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NORTH CAROLINA
Environmental Quality

February 4, 2019

MEMORANDUM **CRC-19-07**

TO: Coastal Resources Commission

FROM: Ken Richardson, *Shoreline Management Specialist*

SUBJECT: Ocean Erodible AEC and Setback Factor Update Study based on 2019 Long-Term Average Annual Shoreline Change Rates

Background

Since 1980, the Division of Coastal Management has updated its oceanfront shoreline change rates approximately once every five years for calculating both oceanfront development setbacks and the landward boundary of the Ocean Erodible Area of Environmental Concern (15A NCAC 07H .0306 and 07H .0304). The last update became effective on January 31, 2013 and is now due to be updated.

Additionally, shoreline change rates are required to be updated every five years to keep North Carolina compliant with Federal Emergency Management Administration (FEMA) guidelines for the Community Rating System (CRS). This ensures that property owners in coastal communities that participate in the National Flood Insurance Program are eligible for fifty (50) additional CRS points, which can reduce insurance rates.

The Commission's setback rules are used to site oceanfront development based on the size of the structure according to the graduated setback provisions in 15A NCAC 7H .0306(a). In areas where there is a high rate of erosion, buildings must be located farther from the shoreline than in areas where there is less erosion. The construction setback equation depicted in Table 1 is used to site oceanfront development and determine the extent of the CRC's jurisdictional area for the Ocean Erodible Area of Environmental Concern (OEA) - the area where there is a substantial possibility of shoreline erosion. A minimum setback factor of two (2) is applied if the erosion rate is less than two feet per year or where there is accretion (see Table 1). This method of siting oceanfront development was initially established by the Coastal Resources Commission (CRC) in 1979.

***Table 1**. This table demonstrates an example of minimum construction setbacks based on structure size and the minimum setback factor of 2.*

Structure Size (square feet)	Construction Setback Equation	Minimum Setback (calculated using Setback Factor = 2 ft./yr.)
Less than 5,000	30 x Setback Factor	60
=>5,000 and < 10,000	60 x Setback Factor	120
=>10,000 and < 20,000	65 x Setback Factor	130
=>20,000 and < 40,000	70 x Setback Factor	140
=>40,000 and < 60,000	75 x Setback Factor	150
=>60,000 and < 80,000	80 x Setback Factor	160
=>80,000 and < 100,000	85 x Setback Factor	170
Greater than 100,000	90 x Setback Factor	180

Summary of 2019 Shoreline Change Rates and Setback Factors

Average annual long-term shoreline change rates are calculated using the “end-point” methodology. This technique of calculating shoreline change rates is consistent with earlier studies and the results can be compared to those from previous studies. Applying the end-point method to the 2019 update study, Staff used the earliest (1933-1962) and most current shorelines (2016) to calculate change rates by measuring distance between the two shorelines (shore-transect intersect) and dividing by time. Raw shoreline change rates are statistically “smoothed and blocked” with neighboring transects to group adjacent shoreline segments that have similar rates into segments that can be assigned a single erosion rate. A “segment” of shoreline is defined as a portion of beach with statistically similar erosion rates and a minimum length of approximately 1,300 feet (400 meters).

Of the 304.5 miles of oceanfront shoreline analyzed, results show that approximately 69 percent of the shoreline is experiencing some degree of erosion, while 30 percent is accreting either due to beach nourishment or natural processes. Of the eroding portions of shoreline, 22.7 percent is eroding at rates less than two feet per year, while 22.9 percent is eroding between two and five feet per year (Table 2). The 2019 statewide mean shoreline change rate is approximately -2 feet per year, which is consistent with previous studies.

Table 2. *This table illustrates a summary of length of shoreline (and percentage) and calculated shoreline change rates. The first row shows approximately 92 miles of oceanfront shoreline with measured accretion; the second row shows approximately 210 miles with measured erosion; and then subsequent rows show a breakdown of erosion from the total length of shoreline with measured erosion (210 miles).*

Shoreline Change Rate Summary:	Miles	%
Accretion (all)	91.6	30.1%
Erosion (all)	209.5	68.8%
Erosion 2ft/Year or Less (>0, <=2)	69.3	22.7%
Erosion 2 to 5 Feet/Year (>2, <=5)	69.7	22.9%
Erosion 5 to 8 Feet Year (>5, <=8)	42.8	14.1%
Erosion More Than 8 Feet/Year	27.6	9.1%
Data Gaps (missing shoreline segment)	1.9	0.6%

The mean shoreline change rate for a segment of beach determines the Ocean Hazard Area Setback Factor. Although the 2019 calculated Setback Factors show similar trends compared to the overall average of all the past six studies (see Table 3), there was a slight erosion rate increase for portions of the coastline north of Cape Lookout, resulting in an increase in the average statewide setback factor. More specifically, erosion rate increases were identified at those areas adjacent to inlets and capes, and along the National Seashore north of Cape Lookout. The following table is a statewide comparison of shoreline length and Setback Factors for all six studies (1980-2016):

Table 3. *This table is a comparison of oceanfront Setback Factors (SBF) that were calculated using long-term average annual shoreline change rates. Values show the length of shoreline (miles and %) for categorized setback factors (far-left column). Total shoreline mileage is the length of shoreline analyzed and should not be interpreted as a "shrinking" or "expanding" shoreline. Of the 304.5 miles, 2 miles of shoreline were considered to have "no data," meaning that only one shoreline was available.*

Erosion Rate Studies	2016	2011	2003	1992	1986	1980
Miles (total)	**304.5**	307.4	312	300	237	245
SBF = 2	**175.1 (57.5%)**	190.2 (61.9%)	193 (62%)	165 (59%)	144 (61%)	149 (61%)
SBF = 2.5 to 5	**66.5 (21.8%)**	62.1 (20.2%)	64 (20%)	54 (19%)	43 (18%)	52 (21%)
SBF = 5.5 to 8	**38.2 (12.6%)**	31.5 (10.2%)	28 (9%)	30 (11%	20 (8%)	22 (9%)
SBF > 8	**22.6 (7.4%)**	20.8 (6.8%)	27 (9%)	32 (11%)	22 (9%)	22 (9%)

The setback rule applies when oceanfront property owners are seeking a Coastal Area Management Act (CAMA) permit for development of new a structure, to expand an existing structure, or to replace an existing structure (requiring more than fifty percent repair) along the ocean shoreline. Based on this analysis, 7,579 existing structures (86.4%) adjacent to the Atlantic shoreline will experience no change in development setback factors, while 984 oceanfront structures (11.2%) will experience an increase in construction setback factors. Table 4 depicts the number of properties affected by changes in erosion rates. Where proposed erosion rates would increase setback factors, it is worth noting that all are located in regions that have historically had relatively high erosion rates. The highest erosion rates are primarily centered around those inlets that have not been regularly engineered for purposes of navigation or erosion control (Brunswick County); and in areas where high erosion is the result of direct impact from persistent nor'easter storms (Dare County).

Table 4. *Count of structures adjacent to Atlantic oceanfront shoreline by county. Values represent the number of structures and percentages to demonstrate how the proposed update will influence construction setback factors for those structures. Data are based on 2016 NC 911 Orthophotos and 2018 county tax office information.*

Location	Total Structures	No Rate Change	% No Change	Lower Rates	% Lower Rates	Higher Rates	% Higher Rates
Brunswick County	2,022	1,842	91.1%	110	5.4%	70	3.4%
New Hanover County	847	825	97.4%	11	1.2%	11	1.2%
Pender County	760	760	100%	0	0%	0	0%
Onslow County	607	558	91.9%	2	<1%	47	7.7%
Carteret County	1,257	1,256	99.9%	0	0%	1	<1%
Hyde County	0	0	100%	0	0%	0	0%
Dare County	2,539	1,750	68.9%	75	2.9%	714	28.1%
Currituck County	745	588	78.9%	16	2.1%	141	18.9%
TOTALS:	**8,777**	**7,579**	**86.4%**	**214**	**2.4%**	**984**	**11.2%**

About 984 properties will experience an increased construction setback factor ranging from one-half foot to three feet per year. These properties have historically had relatively high erosion rates, with small fluctuations, since the first study was done in 1980.

