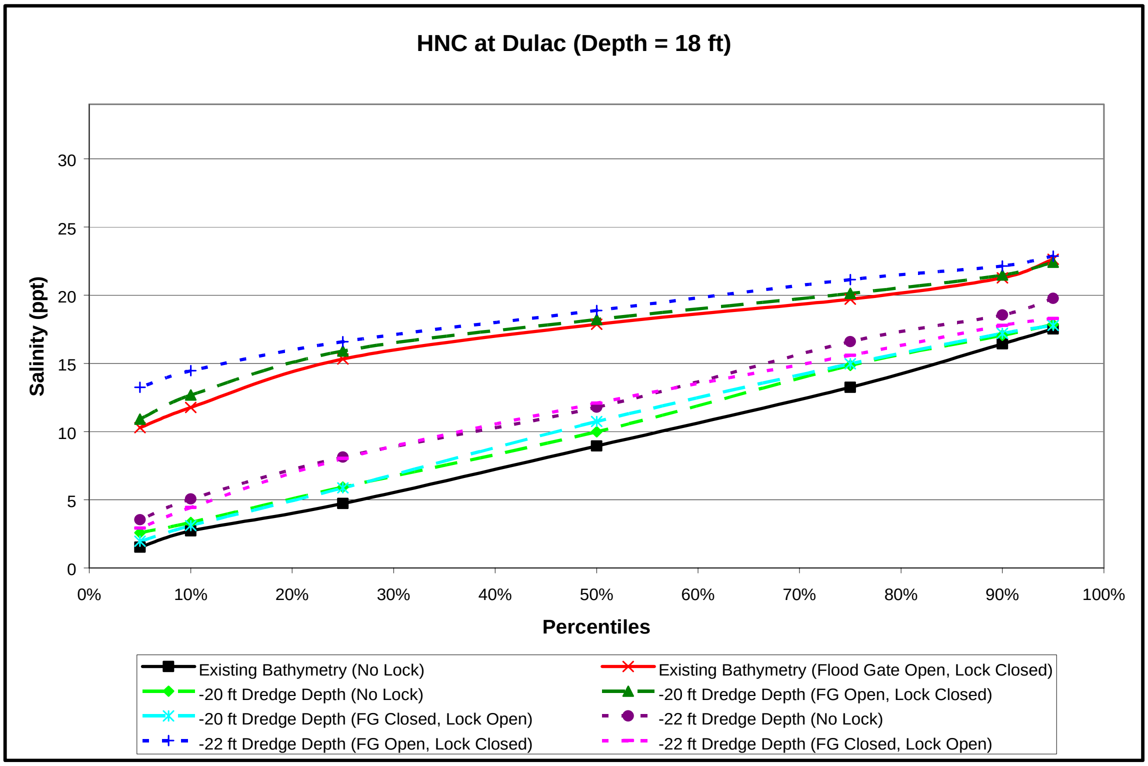


**Figure 22. Salinities at 18-ft Depth in HNC at Dulac for Low-Flow Month**

**Table 9. Salinities at 18-ft Depth in HNC at Dulac for Low-Flow Month**

| Alternative | 95% | 90% | 75% | 50% | 25% | 10% | 5% | Percent Change |
|---|---|---|---|---|---|---|---|---|
| Existing Bathymetry (No Lock) | 16.5 | 14.1 | 11.6 | 5.6 | 2.6 | 1.5 | 1.2 | - |
| Existing Bathymetry (Flood Gate Open, Lock Closed) | 19.4 | 18.3 | 16.4 | 12.4 | 8.5 | 5.2 | 4.4 | 71.6% |
| -20 ft Dredge Depth (No Lock) | 16.7 | 15.0 | 12.6 | 5.7 | 3.3 | 1.9 | 1.6 | 7.4% |
| -20 ft Dredge Depth (FG Open, Lock Closed) | 19.8 | 18.4 | 16.6 | 12.8 | 9.5 | 6.4 | 5.4 | 79.7% |
| -20 ft Dredge Depth (FG Closed, Lock Open) | 16.5 | 14.9 | 12.9 | 6.9 | 3.8 | 1.8 | 1.5 | 13.3% |
| -22 ft Dredge Depth (No Lock) | 16.9 | 15.3 | 13.3 | 7.6 | 4.9 | 3.0 | 2.4 | 23.7% |
| -22 ft Dredge Depth (FG Open, Lock Closed) | 19.9 | 18.6 | 16.3 | 13.4 | 11.0 | 8.0 | 7.1 | 89.3% |
| -22 ft Dredge Depth (FG Closed, Lock Open) | 16.6 | 15.3 | 13.1 | 8.3 | 5.1 | 2.8 | 2.3 | 25.5% |

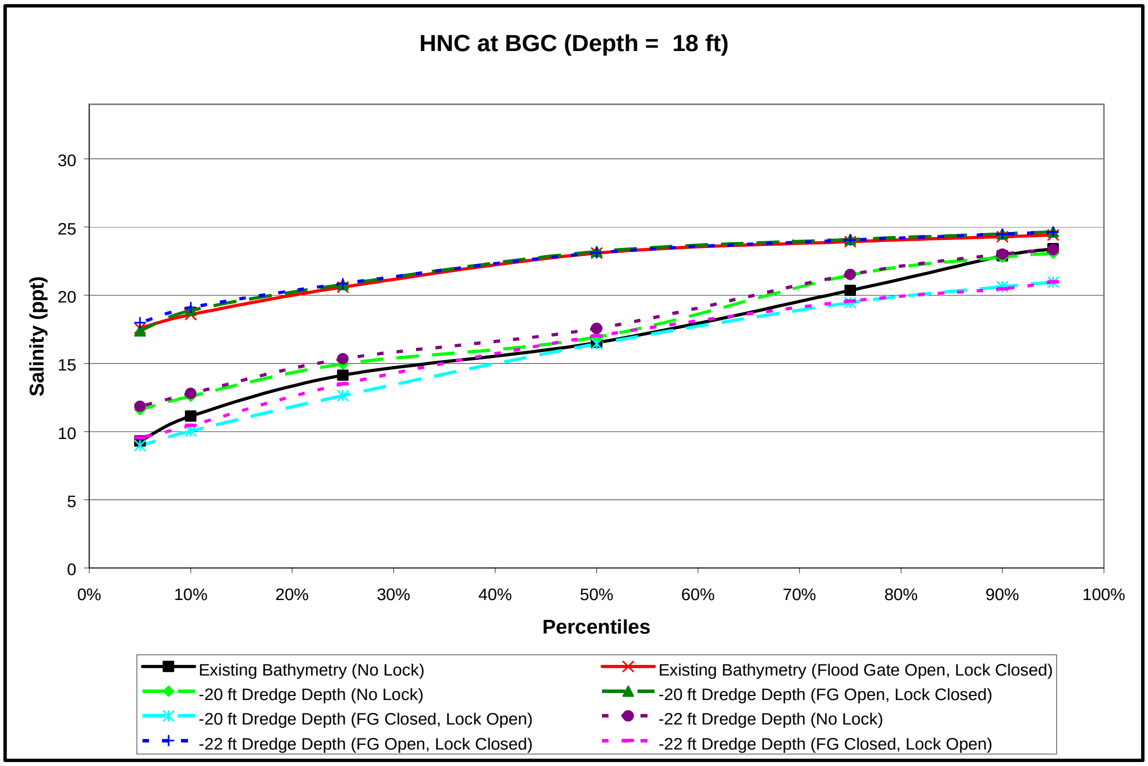


**Figure 23. Salinities at 18-ft Depth in HNC at BGC Confluence for Low-Flow Month**

**Table 10. Salinities at 18-ft Depth in HNC at BGC Confluence for Low-Flow Month**

| Alternative | 95% | 90% | 75% | 50% | 25% | 10% | 5% | Percent Change |
|---|---|---|---|---|---|---|---|---|
| Existing Bathymetry (No Lock) | 23.4 | 22.9 | 20.3 | 16.5 | 14.1 | 11.1 | 9.3 | - |
| Existing Bathymetry (Flood Gate Open, Lock Closed) | 24.4 | 24.3 | 23.9 | 23.1 | 20.6 | 18.6 | 17.6 | 74.1% |
| -20 ft Dredge Depth (No Lock) | 23.1 | 22.8 | 21.5 | 16.9 | 15.0 | 12.6 | 11.6 | 7.6% |
| -20 ft Dredge Depth (FG Open, Lock Closed) | 24.7 | 24.5 | 24.1 | 23.2 | 20.8 | 18.9 | 17.4 | 75.5% |
| -20 ft Dredge Depth (FG Closed, Lock Open) | 21.0 | 20.6 | 19.5 | 16.4 | 12.6 | 10.0 | 9.0 | 11.0% |
| -22 ft Dredge Depth (No Lock) | 23.3 | 23.0 | 21.5 | 17.6 | 15.3 | 12.8 | 11.9 | 18.0% |
| -22 ft Dredge Depth (FG Open, Lock Closed) | 24.6 | 24.5 | 24.0 | 23.1 | 20.9 | 19.1 | 18.0 | 77.0% |
| -22 ft Dredge Depth (FG Closed, Lock Open) | 21.0 | 20.5 | 19.6 | 17.0 | 13.5 | 10.4 | 9.5 | 17.4% |

In the **Falgout Canal**, salinities are very similar for all alternatives. Again, the largest differences of up to 1-1.5 ppt are seen for the "with Project" alternatives with the flood gates open (Figure 24 and Table 11), and the cumulative change in the frequency distribution may be 19026 percent. The cumulative frequency change is less than four percent for other alternatives. We believe that this is a damped effect of increased salinities seen at Dulac for the "flood gate open" alternatives, resulting in some of the salinity increase moving west through the Falgout Canal towards the western lakes. By the time this water reaches Caillou Lake, the differences are less than five percent for all alternatives, as seen in Figure 25 and Table 12 .

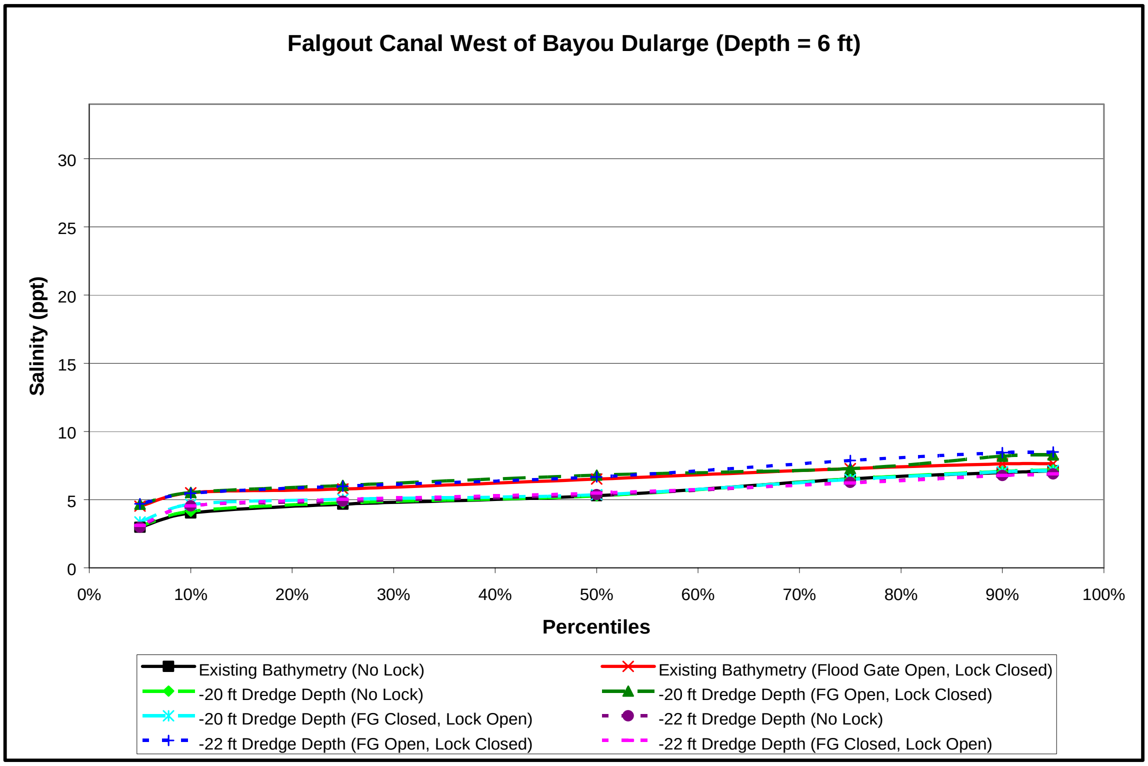


**Figure 24. Salinities at 6-ft Depth in the Falgout Canal for Low-Flow Month**

**Table 11. Salinities at 6-ft Depth in the Falgout Canal for Low-Flow Month**

| Alternative | 95% | 90% | 75% | 50% | 25% | 10% | 5% | Percent Change |
|---|---|---|---|---|---|---|---|---|
| Existing Bathymetry (No Lock) | 7.1 | 7.0 | 6.5 | 5.3 | 4.7 | 4.0 | 3.0 | - |
| Existing Bathymetry (Flood Gate Open, Lock Closed) | 7.6 | 7.6 | 7.3 | 6.5 | 5.8 | 5.5 | 4.5 | 19.4% |
| -20 ft Dredge Depth (No Lock) | 7.2 | 7.1 | 6.5 | 5.3 | 4.8 | 4.1 | 3.1 | 0.9% |
| -20 ft Dredge Depth (FG Open, Lock Closed) | 8.3 | 8.2 | 7.3 | 6.8 | 6.0 | 5.5 | 4.7 | 23.8% |
| -20 ft Dredge Depth (FG Closed, Lock Open) | 7.1 | 7.0 | 6.5 | 5.4 | 5.0 | 4.7 | 3.4 | 3.4% |
| -22 ft Dredge Depth (No Lock) | 6.9 | 6.8 | 6.3 | 5.4 | 4.9 | 4.5 | 3.0 | 0.3% |
| -22 ft Dredge Depth (FG Open, Lock Closed) | 8.5 | 8.5 | 7.9 | 6.7 | 6.0 | 5.5 | 4.7 | 26.0% |
| -22 ft Dredge Depth (FG Closed, Lock Open) | 6.9 | 6.8 | 6.2 | 5.5 | 5.0 | 4.5 | 3.1 | 1.5% |

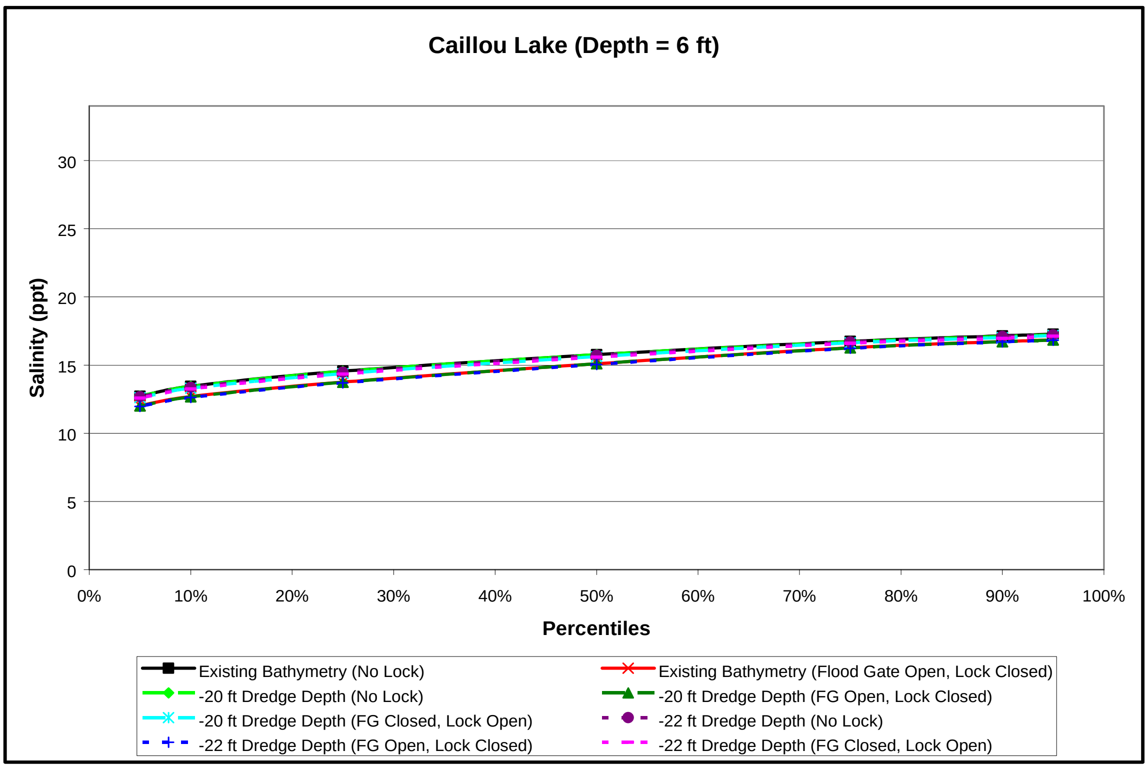


**Figure 25. Salinities at 6-ft Depth in Caillou Lake for Low-Flow Month**

**Table 12. Salinities at 6-ft Depth in Caillou Lake for Low-Flow Month**

| Alternative | 95% | 90% | 75% | 50% | 25% | 10% | 5% | Percent Change |
|---|---|---|---|---|---|---|---|---|
| Existing Bathymetry (No Lock) | 17.3 | 17.1 | 16.7 | 15.8 | 14.6 | 13.4 | 12.7 | - |
| Existing Bathymetry (Flood Gate Open, Lock Closed) | 16.9 | 16.7 | 16.3 | 15.1 | 13.7 | 12.7 | 12.0 | -4.0% |
| -20 ft Dredge Depth (No Lock) | 17.2 | 17.1 | 16.7 | 15.8 | 14.5 | 13.4 | 12.7 | -0.1% |
| -20 ft Dredge Depth (FG Open, Lock Closed) | 16.8 | 16.7 | 16.3 | 15.1 | 13.7 | 12.7 | 12.0 | -4.1% |
| -20 ft Dredge Depth (FG Closed, Lock Open) | 17.2 | 17.0 | 16.6 | 15.6 | 14.4 | 13.3 | 12.6 | -0.9% |
| -22 ft Dredge Depth (No Lock) | 17.2 | 17.1 | 16.7 | 15.7 | 14.5 | 13.4 | 12.7 | -0.3% |
| -22 ft Dredge Depth (FG Open, Lock Closed) | 16.8 | 16.7 | 16.2 | 15.0 | 13.7 | 12.6 | 12.0 | -4.3% |
| -22 ft Dredge Depth (FG Closed, Lock Open) | 17.1 | 17.0 | 16.6 | 15.6 | 14.3 | 13.3 | 12.6 | -1.2% |

## Issue 4: Assess operation of HNC Lock Complex to increase flow along BGC during low flows.

During low-month flows (see Appendix F), the response of the BGC is similar to that found during the average-year simulations. In the BGC to the east of the confluence, the flows are generally small and the differences modest (Figure F4). In the BGC just the west of the confluence, Figure 26 (also Figure F3) and Table 13 show maximum flood (positive) flows changing by less than 18 percent, or flow increases of up to 173 cfs. However, for the alternatives with the lock closed but the flood gate open, the ebb (negative) flows again may increase up to 30 percent (ebb flow increases up to 636 cfs). For the alternatives modeled with the lock open, the peak ebb flows increase by only ten percent (flow increases up to 243 cfs). Cumulative changes in the frequency distributions may by 19-21 percent for “with project” alternatives with the lock closed and flood gate open. The cumulative change for other alternatives is less than ten percent.

During this same period, near-bottom salinities at Houma may increase by 3.7 ppt with only the lock open (compare to an increase of 5.1 ppt with the flood gate open); the near-bottom salinities at Dulac may increase by 2.7 ppt with only the lock open (compare to an increase of 8.4 ppt with the flood gate open); and the near-bottom salinities at in the BGC, just to the west of its confluence with the HNC, may increase by 2.4 ppt with only the lock open (compare to an increase of 8.7 ppt with the flood gate open).

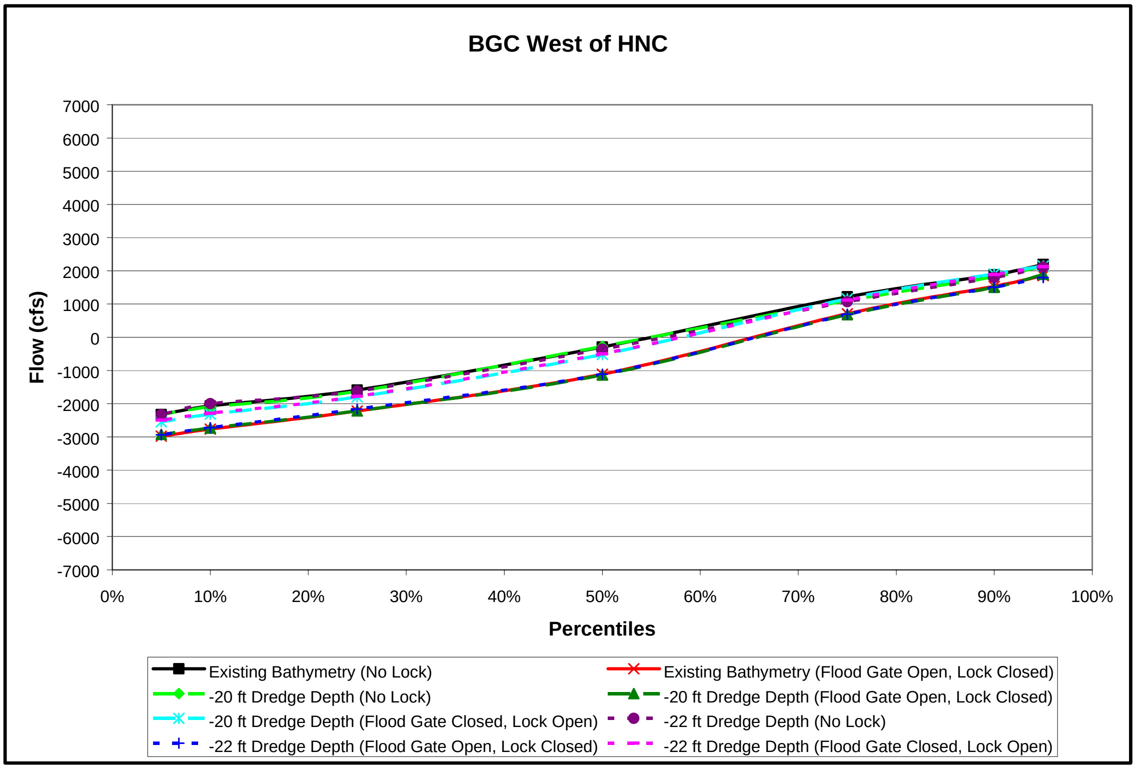


**Figure 26. Low-Month Flows Just West of the Confluence of BGC and HNC**

**Table 13. Exceedance for Low-Month Flows Just West of the Confluence of BGC and HNC**

| Alternative | 95% | 90% | 75% | 50% | 25% | 10% | 5% | Percent Change |
|---|---|---|---|---|---|---|---|---|
| Existing Bathymetry (No Lock) | 2188 | 1882 | 1215 | -291 | -1589 | -2067 | -2330 | - |
| Existing Bathymetry (Flood Gate Open, Lock Closed) | 1855 | 1531 | 710 | -1111 | -2217 | -2762 | -2976 | 21.0% |
| -20 ft Dredge Depth (No Lock) | 2140 | 1819 | 1104 | -273 | -1628 | -2096 | -2324 | -1.9% |
| -20 ft Dredge Depth (Flood Gate Open, Lock Closed) | 1894 | 1503 | 677 | -1131 | -2216 | -2736 | -2925 | 20.4% |
| -20 ft Dredge Depth (Flood Gate Closed, Lock Open) | 2146 | 1907 | 1158 | -517 | -1795 | -2318 | -2547 | 9.3% |
| -22 ft Dredge Depth (No Lock) | 2113 | 1794 | 1067 | -360 | -1615 | -2002 | -2328 | -2.1% |
| -22 ft Dredge Depth (Flood Gate Open, Lock Closed) | 1797 | 1509 | 691 | -1109 | -2162 | -2722 | -2935 | 18.9% |
| -22 ft Dredge Depth (Flood Gate Closed, Lock Open) | 2122 | 1888 | 1113 | -504 | -1777 | -2283 | -2494 | 7.3% |

# 5 References

Murray, S.P., "An Observational Study of the Mississippi-Atchafalaya Coastal Plume", Final Report, OCS Study MMS 98-0040, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, 1998, 513p.

Swarzenski, C.M, "Surface-Water Hydrology of the Gulf Intracoastal Waterway in South-Central Louisiana, 1996-9", U.S. Geological Professional Paper 1672, 2003.

# Annex II

# Water Quality

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# 1.0 WATER QUALITY

## 1.1 Existing Conditions

### 1.1.1 State and Coastal Plain

Louisiana's coastal plain is rich with water resources. These include rivers and streams, lakes, estuaries, and wetlands. Louisianans rely on these resources to support the state's economy as well as basic, daily needs such as drinking water supply. With the presence of humans, these resources need to be protected from anthropogenic pollutants. Pollutants may enter water bodies via point sources and/or nonpoint sources. As defined by the U. S. Environmental Protection Agency (EPA), point sources are discrete conveyances such as pipes or man-made ditches. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need a NPDES (National Pollutant Discharge Elimination System) permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. Nonpoint sources are defined by the Louisiana Department of Environmental Quality (DEQ) as diffuse sources of water pollution that *typically do not enter the water through a discharge pipe, but flow freely across exposed surfaces, transporting sediments from construction sites, agricultural fields and harvested forests.* (DEQ 2007).

The 2010 DEQ Integrated Report (IR) provides documentation of DEQ's progress towards protecting the *chemical, physical, biological, and aesthetic integrity of the water resources and aquatic environment of Louisiana* pursuant to Clean Water Act (CWA) sections 303(d) and 305(b) (DEQ 2010). Section 303(d) of the CWA requires that states list water bodies that are impaired for their designated use, and to formulate a Total Maximum Daily Load (TMDL) for impaired water bodies. An impaired water body is a subsegment of water that is unable to meet the water quality criteria for its designated uses. DEQ defines a subsegment as a named regulatory water body as defined by Louisiana water quality standards regulation LAC 33:IX.1123. They are considered representative of the watershed through which they flow and have numerical criteria assigned to them. DEQ has three categories of primary designated uses for most state waters, including: primary contact recreation, secondary contact recreation, and fish and wildlife propagation. These are defined below, along with secondary designated uses:

- **Primary Contact Recreation (PCR)** is defined by DEQ as any recreational activity that involves or requires prolonged body contact with the water, such as swimming, water skiing, tubing, snorkeling and skin-diving.

- **Secondary Contact Recreation (SCR)** is defined as any recreational activity which may involve incidental or accidental body contact with the water and during which the probability of ingesting appreciable quantities of water is minimal, such as fishing, wading and recreational boating.

- **Fish and Wildlife Propagation (FWP)** is defined as including the use of water for preservation and reproduction of aquatic biota such as indigenous species of fish and invertebrates, as well as reptiles, amphibians, and other wildlife associated with the aquatic environment. This also includes the maintenance of water quality at a level that prevents contamination of aquatic biota consumed by humans.

- **Drinking Water Supply (DWS)** is defined as a surface or underground raw water source which, after conventional treatment, will provide safe, clear, potable, and aesthetically pleasing water for uses which include, but are not limited to, human consumption, food processing and cooking, and inclusion as a liquid ingredient in foods and beverages.

- **Outstanding Natural Resource (ONR)** is defined as water bodies designated for preservation, protection, reclamation, or enhancement of wilderness and aesthetic qualities and ecological regimes, such as those designated under the Louisiana Natural and Scenic Rivers System or those designated by the Office of Environmental Assessment as waters of ecological significance.

- **Oyster Propagation (OYS)** is defined as the use of water to maintain biological systems that support economically important species of oysters, clams, mussels, or other mollusks so that their productivity is preserved and the health of human consumers of these species is protected.

- **Agricultural Use (AGR)** is defined as the use of water for crop spraying, irrigation, livestock watering, poultry operations and other farm purposes not related to human consumption.

- **Limited Aquatic Life and Wildlife (LAL)** is defined as a subcategory of fish and wildlife propagation that recognizes not all water bodies are capable of supporting the same level of species diversity and richness. Examples of water bodies to which this may be applied include intermittent streams and man-made water bodies that lack suitable riparian structure and habitat. (DEQ 2010)

Section 305(b) provides the requirement that each state must provide the following to the Administrator of the EPA:

1. A description of the water quality of all navigable waters in the state;

2. An assessment of the status of waters of the state with regard to their support of recreational activities and fish and wildlife propagation;

3. An assessment of the state's water pollution control activities toward achieving the CWA goal of having water bodies that support recreational activities and fish and wildlife propagation;

4. An estimate of the costs and benefits of implementing the CWA; and

5. A description of the nature and extent of nonpoint sources of pollution and recommendations for programs to address nonpoint source pollution. (DEQ 2010)

The 305(b) assessments are also applied at the subsegment level. According to the 2010 DEQ IR, the most common individual designated uses in the coastal plain include primary contact recreation, secondary contact recreation, fish and wildlife propagation, shellfish propagation, and drinking water supply. In 2010, 84 percent of Louisiana's named water quality management subsegments or watersheds assessed for primary contact recreation were fully supporting the designated use, while 97 percent of those assessed for secondary contact recreation were fully supporting the use, and 33 percent of those assessed for fish and wildlife propagation were fully supporting their designated use. In reference to coastal Louisiana, 100 percent of estuaries assessed for primary contact recreation were fully supporting the use, while 100 percent of those assessed for secondary contact recreation were fully supporting the use, and 71 percent of those assessed for fish and wildlife propagation were fully supporting their use. Of the Louisiana rivers and streams assessed for the primary designated uses, 78 percent were fully supporting primary contact recreation, 95 percent were fully supporting secondary contact recreation, and 29 percent were fully supporting fish and wildlife propagation. Of the Louisiana wetlands assessed for the primary designated uses, 67 percent were fully supporting primary contact recreation, 44 percent were fully supporting secondary contact recreation, and 12 percent were fully supporting fish and wildlife propagation.

Low dissolved oxygen, mercury, and turbidity were cited as the most prevalent causes of impairment for Louisiana water bodies. The leading suspected sources of these impairments include unknown sources, atmospheric deposition, and natural conditions (an indication that the water quality standard is not set appropriately for the assessed water body). Of the estuaries assessed in the 2010 DEQ IR, fecal coliform, mercury, and low dissolved oxygen were the leading causes of impairment. The suspected sources of impairment include unknown sources, atmospheric deposition, and natural conditions. The 2010 DEQ IR for streams indicated that low dissolved oxygen, mercury, and fecal coliform were the leading causes of impairment. The suspected sources of impairment include unknown sources, atmospheric deposition, and natural conditions. For the wetland areas throughout the state assessed at the time the report was written, mercury, low dissolved oxygen, total dissolved solids, sulfates, and chloride were the suspected causes of impairment, while atmospheric deposition, unknown sources, non-irrigated crop production, on-site treatment systems, and drainage/filling/loss of wetlands were the leading sources of impairment. This assessment includes all wetlands, not just coastal area wetlands.

### 1.1.2 Terrebonne Basin

The Terrebonne Basin is located in southeastern Louisiana between the Mississippi River to the north and the Gulf of Mexico to the south. The basin is comprised of lowlands that are prone to flooding except in areas protected by levees. *The coastal portion of the basin is prone to tidal flooding and consists of marshes from fresh to saline* (DEQ 1999). The project area is located in the coastal portion of the basin. Land use in the project area was determined using USGS GAP data collected between 2007 and 2012. The data indicate that approximately 64 percent of the project area is open water, 22 percent is shrubland and grassland, 5 percent is forest and woodland, 4 percent is agricultural, and 4 percent is developed.

The 2010 DEQ IR indicates that 27 water bodies in the Terrebonne basin were either partially or not supporting the designated uses, and that the primary causes of impairment included low dissolved oxygen, fecal coliform, solids/sedimentation, and turbidity. (DEQ, 2011)

### 1.1.3 Houma Navigation Canal

***Water Body Subsegments***

The limits of the proposed project include four water body subsegments of the Houma Navigation Canal from Houma, Louisiana to Terrebonne Bay. The water body subsegment for Gulf of Mexico is also included in the project limits, which is a total of five water body subsegments directly impacted by the proposed project. The water body subsegments are listed in Table 1 with a description of the boundaries of the subsegments. Figure 1 shows the limits of each subsegment.

**Table 1. Water Body Subsegments Included in the Proposed Project**

| Water Body Subsegment Number | Water Body Name | Water Body Type |
|---|---|---|
| LA 120509 | Houma Navigation Canal – Houma to Bayou Pelton | River |
| LA 120508 | Houma Navigation Canal-Bayou Pelton to the boundary between segments 1205 and 1207 (Estuarine) | River |
| LA 120705 | Houma Navigation Canal-From the segment boundary between 1205 and 1207 to Terrebonne Bay (Estuarine) | River |
| LA 120802 | Terrebonne Bay | Estuary |
| LA 120806 | Terrebonne Basin Coastal Bays and Gulf Waters to the State 3 mi limit | Estuary |

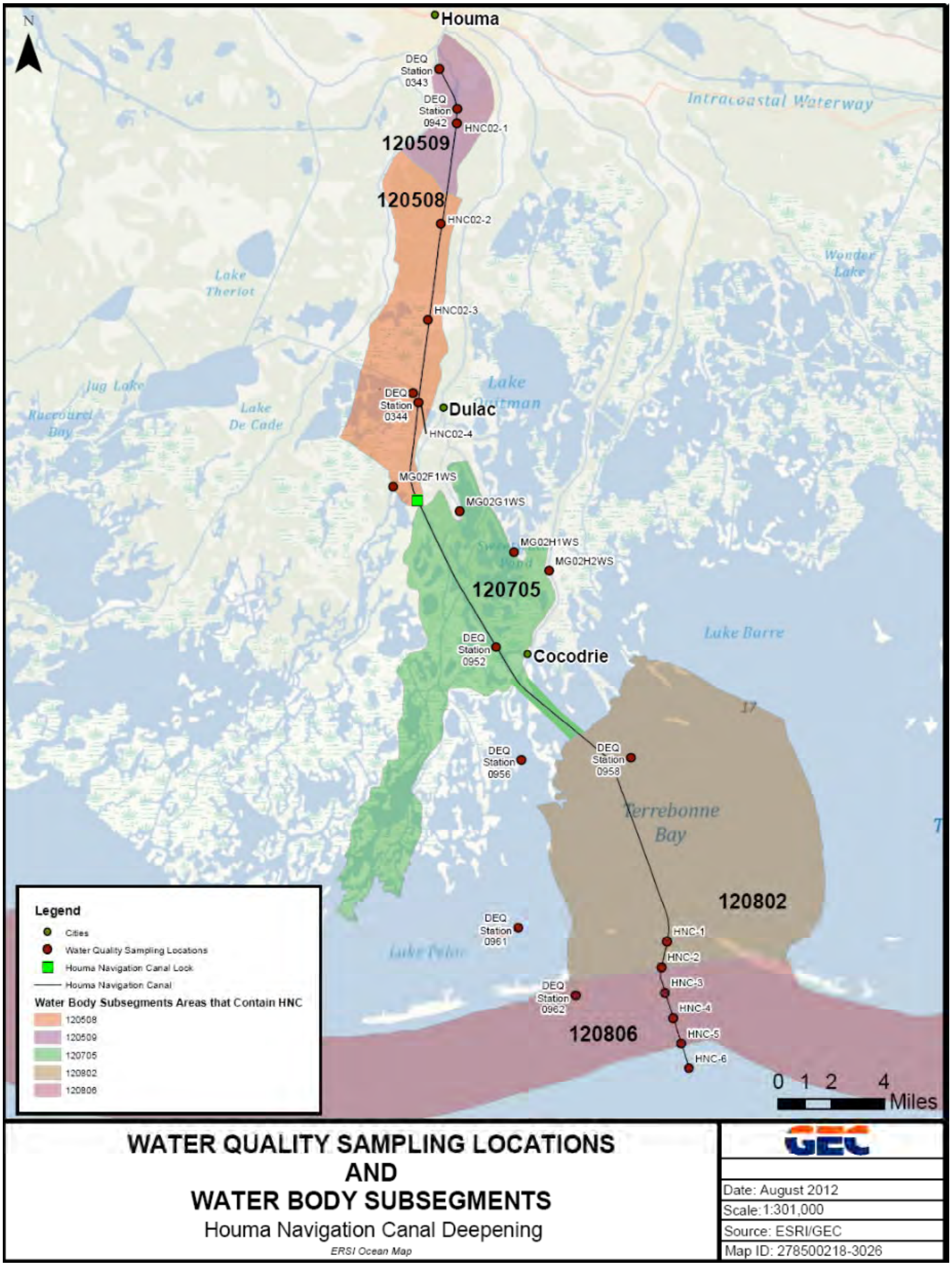


**Figure 1. Water Quality Sampling Locations and Water Body Subsegments**

As mentioned previously, the most common individual designated uses of water bodies in the coastal plain include primary contact recreation, secondary contact recreation, fish and wildlife propagation, shellfish propagation, and drinking water supply. Table 2 lists the designated uses for each of the subsegments of the proposed project. All of the subsegments within the proposed project area are fully supporting their designated uses, and fall within Integrated Report Category (IRC) 1, except for LA 120806. LA 120806 is listed as impaired for fish and wildlife and oyster propagation and is listed in IRC Category 5. Suspected sources of impairment include upstream sources, marina/boating sanitary on-vessel discharges, petroleum/natural gas activities, and waterfowl.

**Table 2. DEQ Assessments of Subsegments Included in the Proposed Project**

| Water Body Subsegment Number | Designated Uses | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | PCR | SCR | FWP | DWS | ONR | OYS | AGR | LAL |
| LA 120508 | F | F | F | | | F | | |
| LA 120509 | F | F | F | F | | | | |
| LA 120705 | F | F | F | | | F | | |
| LA 120802 | F | F | F | | | F | | |
| LA 120806 | F | F | N | | | N | | |

F = Fully Supporting, N=Not Supporting

IRC provides a focused approach to water quality management by clearly determining what management actions are required to protect or improve individual water bodies. There are eight IRC categories and they are as follows:

- *IRC 1*: The specific Water body Impairment Combination (WIC) cited on a previous 303(d) list is now attaining all uses and standards. This category is also used for water bodies that are fully supporting all designated uses.

- *IRC 2*: The water body is meeting some uses and standards, but there is insufficient data to determine if uses and standards associated with the specific WIC cited are being attained.

- *IRC 3*: There is insufficient data to determine if any uses and standards *associated with the specific WIC* are being attained.

- *IRC 4a*: A WIC exists, but a TMDL has been completed for the *specific WIC* cited.

- *IRC 4b*: A WIC exists, but control measures other than a TMDL are expected to result in attainment of designated uses *associated with the specific WIC* cited.

- *IRC 4c*: A WIC exists, but a pollutant (anthropogenic source) does not cause the *specific WIC* cited.

- *IRC 5*: A WIC exists for one or more uses, and a TMDL is required for the *specific WIC* cited. The summary of subsegments categorized as IRC 5 represents Louisiana's 303(d) list.

- *IRC5RC (Revise Criteria)*: WIC exists for one or more uses, and a TMDL is required for the specific WIC cited; however, DEQ will investigate revising criteria due to the possibility that natural conditions may be the source of the water quality criteria impairments.

***Water Quality Standards and Criteria***

The DEQ has established general written water quality standards that are applicable to all waters of the State of Louisiana. The general written standards relate to the condition of the water as affected by waste discharges or human activity as opposed to purely natural phenomena. The standards were last revised in October 2011 and can be obtained at http://www.deq.louisiana.gov/portal/. The DEQ standards provide criteria, which specify general and numerical limitations for various water quality parameters that are required for designated water uses. The general criteria apply at all times to the surface waters of the state, including wetlands, except where specifically exempted in the standards. The general criteria include parameters such as aesthetics; floating, suspended, and settleable solids; taste and odor; toxic substances; oil and grease; foaming or frothing materials; nutrients; turbidity; flow; radioactive materials; biological and aquatic community integrity; and other substances and characteristics that will be developed as needed. The numerical criteria apply to specified water bodies, and to their tributaries, distributaries, and interconnected streams and water bodies contained in the water management subsegment if they are not specifically named therein, unless unique chemical, physical, and/or biological conditions preclude the attainment of the criteria. In those cases, natural background levels of these conditions may be used to establish site specific water quality criteria. Those water bodies officially approved and designated by the state and EPA as intermittent streams, man-made water bodies, or naturally dystrophic waters may be excluded from some or all numerical criteria as stated in LAC 33:IX.1109. Although naturally occurring variations in water quality may exceed criteria, water quality conditions attributed to human activities must not exceed criteria when flows are greater than or at critical conditions (as defined in LAC 33:IX.1115.C).

The EPA has established ambient water quality criteria applicable to surface waters in the study area. The numerical criteria have been developed for various physical parameters, nutrients, metals, PCBs, and organic pesticides for uses of freshwater aquatic life, marine and estuarine aquatic life, and public water supply, respectively. The EPA has also established written water quality criteria, which are applicable to all waters of the United States. EPA's criteria can be obtained at http://www.epa.gov/waterscience/.

### *Sediment Quality Benchmarks*

There are no sediment quality standards promulgated by EPA or by the State of Louisiana. The National Oceanic and Atmospheric Administration (NOAA) has developed a set of sediment quality benchmarks known as Screening Quick Reference Tables, or SQuiRTs, which present sediment benchmarks for inorganic and organic contaminants in sediment. These benchmarks are available at http://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf. These benchmarks, while not criteria or standards, provide a basis on which to evaluate relative sediment quality. The results of the sediment tests were compared to the effects range-low (ER-L), effects range-median (ER-M), threshold effects level (TEL), and probable effects level (PEL) benchmarks for those parameters tested. The benchmarks are defined as:

> **ER-L**: The ER-L represents the lower 10th percentile of chemical concentrations observed or predicted to be associated with biological effects.
>
> **ER-M**: The ER-M benchmark represents the median of chemical concentrations observed or predicted to be associated with biological effects.
>
> **TEL**: The TEL represents the geometric mean of the 15th percentile concentration of the toxic effects data set and the median of the no-effect data set, and represents the concentration below which adverse effects are expected to occur only rarely.
>
> **PEL**: The PEL represents the geometric mean of the 50 percent of impacted, toxic samples and the 85 percent of the non-impacted samples, and represents the level above which adverse effects are frequently expected. (NOAA 2006)

### *TMDL*

The state of Louisiana is working with the EPA to develop Total Maximum Daily Loads (TMDLs) for the water bodies that were included on the state's 303(d) list (see www.deq.state.la.us). Section 303(d) of the CWA requires states to identify, list, and rank for development of TMDLs waters that do not meet applicable water quality standards after implementation of technology – based controls. According to the EPA, developing a TMDL is part of a process whereby impaired or threatened water bodies and the pollutant(s) causing the impairment are systematically identified and a scientifically based strategy -- a TMDL -- is established to correct the impairment or eliminate the threat and restore the water body.

In 2007, EPA developed a TMDL for fecal coliform on Subsegment 120508, Houma Navigation Canal – Bayou Pelton to the boundary between segments 1205 and 1207. The TMDL lists six affected point source dischargers in Subsegment 120508. No other TMDLs were listed within the subsegments included within the project area. TMDL development for LA 120806 is listed as a low priority and there is no target date for completion.

### *NPDES/LPDES*

In 1996, the EPA granted National Pollutant Discharge Elimination System (NPDES) delegation to DEQ. As authorized by the CWA, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. In most cases, the NPDES permit program is administered by authorized states; hence, Louisiana established the Louisiana Pollutant Discharge Elimination System (LPDES) permitting program after receiving delegation authority in 1996. Through this program, DEQ maintains records for point source discharges into waters of the State of Louisiana, including the heavily industrialized portion of the Mississippi River, which is between Baton Rouge and New Orleans. In 1990, the NPDES program was expanded to include the Phase I NDPES Storm Water Discharge Program. This program was established in response to the 1987 Amendments to the CWA and addresses storm water runoff from municipalities with populations of 100,000 or more and construction activity disturbing five or more acres of land. In 1999, Phase II of the program was developed. This phase addresses storm water runoff from certain small municipalities and construction activity disturbing 1 to 5 acres of land.

Currently, there are 59 LPDES permitted dischargers on file with DEQ who discharge either directly into the Houma Navigation Canal (HNC) or into tributaries which ultimately drain into the HNC. Typical discharges are classified as sanitary wastewater, industrial wastewater, and stormwater runoff. A list of permitted facilities located in the study area is presented in Table 3.

### *Data Collection*

Data from 23 sampling locations were analyzed to assess the existing water quality conditions in the project area. Chemical analyses of ambient water, sediment, and standard elutriate were conducted for nine of the samples including HNC02-1, HNC02-2, HNC02-3, HNC02-4, MG02F1WS, MG02G2WS, MG02H1WS, MG02H2WS, and HNC-Lock. Chemical analyses of ambient water, sediment, and standard elutriate and solid phase bioassays were conducted for six of the samples including HNC-1, HNC-2, HNC-3, HNC-4, HNC-5 and HNC-6. Chemical analysis of ambient water was conducted for three of the samples including DEQ Stations 343, 344, 942, 952, 956, 958, 961, and 962. Corps of Engineers Mississippi Valley New Orleans (CEMVN) or contractors performing the work for CEMVN collected 15 samples and DEQ collected the other eight. See Table 4 for a list of the sampling locations (Figure 1) and the collecting agency.

### *Data Analyses*

Data from the 23 sampling locations discussed previously were analyzed and compared to the water quality standards and criteria and the sediment quality benchmarks. Based on DEQ's descriptions, one subsegment of the HNC within the project limits is a fresh water body. The other subsegments are marine water bodies. Therefore, fresh water criteria were only used in the analysis of LA120509. Marine water criteria were used in the analyses of the other subsegments. Results of the analyses for the subsegments are discussed in the following paragraphs and presented in Table 5. Only parameters that were quantified as above detection levels are discussed below. In some samples, it should be noted that there is a difference between

## Table 3. DEQ Permitted Facilities

| AI Number | AI Name | Permit Number | Permit Type |
|---|---|---|---|
| 1969 | Dolphin Services LLC | LA0075779 | Indiv-Minor Industrial |
| 3589 | Tennessee Gas Pipeline Co - Compressor Station 523 | LA0046981 | Indiv-Minor Industrial |
| 8838 | Terrebonne Parish Consolidated Government - Houma Municipal Power | LA0100820 | Indiv-Minor Industrial |
| 9789 | Gulf Island Fabrication Inc - East Yard & West Yard & North Yard | LA0091961 | Indiv-Minor Industrial |
| 10104 | Martin Operating Partnership LP - Dulac Facility | LAG670141 | Gen-LAG67-Hydrostatic Test |
| 11131 | Offshore Specialty Fabricators Inc - North Yard | LA0121525 | Indiv-Minor Industrial |
| 12741 | Sparrows Offshore LLC | LAG480638 | Gen-LAG48-Light Commercial |
| 14434 | Offshore Energy Services Inc | LAG480337 | Gen-LAG48-Light Commercial |
| 17061 | Enterprise Marine Services LLC - Houma Shipyard | LA0104884 | Indiv-Minor Industrial |
| 18772 | Halliburton Energy Services Inc - Dulac Facility | LAG480203 | Gen-LAG48-Light Commercial |
| 18961 | LADOTD - Houma Navigation Canal Bridge | LAG530303 | Gen-LAG53-Sanitary Class I |
| 19562 | Terrebonne Parish Consolidated Government - Houma South WWTP | LA0040274 | Indiv-Major-Sanitary-Minor Mod |
| 20138 | Vacco Marine Inc | LA0084425 | Indiv-Minor Industrial |
| 23522 | Tailing Rents LLC - Tailing Rents | LAG750737 | Gen-LAG75-Exterior Vehicle Wash |
| 23893 | Gulfstream Services Inc | LAG480520 | Gen-LAG48-Light Commercial |
| 24916 | CS Controls Inc | LAG480219 | Gen-LAG48-Light Commercial |
| 27387 | Gulfstream Services Inc - Houma Facility | LAG480143 | Gen-LAG48-Light Commercial |
| 27499 | RCS LLC | LAG480650 | Gen-LAG48-Light Commercial |
| 27507 | North American Fabricators LLC | LAG541433 | Gen-LAG54-Sanitary Class II |
| 29831 | K&B Machine Works Inc | LAG480737 | Gen-LAG48-Light Commercial |
| 29934 | Hope Services Inc | LAG480703 | Gen-LAG48-Light Commercial |
| 31134 | Dishman & Bennett Specialty Co Inc | LAG480003 | Gen-LAG48-Light Commercial |
| 33199 | Elevating Boats - Houma Division | LAG533131 | Gen-LAG53-Sanitary Class I |
| 33756 | Tarpon Rentals Inc | LAG480508 | Gen-LAG48-Light Commercial |
| 43448 | Express Energy Services Operating LP | LAG480324 | Gen-LAG48-Light Commercial |
| 43625 | Total Environmental Solutions Inc - Crozier Heights Subdivision | LAG560179 | Gen-LAG56-Sanitary Class III |
| 43664 | Harvest Fields | LAG560080 | Gen-LAG56-Sanitary Class III |

| AI Number | AI Name | Permit Number | Permit Type |
|---|---|---|---|
| 51919 | Steven's Seafood Inc | LA0125733 | Indiv-Minor Industrial |
| 52035 | Port Marine Vacuum Service Inc | LA0105040 | Indiv-Minor Industrial |
| 74578 | LADOTD - Houma Maintenance Unit | LAG750794 | Gen-LAG75-Exterior Vehicle Wash |
| 80894 | Field Operations Center - T Baker Smith Inc | LAG750610 | Gen-LAG75-Exterior Vehicle Wash |
| 84026 | Mike's Filter & Supply Inc | LAG532758 | Gen-LAG53-Sanitary Class I |
| 84032 | American Recovery LLC - Houma Facility | LAG532759 | Gen-LAG53-Sanitary Class I |
| 84880 | TETRA Applied Tech Inc - Inld Rig | LAG480288 | Gen-LAG48-Light Commercial |
| 86647 | Southern Comfort Waterfront Community | LAG570206 | Gen-LAG57-Sanitary Class IV |
| 87621 | Earl Cato Apartments | LAG531451 | Gen-LAG53-Sanitary Class I |
| 88042 | Marmac LLC McDonough Marine Service Houma Fleet Munson Slip | LA0114839 | Indiv-Minor Industrial |
| 89411 | McDonald's Restaurant | LAG531165 | Gen-LAG53-Sanitary Class I |
| 93630 | Cocodrie Fuel Dock | LAG33A737 | Gen-LAG33-Coastal |
| 98523 | Cocodrie Cove Subdivision | LAG570350 | Gen-LAG57-Sanitary Class IV |
| 100660 | Offshore Specialty Fabricators LLC - South Yard | LA0109991 | Indiv-Minor Industrial |
| 115847 | American Advanced Technologies LLC - Houma Oil Recovery Facility | LA0123072 | Indiv-Minor Industrial |
| 118497 | Hoss Blast Inc | LAG480401 | Gen-LAG48-Light Commercial |
| 128601 | Schmoopy's | LAG531937 | Gen-LAG53-Sanitary Class I |
| 138060 | LASHIP LLC | LAG541787 | Gen-LAG54-Sanitary Class II |
| 148732 | Eagle Drydock & Marine Repairs LLC | LA0122874 | Indiv-Minor Industrial |
| 150915 | Crosby Tugs LLC - Crosby Marine Repair | LA0125814 | Indiv-Minor Industrial |
| 156475 | Preferred Sandblasting LLC | LAG533090 | Gen-LAG53-Sanitary Class I |
| 157385 | Bel-Cro Machine Shop Inc - Bel-Cro Machine Shop | LAG480764 | Gen-LAG48-Light Commercial |
| 158544 | Bourgeois Smoke House | LAG532883 | Gen-LAG53-Sanitary Class I |
| 164317 | Diesel Tech - WWTP | LAG480750 | Gen-LAG48-Light Commercial |
| 165067 | Gulfstream Services Inc - WWTP | LAG480672 | Gen-LAG48-Light Commercial |
| 166339 | Quality Energy Services | LAG533703 | Gen-LAG53-Sanitary Class I |
| 169305 | Apache Louisiana Minerals Inc Well #8 - South Chauvin Field | LAG33A970 | Gen-LAG33-Coastal |
| 171734 | Pup Joint Inc | LAG533539 | Gen-LAG53-Sanitary Class I |
| 177094 | LeCompte Trailer Park LLC | LAG533818 | Gen-LAG53-Sanitary Class I |

| AI Number | AI Name | Permit Number | Permit Type |
|---|---|---|---|
| 180100 | Dolphin Services LLC | LAG534010 | Gen-LAG53-Sanitary Class I |
| 180605 | Frisco Construction Co Inc | LAG480694 | Gen-LAG48-Light Commercial |
| 182812 | Roger Lee Webb - Campground | LAG534221 | Gen-LAG53-Sanitary Class I |

**Table 4. Sampling Locations**

| Station | Latitude/Longitude | Agency | Date Collected |
|---|---|---|---|
| HNC02-1 | 29°32’18.1”/90°42’18.2” | CEMVN | Nov 2002 |
| HNC02-2 | 29°28’59.8”/90°42’50.6” | CEMVN | Nov 2002 |
| HNC02-3 | 29°25’52.3”/90°43’20.9” | CEMVN | Nov 2002 |
| HNC02-4 | 29°23’31.3”/90°43’53.3” | CEMVN | Nov 2002 |
| MG02F1WS | 29°20’13.07”/90°44’47.5” | CEMVN | Sep 2002 |
| MG02G1WS | 29°19’26.5”/90°42’13.5” | CEMVN | Sep 2002 |
| MG02H1WS | 29°17’57.3”/90°40’17.8” | CEMVN | Sep 2002 |
| MG02H2WS | 29°17’38.3”/90°38’54.2” | CEMVN | Sep 2002 |
| HNC-Lock | 29°19’54.5”/90°43’51.5” | CEMVN | Aug 1999 |
| HNC-1 | 29°04’28.14”/90°34’44.4” | CEMVN | Nov 1994 |
| HNC-2 | 29°04’.066”/90°34’42.72” | CEMVN | Nov 1994 |
| HNC-3 | 29°03’36.18”/90°34’34.26” | CEMVN | Nov 1994 |
| HNC-4 | 29°03’12.84”/90°34’24.42” | CEMVN | Nov 1994 |
| HNC-5 | 29°02’38.88”/90°34’21.12” | CEMVN | Nov 1994 |
| HNC-6 | 29°02’19.5”/90°34’17.34” | CEMVN | Nov 1994 |
| DEQ 343 | 29°34’5.652”/90°42’56.03” | DEQ | 1998 |
| DEQ 344 | 29°23’4.952”/90°43’47.18” | DEQ | 1998-2000 (Monthly) |
| DEQ 942 | 29°32’45.77”/90°42’15.34” | DEQ | 2000 (Monthly) |
| DEQ 952 | 29°15’.815”/90°40’54.311” | DEQ | 2000 (Monthly) |
| DEQ 956 | 29°11’17.84”/90°39’59.30” | DEQ | 2000 (Monthly) |
| DEQ 958 | 29°11’20.84”/90°35’52.33” | DEQ | 2000-2004 (Monthly) |
| DEQ 961 | 29°5’45.837”/90°40’8.324” | DEQ | 2000 (Monthly) |
| DEQ 962 | 29°3’30.854”/90°38’.3228” | DEQ | 2000 (Monthly) |

the reporting limit -- or detection sensitivity -- for the CEMVN tests and the target detection sensitivity associated with DEQ standards. Standard field parameters are listed in Table 6 for HNC02-1, 2, 3 and 4. For subsegments LA120509, LA120508, and LA120705, reference sediment for the Bayou Segnette project was used in the analysis. For LA120802, reference sediment collected by the contractor of the 1994 operation and maintenance study (samples HNC-1 through HNC-6 and HNC-Lock) was used in the analysis.

**Table 5. Parameters Exceeding Louisiana Water Quality Criteria and NOAA3 Sediment Benchmarks**

| Water Quality Subsegment | Station | Sample Type | Parameters | Criteria/Standard | Results, ppb[4] |
|---|---|---|---|---|---|
| 120509 | HNC02-1 | Water (Fresh) | Lead | Fresh – Chronic (1.24) | 1.53 |
| | | Elutriate | Arsenic | Drinking Water Supply (10) | 61.7 |
| | | | Copper | Fresh-Acute & Chronic (10.04 & 7.08) | 30.5 |
| | | | Cadmium | Fresh-Chronic (0.64) | 1.19 |
| | | | Lead | Fresh-Chronic (1.24) | 9.09 |
| | | | Zinc | Fresh-Acute & Chronic (66.3 & 60.54) | 335 |
| | | Sediment | None | | |
| | DEQ 343 | Water (Fresh) | None | | |
| | DEQ 942 | Water (Fresh) | None | | |
| 120508 | [1]HNC02-2 | Water (Marine) | Copper | Marine-Acute & Chronic (3.63 & 3.63) | 1.53 |
| | | Elutriate | Arsenic | Marine-Acute & Chronic (69 & 36) | 104 |
| | | | Zinc | Marine-Acute & Chronic (90 & 81) | 829 |
| | | Sediment | Zinc | TEL & ER-L (124 ppm & 150 ppm) | 154 (ppm)[5] |
| | HNC02-3 | Water (Marine) | Copper | Marine-Acute & Chronic (3.63 & 3.63) | 6.53 |
| | | Elutriate | Arsenic | Marine-Acute & Chronic (69 & 36) | 81.9 |
| | | | Copper | Marine-Acute & Chronic (3.63 & 3.63) | 48.3 |
| | | | Lead | Marine-Chronic (8.08) | 11.2 |
| | | | Nickel | Marine-Acute & Chronic (74 & 8.2) | 81.6 |
| | | | Zinc | Marine-Acute & Chronic (90 & 81) | 259 |
| | | Sediment | None | | |

| Water Quality Subsegment | Station | Sample Type | Parameters | Criteria/Standard | Results, ppb[4] |
|---|---|---|---|---|---|
| | HNC02-4 | Water (Marine) | Copper | Marine-Acute & Chronic (3.63 & 3.63) | 6.53 |
| | | Elutriate | Copper | Marine-Acute & Chronic (3.63 & 3.63) | 7.26 |
| | | Sediment | None | | |
| | DEQ 344 | Water (Marine) | Fecal Coliform | Water body subsegment criteria - oyster propagation (median – 14 MPN[6], 10% -43 MPN[7])[7] | 2400 (MPN)[6] |
| 120705 | HNCLock | Water (Marine) | Copper | Marine-Acute & Chronic (3.63 & 3.63) | 4.0 |
| | | | Cyanide | Marine-Acute (1.0) | 9.0 |
| | | Elutriate | Copper | Marine-Acute & Chronic (3.63 & 3.63) | 4.0 |
| | | | Cyanide | Marine-Acute | 7.0 |
| | | Sediment | Nickel | TEL (15.9 ppm) | 19.9 (ppm)[5] |
| | DEQ 952 | Water (Marine) | None | | |
| 120802 | NOD Report | Water | None | | |
| | | Elutriate | None | | |
| | | Sediment | None | | |
| | DEQ 958 | Water (Marine) | None | | |
| | DEQ 956 | Water (Marine) | None | | |
| | DEQ 961 | Water (Marine) | None | | |
| | DEQ 962 | Water (Marine) | None | | |
| [2]N/A | MG02F1 | WS Water (Marine) | None | | |
| | | Elutriate | Mercury | Marine-Chronic (.025) | 0.55 |
| | | Sediment | Arsenic | ER-L & TEL (8.2 ppm & 7.24 ppm) | 10 (ppm)[5] |
| | | | Copper | TEL (18.7 ppm) | 22.7 (ppm)[5] |
| | | | Zinc | TEL (124 ppm) | 124 (ppm)[5] |
| | MG02G1 WS | Water (Marine) | Copper | Marine-Acute & Chronic (3.63 & 3.63) | 33.9 |
| | | Elutriate | None | | |
| | | Sediment | Arsenic | ER-L & TEL (8.2 ppm & 7.24 ppm) | 9.24 (ppm)[5] |
| | | | Copper | TEL (18.7 ppm) | 27.5 |

| Water Quality Subsegment | Station | Sample Type | Parameters | Criteria/Standard | Results, ppb[4] |
|---|---|---|---|---|---|
| | | | | | (ppm)[5] |
| | | | Zinc | TEL (124 ppm) | 133 (ppm)[5] |
| | MG02H1 WS | Water (Marine) | None | | |
| | | Elutriate | None | | |
| | | Sediment | None | | |
| | MG02H2 WS | Water (Marine) | None | | |
| | | Elutriate | None | | |
| | | Sediment | None | | |

[1]Ambient water sample collected at HNC02-1 and HNC02-4 used to represent HNC02-2 and HNC02-3, respectively, and also used in standard elutriate analyses. HNC02-2 is located in a different water quality subsegment than HNC02-1, and they are classified differently; i.e., HNC02-1 is fresh and HNC02-2 is estuarine. Therefore, freshwater criteria applied to HNC02-1 and marine criteria applied to HNC02-2 even though same water sample.
[2]The Morganza to the Gulf of New Mexico Project's sampling locations are not located in the Houma Navigation Canal. However, they are located adjacent to the canal along water quality Subsegment 120705 and provide a perspective on the water and sediment quality conditions in the adjacent water bodies and marshes.
[3]NOAA - National Oceanic and Atmospheric Administration.
[4]ppb - parts per billion.
[5]ppm - parts per million.
[6]MPN - most probable number.
[7]The fecal coliform bacteria median MPN shall not exceed 14 colonies/100 mL, and not more than 10 percent of the samples shall exceed an MPN of 43 colonies/100 mL for a five tube decimal dilution test in those portions of the area most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions.

**Table 6. Standard Field Parameters**

| Site | Date | Time | pH | DO (ppm) | Salinity (ppt) | Temp. (°C) | Water Depth (ft) |
|---|---|---|---|---|---|---|---|
| HNC-02-1 Surface | 21 Nov 2002 | 1030 | 5.64 | 6.94 | 0.1 | 16.9 | 15-20 |
| HNC-02-1 ¾ Depth | 21 Nov 2002 | 1030 | 6.05 | 6.84 | 0.1 | 16.7 | 15-20 |
| HNC-02-1 Bottom | 21 Nov 2002 | 1030 | 5.90 | 7.15 | 0.1 | 16.6 | 15-20 |
| HNC-02-2 Surface | 21 Nov 2002 | 1430 | 5.42 | 6.39 | 0.1 | 17.0 | 20 |
| HNC-02-2 ¾ Depth | 21 Nov 2002 | 1430 | 5.76 | 6.47 | 0.1 | 17.4 | 20 |
| HNC-02-2 Bottom | 21 Nov 2002 | 1430 | 6.51 | 6.40 | 0.1 | 17.5 | 20 |
| HNC-02-3 Surface | 21 Nov 2002 | 1230 | 5.89 | 6.05 | 0.1 | 17.5 | 20 |
| HNC-02-3 ¾ Depth | 21 Nov 2002 | 1230 | 6.01 | 6.19 | 0.1 | 17.6 | 20 |
| HNC-02-3 Bottom | 21 Nov 2002 | 1230 | 6.20 | 6.14 | 0.1 | 17.6 | 20 |
| HNC-02-4 Surface | 21 Nov 2002 | 1130 | 6.05 | 6.27 | 0.2 | 17.3 | 15 |
| HNC-02-4 ¾ Depth | 21 Nov 2002 | 1130 | 6.07 | 6.45 | 0.3 | 19.6 | 15 |
| HNC-02-4 Bottom | 21 Nov 2002 | 1130 | 5.81 | 6.42 | 0.3 | 18.1 | 15 |

<u>LA120509:</u> The chemical analyses of elutriates revealed the presence of eleven metals at station HNC02-1. Antimony, arsenic, barium, beryllium, cadmium, total chromium, copper, lead, manganese, nickel, and zinc were detected. Arsenic, copper, cadmium, lead, and zinc were exceeding the applicable DEQ criteria/standard. Lead was already exceeding the DEQ chronic fresh water criterion in the ambient water analysis. However, copper, cadmium, and zinc were not exceeding the fresh water criteria in the ambient water analysis, and arsenic was not exceeding the drinking water supply criterion for human health protection. DEQ does not have WQS for antimony, barium, beryllium, or manganese. As a point of reference, EPA regulates barium to 2 ppm through the National Primary Drinking Water Regulations (NPDWRs), which are legally enforceable standards that apply to public water systems. EPA recommends a manganese standard of 50 ppb through the National Secondary Drinking Water Standards (NSDWRs), which are non-enforceable guidelines regulating contaminants that may cause cosmetic or aesthetic effects in drinking water. The lab analyses resulted in 419 ppb for barium, which does not exceed the NPDWR. The manganese concentration was 2,290 ppb, which exceeds the NSDWR of 50 ppb. Manganese was already exceeding the NSDWR in the ambient water analysis. EPA regulates antimony and beryllium to concentrations of 6 ppb and 4 ppb, respectively, through the NPDWRs. The lab analyses of HNC02-1 resulted in concentrations of

5.62 ppb for antimony, which is below the NPDWR, and 4.36 ppb for beryllium, which exceeds the NPDWR. Beryllium was not exceeding the NPDWR in the ambient water sample.

The chemical analyses of the sediment revealed the presence of 10 metals at station HNC02-1. None of the results were exceeding the sediment quality benchmarks established by NOAA. The detected metals include arsenic, barium, total chromium, copper, lead, manganese, nickel, selenium, thallium, and zinc. The results for most detected compounds show that test sediment concentrations were generally not noticeably different from the reference sediment concentrations, recognizing that the determined concentrations of duplicate sediment samples often differ by a factor of 3 to 5. However, at HNC02-1, zinc, total organic carbon, and ammonia differed by factors greater than or equal to 5.

Table 5 shows which parameters exceeded the applicable state criteria/standard and the lab analysis result.

<u>LA120508:</u> The ambient water sample collected at HNC02-1 was used to represent HNC02-2 and was also used in the standard elutriate chemical analysis for HNC02-2. HNC02-2 is located in a different water quality subsegment than HNC02-1, and they are classified differently, i.e., HNC02-1 is fresh and HNC02-2 is estuarine. Therefore, freshwater criteria were applied to HNC02-1, and marine criteria were applied to HNC02-2 even though the sample was collected in the same place for both.

The chemical analyses of the elutriate revealed the presence of eleven metals at stations HNC02-2, -3 and -4. Antimony, arsenic, barium, beryllium, cadmium, total chromium, copper, lead, manganese, nickel, and zinc were detected. Arsenic and zinc were exceeding the DEQ acute and chronic marine water criteria at HNC02-2. They were not exceeding the criteria for the ambient water analysis of this station. Arsenic, copper, nickel, and zinc were exceeding the acute and chronic marine water criteria, while lead exceeded the chronic criteria, at HNC02-3. Copper was the only parameter exceeding the criteria for the ambient water analysis of this station. Copper was exceeding the acute and chronic marine water criteria at HNC02-4, which also occurred in the ambient water analysis for this station.

The chemical analyses of the sediment revealed the presence of 10 metals at stations HNC02-2, -3, and -4. Arsenic, barium, total chromium, copper, lead, manganese, nickel, selenium, thallium, and zinc were detected at all three stations. None of the results were exceeding the sediment quality benchmarks at stations HNC02-3 or -4. Zinc exceeded the ER-L at station HNC02-2. The results for most detected compounds show that that test sediment concentrations were generally not noticeably different from the reference sediment concentrations, recognizing that the determined concentrations of duplicate sediment samples often differ by a factor of 3 to 5. However, at HNC02-2, -3, and -4, zinc and total organic carbon differed from the reference sediment by factors greater than 5. Ammonia concentrations at HNC02-4 also differed by a factor greater than 5.

Table 5 shows which parameters exceeded the applicable state criteria/standard and the lab analysis result.

120705: The chemical analyses of the elutriate revealed the presence of four metals and cyanide at station HNC-Lock, which represents data collected at the site of a proposed lock for the Houma Navigation Canal. Arsenic, copper, nickel, selenium, and cyanide were detected. Of the detected parameters, copper and cyanide were exceeding the DEQ acute and chronic marine water criteria and the acute marine criterion, respectively, which also occurred in the ambient water sample analysis.

The chemical analyses of the sediment revealed the presence of eleven metals at station HNC-Lock at concentrations lower than sediment quality benchmarks. The detected metals include arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. The results for most detected compounds show that test sediment concentrations were generally not noticeably different from the reference sediment concentrations. However, at HNC-Lock, zinc differed by a factor of 5 to 6. Table 5 shows which parameters exceeded the applicable state criteria/standard and the lab analysis result. Also, listed in Table 4 are four stations that were collected for the Morganza to the Gulf of Mexico Project. These stations are not located in the Houma Navigation Canal, but they are located adjacent to the canal along water quality Subsegment 120705. The data for these stations provide information on the water and sediment quality conditions in the adjacent water bodies and marshes. Refer to Table 5 for the parameters that exceed applicable criteria/standards and the results.

LA120802: The CEMVN collected data in 1994 in this subsegment, specifically near Wine Island Pass for operation and maintenance efforts. Chemical analyses were conducted on water, elutriate, and sediment samples at six stations (HNC-1 through -6) in the HNC, and solid phase bioassays were conducted on sediment from three stations (HNC-2, -4, and -6). The results of all detected compounds show that test sediment concentrations were not noticeably different than reference sediment concentration and no trends were apparent.

Results of the chemical analyses on the samples indicated no cause for concern. Barium was the only detected compound in the water and elutriate samples. Detected compounds in the sediment were not noticeably different from the reference samples and no trends were apparent. No organics were detected in any sediment sample.

Survival of organisms exposed to test sediments in the solid phase bioassays was not significantly different from survival of organisms exposed to the solid phase of the reference control.

The report stated that the results provided reasonable assurance that dredging and discharge of the material from the test sites would not cause unacceptable impacts to the water column or to benthic organisms found in disposal areas in the Gulf of Mexico. It should be noted that the proposed project in the HNC does not propose ocean dumping of dredged material.

## 1.2 Future Without-Project Conditions

Without the proposed actions of the HNC Deepening project, the coastal plain of Louisiana would still be affected by other activities, natural and man – influenced, that would have both beneficial and detrimental effects to water quality conditions. Some of these activities include state and local water quality management programs; national-level programs to address hypoxia in the northern Gulf of Mexico; the continued erosion/subsidence of the coast; oil and gas development; industrial, commercial and residential development; and federal, state and municipal navigation and flood – damage reduction projects. The future quality of Louisiana's coastal waters depends on a responsible, watershed approach to managing these activities.

Water pollution became a national concern in the late 1960s to early 1970s as many water bodies across the nation were in poor condition. Gilbert M. Masters recalls that, *Lake Erie was pronounced dead, the Cuyahoga River was so polluted it caught on fire, and sewage from 50 million people across the country was discharged into our waterways with little or no treatment* (Masters 1991). Passage of the CWA in 1972 and the establishment of state and federal environmental protection agencies resulted in water pollution control regulations across the nation that have helped restore many water bodies to a healthy condition. However, activities still occur that can have unwanted effects on water quality.

Several existing national and state programs will continue to develop or remain in place to ensure protection of Louisiana's public health and natural resources. Water quality conditions would likely improve with the programs in place. The EPA is leading a national task force formed to address hypoxia in the northern Gulf of Mexico. In 2000, the EPA published the Integrated Assessment of Hypoxia in the Northern Gulf of Mexico, which attributes the hypoxia in the northern Gulf of Mexico to the excessive nutrients in the Mississippi - Atchafalaya River Basin. According to the report (and referring to the hypoxic area), . . .*the largest zone of oxygen - depleted coastal waters in the U.S., and the entire western Atlantic Ocean, is found in the northern Gulf of Mexico on the Louisiana/Texas continental shelf. The area affected is about the size of the State of New Jersey* (USEPA 2000).

As discussed earlier, in 1997 the EPA granted NPDES delegation to DEQ. Through this program, DEQ maintains records for point source discharges into waters of the State of Louisiana including the 59 permits mentioned earlier that discharge into the Houma Navigation Canal and the adjacent water bodies.

Another state initiative is addressing nonpoint source pollution. The State of Louisiana has assessed that nonpoint source pollution accounts for approximately 40 - 50 percent of the State's water quality problems (DEQ 1999). DEQ's Nonpoint Source Pollution Program is continuing to implement watershed initiatives to address nonpoint source pollution sources such as agriculture, home sewage treatment, hydromodification, urban runoff, construction activities, and resource extraction.

As mentioned earlier, the state is also working with the EPA to develop TMDLs for the water bodies that were included on the state's 303(d) list.

There are also local level initiatives to address water quality problems. For example, the Barataria-Terrebonne National Estuary Program is a cooperative agreement between the State of Louisiana and the EPA. A coalition of government, private, and commercial interests is active in collecting/publishing information as well as educating the public to protect the Barataria and Terrebonne Basins.

Some activities that may potentially have negative effects on water quality would also continue to occur without the proposed project. One activity that will continue to occur is industrial, commercial and residential development along the coast and in the vicinity of Houma and the HNC. With this activity comes increased point and nonpoint source pollution from sources such as wastewater treatment facilities and urban runoff from new development. Flood-damage reduction projects will continue to be planned, designed and constructed especially in areas highly susceptible to flood damages due to hurricanes and storm events. With these activities, more alterations to the hydrology of the coast will occur potentially leading to areas of degraded water quality. Some projects such as the Morganza to the Gulf Hurricane Protection Project are incorporating resource-sustainable design techniques that may aid in protecting significant resources such as surface waters of the state. Maintenance dredging will also continue to occur in coastal water bodies as well as the HNC. The inland reaches of the canal are dredged approximately every 10 years while the bar channel is dredged approximately every two to three years to maintain the currently authorized depth. Flood-damage reduction projects and maintenance dredging could lead to new development that would result in increased point and nonpoint source pollution.

The most notable activity that will continue to occur is the ongoing erosion/subsidence or land-loss of the coastal areas. This will continue to unearth the expansive oil and gas infrastructure along the coast of Louisiana. This is a precarious situation, especially during storm events and in navigable waterways. Exposed pipelines are vulnerable to navigation vessels striking them, which could lead to discharges into the Gulf of Mexico as well as other coastal, state water bodies. In the event of discharges, extensive ecological damage would probably occur; the owner(s) of the infrastructure would incur expensive fines and clean-up costs; and vessel operators could be seriously injured. There are other forms of infrastructure that could potentially be exposed due to coastal erosion, including wastewater collection systems and other commercial - industry related systems.

## 1.3 Future With-Project Conditions

### 1.3.1 Alternative 1a – 1c: Deepen to Minus 18 Feet With Lock

***Direct and Indirect Effects***

The construction and refurbishment of earthen retention dikes, rock foreshore protection, and rock retention structures associated with the proposed alternative would have direct and indirect surface water runoff impacts to the adjacent water bodies. Specifically, the construction activities would probably introduce storm water pollutants such as suspended sediments. Storm Water Pollution Prevention Plans (SWPPPs) shall be prepared in accordance with good engineering practices emphasizing storm water Best Management Practices (BMPs) and complying with Best Available Technology Economically Achievable (BAT) and Best Conventional Pollutant Control Technology (BCT). The SWPPP shall identify potential sources of pollution, which may reasonably be expected to affect storm water discharges associated with the construction activity. In addition, the SWPPP shall describe and ensure the implementation of practices which are to be used to reduce pollutants in storm water discharges associated with the construction activity and to assure compliance with the terms and conditions of this permit (USACE 1997).

The dredging activity, the effluent from the CDFs (confined disposal facilities), and the placement of dredged material in the marsh creation sites would also potentially have direct and indirect effects on water quality in the adjacent and surrounding water bodies. The resulting effects would be a factor of the concentration of contaminants, if any, in the sediments to be displaced.

Research of resuspension of sediments during dredging activities has been on-going for at least 20 to 30 years. The USACE has been a leading agency in this research, but there is still a lot of uncertainty in this area due to the many varying parameters from site to site including the type of dredge used, dredge operator skills, hydrodynamics and sediment characteristics (Clausner 2003). The bioaccumulation potential of the constituents in the dredged sediments is an area that is receiving a lot of attention, especially when contaminated sediments are involved. In general, dredging of sediments (clean or contaminated) results in destruction of benthic habitat; adverse impacts to aquatic, terrestrial, and avian food webs; and degraded water quality. Research has shown that, *suspension and dispersal of contaminated sediments could have ecological impacts that extend well beyond the time the physical effects caused by mechanical disturbances (e.g., water column turbidity) have returned to baseline conditions, particularly if persistent and bioaccumulative chemicals are involved* (Su *et al.* 2002).

With respect to the sediments within the proposed project limits, metals and cyanide were detected and exceeded water quality criteria in the elutriates. Lead, copper, and cyanide were already exceeding the Water Quality Standard (WQS) in the ambient water analyses at some of the sample sites. Refer to Table 5 for this information. The elutriate results of metals reported in the Existing Conditions section for the four HNC sites, i.e., HNC02-1 through HNC02-4, and the Morganza to the Gulf of Mexico sites, include the presence of dissolved metals in the sample. According to Su *et al*., metals have a, *high affinity for organic particulates; only that fraction that is freely dissolved is available for bioaccumulation into tissue via the water column* (Su *et al*. 2002). Su *et al.* also state that metals do not generally demonstrate significant food-chain bioaccumulation. Neither bioaccumulation nor toxicity data were collected for the northern three water quality subsegments. The effects of resuspension of the sediments would probably increase dissolved concentrations of some metals (see Table 5) above the WQS that were not previously exceeded; therefore, increasing the potential for bioaccumulation. It should be noted that a standard elutriate test, which is a conservative indicator of expected contaminant release at the point of dredging, was performed (Ludwig 1988). Therefore, contaminant concentrations during dredging activities could be lower than those in the lab analyses. As discussed earlier, biological effects data were collected for LA120802, and no cause for concern was identified.

The placement of dredged material into the five upland CDFs, including sites 1, 2, 3, and 5, would result in the discharge of effluent into the HNC, with the exception of Site 1, which will discharge into Short Cut Canal. The quality of the effluent was modeled to ensure compliance with state WQS, since it is regulated as a discharge under Section 404 of the CWA. DEQ requires the evaluation of the mixing zone, which is the portion of the water body where effluent waters are dispersed into receiving waters. Mixing must be accomplished as quickly as possible to ensure that the effluent is mixed in the smallest practicable area (DEQ 2008). The zone of initial dilution (ZID) is restricted to the immediate point of discharge and must not exceed 10 percent of the size of the mixing zone. WQS do not apply in the ZID. Numeric acute aquatic life criteria apply beginning at the edge of the ZID; chronic aquatic life criteria for toxic substances apply beginning at the edge of the mixing zone; and human health criteria are to be met below the point of discharge after complete mixing. Appendix C of the Inland Testing Manual (ITM) provides guidance for evaluating the size of mixing zones for dredged material discharges including CDFs. The size of a mixing zone depends on a number of factors, including the contaminant or dredged material concentrations in the discharges, concentrations in the receiving water, the applicable WQS, discharge density and flow rate, receiving water flow rate and turbulence, and the geometry of the outlet structure and the receiving water boundaries. The Dilution Volume Method for CDF Effluent Discharges was used for the evaluation of the four CDFs of the proposed project. This is a simplified approach that is applicable in both riverine and estuarine conditions where a discrete discharge source such as a weir is utilized. Refer to Appendix C6.0 of the ITM for the equations and variables involved.

Table 7 illustrates the dilution factors used in the mixing calculations. For CDFs 1, 2, 3 and 5, a dilution factor of 12.20 for Copper was calculated from the sample collected at HNC02-1, which represents the sediment to be placed in these CDFs. Refer to tables 8 and 9 in this document for the model assumptions and the model output as well as the calculated mixing zone required by DEQ. This was the highest dilution factor for this sample; therefore, it was used in the mixing zone evaluation per Appendix B of the ITM. Table 2a in Title LAC 33:IX.1115.C from DEQ provides guidance on water body categorization for the determination of the appropriate dilution and mixing zone application. The HNC was classified as a Category 3, tidal channel with flows greater than 100 cfs. Therefore, the ZID should not exceed 1/30th of the flow and the mixing zone should not exceed 1/3rd of the flow where the flow equals 1/3rd of the average or typical flow averaged over one tidal cycle, irrespective of flow direction. With the available flow and velocity data on hand, the mixing zone requirements would be met for all CDFs with appropriately sized weirs. For CDFs 1, 2, 3 and 5, an initial plume width of a minimum of 30 feet would be required to meet applicable WQS. The weirs for each CDF would be designed to meet these minimum requirements. The weirs would be placed to ensure no overlapping of the mixing zones as also required by DEQ.

The placement of dredged material for the beneficial use of marsh creation in sites 7, 11, 11a, 12, 12a, 13, 13b, 14, 14a, 15, 15a, 16, 16a, 17, 19a, 19c, 19d, 20c, 20e, 20f, 21, 23, 24, Marsh Disposal Area West, Isle Derniers Marsh, Isle Derniers Beach, East Timbalier Island A-07-1, A-07-2, A-07-3, and A-07-4 would not result in point source discharges into the HNC. Rather, the dredged material would discharge into the site; and the suspended material would settle out in the receiving area with probable runoff of the supernatant into adjoining water bodies and marsh/wetland areas. The proposed marsh creation sites would be semi-confined or unconfined. The metals bound to the sediments prior to dredging could remain bound, resulting in potential increases in metal concentrations of the sediments downstream of the disposal area. As discussed earlier, bound metals do not generally demonstrate significant

**Table 7. Dilution Factors**

**Testing for Evaluation of Effluent Water Quality**

| | |
|---|---|
| (orange) | exceeds WQS |
| (blue) | exceeds WQS |
| (yellow) | positive dilution factor |

$D = (C_{ee} - C_{wq})/(C_{wq} - C_{ds})$

where:

D = dilution required to meet the water quality standards

$C_{ee}$ = concentration of the dissolved contaminant in the effluent elutriate (μg/L)

$C_{wq}$ = water quality standard (μg/L)

$C_{ds}$ = background concentration of the contaminant at the disposal site (μg/L)

(** Criteria comes from EPA. No state WQS.)

| Site Location | | Parameter | $C_{ee}$ | $C_{wq}$ | $C_{ds}$ | D |
|---|---|---|---|---|---|---|
| HNC02-1 | | Antimony** | 5.62 | 5.6 | 2.9 | 0.007407 |
| | | Arsenic | 61.7 | 10 | 2.35 | 6.75817 |
| | | Cadmium | 1.19 | 0.64 | 0.9 | -2.11538 |
| | | Chromium, Total | 5.79 | 116 | 1.61 | -0.96346 |
| | | Copper | 30.5 | 7.08 | 5.16 | 12.19792 |
| | | Lead | 9.09 | 1.24 | 1.53 | -27.069 |
| | (ND) | Mercury | 0.19 | 0.012 | 0.19 | -1 |
| | | Nickel | 41.5 | 91.14 | 1.06 | -0.55107 |
| | (ND) | Selenium** | 1.9 | 4.61 | 1.99 | -1.03435 |
| | (ND) | Silver** | 0.9 | 3.2 | 0.99 | -1.04072 |
| | (ND) | Thallium** | 0.9 | 0.24 | 0.99 | -0.88 |
| | | Zinc | 335 | 80.54 | 7.34 | 6.169023 |
| | (ND) | Cyanide | 19.9 | 5.4 | 19.9 | -1 |
| HNC02-2 | | Antimony** | 4.58 | 5.6 | 2.9 | -0.38519 |
| | | Arsenic | 104 | 36 | 2.35 | 2.020802 |
| | | Cadmium | 4.76 | 10 | 0.9 | -0.57363 |
| | | Chromium, Total | 16.1 | 103 | 1.61 | -0.85709 |
| | | Copper | 29.5 | 3.63 | 5.16 | -16.9085 |
| | | Lead | 4.49 | 8.08 | 1.53 | -0.54809 |
| | (ND) | Mercury | 0.19 | 0.025 | 0.19 | -1 |
| | | Nickel | 156 | 8.2 | 1.06 | 20.70028 |
| | (ND) | Selenium** | 1.99 | 71 | 1.99 | -1 |
| | (ND) | Silver** | 0.99 | 1.9 | 0.99 | -1 |
| | (ND) | Thallium** | 0.99 | 1.7 | 0.99 | -1 |
| | | Zinc | 829 | 81 | 7.34 | 10.15477 |
| | (ND) | Cyanide | 19.9 | 1 | 19.9 | -1 |
| HNC02-3 | | Antimony** | 5.51 | 5.6 | 2.9 | -0.03333 |

| | | | | | |
|---|---|---|---|---|---|
| | | Arsenic | 81.9 | 36 | 4.18 | 1.442489 |
| | | Cadmium | 1.33 | 10 | 0.99 | -0.96226 |
| | | Chromium, Total | 6.91 | 103 | 1.89 | -0.95134 |
| | | Copper | 49.3 | 3.63 | 6.53 | -15.4034 |
| | | Lead | 11.2 | 8.08 | 4.08 | 0.778119 |
| | (ND) | Mercury | 0.19 | 0.025 | 0.19 | -1 |
| | | Nickel | 81.6 | 8.2 | 3.28 | 14.9187 |
| | (ND) | Selenium** | 1.99 | 71 | 1.99 | -1 |
| | (ND) | Silver** | 0.99 | 1.9 | 0.99 | -1 |
| | (ND) | Thallium** | 0.99 | 1.7 | 0.99 | -1 |
| | | Zinc | 259 | 81 | 19.8 | 2.908497 |
| | (ND) | Cyanide | 19.8 | 1 | 19.8 | -1 |
| *HNC02-4* | | Antimony** | 3.83 | 5.6 | 2.9 | -0.65566 |
| | | Arsenic | 35.7 | 36 | 4.18 | -0.00943 |
| | | Cadmium | 1.33 | 10 | 0.99 | -0.96226 |
| | | Chromium, Total | 6.72 | 103 | 1.89 | -0.96212 |
| | | Copper | 7.26 | 3.63 | 8.53 | -1.25172 |
| | | Lead | 3.58 | 8.08 | 4.08 | -1.1194 |
| | (ND) | Mercury | 0.19 | 0.025 | 0.19 | -1 |
| | | Nickel | 4.18 | 8.2 | 3.28 | -0.82114 |
| | (ND) | Selenium** | 1.99 | 71 | 1.99 | -1 |
| | (ND) | Silver** | 0.99 | 1.9 | 0.99 | -1 |
| | (ND) | Thallium** | 0.99 | 1.7 | 0.99 | -1 |
| | | Zinc | 11.6 | 81 | 19.8 | -1.13399 |
| | (ND) | Cyanide | 19.9 | 1 | 19.9 | -1 |
| *HNC-Lock* | *(ND)* | Antimony** | 2.99 | 5.6 | 2.99 | -1 |
| | | Arsenic | 13 | 36 | 9 | -0.85185 |
| | (ND) | Cadmium | 0.19 | 10 | 0.2 | -1.00102 |
| | (ND) | Chromium, Total | 1.99 | 103 | 1.99 | -1 |
| | | Copper | 4 | 3.63 | 4 | -1 |
| | (ND) | Lead | 0.99 | 8.08 | 1 | -1.00141 |
| | (ND) | Mercury | 0.19 | 0.025 | 0.199 | -0.94828 |
| | | Nickel | 6 | 8.2 | 4 | -0.52381 |
| | | Selenium** | 36 | 71 | 22 | -0.71429 |
| | (ND) | Silver** | 0.99 | 1.9 | 0.99 | -1 |
| | (ND) | Thallium** | 1.99 | 1.7 | 1.99 | -1 |
| | (ND) | Zinc | 9.99 | 81 | 28 | -1.28109 |
| | | Cyanide | 7 | 1 | 9 | -0.75 |

# Table 8. Mixing Zone Calculations for CDFs 1, 2, 3, and 5 Using March 2003 Data

***Assumptions/Given:***

| | | | |
|---|---|---|---|
| Volume of effluent discharge per unit time, $V_p$ | = | 82 | cfs (per Linda M. and Tom D.) |
| Turbulent dissipation parameter, $\lambda$ | = | 0.001 | (per Dave Elmore) |
| Water column depth, d | = | 18 | ft (per Dave Elmore) |
| Water velocity, $V_w$ | = | 1.4 | ft/sec (per Dave E.) |
| Initial width of plume, 2r | = | 30 | ft (per Tom D.) |
| Dilution factor, D | = | 12.197917 | (from Dilution Sheet) |

***Calculations:***

| | | | |
|---|---|---|---|
| Required volume per unit time, $V_s$ | = | 1000.23 | cfs |
| Required width of the mixing zone, L | = | 39.69 | ft |
| Required time to achieve lateral spread, t | = | 187.52 | sec |
| Length of the mixing zone, x | = | 262.53 | ft |
| Surface area of mixing zone, A | = | 9148.24 | $ft^2$ |

***Mixing Zone Application for Aquatic Life (per DEQ):***

| Category | Description | Flow | ZID | MZ |
|---|---|---|---|---|
| | | Fraction of Flow or Radial Distance (feet) | | |
| 3 | Tidal Channel with flows > than 100 cfs | 1854.50 | 61.82 | 618.17 |

| Flows Recorded March 13, 2003 | | |
|---|---|---|
| Time | Discharge (cfs) | Max V (ft/sec) |
| 730 | 6580 | 1.702 |
| 1500 | 4547 | 1.4 |

**Table 9. Mixing Zone Calculations for CDFs 1, 2, 3, and 5 Using June 2003 Data**

*Assumptions/Given:*

| | | | |
|---|---|---|---|
| Volume of effluent discharge per unit time, $V_p$ | = | 82 | cfs (per Linda M. and Tom D.) |
| Turbulent dissipation parameter, $\lambda$ | = | 0.001 | (per Dave Elmore) |
| Water column depth, d | = | 18 | ft (per Dave Elmore) |
| Water velocity, $V_w$ | = | 1.573 | ft/sec (per Dave E.) |
| Initial width of plume, 2r | = | 30 | ft (per Tom D.) |
| Dilution factor, D | = | 12.197917 | (from Dilution Sheet) |

*Calculations:*

| | | | |
|---|---|---|---|
| Required volume per unit time, $V_s$ | = | 1000.23 | cfs |
| Required width of the mixing zone, L | = | 35.33 | ft |
| Required time to achieve lateral spread, t | = | 105.78 | sec |
| Length of the mixing zone, x | = | 166.39 | ft |
| Surface area of mixing zone, A | = | 5434.98 | $ft^2$ |

***Mixing Zone Application for Aquatic Life (per DEQ):***

| | | Fraction of Flow or Radial Distance (feet) | | |
|---|---|---|---|---|
| Category | Description | Flow | ZID | MZ |
| 3 | Tidal Channel with flows > than 100 cfs | 1083.33 | 36.11 | 361.11 |

| Flows Recorded June 13, 2003 | |
|---|---|
| Time | Discharge (cfs) |
| NA | 4000 |
| NA | 2500 |

foodchain bioaccumulation, and the concentrations in the HNC are not relatively high with respect to the reference sites. Therefore, there does not appear to be cause for concern. The dissolved metals concentrations seen in the elutriate analyses potentially could migrate into the adjacent water bodies, causing bioaccumulation in aquatic life within the water column. However, S. C. Edwards *et al.* state that, *Hg and Cu concentrations increased by up to 7-fold after dredging, but declined to background concentrations within 48 h* (Edwards *et al.* 1995). Therefore, the exposure of aquatic life to metals in the water column would probably be limited. It should be noted that copper concentrations exceeded the WQS in the ambient water sample for the Morganza to the Gulf sites in the area adjacent to the HNC (see Table 2). Also, arsenic exceeded the ER-L, and copper and zinc exceeded the TEL in the Morganza to the Gulf sites sediment samples. Therefore, the aquatic life in these areas, which correspond to the marsh creation sites, are already exposed to elevated levels of some metals.

The Louisiana DEQ's TMDL program would be indirectly impacted by the proposed deepening project. Section 303(d) of the CWA requires the state to identify, list, and rank for development of TMDLs for waters that do not meet applicable water quality standards after implementation of technology-based controls. This is a process whereby impaired or threatened water bodies and the pollutant(s) causing the impairment are systematically identified and a scientifically based strategy -- a TMDL -- is established to correct the impairment or eliminate the threat and restore the water body. An important factor in this process is the flow of water passing through the water body in question. It is critical for DEQ to be aware of the proposed changes to the hydro-dynamics. This would aid DEQ in planning and implementation of TMDLs in the Houma Navigation Canal. CEMVN has begun this coordination.

As discussed in the Existing Conditions section, the elutriate sample from sample site HNC02-1 revealed elevated levels of arsenic that exceeded the water quality criteria. Specifically, the results exceeded the DEQ human health protection criteria for a drinking water supply water body; LA120509 has a designation of drinking water supply. The elutriate concentration of 61.7 ppb for arsenic exceeds the current standard of 10 ppb. The Houma Drinking Water Plant's operation could potentially be affected. The plant personnel have been involved and made aware of the proposed project and the predicted concentrations of contaminants. Through coordination with the facility CEMVN would utilize appropriate dredging operations/techniques, such as dredging the northern water quality Subsegment LA120509, during high water flows, to avoid potential contaminant migration toward the drinking water intake causing the plant to potentially fail regulated contaminant levels in the drinking water.

Increased salinity could result in the release of some metals from the sediment when disturbed. However, some research has shown that saline water does not cause significant increase in contaminant release (specifically mercury, copper, manganese, and iron) from sediment to the water column over that observed for freshwater (Edwards *et al.* 1995). As a precautionary measure it is recommended that the HNC be dredged from north to south to reduce salt water intrusion during dredging.

Salinity modeling efforts for the HNC were performed to determine the effects of channel deepening on salinities in the HNC and its tributaries and distributaries. The salinity assessment includes changes in salinity for the following locations: the Gulf Intracoastal Waterway (GIWW) at Houma, the HNC at Dulac and at Bayou Grand Cailliou, Falgout Canal, and Caillou Lake. In general, significant changes in salinity were observed for the with-project alternatives in the GIWW at Houma, the HNC, and Bayou Grand Caillou, primarily because deepening of the HNC allows for the saline, coastal waters to intrude farther up the HNC.

The salinity levels in the semi-confined and unconfined disposal areas are not expected to change significantly due to the proposed dredge disposal. The CDFs could experience slightly elevated salinity levels during the pumping operation; however, when the pumping has ceased and the material dries, salinities would return to pre-pumping conditions in wet areas. It should be noted that the dredging would take place during high water, during which the water near the CDFs would be less saline than during low water when salinity levels are higher.

### *Cumulative Effects*

With the proposed actions of the alternative, the coastal plain of Louisiana, the Terrebonne Basin, and the HNC would still be affected by other activities and programs that would have both beneficial and detrimental effects on water quality conditions. Some of these activities include state and local water quality management programs; national-level programs to address hypoxia in the northern Gulf of Mexico; oil and gas development; industrial, commercial and residential development; state transportation improvement projects (e.g., Proposed Interstate 49), and federal, state and local navigation and flood-damage reduction projects. The HNC Deepening project needs to consider these other activities, initiate an aggressive coordination plan with the stakeholders involved, and ensure all activities including the HNC Deepening project complement each other. This is critical to ensure the protection of Louisiana's coastal waters and the health of the public that utilizes these waters.

Past actions that have affected water quality in the project area are similar to activities that have occurred in many coastal areas across the United States. The HNC was originally constructed in the early 1960s from the City of Houma to the Gulf of Mexico through Terrebonne Bay. The introduction of this canal to the coastal portion of the Terrebonne Basin changed the hydrologic patterns of the area. Salinity intrusion increased, especially during low water seasons and times of drought, and the transport of pollutants from upstream in the watershed was accelerated due to the creation of an avenue which leads directly to the Bay and Gulf of Mexico. Coastal wetlands can act as filters for the waters that flow through these areas. Coastal Louisiana has experienced coastal land loss at extraordinary rates due to natural and human activities such as navigation canals like the HNC. As these wetlands disappear, the natural filtering mechanisms of the coastal waters are lost as well. Coastal Louisiana and the Terrebonne Basin, including Houma, experienced industrial, commercial, and residential growth throughout the twentieth century. This development resulted in point and nonpoint sources of pollution. As discussed earlier, water pollution became a national concern in the late 1960s to early 1970s, as many water bodies across the nation were in poor condition. Passage of the CWA in 1972 and the establishment of state and federal environmental protection agencies resulted in water pollution control regulations across the nation that have helped to restore many water bodies to a healthy condition.

Present actions that cumulatively affect the water quality in the project area include both activities that are beneficial and detrimental to water quality. As discussed in the Future Without-Project Conditions section, national, state, and local programs exist that both regulate water quality as well as educate and promote the protection of water quality. Industrial and commercial facilities, as well as residential development, continue to exist and occur in the project area. Coastal wetlands continue to be lost due to natural and human causes. Also, oil and gas exploration and development continues to occur. The present actions that tend to indirectly affect water quality in a negative sense are subject to the many laws and regulations that have resulted from the environmental movement in the early 1970s. The science also continues to improve in minimizing impacts as much as practicable.

Actions in the foreseeable future include initiatives to continue to improve water quality conditions as well as restore much of the ecology of coastal Louisiana and Terrebonne Parish.

These actions include the marsh creation sites of the proposed project for the Houma Navigation Canal Deepening. A total of approximately 7,200 acres of marsh creation are proposed that, once established, would act as natural filters for coastal waters of Terrebonne Basin. Also, the Louisiana Coastal Area (LCA) Ecosystem Restoration study proposes an aggressive array of projects along the Louisiana coast that would ideally maintain the current coastal wetlands and potentially increase the acreages of wetlands through various means. Other present actions would continue to occur in the foreseeable future, including industrial, commercial, and residential development; oil and gas development and exploration; navigation and flood control projects, especially those that provide hurricane protection; transportation improvements projects such as the proposed Interstate 49; etc. The LCA study team has taken the initiative to coordinate with the many stakeholders involved in these other activities that would cumulatively affect coastal Louisiana in turn affecting coastal water quality including the waters in the proposed project area. With proper collaboration, these activities could be planned and constructed so that impacts are minimized while areas are allowed to continue to prosper from the many resources available.

## 1.4 Alternative 2a – 2c: Deepen to Minus 20 Feet With Lock

The effects would the essentially the same as Alternative 1.

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# Annex III

# Tow Simulation Waiver

U.S. Army Corps of Engineers
New Orleans District

# HNC Deepening Feasibility Study
# Tow Simulation Waiver




DEPARTMENT OF THE ARMY
ENGINEER RESEARCH AND DEVELOPMENT CENTER, CORPS OF ENGINEERS
COASTAL AND HYDRAULICS LABORATORY
WATERWAYS EXPERIMENT STATION, 3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

CEERD-HN-ND

24 OCT 2007

MEMORANDUM FOR Commander, US Army Engineer District, New Orleans (CEMVN-PM-R/Mr. Crorey Lawton), PO Box 60267, New Orleans, LA 70160-0267

SUBJECT: Ship Simulation Navigation Study Waiver Recommendation, Port of Iberia, New Iberia, LA

1. Reference request from the U.S. Army Corps of Engineer District, New Orleans (MVN) for the U.S. Army Engineer Research and Development Center (ERDC) to conduct a desktop study evaluating a waiver recommendation for the Houma Navigation Canal Deepening Study, Terrebonne Parish, Louisiana, Figure 1. The waiver request is in reference to the requirement for a ship/tow navigation simulation study as described in ER 1110-2-1403, "Studies by Coastal, Hydraulic and Hydrologic Facilities and Others."

2. The Houma Navigation Canal (HNC) is a north-south oriented 36.6-mile navigation channel from the intersection of the Gulf Intracoastal Waterway (GIWW) at Houma, LA to the Gulf of Mexico. The channel was originally constructed with an usable dimension of 150 ft x 15 ft from the GIWW to the beginning of the HNC and 300 ft x 18 ft from the beginning of the HNC to its end at the 18-ft contour in the Gulf of Mexico. The MVN is currently evaluating deepening this channel to a 20-foot depth.

3. Mr. Gary Lynch, ERDC, attended a meeting in Houma, LA in August 2007 to discuss the proposed project and tour the project area. The following district and private industry representatives were in attendance. Each of these individuals is very familiar with the waterway.

Mr. Brian Gannon, FTL Engineering Group, MVN
Mr. Rodney Greenup, Supervisory Project Manager, MVN
Mr. Crorey Lawton, Project Manager, MVN
Mr. Richard Entwhisle, Operations Manager, MVN
Mr. Roy Francis, POC for Gulf Island Fabrication
Mr. Phillip Chauvin, Boat Operator, T. Baker Smith Incorporated

4. The following facts were agreed upon during the August 2007 meeting by those in attendance:

a. Currents in the canal are minimal except for cross-currents at the intersection of HNC and Bayou Grand Caillou (BGC), which can have a magnitude of approximately 2 feet/sec.

b. Barge width is limited by the 180-ft wide Dulac Pontoon Bridge.

c. The design barge (Intermac 650 barge), Figure 2, is currently being used in the canal at drafts allowed by the existing channel.

d. Barge transport of offshore oil rig equipment is sporadic throughout the year.

5. As stated in paragraph 4.c. above, the design barge is currently being used. The barge has transited the 15-ft deep channel at a draft of 17 ft by taking advantage of over depth dredging. Once the project is completed, industry plans to increase that draft to 20 ft. The Intermac 650 is the largest vessel that can be used for transport on the Houma Navigation Canal due to the width constraint of the Dulac Pontoon Bridge, Figure 3.

6. The 180-ft horizontal clearance of the bridge leaves 5-ft clearance on either side of the barge as it transits through. There are 6 tugs shown maneuvering the barge at the bridge crossing in Figure 3, this is typical for this type of maneuver. The barge is somewhat obscured in the photograph because the offshore oil rig "jacket" that is being transported extends beyond the sides of the barge. The jacket also extends beyond the horizontal clearance of the bridge. However, the barge and load can transit the bridge because the vertical clearance from the water level to the lowest height of the jacket is higher than the top elevation of the bridge structure.

7. Without the influence of wind, the lack of current in the reach at the bridge and the number of tugs being used to control the barge make the transit a geometry problem. Wind forces are overcome by the use of a sufficient number of tugs. Additionally, transits are postponed during adverse weather conditions.

8. There is a study currently underway at the Coastal and Hydraulics Laboratory, ERDC, for a proposed lock/floodgate, Figure 4, in the area of the HNC / BGC intersection.

9. Although the proposed lock is 110-ft wide (too narrow for the design barge of this waiver proposal), the flood gate will be 250-ft wide (70 ft wider than the pontoon bridge) and will be open for a majority of the time. Final design of the lock and floodgate are not complete; however, the width of the floodgate is set at 250 ft. The only variable left in the design of the floodgate is its proximity to the lock.

10. As with any cargo movement of this size and bulk, planning and preparedness are at the forefront of the operation. The unique nature of transporting this equipment requires more extreme safety measures than with normal transport of cargo. If the following considerations are included, ERDC agrees with the waiver request for this operation.

a. Transits of the design barge are scheduled during the times the proposed floodgate will be open.

b. The number of tugs remains at the present level (approximately 5) or increases as is deemed necessary for the increase in volume being transported.

c. Sufficient tugs are made available as dictated by weather and current conditions.

d. Transits cease during extreme winds and currents.

11. This waiver is for the tug escorted transportation of offshore equipment only. It is not intended to apply to normal canal traffic where the barge is not simultaneously controlled by multiple tugs.

12. Questions concerning this memorandum should be directed to Mr. Gary Lynch at (601) 634-4165 or Mr. Dennis Webb at (601) 634-2455.

William D. Martin
for THOMAS W. RICHARDSON
Director


Figure 1. Project Location

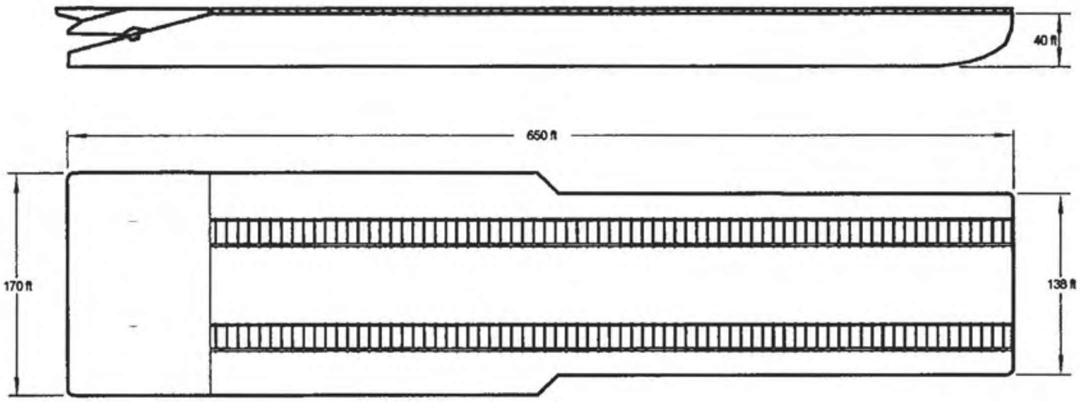



Figure 2. Intermac 650 Barge.

Figure 3. Intermac 650 beginning to go through the Dulac Pontoon Bridge.

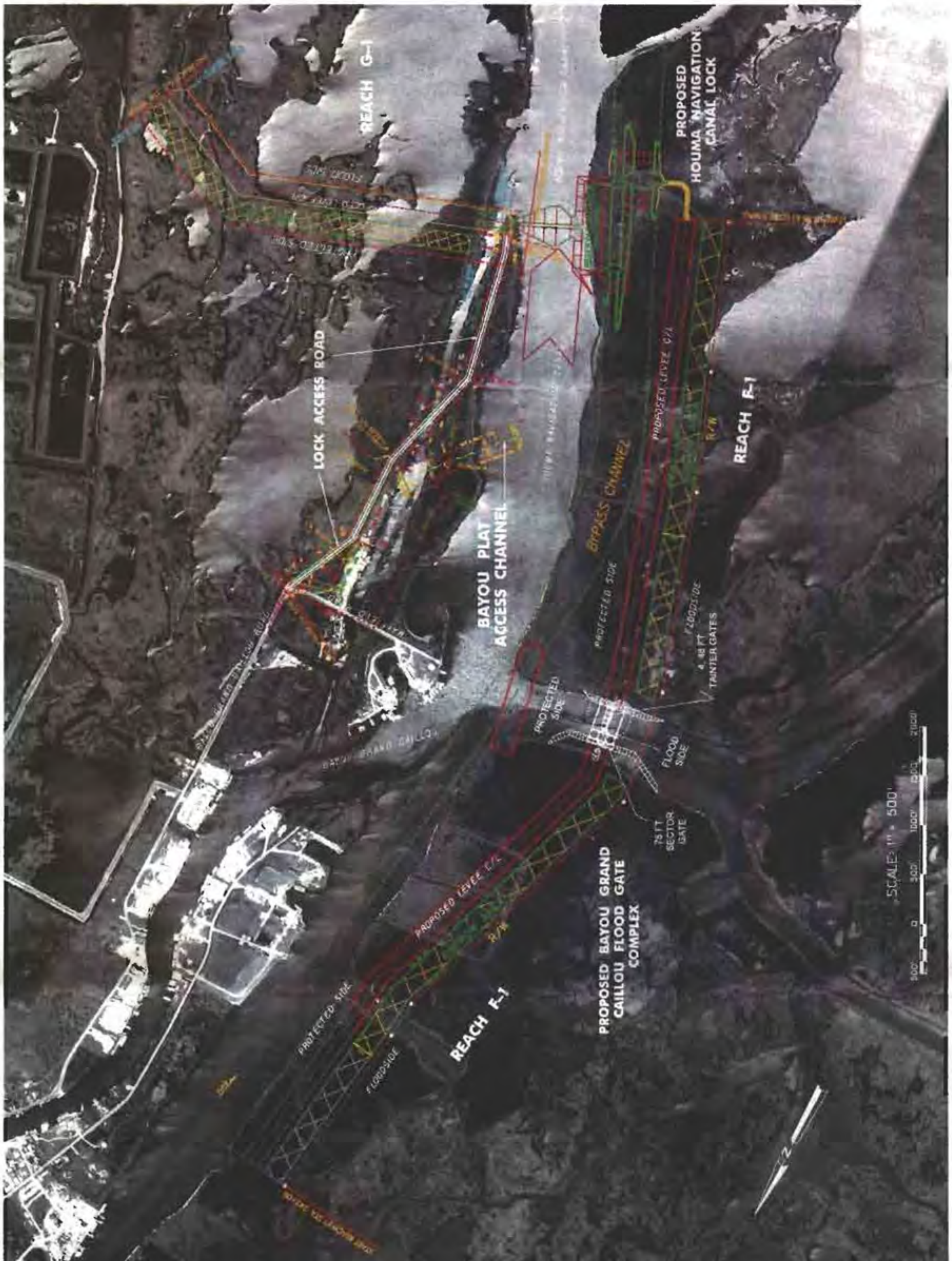


Figure 4. Proposed lock and floodgate.

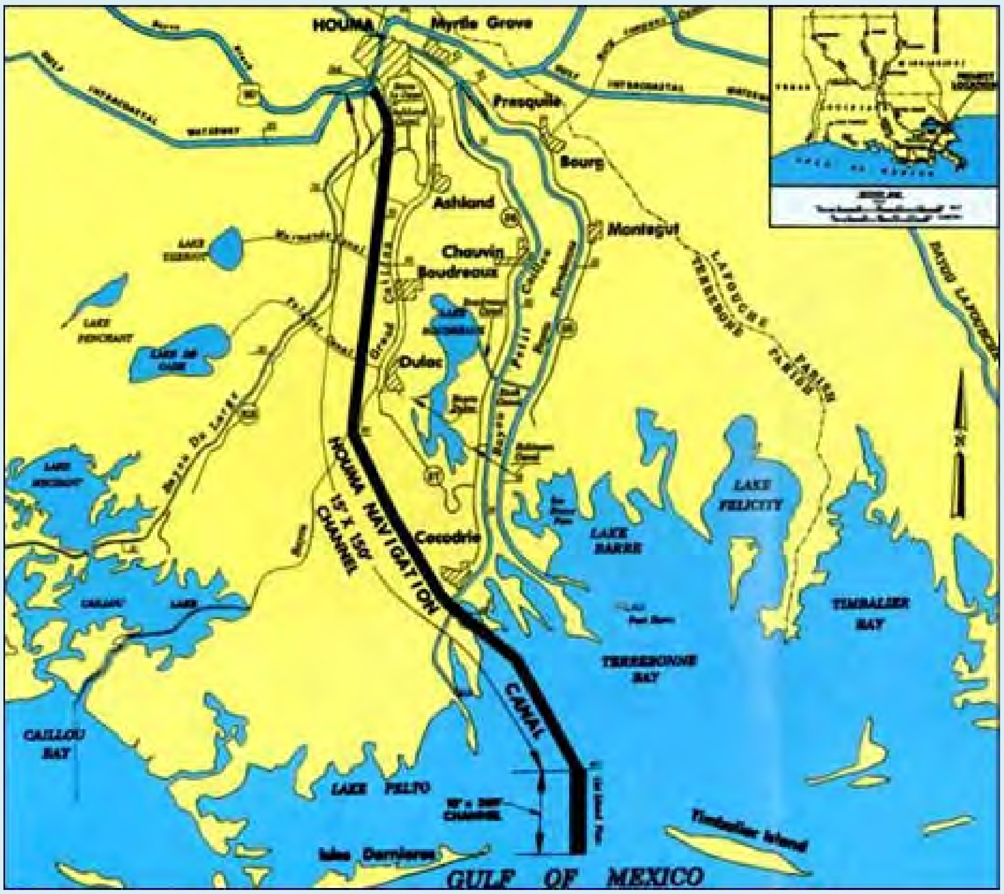
# Annex IV

# Traffic Forecast Study

# Draft Final

# HOUMA NAVIGATION CANAL DEEPENING STUDY

# TRAFFIC FORECAST STUDY




**Prepared by**

**GEC**

**Baton Rouge, Louisiana**

**October 24, 2007**

# Draft Final

# HOUMA NAVIGATION CANAL DEEPENING STUDY

# TRAFFIC FORECAST STUDY

**Contract No. W912P8-07-D-0008**
**Delivery Order No. 0009**
**GEC Project No. 22316909**

**Prepared by**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Telephone – 225/612-3000


October 24, 2007

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

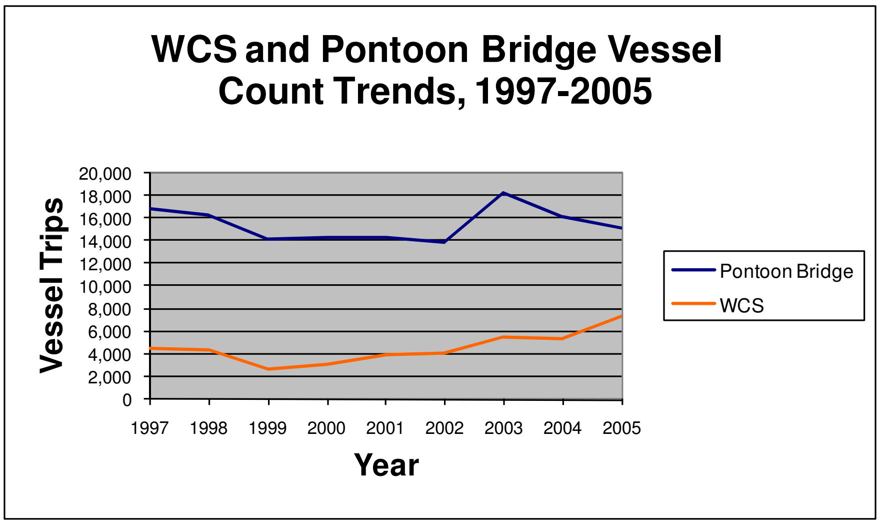
# EXECUTIVE SUMMARY

## EXECUTIVE SUMMARY

A forecast of total HNC vessel traffic for without and with project conditions was prepared to determine the change in traffic and effects on bank erosion. A prior study of deepening identified very small distinct subsets of benefiting vessels most of which did not use the HNC in without project conditions. Consequently, with project vessel projections for the benefiting fleet included only a very small number of vessels compared to total without project non-benefiting vessels.

In order to forecast HNC without project vessel trips, it was necessary to adjust the traditional Corps WCS annual trips and drafts for a large number of vessel trips not reported. Data on HNC vessel transits compiled by the Terrebonne Parish Pontoon Bridge operators indicated that total reported trips for the HNC were between two to three times larger than the WCS statistics for the same period (Figure ES-1). Otherwise, statistically, the annual WCS trips and the Pontoon Bridge trips were quite similar in their trends for the period 1997-2004 (R-square = 0.86).

**Figure ES-1.**




The Bridge data for different categories of vessels were compiled to arrive at annual total vessel transits with allowances for seasonal vessel use, particularly among recreational craft. The Bridge data were then collapsed into the relevant WCS categories by direction and two new categories were added for fishing and recreational vessels. The Bridge data transits were used to adjust the WCS trips upward.

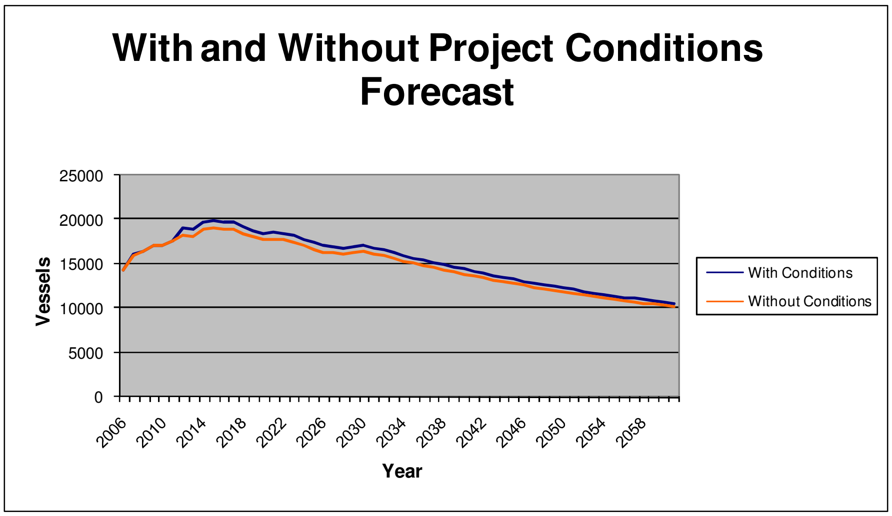
Forecasts for GOM offshore oil/gas production were used to forecast the changes in commercial vessel transits on the HNC that are primarily related to this sector. Separately, forecasts of Louisiana fishing and recreational vessels in Terrebonne Parish were used to forecast the fishing and recreational categories.

The without project condition forecasts were extended from a 2006 baseline to 2061. The with project forecasts reflected a baseline fleet in 2006 of 650 trips, of which 511 represented new trips. Some of the benefiting trips related to changes in requirements for tug assistance for existing movements on the HNC affected by with project conditions. Therefore, the actual new vessel trips for with project conditions is less than benefiting trips.

