CEPRA Beach Monitoring Phase 8
Surveys and Analysis: 2017 Monitoring Year
Volume 2

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Conrad Blucher Institute for Surveying and Science
Texas A&M University-Corpus Christi
6300 Ocean Drive, Unit 5799
Corpus Christi, Texas 78412

Principal Investigator: Ms. Deidre D. Williams
361-825-2714 **FAX:** 361-825-5704
Deidre.Williams@tamucc.edu

CEPRA beach locations monitored during 2017

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Introduction

The CEPRA Beach Monitoring Program provides a comprehensive assessment of beach status over the annual reporting period, key temporal periods of interest, as well as relative to nourishment/dune restoration efforts and storm damage. The project goal is to monitor CEPRA beach nourishment/restoration sites along the Texas Coast and provide an assessment that supports TGLO resource management decisions that are defined in the Beach Monitoring and Maintenance Plan (BMMP). The analysis and guidance provided by this program supports research-based management of these beach resources. Annual beach profile and shoreline position (MHHW) surveys were conducted at eleven (11) CEPRA beach locations during 2017 (Fig. A1). The timing of contract authorization coincided with the landfall of Hurricane Harvey and therefore the annual survey at each CEPRA beach was applied as the post-storm survey.

This report serves to document the surveys and analysis conducted at each CEPRA beach site and provides a summary of the findings to include 1) average rate of shoreline change over study period, 2) estimated beach volume change (Erosion rate as applicable), and 3) Beach Width (relative to Action Width and Target Width). Recommendations for maintenance tasks including nourishment and dune restoration are provided for guidance based on these assessments. The report serves as a guide to allow TGLO staff to prepare for future beach nourishment/restoration where analysis to date indicates potential need within 1 to 5 years. For additional historic information, Williams (2009, 2013-2016) discusses detailed analysis over previous reporting periods (2007-2009, 2007-2012/2013, 2012/2013-2014, 2014-2015 and 2016-2017). Reporting is provided in two volumes with Volume 1 documenting the status of CEPRA beach locations that were not recommended for FEMA review after Harvey. Volume 2 provides the reporting for the seven (7) CEPRA beaches that were recommended for FEMA review after the initial post-Harvey assessment.

CEPRA Beach Surveys

The following sections provide a summarization of analysis over the reporting period (2016 to 2017) as well as historic data for ease of reference. The surveys were initiated late in the summer season and therefore served as both the annual survey and post-storm survey. The date of each survey as well as previous survey dates are provided in Table A1. Two types of surveys were conducted at all sites; 1) shoreline position surveys at MHHW and 2) beach profile surveys. An additional backshore survey was conducted at six beaches to allow for a more detailed documentation of the backshore limit of the beach at sites without well-defined dunes, or anthropogenic limiting structures. In most cases these sites are areas in which active dune restoration is in process or backshore erosion during periods of inundation occurs regularly. Backshore surveys were conducted at, Caplen Beach, Gilchrist Beach, Indianola Beach, Jamaica Beach and Sargent Beach. These surveys provide for the re-evaluation of the functional beach width that is applied to estimate fill volume for nourishment and to document change in backshore limits at these dynamic beach locations with a history of severe backshore and dune erosion.

Data from the survey suites are applied to determine the rate of shoreline change at each beach and also volumetric change where applicable historic data is available. All elevations are reported relative to NAVD88 (U.S. feet). Surveys were conducted by Naismith Marine Services Inc. under the direction of Mr. Jim Naismith and Mr. Seth Gambill, in coordination with CBI. Mr. Naismith reviewed control data and providing review of historic data (performed by entities other than CBI) at each CEPRA beach site to allow for comparative analysis by CBI. Details related to survey protocol are provided in the SOW supplied with the original proposal package.

Comparing shoreline position change over time provides a useful tool for determining the relative stability of a beach. The position of Mean Higher High Water (MHHW) was measured at each beach during the beach profile survey. MHHW was determined at each location through occupation of local control at the closest NOAA tide station. Shoreline recession or advance can be interpreted quickly from this data and hot spots of erosion can be identified or targeted for further investigation. Recession is defined as the landward shift of the shoreline indicating either localized or widespread erosion of the berm and thus narrowing of the beach. Shoreline advance is defined as the seaward migration of the shoreline indicating widespread or localized accretion and thereby an increase in the beach width relative to a specified datum. For each CEPRA beach location, the MHHW shoreline position provides the most conservative estimate of beach width but is only effective as an interpretive tool when combined with beach profile data documentation of the volume and elevation of the berm and duneline. Beach width is reported as the distance from the land limiting feature (seawall, dune toe, vegetation line, sand fencing, revetment or sidewalk) that is unique at each CEPRA Beach location to the position of MHHW. This landward limit established in the original surveys is applied during each successive survey unless otherwise noted. The beach might actually be wider or narrower on any given day dependent on water level, storm surge and wind forcing. This conservative estimate of shoreline position, and thus beach width, provides guidance for local management concerns that are on a shorter temporal scale, particularly where vehicular access or storm impact to backshore infrastructure where a concerns, as well as for small beaches where moderate change in shoreline position can result in substantial impact to the recreational area of the beach.

The rate of shoreline change relative to storm events and beach nourishment activities is provided for each beach where applicable. In addition, the maximum and minimum distance of advance and recession is provided to indicate the degree of alongshore variability. The average rate of shoreline change was calculated applying the end point method to support comparison to BEG shoreline data. Although shoreline position surveys provide valuable insight into localized change that may be indicative of erosion or accretion, this method does not take into account the following; 1) focused erosion and volume change along the backshore and duneline, 2) changes across the immediate nearshore and 3) changes in berm and dune elevation. Therefore, shoreline position change is applied in tandem with beach profile surveys. Together these data provide for a comprehensive assessment, particularly at beach sites with coastal structures such as groins, breakwaters, jetties and inlets because trends in sediment transport may be complicated by the influence of these structures.

Beach profile surveys are conducted to document change across the beach between the landward and offshore limit of sediment exchange. Beach profile surveys were conducted along a regularly spaced, repeatable grid recommended by the TGLO Beach Monitoring and Maintenance Plan (BMMP) at each beach according to the schedule in Table A1. Historic transect locations have been occupied where applicable and based upon analysis the grids were adjusted as recently as the 2014 survey to enhance future analysis capabilities. Existing survey data obtained from other sources was referenced qualitatively where applicable, although quantitative analysis was limited to the surveys conducted by CBI during 2007-2017 due to local changes at CEPRA beaches that limited confirmation of local control that had been applied during the pre-existing surveys by other entities. Change in beach volume was calculated using the average end area method.

Survey data collected by CBI during the 2017 survey year is available for online review through the Coastal Habitat Restoration GIS (CHRGIS) mapping tool and beach profile tool (http://cartogram.tamucc.edu/chrgis/maps/ and http://cartogram.tamucc.edu/chrgis/profiles/). All historic data collected by CBI is available for review on CHRGIS and historic data is provided for reference although CBI is not responsible for the accuracy of the data collected outside of the monitoring program. The CHRGIS Profile Tool provides an online interface for the comparison and query of beach profile data. Plots comparing historic beach profile data and shoreline position data are provided in Appendix A.

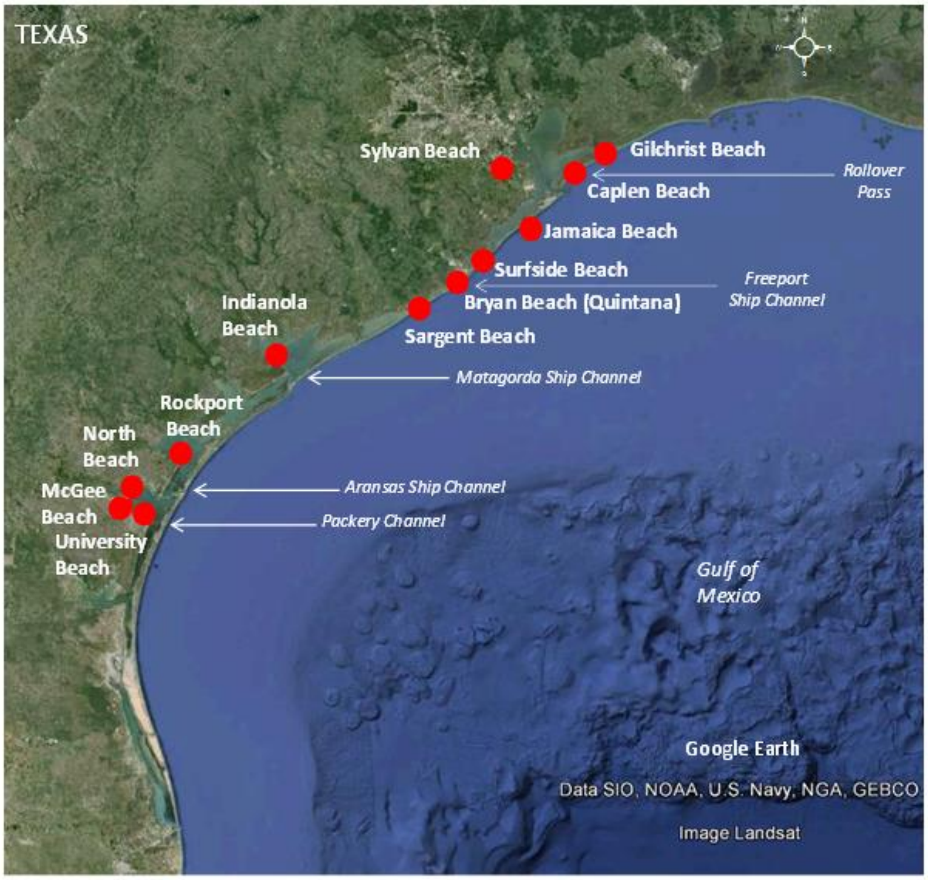

Figure A1. CEPRA bayside and Gulf beaches monitored during 2017

Aerial Imagery

Aerial imagery was applied for the interpretation of changes in vegetative coverage and adjacent regions that may influence the stability of the beach but are located outside of the active survey grid. Post-Harvey aerial imagery was provided by the TGLO during the reporting period. Additional imagery was obtained from the China National Space Administration (CNSA) as well as TNRIS Google imagery and NAIP sources. The images applied were selected based on temporal agreement and adequate resolution. The source and date of the aerial imagery applied at each CEPRA Beach location for the 2017 reporting period is provided in Table A2. The aerial photographs applied in the reporting are available for viewing using the Coastal Habitat Restoration GIS (CHRGIS) mapping tool.

Coastal Habitat Restoration GIS (CHRGIS)

Coastal Habitat Restoration GIS consists of a website and online mapping tools that support resource managers in accessing and reviewing coastal data sets, in particulate beach profile, shoreline position, topography, bathymetry and aerial imagery. All data described in the following report can be visualized and compared and queried using the Mapping Tool (planview) and the Profile Tool (cross section). The CHRGIS Mapping Tool was upgraded to HTML5/JavaScript during 2017 and now supports all current browsers and functions on mobile devices. The link to the website, Mapping Tool and Profile Tool are:

https://cbi.tamucc.edu/CHRGIS/
http://cartogram.tamucc.edu/chrgis/maps/
http://cartogram.tamucc.edu/chrgis/profiles/

Nourishment Criteria

Beach nourishment is recommended when the beach or individual beach cell within a larger beach system reaches 50% of the Target or recommended width or if the rate of shoreline recession indicates 50% of the beach will reach the Action Width within 2 years. Recommendations may also be based on other maintenance triggers that are more specific to each beach such as dune restoration (Jamaica Beach) and sand redistribution to restore nearshore depth (University Beach). A detailed list of Target Width, surveyed width and associated Action Width (width at which nourishment is recommended within 1 to 2 years) for each beach is given in Table 3A and in a table within the narrative assessment section for each beach. With that said, each beach in the monitoring program is unique with often subtle differences in location/orientation along the coast, coastal structures, size, grain size, and influence of primary forcing mechanisms (wind waves, open ocean waves, vessel wake, aeolian transport). Therefore, individualized guidance is provided to accommodate the wide range of issues associated with each location and these alternative guidelines are updated during future annual surveys.

Recommendations

Recommendations for action at the monitoring sites were separated into three Tiers based upon analysis of change over the period for which data was available (Table A4-A5). Recommendations are based on Tiers defined as:

- Deferred: In cases where a beach has been recently nourished within 1 year of the survey date or a nourishment is planned to initiate within 1-year of the survey (Not Applicable 2017)
- Tier 1 Beaches: widespread erosion or hot spots where infrastructure is threatened, Action Width has been reached or is anticipated within 2 years, or widespread dune restoration is ongoing. Initiation of planning toward action is recommended within 1-year. Action is recommended at Tier 1 Beaches within 1-2 years.
- Tier 2 Beaches: special considerations such as limited erosion isolated to hot spots (Rockport Beach), recent nourishment (Multiple locations), or nearshore depth restriction (University Beach).
- Tier 3 Beaches: relatively stable over the available survey history but may require action within 5 years. Annual surveys are recommended to determine if a change in status is warranted. (Not Applicable 2017)

Recommendations are revised annually upon review of additional survey data.

Table A1. Aerial Imagery: Date and Source			
CEPRA Locations	**Source of Aerial Images**	**Date of Aerial Images**	**Additional Information**
Bolivar Peninsula	**Sanborn Aerial**	**9 Sep2017**	**Upper coast post-Harvey**
Indianola Beach	**Sanborn Aerial**	**9 Sep 2017**	**Upper coast post-Harvey**
Jamaica Beach	**Hurricane Harvey: Emergency Response Imagery of the Surrounding Regions**	**Aug 2017**	**Limited metadata: month/year only**
McGee Beach	**Texas Imagery Service**	**30 Aug 2017**	**N/A**
North Beach	**Texas Imagery Service**	**30 Aug 2017**	**N/A**
Bryan Beach (Quintana)	**Hurricane Harvey: Emergency Response Imagery of the Surrounding Regions**	**Aug 2017**	**Limited metadata: month/year only**
Rockport Beach	**Texas Imagery Service**	**30 Aug 2017**	**N/A**
Sargent Beach	**Hurricane Harvey: Emergency Response Imagery of the Surrounding Regions**	**Aug 2017**	**Limited metadata: month/year only**
Surfside Beach	**Hurricane Harvey: Emergency Response Imagery of the Surrounding Regions**	**Aug 2017**	**Limited metadata: month/year only**
Sylvan Beach	**Hurricane Harvey: Emergency Response Imagery of the Surrounding Regions**	**Aug 2017**	**Limited metadata: month/year only**
University Beach	**Texas Imagery Service**	**30 Aug 2017**	**N/A**
Notes: https://storms.ngs.noaa.gov/storms/harvey/download/metadata.html https://tnris.org/texas-imagery-service/			

Table A2. CEPRA Beach Action and Target Width Criteria 2017

*** Project area within larger study area**
^ Post-Nourishment
Note: At or within 10 ft of Action Width (50% Target)

Beach Name	Target Width (ft) (MHHW)	Survey Width Minimum (ft)				Action Width (ft)	Additional Criteria/ Status
Bolivar Peninsula Gilchrist Beach	Historic		**2015**	**2016**	**2017**		**Gilchrist Recommended:**
Jetty to 130+0	120		127-158	130-149	115-168	60	Stable
135+0 to 155+0	120		96-120	93-117	102-125	60	Continue Dune Reinforcement
160+0 to 200+0	120		74-104	72-115	86-114	60	
Caplen Beach							**Caplen Completed:**
Jetty 115+0 to 120+0	120		40-62	20-52	16-25	60	BUDM Feb 2015
110+5 to 105+0*	120		5-73	39-79	16-70	60	BUDM Dec 2016
100+0 to 75+0*	120		64-115	66-98	55-108	60	BUDM Apr 2018
West 20+0 to 70+0	120		46-118	45-99	33-100	60	
West 15+0 to 0+0	120		76-98	70-78	70-73	60	
Indianola Beach	**Design (75 ft)** (MLLW)		**2015 Min**	**2016 Min**	**2017 Min**		**Recommended** Nourishment Cells 1-4 and 7
Cell 1	70		15	15	6	35	**Nourishment: July 2017**
Cell 2	70		18	18	15	35	**Harvey Damage: Renourishment** Cell 7
Cell 3	70		20	13	5	35	
Cell 4	70		38	21	16	35	
Cell 5	70		69	57	45	35	
Cell 6	70		60	44	42	35	
Cell 7	70		63	40	45	35	
Cell 8	70		60	60	60	35	
Cell 9 (Open cell)	NA		N/A	N/A	N/A	N/A	
Jamaica Beach		**2014**	**2015**	**2016**	**2017**		**Recommended**
STA 385+00	120	114	107	86	86	60	Continued dune reinforcement
STA 390+00	120	132	129	98	110	60	
STA 395+00	120	159	154	122	140	60	
STA 400+00	120	137	129	97	113	60	No need for additional nourishment indicated
STA 405+00	120	126	124	92	107	60	
STA 410+00	120	111	107	82	90	60	
STA 415+00	120	122	117	92	98	60	
STA 420+00	120	91	91	66	66	60	
STA 425+00	120	88	82	46	65	60	
McGee Beach	**Record Max 2007**		**Min. 2015**	**Min. 2016**	**Min. 2017**		**Recommended** Relatively Stable Recommendation: South end spot nourishment or redistribution to restore width near multiple structures
South End (Holiday Inn)	100		68	78	62	50	
Central Section	220		184	184	190	110	
North End	240		208	200	200	120	

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Table A2. CEPRA Beach Action and Target Width Criteria 2017

*** Project area within larger study area**
^ Post-Nourishment
Note: At or within 10 ft of Action Width (50% Target)

Beach Name	Target Width (ft) (MHHW)	Beach Width (ft)				Action Width (ft)	Additional Criteria/ Status
North Beach			**2015**	**2016**	**2017**		**Nourishment:**
SWest End at Lex							**April 2016**
STA 2 to STA 6	120		4-60	95-155	67-98	60	Nourishment and
STA 7 to STA 12	100		85-96	164-177	95-160	50	infrastructure
STA 14 to STA 22	100		23-99	92-148	81-143	50	restoration
Beach Parks							
Golf Place (STA 14)	100		23	92	81	50	**Recommendation**
Burleson (STA 24)	100		37	82	78	50	Post-Harvey
Surfside (STA 32 -36)	100		55	70	70	50	FEMA
Gulfspray (STA 46)	100		105	89	95	50	Reimbursement
East End (STA 70)	100		195	103	125	50	**Status** Review IP
Quintana:	**Design** 2005 150 (Max)		**2015**	**2016**	**2017**		**Recommended:** Nourishment/ dune restoration
Bryan Beach							
-25+0 to -5+0	N/A		127-194	95-158	85-144	75	**Nourishment**
0+0*	150		144	155	120	75	Completed
5+0*	150		80	79	60	75	Feb 2016
10+0*	150		76	79	50	75	
15+0*	150		76	72	48	75	
20+0*	150		76	68	39	75	
25+0	150		78	59	32	75	
30+0	150		94	54	39	N/A	
35+0	150		80	45	27	N/A	
Rockport Beach	**Record Max 2007**		**2015**	**2016**	**2017**		**Nourishment Completed:** Jan 2016
East End	80		34-60	70-85	72-105	40	
Center, East and West	100		81-101	90-99	90-99	50	**Stable 2016**
Park Facility	170		168	168	168	85	
West End	80		42-58	47-66	55-72	40	
Sargent Beach	**Revised 2014 (120ft)**	**2014**	**2015**	**2016**	**2017**		**Recommended** Cyclic(Biannual) Nourishment
(STA-25+0-STA -15+0)	N/A	60-87	37-58	21-40	0-25	N/A	
(STA -10+0 -STA 10+0)	N/A	92-101	62-63	28-40	(-6)-28	N/A	
STA 15+0	200	72	54	47	19	100	Consistent high rate of
STA 20+0	200	92	62	40	24	100	erosion
STA 25+0	200	101	63	40	23	100	**Project Area:**
STA 30+0*	200	117	94	54	41	100	-87 cy/ft
STA 35+0*	200	135	127	90	70	100	**Study Area:**
STA 40+0*	200	139	134	87	71	100	-108 cy/ft
STA 45+0*	200	118	99	97	53	100	
STA 50+0*	200	104	90	67	33	100	
STA 55+0	200	107	94	59	35	N/A	**Exposures**
STA 65+0	200	99	96	65	48	N/A	***West:***
STA 70+0 to STA 95+0)	N/A	84-119	102-152	58-95	45-72	N/A	Clay substrate
(STA 100+0-STA 125+0)	N/A	11-94	7-91	(-8)-96	(-19)-32	N/A	**Central:**
							Concrete
							East:
							Revetment

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Table A2. CEPRA Beach Action and Target Width Criteria 2017
*** Project area within larger study area**
^ Post-Nourishment
Note: At or within 10 ft of Action Width (50% Target)

Beach Name	Target Width (ft) (MHHW)	Beach Width (Ft)				Action Width (ft)	Additional Criteria/ Status
Surfside Beach	**Design 2011**	**2015**	**2016**	**2017**			**Recommended: Nourishment**
West End Jetty to -5+0	125	39-71	11-38	5-7		63	Alternatives under review by GLO
Revet(W) 0+0 to 15+0*	125	(-14)-34	(-27)-16	(-57)-0		63	
Revet(C) 20+0-30+0*	125	49-72	22-40	10-23		63	
Revet(E) 35+0* E.	125	121	83	66		63	
40+0-75+0	N/A	93-157	75-130	75-130		N/A	
East end 80+0-105+0	N/A	100-124	65-79	65-79		N/A	
Sylvan Beach	Design 2009	**2014**	**2015**	**2016**	**Oct 2017**		**Partial Nourishment:** Completed May 2017
North Cell							
South End	75	33	30	20	45	37	
Mid-Point S-C	75	32	25	13	30	37	**Recommended:**
Center	75	70	62	48	50-72	37	Full Nourishment to design specification within 2 years. Interim nourishment on south end to restore volume lost during Harvey within 1year
North End	75	107-148	94-130	81-126	95-125	37	
South Cell							
South End	75	40	37	28	59	37	
Mid-Point S-C	75	33	48	19	46	37	
Center	75	70	60	49	49	37	
North End	75	103-141	89-123	78-119	91-119	37	
University Beach	**Design Width 2001**	**2015**	**2016**	**2017**			**Recommended** -Depth Limited -Mechanically redistribute sand from nearshore
West (IR9-IR11)	150	118-175	120-180	105-175		75	
Center (BR2-BR4)	150	104-124	108-130	100-127		75	
East (IR4-IR6)	150	108-118	122-129	117-126		75	

Table A3. Status and Recommendations (2017)
List in order of Relative Priority

Tier 1. Implement Action Within 1-2 years

Beach	Action Width	Area of Concern	Threat to Backshore Infrastructure	Rate of Shoreline Change	Status/ Recommendation
1. Sargent Beach	✓	**Action Width:** **Project Area** STA 15+0 to 50+0 100% of beach in the project area and along the entire study area to the east and west is at or less than the Action Width **Exposures:** ***West*** Clay Substrate (Variable) ***Central/West*** Concrete (Foreshore) ***East*** Revetment (MHHW)	**Imminent** Access, Park Facilities Shoreline is at or approaching revetment east of the project area STA 15+0 to STA -25 Due to erosion of berm and erosion exposing revetment, public access is limited east of FM 457	**Recession ft/yr** **Project Area** -26.7 (2016-2017) -20.6 (2015-2016) -11.5 (2014-2015) **Full Study Area** -27.0 (2016-2017)	**Nourishment** Project Area *(STA 15+0 to 50+0)* **Estimated volume:** **As-Built (120 ft wide)** 201,500 cu yd (> 2X 2016 estimate) ***> Width (200 ft wide)*** 437,500 cu yd ***Add 1,500 ft alongshore to East*** **As-Built (120 ft)** +99,000 cu yd **> Width (200 ft)** +133,000 cu yd
2. Surfside Beach	✓	Narrow beach along revetment and shoreline recession landward of west end of revetment **Action Width** **Project Area** (STA -5+00 to 37+5) 100% at Action Width Revetment STA 0+0 to STA 30+0 100% at Action Width No Beach STA 0+0 to 15+5 Rock reinforcement exposed -5+0 to revetment	**Imminent and Persistent** High historic rate of erosion and recession Limited beach fronting west end of the revetment	**Recession ft/yr** **2016-2017** **Post Harvey** -15.0 **Project Area** -15.2 Study Area **Historic Recession** **Project Area** **-5.0** **2012-2017** -7.0 (2007-2017) -5.5 (2000-2017)	**Recommendation:** **Nourishment** ***Project Area:*** STA -5+0 to STA 37+5 329,000 cu yd ***Revetment Only*** 0+50 to 35+0 250,000 cu yd ***Previously Defined Project Area*** **STA 5 to STA 20** **(for ref.)** 120,000 cu yd **Pending Project** Groins/Nourishment in planning stages as per GLO

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Table A3 Continued. Status and Recommendations (2017)
List in order of Relative Priority

Tier 1. Implement Action Within 1-2 years

Beach	Action Width	Area of Concern	Threat to Backshore Infrastructure	Rate of Shoreline Change	Status/ Recommendation
3. Bryan Beach (Quintana)	✓	Highest rate of recession identified along Project Area and to the to the east and west of the project area over data record (2007-2017) including post-Ike Erosion focused across entire berm Action Width: 90% of project area is at or < Action Width Exception is beach fronting	Threat highest fronting S Lake Dr. Decreasing width of beach increases potential for storm damage to backshore and duneline	**Recession ft/yr** ***Project Area*** -31.0 (2016-2017) -13.4 (2015-2016) ***Full Study Area*** -32.0 (2016-2017) -16.6 (2015-2016)	**Recommendation** Nourishment to Target Width Due to high rate of recession historically and narrow beach at or ±5 ft of Action Width during 2015 and 2016 and less than Action Width during 2017 **Project Area** STA 0+0 to STA 20+0 Fill volume 110,000 cu yd **Nourishment Completed: Mar 2016** BUDM
4. North Beach	✓ 40% of beach fronting Parking Lot at southwest end at Action Width	Beach in Front of City Parks narrow due to focused erosion along the southwest side of the beach that is reinforced by inadequate setback of facilities	Lack of dunes,low elevation along backshore and inadequate setback of facilities and businesses provide for inland damage during periods of high water and onshore forcing	**Recession ft/yr** Erosion Focused on Southwest Side **Post-Harvey Southwest Side** -14.5 **Full Study Area** Pre Post Nourish +6.4 2015-2016 -6.2 (2014-2015) -12.2 (2009-2012) Post-Nourish -9.0 (2007-2016) Pre-Nourish -9.0 (2007-2015)	**Recommendation:** Nourishment of at a minimum of the southwest end fronting the Parking Lot at Lex **Alternative #1** **STA 2+0 to STA 5+0** 31,300 cu yd **Alternative #2** **STA 2+0 to STA 8+0** 24,000 cu yd **Alternative #3** **STA 2+0 to STA 14+0** 13,200 cu yd **Increase Action Width** to 70 ft along southwest end to provide opportunity to plan for nourishment due to rapid recession rate

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Table A3. Status and Recommendations (2017)
List in order of Relative Priority

Tier 1. Implement Action Within 1-2 years

Beach	Action Width	Area of Concern	Threat to Backshore Infrastructure	Rate of Shoreline Change	Status/ Recommendation
5. Rockport Beach	100 % of beach exceed Action Width	West End of beach remains narrow (45-55 ft wide)	None Identified Potential for Compromised Public Access	**Recession ft/yr** +2.4 (Harvey) Pre/Post Nourish +6.0 (2015-2016) -0.4 (2014-2015) -0.8 (2007-2015) -1.34 (2007-2012) Post-Harvey position of MHHW influenced by berm erosion	**Recommendation: Annual Assessment Nourishment** recommended to restore the volume and elevation of the berm that was reduced after Harvey (2017) Completed January 2016 Restore post-2016 nourishment volume and berm elevation
6. Sylvan Beach	✓ North Cell: South End	High recession rate continues in both beach cells Persistent focused erosion along south end of each beach cell Storm deposition in nearshore beyond limit of anticipated onshore exchange	Anticipate need for focused placement on south end within 2 years post-nourishment (2017)	**Recession** Avg Rate per month: -2.9 ft/month (North) -1.7ft/month (South) Episodic Event Rate (Nourish to Harvey) -8.7 ft/event (North) -5.1 ft/event (South) Abbrev. Study Period 5-month Rate (May-Oct 2017) -14.5 ft/event (North) -8.5ft/event (South)	**Recommendation** - Restore Target Width and design elevation at North and South Sylvan - Restore volume lost during Harvey along south end of both beach cells as interim restoration until full restoration is funded. **Completed** May 2017 nourishment
7. Indianola Beach	✓	Cells 1-4: < Action Width Cell 7: Net loss of 30% of June 2017 fill volume	Not imminent Nourishment toward restoring Target Width to support longevity of public access	**Variable ft/yr** Highest Rate Observed to date Post-Harvey Cell 1: -13.4 Cell 2: -3.7 Cell 3: -5.4 Cell 4: -4.1 Cell 7: -19.0	**Recommendation** Nourishment Cells 1-4: < AW Cell 7: Restore post-nourishment volume due to net loss sustained during Harvey

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Table A3. Status and Recommendations (2017)
List in order of Relative Priority

Tier 1. Implement Action Within 1-2 years

Beach	Action	Area of Concern	Threat to Backshore Infrastructure	Rate of Shoreline Change	Status/ Recommendation
8. Bolivar Peninsula **Caplen Beach**	✓	**Action Width:** 40% of Project Area 70% of Study Area **High rate of shoreline recession** after Harvey despite BUDM 2014-2016	Persistent erosion despite multiple frequent BUDM/dune restoration Potential for impact to residential property and public access	**Recession ft/yr** **Project Area** -1.6 Jan 2017 **Full Study Area** -5.33 (2015-Jan2017) -14.3 (2014-2015) -7.7 (2009-2017) -2.8 (2000-2015)	**Recommendation** Continued annual BUDM placement as nourishment and dune reinforcement Supplemental Beach Nourishment to reinforce BUDM

Table A4. Status and Recommendations (2017)					
Tier 2. Implement Action Within 2-3 years					
Beach	**Action Width**	**Area of Concern**	**Threat to Backshore Infrastructure**	**Rate of Shoreline Change**	**Recommendation**
1. Bolivar Peninsula **Gilchrist**	100% > Action Width (2009-2017) 80% < Target Width (2017)	None Identified During 2017	None Identified During 2017	**Recession ft/yr** +3.9 (2016-2017) +0.2 (2015-2016) -11.2 (2014-2015) -2.7 (2000-Jan2017)	**Recommendation:** Although recovery continues the continued support of dune restoration and associated beach nourishment
2. Jamaica Beach	**Project Area:** 100% > Action Width 90% < Target Width **Full Study Area:** 100% > Action Width 80% < Target Width	**Concerns:** No concerns identified during 2017	No imminent threat but Recovering duneline remains low and narrow. Annual assessment are recommended due to high rate of recession during 2016 reporting period	**Recession ft/yr** +12.7 (2016-2017) -23.5 (2015-2016) -2.8 (2014-2015) -4.6 (2013-2016) +1.3 (2000-2016) -1.5 (2006*-2016) *nourishment	**Recommendation:** Continue dune reinforcement due to limited width of duneline, proximity of backshore infrastructure, historic erosion, and recent trend of recession/erosion
3. University Beach	**Depth-Limite Criteria** 100% > Action Width 75% < Target Width	1. Shallow nearshore reduces functionality 2.Shallow nearshore promotes growth of vegetation and potential for wetland development	No imminent threat to infrastructure	**Recession ft/yr** -9.1 (2016-2017) *Highest rate since 2009 tropical season* +3.6 (2015-2016) -3.2 (2001-2016)	**Recommendation:** Redistribute/reclaim sand from inside beach cell to nourish berm and > water depth **Method:** Land-based sand re-distribution Reclaim sand from tombolo Estimated volume of reclaimed sand: 10,000 cu yd

Table A5. 2017 CEPRA Beach Survey Prioritization and Historic Survey Dates
(Revised Dec 2017)
*Application limited by data extent
CBI (Conrad Blucher Institute) NMS (Naismith Marine Surveying)

Bayside Beach Locations		
CEPRA Location	**Anticipated 2018 Survey Date**	**Historic Survey Dates**
North Beach* (previously Corpus Christi Beach)	TBD Revised Upon Contract Authorization	Sep 2007 (CBI-sps City-bps) May 2009 (CBI-NMS) 20 Jun 2012 (CBI-NMS) 22 Jul 2014 (CBI-NMS) 16 Sep 2015 (CBI-NMS) 28 Nov 2016 (CBI-NMS) 06 Sep 2017 (CBI-NMS)
Rockport Beach*	TBD Revised Upon Contract Authorization	Apr 2007 (CBI-NMS) Apr 2009 (CBI-NMS) 29 May 2012 (CBI-NMS) 25 Apr 2014 (CBI-NMS) 15 Sep 2015 (CBI-NMS) 01 Dec 2016 (CBI-NMS) 07 Sept 2017 (CBI-NMS)
Sylvan Beach	TBD Revised Upon Contract Authorization	Apr 2008* Jan 2010 06 Jun 2012 (CBI-NMS) 06 Jun 2013 (CBI-NMS) 15 May 2014 (CBI-NMS) 24 Sep 2015 (CBI-NMS) 30 Nov 2016 (CBI-NMS) 25 Oct 2017 (CBI-NMS)
Indianola Beach	TBD Revised Upon Contract Authorization	Mar 2007 (CBI-NMS) May 2009 (CBI-NMS) 11 Jun 2012 (CBI-NMS) 28 Apr 2014 (CBI-NMS) 17 Sep 2015 (CBI-NMS) 16 Dec 2016 (CBI-NMS) 05 Oct 2017 (CBI-NMS)
University Beach	TBD Revised Upon Contract Authorization	Aug 2001-Aug 2010 (CBI-NMS) 07 Aug 2012 (CBI-NMS) 20 Aug 2014 (CBI-NMS) 03 Nov 2015 (CBI-NMS) 26 Dec 2016 (CBI-NMS) 03 Oct 2017 (CBI-NMS)
McGee Beach	TBD Revised Upon Contract Authorization	Jun 2007 (CBI-NMS) Apr 2009 (CBI-NMS) 01 Jun 2012 (CBI-NMS) 03 Jun 2014 (CBI-NMS) 03 Nov 2015 (CBI-NMS) 26 Dec 2016 (CBI-NMS) 19 Sep 2017 (CBI-NMS)

Table A5. 2017 CEPRA Beach Survey Prioritization and Historic Survey Dates (Revised Dec 2017)
*Application limited by data extent
CBI (Conrad Blucher Institute) NMS (Naismith Marine Surveying)

Gulf Locations		
CEPRA Location	**2017 Survey Date**	**Historic Survey Dates**
Sargent Beach	TBD Revised Upon Contract Authorization	2000 (BEG)* 2008 Nov 2013 (RVE)* 2011 (Coastal Tech.)* 07 Jun 2013 (CBI-NMS) 02 May 2014 (CBI-NMS) 30 Sep 2015 (CBI-NMS) 05 Dec 2016 (CBI-NMS) 10 Oct 2017 (CBI-NMS)
Surfside Beach	TBD Revised Upon Contract Authorization	Apr 2007* Nov 2008* Jan 2010 Jan 2011 11 July 2012 (CBI-NMS) 23 Jul 2014 (CBI-NMS) 24 Sep 2015 (CBI-NMS) 20 Dec 2016 (CBI-NMS) 11 Oct 2017 (CBI-NMS)
Quintana Bryan Beach	TBD Revised Upon Contract Authorization	Mar 2005 Jul 2007 Oct 2008 25 July 2012 (CBI-NMS) 24 Jul 2014 (CBI-NMS) 22 Sep 2015 (CBI-NMS) 20 Dec 2016 (CBI-NMS) 11 Oct 2017 (CBI-NMS)
Bolivar Peninsula Gilchrist Beach Caplen Beach	TBD Revised Upon Contract Authorization	Jul 2009* Mar 2012 (Caplen)* (pre/post-placement) 27 June 2012 (CBI-NMS) 28-31 Jul 2014 (CBI-NMS) 10 Nov 2015 (CBI-NMS) 18 Jan 2017 (CBI-NMS) 29 Nov 2017 (CBI-NMS)
Jamaica Beach	TBD Revised Upon Contract Authorization	2000 (BEG)* 2006 (LAN)* 2008 (TGLO)* 2010 (HDR)* 2011 (HDR)* 2012 (LAN)* 04 Jun 2013 (CBI-NMS) 19 May 2014 (CBI-NMS) 29 Sep 2015 (CBI-NMS) 28 Dec 2016 (CBI-NMS) 07 Nov 2017 (CBI-NMS)

North Beach

North Beach is an urban beach located at the north end of Corpus Christi Bay. The beach is bordered by the entrance to Nueces Bay to the east and the entrance to the Port of Corpus Christi to the west. North Beach was formerly referred to as Corpus Christi Beach until the official name change in July 2012. This beach has a history of beach nourishment initiating with the USACE sponsored project during 1978. In response to sand loss at the north end of the beach, a subsequent nourishment was conducted at the northern terminus and a terminal groin was constructed during 1985. More recently, the beach was nourished in 2001 (CEPRA Cycle 1), with modifications completed during 2002/2003 to improve sand quality. The most recent nourishment was completed during Apr 2016. The 2016 nourishment effort was focused on restoring an adequate width to the southwest end of the eroding beach fronting the parking lot near the Lexington as well as narrow segments fronting three public parks. The 2016 nourishment material included both imported quarry sand and mechanically back-passed sand from the northeast end of the beach. A total of 80,000 cu yd of sand was applied as nourishment, of which 25,000 cu yd was back-passed from the northeast end of the beach.

The majority of the backshore of North Beach is bordered by substantial public and private infrastructure that supports tourism and community access. This includes five public beach parks with associated amenities that are set forward on the beach. Several of the parks include parking that is directly adjacent to the beach (Fig 1). The City of Corpus Christi along with community partners were in the process of shifting several of the parking areas landward at the time of this reporting. Only the far north end of the beach has a natural buffer zone between the beach and backshore development. The buffer zone consists of coppice mounds, low elevation wetland features and grassy flats. In addition, the backshore limit was redefined along several segments of the beach by the construction of the concrete Beachwalk during 2012.

The dominate direction of sediment transport is generally accepted as from the southwest to the northeast with accretion dominating at the northeast end near the terminal groin and erosion dominating at the more southerly end of the beach near the Lexington. The southwest end of North Beach, nearest the Lexington, has a history of exacerbated erosion in response to extended periods of higher than average water level combined with onshore forcing driven by strong winds. The seaward position of infrastructure including sidewalks and parking limit the functionality of the truncated beach profile along a high use, nearly 500 ft long reach at the southwest end of the beach. The most recent episodic erosion events were documented during the summer of 2012, July 2014 and again during the summer and early fall of 2015. The extent of erosion during 2016 was diminished by the nourishment event completed during Mar/Apr 2016.

Monitoring at North Beach includes both beach profile surveys and shoreline position surveys along the entire extent of the 7,000-ft long beach. Beach profile surveys have been conducted during 2007 (City of Corpus Christi), 2009 (CBI, CMP Cycle 12), 2012 (CBI, CEPRA) and 2014-2017 (CBI, CEPRA). CBI has conducted shoreline position surveys during 2007, 2009, 2012, 2014-2017. The shoreline position was surveyed at the 0.89-ft contour, which corresponds to the MHHW elevation at North Beach. Beach profile survey data for 2007 was provided by the City of Corpus Christi although there was limited agreement between the transect grid applied during this survey with the BMMP grid. This survey was limited to 10 profiles that defined the region to an average wade depth of -2 to -4 ft and therefore this data had limited value toward volume calculation. Therefore, the baseline for shoreline change is 2007 but the 2009 data is applied as the baseline for volume change. The location of transects relative to locations of interest are shown in Figure 1.

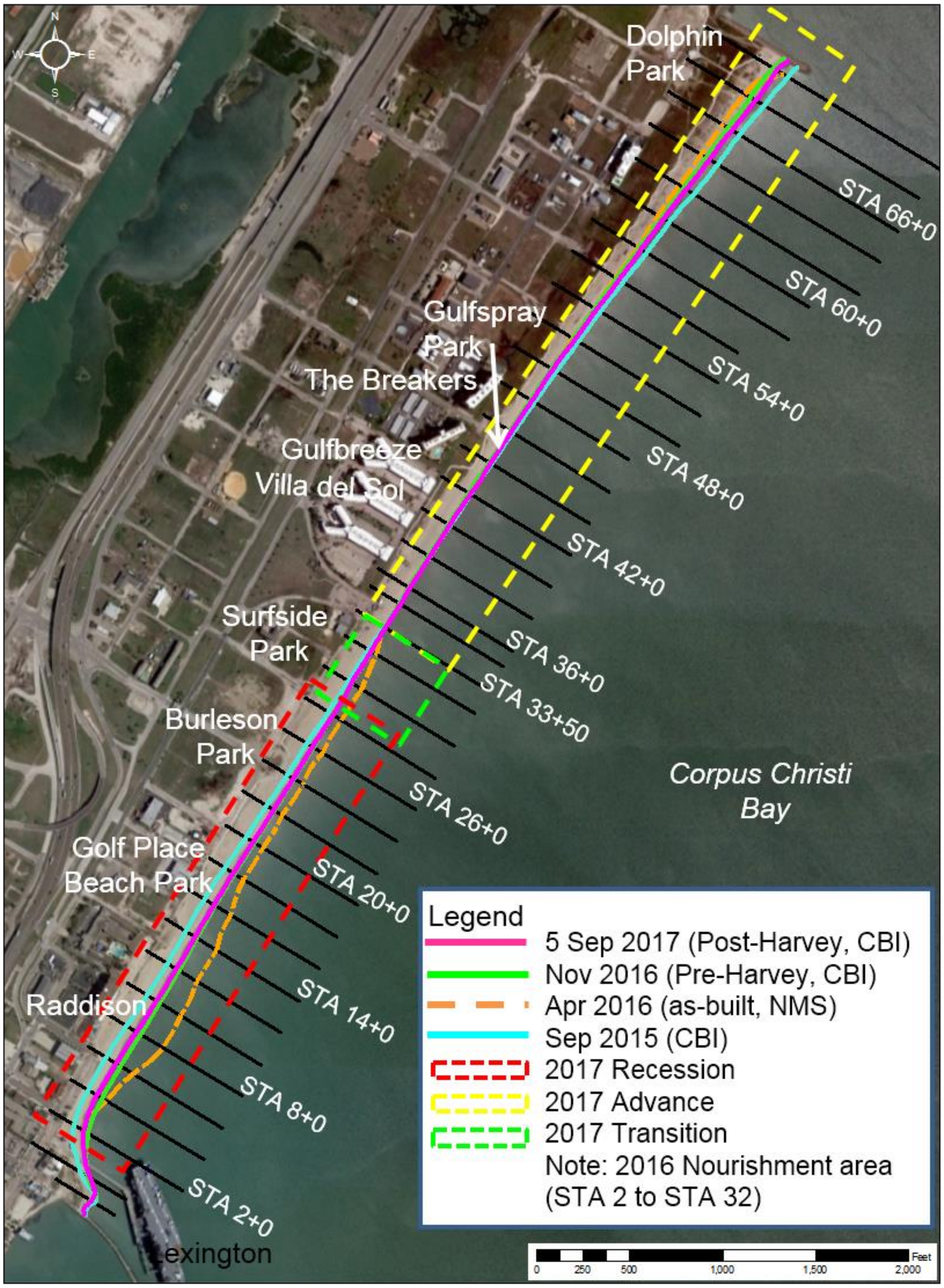

Figure 1. Shoreline position (2017) relative to the location of the three zones and the extent of the 2016 nourishment and backpassing

Shoreline Change Analysis: North Beach
Summary of Shoreline Change Since 2007

Monitoring began at North Beach during 2007, 3 years after the completion of the modifications (2013-2004) to the 2001 nourishment. The 2007 survey is applied as the baseline for shoreline change as no prior data to DOC has been located or provided to date. The 2007 shoreline position along the southeast reach is estimated at 20 to 30 ft landward of the 2004 position based on assessment of available imagery. The shoreline position along the northeast reach is estimated at 25 to 50 ft in advance or seaward of the 2004 position. The 2007 shoreline position between these two distinct zones was in close in agreement with the 2004 shoreline position. The early characterization of differences in trends of erosion and accretion along these three zones has remained consistent over the study period.

As previously reported, the 2016 nourishment was successful in advancing the shoreline position along the southwest end of North Beach where persistent erosion, enhanced over several recent periods of frequent inundation and onshore forcing, had resulted in the loss of functional beach. Erosion in this area damaged backshore infrastructure including the sidewalk and parking lot. The Nov 2016 shoreline position was landward of the as-built shoreline position (April 2016) in the nourishment area with the exception of limited segments at the southwest and northeast ends of the nourishment area. The shoreline along the northeast end of the beach was also positioned landward of the Sep 2015 position due to backpassing but during Nov 2016 the majority of the shoreline had advanced seaward of the post-backpassing position, specifically between STA 50+0 and STA 68+0. The far northeastern end of the beach receded landward of the Mar/Apr 2016 position which may reflect additional backpassing that extended further east that was not captured by the final survey. Shoreline change was limited in alongshore extent and variable in magnitude between STA 50+0 and STA 54+0 at the limit of active backpassing.

The Nov 2016 shoreline was positioned between the 2007 (3-yr post-nourishment) and 2009 (5-yr post-nourishment) positions along the segment between STA 3+0 to STA 14+0. The shoreline was at or within ± 5 ft of the 2007 position along the beach fronting the Radisson (STA 8+0 and STA 12+0). The Nov 2016 shoreline position receded landward of both the Sep 2015, 2009 and 2007 positions from STA 14+0 northeastward to the terminal groin.

Three distinct regions or zones of shoreline change remain clearly defined at North Beach (Fig. 1). A zone of recession that dominates along the southwest end is separated from a zone of shoreline advance at the northeast end by a transition zone that lies between these two distinct reaches and is dependent on forces acting over the year before the survey. During 2014, the distinction between these zones was clearly defined but continued erosion resulted in a revision of the boundaries during 2015, particularly due to the subtle fluctuation between recession and advance along the central segment of the beach and the significant reduction in extent of the zone of accretion at the northeast end of the beach. The transition zone is defined as the reach where shoreline change fluctuates between recession and erosion at a negligible rate. Between 2014 and 2015, recession dominated along greater than 75% of the beach, reducing the extent of the Transition Zone. The nourishment conducted during 2016 moderated the reversed the zones of erosion and accretion and dampened the distinction of a Transition Zone between them. A reversal in the location of the zone of accretion and zone of recession was clearly defined due to the fill placement and backpassing event. No post-nourishment data was provided for the reach between STA 35+0 and 48+0, which roughly corresponds with northeast limit of the segment that has been identified as the transition zone in past surveys. For the purposed of reporting change in this area was taken as null. After Harvey recession extended from STA 2+0 to STA 26+0 resulting a shift in the transition zone toward the southwest (Fig 2 and Fig 3). The stability in shoreline position was limited to the beach segment between STA 28+0 and 33+5 during 2017 (Fig 4). Thus, erosion was more focused along the most southwesterly extent of the beach after Harvey with eroding sediment benefiting the beach adjacent to the northeast (Fig 5).

Persistent erosion at the southwest end of North Beach has predominately been episodic in nature responding to frequent and prolonged periods of elevated water level combined with onshore forcing which is common due to the prevalence of strong southeast winds throughout the year. Erosion causing damage to backshore infrastructure has been isolated to the southwest end of the beach and localized segments fronting public parks. In all cases, damage due to erosion and subsequent shoreline recession along these segments was exacerbated by the proximity of the backshore infrastructure that was constructed significantly with limited to no setback. Therefore, the beach profile is truncated, thereby eliminating the opportunity for development of typical backshore features and in some cases a-typical beach profile morphology. Therefore, the average rate of shoreline change for the full beach is significantly influenced by the lower rate of change that dominates along the transition zone and northeast end of the beach. Thus, the recession rate for the full study area at North Beach does not adequately reflect the high rate of erosion along the southwest end. Therefore, the rate of shoreline change is provided for both the full study area as well as the localized rate along the southwestern reach where the nourishment was focused (Table 1).

Rate of Shoreline Change: North Beach

During the previous reporting period (2014-2015) recession dominated at an average rate of -2.6 ft/yr, nearly triple the 2012-2014 rate of -0.7 ft/yr. Persistent and extensive erosion at the southwest end of the beach has resulted in localized high rates of recession ranging from -6.3 ft/yr to -13.0 ft/yr along the beach fronting the parking area near the Lexington since 2007. A high rate of shoreline change in excess of -100 ft/yr occurred along the nourishment area over the 7-month period post-placement as the fill modified toward equilibrium with the nearshore. Although difficult to quantify, frequent and prolonged periods of water level in excess of MHHW likely contributed to erosion based on the impact such conditions have had at the southwest end in the past. The rate of shoreline change calculated for previously reported intervals of interest are provided for reference in Table 1.

The rate of shoreline position change for the full study area was +1.9 ft reflecting the transport of eroding sediment toward the northeast where sand is temporarily impounded by the terminal groin. The high rate of shoreline recession at -14.5 ft/yr measured after Hurricane Harvey is the highest rate, of change other than that which occurred after Hurricane Ike. The higher rate observed immediately (within 6 months) post-placement is reflective of the nourishment equilibration process and is therefore not included in this comparison.

The average rate of shoreline change at North Beach is skewed by the balance of the erosion on the southwest end of the beach with accretion on the northeast end. Therefore, the rate of shoreline change is also calculated for the zone of focused recession along the southwest side of the beach. Table 1 provides the average rate of shoreline position change for key intervals along specified beach segments. The variability in rate of shoreline position change (Fig 6) relative to alongshore location is shown over the following intervals of interest: 1) post-Harvey (2016-2017), 2) previous annual reporting period (2014-2015), 3) previous biannual reporting period (2012-2014), and 4) historic baseline (2007-2015) which serves as Pre-Harvey/Pre-nourishment background rate. Note that the 2015 to 2016 interval was not included in this comparison due to overt influence of nourishment.

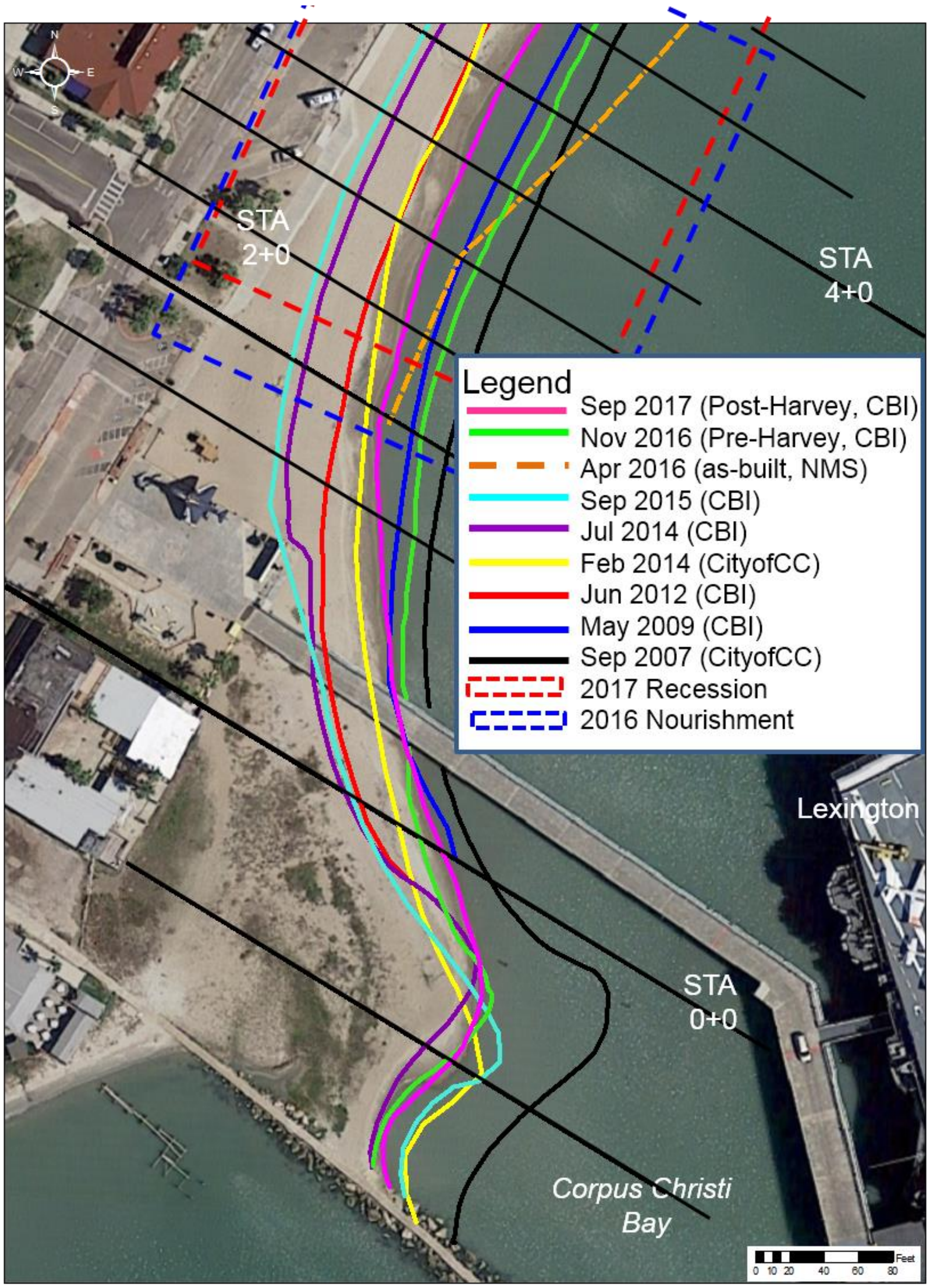

Figure 2. Variability in shoreline posistion at the southwest end refecting influence of erosion during Hurricane Harvey (2017) as compared to the influence of nourishment and to previous more gradual change between 2007 and 2015

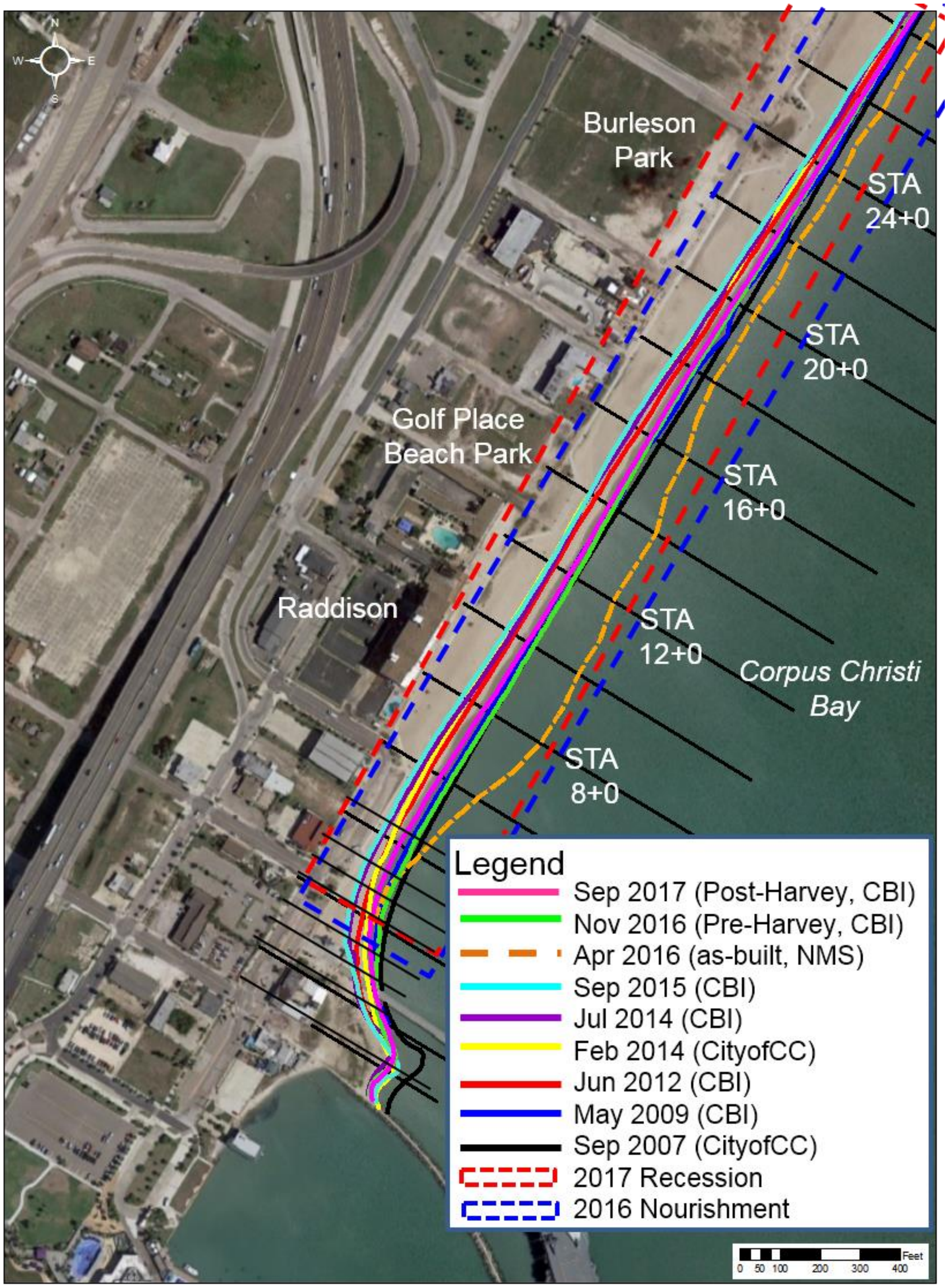

Figure 3. Shoreline recession dominates after Harvey (Sep 2017) with the position receding 20 to 30 ft

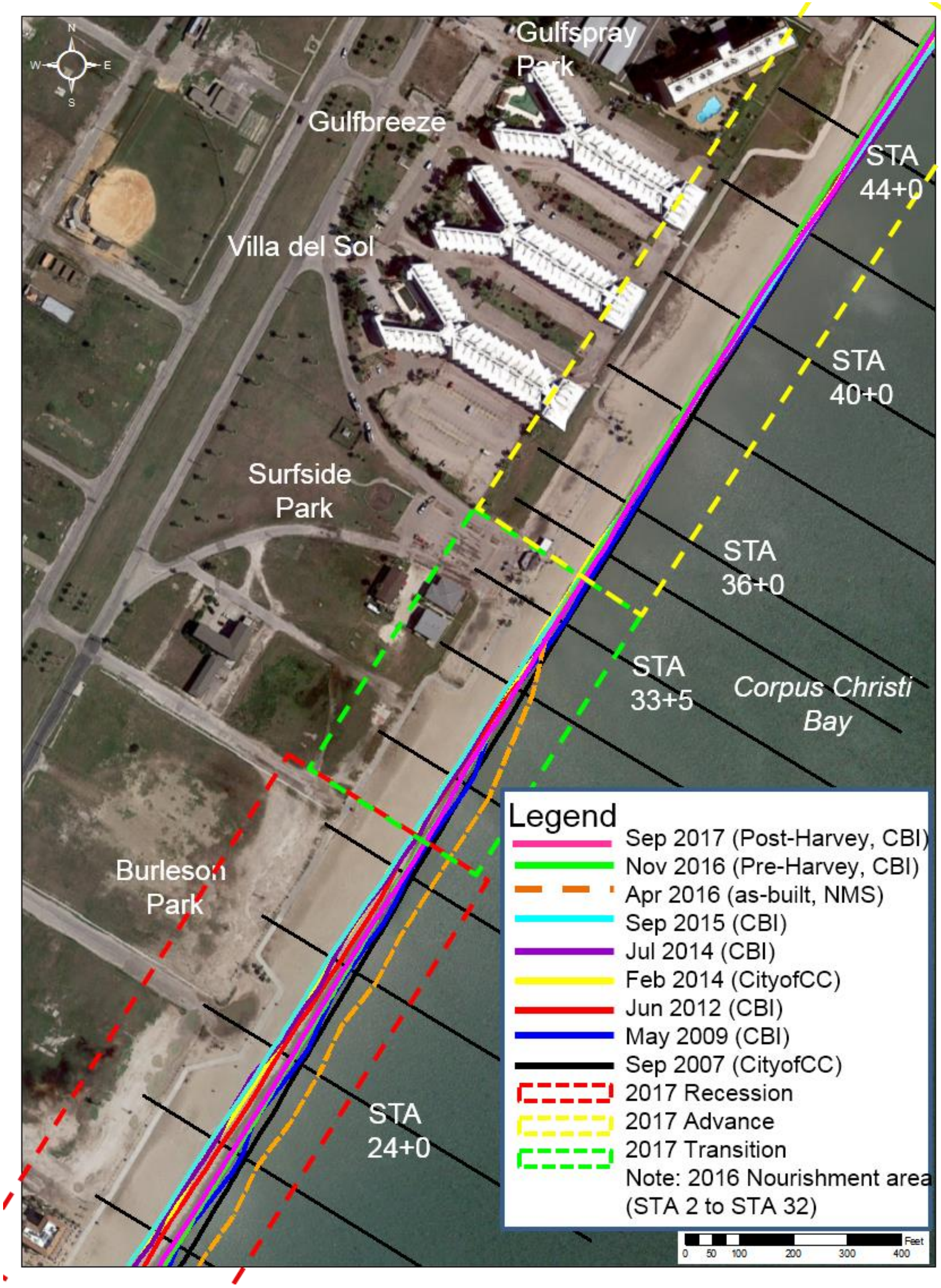

Figure 4. The Zone of Transition shifted toward the southwest as sand eroding along the beach the southwest was transported by strong alongshore current toward the northeast

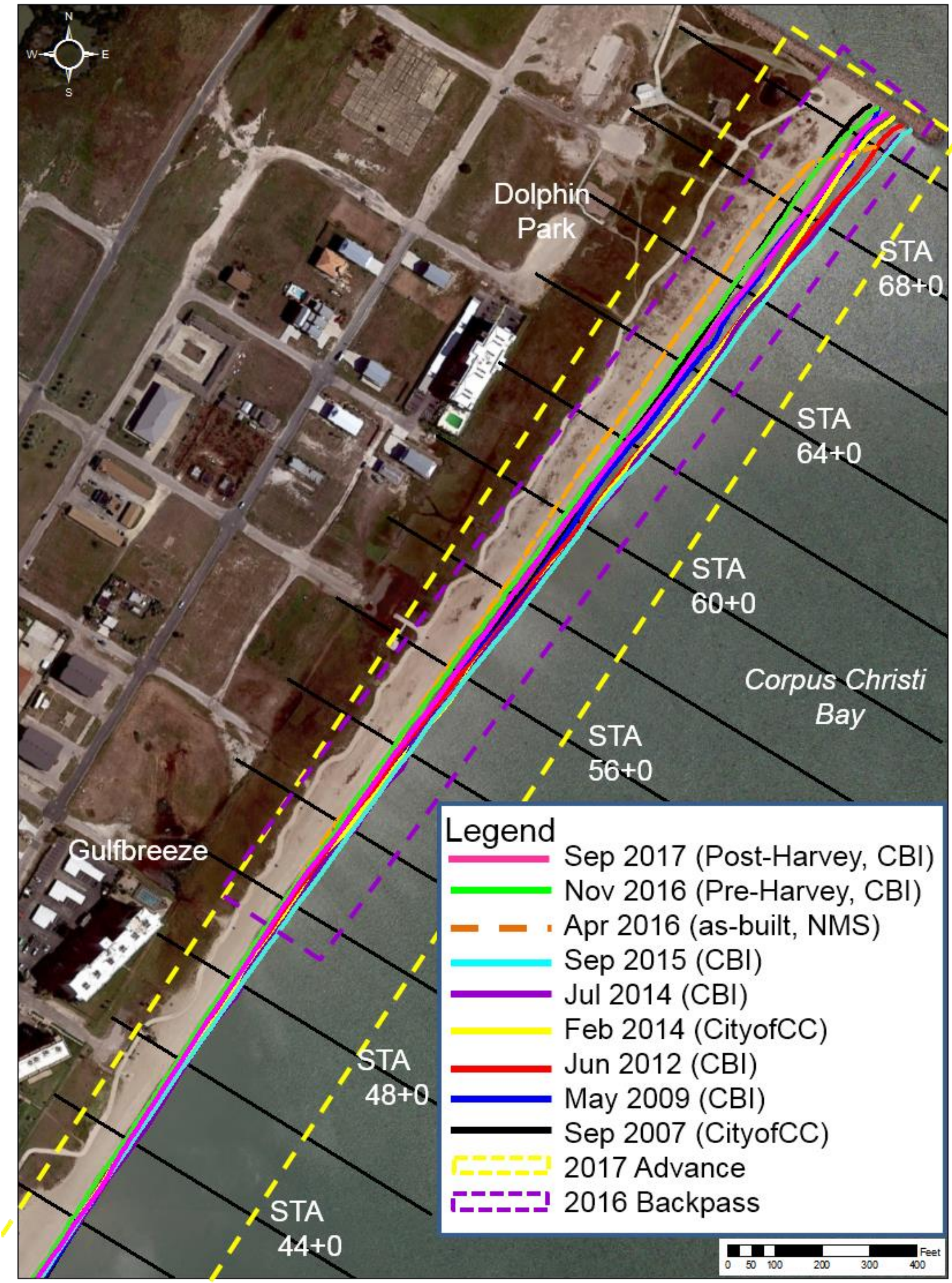

Figure 5. Shoreline advance resumed along the northeast end of the beach as sand eroding to the southwest was transported toward the terminal groin

Table 1. Variability in Average Rate of Shoreline Position Change: North Beach				
Interval (Year)	**Description**	**Rate + Advance - Recession (ft/yr)**	**Max +**	**Min -**
2017 Post-Harvey Reporting Period				
Sep 2017 Nov 2016	Full Study Area 10-month Period (Post-Harvey)	+1.9	+38	-34
Sep 2017 Nov 2016	Southwest End 10-month (Post Harvey)	-14.5	+4	-34
Sep 2015 Sep 2007	Full Study Area: Pre-Harvey/Pre-Nourishment *Background rate*	-2.8	+13	-22
Sep 2017 Sep 2007	Full Study Area: Period of Record *Influence of Nourishment, Ike and Harvey*	-1.3	+39	-48
2016 Focus Areas of Nourishment and Backpassing				
Sep 2017 Nov 2016	Northeast End (Backpass Area) 10- month Post-Harvey 1.5-yr Post-Nourishment	+20.88	+38	0
Sep 2017 Nov 2016	Southwest End (Nourishment) Area) 10- month Post-Harvey 1.5-yr Post-Nourishment	-14.5	+4	-34
Nov 2016 Apr 2016	Northeast End (Backpass Area) 6 month Post-Nourishment Change	+25.4	+71	-76
Nov 2016 Apr 2016	Southwest End (Nourishment) Area) 6 month Post-Nourishment Change	-100.0	-201	+111
Focus Area of Severe Erosion (Parking Area at SE end near Lex)				
Nov 2016 Sep 2015	Southwest end of Lex N/A Equilibration of Nourishment	N/A	N/A	N/A
Sep 2015 Feb 2014	Southwest end of Lex Annual	-6.2	+4	-54
Sep 2014 Jun 2012	Southwest end of Lex Annual	-5.9	+30	-22
Jun 2012 May 2009	Southwest end of Lex Biannual	-12.2	0	-54
May 2009 Sep 2007	Southwest end of Lex Annual	-9.0	+3	-29
Jul 2014 Feb 2014	Southwest end of Lex 4-Month Interval (Full Beach) Severe Erosion fronting Parking Lot	-6.8	+51	-47
Jul 2014 Feb 2014	Southwest end of Lex West end at Lex (Focus Area) Severe Erosion fronting Parking Lot	-9.1	+14	-45
Sep 2015 Sep 2007	Period of Record Pre-Nourishment and Pre-Harvey Background Rate	-9.0	0	-106

Table Continued on Next page

Table 1. Variability in Average Rate of Shoreline Position Change: North Beach				
Interval (Year)	**Description**	**Rate + Advance - Recession (ft/yr)**	**Max +**	**Min -**
Previous Reporting Period Averages				
Nov 2016 Sep 2007	CBI Monitoring Period Post-Nourishment Influence	-1.6	+18	-30
Nov 2016 Sep 2015	Nourishment/Backpassing	+6.4	+92	-95
Sep 2015 Sep 2007	CBI Monitoring Period Average	-2.8	+13	-13
Sep 2015 Sep 2014	Annual survey	-2.6	+12	-13
Sep 2014 Jun 2012	2-yr Avg.	-0.7	+12	-13
Jun 2012 Sep 2009	3-yr Avg. (Tropical Storm Season 2009)	-4.7	+17	-16
Sep 2009 Sep 2007	2-yr Avg. (Contribution Hurricane Ike 2008)	-2.1	+33	-17

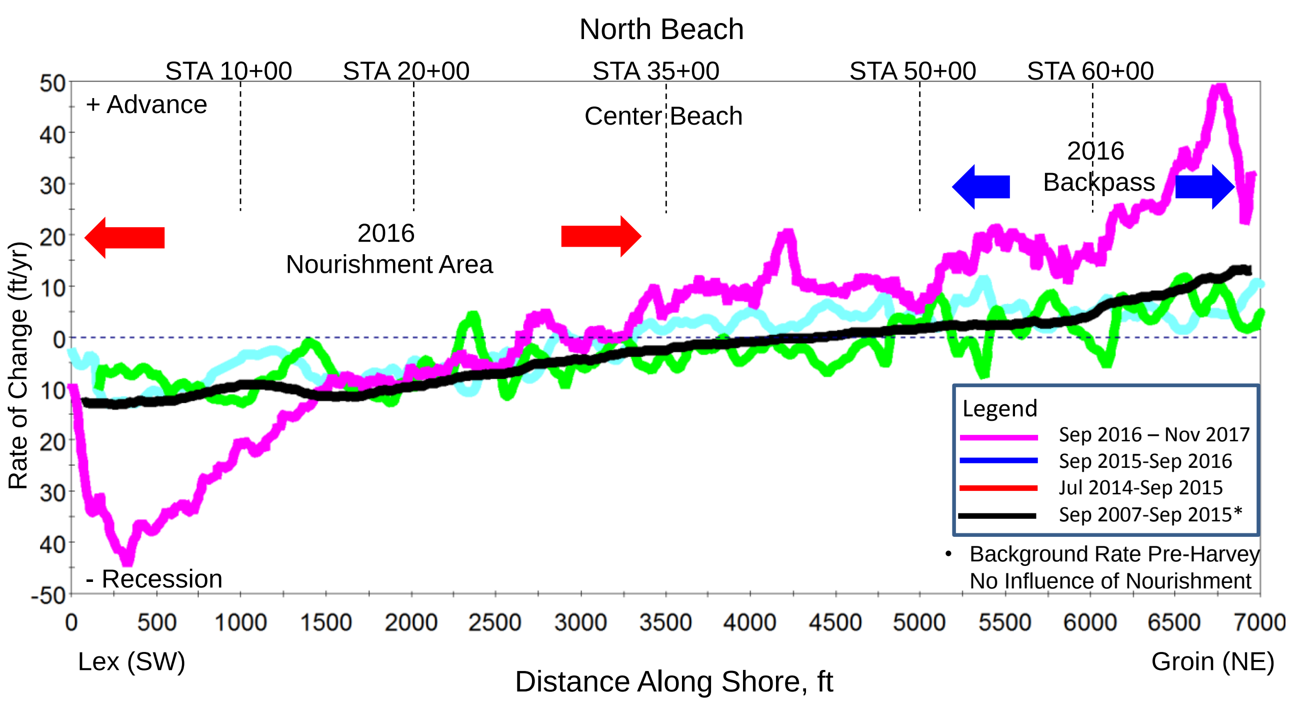

Figure 6. Comparison of variability in rate of shoreline change with alongshore position at North Beach over four intervals: 1) post-Harvey (2016-2017), 2) previous annual reporting period (2014-2015), 3) previous biannual reporting period (2012-2014), and 4) historic (2007-2015) serves as Pre-Harvey/Pre-nourishment background rate. Note 2015-2016 disregarded in this context due to overt influence of nourishment

Beach Width: North Beach

As observed prior to the 2016 nourishment, beach width decreased along the southwest side while the beach width increased along the northeast side between 2016 and 2017. The focused erosion and accretion was interrupted by a short 300 ft long transition zone where the shoreline and therefore beach width was stable. The abbreviated transition zone indicated the recent active transport of sand toward the northeast. The width of the beach along the southwest end fronting the park lot at the Lex has a history of rapid erosion in response to both periodic nuisance flooding as well as storm events (Harvey and Ike).

Due to the high rate of erosion and shoreline recession between Nov 2016 and Sep 2017, the beach width decreased along the entire reach nourished during 2016. During Nov 2016, 100% of the beach was in excess of the Action Width, 7 months post-nourishment. The Target Width at North Beach is 120 ft along the southwest end of the beach where the rate of erosion is the greatest and backshore region has the highest degree of development and infrastructure. The Action Width along the southwest end of the beach is 60 ft. Along the remainder of the beach to the northeast, the Target Width is 100 ft with an Action Width of 50 ft. During Nov 2016, the entire beach was in excess of the Action Width for the first time since 2009 (5-yr post adjusted nourishment survey). The width of the beach ranged from 70 ft at the northeast limit of the nourishment area to 144 ft at the southwest limit of the nourishment area.

Although the entire beach was in excess of the Action Width, the southwest end of the beach was within 10 ft of Action width along former location of erosion at the interface with the parking lot at the Lex. Here the beach width ranged from 66 ft to 98 ft with 65% of the beach within 10 ft of Action Width. The width of the beach fronting the City parks ranged from 70 to 82 ft and fronting Beachwalk widths as narrow as 61 ft were documented along the central segment of the beach. After Harvey, 54% of the beach did not meet the Target Width with the fraction at Target width located along segments with significant setback of backshore infrastructure.

Volumetric Analysis and Morphology: North Beach

Hurricane Harvey impacted North Beach 1.5-yr after a full-scale nourishment project was completed. The nourishment focused on the southeast end of the beach that supports high use access by beach visitors and backshore infrastructure including visitor parking. The beach fronting the parking lot nearest the Lexington was heavily damaged during previous periods of prolonged inundation by nuisance tides. Therefore, the 2016 nourishment was focused along this same region but also stretched further northeast to restore the beach width and elevation fronting three high use public parks. This same region exhibited the greatest impact of erosion that was documented after Hurricane Harvey. Although shoreline recession dominated along the southeast side of the beach at a high rate, the volume of sand that was lost was not as severe as anticipated because as the storm moved onshore rapidly the winds reversed with the strongest winds directed out the northwest which is offshore at this location. The region of concern at North Beach includes the beach segments that front the public access points where the backshore limit is near the shoreline and consists of parking lots, sidewalks (Beachwalk), restroom facilities and picnic areas.

Although the volume lost from the subaerial beach was moderate, the area over which the loss was sustained fronts public access infrastructure that has been damaged by erosion in the past. Between 2016 and 2017, a total of 4,000 cu yd of sand eroded at a rate of --8 cy/ft from the 500-ft long beach segment fronting the parking lot near the Lexington. Approximately 5,800 cyd/ft eroded from the parking lot and adjacent 400 ft of beach immediately adjacent at the Radisson Hotel amounting to a rate of -5.3 cy/d. Along the entire nourishment area there was a net loss of 8,250 cu yd of sand or an erosion rate of -2.6 cy/ft. Although the majority of sand that eroded from the nourishment area was transported alongshore toward the northeast and conserved within the system, the focused volume loss along the southwest end of the beach fronting the parking lot resulted in the approach of the beach to the Action Width. The rapid rate of erosion since nourishment placement, including the influence of Harvey was sufficient to warrant planning toward the next nourishment of the southwest end of the nourishment area.

Table 2. Beach Width: North Beach 2017
Action Width = 60 ft + 10 ft due to proximity of infrastructure (STA 0+50 to STA 6+00) Target Width = 120ft
Action Width = 50 (STA 6+50 to STA 70+00)
≤ Action Width
2016 Nourishment Area

STA	Date and Beach Width (ft)								Location
	Sep 2007	**May 2009**	**Jun 2012**	**Feb 2014**	**July 2014**	**Sep 2015**	**Nov 2016**	**Sep 2017**	**Backshore Status 2015***
1+00	272	N/A	N/A	237	202	240	217	220	Concrete west of Lexington
0+00	191	167	104	130	90	97	144	156	Concrete west of Lexington
0+50	164	142	93	114	67	60	155	130	Parking Lot (Lexington)
2+00	145	120	76	90	49	40	127	98	Parking Lot (Lexington)
2+50	125	98	53	63	27	20	107	80	Parking Lot (Lexington)
3+00	115	87	45	44	17	8	98	68	Parking Lot (Lexington)
3+50	122	94	50	51	24	17	105	73	Set back of pavement
4+00	115	90	45	46	20	13	100	66	Set back of pavement
4+50	109	86	40	36	18	10	95	67	Set back of pavement
5+00	107	86	41	31	17	7	96	68	Set back of pavement
5+50	105	85	39	29	17	4	95	66	Set back of pavement
6+00	132	113	62	54	42	32	122	95	Set back of pavement
6+50	184	168	117	106	96	85	176	151	Full set back to hotel/beachwalk
8+00	178	167	118	102	104	90	177	160	Set back to hotel/beachwalk
10+00	174	162	118	98	111	96	175	157	Set back to hotel/beachwalk
12+00	167	149	106	91	100	93	164	146	Set back to hotel/beachwalk
14+00	106	93	41	23	25	23	92	81	Set back ends Golf Place Park
16+00	169	150	107	84	89	78	142	138	Set back to hotel/beachwalk
18+00	172	148	111	90	96	82	142	134	Parking
20+00	173	150	115	103	105	95	147	140	Set back to hotel/beachwalk
22+00	170	162	119	106	107	99	148	143	Set back to hotel/beachwalk
24+00	101	90	52	44	41	37	82	78	Set back ends at Burleson Park
26+00	165	152	130	114	113	109	149	142	Set back to hotel/beachwalk
28+00	161	153	127	119	125	119	144	147	Set back to hotel/beachwalk
30+00	158	160	130	122	129	122	143	142	Set back to hotel/beachwalk
32+00	86	68	63	58	55	55	70	70	Set back ends at Surfside Park
33+50	96	93	75	70	80	73	80	82	Revised backshore limit Surfside
35+00	86	80	65	60	69	64	65	73	Set back ends at Surfside Park
36+00	84	80	64	66	70	67	64	69	Set back ends at Surfside Park
38+00	156	144	143	141	146	145	137	145	Set back to hotel/beachwalk
40+00	162	162	145	152	156	153	143	149	Set back to hotel/beachwalk
42+00	163	163	156	155	162	159	147	155	Set back to hotel/beachwalk
44+00	69	61	62	63	75	68	54	61	Set back ends beachwalk/ vegetation backshore

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Table 2. Beach Width: North Beach 2017
Action Width = 60 ft + 10 ft due to proximity of infrastructure (STA 0+50 to STA 6+00) Target Width = 120ft
Action Width = 50 (STA 6+50 to STA 70+00)
≤ Action Width

STA	Date and Beach Width (ft)								Location
	Sep 2007	May 2009	Jun 2012	Feb 2014	July 2014	Sep 2015	Nov 2016	Sep 2017	Backshore Status 2015*
46+00	102	101	98	101	107	105	89	95	Set back to hotel and Gulfspray Park
48+00	68	72	66	69	78	76	56	65	Set back to hotel and Gulfspray Park
50+00	82	84	79	84	89	92	65	71	Set back ends at beachwalk/ vegetation backshore
52+00	94	99	99	102	114	110	83	93	Set back ends at beachwalk/ vegetation backshore
54+00	84	89	86	98	104	104	68	79	Set back ends at beachwalk /vegetation backshore
56+00	96	98	103	115	117	117	79	92	Set back ends at beachwalk/ vegetation backshore
58+00	92	99	103	108	106	114	67	82	Set back ends at beachwalk/ vegetation backshore
60+00	110	115	128	135	135	135	89	98	Set back to hotel and Beach Avenue Park
62+00	114	125	148	149	154	164	99	115	Full set back to hotel and Beach Avenue Park
64+00	135	157	180	180	189	197	126	146	Set back ends at beachwalk/ vegetation backshore
66+00	126	154	180	179	184	196	122	151	Set back ends at beachwalk/ vegetation Dolphin Park
68+00	106	142	176	160	186	197	113	143	Set back ends at beachwalk /vegetation backshore
70+00	92	128	170	143	192	195	103	125	Set back ends at beachwalk/ vegetation backshore

Notes:
Nourishment Completed April 2016
Hurricane Harvey Impact 26 August 2017
*backshore redefined as edge of beachwalk/sidewalk unless otherwise noted as vegetation
Baseline initially defined from 2012 survey data and aerial photography
Baseline was initially defined as line of persistent vegetation or first incidence of rock or pavement
No established dune in survey area other than low coppice mounds along east end of beach

Erosion documented after Harvey was focused across the berm crest and foreshore along the south side of the beach while accretion was focused across the foreshore along the northeast side of the beach due to well -developed alongshore sediment transport at North Beach (Fig 7-12). The focused erosion across the foreshore and berm crest along the southwest side of the beach resulted in the landward shift of the entire profile between the -1 to 3 ft contour. The rate of erosion and shoreline recession gradually decreased toward the northeast up to a transition zone located between STA 28+0 to STA 33+5 during Sept 2017 (Fig 13-15). The transition zone shifts laterally based on availability of sand in the system. The Transition Zone shifted from northeast toward the southwest after Harvey (Fig 4). Beyond the Transition Zone accretion along the foreshore increased with approach of the terminal groin where the greatest accretion resulted in partial restoration of the berm and sustained two longshore bars in the nearshore (Fig 16-18).