Table 5. *This table illustrates locations where calculated Setback Factors (SBFs) increased between 2009 and 2016. Although an increase of 3 feet per year was the highest increase in areas adjacent to oceanfront structures, most areas with oceanfront structures only increased by factors ranging between 0.5 and 1.0 feet per year.*

Community	Transect Location	Historical Notes	SBF Change (from 2009 to 2016)	Structure Count	% of Total w/ Higher SBFs
Avon	7316 to 7382	Historical Setback Factors (2 to 6 ft./yr.)	1 to 2	130	13.2%
Bald Head Island	South Beach (998-1000) & (1056-1083)	Historical Setback Factors (4 to 15 ft./yr.)	0.5 to 2.5	17	1.7%
Buxton	7174 to 7189	Historical Setback Factors (5 to 8.5 ft./yr.)	0.5 to 1.5	35	3.6%
Currituck County	9884 to 10065	Historical Setback Factors (2 to 11.5 ft./yr.)	0.5 to 1.5	65	6.6%
Hatteras Village	6776 to 6864	Historical Setback Factors (2 to 5 ft./yr.)	0.5 to 1.5	50	5.1%
Holden Beach	519 to 548	Historical Setback Factors approaching Lockwood Folly Inlet (2.5 to 7.5 ft./yr.)	0.5 to 1.0	53	5.4%
Kill Devil Hills	8963 to 8987	Historical Setback Factors (2 to 6.5 ft./yr.)	0.5 to 1.5	52	5.3%
Kitty Hawk	9059 to 9108	Historical Setback Factors (2 to 4 ft./yr.)	0.5 to 1.0	90	9.1%
Kure Beach	1398 to 1412	Historical Setback Factors (2 to 5.5 ft./yr.)	0.5 to 1.0	11	1.1%
Nags Head	8504 to 8779	Historical Setback Factors (2 to 10 ft./yr.)	0.5 to 1.0	276	28.0%
North Topsail Beach	2926 to 2959	Historical Setback Factors (2 to 3.5 ft./yr.)	0.5 to 1.0	45	4.6%
Salvo-Waves-Rodanthe	7881 to 7959	Historical Setback Factors (2 to 3.5 ft./yr.)	0.5 to 3.0	81	8.2%
Sanderling-Corolla	9784 to 9831	Historical Setback Factors (2 to 7 ft./yr.)	1	76	7.7%
Public Lands				*3*	0.3%

Summary of Fiscal Analysis

If erosion rates were not updated in 2019, the loss of fifty CRS points would not have an immediate negative impact on those communities listed below in Table 6. However, several communities are scheduled to be reevaluated by NFIP in 2019 and 2020, and at that time could potentially benefit by having fifty points awarded and saving five percent in premiums as a direct result of NC updating erosion rates. Although this update alone does not guarantee a community will save five percent in premiums, the 50-points awarded could mean the difference between higher and lower NFIP Classes.

Table 6. *List of oceanfront communities participating in CRS. This table illustrates their current CRS Class, Special Flood Hazard Area (SFHA) Premium discount percentages, CRS points, and point score scenario subtracting 50 points. Based on current points, none of the listed communities would be impacted by the loss of fifty points. It should be noted that those communities identified with an asterisk (*) have an assigned CRS Class that does not correspond to their CRS Points because they did not meet FEMA's prerequisites during their last evaluation; therefore, could not be placed in the Class tier based on scored points.*

	Community	**Current CRS Class**	**% Discount for SFHA(1)**	**% Discount for Non-SFHA**	**CRS Points**	**CRS Points (-50)**	***CRS Class Change if Points Lost***
1	Atlantic Beach	8	10	5	1365	*1315*	*No*
2	Carolina Beach	6	20	10	2058	*2008*	*No*
3	Caswell Beach	6	20	10	2240	*2190*	*No*
4	Duck	7	15	5	1664	*1614*	*No*
5	Emerald Isle	7	15	5	1906	*1856*	*No*
6	Holden Beach	8	10	5	1181	*1131*	*No*
7	Kill Devil Hills	6	20	10	2305	*2255*	*No*
8	Kitty Hawk	6	20	10	2116	*2066*	*No*
9	Kure Beach	8	10	5	1114	*1064*	*No*
10	Nags Head	6	20	10	2076	*2026*	*No*
11	North Topsail Beach*	*5**	25	10	*3600*	*3550*	*No**
12	Oak Island*	*7**	15	5	*2258*	*2208*	*No**
13	Ocean Isle Beach*	*8**	10	5	*2088*	*2038*	*No**
14	Pine Knoll Shores	6	20	10	2134	*2084*	*No*
15	Southern Shores	6	20	10	2153	*2103*	*No*
16	Sunset Beach*	*7**	15	5	*2109*	*2059*	*No**
17	Topsail Beach	5	25	10	2597	*2547*	*No*
18	Wrightsville Beach	7	15	5	1768	*1718*	*No*

About 984 properties will experience an increased construction setback factor ranging from one-half foot to three feet per year. These properties have historically had relatively high erosion rates, with small fluctuations, since the first study was done in 1980. These property owners could be negatively impacted by this change if their home is destroyed by more than fifty percent, and if they are unable to meet the required construction setback as measured from the first line of stable-natural vegetation. It is important to note that this still may not preclude them from rebuilding should their home be destroyed due to a number or grandfathering provisions found within the CRC's rules.

In addition, two hundred and fifteen (215) existing structures adjacent to the Atlantic shoreline will experience a reduced construction setback factor, ranging between 0.5 to 5 feet per year. Although purely speculative, these properties could potentially be permitted and allowed re-development or expansion of the existing structure if new setback requirements can be met and depending on the size of the new construction. These property owners could potentially benefit by being able to expand or re-develop their property to a greater extent possible than what is currently allowed under the existing setback factors. It is not possible to estimate the exact value of this benefit without knowing how many property owners would choose to undertake expansion or redevelopment, or knowing specifics related to construction plans; however, it is estimated that this is an overall positive net influence if compared to existing more restrictive setback requirements.

This update will not have a cost impact on NC DOT and local government projects, or the DCM permit review process or receipts.

Staff Recommendation

The 2018 update study report has been completed and the fiscal analysis has been approved by Office of State Budget and Management (OSBM). DCM staff are recommending that the Commission's approve the report, the updated oceanfront setback factors, the fiscal analysis, and rule amendments.

ATTACHMENT A: CRC Rules Pertaining to Oceanfront Shoreline Change Rates and Setback Factors

ATTACHMENT B: Fiscal Analysis for the 2019 Update of Oceanfront Shoreline Change Rates and Setback Factors

ATTACHMENT C: North Carolina 2019 Oceanfront Setback Factors & Long-Term Average Annual Erosion Rate Update Study

ATTACHMENT A: CRC's Rules Pertaining to Oceanfront Shoreline Change Rates and Setback Factors & Proposed Amendments

15A NCAC 07H .0304 AECS WITHIN OCEAN HAZARD AREAS

The ocean hazard AECs contain all of the following areas:

(1) Ocean Erodible Area. This is the area where there exists a substantial possibility of excessive erosion and significant shoreline fluctuation. The oceanward boundary of this area is the mean low water line. The landward extent of this area is the distance landward from the first line of stable and natural vegetation as defined in 15A NCAC 07H .0305(a)(5) to the recession line established by multiplying the long-term annual erosion rate times 90; provided that, where there has been no long-term erosion or the rate is less than two feet per year, this distance shall be set at 180 feet landward from the first line of stable natural vegetation. For the purposes of this Rule, the erosion rates are the long-term average based on available historical data. The current long-term average erosion rate data for each segment of the North Carolina coast is depicted on maps entitled "North Carolina 2019 Oceanfront Setback Factors & Long-Term Average Annual Erosion Rate Update Study" ~~"2011 Long-Term Average Annual Shoreline Rate Update"~~ and approved by the Coastal Resources Commission on May 5, 2011 (except as such rates may be varied in individual contested cases or in declaratory or interpretive rulings). In all cases, the rate of shoreline change shall be no less than two feet of erosion per year. The maps are available without cost from any Local Permit Officer or the Division of Coastal Management on the internet at http://www.nccoastalmanagement.net.

(2) Inlet Hazard Area. The inlet hazard areas are natural-hazard areas that are especially vulnerable to erosion, flooding, and other adverse effects of sand, wind, and water because of their proximity to dynamic ocean inlets. This area extends landward from the mean low water line a distance sufficient to encompass that area within which the inlet migrates, based on statistical analysis, and shall consider such factors as previous inlet territory, structurally weak areas near the inlet, and external influences such as jetties and channelization. The areas on the maps identified as suggested Inlet Hazard Areas included in the report entitled INLET HAZARD AREAS, The Final Report and Recommendations to the Coastal Resources Commission, 1978, as amended in 1981, by Loie J. Priddy and Rick Carraway are incorporated by reference and are hereby designated as Inlet Hazard Areas, except for:

(a) the Cape Fear Inlet Hazard Area as shown on the map does not extend northeast of the Bald Head Island marina entrance channel; and

(b) the former location of Mad Inlet, which closed in 1997.

In all cases, the Inlet Hazard Area shall be an extension of the adjacent ocean erodible areas and in no case shall the width of the inlet hazard area be less than the width of the adjacent ocean erodible area. This report is available for inspection at the Department of Environmental Quality, Division of Coastal Management, 400 Commerce Avenue, Morehead City, North Carolina or at the website referenced in Item (1) of this Rule. Photocopies are available at no charge.

