**State of Louisiana**

**Coastal Protection and Restoration Authority of Louisiana (CPRA)**

# 2018 Operations, Maintenance, and Monitoring Report: Final Closeout Report

for

# Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016)

State Project Number LA-0016
Priority Project List 18

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Iberia Parish

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2018 Operations, Maintenance, and Monitoring Report
for
Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016)

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## Preface

This demonstration project close-out report includes monitoring data collected from May 2014 through May 2017.

## I. Introduction

The Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) was approved on the 18th project priority list of the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) and is co-sponsored by the United States Department of Agriculture/Natural Resources Conservation Service (USDA/NRCS) and Louisiana's Coastal Protection and Restoration Authority (CPRA). It is located along the northeast Vermilion Bay shoreline in Iberia Parish along Shark Island (Fig. 1). The total length of this shoreline-protection demonstration project is approximately 4,500 linear feet comprised of four shoreline protection products and a reference area.

Both historically and recently, the northeast Vermilion Bay shoreline along Shark Island has retreated at a high rate. The Barrier Island Comprehensive Monitoring Program (BICM) reported that the Cypermort Point – West shoreline, which includes Shark Island, eroded 22.1 ft/yr (6.7 m/yr) from 1930s to 2005 which were among the highest rates west of the Atchafalaya River including along the Gulf of Mexico (Martinez et al. 2009; Fig. 2). More recently, the shoreline erosion rate along Shark Island ranged from 20 to 40+ ft/yr from 2004 to 2012 (Byrnes et al. 2016). As is the case along many bays and water bodies in the coastal zone, the waves directly encounter the marsh, causing erosion without protection from a beach face. Consequently, the water bottoms along the shoreline are old marsh platforms and have very low weight bearing capacity which is too weak to support the weight of rock rip-rap used in traditional breakwaters.

Several shoreline areas within coastal Louisiana consist of unstable soil conditions, subsurface obstructions, accessibility problems, etc., which severely limit the alternatives of shoreline protection. The adopted standard across the state, where conditions allow, is the use of rock rip rap in either a revetment or foreshore installation. The major advantages of using rock are durability, longevity, and effectiveness. However, in areas where rock is not conducive for use and site limitations exist, current "proven" alternatives that provide equivalent advantages are limited. The goal of the LA-0016 demonstration project was to identify and assess alternative methods of shoreline protection developed by private firms. After a Request For Proposals for shoreline protection alternatives garnered 17 proposals, four products were selected:

- Wave Attenuation Devices (WAD®s) by Living Shoreline Solutions, Inc.
- Wave Screen System (WSS) by Royal Engineers & Consulting, LLC.
- EcoSystems Units (ESUs) by Walter Marine Artificial Reefs, Inc.
- Buoyancy Compensated Erosion Control Modular System (BCECMS) by Jansen, Inc.

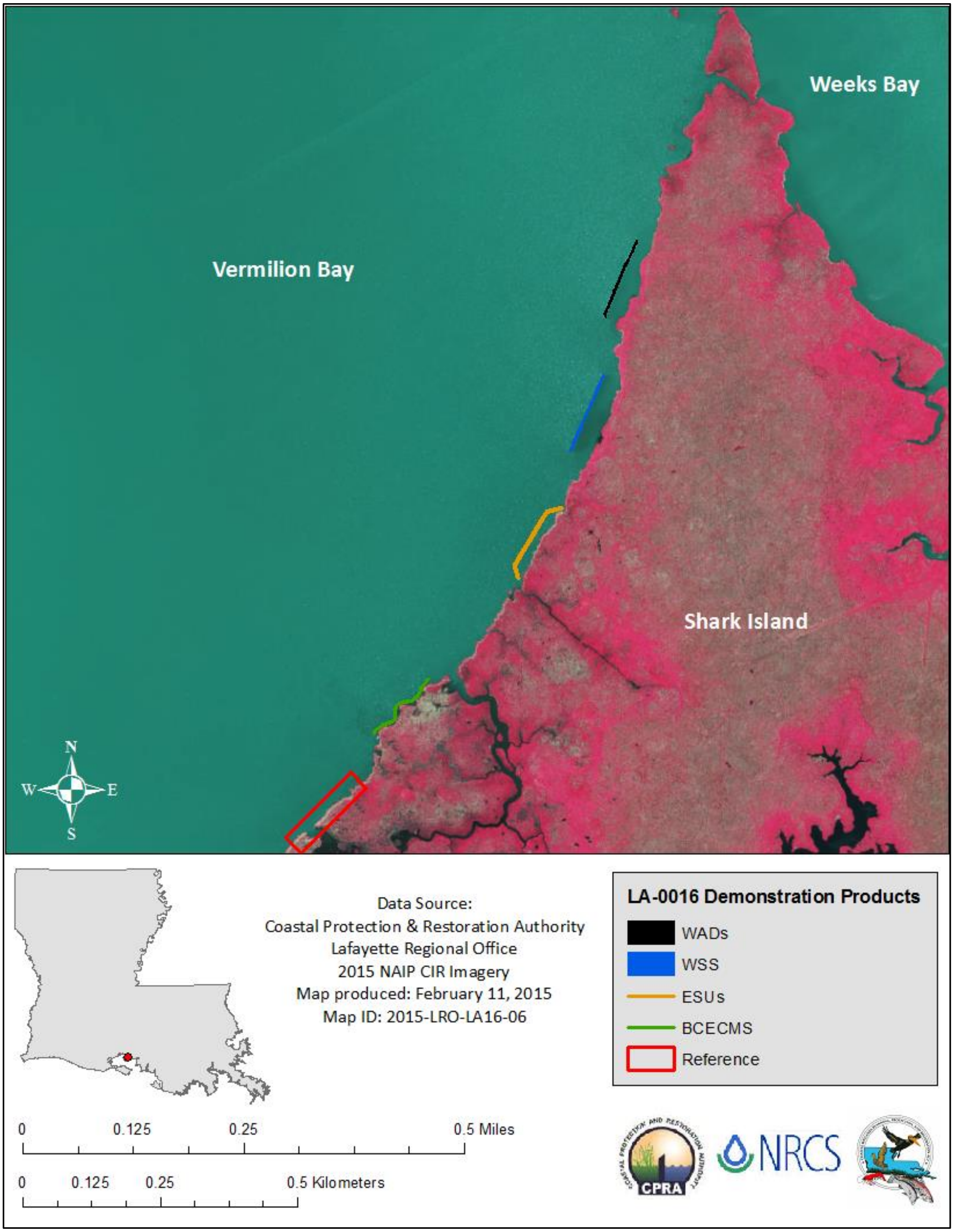



**Figure 1.** The Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) consists of four shoreline protection products and a reference area.

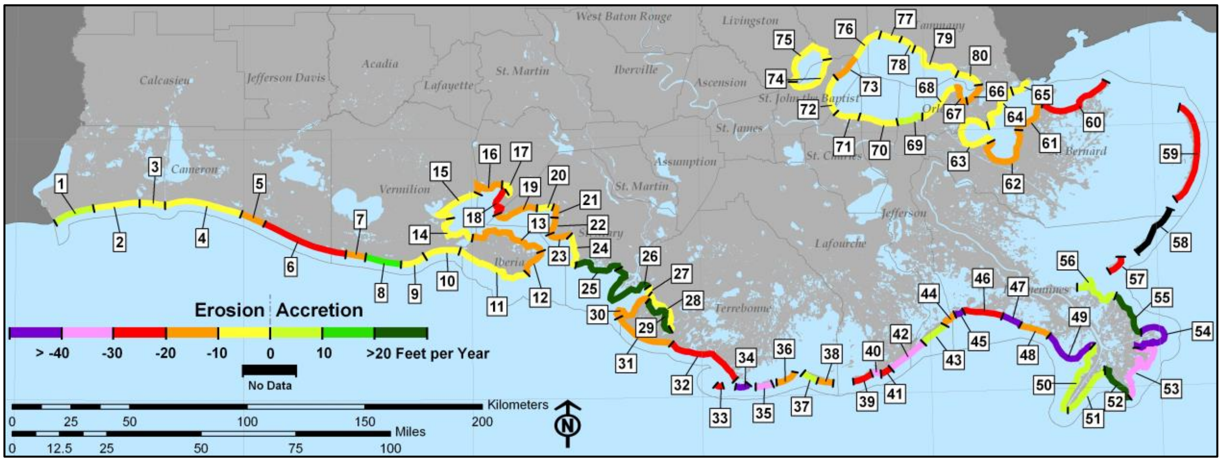



**Figure 2.** Shoreline movement rates across Louisiana from the 1930s to 2005. Reach 18 is Cypremort Point–West, which includes Shark Island. Map is used with permission from Barrier Island Comprehensive Monitoring (BICM) Program**.**

## II. Installation and Maintenance

Because of the proprietary nature of this demonstration project, installation and maintenance was the responsibility of the product owner and was not provided by NRCS or CPRA. Although this was a three-year demonstration project, product owners designed their product for a 20-year life of a standard CWPPRA project. NRCS and CPRA determined the general work area for each product and mandated that the product and construction could not occur on the marsh. Owners determined their products orientation to and distance from the shoreline. Maintenance is described in the individual product reports (see sections IV. C. 1-4b).

## III. Operation Activity

No active operations were associated with this project.

## IV. Monitoring Activity

### A. Monitoring Goals

The goal of LA-0016 is to evaluate shoreline erosion reduction performance of each shoreline protection product.

The objectives to assess the goal are:

1. Significantly reduce shoreline erosion relative to the reference area.
2. Significantly reduce soil volume loss relative to the reference area.
3. Significantly reduce wave transmission reaching the shoreline.

## B. Monitoring Elements

### 1. <u>Topographic and Bathymetric Surveys</u>

Topographic and bathymetric elevation surveys were conducted every six months in the product and reference areas by the NRCS – Crowley Watershed Construction Office. Elevations of the product crests, marsh, and water bottoms both landward and seaward of the product positions were tracked along survey transects perpendicular to the shoreline. Elevation data were collected at 5 ft or less intervals to define distinct morphologic features. Survey transects began approximately 100 ft landward from the averaged shoreline and extended 300 ft into Vermilion Bay from the center line (CL) alignment of the product:

- 37 transects total: each of the four (4) products and the reference area had six (6) transects with 100 ft spacing between transects, and a transect was spaced approximately 150' from each end of a product (7 transects; two products shared an end transect).
- The vegetated shoreline was mapped in each area during each elevation survey to monitor shoreline change.
- The crest elevation of each product unit was measured to monitor product settlement and movement.

Seven elevation surveys were conducted from May 2014 (Baseline) to April 2017 (Increment 6). Horizontal data was collected in the northing and easting coordinate set in Louisiana State Plane – South Zone NAD83; vertical (elevation) data was collected in feet NAVD88, Geoid 03. Survey drawings provided by NRCS from April 2017 (Increment 6) are available in Appendices A-1 - E-1; they display a plan view of each product with the shorelines from each survey, transect cross sections which include the bathymetric, structural, and topographic profiles from the baseline and final surveys, and product crest elevations from the baseline (May 2014) and final (April 2017, ICR 6) surveys. Distances are displayed in units of feet, and elevations are in feet NAVD88 Geoid 03.

*Shoreline movement*

Shoreline movement was determined by calculating the distance between shorelines from one survey period to the next, and cumulatively over the entire monitoring period, using Digital Shoreline Analysis System (DSAS) version 4.0, an ArcGIS application (Thieler et al. 2009). DSAS transects spaced 2 m apart were layered over the shorelines of interest from which distances between shorelines were calculated and rates were determined. Transects that had shoreline that breached into an interior water body were removed from the analyses. For each product, the shoreline movement transects were subdivided into three separate areas: Adjacent (not directly behind the structure), Structure Ends (100 feet from each end of the structure), and Mid Structure (the remaining reach, typically ~300 feet). The Reference transect distances were averaged as a single shoreline area (i.e. not subdivided). Shoreline movement along the transects were averaged for each subdivided product area and the Reference.

For each product area and for the Reference, average (mean ± standard error) shoreline movement from each survey and over time is plotted, and shoreline movement maps for the overall monitoring period (May 2014 – April 2017) are displayed in the Product Discussion section. Incremental shoreline movement maps from one survey to the next for the Reference and each product are in the Appendices. The effectiveness of each product is determined by comparing its shoreline movement to that from the Reference.

*Soil elevation dynamics (elevation and volume change)*

To assess soil elevation dynamics, elevation data from the survey transect coordinates were uploaded to ArcGIS to construct a triangular irregular network (TIN) of each area (products and reference) for the Baseline (May 2014) and final survey (Increment 6, April 2017); the TINs were then rasterized into elevation grids. Marsh elevations from intervening surveys were used if Baseline survey transects did not extend as far into the marsh as the final survey with the assumption that the project did not affect marsh elevation (this only occurred in the Reference area). Soil elevation change between elevation grids was calculated to map soil elevation change contours for each product and Reference area. Soil volume change was calculated within area polygons on either side (landward and bayward) of the shoreline protection products. The polygons represent the middle 300 linear feet of the structure to diminish end erosion effects. The landward polygon extends from the structure to the final shoreline (April 2017), and the bayward polygon extends from the structure out 100 feet. For the Reference area, the 300 ft wide polygon extends landward from the Baseline (May 2014) shoreline to the final shoreline (April 2017). The bayward polygon extends from the Baseline shoreline out 150 feet, which is 50 feet further out than that of the structures to account for the different distances that the structures are located from the shoreline. To standardize comparisons among different sized areas, soil volume change is reported on a volume by area by time basis ($yd^3$/ac/y and $m^3$/ha/y). The effectiveness of each product is determined by calculating the relative difference of soil volume change from the Reference.

## 2. <u>Wave Attenuation</u>

The capacity of the various products to dissipate, or attenuate, waves was assessed by comparing wave heights from an offshore wave gauge for the in-coming wave to a near-shore wave gauge behind each product. Wave gauges were deployed from November 2016 to May 2017, a six-month period of diverse water level and wave conditions. SWCA Environmental Consultants was contracted to conduct wave monitoring; wave gauge deployment, data collection, and wave gauge retrieval was subcontracted to ENCOS, Inc., and data processing, analyses, and report preparation was subcontracted to FTN Associates, LTD. The CPRA monitoring manager provided some additional data interpretation.

The gauges were synchronized to measure water level at a frequency of 10Hz (10 times per second) for 15 minute "bursts" starting every hour. The water levels were synthesized to derive an average surface water elevation (ft NAVD88, Geoid03), significant wave height ($H_s$, ft; the average distance from trough to crest of the highest third of waves), and wave period ($T_p$, sec; average duration of time for a wave from crest to crest) for each 15 minute “burst”. See the contractor reports for more details about the wave gauges, data collection, and data processing methodologies (ENCOS, Inc. 2017; FTN Associates, LTD. 2018).

Wind conditions greatly influence wave direction and velocity in northeastern Vermilion Bay. In addition, calm wave conditions characterized by low $H_s$ and high $T_p$ create uncertainty in wave attenuation data. To determine product effectiveness to dissipate waves, observations used for analyses met the following conditions for the in-coming wave:

1. The wind generating the wave came from the west (i.e., wind angles of $270^o \pm 90^o$ or from $180^o$ to $360^o$) as recorded by the USGS Gage at Vermilion Bay near Cypremort Point, LA (USGS Gage No. 07387040);
2. Significant Wave Height ($H_s$) greater than 0.1 ft at the offshore gauge; and,
3. Wave Period ($T_p$) less than 5 seconds at the offshore gauge.

Wave attenuation ($\alpha$), the reduction of wave height, is derived from $K_t$ as a percentage:

$$\alpha = (1-K_t) \times 100; \text{ where,}$$

$K_t$, the wave transmission coeffiecient, is the proportion of in-coming $H_s$ transmitted nearshore through the shoreline protection product:

$$K_t = H_s \text{ nearshore} / H_s \text{ in-coming.}$$

Increased wave attenuation relates to decreased wave height transmitted through the shoreline protection product.

For each shoreline protection product, average $\alpha$ of observations describes wave conditions experienced over the entire monitoring period from in-coming waves that met the criteria above. Nearshore $H_s$ and $\alpha$ were averaged for different groups of water elevation and in-coming $H_s$ in half-foot intervals; extreme low-water levels (<-0.5 ft NAVD 88) were combined, and high water levels (> 2.0 ft NAVD88) were combined. Average $\alpha$ across these groupings quantifies product performance for the different in-coming wave conditions.

During calm in-coming wave conditions ($H_s < 0.5$ ft), innate, local ripples form behind the structures. Local ripples form a larger proportion of the total wave height during smaller in-coming waves; therefore, $\alpha$ excluding $H_s$ in-coming <0.5 ft is also reported for both the overall monitoring period and across in-coming $H_s$ and water-level conditions.

### C. Product Discussion

The Product Discussion for each product includes sections on product description at construction, modifications and maintenance, structural integrity, and removal provided by NRCS. Due to the relatively small scale of this demonstration project, the production rates and costs may not be representative of a large-scale project. Also included in the Product Discussions are monitoring results and discussion which describe shoreline movement, soil elevation dynamics, and wave attenuation. Shoreline movement and soil elevation dynamics of the Reference area is provided for comparison to the products.

*Reference shoreline movement*

The unprotected Reference area's shoreline eroded almost 160 feet on average over the three-year monitoring period (Fig. 3) producing an overall shoreline movement rate of -51 ft/y (Fig. 4). For the first half of the monitoring period, the shoreline moved at a steady rate of -44 ft/y; the second half was more variable with an active November 2015 - May 2016 (-121 ft/yr), and a little slower movement from May 2016 – April 2017 (-31 ft/y).

*Reference soil elevation dynamics (elevation and volume change)*

As the shoreline eroded in the Reference area, large amounts of soil were exported over the monitoring period (Fig. 5). The area between the baseline shoreline and final shoreline (April 2017) (landward polygon) lost 2,190 cubic yards per acre per year ($yd^3/ac/y$) of soil as the surface elevation changed by as much as 2.52 ft converting from marsh to bay bottom. The area bayward of the baseline shoreline lost 434 $yd^3/ac/y$ of soil over the monitoring period.

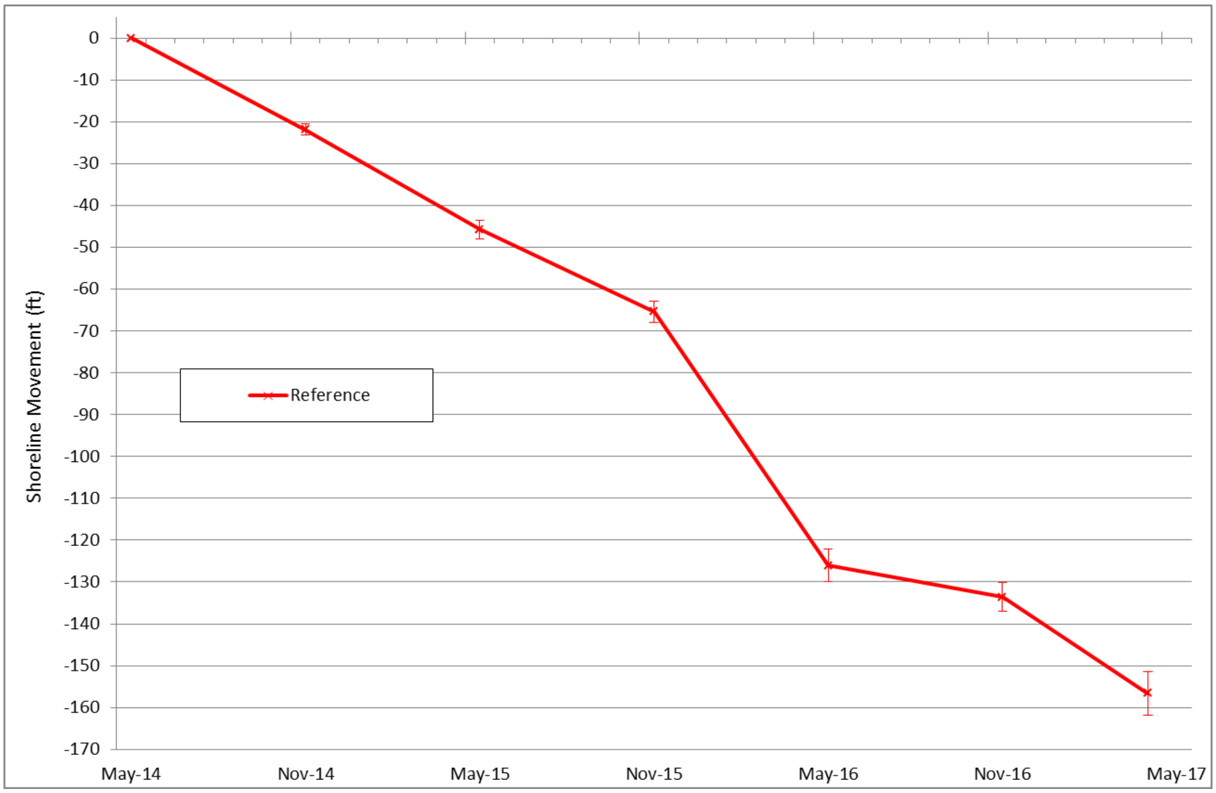



**Figure 3.** Cumulative shoreline change in the Reference area for the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) was measured every six months for the 3-year monitoring period (May 2014 - April 2017). Values are means and standard errors of shoreline movement from DSAS transects.

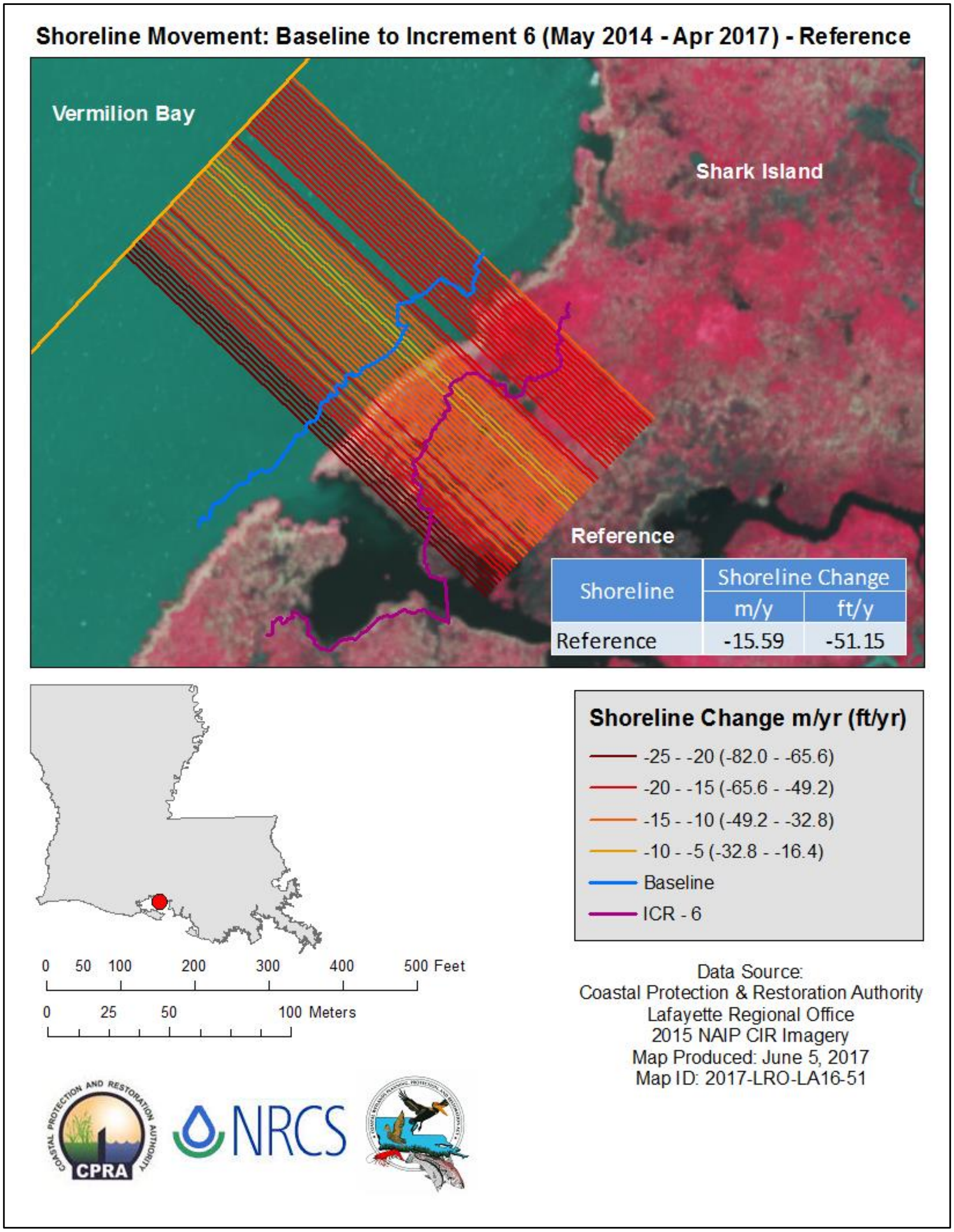
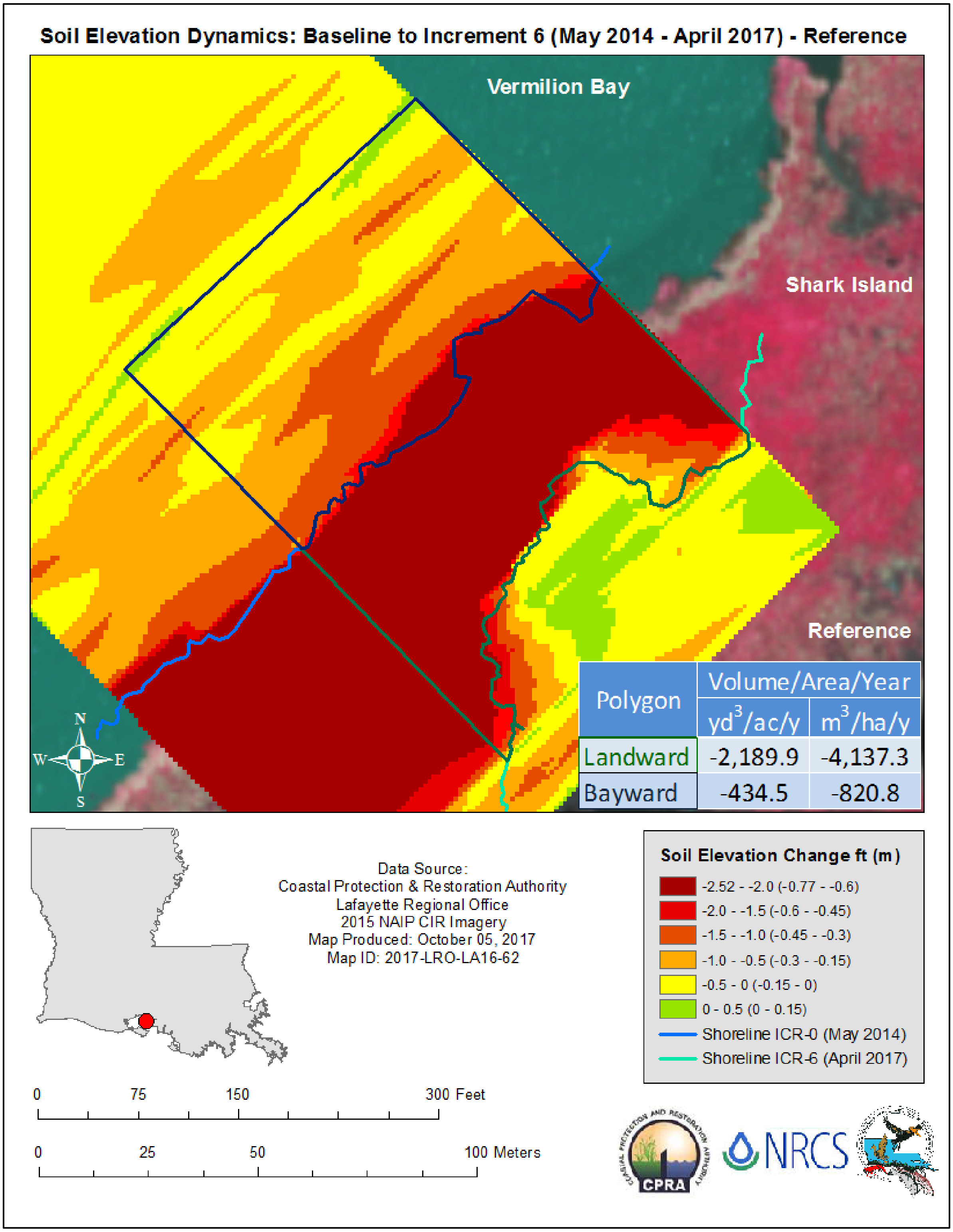



**Figure 4.** Shorelines were mapped and shoreline change calculated in the Reference area of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the 3-year monitoring period (May 2014 - April 2017). Note deleted DSAS transects where the shoreline breached into interior water bodies.




| Polygon | Volume/Area/Year | |
|---|---|---|
| | $yd^3/ac/y$ | $m^3/ha/y$ |
| Landward | -2,189.9 | -4,137.3 |
| Bayward | -434.5 | -820.8 |

**Figure 5.** Soil elevation change was mapped in the Reference area of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the 3-year monitoring period (May 2014 - April 2017). The table displays volume change rates of the inset polygons.

## 1. Living Shoreline Solutions, Inc. – Wave Attenuation Devices (WAD®s)

### a. Product Description

Living Shoreline Solutions, Inc. designed WADs to reduce waves as they transmit through the structure. A WAD is a three-sided pyramid shaped concrete structure with angled sides and triangular-shaped tapered openings on each side; sizes can be customized for site conditions. The installed WADs were 7 ft tall with a 9 ft wide bottom and 3 ft wide, flat top (7,500 pounds). To increase the overall height, a 2.5 ft tall base (6,000 pounds) was connected with 2 inch galvanized metal bands (Fig. 6A) and True bond adhesive, which was ineffective. The WADs were placed in a double row array parallel to shore, consisting of 513 linear feet of WADs on the bayside (78 WADs) and 500 linear feet on the shore side (77 WADs) (Fig. 6B). WADs were installed directly on the bay bottom side-by-side at the bases in approximately 3-4 ft of water and within 60 to 130 feet from the existing shoreline. The average crest elevation was 5.0 ft NAVD88, Geoid03.

| | |
|---|---|
| Performance Time: | 12 calendar days |
| Total Distance Installed: | 513 LF |
| Total Installation Cost: | $719,450.00 |
| Cost per LF: | $1,402.44 |

<u>Major Equipment Used</u>

| | |
|---|---|
| Spud Equipment Barge "JBR 901" | Supply Barge |
| Cat 345C Excavator | Aluminum Deck Boat "Miss Riley" |
| 25' Carolina Skiff | Tug Boat "Little Bob" |
| Tug Boat "Full Steam" | Aluminum Cabin Boat "Mr Brooks" |


**Figure 6.** (A) Installation of Wave Attenuation Devices (WADs). Note metal bands attaching the base to the bottom of the WAD. (B) The initial alignment of WADs at Shark Island along the northeastern shore of Vermilion Bay for LA-0016 Non-rock Alternatives to Shoreline Protection Demonstration Project.

### b. Modifications and Maintenance

The alignment of the product was shifted during installation, because a tugboat scoured a hole on the south end of the project and made the water bottom too deep and irregular. WADs #1 and 3 were moved from the bay side of the structure to the shore side, and the hole was backfilled with seven, smaller WADs (Fig. 7A).

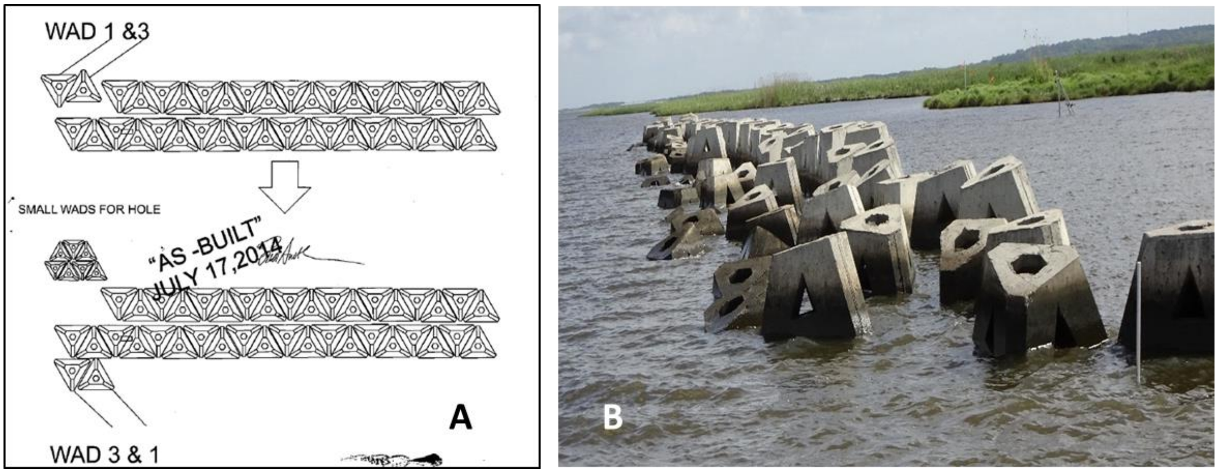



**Figure 7.** (A) The original alignment was modified during construction. (B) Some WADs tilted and/or toppled throughout the three-year monitoring period.

### c. Structural Integrity

The WADs remained in or near the original layout foot print throughout the thee-year monitoring period; however, the overall system had numerous locations where individual WADs settled, shifted, or toppled. The items below are based on observations throughout the monitoring period and/or after removal of the product and should be considered during the design phase of future installations. The considerations provided may not apply to all installations; however, these should be reviewed and addressed to ensure a product life of at least 20 years.

- Numerous WADs settled significantly or toppled during the monitoring period (Fig. 7B).
  - Consider the following options when the water bottom is not firm and/or smooth:
    - Install geotextile fabric or other foundation stabilization method under the product to evenly distribute loading which may increase stability.
    - Install a scour apron on the bayside of the structure to increase stability. The bay side row of WADs had much more movement than the shore side row.
    - Level the water bottom by mechanical means prior to installation.

- The bands that connected the top and base pieces of the WADs were primarily designed to assist in installation (Fig. 6A); however, they did not hold up through the monitoring period, and contributed to WAD shifting and toppling.
  - Consider manufacturing each WAD and base as a single piece. If multiple components are needed, then a better connection method should be considered to ensure stability over a longer duration.

- The concrete on one WAD came completely apart and the concrete was broken into many large pieces. It appeared that the reinforcement fibers used in the concrete mix design were poorly distributed.
  - Consider increasing quality control observations during concrete mixing to ensure even distribution of reinforcement fibers.

### d. Removal

Removal of a product is usually not a consideration in the design of a shoreline protection feature; therefore, only the major equipment used was provided to assist with determining O&M costs on future installations. No access dredging was required for removal of the product.

Major Equipment Used

| | |
|---|---|
| Spud Equipment Barge "Kelly" | Hopper Barge M/G 5805 |
| Kobelco CK850G-2 Crane | Crew Boat |

### e. Results and Discussion

#### i. Topographic and Bathymetric Elevation Dynamics

*Structure Elevations*

Each large WAD (9.5 ft and 6.75 tons each) was deployed without stabilization such as pilings, cables, or geotextile fabric, with the expectation that the individual WAD and adjacent WADS would provide adequate stability. The WADs were installed at an average crest elevation of 5.0 ft NAVD88 Geoid03 ranging from 4.1 to 8.6 ft NAVD88 Geoid03 in May 2014. The upright standing WADs settled 0.9 ft over the three years of surveys to an average elevation of 4.1 ft NAVD88 Geoid03 ranging from 2.1 to 5.3 ft NAVD88 Geoid03 in April 2017 (see Appendix B-1). Shifted and toppled WADs had a final elevation of 0.0 to 4.2 ft NAVD88 Geoid03 by the end of monitoring. Although the WADs varied by elevation and settlement, they did remain in place along their general alignment. The bay bottom elevation at the base of the WADs changed very little, -0.3 ft, over the three-year monitoring period as it averaged -4.1 ft NAVD88 in May 2014 and -4.4 ft NAVD88 in April 2017.

*Shoreline Movement*

Shoreline eroded about 7.8 ft behind the middle 300 ft of the WADs over the three-year monitoring period (Fig. 8) producing an overall rate of -2.6 ft/y (Fig. 9). Shoreline behind the ends of the WADs eroded in a similar pattern as behind the middle but at a little faster rate. Shoreline movement adjacent to the WADs was less than the Reference but followed a similar pattern (Fig. 8). Over the three-year monitoring period, shoreline movement behind the middle of the WADs was 95% less than the Reference.

*Soil Elevation Dynamics (Elevation and Volume Change)*

From the baseline survey in May 2014 to the end of monitoring in April 2017, the area in the landward polygon accumulated 218 $yd^3$/ac/y of soil while the area in the bayward polygon lost 292 $yd^3$/ac/y (Fig. 10). Landward, the difference in soil-volume change rates between the WADs and Reference area was 2,408 $yd^3$/ac/y as the Reference area lost 2,190 $yd^3$/ac/y (Fig. 5). Bayward, the difference in soil-volume change rates between the WADs and Reference area was 142.5 $yd^3$/ac/y as the Reference area lost 434.5 $yd^3$/ac/y (Fig. 5).

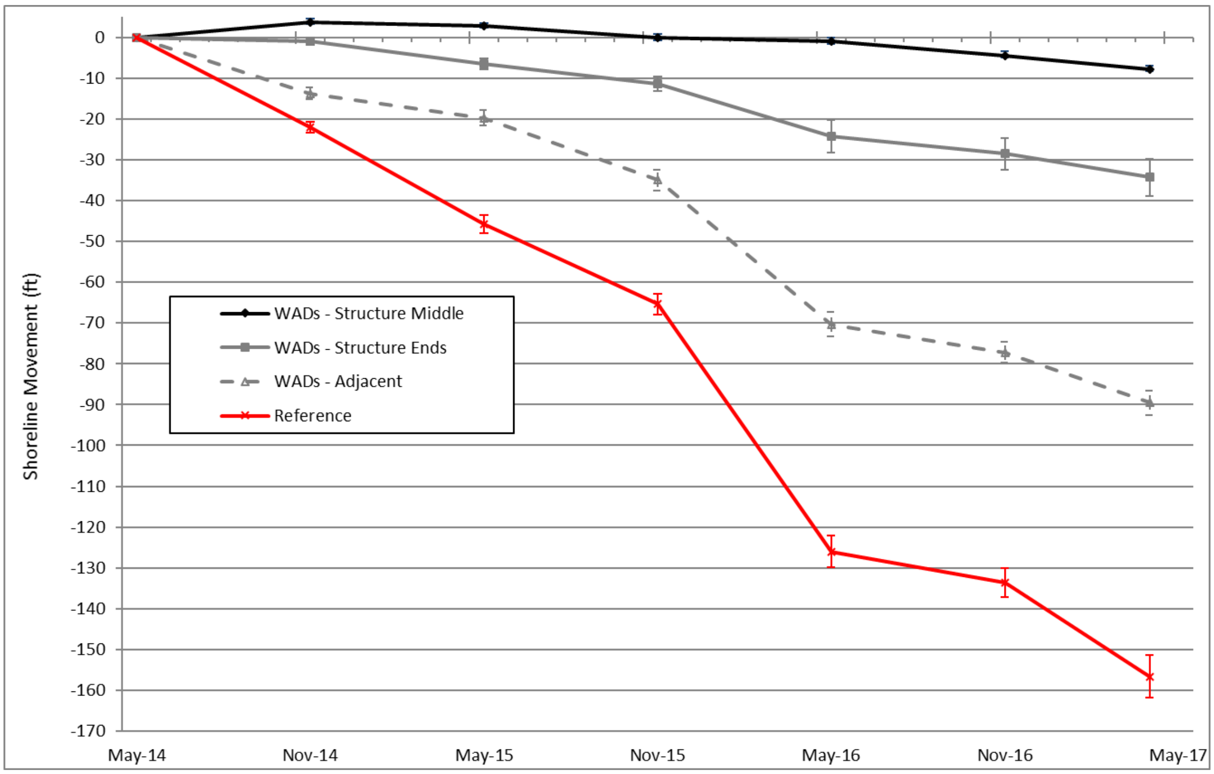



**Figure 8.** Cumulative shoreline change behind different parts of Living Shoreline Solutions' Wave Attenuation Devices (WAD®s) and along the Reference area for the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) was determined every six months for the 3-year monitoring period (May 2014 - April 2017). Values are means and standard errors of shoreline movement of DSAS transects.

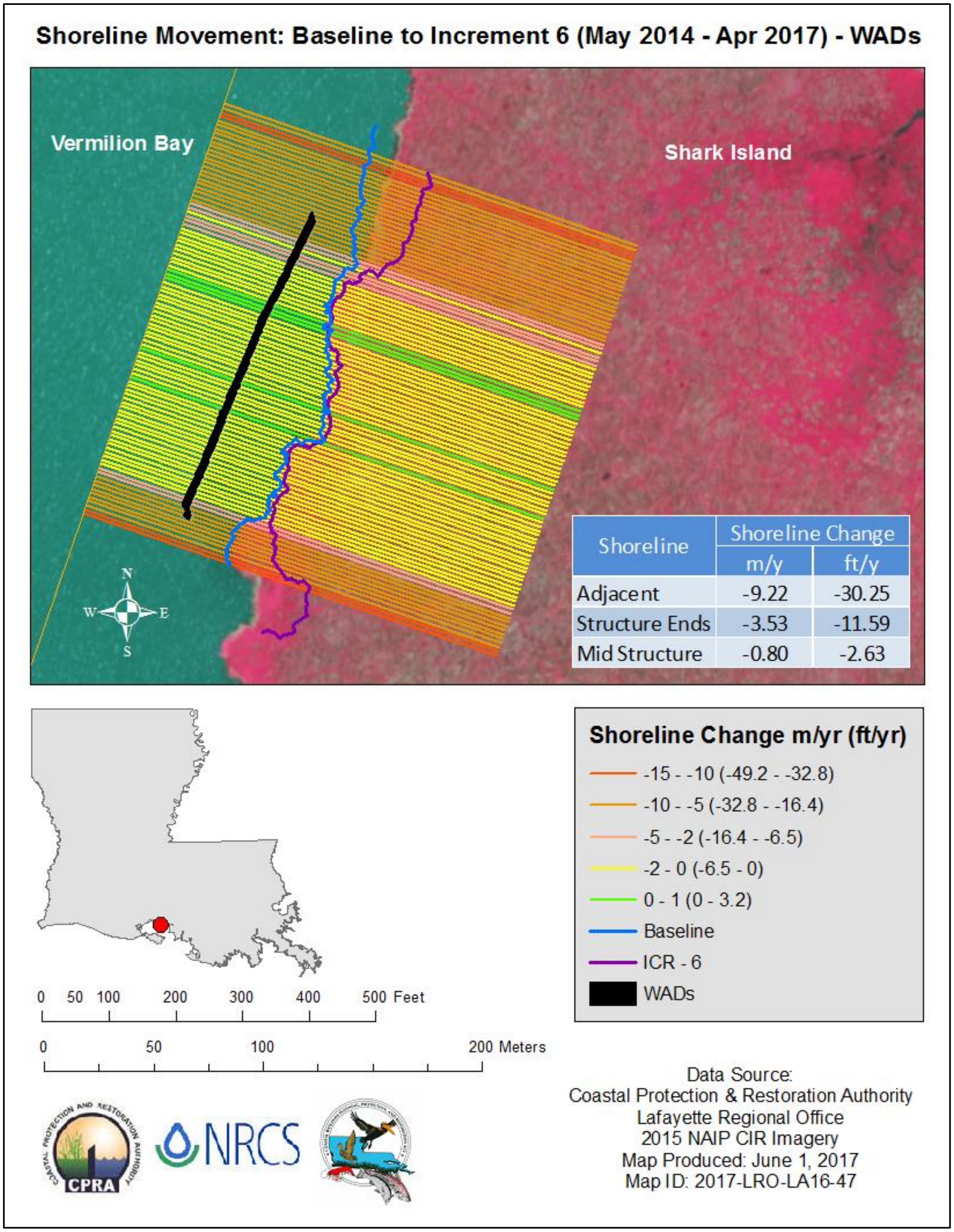



**Figure 9.** Shorelines were mapped and shoreline change calculated behind different parts of Living Shoreline Solutions' Wave Attenuation Devices (WAD®s) of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the 3-year monitoring period (May 2014 - April 2017).