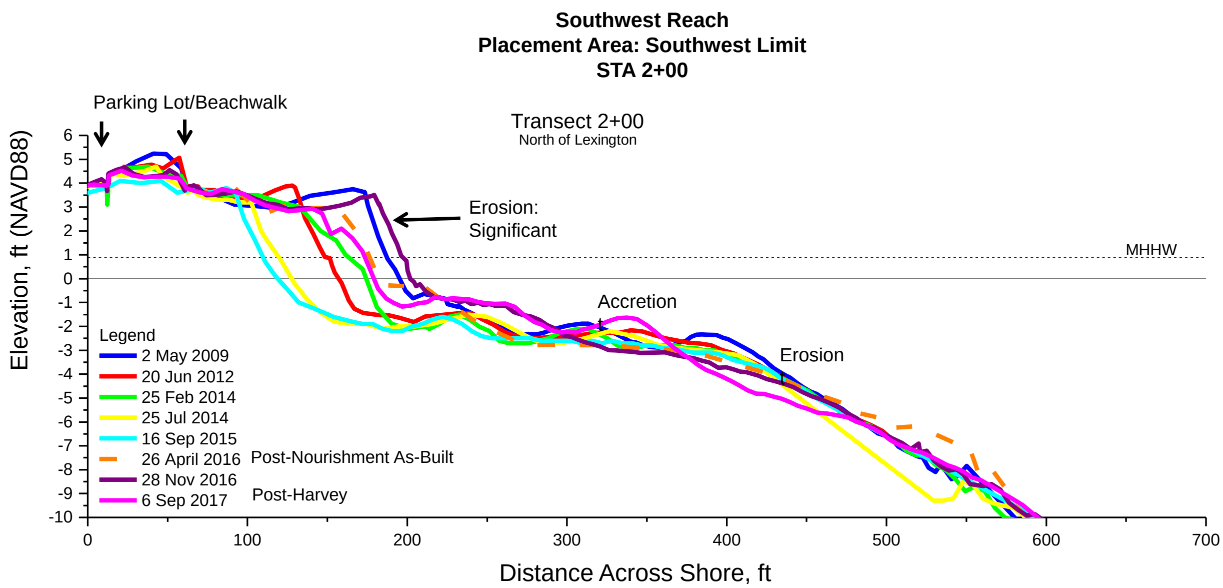


Figure 7. Southwest End: severe erosion during 2017 followed a year of accretion (Apr 2016 to Nov 2016) as the fill modified to a larger fill volume placed toward the northeast along the beach

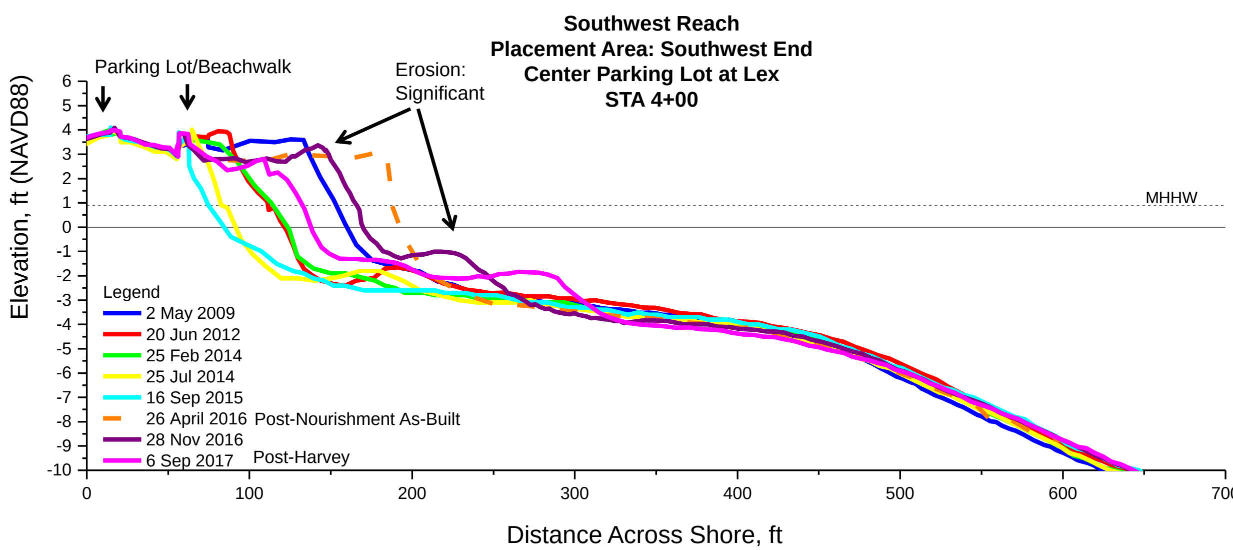


Figure 8. Southwest End: High rate of erosion fronting the center of the Parking Lot (Lex) resulted in cumulative loss of 75% of fill by Nov 2017; a 50 ft set back in berm crest and decrease in berm elevation

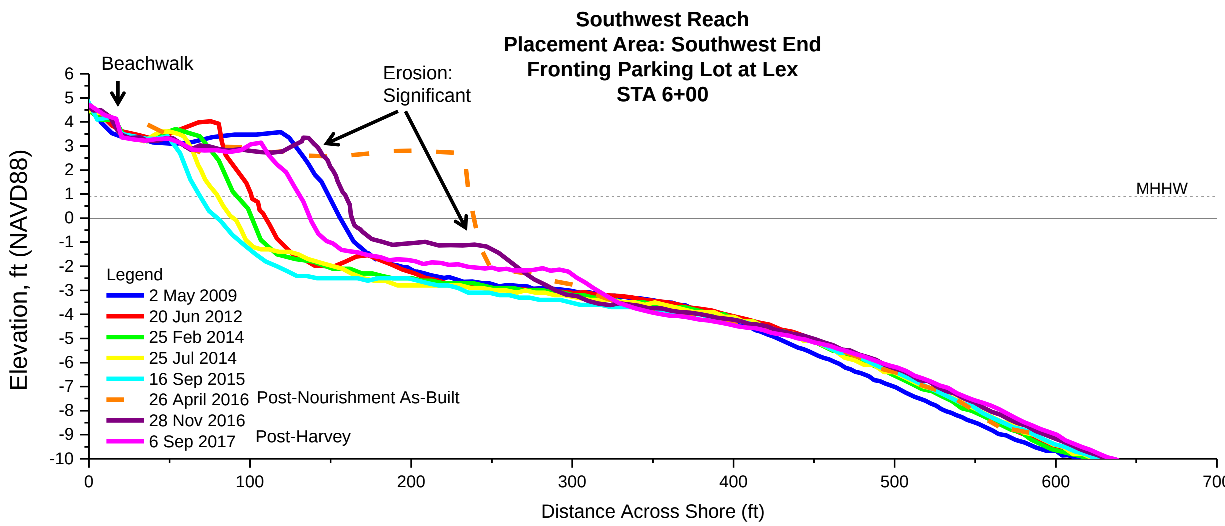


Figure 9. Southwest End: Cumulative loss of 75% of the fill placed during Apr 2016 after Harvey (Sep 2017)

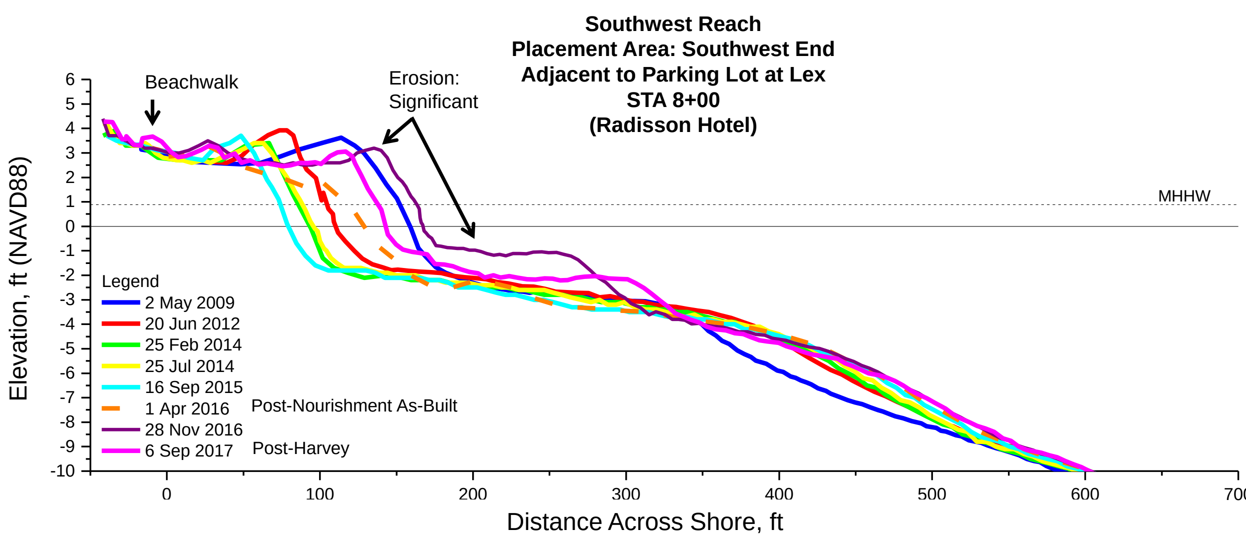


Figure 10. Northeast of Parking Lot: After a brief period of accretion related to adjacent fill placement, erosion resumed along the beach adjacent to the parking lot after Harvey, with the berm width less than the 2009 (Post-Ike/6-yr post-nourishment) width

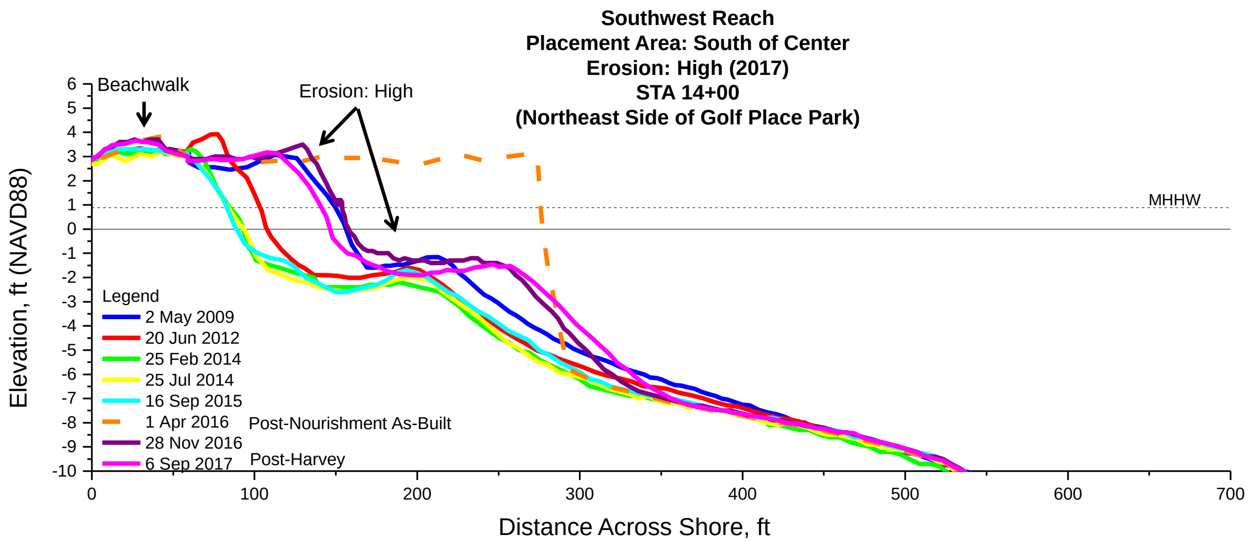


Figure 6. Southwest of Center Nourishment Area: Moderate erosion across entire berm and immediate nearshore with the berm profile landward of the 2009 Post-Ike/6-yr post-nourishment position

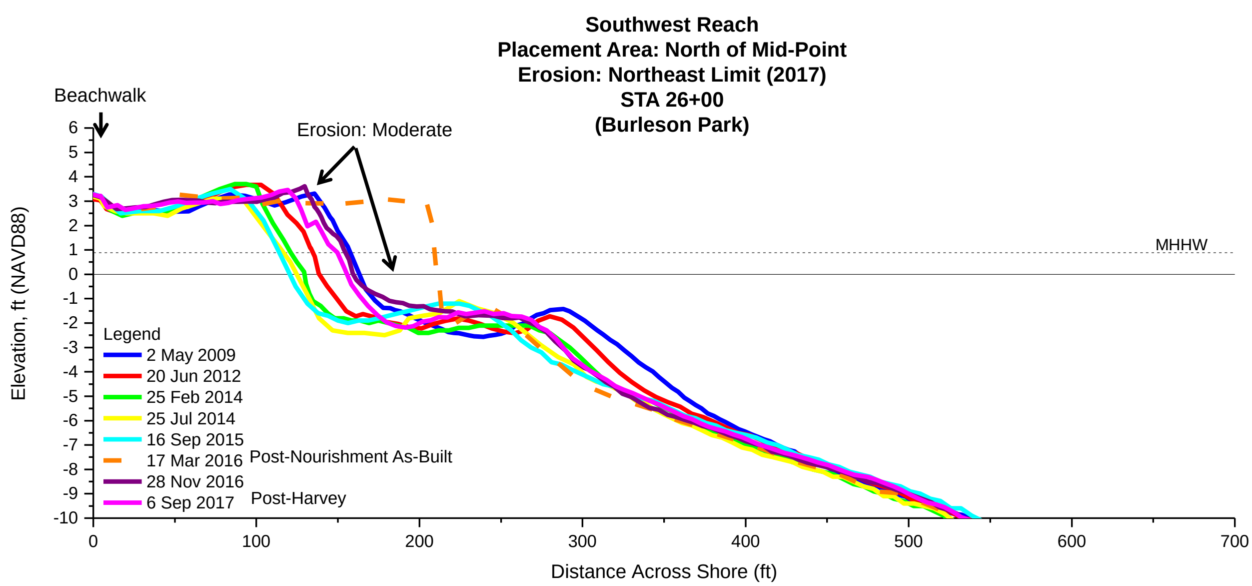


Figure 7. Southwest of Transition Zone: Northwest limit of significant erosion along the nourishment area. Erosion moderated and was focused at the berm crest and foreshore after Harvey (Sep 2017)

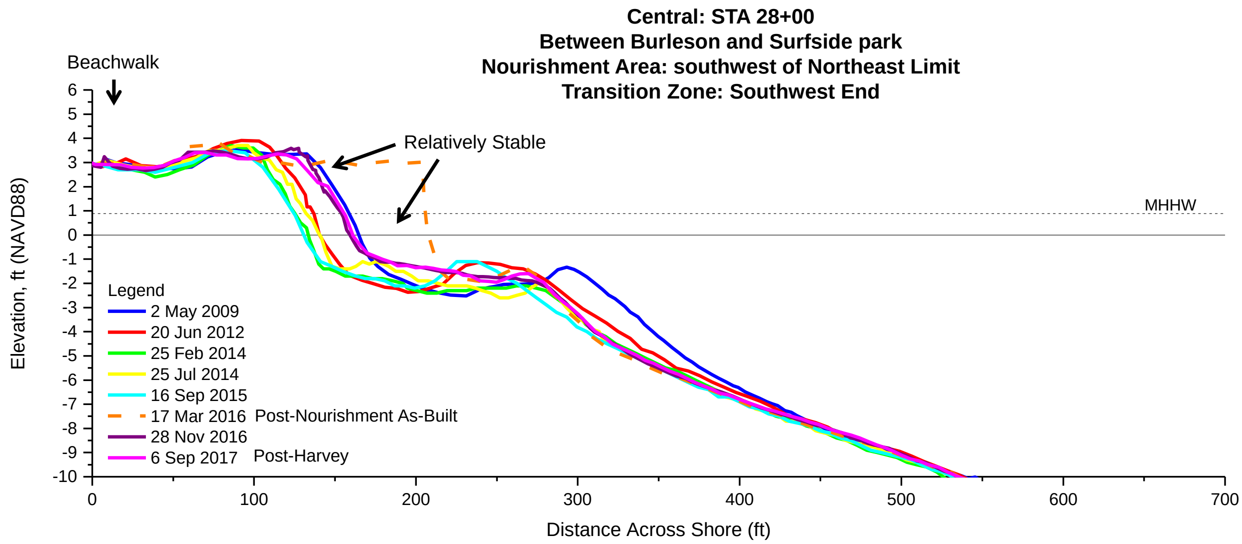


Figure 8. Transition Zone (Southwest End): Stable berm with moderate erosion in immediate nearshore

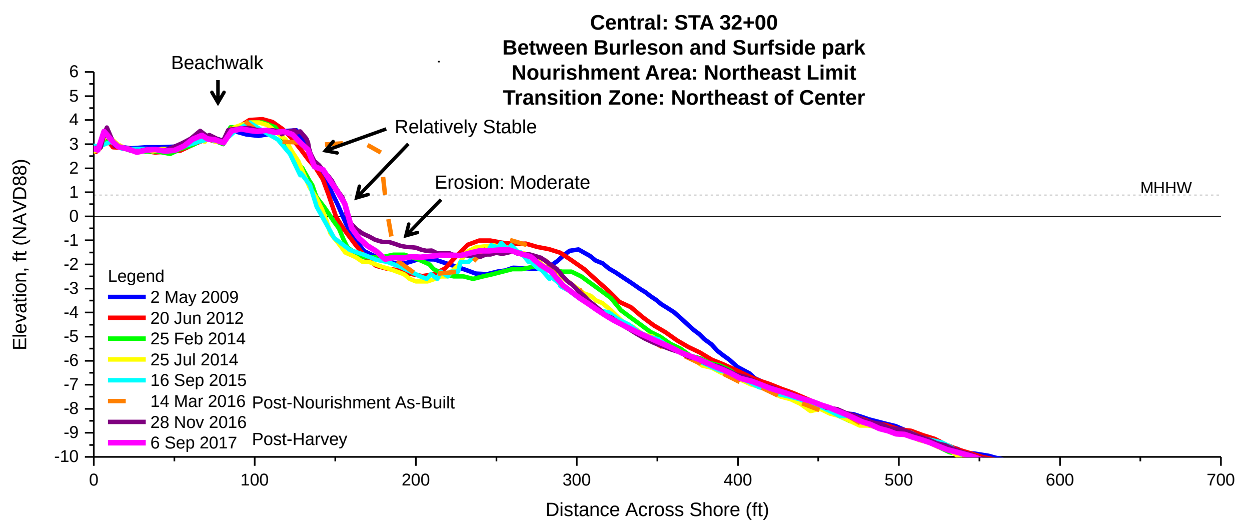


Figure 9. Transition Zone (Northeast of Center): Stable beach profile measured after Harvey with limited erosion in immediate nearshore within the Transition Zone and Northwest end of the nourishment area

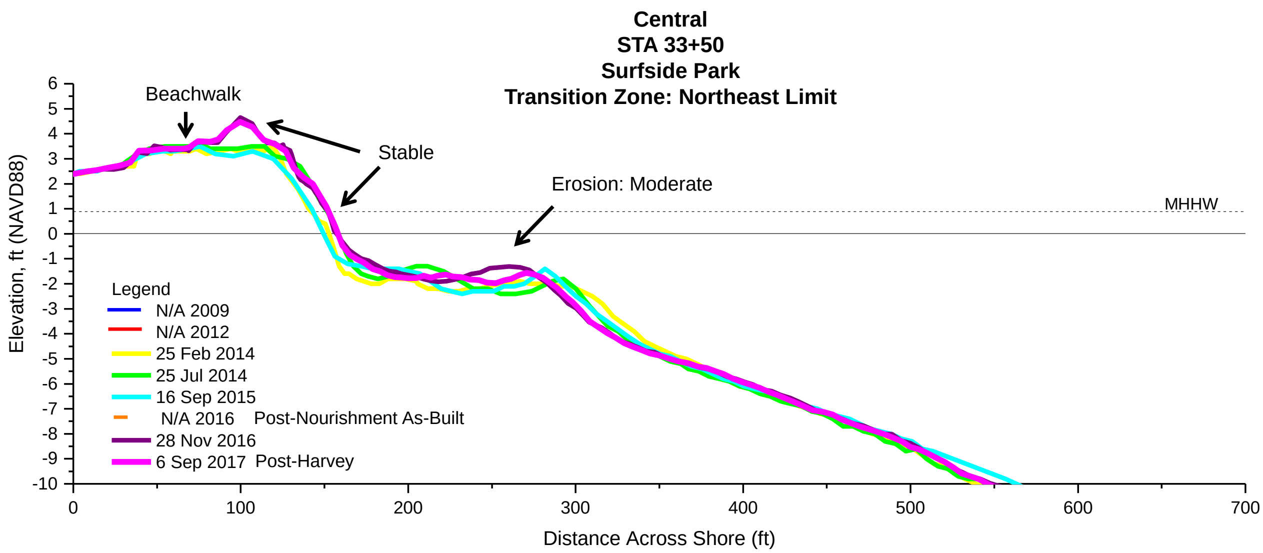


Figure 10. Transition Zone (Northeast Limit): Stable beach profile with only minimal erosion in the nearshore

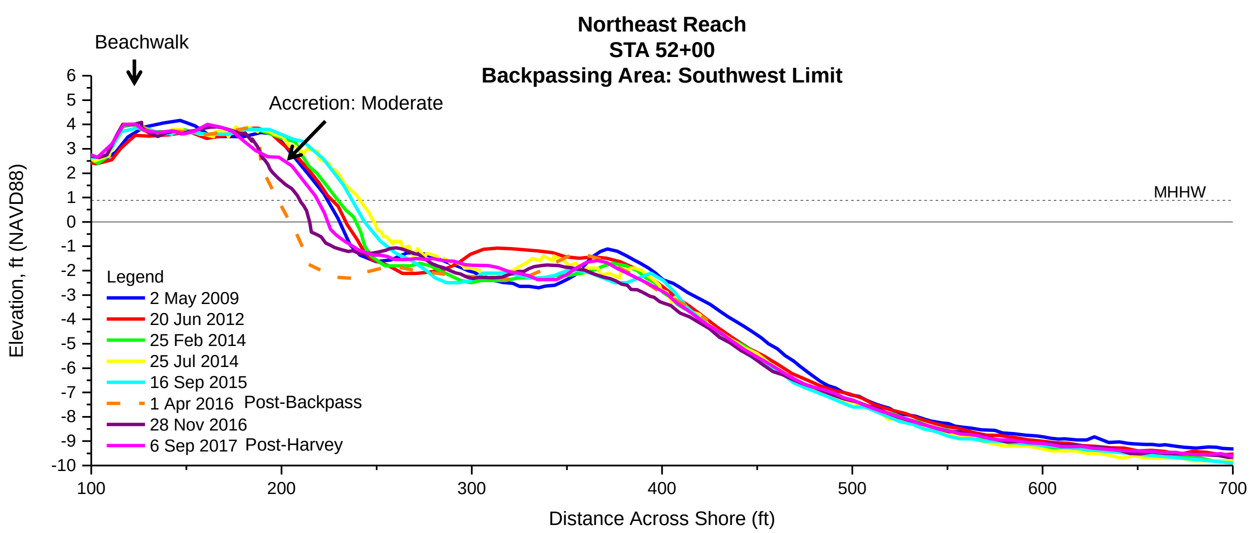


Figure 11. Backpass Area: Accretion dominates during Nov 2016 along the southwest limit of backpassing

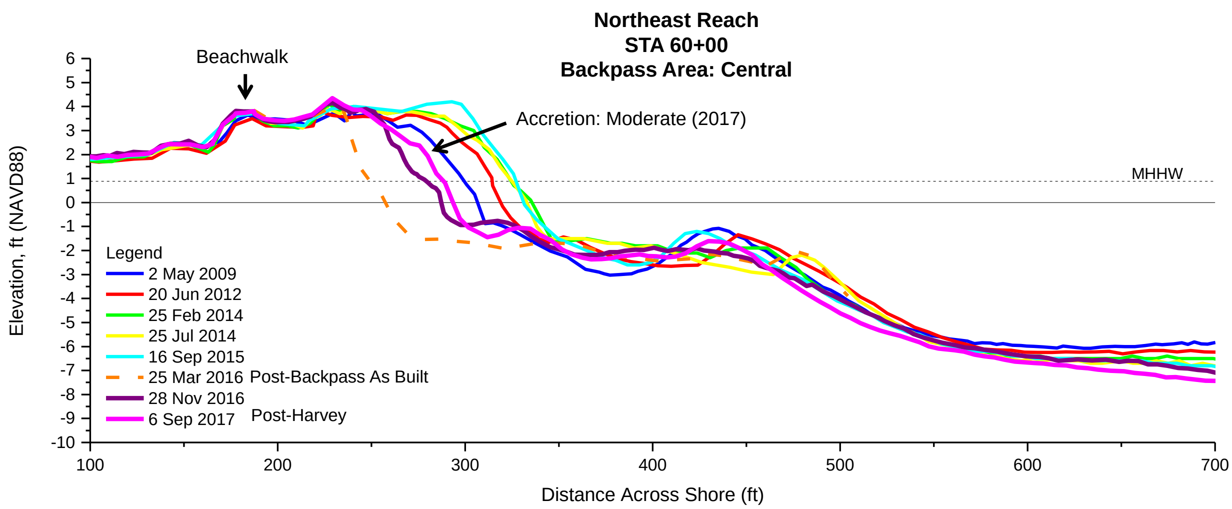


Figure 12. Backpass Area: During 2017, the beach continued gradual recovery after significant sand volume was backpassed to southern end of the beach during 2016

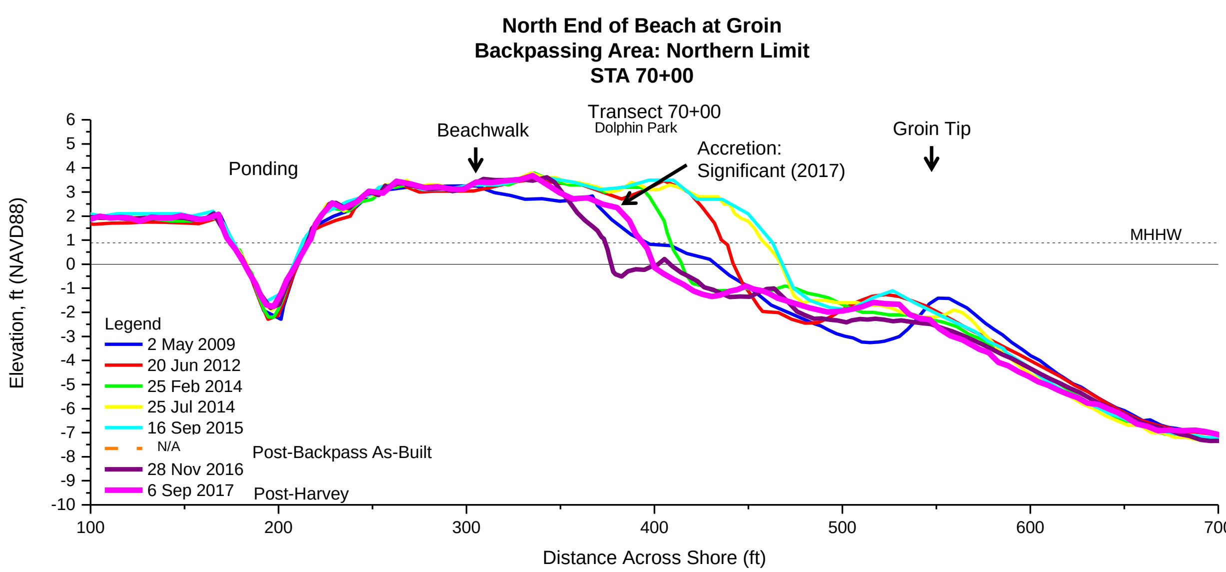


Figure 13. Maximum accretion and increase in beach width documented near terminal groin between Nov 2016 and Sep 2017

Recommendations: North Beach

Planning toward nourishment is recommended in order to re-establish the Target Width along the beach fronting infrastructure that supports public access along a high usage segment of North Beach. Erosion along the beach fronting the parking area and sidewalk near the Lexington accelerated between 2016 and the 2017 after Harvey. The width of the beach decreased to within 10 ft of the Action Width (60 ft). The rate of recession was -14.5 along the nourishment area. The background average rate of shoreline recession along this segment of the beach calculated for the longest period of record that was not interrupted by the impacted by nourishment or storm forcing within one year, is -9 ft/yr and the range is -6 ft/yr to -12 ft/yr over the project record. Conservatively, at this rate the beach fronting the parking lot on the southwest end near the Lex would meet Action Width within one year and at this rate would erode up to the backshore infrastructure within 5 to 7 years. Initiating nourishment planning during 2018 would support nourishment placement before the critical stage of erosion and undermining of backshore infrastructure initiates. Based on the post-Harvey status, which includes both narrow beach widths at high usage public access points and a high rate of shoreline recession, as well as a history of focused erosion fronting the parking lot near the Lex, nourishment should be planned for within 2 years. Public access points are defined for the purposes of this reporting as backshore parking lots and park facilities.

The recommended nourishment footprint exceeds the area of immediate need in order to provide for the uniform integration of the fill with wider sections of beach between public access points. Although the functional beach width is indeed wider along beach segments adjacent to the public parks and parking lots, and well in excess of the Action width, the offshore limit of the beach is consistent with the adjacent narrow segments. This is because the backshore of these wider segments is appropriately set back an additional 50 to 100 ft compared to the backshore infrastructure at the public access points. These wider segments of the beach are eroding at the same rate as the adjacent narrow beach segments but do not have the backshore limitation that segments fronting public access points have. Therefore, for the nourishment to prove most effective, the footprint of fill placement should include the wider segments that separate the public access points and restore these segments to the same seaward limit.

Southwest (Nourishment Area)

The proximity of public access points to the shoreline along this stretch of beach provides challenges from the perspective of beach management because the width of the beach in front of these access points are limited by the facilities themselves. The public facilities function as the backshore limit instead of natural features such as low dunes or wetlands. Three Alternatives that vary in alongshore extent, in order to accommodate potential budget limitations, were investigated. The placement of fill uniformly alongshore has been shown to exceed performance of spot nourishment. Therefore, the most effective nourishment alternative consists of fill placement consistently along the entire beach segment from STA 2+0 to STA 35+0 (Alternative #1). The extent of Alternative #1 covers the full extent of the area experiencing erosion since the fill 2016 placement. Erosion has dominated, with the exception of after nourishment, along this segment since 2007. Alternative #1 consists of the placement of 31,300 cu yd of fill material along a 3,400-ft long beach segment (STA 2+0 to STA 35+0) and includes three parks. Alternative #2 consists of 24,000 cu yd along 2,600 ft segment (STA 2+0 to STA 28+0) of the beach and includes two parks. Alternative #3 consists of 13,200 cu yd placed along a 1,200-ft long beach segment (STA 2+0 to STA 14+0) and is focused on the beach fronting the parking lot near the Lex. For all Alternatives, the fill material would be placed from the landward limit or maximum elevation of 3 ft (NAVD88) offshore to restore beach volume and elevation compromised between nourishment events and provide for proper slope for drainage. The location of the three nourishment Alternatives is shown in Figure 19.

Northeast (Transition and Backpass Zone)

The northeast side of the beach began to exhibit downdrift benefit from the erosion of the 2016 fill placement along the southwest side of the beach within the first year after placement. Accretion resulted in an increase in beach width in 2016 and during 2017, likely reinforced by Hurricane Harvey's influence on erosion of the southeast end. The beach width along the northeast end between STA 50+0 and STA 70+0 decreased in width with the width decreasing by approximately 100 ft between STA 64+0 to STA 68+0 due to backpass of sand to the southwest end. By Sep 2017, the beach width had recovered to approximately 50% of the pre-backpass width (2016). During 2017, the beach width increased between 10 and 30 ft. The northeastern reach remained well in excess of the Action Width with the narrowest segments related to the seaward position of Beachwalk which functions as the backshore limit. Based on historic performance, both quantified by CBI surveys since 2007 and interpreted from aerial imagery prior to 2007, the beach in this area is anticipated to gradually increase in width as the southeast beach continues to erode. Despite the temporary narrow width of the beach along the northeast end, the beach is functionally stable due to the wide vegetated backshore (60 to 100 ft wide) that provides additional stability and protection to adjacent public and private backshore infrastructure. The greatest challenge along the backshore of the northeast side of the beach is the persistent pooling of water that reportedly discourage public access.

Additional Considerations

As previously reported, North Beach has a varied backshore infrastructure that provides challenges from a beach maintenance perspective. Wind-blown transport of sand is prevalent at North Beach and may result in significant sand loss because coppice dune formation is not promoted or facilitated due to the presence of sidewalks and other backshore infrastructure. Although sand accumulates on sidewalks, backshore infrastructure limits the region available for natural accretion in the form of coppice dunes that could potentially function as storage for windblown sand and provide a barrier to surge during storms. The beach elevation at North Beach is limited by the existing elevation of the backshore infrastructure (sidewalks, parking lots and roadways) at approximately 3.0 ft. The northeast end of the beach benefits from not only the sheltering effect of the terminal groin but also the substantial setback of infrastructure such that low elevation dunes and a highly vegetated backshore environment have developed. On the southwest side of the beach, the implementation of an increase in elevation of the adjacent backshore infrastructure during opportunities for restoration or revitalization would provide for the increase of the elevation of the berm in the future while affording additional protection against nuisance flooding. Shifting infrastructure landward, such as at the Park waterfront facilities would promote a more stable beach environment while also protecting the infrastructure. Set back of facilities is recommended, as the facilities require renovation or re-construction.

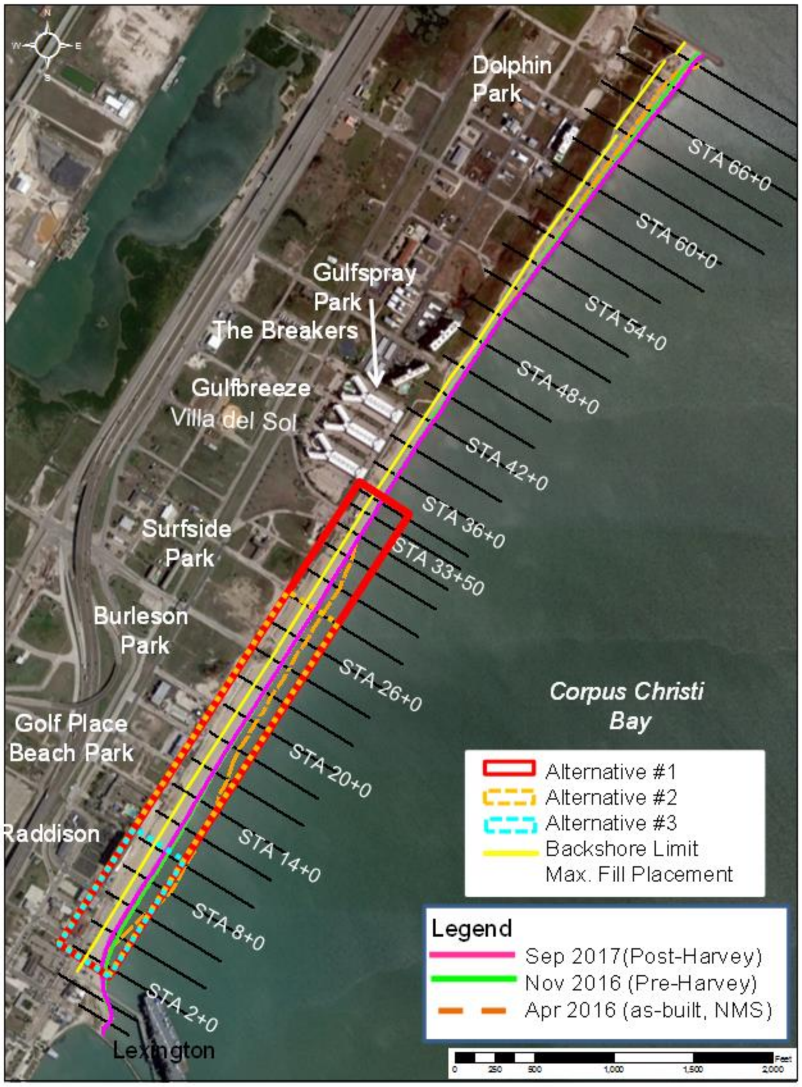


Figure 14. Alongshore extent of nourishment for Alternatives 1-3

Quintana Beach: Bryan Beach

Quintana Beach refers to the nearly 3-mile stretch of Gulf beach that is located southwest of the Freeport Ship Channel and northeast of the Brazos River (Fig 20). Sediment transport is largely compartmentalized due to limitations imposed by the inlet to the east and river to the west. Bryan Beach, Cortez Beach as well as Quintana County Beach Park are located in this area. The majority of this region is within CBRA boundaries, excluding the 2,000-ft long segment defined as Bryan Beach. Prior to 2014, the monitoring effort included Cortez Beach that is located approximately 1.4 miles southwest of the Freeport Ship Channel, and northeast of Bryan Beach. The Bryan Beach project area is located less than 1-mile southwest of Cortez Beach, bordered to the southwest by Bryan Beach Road. The Bryan Beach project area is defined as the section of Quintana Beach between STA 0+0 and STA 20+0 (Fig 21). There are limited historic data available describing this section of Quintana Beach in its entirety. In addition, with the removal of the Cortez Beach survey, the survey extent from 2014 to 2017 no longer extends to the Freeport Ship Channel, which limits a more comprehensive investigation of the complexities of sediment transport southwest of the Freeport Ship Channel. This reporting focuses on changes occurring at Bryan Beach between 2016 and 2017 specifically influenced by Hurricane Harvey, and in the context of the previous reporting describing changes observed since the 2005 nourishment and more limitedly since 2000 (BEG) with regard to shoreline position change.

Three CEPRA nourishment and dune restoration projects have been completed at Bryan Beach. A dune restoration project was completed during Sep 2003 (CEPRA 1154) and subsequent nourishment conducted during Mar 2005 (CEPRA 1175). The original placement (2005) extended along a 1,850-ft section of beach. The more recent nourishment completed during Mar 2016 (CEPRA 1571) was a FEMA Public Assistance program repair related to beach loss during Hurricanes Ike and Rita. Additional stabilization though the placement of sand fencing along the dune line as well as planting of vegetation and placement of Christmas trees has been implemented by Brazoria County. In addition, Cortez Beach and ultimately Bryan Beach may have indirectly benefited from offshore placement of sand dredged from the Freeport Ship Channel as well as sand eroding from the nourishment efforts at Surfside Beach located just north of the Freeport jetties. It is difficult to quantify the contribution of these placement activities, particularly at Bryan Beach which lies well to the west of these placement areas.

Over the previous reporting period, Bryan Beach was relative stable despite frequent and persistent periods of inundation during 2016. Relative stability during the previous reporting period reflected the influence of the nourishment project that was completed during March 2016. The shoreline was relatively stable within the project area and the nourishment provided for an increase in elevation across the berm and backshore fronting the narrow low-elevation restored duneline. There was limited indication of indirect benefit of the fill placement alongshore to the east and west but the fill may have contributed to the overall stability during 2016.

High recession rates dominated after Hurricane Harvey impacted the area in August 2017, in part due to inundation during an extended period of water in excess of MHHW (Fig 22). The rate of recession was second only to that measured after Hurricane Ike in 2008. Erosion was focused at the berm crest, although the net rate of erosion was moderate and on the same order of magnitude above the -10 ft contour as that documented in past reporting periods due to significant impoundment in the nearshore beyond the -10 ft contour during 2017.

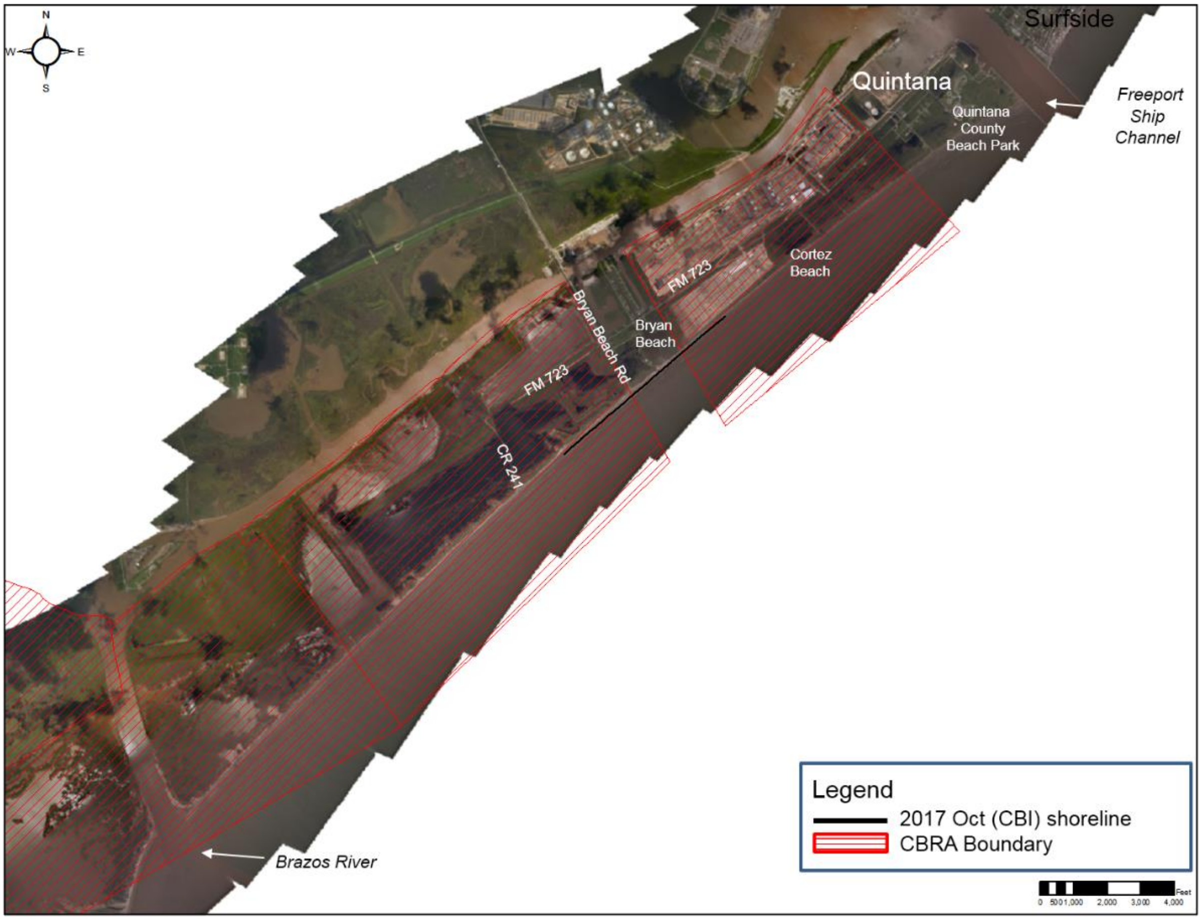


Figure 20. Location of Bryan Beach relative to key features relevant to the Quintana Beach area

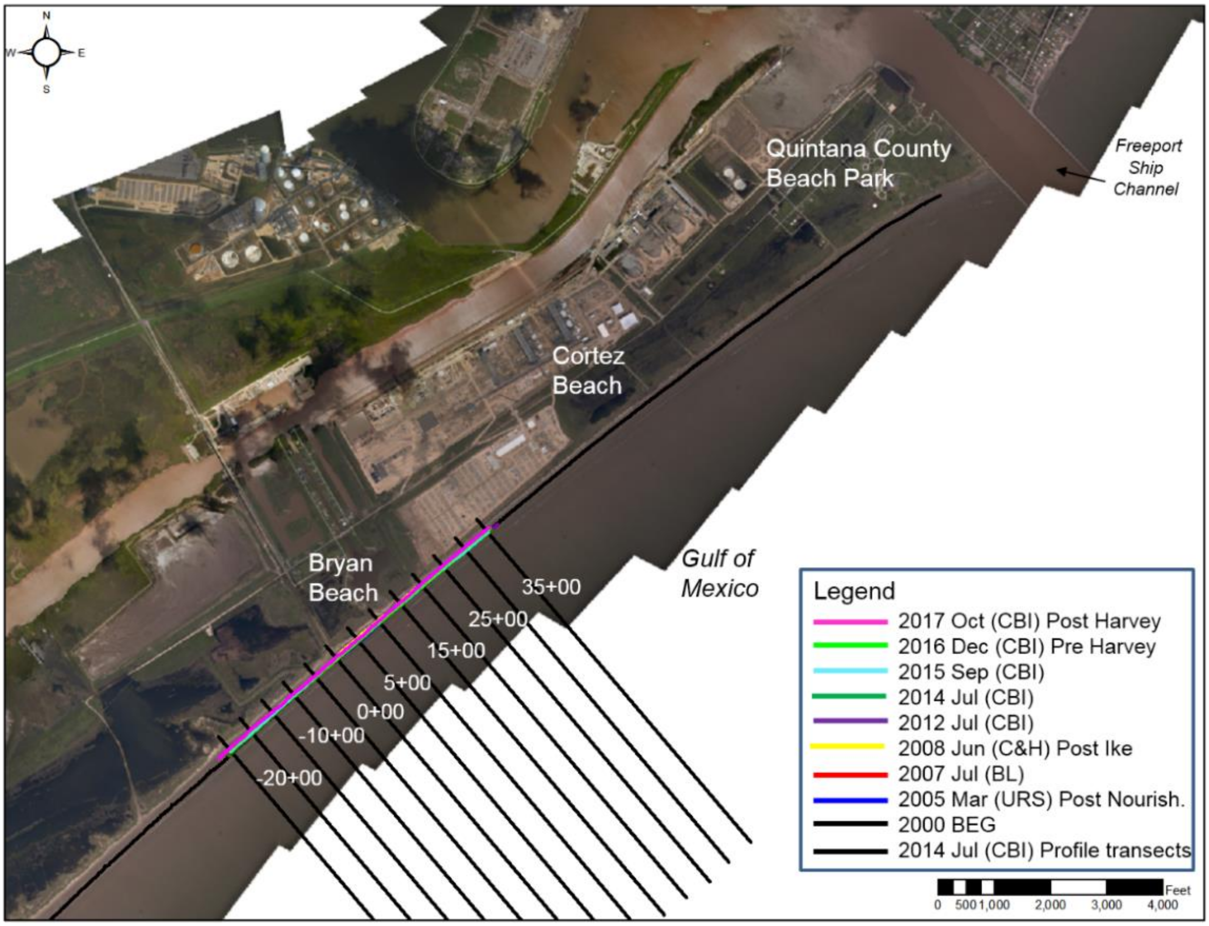


Figure 151. Transect locations at Bryan Beach relative to Quintana County Beach Park and CBRA Boundaries

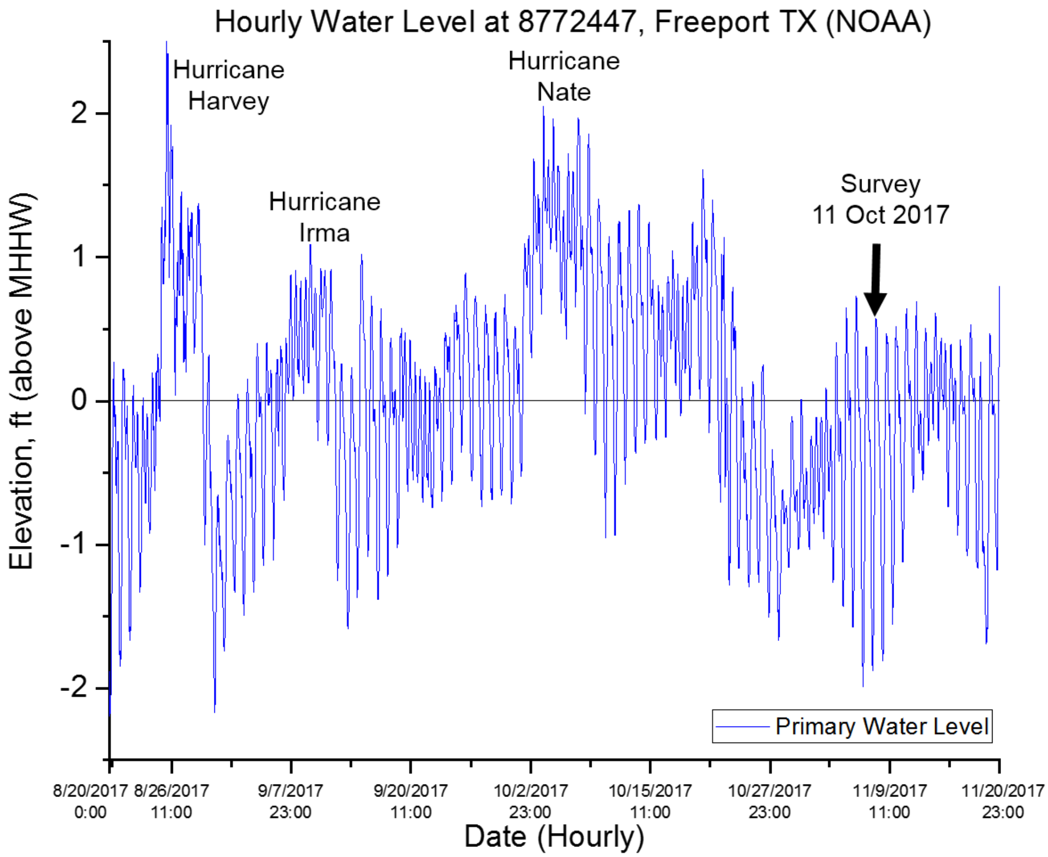


Figure 22. Elevated water level in excess of 1 to 2.5-ft MHHW (Freeport, USCG Station) influenced by Harvey, Irma and Nate and reinforced by lunar perigee in advance of the Oct 2017 survey

Shoreline Analysis: Bryan Beach

The shoreline along the Project Area at Bryan Beach was landward of the 2016 position after Hurricane Harvey. Recession dominated along the majority of the Study Area from STA 35+0 at the east end to STA -5+0, located west of the Project Area and Bryan Beach Rd. The rate of recession at Bryan Beach was on the order of that observed after Hurricane Ike during 2008 and the highest observed at CEPRA beaches monitored along the Texas Coast after Harvey. The average rate of shoreline change was -31 ft/yr along the Project Area and -32 ft/yr along the Study Area. Taking into account the background rate calculated for the period prior to impact by Hurricane Ike the rate of shoreline change attributable to Harvey is estimated at approximately -25 to -26 ft/yr.

During August 2017, the influence of the fill placement completed during Mar 2016 was no longer evident along the Project Area but downdrift benefit was indicated to the west where the rate of shoreline recession was lowest (Fig 23-25). The rate of shoreline change over key periods since 2000 (BEG shoreline data) is provided in Table 1. The variability in rate of shoreline change with alongshore position in the Project Area over the 1) 2016-2017 (Post-Harvey) 2) 2015-2016 (Previous reporting period), 3) 2014-2015 (Annual) and 3) 2005-2017 (full study period post-original nourishment) are compared in Figure 26. Applying the BEG 2000 shoreline for an estimate of historic change in this area indicated a relatively low 17-year average rate of change in shoreline position at -2.4 ft/yr for the Project Area and -2.9 ft/yr over the Study Area. The rate calculated over the pre-Ike period of low storm incidence provides insight into the background rate of recession by eliminating both the extreme recession that occurred during Ike as well as shoreline advance related to both limited natural recovery and transients benefits of nourishment. The average rate of shoreline position change prior to Harvey (2000-2007) was -0.53 ft.

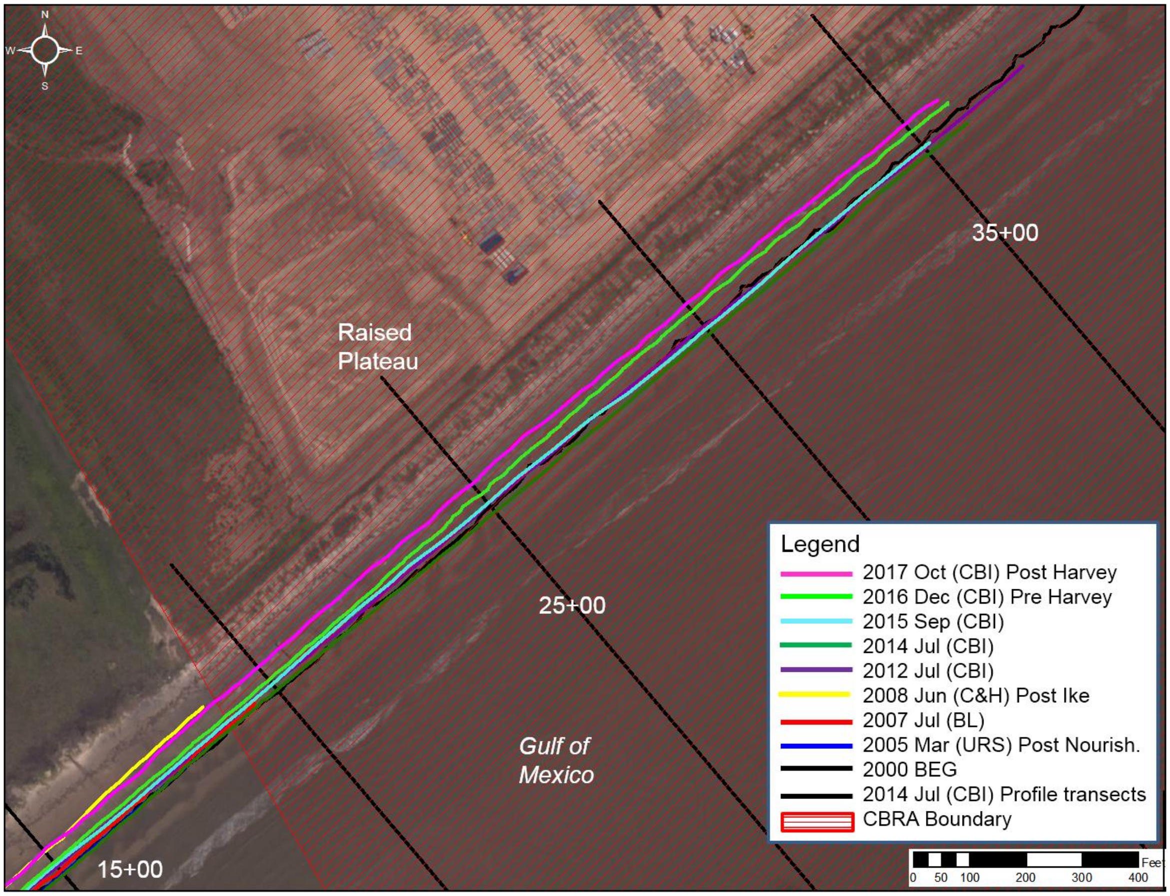


Figure 23. East End of Project Area and Eastern Study Area: 2017 shoreline position was at most landward position since Hurricane Ike (2008)

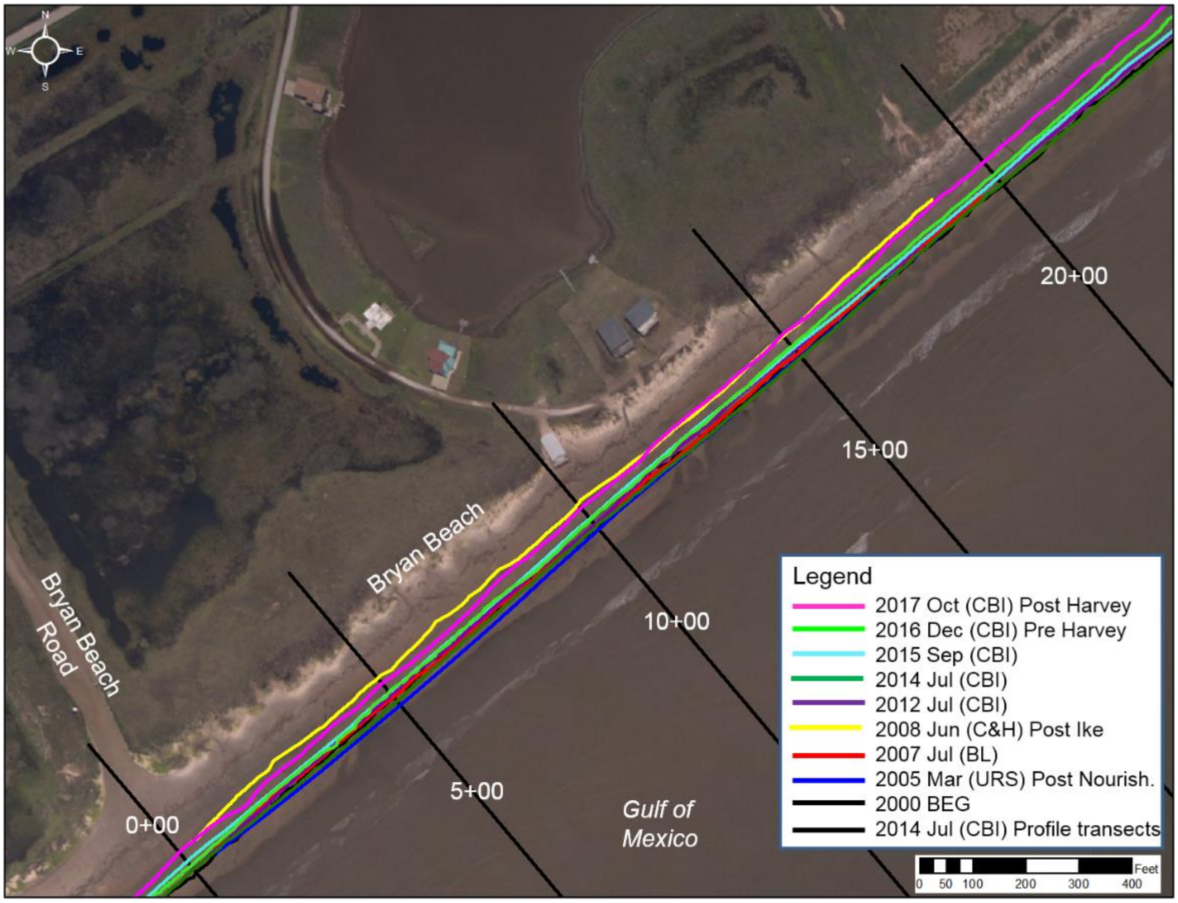


Figure 24. Project Area: Shoreline recession dominated along entire project area between 2016 and 2017 due to influence of Harvey and decrease in effectiveness of 2016 fill placement

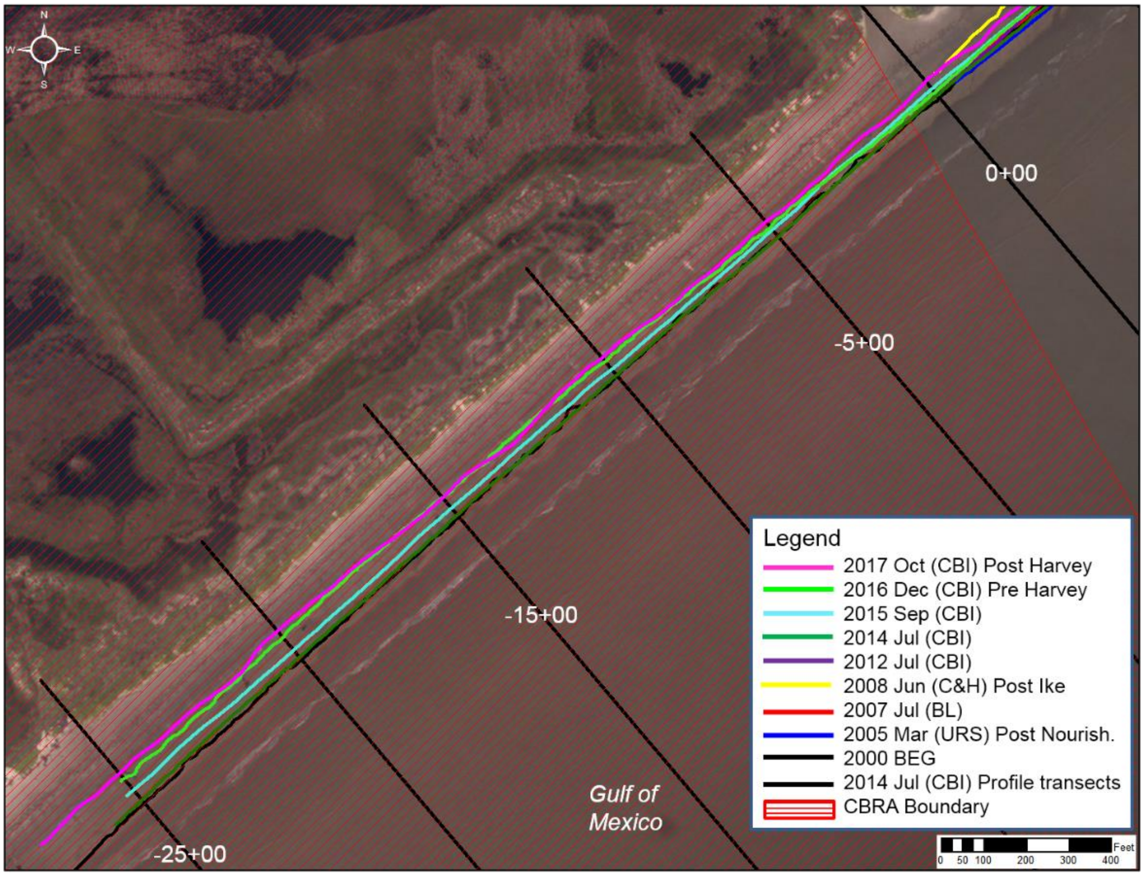


Figure 25. Relative stability of shoreline west of the Project Area due in part to downdrift benefit of fill placed in 2016

Table 1. Variability in Rate of Shoreline Position Change: Bryan Beach (2017)		
Limited Project Area (STA 0+00 to STA 20+00)		
Interval (Year)	**Description (influences)**	**Rate of Change** + Advance - Recession (ft/yr)
2016-2017	Annual Survey (Post-Harvey)	-31.0
2012-2017	5yr Average	-5.8
2005-2017	12-yr Post 1st Nourishment (Data Record)	-3.4
2000-2017	BEG Historic	-2.4
Previous Reporting Periods		
2000-2016	BEG Historic	-1.0
2012-2016	4yr Average	-1.6
2015-2016	Annual Survey	+0.2
2014-2015	Annual Survey	-16.6
2012-2014	Bi-annual Survey	+6.3
Long-term Intervals of Significance		
2000-2008	Pre-Ike (background rate)	-5.6
2008-2016	Post-Ike History	-1.6
2007-2016	Pre- Ike Shoreline Position	-1.3
2005-2016	Pre- 1st Nourishment (Data Record)	-2.0
Event Intervals of Interest		
2008-2012	Post-Ike Recovery	+10.1
2007-2008	Post-Ike	-37.6
2005-2007	2-yr post-nourishment	-6.0
Full Study Area (STA -25+00 to STA 35+00)		
2016-2017	Annual Survey (Post-Harvey)	-32.0
2000-2017	BEG Historic	-2.9
2000-2016	BEG Historic	-0.3
2015-2016	Annual Survey	-13.4
2014-2015	Annual Survey	-16.1
Notes: Nourishment Summary		
Dune Restoration: Sep 2003, Beach nourishment Mar 2005, Beach nourishment Feb 2016		

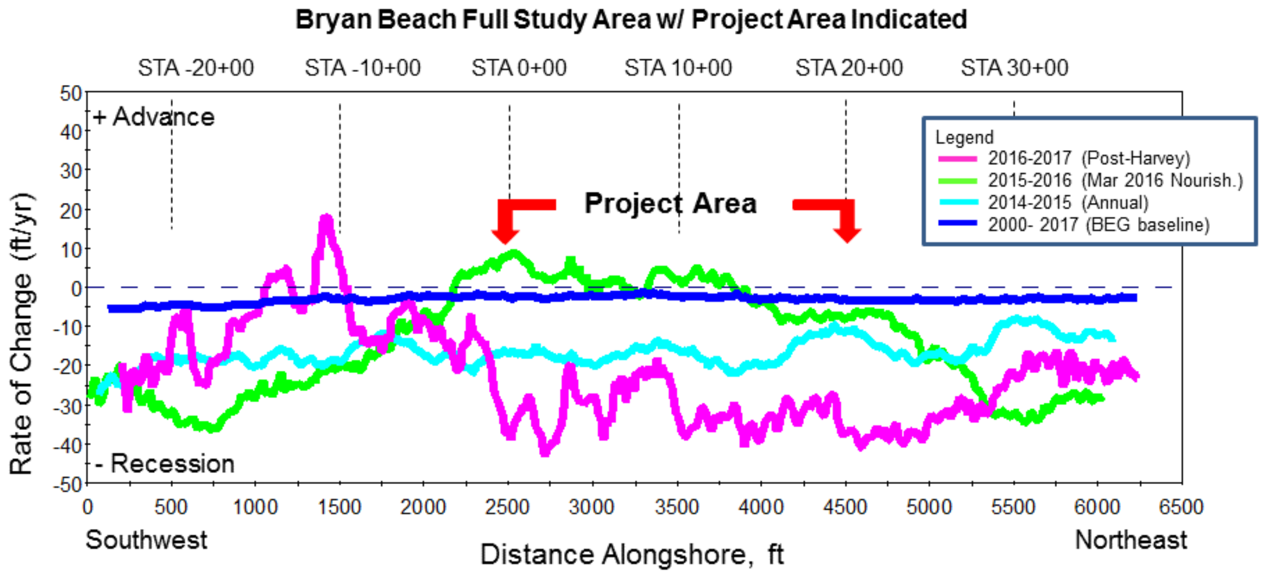


Figure 26. Alongshore variability in rate of shoreline change in the Project Area and broader Study Area over the following intervals; 1) 2016-2017 (Post-Harvey) 2) 2015-2016 (Previous reporting period), 3) 2014-2015 (Annual) and 4) 2000-2017 (full study period BEG baseline)

Beach Width: Bryan Beach

After Harvey, 90% of the project area was at or within 5 ft of the Action Width (75 ft), an increase of 20 % compared with the previous 2016 reporting period (Table 2). The width of the beach in the study area (STA -25+0 to STA 35+0) generally decreased from west toward the east, consistent with past reporting. In the Project Area, the beach was widest (120 ft) at the western limit (STA 0+0) and the narrowest (39 ft) at the eastern limit (STA 20+0). The width of the beach east of the Project Area was also less than Action Width, ranging from 27 to 39 ft. West of the Project Area, the beach width ranged from 85 to 144 ft. After Harvey, 100 % of the Study Area remained well under the Target Width (150 ft).

The average change in the beach width along the Project Area after Harvey was -27 ft with a minimum of -20 and a maximum of -35 ft at the west end. The average change in beach width along the entire Study Area was -19.0 ft.

Table 2. Change in Beach Width: Bryan Beach (2005 to 2017)
Target Width (TW) = 150 (2005 Design Max) ft Action Width (AW) = 75 ft
Within 5 ft of Action Width ▬ Action Width in Project Area
*New Transect 2014

STA	Beach Width									▲	▲
	2000	2005	2007	2008	Jul 2012	May 2014 (Rev. 2015)	Sep 2015	Dec 2016	Post-Harvey Oct 2017	2016 2017	Action Width
-25+00*	234	144	N/A	N/A	N/A	224	194	158	144	-14	69
-20+00*	164	85	N/A	N/A	N/A	155	135	95	85	-10	10
-15+00*	152	95	N/A	N/A	N/A	148	128	105	95	0	20
-10+00*	147	94	N/A	N/A	N/A	145	127	122	94	-11	19
-5+00*	149	104	N/A	N/A	N/A	150	130	122	104	-18	29
0+00 (West End)	170		155(est.)	115 est.)	**157**	**160**	144	155	120	-35	45
5+00	93	120	93	45	**87**	**103**	80	79	60	-35	45
10+00	97	60	92	40	**90**	**94**	76	79	50	-20	-15
15+00	98	50	90	46	**81**	**100**	76	72	48	-29	-25
20+00 (East end)	94	48	84	N/A	**76**	**90**	76	68	39	-24	-27
25+00	86		N/A	N/A	78	97	78	59	32		-75
30+00	90	39	N/A	N/A	92	105	94	54	39	-29	-36
35+00	72	32	N/A	N/A	83	95	80	45	27	-27	-43

Beach Morphology: Bryan Beach

Erosion at Bryan Beach was focused predominantly along the berm and foreshore between 2016 and 2017, which is consistent with the focus of erosion documented in previous reporting. The restored dune system experienced minor erosion of the low elevation primary dune whereas the foredune was relatively stable with the exception of minor erosion at STA 15+0 near the eastern limit of the Project Area. Areas of erosion along the backshore were intermittent along the Project Area. Dune and backshore erosion were most well developed near the west end of the Project Area (STA 0+0). Although limited influence of the 2016 nourishment remained evident along the Project Area with erosion dominating along 90% of the nourished beach, there was evidence of downdrift benefit along the beach to the west the Project Area. The recent relative stability of the dune system along Bryan Beach, despite storm forcing can be attributed, in part, to the ongoing restoration that has also included sand fencing along the majority of the backshore in the project area and ongoing nourishment. The relatively low and narrow dunes along this segment of the beach continue to represent a weak barrier in comparison to the adjacent backshore limit to the immediate east (mechanically enhanced) and west (natural dunes)

During the previous reporting, the beach in the Project Area had exhibited greater stability than the adjacent beach to the east and west. After Harvey erosion dominated along the Project Area and the adjacent beach to the east. Stability increased along the beach west of the Project Area, likely related to downdrift benefit of the 2016 nourishment and deposition of sand that eroded along the project area to the east. (Figs 27-34). The narrow dune system fronting South Lake Drive represents the area with the greatest opportunity for compromise during storm surge due to the limiting nature of the backshore infrastructure that influences the landward extent of dune expansion and degree of stabilization (Fig 29 and 31).

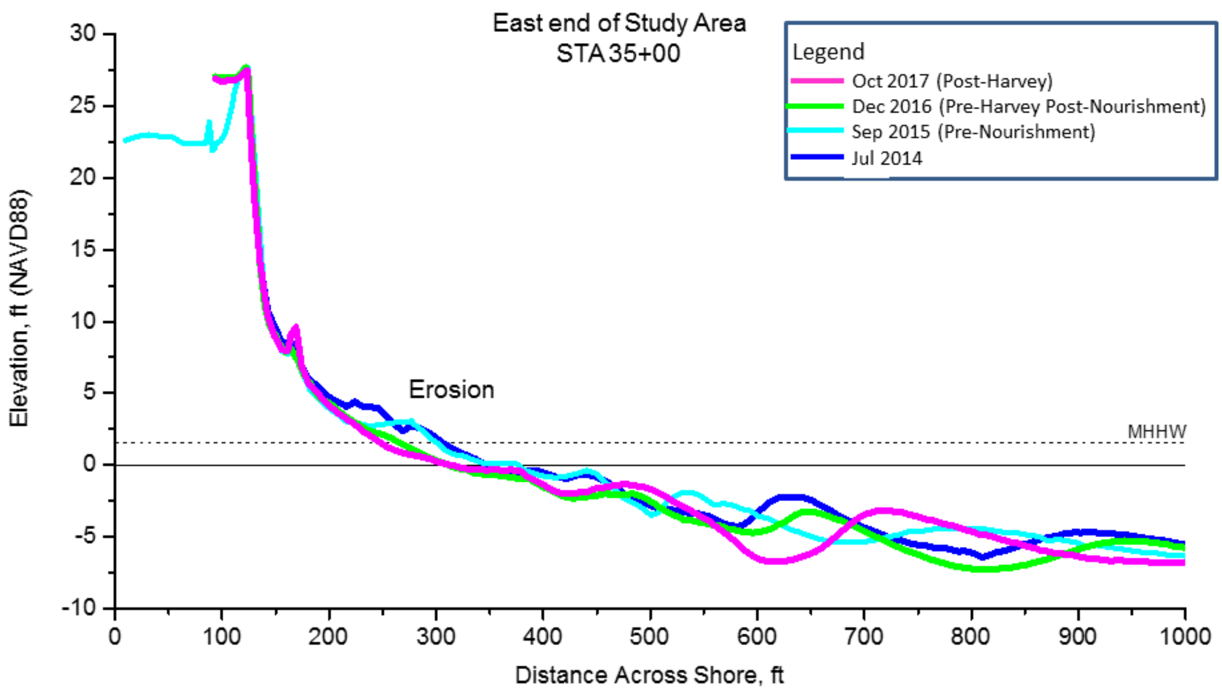


Figure 27. East End of Study Area: Backshore stability with erosion across berm crest (2017)

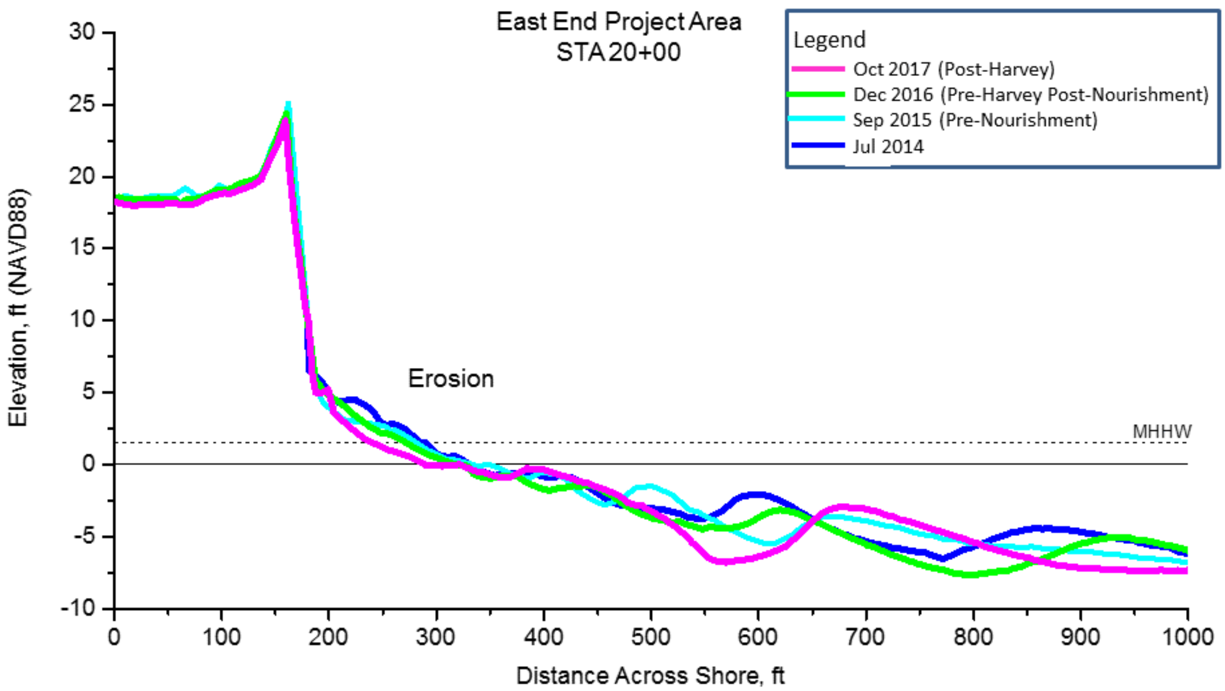


Figure 28. West of Project Area: Erosion dominates across the berm and foreshore (2015-2016)

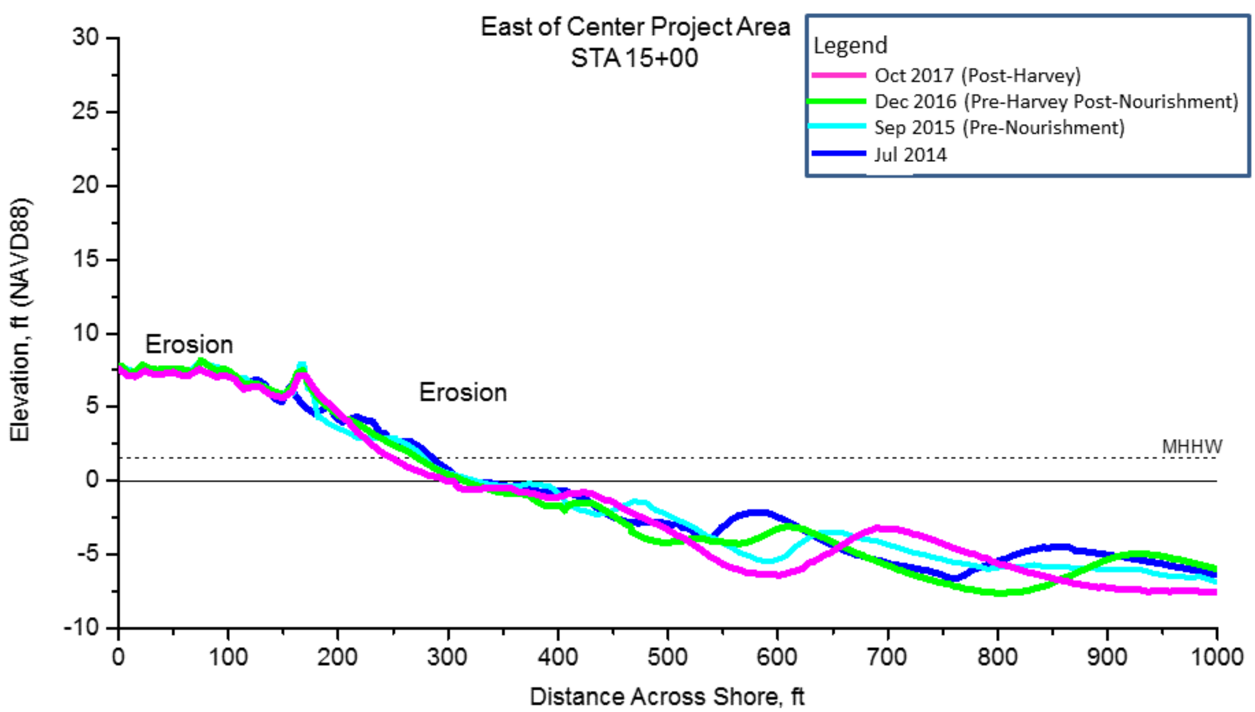


Figure 29. West of Center Project Area: Erosion across berm and foreshore (2017)

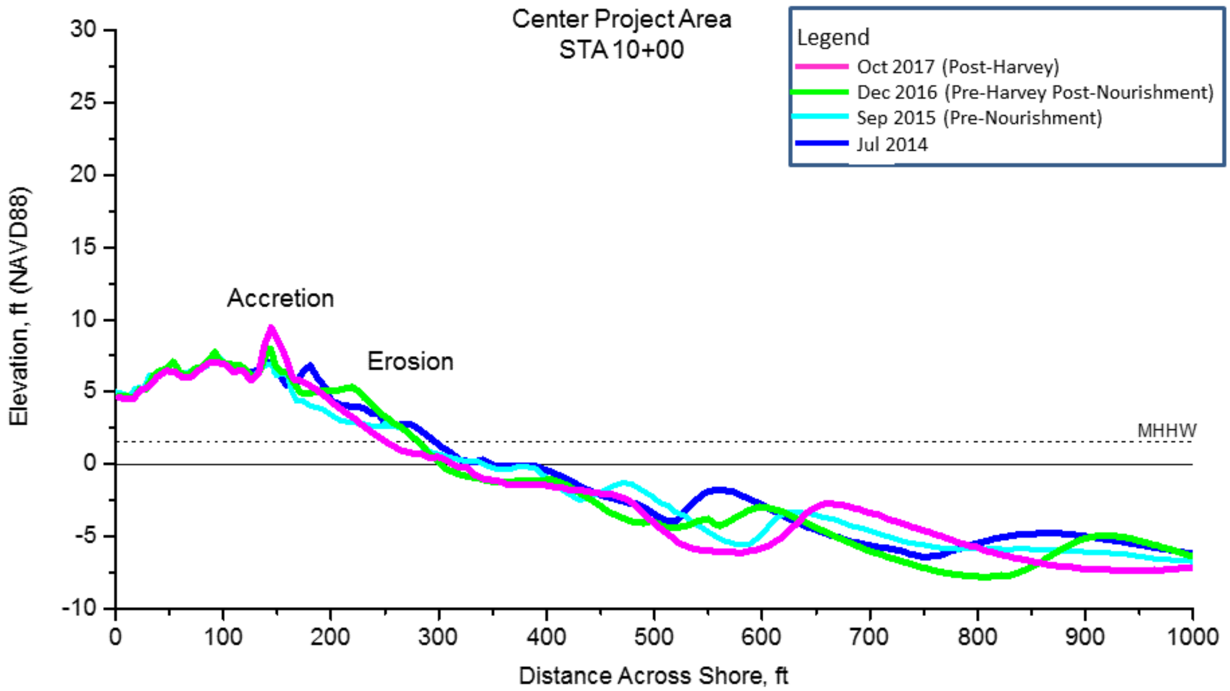


Figure 30. Center Project Area: Significant erosion across entire berm and foreshore with accretion at duneline (2017)

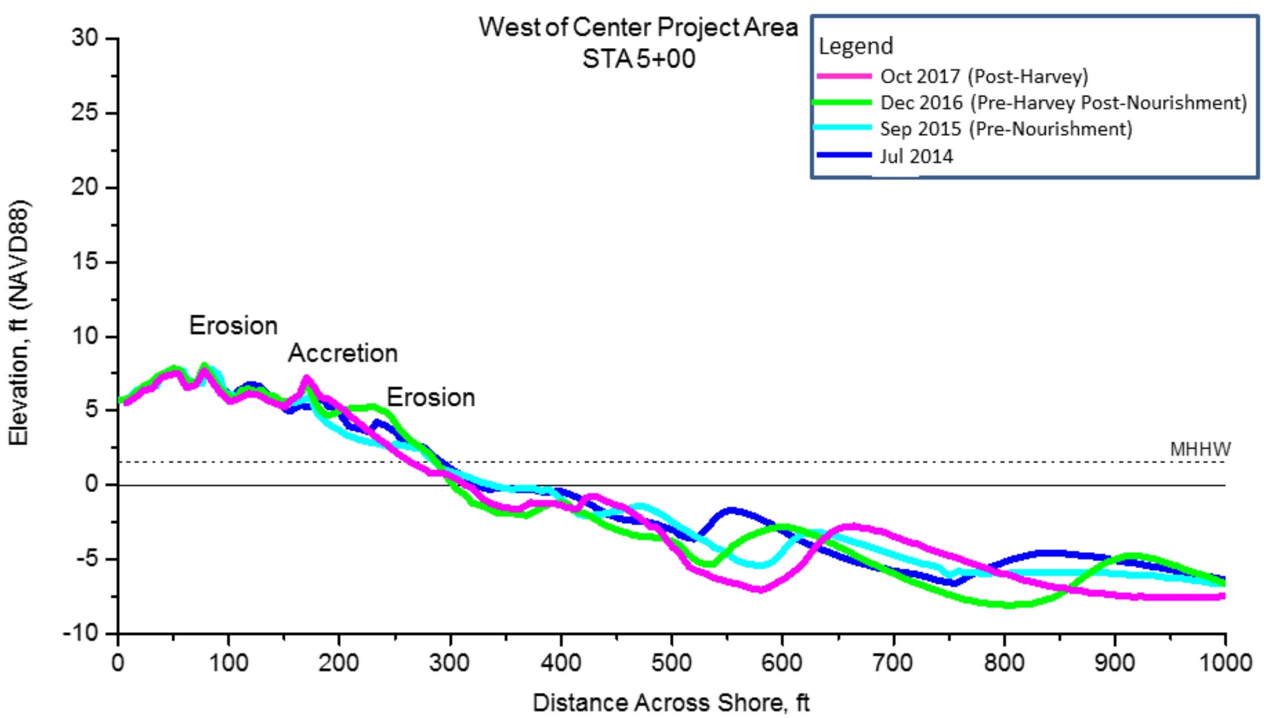


Figure 16. West of Center Project Area: Significant erosion across berm crest and foreshore. Erosoin landward of acreting primary dune (2017)

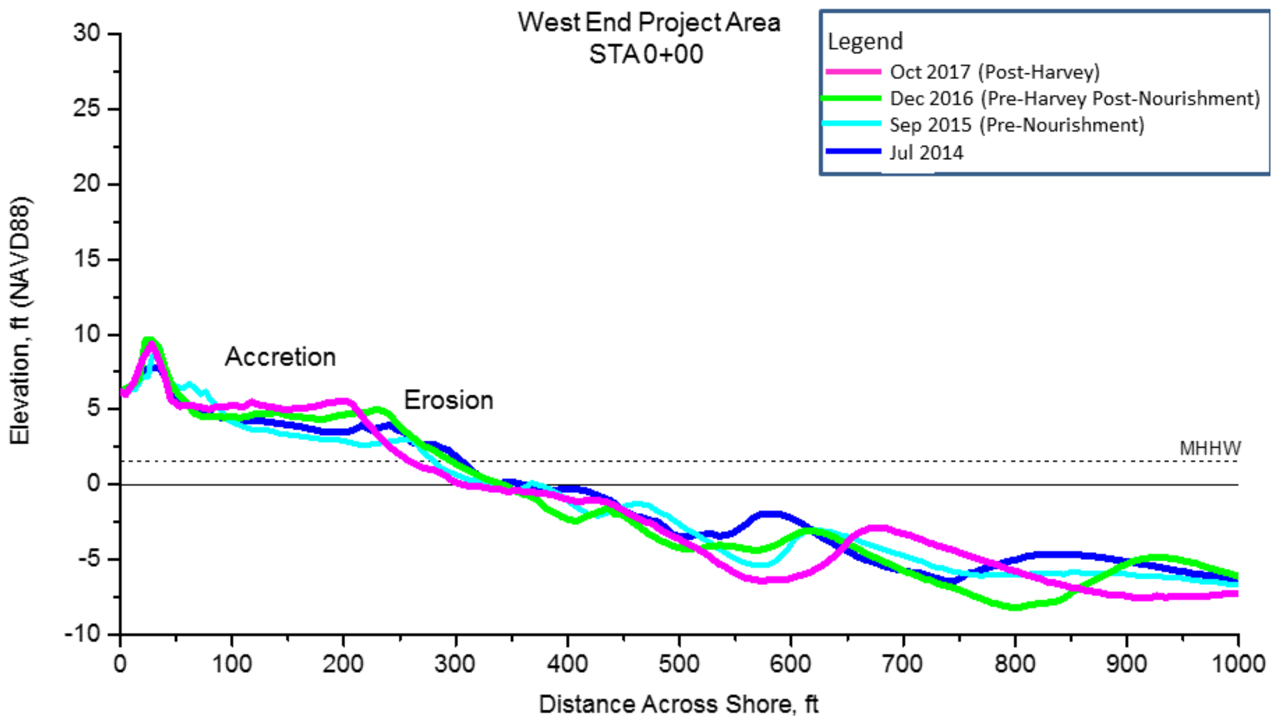


Figure 32. West End of Project Area: Backshore accretion offset by significant erosion across berm and foresshore (2017)

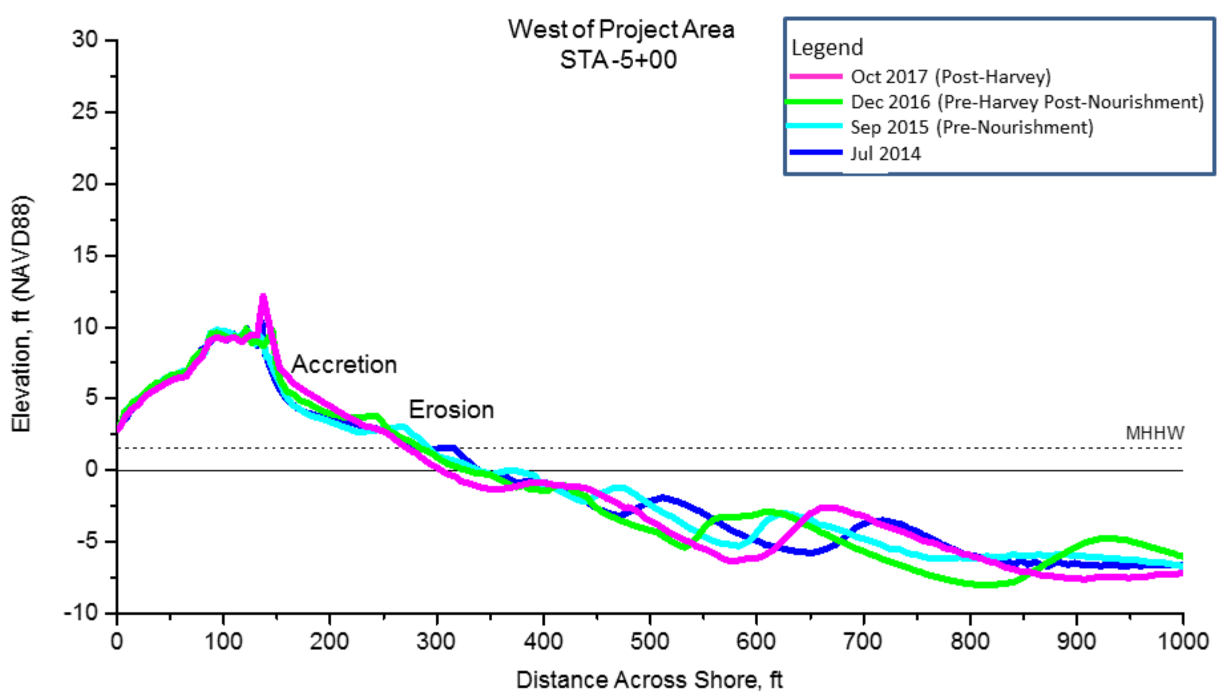


Figure 33. West of Project Area: Accretion along backshore with continued but moderated erosion across the berm and nearshore (2017)

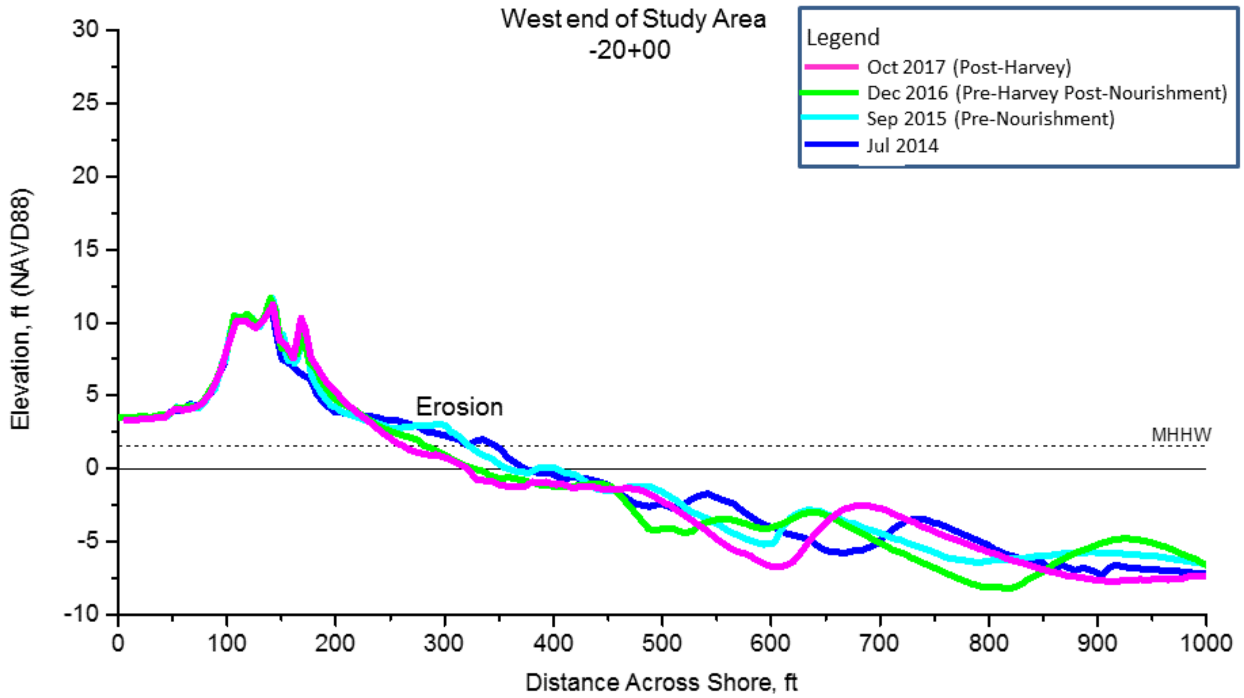


Figure 34. West End of Study Area: Erosion continues across the berm and foreshore at moderated rate at the west end of the Study Area (2017)

Volumetric Analysis and Nearshore Morphology: Bryan Beach

Erosion dominated across the foreshore and berm in the Project Area while generally accretion dominated across the nearshore offshore of the -10 ft contour with the exception of the offshore shelf. The offshore shelf continued to erode primarily west of the Project Area and was relatively stable along the Project Area and along the east end of the Study Area. Accretion continued along the offshore section of the profile where during 2016, a large-scale bar-like feature developed between the -20 and -25 ft contour (Fig 36-39). This area of deposition expanded landward up to the -10 ft contour. Although these features were most developed along the project area between STA 0+0 and STA 20+0, smaller scale accretionary features were also evident to a lesser degree alongshore to the eastern and western limit of the study area (STA 35+0 and STA -25+0, respectively) as shown in Figures 35 and 42. The decrease in the degree of development of these features beyond the project boundaries indicates the influence of the eroding fill placement during storm forcing. The well-developed wide region of accretion extends from 1,500 to 5,000 ft from the shoreline (MHHW) and may represent a region of discontinuity in sediment transport were strong alongshore currents transport sand eroding from the berm beyond the limit of future exchange with the subaerial beach and immediate nearshore. The variability in nearshore morphology seaward of the -10 ft contour along the study area from east to west is shown in Figures 35 to 42.

Due to the continued deposition indicated along an offshore area of variable morphology that was identified during 2016, volumetric analysis was conducted over two sections of the profile in an effort to isolate and quantify the order of magnitude of volume change relevant to the Project Area.

Volume change was quantified from the duneline to the -10 ft contour and over the offshore region from the -10 ft contour to -28 ft (DOC).

Erosion dominated along the Project Area between 2016 and the Post-Harvey survey with net change of -13,000 cy/yr which was in agreement in order of magnitude of that calculated during 2014 (-13,500 cy/yr) and 2015 (-11,400 cy/yr). In contrast, accretion dominated offshore of the -10 ft contour, with a gain of 37,000 cu yd between the -10 ft and -28 ft (DOC) contour. Large-scale features, well in excess of longshore bar dimensions have been identified offshore of the -10 to -15 ft contour along Bryan Beach. Similar areas of large-scale accretion and erosion have also been identified along Bolivar Peninsula in the past. The transient nature of these large-scale features that accrete and erode over annual and biannual periods, along with minimal longshore bar development in the nearshore indicates these features are representative of regional sediment transport that may integrate with local recovery.

The rate of erosion was estimated for the reporting period (2016-2017) along the project reach (STA 0+0 to STA 20+0) and the full study area from (STA -25+0 to STA 35+0). The erosion rate along the full study area was investigated to identify trends in sediment transport related to changes in morphology offshore of the -10 to -20 ft contour.