(3) Unvegetated Beach Area. Beach areas within the Ocean Hazard Area where no stable natural vegetation is present may be designated as an Unvegetated Beach Area on either a permanent or temporary basis as follows:

(a) An area appropriate for permanent designation as an Unvegetated Beach Area is a dynamic area that is subject to rapid unpredictable landform change due to wind and wave action. The areas in this category shall be designated following studies by the Division of Coastal Management. These areas shall be designated on maps approved by the Coastal Resources Commission and available without cost from any Local Permit Officer or the Division of Coastal Management on the internet at the website referenced in Item (1) of this Rule.

(b) An area that is suddenly unvegetated as a result of a hurricane or other major storm event may be designated by the Coastal Resources Commission as an Unvegetated Beach Area for a specific period of time, or until the vegetation has re-established in accordance with 15A NCAC 07H .0305(a)(5). At the expiration of the time specified or the re-establishment of the vegetation, the area shall return to its pre-storm designation.

History Note: *Authority G.S. 113A-107; 113A-107.1; 113A-113; 113A-124;*
Eff. September 9, 1977;
Amended Eff. December 1, 1993; November 1, 1988; September 1, 1986; December 1, 1985;
Temporary Amendment Eff. October 10, 1996;
Amended Eff. April 1, 1997;
Temporary Amendment Eff. October 10, 1996 Expired on July 29, 1997;
Temporary Amendment Eff. October 22, 1997;
Amended Eff. July 1, 2016; September 1, 2015; May 1, 2014; February 1, 2013; January 1, 2010; February 1, 2006; October 1, 2004; April 1, 2004; August 1, 1998.

15A NCAC 07h .0306 GENERAL USE STANDARDS FOR OCEAN HAZARD AREAS

(a) In order to protect life and property, all development not otherwise specifically exempted or allowed by law or elsewhere in the Coastal Resources Commission's rules shall be located according to whichever of the following is applicable:

(1) The ocean hazard setback for development shall be measured in a landward direction from the vegetation line, the static vegetation line, or the measurement line, whichever is applicable.

(2) In areas with a development line, the ocean hazard setback shall be set in accordance with Subparagraphs (a)(3) through (9) of this Rule. In no case shall new development be sited seaward of the development line.

(3) In no case shall a development line be created or established on state owned lands or oceanward of the mean high water line or perpetual property easement line, whichever is more restrictive.

(4) The ocean hazard setback shall be determined by both the size of development and the shoreline long term erosion rate as defined in Rule .0304 of this Section. "Development size" is defined by total floor area for structures and buildings or total area of footprint for development other than structures and buildings. Total floor area includes the following:
   (A) The total square footage of heated or air-conditioned living space;
   (B) The total square footage of parking elevated above ground level; and
   (C) The total square footage of non-heated or non-air-conditioned areas elevated above ground level, excluding attic space that is not designed to be load-bearing.

   Decks, roof-covered porches, and walkways shall not be included in the total floor area unless they are enclosed with material other than screen mesh or are being converted into an enclosed space with material other than screen mesh.

(5) With the exception of those types of development defined in 15A NCAC 07H .0309, no development, including any portion of a building or structure, shall extend oceanward of the ocean hazard setback. This includes roof overhangs and elevated structural components that are cantilevered, knee braced, or otherwise extended beyond the support of pilings or footings. The ocean hazard setback shall be established based on the following criteria:
   (A) A building or other structure less than 5,000 square feet requires a minimum setback of 60 feet or 30 times the shoreline erosion rate, whichever is greater;
   (B) A building or other structure greater than or equal to 5,000 square feet but less than 10,000 square feet requires a minimum setback of 120 feet or 60 times the shoreline erosion rate, whichever is greater;
   (C) A building or other structure greater than or equal to 10,000 square feet but less than 20,000 square feet requires a minimum setback of 130 feet or 65 times the shoreline erosion rate, whichever is greater;
   (D) A building or other structure greater than or equal to 20,000 square feet but less than 40,000 square feet requires a minimum setback of 140 feet or 70 times the shoreline erosion rate, whichever is greater;
   (E) A building or other structure greater than or equal to 40,000 square feet but less than 60,000 square feet requires a minimum setback of 150 feet or 75 times the shoreline erosion rate, whichever is greater;

(F) A building or other structure greater than or equal to 60,000 square feet but less than 80,000 square feet requires a minimum setback of 160 feet or 80 times the shoreline erosion rate, whichever is greater;

(G) A building or other structure greater than or equal to 80,000 square feet but less than 100,000 square feet requires a minimum setback of 170 feet or 85 times the shoreline erosion rate, whichever is greater;

(H) A building or other structure greater than or equal to 100,000 square feet requires a minimum setback of 180 feet or 90 times the shoreline erosion rate, whichever is greater;

(I) Infrastructure that is linear in nature, such as roads, bridges, pedestrian access such as boardwalks and sidewalks, and utilities providing for the transmission of electricity, water, telephone, cable television, data, storm water, and sewer requires a minimum setback of 60 feet or 30 times the shoreline erosion rate, whichever is greater;

(J) Parking lots greater than or equal to 5,000 square feet require a setback of 120 feet or 60 times the shoreline erosion rate, whichever is greater;

(K) Notwithstanding any other setback requirement of this Subparagraph, a building or other structure greater than or equal to 5,000 square feet in a community with a static line exception in accordance with 15A NCAC 07J .1200 requires a minimum setback of 120 feet or 60 times the shoreline erosion rate in place at the time of permit issuance, whichever is greater. The setback shall be measured landward from either the static vegetation line, the vegetation line, or measurement line, whichever is farthest landward; and

(L) Notwithstanding any other setback requirement of this Subparagraph, replacement of single-family or duplex residential structures with a total floor area greater than 5,000 square feet, and commercial and multi-family residential structures with a total floor area no greater than 10,000 square feet, shall be allowed provided that the structure meets the following criteria:

(i) the structure was originally constructed prior to August 11, 2009;

(ii) the structure as replaced does not exceed the original footprint or square footage;

(iii) it is not possible for the structure to be rebuilt in a location that meets the ocean hazard setback criteria required under Subparagraph (a)(5) of this Rule;

(iv) the structure as replaced meets the minimum setback required under Part (a)(5)(A) of this Rule; and

(v) the structure is rebuilt as far landward on the lot as feasible.

(6) If a primary dune exists in the AEC on or landward of the lot where the development is proposed, the development shall be landward of the crest of the primary dune, the ocean hazard setback, or development line, whichever is farthest from vegetation line, static vegetation line, or measurement line, whichever is applicable. For existing lots, however, where setting the development landward of the crest of the primary dune would preclude any practical use of the lot, development may be located oceanward of the primary dune. In such cases, the development may be located landward of the ocean hazard setback, but shall not be located on or oceanward of a frontal dune or the development line. The words "existing lots" in this Rule shall mean a lot or tract of land that, as of June 1, 1979, is specifically described in a recorded plat and cannot be enlarged by combining the lot or tract of land with a contiguous lot or tract of land under the same ownership.

(7) If no primary dune exists, but a frontal dune does exist in the AEC on or landward of the lot where the development is proposed, the development shall be set landward of the frontal dune, ocean hazard setback, or development line, whichever is farthest from the vegetation line, static vegetation line, or measurement line, whichever is applicable.

(8) If neither a primary nor frontal dune exists in the AEC on or landward of the lot where development is proposed, the structure shall be landward of the ocean hazard setback or development line, whichever is more restrictive.

(9) Structural additions or increases in the footprint or total floor area of a building or structure represent expansions to the total floor area and shall meet the setback requirements established in this Rule and 15A NCAC 07H .0309(a). New development landward of the applicable setback may be cosmetically, but shall not be structurally, attached to an existing structure that does not conform with current setback requirements.

(10) Established common law and statutory public rights of access to and use of public trust lands and waters in ocean hazard areas shall not be eliminated or restricted. Development shall not encroach upon public accessways, nor shall it limit the intended use of the accessways.

(11) Development setbacks in areas that have received large-scale beach fill as defined in 15A NCAC 07H .0305 shall be measured landward from the static vegetation line as defined in this Section, unless a development line has been approved by the Coastal Resources Commission in accordance with 15A NCAC 07J .1300.