The pattern of HNC traffic for both without and with project conditions is largely determined by the GOM offshore oil and gas production forecast. This forecast shows production increasing from 2006 to 2015 and then gradually declining to 2030. For purposes of the Corps' 50-year forecast, Energy Information Administration forecasts were extended out from 2030 to 2061.

The general pattern of HNC traffic for the forecast for the major vessel categories for without project conditions is shown in Figure ES-2. For without project conditions the total base year HNC traffic rose from 14,339 vessel trips in 2006 to 18,289 trips in 2012 and peaked at 19,133 trips at 2015. Total annual HNC vessel trips under without project conditions then declined to 16,217 by 2031, 13,681 by 2041, 11,730 by 2051 and 10,247 by 2061. By the end of the forecast traffic (total annual vessel trips) would be nearly 30 percent less than it was at the 2006 baseline.

**Figure ES-2.**




Note: With project conditions assumed to be in effect in 2012.

For with project conditions, the baseline fleet of all benefiting vessels was 650 trips in 2006 that represented a net increase of 511 new trips. The number of benefiting trips and new trips under with project conditions increased to 916/719 at 2012 (start of with project conditions) and peaked at 976/766 at 2015. The annual benefiting and new trips declined as follows: 809/636 by 2031; 641/503 by 2041; 508/400 by 2051; and 403/316 by 2061. The HNC forecast of total vessels for with project conditions is quite similar to without project conditions because of the very small number of benefiting new trips affected by with project conditions as shown in Figure ES-2.

As a result of new trips under with project conditions, total HNC traffic is projected to be 19,009 in 2012 (start of with project conditions). The total annual number of vessel trips peaks at 19,900 in 2015 and then declines to 16,853 in 2031, 14,185 in 2041, 12,129 in 2061 and 10,563 in 2051. The increase in total traffic between without and with project conditions is quite small. For example, total annual vessel transits under with project conditions increases 720 vessels in 2012 (rounded) or 3.9 percent. Total vessel transits increase 316 vessels in 2061 or 3.1 percent.

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# HOUMA NAVIGATION CANAL DEEPENING STUDY

## INTRODUCTION

The purpose of this report is to present a marine traffic base and forecast in support of the wake and wave bank erosion study that is being performed as part of the Houma Navigation Canal Deepening Study. The Waterborne Commerce Statistics Center (WCSC) is typically the source of historical data on which to base a forecast. However, the WCSC data are not designed to capture all vessel movements. This is particularly important under circumstances such as those encountered on the Houma Navigation Canal (HNC) where much of the vessel traffic is not constituted by commercial vessels engaged in trade between ports.

The first objective of the study was to identify a without-project vessel fleet that was representative of the universe of all vessels actually transiting the HNC. Logs of vessel movements on the HNC below Houma are kept by the tenders of the Terrebonne Parish Pontoon Bridge at Dulac. The logs are recorded manually by bridge tenders 24 hours a day 365 days a year and therefore provide a complete account of all vessel movements on the HNC below Houma upbound from and downbound to the Gulf of Mexico (GOM).

The logs were analyzed for the period of record to develop a profile of the entire without-project fleet and were used to adjust the WCSC data tables from the economic analysis for the deepening study. Oil & gas production forecasts, platform forecasts, private boat registration trends, and commercial fishing vessel trip trends were used to develop without and with project conditions forecasts for vessel trips. This information was developed for the sole purpose of estimation of wake and wave damages as a function of the total numbers and sizes of vessels using the HNC under without and with project conditions.

## VESSEL COUNT COMPARISONS

The Waterborne Commerce Statistics (WCS) for the HNC provide information on cargo type, vessel trips, and drafts for commercial vessels engaged in trade between ports. This is actually a subset of the total population of vessels and cargo transiting the HNC. Commercial vessels that sail between the HNC and the GOM for offshore work related to oil and gas drilling, exploration, and platform servicing are not considered cargo trips by the WCS because these vessels do not call at a specific "port" offshore. In addition, there are a large number of private vessels and commercial fishing vessels that regularly use the HNC. Therefore, there is a significant amount of vessel activity that is not covered by the WCS.

A profile of the universe of vessels transiting the HNC below Houma is available from logs by the tenders at the Terrebonne Parish Pontoon Bridge at Dulac. The logs are recorded manually by the bridge tenders 24 hours a day 365 days a year. Paper copies of the tender logs were obtained for 2005 and 2006 plus totals for the period 1997-2004 from the Terrebonne Parish Department of Public Works. Trips by vessel type were compiled from the logs to determine monthly and yearly totals.

The logs contain seven fields in which the tender records information about the vessels transiting the HNC: (1) vessel name; (2) destination; (3) time; (4) identification number; (5) draft; (6) width; and (7) loaded or transporting. Information is almost always recorded for vessel name, destination, and time. In some cases, the type of vessel is given in the place of a name. The destination field represents the direction the vessel was traveling, with north indicating upbound and south indicating downbound. The identification number represents the type of vessel:

1--tug boat in tow
2--tug boat (light boat)
3--offshore supply
4--rig jacket
5--trawl boat
6--oyster boat
7--Lafitte skiff
8--crew boat
9--pleasure boat

Information is often not recorded for draft, width, and loaded or transporting. The width field covers width and length. The loaded or transporting field represents cargo (if any) as indicated by such things as material carried or barge type. An example of the type of information that is contained in the logs is shown in Table 1 using the first 10 entries for June 1, 2006.

**Table 1. Pontoon Bridge Tender Log Example**

| Date | Vessel Name | Destination | Time | Id# (Type) | Draft | Width | Loaded or Transporting |
|---|---|---|---|---|---|---|---|
| 6/1/2006 | Dixie | North | 745 | 1 | 3' | CBC 1266 | Empty Deck Barge |
| 6/1/2006 | Monica Callois | North | 752 | 3 | | | |
| 6/1/2006 | Typhoon Express | North | 800 | 8 | | | |
| 6/1/2006 | Master Bryant | South | 810 | 7 | | | |
| 6/1/2006 | Big Daddy | South | 930 | 9 | | | |
| 6/1/2006 | Crab Boat | South | 955 | C/B | | | |
| 6/1/2006 | P-Boat | North | 1025 | 9 | | | |
| 6/1/2006 | Josie and Jace | South | 1040 | 7 | | | |
| 6/1/2006 | Elkhorn River | North | 1047 | 3 | | | |
| 6/1/2006 | Tatam Ann | North | 1150 | 2 | | | |

Source: Terrebonne Parish Department of Public Works.

The monthly annual data for the Pontoon Bridge for the period 1997-2006 are shown in Table 2. Figure 1 and Table 3 show that the Pontoon Bridge data are generally three to four times greater than the WCS data.

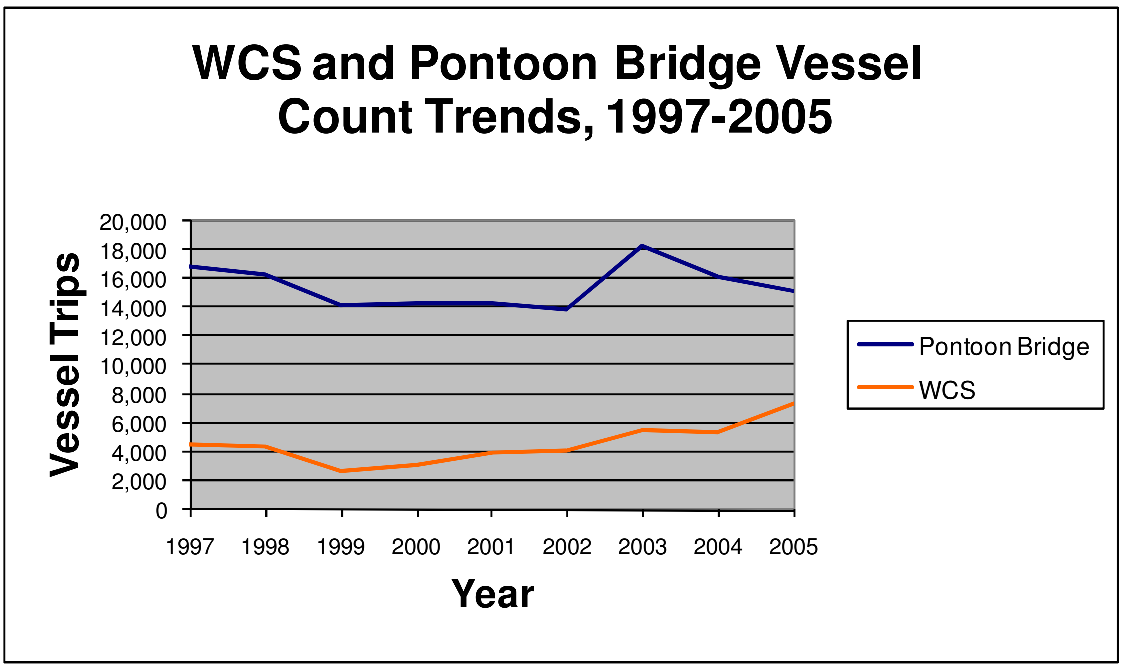
## 2006 COMPARISONS

The WCS data in Table 3 indicate a larger increase from 2004 to 2005 compared to any previous years since 1997. This increase is not reflected in the Pontoon Bridge data which show a decline from 2004 to 2005. In addition, the Pontoon Bridge data are usually three to four

**Table 2. Pontoon Bridge Monthly and Annual Vessel Traffic Counts, 1997-2006**

| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|
| **January** | 1,345 | 991 | 884 | 802 | 938 | 823 | 1,110 | 911 | 967 | 892 |
| **February** | 1,154 | 1,006 | 698 | 795 | 980 | 713 | 896 | 1,057 | 1,009 | 798 |
| **March** | 1,360 | 1,055 | 933 | 926 | 1131 | 766 | 1,156 | 1,190 | 1,178 | 1,073 |
| **April** | 1,254 | 1,037 | 964 | 961 | 1239 | 1,026 | 1,536 | 1,238 | 1,223 | 1,111 |
| **May** | 1,589 | 1,800 | 1,517 | 1,401 | 1,692 | 1,675 | 2,080 | 1,887 | 1,497 | 1,437 |
| **June** | 1,389 | 1,515 | 1,341 | 1,485 | 1,400 | 1,422 | 1,930 | 1,515 | 1,574 | 1,507 |
| **July** | 1,672 | 1,356 | 1,171 | 1,327 | 635 | 1,227 | 1,287 | 1,527 | 1,687 | 1,242 |
| **August** | 1,536 | 1,730 | 1,606 | 1,610 | 1,729 | 1,276 | 2,046 | 1,597 | 1,447 | 1,673 |
| **September** | 1,471 | 2,108 | 1,394 | 1,548 | 1,306 | 1,600 | 1,584 | 1,770 | 1,305 | 1,537 |
| **October** | 1,488 | 1,446 | 1,480 | 1,080 | 1,306 | 1,458 | 1,683 | 1,449 | 1,134 | 1,331 |
| **November** | 1,208 | 1,191 | 1,124 | 1,287 | 1,045 | 1,120 | 1,518 | 927 | 1,143 | 1,181 |
| **December** | 1,368 | 1,005 | 1,011 | 1,055 | 971 | 768 | 1,485 | 1,107 | 999 | 687 |
| **Total** | **16,834** | **16,240** | **14,123** | **14,277** | **14,372** | **13,874** | **18,311** | **16,175** | **15,163** | **14,469** |

Source: Terrebonne Parish Department of Public Works.




Sources: G.E.C. Inc., based on Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

**Figure 1. WCS and Pontoon Bridge Vessel Count Trends, 1997-2005**

**Table 3. WCS and Pontoon Bridge Vessel Traffic Counts, 1997-2005**

| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|
| **Pontoon Bridge** | 16,834 | 16,240 | 14,123 | 14,277 | 14,372 | 13,874 | 18,311 | 16,175 | 15,163 |
| **WCS** | 4,549 | 4,439 | 2,647 | 3,065 | 3,945 | 4,054 | 5,481 | 5,436 | 7,382 |

Sources: WCS and Terrebonne Parish Department of Public Works.

times higher than the WCS data, but only a little over twice as high in 2005. The increase in WCS vessel trips and the decrease in the bridge data might be related to the hurricanes of Katrina and Rita in 2005. With damage to the offshore platforms, vessel traffic associated with the oil and gas industry would have been more prevalent than in normal years in order to bring the wells back online. In addition, normal ports of call for some vessels might have been damaged by the storms, with vessels diverting to protected ports like Houma for service.

The monthly totals for the Pontoon Bridge for 2005 and 2006 are shown in Table 4.

**Table 4. Pontoon Bridge Monthly Totals, 2005 and 2006**

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2005** | 967 | 1,009 | 1,178 | 1,223 | 1,497 | 1,574 | 1,687 | 1,447 | 1,305 | 1,134 | 1,143 | 999 | 15,163 |
| **2006** | 875 | 818 | 1,063 | 1,091 | 1,414 | 1,491 | 1,242 | 1,662 | 1,576 | 1,356 | 1,210 | 697 | 14,495 |

Source: Terrebonne Parish Department of Public Works.

As can be seen from the table, vessel trips in the latter part of 2005 were generally lower than for the same time period in 2006, and the first two months of 2006 were lower than normal. These storms destroyed many fishing vessels and pleasure boats, which constitute a large proportion of the vessel traffic on the HNC.

Table 5 shows counts by vessel type for the Pontoon Bridge for the first half of 2006. These data represent slightly less than half of the total number of vessels that transited the bridge in that year. The distribution of vessel types for these months is shown in Table 6, and a rank ordering is provided in Table 7.

As can be seen from Table 7, tug boats in tow at 39.2 percent constitute the largest category of usage for the first six months of 2006. Pleasure boats at 16 percent constitute the second largest category, but only because of high usage during the warmer months of May and June. Tug boats at 14.7 percent constitute the third largest category, dominating over pleasure boats in January, February, and March and slightly exceeding pleasure boats in April. Crew boats at 9.3 percent, offshore supply vessels at 7.9 percent, and trawl boats at 5.1 percent make fairly significant contributions to the totals, followed by the other category of vessels at 2.9 percent, Lafitte skiffs at 2.6 percent, oyster boats at 1.5 percent, and rig jackets at 0.9 percent.

**Table 5. Pontoon Bridge Vessel Counts by Type, January through June 2006**

| ID # | Type of Boat | January | February | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Tug Boat in Tow | 415 | 387 | 446 | 388 | 441 | 559 | 2,636 |
| 2 | Tug Boat (Light Boat) | 164 | 134 | 161 | 180 | 155 | 194 | 988 |
| 3 | Offshore Supply | 73 | 86 | 97 | 94 | 86 | 96 | 532 |
| 4 | Rig Jacket | 11 | 8 | 9 | 12 | 15 | 6 | 61 |
| 5 | Trawl Boat | 31 | 36 | 31 | 71 | 106 | 66 | 341 |
| 6 | Oyster Boat | 22 | 3 | 26 | 21 | 18 | 8 | 98 |
| 7 | Lafitte Skiff | 11 | 12 | 7 | 28 | 74 | 45 | 177 |
| 8 | Crew Boat | 85 | 94 | 159 | 98 | 84 | 104 | 624 |
| 9 | Pleasure Boat | 49 | 31 | 94 | 175 | 373 | 356 | 1,078 |
| | Other | 14 | 9 | 34 | 18 | 60 | 57 | 192 |
| | **Total** | 875 | 800 | 1,064 | 1,085 | 1,412 | 1,491 | 6,727 |

Source: Terrebonne Parish Department of Public Works.

**Table 6. Pontoon Bridge Vessel Type Distributions, January through June 2006**

| ID # | Type of Boat | January | February | March | April | May | June |
|---|---|---|---|---|---|---|---|
| 1 | Tug Boat in Tow | 47.43% | 48.38% | 41.92% | 35.76% | 31.23% | 37.49% |
| 2 | Tug Boat (Light Boat) | 18.74% | 16.75% | 15.13% | 16.59% | 10.98% | 13.01% |
| 3 | Offshore Supply | 8.34% | 10.75% | 9.12% | 8.66% | 6.09% | 6.44% |
| 4 | Rig Jacket | 1.26% | 1.00% | 0.85% | 1.11% | 1.06% | 0.40% |
| 5 | Trawl Boat | 3.54% | 4.50% | 2.91% | 6.54% | 7.51% | 4.43% |
| 6 | Oyster Boat | 2.51% | 0.38% | 2.44% | 1.94% | 1.27% | 0.54% |
| 7 | Lafitte Skiff | 1.26% | 1.50% | 0.66% | 2.58% | 5.24% | 3.02% |
| 8 | Crew Boat | 9.71% | 11.75% | 14.94% | 9.03% | 5.95% | 6.98% |
| 9 | Pleasure Boat | 5.60% | 3.88% | 8.83% | 16.13% | 26.42% | 23.88% |
| | Other | 1.60% | 1.13% | 3.20% | 1.66% | 4.25% | 3.82% |
| | **Total** | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% |

Source: Terrebonne Parish Department of Public Works.

**Table 7. Vessel Traffic Ranking**

| ID # | Type of Boat | Total | Distribution |
|---|---|---|---|
| 1 | Tug Boat in Tow | 2636 | 39.2% |
| 9 | Pleasure Boat | 1078 | 16.0% |
| 2 | Tug Boat (Light Boat) | 988 | 14.7% |
| 8 | Crew Boat | 624 | 9.3% |
| 3 | Offshore Supply | 532 | 7.9% |
| 5 | Trawl Boat | 341 | 5.1% |
| | Other | 192 | 2.9% |
| 7 | Lafitte Skiff | 177 | 2.6% |
| 6 | Oyster Boat | 98 | 1.5% |
| 4 | Rig Jacket | 61 | 0.9% |
| | **Total** | 6,727 | 100.0% |

Source: Terrebonne Parish Department of Public Works.

## JANUARY AND JUNE 2005 AND 2006 VESSEL TYPE COMPARISONS

Table 8 compares the vessels by type for January and June of 2005 and 2006. As can be seen from the table, January and June 2005 registered a greater number of trips than January and June 2006 (as is the case for the intervening months). However, this is not the case for vessel types. Vessel traffic was higher in 2005 than in 2006 for the months primarily because of the much larger number of upbound tugs in tow. The vessel categories vary between the two years in other categories, but not as sharply.

**Table 8. Pontoon Bridge Vessels by Type, January and June 2005 and 2006**

| Direction of Vessel Type | June 2006 Count | June 2005 Count | January 2006 Count | January 2005 Count |
|---|---|---|---|---|
| Upbound Tug Boat in Tow (1a) | 266 | 341 | 210 | 237 |
| Downbound Tug Boat in Tow (1b) | 293 | 306 | 205 | 234 |
| Upbound Tug Boat (Light Boat) (2a) | 106 | 117 | 82 | 109 |
| Downbound Tug Boat (Light Boat) (2b) | 88 | 127 | 82 | 103 |
| Upbound Offshore Supply (3a) | 47 | 41 | 35 | 50 |
| Downbound Offshore Supply (3b) | 49 | 37 | 38 | 47 |
| Upbound Rig Jacket (4a) | 1 | 14 | 5 | 14 |
| Downbound Rig Jacket (4b) | 5 | 11 | 6 | 13 |
| Upbound Trawl Boat (5a) | 41 | 24 | 16 | 16 |
| Downbound Trawl Boat (5b) | 25 | 33 | 15 | 17 |
| Upbound Oyster Boat (6a) | 3 | 4 | 9 | 3 |
| Downbound Oyster Boat (6b) | 5 | 4 | 13 | 6 |
| Upbound Lafitte Skiff (7a) | 23 | 22 | 5 | 3 |
| Downbound Lafitte Skiff (7b) | 22 | 20 | 6 | 3 |
| Upbound Crew Boat (8a) | 51 | 81 | 45 | 44 |
| Downbound Crew Boat (8b) | 53 | 72 | 40 | 58 |
| Upbound Pleasure Boat (9a) | 174 | 133 | 23 | 9 |
| Downbound Pleasure Boat (9b) | 182 | 149 | 26 | 7 |
| Upbound Other (10a) | 31 | 17 | 7 | 1 |
| Downbound Other (10b) | 26 | 21 | 7 | 4 |
| **Totals** | **1,491** | **1,574** | **875** | **978** |

Source: Terrebonne Parish Department of Public Works.

Table 9 shows the vessel distributions for January and June 2005 and 2006. The distributions are fairly similar for most of the vessel categories. The largest difference is in upbound tug boats in tow, but with only 3.82 percent difference between June 2005 and June 2006. This will be important for consistency in assigning vessel distributions later on in the forecast. The largest percentage of vessels is once again tug boats in tow for both months and years. Pleasure vessels take second place in June 2005 and 2006, but decline dramatically in January because this is not within the peak pleasure boating season. Crew boats are third and supply boats are fourth in both months and years as well. Fishing vessels, other boats, and rig jackets finish with fairly similar distributions.

**Table 9. Pontoon Bridge Vessel Type Distributions by Direction, January and June 2005 and 2006**

| Direction of Vessel Type | June 2006 Distribution | June 2005 Distribution | January 2006 Distribution | January 2005 Distribution |
|---|---|---|---|---|
| Upbound Tug Boat in Tow (1a) | 17.84% | 21.66% | 24.00% | 24.23% |
| Downbound Tug Boat in Tow (1b) | 19.65% | 19.44% | 23.43% | 23.93% |
| Upbound Tug Boat (Light Boat) (2a) | 7.11% | 7.43% | 9.37% | 11.15% |
| Downbound Tug Boat (Light Boat) (2b) | 5.90% | 8.07% | 9.37% | 10.53% |
| Upbound Offshore Supply (3a) | 3.15% | 2.60% | 4.00% | 5.11% |
| Downbound Offshore Supply (3b) | 3.29% | 2.35% | 4.34% | 4.81% |
| Upbound Rig Jacket (4a) | 0.07% | 0.89% | 0.57% | 1.43% |
| Downbound Rig Jacket (4b) | 0.34% | 0.70% | 0.69% | 1.33% |
| Upbound Trawl Boat (5a) | 2.75% | 1.52% | 1.83% | 1.64% |
| Downbound Trawl Boat (5b) | 1.68% | 2.10% | 1.71% | 1.74% |
| Upbound Oyster Boat (6a) | 0.20% | 0.25% | 1.03% | 0.31% |
| Downbound Oyster Boat (6b) | 0.34% | 0.25% | 1.49% | 0.61% |
| Upbound Lafitte Skiff (7a) | 1.54% | 1.40% | 0.57% | 0.31% |
| Downbound Lafitte Skiff (7b) | 1.48% | 1.27% | 0.69% | 0.31% |
| Upbound Crew Boat (8a) | 3.42% | 5.15% | 5.14% | 4.50% |
| Downbound Crew Boat (8b) | 3.55% | 4.57% | 4.57% | 5.93% |
| Upbound Pleasure Boat (9a) | 11.67% | 8.45% | 2.63% | 0.92% |
| Downbound Pleasure Boat (9b) | 12.21% | 9.47% | 2.97% | 0.72% |
| Upbound Other (10a) | 2.08% | 1.08% | 0.80% | 0.10% |
| Downbound Other (10b) | 1.74% | 1.33% | 0.80% | 0.41% |
| **Totals** | 100.00% | 100.00% | 100.00% | 100.00% |

Source: Terrebonne Parish Department of Public Works.

## 2006 VESSEL DISTRIBUTIONS

Vessel distributions were calculated for the entire year of 2006 and then applied to the total vessel counts for 1997-2005. All of the distributions, with the exception of rig jackets, were divided in half to show their direction. In all of the months that the bridge data was electronically entered, the direction of vessels was evenly distributed at around 50 percent in both directions. However, the rig jacket category was divided 60 percent downbound and 40 percent upbound because jackups were added to this category. Rig jackets move downbound because they are manufactured in Houma. Jackups increase the upbound movements in the rig jacket categories, but not enough to make the movements even in both directions. The distributions for 2006 are shown in tables 10 and 11. These distributions were applied to the yearly totals for the period 1997-2005 to provide an estimate of the number of vessel trips by type for the period, as shown in Table 12.

**Table 10. Pontoon Bridge Vessel Type Distributions, 2006**

| ID # | Type of Boat | Distribution |
|---|---|---|
| **1** | Tug Boat in Tow | 41.52% |
| **2** | Tug Boat (Light Boat) | 14.12% |
| **3** | Offshore Supply | 7.53% |
| **4** | Rig Jacket | 0.86% |
| **5** | Trawl Boat | 4.86% |
| **6** | Oyster Boat | 1.26% |
| **7** | Lafitte Skiff | 5.21% |
| **8** | Crew Boat | 10.06% |
| **9** | Pleasure Boat | 12.20% |
| | Other | 2.37% |
| | **Total** | 100.00% |

Source: Terrebonne Parish Department of Public Works.

**Table 11. Pontoon Bridge Vessel Type Distributions by Direction, 2006**

| ID # | Type of Boat | Upbound | Downbound |
|---|---|---|---|
| **1** | Tug Boat in Tow | 20.76% | 20.76% |
| **2** | Tug Boat (Light Boat) | 7.06% | 7.06% |
| **3** | Offshore Supply | 3.77% | 3.77% |
| **4** | Rig Jacket (Upbound 40%) | 0.34% | 0.52% |
| **5** | Trawl Boat | 2.43% | 2.43% |
| **6** | Oyster Boat | 0.63% | 0.63% |
| **7** | Lafitte Skiff | 2.61% | 2.61% |
| **8** | Crew Boat | 5.03% | 5.03% |
| **9** | Pleasure Boat | 6.10% | 6.10% |
| | Other | 1.19% | 1.19% |

Source: Terrebonne Parish Department of Public Works.

**Table 12. Pontoon Bridge Vessel Counts by Type and Direction, 1997 through 2005**

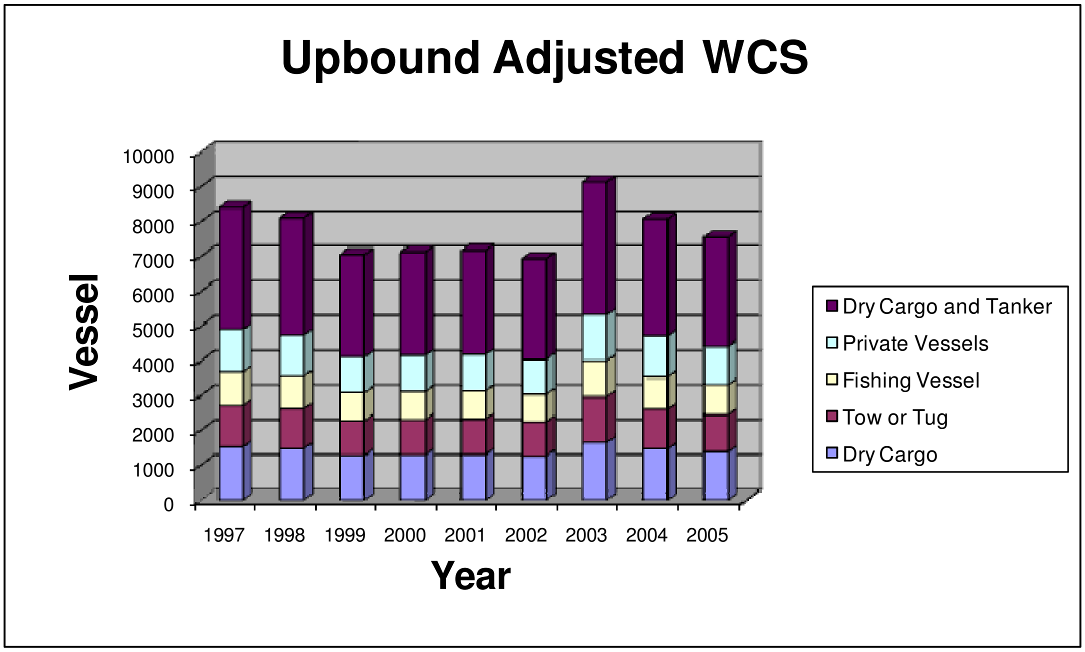
| Direction of Vessel Type | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|
| Upbound Tug Boat in Tow (1a) | 3,495 | 3,371 | 2,932 | 2,964 | 2,984 | 2,880 | 3,801 | 3,358 | 3,148 |
| Downbound Tug Boat in Tow (1b) | 3,495 | 3,371 | 2,932 | 2,964 | 2,984 | 2,880 | 3,801 | 3,358 | 3,148 |
| Upbound Tug Boat (Light Boat) (2a) | 1,188 | 1,147 | 997 | 1,008 | 1,015 | 980 | 1,293 | 1,142 | 1,071 |
| Downbound Tug Boat (Light Boat) (2b) | 1,188 | 1,147 | 997 | 1,008 | 1,015 | 980 | 1,293 | 1,142 | 1,071 |
| Upbound Offshore Supply (3a) | 635 | 612 | 532 | 538 | 542 | 523 | 690 | 610 | 572 |
| Downbound Offshore Supply (3b) | 635 | 612 | 532 | 538 | 542 | 523 | 690 | 610 | 572 |
| Upbound Rig Jacket (4a) 40% | 57 | 55 | 48 | 49 | 49 | 47 | 62 | 55 | 52 |
| Downbound Rig Jacket (4b) 60% | 88 | 84 | 73 | 74 | 75 | 72 | 95 | 84 | 79 |
| Upbound Trawl Boat (5a) | 409 | 395 | 343 | 347 | 349 | 337 | 445 | 393 | 368 |
| Downbound Trawl Boat (5b) | 409 | 395 | 343 | 347 | 349 | 337 | 445 | 393 | 368 |
| Upbound Oyster Boat (6a) | 106 | 102 | 89 | 90 | 91 | 87 | 115 | 102 | 96 |
| Downbound Oyster Boat (6b) | 106 | 102 | 89 | 90 | 91 | 87 | 115 | 102 | 96 |
| Upbound Lafitte Skiff (7a) | 439 | 424 | 369 | 373 | 375 | 362 | 478 | 422 | 396 |
| Downbound Lafitte Skiff (7b) | 439 | 424 | 369 | 373 | 375 | 362 | 478 | 422 | 396 |
| Upbound Crew Boat (8a) | 847 | 817 | 710 | 718 | 723 | 698 | 921 | 814 | 763 |
| Downbound Crew Boat (8b) | 847 | 817 | 710 | 718 | 723 | 698 | 921 | 814 | 763 |
| Upbound Pleasure Boat (9a) | 1,027 | 991 | 862 | 871 | 877 | 846 | 1,117 | 987 | 925 |
| Downbound Pleasure Boat (9b) | 1,027 | 991 | 862 | 871 | 877 | 846 | 1,117 | 987 | 925 |
| Upbound Other (10a) | 200 | 193 | 168 | 170 | 171 | 165 | 218 | 192 | 180 |
| Downbound Other (10b) | 200 | 193 | 168 | 170 | 171 | 165 | 218 | 192 | 180 |

Source: Terrebonne Parish Department of Public Works.

## VESSEL TYPES ADJUSTED INTO WCS

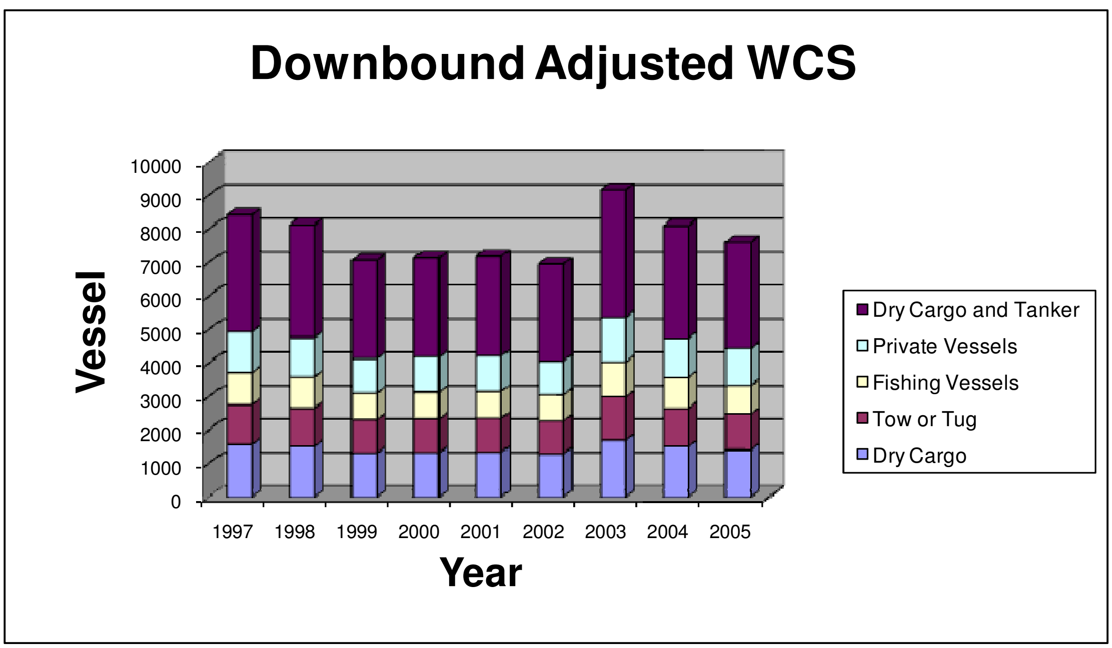
The Pontoon Bridge data were separated into five categories: (1) dry cargo and tanker self propelled; (2) private vessels; (3) fishing vessels; (4) tow or tug; and (5) dry cargo and tanker non-self propelled. The dry cargo and tanker category was combined from both the self and non-self propelled categories in the WCS data because of the lack of cargo type information in the bridge data. Self propelled dry cargo and tanker represents the rig jacket, supply, and crew boat vessels in the bridge data. Non-self propelled dry cargo and tanker represents the tug boat in tow category in the bridge data. In order to match up the WCS and bridge data, two new categories were created to accommodate the private and commercial fishing vessels. Private vessels include pleasure boats and the vessels that had to be included in the other category. The fishing vessel category includes trawl boats, oyster boats, and Lafitte skiffs from the bridge data. Tug or tow represents the tug boat (light boat) category from the bridge data.

Figures 2 through 4 show the distributions of the vessel traffic and mimic the bridge data in Figure 1. Tables 13 through 21 provide the adjusted WCS tables.



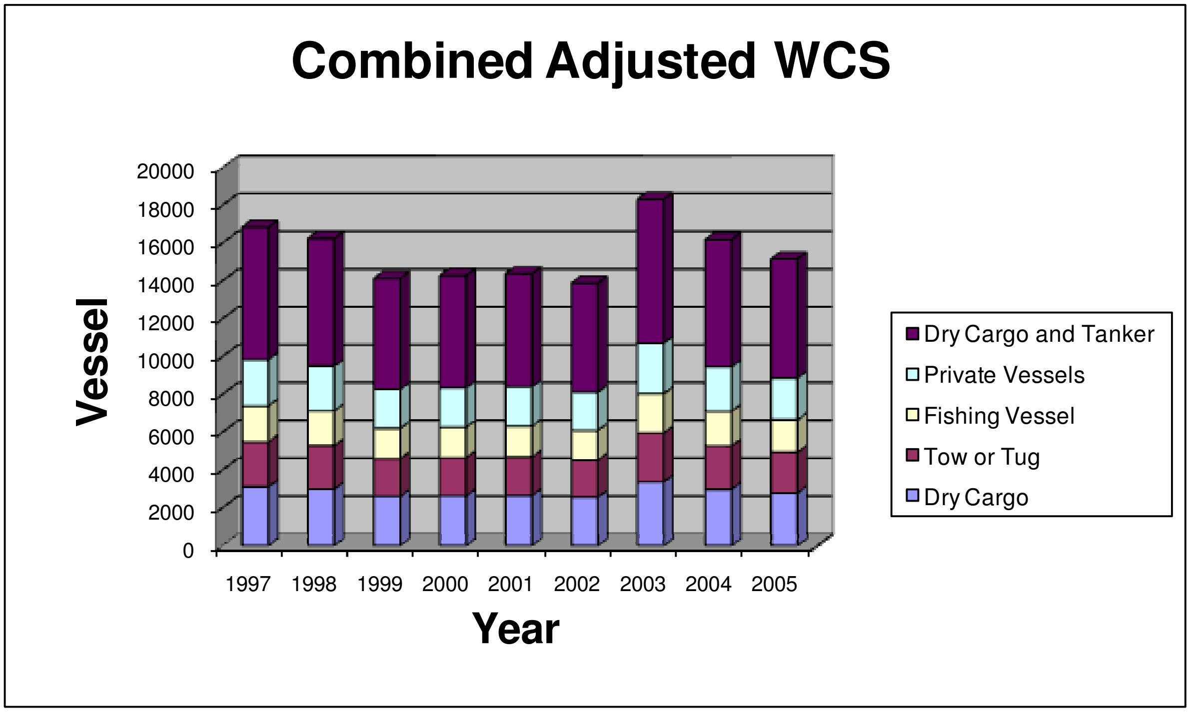

Sources: G. E.C., Inc., based on Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

**Figure 2. Upbound Adjusted WCS**




Sources: G. E.C., Inc., based on Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

**Figure 3. Downbound Adjusted WCS**




Sources: G. E.C., Inc., based on Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

**Figure 4. Combined Adjusted WCS**

## Table 13. 2005 Adjusted WCS

| 2005 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upbound | | | | | | Downbound | | | | | |
| | Self Propelled Vessels | | | | | Non-Self Propelled | Self Propelled Vessels | | | | | Non-Self Propelled |
| Draft | Total | Dry Cargo | Tow or Tug | Fishing | Private | Dry Cargo and Tanker | Total | Dry Cargo | Tow or Tug | Fishing | Private | Dry Cargo and Tanker |
| **Domestic** | | | | | | | | | | | | |
| 15 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 12 | 12 | 0 | 0 | 0 | 0 | 13 | 13 | 0 | 0 | 0 | 0 |
| 13 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 50 | 30 | 0 | 0 | 0 | 19 | 6 | 6 | 0 | 0 | 0 | 0 |
| 10 | 52 | 0 | 15 | 0 | 0 | 37 | 37 | 19 | 14 | 0 | 0 | 4 |
| 9 | 208 | 6 | 63 | 0 | 0 | 139 | 75 | 0 | 61 | 0 | 0 | 15 |
| 8 | 272 | 0 | 60 | 0 | 0 | 212 | 74 | 0 | 53 | 0 | 0 | 21 |
| 7 | 504 | 24 | 192 | 0 | 0 | 288 | 199 | 19 | 170 | 0 | 0 | 10 |
| ≤6 | 6,458 | 1,308 | 740 | 859 | 1,105 | 2,446 | 7,191 | 1,356 | 773 | 859 | 1,105 | 3,098 |
| **Total** | **7,568** | **1,386** | **1,071** | **859** | **1,105** | **3,148** | **7,595** | **1,413** | **1,071** | **859** | **1,105** | 3,148 |

Sources: Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

## Table 14. 2004 Adjusted WCS

| | 2004 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upbound | | | | | | Downbound | | | | | |
| | Self Propelled Vessels | | | | | Non-Self Propelled | Self Propelled Vessels | | | | | Non-Self Propelled |
| **Draft** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** |
| **Domestic** | | | | | | | | | | | | |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 13 | 0 | 0 | 0 | 0 |
| 14 | 3 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 3 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 16 | 12 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 10 | 0 | 0 | 0 | 0 | 10 | 253 | 0 | 69 | 0 | 0 | 183 |
| 10 | 534 | 485 | 25 | 0 | 0 | 24 | 578 | 519 | 16 | 0 | 0 | 43 |
| 9 | 205 | 25 | 89 | 0 | 0 | 90 | 294 | 0 | 76 | 0 | 0 | 218 |
| 8 | 399 | 37 | 163 | 0 | 0 | 198 | 539 | 13 | 135 | 0 | 0 | 391 |
| 7 | 408 | 112 | 157 | 0 | 0 | 139 | 601 | 139 | 125 | 0 | 0 | 336 |
| ≤6 | 6,496 | 808 | 707 | 917 | 1,179 | 2,885 | 5,824 | 823 | 720 | 917 | 1,179 | 2,184 |
| **Total** | **8,075** | **1,478** | **1,142** | **917** | **1,179** | **3,358** | **8,104** | 1,508 | **1,142** | **917** | **1,179** | **3,358** |

Sources: Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

## Table 15. 2003 Adjusted WCS

| | 2003 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upbound | | | | | | Downbound | | | | | |
| | Self Propelled Vessels | | | | | Non-Self Propelled | Self Propelled Vessels | | | | | Non-Self Propelled |
| **Draft** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** |
| **Domestic** | | | | 0 | 0 | | | | | | | |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 |
| 15 | 5 | 5 | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 |
| 14 | 19 | 19 | 0 | 0 | 0 | 0 | 26 | 25 | 1 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 |
| 12 | 22 | 14 | 8 | 0 | 0 | 0 | 57 | 45 | 7 | 0 | 0 | 5 |
| 11 | 19 | 19 | 0 | 0 | 0 | 0 | 20 | 10 | 0 | 0 | 0 | 10 |
| 10 | 198 | 156 | 12 | 0 | 0 | 31 | 318 | 305 | 13 | 0 | 0 | 0 |
| 9 | 419 | 217 | 74 | 0 | 0 | 127 | 147 | 75 | 62 | 0 | 0 | 10 |
| 8 | 257 | 33 | 66 | 0 | 0 | 158 | 75 | 20 | 55 | 0 | 0 | 0 |
| 7 | 273 | 14 | 152 | 0 | 0 | 107 | 174 | 10 | 149 | 0 | 0 | 15 |
| ≤6 | 7,929 | 1,196 | 981 | 1,038 | 1,335 | 3,379 | 8,336 | 1,196 | 1,006 | 1,038 | 1,335 | 3,761 |
| **Total** | **9,141** | **1,674** | **1,293** | **1,038** | **1,335** | **3,801** | **9,174** | **1,707** | **1,293** | **1,038** | **1,335** | **3,801** |

Sources: Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

## Table 16.  2002 Adjusted WCS

| 2002 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Upbound** | | | | | | **Downbound** | | | | | |
| | **Self Propelled Vessels** | | | | | **Non-Self Propelled** | **Self Propelled Vessels** | | | | | **Non-Self Propelled** |
| **Draft** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** |
| **Domestic** | | | | | | | | | | | | |
| 15 | 5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 27 | 21 | 1 | 0 | 0 | 5 | 21 | 21 | 0 | 0 | 0 | 0 |
| 13 | 5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 11 | 11 | 1 | 0 | 0 | 0 | 118 | 52 | 3 | 0 | 0 | 63 |
| 11 | 1 | 0 | 1 | 0 | 0 | 0 | 42 | 10 | 0 | 0 | 0 | 32 |
| 10 | 76 | 74 | 2 | 0 | 0 | 0 | 138 | 41 | 28 | 0 | 0 | 69 |
| 9 | 328 | 63 | 119 | 0 | 0 | 146 | 233 | 52 | 112 | 0 | 0 | 69 |
| 8 | 133 | 63 | 64 | 0 | 0 | 5 | 245 | 41 | 56 | 0 | 0 | 148 |
| 7 | 331 | 53 | 160 | 0 | 0 | 119 | 208 | 21 | 145 | 0 | 0 | 42 |
| ≤6 | 6,007 | 983 | 632 | 787 | 1,011 | 2,594 | 5,946 | 1,055 | 635 | 787 | 1,011 | 2,457 |
| **Total** | **6,926** | **1,268** | **980** | **787** | **1,011** | **2,880** | **6,951** | **1,293** | **980** | **787** | **1,011** | **2,880** |

Sources:  Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

## Table 17.  2001 Adjusted WCS

| | 2001 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upbound | | | | | | Downbound | | | | | |
| | Self Propelled Vessels | | | | | Non-Self Propelled | Self Propelled Vessels | | | | | Non-Self Propelled |
| Draft | Total | Dry Cargo | Tow or Tug | Fishing | Private | Dry Cargo and Tanker | Total | Dry Cargo | Tow or Tug | Fishing | Private | Dry Cargo and Tanker |
| **Domestic** | | | | | | | | | | | | |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 14 | 5 | 5 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| 12 | 17 | 0 | 1 | 0 | 0 | 15 | 1 | 0 | 1 | 0 | 0 | 0 |
| 11 | 49 | 13 | 0 | 0 | 0 | 36 | 51 | 25 | 0 | 0 | 0 | 26 |
| 10 | 337 | 255 | 10 | 0 | 0 | 72 | 259 | 243 | 15 | 0 | 0 | 0 |
| 9 | 300 | 3 | 163 | 0 | 0 | 134 | 234 | 20 | 176 | 0 | 0 | 38 |
| 8 | 483 | 21 | 111 | 0 | 0 | 351 | 138 | 22 | 110 | 0 | 0 | 6 |
| 7 | 415 | 55 | 112 | 0 | 0 | 248 | 194 | 45 | 124 | 0 | 0 | 26 |
| ≤6 | 5,569 | 962 | 618 | 814 | 1,048 | 2,126 | 6,318 | 982 | 587 | 814 | 1,048 | 2,888 |
| **Total** | **7,174** | **1,314** | **1,015** | **814** | **1,048** | **2,984** | **7,200** | **1,339** | **1,015** | **814** | **1,048** | **2,984** |

Sources:  Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

## Table 18. 2000 Adjusted WCS

| 2000 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upbound | | | | | | Downbound | | | | | |
| | Self Propelled Vessels | | | | | Non-Self Propelled | Self Propelled Vessels | | | | | Non-Self Propelled |
| **Draft** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** |
| **Domestic** | | | | | | | | | | | | |
| 15 | 7 | 0 | 0 | 0 | 0 | 7 | 23 | 23 | 0 | 0 | 0 | 0 |
| 14 | 54 | 52 | 3 | 0 | 0 | 0 | 57 | 57 | 0 | 0 | 0 | 0 |
| 13 | 17 | 17 | 0 | 0 | 0 | 0 | 11 | 11 | 0 | 0 | 0 | 0 |
| 12 | 189 | 189 | 0 | 0 | 0 | 0 | 307 | 307 | 0 | 0 | 0 | 0 |
| 11 | 7 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 175 | 0 | 15 | 0 | 0 | 160 | 28 | 11 | 17 | 0 | 0 | 0 |
| 9 | 284 | 9 | 130 | 0 | 0 | 146 | 227 | 11 | 162 | 0 | 0 | 53 |
| 8 | 362 | 34 | 98 | 0 | 0 | 229 | 157 | 45 | 100 | 0 | 0 | 11 |
| 7 | 940 | 215 | 191 | 0 | 0 | 534 | 505 | 262 | 228 | 0 | 0 | 16 |
| ≤6 | 5,092 | 790 | 570 | 810 | 1,041 | 1,881 | 5,839 | 603 | 501 | 810 | 1,041 | 2,885 |
| **Total** | **7,127** | **1,305** | **1,008** | **810** | **1,041** | **2,964** | **7,153** | **1,331** | **1,008** | **810** | **1,041** | **2,964** |

Sources: Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

## Table 19. 1999 Adjusted WCS

| 1999 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upbound | | | | | | | Downbound | | | | | |
| | Self Propelled Vessels | | | | | Non-Self Propelled | Self Propelled Vessels | | | | | Non-Self Propelled |
| Draft | Total | Dry Cargo | Tow or Tug | Fishing | Private | Dry Cargo and Tanker | Total | Dry Cargo | Tow or Tug | Fishing | Private | Dry Cargo and Tanker |
| **Domestic** | | | | | | | | | | | | |
| 14 | 34 | 34 | 0.00 | 0 | 0 | 0 | 23 | 19 | 4 | 0 | 0 | 0 |
| 13 | 123 | 115 | 0.00 | 0 | 0 | 9 | 130 | 130 | 0 | 0 | 0 | 0 |
| 12 | 72 | 30 | 7.07 | 0 | 0 | 35 | 29 | 24 | 5 | 0 | 0 | 0 |
| 11 | 69 | 17 | 0.00 | 0 | 0 | 52 | 18 | 14 | 4 | 0 | 0 | 0 |
| 10 | 208 | 59 | 8.84 | 0 | 0 | 140 | 46 | 14 | 9 | 0 | 0 | 23 |
| 9 | 379 | 25 | 56.57 | 0 | 0 | 297 | 77 | 29 | 14 | 0 | 0 | 34 |
| 8 | 436 | 166 | 139.66 | 0 | 0 | 131 | 244 | 168 | 76 | 0 | 0 | 0 |
| 7 | 647 | 89 | 321.75 | 0 | 0 | 236 | 289 | 82 | 196 | 0 | 0 | 11 |
| ≤6 | 5,082 | 756 | 463.18 | 801 | 1,030 | 2,033 | 6,219 | 836 | 689 | 801 | 1,030 | 2,863 |
| **Total** | **7,050** | **1,291** | **997.08** | **801** | **1,030** | **2,932** | **7,076** | **1,316** | **997** | **801** | **1,030** | **2,932** |

Sources: Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

## Table 20. 1998 Adjusted WCS

| | 1998 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upbound | | | | | | Downbound | | | | | | |
| | Self Propelled Vessels | | | | | Non-Self Propelled | Self Propelled Vessels | | | | | Non-Self Propelled |
| Draft | Total | Dry Cargo | Tow or Tug | Fishing | Private | Dry Cargo and Tanker | Total | Dry Cargo | Tow or Tug | Fishing | Private | Dry Cargo and Tanker |
| **Domestic** | | | | | | | | | | | | |
| 14 | 8 | 8.25 | 0.00 | 0 | 0 | 0 | 8 | 8 | 0 | 0 | 0 | 0 |
| 13 | 25 | 24.74 | 0.00 | 0 | 0 | 0 | 127 | 118 | 0 | 0 | 0 | 9 |
| 12 | 107 | 82.46 | 14.61 | 0 | 0 | 10 | 77 | 67 | 0 | 0 | 0 | 9 |
| 11 | 31 | 0.00 | 0.00 | 0 | 0 | 31 | 9 | 0 | 0 | 0 | 0 | 9 |
| 10 | 168 | 65.97 | 9.13 | 0 | 0 | 93 | 82 | 34 | 11 | 0 | 0 | 38 |
| 9 | 605 | 74.22 | 32.86 | 0 | 0 | 498 | 115 | 0 | 49 | 0 | 0 | 66 |
| 8 | 611 | 24.74 | 202.65 | 0 | 0 | 384 | 320 | 17 | 162 | 0 | 0 | 141 |
| 7 | 1,274 | 593.74 | 213.61 | 0 | 0 | 467 | 1024 | 690 | 194 | 0 | 0 | 141 |
| ≤6 | 5,277 | 610.23 | 673.68 | 921 | 1,184 | 1,888 | 6,373 | 580 | 730 | 921 | 1,184 | 2,958 |
| **Total** | **8,107** | **1,484.34** | **1,146.54** | **921** | **1,184** | **3,371** | **8,136** | **1,514** | **1,147** | **921** | **1,184** | **3,371** |

Sources: Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

## Table 21. 1997 Adjusted WCS

| | 1997 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upbound | | | | | | Downbound | | | | | |
| | Self Propelled Vessels | | | | | Non-Self Propelled | Self Propelled Vessels | | | | | Non-Self Propelled |
| **Draft** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** | **Total** | **Dry Cargo** | **Tow or Tug** | **Fishing** | **Private** | **Dry Cargo and Tanker** |
| **Domestic** | | | | | | | | | | | | |
| 12 | 18 | 4 | 5 | 0 | 0 | 9 | 18 | 8 | 2 | 0 | 0 | 7.39 |
| 11 | 213 | 16 | 1 | 0 | 0 | 196 | 79 | 77 | 1 | 0 | 0 | 0.00 |
| 10 | 211 | 12 | 4 | 0 | 0 | 196 | 33 | 8 | 18 | 0 | 0 | 7.39 |
| 9 | 338 | 0 | 36 | 0 | 0 | 302 | 30 | 4 | 18 | 0 | 0 | 7.39 |
| 8 | 488 | 24 | 99 | 0 | 0 | 365 | 361 | 19 | 290 | 0 | 0 | 51.72 |
| 7 | 416 | 213 | 105 | 0 | 0 | 98 | 808 | 174 | 301 | 0 | 0 | 332.48 |
| ≤6 | 6,720 | 1,269 | 939 | 954 | 1,227 | 2,330 | 7,105 | 1,279 | 556 | 954 | 1,227 | 3,088.37 |
| **Total** | **8,404** | **1,539** | **1,188** | **954** | **1,227** | **3,495** | 8,433 | **1,569** | **1,188** | **954** | **1,227** | **3,494.74** |

Sources: Waterborne Commerce Statistics and Terrebonne Parish Department of Public Works.

## FORECAST OF ADJUSTED WCS VESSEL TRAFFIC BY CATEGORY

### Sources Used for Forecasting Dry Cargo and Tanker and Tow or Tug

The most important data set for forecasting the dry cargo and tanker and tow or tug categories is the Oil and Gas Production Forecast for the GOM prepared by the Energy Information Administration (EIA) in February 2007. These forecasts provide shallow water and deep water projections for the period 2004-2030. These projections were used to forecast the self propelled dry cargo and tanker and tow or tug as well as the non-self propelled dry cargo and tanker. Unfortunately, there is no way to determine how much of this production is supported by industries on the HNC. However, the information provides a good indication of the amount of activity that can be expected to take place in the GOM.

Table 22 shows the shallow and deep water forecast for the period 2004-2030 for the GOM as provided by the EIA in its *Annual Energy Outlook for 2007*. Based on an average annual rate of change from 2004 to 2030, shallow water oil production is expected to decrease by 1.9 percent but deep water oil production is expected to increase by 3.3 percent. Overall, an increase of 2.1 percent is expected.

Table 23 shows the shallow and deep water natural gas production forecast for the GOM derived from the same publication. Based on an average annual rate of change from 2004 to 2030, shallow water gas production is expected to decrease by 2.4 percent, and deep water production is expected to rise by 1.8 percent. The overall effect will be a decrease of 0.1 percent.

To transform this information into vessel trips, it was determined how many vessels would be needed per million barrels of oil and per trillion cubic feet of natural gas to support this level of production. Figures 5 and 6 illustrate the oil and gas forecasts for the period 2004-2030. A trendline was fitted to the overall production level to indicate the expected increase or decrease. The R-square values for the fitted trendlines to the overall production level in the crude oil and gas projections were too low for them to be used effectively for the WCS forecasts. The R-square value is 0.41 for crude oil and 0.1 for natural gas, neither of which would represent the data sufficiently.

Because the EIA forecasts extend only to 2030, additional information was needed to extend the forecast over the life of the project. This was done by using the number of deepwater production platforms that are expected to be put in place, as shown in Table 24 and Figure 7, with the trendline indicating the overall yearly percent change in the data.

The forecast in Figure 7 ends in 2050 rather than at the projects end in 2061. Copying the last 10 years over to extend the forecast out to 2060 is problematic. Using the projections to 2050 proved effective and provided the best fit for the projection once the numbers were plugged back in.

**Table 22. Crude Oil Production Forecast**
**(million barrels per day)**

| Year | Gulf | Shallow < 200 Meters | Deep >200 Meters |
|---|---|---|---|
| 2004 | 1.49 | 0.50 | 0.99 |
| 2005 | 1.31 | 0.47 | 0.84 |
| 2006 | 1.37 | 0.42 | 0.95 |
| 2007 | 1.75 | 0.47 | 1.28 |
| 2008 | 1.86 | 0.36 | 1.50 |
| 2009 | 1.93 | 0.35 | 1.58 |
| 2010 | 1.96 | 0.34 | 1.62 |
| 2011 | 2.07 | 0.33 | 1.74 |
| 2012 | 2.18 | 0.33 | 1.85 |
| 2013 | 2.15 | 0.32 | 1.83 |
| 2014 | 2.24 | 0.31 | 1.93 |
| 2015 | 2.28 | 0.30 | 1.98 |
| 2016 | 2.28 | 0.33 | 1.95 |
| 2017 | 2.28 | 0.33 | 1.95 |
| 2018 | 2.23 | 0.32 | 1.90 |
| 2019 | 2.19 | 0.32 | 1.87 |
| 2020 | 2.17 | 0.32 | 1.85 |
| 2021 | 2.19 | 0.31 | 1.88 |
| 2022 | 2.19 | 0.31 | 1.88 |
| 2023 | 2.19 | 0.31 | 1.89 |
| 2024 | 2.14 | 0.30 | 1.83 |
| 2025 | 2.13 | 0.30 | 1.83 |
| 2026 | 2.10 | 0.30 | 1.80 |
| 2027 | 2.10 | 0.30 | 1.80 |
| 2028 | 2.09 | 0.29 | 1.80 |
| 2029 | 2.12 | 0.29 | 1.82 |
| 2030 | 2.17 | 0.29 | 1.89 |
| Change | 2.1% | -1.9% | 3.3% |

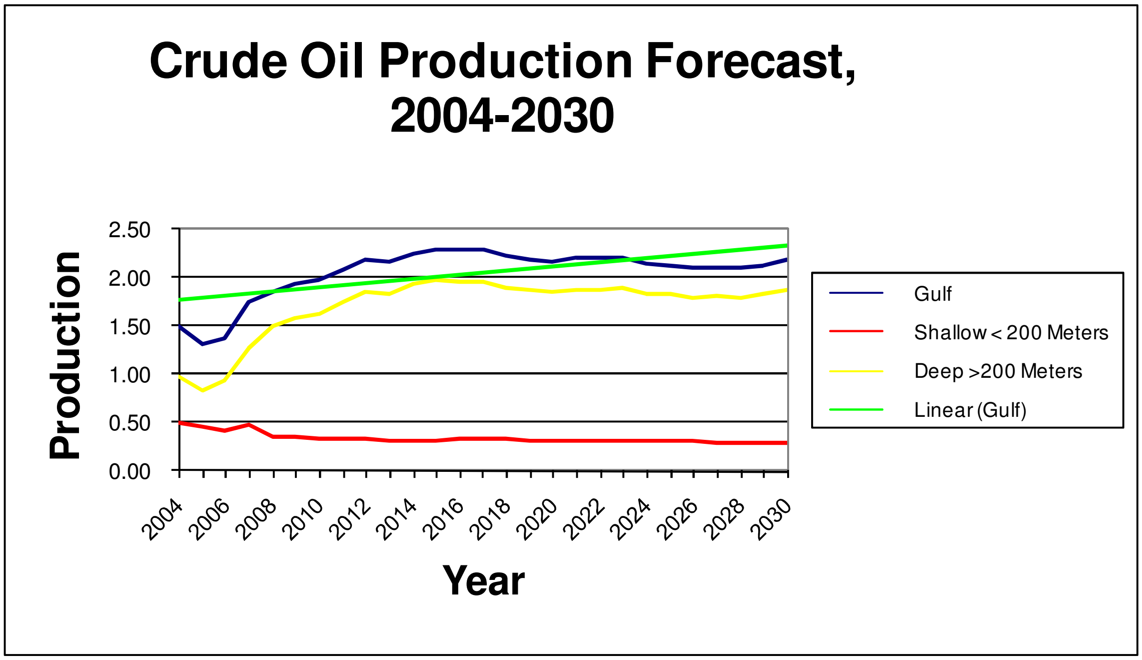
Source: Energy Information Administration, *Annual Energy Outlook for 2007*, Table 103.

**Table 23. Natural Gas Production Forecast**
**(trillion cubic feet)**

| Year | Gulf | Shallow <200 Meters | Deep >200 Meters |
|---|---|---|---|
| 2004 | 4.17 | 2.46 | 1.71 |
| 2005 | 3.35 | 1.98 | 1.37 |
| 2006 | 3.42 | 2.08 | 1.34 |
| 2007 | 3.62 | 1.90 | 1.72 |
| 2008 | 3.68 | 1.74 | 1.93 |
| 2009 | 3.91 | 1.67 | 2.24 |
| 2010 | 3.86 | 1.59 | 2.27 |
| 2011 | 3.99 | 1.53 | 2.46 |
| 2012 | 4.17 | 1.52 | 2.65 |
| 2013 | 4.22 | 1.52 | 2.70 |
| 2014 | 4.50 | 1.51 | 2.99 |
| 2015 | 4.54 | 1.49 | 3.05 |
| 2016 | 4.51 | 1.48 | 3.02 |
| 2017 | 4.52 | 1.47 | 3.04 |
| 2018 | 4.37 | 1.45 | 2.92 |
| 2019 | 4.20 | 1.42 | 2.78 |
| 2020 | 4.07 | 1.39 | 2.68 |
| 2021 | 4.05 | 1.36 | 2.69 |
| 2022 | 4.00 | 1.34 | 2.66 |
| 2023 | 3.89 | 1.31 | 2.58 |
| 2024 | 3.77 | 1.29 | 2.48 |
| 2025 | 3.53 | 1.26 | 2.27 |
| 2026 | 3.39 | 1.24 | 2.14 |
| 2027 | 3.32 | 1.20 | 2.13 |
| 2028 | 3.28 | 1.15 | 2.13 |
| 2029 | 3.28 | 1.13 | 2.16 |
| 2030 | 3.23 | 1.09 | 2.14 |
| Change | -0.1% | -2.4% | 1.8% |

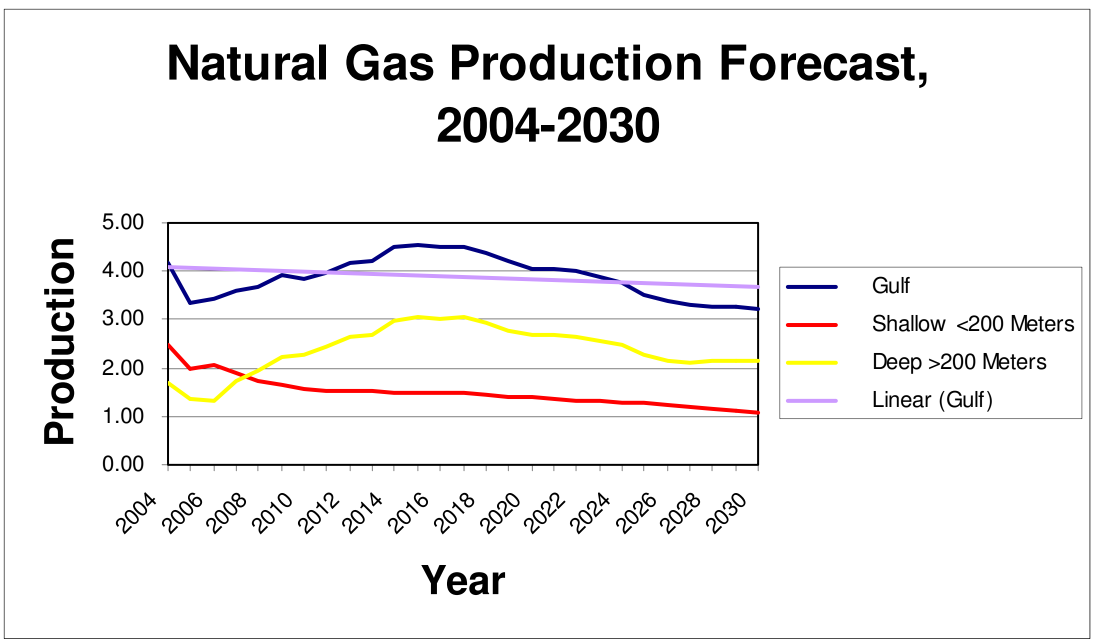
Source: Energy Information Administration, *Annual Energy Outlook for 2007*, Table 104.

.




Source: Energy Information Administration.

**Figure 5. Crude Oil Production Forecast, 2004-2030**




Source: Energy Information Administration.

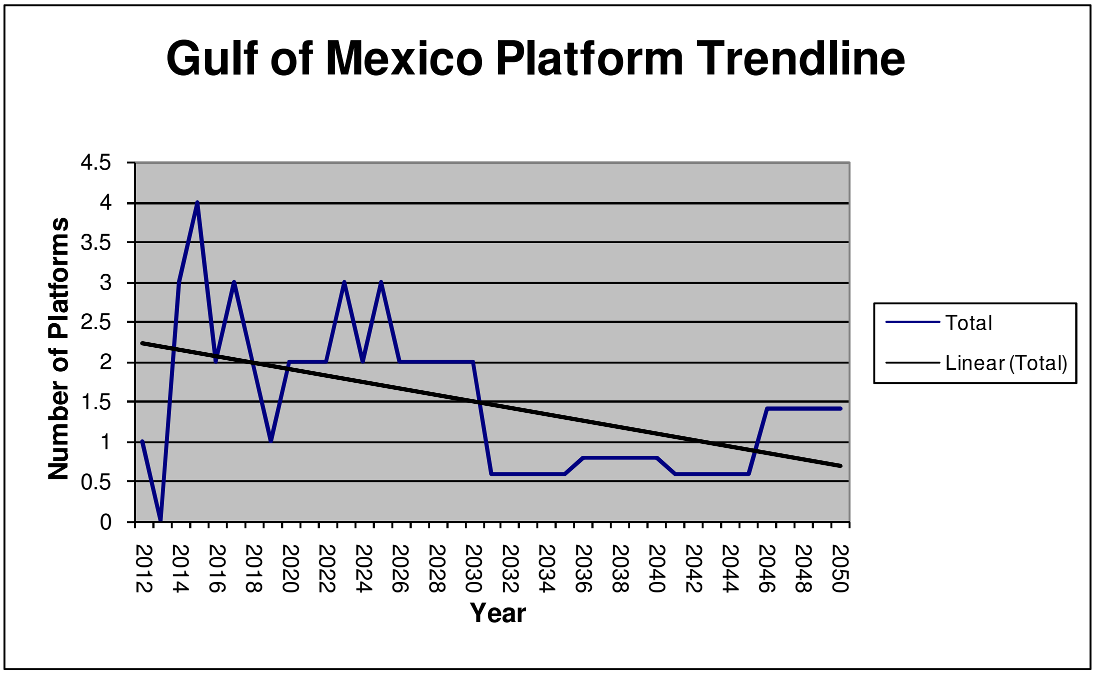
**Figure 6. Natural Gas Production Forecast, 2004-2030**

## Table 24. Gulf of Mexico Production Platform Forecast

| Year | FPS | FPSO | SPAR | TLP | Year | Total |
|---|---|---|---|---|---|---|
| 2012 | 1 | 0 | 0 | 0 | 2012 | 1 |
| 2013 | 0 | 0 | 0 | 0 | 2013 | 0 |
| 2014 | 0 | 0 | 3 | 0 | 2014 | 3 |
| 2015 | 0 | 0 | 3 | 1 | 2015 | 4 |
| 2016 | 0 | 0 | 1 | 1 | 2016 | 2 |
| 2017 | 1 | 0 | 2 | 0 | 2017 | 3 |
| 2018 | 0 | 0 | 2 | 0 | 2018 | 2 |
| 2019 | 0 | 0 | 1 | 0 | 2019 | 1 |
| 2020 | 0 | 1 | 0 | 1 | 2020 | 2 |
| 2021 | 1 | 0 | 1 | 0 | 2021 | 2 |
| 2022 | 0 | 2 | 0 | 0 | 2022 | 2 |
| 2023 | 0 | 0 | 3 | 0 | 2023 | 3 |
| 2024 | 0 | 0 | 0 | 2 | 2024 | 2 |
| 2025 | 0 | 0 | 3 | 0 | 2025 | 3 |
| 2026 | 0 | 0 | 1.4 | 0.6 | 2026 | 2 |
| 2027 | 0 | 0 | 1.4 | 0.6 | 2027 | 2 |
| 2028 | 0 | 0 | 1.4 | 0.6 | 2028 | 2 |
| 2029 | 0 | 0 | 1.4 | 0.6 | 2029 | 2 |
| 2030 | 0 | 0 | 1.4 | 0.6 | 2030 | 2 |
| 2031 | 0.2 | 0 | 0.2 | 0.2 | 2031 | 0.6 |
| 2032 | 0.2 | 0 | 0.2 | 0.2 | 2032 | 0.6 |
| 2033 | 0.2 | 0 | 0.2 | 0.2 | 2033 | 0.6 |
| 2034 | 0.2 | 0 | 0.2 | 0.2 | 2034 | 0.6 |
| 2035 | 0.2 | 0 | 0.2 | 0.2 | 2035 | 0.6 |
| 2036 | 0.2 | 0 | 0.2 | 0.4 | 2036 | 0.8 |
| 2037 | 0.2 | 0 | 0.2 | 0.4 | 2037 | 0.8 |
| 2038 | 0.2 | 0 | 0.2 | 0.4 | 2038 | 0.8 |
| 2039 | 0.2 | 0 | 0.2 | 0.4 | 2039 | 0.8 |
| 2040 | 0.2 | 0 | 0.2 | 0.4 | 2040 | 0.8 |
| 2041 | 0 | 0 | 0.4 | 0.2 | 2041 | 0.6 |
| 2042 | 0 | 0 | 0.4 | 0.2 | 2042 | 0.6 |
| 2043 | 0 | 0 | 0.4 | 0.2 | 2043 | 0.6 |
| 2044 | 0 | 0 | 0.4 | 0.2 | 2044 | 0.6 |
| 2045 | 0 | 0 | 0.4 | 0.2 | 2045 | 0.6 |
| 2046 | 0 | 0.6 | 0.8 | 0 | 2046 | 1.4 |
| 2047 | 0 | 0.6 | 0.8 | 0 | 2047 | 1.4 |
| 2048 | 0 | 0.6 | 0.8 | 0 | 2048 | 1.4 |
| 2049 | 0 | 0.6 | 0.8 | 0 | 2049 | 1.4 |
| 2050 | 0 | 0.6 | 0.8 | 0 | 2050 | 1.4 |
| Total | 5 | 6 | 34 | 12 | | 57 |

Notes: 1 – FPS, FPSO, SPAR, and TLP represent major offshore deepwater floating oil/gas platforms categories.
2 – Fractional platforms reflect disaggregation of five year intervals to annual periods.

Source: G.E.C., Inc.




Source: G.E.C., Inc.

**Figure 7. Gulf of Mexico Platform Trendline**

### Sources Used for Forecasting Private Vessels

The number of boats registered in Terrebonne Parish from 1988 to 2007 was used to forecast pleasure vessels and those that were included in the other category in the bridge logs. The number of boats registered in Terrebonne Parish has been increasing steadily over the past 10 years and is expected to increase in the future. Therefore, the yearly percent increase was used to forecast the private vessel WCS data, as shown in Table 25 and Figure 8. The trendline in Figure 8 has a high R-square value of 0.86, which means it has an excellent linear trend and represents the movement in the data well.

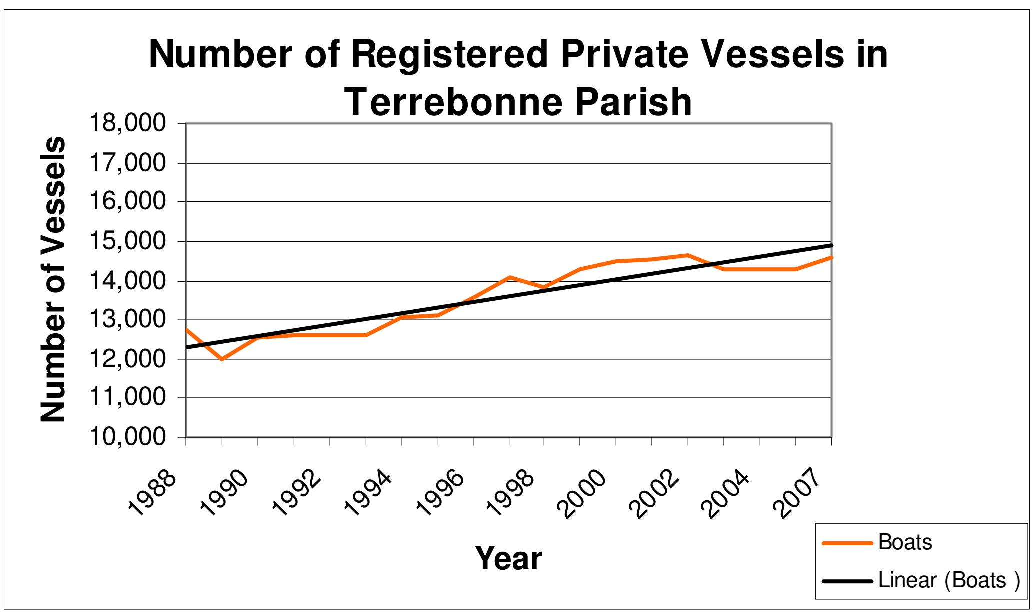
### Sources Used for Forecasting Commercial Fishing Vessels

The Louisiana fishing industry has been severely affected by tropical storms, increasing operating cost, and increasing imports. Yearly trips taken by commercial fishing vessels in Louisiana from 2000 to 2006 are shown in Table 26, with Figure 9 illustrating the downward trend. This trendline has an R-square value of 0.89, which means it has a excellent linear trend and represents the movement in the data well.

**Table 25. Number of Registered Private Vessels in Terrebonne Parish**

| Year | Boats |
|---|---|
| 1988 | 12,736 |
| 1989 | 11,989 |
| 1990 | 12,534 |
| 1991 | 12,593 |
| 1992 | 12,579 |
| 1993 | 12,615 |
| 1994 | 13,064 |
| 1995 | 13,129 |
| 1996 | 13,572 |
| 1997 | 14,057 |
| 1998 | 13,828 |
| 1999 | 14,266 |
| 2000 | 14,480 |
| 2001 | 14,526 |
| 2002 | 14,635 |
| 2003 | 14,272 |
| 2004 | 14,281 |
| 2005 | 14,285 |
| 2007 | 14,602 |

Source: Louisiana Department of Wildlife and Fisheries.



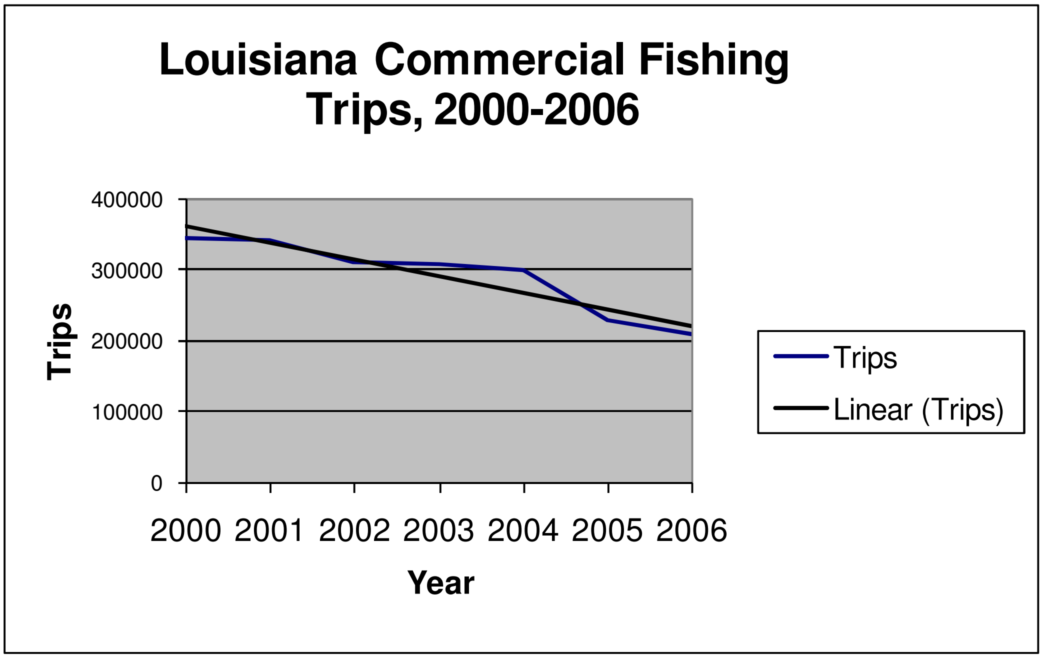

Sources: G.E.C., Inc., and Louisiana Department of Wildlife and Fisheries.

**Figure 8. Boats Registered in Terrebonne Parish**

**Table 26. Louisiana Commercial Fishing Trips, 2000-2006**

| Year | Trips |
|---|---|
| 2000 | 344,875 |
| 2001 | 341,936 |
| 2002 | 310,705 |
| 2003 | 307,079 |
| 2004 | 298,317 |
| 2005 | 228,322 |
| 2006 | 208,049 |

Source: Louisiana Department of Wildlife and Fisheries.




Sources: G.E.C., Inc., and Louisiana Department of Wildlife and Fisheries.

**Figure 9. Louisiana Commercial Fishing Trips, 2000-2006**

**Vessel Calculations**

Because most of the vessel traffic that transits the HNC is involved in the oil and gas industry, it is important to establish a logical path for associating the available sources with the vessels. The oil and gas production forecast was used to develop a vessel forecast for the years 2004 through 2030 by relating the number of vessels needed to accommodate the production levels. For example, the bridge data and oil and gas production data for 2004 through 2006 were compared by dividing the number of total barrels produced by the number of vessels for each year. The average of barrels per vessel was then used to apply to the rest of the years up to 2030. An example of the calculation is shown below for the dry cargo category:

1.49 million barrels of oil in 2004/2,986 dry cargo vessels in 2004 = 499 barrels/vessel.

This was done for 2005 and 2006, and then the number of barrels/vessel was averaged.

(499+507+514)/3=507 barrels/vessels.

This was done for Gas Production the same way.

4.17 trillion ft^3 of gas in 2004/2,986 dry cargo vessels in 2004=1.4 million ft^3/vessel.

This again was done for 2005 and 2006, and ft^3 of gas/vessels was averaged.

(1.4+1.3+1.3)=1.33 ft^3 of gas/vessels.

Finally, this was applied to both the oil and gas forecast to determine the number of vessels supported by each and then plotted on a graph. This was done by taking the forecasted amount of oil and gas and dividing it by production/vessel to determine the number of vessels in that year. An example of this is shown below.

1.49 million barrels of oil/507 barrels/vessels = 2,947 vessel for oil production.

4.17 trillion ft^3 of natural gas/1.33 million ft^3/vessels= 3,135 vessels for gas production.

Once this had been done for all of the years, the two lines were averaged to determine the number of vessels for that year.

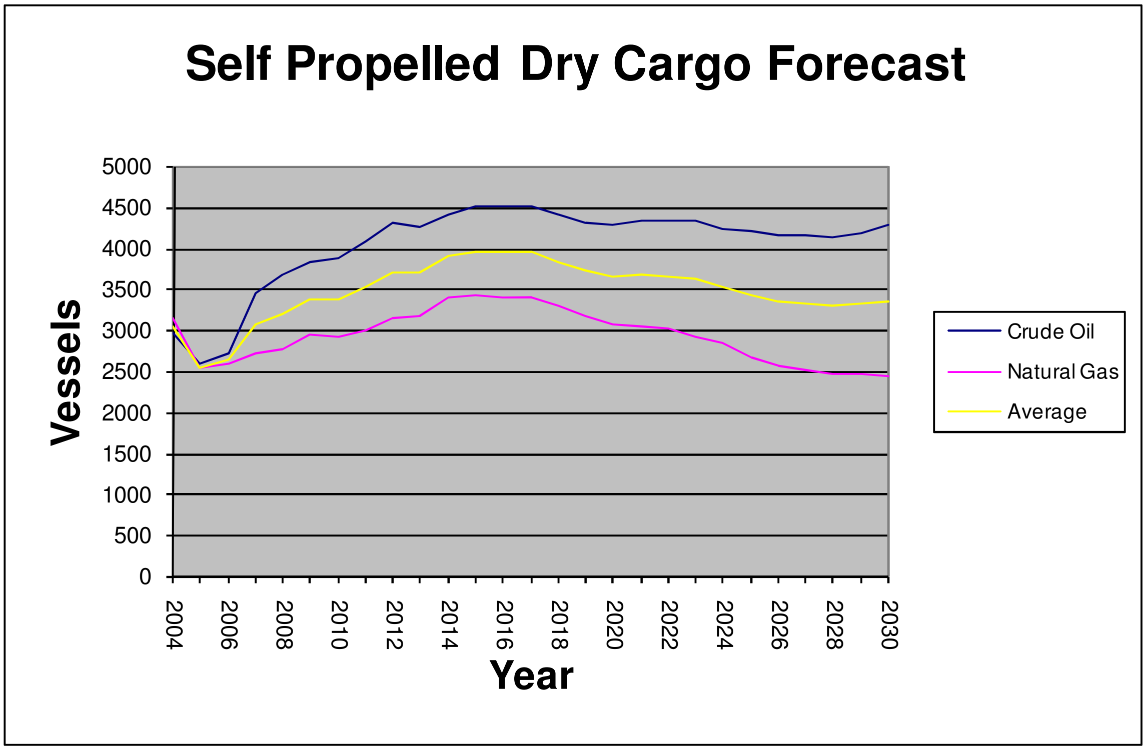
(2,947+3,135)/2= 3,041 vessels.

Because this is relatively close to the original amount of vessels trips that were reported (2,947), it was determined that this would be a good estimator rather than a straightline forecast. The results are shown in Figure 10 for the dry cargo category.

As can be seen in Figure 10, the average line that represents the forecast reported for without conditions vessels follows the same path as that in figures 5 and 6, covering both the overall increase in oil production and the overall decrease in gas production.

The remaining period of 2031 to 2061 was determined by using the GOM deepwater platform rate of decline trendline shown in Figure 7 beginning in 2015 because this is the highest year for new deepwater platforms in the GOM. The trendline indicates a yearly decrease of 2.3 percent a year in installation of deepwater platforms. A simple straightline decrease from 2015 to 2050 was tried, but it resulted in a low R-square value of 0.34. When the decrease of 2.3 percent was graphed with the original data, it resulted in a higher R-square value of 0.48. This means that this line represents the forecasted line more accurately than the straightline forecast.

The decrease in platforms by 2.3 percent was determined in the calculations below using the values of the trendline.




Source: G.E.C., Inc.

**Figure 10. Self Propelled Dry Cargo Forecast**

0.5 – 2.375 = -1.875

-1.87 5/2.375= -0.78947 = Total Percent Change

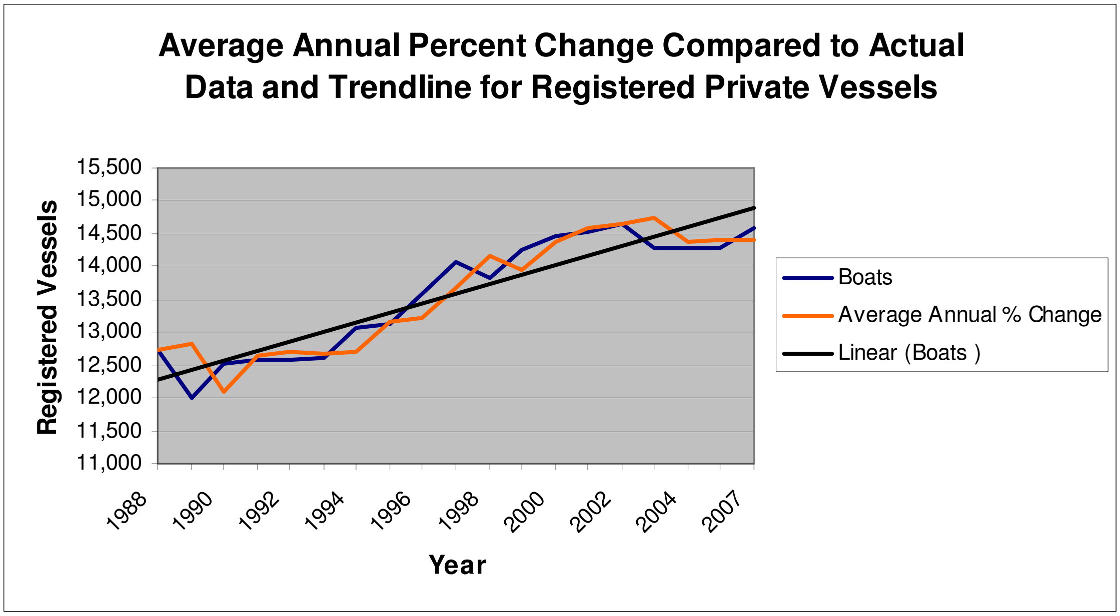
-0.78947/35 years = -0.023 = - 2.3% Change/Year

The rate at which the private vessels were changing was determined through a simple total average annual percent change between the first and last year. The change in the trendline was close to the average annual percent change from the first year to the last. However, the fit of the trendline was not as good as that of the average annual percent change. The average annual percent change in the data has an R-square of 0.87 compared to 0.86 in the trendline. Figure 11 shows the fit with the average annual percent change plugged into the data. The calculations for how the average annual percent change was determined are shown below with a 0.77 percent annual increase in the number of vessels registered in Terrebonne Parish.

14,602 – 12,736 = 1,866 Total Change

1,866 /12,736 = 14.65% Total Percent Change

14.65% /19 years = 0.77% Yearly Percent Change




Source: G.E.C., Inc.

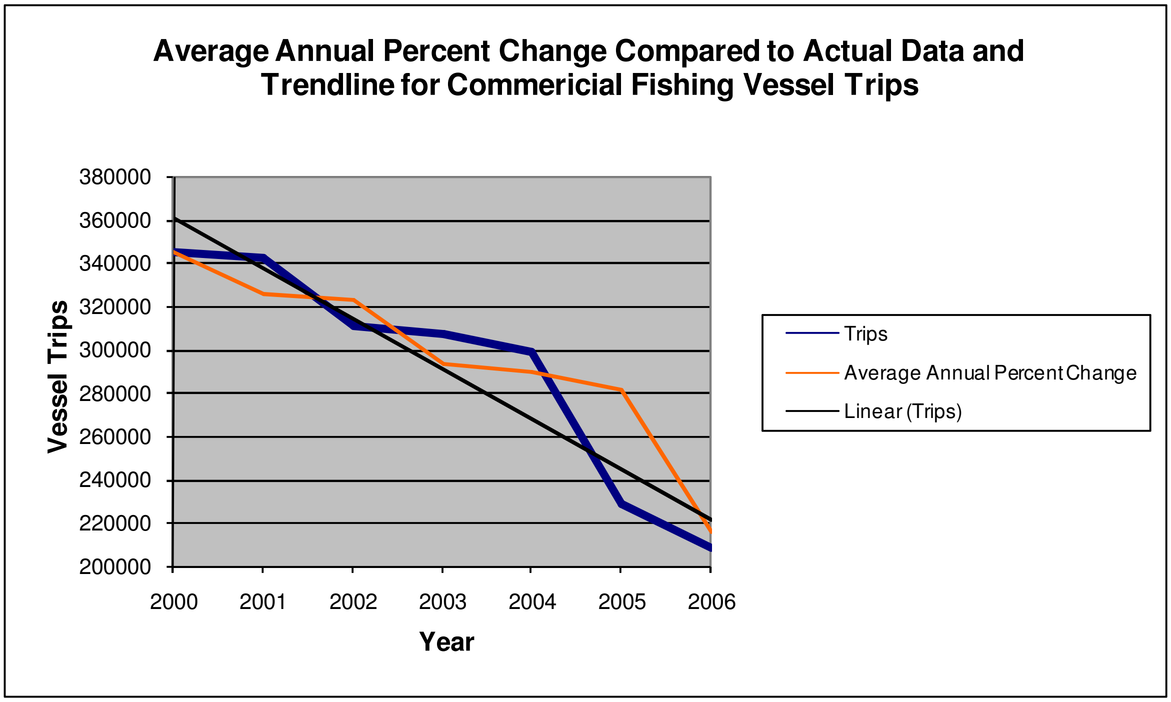
**Figure 11. Average Annual Percent Change Compared to Actual Data and Trendline for Registered Private Vessels**

Finally, for the commercial fishing category, historical data were used to develop a yearly percent change. This was done in the same manner as with private vessels by using the total percent change from the first year to the last to determine the yearly change. Once again, there was a trendline fitted to the data, and it was determined that the change in the trendline was about the same percentage decrease as in the average annual percent change. However, because vessel trips are decreasing at such a dramatic rate, the more conservative average annual percent change was used so that the vessel trips would be slightly higher in the forecast. Figure 12 shows the average annual percent change, historical fishing trip data, and the trendline. As can be seen, the slope of the trendline is steeper, which means it has a greater percent change than the average annual percent change. The calculations below show the average annual percent change calculations for the number of commercial fishing vessel trips decreasing by a rate of 5.7 percent per year.

208,049 – 344,875 = -136,826 Total Change

-136,826 / 344,875 = -40% Total Percent Change

-40% / 7 = -5.7% Yearly Percent Change




Source: G.E.C., Inc.

**Figure 12. Average Annual Percent Change Compared to Actual Data and Trendline for Commercial Fishing Vessel Trips**

## WITHOUT PROJECT CONDITIONS FORECAST

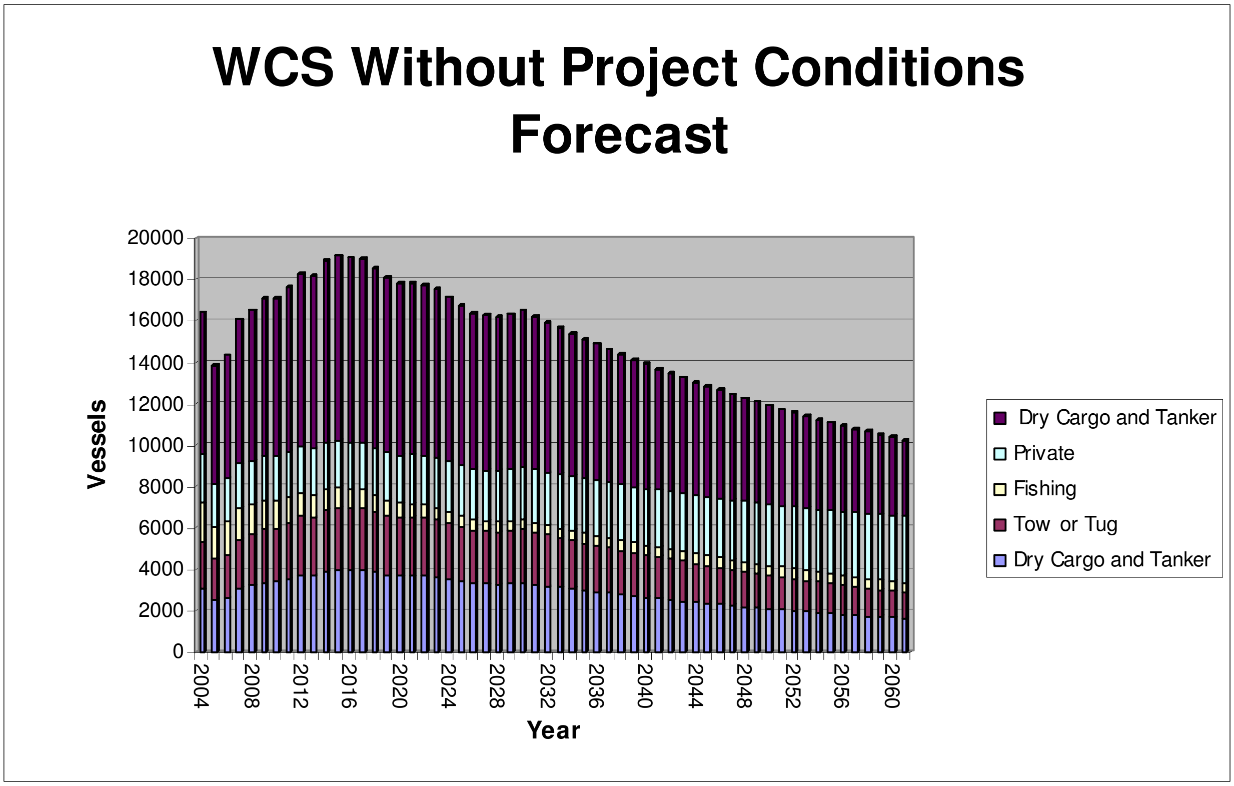
A forecast for the adjusted WCS data was made using these sources and procedures. The forecast oil and gas production will peak around the year 2015 in the GOM. After 2015, a decline will be followed by a small increase in production, after which there will be a sustained gradual decrease. It is important to understand that the decline in the level of vessel traffic is also attributable to the decline in commercial fishing vessels. Private boats are the only category of vessels expected to increase over this period. Figure 13 and Table 26 provide the without conditions vessel forecast.

### Dry Cargo

Dry Cargo and Tanker self-propelled vessel trips are projected to increase to 2015, peaking at 3,960, then decline through 2028, then increase to 3,360 in 2030, and then decline steadily to 1,633 in 2061. These peaks and declines reflect expected oil and gas production levels in the GOM.

### Tow or Tug

Tow or Tug vessel trips are expected to peak in 2015 at 3,030, then decline, then experience a slight rise in 2030 to 2,571, and then experience a slow decline to 1,250 in 2061. These changes also reflect expected oil and gas production levels in the GOM.




Source: G.E.C., Inc.

**Figure 13. WCS Without Project Conditions Forecast**

**Table 27. WCS Without Conditions Forecast**

| Year | Self Propelled Vessels | | | | Non-Self Propelled | Total |
|---|---|---|---|---|---|---|
| | Dry Cargo and Tanker | Tow or Tug | Fishing | Private | Dry Cargo and Tanker | |
| 2004 | 3,041 | 2,326 | 1,834 | 2,358 | 6,853 | 16,413 |
| 2005 | 2,548 | 1,949 | 1,588 | 2,042 | 5,743 | 13,870 |
| 2006 | 2,637 | 2,018 | 1,637 | 2,103 | 5,944 | 14,339 |
| 2007 | 3,085 | 2,361 | 1,543 | 2,119 | 6,953 | 16,061 |
| 2008 | 3,213 | 2,458 | 1,455 | 2,136 | 7,240 | 16,502 |
| 2009 | 3,376 | 2,584 | 1,372 | 2,152 | 7,609 | 17,093 |
| 2010 | 3,389 | 2,593 | 1,294 | 2,169 | 7,638 | 17,082 |
| 2011 | 3,541 | 2,710 | 1,220 | 2,185 | 7,980 | 17,636 |
| 2012 | 3,717 | 2,844 | 1,150 | 2,202 | 8,376 | 18,289 |
| 2013 | 3,708 | 2,838 | 1,084 | 2,219 | 8,357 | 18,207 |
| 2014 | 3,898 | 2,983 | 1,022 | 2,236 | 8,786 | 18,926 |
| 2015 | 3,960 | 3,030 | 964 | 2,253 | 8,925 | 19,133 |
| 2016 | 3,948 | 3,021 | 909 | 2,271 | 8,897 | 19,045 |

| Year | Self Propelled Vessels | | | | Non-Self Propelled | Total |
|---|---|---|---|---|---|---|
| | Dry Cargo and Tanker | Tow or Tug | Fishing | Private | Dry Cargo and Tanker | |
| 2017 | 3,950 | 3,023 | 857 | 2,288 | 8,903 | 19,021 |
| 2018 | 3,840 | 2,939 | 808 | 2,306 | 8,655 | 18548 |
| 2019 | 3,735 | 2,858 | 762 | 2,324 | 8,417 | 18,096 |
| 2020 | 3,666 | 2,805 | 718 | 2,342 | 8,261 | 17,792 |
| 2021 | 3,685 | 2,820 | 677 | 2,360 | 8,304 | 17,845 |
| 2022 | 3,665 | 2,805 | 639 | 2,378 | 8,260 | 17,745 |
| 2023 | 3,625 | 2,774 | 602 | 2,396 | 8,170 | 17,568 |
| 2024 | 3,524 | 2,697 | 568 | 2,414 | 7,942 | 17,144 |
| 2025 | 3,425 | 2,621 | 535 | 2,433 | 7,718 | 16,731 |
| 2026 | 3,344 | 2,559 | 505 | 2,452 | 7,536 | 16,396 |
| 2027 | 3,322 | 2,542 | 476 | 2,471 | 7,487 | 16,297 |
| 2028 | 3,294 | 2,521 | 476 | 2,490 | 7,425 | 16,206 |
| 2029 | 3,321 | 2,542 | 476 | 2,509 | 7,484 | 16,331 |
| 2030 | 3,360 | 2,571 | 476 | 2,528 | 7,572 | 16,508 |
| 2031 | 3,283 | 2,512 | 476 | 2,548 | 7,398 | 16,217 |
| 2032 | 3,207 | 2,455 | 476 | 2,567 | 7,228 | 15,933 |
| 2033 | 3,133 | 2,398 | 476 | 2,587 | 7,062 | 15,656 |
| 2034 | 3,061 | 2,343 | 476 | 2,607 | 6,899 | 15,386 |
| 2035 | 2,991 | 2,289 | 476 | 2,627 | 6,741 | 15,124 |
| 2036 | 2,922 | 2,236 | 476 | 2,647 | 6,586 | 14,867 |
| 2037 | 2,855 | 2,185 | 476 | 2,668 | 6,434 | 14,618 |
| 2038 | 2,789 | 2,135 | 476 | 2,688 | 6,286 | 14,374 |
| 2039 | 2,725 | 2,086 | 476 | 2,709 | 6,142 | 14,137 |
| 2040 | 2,662 | 2,038 | 476 | 2,730 | 6,000 | 13,906 |
| 2041 | 2,601 | 1,991 | 476 | 2,751 | 5,862 | 13,681 |
| 2042 | 2,541 | 1,945 | 476 | 2,772 | 5,728 | 13,462 |
| 2043 | 2,483 | 1,900 | 476 | 2,793 | 5,596 | 13,248 |
| 2044 | 2,426 | 1,857 | 476 | 2,815 | 5,467 | 13,040 |
| 2045 | 2,370 | 1,814 | 476 | 2,836 | 5,341 | 12,838 |
| 2046 | 2,316 | 1,772 | 476 | 2,858 | 5,218 | 12,640 |
| 2047 | 2,262 | 1,731 | 476 | 2,880 | 5,098 | 12,448 |
| 2048 | 2,210 | 1,692 | 476 | 2,902 | 4,981 | 12,261 |
| 2049 | 2,159 | 1,653 | 476 | 2,925 | 4,867 | 12,079 |
| 2050 | 2,110 | 1,615 | 476 | 2,947 | 4,755 | 11,902 |
| 2051 | 2,061 | 1,578 | 476 | 2,970 | 4,645 | 11,730 |
| 2052 | 2,014 | 1,541 | 476 | 2,993 | 4,538 | 11,562 |
| 2053 | 1,968 | 1,506 | 476 | 3,016 | 4,434 | 11,399 |
| 2054 | 1,922 | 1,471 | 476 | 3,039 | 4,332 | 11,241 |
| 2055 | 1,878 | 1,437 | 476 | 3,063 | 4,232 | 11,086 |
| 2056 | 1,835 | 1,404 | 476 | 3,086 | 4,135 | 10,936 |
| 2057 | 1,793 | 1,372 | 476 | 3,110 | 4,040 | 10,790 |
| 2058 | 1,751 | 1,340 | 476 | 3,134 | 3,947 | 10,649 |
| 2059 | 1,711 | 1,310 | 476 | 3,158 | 3,856 | 10,511 |
| 2060 | 1,672 | 1,279 | 476 | 3,182 | 3,768 | 10,377 |
| 2061 | 1,633 | 1,250 | 476 | 3,207 | 3,681 | 10,247 |

Source: G.E.C., Inc.

### Tow or Tug in Tow

This category represents the non-self propelled dry cargo and tanker vessels, which account for the largest percentage of vessel traffic on the HNC. As with the other two oil and gas related categories, trips are expected to reach a peak of 8,925 in 2015, then decline, then increase slightly in 2030 at 7,572, then decline to 2061.

### Commercial Fishing Vessels

The forecast for commercial fishing vessels represents the largest percentage decrease for all the categories. The commercial fishing industry has been negatively affected by cheaper imports, high operating costs, over fishing, and storms. Fishing trips are expected to decline as long as the market conditions remain the same. The forecast was extended only to 2027 at 476 vessel trips per year because further extension would result in no vessel trips for this category and it is assumed that there will always be some commercial fishing in Louisiana.

### Private Vessels

Private vessels trips are the only category that is predicted to increase over this period. The increase in privately owned vessels is a national trend that has been taking place for many years. Based on this trend and the historic data obtained for Louisiana, this category is expected to increase throughout the projection period, rising from 2,358 vessel trips in 2004 to 3,207 in 2061. The increase is expected to be small from year to year.

## FORECAST OF ADJUSTED WCS FOR WITH PROJECT

### Baseline NED Benefiting Vessel Trips

The vessel trips for the HNC under with project conditions are shown in Table 28. There are a total of 701 baseline trips in 2006 that would be affected by with project conditions. Of these, 511 represent the total number of new 2006 baseline trips for the HNC. The tug assisted trips, 134 tug/barge and five dry cargo trips, would continue from without project conditions but with deeper drafts. The tug/barge assists would continue but with deeper draft ocean tugs replacing shallower draft river tugs. The OSV trials would continue but without the need for tug assistance. Under with project conditions, because of deeper loadings there would be a reduction in the number of projected trips in the baseline from trips under without project conditions affecting tug/barges and also dry cargo (OSV). The net change (increase) in with project trips is 511 for the baseline in year 2006.

Table 29 indicates the number of with project vessel trips and sailing draft distributions. The 701 affected baseline trips in 2006 consist of 139 tug assistance trips. The 511 increased trips would have draft distributions as follows: (1) light tugs would be 25 percent at 15 feet, 50 percent at 16 feet, and 25 percent at 17 feet; (2) tug/barges (including former tug assistance) would be 25 percent at 16 feet, 50 percent at 17 feet, and 25 percent at 18 feet; and (3) dry cargo (including former tug assistance) would be 50 percent at 15 feet and 50 percent at 16 feet.

**Table 28. HNC Base Year Benefiting Vessel Trips for With Project Conditions**

| Activity | Vessel | Category | Quantity | Trips per Vessel | Baseline Trips | Increased Trips |
|---|---|---|---|---|---|---|
| Rerouting | Tugs | Light Tug | 60 | 2 | 120 | 120 |
| | Barges | Tug/barge | 10 | 6 | 60 | 60 |
| | Tug trials | Light Tug | 4 | 1 | 4 | 4 |
| | OSV trials | Dry Cargo | 6 | 1 | 6 | 6 |
| Tug Assistance | Barges | Tug/barge | 50 | 1 | 134 | |
| | OSV trials | Dry Cargo | 6 | 1 | 5 | |
| Diversions | Tug barges | Tug/barge | 3 | 24 | 72 | 72 |
| | Tugs | Light Tug | 60 | 1 | 120 | 120 |
| | Jackups | Dry Cargo | 10 | 2 | 20 | 20 |
| Deeper Loading | Risers | Tug/barge | 400 | 1 | 134 | 134 |
| | Loadouts | Tug/barge | 3 | 1 | 2 | -1 |
| | Rigs | Dry Cargo | 6 | 8 | 24 | -24 |
| Total | | | 618 | 49 | 701 | 511 |

Note: With project conditions assumed to be in effect in 2012.

Source: G.E.C., Inc.

**Table 29. Number of With Project Vessel Trips and Draft Distributions**

| Increased Trips | Baseline Trips | Increased Trips | 14-ft Draft | 15-ft Draft | 16-ft Draft | 17-ft Draft | 18-ft Draft |
|---|---|---|---|---|---|---|---|
| Light Tug | 244 | 244 | | 25% | 50% | 25% | |
| Tug/barge | 292 | 265 | | | 25% | 50% | 25% |
| Dry Cargo | 26 | 2 | | 50% | 50% | | |
| Subtotal | 562 | 511 | | | | | |
| Tug Assist Trips | | Deeper Draft Trips | | | | | |
| Tug/barge | 134 | 134 | | | 25% | 50% | 25% |
| Dry Cargo | 5 | 5 | | 50% | 50% | | |
| Subtotal | 139 | 139 | | | | | |
| Total | 701 | 650 | | | | | |

Source: G.E.C., Inc.

### Projected NED Benefiting Vessel Trips

Table 30 contains the changes in the annual number of vessel trips in with project conditions compared to without project conditions, representing increases or decreases in annual trips by activity, vessel, and category for the NED benefits. The net baseline trips, beginning in 2006, are displayed by activity, vessel, and category. Activity refers to the particular use of the HNC with regard to vessel trips characterized as rerouted, tug assisted, diverted, or deeper loading. Vessel refers to the navigation affected by with project conditions such as tugs, barges, tug trials, OSV trials, tug barges, jackups, etc. Category refers to the WCS vessel category such as light tug, tug/barge, dry cargo, etc.

## Table 30. Change in the Number of Vessel Trips in With Project Conditions by Activity, Vessel and Category: 2012 - 2061

| Year | Activity Vessel Category Growth | Rerouting Tugs Light Tug | Rerouting Barges Tug/Barge | Rerouting Tug Trials Light Tug | Rerouting OSV Trials Dry Cargo | Tug Assist Barges Tug/Barge | Tug Assist OSV Trials Dry Cargo | Diversions Barge Tug/Barge | Diversions Tugs Light Tug | Diversions Jackups Dry Cargo | Deeper Loading Barges - Risers Tub/Barge | Deeper Loading Barge - Load outs Tug/barge | Deeper Loading OSV - Rigs Dry Cargo | Total Trips (all vessels) | Increased Trips Light Tug | Increased Trips Tug/Barge | Increased Trips Dry Cargo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | | | | | | | | | | | | | | | | | |
| 2006 | | 120 | 60 | 4 | 6 | 134 | 5 | 72 | 120 | 20 | 134 | -1 | -24 | 650 | 244 | 265 | 2 |
| 2007 | 16.98% | 140 | 70 | 5 | 7 | 157 | 6 | 84 | 140 | 23 | 157 | -1 | -28 | 760 | 285 | 310 | 2 |
| 2008 | 4.13% | 146 | 73 | 5 | 7 | 163 | 6 | 88 | 146 | 24 | 163 | -1 | -29 | 792 | 297 | 323 | 2 |
| 2009 | 5.09% | 154 | 77 | 5 | 8 | 172 | 6 | 92 | 154 | 26 | 172 | -1 | -31 | 832 | 312 | 339 | 3 |
| 2010 | 0.38% | 154 | 77 | 5 | 8 | 172 | 6 | 93 | 154 | 26 | 172 | -1 | -31 | 835 | 314 | 341 | 3 |
| 2011 | 4.49% | 161 | 81 | 5 | 8 | 180 | 7 | 97 | 161 | 27 | 180 | -1 | -32 | 873 | 328 | 356 | 3 |
| 2012 | 4.96% | 169 | 85 | 6 | 8 | 189 | 7 | 101 | 169 | 28 | 189 | -1 | -34 | 916 | 344 | 373 | 3 |
| 2013 | -0.22% | 169 | 84 | 6 | 8 | 188 | 7 | 101 | 169 | 28 | 188 | -1 | -34 | 914 | 343 | 373 | 3 |
| 2014 | 5.12% | 177 | 89 | 6 | 9 | 198 | 7 | 106 | 177 | 30 | 198 | -1 | -35 | 961 | 361 | 392 | 3 |
| 2015 | 1.59% | 180 | 90 | 6 | 9 | 201 | 8 | 108 | 180 | 30 | 201 | -2 | -36 | 976 | 366 | 398 | 3 |
| 2016 | -0.31% | 180 | 90 | 6 | 9 | 201 | 7 | 108 | 180 | 30 | 201 | -1 | -36 | 973 | 365 | 397 | 3 |
| 2017 | 0.07% | 180 | 90 | 6 | 9 | 201 | 7 | 108 | 180 | 30 | 201 | -1 | -36 | 974 | 365 | 397 | 3 |
| 2018 | -2.78% | 175 | 87 | 6 | 9 | 195 | 7 | 105 | 175 | 29 | 195 | -1 | -35 | 947 | 355 | 386 | 3 |
| 2019 | -2.75% | 170 | 85 | 6 | 8 | 190 | 7 | 102 | 170 | 28 | 190 | -1 | -34 | 921 | 346 | 375 | 3 |
| 2020 | -1.85% | 167 | 83 | 6 | 8 | 186 | 7 | 100 | 167 | 28 | 186 | -1 | -33 | 903 | 339 | 368 | 3 |
| 2021 | 0.51% | 168 | 84 | 6 | 8 | 187 | 7 | 101 | 168 | 28 | 187 | -1 | -34 | 908 | 341 | 370 | 3 |
| 2022 | -0.53% | 167 | 83 | 6 | 8 | 186 | 7 | 100 | 167 | 28 | 186 | -1 | -33 | 903 | 339 | 368 | 3 |
| 2023 | -1.08% | 165 | 82 | 5 | 8 | 184 | 7 | 99 | 165 | 27 | 184 | -1 | -33 | 894 | 335 | 364 | 3 |
| 2024 | -2.80% | 160 | 80 | 5 | 8 | 179 | 7 | 96 | 160 | 27 | 179 | -1 | -32 | 869 | 326 | 354 | 3 |
| 2025 | -2.82% | 156 | 78 | 5 | 8 | 174 | 6 | 93 | 156 | 26 | 174 | -1 | -31 | 844 | 317 | 344 | 3 |
| 2026 | -2.35% | 152 | 76 | 5 | 8 | 170 | 6 | 91 | 152 | 25 | 170 | -1 | -30 | 824 | 309 | 336 | 3 |
| 2027 | -0.66% | 151 | 76 | 5 | 8 | 169 | 6 | 91 | 151 | 25 | 169 | -1 | -30 | 819 | 307 | 334 | 3 |
| 2028 | -0.83% | 150 | 75 | 5 | 7 | 167 | 6 | 90 | 150 | 25 | 167 | -1 | -30 | 812 | 305 | 331 | 2 |
| 2029 | 0.80% | 151 | 76 | 5 | 8 | 169 | 6 | 91 | 151 | 25 | 169 | -1 | -30 | 819 | 307 | 334 | 3 |
| 2030 | 1.18% | 153 | 76 | 5 | 8 | 171 | 6 | 92 | 153 | 25 | 171 | -1 | -31 | 828 | 311 | 338 | 3 |
| 2031 | -2.30% | 149 | 75 | 5 | 7 | 167 | 6 | 90 | 149 | 25 | 167 | -1 | -30 | 809 | 304 | 330 | 2 |
| 2032 | -2.30% | 146 | 73 | 5 | 7 | 163 | 6 | 88 | 146 | 24 | 163 | -1 | -29 | 790 | 297 | 322 | 2 |
| 2033 | -2.30% | 143 | 71 | 5 | 7 | 159 | 6 | 86 | 143 | 24 | 159 | -1 | -29 | 772 | 290 | 315 | 2 |
| 2034 | -2.30% | 139 | 70 | 5 | 7 | 156 | 6 | 84 | 139 | 23 | 156 | -1 | -28 | 755 | 283 | 308 | 2 |
| 2035 | -2.30% | 136 | 68 | 5 | 7 | 152 | 6 | 82 | 136 | 23 | 152 | -1 | -27 | 737 | 277 | 301 | 2 |
| 2036 | -2.30% | 133 | 66 | 4 | 7 | 148 | 6 | 80 | 133 | 22 | 148 | -1 | -27 | 720 | 270 | 294 | 2 |
| 2037 | -2.30% | 130 | 65 | 4 | 6 | 145 | 5 | 78 | 130 | 22 | 145 | -1 | -26 | 704 | 264 | 287 | 2 |
| 2038 | -2.30% | 127 | 63 | 4 | 6 | 142 | 5 | 76 | 127 | 21 | 142 | -1 | -25 | 687 | 258 | 280 | 2 |
| 2039 | -2.30% | 124 | 62 | 4 | 6 | 138 | 5 | 74 | 124 | 21 | 138 | -1 | -25 | 672 | 252 | 274 | 2 |
| 2040 | -2.30% | 121 | 61 | 4 | 6 | 135 | 5 | 73 | 121 | 20 | 135 | -1 | -24 | 656 | 246 | 268 | 2 |
| 2041 | -2.30% | 118 | 59 | 4 | 6 | 132 | 5 | 71 | 118 | 20 | 132 | -1 | -24 | 641 | 241 | 261 | 2 |
| 2042 | -2.30% | 116 | 58 | 4 | 6 | 129 | 5 | 69 | 116 | 19 | 129 | -1 | -23 | 626 | 235 | 255 | 2 |
| 2043 | -2.30% | 113 | 56 | 4 | 6 | 126 | 5 | 68 | 113 | 19 | 126 | -1 | -23 | 612 | 230 | 249 | 2 |
| 2044 | -2.30% | 110 | 55 | 4 | 6 | 123 | 5 | 66 | 110 | 18 | 123 | -1 | -22 | 598 | 224 | 244 | 2 |
| 2045 | -2.30% | 108 | 54 | 4 | 5 | 120 | 4 | 65 | 108 | 18 | 120 | -1 | -22 | 584 | 219 | 238 | 2 |
| 2046 | -2.30% | 105 | 53 | 4 | 5 | 118 | 4 | 63 | 105 | 18 | 118 | -1 | -21 | 571 | 214 | 233 | 2 |
| 2047 | -2.30% | 103 | 51 | 3 | 5 | 115 | 4 | 62 | 103 | 17 | 115 | -1 | -21 | 558 | 209 | 227 | 2 |
| 2048 | -2.30% | 101 | 50 | 3 | 5 | 112 | 4 | 60 | 101 | 17 | 112 | -1 | -20 | 545 | 204 | 222 | 2 |
| 2049 | -2.30% | 98 | 49 | 3 | 5 | 110 | 4 | 59 | 98 | 16 | 110 | -1 | -20 | 532 | 200 | 217 | 2 |
| 2050 | -2.30% | 96 | 48 | 3 | 5 | 107 | 4 | 58 | 96 | 16 | 107 | -1 | -19 | 520 | 195 | 212 | 2 |
| 2051 | -2.30% | 94 | 47 | 3 | 5 | 105 | 4 | 56 | 94 | 16 | 105 | -1 | -19 | 508 | 191 | 207 | 2 |
| 2052 | -2.30% | 92 | 46 | 3 | 5 | 102 | 4 | 55 | 92 | 15 | 102 | -1 | -18 | 496 | 186 | 202 | 2 |
| 2053 | -2.30% | 90 | 45 | 3 | 4 | 100 | 4 | 54 | 90 | 15 | 100 | -1 | -18 | 485 | 182 | 198 | 1 |
| 2054 | -2.30% | 87 | 44 | 3 | 4 | 98 | 4 | 52 | 87 | 15 | 98 | -1 | -17 | 474 | 178 | 193 | 1 |
| 2055 | -2.30% | 85 | 43 | 3 | 4 | 95 | 4 | 51 | 85 | 14 | 95 | -1 | -17 | 463 | 174 | 189 | 1 |
| 2056 | -2.30% | 83 | 42 | 3 | 4 | 93 | 3 | 50 | 83 | 14 | 93 | -1 | -17 | 452 | 170 | 184 | 1 |
| 2057 | -2.30% | 82 | 41 | 3 | 4 | 91 | 3 | 49 | 82 | 14 | 91 | -1 | -16 | 442 | 166 | 180 | 1 |
| 2058 | -2.30% | 80 | 40 | 3 | 4 | 89 | 3 | 48 | 80 | 13 | 89 | -1 | -16 | 432 | 162 | 176 | 1 |
| 2059 | -2.30% | 78 | 39 | 3 | 4 | 87 | 3 | 47 | 78 | 13 | 87 | -1 | -16 | 422 | 158 | 172 | 1 |
| 2060 | -2.30% | 76 | 38 | 3 | 4 | 85 | 3 | 46 | 76 | 13 | 85 | -1 | -15 | 412 | 155 | 168 | 1 |
| 2061 | -2.30% | 74 | 37 | 2 | 4 | 83 | 3 | 45 | 74 | 12 | 83 | -1 | -15 | 403 | 151 | 164 | 1 |

Notes: Activity refers to the use of the HNC with regard to existing vessel trips characterized as rerouted, tug assisted, diverted, or deeper loading.
Vessel refers to the navigation affected such as tugs, barges, tug trials, OSV trials, tug barge, jackups, etc.
Category refers to the WCS vessel category such as light tug, tug/barge, dry cargo, etc.

Source: G.E.C., Inc.

The annual change in offshore GOM oil and gas production (refer to Table 30) is used to adjust the 2006 baseline vessels to arrive at the changes in annual benefiting vessel trips under with project conditions. In some instances, the 2006 baseline has fewer trips in with project conditions, such as deeper loading, than in without project conditions, resulting in a reduction (negative) in vessel trips. The 2006 net change baseline is adjusted annually for the period 2007-2061 to include HNC with project conditions for the period 2012-2061. The change in total trips is recorded for all vessels (Total Trips) and for the increased vessel trips, excluding tug assisted trips.

Total net changes in HNC trips are compiled for the categories of light tug, tug/barge, and dry cargo. The baseline net changes in benefiting vessels increase from 2006 to 2015 and decline thereafter (except 2017) consistent with the GOM offshore oil and gas production forecasts. After 2040, the baseline net change in annual vessels is less than 2006. The NED benefits will reflect that there are increased benefiting vessel trips from 2012 to 2040 compared to the 2006 baseline.

The three columns of Table 30 reflecting net increased trips by category (light tug, tug/barge, and dry cargo) will be used to increase the without project adjusted WCS projections.

## WITH PROJECT CONDITIONS FORECAST

The with project conditions forecast was calculated by adding the additional vessels to their respective category. These additional vessels can be seen from Table 29 and were adjusted by the same percentages as the without project conditions. Figure 14 and Table 31 show this forecast.