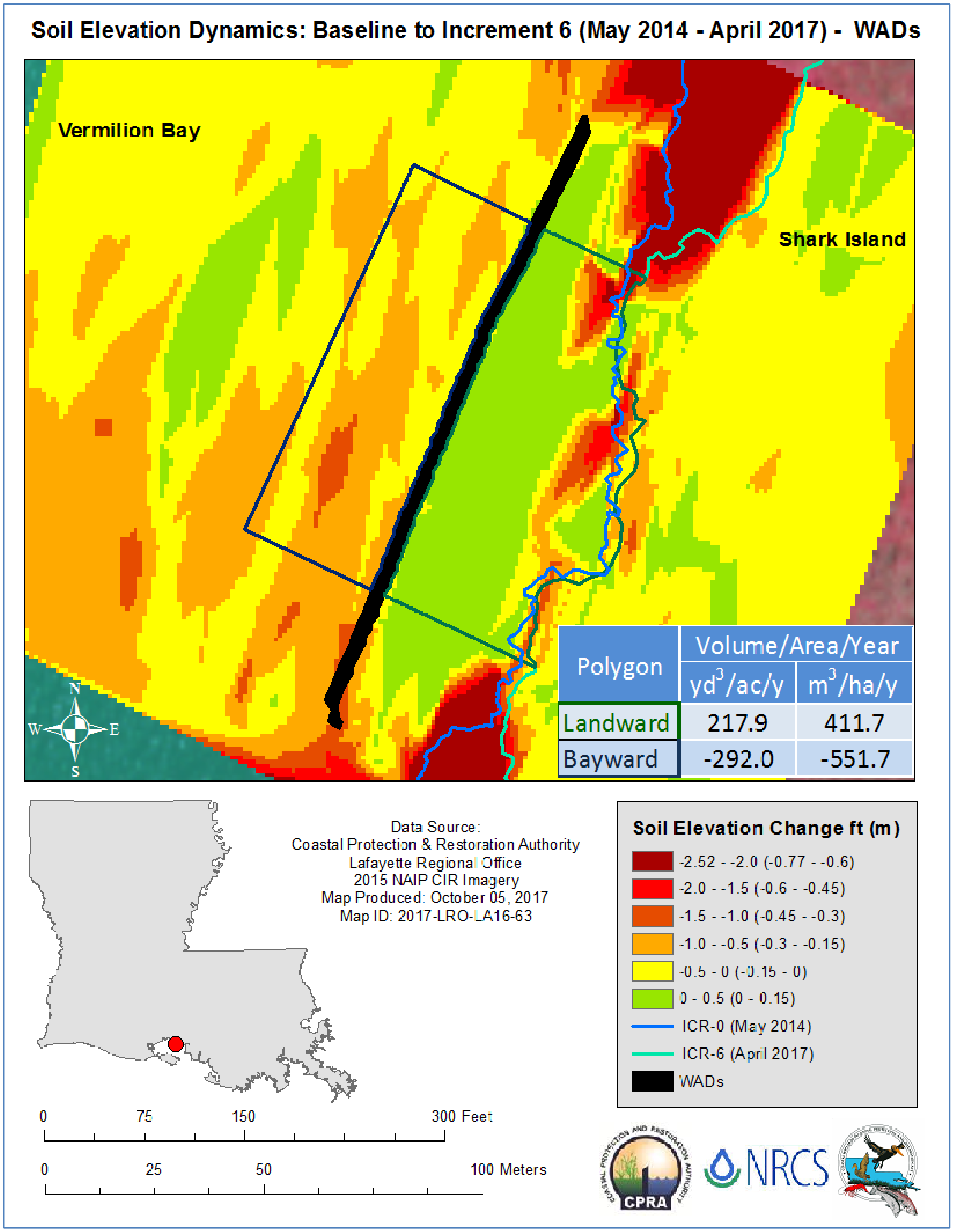



**Figure 10.** Soil elevation change was mapped in Living Shoreline Solutions' Wave Attenuation Devices (WAD®s) area of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the 3-year monitoring period (May 2014 - April 2017). The table displays volume change rates of the inset polygons.

### ii. Wave Attenuation

Averaged over 931 observations from November 2016 – May 2017, the WADs attenuated waves (α) by 49% over the monitoring period. Across the 21 in-coming $H_s$ and water-level groups (Table 1), α averaged 64%. After removing 87% of the observations to reduce the influence of ripples during calm conditions (in-coming $H_s$ < 0.5 ft), α averaged 70% over the remaining 118 observations and 74% across the remaining 14 in-coming $H_s$ and water-level groups. The effective α of the WADs may be attributable to the structure elevation of the upright WADs (4.1 ft NAVD88, Geoid 03) being about 3 ft above mean water level (0.93±0.95 ft NAVD88, Geoid 03) at the time of monitoring. However, the tapering of each WAD created increasing gaps between WADs at the water surface which may have caused the lower α during higher water levels and in-coming $H_s$. Although many of the bayside WADs were leaning or toppled, they still broke waves and most of the marshside WADs maintained their position.

**Table 1.** Ranges of water surface elevation and significant wave heights from incoming waves categorize significant wave heights ($H_s$) and wave attenuation (α) behind the Wave Attenuation Devices (WADs). N is the number of hourly wave observations, and $H_s$ and α values are means and one standard deviation.

| Water Surface Elevation (ft, NAVD88) | Wave Variables | $H_s$ (ft) - In-coming Wave | | | |
|---|---|---|---|---|---|
| | | 0.1 - 0.5 | 0.5 - 1.0 | 1.0 - 1.5 | 1.5 - 2.0 |
| -2.5 to -0.5 | N | 168 | 31 | | |
| | $H_s$ (ft)±SD | 0.09±0.05 | 0.14±0.06 | | |
| | α (%)±SD | 66±18 | 77±9 | | |
| -0.5 to 0.0 | N | 109 | 14 | | |
| | $H_s$ (ft)±SD | 0.1±0.03 | 0.18±0.03 | | |
| | α (%)±SD | 49±19 | 69±5 | | |
| 0.0 to 0.5 | N | 137 | 7 | 4 | |
| | $H_s$ (ft)±SD | 0.12±0.04 | 0.21±0.04 | 0.13±0.15 | |
| | α (%)±SD | 39±19 | 70±3 | 89±12 | |
| 0.5 to 1.0 | N | 134 | 11 | 4 | 1 |
| | $H_s$ (ft)±SD | 0.12±0.05 | 0.21±0.05 | 0.12±0.02 | 0.1 |
| | α (%)±SD | 40±21 | 66±8 | 91±1 | 93 |
| 1.0 to 1.5 | N | 113 | 12 | 4 | 1 |
| | $H_s$ (ft) ±SD | 0.13±0.05 | 0.26±0.08 | 0.16±0.09 | 0.15 |
| | α (%)±SD | 42±22 | 65±10 | 86±9 | 90 |
| 1.5 to 2.0 | N | 79 | 10 | 3 | |
| | $H_s$ (ft)±SD | 0.12±0.06 | 0.27±0.09 | 0.3±0.07 | |
| | α (%)±SD | 40±22 | 57±19 | 75±1 | |
| 2.0 to 4.5 | N | 73 | 13 | 3 | |
| | $H_s$ (ft)±SD | 0.16±0.08 | 0.3±0.1 | 0.47±0.12 | |
| | α (%)±SD | 33±19 | 55±13 | 65±10 | |

## 2. Royal Engineers & Consulting, LLC – Wave Screen System (WSS)

### a. Product Description

Royal Engineers & Consulting, LLC was the contracted designer and builder of the WSS for the LA-0016 project, and Integrated Shoreline Solutions, LLC owned the rights. The WSS was designed to reduce waves without scouring around the structure, thereby causing sediments in the water to fall out between the structure and shoreline. The WSS was a continuous linear feature consisting of two, parallel, walls of perforated Ultra High Molecular Weight Polyethylene (UHMW-PE) sheeting supported by steel pilings and framing spaced 10 feet apart. The UHMW-PE was chosen for UV resistance. The perforated walls had three, 6-inch holes per 3 feet wide sections and hung down 4 feet from mean high water such that they were 1-1.5 feet above the bay bottom to allow water to pass through and prevent scour at the base of the structure from wave deflection (Fig. 11). The final constructed feature was 502 linear feet in approximately 4-4.5 feet of water. The average crest elevation was 1.93 ft NAVD88, Geoid03.

| | |
|---|---|
| Performance Time: | 35 calendar days |
| Total Distance Installed: | 502 LF |
| Total Installation Cost: | $750,474.69[1/] |
| Cost per LF: | $1,494.97 |

[1/] This product required access dredging due to the size and draft of the installation equipment. The final cost for access dredging was $212,617.00 and is not included in the reported total installation cost.

<u>Major Equipment Used</u>

- Spud Equipment Barge "Fathom Innovation"
- Spud Supply Barge (CSB-03)
- Tug Boat "Ms Addi"
- Cabin Boat w/ twin engines (LA-6502-FB)
- Large Generator & Hydraulic Engine MKT(060106)
- Link Belt Crane (LS-248H II)
- Supply Barge (Foam Barge)
- JLG Bucket Lifter 600A(976199)
- Vibrating Hammer MKT (V35)

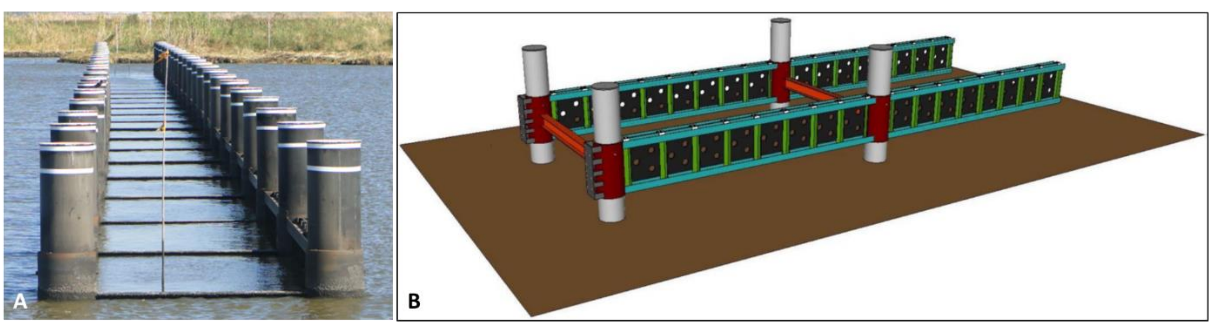



**Figure 11.** (A) The alignment of Integrated Shoreline Solutions' Wave Screen System (WSS) at Shark Island along the northeastern shore of Vermilion Bay for LA-0016 Non-rock Alternatives to Shoreline Protection Demonstration Project. (B) An isometric drawing of the WSS showing the piles, panels, bracing, and casing.

### b. Modifications and Maintenance

No modifications were conducted during or after construction.

### c. Structural Integrity

Structural integrity of the WSS was maintained throughout the three-year monitoring period. The items below are based on observations throughout the monitoring period and/or after removal of the product and should be considered during the design phase of future installations. The considerations provided may not apply to all installations; however, these should be reviewed and addressed to ensure a product life of at least 20 years.

- The 24” diameter steel piles had noticeable surface rust on the outer face; however, no flaking was present (Fig. 12A). The rust was primarily noticed at, but not limited to, locations where the coating was removed for field welds or by damage during installation. Royal touched up the coating in several locations within the monitoring period.
    - Consider requiring a thicker protective coating and verifying uniform thickness during quality control activities prior to installation of all steel components.

- The upper support beams that span between each of the 24” diameter piles had noticeable rust on all surfaces (Fig. 12B).
    - Consider requiring a thicker protective coating and verifying uniform thickness during quality control activities prior to installation of all steel components.

- Water was trapped between the webs of the support beams and could not drain (Fig. 12B).
    - Consider installing small drainage holes in the upper beams. Install holes before protective coating is applied, and size holes such that protective coating does not prevent drainage by closing holes.

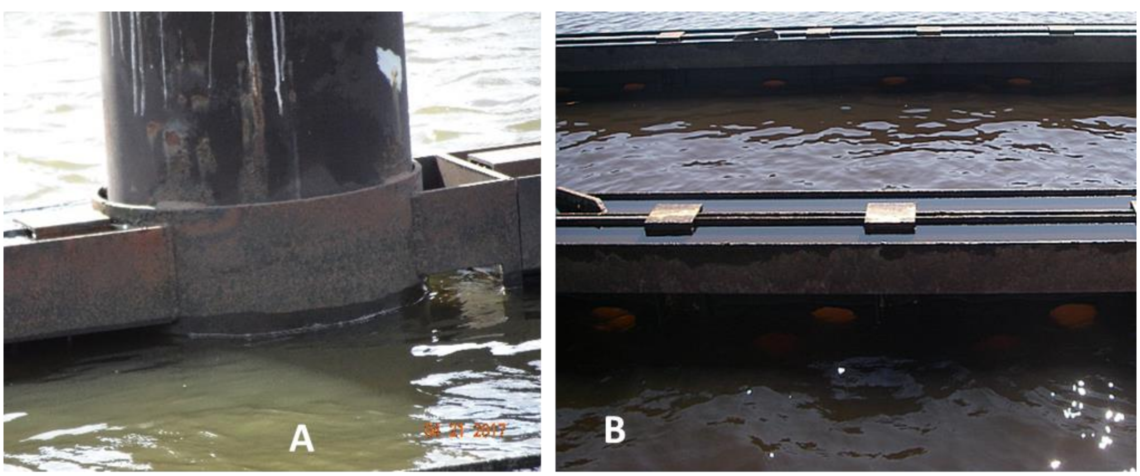



**Figure 12.** (A) Rust was observed on the steel piles and beam that support the Wave Screen System. (B) Water was trapped on the top surface of the beams.

- Noticeable surface rust on the inner face of 24" diameter steel piles was observed. This rust was flaking off on all parts of the pile above the mudline. This installation had no protective coating on the inside of the pile.
  - Consider installing a protective coating on the inner surface of steel piles from at least the mudline to the top of pile. Uniformity and thickness should be checked during quality control activities prior to installation.

- The 1.5" diameter round bar stock used to pin the structure to the 24" piles were all in good shape. The hole through the 26" diameter pile cap was welded to the pin and the protective coating was reapplied; however, the hole through the 24" pile could not be sealed and this allowed water to enter the inside of the pile and become trapped possibly accelerating rust on the interior.
  - Consider revising the design in such a way that the hole where the pin goes through the pile can be sealed if the inside of the 24" pile is not coated.

- Considerable accumulation of barnacles reduced the diameter of the 6" holes through the perforated panels which may change the effectiveness of the structure over longer durations.
  - Consider increasing the diameter of the 6" hole through the perforated panels or planning maintenance events to remove barnacles throughout the project life.

### d. Removal

Removal of a product is usually not a consideration in the design of a shoreline protective feature; therefore, only major equipment was provided to assist with determining O&M costs on future installations. No access dredging was required for removal of the product.

Major Equipment Used

| | |
|---|---|
| Spud Equipment Barge "Kelly" | Kobelco CK850G-2 Crane |
| Spud Supply Barge (IBR 904) | Spud Supply Barge EBMS-101 |
| Deck Boat "Mr. Gage" | Crew Boat "Barbara Ann" |
| Large Generator & Hydraulic Engine MKT(060102) | Vibrating Hammer MKT (V208) |

### e. Results and Discussion

#### i. Topographic and Bathymetric Elevation Dynamics

*Structure Elevations*

The WSS was installed to an average crest elevation of 1.93 ft NAVD88 Geoid03 and slightly settled to 1.88 ft NAVD88 Geoid03 by the end of three-year monitoring period; most of the settling occurred in the first two months. The bay bottom accreted an average of 0.63 feet of sediment underneath the WSS by the end of the three-year monitoring period as elevation averaged -3.5 ft NAVD88, ranging from -2.8 to -4.0 ft NAVD88, during the baseline measurement in May 2014 and -2.9 ft NAVD88, ranging from -1.5 to -4.0 ft NAVD88, in the April 2018 survey (see Appendix C-1).

*Shoreline Movement*

Shoreline eroded only about 5 ft behind the middle 300 ft of the WSS over the three-year monitoring period (Fig. 13) producing an overall rate of -1.8 ft/y (Fig 14). Shoreline behind the ends of the WSS eroded in a similar pattern as behind the middle but at a greater rate. Shoreline movement adjacent to the WSS was less than the Reference but followed a similar pattern (Fig. 13). Over the three-year monitoring period, shoreline movement behind the middle of the WSS was 98.5% less than the Reference.

*Soil elevation dynamics (elevation and volume change)*

Soil volume change was determined within landward and bayward polygons for the whole monitoring period from elevation surveys conducted in May 2014 and April 2017 (Fig. 15). Landward, the difference in soil-volume change rates between the WSS and Reference area was 2,766 $yd^3$/ac/y as the Reference area lost 2,190 $yd^3$/ac/y (Fig. 5). Bayward, the difference in soil-volume change rates between the WSS and Reference area was 873 $yd^3$/ac/y as the Reference area lost 434.5 $yd^3$/ac/y (Fig. 5).

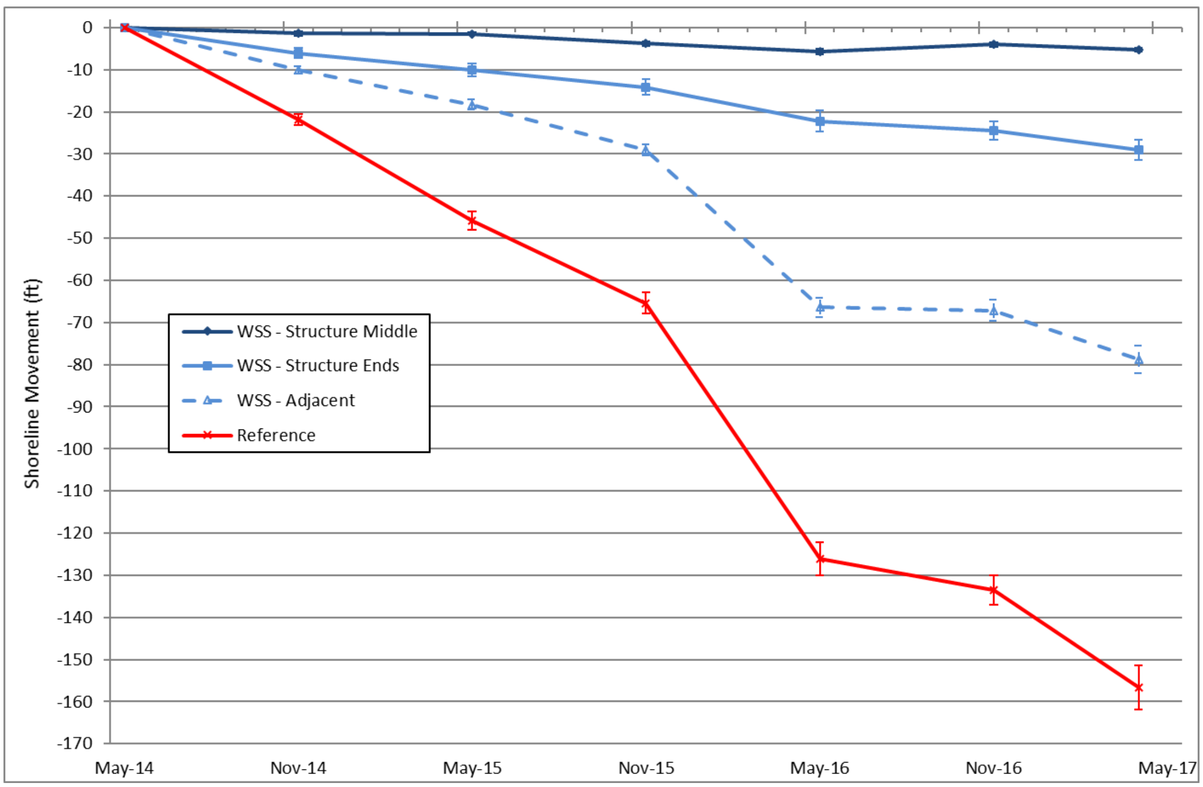



**Figure 13.** Cumulative shoreline change behind different parts of Integrated Shoreline Solutions' Wave Screen System (WSS) and along the Reference area for the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) was determined every six months for the 3-year monitoring period (May 2014 - April 2017). Values are means and standard errors of shoreline movement of DSAS transects.

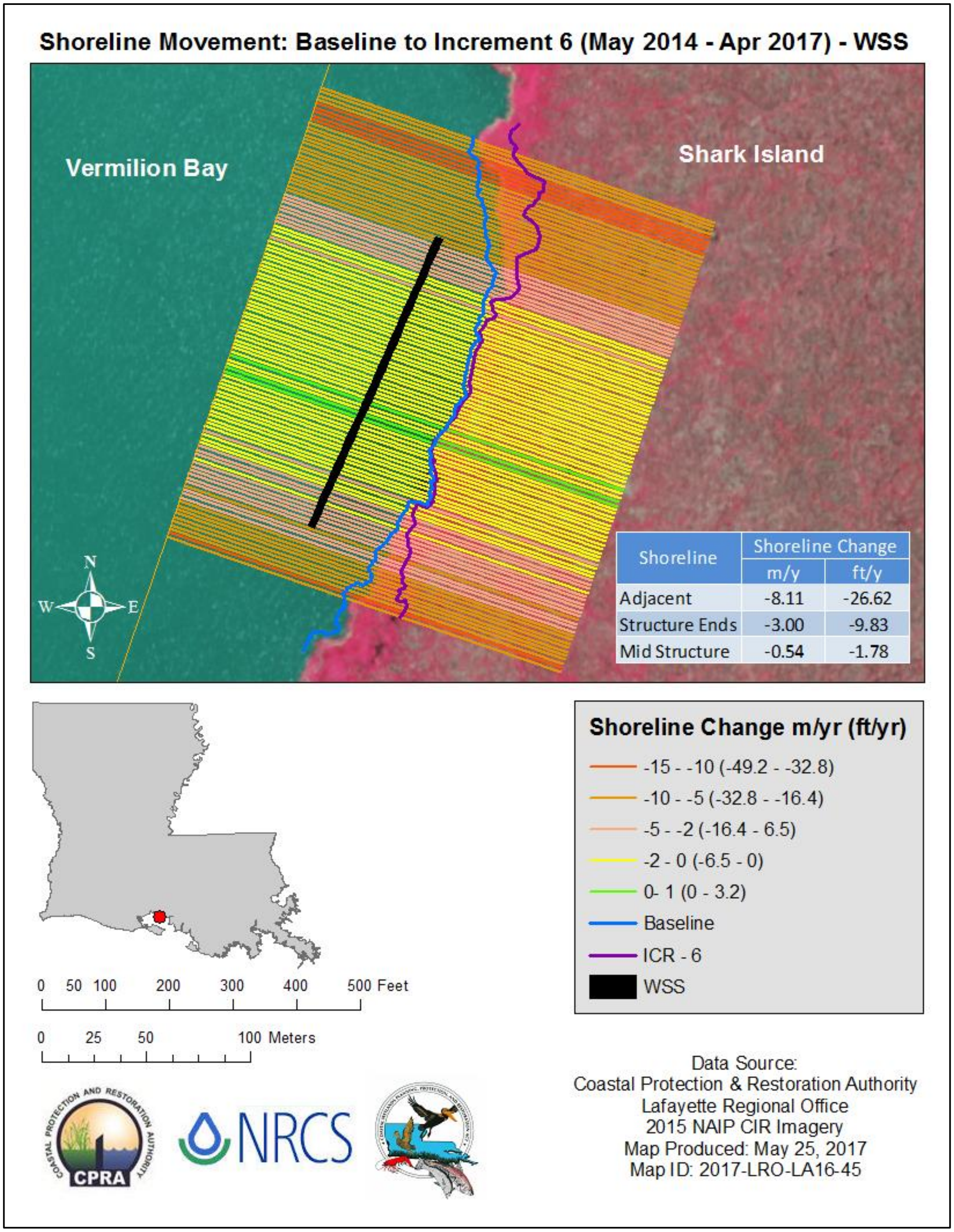



**Figure 14.** Shorelines were mapped and shoreline change calculated behind different parts of Integrated Shoreline Solutions' Wave Screen System (WSS) of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the 3-year monitoring period (May 2014 - April 2017).

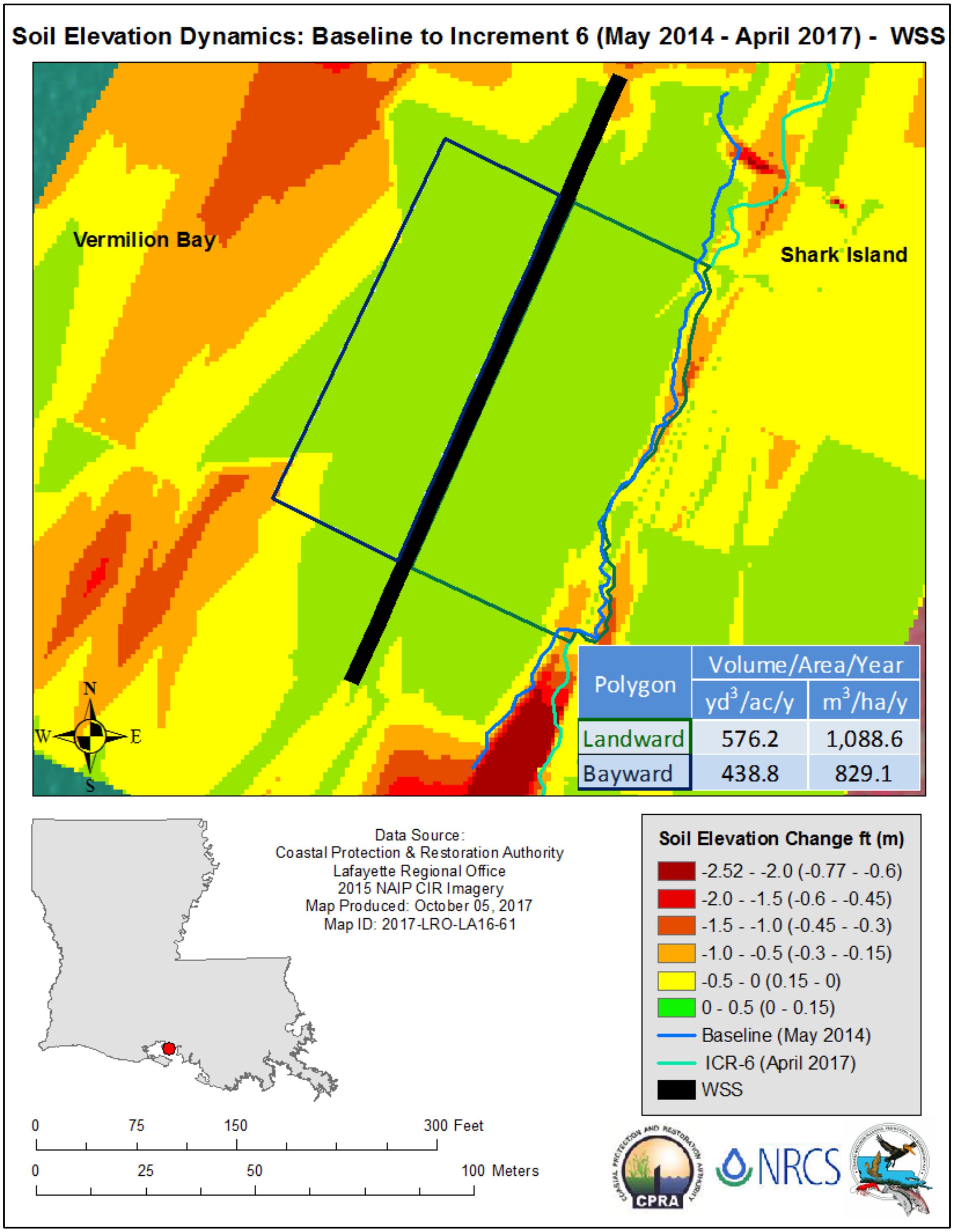



**Figure 15.** Soil elevation change was mapped in Integrated Shoreline Solutions' Wave Screen System (WSS) area of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the 3-year monitoring period (May 2014 - April 2017). The table displays volume change rates of the inset polygons.

### ii. Wave Attenuation

Averaged over 771 observations from Nov 2016 – Jan 2017, the WSS attenuated waves (α) by 73% over the monitoring period. Rapid sediment retention fouling the wave gauge sensors shortened the wave-monitoring period. Across the 21 in-coming $H_s$ and water-level groups (Table 2), α averaged 76%. After removing 88% of the observations to reduce the influence of ripples during calm conditions (in-coming $H_s$ < 0.5 ft), α averaged 83% over the remaining 95 observations and 80% across the remaining 14 in-coming $H_s$ and water-level groups. As water level increased, α decreased because the low structure elevation at the time of wave monitoring (1.88 ft NAVD88, Geoid 03) allowed waves to pass over the structure. However, the shallow condition behind the structure caused by sediment retention influenced the overall effective α.

**Table 2.** Ranges of water surface elevation and significant wave heights from incoming waves categorize significant wave heights ($H_s$) and wave attenuation (α) behind the Wave Screen System (WSS). N is the number of hourly wave observations, and $H_s$ and α values are means and one standard deviation.

| Water Surface Elevation (ft, NAVD88) | Wave Variables | $H_s$ (ft) - In-coming Wave | | | |
|---|---|---|---|---|---|
| | | 0.1 - 0.5 | 0.5 - 1.0 | 1.0 - 1.5 | 1.5 – 2.0 |
| -2.5 to -0.5 | N | 147 | 30 | | |
| | $H_s$ (ft)±SD | 0.01±0.02 | 0.01±0.03 | | |
| | α (%)±SD | 96±5 | 98±4 | | |
| -0.5 to 0.0 | N | 83 | 13 | | |
| | $H_s$ (ft)±SD | 0.03±0.02 | 0.06±0.03 | | |
| | α (%)±SD | 86±12 | 91±5 | | |
| 0.0 to 0.5 | N | 120 | 5 | 4 | |
| | $H_s$ (ft)±SD | 0.07±0.03 | 0.1±0.05 | 0.11±0.1 | |
| | α (%)±SD | 58±2 | 87±7 | 91±9 | |
| 0.5 to 1.0 | N | 114 | 8 | 4 | 1 |
| | $H_s$ (ft)±SD | 0.06±0.04 | 0.17±0.07 | 0.06±0.01 | 0.11 |
| | α (%)±SD | 60±25 | 72±11 | 96±0.01 | 93 |
| 1.0 to 1.5 | N | 103 | 6 | 3 | 1 |
| | $H_s$ (ft) ±SD | 0.06±0.05 | 0.21±0.13 | 0.09±0.02 | 0.11 |
| | α (%)±SD | 68±23 | 71±12 | 92±2 | 93 |
| 1.5 to 2.0 | N | 64 | 5 | 2 | |
| | $H_s$ (ft)±SD | 0.06±0.06 | 0.25±0.19 | 0.34±0.2 | |
| | α (%)±SD | 71±24 | 70±18 | 71±21 | |
| 2.0 to 4.5 | N | 45 | 10 | 3 | |
| | $H_s$ (ft)±SD | 0.17±0.1 | 0.41±0.2 | 0.56±0.09 | |
| | α (%)±SD | 44±25 | 46±23 | 44±9 | |

### 3. Walter Marine Artificial Reefs, Inc. - EcoSystem Units (ESUs)

#### a. <u>Product Description</u>

The ESUs were installed half way through the LA-0016 project life in November 2015; monitoring resumed on the schedule of the other products and lasted for one and one-half years. They are designed to convert wave energy to calm water. The ESUs structure consists of pile-supported concrete units; the pile is 12 inch fiberglass tubing driven down to about 60 ft. Each unit is comprised of 1 ft tall × 4.9 ft wide plates stacked to a desired elevation (Fig. 16A). Each plate was constructed with fiberglass reinforced concrete weighing approximately 1100 lbs (Fig. 16A). An average of seven (7) plates per pile were installed in approximately 4’ of water to an average crest elevation of 3.0 ft NAVD88, Geoid03. The piles were driven at 5 ft. on-center allowing for a gap of 0.2 ft between units. The final constructed feature spanned ~500 linear feet of shoreline as the ends flared toward the marsh (Figs. 1 and 16B); it consisted of 545 linear feet of ESUs with 787 plates installed on 105 piles (Fig. 16).


**Figure 16.** (A) Stacks of EcoSystem Units (ESUs) plates prior to installation. Note hole in the middle of plates for placement around a piling. (B) The northern end of the ESUs after removal of top plate and added brace to stabilize the pilings at Shark Island along the northeastern shore of Vermilion Bay for LA-0016 Non-rock Alternatives to Shoreline Protection Demonstration Project.

| | |
|---|---|
| Performance Time: | 13 calendar days |
| Total Distance Installed: | 545 LF |
| Total Installation Cost: | $677,156.00 |
| Cost per LF: | $1,242.49 |

<u>Major Equipment Used</u>

- Pusher Tender “Maranatha”
- 100’ Supply Barge with fixed boom and crane/loader
- 20’ Aluminum Workboat with 150 HP motor
- Trackhoe with Vibratory Hammer
- 2 – 60’ Work Barges
- 20’ Work Barge
- 5500 kW Generator

### b. Modifications and Maintenance

The flexibility of the fiberglass pilings and wave action caused the upper plates of adjacent units to contact each other and ultimately caused several of the upper concrete plates to break. Walter Marine removed the upper plate of each unit and connected each unit together by bolting a fiberglass C-channel brace across the top of the fiberglass pilings to prevent contact between units. After the modification, there were 675 plates remaining on the 105 piles.

### c. Structural Integrity

The structural integrity of the ESUs was stabilized following the initial breakage of the upper plates. The items below are based on observations throughout the monitoring period and/or after removal of the product and should be considered during the design phase of future installations. The considerations provided may not apply to all installations; however, these should be reviewed and addressed to ensure a product life of at least 20 years.

- Several of the upper concrete plates broke during the early monitoring period (Fig. 17A).
  - Consider modifying the fiberglass pile installed through the center of each unit to reduce the flexibility. Or, consider an alternate pile material.

- The fiberglass C-channel added to prevent contact between each unit was splitting in several locations (Fig. 17B).
  - Consider thicker fiberglass or using a different material for the C-channel. Or, design another method to keep units from coming into contact with one another.


**Figure 17.** (A) Breakage of upper plates was caused by flexibility of the fiberglass pile. (B) The C-channel used for bracing the piles cracked and split by the end of the one and one-half year monitoring period.

### d. Removal

As of the date of this report being written, Walter Marine Artificial Reefs, Inc. has removed the fiberglass C-channel brace, top collar, and concrete plates, but has not removed the fiberglass piles. Equipment used thus far is unknown to NRCS and CPRA.

### e. Results and Discussion

#### i. Topographic and Bathymetric Elevation Dynamics

*Structure Elevation*

The ESUs were installed at an average crest elevation (surveyed on the top plate) of 2.72 ft NAVD88 Geoid03 in November 2015. The crest elevation was 1.66 ft NAVD88 Geoid03 by the end of the one and one-half year monitoring period. The top elevation decrease included removal of the 1 ft thick top plate from each unit. However, the C-channel brace used to stabilize the ESU pilings compensated for the loss in elevation for an estimated elevation of 2.7 ft NAVD88 Geoid03. The bay bottom elevation changed very little at the base of the ESUs along the center span averaged -4.01 ft NAVD88 during the baseline measurement in November 2015 and -4.04 ft NAVD88 by the end of the one and one-half year monitoring period (see Appendix D-1).

*Shoreline Movement*

Shoreline eroded about 13 feet behind the middle 300 ft of the ESUs over its one and one-half year monitoring period (Fig. 18) producing an overall rate of -9.1 ft/y (Fig 19). Shoreline behind the ends of the ESUs eroded similarly to behind the middle because of the wings extending toward the shoreline. Shoreline movement adjacent to the ESUs was less than the Reference but followed a similar pattern (Fig. 18). Shoreline movement behind the middle of the ESUs was 82% less than the Reference over the same one and one-half year monitoring period.

*Soil elevation dynamics (elevation and volume change)*

From construction in November 2015 to the end of monitoring in April 2017, the area in the landward polygon lost 38 $yd^3$/ac/y of soil, mainly at the shoreline, and the area in the bayward polygon accumulated about 240 $yd^3$/ac/y (Fig. 20). Landward, the difference in soil-volume change rates between the ESUs and Reference area was 3,597 $yd^3$/ac/y as the Reference area lost 3,635 $yd^3$/ac/y (Fig. 21). Bayward, the difference in soil-volume change rates between the ESUs and Reference area was 1,023 $yd^3$/ac/y as the Reference area lost 783 $yd^3$/ac/y (Fig. 21).

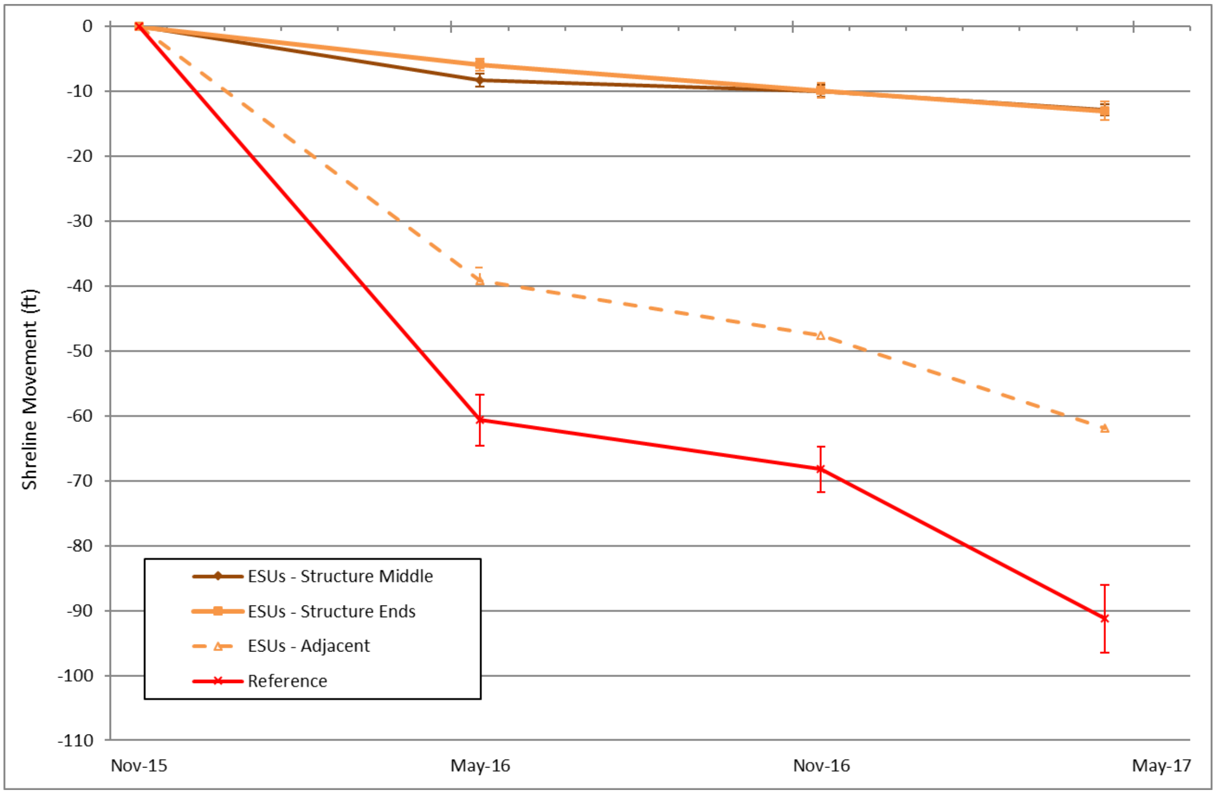



**Figure 18.** Cumulative shoreline change behind different parts of Walter Marine's EcoSystem Units (ESUs) and along the Reference area for the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) was determined every six months for the one and one-half year monitoring period (Nov 2015 - April 2017). Values are means and standard errors of shoreline movement of DSAS transects.

