State of Louisiana

Coastal Protection and Restoration Authority of Louisiana (CPRA)

2018 Operations, Maintenance, and Monitoring Closeout Report

for

Big Island Mining (AT-03)

State Project Number AT-03
Priority Project List 2

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St. Mary Parish

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Operations, Maintenance, and Monitoring Report
for
Big Island Mining
(AT-03)

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Preface

This report includes monitoring data collected through December 2016, and annual Maintenance Inspections through May 2017. The Big Island Mining (AT-03) project is federally sponsored by the National Marine Fisheries Service (NMFS) and locally sponsored by the Coastal Protection and Restoration Authority of Louisiana (CPRA) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III). AT-03 is listed on the 2nd CWPPRA Priority Project List (PPL-02).

The 2018 report is the 2nd in a series of OM&M reports since the end of project construction in October 1998 and is the final manuscript written for the AT-03 project. This Operations, Maintenance, and Monitoring Report as well as an earlier report (Curole and Babin 2010b) in this series are posted on the Coastal Protection and Restoration Authority (CPRA) website at *http://cims.coastal.louisiana.gov/DocLibrary/DocumentSearch.aspx* and on the official CWPPRA website at http://www.lacoast.gov/new/Projects/Info.aspx?num=AT-03 .

I. Introduction

The Big Island Mining (AT-03) project is a sediment diversion and marsh creation restoration project located inside the Atchafalaya Delta. The project lies within the Louisiana Department of Wildlife and Fisheries (LDWF) administered Atchafalaya Delta Wildlife Management Area (WMA) and is positioned approximately 26 km (16 mi) south of Morgan City in St. Mary Parish, Louisiana (Figure 1). The AT-03 project is situated directly across the Atchafalaya River from the Atchafalaya Sediment Delivery (AT-02) project (Figures 1 and 2) and was placed between Big and Shell Islands (Figure 3). The AT-03 project area consists of 1,119 ha (2,765 acres) of fresh marsh, scrub-shrub, wetland forested, beach/bar/flat, submerged aquatics, and open water habitats and has a 427 ha (1,054 acre) reference area (Figure 3).

Atchafalaya Delta growth was originated in 1952 with the deposition of prodelta clay sediments into Atchafalaya Bay. The aggradation of prodelta clay continued until 1962 when distal bar sediments (interlaminated thin sands, silts, and clays) began to accumulate on the bay bottom and form an embryonic subaqueous delta. By the early 1970’s, sand rich distributary mouth bar sediments began to aggrade the Atchafalaya River-Atchafalaya Bay interface and establish subaerial mid-channel bar and levee facies (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992; Majersky et al. 1997; Roberts 1998;). The substantial floods of 1973, 1974, and 1975 hastened the emergence of the sudaerial delta through the frictional deposition of larger grained sediments. These deposits were formed into a bifurcating network of mid-channel bars and secondary and tertiary distributary channels. During this time, seaward channel elongation and bifurcation were the geological mechanisms governing delta growth (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992; Roberts 1998;). In this period of rapid delta development, 1973 to

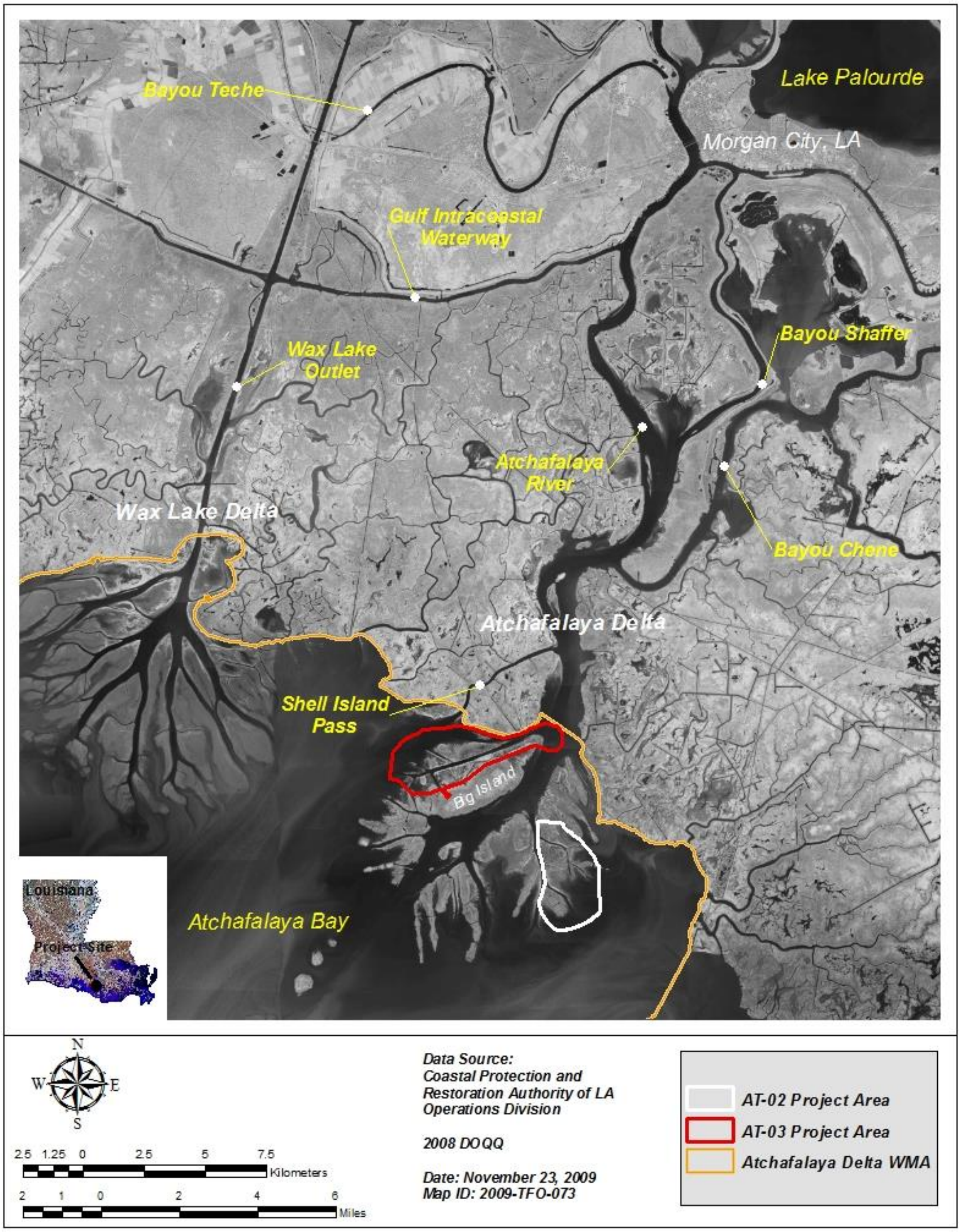


Figure 1. Location and vicinity of the Big Island Mining (AT-03) project.

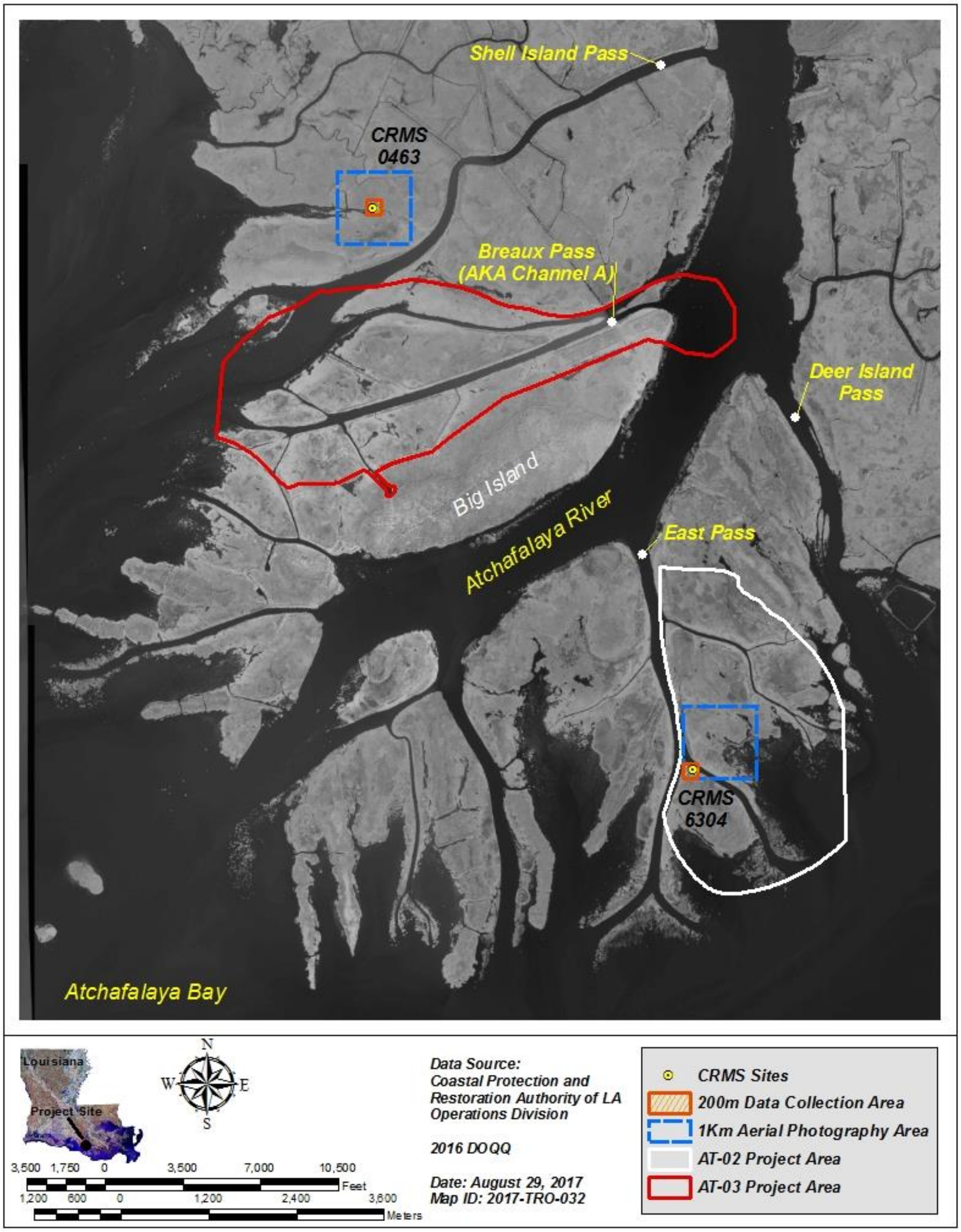


Figure 2. **Location of the Atchafalaya Sediment Delivery (AT-02) project across the Atchafalaya River from the Big Island Mining (AT-03) project. The position of two CRMS-*Wetlands* sites are also shown. CRMS0463 is situated north of the AT-03 project area.**

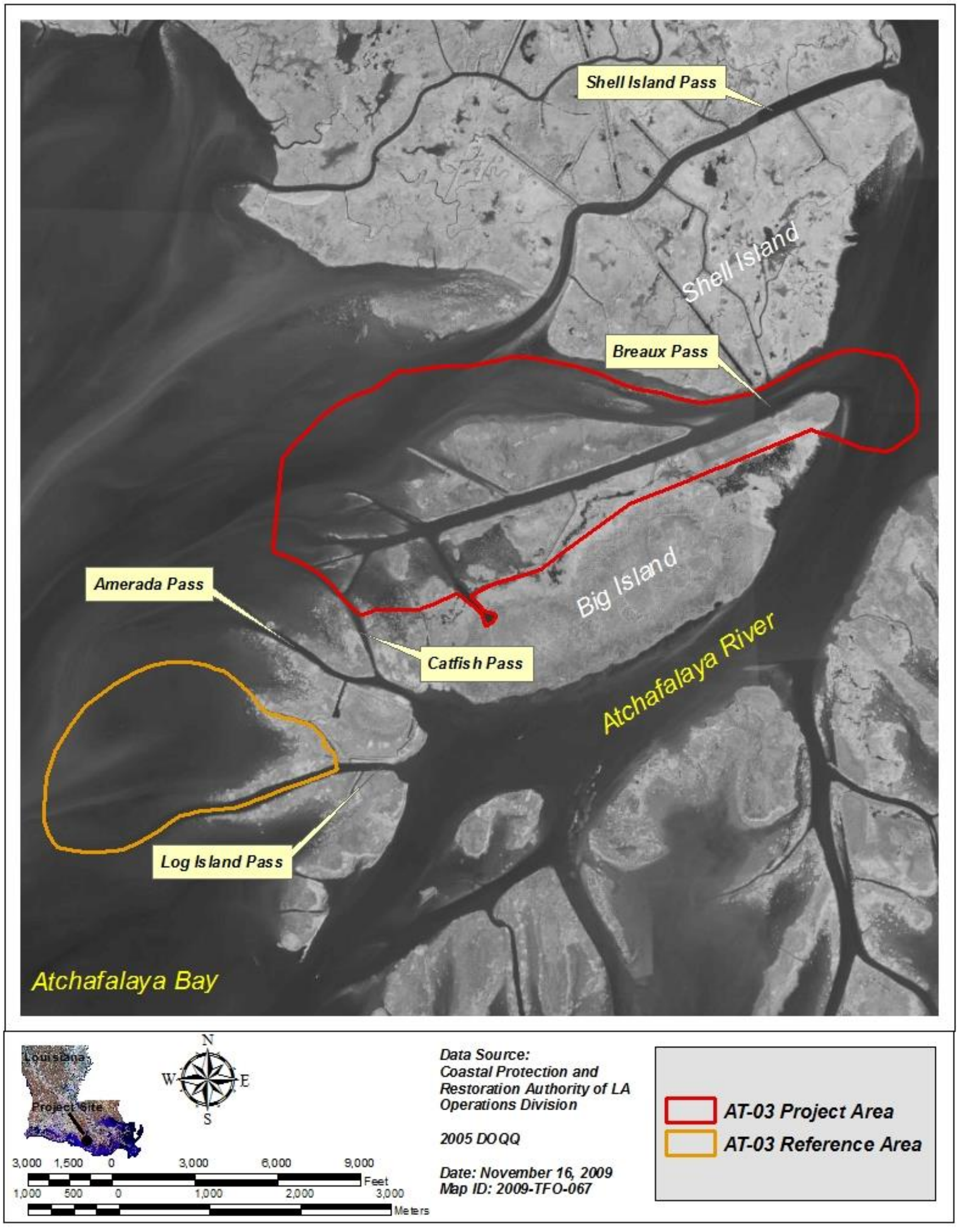


Figure 3. Location of the Big Island Mining (AT-03) project and reference areas.

1976, the land in the Atchafalaya Delta expanded at a rate of 525 ha/yr (1,297 acres/yr) (van Heerden et al. 1991). After 1976, channel abandonment and lobe fusion became the dominant geological processes forcing delta growth. These processes are initiated when subaqueous bars form across tertiary channels leading to deposition of fine grained sediments, channel narrowing, and lobe fusion (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992; Roberts 1998). van Heerden et al. (1991) reported that the rate of land creation in the delta slowed to 193 ha/yr (477 acres/yr) from 1977 to 1991, a period dominated by channel abandonment and lobe fusion. Since this early period of subaerial delta growth, spring floods have arisen along the Atchafalaya River in 1979, 1983, 1984, 1993, 1997 (Trotter et al. 1998), 2001, 2008, and 2011 (DeHaan et al. 2012). Moreover, sediment deposition and subaerial lobe creation in the Atchafalaya Delta generally occur during the late winter and spring when river stages and discharges are highest. The overlying distributary mouth bar facies in the Atchafalaya River Delta consists of approximately 60% sand and have been estimated to be 3.0 m (9.8 ft) thick (Majersky et al. 1997; Roberts 1998).

The construction and maintenance of the Lower Atchafalaya River Bay and Bar navigation channel is slowing sediment deposition and subaerial lobe creation in the Lower Atchafalaya River Delta and providing a path for sediment transport into the Gulf of Mexico (van Beek 1979; Roberts 1998). This channel, extends the entire length of the Lower Atchafalaya River (the Atchafalaya River south of Morgan City, LA) and Atchafalaya Bay into the Gulf of Mexico, was constructed and is maintained by U. S. Army Corp of Engineers (USACE). The Lower Atchafalaya River Bay and Bar navigation channel was initially constructed in 1939 to a depth of 3 m (10 ft) and a width of 30 m (100 ft). This navigation channel was expanded to its present dimensions [6 m (20 ft) deep by 122 m (400 ft) wide] in 1974 and has been sustained through annual maintenance dredging (Penland et al. 1996; Penland et al. 1997). Approximately, 12,232,880 m^3/yr (16,000,000 yd^3/yr) of sediments are dredged annually from the Lower Atchafalaya River to maintain the Lower Atchafalaya River Bay and Bar navigation channel (Mashriqui et al. 1997). To dispose of this large volume of sediments, dredged materials have been used to construct islands along the edges of the navigation channel. These artificially built islands have been placed at considerably higher elevations than the naturally created deltaic lobes (van Beek 1979; Sasser and Fuller 1988; Penland et al. 1996; Penland et al. 1997). Creation of dredged material islands in the Atchafalaya River Delta began in 1974 with the expansion of the Lower Atchafalaya River Bay and Bar navigation channel. During the period from 1974 to 1987, the vast majority of dredged materials were placed on the western banks of the Lower Atchafalaya River Delta. Big Island was constructed during this period (Figure 3). This island extends for 3.2 km (2 mi) along the western delta and is the largest dredged material spoil area constructed in the Atchafalaya Delta. However since 1987, large amounts of dredged materials have also been deposited along the eastern banks of the Atchafalaya River Delta (Penland et al. 1996; Penland et al. 1997). As of 1996, 72% of the total area of the Atchafalaya River Delta was created by deposition of dredged materials while only 28% of the total area was created through natural processes (Penland et al. 1997).

The naturally created deltaic lobe islands of the Lower Atchafalaya River are generally composed of fresh marsh and mudflat habitats (Penland et al. 1996; Penland et al. 1997).

Johnson et al. (1985) documented the initial colonization and spatial distribution of the naturally created Lower Atchafalaya River deltaic lobe islands as consisting of a *Salix nigra Marsh.* (black willow) association on the higher elevated upstream end of the lobe islands, a *Typha latifloia L.* (broadleaf cattail) association at intermediate elevations, and a *Sagittaria latifloia Willd.* (broadleaf arrowhead) association at intermediate and lower elevations. Later vegetation surveys showed increases in species diversity and reductions in vegetative cover in the plant community on these deltaic lobes (Sasser and Fuller 1988; Shaffer et al. 1992). In contrast, the vegetative communities on many of the constructed islands differ greatly from the naturally created islands due to placement of dredged material at higher elevations than the deltaic lobe islands. The vegetative communities on these dredged material islands are mainly composed wetland scrub-shrub, wetland forested, and bare ground habitats (Penland et al. 1996; Penland et al. 1997).

Big Island impedes fluvial discharge to the western Atchafalaya Delta because of its large size, high elevation, and critical placement in the northwestern reaches of the delta. Since Big Island lowers river discharge, sediment transport is reduced and delta growth is minimized westward (van Heerden 1983). Therefore, the planform geometry and the geomorphology of the western delta have been altered by construction of this large spoil area. The rate of subaerial land growth inside the AT-03 project area has been estimated to be 2 ha/yr (4 acres/yr) from 1956 to 1978 and 1 ha/yr (3 acres/yr) from 1978 to 1990 (Barras et al. 1994).

The Big Island Mining (AT-03) project will attempt to enhance sediment transport and delta growth in the northwestern delta by construction of a distributary network of channels and dredged material islands. The following synopsis was summarized from the AT-03 engineering closure report (Mayer 1998). One secondary [Channel A (CA)] (aka Breaux Pass) and five tertiary channels [Channel B (CB), Channel C (CC), Channel D (CD), Channel E (CE), and Channel F (CF)] were constructed for the AT-03 project (Figure 4). The channels were dredged to a depth of -3 m (-10 ft) NGVD 29 and the corresponding lengths CA 6,400 m (21,000 ft), CB 1,676 m (5,500 ft), CC 610 m (2,000 ft), CD 1,219 m (4,000 ft), CE 1,280 m (4,200 ft), and CF 670 m (2,200 ft). The materials dredged from these channels were placed into Disposal Area 1 (DA1) [45 ha (111 acres)], Disposal Area 5 (DA5) [131 ha (323 acres)], Disposal Area 6 (DA6) [90 ha (222 acres)], Disposal Area 8 (DA8) [61 ha (150 acres)], and Disposal Area 9 (DA9) [47 ha (115 acres)] (Figure 4). The 5 disposal areas were built to elevations ranging from 0.6 to 1.2 m (2 to 4 ft) NGVD 29. Earthen containment dikes were constructed for all disposal areas at a 0.9 m (3 ft) NGVD 29 elevation. After construction, the containment dikes were gapped in several locations. In 2006 additional gaps were added to the containment dikes for fisheries research (Thompson and Peterson 2006). Construction of the AT-03 project began on January 25, 1998 and was completed by October 8, 1998. The Atchafalaya Sediment Delivery (AT-02) project is a similar sediment diversion and marsh creation project in the Atchafalaya Delta that was constructed simultaneously with the AT-03 project in 1998.

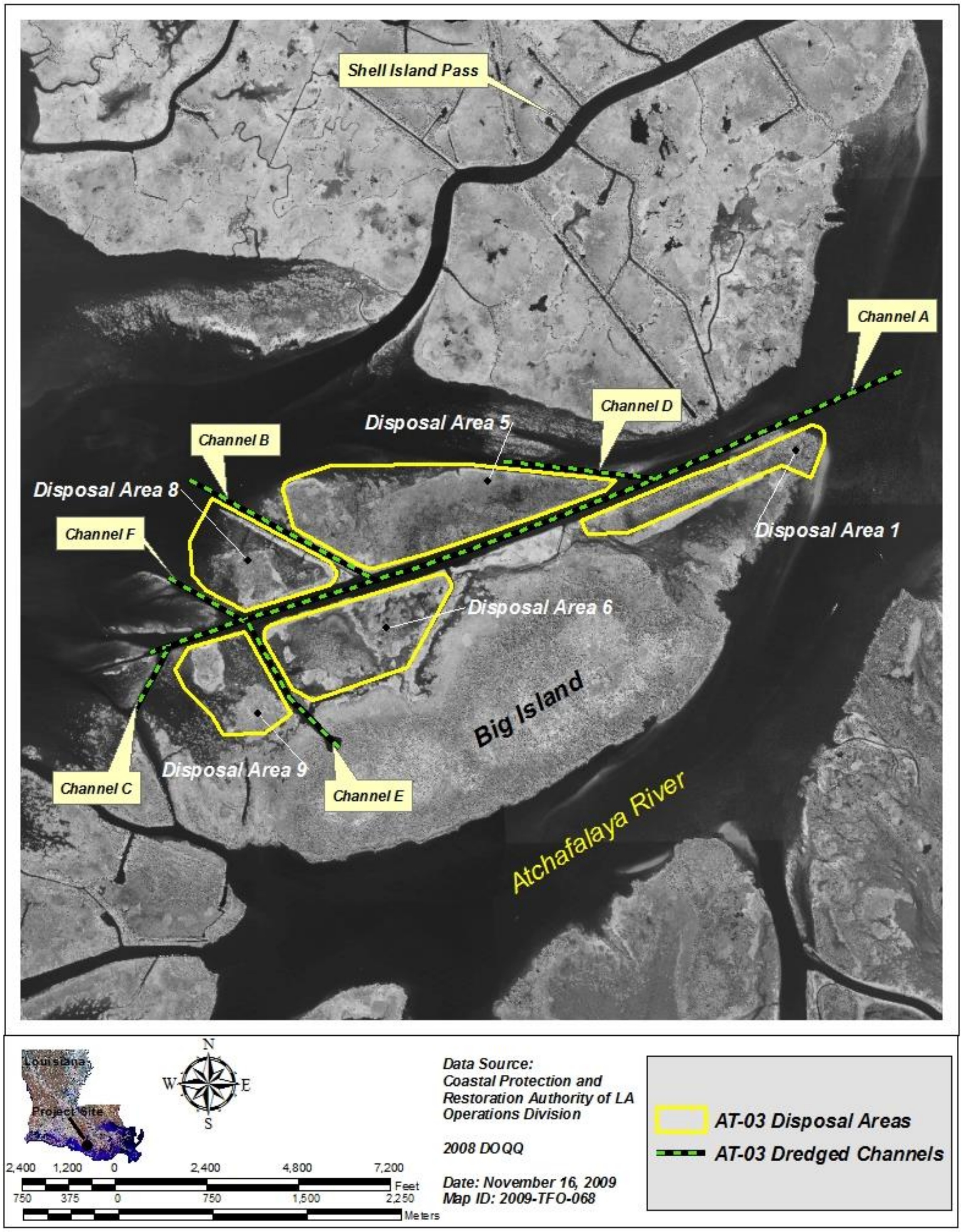


Figure 4. Location of the Big Island Mining (AT-03) project features.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the project inspections of the Big Island Mining (AT-03) is to evaluate the constructed project features, identify any deficiencies and prepare a report detailing the condition of such features and to recommend corrective actions needed, if any. Should it be determined that corrective actions were needed, CPRA would provide, in report form, a detailed cost estimate for engineering, design, supervision, inspection, construction contingencies, and an assessment of the urgency of such repairs. Photographs of the inspection are located in Appendix A (A-1–A-10).