(12) In order to allow for development landward of the large-scale beach fill project that cannot meet the setback requirements from the static vegetation line, but can or has the potential to meet the setback requirements from the vegetation line set forth in Subparagraphs (a)(1) and (a)(5) of this Rule, a local government, group of local governments involved in a regional beach fill project, or qualified "owners' association" as defined in G.S. 47F-1-103(3) that has the authority to approve the locations of structures on lots within the territorial jurisdiction of the association and has jurisdiction over at least one mile of ocean shoreline, may petition the Coastal Resources Commission for a "static line exception" in accordance with 15A NCAC 07J .1200. The static line exception shall apply to development of property that lies both within the jurisdictional boundary of the petitioner and the boundaries of the large-scale beach fill project. This static line exception shall also allow development greater than 5,000 square feet to use the setback provisions defined in Part (a)(5)(K) of this Rule in areas that lie within the jurisdictional boundary of the petitioner, and the boundaries of the large-scale beach fill project. If the request is approved, the Coastal Resources Commission shall allow development setbacks to be measured from a vegetation line that is oceanward of the static vegetation line under the following conditions:

(A) Development meets all setback requirements from the vegetation line defined in Subparagraphs (a)(1) and (a)(5) of this Rule;

(B) Development setbacks shall be calculated from the shoreline erosion rate in place at the time of permit issuance;

(C) No portion of a building or structure, including roof overhangs and elevated portions that are cantilevered, knee braced, or otherwise extended beyond the support of pilings or footings, extends oceanward of the landward-most adjacent building or structure. When the configuration of a lot precludes the placement of a building or structure in line with the landward-most adjacent building or structure, an average line of construction shall be determined by the Division of Coastal Management on a case-by-case basis in order to determine an ocean hazard setback that is landward of the vegetation line, a distance no less than 30 times the shoreline erosion rate or 60 feet, whichever is greater;

(D) With the exception of swimming pools, the development defined in Rule .0309(a) of this Section shall be allowed oceanward of the static vegetation line; and

(E) Development shall not be eligible for the exception defined in Rule .0309(b) of this Section.

(b) No development shall be permitted that involves the removal or relocation of primary or frontal dune sand or vegetation thereon that would adversely affect the integrity of the dune. Other dunes within the ocean hazard area shall not be disturbed unless the development of the property is otherwise impracticable. Any disturbance of these other dunes shall be allowed only to the extent permitted by 15A NCAC 07H .0308(b).

(c) Development shall not cause irreversible damage to historic architectural or archaeological resources as documented by the local historic commission, the North Carolina Department of Natural and Cultural Resources, or the National Historical Registry.

(d) Development shall comply with minimum lot size and set back requirements established by local regulations.

(e) Mobile homes shall not be placed within the high hazard flood area unless they are within mobile home parks existing as of June 1, 1979.

(f) Development shall comply with the general management objective for ocean hazard areas set forth in 15A NCAC 07H .0303.

(g) Development shall not interfere with legal access to, or use of, public resources, nor shall such development increase the risk of damage to public trust areas.

(h) Development proposals shall incorporate measures to avoid or minimize adverse impacts of the project. These measures shall be implemented at the applicant's expense and may include actions that:

(1) minimize or avoid adverse impacts by limiting the magnitude or degree of the action;

(2) restore the affected environment; or

(3) compensate for the adverse impacts by replacing or providing substitute resources.

(i) Prior to the issuance of any permit for development in the ocean hazard AECs, there shall be a written acknowledgment from the applicant to the Division of Coastal Management that the applicant is aware of the risks associated with development in this hazardous area and the limited suitability of this area for permanent structures.

The acknowledgement shall state that the Coastal Resources Commission does not guarantee the safety of the development and assumes no liability for future damage to the development.

(j) All relocation of structures shall require permit approval. Structures relocated with public funds shall comply with the applicable setback line and other applicable AEC rules. Structures, including septic tanks and other essential accessories, relocated entirely with non-public funds shall be relocated the maximum feasible distance landward of the present location. Septic tanks shall not be located oceanward of the primary structure. All relocation of structures shall meet all other applicable local and state rules.

(k) Permits shall include the condition that any structure shall be relocated or dismantled when it becomes imminently threatened by changes in shoreline configuration as defined in 15A NCAC 07H .0308(a)(2)(B). Any such structure shall be relocated or dismantled within two years of the time when it becomes imminently threatened, and in any case upon its collapse or subsidence. However, if natural shoreline recovery or beach fill takes place within two years of the time the structure becomes imminently threatened, so that the structure is no longer imminently threatened, then it need not be relocated or dismantled at that time. This permit condition shall not affect the permit holder's right to seek authorization of temporary protective measures allowed pursuant to 15A NCAC 07H .0308(a)(2).

History Note: Authority G.S. 113A-107; 113A-113(b)(6); 113A-124;
Eff. September 9, 1977;
Amended Eff. December 1, 1991; March 1, 1988; September 1, 1986; December 1, 1985;
RRC Objection due to ambiguity Eff. January 24, 1992;
Amended Eff. March 1, 1992;
RRC Objection due to ambiguity Eff. May 21, 1992;
Amended Eff. February 1, 1993; October 1, 1992; June 19, 1992;
RRC Objection due to ambiguity Eff. May 18, 1995;
Amended Eff. August 11, 2009; April 1, 2007; November 1, 2004; June 27, 1995;
Temporary Amendment Eff. January 3, 2013;
Amended Eff. September 1, 2017; February 1, 2017; April 1, 2016; September 1, 2013.

15A NCAC 07J .0210 REPLACEMENT OF EXISTING STRUCTURES

Replacement of structures damaged or destroyed by natural elements, fire or normal deterioration is considered development and requires CAMA permits. Replacement of structures shall be permitted if the replacements is consistent with current CRC rules. Repair of structures damaged by natural elements, fire or normal deterioration is not considered development and shall not require CAMA permits. The CRC shall use the following criteria to determine whether proposed work is considered repair or replacement.

(1) NON-WATER DEPENDENT STRUCTURES. Proposed work is considered replacement if the cost to do the work exceeds 50 percent of the market value of an existing structure immediately prior to the time of damage or the time of request. Market value and costs are determined as follows:

- (a) Market value of the structure does not include the value of the land, value resulting from the location of the property, value of accessory structures, or value of other improvements located on the property. Market value of the structure shall be determined by the Division based upon information provided by the applicant using any of the following methods:
  - (i) appraisal;
  - (ii) replacement cost with depreciation for age of the structure and quality of construction; or
  - (iii) tax assessed value.
- (b) The cost to do the work is the cost to return the structure to its pre-damaged condition, using labor and materials obtained at market prices, regardless of the actual cost incurred by the owner to restore the structure. It shall include the costs of construction necessary to comply with local and state building codes and any improvements that the owner chooses to construct. The cost shall be determined by the Division utilizing any or all of the following:
  - (i) an estimate provided by a North Carolina licensed contractor qualified by license to provide an estimate or bid with respect to the proposed work;
  - (ii) an insurance company's report itemizing the cost, excluding contents and accessory structures; or
  - (iii) an estimate provided by the local building inspections office.

(2) WATER DEPENDENT STRUCTURES. The proposed work is considered replacement if it enlarges the existing structure. The proposed work is also considered replacement if:

(a) in the case of fixed docks, piers, platforms, boathouses, boatlifts, and free standing moorings, more than 50 percent of the framing and structural components (beams, girders, joists, stringers, or pilings) must be rebuilt in order to restore the structure to its pre-damage condition. Water dependent structures that are structurally independent from the principal pier or dock, such as boatlifts or boathouses, are considered as separate structures for the purpose of this Rule;

(b) in the case of boat ramps and floating structures such as docks, piers, platforms, and modular floating systems, more than 50 percent of the square feet area of the structure must be rebuilt in order to restore the structure to its pre-damage condition;

(c) in the case of bulkheads, seawalls, groins, breakwaters, and revetments, more than 50 percent of the linear footage of the structure must be rebuilt in order to restore the structure to its pre-damage condition.

History Note: *Authority G.S. 113A-103(5)b.5.; 113A-107(a),(b);*
Eff. July 1, 1990;
Amended Eff. August 1, 2007.

North Carolina 2019 Oceanfront Setback Factors & Long-Term Average Annual Erosion Rate Update Study

Methods Report

N.C. Department of Environmental Quality - Division of Coastal Management

Updated: 1/16/2019

The purpose of this study is to update ocean hazard construction setback factors and Ocean Erodible Area of Environmental Concern; which are based on long-term average annual shoreline change rates.

CONTENTS

INTRODUCTION

The purpose of this study is to update ocean hazard construction Setback Factors and the Ocean Erodible Area of Environmental Concern which are based on the long-term average annual oceanfront shoreline change rates, commonly referred to as "erosion rates." Initially established by the Coastal Resource Commission (CRC) under the Coastal Area Management Act (CAMA) in 1979, the long-term average annual shoreline change rates have been updated periodically since 1980, with the last update study completed in 2011, and effective on January 31, 2013. Oceanfront construction Setback Factors are used to site oceanfront development and determine the landward extent of the Ocean Erodible Area (OEA) within the Ocean Hazard Area of Environmental Concern (AEC), or the area where there is a substantial possibility of excessive shoreline erosion.