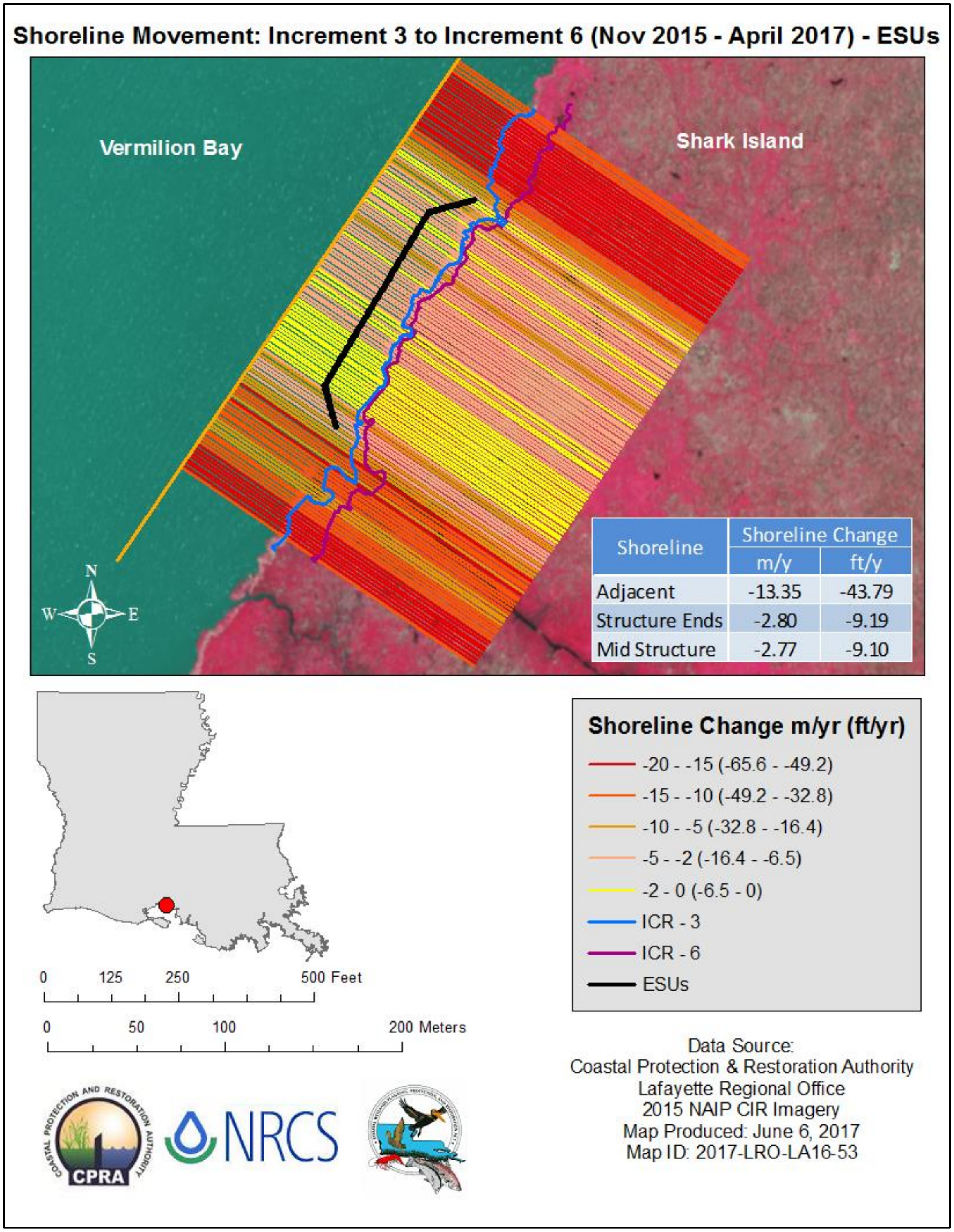
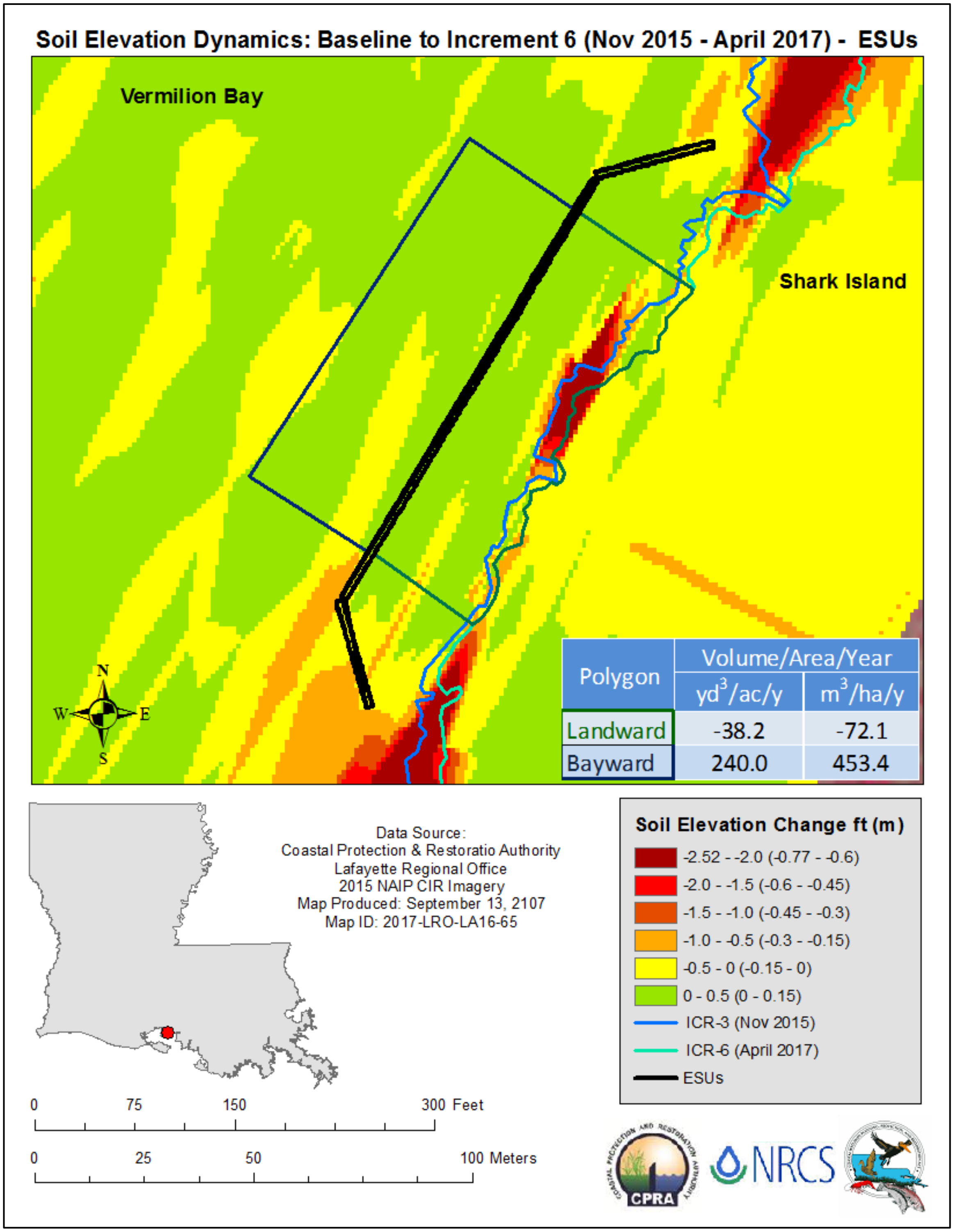
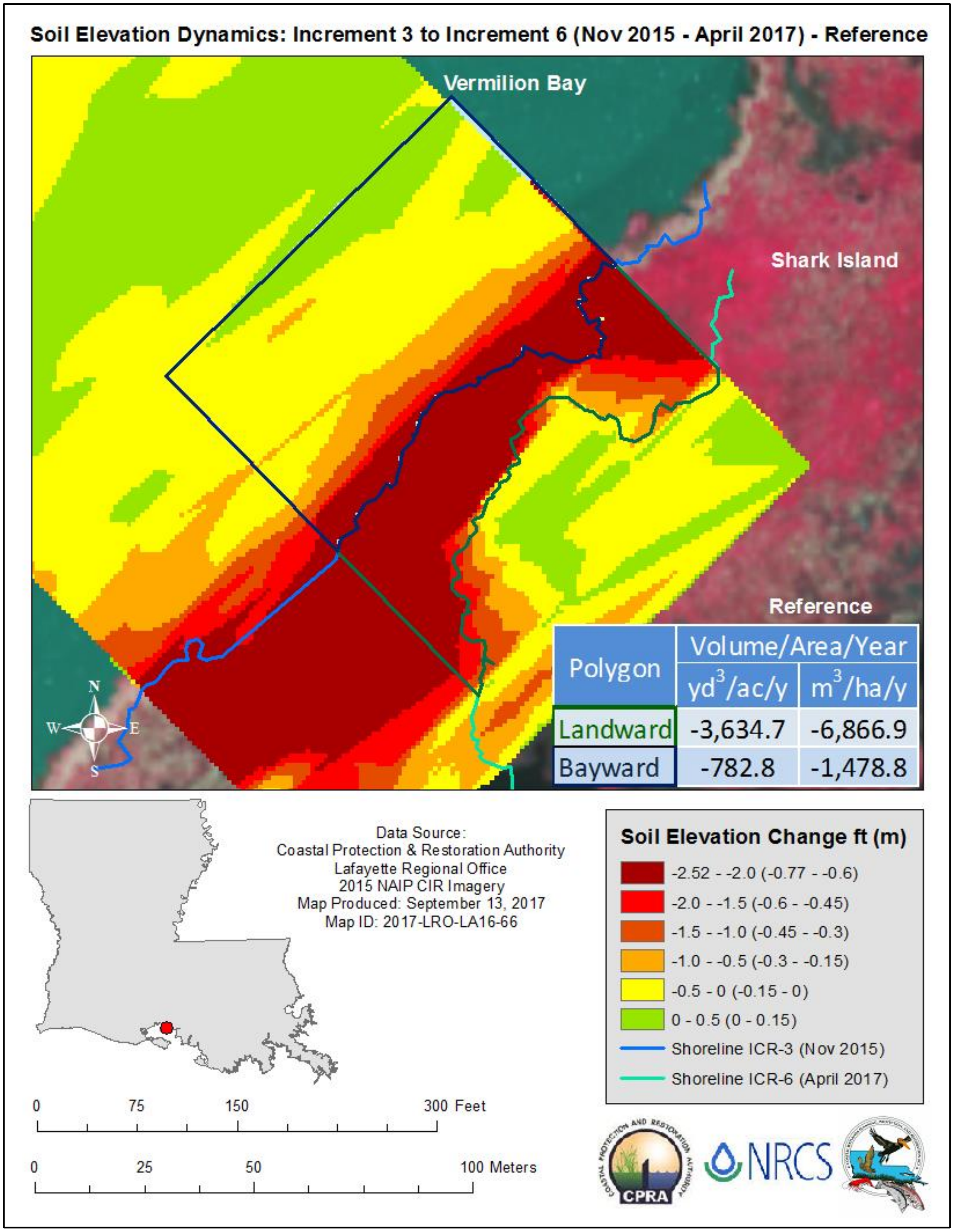



**Figure 19.** Shorelines were mapped and shoreline change calculated behind different parts of Walter Marine's EcoSystem Units (ESUs) of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the one and one-half year monitoring period (Nov 2015 - April 2017).




| Polygon | Volume/Area/Year | |
|---|---|---|
| | $yd^3/ac/y$ | $m^3/ha/y$ |
| Landward | -38.2 | -72.1 |
| Bayward | 240.0 | 453.4 |

**Figure 20.** Soil elevation change was mapped in Walter Marine's EcoSystem Units (ESUs) area of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the one and one-half year monitoring period (Nov 2015 - April 2017). The table displays volume change rates of the inset polygons.




| Polygon | Volume/Area/Year | |
|---|---|---|
| | yd³/ac/y | m³/ha/y |
| Landward | -3,634.7 | -6,866.9 |
| Bayward | -782.8 | -1,478.8 |

**Figure 21.** Soil elevation change was mapped in the Reference area of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for a one and one-half year monitoring period (Nov 2015 - April 2017). The table displays volume change rates of the inset polygons on either side of the November 2015 shoreline.

### ii. Wave Attenuation

Averaged over 981 observations from Nov 2016 – May 2017, the ESUs attenuated waves (α) by 53% over the monitoring period. Across the 21 in-coming $H_s$ and water-level groups (Table 3), α averaged 59%. After removing 88% of the observations to reduce the influence of ripples during calm conditions (in-coming $H_s < 0.5$ ft), α averaged 65% over the remaining 117 observations and 64% across the remaining 14 in-coming $H_s$ and water-level groups. As water level increased, α decreased because the low structure elevation at the time of monitoring (2.7 ft NAVD88, Geoid 03) allowed waves to pass over the structure. The distance from the structure to the wave gage position along the shoreline of about 60 ft may have been enough for small wave generation via wind fetch; however, the ends of the structure extending towards the shoreline provided protection against waves approaching from more northerly or southerly directions.

**Table 3.** Ranges of water surface elevation and significant wave heights from incoming waves categorize significant wave heights ($H_s$) and wave attenuation (α) behind the EcoSystem Units (ESUs). N is the number of hourly wave observations, and $H_s$ and α values are means and one standard deviation.

| **Water Surface Elevation (ft, NAVD88)** | **Wave Variables** | **$H_s$ (ft) - In-coming Wave** | | | |
|---|---|---|---|---|---|
| | | **0.1 - 0.5** | **0.5 - 1.0** | **1.0 - 1.5** | **1.5 – 2.0** |
| -2.5 to -0.5 | N | 168 | 31 | | |
| | $H_s$ (ft)±SD | 0.11±0.04 | 0.17±0.03 | | |
| | α (%)±SD | 59±18 | 72±5 | | |
| -0.5 to 0.0 | N | 106 | 14 | | |
| | $H_s$ (ft)±SD | 0.11±0.04 | 0.17±0.04 | | |
| | α (%)±SD | 50±15 | 71±7 | | |
| 0.0 to 0.5 | N | 139 | 7 | 4 | |
| | $H_s$ (ft)±SD | 0.12±0.04 | 0.23±0.05 | 0.4±0.1 | |
| | α (%)±SD | 43±17 | 67±7 | 67±10 | |
| 0.5 to 1.0 | N | 148 | 11 | 4 | 1 |
| | $H_s$ (ft)±SD | 0.09±0.04 | 0.21±0.05 | 0.48±0.1 | 0.49 |
| | α (%)±SD | 54±18 | 67±7 | 63±8 | 68 |
| 1.0 to 1.5 | N | 142 | 12 | 4 | 1 |
| | $H_s$ (ft) ±SD | 0.1±0.04 | 0.31±0.16 | 0.35±0.21 | 0.63 |
| | α (%)±SD | 52±20 | 58±23 | 70±16 | 59 |
| 1.5 to 2.0 | N | 87 | 10 | 3 | |
| | $H_s$ (ft)±SD | 0.09±0.06 | 0.26±0.12 | 0.39±0.13 | |
| | α (%)±SD | 52±23 | 60±21 | 68±4 | |
| 2.0 to 4.5 | N | 74 | 12 | 3 | |
| | $H_s$ (ft)±SD | 0.14±0.07 | 0.36±0.13 | 0.49±0.13 | |
| | α (%)±SD | 40±20 | 48±15 | 52±14 | |

### 4. Jansen, Inc. - Buoyancy Compensated Erosion Control Modular System (BCECMS)

#### a. Product Description

Jansen, Inc. was the contracted designer and builder of the BCECMS for the LA-0016 project, and Louisiana Shoreline Solutions, LLC owned the rights. The BCECMS was designed to provide a wave barrier throughout the water column while allowing water to pass between the individual modules to equalize hydrostatic pressure on either side of the structure. The 10 ft long by 7 ft tall trapezoidal modules have a base width of 6 ft and a crest width of 2 ft. The modules are composed of a polystyrene foam core encased in concrete. Each module settled about one foot into the bay bottom and was stabilized with two vertical and two diagonal 60 ft pin piles (Fig. 22A). The final constructed BCECMS was ~515 linear ft articulating with the shoreline consisting of 48 modules and 192 pin piles. The straight-line linear distance between terminal points was 460 feet. Each module was installed on the bay bottom in approximately 2-3 ft of water and within 5-30 ft from the existing shoreline. The average crest elevation was 3.5 ft NAVD88, Geoid03 (Fig. 22B).

| | |
|---|---|
| Performance Time: | 19 calendar days |
| Total Distance Installed: | 515 LF |
| Total Installation Cost: | $1,040,660.00 |
| Cost per LF: | $2,060.71 |

Major Equipment Used

- Equipment & Supply Barge “Marc 1” (38’ x 140’)
- Cat 336E Excavator w/ Pipe Handler
- 480 Volvo Excavator w/ Lift Boom
- Collons 20,000 lb. Hydraulic Hammer
- 350A Welding Machine
- Small Tug Boat
- 20’ Fiberglass Boat
- Air Compressor (56942z)
- 25k Generator (530609)
- Cement Mixer

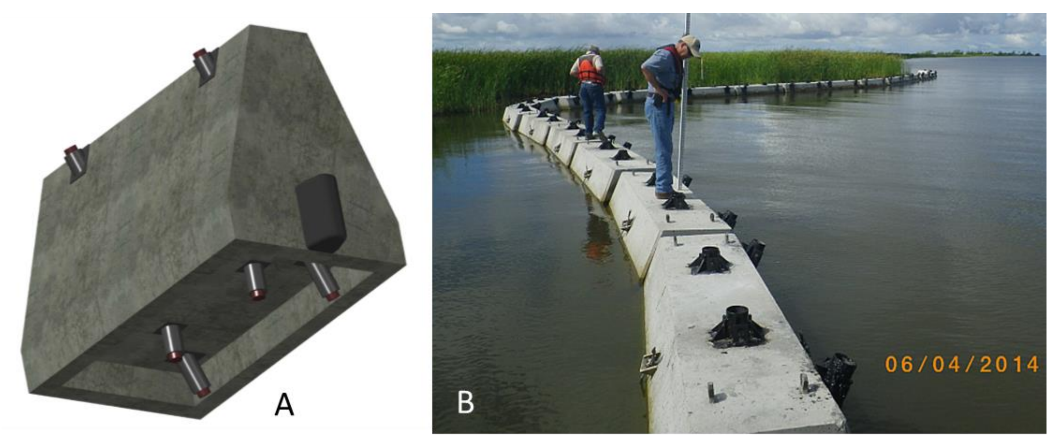



**Figure 22.** (A) A bottom-view, isometric drawing of a Buoyancy Compensated Erosion Control Modular System (BCECMS) module displays position of pin pilings. (B) The southern half of the BCECMS at Shark Island along the northeastern shore of Vermilion Bay for LA-0016 Non-rock Alternatives to Shoreline Protection Demonstration Project.

### b. Modifications and Maintenance

Several bolts used to connect the module to the piles sheared off shortly after construction completion. Jansen fixed this problem by welding four gusset plates on each pile that connected the pile to the base plate on top of each module.

### c. Structural Integrity

Structural integrity of the BCECMS was maintained throughout the three-year monitoring period after base plate modifications. The items below are based on observations throughout the monitoring period and/or after removal of the product and should be considered during the design phase of future installations. The considerations provided may not apply to all installations; however, these should be reviewed and addressed to ensure a product life of at least 20 years.

- Driving some of the piles used to support each module was very difficult; a few piles bent severely during the driving operation.
  - Consider using a larger driving hammer during installation and/or thicker piling walls.

- Each of the support piles and metal connection plates observed during removal had flaking rust, mainly on the upper 6 feet of each pile (Fig. 23A).
  - Consider a different material or requiring a protective coating and verifying uniform thickness during quality control activities prior to installation of all steel components.

- The gusset plates on one module completely failed during the monitoring period. The batter piles limited downward settlement to less than 1 foot (Fig. 23B).
  - Consider changing the design of the connection between the module and piles or increase quality control on welding operations of the gusset plates.


**Figure 23.** (A) Flaking rust was observed on metal piles and connection plates by the end of the three-year monitoring period. (B) One module settled down the support piles about half a foot because of failed connections with the base plates.

- Jansen had a lot of difficulty removing the batter piles and vertical piles because the piles were cut very short above the units when they were originally placed and that area of the piles were corroded thus making it difficult to connect for removal. Some piles were cut off below the module to have enough room to grab with equipment. They used heavy oilfield pipe extraction tools to place inside of pin piles and pull piles out with a crane or placed another tool inside of piles down to about -25 feet and cut them off.
    - Consider increasing the length of pile protruding out of the top of each module to facilitate removal and repairs. The length should be based on equipment planned to remove piles.

### d. Removal

Removal of a product is usually not a consideration in the design of a shoreline protection feature; therefore, only the major equipment used was provided to assist with determining O&M costs on future installations. No access dredging was required for removal of the product.

Major Equipment Used

| | |
|---|---|
| Mantis 70 Ton Hydraulic Crane with 110' Boom | Spud Barge – "Liza Jane" |
| Spear – Oilfield Pipe Extraction Tool (fit inside Pin Piles) | Material Barge - "Charity" |
| Oilfield Pipe Cutter – inserted inside Pin Piles | Deck Boat – "Mr. Carter" |
| Crew Boat – "Mr. Collin" | |

### e. Results and Discussion

#### i. Topographic and Bathymetric Elevation Dynamics

*Structure Elevation*

The BCECMS maintained an average crest elevation of 3.1 ft NAVD88 Geoid03 throughout the three-year monitoring period aside from the one module with failed base plate connections that settled 0.56 ft. The bay bottom elevation at the base of the BCECMS averaged -3.82 ft NAVD88 Geoid 03, ranging -4.5 to -2.65 ft NAVD88 Geoid03, during the baseline measurement in May 2014 and -4.75 ft NAVD88, ranging -5.4 to -3.88 ft NAVD88 Geoid03, by April 2017 (see Appendix E-1). The -0.93 ft of bay bottom elevation change is indicative of scour along the base of the structure.

*Shoreline Movement*

Shoreline eroded about 17 feet behind the middle 260 ft of the BCECMS over the three-year monitoring period producing an overall rate of -5.9 ft/y despite small shoreline progradations initially and in May – Nov 2016 (Figs. 24 and 25). Shoreline behind the ends of the BCECMS eroded in a similar pattern as behind the middle but at a greater rate. Shoreline movement adjacent to the BCECMS was similar to the Reference. Over the three-year monitoring period, shoreline movement behind the middle of the BCECMS was about 88.5% less than the Reference (Fig. 24).

*Soil elevation dynamics (elevation and volume change)*

From the baseline survey in May 2014 to the end of monitoring in April 2017, the area in the landward polygon lost 500 $yd^3/ac/y$ of soil and the area in the bayward polygon lost 300 $yd^3/ac/y$ (Fig. 26). Landward, the difference in soil-volume change rates between the BCECMS and Reference area was 1,686 $yd^3/ac/y$ as the Reference area lost 2,190 $yd^3/ac/y$ (Fig. 5). Bayward, the difference in soil-volume change rates between the BCECMS and Reference area was 135.5 $yd^3/ac/y$ as the Reference area lost 434.5 $yd^3/ac/y$ (Fig. 5). Much of the soil volume loss on the landward side is attributable to trench formation between the BCECMS and the marsh (see Appendix E-1 Cross Sections sheets).

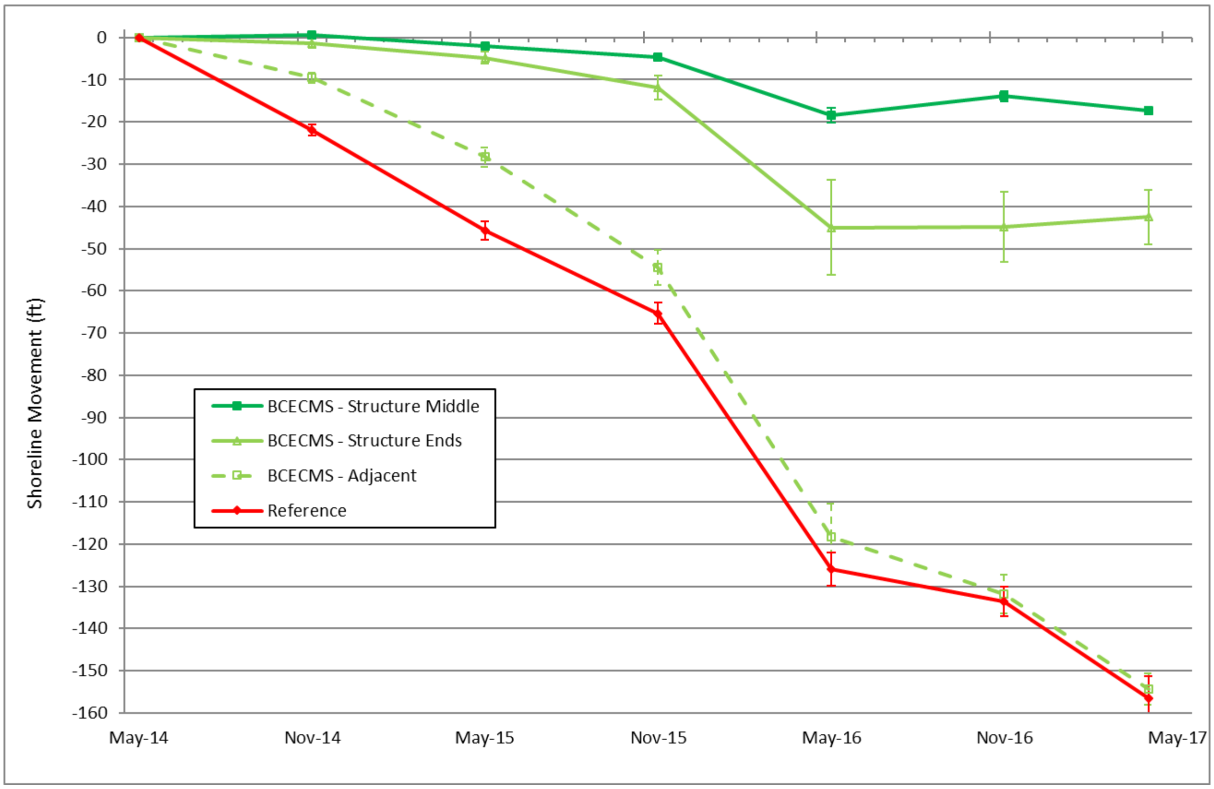



**Figure 24.** Cumulative shoreline change behind different parts of Jansen's Buoyancy Compensated Erosion Control Modular System (BCECMS) and along the Reference area for the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) was determined every six for the 3-year monitoring period (May 2014 - April 2017). Values are means and standard errors of shoreline movement of DSAS transects.

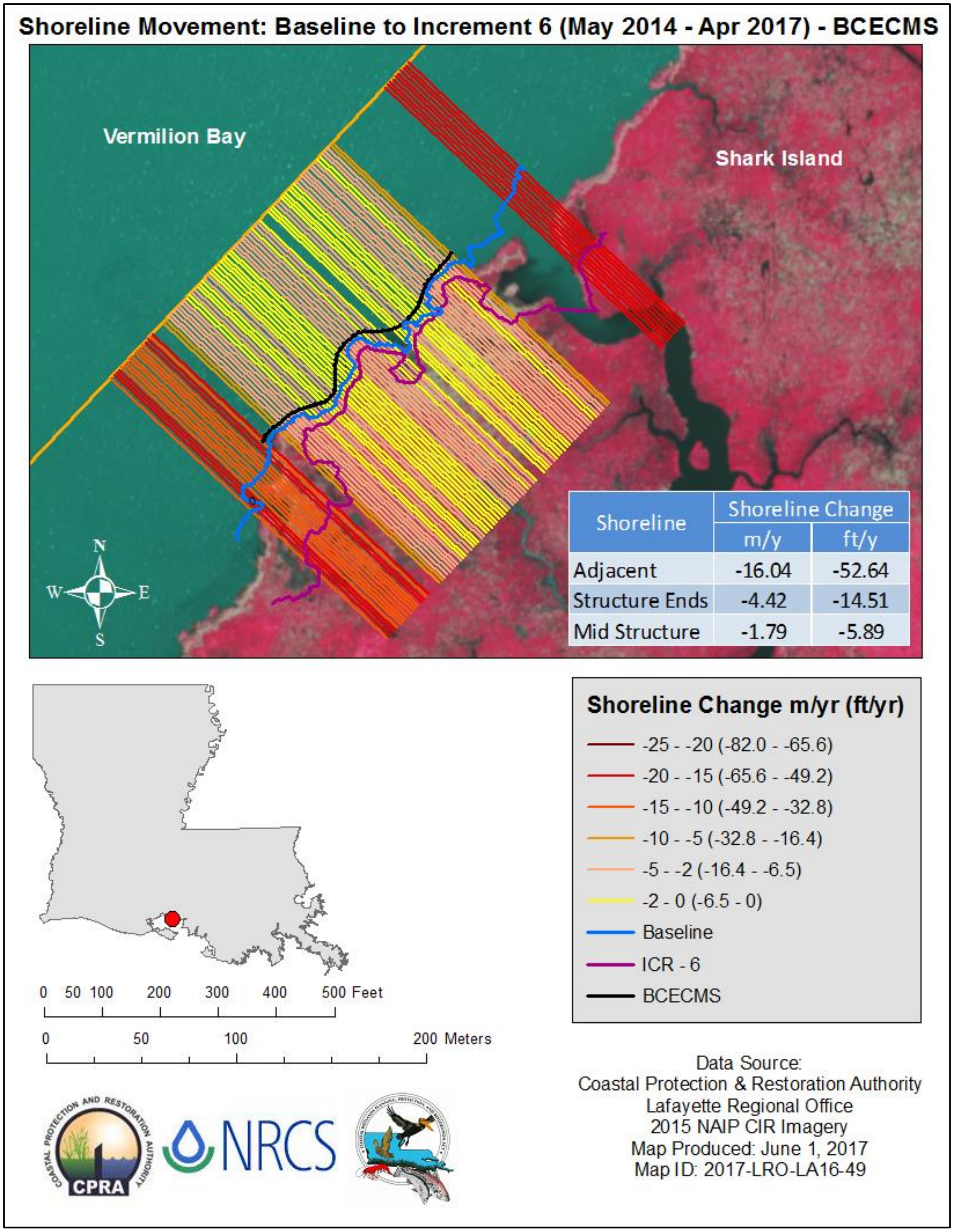



**Figure 25.** Shorelines were mapped and shoreline change calculated behind different parts of Jansen's Buoyancy Compensated Erosion Control Modular System (BCECMS) of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the 3-year monitoring period (May 2014 - April 2017). Note deleted DSAS transects where the shoreline breached into interior water bodies.

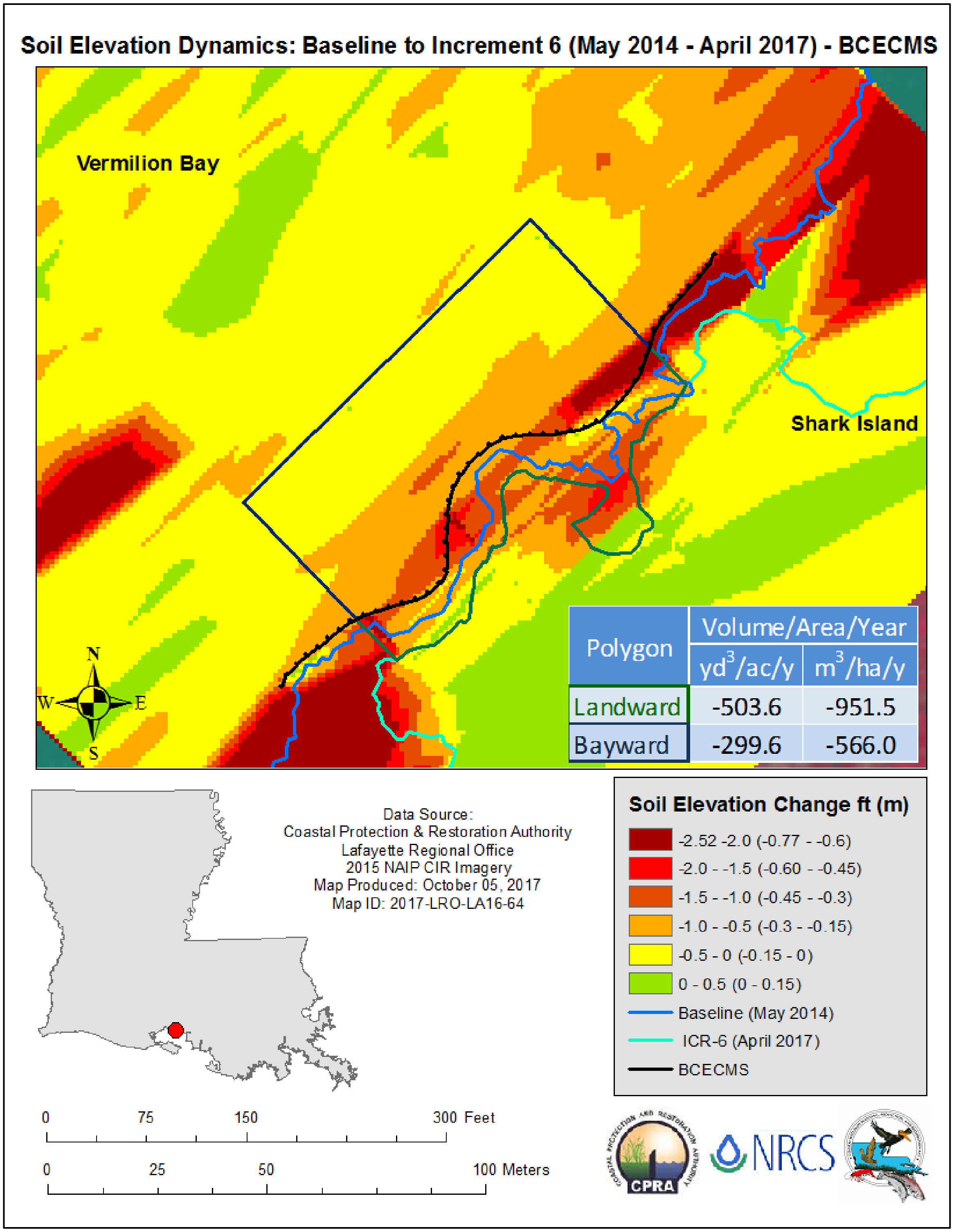



**Figure 26.** Soil elevation change was mapped in Jansen, Inc.'s Buoyancy Compensated Erosion Control Modular System (BCECMS) area of the Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) for the 3-year monitoring period (May 2014 - April 2017). The table displays volume change rates of the inset polygons.

### ii. Wave Attenuation

Averaged over 1015 observations from Nov 2016 – May 2017, the BCECMSs attenuated waves (α) by 70% over the monitoring period. Across the 21 in-coming $H_s$ and water-level groups (Table 4), α averaged 79%. After removing 88% of the observations to reduce the influence of ripples during calm conditions (in-coming $H_s$ < 0.5 ft), α averaged 81% over the remaining 118 observations and 83% across the remaining 14 in-coming $H_s$ and water-level groups. The effectiveness of reducing wave energy generally appears to be uniform over the range of the water levels encountered in the study and improved at higher incoming $H_s$. The effective α of the BCECMSs may be attributable to the structure elevation at the time of wave monitoring (3.13 ft NAVD88, Geoid 03) being about 2.2 ft above mean water level (0.93±0.95 ft NAVD88, Geoid 03). Also, the short distance from the structure to the wave gage position along the shoreline (2-25 ft) decreased wind fetch for wave formation.

**Table 4.** Ranges of water surface elevation and significant wave heights from incoming waves categorize significant wave heights ($H_s$) and wave attenuation (α) behind the Buoyancy Compensated Erosion Control Modular System (BCECMS). N is the number of hourly wave observations, and $H_s$ and α values are means and one standard deviation.

| Water Surface Elevation (ft, NAVD88) | Wave Variables | $H_s$ (ft) - In-coming Wave | | | |
|---|---|---|---|---|---|
| | | 0.1 - 0.5 | 0.5 - 1.0 | 1.0 - 1.5 | 1.5 – 2.0 |
| -2.5 to -0.5 | N | 168 | 31 | | |
| | $H_s$ (ft)±SD | 0.08±0.03 | 0.12±0.02 | | |
| | α (%)±SD | 71±10 | 79±4 | | |
| -0.5 to 0.0 | N | 111 | 14 | | |
| | $H_s$ (ft)±SD | 0.07±0.02 | 0.13±0.03 | | |
| | α (%)±SD | 63±15 | 79±3 | | |
| 0.0 to 0.5 | N | 144 | 7 | 4 | |
| | $H_s$ (ft)±SD | 0.07±0.03 | 0.14±0.04 | 0.12±0.11 | |
| | α (%)±SD | 60±22 | 80±7 | 90±9 | |
| 0.5 to 1.0 | N | 149 | 11 | 4 | 1 |
| | $H_s$ (ft)±SD | 0.06±0.04 | 0.15±0.04 | 0.11±0.01 | 0.1 |
| | α (%)±SD | 66±24 | 76±7 | 92±1 | 93 |
| 1.0 to 1.5 | N | 141 | 12 | 4 | 1 |
| | $H_s$ (ft) ±SD | 0.06±0.04 | 0.17±0.08 | 0.11±0.07 | 0.12 |
| | α (%)±SD | 70±24 | 78±11 | 90±8 | 92 |
| 1.5 to 2.0 | N | 92 | 10 | 3 | |
| | $H_s$ (ft)±SD | 0.04±0.04 | 0.12±0.06 | 0.19±0.04 | |
| | α (%)±SD | 76±2 | 82±12 | 85±1 | |
| 2.0 to 4.5 | N | 92 | 13 | 3 | |
| | $H_s$ (ft)±SD | 0.03±0.03 | 0.13±0.09 | 0.32±0.14 | |
| | α (%)±SD | 82±14 | 82±10 | 69±12 | |

## V. Discussion

All of the alternatives to rock rip-rap breakwaters assessed in LA-0016 provided protection against shoreline erosion. The four products all reduced the rates of soil volume loss by at least 77%, reduced shoreline change rates by at least 82%, and attenuated in-coming wave heights >0.5 ft by at least 65% (Table 5). The products that allowed wave energy to pass through the structure (WADs and WSS) saw increases in soil volume between the structure and the marsh and less shoreline loss; a large mudflat of accumulated sediment formed behind the WSS. The products that blocked waves (ESUs and BCECMS) had less soil volume loss than the reference but did not increase soil volume. All products provided protection from shoreline erosion. The initial construction cost for all of these non-rock alternatives is higher than rock rip-rap breakwaters which typically range $500 to $750 per linear foot; however, in weak soil conditions in which these alternatives would be used, rock rip-rap is anticipated to be more expensive over all due to the costs of additional rock required to maintain structure elevation through time.

**Table 5.** Summary of primary performance measures for Non-rock Alternatives to Shoreline Protection Demonstration Project (LA-0016) including soil volume change, shoreline change behind the middle of the structure, wave attenuation of in-coming waves >0.5 ft, and cost per linear foot (fabrication, mobilization, and installation).

| Product | Soil Volume Change Rate ($yd^3$/ac/y) | Shoreline Change Rate (ft/y) | Wave Attenuation (%) | Cost ($) per Linear Foot |
|---|---|---|---|---|
| WSS | 576.2 | -1.78 | 83 | $1,494.97 |
| WADs | 217.9 | -2.63 | 70 | $1,402.44 |
| ESUs | -38.2 | -9.10 | 65 | $1,242.49 |
| BCECMS | -503.6 | -5.89 | 81 | $2,060.71 |
| Reference | -2,189.8 | -51.15 | NA | NA |

## VI. Conclusions

### a. Project Effectiveness

All four non-rock products evaluated achieved the primary objectives in that they:

1. Significantly reduced shoreline erosion relative to the reference area.
2. Significantly reduced soil volume loss relative to the reference area.
3. Significantly attenuated waves reaching the shoreline.

### b. Recommended Improvements

All metal components should be non-corrosive. If protective coatings are used to prevent metal corrosion, then they should be inspected rigorously during manufacturing, prior to installation, after installation, and after any maintenance.

### c. Lessons Learned

Products that allowed water to pass through the structure as they attenuated the waves (WSS and WADs) accumulated soil between the structure and the shoreline while products that diverted water around the structures (BCECMS and ESUs) reduced soil erosion but did not accumulate soil between the structure and the shoreline by the end of the three year monitoring period.

Many previous shoreline monitoring efforts have only considered shoreline location and shoreline movement. This study also included topographic/bathymetric elevation surveys across the feature perpendicular to the shoreline and those surveys allowed for calculation of soil volume change. The additional survey data was beneficial to project assessment and is recommended for future shoreline protection projects; especially for short-term monitoring as soil elevation dynamics respond faster than shoreline changes.

Three years of monitoring was a sufficient amount of time given the short lengths of the shoreline protection structures. Erosion from adjacent, unprotected areas would have overwhelmed the structure areas over a longer period of time.

## VII. Literature Cited

Byrnes, M.R., J.L. Berlinghoff, S.F. Griffee, S.G. Underwood, D.M. Lee, and S. Khalil. 2016. Louisiana Barrier Island Comprehensive Monitoring Program (BICM): Phase 2 – Shoreline Compilation and Change Assessment. Prepared for Louisiana Coastal Protection and Restoration Authority (CPRA) by Applied Coastal Research and Engineering. Baton Rouge, LA.

ENCOS, Inc. 2017. Decommission of Data Collection Platforms for LA-0016 Non-Rock Alternatives Shoreline Protection Demonstration Project. Prepared for SWCA Environmental Consultants. 16 pp plus Appendices. Available online at https://cims.coastal.louisiana.gov/RecordDetail.aspx?Root=0&sid=21361

FTN Associates Ltd. 2018. Technical Memorandum: LA-0016 Non-Rock Alternatives to Shoreline Protection Demonstration Project, Iberia Parish, Louisiana: Wave Monitoring Data Processing and Calculation of Wave Transmission Coefficients. FTN No. R11659-1144-001. 20 pp plus Attachment. Available online at https://cims.coastal.louisiana.gov/RecordDetail.aspx?Root=0&sid=21360

Martinez, L., S. O'Brien, M. Bethel, S. Penland, and M. Kulp. 2009. Louisiana Barrier Island Comprehensive Monitoring Program (BICM), Volume 2: Shoreline Changes and Barrier Island Land Loss 1800s-2005. University of New Orleans, Pontchartrain Institute for Environmental Sciences, New Orleans, LA. 32 pp.

Theiler, E.R., E.A. Himmelstoss, J.L.Zichichi, and A. Ergul. 2009. Digital Shoreline Analysis System (DSAS) version 4.0 – An ArcGIS extension for calculating shoreline change. U.S. Geological Survey Open-File Report 2008-1278. Available online at http://pubs.usgs.gov/of/2008/1278/

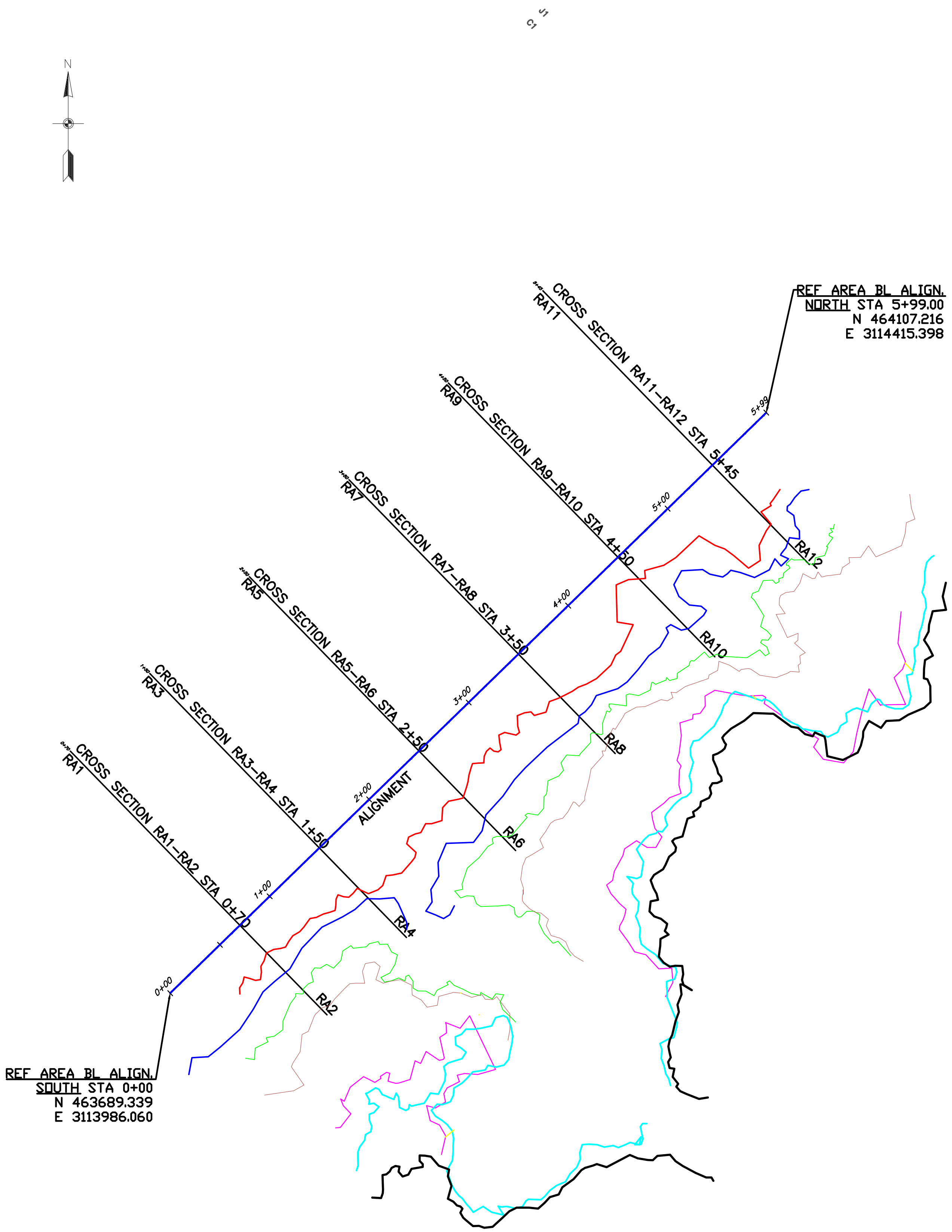
# APPENDIX A

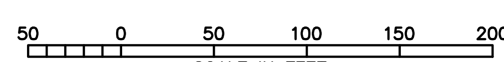
## Reference Area

**APPENDIX A - 1**

**Topographic/Bathymetic Survey Drawings**

(Distances are in feet, and Elevations are in feet NAVD88 Geoid 03)




SURVEY CONTROL: STATION NAME - "TBM-SHARK3"
MONUMENT LOCATION: LOCATED ON SHARK ISLAND IN IBERIA PARISH, LOUISIANA. THE TEMPORARY BENCHMARK IS SET ON THE NORTHEAST BANK OF AN OLD OILFIELD LOCATION CANAL AND LOCATED APPROXIMATELY 370' SOUTHEAST FROM THE INTERSECTION OF THE NORTHEAST BANK AND VERMILION BAY. IT IS APPROXIMATELY 320' SOUTHEAST OF MONUMENT "TBM-SHARK 2".

MONUMENT DESCRIPTION: ROUND WOODEN FENCE POST DRIVEN INTO GROUND AND PROTRUDING FROM THE GROUND ABOUT 1.0". MONUMENT IS MARKED WITH A BRASS TAG LABELED "SHARK 3". THERE IS A PK NAIL IN THE CENTER ON THE TOP OF THE POST.