### Dry Cargo

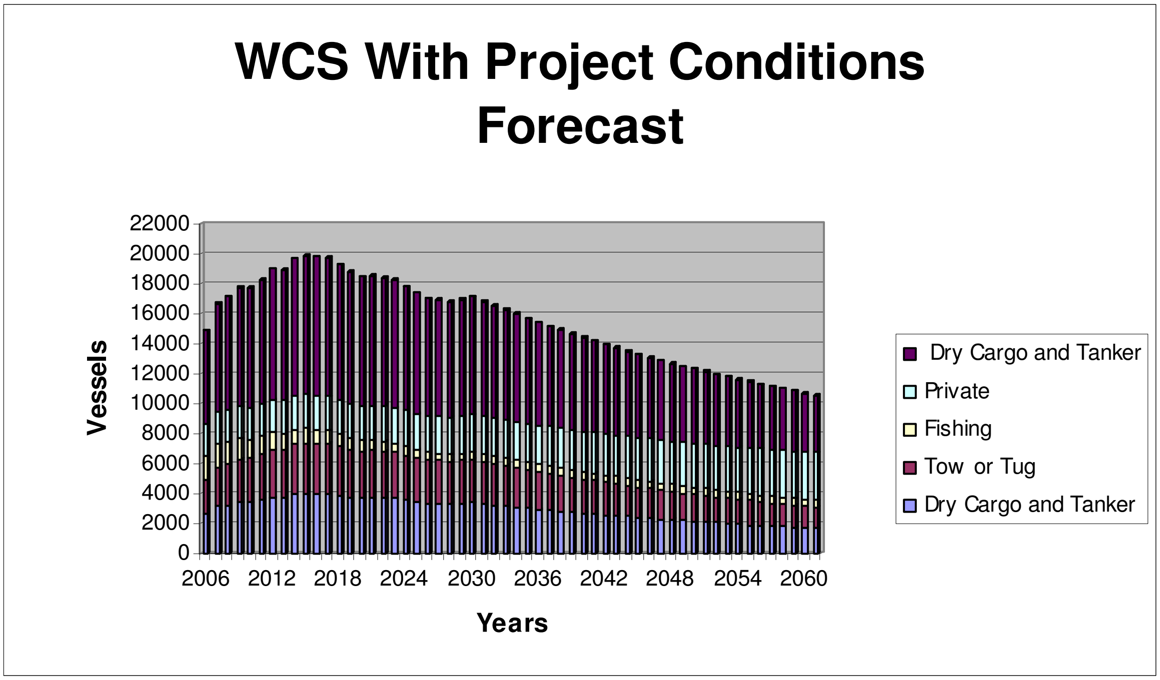
Once again, the number of self propelled dry cargo and tanker category will increase up to the year 2015 with 3,963 vessel trips. There will also be a smaller peak of 3,363 vessel trips in 2030. From 2030 there will be a steady decrease in the number of vessel trips that last until the end of the forecast in the year 2061, ending with 1,635 trips.

### Tow or Tug

Tow or tug vessel trips again follow the rest of the vessel categories that are associated with the oil and gas industry. The vessel trips will reach their highest point in 2015 with 3,397 trips and again peak in 2030 with 2,882 trips. Again, after 2030 there will be a steady decrease to 2061, ending with 1,401.

### Tow or Tug in Tow

The non-self propelled dry cargo and tanker category with the adjusted increased vessel trips remains the largest category in the data. These vessels will reach their highest point in 2015 with 9,232 trips and reach a smaller peak in 2030 with 7,910 trips. After 2030, they will continue to decrease to 2061, with a final number of 3,845 trips.




Note: With project conditions assumed to be in effect in 2012.

Source: G.E.C., Inc.

**Figure 14. WCS With Project Conditions Forecast**

**Table 31. With Project Conditions WCS Forecast**

| | Self Propelled Vessels | | | | Non-Self Propelled | |
|---|---|---|---|---|---|---|
| Year | Dry Cargo and Tanker | Tow or Tug | Fishing | Private | Dry Cargo and Tanker | Total |
| 2006 | 2,637 | 2,018 | 1,637 | 2,103 | 5,944 | 14,339 |
| 2007 | 3,085 | 2,361 | 1,543 | 2,119 | 6,953 | 16,061 |
| 2008 | 3,213 | 2,458 | 1,455 | 2,136 | 7,240 | 16,502 |
| 2009 | 3,376 | 2,584 | 1,372 | 2,152 | 7,609 | 17,093 |
| 2010 | 3,389 | 2,593 | 1,294 | 2,169 | 7,638 | 17,082 |
| 2011 | 3,541 | 2,710 | 1,220 | 2,185 | 7,980 | 17,636 |
| 2012 | 3,719 | 3,188 | 1,150 | 2,202 | 8,750 | 19,009 |
| 2013 | 3,711 | 3,181 | 1,084 | 2,219 | 8,730 | 18,925 |
| 2014 | 3,901 | 3,344 | 1,022 | 2,236 | 9,177 | 19,681 |
| 2015 | 3,963 | 3,397 | 964 | 2,253 | 9,323 | 19,900 |
| 2016 | 3,951 | 3,386 | 909 | 2,271 | 9,294 | 19,810 |
| 2017 | 3,953 | 3,388 | 857 | 2,288 | 9,300 | 19,786 |
| 2018 | 3,843 | 3,294 | 808 | 2,306 | 9,041 | 19,293 |
| 2019 | 3,738 | 3,204 | 762 | 2,324 | 8,793 | 18,819 |
| 2020 | 3,668 | 3,144 | 718 | 2,342 | 8,630 | 18,502 |

| Year | Self Propelled Vessels | | | | Non-Self Propelled | Total |
|---|---|---|---|---|---|---|
| | Dry Cargo and Tanker | Tow or Tug | Fishing | Private | Dry Cargo and Tanker | |
| 2021 | 3,687 | 3,160 | 677 | 2,360 | 8,674 | 18,559 |
| 2022 | 3,668 | 3,144 | 639 | 2,378 | 8,628 | 18,455 |
| 2023 | 3,628 | 3,110 | 602 | 2,396 | 8,535 | 18,270 |
| 2024 | 3,526 | 3,023 | 568 | 2,414 | 8,296 | 17,827 |
| 2025 | 3,427 | 2,938 | 535 | 2,433 | 8,062 | 17,395 |
| 2026 | 3,346 | 2,868 | 505 | 2,452 | 7,872 | 17,044 |
| 2027 | 3,325 | 2,850 | 476 | 2,471 | 7,820 | 16,941 |
| 2028 | 3,297 | 2,826 | 476 | 2,490 | 7,756 | 16,844 |
| 2029 | 3,323 | 2,849 | 476 | 2,509 | 7,818 | 16,975 |
| 2030 | 3,363 | 2,882 | 476 | 2,528 | 7,910 | 17,159 |
| 2031 | 3,285 | 2,816 | 476 | 2,548 | 7,728 | 16,853 |
| 2032 | 3,210 | 2,751 | 476 | 2,567 | 7,550 | 16,554 |
| 2033 | 3,136 | 2,688 | 476 | 2,587 | 7,377 | 16,263 |
| 2034 | 3,064 | 2,626 | 476 | 2,607 | 7,207 | 15,980 |
| 2035 | 2,993 | 2,566 | 476 | 2,627 | 7,041 | 15,703 |
| 2036 | 2,924 | 2,507 | 476 | 2,647 | 6,879 | 15,434 |
| 2037 | 2,857 | 2,449 | 476 | 2,668 | 6,721 | 15,171 |
| 2038 | 2,791 | 2,393 | 476 | 2,688 | 6,566 | 14,915 |
| 2039 | 2,727 | 2,338 | 476 | 2,709 | 6,415 | 14,665 |
| 2040 | 2,665 | 2,284 | 476 | 2,730 | 6,268 | 14,422 |
| 2041 | 2,603 | 2,231 | 476 | 2,751 | 6,124 | 14,185 |
| 2042 | 2,543 | 2,180 | 476 | 2,772 | 5,983 | 13,954 |
| 2043 | 2,485 | 2,130 | 476 | 2,793 | 5,845 | 13,729 |
| 2044 | 2,428 | 2,081 | 476 | 2,815 | 5,711 | 13,510 |
| 2045 | 2,372 | 2,033 | 476 | 2,836 | 5,579 | 13,297 |
| 2046 | 2,317 | 1,986 | 476 | 2,858 | 5,451 | 13,089 |
| 2047 | 2,264 | 1,941 | 476 | 2,880 | 5,326 | 12,887 |
| 2048 | 2,212 | 1,896 | 476 | 2,902 | 5,203 | 12,690 |
| 2049 | 2,161 | 1,852 | 476 | 2,925 | 5,084 | 12,498 |
| 2050 | 2,111 | 1,810 | 476 | 2,947 | 4,967 | 12,311 |
| 2051 | 2,063 | 1,768 | 476 | 2,970 | 4,852 | 12,129 |
| 2052 | 2,015 | 1,728 | 476 | 2,993 | 4,741 | 11,952 |
| 2053 | 1,969 | 1,688 | 476 | 3,016 | 4,632 | 11,780 |
| 2054 | 1,924 | 1,649 | 476 | 3,039 | 4,525 | 11,613 |
| 2055 | 1,879 | 1,611 | 476 | 3,063 | 4,421 | 11,450 |
| 2056 | 1,836 | 1,574 | 476 | 3,086 | 4,320 | 11,292 |
| 2057 | 1,794 | 1,538 | 476 | 3,110 | 4,220 | 11,138 |
| 2058 | 1,753 | 1,502 | 476 | 3,134 | 4,123 | 10,988 |
| 2059 | 1,712 | 1,468 | 476 | 3,158 | 4,028 | 10,842 |
| 2060 | 1,673 | 1,434 | 476 | 3,182 | 3,936 | 10,701 |
| 2061 | 1,635 | 1,401 | 476 | 3,207 | 3,845 | 10,563 |

Note: With project conditions assumed to be in effect in 2012.

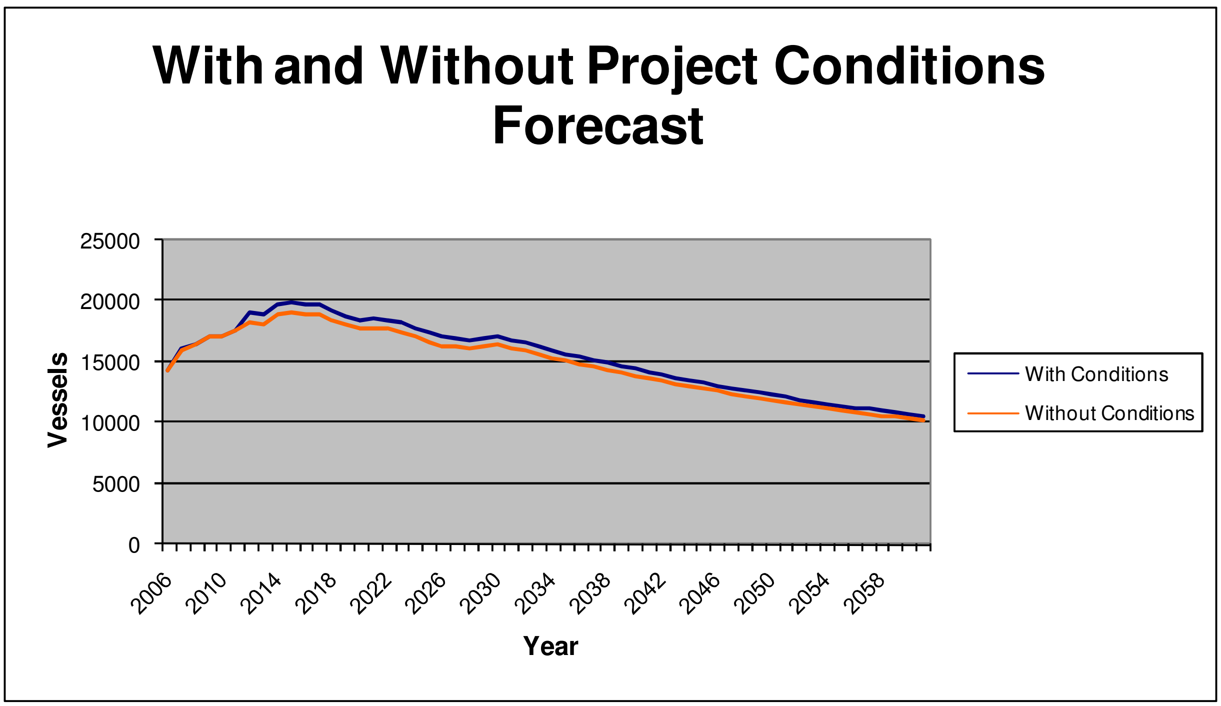
Source: G.E.C., Inc.

### Commercial Fishing and Private Vessels

Fishing and private vessel trips did not change in the with project conditions forecast because the deeper draft will not affect them. All vessels in these categories draw less than six feet.

## WITH AND WITHOUT PROJECT CONDITIONS FORECAST

There is little difference between the without and with project conditions forecast. The with project conditions is only slightly higher and follows the without forecast exactly. Figure 15 and Table 32 show the comparison between the two. In the with project conditions forecast, the number of private vessels and fishing remains the same because these vessels would not be affected by a deeper draft in the HNC. The remaining vessel categories all increase by their adjusted number to give the with forecast conditions a slightly higher number of vessel trips. As the forecasts reach the year 2061, they get closer together to end just above the 10,000 vessel trip mark.




Note: With project conditions assumed to be in effect in 2012.

Source: G.E.C., Inc.

**Figure 15. With and Without Project Conditions Forecast**

## Table 32. With and Without Project Conditions Forecast

| Year | With Conditions | Without Conditions |
|---|---|---|
| 2006 | 14,339 | 14,339 |
| 2007 | 16,061 | 16,061 |
| 2008 | 16,502 | 16,502 |
| 2009 | 17,093 | 17,093 |
| 2010 | 17,082 | 17,082 |
| 2011 | 17,636 | 17,636 |
| 2012 | 19,009 | 18,289 |
| 2013 | 18,925 | 18,207 |
| 2014 | 19,681 | 18,926 |
| 2015 | 19,900 | 19,133 |
| 2016 | 19,810 | 19,045 |
| 2017 | 19,786 | 19,021 |
| 2018 | 19,293 | 18,548 |
| 2019 | 18,819 | 18,096 |
| 2020 | 18,502 | 17,792 |
| 2021 | 18,559 | 17,845 |
| 2022 | 18,455 | 17,745 |
| 2023 | 18,270 | 17,568 |
| 2024 | 17,827 | 17,144 |
| 2025 | 17,395 | 16,731 |
| 2026 | 17,044 | 16,396 |
| 2027 | 16,941 | 16,297 |
| 2028 | 16,844 | 16,206 |
| 2029 | 16,975 | 16,331 |
| 2030 | 17,159 | 16,508 |
| 2031 | 16,853 | 16,217 |
| 2032 | 16,554 | 15,933 |
| 2033 | 16,263 | 15,656 |
| 2034 | 15,980 | 15,386 |
| 2035 | 15,703 | 15,124 |
| 2036 | 15,434 | 14,867 |
| 2037 | 15,171 | 14,618 |
| 2038 | 14,915 | 14,374 |
| 2039 | 14,665 | 14,137 |
| 2040 | 14,422 | 13,906 |
| 2041 | 14,185 | 13,681 |
| 2042 | 13,954 | 13,462 |
| 2043 | 13,729 | 13,248 |
| 2044 | 13,510 | 13,040 |
| 2045 | 13,297 | 12,838 |
| 2046 | 13,089 | 12,640 |
| 2047 | 12,887 | 12,448 |
| 2048 | 12,690 | 12,261 |
| 2049 | 12,498 | 12,079 |
| 2050 | 12,311 | 11,902 |

| Year | With Conditions | Without Conditions |
|---|---|---|
| 2051 | 12,129 | 11,730 |
| 2052 | 11,952 | 11,562 |
| 2053 | 11,780 | 11,399 |
| 2054 | 11,613 | 11,241 |
| 2055 | 11,450 | 11,086 |
| 2056 | 11,292 | 10,936 |
| 2057 | 11,138 | 10,790 |
| 2058 | 10,988 | 10,649 |
| 2059 | 10,842 | 10,511 |
| 2060 | 10,701 | 10,377 |
| 2061 | 10,563 | 10,247 |

Note: With project conditions assumed to be in effect in 2012.

Source: G.E.C., Inc.

## VESSEL DRAFTS

### WCS Without Project Conditions Vessel Draft Distributions

Vessel drafts for the without project conditions are shown in Table 33 and were derived from the original WCS data from the years 1997 through 2005. The number of vessels was cumulated by type and by draft in order to get the distribution that would be easily applied to the without project conditions forecast to compute WCS vessel drafts for a particular year.

### WCS With Project Conditions Vessel Draft Distributions

The with project conditions draft distributions were calculated by adding the additional number of vessel trips with the exception of tug assist vessels, which was averaged for the entire forecast from the tug assist barges tug/barges category from Table 30 and then added to their WCS category. The distributions for these additional vessels were taken from Table 29 as well as the additional trips that were added to the distributions. As can be seen in Table 34, the percentage of vessels for the deeper drafts increases slightly for the with project conditions and, as before, these can be placed in any year of the forecast to determine the expected vessels drafts for a particular year and category.

## CONCLUSIONS

Annual counts of all vessels transiting under the Terrebonne Parish Pontoon Bridge are substantially higher than WCS annual total commercial vessel trips and drafts for the HNC. The trend of higher Bridge total annual vessel transits compared to WCS total annual vessel transits has been clearly identified and statistically corroborated (refer to Figure 1). The Bridge counts were used to adjust the HNC counts upward to reflect subsets of traffic that is not reported by WCS.

**Table 33. WCS Without Project Conditions Vessel Draft Distributions**

| Combined Upbound and Downbound Without Conditions Distributions | | | | | |
|---|---|---|---|---|---|
| | Self Propelled | | | | Non-Self Propelled |
| Draft | Dry Cargo and Tanker | Fishing | Private | Tow or Tug | Dry Cargo and Tanker |
| 18 | 0.07% | 0% | 0% | 0.007% | 0.02% |
| 17 | 0.02% | 0% | 0% | 0.003% | 0.1% |
| 16 | 0.09% | 0% | 0% | 0.0% | 0.04% |
| 15 | 1.1% | 0% | 0% | 0.1% | 0.2% |
| 14 | 1.2% | 0% | 0% | 0.1% | 0.1% |
| 13 | 1.8% | 0% | 0% | 0.1% | 0.1% |
| 12 | 3.8% | 0% | 0% | 0.4% | 0.4% |
| 11 | 3.9% | 0% | 0% | 0.6% | 0.6% |
| 10 | 7.3% | 0% | 0% | 1.2% | 1.3% |
| 9 | 3.8% | 0% | 0% | 5.2% | 2.8% |
| 8 | 3.9% | 0% | 0% | 6.3% | 3.9% |
| 7 | 6.2% | 0% | 0% | 10.5% | 4.0% |
| <6 | 66.9% | 100% | 100% | 75.5% | 86.4% |
| Total | 100.0% | 100% | 100% | 100% | 100.0% |

Source: G.E.C., Inc.

**Table 34. WCS With Project Conditions Vessel Draft Distributions**

.

| Combined Upbound and Downbound For With Conditions | | | | | |
|---|---|---|---|---|---|
| | Self Propelled | | | | Non-Self Propelled |
| Draft | Dry Cargo and Tanker | Fishing | Private | Tow or Tug | Dry Cargo and Tanker |
| 18 | 0.07% | 0% | 0% | 0.01% | 0.6% |
| 17 | 0.02% | 0% | 0% | 0.21% | 1.3% |
| 16 | 0.12% | 0% | 0% | 0.42% | 0.7% |
| 15 | 1.16% | 0% | 0% | 0.30% | 0.2% |
| 14 | 1.20% | 0% | 0% | 0.11% | 0.1% |
| 13 | 1.77% | 0% | 0% | 0.10% | 0.1% |
| 12 | 3.80% | 0% | 0% | 0.37% | 0.4% |
| 11 | 3.88% | 0% | 0% | 0.59% | 0.6% |
| 10 | 7.26% | 0% | 0% | 1.14% | 1.3% |
| 9 | 3.85% | 0% | 0% | 5.17% | 2.8% |
| 8 | 3.90% | 0% | 0% | 6.22% | 3.8% |
| 7 | 6.17% | 0% | 0% | 10.33% | 3.9% |
| <6 | 66.82% | 100% | 100% | 74.55% | 85.0% |
| Total | 100.00% | 100% | 100% | 100.00% | 100.0% |

Source: G.E.C., Inc.

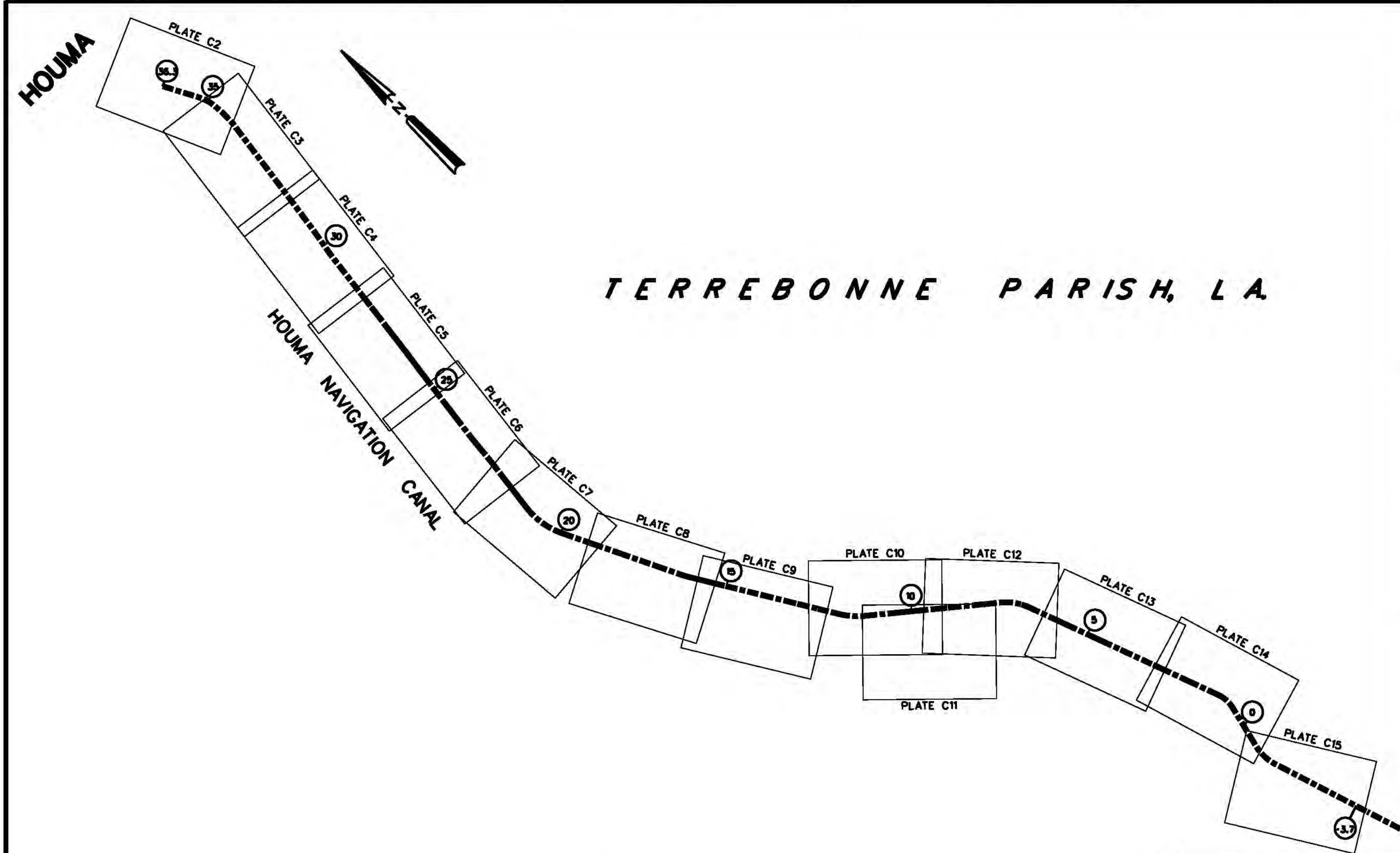
The adjusted WCS traffic of annual vessels was then projected for the period 2006-2061 to capture vessel traffic for the period of without project conditions (refer to Table 27). Forecasts of vessel traffic on the HNC were related to GOM offshore oil and gas production projections and projections for commercial fishing and recreational vessels. For without project conditions, the total base year HNC traffic rose from 14,339 vessel trips in 2006 to 18,289 trips in 2012 and peaked at 19,133 trips in 2015. Total annual HNC vessel trips under without project conditions then declined to 16,217 by 2031, 13,681 by 2041, 11,730 by 2051, and 10,247 by 2061. By the end of the forecast, traffic (total annual vessel trips) would be nearly 30 percent less than it was at the 2006 baseline.

For the with project conditions, the numbers of benefiting vessels were projected from a 2006 baseline to 2061. Not all of the benefiting vessels represented new traffic because a portion was related to tug assistance provided to existing vessels that would continue to move under with project conditions. The baseline fleet of all benefiting vessels was 650 trips in 2006, which represented a net increase of 511 new trips. The number of benefiting trips and new trips under with project conditions increased to 916/719 in 2012 (start of with project conditions) and peaked at 976/766 in 2015. The annual benefiting and new trips declined as follows: 809/636 in 2031; 641/503 in 2041; 508/400 in 2051; and 403/316 in 2061.

As a result of new trips under with project conditions, total HNC traffic is projected to be 19,009 in 2012 (start of with project conditions). The total annual number of vessel trips peaks at 19,900 in 2015 and then declines to 16,853 in 2031, 14,185 in 2041, 12,129 in 2061, and 10,563 in 2051. The increase in total traffic between without and with project conditions is quite small. For example, total annual vessel transits under with project conditions increases 720 vessels in 2012 (rounded) or 3.9 percent. Total vessel transits increase 316 vessels in 2061 or 3.1 percent.

# Annex V

# Plates




HOUMA NAVIGATION CANAL

HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT

MILE 36.0 TO MILE (-)15.0
TERREBONNE PARISH, LOUISIANA

PLATE INDEX (C2 - C15)

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

| | | | |
|---|---|---|---|
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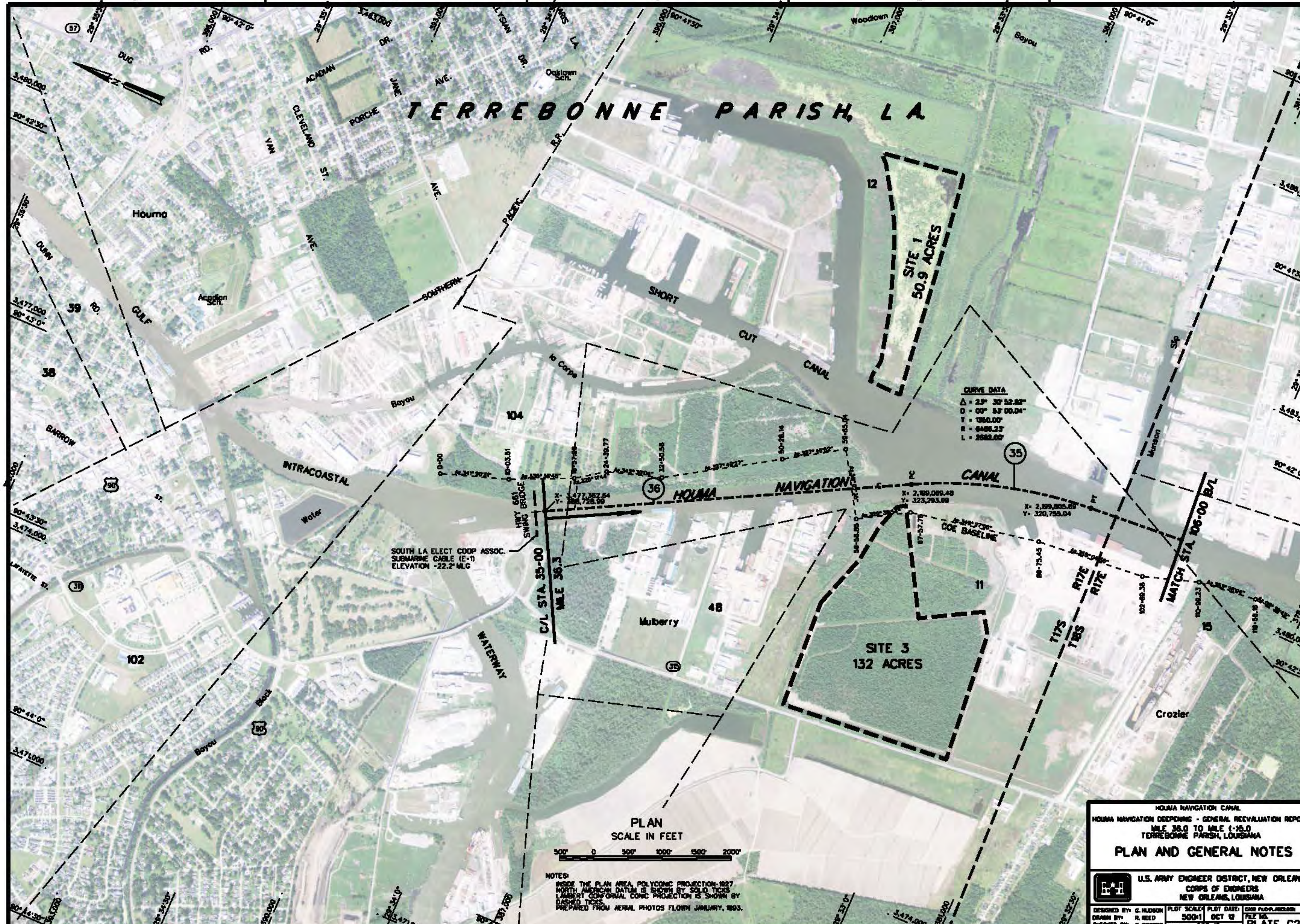
| DRAWN BY: R. REED | | | FILE NO. PLATE C1 |
| CHECKED BY: B. ROGERS | DATE: OCT 12 | | |

PLATE C1




HOUMA NAVIGATION CANAL

HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT

MILE 36.0 TO MILE (-)5.0

TERREBONNE PARISH, LOUISIANA

PLAN AND GENERAL NOTES

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS

CORPS OF ENGINEERS

NEW ORLEANS, LOUISIANA

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| DRAWN BY: R. REED | | | |
| CHECKED BY: G. ROGERS | DATE: OCT 12 | | |

PLATE C2

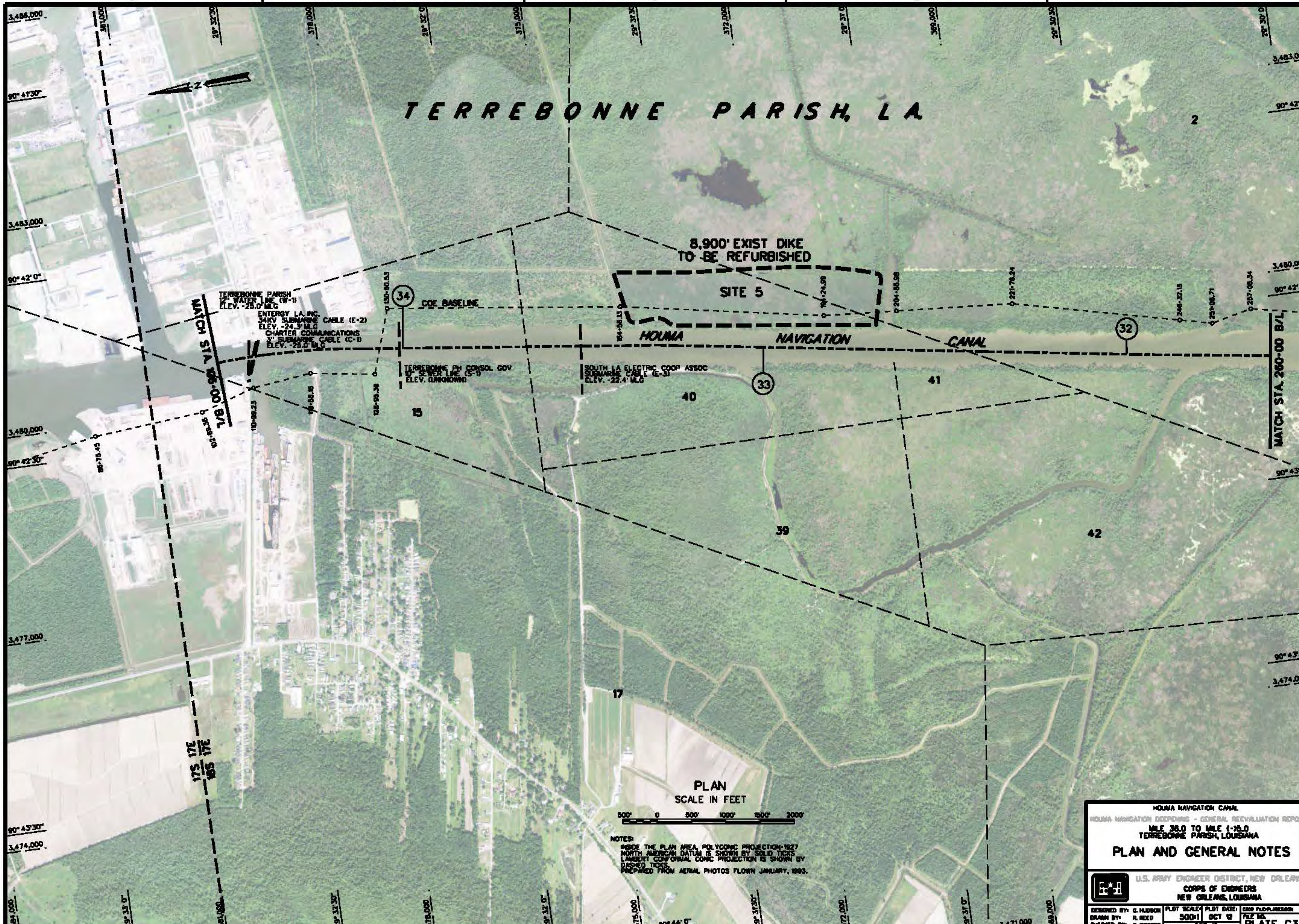
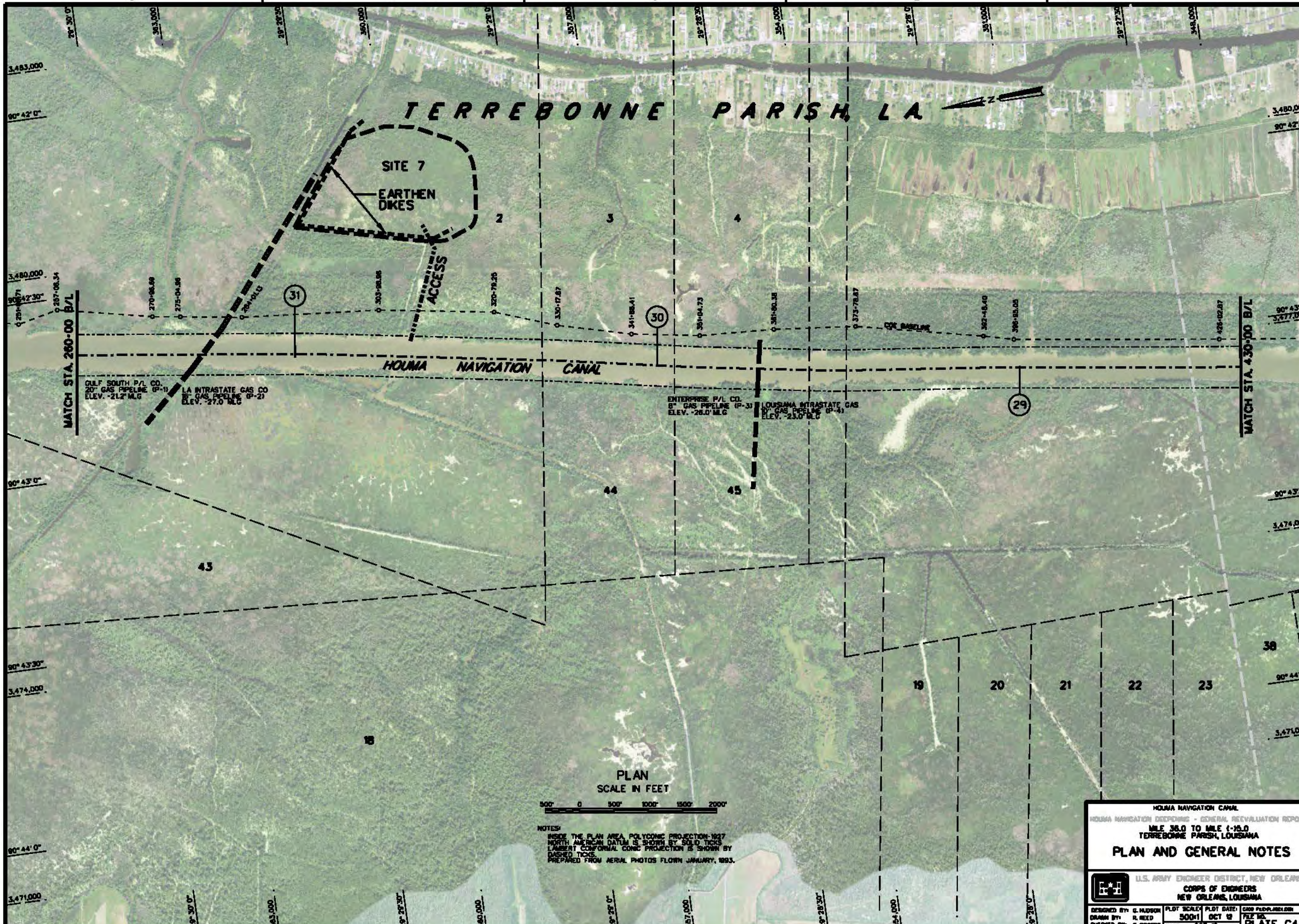

TERREBONNE PARISH, LA
8,900' EXIST DIKE
TO BE REFURBISHED
SITE 5
HOUMA NAVIGATION CANAL
COE BASELINE
MATCH STA. 96+00 B/L
MATCH STA. 260+00 B/L
TERREBONNE PARISH
12" WATER LINE (W-1)
ELEV. -25.0' MLG
ENTERGY LA. INC.
34KV SUBMARINE CABLE (E-2)
ELEV. -24.3' MLG
CHARTER COMMUNICATIONS
3" SUBMARINE CABLE (C-1)
ELEV. -25.0' MLG
TERREBONNE PH CONSOL GOV
10" SEWER LINE (S-1)
ELEV. UNKNOWN
SOUTH LA ELECTRIC COOP ASSOC
SUBMARINE CABLE (E-3)
ELEV. -22.4' MLG
34
33
32
2
15
17
39
40
41
42
T17S R17E
T18S R17E
PLAN
SCALE IN FEET
500' 0 500' 1000' 1500' 2000'
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1927 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS.
PREPARED FROM AERIAL PHOTOS FLOWN JANUARY, 1993.
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
PLAN AND GENERAL NOTES
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
DESIGNED BY: G. HUDSON
DRAWN BY: R. REED
CHECKED BY: G. ROGERS
PLOT SCALE: 500:1
PLOT DATE: OCT 12
DATE: OCT 12
FILE NO. PLATE C3

PLATE C3




HOUMA NAVIGATION CANAL
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MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

PLAN AND GENERAL NOTES

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
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NEW ORLEANS, LOUISIANA

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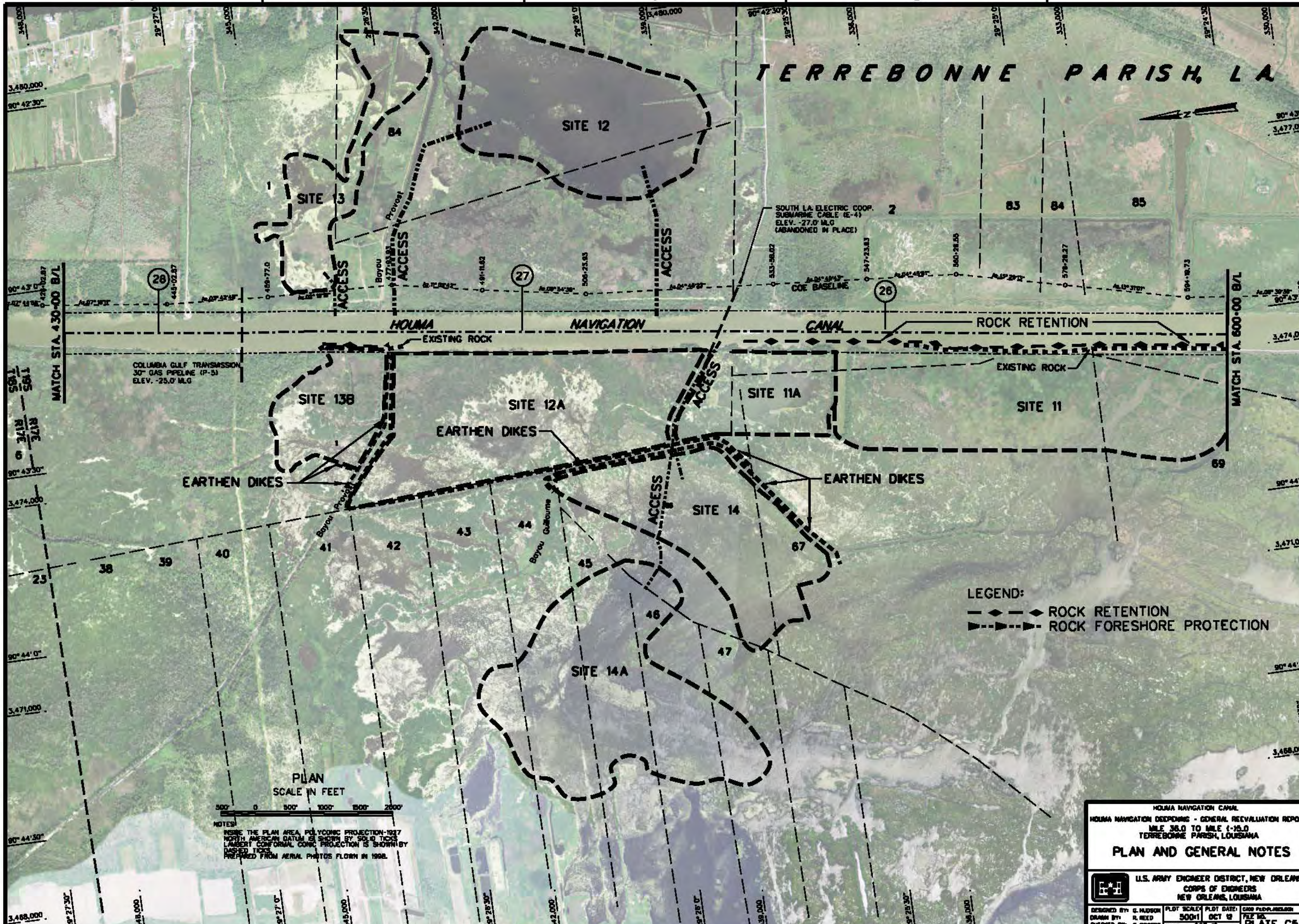
|---|---|---|---|
| DESIGNED BY: G. HUDSON | PLOT SCALE: 500:1 | PLOT DATE: OCT 12 | CADD FILE: PLATEC4.DGN |
| DRAWN BY: R. REED | DATE: OCT 12 | | FILE NO. PLATE C4 |
| CHECKED BY: G. ROGERS | | | |

PLATE C4


TERREBONNE PARISH, LA
SITE 12
SITE 13
SITE 13B
SITE 12A
SITE 11A
SITE 11
SITE 14
SITE 14A
ACCESS
HOUMA NAVIGATION CANAL
ROCK RETENTION
EXISTING ROCK
EARTHEN DIKES
COE BASELINE
MATCH STA. 430+00 B/L
MATCH STA. 600+00 B/L
COLUMBIA GULF TRANSMISSION
30" GAS PIPELINE (P-3)
ELEV. -25.0' MLG
SOUTH LA. ELECTRIC COOP.
SUBMARINE CABLE (E-4)
ELEV. -27.0' MLG
(ABANDONED IN PLACE)
Bayou Provost
Bayou Grand Guillaume
LEGEND:
ROCK RETENTION
ROCK FORESHORE PROTECTION
PLAN
SCALE IN FEET
500' 0 500' 1000' 1500' 2000'
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1927 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS. LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS.
PREPARED FROM AERIAL PHOTOS FLOWN IN 1998.
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HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
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PLAN AND GENERAL NOTES
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
DESIGNED BY: G. HUDSON
DRAWN BY: R. REED
CHECKED BY: G. ROGERS
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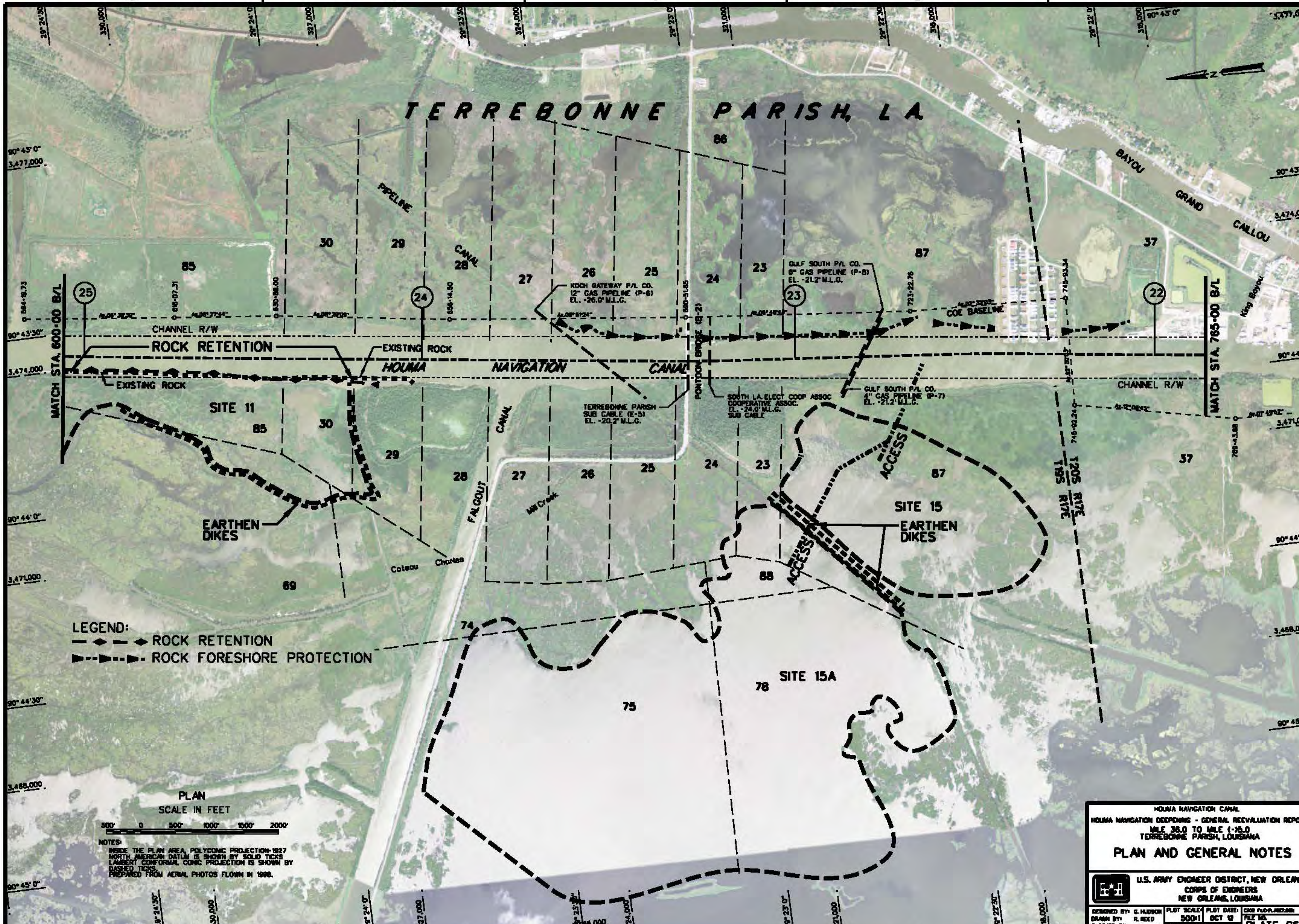
PLATE C5




PLAN

SCALE IN FEET

500' 0 500' 1000' 1500' 2000'

NOTES:

INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1927 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS.
PREPARED FROM AERIAL PHOTOS FLOWN IN 1998.

HOUMA NAVIGATION CANAL

HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT

MILE 36.0 TO MILE (-)5.0

TERREBONNE PARISH, LOUISIANA

**PLAN AND GENERAL NOTES**

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

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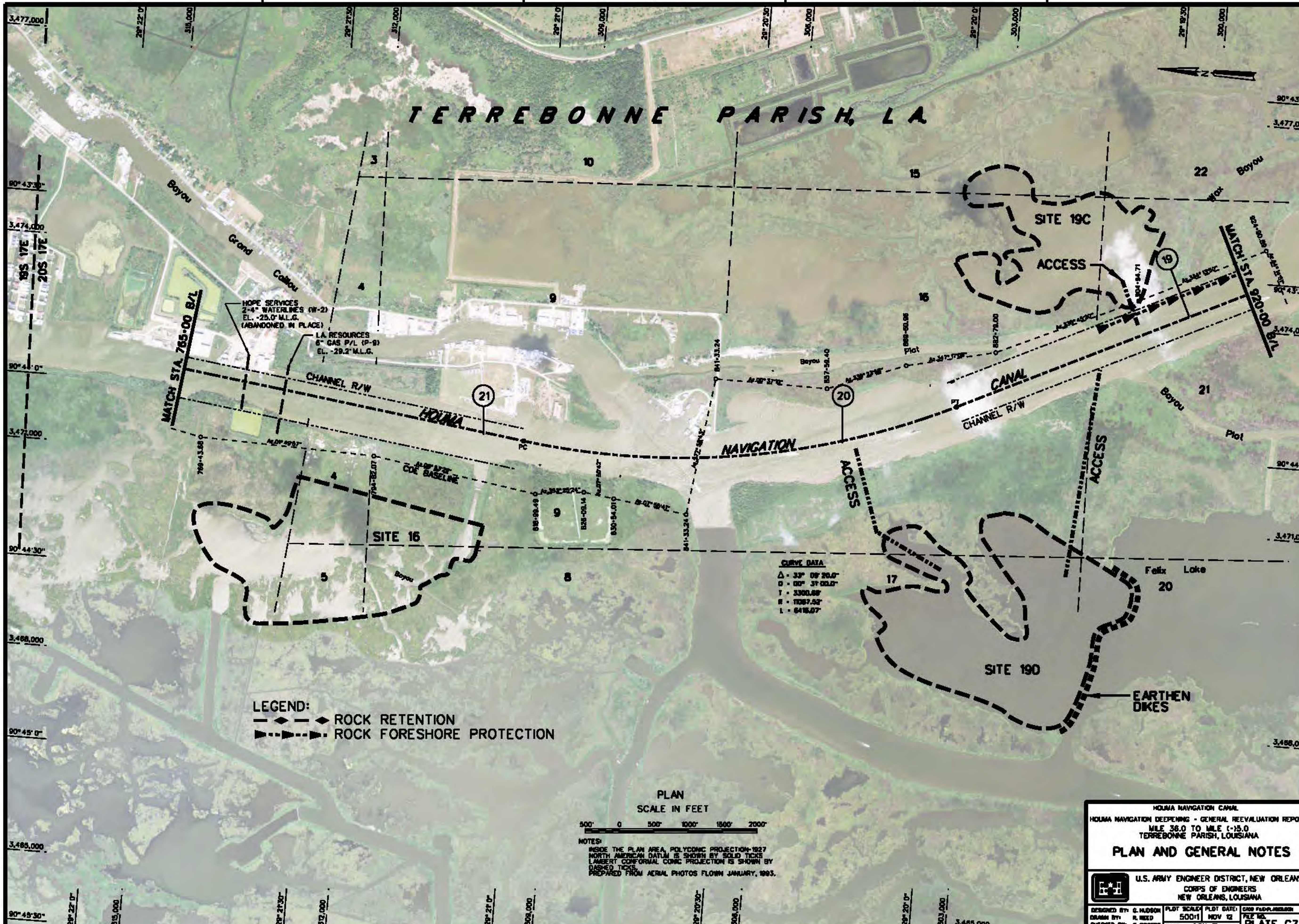
|---|---|---|---|
| DESIGNED BY: G. HUDSON | PLOT SCALE: 500:1 | PLOT DATE: OCT 12 | CADD FILE: |
| DRAWN BY: R. REED | | | FILE NO. PLATE C6 |
| CHECKED BY: G. ROGERS | DATE: OCT 12 | | |

PLATE C6


TERREBONNE PARISH, LA.
SITE 19C
ACCESS
SITE 16
SITE 19D
ACCESS
ACCESS
HOUMA NAVIGATION CANAL
CHANNEL R/W
CDE BASELINE
MATCH STA. 765+00 B/L
MATCH STA. 920+00 B/L
Bayou Grand Caillou
Felix Lake
EARTHEN DIKES
HOPE SERVICES
2-4" WATERLINES (W-2)
EL. -25.0' M.L.G.
(ABANDONED IN PLACE)
LA RESOURCES
6" GAS P/L (P-9)
EL. -29.2' M.L.G.
CURVE DATA
LEGEND:
ROCK RETENTION
ROCK FORESHORE PROTECTION
PLAN
SCALE IN FEET
500' 0 500' 1000' 1500' 2000'
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1927
NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS
LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY
DASHED TICKS.
PREPARED FROM AERIAL PHOTOS FLOWN JANUARY, 1993.
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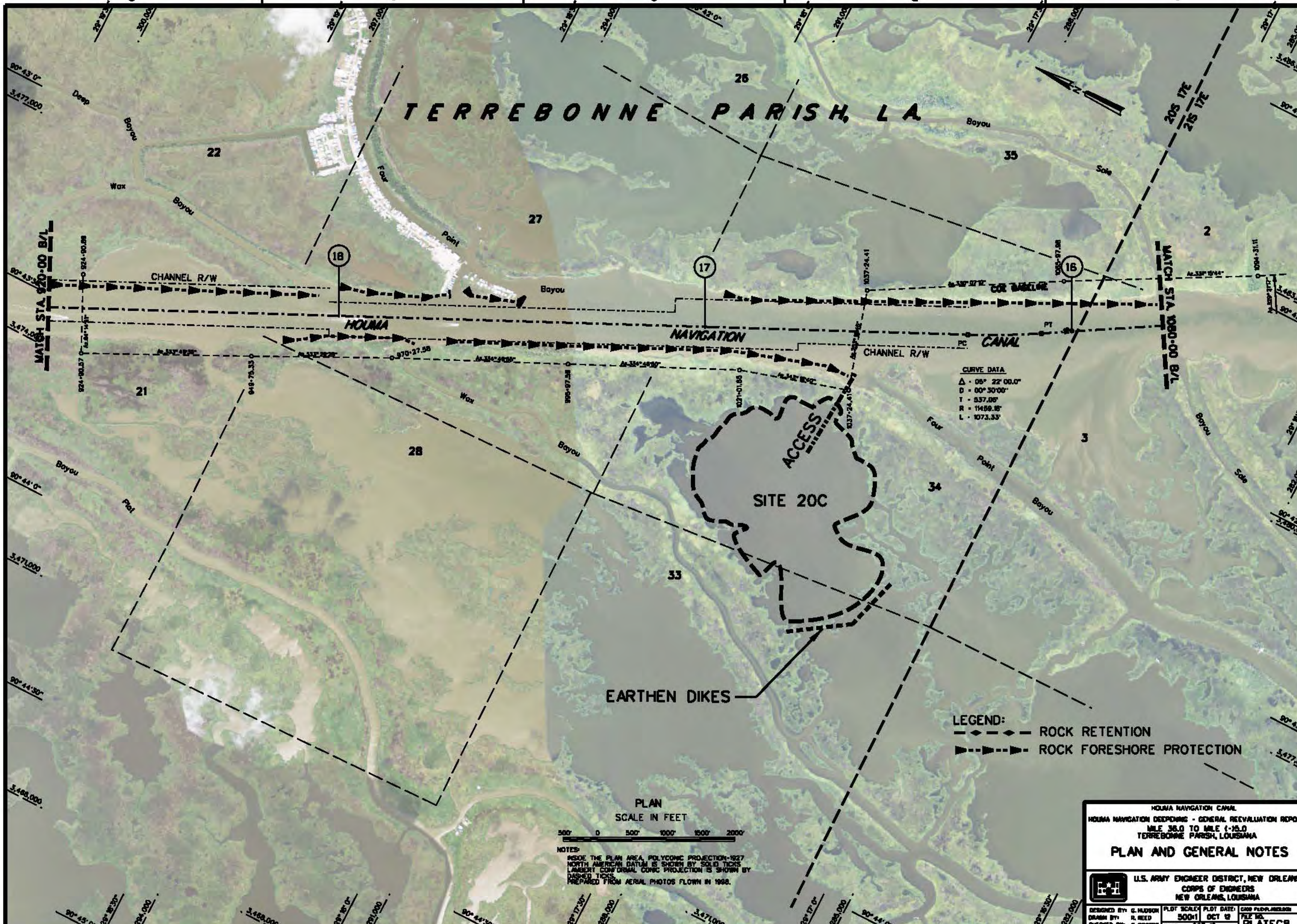
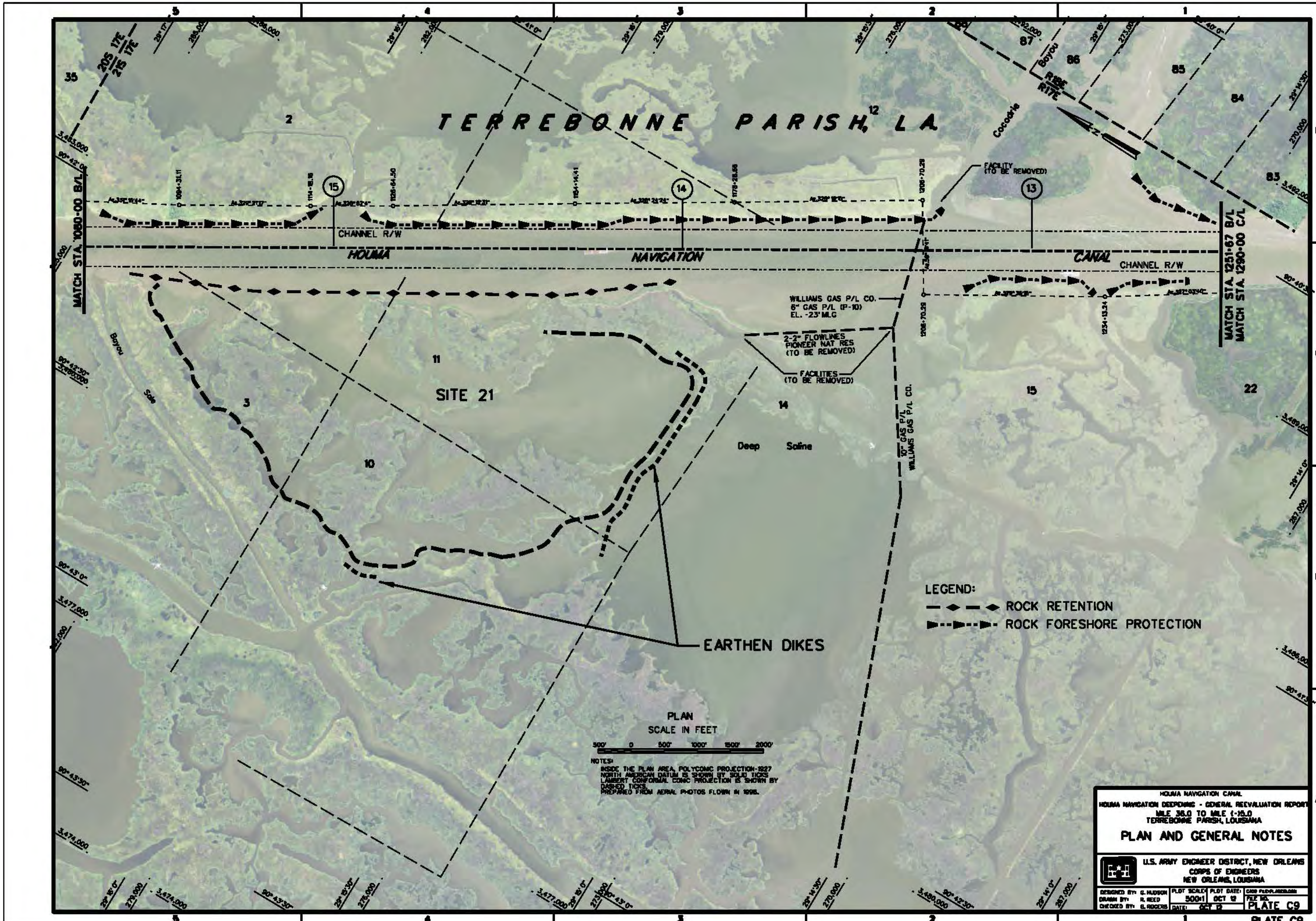
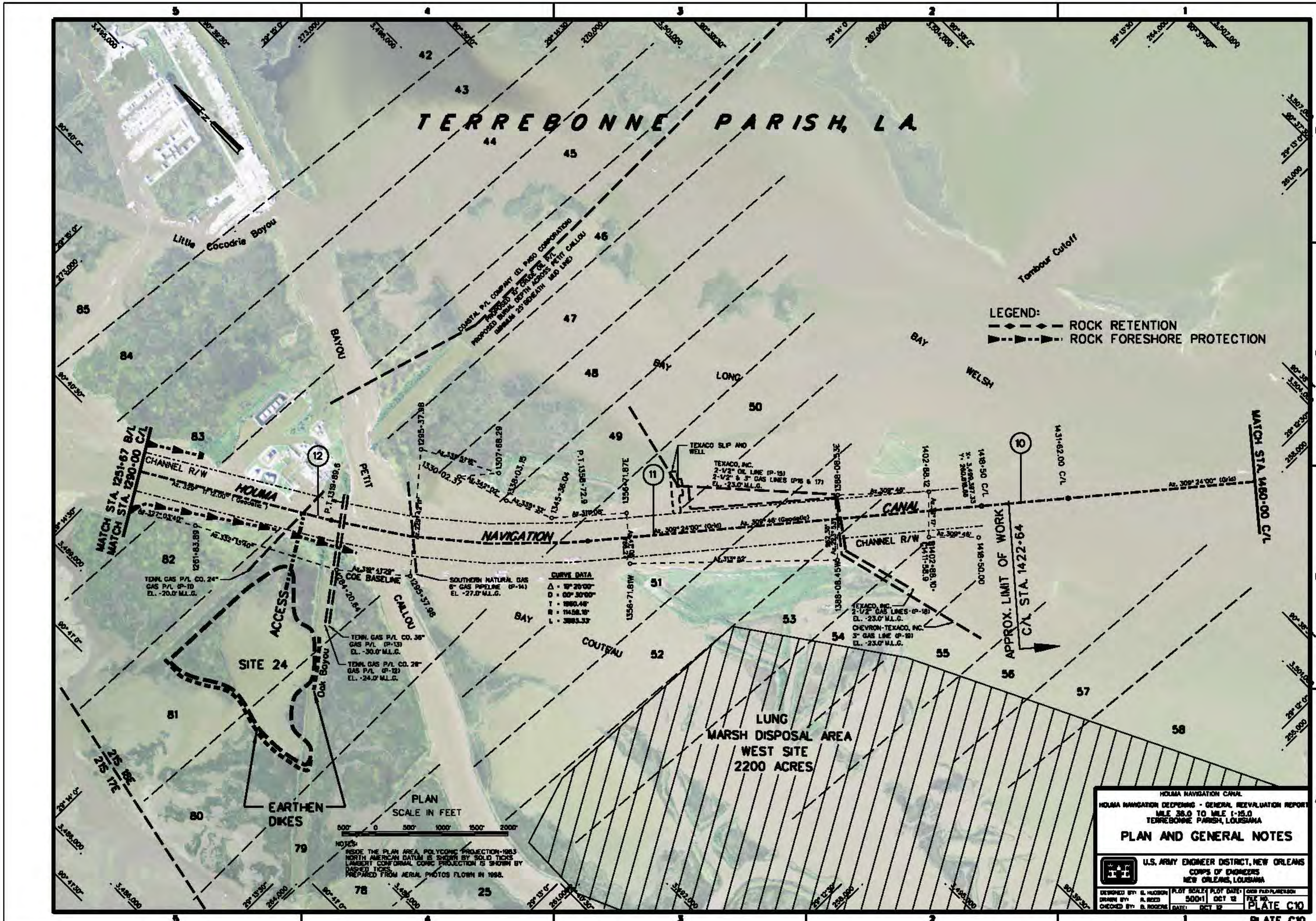
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
PLAN AND GENERAL NOTES
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
DESIGNED BY: G. HUDSON
DRAWN BY: R. REED
CHECKED BY: G. ROGERS
PLOT SCALE: 500:1
PLOT DATE: NOV 12
DATE: NOV 12
PLATE C7



TERREBONNE PARISH, LA.
HOUMA
NAVIGATION
CANAL
CHANNEL R/W
SITE 20C
ACCESS
EARTHEN DIKES
MATCH STA 920+00 B/L
MATCH STA 1080+00 B/L
CURVE DATA
Δ = 05° 22' 00.0"
D = 00° 30' 00"
T = 537.05'
R = 11459.16'
L = 1073.33'
LEGEND:
ROCK RETENTION
ROCK FORESHORE PROTECTION
PLAN
SCALE IN FEET
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1927 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS. LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS.
PREPARED FROM AERIAL PHOTOS FLOWN IN 1998.
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
PLAN AND GENERAL NOTES
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
PLATE C8

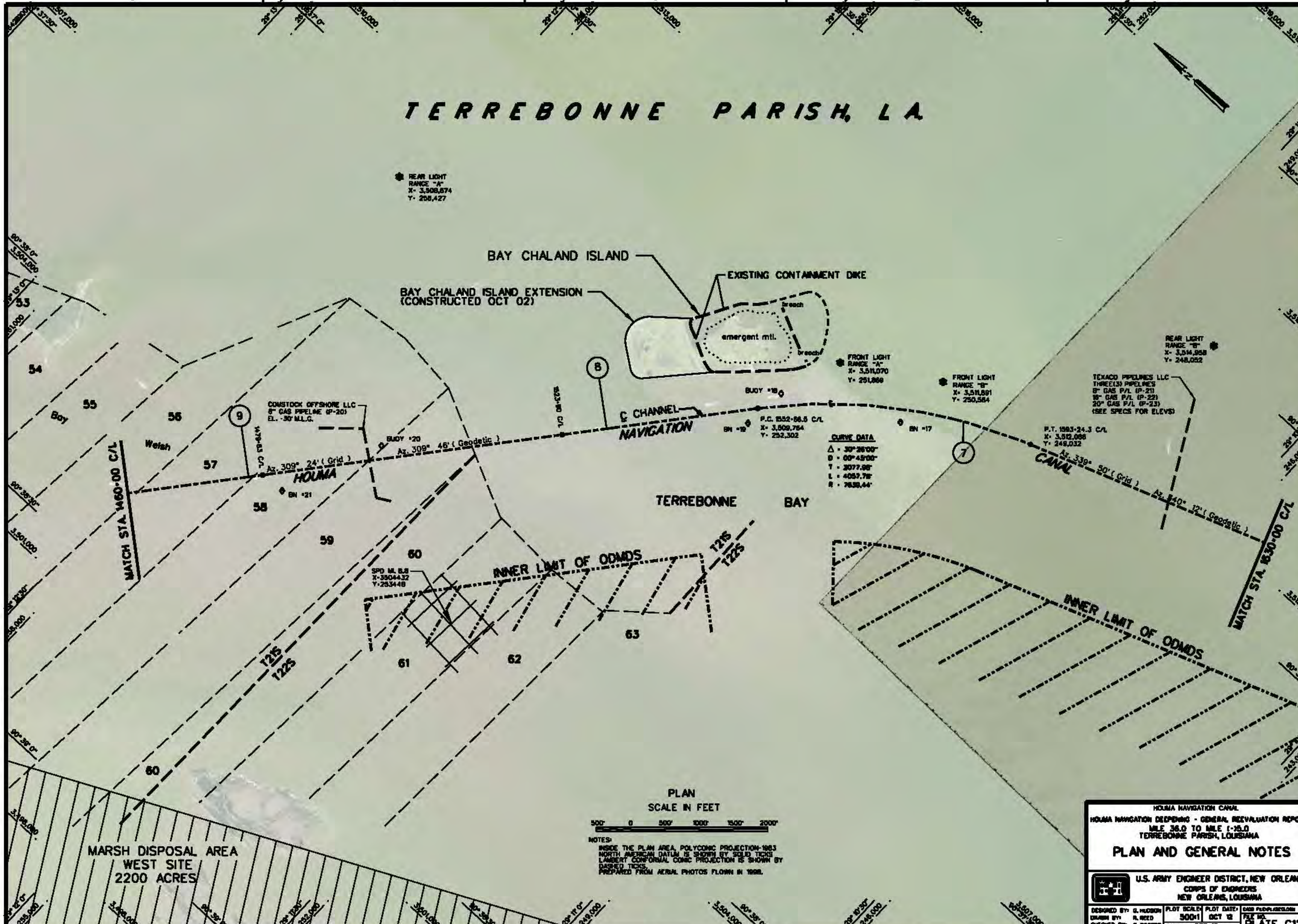


TERREBONNE PARISH, LA.
HOUMA NAVIGATION CANAL
CHANNEL R/W
MATCH STA. 1060+00 B/L
MATCH STA. 1251+67 B/L
MATCH STA. 1290+00 C/L
FACILITY (TO BE REMOVED)
WILLIAMS GAS P/L CO. 6" GAS P/L (P-10) EL. -23' MLG
2-2" FLOWLINES PIONEER NAT RES (TO BE REMOVED)
FACILITIES (TO BE REMOVED)
10" GAS P/L WILLIAMS GAS P/L CO.
SITE 21
Deep Saline
Bayou Sale
Bayou Cocodrie
R16E R17E
20S 17E 21S 17E
EARTHEN DIKES
LEGEND:
ROCK RETENTION
ROCK FORESHORE PROTECTION
PLAN
SCALE IN FEET
500' 0 500' 1000' 1500' 2000'
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1927 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS.
PREPARED FROM AERIAL PHOTOS FLOWN IN 1998.
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
PLAN AND GENERAL NOTES
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
DESIGNED BY: G. HUDSON
DRAWN BY: R. REED
CHECKED BY: G. ROGERS
PLOT SCALE: 500:1
PLOT DATE: OCT 12
DATE: OCT 12
FILE NO. PLATE C9
PLATE C9


TERREBONNE PARISH, LA.
Little Cocodrie Bayou
Tambour Cutoff
LEGEND:
ROCK RETENTION
ROCK FORESHORE PROTECTION
BAYOU PETIT CAILLOU
BAY LONG
BAY WELSH
BAY COUTEAU
HOUMA NAVIGATION CANAL
CHANNEL R/W
MATCH STA. 1251+67 B/L
MATCH STA. 1290+00 C/L
MATCH STA. 1460+00 C/L
APPROX. LIMIT OF WORK
C/L STA. 1422+64
COE BASELINE
SITE 24
ACCESS
Oak Bayou
EARTHEN DIKES
LUNG
MARSH DISPOSAL AREA
WEST SITE
2200 ACRES
TEXACO SLIP AND WELL
SOUTHERN NATURAL GAS 6" GAS PIPELINE (P-14) EL. -27.0' M.L.G.
TENN. GAS P/L CO. 24" GAS P/L (P-10) EL. -20.0' M.L.G.
TENN. GAS P/L CO. 36" GAS P/L (P-13) EL. -30.0' M.L.G.
TENN. GAS P/L CO. 26" GAS P/L (P-12) EL. -24.0' M.L.G.
CURVE DATA
PLAN
SCALE IN FEET
500' 0 500' 1000' 1500' 2000'
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS. LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS.
PREPARED FROM AERIAL PHOTOS FLOWN IN 1998.
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)15.0
TERREBONNE PARISH, LOUISIANA
PLAN AND GENERAL NOTES
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
DESIGNED BY: G. HUDSON
DRAWN BY: R. REED
CHECKED BY: B. ROGERS
PLOT SCALE: 500:1
PLOT DATE: OCT 12
DATE: OCT 12
PLATE C10
PLATE C10

TERREBONNE PARISH, LA.
HOUMA NAVIGATION CANAL
CHANNEL R/W
COE BASELINE
MATCH STA. 1460+00 C/L
APPROX. LIMIT OF WORK C/L STA. 1422+64
INNER LIMIT OF ODMDS
TEXACO SLIP AND WELL
TEXACO, INC. 2-1/2" OIL LINE (P-15) 2-1/2" & 3" GAS LINES (P16 & 17) EL. -23.0' M.L.G.
TEXACO, INC. 2-1/2" GAS LINES (P-18) EL. -23.0' M.L.G.
CHEVRON-TEXACO, INC. 3" GAS LINE (P-19) EL. -23.0' M.L.G.
COMSTOCK OFFSHORE LLC 8" GAS PIPELINE (P-20) EL. -30' M.L.G.
CURVE DATA
BAY COUTEAU
LUNG MARSH DISPOSAL AREA WEST SITE 2200 ACRES
PLAN
SCALE IN FEET
500' 0 500' 1000' 1500' 2000'
NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS.
PREPARED FROM AERIAL PHOTOS FLOWN IN 1998.
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
PLAN AND GENERAL NOTES
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA
DESIGNED BY: G. HUDSON
DRAWN BY: R. REED
CHECKED BY: G. ROGERS
PLOT SCALE: 500:1
PLOT DATE: OCT 12
DATE: OCT 12
FILE NO. PLATE C11


PLATE C11



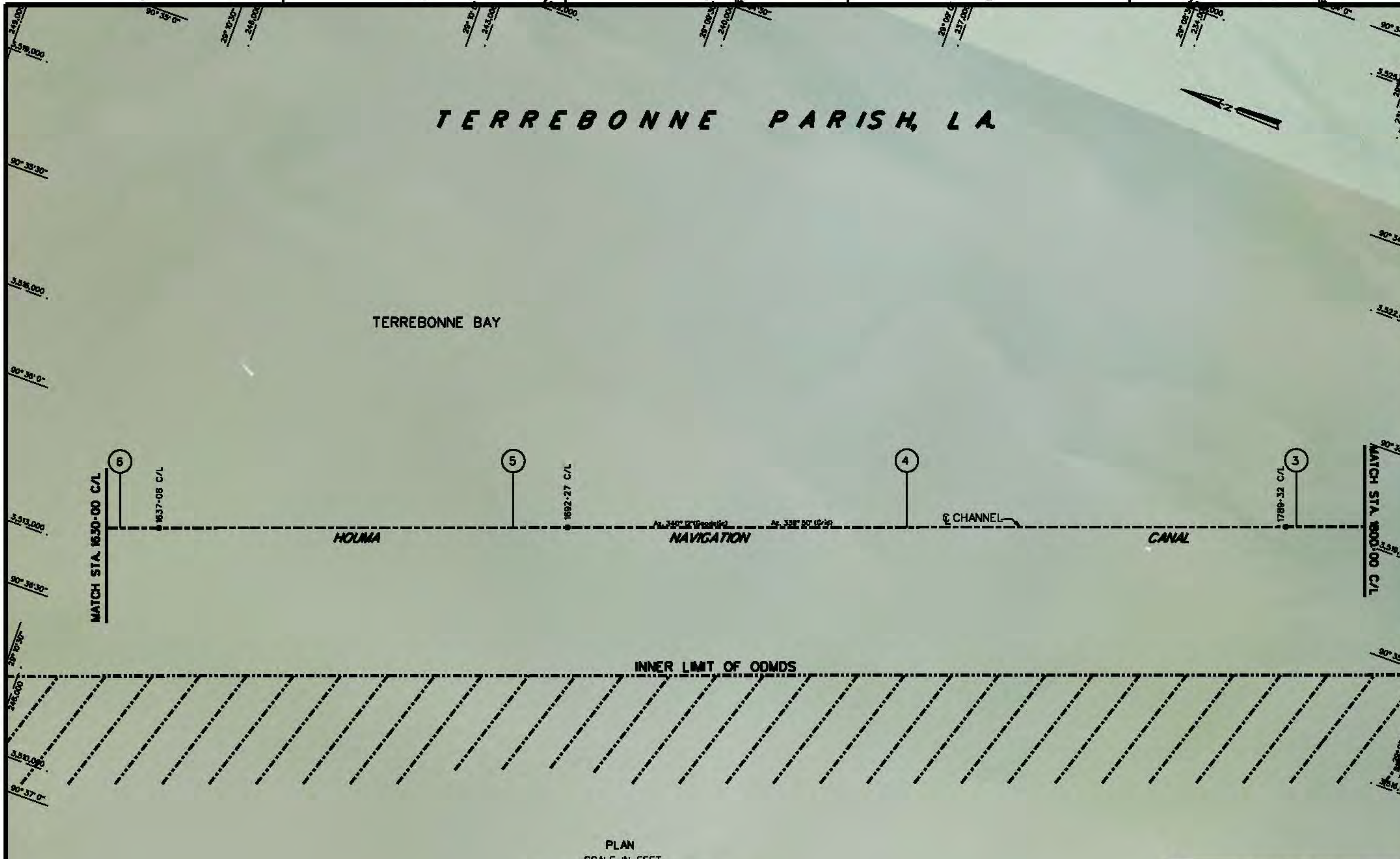

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)6.0
TERREBONNE PARISH, LOUISIANA

PLAN AND GENERAL NOTES

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

| | | | |
|---|---|---|---|
| DESIGNED BY: G. HUDSON<br>DRAWN BY: R. REED<br>CHECKED BY: E. ROGERS | PLOT SCALE: 500:1 | PLOT DATE: OCT 12 | FILE NO. PLATE C12 |
| | DATE: OCT 12 | | |

PLATE C12



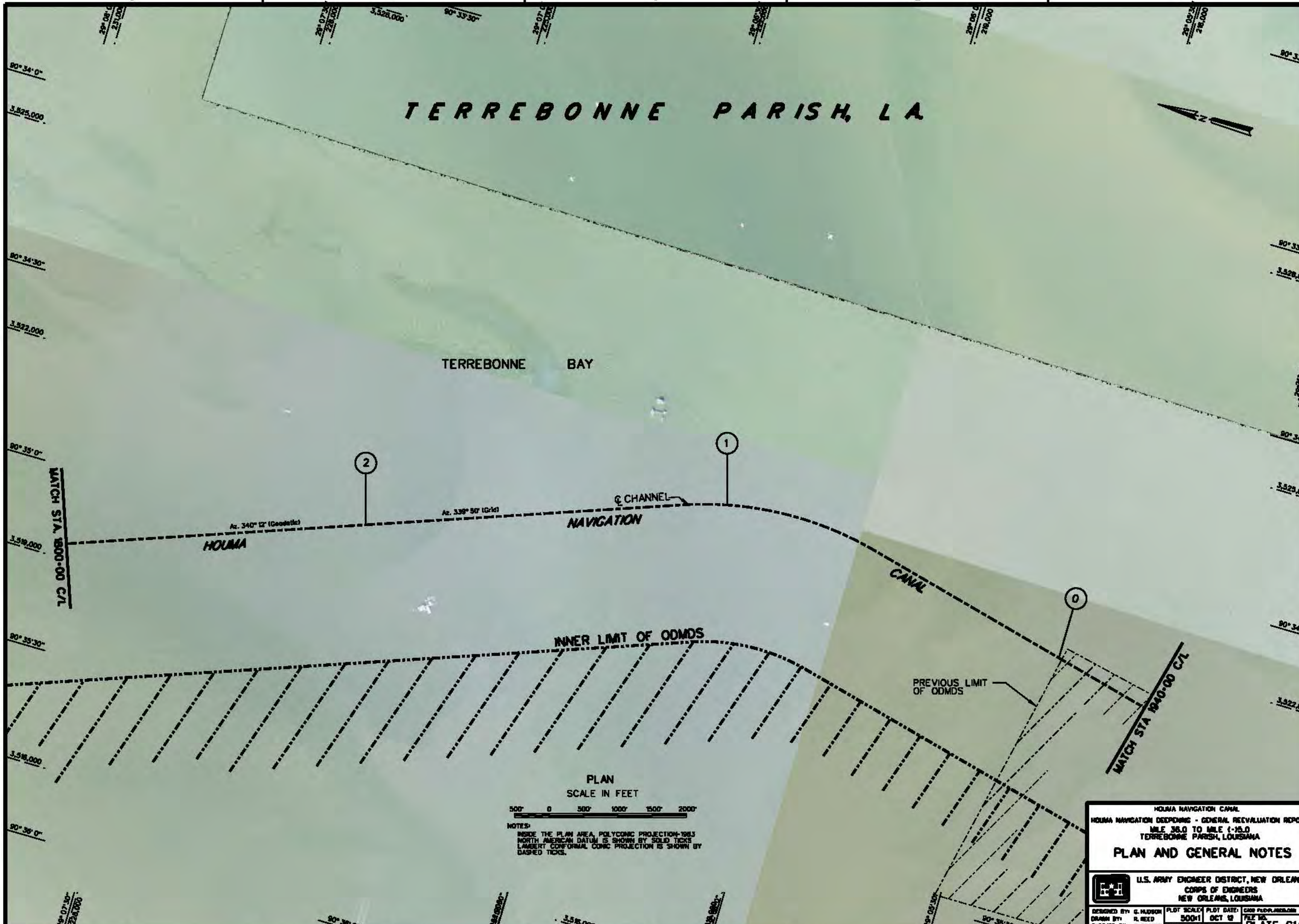

NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS.

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

## PLAN AND GENERAL NOTES

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

| | | | |
|---|---|---|---|
| DESIGNED BY: G. HUDSON | PLOT SCALE: 500:1 | PLOT DATE: OCT 12 | CADD FILE: |
| DRAWN BY: R. REED | | | FILE NO. PLATE C13 |
| CHECKED BY: G. ROGERS | DATE: OCT 12 | | |




HOUMA NAVIGATION CANAL

HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT

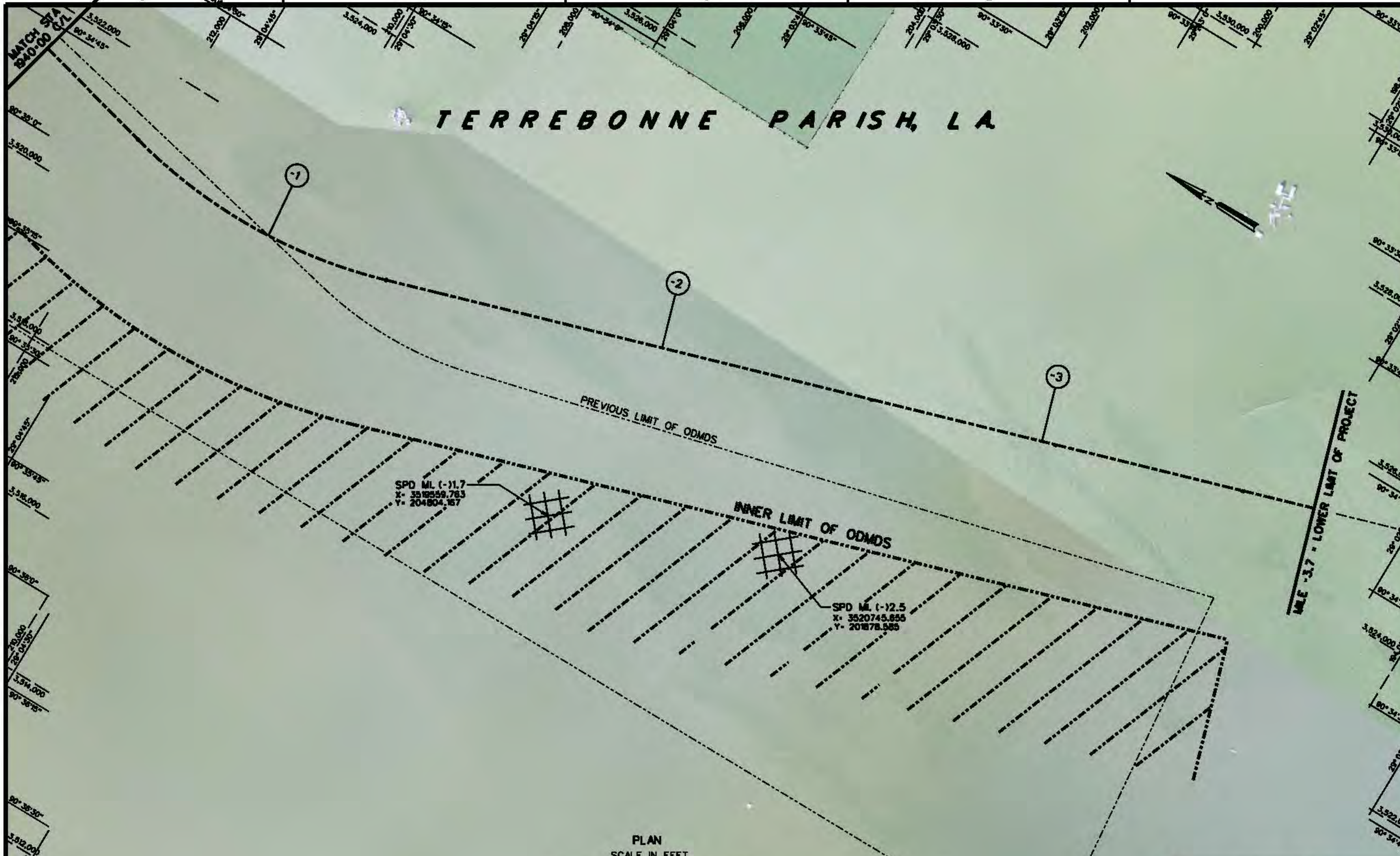
MILE 36.0 TO MILE (-)5.0

TERREBONNE PARISH, LOUISIANA

# PLAN AND GENERAL NOTES

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

| | | | |
|---|---|---|---|
| DESIGNED BY: G. HUDSON<br>DRAWN BY: R. REED<br>CHECKED BY: G. ROGERS | PLOT SCALE: 500:1<br>DATE: OCT 12 | PLOT DATE: OCT 12 | FILE NO. PLATE C14 |




PLAN
SCALE IN FEET
500' 0 500' 1000' 1500' 2000'

NOTES:
INSIDE THE PLAN AREA, POLYCONIC PROJECTION-1983 NORTH AMERICAN DATUM IS SHOWN BY SOLID TICKS LAMBERT CONFORMAL CONIC PROJECTION IS SHOWN BY DASHED TICKS.

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

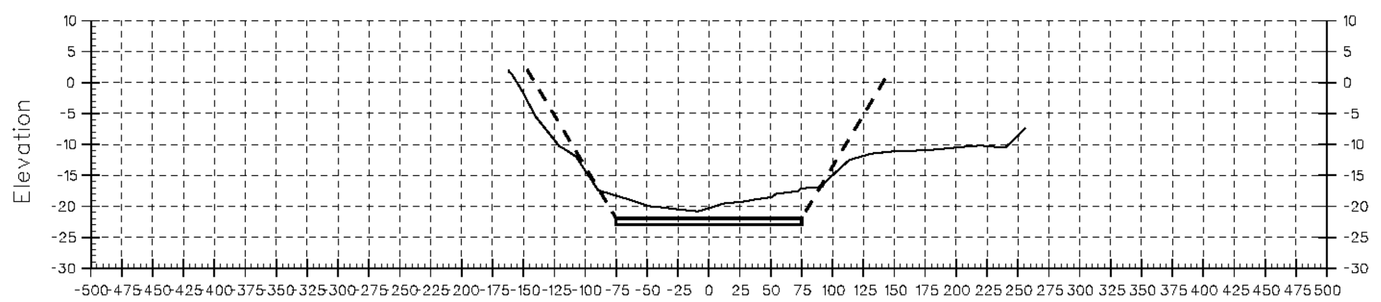
PLAN AND GENERAL NOTES

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

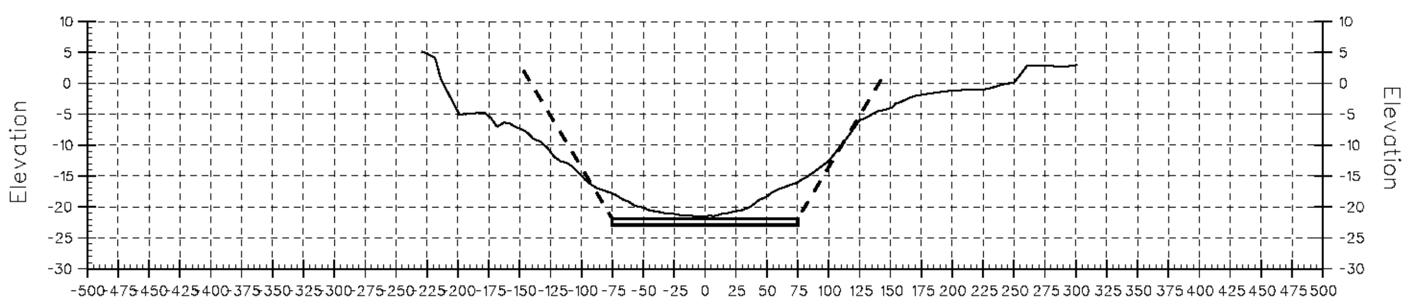
| | | | |
|---|---|---|---|
| DESIGNED BY: G. HUDSON<br>DRAWN BY: R. REED<br>CHECKED BY: G. ROGERS | PLOT SCALE: 500:1<br>DATE: OCT 12 | PLOT DATE: OCT 12 | FILE NO.<br>PLATE C15 |

EAST BANK

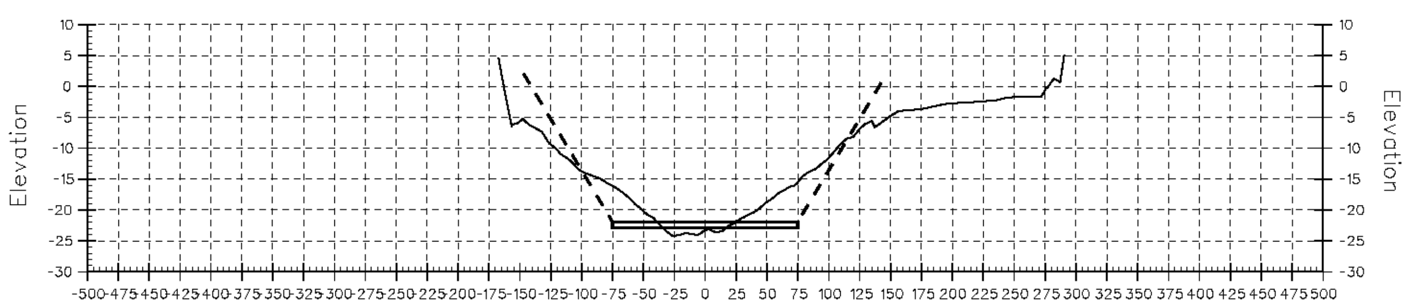
WEST BANK



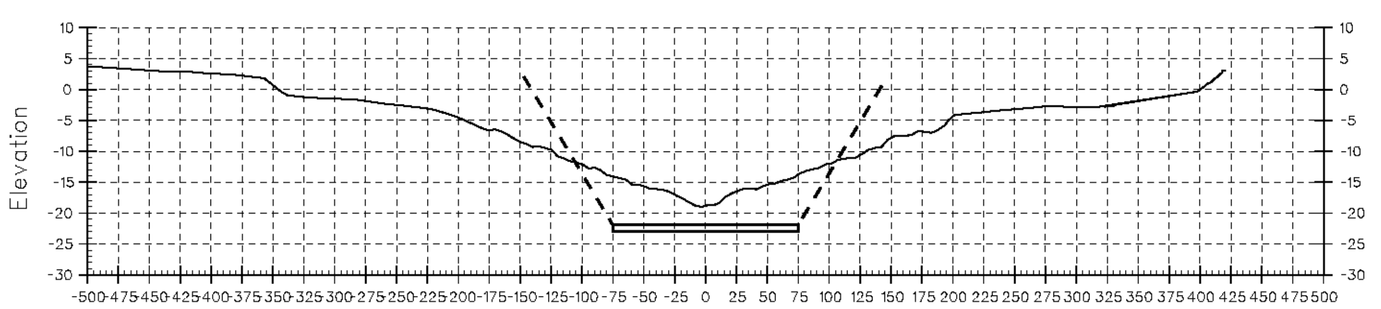
65+00



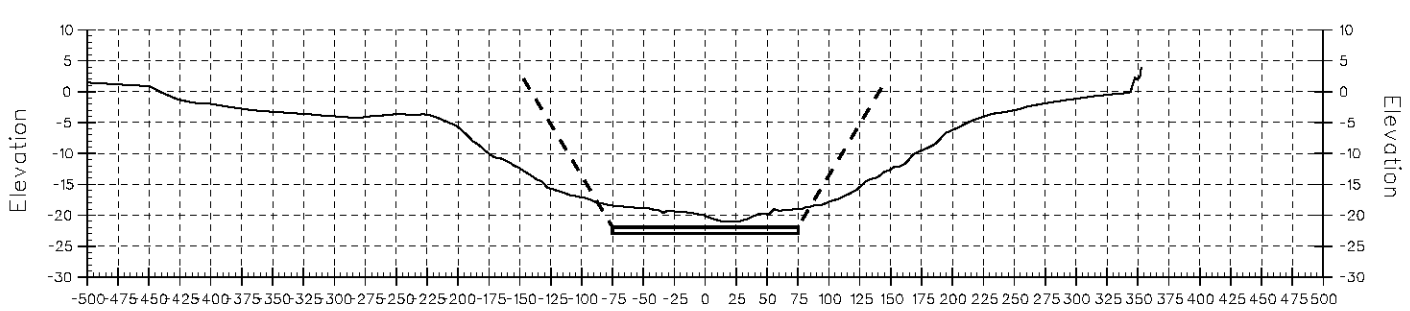
155+00



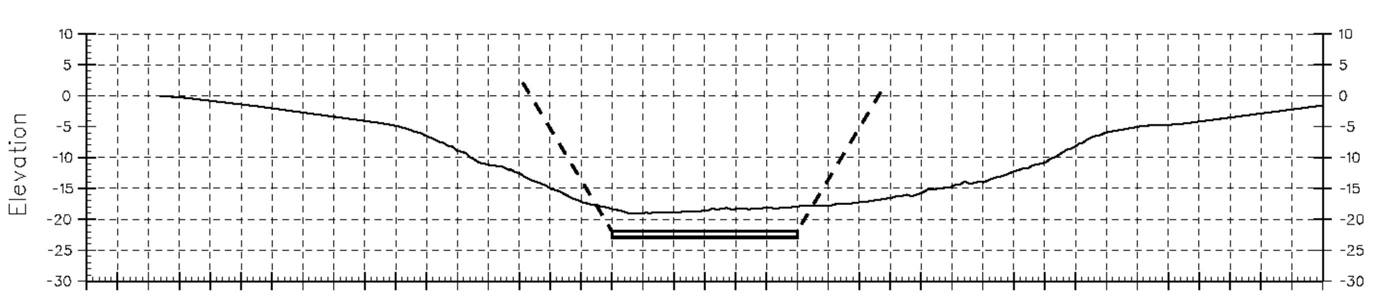
385+00



670+00



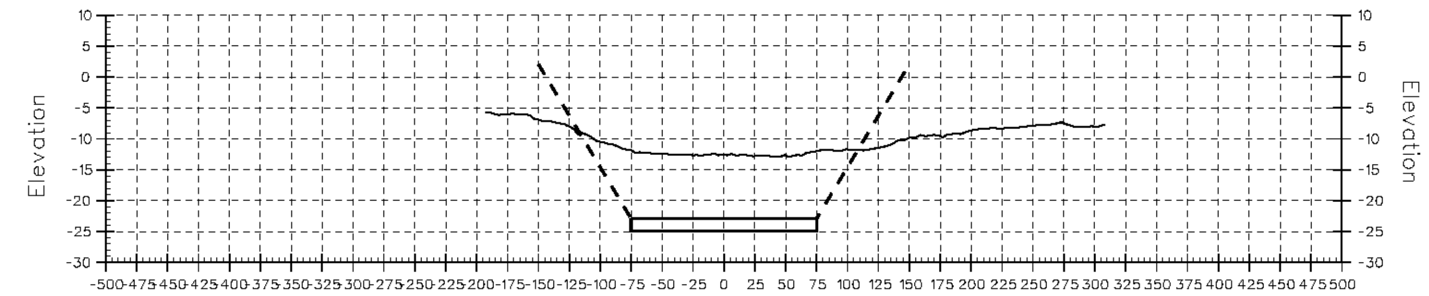
925+00



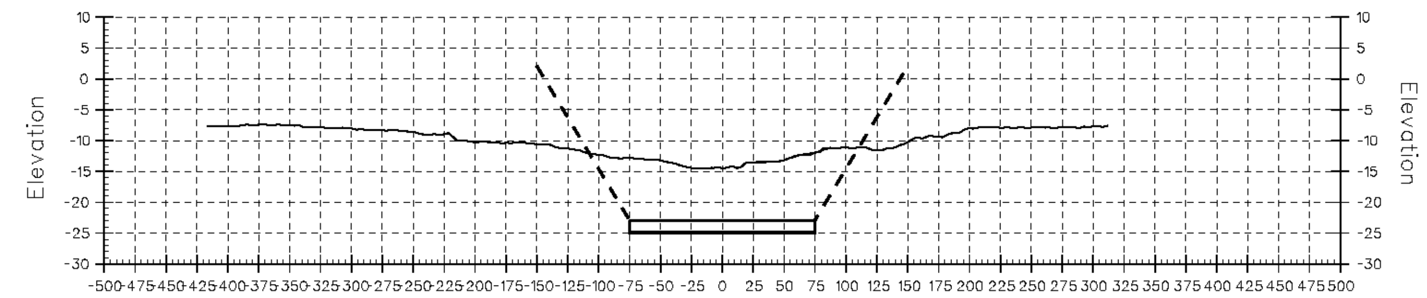
1210+00

EAST BANK

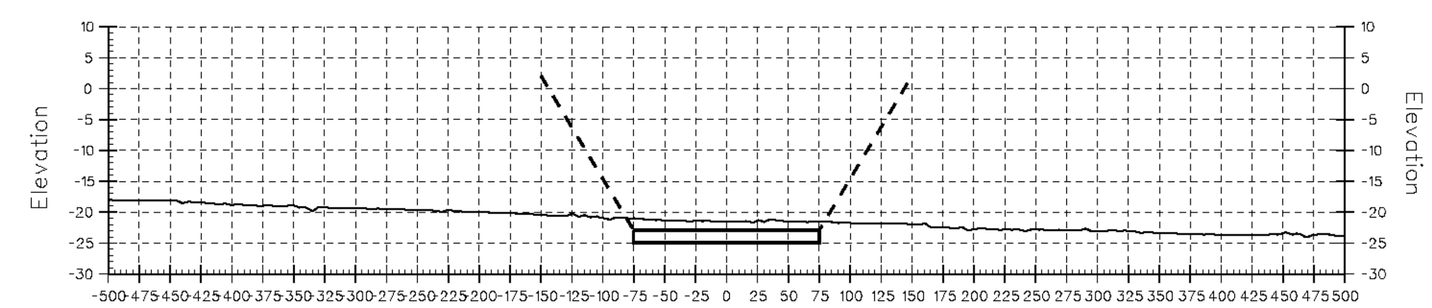
WEST BANK



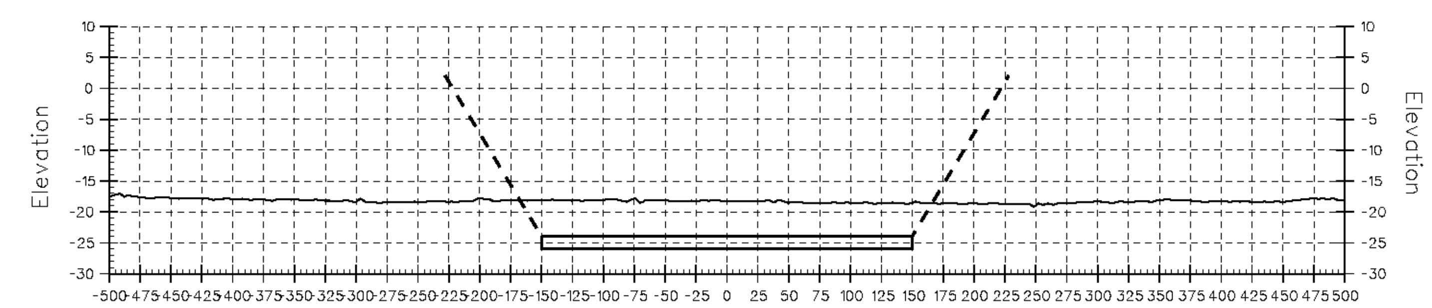
1460+00



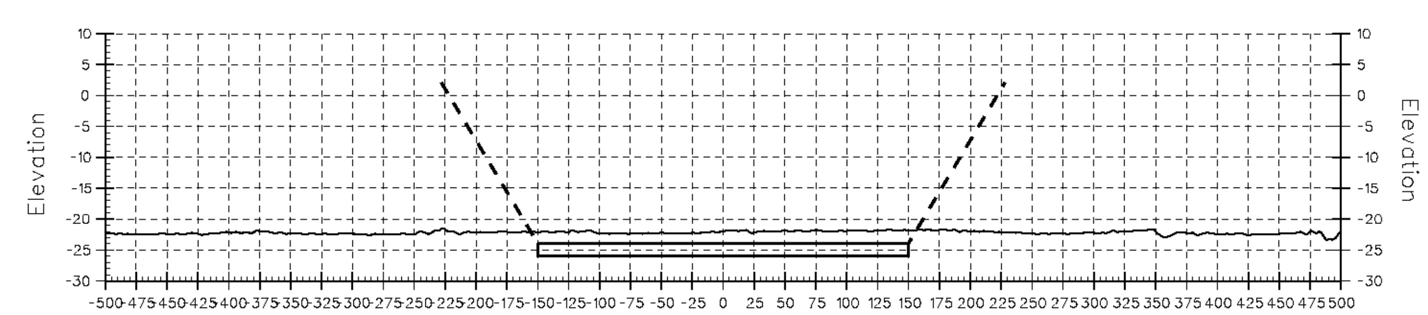
1630+00



1935+00



2040+00



2150+00

NOTES:

1. ELEVATIONS SHOWN REFLECT NAVD88 DATUM.
2. THEORETICAL CHANNEL SIDE SLOPES ARE 1V ON 3H.
3. SIDE SLOPES ARE INCLUDED IN THEORETICAL SECTION WHICH INCLUDES ADVANCE MAINTENENCE.
4. OVERDEPTH IS INDICATED BY THE BOTTOM BOX CUT SECTION.

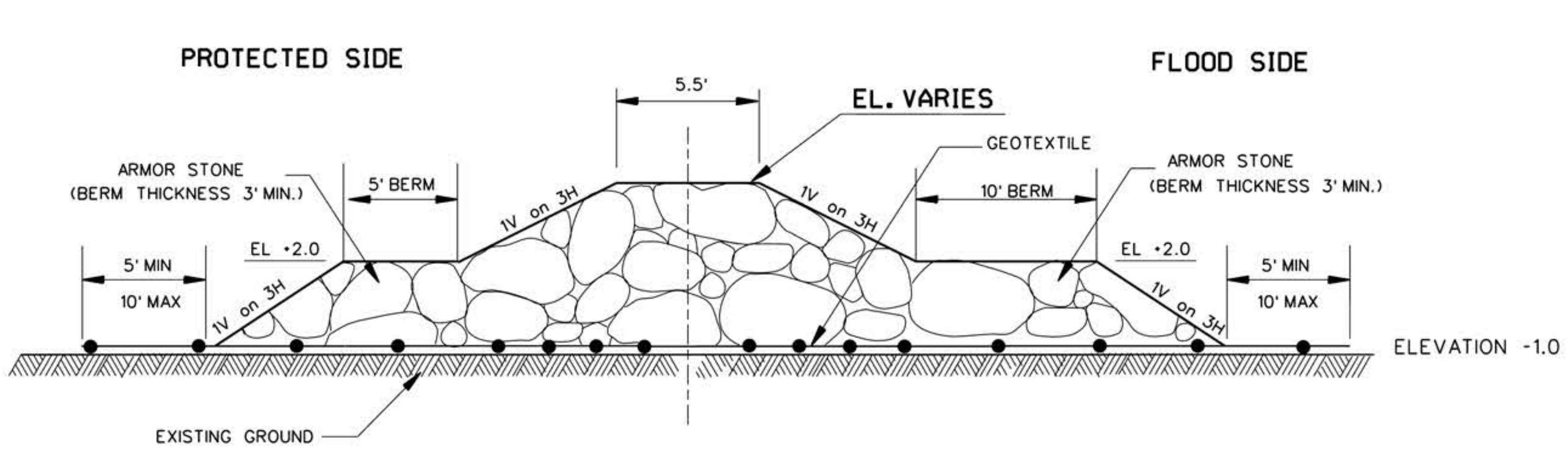
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

# TYPICAL SECTIONS -20' NAVD88 PROJECT

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

| DESIGNED BY: T.DORCEY<br>DRAWN BY: TD/RB<br>CHECKED BY: R.BROUSSARD | PLOT SCALE: 500:1 | PLOT DATE: MAR 10 | CADD FILE: HO20083.DGN |
|---|---|---|---|
| | DATE: MAR 10 | | FILE NO. |

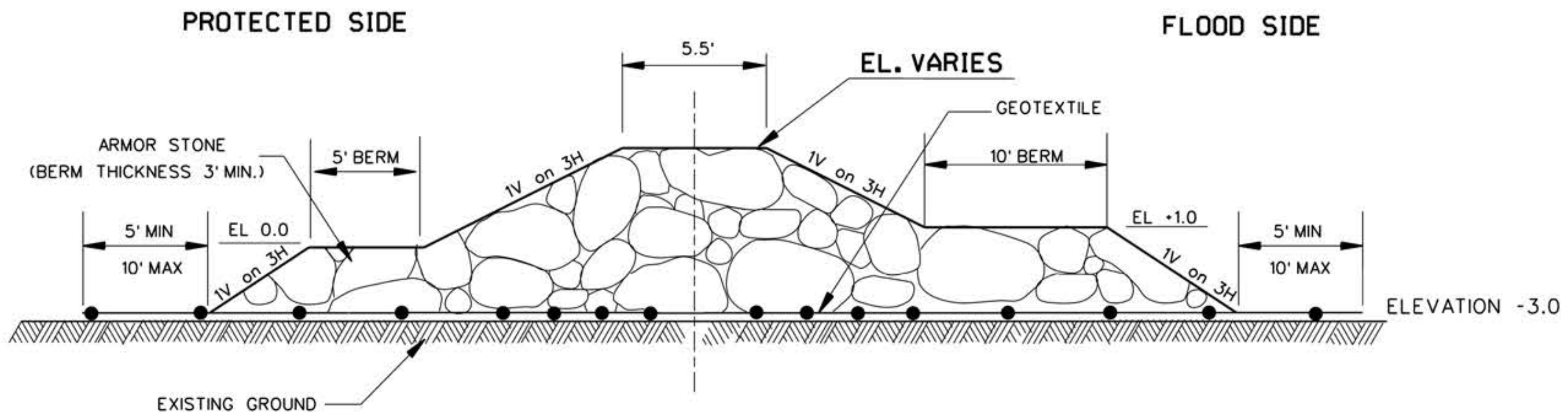
PLATE C16




TYPICAL DISPOSAL RETENTION AND EROSION CONTROL DIKE
IMAGE 1

HNC Mile 20.6 to Mile 20.1 (EB); HNC Mile 17.1 to Mile 16.9 (WB);
HNC Mile 16.7 to Mile 16.5 (EB); HNC Mile 16.1 to Miile 15.9 (EB)

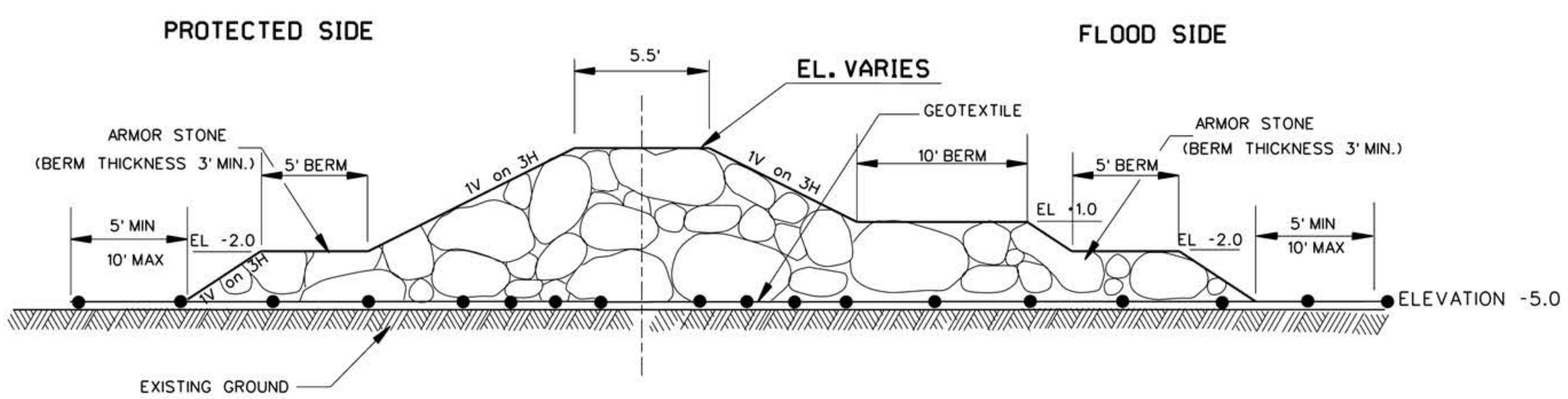
NOT TO SCALE




TYPICAL DISPOSAL RETENTION AND EROSION CONTROL DIKE
IMAGE 2

HNC Mile 18.7 to Mile 18.2 (EB); HNC Mile 15.6 to Mile 14.8 (WB);
HNC Mile 14.3 to Mile 14.1 (WB)

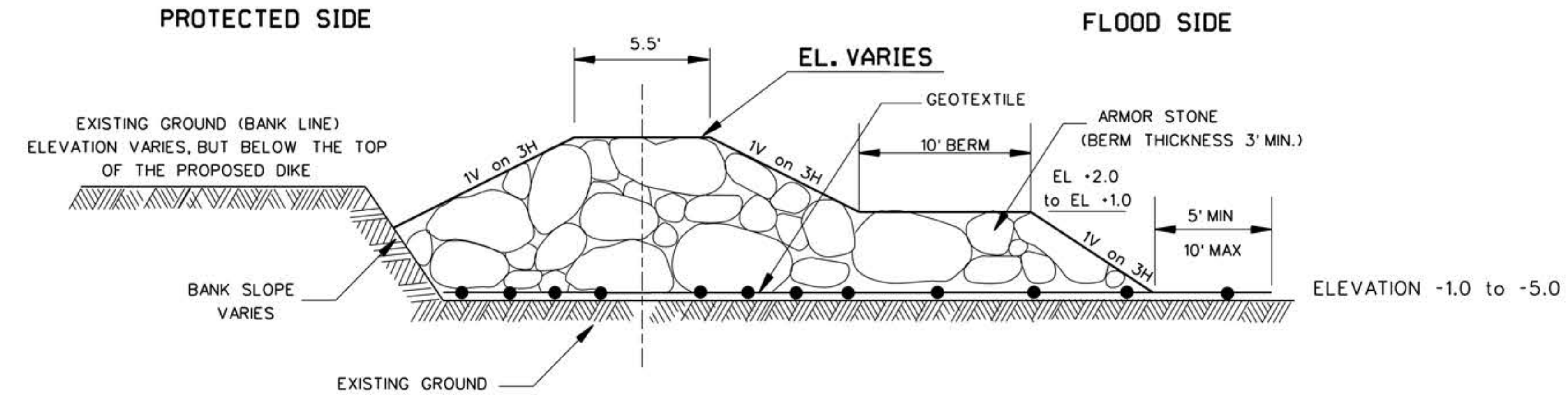
NOT TO SCALE




TYPICAL DISPOSAL RETENTION AND EROSION CONTROL DIKE
IMAGE 3

HNC Mile 14.8 to Mile 14.3 (WB)

NOT TO SCALE

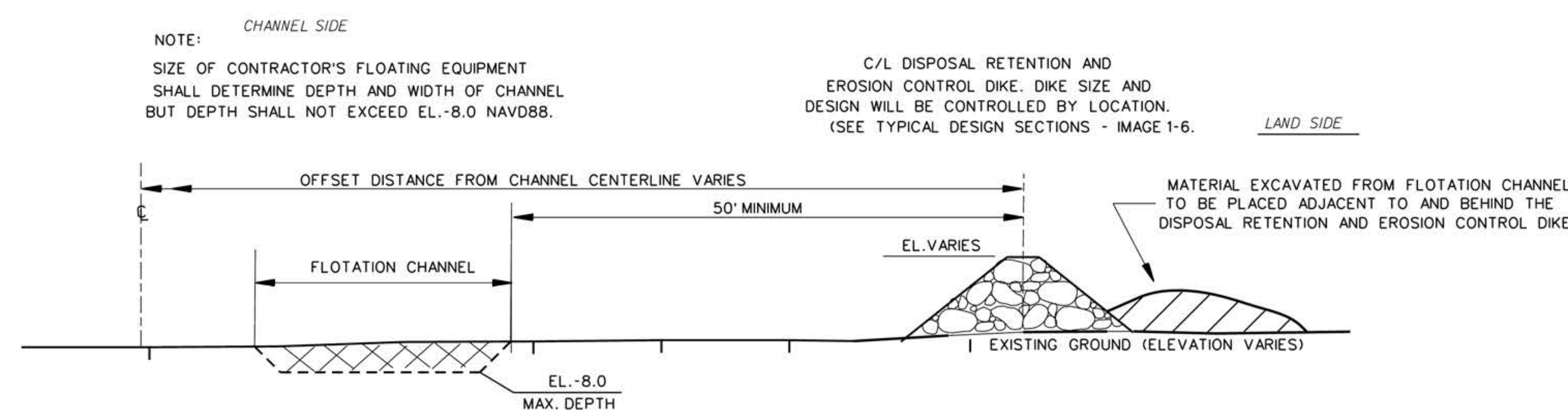


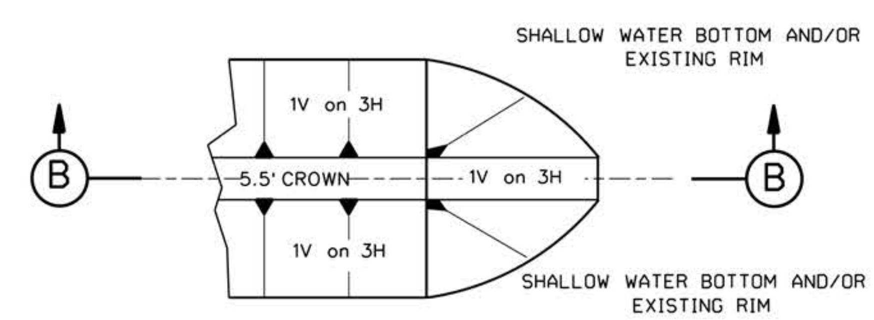

TYPICAL DISPOSAL RETENTION AND EROSION CONTROL DIKE
IMAGE 4

HNC Mile 26.1 to Mile 23.7 (WB); HNC Mile 22.8 to Mile 20.7 (WB)
HNC Mile 19.1 to Mile 17.8 (WB); HNC Mile 17.6 to Mile 17.1 (WB)
HNC Mile 16.9 to Mile 16.6 (WB); HNC Mile 13.1 to Mile 12.4 (WB)
HNC Mile 12.4 to Mile 11.9 (WB)

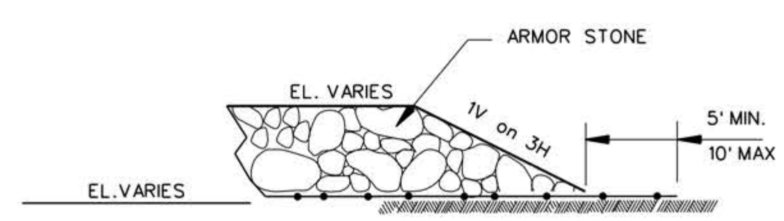
HNC Mile 23.6 to Mile 22.0 (EB); HNC Mile 20.1 to Mile 19.7 (EB)
HNC Mile 19.2 to Mile 18.7 (EB); HNC Mile 18.2 to Mile 17.7 (EB)
HNC Mile 16.9 to Mile 16.7 (EB); HNC Mile 16.5 to Mile 16.1 (EB)
HNC Mile 15.9 to Mile 13.3 (EB); HNC Mile 12.6 to Mile 12.3 (EB)

NOT TO SCALE




PLAN




SECTION B

END DETAIL 1

NOT TO SCALE

GENERAL NOTES:

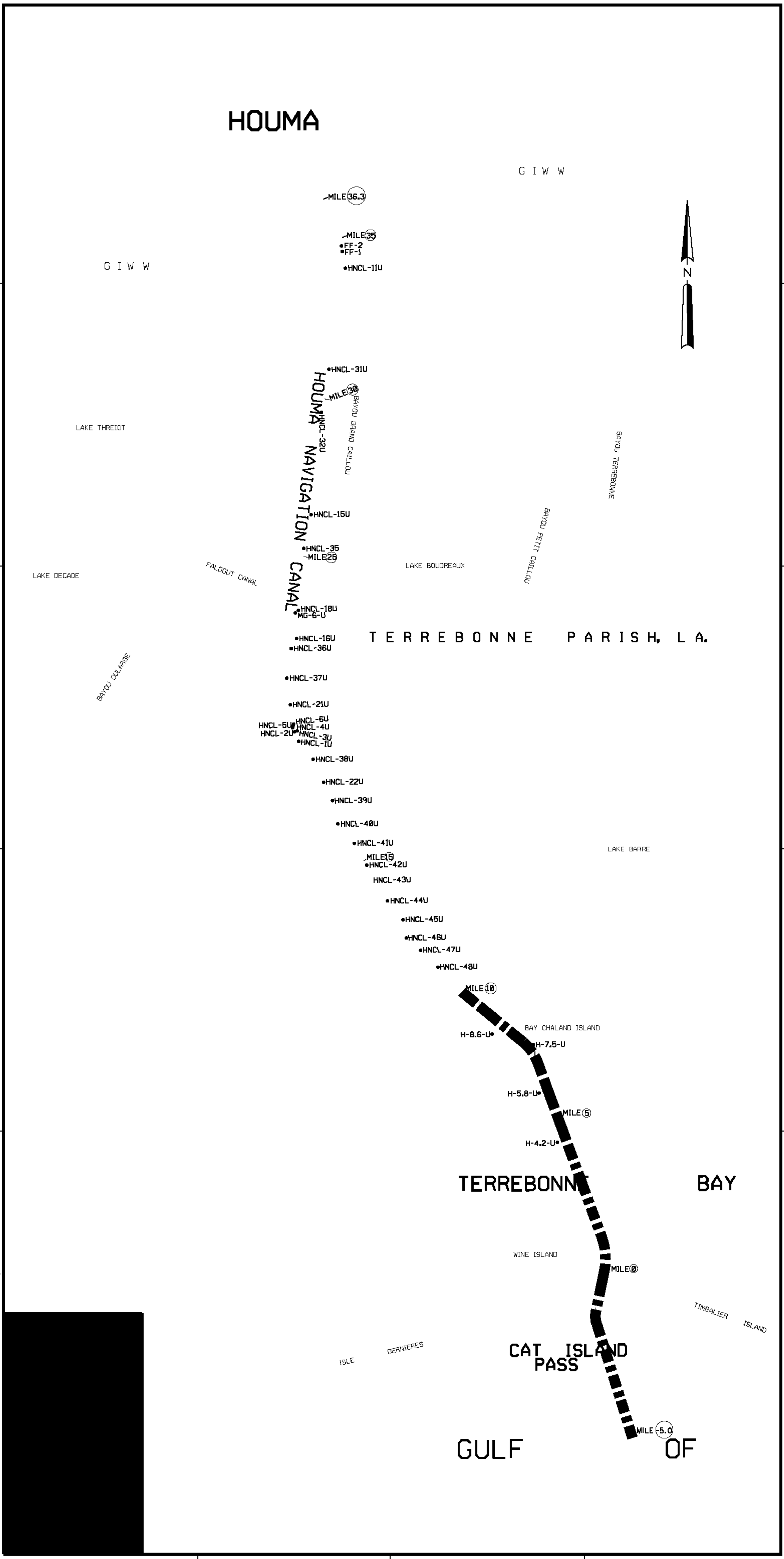
1. ALL ELEVATIONS ARE IN FEET AND REFER TO NAVD88 (POST 83 EPOCH).
2. THE CROWN ELEVATION FOR THE EROSION CONTROL DIKE IS DESIGNED AT +5.0' NAVD88. THE CROWN ELEVATION FOR THE DISPOSAL RETENTION DIKE IS DESIGNED AT +6.0' NAVD88. (NOTE: THE CROWN OF DISPOSAL RETENTION AND EROSION CONTROL DIKE WILL BE OVERBUILT TO COMPENSATE FOR ANTICIPATED SETTLEMENT OVER A 2-YEAR PERIOD.
3. GEOTEXTILE FABRIC WILL BE PLACED UNDER THE ENTIRE FOOTPRINT OF THE DIKES PLUS 10-FEET (MAX). ALL SLOPES ARE 1V ON 3H. THE PROTECTED SIDE BERM IS 5' WIDE AND THE CHANNEL SIDE BERM IS 10' WIDE. THE BERMS WILL REQUIRE A MINIMUM 3-FOOT THICKNESS.
4. FOR IMAGE 4 , THE PROTECTED SIDE BERM WILL BE ELIMINATED. WHERE THE BOTTOM ELEVATION OF THE DIKE IS BELOW -1.0', THE MINIMUM ELEVATION FOR THE CHANNEL SIDE BERM IS +1.0'.
5. THE FLOTATION CHANNEL (SLOPE INTERSECTION WITH NATURAL GROUND) SHALL NOT BE CONSTRUCTED ANY CLOSER THAN 50-FEET FROM THE CENTERLINE OF THE DIKE.
6. EB=EAST BANK. WB=WEST BANK.