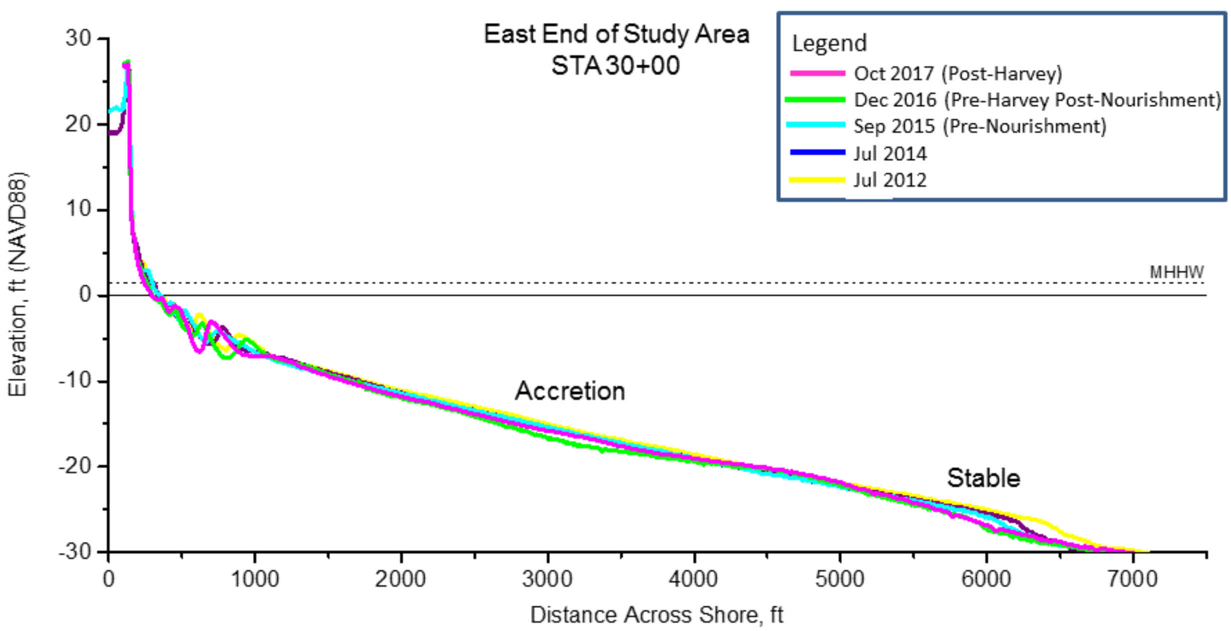


Figure 35. East End of Study Area: Increasing erosion across entire berm and foreshore with the shelf-like feature stabilizing (2017)

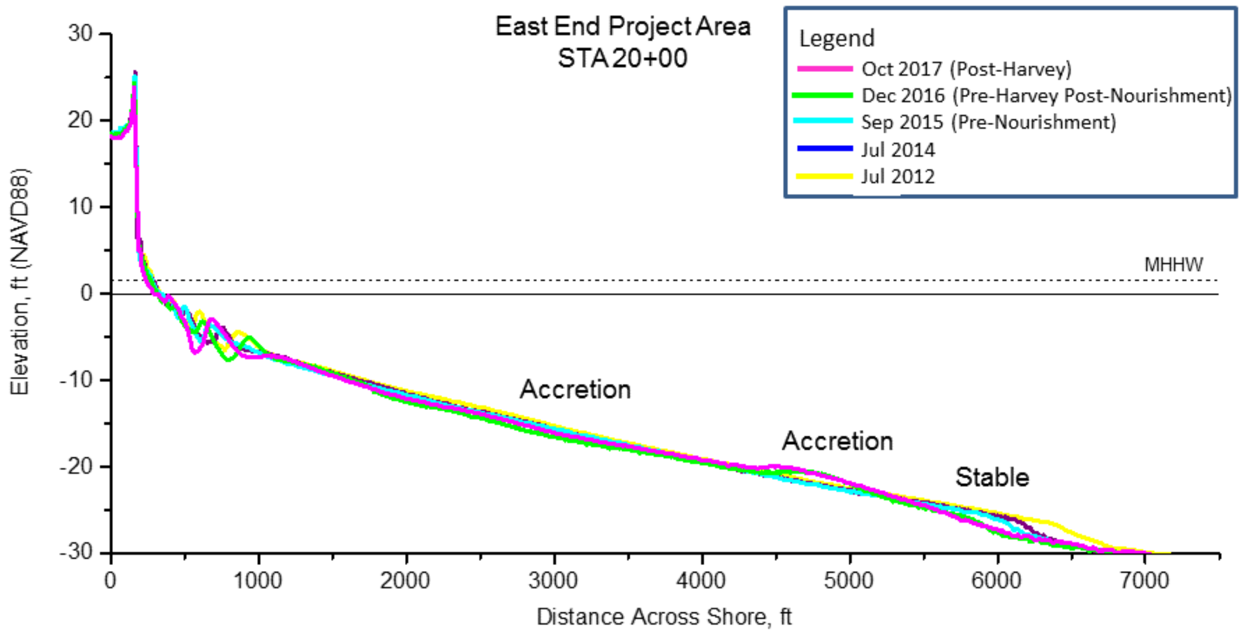


Figure 36. East End of Study Area: Accretion dominated seaward of the -10 ft contour terminating at the formerly eroding shelf-like feature (2017)

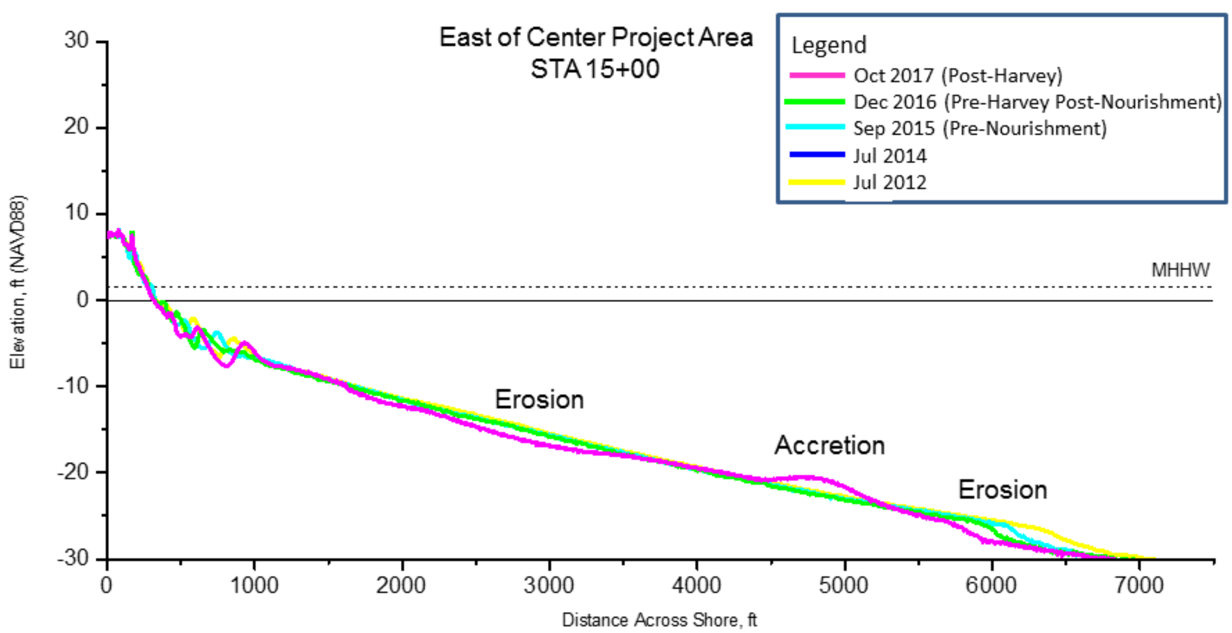


Figure 37. East of Center Project Area: Area of offshore accretion flanked by landward erosion and continued erosion of the shelf-like feature seaward (2017)

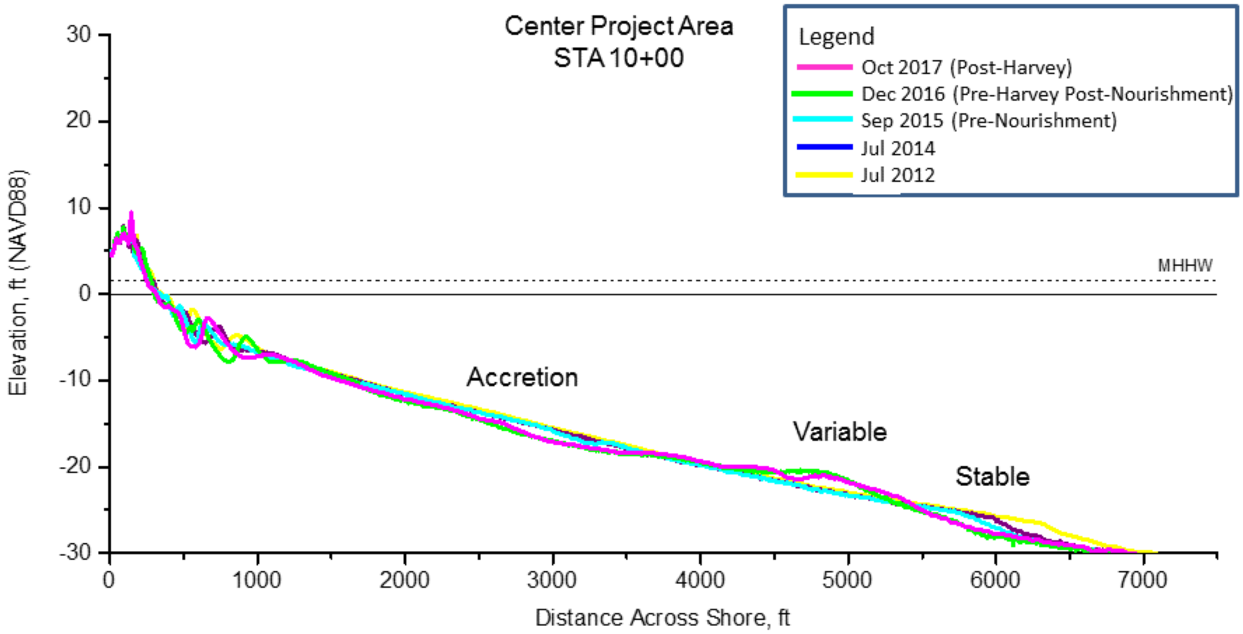


Figure 38. Center Project Area: Accretion dominated offshore of the -10 ft contour with intermittent erosion across the wide elevated feature followed by the stable shelf-like feature (2017)

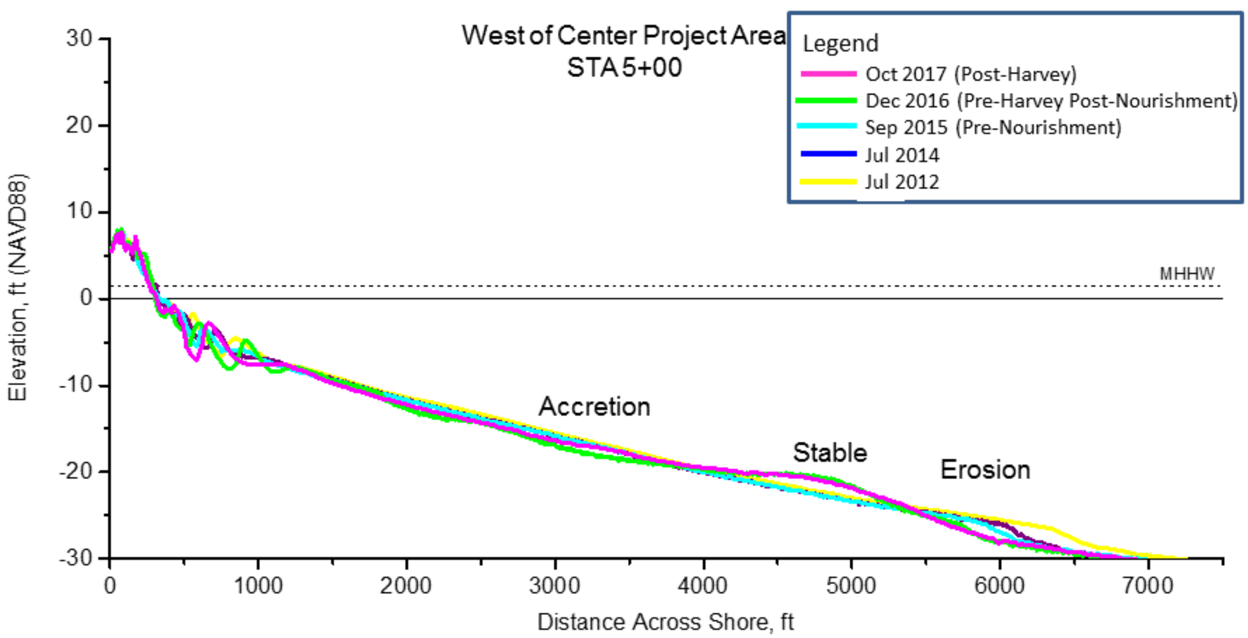


Figure 39. West of Center Project Area: Stable offshore raised feature flanked by accretion landward to the --10 contour and continued erosion of the offshore shelf-like feature (2017)

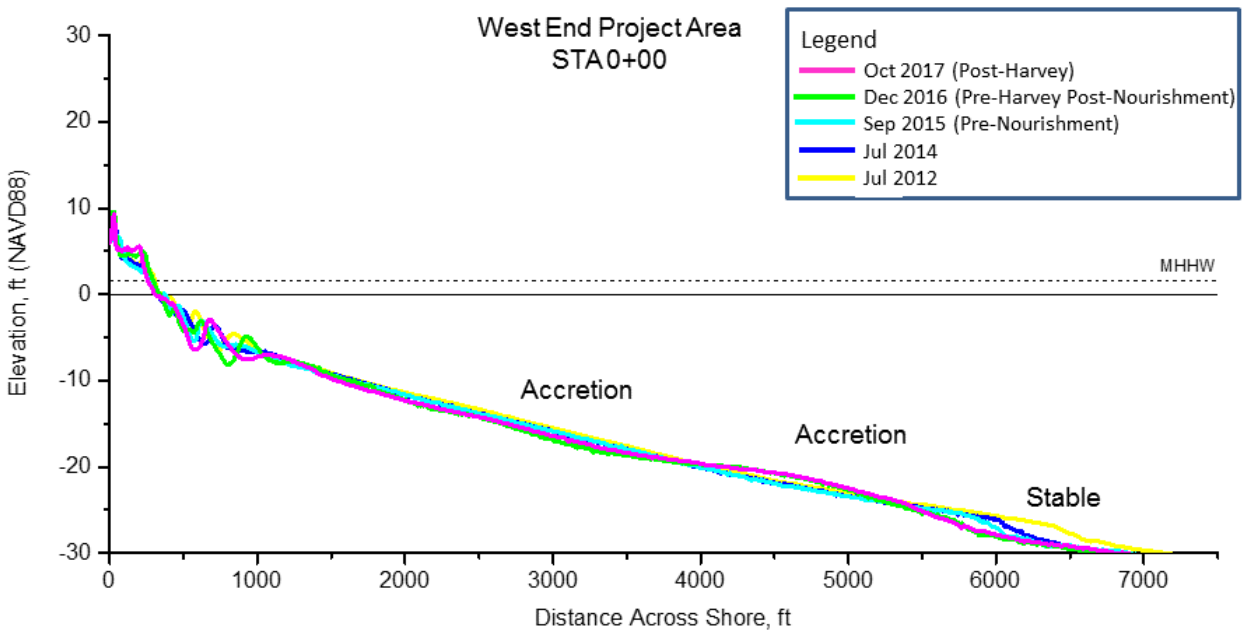


Figure 40. West End of Project Area: Accretion dominated seaward of the -10-ft contour and the shelf-like offshore feature stabilized during 2017

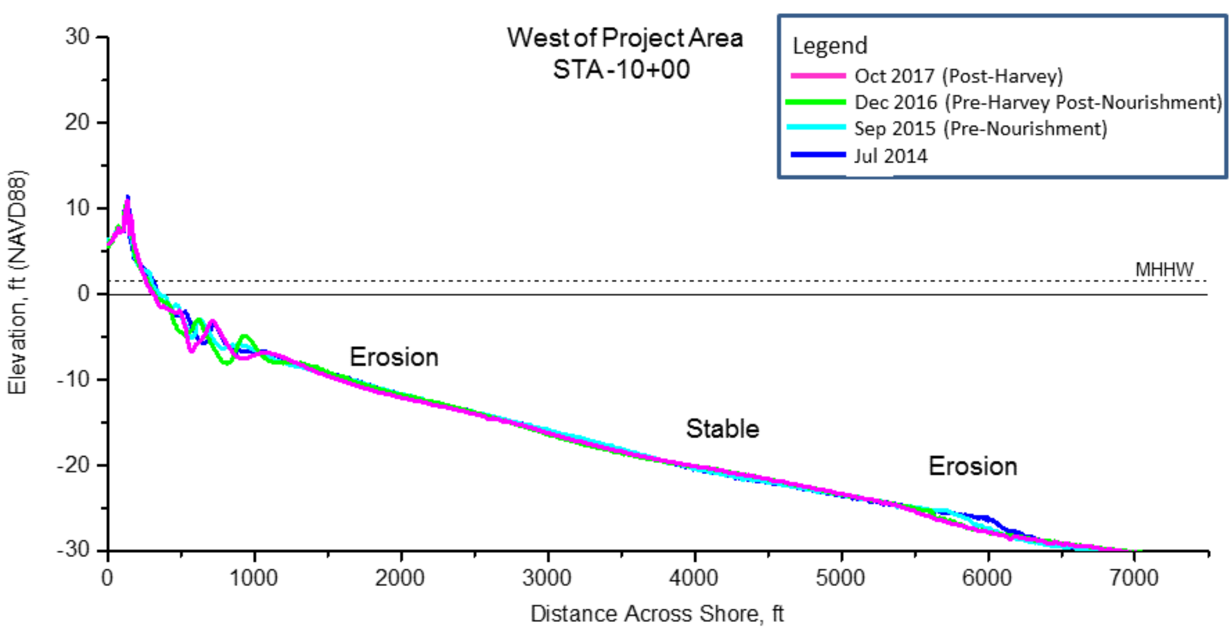


Figure 41. West End of Project Area: Decreasing stability west of the Project Area with erosion dominating from the -10 ft to -20 ft contour and at the offshore shelf-like feature (2017)

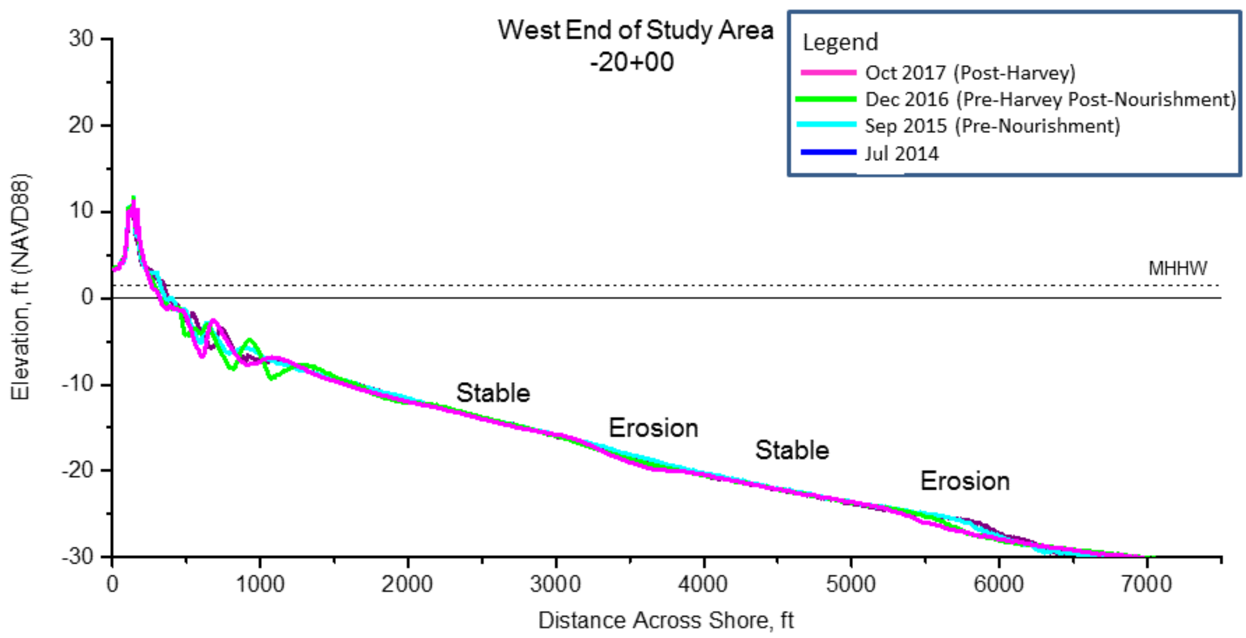


Figure 42. West End of Study Area: Intermittent stability and erosion seaward of the -10 ft contour with focused erosion at across the shelf-like offshore feature (2017)

Recommendations: Bryan Beach

Nourishment is recommended at Bryan Beach as soon as feasible and well within 2 years, based on the following criteria; 1) 90% of the beach in the Project Area and east of the Project Area was at or within 5 ft of the Action Width over the last two reporting periods despite nourishment completed during the 2016 reporting period, 2) High rate of shoreline recession along the adjacent beach to the east during 2017, 3) high rate of shoreline recession in the Project Area during previous 2016 reporting period (-13.5 ft/yr), 4) recent history of backshore erosion (2014 and 2015) and historically narrow dune system fronting infrastructure.

The estimated volume of sand required to restore the beach to a Target Width of 150 ft along the 2,000 ft project area is, at a minimum, 111,000 cu yd applying an offshore limit at the -10 ft contour and a berm elevation of 5.0 ft (NAVD88). The volume required to restore the beach to Target Width increased by 37,000 cu yd between the 2016 survey and the post-Harvey survey. At the time of the December survey, approximately 9 months after the fill placement, the backshore and duneline was stable although continued reinforcement is recommended both due to the history of erosion at along Bryan Beach and the beach extending to Freeport Ship Channel as well as due to the narrow and relatively low recovering dune system.

Rockport Beach

Rockport Beach is a nearly one-mile long community beach fronting Aransas Bay. Although the majority of the beach was relatively stable in width, erosion at Rockport Beach resulted in a decrease in beach elevation and width along the east and west ends such that a focused nourishment was completed during December 2015 and January 2016 (CEPRA Cycle 1603). A previous nourishment was conducted during 2004 (CEPRA Cycle 2 and 3) and the original nourishment was completed in 1988. The beach is stabilized to the east by a 750-ft long groin that minimizes interaction between the beach and nearby Leggett Light Channel at the entrance to Little Bay (Fig 43). The western boundary is formed by a groin that is an extension of Rockport Harbor. The Aransas County Navigation District (ACND) maintains the beach, which consists of surface grading mostly related to user redistribution of sand during recreation (reported as children digging large holes).

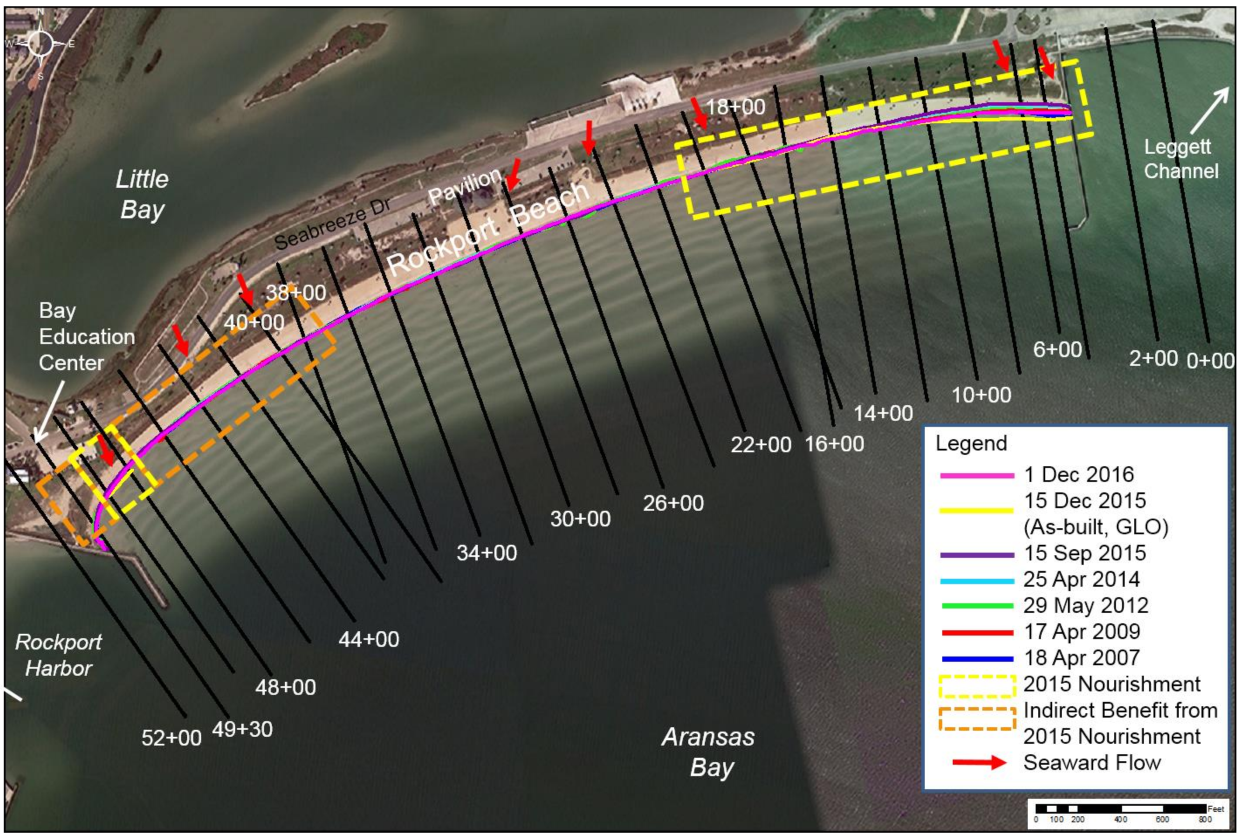


Figure 43. Location of 2015/2016 nourishment areas along the east and west end of Rockport Beach relative to transect locations and the pre-Harvey (Dec 2016) and post-Harvey (2017) shoreline positions

The majority of the beach, excluding the area fronting the park facilities is relatively narrow (30 to 100-ft wide), the width of the wide flat nearshore is exaggerated with depths of less than 3 ft (NAVD88) extending up to 700 ft offshore from MHHW. Analysis of beach profiles along Rockport Beach shows that the nearshore region does not approach the equilibrium profile for the native sand or from borrow sand sources that have been applied during nourishment. This type of elongated, flat nearshore region has been identified at other bayside beach locations along the south-central Texas coast, including the nearshore surrounding University Beach, and is indicative of a relic shoreline feature overlain with a veneer of sand. The prediction of sediment transport in such a system is challenging as the predictive tools rely on application of the equilibrium profile related to grain size. Therefore, analysis at Rockport Beach has been adapted to address the unique nearshore morphology.

The beach has consistently exhibited greater stability related to beach width along center beach than along the east and west end where the beach has historically eroded at a faster rate. Although the width of the central section of Rockport Beach has exhibited relative stability since 2007, the elevation across the berm has decreased as observed along the majority of remaining beach. The narrow east and west ends of the beach met or approached the Action Width between 2012 and 2015, prior to nourishment. Localized nourishment was recommended (Tier 2) in 2013 reporting. The most recent nourishment effort was reportedly completed January 08, 2016, although the as-built surveys are dated December 2015. The nourishment consisted of the placement of a reported volume of 6,581 cu yd on the beach with a focus on increasing the width and elevation of the narrow sections that existed at the east and west ends. The nourishment area extended along the beach between STA 5+0 and STA 20+0 (East End) and between STA 44+0 and STA 49+0 (West End), although site reports and the Dec 2016 survey indicated that the nourishment actually extended further along the berm on the west side up to STA 38+0 (Fig 43). The majority of the sand volume placed during 2015/2016 was along the eastern end of the beach according to the as-built survey.

Response Hurricane Harvey

This report documents the response of Rockport Beach to forcing that occurred between the 2016 survey (nearly one year post-nourishment), and the Sep 2017 survey (Post-Hurricane Harvey). The focus of the analysis was on determining the degree of impact of Hurricane Harvey on Rockport Beach. Rockport Beach is located just east of the point of landfall (St. Jose Island) as Hurricane Harvey moved onshore on 26 Aug 2017.

Changes in morphology at Rockport Beach indicate that the majority of storm forcing was distributed over the wide shallow nearshore during both storm surge (> 4 ft NAVD88) and along the seaward limit of the nearshore shelf. Erosion occurring as the storm approached the coast was followed by equal, perhaps greater erosion that occurred once the storm moved further onshore. Once the storm moved onshore, the direction of wind forcing reversed and water began to recede flowing toward Aransas Bay from both the mainland and Little Bay. For a period of time, as the water receded, water likely flowed uniformly or sheet-like over the berm into the nearshore. Changes that resulted from both onshore and offshore forcing included; 1) focused erosion at the berm crest along the east side of the beach (STA 5+0 to STA 30+0), 2) features similar to washovers that functioned as shallow drainage channels fed by receding water from the north, 3) accretion across the foreshore, and 4) dampening or elimination of the bar system along the flat nearshore. Despite the most substantial loss of sand observed since monitoring began in 2007, there was limited change in the position of MHHW because of the redistribution of sand that eroded from the berm crest seaward across the foreshore and immediate nearshore. The limited damage to the foreshore is owed to the rapid onshore progression of the storm. Once the storm moved onshore, the winds reversed limiting energy focused on the subaerial beach.

Conditions during Harvey exacerbated erosion/scour at the offshore limit of the nearshore shelf in the prior location of more limited and gradual erosion/scour. Large-scale erosion/scour along the offshore limit of the shelf is attributed to episodic high velocity/duration alongshore flow that was generated by strong winds as the hurricane approached and made landfall. The wind conditions intensified with approach of the storm toward the coast and strong winds directed out of the north to east dominating, up until the failure of the monitoring station, shown in Figure 44. The alongshore flow generated by the strong east to west longshore current was potentially reinforced by the subsequent exit of storm waters through Leggett Channel as high water levels subsided. The potential for interaction between focused alongshore water flow and the offshore limit of the nearshore shelf can be inferred from aerial imagery taken during two representative periods of 1) west to east forcing after Harvey (Fig 45A) as compared to, 2) east to west forcing during Dec 2008 (Fig 45B). Erosion/scour stimulated by the strong alongshore flow was greatest along the edge of the shelf near the east groin and decreased in magnitude with distance toward the west.

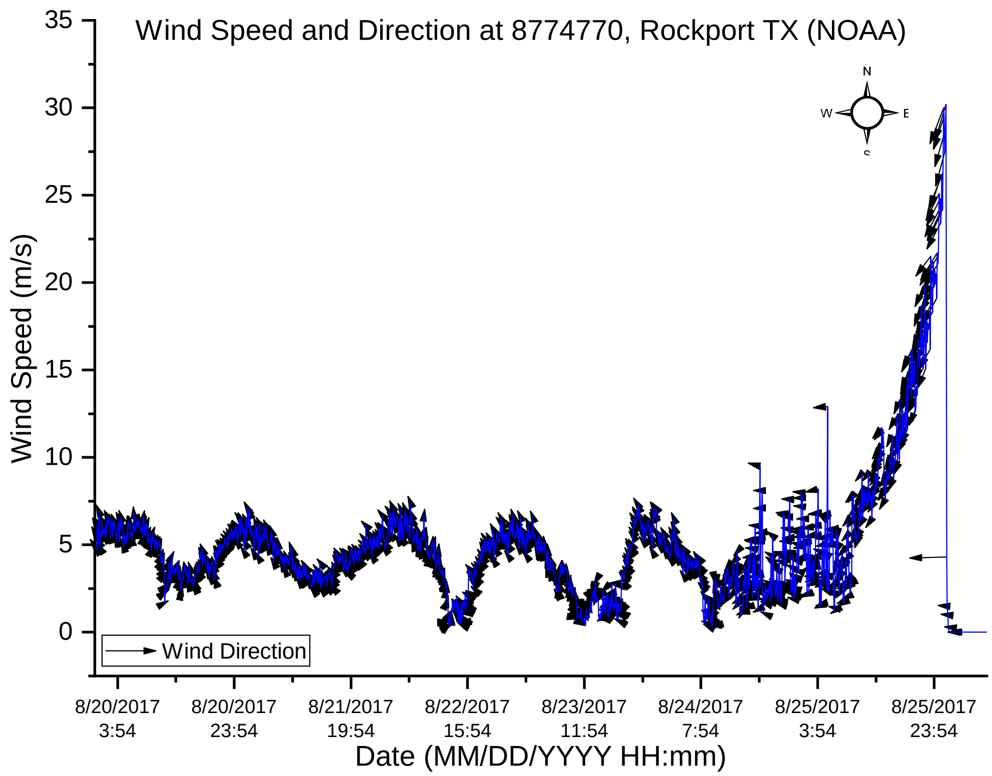


Figure 44. With approach of Harvey, wind was directed out of the east and northeast with speeds of up to 30 m/s (67 mph), measurements terminate with failure of the monitoring station. The direction and magnitude of wind forcing reinforced longshore current that was directed toward the west along Rockport Beach

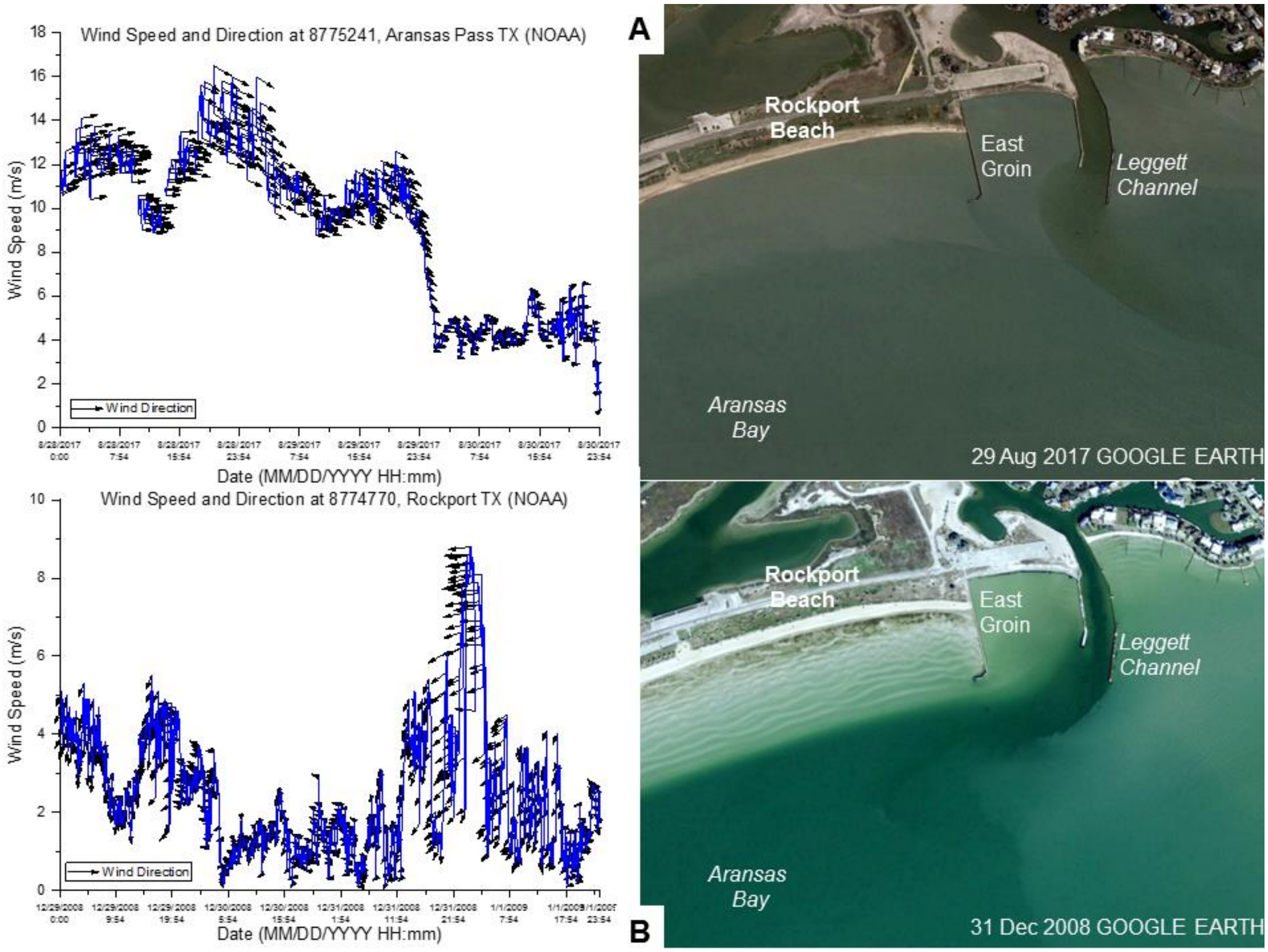


Figure 45. Two examples of the influence of wind direction on the direction of current flow abutting the nearshore shelf along Rockport Beach and on the directionality of outflow from Leggett Channel located to the east of the east groin; A) wind directed out of the west and northwest and B) wind directed out of the east and northeast

Shoreline Analysis: Rockport Beach

Since CBI monitoring/assessment began in 2007, Rockport Beach has been the most stable of the CEPRA beaches based, in part on the low average rate of shoreline change. The recent (Dec 2015/Jan 2016) nourishment addressed limited recession focused along the narrow (< Action Width) east and west segments of the beach, while the shoreline along the central beach remained relatively stable. The nourishment area extended along the beach between STA 5+0 and STA 20+0 (East End) and between STA 44+0 and STA 49+0 (West End), although site reports and the Dec 2016 survey indicated that the nourishment actually extended further along the berm on the west side up to STA 38+0 (Fig 43). The December 2016 survey served as the first full post-nourishment survey since the nourishment was completed because the as-built survey was limited to the areas of direct placement and did not extend to DOC. The post-nourishment (Dec 2016) shoreline position was not only in advance of the 2015 position along the east and west ends of the beach but was also within 10 ft of the 2007 shoreline position along 90% of the beach. The only reach that remained landward of the 2007 position was along the most eastern 150-ft long segment immediately adjacent to the east groin.

The Sep 2017 shoreline position remained in close agreement with and along intermittent segments seaward (advance) of the 2016 post-nourishment shoreline position. The 2017 shoreline position relative to the previous surveys conducted between 2007 and 2016 is shown along the following beach segments 1) East side (Fig 46), 2) Center (Fig 47) and 3) West side (Fig 48) of the beach. The shoreline was measured at the position of MHHW determined at an elevation of 1.10 ft (NAVD88) at Rockport Beach as reported by Naismith Marine Services.

Shoreline advance was indicated intermittently alongshore, with segments of minimal recession along the beach from east to west as a result of the offshore component of storm forcing during Hurricane Harvey. The highest rate of recession remained at the east and west ends of the beach in the area of the 2015/2016 nourishment. The highest rate of shoreline advance was along the central section of the beach fronting the park facilities. The central section of the beach continues to exhibit the greatest stability since the original nourishment including after Harvey with the narrower east and west end of the beach historically eroding at a faster rate. The narrow beach width along the east and west ends is reinforced by backshore conditions resulting from some management practices and vegetative growth. The average rate of shoreline position change was +2.5 ft/yr between Dec 2016 and Sep 2017. Figure 49 shows the comparison of alongshore variability in the rate of shoreline change for the following intervals of significance 1) Post-Harvey (2016-2017), 2) post-nourishment (2015-2016), 3) pre-nourishment (2014-2015) and 3) full study period (2007-2017).

Despite erosion that occurred during Hurricane Harvey, which effectively eliminated the benefit of the 2015/2016 nourishment, Rockport Beach is more stable than prior to the 2003 nourishment with regard to stability of shoreline position. The pre-nourishment assessment conducted by Coastal Planning and Engineering (CPE 2002) reported the average rate of shoreline change from 1988 to 2002 at -4.2 ft/yr with the greatest change occurring along the eastern and western section of the beach which had a higher localized rate of change at up to -8.4 ft/yr. During the CPE assessment conducted during 2002, the eastern end of the beach was reportedly devoid of subaerial beach. Shoreline change has moderated since the beach was originally nourished in 2003, with rates ranging from +0.5 ft/yr during periods of limited storm and inundation to -1.5 ft/yr with an average rate of -0.8 ft/yr between 2007 and 2016. The most recent assessment of long-term performance indicating an average rate of +0.3 ft/yr, effectively stable, over the full study period (2007-2017). The gradual progression toward shoreline stability is in high contrast to the rate of shoreline change documented (CPE 2002) prior to the original nourishment in 2003. With that said, performance at Rockport Beach is limiting by both the gradual and episodic decrease in beach elevation and volume.

Beach Width: Rockport Beach

The width of Rockport Beach remained relatively stable despite wide spread erosion that occurred during Hurricane Harvey. The offshore limit at MHHW was maintained due to the redistribution of sand seaward across the berm and into the foreshore and immediate nearshore as flood waters subsided. The entire beach was in advance of the Action Width with the exception of a short segment focused at STA 46+0 (Table 2). The width of the beach ranged from 45 ft (west end) to 174 ft at center beach. The beach remained substantially wider in the central region primarily due to design, which includes the setback of park facilities and pavilion. Approximately 70% of the beach remained at less than the Target Width, including segments more centrally located. The east and west ends of the beach remained well under the Target Width of 80 ft. The west end of the beach was approaching the Action Width with beach widths ranging from 47 to 67 ft.

Table 1. Variability in Rate of Shoreline Position Change: Rockport Beach (2017)				
Interval (Year)	**Description Contributing Factors**	**Rate of Change (ft/yr)**	**Maximum Advance (ft)**	**Maximum Recession (ft)**
2016-2017	Annual/Post-Harvey	+2.5	+18	-7
2007-2017	Period of Record	+0.3	+18	-16
2015-2016	Annual Pre/Post Nourishment	+6.0	+40	-9
2007-2016	CBI Monitoring Period Post-Nourish	+0.0	+12	-18
2007-2015	CBI Monitoring Period Pre-Nourish	-0.75	+8	-47
2014-2015	Annual No significant storms or events	-0.40	+10	-11
2012-2014	Biannual No significant storms or events	+ 0.52	+14	-22
2009-2012	Tropical Storm Season (2009)	- 1.45	+21	-26
2007-2009	Hurricane Ike (2008)	- 1.21	+14	-25

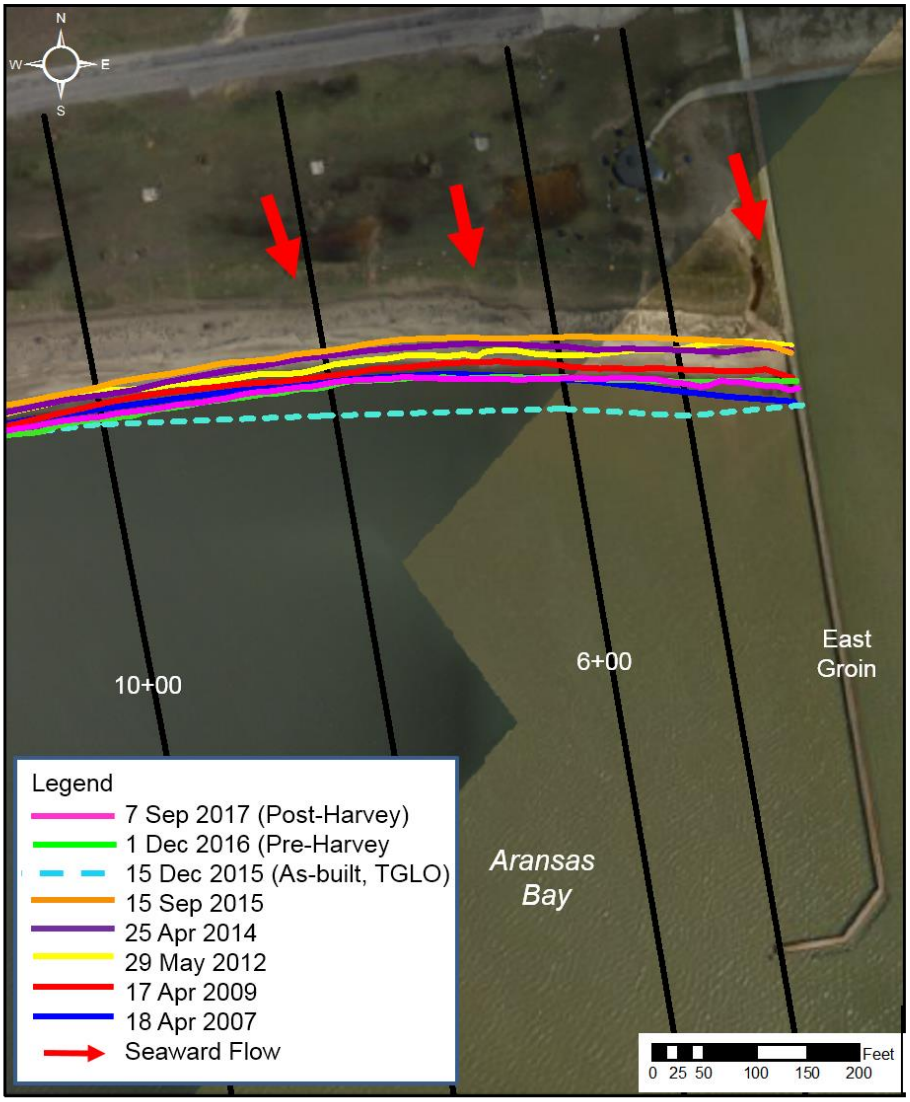


Figure 46. East End: Intermittent advance and recession along the East End of the beach after Harvey (Sep 2017)

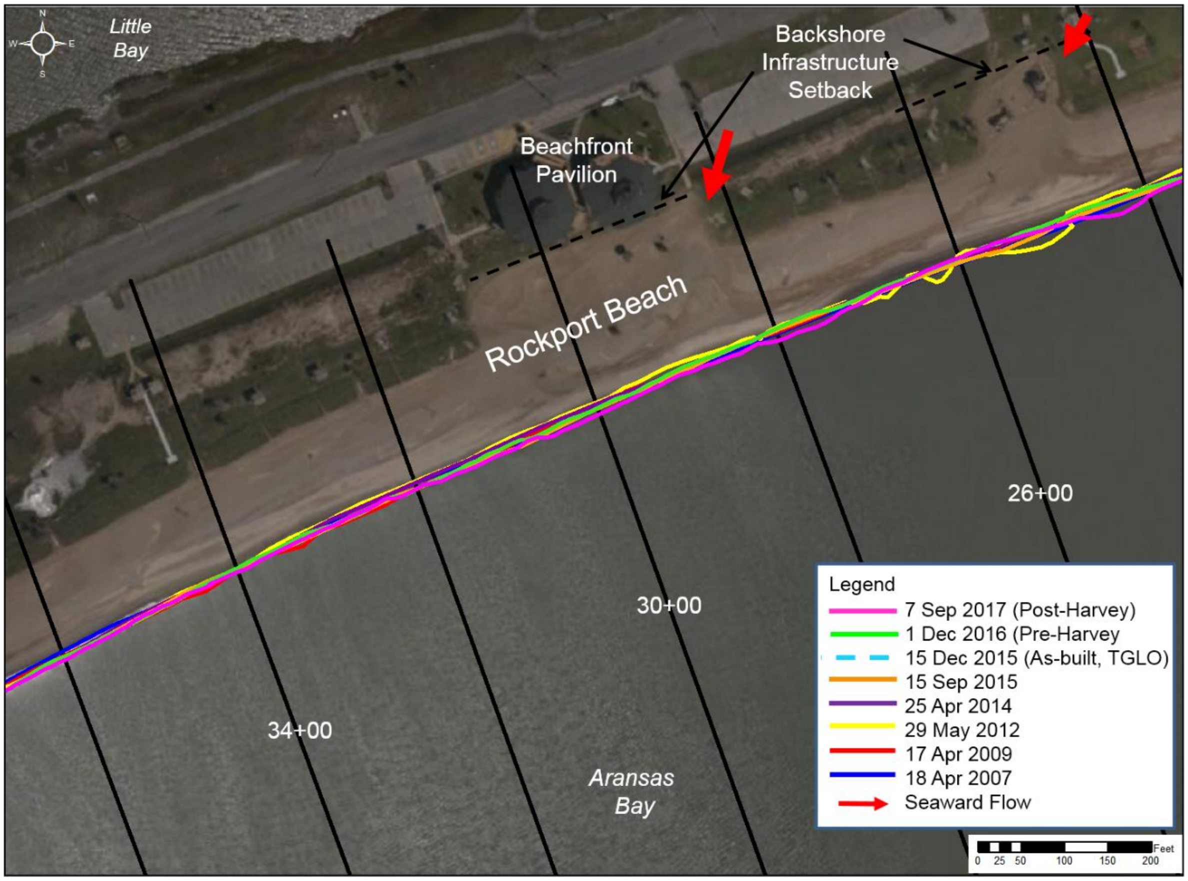


Figure 47. Center Beach: Shoreline advance dominated due to transport of sand from berm and specifically berm crest seaward toward the foreshore as storm surge subsided. Note areas with evidence of focused offshore-directed flow of receded water (2017)

Volumetric Analysis: Rockport Beach

Erosion resulting from direct onshore, offshore and alongshore forcing during Hurricane Harvey reduced the volume of Rockport Beach to well in excess of the nourishment volume (reported as 6,580 cu yd) placed during Dec 2015/Jan 2016. The recent nourishment not only increased the width of the beach along the east and west ends, but also restored the design elevation (3.5 ft NAVD88 within the nourishment zone (3.5 ft NAVD88). Volume change was calculated for the region extending from the baseline, initiating at the dune crest or other landward limiting feature when absent, to beyond the end of the shallow nearshore shelf at the -8 ft contour.

Between Dec 2016 and Sep 2016, an estimated total volume of 11,900 cu yd of sand eroded from Rockport Beach. Of that volume, the loss of approximately 8,000 to 10,000 cu yd was attributed to forcing during Hurricane Harvey based on the typical background erosion rate of 1,000 to 3,8000 cy/yr that has been measured since 2007. The greatest erosion was calculated along the east end of the beach at 5,488 cu yd due to the contribution of the severe erosion near the seaward limit of the nearshore shelf. Comparable volume losses of 3,140 cu yd and 3,522 cu yd were identified along center beach and the west end, respectively, and are more representative of loss affecting the active region of sediment transport.

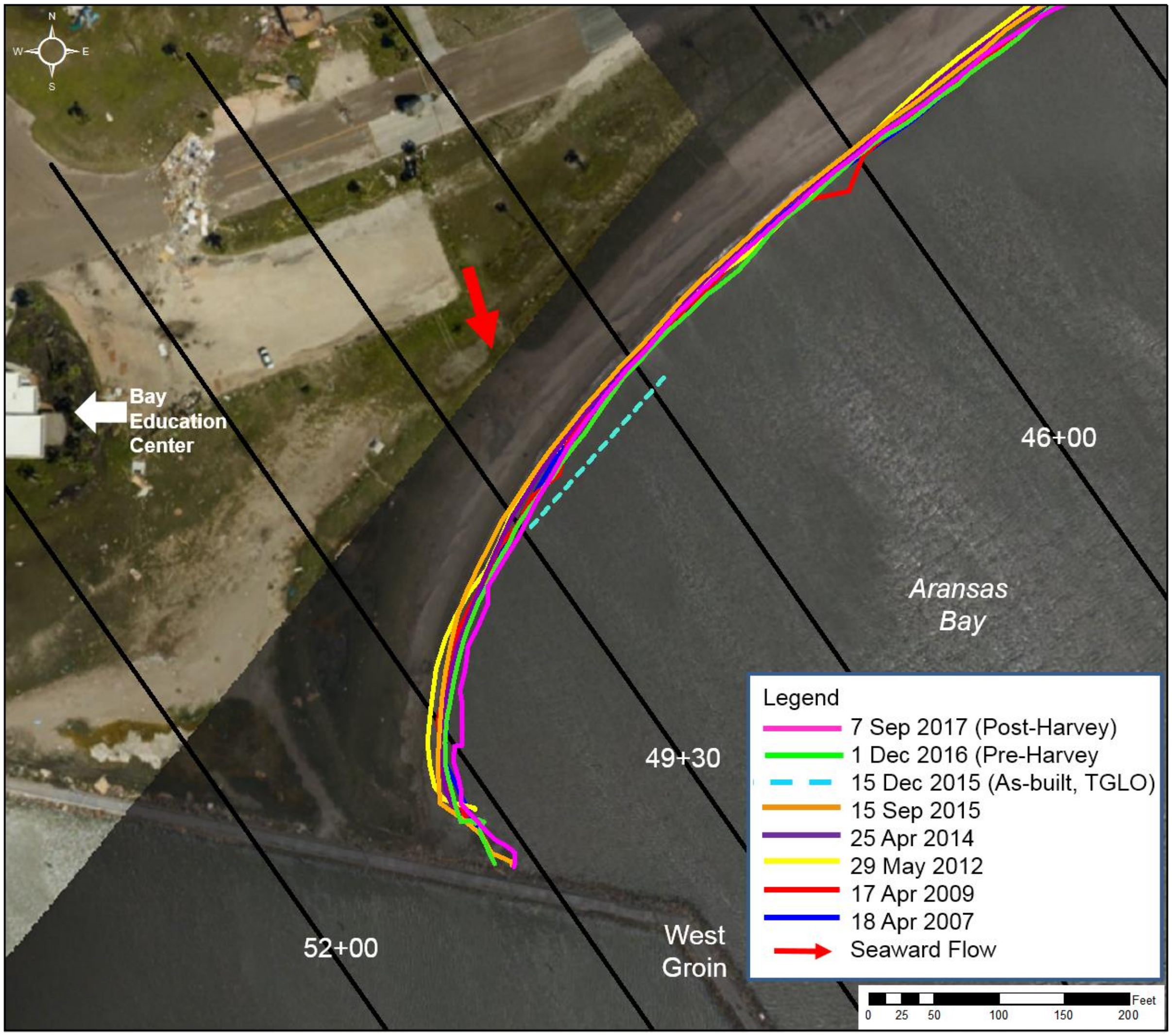


Figure 48. West End: Intermittent shoreline advance and recession with advance at the west end and in areas of focused runoff evident in aerials during Harvey (2017)

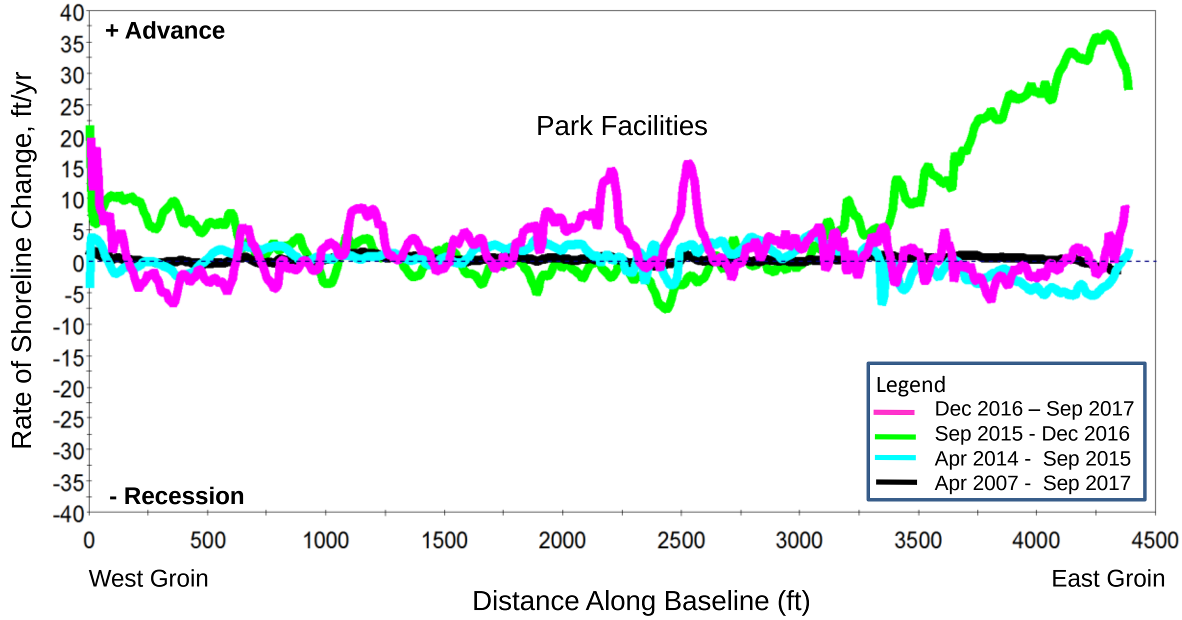


Figure 49. Comparison of the variability in rate change in shoreline position with alongshore location; 1) prior to nourishment (2014-2015), 2) post-nourishment (2015-2016), 3) Post-Harvey (2017), and 4) over the full study period (2007-2017)

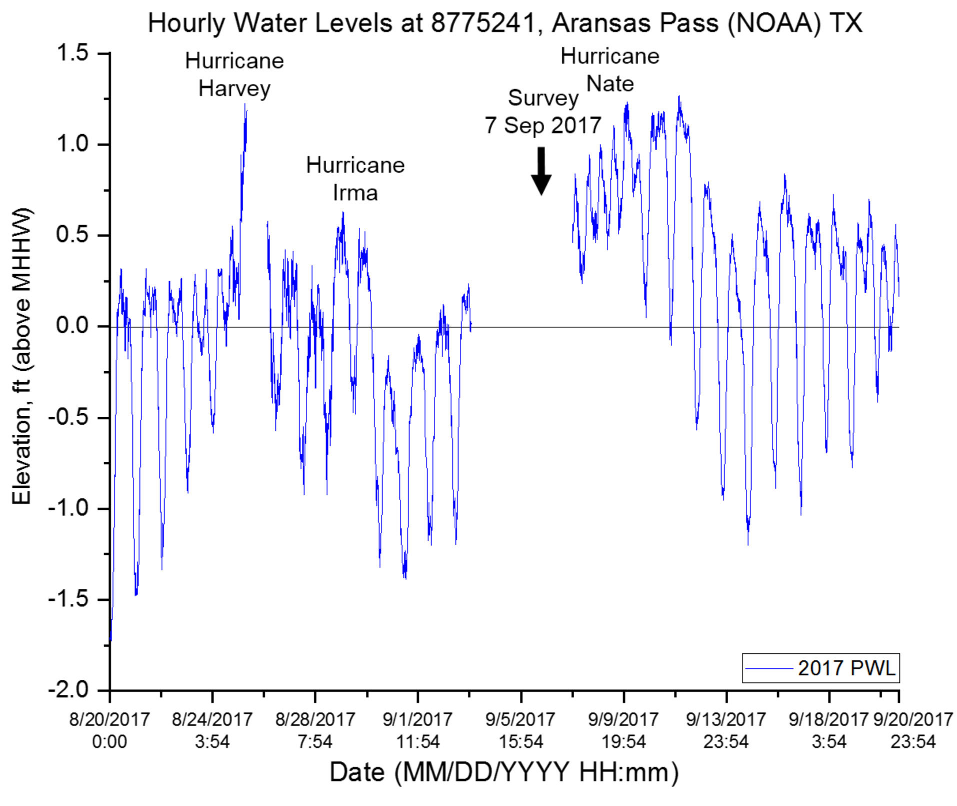


Figure 50. Extreme fluctuations in water level measured near Rockport Beach during and after Hurricane Harvey

The most significant erosion was identified at the berm crest, across the entire nearshore, and at the seaward limit of the nearshore shelf, east of center beach. The relative stability of the berm and foreshore can be attributed, in part, to the storm raising the water level above the entire berm and rapid onshore progression of the storm. In addition, the strongest winds were not directed onshore, thereby the beach avoided direct prolonged wave attack. Additional stability of the beach at MHHW and along the foreshore was reinforced, as sand was redistributed across-shore as high waters receded. Morphologic change resulting from this sheet-like onshore and offshore flow both in the nearshore included the dampening of bar development forming a flat, featureless shelf along approximately 50% of the beach (east of center beach). The significant reduction in development, and in some areas the elimination of the formerly well-developed multiple (8-12) longshore bar system is indicative of episodic sheet flow of water due to strong wind forcing. Prior to Hurricane Harvey, erosion at the seaward end of the nearshore shelf was gradual representing an insignificant volume loss annually. Exacerbated erosion at the offshore limit of the nearshore shelf accounted for approximately 20 % of the volume lost from the beach cell.

The stability of Rockport Beach is attributed, in large part, to the wide flat barred nearshore region that disperses wave energy and protects the foreshore and berm from direct wave attack under typical and moderate storm forcing conditions. Sand eroding from the berm migrates into the wide nearshore where it is impounded and frequently redistributed alongshore rather than transported out of the system, as indicated by previous low annual volume loss. During Harvey, the seaward limit of the wide flat nearshore shelf eroded reducing the width of the nearshore shelf along the beach east of center beach. Strong alongshore currents directed out of the east developed with approach of the hurricane due to strong winds directed out of the east (Fig 44). At the seaward limit of the nearshore shelf, the combination of wind forcing and as water levels subsided, the contribution from channelized flow through Leggett Channel, resulted in a strong alongshore current that scoured the shelf as the current interacted with the groin as well as the “edge” of the nearshore shelf.

Erosion of the seaward limit of the nearshore shelf is evident along both the nearshore shelf located east of the east groin outside of the beach limits as well as west of the of east groin (Fig. 51). The greatest erosion extended east of center beach up to the east groin (Fig 52). The most significant erosion was documented closest to the east groin (Fig 53 and 54). The edge of the nearshore shelf effectively formed the bank along which the strong east to westward flow abutted. The flow focused along the edge of the nearshore shelf and interacted with the groin to exacerbate erosion of the most offshore 30 to 60 ft section. The impact of the alongshore flow on erosion of the shelf decreased with distance westward toward center beach, with a less defined influence west of STA 22+0 (Fig 55). The wind-driven alongshore current was further reinforced channelized flow exiting Leggett Channel in the aftermath of Harvey as storm surge receded. Leggett Channel is located adjacent to, and east of the east groin. The decrease in erosion/scour with distance from Leggett Channel may support that the contribution from the outflow of the channel was significant. As surge receded the exiting flow from Leggett Channel potentially reinforced the alongshore flow directed to the west. Although slow gradual erosion was documented at the seaward end of the nearshore shelf in the past, the rate of change during Harvey exceeded the change documented over the previous 9 years of monitoring. The morphology along beach profiles extending from landward of the dune offshore to DOC along locations representative of the East End, Center Beach and West End are shown in Figures 51-59. A focused view of the berm and immediate nearshore at key locations along the beach are shown in Figures 60-67.

Table 2.
Beach Width: Rockport Beach (2007-2017)
Action Beach Width = 40 (East/West End) 50 (East/West of Center) 85 (Center) Action Width +5 ft
Target Width= 80 (East/West End), 100 (East/West of Center), 160 (Center)
*Influenced by nourishment completed during Dec 2015/Jan 2016

Station	Width, ft						
	2007	2009	2012	2014	2015	2016*	Post Harvey
Groin East End	79	54	29	33	33	70	72
STA 5+00 East End	80	60	40	43	34	70	75
STA 6+00 East End	75	62	54	46	39	76	76
STA 8+00 East End	71	67	60	50	46	75	83
STA 10+00 East End	78	74	63	63	59	85	105
STA 12+00 East of Center	98	96	90	89	87	106	94
STA 14+00 East of Center	88	86	84	83	82	92	89
STA 16+00 East of Center	82	83	74	81	82	87	89
STA 18+00 East of Center	85	78	76	82	81	85	94
STA 20+00 East of Center	94	92	89	91	92	92	89
STA 22+00 East of Center	92	89	82	90	91	90	99
STA 24+00 East of Center	96	90	90	91	95	91	90
STA 26+00 East of Center	95	94	87	91	95	90	103
STA 28+00 East of Center	96	94	90	93	92	90	174
STA 30+00 Center	168	162	161	163	168	168	104
STA 32+00 West of Center	98	106	98	99	105	106	102
STA 34+00 West of Center	101	102	101	100	101	99	101
STA 36+00 West of Center	93	97	99	100	101	99	99
STA 38+00 West of Center	85	87	86	90	88	93	88
STA 40+00 West of Center	81	80	82	84	85	87	81
STA 42+00 West of Center	81	79	78	79	80	84	70
STA 44+00 West	63	65	53	57	58	65	54
STA 46+00 West	57	60	52	51	50	55	45
STA 48+00 West End	45	44	41	42	40	47	70
STA 49+30 West End	65	65	57	59	54	66	55
STA 50+50 West End	47	45	36	46	42	49	72

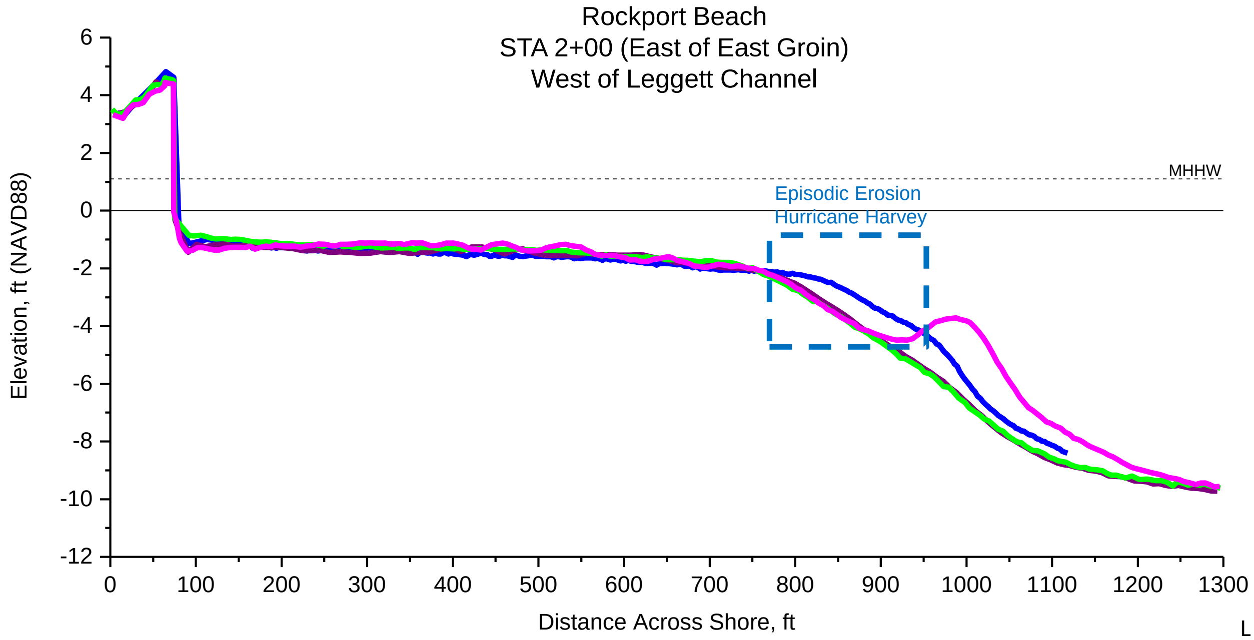


Figure 51. East of Rockport Beach (Between Leggett Channel and East Groin): Focused erosion at offshore limit of the shallow nearshore (2017)

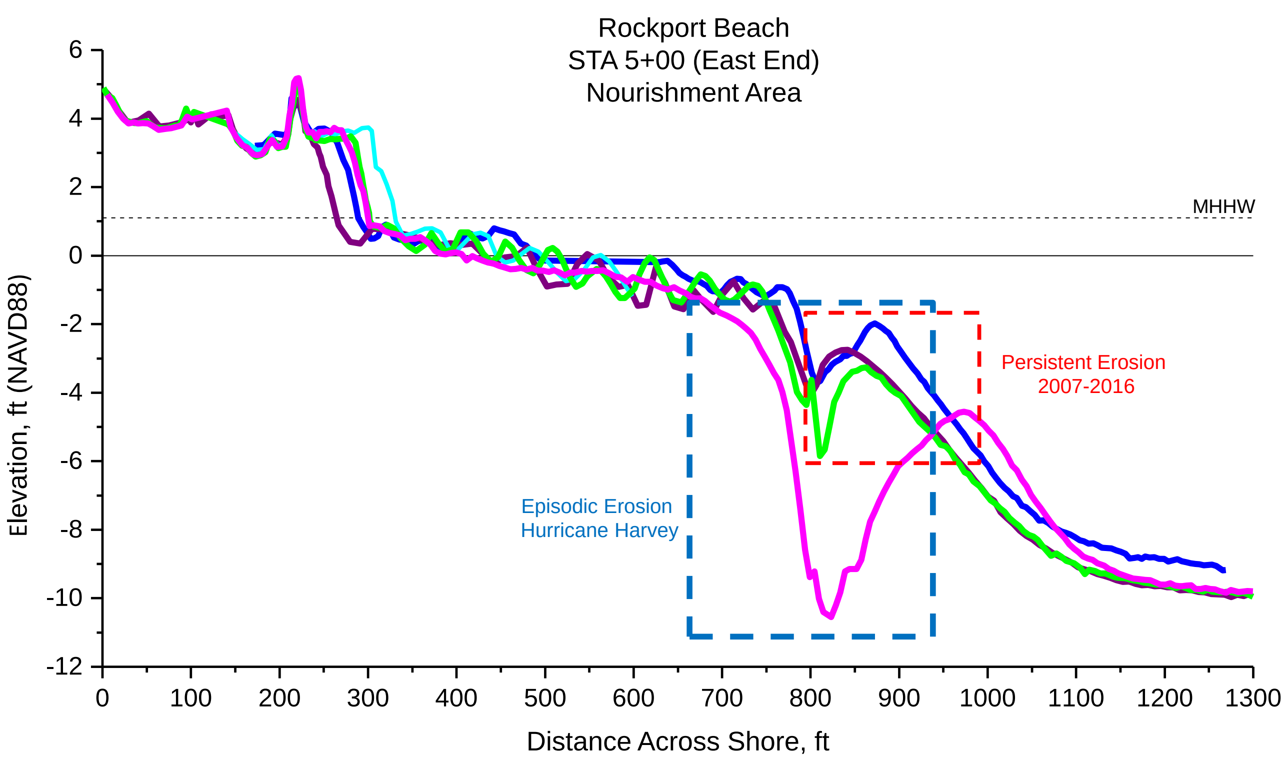


Figure 52. East End at East Groin (Nourishment Area): Episodic focused erosion at the seaward limit of shallow nearshore shelf related to strong alongshore flow enhanced by runoff and wind. Erosion was exacerbated by the influence of proximity of the East Groin. Note the lack of bar development in nearshore

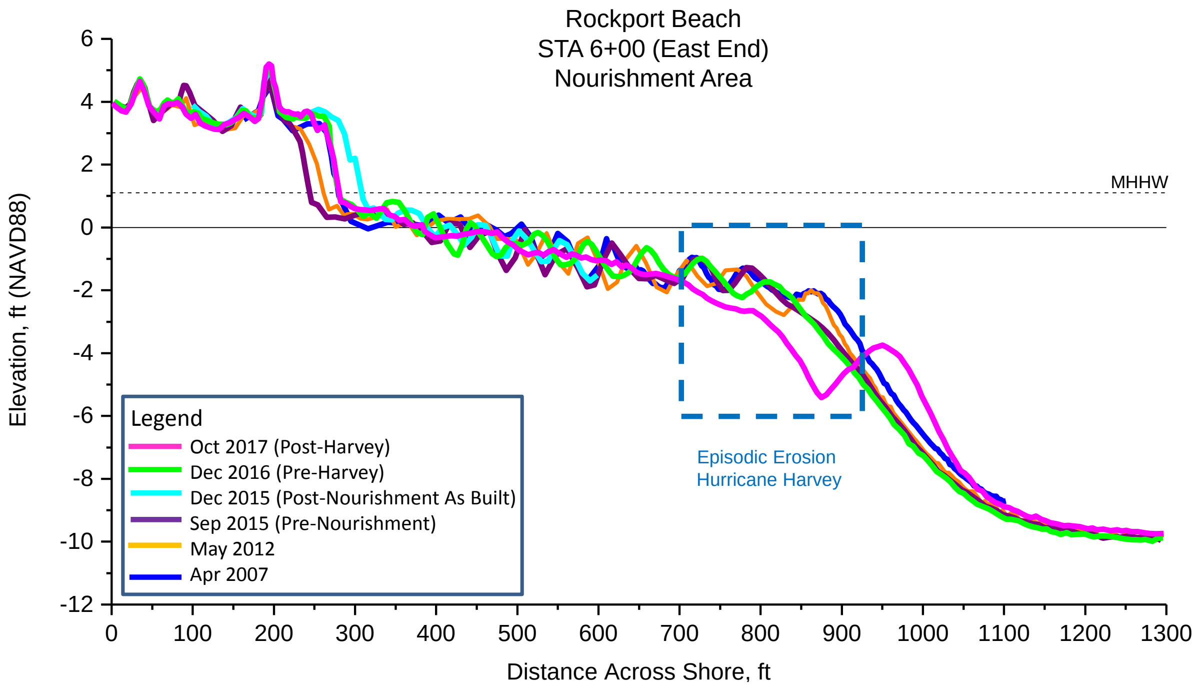


Figure 53. East Side (Nourishment Area): Focused erosion at the seaward limit of the shallow nearshore shelf that is evidence of alongshore continuity of a linear alongshore erosional feature due to scour by strong alongshore flow during Harvey (2017)

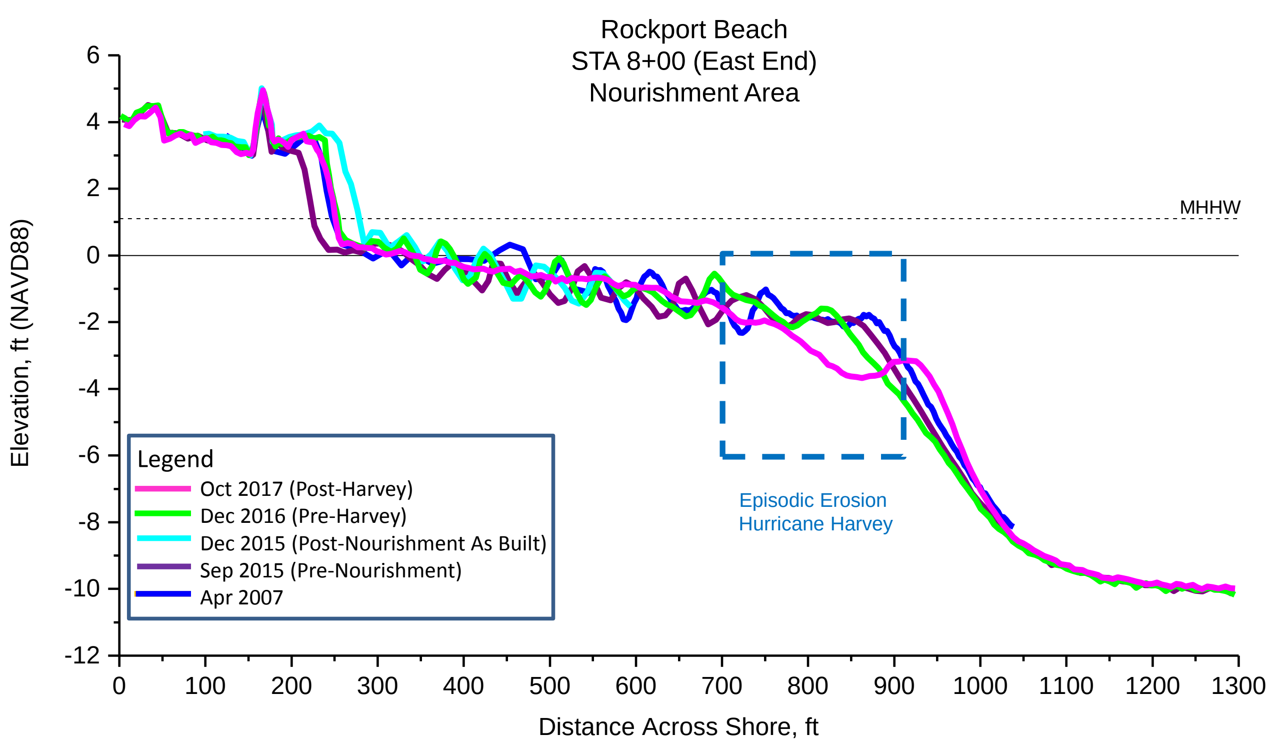


Figure 54. East Side (Nourishment Area): Continued but less developed erosion/scour focused at the seaward limit of the shallow nearshore shelf (2017)

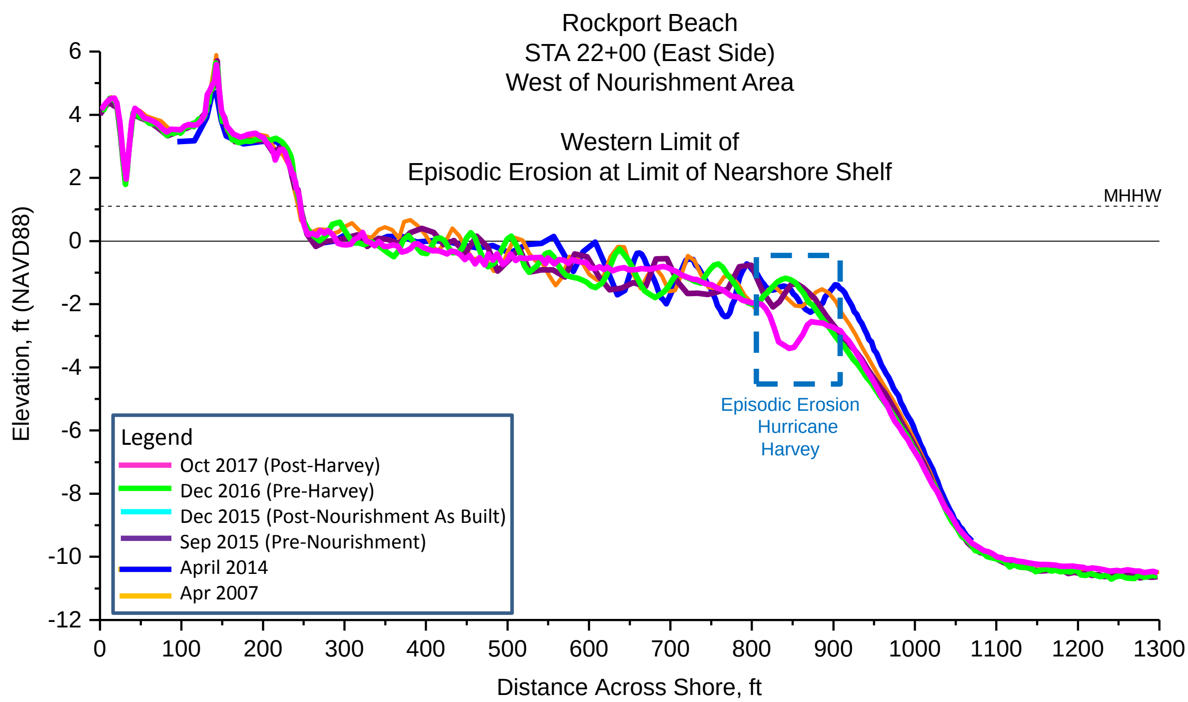


Figure 55. East of Center Beach (West End Nourishment Area): Continued evidence of focused erosion at the offshore limit of nearshore shelf. Dampened bar development along the remaining nearshore (2017)

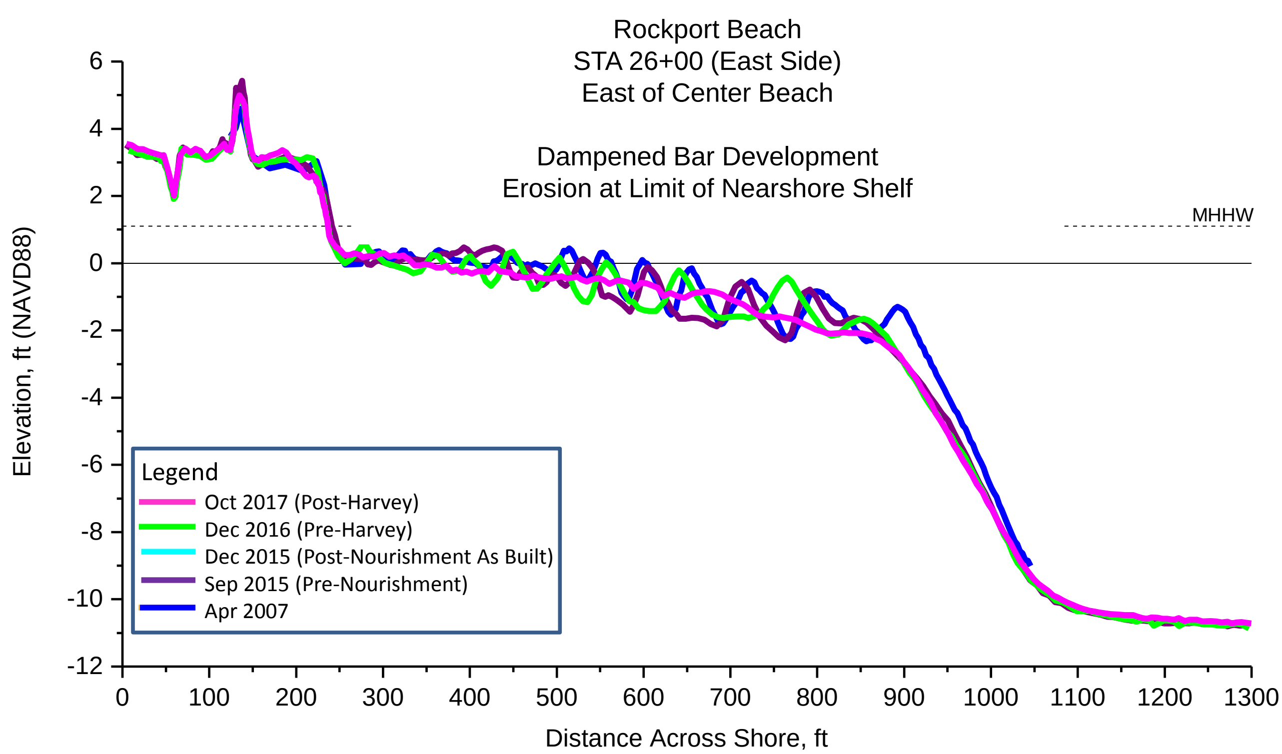


Figure 56. East of Center Beach (West of Nourishment Area): Limited erosion at offshore limit of the nearshore shelf, dampened but evident bar development near end of nearshore (2017)

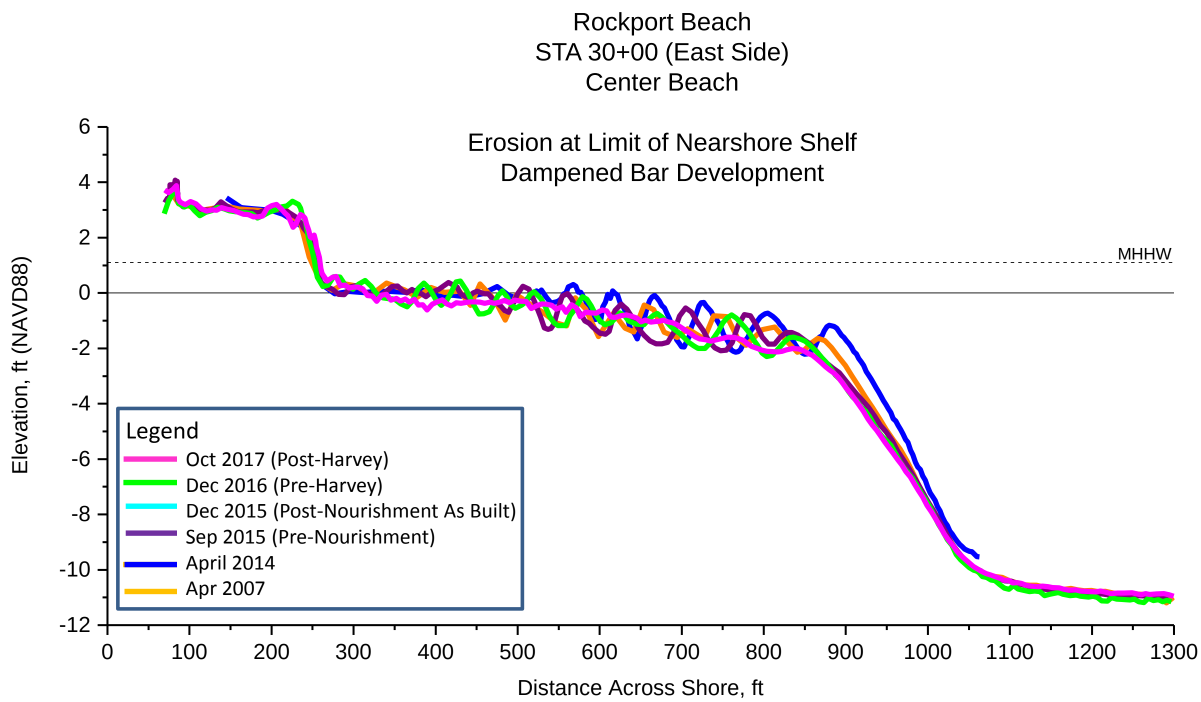


Figure 57. Center Beach: Dampened bar development and limited erosion along seaward limit of the nearshore shelf

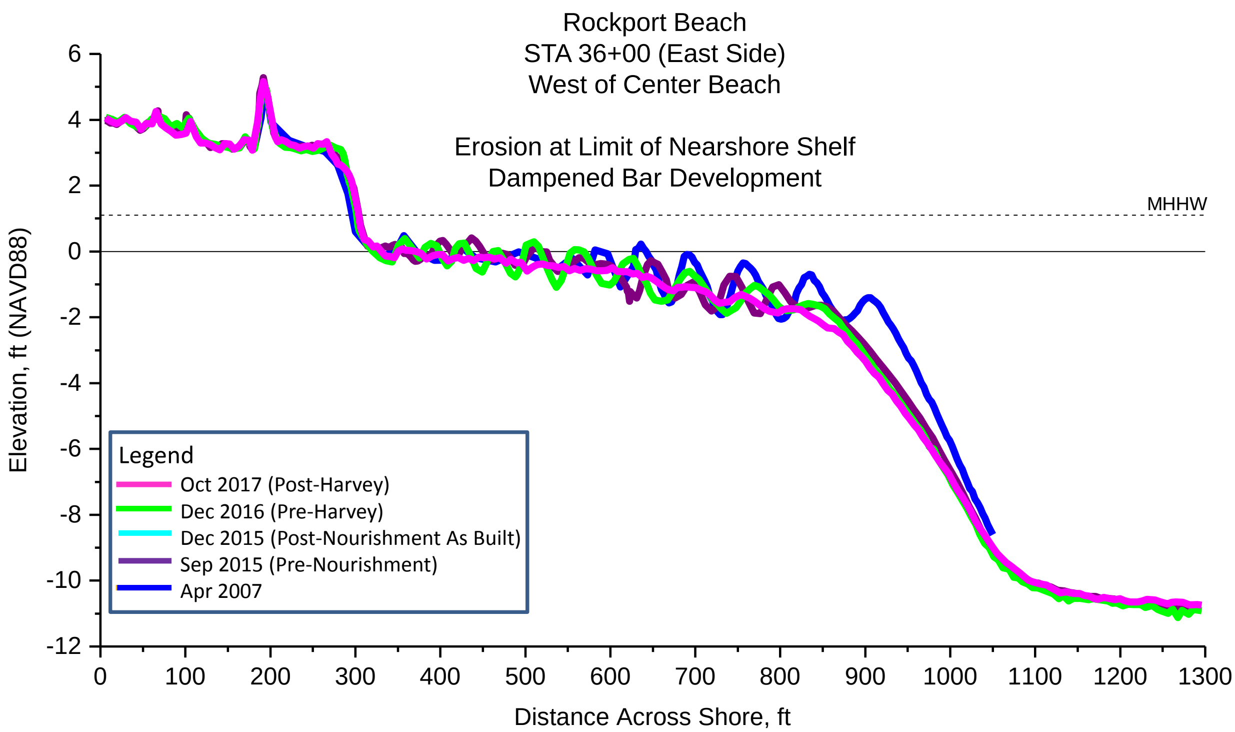


Figure 58. West of Center Beach: Dampened bar development with limited erosion and bar formation at seaward limit of nearshore shelf (2017)

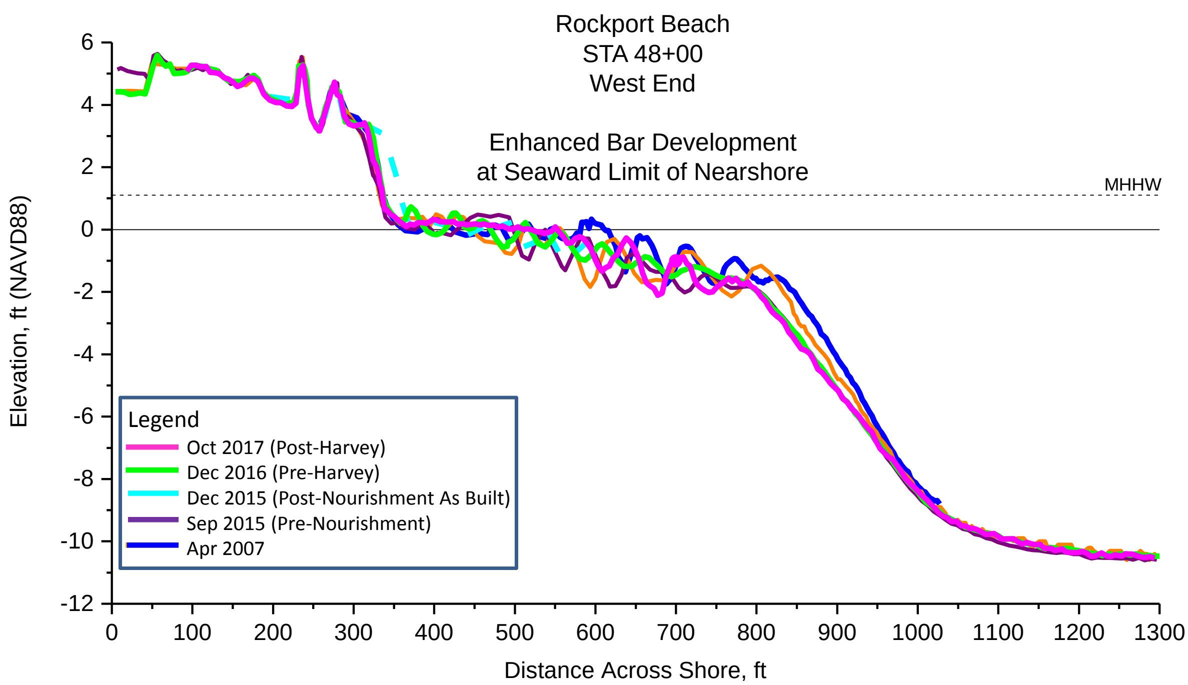


Figure 59. West End (Nourishment Area): Accretion and dampened bar development nearest shoreline with fully developed bars near seaward limit of relatively stable nearshore shelf (2017)