STAMPING: "SHARK 3"
DATE: JUNE 3, 2014

MONUMENT ESTABLISHED BY: USDA-NRCS CROWLEY WATERSHED OFFICE

ADJUSTED NAD83 GEODETIC POSITION (2011) (EPOCH:2010.0000)

LAT: 29-46-14.07 NORTH
LONG: 91-51-45.87 WEST

ADJUSTED NAD 83 DATUM LSZ (1702)

N=462,448.963

E=3,112,873.741

ADJUSTED NAVD88 ELEVATION

3.07 FEET / 0.936 METERS

ELLIPSOID HEIGHT: -25.183 METERS

GEOID 03 HEIGHT: -26.119 METERS

PLAN and PROFILE LINE COLOR LEGEND

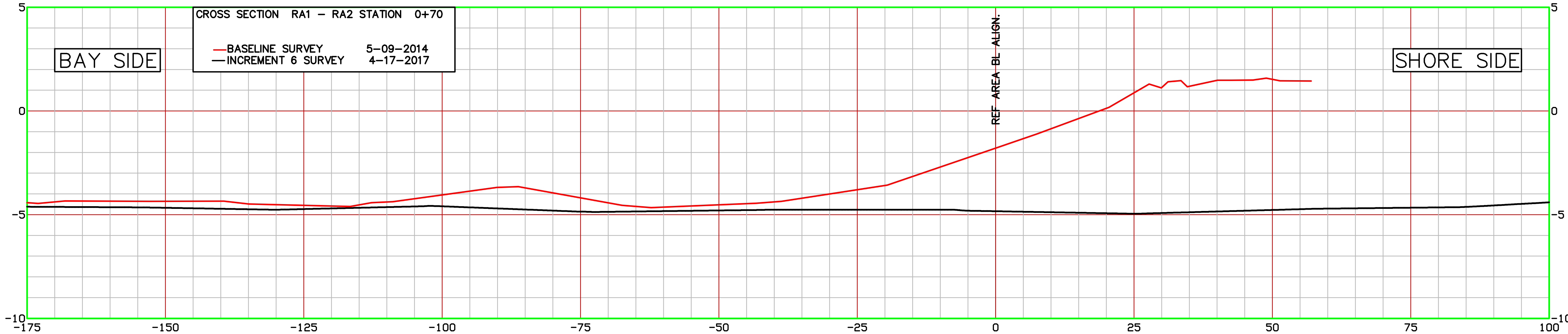
| | |
|---|---|
| red | BASELINE 5.09.2014 Survey |
| blue | ICR–1 [0.5 years] 11.03.2014 Survey |
| green | ICR–2 [1.0 years] 04.30.2015 Survey |
| brown | ICR–3 [1.5 years] 11.05.2015 Survey |
| magenta | ICR–4 [2.0 years] 04.28.2016 Survey |
| cyan | ICR–5 [2.5 years] 11.10.2016 Survey |
| black | ICR–6 [3.0 years] 04.17.2017 Survey |

| | | DATE |
|---|---|---|
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

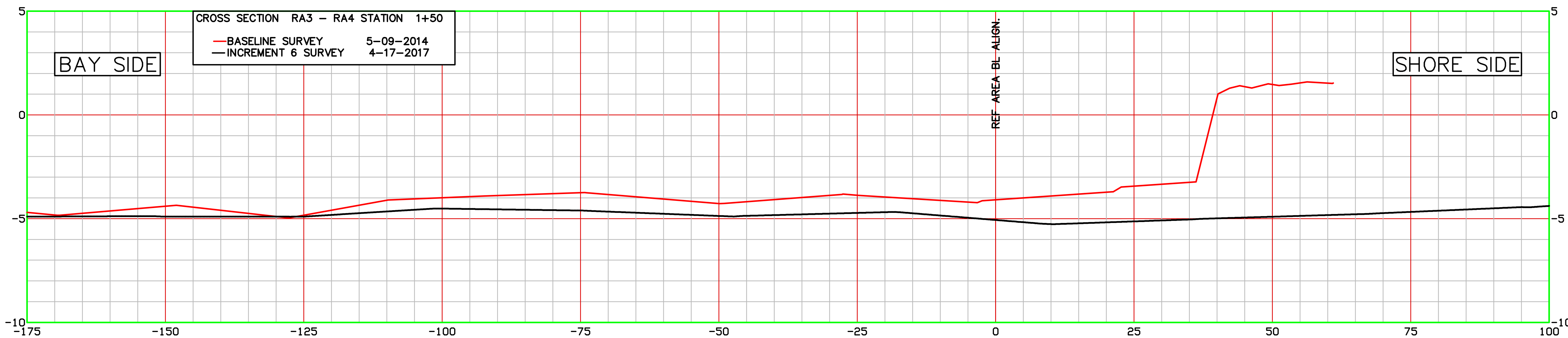
PLAN VIEW DRAWING
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
REFERENCE AREA
IBERIA PARISH, LOUISIANA

USDA United States Department of Agriculture
Natural Resources Conservation Service

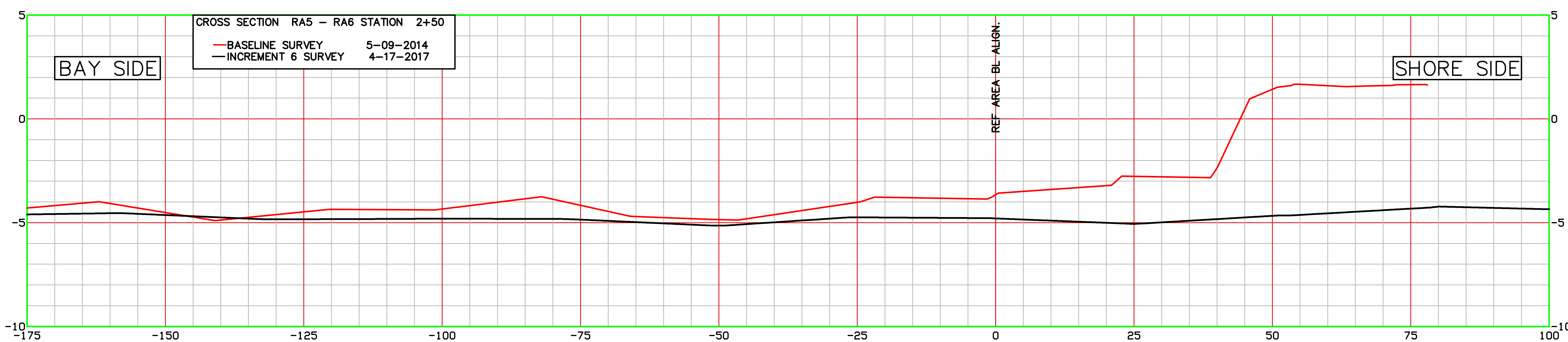
FILE NAME
REF AREA MONT.
DRAWING NAME
REF AREA ICR 6




CROSS SECTION RA1 – RA2 STA 0+70




CROSS SECTION RA3 – RA4 STA 1+50




CROSS SECTION RA5 – RA6 STA 2+50

| | | |
|---|---|---|
| | | DATE |
| DESIGNED | A. GREMILLION | 02/18 |
| DRAWN | D. GARBER | 02/18 |
| CHECKED | B. SAMSON | 02/18 |
| APPROVED | | |

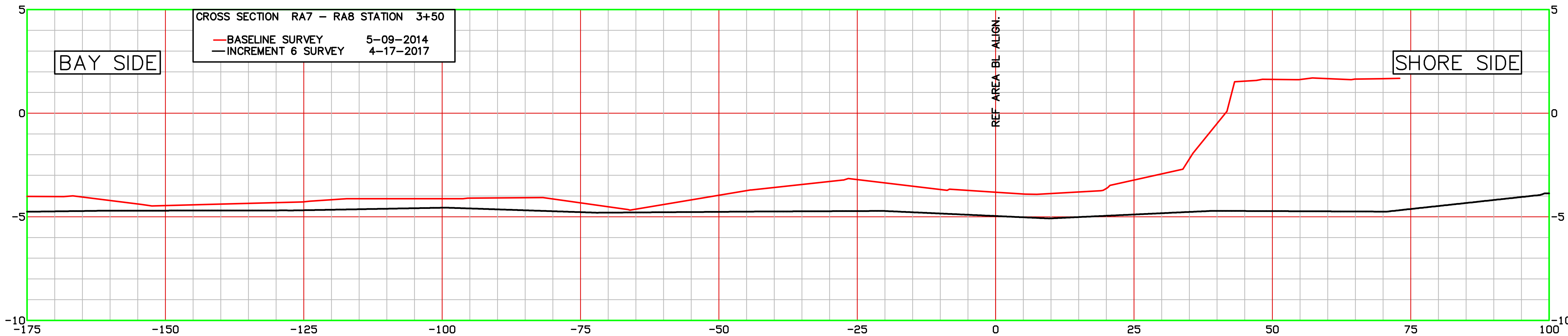
CROSS SECTIONS
LA-16 MONITORING SURVEYS ICR-6 [3.0 YEARS]
REFERENCE AREA
IBERIA PARISH, LOUISIANA

United States Department of Agriculture
USDA
Natural Resources Conservation Service

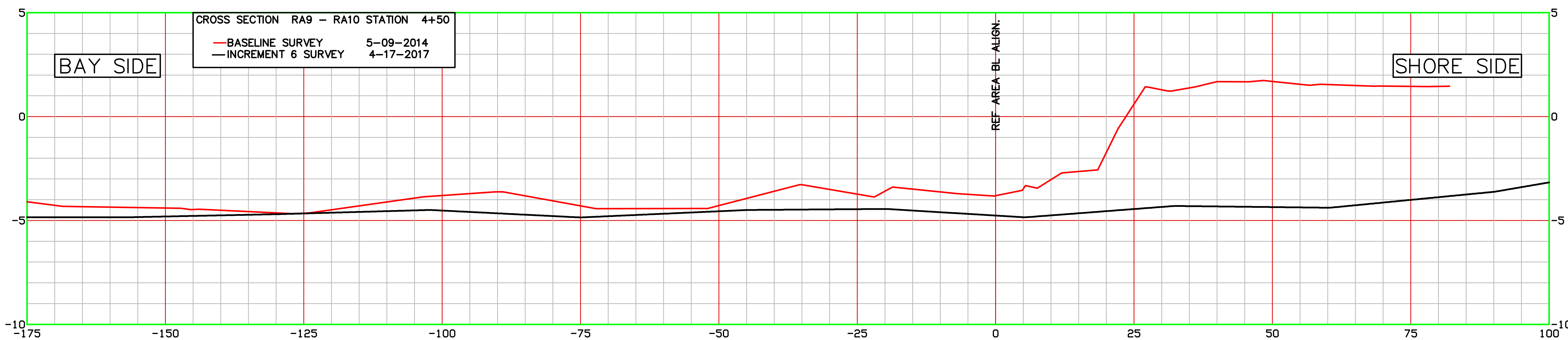
FILE NAME
REF AREA MONT.

DRAWING NAME
REF AREA ICR 6

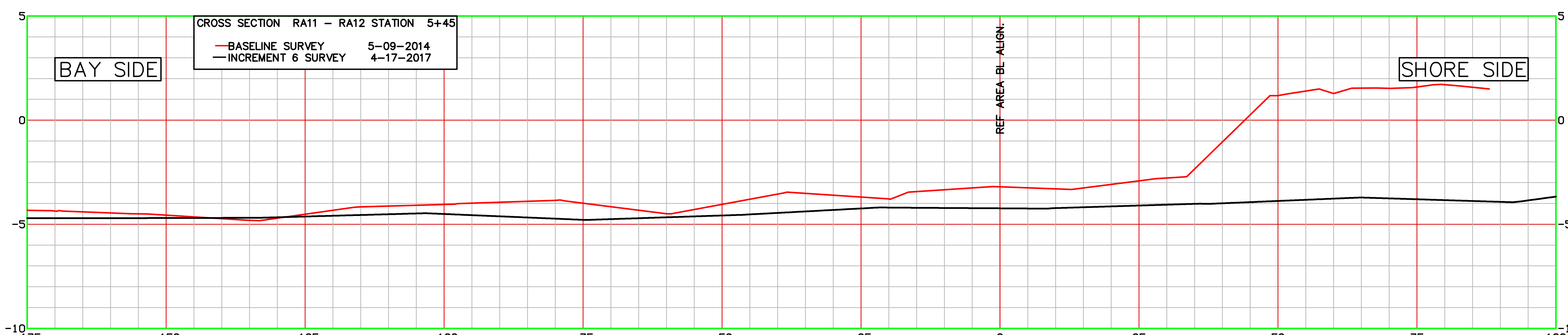
SHEET 02 of 03




CROSS SECTION RA7 – RA8 STA 3+50




CROSS SECTION RA9 – RA10 STA 4+50




CROSS SECTION RA11 – RA12 STA 5+45

| | | |
|---|---|---|
| | | DATE |
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

CROSS SECTIONS
LA-16 MONITORING SURVEYS ICR-6 [3.0 YEARS]
REFERENCE AREA
IBERIA PARISH, LOUISIANA

United States Department of Agriculture
Natural Resources Conservation Service

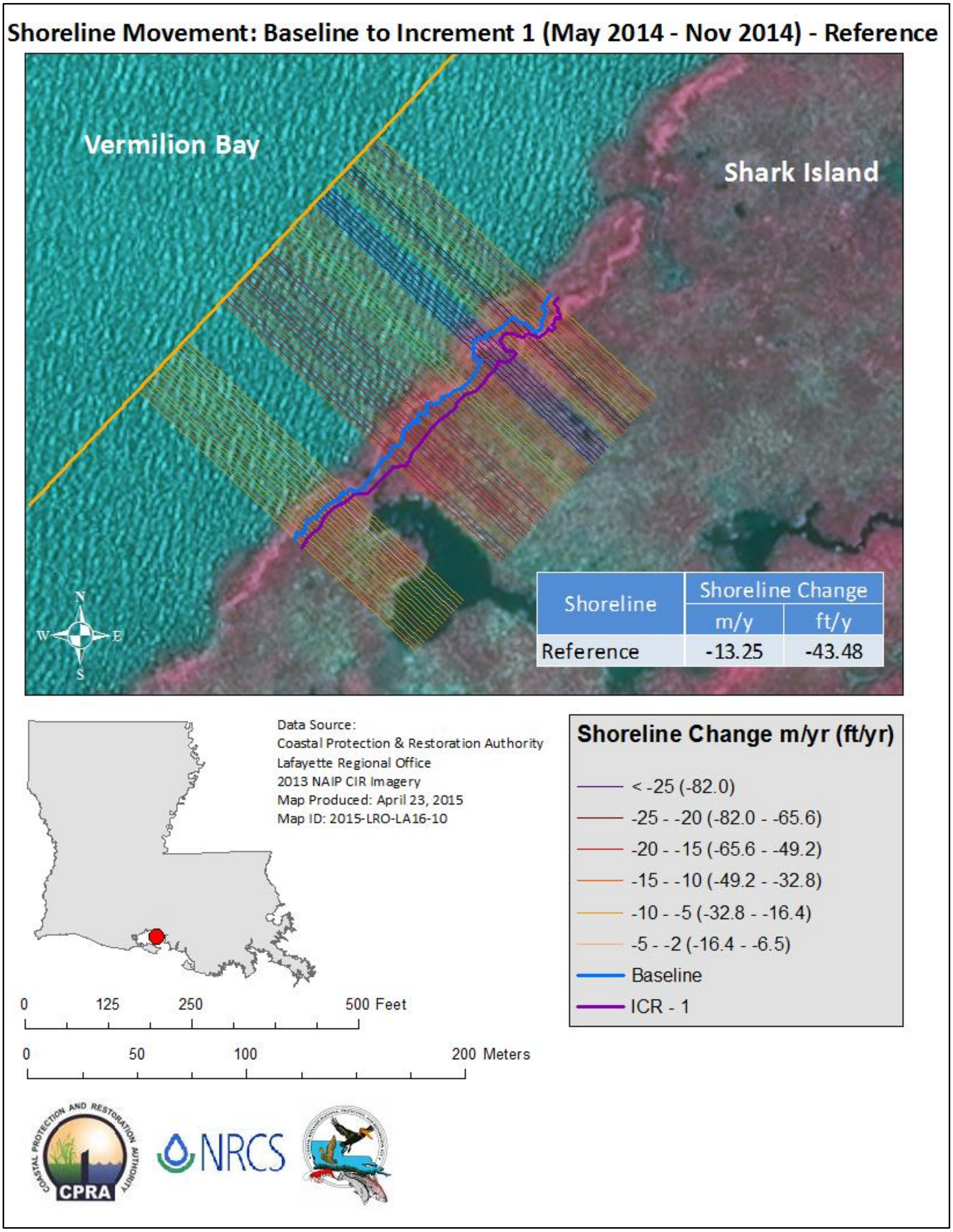
FILE NAME
REF AREA MONT.

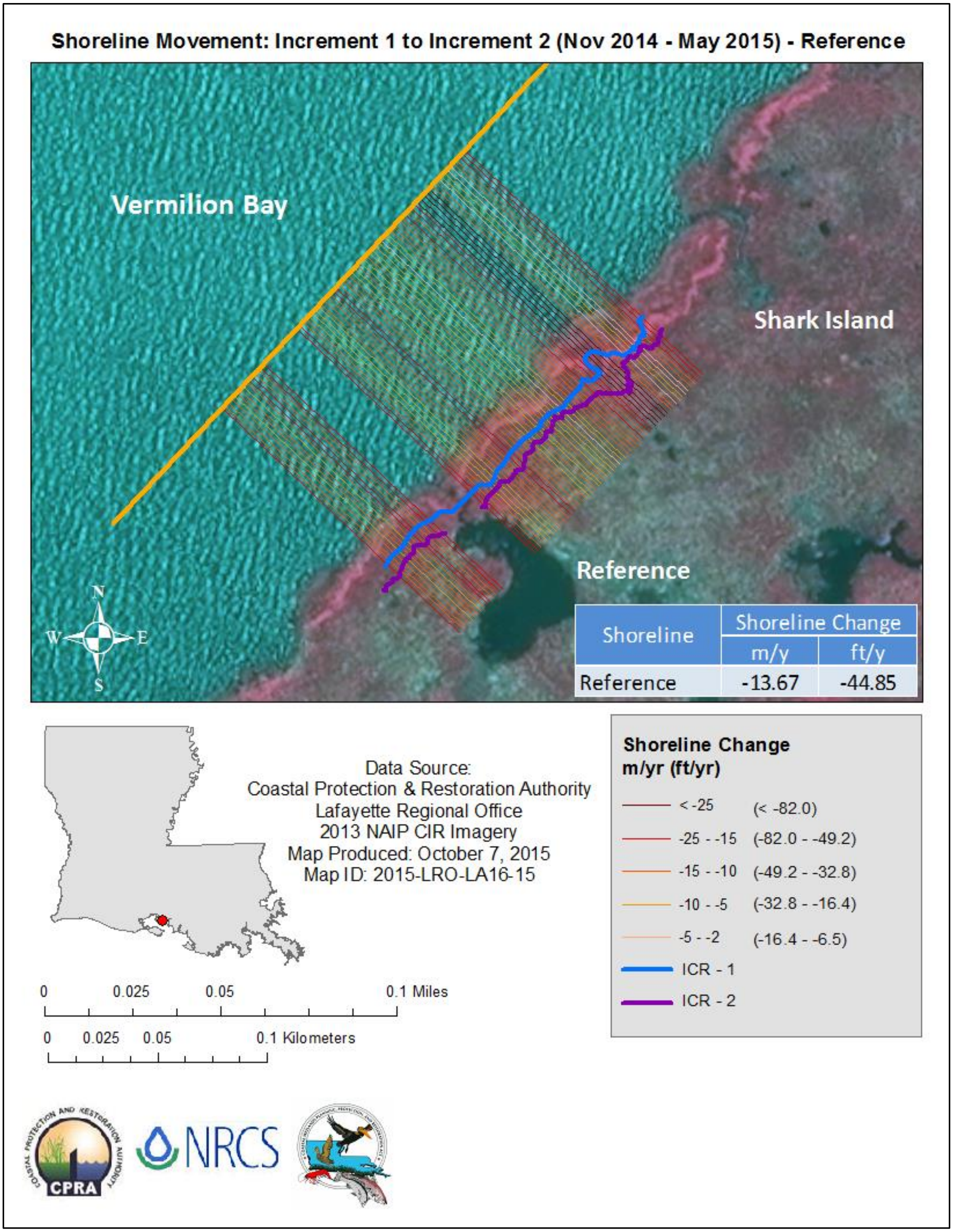
DRAWING NAME
REF AREA ICR 6

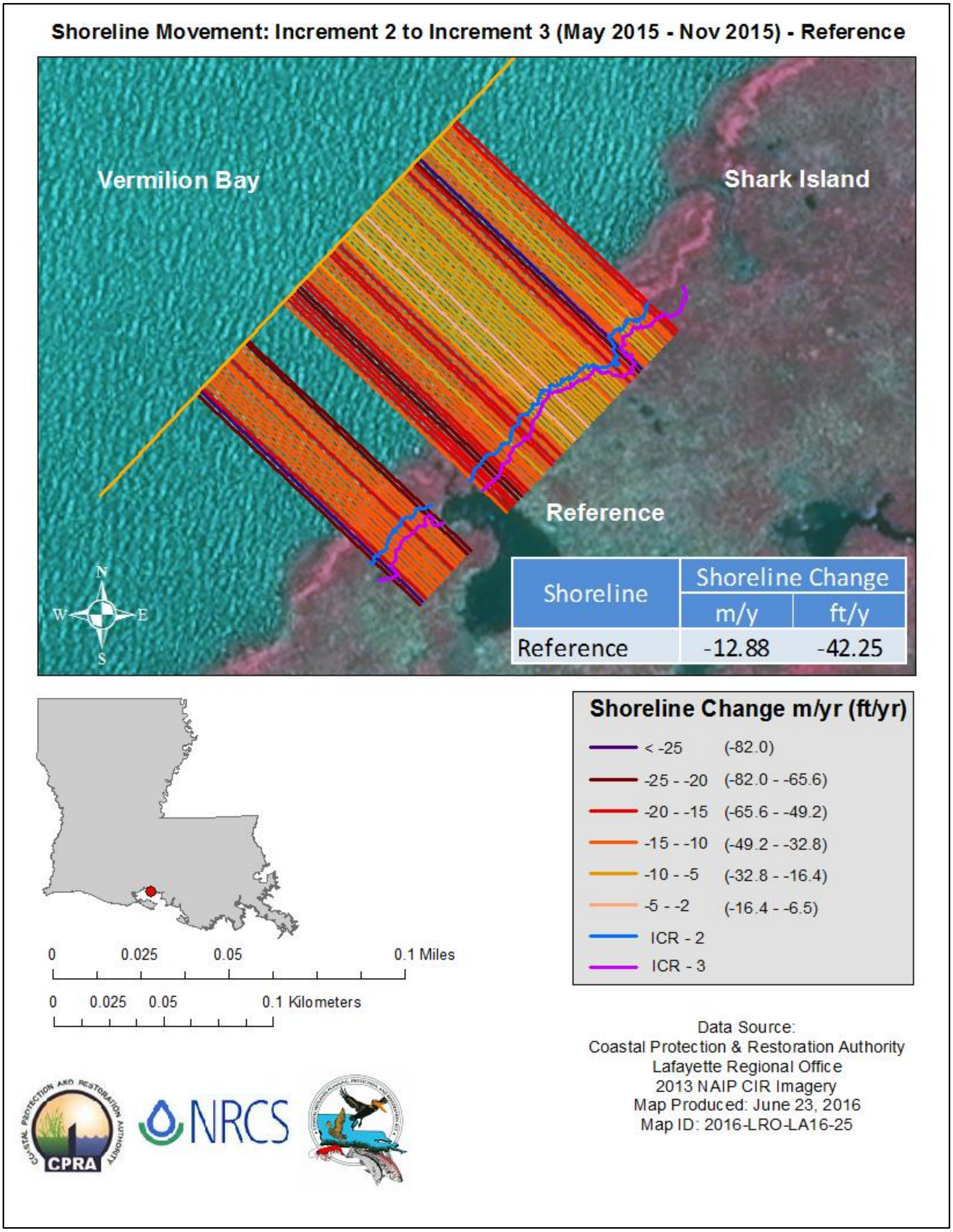
SHEET 03 of 03

## APPENDIX A - 2

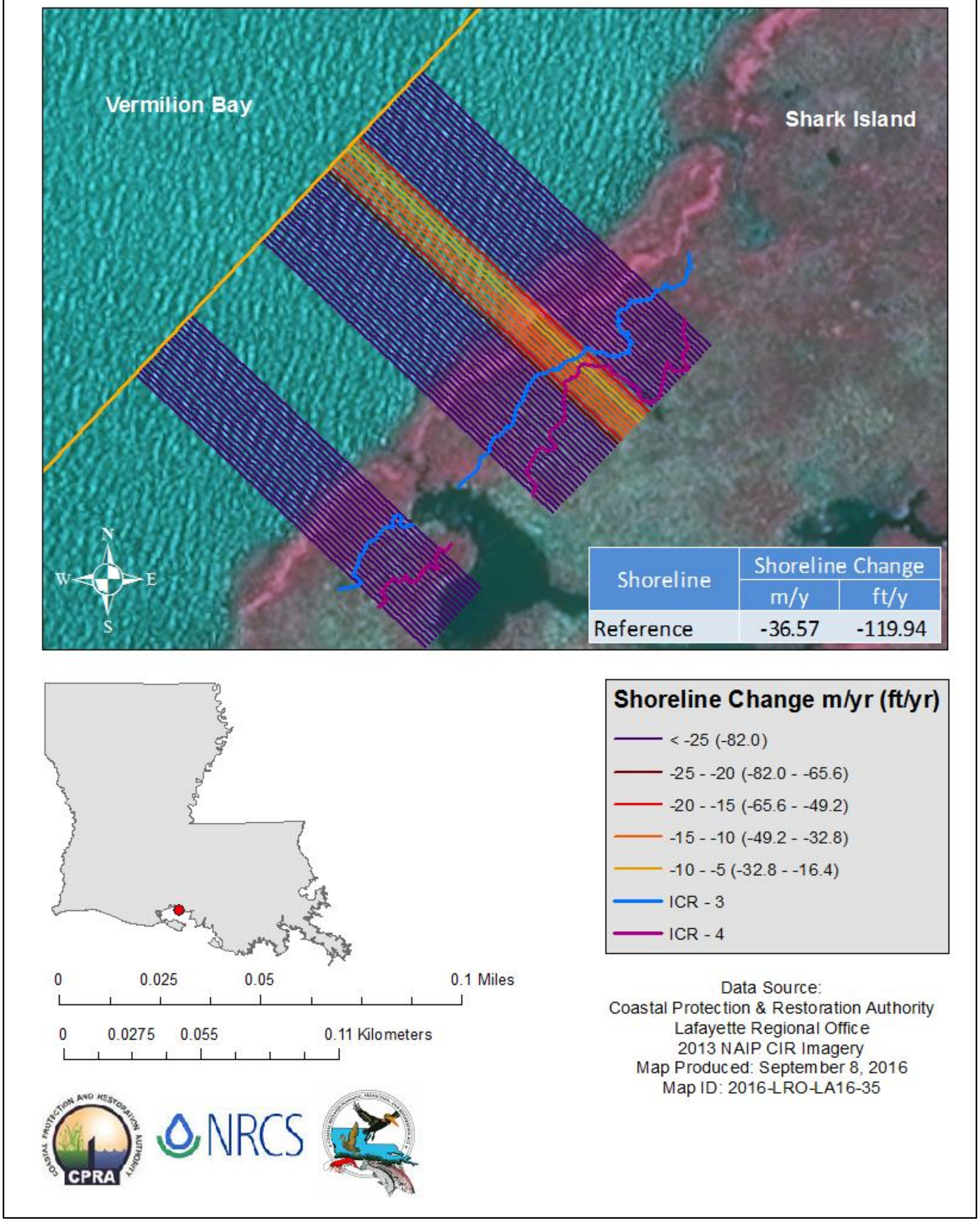
## Incremental Shoreline Change Maps


Shoreline Movement: Baseline to Increment 1 (May 2014 - Nov 2014) - Reference
Vermilion Bay
Shark Island
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Reference
-13.25
-43.48
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: April 23, 2015
Map ID: 2015-LRO-LA16-10
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.6)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
Baseline
ICR - 1
0 125 250 500 Feet
0 50 100 200 Meters
NRCS

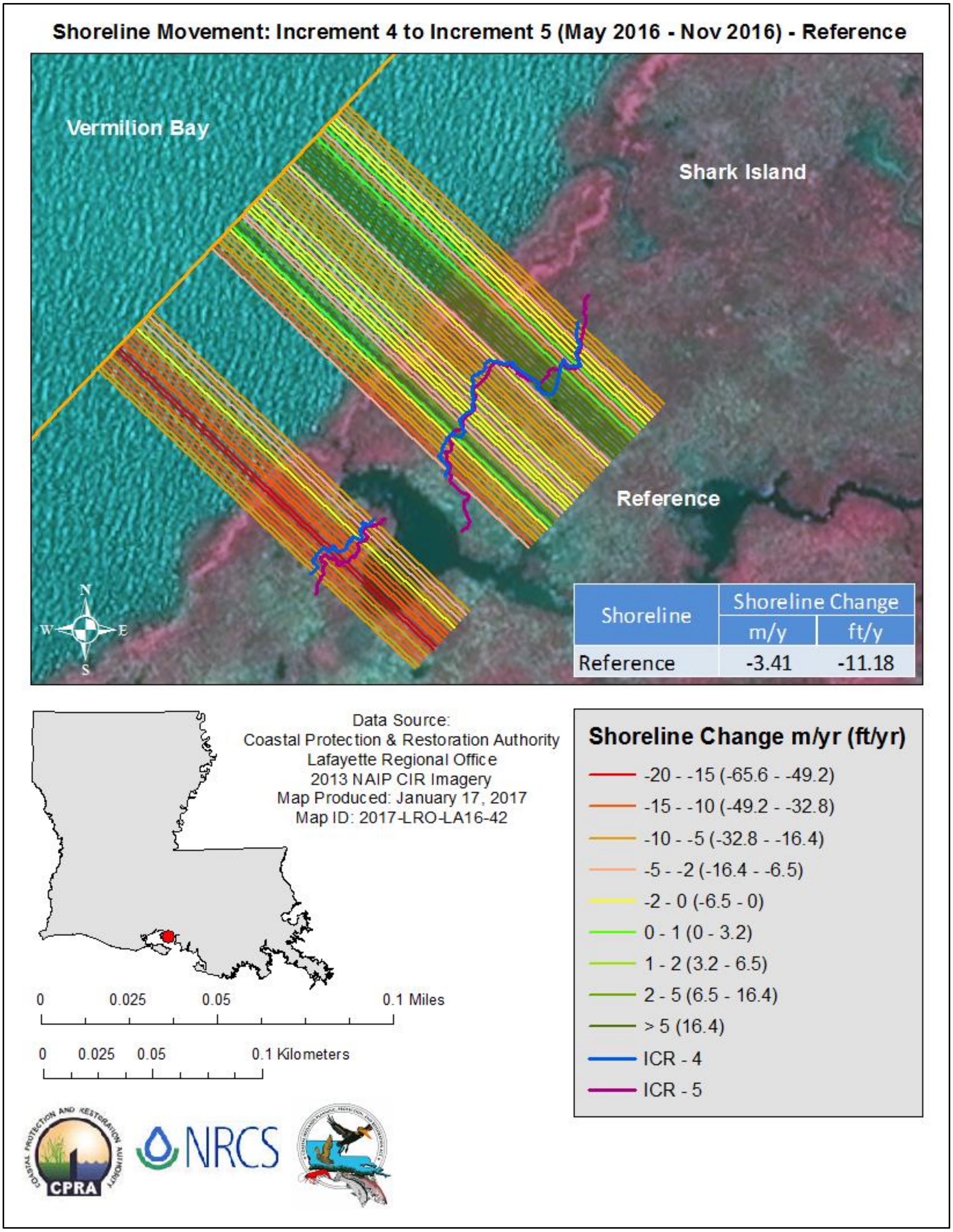

Shoreline Movement: Increment 1 to Increment 2 (Nov 2014 - May 2015) - Reference
Vermilion Bay
Shark Island
Reference
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Reference
-13.67
-44.85
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: October 7, 2015
Map ID: 2015-LRO-LA16-15
Shoreline Change
m/yr (ft/yr)
< -25 (< -82.0)
-25 - -15 (-82.0 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
ICR - 1
ICR - 2
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
CPRA
NRCS

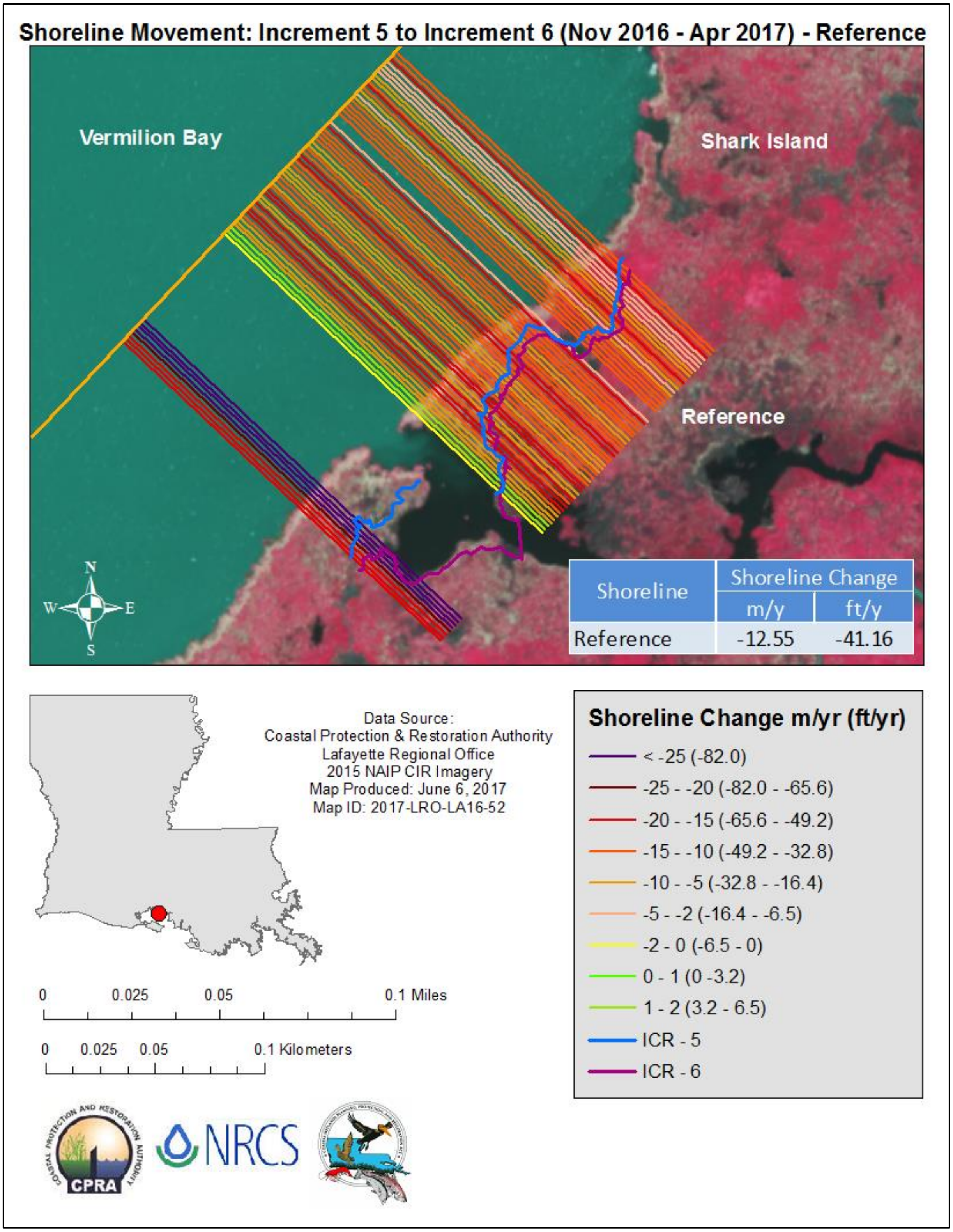

Shoreline Movement: Increment 2 to Increment 3 (May 2015 - Nov 2015) - Reference
Vermilion Bay
Shark Island
Reference
Shoreline
Shoreline Change
m/y
ft/y
Reference
-12.88
-42.25
N
W
E
S
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.6)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
ICR - 2
ICR - 3
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: June 23, 2016
Map ID: 2016-LRO-LA16-25
CPRA
NRCS

**Shoreline Movement: Increment 3 to Increment 4 (Nov 2015 - May 2016) - Reference**




| Shoreline | Shoreline Change | |
|---|---|---|
| | m/y | ft/y |
| Reference | -36.57 | -119.94 |


Shoreline Movement: Increment 4 to Increment 5 (May 2016 - Nov 2016) - Reference
Vermilion Bay
Shark Island
Reference
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Reference
-3.41
-11.18
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: January 17, 2017
Map ID: 2017-LRO-LA16-42
0
0.025
0.05
0.1 Miles
0
0.025
0.05
0.1 Kilometers
Shoreline Change m/yr (ft/yr)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 3.2)
1 - 2 (3.2 - 6.5)
2 - 5 (6.5 - 16.4)
> 5 (16.4)
ICR - 4
ICR - 5
NRCS
CPRA


Shoreline Movement: Increment 5 to Increment 6 (Nov 2016 - Apr 2017) - Reference
Vermilion Bay
Shark Island
Reference
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Reference -12.55 -41.16
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2015 NAIP CIR Imagery
Map Produced: June 6, 2017
Map ID: 2017-LRO-LA16-52
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.6)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 -3.2)
1 - 2 (3.2 - 6.5)
ICR - 5
ICR - 6
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
NRCS

# APPENDIX B

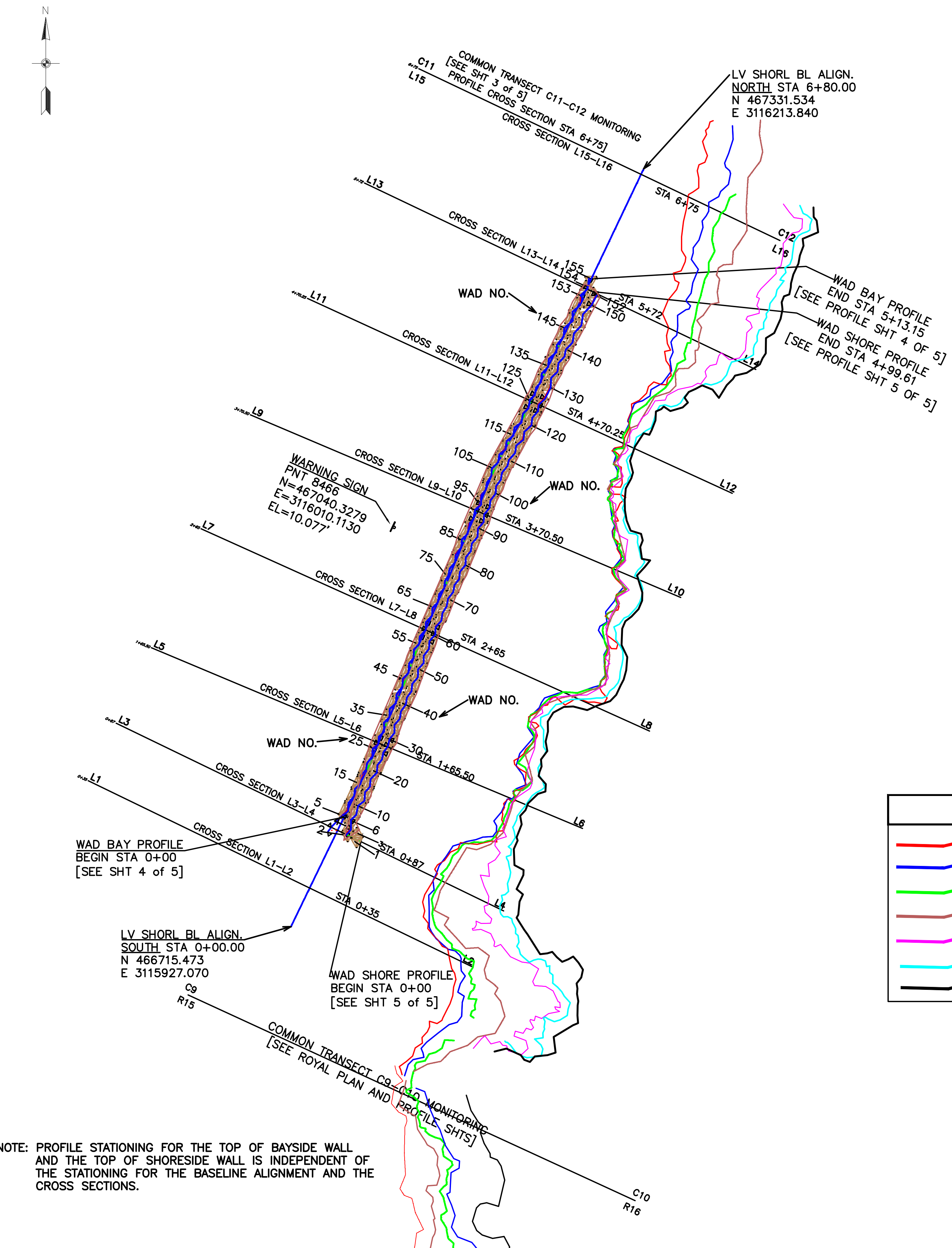
## Wave Attenuation Devices (WAD®s)

## Living Shoreline Solutions, Inc.

## APPENDIX B - 1

## Topographic/Bathymetic Survey Drawings

(Distances are in feet, and Elevations are in feet NAVD88 Geoid 03)




NOTE: PROFILE STATIONING FOR THE TOP OF BAYSIDE WALL AND THE TOP OF SHORESIDE WALL IS INDEPENDENT OF THE STATIONING FOR THE BASELINE ALIGNMENT AND THE CROSS SECTIONS.

SURVEY CONTROL: STATION NAME - "TBM-SHARK3"
MONUMENT LOCATION: LOCATED ON SHARK ISLAND IN IBERIA PARISH, LOUISIANA. THE TEMPORARY BENCHMARK IS SET ON THE NORTHEAST BANK OF AN OLD OILFIELD LOCATION CANAL AND LOCATED APPROXIMATELY 370' SOUTHEAST FROM THE INTERSECTION OF THE NORTHEAST BANK AND VERMILION BAY. IT IS APPROXIMATELY 320' SOUTHEAST OF MONUMENT "TBM-SHARK 2".

MONUMENT DESCRIPTION: ROUND WOODEN FENCE POST DRIVEN INTO GROUND AND PROTRUDING FROM THE GROUND ABOUT 1.0". MONUMENT IS MARKED WITH A BRASS TAG LABELED "SHARK 3". THERE IS A PK NAIL IN THE CENTER ON THE TOP OF THE POST.