The coast of North Carolina continually changes in response to wind, waves, and fluctuating sea levels, as well as human influences. These coastal processes redistribute sand within the dune, beach, and nearshore systems. Geographic, geological and oceanographic differences collectively influence sediment availability, distribution, and transport, which when better understood can help to explain why trends of erosion and accretion differ along all portions of N.C.'s barrier island shorelines. Both short- and long-term changes can be dramatically different depending on where changes are measured and how much time passes between storm events. Factors used to try and predict short-term changes are less understood than those affecting long-term changes for a variety of reasons. Short-term changes are easily influenced by storm events and require routine monitoring, analyses, and modeling using high-resolution data to anticipate changes and anticipate where erosion will be the most extreme. Although factors affecting long-term changes are complex, the positions of the shoreline over a longer period can reveal trends in shoreline movement - unless beaches are nourished on a periodic cycle (NCDCM, 2016).

Because beaches gain sand (accrete), and lose sand (erode) through a variety of natural forces and human actions and can erode rapidly during a single event (hurricane), Ocean Hazard Setback Factors are established in an effort to minimize losses of life and property resulting from storms, long-term erosion, prevent encroachment of permanent structures on public beach areas, preserve the natural ecological conditions of the barrier dune and beach systems, and reduce public costs of inappropriately sited development.

Since the first study in 1979 (Tafun, Rogers, and Langfelder, 1979), North Carolina's oceanfront shoreline change rates have been calculated using the end-point method. This method uses the earliest and most current shorelines and shore-perpendicular transects, where the distance between the two shorelines is measured at each transect. Raw shoreline position change rates are then calculated by dividing distance between the two shorelines (shore-transect intersect) by time, or number of years between the two shorelines (Figure 1). To calculate Setback Factors, these data are then "smoothed" using a 17-point running average, and "blocked" to identify shoreline segments, or "blocked areas" that have similar rates.

Technological advances in Geographic Information Systems (GIS) have made calculation of end-point rates a relatively time-efficient process compared to techniques employed in earlier studies. Raw end-point rates were calculated using Environmental Systems Research Institute's (*ESRI*) *ArcGIS 10.6 ArcMap* GIS software with the United States Geological Survey's (USGS) Digital Shoreline Analysis System (DSAS) 4.3.4730 (Thieler, Himmelstoss, Zichichi, and Ergul, 2009) extension for *ArcMap*. The GIS tool requires three essential spatial data map layers; an early shoreline, a current shoreline, and a transect map layer perpendicular to the two shorelines.

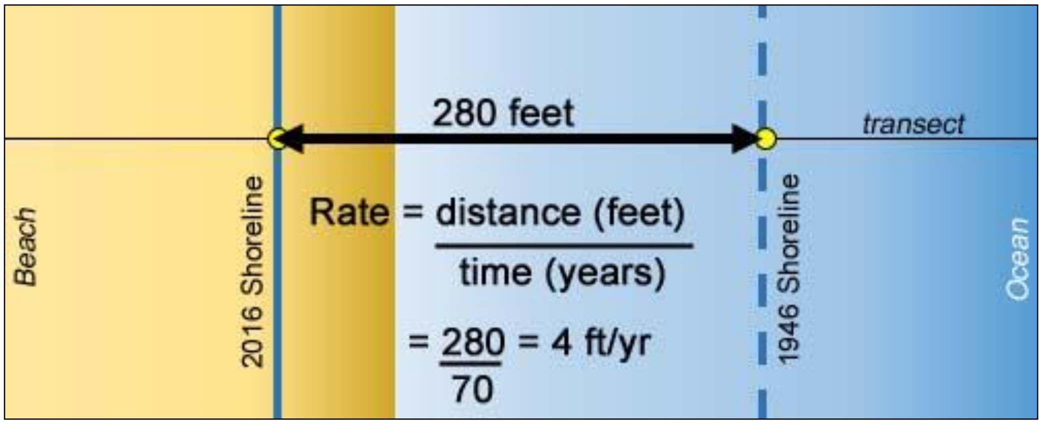

Figure 1. This example illustrates a shore-perpendicular transect where there is 280 feet between the early (1946) shoreline and current (2016) shoreline, and a period of 70 years. The shoreline change rate in this example is equal to 4 feet/year (where rate = distance/time = 280/70 = 4 ft/yr.). Since the most recent shoreline moved landward from its early position, the results would indicate erosion.

Shoreline Identification

When interpreted from aerial photography, North Carolina's oceanfront shoreline is defined as the "wet-dry line". This "line in the sand" references an interpretation where the wet sand ends and the dry sand begins and is typically distinguished by contrasting sediment color or shade, hence "wet-dry" (Figures 2 and 3). Wet-dry shoreline interpretation is the most readily identifiable and considered in the worst case to be between high and low tides (*e.g.*, Crowell, Leatherman, and Buckley, 1991; Dolan R. , Hayden, May, and May, 1980; Overton and Fisher, 2003).

Figure 2. Interpretation of the "wet-dry" shoreline is illustrated here

Figure 3. Wet-dry shoreline interpreted using imagery.

The early shoreline used in this study is also the same shoreline used in 2003 Overton and Fisher study, and the 2011 NC Division of Coastal Management (DCM) studies and was digitized by the North Carolina State University (NCSU) Kenan Natural Hazards Mapping Program. It represents a composite of both Mean High Water (MHW) shorelines digitized from National Ocean Survey Topographic Surveys (NOS T-sheets) (1933-1952), and wet-dry line interpretations made from historical (1940-1962) imagery (Overton and Fisher, 2003). Use of NOS T-sheet shorelines is accepted by other researchers and has been adopted by the USGS in their shoreline erosion studies. A statewide set of NOS T-sheets for a single year do not exist; therefore, early dates do vary between 1933 and 1952. For approximately 30 miles of the state's oceanfront shoreline (north of Oregon Inlet to North Carolina/Virginia State line) T-sheets were not available when the early shoreline was digitized. For this portion of the coast, a collection of early photography (1940–1962) was used to digitize a wet-dry shoreline. By using this early shoreline, consistent comparisons at each transect can be made between the multiple shoreline change rate studies (Appendix B).

The most current shoreline used in this study is a wet-dry interpretation digitized at a map scale of 1:1,000 utilizing 2016 North Carolina color imagery (6-inch pixel resolution). However, at Onslow Beach and Brown's Island, 2017 imagery (1-meter pixel resolution) was available and used due to an imagery data gap in 2016.

Transect Locations

Transects used in this study are generally perpendicular to the shoreline, spaced 50 meters (approximately 164 feet) apart, and spatially consistent with those used in the 1992, 2003 and 2011 update studies. It is expected that they are also spatially like those established by Dr. Robert Dolan in his early shoreline erosion rate studies since they have similar spacing and end-point coordinates (Dolan, Hayden, and Heywood, 1978); however, it is not possible to confirm since they did not exist in a digital form prior to the 1992 study (Overton and Fisher, 2003). For this reason, only comparison of ocean hazard Setback Factors from this and earlier studies can be made, and not the actual shoreline change rates.

Study Area

North Carolina's wave-dominated barrier island coastline is defined by a series of prominent cuspate forelands (Cape Fear, Cape Lookout, and Cape Hatteras) (Hoyt, 1971) and embayments (Long Bay and Onslow Bay) with approximately 320 miles of oceanfront shoreline (Figure 4).

Approximately 66% of this shoreline is located on predominate east-facing beaches, while 34% are on southerly-facing beaches.

Beaches in North Carolina, are in a state of constant fluctuation due to normal erosional actions of wind, water, and sediment supply. The region's geologic makeup is a significant factor regarding sediment supply: North Carolina's northern coast is flatter and more sediment rich than the steeper, sediment-poor southern coast. North Carolina's combination of simple and complex barrier islands, shoreface orientation, and inlet systems also influence the sediment budgets among the state's beaches (Riggs & Ames, 2003). Some inlets, for example, tend to migrate in the same general direction over time, while others oscillate back and forth. This difference influences whether the beaches adjacent to the inlets experience chronic or short-term erosion or accretion and presents enormous management challenges and costs for property owners, local governments, and the state.

In 2016, annual significant wave heights in Long Bay ranged 1.1 to 18.2 feet and averaged 3.3 feet at buoy station 41108; in Onslow Bay heights ranged 1.2 to 21.2 feet and averaged 4.5 feet at buoy station 41159; and north of Cape Hatteras heights ranged 1.0 to 17.7 feet and averaged 4.0 feet at buoy station 44100 (National Oceanic and Atmospheric Administration, 2018). In one study using 2006 NOAA data (Limber, List, and Warren, 2007a.), semidiurnal tides ranged on average from approximately 3.3 feet along the northern coast to approximately 4.9 feet near the North Carolina/South Carolina border. Regional and local beach morphology is controlled by a combination of prevailing oceanographic conditions (Ashton, 2001), periodic storm events (Morton and Sallenger, 2003), inlet-related processes (Fenster and Dolan, 1996), and by underlying, antecedent geology (Riggs, Cleary, and Snyder, 1995).