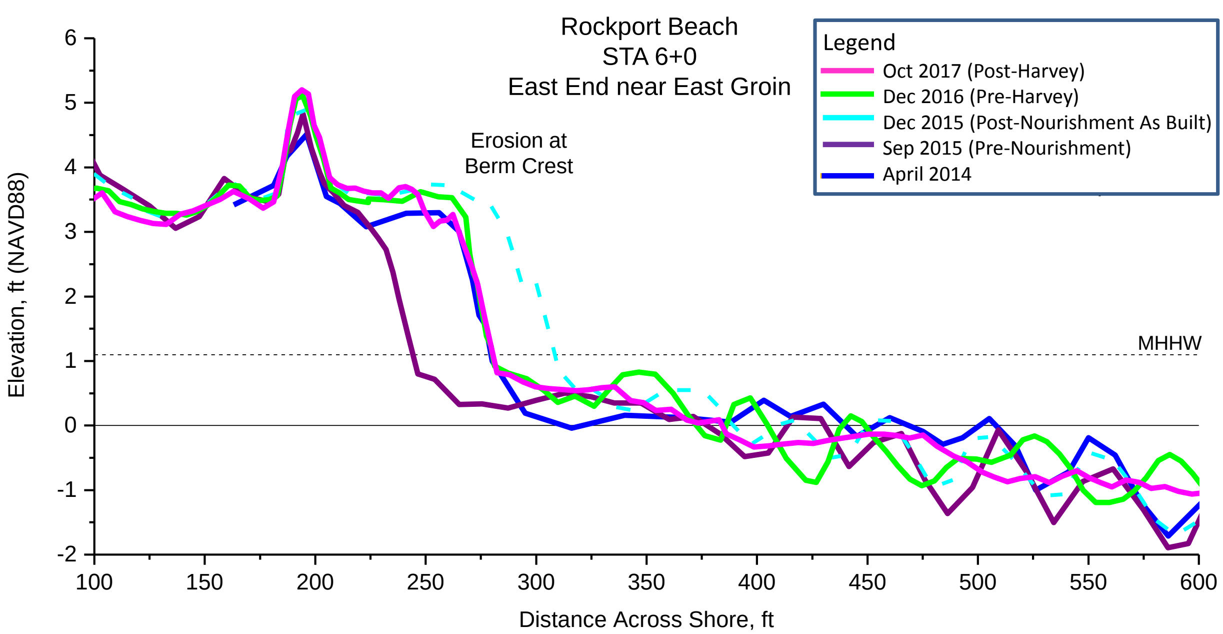


Figure 60. East End (Nourishment Area): Erosion focused at berm crest, stable shoreline and limited erosion in immediate nearshore (2017)

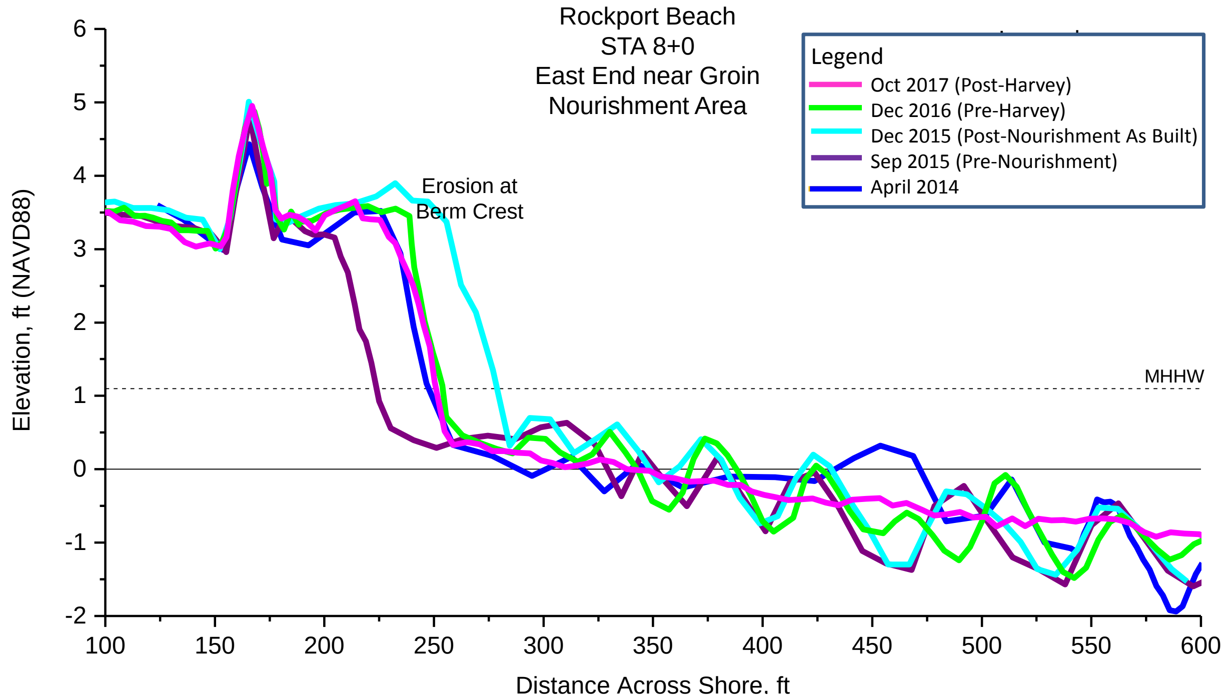


Figure 61. East End (Nourishment Area): Erosion at berm crest, foreshore and dampened bar formation

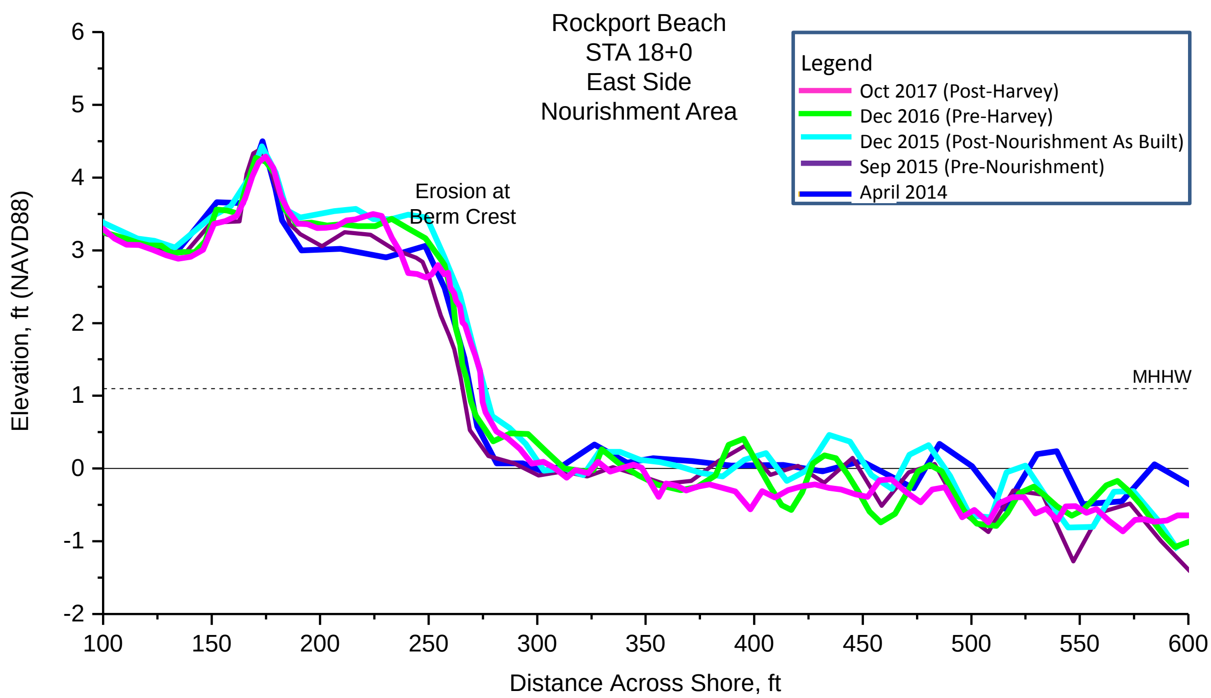


Figure 62. East Side (West End of Nourishment Area): Erosion focused at berm crest, accretion at foreshore and erosion in immediate nearshore (2017)

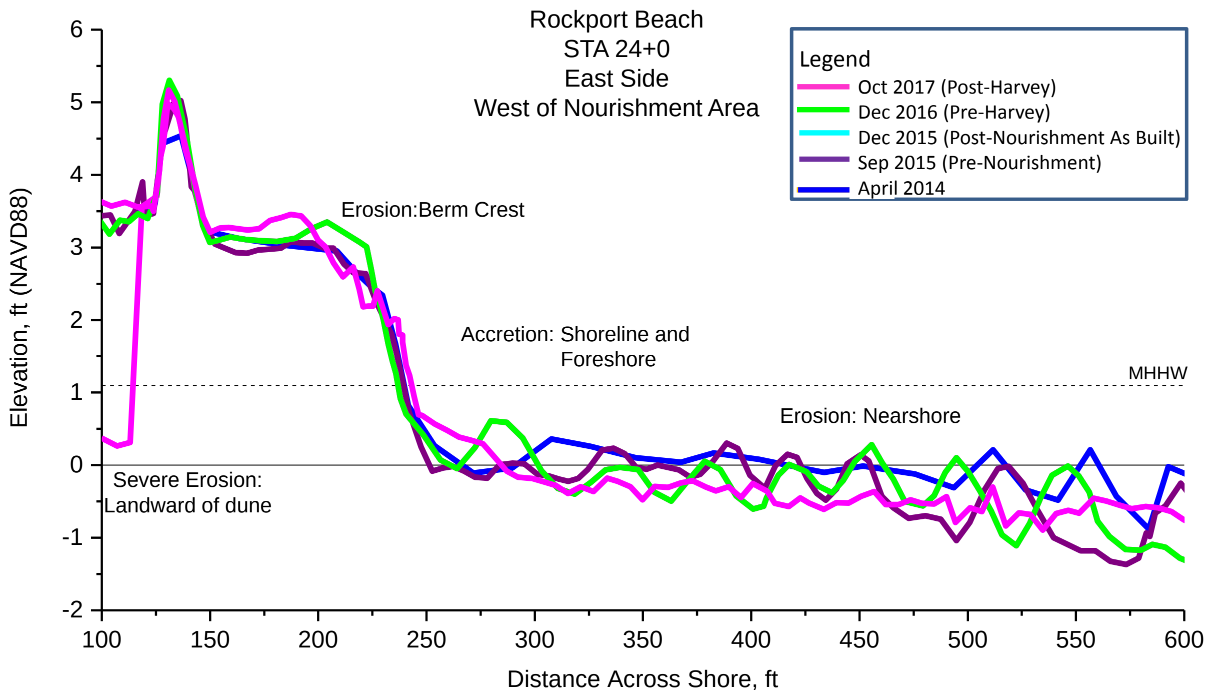


Figure 63. East Side (West of Nourishment Area): Severe erosion landward of duneline, accretion across backshore and foreshore with erosion focused at berm crest and in nearshore (2017)

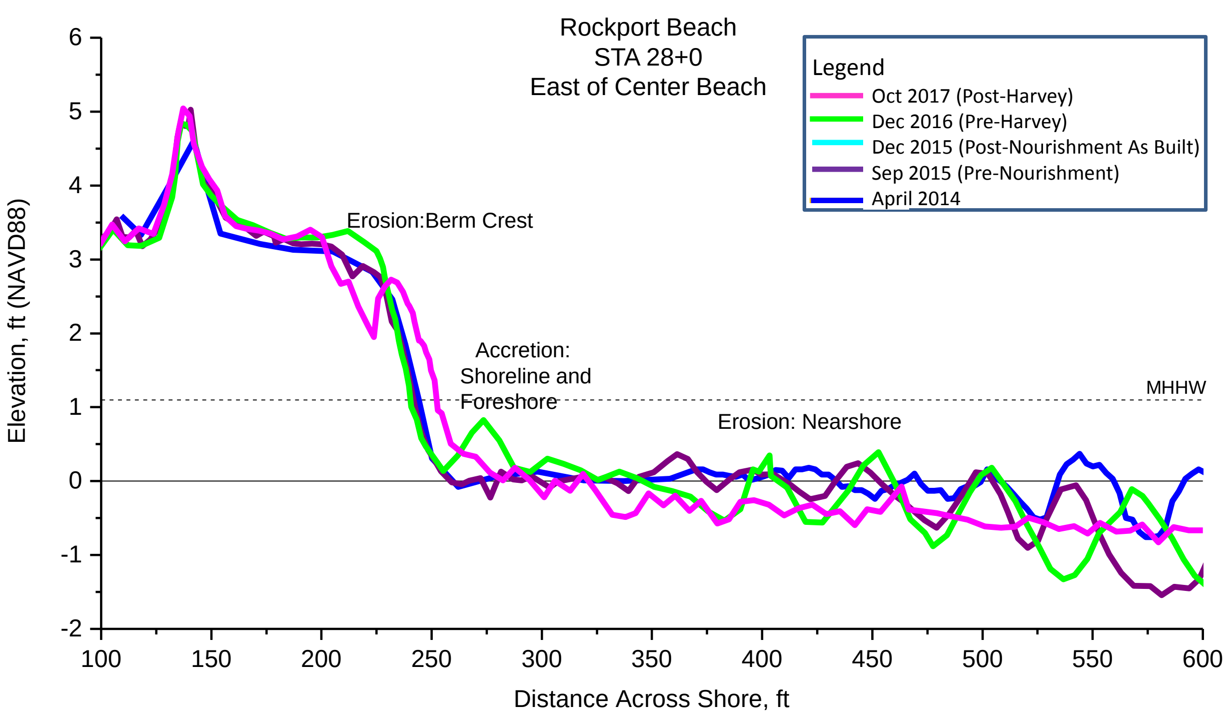


Figure 64. East of Center: Stable backshore, erosion focused at berm crest and nearshore with accretion across foreshore and erratic bar formation (2017)

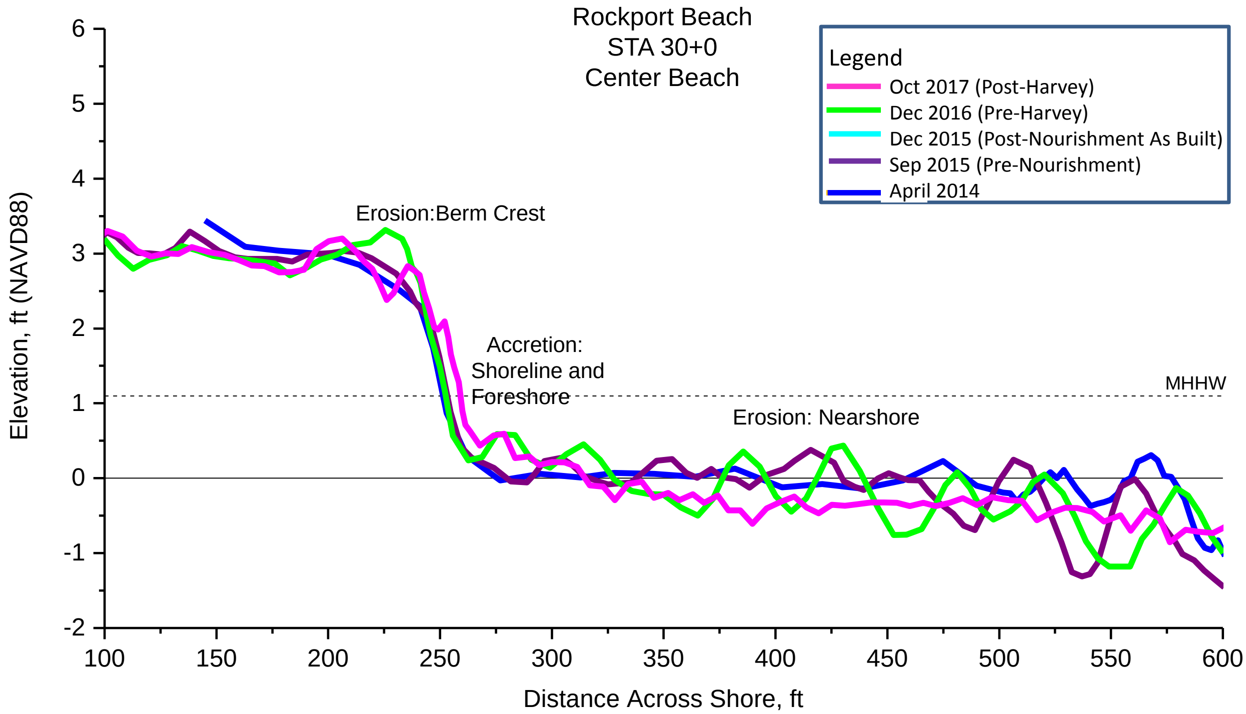


Figure 65. Center Beach: Erosion focused at berm crest and nearshore with accretion across foreshore (2017)

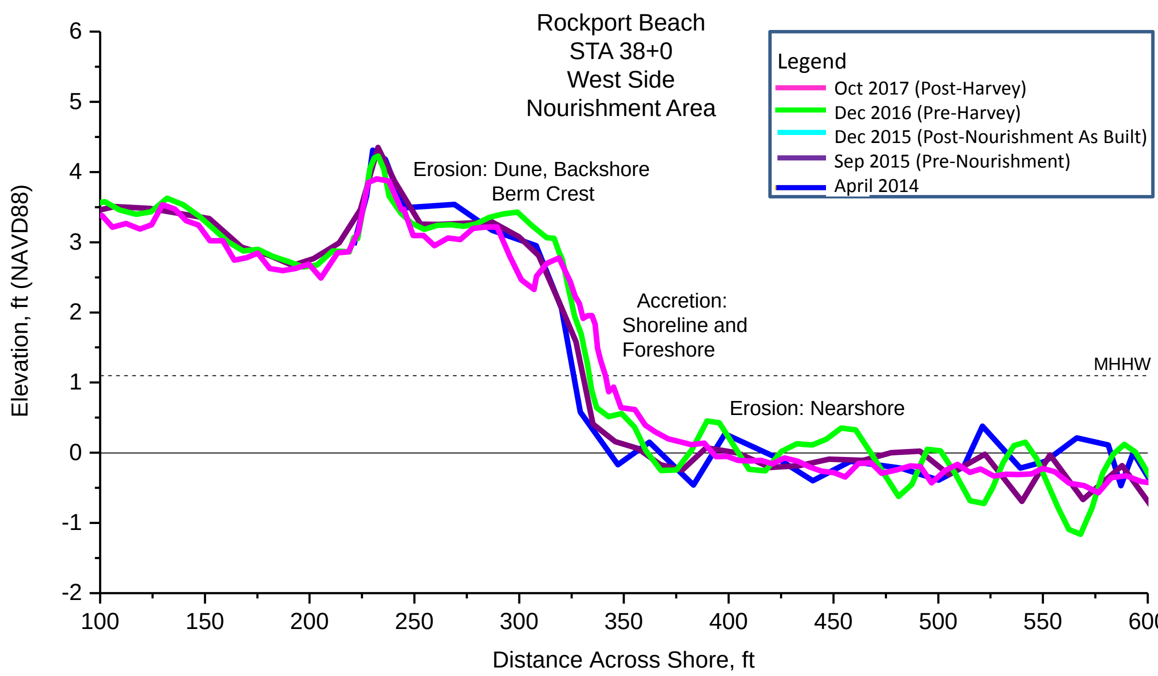


Figure 66. West Side (Nourishment Area): Erosion at dune, backshore, berm, and focused at berm crest with accretion across the foreshore and immediate nearshore and dampened bar development (2017)

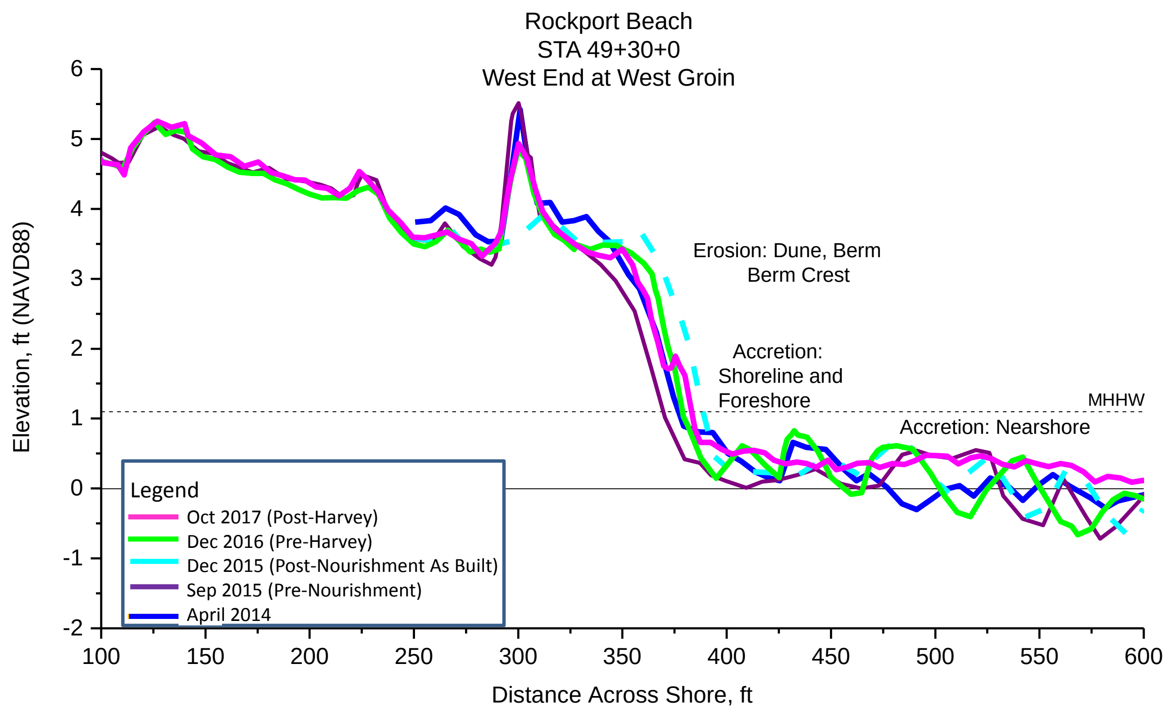


Figure 67. West End (Nourishment Area): Erosion across berm crest and foreshore with accretion in immediate nearshore as large shoal rather than bars (2017)

Recommendations: Rockport Beach

Erosion at Rockport Beach occurred due to forcing that was directed onshore, offshore, and alongshore as Hurricane Harvey made landfall. Onshore forcing resulted in storm surge inundating the beach and surrounding Rockport landward of Little Bay. As the storm moved landward, strong winds reversed to force the elevated storm waters back across the beach toward Aransas Bay, initially as concentrated sheet flow. As water levels dropped, focused erosion generated the development of preferential spillovers or shallow channels focusing water across the backshore and berm. Wind reinforced concentrated sheet flow moved across the nearshore and eliminated sections of the longshore bar system. Finally, wind-driven alongshore flow was the primary agent of focused erosion/scour at the limit of the protective shallow nearshore shelf.

The width of Rockport Beach, relative to the MHHW shoreline position, remained relatively stable after Harvey, although the elevation of the beach was 1 to 2 ft under the design elevation. Shoreline advance was indicated along center beach and intermittently along the east and west segments. Although the shoreline position was relatively stable after Harvey, a complete assessment of stability based on this factor alone was not sufficient to evaluate the overall stability of the beach. This is particularly relevant for nourishment planning. A more comprehensive investigation indicated that the stability of the shoreline was related to the deposition of sand that eroded from the berm, specifically the berm crest. As the berm crest eroded receding water redistributed the sand along the foreshore and immediate nearshore. The post-Harvey survey captured the shoreline in a state of transition after the storm, rather than a seasonal peak. In addition, the foreshore is the most dynamic zone of forcing under typical conditions at Rockport Beach, therefore rapid change along the foreshore is anticipated in the future.

Despite the stability of the shoreline position between 2016 and 2017, both beach elevation and volume decreased during Harvey. A total of 11,000 cu yd of sand eroded from the beach cell, which was nearly double the 6,500 cu yd of sand applied during the recent nourishment completed during 2016. The volume loss attributed to forcing during Harvey exceeded the annual average rate of erosion, calculated since 2007, by 8,000 to 10,000 cu yd/yr.

Renourishment is recommended due to the episodic volume loss sustained at Rockport Beach during Hurricane Harvey, in addition to changes in the nearshore and offshore limit of the nearshore shelf that may influence beach stability over subsequent years to come. Nourishment is recommended to restore both the Target Width and restore the design elevation (3.5 ft NAVD88) of the beach, which decreased by on average 1 to 2 ft with up to a 2 ft deficit between the 2017 elevation and design elevation. Maintaining the design elevation is critical to future beach performance under storm forcing conditions. The estimated volume required to restore both the Target Beach Width at the design elevation (3.5 ft) along the entire beach is 8,800 cu yd. This includes approximately 2,100 cu yd placed on the east side (east groin to STA 22+0), 4,000 cu yd placed on the west side (west groin to STA 42+0) and 2,700 cu yd placed on the central section of the beach (STA 24+0 to STA 40+0).

Sargent Beach

Introduction

The Sargent Beach study area encompasses approximately 4 miles of shoreline along Matagorda Peninsula in Matagorda County (Fig 68). The west end of the larger uninterrupted beach terminates at Mitchell's Cut while the east end is bordered by Cedar Lakes Pass, a small ephemeral inlet. Mitchell's Cut is located 2.5 miles from the nourishment center (FM 457) and approximately 1.0 mile from the west end of the study area. Mitchell's Cut serves as the primary sediment sink for sand eroding along Sargent Beach due to the dominance of southwesterly-directed longshore currents and close proximity. The Mouth of the Colorado River is located approximately 20 miles to the southwest and the Brazos River and Freeport Ship Channel are located approximately 15 miles and 22 miles, respectively, to the northeast. Sediment transport into the area is limited by both the proximity of Mitchell's Cut at the west end and larger inlets to the north (Freeport Ship Channel) and south (Mouth of the Colorado River) which together compartmentalize the region. Thus, Sargent beach is isolated, with regard to sediment transport, resulting in finite sand resources and a historically high rate of erosion and shoreline recession. The dominance of alongshore sediment transport toward the southwest is confirmed by tracking transient pockets of accretion that were documented as they migrated toward to the west as beach fill placed during the spring of 2013 was redistributed alongshore.

Sargent Beach is unique to the CEPRA Beach Monitoring Program in that it is the only Gulf beach in the monitoring program that is located along a mainland peninsula that functions as a barrier island. The beach is composed of a veneer of sand that overlays the clay substrate that is intermittently exposed during periodic erosion of the overlaying sand. The GIWW is located in close proximity to the Gulf of Mexico at Sargent Beach. Along the reach landward of Sargent Beach, the GIWW was constructed by excavating the Matagorda Peninsula to leave a narrow section of the peninsula isolated between the GIWW and the Gulf. Persistent erosion has threatened to breach the GIWW in the past, therefore in 1998; the USACE built an eight-mile long revetment landward of the shoreline and seaward of the GIWW in anticipation of continued erosion and subsequent shoreline recession. The top of the revetment remains intermittently exposed along the entire shoreline at elevations of approximately 3 to 6 ft NAVD88. The revetment construction project did not provide for beach maintenance or nourishment and therefore erosion has persisted with the shoreline at or approaching the edge of the revetment east of FM 457. Erosion at Sargent Beach is exacerbated by intermittent exposure and subsequent episodic erosion of clay substrate as the veneer sand erodes which is particularly evident along the beach west of the nourishment area. Continued erosion has resulted in a narrow beach that potentially limits public access. In an effort to restore and maintain access, a beach nourishment project was initiated at Sargent Beach (CEPRA 1532, Cycle 7) during 28 January 2013 and completed 13 March 2013.

Highway 457 intersects the project site at the western limit (STA 50+0) of the placement area that extends eastward to STA 15+0. The beach to the east and west of the Project Area is referred to in the report as the East Sargent and West Sargent respectively. The characteristics and challenges along each "side" of the beach are unique. East Sargent continues to erode with shoreline recession dominating such that the revetment that was exposed continuously along a 3,500 ft segment of the beach during December 2016 expanded westward to 4,000 ft after Hurricane Harvey. Due to the dominance of longshore sediment transport toward the southwest, limited to null indirect benefit from the fill placement has been documented along East Sargent. In contrast, West Sargent has demonstrated transient indirect benefit from the fill placement as sand has migrated predominantly toward the southwest. The migration of sediment toward the west was evident after Hurricane Ike. Prior to the 2013 nourishment, erosion and shoreline recession dominated along West Sargent to the point that the clay substrate was intermittently exposed. Exposure of the clay substrate has continued along the most western extreme of the study area despite migration of fill material from the Project Area. The exposure of clay was identified from the foreshore to backshore along this section of beach. A greater area of exposed clay was visually evident after Hurricane Harvey, initiating further to the east within the Project Area (STA 45+0).

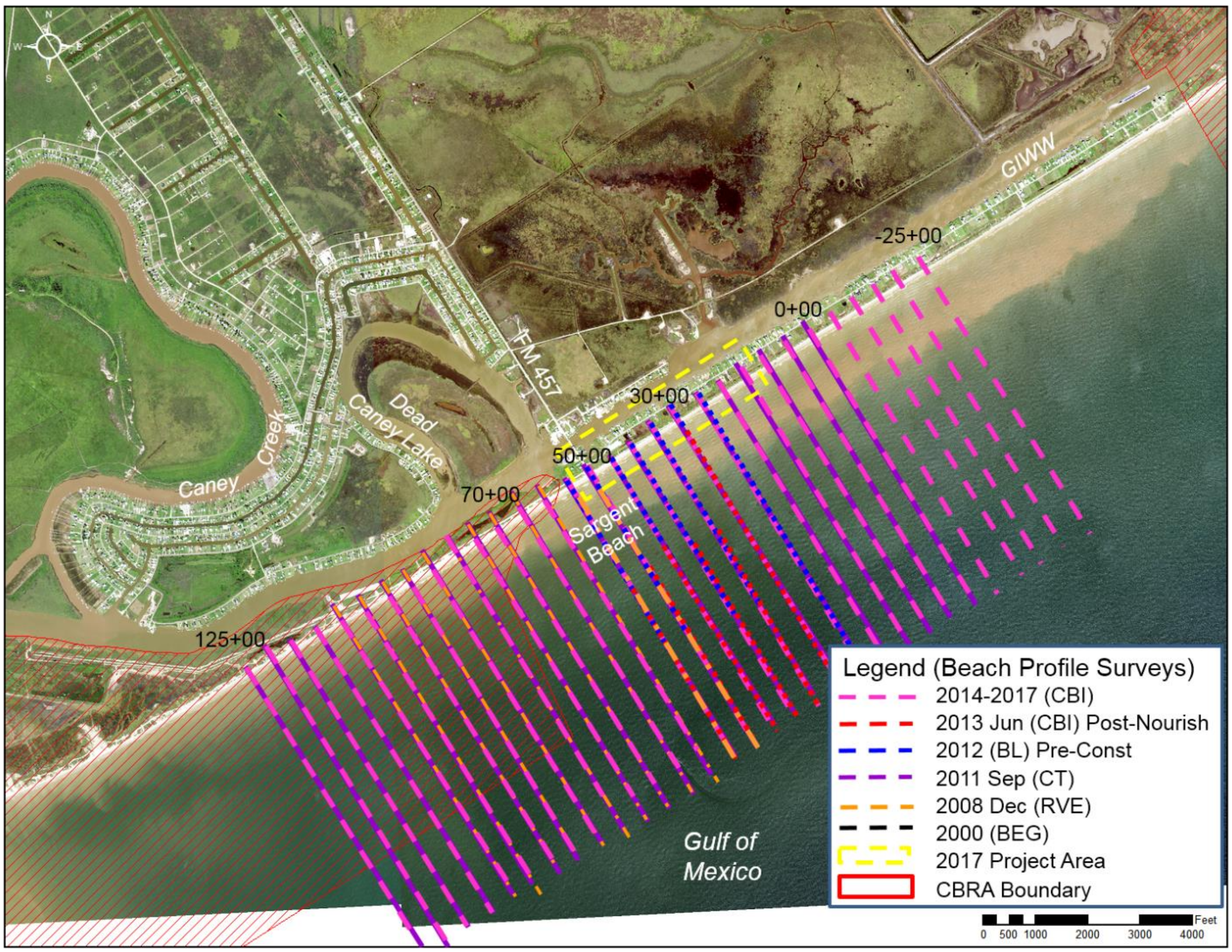


Figure 68. Comparison of alongshore extent of data coverage and beach fill location at Sargent Beach

Historic Data Review

As reported previously, historic review of data and shoreline position change on a larger central to upper Gulf Coast scale has been described in detail by Morton and Piper (1974) and Stauble et al (1994). Thomas and Dunkin (2012) reported on historic change, derived primarily from BEG shoreline data, specific to the Matagorda Peninsula. The dominance of high rates of erosion and shoreline recession has been well documented. Seelig and Sorenson (1973) specifically describe erosion at Sargent Beach and the contributions of historic change in neighboring inlet and river systems along with a discussion of coastal processes acting along the central Texas Coast. Stauble et al (1994) described the high rate of shoreline recession in this region as attributed to the clay composition of the peninsula where the terraces break off in cohesive units resulting in a shoreline that recedes at a higher rate than regions composed completely of sandy material. Furthermore, Stauble discusses the limitations associated with quantification of sediment transport and model application at Sargent Beach due to the clay substrate underlying the beach. Previous studies in this area conducted by Stauble (1994) and Thomas and Dunkin (2012), provide a review of historic analysis based on trends in shoreline recession interpreted from aerial photography as well as limited historic beach profile data, a Lidar data set (2000) and the 2014 BEG report (Paine et. al) provides an assessment of long-term shoreline movement between 1938 and 2012. These previous studies were in support of large-scale analysis of shoreline change as applied to the investigation of structural alternatives to limit erosion along this section of the coast.

Data Availability

This study primarily focuses on changes identified after Hurricane Harvey between Nov 2016 and Oct 2017. Previous reporting, (Williams 2014-2016) has discussed the limitations in the application of select historic data to analysis due to the limited agreement in alongshore and offshore extent of available historic data in previous reporting. The 2013 nourishment area comprised a relatively limited region of approximately 3,600 ft within a larger study area to the east and west that extends an additional 2 miles alongshore. In addition to the survey and analysis conducted annually (2013-2017) by CBI, three historic data sets (2008, 2011, 2012 and a 2000 BEG shoreline survey) were applied to historic analysis of recent erosion rates and shoreline position change. The 2012 data sets introduced an additional spatial limitation in that the survey did not extend to DOC.

Beach Nourishment (2013): Sargent Beach

Although the specifics of the beach nourishment conducted during 2013 are described in previous reporting (Williams 2014) the following summary is provided for continuity and ease of reference. The final placement area was adjusted from original plans described in the BMMP due to 1) re-assessment of benefit, 2) conflict with CBRS boundaries, and 3) re-evaluation relative to excessive sand loss driven by high-energy conditions encountered during placement. The original CEPRA (1376) project description proposed the nourishment area between STA 50+0 and STA 125+0 (noted as STA 0+0 to STA 55+0 in the BMMP) which is located to the west of FM 457. According to Coastal Tech Inc., the placement area was redefined during planning stages to avoid the CBRS boundary and was ultimately shifted predominantly to the east of FM 457. The original design consisted of 133,000 cu yd of sand placed along a 2,500-ft stretch of beach (STA 25+0 to STA 50+0). The proposed 300-ft wide design beach fill was at an elevation of 5 ft, with a tie in at the existing low bluff elevation of approximately 5 to 6 ft (NAVD88). The design did not include dune restoration. The fill material consisted of sand (median grain size = 0.35 mm) that was transported to the site by barge, due to bridge load restrictions, from an offsite DA owned by the Port of Bay City.

During contract negotiations, the fill design was reduced to 78,470 cu yd of sand that was to be placed along 2,065 ft of the beach and having a tie in elevation of 5 to 6 ft (NAVD88) along the backshore (as reported by Coastal Technology Corporation). Construction began in January 2013, a particularly dynamic time of the year along the Texas Coast. Due to frequent inundation and strong wave forcing, the project design was further modified to protect the sand as it was placed along the beach and to conserve the volume of the berm. The width of the fill area was decreased to 120 ft and the fill was extended to a total of 3,600-ft alongshore (STA 30+0 to STA 65+0). Upon completion, 13 March 2013, the final volume of sand placed at the site was reported as 87,271 cu yd. The volume was based on truckload rather than an as-built survey upon completion. Although sand was placed within the revised design template, sand migrated toward the west (STA 65+0) as identified in the 2014 survey. Despite the natural migration of sand westward and lack of survey data to define the eastern limit, the Project Area is defined as from STA 50+0 to STA 15+0.

Post-Harvey Shoreline Position Change: Sargent Beach

Shoreline recession dominated along the Study Area with the shoreline well landward of the Dec 2016 position along 90% of the Study Area and 100% of the Project Area during Oct 2017 (Fig 69-74). The Oct 2017 shoreline position was also well landward of the post-nourishment position along the entire Project Area (Fig 69). The highest rate of recession was focused along the Project Area and the west end of the Study Area. The rate of recession was lower toward the east due to the limiting influence of the exposed revetment and reduced sand supply due to previously high rates of erosion. Although recession dominated, the shoreline was in close agreement with the Dec 2016 position west of the Project Area between STA 75+0 and STA 80+0 and east of the Project Area between STA 5+0 and STA 10+0 (Fig 71 and Fig 73). The position of MHHW at these two locations was influenced by the exposure of the concrete structure to the west and the revetment to the east. The westward migration of the fill material along with native sand has been documented since the 2014 survey.

The post-Harvey Oct 2017 shoreline position was located landward of both the 2008 (post-Ike provided by TGLO) and 2011 (pre-nourishment) positions from STA 50+0 (west limit of Project Area) to STA -25+0 (east limit) and along the entire west end (STA 100+0 to STA 125+0) of the Study Area (Fig 74). The 2017 post-Harvey shoreline position was the most landward position of record at Sargent Beach and was influence by onshore and alongshore forcing that occurred an extended period of water levels in excess of MHHW (Fig 75). Between these two areas (STA 55+0 to STA 95+0) of consistent shoreline recession, the shoreline position was variable with intermittent segments of advance that were likely related to the contribution of the downdrift migration of the fill material (Fig 72 and 73).

Figures 68-74 show both key features of the study area and project area as well as the shoreline position from 2000 to 2017. Review of shoreline change at higher resolution is available online via the CHRGIS mapping tool (http://cartogram.tamucc.edu/chrgis/maps/). The 2000 BEG digitized shoreline and the 2014-2016 CBI surveys cover the entire study area as redefined in 2014. The 2000 BEG shoreline serves as the baseline for the identification of recent decadal change. The datum of the BEG data is estimated at MHW (Gibeaut et. al. 2001). The June 2013 post-nourishment survey was applied to assess change since project completion and the 2012 data set is applied to assess performance of the fill placement relative to the pre-nourishment condition. The following section provides previously reported details on the alongshore limitations of the historic data for ease of reference when reviewing the rate of change along project areas.

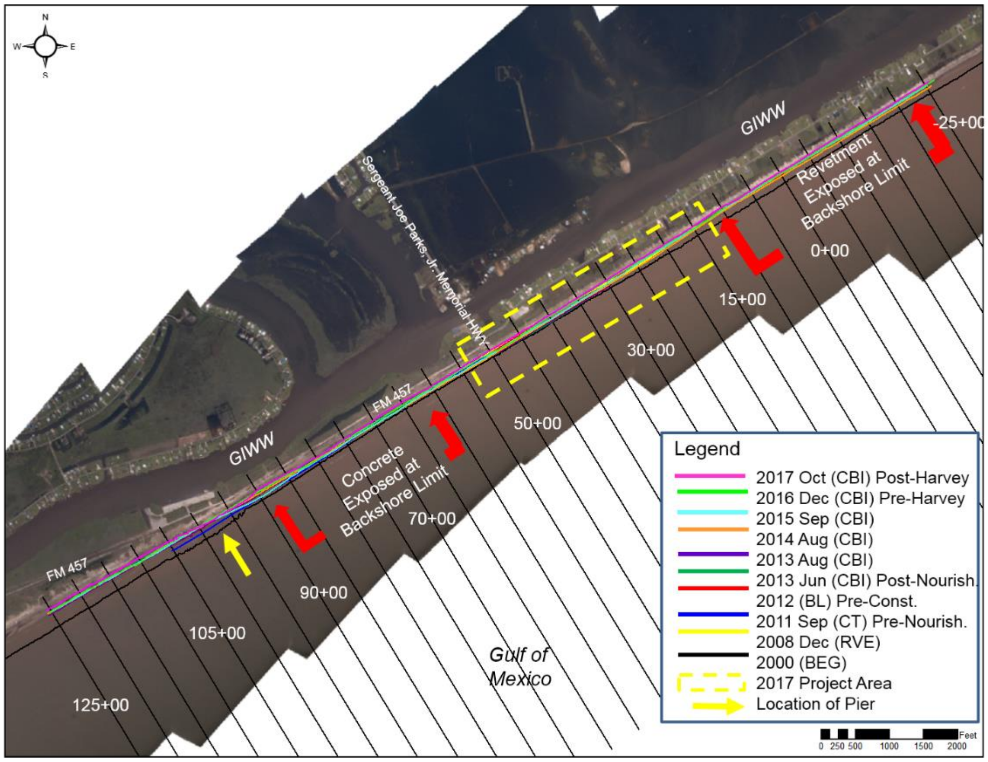


Figure 69. Location of Project Area within the larger Study Area as well as historic shoreline position and key 2017 features at Sargent Beach

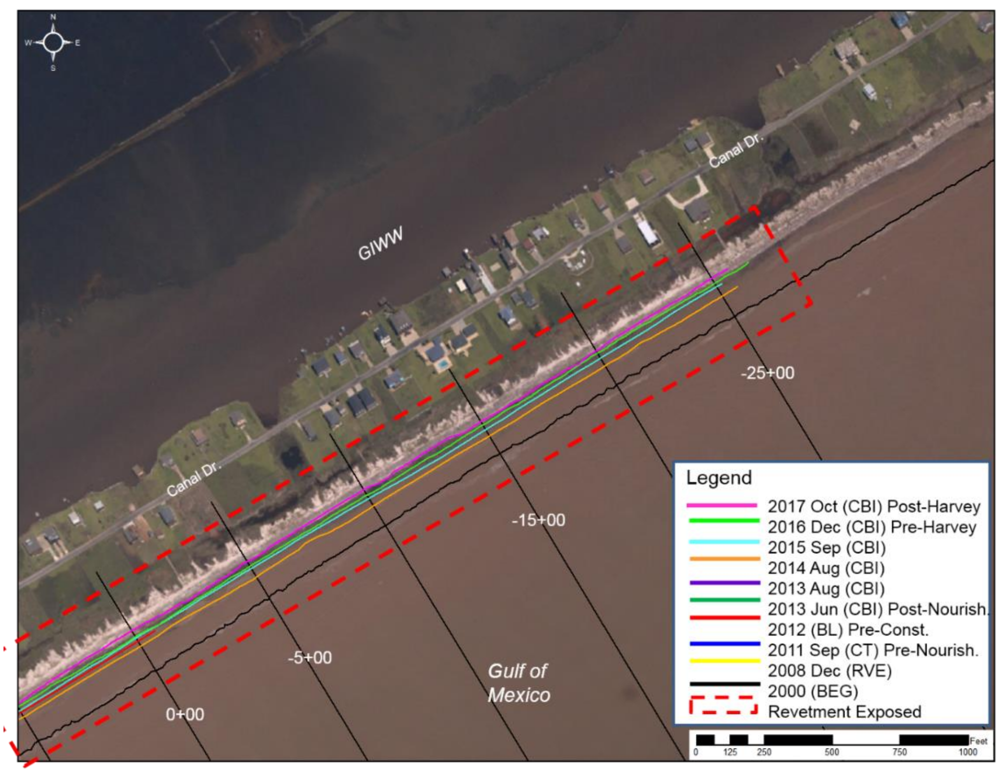


Figure 70. Recession reinforced by Harvey, continued to dominate along east end of the Study Area between Dec 2016 and Oct 2017

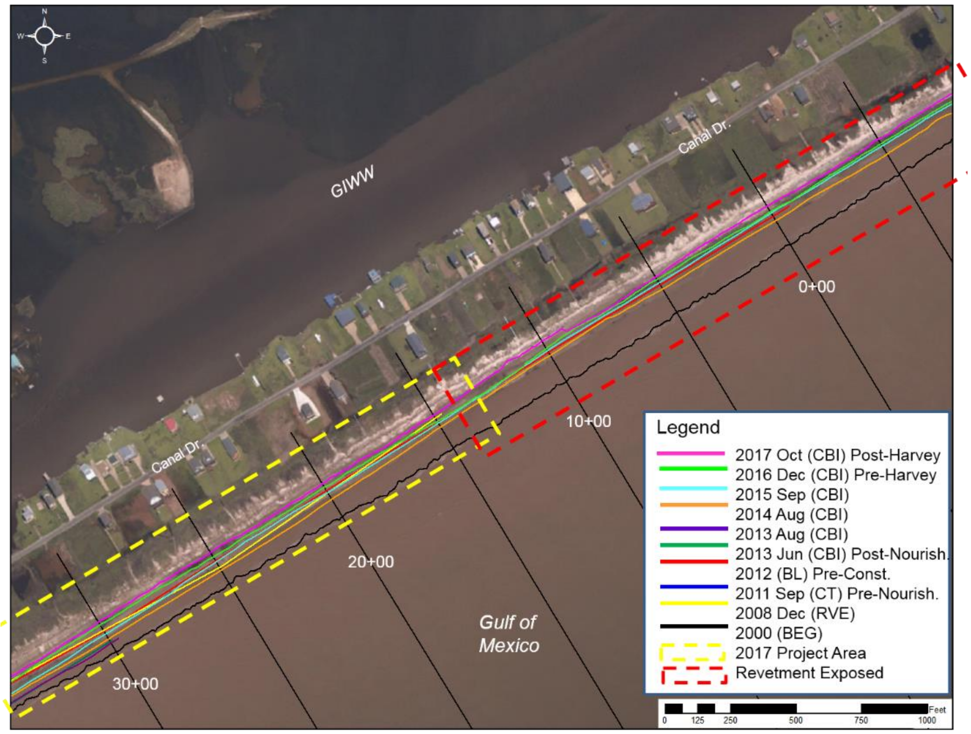


Figure 71. Shoreline recession dominated along the east end of the Project Area between 2016 and 2017

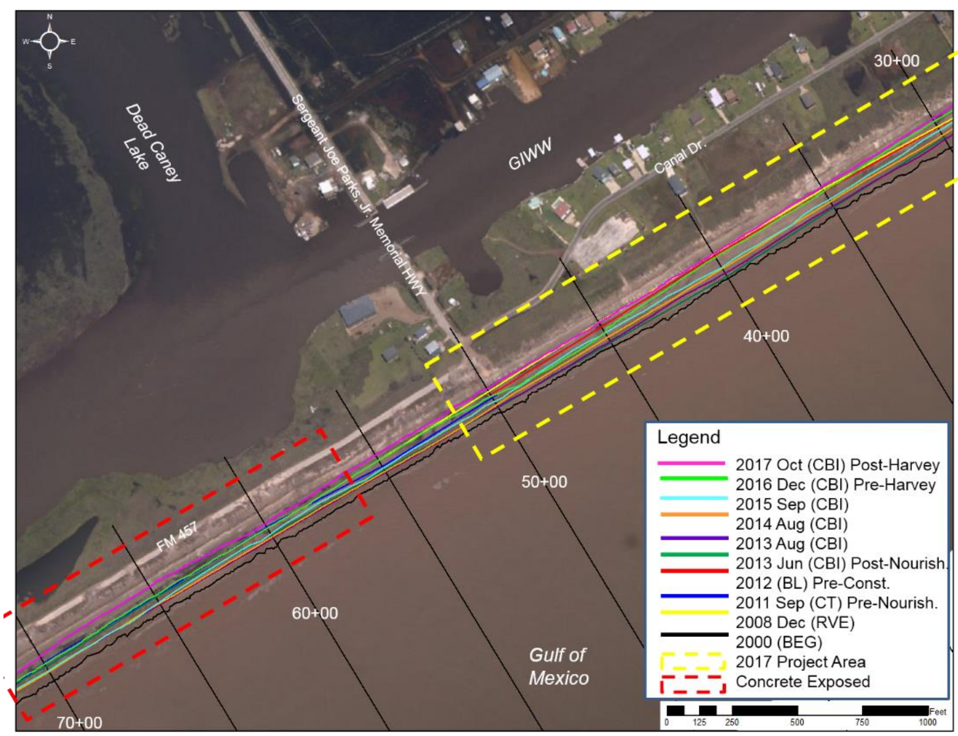


Figure 72. The shoreline along the west end of the Study Area as well as west of the Project Area after Harvey (Oct 2017) was the most landward since monitoring began in 2008

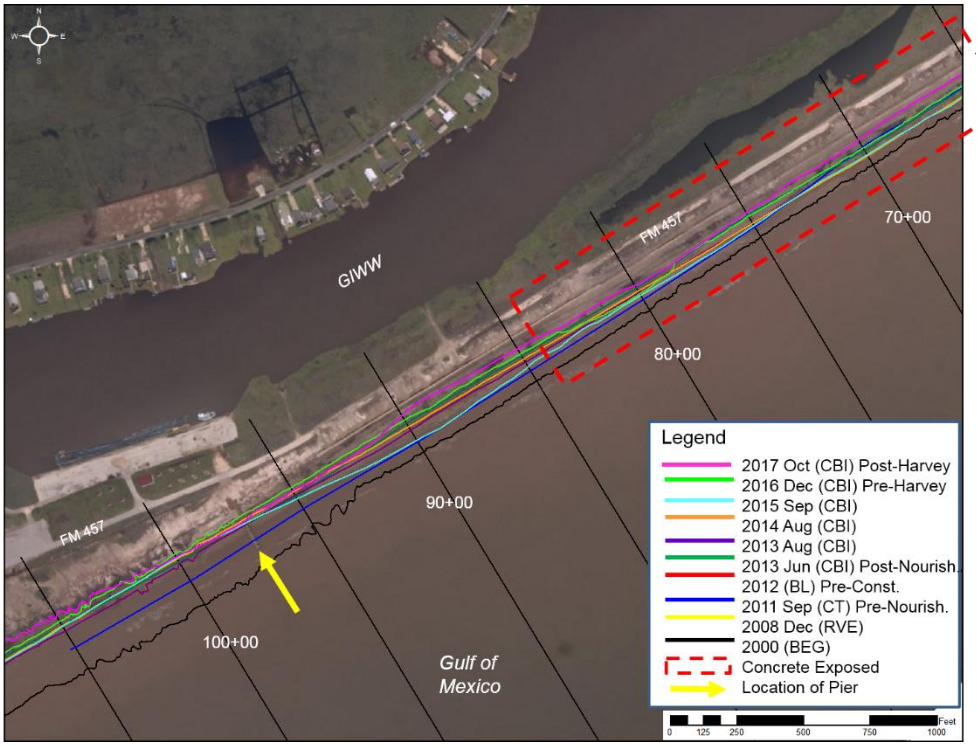


Figure 73. The shoreline position was relatively stable west of STA 90+0 to STA 100+0 where a clay outcrop has been documented

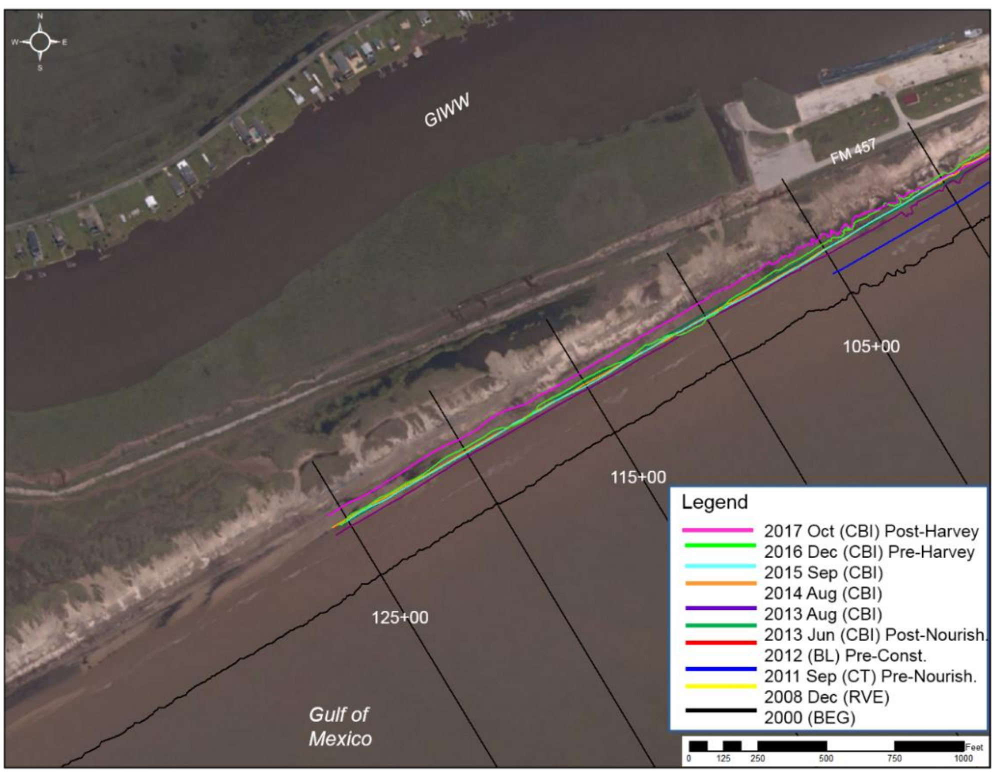


Figure 174. Extreme shoreline recession at the west end of the Study Area where the shoreline was landward of the baseline exposing the clay substrate

Rate of Change in Shoreline Position

Background Historic Trends in Shoreline Recession Rate: Sargent Beach

The following information is from previous reporting and is provided for context and ease of reference. Previous analysis of historic shoreline change along the Texas Gulf Coast defined Sargent Beach as the fastest eroding shoreline along the Texas Gulf coast (Seelig and Sorenson, 1973; Morton and Piper, 1974; and Stauble et al., 1994). Analysis of historic shoreline position change between the 1800's and the 1970's identified that the shoreline at Sargent receded nearly 1,800 ft at an average rate of about -13 ft/yr with peak rates of up to -40 ft/yr (Morton and Piper, 1974). The rate of shoreline change (end-point method) has been calculated by Paine et al. (2012 and 2014) and is provided on the BEG Texas Shoreline Change website. The BEG data was applied to calculate an average rate of shoreline change over a period of a decade due to lack of reliable survey data before 2012. The BEG (2014) estimated rate of shoreline change ranged from -22 to -28 ft/yr over the two long-range calculation intervals (1930-2012 and 1950-2012). The BEG average rate for the shorter period (2002-2012) was significantly lower at -8.9 to -10.4 ft/yr (full study area to project area, respectively). Based on annual CBI surveys and analysis since 2013, the average rate of shoreline recession within the project area has incrementally increased each year since the placement in 2013, ranging from a rate of -5.0 ft/yr (2014) to -23.0 ft/yr (2016) as shown in Table 1 and described in sections to follow.

Baseline Data and Methodology

The average rate of shoreline position change is reported relative to two spatially limited, pre-nourishment shoreline position surveys that vary in alongshore extent. The 2011 shoreline was surveyed along a linear reach at MHHW (1.3 ft NAVD88), while the 2008, 2012 and 2013 shoreline positions were interpolated along the 1.3 ft contour based on application of beach profile survey data due to lacking or inadequate alongshore data. The Jun 2013 shoreline position was applied as the post-construction or as-built position but this data set is limited in alongshore resolution. In addition, this data set has wide transect spacing and therefore may not capture feature detail provided by the Aug 2013 data set. The Aug 2013 shoreline was conducted as a standalone 1-month post-nourishment survey with no beach profile surveys. Both the 2011 and 2012 shorelines were applied as the pre-construction position to provide an envelope of change because neither survey extended across the entire study area. The 2012 shoreline was applied to verify that the 2011 data were representative of the pre-construction condition of the beach for subsequent analysis of volume change. Two shoreline position surveys were conducted during 2014 (May and August). The August 2014 shoreline was selected for application due to the detail as well as the temporal agreement with the 2015 and 2016 survey. There was significant seasonal variation between the timing of the 2014, 2015 and 2016 surveys, therefore the discussion of trend analysis is provided for reference but should be applied noting the contributing forcing event occurring prior during each survey year.

The average rate of shoreline change was calculated for within the project limits and along the broader study area, which extends to the east and west of the placement area. This allowed for the assessment of both fill stability as well as the influence of erosion and alongshore migration of the fill material on the adjacent shoreline. Reference data sets were limited to the BEG shoreline (2000), the pre-nourishment shoreline (2011 and 2012), the post-nourishment shoreline (Jun 2013) and the 1-month post-nourishment shoreline (Aug 2013).

Pre-Harvey Rate of Shoreline Change: Sargent Beach (2013-2016)

Post-Nourishment and Pre-Harvey: Placement Area including Region of Downdrift Benefit (Expanded Project Limits)

The rate of shoreline recession in the project area has increased annually since the placement completed in 2013 (Table 1). The lowest average annual rate was observed over the first year post-placement at -5.0 ft/yr, increasing to -11.5 ft/yr during 2015 and with the rate effectively doubling over the third year (2016) at -23.ft/yr. The average rate of change over the 3-year post-nourishment period in the project area was -13.3 ft/yr. The annual rate of recession along with, the 3-year average, fell well within the envelope of historic change established by the BEG for this section of coastline. The maximum and minimum rate of change over several study intervals along both the full study area as well as the project area were calculated applying the endpoint method. These measurements were compared to the BEG calculations that are provided on the BEG Texas Shoreline Change website. Of interest is that the BEG rates, ranging from -10.4 ft/yr to -13.6 ft/yr, observed over the 2002-2012 interval describing the period immediately prior to the nourishment, were lower than those observed over the longer historic intervals. The CBI calculation, based on shoreline position surveys, for a similar period (2000-2012) along the beach and limited by the extent of the 2012 data also reflected a lower rate of shoreline change (-7.7 ft/yr) over this 12-year interval immediately preceding nourishment.

Over the previous reporting period there were three factors contributing to the increase in the rate of shoreline recession and accelerated erosion documented between Sep 2015 and Dec 2016. These factors included; 1) Exhaustion of fill material from project site, 2) influence of winter storms over fall and winter season and 3) high number of sustained high water level events, some likely accompanied by onshore forcing that preceded the 2016 survey. The increase in the rate of recession along the project reach as opposed to the full study area is attributed to the continued erosion of the remaining fill material within the placement area and migration of sand toward the west, temporarily moderating the rate of recession west of the placement area.

Table 1. Rate of Shoreline Position Change 2017: Sargent Beach ***Survey conducted after winter storm influence and high # nuisance tides during 2016**					
Project Area: 2013 Nourishment Area as Defined by TGLO **STA 50+0 to STA 15+0 (Stations Occupied)** **(Only 2014-2017 surveys cover the full 2013 project area)** **Note: Data extent varies by survey year** **STA 30+00 to 125+00 defines limits of 2013 post-nourishment survey (Limited Study Area Extent)**					
Interval (Year)	**Description**	**Location (Station #)**	**Rate + Advance - Recession ft/yr**	**Max Δ + Advance ft**	**Max Δ - Recession ft**
Dec 2016 Oct 2017	Post-Harvey	STA 15+0 to 50+0	-26.7	0	-56
Sep 2015 Dec 2016	Annual (Pre-Harvey)	STA 15+0 to 50+0	-20.5	12	-47
2000-2017		STA 15+0 to 50+0	-7.3	0	-168
Limited Project Extent: 2013 Nourishment Area (with documentation including area of downdrift influence **(Only CBI surveys 2014-2017 cover full 2013 project area)** **Note: STA 30+00 to 70+00 defines limits of 2013 nourishment area relative to limits of pre-nourishment data**					
Interval (Year)	**Description**	**Location (Station #)**	**Rate + Advance - Recession ft/yr**	**Max Δ + Advance ft**	**Max Δ - Recession ft**
Dec 2016 Oct 2017	Post- Harvey	STA 30+00 to 70+00	-31.8	0	-56
Sep 2015 Dec 2016	Annual*	STA 30+00 to 70+00	-23.0	+12	-47
Aug 2014 Sep 2015	Annual	STA 30+00 to 70+00	-11.5	+6	-27
Jun 2013 Dec 2017	4-yr Post-Nourishment (Harvey Influence)	STA 15+0 to 50+0	-19.0	0	-97
Jun 2013 Dec 2016	3.5-yr* avg Post-nourishment	STA 30+00 to 70+00	-13.3	0	-87
Jun 2013 Sep 2015	2-yr avg. post-nourishment	STA 30+00 to 70+00	-8.2	+30	-48
Jun 2013 Aug 2014	1-yr post-nourishment	STA 30+00 to 70+00	-5.0	+28	-35
May 2000 Dec 2016	Historic Influence: Hurricanes and fill placement	STA 30+00 to 70+00	-4.9	0	-82
Dec 2016 Oct 2017	Annual and Post- Harvey	STA 30+00 to 125+00	-29.3		
Sep 2015 Dec 2016	Annual*	STA 30+00 to 125+00	-25.0	+15	-89
Aug 2014 Sep 2015	Annual	STA 30+00 to 125+00	+2.7	+65	-27
Jun 2013 Dec 2016	3.5-yr* Post-nourishment	STA 30+00 to 125+00	-7.2	+29	-87
Jun 2013 Aug2015	2-year Post-Nourishment	STA 30+00 to 125+00	+1.9	80	48
Aug 2013 Aug 2014	12-Month Analysis (Aug 2013 extent)	STA 30+00 to 125+00	-12.8	+4	-46

Table 1. Continued on Next Page

Table 1. Rate of Shoreline Position Change 2017: Sargent Beach (Continued) *Survey conducted after winter storm influence and high # nuisance tides during 2016					
Interval (Year)	**Description**	**Location (Station #)**	**Rate + Advance - Recession (ft/yr)**	**Max Δ + Advance (ft)**	**Max Δ - Recession (ft)**
May 2000 Dec 2016	16-year	STA 30+00 to 125+00	-7.8	0	-248
May 2000 Nov 2012	12-year Compare to BEG	STA 15+00 to 55+00	-7.7	0	-139
May 2000 Sep 2011	East End Pre-nourishment (2011 extent)	STA 0+00 to 50+00	-9.1	0	-143
Extended Study Area: Includes extended eastern limit (STA -25+00 to STA 125+0 Historic Comparison 2000, 2014-2017 (Extended Eastern Extent)					
Oct 2017 Dec 2016	Annual	STA -25+00 to 125+00	-27.0	+28	-72
Aug 2014 Dec 2016	2-yr average*	STA -25+00 to 125+00	-14.2	+17	-65
Sep 2015 Dec 2016	12-month Analysis	STA -25+00 to 125+00	-20.6	+15	-76
Aug 2014 Sep 2015	12-Month Analysis	STA -25+00 to 125+00	-7.4	+65	-45
May 2000 Dec 2016	16 Year Estimate	STA -25+00 to 125+00	-7.9	0	-248

Post-Harvey Rate of Shoreline Change: Sargent Beach

The rate of shoreline change is provided at key study intervals for four alongshore segments of the beach, the alongshore extent of which are limited by available historic data as described in previous reporting (Table 1). Only the data sets from 2014 to 2017 and the BEG 2000 shoreline cover the entire Project Area. The Project Area is defined as the design placement area from STA 15+0 to STA 50+0, although the actual placement extended further to the west due to active forcing and downdrift transport during placement. The average rate of shoreline change along the entire Study Area was -27.0 ft/yr, exceeding the rate of the previous reporting period (-20.6 ft/yr) by 25 %. The rate of shoreline change along the project reach (limited by data extent) since nourishment was -19.0 ft/yr (June 2013 to Dec 2017). The rate of shoreline recession during Oct 2017 was the highest documented in the Project Area and Study Area since monitoring began in 2013. The annual rate of shoreline change in the Project Area and Study Area over the present reporting period was -23.0 ft/yr (Sep 2015 to Dec 2016).

The high variability in the rate of shoreline position change with alongshore position in the Study Area is shown in Figure 8. Comparison of rate of shoreline change relative to alongshore position along the full Study Area is provided over the following key intervals; 1) 2016-2017 (Post-Harvey), 2) 2015-2016 (Previous annual reporting period), 3) 2014-2015 (Annual), and 4) 2000-2017 (BEG baseline). The intervals of investigation were limited by the alongshore extent of the existing data sets prior to 2014.

Beach Width and Morphology: Sargent Beach

Design Specifications, Target Width and Action Width

The originally proposed 300-ft design width for Sargent Beach was reportedly reduced to 200 ft during construction in 2013 with the expectation of a post-construction width of 120 ft after extensive erosion during placement. Based on the experience reported during the 2013 placement, the Target Width applied for monitoring and future Sargent nourishment projects is proposed at minimum of 200 ft but is challenging both economically and from a borrow source identification perspective. Restoring the beach to the original design width of 300 ft would moderate losses that might occur during placement, particularly if placed during a less dynamic season. The Action Width associated with the wider initial beach is 100 ft, which will provide for planning time due to the high rate of erosion that continues along Sargent Beach. The actual functional width of the beach is influenced by shifts in the LOV. The Between 2014 and 2015, the LOV shifted substantially landward intermittently along the beach, particularly west of the project area, which may support the perception that the beach was wider than the surveys indicated during 2015. The width of the beach is calculated from the 2013 LOV position where data is available and from the 2014 position along the remainder of the study area as indicated in Table 2. Going forward, the backshore baseline will be re-evaluated and adjusted to account for the severe erosion and shoreline and backshore recession that was influenced by Harvey during 2017. The following section is provided for ease of reference and documents background related to the application of the 2013 and 2014 LOV along the Study Area.

Baseline for Beach Width Calculations: Line of Vegetation

As reported previously, the acting landward limit of Sargent Beach was taken as the LOV initially measured during both the Aug 2013 and Aug 2014 surveys in order to establish a baseline for calculating beach width (extended eastward) in the absence of well-defined backshore features such as a duneline. The LOV measured during 2014 extended the full length of the expanded survey grid but due to the seaward shift noted in the placement area it was applied only to the region to the east of the project limit. Calculations relative to both the 2013 and 2014 LOV are provided in Table 2 for comparison.

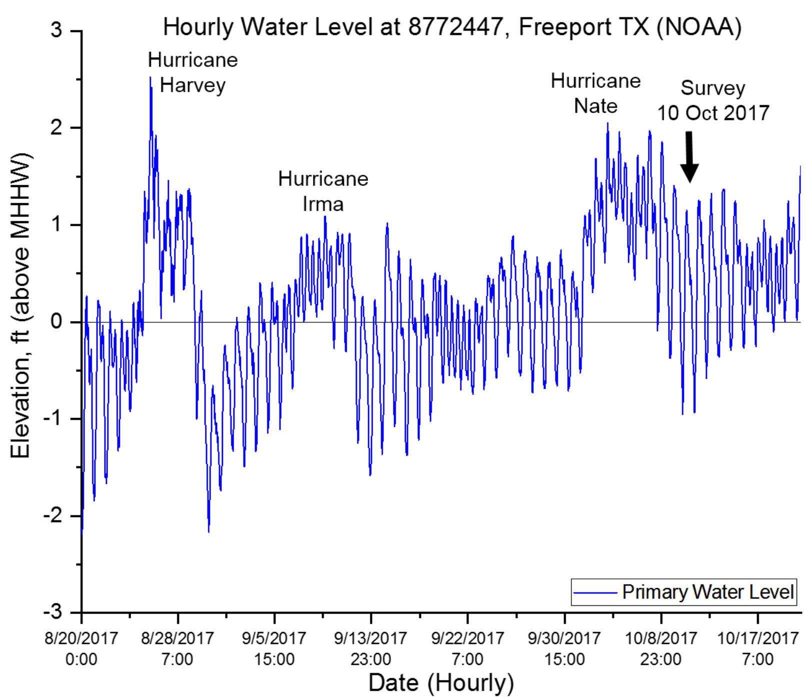


Figure 75. Persistent high water level in excess of MHHW prior to the survey at Sargent Beach in Oct 2017 (Freeport, USCG Station)

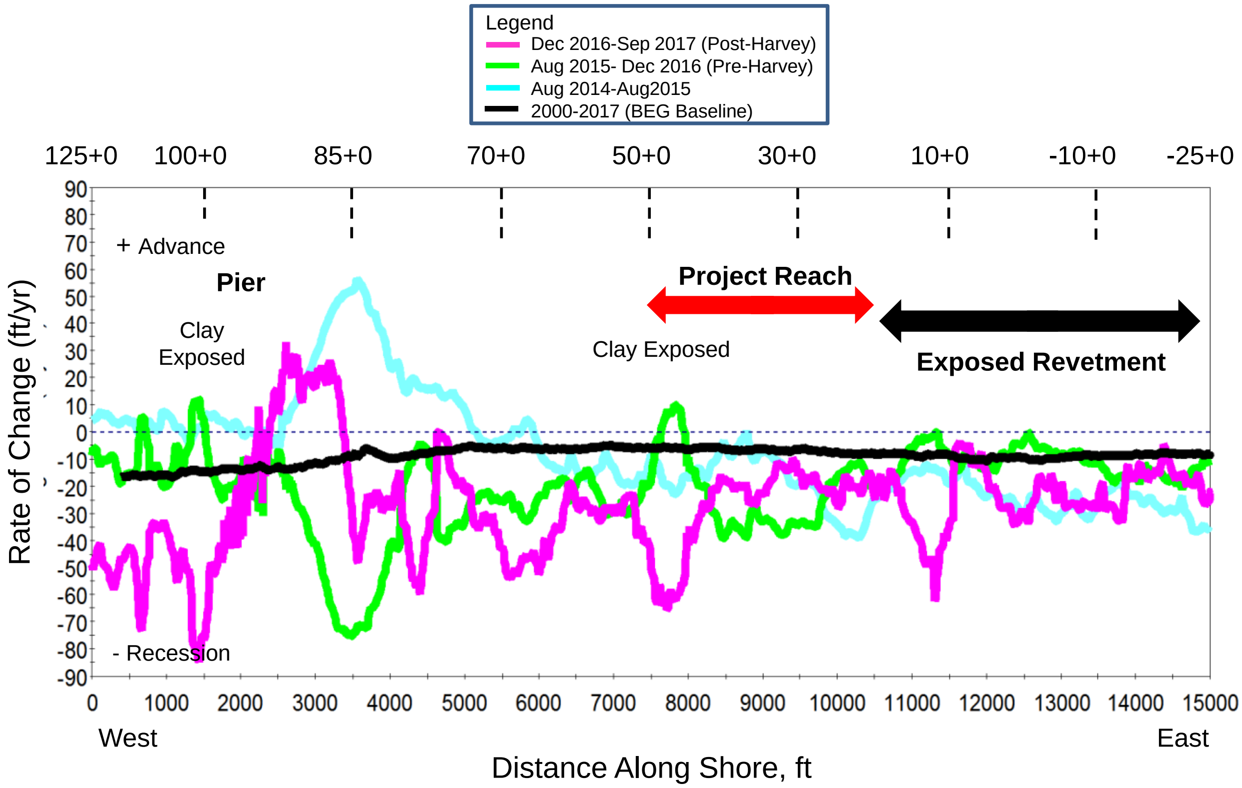


Figure 76. Comparison of rate of shoreline change relative to alongshore position along the full Study Area over 1) 2016-2017 (Post-Harvey), 2) 2015-2016 (Previous Reporting Period), 3) 2014-2015 (Annual), and 4) 2000-2017 (BEG baseline)

During 2014, the LOV was measured directly to determine if change had occurred relative to the placement of the beach fill. The 2014 LOV was in close agreement with the 2013 position along the shoreline west of the project limits. Within the project boundaries, the 2014 LOV agreed with the 2013 LOV from STA 65+0 to STA 45+0. After this point, the 2014 LOV shifted seaward and was in advance of the 2013 LOV from STA 45+0 to STA 30+0. The deviation corresponded to the exposure of the revetment where vegetation re-established seaward of a pathway related to frequent vehicle access.

Although the 2013 and 2014 LOV serve as the baseline surveys of the LOV continue to document the dynamic state of the backshore at Sargent Beach. As previously reported, during 2015 the density and seaward extent of vegetation decreased along the entire study area between September 2014 and Aug 2015. Although the 2015 position of the LOV was generally in close agreement with the 2014 LOV along the majority of the placement area and immediately east thereof (STA 15+0 to STA 55+0); the 2015 LOV was significantly landward along the east end and west end of the study area. The landward shift in the LOV resulted from extensive backshore erosion that occurred along the majority of the beach between the 2014 and 2015 surveys. The region of landward recession of the LOV included the section of beach with the highest rate of shoreline advance during this time (STA 75+0 to STA 95+0). The landward shift in the LOV west of the project area appears to be related to inundation and erosion of the clay substrate along this reach. The extreme recession of the LOV was related to periods of inundation due to both nuisance tides as well as the influence of Tropical Storm Bill during which the water level at Freeport (USCG Monitoring Station) reached nearly 3 ft above MHHW on 16 June 2015. During the 2015 event erosion was focused on backshore and berm crest. Figure 75 shows a comparison of the increase in water level above MHHW after 2014.

Although no tropical storms impacted Sargent during 2016, there were successive periods of inundation that occurred frequently over the course of the year. Erosion accelerated at Sargent Beach during 2015 and subsequently during 2016 as periodic inundation events dominated in contrast to more typical water level signal observed during 2014. The cumulative impact of this series of moderate inundation events during 2016 was erosion more focused across the berm rather than along the backshore as observed during 2015. Therefore, only a moderate degree of recession in LOV was observed along the entire beach with only two segments with significant recession, and moderate recession in a former region of accelerated LOV recession west of the project area.

Beach Width: Summary of Baseline and Post-nourishment Assessment (2013-2015)
The beach width measured for both the pre-nourishment limited surveys (2008, 2011, and 2012) and the two post-nourishment surveys conducted by CBI (June 2013 and August 2013) serve as a baseline for continued monitoring (Table 2). As described in previous reporting, extensive erosion occurred during fill placement such that the June 2013 post-nourishment survey, conducted 3-months after completion, documented a maximum beach width of 173 ft at STA 45+0 and an average beach width of 124 ft along the entire nourishment area which is well under the revised Target Width of 200 ft. One year post-nourishment (Jun 2013 to Aug 2014) there was a general decrease in beach width along the entire project area from STA 30+0 to STA 65+0 with an average width of 115 ft in the project area and a range of 99 to 139 ft. The beach width continued to decrease and by Sep 2015, the average width was 103 ft with a range of 90 to 134 ft. The widest section of the beach was located between STA 30+0 and STA 40+0 during 2014 and further west between STA 35+0 and STA 40+0 during 2015. The beach approached the Action Width during 2014 along 1,000 ft of the placement area (STA 50+0 to STA 60+0). Nearly the entire 3,500 ft placement area (STA 45+0 and STA 65+0) with the exception of 500 ft between STA 35+0 and 40+0 was at the Action Width during 2015.

Beach Width: Pre-Harvey Summary 2015-2016
During December 2016, the width of the beach within the project limits as well as to the east and west along the entire study area was less than the Target Width of 200 ft and well under the Action Width of 100 ft (Table 2). In the Project Area the beach width ranged from 54 ft to 97 ft with an average width of 75 ft (STA 30+0 to STA 55+0). The average beach width in the project area during 2015 was 106 ft. The average pre-nourishment beach width (2012) along the same limits was 65 ft, indicating near agreement with the pre-nourishment condition. Erosion was primarily focused across the berm while erosion was focused along the backshore elevated region was less pronounced than during 2015. With limited backshore erosion occurring over the reporting period, the 2016 position of the LOV was in close agreement with the 2015 LOV position along the majority of the study area with few and isolated exceptions. The following two sections discuss a comparison of LOV and revetment exposure during 2016 to the previous study period during which backshore erosion at Sargent Beach was well developed.

Beach Width: Post-Harvey (2016-2017)

Project Area

Not only was the beach width well under the Action Width (100 ft) along 100% of the Project Area, but the width in the Project Area was less than the baseline width prior to nourishment (2013). The beach width during Oct 2017 ranged from 19 to 71-ft wide with an average width of 42 ft. The beach was at its maximum width of 71 ft at the west end between STA 45+0 and STA 50+0 and at the minimum width of 19 ft at the east end (STA 15+0). Of particular interest is that the width of the beach at the east end of the Project Area was further limited by the location of the revetment that functioned as the backshore limit.

Study Area

The width of 90% of the beach along the Study Area, including the Project Area, was less than the Action Width recommended for the Project Area and at the minimum width recorded since monitoring began. The area of exception is the limited segment between STA 90+0 and STA 100+0 that was influenced by the transition of sand migrating alongshore toward the west from the Project Area. Along several segments, the beach eroded landward of the backshore limit, effectively initiating a beach "set back". The backshore limit was defined prior to the exposure of the revetment to the east (STA 0+0) of the Project Area and was based on the pre-Harvey morphology and elevation along the west end. The beach was at the minimum width observed since monitoring began, including after Hurricane Ike. The maximum width was an isolated 72 ft at STA 95+0. Along segments fronting STA -10+0 to the east of the Project Area and STA 105+0, 120+0 and 125+0 along the west end of the Study Area the beach shifted up to 19 ft landward of the former backshore limit, effectively initiating a set-back beach condition with the backshore functioning and the berm. The average beach width based on the previously defined backshore limit was 29 ft. The backshore limit will require adjustment and perhaps alignment with the revetment to the east and west of the Project Area to accommodate the episodic erosion prepare for continued future erosion events. Due to the continued westward expansion of revetment exposure, it is anticipated that without aggressive restoration measures, the revetment will serve as the backshore limit along the entire Project Area in the foreseeable future.

Table 2. Comparison of Beach Width Over Key Study Periods: Sargent Beach

Target Width = 200 ft   Action Width = 100 ft (Project Area)

Decrease   Increase   N/A

Location	Pre- Nourishment				Post-Nourish.	2-Month Post-Nourish.	Year 1 Post-Nourish.		Year 2 Post-Nourish.		Year 3 Post-Nourish.		Year 4 Post-Nourish. Post-Harvey	
Transect ID	2011		2012		Jun-13	Aug-13	Aug-14		Aug-15		Dec-16		Oct-17	
	2013	2014	2013	2014	2013	2013	2013	^2014	2013	^2014	2013	^2014	2013	^2014
	LOV	LOV	LOV	LOV	LOV	LOV	LOV	LOV	LOV	LOV	LOV	LOV	LOV	LOV
-25+00	--	--	--	--	--	--	--	78^	--	37	--	21	--	0
-20+00	--	--	--	--	--	--	--	83^	--	51	--	30	--	20
-15+00	--	--	--	--	--	--	--	85^	--	58	--	40	--	25
-10+00	--	--	--	--	--	--	--	87^	--	55	--	40	--	17
-5+00	--	--	--	--	--	--	--	84^	--	48	--	39	--	20
0+00	59	--	--	--	--	--	--	80^	--	47	--	39	--	14
5+00	62	--	--	--	--	--	--	75^	--	45	--	39	--	28
10+00	50	--	--	--	--	--	--	60^	--	40	--	28	--	-6
15+00*	51	--	32	--	--	--	--	72^	--	54	--	47	--	19
20+00*	53	--	63	--	--	--	--	92^	--	62	--	40	--	24
25+00*	60	--	89	--	--	--	--	101^	--	63	--	40	--	23
30+00*		**81**		**77**	**127**	**136**	**117**		**94**		**54**		**41**	
35+00*		**92**		**80**	**162**	**157**	**135**		**127**		**90**		**70**	
40+00*		**80**		**74**	**173**	**158**	**139**		**134**		**87**		**71**	
45+00*		**70**		**52**	**142**	**138**	**118**		**99**		**97**		**53**	
50+00*		**57**		**46**	**117**	**113**	**104**		**90**		**67**		**33**	
55+00		**--**		**58**	**102**	**112**	**107**		**94**		**59**		**35**	
60+00		**--**		**--**	**96**	**110**	**105**		**92**		**67**		**48**	
65+00		**--**		**--**	**73**	**104**	**99**		**96**		**65**		**24**	
70+00		--		--	96	117	119		115		84		50	
75+00		--		--	60	95	95		106		64		49	
80+00		--		--	70	90	84		102		95		60	
85+00		--		--	83	111	98		130		75		54	
90+00		--		--	78	109	93		152		63		45	
95+00		--		--	96	90	75		104		58		72	
100+00		--		--	25	31 (clay)	11		7		-8		5	
105+00		--		--	31	55	32		36		14		-9	
110+00		--		--	77	102	89		91		96		32	
115+00		--		--	57	87	65		74		50		22	
120+00		--		--	49	61	42		47		29		-8	
125+00		--		--	38	57	27		33		27		-19	

Notes: --No data available
* **2013 Placement Area**
** Interpolated shoreline position from limited available data
^ LOV 2014 applied where LOV 2013 unavailable

Revetment Exposure

The degree of intermittent exposure of the revetment along Sargent beach has increased since monitoring began in 2012. The most significant episodic exposure was stimulated by extensive backshore erosion observed during 2015 with forcing during Harvey exacerbating existing exposure and initiating additional intermittent exposure westward into the Project Area. Since that time, persistent exposure has increased in a westerly direction toward the Project Area. Erosion along the backshore and revetment exposure had a greater impact with regard to beach width east of the project limits due to the proximity and alongshore alignment of the revetment to the pre-construction shoreline position. The increase in periodic inundation during 2016 reinforced the erosion that occurred across the berm east of the project area during 2015. During 2015 the revetment was intermittently exposed along a stretch of approximately 3,000 ft of the study site, with the most significant reach of consistent exposure between STA 0+0 and STA -25+0. Continued erosion of the backshore and low dunes between May 2014 and Sep 2015 not only exposed a greater cross section of the revetment than identified during 2014 but also extended the previously reported alongshore extent of exposure an additional 1,000-ft further east. During 2016 the extent of revetment exposure at the berm interface expanded toward the placement area increasing incidence of persistent revetment exposure along 3,500 ft alongshore from STA 10+0 to STA -25+0. The elevation of the exposed revetment was between 3 ft (seaward) to 6 ft (landward). Hurricane Harvey reinforced the cumulative impact of erosion experience over the preceding two reporting periods. During 2017 the revetment was continuously exposed from STA -25+0 to STA 15+0 with intermittent exposure between occupied survey transects identified westward to STA 25+0. As the exposure of the revetment continues to expand westward the integrity of future nourishment activities will become threatened and with a more challenging restoration process due the interaction of waves and currents with the hard structure.

Beach Profile Morphology: Sargent Beach

The beach and nearshore morphology at Sargent Beach changed dramatically in response to forcing during Harvey. Erosion dominated across the entire beach from the low dune or upland where absent, as well as across the berm and foreshore (Figs 77-88). The greatest erosion occurred offshore of the -10 to -15 ft contour where episodic erosion of the nearshore shelf was well-developed although intermittent along the Study Area including 100% of the Project Area. After Harvey, the discontinuity in sediment transport between the profile seaward of -10 to -15 ft contour and the landward section of the profile was clearly defined (Figs 89-99). The difference in forcing between these two regions, combined with strong alongshore currents that transport sediment toward the west beyond the littoral cell, limit the potential for recovery of sand once transported seaward of the -10 to -15 ft contour.

Prior to Harvey, no benefit of the fill placement was evident along 75% of the Project Area with the beach profile landward of the pre-nourishment profile limit defined by the 2008 or 2011 survey (limited by alongshore extent of data set). After Harvey, volume loss was in excess of the remaining fill in 2016 along the remaining 25% of the beach with 100 % of the beach profile along the Project Area shifted landward of the pre-nourishment profile position. In other words, the beach eroded landward of the pre-nourishment condition (2008-2012, dependent on data set limitations) which resulted in a setback of the beach such that the former backshore and upland along the west end functioned as the berm after Harvey.

The only segment of beach along the Study Area that demonstrated relative stability was located just west of the Project Area at STA 60+0 and STA 80+00 (Fig 18 and 19). The intermittent and limited areas of relative stability are likely transient and related to the westward migration of sand rapidly eroding from the beach to the east. Erosion further west between STA 85+0 to STA 105+00 was non-uniform reflecting the response of the exposure of the clay substrate. At the west end of the Study Area erosion was uniform and extended from the upland/dune across the entire berm and foreshore as well as into the immediate nearshore as indicated along STA 110+0 and STA 125+0 (Fig 99 and 100, respectively).

The nearshore region beyond the -10 ft contour was characterized by non-uniform development of discontinuous, variable morphology with alongshore location. Undulating, non-linear bar and shoal-like features that may be more indicative of lenses of sand being transported toward the west rather than alongshore bars. As previously reported, the lack of alongshore continuity of these features indicates transient sand movement that may be seasonal, episodic or regional. This hypothesis is further supported by the high variability in the offshore features over time, particularly in contrast to the relatively featureless region captured during the 2014 survey. The non-linear characterization is drawn from the lack of continuity in features between adjacent profiles (Fig 77-100).

As previously reported instability related the exposure of the clay substrate has been identified along both the foreshore and nearshore along the Sargent Beach. Changes in morphology since 2008/2011 (limited by alongshore extent of historic data sets) indicate that there are two reasons for the high degree of variability in the morphology in the nearshore and high rates of erosion that are cyclic or storm related; 1) Discontinuity in sediment transport: large-scale regional transport of sand alongshore seaward of the -10 to -15 ft contour, that does not support subsequent onshore transport toward stability or recovery and 2) Scour seaward of the -10 to -15 ft contour that removes the transient sand veneer to expose the clay substrate to direct erosion/scour. Once the clay substrate has been exposed, subsequent erosion has resulted in large-scale failure of sections of the nearshore shelf, similar to that observed along the berm crest and foreshore. Sediment eroding from the nearshore shelf is rapidly transported westward by strong alongshore currents. The greatest degree of erosion in the nearshore that has been captured by annual surveys was documented after Harvey. The erosion of the nearshore region seaward of the 10-15 ft contour abruptly reduced the profile elevation from 2 to 3 ft compared to the 2016 survey.