An inspection of the Big Island Mining (At-03) was held on May 17, 2017 under partly cloudy skies and warm temperatures. In attendance were Ben Hartman and Glen Curole of CPRA, Richard Hartman of the National Marine Fisheries Service (NMFS), and David LeBlanc with the Louisiana Department of Wildlife and Fisheries (LDWF). The attendees met at the Berwick Public Boat Launch in St. Mary Parish. The inspection began at approximately 9:00 a.m. and ended at 11:30 a.m.

The field trip included a visual inspection of adjacent marsh and channels.

b. Inspection Results

Inspection of the Big Island Mining Project (AT-03) began at the head of Channel "A", known as "Breaux's Pass", near the beginning of the reach at Sta. 20+00. Since the completion of dredging of Breaux's Pass, the entrance has experienced shoaling that has made it difficult to access the channel. In 2009, the LDWF dredged and marked the entrance for access to the island. The latest bathymetric data available was collected during October of 2016 with current channel conditions outlined in Section C "Monitoring Results and Discussion".

Channel "D" is the first channel along the north bank of Breaux's Pass and extends northwest between Shell Island and dredge disposal area #5. As noted in previous inspections, Channel "D" has completely shoaled in and we were unable to access the channel during our inspection. It is apparent that very little flow is occurring in Channel "D" and the areas that have shoaled are vegetated with broken marsh.

Channel "B" is a tertiary distributary channel along the north bank of Breaux's Pass extending in a northwesterly direction towards Shell Island Pass. The channel was not accessible during our inspection. There was a large vegetated marsh platform at the entrance and the channel was completely clogged with water hyacinth. The amount of water hyacinth present would indicate shoaling at the mouth of the channel and that there is very little flow in the channel to clear the vegetation. A bathymetric survey of the channel was included in the 2016 survey.

Channel E (CE) is the first channel located along the south bank of Breaux's Pass extending to a cul-da-sac on the interior of Big Island. CE is frequently used by the Louisiana Department of Wildlife and Fisheries (LDWF) for access to public hunting grounds and biological data collection stations. The LDWF has been wheel washing this channel regularly to maintain public access to the interior of the island. We did not have difficulty traveling CE and water depths were adequate for access. Water depths increased as we traveled closer to the cul-da-sac.

Channel C (CC) is a small distributary channel at the end of Breaux's Pass extending in a southwesterly direction leading into Catfish Pass. In 2009, LDWF dredged the head of the channel for access from CC to Catfish Pass. The channel that LDWF dredged appears to have shoaled again. We were able to idle through the channel to Catfish Pass with guidance from LDWF. The PVC markers placed after dredging are still visible and are surrounded by marsh and vegetation.

Channel F is approximately 2,400 linear feet and extends in a northwesterly direction towards Shell Island Pass. CF was accessible by boat and appeared to be clear of any vegetation at the time of the inspection. Shoaling does not appear to be a problem with Channel "F" as with the other channels.

c. Maintenance Recommendations

Overall, the Big Island Mining (AT-03) project was exhibiting substantial shoaling throughout the distributary and tertiary channels of the project. Since this project is close to the end of its 20 year life, we are not recommending maintenance dredging to open any of the distributary or tertiary channels.

i. Immediate/ Emergency Repairs

None

ii. Programmatic/ Routine Repairs

None

d. Maintenance History

Since completion of the Big Island Mining (AT-03) project in October 1998, no maintenance dredging or marsh creation efforts have been recommended or undertaken.

III. Operations Activity

As outlined above, no maintenance, dredging or marsh creation efforts have been recommended or undertaken.

a. Operation Plan

The original O&M plan outlined the following completed project features jointly accepted by CPRA and NMFS as requiring maintenance dredging, repair, and/or rehabilitation throughout the 20 year life of the project.

1. Maintenance Dredging of 21,000 ft. of distributary channel from the Atchafalaya River along the northern side of Big Island.

Maintenance Assumptions: Sediment material will fill the channel from -10.0 ft. bottom to an elevation of -6.0 ft. NGVD. The 21,000 linear ft. main channel will require maintenance dredging at year 7 and 14.

Year 7 - Dredging approximately 50,000 yd^3 of material from channel.

Year 14 - Dredging approximately 50,000 yd^3 of material from channel.

b. Actual Operations

No activity.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS-*Wetlands*) for CWPPRA, updates were made to the AT-03 Monitoring Plan to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There is one CRMS sites located in close proximity to the project and will be used as a reference site, CRMS0463. This site was added on December 13, 2006.

a. Monitoring Goals

The Big Island Mining (AT-03) project is designed to enhance natural delta building processes by creating an avenue for sediment transport to areas north and west of Big Island and to construct dredged material islands with excavated sediments. The objectives of this project are to establish a sediment delivery system in the western portion of the Atchafalaya delta, thereby enhancing the system's natural delta-building potential and to utilize dredged material from the creation of the distributary channels to create delta lobe islands suitable for establishment of emergent marsh.

The specific measurable goals established to evaluate the effectiveness of the project are:

1. To increase the project areas delta-building potential through the establishment of effective distributary channels.

2. Create approximately 340 ha (850 acres) of delta lobe islands through the beneficial use of dredged material at elevations suitable for emergent marsh vegetation.

3. Increase the rate of subaerial growth in the project area to that measured from historical photographs since 1956.

b. Monitoring Elements

The following monitoring elements will provide the information necessary to evaluate the specific goals listed above:

Elevation

Topographic surveys were employed to document elevation and volume changes inside the Big Island Mining (AT-03) project disposal areas. Pre-construction (July 1998) and as-built (November 1998) elevation data were collected using cross sectional survey methods (500 ft intervals) with a centerline profile. Five disposal areas (DA) were surveyed during the pre-construction and as-built periods (DA1, DA5, DA6, DA8, and DA9). Subsequent post-construction topographic surveys were conducted without a centerline profile and DA6, DA8, and DA9 were not surveyed due to budgetary constraints. In addition, the DA1 post-construction surveys were condensed from 13 to 6 transects. These post-construction surveys were performed in May 2008 and October 2016. All survey data were established using or adjusted to tie in with the Louisiana Coastal Zone (LCZ) GPS Network, a coastal primary and secondary benchmark network maintained by CPRA (CPRA 2016).

The July 1998, November 1998, May 2008, and October 2016 survey data were re-projected horizontally and vertically to the Universal Transverse Mercator map projection (UTM), the North American Datum of 1983 (NAD83) horizontal datum, and the North American Vertical Datum of 1988 (NAVD 88) vertical datum in meters using Corpscon® software. The re-projected data were imported into ArcView® software for surface interpolation. Triangulated irregular network models (TIN) were produced from the point data sets. Next, the TIN models were converted to grid models (2.0 m^2 cell size), and the spatial distribution of elevations were mapped. The grid models were clipped to the AT-03 disposal area polygons to estimate elevation and volume changes within the fill area.

Elevation changes from July 1998-November 1998, November 1998-May 2008, and November 1998-October 2016 were calculated by subtracting the corresponding grid models using the Light Detection and Ranging (LIDAR) Data Handler extension of ArcView® software. After the elevation change grid models were generated, the spatial distribution of elevation changes in the AT-03 disposal areas were mapped in half meter elevation classes. Lastly, volume changes in the disposal areas were calculated in cubic meters (m3) using the Cut/Fill Calculator function of the LIDAR Data Handler extension of ArcView® GIS. Note, these elevation and volume calculations are valid only for the extent of the survey area.

Bathymetry

Bathymetric surveys were employed to document sedimentation patterns in the Big Island Mining (AT-03) dredged secondary and tertiary channels. Pre-construction (July 1998) and as-built (November 1998) elevation data were collected using cross sections spaced 100 ft apart and centerline profiles. One secondary (CA) and five tertiary (CB, CC, CD, CE, and CF) channels were surveyed during the pre-construction and as-built periods. Subsequent post-construction bathymetric surveys were conducted using 500 ft intervals and centerline profiles. These post-construction surveys were performed in May 2008 and October 2016. The surveys were reduced in scope due to budgetary constraints. All survey data were established using or adjusted to tie in with the LCZ GPS Network (CPRA 2016).

The July 1998, November 1998, May 2008, and October 2016 survey data were re-projected horizontally and vertically to the UTM NAD83 coordinate system and the NAVD 88 vertical datum in meters using Corpscon® software. The re-projected data were imported into ArcView® software for surface interpolation. Triangulated irregular network models (TIN) were produced from the point data sets. Next, the TIN models were converted to grid models (2.0 m2 cell size), and the spatial distribution of elevations were mapped. The grid models were clipped to the AT-03 dredged channel polygons to estimate elevation and volume changes within each channel.

Elevation changes from July 1998-November 1998, November 1998-May 2008, and November 1998-October 2016 were calculated by subtracting the corresponding grid models using the LIDAR Data Handler extension of ArcView® software. After the elevation change grid models were generated, the spatial distribution of elevation changes in the AT-03 dredged channels were mapped in half meter elevation classes. Lastly, volume changes in the dredged channels were calculated in cubic meters (m3) using the Cut/Fill Calculator function of the LIDAR Data Handler extension of ArcView® software. Note, these elevation and volume calculations are valid only for the extent of the survey area.

Vegetation

Vegetation stations were established in the Big Island Mining (AT-03) project area to document species composition and percent cover over time. Random plots were placed on DA1 and DA5 (Figure 5). Vegetation data were collected in October 1999 (1 year post-construction), October 2002 (4 years post-construction), and October 2007 (9 years post-construction) via the semi-quantitative Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974; Sawyer and Keeler-Wolf 1995; Barbour et al. 1999). Plant species inside each $4m^2$ plot were identified, and cover values were ocularly estimated using Braun-Blanquet units (Mueller-Dombois and Ellenberg 1974) as described in Steyer et al. (1995). The cover classes used were: solitary, <1%, 1-5%, 6-25%, 26-50%, 51-75%, and 76-100%. After sampling the plot, the residuals within a 5 m (16 ft) radius were inventoried. Thirty-six (36) stations were sampled in 1999, 35 stations were sampled in 2002, and 36 stations were sampled in 2007.

No reference area was established to compare vegetation communities on the naturally occurring delta islands and the AT-03 disposal areas. However, historical data from Log and Hawk Islands (1979-1998) were obtained from Louisiana State University/Coastal Ecology Institute (LSU/CEI) (Figure 5). This vegetation data were used to establish community colonization and succession trends on a prograding delta island. The LSU/CEI data were also collected with the Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974) and had a $1m^2$ plot size. LSU/CEI sampled 48 vegetation stations in 1979, 58 stations in 1980, 58 stations in 1982, and 66 stations in 1998.

Relative cover and importance value (IV) were calculated to summarize vegetation data. Both these parameters were grouped by disposal area and year in the project area while the reference area was grouped by year. Relative cover represents the cover of each species as a percentage of total cover (Barbour et al. 1999). An IV is calculated using a minimum of two relative measures. The following IV formula was applied to this analysis: IV = (relative cover + relative frequency)/2. IV represents each species relative contribution to the vegetative community (Barbour et al. 1999). Since relative cover and IV are relative measures, each species earns a value ranging from 0 to 100.

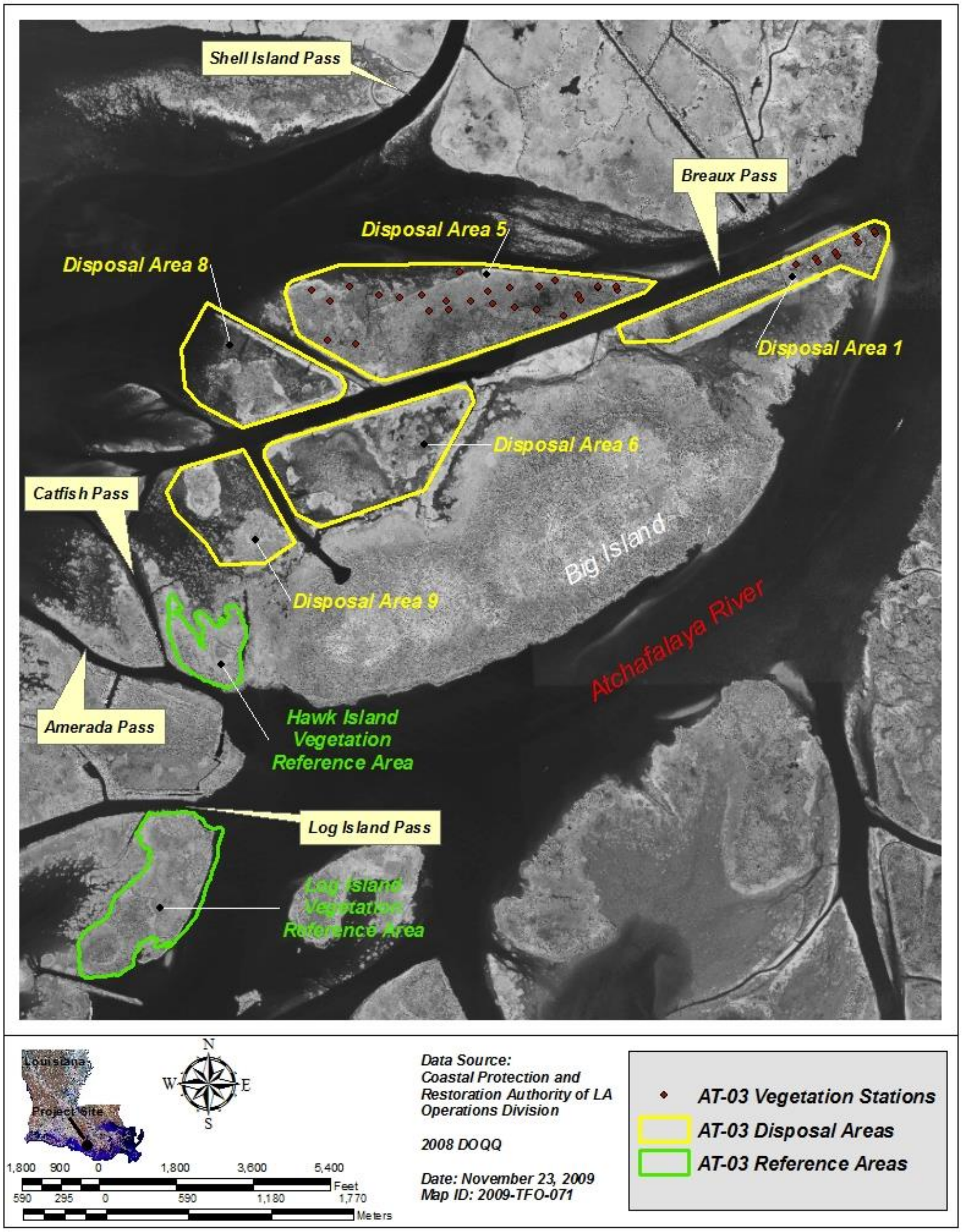


Figure 5. **Location of the Big Island Mining (AT-03) vegetation stations and LSU/CEI's Log and Hawk Islands vegetation reference areas.**

Habitat Mapping

The U.S. Geological Survey's Wetland and Aquatic Research Center (USGS/WARC) obtained 1:12,000 to 1:40,000 scale color infrared (CIR) aerial photography to delineate habitats over time. These aerial images were classified and photo-interpreted to perform habitat analysis of the Big Island Mining (AT-03) project [1,119 ha (2,765 acres)] and reference [427 ha (1,054 acres)] areas. Pre-construction aerial photographs were acquired on December 19, 1994 and November 24, 1997 at a 1:12,000 scale while post-construction photographs were acquired on November 3, 1998 (1:40,000 scale), November 15, 2000 (1:12,000 scale), October 29, 2007 (1:12,000 scale), and November 13, 2016 (1:16,000 scale) (Figure 6). The 1998 image was obtained from LDWF at the larger scale, and habitats were not classified in the reference area in 1994 and 2016. Aerial photographs were scanned at 300 pixels per inch and georectified using ground control data collected with a global positioning system (GPS) and digital ortho quarter quads. These individually georectified frames were assembled to produce a mosaic of the project and reference areas.

Using the National Wetlands Inventory (NWI) classification system, the 1994, 1997, 1998, 2000, 2007, and 2016 photography were photointerpreted by USGS/WARC personnel and classified to the subclass level (Cowardin et al. 1979). The habitat delineations were transferred to 1:6,000 scale mylar base maps and digitized. After being checked for quality and accuracy, the resulting digital data were analyzed using geographic information systems (GIS) to determine habitat change over time in the project and reference areas. The habitat types were aggregated into nine habitat classes for the purpose of mapping change. Habitat changes inside the project area were calculated for the following intervals 1994-1997, 1994-1998, 1998-2000, and 1998-2007 while the reference area habitat changes were evaluated from 1997-1998, 1998-2000, 1998-2007, and 1998-2016.

Subaerial and Subaqueous Growth

Subaerial and subaqueous growth in the project area were qualitatively delineated by comparing NWI habitat assessments. These comparisons were undertaken for the 1998 and 2007 interval and repeated for the 1998 and 2016 interval. Areas showing growth were classified as either subaerial growth, subaqueous to subaerial growth, or subaqueous growth. Subaerial growth occurred when the open water-fresh habitat was converted to subaerial land (fresh marsh, upland barren, wetland forested, or wetland scrub-shrub habitats). Subaqueous to subaerial growth arose when beach/bar/flat or submerged aquatics habitats were transformed to subaerial land. Subaqueous growth transpired when the open water-fresh habitat was changed to beach/bar/flat or submerged aquatics habitats. Once classified, these areas were outlined using ESRI shapefiles (polygon) to calculate spatial growth in the project area from 1998 to 2007 and 1998 to 2016.

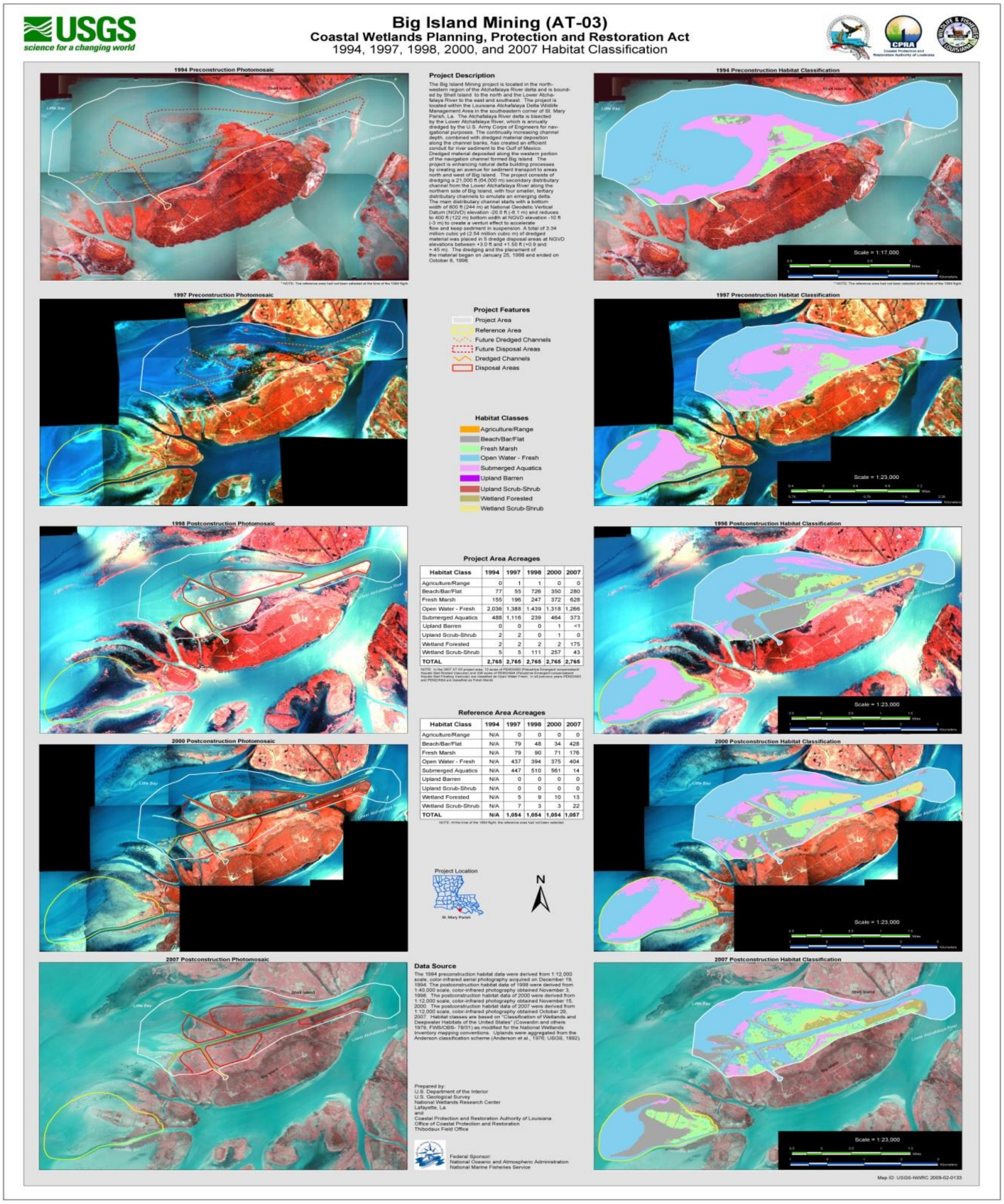


Figure 6. **Pre-construction (1994 and 1997), as-built (1998), and post-construction (2000 and 2007) photomosaics and habitat analysis of the Big Island Mining (AT-03) project and reference areas.**

Land Area Change

As previously mentioned one CRMS-*Wetlands* site (CRMS0463) is located in close proximity to the AT-03 project area and was used to characterize the land changes within the site over a 30 year interval. Land area change assessments were performed on a 1.0 km^2 (0.4 mi^2) portion of the project area at the CRMS0463 site (Figure 2) to evaluate land change and to determine annual rates of land change (Folse et al. 2018). The U.S. Geological Survey's Wetland and Aquatic Research Center (USGS/WARC) obtained cloud free 30 m Landsat imagery to delineate land and water habitats over time. Landsat thematic mapper (TM) images were captured from 1984-2010 and Landsat operational land imager (OLI) digital maps were acquired from 2013-2016. These images were normalized, interpreted, processed, and verified for quality and accuracy using protocols established in Couvillion et al. (2017). Specifically, a modified normalized difference water index (mNDWI) and supervised and unsupervised grouping methods were used to classify areas of the imagery as land or water. After the images were interpreted, regression lines were created to show the land area change trends over time for the site.

c. Monitoring Results and Discussion

Elevation

The Big Island Mining (AT-03) project disposal areas experienced differential volume reductions since construction was completed in 1998. Elevation change and volume distributions for the AT-03 disposal areas are shown in Figure 7 (July 1998-November 1998), Figure 8 (November 1998-May2008), and Figure 9 (November 1998-October 2016). Elevation grid models for the July 1998 (pre-construction), November 1998 (as-built), May 2008 (post-construction) and October 2016 (post-construction) disposal area surveys are also provided in Appendix B (B-1–B-4). Table 1 lists the volume changes and percentages within the disposal areas over time.