Figure 4. Study Area

The following sections detail the methodology and summarize findings for each island or oceanfront town starting at Sunset Beach in the south and ending in the north at the North Carolina-Virginia state line. Large maps (11 x 17 inch) are in Appendix A, and graphs illustrating rates calculated in this study relative to those calculated in the 2003 and 2011 studies are in Appendix B.

METHODOLOGY

Shoreline Preparations for Digital Shoreline Analysis System (DSAS)

Prior to the release of DSAS v4.2, shorelines were required to be digitized with the same spatial orientation. For example, when digitizing a shoreline on an east-west barrier island, all shorelines were required to consistently start from either the east or west side of the island so that each would have the same spatial left and right orientation. With the release of DSAS v4.2, this digitizing requirement was no longer necessary. DSAS does however require data to be managed within a personal Geodatabase in meter units in a projected coordinate system (Universal Transverse Mercator). In addition, there are specifications for naming and formatting attributes for shoreline, transect, and baseline GIS data.

Shoreline data require “DATE_” and “UNCERTAINTY” fields (Table 1). The “DATE” field stores the shoreline date and is referenced by DSAS when calculating the erosion rate according to the distance divided by time formula; and the “UNCERTAINTY” field accounts for positional uncertainties associated with natural influences (wind, waves, tide) or digitizing and measurement uncertainties. These fields must be created in GIS using the format shown in the table below.

Attribute Name	Attribute Data Type	Format
DATE_	Text	Field length = 10 Format = mm/dd/yyyy
UNCERTAINTY	Any numeric field	Double (*used in this study*)

Table 1. Attribute fields required by DSAS for shoreline GIS data.

Baseline and Transect Preparations for DSAS

Transects used in this study are believed to be geographically consistent with those defined in N.C.’s first erosion rate study (Tafun, Rogers, and Langfelder, 1979; Dolan, Hayden, and Heywood, 1978), and utilized in subsequent update studies thereafter. However, not until the 1992 update study (Benton, Bellis, Overton, Fisher, Hench, and Dolan, 1997) were these data were used in a

GIS environment, and not until the 2003 study (Overton and Fisher, 2003) that they were created as vector GIS data.

DSAS does require transect data to have several attribute fields associated with each unique identifier: *OBJECTID, SHAPE, BASELINEID, GROUP, TRANSORDER, PROCTIME, AUTOGEN, STARTX, STARTY, ENDX, ENDY,* and *AZIMUTH* (Thieler, Himmelstoss, Zichichi, and Ergul, 2009) (Table 2). When transects are cast from a baseline these attributes fields are automatically generated by DSAS. For transects not cast using DSAS (i.e. pre-existing transects like those used in this study), a few attributes (*BASELINEID*, *GROUP*, and *TRANSORDER)* are defined by the analyst prior to initiating the calculation.

Attribute Name	Data Type	Purpose
BASELINEID	Long Integer	DSAS can assign these values if left empty. Baseline segments with an ID equal to zero will be ignored by DSAS; no transects cast and will not be included in the analysis.
GROUP	Long Integer	Values in this field are assigned by DSAS and are based on analyst input for grouping transects. This field is used to aggregate shoreline data and the resulting measurement locations established by the transects into groups.
TRANSORDER	Long Integer	Can be assigned by DSAS, or the analyst. Each transect must have its own unique number. This field is used to sort transect data in a predetermined order

Table 2. Attribute fields required by DSAS for transect GIS data.

DSAS baselines are digitized by the analyst and serve as a starting point for casting shore-perpendicular transects and can be digitized either onshore or offshore at an offset-distance from all shorelines defined by the analyst. Although this study used pre-existing transects, DSAS still requires a baseline to be specified and contain specific attributes (Table 3).

Attribute Name	Data Type	Purpose
ID	Long Integer	DSAS uses this value to determine the ordering sequence of transects when the baseline contains multiple segments.
Group	Long Integer	Used for data management purposes to aggregate transects based on physical variations alongshore (i.e. shoreline type)
OFFshore	Short Integer	Used by DSAS to determine which direction to cast transects. A value of "0" indicates that the baseline is onshore, or landward of the input shorelines. A value of "1" indicates that the baseline is offshore, or seaward of the input shorelines.
CastDir	Short Integer	Used in conjunction with "OFFshore." A value of "0" will result in transects being cast to the left of the baseline based on segment flow. A value of "1" will result in the transect being cast to the right of the baseline based on segment flow direction.

Table 3. Attribute fields required by DSAS for baseline GIS data.

Digital Shoreline Analysis System (DSAS) and Statistical Analysis

As previously mentioned, all data used must be managed within a Personal Geodatabase using ArcGIS (ArcMap and ArcCatalog). The Geodatabase is a Microsoft Access® database designed to store and serve spatial data and provides data structure to enforce topology rules, or spatial data relationships. Additionally, DSAS requires data to be in meters, rather than feet (Figure 5). For purposes of presenting results in this report, data are converted from meters to feet.

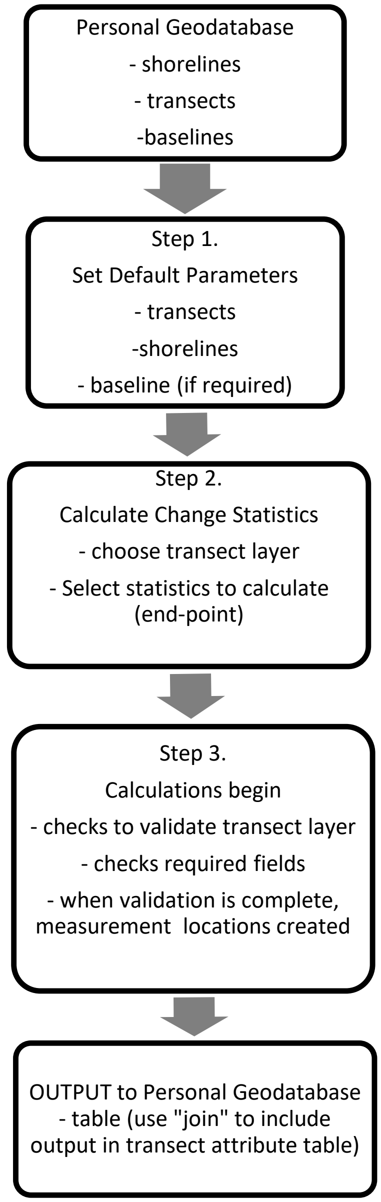

Figure 5. DSAS Workflow

Once the data were stored in the Geodatabase and properly attributed, DSAS is used within ArcMap as a GIS Extension to calculate shoreline change rates. First, data parameters were established by opening the *Set Default Parameters* user dialog (Figures 6 and 7), then selecting the *Shoreline Calculation Settings* tab. Required parameters include identifying the shoreline layer, selecting the date (*DATE*) and uncertainty fields (default 4.4 meters), then selecting Intersection Parameters (*Closest Intersection*). The intersection point defines which part of the shoreline to analyze where a single transect might intersect the same shoreline twice (*e.g.* inlets and spits). Closest Intersection was selected to avoid using shoreline segments not considered to be oceanfront.

Figure 6. DSAS toolbar - Set/Edit Parameters

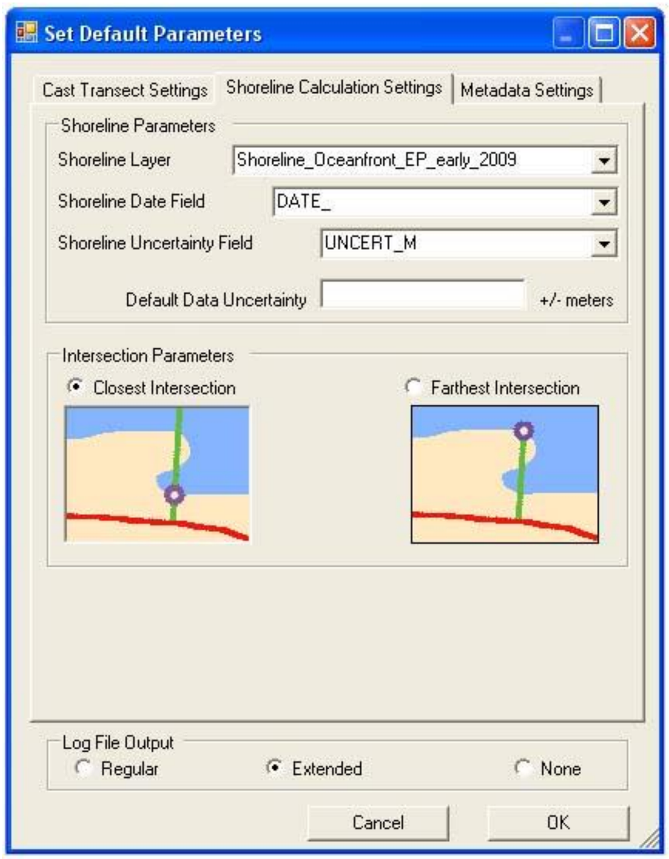

Figure 7. DSAS Set Default Parameter

Transect data layer were identified using the *DSAS Toolbar* and selecting it from the *Transect Layer* dropdown menu (Figure 8). This menu will only list qualified transect layers from the ArcMap document. If the transect layer is not properly attributed (*BASELINEID, GROUP, TRANSORDER*) it will not be recognized as a qualified option.