Table 3. Beach Width: Sargent Beach
Notes: N/A indicates no survey data for transect location
***Project Area**

Location	Pre-Nourishment	Pre- Nourish. / Post Nourish.	2-month Post Nourish.	Year 1 Post Nourish.	Year 2 Post Nourish.	Year 3 Post Nourish.	Year 4 Post Nourish.	Baseline	Post Nourish. to 2017
Transect ID	Δ 2011 2012	Δ 2012 Jun 2013	Δ Jun 2013 Aug 2013	Δ 2013 2014	Δ 2014 2015	Δ 2015 2016	Δ 2016 2017	Δ 2012 2017	Δ Jun 2013 2017
-25+00	N/A	N/A	N/A	N/A	-41	-16	-21	–	–
-20+00	N/A	N/A	N/A	N/A	-32	-21	-10	–	–
-15+00	N/A	N/A	N/A	N/A	-27	-18	-15	–	–
-10+00	N/A	N/A	N/A	N/A	-32	-15	-23	–	–
-5+00	N/A	N/A	N/A	N/A	-36	-9	-19	–	–
0+00	N/A	N/A	N/A	N/A	-33	-8	-25	–	–
5+00	N/A	N/A	N/A	N/A	-30	-6	-11	–	–
10+00	N/A	N/A	N/A	N/A	-20	-12	-34	–	–
15+00*	**-19**	**N/A**	**N/A**	**N/A**	**-18**	**-7**	**-28**	**-13**	**–**
20+00*	**10**	**N/A**	**N/A**	**N/A**	**-30**	**-22**	**-16**	**-39**	**–**
25+00*	**29**	**N/A**	**N/A**	**N/A**	**-38**	**-23**	**-17**	**-66**	**–**
30+00*	**-4**	**50**	**9**	**-19**	**-23**	**-40**	**-13**	**-36**	**-86**
35+00*	**-12**	**82**	**-5**	**-22**	**-8**	**-37**	**-20**	**-10**	**-92**
40+00*	**-6**	**99**	**-15**	**-19**	**-5**	**-47**	**-16**	**-3**	**-102**
45+00*	**-18**	**90**	**-4**	**-20**	**-19**	**-2**	**-44**	**1**	**-89**
50+00*	**-11**	**71**	**-4**	**-9**	**-14**	**-23**	**-34**	**-13**	**-84**
55+00	N/A	44	10	-5	-13	-35	-24	-23	-67
60+00	N/A	N/A	14	-5	-13	-25	-19	–	-48
65+00	N/A	N/A	31	-5	-3	-31	-41	–	-49
70+00	N/A	N/A	21	2	-4	-31	-34	–	-46
75+00	N/A	N/A	35	0	11	-42	-15	–	-11
80+00	N/A	N/A	20	-6	18	-7	-35	–	-10
85+00	N/A	N/A	28	-13	32	-55	-21	–	-29
90+00	N/A	N/A	31	-16	59	-89	-18	–	-33
95+00	N/A	N/A	-6	-15	29	-46	14	–	-24
100+00	N/A	N/A	6	-20	-4	-15	13	–	-20
105+00	N/A	N/A	24	-23	4	-22	-23	–	-40
110+00	N/A	N/A	25	-13	2	5	-64	–	-45
115+00	N/A	N/A	30	-22	9	-24	-28	–	-35
120+00	N/A	N/A	12	-19	5	-18	-37	–	-57
125+00	N/A	N/A	19	-30	6	-6	-46	–	-57
Avg	-3.88	78	14.05	-13.95	-8.65	-24.10	-23.35	-22.44	-51.20

Notes:
*** 2013 Placement Area**
Baseline = approx. change after Hurricane Harvey
– No data available

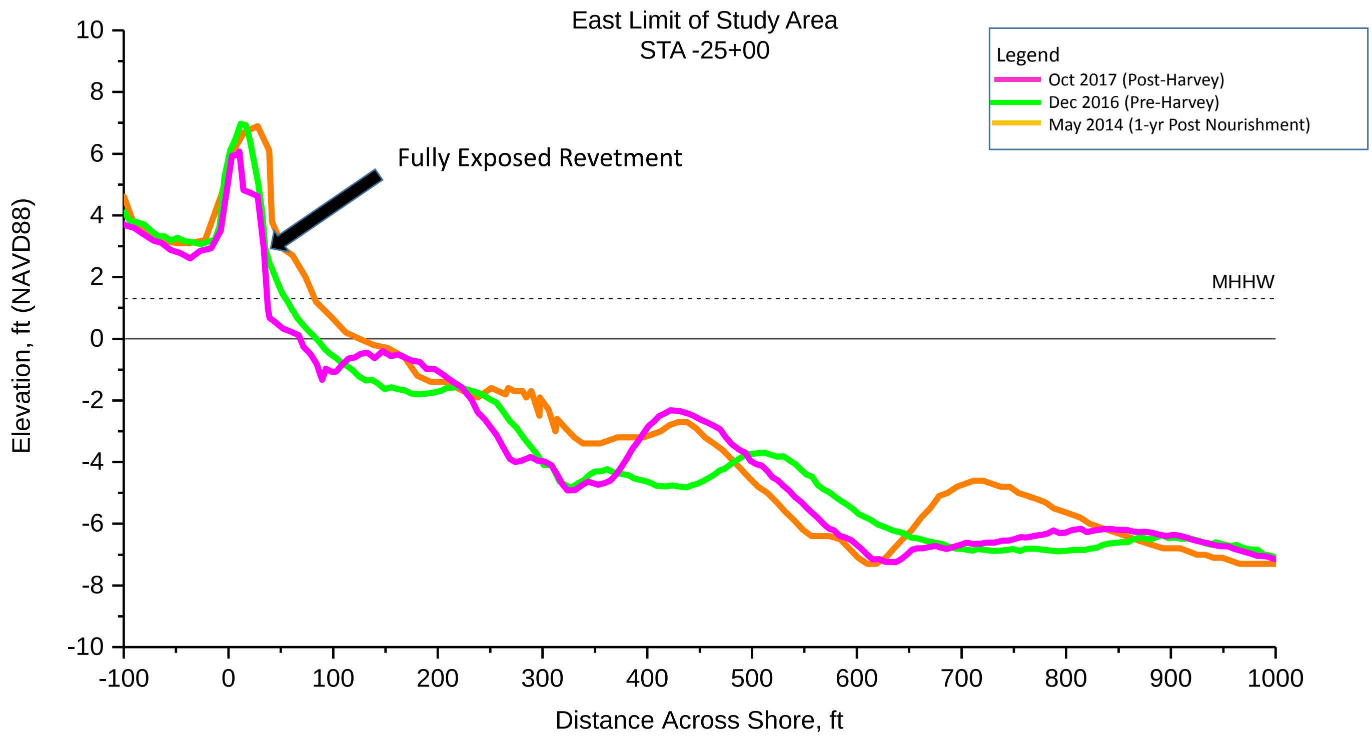


Figure 77. East End of Study Area: Erosion fully exposes revetment between Dec 2016 and Oct 2017

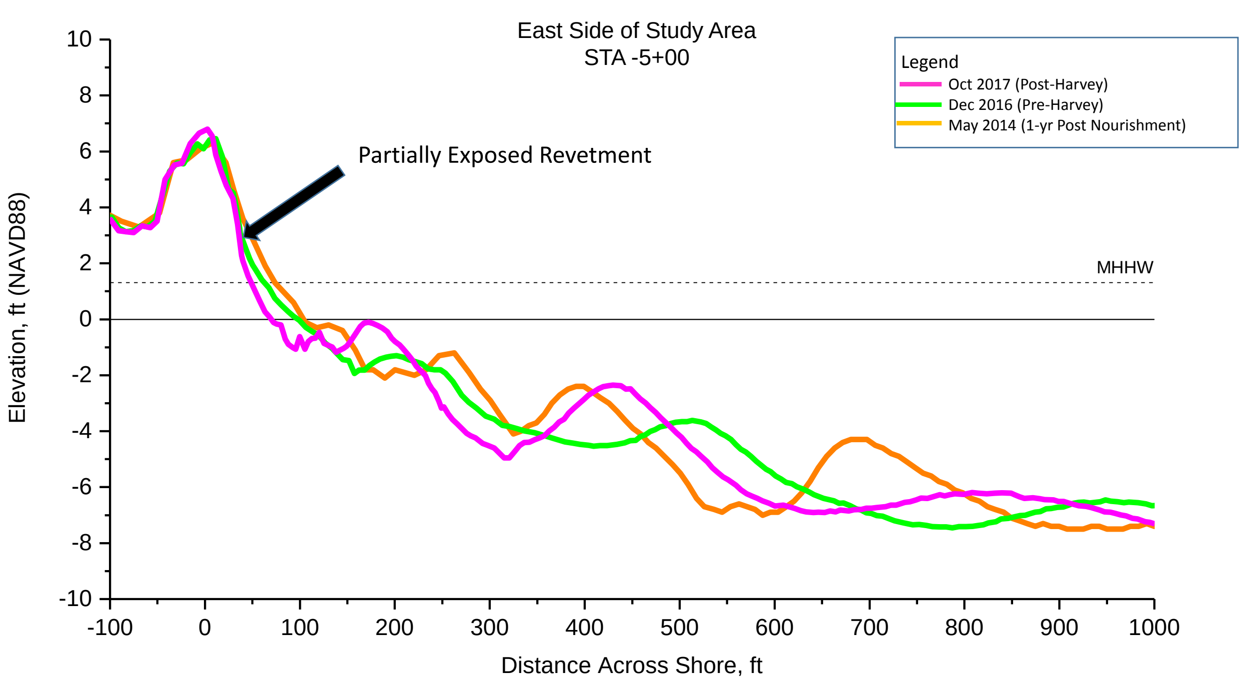


Figure 78. East Side of Study Area: Partially exposed revetment with limited seaward berm, typical of backshore from STA -5+0 to STA 10+0 (Oct 2017)

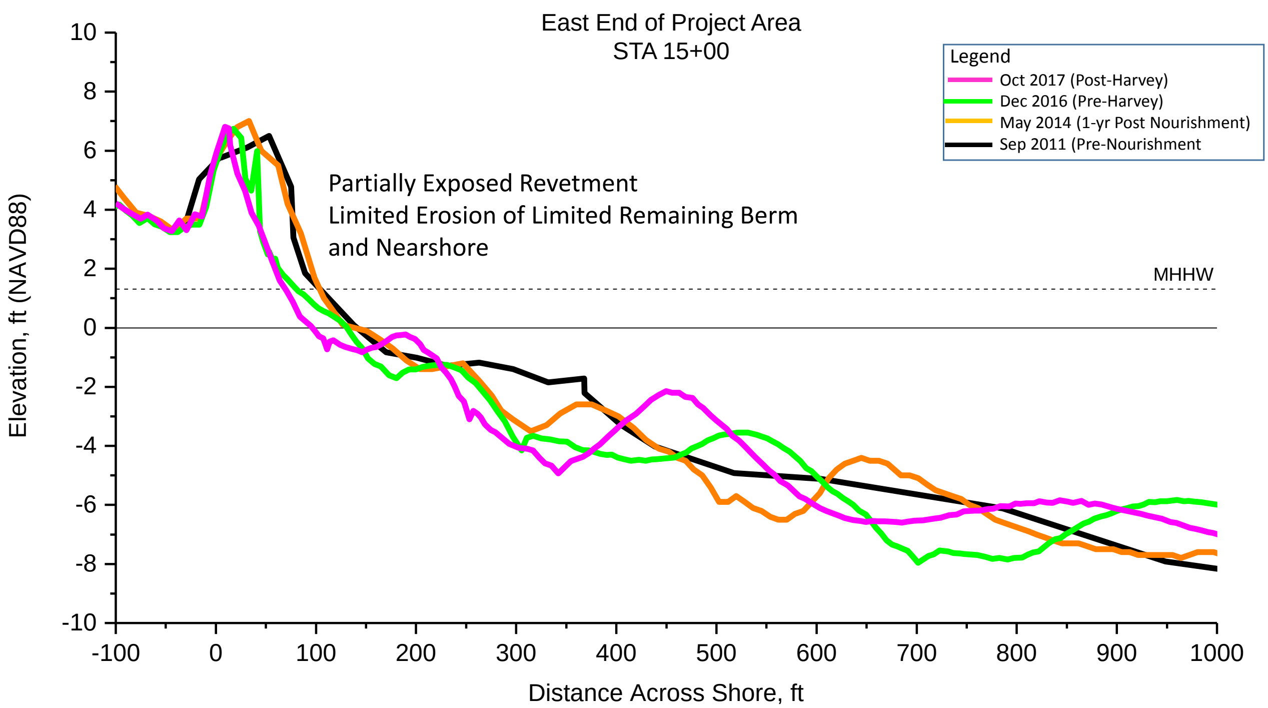


Figure 79. East of Project Area: No evidence of benefit of 2013 nourishment has been identified through survey data (2014-2017). The 2017 berm profile was landward of pre-nourishment 2011 profile. Rate of erosion was limited due to limited sand fronting the revetment

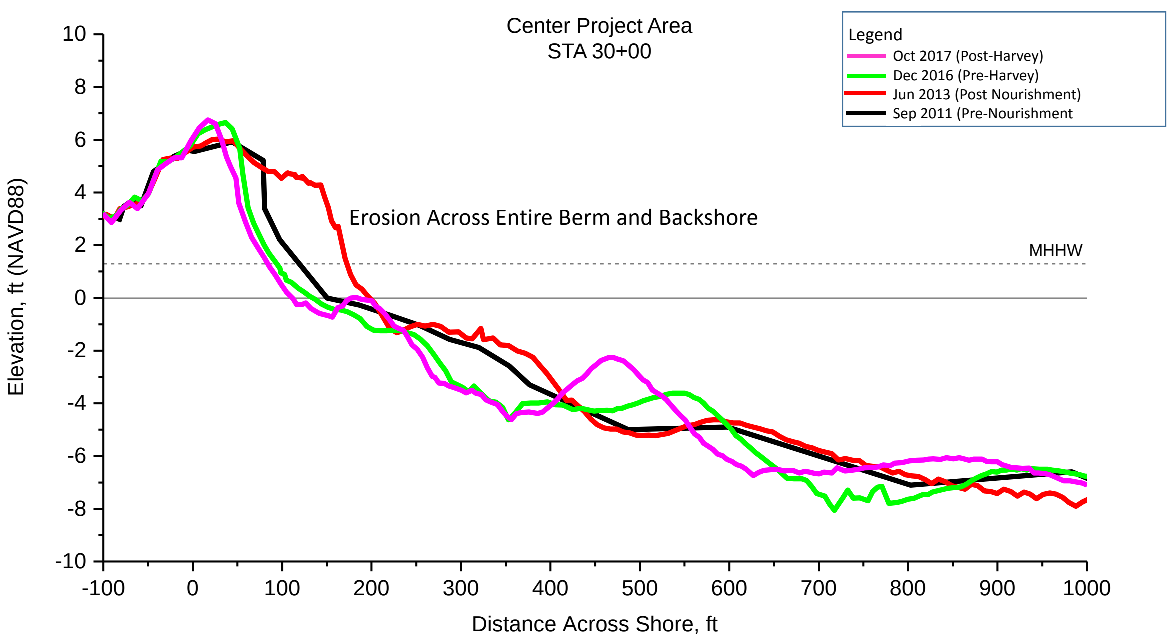


Figure 80. Center Project Area: Erosion across entire berm. Landward shift of the 2017 profile beyond the pre-nourishment profile (2011) position that began in 2016 and continued during 2017

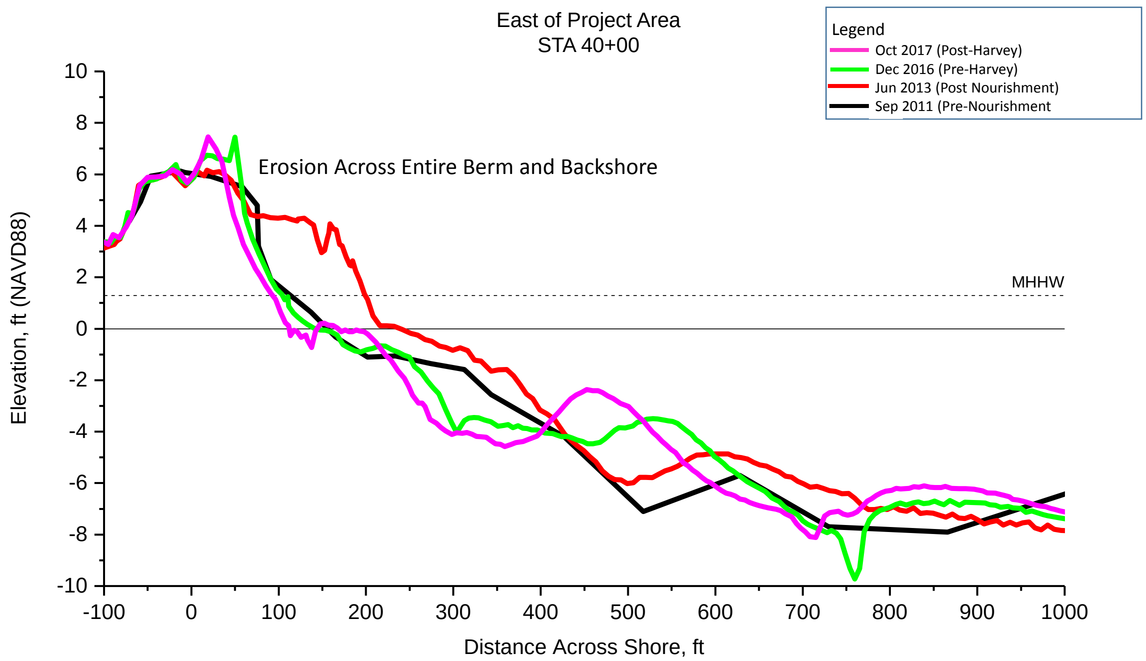


Figure 81. East-Center Project Area: Erosion of berm/backshore and nearshore with the 2017 profile landward of the pre-nourishment 2011 profile

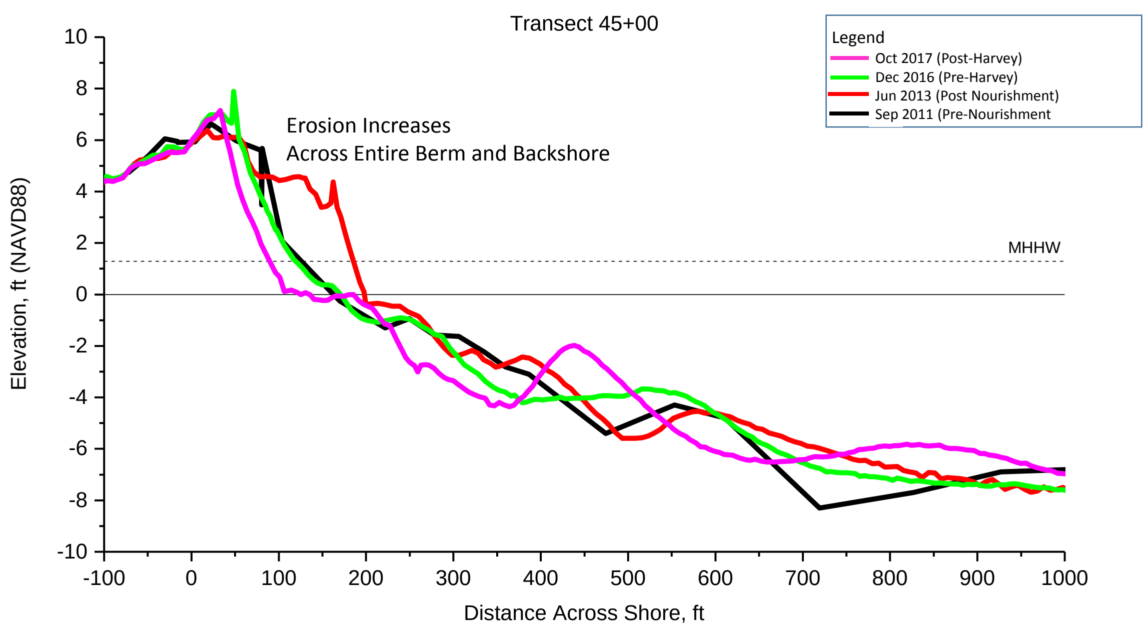


Figure 82. East of Center Project Area: Erosion increases west of STA 45+0 and focusing across the berm to backshore and into the nearshore up to the -4 contour (2017)

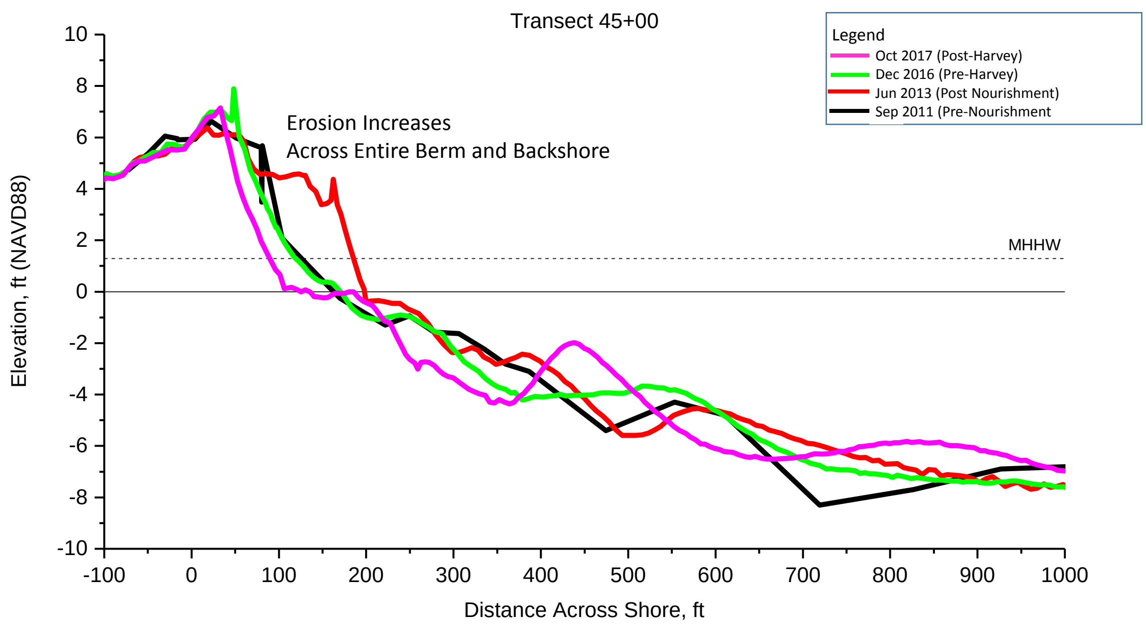


Figure 83. West End Project Area: Area of highest erosion rate in Project Area. Beach eroded landward of baseline profile with significant erosion in the immediate nearshore during 2017

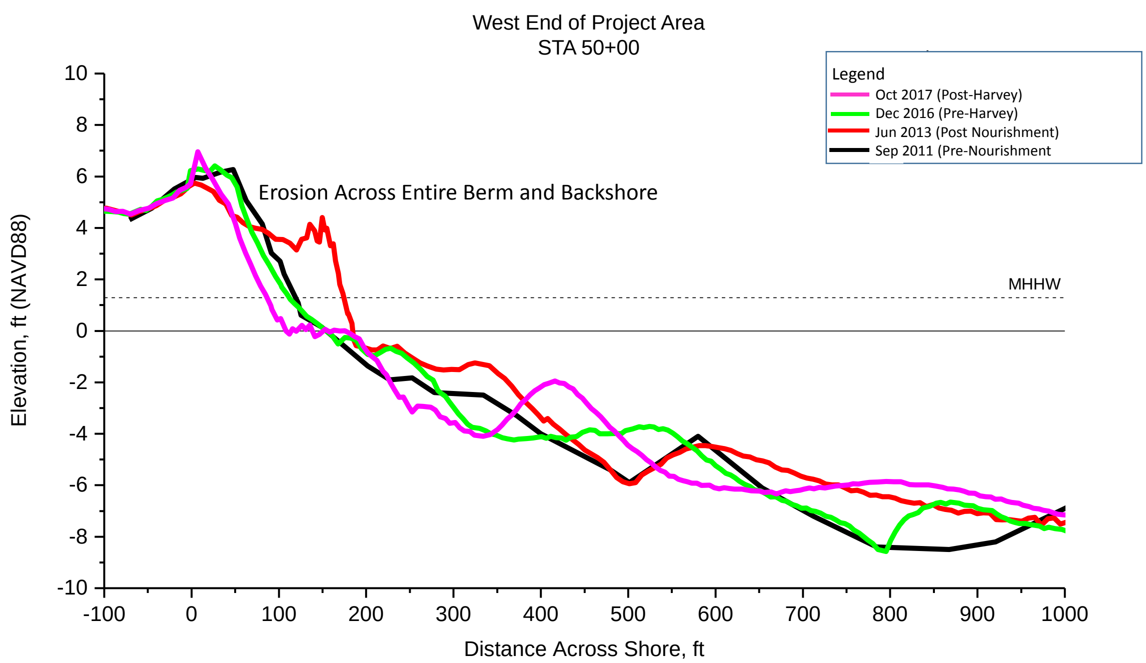


Figure 84. West Limit of Project Area: Continued westward progression of high erosion rate in Project Area. Beach eroded landward of baseline profile during 2017

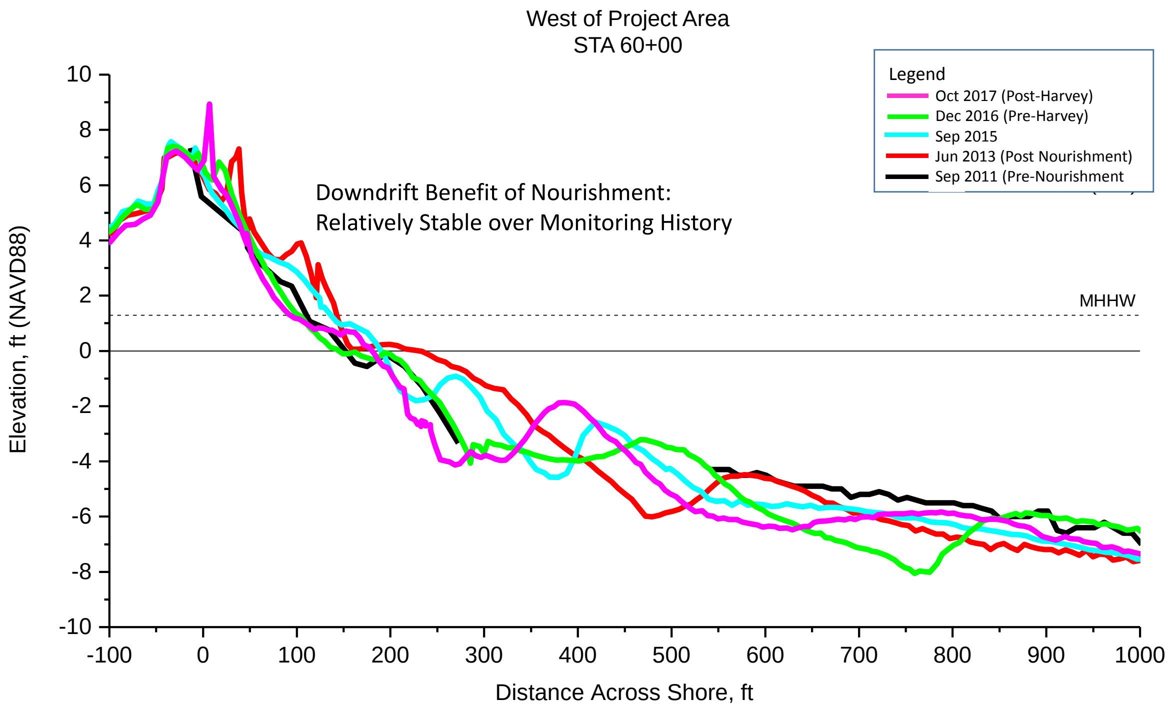


Figure 85. West of Project Area: Relatively stable segment of beach over the reporting period (2016-2017) and since 2011 pre-nourishment survey

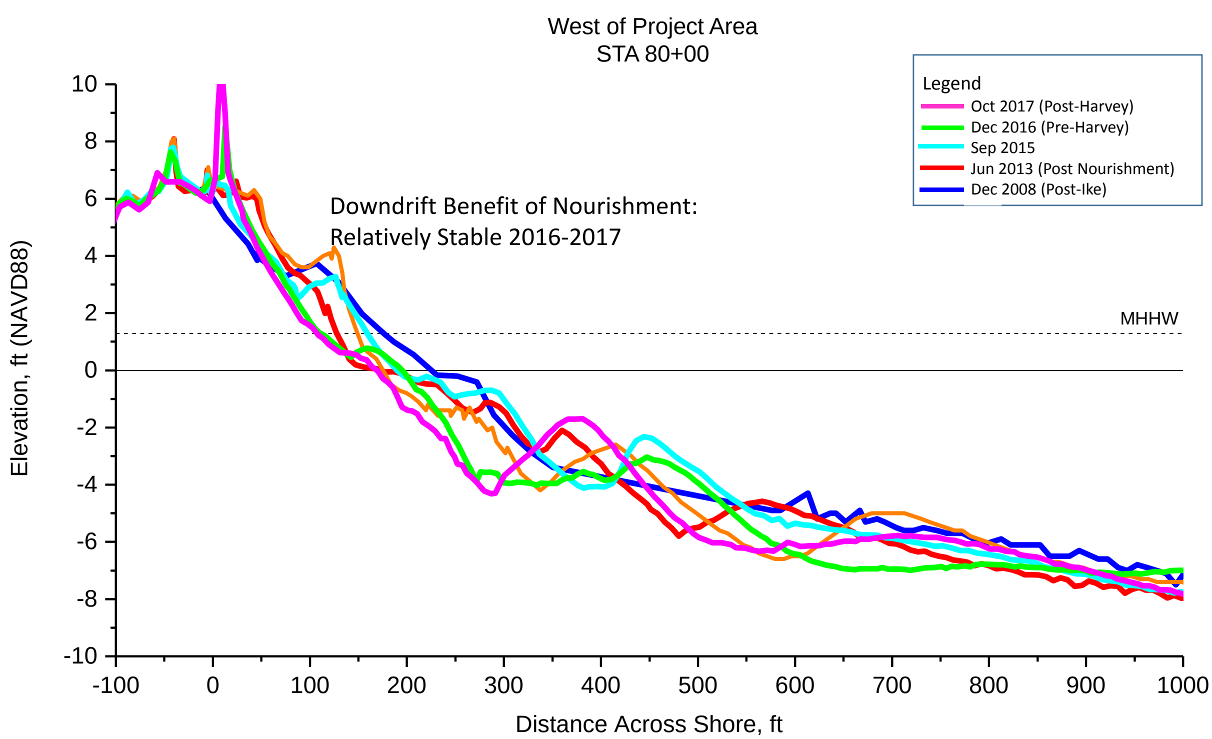


Figure 86. West of Project Area: Limited erosion along limited segment west of the Project Area during 2017 due to downdrift benefit of 2013 fill placement

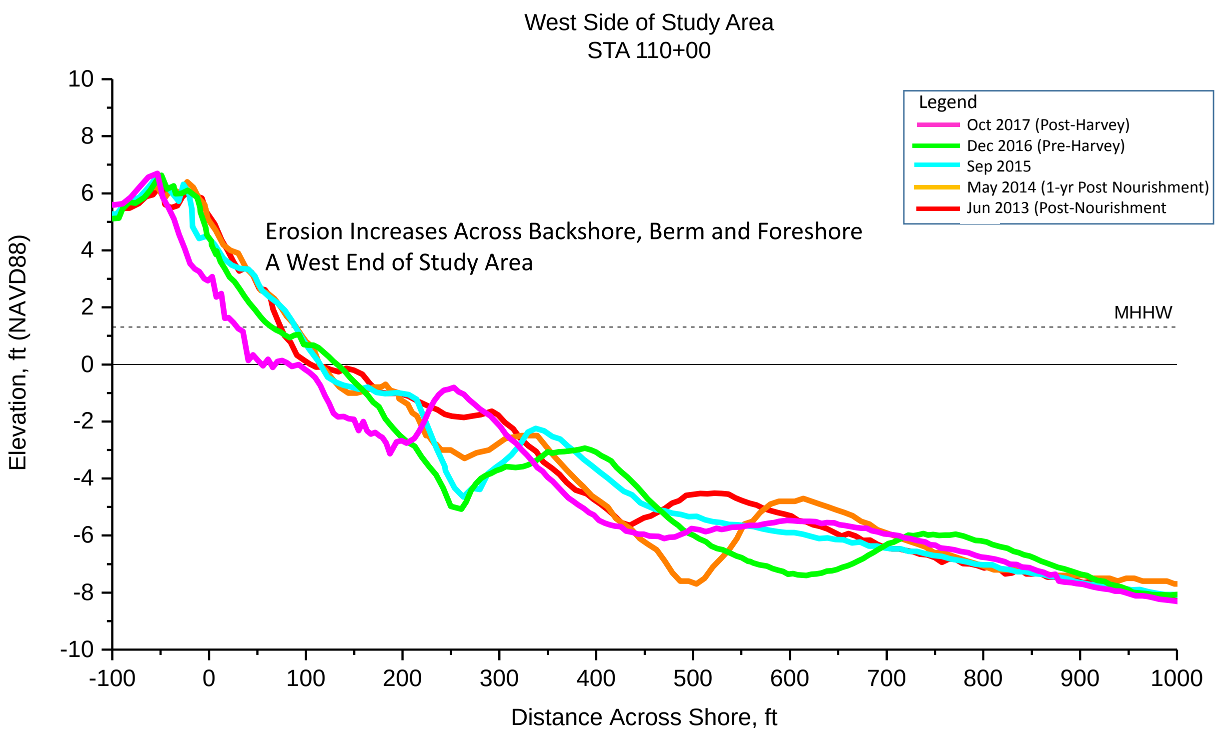


Figure 87. West end of Study Area: Erosion resumes and increases across entire profile from backshore to across berm and into the immediate nearshore (2017)

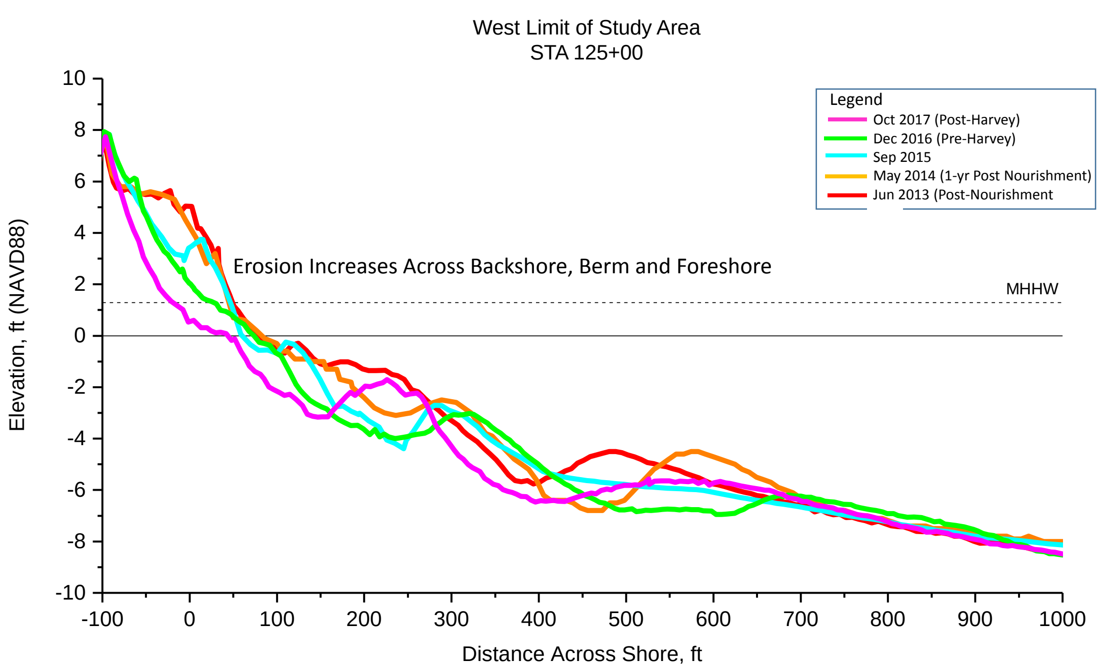


Figure 88. West Limit of Study Area: Erosion increases across backshore, berm and foreshore during 2017 resulting in the most landward beach profile since 2013 (no data prior to 2013).

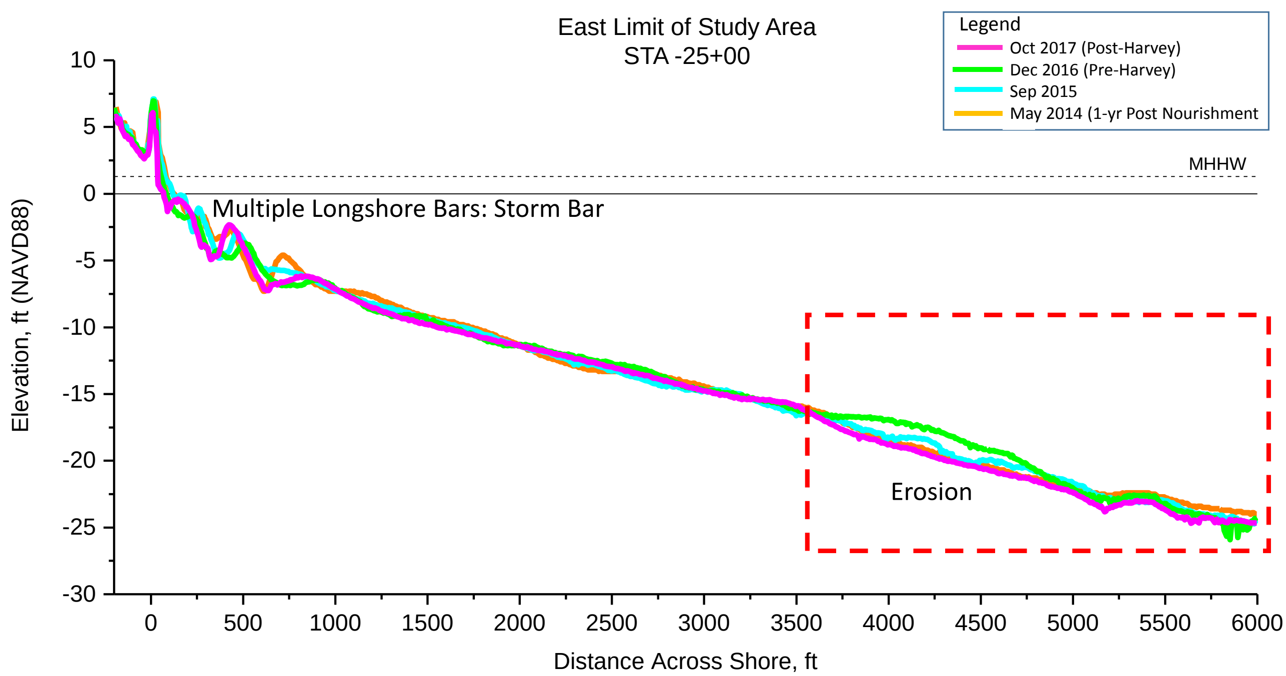


Figure 89. East Limit of Study Area: Significant erosion seaward of the -15 ft contour with no transient accretionary offshore features (2017)

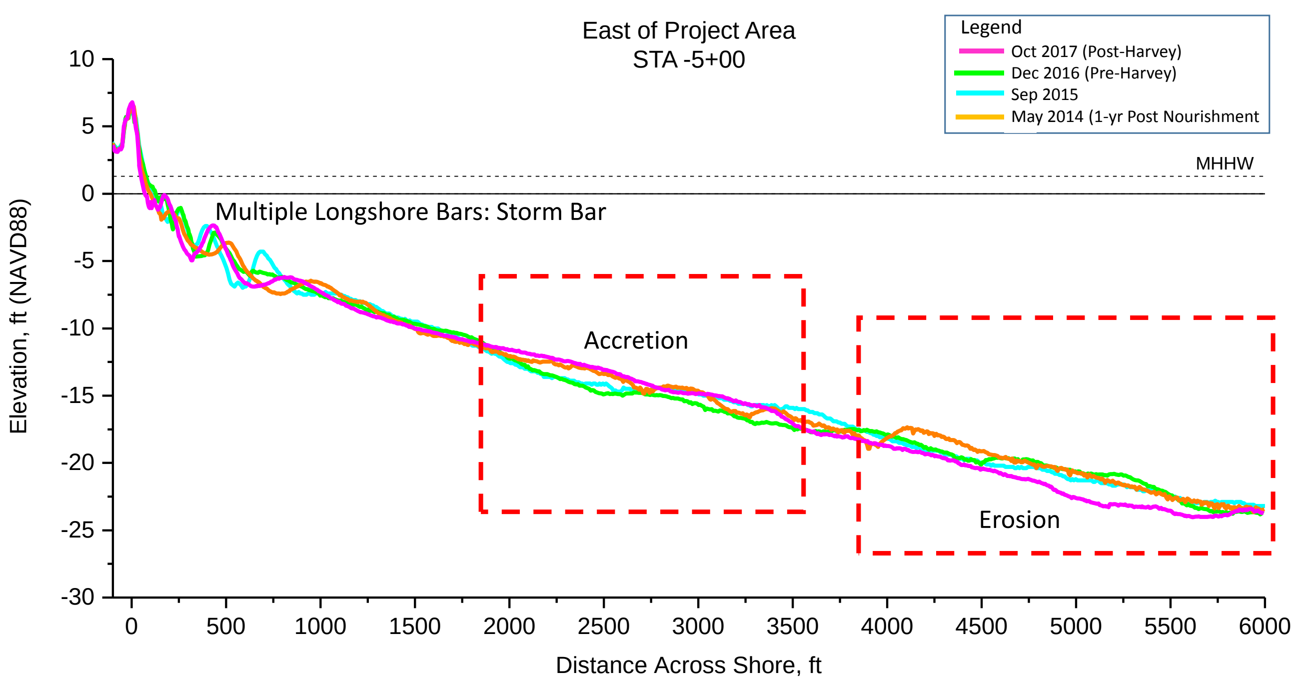


Figure 90. East of Project Area: Featureless relatively uniform accretion between the -10 ft and -18 ft contour with erosion developing seaward of the -20 ft contour (2017)

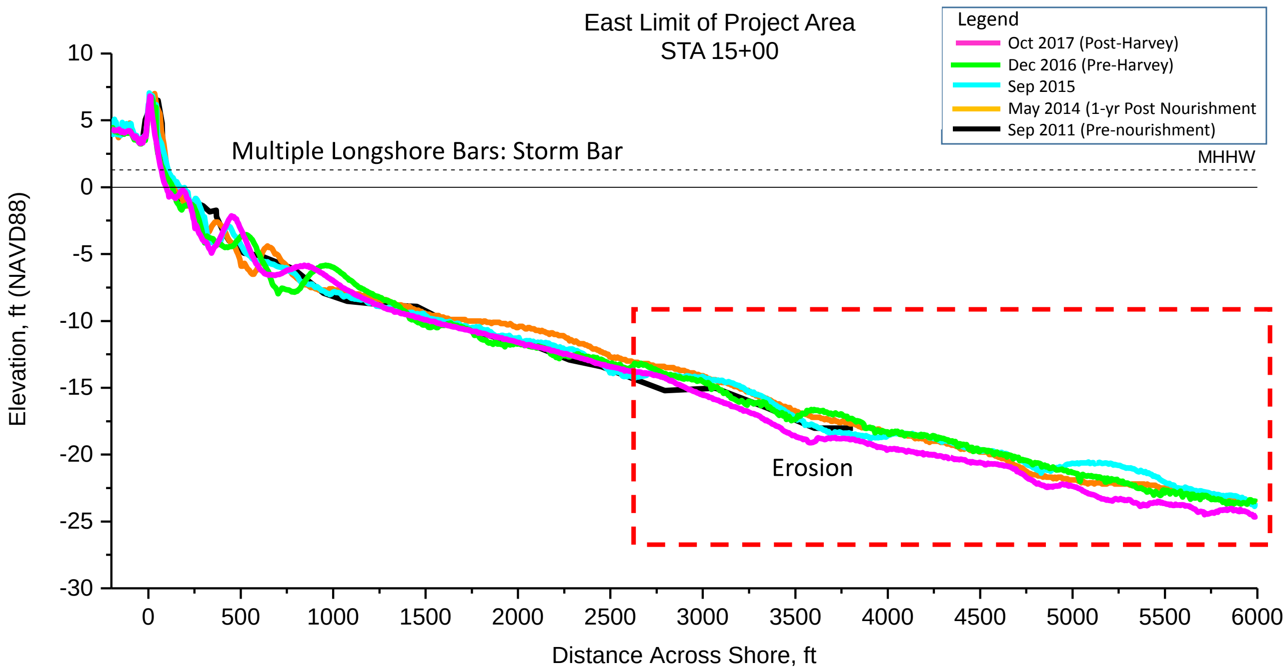


Figure 91. East Limit of Project Area: Erosion increases seaward of the -15 ft contour at the eastern limit of the Project Area (2017)

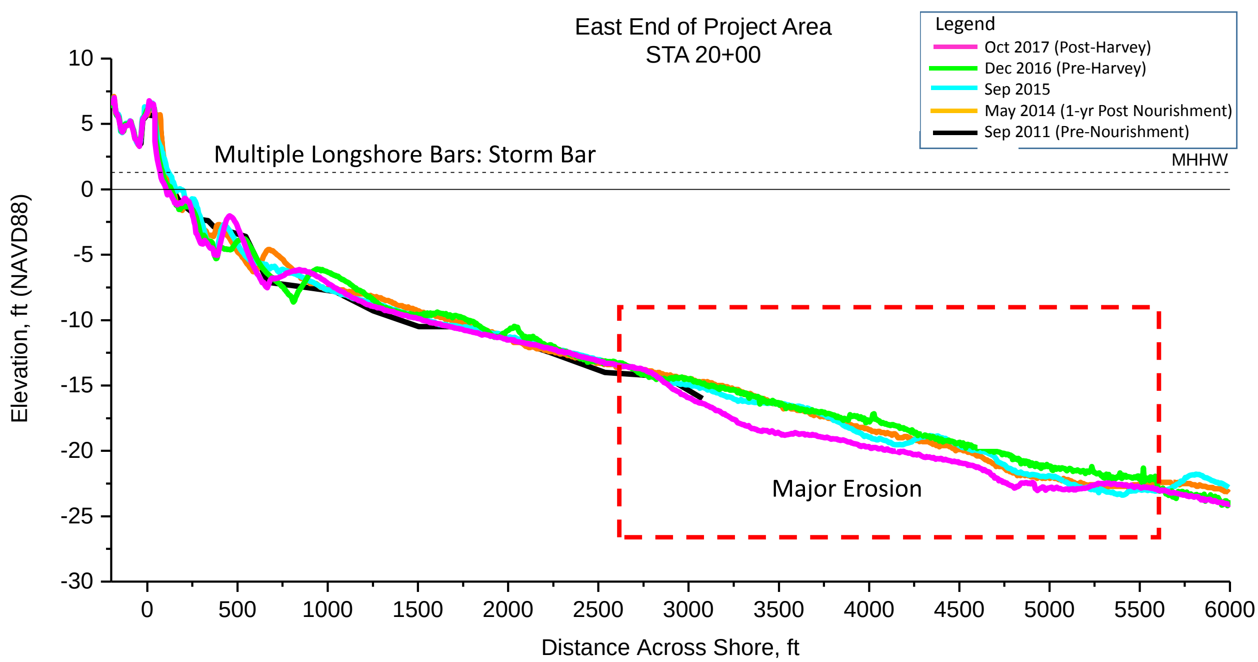


Figure 92. East End of Project Area: High rate of erosion seaward of -15 ft contour increases eastward into the Project Area (2017)

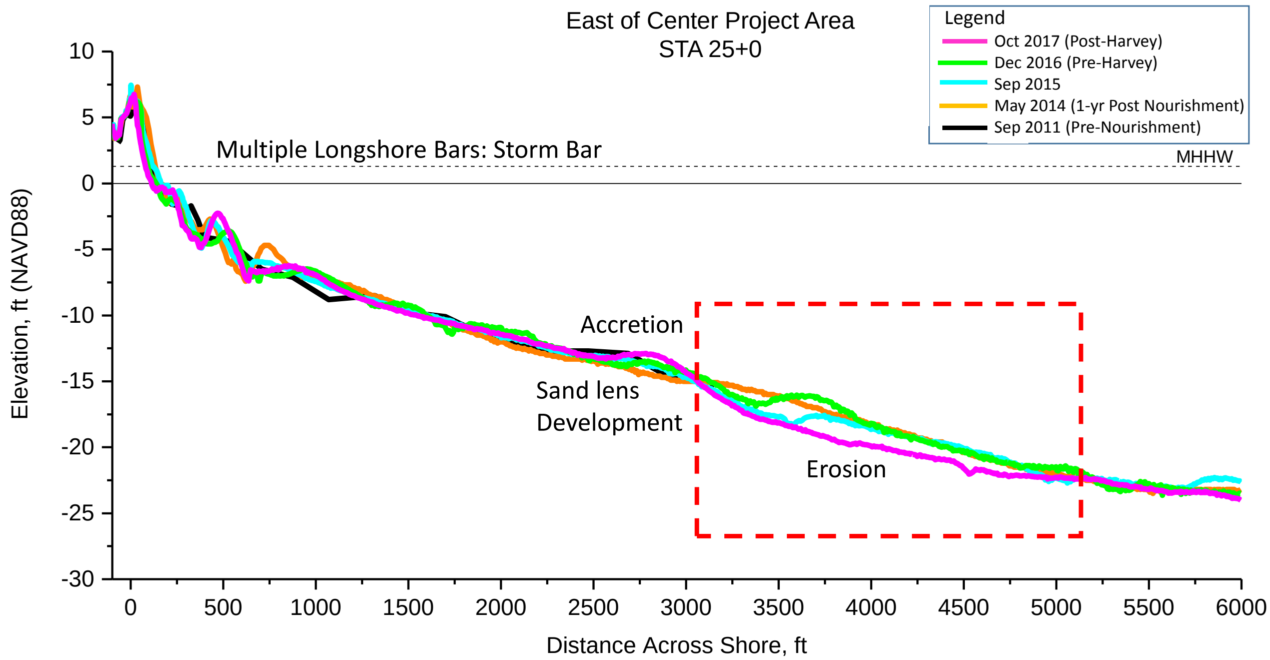


Figure 93. East of Center Beach: High rate of erosion continues eastward toward project center with lens development offshore of -15 ft and -10 ft contour, respectively (2017)

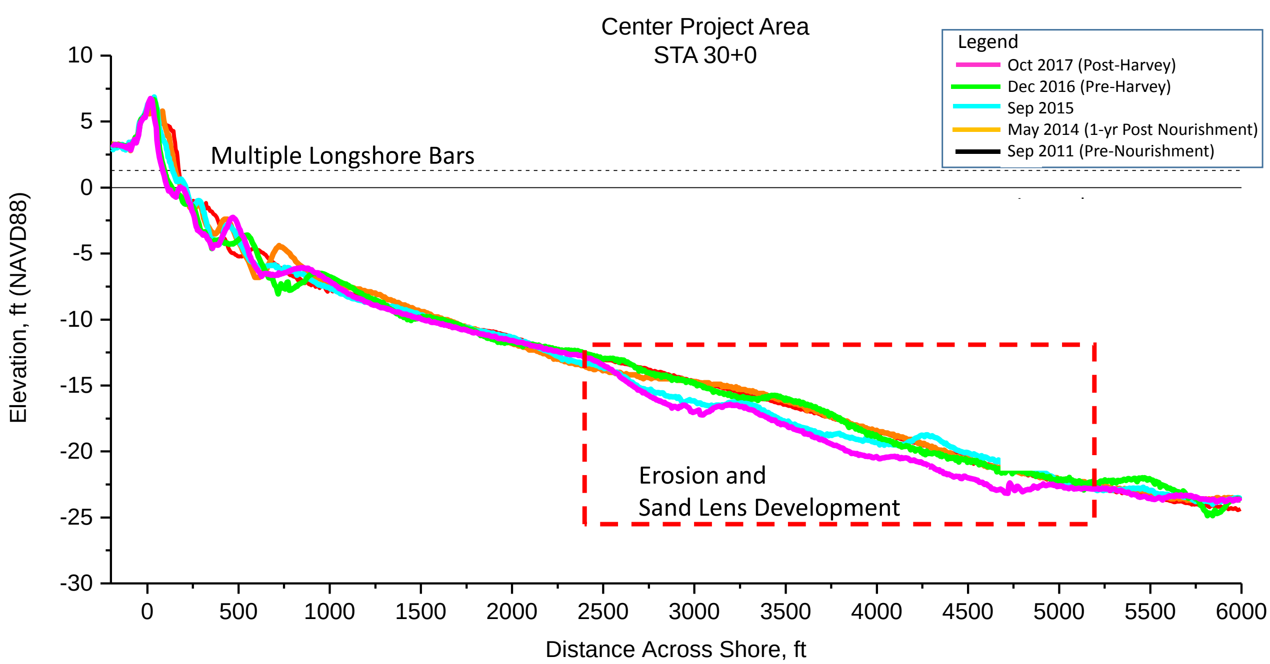


Figure 94. Center Beach: Highest rate of erosion and lens development offshore of -15 ft contour at center beach (2017)

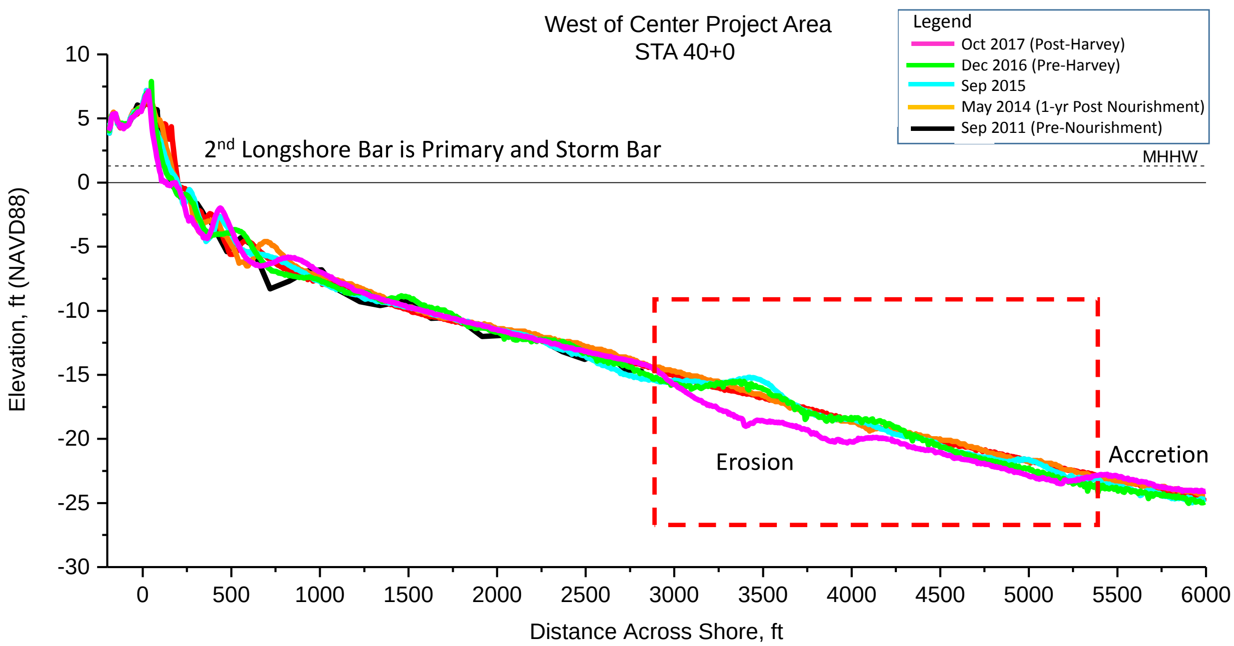


Figure 95. West of Center Beach: Focused erosion at limit of modified active region of sediment transport seaward of the -15 ft contour (2017)

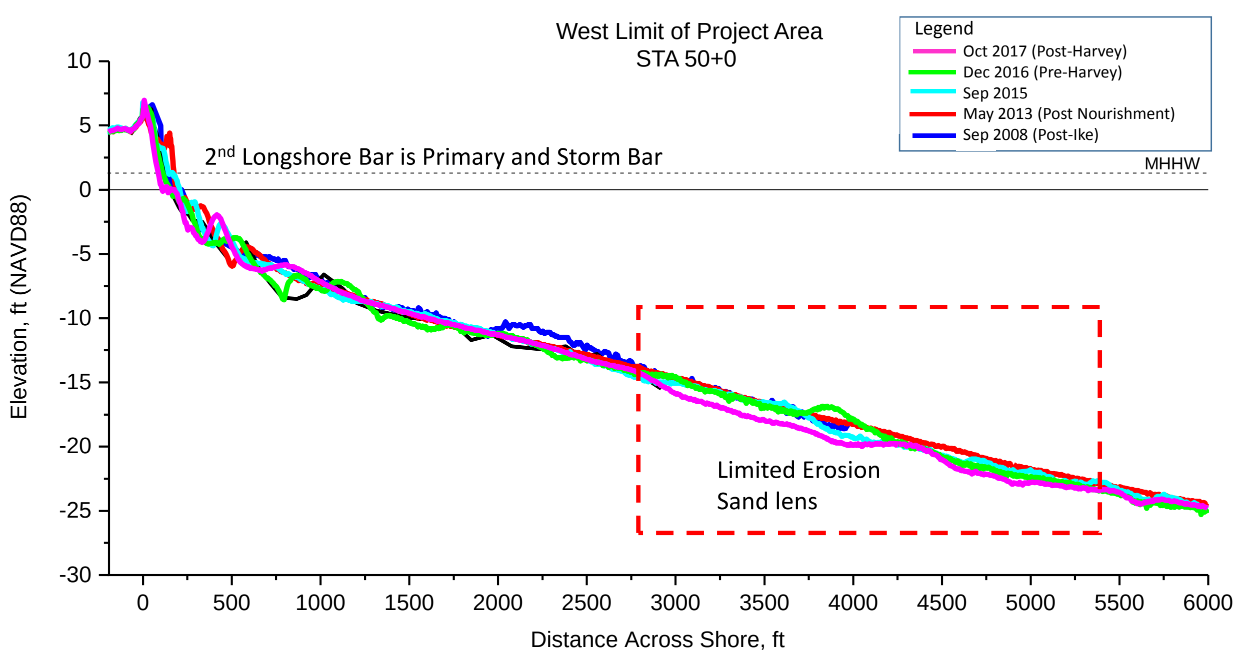


Figure 96. West Limit Project Area: Limited erosion with sand lens development along west end of Project Area (2017)

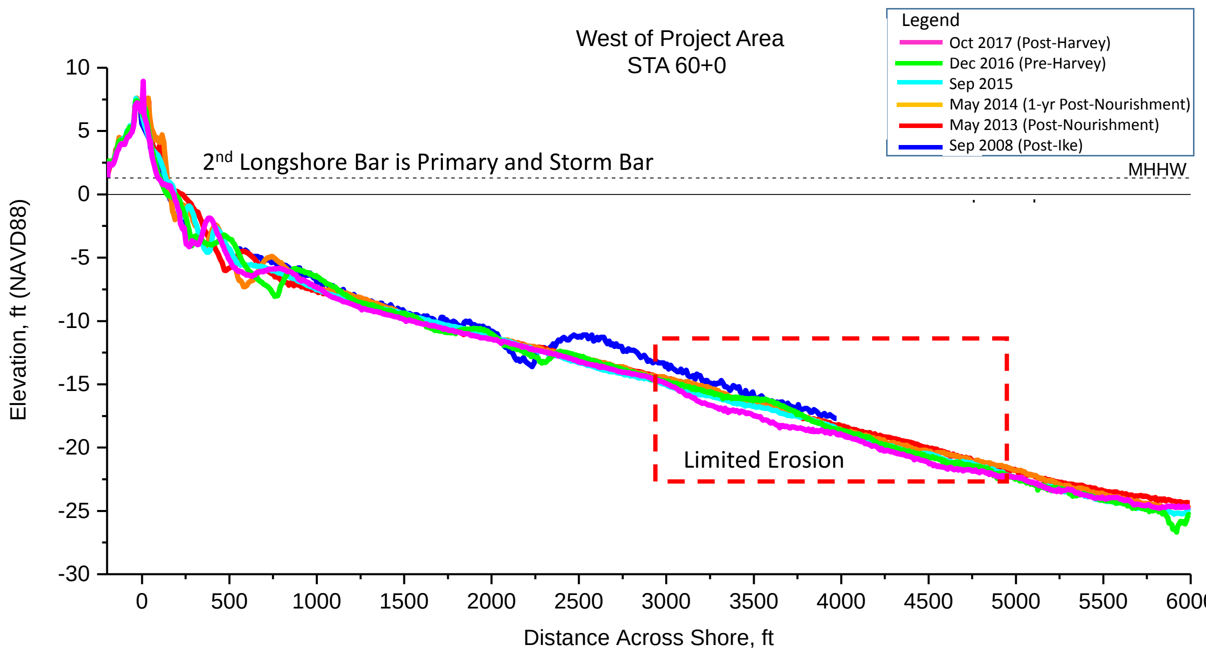


Figure 97. West of Western Limit of Project Area: Limited erosion of beach segment with greatest stability relative to adjacent beach (2017)

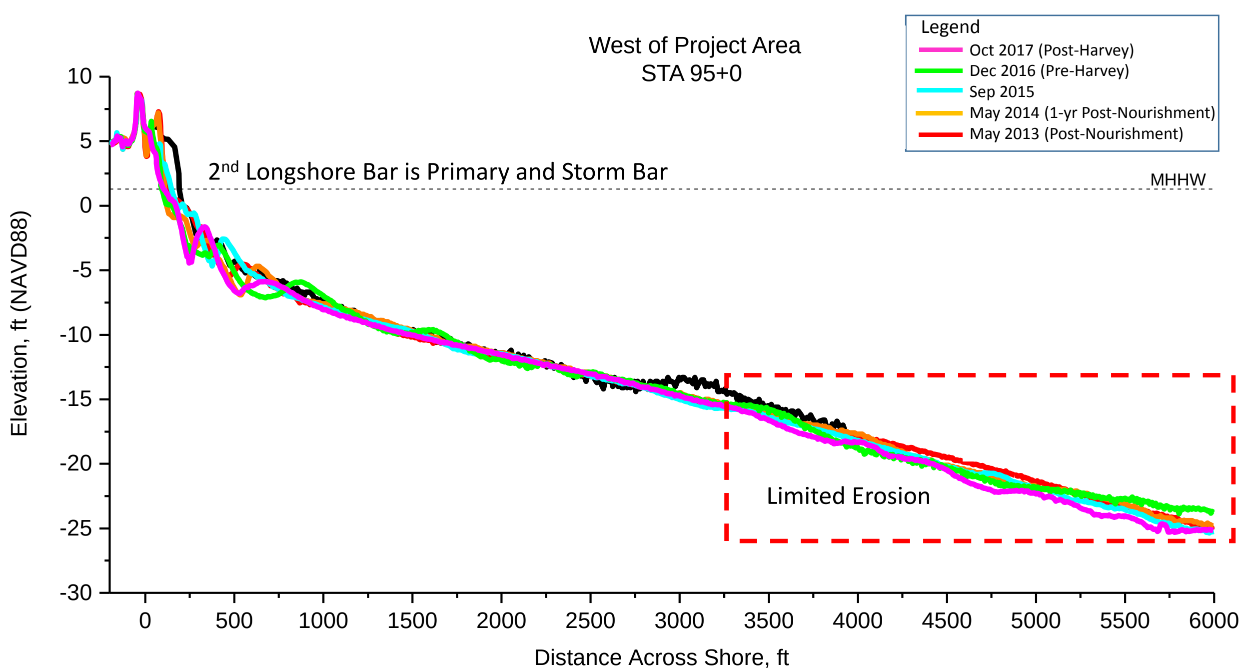


Figure 98. West of Project Area: Limited erosion and sand lens development along segment influenced by 2013 fill placement as sand continued to migrate westward (Evidence of relative stability of subaerial beach) during Oct 2017

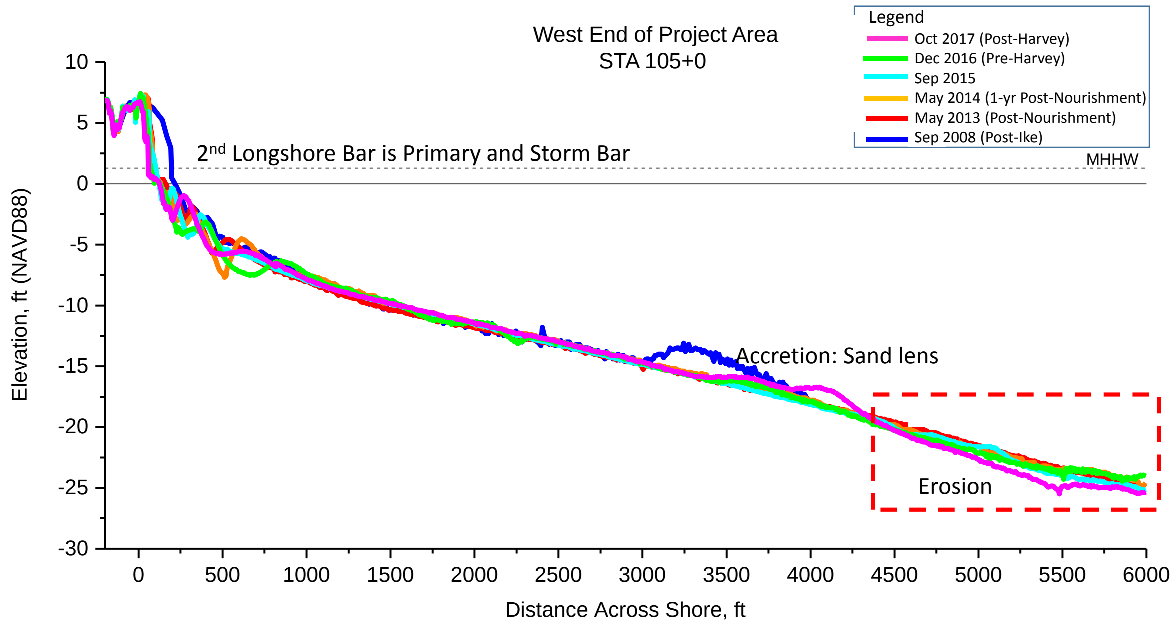


Figure 99. West End of Project Area: Development of sand lens followed by erosion seaward of the -20 ft contour, representative of the segment at STA 105+0 and to lesser degree STA 110+0 (2017)

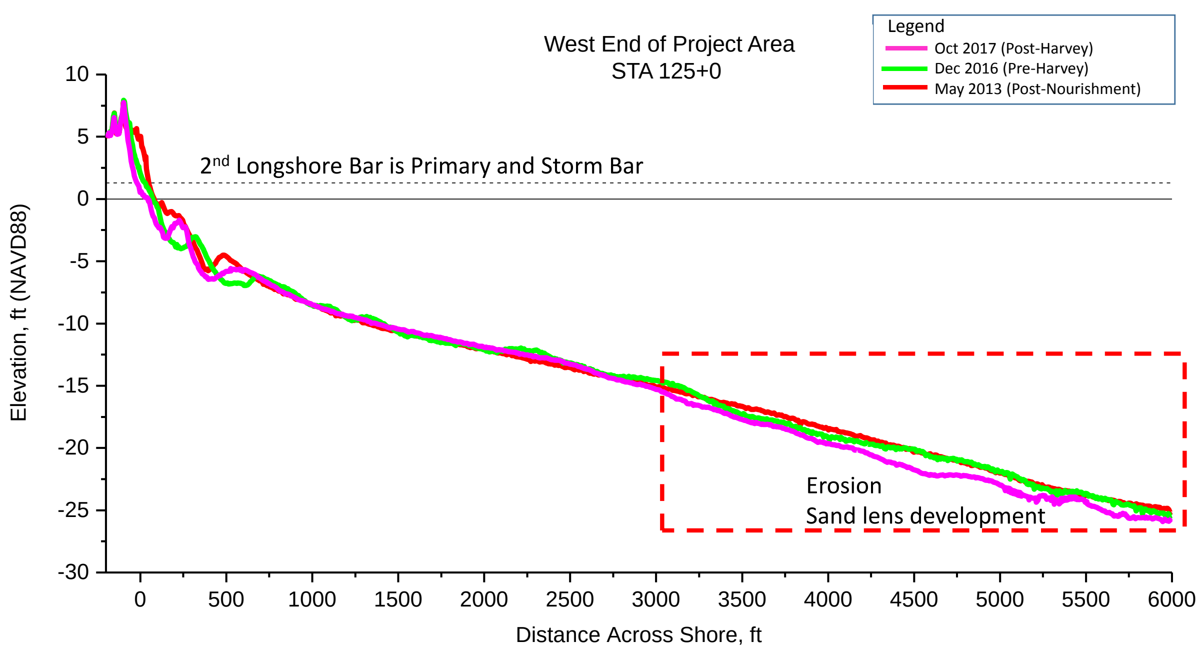


Figure 100. West Limit of Study Area: Moderate erosion seaward of the -15 ft contour and limited development of offshore accretionary features during 2017

Sargent Beach: Volumetric Analysis

Extensive erosion at Sargent Beach reflected the magnitude of forcing along this section of the Texas Coast during an extended period of high water initiated during Hurricane Harvey and reinforced due to both the influence of two subsequent hurricanes in the Gulf (Irma and Nate) and seasonal meteorological influences. During this time, water was in excess of MHHW by up to 2.5 ft for extended periods (Fig 75). Erosion along the nearshore seaward of the -10 to -15 ft contour was related to strong alongshore currents that were influenced by the change in flow dynamic during this period. Prior to 2016, erosion dominated across the subaerial beach and into the immediate nearshore but accretion dominated in the offshore reach of the nearshore beyond the -15 ft contour. After Harvey, erosion dominated across the entire beach profile along the entire Study Area with the exception of one isolated area near the west end at STA 105+0 where an offshore elevated bar-like feature was well developed contributing to net accretion in that area (Fig 99). Along the remainder of the beach, erosion dominated seaward of the -15 ft contour and was focused along the most offshore segment. Along this section of the profile, morphology was representative of contributions from scour and alongshore movement of features referred to here as large-scale sand lenses. The changes in morphology indicate that scour of the veneer of sand along this most offshore segment of the profile may have exposed the clay substrate to strong currents resulting in large scale failure of the formerly underlying material. This would account for the extreme erosion and non-typical morphology identified seaward of -15 ft contour.

Erosion dominated both along the Project Area (STA 15+0 to STA 50+0) as well as along the Study Area at Sargent Beach between 2016 and 2017. Volume change was calculated along three sections 1) Subaerial (dune crest to -2 ft), 2) Modified active region of sediment transport (Dune crest to -15 ft) and 3) Standard active region of sediment transport base on DOC (Dune crest to -23 ft). The three regions were employed to increase insight into the decoupling of sediment transport between the nearshore, defined as landward of -10 to -15 ft contour, and the offshore section located seaward of the -15 ft contour. This decoupling or independence with regard to sediment sharing between the offshore region and the berm is key to estimating the volume of sand for the purposes of estimating future nourishment volumes. Between Dec 2016 and Aug 2017, a net volume of -12,200 cu yd of sediment eroded from the *subaerial region* (-2 ft) which composes a fraction of the volume eroding from the two larger scale calculation areas. A total of -21,000 cu yd of sediment eroded from across the *modified active region of sediment transport* (-15 ft) in the Project Area and 117,000 cu yd across the Study Area. The net loss of sand across the *standard active region of sediment transport* ending at the DOC (-23 ft) was the greatest reported to date with a net volume of 387,500 cu yd of sediment eroding from the Project Area. The magnitude of the volume of sediment eroding along the entire Study Area offshore to the DOC (-23ft) was daunting at -1,230,750 cu yd.

The erosion rate along both the Project Area and entire Study Area were at the highest rates measured since monitoring began in 2012. The rate of erosion along *standard active region of sediment transport* over the entire Study Area and Project Area, -87 cy/ft and -108 cy/ft, respectively, reflected the influence of the extreme offshore erosion seaward of the -15 ft contour. More applicable to nourishment planning is the rate of erosion calculated for the *modified active region of active sediment transport* ending at the -15 ft contour where the net rate of erosion along the Project Area and Study Area was -5.6 cy/ft and -7.8 cy/ft, respectively.

Discussion and Recommendations: Sargent Beach

Sargent Beach experienced severe erosion during Harvey that exacerbated the background erosion ongoing along this eroding segment of coastline. Sargent Beach is recommended for nourishment as soon as feasible but within 1-2 years to get ahead of anticipated continued erosion now that there is no longer a measureable benefit of the 2013 nourishment. It is anticipated that additional measures will be required to provide for greater stability of future nourishment that may include additional structures, the study of which is underway. Planning toward the application of coastal structures will require intensive analysis to determine the potential impact on an already compromised segment of the Texas Coast in order to avoid exacerbating erosion relative to the interaction of waves, surge and currents with proposed and existing structures. Sargent Beach is recommended for nourishment due to the following contributing factors; 1) persistent high rate of shoreline recession and erosion, 2) 100% of the beach at or under the Action Width, and 3) complete exhaustion of the benefit of the beach fill placed in the Project Area during 2013.

Nourishment Planning

The Post-Harvey Oct 2017 beach profile survey was applied as the base template to estimate the volume required to increase the width of the beach to 200 ft in the Project Area (STA 15+0 to STA 50+0). Alternative #1 requires an estimated volume of 437,500 cu yd is the minimum recommended to increase the beach to the Target Width along the original 3,600 ft alongshore project extent. The nourishment footprint of the full nourishment initiates at the 2013 LOV with a maximum tie in elevation of 5 ft (NAVD88), located at or within 10 ft landward of the LOV. Increasing the beach fill tie in elevation, particularly east of HWY 457 (STA 50+0) may increase stability and limit exposure of revetment along this reach as well as increase the potential for downdrift benefits post- nourishment. The offshore limit of the total fill was designated at the modified active region of sediment transport at -15 ft NAVD to allow for intersection of the fill with the existing profile. The standard DOC was not applied as the offshore limit for calculation of fill volume for two reasons 1) evidence of an apparent decoupling in sediment transport between the beach/immediate nearshore and offshore region beyond the 10 to -15 ft contour and 2) prohibitive cost of implementation of Alternative #1. For context, of the total nourishment volume, 250,000 cu yd was associated with the subaerial berm and foreshore with an offshore limit defined at -2 ft (NAVD88). An alternative approach (Alternative #2) is to restore the beach to the 2013 as-built width of 120 ft, with an elevation of 5 ft. Alternative #2 would reduce the sand volume by nearly 50% at 201,500 cu yd with 100,000 cu yd allocated to the subaerial region.

Extending the nourishment east of STA 15+0 would support long-term management of the high rate of recession and erosion in the Project Area by; 1) providing for tapering of the fill to better integrate with the the existing narrow beach further to the east up to STA 5+0 and 2) increasing potential for downdrift benefit over an extended timeframe. Extending the nourishment 1,000 ft further east along the area of most exacerbated erosion and where the revetment is persistently exposed would require a a minimum the addition of ; 1) 133,000 cu yd of sand to restore a 200 ft wide beach or 2) 99,000 cu yd to restore a 120 ft wide beach. The high volume of fill required for this additional section is due to the exacerbated erosion that has occurred east of the Project Area.

The expansion toward the east is recommended due to the increasingly narrow beach and exposure of the revetment along this reach. In addition, the eastward expansion would provide for incremental stabilization in the original project area as sand migrates westward after placement. To extend the project an additional 1,500 ft alongshore would increase the estimated fill volume to a total of 373,000 cu yd. Due to the continued rapid rate of erosion and shoreline recession, not only along Project Area but also along the adjacent beach toward the east, biannual (2-year) cyclic nourishment is recommended for a placement of the original volume and extent. Implementation of the larger scale alternative increase the potential to extend the nourishment cycle an additional 1 to 3 years although annual review is recommended. As previously reporting, the investigation of alternatives that include coastal structures such as groins, detached breakwaters and alternate placement strategies is warranted at this location unless a nearby sustainable and dedicated sand source is identified for at a minimum of biannual nourishment.

Surfside Beach

Surfside Beach is located in the Village of Surfside Beach, Brazoria County. The beach is located on Follett's Island north of the Freeport Ship Channel between the Freeport Jetty and HWY 332 but the study area extends an additional mile toward the east (Fig 101). The beach has historically experienced accelerated erosion and shoreline recession to the point that substantial public and private infrastructure has been destroyed. Surveys in the area have been conducted at varying alongshore extents related to nourishment projects and construction/repair of the revetment. Therefore, the definition of the project area in the past has varied in alongshore extent based on data availability. The 2017 revised Project Area is defined as STA -5+0 to STA 35+70 which encompasses the footprint of all former projects as well as the entire area that has experienced exacerbated erosion since monitoring began in 2012. The former project area was defined for the purposes of this reporting as the beach from STA 15+0 to STA 35+0, which encompassed the greatest region of data overlap related to previous restoration projects. In addition, analysis was conducted along the entire revetment (STA 0+50 to STA 35+40) in order to provide greater insight into the influence of the placement of fill on beach stability fronting the structure. In addition, the full study area includes the small section of beach extending from the end of the revetment westward to the Freeport Ship Channel (STA -10+0 to STA 100+0).

The 2017 assessment documents change between 2016 and the post-Harvey survey conducted during 2017. The focus of this reporting is to describe the post-storm condition of the beach. An extended period of persistent high water levels that was initiate by Hurricane Harvey was experienced prior to the Oct 2017 survey. Persistent elevated water levels sustained at 1 to 3 ft above MHHW, measured at Freeport Ship Channel, and onshore forcing resulted in prolonged periods of inundated of Gulf beaches (Fig 102). The narrow beach with limited natural backshore and no duneline made Surfside Beach particularly susceptible to significant erosion that exacerbated existing challenges in maintenance.

Nourishment History

Three beach nourishment projects have been completed since 2011 along with placement of armor stone and revetment repair. The first two restoration projects were completed during March 2011 and March 2012 (just three months prior to the 2012 survey). These projects were conducted under CEPRA 1015, 1109, 1471 and emergency project CEPRA 1511. The most recent restoration effort at Surfside included nourishment, revetment repair and armor placement. This limited, small-scale nourishment project (CEPRA 1570) was completed seaward and adjacent to the westernmost section of the revetment during March 2015. The 2015 nourishment included the placement of a reported 20,603 cu yd, reported as 26,533 tons of sand seaward of the revetment along approximately 1,300 ft of shoreline between STA 0+0 and STA 12+0 as reported by Coast and Harbor (2015). Evidence of the influence of the 2015 nourishment was clearly indicated in beach profiles from STA 10+0 to STA 20+0 and to a lesser degree in the shoreline position data from STA 5+50 eastward to STA 40+0 during the Sep 2015 survey. Any residual benefit of the 2015 nourishment was limited to likely transitory impoundment in the nearshore during Dec 2016.

Due to development along this segment of Follet's Island, the backshore along the project area is devoid of a dune system along a continuous 3,400-ft stretch of beach backed by a revetment that extends the entire length of Beach Dr. Dunes are present to the east of the project area and intermittent isolated dunes are located west of the project area. The isolated dunes are located along the west end of the beach between the parking lot at the Freeport jetty and STA -5+0 and east of the revetment between STA 40+0 and 45+0 and along the beach further east of HWY 342 (STA 45+0 to STA 100+0). Due to the lack of dunes in the project area, backshore infrastructure, such as Beach Dr. and the revetment, function as the landward limit of the beach in the project area.

The 2012 survey was focused on the project area but more recent surveys expanded the assessment area to the east and west. The 2014-2016 CBI data not only agrees with the extent of the 2012 survey data (STA -10+0 to STA 45+0) but also extends an additional mile toward the east and up to the jetty to the west in order to increase understanding of sediment transport along this region of persistent erosion.

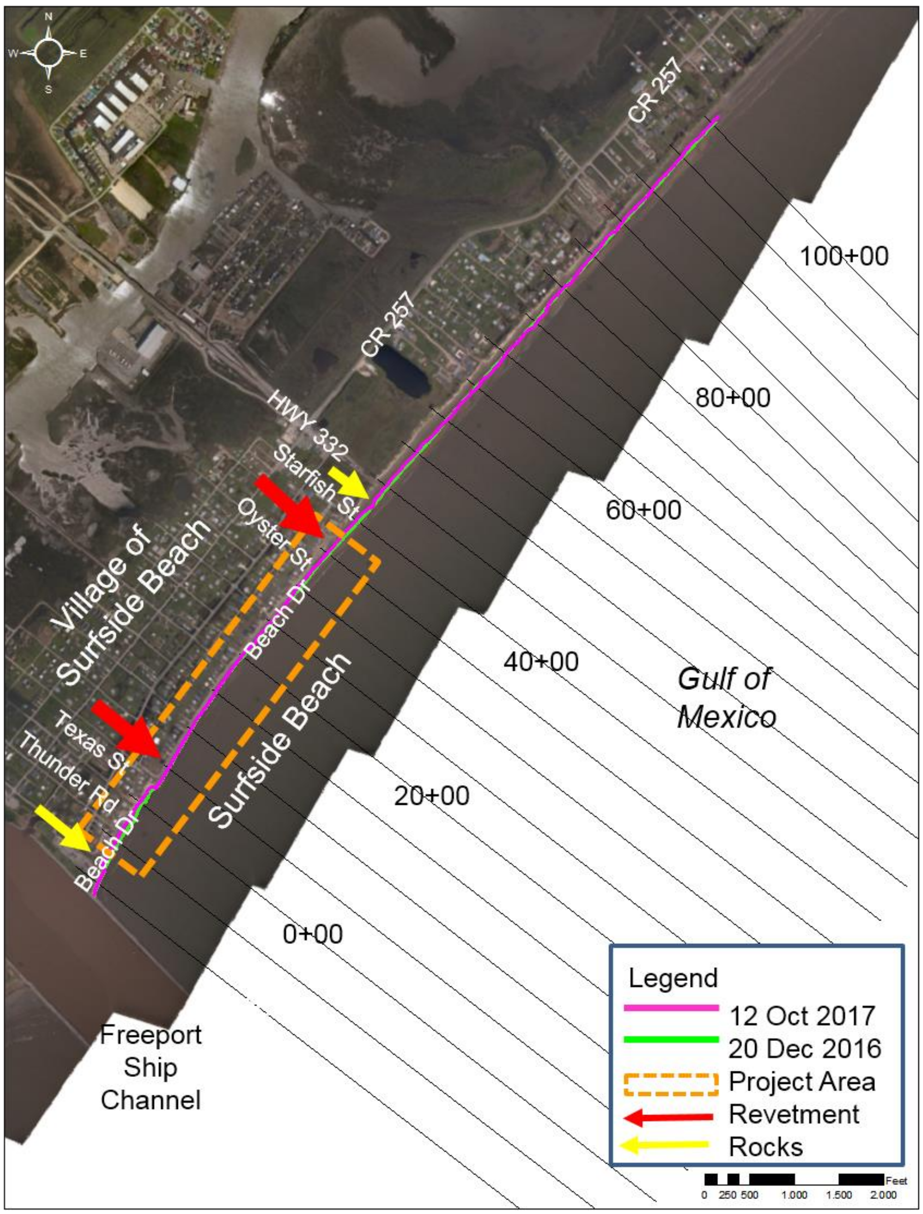


Figure 101. Variability in shoreline position between 2016 and 2017 along the full Study Area with the revised Project Area indicated

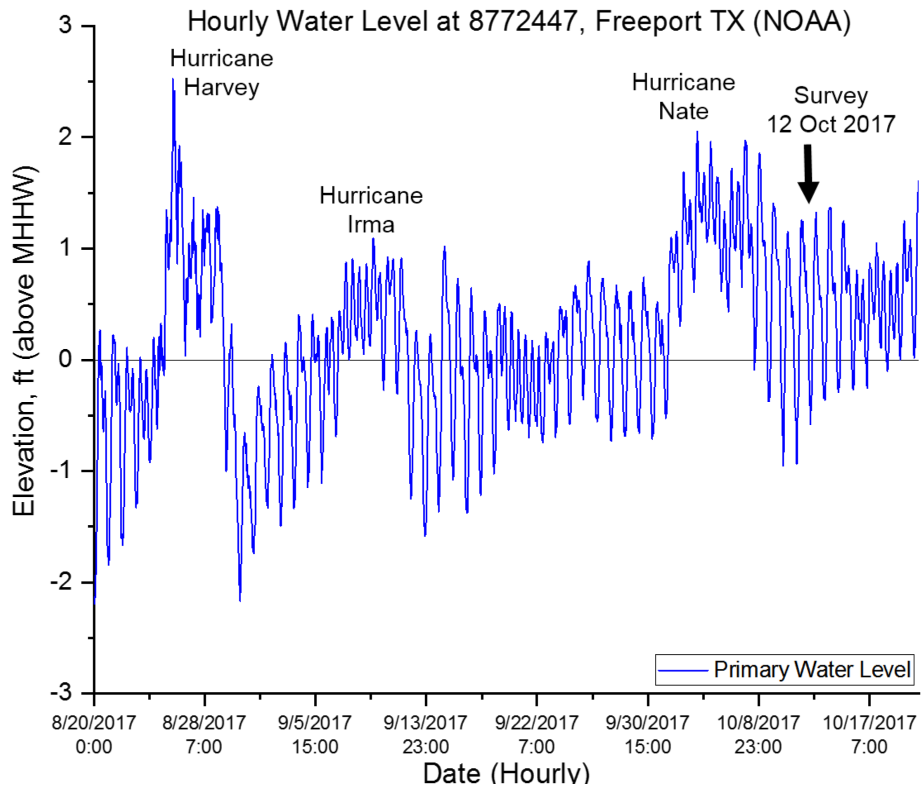


Figure 102. Frequency and persistence of water levels in excess of MHHW at Freeport prior to the Oct 2017 survey

Previous reporting (Williams 2013, 2015 and 2016) has described the influence of the highly variable extent of the available data sets on historic project assessment. The analysis conducted during the 2016 reporting period focused on changes occurring between the 2015 and 2016 CBI surveys as well as the assessment of the performance of the 2015 nourishment. Historic change in the rate of shoreline change and beach width at key temporal intervals are provided for continuity. Abbreviated data sets obtained from previous construction/nourishment projects were applied were possible (2007, 2010, and 2011). The BEG 2003 shoreline was applied for investigation of change in excess of a decade.

Beach Width: Surfside Beach

Erosion dominated along the entire beach both in the Project Area along the revetment and adjacent beach to the west, as well as along the broader study area to the east. Erosion was most severe along the west section of the revetment extending up to jetty at the Freeport Ship Channel. The beach width was less than Action Width along 90% of the beach fronting the revetment and 100% of the beach from STA 30+0 to the Freeport Ship Channel (Table 2). The average beach width along the revetment was 22 ft during Oct 2017 as opposed to 39 ft during 2016, keeping in mind that an approximately 1,700-ft long segment was devoid of subaerial beach. The average beach width after Harvey was in close agreement with the average width documented after Hurricane Ike (18 ft). To the west of the revetment, the beach remained landward of the adjacent structure. The extension of beach nourishment further to the west along the revetment and to the west of the revetment would support overall longevity of Surfside Beach by reinforcing the benefit of the placement directly along the revetment. Extended nourishment westward would reduce challenges associated with the beach that lies effectively in a gap between two segments of revetment.

Table 1. Beach Width: Surfside Beach (2007-2017)

Design Width = 125 ft Action Width = 63 ft
≤ Action Width (+5 ft) (shaded)
***Historic Project Area**
Note: N/A indicates no survey data for transect location

		Original Study Area: Beach Width, ft							
Station	**2007**	**2009**	**2011**	**2012**	**2014**	**2015**	**2016**	**2017** Post Harvey	**Location**
-10+00	N/A	62	N/A	40	41	39	0	7	West end
-5+00*	**N/A**	**89**	**N/A**	**90**	**85**	**71**	**38**	**5**	Jettyview Rd.
0+00*	**N/A**	**4**	**N/A**	**19**	**-9**	**-14**	**-27**	**-57**	West of revetment
5+00*	**N/A**	**0**	**N/A**	**0**	**0**	**0**	**0**	**0**	Revetment/Beach Dr.
10+00*	**N/A**	**7**	**N/A**	**39**	**0**	**26**	**0**	**0**	Revetment/Beach Dr.
15+00*	**N/A**	**9**	**101**	**70**	**0**	**30**	**0**	**0**	Revetment/Beach Dr.
20+00*	**119**	**8**	**102**	**91**	**30**	**58**	**17**	**13**	Revetment/Beach Dr.
25+00*	**108**	**11**	**85**	**80**	**53**	**49**	**30**	**23**	Revetment/Beach Dr.
30+00*	**111**	**10**	**74**	**72**	**55**	**72**	**37**	**10**	Revetment/Beach Dr.
35+00*	**148**	**52**	**118**	**131**	**116**	**121**	**83**	**66**	Revetment/Beach Dr.
40+00	N/A	111	N/A	202	141	149	128	96	Starfish Rd
45+00	N/A	101	N/A	173	167	157	139	113	HWY 332
Average Project Area	122	18	96	89	51	67	38	22	

Shoreline Analysis: Surfside Beach

Shoreline recession dominated along the entire study area between December 2016 and after Harvey (Oct 2017). The shoreline was consistently landward of the 2016 position up to STA 55+0 after which there intermittent short segments of recession and advance from STA 55+0 to 75+0. The shoreline was landward of the 2015 position along the entire study area up to HWY 332. East of this point the magnitude of recession moderated and in some areas the 2015 and 2016 shorelines are close in agreement. The magnitude of recession was likely influenced by both winter seasonal forcing as well as a previous year dominated by periodic coastal flooding due to higher than average sustained water levels.

The greatest shoreline recession was focused along the persistently eroding project area and the entire revetment. The region experiencing the most significant shoreline recession was located west of the revetment from STA -0+50 to STA 0+50, along the revetment between STA 15+0 and STA 25+0, and between STA 30+0 and STA 40+0 at the east end of the revetment (Figs 103-108). The revetment effectively served as the shoreline along the western section of Beach Dr. with no subaerial beach alongshore some 1,600 ft, from the west end of the revetment to STA 15+50. This alongshore reach, devoid of emergent beach extends beyond the limit of the 2015 reach by an additional 800 ft. Although the 2016 shoreline position is well landward (-50 to -130 ft) of the 2000 BEG shoreline, there is closer agreement east of HWY 332 with proximity toward Freeport Ship Channel. The range of offset between the 2016 shoreline position and the 2000 BEG position along the west end ranges from +10 to -50 ft.