Approximately 1,723,042 m^3 (2,253,653 yd^3) of sediment were deposited during construction in DA1, DA5, DA6, DA8, and DA9 (Figure 7 and Table 1). For the first post-construction period (1998-2008), sediment volume decreased by 57% in DA1 and 8% in DA5. The total sediment volume loss in the disposal areas from 1998 to 2008 was approximately 136,885 m^3 (179,039 yd^3), an 18% reduction in volume (Figure 8 and Table 1). The volume loss in DA1 correlates favorably with Atchafalaya Sediment Delivery (AT-02) disposal area 1 (DA1) and disposal area 4 (DA4), which were condensed by 51% and 58% from 1998 to 2008 (Curole and Babin 2010a). While DA1 consolidated to less than half its fill volume, DA5 retained over 90% of its fill volume. Figure 8 shows areas where volume increased or decreased from 1998 to 2008. Comparing this figure to the earlier elevation change grid model (Figure 7) reveals that the parts of DA5 that gained volume in 2008 were filled to the lowest elevation in 1998. The as-built (Figure C-2) and post-construction (Figure C-3) elevation grid models and habitat maps reaffirm this point. Habitats in the northwestern part of DA5 were converted from open water–fresh, submerged aquatics, and beach/bar/flat habitats in 2000 to fresh marsh in 2007 (Figure 6). Although no accretion plots were established in DA5, topographic data suggest that sediments were deposited in the post-construction period. Therefore, it is plausible to infer that the areas of low relief in DA5 probably accreted mitigating volume losses in this disposal area. The movement of sediments into the northwestern part of DA5 was aided by the erosion of the containment dike. Approximately, 914 m (3,000 ft) of this earthen structure eroded and/or subsided either during or immediately after construction in 1998. By 2000, 1,433 m (4,700 ft) of the dike had degraded. The close proximity of Shell Island Pass and the Atchafalaya River and the low relief probably induced sedimentation in this section of DA5.

During the second post-construction interval (1998-2016), DA1 recovered a portion of the sediment volume that it lost during the earlier post-construction interval while DA5 more than doubled its volume deficit. DA1 gained 15,095 m^3 (19,744 yd^3) of sediment from 2008 to 2016, which was the largest volume gain documented in an AT-02 or AT-03 disposal area for this interval (Curole and Hartman 2018). In contrast, DA5's sediment volume declined by 67,837 m^3 (-88,727 yd^3) from 2008 to 2016. For the entire 18 year post construction period (1998-2016), sediment volume was reduced by 47% in DA1 and by 20% in DA5 (Figure 9 and Table 1). The DA1 percentage relates well with the average volume loss reported (-43%) for AT-02's DA1 and DA4 (Curole and Hartman 2018). Remarkably, DA5 retained 473,203 m^3 (618,926 yd^3) of sediment or 80% of its constructed volume. As previously noted sedimentation is likely occurring in the low lying northern reaches of DA5 while the interior and southern reaches are not accreting at the same rate (Figure 9). Sedimentation in DA1 also transpired in low relief areas along the shorelines of the Atchafalaya River and CA from 2008-2016 (Figure 9). Moreover, the position of DA1 directly on the shoreline of the Atchafalaya River probably influenced the increased sedimentation in this disposal area. A likely catalyst driving sedimentation increases in DA1 was the massive flood of 2011. This flood event produced flood stages and discharges that approached the largest Mississippi River flood events recorded (floods of 1927, 1973, and 1993) and required that the Morganza Floodway be opened causing greater discharges to be guided into the Atchafalaya Basin (DeHaan et al. 2012). In the aftermath of the 2011 flood, it was determined that sedimentation increased over a large area of the Atchafalaya Basin (Falcini et al. 2012), the Wax Lake Delta's subaerial extent expanded and elevated (Carle et al. 2015), and nitrate reduction was enhanced through inundation of the basin (Scott et al. 2014) during this flood event. It is not clear why DA5 did not accrete at a higher rate after such a large sedimentation event as the great flood of 2011. Did subsidence, settlement, or the location of this disposal area along aggrading channels (CA, CB, and CD) (Figure 9) hinder further sedimentation? Yes, all these variables likely influenced DA5's sediment volume by 2016, but the extent of each variables influence cannot be determined from this data. What is clear from the data is that 18 years after construction DA5 preserved a substantial quantity of its constructed sediment volume, which tips the needle towards a sustainable created wetland habitat.

Table 1. Sediment volume changes (m^3) and percentages at the Big island Mining (AT-03) disposal areas (DA1 and DA5) over time.

AT-03 Disposal Area	Mar 1998 (Pre) - May 1998 (As-blt) (m3)	May 1998 (As-blt) - May 2008 (10 Yr Post) (m3)	Percent Volume Loss (%)	May 1998 (As-blt) - Oct 2016 (18 Yr Post) (m3)	Percent Volume Loss (%)
DA1	154,131	-87,855	-57	-72,759	-47
DA5	590,070	-49,030	-8	-116,867	-20
Total	744,201	-136,885	-18	-189,626	-25

Bathymetry

Massive quantities of sediment have aggraded the Big Island Mining (AT-03) dredged channels since construction was completed in 1998. This sedimentation has raised channel contours and volumes. Elevation change and volume distributions for the AT-03 channels are shown in Figure 7 (July 1998-November 1998), Figure 8 (November 1998-May 2008), and Figure 9 (November 1998-October 2016). Elevation grid models for the July 1998 (pre-construction), November 1998 (as-built), May 2008 (post-construction) and October 2016 (post-construction) channel surveys are also provided in Appendix B (B-1–B-4). Table 2 also lists the volume changes and percentages within the dredged channels over time. Figure 10 is an elevation grid model that displays the extended CA (A-1 and A-2) contours.

Approximately 2,314,802 m^3 (-3,027,646 yd^3) of sediment were removed from the secondary and tertiary channels during construction in 1998 (Figure 7 and Table 2). In the

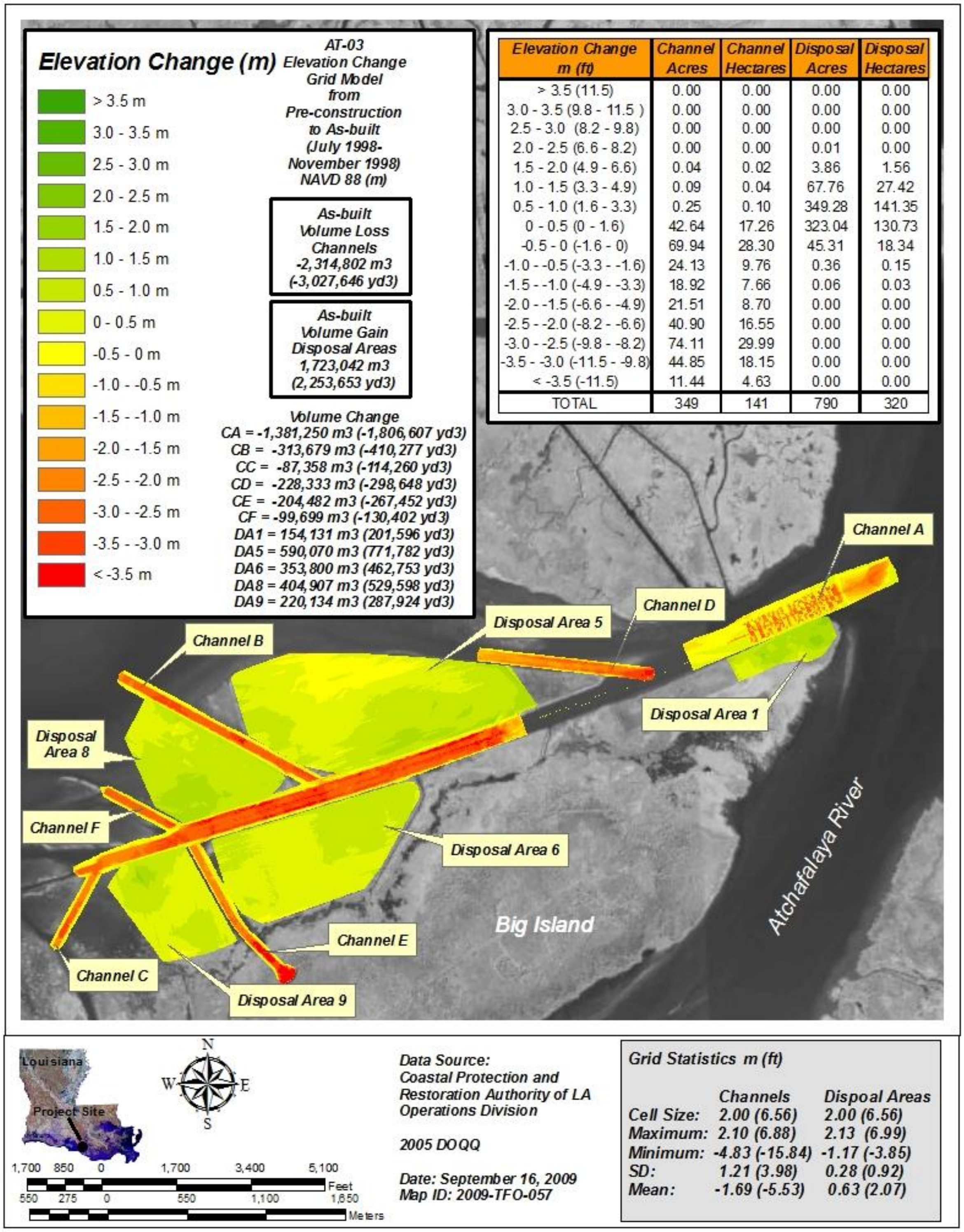


Figure 7. **Elevation and volume change grid model from pre-construction (1998) to post-construction (1998) at the Big Island Mining (AT-03) project.**

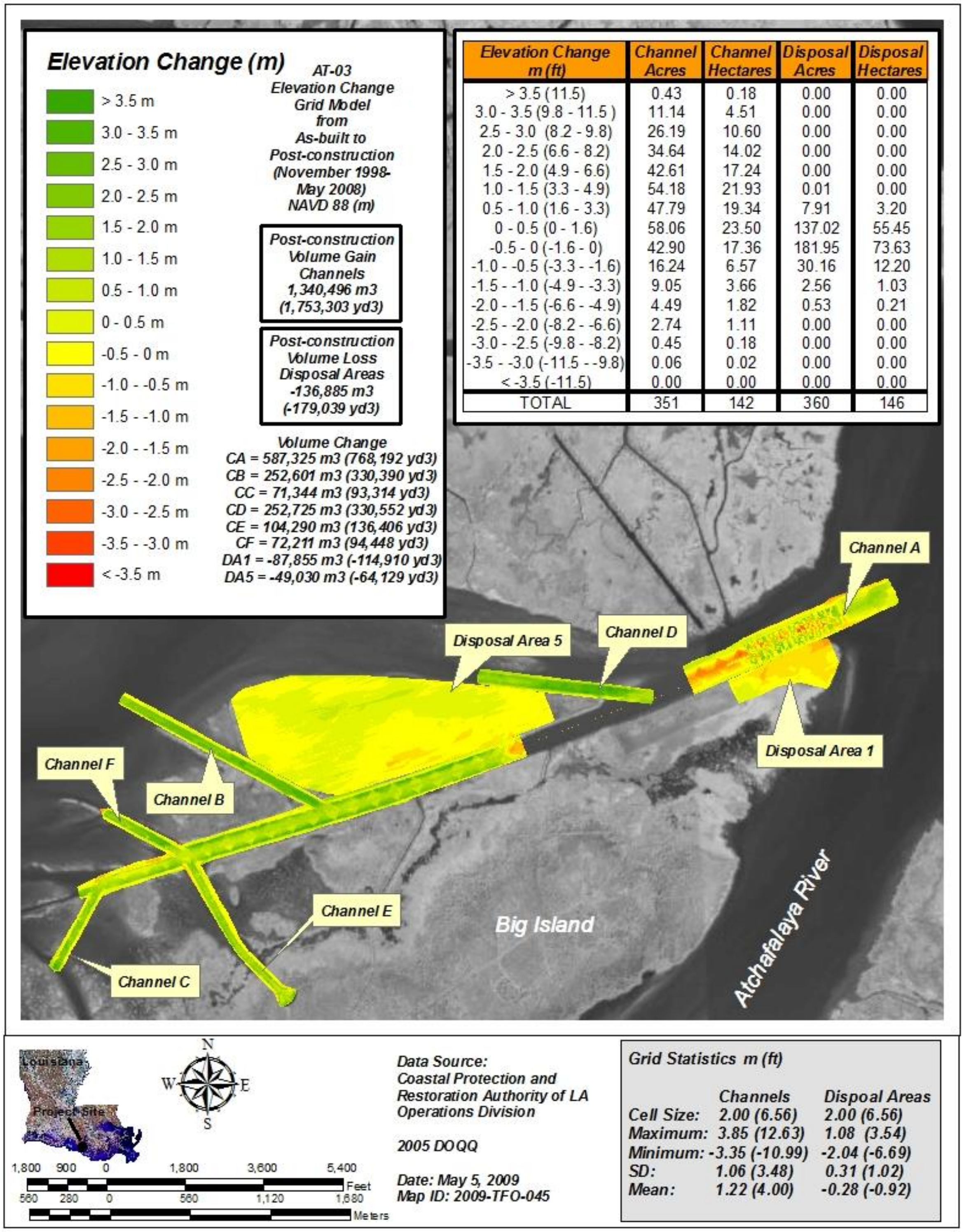
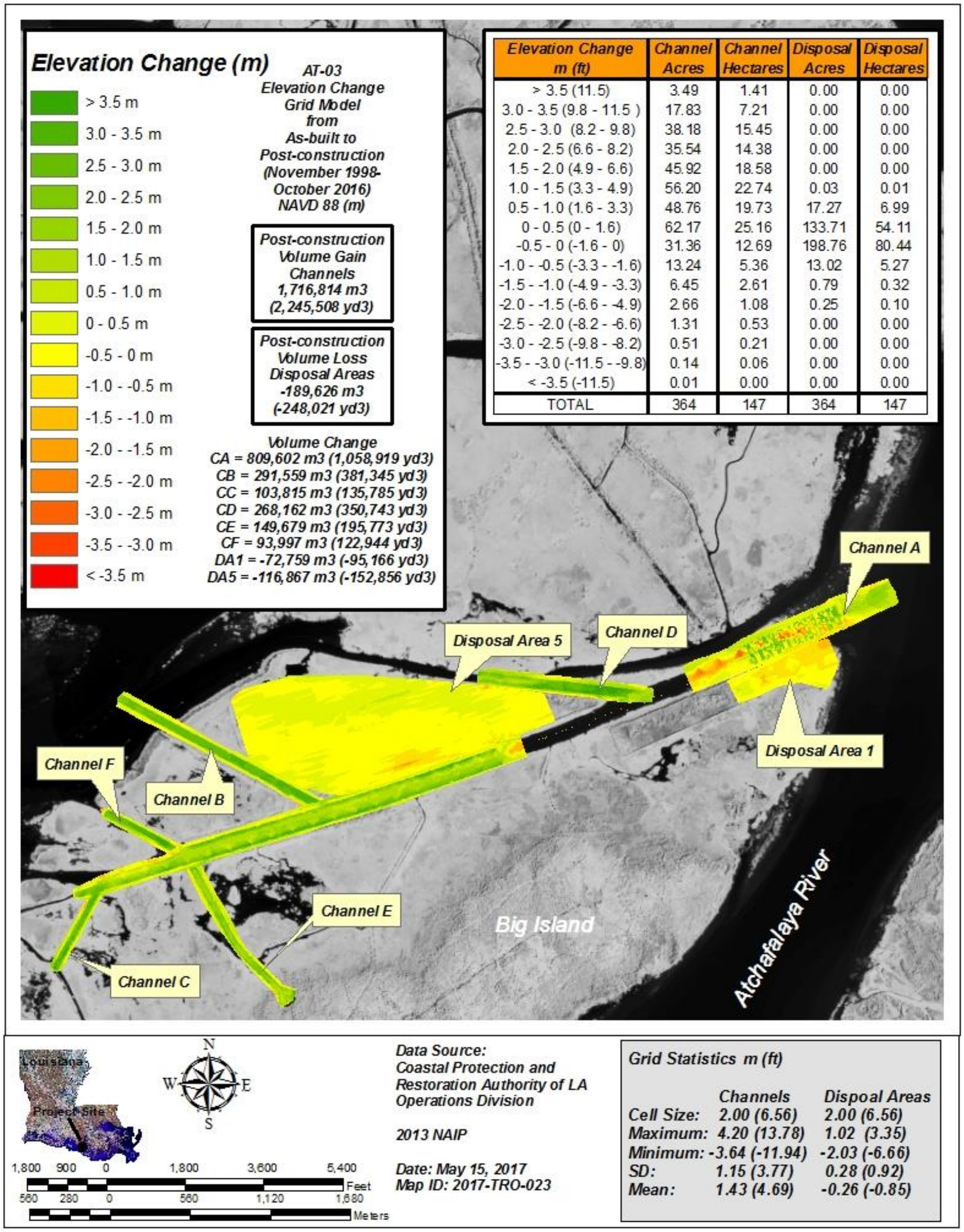
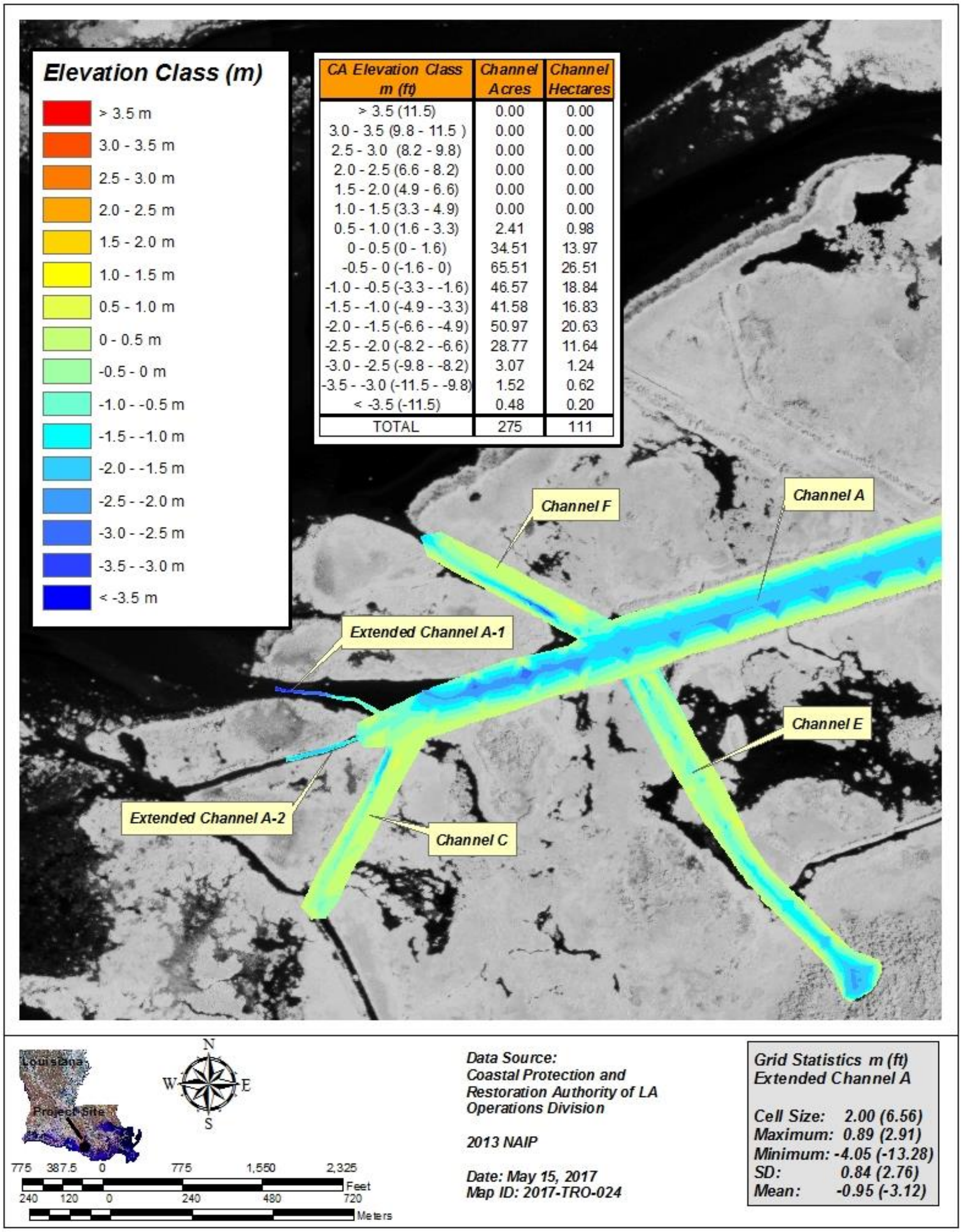


Figure 8. **Elevation and volume change grid model from as-built (1998) to post-construction (2008) at the Big Island Mining (AT-03) project.**



Elevation Change m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	3.49	1.41	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	17.83	7.21	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	38.18	15.45	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	35.54	14.38	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	45.92	18.58	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	56.20	22.74	0.03	0.01
0.5 - 1.0 (1.6 - 3.3)	48.76	19.73	17.27	6.99
0 - 0.5 (0 - 1.6)	62.17	25.16	133.71	54.11
-0.5 - 0 (-1.6 - 0)	31.36	12.69	198.76	80.44
-1.0 - -0.5 (-3.3 - -1.6)	13.24	5.36	13.02	5.27
-1.5 - -1.0 (-4.9 - -3.3)	6.45	2.61	0.79	0.32
-2.0 - -1.5 (-6.6 - -4.9)	2.66	1.08	0.25	0.10
-2.5 - -2.0 (-8.2 - -6.6)	1.31	0.53	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	0.51	0.21	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	0.14	0.06	0.00	0.00
< -3.5 (-11.5)	0.01	0.00	0.00	0.00
TOTAL	364	147	364	147

Figure 9. **Elevation and volume change grid model from as-built (1998) to post-construction (2016) at the Big Island Mining (AT-03) project.**



CA Elevation Class m (ft)	Channel Acres	Channel Hectares
> 3.5 (11.5)	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	0.00	0.00
0.5 - 1.0 (1.6 - 3.3)	2.41	0.98
0 - 0.5 (0 - 1.6)	34.51	13.97
-0.5 - 0 (-1.6 - 0)	65.51	26.51
-1.0 - -0.5 (-3.3 - -1.6)	46.57	18.84
-1.5 - -1.0 (-4.9 - -3.3)	41.58	16.83
-2.0 - -1.5 (-6.6 - -4.9)	50.97	20.63
-2.5 - -2.0 (-8.2 - -6.6)	28.77	11.64
-3.0 - -2.5 (-9.8 - -8.2)	3.07	1.24
-3.5 - -3.0 (-11.5 - -9.8)	1.52	0.62
< -3.5 (-11.5)	0.48	0.20
TOTAL	275	111

Figure 10. **2016 elevation grid model showing the extended CA (A-1 and A-2) contours at the Big Island Mining (AT-03) project.**

Table 2. Sediment volume changes (m^3) and percentages at the Big Island Mining (AT-03) dredged channels (CA, CB, CC, CD, CE, and CF) over time.