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL EVALUATION REPORT
MILE 36.0 to MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

**THEORETICAL SECTIONS, DETAILS AND GENERAL NOTES**

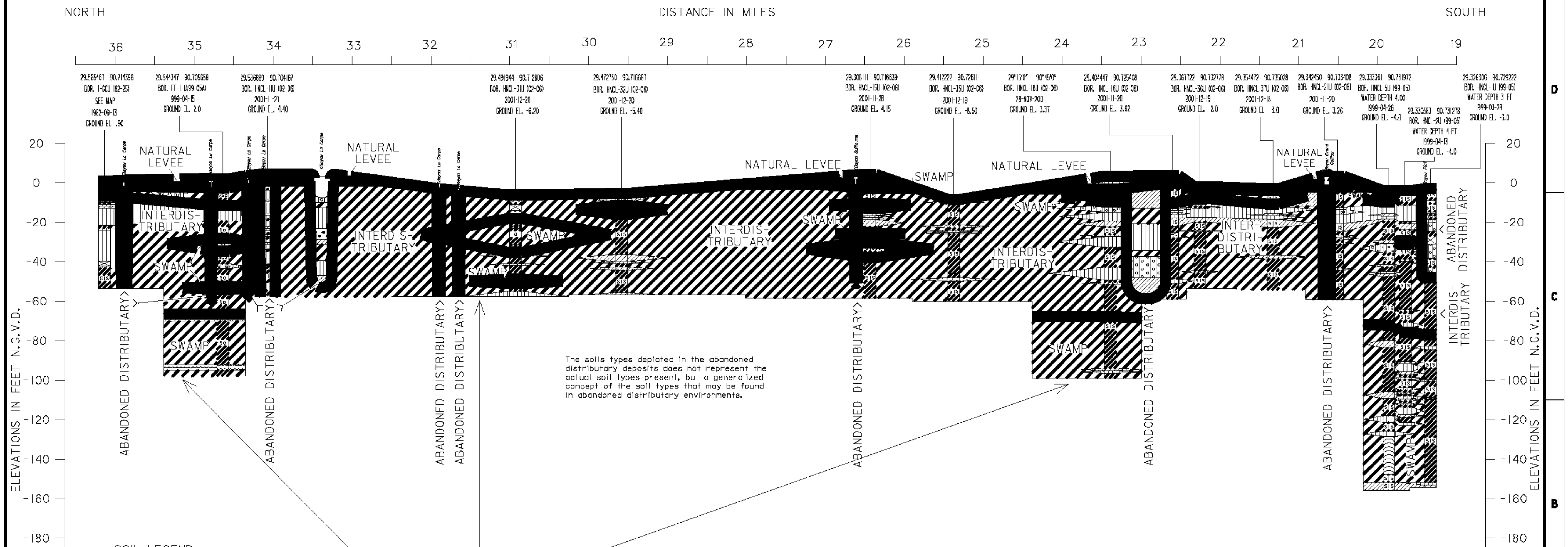
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA

| | | |
|---|---|---|
| DESIGNED BY: TD<br>DRAWN BY: TD<br>CHECKED BY: RB | PLOT SCALE: 400:1 | PLOT DATE: MARCH 06 |
| | DATE: X | CADD FILE: X<br>FILE NO. X |



HOUMA
G I W W
G I W W
MILE 36.3
MILE 35
FF-2
FF-1
HNCL-11U
HNCL-31U
MILE 30
HOUMA NAVIGATION CANAL
HNCL-32U
BAYOU GRAND CAILLOU
LAKE THREIOT
BAYOU TERREBONNE
HNCL-15U
BAYOU PETIT CAILLOU
HNCL-35
MILE 25
LAKE BOUDREAUX
LAKE DECADE
FALGOUT CANAL
HNCL-18U
MG-6-U
HNCL-16U
HNCL-36U
TERREBONNE PARISH, LA.
BAYOU DULARGE
HNCL-37U
HNCL-21U
HNCL-5U
HNCL-2U
HNCL-6U
HNCL-4U
HNCL-3U
HNCL-1U
HNCL-38U
HNCL-22U
HNCL-39U
HNCL-40U
HNCL-41U
LAKE BARRE
MILE 15
HNCL-42U
HNCL-43U
HNCL-44U
HNCL-45U
HNCL-46U
HNCL-47U
HNCL-48U
MILE 10
BAY CHALAND ISLAND
H-8.6-U
H-7.5-U
H-5.8-U
MILE 5
H-4.2-U
TERREBONNE BAY
WINE ISLAND
MILE 0
TIMBALIER ISLAND
ISLE DERNIERES
CAT ISLAND PASS
MILE -5.0
GULF OF


PLATE G1




SOIL LEGEND

- CH - FAT CLAY
- CL - LEAN CLAY
- OH - ORGANIC CLAY
- PT - PEAT
- ML - SILT
- SM - SILTY SAND
- SP - SAND POORLY-GRADED
- Wd - WOOD
- SI - SHELLS
- NO SAMPLE

HORIZONTAL SCALE IN MILES

NATURAL LEVEE - PREDOMINANTLY FAT AND LEAN CLAYS AND SILTS WITH SOME SAND LAYERS

ABANDONED DISTRIBUTARY - INTERBEDDED LAYERS OF SANDS, SILTS, AND CLAYS

INTERDISTRIBUTARY - INTERBEDDED LAYERS OF FAT AND LEAN CLAYS, SILTS, SILTY SANDS, AND SANDS

SWAMP - PREDOMINANTLY ORGANIC CLAYS, FAT CLAYS, AND PEATS WITH OCCASIONAL SAND AND SILT LAYERS AND WOOD

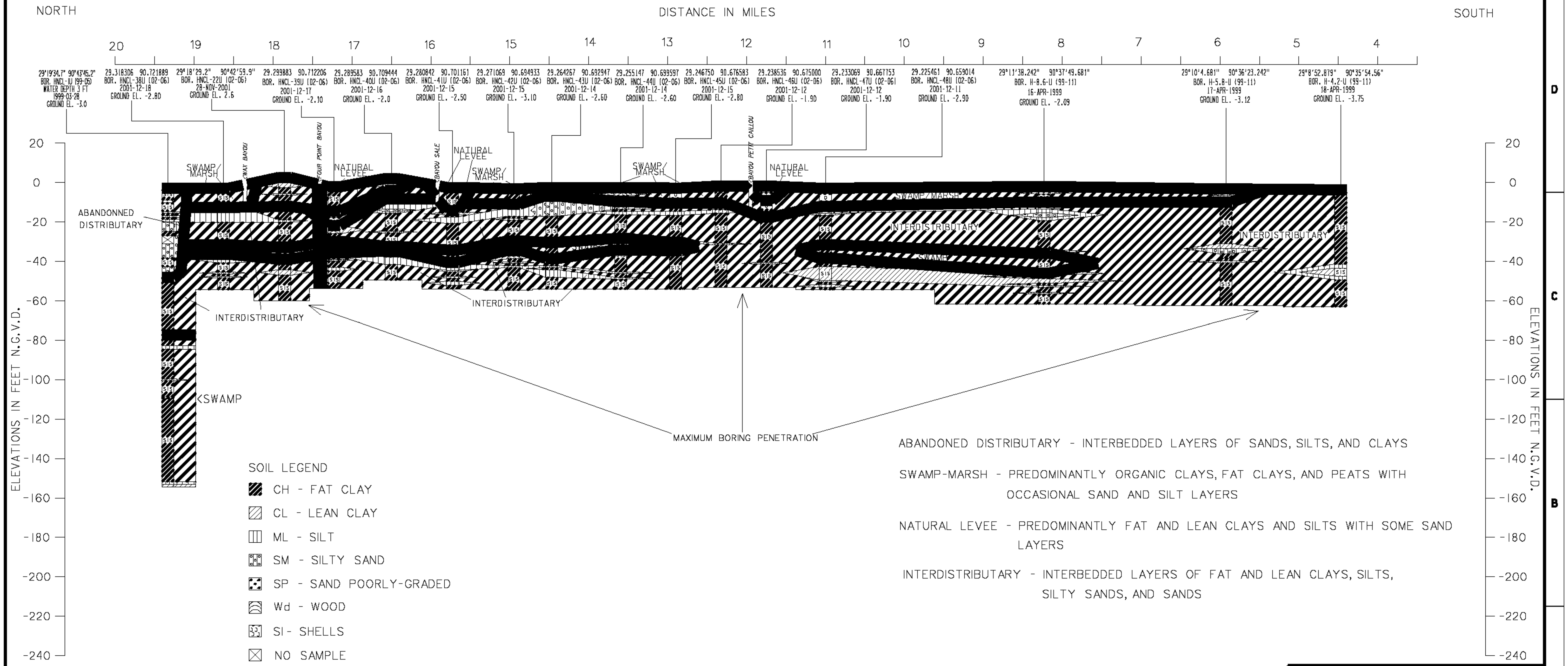
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION - DEEPENING GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

# SOIL AND GEOLOGIC PROFILE

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

DESIGNED BY: T. CREASY
DRAWN BY: T. CREASY
CHECKED BY: D. BRITSCH
PLOT SCALE: 1:20
PLOT DATE: APR 03
CADD FILE: houmnavcanl
FILE NO.
DATE: APR 03

PLATE G2




SOIL LEGEND

- CH - FAT CLAY
- CL - LEAN CLAY
- ML - SILT
- SM - SILTY SAND
- SP - SAND POORLY-GRADED
- Wd - WOOD
- SI - SHELLS
- NO SAMPLE

ABANDONED DISTRIBUTARY - INTERBEDDED LAYERS OF SANDS, SILTS, AND CLAYS

SWAMP-MARSH - PREDOMINANTLY ORGANIC CLAYS, FAT CLAYS, AND PEATS WITH OCCASIONAL SAND AND SILT LAYERS

NATURAL LEVEE - PREDOMINANTLY FAT AND LEAN CLAYS AND SILTS WITH SOME SAND LAYERS

INTERDISTRIBUTARY - INTERBEDDED LAYERS OF FAT AND LEAN CLAYS, SILTS, SILTY SANDS, AND SANDS

HORIZONTAL SCALE IN MILES

½ ¼ 0 ¼ ½

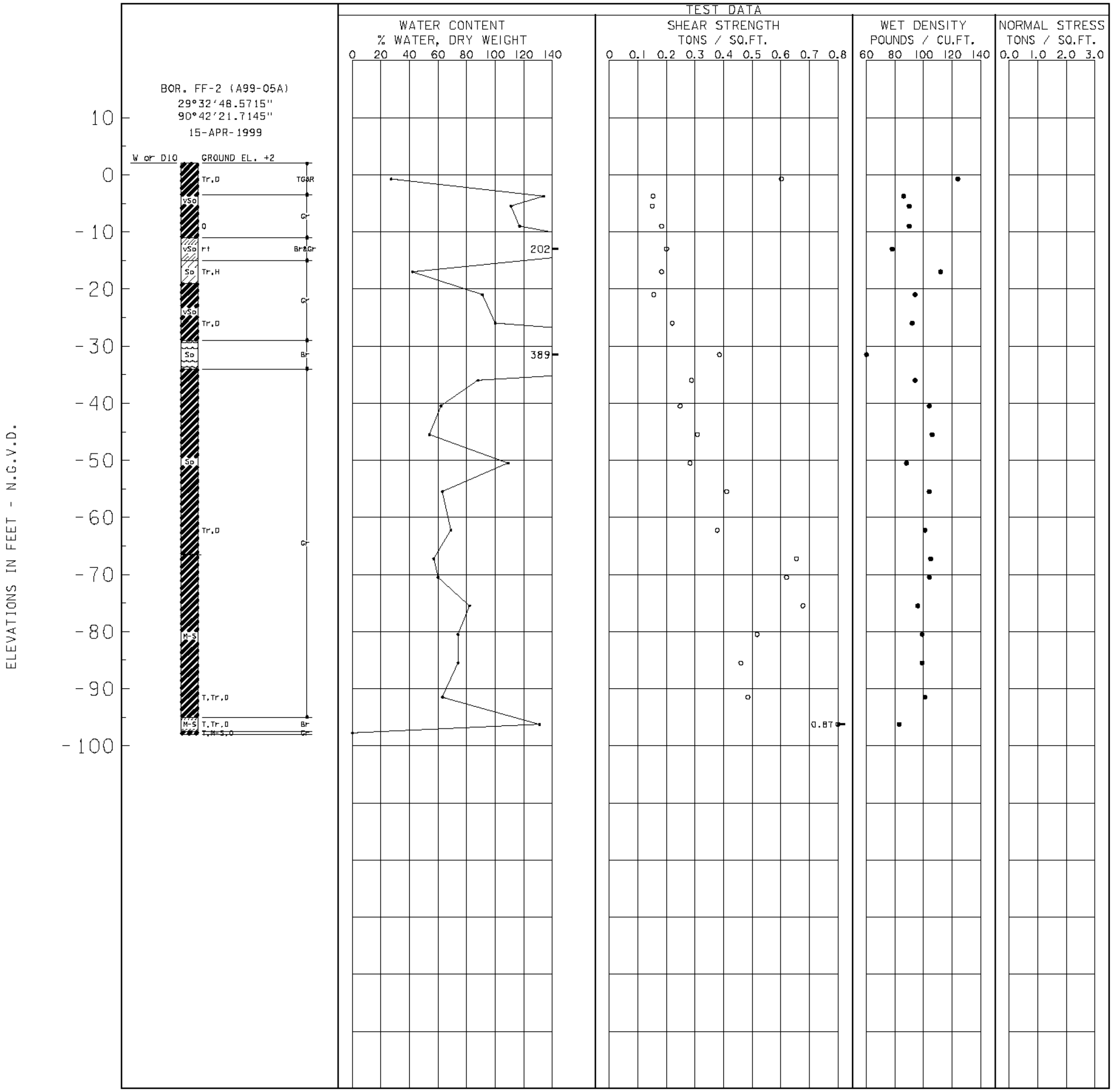
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

# SOIL AND GEOLOGIC PROFILE

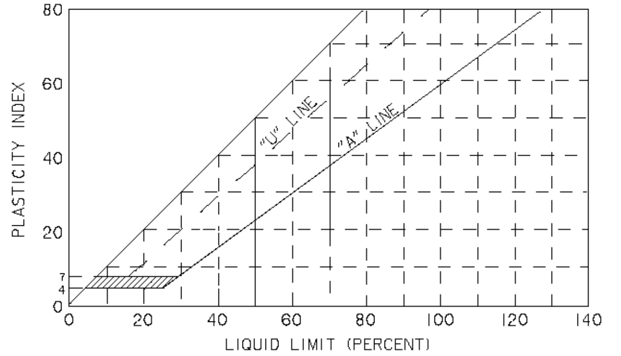
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA

| | | | |
|---|---|---|---|
| DESIGNED BY: D. DILLON<br>DRAWN BY: D. DILLON<br>CHECKED BY: D. BRITSCH | PLOT SCALE: 1:20 | PLOT DATE: APR 03 | CADD FILE: houmnavcan2 |
| | DATE: APR 03 | | FILE NO. |

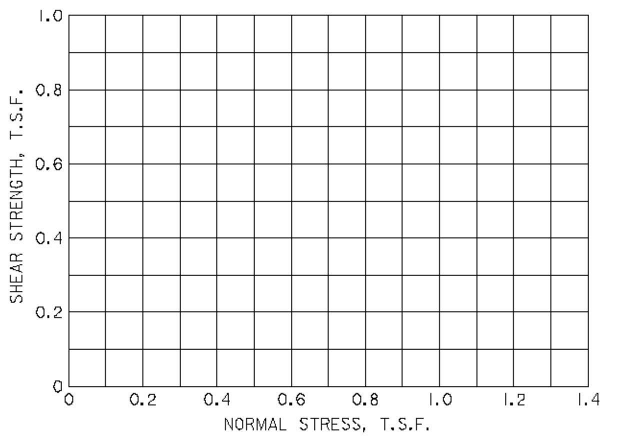
PLATE G3




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
◧ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

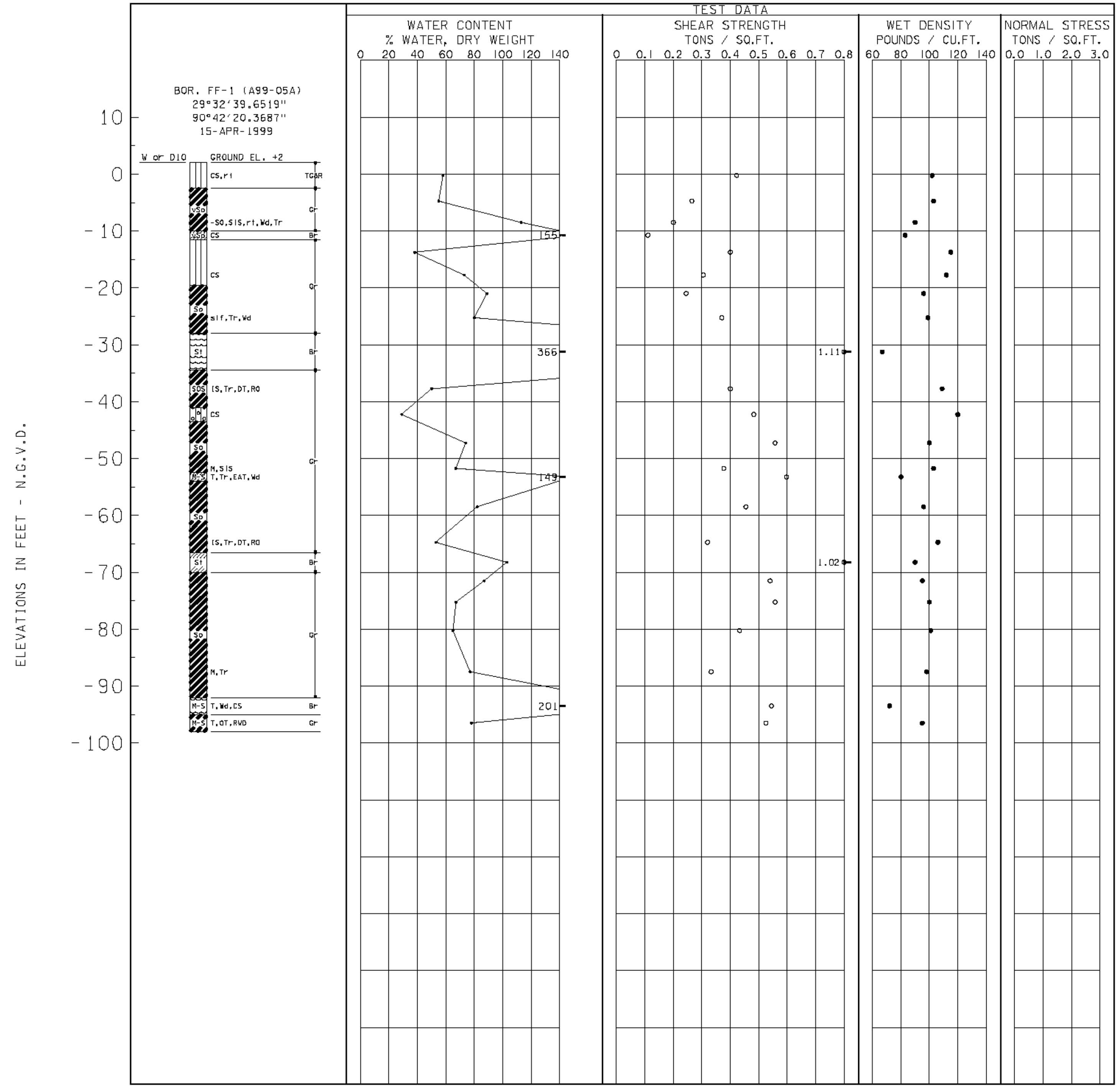
$\omega_P$ — $\omega_N$ — $\omega_L$ ATTERBERG LIMITS

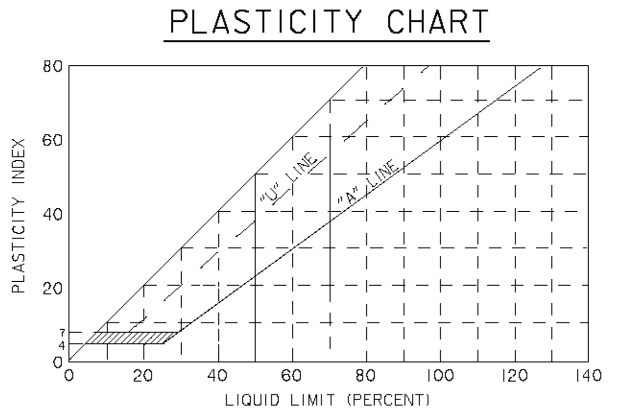
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**GENERAL BORING**
**BOR. FF-2**

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

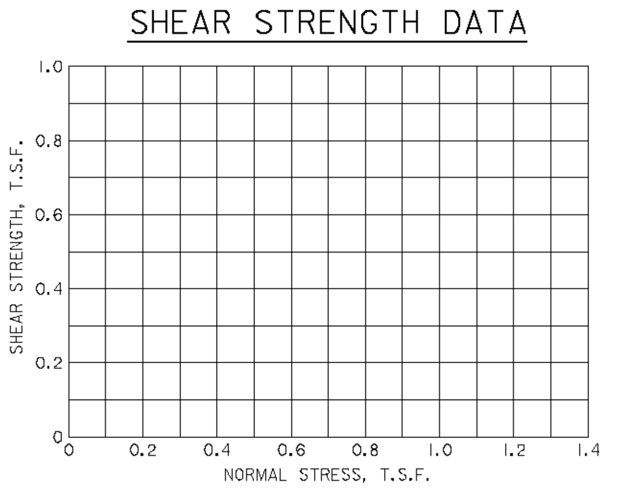
| | | | |
|---|---|---|---|
| DESIGNED BY: JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: APR 03 | CADD FILE: A1958I.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: JOLISSAINT | DATE: APR 03 | | |




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |




## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

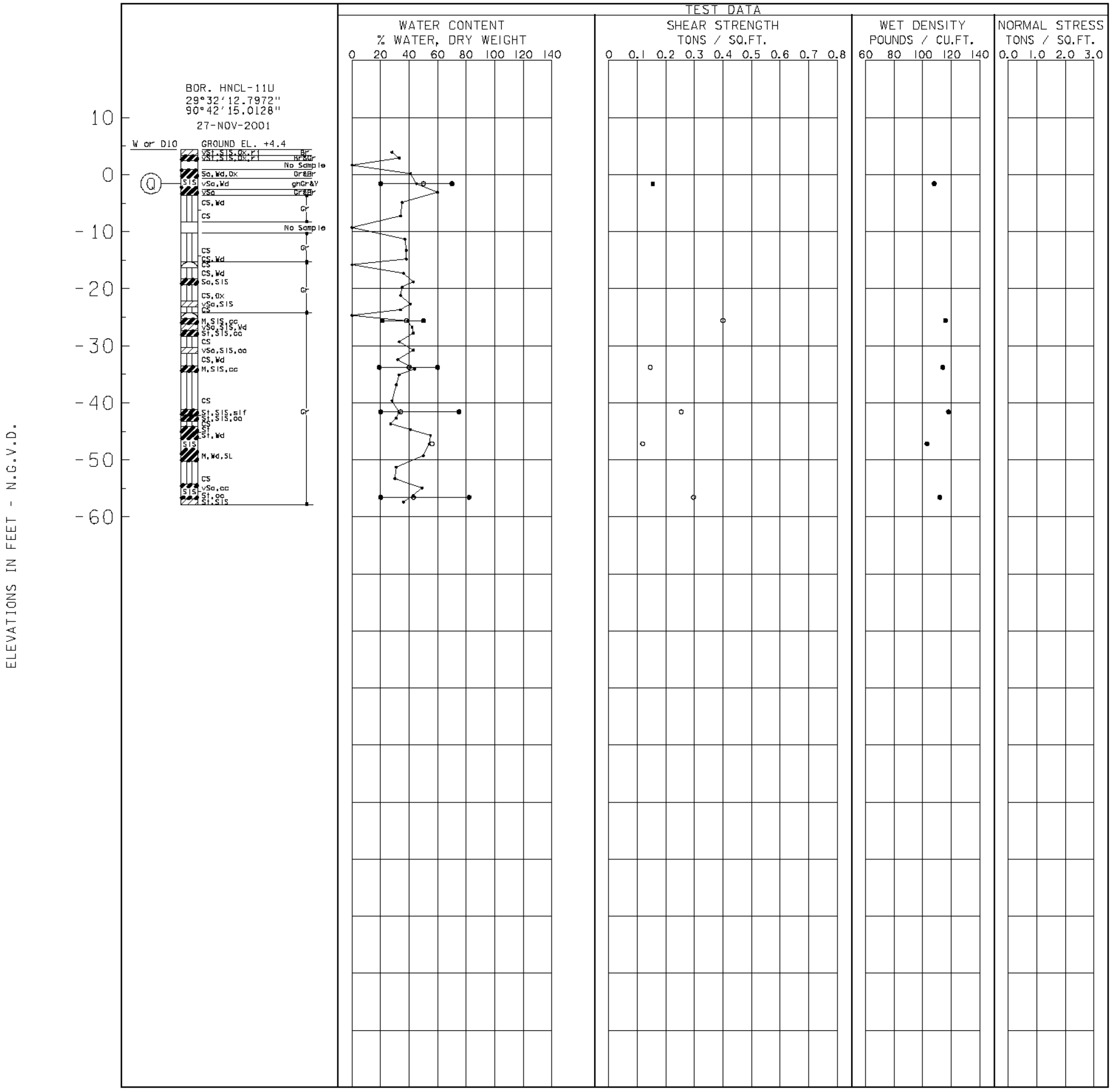
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

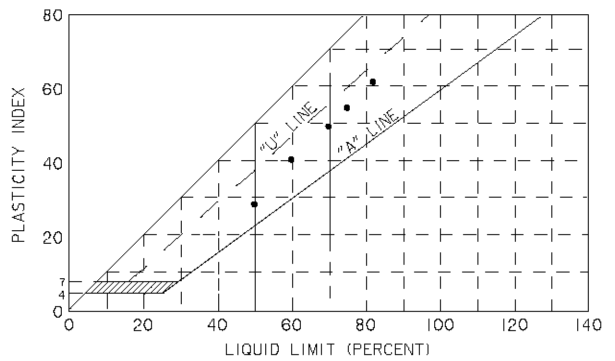
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**GENERAL BORING**
**BOR. FF-1**

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

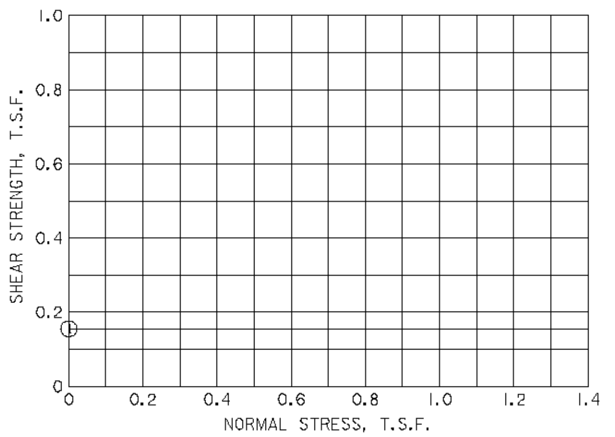
| DESIGNED BY: JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: APR 03 | CADD FILE: A19580.DGN |
|---|---|---|---|
| | DATE: APR 03 | | FILE NO. |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -1.6 | Q | 0.0 | 0.155 | CH |

## NOTES

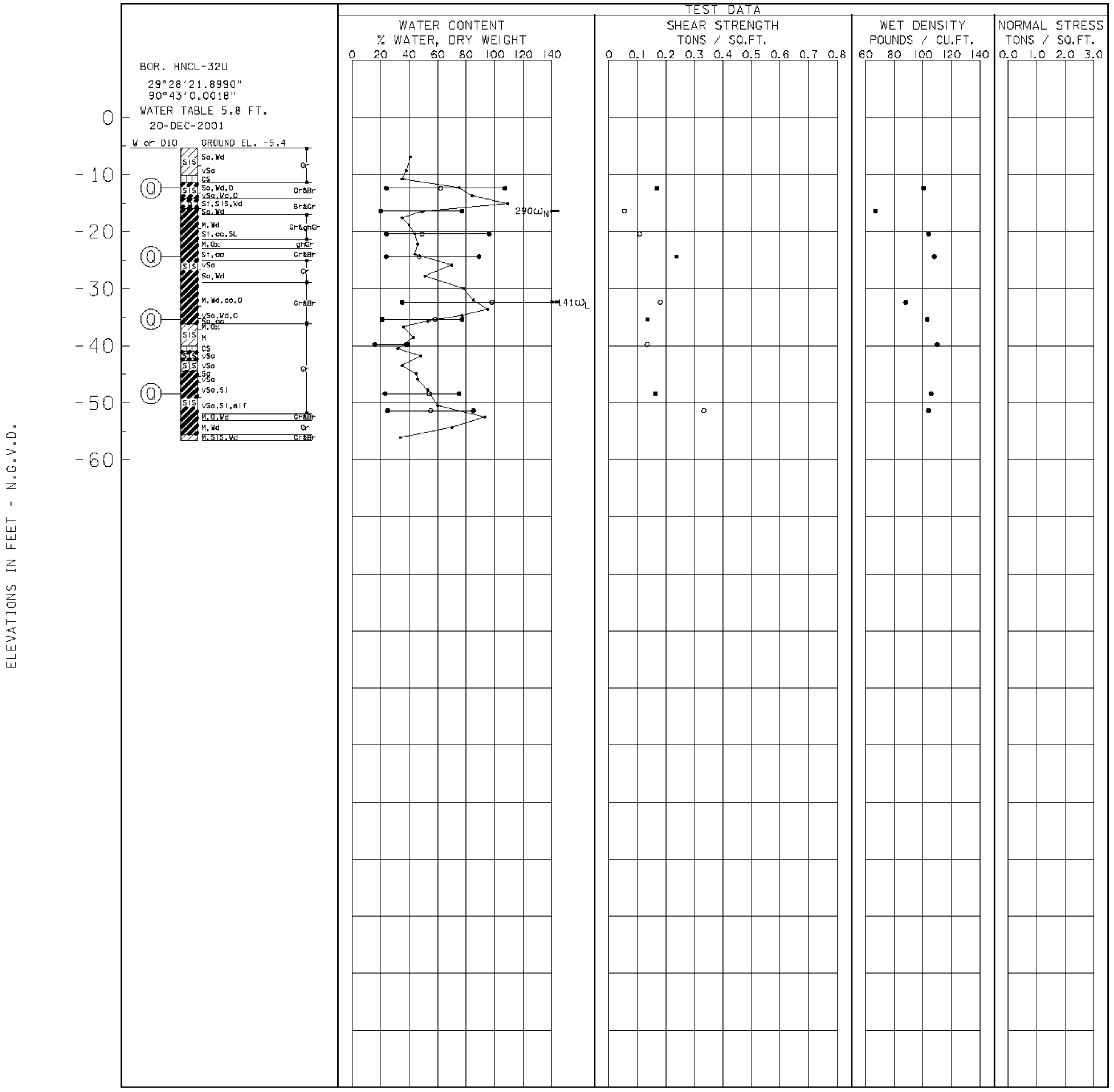
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

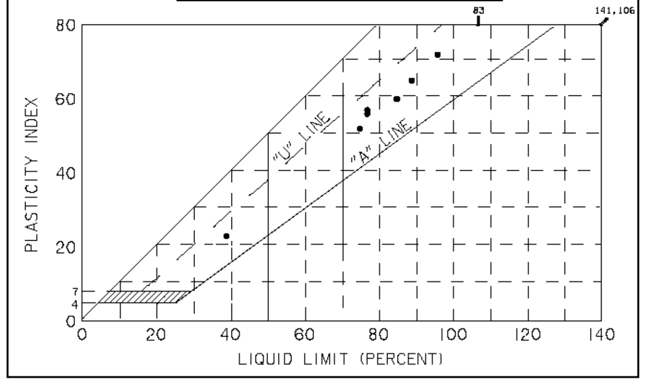
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-11U**

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

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-11U.DGN |
| | DATE: MAY 03 | | FILE NO. |



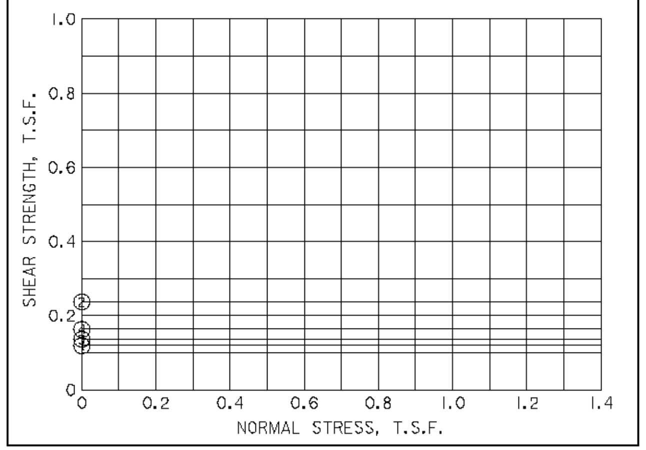

## PLASTICITY CHART




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -12.4 | Q | 0.0 | 0.169 | CH |
| 2 | -24.4 | Q | 0.0 | 0.237 | CH |
| 3 | -35.4 | Q | 0.0 | 0.136 | CH |
| 4 | -48.4 | Q | 0.0 | 0.163 | CH |

## SHEAR STRENGTH DATA




## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

$\omega_P$ — $\omega_N$ — $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.

FOR SOIL BORING LEGEND SEE PLATE G39.

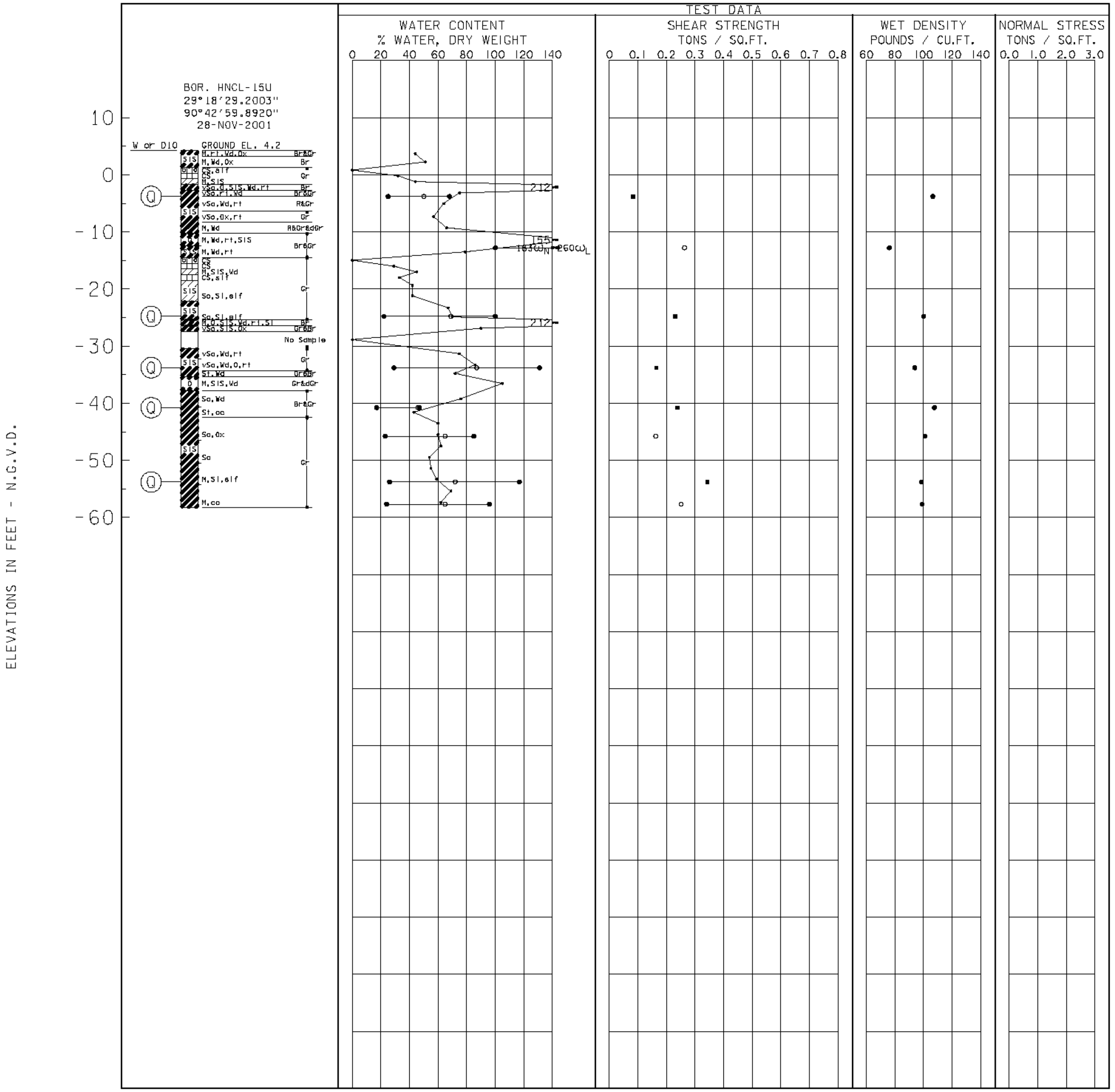
FOR LOCATION OF BORINGS SEE PLATE G1

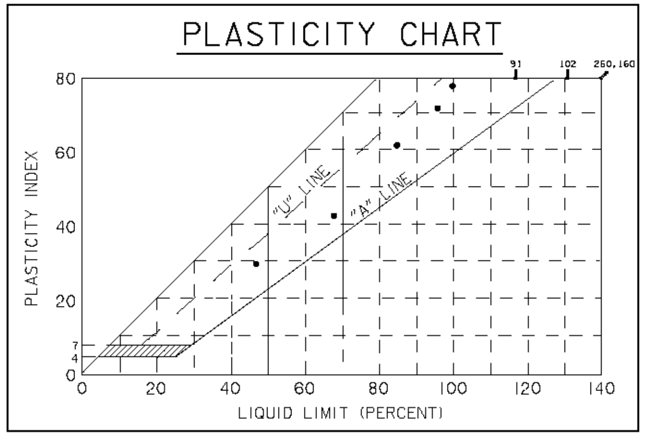
FOR DETAILED TEST DATA SEE ANNEX 2

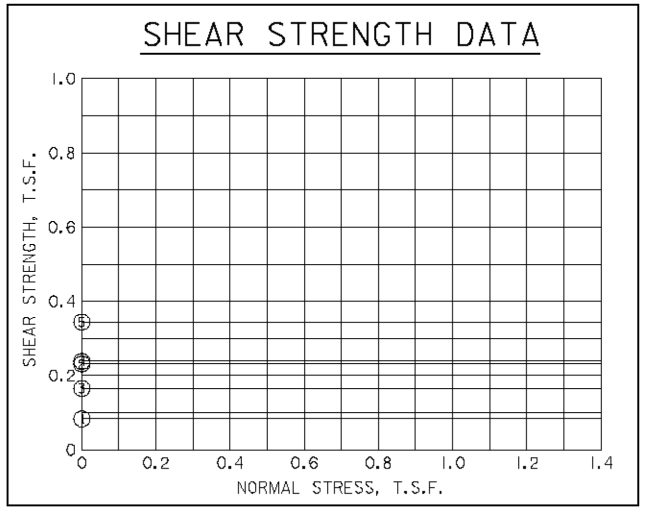
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-32U**

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

| | | | |
|---|---|---|---|
| DESIGNED BY: JOLISSAINT<br>DRAWN BY: HAROLD<br>CHECKED BY: JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: APR 03 | CADD FILE: HNCL-32U.DGN<br>FILE NO. |
| | DATE: APR 03 | | |




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -3.8 | Q | 0.0 | 0.083 | CH |
| 2 | -24.8 | Q | 0.0 | 0.231 | CH |
| 3 | -33.8 | Q | 0.0 | 0.165 | CH |
| 4 | -40.8 | Q | 0.0 | 0.238 | CL |
| 5 | -53.8 | Q | 0.0 | 0.344 | CH |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

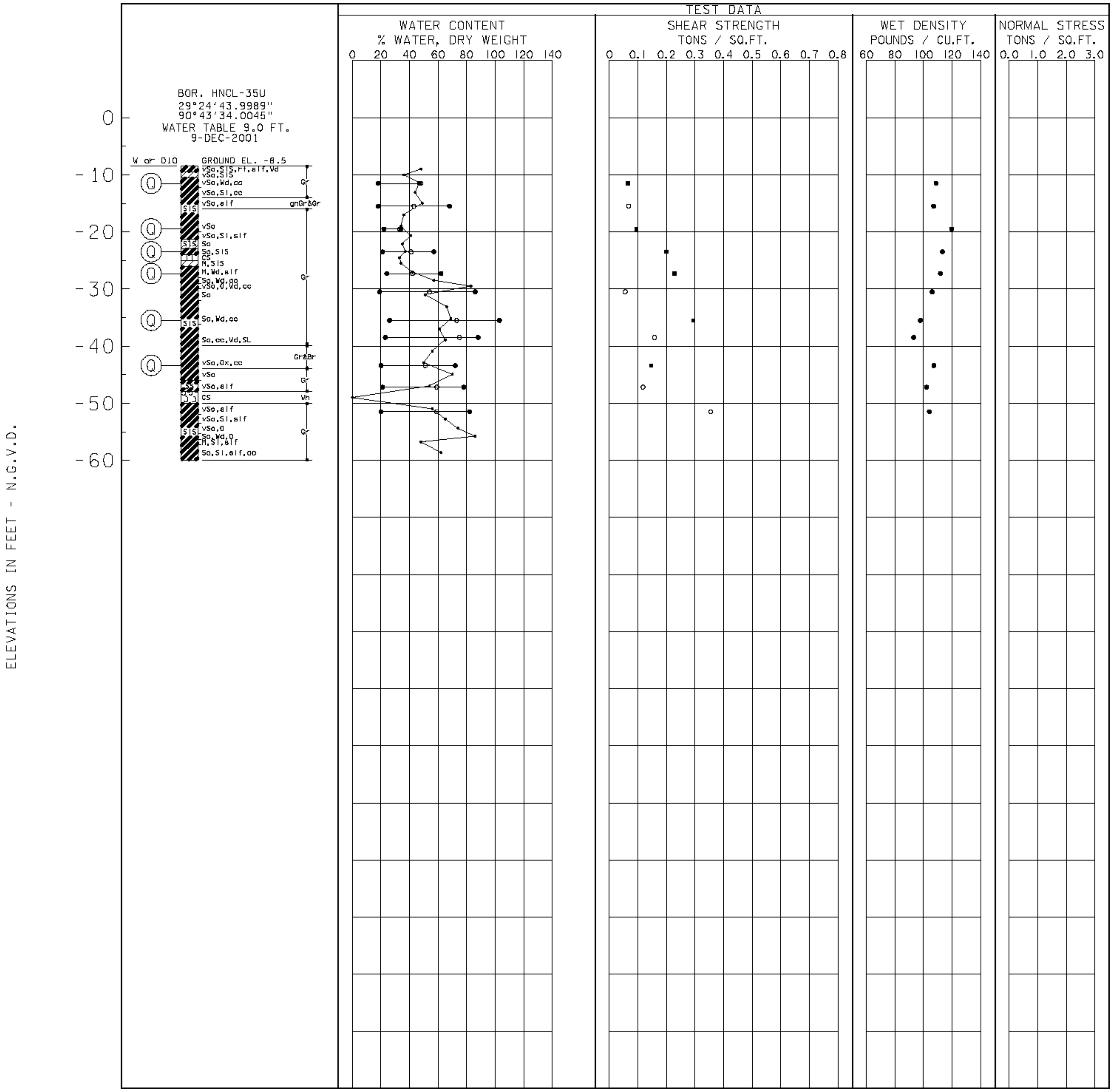
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-15U**

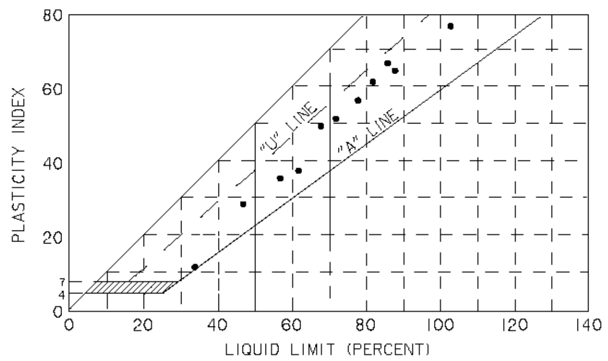
**U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS**
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA

| DESIGNED BY: JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: APR 03 | CADD FILE: HNCL-15U.DGN |
|---|---|---|---|
| DRAWN BY: HAROLD | | | FILE NO. |
| CHECKED BY: JOLISSAINT | DATE: APR 03 | | |

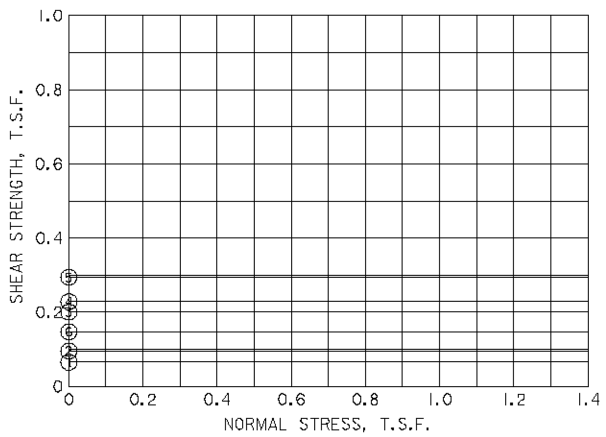
PLATE G9




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -11.5 | Q | 0.0 | 0.065 | CL |
| 2 | -19.5 | Q | 0.0 | 0.095 | CL |
| 3 | -23.5 | Q | 0.0 | 0.200 | CH |
| 4 | -27.3 | Q | 0.0 | 0.228 | CH |
| 5 | -35.5 | Q | 0.0 | 0.294 | CH |
| 6 | -43.4 | Q | 0.0 | 0.147 | CH |

## NOTES

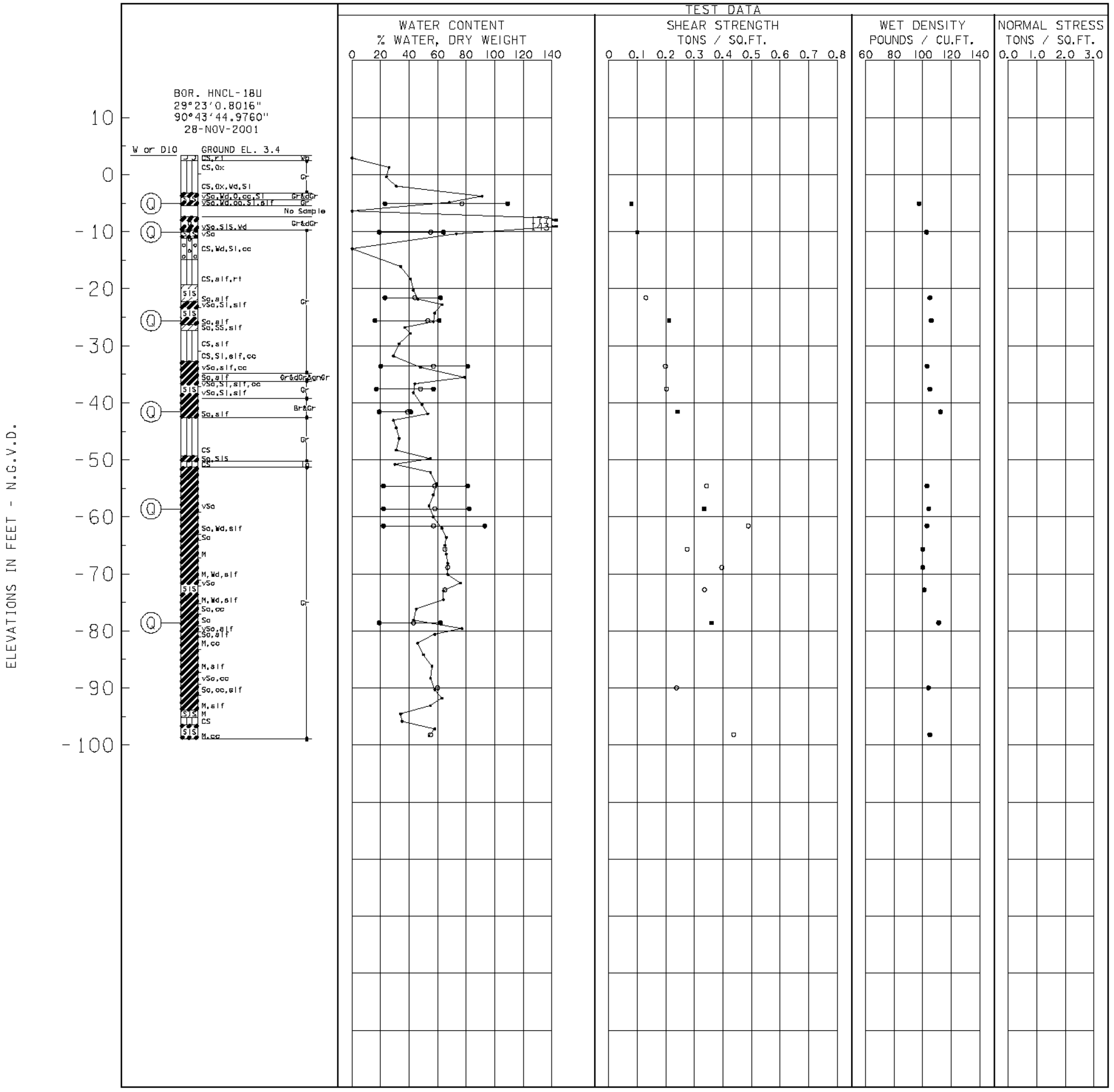
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

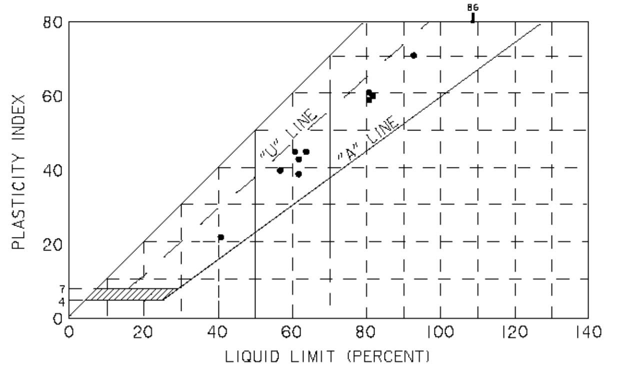
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-35U**

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

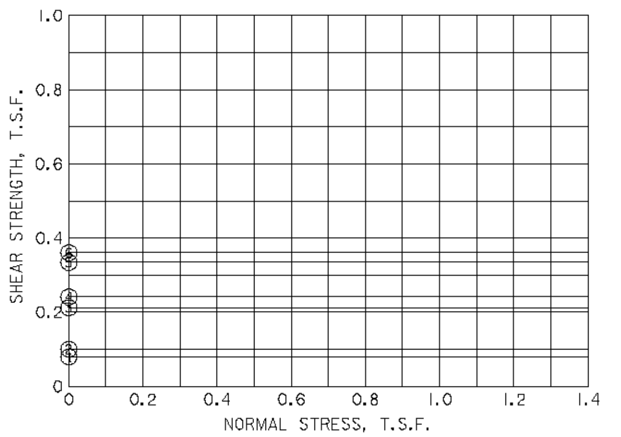
| | | | |
|---|---|---|---|
| DESIGNED BY: JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: APR 03 | CADD FILE: HNCL-35U.DGN |
| DRAWN BY: HAROLD | | | FILE NO. |
| CHECKED BY: JOLISSAINT | DATE: APR 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE NO. | ENVELOPE EL. | TYPE | STRENGTH Φ | STRENGTH C - TSF | CLASS |
|---|---|---|---|---|---|
| 1 | -5.1 | Q | 0.0 | 0.079 | CH |
| 2 | -10.1 | Q | 0.0 | 0.100 | CH |
| 3 | -25.6 | Q | 0.0 | 0.212 | CH |
| 4 | -41.6 | Q | 0.0 | 0.241 | CL |
| 5 | -58.6 | Q | 0.0 | 0.334 | CH |
| 6 | -78.6 | Q | 0.0 | 0.360 | CH |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
◼ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

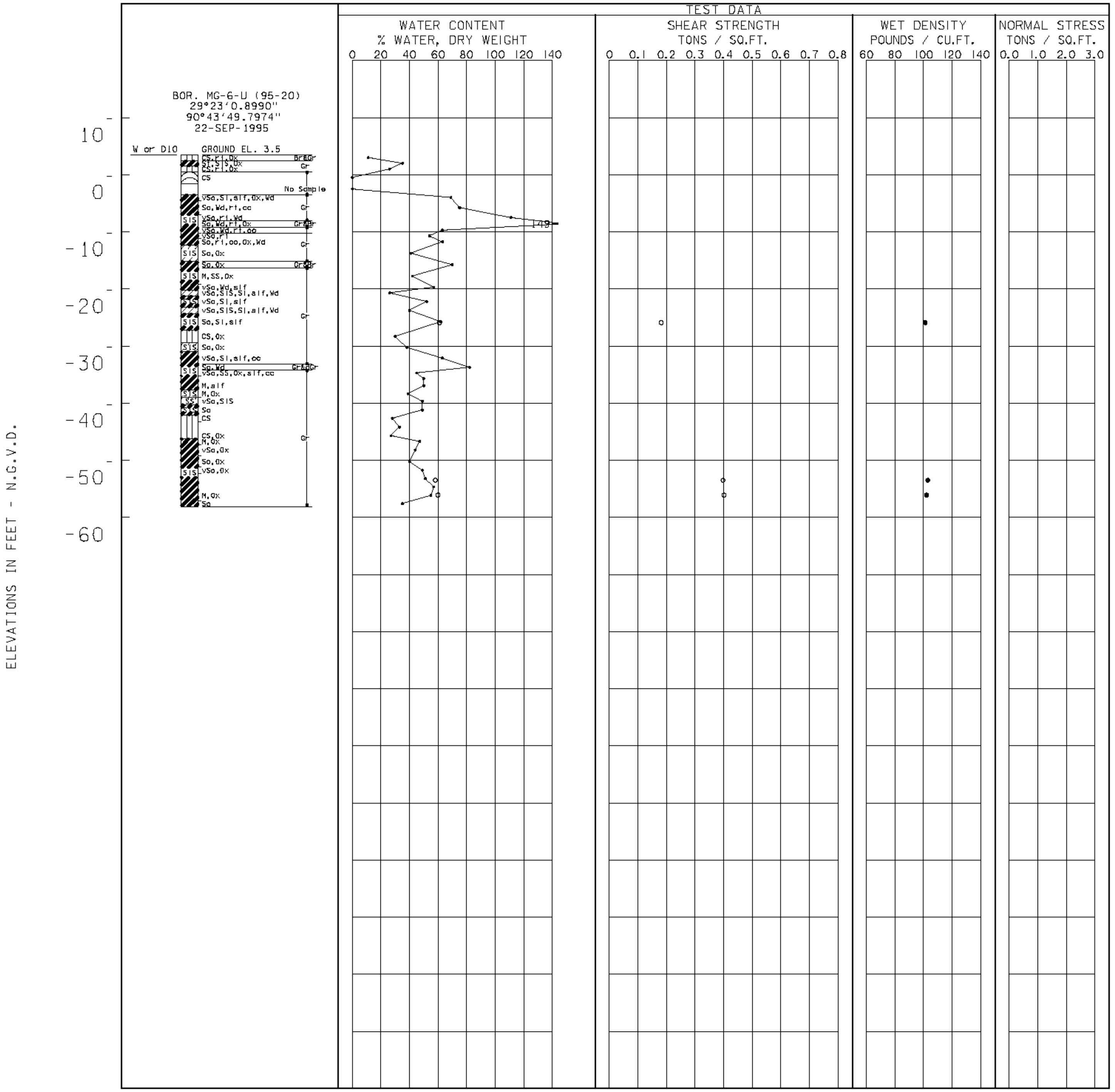
$\omega_P$ — $\omega_N$ — $\omega_L$ ATTERBERG LIMITS

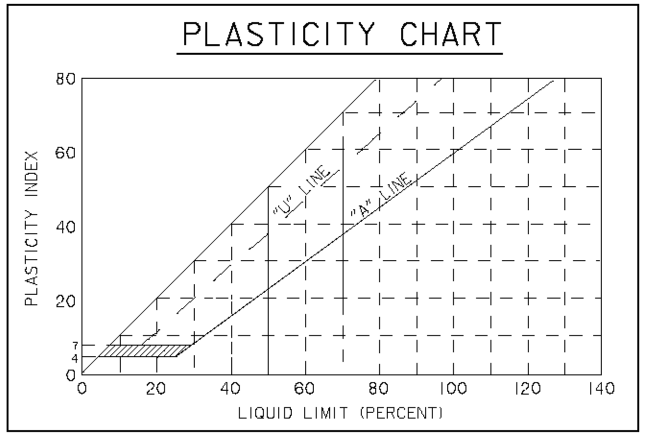
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

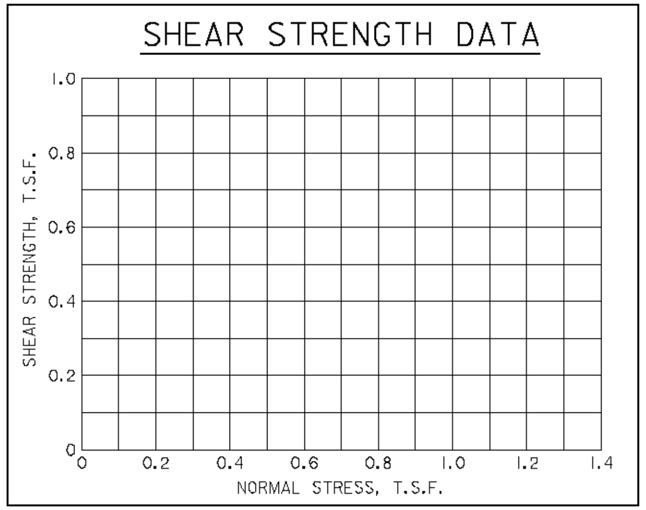
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-18U**

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

| | | | |
|---|---|---|---|
| DESIGNED BY: JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: APR 03 | CADD FILE: HNCL-18U.DGN |
| | DATE: APR 03 | | FILE NO. |




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |

## NOTES

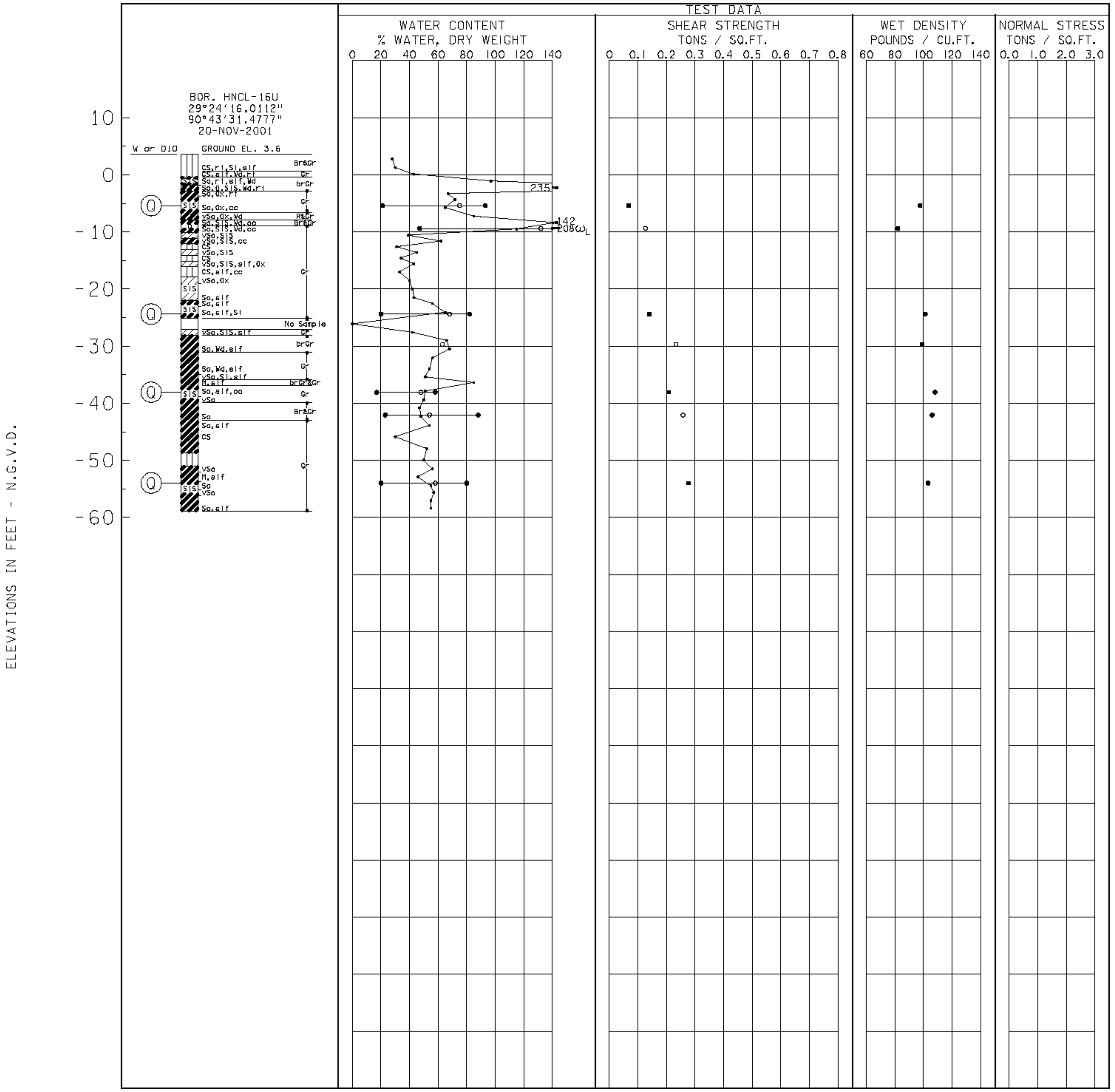
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊞ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

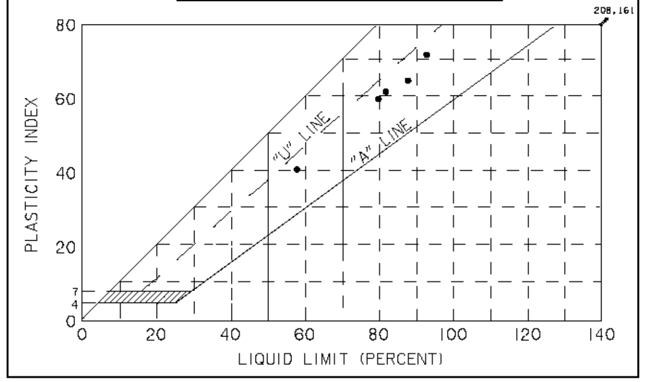
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. MG-6-U**

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

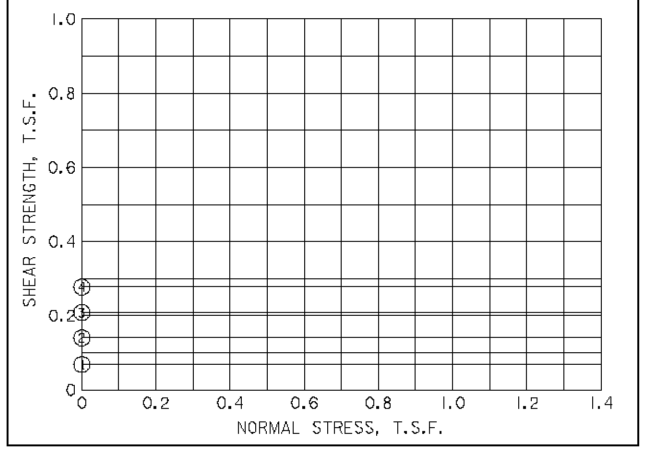
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: A18815.DGN<br>FILE NO. |
| | DATE: MAY 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -5.4 | Q | 0.0 | 0.068 | CH |
| 2 | -24.4 | Q | 0.0 | 0.140 | CH |
| 3 | -38.1 | Q | 0.0 | 0.208 | CH |
| 4 | -54.0 | Q | 0.0 | 0.277 | CH |

## NOTES

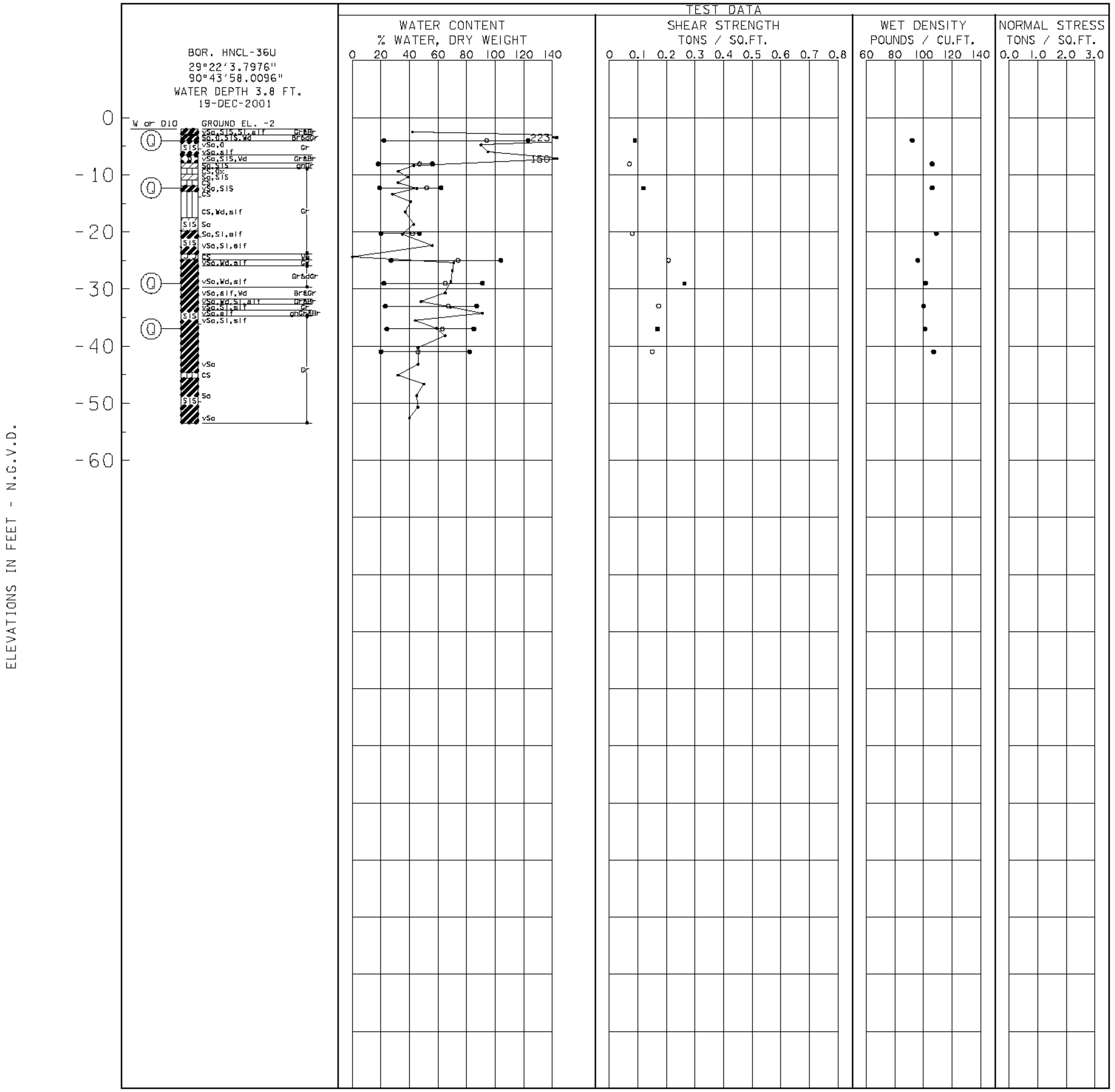
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

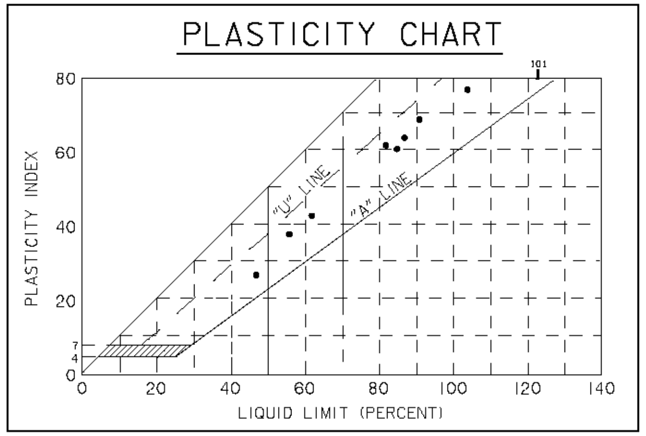
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-16U**

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

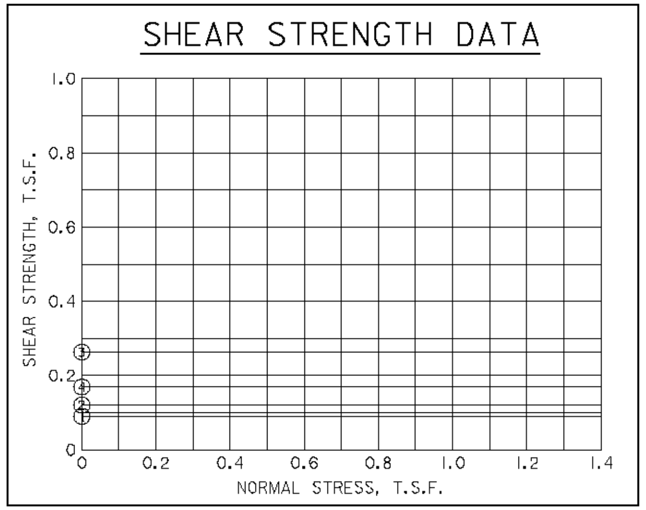
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-16U.DGN |
|---|---|---|---|
| DRAWN BY: C. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




# TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -4.0 | Q | 0.0 | 0.090 | CH |
| 2 | -12.3 | Q | 0.0 | 0.120 | CH |
| 3 | -29.0 | Q | 0.0 | 0.263 | CH |
| 4 | -37.0 | Q | 0.0 | 0.169 | CH |




# NOTES

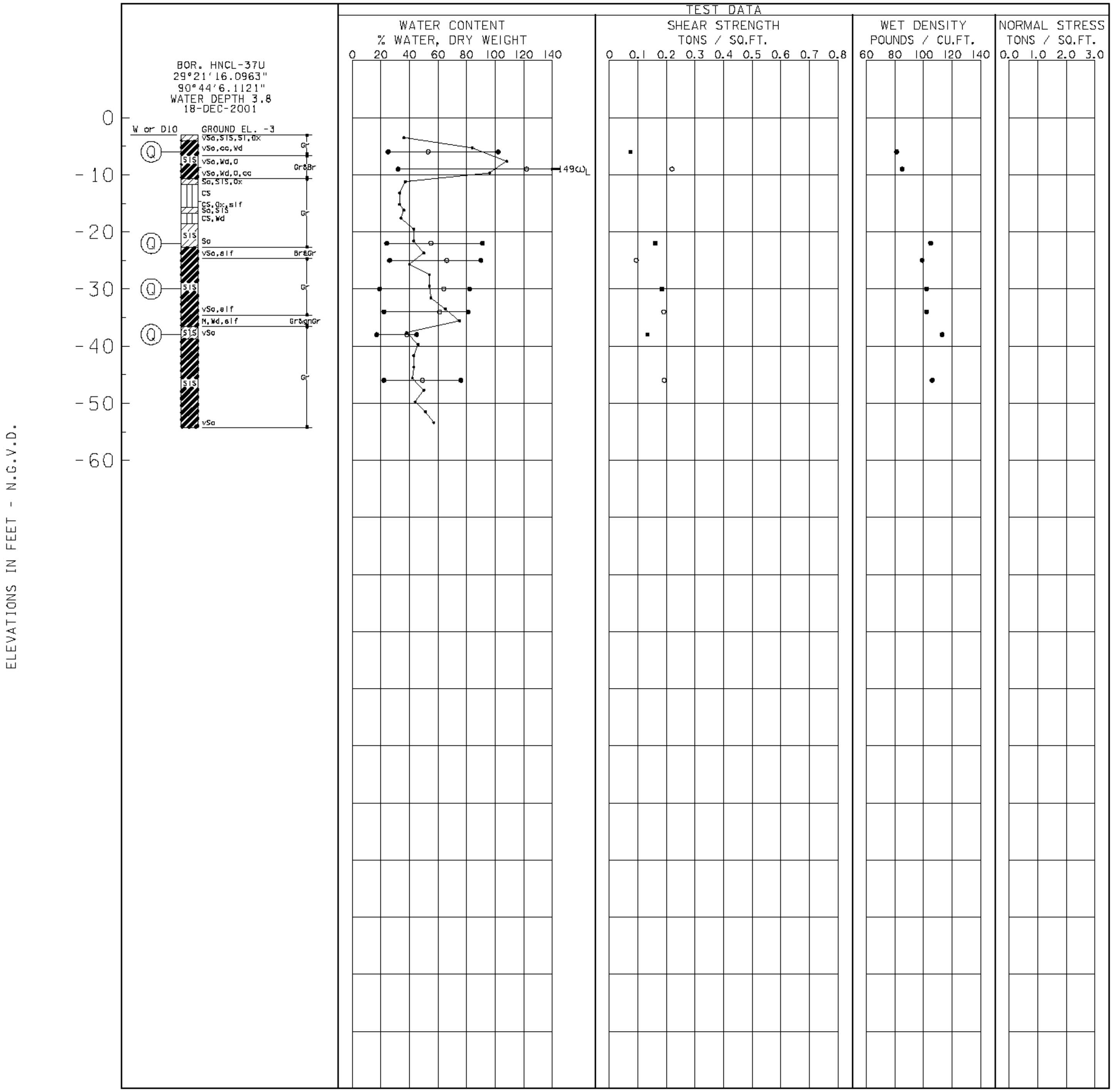
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
□ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

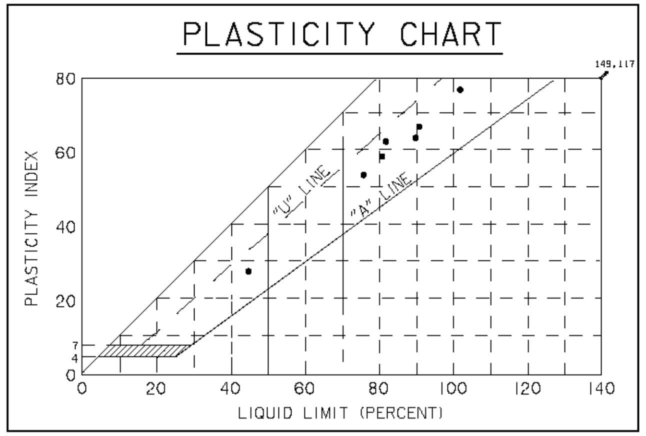
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-36U**

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

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-36U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |



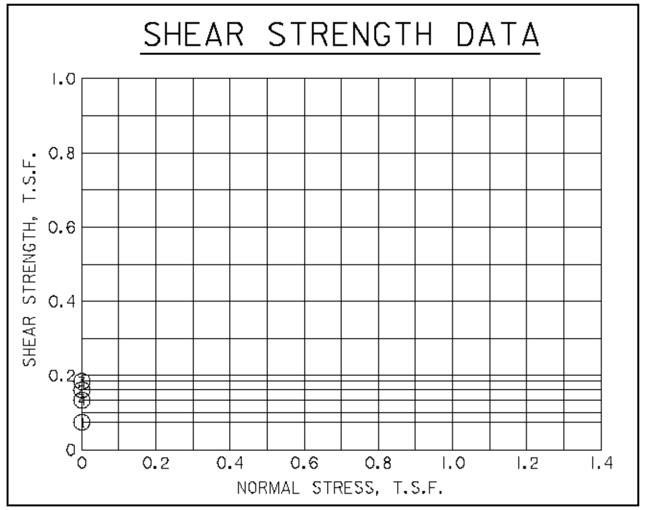

## PLASTICITY CHART




## TABULAR TEST DATA

| ENVELOPE NO. | ENVELOPE EL. | TYPE | STRENGTH Φ | STRENGTH C - TSF | CLASS |
|---|---|---|---|---|---|
| 1 | -6.0 | Q | 0.0 | 0.074 | CH |
| 2 | -22.0 | Q | 0.0 | 0.161 | CH |
| 3 | -30.0 | Q | 0.0 | 0.184 | CH |
| 4 | -38.0 | Q | 0.0 | 0.133 | CL |

## SHEAR STRENGTH DATA




## NOTES

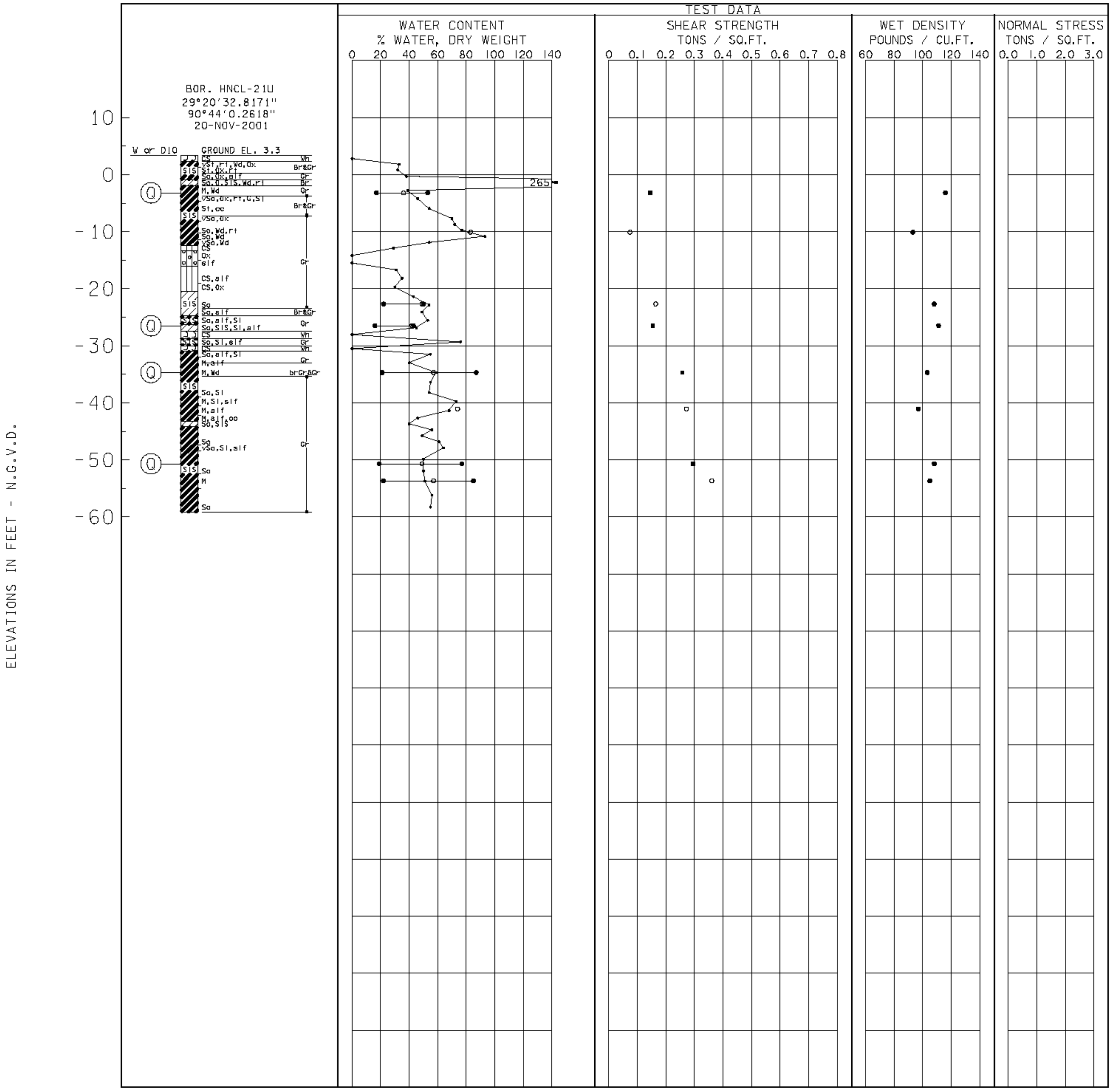
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

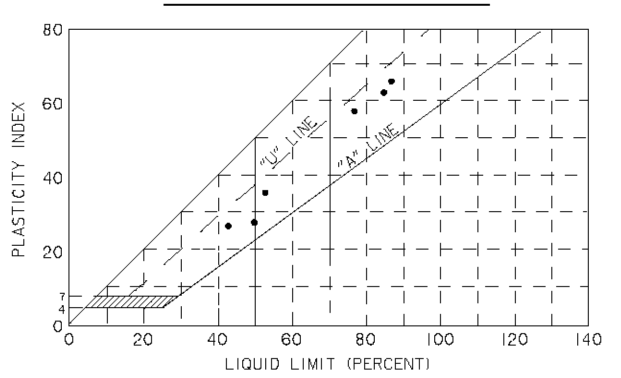
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-37U**

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

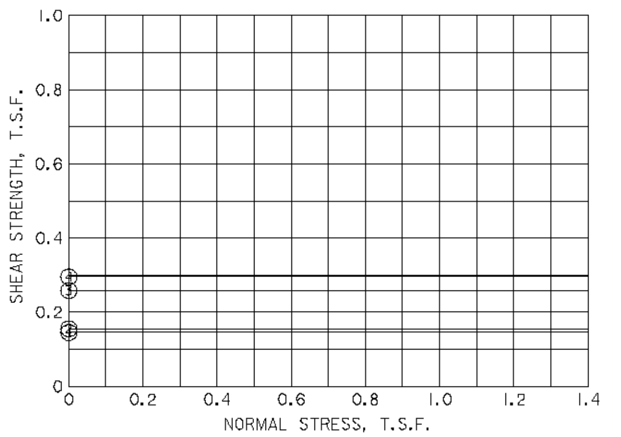
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-37U.DGN<br>FILE NO. |
| | DATE: MAY 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -3.2 | Q | 0.0 | 0.145 | CH |
| 2 | -26.5 | Q | 0.0 | 0.155 | CL |
| 3 | -34.7 | Q | 0.0 | 0.258 | CH |
| 4 | -50.7 | Q | 0.0 | 0.295 | CH |

## NOTES

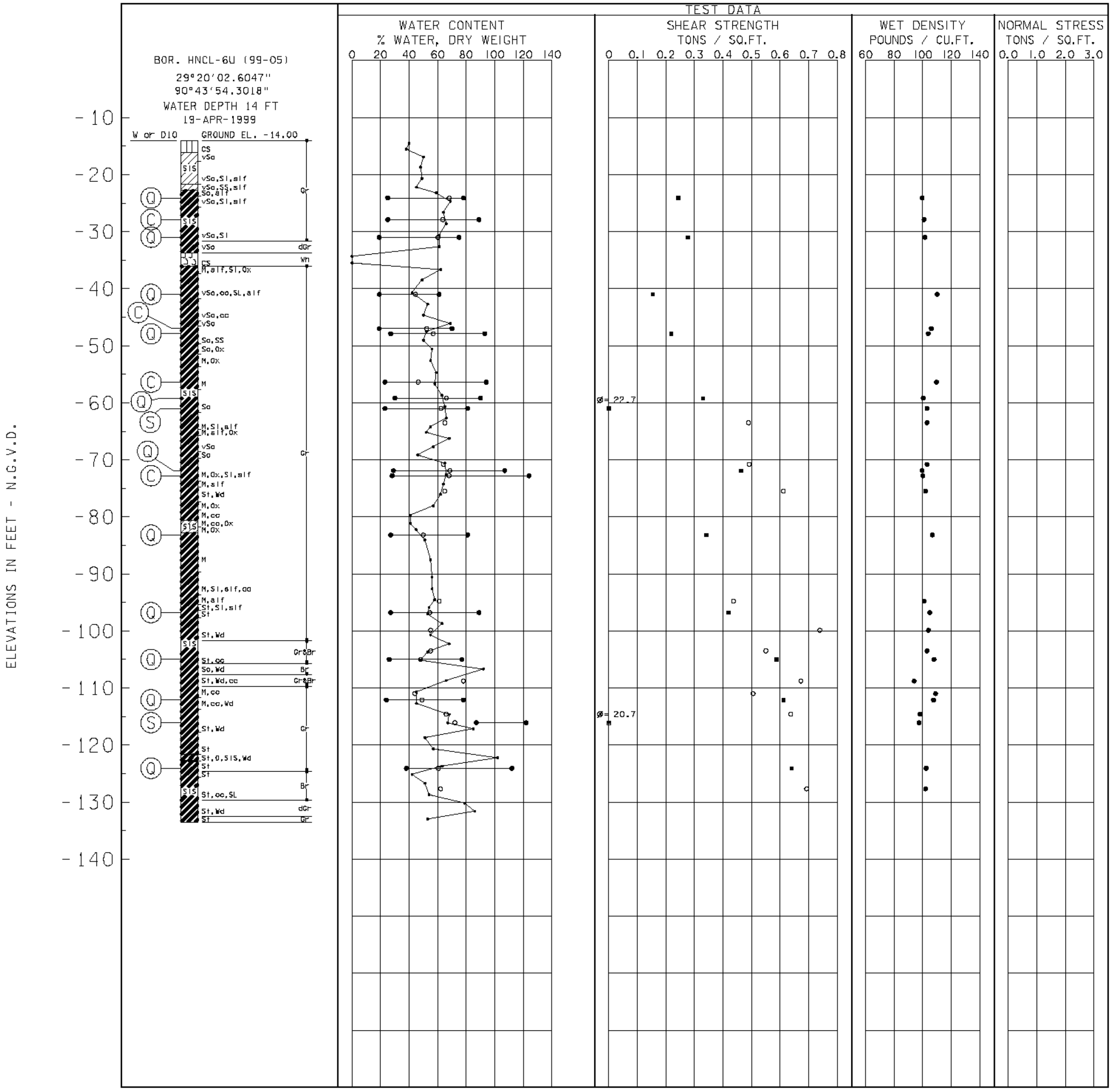
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ — $\omega_N$ — $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE GI
FOR DETAILED TEST DATA SEE ANNEX 2

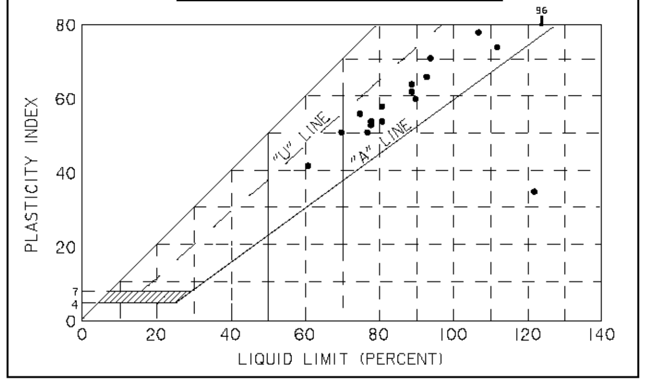
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-21U**

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

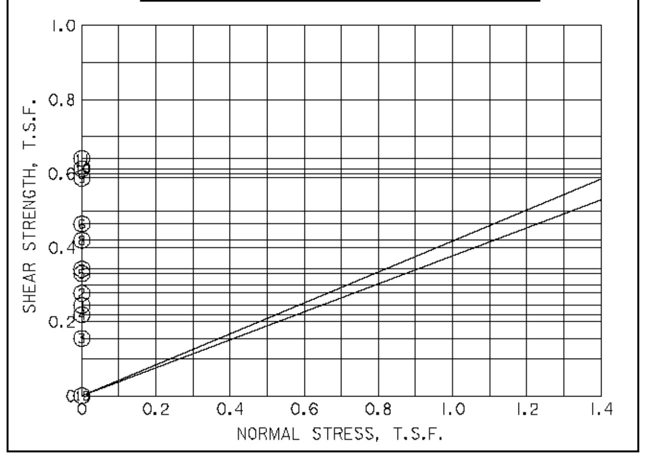
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-21U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




# PLASTICITY CHART




# SHEAR STRENGTH DATA




# TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -24.1 | Q | 0.0 | 0.244 | CH |
| 2 | -31.0 | Q | 0.0 | 0.277 | CH |
| 3 | -41.0 | Q | 0.0 | 0.155 | CH |
| 4 | -47.9 | Q | 0.0 | 0.219 | CH |
| 5 | -59.2 | Q | 0.0 | 0.330 | CH |
| 6 | -71.9 | Q | 0.0 | 0.464 | CH |
| 7 | -83.2 | Q | 0.0 | 0.342 | CH |
| 8 | -96.8 | Q | 0.0 | 0.420 | CH |
| 9 | -105.0 | Q | 0.0 | 0.568 | CH |
| 10 | -112.1 | Q | 0.0 | 0.613 | CH |
| 11 | -124.1 | Q | 0.0 | 0.641 | CH |
| 12 | -61.0 | S | 22.7 | 0.000 | CH |
| 13 | -116.1 | S | 20.7 | 0.000 | CH |
| 14 | -27.9 | C | | | CH |
| 15 | -47.0 | C | | | CH |
| 16 | -56.4 | C | | | CH |
| 17 | -72.8 | C | | | CH |

# NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

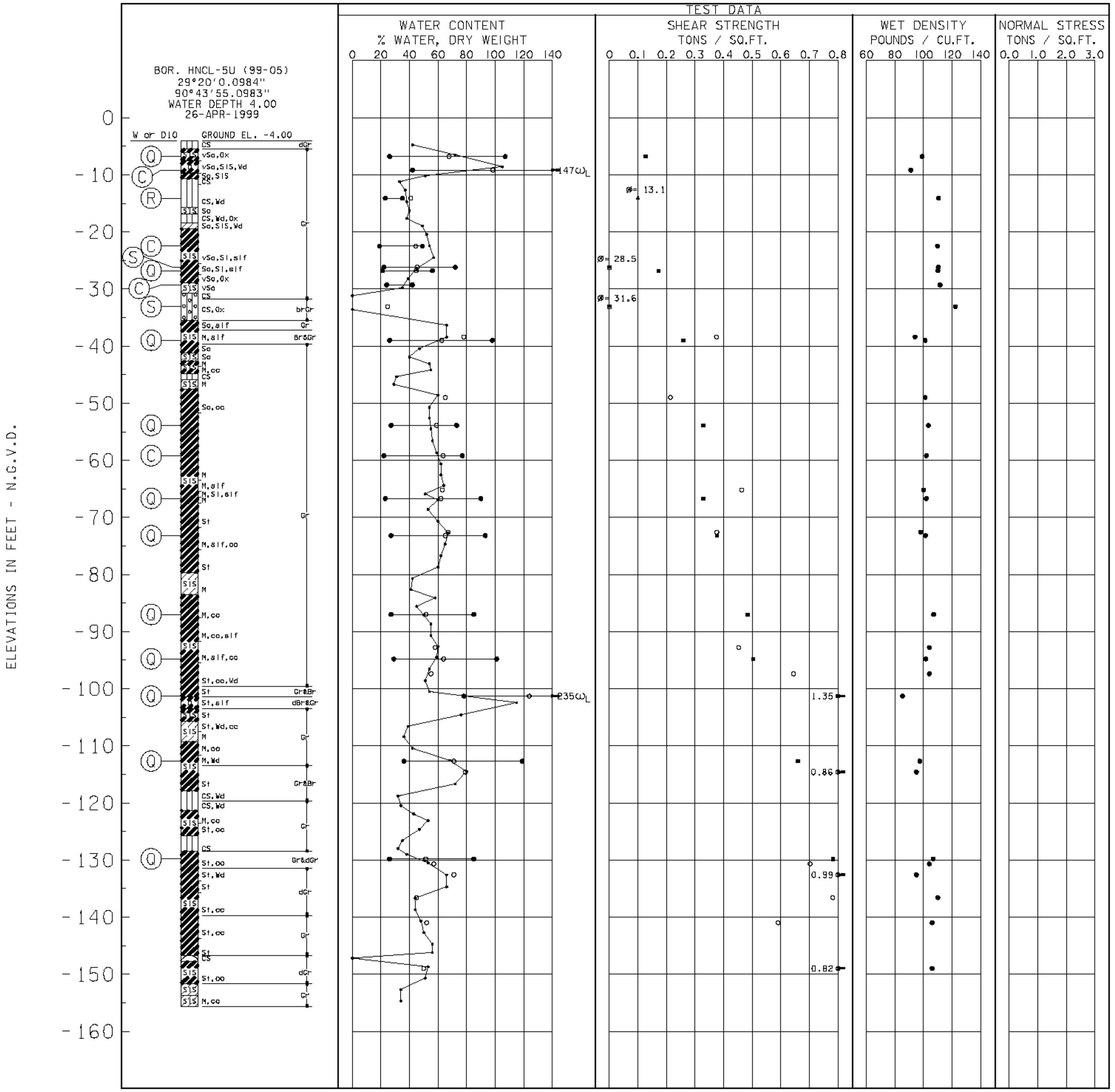
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.

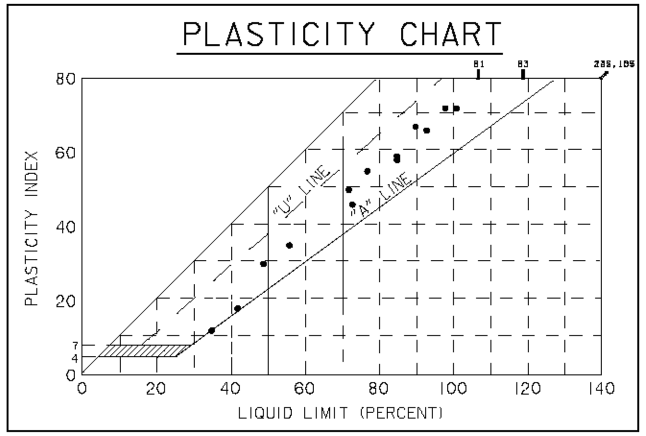

FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

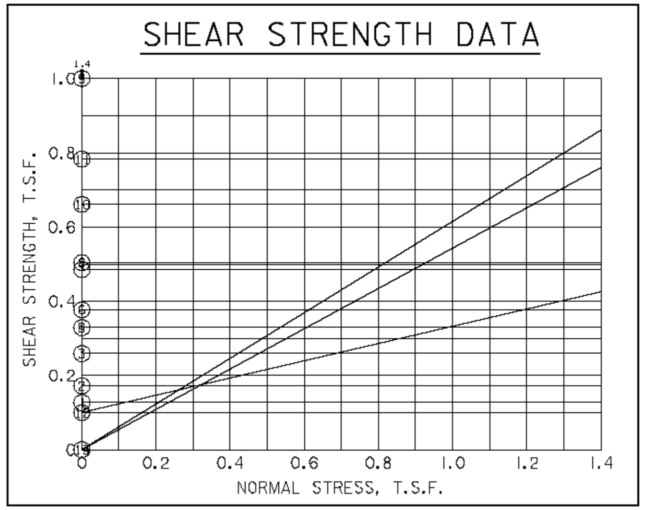

HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-6U**

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

| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: C. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-6U.DGN<br>FILE NO. |
|---|---|---|---|
| | DATE: MAY 03 | | |




# TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -6.8 | Q | 0.0 | 0.127 | CH |
| 2 | -26.8 | Q | 0.0 | 0.172 | CH |
| 3 | -39.0 | Q | 0.0 | 0.259 | CH |
| 4 | -53.9 | Q | 0.0 | 0.329 | CH |
| 5 | -66.7 | Q | 0.0 | 0.329 | CH |
| 6 | -73.2 | Q | 0.0 | 0.377 | CH |
| 7 | -87.0 | Q | 0.0 | 0.485 | CH |
| 8 | -94.8 | Q | 0.0 | 0.504 | CH |
| 9 | -101.3 | Q | 0.0 | 1.350 | OH |
| 10 | -112.7 | Q | 0.0 | 0.661 | CH |
| 11 | -129.8 | Q | 0.0 | 0.783 | CH |
| 12 | -14.1 | R | 13.1 | 0.100 | CL |
| 13 | -26.2 | S | 28.5 | 0.000 | CH |
| 14 | -33.1 | S | 31.6 | 0.000 | SM |
| 15 | -9.2 | C | | | CH |
| 16 | -22.5 | C | | | CL |
| 17 | -29.3 | C | | | CL |
| 18 | -59.2 | C | | | CH |

# NOTES

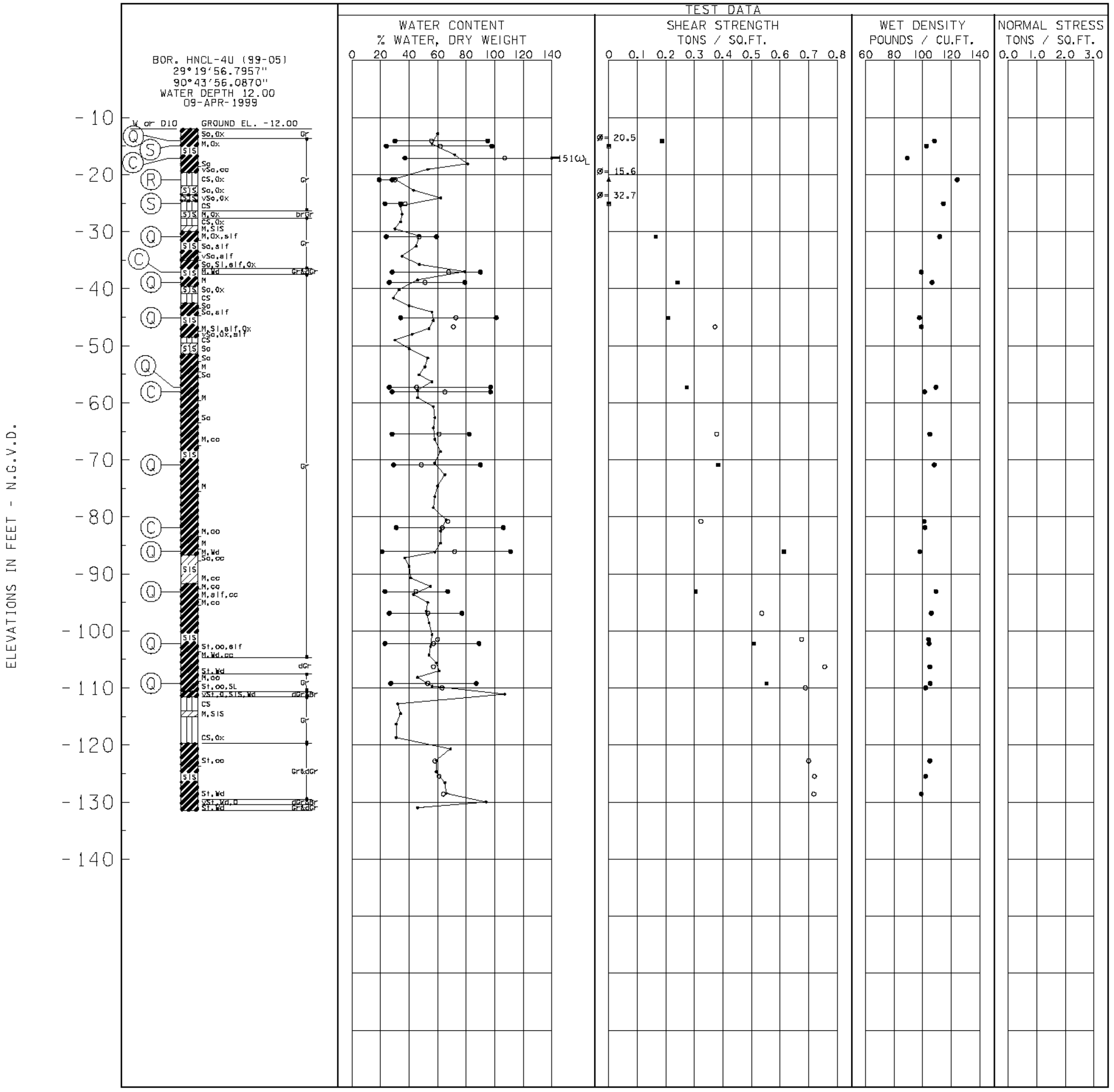
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ — $\omega_N$ — $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

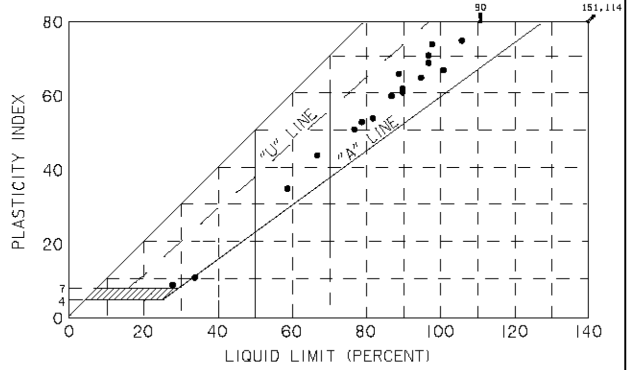
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-5U**

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

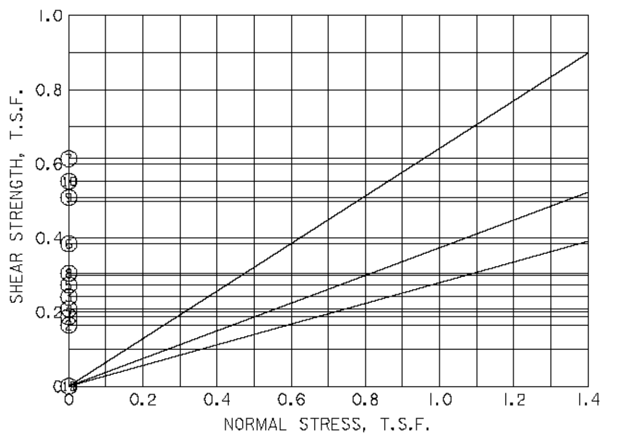
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-5U.DGN |
| | DATE: MAY 03 | | FILE NO. |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE NO. | ENVELOPE EL. | TYPE | STRENGTH Φ | STRENGTH C - TSF | CLASS |
|---|---|---|---|---|---|
| 1 | -14.1 | Q | 0.0 | 0.187 | CH |
| 2 | -30.9 | Q | 0.0 | 0.165 | CH |
| 3 | -38.9 | Q | 0.0 | 0.241 | CH |
| 4 | -45.1 | Q | 0.0 | 0.208 | CH |
| 5 | -57.3 | Q | 0.0 | 0.273 | CH |
| 6 | -70.9 | Q | 0.0 | 0.384 | CH |
| 7 | -86.1 | Q | 0.0 | 0.614 | CH |
| 8 | -93.1 | Q | 0.0 | 0.305 | CH |
| 9 | -102.2 | Q | 0.0 | 0.509 | CH |
| 10 | -109.2 | Q | 0.0 | 0.553 | CH |
| 11 | -20.9 | R | 15.6 | 0.000 | CL |
| 12 | -15.0 | S | 20.5 | 0.000 | CH |
| 13 | -25.1 | S | 32.7 | 0.000 | CL |
| 14 | -17.1 | C | | | CH |
| 15 | -37.1 | C | | | CH |
| 16 | -58.1 | C | | | CH |
| 17 | -81.9 | C | | | CH |

## NOTES

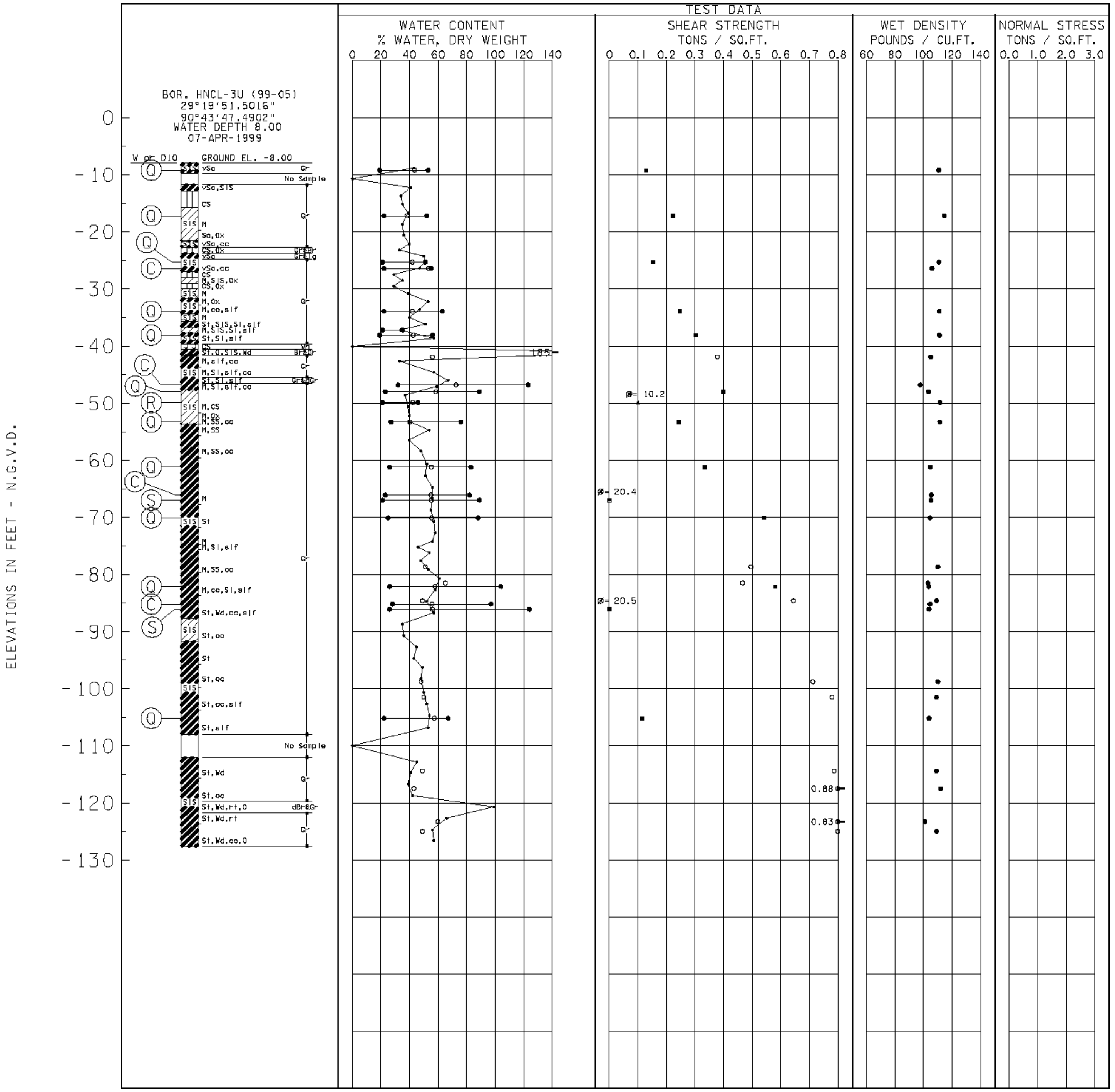
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
□ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ — $\omega_N$ — $\omega_L$ ATTERBERG LIMITS

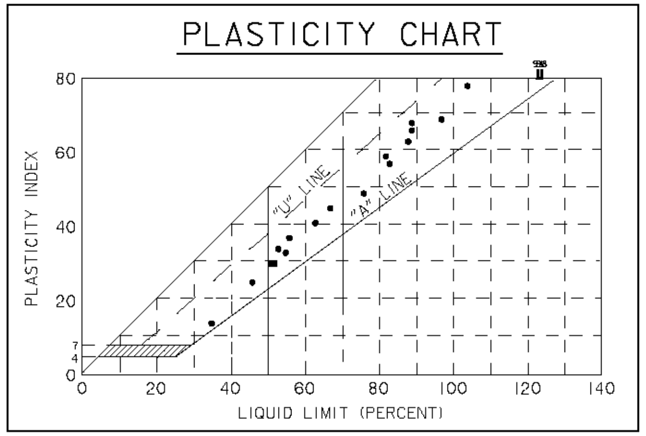
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

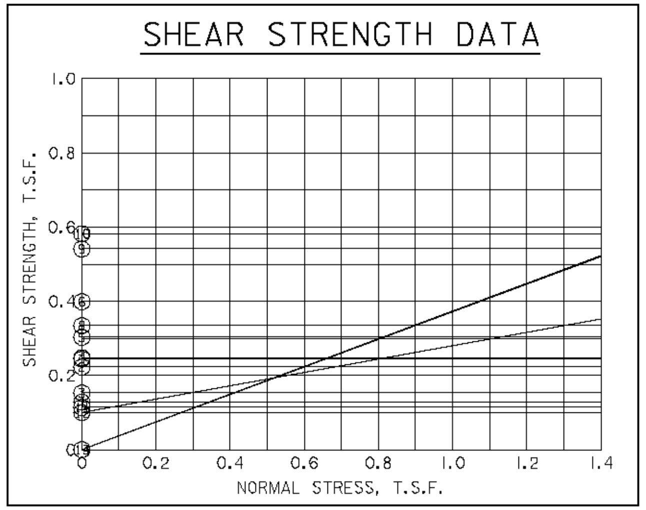
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-4U**

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

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-4U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## TABULAR TEST DATA

| ENVELOPE NO. | ENVELOPE EL. | TYPE | STRENGTH Φ | STRENGTH C - TSF | CLASS |
|---|---|---|---|---|---|
| 1 | -9.2 | Q | 0.0 | 0.128 | CH |
| 2 | -17.2 | Q | 0.0 | 0.223 | CH |
| 3 | -25.3 | Q | 0.0 | 0.153 | CH |
| 4 | -33.9 | Q | 0.0 | 0.248 | CH |
| 5 | -38.1 | Q | 0.0 | 0.303 | CH |
| 6 | -48.0 | Q | 0.0 | 0.399 | CH |
| 7 | -53.3 | Q | 0.0 | 0.244 | CH |
| 8 | -61.2 | Q | 0.0 | 0.334 | CH |
| 9 | -70.1 | Q | 0.0 | 0.541 | CH |
| 10 | -82.1 | Q | 0.0 | 0.582 | CH |
| 11 | -105.2 | Q | 0.0 | 0.114 | CH |
| 12 | -49.9 | R | 10.2 | 0.100 | CL |
| 13 | -67.0 | S | 20.4 | 0.000 | CH |
| 14 | -86.1 | S | 20.5 | 0.000 | CH |
| 15 | -26.4 | C | | | CH |
| 16 | -46.8 | C | | | CH |
| 17 | -66.1 | C | | | CH |
| 18 | -85.2 | C | | | CH |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.