The dominance of recession at Surfside Bach was reflected by the high rate of recession resuming as the influence of the recent nourishment diminishes. The rate of recession increased along the entire study area with the highest rate of change of -23.4 ft/yr in the project area, -19.2 ft/yr along the revetment and -17.9 ft/yr along the full study area. Although there was alongshore variability in the rate of recession there was no indication of stability or indirect benefit of the previous nourishment exhibited in shoreline position. The average rate of shoreline change for specific regions in the study area over intervals of significance is provided in Table 2.

Figure 109 and 110 show the variability in rate of change in shoreline position with alongshore location in the Study Area (Fig 109) and in the Project Area (Fig 110); 1) before nourishment, 2) after nourishment, 3) over recent study periods, and 4) over the historic interval (2000-2017). The average rate of change along the revetment was -19.2 ft/yr, in contrast to the +13.5 ft/yr (2014-2015) measured during a nourishment year and in excess of that observed the year prior to nourishment (-15 ft/yr).

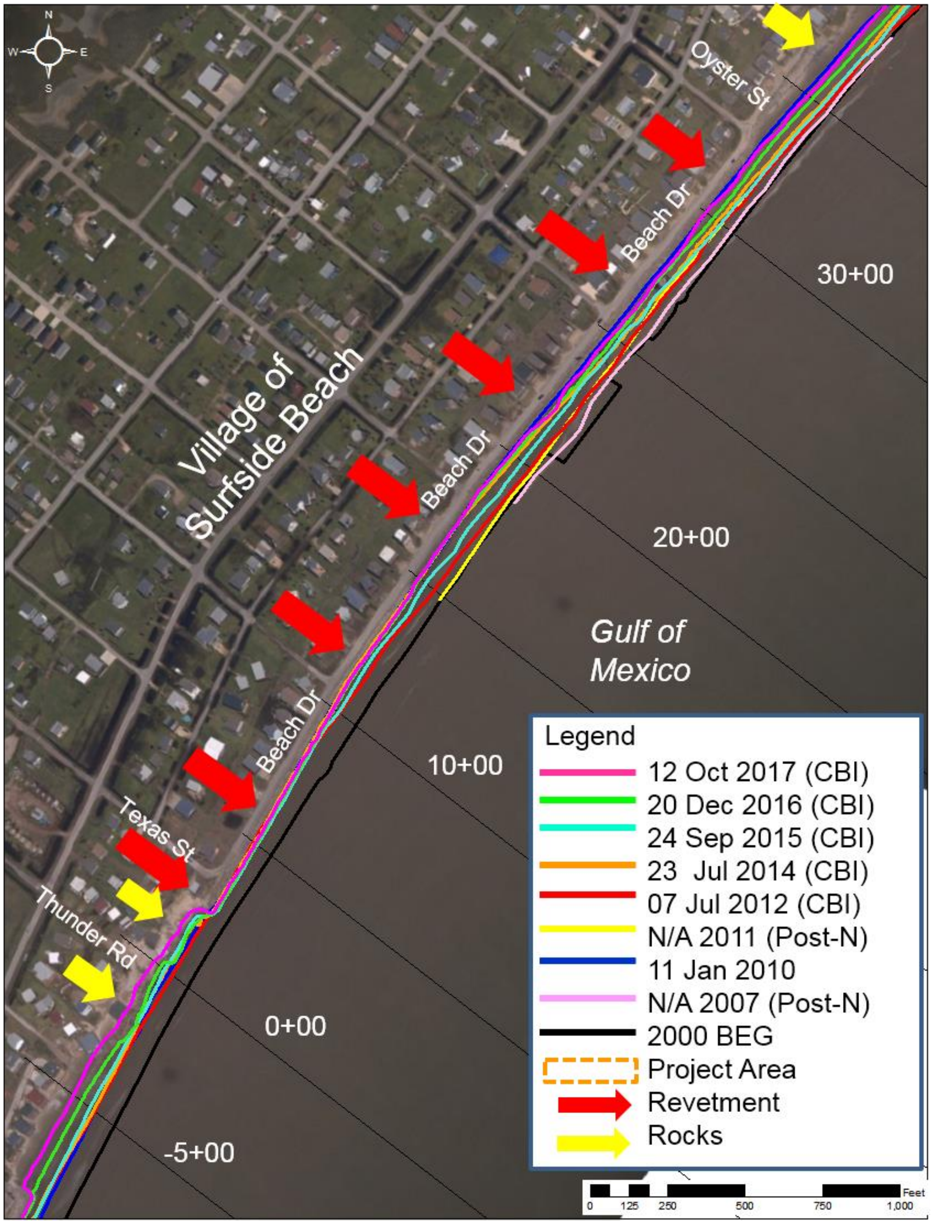


Figure 103. Recession dominated along the entire beach fronting the revetment between 2016 and 2017

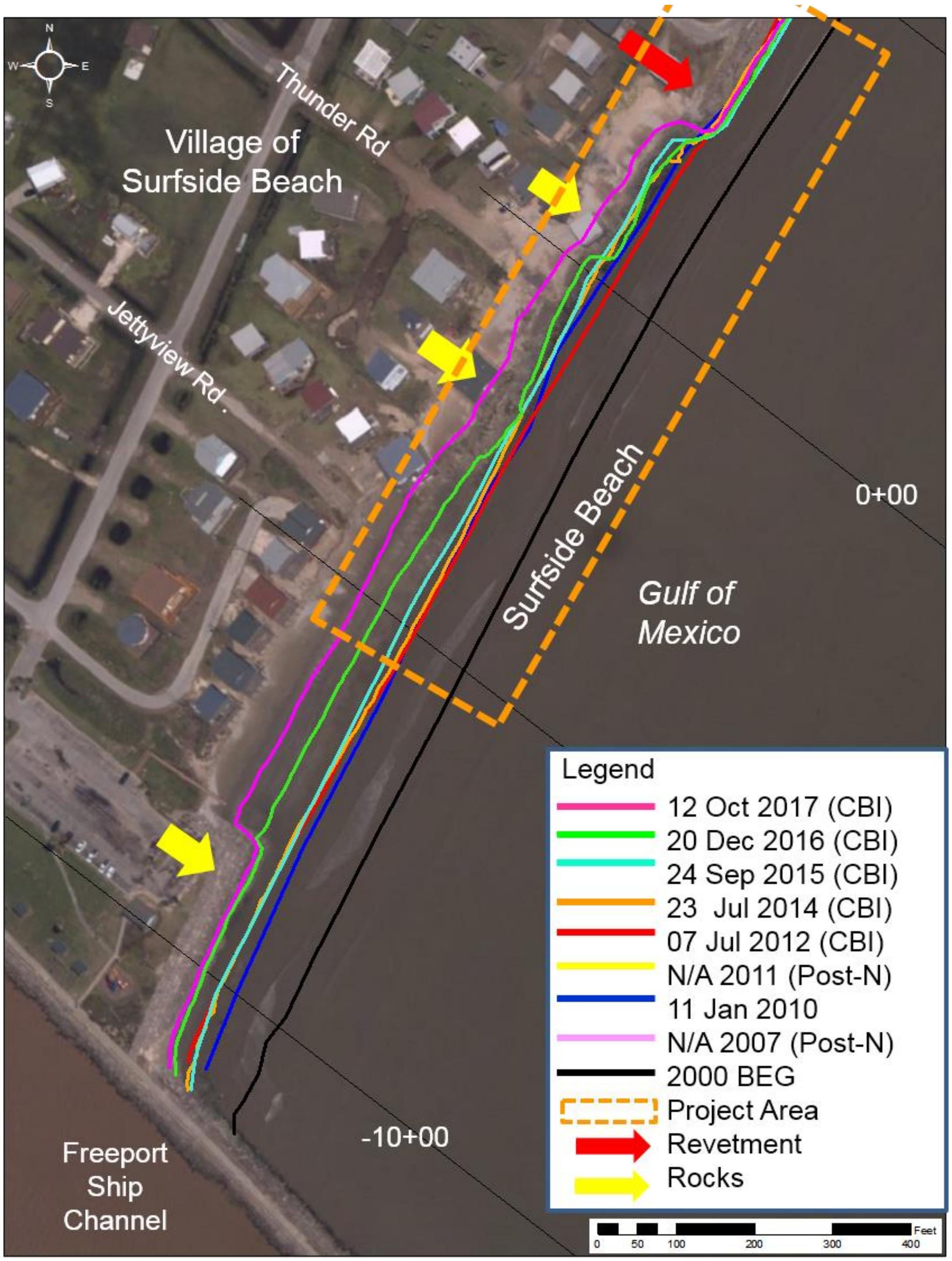


Figure 104. Variability in shoreline position west of the revetment at Surfside Beach (2000-2017) with 2017 position well landward of shoreline data record (2000-2017) and survey data record (2010-2017)

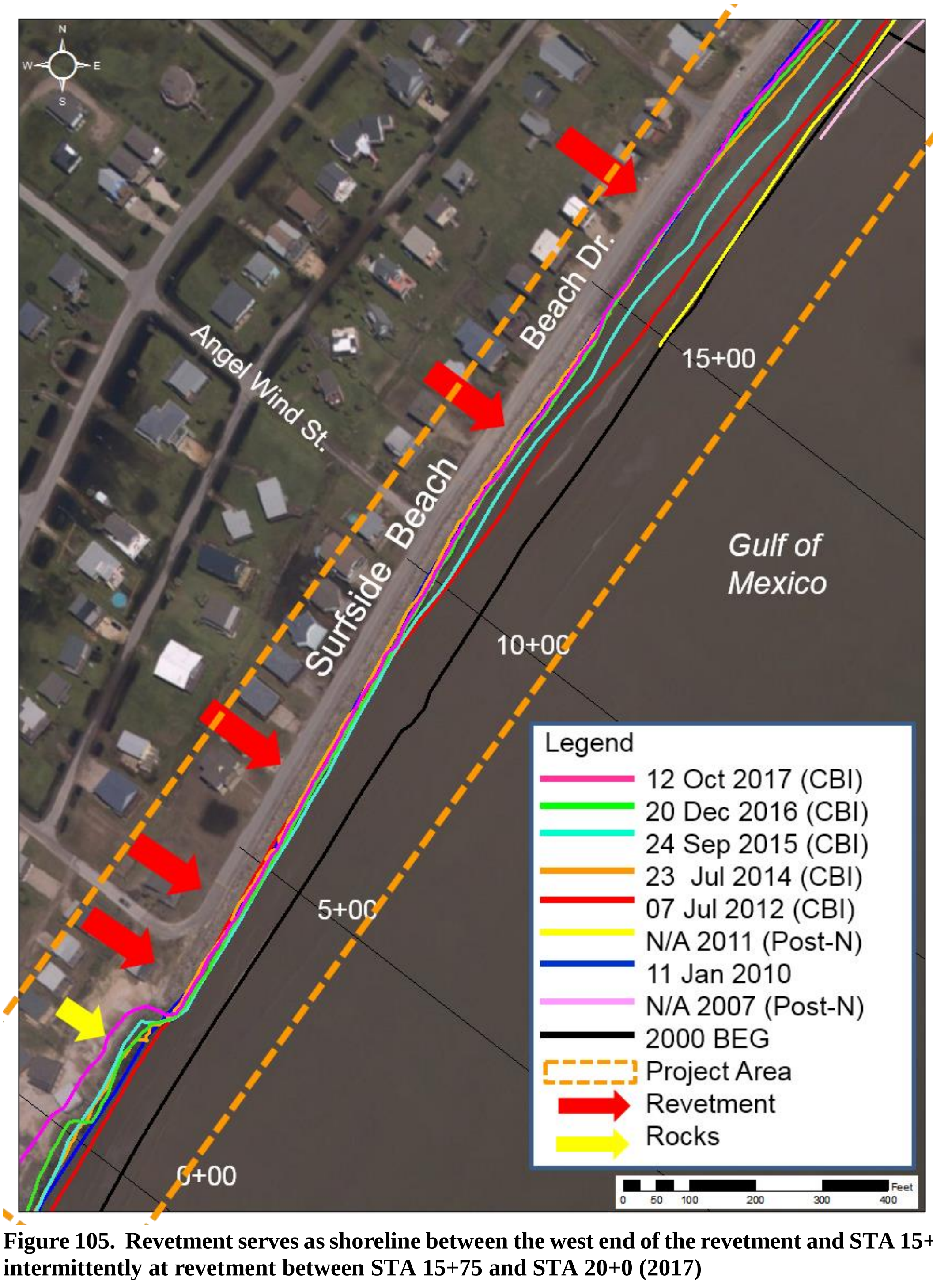


Figure 105. Revetment serves as shoreline between the west end of the revetment and STA 15+75 with shoreline intermittently at revetment between STA 15+75 and STA 20+0 (2017)

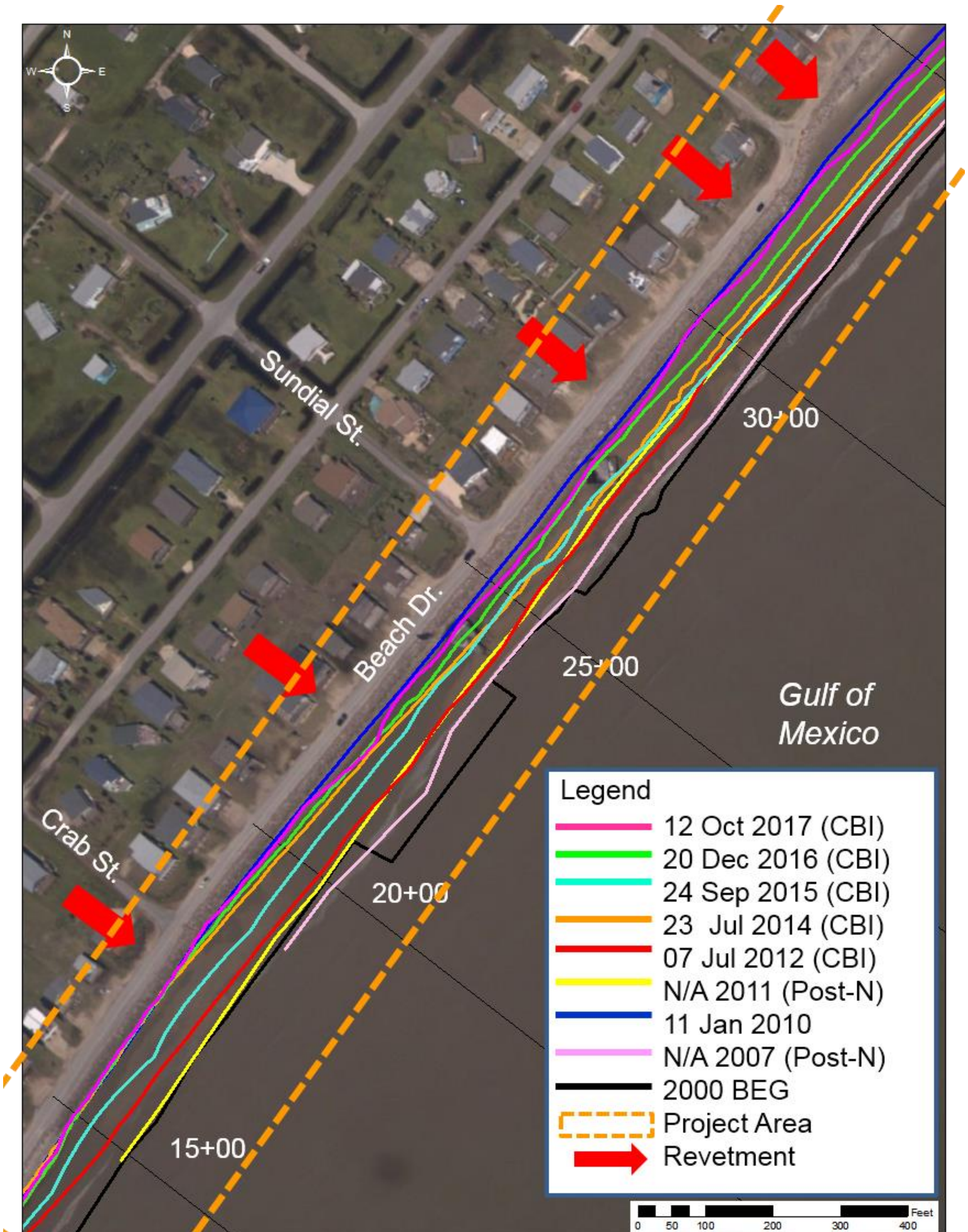


Figure 106. Extremes in shoreline position over data record along the central section of the revetment at Surfside Beach (2000-2017)

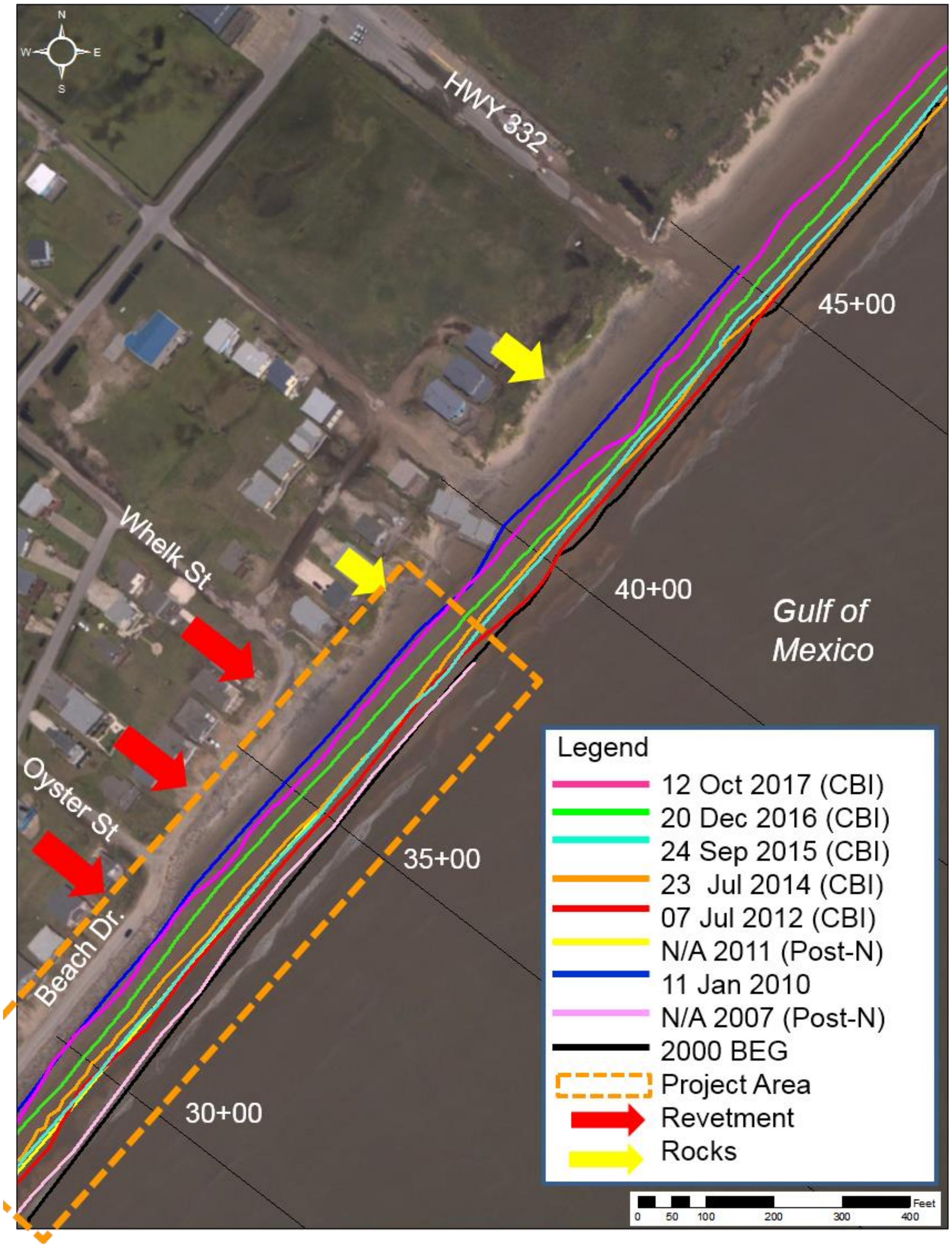


Figure 107. Shoreline in close agreement with 2010 position well landward of 2007 pre-Ike position (2000-2017)

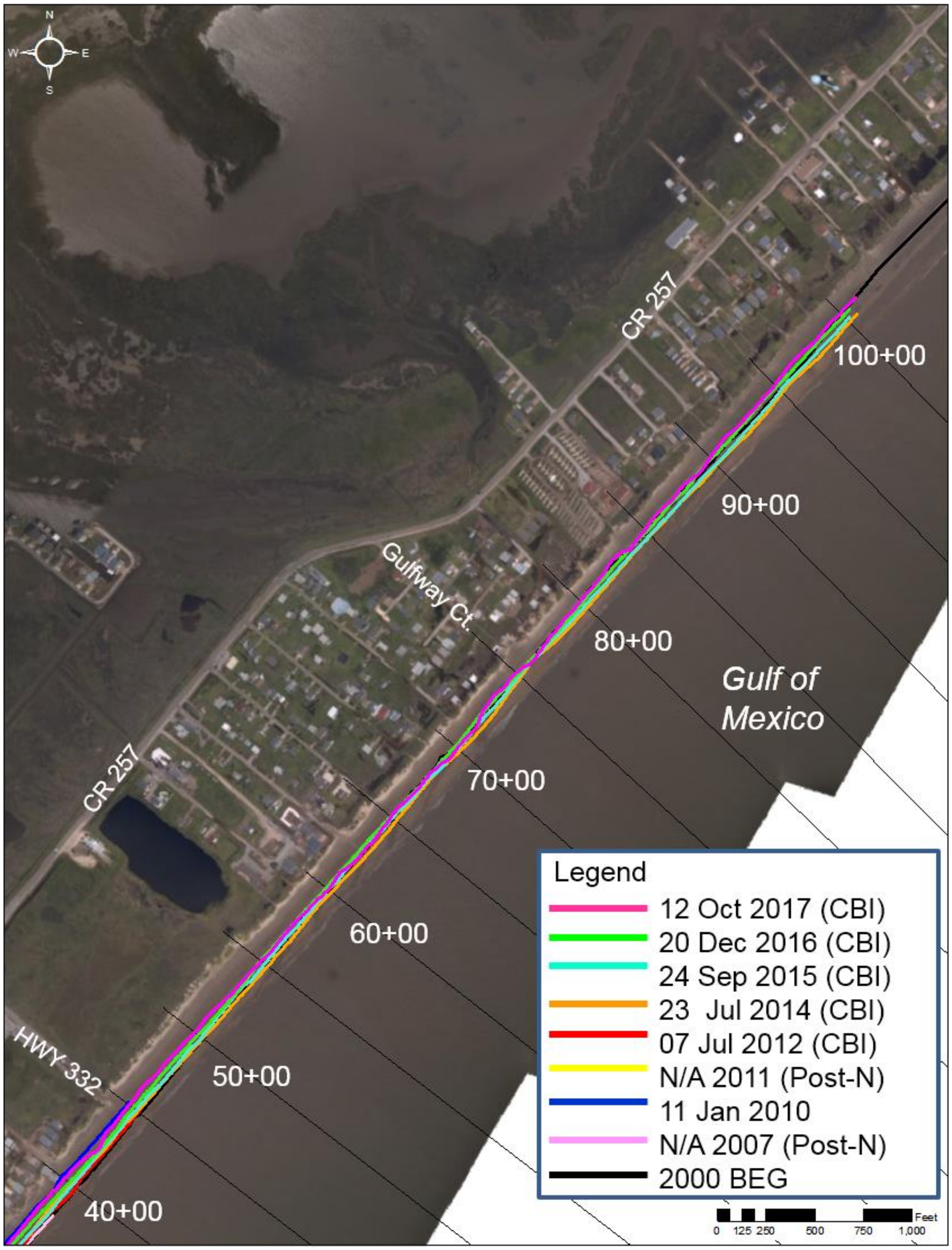


Figure 108. Recession primarily dominated along the beach east of HWY 332 with only intermittent shoreline advance identified along small alongshore segments between STA 50+0 and STA 90+0 (2017)

Table 2. Rate of Shoreline Change: Surfside (2017) *** Limited by data extent**				
Year	**2017 Redefine Project Area** **(limited by available data)**	**Avg. Rate ft/yr**	**Max Recession ft/yr**	**Max Advance ft/yr**
2016-2017 Post-Harvey	STA -5+0 to STA 37+5 1 Hurricane	-17.4	-53	+3
2015-2016 Annual	STA -5+0 to STA 37+5 1 fill and 1 tropical storm	-17.2	-47	+13
2015-2017 Biannual	STA -5+0 to STA 37+5 2-yr Post-Nourishment	-18.1	-75	0
Year	**Former Project Segments Limited by Data Extent**	**Avg. Rate**	**Max Recession**	**Max Advance**
2016-2017 Post-Harvey	STA 15+00 to STA 35+40 1 Hurricane	-11.3	-31	+3
2015-2016 Annual	STA 15+00 to STA 35+40 1 fill and 1 tropical storm	-23.4	-38	0
2014-2015 Annual Post Fill	STA 15+00 to STA 35+40 1 fill and 1 tropical storm	+13.0	-7	+38
2012-2014 Pre Fill	STA 15+00 to STA 35+40 1 fill and 0 tropical storms	-18.3	-35	0
2012-2015 Post Fill	STA 15+00 to STA 35+40 2 fill and 0 tropical storms	-6.8	-12	+1
2007*-2016 Baseline	STA 20+00 to STA 35+40 4 Beach Fills (2007, Mar 2011, Feb 2012, Mar 2015)	-6.3	-11	0
2000-2016 Historic	STA 15+00 to STA 35+40 4 Beach Fills (2007, Mar 2011, Feb 2012, Mar 2015)	-5.5	-7	0
2007*-2014 Baseline pre-2015 fill	STA 20+00 to STA 35+40 3 Beach Fills (2007, Mar 2011 and Feb 2012)	-6.5	-14	0
2007*-2010 Ike Influence	STA 20+00 to STA 35+40 1 Beach Fill (2007) Includes Ike impact	-29.9	-47	0
Year	**Revetment (limited by available data)**	**Avg. Rate**	**Max Recession**	**Max Advance**
2016-2017 Post-Harvey	STA 0+50 to STA 35+40 1 Hurricane	-11.0	-31	+3
2015-2016 Annual	STA 0+50 to STA 35+40 1 fill and 1 tropical storm	-19.2	-38	0
2014-2015 Annual	STA 0+50 to STA 35+40 1 fill and 1 tropical storm	+13.9	-7	+38
2012-2014 Biannual Pre Fill	STA 0+50 to STA 35+40 1 fill and 1 tropical storm	-15.0	-35	+4
Year	**Full Study Area (Limited by available data)**	**Avg. Rate**	**Max Recession**	**Max Advance**
2016-2017 Post-Harvey	STA -10+00 to STA 100+00 1 Hurricane	-15.2	-53	+22
2015-2016 Annual	STA -10+00 to STA 100+00 1 beach fill and 1 tropical storm	-17.9	-47	+16.6
2014-2015 Annual	STA -10+00 to STA 100+00 1 beach fill and 1 tropical storm	-2.1	-28	+38
2000-2017 Historic	STA -10+00 to STA 100+00 4 beach fill and multiple tropical storms including Ike and Harvey	-3.5	-10	+1
Notes	Nourishment: 2007 (baseline), Nov 2010, Mar 2011, Jan/Feb 2012 and Mar 2015 Revetment: constructed 2008, repaired 2011 No dredge placement Freeport Jetty (-10+00) to Jettyview Rd. (-5+00)			

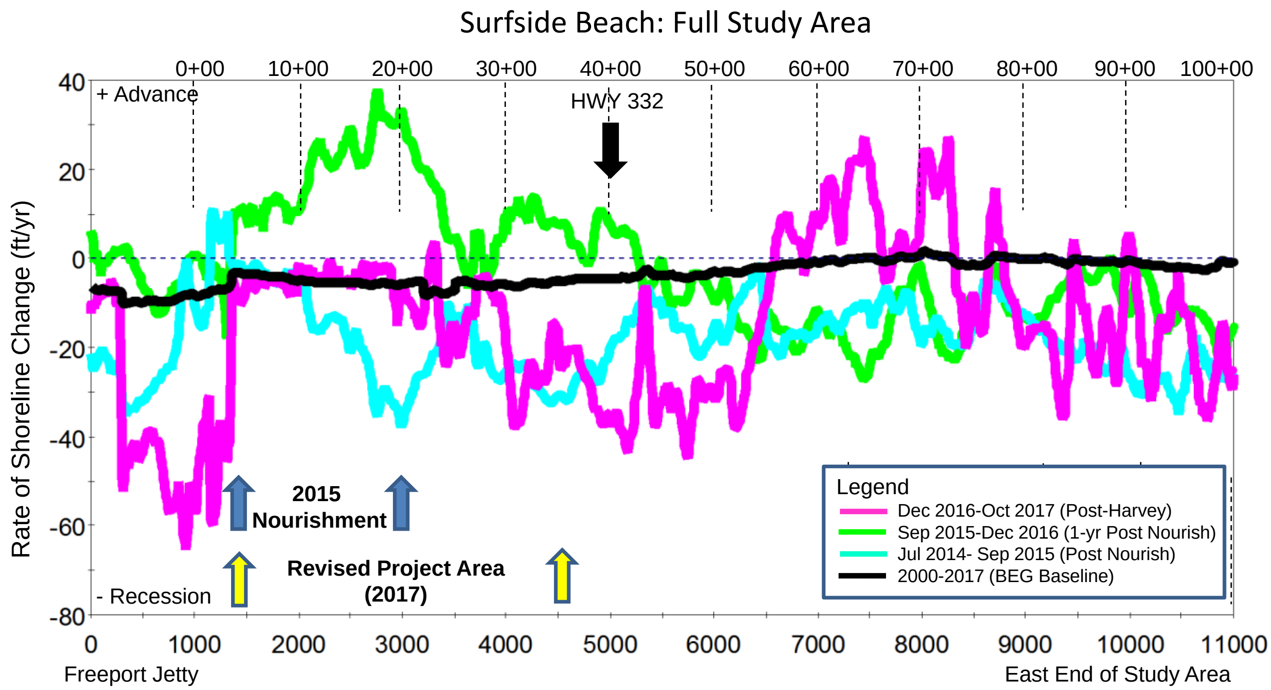


Figure 109. Comparison of variability in rate of shoreline position change with alongshore location from the jetty at the Freeport Ship Channel to the extended east end of the full study area at key reporting intervals

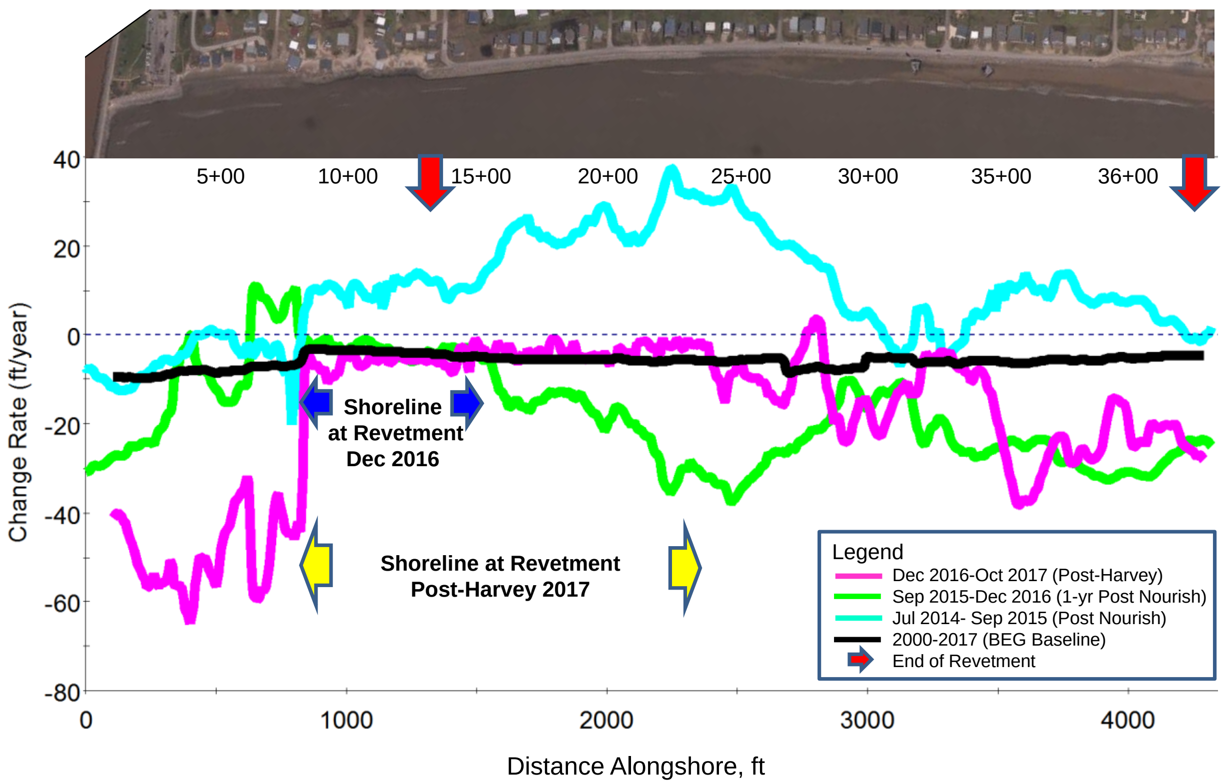


Figure 110. Comparison of variability in the rate of shoreline change with alongshore position in the Project Area over key intervals 1) Post Harvey (2016-2017) after nourishment (2015) and after Harvey (2017)

Volumetric Analysis and Beach Morphology: Surfside Beach

Over the study period (2016 to 2017), erosion dominated across the entire beach profile extending from the dune or backshore limiting feature to the -10 to -15 ft contour along the Study Area at Sargent Beach (Fig 111-117). Accretion was indicated only along a small submerged segment of the Project Area fronting the revetment between STA 20+0 and STA 35+0 (Fig 115 and 116). Accretion in this area was likely transient and related to the alongshore redistribution of sand initiated by Hurricane Harvey. Accretion in this area did not translate to an increase in berm width but instead was focused in the immediate nearshore. Along the remainder of the project area erosion was focused across both the subaerial (dry beach), as well as across the nearshore up to the -15 ft contour.

Changes in nearshore morphology indicate that the majority of sediment exchange was limited to the region between the berm and the 10 to -15 ft contour. There was limited to no feature development seaward of this elevation along the majority of the Study Area from STA -10+0 to STA 100+0, with the exception of the larger scale erosion indicated offshore of the -20 ft contour near the Freeport Ship Channel (Figs 121-126). The contribution of sediment exchange seaward of this limit is considered negligible and therefore the offshore limit of active sediment transport was taken as -15 ft. Beyond the -15 ft contour, erosion was insignificant with the exception of the most offshore extent of the profile along transects located close to the influence of current interaction related to the Freeport Ship Channel Jetty between STA -10 and STA 5+0 (Fig 121 and 122) and to a lesser extent up to STA 25+0 (Fig. 123).

The changes in morphology between 2016 and 2017 are indicative of a period of persistent fluctuating range of water levels combined with onshore forcing and alongshore sediment transport such that as sand eroded it was transported either offshore beyond the limits of the active region of sediment transport or exited the littoral cell to the west. The net change in sand volume in the Project Area at Surfside Beach was approximately -11,525 cu yd (-2.6 cy/ft). This relatively low rate in comparison to the actual footprint of beach in the Project Area is indicative of the contribution of sand transported into Project Area alongshore from the east as well as the general absence of the contribution of the fraction that would have been attributed to the former beach that eroded from the majority of the revetment. The net change in sand volume in the Study Area was -77,500 cu yd (-7 cy/ft).

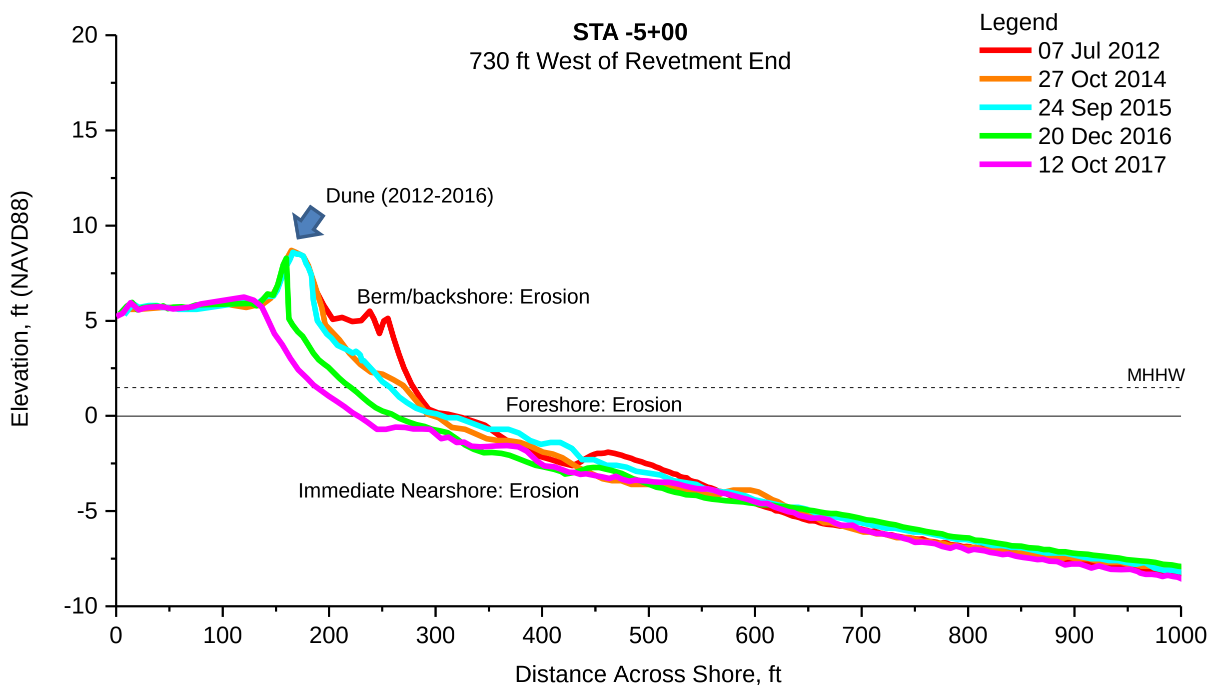


Figure 111. West of Revetment: Complete erosion of dune and severe erosion of berm and shoreface (2016-2017)

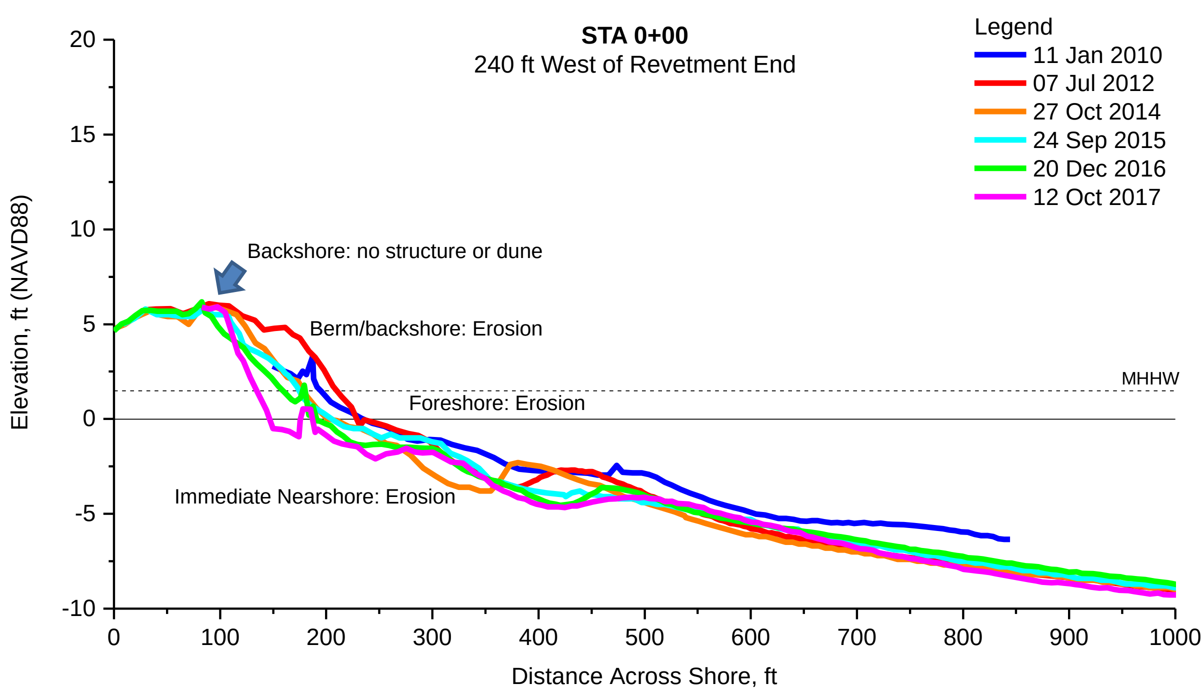


Figure 112. West of Revetment: Severe erosion of backshore, berm and nearshore exposing rock (Oct 2017)

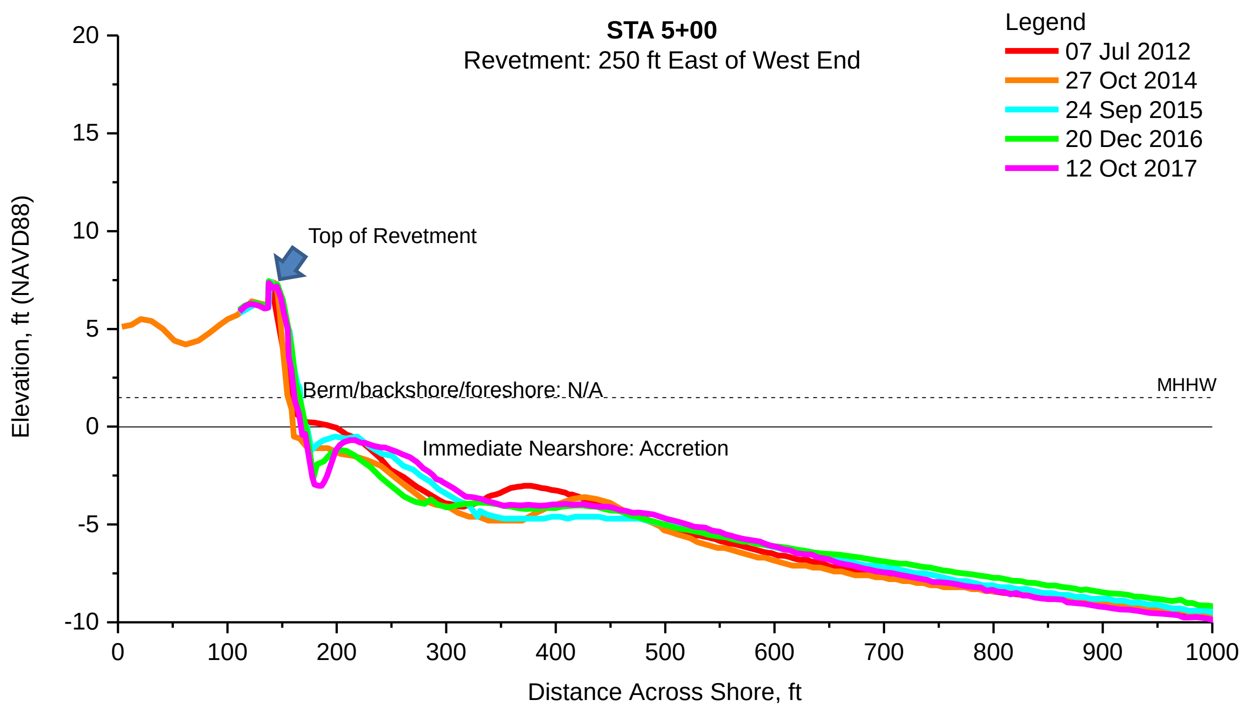


Figure 113. West End of Revetment: No subaerial beach with revetment serving as shoreline (2010-2017) and deep scour at base of revetment

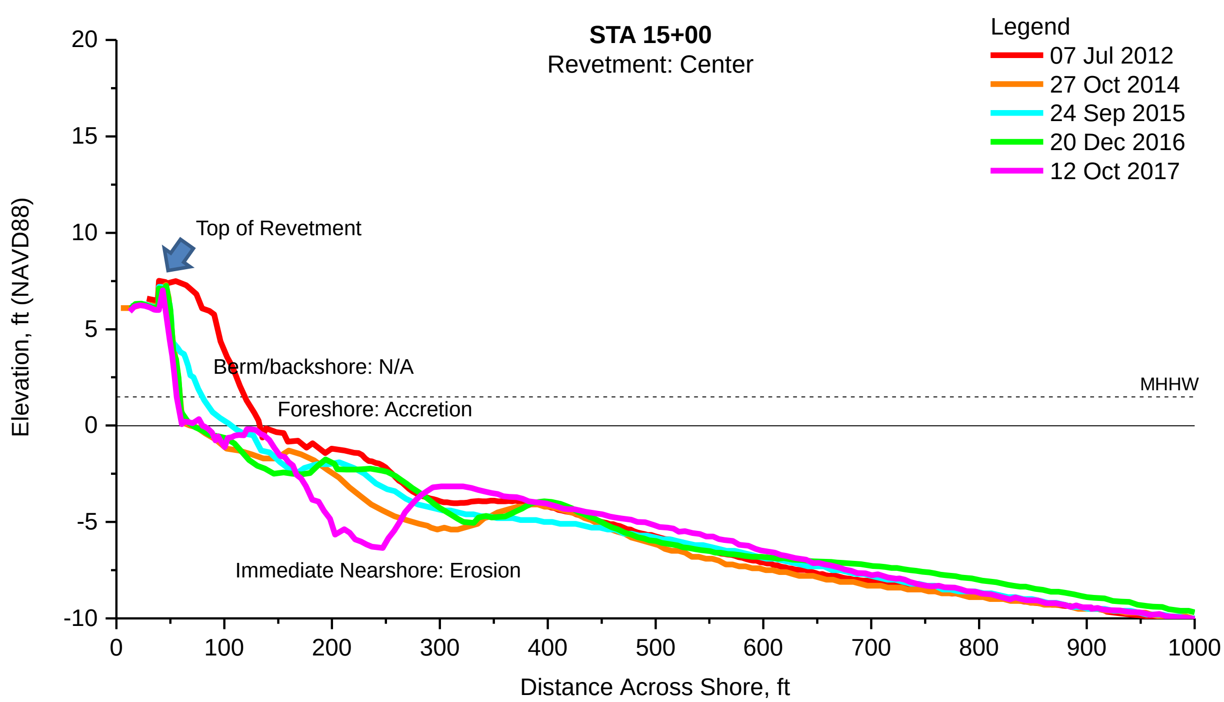


Figure 114. West of Center Revetment: No significant subaerial (dry beach) with nearshore accretion landward of focused area of significant scour (storm trough) in immediate nearshore (2017)

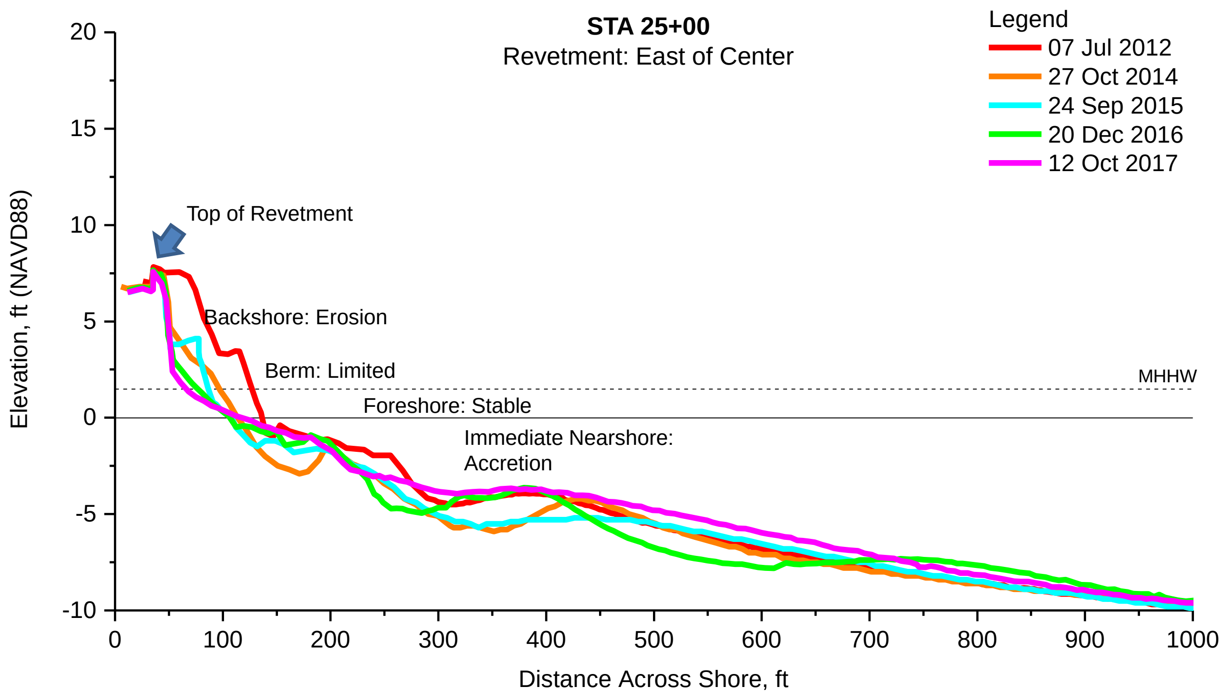


Figure 115. East of Center Revetment: Limited subaerial (dry beach) with erosion at base of revetment and nearshore accretion (2017) in area of former erosion (2015-2016).

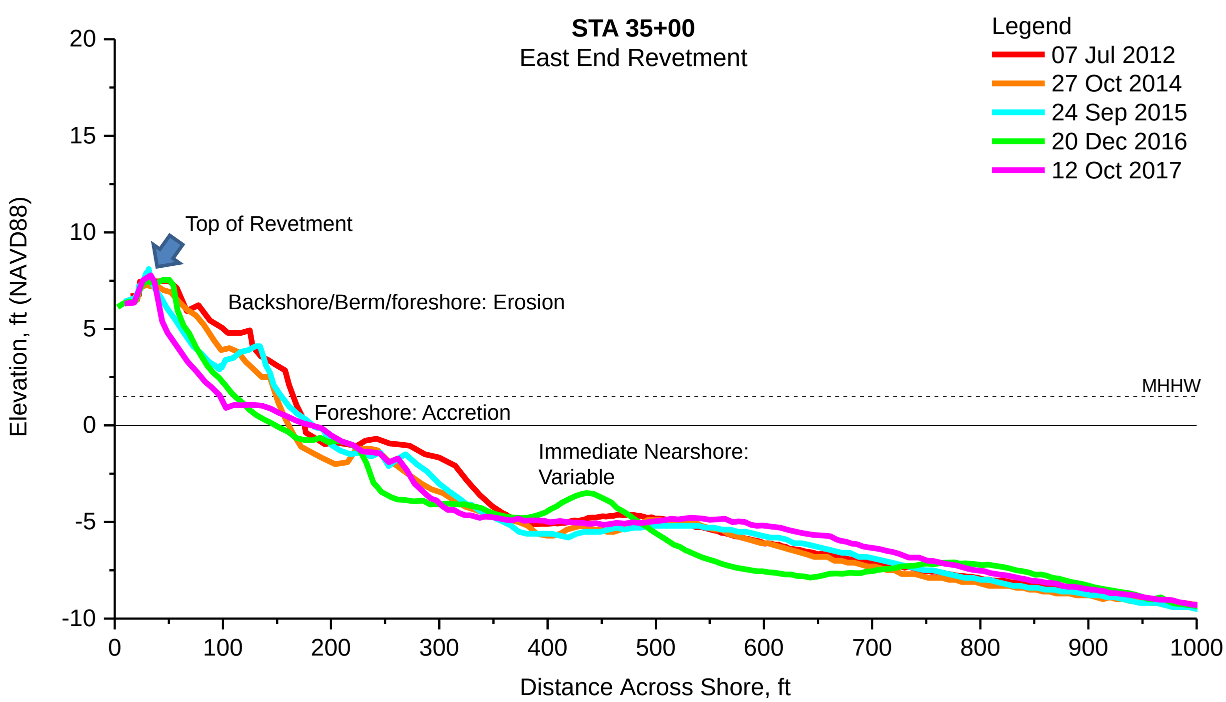


Figure 116. East End of Revetment: Significant erosion of backshore and berm across widest segment of pedestrian beach, with accretion in immediate nearshore (2017)

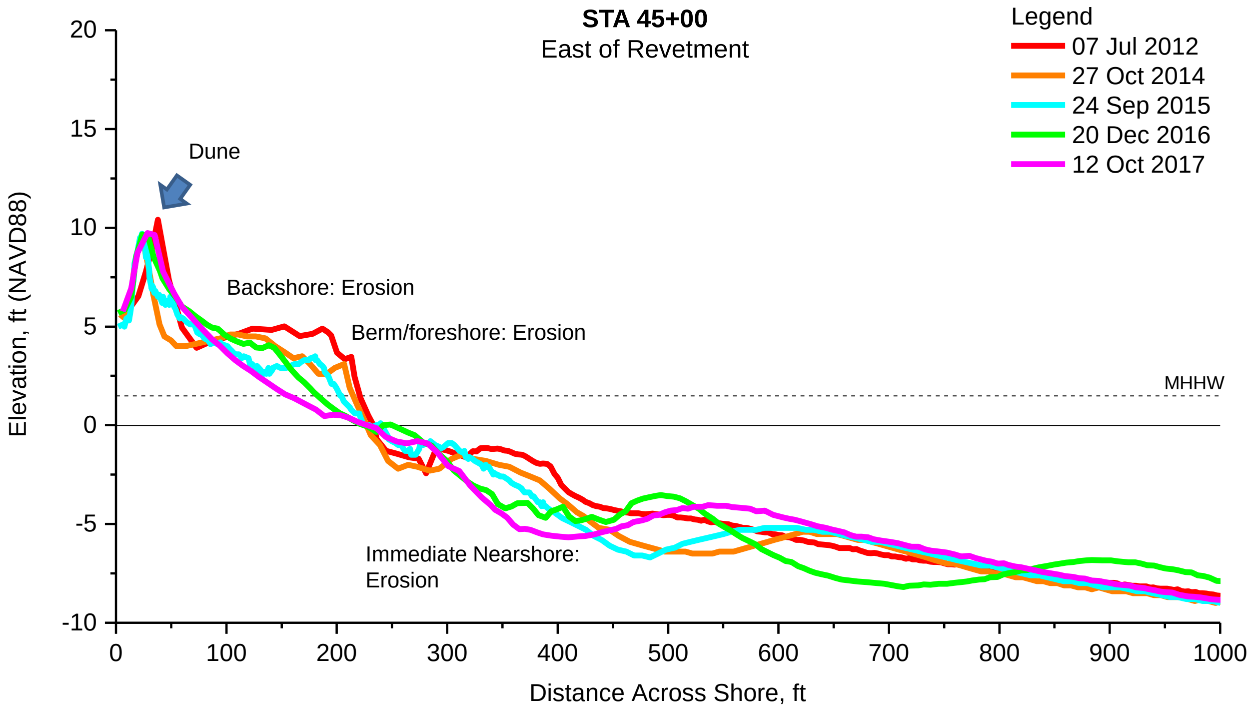


Figure 117. East of Revetment: Stable dune, erosion across backshore, berm and foreshore as well as deep region of erosion in the immediate nearshore

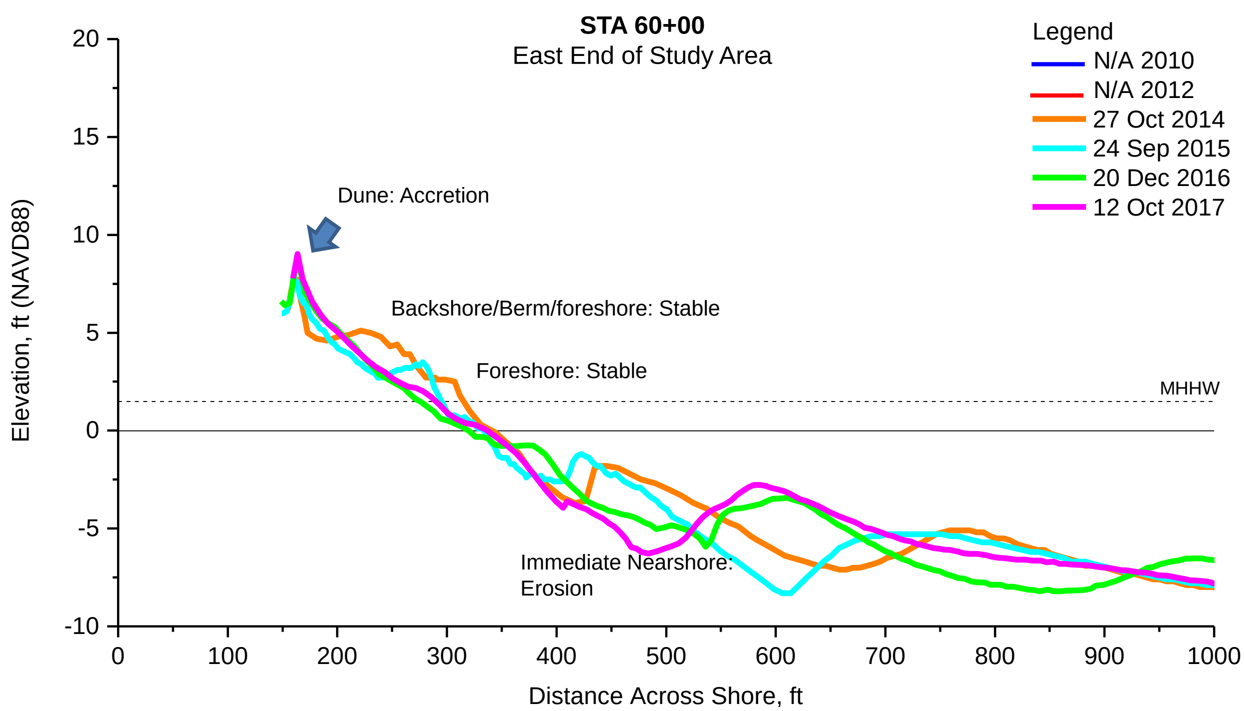


Figure 118. East end of Study Area: Stable dune, backshore and foreshore with significant erosion in immediate nearshore (2017)

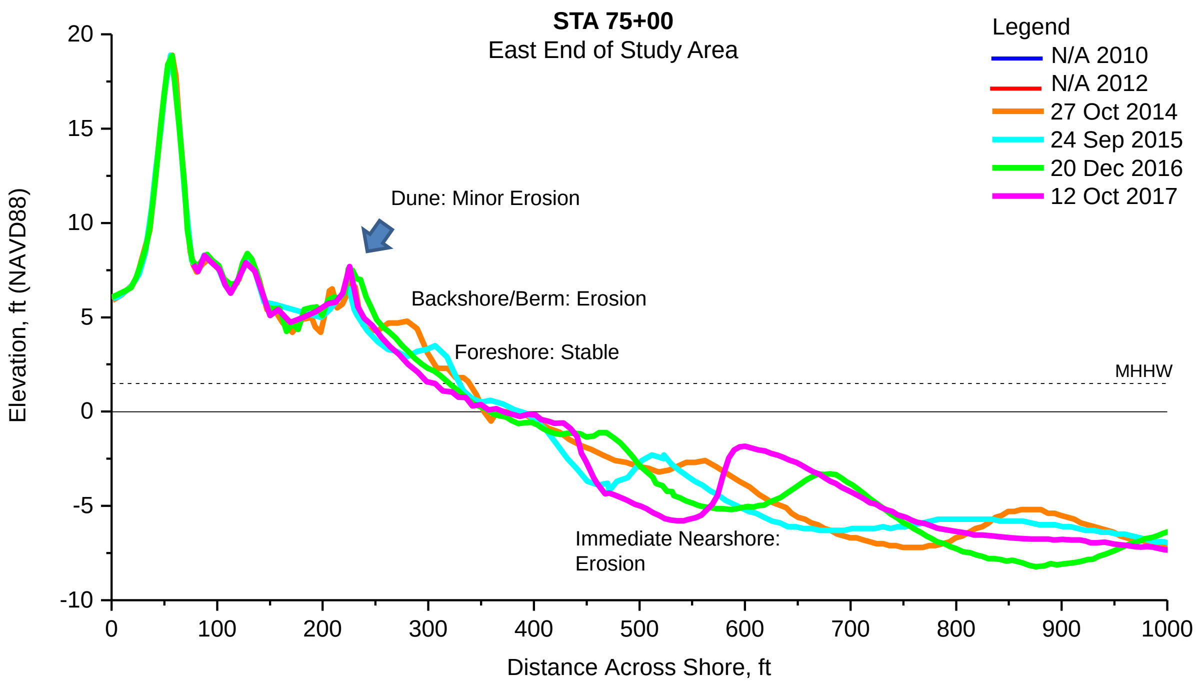


Figure 119. East End of Study Area: Erosion from dune crest across backshore and berm with a stable foreshore located landward of severe erosion in the immediate nearshore (2017)

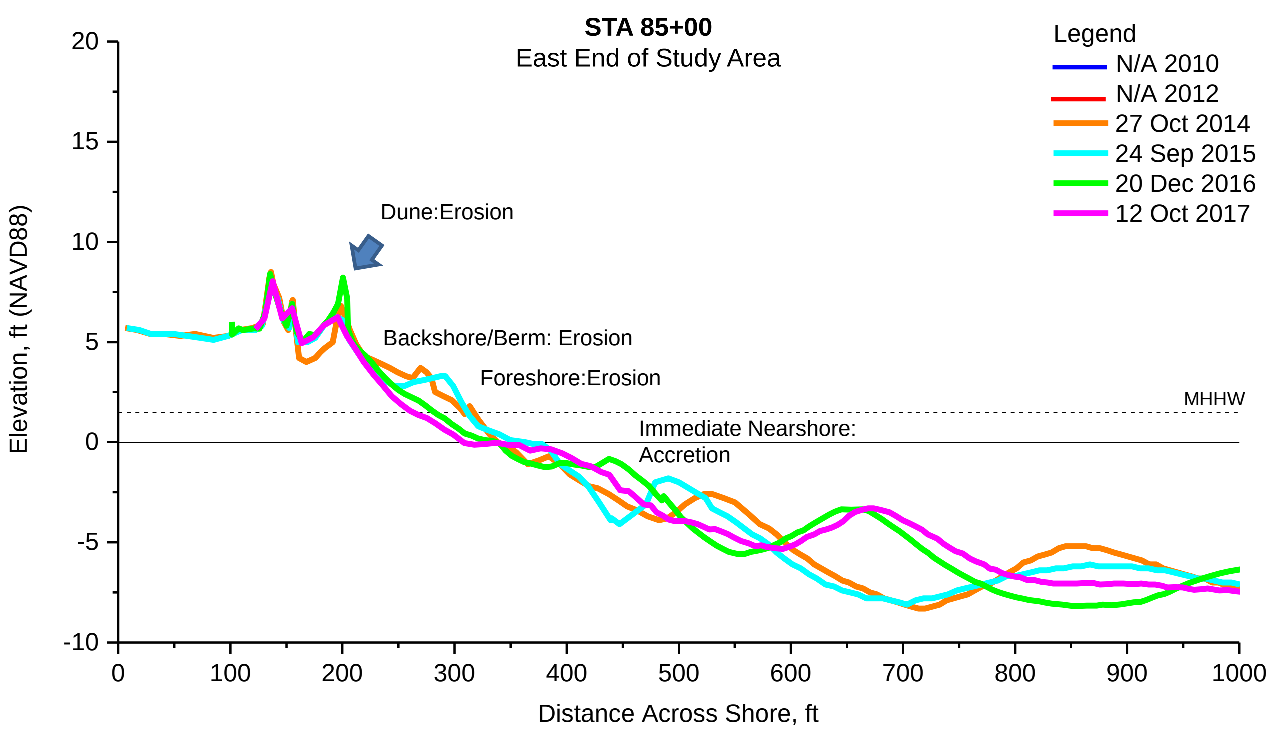


Figure 120. East End of Study Area: Erosion of dune, backshore, foreshore and variable in the immediate nearshore. Location is representative of beach from STA 85+0 to STA 100+0 (2017)

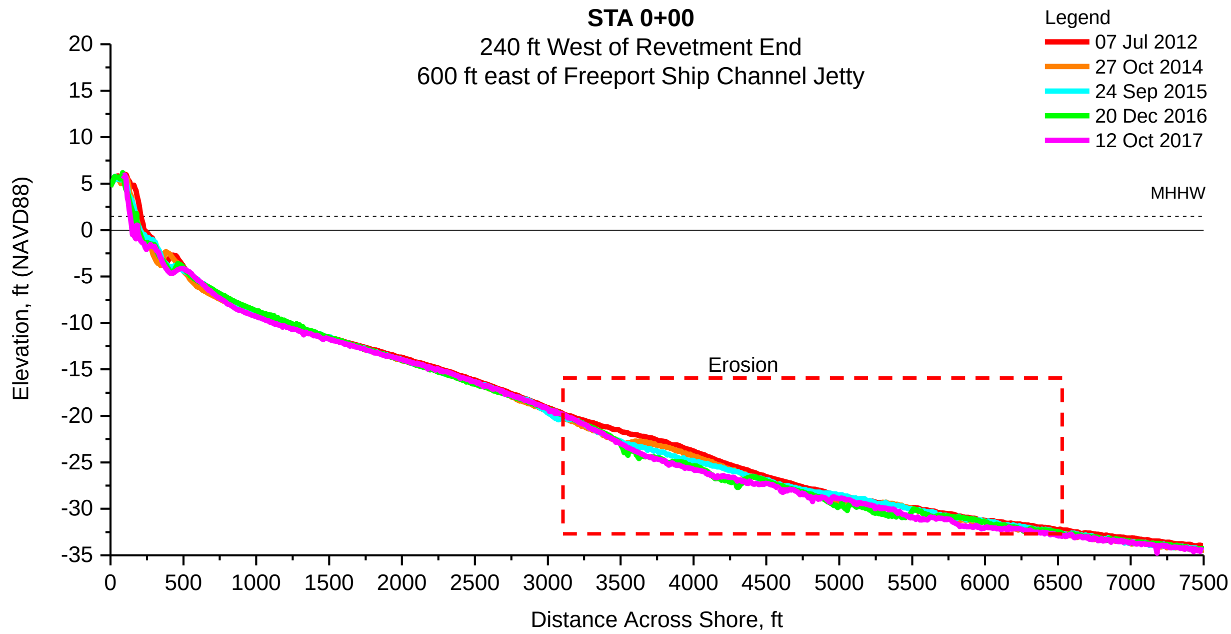


Figure 121. East End Study Area: Focused erosion offshore between the -20 and -30 ft contour (2016-2017)

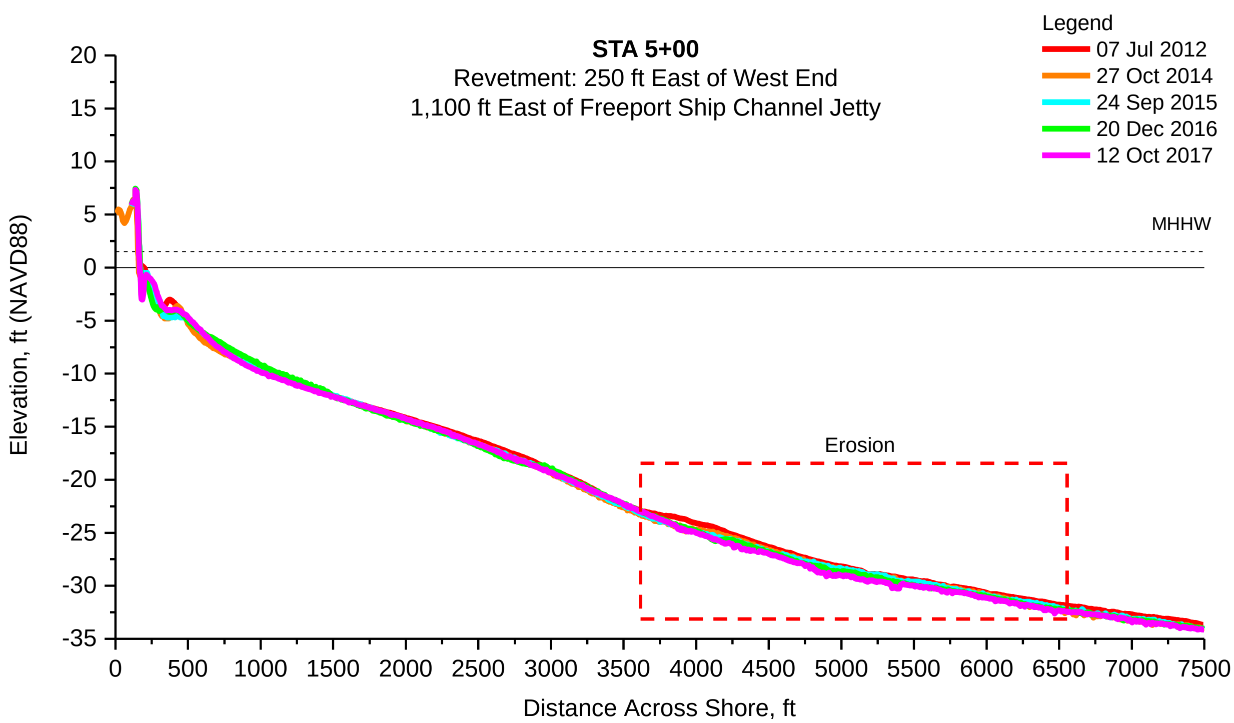


Figure 122. West End of Revetment: Focused erosion offshore between the -20 and -30 ft contour (2016-2017)

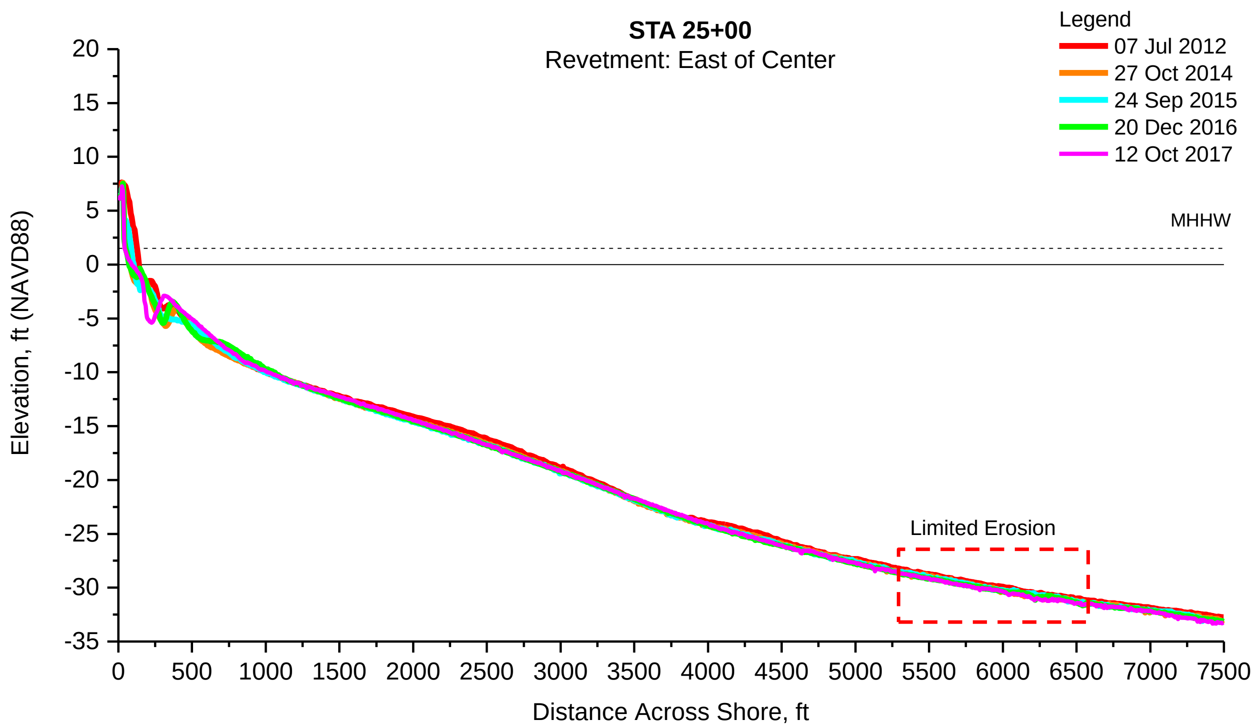


Figure 123. Revetment East of Center: Limited erosion in nearshore seaward of the -25 ft contour (2016-2017)

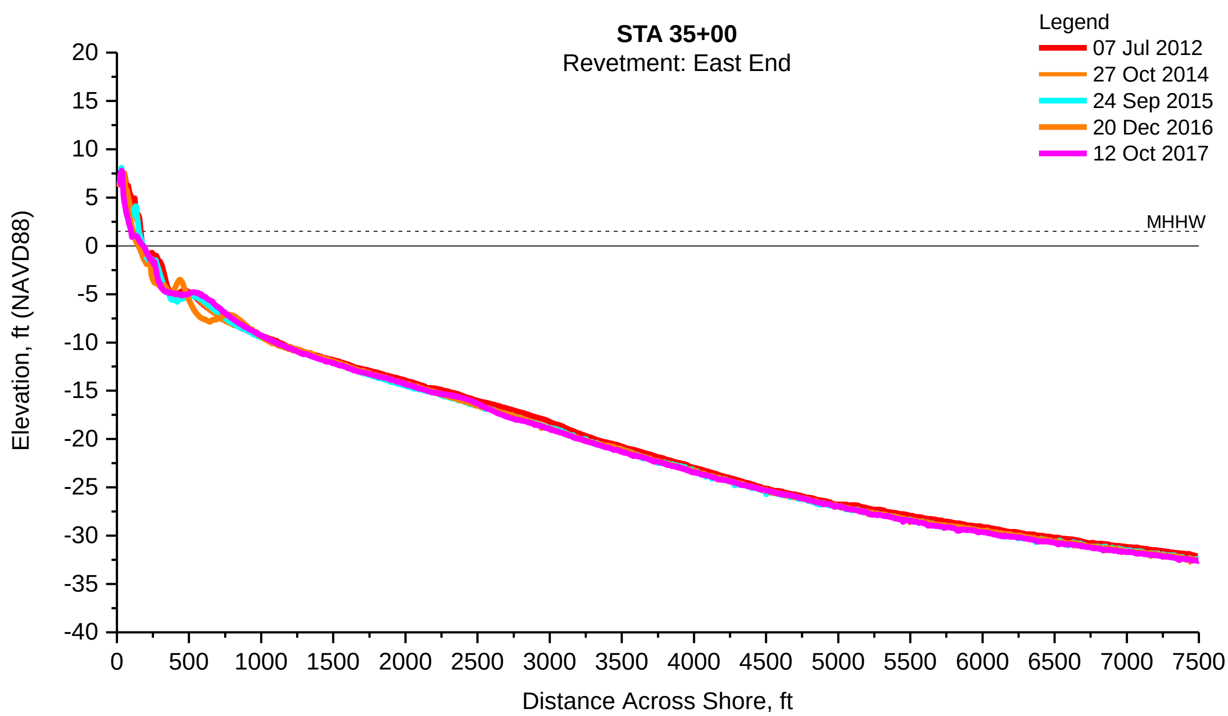


Figure 124. East End of Revetment: Profiles in agreement seaward of the -20 ft contour (2016-2017)

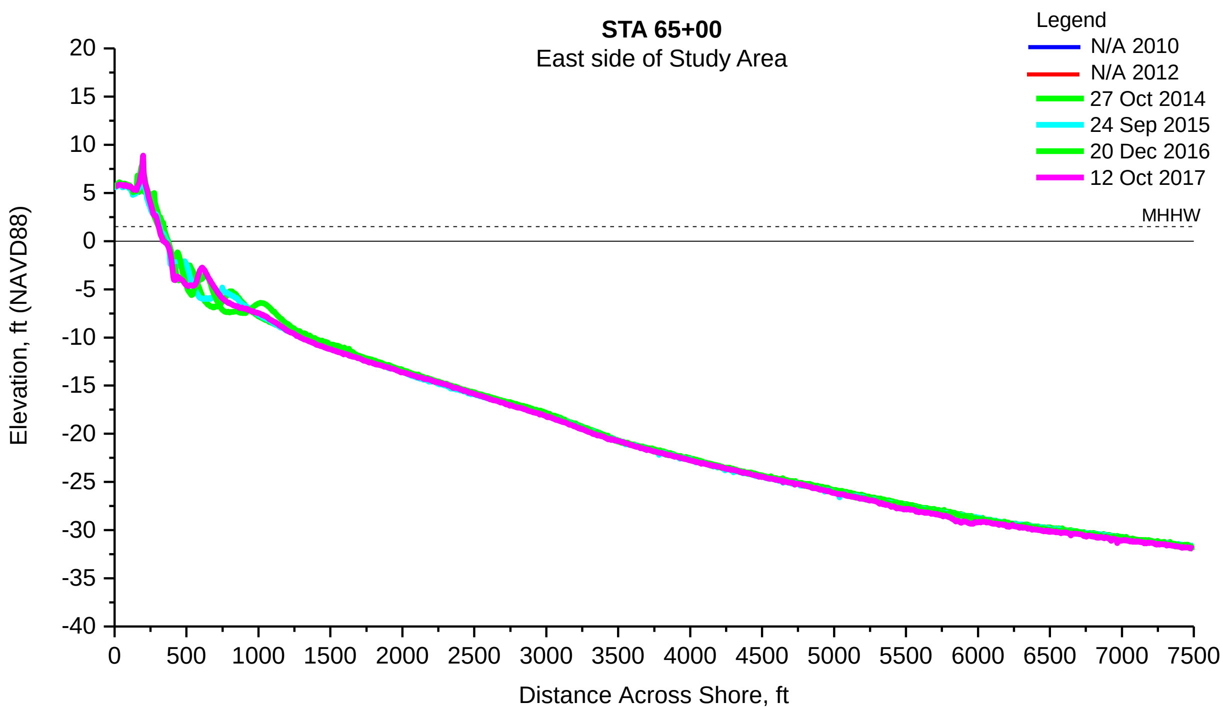


Figure 125. East of Revetment along East Side of Study Area: limited to no change in profile elevation seaward of the -20 ft contour

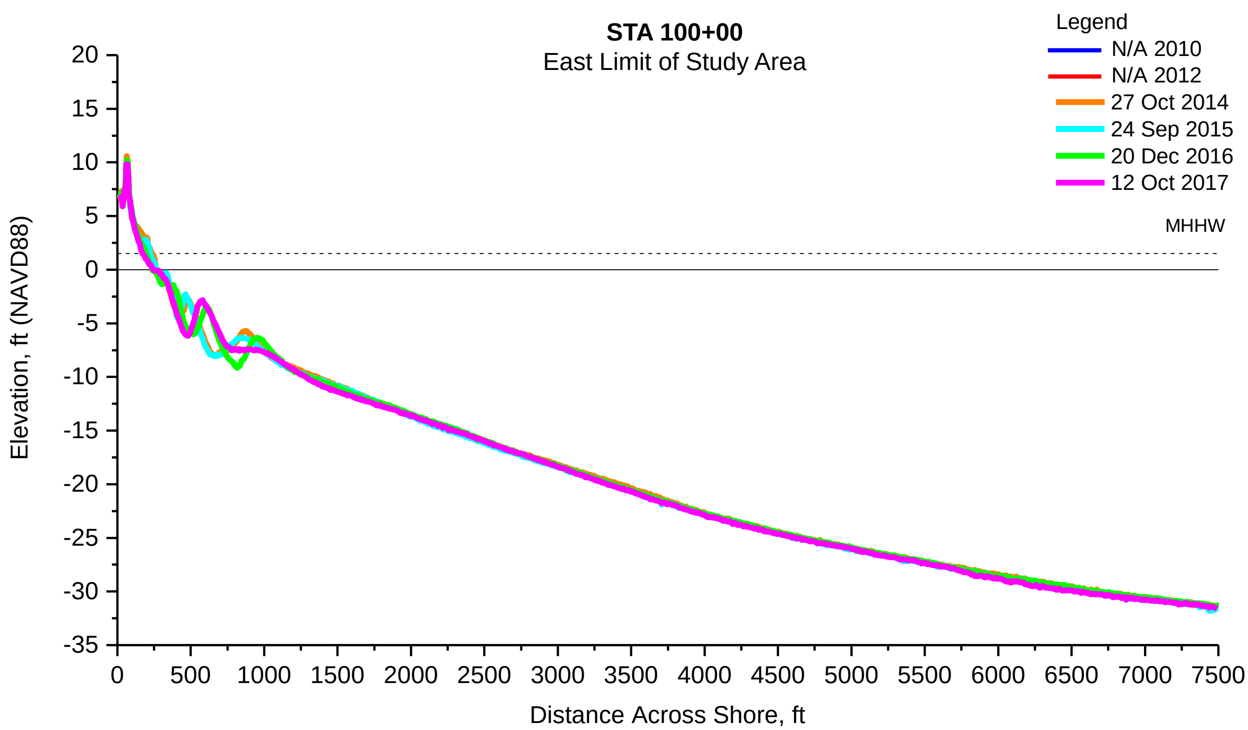


Figure 126. East Limit of Study Area: Negligible erosion seaward of the -20 ft contour

Recommendations: Surfside Beach
Erosion dominated along the entire Study Area with exacerbation of severe erosion along the revetment and immediately adjacent to the west. No remaining benefit from the fill placement (March 2015) was identified along the revetment during Oct 2017, with 90 % of the beach fronting the revetment at a width of less than 63 ft (Action Width). A primary beach management concern is that along 40% of the Project Area significant subaerial (dry beach) exposure was either; 1) completely absent (west side of revetment) or 2) the beach was set back landward of the revetment (west of revetment). Surfside Beach meets the two primary and two se criteria to initiate nourishment planning and implementation within one year; 1) 90% of the beach was under the Action Width and 2) high recent and historic shoreline recession rate that threaten to compromise remaining narrow beach. Secondary criteria include; 1) Complete elimination of significant exposure of subaerial (dry beach) beach along 1,700 ft, of shoreline and 2) Imminent threat to backshore public and private infrastructure and public access.

The rate of shoreline recession both in the Project Area and along the adjacent beach to the east and west has been in excess of -15 ft/yr with the exception of the 2014-2015 reporting period. Persistent erosion of the beach between STA -5+00 and the west end of the revetment has resulted in the recession of the shoreline to a position landward of the west end of the revetment and Beach Dr. The beach between the revetment fronting Beach Drive and the revetment closer to the Freeport Ship Channel lies recessed with no indication of a tendency for recovery. This offers the opportunity for undermining of the west end of the revetment along Beach Drive. Including this relatively small beach segment in nourishment planning would restore continuity between adjacent segments of the beach as well as contribute to and reinforce overall success of the original project footprint as well as benefiting community access in general by expanding the accessible region of beach. Extending the nourishment to STA -10+0 would further reinforce the success of the nourishment by increasing continuity of the fill.

Three nourishment Alternatives are provided to assist in planning, in absence of implementation of larger scale projects that include coastal structures. Although the three Alternative provide for the accommodation of funding and resource restrictions, Alternative #1 provides the greatest potential in increasing the longevity of the nourishment over that documented in the past. Alternative #1 provides for the restoration of the beach to a design width of 125 ft within along the Project Area but with westward extension of an additional 500 ft (STA -10+0 to 35+7). Alternative #1 would require an estimated minimum volume of 329,000 cu yd and restore not only the beach fronting the revetment but also the beach that is presently set back between the revetment and the revetment near the Freeport Ship Channel. Based on the expansion of erosion not only toward the east but also toward the west, Alternative #1 provides for the greatest potential for increasing the fill longevity. Alternative #2 provides for the nourishment of the beach along the Project Area as defined from STA -5+0 to STA 35+7. Alternative #2 requires a minimum of 292,000 cu yd of sand. Alternative #3 provides for nourishment along the revetment where the exposed beach was absent during Oct 2017 after Harvey. The extent of Alternative #3 is defined as STA 0+5 to STA 25+0. Alternative #3 would require an estimated minimum volume of 190,000 cu yd of sand to restore the beach to Target Width. The three Alternatives include a tie in between 5.5 and 6 ft (NAVD88) as well as the application of a design closure depth of at a minimum -10 ft (NAVD88), which corresponds to the average offshore limit of significant profile change since 2012. The two Alternatives were designed to accommodate a range of funding and/or sand resource limitations. Although Alternative #2 and 3 reduce cost and resources needed, based on review of the past performance of smaller fill placements it was determined that the application of partial restoration is not effective for long-term management of beach erosion at Surfside Beach. Therefore, this reporting recommends Alternative #1 for application in the absence of, or as an intermediate step toward, additional stabilizing structural alternatives.

Indianola Beach

Indianola Beach is located on the west shore of Matagorda Bay and consists of what are effectively eight small (150 to 450-ft long) beach compartments, referred to in this report as "cells," that are stabilized by a variable groin field. The orientation and size of the groin system is unique to each cell providing varying degrees of stabilization. The existing beach was nourished and structures were constructed in 2003. One partial nourishment has been performed to date. The nourishment of Cell 7 with a volume of 2,453 cu yd of sand was completed 15 June 2017 just two month prior to Hurricane Harvey. Indianola Beach was first recommended for partial nourishment of Cells 1-3 and 7 during 2014 reporting period based on Action Width (Cells 1-3) and threat to backshore infrastructure (Cell 7).

The beach has been surveyed and assessed annually or biannual since 2007. Beach profile surveys were originally conducted along a grid that was applied during project development with the grid subsequently revised twice to accommodate the limitations represented by the proximity of the structures to the design transect locations and high responsiveness related to the relatively small size of the beach cells (Fig 127 and 128). To facilitate analysis and reporting, the beach was broken into nine cells and two revetment sections. Cell 9 was not part of the nourishment project and therefore was not evaluated for nourishment but volume change and recession rate is included due to the transient sand sharing capacity of Cell 9, located at the southern terminus of the beach cell system. Changes in sand volume and shoreline morphology as well as changes in the nearshore fronting the revetment are reviewed annually to determine whether impoundment is occurring along the revetment between the two reaches of beach cells. The northern reach consists of seven groins that separate the beach into six cells. The southern reach consists of three cells, two of which are compartmentalized (Cell 7 and 8). The two most southern cells along the north reach (Cell 5 and 6) and a central T-shaped groin and terminal arcuate groins further stabilize southern reach (Cell 7 and 8). A low elevation articulated revetment separates the north reach from the south reach, depicted in figures as RV1 and RV2. A small beach is located north of RV1 bordering the Cell 6 groin and more recently, another small beach has developed north of Cell 7 along RV2. Loss of sand from Cell 7 likely contributed to the development of this accretionary feature.

As described in previous reporting, monitoring of bayside beaches along the Texas Coast has documented rapid change in shoreline position and beach width in response to reversals in the direction of seasonal forcing and in some cases shorter period small (winter front) and large (tropical storm) event forcing. At Indianola Beach, this characteristic of rapid seasonal response adds challenges to the analysis of longer-term annual trends in shoreline position change because segments of erosion and accretion may reverse from one end of the beach to the other over short temporal scales of months, weeks or even days. Although an increase in understanding of the seasonality of sediment transport has been supported by surveys conducted during the spring and winter, the most effective long-term monitoring and assessment is supported by conducting surveys as close to the same time each year, as is possible within administrative constraints. This will provide for consistency and highest potential for the identification of annual trends over time. Adhering to a summer survey schedule reduces the influence of these seasonal short-term responses and subsequent incorrect assumptions related to nourishment needs. Therefore, recommendations toward nourishment at Indianola Beach are conservative and based on the identification of trends over several annual surveys and possibly deferred if the preceding survey period did not correspond to a period preceded by similar seasonal forcing conditions. In general, summer forcing with winds directed out of the southeast results in accretion along the north end of each beach cell. In contrast, winter forcing directed out of the north-to-north west results in accretion at the south end of the beach. The mid-point of each beach cell has been relatively stable despite differences in the direction of forcing and serves as a pivotal point in seasonal transition of sediment transport.