AT-03 Channel	Mar 1998 (Pre) - May 1998 (As-blt) (m3)	May 1998 (As-blt) - May 2008 (10 Yr Post) (m3)	Percent Volume Gain (%)	May 1998 (As-blt) - Oct 2016 (18 Yr Post) (m3)	Percent Volume Gain (%)
CA	-1,381,250	587,325	43	809,602	59
CB	-313,679	252,601	81	291,559	93
CC	-87,358	71,344	82	103,815	119
CD	-228,333	252,725	111	268,162	117
CE	-204,482	104,290	51	149,679	73
CF	-99,699	72,211	72	93,997	94
Total	-2,314,802	1,340,496	58	1,716,814	74

post-construction period, sediment volume increased by 43% in CA, 81% in CB, 82% in CC, 111% in CD, 51% in CE, and 72% in CF from 1998 to 2008 (Figure 8 and Table 2). The total sediment volume gain in the dredged channels from 1998 to 2008 was approximately 1,340,496 m^3 (1,753,303 yd^3), a 58% expansion in volume. It appears that the secondary channel (CA) experienced less shoaling than the tertiary channels (CB, CC, CD, CE, and CF). Although CA added 587,325 m^3 (768,192 yd^3) of sediment to its bedload, the 2008 average channel contour, -1.16 m (-3.80 ft) NAVD 88, was considerably deeper than the tertiary channels, -0.65 m (-2.14 ft) NAVD 88 (Figure 8 and C-3). Furthermore, CA aggraded by 0.66 m (2.17 ft) while the tertiary channels aggraded by 1.33 m (4.35 ft) during the first ten year period after construction (Figure 8 and C-3). Among the tertiary channels, CB [1.58 m (5.18 ft)] and CD [1.88 m (6.17 ft)] exhibited the densest deposits of sediment while CE [0.87 m (2.85 ft)] exhibited the thinnest deposits. Shoaling of CB led to the formation of a subaerial bar at the intersection of CB and CA restricting flow into the tertiary channel. CB seems to be experiencing the fluvial process of channel abandonment and partial lobe fusion (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992; Roberts 1998). CD was the deepest channel dredged (Figure 7), and its position on the upstream end of DA5 probably aided in sediment deposition. Surprisingly, CD was the deepest channel pre-construction (Figure C-1). CE is a cul-de-sac channel that bisects a large pond and does not have defined banks along most of its watercourse. As a result, these attributes probably contributed to lower sedimentation in the southern end of this channel (Figure C-3). In addition, CE is utilized extensively by LDWF to access Big Island. Wheel washing by the frequent boat traffic likely aids deepening CE contours.

During the second post-constriction interval (1998-2016), all channels continued to aggrade. Sediment volume increased by 59% in CA, 93% in CB, 119% in CC, 117% in CD, 73% in CE, and 94% in CF from 1998 to 2008 (Figure 9 and Table 2). The total sediment volume gain in the dredged channels from 1998 to 2008 was approximately 1,716,814 m^3 (2,245,509 yd^3), a 74% expansion in volume. Similar to the 1998-2008 interval, the secondary channel (CA) incurred less shoaling than the tertiary channels (CB, CC, CD, CE, and CF). CA aggraded by 0.92 m (3.17 ft) while the tertiary channels aggraded by 1.54 m (5.05 ft) for the 1998-2016 interval. Of the tertiary channels, sedimentation in CE (73%) was a little less than the other channels, which all shoaled beyond the 90% threshold of their as-built volume leaving less than 10% of (CB and CF) or exceeding (CC and CD) the constructed channel volumes (Table 2). The resulting contours were -0.95 m (-3.11 ft) for CA and -0.36 m (-1.18 ft) for the tertiary channels (Figure C-4). Figure 10 shows that a portion of the CA discharge is being distributed through channels A-1 and A-2 providing a direct outlet into Atchafalaya Bay. Unpredictably, no bedrock erosion seems to have ensued after the 2011 flood (DeHaan et al. 2012) although this event transported larger grained sediments (Heitmuller et al. 2016) that have been reported to wear away the channel bottoms of the Wax Lake Delta (Shaw et al. 2013). In contrast, the AT-02 channels did incur bedrock erosion during the 1998-2016 interval (Curole and Hartman 2018). The extensive shoaling occurring in the secondary and tertiary channels signifies that the AT-03 dredged channels are not hydraulically efficient. Moreover, the discharge flowing (flow energy) through these distributaries could not maintain the channel morphology (DuMars 2002; Letter et al. 2008) and cross sectional area (Roberts and van Heerden 1992; Mashriqui 2003). In addition, constructing tertiary channels at acute angles does not fit the river mouth bar model of delta growth (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992; Roberts 1998; DuMars 2002; Mashriqui 2003; Edmonds and Slingerland 2007; Edmonds and Slingerland 2008; Letter et al. 2008), which is the dominant mechanism forcing delta expansion (Edmonds and Slingerland 2007). The construction and annual maintenance of the Lower Atchafalaya River Bay and Bar navigation channel (Roberts 1998; DuMars 2002; Mashriqui 2003), the construction of the AT-03 project on a concave bendway of the Atchafalaya River (Letter et al. 2008), and the low contours surrounding the dredged channels during the pre- and post-construction periods probably influenced a reduced discharge into the AT-03 channels. The secondary and tertiary channels experienced considerable aggradation since construction diminishing the delta-building potential of this created sub-delta. Therefore, the goal to establish an effective network of distributary channels has not been attained after 18 years post-construction.

Vegetation

The Big Island Mining (AT-03) vegetation data show that different vegetation communities inhabit the disposal areas and the historical reference areas. Moreover, the disparities in these communities appear to be related to elevation differences. The results of the relative cover and importance value (IV) analysis are graphically illustrated in Figure 11 and Figure 12 for disposal area habitats. The LSU/CEI vegetation data are delineated in Figures 13 (relative cover) and 14 (IV). Note the differences between relative cover and IV is correlated with the frequency that a species populates vegetation plots. For example if a species is found in only a few plots with a high cover value, the species is likely to have a high relative cover value but probably will not have a high IV. The dominant species found in DA1 was Salix nigra Marsh. (black willow) while this species remains dominant over time the understory species have changed from 1999 to 2007. The changes in the DA1 community are probably a result of elevation differences incurred between 1999 and 2007 (Figure 8). The dominant species found in DA5 in 1999 was Sagittaria latifloia Willd. (broadleaf arrowhead). By 2007, Zizaniopsis miliacea (Michx.) Doell & Aschers. (giant cutgrass) and Alternanthera philoxeroides (Mart.) Griseb. (alligatorweed) became the dominant species. Subsidence and accretion in DA5 (Figure 8) probably was a factor influencing change in this disposal area. Figure 11 and Figure 12 show the differences in DA1 and DA5 vegetation communities from 1999 to 2007. Although there are many differences, there are also some similar trends in the DA1 and DA5 vegetation communities. Both disposal areas experienced increases in species diversity and mean cover since 1999. In addition, both disposal have undergone primary succession and continue to change over time. The LSU/CEI historical reference areas have different vegetation community structures than the AT-03 disposal areas. One of the fundamental differences between the project and historical data sets is the naturally created deltaic lobe islands were established at low relief (Sasser and Fuller 1988; Shaffer et al. 1992; Johnson et al. 1985; Penland et al. 1996; Penland et al. 1997). However, the 1998 Hawk and Log Island data and the 2007 DA5 data demonstrate similarities between these vegetation communities (Figures 11, 12, 13, and 14). Vegetation data show that different vegetation communities inhabit the disposal areas and the historical reference areas.

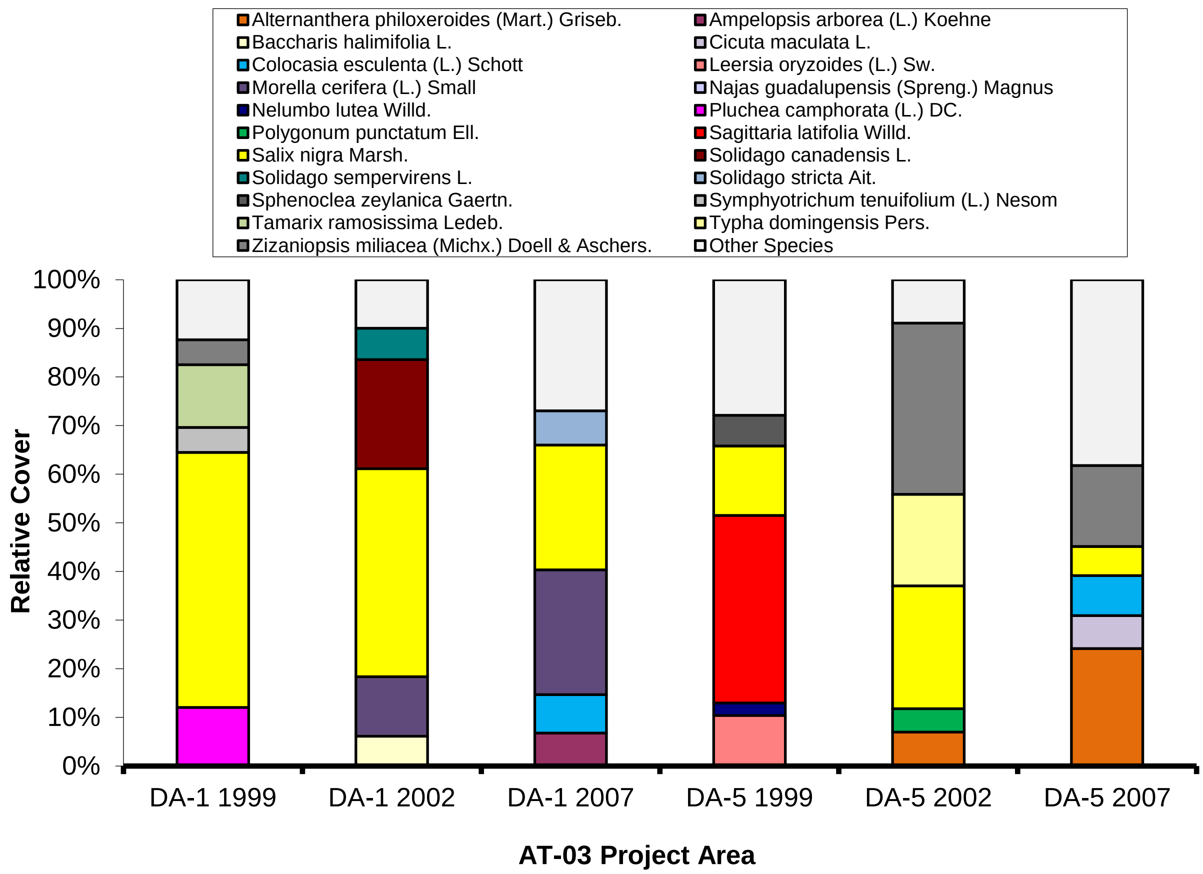


Figure 11. **Relative cover of the top five vegetation species populating the Big Island Mining (AT-03) disposal areas from 1999 to 2007. Ocular vegetation data were grouped by disposal area and year.**

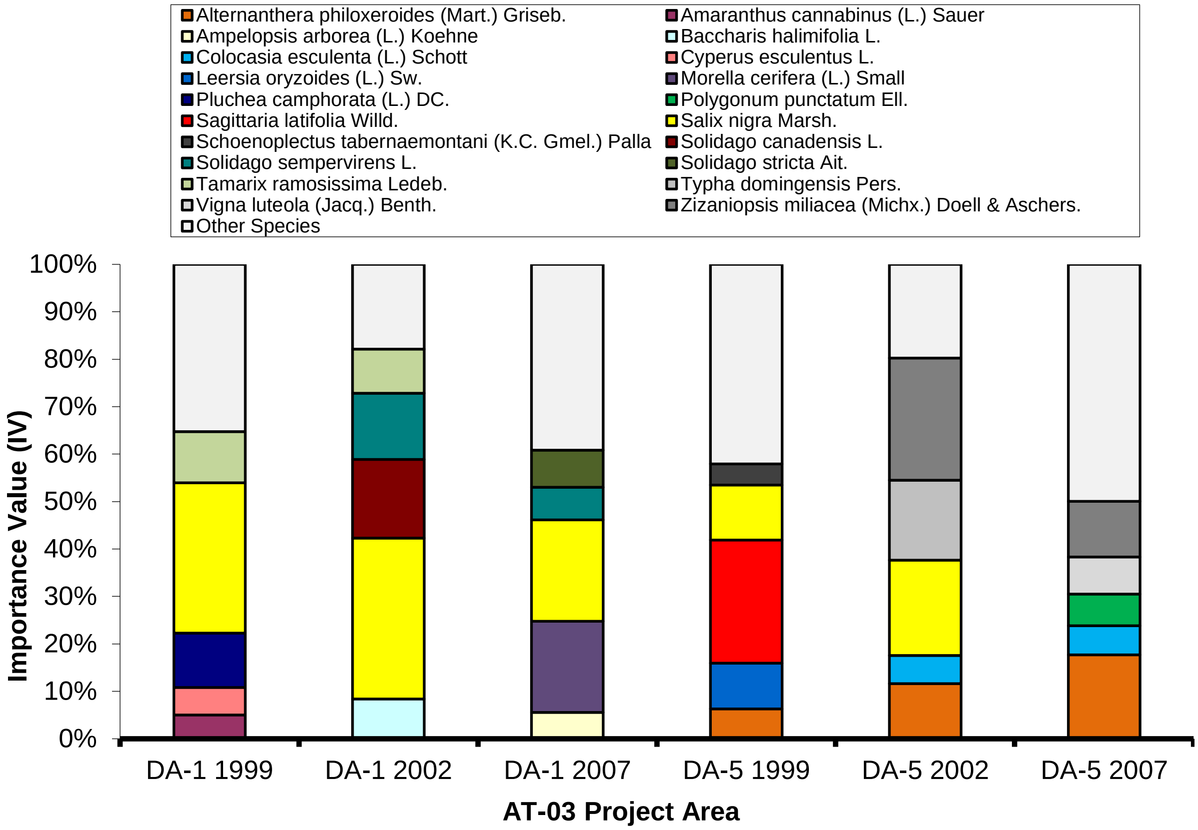


Figure 12. **Importance value (IV) of the top five vegetation species populating the Big Island Mining (AT-03) disposal areas from 1999 to 2007. Ocular vegetation data were grouped by disposal area and year.**

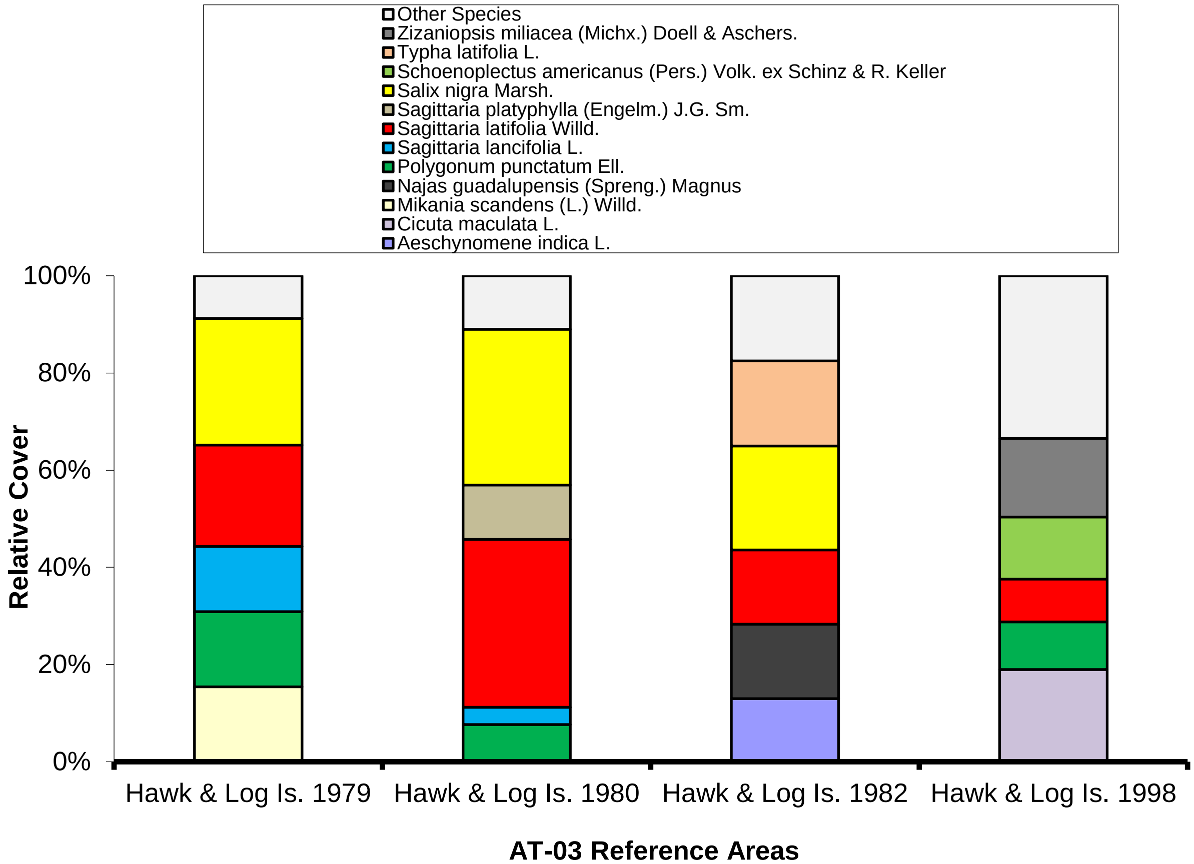


Figure 13. Relative cover of the top five vegetation species populating the Big Island Mining (AT-03) historical reference area from 1979 to 1998. Ocular vegetation data were grouped by year. Vegetation data provided courtesy of Louisiana State University/Coastal Ecology Institute (LSU/CEI).

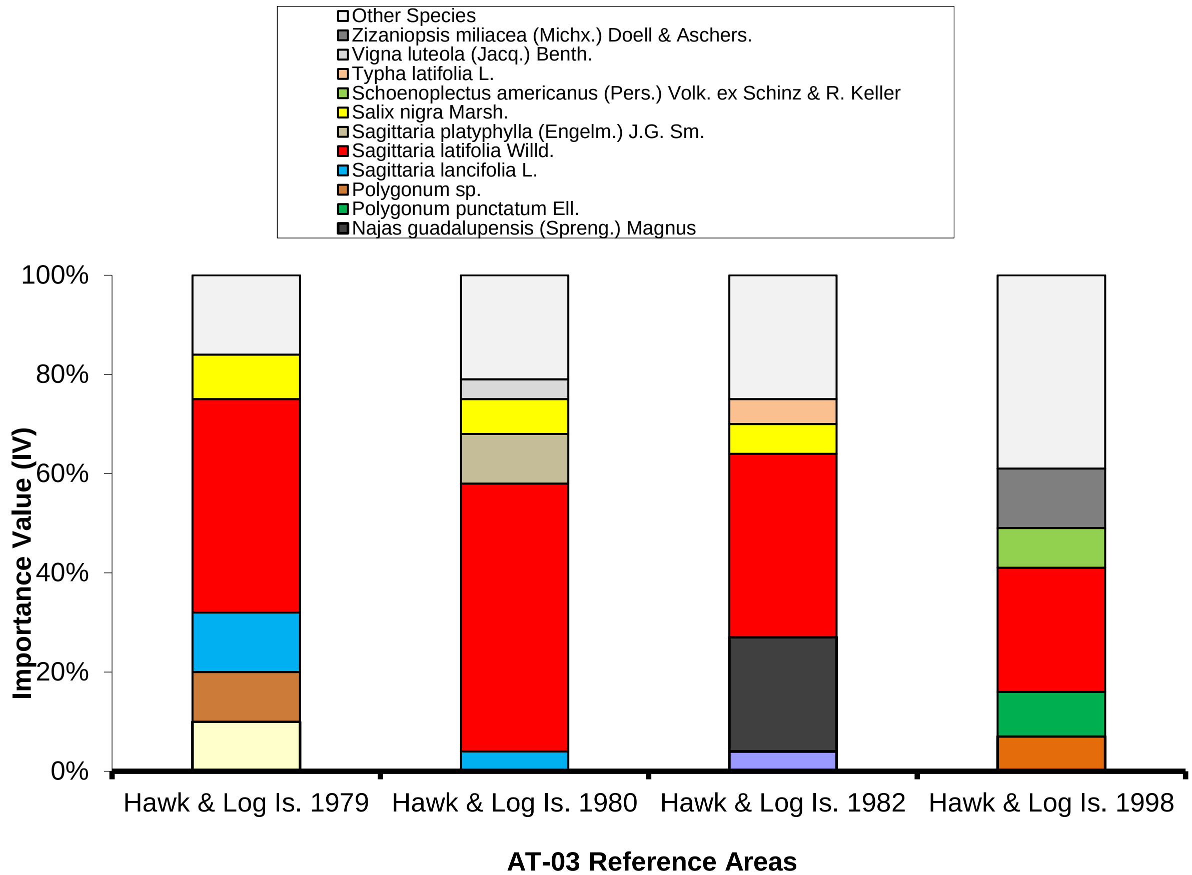


Figure 14. **Importance value (IV) of the top five vegetation species populating the Big Island Mining (AT-03) historical reference area from 1979 to 1998. Ocular vegetation data were grouped by year. Vegetation data provided courtesy of Louisiana State University/Coastal Ecology Institute (LSU/CEI).**

Habitat Mapping

The Big Island Mining (AT-03) project area experienced habitat colonization, succession, and disturbance since construction was completed in 1998. Combined mosaics and habitat maps for nearly all sampling intervals (1994, 1997, 1998, 2000, and 2007) are chronologically arranged in Figure 6 while the 2016 habitat map is displayed in Figure 15. Individual mosaics and habitat maps for each interval are located in appendix D (D-1 to D-10) for clarity and will not be referred to again in this text. By 1998, the project area consisted of 52% open water-fresh, 26% beach/bar/flat, 9% fresh marsh, 9% submerged aquatics, 4% wetland scrub-shrub, and 0.1% wetland forested habitats (Figure 6 and Table 3). The initial post-construction (as-built) habitat change analysis of the project area (1994-1998) show increases in beach/bar/flat (843%), wetland scrub-shrub (2,120%) and fresh marsh (59%) habitats and decreases in submerged aquatics (-51%) and open water-fresh (-29%) habitats (Figure 6 and Table 4).