Figure 8. DSAS toolbar – will list qualified transect layers within ArcMap project.

With default parameters established and a transect layer identified, the last step is to select the output statistics (Figures 9 and 10). Once the *Calculate Change Statistics* dialog window opens, the only requirements are to: 1) select statistics to calculate; 2) apply confidence interval (accepted default 95 percent), and; 3) start calculation algorithms.

Figure 9. DSAS toolbar - Calculate Shoreline Change Statistics.

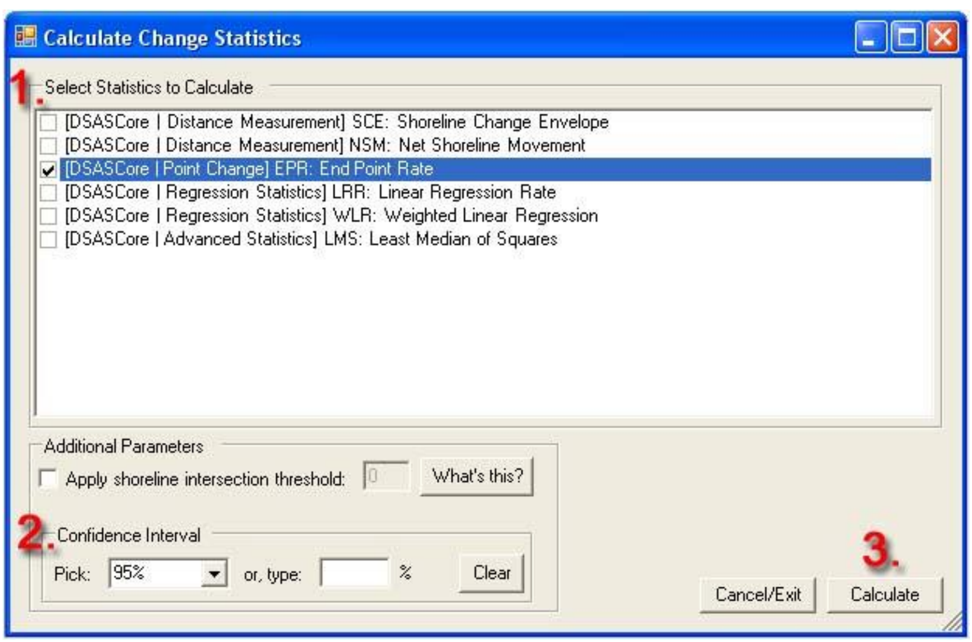

Figure 10. DSAS Calculate Change Statistics.

Long-term average annual shoreline change rates were calculated at 9,802 transects (approximately 305 miles of shoreline). No rates were calculated at 66 transects (approximately 2 miles of shoreline) because of “missing” shoreline segments. These gaps in the shoreline data are specific to areas where inlets have either closed (*e.g.* Madd, Corncake, Moore’s, and Old Topsail inlets) or have changed significantly due to accretion or erosion (*e.g.* New Topsail Inlet at Topsail Beach). For example, where early data might show a shoreline at an active inlet, current data will show a complete shoreline (not separated by channel) if the inlet has closed; thus, resulting in only one shoreline for that specific location.

DSAS generates raw end-point shoreline change rate data as a table inside the Geodatabase. To perform spatial queries, the tabular data must be joined to the transect GIS data by common attributes *(TRANSORDER* and *OBJECTID*) using ArcMap. Additional data processing (smoothing and blocking) required data to be imported into a Microsoft Excel 2016® spreadsheet to take advantage of its available math functions.

Long-Term Average Annual Shoreline Change Rate Calculations

Smoothing

Smoothing raw data has been applied in all previous studies, and effectively filters short-term dynamic shoreline phenomena such as beach cusps, smaller sand waves, and the attachment of landward migrating portions of offshore bar systems. Cusps and similar features range in size from approximately 5 feet to 5,000 feet and have a life span ranging from days (smaller features) to seasons or years (larger sand waves) (Dolan and Ferm, 1968) (Davis, 1978). Bars generally range around 328 feet in length with migration and attachment rates ranging from seasons to years (Davis, 1978). Variations associated with larger, longer lived features such as capes are not filtered by the smoothing.

The procedure for spatially smoothing shoreline change rate data is a simple moving average, or running mean technique described by Davis, 1973. Commonly referred to as “17-point running average,” this technique by default consists of at least 17 transects (approximately 0.5 miles of shoreline), and an average is calculated for each of the 17 transects, each time centered on the ninth transect (with 8 transects on each side). This spatially averaged value is the "smoothed rate." Approaching inlets, the number of transects used in the average is decreased by two (dropping one from each side of the centered transect calculation) until the end transect is reached. The last value is calculated by taking the weighted average using the last two transects.

$$\mathbf{R_s = (2 \times T_1 + T_2) / 3}$$

$\boldsymbol{R_s}$ *= smoothed rate*

$\boldsymbol{T_1}$ *= erosion rate at last transect adjacent to the inlet*

$\boldsymbol{T_2}$ *= erosion rate at second to last transect adjacent to inlet*

As can be seen in Figure 11, results from smoothing are most noticable in areas experiencing accelerated erosion or accretion (*e.g.* near inlets).

Blocking

The technique of "blocking" smoothed rate data creates spatially uniform rate segments. In other words, blocking groups neighboring transects along the same shoreline segment that have similar smoothed shoreline change rates. This allows for management of like sections of shoreline that have the same or similar shoreline change rates, rather than having to refer rates at each individual transect. Blocked shoreline change rate data serve as Setback Factors (historically referred to as "erosion rates"), and used to calcualte the construction setback within Ocean Hazard AEC, and to calculate the landward boundary of the Ocean Erodible Area (OEA) (Figure 11).

Blocking procedures, itemized below, represent refinments and clarifications of procedures established by and used in all previous update studies. These refinements and clarifications are the result of improved accuracy of the data brought about by improvements in the shoreline delineation methodology and quantitative requirements that allow for increased repeatabiltiy of results. Transect spacing was reduced from 328 (100 meters) and 984 feet (~300 meters) (1980

Dolan study) to 164 feet (50 meters) in subsequent studies; and in the 2003 Overton and Fisher update study, the minimum number of transects required for blocking was reduced by half (from 16 to 8). In areas experiencing an accelerated change in rates, this refinement resulted in smaller blocked groups. The following list describes the process, or "rules" of blocking:

1. Group "like" erosion rate segments based on rate at transect (*e.g.,* 2.0, 2.2, 2.1, 2.5, 2.6, 2.1, . . . 2.9) and use the mean of each segment as the blocked rate. Transitioning at one-foot intervals are prefered for rate block boundaries. Fractional rates are rounded down to the nearest foot, or half foot interval for segments dominated by a half foot value and do not have values greater than the next highest one foot interval (*e.g.*, a rate segment equal to 5.4 would be rounded to 5.0; and 5.7 would be rounded to 5.5).

2. Blocked shoreline change rate segments must be comprised of at least eight (8) transects. In areas experiencing rapid erosion or accretion (*e.g.,* approaching inlets), it is not always possible achieve a one-foot transition from one blocked rate segment to the next, thus making it necessary to evaluate segments based on its mean so that transitions from one blocked segement to the next was as near to the one-foot interval as feasible.

3. In areas where blocked segments transition from one value to another (*e.g.*, from 3 to 4 feet per year) a determination must be made to select the transect that will serve as a delineation between the change in values. The lower rate would be applied towards the higher blocked segment.

4. Where two blocked boundaries meet and divide a property or parcel, the lower of the two blocked rates is applied in the direction of the higher rate in order to give the property owner the benefit of the lower rate. Where a large parcel containing multi-family structures was divided by a transition boundary, the lower of the two blocked rates is applied towards the higher rate so that no structure was split and also giving the structure the benefit of the lower rate.