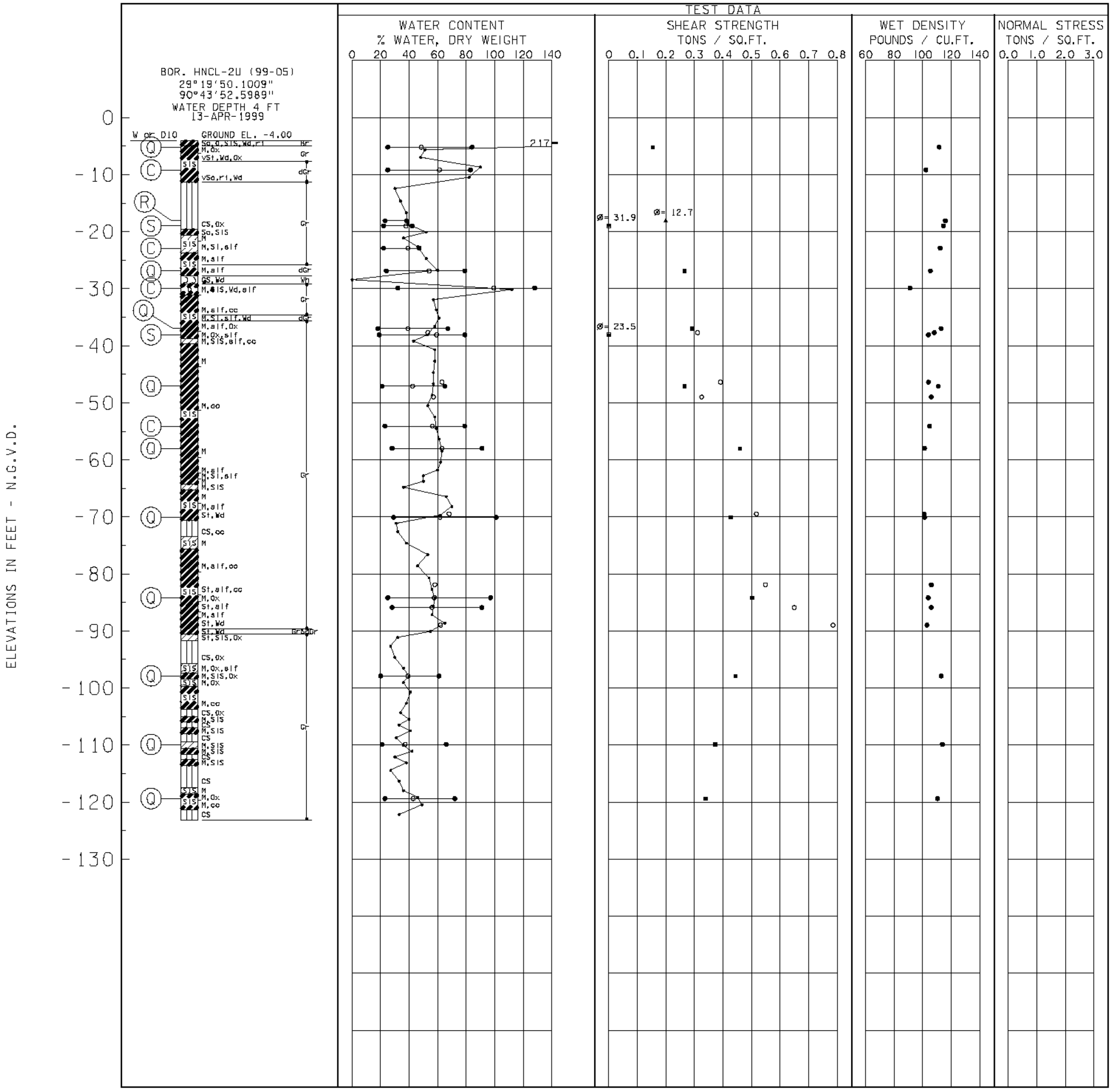

FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2


HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

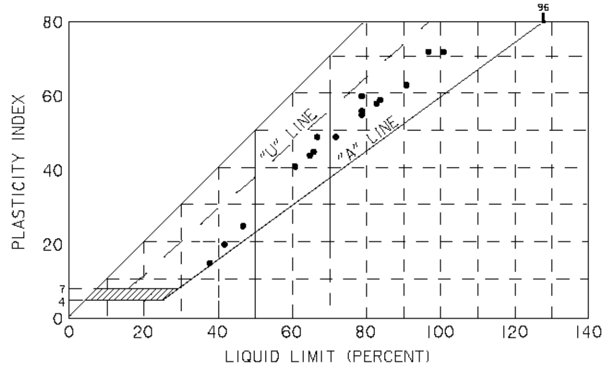
**UNDISTURBED BORING**
**BOR. HNCL-3U**


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

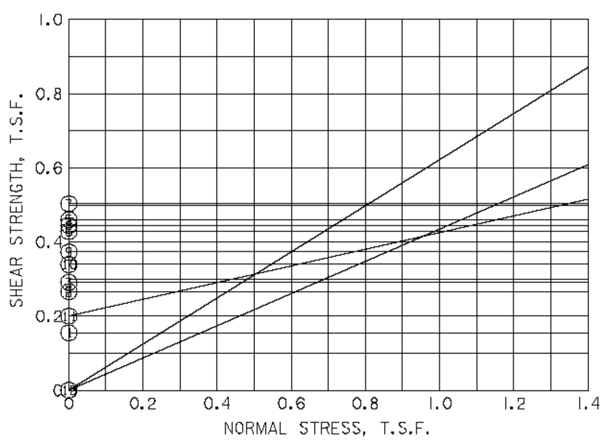

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-3U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -5.2 | Q | 0.0 | 0.155 | CH |
| 2 | -26.9 | Q | 0.0 | 0.266 | CH |
| 3 | -37.0 | Q | 0.0 | 0.291 | CH |
| 4 | -47.1 | Q | 0.0 | 0.266 | CH |
| 5 | -58.0 | Q | 0.0 | 0.460 | CH |
| 6 | -70.1 | Q | 0.0 | 0.428 | CH |
| 7 | -84.2 | Q | 0.0 | 0.503 | CH |
| 8 | -97.9 | Q | 0.0 | 0.445 | CH |
| 9 | -109.9 | Q | 0.0 | 0.373 | CH |
| 10 | -119.4 | Q | 0.0 | 0.339 | CH |
| 11 | -18.1 | R | 12.7 | 0.200 | CL |
| 12 | -19.0 | S | 31.9 | 0.000 | CL |
| 13 | -38.1 | S | 23.5 | 0.000 | CH |
| 14 | -9.2 | C | | | CH |
| 15 | -22.9 | C | | | CL |
| 16 | -29.9 | C | | | CH |
| 17 | -54.1 | C | | | CH |

## NOTES

- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.

FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

HOUMA NAVIGATION CANAL

**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**

MILE 36.0 TO MILE (-)5.0

TERREBONNE PARISH, LOUISIANA

**UNDISTURBED BORING**

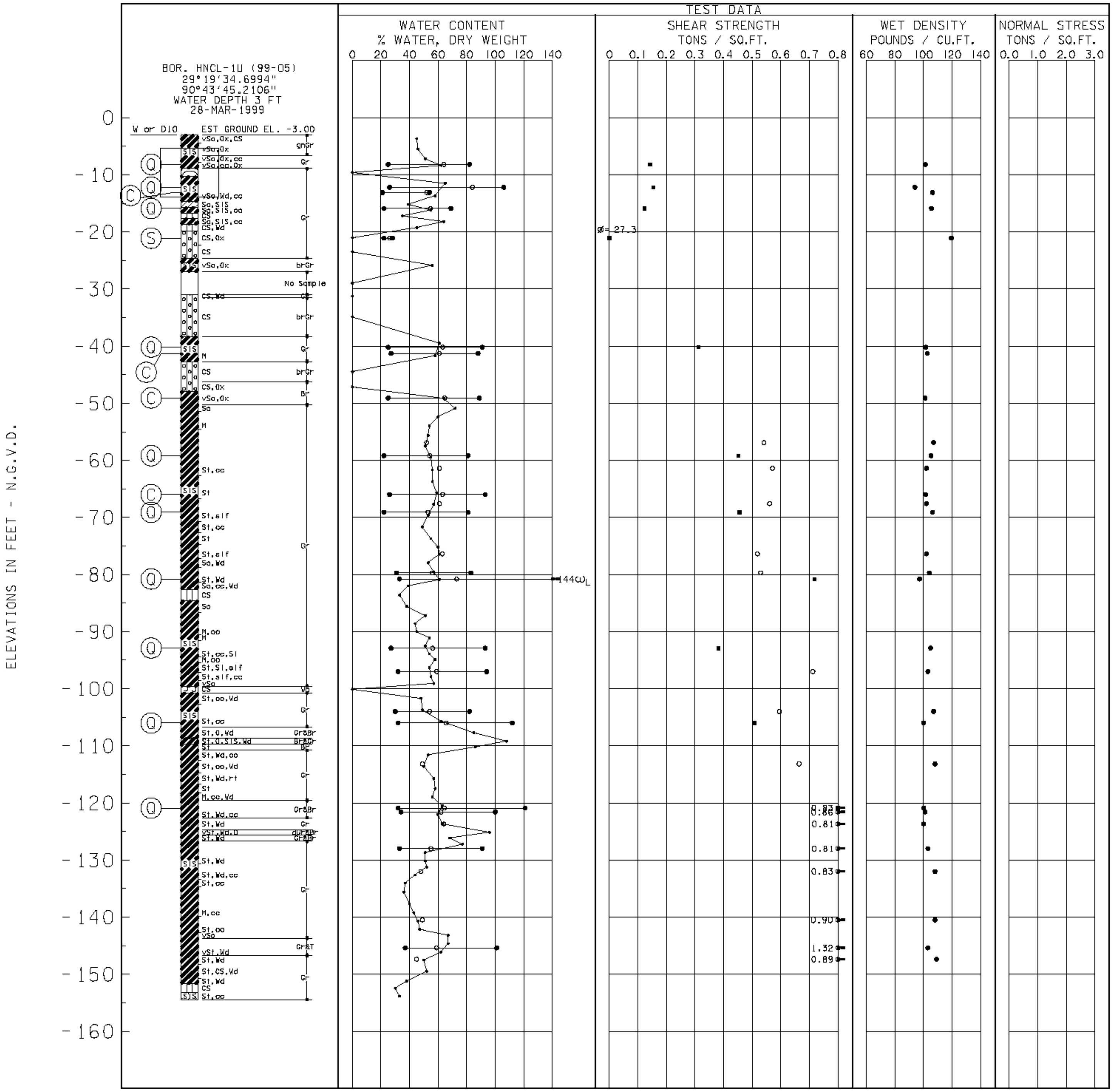
**BOR. HNCL-2U**

**U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS**

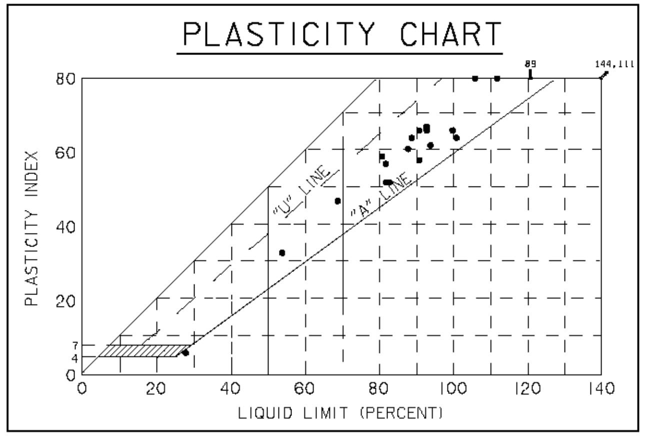
CORPS OF ENGINEERS

NEW ORLEANS, LOUISIANA

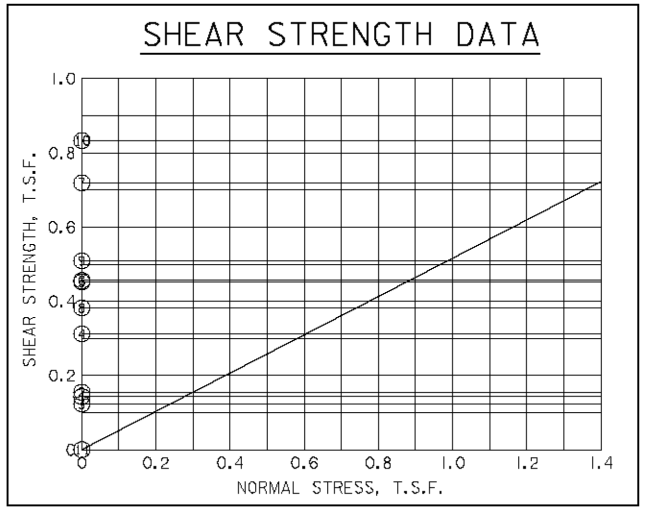
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-2U.DGN |
| DRAWN BY: C. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




# PLASTICITY CHART




# SHEAR STRENGTH DATA




# TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -8.2 | Q | 0.0 | 0.143 | CH |
| 2 | -12.2 | Q | 0.0 | 0.155 | CH |
| 3 | -15.9 | Q | 0.0 | 0.123 | CH |
| 4 | -40.2 | Q | 0.0 | 0.312 | CH |
| 5 | -59.2 | Q | 0.0 | 0.452 | CH |
| 6 | -69.1 | Q | 0.0 | 0.456 | CH |
| 7 | -80.8 | Q | 0.0 | 0.719 | CH |
| 8 | -92.9 | Q | 0.0 | 0.382 | CH |
| 9 | -106.0 | Q | 0.0 | 0.509 | CH |
| 10 | -120.9 | Q | 0.0 | 0.833 | CH |
| 11 | -21.1 | S | 27.3 | 0.000 | SM |
| 12 | -13.1 | C | | | CH |
| 13 | -41.3 | C | | | CH |
| 14 | -49.1 | C | | | CH |
| 15 | -66.0 | C | | | CH |

# NOTES

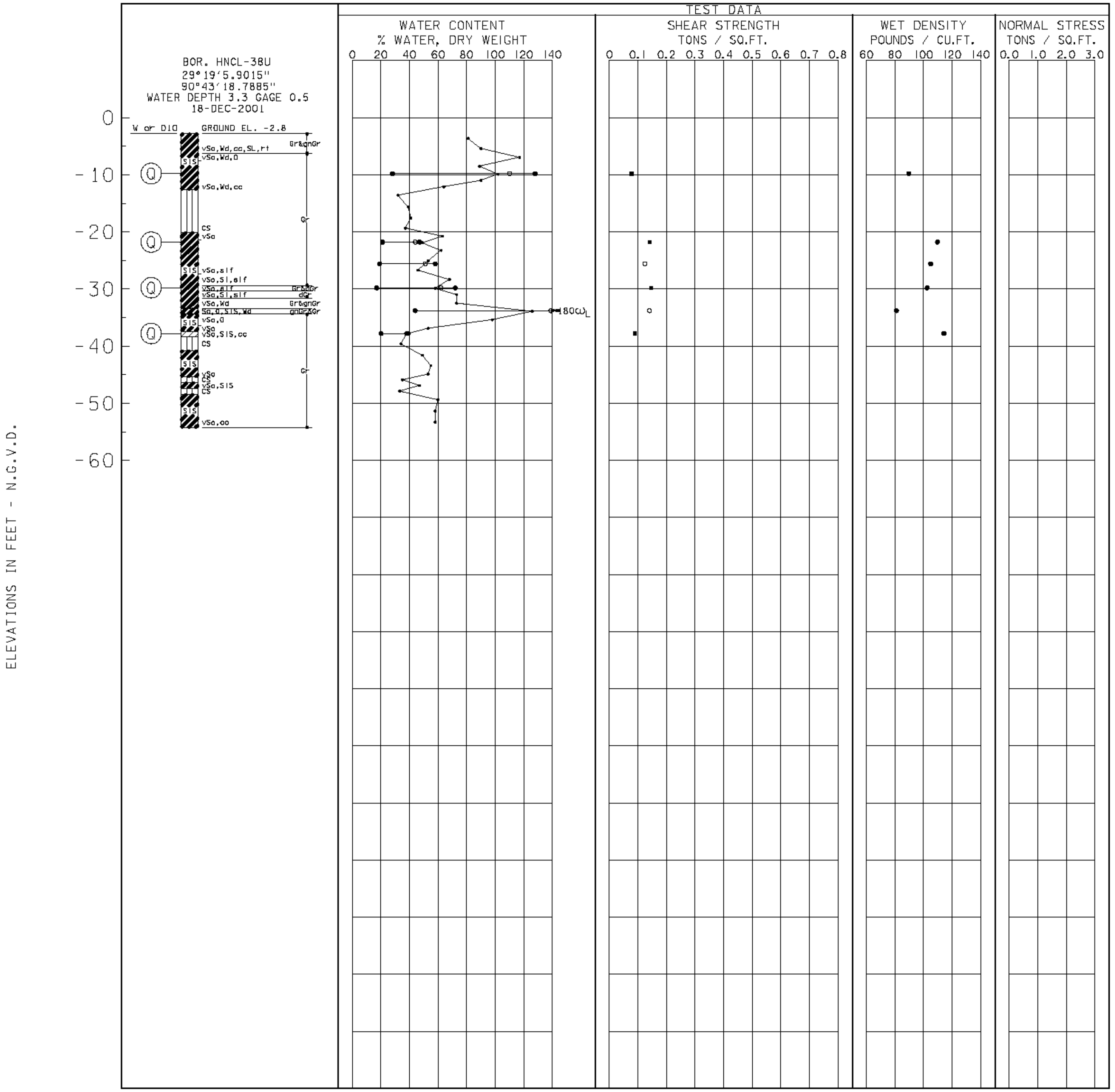
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ — $\omega_N$ — $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

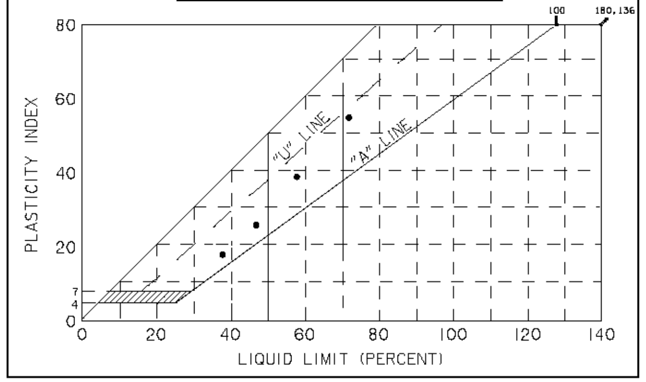
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-1U**

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

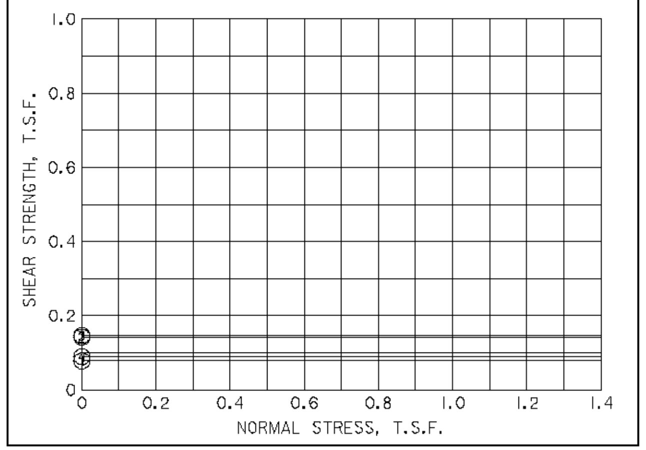
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-1U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -9.8 | Q | 0.0 | 0.078 | CH |
| 2 | -21.8 | Q | 0.0 | 0.142 | CL |
| 3 | -29.8 | Q | 0.0 | 0.146 | CH |
| 4 | -37.8 | Q | 0.0 | 0.089 | CL |

## NOTES

- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

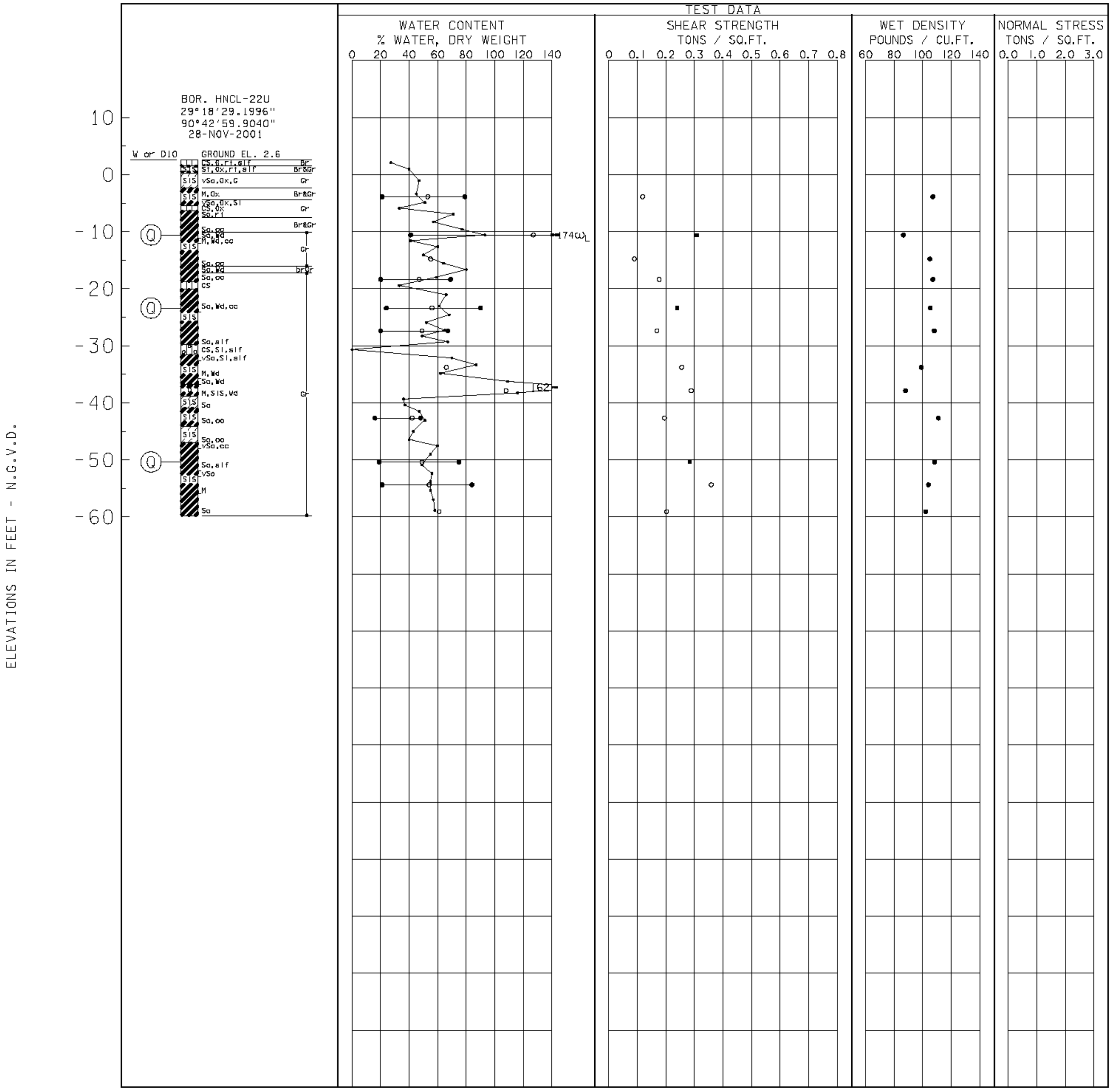
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

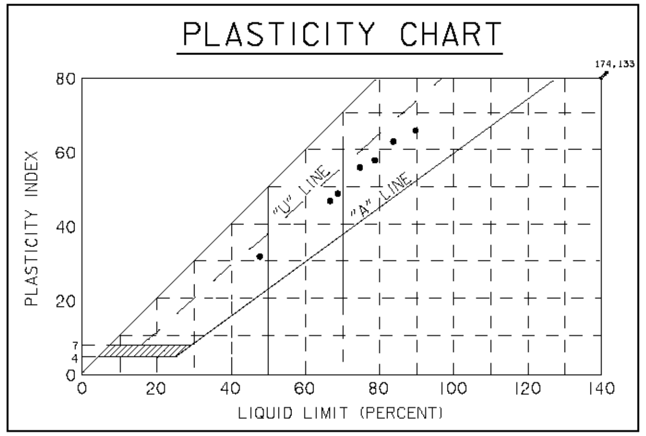
BORING WAS TAKEN WITH A 5 INCH DIAMETER
STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

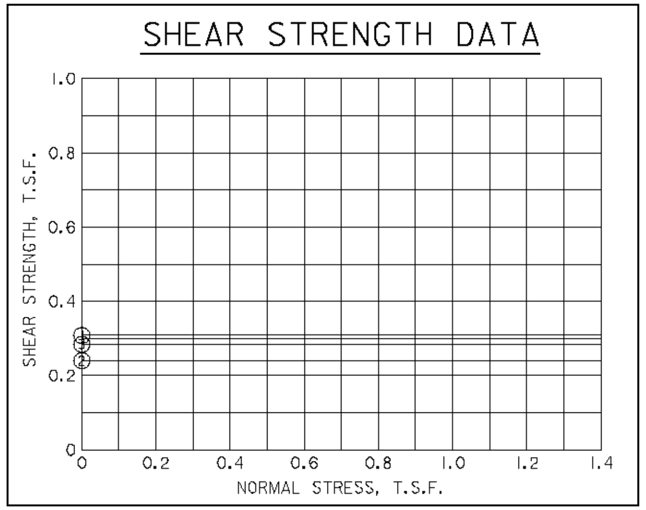
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-38U**

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

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-38U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -10.6 | Q | 0.0 | 0.308 | CH |
| 2 | -23.4 | Q | 0.0 | 0.240 | CH |
| 3 | -50.4 | Q | 0.0 | 0.284 | CH |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

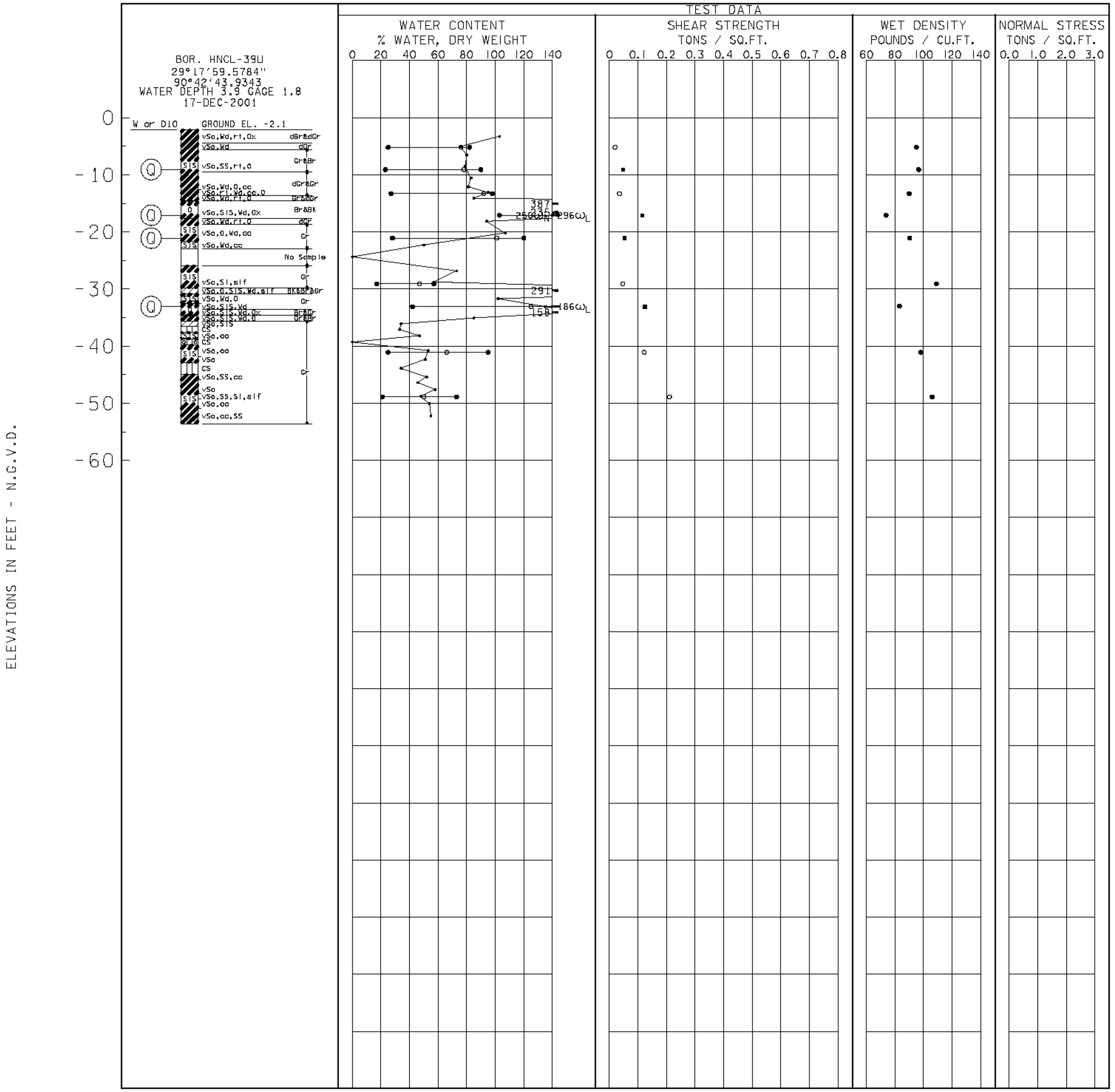
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

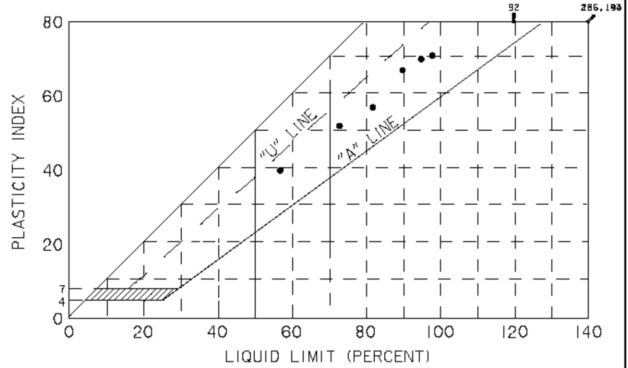
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-22U**

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

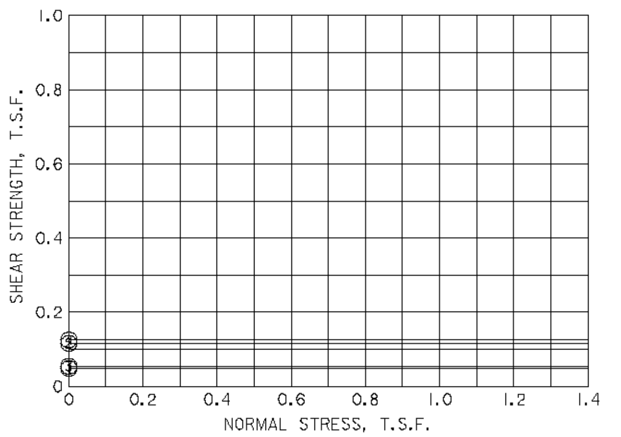
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: C. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-22U.DGN<br>FILE NO. |
| | DATE: MAY 03 | | |




# PLASTICITY CHART




# SHEAR STRENGTH DATA




# TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -9.1 | Q | 0.0 | 0.048 | CH |
| 2 | -17.1 | Q | 0.0 | 0.116 | CH |
| 3 | -21.1 | Q | 0.0 | 0.054 | CH |
| 4 | -33.1 | Q | 0.0 | 0.125 | CH |

# NOTES

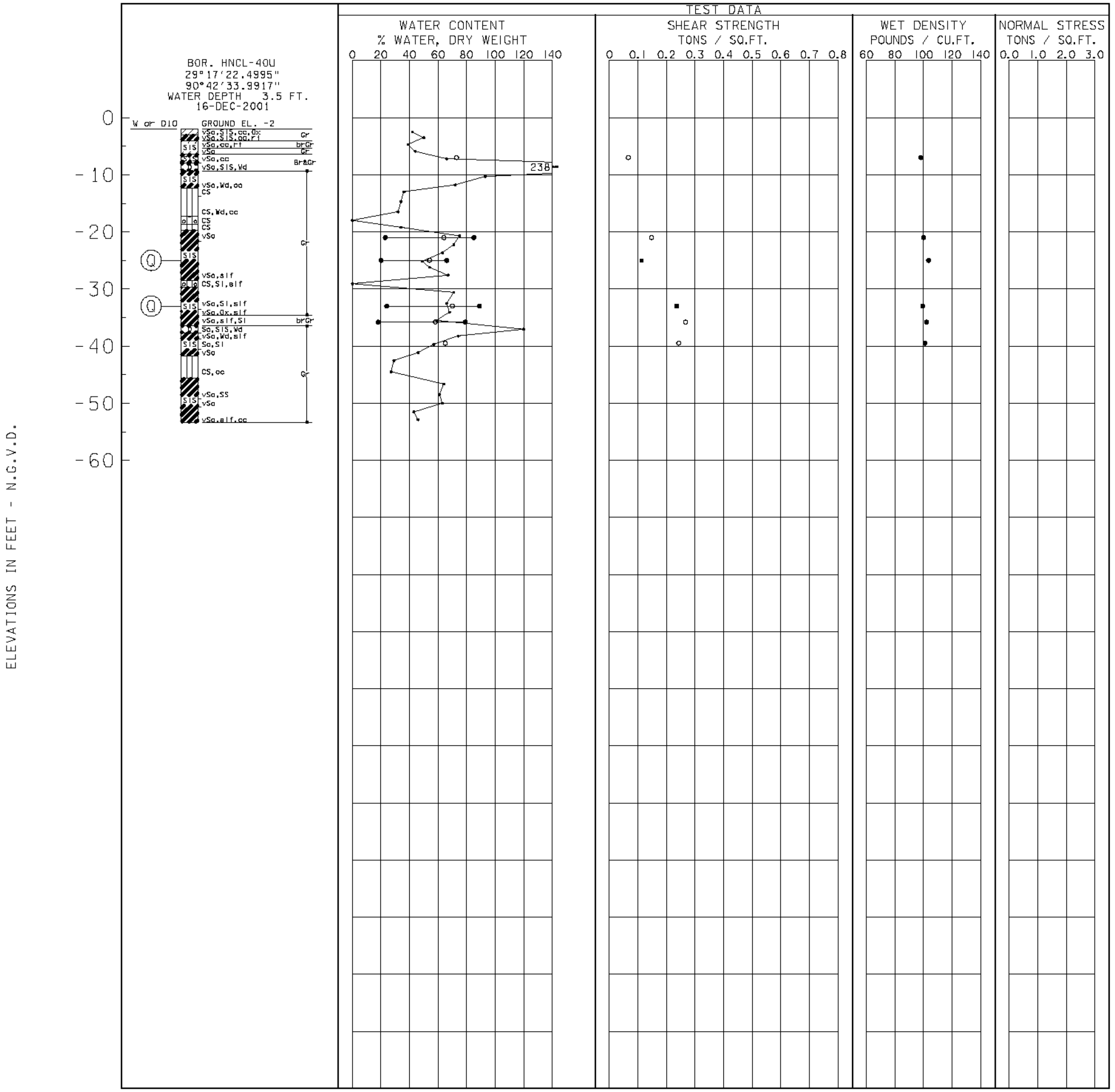
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

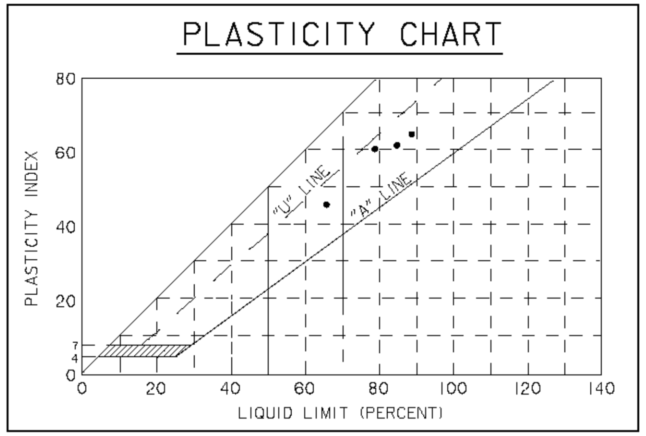
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-39U**

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

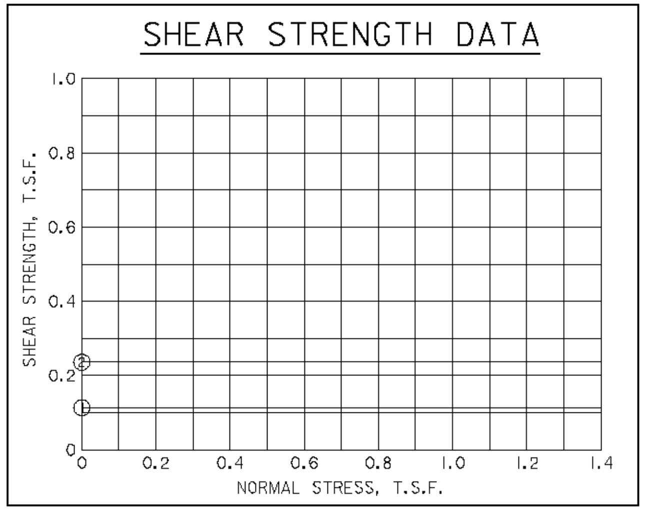
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-39U.DGN |
|---|---|---|---|
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## TABULAR TEST DATA

| ENVELOPE NO. | ENVELOPE EL. | TYPE | STRENGTH Φ | STRENGTH C - TSF | CLASS |
|---|---|---|---|---|---|
| 1 | -25.0 | Q | 0.0 | 0.113 | CH |
| 2 | -33.0 | Q | 0.0 | 0.236 | CH |




## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

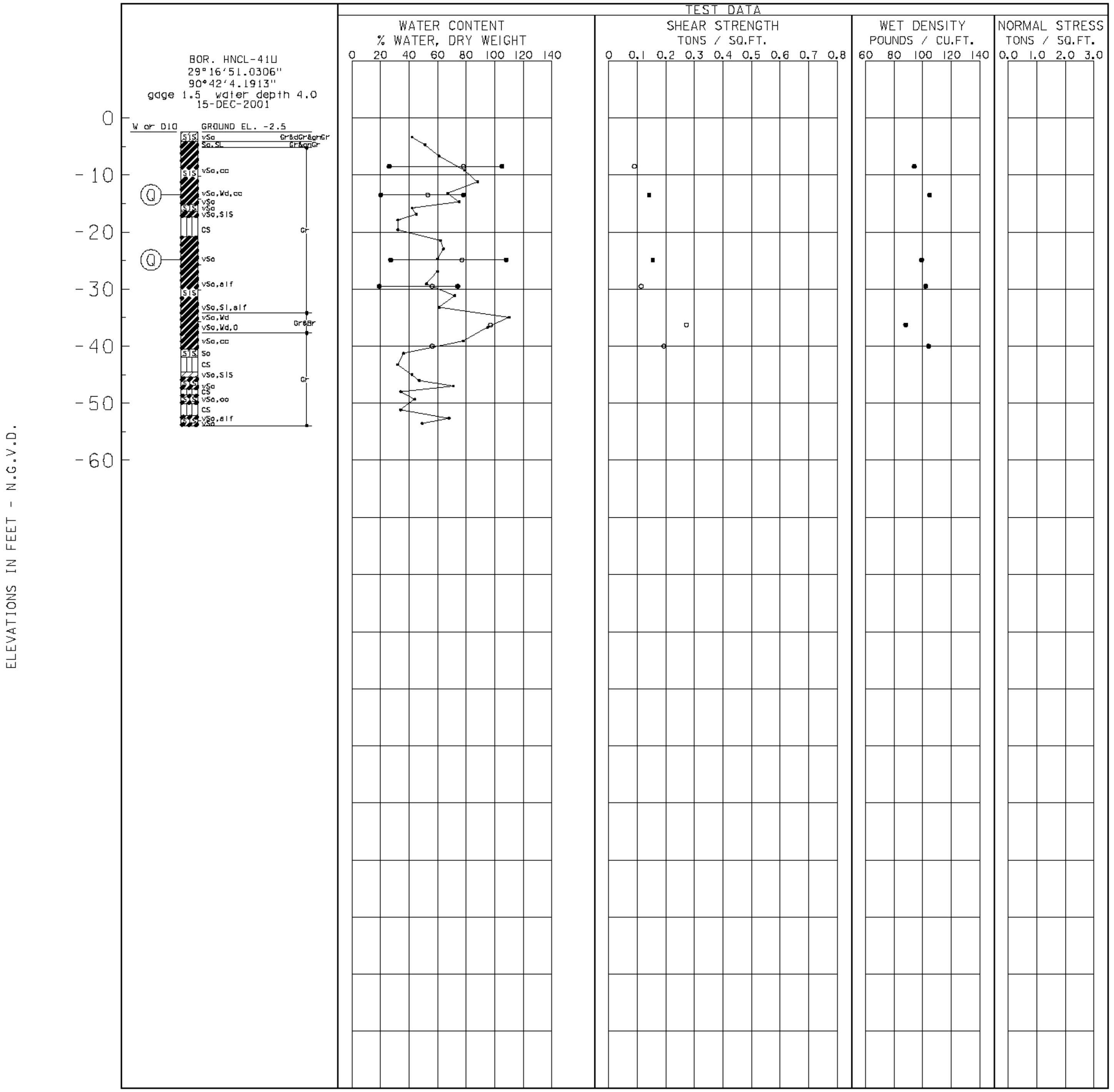
$\omega_P$ — $\omega_N$ — $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

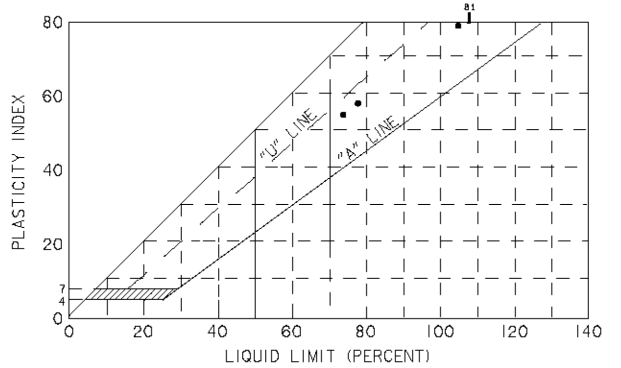
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-40U**

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

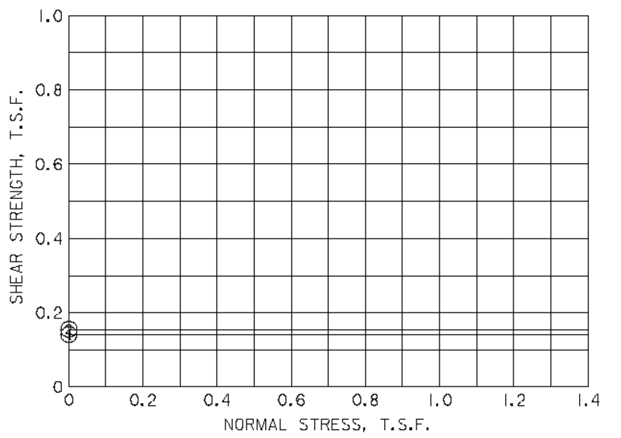
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-40U.DGN |
|---|---|---|---|
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




# PLASTICITY CHART




# SHEAR STRENGTH DATA




# TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -13.5 | Q | 0.0 | 0.141 | CH |
| 2 | -24.9 | Q | 0.0 | 0.155 | CH |
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# NOTES

- ○ - (UC) UNCONFINED COMPRESSION TEST
- ▣ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

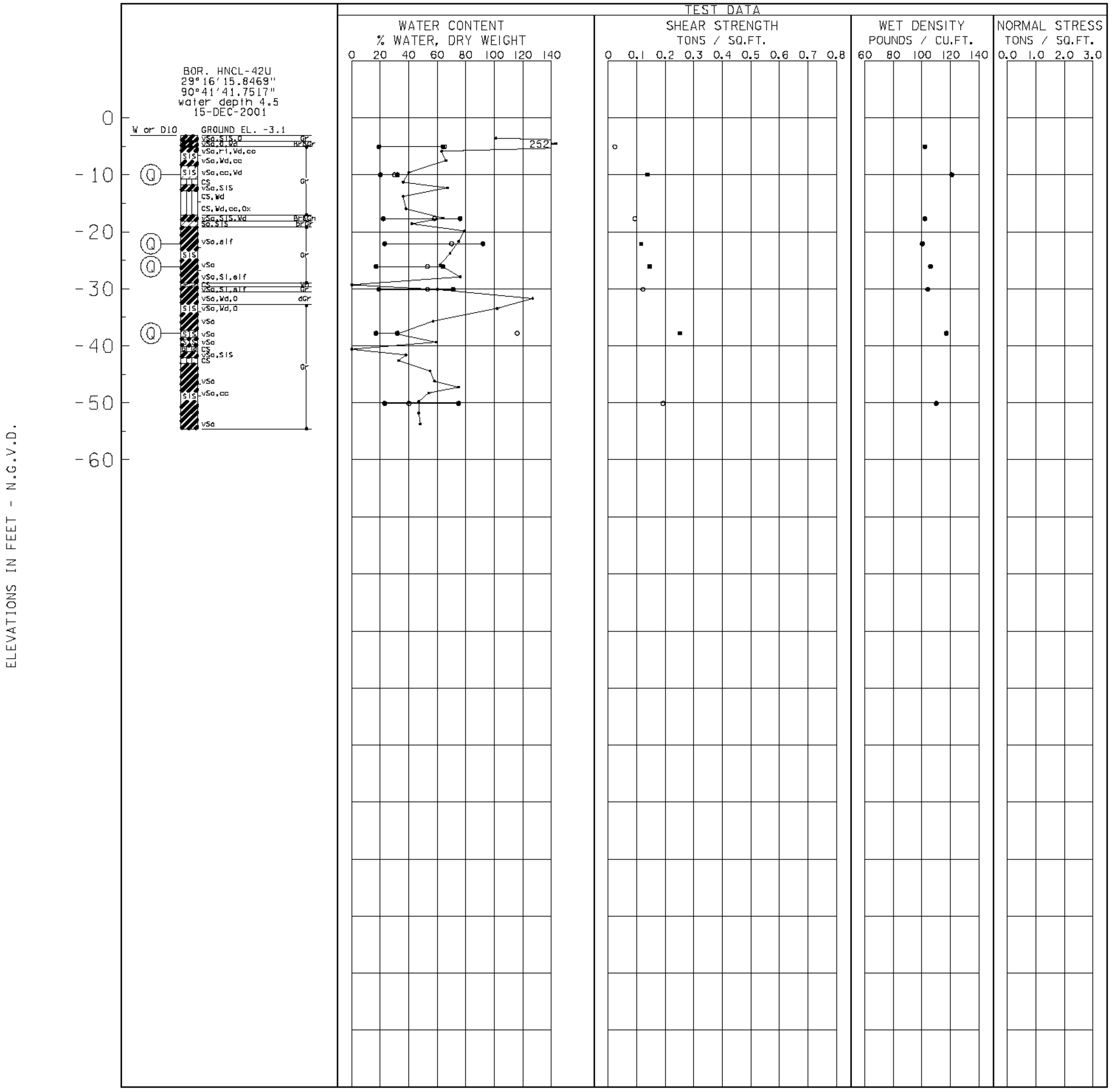
BORING WAS TAKEN WITH A 5 INCH DIAMETER
STEEL TUBE PISTON TYPE SAMPLER.

FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

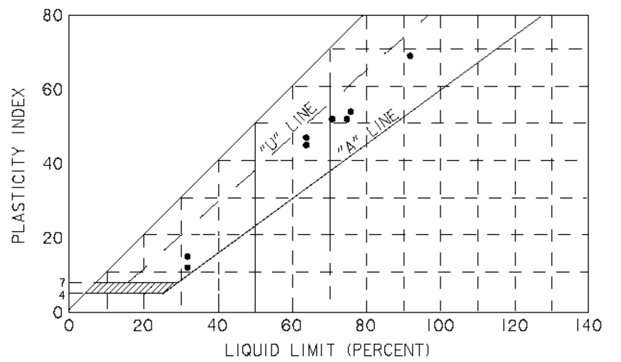
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-41U**

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

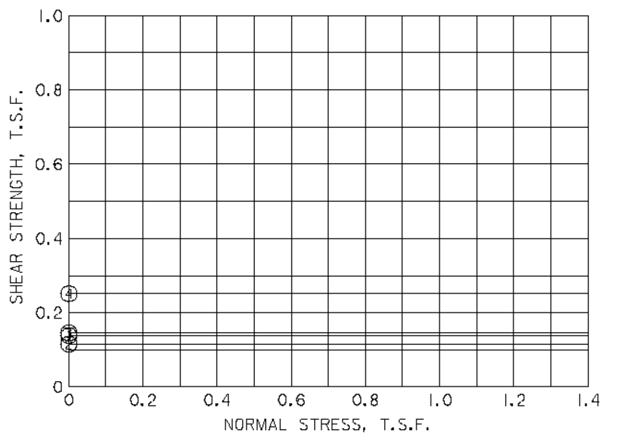
| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-41U.DGN |
|---|---|---|---|
| | DATE: MAY 03 | | FILE NO. |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | c - TSF | |
| 1 | -10.0 | Q | 0.0 | 0.138 | CL |
| 2 | -22.1 | Q | 0.0 | 0.115 | CH |
| 3 | -26.1 | Q | 0.0 | 0.145 | CH |
| 4 | -37.8 | Q | 0.0 | 0.251 | CL |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

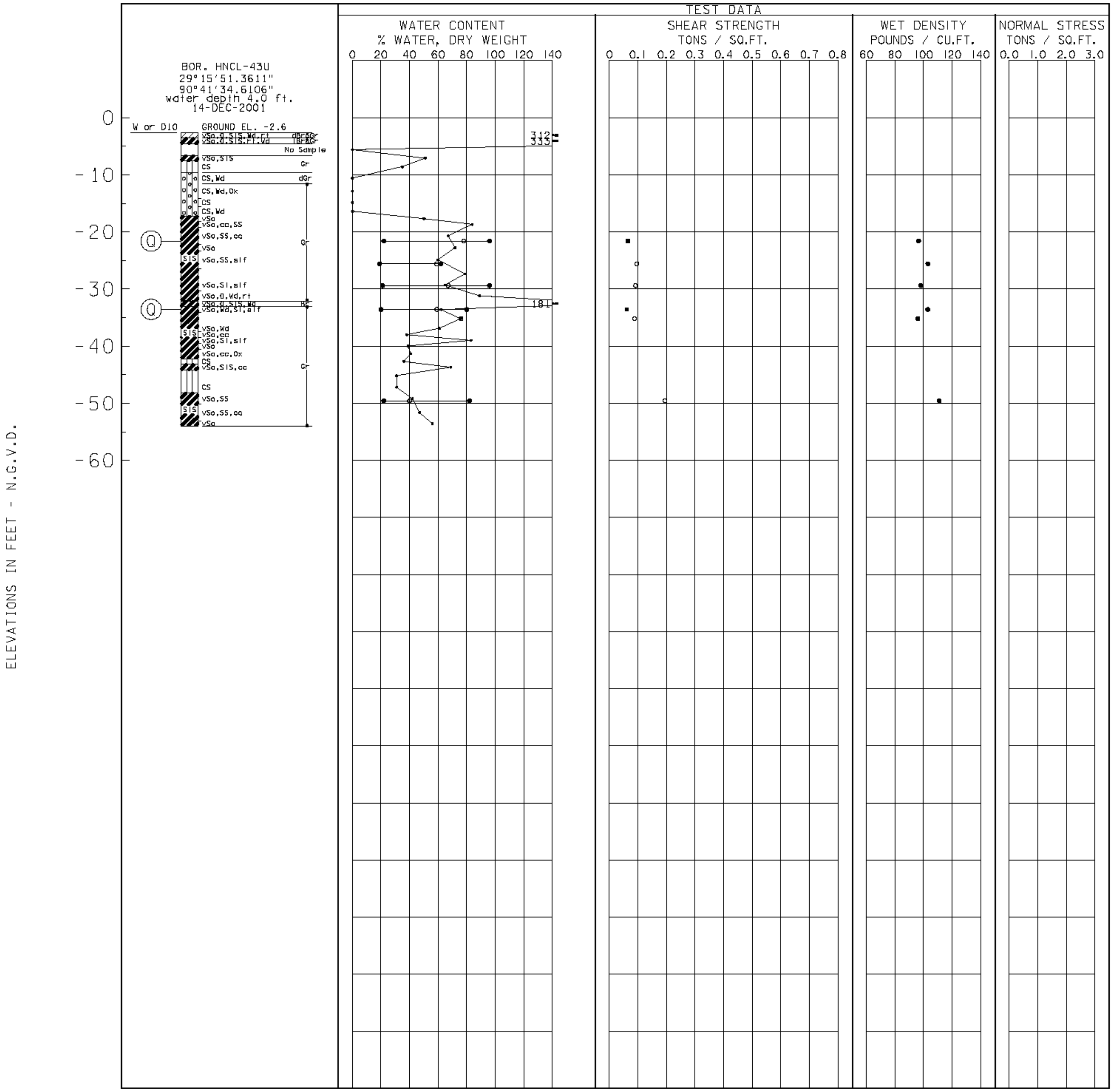
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

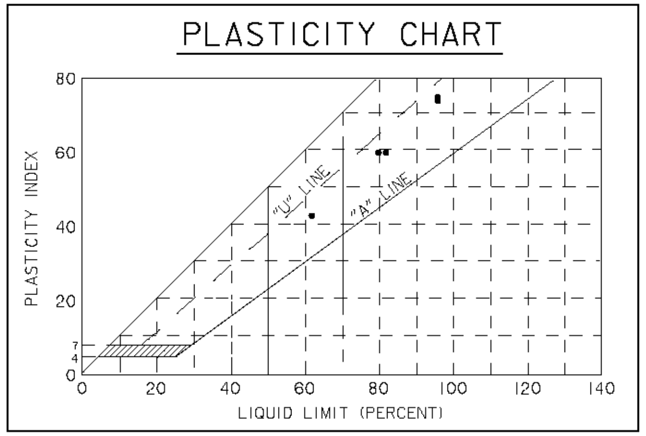
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

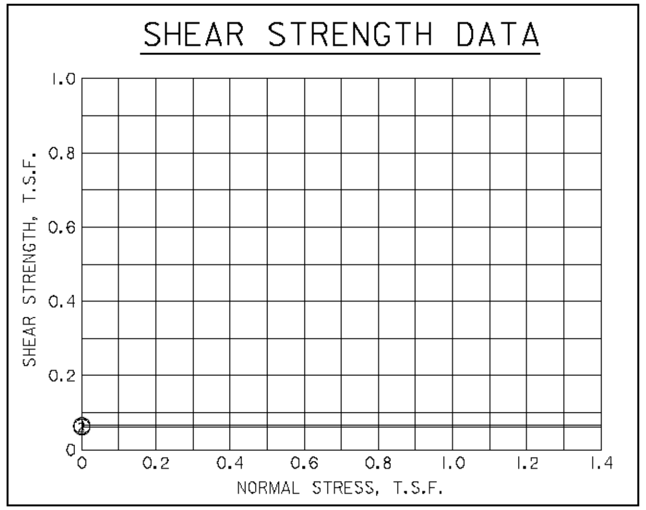
**UNDISTURBED BORING**
**BOR. HNCL-42U**

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

| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-42U.DGN |
|---|---|---|---|
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## TABULAR TEST DATA

| ENVELOPE NO. | ENVELOPE EL. | TYPE | STRENGTH Φ | STRENGTH C - TSF | CLASS |
|---|---|---|---|---|---|
| 1 | -21.6 | Q | 0.0 | 0.065 | CH |
| 2 | -33.6 | Q | 0.0 | 0.061 | CH |

## NOTES

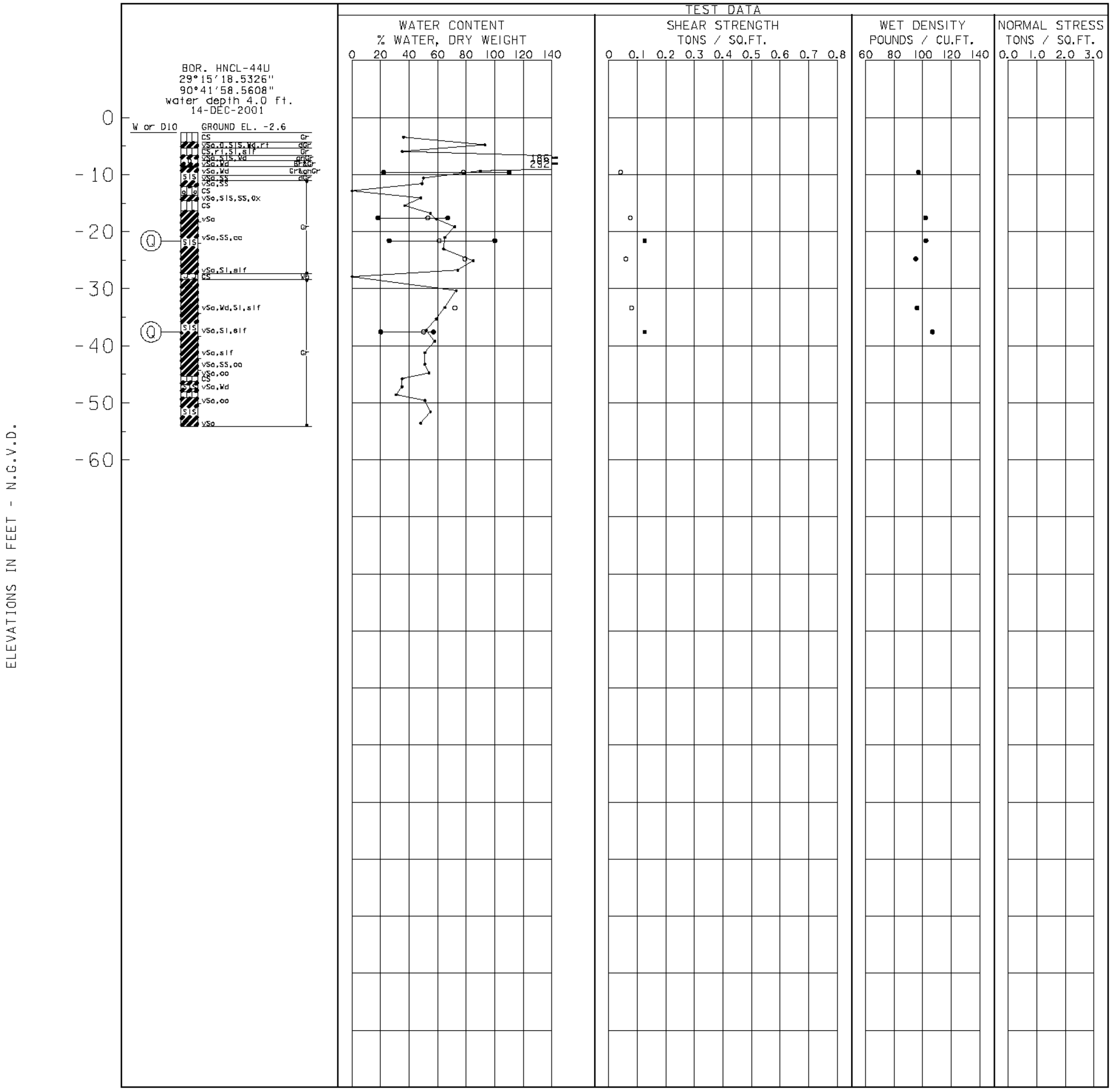
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

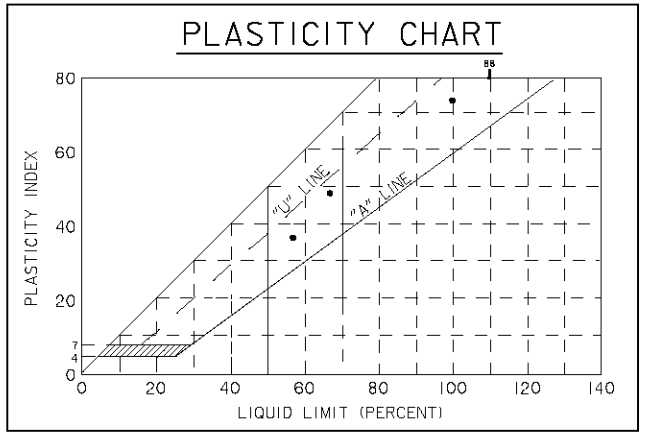
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

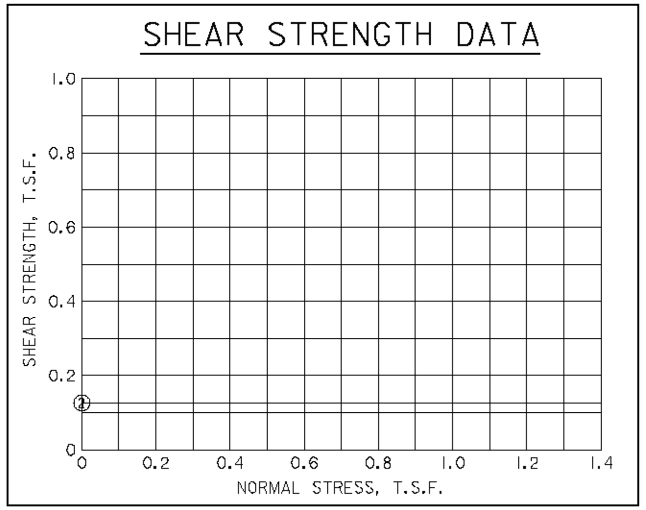
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-43U**

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

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-43U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## TABULAR TEST DATA

| ENVELOPE NO. | ENVELOPE EL. | TYPE | STRENGTH Φ | STRENGTH C - TSF | CLASS |
|---|---|---|---|---|---|
| 1 | -21.6 | Q | 0.0 | 0.126 | CH |
| 2 | -37.6 | Q | 0.0 | 0.126 | CH |

## NOTES

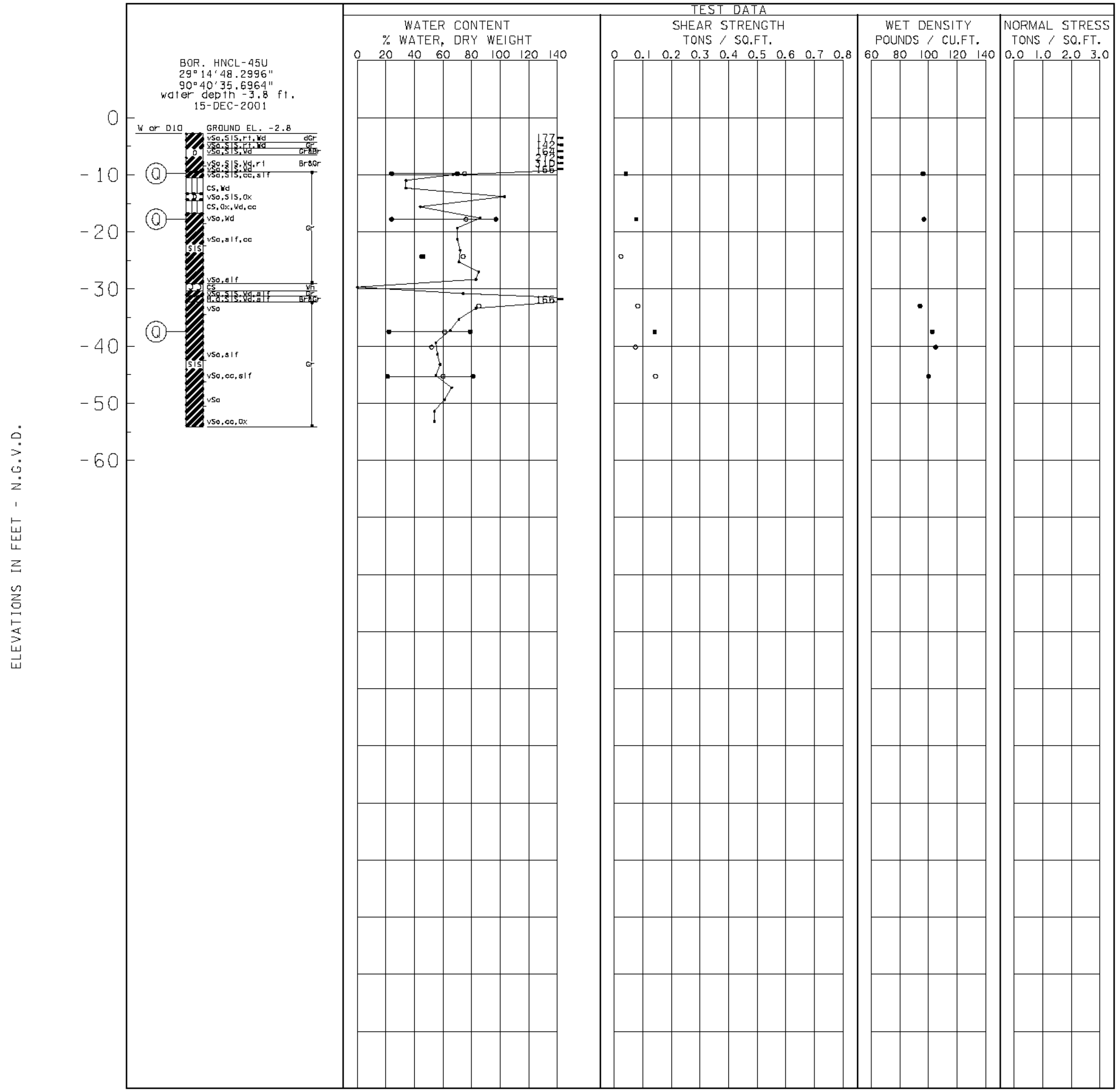
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

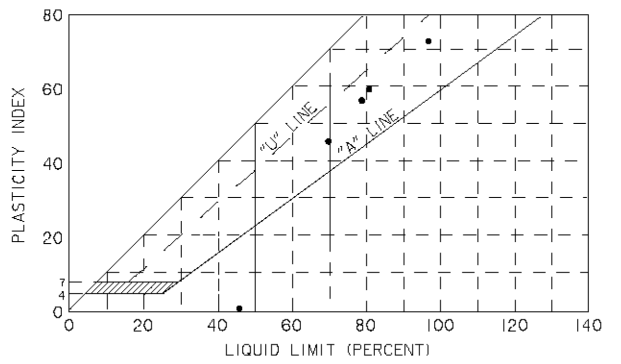
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-44U**

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

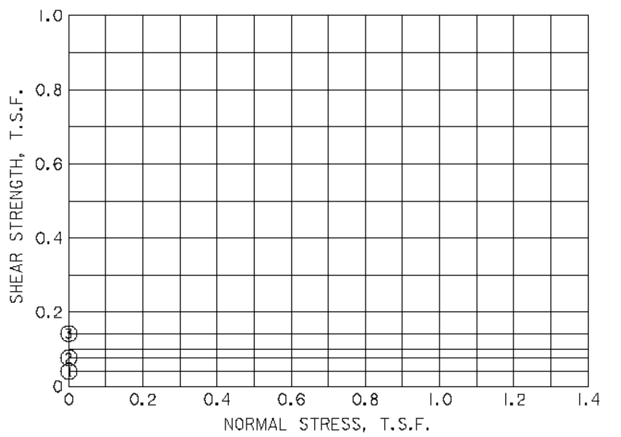
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-44U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE NO. | ENVELOPE EL. | TYPE | STRENGTH Φ | STRENGTH C - TSF | CLASS |
|---|---|---|---|---|---|
| 1 | -9.8 | Q | 0.0 | 0.040 | CH |
| 2 | -17.8 | Q | 0.0 | 0.077 | CH |
| 3 | -37.5 | Q | 0.0 | 0.142 | CH |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

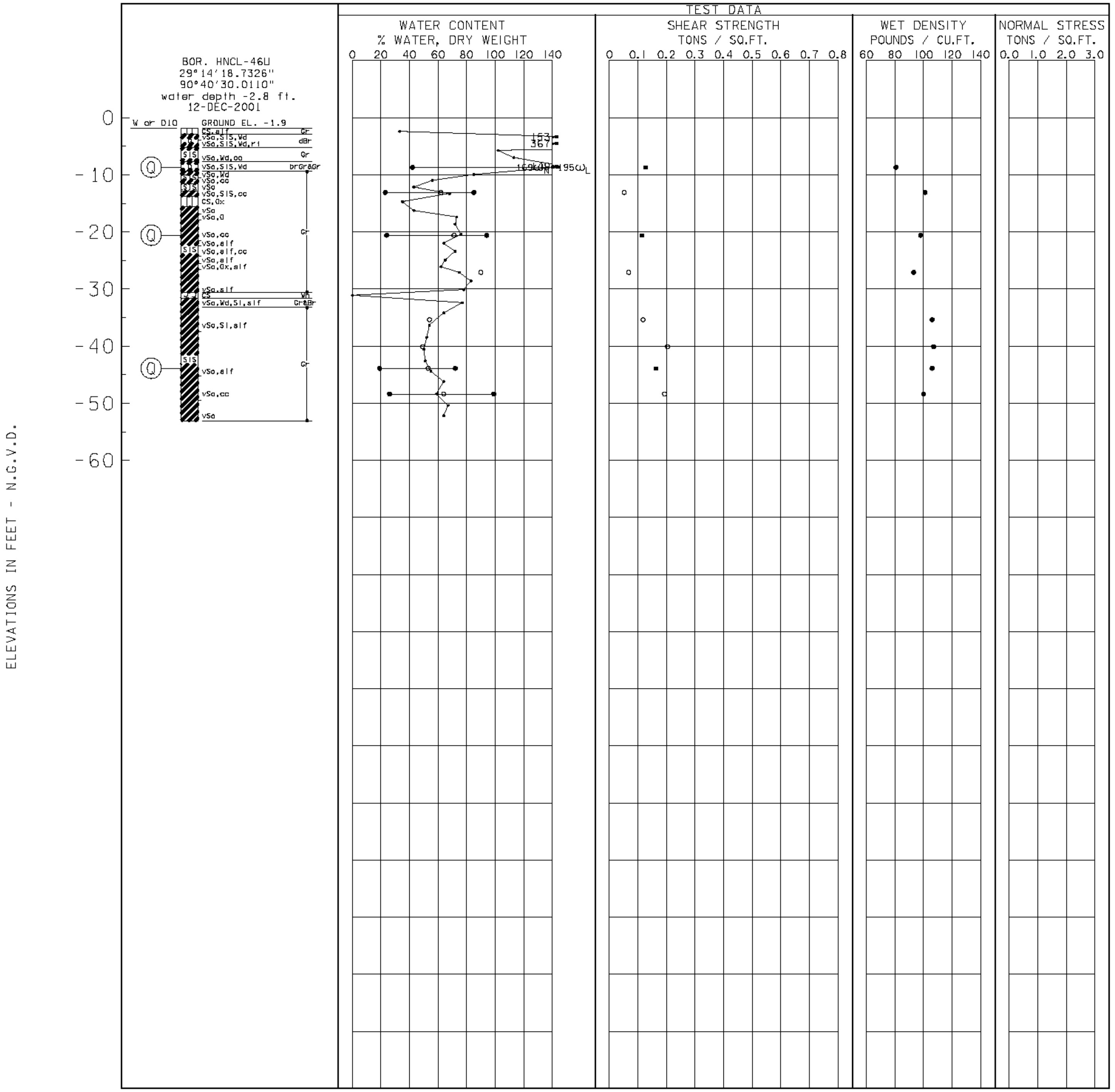
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

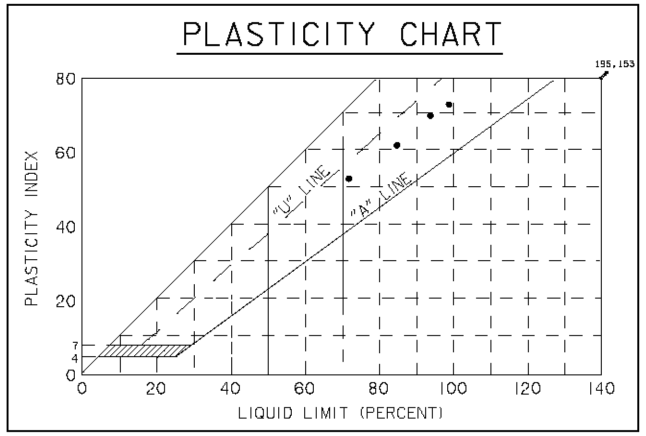
**UNDISTURBED BORING**
**BOR. HNCL-45U**

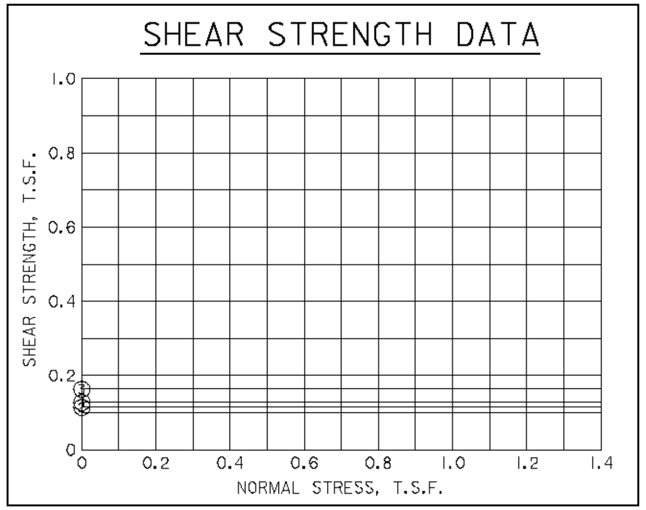
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA

| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-45U |
|---|---|---|---|
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |

PLATE G31




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -8.7 | Q | 0.0 | 0.127 | CH |
| 2 | -20.6 | Q | 0.0 | 0.114 | CH |
| 3 | -43.9 | Q | 0.0 | 0.163 | CH |

## NOTES

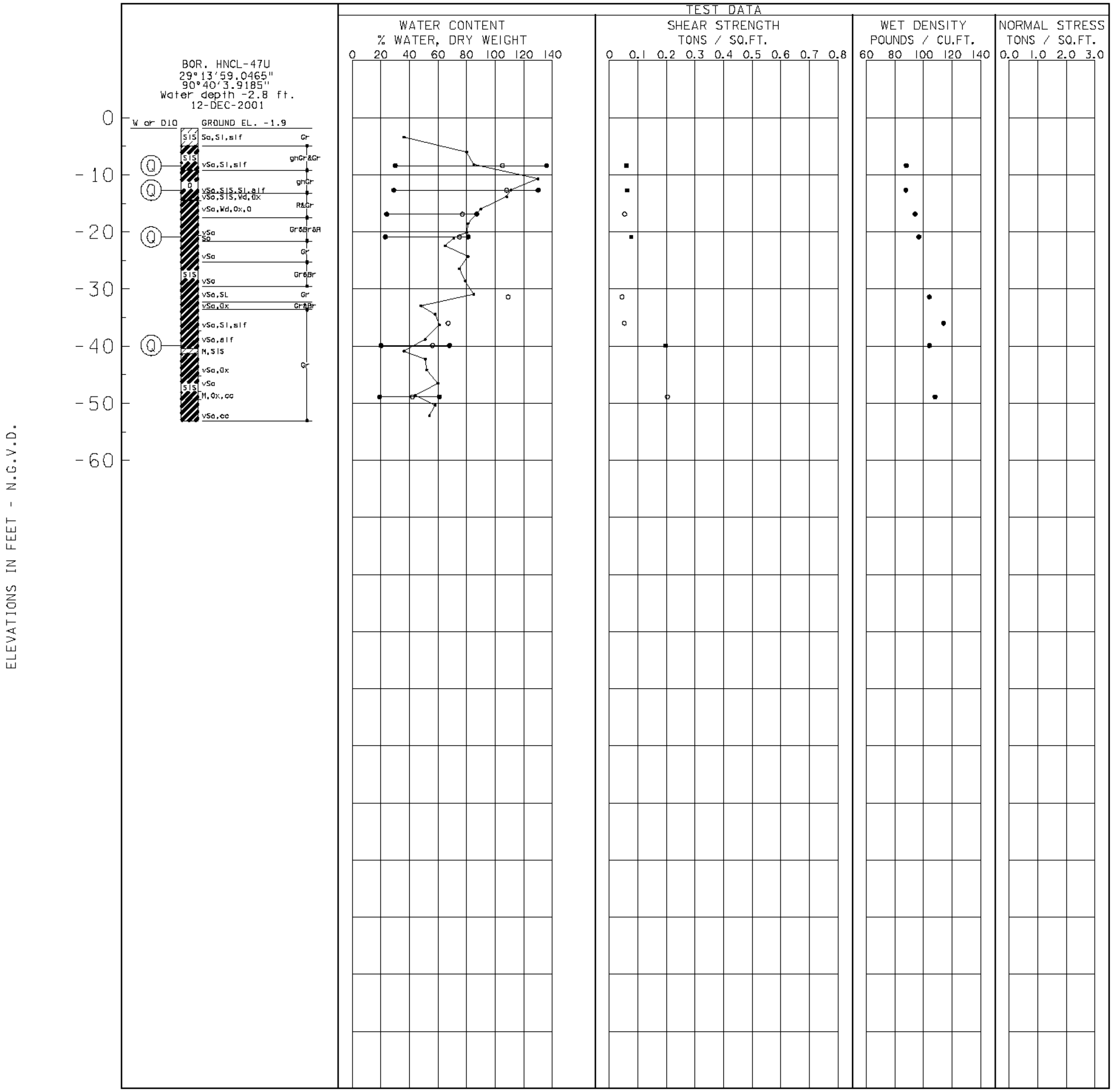
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ — $\omega_N$ — $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

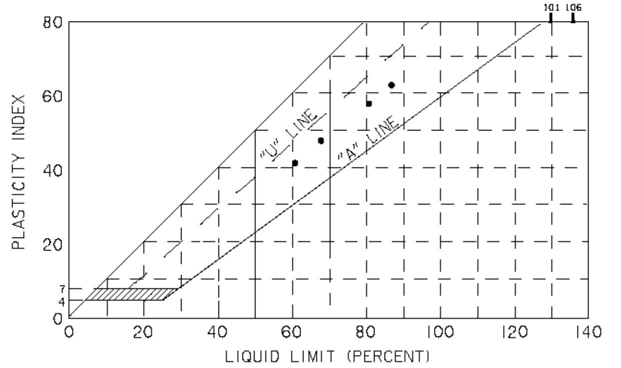
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-46U**

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

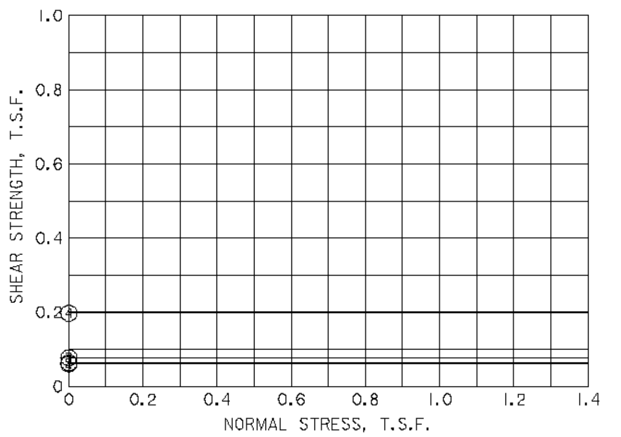
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-46U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -8.4 | Q | 0.0 | 0.060 | CH |
| 2 | -12.7 | Q | 0.0 | 0.063 | CH |
| 3 | -20.9 | Q | 0.0 | 0.077 | CH |
| 4 | -39.9 | Q | 0.0 | 0.197 | CH |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

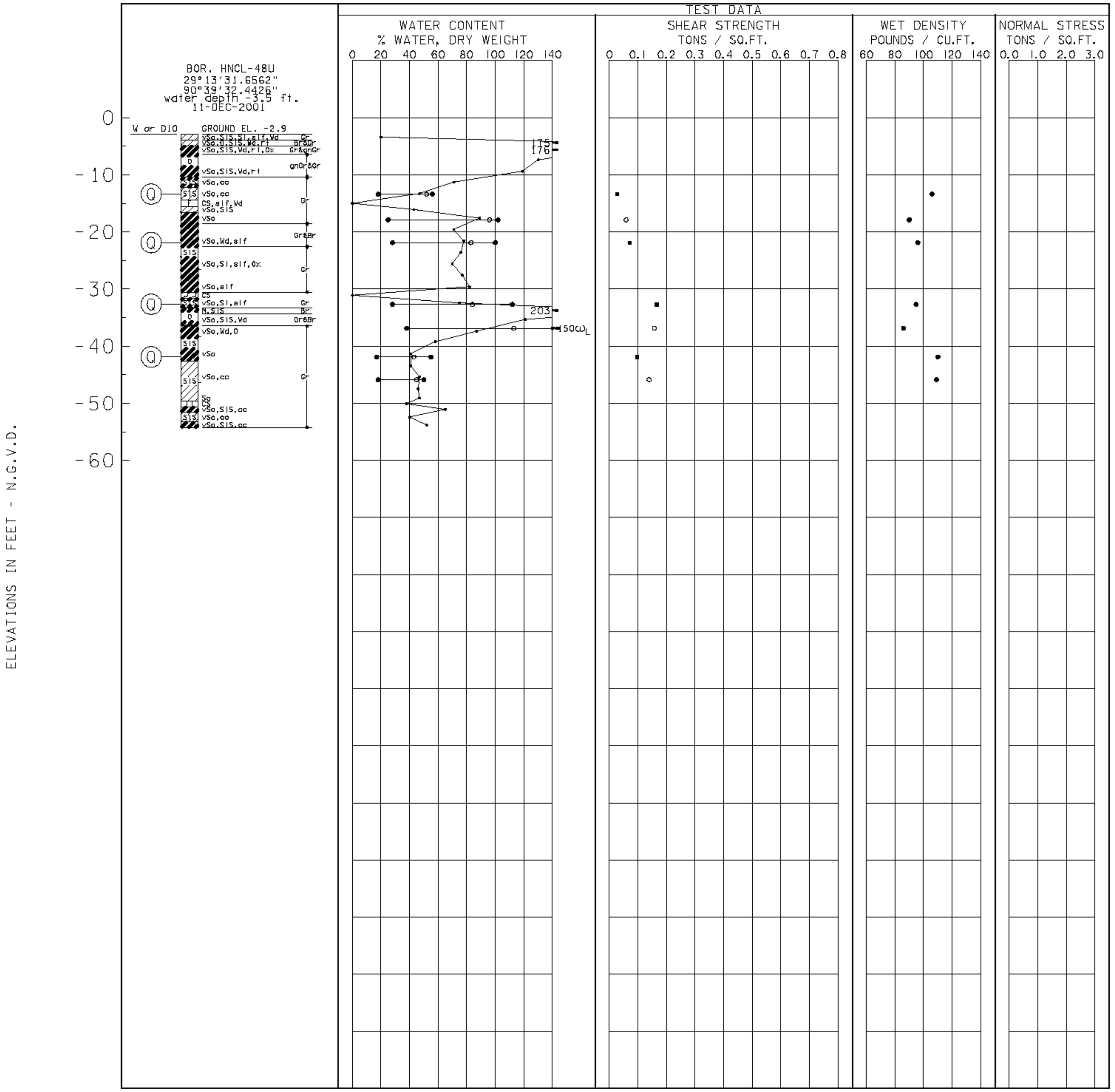
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

**UNDISTURBED BORING**
**BOR. HNCL-47U**

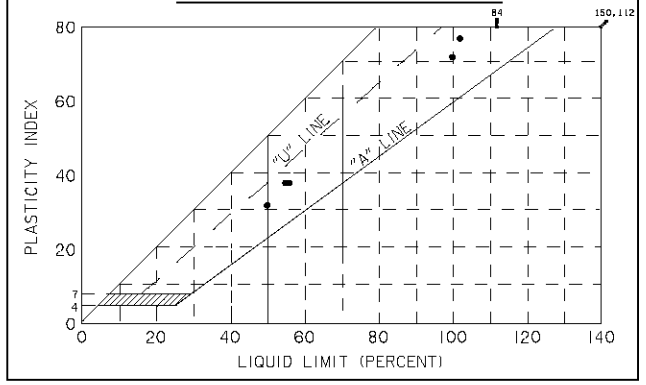
**U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS**
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA

| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-47U.DGN |
|---|---|---|---|
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |

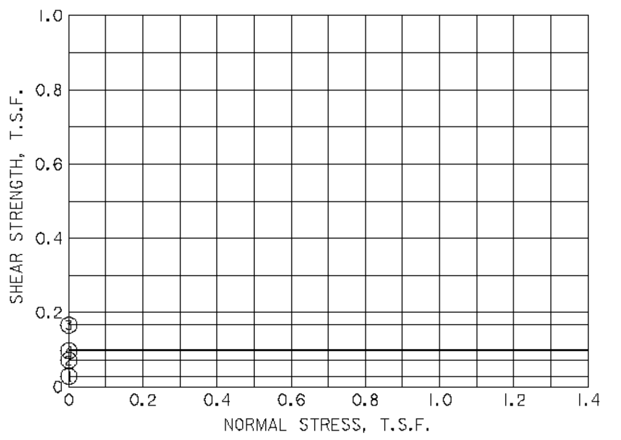
PLATE G33




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -13.4 | Q | 0.0 | 0.028 | CH |
| 2 | -21.9 | Q | 0.0 | 0.071 | CH |
| 3 | -32.7 | Q | 0.0 | 0.166 | CH |
| 4 | -41.9 | Q | 0.0 | 0.097 | CH |

## NOTES

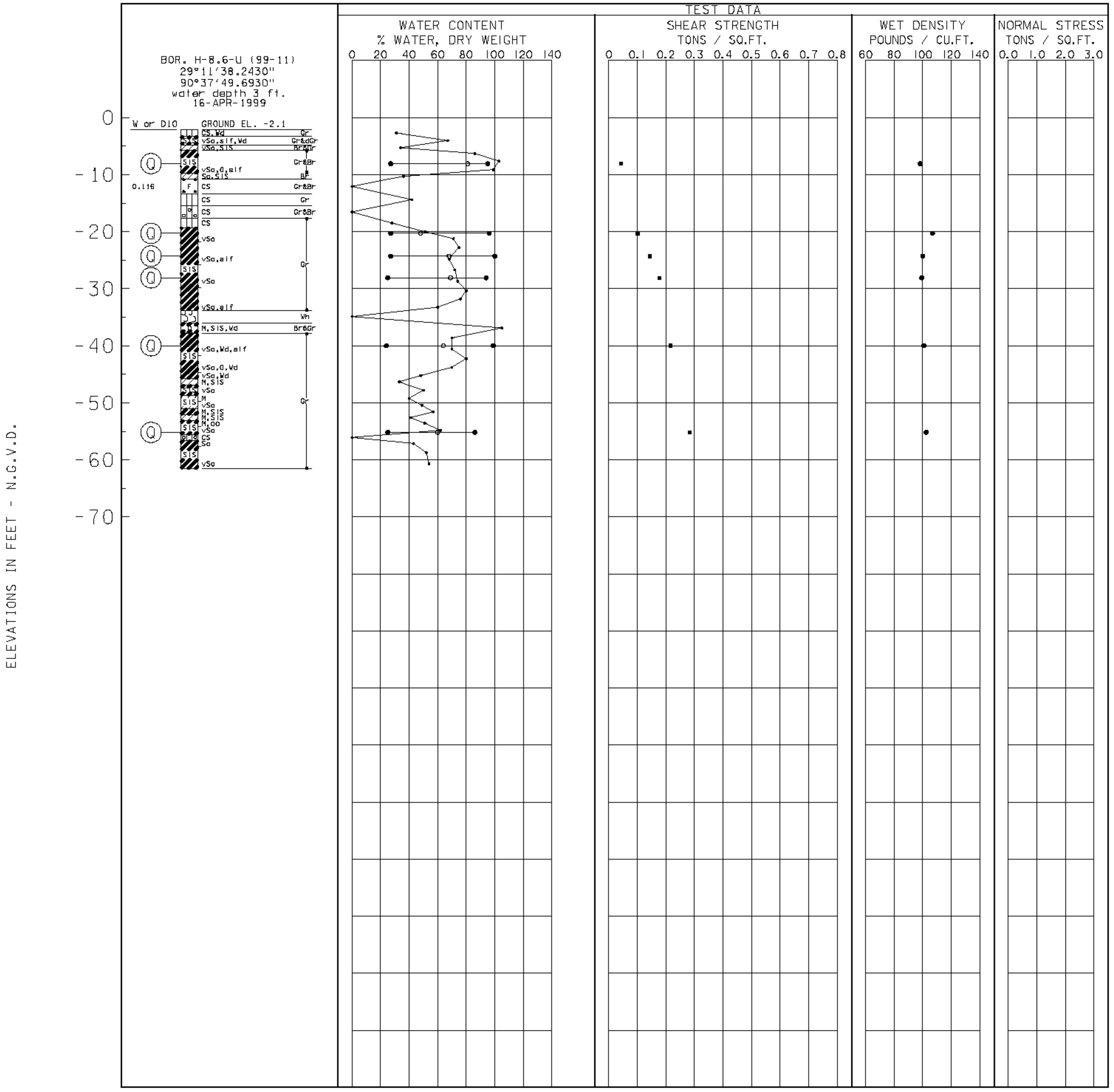
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

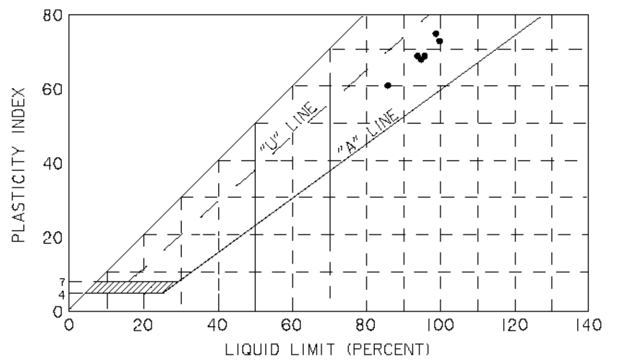
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**UNDISTURBED BORING**
**BOR. HNCL-48U**

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

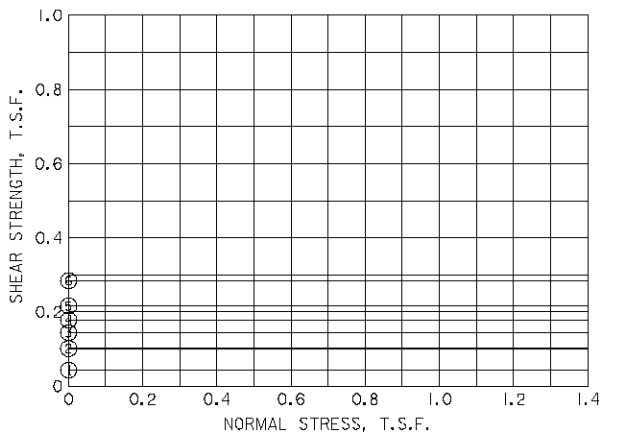
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: HNCL-48U.DGN |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -8.1 | Q | 0.0 | 0.043 | CH |
| 2 | -20.3 | Q | 0.0 | 0.101 | CH |
| 3 | -24.3 | Q | 0.0 | 0.144 | CH |
| 4 | -28.1 | Q | 0.0 | 0.178 | CH |
| 5 | -40.0 | Q | 0.0 | 0.216 | CH |
| 6 | -55.2 | Q | 0.0 | 0.284 | CH |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.

FOR SOIL BORING LEGEND SEE PLATE G39.

FOR LOCATION OF BORINGS SEE PLATE G1

FOR DETAILED TEST DATA SEE ANNEX 2

HOUMA NAVIGATION CANAL

HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT

MILE 36.0 TO MILE (-)5.0

TERREBONNE PARISH, LOUISIANA

**UNDISTURBED BORING**

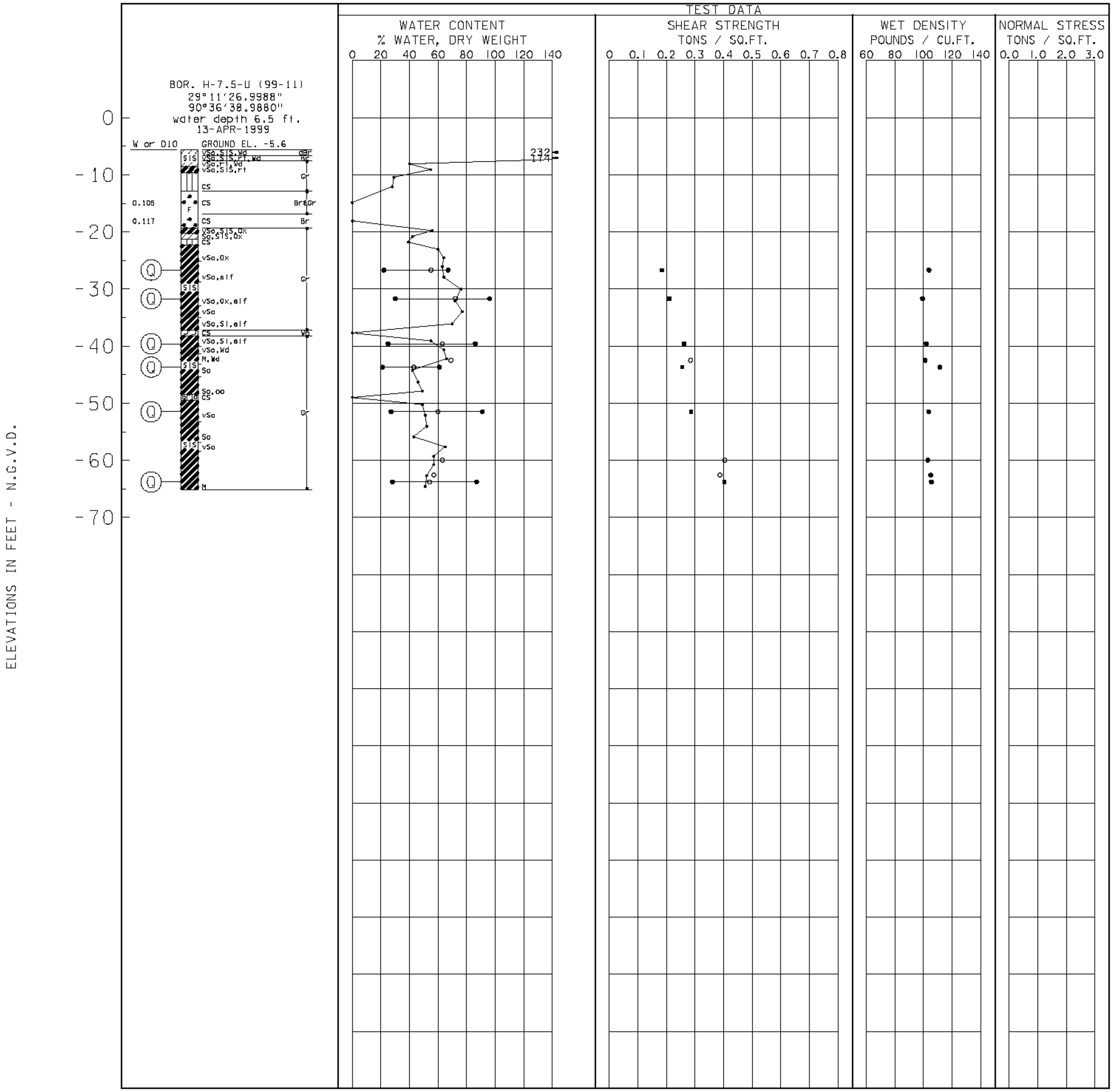
**BOR. H-8.6-U**

**U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS**

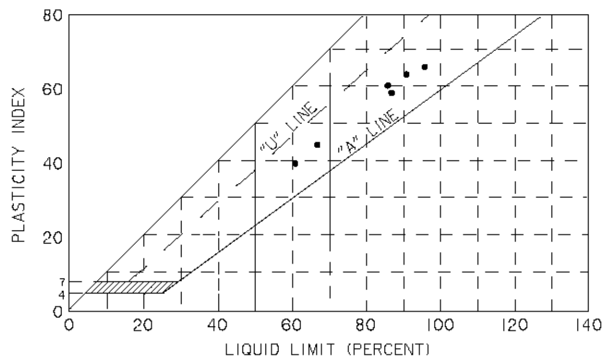
CORPS OF ENGINEERS

NEW ORLEANS, LOUISIANA

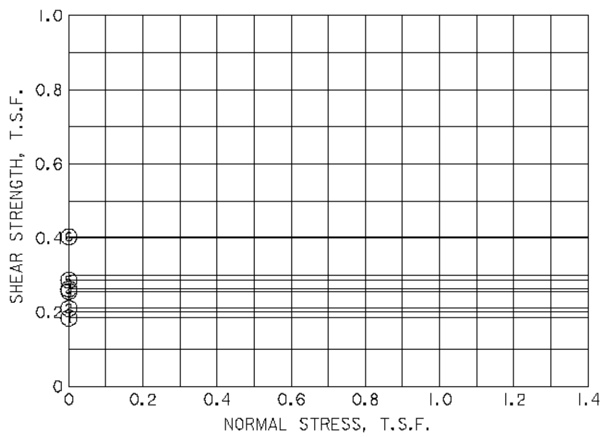
| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: H-8.6U |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -26.7 | Q | 0.0 | 0.184 | CH |
| 2 | -31.7 | Q | 0.0 | 0.210 | CH |
| 3 | -39.6 | Q | 0.0 | 0.262 | CH |
| 4 | -43.7 | Q | 0.0 | 0.256 | CH |
| 5 | -51.5 | Q | 0.0 | 0.286 | CH |
| 6 | -63.8 | Q | 0.0 | 0.403 | CH |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

$\omega_P$ ● — ○ $\omega_N$ — ● $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.

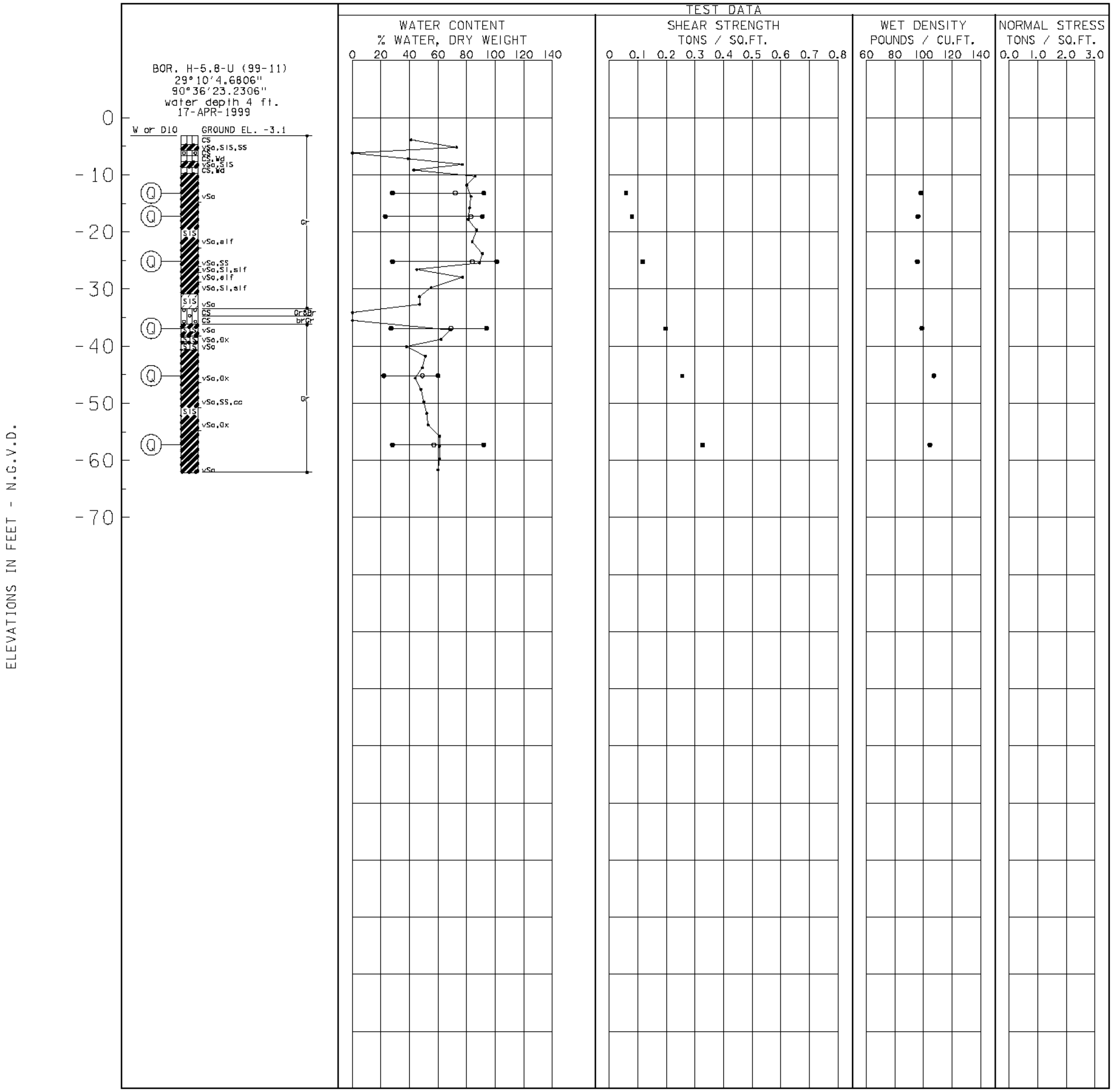
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

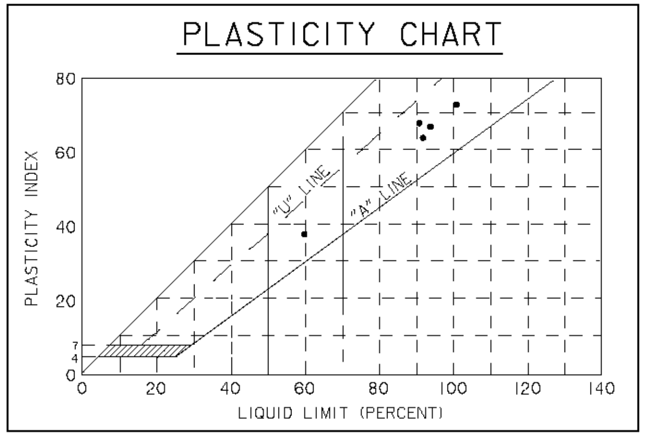
HOUMA NAVIGATION CANAL
**HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT**
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

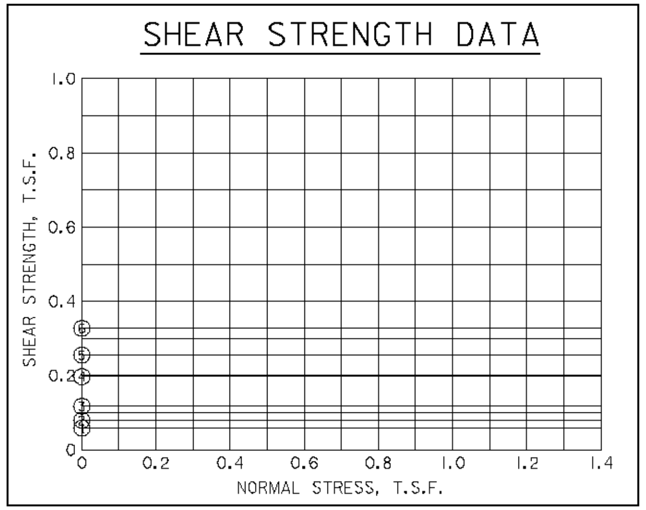
# UNDISTURBED BORING
# BOR. H-7.5-U

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

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: H-7.5U |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




## TABULAR TEST DATA

| ENVELOPE NO. | ENVELOPE EL. | TYPE | STRENGTH Φ | STRENGTH C - TSF | CLASS |
|---|---|---|---|---|---|
| 1 | -13.2 | Q | 0.0 | 0.058 | CH |
| 2 | -17.3 | Q | 0.0 | 0.079 | CH |
| 3 | -25.2 | Q | 0.0 | 0.117 | CH |
| 4 | -36.9 | Q | 0.0 | 0.197 | CH |
| 5 | -45.2 | Q | 0.0 | 0.255 | CH |
| 6 | -57.3 | Q | 0.0 | 0.327 | CH |

## NOTES

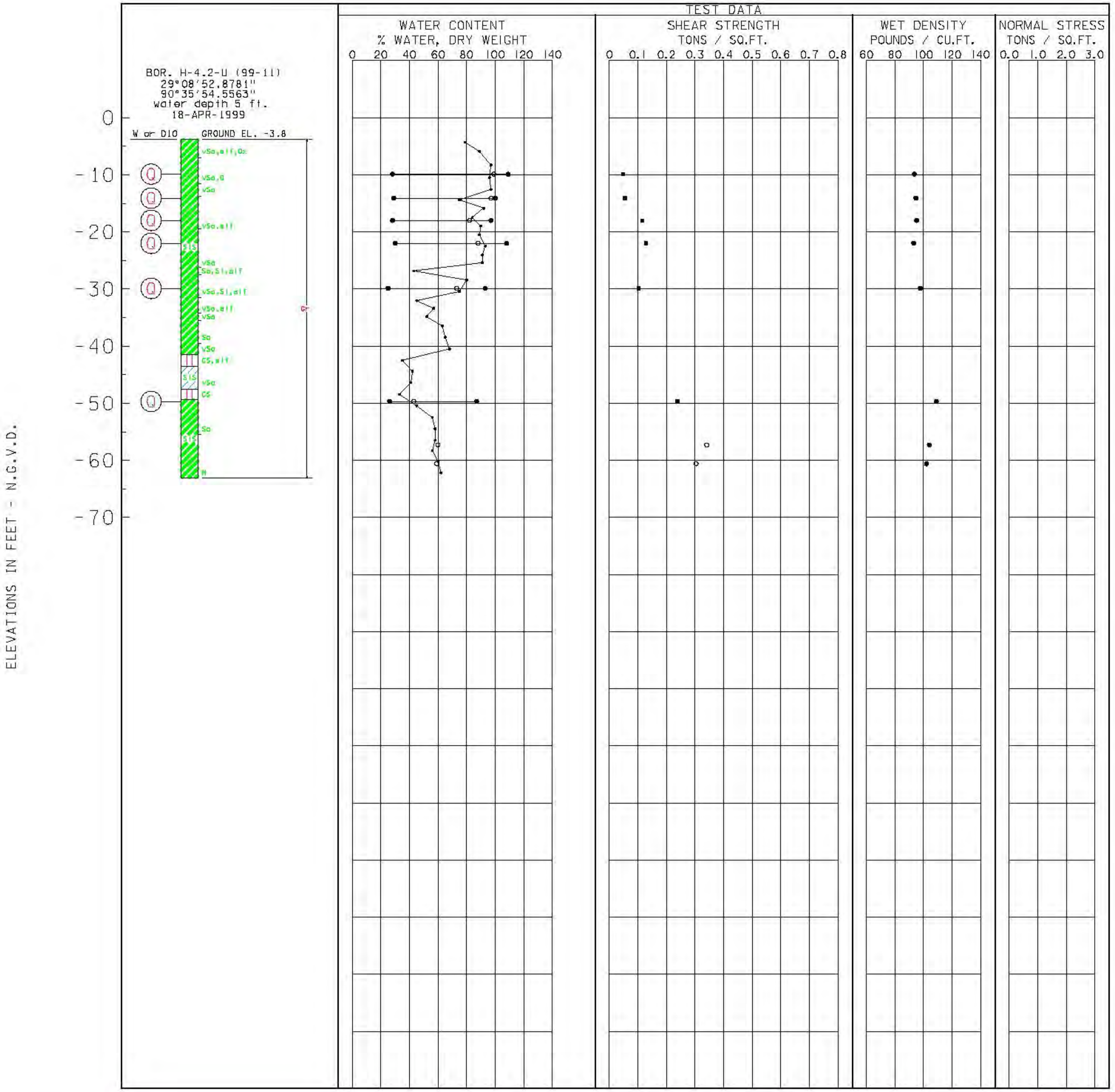
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

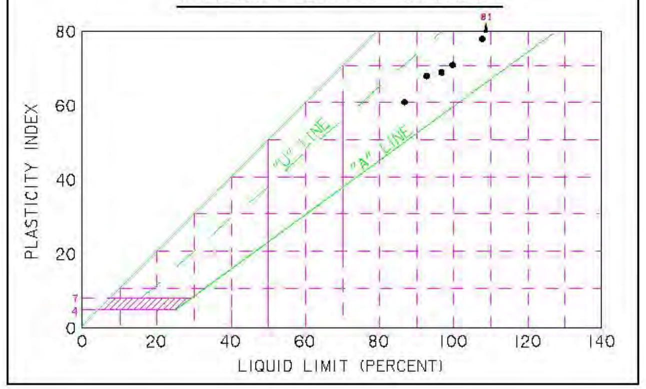
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONE PARISH, LOUISIANA
**GENERAL BORING**
**BOR. H-5.8-U**

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

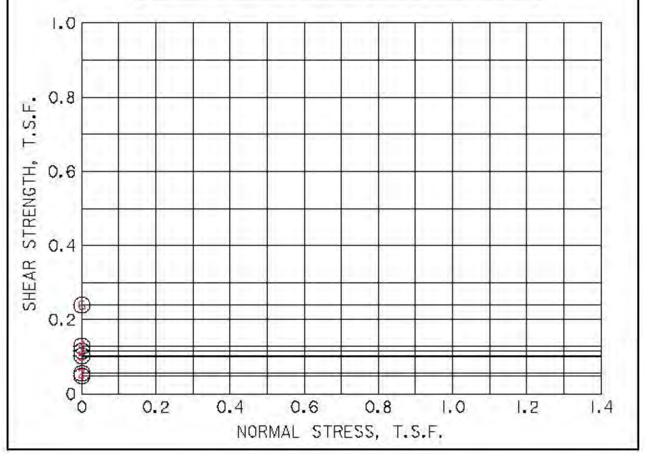
| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: H-5.8U<br>FILE NO. |
|---|---|---|---|
| | DATE: MAY 03 | | |




## PLASTICITY CHART




## SHEAR STRENGTH DATA




## TABULAR TEST DATA

| ENVELOPE | | TYPE | STRENGTH | | CLASS |
|---|---|---|---|---|---|
| NO. | EL. | | Φ | C - TSF | |
| 1 | -9.9 | Q | 0.0 | 0.048 | CH |
| 2 | -14.1 | Q | 0.0 | 0.055 | CH |
| 3 | -18.0 | Q | 0.0 | 0.115 | CH |
| 4 | -22.0 | Q | 0.0 | 0.129 | CH |
| 5 | -29.9 | Q | 0.0 | 0.102 | CH |
| 6 | -49.7 | Q | 0.0 | 0.239 | CH |

## NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

$\omega_P$ $\omega_N$ $\omega_L$ ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE G39.
FOR LOCATION OF BORINGS SEE PLATE G1
FOR DETAILED TEST DATA SEE ANNEX 2

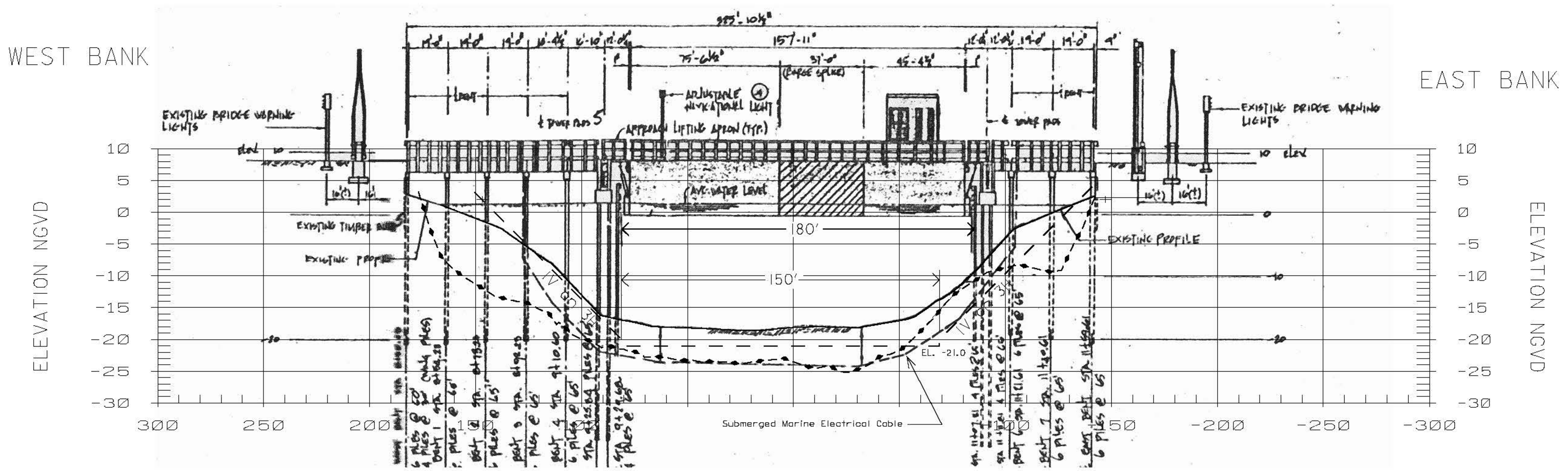
HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

**UNDISTURBED BORING**
**BOR. H-4.2-U**

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

DESIGNED BY: R. JOLISSAINT
DRAWN BY: G. BROWN
CHECKED BY: R. JOLISSAINT
PLOT SCALE: 20:1
PLOT DATE: MAY 03
DATE: MAY 03
CADD FILE: H-4.2U
FILE NO.

PLATE G38




***Bridge – Cross Section***

DULAC BRIDGE

— — · Dredge Template 150' Wide 1V on 3H to -21 NGVD

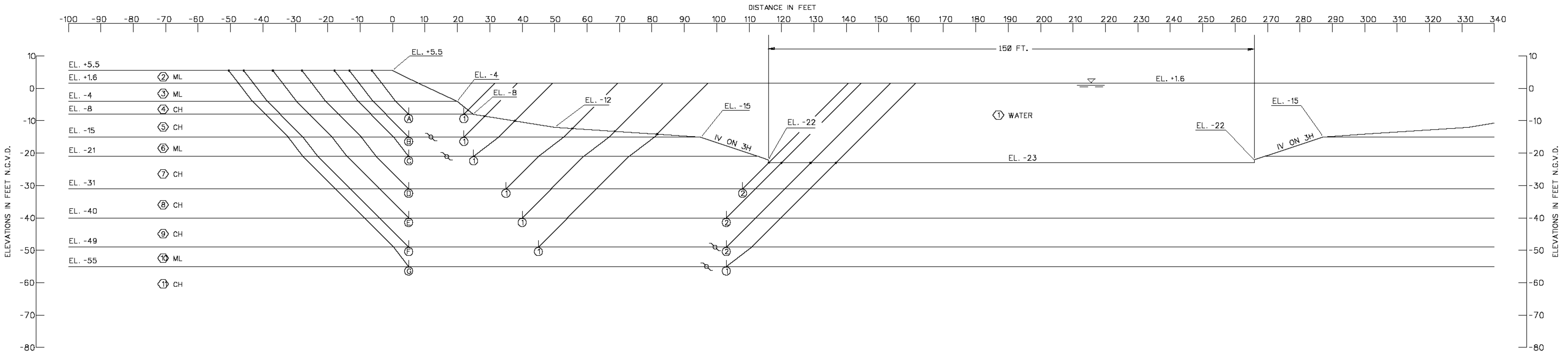
-◆-◆- 2002 Multibeam Survey

——— Historical Survey (1995)

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**DULAC BRIDGE**
**Sta. 719+40.00 Mile 23.3**

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

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: H-7.5U |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 03 | | |




| ASSUMED FAILURE SURFACE | | RESISTING FORCES | | | DRIVING FORCES | | SUMMATION OF FORCES | | FACTOR OF SAFETY |
|---|---|---|---|---|---|---|---|---|---|
| NO. | ELEV. | $R_A$ | $R_B$ | $R_P$ | $D_A$ | $-D_P$ | RESISTING | DRIVING | |
| A 1 | -8.0 | 6825 | 4590 | 719 | 9742 | 2924 | 12134 | 6818 | 1.78 |
| B 1 | -15.0 | 11461 | 5262 | 4255 | 22214 | 9236 | 20978 | 12978 | 1.62 |
| C 1 | -21.0 | 15894 | 7467 | 7680 | 36574 | 18104 | 31041 | 18470 | 1.68 |
| D 1 | -31.0 | 23974 | 11550 | 13550 | 69440 | 40706 | 49074 | 28734 | 1.71 |
| D 2 | -31.0 | 23974 | 39655 | 6230 | 69440 | 34990 | 69859 | 34450 | 2.03 |
| E 1 | -40.0 | 31175 | 14000 | 20070 | 106188 | 68247 | 65245 | 37941 | 1.72 |
| E 2 | -40.0 | 31175 | 39200 | 13362 | 106188 | 59814 | 83737 | 46374 | 1.81 |
| F 1 | -49.0 | 40176 | 20000 | 28404 | 150390 | 103047 | 88580 | 47343 | 1.87 |
| F 2 | -49.0 | 40176 | 48970 | 22366 | 150390 | 91063 | 111512 | 59327 | 1.88 |
| G 1 | -55.0 | 47576 | 5871 | 30307 | 184718 | 116646 | 136594 | 68072 | 2.01 |

| STRATUM NO. | SOIL TYPE | TOTAL UNIT WEIGHT P.C.F. | C - UNIT COHESION - P.S.F. | | FRICTION ANGLE DEGREES |
|---|---|---|---|---|---|
| | | | CENTER OF STRATUM | BOTTOM OF STRATUM | |
| | | VERT. 1 | VERT. 1 | VERT. 1 | |
| 1 | WATER | 62 | 0 | 0 | 0 |
| 2 | ML | 117 | 200 | 200 | 15 |
| 3 | ML | 117 | 200 | 200 | 15 |
| 4 | CH | 93 | 270 | 270 | 0 |
| 5 | CH | 85 | 330 | 330 | 0 |
| 6 | ML | 117 | 200 | 200 | 15 |
| 7 | CH | 97 | 385 | 385 | 0 |
| 8 | CH | 74 | 400 | 400 | 0 |
| 9 | CH | 110 | 500 | 500 | 0 |
| 10 | ML | 117 | 200 | 200 | 15 |
| 11 | CH | 100 | 600 | 600 | 0 |

## NOTES

⬡ -- STRATUM NUMBER
○ -- WEDGE NUMBER
-- CROSSOVER POINT
$\phi$ -- ANGLE OF INTERNAL FRICTION, DEGREES
C -- UNIT COHESION, P.S.F.
∇ -- STATIC WATER SURFACE
D -- HORIZONTAL DRIVING FORCE IN POUNDS
R -- HORIZONTAL RESISTING FORCE IN POUNDS
A -- AS A SUBSCRIPT,REFERS TO ACTIVE WEDGE
B -- AS A SUBSCRIPT REFERS TO CENTRAL BLOCK
P -- AS A SUBSCRIPT REFERS TO PASSIVE WEDGE

FACTOR OF SAFETY $= \frac{R_A + R_B + R_P}{D_A - D_P}$

## GENERAL NOTES

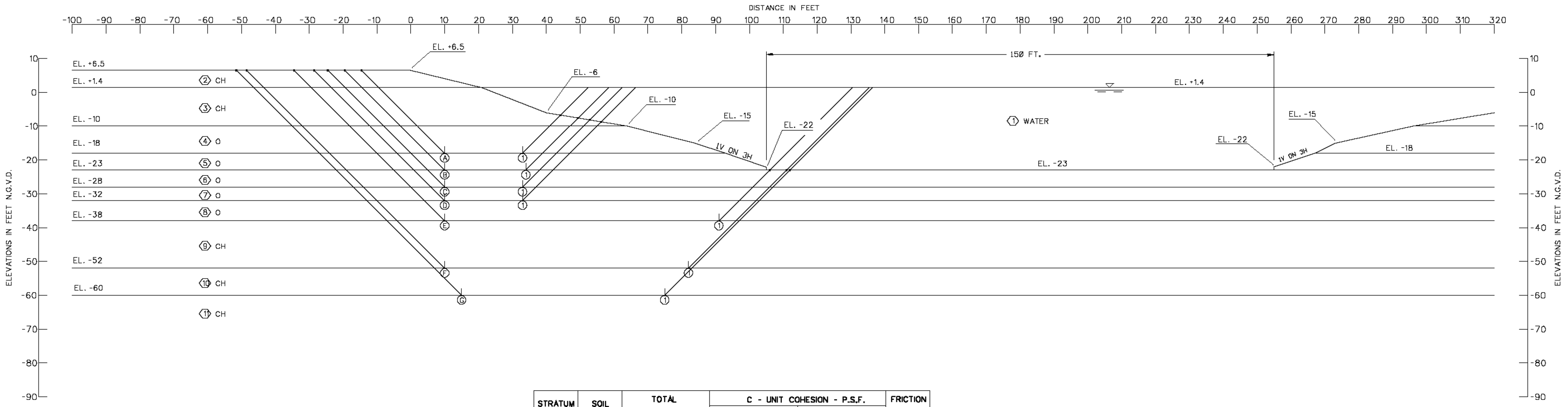
CLASSIFICATION STRATIFICATION SHEAR STRENGTHS AND UNIT WEIGHTS OF THE SOIL WERE BASED ON THE RESULTS OF THE UNDISTURBED BORINGS. SEE BORING DATA PLATES.