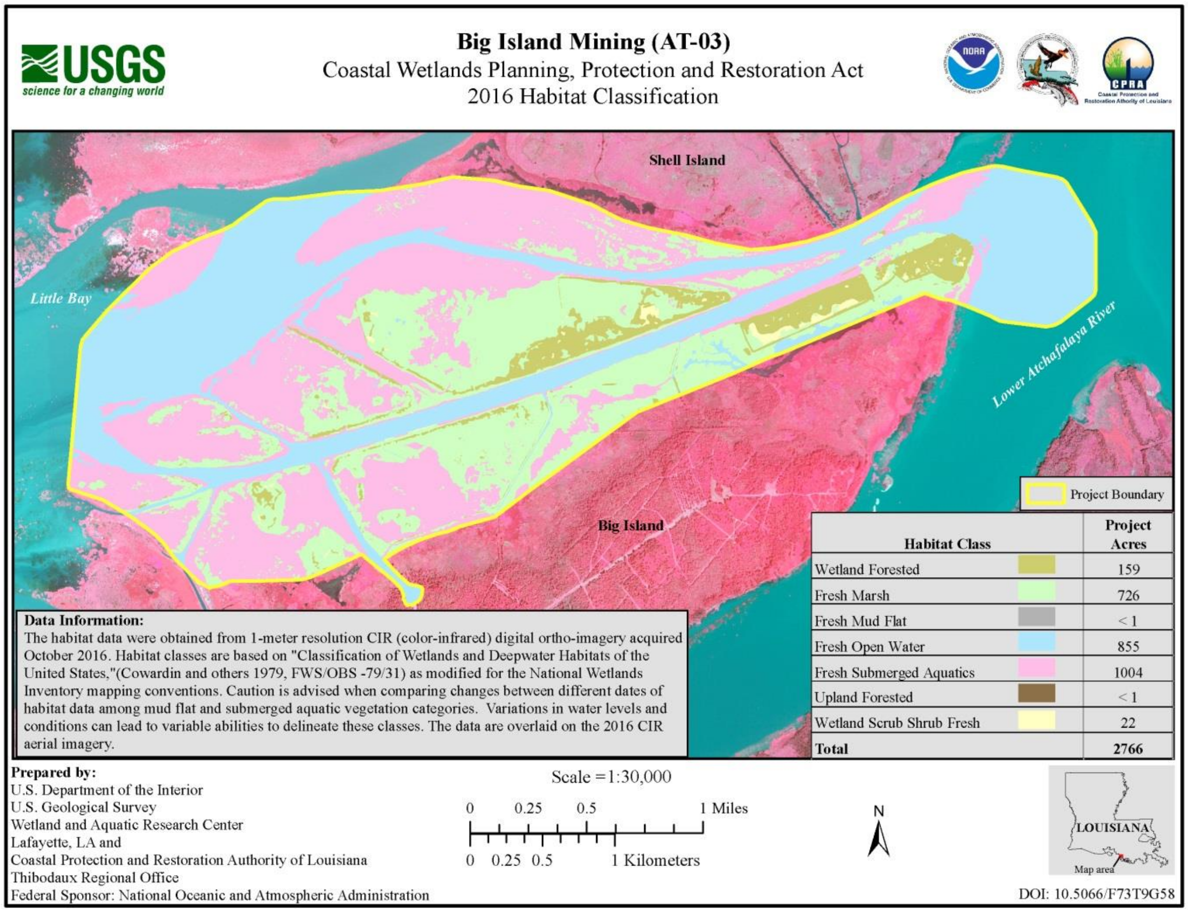


Figure 15. **2016 post-construction habitat analysis of the Big Island Mining (AT-03) project area.**

The large expanse of beach/bar/flat habitat in 1998 is probably due to the short duration between project completion (October 1998) and the as-built aerial photography (November 1998) while the AT-02 project had a full vegetative growing season before the as-built aerial image was captured (Curole and Hartman 2018). The populations of beach/bar/flat, fresh marsh, wetland scrub-shrub, and submerged aquatics are reflective of this. It was too soon after construction for large acreages of beach/bar/flat that was built later in the construction cycle to colonize with fresh marsh or wetland scrub-shrub species. Although fresh marsh and wetland scrub-shrub habitats did undergo sizeable growth in 1998, the expanse of these habitats should have been greater. The considerable enlargement of these habitats in the disposal areas by 2000 suggest untimely as-built habitat mapping (Tables 3, 4, and Figure 6). Additionally, the spread of wetland scrub-shrub habitats in the disposal areas in 1998 and 2000 signifies higher elevated wetlands were constructed. The declines in submerged aquatics habitat in 1998 are probably related to the creation of the disposal areas and channel dredging in areas once inhabited by submerged aquatics. Moreover, these disturbances to water bottoms were too recent for submerged aquatics species to recover. Subsequent (1998-

Table 3. **National Wetlands Inventory (NWI) habitat classes, acreages, and percentages photo-interpreted from 1994, 1997, 1998, 2000, 2007, and 2016 aerial photography for the Big Island Mining (AT-03) project**

Habitat Class Project Area	*1994 Acres (%)*	*1997 Acres (%)*	*1998 Acres (%)*	*2000 Acres (%)*	*2007 Acres (%)*	*2016 Acres (%)*
Agriculture/Range	0	1 (<1)	1 (<1)	0	0	0
Beach/Bar/Flat	77 (3)	55 (20)	726 (26)	350 (13)	280 (10)	<1
Fresh Marsh	155 (6)	196 (7)	247 (9)	372 (13)	628 (23)	726 (26)
Open Water-Fresh	2,036 (74)	1,388 (50)	1,439 (52)	1,318 (48)	1,266 (46)	855 (31)
Submerged Aquatics	488 (18)	1,116 (40)	239 (9)	464 (17)	373 (13)	1,004 (36)
Upland Barren	0	0	0	1 (<1)	<1	0
Upland Scrub-Shrub	2 (<1)	2 (<1)	0	1 (<1)	0	0
Wetland Forested	2 (<1)	2 (<1)	2 (<1)	2 (<1)	175 (6)	159 (6)
Wetland Scrub-Shrub	5 (<1)	5 (<1)	111 (4)	257 (9)	43 (2)	22 (1)
TOTAL	2,765	2,765	2,765	2,765	2,765	2,766

Table 4. **Habitat change and percent differences for the intervals listed below for the Big Island Mining (AT-03) project. These changes were derived from the NWI habitat classes recorded in Table 3.**

Habitat Class Project Area	*94-97 Change (%)*	*94-98 Change (%)*	*98-00 Change (%)*	*98-07 Change (%)*	*98-16 Change (%)*	*94-16 Change (%)*
Agriculture/Range	1	1	-1 (-100)	-1 (-100)	-1 (-100)	-77 (-99)
Beach/Bar/Flat	-22 (-29)	649 (843)	-376 (-52)	-446 (-61)	-726 (-100)	-571 (368)
Fresh Marsh	41 (26)	92 (59)	125 (51)	381 (154)	479 (194)	-1181 (-58)
Open Water-Fresh	-648 (-32)	-597 (-29)	-121 (-8)	-173 (-12)	-584 (-41)	-516 (106)
Submerged Aquatics	628 (129)	-249 (-51)	225 (94)	134 (56)	765 (320)	765 (320)
Upland Barren	0	0	1	0	0	0
Upland Scrub-Shrub	0	-2 (-100)	1	0	0	-2 (-100)
Wetland Forested	0	0	0	173 (8,650)	157 (7,850)	157 (7,850)
Wetland Scrub-Shrub	0	106 (2120)	146 (132)	-68 (-61)	-89 (-80)	17 (340)
TOTAL	0	0	0	0	1	1

2000, 1998-2007, and 1998-2016) post-construction habitat change analysis reveals fresh marsh gains in 2000, 2007, 2016; wetland forested gains in 2007 and 2016; and wetland scrub-shrub gains in 2000 and losses in 2007 and 2016 (Figures 6, 15, and Table 4). In 2016, the project area consisted of 31% open water-fresh, 26% fresh marsh, 36% submerged aquatics, <1% beach/bar/flat, 6% wetland forested, and 1% wetland scrub-shrub habitats (Table 3 and Figure 6). By the time of this terminal sampling event, a considerable acreage of beach/bar/flat habitat was converted to either fresh marsh or submerged aquatic habitats, and a large part of the wetland scrub-shrub habitat underwent succession to form wetland forested and fresh marsh habitats (Figures 6 and 15). Over time fresh marsh species continued to expand their range through colonization of beach/bar/flat habitat and areas displaying elevation change (Figures 6, 8, 9, and 15). In fact, accretionary processes occurring in the northern quadrant of DA5 aided in the conversion of open water–fresh, submerged aquatics, and beach/bar/flat habitats in 2000 to fresh marsh in 2007 (Figures 6 and 8). The sizeable reduction in wetland scrub-shrub habitat from 2000 to 2007 (-83%) and an additional -49% loss from 2007 to 2016 is attributable to forest maturation in DA1 and DA5 (Figures 6 and 15) and elevation declines in DA1 and DA5 (Figures 8 and 9). Furthermore, a -30% decrease in woody vegetation occurred between 2000 and 2016 primarily due to subsidence in the higher elevated portions of DA5 (Figures 8 and 9). Alteration of scrub-shrub to marsh habitat has been found to be initiated by sediment consolidation on other marsh creation projects (Boshart 2003). In closing, the project area has been altered since construction through succession and disturbance (sediment additions and subsidence).

The Big Island Mining (AT-03) project did not reach its beneficial use of dredge material acreage goal. Approximately, 284 ha (702 acres) of emergent wetland habitats were created for the nineteen year period from 1997 (pre-construction) to 2016 (post-construction). Moreover, 221 ha (547 acres) of the wetland habitats were established after construction from 1998 (as-built) to 2016 (post-construction). The creation of 284 ha (702 acres) of emergent wetland habitats approaches but does not attain the projected goal to create 344 ha (850 acres) of delta lobe islands in the project area. Furthermore, only 235 ha (581 acres) of emergent wetlands were constructed in the disposal areas over the project life (1998-2016). The primary reason that this goal fell short of its beneficial use of dredge material acreage goal is large acreages of DA6 (49%), DA8 (65%), and DA9 (61%) were established at low elevations and remained subaqueous throughout the project life (Figures 4, 6, and 15). In fact, 62-68% of these disposal areas were established at elevations below +0.3 m (+1.0 ft) NGVD 29 (Mayer 1998). Other dredge and fill restoration projects have also failed to reach their emergent marsh vegetation acreage goals due to under filling creation areas (Curole 2001; Curole and Hartman 2016).

The Big Island Mining (AT-03) project area experienced considerable subaqueous growth and modest subaerial growth before construction. Pre-construction habitat change analysis of the project area (1994-1997) show increases in submerged aquatics (129%) and fresh marsh (26%) habitats and decreases in and open water-fresh (-32%) and beach/bar/flat (-29%) habitats while wetland scrub-shrub and wetland forested habitats remain unchanged (Table 4 and Figure 6). During this 3 year pre-construction interval, extensive conversion of open water-fresh to submerged aquatics habitat transpired and small acreages of naturally created beach/bar/flat and submerged aquatics habitat were colonized by fresh marsh vegetation. The distribution and abundance of submerged aquatic habitats can be ephemeral because these environments are very susceptible to changes in light penetration. Increases or decreases in light penetration alternatively regulate the growth or declines in this habitat (Cho and Poirrier 2005; Koch 2001). Although submerged aquatics environments are very dynamic, habitat expansion at a rate of 87 ha/yr (214 acres/yr) is noteworthy (Table 4 and Figure 6). Fresh marsh habitat enlarged its areal extent by 17 ha (41 acres) or 6 ha/yr (14 acres/yr) in the pre-construction period (Table 4 and

Figure 6). The substantial spring flood of 1997 probably induced these increases in submerged aquatics and fresh marsh habitats (Trotter et al. 1998; DeHaan et al. 2012). While the rate of fresh marsh development was appreciably higher following construction, the pre-construction data illustrates that subaerial growth was occurring in the project area before construction.

Subaerial and Subaqueous Growth

The Big Island Mining (AT-03) project area experienced subaerial growth, subaqueous to subaerial conversion, and subaqueous growth since construction. Figures 16 and 17 delineate the growth in the project area from 1998 to 2007 and from 1998 to 2016. Large acreages of subaqueous habitats were converted to subaerial habitats (subaqueous to subaerial) inside the AT-03 disposal areas from 1998 to 2007 (Figure 16 and Table 5). This occurred primarily through the colonization of beach/bar/flat habitat by fresh marsh vegetation. It is important to note that the 1998 habitats were derived from aerial images captured less than 1 month after construction was completed. Therefore, the disposal areas were not given time to vegetate before the habitats were classified in 1998 and a large expanse of barren habitats remained (Figure 6). By 2000, vegetated wetlands enlarged their areal extent in the disposal areas. The subaqueous to subaerial conversion in the AT-03 disposal areas continued to develop after 2000 principally in DA5, DA8, and DA9 (Figure 6). However, these acreages declined by 27 ha (67 acres) in 2016 due to small reductions in this growth class in DA5, DA6, DA8, and DA9 (Figure 17 and Table 5). Very little subaerial (open water-fresh to subaerial habitat) or subaqueous (open water-fresh to beach/bar/flat or submerged aquatics habitat) growth arose in the disposal areas (Table 5). The largest part of this subaerial and/or subaqueous growth occurred along the edges of the disposal areas for the 1998-2007 interval (Figure 16). This trend in of minimal subaerial and subaqueous growth inside the AT-03 disposal areas continued for the 1998-2016 interval (Figure 17 and Table 5).

Outside the disposal areas subaerial growth emerged in very small acreages at a few locations within the project area for the 1998-2007 interval (Table 5). The majority of subaerial growth transpired along channel banks on the edge the disposal areas, on the remains of subsided spoil banks (remnant channels), and the area between DA5 and Shell Island (Figure 17). Additionally, the formation of subaerial bars on the upstream ends of CB and CD has restricted flow, the distributary potential of these channels, and began to colonize with emergent vegetation. Interestingly, a large part of the subaerial growth at the mouth of CA materialized along the remains of degraded spoil banks (remnant channels) (Figure 16), and the subaerial growth between DA5 and Shell Island took place adjacent to submerged aquatic beds. Subaerial growth moderately accelerated its growth outside of the disposal areas for the 1998-2016 interval (Table 5). This expansion in subaerial growth transpired in locations, consistent with the earlier 1998-2007 interval (Figure 17). The 1998-2016 subaerial growth was particular prominent along the remnant channels the bar on the upstream end of CD, and the area between DA5 and Shell Island. These expansions in subaerial habitats were likey catalyzed by the substantial Mississippi River flood of 2011 (DeHaan et al. 2012).

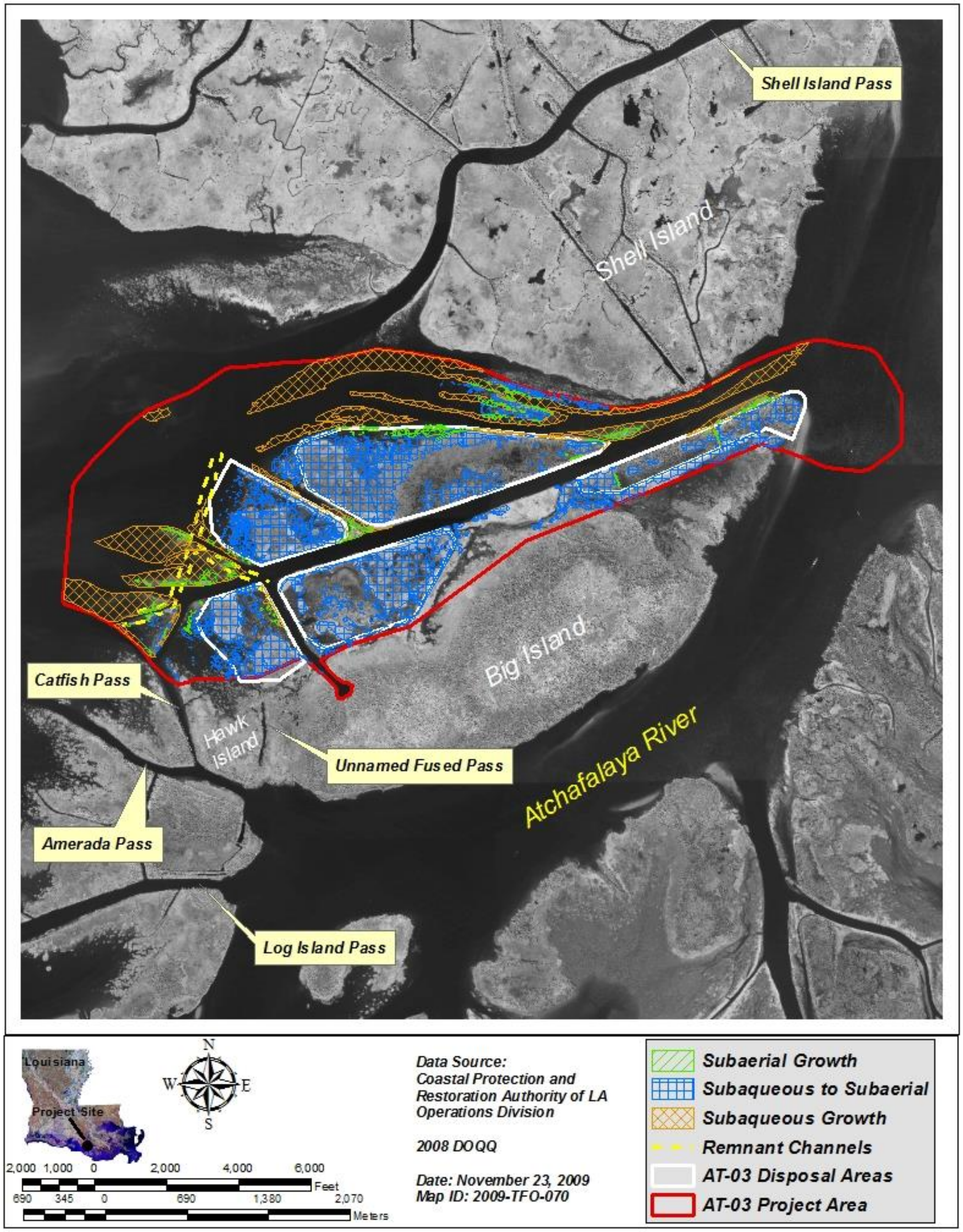


Figure 16. **Location of areas experiencing subaerial growth, subaqueous to subaerial conversion, and subaqueous growth inside the Big Island Mining (AT-03) project area from 1998 to 2007.**

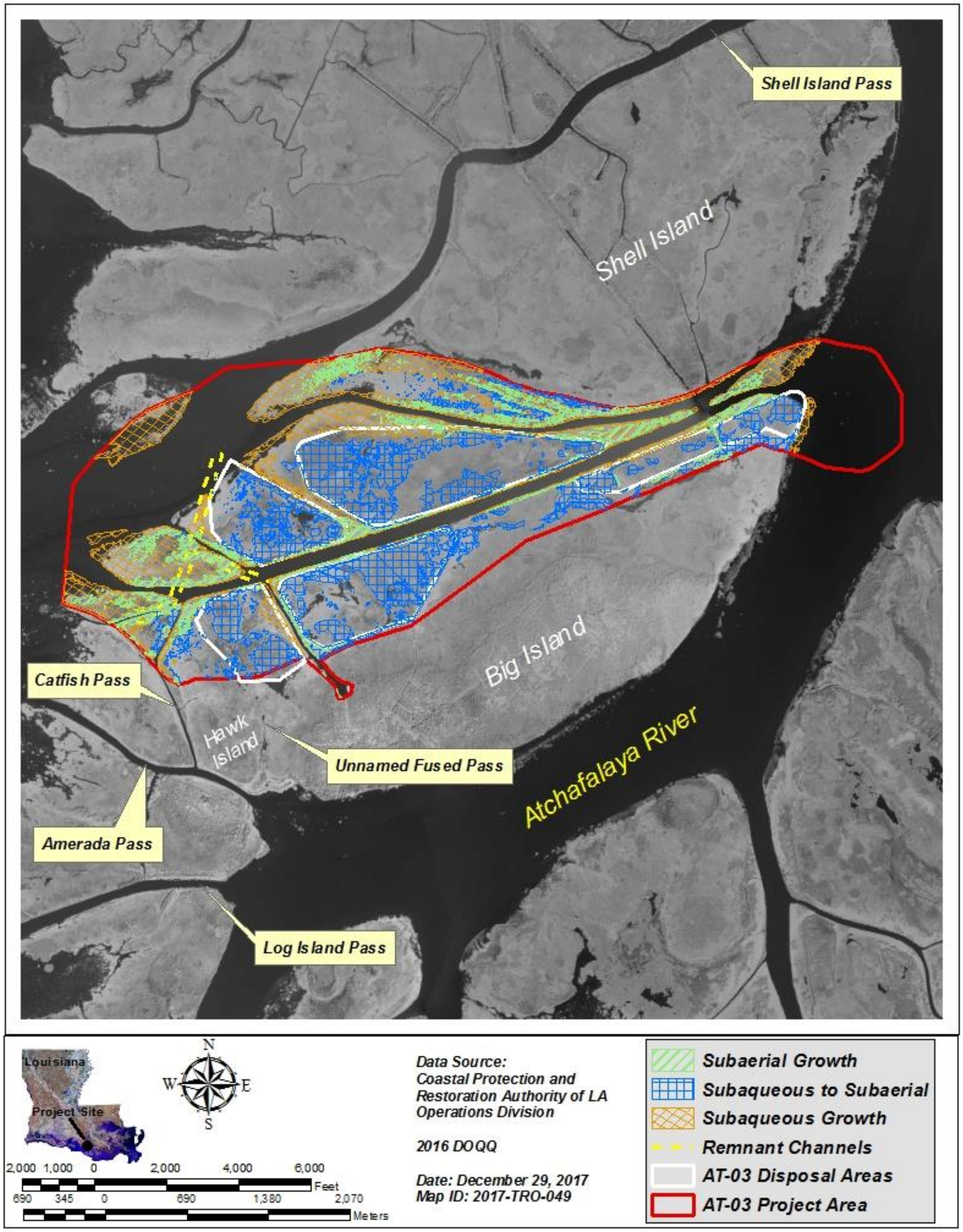


Figure 17. **Location of areas experiencing subaerial growth, subaqueous to subaerial conversion, and subaqueous growth inside the Big Island Mining (AT-03) project area from 1998 to 2016.**

Table 5. **Subaerial growth, subaqueous to subaerial conversion, and subaqueous growth occurring inside and outside the disposal areas at the Big Island Mining (AT-03) project from 1998 to 2007 and 1998 to 2016. Data reported in acres, acres/yr, and percentage (%).**

AT-03 Area	1998-2007 Acres	1998-2007 Acres/yr	1998-2007 %	1998-2016 Acres	1998-2016 Acres/yr	1998-2016 %	Classes
Outside DA	22.6	2.5	75.4	119.1	6.6	95.8	*Subaerial*
Inside DA	7.4	0.8	24.6	5.2	0.3	4.2	*Subaerial*
Total	29.9	3.3		124.3	6.9		*Subaerial*
Outside DA	81.3	9.0	16.9	120.6	6.7	26.4	*Subaqueous to Subaerial*
Inside DA	401.0	44.6	83.1	335.8	18.6	73.6	*Subaqueous to Subaerial*
Total	482.3	53.6		456.1	25.3		*Subaqueous to Subaerial*
Outside DA	349.6	38.9	95.4	486.2	27.0	95.3	*Subaqueous*
Inside DA	16.8	1.9	4.6	24.0	1.3	4.7	*Subaqueous*
Total	366.4	40.7		510.2	28.3		*Subaqueous*

Subaqueous to subaerial conversions outside the disposal areas surfaced on the landward border of some disposal areas, at the northern junction of DA5 and CB, and the area between DA5 and Shell Island for the 1998-2007 interval (Figure 16 and Table 5). The conversions of beach/bar/flat and submerged aquatics habitats to fresh marsh on the disposal area borders were the result of vegetation colonization and perhaps vertical accretion. In addition, the area between DA5 and Shell Island experienced small amounts of submerged aquatics to fresh marsh conversion. For the 1998-2016 interval, the growth of the subaqueous to subaerial class slowed a little (Table 5) although the acreage of this class in the area between DA5 and Shell Island seems to have increased.