STAMPING: "SHARK 3"
DATE: JUNE 3, 2014

MONUMENT ESTABLISHED BY: USDA-NRCS CROWLEY WATERSHED OFFICE

ADJUSTED NAD83 GEODETIC POSITION (2011) (EPOCH:2010.0000)

LAT: 29-46-14.07 NORTH
LONG: 91-51-45.87 WEST

ADJUSTED NAD 83 DATUM LSZ (1702)

N=462,448.963

E=3,112,873.741

ADJUSTED NAVD88 ELEVATION

3.07 FEET / 0.936 METERS

ELLIPSOID HEIGHT: -25.183 METERS

GEOID 03 HEIGHT: -26.119 METERS

| PLAN and PROFILE LINE COLOR LEGEND |
|---|
| BASELINE 5.09.2014 Survey |
| ICR–1 [0.5 years] 11.03.2014 Survey |
| ICR–2 [1.0 years] 04.30.2015 Survey |
| ICR–3 [1.5 years] 11.05.2015 Survey |
| ICR–4 [2.0 years] 04.28.2016 Survey |
| ICR–5 [2.5 years] 11.10.2016 Survey |
| ICR–6 [3.0 years] 04.17.2017 Survey |

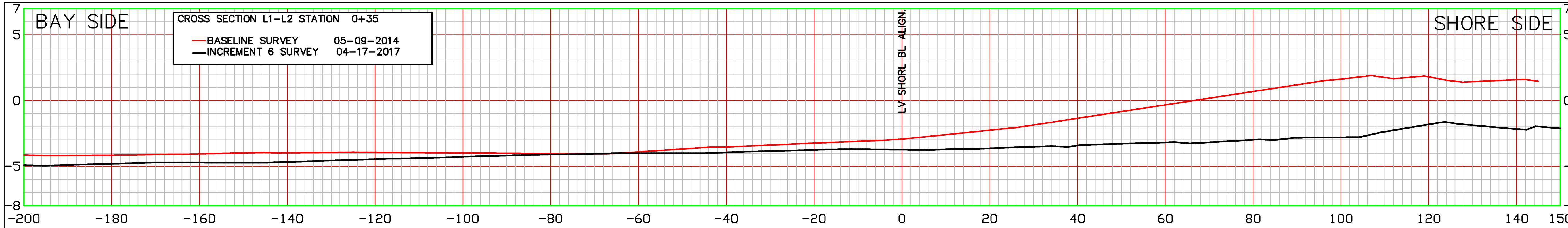
50 0 50 100 150 200
SCALE IN FEET

| | | DATE |
|---|---|---|
| DESIGNED | | 02/18 |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | |

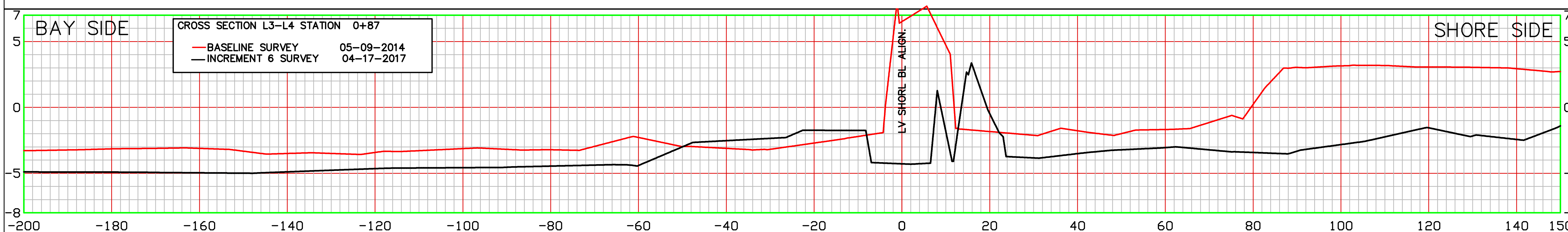
PLAN VIEW DRAWING
LA-16 MONITORING SURVEYS ICR-6 [3.0 YEARS]
LIVING SHORELINES SOLUTIONS, INC.
IBERIA PARISH, LOUISIANA

United States Department of Agriculture
USDA
Natural Resources Conservation Service

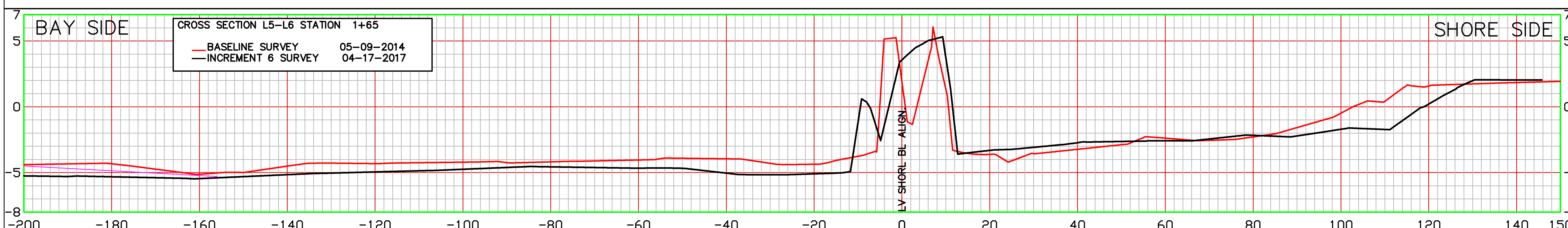
FILE NAME
LV SHORL MONT.
DRAWING NAME
LV SHORL ICR 6
SHEET 01 of 05



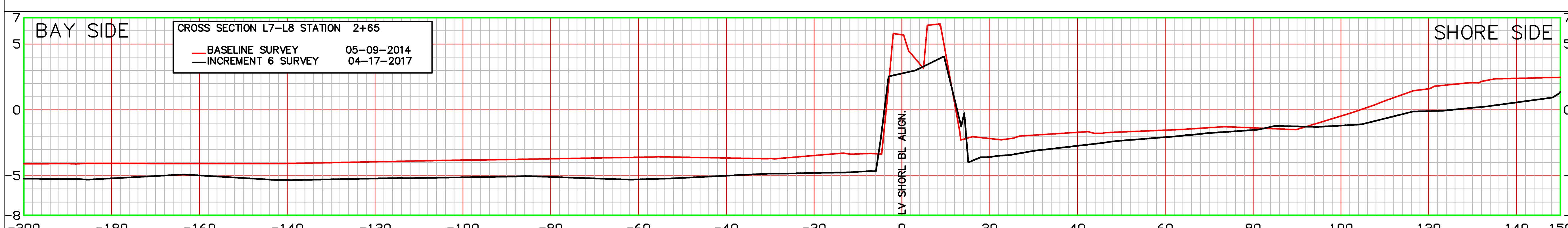

CROSS SECTION L1 – L2 STA. 0+35




CROSS SECTION L3 – L4 STA. 0+87




CROSS SECTION L5 – L6 STA. 1+65.5




CROSS SECTION L7 – L8 STA. 2+65

| | | |
|---|---|---|
| | | DATE |
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

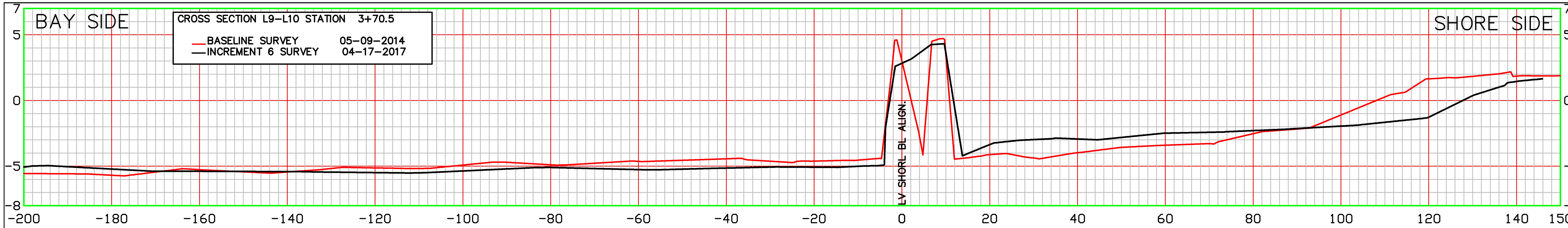
CROSS SECTIONS
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
LIVING SHORELINES SOLUTIONS, INC.
IBERIA PARISH, LOUISIANA

United States Department of Agriculture
USDA
Natural Resources Conservation Service

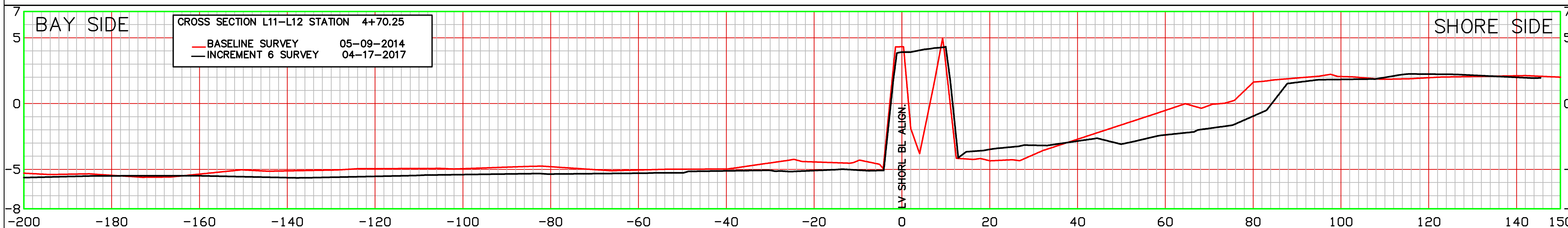
FILE NAME
LV SHORL MONT.

DRAWING NAME
LV SHORL ICR 6

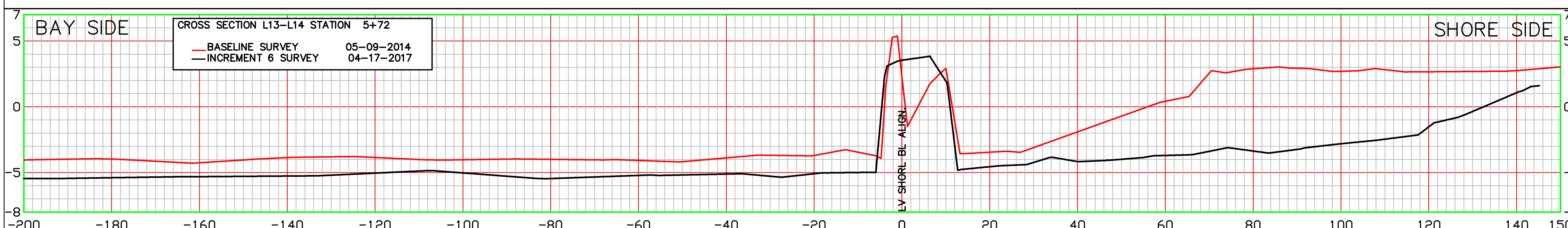
SHEET 02 of 05



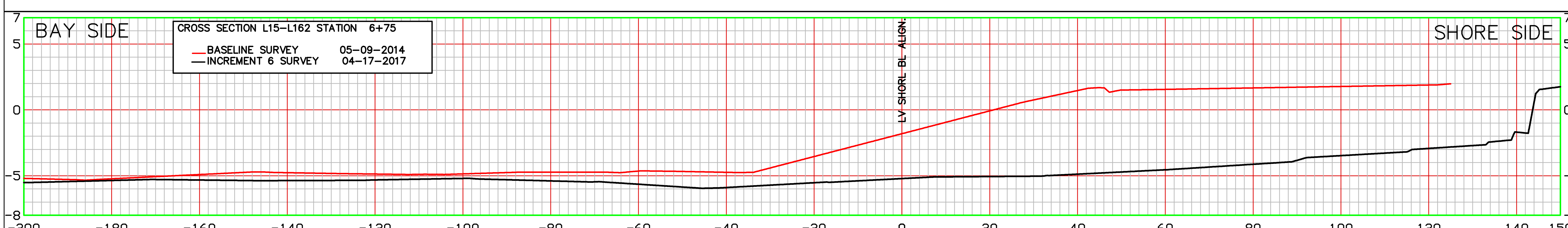

CROSS SECTION L9 – L10 STA. 3+70.5




CROSS SECTION L11 – L12 STA. 4+70.25




CROSS SECTION L13 – L14 STA. 5+72




CROSS SECTION L15 – L16 (C11 – C12) STA. 6+75

| | | DATE |
|---|---|---|
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

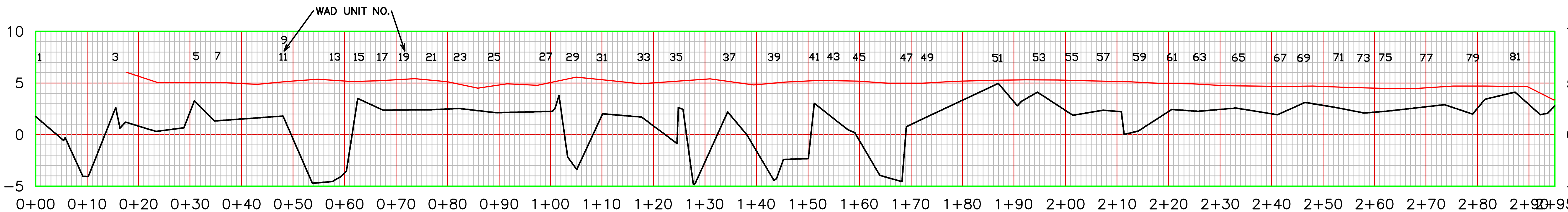
CROSS SECTIONS
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
LIVING SHORELINES SOLUTIONS, INC.
IBERIA PARISH, LOUISIANA

United States Department of Agriculture
Natural Resources Conservation Service

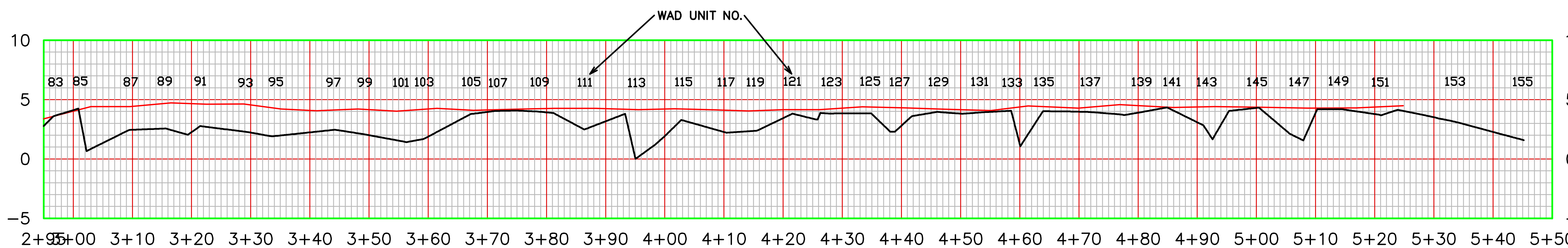
FILE NAME
LV SHORL MONT.

DRAWING NAME
LV SHORL ICR 6

SHEET 03 of 05




TOP OF BAY SIDE WALL PROFILE – STA. 0+00 to STA. 2+95




TOP OF BAY SIDE WALL PROFILE – STA. 2+95 to STA. 5+33

| | |
|---|---|
| BASELINE SURVEY | 05–09–2014 |
| INCREMENT 6 SURVEY | 04–17–2017 |

NOTE: PROFILE STATIONING FOR THE TOP OF BAYSIDE WALL AND THE TOP OF SHORESIDE WALL IS INDEPENDENT OF THE STATIONING FOR THE BASELINE ALIGNMENT AND THE CROSS SECTIONS.

| | | DATE |
|---|---|---|
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

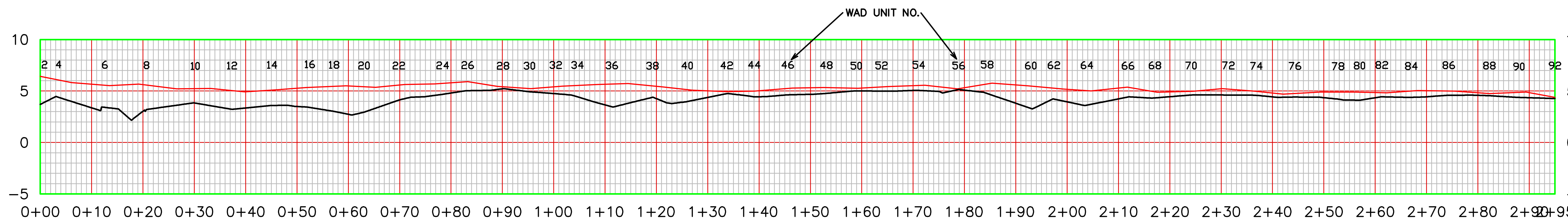
PROFILE OF UNITS BAY SIDE
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
LIVING SHORELINES SOLUTIONS, INC.
IBERIA PARISH, LOUISIANA

USDA United States Department of Agriculture
Natural Resources Conservation Service

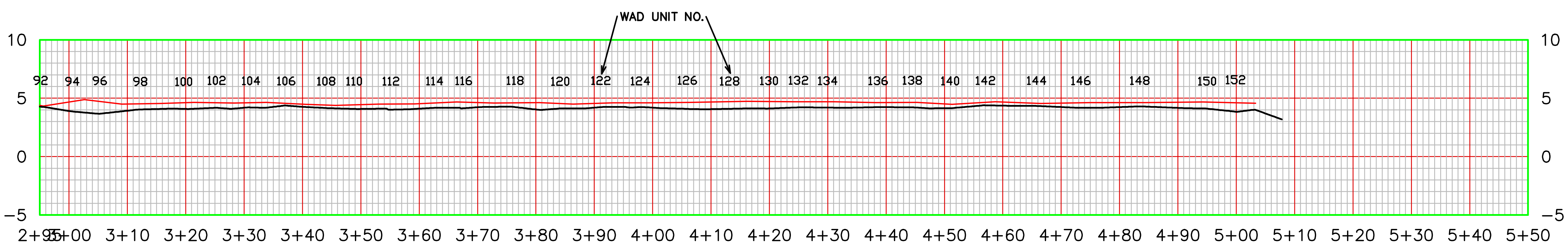
FILE NAME
LV SHORL MONT.

DRAWING NAME
LV SHORL ICR 6

SHEET 04 of 05




TOP OF SHORE SIDE WALL PROFILE — STA. 0+00 to STA. 2+95




TOP OF SHORE SIDE WALL PROFILE — STA. 2+95 to STA. 5+02

| | | |
|---|---|---|
| — | BASELINE SURVEY | 05–09–2014 |
| — | INCREMENT 6 SURVEY | 04–17–2017 |

NOTE: PROFILE STATIONING FOR THE TOP OF BAYSIDE WALL AND THE TOP OF SHORESIDE WALL IS INDEPENDENT OF THE STATIONING FOR THE BASELINE ALIGNMENT AND THE CROSS SECTIONS.

| | | DATE |
|---|---|---|
| DESIGNED | A. GREMILLION | 02/18 |
| DRAWN | D. GARBER | 02/18 |
| CHECKED | B. SAMSON | 02/18 |
| APPROVED | | |

PROFILE OF UNITS SHORE SIDE
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
LIVING SHORELINES SOLUTIONS, INC.
IBERIA PARISH, LOUISIANA

USDA United States Department of Agriculture
Natural Resources Conservation Service

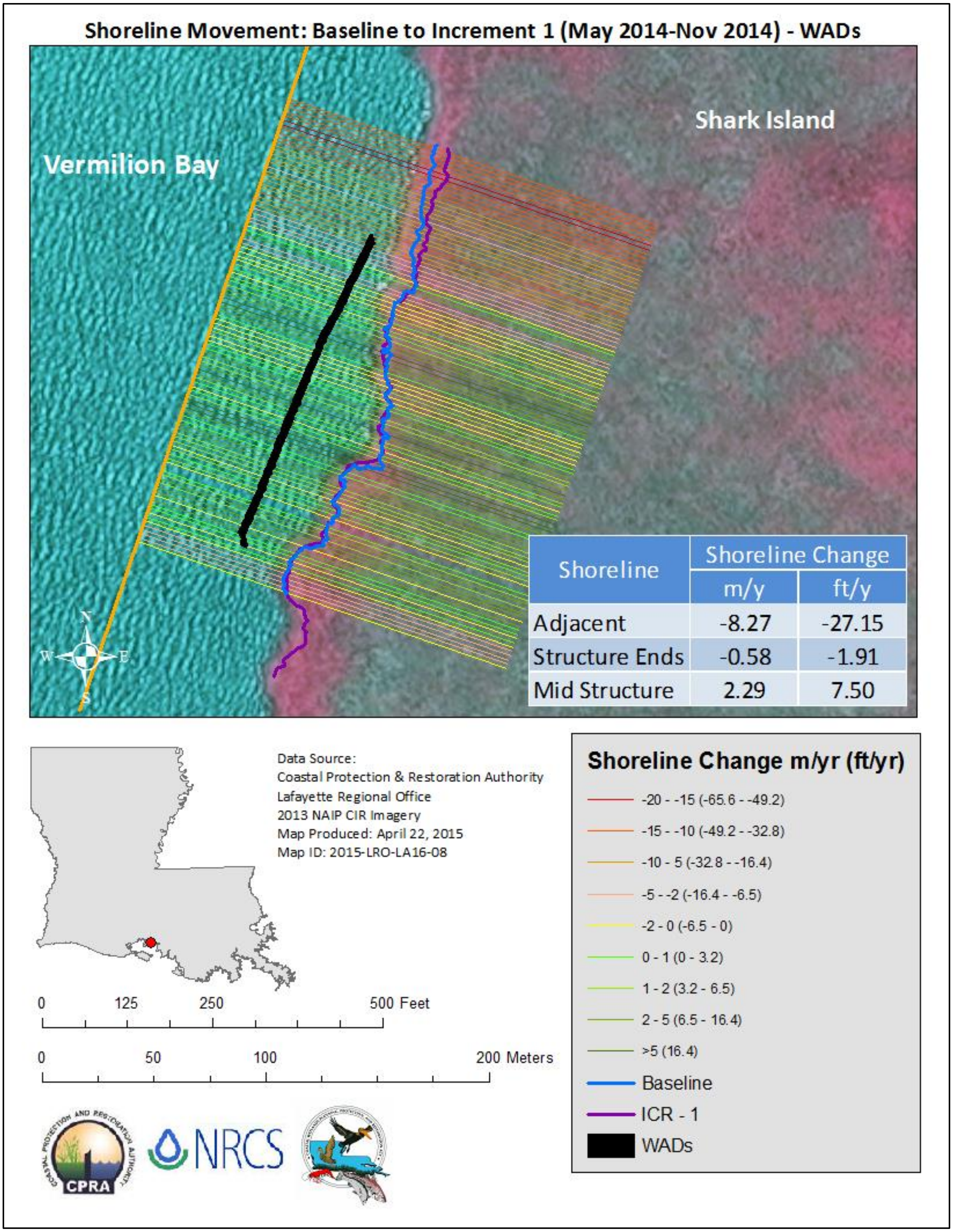
FILE NAME
LV SHORL MONT.

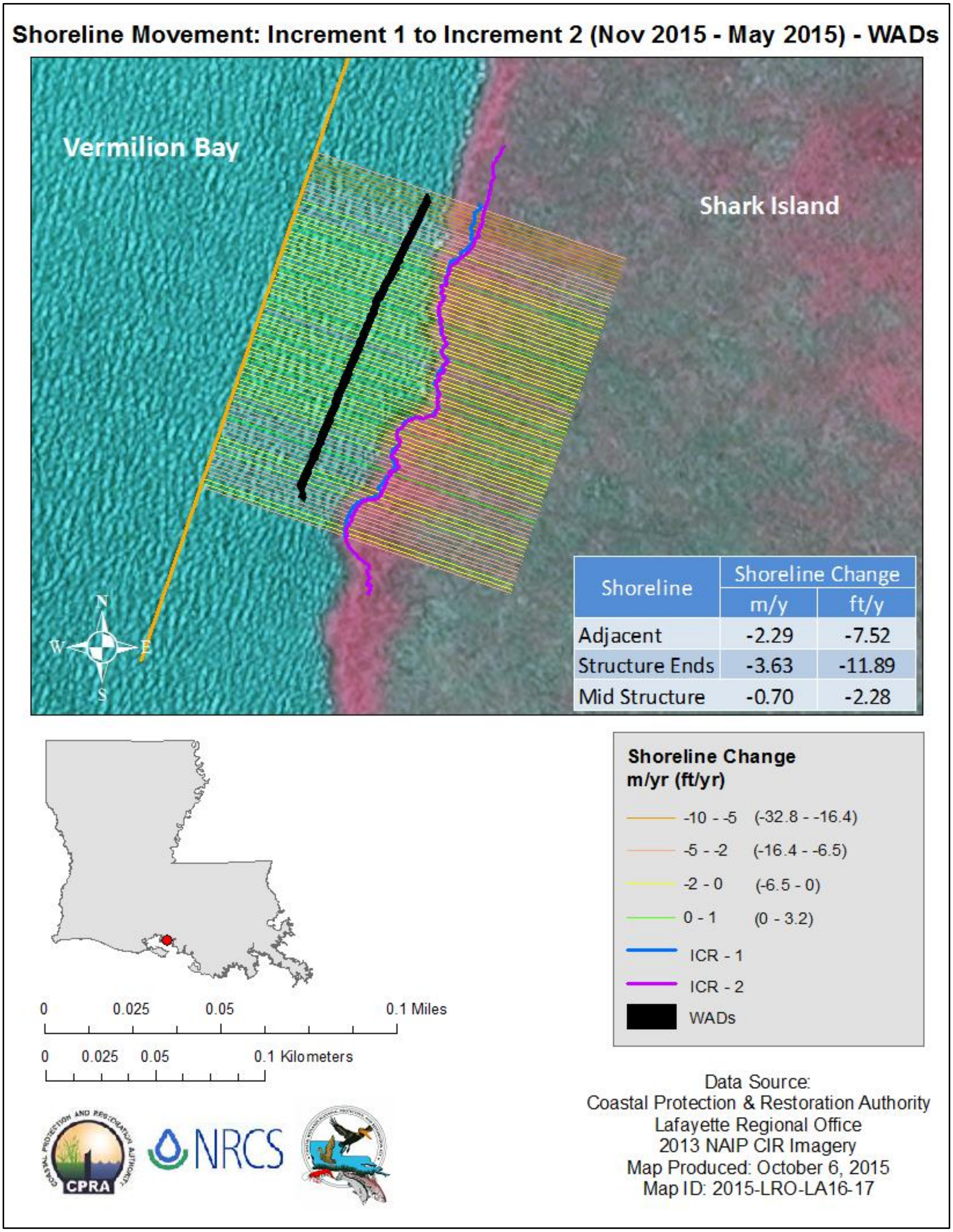
DRAWING NAME
LV SHORL ICR 6

SHEET 05 of 05

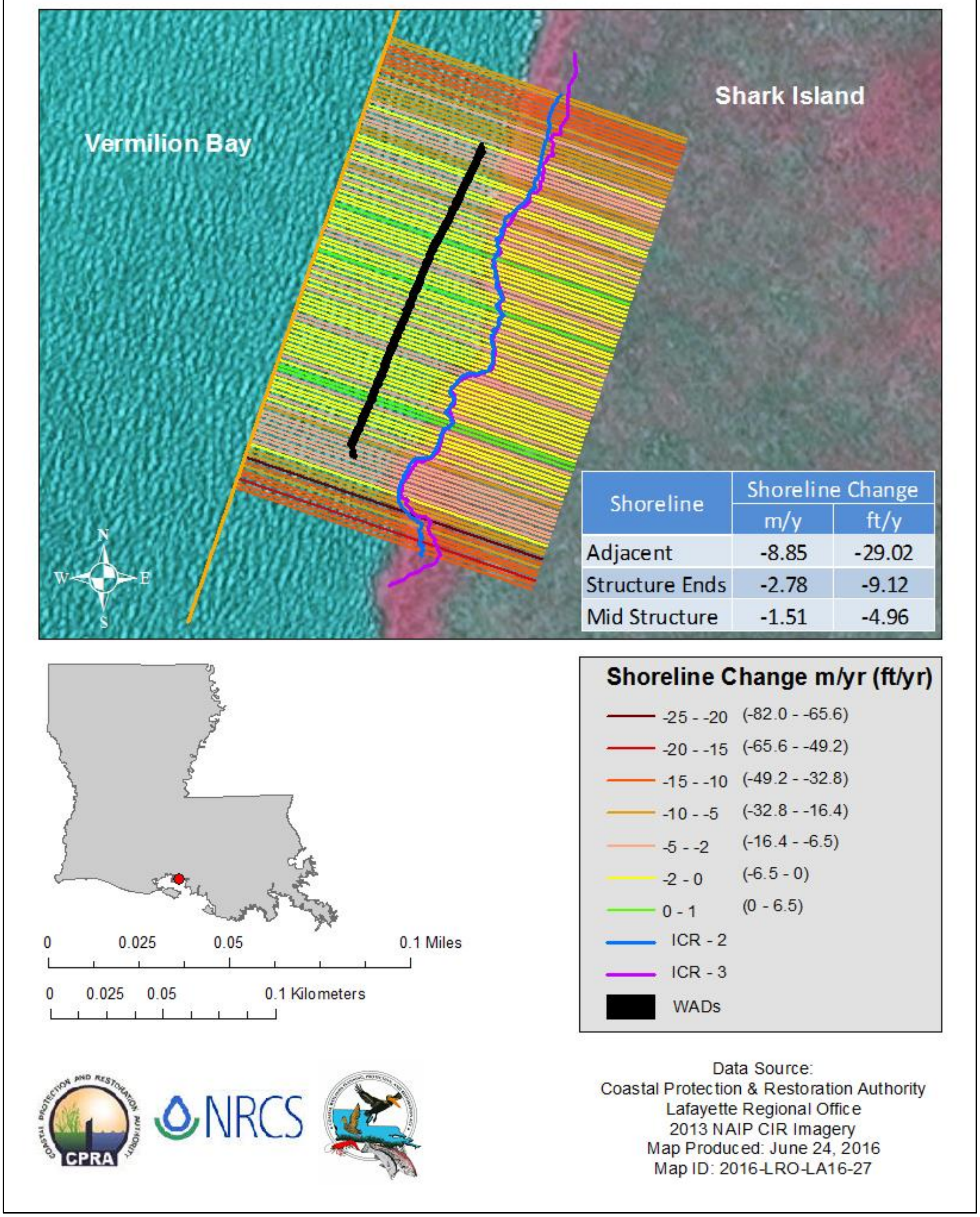
**APPENDIX B - 2**

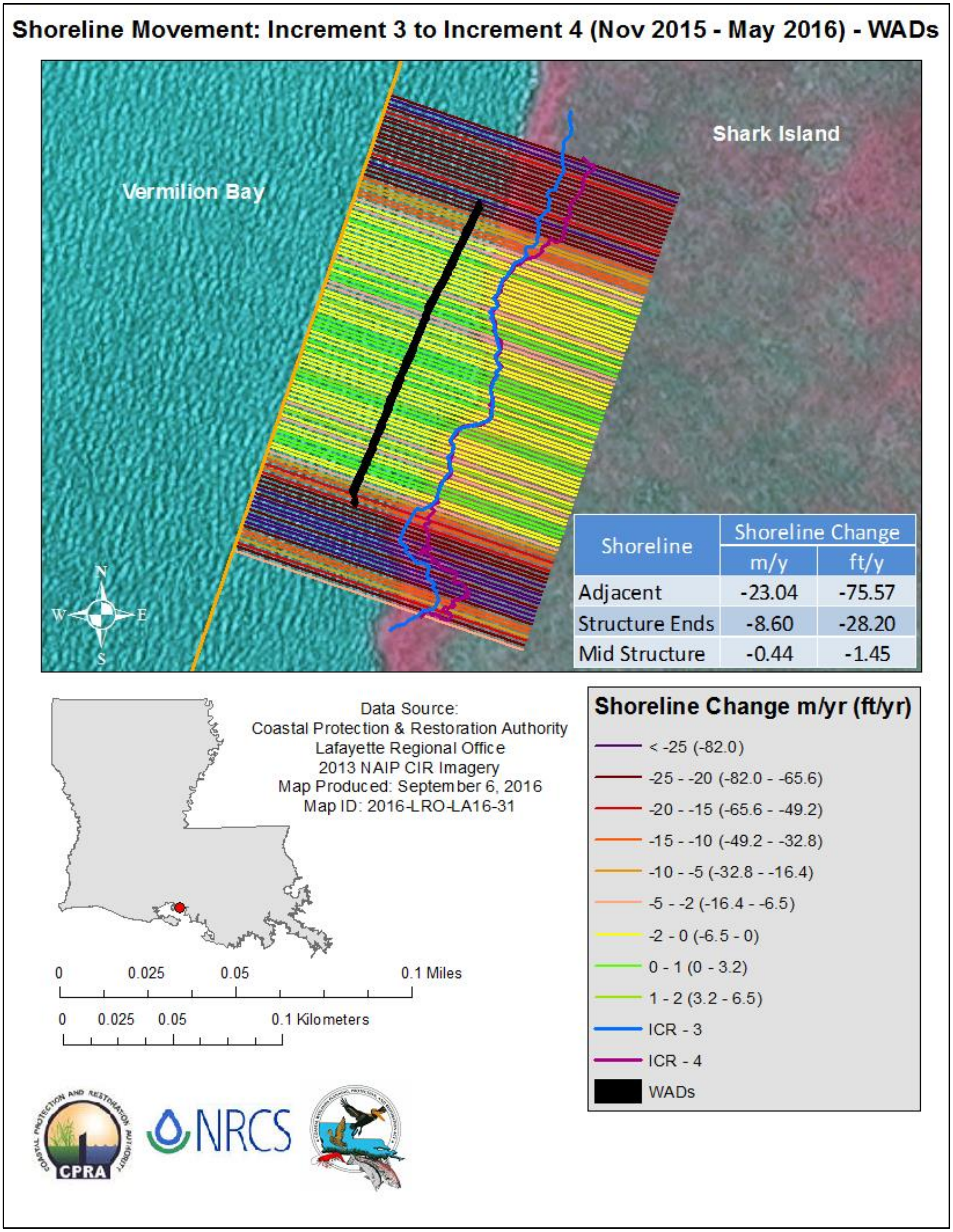
**Incremental Shoreline Change Maps**

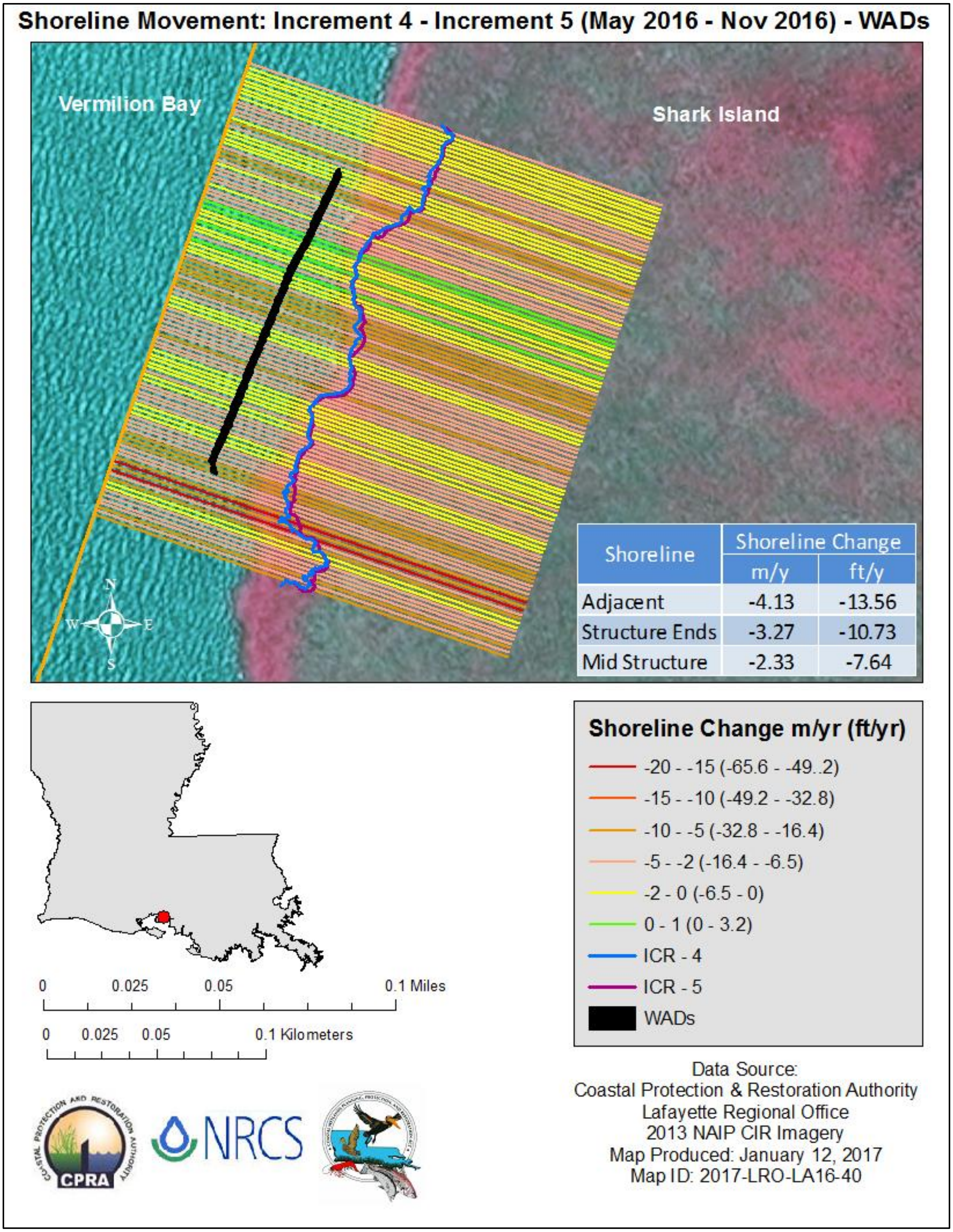

Shoreline Movement: Baseline to Increment 1 (May 2014-Nov 2014) - WADs
Shark Island
Vermilion Bay
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -8.27 -27.15
Structure Ends -0.58 -1.91
Mid Structure 2.29 7.50
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: April 22, 2015
Map ID: 2015-LRO-LA16-08
0 125 250 500 Feet
0 50 100 200 Meters
Shoreline Change m/yr (ft/yr)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - 5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 3.2)
1 - 2 (3.2 - 6.5)
2 - 5 (6.5 - 16.4)
>5 (16.4)
Baseline
ICR - 1
WADs
CPRA
NRCS

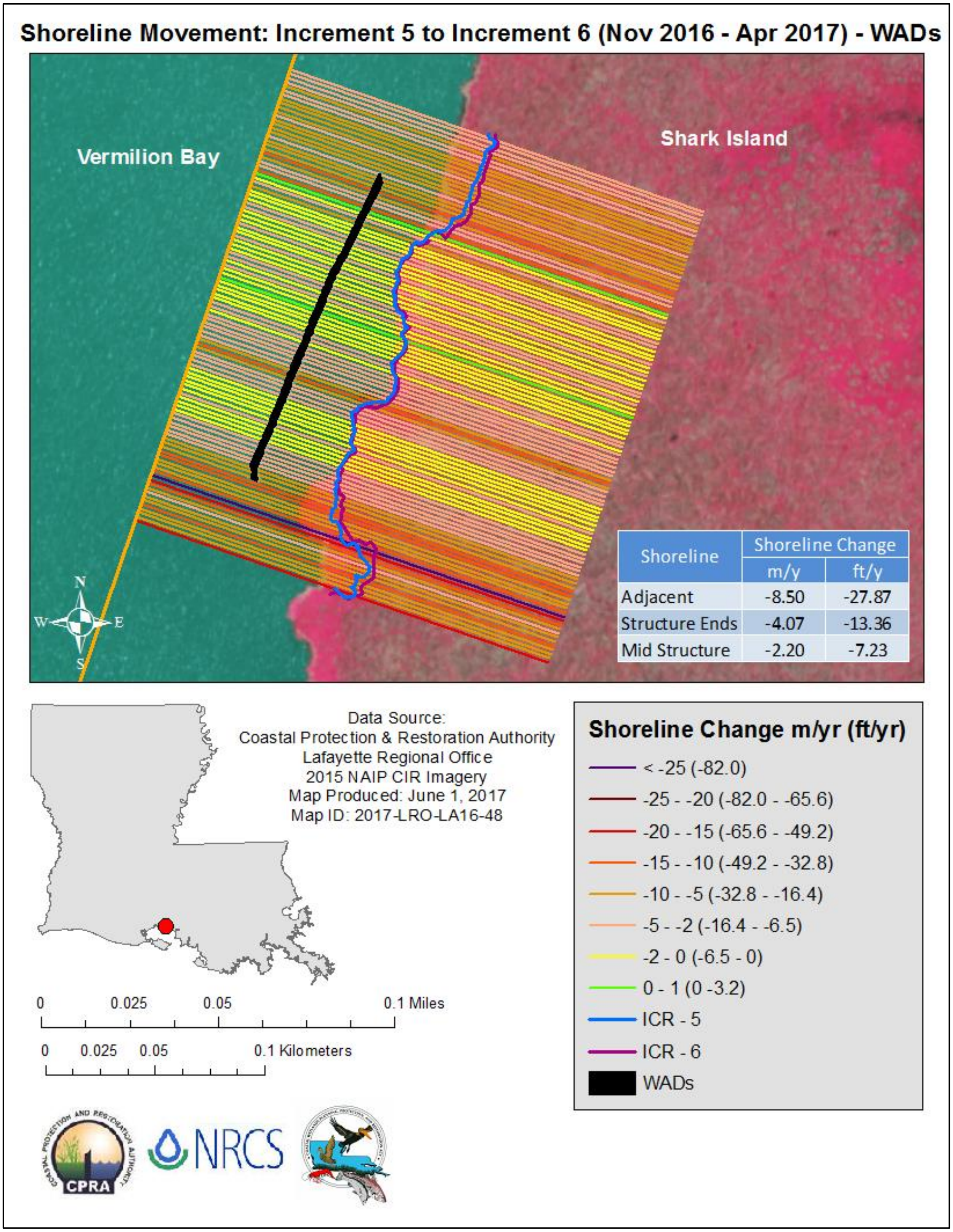

Shoreline Movement: Increment 1 to Increment 2 (Nov 2015 - May 2015) - WADs
Vermilion Bay
Shark Island
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -2.29 -7.52
Structure Ends -3.63 -11.89
Mid Structure -0.70 -2.28
N
W
E
S
Shoreline Change
m/yr (ft/yr)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 3.2)
ICR - 1
ICR - 2
WADs
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
CPRA
NRCS
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: October 6, 2015
Map ID: 2015-LRO-LA16-17

**Shoreline Movement: Increment 2 to Increment 3 (May 2015 - Nov 2015) - WADs**




Shoreline Movement: Increment 3 to Increment 4 (Nov 2015 - May 2016) - WADs
Shark Island
Vermilion Bay
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -23.04 -75.57
Structure Ends -8.60 -28.20
Mid Structure -0.44 -1.45
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: September 6, 2016
Map ID: 2016-LRO-LA16-31
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.6)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 3.2)
1 - 2 (3.2 - 6.5)
ICR - 3
ICR - 4
WADs
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
CPRA
NRCS

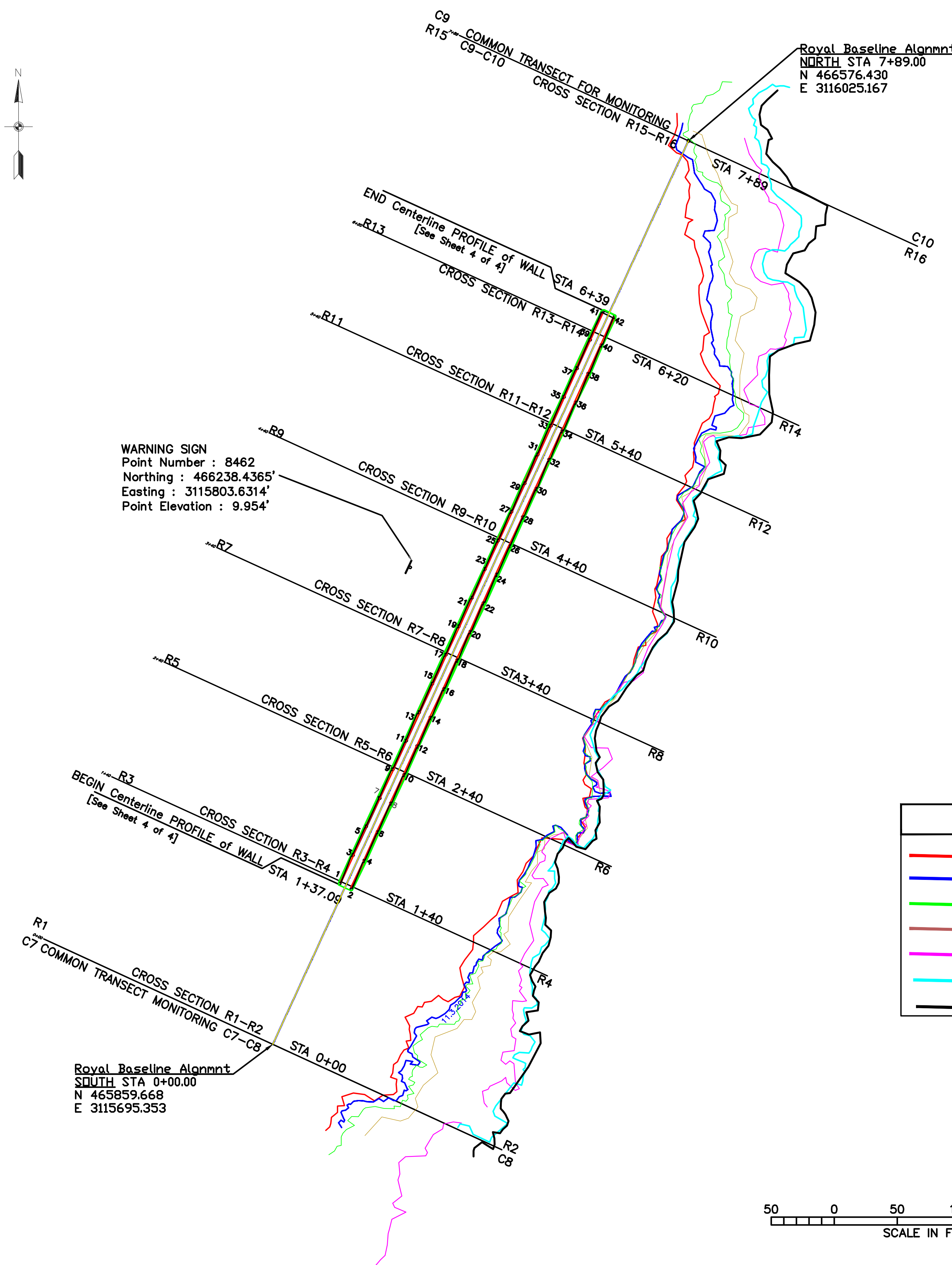

Shoreline Movement: Increment 4 - Increment 5 (May 2016 - Nov 2016) - WADs
Vermilion Bay
Shark Island
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -4.13 -13.56
Structure Ends -3.27 -10.73
Mid Structure -2.33 -7.64
N
W
E
S
Shoreline Change m/yr (ft/yr)
-20 - -15 (-65.6 - -49..2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 3.2)
ICR - 4
ICR - 5
WADs
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
NRCS
CPRA
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: January 12, 2017
Map ID: 2017-LRO-LA16-40


Shoreline Movement: Increment 5 to Increment 6 (Nov 2016 - Apr 2017) - WADs
Vermilion Bay
Shark Island
Shoreline | Shoreline Change m/y | ft/y
Adjacent | -8.50 | -27.87
Structure Ends | -4.07 | -13.36
Mid Structure | -2.20 | -7.23
N
W
E
S
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2015 NAIP CIR Imagery
Map Produced: June 1, 2017
Map ID: 2017-LRO-LA16-48
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.6)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 -3.2)
ICR - 5
ICR - 6
WADs
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
CPRA
NRCS

## APPENDIX C - 1

### Topographic/Bathymetic Survey Drawings

(Distances are in feet, and Elevations are in feet NAVD88 Geoid 03)




SURVEY CONTROL: STATION NAME - "TBM-SHARK3"
MONUMENT LOCATION: LOCATED ON SHARK ISLAND IN IBERIA PARISH, LOUISIANA. THE TEMPORARY BENCHMARK IS SET ON THE NORTHEAST BANK OF AN OLD OILFIELD LOCATION CANAL AND LOCATED APPROXIMATELY 370' SOUTHEAST FROM THE INTERSECTION OF THE NORTHEAST BANK AND VERMILION BAY. IT IS APPROXIMATELY 320' SOUTHEAST OF MONUMENT "TBM-SHARK 2".