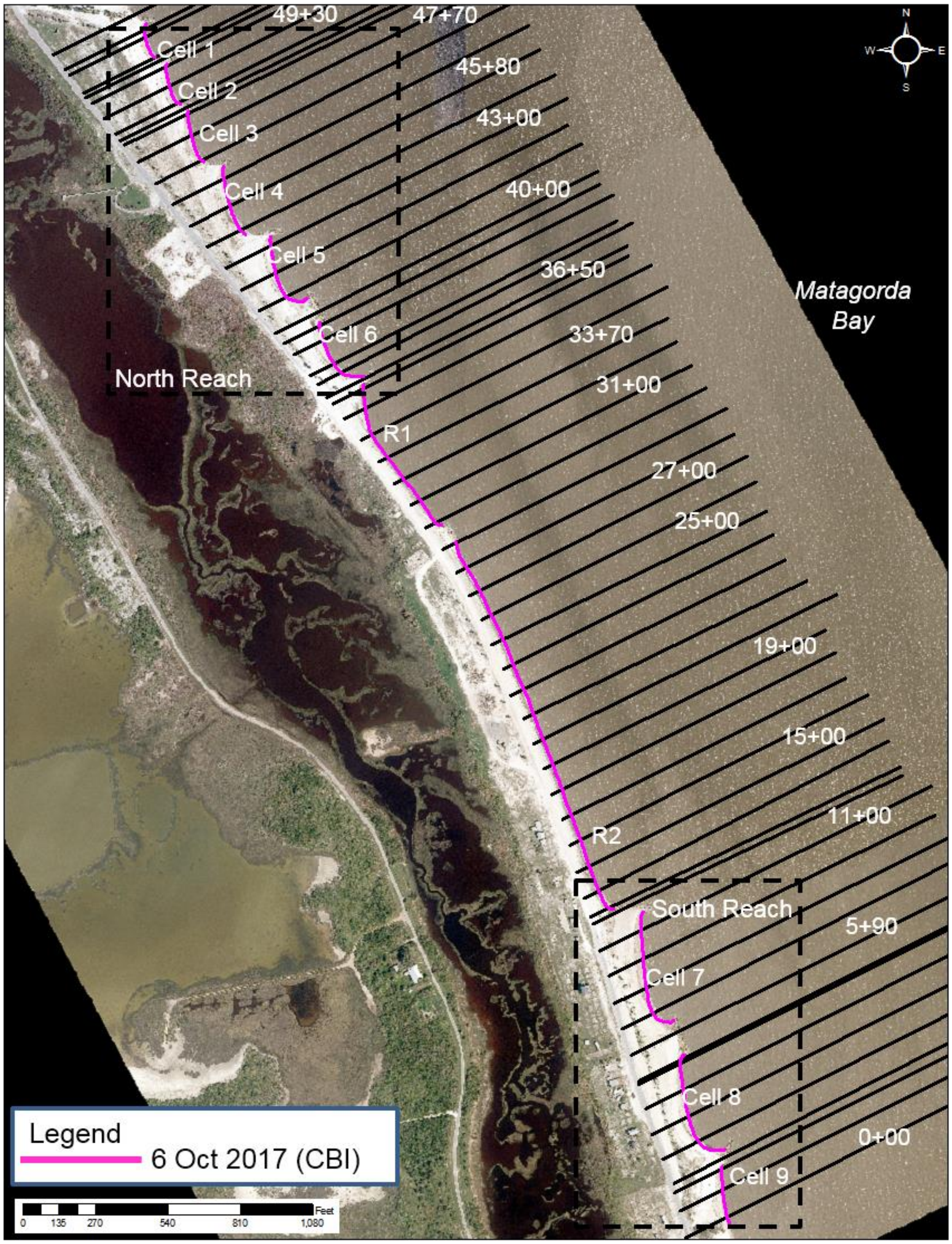


Figure 1827. 2017 Shoreline position relative to orientation and location of beach cells and survey transect locations at Indianola Beach

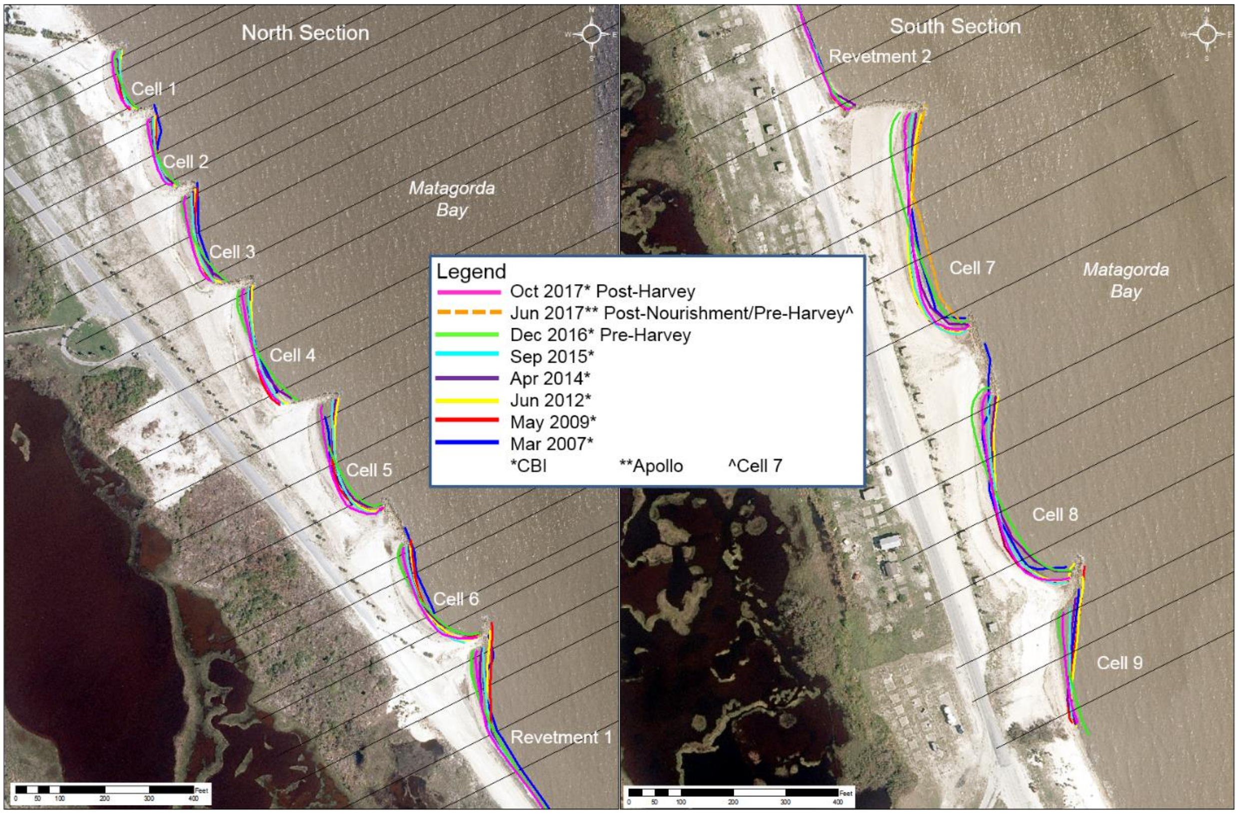


Figure 128. In response to onshore forcing during Hurricane Harvey, shoreline recession dominated in Cells 1-9

During Hurricane Harvey, onshore forcing and water levels in excess of 6.5 ft above MHHW accompanied the storm with water levels of 1-2 ft above MHHW persisting between Harvey and the Oct 2017 survey (Fig 129). Water level was measured at the NOAA station located 15 miles to the north at Port Lavaca. Along the North Reach, the force of the surge, driven by onshore winds in excess of 25 m/s (Fig 130) redistributed sediment beyond the typical backshore limit toward the upland along Cells 1-4 (Figs 131 and 132). The storm surge resulted in the breach of N. Ocean Dr. from the south end of Cell 6 along the revetment to Cell 7. Interpretation of aerial imagery taken 09 Sep 2017 indicated that sediment was deposited on N. Ocean Dr. along the majority of the road adjacent to the low revetment (Maximum Elevation = 4.0 ft NAVD88). Evidence of the extent of the breach is indicated by the deposition on the road and landward of the road that is evident south of Cell 6 in post-storm aerial imagery (Fig. 133). The elevation of the area landward of Cells 1-3 ranges from 7 to 9 ft (NAVD88) therefore landward deposition was limited at the upland boundary. Sediment deposited on the road, toward the landward limit of the beach cells and south of Cell 6 and Cell 8 was reclaimed and mechanically redistributed along the damaged backshore of the beach cells as post-Harvey road recovery was underway. The material was variable in composition and included sand, whole shell, and shell hash that is typical of native beaches in the area. The higher than typical berm features that are evident in the beach profiles (Cells 4-6) were not directly due to storm forcing but a result of mechanical placement of reclaimed sediment covering the roadway after Harvey that was part of a larger maintenance operation for public safety. These berm-like features are noted in the photo compilation, beach profile plots and reporting. The significance of these observations is that the rate of erosion and net volume loss reported for the beach cells where temporary stockpile berms were identified may under estimate the actual losses sustained during Harvey.

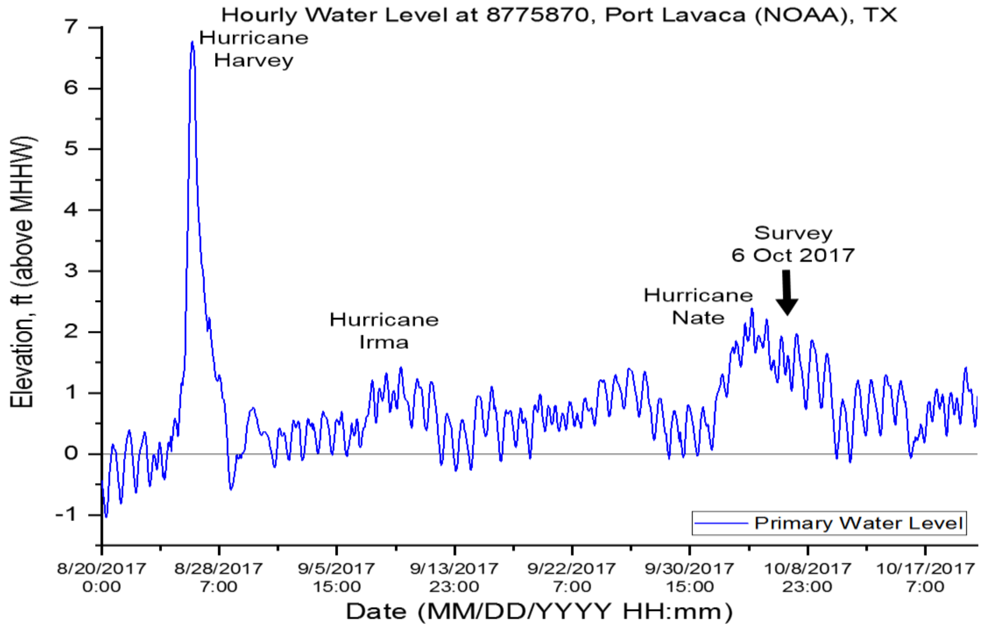


Figure 129. Persistence of water levels in excess of MHHW by up to 7 ft at Port Lavaca, Texas located 15 mi north of Indianola Beach

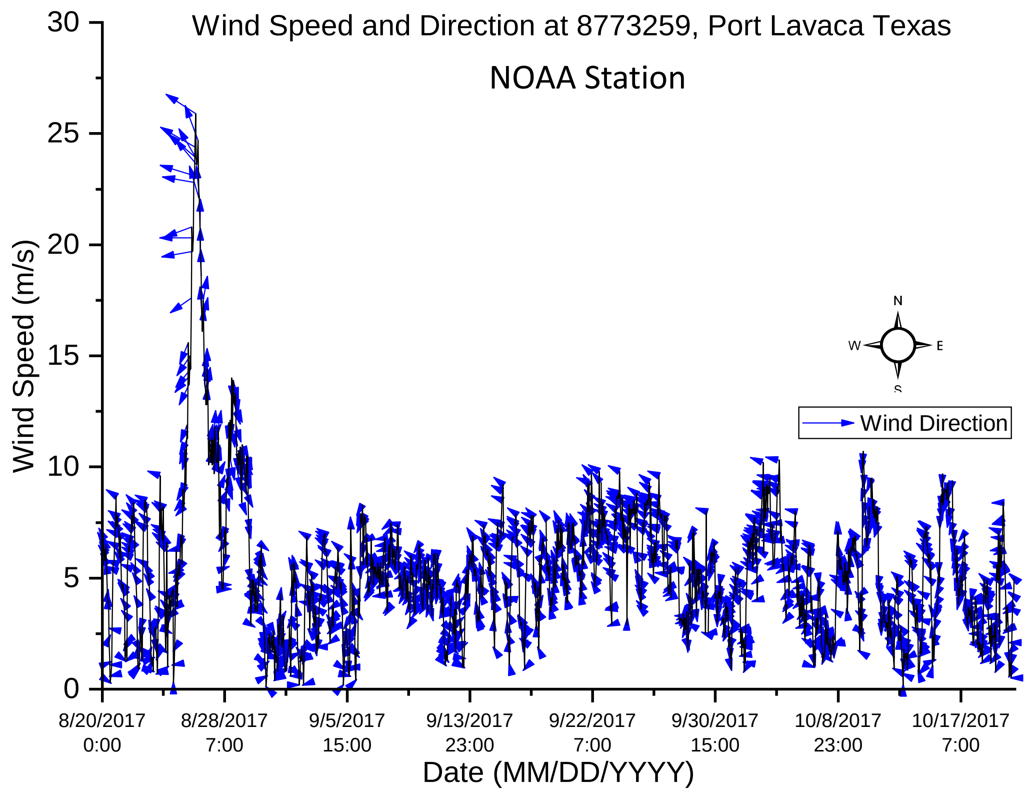


Figure 130. Wind speeds up to 25 m/s were directed out of the east and east-southeast as water level increased during approach of Hurricane Harvey

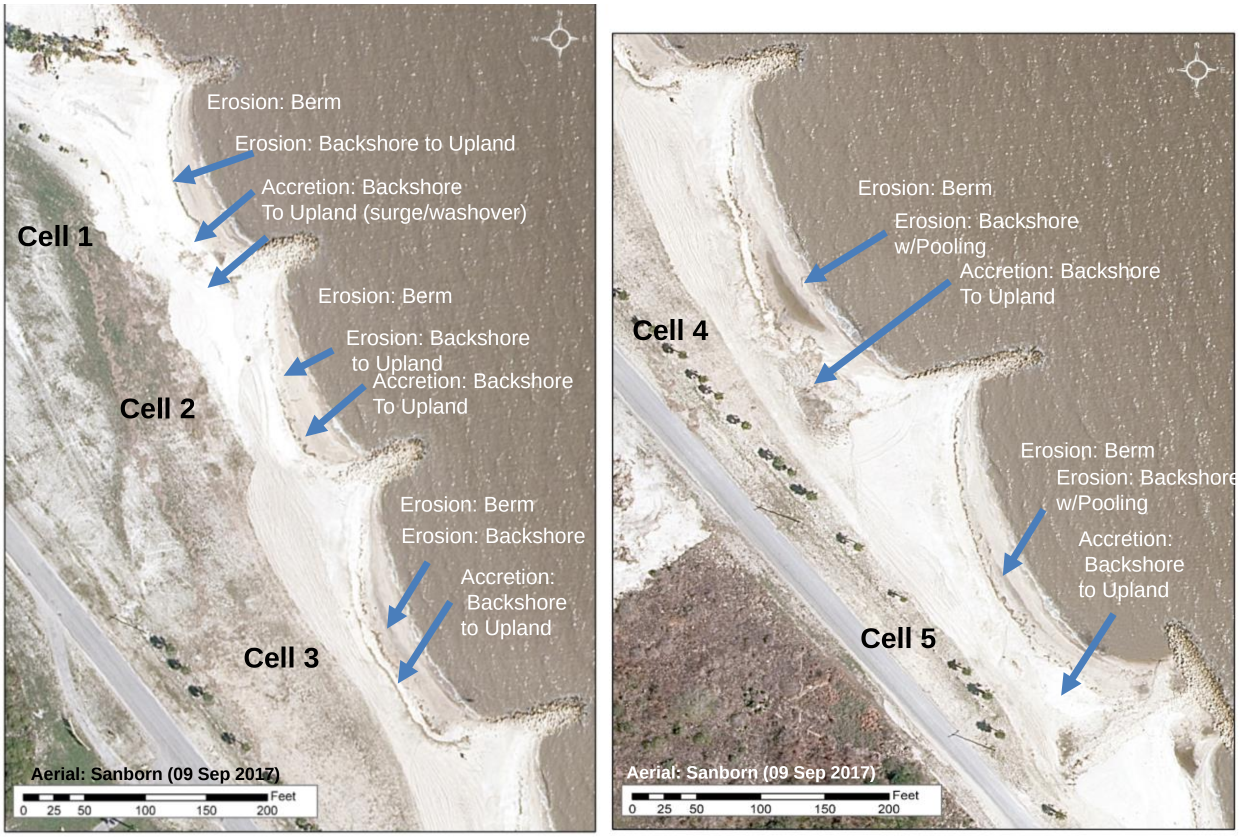


Figure 131. Focus of erosion and backshore deposition after Harvey along the North Reach (Cells 1-5)

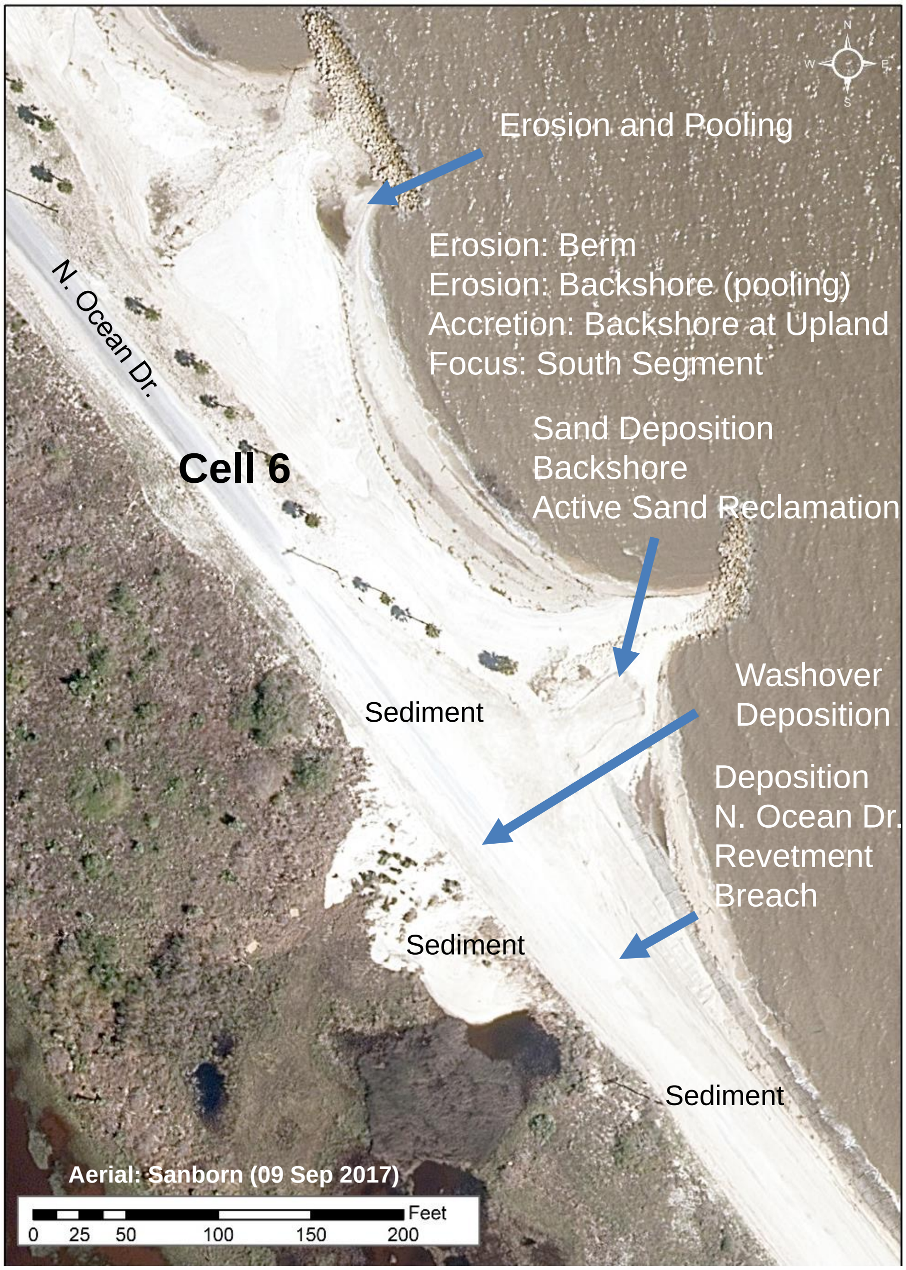


Figure 132. Focus of erosion as well as deposition across the backshore, upland and roadway during Harvey storm surge

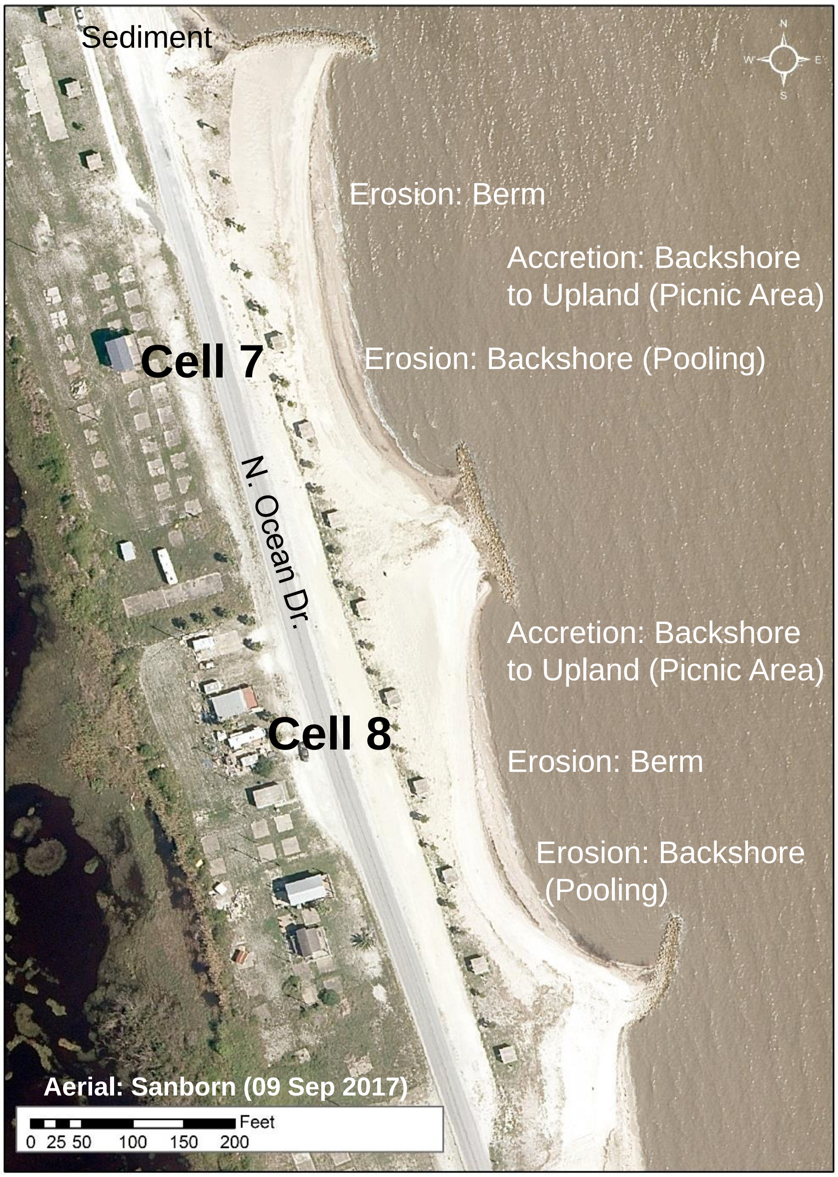


Figure 133. Erosion across berm and backshore with accretion at backshore limit and upland boundary in Cells 7 and 8

Shoreline Analysis: Indianola Beach

Shoreline change, measured during early spring, summer and early in the winter season between 2007 and 2016, has provided insight into the rapid seasonal changes that occur at Indianola Beach relative to reversals in wind and onshore forcing. The survey conducted within one months of Hurricane Harvey provided insight into episodic response of Indianola Beach during a period of both water levels in excess of 6.5 ft MHHW and onshore forcing. The previous reporting period (Dec 2016) provided insight into shoreline change driven by the first few months of winter forcing. Wind is persistently directed out of the east and southeast at Indianola Beach, driving sediment transport predominantly toward the north end of each beach cell from spring to fall. Periodic wind reversals due to frontal systems moving off the coast from late fall to early spring, force sediment transport toward the south in successive pulses over the course of the winter season. The Dec 2016 survey captured the transition from the summer shoreline orientation to the winter shoreline orientation, effectively approaching the winter seasonal reversal in orientation. Such reversals in shoreline orientation are evident over short temporal periods due to the small size of the beaches and due to the limitations on sediment transport imposed by the terminal groins as well as near reversal in forcing. The comparison of seasonal shoreline positions to date provides an envelope of change (maximum and minimum) that can be expected at Indianola Beach. This envelope of change provides for a better understanding of conditions that can be anticipated in the future and can be applied to identify outlier assessment periods. These outlier periods may indicate transition rather than a change in overall trend that could otherwise trigger nourishment planning. Identifying transitions in sediment transport as opposed to longer-term trends will support successful nourishment planning. Without adherence to a seasonal survey schedule, shoreline analysis is a less effective tool for assessment and falls secondary to volume analysis.

Hurricane Harvey arrived at the end of the summer season when the seasonal shoreline position would typically be at its most advanced or seaward on the north end of each beach cell and the most recessed or landward at the south end. The direction of forcing during Harvey, as wind strength and water level reached a peak on Aug 00 2017, was out of the east/northeast as the wind speed rapidly increased. The wind was directed out of the east to southeast at peak speed. This direction of forcing ranged from onshore to side-onshore at Indianola Beach. Onshore-directed winds combined with increasing water level of this magnitude increased the fraction of sediment transport associated with the cross-shore component. The alongshore component was likely a factor during the period prior to or after waters subsided to within the range normally acting over the berm.

Recession dominated along the south end of each beach cell after Harvey, with limited advance along the north end in Cells 3, 4, 6, and 8 (Figs 134-136), while more uniform shoreline recession was documented in Cell 1, 2 and 7 (Fig 134 and 136). Shoreline advance observed along the north end of these beach cells may not have been attributable to Harvey, but rather an artifact of summer forcing that preceded the storm. Rather, it is more likely that erosion also occurred to some degree on the north end as evidenced in Cell 7 and in Cell 1. This hypothesis is based on the change in shoreline position measured in Cell 7 where the nourishment was completed just two months prior to the storm and was therefore not influenced by an entire season of summer forcing. In Cell 7 shoreline recession dominated along the entire beach cell, although the greatest recession was along the south end (Fig 136). In the past, shoreline change within the series of beach cells followed the same general trend resulting in similar shoreline planform shape for any one season. Therefore, it is likely that accretion dominated at the north end over the summer period in advance of Harvey, and that the peak signature summer orientation was eliminated, or reduced during Harvey. Although recession dominated along each of the eight beach cells, Cell 7 was selected for the initial discussion because the change under forcing associated with Harvey was clearly defined due to the brief interval between completion of the nourishment (Jun 2017) and the forcing during Harvey. After Harvey, the shoreline along the south end of Cell 7 approached the maximum landward position measured in 2009, 2012 and 2015, indicating limited benefit of the recent June 2017 nourishment remained on the south end. The shoreline receded up to 35 ft along the south side of Cell 7. The beach receded 20 ft at the former location of the pivotal mid-section of the beach, with the segment of least change, shifting toward the north some 65 ft. At the north end, recession moderated slightly in comparison to the south end with landward shift in shoreline position of 20 to 30 ft. The result was nearly uniform recession from north to south that is characteristic of cross-shore episodic erosion due to storm surge. Although Cell 1 was not nourished prior to Harvey, the change in shoreline position was very similar to that observed in Cell 7. The shoreline receded approximately 10 to 15 ft along the southern segment and 5 to 10 ft along the northern segment. Because recession was uncharacteristically uniform alongshore, there was no pivotal mid-point of null change at center beach that has been well developed in all past surveys. In the remaining beach cells only Cell 2, 3 and 5 demonstrated variable and limited indication of shoreline advance at the north end of the beach further reinforcing the hypothesis that onshore forcing was the primary agent of sediment transport during Harvey. Shoreline recession dominated at the south end and advance at the north end in the remaining two beach cells (Cell 6 and 8). The magnitude of the offshore position after the surge during Harvey indicates that the offshore position of the shoreline was likely at the summer peak prior to Harvey.

Over previous monitoring intervals (2007-2016) the average rate of shoreline position change in each cell was relatively low (Table 1). The average annual rate of shoreline position change for the suite of cells over the current reporting period (2016-2017) was the highest of record at -10.4 ft/yr due to the influence of Hurricane Harvey. In the past, the average rate for the suite of cells has ranged from +1.3 ft/yr (2012-2014) to -1.7 ft/yr (2015-2016) with the variability influenced by differences in survey season. Between Dec 2016 and Oct 2017, the highest rate of recession was identified in Cell 1 and Cell 5 (-12.3 ft/yr, and -18 ft/yr, respectively) and the lowest rate was in Cell 6 (-6.1 ft/yr). Cell 7 was assessed independently due to the fill placement that was completed within two months of Hurricane Harvey and the short assessment interval (Jun 2016 to Oct 2017). The monthly rate of recession in Cell 7 was -6.5 ft/month with an event rate ranging from -13.0 ft/event (26 Aug 2017) to -26.0 ft/event (06 Oct 2017). The range in the event rate is an estimate of the recession directly associated with Harvey over the period from 26 Aug 2017 to 06 Oct 2017.

As evident by the variability in rate of shoreline position change and volume change, despite the close proximity of adjacent cells, each cell appears to function, for the most part, independently with limited sediment exchange under typical conditions. Opportunity for exchange is limited to peak periods in seasonal alongshore sediment transport (end of summer season, end of winter season) when sediment reaches maximum capacity of the groins, or as demonstrated during Harvey, under the forcing of surge events and associated mechanical redistribution of sand within the beach cells.

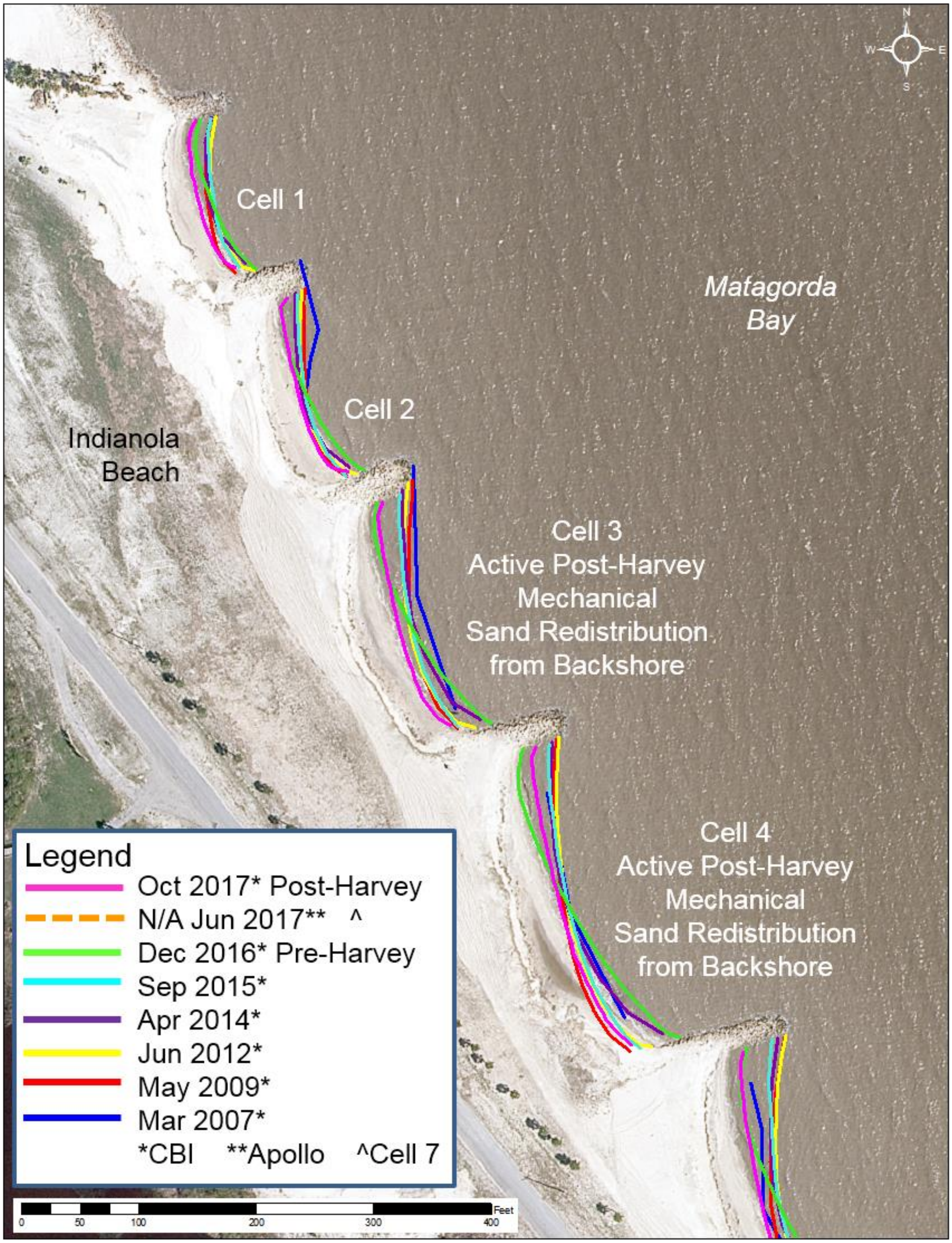


Figure 134. After Harvey (Oct 2017) the most uniform shoreline recession since 2007 was documented along the beach from north to south in Cells 1-4 (Post-Harvey 2017)

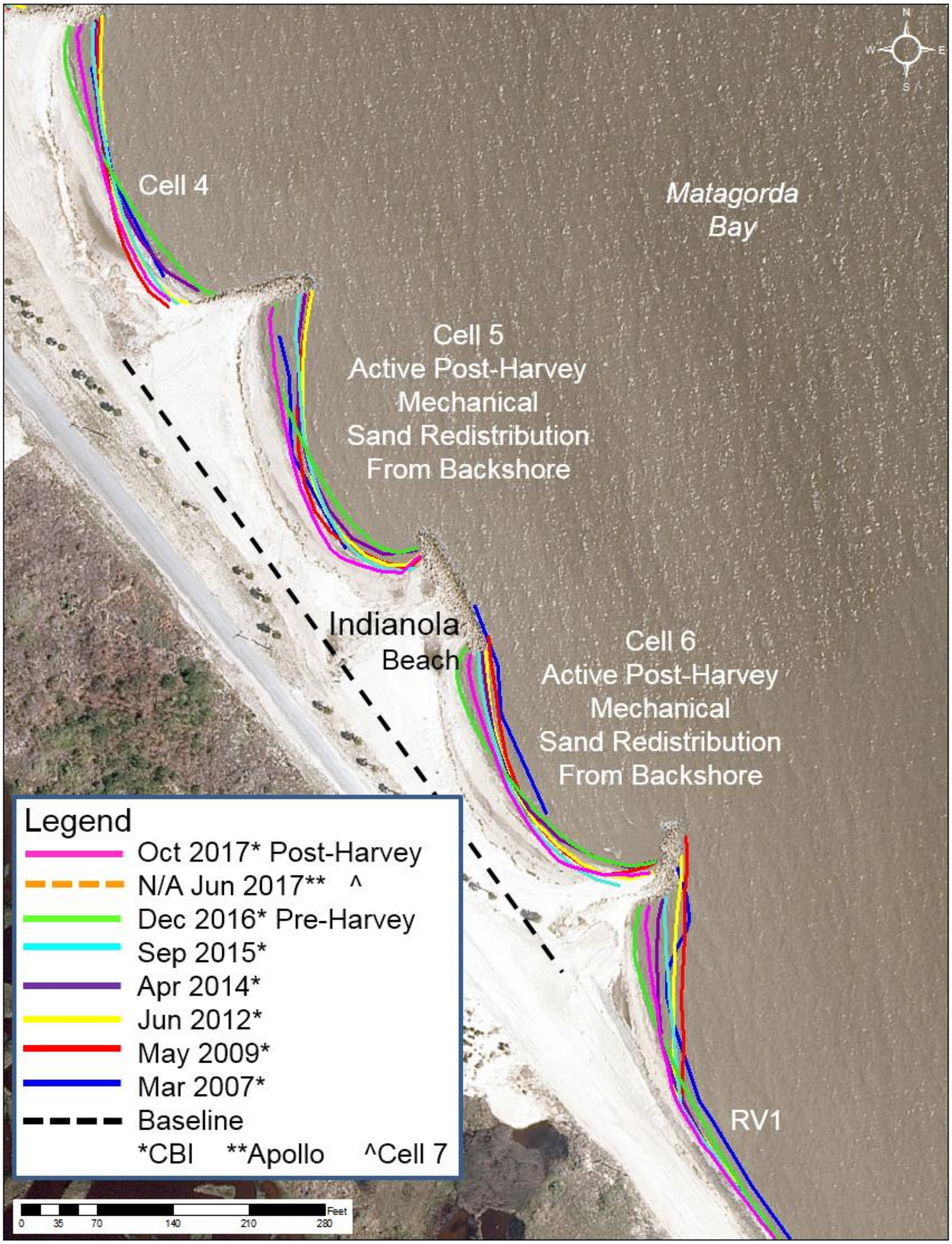


Figure 135. After Harvey (Oct 2017), the most uniform shoreline recession since 2007 was documented along the beach from north to south in Cells 5 and 6

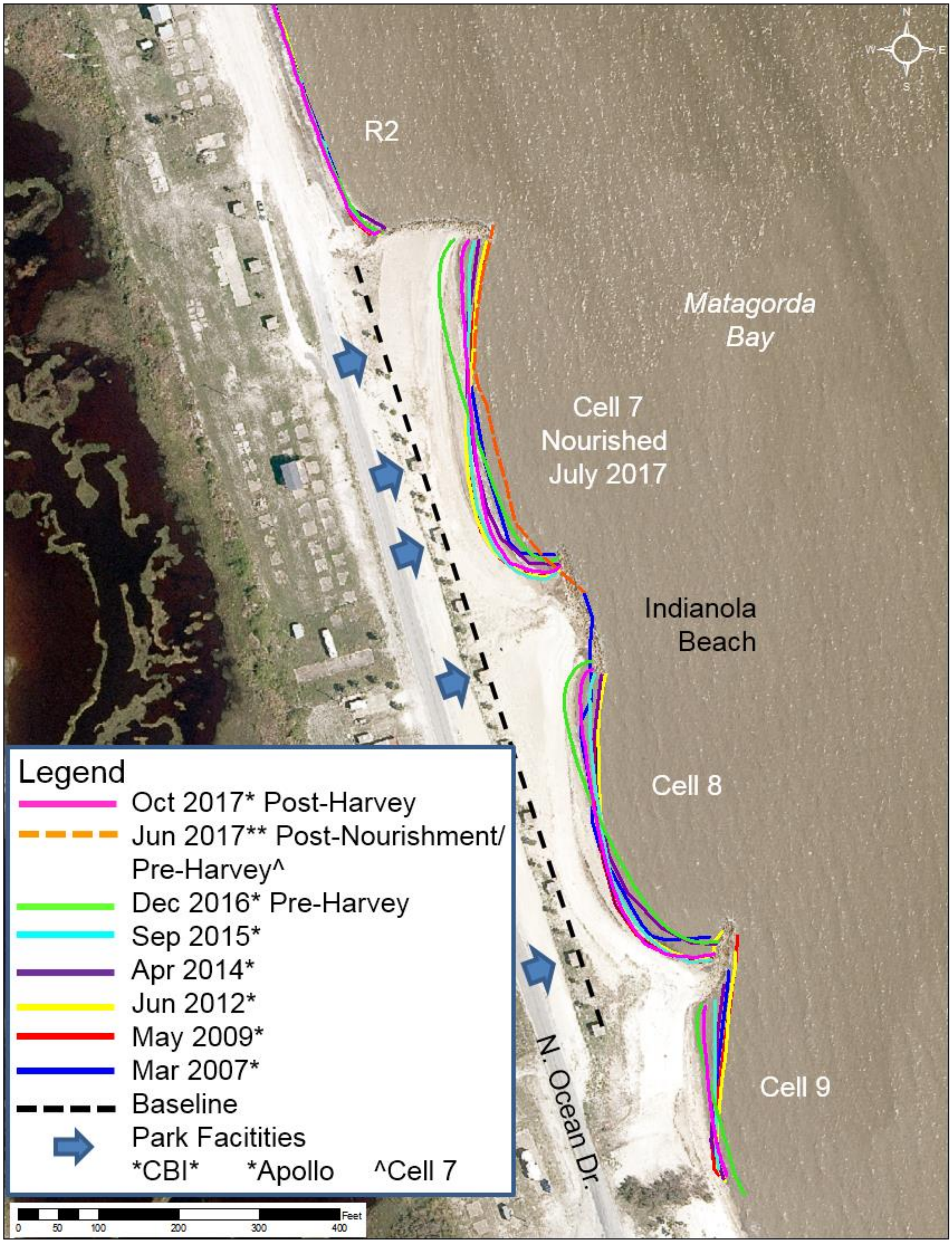


Figure 136. After Harvey (2017) the most uniform shoreline recession since 2007 was observed along the beach from north to south in Cells 7 and 8

Table 1. Variability in Rate of Shoreline Position Change: Indianola Beach Cells 1-9 2017

Location NW to SE	Interval (yr)	Avg. Rate of Change (ft/yr)		Max Change (ft)	
Cell 1		**+ Advance**	**- Recession**	**-Recession**	**+Advance**
Post-Harvey	2016-2017		-12.3	-15	0
Annual 2016	2015-2016		-1.7	-11	+8
Full Study Period	2007-2016		-1.2	-11	+2
Annual (2015)	2014-2015		-0.9	-26	+11
Biennial	2012-2014 (Apr)		-0.6	-6	+5
Triennial	2009-2012	+1.7		0	+10
Influence Ike	2007-2009		-2.4	-33	+11
Cell 2					
Post-Harvey	2016-2017		-8.4	-17	+1.0
Annual (2016)	2015-2016		-0.3	-14	+14
Full Study Period	2007-2017 Offseason		-1.3	-30	+6
Annual (2015)	2014-2015		-0.4	-26	+15
Biennial	2012-2014 (Apr)		-0.5	-6	+5
Triennial	2009-2012		-0.4	-4	+6
Influence Ike	2007-2009		-2.9	-16	0
Cell 3					
Post-Harvey	2016-2017		-11.7	-28	+5
Annual 2016	2015-2016		-1.7	-22	+23
Full Study Period	2007-2017 Offseason		-2.3	-36	+16
Annual (2015)	2014-2015		-2.6	-41	+9
Biennial	2012-2014 (Apr)	+2.6		-4	+15
Triennial	2009-2012		-0.7	-5	+5.0
Influence Ike	2007-2009		-4.8	-18	0
Cell 4					
Post-Harvey	2016-2017		-8.5	-31	+14
Annual 2016	2015-2016		-0.1	-27	29
Full Study Period	2007-2017 Offseason		-1.0	-23	+24
Annual (2015)	2014-2015		-2.7	-37	+10
Biennial	2012-2014 (Apr)	+1.4		-6	+24
Triennial	2009-2012	+1.7		0	+11
Influence Ike	2007-2009		-3.3	-25	+15
Cell 5					
Post-Harvey	2016-2017		-18.0	-37	+2
Annual 2016	2015-2016		-1.6	-29	+35
Full Study Period	2007-2016		-1.0	-12	+24
Annual (2015)	2014-2015		-2.5	-32	+9
Biennial	2012-2014 (Apr)	+0.2		-20	+35
Triennial	2009-2012	+1.4		-2	+9
Post-Ike	2007-2009	+2.5		-8	+34
Cell 6					
Post-Harvey	2016-2017		-6.1	-21	+15
Annual 2016	2015-2016	+2.0		-24	+29
Full Study Period	2007-2017 Offseason		-2.0	-42	0
Annual (2015)	2014-2015		-6.4	-34	+11
Biennial	2012-2014 (Apr)	+1.8		-5	+22
Triennial	2009-2012		-1.0	-18	+1
Influence Ike	2007-2009		-5.5	-25	1
Cell 7					
Post-Harvey and Post-Nourishment	Jun2017-Oct2017		-6.5ft/month (-13ft/event)	-46	+4
Annual 2016	2015-2016		-4.4	-37	+34
Full Study Period	2007-2017 Off Season		-0.9	-25	0
Annual (2015)	2014-2015		-3.2	-24	+10
Biennial	2012-2014 (Apr)	+2.6		-16	+21
Triennial	2009-2012		-0.2	-5	+5

Influence Ike	2007-2009		-4.9	-23	1

Table 1. Continued

Variability in Rate of Shoreline Position Change: Indianola Beach Cells 1-9 2017

Location NW to SE	**Interval (yr)**	**Avg. Rate of Change (ft/yr)**		**Max Change (ft)**	
Cell 1	**Date**	**+ Advance**	**- Recession**	**-Recession**	**+Advance**
Cell 8					
Post-Harvey	2016-2017		-8.2	-42	24
Annual 2016	2015-2016		-6.0	-38	+30
Full Study Period	2007-2016 Offseason		-0.5	-37	+43
Annual (2015)	2014-2015		-4.64	-37	+1
Full Study Period	2007-2015	0	0	-43	+14
Biennial	2012-2014 (Apr)	+3.0		-8	+29
Triennial	2009-2012	+1.7		0	+10
Influence Ike	2007-2009		-0.9	-34	+50
Cell 9					
Post-Harvey	2016-2017		-2.6	-13	+9
Annual 2016	2015-2016		-2.2	-23	+24
Full Study Period	2007-2016		-0.8	-33	+15
Annual (2015)	2014-2015		-0.7	-8	0
Biennial	2012-2014 (Apr)		-3.8	-12	+3
Triennial	2009-2012	+0.9		-1	+7
Biennial	2007-2009	+0.5		-8	+7

Average Rate of Change in Shoreline over Intervals of interest: Indianola Beach (ft/yr)

Average Cell 1-8 2007-2009	**Average Cell 1-8 2009-2012**	**Average Cell 1-8 2012-2014**	**Average Cell 1-8 2014-2015**	**Average Cell 1-8 2007-2016**	**Average Cell 1-8 2015-2016**	**Average Cell 1-8 Pre/Post Harvey Excluding Cell 7**
-2.2	+0.5	+1.3	-2.9	-0.6	-1.7	-10.4

Beach Width: Indianola Beach

The average beach width of all cells decreased after Hurricane Harvey. The most significant decrease in beach width was focused along the southern section of each cell. Of the eight beach cells at Indianola three (Cell 1-3) met the Action Width criteria along 100% of the beach and a fourth (Cell 4) was at Action Width along 75% of the beach during Oct 2017. The beach along the southern side of Cells 1-4 was under the Action Width by 15 to 35 ft. Beach Cells 5-8 were in excess of Action Width (35 ft) but under Target Width (70 ft). The beaches in the four remaining cells located further south were at Target width only on the north end but well under Target Width along 75% of the beach cell from center beach southward. Beach width was calculated for each individual beach cell due to their relative independence (Table 2). Rather than applying an average width, the beach width was measured at the intersection of each transect location and at locations between transects that reflected a minimum beach width to better represent the character of the small beach cells. The Target Width at Indianola is 70 ft MHHW, based on the URS report (2001) stating a design width of 75 ft (MLLW) and the associated Action Width is 35 ft. The difference in applied Target Width is due to differences in determination of the backshore limit and was influenced by the offshore limit of the groins.

Based upon the Action Width criteria, Cells 1-4 continued to qualify as Tier 1 recommended nourishment locations (Table 2) during 2017. The width of the beach in Cells 1-4 has consistently met the Action Width criteria since 2007. Beach Cells 5-8 did not meet the Action Width criteria for nourishment during 2017 but due to erosion that extended up to park infrastructure and shoreline recession that occurred during Harvey, nourishment is recommended in order to stabilize the beach and increase the elevation to protect the backshore infrastructure and support project longevity. The shoreline along recently nourished Cell 7, along with Cell 8, have significant backshore park infrastructure and are in close proximity to N. Ocean Drive. Cell 7 experienced focused recession along the south side to the point where this cell was recommended for focused nourishment during 2015. The narrow width of the beach along the southern segment in Cell 7 after Harvey indicates that no benefit of the June 2017 nourishment remained at the south end.

Table 2. Beach Width: Indianola Beach 2017 (Post-Harvey)
Action Width = 35 ft Target Width = 70 ft
Indicates at or within 5 ft of Action Width
Note: Stations are approximately located at N, Center and S in most Cells
Minimum Width are provided as applicable

Cell #	2007	2009	2012	April 2014	May 2014	Sep 2015	Dec 2016	Oct 2017	
	Width on Station								
Cell 1									
North (N) 49+3	29	38	45	35	26	37	26	22	
Center (C) 49+0	19	23	26	25	20	28	22	12	
South (S) 48+2	39	12	22	25	43	19	28	16	
Min. Width (ft)	19(C) 20(S)	17(C) 9(S)	20(C) 15(S)	17(C) 16(S)	20(C) 34(S)	20(C) 15(S)	20(C) 20(S)	8 (C) 6 (S)	
Cell 2									
North (N) 47+7	64	56	56	50	38	52	38	38	
Center (C) 47+0	26	24	24	22	21	27	25	18	
South (S) 46+3	32	23	23	30	48	23	35	17	
Min. Width (ft)	20(C) 25(S)	19(C) 18(S)	19(C) 18(S)	17(C) 19(S)	21(C) 24(S)	20(C) 18(S)	25(C) 29(S)	15 (SC) 14 (S)	
Cell 3									
North (N) 45+8	73	70	64	60	48	57	33	36	
Center (C) 45+0	37	29	26	29	24	26	20	15	
South (S) 44+0	24	14	18	27	42	16	37	5	
Min. Width (ft)	34 (C) 26 (S)	18(C) 11(S)	11(C) 20(S)	23(C) 23(S)	20(C) 21(S)	13(C) 16(S)	20(C) 26(S)	10 (C) 5 (S)	
Cell 4									
North (N) 43+0	61	67	69	63	54	63	38	51	
Center (C) 42+0	32	26	30	30	31	33	36	24	
South (S) 41+0	32	13	24	37	48	23	49	19	
Min. Width (ft)	30(C) 32(S)	16(C) 11(S)	24(C) 20(S)	27(C) 28(S)	28(C) 37(S)	24(C) 21(S)	32(C) 37(S)	18 (C) 16 (S)	
Cell 5									
North (N) 40+0	97	123	125	118	107	116	87	87	
Center (C) 39+0	57	63	71	69	70	70	70	57	
South (S) 38+0	58	61	64	70	85	62	78	48	
Min. Width (ft)	57(C) 57(S)	49(C) 53(S)	56(C) 61(S)	61(C) 67(S)	66(C) 73(S)	57(C) 60(S)	69(C) 70(S)	48 (C) 45 (S)	
Cell 6									
North (N) 36+5	116	112	107	103	88	100	76	89	
Center (C) 36+0	88	84	78	79	68	75	62	69	
(CS) 35+0	65	53	52	54	59	47	60	46	
South (S) 34+6	73	55	57	64	76	51	67	46	
Min. Width (ft)	65(C) 67(S)	53(C) 52(S)	52(C) 59(S)	54(C) 53(S)	55(C) 59(S)	49(C) 44(S)	56(C) 57(S)	50 (C) 42 (S)	
Cell 7								Jun 2017	Oct 2017
North (N) 11+0	111	124	124	116	101	113	73	133	102
Center (C) 10+0	79	75	80	75	77	75	62	102	79
(CS) 9+0	67	46	42	53	56	46	68	91	54
South (S) 8+0	64	42	42	59	63	44	73	88	50
Min. Width (ft)	75(C) 64(S)	59(C) 32(S)	61(C) 33(S)	68(C) 49(S)	63(C) 51(S)	46(C) 40(S)	63(N) 65(S)	N/A	48 (C) 45 (S)
Cell 8									
North (N) 5+9	104	119	122	117	93	103	68	90	
Center (C) 5+0	69	81	83	78	76	76	62	69	
(CS) 4+0	55	54	57	61	65	60	70	57	
South (S) 3+6	75	62	71	91	97	70	94	64	
Min. Width (ft)	64(C) 49(S)	63(C) 49(S)	65(C) 57(S)	65(C) 61(S)	70(C) 65(S)	70(C) 60(S)	60(N) 70(S)	56 (C) 57 (S)	

Volumetric Analysis: Indianola Beach

Although shoreline change has been highly variable between seasonally distinct surveys, overall, the annual net volume change within each beach cell has been relatively low (2007-2016). The two exceptions are after Harvey and between 2014 and 2015, a period of active tropical weather along the Texas coast. Accretion dominated at a negligible rate at Indianola beach over the previous reporting period (Sep 2015 and Dec 2016). Due to the confined nature of each beach cell, volume change was calculated individually and is provided in Table 3 along with cumulative values for the suite of cells.

A large volume of sediment was redistributed beyond the defined backshore limit of the beach cells, breaching N. Ocean Dr. along the south end of the North Reach during Harvey. Evidence of the breach of N. Ocean Dr. was more prevalent along the North Reach than the South Reach due to the low elevation of the backshore along Cells 4-6 and along the low-elevation revetment. Sediment deposited on the roadway during the storm was mechanically removed to restore usage with continued evidence of redistribution to the nearest beach cells during the October 2017 survey. Therefore, the estimated magnitude of volume change was considered conservative along the North Reach as the source of sand that was ultimately placed on the individual beach cells was attributable to the larger littoral system. In addition, it is unknown if sand placement continued after the October placement and therefore the 2018 survey will be applied to verify nourishment requirements.

As anticipated, accretion was generally greater in the larger beach cells (Cell 5, 7 and 8) than the smaller beach cells (Cell 1-4). The exception was Cell 6 that had a relatively low net accretion rate of 250 cu yd between 2016 and 2017. The low rate of accretion in Cell 6 may have been the result of preferential mechanical redistribution of sediment to Cell 6 as the road was cleared of sand after flooding. In the remaining beach cells, the net volume loss ranged from -600 cu yd (Cell 8) to -900 cu yd (Cell 7) in the larger cells and from -140 cu yd (Cell 4) to -330 cu yd (Cell 1) in the smaller cells. The larger volume loss in Cell 7 may be related to the increase in volume available for transport due to the nourishment completed in June 2017.

As described in previous reporting, volume change was calculated from the landward limiting feature, at approximately 4.5 ft (north reach) to 6 ft (south reach), offshore to the first occurrence of -3 to -4 ft which falls between 200 to 300 ft offshore of MHHW. The offshore segment of the beach profile is indicative of a submerged limiting feature overlain by sand along most of the study area. There was limited to no change in the offshore region after Harvey, which supports the presence of the limiting subsurface. Changes in profile morphology in Cells 1-6 indicate that sediment exchange between the nearshore and berm is limited and likely transient in response to storms and seasonal shifts in forcing. It is more likely that there is limited alongshore sediment sharing between the cells over sediment sharing with the nearshore region beyond 350 ft offshore. Significant changes in morphology indicative of sediment exchange were identified from MHHW up to approximately 350-ft offshore. After this point, the beach profile intersects a stable flat raised offshore region that maintains a depth of -3 ft and in some cases increases in elevation before beginning a gradual increase in slope with offshore position. The seaward region up to 1,000 ft offshore remains relatively shallow. The offshore region is deepest along the northern reach with maximum more offshore elevations of between -4 and -5.5 ft. The depth of the offshore limit progressively decreases further toward the south with a maximum of only -3.5 ft observed fronting Cell 7 and Cell 8. The immediate nearshore, up to 200 ft offshore, may function as a transient repository of sand migrating both between the cells and alongshore in general. The narrow beach observed in cells 1-4 has a more limited region of exchange with the nearshore than does the wider beach and nearshore fronting Cells 7 and 8.

Table 3. Net Volume Change: Indianola Beach (Cells 1-8) 2017									
Annual Net Volume Change (cu yd)									
Survey Date	**Cell 1**	**Cell 2**	**Cell 3**	**Cell 4**	**Cell 5**	**Cell 6**	**Cell 7**	**Cell 8**	**Total**
Jun 2017 to Oct 2017 (June Nourishment)	N/A	N/A	N/A	N/A	N/A	N/A	-775	N/A	N/A
Dec 2016 to Oct 2017 Post-Harvey	-330	-240	-200	-140	-900	+250	N/A	-600	-2,935
Sep 2015 to Dec 2016	+108	+112	+67	-4	+132	+322	+749	+558	+2,044
2014 to Sep 2015	-360	-100	-400	-400	-500	-600	-600	-1,100	-4,060
Rate of Volume Change (cy/ft)									**Avg.**
Oct 2017	-2.4	-1.5	-1.0	-0.5	-3.0	+0.8	-1.7	-1.2	-1.3
Dec 2016	-2.6	-0.5	-1.9	-1.3	-1.6	-1.7	-1.2	-2.6	-1.7
Sep 2015	-0.8	-0.7	-0.3	0	-0.4	-1.1	-1.6	-1.1	-0.8

Beach Morphology: Indianola Beach

Changes in morphology in the beach cells at Indianola, were representative of a period of transition due to 1) damage that occurred during Harvey, and in select cells, 2) active sediment placement as N. Ocean Dr. was cleared of sand deposited during the storm. Cell 1, was selected as representative of impact of Hurricane Harvey on Cells 1-4 (Fig 137). Erosion was nearly uniform alongshore and focused at the berm crest and foreshore. Cells 5 and 6 demonstrated the high level of mechanical redistribution of sand recovered from N. Ocean Dr. to the backshore (Figs 138-140). The evidence of the backshore berm placement is clearly defined in the beach profiles located in Cell 5 and 6. The profiles also indicate that in Cells 5 and 6 erosion was greater on the south end of the beach cells between Dec 2016 and Oct 2017. Cell 7 provided the most accurate assessment of the impact of Harvey on the beach (Figs 141 and 142). In the case of Cell 7, the transition included the erosion of the recent fill placement just two months prior to Harvey. Onshore forcing resulted in erosion across the berm and backshore as the water level rose and surged onshore. This resulted in more uniform erosion and a landward shift of the beach profile between the foreshore and upland between the fill placement in June 2017 and the post-Harvey survey (Oct 2017). As at other beaches along the Texas coast, the changes in morphology reflected both evidence of erosion and accretion as sand eroding from the berm was redeposited across the backshore and upland as water levels rose and as combined with onshore forcing.

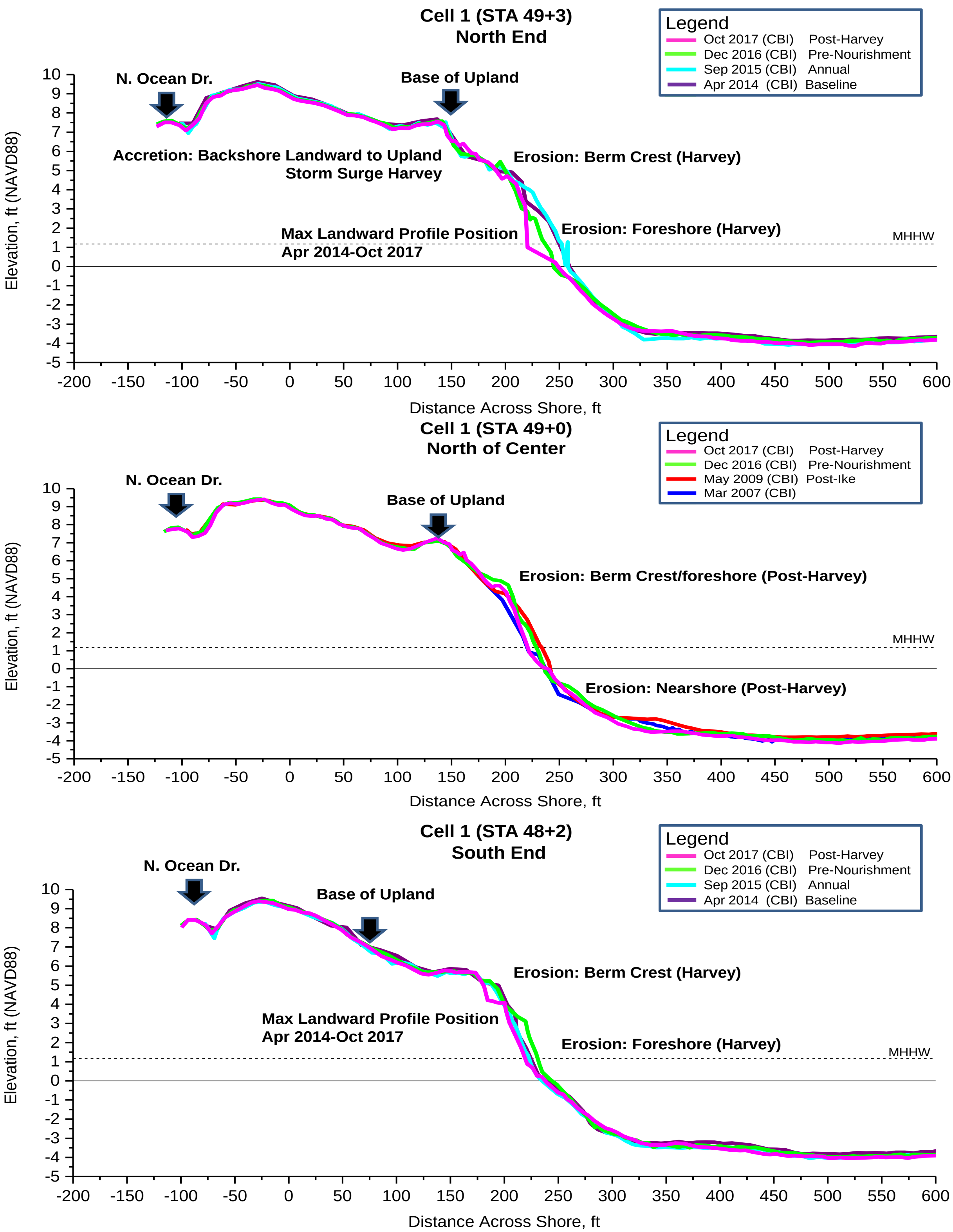


Figure 19. Cell 1: Erosion clearly dominated across the backshore, berm and foreshore after Harvey. Cell 2 demonstrated a similar trend but erosion at north end was not as well developed

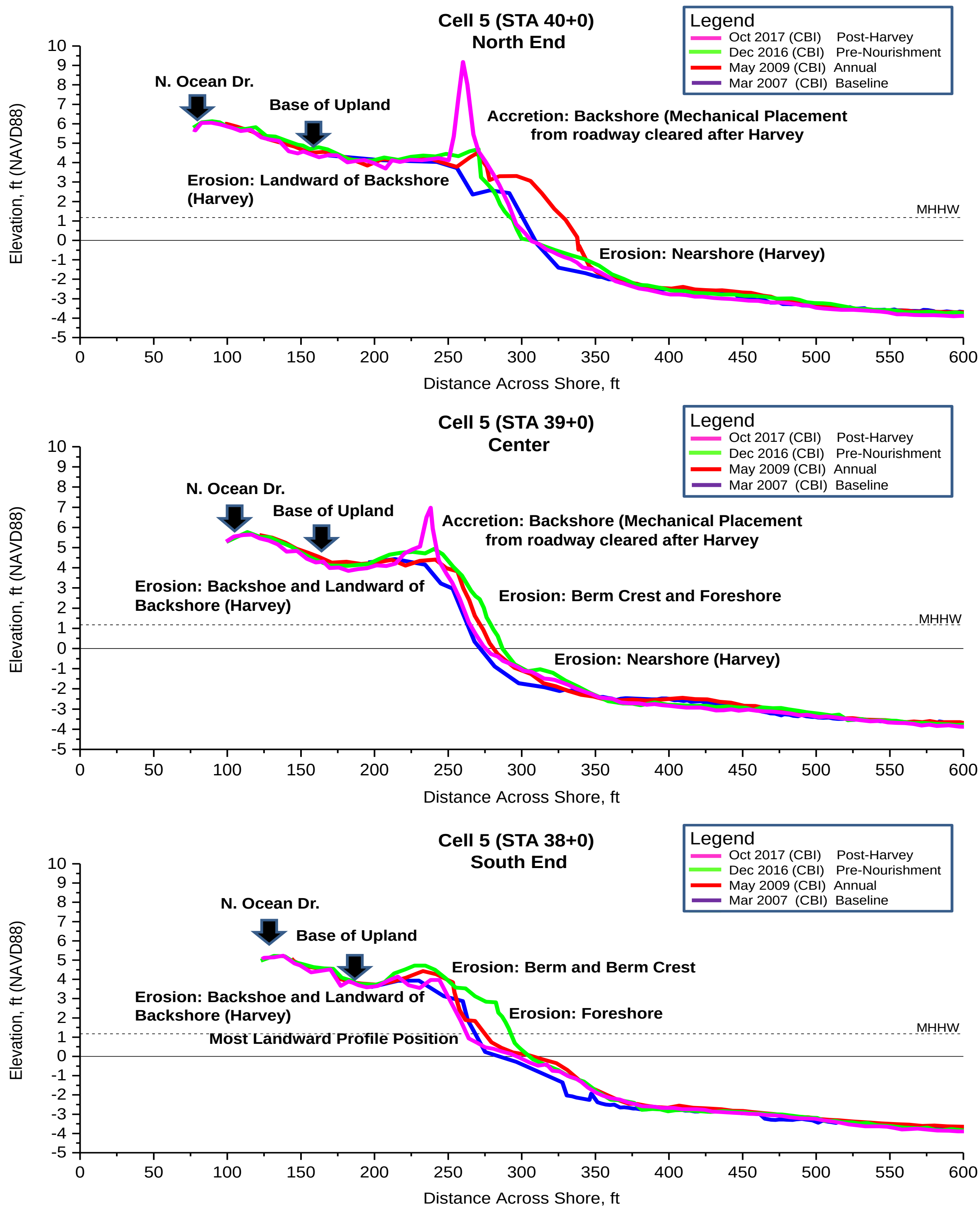


Figure 138. Cell 5: Erosion dominated from center beach to the south end and was focused across the berm and foreshore. Accretion across the backshore was due to mechanical placement of sediment that covered the road after Harvey. Limited accretion at the north end may be attributed to mechanical redistribution of sand rather than deposition during Harvey.

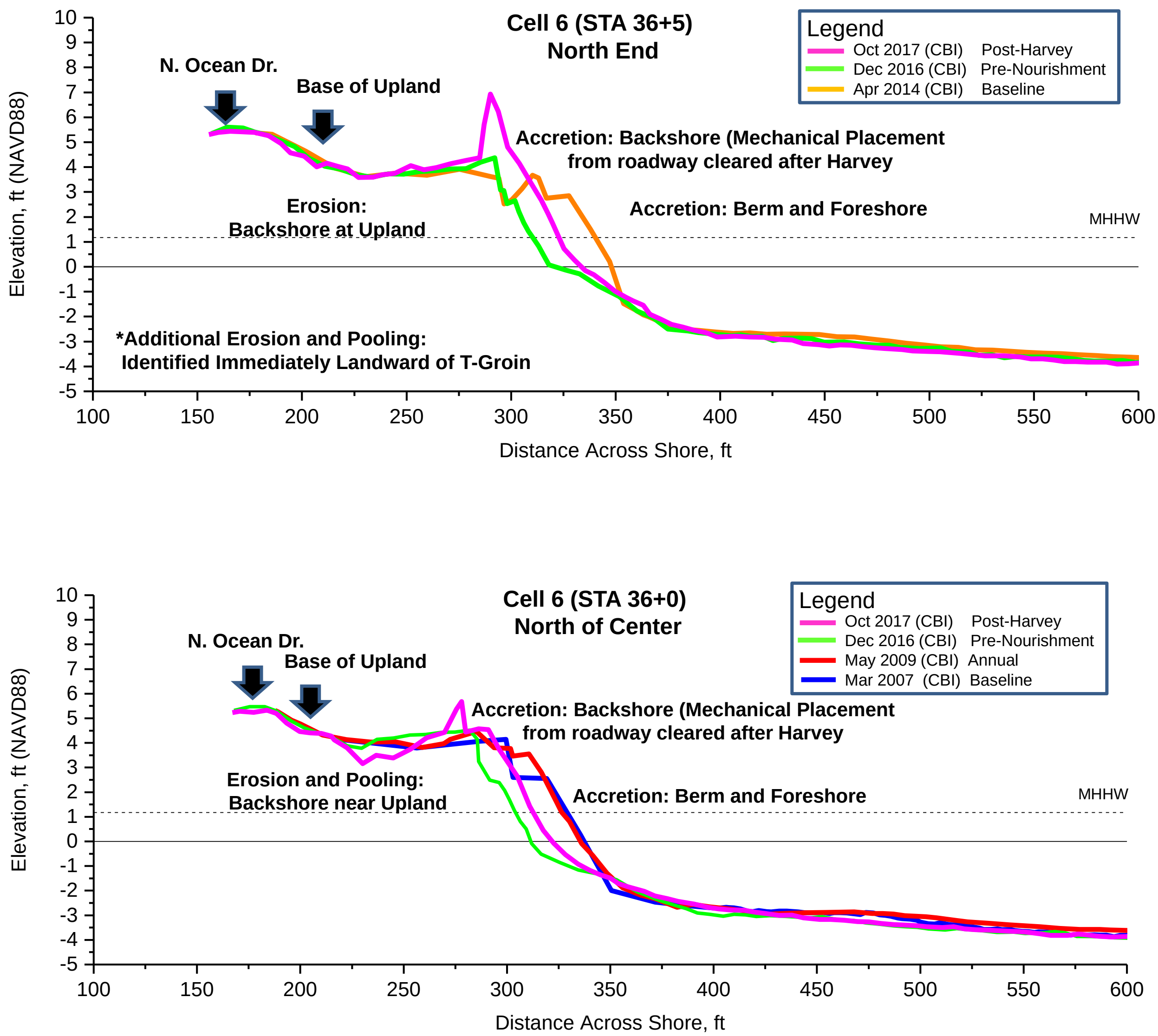
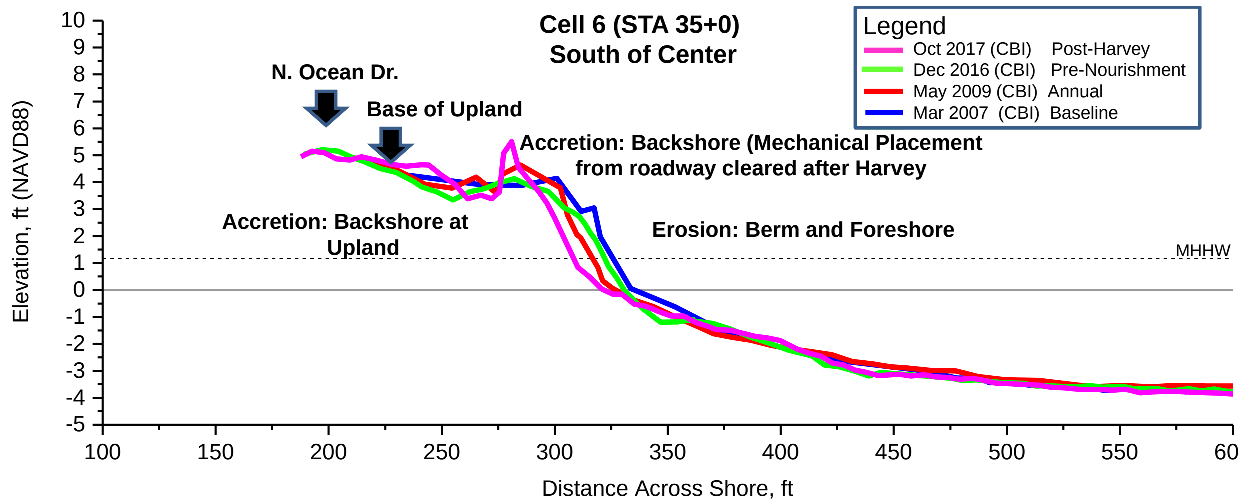


Figure 209. The northern segment of Cell 6 indicating both placement of sediment recovered from the adjacent roadway and accretion on the north end of the beach. Note the erosion across the backshore close to center beach



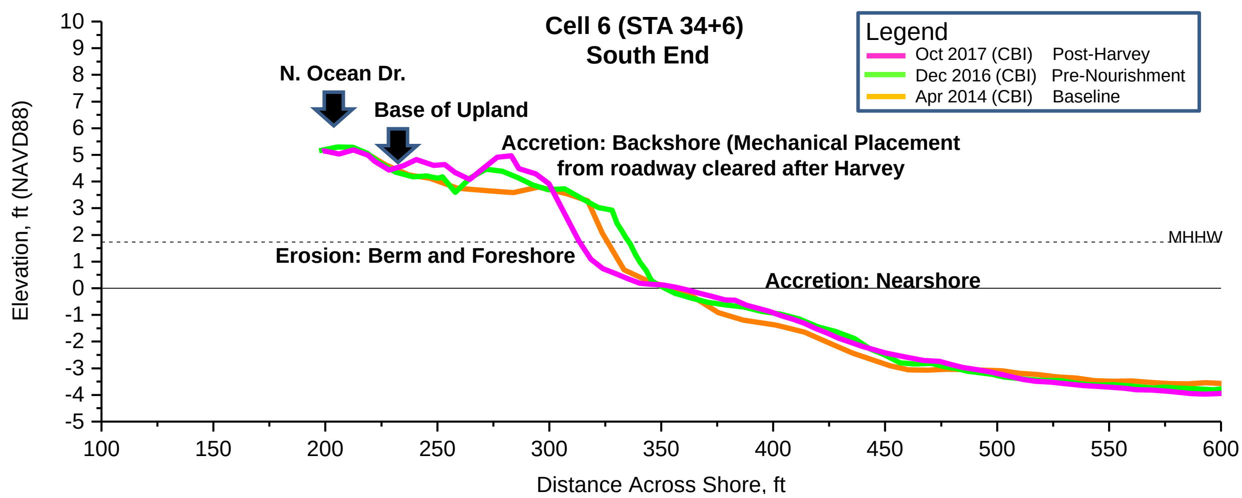
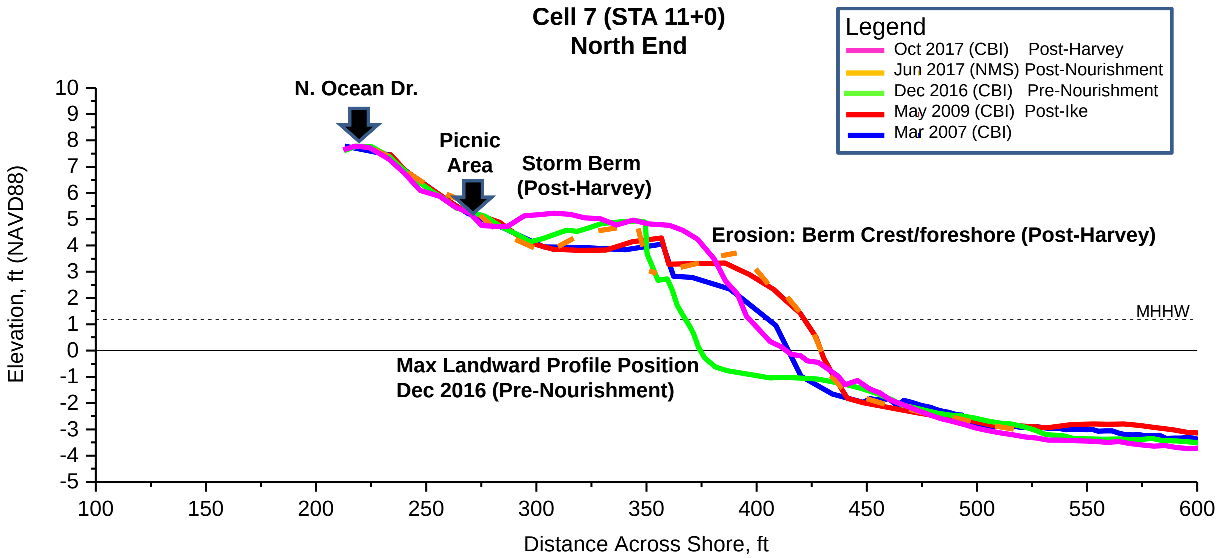


Figure 140. The southern segment of Cell 6 indicating both placement of sediment recovered from the adjacent roadway as a backshore berm and significant erosion across the berm and foreshore



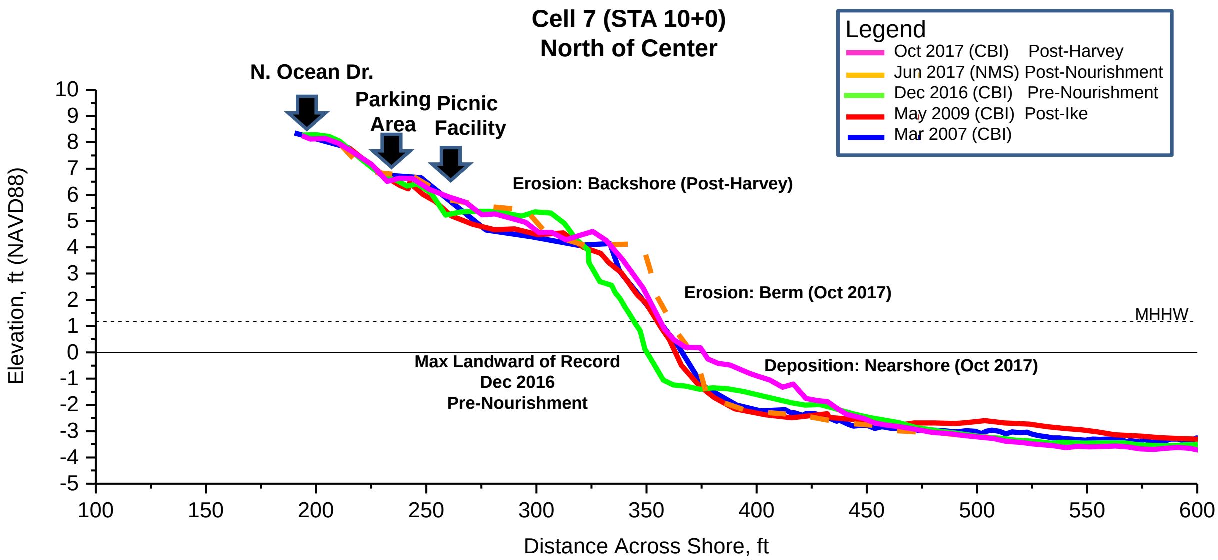
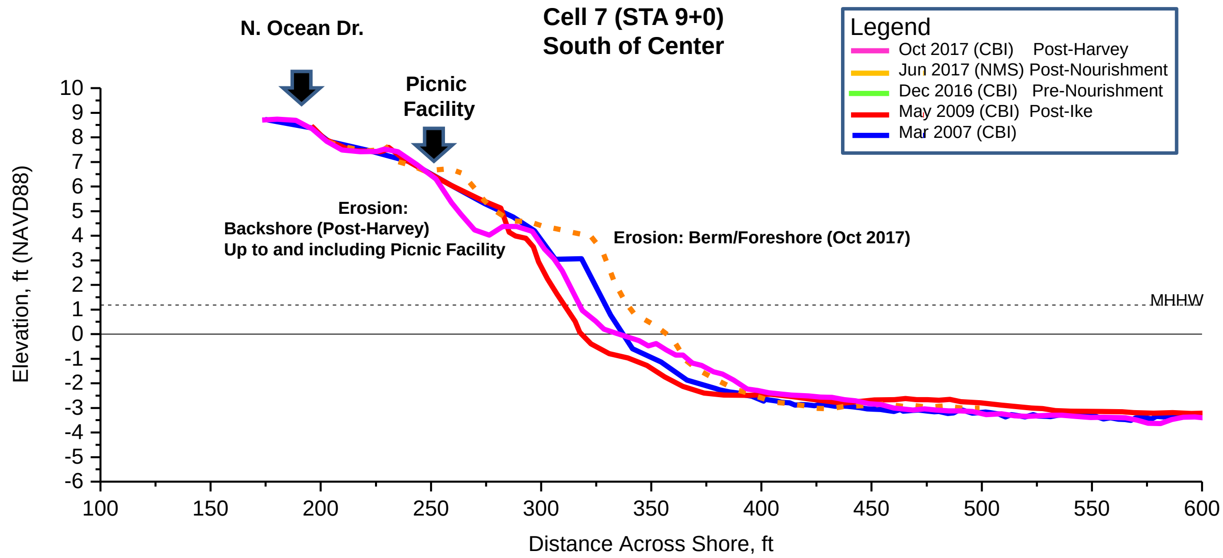


Figure 141. Erosion dominated from center beach northward in Cell 7 between fill placement (Jun 2017) and the post-Harvey survey (Oct 2017)



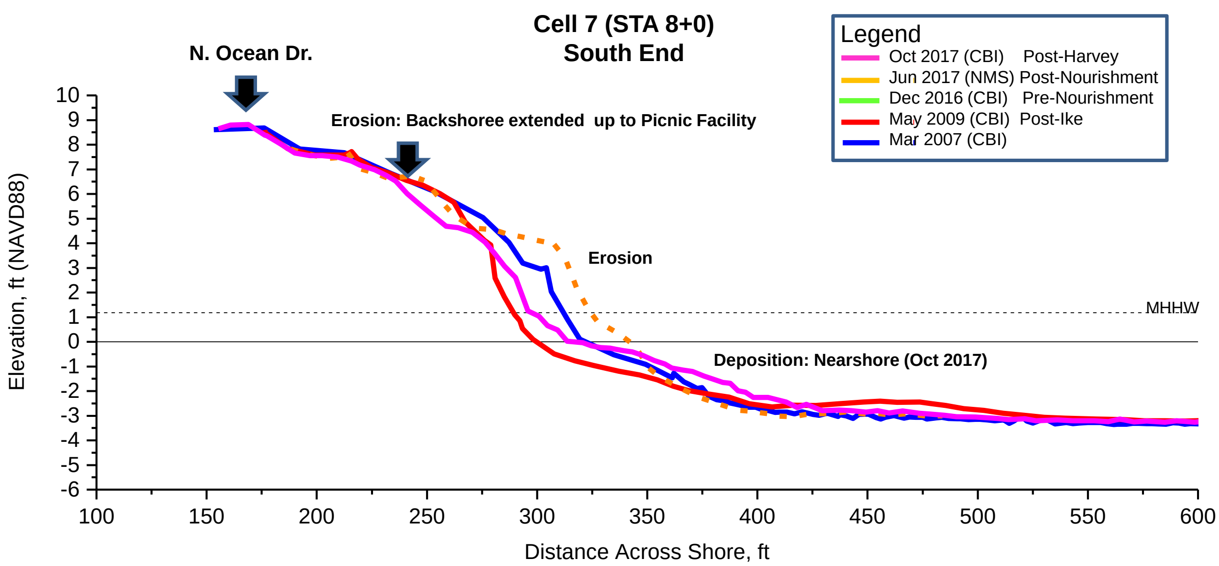


Figure 142. Erosion dominated from center beach southward after Hurricane Harvey with erosion extending from the foreshore to the backshore all the way up to the picnic facilities at an elevation of approximately 6 ft (NAVD88)

Recommendations: Indianola Beach

Onshore forcing during Harvey resulted in an increase in the rate of recession in the suite of eight (8) nourished beach cells as well as an increase in the rate of erosion in all cells with the exception of Cell 6. The increase in volume in Cell 6 may have been influenced by mechanical placement as the nearby roadway was cleared of sediment after Harvey. The greater degree of erosion after Harvey as opposed to Ike was due to onshore forcing combined with persistent high water levels in excess of 6.5 ft MHHW. The estimated total volume of sand that eroded during Harvey is likely conservative due to the active placement of sediment on the beaches as the adjacent road was cleared of sediment after water receded.

Indianola Beach is recommended for renourishment to restore the Target Width of 70 ft to Cells 1-8. The primary factors considered in recommending the beach cells for renourishment are (in order of precedence): 1) beach at or within 5 ft of Action Width (Cells 1-4), 2) erosion of significant volume of recent fill placement (Cell 7), and 3) restoration of Target Width to protect backshore public infrastructure (Cell 7 and 8). The nourishment volume required to restore beach Cells (1-8) is provided in Table 4. The fill volume required to restore each cell to Target Width ranged from a minimum of 1,040 cu yd in Cell 5 to 3,170 cu yd in Cell 3. The total volume estimated to restore Cells 1-8 to their respective Target Width was 15,350 cu yd, based on the application of the Oct 2017 profile as the base template for design. The Target Width was taken at 70 ft and the elevation at 3.5 to 4.0 ft (NAV88).

The recommendation for restoration of Target Width to the suite of beach cells at Indianola Beach is based on performance to date and damage assessed after Harvey. To accommodate budgetary constraints the order of precedent is; Cells 1-4 and Cell 7 (Tier 1). Cells 5, 6 and 8 (Tier 2). Cell 1-3 have previously been recommended for nourishment as the beach cells gradually reached the Action Width. The beach width was also evaluated along segments that fall between transects. After Harvey, segments between transects ranged from 5 to 15 ft wide in Cells 1-4. The proximity of the N. Ocean Drive was a supporting factor in the recommendation of Cells 5 and 6 for nourishment as these two beach cells have the greatest ease of access for users with limitations along the North Reach. The proximity of backshore public infrastructure landward of Cells 7 and 8 was a supporting factor in the recommendation of restoration of Target Width at these two beaches in order to protect public access and utilization of the only beachfront park facilities located in the two reaches. Due to the possibility that additional sediment was placed on the beaches after October 2017 it is recommended that nourishment recommendations be re-evaluated after the 2018 survey.

Table 4. Indianola Beach: Nourishment Recommendation Options (Post-Harvey 2017)
Based on Width Measured from shoreline position at MHHW
*** At Action Width**
**** 75% at Action Width**
^ 75% < Target Width
Restore Nourishment Volume Lost During Harvey

Beach Cell	Estimated Volume (cu yd) Target Width= 70 ft Tie in = 4.0 ft (NAVD88) Cu yd	Estimate Volume/ft Target Width= 70 ft Tie in = 4.0 ft NAVD88) Cy/ft
Cell 1*	2,140	15
Cell 2*	2,130	13
Cell 3*	3,170	15
Cell 4**	2,990	11
Cell 5^	1,040	4
Cell 6^	1,120	4
Cell 7^	1,520	4
Cell 8^	1,240	3
Total	**15,350**	N/A

As reported during 2015 and 2016, additional recommendations include coordinating the seasonal schedule of annual surveys at Indianola Beach to provide for improvement in the level of analysis and recommendations that can be derived from the agreement in seasonality of data sets. The Apr 2014 and Dec 2016 surveys documented the rapid reversal in sediment transport at Indianola Beach that can occur during the spring and the winter seasons. Insuring prompt authorization or multi-year contracts to support conducting surveys during the same season each year, with preference to late May to September, provides the best opportunity to compare successive years of survey data toward making more accurate determinations of long-term change that is not influenced by short-term seasonal or in the case of 2017, event forcing. The 2018 survey will serve to document the recovery period after Harvey and assist in determining if some level of post-storm recovery is identifiable at Indianola Beach.

Sylvan Beach

Introduction

Sylvan Beach is located on the west shore of Galveston Bay in the City of La Porte, Harris County, Texas (Fig 143). Sylvan Beach was a popular recreational destination in the early 20th century. The beach itself was bordered by a historic park with many amenities and was referred to as the "Grove." It is generally recognized that after the opening of the Houston Ship Channel in 1928, wave action initiating from navigation along with wind waves due to prevailing onshore-directed wind began to erode the small native bayside beach. These forces combined with regional subsidence, and hurricanes (Carla 1961) resulted in the complete erosion of Sylvan Beach and the subsequent fortification of the shoreline with riprap.