The subaqueous growth class expanded at a faster rate than the other classes on the outside of the AT-03 disposal areas for the 1998-2007 interval. This trend continued for the 1998-2016 interval but at a slower rate (Figures 16, 17, and Table 5). Several noteworthy subaqueous features were created in the project area over time. The first of these features is a predominantly subaqueous bar that formed during the 1998-2007 interval and extends from the Atchafalaya River to CD. This bar forms a partial barrier to fluvial discharge and narrows the entrance to the secondary channel (CA). By 2016, a large portion of this bar became subaerial (Figures 16 and 17). The second feature is the expanding submerged aquatic beds between DA5 and Shell Island. These beds have been increasing their areal extent since 1997 (Figure 6), and subaerial fresh marsh habitats have formed intermittently along its length (Figures 15, 16, and 17). The third feature is the formation of subaqueous bars at the mouth of CA (Figures 6, 15, 16, and 17). These bars are predominantly subaqueous with subaerial fresh marsh found on the outer perimeter of several banks. It appears that these geomorphic features formed in the low contour mouth of the secondary channel (CA). Nearly all the subaerial portions of these bars overlie degraded spoil banks of remnant channels (Figures 16 and 17). These spoil banks seem to have facilitated sedimentation and bar formation at this location. The southern bar began aggrading around 1997 (Figure 6) receiving sediments from Catfish Pass (Figures 16 and 17). This bar expanded between 2000 and 2016 aggregating discharge from CA and Catfish Pass. Likewise the northern bar probably has received discharge from CA, Shell Island Pass, and the small channel between DA5 and Shell Island (Figures 6, 15, 16, and 17). The creation of these bars infers that some bedload transport is occurring within the project area (Edmonds and Slingerland 2007). Outside the project area, Catfish Pass is progressively aggrading and narrowing and Hawk Island is fusing with Big Island (Figures 6, 16, and 17). Therefore, channels in the immediate vicinity of the project area are also shoaling and contracting, like the AT-03 tertiary channels (DuMars 2002; Letter et al. 2008; Roberts and van Heerden 1992; Mashriqui 2003). Moreover, the unnamed Hawk Island Pass is undergoing channel abandonment and lobe fusion and is barely visible on 2016 CIR imagery (Roberts and van Heerden 1992; Roberts 1998; van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991). While the formation of these bars and other features is notable, these features do not fit the river mouth bar model of delta growth (Edmonds and Slingerland 2007).

Table 6 shows the growth of the three subaerial and subaqueous growth classes for the 1998-2007 and 1998-2016 intervals. Percent differences reveal that the later interval had a sizable increase in its subaerial growth rate and the growth rate for the subaqueous class slowed while the subaqueous to subaerial class incurred minor erosion. Although the growth rate slowed over time, approximately 39 ha (97 acres) of subaerial and 58 ha (144 acres) of subaqueous habitats were created in the project area from 2007 to 2016 (Table 6). In conclusion, the goal to increase the rate of subaerial growth in the project area was achieved because the subaerial growth rate for the 1998-2007 [5 ha/yr (12 acres/yr)] and the 1998-2016 [5 ha/yr (13 acres/yr)] (subaerial + subaqueous to subaerial) intervals exceeded the pre-construction growth rates estimates of 2 ha/yr (4 acres/yr) from 1956 to 1978 and 1 ha/yr (3 acres/yr) from 1978 to 1990 (Barras et al. 2004).

Table 6. **Subaerial growth, subaqueous to subaerial conversion, subaqueous growth, and subaerial + subaqueous to subaerial conversion acreage changes and percent differences for the intervals listed below for the Big Island Mining (AT-03) project. These changes were derived from the classes recorded in Table 5.**

1998-2007 Acres	1998-2016 Acres	Change Acres	2007-2016 % Diff	Classes
29.9	124.3	94.4	315.4	*Subaerial*
482.3	456.1	-26.1	-5.4	*Subaqueous to Subaerial*
366.4	510.2	143.9	39.3	*Subaqueous*
512.0	580.5	68.5	13.4	*Subaerial + Subaqueous to Subaerial*

Land Area Change

The land area change assessment of CRMS0463 showed that a 1.0 km^2 (0.4 mi^2) square portion of this AT-03 reference site increased in land area over the 30 year interval. Figure 18 displays the trend in the regression line for the 1984 to 2016 interval and estimates the acreage gain at 0.51 ha/yr (1.3 acres/yr) inside the CRMS site. The acreage increases seen in the regression line generally support the trends seen in the AT-03 assessment and point toward continued growth in the project area. The trend seen in the AT-02 CRMS site (CRMS-6304) also reinforces growth but at a higher rate than the CRMS0463 site (Curole and Hartman 2018). These comparisons are similar to the AT-02/AT-03 subaerial growth relationship.

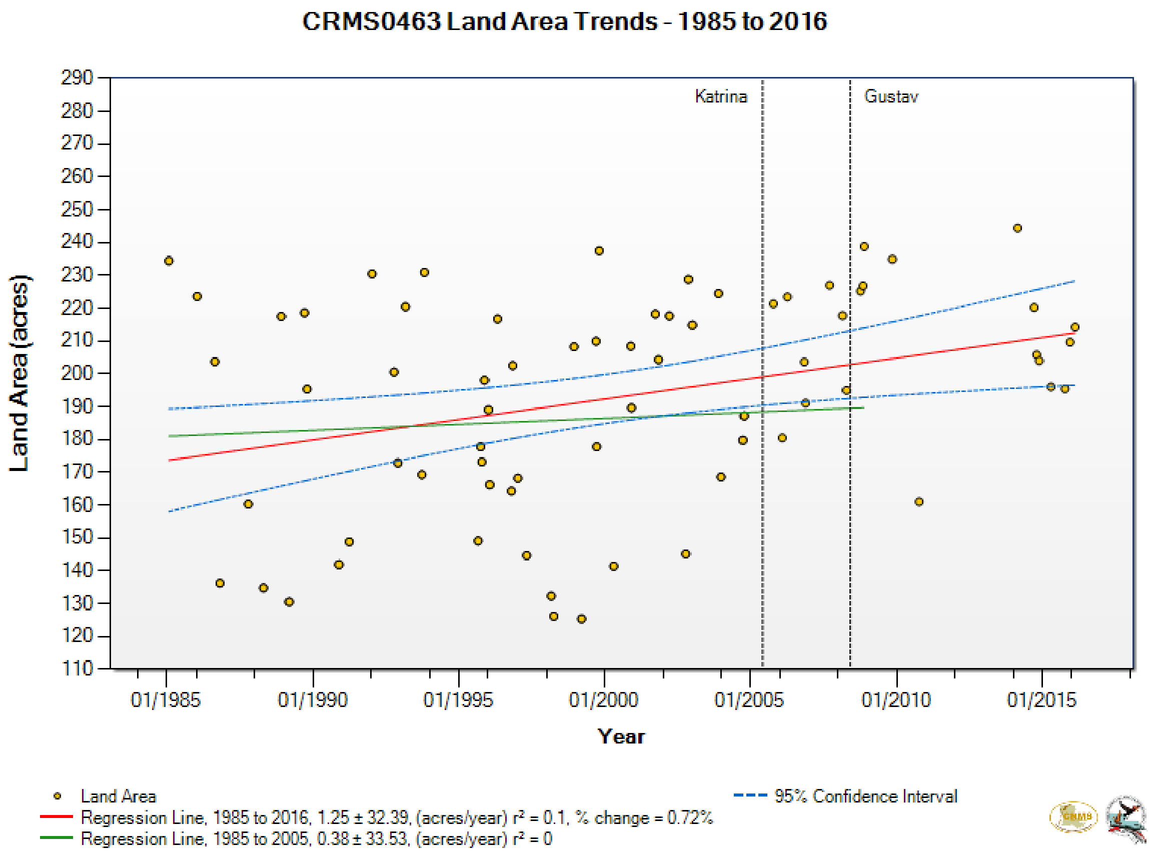


Figure 18. Site scale land area change for CRMS0463. Land area values are displayed for all cloud free Landsat images available for 1984-2016. The red line depicts the land change trend for the entire period of record.

V. Conclusions

a. Project Effectiveness

The results of the Big Island Mining (AT-03) project reveal that two of the project goals have not been achieved to date while the third goal was attained. The first goal to increase the project areas delta-building potential through the establishment of effective distributary channels has not been achieved to date because large scale aggradation transpired in the secondary and tertiary channels during the post-construction period. The constructed channels are also experiencing channel narrowing and modifications to their channel morphology. Moreover, this extensive shoaling and narrowing occurring in the secondary and tertiary channels indicates that the dredged channels are not hydraulically efficient. Therefore, these channels are transporting a reduced discharge and have a lowered delta-building potential.

The second goal to create approximately 340 ha (850 acres) of delta lobe islands through the beneficial use of dredged material at elevations suitable for emergent marsh vegetation has not been accomplished as of fall 2016 because only 284 ha (703 acres) were created. While colonization of the disposal areas continued to expanded over time, the project fell 59 ha (147 acres) short of its goal. The fate of this goal was likely predetermined when large acreages of DA6, DA8, and DA9 were established at lower than desired elevations.

The third goal to increase the rate of subaerial growth in the project area was achieved because the subaerial growth rate of 5 ha/yr (13 acres/yr) (subaerial + subaqueous to subaerial) from 1998-2016 exceeded the pre-construction growth rates estimates of 2 ha/yr (4 acres/yr) from 1956 to 1978 and 1 ha/yr (3 acres/yr) from 1978 to 1990 (Barras et al. 2004). Therefore, the creation of the dredged channels and disposal areas seems to have improved the subaerial growth rate. In conclusion, the AT-03 project has not been successful in establishing an effective distributary channel network and creating 340 ha (850 acres) of delta lobe islands, but the AT-03 project was successful in increasing the subaerial growth rate during the 18-year post-construction period.

b. Recommended Improvements

The Big Island Mining (AT-03) project would have been more sustainable if the following improvements would have been incorporated into the design of the project. The first step in the design process should have been to conduct a geomorphic assessment of the area surrounding the diversion location. The process would help select a diversion location that is conducive to sediment transport. Secondly, a conceptual model should have been created. This type of model estimates the hydrodynamics and sediment transport capacity of the overall system (the river and the receiving basin). Thirdly, a hydrodynamic and sediment transport model should have been created. These models quantify water and sediment discharge and forecast morphological changes to channels and landscapes. If these three steps would have been undertaken, the future outcome of the diversion could have been predicted, and the AT-03 channels would not have aggraded so rapidly.

The monitoring regime of the Big Island Mining (AT-03) project should have been expanded to estimate the geomorphic processes affecting the project area. The current data collection scheme is very reactionary (passive). The data collected from these methods only confirm what already happened. The data show where the channel has shoaled or where new landforms are visible. This data leads to speculation as to why the channel shoaled or why the new landforms were created. A more dynamic sampling protocol is needed to determine the mechanisms forcing geomorphic change in the project area. This protocol should include quantitative estimates of discharge (Q) during flood and non-flood conditions. The discharge measurements should consist of water velocity and volume, suspended sediment concentrations, and channel stratigraphy. The suspended sediment and channel stratigraphy data should be qualitative and quantitative to estimate the probability of geomorphic change in the project area. In addition, the habitat mapping, bathymetry, and topography procedures still need to be collected to locate change within the project area over time. Moreover, the data collected from this type of sampling regime could be used to not only foresee changes in the project area but also could be used to design more sustainable sediment diversion projects.

c. Lessons Learned

Several channel morphology and sediment transport lessons were learned from the Big Island Mining (AT-03) project. The first lesson is that constructing tertiary channels at acute angles did not increase the delta-building potential or the rate of subaerial growth because these channels aggraded so rapidly. Although delta channels typically are formed at acute angles, these channels are forced into this shape by concentrated discharge and bedload transport. The channel locations are not predetermined. Deltas extend seaward through channel elongation and bifurcation or avulsion. Channel elongation and bifurcation is the dominant mechanism expanding deltas seaward. Therefore, it would have probably been more conducive to dredge a secondary channel and let the discharge determine the location of the tertiary channels. Secondly, the project was constructed in an area with low contours and the dredged channels discharged into shallow basins. Therefore, during low discharge events, the channels probably aggraded quickly. Thirdly, the sediment diversion seems to be built on the wrong side of a concave bendway of the Atchafalaya River. This lowers discharge and causes aggradation in the dredged channels.

One disposal area lesson was learned from the Big Island Mining (AT-03) project. Containment dikes in high sediment environments should be degraded or have wider and more frequent gaps because only the portion of DA5 adjacent to a degraded dike accreted. Other portions of DA1 and DA5 experienced volume losses. Therefore, degrading or expanded gapping of containment dikes should be considered after constructing marsh creations projects in high sediment environments.

One habitat mapping lesson was learned from the Big Island Mining (AT-03) project. The Atchafalaya Sediment Delivery (AT-02) and Big Island Mining (AT-03) projects are excellent examples of why the temporal consistency is important when creating as-built habitat maps for marsh creation projects. The AT-02 project had one full growing season before the habitat maps were created while the AT-03 maps were created soon after construction was complete. The results of these maps reflected this. All the confined AT-02 disposal areas (DA1, DA2, and DA3) were colonized with vegetation for the as-built habitat map. As for AT-03, only DA1 had large percentages of vegetative cover for the as-built habitat map. The fact that the as-built habitat maps were collected at different temporal points of vegetation colonization construed the results a little. AT-03 showed greater conversion of beach/bar/flat habitats to fresh marsh and wetland scrub-shrub within the disposal areas over time while AT-02 did not because the AT-02 confined disposal areas were already colonized when the as-built map was delineated. In conclusion, temporal timing of as-built habitat maps is necessary when comparisons between projects are to be undertaken. Moreover, if the baseline mapping events of paired projects have similar timings, the early vegetation colonization assessments should likewise follow the same trajectory.

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Appendix A
(Inspection Photographs)

Figure A-1. **View of CA near its junction with the Atchafalaya River looking southwest. DA1 is on the immediate left side of the image while DA5 is on the right in the background behind the vegetated bar.**

Figure A-2. **View of CB at its junction with CA. Note the vegetated bar that extends across the entire width of this channel.**

Figure A-3. View of CC looking northeast.

Figure A-4. View of CD at its intersection with CA.

Figure A-5. **View of Extended Channel A-2 looking west.**

Figure A-6. **View of Extended Channel A-1 looking west.**

Figure A-7. **View of CF from its confluence with CA and CE.**

Figure A-8. **View of CE from its confluence with CA and CF.**

Figure A-9. **View of the cul-de-sac at the terminal end of CE.**

Figure A-10. **View of CF looking northwest.**

Appendix B
(Elevation Grid Models)

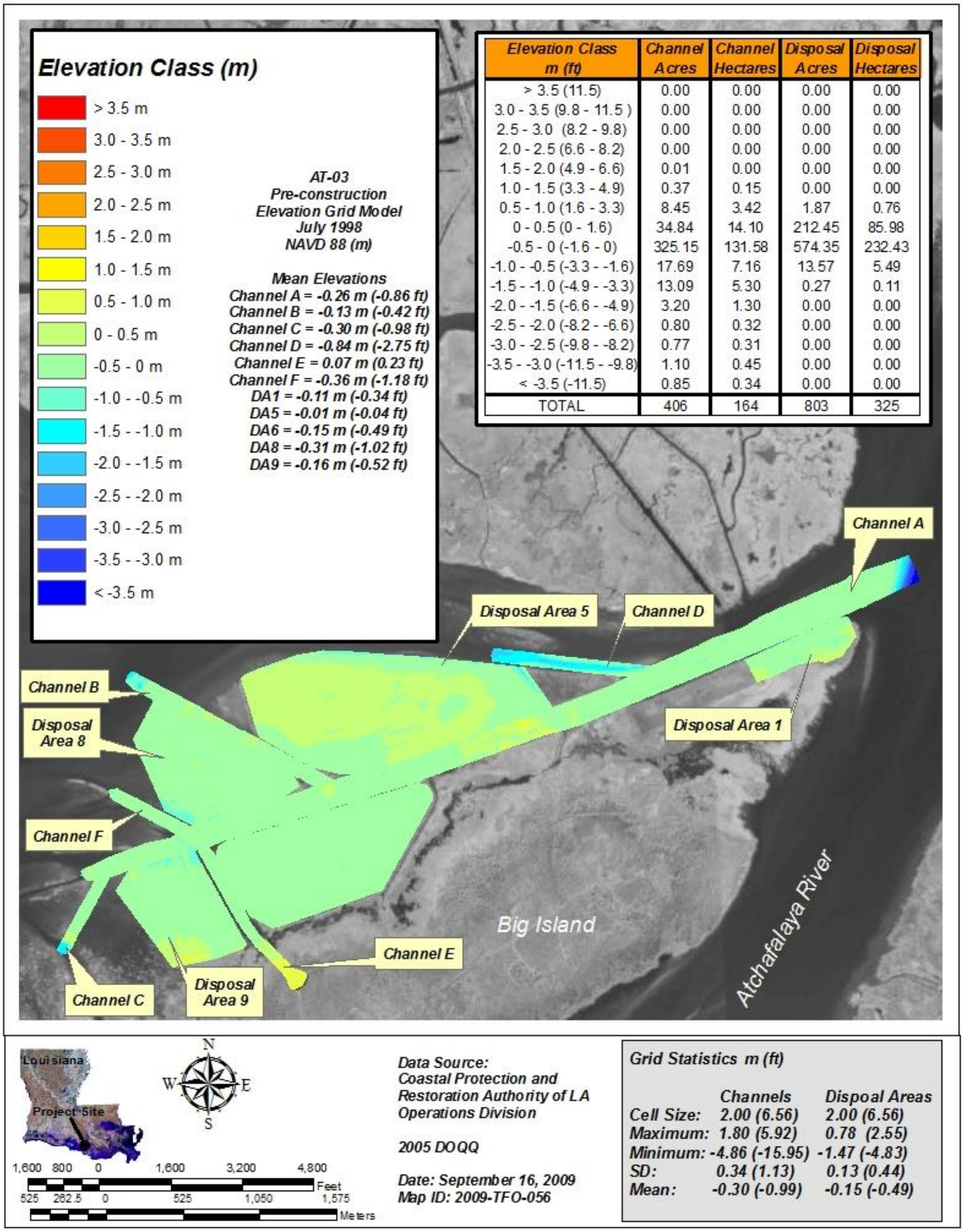


Figure B-1. **Pre-construction (1998) elevation grid model at the Big Island Mining (AT-03) project.**