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
REACH I - MILE 35.0 TO 33.5
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

# STABILITY ANALYSIS

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

| DESIGNED BY:R. JOLISSAINT<br>DRAWN BY:G. BROWN<br>CHECKED BY:R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: |
|---|---|---|---|
| | DATE: MAY 03 | | FILE NO. |




| ASSUMED FAILURE SURFACE | | RESISTING FORCES | | | DRIVING FORCES | | SUMMATION OF FORCES | | FACTOR OF SAFETY |
|---|---|---|---|---|---|---|---|---|---|
| NO. | ELEV. | $R_A$ | $R_B$ | $R_P$ | $D_A$ | $-D_P$ | RESISTING | DRIVING | |
| A 1 | -18.0 | 9126 | 6210 | 5470 | 29976 | 14883 | 20806 | 15093 | 1.38 |
| B 1 | -23.0 | 11826 | 6480 | 7869 | 43768 | 24021 | 26175 | 19747 | 1.33 |
| C 1 | -28.0 | 15826 | 8050 | 11669 | 60059 | 35851 | 35545 | 24208 | 1.47 |
| D 1 | -32.0 | 18626 | 8050 | 14269 | 74892 | 46867 | 40945 | 28025 | 1.46 |
| E 1 | -38.0 | 22826 | 28350 | 11000 | 100071 | 54324 | 62176 | 45747 | 1.36 |
| F 1 | -52.0 | 35426 | 32400 | 23602 | 173043 | 108855 | 91428 | 64188 | 1.42 |
| G 1 | -60.0 | 45026 | 36000 | 33202 | 222140 | 150034 | 114228 | 72106 | 1.58 |

| STRATUM NO. | SOIL TYPE | TOTAL UNIT WEIGHT P.C.F. | C - UNIT COHESION - P.S.F. CENTER OF STRATUM | BOTTOM OF STRATUM | FRICTION ANGLE DEGREES |
|---|---|---|---|---|---|
| | | VERT. 1 | VERT. 1 | VERT. 1 | |
| 1 | WATER | 62 | 0 | 0 | 0 |
| 2 | CH | 105 | 80 | 80 | 0 |
| 3 | CH | 105 | 175 | 270 | 0 |
| 4 | O | 97 | 270 | 270 | 0 |
| 5 | O | 100 | 270 | 270 | 0 |
| 6 | O | 100 | 400 | 400 | 0 |
| 7 | O | 100 | 350 | 350 | 0 |
| 8 | O | 96 | 350 | 350 | 0 |
| 9 | CH | 104 | 450 | 450 | 0 |
| 10 | CH | 99 | 600 | 600 | 0 |
| 11 | CH | 99 | 600 | 600 | 0 |

## NOTES

- ⬡-- STRATUM NUMBER
- ○-- WEDGE NUMBER
- -- CROSSOVER POINT
- $\phi$ -- ANGLE OF INTERNAL FRICTION, DEGREES
- C -- UNIT COHESION, P.S.F.
- ▽ -- STATIC WATER SURFACE
- D -- HORIZONTAL DRIVING FORCE IN POUNDS
- R -- HORIZONTAL RESISTING FORCE IN POUNDS
- A -- AS A SUBSCRIPT,REFERS TO ACTIVE WEDGE
- B -- AS A SUBSCRIPT REFERS TO CENTRAL BLOCK
- P -- AS A SUBSCRIPT REFERS TO PASSIVE WEDGE

FACTOR OF SAFETY $= \dfrac{R_A + R_B + R_P}{D_A - D_P}$

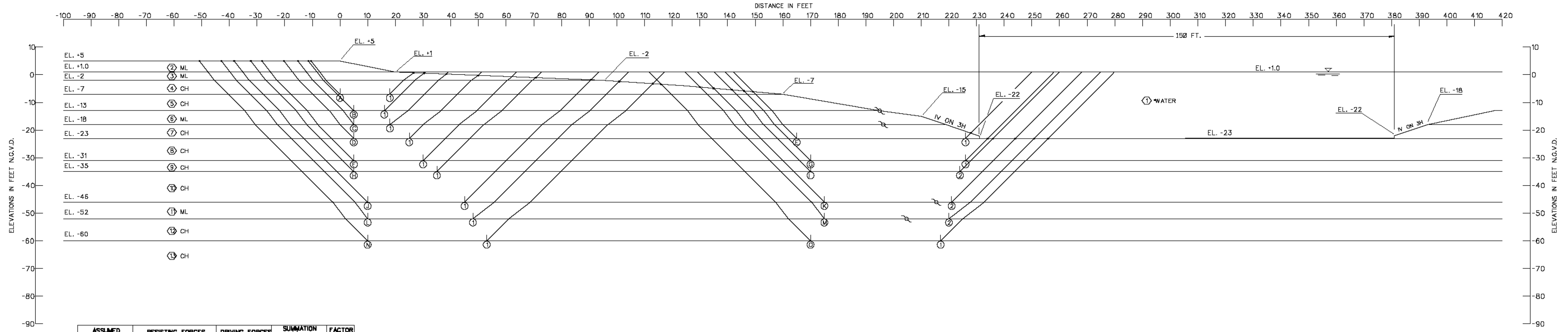
## GENERAL NOTES

CLASSIFICATION STRATIFICATION SHEAR STRENGTHS AND UNIT WEIGHTS OF THE SOIL WERE BASED ON THE RESULTS OF THE UNDISTURBED BORINGS. SEE BORING DATA PLATES.

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
REACH 2 - MILE 33.5 TO 24.15
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
**STABILITY ANALYSIS**

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

| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: |
|---|---|---|---|
| | DATE: MAY 03 | | FILE NO. |




| ASSUMED FAILURE SURFACE | | | RESISTING FORCES | | | DRIVING FORCES | | SUMMATION OF FORCES | | FACTOR OF SAFETY |
|---|---|---|---|---|---|---|---|---|---|---|
| NO. | | ELEV. | $R_A$ | $R_B$ | $R_P$ | $D_A$ | $-D_P$ | RESISTING | DRIVING | |
| A | 1 | -7.0 | 4711 | 2700 | 3077 | 8146 | 3475 | 10488 | 4671 | 2.25 |
| B | 1 | -13.0 | 7111 | 2200 | 5381 | 17453 | 10340 | 14692 | 7113 | 2.07 |
| C | 1 | -18.0 | 10897 | 3510 | 10242 | 28360 | 18592 | 24649 | 9768 | 2.52 |
| D | 1 | -23.0 | 13745 | 5400 | 12553 | 42211 | 29432 | 31698 | 12779 | 2.48 |
| E | 1 | -23.0 | 7687 | 16470 | 1053 | 23708 | 18079 | 25210 | 5629 | 4.48 |
| F | 1 | -31.0 | 19553 | 10000 | 17973 | 69538 | 52130 | 47526 | 17408 | 2.73 |
| G | 1 | -31.0 | 13597 | 22400 | 5809 | 44535 | 33529 | 41806 | 11006 | 3.80 |
| H | 1 | -35.0 | 22753 | 12000 | 20911 | 85600 | 65581 | 55664 | 20019 | 2.78 |
| H | 2 | -35.0 | 22753 | 87600 | 9010 | 85600 | 43771 | 119363 | 41829 | 2.85 |
| I | 2 | -35.0 | 16933 | 21600 | 9010 | 57614 | 43771 | 47543 | 13843 | 3.43 |
| J | 1 | -46.0 | 32939 | 18375 | 30502 | 137569 | 111009 | 81816 | 26560 | 3.08 |
| J | 2 | -46.0 | 32939 | 110704 | 19198 | 137569 | 80406 | 162841 | 57163 | 2.85 |
| K | 2 | -46.0 | 27322 | 24079 | 19198 | 101678 | 80406 | 70599 | 21272 | 3.32 |
| L | 1 | -52.0 | 40798 | 24700 | 42060 | 171782 | 141208 | 107558 | 30574 | 3.52 |
| L | 2 | -52.0 | 40798 | 136126 | 27533 | 171782 | 105696 | 204457 | 66086 | 3.09 |
| M | 2 | -52.0 | 33607 | 28876 | 27533 | 131621 | 105696 | 90016 | 25925 | 3.47 |
| N | 1 | -60.0 | 51617 | 27950 | 51999 | 224041 | 187445 | 131566 | 36596 | 3.60 |
| O | 1 | -60.0 | 44602 | 30550 | 37607 | 179194 | 146385 | 112759 | 32809 | 3.44 |

| STRATUM NO. | SOIL TYPE | TOTAL UNIT WEIGHT P.C.F. | C - UNIT COHESION - P.S.F. | | FRICTION ANGLE DEGREES |
|---|---|---|---|---|---|
| | | | CENTER OF STRATUM | BOTTOM OF STRATUM | |
| | | VERT. 1 | VERT. 1 | VERT. 1 | |
| 1 | WATER | 62 | 0 | 0 | 0 |
| 2 | ML | 117 | 200 | 200 | 15 |
| 3 | ML | 117 | 200 | 200 | 15 |
| 4 | CH | 95 | 150 | 150 | 0 |
| 5 | CH | 102 | 200 | 200 | 0 |
| 6 | ML | 117 | 200 | 200 | 15 |
| 7 | CH | 105 | 270 | 270 | 0 |
| 8 | CH | 100 | 363 | 400 | 0 |
| 9 | CH | 100 | 400 | 400 | 0 |
| 10 | CH | 107 | 463 | 525 | 0 |
| 11 | ML | 117 | 200 | 200 | 15 |
| 12 | CH | 102 | 650 | 650 | 0 |
| 13 | CH | 102 | 650 | 650 | 0 |

## NOTES

- -- STRATUM NUMBER
- -- WEDGE NUMBER
- -- CROSSOVER POINT
- $\phi$ -- ANGLE OF INTERNAL FRICTION, DEGREES
- C -- UNIT COHESION, P.S.F.
- $\nabla$ -- STATIC WATER SURFACE
- D -- HORIZONTAL DRIVING FORCE IN POUNDS
- R -- HORIZONTAL RESISTING FORCE IN POUNDS
- A -- AS A SUBSCRIPT, REFERS TO ACTIVE WEDGE
- B -- AS A SUBSCRIPT REFERS TO CENTRAL BLOCK
- P -- AS A SUBSCRIPT REFERS TO PASSIVE WEDGE

$$\text{FACTOR OF SAFETY} = \frac{R_A + R_B + R_P}{D_A - D_P}$$

## GENERAL NOTES

CLASSIFICATION STRATIFICATION SHEAR STRENGTHS AND UNIT WEIGHTS OF THE SOIL WERE BASED ON THE RESULTS OF THE UNDISTURBED BORINGS. SEE BORING DATA PLATES.

**HOUMA NAVIGATION CANAL**

HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT

**REACH 3 - MILE 24.15 TO 20.7**

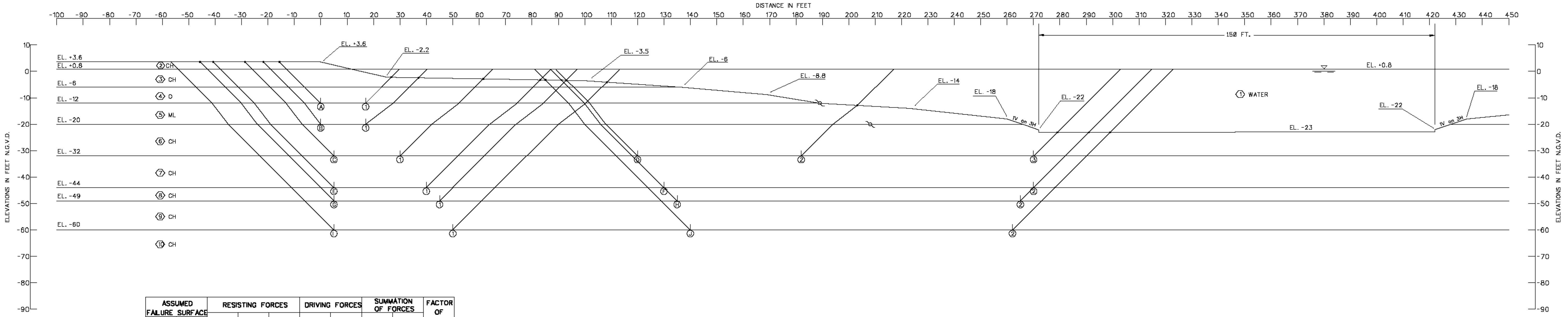
MILE 36.0 TO MILE (-)15.0

TERREBONNE PARISH, LOUISIANA

**STABILITY ANALYSIS**

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

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT | PLOT SCALE: 30:1 | PLOT DATE: MAY 05 | CADD FILE: |
| DRAWN BY: G. BROWN | | | FILE NO. |
| CHECKED BY: R. JOLISSAINT | DATE: MAY 05 | | |




| ASSUMED FAILURE SURFACE NO. | | ASSUMED FAILURE SURFACE ELEV. | RESISTING FORCES $R_A$ | RESISTING FORCES $R_B$ | RESISTING FORCES $R_P$ | DRIVING FORCES $D_A$ | DRIVING FORCES $-D_P$ | SUMMATION OF FORCES RESISTING | SUMMATION OF FORCES DRIVING | FACTOR OF SAFETY |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | -12.0 | 5372 | 3400 | 3644 | 13215 | 7515 | 12416 | 5700 | 2.18 |
| B | 1 | -20.0 | 11292 | 5100 | 11282 | 30042 | 20547 | 27674 | 9495 | 2.91 |
| C | 1 | -32.0 | 18492 | 7500 | 18046 | 68135 | 52754 | 44038 | 15381 | 2.86 |
| C | 2 | -32.0 | 18492 | 53100 | 11973 | 68135 | 43467 | 83565 | 24668 | 3.39 |
| C | 3 | -32.0 | 18492 | 79500 | 5402 | 68135 | 35400 | 103394 | 32735 | 3.16 |
| D | 3 | -32.0 | 14622 | 45000 | 5402 | 50762 | 35400 | 65024 | 15362 | 4.23 |
| E | 1 | -44.0 | 30493 | 17500 | 29818 | 121672 | 100063 | 77811 | 21609 | 3.60 |
| E | 2 | -44.0 | 30493 | 132500 | 17407 | 121672 | 72125 | 180400 | 49547 | 3.64 |
| F | 1 | -44.0 | 26655 | 70000 | 17407 | 97266 | 72125 | 114062 | 25141 | 4.54 |
| G | 1 | -49.0 | 35493 | 20000 | 34715 | 148418 | 124087 | 90208 | 24331 | 3.71 |
| G | 2 | -49.0 | 35493 | 130000 | 22407 | 148418 | 92392 | 187900 | 56026 | 3.35 |
| H | 2 | -49.0 | 31655 | 65000 | 22407 | 120879 | 92392 | 119062 | 28487 | 4.18 |
| I | 1 | -60.0 | 48693 | 27000 | 47613 | 216319 | 185982 | 123306 | 30337 | 4.06 |
| I | 2 | -60.0 | 48693 | 154200 | 35609 | 216319 | 145402 | 238502 | 70917 | 3.36 |
| J | 2 | -60.0 | 44930 | 73200 | 35609 | 182532 | 145402 | 153739 | 37130 | 4.14 |

| STRATUM NO. | SOIL TYPE | TOTAL UNIT WEIGHT P.C.F. VERT. 1 | C - UNIT COHESION - P.S.F. CENTER OF STRATUM VERT. 1 | C - UNIT COHESION - P.S.F. BOTTOM OF STRATUM VERT. 1 | FRICTION ANGLE DEGREES |
|---|---|---|---|---|---|
| 1 | WATER | 62 | 0 | 0 | 0 |
| 2 | CH | 111 | 130 | 130 | 0 |
| 3 | CH | 111 | 165 | 200 | 0 |
| 4 | O | 95 | 200 | 200 | 0 |
| 5 | ML | 117 | 200 | 200 | 15 |
| 6 | CH | 105 | 300 | 300 | 0 |
| 7 | CH | 105 | 500 | 500 | 0 |
| 8 | CH | 103 | 500 | 500 | 0 |
| 9 | CH | 103 | 600 | 600 | 0 |
| 10 | CH | 103 | 600 | 600 | 0 |

## NOTES

- -- STRATUM NUMBER
- -- WEDGE NUMBER
- -- CROSSOVER POINT
- $\phi$ -- ANGLE OF INTERNAL FRICTION, DEGREES
- C -- UNIT COHESION, P.S.F.
- ▽ -- STATIC WATER SURFACE
- D -- HORIZONTAL DRIVING FORCE IN POUNDS
- R -- HORIZONTAL RESISTING FORCE IN POUNDS
- A -- AS A SUBSCRIPT, REFERS TO ACTIVE WEDGE
- B -- AS A SUBSCRIPT REFERS TO CENTRAL BLOCK
- P -- AS A SUBSCRIPT REFERS TO PASSIVE WEDGE

$$\text{FACTOR OF SAFETY} = \frac{R_A + R_B + R_P}{D_A - D_P}$$

## GENERAL NOTES

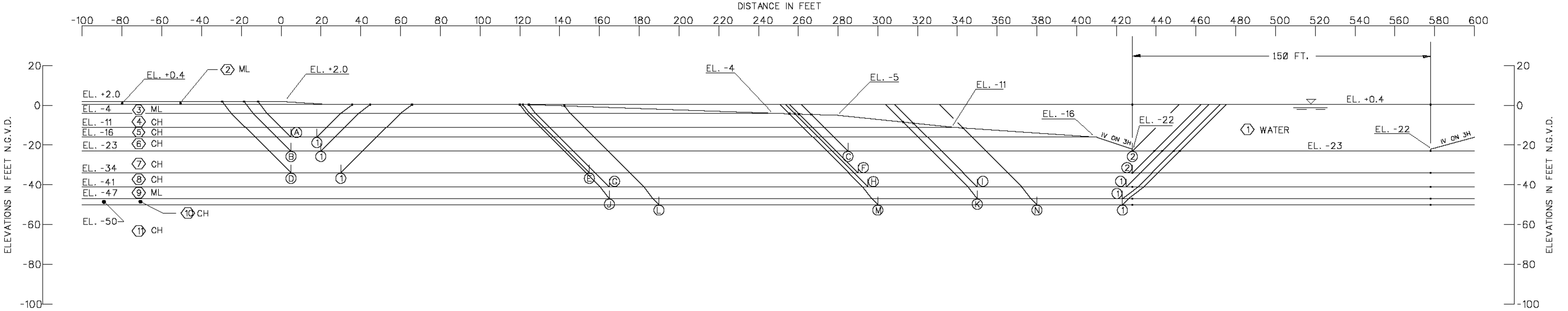
CLASSIFICATION STRATIFICATION SHEAR STRENGTHS AND UNIT WEIGHTS OF THE SOIL WERE BASED ON THE RESULTS OF THE UNDISTURBED BORINGS. SEE BORING DATA PLATES.

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
REACH 4 - MILE 20.7 TO 17.25
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

# STABILITY ANALYSIS

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

| | | | |
|---|---|---|---|
| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: C. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: |
| | DATE: MAY 03 | | FILE NO. |




| ASSUMED FAILURE SURFACE | | RESISTING FORCES | | | DRIVING FORCES | | SUMMATION OF FORCES | | FACTOR OF SAFETY |
|---|---|---|---|---|---|---|---|---|---|
| NO. | ELEV. | $R_A$ | $R_B$ | $R_P$ | $D_A$ | $-D_P$ | RESISTING | DRIVING | |
| A 1 | -16.0 | 6321 | 2600 | 6524 | 17347 | 14405 | 15445 | 2942 | 5.25 |
| B 1 | -23.0 | 9121 | 3000 | 9324 | 32676 | 28335 | 21445 | 4341 | 4.94 |
| B 2 | -23.0 | 9121 | 84600 | 36 | 32676 | 17085 | 93757 | 15591 | 6.01 |
| C 2 | -23.0 | 6515 | 28600 | 36 | 22581 | 17085 | 35151 | 5496 | 6.40 |
| D 1 | -34.0 | 15281 | 7000 | 15484 | 66511 | 60017 | 37765 | 6494 | 5.82 |
| D 2 | -34.0 | 15281 | 118440 | 6163 | 66511 | 39198 | 139884 | 27313 | 5.12 |
| E 2 | -34.0 | 14389 | 76440 | 6163 | 59151 | 39198 | 96992 | 19953 | 4.86 |
| F 2 | -34.0 | 12730 | 38640 | 6163 | 51325 | 39198 | 57533 | 12127 | 4.74 |
| G 1 | -41.0 | 19425 | 93600 | 11204 | 85120 | 59836 | 124229 | 25284 | 4.91 |
| H 1 | -41.0 | 17788 | 46800 | 11204 | 75880 | 59836 | 75792 | 16044 | 4.72 |
| I 1 | -41.0 | 16552 | 27000 | 11204 | 69823 | 59836 | 54756 | 9987 | 5.48 |
| J 1 | -47.0 | 25409 | 103200 | 18143 | 112169 | 81799 | 146752 | 30370 | 4.83 |
| K 1 | -47.0 | 21623 | 29200 | 18143 | 94450 | 81799 | 68966 | 12651 | 5.45 |
| L 1 | -50.0 | 27455 | 93200 | 20431 | 124939 | 94314 | 141086 | 30625 | 4.61 |
| M 1 | -50.0 | 25569 | 49200 | 20431 | 115355 | 94314 | 95200 | 21041 | 4.52 |
| N 1 | -50.0 | 23042 | 17200 | 20431 | 105177 | 94314 | 60673 | 10863 | 5.58 |

| STRATUM NO. | SOIL TYPE | TOTAL UNIT WEIGHT P.C.F. | C - UNIT COHESION - P.S.F. | | FRICTION ANGLE |
|---|---|---|---|---|---|
| | | | CENTER OF STRATUM | BOTTOM OF STRATUM | |
| | | VERT. 1 | VERT. 1 | VERT. 1 | DEGREES |
| 1 | WATER | 62 | 0 | 0 | 0 |
| 2 | ML | 117 | 200 | 200 | 15 |
| 3 | ML | 117 | 200 | 200 | 15 |
| 4 | CH | 96 | 133 | 160 | 0 |
| 5 | CH | 96 | 200 | 200 | 0 |
| 6 | CH | 96 | 200 | 200 | 0 |
| 7 | CH | 100 | 280 | 280 | 0 |
| 8 | CH | 105 | 360 | 360 | 0 |
| 9 | ML | 117 | 200 | 200 | 15 |
| 10 | CH | 105 | 400 | 400 | 0 |
| 11 | CH | 105 | 400 | 400 | 0 |

## NOTES

⬡ -- STRATUM NUMBER
○ -- WEDGE NUMBER
-- CROSSOVER POINT
$\phi$ -- ANGLE OF INTERNAL FRICTION, DEGREES
C -- UNIT COHESION, P.S.F.
▽ -- STATIC WATER SURFACE
D -- HORIZONTAL DRIVING FORCE IN POUNDS
R -- HORIZONTAL RESISTING FORCE IN POUNDS
A -- AS A SUBSCRIPT, REFERS TO ACTIVE WEDGE
B -- AS A SUBSCRIPT REFERS TO CENTRAL BLOCK
P -- AS A SUBSCRIPT REFERS TO PASSIVE WEDGE

$$\text{FACTOR OF SAFETY} = \frac{R_A + R_B + R_P}{D_A - D_P}$$

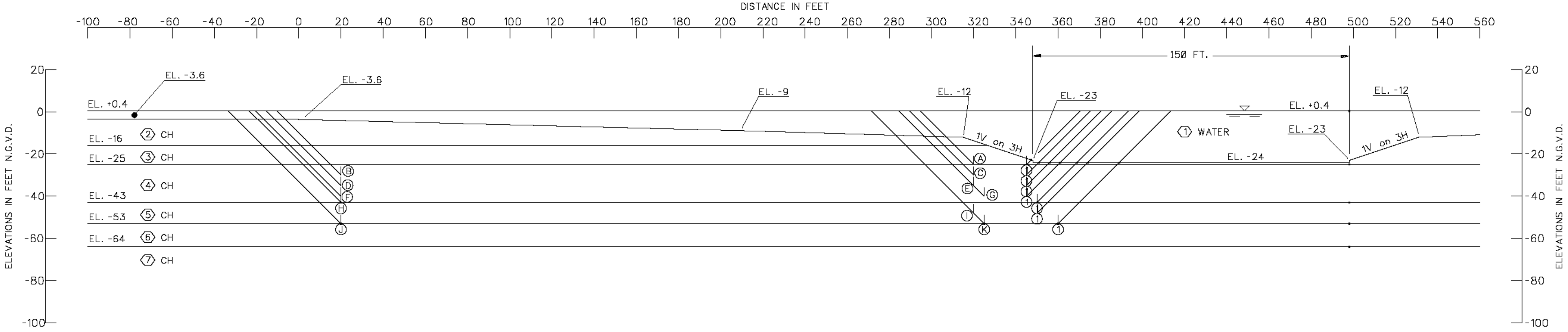
## GENERAL NOTES

CLASSIFICATION STRATIFICATION SHEAR STRENGTHS AND UNIT WEIGHTS OF THE SOIL WERE BASED ON THE RESULTS OF THE UNDISTURBED BORINGS. SEE BORING DATA PLATES.

HOUMA NAVIGATION CANAL
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT
REACH 5 - MILE 17.25 TO 10.0
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA
# STABILITY ANALYSIS

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

| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: G. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE:<br>FILE NO. |
|---|---|---|---|
| | DATE: MAY 03 | | |




| ASSUMED FAILURE SURFACE | | RESISTING FORCES | | | DRIVING FORCES | | SUMMATION OF FORCES | | FACTOR OF SAFETY |
|---|---|---|---|---|---|---|---|---|---|
| NO. | ELEV. | $R_A$ | $R_B$ | $R_P$ | $D_A$ | $-D_P$ | RESISTING | DRIVING | |
| A 1 | -25.0 | 4635 | 7750 | 910 | 22860 | 20236 | 13295 | 2624 | 5.07 |
| B 1 | -30.0 | 10398 | 162500 | 4467 | 40411 | 29620 | 177365 | 10791 | 16.44 |
| C 1 | -30.0 | 8718 | 12500 | 4467 | 34260 | 29620 | 25685 | 4640 | 5.54 |
| D 1 | -35.0 | 14448 | 162500 | 8518 | 55642 | 41426 | 185466 | 14216 | 13.05 |
| E 1 | -35.0 | 12800 | 12500 | 8518 | 48161 | 41426 | 33818 | 6735 | 5.02 |
| F 1 | -40.0 | 18498 | 162500 | 12569 | 73350 | 55707 | 193567 | 17643 | 10.97 |
| G 1 | -40.0 | 16850 | 10000 | 12569 | 64036 | 55707 | 39419 | 8329 | 4.73 |
| H 1 | -43.0 | 20928 | 165000 | 15001 | 85162 | 65320 | 200929 | 19842 | 10.13 |
| I 1 | -48.0 | 24365 | 15000 | 20002 | 96084 | 83638 | 59367 | 12446 | 4.77 |
| J 1 | -53.0 | 30928 | 272000 | 25006 | 131271 | 104586 | 327934 | 26685 | 12.29 |
| K 1 | -53.0 | 29365 | 28000 | 25006 | 118618 | 104586 | 82371 | 14032 | 5.87 |

| STRATUM NO. | SOIL TYPE | TOTAL UNIT WEIGHT P.C.F. | C - UNIT COHESION - P.S.F. | | FRICTION ANGLE DEGREES |
|---|---|---|---|---|---|
| | | | CENTER OF STRATUM | BOTTOM OF STRATUM | |
| | | VERT. 1 | VERT. 1 | VERT. 1 | |
| 1 | WATER | 62 | 0 | 0 | 0 |
| 2 | CH | 96 | 105 | 105 | 0 |
| 3 | CH | 96 | 208 | 310 | 0 |
| 4 | CH | 99 | 405 | 500 | 0 |
| 5 | CH | 105 | 500 | 500 | 0 |
| 6 | CH | 105 | 650 | 800 | 0 |
| 7 | CH | 105 | 800 | 800 | 0 |

## NOTES

- ⬡ -- STRATUM NUMBER
- ○ -- WEDGE NUMBER
- -- CROSSOVER POINT
- $\phi$ -- ANGLE OF INTERNAL FRICTION, DEGREES
- C -- UNIT COHESION, P.S.F.
- ▽ -- STATIC WATER SURFACE
- D -- HORIZONTAL DRIVING FORCE IN POUNDS
- R -- HORIZONTAL RESISTING FORCE IN POUNDS
- A -- AS A SUBSCRIPT, REFERS TO ACTIVE WEDGE
- B -- AS A SUBSCRIPT REFERS TO CENTRAL BLOCK
- P -- AS A SUBSCRIPT REFERS TO PASSIVE WEDGE

FACTOR OF SAFETY $= \frac{R_A + R_B + R_P}{D_A - D_P}$

## GENERAL NOTES

CLASSIFICATION STRATIFICATION
SHEAR STRENGTHS AND UNIT WEIGHTS OF THE SOIL WERE BASED ON THE RESULTS OF THE UNDISTURBED BORINGS. SEE BORING DATA PLATES.

# HOUMA NAVIGATION CANAL

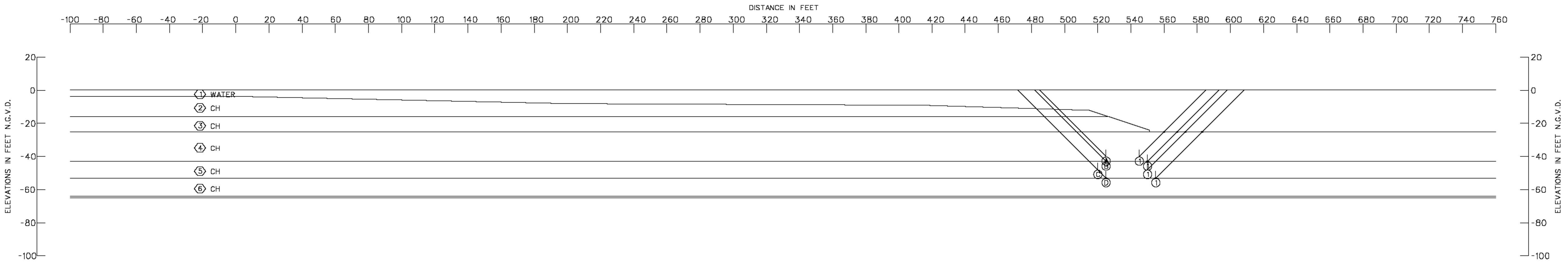
HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT

REACH 6 - MILE 10.0 TO 0.0
MILE 36.0 TO MILE (-)5.0
TERREBONNE PARISH, LOUISIANA

# STABILITY ANALYSIS

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

| DESIGNED BY: R. JOLISSAINT<br>DRAWN BY: C. BROWN<br>CHECKED BY: R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE:<br>FILE NO. |
|---|---|---|---|
| | DATE: MAY 03 | | |




| ASSUMED FAILURE SURFACE | | RESISTING FORCES | | | DRIVING FORCES | | SUMMATION OF FORCES | | FACTOR OF SAFETY |
|---|---|---|---|---|---|---|---|---|---|
| NO. | ELEV. | $R_A$ | $R_B$ | $R_P$ | $D_A$ | $-D_P$ | RESISTING | DRIVING | |
| A 1 | -40.0 | 16850 | 10000 | 12150 | 64036 | 55429 | 39000 | 8607 | 4.53 |
| B 1 | -43.0 | 19300 | 12500 | 14580 | 75062 | 64733 | 46380 | 10329 | 4.49 |
| C 1 | -48.0 | 24365 | 15000 | 19580 | 96083 | 82880 | 58945 | 13203 | 4.46 |
| D 1 | -53.0 | 29365 | 24000 | 24580 | 118618 | 103613 | 77945 | 15005 | 5.19 |

| STRATUM NO. | SOIL TYPE | TOTAL UNIT WEIGHT P.C.F. | C - UNIT COHESION - P.S.F. | | FRICTION ANGLE DEGREES |
|---|---|---|---|---|---|
| | | | CENTER OF STRATUM | BOTTOM OF STRATUM | |
| | | VERT. 1 | VERT. 1 | VERT. 1 | |
| 1 | WATER | 62 | 0 | 0 | 0 |
| 2 | CH | 96 | 105 | 105 | 0 |
| 3 | CH | 96 | 208 | 310 | 0 |
| 4 | CH | 99 | 405 | 500 | 0 |
| 5 | CH | 105 | 500 | 500 | 0 |
| 6 | CH | 105 | 650 | 800 | 0 |
| 7 | CH | 105 | 800 | 800 | 0 |

## NOTES

◇ -- STRATUM NUMBER
○ -- WEDGE NUMBER
ꝋ -- CROSSOVER POINT
$\phi$ -- ANGLE OF INTERNAL FRICTION, DEGREES
C -- UNIT COHESION, P.S.F.
▽ -- STATIC WATER SURFACE
D -- HORIZONTAL DRIVING FORCE IN POUNDS
R -- HORIZONTAL RESISTING FORCE IN POUNDS
A -- AS A SUBSCRIPT,REFERS TO ACTIVE WEDGE
B -- AS A SUBSCRIPT REFERS TO CENTRAL BLOCK
P -- AS A SUBSCRIPT REFERS TO PASSIVE WEDGE

FACTOR OF SAFETY $= \frac{R_A + R_B + R_P}{D_A - D_P}$

## GENERAL NOTES:

CLASSIFICATION, STRATIFICATION, SHEAR STRENGTH, AND UNIT WEIGHT OF THE SOIL WERE BASED ON THE RESULTS OF UNDISTURBED BORINGS. SEE BORING DATA PLATES.

# HOUMA NAVIGATION CANAL

HOUMA NAVIGATION DEEPENING - GENERAL REEVALUATION REPORT

REACH 7 - MILE 0 TO -4.5

MILE 36.0 TO MILE (-)5.0

TERREBONNE PARISH, LOUISIANA

# STABILITY ANALYSIS

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

| | | | |
|---|---|---|---|
| DESIGNED BY:R. JOLISSAINT | PLOT SCALE: 20:1 | PLOT DATE: MAY 03 | CADD FILE: |
| DRAWN BY:G. BROWN | | | FILE NO. |
| CHECKED BY:R. JOLISSAINT | DATE: MAY 03 | | |

# Annex VI

# Foreshore Protection and Rock Retention Cost Analysis

# COST JUSTIFICATION OF FORESHORE PROTECTION ON THE INLAND REACH

## 1.0 Foreshore Protection

On the Inland Reach (Mile 36.3 to Mile 10.1), foreshore protection is a proposed feature for all of the project alternatives, excluding the No Action Alternative. The No Action Alternative would continue to maintain the HNC to the authorized depth of 15 feet. The No Action Alternative will utilize the same disposal plan as 18-foot and 20-foot depth alternatives. Rock retention dikes would be located near the channel to confine disposal areas located adjacent to the channel. The foreshore protection would be placed along the channel to reduce bank erosion. The rock retention dikes would also reduce bank erosion. The following is a cost and benefit comparison with and without foreshore protection.

## 2.0 Bank Erosion Historic Rate

Channel bank erosion is a serious problem in many locations along the HNC Inland Reach. The original canal was approximately 250 foot wide. In many reaches, the canal is 450 feet to 1,000 feet wide. Historic bank erosion rates were calculated from measurements from the west bank to the east bank based on aerial photography taken in 1998 and 2005 (Table 1). Based on the historic rate of bank erosion along the Inland Reach of the HNC, 12.93 acres of marsh land are lost each year.

**Table 1. Historic Bank Erosion Estimates**

| Mile | West Bank (feet/year) | East Bank (feet/year) |
|---|---|---|
| 36.6 to 31.6 | 2.5 | 0 |
| 31.1 to 26.6 | 1 | 2.7 |
| 26.1 to 21.6 | 2.6 | 2.9* |
| 21.1 to 16.6 | 3.8 | 0.6 |
| 16.1 to 11.6 | 5.3 | 1 |

* Erosion rate calculated exclusive of value indicating placement of fill between 1998 and 2005.

## 3.0 Bank Erosion Causes

Bank erosion is the result of several factors including sea level rise, subsidence, and wave action. The predominant cause of erosion is wave action created by vessel traffic. This wave action affects the canal banks and newly placed dredged material. A study of boat traffic on the HNC (Annex IV) showed that 31.9 percent of the boat traffic consisted of light tugs, crew boats and offshore supply vessels. These classes of vessels produce the largest wakes.

## 4.0 Foreshore Protection

Foreshore protection is recommended to reduce bank erosion, maintenance costs, and environmental impacts. Foreshore protection is a graded stone bank revetment. Rock retention dikes are constructed along the Inland Reach to contain the disposal material. Rock retention dikes will also reduce bank erosion. The location and cost of foreshore protection are presented in Table 2.

During maintenance of the deepening alternatives, approximately 13.1 miles of foreshore protection would be constructed or refurbished along the Inland Reach (6 miles along the west bank and 7.1 miles along the east bank). In addition to the foreshore protection, approximately 1.6 miles of rock retention dikes would be constructed on the Inland Reach. Rock retention dikes, earthen dikes, and closures with weirs would also be constructed to retain the dredged material placed within the disposal sites.

**Table 2. Foreshore Rock and Fabric Location, Quantity, and Cost**

| Reach | Reach Miles | Bank Side | Tons | Rock Cost | SY | Fabric Cost |
|---|---|---|---|---|---|---|
| 27.6 to 27.4 | 0.2 | WB | 1,900 | $114,000 | 0 | $0 |
| 26.4 to 25.9 | 0.5 | WB | 26,600 | $1,596,000 | 12,800 | $76,800 |
| 25.9 to 24.1 | 1.8 | WB | 21,300 | $1,278,000 | 0 | $0 |
| 23.7 to 22.4 | 1.2 | EB | 59,100 | $3,546,000 | 28,500 | $171,000 |
| 22.2 to 22.1 | 0.1 | EB | 9,800 | $588,000 | 4,700 | $28,200 |
| 19.2 to 17.5 | 1.5 | EB | 99,500 | $5,970,000 | 47,900 | $287,400 |
| 19.1 to 17.8 | 1.3 | WB | 18,200 | $1,092,000 | 8,750 | $52,500 |
| 17.7 to 16.7 | 1.0 | WB | 67,400 | $4,044,000 | 32,500 | $195,000 |
| 16.9 to 13.3 | 3.6 | EB | 213,000 | $12,780,000 | 102,600 | $615,600 |
| 13.2 to 11.9 | 1.3 | WB | 75,900 | $4,554,000 | 36,600 | $219,600 |
| 12.7 to 12.3 | 0.4 | EB | 27,100 | $1,626,000 | 13,000 | $78,000 |
| **Total Rock Cost** | $37,188,000 | | | | | |
| **Total Fabric Cost** | $1,724,100 | | | | | |
| **Total Rock and Fabric** | $38,912,100 | | | | | |
| **Total Maint Cost** | $37,188,000 | | | | | |

## 5.0 Justification of Foreshore Protection

The foreshore protection would be constructed on the Inland Reach to reduce bank erosion and maintenance cost. The rock retention dikes would be constructed along the Inland Reach to confine the disposal areas and reduce shoaling and maintenance costs.

Dredge quantities on Inland Reach with foreshore protection are presented in Table 3. The comparison of costs with and without the foreshore protection assumes the following conditions:

1. Cost with foreshore protection:
   - The volume of dredged material on the Inland Reach would be reduced by 5 percent.
   - The historic rate of bank erosion and land loss will be reduced by 10 percent.
2. Cost without foreshore protection:
   - The shoaling rate on the lower reach of the Inland Reach (Mile 22 to Mile 11), will increase over time because the lower reach will convert to open water and the shoaling rate and the maintenance cycle will increase to the shoaling rate of the Terrebonne Bay Reach. The estimated rate of conversion to open water is 0.10 miles per year. Dredge quantities without foreshore protection are presented in Table 4 and the cost of maintenance dredging is presented in Table 5.
   - The volume of maintenance dredging on the upper reach of the Inland Reach (Mile 36.3 to Mile 16) will be the same as the historic shoaling rate.
   - Land loss will continue at the historic rate. The cost to rebuild land to mitigate for land loss is presented in Table 6.

**Table 3. Dredge Maintenance Quantities and Cost with Foreshore Protection**

| Reach | CY | Unit Price | Dredging Cost |
|---|---|---|---|
| **15-Foot Channel (No Action Plan)** | | | |
| 36.3 to 34.5 | 99,650 | $5.77 | $574,981 |
| 24.0 to 22.0 | 99,650 | $8.01 | $798,197 |
| 22.0 to 19.7 | 99,650 | $5.72 | $569,998 |
| 36.3 to 34.0 | 99,650 | $5.77 | $574,981 |
| 34.0 to 32.0 | 199,600 | $4.45 | $888,220 |
| 32.0 to 29.5 | 150,700 | $6.40 | $964,480 |
| 29.5 to 28.0 | 150,700 | $4.35 | $655,545 |
| 28.0 to 26.0 | 199,600 | $3.71 | $740,516 |
| 26.0 to 24.0 | 199,600 | $4.11 | $820,356 |
| 24.0 to 22.0 | 99,650 | $8.01 | $798,197 |

| Reach | CY | Unit Price | Dredging Cost |
|---|---|---|---|
| 22.0 to 20.0 | 99,650 | $5.72 | $569,998 |
| 20.0 to 18.0 | 199,600 | $3.46 | $690,616 |
| 18.0 to 16.0 | 199,600 | $3.23 | $644,708 |
| 16.0 to 13.0 | 301,300 | $3.21 | $967,173 |
| 13.0 to 11.0 | 231,400 | $2.96 | $684,944 |
| **Subtotal** | **2,430,000** | **$4.50** | **$10,942,908** |
| **Total** | | **50-Year Cost** | **$54,714,540** |
| **18-Foot Channel** | | | |
| 36.3 to 34.5 | 101,600 | $5.39 | $547,624 |
| 24.0 to 22.0 | 101,600 | $8.00 | $812,800 |
| 22.0 to 19.7 | 101,600 | $5.71 | $580,136 |
| 36.3 to 34.0 | 101,600 | $5.39 | $547,624 |
| 34.0 to 32.0 | 203,600 | $4.25 | $865,300 |
| 32.0 to 29.5 | 153,700 | $5.84 | $897,608 |
| 29.5 to 28.0 | 153,700 | $4.17 | $640,929 |
| 28.0 to 26.0 | 203,600 | $3.37 | $686,132 |
| 26.0 to 24.0 | 203,600 | $3.92 | $798,112 |
| 24.0 to 22.0 | 101,600 | $8.00 | $812,800 |
| 22.0 to 20.0 | 101,600 | $5.71 | $580,136 |
| 20.0 to 18.0 | 203,600 | $3.10 | $631,160 |
| 18.0 to 16.0 | 203,600 | $3.10 | $631,160 |
| 16.0 to 13.0 | 307,300 | $3.06 | $940,338 |
| 13.0 to 11.0 | 236,000 | $2.75 | $649,000 |
| **Subtotal** | **2,478,300** | **$4.29** | **$10,620,859** |
| **Total** | | **50-Year Cost** | **$53,104,295** |
| **20-Foot Channel** | | | |
| 36.3 to 34.5 | 109,600 | $5.34 | $585,264 |
| 24.0 to 22.0 | 109,600 | $7.41 | $812,136 |
| 22.0 to 19.7 | 109,600 | $5.29 | $579,784 |
| 36.3 to 34.0 | 109,600 | $5.34 | $585,264 |
| 34.0 to 32.0 | 219,600 | $3.94 | $865,224 |
| 32.0 to 29.5 | 165,800 | $6.09 | $1,009,722 |
| 29.5 to 28.0 | 165,800 | $3.88 | $643,304 |
| 28.0 to 26.0 | 219,600 | $3.20 | $702,720 |
| 26.0 to 24.0 | 219,600 | $3.55 | $779,580 |
| 24.0 to 22.0 | 109,600 | $7.41 | $812,136 |
| 22.0 to 20.0 | 109,600 | $5.29 | $579,784 |
| 20.0 to 18.0 | 219,600 | $2.96 | $650,016 |

| Reach | CY | Unit Price | Dredging Cost |
|---|---|---|---|
| 18.0 to 16.0 | 219,600 | $2.79 | $612,684 |
| 16.0 to 13.0 | 331,400 | $2.94 | $974,316 |
| 13.0 to 11.0 | 254,500 | $2.62 | $666,790 |
| **Subtotal** | **2,673,100** | **$4.06** | **$10,858,724** |
| **Total** | | **50-Year Cost** | **$54,293,620** |

**Table 4. Inland Reach to Terrebonne Bay Reach Conversion (Mile 11.0 to 16.0)**

| | To Date Miles Converted | No. Cycles | Quantity Dredged | Quantity Converted | 50-Year Dredging Quantity |
|---|---|---|---|---|---|
| **No Action Plan** | | | | | |
| Year 10 | 1 | **5** | 331,000 | 110,333 | 551,667 |
| Year 20 | 2 | **5** | 331,000 | 220,667 | 1,103,333 |
| Year 30 | 3 | **5** | 331,000 | 331,000 | 1,655,000 |
| Year 40 | 4 | **5** | 331,000 | 441,333 | 2,206,667 |
| Year 50 | 5 | **5** | 331,000 | 551,667 | 2,758,333 |
| **18-Foot Depth Plan** | | | | | |
| Year 10 | 1 | **5** | 360,800 | 120,267 | 601,333 |
| Year 20 | 2 | **5** | 360,800 | 240,533 | 1,202,667 |
| Year 30 | 3 | **5** | 360,800 | 360,800 | 1,804,000 |
| Year 40 | 4 | **5** | 360,800 | 481,067 | 2,405,333 |
| Year 50 | 5 | **5** | 360,800 | 601,333 | 3,006,667 |
| **20-Foot Depth Plan** | | | | | |
| Year 10 | 1 | **5** | 374,000 | 124,667 | 623,333 |
| Year 20 | 2 | **5** | 374,000 | 249,333 | 1,246,667 |
| Year 30 | 3 | **5** | 374,000 | 374,000 | 1,870,000 |
| Year 40 | 4 | **5** | 374,000 | 498,667 | 2,493,333 |
| Year 50 | 5 | **5** | 374,000 | 623,333 | 3,116,667 |

## Table 5. Dredge Maintenance Quantities and Cost without Foreshore Protection

| Cycle | Shoaling Increase | Reach | Dredging Quantity | Unit Cost | Dredging Cost |
|---|---|---|---|---|---|
| **15-Foot Channel (No Action Plan)** | | | | | |
| 10-year | 5% | 36.3 to 22.0 | 1,398,450 | $5.28 | $7,385,469 |
| | | 22.0 to 20.0 | 99,650 | $5.72 | $569,998 |
| | | 20.0 to 18.0 | 199,600 | $3.46 | $690,616 |
| | | 18.0 to 16.0 | 199,600 | $3.23 | $644,708 |
| | | 16.0 to 13.0 | 301,300 | $3.21 | $967,173 |
| | | 13.0 to 11.0 | 115,700 | $2.96 | $342,472 |
| | | Quantity Converted | 551,667 | $3.62 | $1,997,033 |
| | | **Subtotal** | **2,865,967** | | **$12,597,469** |
| | | | | | |
| 20-year | 5% | 36.3 to 22.0 | 1,398,450 | $5.28 | $7,385,469 |
| | | 22.0 to 20.0 | 109,615 | $5.72 | $626,998 |
| | | 20.0 to 18.0 | 219,560 | $3.46 | $759,678 |
| | | 18.0 to 16.0 | 219,560 | $3.23 | $709,179 |
| | | 16.0 to 13.0 | 331,430 | $3.21 | $1,063,890 |
| | | 13.0 to 11.0 | 0 | $2.96 | $0 |
| | | Quantity Converted | 1,103,333 | $3.62 | $3,994,067 |
| | | **Subtotal** | **2,865,967** | | **$14,539,280** |
| | | | | | |
| 30-year | 5% | 36.3 to 22.0 | 1,398,450 | $5.28 | $7,385,469 |
| | | 22.0 to 20.0 | 109,615 | $5.72 | $626,998 |
| | | 20.0 to 18.0 | 219,560 | $3.46 | $759,678 |
| | | 18.0 to 16.0 | 219,560 | $3.23 | $709,179 |
| | | 16.0 to 13.0 | 220,953 | $3.21 | $709,260 |
| | | 13.0 to 11.0 | 0 | $2.96 | $0 |
| | | Quantity Converted | 1,655,000 | $3.62 | $5,991,100 |
| | | **Subtotal** | **3,823,138** | | **$16,181,683** |
| | | | | | |
| 40-year | 5% | 36.3 to 22.0 | 1,398,450 | $5.28 | $7,385,469 |
| | | 22.0 to 20.0 | 109,615 | $5.72 | $626,998 |
| | | 20.0 to 18.0 | 219,560 | $3.46 | $759,678 |
| | | 18.0 to 16.0 | 219,560 | $3.23 | $709,179 |
| | | 16.0 to 13.0 | 110,477 | $3.21 | $354,630 |

| Cycle | Shoaling Increase | Reach | Dredging Quantity | Unit Cost | Dredging Cost |
|---|---|---|---|---|---|
| | | 13.0 to 11.0 | 0 | $2.96 | $0 |
| | | Quantity Converted | 2,206,667 | $3.62 | $7,988,133 |
| | | **Subtotal** | **4,264,328** | | **$17,824,087** |
| | | | | | |
| 50-year | 5% | 36.3 to 22.0 | 1,398,450 | $5.28 | $7,385,469 |
| | | 22.0 to 20.0 | 109,615 | $5.72 | $626,998 |
| | | 20.0 to 18.0 | 219,560 | $3.46 | $759,678 |
| | | 18.0 to 16.0 | 219,560 | $3.23 | $709,179 |
| | | 16.0 to 13.0 | 0 | $3.21 | $0 |
| | | 13.0 to 11.0 | 0 | $2.96 | $0 |
| | | Quantity Converted | 2,758,333 | $3.62 | $9,985,167 |
| | | **Subtotal** | **4,705,518** | | **$19,466,490** |
| | | | | | |
| | | | **50-Year Cost W/O Rock** | | **$80,609,009** |
| **18-Foot Channel** | | | | | |
| 10-year | 5% | 36.3 to 22.0 | 1,497,510 | $5.04 | $7,548,518 |
| | | 22.0 to 20.0 | 111,760 | $5.71 | $638,150 |
| | | 20.0 to 18.0 | 223,960 | $3.10 | $694,276 |
| | | 18.0 to 16.0 | 223,960 | $3.10 | $694,276 |
| | | 16.0 to 13.0 | 338,030 | $3.06 | $1,034,372 |
| | | 13.0 to 11.0 | 118,000 | $2.75 | $324,500 |
| | | Quantity Converted | 601,333 | $3.47 | $2,086,627 |
| | | **Subtotal** | **3,114,553** | | **$13,020,718** |
| | | | | | |
| 20-year | 5% | 36.3 to 22.0 | 1,497,510 | $5.04 | $7,548,518 |
| | | 22.0 to 20.0 | 109,615 | $5.71 | $625,902 |
| | | 20.0 to 18.0 | 219,560 | $3.10 | $680,636 |
| | | 18.0 to 16.0 | 219,560 | $3.10 | $680,636 |
| | | 16.0 to 13.0 | 331,430 | $3.06 | $1,014,176 |
| | | 13.0 to 11.0 | 0 | $2.75 | $0 |
| | | Quantity Converted | 1,202,667 | $3.47 | $4,173,253 |
| | | **Subtotal** | **3,114,553** | | **$14,723,121** |
| | | | | | |
| | | | | | |

| Cycle | Shoaling Increase | Reach | Dredging Quantity | Unit Cost | Dredging Cost |
|---|---|---|---|---|---|
| 30-year | 5% | 36.3 to 22.0 | 1,497,510 | $5.04 | $7,548,518 |
| | | 22.0 to 20.0 | 109,615 | $5.71 | $625,902 |
| | | 20.0 to 18.0 | 219,560 | $3.10 | $680,636 |
| | | 18.0 to 16.0 | 219,560 | $3.10 | $680,636 |
| | | 16.0 to 13.0 | 225,353 | $3.06 | $689,581 |
| | | 13.0 to 11.0 | 0 | $2.75 | $0 |
| | | Quantity Converted | 1,804,000 | $3.47 | $6,259,880 |
| | | **Subtotal** | **4,075,598** | | **$16,485,153** |
| | | | | | |
| 40-year | 5% | 36.3 to 22.0 | 1,497,510 | $5.04 | $7,548,518 |
| | | 22.0 to 20.0 | 109,615 | $5.71 | $625,902 |
| | | 20.0 to 18.0 | 219,560 | $3.10 | $680,636 |
| | | 18.0 to 16.0 | 219,560 | $3.10 | $680,636 |
| | | 16.0 to 13.0 | 112,677 | $3.06 | $344,791 |
| | | 13.0 to 11.0 | 0 | $2.75 | $0 |
| | | Quantity Converted | 2,405,333 | $3.47 | $8,346,507 |
| | | **Subtotal** | **4,564,255** | | **$18,226,989** |
| | | | | | |
| 50-year | 5% | 36.3 to 22.0 | 1,497,510 | $5.04 | $7,548,518 |
| | | 22.0 to 20.0 | 109,615 | $5.71 | $625,902 |
| | | 20.0 to 18.0 | 219,560 | $3.10 | $680,636 |
| | | 18.0 to 16.0 | 219,560 | $3.10 | $680,636 |
| | | 16.0 to 13.0 | 0 | $3.06 | $0 |
| | | 13.0 to 11.0 | 0 | $2.75 | $0 |
| | | Quantity Converted | 3,006,667 | $3.47 | $10,433,133 |
| | | **Subtotal** | **5,052,912** | | **$19,968,825** |
| | | | **50-Year Cost W/O Rock** | | **$82,424,807** |
| **20-Foot Channel** | | | | | |
| 10-year | 5% | 36.3 to 22.0 | 1,615,320 | $4.79 | $7,743,891 |
| | | 22.0 to 20.0 | 120,560 | $5.29 | $637,762 |
| | | 20.0 to 18.0 | 241,560 | $2.96 | $715,018 |
| | | 18.0 to 16.0 | 241,560 | $2.79 | $673,952 |
| | | 16.0 to 13.0 | 364,540 | $2.94 | $1,071,748 |
| | | 13.0 to 11.0 | 139,975 | $2.62 | $366,735 |

| Cycle | Shoaling Increase | Reach | Dredging Quantity | Unit Cost | Dredging Cost |
|---|---|---|---|---|---|
| | | Quantity Converted | 623,333 | $3.28 | $2,044,533 |
| | | **Subtotal** | **3,346,848** | | **$13,253,639** |
| | | | | | |
| 20-year | 5% | 36.3 to 22.0 | 1,615,320 | $4.79 | $7,743,891 |
| | | 22.0 to 20.0 | 120,560 | $5.29 | $637,762 |
| | | 20.0 to 18.0 | 241,560 | $2.96 | $715,018 |
| | | 18.0 to 16.0 | 241,560 | $2.79 | $673,952 |
| | | 16.0 to 13.0 | 364,540 | $2.94 | $1,071,748 |
| | | 13.0 to 11.0 | 0 | $2.62 | $0 |
| | | Quantity Converted | 1,246,667 | $3.28 | $4,089,067 |
| | | **Subtotal** | **3,346,848** | | **$14,931,437** |
| | | | | | |
| 30-year | 5% | 36.3 to 22.0 | 1,615,320 | $4.79 | $7,743,891 |
| | | 22.0 to 20.0 | 120,560 | $5.29 | $637,762 |
| | | 20.0 to 18.0 | 241,560 | $2.96 | $715,018 |
| | | 18.0 to 16.0 | 241,560 | $2.79 | $673,952 |
| | | 16.0 to 13.0 | 243,027 | $2.94 | $714,498 |
| | | 13.0 to 11.0 | 0 | $2.62 | $0 |
| | | Quantity Converted | 1,655,000 | $3.28 | $5,428,400 |
| | | **Subtotal** | **4,117,027** | | **$15,913,522** |
| | | | | | |
| 40-year | 5% | 36.3 to 22.0 | 1,615,320 | $4.79 | $7,743,891 |
| | | 22.0 to 20.0 | 120,560 | $5.29 | $637,762 |
| | | 20.0 to 18.0 | 241,560 | $2.96 | $715,018 |
| | | 18.0 to 16.0 | 241,560 | $2.79 | $673,952 |
| | | 16.0 to 13.0 | 121,513 | $2.94 | $357,249 |
| | | 13.0 to 11.0 | 0 | $2.62 | $0 |
| | | Quantity Converted | 2,206,667 | $3.28 | $7,237,867 |
| | | **Subtotal** | **4,547,180** | | **$17,365,739** |
| | | | | | |
| 50-year | 5% | 36.3 to 22.0 | 1,615,320 | $4.79 | $7,743,891 |
| | | 22.0 to 20.0 | 120,560 | $5.29 | $637,762 |
| | | 20.0 to 18.0 | 241,560 | $2.96 | $715,018 |
| | | 18.0 to 16.0 | 241,560 | $2.79 | $673,952 |

| Cycle | Shoaling Increase | Reach | Dredging Quantity | Unit Cost | Dredging Cost |
|---|---|---|---|---|---|
| | | 16.0 to 13.0 | 0 | $2.94 | $0 |
| | | 13.0 to 11.0 | 0 | $2.62 | $0 |
| | | Quantity Converted | 2,758,333 | $3.28 | $9,047,333 |
| | | **Subtotal** | **4,977,333** | | **$18,817,956** |
| | | | | | |
| | | | **50-Year Cost W/O Rock** | | **$80,282,293** |

**Table 6. Cost to Rebuild Land**

| Cost to Rebuild Land | 15-Foot Channel | 18-Foot Channel | 20-Foot Channel |
|---|---|---|---|
| Area (sq ft) | 563,231 | 563,231 | 563,231 |
| Depth (ft) | 6 | 6 | 6 |
| Volume (cy) | 125,162 | 125,162 | 125,162 |
| Mob/Demob | 0 | 0 | 0 |
| Dike Construction | 1,379,000 | 1,379,000 | 1,379,000 |
| Unit Cost (dredging) | $3.62 | $3.47 | $3.28 |
| Land Loss (ac/yr) | 12.9 | 12.9 | 12.9 |
| Land Loss /10 year cycle (cy) | 1,251,624 | 1,251,624 | 1,251,624 |
| Cost to Rebuild Land/10-Year Cycle | $5,909,879 | $5,722,135 | $5,484,327 |
| Total Cost to Recreate Land | $29,549,394 | $28,610,676 | $27,421,634 |

## 6.0 Summary and Conclusions

Bank erosion and land loss on the HNC Inland Reach has become a significant problem. The estimated rate of land loss is 12.93 acres per year. The primary cause of the bank erosion and land loss is wave action created by boat wakes. To reduce bank erosion, maintenance cost and environmental impacts a graded stone foreshore or bank revetment is recommended. A comparison of construction and maintenance cost with and without the foreshore protection, land loss, and marsh creation shows the proposed foreshore protection is the least cost option. The cost summary for the 18-foot and 20-foot depth options is presented in Table 7.

**Table 7. Cost Summary**

| Depth Option | Cost Without Rock | Cost With Rock |
|---|---|---|
| **15-Foot Channel (No Action Plan)** | | |
| Total Rock Construction Cost | $0 | $38,912,100 |
| Total Rock Maintenance Cost | $0 | $37,188,000 |
| 50-Year Dredging Cost | $80,609,009 | $54,714,540 |
| 50-Year Land Loss Costs | $29,549,394 | $2,954,939 |
| 50-Year Value of Land Created | | $29,549,394 |
| Total Cost (50 years) | $110,158,404 | $104,220,185 |
| **18-Foot Channel** | | |
| Total Rock Construction Cost | $0 | $38,912,100 |
| Total Rock Maintenance Cost | $0 | $37,188,000 |
| 50-Year Dredging Cost | $82,424,807 | $53,104,295 |
| 50-Year Land Loss Costs | $28,610,676 | $2,861,068 |
| 50-Year Value of Land Created | | $28,610,676 |
| Total Cost (50 years) | $111,035,483 | $103,454,786 |
| **20-Foot Channel** | | |
| Total Rock Construction Cost | $0 | $38,912,100 |
| Total Rock Maintenance Cost | $0 | $37,188,000 |
| 50-Year Dredging Cost | $80,282,293 | $54,293,620 |
| 50-Year Land Loss Costs | $27,421,634 | $2,742,163 |
| 50-Year Value of Land Created | | $27,421,634 |
| Total Cost (50 years) | $107,703,926 | $105,714,250 |

# Annex VII

# Cat Island Pass Erosion Desktop Study

ERDC/CHL TR-08-X

Coastal & Hydraulics Laboratory

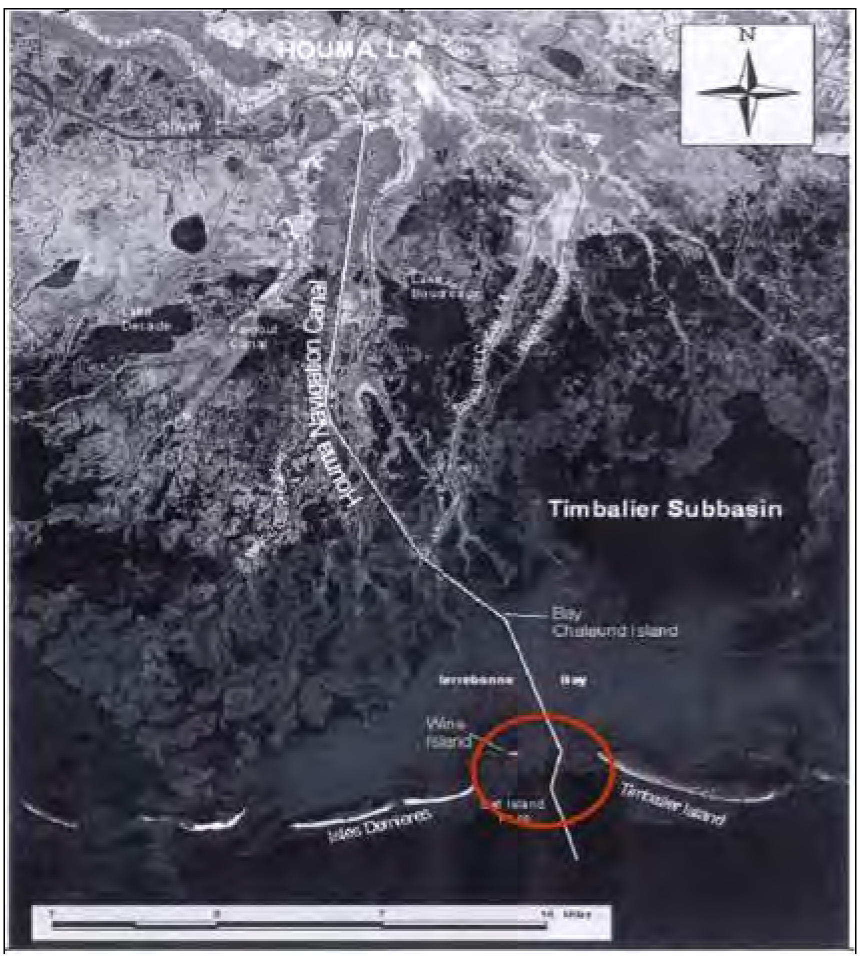
US Army Corps of Engineers®
Engineer Research and Development Center

*USACE District, New Orleans*

# Scoping Study to Evaluate Deepening of Houma Navigation Channel at Cat Island Pass, Louisiana

Julie Dean Rosati

February 2008




Preliminary report approved for review.

# Scoping Study to Evaluate Deepening of Houma Navigation Channel at Cat Island Pass, Louisiana

**Prepared by:**

**US Army Corps of Engineers**
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**Authored By:**

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**10 April 2008**
**Julie Dean Rosati** **Date**

**Approved By:**

**10 April 2008**
**Ty V. Wamsley** **Date**

**Prepared for:**

**US Army Corps of Engineers**
**New Orleans District (MVN)**
**7400 Leake Avenue**
**New Orleans, Louisiana 70118**

**Accepted By:**

James McCrorey for 10 Apr 08 | Brian J. Gannon 10 Apr 2008

**Crorey M. Lawton, MVN** **Date** **Brian J. Gannon, MVN** **Date**

USACE District, New Orleans

ERDC/LAB TR-08-X
February 2008

# Scoping Study to Evaluate Deepening of Houma Navigation Channel at Cat Island Pass, Louisiana

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Draft report

Approved for review by USACE District, New Orleans

Prepared for U.S. Army Corps of Engineers District, New Orleans
Washington, DC 20314-1000

**Abstract:** A scoping study was conducted to evaluate the potential increase in shoaling and sources of this sediment due to deepening of the Houma Navigation Channel in the vicinity of Cat Island Pass, Louisiana. The study used existing information culled from the literature and historical maintenance dredging rates to develop historical and forecast with-deepening sediment budgets. Conclusions from this study were that deepening the channel from 18 ft to 20 ft (relative to Mean Low Gulf) would increase the shoaling rate from the present 250,000 cu yd/yr to 290,000 cu yd/yr, and the likely source of shoaling would be sediment that is presently bypassed naturally around the channel. It was recommended that all environmentally-acceptable sediment dredged from Cat Island Pass be placed on the downdrift barrier island, East Island, part of the Isle Dernieres barrier island system. Clays and silts should be placed on the bayside of the island, and sand similar to or coarser than the existing beach sand should be placed downdrift of the nodal zone on the Gulf side of East Island. Sediment dredged from Cat Island Pass has been placed in a designated dredged material disposal site located 2500-ft west of the channel. Based on morphologic change in the region from 1980 to 2006, it appears that sediment may be transported back into the channel. It is recommended that, if sediment cannot be placed on either East Island or Timbalier Island, that the dredged material disposal site be moved further to the west, away from the channel. Finally, based on movement of Timbalier Island and Cat Island Pass over the past 100 years, it is recommended that the channel be moved further to the west to avoid future impingement by Timbalier Island.

# Contents

# Figures and Tables

## Figures

## Tables

# Preface

This study was commissioned by the U.S. Army Engineer New Orleans District (MVN). Project Manager at the MVN was Mr. Crorey Lawton (MVN-PM-R); both Mr. Lawton and Mr. David Beck (MVN-ED-LW) provided valuable assistance in obtaining Operation and Maintenance information for the study. Mr. Syed Khalil and Mr. Darin Lee, both at the Louisiana Department of Natural Resources (LDNR), provided bathymetric grid data in the Geographic Information System. Work described in this study was conducted by the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), in collaboration with MVN and LDNR staff.

This draft report was prepared by Ms. Julie Dean Rosati, Coastal Processes Branch, HF-CI, CHL. This report was reviewed by Mr. Lawton, Mr. Khalil, Mr. Ty V. Wamsley, HF-C, CHL, Dr. Ping Wang at the University of South Florida, and Mr. Harley Winer, MVN-ED-HC. Work was performed under the general administrative supervision of Mr. Thomas W. Richardson, Director, CHL, and Dr. William D. Martin, Deputy Director, CHL.

# Unit Conversion Factors

| Multiply | By | To Obtain |
|---|---|---|
| cubic yards | 0.7645549 | cubic meters |
| degrees (angle) | 0.01745329 | radians |
| feet | 0.3048 | meters |
| miles (nautical) | 1,852 | meters |
| miles (U.S. statute) | 1,609.347 | meters |
| square feet | 0.09290304 | square meters |
| square miles | 2.589998 E+06 | square meters |
| yards | 0.9144 | meters |

# 1 Introduction

## Overview

Since 1974, the U.S. Army Engineer District, New Orleans (MVN) has maintained the 36.6-mile Houma Navigation Channel (HNC) at 18-ft depth relative to Mean Low Gulf [1] (MLG) and 300-ft bottom width. The HNC extends from Houma, Louisiana through Cat Island Pass, and this entrance is bordered by Timbalier Island on the east and East Island, part of the Isle Dernieres islands, on the west (Figure 1).

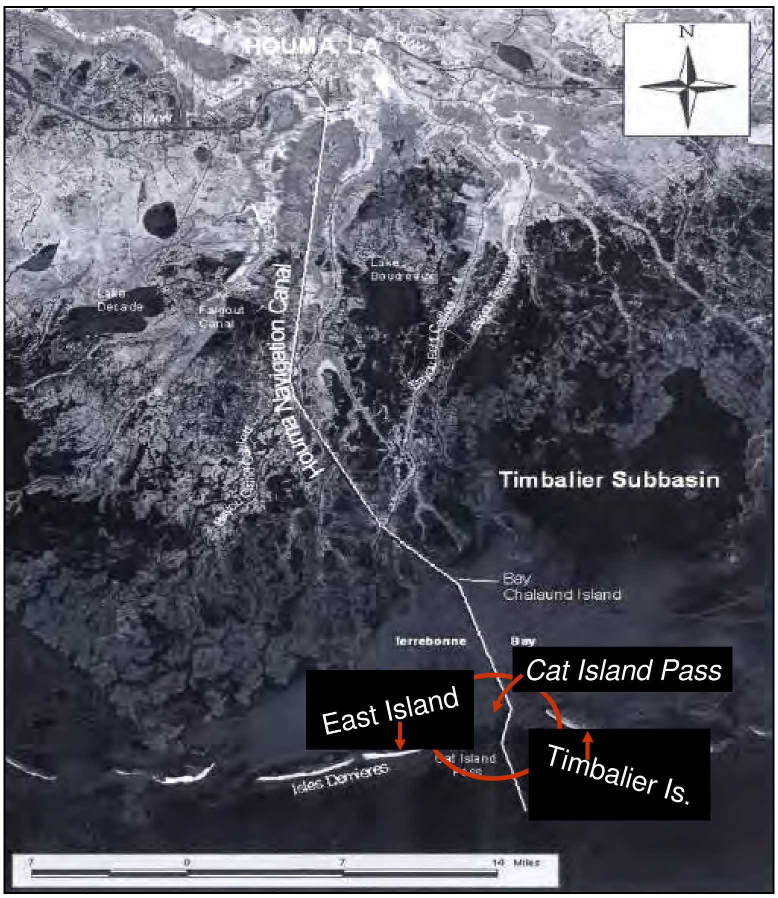



Figure 1. Houma Navigation Channel, Cat Island Pass, and adjacent barrier islands

[1] Mean Low Gulf (MLG) is a hydrographic tidal datum that includes local forcing due to tide, wind, current, and Mississippi River flow. As of June 2006, the relationship between MLG and National Geodetic Vertical Datum of 1988 (NAVD88) was established for various locations on the south shore of Lake Pontchartrain (Rigolets MLG=-0.662 ft NAVD88; 17th Street Canal MLG=-0.528 ft NAVD88; Bayou Labranche MLG=-0.373 ft NAVD88) (Mugnier 2006).

MVN is evaluating deepening the channel to 20 ft MLG which will generate 13 million cubic yards of new work dredged material along the entire length of the channel. MVN intends to conduct the new work, maintain the deepened channel, and place the dredged sediment to best uphold the USACE's Environmental Operating Principles[2], in particular, to "seek balance and synergy between human development and natural systems," and to "mitigate cumulative impacts to the environment." For the HNC and particularly Cat Island Pass, application of these principles requires an understanding of how the deepened channel will change coastal processes and morphology in the region, and points to the need for development of a plan to mitigate any negative consequences of the channel deepening and future maintenance.

This study was designed as a scoping-level effort using existing information (literature, data, and dredging history) to develop an understanding of historical and potential future with-deepening processes at the site, and to provide information for use in developing a dredged material placement plan for the deepened channel.

## Problem Statement

MVN and the Louisiana Department of Natural Resources (LDNR) are concerned about the barrier islands adjacent to the HNC, which are critically eroding and migrating rapidly (Figure 2). These barrier islands must be maintained as morphologic features to sustain the low-energy, lower-salinity estuarine characteristics of Timbalier Bay and the fragile interior wetlands. In addition, future migration of the islands may alter tidal currents and sediment transport in Cat Island Pass as well as shoaling rates in the HNC in the vicinity of the islands.

In 1998, MVN realigned HNC at Cat Island Pass to avoid unnecessary shoaling and negative impact to the islands, and another realignment may be considered if beneficial to reduce channel shoaling. Ideally, the dredged sediment would be placed on the adjacent barrier islands such that sediment would remain in the barrier island system and not shoal in the channel.

[2] http://www.hq.usace.army.mil/cepa/envprinciples.htm

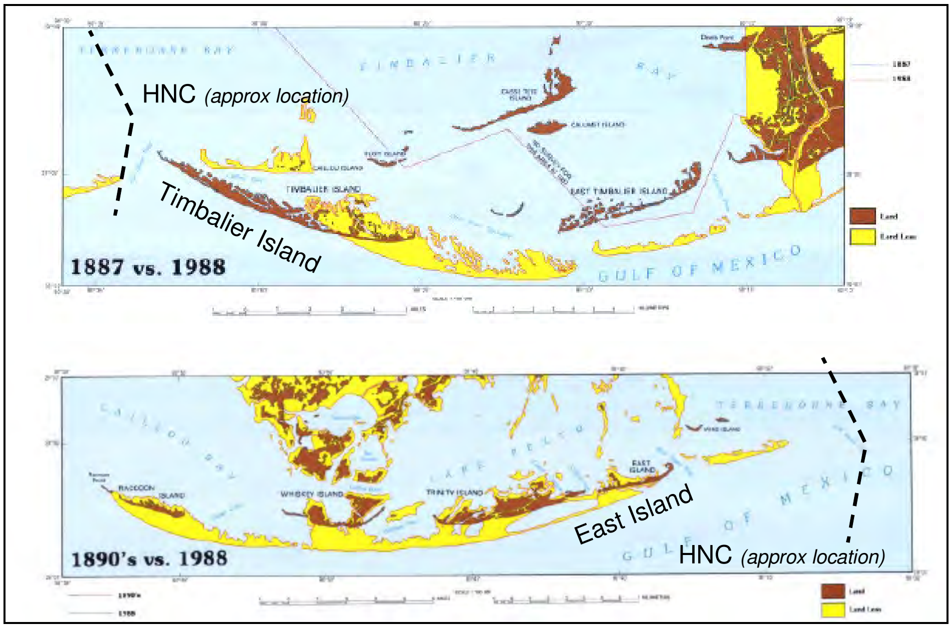



Figure 2. Long-term evolution of barrier islands adjacent to the HNC (adapted from McBride et al. 1992)

Based on experience at other navigation channels that have been deepened and widened (Rosati 2005), it is anticipated that the deepened channel will increase the maintenance dredging rate. Data in the Rosati (2005) study only included navigation channels that were immediately adjacent to barrier islands or beaches and were protected by jetties. Because the HNC channel is located some distance away from the adjacent barrier islands, there is speculation that the increase in shoaling may be less than as observed at other navigation channels. However, it is expected that the absence of jetties would potentially increase the shoaling rate. These two factors may offset one another to some extent.

In addition, it is not clear what the source of the shoaled sediment would be, whether it would be from the adjacent barrier islands, offshore shoals, or from within the estuary. There may be a small (possibly negligible) increase in tidal prism with deepening, which potentially could modify tidal current magnitudes and patterns.

In this study, existing historical data and available literature were evaluated to address these questions:

(a) What will be the increase in channel shoaling, if any, with channel deepening? What will be the change to tidal prism with deepening?

(b) What will be the source of the shoaled sediment? Will the adjacent bathymetry increase in depth, or will adjacent barrier islands be eroded?

(c) Should the channel be realigned to reduce maintenance dredging rates?

(d) Based on (a) and (b), what are the recommend placement locations on Timbalier and East Islands to best restore the islands? Are there certain placement locations that will be more likely to minimize transport of placed sand back into the channel?

(e) What are possible monitoring plans (minimal and moderate-level funding and effort) to determine the success of such placement?

To address these questions, historical and with-deepened sediment budgets have been developed herein based on existing bathymetric and shoreline position data, an analysis of maintenance dredging rates, and existing literature.

## Overview of Report

This report is organized in four chapters. Chapter 1 presents an introduction to the study. Chapter 2 reviews available literature and historical information that was applied to improve understanding of processes at the study site, evaluate possible realignment of the channel, and develop the sediment budgets. Chapter 3 presents the sediment budgets, and Chapter 4 makes recommendations for future placement of dredged material, monitoring, and additional study.

# 2 Project History

## Overview

This chapter summarizes literature, existing data, historical dredging records, and coastal processes for the study area. The purpose of this summary is to develop an understanding of processes and available data for the region, which was then applied for analysis and formulation of the sediment budget.

## Coastal Setting

### Barrier Islands

The HNC extends from the Gulf Intercoastal Waterway (GIWW) at Houma, Louisiana into Timbalier Bay through Cat Island Pass and into the Gulf of Mexico (see Figure 1). Cat Island Pass is bordered by Timbalier Island on the east and East Island, part of the Isle Dernieres islands, on the west. These barrier islands were formed as old Mississippi River deltas were reworked by coastal processes (Figure 3).

This erosion, along with compaction of deltaic sediments and regional subsidence, caused flooding of the bays. Terrebonne Bay and its barrier islands within the HNC study area were formed as the Teche delta (formed 3500-2800 years before present) and LaFourche delta (formed 1000-300 years before present) eroded, compacted, and subsided (Figure 4). The present location of the Mississippi River Balize delta directs river sediment offshore of the continental shelf. Sediment to nourish the barrier islands in the study area is derived through cannibalism of existing headlands and islands. For example, Timbalier Island is primarily a spit feature with sand that is derived from the LaFourche headland to the east (see Stage 1 in Figure 3). Sand forming the Isle Dernieres has been reworked from the Teche and La Fourche deltas (see Stage 2 in Figure 3).

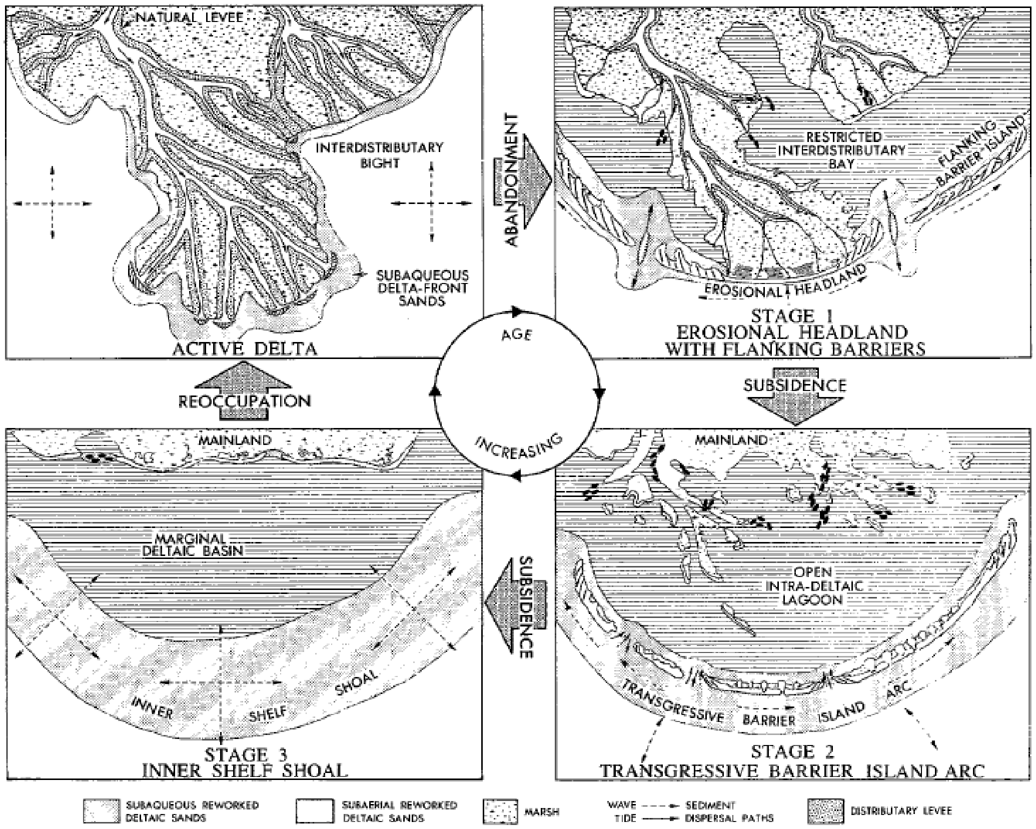



Figure 3. Model for formation of barrier islands from abandoned Mississippi River deltas (from Penland and Boyd 1981)

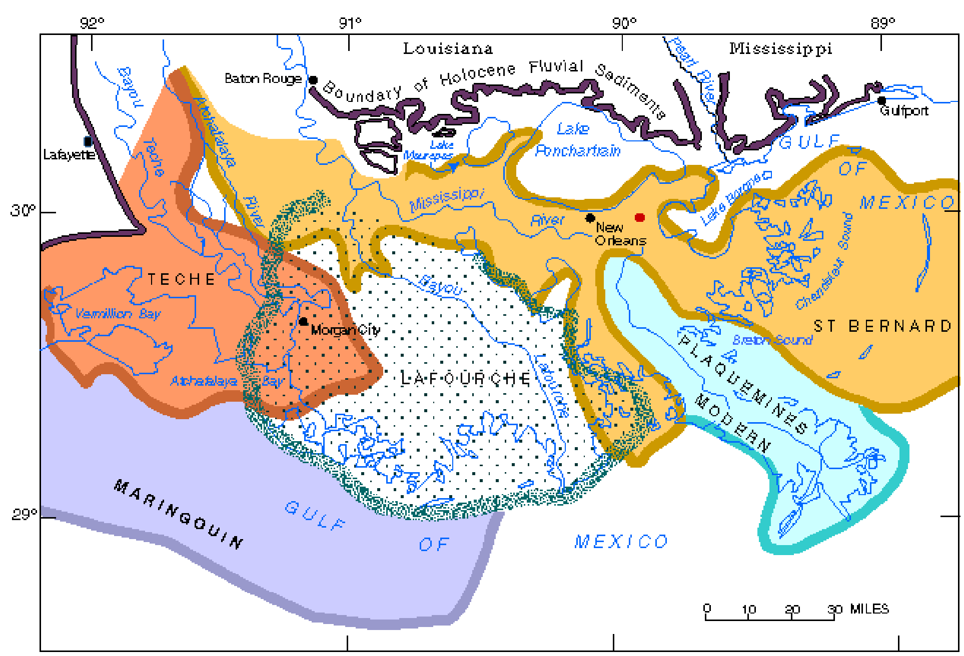



Figure 4. Location of Mississippi River deltaic lobes (modified from Frasier 1967)

### Coastal Processes

Louisiana is a low-energy coast with diurnal tides having a mean range of 1.3 ft. Wave Information Study (WIS) hindcast data are available for Stations 125 and 126 offshore of the project area. Station 125 is located directly offshore of Isle Dernieres at latitude 28.58°N, longitude -90.75°W, at a depth of 59 ft (18 m)[3]. The WIS data for Station 125 indicate a mean deepwater significant wave height equal to 3.6 ft with standard deviation equal to 2 ft (1.1 ± 0.6 m) and peak wave period equal to 5 ± 1.4 sec for the 20-year period 1980-1999. Maximum conditions during this 20-year period occurred on October 28, 1985 with significant height 26.3 ft (8 m) and peak period 13 sec. WIS Station 126 is located east of Station 125, at latitude 28.58°N, longitude -90.58 °W in 66 ft (20 m) depth. Station 125 has the same mean wave statistics, and the maximum conditions occurred on the same date although the maximum significant wave height was slightly higher at 27.6 ft (8.4 m) with 14 sec period.

Approximately 20-30 cold fronts pass through the study area each year from September to May in the Northern Gulf of Mexico. Storms that do not inundate the barrier islands erode sediment from the Gulf side of the barrier islands and deposit it offshore or alongshore. Waves generated by northerly winds as cold fronts, tropic storms, and hurricanes pass can subsequently erode bay side beaches and deposit sediment in the bay. These storms typically create a net volume deficit to the barrier islands. In contrast, storms with wave conditions and storm surge that overwash or inundate the islands erode sediment from the Gulfside and deposit it on the bay side of the barrier island (Dingler and Reiss 1991). Storms that overwash and inundate the islands are more likely to migrate the islands as a morphologic feature and maintain sediment volume. The frequency of tropical storms and hurricanes in Louisiana is approximately every 1.6 and 4.1 year, respectively (Neumann et al. 1978, Nummedal 1982).

Based on data from 1947-1999, long-term relative sea level rise at Grand Isle, approximately 40 miles east of the HNC, is 3.23 ft/century with standard deviation of 0.12 ft/century (9.8 ± 0.36 mm/yr) (Figure 5).

[3] http://frf.usace.army.mil/cgi-bin/wis/atl/atl_main.html

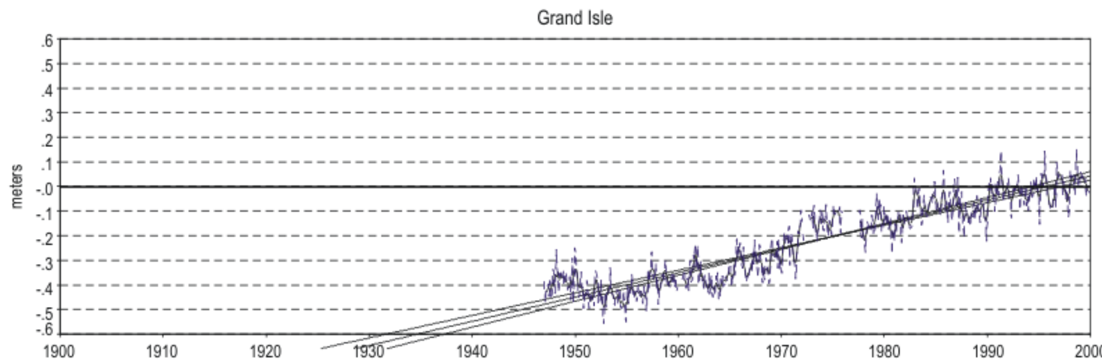
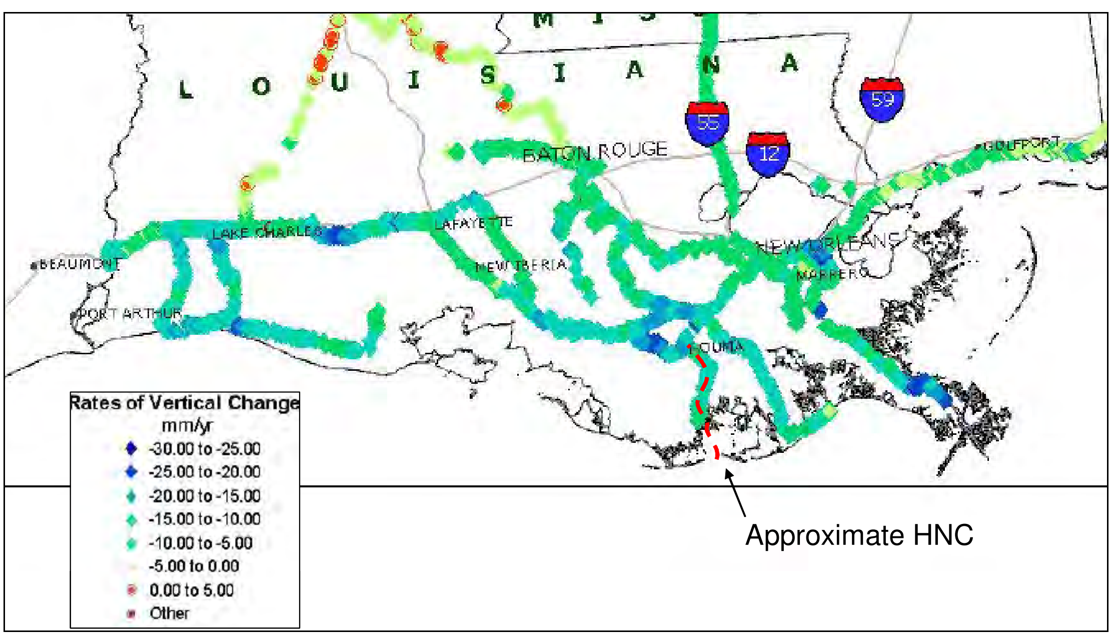



Figure 5. Sea level data from 1947-1999 for Grand Isle, Louisiana (from http://tidesandcurrents.noaa.gov/index.shtml)

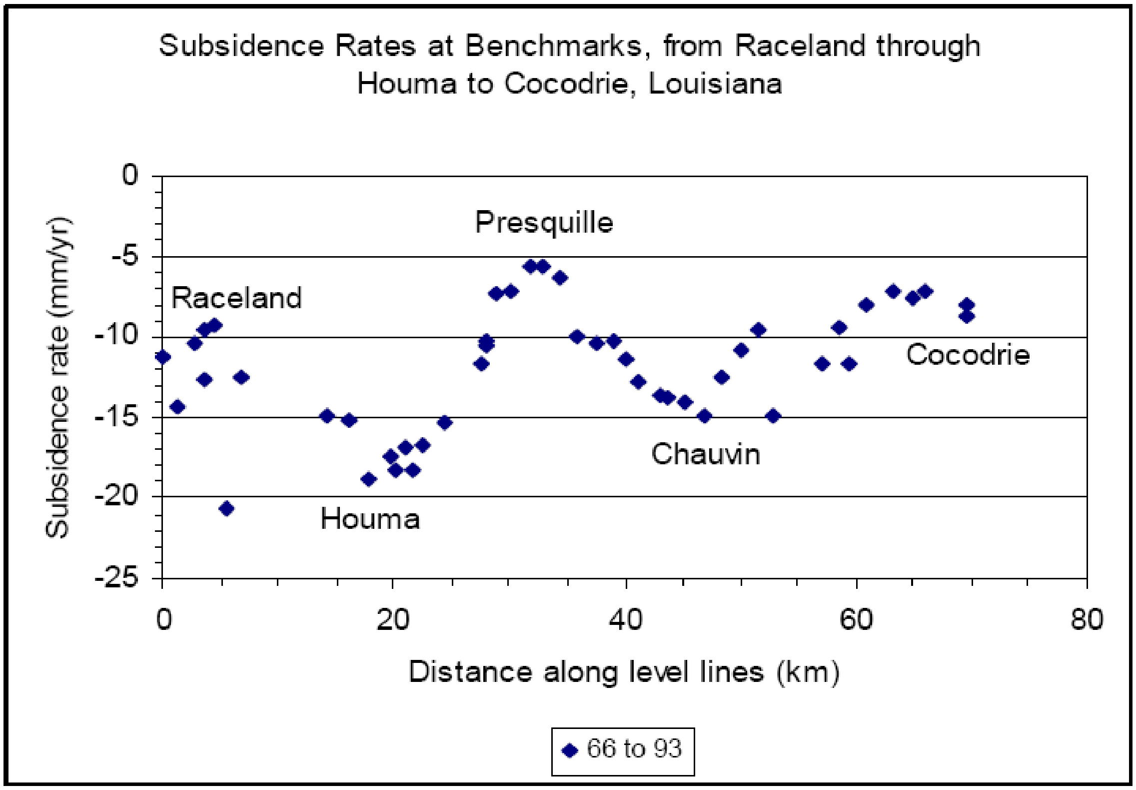
Net longshore sediment transport in the region is generally from east-to-west, although reversals in direction can occur in the vicinity of inlets and passes and during storm events (e.g., Suter and Penland 1987, Dingler and Reiss 1991, Debusschere et al. 1991, Jaffe et al. 1997).

### Subsidence

Shingle and Dokka (2004) established subsidence rates for the lower Mississippi Valley and northern Gulf Coast based on benchmark elevations and water level data. Figure 6 shows subsidence rates for southern Louisiana, which range from 1.64 to 6.23 ft/century (5 to 19 mm/year).




a. Regional rates




b. Detailed rates within region of HNC (from 1966-1993)

Figure 6. Subsidence rates for project area (from Shingle and Dokka 2004)

## Previous Studies

Based on morphological observations and bed form type and orientation, Suter and Penland (1987) presented a subjective analysis of sediment transport pathways around Cat Island Pass. Their discussion of net long-shore transport and transport through Cat Island Pass is interpreted herein (Figure 7). The solid arrows in Figure 7 represent likely pathways and the dashed arrow indicates a possible return of sediment back into Cat Island Pass after it has bypassed the channel. The net longshore transport from east to west was evident from the well-develop swash platform at Wine Island Pass and the lack of a marginal flood channel. They concluded that the Cat Island Pass system "is not totally a sediment sink but does in fact interact with the adjacent barrier shorelines."

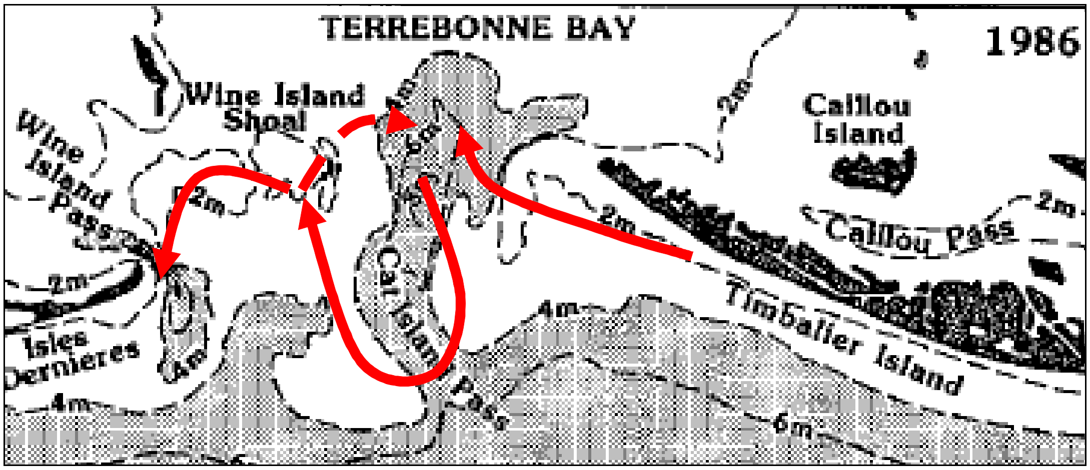



Figure 7. Potential sand transport patterns in the vicinity of Cat Island Pass (based on Suter and Penland 1987)

Suter and Penland also presented the minimum cross-sectional area of the Cat Island Pass complex as it has varied from 1891 to 1986 (Figure 8) (note that dredging of the Pass began in 1959). These cross-sections show several processes of interest for the HNC: (1) western Timbalier Island has continually migrated west into the Cat Island Pass complex through time; (2) Calliou Island and Calliou Pass were absorbed into the Cat Island Pass complex by 1934; and (3) the location of Wine Island Pass and eastern Isle Dernieres have been relatively stable through time. Using this figure, the rate of migration for western Timbalier Island can be estimated as: 250 ft/yr to the west (77 m/yr), 300 ft/yr to the west (93 m/yr), and 190 ft/yr to the east (58 m/yr) from 1891-1934, 1934-1974, and 1974-1986, respectively. The average rate for the entire period is 220 ft/yr to the west (66 m/yr).

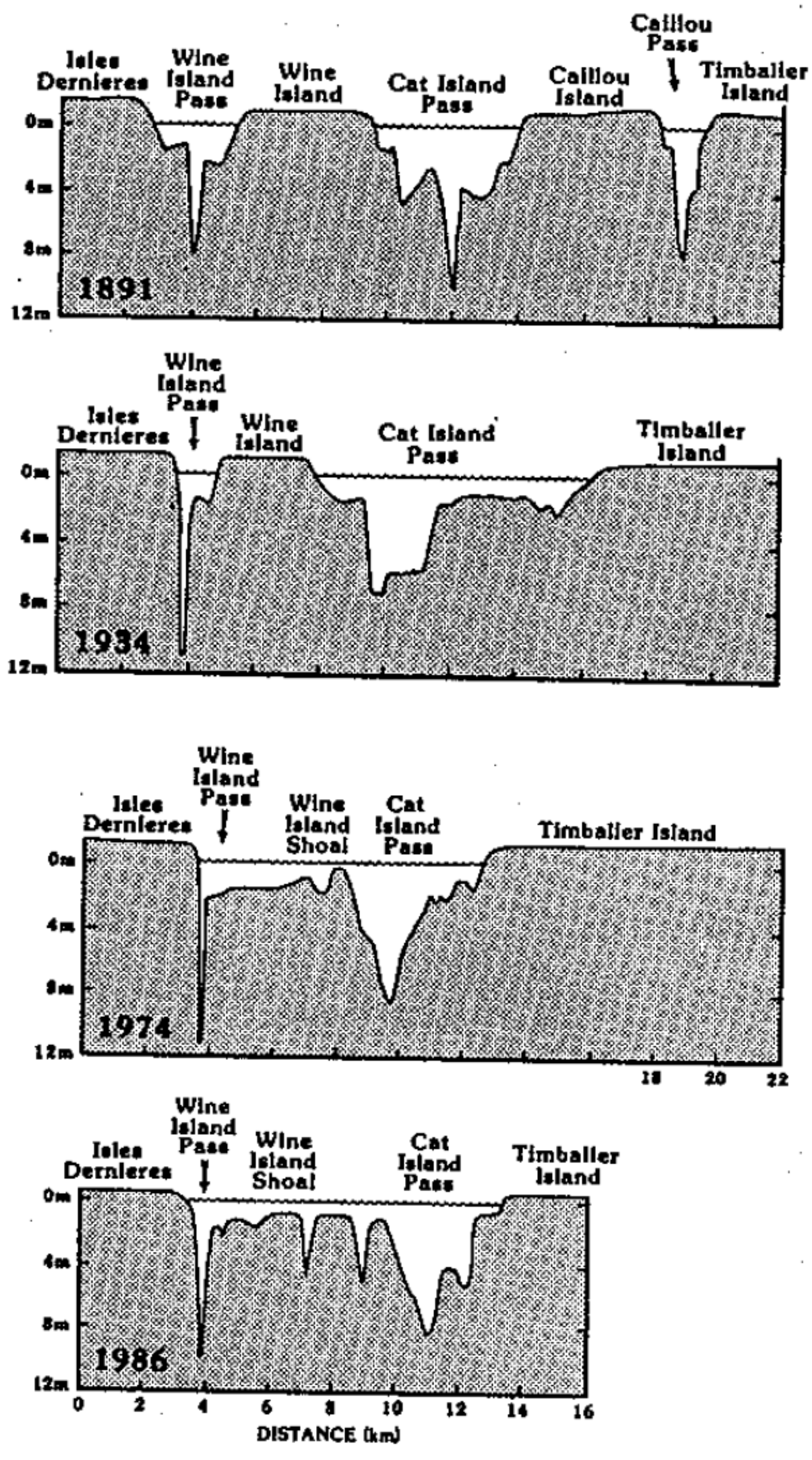



Figure 8. Minimum inlet cross-section for Cat Island Pass complex (from Suter and Penland 1987)

Jones (1987) discussed a previous restoration of East Island in 1985 using sand dredged by MVN from Cat Island Pass. The project was deemed essential and solely funded by Terrebonne Parish because “Terrebonne’s barrier islands are considered to be a key element in the short term survival of Terrebonne’s wetlands. If the islands are lost, it is estimated that Terrebonne’s land loss would accelerate geometrically.” Because the sand dredged from the Pass was a slurry, a dike was constructed to contain the dredged sediment. To avoid construction over existing wetlands and to protect against future breaches, the project was constructed at a site of an active washover feature. Total construction time was 29 days, including construction of the dikes and placement of the dredged sand.

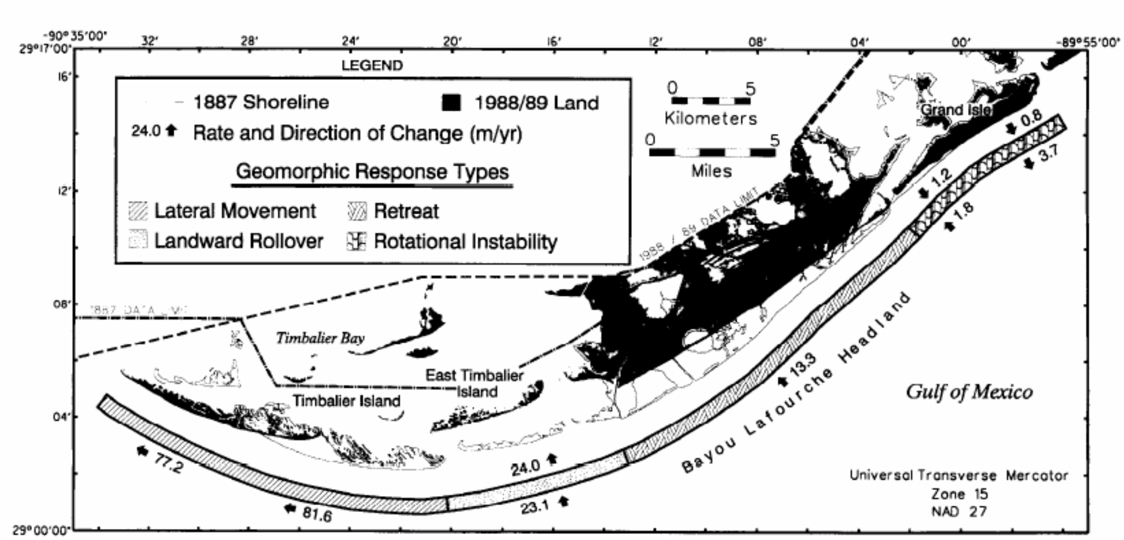
Debusschere et al. (1991) monitored morphologic changes of the Isle Dernieres islands between 1984 and 1989 using an aerial videotape mapping system. Of pertinence to the study herein is that East Island recovered more rapidly after storms than the other portions of the Isle Dernieres. The authors attributed this recovery to the sediment supply available to East Island via bypassing across Cat Island Pass.

McBride et al. (1995) characterized geomorphic barrier island response using data from Louisiana, Mississippi, Georgia, and Florida. Data from Louisiana included an assessment of long-term shoreline change for Timbalier and East Islands (Figure 9). Between 1887 and 1988/89, the morphologic evolution of Timbalier Island was characterized as “lateral movement” to the west at a rate between 270 ft/yr (81.6 m/yr) (eastern portion) and 250 ft/yr (77.2 m/yr) (western portion). No changes are noted for the bayshore. If an active profile of 3.5 ft berm elevation (Jones 1987) plus 6 ft for the depth of closure (Campbell et al. 2006), which totals approximately 10 ft, is multiplied by an average island width of 2300 ft and the difference in east and west migration rates, Timbalier Island is estimated to have had a change in island volume equal to (10 ft)(-20 ft/yr)(2300 ft)(1 cu yd/27 cu ft) = -17,000 cu yd/yr[4].

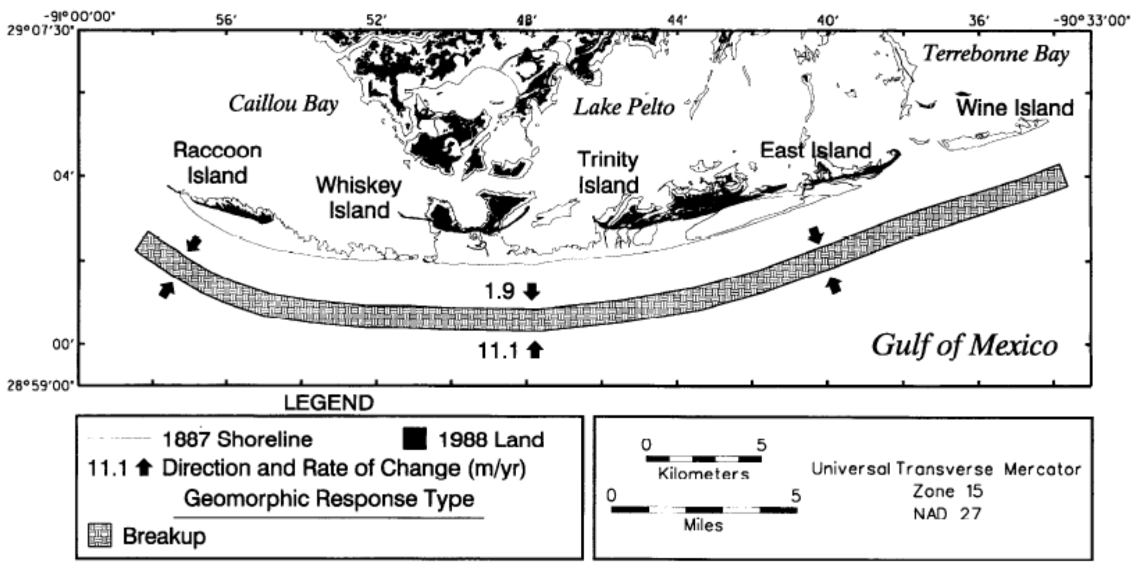
The Isle Dernieres including East Island were characterized by McBride et al. as “breakup” type of geomorphic evolution, indicating that the island system is susceptible to breaching during storms and disintegration. Shoreline change rates for the Isle Dernieres were erosion of the Gulf and Bay shorelines at 36.4 and 6.2 ft/yr (11.1 and 1.9 m/yr), respectively. Applying these rates with a 10-ft active depth and an average island length of

[4] However, some of this volume change likely represents erosion of silts and clays which is then lost from the barrier island system.

8.5 miles (45,000 ft), calculation of island volume change gives
(10 ft) (-36.4 + -6.2 ft)(45,000 ft)(1 cu yd/27 cu ft) = -710,000 cu yd/yr4.




a. Bayou LaFourche Headland, including Timbalier Island, 1887-1988/89




b. Isle Dernieres, including East Island, 1887-1988

Figure 9. Shoreline change and geomorphic characterization for Timbalier and East Island (from McBride et al. 1995)

Jaffee et al. (1997) analyzed 1930s and 1980s bathymetry offshore of present-day Cat Island Pass. Bathymetric change calculations and subsequent sediment sampling indicated a sandy deposit of 78 Million cu yd (60 Million cu m) (Figure 10). Jaffee et al. described this accumulation as "massive sediment bypassing" offshore of the 9-km-wide Cat Island/Wine Island Pass system and related it to "changes in shoreline orientation, closing of transport pathways to a large bay to the east and the presence of tidal inlets." Numerical modeling of this system by Jaffee et al. indicated that bypassing was episodic, forced by large storms and hurricanes. Sediment sampling of the deposit showed that it was primarily sand. The authors predicted that erosion of Isle Dernieres, the barrier island system to the west, would likely decrease as sand continued bypassing via the large offshore deposit. For comparison and further discussion, the 1980s to 2006 bathymetric difference calculations are shown in Figure 11.

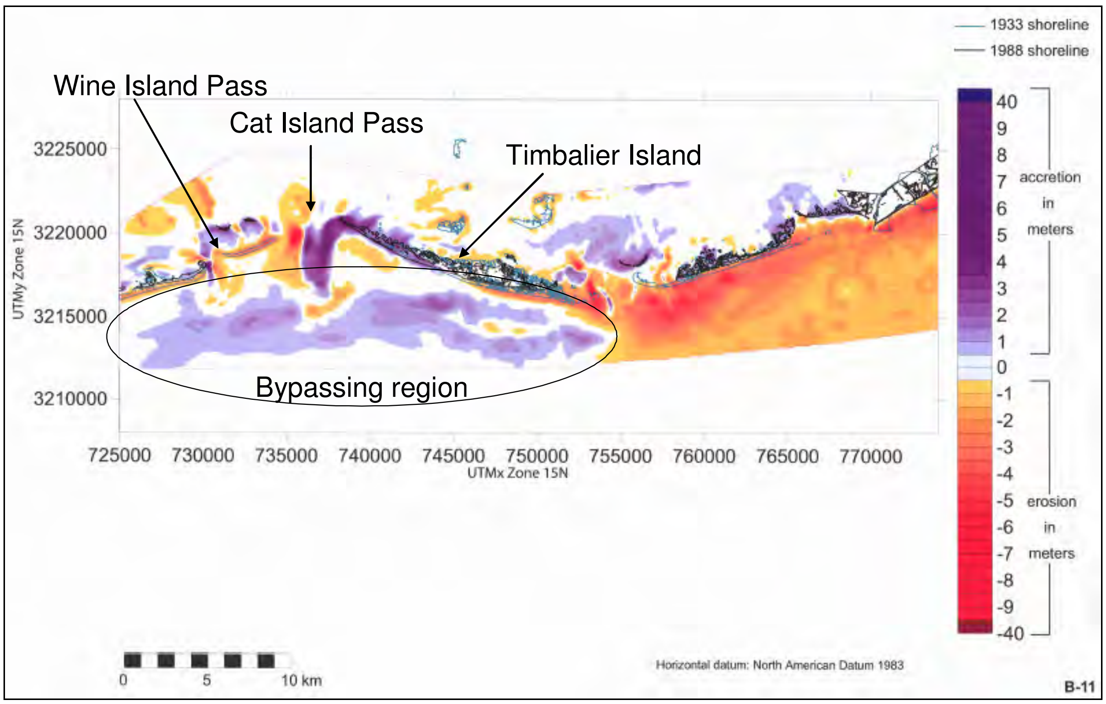



Figure 10. Bathymetric change for 1930s-1980s for Timbalier Island region (courtesy LDNR)

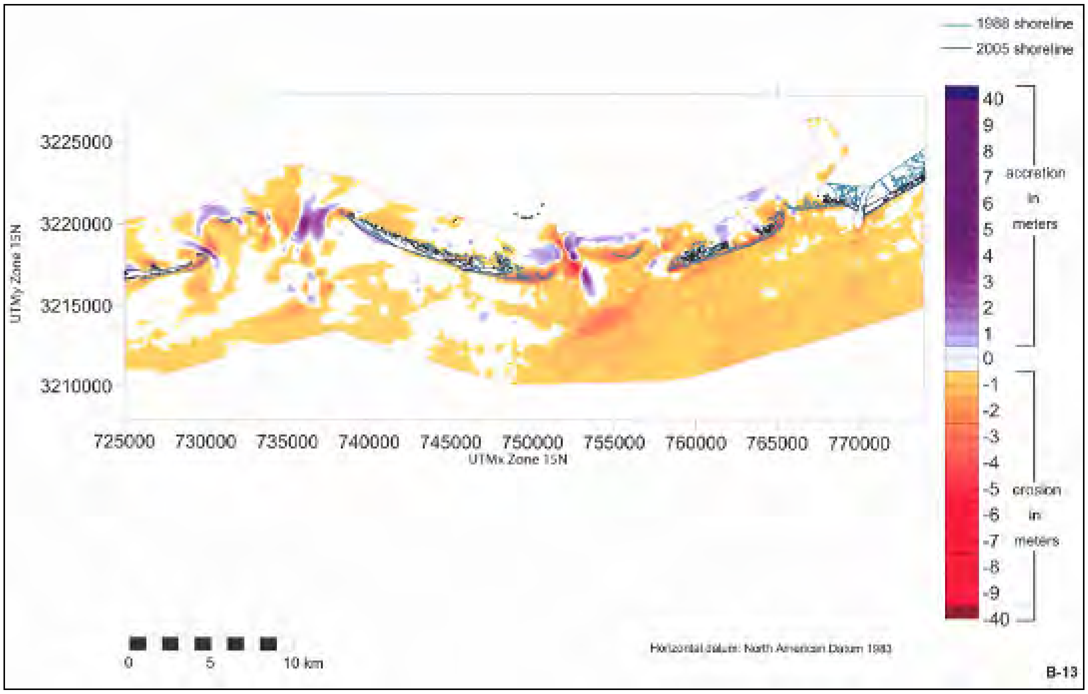



Figure 11. Bathymetric change from 1980s -2006 for Timbalier Island region (courtesy LDNR)

Although the bypassing offshore of Cat Island Pass discussed by Jaffee et al. may be realistic, comparison of the 1930s to 1980s change with the 1980s to 2006 change raises some questions about the data and its applicability to the present study. First, the bypassing region evident in the 1930s-1980s comparison (Figure 10) is not apparent in the 1980s-2006 data (Figure 11); in fact, erosion is observed offshore. It is possible that there was an error with the 1930s or 1980s data or a datum shift. Second, there is an apparent discontinuity between changes calculated east and west of Timbalier Island for the 1930s to 1980s calculations as evident by the magnitude of erosion in the eastern part of the region. Although this erosion may be real, a datum shift between adjoining data sets would also create an apparent erosion signal. Both of these observations raise some questions about the magnitude of bypassing inferred from the 1930s to 1980s comparison. It is likely that erosion offshore includes clays and silts which are different than the sand shoaling in Cat Island Pass. Finally, the magnitude of the bypassing feature indicates an accretion rate of 1.5 Mill cu yd/yr (1.2 Mill cu m/yr), an extremely high magnitude of change for this low-energy coast.

Stone and Zhang (2001) calculated potential longshore sand transport rates for Isle Dernieres and Timbalier Island using a wave transformation model (Figure 12). Application of this type of procedure to estimate longshore sand transport rates is limited because inlet and storm processes are not fully represented, and the state-of-the-art for predictive relationships for longshore transport rates are often only good within an order-of-magnitude. Note, too, that these relationships predict sand transport and not finer sediments such are found in the study area. Nevertheless, these calculations give an indication of sand transport rate magnitude and direction for the Gulf beaches.