MONUMENT DESCRIPTION: ROUND WOODEN FENCE POST DRIVEN INTO GROUND AND PROTRUDING FROM THE GROUND ABOUT 1.0". MONUMENT IS MARKED WITH A BRASS TAG LABELED "SHARK 3". THERE IS A PK NAIL IN THE CENTER ON THE TOP OF THE POST.

STAMPING: "SHARK 3"
DATE: JUNE 3, 2014

MONUMENT ESTABLISHED BY: USDA-NRCS CROWLEY WATERSHED OFFICE

ADJUSTED NAD83 GEODETIC POSITION (2011) (EPOCH:2010.0000)

LAT: 29-46-14.07 NORTH
LONG: 91-51-45.87 WEST

ADJUSTED NAD 83 DATUM LSZ (1702)

N=462,448.963

E=3,112,873.741

ADJUSTED NAVD88 ELEVATION

3.07 FEET / 0.936 METERS

ELLIPSOID HEIGHT: -25.183 METERS

GEOID 03 HEIGHT: -26.119 METERS

| PLAN and PROFILE LINE COLOR LEGEND |
|---|
| BASELINE 5.09.2014 Survey |
| ICR–1 [0.5 years] 11.03.2014 Survey |
| ICR–2 [1.0 years] 04.30.2015 Survey |
| ICR–3 [1.5 years] 11.05.2015 Survey |
| ICR–4 [2.0 years] 04.28.2016 Survey |
| ICR–5 [2.5 years] 11.10.2016 Survey |
| ICR–6 [3.0 years] 04.17.2017 Survey |

50 0 50 100 150 200
SCALE IN FEET

| | | DATE |
|---|---|---|
| DESIGNED | A. GREMILLION | 02/18 |
| DRAWN | D. GARBER | 02/18 |
| CHECKED | B. SAMSON | 02/18 |
| APPROVED | | |

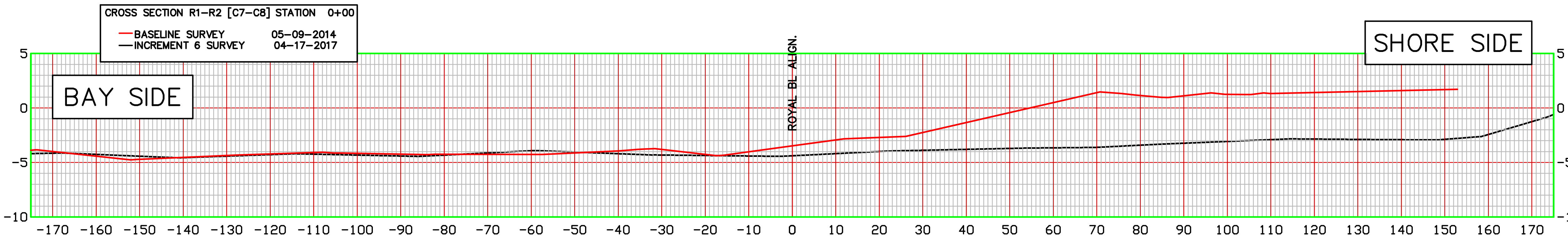
PLAN VIEW DRAWING
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
ROYAL ENGINEERS
IBERIA PARISH, LOUISIANA

United States Department of Agriculture
USDA
Natural Resources Conservation Service

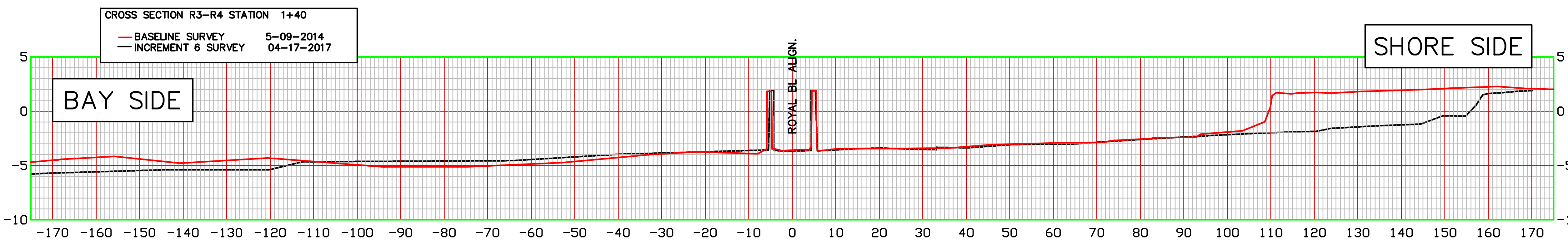
FILE NAME
ROYAL MONT.

DRAWING NAME
ROYAL ICR 6

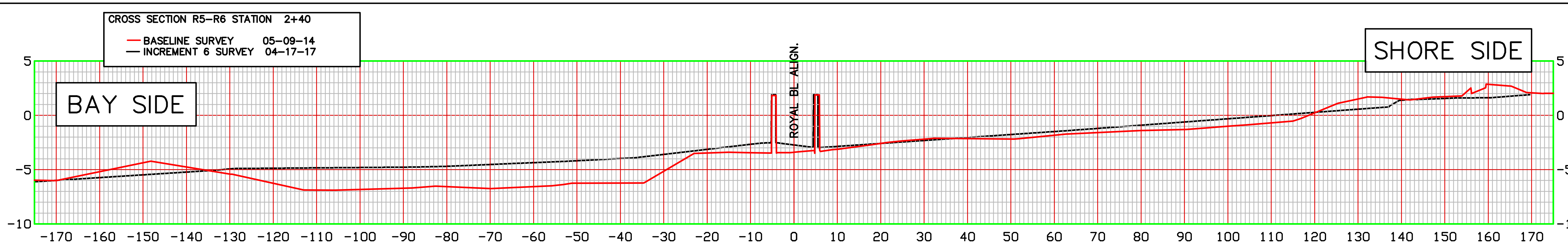
SHEET 01 of 04



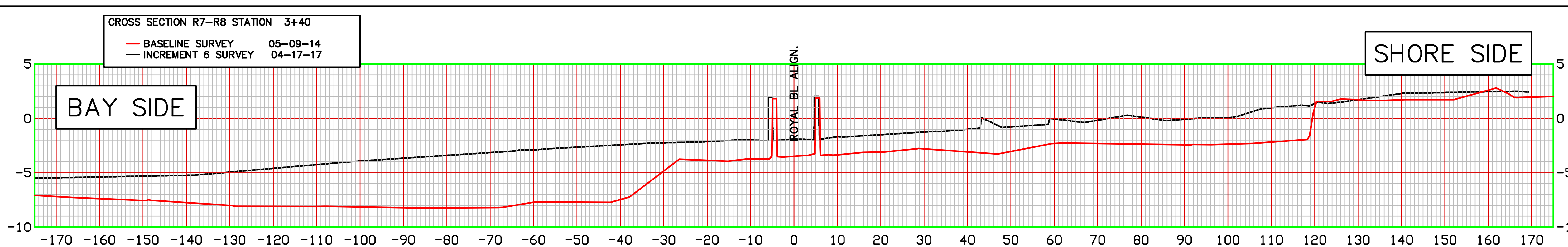

CROSS SECTION R1–R2 [C7–C8] STA. 0+00




CROSS SECTION R3–R4 STA. 1+40




CROSS SECTION R5–R6 STA. 2+40




CROSS SECTION R7–R8 STA. 3+40

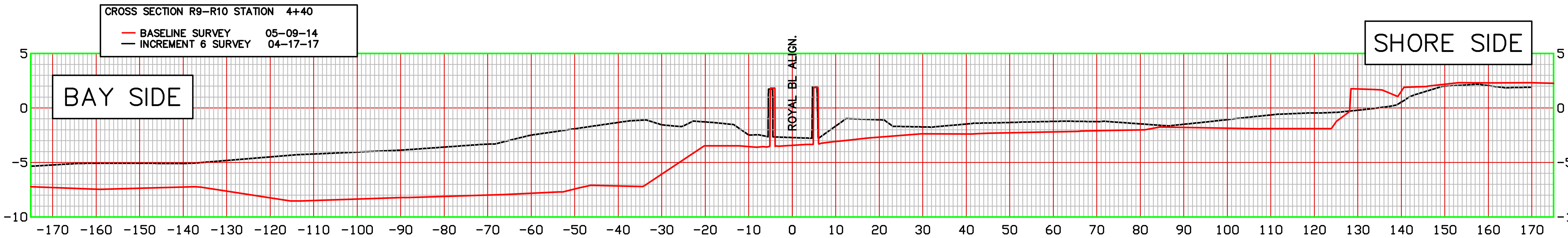
| | | DATE |
|---|---|---|
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

CROSS SECTIONS
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
ROYAL ENGINEERS
IBERIA PARISH, LOUISIANA

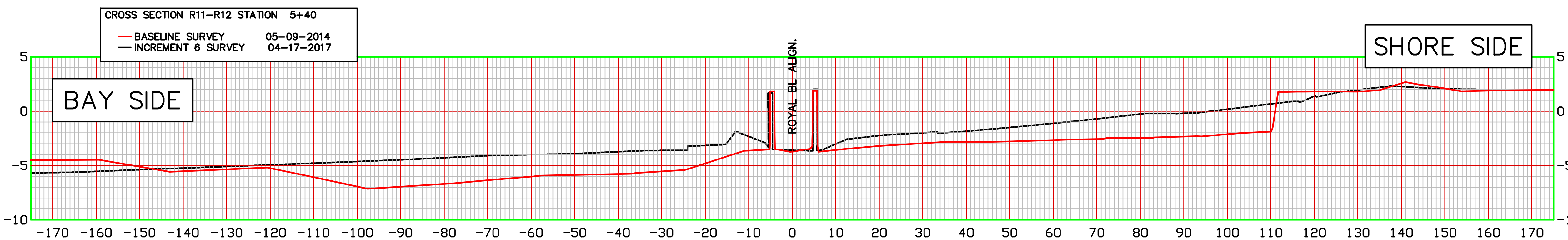
United States Department of Agriculture
USDA
Natural Resources Conservation Service

FILE NAME
ROYAL MONT.
DRAWING NAME
ROYAL ICR 6

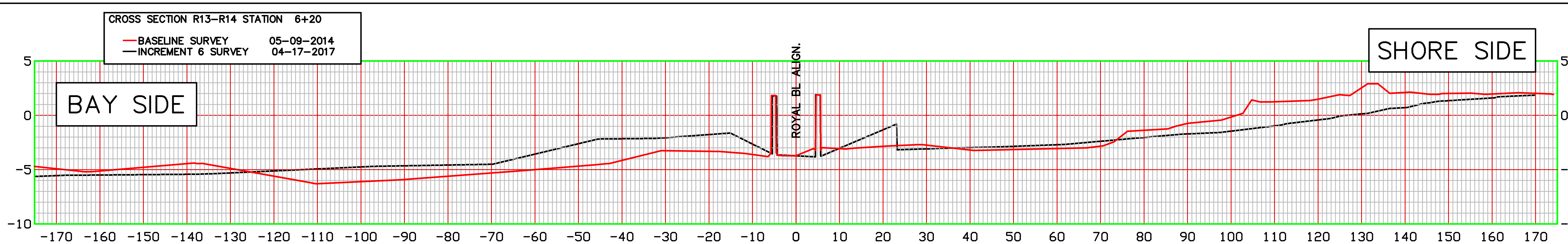
SHEET 02 of 04



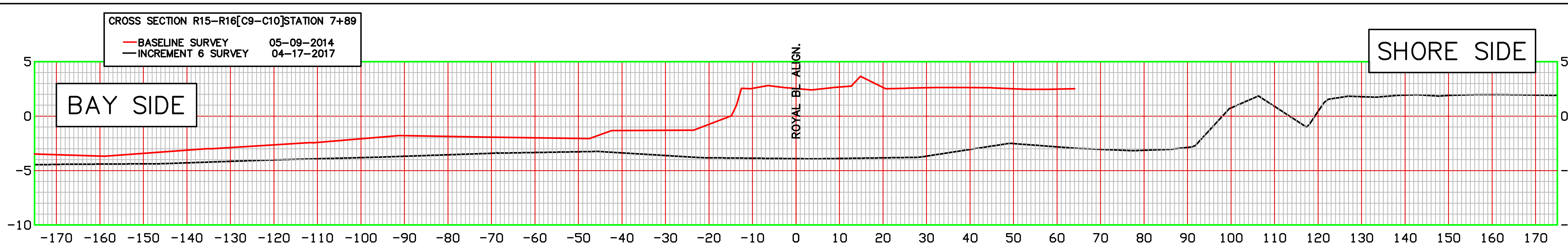

CROSS SECTION R9–R10 STA. 4+40




CROSS SECTION R11–R12 STA. 5+40




CROSS SECTION R13–R14 STA. 6+20



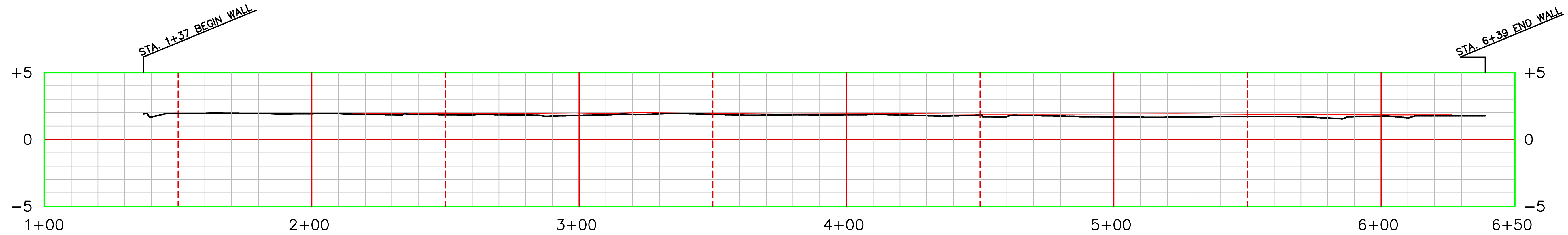

CROSS SECTION R15–R16 [C9–C10] STA. 7+89

| | | DATE |
|---|---|---|
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

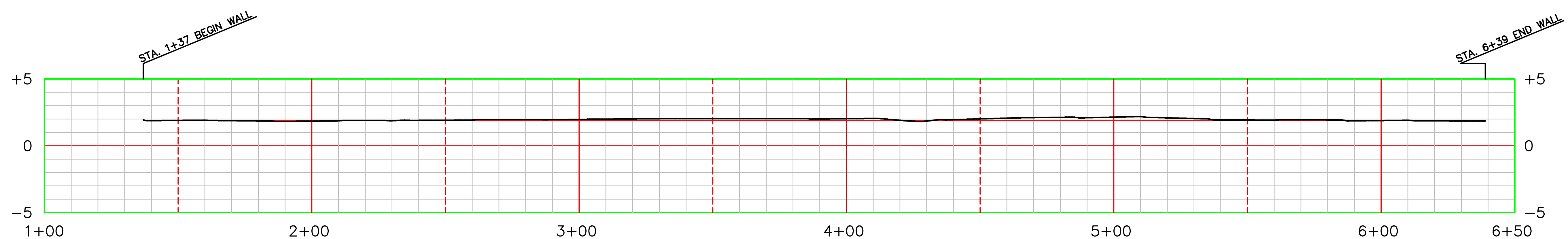
CROSS SECTIONS
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
ROYAL ENGINEERS
IBERIA PARISH, LOUISIANA

USDA United States Department of Agriculture
Natural Resources Conservation Service

FILE NAME ROYAL MONT.
DRAWING NAME ROYAL ICR 6
SHEET 03 of 04




CENTERLINE PROFILE – BAY SIDE WALL




CENTERLINE PROFILE – SHORE SIDE WALL

| | |
|---|---|
| BASELINE SURVEY | 05-09-14 |
| INCREMENT 6 SURVEY | 04-17-17 |

REVISIONS

| NO. | DATE | APPROVED | TITLE |
|---|---|---|---|
| M1 | XX/XX/09 | INTIALS | XXX |

| | | |
|---|---|---|
| DESIGNED | MASTER ENGINEER | 02/09 |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

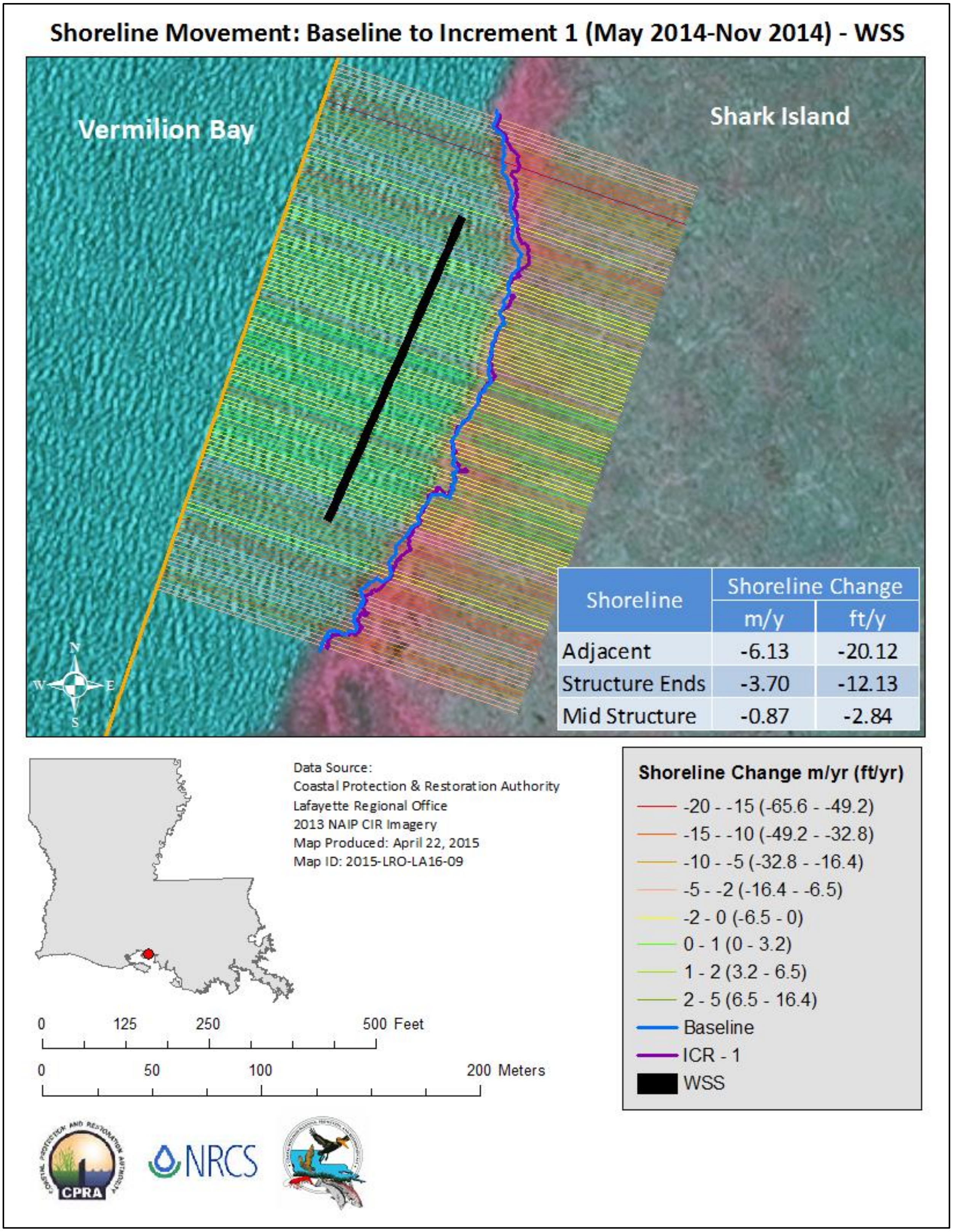
PROFILE OF WALL – BAY SIDE & SHORE SIDE
LA-16 MONITORING SURVEYS ICR-6 [3.0 YEARS]
ROYAL ENGINEERS
IBERIA PARISH, LOUISIANA

United States Department of Agriculture
Natural Resources Conservation Service

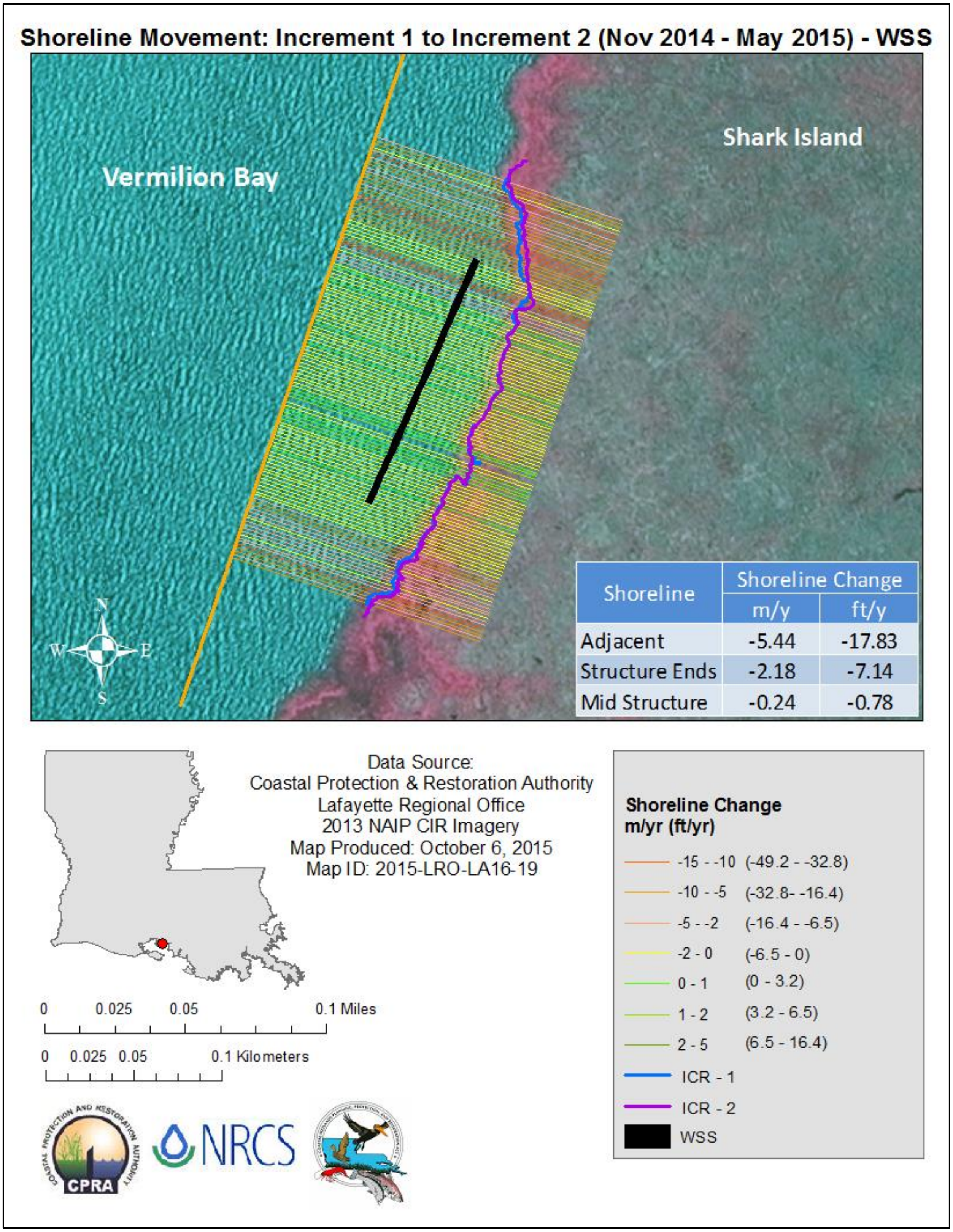
FILE NAME ROYAL MONT.
DRAWING NAME ROYAL ICR 6
SHEET 04 of 04

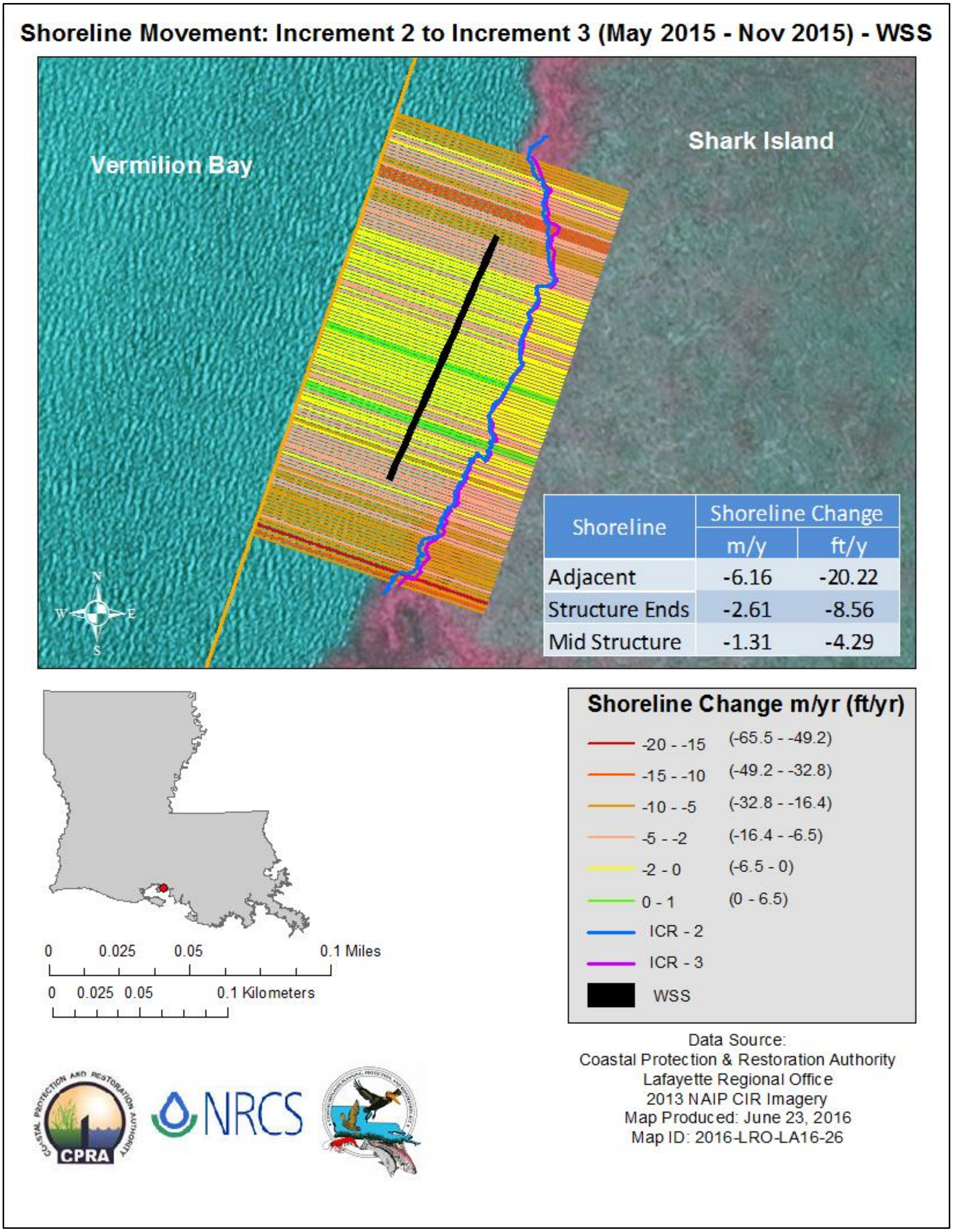
## APPENDIX C - 2

## Incremental Shoreline Change Maps

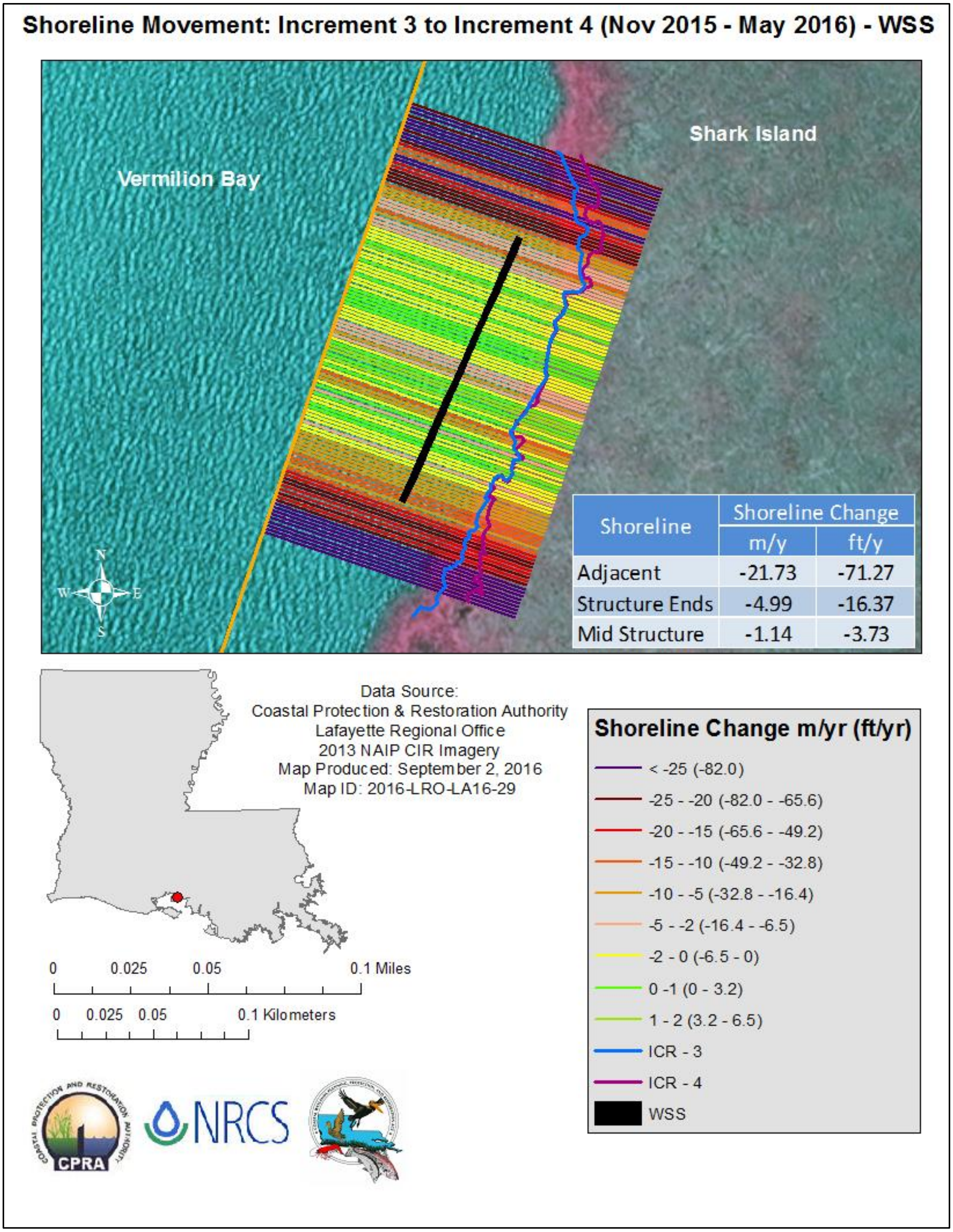


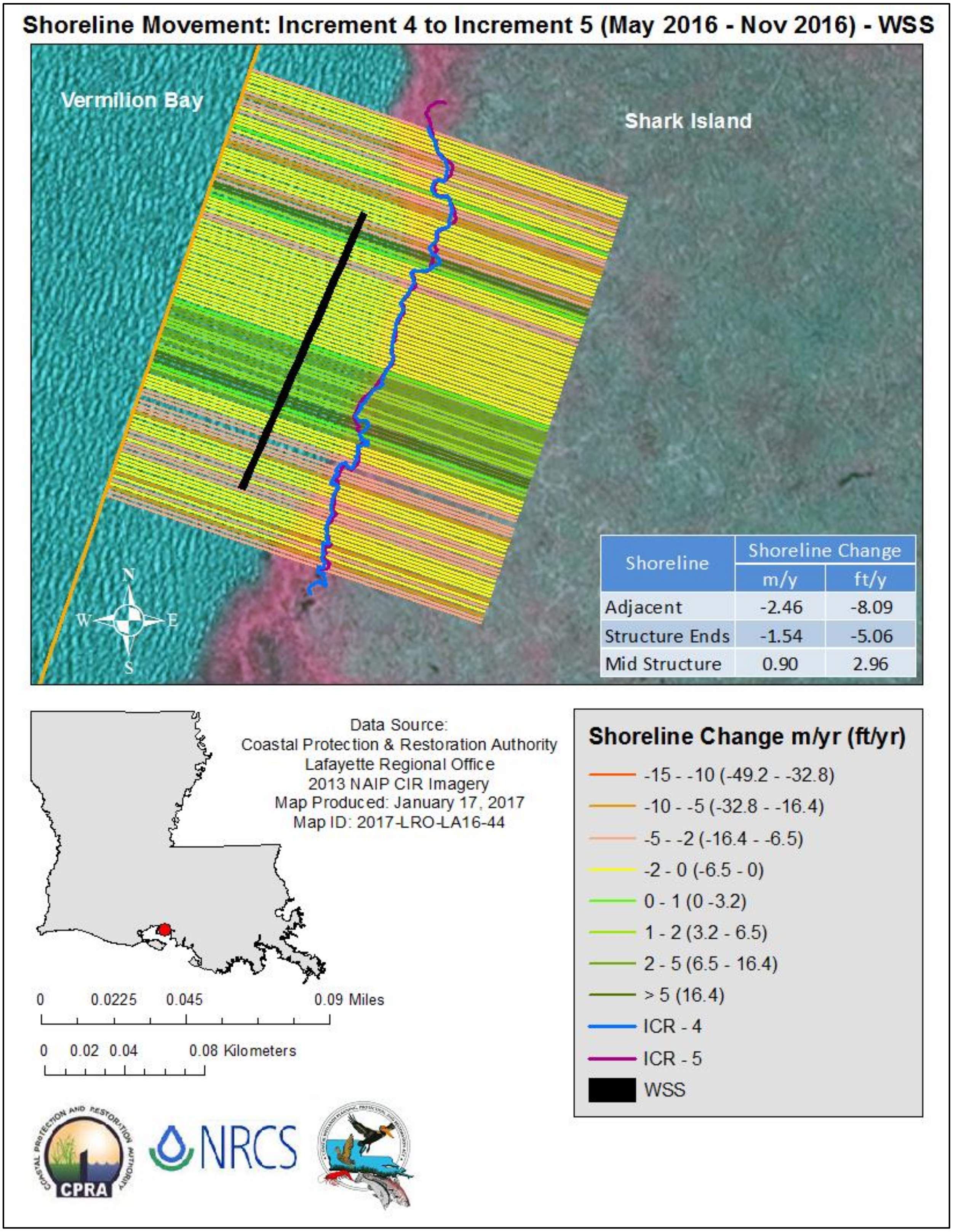

| Shoreline | Shoreline Change | |
|---|---|---|
| | m/y | ft/y |
| Adjacent | -6.13 | -20.12 |
| Structure Ends | -3.70 | -12.13 |
| Mid Structure | -0.87 | -2.84 |


Shoreline Movement: Increment 1 to Increment 2 (Nov 2014 - May 2015) - WSS
Shark Island
Vermilion Bay
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -5.44 -17.83
Structure Ends -2.18 -7.14
Mid Structure -0.24 -0.78
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: October 6, 2015
Map ID: 2015-LRO-LA16-19
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
Shoreline Change
m/yr (ft/yr)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8- -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 3.2)
1 - 2 (3.2 - 6.5)
2 - 5 (6.5 - 16.4)
ICR - 1
ICR - 2
WSS
NRCS
CPRA



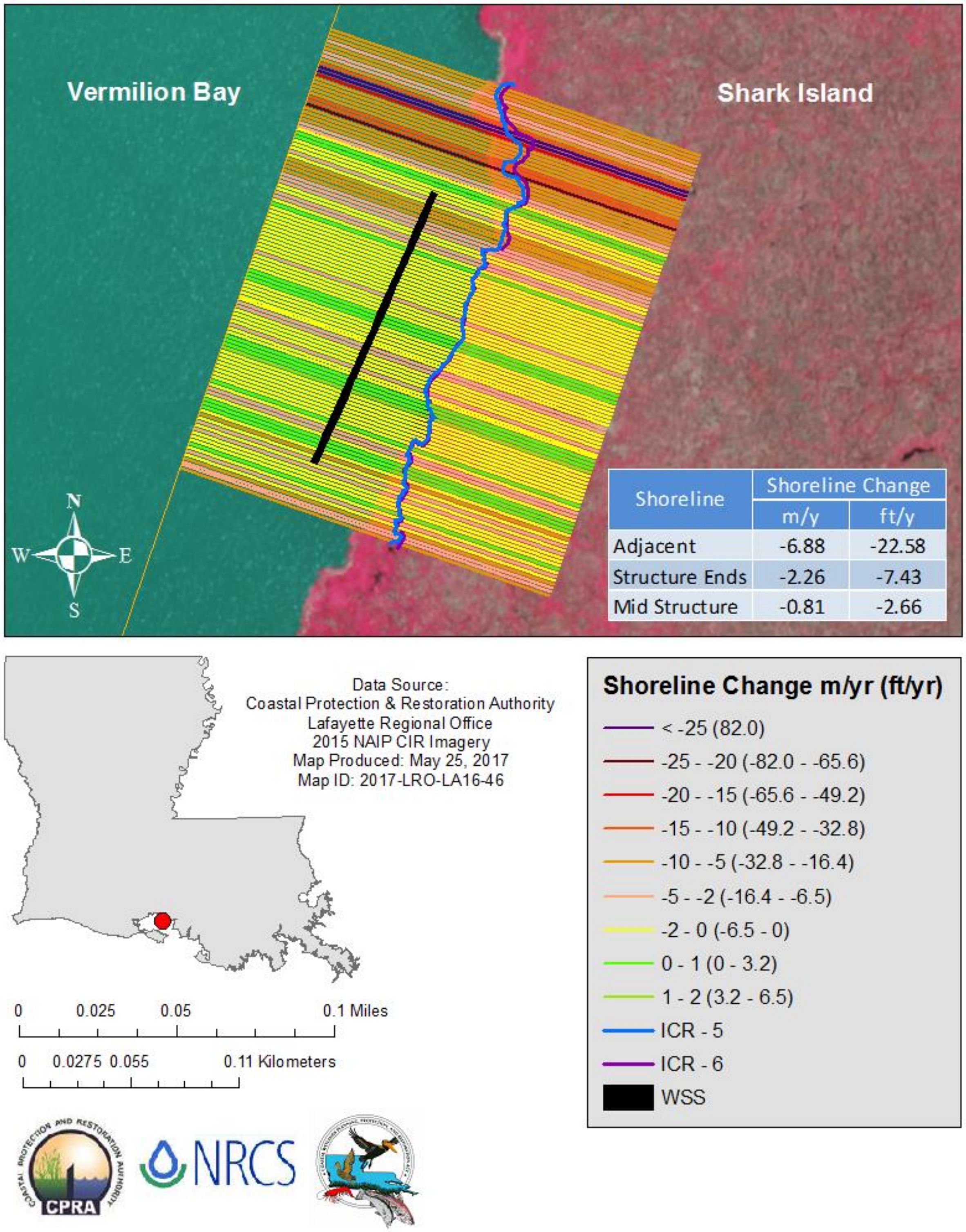
Shoreline Movement: Increment 2 to Increment 3 (May 2015 - Nov 2015) - WSS
Shark Island
Vermilion Bay
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -6.16 -20.22
Structure Ends -2.61 -8.56
Mid Structure -1.31 -4.29
N
W
E
S
Shoreline Change m/yr (ft/yr)
-20 - -15 (-65.5 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 6.5)
ICR - 2
ICR - 3
WSS
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: June 23, 2016
Map ID: 2016-LRO-LA16-26
NRCS
CPRA


Shoreline Movement: Increment 3 to Increment 4 (Nov 2015 - May 2016) - WSS
Shark Island
Vermilion Bay
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -21.73 -71.27
Structure Ends -4.99 -16.37
Mid Structure -1.14 -3.73
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: September 2, 2016
Map ID: 2016-LRO-LA16-29
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.6)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 -1 (0 - 3.2)
1 - 2 (3.2 - 6.5)
ICR - 3
ICR - 4
WSS
CPRA
NRCS




| Shoreline | Shoreline Change | |
|---|---|---|
| | m/y | ft/y |
| Adjacent | -2.46 | -8.09 |
| Structure Ends | -1.54 | -5.06 |
| Mid Structure | 0.90 | 2.96 |

**Shoreline Movement: Increment 5 to Increment 6 (Nov 2016 - Apr 2017) - WSS**



# APPENDIX D

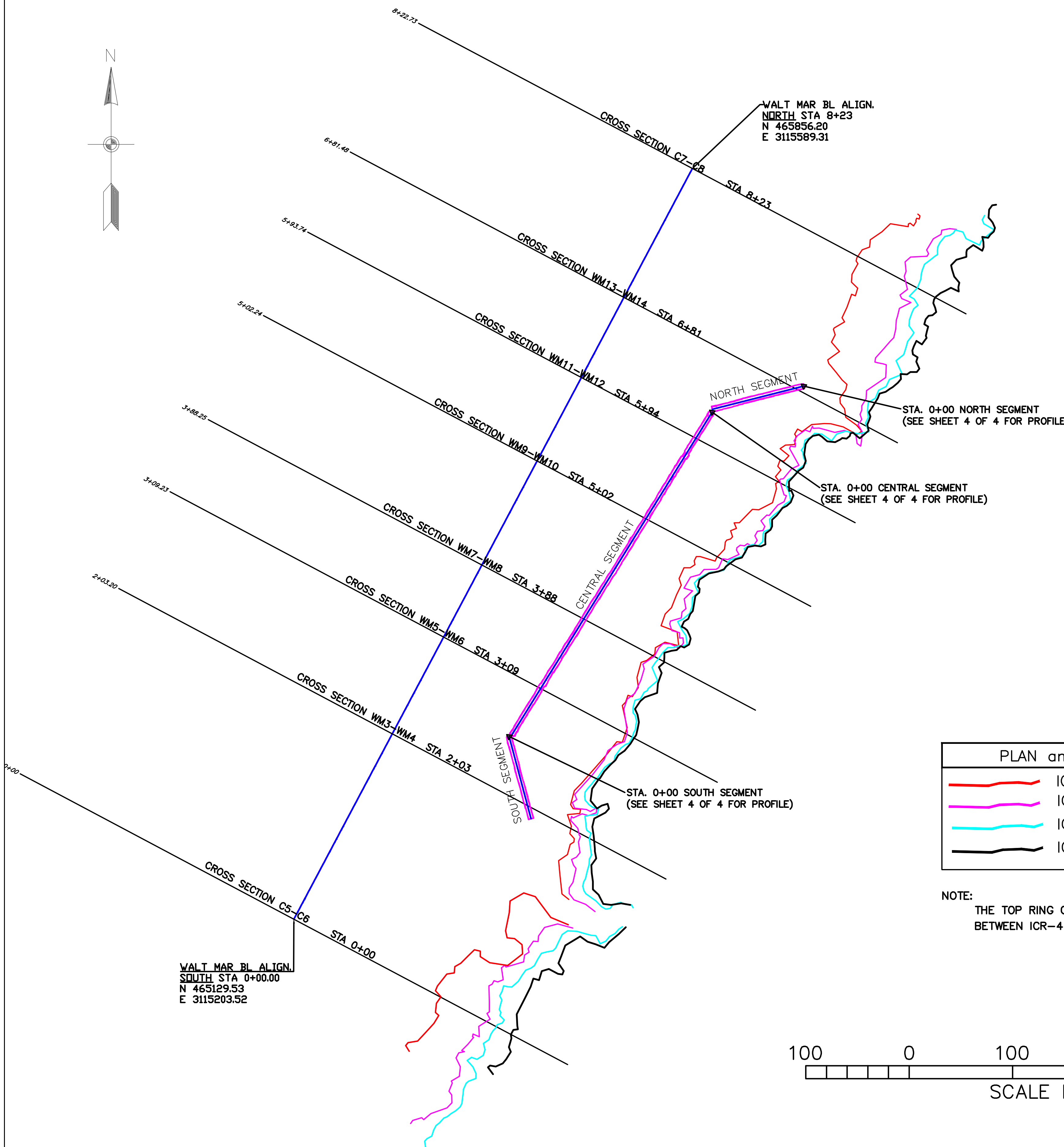
## EcoSystem Units (ESUs)

## Walter Marine Artificial Reefs, Inc.

## APPENDIX D - 1

## Topographic/Bathymetic Survey Drawings

(Distances are in feet, and Elevations are in feet NAVD88 Geoid 03)




SURVEY CONTROL: STATION NAME - "TBM-SHARK3"
MONUMENT LOCATION: LOCATED ON SHARK ISLAND IN IBERIA PARISH, LOUISIANA. THE TEMPORARY BENCHMARK IS SET ON THE NORTHEAST BANK OF AN OLD OILFIELD LOCATION CANAL AND LOCATED APPROXIMATELY 370' SOUTHEAST FROM THE INTERSECTION OF THE NORTHEAST BANK AND VERMILION BAY. IT IS APPROXIMATELY 320' SOUTHEAST OF MONUMENT "TBM-SHARK 2".