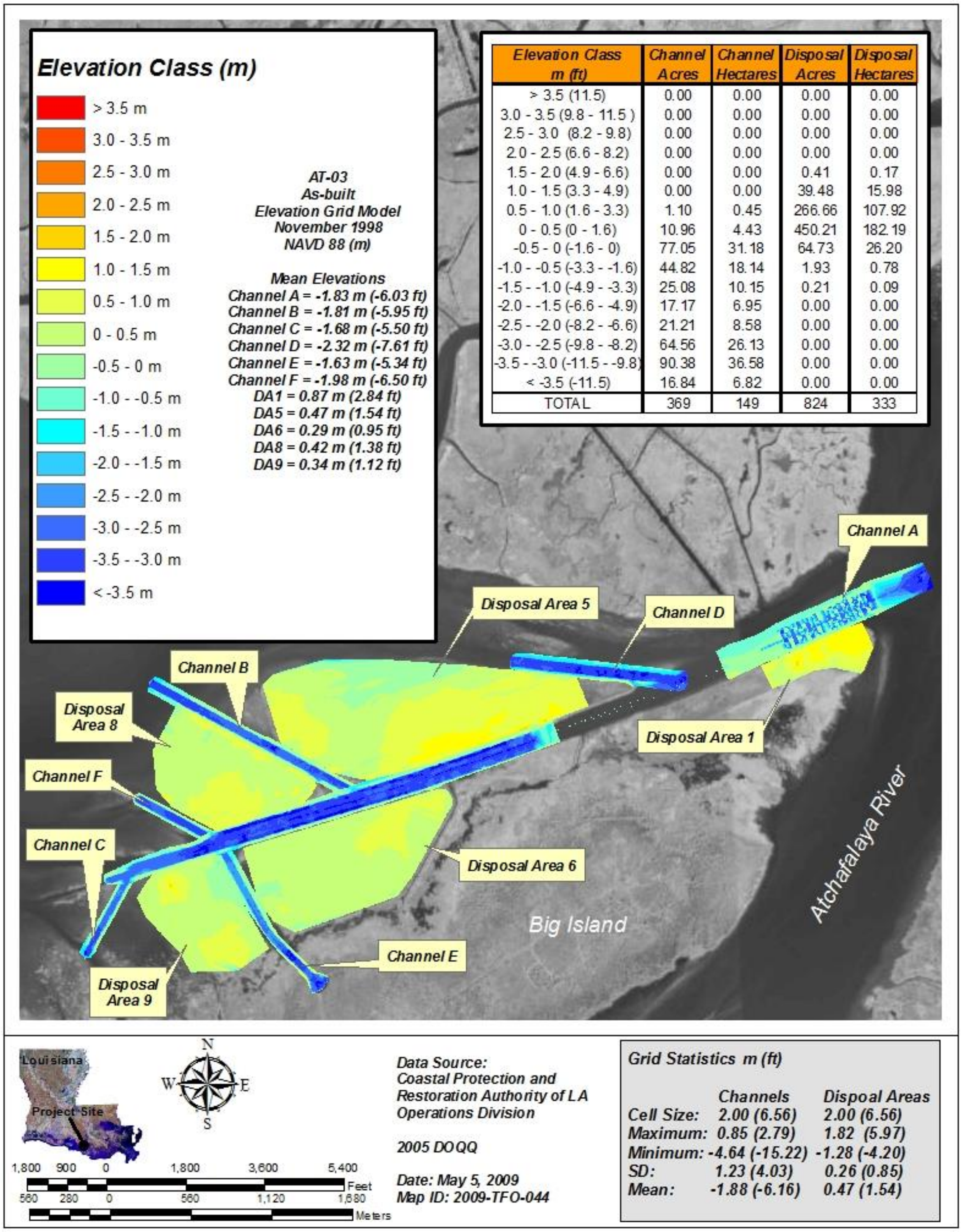
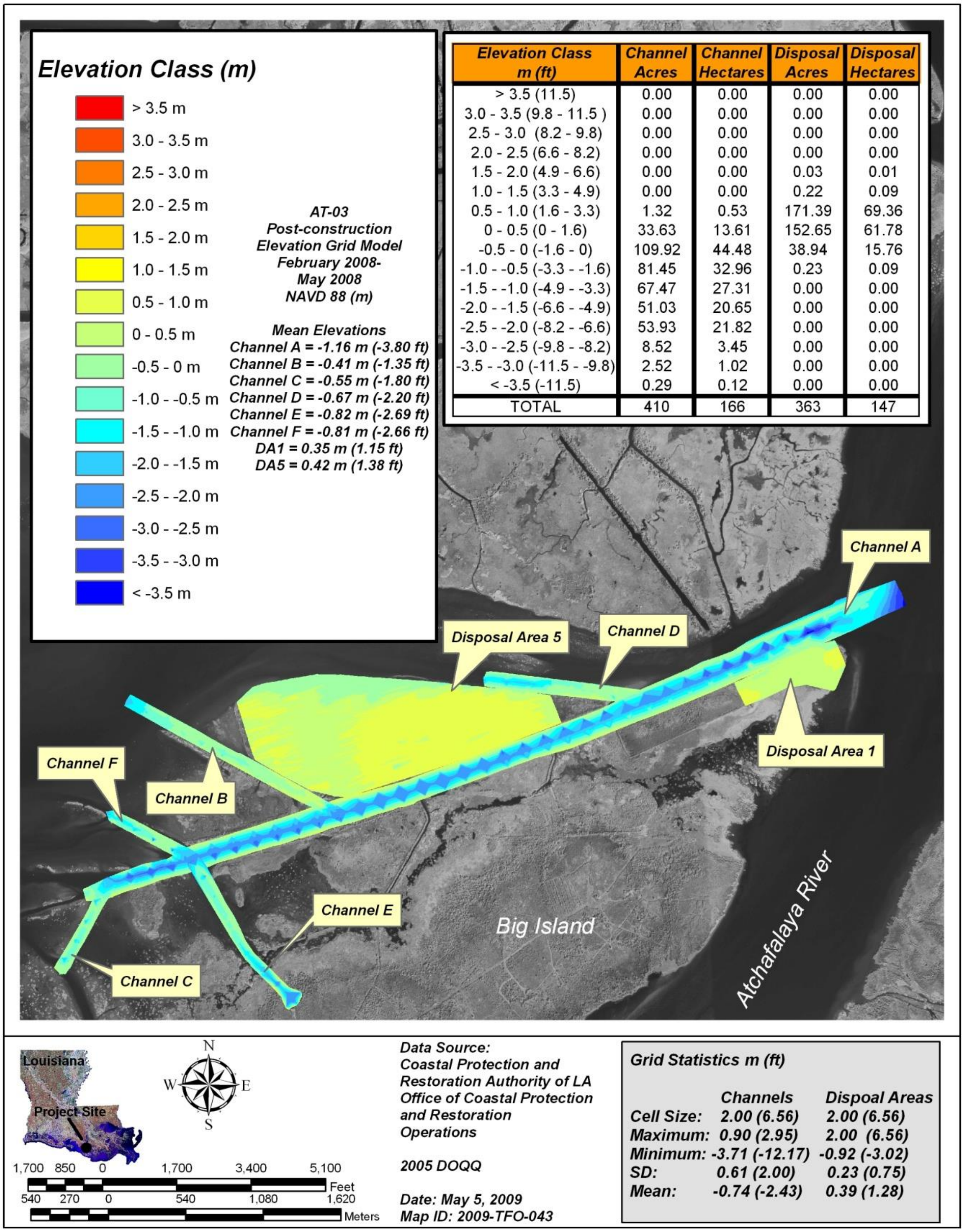


Figure B-2. **As-built (1998) elevation grid model at the Big Island Mining (AT-03) project.**

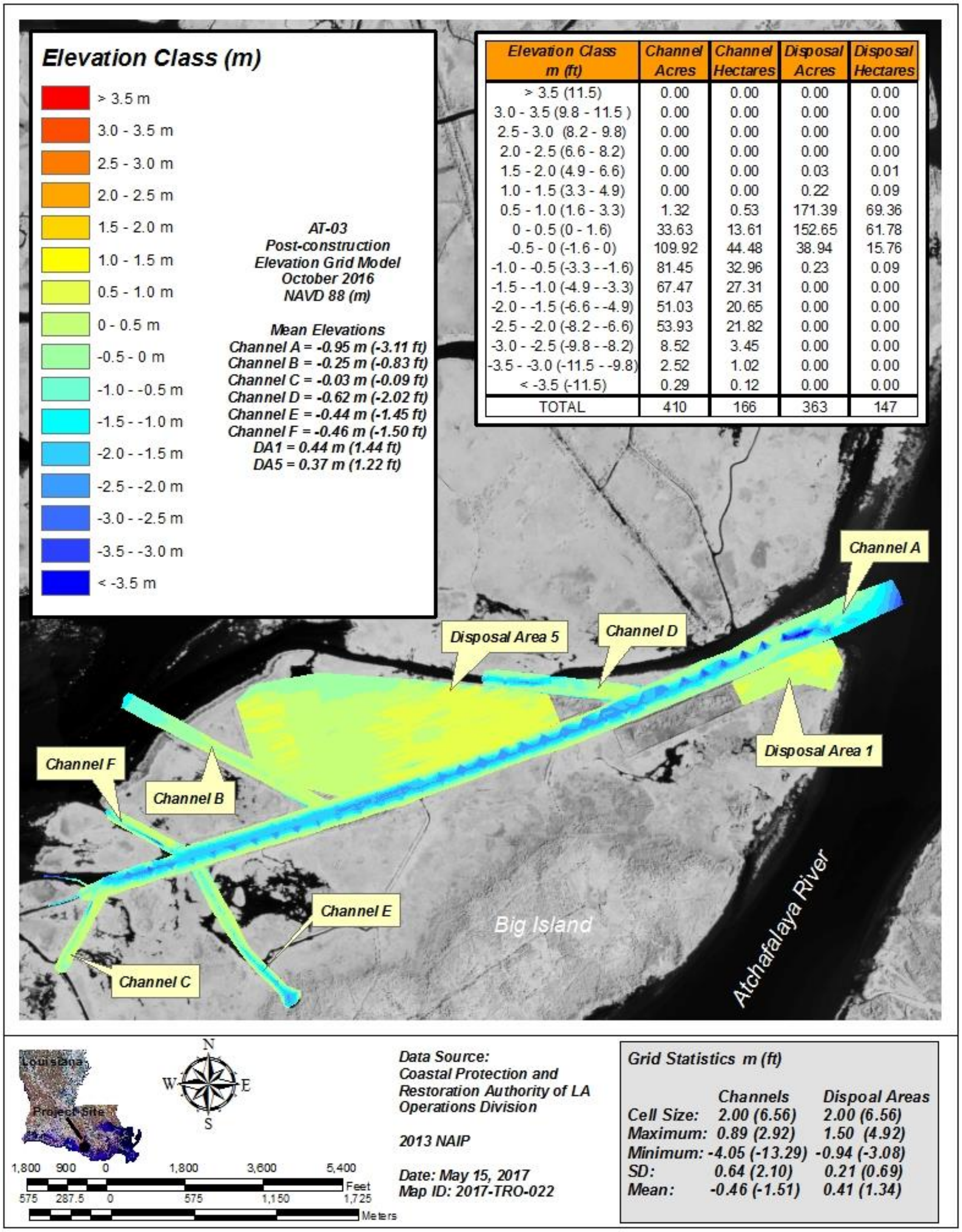


Elevation Class m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	0.00	0.00	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00	0.03	0.01
1.0 - 1.5 (3.3 - 4.9)	0.00	0.00	0.22	0.09
0.5 - 1.0 (1.6 - 3.3)	1.32	0.53	171.39	69.36
0 - 0.5 (0 - 1.6)	33.63	13.61	152.65	61.78
-0.5 - 0 (-1.6 - 0)	109.92	44.48	38.94	15.76
-1.0 - -0.5 (-3.3 - -1.6)	81.45	32.96	0.23	0.09
-1.5 - -1.0 (-4.9 - -3.3)	67.47	27.31	0.00	0.00
-2.0 - -1.5 (-6.6 - -4.9)	51.03	20.65	0.00	0.00
-2.5 - -2.0 (-8.2 - -6.6)	53.93	21.82	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	8.52	3.45	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	2.52	1.02	0.00	0.00
< -3.5 (-11.5)	0.29	0.12	0.00	0.00
TOTAL	410	166	363	147

Grid Statistics m (ft)

	Channels	Dispoal Areas
Cell Size:	2.00 (6.56)	2.00 (6.56)
Maximum:	0.90 (2.95)	2.00 (6.56)
Minimum:	-3.71 (-12.17)	-0.92 (-3.02)
SD:	0.61 (2.00)	0.23 (0.75)
Mean:	-0.74 (-2.43)	0.39 (1.28)

Figure B-3. Post-construction (2008) elevation grid model at the Big Island Mining (AT-03) project..



Elevation Class m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	0.00	0.00	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00	0.03	0.01
1.0 - 1.5 (3.3 - 4.9)	0.00	0.00	0.22	0.09
0.5 - 1.0 (1.6 - 3.3)	1.32	0.53	171.39	69.36
0 - 0.5 (0 - 1.6)	33.63	13.61	152.65	61.78
-0.5 - 0 (-1.6 - 0)	109.92	44.48	38.94	15.76
-1.0 - -0.5 (-3.3 - -1.6)	81.45	32.96	0.23	0.09
-1.5 - -1.0 (-4.9 - -3.3)	67.47	27.31	0.00	0.00
-2.0 - -1.5 (-6.6 - -4.9)	51.03	20.65	0.00	0.00
-2.5 - -2.0 (-8.2 - -6.6)	53.93	21.82	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	8.52	3.45	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	2.52	1.02	0.00	0.00
< -3.5 (-11.5)	0.29	0.12	0.00	0.00
TOTAL	410	166	363	147

Grid Statistics m (ft)

	Channels	Dispoal Areas
Cell Size:	2.00 (6.56)	2.00 (6.56)
Maximum:	0.89 (2.92)	1.50 (4.92)
Minimum:	-4.05 (-13.29)	-0.94 (-3.08)
SD:	0.64 (2.10)	0.21 (0.69)
Mean:	-0.46 (-1.51)	0.41 (1.34)

Figure B-4. Post-construction (2016) elevation grid model at the Big Island Mining (AT-03) project.

Appendix C
(Habitat Maps)

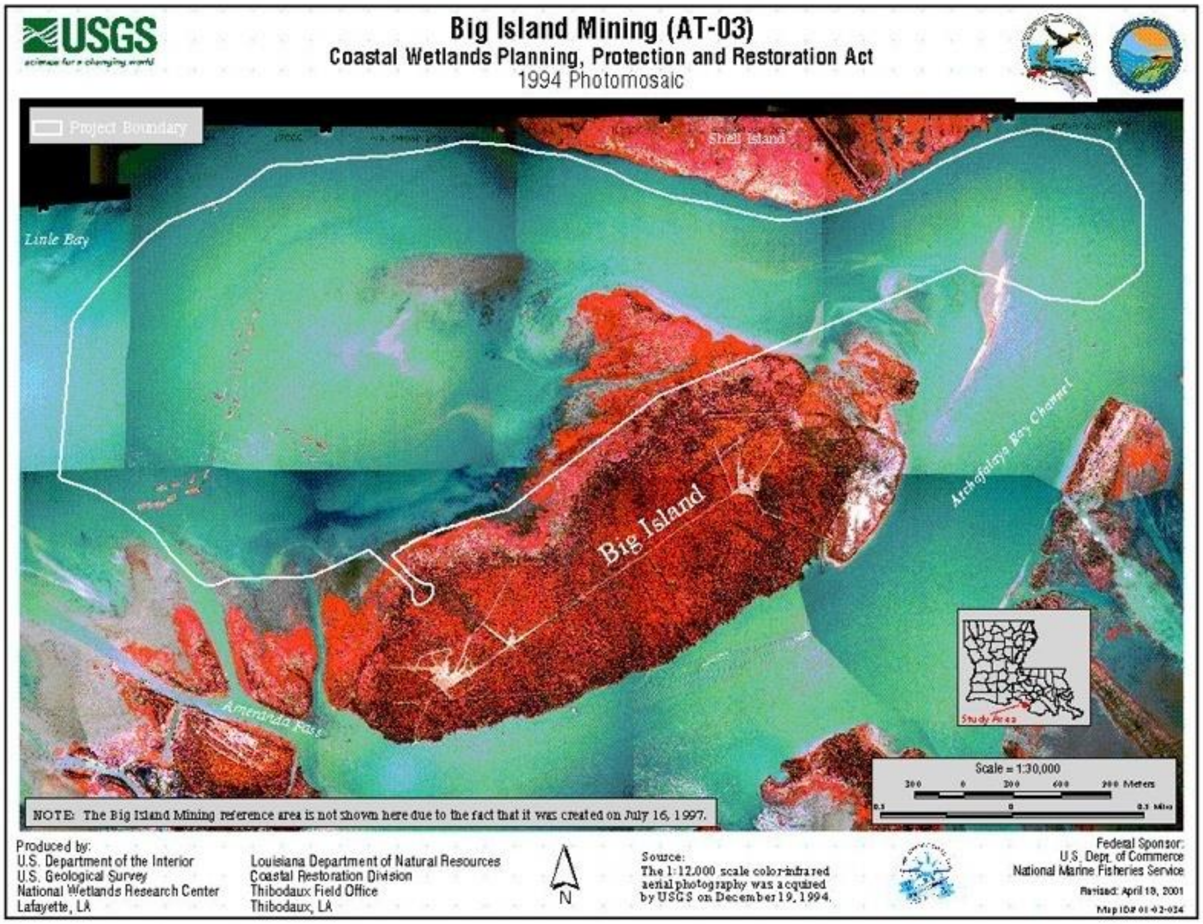


Figure C-1. **Pre-construction (1994) photomosaic of the Big Island Mining (AT-03) project area.**

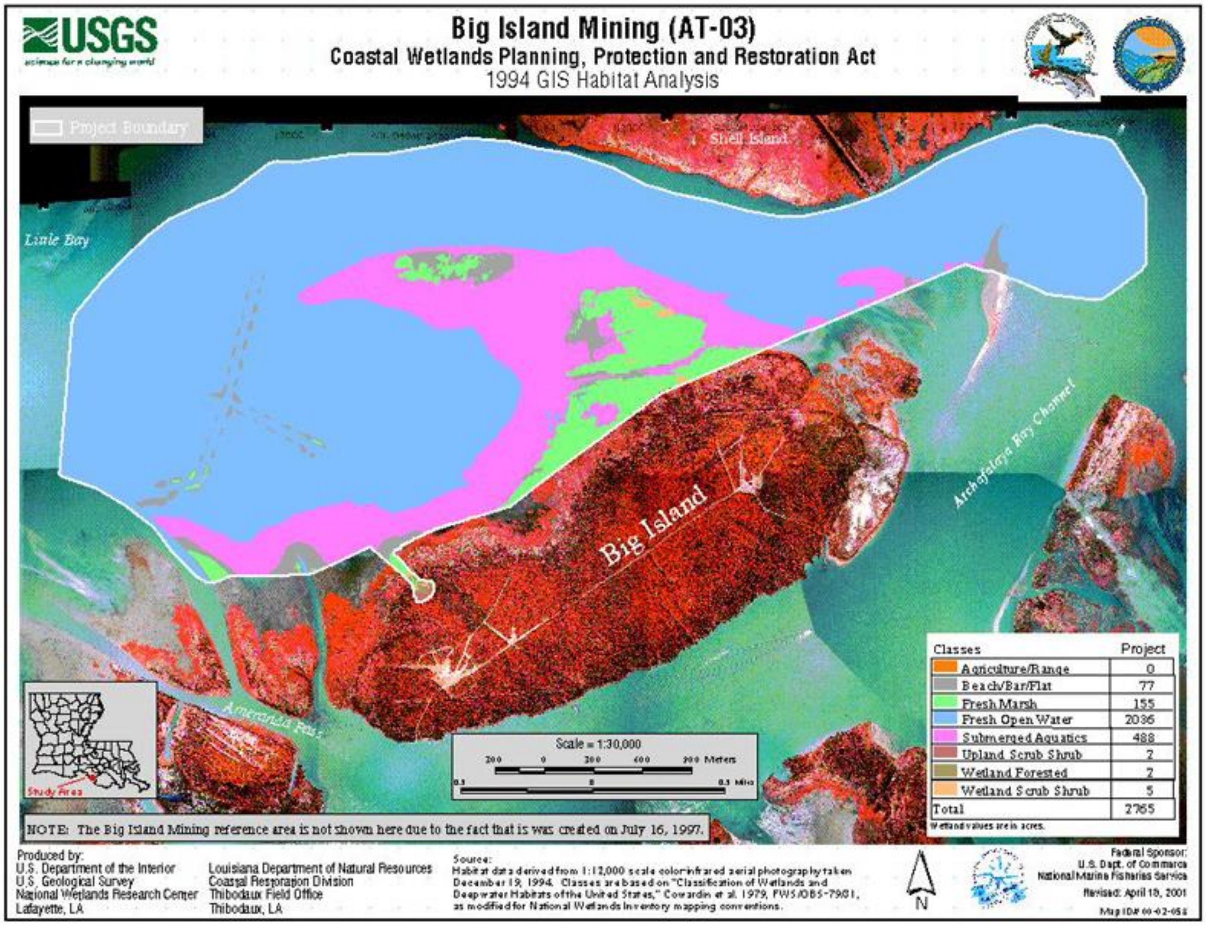


Figure C-2. **Pre-construction (1994) habitat analysis of the Big Island Mining (AT-03) project area.**

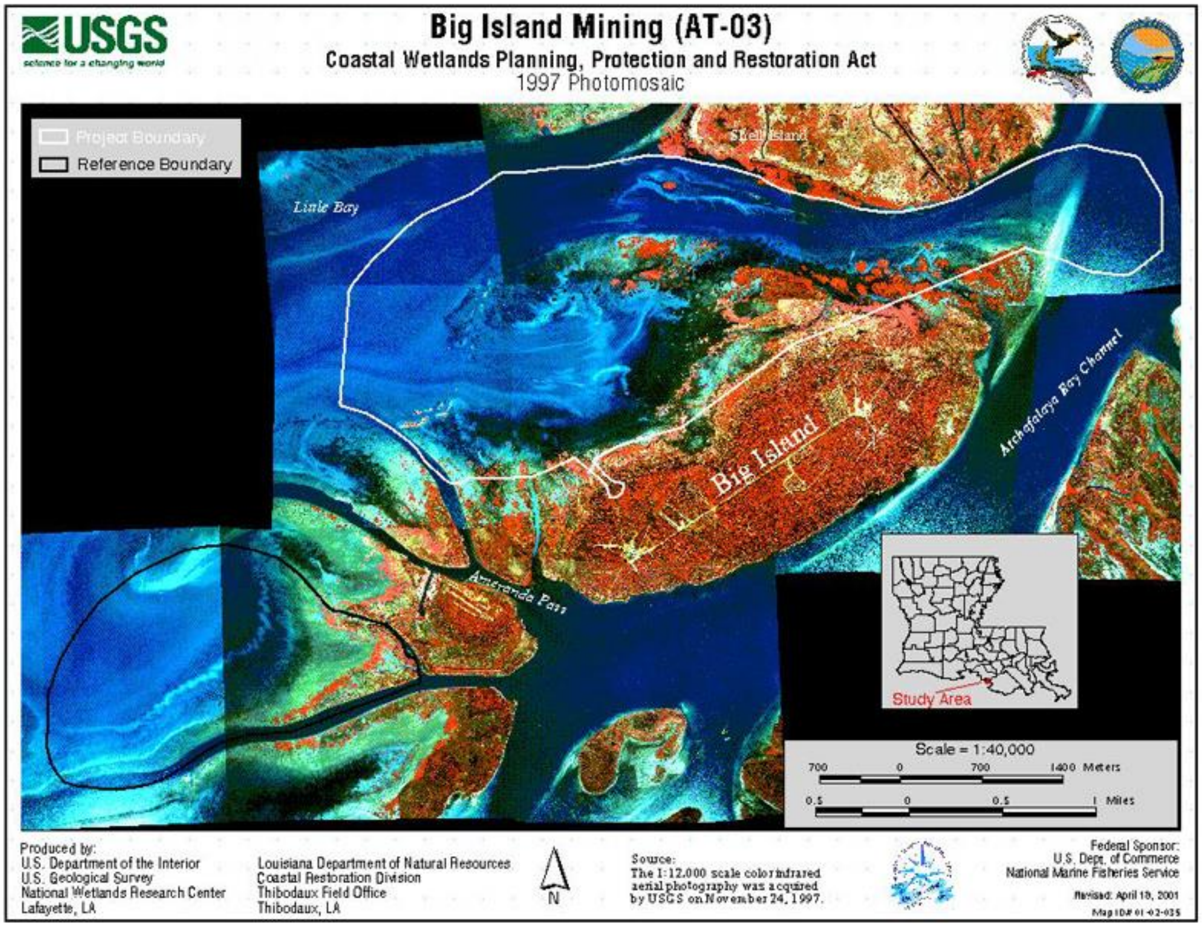


Figure C-3. **Pre-construction (1997) photomosaic of the Big Island Mining (AT-03) project and reference areas.**