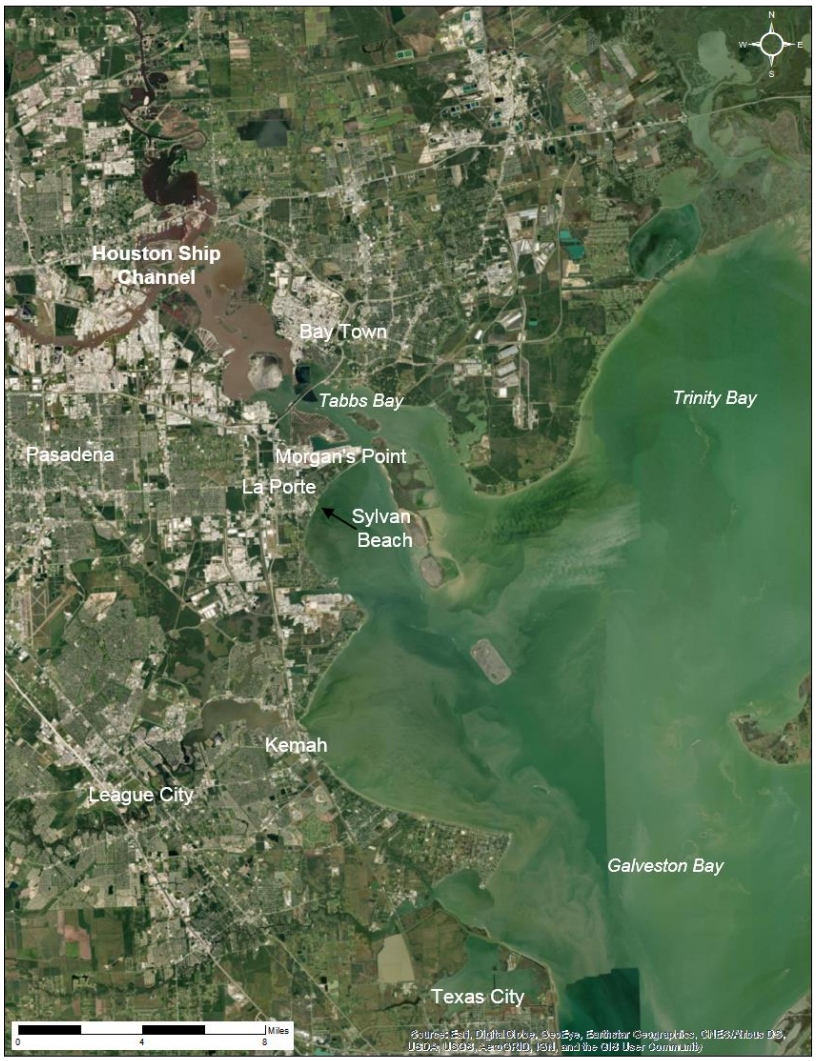


Figure 2143. Location of Sylvan Beach along west shore of Galveston Bay near Morgan's Point

Initial Construction/Restoration:

Due to historic loss of this Harris County community beach, a beach restoration project consisting of two beach cells was completed in November 2009. The beach cells are referred to as North

Sylvan and South Sylvan for reporting purposes. The beach cells were constructed between April and November 2009, facilitated by CEPRA (CEPRA 1404) grant funding. Each beach cell includes two arcuate terminal groins and fill material consisting of coarser than native, beach-quality sand borrowed from an upland source (Trinity River). North and South Sylvan Beach are approximately 500-ft long, although the length of the shoreline itself is truncated by about 50 ft due to the curvature of the groins. According to the BMMP, approximately 17,000 cu yd of sand was originally placed to create each beach for a project total of 34,000 cu yd (reported as 46,000 ton). The landward boundary of the beach, previously consisting of a deteriorating bulkhead and concrete riprap, was replaced with articulated pavement and a sidewalk bordering a partially exposed rock revetment. The landward edge of each beach was designed to intersect the hardened backshore limit with minimal difference in elevation, although sand accumulation at this interface has been documented in excess of the elevation of the sidewalk. The design width of the beach was specified at 75 ft with an average berm elevation of 3 ft.

Nourishment History:
The two beach cells at Sylvan Beach were first nourished during May 2013. Fill placement was focused along the south-end of each beach. Persistent erosion has been documented along the southern segment, since construction was completed in 2010. It is important to note that the volume of sand that Harris County reportedly placed on the beach during 2013 was approximately half that recommended by URS in their maintenance report (URS, 2013) and recommended by the CEPRA Beach Monitoring Program. The purpose of the nourishment conducted by Harris County was not to restore the beach to the original design template but to alleviate the accelerated erosion on the south end of each beach cell, thereby restoring recreational access. According to Harris County officials, approximately 1,500 cu yd (reported as 2,000 ton) of sand was placed on the North Sylvan and 2,300 cu yd (reported as 3,000 ton) of sand was placed on the South Sylvan. The nourishment was initiated and conducted by Harris County and was not funded by CEPRA or other TGLO resources. CBI surveyed the two beach cells within 2 weeks of completion on 06 June 2013, although this was not coordinated, but rather, coincidentally aligning with contract authorization. Harris County provided no post-nourishment survey data only reported the estimated fill volume applied to each cell.

During the previous reporting period, Harris County staff indicated that a second, small-scale nourishment that was planned for 2016 was delayed. Ultimately, the fill placement was completed during May 2017. Harris County planned and funded the renourishment that was conducted independently by Harris County with no coordination with the TGLO. Harris County did not provide post-nourishment survey data by the time of this reporting. The lack of post-nourishment survey data restricted the level of assessment that was possible, particularly with the influence of Hurricane Harvey complicating interpretation. Harris County staff initially reporting an incorrect fill volume that was significantly larger than that reported to TGLO staff during later communication, which further complicated the assessment process. Sand was reportedly placed across the south segment of the beach with the intent of restoring public access. Approximately 4,232 cu yd (reported as 5,501.98 ton) of sand was placed on the two beaches. A fill volume of 2,176 cu yd (reported as 2,829.04 ton) was placed on North Sylvan and a fill volume of 2,056 cu yd (reported as 2,672.94 ton) on South Sylvan. Although the fill volume was in excess of the 2013 fill volume reported by Harris County, the reported volume was approximately 50% of the volume recommended to restore the Target Width and design elevation. The 2017 nourishment volume was equal to approximately 10% of the original volume of sand placed during construction.

Hurricane Harvey

Hurricane Harvey impacted the Harris County area between 26 Aug 2017 and 29 Aug 2017. The undocumented nourishment completed during May 2017 complicated the storm damage assessment at Sylvan Beach. Although originally the 2010 (post-construction) shoreline and beach profile were applied as the 2017 nourishment template, ultimately the 2013 (post-nourishment) shoreline position was applied to estimate the rate of shoreline change and the Dec 2016 profile modified to accommodate for the reported sand volume was applied to estimate the May 2017 nourishment template. The 2013 shoreline position was selected for application to estimate the May 2017 post-nourishment position based on: 1) reasonable agreement between the pre-2016 nourishment (Dec 2016) shoreline position and the pre-2013 nourishment (Jun 2012) shoreline position and 2) reasonable agreement in nourishment volume reported by Harris County in 2013 and 2017. The rate of shoreline change derived from this estimation was conservatively applied application to post-storm damage assessment and nourishment planning, representing the minimum change that can be attributed to Hurricane Harvey in the absence of post-nourishment survey data. The estimated rate of change is considered the minimum primarily because Harris County had initiated rapid post-storm recovery, which modified morphology at Sylvan Beach. The CBI survey and aerial imagery (Google Earth) both documented post-storm beach maintenance that was conducted in both beach cells. Additional insight into the forcing that acted at Sylvan Beach during Harvey was derived from interpretation of aerial imagery (Fig 144ab and 145ab) in combination with water level and wind data (Fig 146 and 147, respectively). Aerial images indicated substantial influence of both water levels well in excess of MHHW and onshore forcing prior to the 31 Aug 2017 photo, taken within one week after Harvey (Fig 146). Influence of the storm was still evident during 02 Sep 2017, during a peak period of astronomical high water apparently reinforced by Tropical Storm Irma in the Gulf of Mexico (Fig 147). Active post-Harvey mechanical redistribution of sand is evident in the 31 Aug 2017 photo while recent inundation up to the sidewalk, particularly along North Sylvan, is evident in the 02 Sep 2017 photo. Water levels in excess of 3.5 ft above MHHW were recorded at nearby Morgan Point during Hurricane Harvey. Water levels at this elevation would clearly inundate the entire beach (typical berm elevation ranging from 1.5 to 3 ft) in each cell and combined with onshore forcing breached structures along the backshore. The water level immediately prior to and during 02 Sep 2017 was under 1 ft above MHHW. The degree of inundation shown in the Sep 2017 photo, particularly at North Sylvan indicates that the elevation of the beach was exceeded by a combination of water levels of 1.5 ft above MHWW in combination with either onshore forcing or the influence of ship wakes. Periodic inundation of Sylvan Beach has been reported in association with ship wake progression across Galveston Bay during periods of higher water levels.

Monitoring History

Monitoring was initiated at Sylvan Beach during June 2012 with subsequent surveys conducted during June 2013 (immediately post-nourishment), July 2014 (1-year post-nourishment), September 2015 (2-years post-nourishment), November 2016 (3-years post-nourishment and 7-years after construction) and October 2017 (Post-Harvey). The beach profile survey grid consists of 17 transects at 100-ft spacing and includes the submerged region between the beach cells (Fig 148). Each transect extends to a depth of -10 ft, well beyond the anticipated depth of closure originally estimated at between -5 and -8 ft, based on similar bayside beaches adjacent to shallow nearshore regions. The actual depth of closure at Sylvan Beach may be revised as the beach continues to be nourished and approaches what may be a transient equilibrium due to the frequency of nourishment required. Preliminary calculations based on data from 2012-2016 and again in 2017 indicate that the depth of closure is at approximately -7.0 ft. Pre-construction data (Apr 2008 and Jan 2010) have been applied to provide for comprehensive project analysis, although the 2010 data for the region between the beach cells does not extend an adequate distance offshore. Assessment of Sylvan Beach has been previously described for the period of equilibration from 2010 to 2012 and post-nourishment 2013 (Williams 2013), one and two years post nourishment (Williams 2014 and 2015) and three years after renourishment (2013-2016). This reporting documents the changes since Dec 2016 including an estimate of change due to an unreported nourishment (May 2017) and the post-Harvey (Oct 2017) condition. Results from previous analysis is provided in Tables 1-5 for ease of reference.

Figure 144. Aerial images taken during A) 31 Aug 2017 and B) 02 Sep 2017 at North Sylvan show damage after Hurricane Harvey and impact of continued inundation over the following week (Google Earth)

Figure 145. Aerial images taken during A) 31 Aug 2017 and B) 02 Sep 2017 at South Sylvan show damage after Hurricane Harvey and impact of continued inundation over the following week (Google Earth)

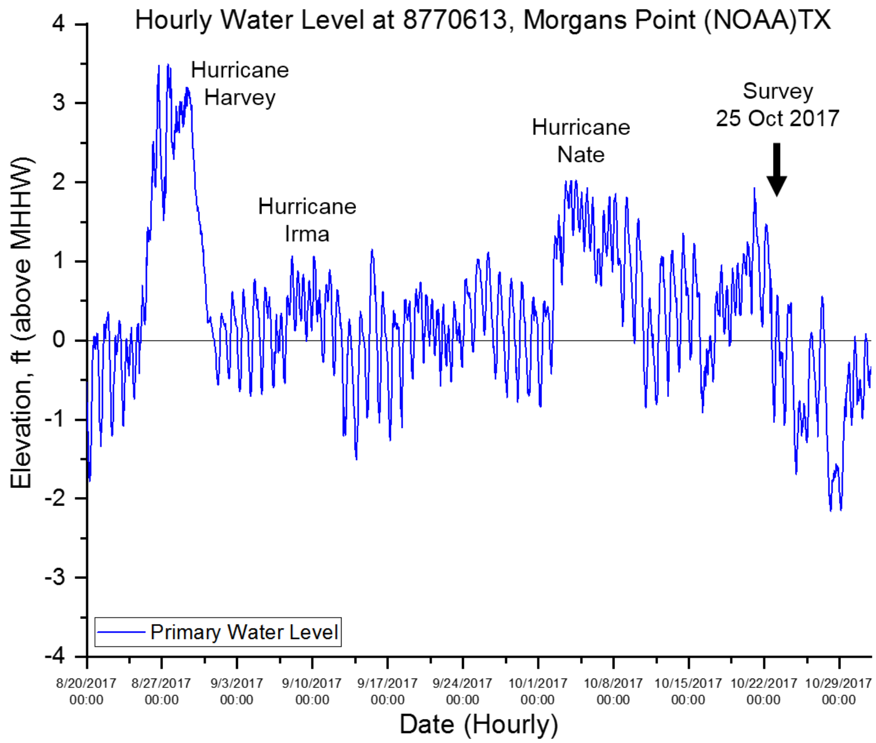


Figure 146. Water levels up to 3.5 ft above MHHW during Harvey and up to 2.0 ft above MHHW between Harvey and the Oct survey

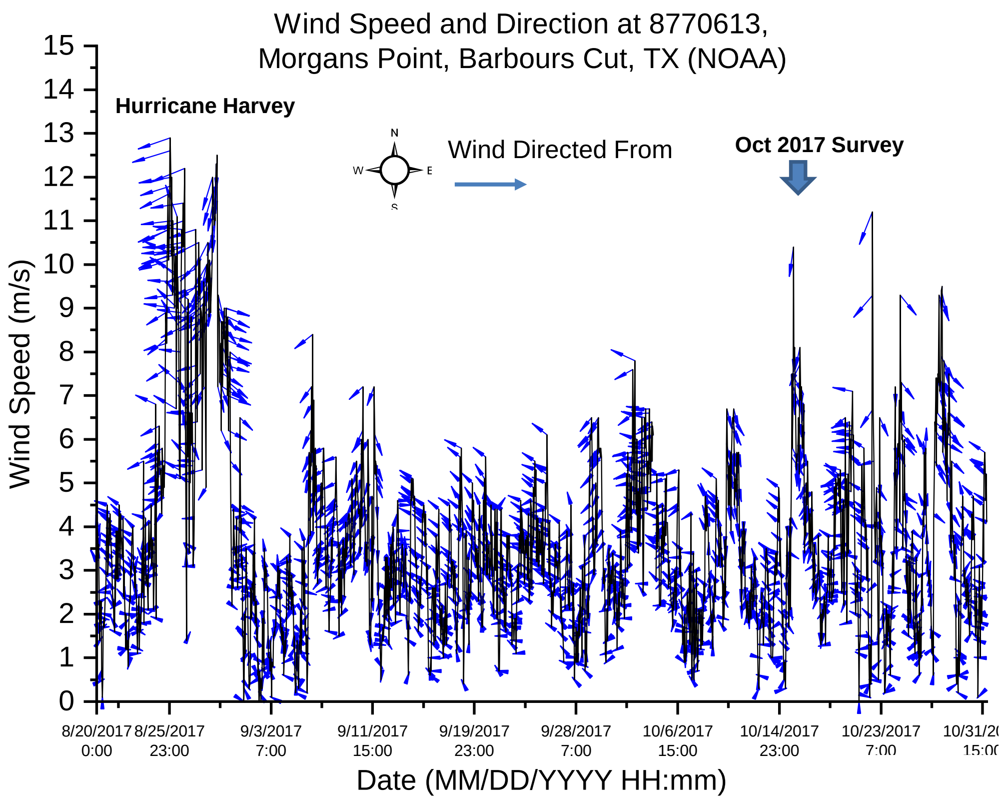


Figure 147. As winds increased during Harvey, the direction of approach varied from out of the east, northeast and southeast. Strong onshore directed wind dominated at Sylvan Beach periodically over the course of the two months following the storm

Base Aerial Photography

The aerial photography applied as the base image for Sylvan Beach reporting graphics was obtained from the following source:

Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), Remote Sensing Division. *Hurricane Harvey: Emergency Response Imagery of the Surrounding Regions.* Silver Spring, MD: NOAA's Ocean Service, National Geodetic Survey (NGS). Aug 2017. https://storms.ngs.noaa.gov/storms/harvey/index.html
https://storms.ngs.noaa.gov/storms/harvey/download/metadata.html

Figure 148. Transect location and orientation of the two beach cells at Sylvan Beach Park

Shoreline Change Analysis: Sylvan Beach

As in the past, the planview orientation of the shoreline and the location of focused erosion along the south end of each beach cell remained relatively consistent between the two beach cells, despite the influence of Hurricane Harvey and active mechanical redistribution of sand (Fig 149-151). The agreement in morphology and planform shape can be attributed to 1) similar size and sand volume, 2) exposure to same fluctuation in water level, 3) exposure to vessel wake action, 4) same orientation relative to the wave approach and 5) similar and regular maintenance redistribution of sand across the berm and from the north end to the south end. The difference observed between the higher rate of shoreline recession at South Sylvan as opposed to North Sylvan is attributed to the active mechanical redistribution of sand that was ongoing at Sylvan Beach during the post-Harvey survey (25 Oct 2017) and immediately after post-Harvey as documented by aerial imagery (Fig 144a and 145a). Sand was mechanically redistributed toward the south end and across the foreshore from areas of storm deposition along the backshore. Storm deposition was focused on the north end of each beach cell and along the backshore, including the adjacent sidewalk. Although unconfirmed by Harris County, the process of sand redistribution may have occurred several times after Harvey in order to restore a more uniform berm width and elevation both immediately after Harvey as well as after subsequent periods of high water in excess of MHHW over the following months. The partial redistribution of sand during the survey influenced the rate of recession that was calculated. The rate of shoreline recession was greater at North Sylvan than at South Sylvan where grading and redistribution had been completed immediately prior to the survey. Thus, the post-Harvey rate of shoreline recession was likely higher than the Oct 2017 data indicates in both beach cells due to both the influence of Harvey and post-storm sand management as crews restored use of the backshore facilities (sidewalk) as well as the beach itself. A brief summary of previously identified trends in shoreline change since construction follows for ease of reference.

Prior Trends in Shoreline Position Change

Between 2010 (post-construction) and 2012, shoreline recession dominated along both the North Sylvan and South Sylvan with accelerated recession consistently observed along the south side of the beach. Between 2013 and 2014, shoreline recession dominated at Sylvan, although the shoreline along the north side of each beach cell significantly advanced to beyond the post-construction (2010) position. Between 2014 and 2015, the shoreline receded landward along the entire beach in both beach cells, with the greatest recession observed on the north side as opposed to the south side where rapid recession had dominated since construction. During November 2016, the shoreline along the central and south side of the two beach cells receded and approached the 2012 pre-nourishment position to within 5 to 10-ft, with the exception of a short segment along the north end of each beach cell where the shoreline was landward of the 2012 position.

2017 Assessment of Shoreline Change

Assessment of shoreline change between Dec 2016 and Oct 2017 (after Harvey) was challenging due to contributions from Hurricane Harvey, undocumented nourishment conducted within three months prior to Harvey (May 2017), and active post-Harvey site management of sand deposition and erosion through beach grooming. The 2013 shoreline position was applied to estimate the 2016 post-nourishment position due to 1) agreement between the pre-2017 nourishment (Dec 2016) shoreline position and the pre-2013 nourishment (Jun 2012) shoreline position and 2) reasonable agreement in nourishment volume reported by Harris County to TGLO Staff (Fig 152).

Application of the estimated 2017 post-nourishment template indicated that recession dominated in both beach cells between May 2017 and the post-Harvey survey (Oct 2017). Shoreline recession dominated along each beach cell, focused along the south end of each beach cell with North Sylvan demonstrating the most landward shoreline position located along the southern half of the beach (Fig 152). The degree of erosion and shoreline recession at North Sylvan was greater than at South Sylvan, as indicated through survey data, onsite observations and interpretation of post-storm aerial imagery. The difference in shoreline recession in the two beach cells may reflect differences in sand maintenance practices after Harvey. The post-Harvey survey was conducted as sand was being redistributed from north to south at North Sylvan, whereas sand was redistributed along South Sylvan prior to the survey. The Oct 2017 shoreline position was located in advance of the Dec 2016 shoreline, despite the storm influence, which is attributable to the stabilizing contribution of the nourishment completed three months prior to Hurricane Harvey (May 2017). Of note, the Dec 2016 shoreline position and the 2012 shoreline position represent both the pre-nourishment position and the most landward positions documented since construction.

The rate of change in shoreline position between May 2017 and Sep 2017 was evaluated as a post-storm episodic response over two intervals 1) May 2017 (estimated post-nourishment) to Aug 2017 (estimated post-Harvey) and 2) May 2017 (estimated post-nourishment) to the 25 Oct 2017 survey date. The rate of shoreline position change was also evaluated over the project lifespan 2010-2017, as compared to prior annual recorded rates of change in shoreline position. The rate of shoreline position change for previous intervals of significance is provided in Table 1. The datum applied to define the seaward limit of Sylvan Beach is MHHW (1.3 ft NAVD88). Note that the annual surveys are reflective of an approximately 12-month period while the interval between the May 2017 nourishment and Hurricane Harvey (Oct 2017) reflects an approximately 3 month period and is considered episodic in nature.

Standard plots showing the comparison of the average rate of shoreline change over annual intervals are effective but can be confusing in the context of the shorter intervals of study and specifically episodic events. Therefore, both a monthly and event rate of change are provided for the period after the May 2017 nourishment to more reasonably reflect the change that occurred between these short intervals of investigation. Figure 153 and 154 show the rate of change over the full project record (Jan 2010 to Oct 2017) as compared to key milestone intervals over the projects history (Fig 155 and 156). The episodic rate of change is provided to describe the magnitude of recession that occurred between the partial nourishment completed in May 2017, just three months prior to Hurricane Harvey, acknowledging that this is a rate reflective of episodic change calculated over a brief period of interest (May 2017 to Oct 2017). The monthly average rate of change at North Sylvan (-2.9 ft/month) was nearly double the rate calculated at South Sylvan (-1.7 ft/month). The average rate of change over the brief episodic event (May 2017 to Aug 2017) was -8.7 ft/event (North Sylvan) and -5.1 ft/event at South Sylvan. The average rate of change over the abbreviated study period (May 2017 to Oct 2017) event was -14.5 ft/event (North Sylvan) and -8.5 ft/event (South Sylvan). The maximum change in shoreline position was -20 ft (North Sylvan) and -14 ft (South Sylvan). The rate of change over the full study period since construction (Jan 2010 to Oct 2017) was -2.9 ft/yr (North Sylvan) and -2.5 ft/yr (South Sylvan),which takes into account two nourishment events and the impact of Hurricane Harvey.

The event-driven, short-term average rate of monthly change in shoreline position after Harvey ranged from -1.7 ft/month (South Sylvan) to -2.9 ft/month (North Sylvan). The event driven rate is 3 to 4 times higher than the average monthly rate (-0.5 ft/month) observed since 2010. The rate of change was also in excess of the highest rate (-1.3 ft/month) observed over the two years following the original full restoration placement (2010-2012) during which a peak rate can be anticipated as the fill comes to equilibrium with the surrounding nearshore bay bottom.

Although shoreline recession has dominated at both beaches since construction, the rate of recession decreased significantly after the renourishment in 2013, prior to Hurricane Harvey. The post-nourishment (2013-2015) average rate of shoreline position change was approximately 50% of that measured 2-years post-construction (2010-2012). The rate of recession measured over the previous reporting period (2015-2016) remained lower than the post-construction rate at both North and South Sylvan but increased from that measured during 2014-2015 reporting period to -9.6 ft/yr (North Sylvan) and -8.5 ft/yr (South Sylvan). Since the 2013 nourishment, the rate of shoreline recession at both North and South Sylvan remained significantly lower than the -15 ft/yr that was observed after the initial fill placement (2010), This decrease in rate of shoreline position change over time is indicative of 1) the nourishment successfully increasing the stability of the original beach fill, 2) the influence of localized impoundment of sand eroding from the berm in the immediate nearshore (-1 to -5 ft contour) as beach profile approaches equilibrium. After nourishment, the rate of shoreline recession continued at a lower rate than after initial construction at -5 ft/yr as opposed to -15 ft/yr. The annual survey planned during October 2017 will provide documentation of how significant the influence of Harvey is on the annual average rate of shoreline change between 2017 and 2018. Figures 149-152 show a comparison of the alongshore variability in rate of shoreline position change after the 2013 nourishment. Not only did the rate of recession on the south side of each beach cell moderate over time but the rate of advance on the north side of the beach also moderated over time yielding a much more uniform net rate of recession over the 3-year post-nourishment assessment period (2013-2016).

Sylvan beach provides a unique opportunity to monitor the agreement in response of duplicate beaches under near identical forcing conditions. The greatest difference in shoreline response documented between the two beach cells was documented after Hurricane Harvey. This difference in response is be attributed to; 1) differences in the actual versus reported nourishment volume placed in the beach cells during May 2017, 2) influence of extremes in water level and forcing that occurred during and after Hurricane Harvey, and 3) mechanical redistribution of sand after Harvey. Despite the post-storm difference in rate of change, the average rate of change remained relatively consistent between North Sylvan (-2.9 ft/yr) and South Sylvan (-2.5 ft/yr) over the full study period (2010-2017).

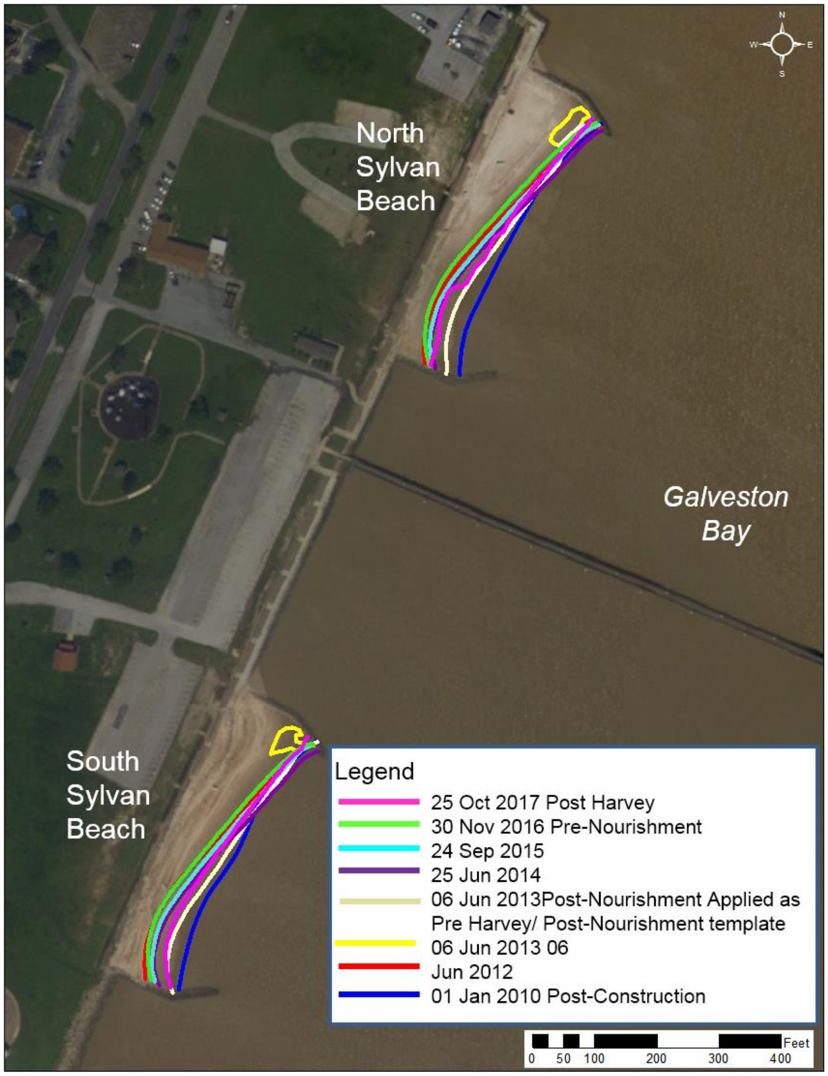


Figure 149. Shoreline position change from post-construction (2010) to post-Harvey (2017)

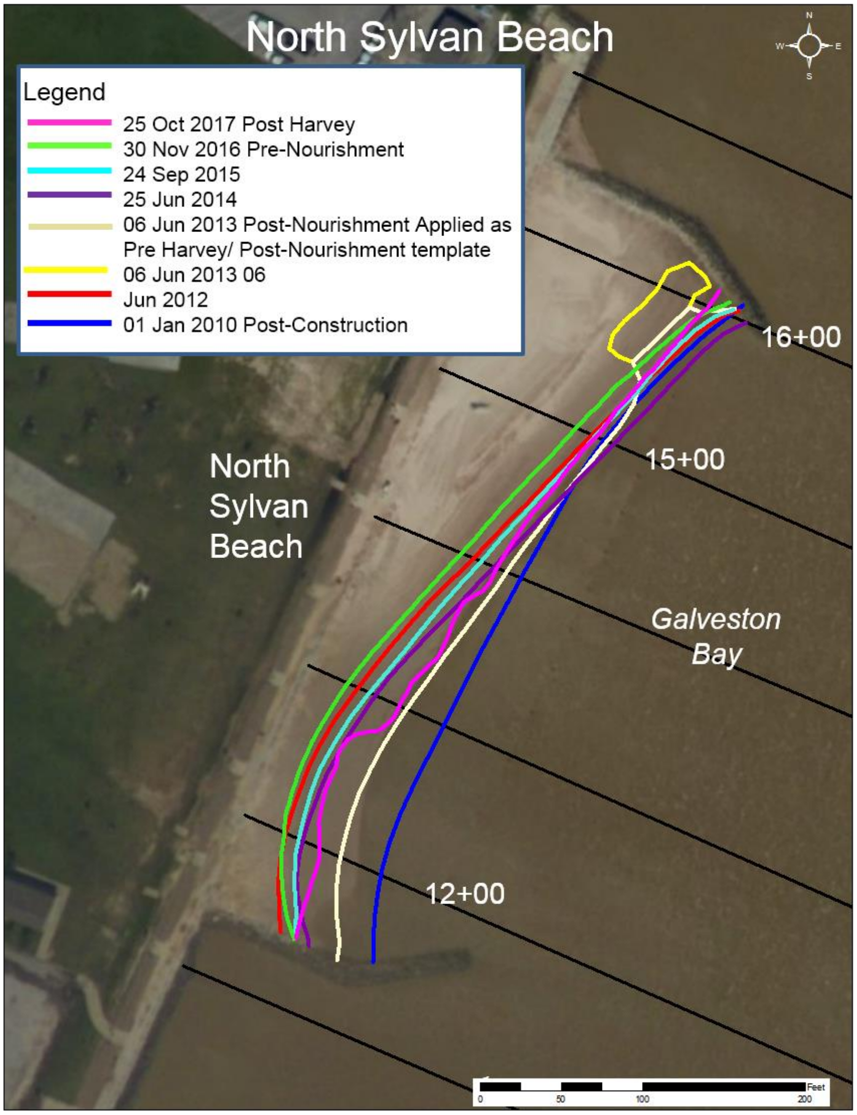


Figure 150. Shoreline recession continues to dominate on south side of North Sylvan beach

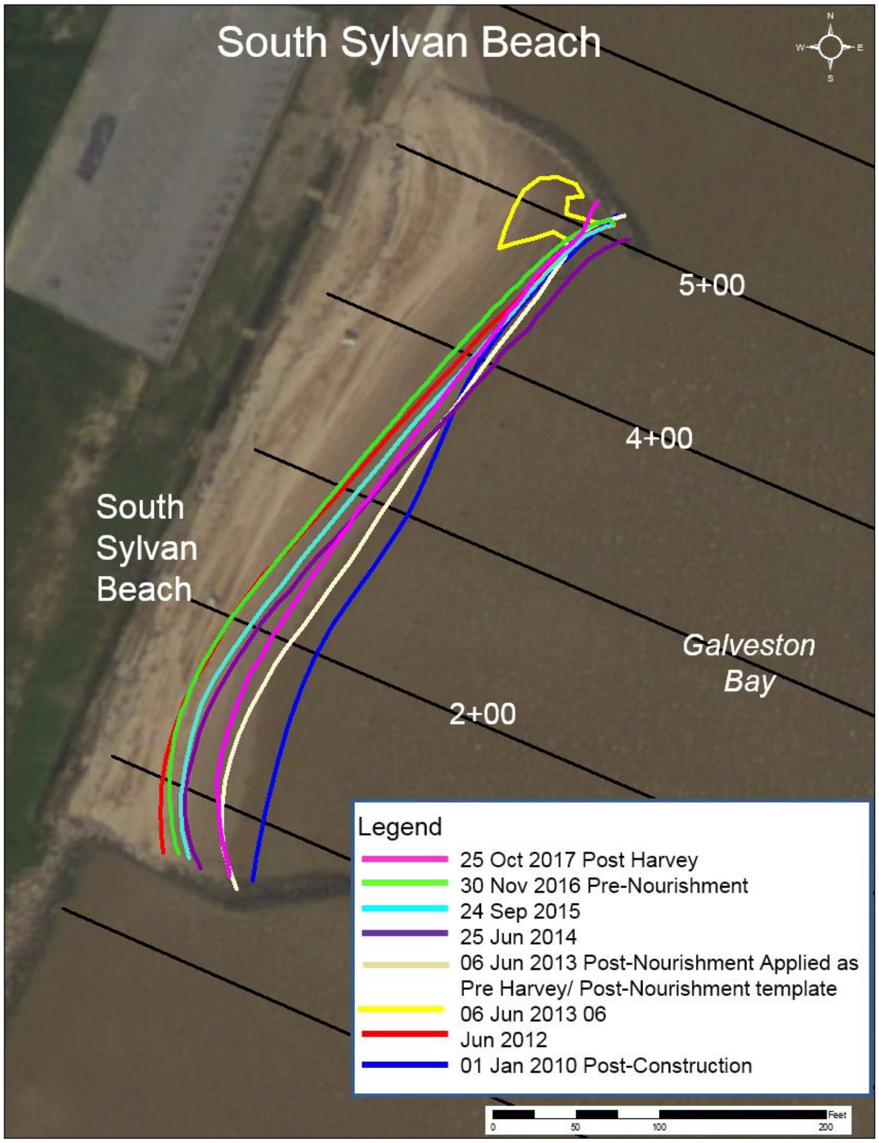


Figure 151. Shoreline recession continues to dominate along the south side of South Sylvan beach

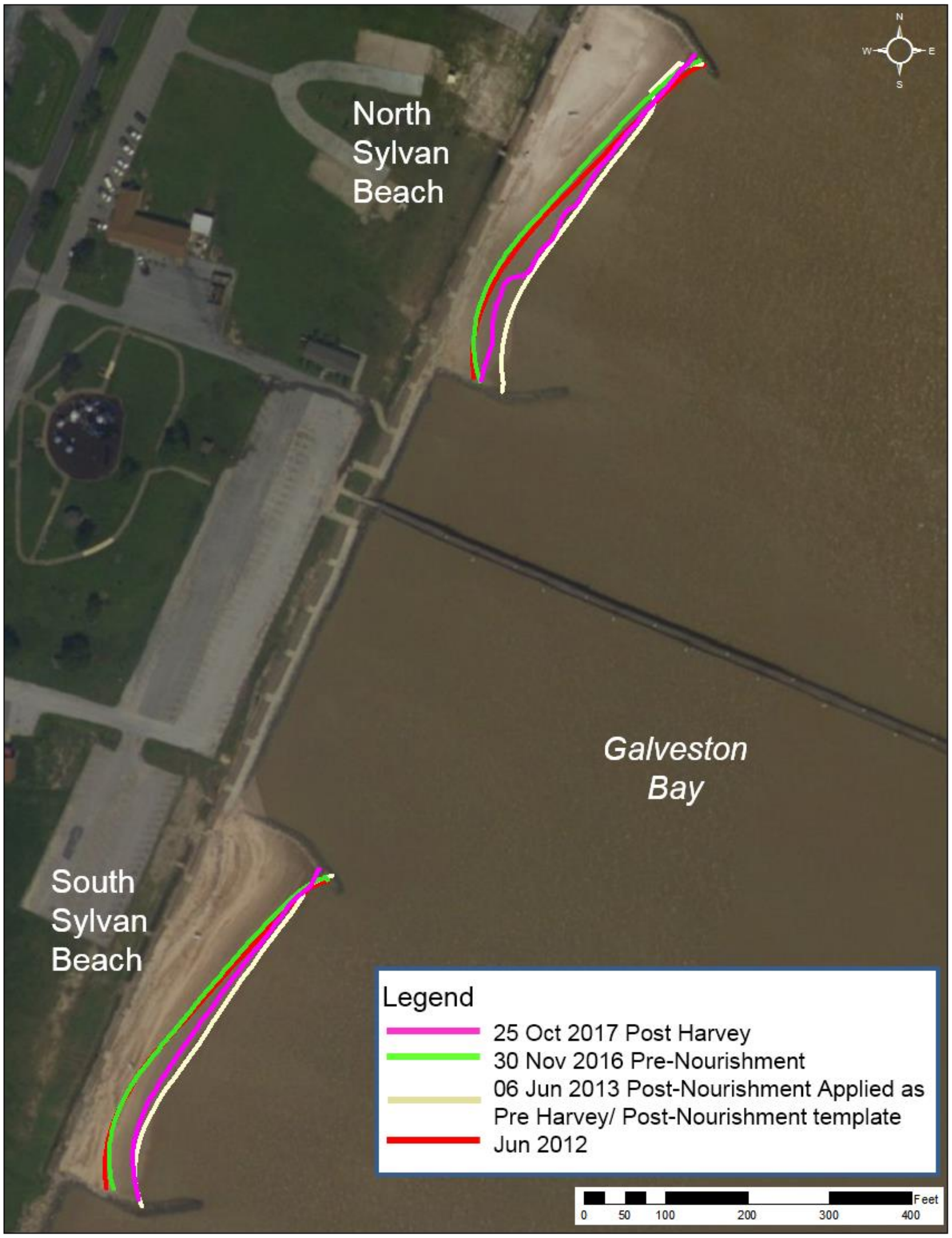


Figure 152. Application of 2013 post-nourishment shoreline as template approximation of May 2017 nourishment shoreline position as compared to post-construction position and post-Harvey position

Table 1: Variability in Rate of Shoreline Position Change: Sylvan Beach (2017) North Sylvan					
Location	**Interval (Year)**	**Description**	**Rate of Change (ft/yr) + Advance - Recession**	**Max (+) Change (ft)**	**Max (-) Change (ft)**
2017 Reporting Period					
North Sylvan	Dec 2016 Oct 2017	Annual Survey *Includes contribution of Nourishment conducted May 2017 and Harvey Aug 2017*	+20	39	-10
North Sylvan	May 2017 (Estimated based on Volume reported by Harris County) Oct 2017	Estimated Post-Nourishment and Post-Harvey	Average Monthly Rate (May 2017 to Oct 2017) -2.9 ft/month Episodic Event 3-month Rate: (Nourish to Harvey) -8.7 ft/event Abbreviated Study Period 5-month Event Rate: (May 2017-Oct 2017) -14.5 ft/event	2.4 7 12	-6 -18 -30
North Sylvan	2010-2017	7-yr Study Period includes -Construction and -1 partial nourishment -1 Nourishment to Specification (as reported by Harris County)	-2.9	0	-54
Cumulative Intervals of Significance					
North Sylvan	2010-2016	Pre-Harvey 6-yr Study Period includes -Construction -1 partial nourishment	-5.9	0	-72
North Sylvan	2013-2016	3-yr Post-nourishment	-6.5	+37	-43
North Sylvan	2010-2015	5-yr Study Period includes Construction and partial nourishment	-5.0	0	-61
North Sylvan	2013-2015	2-yr Post-nourishment	-6.6	33	-14
Annual and Biannual Intervals					
North Sylvan	2015-2016	Annual *3rd yr Post-Nourishment*	-9.6	0	-15
North Sylvan	2014-2015	Annual *2nd yr Post-Nourishment*	*-5.6*	0	-13
North Sylvan	2013-2014	Annual *1st yr Post-Nourishment*	-7.9	26	-31
North Sylvan	*2012-2013*	Annual *Post-Nourishment*	*+20.0 (Fill Influence)*	46 (Fill)	-16 (pooling)
North Sylvan	2010-2012	Biannual *2-yrs Post-construction*	-15.0	0	-63
Table 1 Continued on Next Page					

Table 1: Continued					
Variability in Rate of Shoreline Position Change: Sylvan Beach (2017)					
Location	**Interval (Year)**	**Description**	**Rate of Change (ft/yr) + Advance - Recession**	**Max (+) Change (ft)**	**Max (-) Change (ft)**
2017 Reporting Period					
South Sylvan	Dec 2016 Oct 2017	Annual Survey *Includes undocumented Nourishment conducted May 2017*	20.5	44	-11
South Sylvan	May 2017 (Estimated based on Volume reported by Harris County & agreement with 2013 nourishment) Oct 2013	Estimated Post-Nourishment and Post-Harvey	Average Monthly Rate (May 2017 and Oct 2017) -1.7 ft/month Episodic Event 3-month Rate: (Nourish to Harvey) -5.1 ft/event Abbreviated Study Period 5-month Event Rate: (May 2017-Oct 2017) -8.5 ft/event	2 6 10	6 18 -28
South Sylvan	2010-2017	7-yr Study Period includes -Construction and -1 partial nourishment -1 Nourishment to Specification (as reported by Harris County)	-2.5	0	-38
Cumulative Intervals of Significance					
South Sylvan	2010-2016	6-yr Study Period includes Construction and one partial nourishment	-5.3	0	-74
South Sylvan	2013-2016	3-yr Post-nourishment	-7.8	0	-50
South Sylvan	*2010-2015*	5-yr Study Period includes Construction and partial nourishment	*-4.8*	*2*	*-63*
South Sylvan	*2013-2015*	2-yr Post Nourishment	*-7.5*	*5*	-42
Annual and Biannual Intervals					
South Sylvan	2015-2016	Annual *3rd yr Post-Nourishment*	-8.5	0	-12
South Sylvan	2014-2015	Annual *2nd yr Post-Nourishment*	-6.3	0	13
South Sylvan	2013-2014	Annual *1st yr Post-Nourishment*	-9.5	37	17
South Sylvan	*2012-2013*	Annual *Post-Nourishment*	*+25.0 (Fill Placement)*	61 *(Fill)*	*5 (pooling)*
South Sylvan	2010-2012	Biannual *2-yrs Post-construction*	-15.7	0.4	66

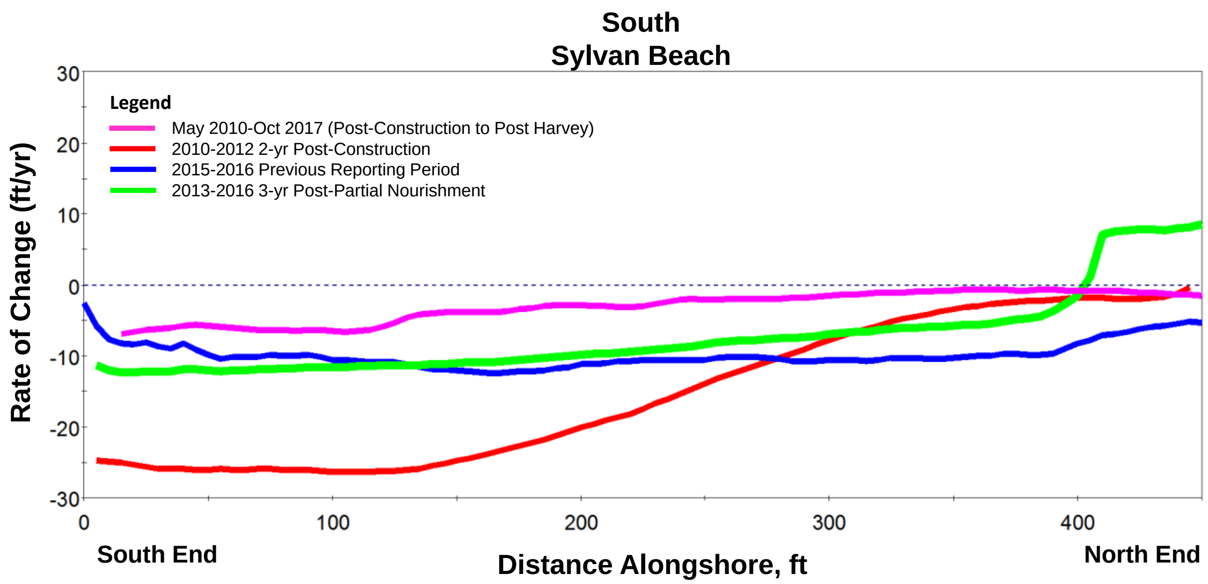


Figure 153. Moderation in the rate of shoreline position change after the 2013 renourishment as compared to after the 2010 initial placement at South Sylvan

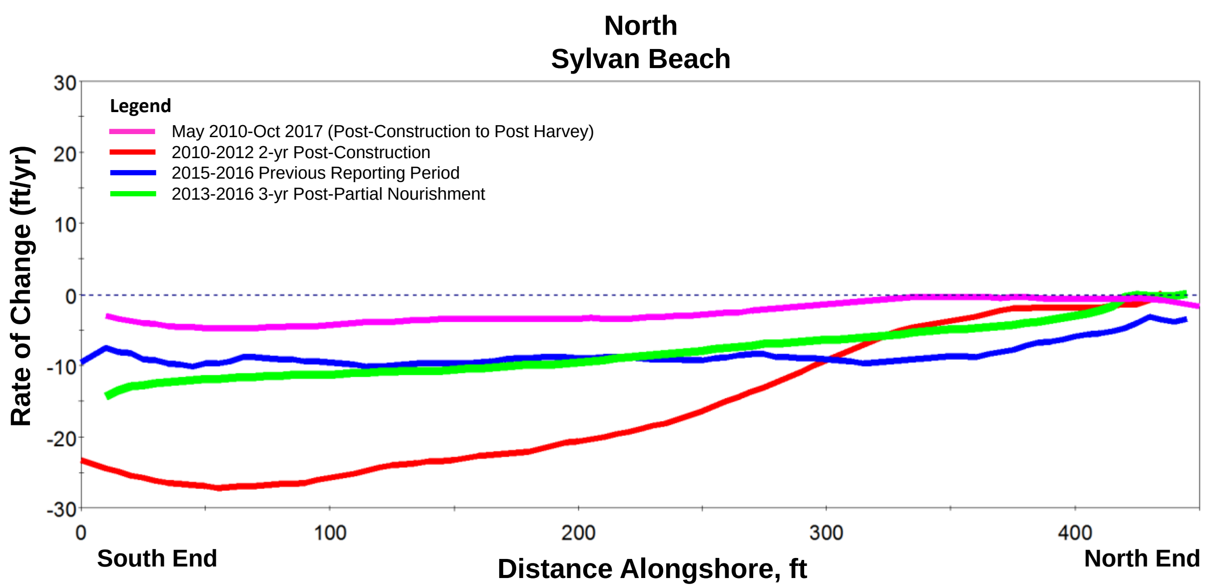


Figure 22. Moderation in the rate of shoreline position change after the 2013 renourishment as compared to after the 2010 initial placement at North Sylvan

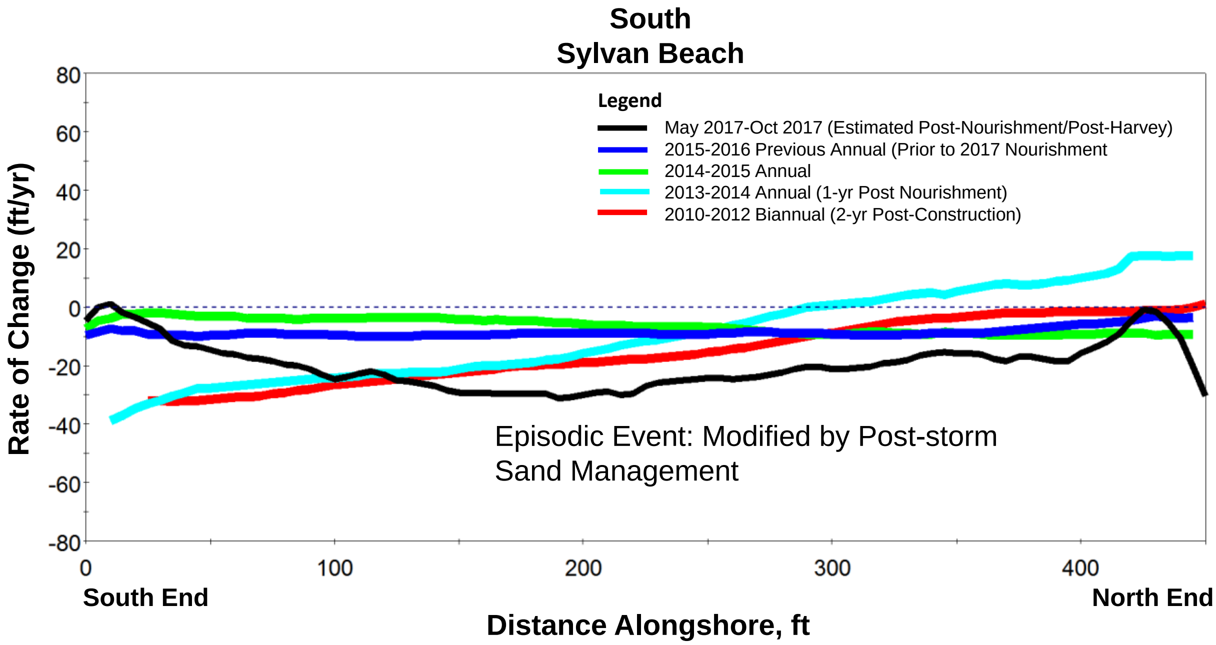


Figure 155. Comparison of episodic event rate of shoreline position change with alongshore position to annual rate of change since construction at North Sylvan

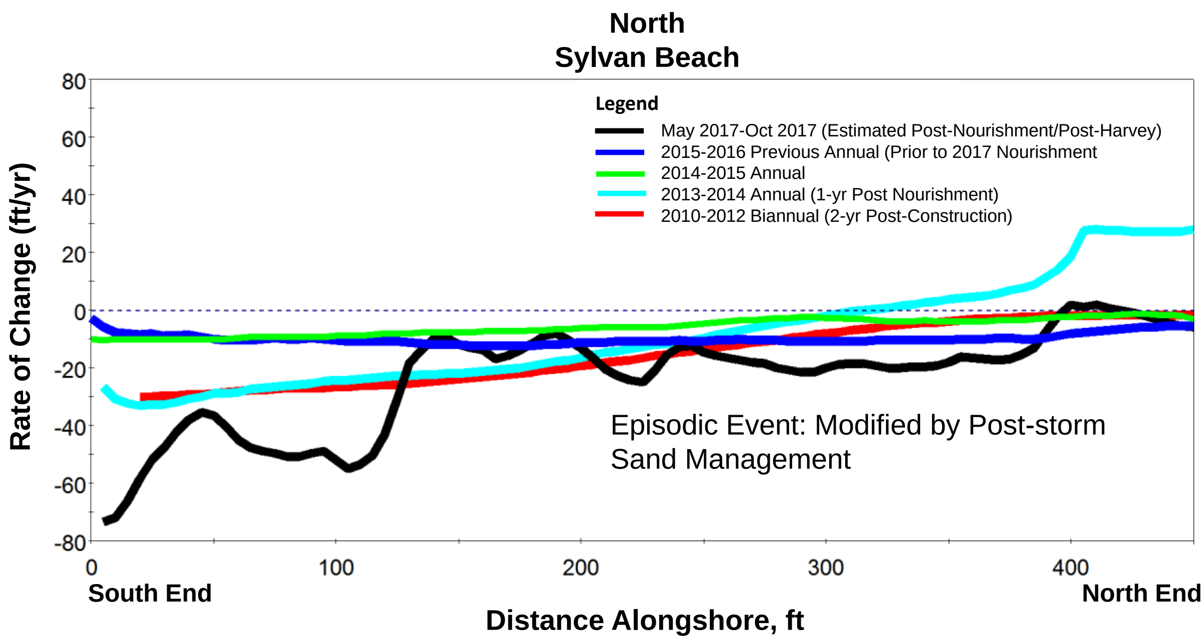


Figure 156. Comparison of episodic event rate of shoreline position change with alongshore position to annual rate of change since construction at South Sylvan

Beach Width: Sylvan Beach

After Harvey, the width of the beach decreased along the entire beach cell with the greatest change along the southern segment. The segment from center beach toward the south groin, at both North and South Sylvan, was less than Target Width (75 ft) while the segment north of center remained in excess of the Target Width, as observed since 2012. The entire beach along South Sylvan was in excess of the Action Width while a segment near the south end of North Sylvan was at Action Width. The limited segment of beach that reached the Action Width after Harvey was attributed to; 1) an increase in stability of the south end of the beach resulting from the nourishment completed less than three months before the storm and 2) mechanical redistribution of sand prior to the survey and during the Harvey recovery process. The width of each beach cell, measured along the historically occupied transects, ranged from 45 ft at the south end to 125 ft at the north end (North Sylvan) and from 50 ft to 118 ft (South Sylvan). For comparison, the beach width measured during each survey since 2010 is provided in Table 2. The narrowest beach segment was measured along the south side of North Sylvan between STA 12+0 and STA 13+0 where the beach was less than Action Width at 29 ft. The minimum beach width at South Sylvan was located between STA 1+0 and STA 2+0 where the beach was at 47 ft during Oct 2017. The change in beach width at North Sylvan ranged from -7 ft to -20 ft while the change in beach width at South Sylvan ranged from -3 ft to -14 ft between the May 2017 nourishment and Oct 2017. The difference in beach width after Harvey and that measured between previous surveys is provided in Table 3. The post-Harvey difference in beach width is referenced to two periods; 1) the last monitoring survey conducted during Dec 2016 and 2) the estimated width based on the reported May 2017 nourishment volume (application of the 2013 shoreline position template).

Table 2. Beach Width: Sylvan Beach (2017)
Note: Estimated based on May 2017 nourishment taken as 2013 Post-Nourishment MHHW position

< Target Width (TW) = 7[illegible]			Action Width (A[illegible] 37 ft					(within 5 ft)
			Beach Width (ft)					
Transect North Beach	16 January 2010 Post-Construction	06 June 2012	06 June 2013 Post-Nourish.	15 May 2014	24 Sep 2015	30 Nov 2016	May 2017 Estimated*	Oct 2017 Post Harvey
12+0	83	22	56	33	30	20	56	45
12+5**	80	18	50	30	24	12	50	30
13+0	78	25	58	36	33	18	58	50
13+5	84	40	68	34	46	35	68	60
14+0	85	52	75	70	62	48	78	72
15+0	98	87	102	107	94	81	102	95
16+0	138	134	88 (136 ft adjacent) Pooling observed	148	130	126	132 estimated	125
			Beach Width (ft)					
Transect South Beach	16 January 2010 Post-Construction	06 June 2012	06 June 2013 Post-Nourish.	15 May 2014	24 Sep 2015	2016	May 2017 Estimated*	Sep 2017 Post Harvey
1+0	88	24	62	40	37	28	64	59
1+5	80	18	55	32	28	19	55	46
2+0	78	23	60	40	35	23	60	50
2+5	84	35	70	50	48	36	70	56
3+0	94	52	79	70	60	49	75	68
4+0	95	84	99	103	89	78	78	91
5+0	127	125	78 (115 S 130 N) Pooling observed	141	125	119	118	118
Summary: Design Width (DW) Target Width	South >TW Center >TW North	South < AW Center <TW North	South: < TW Center = TW North: > TW (Exception pooling region)	South: <TW Center <TW	South: <AW Center: <TW	South <AW Center <TW	South <TW Center ≥TW North	South >AW Center <TW North

(TW)	>TW	> TW		North: >TW	North: >TW	North >TW	≥TW	≥TW

Table 3. Change in Beach Width: Sylvan Beach (2017)
***Estimated based on reported sand volume placed during May 2017 (2013 Shoreline applied as template)**

North Beach Transects	Beach Width Change (ft)								
	Δ 2010 2012	Δ 2012 2013	Δ 2013 2014	Δ 2014 2015	Δ 2015 2016	Post Nourish* Δ Dec 2016 May 2017	Post Harvey Δ May 2017 Oct2017	Δ 2016 Oct 2017	**Project Baseline** Δ 2010 2017
12+0	-61	34	-23	-3	-10	36	-11	25	-38
12+5	-62	32	-20	-6	-12	38	-20	18	-50
13+0	-53	28	-22	-3	-15	40	-8	32	-28
13+5	-44	23	-34	12	-11	33	-8	25	-24
14+0	-33	23	-5	-8	-14	30	-6	24	-13
15+0	-11	11	9	-13	-13	21	-7	14	-3
-3	-4	-46	60	-18	-4	6	-7	-1	-13
Average Change over Entire Beach	-38	17	-6	-9	-11	29	-10	20	-24
South Beach Transects	**Beach Width Change (ft)**								
	Δ 2010 2012	Δ 2012 2013	Δ 2013 2014	Δ 2014 2015	Δ 2015 2016	Post Nourish* Δ 2016 May 2017	Post Harvey Δ May 2017 Oct 2017	Δ 2016 2017	**Baseline** Δ 2010 2017
1+0	-64	38	-22	-3	-9	36	-5	31	-29
1+5	-62	37	-23	-4	-9	36	-9	27	-34
2+0	-55	37	-20	-5	-12	37	-10	27	-28
2+5	-49	35	-20	-2	-12	34	-14	20	-28
3+0	-42	27	-9	-10	-11	26	-7	19	-26
4+0	-11	15	4	-14	-11	0	13	13	-4
5+0	-2	-47	63	-18	-4	-1	0	-1	-9
Average Change over Entire Beach	-41	20	-4	-8	-10	24	-5	18	-19

Volumetric Analysis and Morphology: Sylvan Beach 2015

Prior to Hurricane Harvey, shoreline recession dominated at both North Sylvan and South Sylvan, although the net change in sand volume within each beach cell was less than 1,000 cu yd between 2015 and 2016 (Table 4). Since placement in 2010, sand has eroded from the berm and deposited in the immediate nearshore. During this process, the elevation between the fill and deeper bay bottom moderated as the beach profile approached equilibrium. Sand preferentially eroded from the south end of the berm and migrated alongshore to the north end where it was impounded resulting in an increase in elevation, offshore extent and volume both of the subaerial and submerged sections of the profile (Fig 157 and 158). The transport of sand within the offshore limit of active sediment transport (DOC estimated at -7 ft) explains continued shoreline recession with limited volume loss. Agreement in the offshore extent of the nearshore profile was well defined during 2014-2016, and to a lesser degree during 2012 when the profile was still reflective of the recent construction. The post-Harvey (Oct 2017) survey captured a period of what was anticipated as transient impoundment in the immediate nearshore after the hurricane. Localized impoundment of sand that eroded from the berm resulted in significant accretion across the nearshore section of the profile between the -2 and -6 ft contour such that the profile exceeding the most-offshore extent documented since construction. The Oct 2017 survey captured the transient deposition of sand within the outer limit of the active region of sediment transport. Therefore, the potential for subsequent net erosion at a higher rate than during a typical year is likely over the course of the months following Harvey.

A significant volume of sand eroded between the May 2017 fill placement and the post-Harvey survey conducted during Oct 2017. The estimated net sand volume that eroded from North Sylvan was 1,609 cu yd, with 1,687 cu yd attributed to the subaerial beach. The post-Harvey erosion at North Sylvan accounted for 74% of the reported May 2017 fill volume with 65% of the fill loss documented at the south end. Erosion dominated along the entire beach including the north end of North Sylvan. The net volume of sand that eroded from South Sylvan between May 2017 and Oct 2017 was 480 cu yd with 910 cu yd attributed to the subaerial beach and over 400 cu yd of sand deposited in the immediate nearshore. Erosion at South Sylvan accounted for 44% of the fill material placed during May 2017, with 23% of the erosion documented south of center beach. The lower net loss of sand at South Sylvan reflects the contribution of the impoundment of sediment in the nearshore beyond the typical offshore limit of the nearshore profile. A significant volume of sand was impounded in the nearshore at South Sylvan and although erosion dominated from center beach south, accretion dominated on the north end due to storm deposition. Based on the agreement in the offshore extent of the nearshore profile since 2013, sand that was transported into the immediate nearshore at South Sylvan during Harvey will be exposed to longshore currents capable of transporting the sand outside of the range of possible sediment exchange with the berm. Sand deposited beyond the limit of active sediment exchange with the berm is transient in stability and therefore at a risk for erosion over the months following Harvey. In addition, sand transported toward the north end of each beach may be lost as the storage capacity of the beach cell is exceeded. The storage capacity of the beach cell is defined and limited by the length of the north groin. Taking into consideration the opportunity for continued erosion of sand that was impounded between the -1 and -6 ft contour during Harvey, the total impact of erosion initiated by Harvey could increase significantly, particularly at South Sylvan.

The estimated volume of sand required to restore North Sylvan and South Sylvan to the design width and elevation, applying the Oct 2017 profile template, was 2,800 cu yd and 2,400 cu yd, respectively, for a total volume of 5,200 cu yd. The estimated fill volume is the minimum estimated to restore the each beach to a width of 75ft (Target Width) at a berm elevation of 3 ft. The Oct 2017 (Post-Harvey) beach profile was applied as the base template for nourishment planning although a future survey is recommended closer to the actual time of mobilization due to the rapid rate of erosion documented along the south end of each beach cell. The volume of sand

placed as fill at Sylvan Beach and recommended over previous reporting periods is provided in Table 5.
The difference in the degree of erosion calculated between North Sylvan and South Sylvan has been identified during Harvey but also during the previous reporting period (2016). The differences may be attributed to factors described in the previous sections but also may be influenced by limitations in analysis introduced by transect spacing and interpolation between beach profiles. In order to increase the accuracy of analysis, two additional transects introduced between the existing transects on the south end of the beach are recommended. This will reduce transect spacing on the south side, where change is greatest, to 50 ft. To accommodate the cost of the additional transects, two transects in the region of limited change between the beach cells will be eliminated. Future surveys will provide for a better understanding of any developing variability between the two beach cells.

Since construction, volume change in the nearshore region that lies between the two beach cells has been minimal with the only areas of significant accretion focused immediately adjacent to the groins (Fig 159 and 160). After construction, there was an initial burst of accretion south of each beach cell with limited change up until Hurricane Harvey when a sandbar was superimposed over the existing area of accretion located south of North Sylvan. Transient accretion was documented north of the beach cells, due to the transect location lying beyond the northern limit of the small beach extent. Aerial images have documented the existence of the small crescent beaches north of both North Sylvan and South Sylvan. The small beaches located south of each beach cell are not as well developed as those located north of the beach cells. The small beaches that have developed north of each cell are exposed during lower water levels and have been visible in aerial imagery since 2015 (Google Earth Mar to Dec 2015). Although there are no beach profile transects in the exact location of the peak development of the emergent beaches there are transects located at the outer limit of the features. The outer limit of the small crescent beaches expanded northward during Harvey at both North and South Sylvan. Evidence of accretion on the north side and the south side of each beach cell is indicated along the beach profiles at STA 0+0, STA 6+0, STA 11+0 and STA 17+0. The transects that provide limited documentation of the small beaches are located between 35 to 50 ft beyond the groins, thus providing evidence of the small nature of these areas of deposition. Although the submerged expression of these features has been more evident in the profiles south of the beaches this is due to the closer proximity of the transects at 25 and 30 ft as opposed to the profiles north of the beach cells that are at a distance of 50 ft from the groins. The presence of persistent emergent beaches north of each beach cell indicates the contribution of ; 1) Beach erosion and sand transport around the tip of the north groins, 2) sediment transport over the low-elevation groins, and perhaps funneled along the sidewalk, during surge events and 2) wind transport over the low groins (to a lesser extent.) Prior to Harvey, the sand entering these areas of impoundment from erosion within the beach cells has been limited based on the low erosion rate measured at these beaches to date; therefore accretion in this area has likely been supplemented by a contribution of native sand from the surrounding nearshore. Accretion adjacent to the north groins is supported by the sheltering afforded by not only the groin but also by the entire beach functioning as a headland, particularly as related to the influence of ship wakes and onshore forcing by wind directed out the southeast which continue to contribute to erosion at Sylvan Beach. The only other area of interest outside of the beach cells is the region of disorganized morphology that continues about 45-ft south of the pier along STA 9+0. This region has been described in previous reporting and has no influence on the nearby beach cells.

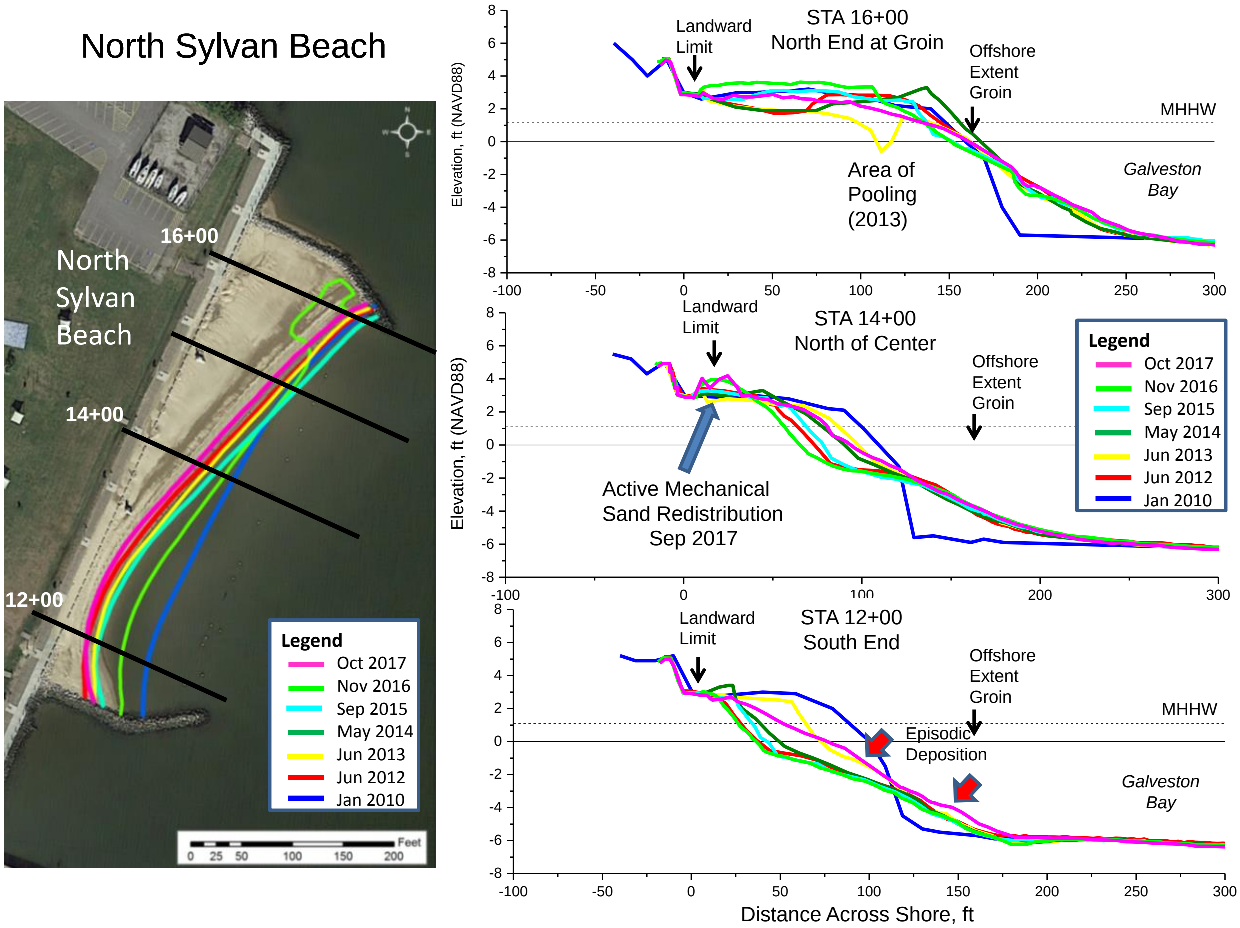


Figure 237. Change in beach profile and shoreline position at key locations at North Sylvan Beach 2010-2016

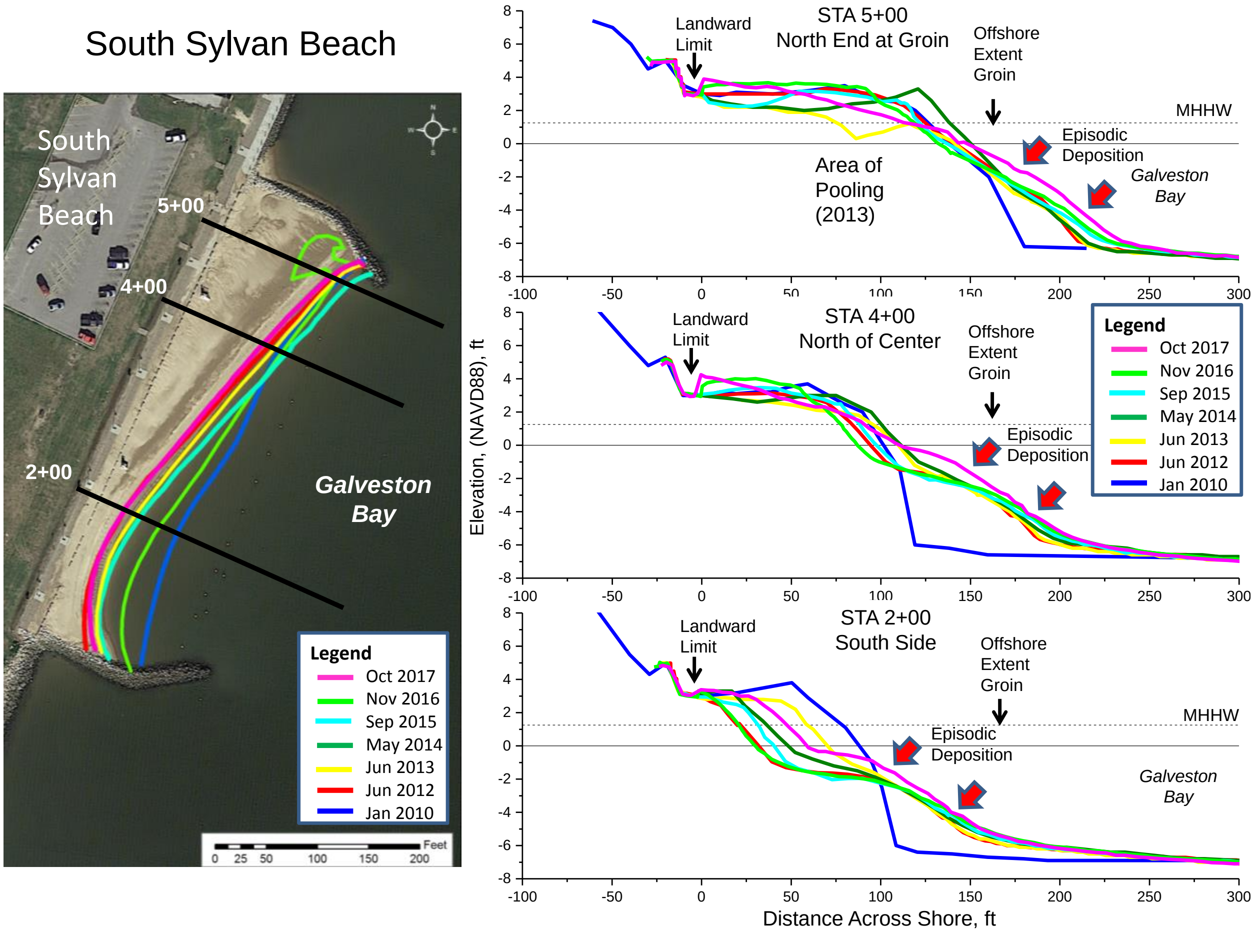
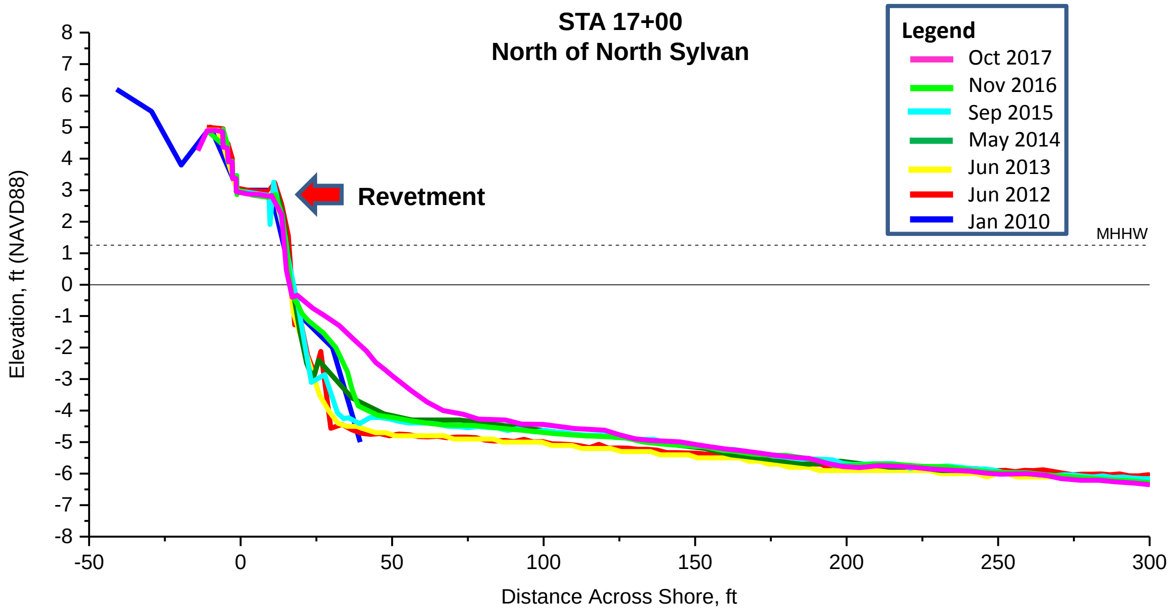


Figure 158. Change in beach profile and shoreline position at key locations at South Sylvan Beach 2010-2016

Table 4. Change in Volume: Sylvan Beach (2010-2017)				
North Sylvan Beach	**Total Beach** **cu yd (net)**	**South End (Placement Area) cu yd (est.)**	**North End** **cu yd (est.)**	**Notes:**
Date				
May 2017-Sep 2017 Post-Harvey	-1,609 DOC -1,687 Subaerial	-1,420	-189	Post-Harvey Estimated based on reported sand volume placed May 2017 and application of modified 2016 profile 65% of fill lost from south end 74% of total fill lost from cell
May 2017 Reported Fill Placement	+2,176 Fill	+2,176 Fill	0	Estimated Post-Nourishment based on reported sand volume placed May 2017
2015-2016	-720	-550	-170	3-year Post-Nourishment
2014-2015	-50	-200	+150	2-year Post-Nourishment
2013-2014	-20	-600	+580	1-year Post-Nourishment
2012-2013	+155	+1,175	-1,020	Fill Volume (URS reported) 1,500 cu yd
2010-2012	+10	-1470	+1480	2-year Post-Construction
South Sylvan Beach	**Total Beach cu yd (net)**	**South End (Placement Area) cu yd (est.)**	**North End cu yd (est.)**	**Notes:**
Date				
2016-2017 Post-Harvey	-480 DOC -910 Subaerial	-885	405	Overall loss to south end of beach estimated at 1,290 cu yd 44% of fill lost from south end 23% of total fill volume lost from cell
2016-2017 Post-Nourishment	2,056	2,056	0	Estimated Post-Nourishment based on reported sand volume placed May 2017
2015-2016	+200	-110	+310	3-year Post-Nourishment
2014-2015	-445	-120	-325	2-year Post-Nourishment
2013-2014	+180	-810	+990	1-year Post-Nourishment
2012-2013	+930	+1,600	-670	Fill Volume (URS reported) 2,300 cu yd
2010-2012	+430	-855	+1285	2-year Post-Construction



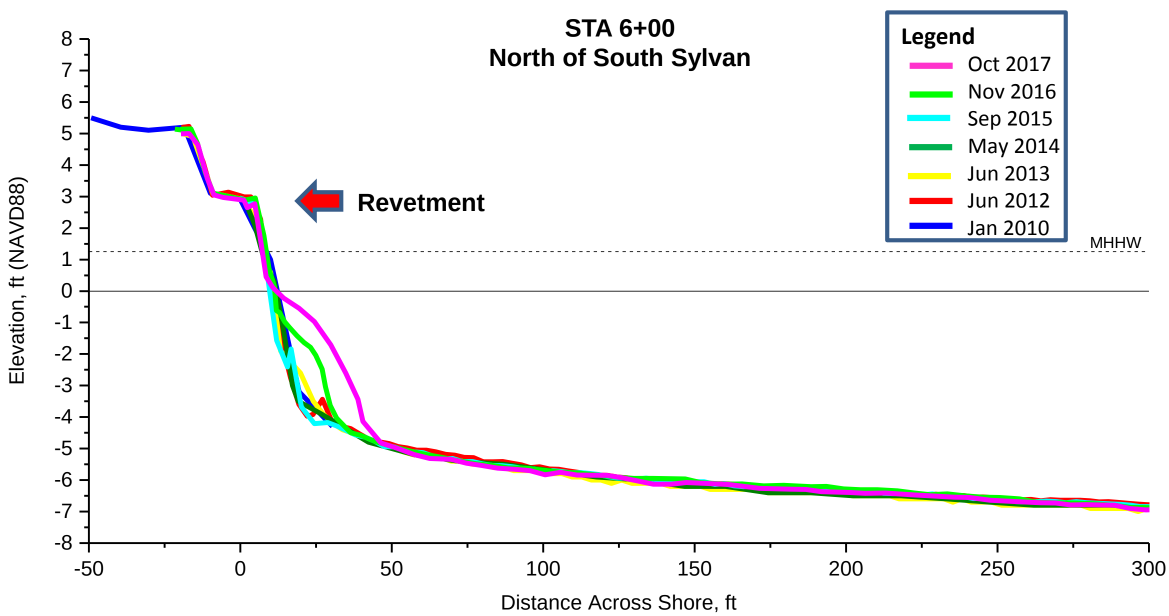


Figure 159. Most significant accretion since construction located in the nearshore immediately north of each beach cell after Hurricane Harvey

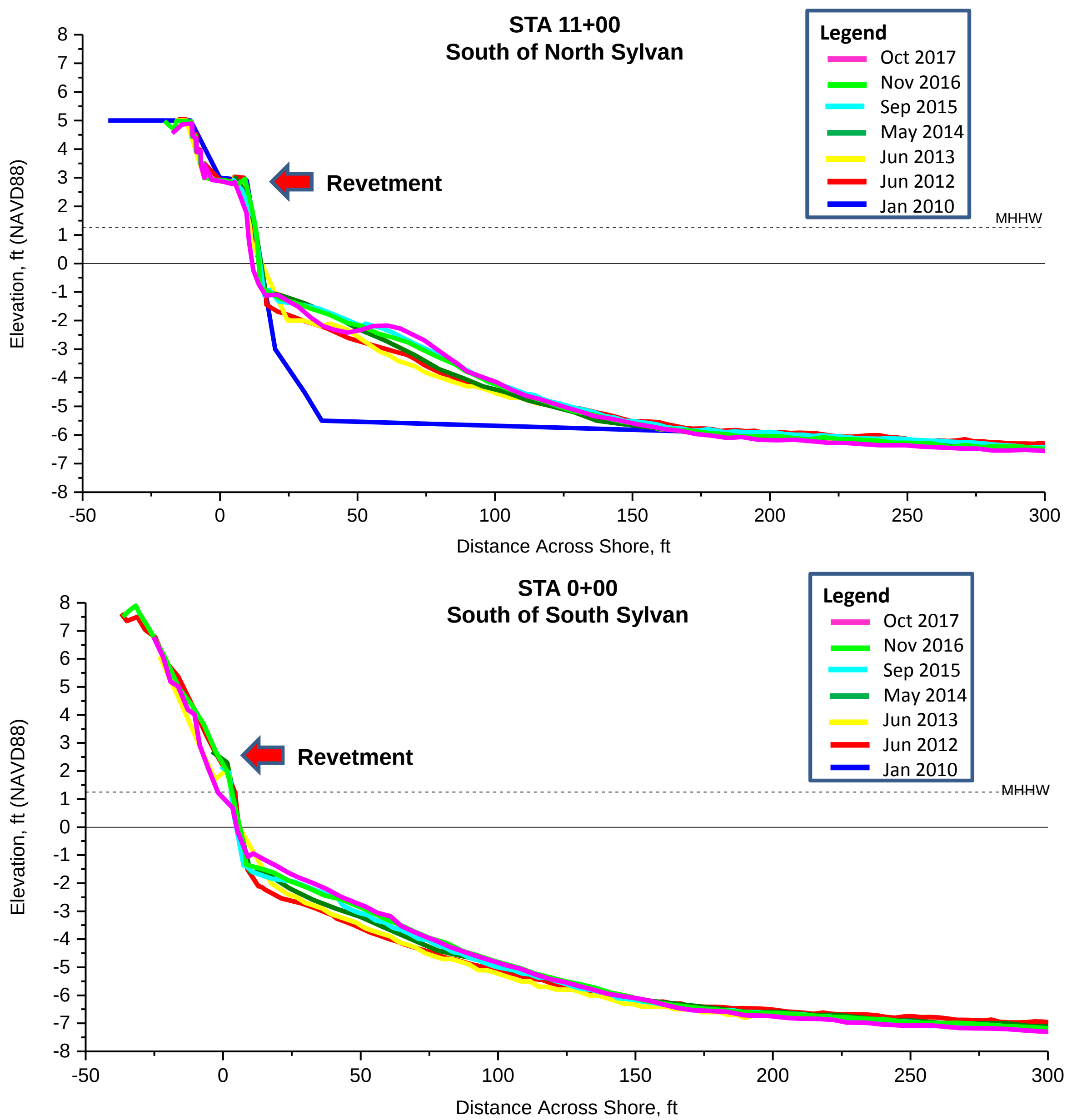


Figure 160. Limited accretion in the nearshore located immediately south of each beach cell after Hurricane Harvey (Oct 2017)

Table 5. Nourishment at Sylvan Beach: Recommendation and History of Fill Placement	
Year and Extent	**Volume**
Recommended: 2017 Profile Template based on Oct 2017 Restore *Target Width*	
North Sylvan T12-T16	2,800
South Sylvan T1-T5	2,400
Total: minimum	5,200
Estimated FEMA Recommendation: 2017 Profile Template based on Oct 2017 Restore to estimated *May 2017 Fill Template*	
North Sylvan T12-T16	1,700
South Sylvan T1-T5	1,100
Project Total	2,800
Conducted: Nourishment May 2017 (Reported by Harris County)	
2017 North Sylvan T12-T14	2,176
South Sylvan T1-T4	2,056
Actual Project Total	4,232 (Reported as 5,501.98 ton)
Recommended: 2016 Project Template (Not Placed)	
2016 North Sylvan T12-T14	6,300
South Sylvan T1-T4	4,800
Project Total	11,100
Recommended: 2015 Profile Template (Not Placed)	
North Sylvan T12-T14 Full profile to 3 ft berm elevation	3,600
South Sylvan T1-T4 Full Profile; to 3ft berm elevation	3,700
Project Total	7,300
Conducted: 2013 Nourishment (Reported by Harris County)	
North Sylvan T12-T16 Full profile to 3 ft berm elevation	1,500 (Reported as 2,000 ton)
South Sylvan T1-T5 Full Profile; to 3ft berm elevation	2,300 (Reported as 3,000 ton)
Project Total	3,800 Reported as 5,000 ton)

Discussion and Recommendations: Sylvan Beach 2016

The elevated water level and onshore forcing that occurred during Hurricane Harvey resulted in erosion and sand redistribution across the entire berm and into the nearshore with the greatest erosion focused along the south side of each beach cell. Volume loss was higher at North Sylvan, which may be attributed to several factors including; the configuration of the May 2017 nourishment, post-storm management of sand, or subtle differences related to storm forcing during Hurricane Harvey. The greatest erosion was identified at the berm crest and along the foreshore, with minimal erosion documented in the nearshore fronting the beach cells.

Due to the episodic nature of erosion that occurred during Harvey, a significant volume of sand was transported into the immediate nearshore between the 0 and -6 ft contour. The Oct 2017 survey documented the most significant introduction of sand into the nearshore due to erosion of the berm since construction. Deposition in the nearshore was particularly well defined at South Sylvan. This resulted in the greatest increase in elevation and therefore offshore shift in the beach profile, between the -1 and -7ft contour that has been documented since construction. Based on changes in the beach profile that occurred after construction and after the 2013 nourishment, it is anticipated that erosion will dominate in the nearshore as the profile adjusts and approaches agreement with the pre-storm established nearshore profile extent. The region of nearshore accretion was located near the limit of the sheltering influence of the groins and was therefore subject to alongshore currents driven toward the north by persistent onshore winds that dominate along the upper Texas coast. Thus, after Harvey there was the potential for continued accelerated erosion across the nearshore section of the beach profile over the course of the following year.

Based on performance to date, each beach cell will likely continue to require localized nourishment of the beach south of center at regular, biannual or triennial intervals to maintain stability and consistent recreational access. While surveys indicate that prior to Harvey, the beach profile had reached a maximum offshore limit, an abundance of sand was transported into the nearshore during Harvey and based on prior agreement in profile limits, is anticipated nearshore erosion would continue over the course of the following year. Erosion in the nearshore will become more significant as the north end of the beach exceeds the storage capacity afforded by the offshore extent of the groins. As reported previously, once each beach cell reaches the limit of its storage capacity, sand will exit the beach cell around the north groin and enter the surrounding nearshore region outside of the active beach profile. Therefore, the impact of the initial sand loss during Harvey may be compounded, as the transient region of post-storm impoundment is made available to continued erosion by longshore currents. The loss of subaerial sand along with the likelihood of additional erosion in the immediate nearshore over the year after Harvey provides for the potential undermining of the remaining stability afforded by the limited May 2017 nourishment.

Although replenishing the sand lost during Harvey would alleviate recreational access issues in the interim, the most effective plan for Sylvan Beach is to restore the beach to Target Width and design elevation. This would require an estimated minimum fill volume of 2,800 cu yd at North Sylvan and 2,400 cu yd at South Sylvan. Restoring only the volume lost during Harvey would provide limited benefit due to; 1) the likelihood of continued erosion over the year following Harvey and 2) the May 2017 fill volume was/is not adequate to restore the beach to Target Width and elevation. Once the Target Width at Sylvan Beach is restored from center beach to the south groin then scheduled periodic localized re-nourishment is recommended to alleviate focused erosion on the south end of the beach cells between larger scale nourishment designed to restore the beach to the original design template. An alternate interim nourishment plan could be to redistribute sand accumulating on the north end of the beach toward the south end more frequently while maintaining both a minimum width of 75 ft and minimum berm elevation of 3 ft along the beach north of center. Should redistribution from north to south be implemented on a large scale, it is recommended that the effort is coordinated with TGLO staff to ensure its success toward meeting long-term CEPRA goals.

Post-Harvey, both North Sylvan and South Sylvan Beach met the following criteria for nourishment; 1) 75% of beach was less than Target Width in both beach cells, 2) segment south of center beach at North Sylvan at the Action Width and 2) The high average rate of shoreline recession observed in the past would result in the south end of the beach at Action Width or less within 1 to 3 years at the 3-yr post-nourishment average rate of -6.5 ft/yr (North Sylvan) and -7.8 ft/yr (South Sylvan) and within 1 to 2 years if the recent (2015-2016) rate of -8.5 ft/yr (North Sylvan) and -9.6 ft/yr (South Sylvan) was maintained. The beach would experience at a minimum of impaired recreational usage within 1 year and the potential for damage to backshore infrastructure along the south side would increase after 2 years. Although the north side of the beach could initially remain stable, due to the prevalence of sediment transport directed toward the north, the stability of the overall beach would deteriorate if the south end of the beach is not maintained in excess of Action Width.

Prior to the partial nourishment conducted during May 2017, both North Sylvan and South Sylvan met the criteria for renourishment based on the 2016 assessment. In the absence of the recent nourishment completed during May 2017 the recommendation for renourishment was within one year of 2016 reporting. The sand volume reportedly placed at Sylvan Beach during May 2017 was well under the minimum volume estimated to restore the beach to the original design specifications. Due to the loss of significant volume of sand in close agreement with the volume of the May 2017 nourishment Sylvan is recommended as Tier 1 nourishment as indicated in preliminary post-Harvey reporting and FEMA documentation. Due to the high rate of recession observed since construction, it is anticipated that continued erosion has further reduced the volume of sand within the active region of sediment transport over the year following Harvey. The recommendation for the restoration of Sylvan Beach to the design template is also supported by the documentation of 1) the high rate of shoreline recession observed at this narrow beach since construction, 2) the prevalence for accelerated erosion along the south side of the beach and 3) need to maintain berm elevation in excess of 3.0 ft (NAVD88) to protect against reported significant overtopping due to ship wake which impacts the beach similar to a short duration surge event.

As provided during the last reporting period, the following guidelines are recommended to assist Harris County officials in effectively maintaining Sylvan Beach to the original design width and elevation and toward improved project longevity.

1. Coordination of all nourishment activities with TGLO Staff.
2. Design renourishment to include restoration of berm height across the length of the beach, regardless of whether the beach width is in excess of the Action or Target Width.
3. Review methods of mechanical sand redistribution from the north end to the south end during maintenance activities. Restrict sand redistribution from the backshore and berm

unless overfill material is placed there during nourishment for that express purpose or when the elevation is in well in excess of the design elevation (3 ft, NAVD88).

4. Conduct a pre-nourishment survey within one month of the anticipated nourishment to provide the most effective template for calculating the fill volume due to accelerated erosion rates.
5. Place fill from the south groin to center beach or alongshore location corresponding to Target Width of 75 ft at the time of placement in both beach cells.
6. Increase the fill volume by 500 cu yd per beach in the absence of a pre-construction survey.
7. Conduct a post-nourishment survey within one week of fill placement for application to assessment of project longevity, FEMA post-storm assessment, and future nourishment planning.

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