MONUMENT DESCRIPTION: ROUND WOODEN FENCE POST DRIVEN INTO GROUND AND PROTRUDING FROM THE GROUND ABOUT 1.0". MONUMENT IS MARKED WITH A BRASS TAG LABELED "SHARK 3". THERE IS A PK NAIL IN THE CENTER ON THE TOP OF THE POST.

STAMPING: "SHARK 3"
DATE: JUNE 3, 2014

MONUMENT ESTABLISHED BY: USDA-NRCS CROWLEY WATERSHED OFFICE

ADJUSTED NAD83 GEODETIC POSITION (2011) (EPOCH:2010.0000)

LAT: 29-46-14.07 NORTH
LONG: 91-51-45.87 WEST

ADJUSTED NAD 83 DATUM LSZ (1702)

N=462,448.963

E=3,112,873.741

ADJUSTED NAVD88 ELEVATION

3.07 FEET / 0.936 METERS

ELLIPSOID HEIGHT: -25.183 METERS

GEOID 03 HEIGHT: -26.119 METERS

| PLAN and PROFILE LINE COLOR LEGEND | | |
|---|---|---|
| ICR–3 | 11.18.2015 | Survey [BASELINE] |
| ICR–4 | 04.28.2016 | Survey |
| ICR–5 | 11.10.2016 | Survey |
| ICR–6 | 04.17.2017 | Survey |

NOTE:
THE TOP RING OF THE WALTER MARINE CONSTRUCTION FEATURE WAS REMOVED BETWEEN ICR–4 (04–28–2016) AND ICR–5 (11–10–2016).

100 0 100 200 300 400
SCALE IN FEET

| | | |
|---|---|---|
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

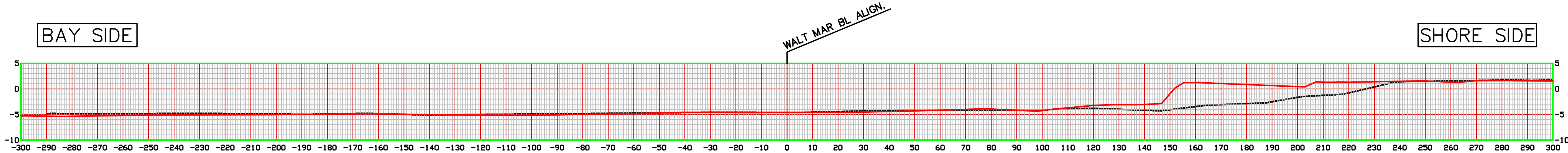
PLAN VIEW DRAWING
LA–16 MONITORING SURVEYS ICR–6
WALTER MARINE CONSTRUCTION
IBERIA PARISH, LOUISIANA

USDA United States Department of Agriculture
Natural Resources Conservation Service

FILE NAME
WALT MAR MONT.

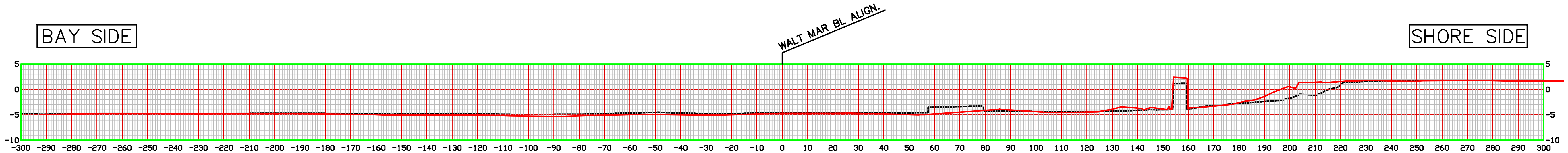
DRAWING NAME
WALT MAR ICR 6

SHEET 01 of 04



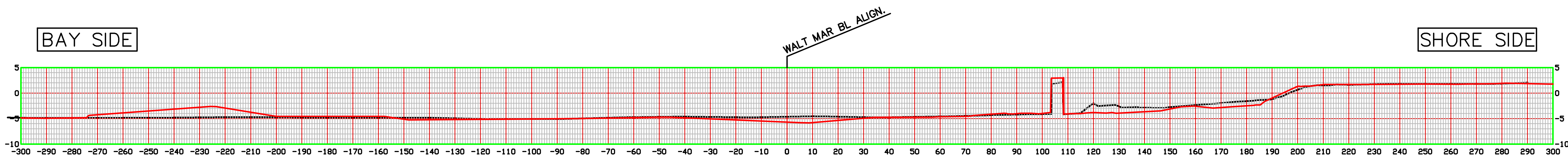

CROSS SECTION STA 0+00

CROSS SECTION C5 – C6 STATION 0+00
BASELINE SURVEY 11–18–2015
INCREMENT 6 SURVEY 4–17–2017



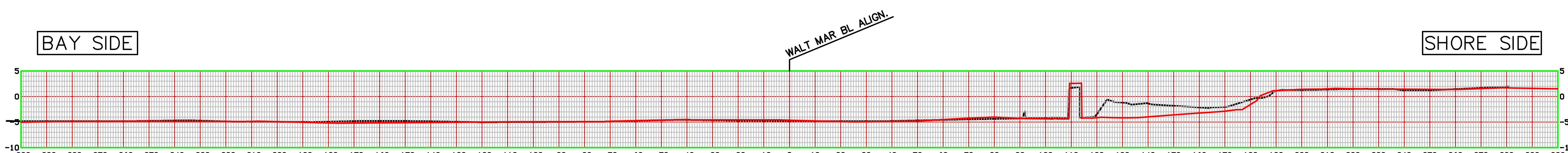

CROSS SECTION STA 2+03

CROSS SECTION WM3–WM4 STATION 2+03
BASELINE SURVEY 11–18–2015
INCREMENT 6 SURVEY 4–17–2017




CROSS SECTION STA 3+09

CROSS SECTION WM5–WM6 STATION 3+09
BASELINE SURVEY 11–18–2015
INCREMENT 6 SURVEY 4–17–2017




CROSS SECTION STA 3+88

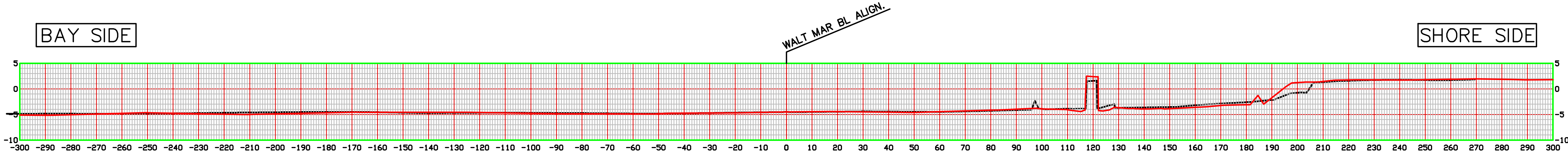
CROSS SECTION WM7–WM8 STATION 3+88
BASELINE SURVEY 11–18–2015
INCREMENT 6 SURVEY 4–17–2017

| | | |
|---|---|---|
| DESIGNED | | DATE |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

CROSS SECTIONS
LA–16 MONITORING SURVEYS ICR–6
WALTER MARINE CONSTRUCTION
IBERIA PARISH, LOUISIANA

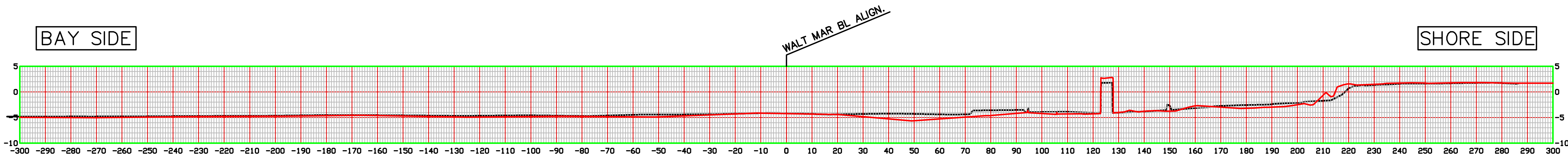
United States Department of Agriculture
Natural Resources Conservation Service

FILE NAME WALT MAR MONT.
DRAWING NAME WALTER MAR ICR 6
SHEET 02 of 04



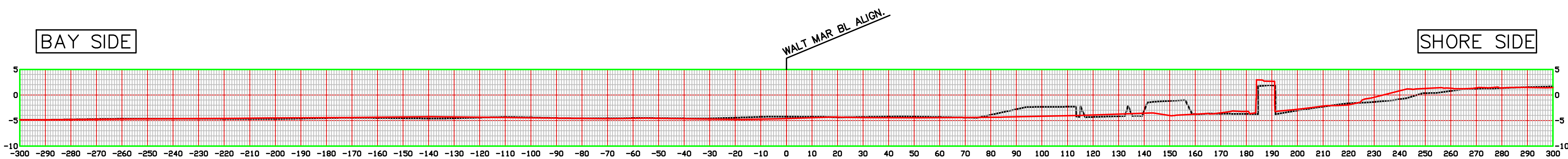

CROSS SECTION STA 5+02

| CROSS SECTION WM9–WM10 STATION 5+02 | |
|---|---|
| BASELINE SURVEY | 11–18–2015 |
| INCREMENT 6 SURVEY | 4–17–2017 |



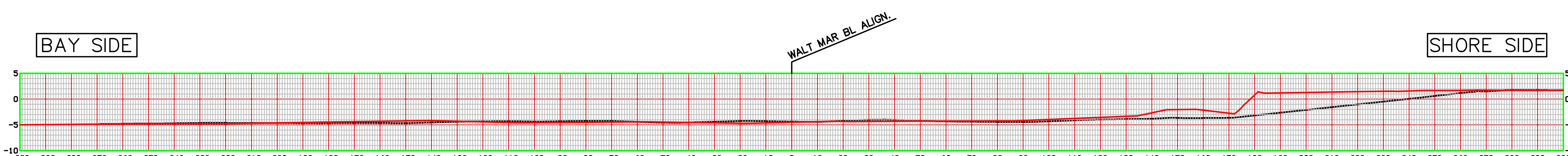

CROSS SECTION STA 5+93.74

| CROSS SECTION WM11–WM12 STATION 5+94 | |
|---|---|
| BASELINE SURVEY | 11–18–2015 |
| INCREMENT 6 SURVEY | 4–17–2017 |




CROSS SECTION STA 6+81.48

| CROSS SECTION WM13–WM14 STATION 6+81 | |
|---|---|
| BASELINE SURVEY | 11–18–2015 |
| INCREMENT 6 SURVEY | 4–17–2017 |




CROSS SECTION STA 8+22.73

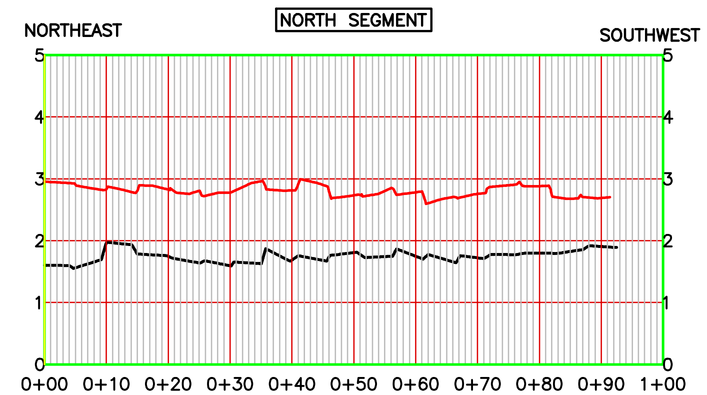
| CROSS SECTION C7–C8 STATION 8+23 | |
|---|---|
| BASELINE SURVEY | 11–18–2015 |
| INCREMENT 6 SURVEY | 4–17–2017 |

| | | DATE |
|---|---|---|
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

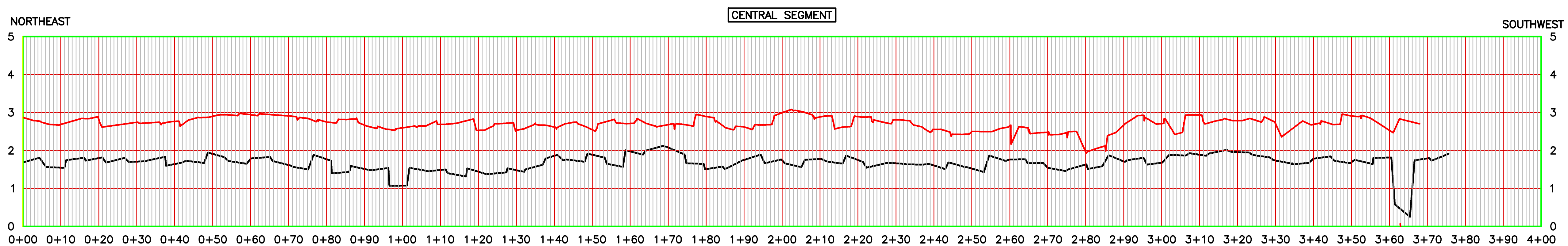
CROSS SECTIONS
LA–16 MONITORING SURVEYS ICR–6
WALTER MARINE CONSTRUCTION
IBERIA PARISH, LOUISIANA

United States Department of Agriculture
USDA
Natural Resources Conservation Service

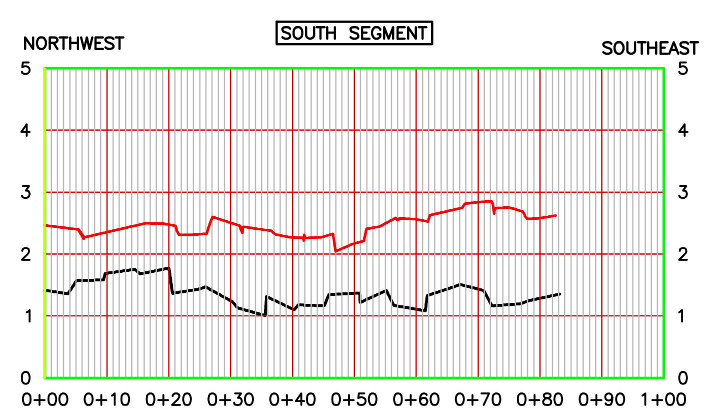
FILE NAME
WALT MAR MONT.
DRAWING NAME
WALT MAR ICR 6
SHEET 03 of 04




WALTER MARINE TOP OF DISCS ICR-6 PROFILE




WALTER MARINE TOP OF DISCS ICR-6 PROFILE




WALTER MARINE TOP OF DISCS ICR-6 PROFILE

| | |
|---|---|
| BASELINE SURVEY | 11-18-2015 |
| INCREMENT 6 SURVEY | 4-17-2017 |

| | | DATE |
|---|---|---|
| DESIGNED | | |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

TOP OF DISCS PROFILE
LA-16 MONITORING SURVEYS ICR-6
WALTER MARINE CONSTRUCTION
IBERIA PARISH, LOUISIANA

USDA United States Department of Agriculture
Natural Resources Conservation Service

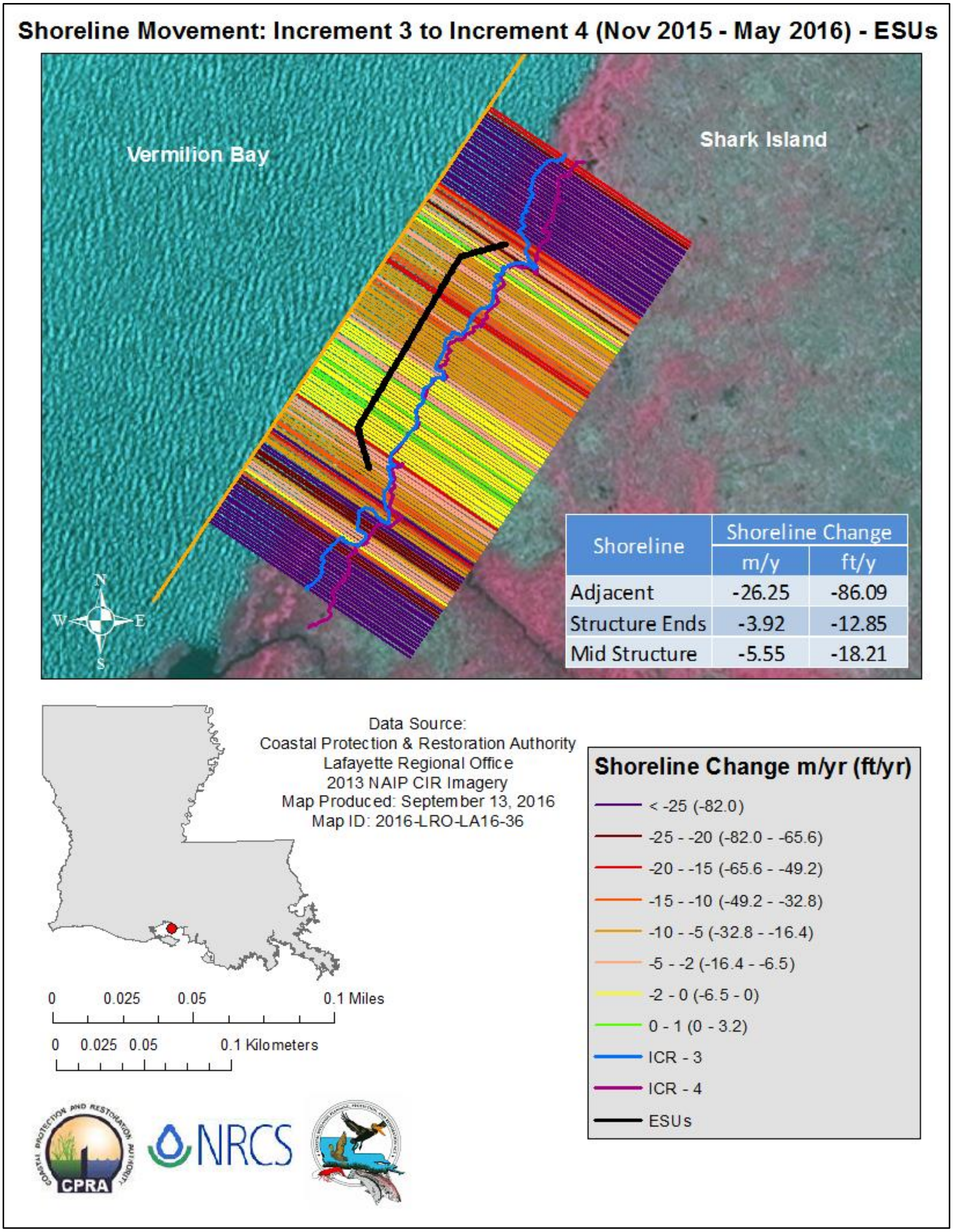
FILE NAME
WALT MAR MONT.

DRAWING NAME
WALT MAR ICR 6

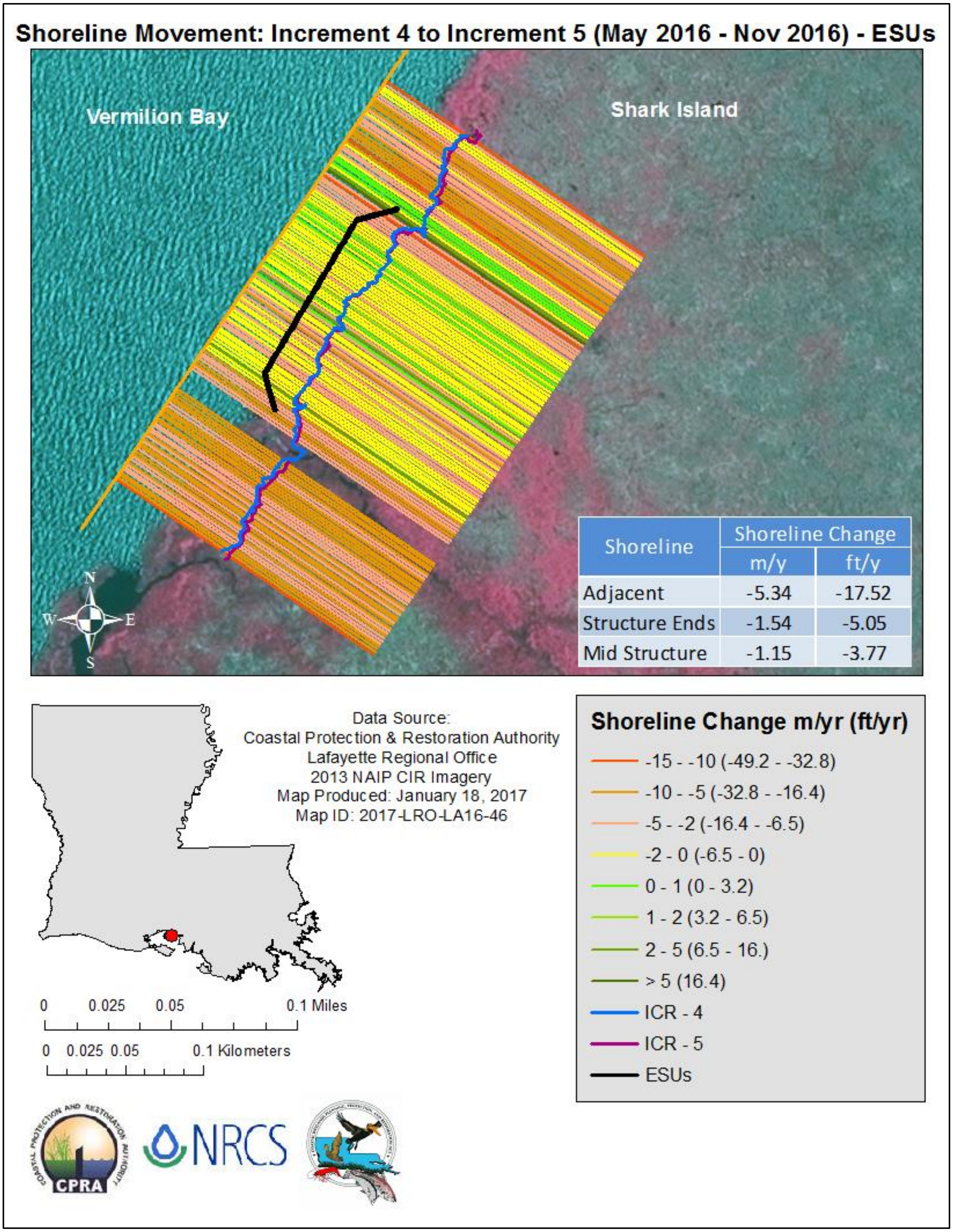
SHEET 04 of 04

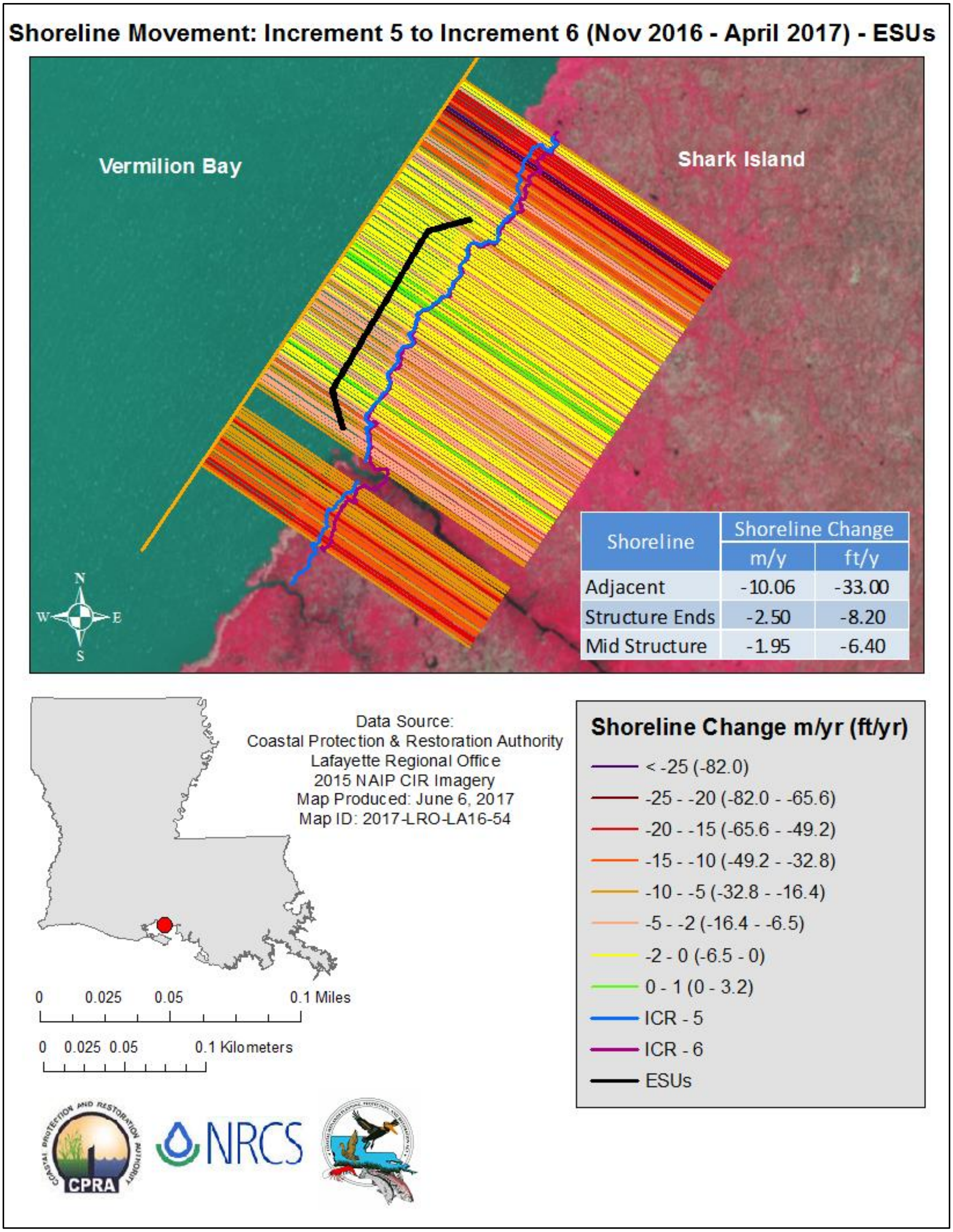
## APPENDIX D - 2

## Incremental Shoreline Change Maps




| Shoreline | Shoreline Change | |
|---|---|---|
| | m/y | ft/y |
| Adjacent | -26.25 | -86.09 |
| Structure Ends | -3.92 | -12.85 |
| Mid Structure | -5.55 | -18.21 |


Shoreline Movement: Increment 4 to Increment 5 (May 2016 - Nov 2016) - ESUs
Vermilion Bay
Shark Island
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -5.34 -17.52
Structure Ends -1.54 -5.05
Mid Structure -1.15 -3.77
N
W
E
S
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: January 18, 2017
Map ID: 2017-LRO-LA16-46
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
Shoreline Change m/yr (ft/yr)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 3.2)
1 - 2 (3.2 - 6.5)
2 - 5 (6.5 - 16.)
> 5 (16.4)
ICR - 4
ICR - 5
ESUs
CPRA
NRCS


Shoreline Movement: Increment 5 to Increment 6 (Nov 2016 - April 2017) - ESUs
Vermilion Bay
Shark Island
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -10.06 -33.00
Structure Ends -2.50 -8.20
Mid Structure -1.95 -6.40
N
W
E
S
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2015 NAIP CIR Imagery
Map Produced: June 6, 2017
Map ID: 2017-LRO-LA16-54
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.6)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 3.2)
ICR - 5
ICR - 6
ESUs
CPRA
NRCS

# APPENDIX E

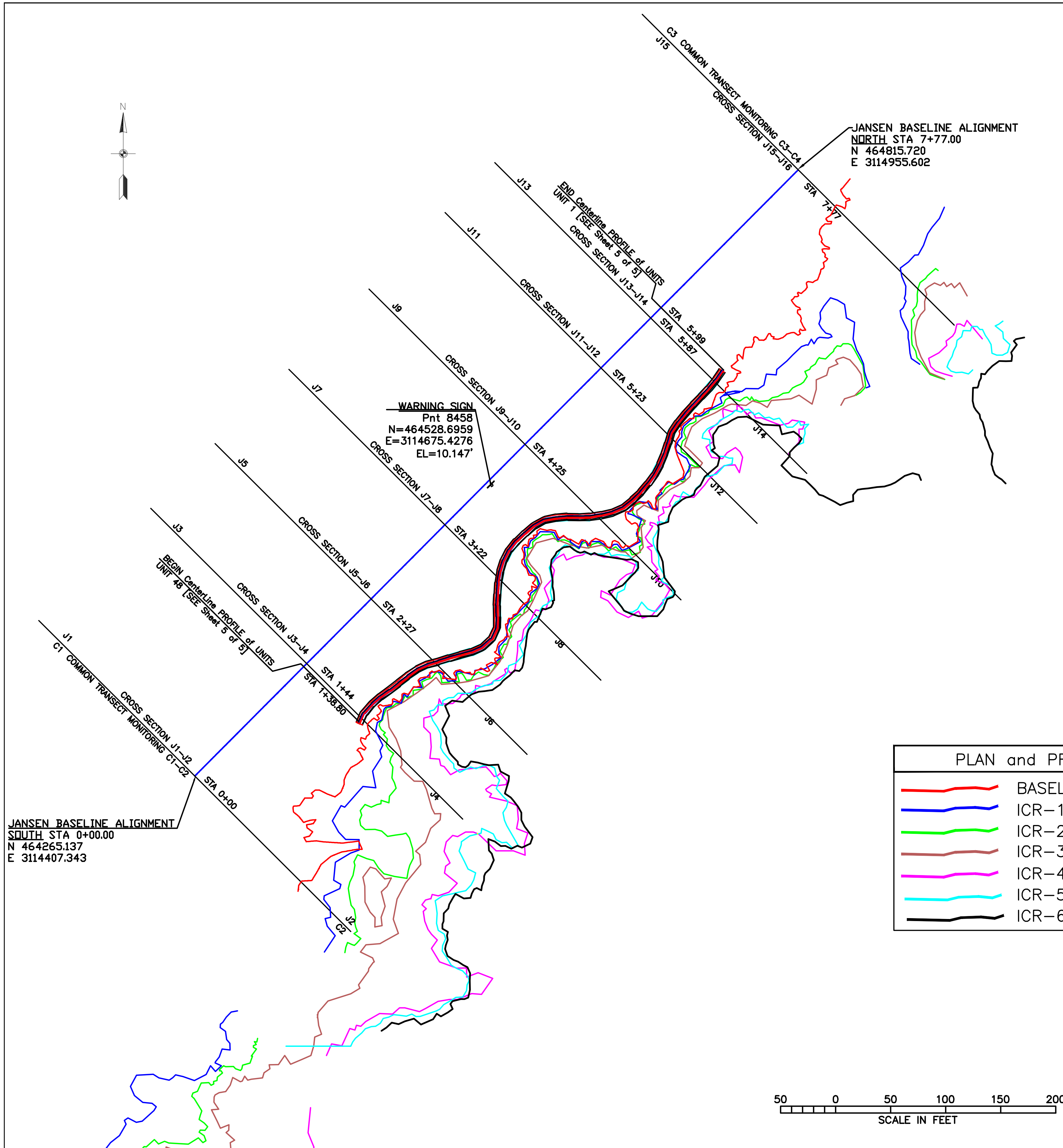
## Buoyancy Compensated Erosion Control Modular System (BCECMS)

## Jansen, Inc.

**APPENDIX E - 1**

**Topographic/Bathymetic Survey Drawings**

(Distances are in feet, and Elevations are in feet NAVD88 Geoid 03)




SURVEY CONTROL: STATION NAME - "TBM-SHARK3"
MONUMENT LOCATION: LOCATED ON SHARK ISLAND IN IBERIA PARISH, LOUISIANA. THE TEMPORARY BENCHMARK IS SET ON THE NORTHEAST BANK OF AN OLD OILFIELD LOCATION CANAL AND LOCATED APPROXIMATELY 370' SOUTHEAST FROM THE INTERSECTION OF THE NORTHEAST BANK AND VERMILION BAY. IT IS APPROXIMATELY 320' SOUTHEAST OF MONUMENT "TBM-SHARK 2".

MONUMENT DESCRIPTION: ROUND WOODEN FENCE POST DRIVEN INTO GROUND AND PROTRUDING FROM THE GROUND ABOUT 1.0". MONUMENT IS MARKED WITH A BRASS TAG LABELED "SHARK 3". THERE IS A PK NAIL IN THE CENTER ON THE TOP OF THE POST.

STAMPING: "SHARK 3"
DATE: JUNE 38, 2014

MONUMENT ESTABLISHED BY: USDA-NRCS CROWLEY WATERSHED OFFICE

ADJUSTED NAD83 GEODETIC POSITION (2011) (EPOCH:2010.0000)

LAT: 29-46-14.07 NORTH
LONG: 91-51-45.87 WEST

ADJUSTED NAD 83 DATUM LSZ (1702)

N=462,448.963

E=3,112,873.741

ADJUSTED NAVD88 ELEVATION

3.07 FEET / 0.936 METERS

ELLIPSOID HEIGHT: -25.183 METERS

GEOID 03 HEIGHT: -26.119 METERS

| PLAN and PROFILE LINE COLOR LEGEND |
|---|
| BASELINE 5.09.2014 Survey |
| ICR-1 [0.5 years] 11.03.2014 Survey |
| ICR-2 [1.0 years] 04.30.2015 Survey |
| ICR-3 [1.5 years] 11.05.2015 Survey |
| ICR-4 [2.0 years] 04.28.2016 Survey |
| ICR-5 [2.5 years] 11.10.2016 Survey |
| ICR-6 [3.0 years] 04.17.2017 Survey |

| | | DATE |
|---|---|---|
| DESIGNED | A. GREMILLION | 02/18 |
| DRAWN | | |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

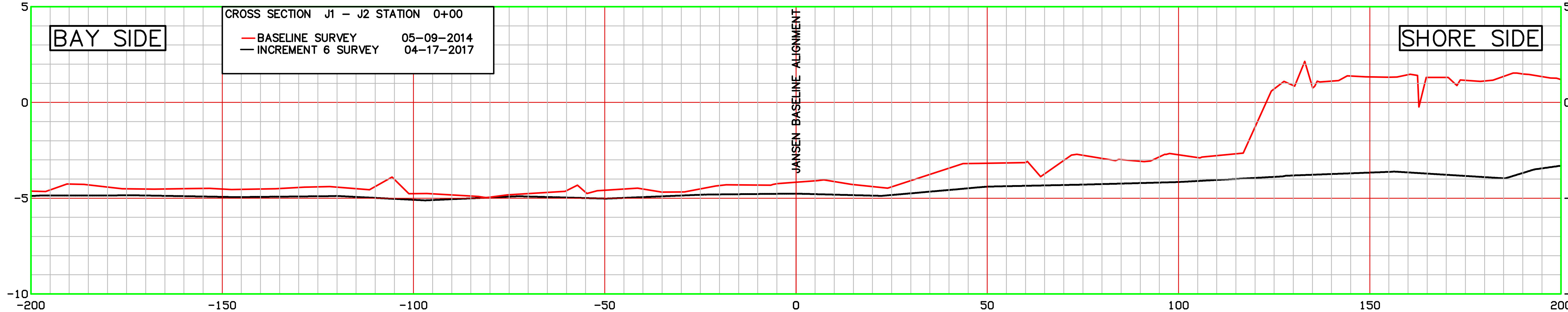
PLAN VIEW DRAWING
LA-16 MONITORING SURVEYS ICR-6 [3.0 YEARS]
JANSEN, INC.
IBERIA PARISH, LOUISIANA

USDA
United States Department of Agriculture
Natural Resources Conservation Service

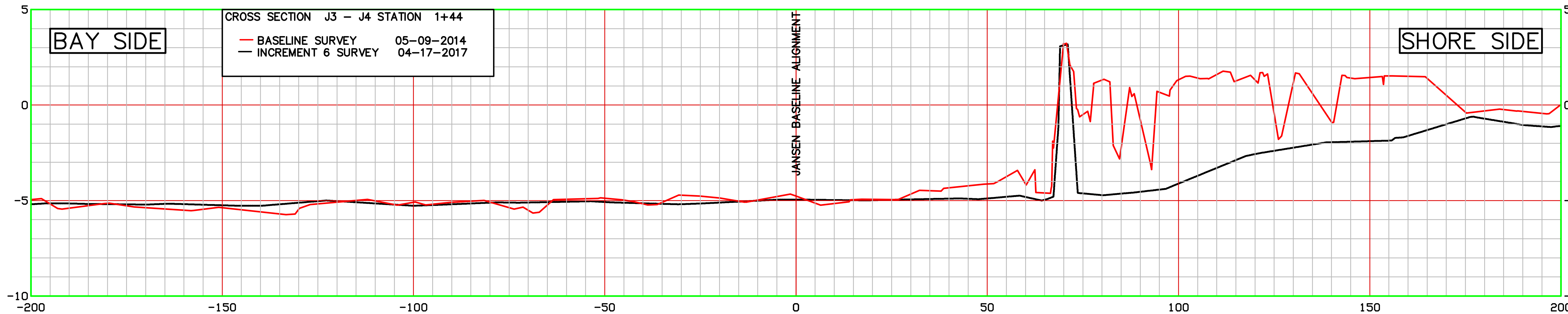
FILE NAME
JANSEN MONT.