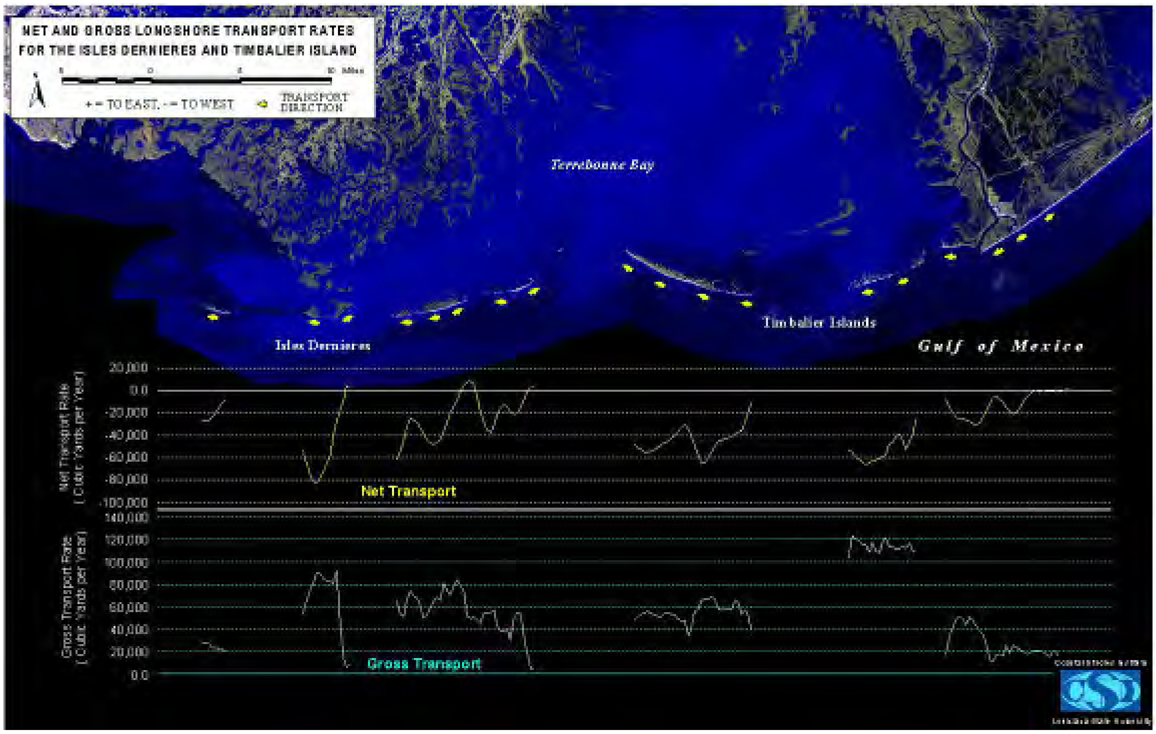



Figure 12. Potential net and gross longshore sand transport rates for Isle Dernieres and Timbalier Islands (from Stone and Zhang 2001)

A "calculated" sand budget was formulated using these potential longshore transport rates, and is shown in Figure 13. These calculations indicate that sand shoaling in the HNC at Cat Island Pass should be approximately 50,000 cu yd/year, whereas actual shoaling is approximately 5 times this rate. It is likely that inlet, storm, cross-shore transport, and fine sediment shoaling processes account for the difference between measurements and calculations. Application of Stone and Zhang's longshore sediment transport calculations implies that the Gulfside of Timbalier Island has a net erosion of 40,000 cu yd/yr, and the Gulfside of East Island is eroding at 65,000 cu yd/yr.

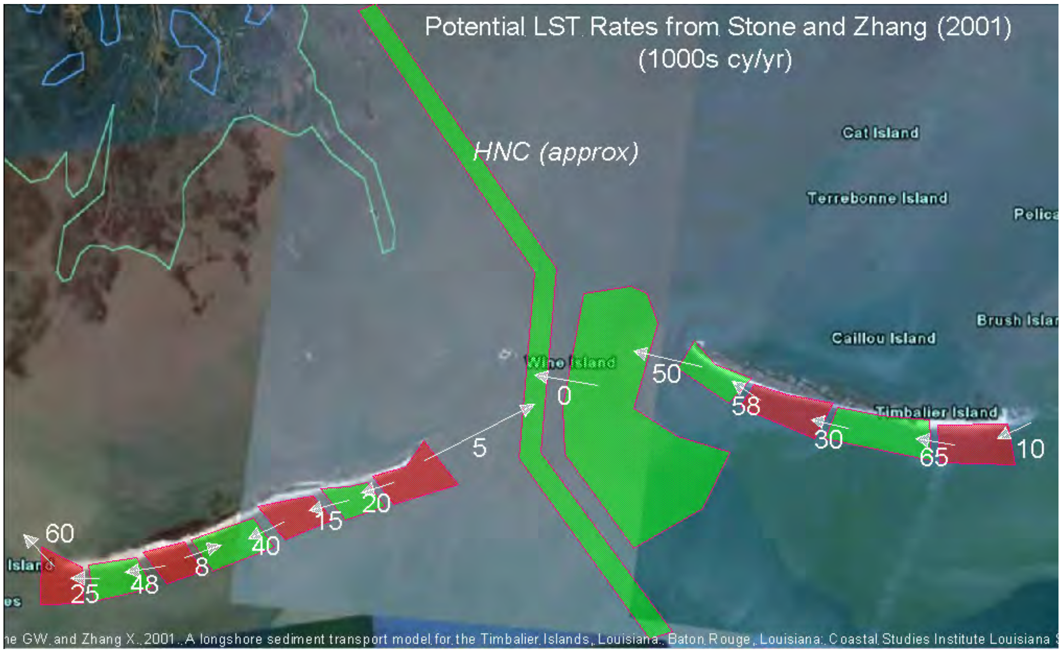



Figure 13. Application of net longshore transport rates from Stone and Zhang (2001) into a calculated sediment budget for sand transport under non-storm conditions

For this study, LDNR provided the bathymetric data and difference grids as shown in Figures 10 and 11. These calculations are discussed in more detail in the following chapter.

## Engineering Activities

### Houma Navigation Channel

*History*

The HNC was constructed by the State of Louisiana's Department of Public Works in 1959. The State of Louisiana later requested that the U.S. Army Corps assume maintenance of the channel, and the Corps was authorized to maintain the channel for navigation under the River and Harbor Act of 23 October 1962[5]. Maintenance by MVN was initiated on 27 November 1964 at original channel dimensions of 15 ft MLG depth by 150 ft wide from the Gulf Intercoastal Waterway (GIWW) at Houma, LA to Cat

[5] Personal communication, Mr. David Beck, CEMVN-ED-L, 20 September 2007.

Island Pass, and 18 ft MLG from Cat Island Pass to the Gulf of Mexico [6]. On 23 August 1973, authority was given to increase channel depth to 18 ft MLG and widen the channel to 300 ft from Cat Island Pass to the Gulf of Mexico. This improvement was completed in July 1974. In 1998, Cat Island Pass was realigned approximately 1200 ft (360 m) to the west to reduce channel shoaling and avoid future impingement by the migrating Timbalier Island (Figure 14). HNC history is summarized in the first four columns of Table 1.

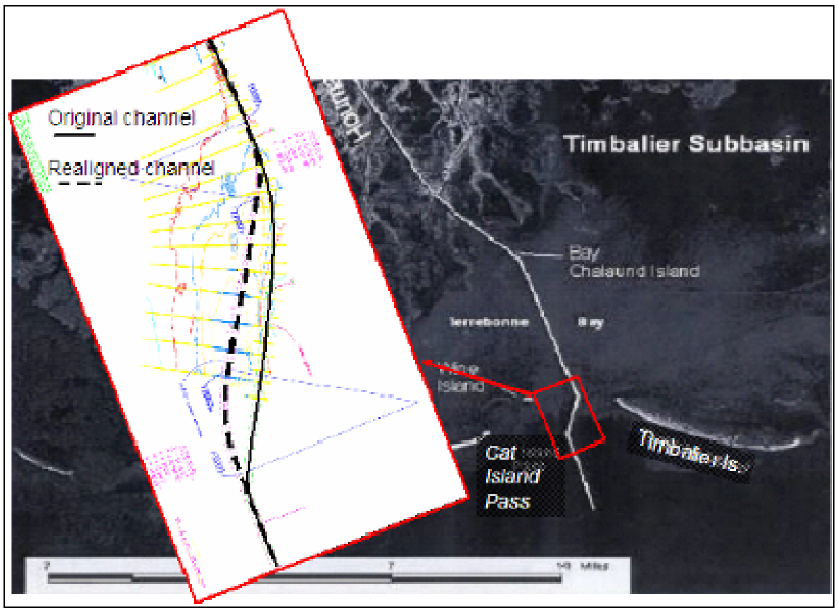



Figure 14. Cat Island Pass original and realigned channel locations

Presently, fine sand dredged from Cat Island Pass is placed at either of two single point discharge (SPD) locations west of the channel (Figure 15). The SPD's are located at Mile -1.7 and at Mile -2.5 and are approx. 2500-ft west of the channel[7].

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[6] http://www.mvn.usace.army.mil/pd/projectsList/home.asp?projectID=33&directoryFilePath=ProjectData%5C Updated 15 June 2007, Accessed 15 October 2007.

[7] Personal communication, Mr. David Beck, 30 October 2007.

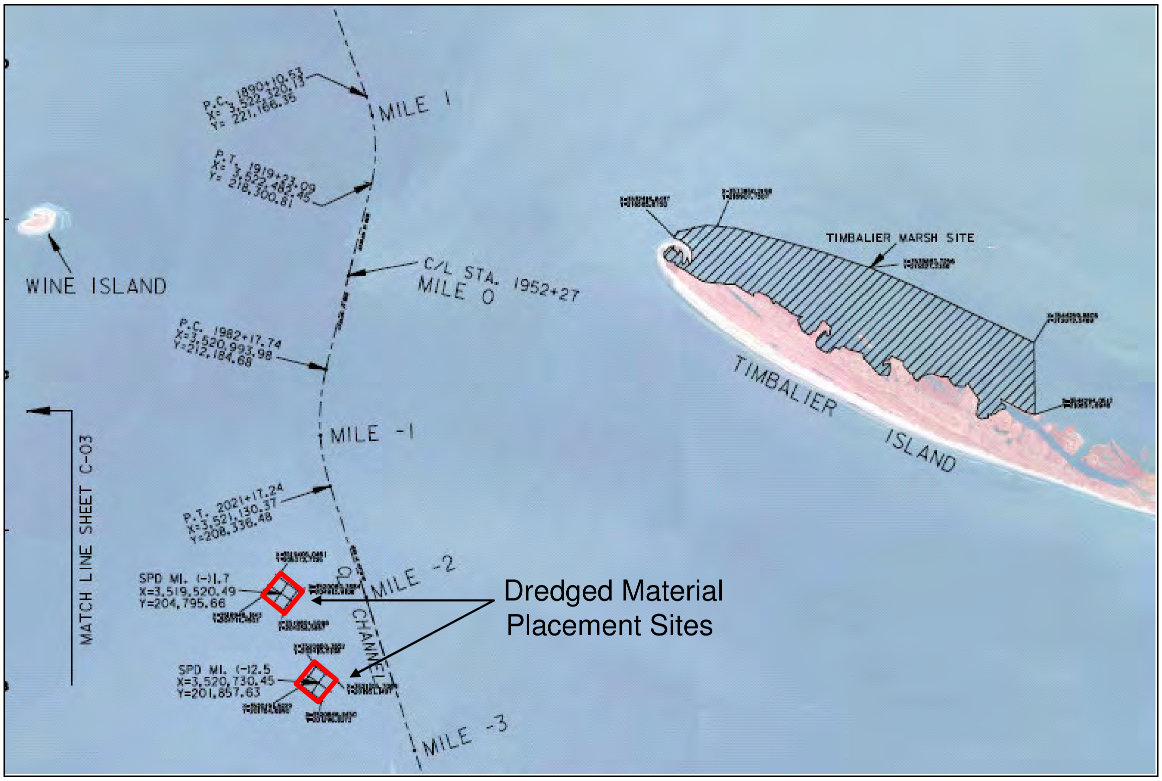



Figure 15. Location of dredged material placement sites west of Cat Island Pass

*Shoaling*

To evaluate the historical shoaling rate at Cat Island Pass, the cumulative maintenance dredged volume provided by MVN was plotted versus time for both Cat Island Pass and the Terrebonne Bay portion of the HNC (Figure 16). Maintenance dredging records were analyzed as a proxy for natural shoaling in the channel. The slope of the cumulative volume trend line gives the average shoaling rate over a period of time. For the entire data set, the average shoaling rates in Cat Island Pass and Terrebonne Bay were 228,000 and 560,000 cu yd/yr, respectively.

Table 1. History of Houma Navigation Channel

| Date | Authority | Dimensions (ft relative to MLG) H= Gulf Intercoastal Waterway at Houma; CIP=Cat Is. Pass | Description | Maintenance Dredging Rate (no new work) | |
|---|---|---|---|---|---|
| | | | | Houma Navigation Channel (cu yd/yr) | Cat Island Pass Channel (cu yd/yr) |
| 1959 | - | H to CIP: 15 x 150;<br>CIP to Gulf: 15 x 150 | Channel constructed by Louisiana Department of Public Works | ? | ? |
| 27 Nov 64 | River and Harbor Act 23 Oct 62 | Same | Corps assumed maintenance for navigation | 423,600 | 86,000 |
| July 74 | Section 5 of River and Harbor Act approved 4 Mar 1915 | H to CIP: 15 x 150, adv maintenance & overdepth is 3 ft;<br>CIP to Gulf: 18 x 300, adv maintenance & overdepth is 4 ft | Entire channel at 18 ft depth MLG x 300 ft width | 613,000 | 291,200 |
| 1998 | | Same | Cat Island Pass realignment completed with maintenance dredging[1] | 613,000 | 248,500 |
| Proposed | | H to CIP: 20 x 150 ft, adv maintenance & overdepth is 3 ft;<br>CIP to Gulf: 20 x 300 ft, adv maintenance & overdepth is 4 ft | Proposed deepening | ? | ? |

[1] Personal communication, Mr. David Beck, CEMVN-ED-L, 20 September 2007.

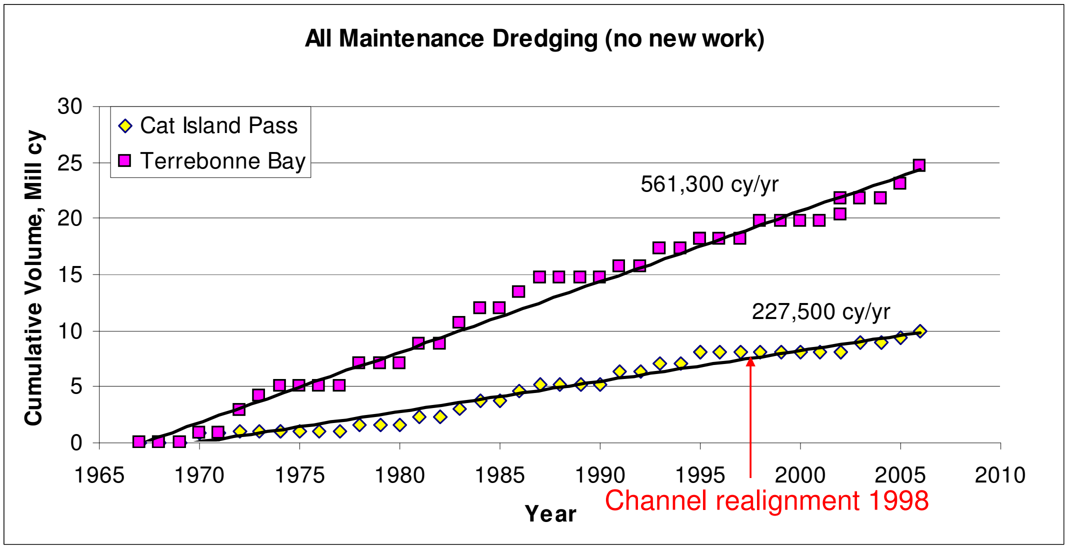



Figure 16. Average shoaling rate for Cat Island Pass and Terrebonne Bay based on maintenance dredging records, 1967-2006

These same data were analyzed for various periods of the maintenance dredging record to indicate how changes to the channel such as deepening and widening in 1974 and realignment of Cat Island Pass in 1998 modified the shoaling rates (Figure 17).

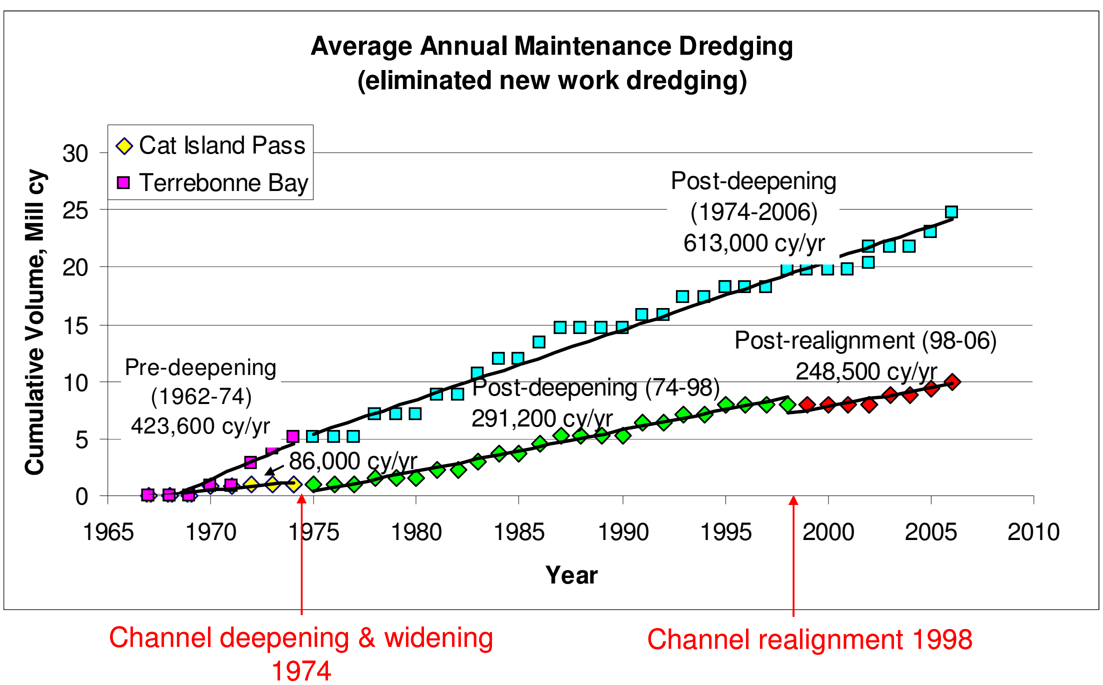



Figure 17. Cat Island Pass and Terrebonne Bay maintenance dredging rates evaluated for time periods corresponding to changes in channel configuration

The analysis shown in Figure 17 is also summarized in the last columns of Table 1. Deepening (from 15 to 18 ft) and widening (from 150 to 300 ft) of Cat Island Pass in 1974 increased channel shoaling by 205,200 cu yd/year (from 86,000 to 291,200 cu yd/yr). However, realignment of Cat Island Pass to the west in 1998 was effective in reducing the shoaling rate by 42,700 cu yd/yr (from 291,200 to 248,500 cu yd/yr).

Rosati (2005) developed an empirical relationship that estimates the increase in shoaling with channel improvement (deepening, widening, and lengthening) to the increase in volume over the pre-dredging channel volume. The reasoning behind this concept is that natural coastal processes work to restore the channel to its original dimensions (the pre-dredged volume equal to depth · width · length) at a rate that is related to the difference between the natural and dredged volumes. The shoaling rate, $S$, is related to the increase in dredged volume as compared to the pre-dredged channel volume, $V_d$, as follows,

$$S = 0.0613\, V_d \;(yr^{-1}) \tag{1}$$

Any consistent units may be used. To evaluate whether this relationship is applicable to Cat Island Pass, historical channel dimensions and shoaling rates were compared with Equation (1). Results of this analysis are shown in Table 2 and Figure 18.

Table 2. Channel Dimensions and Maintenance Dredging Rate, Cat Island Pass

| Date | Channel Dimensions | | | Maintenance Dredging Rate (1000s cu yd/yr) | |
|---|---|---|---|---|---|
| | Depth, ft | Width, ft | Length, mi | Actual | Predicted |
| 1959 – Natural Dimensions (assumed) | 15 | 150 | 0.25 [1] | ? | 0 |
| 1962 – 1974 | 15 | 150 | 3.9 | 86.0 | 98 |
| 1974 – 1998 | 18 | 300 | 3.9 | 291.2 | 245 |
| 1998 – 2006 (realigned) | 18 | 300 | 3.9 | 248.5 | 245 |
| Proposed (2008) | 20 | 300 | 4.1 [2] | ? | 288 |

[1] From the 1930s bathymetry.
[2] Personal communication, Mr. Crorey Lawton, MVN (18 October 2007).

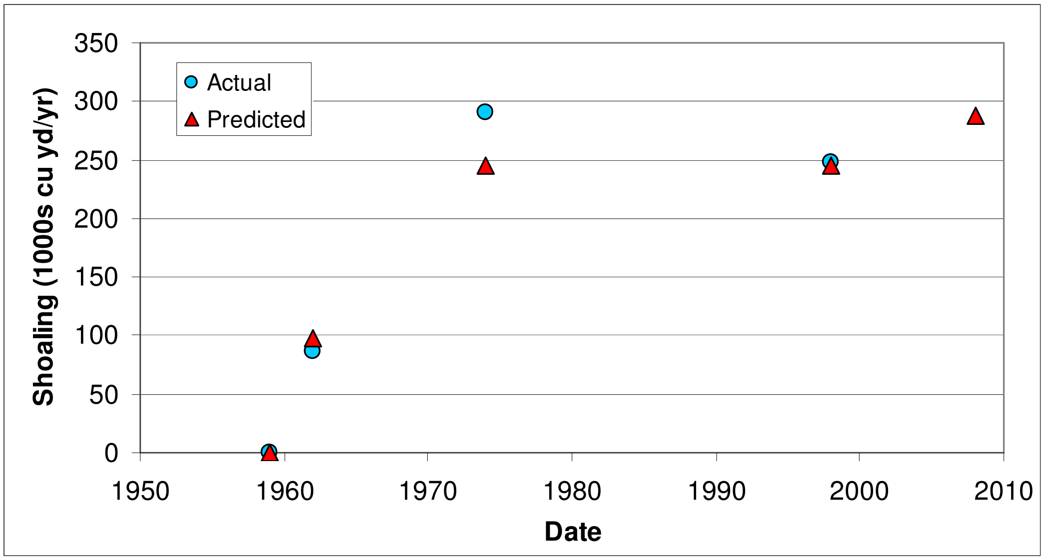



Figure 18. Comparison between actual and predicted shoaling at Cat Island Pass

Thus, the shoaling rate with the proposed improvement is estimated to increase approximately 15% from the existing maintenance dredging rate, or approximately 40,000 cu yd/yr. If Timbalier Island migrates further west, it is likely that the shoaling rate with the deepened channel will exceed this estimate unless the channel is realigned again.

*Migration*

The migration rate of the thalweg of Cat Island Pass as observed from the bathymetric data was estimated as 42 ft/yr (1930s-1980s) and 26 ft/yr (1980s-2006) to the west. It is likely that the location of the channel thalweg after 1967 is influenced by channel dredging and realignment in 1998, thus the migration rate for the earlier time period is probably more representative of natural channel migration, on the order of 40 ft/yr to the west. However, Timbalier Island has been migrating to the west more rapidly than the channel, estimated as 220 ft/yr from 1891-1986 (average from Suter and Penland 1987, see Figure 8), and 250 ft/yr from 1887-1988/89 (from McBride et al. 1995, see Figure 9a).

*Tidal Prism*

Tidal prism is defined as the volume of water that enters a tidal inlet during flood flow. Jarrett (1976) developed a relationship for tidal prism, $P$, as a function of inlet cross sectional area, $A_c$, which for Gulf Coast non-jettied inlets is

$$A_c(sq\ ft) = 5.02 \cdot 10^{-4} P^{0.84} (ft^3)$$
$$or \tag{2}$$
$$P = 8470\, A_c^{\ 1.19}$$

The minimum cross-sectional area for Cat Island Pass has increased through time, approximately 346,000 sq ft , 350,000 sq ft, and 364,000 sq ft in 1930, 1980, and 2006, respectively (Figure 19) . Applying Equation (2) with these cross-sectional areas implies that tidal prism has increased from $3.31 \times 10^{10}$ cu ft in the 1930s, to $3.35 \times 10^{10}$ cu ft in the 1980s and $3.51 \times 10^{10}$ cu ft in 2006, an overall increase of 6%. A natural increase in tidal prism may result from changes in the dynamics of adjacent inlets, deepening of channels, as well as an increase in bay area such has occurred in Louisiana with erosion and wetland loss.

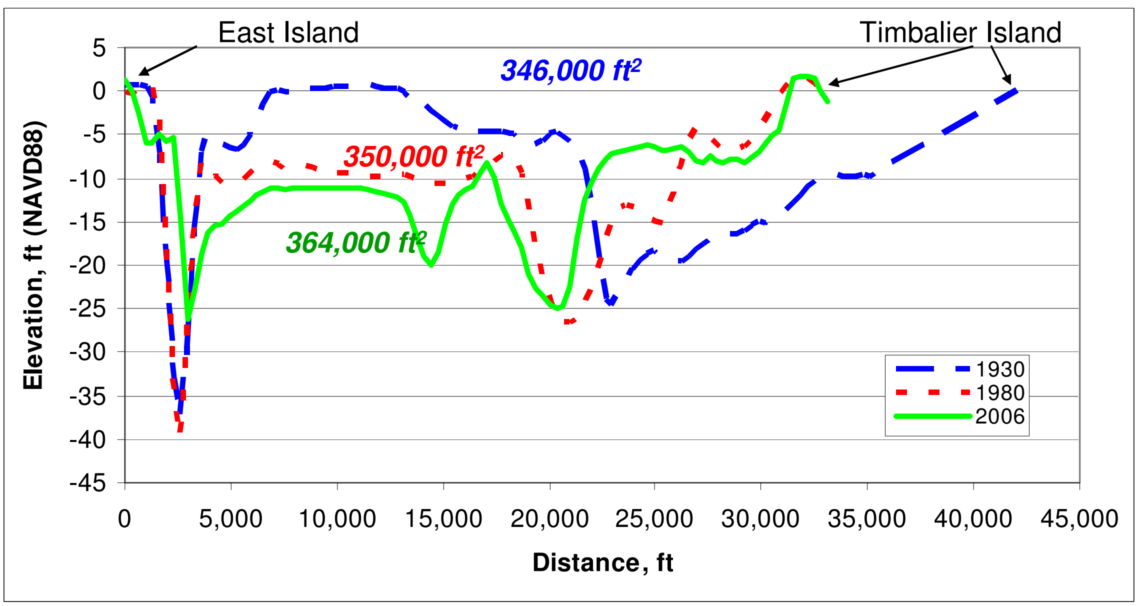



Figure 19. Minimum cross-sectional area for Cat Island Pass between East and Timbalier Islands

Applying Equation (2) with an increase in area of 2 ft by 300 ft = 600 sq ft, the tidal prism is expected to increase by 194 Mill cu ft, which equates to an increase of only 0.01% from the 2006 cross-sectional area. In view of the natural changes in tidal prism ongoing in the Terrebonne Bay and Cat Island Pass system, the additional increase in area will be insignificant to tidal currents and sediment transport.

# 3 Sediment Budgets

## Overview

This chapter presents volumetric change calculations for three historical time periods, 1930s to 1980s, 1930s to 2006, and 1980s to 2006. From these volumetric changes as well as dredging records, an historical sediment budget and a hypothetical with-project sediment budget were formulated. The purpose of the sediment budgets is to develop an understanding of the sediment transport magnitudes and pathways that have occurred in the past, and apply this knowledge to forecast how sediment transport will change in the future with channel improvement. Using the sediment budget, recommendations are made for placement of dredged material on the adjacent islands to best mitigate for erosion of the islands and minimize future dredging.

A sediment budget is an accounting of gains and losses within a specified area (cell), or a series of connected cells, over a given period of time. The difference between sources (inputs) to and sinks (outputs) from a cell must equal the rate of observed volume change in that cell, including all engineering activities,

$$\sum Q_{source} - \sum Q_{sink} - \Delta V + P - R = 0 \qquad (3)$$

Where $Q_{source}$ and $Q_{sink}$ are the sources and sinks to the cell, respectively, $\Delta V$ is the volume change in the cell, $P$ is any placement (e.g., dredged sediment placement or beach nourishment) in the cell, and $R$ is any removal (e.g., dredging) from the cell. Typically, sediment budget cells are defined to represent a morphologic region (e.g., barrier island, ebb tidal shoal) or specified such that the cell is located at regions of known transport rates (e.g., jetty structure, dredged material placement sites).

The first step in formulating a sediment budget is to develop a conceptual budget which quantifies the initial understanding of sediment transport pathways, sources, and sinks within the region. Often the conceptual budget is based on available information in the literature (e.g., Figure 13) and preliminary analyses. Next, a macro-budget can be formulated using the volumetric change data. The macro-budget considers all volumetric change in one large cell. The purpose of the macro-budget is to determine whether the budget can be balanced with the available volumetric change data and within the understanding of sediment transport pathways, sources, and sinks. Once the macro-budget is balanced, a detailed budget can be formulated with multiple interconnected sediment budget cells.

## Conceptual Sediment Budget

The conceptual sediment budget was developed based on knowledge of sediment transport magnitudes and pathways discussed in the literature and analysis of dredging and placement records. As a first step, the potential longshore sand transport rate calculations presented by Stone and Zhang (2001) were combined with the maintenance dredging rate at Cat Island Pass (approximately 250,000 cu yd/yr) and placement west of the channel. The conceptual sediment budget is shown in Figure 20. The conceptual budget was balanced by directing 195,000 cu yd/yr from the placement site back into the channel, with the placement site shoaling at 55,000 cu yd/yr. The validity of this assumption will be tested with volumetric change calculations in the next section.

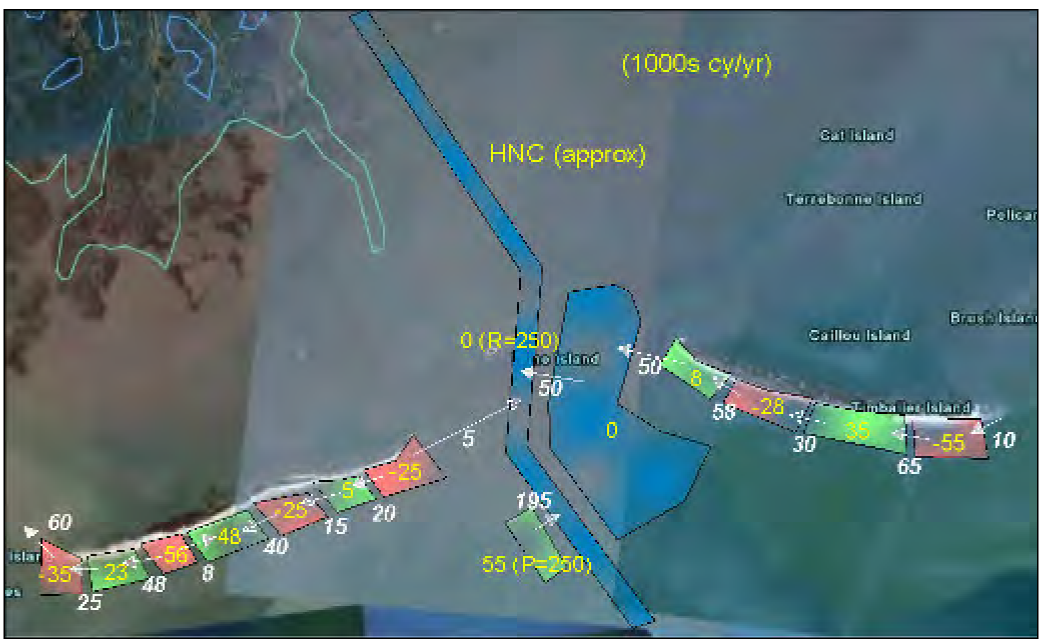


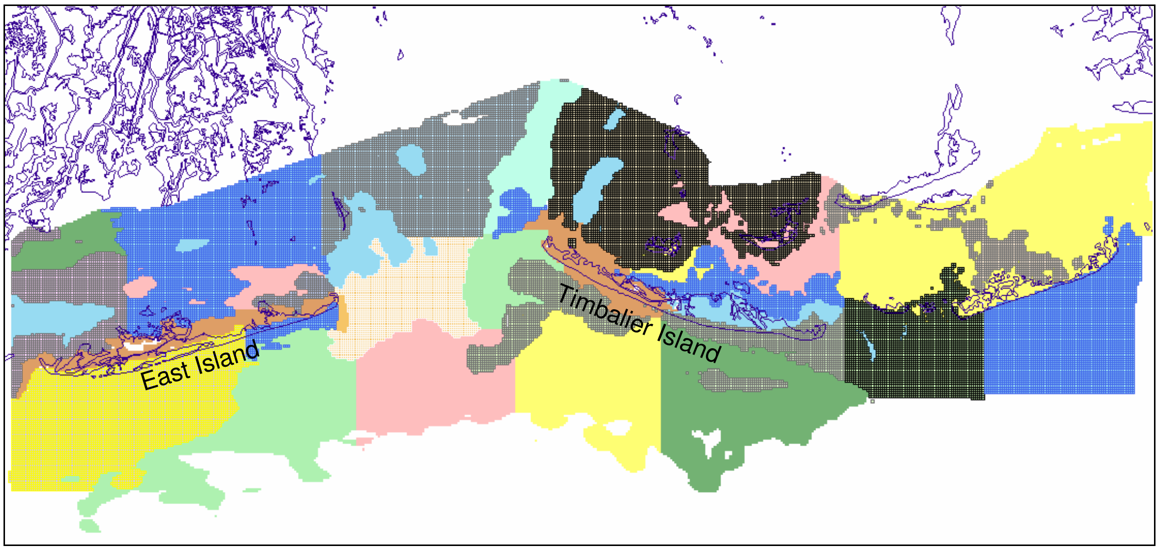

Figure 20. Conceptual sediment budget

## Historical Sediment Budgets

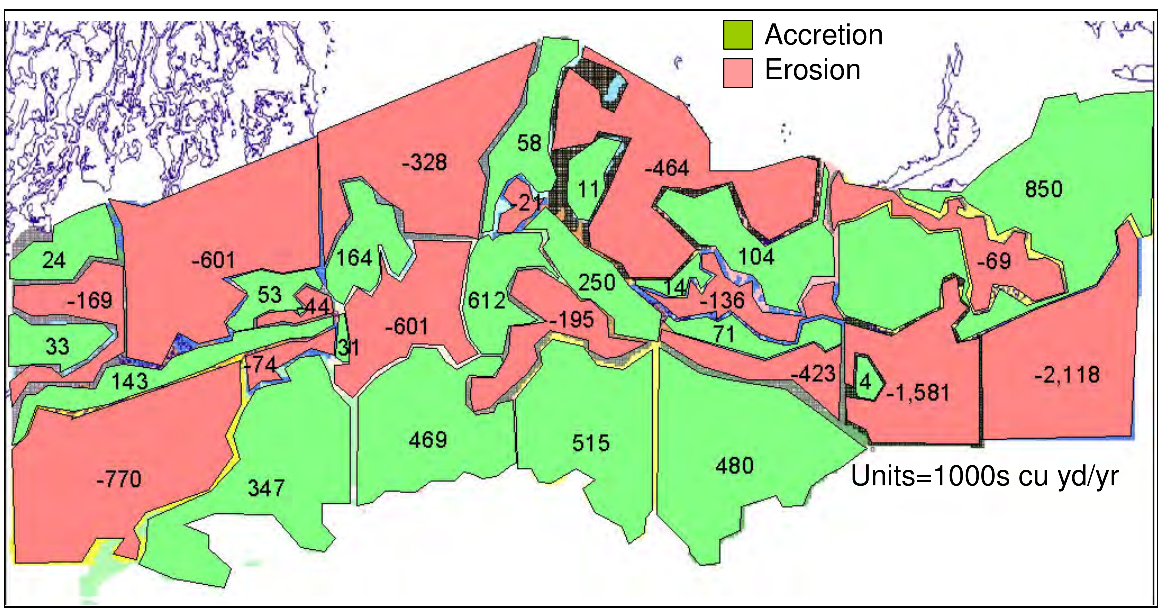
### Volumetric Change

Volumetric change for formulating the sediment budgets was calculated from bathymetric grids provided by LDNR for 1930s, 1980s, and 2006, as well as the historical dredging records. LDNR provided bathymetric data that had been adjusted as follows: (1) the 1980 data were adjusted for relative sea level rise by subtracting 0.52 ft (0.16 m) from the measured depths, based on a relative sea level rise rate of 0.03 ft/yr (0.92 cm/yr) at the Grand Isle tide gauge; (2) the 1930s data were adjusted by 1.5 ft (0.5 m) to account for relative sea level rise and a seafloor change analysis as conducted by List et al. (1994); and (3) both data sets were adjusted by 0.49 ft (0.15 m) to convert from Mean Lower Low Water to National Vertical Datum of 1988 (NAVD88). By making these adjustments to correct for relative sea level rise and seafloor changes, the volume changes should only represent the amount of change induced by physical processes.

The data were provided in meters with horizontal coordinates relative to North American Datum 1983 and vertical datum relative to NAVD88. Barrier island elevations were set at 1.5 ft (0.5 m), which is a representative value for these islands. Using the difference between bathymetric surfaces, accretionary and erosional areas were defined and volume change calculated in a Geographical Information System (GIS) as shown in Figure 21 (1930s to 1980s), Figure 22 (1930s to 2006), and Figure 23 (1980s to 2006).

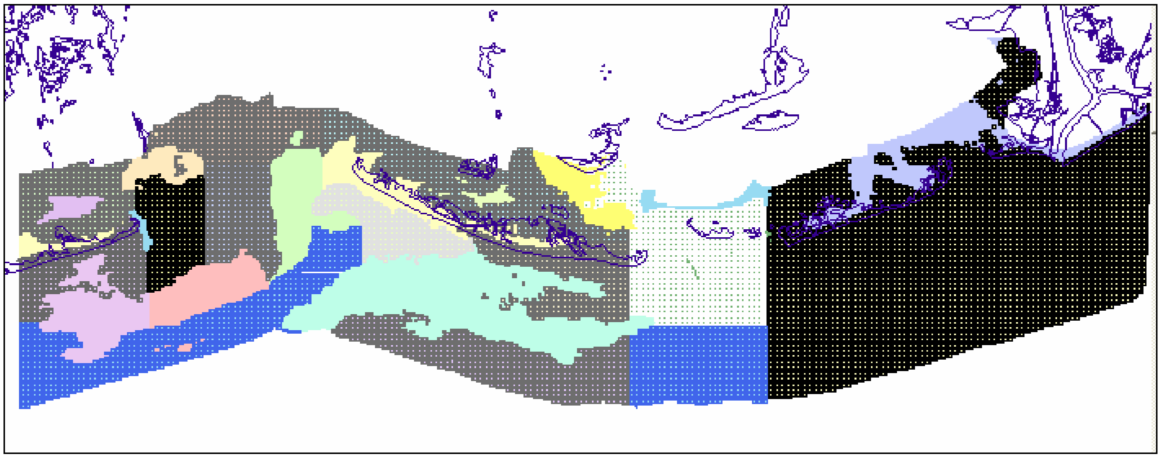



a. Polygons for analysis

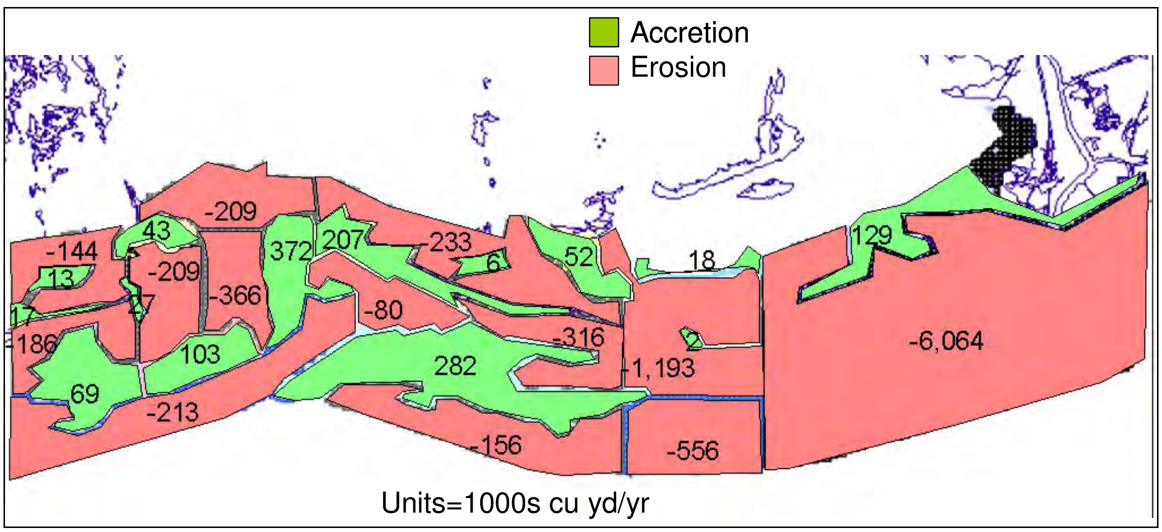



b. Volume changes

Figure 21. Volume changes for the 1930s to 1980s time period

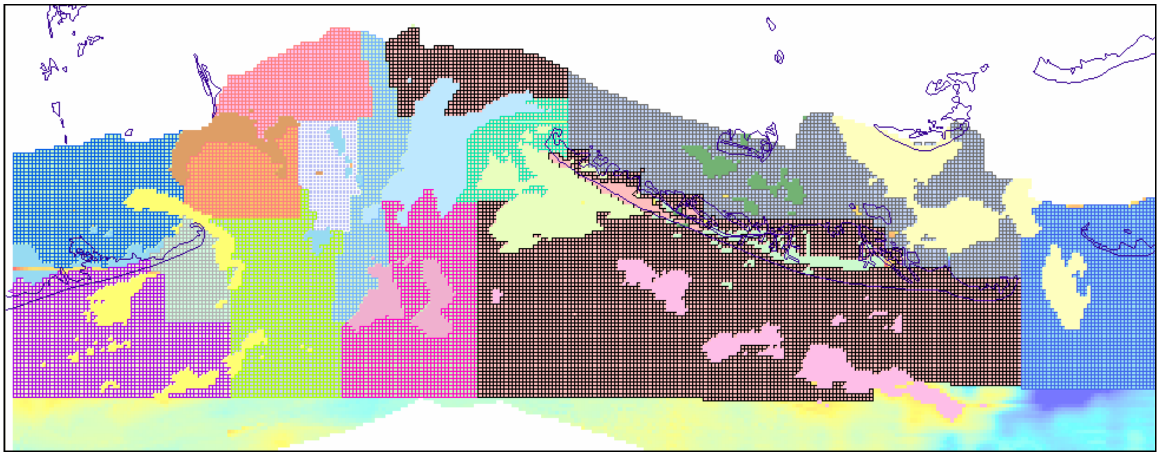


a. Polygons for analysis

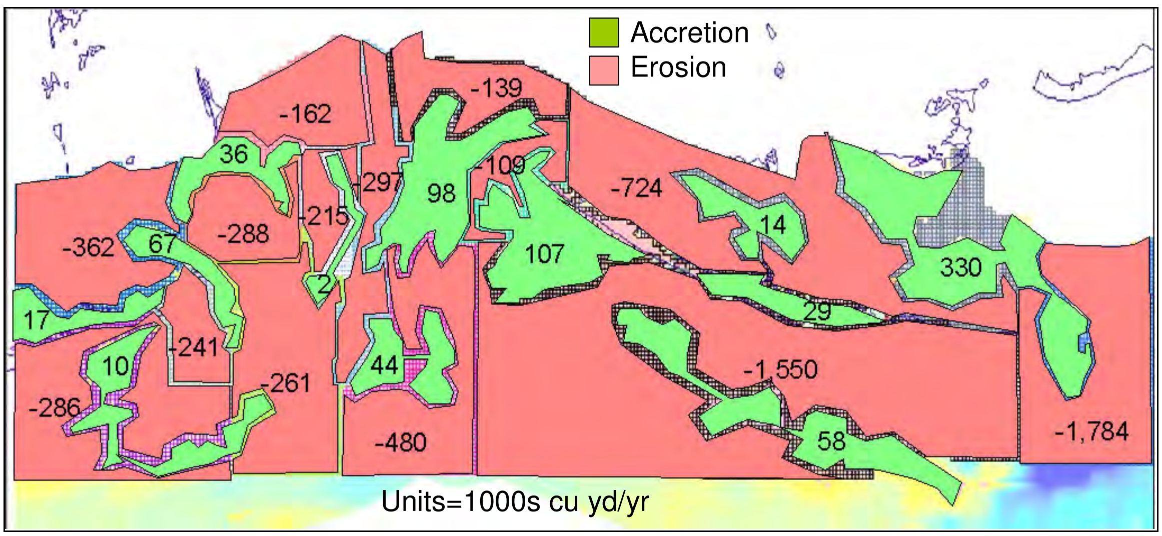



b. Volume change

Figure 22. Volume changes for the 1930s to 2006 time period



a. Polygons for analysis




b. Volume change

Figure 23. Volume changes for the 1980-2006 period

Several common trends can be observed in the volumetric change data, as discussed below.

(1) For each time period, there has been a net volumetric loss to the region that totals -3.4, -8.6, and -5.2 Mill cu yd/yr for 1930-1980, 1930-2006, and 1980-2006, respectively. Considering the area covered in each time period, these volumetric changes, if evenly spread out over the entire area, equal -0.014, -0.051, and -0.074 cu ft/sq ft/yr (or ft/yr) for 1930-1980, 1930-2006, and 1980-2006, respectively. Because these losses are extremely large for this relatively low-energy coast, and because the data do

not balance erosion with deposition, questions arise as to the applicability of the data. It is possible that the losses represent a majority of silt and clay sediments which are removed from the nearshore system. It is also possible that the volumetric changes in the offshore zones do not represent sediment movement but rather movement of a reference datum or local geologic faulting. In either case, the offshore volumetric changes would not represent nearshore sand transport, which is the type of material captured in Cat Island Pass and the focus of this analysis. Thus, the sediment budget analysis only considered barrier island and inlet-related volumetric changes.

(2) For each of the time periods, an infilling region can be observed as Cat Island Pass migrates to the west and sand fills in the old channel. For each of the time periods, this infilling rate is 612,000, 372,000, and 98,000 cu yd/yr from 1930-1980, 1930-2006, and 1980-2006. Scouring of the adjacent cell to the west as Cat Island Pass migrates west is -601,000, -366,000, and -297,000 cu yd/yr. (Note that these erosion rates include some dredging after 1964.) The agreement between the infilling and scouring rate (except for the latter time period which is influenced by dredging events), lends evidence that transport of sand is from east-to-west in this region, and that the magnitude of gross transport is on the order of these values.

(3) The magnitude of volume change calculations that include the 1930 data gives some doubt to the reference datum for the 1930 data. The shape of morphology change with the 1930 data appears reasonable; however, the magnitude of change is too great to represent sand transport on a low-energy coast. Thus, volumetric changes in the vicinity of Cat Island Pass for the latter time period (1980-2006) were considered in the sediment budget.

(4) The morphologic change features in the vicinity of Cat Island Pass, together with knowledge gained through the literature review, indicate possible transport pathways. These pathways are conceptualized in Figure 24 using the 1980s to 2006 (and 1930s to 1980s to extend coverage west) morphologic change. In general, warmer colors (red to yellow) indicate transport pathways and deposition; cooler colors (light to dark blue) show areas of scour or erosion. The hypothetical patterns shown in Figure 24 are not definitive but represent one possible interpretation of the mor-

phologic change. Arrows represent possible directions of sediment transport for conditions when sediment is mobilized in these regions.

The Cat Island Pass inlet system is very complex and has many transport pathways that may repeat and reverse during typical tidal cycles. A dashed curve is shown for a possible pathway from the Cat Island Pass dredged material placement site into the channel and back towards East Island. This conceptualization indicates that there might be transport of the dredged sediment back into the channel. Possible placement sites that appear to be relatively stable include the bayside of East and Timbalier Islands, within the central portion of each bayside shoreline.

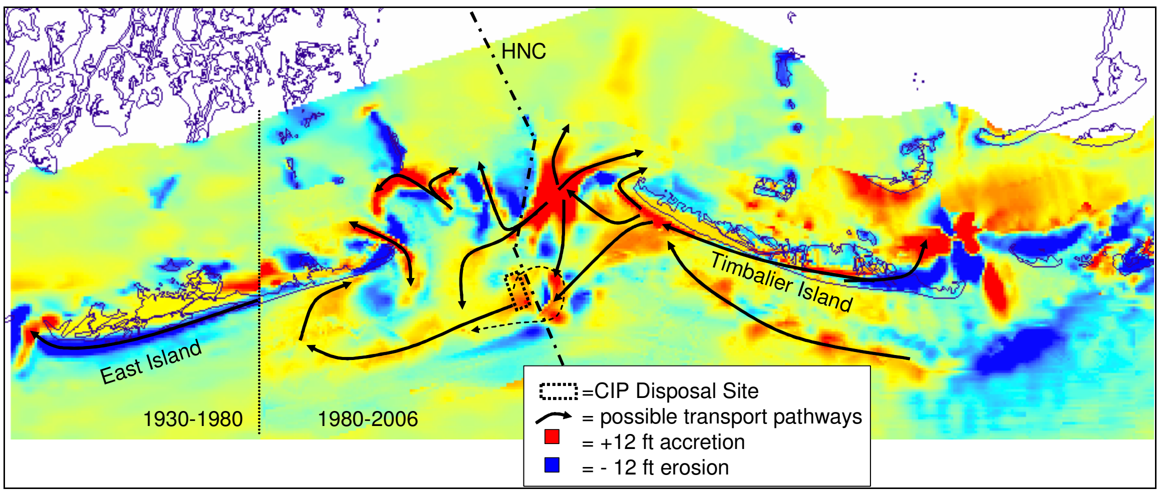
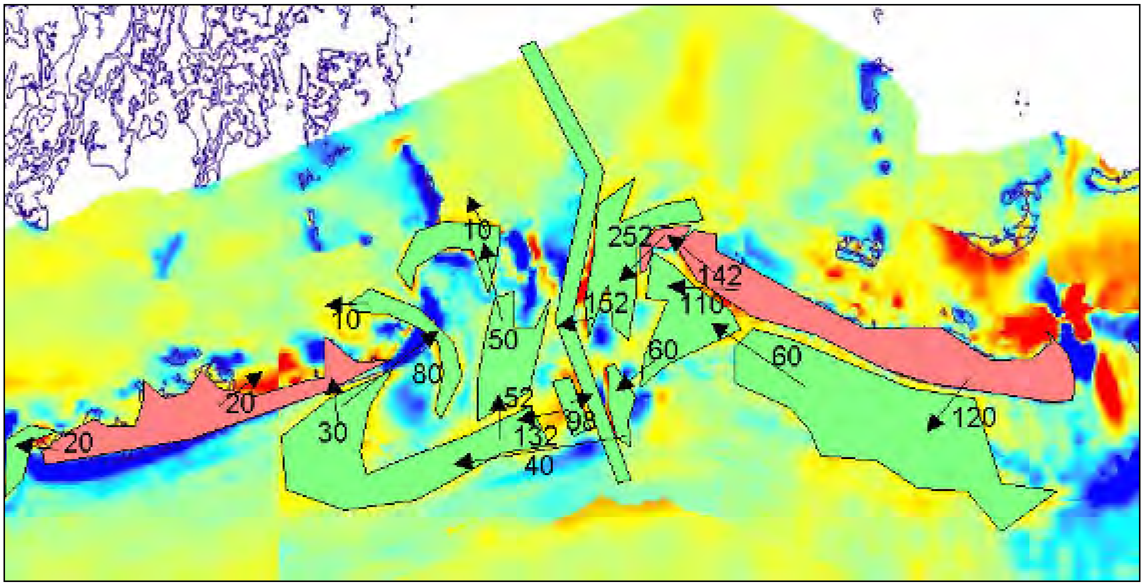


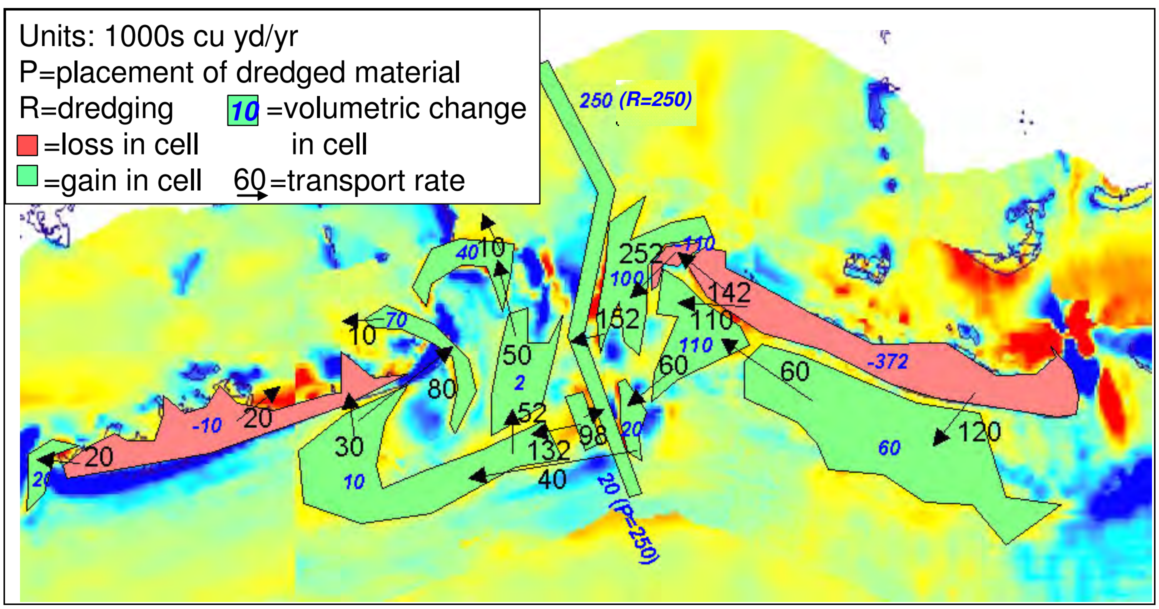

Figure 24. One conceptualization of possible net transport pathways in vicinity of Cat Island Pass as evidenced from 1980s to 2006 morphologic change (1930s to 1980s change used to extend coverage west)

## Formulation

The sediment budgets focused on the barrier islands and morphology of Cat Island and Wine Island Passes, with offshore and bay volumetric changes de-emphasized. The net sediment transport pathways conceptualized in the previous section were applied to develop the historical sediment budget (Figure 25). It is emphasized that the magnitudes of transport rates in the historical sediment budget are approximate due to the uncertainty in the volumetric change calculations.




a. Transport rates




b. Transport rates and net volumetric change in each cell

Figure 25. Historical sediment budget based on 1980s to 2006 volumetric change

## Hypothetical With-Deepening Sediment Budget

The with-deepening sediment budget was developed by modifying the historical sediment budget to reflect an anticipated increase in channel shoaling of 40,000 cu yd/yr. A total of 290,000 cu yd/yr was placed in the designated dredged material disposal site. Based on the sediment transport pathways, it was assumed that the additional shoaling was intercepted from the natural bypassing of Cat Island Pass (Figure 26). This is only one possible conceptualization of the with-deepening sediment budget, and many other alternative budgets could be formulated.

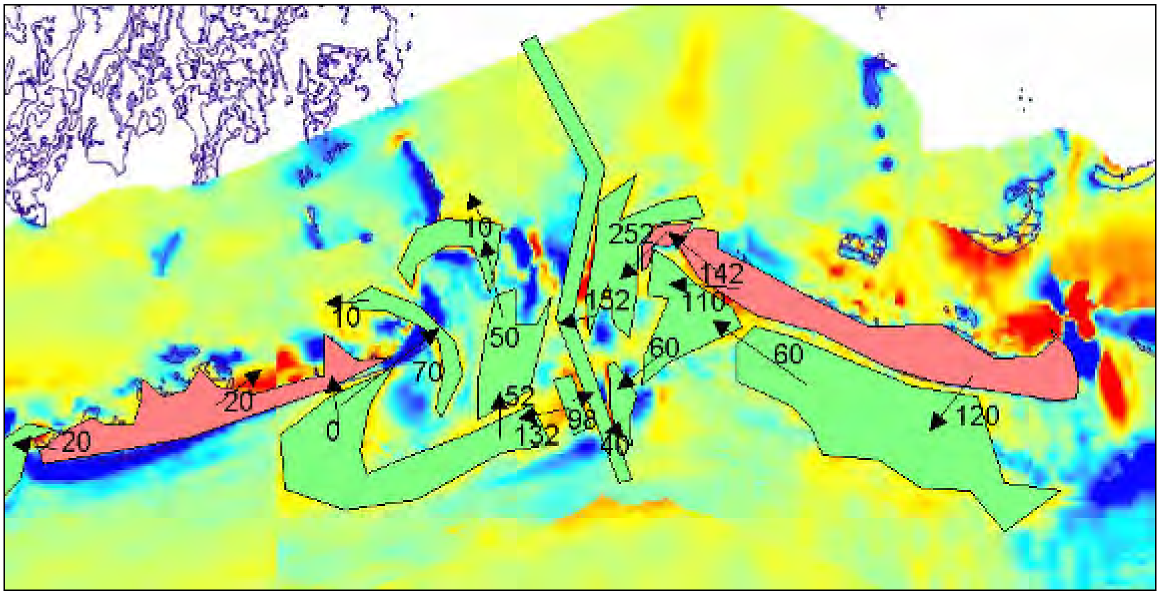
## Potential Dredged Material Placement Locations

The present-day source of sediment for Louisiana's barrier islands is cannibalization of existing headlands and islands. If these islands are to provide protection for Terrebonne Bay, an external source of sediment must be provided for long-term sustainability. The deepening and lengthening of Cat Island Pass as well as regular maintenance dredging will provide sediment that can be used to nourish the existing islands in the region.

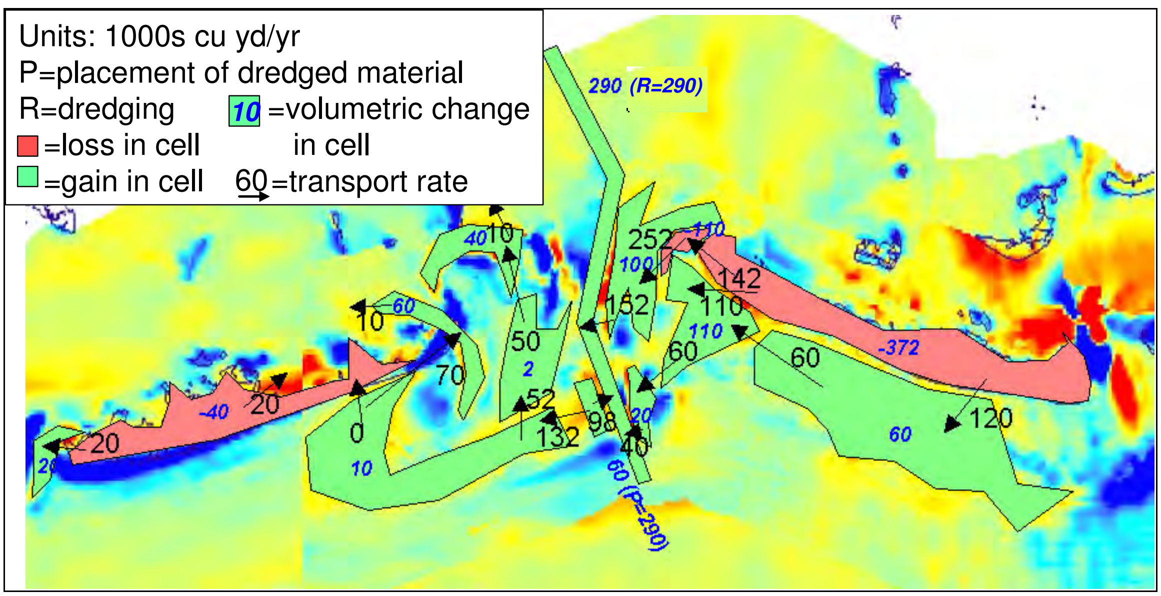
Based on the sediment budget and literature review, recommendations for placement of dredged sediment are as follows:

- All sediment (fines and sand) should be placed on the barrier islands if environmentally acceptable. The barrier islands are comprised of a thin veneer of sand that overlays a core of fine sediments. Thus, these types of sediments are not foreign to the barrier island and marsh system.

- Sediment should be placed on East Island to continue the natural bypassing process across Cat Island Pass that will be disrupted by the deepened and lengthened channel. Sediment could be placed on Timbalier Island in the case of extreme erosion or a breach; however, it may be that this sediment will return to shoal in the channel.




a. Transport rates




b. Transport rates and net volumetric change in each cell

Figure 26. Hypothetical with-deepening sediment budget based on 1980s to 2006 volumetric change

- For longevity of the fill, clays and silts should be placed on the bay side of East Island. These types of sediment will vegetate more readily than sand and create wetland habitat. Ideal locations are vulnerable portions of the island, such as locations of overwash, narrow portions of the island, or abandoned canals that weaken the island (see examples in Figure 27). Placement on the bayside has several advantages as compared to Gulf side deposition: it is less likely to experience energetic wave conditions; it will provide a platform on which the island can overwash and thus maintain its form; and fine sediment will not erode as rapidly and may eventually become vegetated, thereby creating new marsh. Sand of equal or greater size than the native sand can be placed on the Gulfside of East Island far enough to the west such that sand will not transport back into the channel.

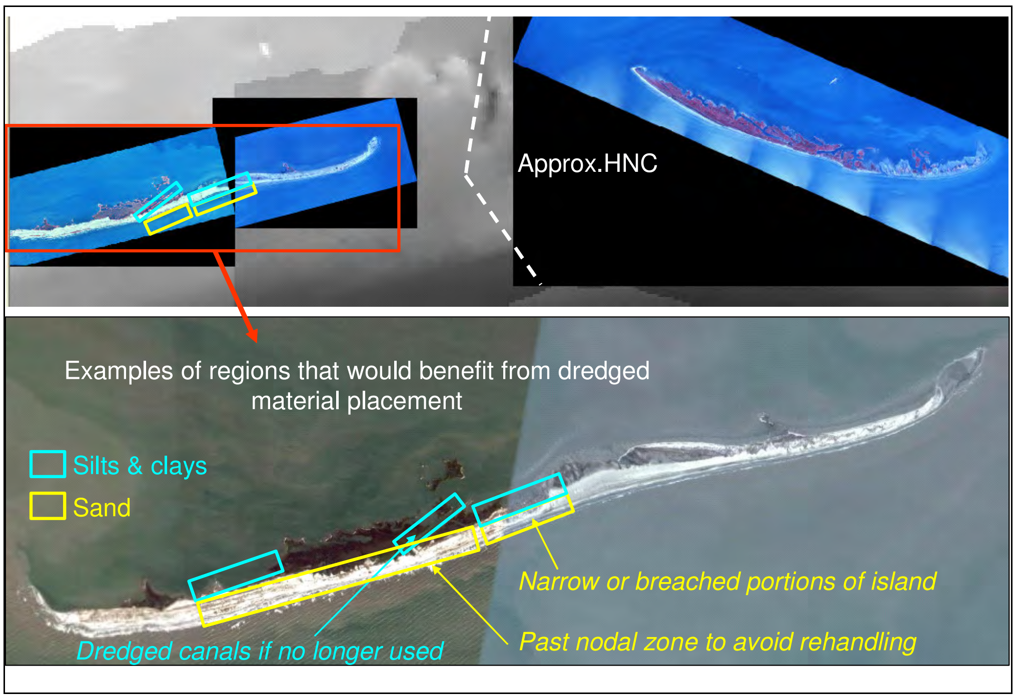



Figure 27. Possible locations of dredged material placement on East Island

# 4 Conclusions and Recommendations

This scoping-level study was performed in support of MVN to provide preliminary estimates for how deepening the Houma Navigation Channel at Cat Island Pass would change historical shoaling rates, determine the source of any shoaled sediment, and make recommendations for placement of the sediment. A literature review was conducted as well as desktop analyses to develop historical and hypothetical with-deepening sediment budgets.

This study had the following findings:

- Deepening and lengthening Cat Island Pass will increase the maintenance dredging from approximately 250,000 to 290,000 cu yd/yr, or approximately a 15% increase. It is likely that this maintenance dredging rate will increase in the future due to migration of Timbalier Island to the west unless the channel is realigned further to the west.

- Historically, the source of the shoaled sediment in the channel has been from the east, via erosion of the LaFourche headland and transport along Timbalier Island, to the ebb tidal shoal and across the channel. With channel deepening, it is anticipated that these transport pathways east of the channel will continue, although the deeper channel will intercept natural sand presently bypassing the channel and increase shoaling by 40,000 cu yd/yr.

- Estimates for migration of Cat Island Pass range from 26 ft/yr (1980s-2006) to 42 ft/yr (1930s to 1980s) to the west. It is likely that channel position after 1967 was controlled by dredging; thus, the better estimate for natural channel migration is approximately 40 ft/yr. However, Timbalier Island is migrating west more rapidly, at 250 ft/yr.

- The tidal prism through Cat Island Pass was estimated to have increased 21% from the 1930s to 2006 due to natural deepening of the pass, possibly changes in dynamics between adjacent inlets, and an increase in bay area due to beach erosion and wetland loss. It was estimated that tidal prism will increase by an insignificant amount, approximately 0.01%, due to the increase in channel area as a result of deepening (2 ft by 300 ft = 600 sq ft).

- Previous studies as well as the historical sediment budgets indicate that natural bypassing from Timbalier Island, through Cat Island Pass, to East Island and the Isle Dernieres occurs. Deepening and lengthening the channel is anticipated to disrupt this natural bypassing to some degree.

Recommendations from this study are as follows:

- Sediment dredged from Cat Island Pass should be placed on East Island, downdrift of the channel. If logistics permit, it is recommended that fine clay and silt be placed on the bay side of the island in locations of existing overwash fans, narrow portions of the island, or to fill any abandoned canals that weaken the island. The sediment could be pumped into a diked area to allow settlement of the slurry while dewatering. Sand compatible or coarser than the native sand on East Island should be placed on the Gulfside of the island, far enough to the west such that it will not transport to the east and shoal in the channel.

- At a minimum, controlled aerial photography at yearly intervals is recommended to monitor the placed sediment as well as a control section of beach. Aerial photography will allow shoreline position and habitat type to be quantified for the placement site and control beach. Comparison of these two areas will quantify the benefits of the placement and facilitate adaptive management of the Operation & Maintenance activity for future nourishment cycles. Data already being collected include offshore wave, current, and water level information (from the Wave-Current-Surge Information System Station CSI-5, see WAVCIS[8]) and regular dredging volume information.

[8] See http://wavcis.csi.lsu.edu/.

- If funding allows, a more intensive monitoring effort would include LiDAR data of the subaerial barrier islands and nearshore bathymetry of the Cat Island Pass area [9].

- Depending on cost, it may be feasible and desirable to realign Cat Island Pass further to the west to minimize future dredging. Estimates are that Timbalier Island continues to migrate west into Cat Island Pass, which will bring the sediment source for channel infilling closer to the channel through time. Also, realignment of Cat Island Pass further to the west will better facilitate logistics of placement of dredged sediment on East Island.

- If sediment cannot be placed on the islands, and the Single Point Discharge (SPD) placement locations west of the channel continue to be used, it is recommended that these locations be sited further away from the channel than the present sites 2500-ft west of the channel, and sited as close to the barrier islands as possible. With the complex sediment transport pathways in Cat Island Pass, it is likely that the present location of these disposal sites returns sediment to the channel.

[9] See http://shoals.sam.usace.army.mil/.

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# Annex VIII

# Value Engineering Study

DOD SERVICE: USACE
CONTROL NO: CEMVN-VE-02-06
VALUE ENGINEERING OFFICER: Frank Vicidomina

Value Engineering Study on the

# HOUMA
# NAVIGATION CANAL

# HOUMA, LOUISIANA

## MAY 2002
## U.S. Army Engineer District, NEW ORLEANS

**VALUE ENGINEERING FIRM NAME:** OVEST
ADDRESS: 100 W. Oglethorpe Ave
Savannah, Georgia 31401
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**VALUE ENGINEERING STUDY TEAM CO-LEADERS:** Eara Merritt 912-652-5448
Frank Vicidomina 504-862-1251

**VALUE ENGINEERING STUDY TEAM MEMBERS**

Frank Vicidomina
Meredith Godoi
Eddie Olivier, Jr
Whitney Ledet
Robert Jolissaint
Nathan Dayan
Eara Merritt

VALUE ENGINEERING TEAM STUDY

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Supporting Documents:

## VALUE ENGINEERING TEAM STUDY

## PROJECT DESCRIPTION AND BACKGROUND

PROJECT TITLE: Houma Navigation Canal
PROJECT LOCATION: Houma, LA

The Houma Navigation Canal (HNC) is a north-south oriented 36.6 mile navigation channel form the intersection of Gulf Intracoastal Waterway (GIWW) at Houma, Louisiana to the Gulf of Mexico. The channel was originally constructed with a usable dimension of 15 feet by 150 feet from GIWW to Mile 0 and an 18 foot contour of the Gulf of Mexico. The New Orleans District proposes to construct a flood protection project known as the Morganza, Louisiana to the Gulf of Mexico Hurricane Protection Project. One feature of the Morganza Project is a multipurpose lock located in the HNC, south of the town of Dulac, Louisiana. The authorized depth of the channel is related to the sill depth of the proposed lock. Therefore any changes in the authorized depth of the HNC will affect the HNC lock sill depth and require modification to the on-going lock design.

The primary purpose of the canal deepening study is to identify the most economic depth for the Houma Navigation Canal. The Louisiana Department of Transportation and Development (DOTD) will act as the non-Federal sponsor for the study and the Terrebonne Port Commission has indicated a willingness to act as the local sponsor for construction. For Federal navigation projects deeper than –20 feet NGVD, the non-Federal project cost-share increases from 20% to 35%. In accordance with ER 1105-2-100, dated April 22, 2000, "If the non-Federal sponsor identifies a constraint to maximum physical project size or a financial constraint due to limited resources, and if net benefits are increasing as the constraint is reached, the requirement to formulate larger scale plans in an effort to identify the NED plan is suspended. The constrained plan may be recommended." The Terrebonne Port Commission has limited the analysis in this study to a maximum channel depth of –20 feet NGVD.

The sill depth for the Houma Navigation Canal lock is dependent upon the authorized depth of the channel. Cost estimates for structures at various sill depths will be developed under contract independent of this study. Identification of the final lock sill depth will be a direct result of this general re-evaluation study and navigational safety and maintenance concerns.

Existing and future hydrologic conditions will be considered for the current channel and the channel depth will be optimized according to an economic analysis of benefits and costs. Project features will be fully evaluated with respect to the latest economic and environmental regulations for acceptability under current Federal laws and regulations.

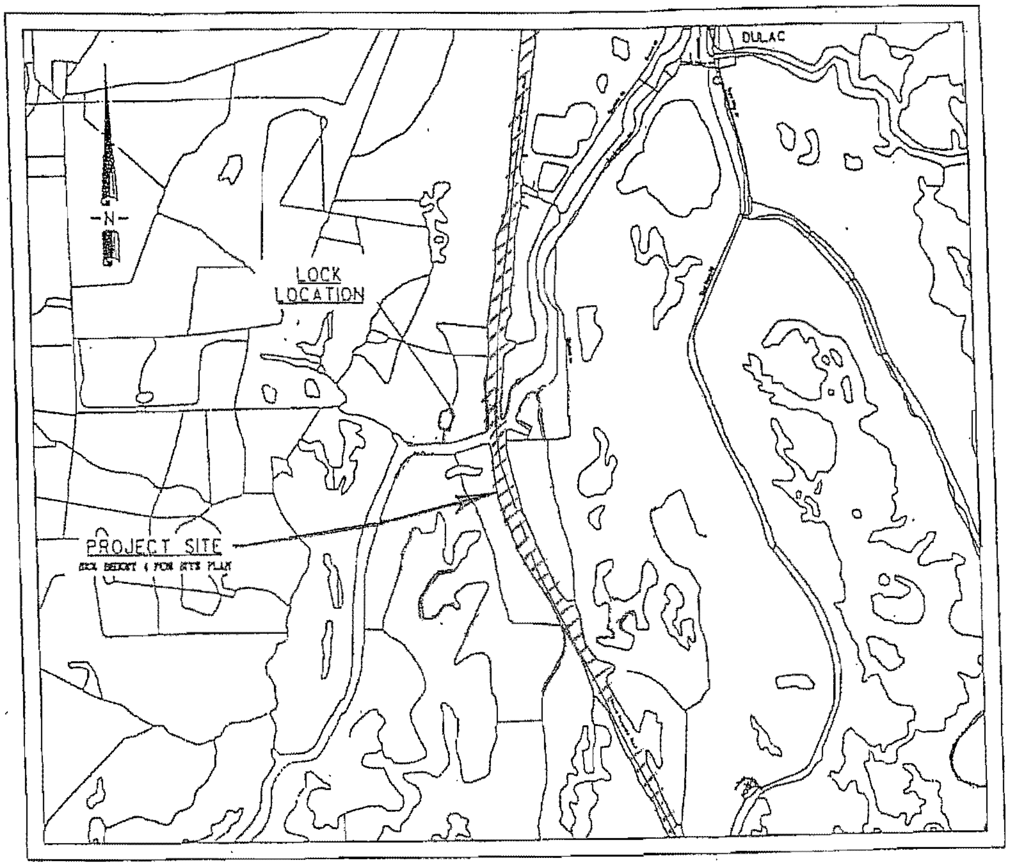
Plans will be developed to assure that a range of viable alternative plans are developed; that the plan features are refined, to the extent practical, to minimize costs and maximize benefits; and the separable project features are identified and incrementally analyzed. Input from all District elements will be analyzed to assure that all plan features are developed to an appropriate scope; that plan features and analysis are consistent with each other; that all adverse effects of the plan that may require modifications to the project are identified; and that appropriate modifications are included in the plan.

VALUE ENGINEERING TEAM STUDY

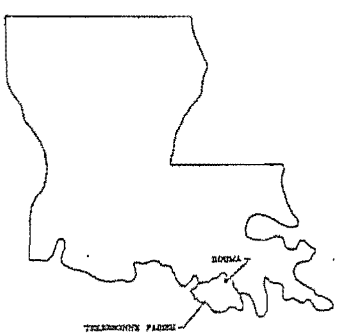
PROJECT DESCRIPTION AND BACKGROUND

PROJECT TITLE: Houma Navigation Canal
PROJECT LOCATION: Houma, LA

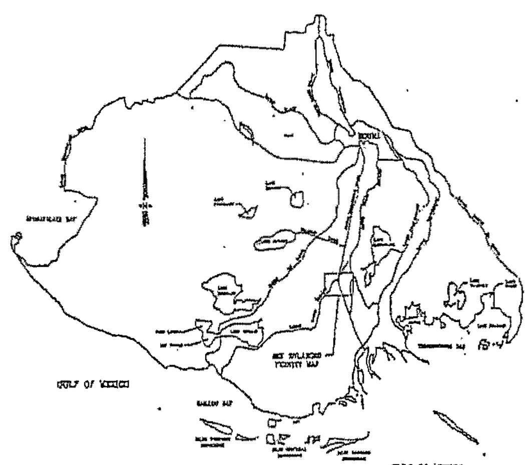
## PROJECT LOCATION MAP




ENLARGED VICINITY MAP



STATE VICINITY MAP



TERREBONNE PARISH VICINITY MAP

VALUE ENGINEERING TEAM STUDY

PROJECT DESCRIPTION AND BACKGROUND

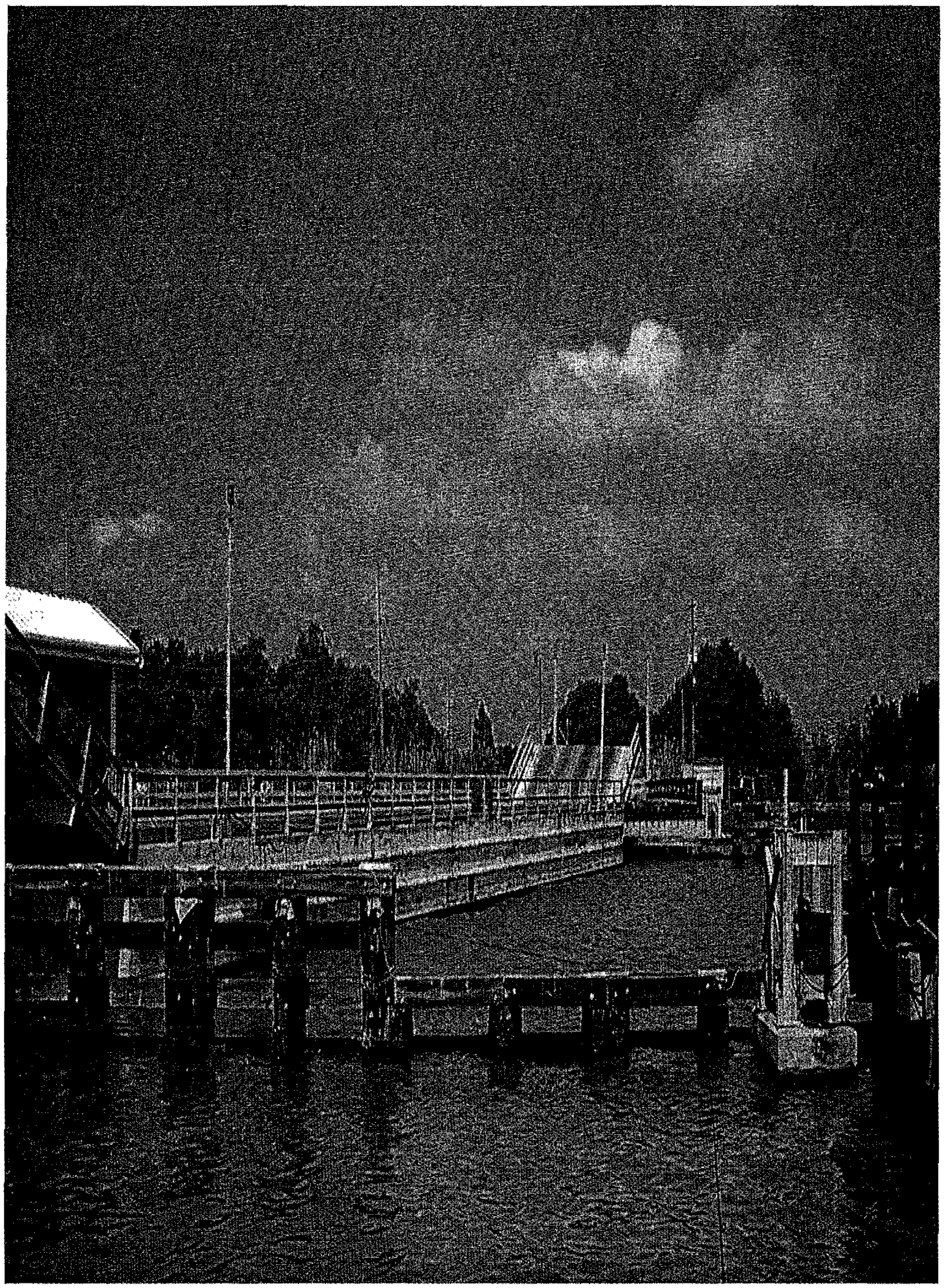
PROJECT TITLE: Houma Navigation Canal

PROJECT LOCATION: Houma, LA

**PHOTO OF HOUMA NAVIGATION CANAL**
**(SOUTH OF PLANNED LOCK SITE)**

PROJECT TITLE: Houma Navigation Canal
PROJECT LOCATION: Houma, LA

**DULAC BRIDGE CLOSING INTO POSITION**

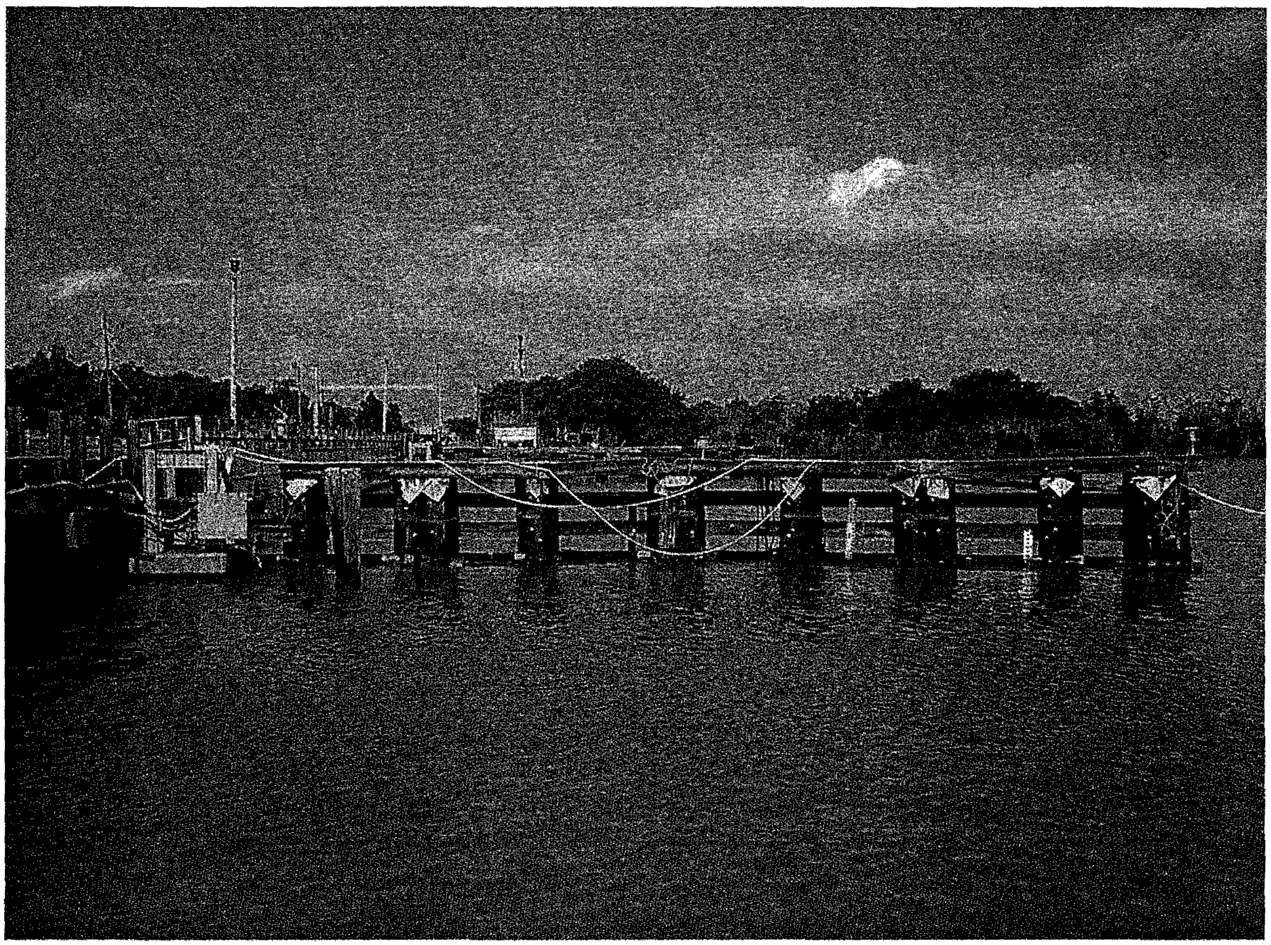


PROJECT TITLE: Houma Navigation Canal
PROJECT LOCATION: Houma, LA

**ROAD END SECTION UNDER DULAC BRIDGE LOOKING WEST**

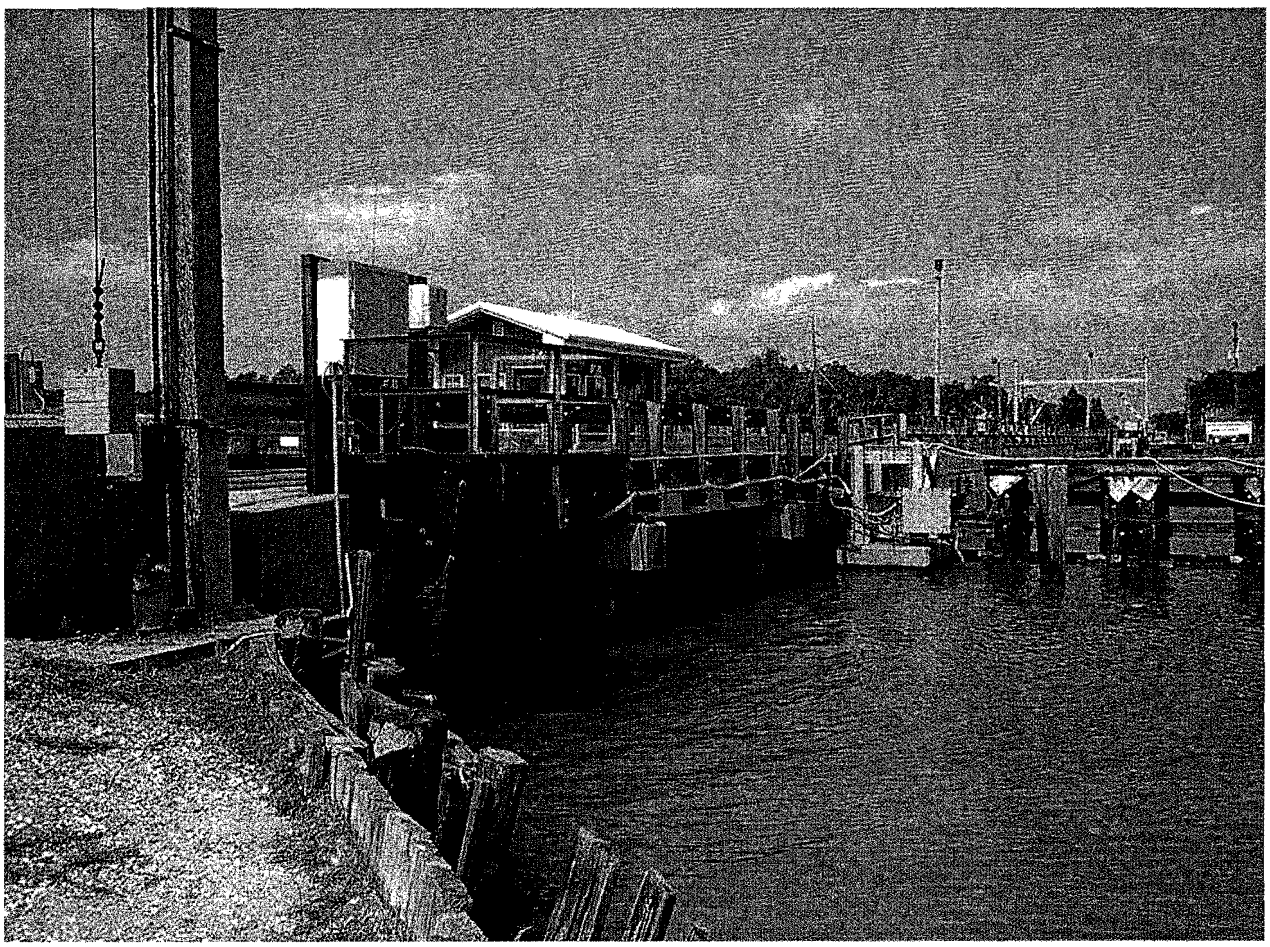
PROJECT TITLE: Houma Navigation Canal
PROJECT LOCATION: Houma, LA

**DULAC BRIDGE FENDERING SYSTEM**



PROJECT TITLE: Houma Navigation Canal
PROJECT LOCATION: Houma, LA

**VIEW UNDER DULAC BRIDGE AT ROAD END, LOOKING WEST**



PROJECT TITLE: Houma Navigation Canal
PROJECT LOCATION: Houma, LA

**VIEW UNDER DULAC BRIDGE AT ROAD END, LOOKING WEST**

PROJECT TITLE: Houma Navigation Canal
PROJECT LOCATION: Houma, LA

**VIEW ACROSS HOUMA NAVIGATION CANAL SHOWING BARGE WAKE**

PROJECT TITLE: Houma Navigation Canal
PROJECT LOCATION: Houma, LA

**VIEW ACROSS HOUMA NAVIGATION CANAL SHOWING TUG WAKE**

## VALUE ENGINEERING TEAM STUDY

## EXECUTIVE SUMMARY

The Value Engineering Study was initiated during the VE workshop/conference conducted in New Orleans, during the week of 29 April – 3 May 2002 and based on design information as provided by the New Orleans District, U.S. Army Corps of Engineers. The VE Team was comprised of staff from the OVEST office, LA Dept of Transportation, and the New Orleans District Team member. A list of VE Team members and consulted staff can be found at Appendix A.

Value Engineering is a process used to study the functions a project is to deliver. As a result, VE takes a critical look at how these functions are met and develops alternative ways to achieve the equivalent function while increasing the value to cost ratio of the project. In the end, it is hoped that the project will realize a reduction in cost, but the value relationship is the focus of VE rather than simply reducing cost. The project was studied using the Corps of Engineers standard Value Engineering (VE) methodology, consisting of five phases:

Information Phase: The Team studied drawings, figures, descriptions of project work, and cost estimates to fully understand the work to be performed and the functions to be achieved. Cost Models (see Appendix C) were compared to determine areas of relative high cost to ensure that the team focused on those parts of the project which offered the most potential for cost savings.

Speculation Phase: The Team speculated by conducting brainstorming sessions to generate ideas for alternative designs. All team members contributed ideas and critical analysis of the ideas was discouraged (see Appendix B).

Analysis Phase: Evaluation, testing and critical analysis of all ideas generated during speculation was performed to determine potential for savings and possibilities for risk. Ideas were ranked by priority for development. Ideas which did not survive critical analysis were deleted.

Development Phase: The priority ideas were developed into written proposals by VE team members during an intensive technical development session. Proposal descriptions, along with sketches, technical support documentation, and cost estimates were prepared to support implementation of ideas. Additional VE Team Comments were included for items of interest which were not developed as proposals, and these comments follow the study proposals.

Presentation Phase: Presentation is a two-step process. First, the published VE Study Report is distributed for review by project supporters and decision makers. The Presentation is to be coordinated following the initial review of the report by New Orleans District VEO. Coordination resulting from review comments and the Presentation conference may be further coordinated through OVEST as needed.

## VALUE ENGINEERING TEAM STUDY

## SUMMARY OF PROPOSALS

Numerous potential ideas to improve the project or reduce costs were generated during the Speculation Phase of this study. The Analysis Phase of the study screened the number of ideas for development. Some ideas were designated as design comments and are included in this report following the proposals.

| PROPOSAL NO. | DESCRIPTION | POTENTIAL SAVINGS |
|---|---|---|
| C-1 | Optimize Non-Dredging Rock | $ 44,500,000 |
| C-2 | Consider Geotubes in Lieu of Rock Below Mile 18 | $ 31,000,000 |
| C-3 | Consider Vinyl Sheetpile Cells in Lieu of Rock Below Mile 18 | $ 20,000,000 |
| C-4 | Consider Revetted PVC Pipe Structures in Lieu of Rock Below Mile 18 | $ 15,000,000 |
| C-5 | Eliminate “Kidney” Shaped Island Work | $ 8,000,000 |
| C-6 | Eliminate Overdepth Dredging | $ 3,000,000 |
| C-7 | Change Kidney Shaped Island to Circle | $ 1,660,000 |
| C-8 | Use Dustpans with Pipeline to Dredge Navigation Channel | $ 1,371,000 |

VALUE ENGINEERING PROPOSAL

| | | |
|---|---|---|
| PROPOSAL NO: | C-1 | PAGE NO: 1 OF 2 |
| DESCRIPTION: | Optimize Non-Dredging Rock | |

ORIGINAL DESIGN:

The original design includes items for retention dikes and armor stone for mitigation and protection of already degrading shoreline. Wave wash is cited as the cause of the shoreline damage.

PROPOSED DESIGN:

Retain all stone strictly related to the dredging work (spoil containment).

ADVANTAGES:

Reduces project costs.

DISADVANTAGES:

Does not protect areas with existing problems.

JUSTIFICATION:

It is questionable as to whether or not "with project" wave-wash conditions will induce significant bank erosion. The rock cost associated exclusively with erosion control is very significant. The appropriateness of mitigating existing erosion with new construction in lieu of O&M funds is also at issue.

| | COST ESTIMATE WORKSHEET | | | | |
|---|---|---|---|---|---|
| | PROPOSAL NO.: C-1 Optimize Non-Dredging Rock | | | | PAGE 2 OF 2 |
| | DELETIONS | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | Estimated rock unreated directly to dredging | LS | 1 | $31,800,000.00 | $31,800,000 |
| | spoil containment (Armor Stone & related | | | | $0 |
| | material) | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Deletions | | $31,800,000 |
| | ADDITIONS | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Additions | | $0 |
| | | | Net Savings | | $31,800,000 |
| | | * | Markups | 40.00% | $12,720,000 |
| | | | Total Savings | | $44,520,000 |
| * | Markups include: | | | | |

DESCRIPTION: Consider Geotubes in Lieu of Rock Below Mile 18.0

ORIGINAL DESIGN:

Current plan indicates all rock scour protection and disposal containment structures below mile 18.0.

PROPOSED DESIGN:

A single layer of geotubes can be filled for use as breakwater and/or retention dike. See Figure 1 and supporting information in Appendix E. The design requires tubes to be overfilled to allow for consolidation of the pumped fill and the foundation beneath the tube. Scour aprons are recommended as shown on Figure 2. Figures 3, 4, and 5 (Appendix E) show the geotube configurations (and fabric properties) required for various ground surface elevations (GSE). Tubes are assumed to be filled with dredged material. Design estimates are summarized as follows:

| GSE | Circumference (ft) | Required Fabric Tensile Strength (lb/in) |
|---|---|---|
| -2 | 45 | 1025 |
| -4 | 70 | 2165 |
| -6 | 90 | 3910 |

ADVANTAGES:

1. Geotubes are relatively inexpensive to construct and fill.
2. Rock will likely require a very large foundation base to reduce settlement rate.
3. Geotubes have been shown to be environmentally friendly, even being used in places as an artificial habitat for marine organisms.
4. When filled with the type of material proposed for this job and used in shallow water or as retention dikes, geotubes promote rapid growth of vegetation.

DISADVANTAGES:

1. Geotubes are not always permanent, depending of the forces on them.
2. If the tubes remain exposed to sunlight, the UV rays will eventually degrade the exposed fabric.
3. There is exposure to vandalism, but it is not easy to cut the fabric by hand.
4. Due to the foundation and type of dredged material available for filling the tubes, the tubes will consolidate and the foundation will settle such that the crest of the tubes may be less than half of the initial height within months of filling.

JUSTIFICATION:

Soil conditions below mile 18.0 are expected to be poor and not supportive of heavy structure. Rock may not, therefore, be a cost effective option. The proposed structures would not endanger life or property if damaged or failed. Geotubes have been used successfully for these applications throughout the country. The designs call for the tubes to be filled to heights that provide the required protection for some time. When it becomes necessary, the height can be restored by repumping the tubes or placing additional tubes. If a more permanent fix is desired, repairs can be made with rock. Durability of the tubes, particularly filled with poor quality dredge material, is a concern. "Non-life-safety" application should permit a relatively high degree of allowable failure percentage.

| | | | | | |
|---|---|---|---|---|---|
| | **COST ESTIMATE WORKSHEET** | | | | |
| | PROPOSAL NO.: C-2 Consider Geotubes in Lieu of Rock Below Mile 18 | | | | PAGE 3 OF 3 |
| | **DELETIONS** | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | Shallow (2-3 ft water depth) rock structures | LS | 1 | $9,500,000.00 | $9,500,000 |
| | Deep (5-6 ft water depth) rock structures | LS | 1 | $31,800,000.00 | $31,800,000 |
| | (Rock below Mile 18.0) | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Deletions | | $41,300,000 |
| | **ADDITIONS** | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | Geotubes structures (2-3 ft water depth) | LF | 38,000 | $150.00 | $5,700,000 |
| | Geotubes structures (5-6 ft water depth) | LF | 54,000 | $250.00 | $13,500,000 |
| | | | | | $0 |
| | | | Total Additions | | $19,200,000 |
| | | | Net Savings | | $22,100,000 |
| | | * | Markups | 40.00% | $8,840,000 |
| | | | Total Savings | | $30,940,000 |
| * | Markups include: | | | | |

VALUE ENGINEERING PROPOSAL

PROPOSAL NO: C-3 PAGE NO: 1 OF 4

DESCRIPTION: Consider Vinyl Sheetpile Cells in Lieu of Rock Below Mile 18.0

ORIGINAL DESIGN:

Current plan indicates all rock scour protection and disposal containment structures below mile 18.0.

PROPOSED DESIGN:

Vinyl sheetpile cells with dredge fill could be used in lieu of rock (See Attachment Sketch and cost estimate).

ADVANTAGES:

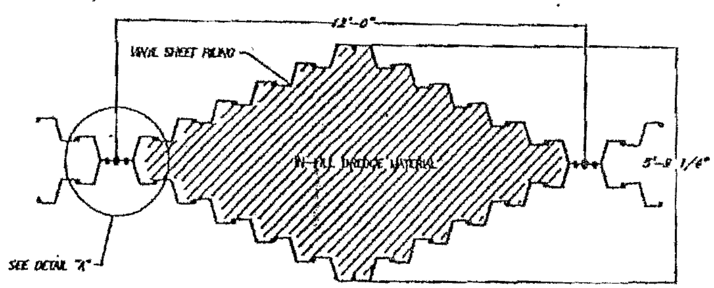
1. Vinyl sheetpile cells are relatively lightweight.
2. Relatively east to install.
3. No corrosion in saltwater.

DISADVANTAGES:

1. Long term performance when exposed to sunlight is questionable.
2. Does not create habitat as would rock-water interface.
3. Un-tested structure.

JUSTIFICATION:

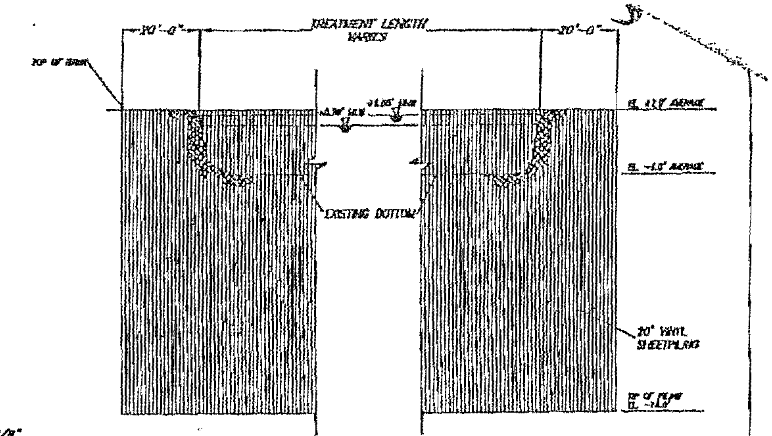
Expected poor soil conditions below mile 18.0 would indicate that rock may not be a cost effective option. Vinyl sheetpile cells are being field tested by the LA Dept of Natural Resources at he time of this study. Performance and cost data should be available prior to construction of this project.




PLAN OF TYPICAL MODULE
DUO SINUSOIDAL VINYL SHEET PILE

HORIZONTAL SCALE: 1" = 4'

2' 0 2' 4' 6' 8'




TYPICAL ELEVATION

VERTICAL SCALE: 1" = 10'

5' 0 5' 10' 15' 20'

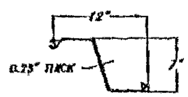
HORIZONTAL SCALE: 1" = 40'

20' 0 20' 40' 60' 80'

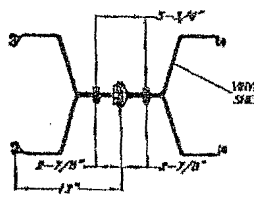
NOTE:

| LOCATION | LENGTH (FT.)* |
|---|---|
| V1 | 612 |
| V2 | 408 |
| V3 | 729 |

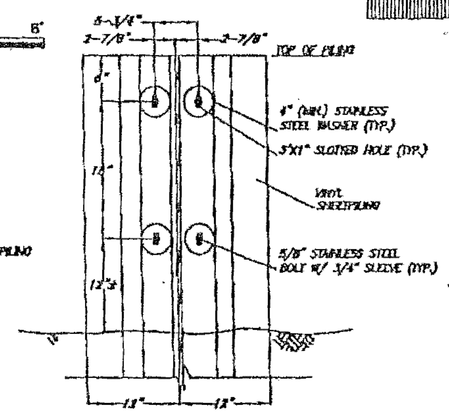
* INCLUDING 20' TIE-IN FOR EACH END OF SHEET PILE.




VINYL SHEET PILE SECTION
SCALE: N.T.S.




DETAIL "A" PLAN
SCALE: N.T.S.




DETAIL "A" PROFILE
SCALE: N.T.S.

NOTES:
DATUM IS NAVD 88
NAVIGATIONAL WARNING SIGN REQUIRED.

SHEETPILE LAYOUT & SECTION

LOUISIANA DEPARTMENT OF NATURAL RESOURCES
MANDALAY BANK PROTECTION DEMO PROJECT (TE-41)
SECTIONS 1-3, T18S - R16E & SECTION 16, T18S - R17E
TERREBONNE PARISH, LOUISIANA

| Date: | Drawn By: | Sheet No.: | Revisions: No.: | Date: |
|---|---|---|---|---|
| 05/09/01 | CDL | 4 of 9 | 1 | 09/19/2001 |
| | Approved By: | File No.: | | |

COASTAL ENGINEERING AND ENVIRONMENTAL CONSULTANTS, INC.
Engineers – Scientists – Planners – Environmental Consultants
107 Buston Drive Houma, Louisiana 70363

## Engineer's Opinion of Probable Cost
## Mandalay Bank Demonstration Project (TE-41)
## DNR Project No. 250-00-31
CEEC Project No. 1768

Blowout Treatment

**Duo-Sinusoid Vinyl Sheet Pile System**

| Description | Location | Length (Ft) | Depth (Ft) | Sides (Ea) | Est. Quantity | Unit | Unit Cost | Total |
|---|---|---|---|---|---|---|---|---|
| Mobilization & Demobilization | V1,V2,V3 | - | - | - | 1 | LS | $ 12,000.00 | $ 12,000.00 |
| Clearing & Grubbing | V1,V2,V3 | - | - | - | 1 | LS | $ 5,000.00 | $ 5,000.00 |
| Vinyl Sheet Piling | V1 | 612 | 20 | 2 | 24,480 | SF | $ 4.25 | $ 104,040.00 |
| Vinyl Sheet Piling | V2 | 408 | 20 | 2 | 16,320 | SF | $ 4.25 | $ 69,360.00 |
| Vinyl Sheet Piling | V3 | 729 | 20 | 2 | 29,160 | SF | $ 4.25 | $ 123,930.00 |
| In Situ Fill Material | V1,V2,V3 | - | - | - | 560 | CY | $ 3.00 | $ 1,680.00 |
| Warning Signs | V1, V2, V3 | - | - | - | 3 | EA | $ 2,000.00 | $ 6,000.00 |
| | | | | | | | Sub-Total | $ 322,010.00 |
| | | | | | | | 15% Contingency | $ 48,301.50 |
| | | | | | | | **Total** | **$ 370,312.00** |

Duo-Sinusoid Vinyl Sheet Pile System: Unit Cost = $211.73/ LF

| | | | | | |
|---|---|---|---|---|---|
| | **COST ESTIMATE WORKSHEET** | | | | |
| | | | | | |
| | PROPOSAL NO.: C-3 Consider Vinyl Sheetpile Cells in Lieu of Rock Below Mile 18 | | | | PAGE 4 OF 4 |
| | | | | | |
| | **DELETIONS** | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | Shallow (2-3 ft water depth) rock structures | LS | 1 | $9,500,000.00 | $9,500,000 |
| | Shallow (5-6 ft water depth) rock structures | LS | 1 | $31,800,000.00 | $31,800,000 |
| | (rock below mile 18.0) | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Deletions | | $41,300,000 |
| | | | | | |
| | **ADDITIONS** | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | Vinyl Sheetpile Cells (2-3 ft water) | LF | 38,000 | $212.00 | $8,056,000 |
| | Vinyl Sheetpile Cells (5-6 ft water) | LF | 54,000 | $350.00 | $18,900,000 |
| | | | | | $0 |
| | | | Total Additions | | $26,956,000 |
| | | | | | |
| | | | Net Savings | | $14,344,000 |
| | | * | Markups | 40.00% | $5,737,600 |
| | | | Total Savings | | $20,081,600 |
| | | | | | |
| | | | | | |
| * | Markups include: | | | | |

VALUE ENGINEERING PROPOSAL

PROPOSAL NO: C-4 PAGE NO: 1 OF 4

DESCRIPTION: Consider Reveted PVC Pipe Structures in Lieu of Rock Below Mile 18.0

ORIGINAL DESIGN:

Current plan indicates all rock scour protection and retainment structures below mile 18.0.

PROPOSED DESIGN:

Reveted PVC pipe structures could be used in lieu of rock (See attached sketch and cost estimate).

ADVANTAGES:

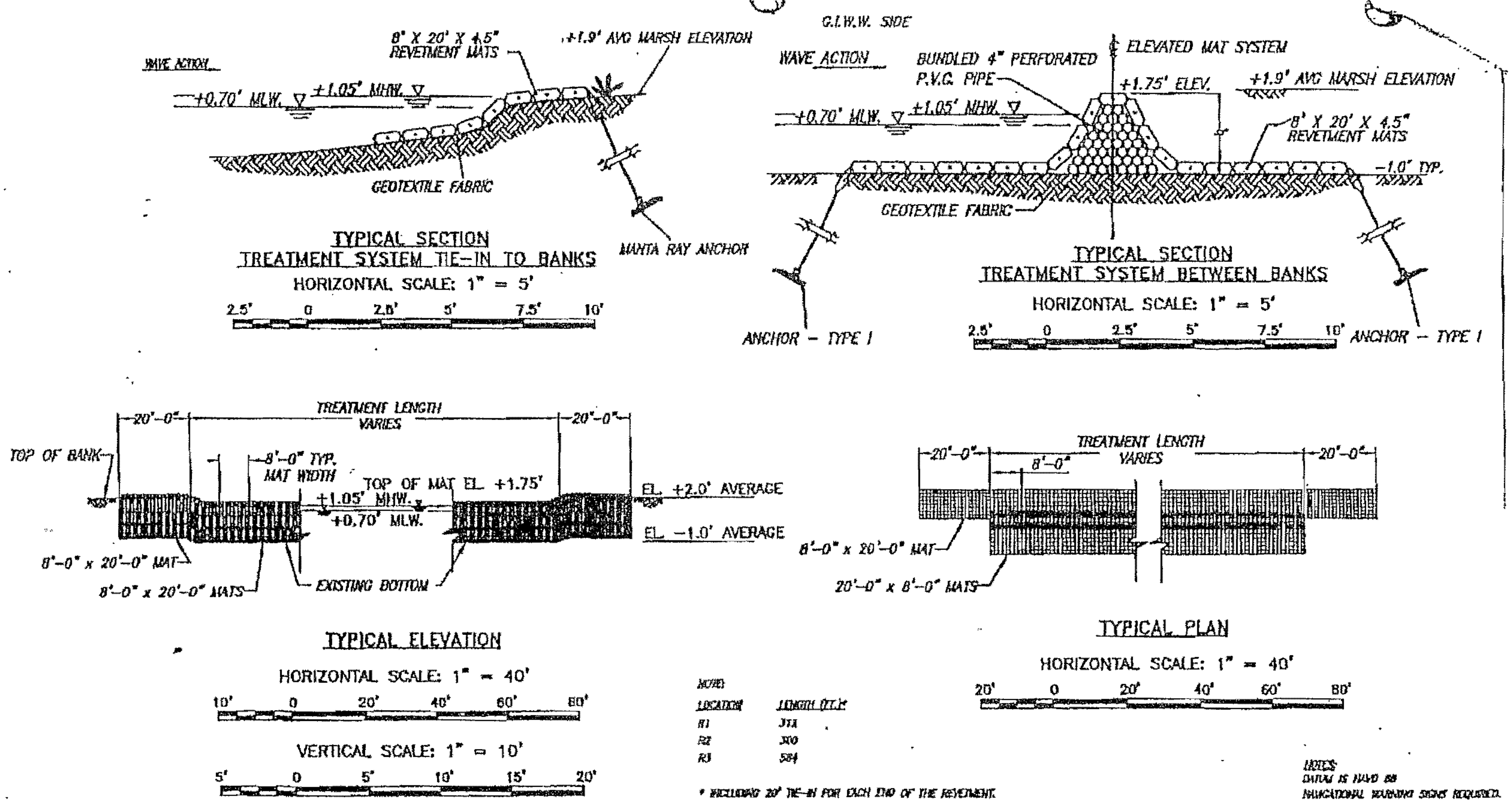
1. Relatively lightweight structure.
2. Relatively easy to install.
3. No corrosion in saltwater.
4. Existing Corps mat sinking until may be retrofitted for use.

DISADVANTAGES:

1. Un-tested structure.
2. Potential release of large quantity of PVC pipe as a result of large failure (hurricane) is a concern.

JUSTIFICATION:

Expect poor soil conditions below mile 18.0 would indicate that rock may not be a cost effective option. Reveted PVC pipe structures are being tested by the LA Dept of Natural Resources at the time of this study. Performance and cost data should be available prior to construction of this project.




## REVETMENT LAYOUT & SECTION

**LOUISIANA DEPARTMENT OF NATURAL RESOURCES**
**MANDALAY BANK PROTECTION DEMO PROJECT (TE-41)**
**SECTIONS 1-3, T18S - R16E & SECTION 16, T18S - R17E**
**TERREBONNE PARISH, LOUISIANA**

| Date: 05/09/01 | Drawn By: CDL | Sheet No.: 3 of 9 | Revisions: No.: 1 | Date: 09/19/2001 |
|---|---|---|---|---|
| Scale: | Approved By: | File No.: | | |

Coastal Engineering and Environmental Consultants, Inc.

VALUE ENGINEERING PROPOSAL
PROPOSAL NO: C-4
DRAWING NO. 1
PAGE NO: 2 OF 4

DRAWING NO. 2

## Engineer's Opinion of Probable Construction Cost
## Mandalay Bank Demonstration Project (TE-41)
DNR Project No. 250-00-31
CEEC Project No. 1768

### Blowout Treatments

**Revetment Mats System**

| Description | Location | Est. Quantity | Unit | Unit Cost | Total |
|---|---|---|---|---|---|
| Mobilization & Demobilization | R1, R2, R3 | 1 | LS | $ 10,000.00 | $ 10,000.00 |
| Clearing and Grubbing | R1, R2, R3 | 1 | LS | $5,000.00 | $ 5,000.00 |
| Concrete Revetment Mats | R1, R2, R3 | 141 | Ea | $ 820.00 | $ 115,620.00 |
| Elevated Shoreline System | R1, R2, R3 | 1,196 | LF | $ 6.00 | $ 7,176.00 |
| Anchors- Type I | R1, R2, R3 | 282 | Ea | $ 110.00 | $ 31,020.00 |
| Equipment & Labor | R1, R2, R3 | 1 | LS | $ 71,177.00 | $ 71,177.00 |
| Settlement Plates | R1, R2, R3 | 3 | EA | $ 500.00 | $ 1,500.00 |
| Warning Signs | R1, R2, R3 | 3 | EA | $ 2,000.00 | $ 6,000.00 |
| | | | | Sub-Total | $247,493.00 |
| | | | | 15% Contingency | $37,123.95 |
| | | | | TOTAL | $284,616.95 |

**Revetment Mat System: Unit cost = $237.98 / LF**

| | | | | | |
|---|---|---|---|---|---|
| | **COST ESTIMATE WORKSHEET** | | | | |
| | | | | | |
| | PROPOSAL NO.: C-4 Consider Revetted PVC Pipe Structures in Lieu of | | | | PAGE 4 OF 4 |
| | Rock Below Mile 18 | | | | |
| | **DELETIONS** | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | Shallow (2-3 ft water depth) rock structures | LS | 1 | $9,500,000.00 | $9,500,000 |
| | Deep (5-6 ft water depth) rock structures | LS | 1 | $31,800,000.00 | $31,800,000 |
| | (Rock below Mile 18) | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Deletions | | $41,300,000 |
| | | | | | |
| | **ADDITIONS** | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | Reveted PVC pipe structures (2-3 ft water) | LF | 38,000 | $238.00 | $9,044,000 |
| | Reveted PVC pipe structures (5-6 ft water) | LF | 54,000 | $400.00 | $21,600,000 |
| | | | | | $0 |
| | | | Total Additions | | $30,644,000 |
| | | | | | |
| | | | Net Savings | | $10,656,000 |
| | | * | Markups | 40.00% | $4,262,400 |
| | | | Total Savings | | $14,918,400 |
| | | | | | |
| | | | | | |
| * | Markups include: | | | | |

VALUE ENGINEERING PROPOSAL

PROPOSAL NO: C-5 PAGE NO: 1 OF 5

DESCRIPTION: Eliminate "Kidney" Island Work

ORIGINAL DESIGN:

Current design specifies that material from lower reach (approximately miles 7 to 10) be pumped to disposal inside of a rock containment dike to form a kidney shaped island. Available dredging material quantity was estimated on the basis of constructing a 200 foot wide channel

PROPOSED DESIGN:

Eliminate construction of the containment dike and pumping dredged material to form the island.

ADVANTAGES:

1. Eliminates unnecessary construction of a very excessive containment dike, since insufficient material will be available to fill it.
2. Reduces long distance pumping requirement.
3. Deletes unneeded project feature.

DISADVANTAGES:

Would not create relatively small amount of marsh habitat.

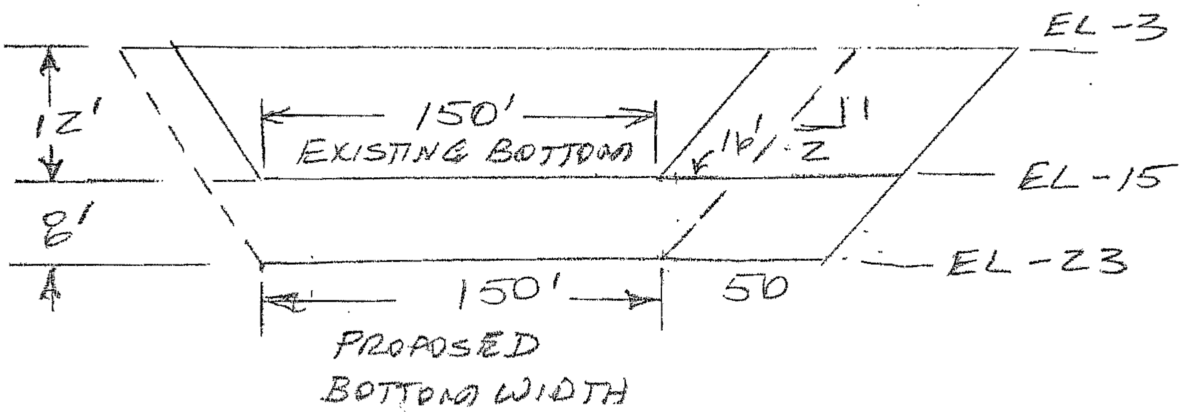
JUSTIFICATION:

The original project design was based on a 200 foot wide channel bottom. This required significant disposal area in the open bay reach, and the solution was creation of an environmental island. The project has since been revised to be a 150 foot wide channel bottom, which significantly reduces the amount of dredged material available to construct the kidney island and extended Bay Chaland island. Only about 1.3 million CY of disposal will be available from mile 10 to mile 6, not 2.8 million as originally estimated. That will provide sufficient quantity to construct only the Bay Chaland island extensions, leaving nothing for the "kidney" island. _ Cost per acre of created marsh habitat would be prohibitive. Alternate open water disposal may be prudent for this part of the project.

DRAWING NO. 1

Drawing No. 2

**CALCULATIONS**




MILE 6 TO 10

VOL. AVAILABLE, 150' BOTTOM WIDTH

$$150' \times 8' = 1200 \text{ FT}^2$$

$$\frac{16 \times 8}{2} \times 2 = 128 \text{ FT}^2$$

$$16 \times 12 \times 2 = \underline{384 \text{ FT}^2}$$

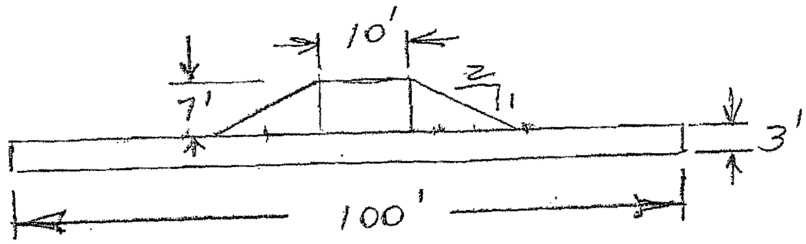
$$1712 \text{ FT}^2$$

$$4 \text{ MI} \times 5280 \text{ FT/MI} \times \frac{1712 \text{ FT}^2}{27} = 1{,}340{,}000 \text{ CY}$$

(REDUCTION OF 1,460,000 CY FROM 2.8 MILLION ORIGINAL ESTIMATE)

DRAWING NO 3

**CALCULATIONS**




DIKE VOLUME $7 \times 10 = 70 \text{ FT}^2$

$$2 \times \frac{7 \times 14}{2} = 98 \text{ FT}^2$$

$168 \text{ FT}^2$

BASE VOLUME $3 \times 100 = 300 \text{ FT}^2$

TOTAL $468 \text{ FT}^2$

PERIMETER $\cong$ 8,000 FT

STONE QUANTITY $= \frac{8,000}{27} \times 468 \cong 139,000$ CY

GEOTEXTILE, USE 125' WIDE

$$\frac{125}{9} \times 8000 \cong 110,000 \text{ SY}$$

| | COST ESTIMATE WORKSHEET | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | PROPOSAL NO.: C-5 Eliminate "Kidney" Island Work | | | | PAGE 5 OF 5 |
| | | | | | |
| | DELETIONS | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | | | | | |
| ** | Containment dike stone | CY | 139,000 | $38.40 | $5,337,600 |
| | Geotextile base | SY | 110,000 | $5.00 | $550,000 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Deletions | | $5,887,600 |
| | | | | | |
| | ADDITIONS | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Additions | | $0 |
| | | | | | |
| | | | Net Savings | | $5,887,600 |
| | | * | Markups | 42.00% | $2,472,792 |
| | | | Total Savings | | $8,360,392 |
| | | | | | |
| | | | | | |
| * | Markups include: Contingency (25%) , E&D (7%)and SIOH (7%) | | | | |
| | | | | | |
| ** | For simplicity, dike estimate is based on a solid stone structure. | | | | |
| | | | | | |
| | Unit Cost $24/Ton x 1.6 ton/CY = $38.40/CY | | | | |

VALUE ENGINEERING PROPOSAL

PROPOSAL NO: C-6 PAGE NO: 1 OF 3
DESCRIPTION: Eliminate Overdepth

ORIGINAL DESIGN:

Current design specifies project depth, plus 2 feet of advance maintenance, plus 1 foot of allowable overdepth.