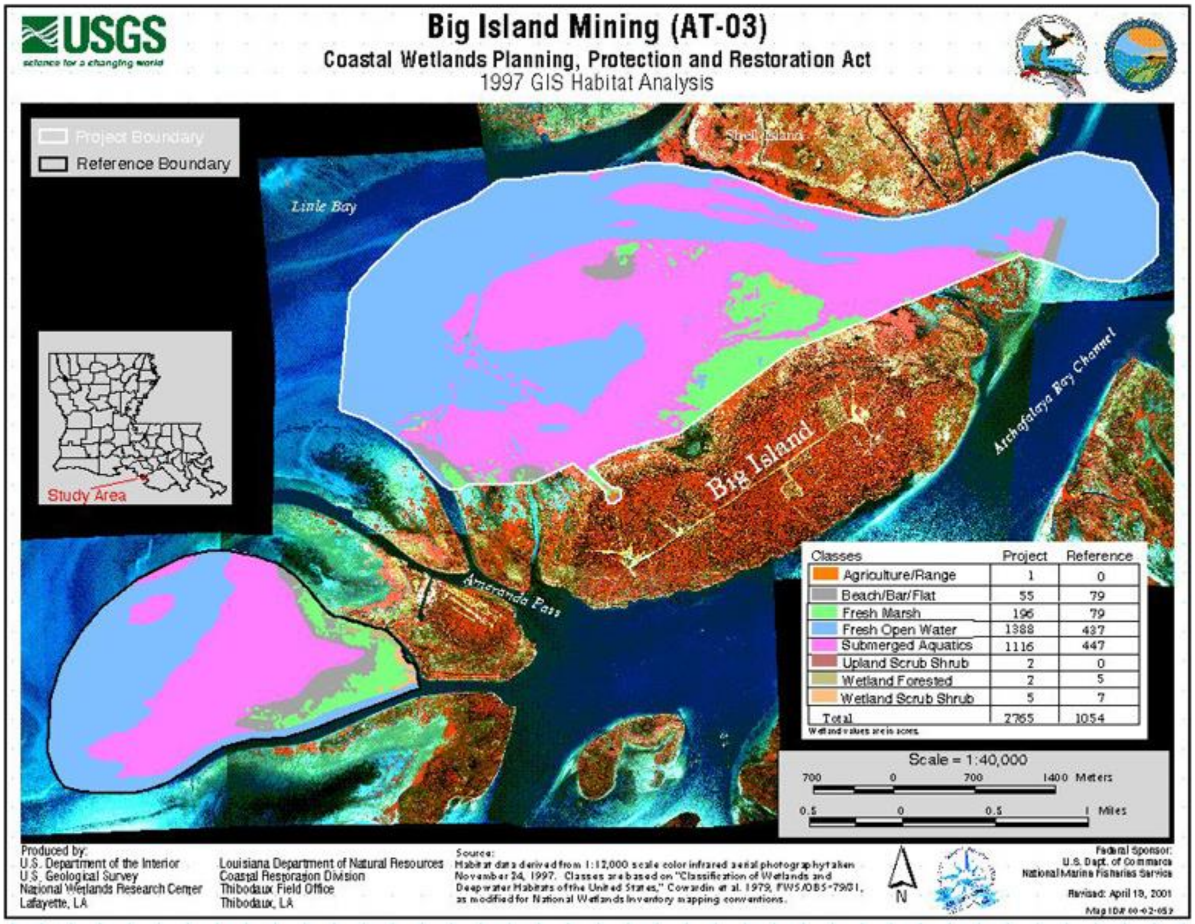


Figure C-4. **Pre-construction (1997) habitat analysis of the Big Island Mining (AT-03) project and reference areas.**

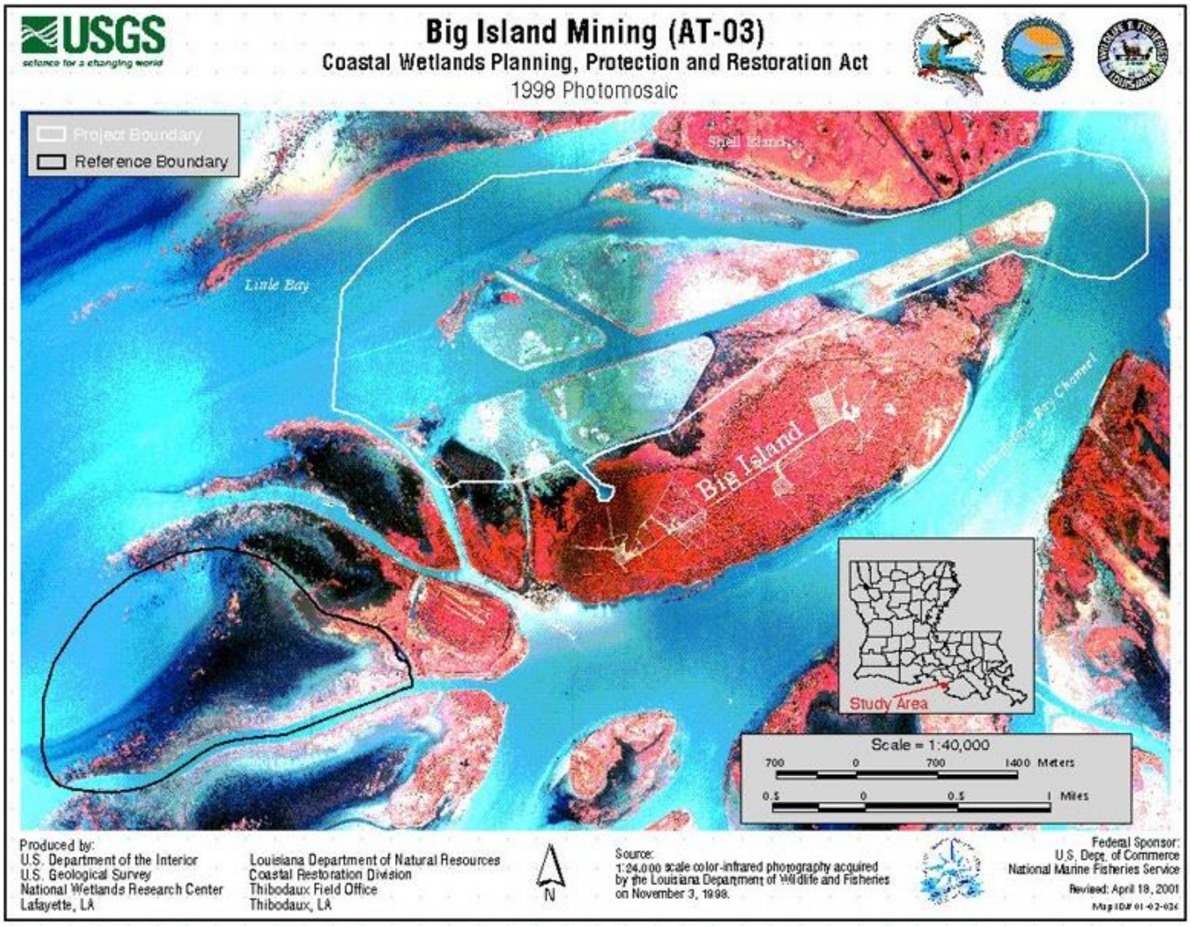


Figure C-5. **As-built (1998) photomosaic of the Big Island Mining (AT-03) project and reference areas.**

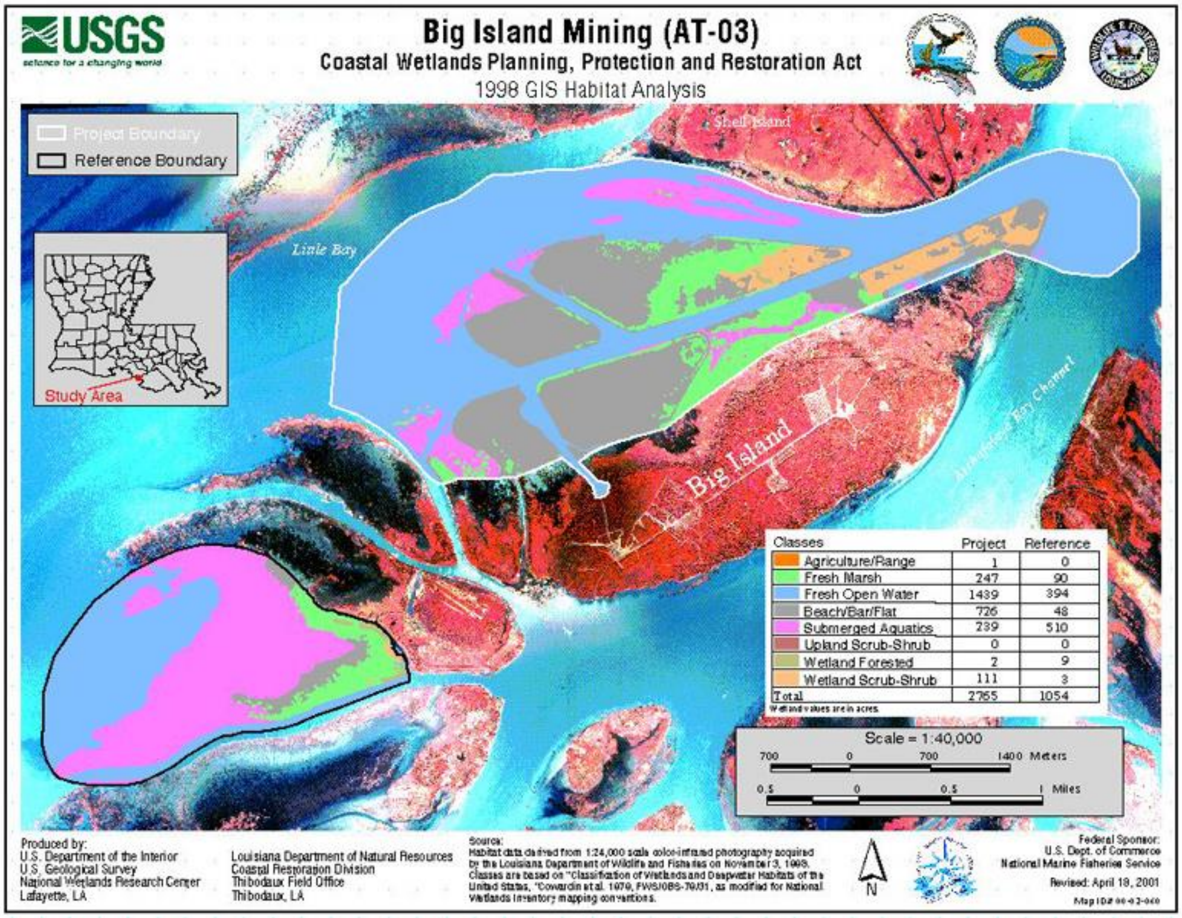


Figure C-6. As-built (1998) habitat analysis of the Big Island Mining (AT-03) project and reference areas.

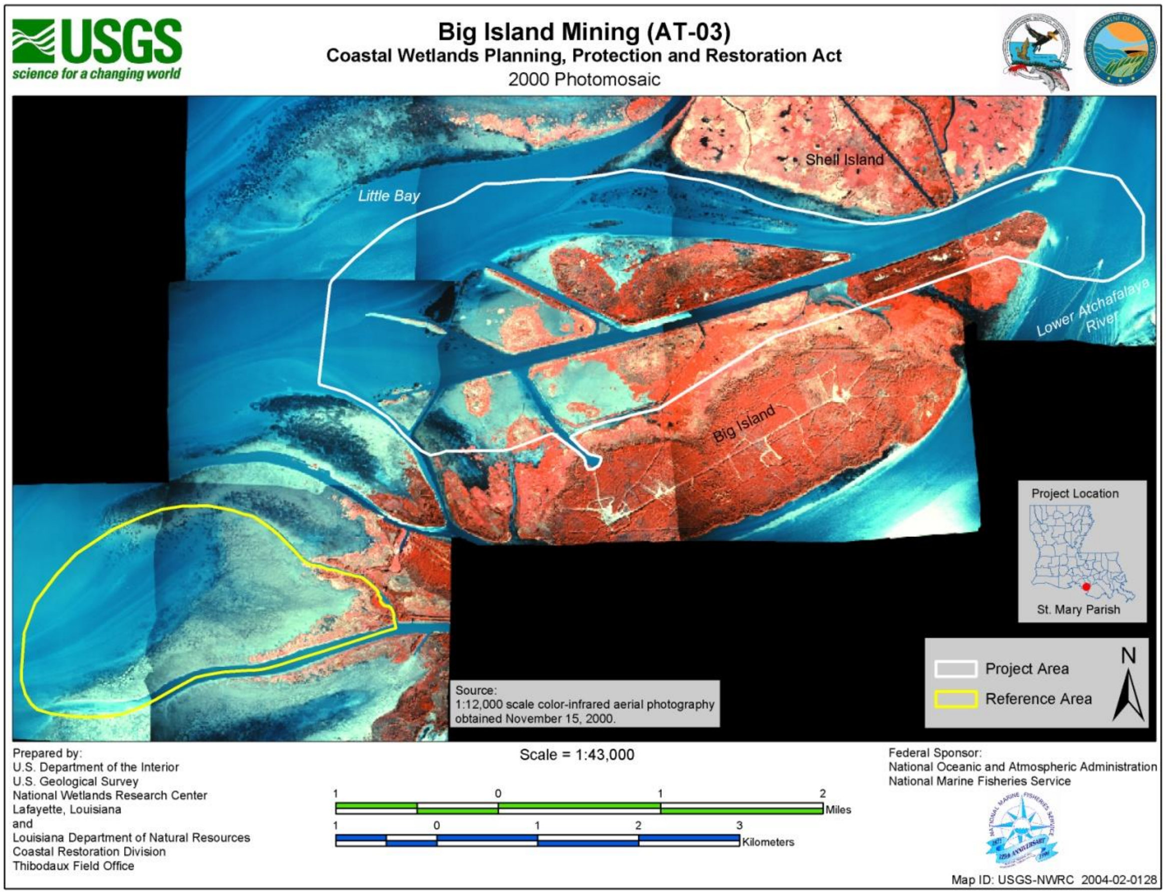
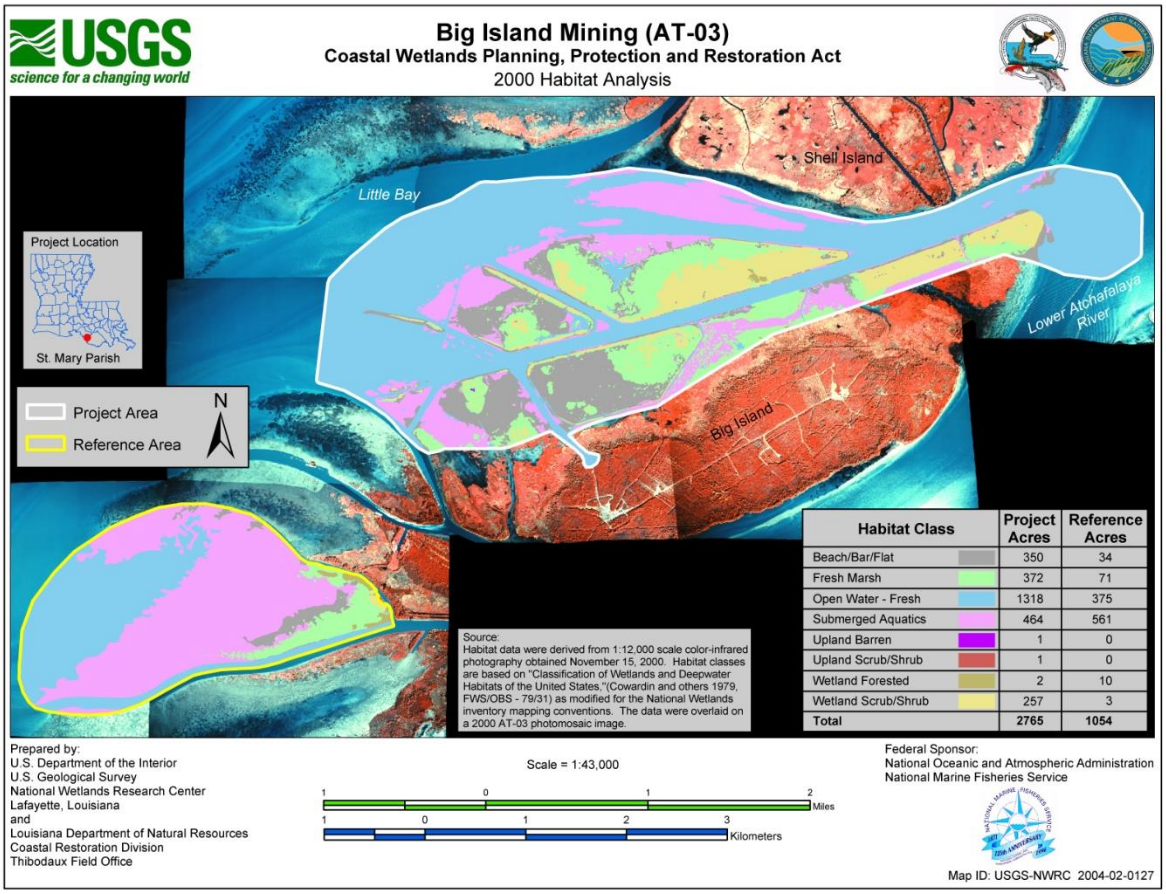


Figure C-7. Post-construction (2000) photomosaic of the Big Island Mining (AT-03) project and reference areas.



Habitat Class	Project Acres	Reference Acres
Beach/Bar/Flat	350	34
Fresh Marsh	372	71
Open Water - Fresh	1318	375
Submerged Aquatics	464	561
Upland Barren	1	0
Upland Scrub/Shrub	1	0
Wetland Forested	2	10
Wetland Scrub/Shrub	257	3
Total	2765	1054

Figure C-8. **Post-construction (2000) habitat analysis of the Big Island Mining (AT-03) project and reference areas.**

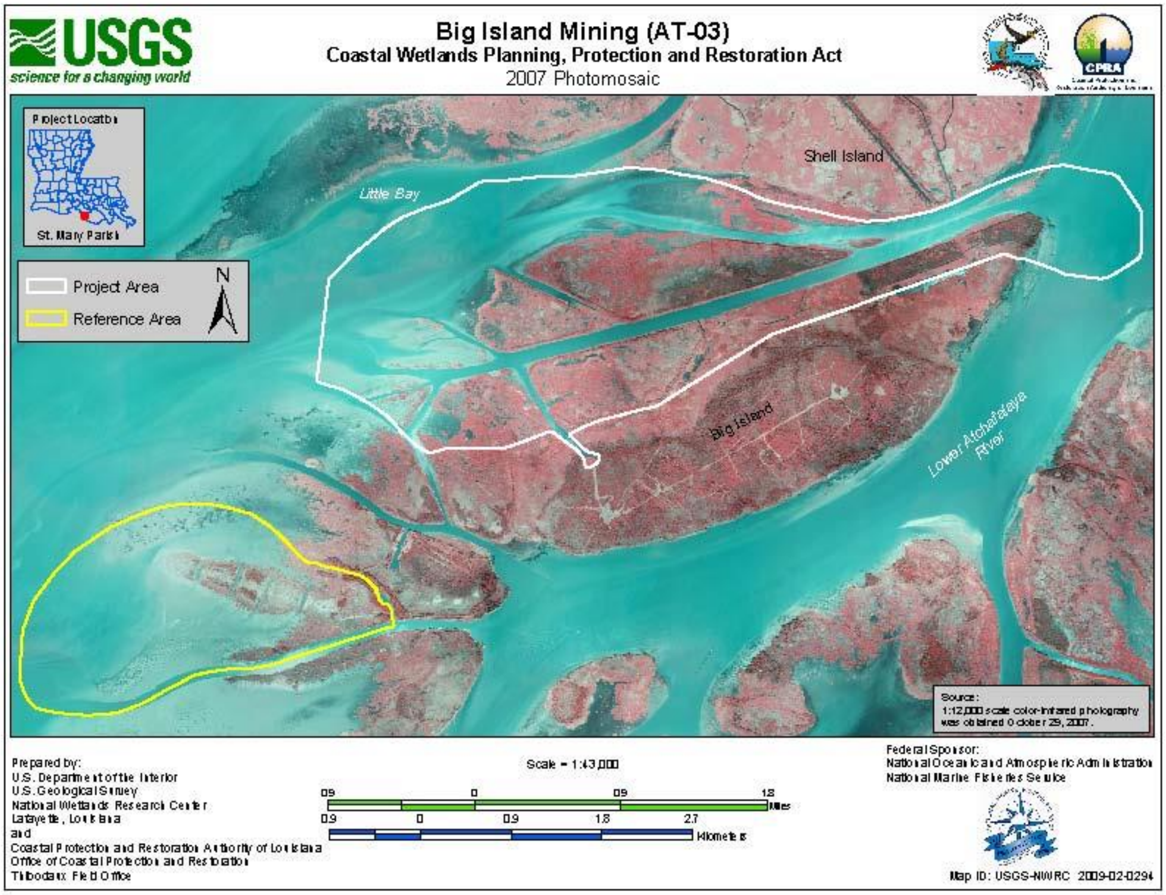


Figure C-9. Post-construction (2007) photomosaic of the Big Island Mining (AT-03) project and reference areas.

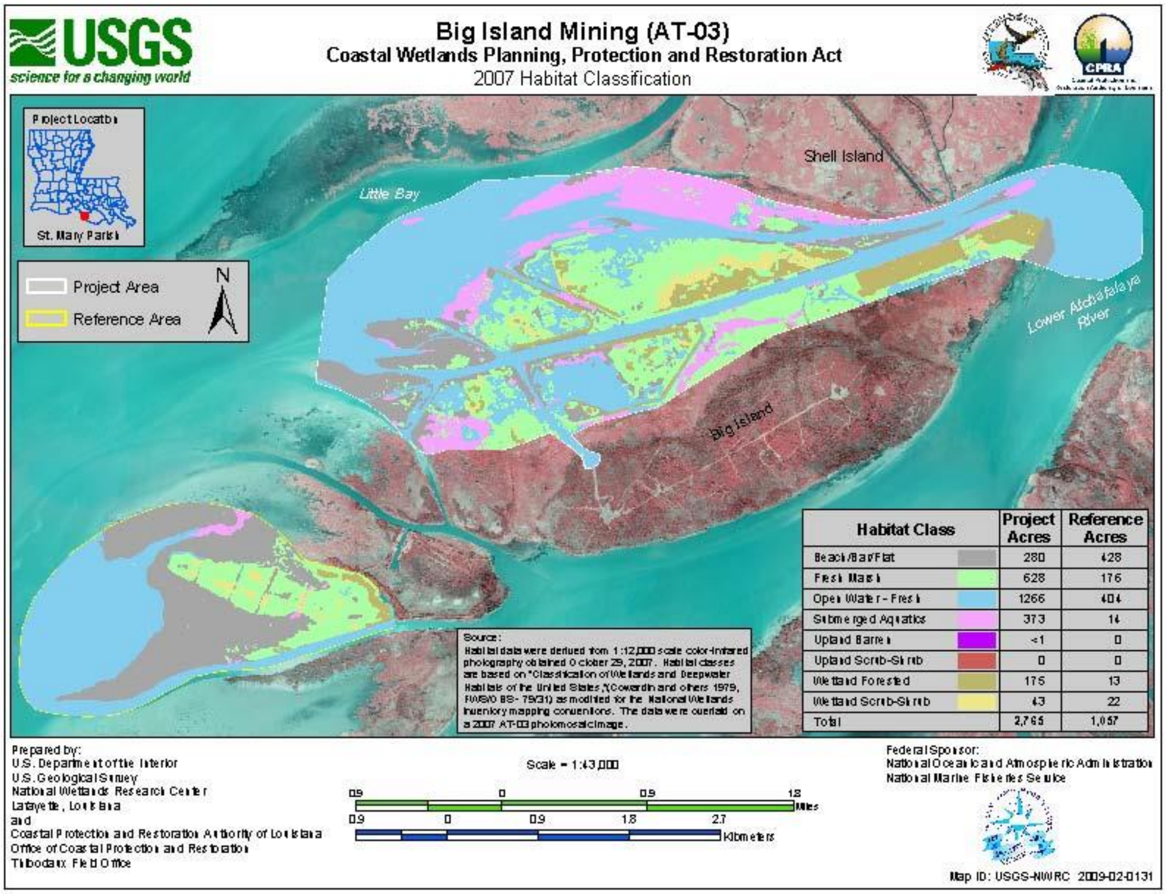


Figure C-10. Post-construction (2007) habitat analysis of the Big Island Mining (AT-03) project and reference areas.