DRAWING NAME
JANSEN ICR 6

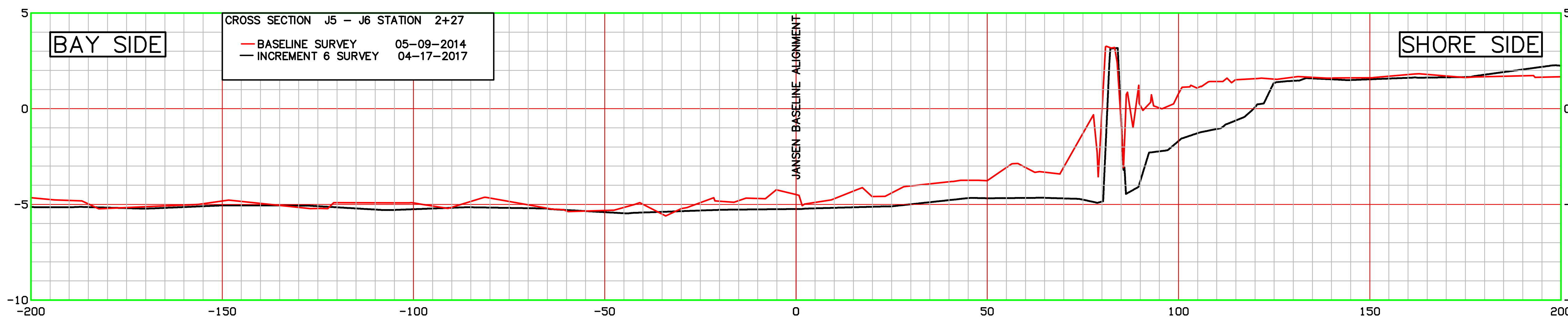
SHEET 01 of 05




CROSS SECTION J1–J2 [C1–C2] STA 0+00




CROSS SECTION J3–J4 STA 1+44



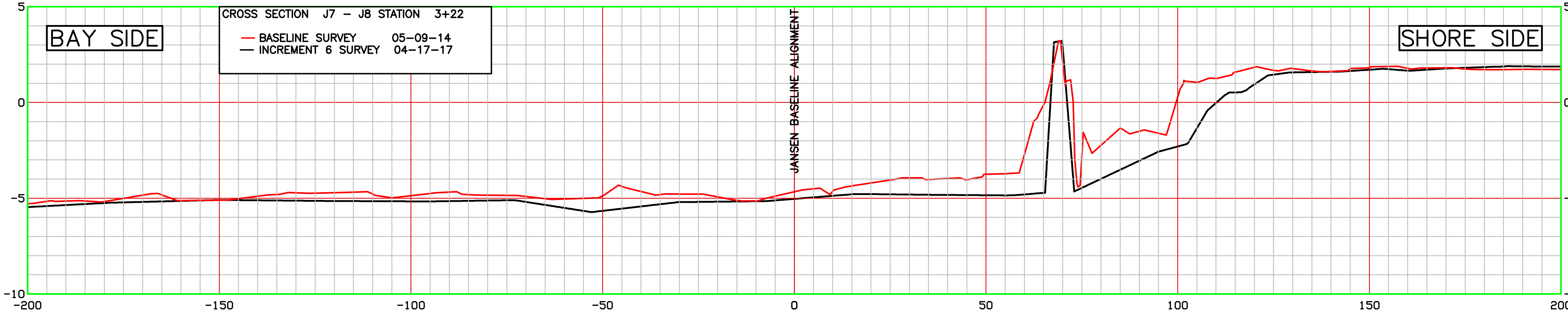

CROSS SECTION J5–J6 [C1–C2] STA 2+27

| | | |
|---|---|---|
| DESIGNED | | DATE |
| DRAWN | A. GREMILLION | 02/18 |
| CHECKED | D. GARBER | 02/18 |
| APPROVED | B. SAMSON | 02/18 |

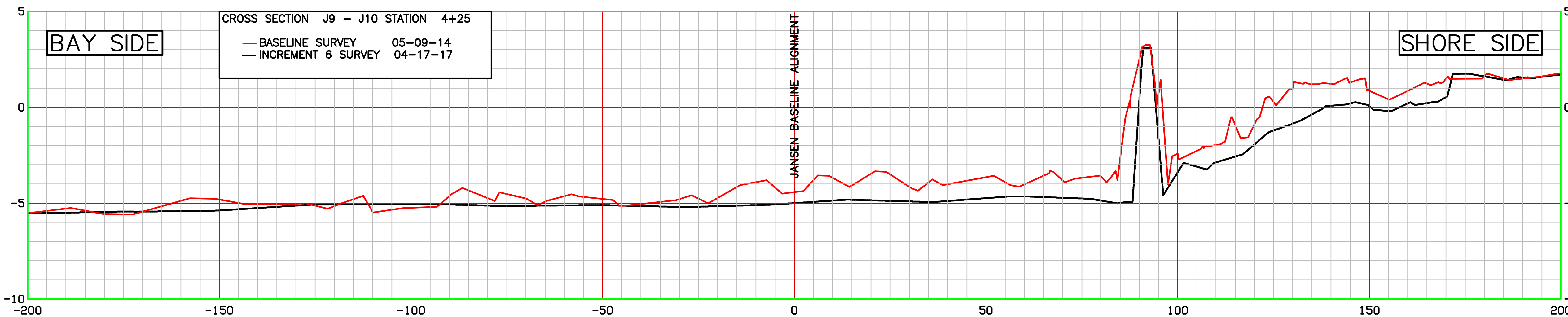
CROSS SECTIONS
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
JANSEN, INC.
IBERIA PARISH, LOUISIANA

USDA United States Department of Agriculture
Natural Resources Conservation Service

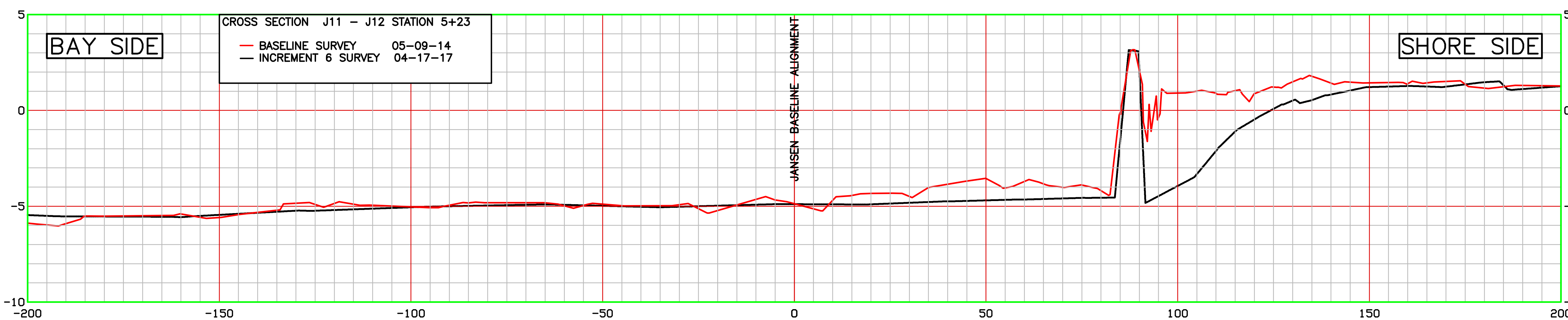
FILE NAME JANSEN MONT.
DRAWING NAME JANSEN ICR 6
SHEET 02 of 05




CROSS SECTION J7–J8 STA 3+22




CROSS SECTION J9–J10 STA 4+25



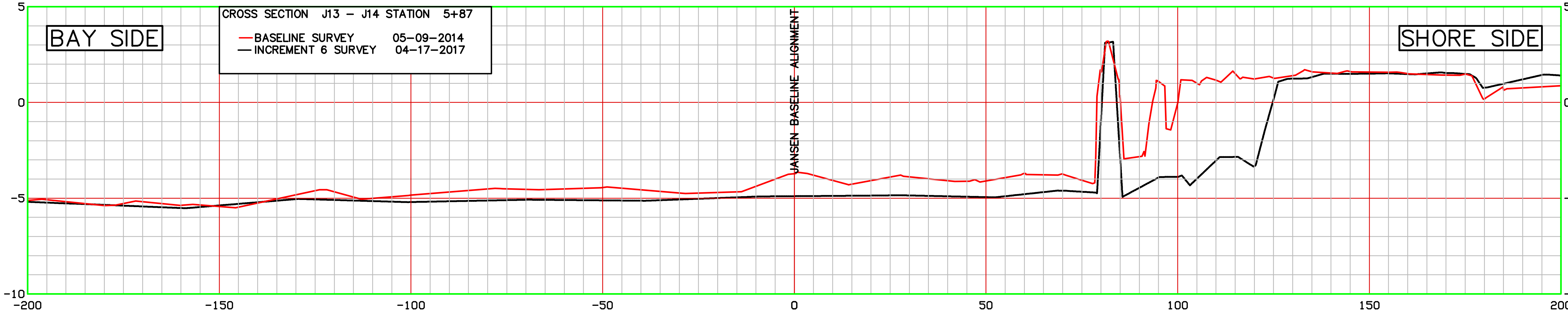

CROSS SECTION J11–J12 STA 5+23

| | | |
|---|---|---|
| | | DATE |
| DESIGNED | A. GREMILLION | 02/18 |
| DRAWN | D. GARBER | 02/18 |
| CHECKED | B. SAMSON | 02/18 |
| APPROVED | | |

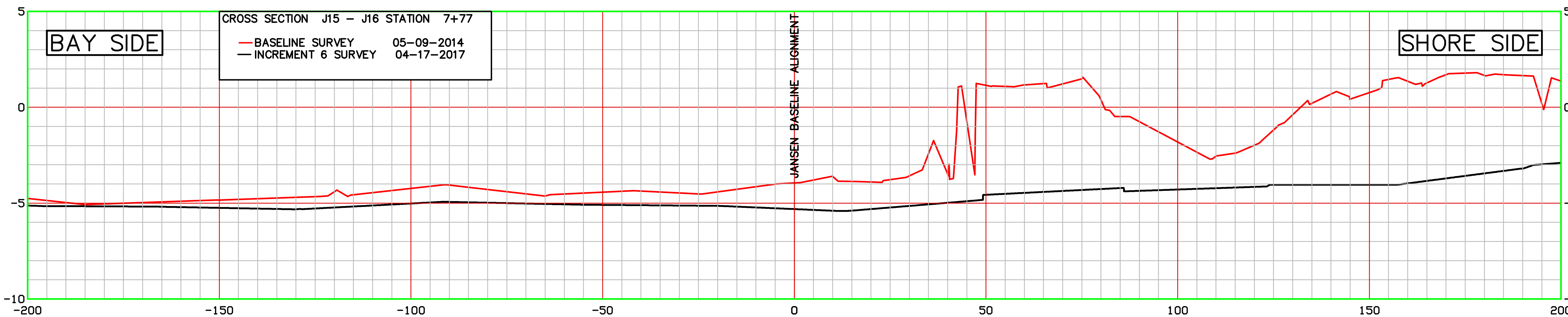
CROSS SECTIONS
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
JANSEN, INC.
IBERIA PARISH, LOUISIANA

United States Department of Agriculture
USDA
Natural Resources Conservation Service

FILE NAME
JANSEN MONT.
DRAWING NAME
JANSEN ICR 6
SHEET 03 of 05




CROSS SECTION J13–J14 STA 5+87




CROSS SECTION J15–J16 [C3–C4] STA 7+77

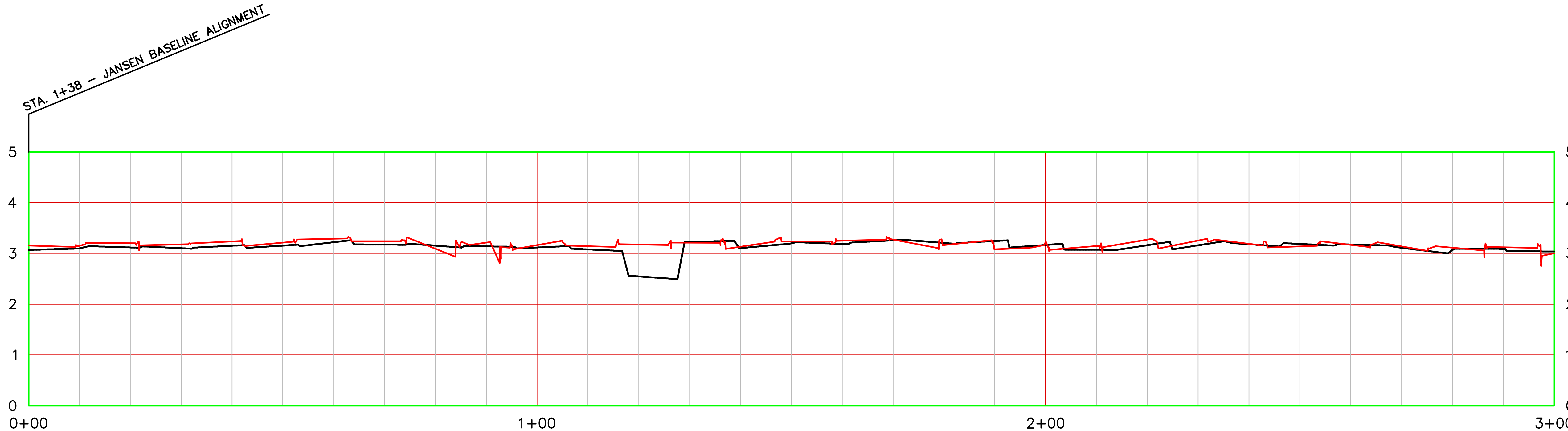
| | | DATE |
|---|---|---|
| DESIGNED | A. GREMILLION | 02/18 |
| DRAWN | D. GARBER | 02/18 |
| CHECKED | B. SAMSON | 02/18 |
| APPROVED | | |

CROSS SECTIONS
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
JANSEN, INC.
IBERIA PARISH, LOUISIANA

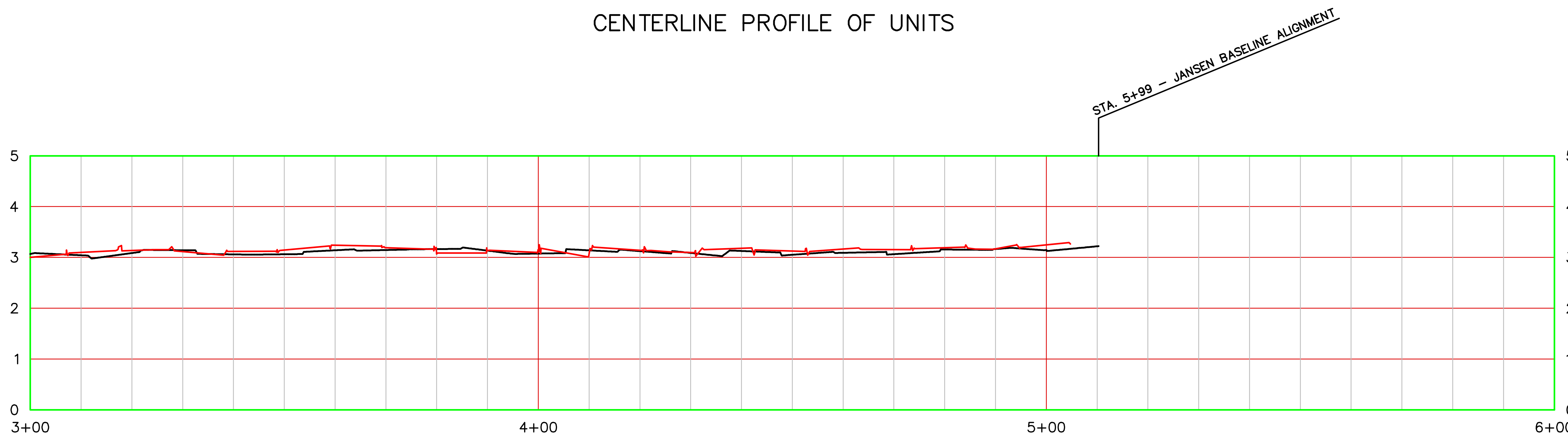
United States Department of Agriculture
Natural Resources Conservation Service

FILE NAME
JANSEN MONT.

DRAWING NAME
JANSEN ICR 6




CENTERLINE PROFILE OF UNITS




CENTERLINE PROFILE OF UNITS (continued)

| | |
|---|---|
| BASELINE SURVEY | 05–09–14 |
| INCREMENT 6 SURVEY | 04–17–17 |

| | | DATE |
|---|---|---|
| DESIGNED | A. GREMILLION | 02/18 |
| DRAWN | D. GARBER | 02/18 |
| CHECKED | B. SAMSON | 02/18 |
| APPROVED | | |

TOP OF UNITS PROFILE
LA–16 MONITORING SURVEYS ICR–6 [3.0 YEARS]
JANSEN, INC.
IBERIA PARISH, LOUISIANA

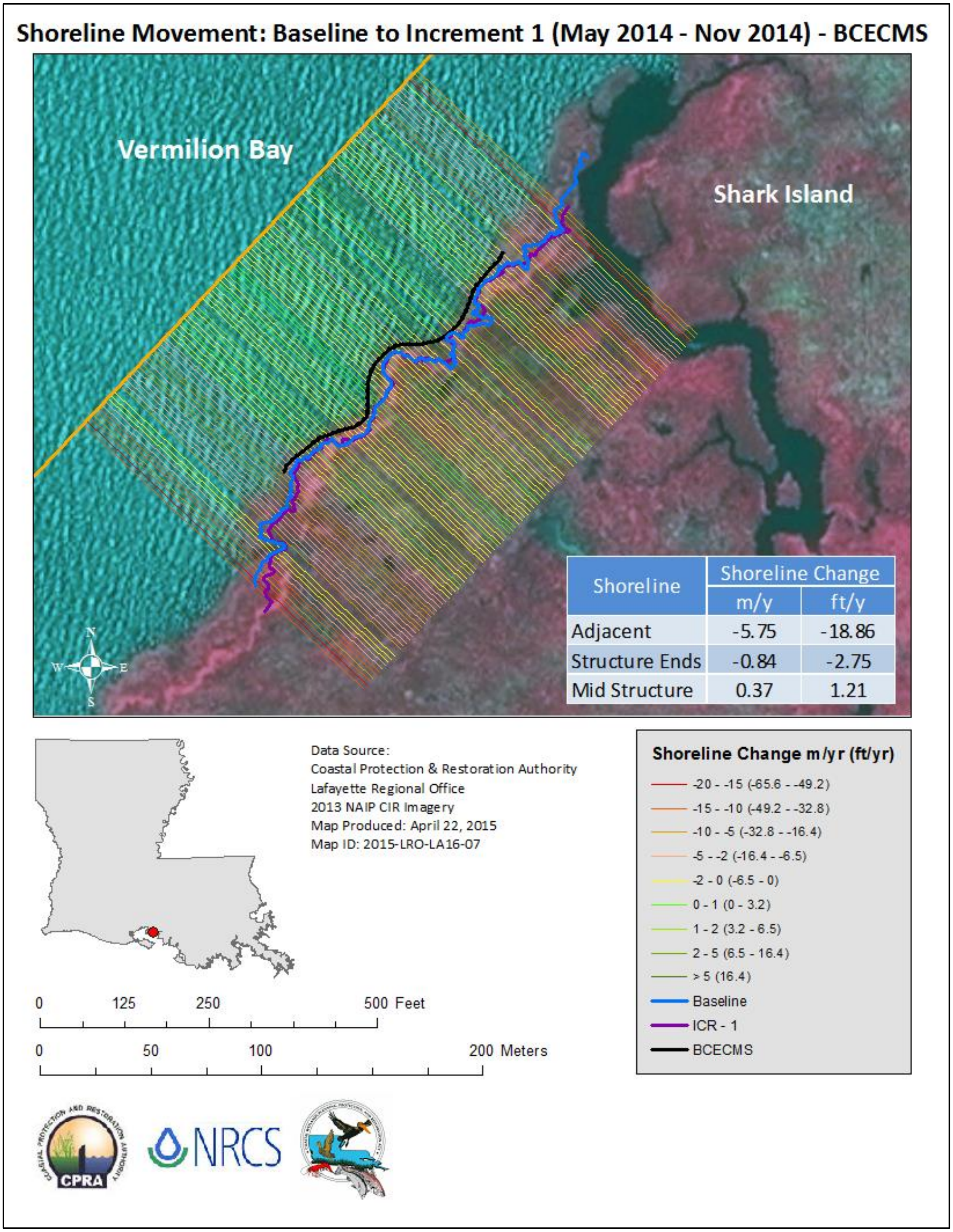
United States Department of Agriculture
Natural Resources Conservation Service

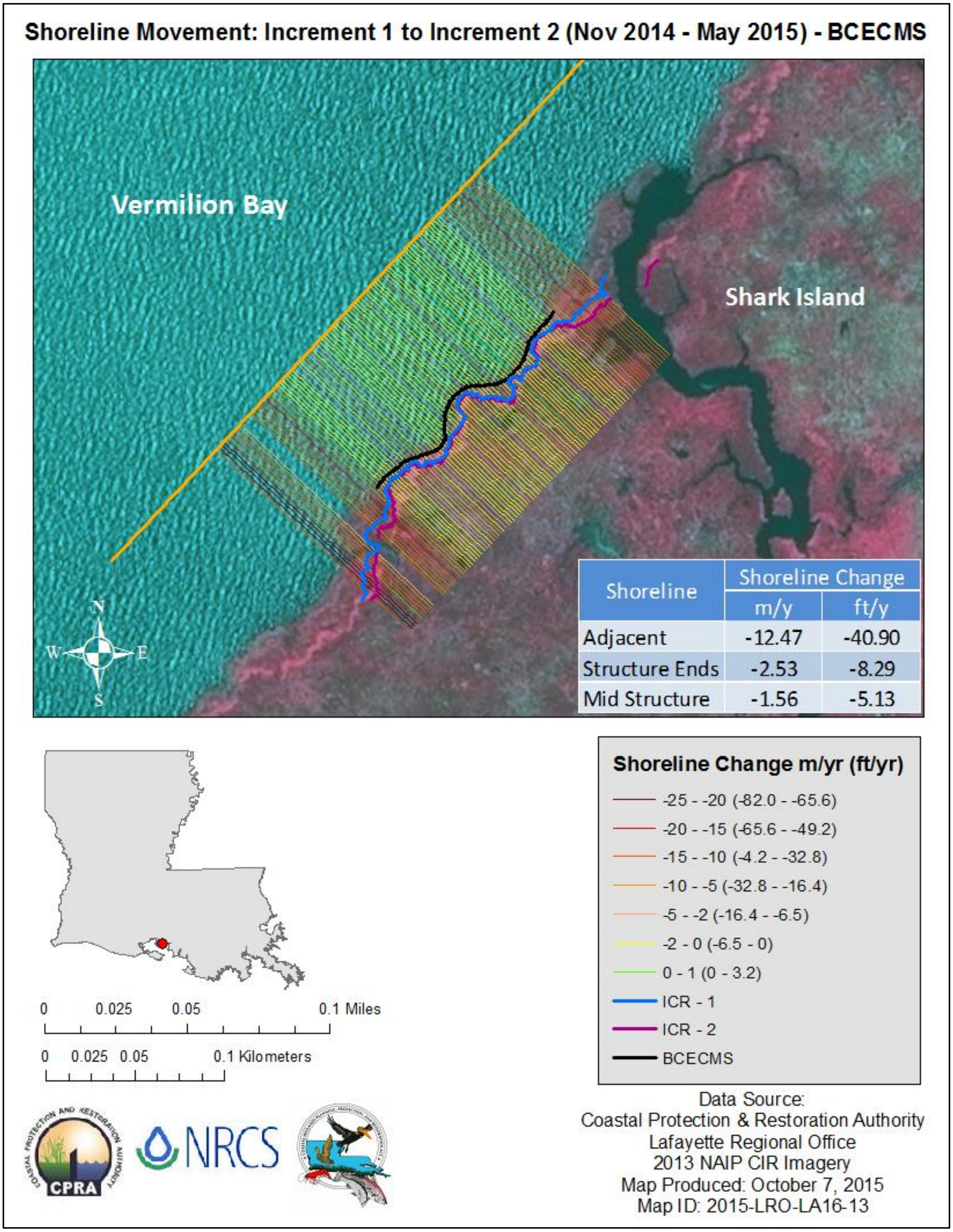
FILE NAME
JANSEN MONT.
DRAWING NAME
JANSEN ICR 6

SHEET 05 of 05

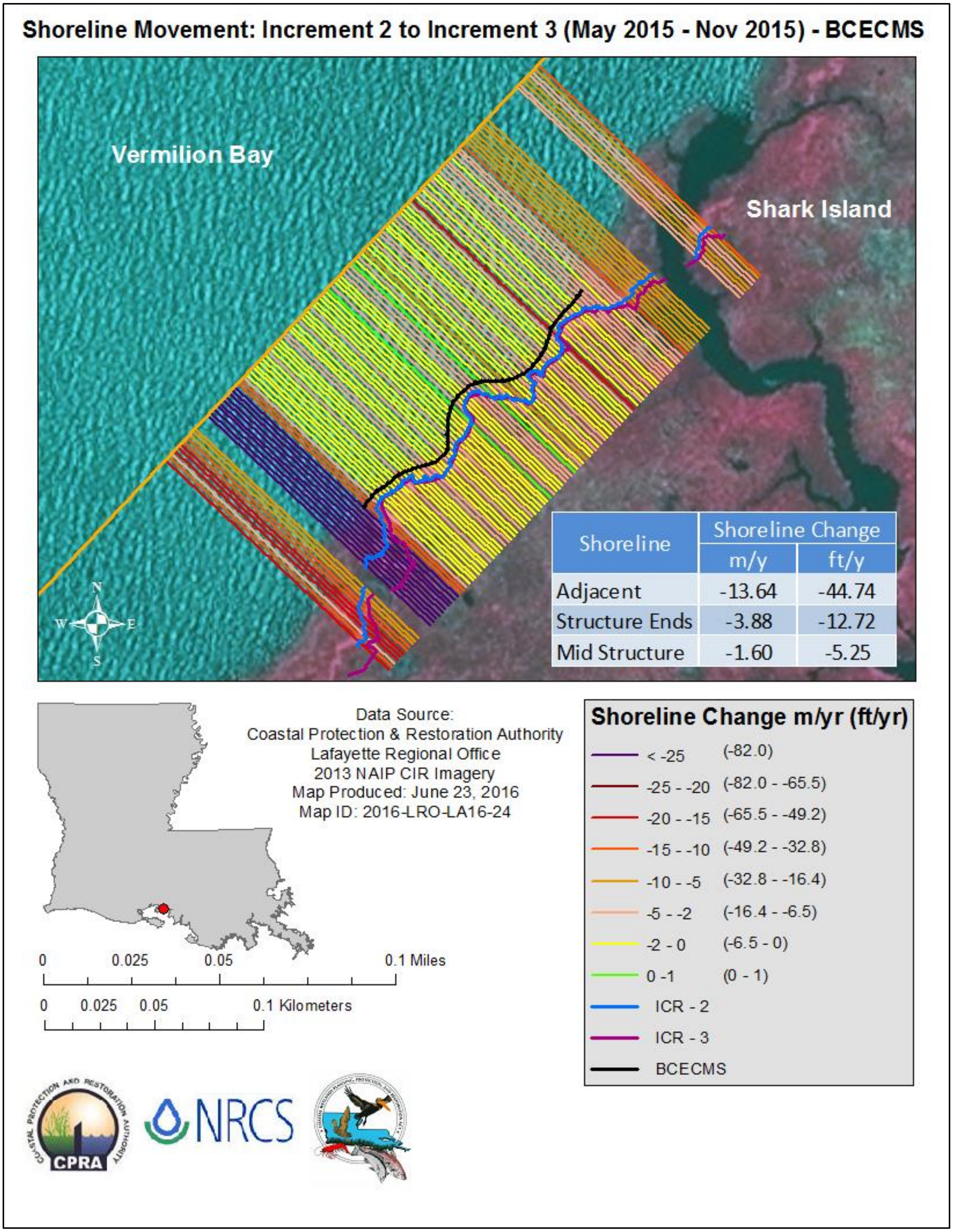
# APPENDIX E - 2

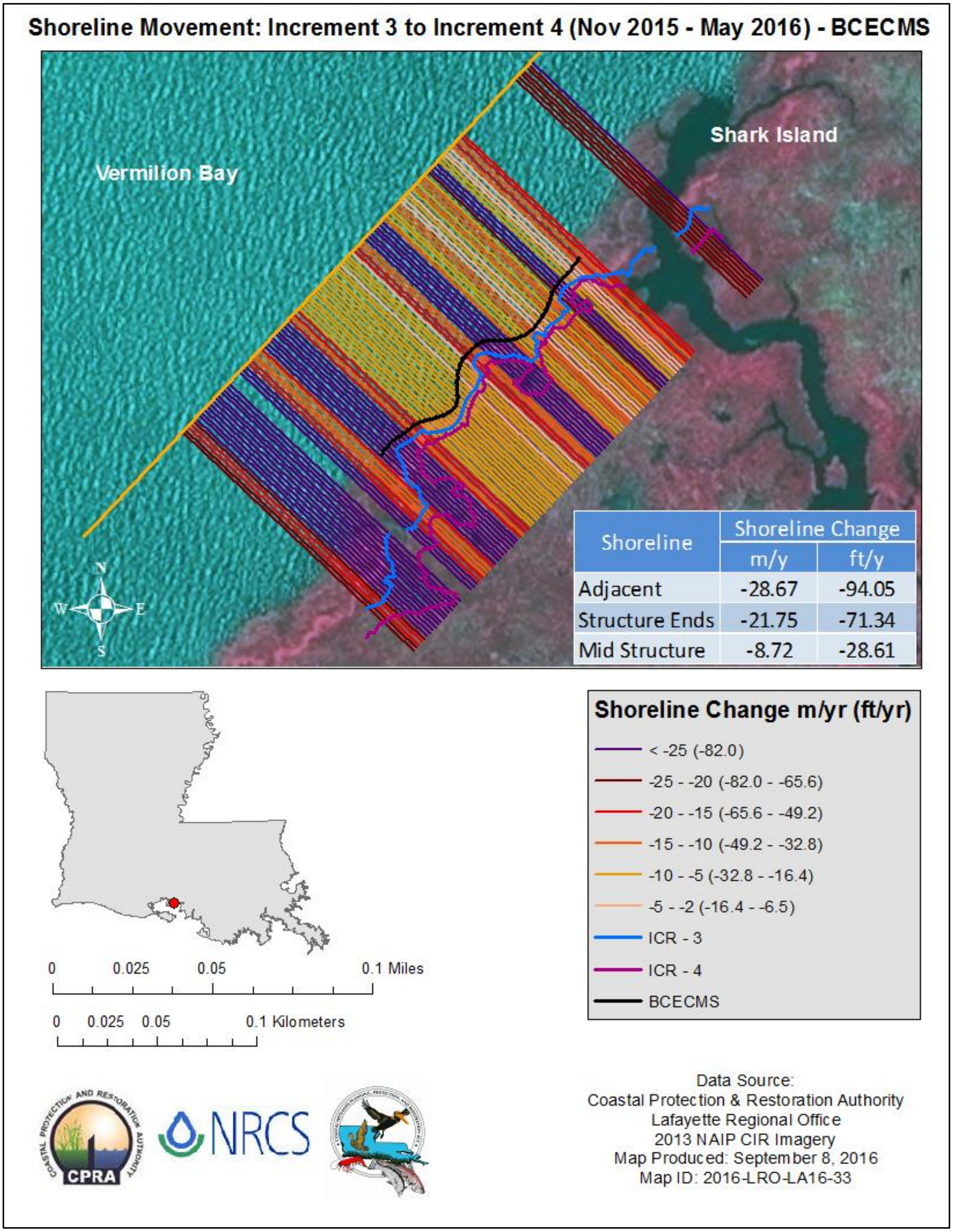
## Incremental Shoreline Change Maps


Shoreline Movement: Baseline to Increment 1 (May 2014 - Nov 2014) - BCECMS
Vermilion Bay
Shark Island
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -5.75 -18.86
Structure Ends -0.84 -2.75
Mid Structure 0.37 1.21
N
W
E
S
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: April 22, 2015
Map ID: 2015-LRO-LA16-07
Shoreline Change m/yr (ft/yr)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 - 3.2)
1 - 2 (3.2 - 6.5)
2 - 5 (6.5 - 16.4)
> 5 (16.4)
Baseline
ICR - 1
BCECMS
0 125 250 500 Feet
0 50 100 200 Meters
CPRA
NRCS



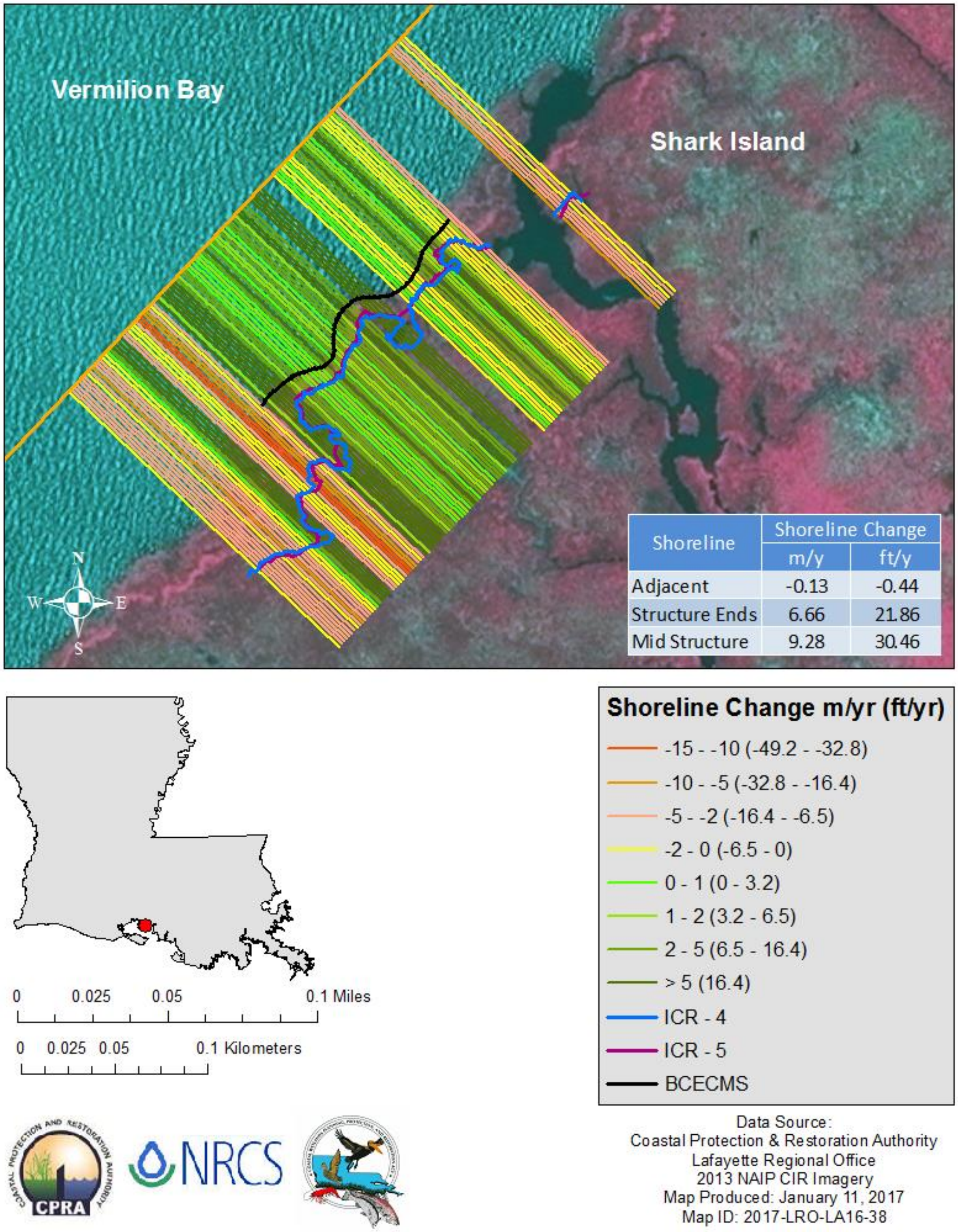

| Shoreline | Shoreline Change | |
|---|---|---|
| | m/y | ft/y |
| Adjacent | -12.47 | -40.90 |
| Structure Ends | -2.53 | -8.29 |
| Mid Structure | -1.56 | -5.13 |

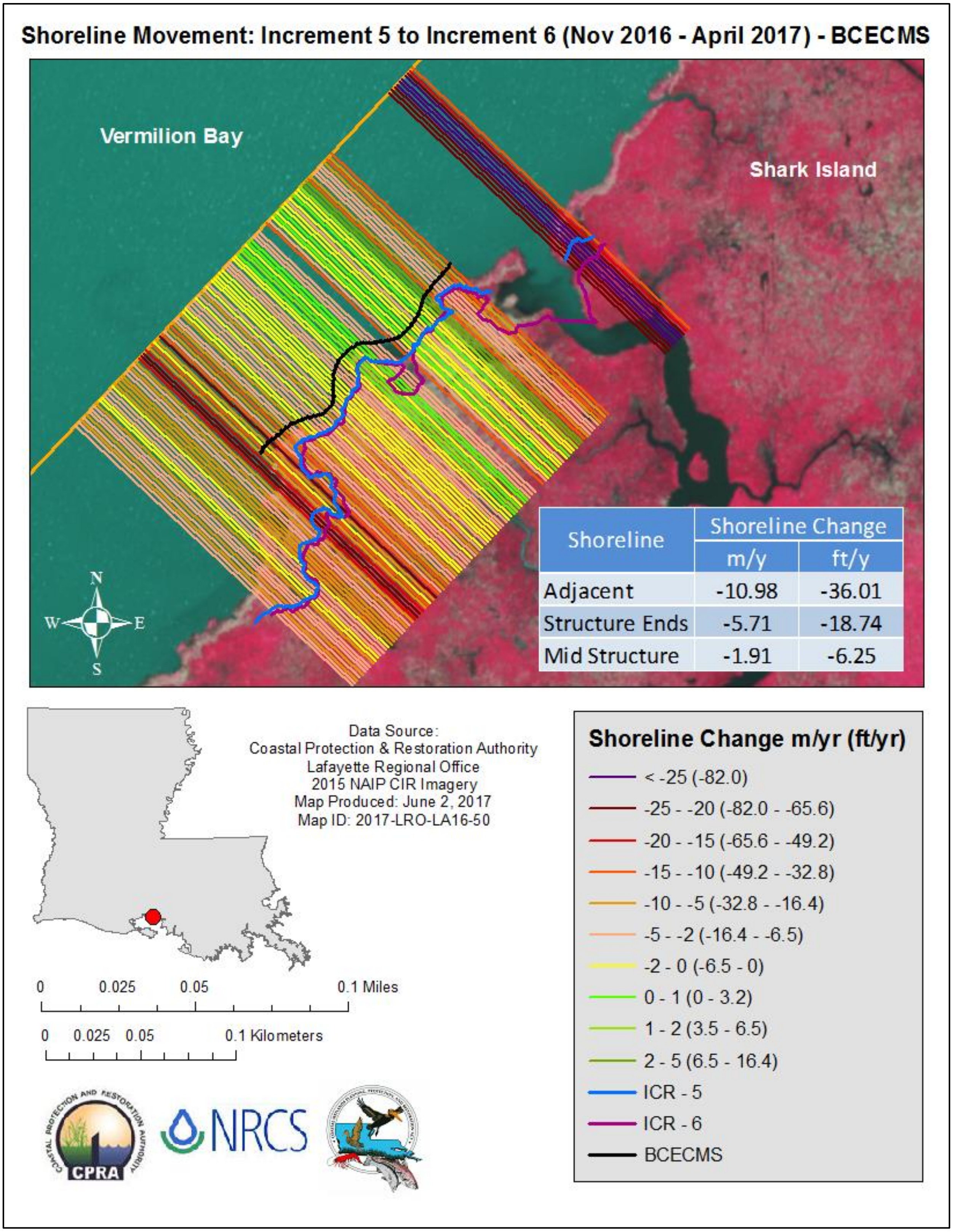

Shoreline Movement: Increment 2 to Increment 3 (May 2015 - Nov 2015) - BCECMS
Vermilion Bay
Shark Island
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -13.64 -44.74
Structure Ends -3.88 -12.72
Mid Structure -1.60 -5.25
N
W
E
S
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: June 23, 2016
Map ID: 2016-LRO-LA16-24
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.5)
-20 - -15 (-65.5 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 -1 (0 - 1)
ICR - 2
ICR - 3
BCECMS
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
CPRA
NRCS



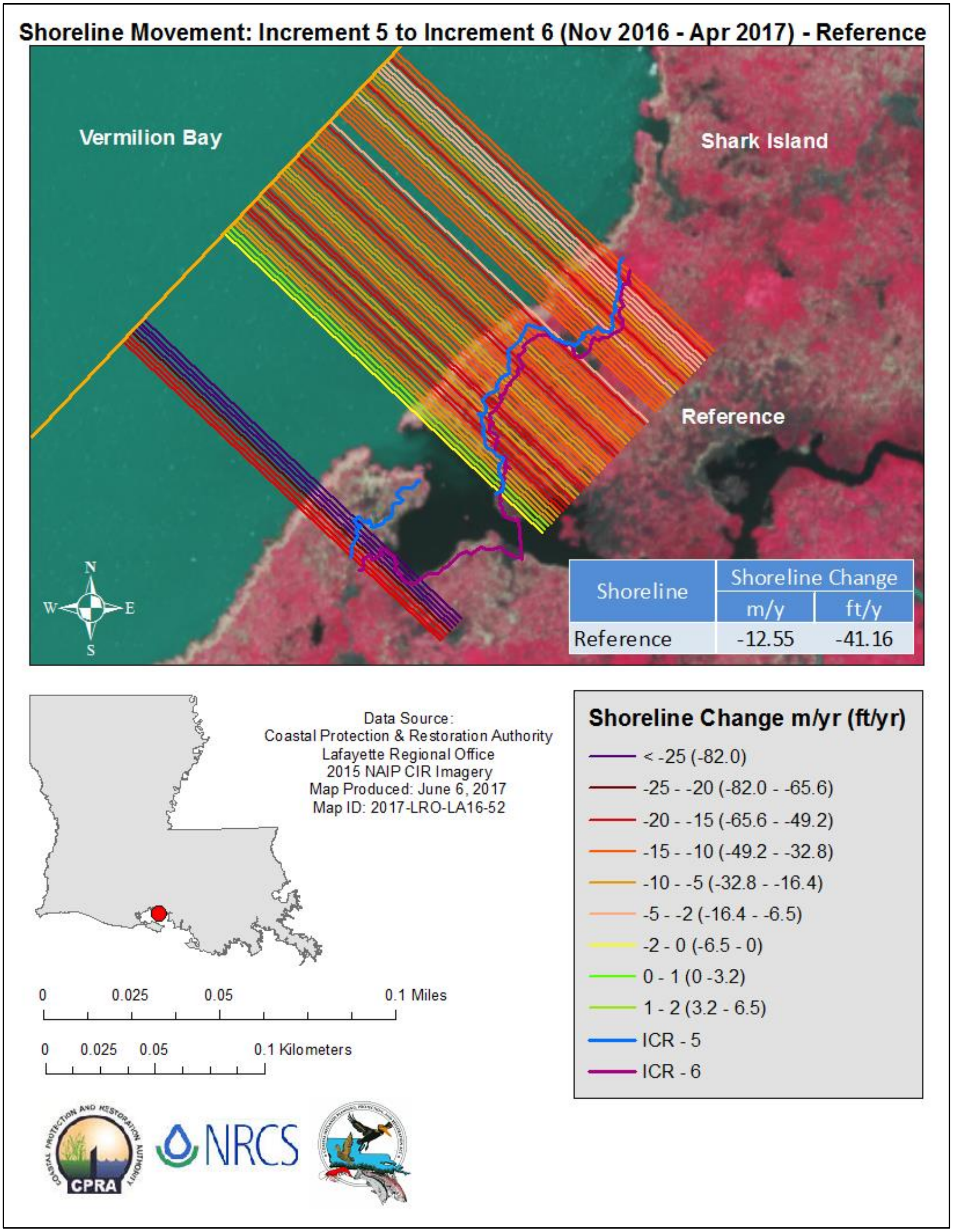
Shoreline Movement: Increment 3 to Increment 4 (Nov 2015 - May 2016) - BCECMS
Shark Island
Vermilion Bay
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Adjacent -28.67 -94.05
Structure Ends -21.75 -71.34
Mid Structure -8.72 -28.61
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.6)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
ICR - 3
ICR - 4
BCECMS
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
NRCS
CPRA
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2013 NAIP CIR Imagery
Map Produced: September 8, 2016
Map ID: 2016-LRO-LA16-33

## Shoreline Movement: Increment 4 to Increment 5 (May 2016 - Nov 2016) - BCECMS






| Shoreline | Shoreline Change | |
|---|---|---|
| | m/y | ft/y |
| Adjacent | -10.98 | -36.01 |
| Structure Ends | -5.71 | -18.74 |
| Mid Structure | -1.91 | -6.25 |


Shoreline Movement: Increment 5 to Increment 6 (Nov 2016 - Apr 2017) - Reference
Vermilion Bay
Shark Island
Reference
N
W
E
S
Shoreline
Shoreline Change
m/y
ft/y
Reference
-12.55
-41.16
Data Source:
Coastal Protection & Restoration Authority
Lafayette Regional Office
2015 NAIP CIR Imagery
Map Produced: June 6, 2017
Map ID: 2017-LRO-LA16-52
Shoreline Change m/yr (ft/yr)
< -25 (-82.0)
-25 - -20 (-82.0 - -65.6)
-20 - -15 (-65.6 - -49.2)
-15 - -10 (-49.2 - -32.8)
-10 - -5 (-32.8 - -16.4)
-5 - -2 (-16.4 - -6.5)
-2 - 0 (-6.5 - 0)
0 - 1 (0 -3.2)
1 - 2 (3.2 - 6.5)
ICR - 5
ICR - 6
0
0.025
0.05
0.1 Miles
0
0.025
0.05
0.1 Kilometers
CPRA
NRCS