PROPOSED DESIGN:

Eliminate the 1 foot of allowable overdepth.

ADVANTAGES:

1. Eliminates unnecessary dredging and overpayment.
2. Reduces the "sump" depth that actually encourages deposition, particularly in open bays.
3. Reduces allowable paid depth, which the contractor always captures for payment.

DISADVANTAGES:

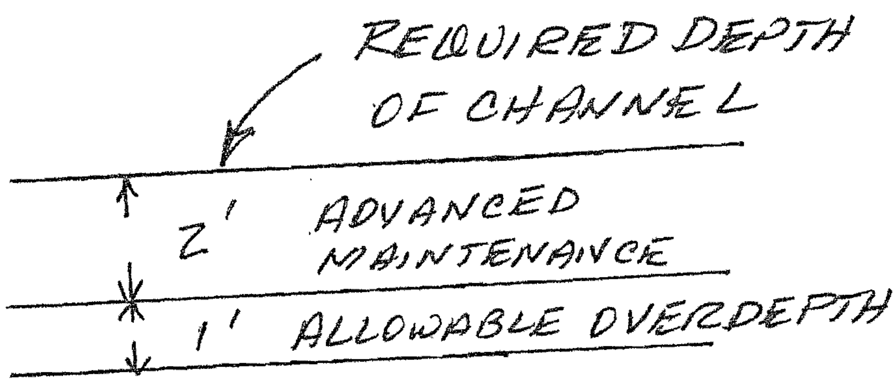
May require earlier first O&M cycle.

JUSTIFICATION:

Many years ago, allowable overdepth was included to account for inaccuracies in surveys, and inability of the dredging contractor to hit the payline. It was a tolerance for this known inaccuracy. Today surveying and dredging techniques are so accurate that the payline can be hit within inches. So whatever tolerance is allowable for payment, the dredging contractor will capture all of that to increase his profit. Total depth including overdepth tolerance becomes the payline. Overdepth tolerance is not needed.

Drawing No. 1

**ORIGINAL DESIGN**



## COST ESTIMATE WORKSHEET

| | | | | |
|---|---|---|---|---|
| PROPOSAL NO.: C-6 Eliminate Overdepth | | | | PAGE 3 OF 3 |

### DELETIONS

| ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
|---|---|---|---|---|
| Overdepth quantity: | | | | |
| mile 36.3 to 34.5 | CY | 52,800 | $1.45 | $76,560 |
| mile 34.5 to 32 | CY | 73,350 | $1.45 | $106,358 |
| mile 32 to 30 | CY | 58,670 | $1.25 | $73,338 |
| mile 30 to 28 | CY | 58,670 | $1.00 | $58,670 |
| mile 28 to 24 | CY | 117,400 | $1.40 | $164,360 |
| mile 24 to 22 | CY | 58,670 | $1.90 | $111,473 |
| mile 22-20 | CY | 58,670 | $1.45 | $85,072 |
| mile 20-18 | CY | 58,670 | $3.10 | $181,877 |
| mile 18-14.5 | CY | 102,670 | $2.55 | $261,809 |
| mile14.5-11.5 | CY | 88,000 | $2.40 | $211,200 |
| mile 11.5-10 | CY | 44,000 | $2.00 | $88,000 |
| mile 10-6 | CY | 117,400 | $1.05 | $123,270 |
| mile 6-4 | CY | 58,670 | $1.20 | $70,404 |
| mile 4-2 | CY | 58,670 | $1.25 | $73,338 |
| mile 2 to 0 | CY | 58,670 | $2.75 | $161,343 |
| mile 0 to -3.5 (300 foot wide) | CY | 205,350 | $2.75 | $564,713 |
| | | Total Deletions | | $2,411,782 |

### ADDITIONS

| ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
|---|---|---|---|---|
| | | | | $0 |
| | | | | $0 |
| | | | | $0 |
| | | Total Additions | | $0 |
| | | | | |
| | | Net Savings | | $2,411,782 |
| | * | Markups | 42.00% | $1,012,948 |
| | | Total Savings | | $3,424,730 |

* Markups include: Contingency (25%) , E&D (7%)and SIOH (7%)

VALUE ENGINEERING PROPOSAL

| | | |
|---|---|---|
| PROPOSAL NO: | C-7 | PAGE NO: 1 OF 3 |
| DESCRIPTION: | Change "Kidney" Shaped Island to Circle | |

ORIGINAL DESIGN:

The current plan is to dispose of dredge material in an area between mile 8.0 and 9.0 to form a "kidney" shaped island. To confine the material, rock would be placed around the island.

PROPOSED DESIGN:

The dredge material would be disposed in the same area and rock would surround the island to confine the material but the shape of the island would be changed to a circle.

ADVANTAGES:

1. More efficient to contain the spoil-geometrically (largest area for circumference).
2. Use less rock.

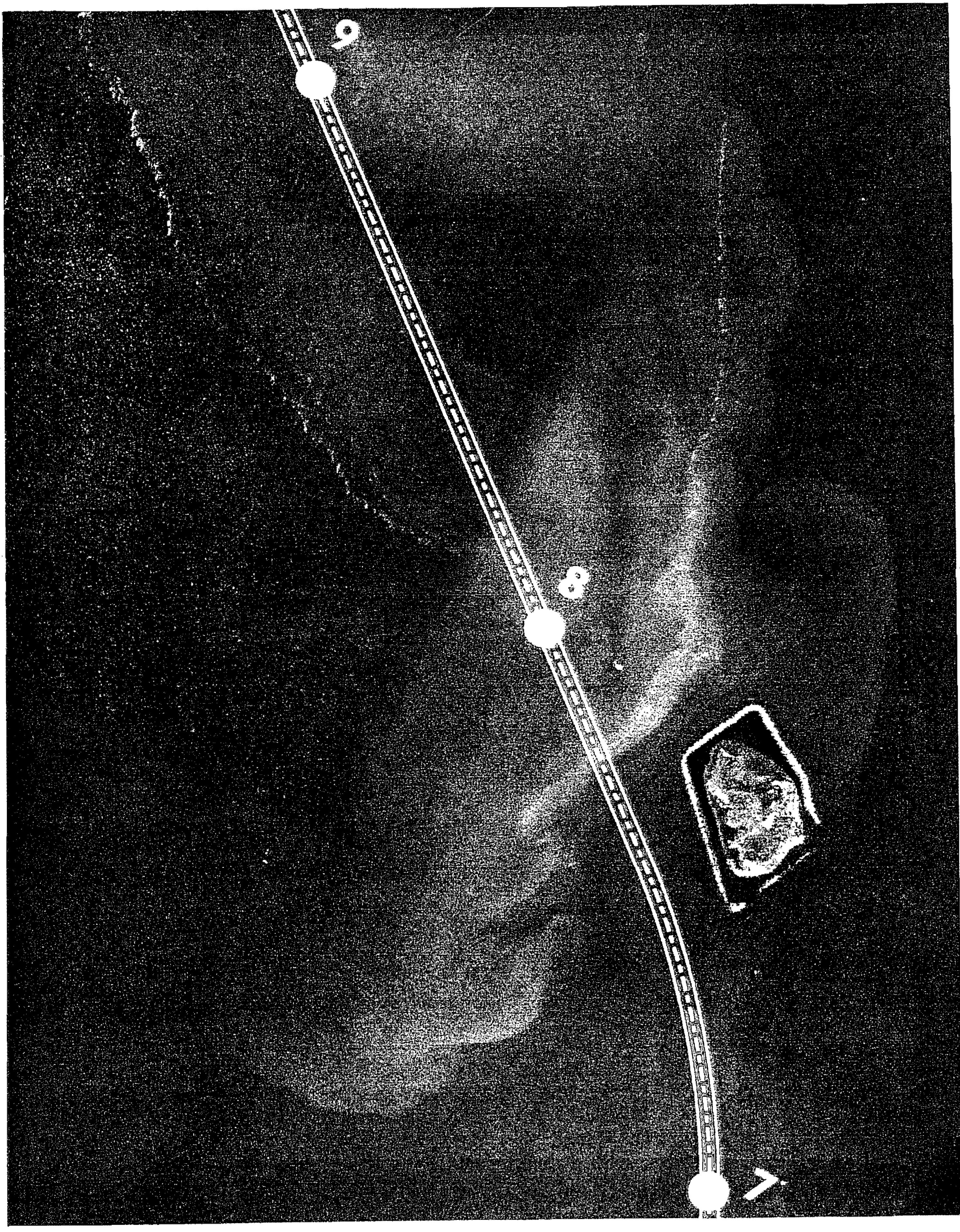
DISADVANTAGES:

The island would be round instead of resembling an island shape.

JUSTIFICATION:

This change would save money and disadvantages would be minor.

**MAP**



| | COST ESTIMATE WORKSHEET | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | PROPOSAL NO.: C-7 | | | | PAGE 2 OF 2 |
| | | | | | |
| | DELETIONS | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | Containment dike stone geotextile base | CY | 139,000 | $38.40 | $5,337,600 |
| | (ref proposal C-5) | SY | 110,000 | $5.00 | $550,000 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Deletions | | $5,887,600 |
| | | | | | |
| | ADDITIONS | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | (Assume 20% reduction) | | | | $0 |
| | Containment dike stone | CY | 111,000 | $38.40 | $4,262,400 |
| | Geotextile base | SY | 88,000 | $5.00 | $440,000 |
| | | | Total Additions | | $4,702,400 |
| | | | | | |
| | | | Net Savings | | $1,185,200 |
| | | * | Markups | 40.00% | $474,080 |
| | | | Total Savings | | $1,659,280 |
| | | | | | |
| | | | | | |
| * | Markups include: Contingency (25%) , E&D (7%)and SIOH (7%) | | | | |

VALUE ENGINEERING PROPOSAL

PROPOSAL NO: C-8 

DESCRIPTION: Use Dustpan with Pipeline to Dredge Navigation Canal

ORIGINAL DESIGN:

The current plan is to use cutterhead dredge units with disposal to adjacent sites for dredging of the Houma Navigation Canal.

PROPOSED DESIGN:

Use a modified dustpan unit (adding pumping horsepower and flexible discharge pipeline) to dredge the Navigation Canal.

ADVANTAGES:

Provides required dredging using more efficient equipment and reduced cost.

DISADVANTAGES:

1. Dustpan dredges are not as mobile as cutterhead dredges.
2. Unproven method.

JUSTIFICATION:

While use of dustpan dredges in the Navigation Canal is not preferable for maneuverability considerations, adequate safety can be achieved. For the purposes of this estimate, consider that 20% of the total dredging can be accomplished by dustpan dredges.

| | | | | | |
|---|---|---|---|---|---|
| | **COST ESTIMATE WORKSHEET** | | | | |
| | | | | | |
| | PROPOSAL NO.: C-8 Use Dustpan with Pipeline to Dredge Navigation Canal | | | | PAGE 2 OF 2 |
| | | | | | |
| | **DELETIONS** | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | | | | | |
| ** | Cutterhead Dredging | CY | 2,176,000 | $1.45 | $3,155,200 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Deletions | | $3,155,200 |
| | | | | | |
| | **ADDITIONS** | | | | |
| | | | | | |
| | ITEM | UNITS | QUANTITY | UNIT COST | TOTAL |
| | Dustpan with flexible discharge pipeline | CY | 2,176,000 | $1.00 | $2,176,000 |
| | | | | | $0 |
| | | | | | $0 |
| | | | Total Additions | | $2,176,000 |
| | | | | | |
| | | | Net Savings | | $979,200 |
| | | * | Markups | 40.00% | $391,680 |
| | | | Total Savings | | $1,370,880 |
| | | | | | |
| | | | | | |
| * | Markups include: Contingency (25%) , E&D (7%)and SIOH (7%) | | | | |
| | | | | | |
| ** | Based on 10,880,000 CY total project dredging, assuming Dustpans can safely handle 20% of total. | | | | |

1. **Share Dike Costs in Bay with Louisiana Coastal Projects (Speculation List Item No 57):** The project involves constructing three kidney shaped disposal dikes in Terrebonne Bay. The design was developed by various environmental agencies in order to comply with coastal restoration projects. Since there are more cost effective methods for disposing of dredge material, the costs associated with construction of these dikes shared cost with other coastal restoration projects such as Coast 2050 or CWPPRA should be considered.

2. **Cost Share with O&M (Speculations List Item No 58):** A portion of the proposed rock dikes along the HNC and in Terrebonne Bay would be required in the future for containment of dredge material from the regular O&M cycle. Many of these containment areas were originally conceived under the Corps O&M Program and are scheduled to be constructed in the future.

3. **Re-Visit Dredging Quantities and Containment Structure Requirements (Speculation List Item No 47):** The current cost estimate indicates dredging quantities associated with a 20-ft. design depth and a 200-ft. width. Plan changes call for evaluation only a 150-ft. wide channel with a design depth of either 18 or 20 feet. Obviously, design dredge quantities will be re-calculated. However, it is most important that current disposal areas, particularly new containment dike structures, be aggressively reduced and consolidated along with expected reductions in required dredge disposal quantities.

4. **Eliminate Rock Dike for Erosion Purposes**: Current plan calls for a rock dike the length of channel to prevent erosion of channel sides. Observation of barge and tug traffic indicates that wave and wake action is minimal or non-existent. Comparison of aerial photographs from the last 20 years also shows little or no bankline recession attributable to wave/wake driven erosion. Therefore, elimination of rock dikes for shoreline erosion protection should be considered.

5. **Address Necessity of Dredging in Miles 1-6**: Depending on whether the plan is an 18 or 20 foot depth, dredging in miles 1-6 can be eliminated from the project. For the 18 foot depth, the existing channel is deep enough, and sedimentation in this reach is minimal, mostly "Fluff" which is dissipated easily, fills back into any dredged channel quickly, and presents no restriction to passing barge/boat traffic. Careful reevaluation of necessity for advance maintenance and overdepth dredging requirements in mile 1-6 should be made.

6. **Address/Integrate Utility Relocation Costs into Decision-Making Strategies (Speculation List Item No 68):** The current cost estimate does not include expected relocation costs for various oil and gas pipelines, electrical and communication cables, waterlines, etc. These costs, particularly that for any major oil and gas pipeline relocation, may be significant and have an impact on project selection. Current project cost information should be noted accordingly so that significant increases may be expected if utility relocations are indeed significant.

7. **Identify Navigation and Environment Features/Identify Additional Sponsors (Speculation List Item No 14 and 15):** The biggest concern on this project is the rock quantities. The purpose of using rock for navigation is to contain dredge material and protect the banks due to waves caused by an increase in traffic. Without deepening the channel, the rock would be for future erosion problems; this is an environmental concern. Therefore, there may be a need for additional sponsor or another fund source such as DNR. This additional sponsor could cover the environmental portion of the project.

8. **Get a Firm Handle on the Dike Cross Section Geometry (Speculation List Item No 30):** The rock dike cross section geometry will determine the amount of rock required. Rock dikes are proposed for dredge retention and erosion control. Dike elevations are based on either the dredge spoil height and/or wake size from vessels in the channel. The required height in conjunction with the soil bearing capacity will determine the cross section geometry of the dikes. Establish the maximum wake generated from the vessels using the channel. Finalize the locations of the dredge spoil areas. (Refer to Item 70). Soil conditions and required dike height will dramatically affect cross section design and cost.

9. **Reduce Channel Width at the Bridge (Speculation List Item No 33)**: The bridge at Dulac adequately serves the community without undue restrictions on navigation. The existing barge swing bridge has a 180 ft clear span. To accommodate two way traffic the proposed channel width is 150 ft. However, for the design vessel through the bridge there will only be one way traffic. A narrower section through the bridge wouldn't limit the design vessel but would reduce the dredging. Without removing material from the bridge approach pilings the existing bridge can remain without being modified. (Refer to Item 50)

10. **Add Piles to the Bridge (Speculation List Item No 50):** If the proposed 150 ft channel is required through the bridge then material will need to be removed from the 65 ft long pilings supporting the bridge approaches. Long piles added to the ends of the pile bents could replace the pile capacity lost to dredging. Adding the piles would have minimal impact on traffic and navigation. (Refer to Item 33)

11. **Segmented Erosion Control Structures (Speculation List Item No 65)**: Rock dikes are proposed continuously lining both sides of the channel south of the lock to mile 10.5. Dredged material will be retained behind the dikes in some areas. However, the dikes placed strictly for erosion control could be segmented to break up the vessel wake and at the same time reducing the quantity of rock needed. Segment opening sizes will need to be calculated based on the vessel wake. Segmenting the dikes would allow access to the areas behind the dikes for fishing and utility maintenance as well as reduce cost.

12. **Use Marginal Factors of Safety for the Dike Design (Speculation List Item No 75):** Engineering Division Geotechnical Branch is currently investigating more representative failure criteria for the design of rock dikes. The proposed changes will better represent the failure criteria than the existing methods. Once implemented, reducing the design factor of safety can be addressed based on the consequences of failure.

13. **Assess Cost Per Acre of Kidney Island (Speculation List Item No 44):** Island dimensions are approximately 3000 feet long by 1000 feet wide, or roughly 70 acres. Estimated cost of retention dikes is $ 10.4 million (see proposal #. . . ), or about $ 150,000 per acre. This is very expensive for mitigation acreage. Much better use can be made of this investment by recreating marsh in other areas adjacent to the channel, yielding significantly more environmental benefits. In addition, the channel width has been reduced from the original plan, and as indicated in Proposal # . . . there is now only enough dredged material available in the mile 6 to 10 reach to build the Bay Chaland island extensions.

14. **Provide Tax Incentive for Barges to Lighten Loads (Speculation List Item No 36):** The economic justification for the HNC deepening is the difference in cargo cost for a partially loaded barge and a fully loaded barge. Presently the industry in the area is using a barge that has a draft of 18 feet fully loaded. The companies are only loading them partially so that they have a draft of less then 18 feet. By doing this, they are able to pass down the HNC at the authorized 15 feet depth. If the money that would be used to deepen were instead applied to a tax incentive to lighten loads, then there would be no environmental impacts to mitigate. This in turn would save the government money. This also would meet the requirements of a non-structural alternative.

15. **Consider Alternative Erosion Control Methods – Oyster Shell, Grass planting, Mangrove Planting, Geomat, ACM, Biomats (coconut fiber mats, Bionet, etc), Bio-logs, and Floating Booms (Speculation List Items Nos 61, 62, 66, 67, 69, and 77):** **Oyster** shell can be added to the shoreline to provide habitat as well as reduce the rate of erosion. Oyster shell is a limited resource and may be expensive to use. Oyster shell reduces erosion by reflecting some of the wave energy, as well as absorbing some of it. It is a cross between a hard structure that does not move and a soft structure that absorbs the wave energy by being moved around.

Meyer, D.L. , et al. 1996. The Function of Created Intertidal Oyster Reefs as Habitat for Fauna and Marsh Stabilization, and the Potential Use of Geotextile in Oyster Reef Construction. Presentation at the International Conference on Shellfish Restoration. NMFS Beaufort Lab.

**Plantings** reduce shoreline erosion by attenuating the wave energy as well as holding soil together with their roots. Several different plants may be used depending on the soil, and salinity. Several grasses could be looked at including *Spartina alterniflora*, or *S. patens*. Black mangroves could also be used. The drawback to black mangroves is that south Louisiana is its northern limit and a sever freeze will kill them.

**Geomat** or geotextile cloth can be used to hold soil in place. Oysters will colonize the surface. The material has to be fixed in place and may be susceptible to movement in large storm events.

The existing **Articulated Concrete Mattress** (ACM) floating plant has become available for work outside of the Mississippi and Atchafalaya river systems. A trial application for marsh shoreline erosion abatement is currently being considered for a reach of the GIWW just east of New Orleans. Success of this trial in combination with some for of retrofitting of the unit, based on lessons learned from the trail, could make this a viable option for this project. Required depth of floating unit drat, weight of ACM and overall unit cost are issues.

**Biomats** are blankets of coconut fiber or straw on which wetland plants have been grown, essentially forming a living carpet that can be placed wherever shoreline stabilization is needed. They keep the soil from washing away while the plants become established and will eventually rot away.

A **biolog** is a tube of biodegradable coconut fiber about 12 inches in diameter and several feet long. Stream-restoration workers stake them, end-to-end, along fragile watershed shorelines and plant seedlings in them. The plants grow through the biolog, extending their roots into the soil beneath within a few weeks, stabilizing the shoreline in the process. Biologs are an environmentally sound restoration technique for stopping shoreline erosion
http://www.weemscreek.org/proj-sources.html#biologs
http://www.internationalcoir.com/html/i0410pro.htm

**Floating Boom** could reduce wave levels which in turn could reduce erosion.

# SUPPORTING DOCUMENTS

# CONTACT DIRECTORY

VALUE ENGINEERING TEAM STUDY

APPENDIX A: CONTACT DIRECTORY

| NAME | ORGANIZATION | TEL/FAX NUMBERS |
|---|---|---|
| Frank Vicidomina | CEMVN-VE | 504-862-1251 |
| Meredith Godoi | LADOTD | 225-274-4349/4351 |
| Eddie Oliver, Jr. | LADOTD | 225-274-4326/4333 |
| Whitney Ledet | LADOTD | 225-274-4325/4322 |
| Clyde Martin | LADOTD | 225-274-4346 |
| Daniel Whalen | COE-PM-AN | 504-862-2852 |
| Robert Jolissaint | EN-FD | 504-862-2961/1091 |
| Nathan Dayar | EN-PM-RS | 504-862-2530 |
| Rick Broussard | COE ED-LN | 504-862-2402/1585 |
| Janis Hote | COE ED-HC | 504-862-2489/2471 |
| Michael Palmieri | COE RE-E | 504-862-2891/1299 |
| Rodney Greenup | USACE | 504-862-2613/2572 |
| Eara Merritt | OVEST | 912-652-5171/5956 |
| | | |
| | | |

# SPECULATION LIST

√ = Develop; X = Delete; C = Comment

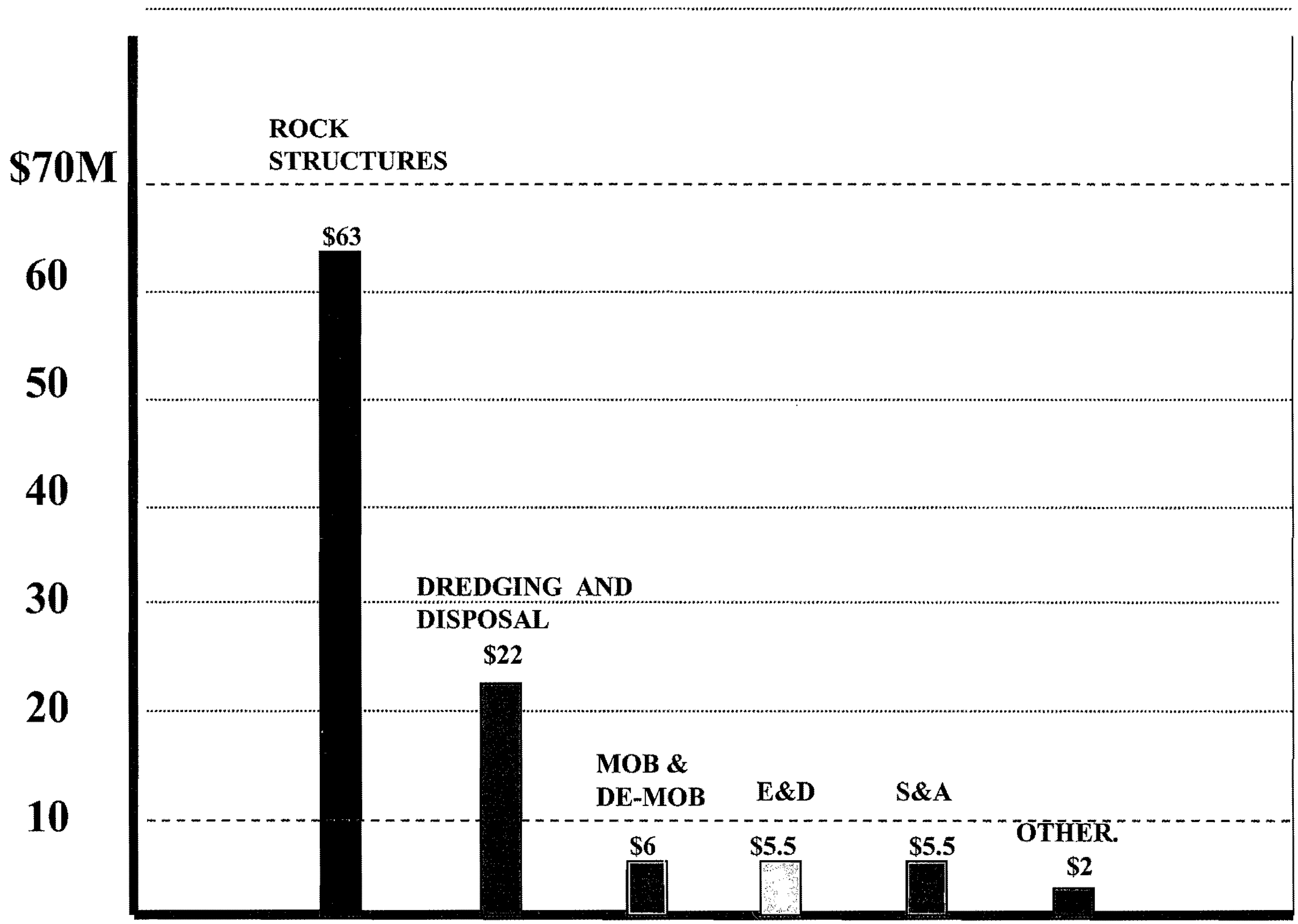
1. √ Reduce scope (eliminate dredging mile 0 to 10).
2. X Build jetty through bay.
3. √ Use alternate material for erosion protection other than rock dikes.
4. C Use oyster shells for marsh protection.
5. X Move lock and levee south.
6. X Move north.
7. C Optimize non-dredging rock
8. √ Seek alternate mitigation measures.
9. BD Increase flow in HNC from GIWW.
10. BD Increase flow in HNC from Miss. River.
11. √ Use geotubes south of lock.
12. √ Use vinyl sheetpile cells south of lock.
13. X Use soil mixing.
14. C Identify additional sponsors.
15. C Identify navigation and environmental features.
16. √ Pump dredge material farther to existing marsh areas.
17. X Build unconfined islands.
18. √ Open water disposal at lower end of project.
19. √ Use unconfined disposal throughout.
20. √ Construct containment dikes of other material than rock.
21. C Do not deepen channel.
21a. C Transfer to LA Coastal
22. BD No Action
23. X Increase water flow in Grand Caillou.
24. BD Reduce lock wall heights to 8'.
25. X Relocate businesses.
26. X Deepen adjacent ports instead.
27. X Deepen to 35'.
28. √ Change kidney shaped island to circle.
29. √ Pump inland to damaged marshes in lieu of kidney island.
30. C Get firm handle on rock dike design (South of lock )
31. √ Use erodible material for marsh containment dikes
32. BD Investigate existing.bridge design vs modifications
33. C Reduce channel width at bridge.
34. BD Consult DOTD on bridge options
35. X Match lock clearance with bridge clearance.
36. C Provide tax incentive for barges to lighten loads.
37. C Slow speed of traffic.
38. X Relocate bridge to lock
39. BD Look at 18' channel
40. X Get more acreage for disposal sites.
41. X Raise height of disposal sites.
42. X Grade banks in lieu of rock
43. X Rock coast in lieu of channel
44. C Assess cost per acre of kidney island.
45. X Reduce bottom width to approximately 130'

√ = Develop; X = Delete; C = Comment

46. ? Close off Bayou Grand Caillou
47. C Revisit current estimate of dredging quantities.
48. BD Revisit design vessel
49. X Straighten channel.
50. C Add additional piles to bridge to reinforce.
51. X Replace bridge.
52. X Look at boats in lieu of channel modifications
53. X Build blimp port
54. X Yield to millenium port
55. X Replace bridge with ferry.
56. X Privatize canal.
57. C Share dike costs in bay with LA coastal projects.
58. C Cost share with O& M.
59. C Reduce project (mile 0 to 4.5), no advance maintenance
60. X Toll Channel
61. √ Plant grasses to prevent erosion.
62. √ Plant black mangroves.
63. X Create shoreline benches to mitigate wave erosion.
64. X Relocate Terrebonne port (south)
65. √ Use segmented erosion control structures.
66. √ Use geomat.
67. √ Use articulated concrete mat.
68. C Address/integrate relocation costs into decision making.
69. √ Investigate "coconut fiber" mats and tubes.
70. √ Eliminate kidney island for lack of available dredge material (150' wide channel produces less material).
71. √ Use revetted PVC pipe dikes.
72. X Shredded tire dikes.
73. X Radial tire dikes.
74. X Use 3-4 big disposal islands.
75. C Use marginal geotech factors of safety on dike designs.
76. X Explore additional recreation opportunities.
77. √ Use floating booms
78. X Use abandoned vessels channelside to reduce erosion.
79. X Install mooring facilities along erosion sites.
80. X Inflatable weir to keep salt water wedge out.
81. √ Use Dustpan with long tail and pump
82. X Use material out of existing disposal sites (original project construction) to construct retention sites.
83. √ Eliminate overdepth

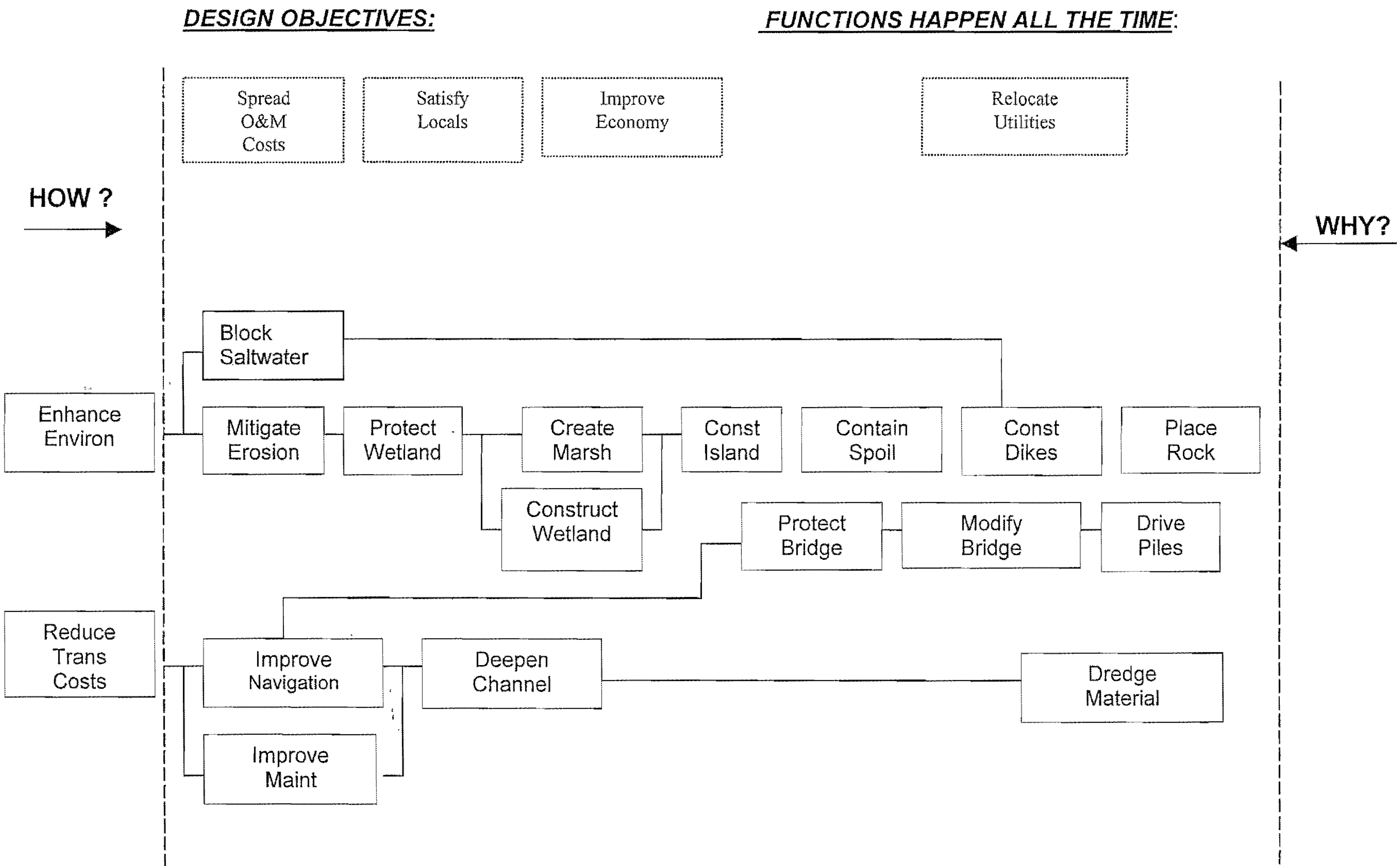
# COST ESTIMATE AND MODEL

# Houma Navigation Canal - Total Cost $104M



# FUNCTION ANALYSIS SYSTEM TECHNIQUE (FAST) DIAGRAM

# HOUMA NAVIGATION CANAL




FUNCTION ANALYSIS SYSTEM TECHNIQUE (FAST DIAGRAM)

# SUPPORTING DOCUMENTS

6/20/01

| COST ESTIMATE | | | | SHEET 1 OF 2 | |
|---|---|---|---|---|---|
| PROJECT: Houma Navigation Canal, Section 107 Widening/Deepening Study, Mile 36.3 to Mile 22.0 GIWW to Cat Island Pass, Terrebonne Parish, LA. | | | | DATE: 07 Nov 00/20 Jun 01 By TD/JP (ED-C) 12/07 Filename hnc107a | |
| ITEM | DESCRIPTION | QUANTITY | UNIT | UNIT COST | AMOUNT |
| | | | | | |
| 1. | **Mobilization and Demobolization** | | LS | $760,000.00 | $760,000.00 |
| | | | | | |
| 2 | **Dredging and Disposal (Mile 36.3 to Mile 22.0)** | | | | |
| | Channel to be excavated to -22 MLG; 1v/2h side slope | | | | |
| | 200-foot bottom width | | | | |
| | | | | | |
| A | **HNC Mile 36.3 to HNC Mile 34.5** | 425000 | CY | $1.45 | $616,250.00 |
| | Material to be placed within the confined upland | | | | |
| | areas (Site 2 and/or Site 3 ) opposite HNC Mile 35.5. | | | | |
| | No height restriction. Dike construction and/or | | | | |
| | maitnenance not required. | | | | |
| | | | | | |
| B | **HNC Mile 34.5 to HNC Mile 32.0** | 575000 | CY | $1.45 | $833,750.00 |
| | Material to be placed within the confined upland | | | | |
| | areas (Site 4, Site 5 and Site 6) along the east bank | | | | |
| | of the HNC between Mile 34 and Mile 31.7. No height | | | | |
| | restriction. | | | | |
| | | | | | |
| (1) | **Dike Maintenance/Refurbishment (Site4/5)** | 16200 | LF | $6.00 | $97,200.00 |
| (2) | **Earthen Retention Dikes (Site 6)** | 10500 | LF | $7.25 | $76,125.00 |
| | | | | | |
| C | **HNC Mile 32.0 to HNC Mile 30.0** | 525000 | CY | $1.25 | $656,250.00 |
| | Material to be placed in the designated (mandatory) | | | | |
| | wetland areas (Site 7 and Site 8) opposite HNC | | | | |
| | Mile 31.7. Elevation of material placed within Site 7 | | | | |
| | and Site 8 not to exceed +3.0' MLG. Confined Upland | | | | |
| | Site 7a to be utilized as a secondary area. | | | | |
| | | | | | |
| (1) | **Dike Maintenance/Refurbishment (Site 7a)** | 7400 | LF | $5.75 | $42,550.00 |
| (2) | **Earthen Retention Dikes (Site 7/8) (ME)** | 7500 | LF | $30.00 | $225,000.00 |
| | | | | | |
| D | **HNC Mile 30 to HNC Mile 28.0** | 700000 | CY | $1.00 | $700,000.00 |
| | Material to be placed within the confined upland areas | | | | |
| | (Site 9 and Site 10) between Mi 29.6 and Mi 28.0 | | | | |
| | along the east bank of the HNC. Confined Site 9a/10a | | | | |
| | secondary areas. No height restriction. | | | | |
| | | | | | |
| (1) | **Dike Maintenance/Refurbishment (Site 9/10)** | 18500 | LF | $5.75 | $106,375.00 |
| (2) | **Earthen Retention Dikes (Site 9a/10a) (ME)** | 11300 | LF | $23.00 | $259,900.00 |
| | | | | | |
| | **ME = Marsh Equipment** | | | | |

Sum Total: $93 288,875.00

| COST ESTIMATE | | | | SHEET 2 OF 2 | |
|---|---|---|---|---|---|
| PROJECT: Houma Navigation Canal, Section 107<br>Widening/Deepening Study, Mile 36.3 to Mile 22.0<br>GIWW to Cat Island Pass, Terrebonne Parish, LA. | | | | DATE: 07 Nov 00/20 Jun 01<br>By TD/JP (ED-C) 07 Dec<br>Filename hnc107b | |
| ITEM | DESCRIPTION | QUANTITY | UNIT | UNIT COST | AMOUNT |
| | | | | | |
| E | **HNC Mile 28 to HNC Mile 24** | 850000 | CY | $1.40 | $1,190,000.00 |
| | Material to be placed in the designated wetland areas | | | | |
| | (Sites 11-14) between HNC Mile 27.5 and Mile 25.4. | | | | |
| | Site 11 is mandatory. Site 12 and 13 are primary. | | | | |
| | Site 14 is secondary. Elevation of material placed | | | | |
| | within the aforementioned sites shall not exceed | | | | |
| | +3.5' MLG. | | | | |
| | | | | | |
| (1) | **Rock Retention Structure (7100 LF)** | | | | |
| a. | **Geotextile** | 47600 | SY | $5.00 | $238,000.00 |
| b. | **Stone (Actual)** | 26500 | TONS | $24.00 | $636,000.00 |
| c. | **Core (Crushed limestone)** | 6800 | CY | $36.00 | $244,800.00 |
| | | | | | |
| (2) | **Earthen Retention Dikes** | 2200 | LF | $17.00 | $37,400.00 |
| | | | | | |
| F | **HNC Mile 24 to HNC Mile 22** | 310000 | CY | $1.90 | $589,000.00 |
| | Material to be placed in the open water area (Site 15) | | | | |
| | west of HNC Mile 22.5. Elevation of material placed | | | | |
| | within Site 15 shall not exceed +3.5' MLG. | | | | |
| | | | | | |
| | | | | | |
| | **Sub Total** | | | | $7,308,600.00 |
| | **Contingency (25%)** | | | | $1,827,150.00 |
| | **Total** | | | | $9,135,750.00 |
| | | | | | or 9.1 M |

| COST ESTIMATE | | | | SHEET 1 OF 2 | |
|---|---|---|---|---|---|
| PROJECT: Houma Navigation Canal, Section 107<br>Widening/Deepening Study, Mile 22.0 to Mile 11. 5<br>Terrebonne Parish, LA | | | | DATE: 07 Nov 00/20 Jun 01<br>By TD/JP (ED-C) 07 Dec<br>Filename hnc107c.xls | |
| ITEM | DESCRIPTION | QUANTITY | UNIT | UNIT COST | AMOUNT |
| 1 | **Mobilization and Demobolization** | | | 760,000 | $760,000.00 |
| | | | | | |
| 2 | **Dredging and Disposal (Mile 22.0 to Mile 11.5)** | | | | |
| | Channel to be excavated to -22 MLG; 1v2/h side | | | | |
| | slope and 200-foot bottom width | | | | |
| | | | | | |
| A | **HNC Mile 22 to HNC Mile 20** | 450000 | CY | $1.45 | $652,500.00 |
| | Material to be placed within the desiganted wetland | | | | |
| | and confined upland area(s) (Site 16, 17 and 18) | | | | |
| | between HNC Mile 21.5 and Mile 20.2. Elevation of | | | | |
| | material placed within Site 16 shall not exceed +3.5' | | | | |
| | MLG. Ho height restriction for Site 17 and 18. Site | | | | |
| | 16 is mandatory. Site 17/18 are secondary | | | | |
| | | | | | |
| | **Rock Retention Structure (7100 LF)** | | | | |
| a | **Geotextile** | 44200 | SY | $5.00 | $221,000.00 |
| b | **Stone (Actual)** | 30800 | TONS | $24.00 | $739,200.00 |
| c | **Core (Crushed limestone)** | 4500 | CY | $36.00 | $162,000.00 |
| | | | | | |
| B | **HNC Mile 20 to HNC Mile 18.0** | 175000 | CY | $3.10 | $542,500.00 |
| | Material to be placed within the confined wetland | | | | |
| | areas ( Site 19a/Site 19b). Elelvation of material | | | | |
| | placed within Site 19/19A shall not exceed +3.5' | | | | |
| | MLG. Confined Upland Site 18 is secondary. No | | | | |
| | height restirction. | | | | |
| | | | | | |
| (1) | **Rock Retention Structure (4500 LF)** | | | | |
| a | **Geotextile** | 34900 | SY | $5.00 | $174,500.00 |
| b | **Stone (Actual)** | 26000 | TONS | $24.00 | $624,000.00 |
| c | **Core (Crushed Limestone)** | 7500 | CY | $36.00 | $270,000.00 |
| | | | | | |
| (2) | **Earthen Retention Dikes (Rear 19a) (ME)** | 3000 | LF | $34.00 | $102,000.00 |
| | | | | | |
| C | **HNC Mile 18.0 to HNC Mile 14.5** | 350000 | CY | $2.55 | $892,500.00 |
| | Material to be placed within the open water areas | | | | |
| | (Site 20a, 20b, 20c & 20d) between HNC Mile 17 and | | | | |
| | Mile 16.2. Site 20a and 20b are primary. Site 20c/20d | | | | |
| | are secondary. Material placed within 20a-d shall | | | | |
| | not exceed +3.5' MLG. | | | | |
| | | | | | |
| (1) | **Rock Retention Structure (7200 LF)** | | | | |
| a | **Geotextile** | 47300 | SY | $5.00 | $236,500.00 |
| b | **Stone (Actual)** | 33700 | TONS | $24.00 | $808,800.00 |
| c | **Core (Crushed Limestone)** | 6200 | CY | $36.00 | $223,200.00 |
| | | | | | |
| (2) | **Earthen Retention Dikes (Site 20a) (ME)** | 3000 | LF | $28.00 | $84,000.00 |
| (3) | **Earthen Retention Dikes (Site 20d) (ME)** | 9500 | LF | $21.00 | $199,500.00 |
| (4) | **Dike Maintenance/Refurbishment (Site 20b)** | 2400 | LF | $14.75 | $35,400.00 |
| | **(ME)** | | | | |
| | **ME = Marsh Equipment** | | | | |

| COST ESTIMATE | | | | SHEET 2 OF 2 | |
|---|---|---|---|---|---|
| PROJECT: Houma Navigation Canal, Section 107<br>Widening/Deepening Study, Mile 22.0 to Mile 11.5<br>Terrebonne Parish, LA. | | | | DATE: 07 Nov 00/20 Jun 01<br>By TD/JP (ED-C 7 Dec 00)<br>Filename hnc107d.xls | |
| ITEM | DESCRIPTION | QUANTITY | UNIT | UNIT COST | AMOUNT |
| J | **HNC Mile 14.5 to HNC Mile 11.5** | 430,000 | CY | $2.40 | $1,032,000.00 |
| | Material to be placed within the open water area(s) | | | | |
| | within Site 21 West of HNC Mile 15.0. Elevation of | | | | |
| | material placed within Site 21 shall not exceed +3.5' | | | | |
| | MLG. Site 21a is secondary. | | | | |
| | | | | | |
| (1) | **Rock Retention Structure (8300 LF)** | | | | |
| a | **Geotextile** | 70,000 | SY | $5.00 | $350,000.00 |
| b | **Stone (Actual)** | 50,000 | TONS | $24.00 | $1,200,000.00 |
| c | **Core (Crushed limestone)** | 8,200 | CY | $36.00 | $295,200.00 |
| | | | | | |
| (2) | **Earthen Dikes/Closures (Site 21a) (ME)** | 3,000 | LF | $22.00 | $66,000.00 |
| (3) | **Earthen Dikes (ME)** | 14,200 | LF | $18.00 | $255,600.00 |
| | | | | | |
| | **ME = Marsh Equipment** | | | | |
| | | | | | |
| | **Sub Total** | | | | $9,926,400.00 |
| | **Contingency (25%)** | | | | $2,481,600.00 |
| | **Total** | | | | $12,408,000.00 |
| | | | | | **or 12.4 M** |

| COST ESTIMATE | | | | SHEET 1 OF 1 | |
|---|---|---|---|---|---|
| PROJECT: Houma Navigation Canal, Section 107<br>Widening/Deepening Study, Mile 11.5 to Mile 6.0<br>Terrebonne Parish, LA | | | | DATE: 07 Nov 00/20 Jun 01<br>By TD/JP (ED-C 07 Dec 00)<br>Filename hnc107e.xls | |
| ITEM | DESCRIPTION | QUANTITY | UNIT | UNIT COST | AMOUNT |
| 1 | **Mobilization and Demobilization** | | LS | 760000 | $760,000.00 |
| | | | | | |
| 2 | **Dredging and Disposal (Mile 11.5 to Mile 10.0)** | | | | |
| | Channel to be excavated to -22 MLG; 1v/2h side slope | | | | |
| | and 200-foot bottom width | | | | |
| | | | | | |
| | **HNC Mile 11.5 to Mile 10.0** | 225000 | CY | $2.00 | $450,000.00 |
| | Material to be placed within the designated wetland | | | | |
| | areas (Site 22, 23 and 24) between HNC Mile 11.8 | | | | |
| | and HNC Mi 10.2. Elevation of material shall not | | | | |
| | exceed +3.5' MLG. | | | | |
| | | | | | |
| (1) | Rock Retention Structure (11100 LF) | | | | |
| a | Geotextile | 70900 | SY | $5.00 | $354,500.00 |
| b | Stone (Actual) | 50000 | TONS | $24.00 | $1,200,000.00 |
| c | Core (Crushed Limestone) | 8200 | CY | $36.00 | $295,200.00 |
| | | | | | |
| (2) | Earthen Retention Dikes (Site 24) (ME) | 3800 | LF | $21.00 | $79,800.00 |
| | | | | | |
| 3 | **Dredging and Disposal (Mile 10.0 to Mile 6.0)** | | | | |
| | Channel to be excavated to -23' MLG; 1v/2h side | | | | |
| | slope(s) by 200' channel width | | | | |
| | | | | | |
| A | **HNC Mile 10.0 to HNC Mile 8.0** | 1400000 | CY | $1.05 | $1,470,000.00 |
| | Material to be placed within the contained rock cell | | | | |
| | west of HNC Mile 8.6. The crown ht. shall be +5.0' | | | | |
| | MLG at the front, tapering to +4.0' MLG at the back, to | | | | |
| | allow for dredge material overflow at the rear of the | | | | |
| | cell. The rock cell shall consist of an initial (primary) | | | | |
| | discharge area with secondary areas separated by | | | | |
| | interior cross dikes. 60 acres (See plans for details). | | | | |
| | | | | | |
| (1) | **Armor Stone (Actual)** | 100000 | TONS | $24.00 | $2,400,000.00 |
| (2) | **Core Material** | 53000 | CY | $36.00 | $1,908,000.00 |
| (3) | **Geotextile** | 160000 | SY | $5.00 | $800,000.00 |
| | | | | | |
| B | **HNC Mile 8.0 to HNC Mile 6.0** | 1400000 | CY | $1.05 | $1,470,000.00 |
| | Material to be placed within the contained rock cell | | | | |
| | to be extended (enlarged) at Bay Chaland Island | | | | |
| | east of Mile 7.7. The extensions to Bay Chaland | | | | |
| | Island shall be of the same design criteria as the new | | | | |
| | rock cells constructed west of the HNC at Mile 8.6, | | | | |
| | 5.8 and 4.2. 60 acres (See plans for details). | | | | |
| | | | | | |
| (1) | **Armor Stone (Actual)** | 115000 | TONS | $24.00 | $2,760,000.00 |
| (2) | **Core Material** | 65000 | CY | $36.00 | $2,340,000.00 |
| (3) | **Geotextile** | 170000 | SY | $5.00 | $850,000.00 |
| | | | | | |
| | **Sub-Total** | | | | $17,137,500.00 |
| | **Contingency (25%)** | | | | $4,284,375.00 |
| | **Total** | | | | $21,421,875.00 |

| COST ESTIMATE | | | | SHEET 1 OF 1 | |
|---|---|---|---|---|---|
| PROJECT: Houma Navigation Canal, Section 107<br>Widening/Deepening Study, Mile 6.0 to Mile 2.0<br>Terrebonne Parish, LA | | | | DATE: 07 Nov 00<br>By TD/JP (ED-C 07 Dec 00)<br>Filename hnc107f.xls | |
| ITEM | DESCRIPTION | QUANTITY | UNIT | UNIT COST | AMOUNT |
| 1 | **Mobilization and Demobilization** | | LS | 760000 | $760,000.00 |
| | | | | | |
| 2 | **Dredging and Disposal (Mile 6.0 to 2.0)** | | | | |
| | Channel to be excavated to -23 MLG; 1v/2h side | | | | |
| | slope by 200' channel width | | | | |
| | | | | | |
| A | **HNC Mile 6.0 to HNC Mile 4.0** | 1300000 | CY | $1.20 | $1,560,000.00 |
| | Material to be placed within the contained rock cell | | | | |
| | to be extended (enlarged) at Bay Chaland Island | | | | |
| | east of Mile 7.7. The extensions to Bay Chaland | | | | |
| | island shall be of the same design criteria as the new | | | | |
| | rock cells constructed west of the HNC at Mile 8.6, | | | | |
| | 5.8 and 4.2. Sixty(60) acres (See plans for details) | | | | |
| | | | | | |
| (1) | **Armor Stone (Actual)** | 160000 | TONS | $24.00 | $3,840,000.00 |
| (2) | **Core Material** | 110000 | CY | $36.00 | $3,960,000.00 |
| (3) | **Geotextile** | 230000 | SY | $5.00 | $1,150,000.00 |
| | | | | | |
| | **HNC Mile 4.0 to HNC Mile 2.0** | 1200000 | CY | $1.25 | $1,500,000.00 |
| | Material to be placed within the contained rock cell | | | | |
| | west of HNC Mile 4.2. Dike design and disposal | | | | |
| | criteria consistent with the rock cells constructed | | | | |
| | west of the HNC at Mile 8.6 and 5.8. 45 acres | | | | |
| | | | | | |
| (1) | **Armor Stone (Actual)** | 225000 | TONS | $24.00 | $5,400,000.00 |
| (2) | **Core Material** | 135000 | CY | $36.00 | $4,860,000.00 |
| (3) | **Geotextile** | 285000 | SY | $5.00 | $1,425,000.00 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | **Sub-total** | | | | $24,455,000.00 |
| | **Contingency (25%)** | | | | $6,113,750.00 |
| | **Total** | | | | $30,568,750.00 |

| ST ESTIMATE | | | | SHEET 1 OF 1 | |
|---|---|---|---|---|---|
| OJECT: Houma Navigation Canal, Section 107<br>lening/Deepening Study, Mile 2.0 to Mile (-)3.5<br>errebonne Parish, LA. | | | | DATE: 07 Nov 00<br>By TD/JP (ED-C 07 Dec 00)<br>Filename hnc107g.xls | |
| EM | DESCRIPTION | QUANTITY | UNIT | UNIT COST | AMOUNT |
| | | | | | |
| 1 | **Mobilization and Demobilization** | | LS | 710,000 | $710,000.00 |
| | | | | | |
| 2 | **Dredging and Disposal (Mile 2.0 to Mile (-)3.5)** | | | | |
| | Channel to be excavated to -25' MLG; 1v/2h side | | | | |
| | slopes by 300' bottom width | | | | |
| | | | | | |
| | Material to be placed at the single point discharge | 1400000 | CY | $2.75 | $3,850,000.00 |
| | location(s) within Cat Island Pass at approximate HNC | | | | |
| | Mile (-)1.7 and Mile (-2.5) (See plans for details) | | | | |
| | | | | | |
| | | | | | |
| | Sub-total | | | | $4,560,000.00 |
| | Contingency (25%) | | | | $1,140,000.00 |
| | Total | | | | $5,700,000.00 |

| ESTIMATE | SHEET 1 OF 1 |
| --- | --- |
| ECT: Houma Navigation Canal, Section 107<br>ng/Deepening Study, Dike Construction, Mile<br>16.6 (East/West Bank) Terrebonne Parish, LA | DATE: 15 Jun 01<br>By TD/JP (ED-C)<br>Filename hnc107h.xls |

| DESCRIPTION | QUANTITY | UNIT | UNIT COST | AMOUNT |
| --- | --- | --- | --- | --- |
| **Mobilization and Demobilization** | | LS | | |
| | | | | |
| **Foreshore Dike Construction** | | | | |
| 36 inch stone. Dike constructed to +6.0' MLG. Core | | | | |
| ht +3.5 MLG w 1 on 2.5 side slopes. Dike(s) to be | | | | |
| constructed along the east and west bank of the | | | | |
| Houma Navigation Canal between HNC Miles 23.2 | | | | |
| and 11.9. | | | | |
| | | | | |
| **HNC Mile 23.2 to 22.1 (East Bk 6100 LF)** | | | | |
| | | | | |
| Geotextile | 37,900 | SY | $5.00 | $189,500 |
| Stone (Actual) | 26,500 | TONS | $24.00 | $636,000 |
| Core (Crushed Limestone) | 3,850 | CY | $36.00 | $138,600 |
| | | | | |
| **HNC Mile 22.8 to 21.8 (West Bk 4985 LF)** | | | | |
| | | | | |
| Geotextile | 36,000 | SY | $5.00 | $180,000 |
| Stone (Actual) | 26,400 | TONS | $24.00 | $633,600 |
| Core (Crushed Limestone) | 6,850 | CY | $36.00 | $246,600 |
| | | | | |
| **HNC Mile 19.2 to 17.1 (East Bk 10875 LF)** | | | | |
| | | | | |
| Geotextile | 82,000 | SY | $5.00 | $410,000 |
| Stone (Actual) | 61,000 | TONS | $24.00 | $1,464,000 |
| Core (Crushed Limestone) | 16,700 | CY | $36.00 | $601,200 |
| | | | | |
| **HNC Mile 19.1 to 16.6 (West Bk 12550 LF)** | | | | |
| | | | | |
| Geotextile | 81,200 | SY | $5.00 | $406,000 |
| Stone (Actual) | 56,500 | TONS | $24.00 | $1,356,000 |
| Core (Crushed Limestone) | 9,900 | SY | $36.00 | $356,400 |
| **Sub-Total** | | | | $6,617,900 |
| **Contingency (25%)** | | | | $1,654,475 |
| **Total** | | | | $8,27[illegible],[illegible]75 |

| COST ESTIMATE | | | | SHEET 1 OF 1 | |
|---|---|---|---|---|---|
| PROJECT: Houma Navigation Canal, Section 107 Widening/Deepening Study, Dike Construction, Mile 15.6 - 11.9 (East/West Bank) Terrebonne Parish, LA | | | | DATE: 15 Jun 01<br>By TD/JP (ED-C)<br>Filename hnc107i.xls | |
| ITEM | DESCRIPTION | QUANTITY | UNIT | UNIT COST | AMOUNT |
| 1 | **Mobilization and Demobilization** | | LS | | |
| | | | | | |
| 2 | **Foreshore Dike Construction** | | | | |
| | 36 inch stone. Dike constructed to +6.0' MLG. Core ht +3.5 MLG w 1 on 2.5 side slopes. Dike(s) to be constructed along the east and west bank of the Houma Navigation Canal between HNC Miles 15.6 and 11.9. | | | | |
| | | | | | |
| A | **HNC Mile 15.6 - 12.8 (East Bk 14800 LF)** | | | | |
| | | | | | |
| 1 | Geotextile | 96,600 | SY | $5.00 | $483,000 |
| 2 | Stone (Actual) | 68,000 | TONS | $24.00 | $1,632,000 |
| 3 | Core (Crushed Limestone) | 15,500 | CY | $36.00 | $558,000 |
| | | | | | |
| B | **HNC Mile 13.2 to 12.4 (West Bk 6450 LF)** | | | | |
| | | | | | |
| 1 | Geotextile | 41,600 | SY | $5.00 | $208,000 |
| 2 | Stone (Actual) | 29,200 | TONS | $24.00 | $700,800 |
| 3 | Core (Crushed Limestone) | 5,000 | CY | $36.00 | $180,000 |
| | | | | | |
| C | **HNC Mile 12.7 to 11.9 (West Bk 4800 LF)** | | | | |
| | | | | | |
| 1 | Geotextile | 33,100 | SY | $5.00 | $165,500 |
| 2 | Stone (Actual) | 23,900 | TONS | $24.00 | $573,600 |
| 3 | Core (Crushed Limestone) | 5,200 | CY | $24.00 | $124,800 |
| | | | | | |
| | **Sub-Total** | | | | $4,625,700 |
| | **Contingency (25%)** | | | | $1,156,425 |
| | **Total** | | | | $5,782,125 |

# Channel Deepening Analysis

## Project Area Description

The Houma Navigation Canal is a north-south oriented 36.6-mile navigation channel from the intersection of the Gulf Intracoastal Waterway (GIWW) at Houma, La to the Gulf of Mexico. Terrebonne Parish constructed the canal in 1962 to provide direct access to the nearby resources of the Gulf of Mexico. The channel was constructed with a usable dimension of 15 feet by 150 feet from the GIWW to Mile 0. It has an 18-foot by 300-foot dimension from Mile 0 through Cat Island Pass to the 18-foot contour of the Gulf. The Federal government assumed the maintenance of the channel in 1962 through Congressional legislation.

## Existing Conditions

There are many and varied businesses located along the 36.6 miles of the Houma Navigation Canal. The navigation needs of the firms are at present being met by the existing dimensions of the channel. The vast majority of the current traffic on the canal are self-propelled boats used for support of the offshore oil and gas industry, including support vessels and tug/tow boats, and local area commercial fishing vessels. Almost all of the remaining tonnage on the Houma Navigation Canal is composed of petroleum barges and barges carrying gravel type loads. The 1998 vessel trips are detailed in the table below.

**Houma Navigation Canal**
**1998 Vessel Trips**

| Vessel Type | Up | Down | Total | % of Total |
|---|---|---|---|---|
| 1 | 964 | 886 | 1,850 | 42% |
| 2 | 69 | 32 | 101 | 2% |
| 3 | 705 | 716 | 1,421 | 32% |
| 4 | 339 | 292 | 631 | 14% |
| 5 | 204 | 236 | 440 | 10% |
| 6 | - | - | - | 0% |
| | 2,281 | 2,162 | 4,443 | 100% |

Type 1 - self-propelled, Dry
Type 2 - self-propelled, Tanker
Type 3 - Towboat or Tugboat
Type 4 – Non-Self-Propelled, Dry
Type 5 – Non-Self-Propelled, Tanker
Type 6 - Other

Source: Waterborne Commerce of the United States - 1998 - Part 2

An examination of the data shows that most of the traffic on the canal is composed of vessel type 1 and vessel type 3. These two together amounted to 74% of all traffic on the waterway for calendar year 1998. The reporting for vessel type 3 is towboats or tugboats without barges and vessel type 1 is mostly oil field service boats. Large rig structure movements are generally not included in the Waterborne Commerce data. Also, commercial fishing vessels activity is generally not reported in these statistics and therefore these numbers are conservative.

## Future Without Project

The volume of traffic on the Houma Navigation Canal is influenced to a large extent by the fortunes of the offshore oil and gas industry. Vessel traffic as reported in the Waterborne Commerce data shows a slight decline in total vessel trips over the last several years. Total vessel trips for the three-year period 1996 through 1998 are 5,204, 4,582 and 4,443 respectively. This is an average annual decline of 7.5%. The year-to-year decline shows a slowing in the negative growth (e.g. from 1997 to 1998 the decline was only 5%). Offshore oil and gas activity was growing during this same period. This implies that activity on the Houma Navigation Canal will decline to a minimum level of activity and stay there well into the future if no changes are made to the channel.

## Future With Project

Deepening the channel in the Houma Navigation Canal will allow for growth in marine activity that the present depth does not allow. The trend in the offshore oil and gas industry is for exploration and production in deeper and deeper water. This has two important implications for the Houma Navigation Canal. Deepwater activity requires larger service vessels as well as a greater financial commitment for any given project. Therefore firms that can build, service and maintain larger vessels at the lowest cost will win contracts that would otherwise go to overseas competitors. Deepening the channel will allow the deeper draft service boats to use Houma Navigation Canal not only as a base of operations but also take advantage of the near by construction and repair facilities located along the canal. Also, the strategic location of the canal allows for less costly trips to the deepwater tracts in the Gulf. These advantages give rise to substantial NED benefits.

### Source of Benefits

The benefits of deepening the channel in the Houma Navigation Canal are derived mainly from cost reduction for the navigation interests in the area. Most deep draft vessels that could be serviced and/or repaired at facilities on the canal are currently being diverted to other facilities that have deeper draft channels. This diversion increases a vessel's total operating costs. Many firms located on the Houma Navigation Canal maintain satellite offices at deepwater ports for the purpose of servicing, maintaining and repairing their deeper draft vessels. Also, some of these vessels are constructed at firms located on the Houma Navigation Canal and must be completely "unloaded", towed down the canal and sent to a facility that has a deeper channel and then loaded (filled with fuel, water, etc,) before it can be put into service. This adds to the costs of these boats. Deepening the channel would alleviate this situation and net to a true NED benefit.

Estimation of Benefits

The Terrebonne Parish Consolidated Government Department of Planning & Economic Development contacted with the consulting firm Loren C. Scott & Associates, Inc. to determine the economic impact of deepening the Houma Navigation Canal. The contractor was charged with determining if there was an economic benefit for changing the dimensions of the channel from 15 feet deep by 150 feet bottom width to 20 feet deep or greater with a 200 feet bottom width. The contractor contacted the New Orleans district for assistance in designing his questionnaire. He was informed that any benefits must be verifiable and be NED benefits. The contractor's questionnaire was reviewed and met these criteria. The survey was conducted in the spring of 2000 and final report was issued in May of that year. A copy of the report was sent to the Corps of Engineers New Orleans District.

This report forms the basis for determining the benefits of dredging the channel. The report listed 12 large firm on the Houma Navigation Canal that indicated saving from deepening the channel to 20 feet or more. The firms' responses to the contractor's survey were reviewed to determine applicability to Corps standards, i.e. are the saving claimed true NED benefits. Most of these firms were contacted again to verify the annual average savings data they provided to the contractor. Eight of the 12 firms met the requirements for NED savings. The table below summarizes the savings.

| | | 20+ Feet Deep Per Yr Savings | **Reasons for Savings** |
|---|---|---|---|
| 1 | Cenac Towing | $1,300,000 | Transit savings |
| 2 | Chet Morrison Contractors | $2,000,000 | Launch fully loaded vessels |
| 3 | Edison Chouest | $2,000,000 | Consolidating of work in one facility |
| 4 | Gulf Coast International Insp. | $500,000 | Consolidating Facilities |
| 5 | Mamou Heavy Lift | $5,000,000 | Use of larger more efficient equipment |
| 6 | Offshore Specialty Fab. | $3,000,000 | Use of larger more efficient equipment |
| 7 | Quality Shipyards | $300,000 | Rigs and vessels could float in directly |
| 8 | Skagit/SMATCO | $400,000 | More efficient use of equipment |
| | **Total** | $ 14,500,000 | |

Estimation of Costs

The Houma navigation Canal is currently maintained to an authorized depth of 15 feet with a bottom width of 150 feet. This project would deepen the channel an additional 5 feet and widen the bottom to 200 feet. Deepening and widening the channel will also require bank stabilization along certain reaches. The total cost of this project will be the initial cost of deepening and widening and the incremental maintenance cost for the extra width and depth. The NOD engineering branch has estimated the costs of construction and incremental maintenance for the 50-year life of the project.

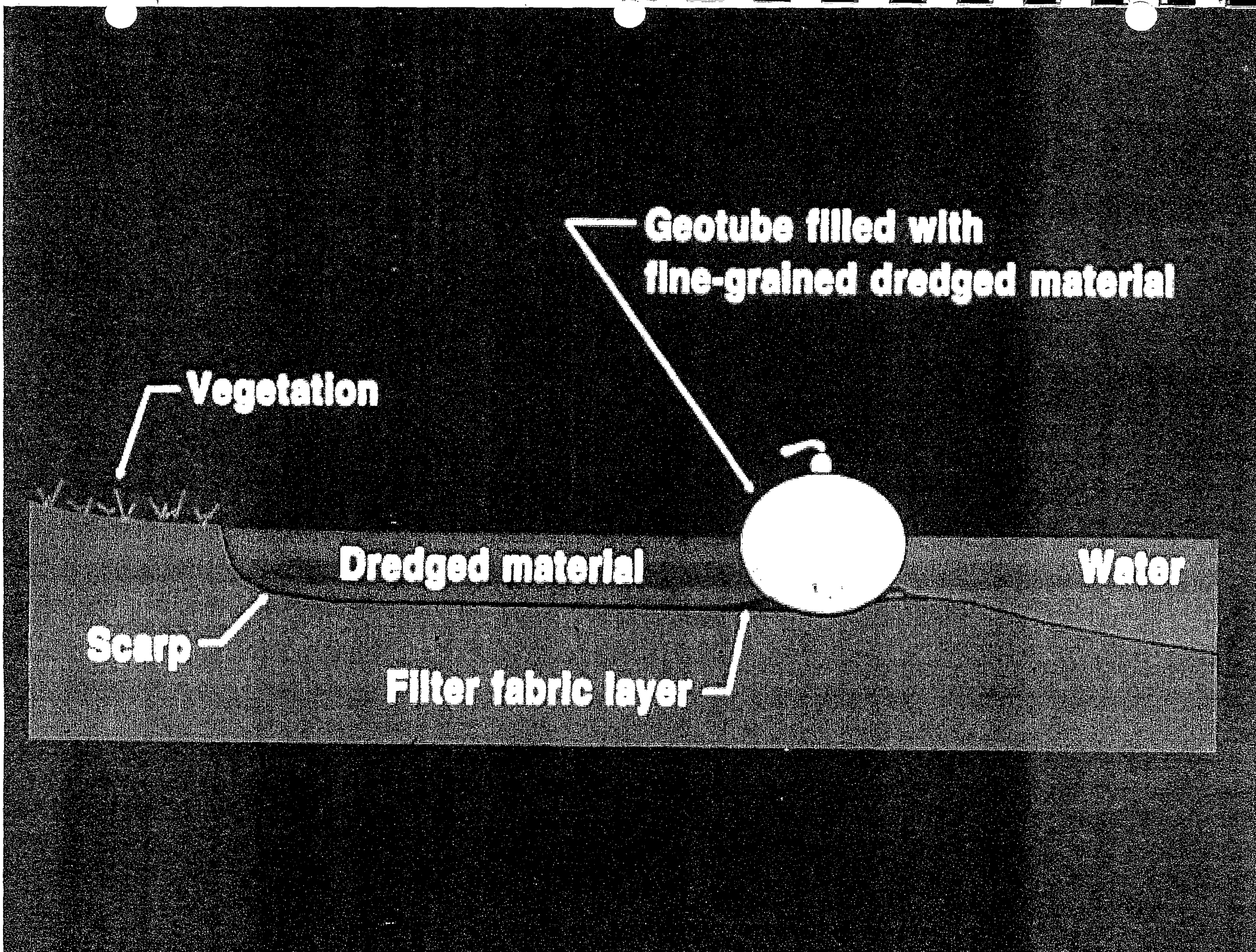
**Houma Navigation Canal Sec. 107 CAP Project**
**Incremental Costs**
**Authorized Channel Depth –20 feet NGVD***

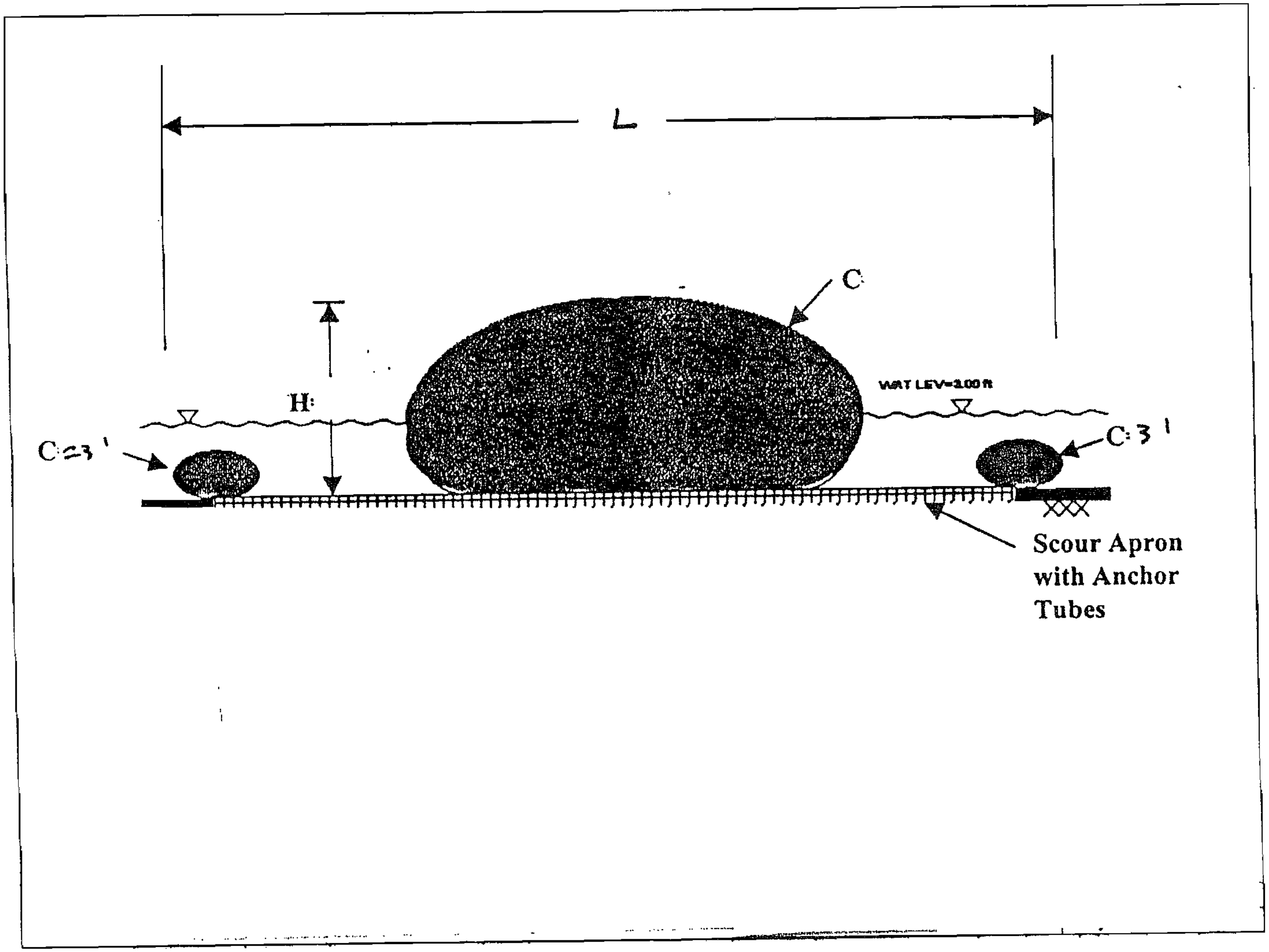
| Maintenance Cycle | Maintenance Costs | First Costs |
|---|---|---|
| 2002 | | $12,000,000 |
| 2003 | | $36,114,625 |
| 2004 | | $30,568,750 |
| 2005 | | $20,565,500 |
| 2009 | $760,000 | |
| 2013 | $760,000 | |
| 2017 | $760,000 | |
| 2021 | $760,000 | |
| 2025 | $760,000 | |
| 2029 | $760,000 | |
| 2033 | $760,000 | |
| 2037 | $760,000 | |
| 2041 | $760,000 | |
| 2045 | $760,000 | |
| 2049 | $760,000 | |
| 2053 | $760,000 | |

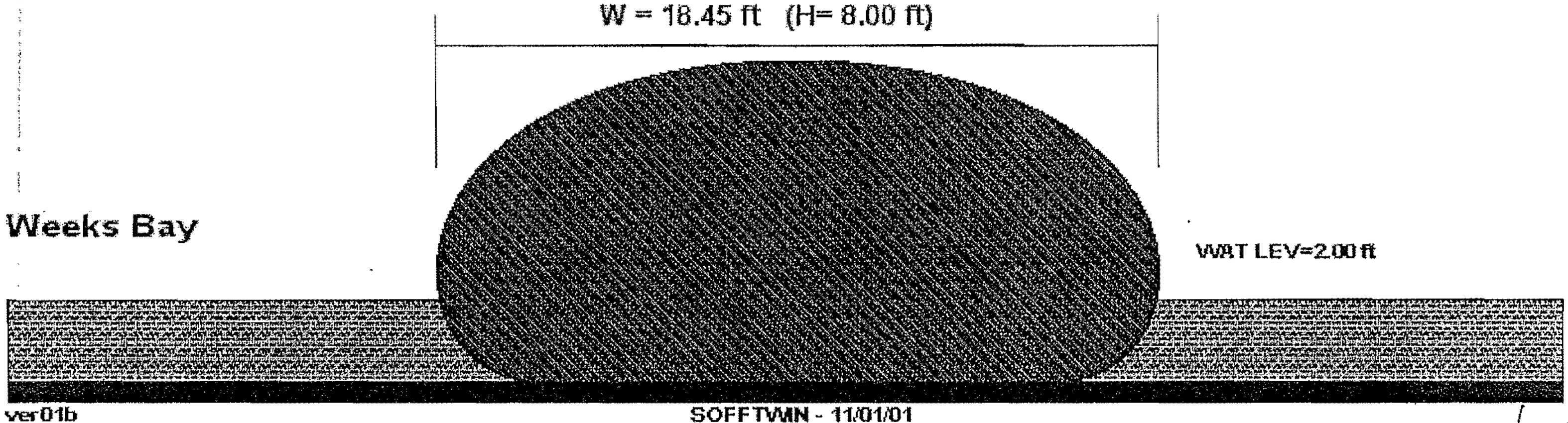
*Actual channel depth -23.0' NGVD for maintenance

## Calculation of Benefit-Cost Ratio

The cost/benefit ratio for a project is calculated determining the average annual benefits derived from implementation of the project and dividing it by the average annual cost of the project. The average costs and benefits are derived by determining the present value of both streams and amortizing that amount over the life of the project. Both the benefits and costs are discounted and amortized at the appropriate federal interest rate. The current rate of 6 3/8% was used in this calculation. The average annual benefit for this deepening project is $14,500,000 and the average annual cost is $7,411,168. This gives a benefit to cost ratio of 2.0.


Geotube filled with
fine-grained dredged material
Vegetation
Dredged material
Water
Scarp
Filter fabric layer


L
C:
H:
WAT LEV=3.00 ft
C:=3'
C:3'
Scour Apron
with Anchor
Tubes



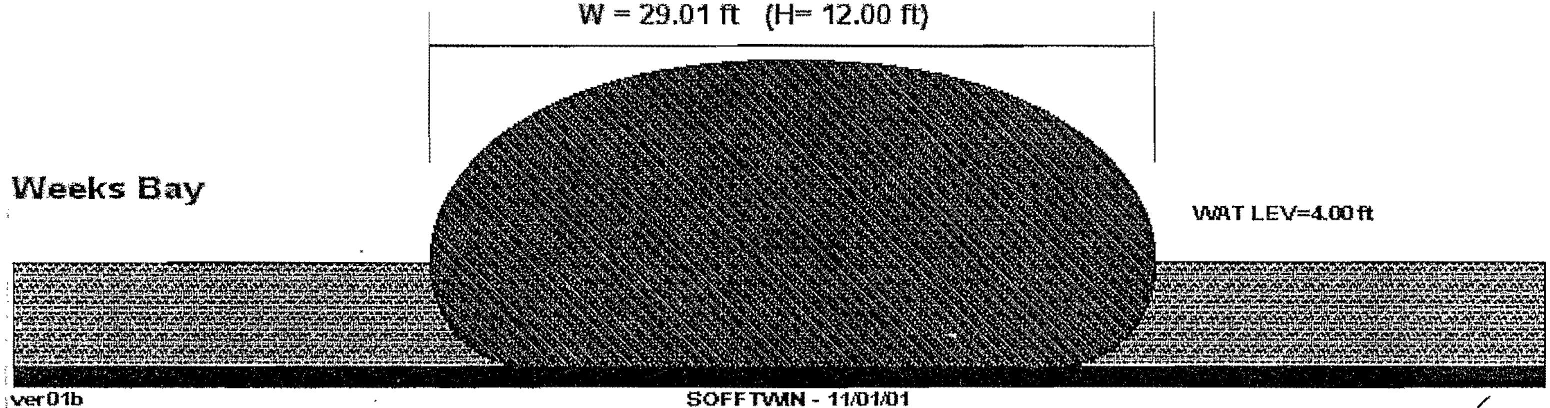

( GSE = -2

GIVEN C = 45.00 ft H = 8.00 ft SPG = 2.00 FS = 5.00

| | | |
|---|---|---|
| DENSITY OF SLURRY | = | 124.8 pcf |
| TUBE CIRCUMFERENCE, C | = | 45.00 ft |
| EX PRESS -TOP OF TUBE, P | = | 2.120 ft (water) 0.9185 psi |
| WORKING CIRCUM FORCE, Tcir | = | 205.1 lbs/in 2460.8 lbs/ft |
| WORKING AXIAL FORCE, Tax | = | 129.2 lbs/in 1550.4 lbs/ft |
| TOTAL HEIGHT OF TUBE, H | = | 7.999 ft |
| TOTAL WIDTH OF TUBE, W | = | 18.45 ft |
| BASE CONTACT WIDTH OF TUBE | = | 13.39 ft |
| END AREA OF TUBE | = | 124.8 sq ft 77.41 % FULL |
| TUBE VOLUME, V | = | 4.621 cu yd/ft 933.2 gal/ft |
| FABRIC AREA TO VOL RATIO,R | = | 1.082 sq yd/cu yd |
| BASE PRESSURE | = | 7.851 psi 18.12 ft (water) |
| REQ'D CIRCUM STRENGTH T | = | 1025. lbs/in 12304. lbs/ft |
| REQ'D AXIAL STRENGTH | = | 646.0 lbs/in 7752.1 lbs/ft |

| |
|---|
| Weeks Bay |
| CWPPRA |

Fig 3




GIVEN C = 70.00 ft H = 12.00 ft SPG = 2.00 FS = 5.00

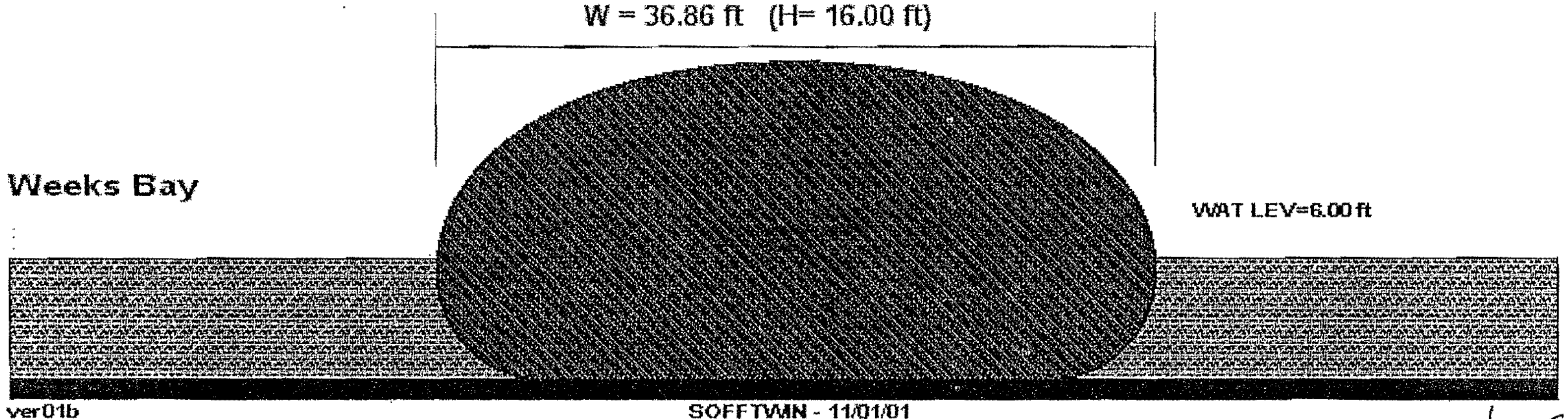
CGSE = -4

| | | |
|---|---|---|
| DENSITY OF SLURRY | = | 124.8 pcf |
| TUBE CIRCUMFERENCE, C | = | 70.06 ft |
| EX PRESS -TOP OF TUBE, P | = | 2.580 ft (water) 1.118 psi |
| WORKING CIRCUM FORCE, Tcir | = | 433.1 lbs/in 5196.9 lbs/ft |
| WORKING AXIAL FORCE, Tax | = | 262.6 lbs/in 3151.3 lbs/ft |
| TOTAL HEIGHT OF TUBE, H | = | 11.99 ft |
| TOTAL WIDTH OF TUBE, W | = | 29.01 ft |
| BASE CONTACT WIDTH OF TUBE | = | 21.36 ft |
| END AREA OF TUBE | = | 295.2 sq ft 75.57 % FULL |
| TUBE VOLUME, V | = | 10.93 cu yd/ft 2208. gal/ft |
| FABRIC AREA TO VOL RATIO,R | = | 0.7120 sq yd/cu yd |
| BASE PRESSURE | = | 11.51 psi 26.56 ft (water) |
| REQ'D CIRCUM STRENGTH T | = | 2165. lbs/in 25985. lbs/ft |
| REQ'D AXIAL STRENGTH | = | 1313. lbs/in 15757. lbs/ft |





Fig. 14.




LGSE = -6

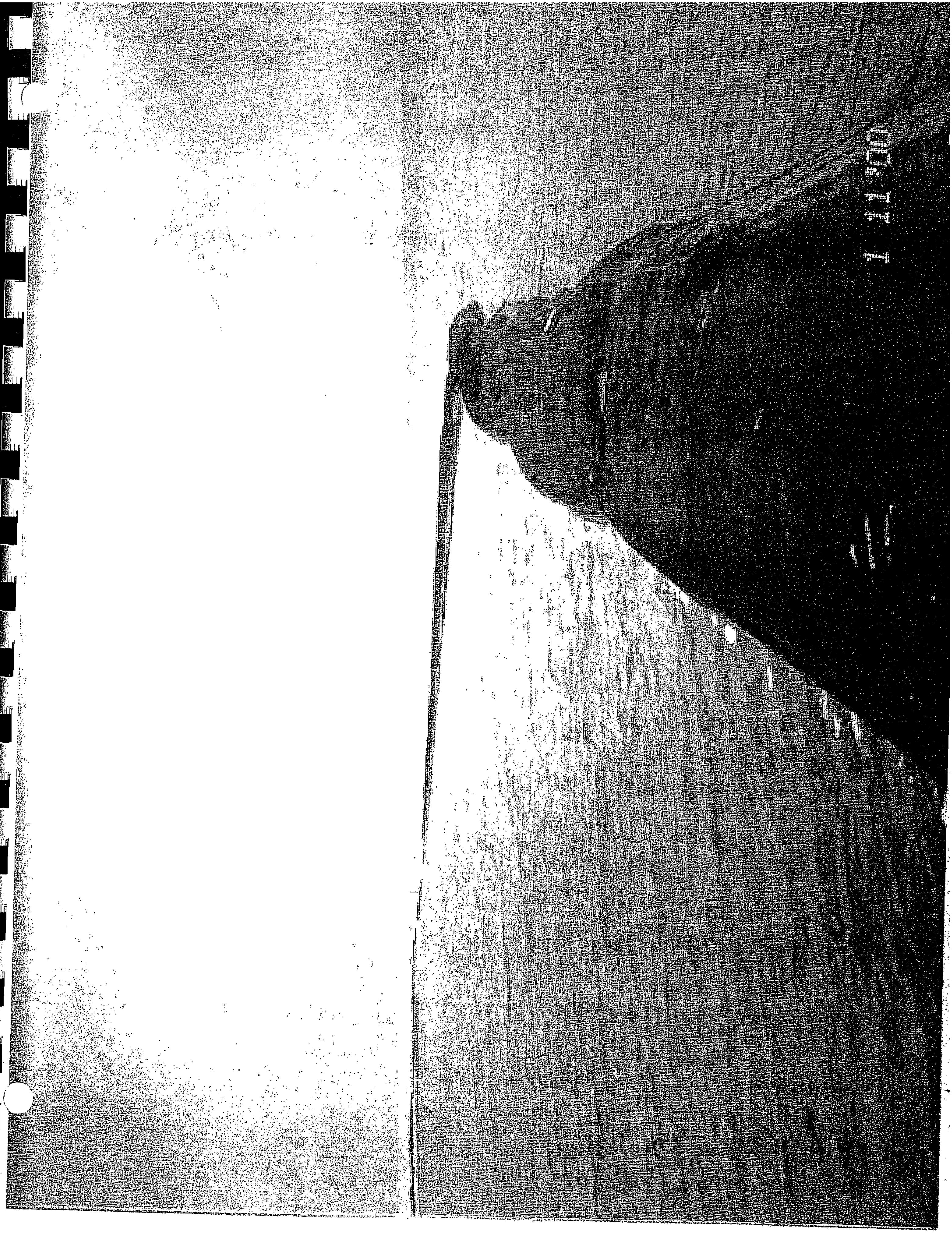
GIVEN C = 90.00 ft H = 16.00 ft SPG = 2.00 FS = 5.00

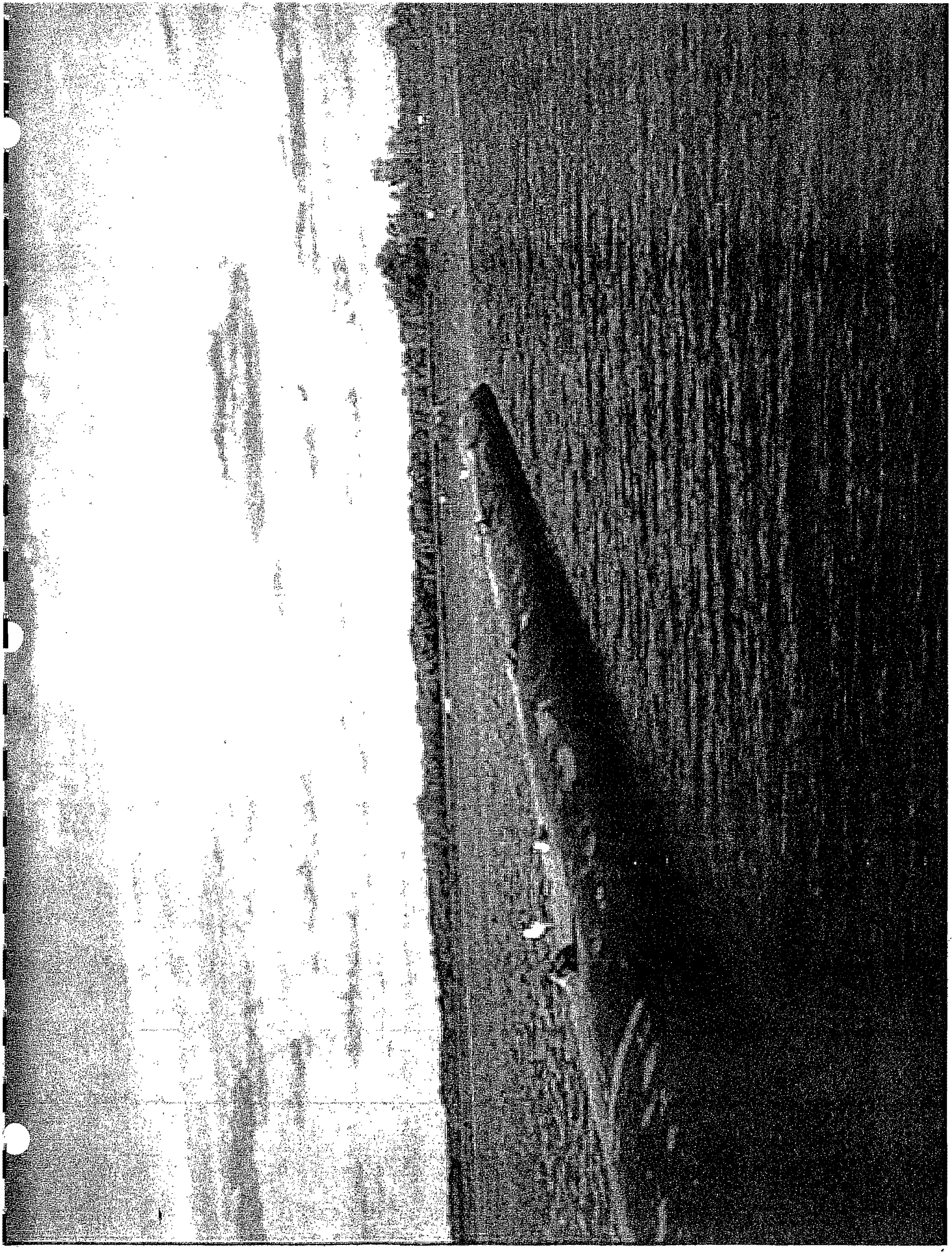
| | | |
|---|---|---|
| DENSITY OF SLURRY | = | 124.8 pcf |
| TUBE CIRCUMFERENCE, C | = | 89.92 ft |
| EX PRESS -TOP OF TUBE, P | = | 3.938 ft (water) 1.707 psi |
| WORKING CIRCUM FORCE, Tcir | = | 782.0 lbs/in 9384.2 lbs/ft |
| WORKING AXIAL FORCE, Tax | = | 462.0 lbs/in 5544.2 lbs/ft |
| TOTAL HEIGHT OF TUBE, H | = | 16.00 ft |
| TOTAL WIDTH OF TUBE, W | = | 36.86 ft |
| BASE CONTACT WIDTH OF TUBE | = | 26.43 ft |
| END AREA OF TUBE | = | 499.4 sq ft 77.62 % FULL |
| TUBE VOLUME, V | = | 18.50 cu yd/ft 3735. gal/ft |
| FABRIC AREA TO VOL RATIO,R | = | 0.5402 sq yd/cu yd |
| BASE PRESSURE | = | 15.57 psi 35.94 ft (water) |
| REQ'D CIRCUM STRENGTH T | = | 3910. lbs/in 46921. lbs/ft |
| REQ'D AXIAL STRENGTH | = | 2310. lbs/in 27721. lbs/ft |

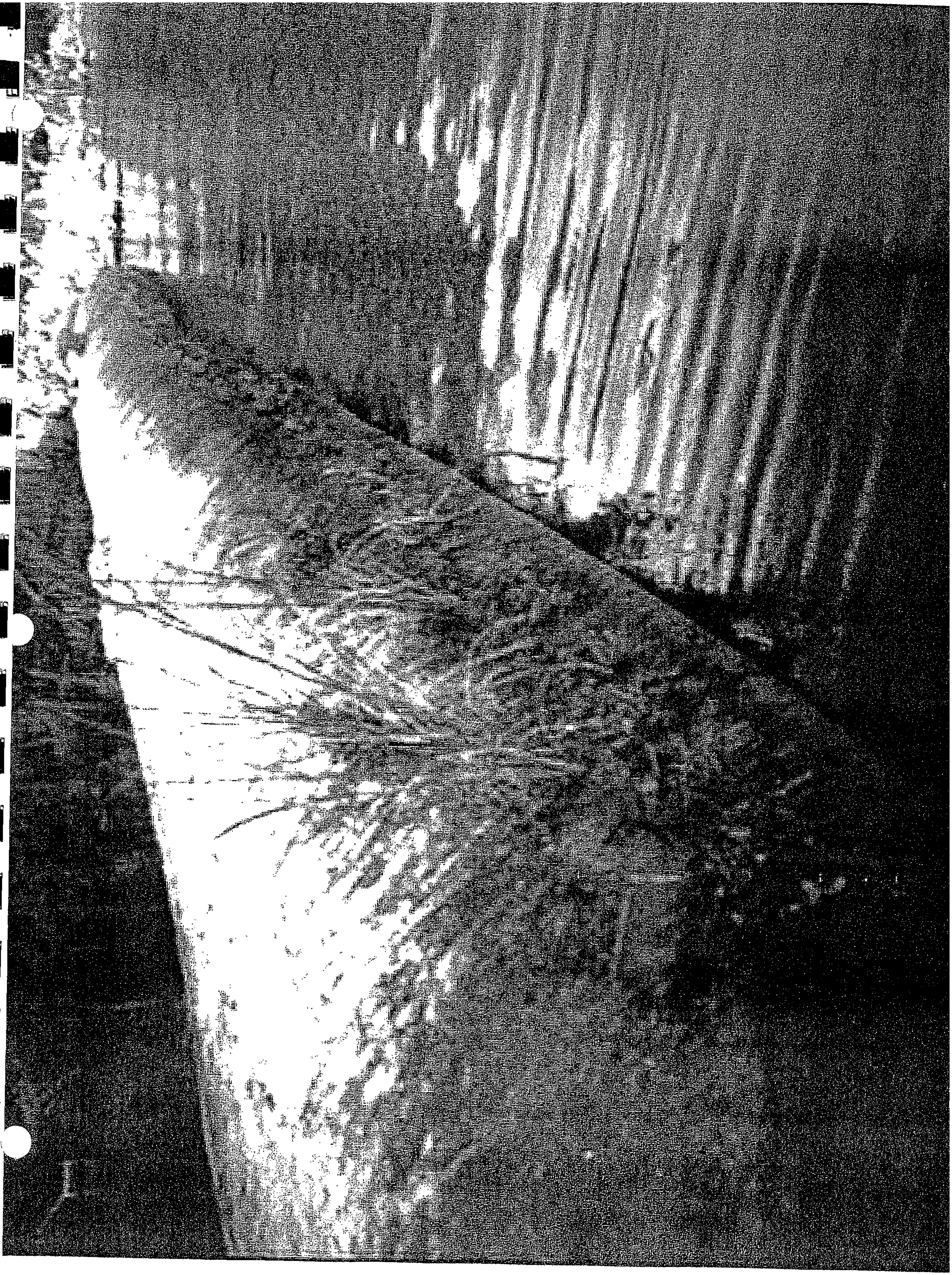
Weeks Bay
CWPPRA

4

Fig 5







**Cost Estimates:**

| | | |
|---|---|---|
| Geotubes for 2 foot depth @ $150/lf for 3 miles (15,840 ft) | = | $2,376,000 |
| Contingencies (25%) | | . 594,000 |
| Subtotal: | | 2,970,000 |
| E&D, S&A (15%) | | 445,000 |
| **TOTAL:** | | **($3.4 million)** |

| | | |
|---|---|---|
| Geotubes for 4 foot depth @ $200/lf for 15,840 lf | = | $3,168,000 |
| Contingencies (25%) | | 792,000 |
| Subtotal: | | 3,960,000 |
| E&D, S&A (15%) | | 594,000 |
| **TOTAL:** | | **($4.6 million)** |

| | | |
|---|---|---|
| Geotubes for 6 foot depth @ $250/lf for 15,840 lf | = | $3,960,000 |
| Contingencies (25%) | | 990,000 |
| Subtotal: | | 4,950,000 |
| E&D, S&A (15%) | | 745,000 |
| **TOTAL:** | | **($5.7 million)** |

# Geotextile Tube Structures for Wetlands Restoration and Protection: An Overview of Information From the National Workshop on Geotextile Tube Applications

by Jack E. Davis[1] and Mary C. Landin[2]

**Background**

In recent years, the U.S. Army Corps of Engineers (USACE) has increasingly used geotextile tubes to provide temporary or permanent breakwaters, especially when coupled with a goal of using dredged material for wetland restoration or other natural resource beneficial uses. The first application of geotextile fabrics for wetlands and habitat development occurred in the early 1970s in Galveston Bay, Texas, and later in Core Sound, North Carolina. Large nylon bags (12 ft x 4 ft x 3 ft) were filled in place hydraulically with sandy dredged material to form stacked breakwaters. By the mid-1980s, the Corps was testing and using 100-ft-long, 3-ft-diam Longard tubes made of low-tensile-strength geotextiles. These were all used in underwater situations to improve water quality, to provide surge protection, and to protect sea grass and other aquatic habitats. Their construction was awkward, and the tubes were very difficult to fill. They were not very stable, and their use declined.

In the early 1990s, USACE developed a renewed interest in evaluating and using custom-made geotextile tubes as containment dikes for the placement of dredged material. After placement, the tubes act as erosion protection structures for the dredged material, and for any intertidal wetlands that may develop. In some places, the tubes are being used as low-crested, reef-type breakwaters placed offshore of existing or newly restored wetlands.

The new interest in geotextiles tubes is twofold. First, they can be deployed relatively quickly, with several hundred feet being placed in a day. Second, they are relatively inexpensive, with cost being based largely on the application and when they are constructed. The tubes are delivered to the site either rolled up (Figure 1) or folded like an accordion. The tubes, which have ranged between 8 and 45 ft in circumference and anywhere from 100 to 1,000 ft long, are spread out along a desired alignment (long tubes are usually deployed a few hundred feet at a time). The tube is then filled with sediment, which is supplied to the tube in a slurry from a pump, usually from a dredge. Mobilization of the dredge is usually the largest cost in deploying a tube. In most projects, a dredge is probably already mobilized as part of a channel maintenance project. Therefore, mobilization of a dredge is usually not included in the cost of constructing the tube. In some recent projects in Texas, constructed costs were around $50 per linear foot of project. In one project, where a dredge had to be mobilized to fill a short tube, costs exceeded $200 per linear foot.

Figure 1. Geotextile tubes being delivered to project site

**National Workshop on Geotextile Tube Applications**

During the planning for use of geotextile tubes, many questions are raised about the best techniques for designing, deploying, filling, and handling the tubes. After responding to numerous requests for assistance in this regard, and realizing that information is exceedingly limited regarding geotextile tube structures, WES developed a workshop to document recent experiences with geotextile tubes (Davis and Landin 1997). Discussions at the workshop focused on specific case studies, experiences with deploying and filling tubes, hydrodynamic and geotechnical engineering design, geotextile fabric characteristics, and risk and contingency planning. Fifty participants at the workshop came from USACE Headquarters, Districts and laboratories, the Port of Houston Authority, academia, engineering consulting firms, material suppliers, and dredging contractors. The workshop was held in Galveston, Texas, 15-17 August 1995, and was hosted by the U.S. Army Engineer District, Galveston. The workshop was cosponsored by the USACE Wetlands Research Program, Dredging Research Program, and Dredging Operations Technical Support Program, all of which were conducted by and managed at WES.

The workshop produced two significantly important deductions; (a) limitations of geotextile tubes were identified, and (b) criteria for geotextile tube applications were developed. It was determined that, in general, geotextile tubes have worked well for wetlands restoration and protection projects. Geotextile tubes discussed at the workshop are basically two sheets of fabric sewn together along their edges and filled with dredged material. More complicated tube designs have been used, but the more complicated the design, the more expensive it is to manufacture and utilize. Fine-grained sediments have been used as filler for tubes, but post-construction consolidation of the fill material can become a problem unless alternative measures to alleviate such situations are anticipated in advance. Unless otherwise noted, it was assumed that sand was used as the filler material.

**Limitations of Geotextile Tubes**

Concerns raised at the workshop were the same as those previously promulgated by Pilarczyk (1995) in his review of novel systems for coastal engineering. Participants were concerned about; (a) fabric resistance to puncture and abrasion, (b) fabric degradation in the environment, especially due to ultraviolet (UV) light exposure, (c) difficulty with placing a tube precisely on alignment, (d) difficulty with achieving a consistent crest height along the length of the tube, and (e) lack of hydraulic, hydrodynamic, and geotechnical design guidance.

Experience indicates geotextile tube resistance to punctures and abrasion is low. Puncturing the material with a blunt object (e.g., bow of a boat) is not easy; however, it takes little effort to puncture even the highest strength material (e.g., 1,000 lb/in. tensile strength) with a sharp object like a knife. Consequently, in almost any area where the public has had easy access, the tubes have been vandalized (possibly from curiosity about what is inside). Debris (e.g., a stump with pointed roots) that is forced against the tube by waves or currents may puncture and abrade the material and, although it was not reported at the workshop, participants suspected that ice could also abrade or puncture the fabric. The fabric also can be abraded during shipping and handling, and during deployment. For example, tubes deployed off the deck of a barge could be torn by any sharp edge or protrusion on the deck. Tubes have been damaged by equipment (e.g., dredge pipe flanges) that was dragged across the tubes during construction. Workshop participants noted that torn tubes will usually lose sediment only within a few feet on either side of the tear. Most of the tube beyond the damaged section will remain intact.

Figure 2. Geotextile tube tears due to ultraviolet sunlight damage

Fabric degradation rates due to natural UV light are unknown. Laboratory tests exposing fabrics to intense UV radiation have been conducted and the results suggest that the fabric is resistant to a degree, but the results cannot be extrapolated to actual field applications. Some workshop participants suggested that tubes could last several decades (20-50 years) in the field, but others contended that without data, an estimate of 10-20 years might be better for planning. Since the workshop, tubes (originally 400 lb/in. tensile strength) have been inspected along the Texas coast, and it is suspected that the tubes are tearing where fabric has been weakened by sunlight (Figure 2). This particular tube is 4 years old and is exposed to sunlight most of the time. The effect of ultraviolet light is significantly reduced or eliminated when tubes are submerged or covered by sediments and marine growths.

The constructed quality (final height and alignment) of the tube depends on the skill of the construction contractors, the quality of the fill material, and the environmental conditions under which the deployment and filling take place. The skill and experience of some contractors are increasing within the dredging industry, but no method has yet been widely accepted or documented as the best approach to deploy and fill tubes. If fill material is used that consolidates over time, the height of the tube will decrease over time, possibly to a height that is insufficient for the tube's intended purpose. Deploying tubes in waves and currents can make holding the tubes on a given alignment very difficult. If the tube is not placed directly on a given bed elevation, variations in the bed elevation can cause variations in the tube crest elevation. Also, a tube may twist (roll slightly) to one side during filling. When such a twist occurs, it moves off alignment, and puts the filling ports to the side of the tube instead of on top. Figure 3 shows the variation in crest elevation along a tube and from one tube to the next. In the foreground, the filling port is seen off-center, suggesting that the tube may have rolled slightly during filling. Figure 4 shows the variability in the alignment of a tube.

Some variations of crest height cannot be avoided. If the contractor stops filling a tube prematurely, because of weather, for example, sand in the tube will stabilize and tend to flatten the tube. Once that happens, it is very difficult to pump the tube up higher. Also, low spots always occur near the filling ports, with random undulations elsewhere. It is not surprising to find variations of one-half foot or more along the length of the tube. Based on conclusions from the workshop, it is expected that more than 5 ft in final tube height cannot readily be achieved regardless of the size of the tube used. Greater final tube height may be possible to achieve, but it has not been the dominant experience of the workshop participants.

Existing guidance is limited for designing and predicting the stability of tube structures. Some techniques modified from other structure design criteria were discussed at the workshop. It was suggested that the U.S. Army Corps of Engineers (1984) or Minikin (1983) methods for predicting loads on vertically faced structures could be used. Similarly, techniques recommended by Goda (1985) and Walton et al. (1989) could be used. The resisting forces (bed friction and weight) can be estimated. A force balance will then indicate whether the tube is likely to move due to wave and current loading. Suggested friction angles provided at the workshop are 18 deg for fabric on fabric (i.e., stacked tubes) and 25 deg for fabric on sand. WES maintains a discrete-element model that can be used to simulate the deformation of a tube in two-dimensional cross section under loading. Sprague (1995) offers a graphical technique for estimating the strength of fabric needed for an application. Most participants agreed that if there is concern about the strength of the fabric, then stronger fabrics should be utilized (fabrics with at least 1,000 lb/in. fabric tensile strengths are available). Sprague (1995) also presents a technique for selecting the spacing for filling ports along the crest of the tube. However, all of the approaches discussed in the literature disregard the three-dimensional nature of the tubes.

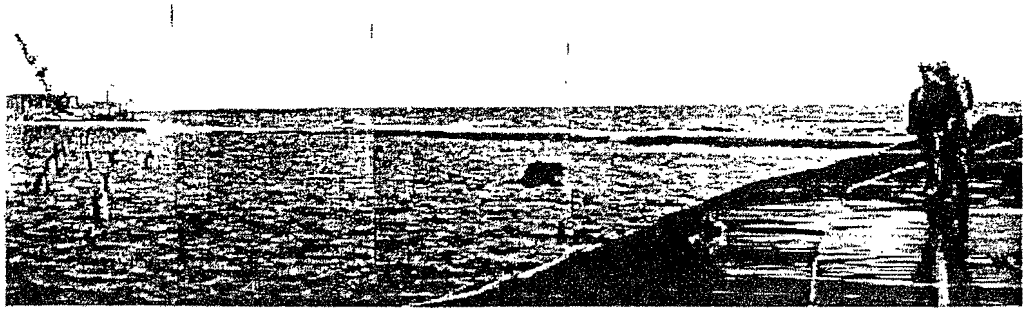


Figure 3. Variation in crest elevation along a geotextile tube, and from one tube to the next

## Criteria for Geotextile Tube Applications

Based on the limitations of geotextile tubes and the assembled experiences of the participants, general criteria were compiled that can be used to indicate appropriate applications for geotextile tubes. (Pilarczyk (1995) also identifies several of these criteria). The criteria essentially state the conditions under which the participants noted successes in geotextile tube projects. The criteria may not be entirely complete, but will serve as a fundamental guide for geotextile tube siting applications. The criteria list is not prioritized.

**Shallow Water, Low Tidal Range, Low Wave Energy:** Tubes have been used successfully where water depths are small (<<3 ft), where the tidal range is small (<<3 ft), where fetches are less than 15 miles, and where the depth for a considerable distance offshore is less than 10 ft. Wave climate is low in these areas, so the large mass of the tubes makes them very stable.

**Temporary:** A good use for a geotextile tube is as a temporary structure, although this utilization carries several implications. First, a tube could be ideally used as a truly temporary structure. Tubes have been placed as groins to prevent the possible migration of beachfill sand into a nearby bed of sea grass. There was great uncertainty regarding which way sand from the project would migrate. Rather than spend money studying the coastal processes in this very small area, the groin was installed as a precaution. After construction of the beachfill, the real transport characteristics of the site could be readily observed. Second, a temporary tube could be one that has scheduled maintenance (i.e., it will be repaired or replaced when damaged). Third, a temporary tube could be hidden and only become effective during certain conditions. Geotextile tubes have been buried in the berm or dune of a beach and only become effective when erosion exposes them (for instance, during a storm). Once exposed, maintenance is usually required to repair and/or rebury it. A hidden tube is not exposed to vandalism or debris damage, and it blends into the environment well.

**No threat to life or property:** Geotextile tubes are effective structures as long as they remain intact but, since their durability is uncertain, depending on them to protect life or property for long periods of time (without maintenance) is not recommended. A good application, then, is one where no risk to life or property exists should the tube fail.

**Flexible height and alignment requirements:** Since aligning geotextile tubes during placement and achieving consistent crest elevation along the length of the tubes may be very difficult, the best applications for geotextile tubes are where variations in these parameters are tolerable.

**Associated with an existing dredging project:** The growing popularity of geotextile tubes is due to several factors, the main one being that they are usually less expensive than other protection or containment alternatives. Geotextile tubes are most cost- effective when used in conjunction with a dredging project because the cost of mobilizing a dredge to fill the tubes is minimized. The cost of tube construction is maximized when a dredge has to be mobilized on short notice to fill a small section of tube.

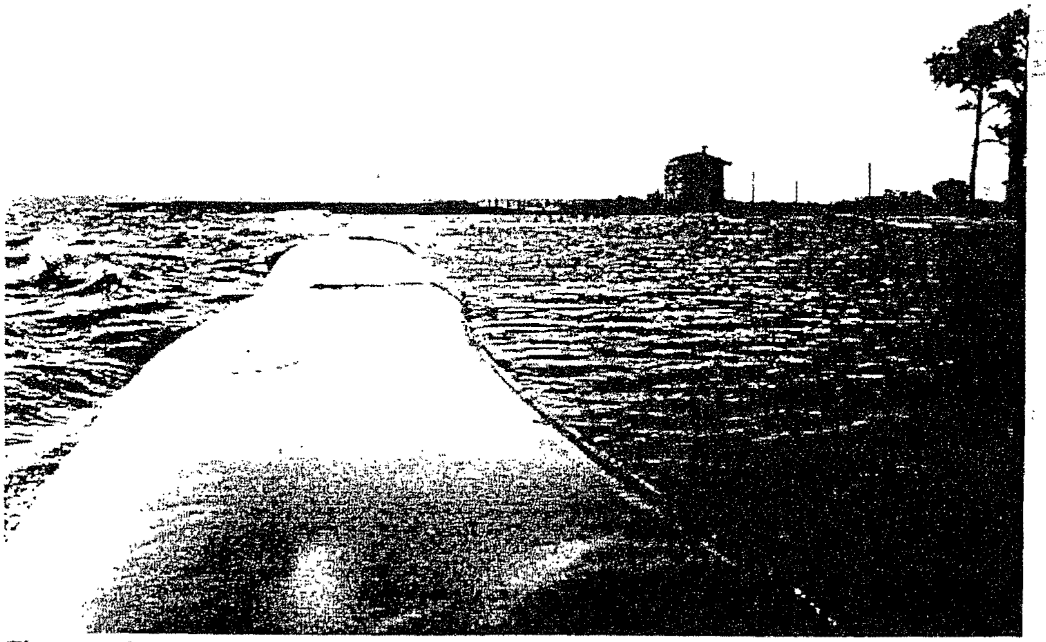


Figure 4. Variation in the alignment of a geotextile tube

**Success in Wetlands Restoration Protection**

USACE has constructed wetlands restoration projects on disposed dredged material using geotextile tubes as containment dikes and for erosion protection in the Chesapeake Bay near Smith Island, Barren Island, the Pokomoke River, and Eastern Neck National Wildlife Refuge, along the Gulf Intracoastal Waterway in West Bay north of Galveston Island, and near the Aransas National Wildlife Refuge in Texas. These wetlands restoration projects were initiated in areas where wetlands once existed. The areas are generally in shallow water with low tidal ranges and, consequently, low wave energies. Because the area in the lee of the structures is intertidal marsh, the tubes were built to low elevations so that they would be sufficient to protect the root mat of the marsh from erosion. The naturally low and wide cross-sectional shape of a geotextile tube makes it stable and suitable for this application. Figure 5 is an aerial view of one of the projects near the Aransas National Wildlife Refuge.

Low wave energy conditions limit the amount of toe scour that occurs at the tube. A tube should have a geotextile scour apron to prevent toe erosion. The aprons placed at some USACE structures have performed well, suffering little or no damage after several years of service. Some have silted over. However, it is likely that in higher wave energy environments, the apron would not be as effective except perhaps as a temporary measure. Any other type of apron (e.g., stone or concrete) would increase the cost of the project and may damage the tube fabric.

The tubes used in the USACE wetland projects are not necessarily temporary or hidden, but could be maintained. The projects are near navigation channels, so the opportunity for maintenance during subsequent dredging cycles is readily available. The projects are in remote areas of bays where public access is difficult, so the risk of vandalism is low. However, the potential for damage due to debris is always present.

Remoteness of the wetland projects inherently satisfies the criterion that no life or property be at risk in the event of tube failure. The only thing at risk if the geotextile tube is damaged is potential erosion of a portion of the wetland that was restored. Such erosion may actually be ecologically desirable. After the wetlands have developed behind the geotextile tubes, it is often desirable to open up the area to the ingress and egress of marine organisms. Removal of a tube is an option. Furthermore, when part of the wetland is eroded, it often remains as shallow open water or as a mud flat, both of which provide diversity of habitat.

Random height variations along the length of a geotextile tube cause a varying amount of wave transmission into the marsh along the tube. This varying wave energy results in a somewhat random and natural-looking plant growth and propagation pattern in the lee of the tubes.

All the USACE wetland projects have been associated with existing maintenance dredging where the maintenance material was to be used beneficially. Geotextile tubes provided a means for containing the material and protecting the marsh from erosion in a cost-effective manner. If the projects had been developed separately from maintenance dredging, the costs for the projects would have been excessive.

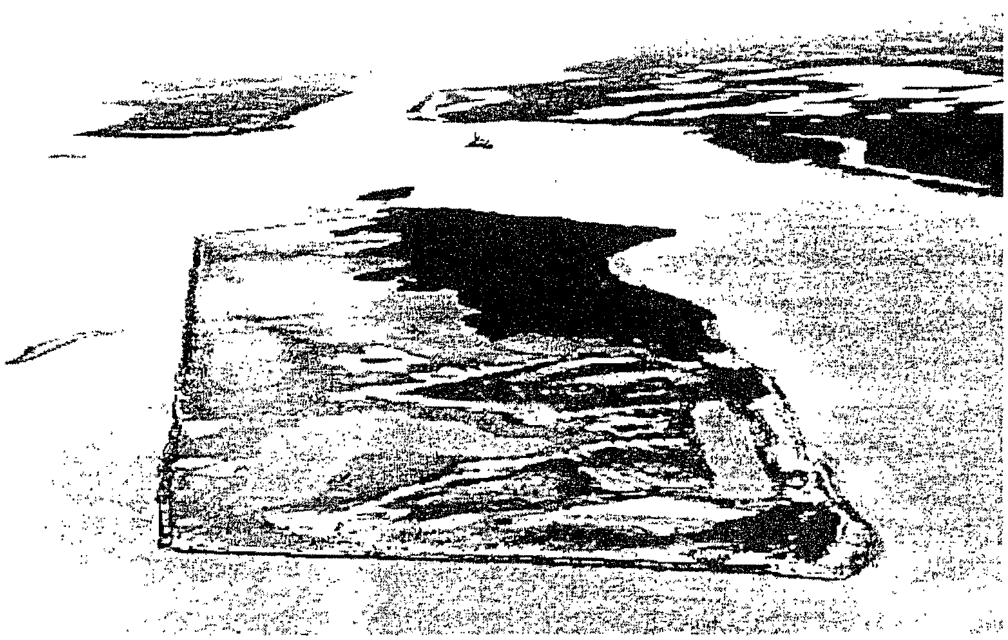


Figure 5. Use of geotextile tubes in wetlands restoration project, Aransas National Wildlife Refuge, Texas

**Conclusions**

Geotextile tubes are being considered by the U.S. Army Corps of Engineers for alternative structure designs at several different applications. Many of these uses severely challenge designers because of the limitations of geotextile tubes. They can be punctured and abraded easily by vandals, debris, and ice; their life expectancy after prolonged exposure to UV light is unknown; and they are difficult to construct to precise alignment and crest elevations. Yet, used as temporary structures, as hidden components of structures, in shallow water with low wave energy and tidal regimes, on projects where there is no risk to life or property in the event of failure, on projects where inspections and maintenance will be established, and/or on projects where sand is being dredged, geotextile tubes can be very effective.

Wetlands restoration projects developed on dredged material placed to intertidal elevations satisfy many criteria necessary for successful geotextile tube application. If funds are available to develop a marsh habitat, the relatively low costs of geotextile tubes makes them an attractive alternative for erosion protection and dredged material containment. Costs for placement of geotextile tubes in several Texas projects varied from $50 to $100 per linear foot. In projects where a dredge was mobilized to fill a short tube, costs approached $200 per linear foot. Geotextile tube containment dikes were generally more expensive than unprotected earthen dikes, but less expensive than an equivalent riprap structure.

Pilarczyk (1995) notes that many worthwhile applications for geotextile tubes exist, but they should not be considered for general coastal engineering applications. The criteria identified at the national workshop, though not all-encompassing, may serve as a reasonable guide because they avoid or minimize the effects of geotextile limitations. While the construction of geotextile tubes is conceptually easy to understand, it should be remembered that these are massive structures. Therefore, to have a successful project, foundation, scour, overtopping, and flanking protection must be given great consideration in design.

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