5. For segments that result in measured accretion, or where measured erosion rates are less than two (2.0) feet per year, they are assigned the default minimum, a blocked rate value (Setback Factor) of two (2) in accordance with the minimum Ocean Hazard setback of 60 feet, or 30 times the Setback Factor based on blocked shoreline change rates (15A NCAC 07H .0306(a)(2)(A).

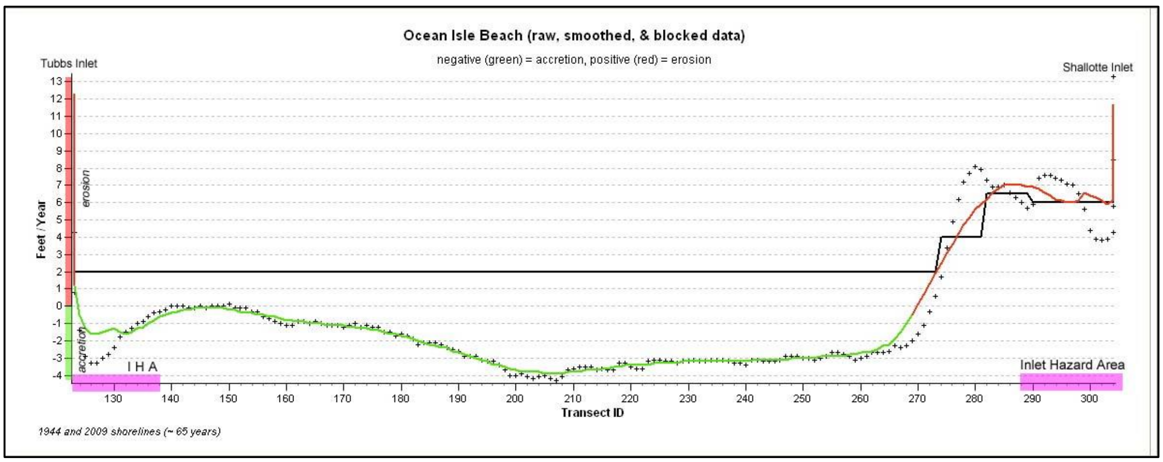

Figure 11. Example of Raw (points), Smoothed (solid green and red line), and Blocked (solid black line) data.

RESULTS

A statistical summary of the blocked shoreline change rates (Setback Factors) was calculated for this study, just as done in previous studies. These data are presented in below (Table 4). The percentages of shorelines are computed by dividing the number of miles of shoreline mapped in a given category (*e.g.*, Accreting) by the total number of miles of shoreline in a category (*e.g.*, south-facing). For purposes of this study, "south-facing" beaches are defined as those with shorelines, or beach faces, generally perpendicular and between South-East and South-West (135° – 225°); while "east-facing" between North-East and South-East (45° – 135°).

Statewide, the average blocked erosion rate value, or setback factor is 3.7, which is a slight increase (<1.0 ft.) relative to the average (3.4) calculated in the 2011 DCM update study using the 2009 shoreline. The average shoreline change rate for this study was 2.1 feet per year (erosion), and the median was 1.6 feet per year (erosion).

Table: 4A	Shoreline Length & Measured Erosion and Accretion Rate Comparison		
	South-Facing Beach Miles (% of total shoreline length)	**East-Facing Beach** Miles (% of total of total shoreline length)	**Statewide Totals** Miles (% of total shoreline length)
Miles of Shoreline Mapped & Analyzed	103.7 (34.1%)	200.8 (65.9%)	304.5
Measured Accretion	45.8 (44.2 %)	53.6 (26.3%)	103.7 (34.1%)
Measured Erosion	56.3 (54.3%)	147.1 (72.2%)	200.9 (65.4%)
No Output (*missing one of two shorelines*)	0.8 (<1%)	2.8 (1%)	2.8 (>1%)

Table: 4B	Shoreline Change Rate Statistical Comparison		
	South-Facing Beach (ft./yr.)	**East-Facing Beach** (ft./yr.)	**Statewide** (ft./yr.
Average Shoreline Change Rate (ft/yr.)	2.8 ft/yr. (erosion)	<1.0 ft/yr. (erosion)	2.1 ft/yr. (erosion)
Median Shoreline Change Rate (ft/yr.)	<1.0 ft/yr. (erosion)	2.5 ft/yr. (erosion)	1.6 ft/yr. (erosion)

Table: 4C	Setback Factor Comparison (Minimum = 2 feet)		
	South-Facing Beach Miles (% of total shoreline length)	**East-Facing Beach** Miles (% of total of total shoreline length)	**Statewide Totals** Miles (% of total shoreline length)
Setback Factor (=2 ft)	76.5 (73.8%)	98.3 (49.0%)	174.6 (57.3%)
Setback Factor (between 2.5 & 5.0 ft)	13.0 (12.5%)	52.9 (26.3%)	67.1 (22.1%)
Setback Factor (between 5.5 & 8.0 ft)	9.5 (9.2%)	29.7 (14.8%)	38.7 (12.7%)
Setback Factor (>8.0 ft)	3.9 (3.8%)	18.5 (9.2%)	22.7 (7.4%)
Average Setback Factor (ft)	3.0	4.0	3.5
Median Setback Factor (ft)	2.0	3.0	2.0

Table 4. Summary of shoreline change rates and Setback Factors. **(4A)** Summarizes length of shoreline mapped and analyzed, and percentages of shoreline where either accretion or erosion was measured. **(4B)** Summarizes average and median shoreline change rates for south and east-facing beaches, and statewide totals. Although these values do include all measured accretion, the statewide values reflected erosion overall. **(4C)** Summarizes length of shoreline and percentage of the total shoreline, and its calculated Setback Factor. Because of migrating or closed inlets, not all locations near inlets had two shorelines (no early or 2016 shoreline). As a result, the analysis could not be performed for less than 1% of the total study area. Therefore, lengths and percentages in Table 4 when summed, may not always equal one hundred percent. It is important to note that the minimum setback factor is 2 as referenced in Rule *15A NCAC 07H.0306(a)(2)(A)*. A setback factor equal to 2 means that erosion is less than two feet per year, or accretion was measured. Setback factors greater than 2 do correspond to calculated erosion rates.

	2016 South Facing Miles (% of total)	2009 South Facing Miles (% of total)	Change (miles)
Miles of Shoreline Mapped/Analyzed	103.7 (34.1%)	103.9	0.2 (decrease)
Setback Factor (2 ft)	76.5 (73.8%)	77.3 (74.4%)	0.8 (decrease)
Setback Factor (2.5 to 5.0 ft)	13.0 (12.5%)	13.8 (13.3%)	0.8 (decrease)
Setback Factor (5.5 to 8.0 ft)	9.5 (9.2%)	9.0 (8.7%)	0.5 (increase)
Setback Factor (>8.0 ft)	3.9 (3.8%)	3.6 (3.5%)	0.3 (increase)

Table 5. 2018 update study summary of blocked shoreline change rates (Setback Factors), and comparison of change from previous study (2011) for south-facing beaches. This table is an illustrative comparison of total length of shoreline mapped and analyzed, and its calculated construction Setback Factor, where sixty feet is the minimum construction setback (2 ft. x 30 = 60 ft.). Length shown in the row labeled "Setback Factor (2 ft)" is inclusive of length of all accreting sections of shoreline, and those calculated to be eroding at two feet per year or less.

	2016 East Facing Miles (% of total)	2009 East Facing Miles (% of total)	Change (miles) from 2009 to 2016
Miles of Shoreline Mapped/Analyzed	200.8 (65.9%)	203.5	2.7 (decrease)
Setback Factor (2 ft)	98.3 (49.0%)	112.8 (55.4%)	14.5 (decrease)
Setback Factor (2.5 to 5.0 ft)	52.9 (26.3%)	48.3 (23.7%)	4.6 (increase)
Setback Factor (5.5 to 8.0 ft)	29.7 (14.8%)	22.4 (11.0%)	7.3 (increase)
Setback Factor (>8.0 ft)	18.5 (9.2%)	17.2 (8.5%)	1.3 (increase)

Table 6. 2018 update study summary of blocked shoreline change rates (setback factors), and comparison of change from previous study (2011) for east-facing beaches. This table is an illustrative comparison of total length of shoreline mapped and analyzed, and its calculated construction Setback Factor, where sixty feet is the minimum construction setback (2 ft. x 30 = 60 ft.). Length shown in the row labeled "Setback Factor (2 ft)" is inclusive of length of all accreting sections of shoreline, and those calculated to be eroding at two feet per year or less.

Shoreline change rates and setback factors calculated in this study can be compared to those presented in the 2011, and 2003 update study reports (NC DCM, 2011; Overton and Fisher, 2003) because they exist in digital and GIS format, and use the same early shoreline. However, setback factors from these studies (2018, 2011, and 2003) can only be generally compared to those calculated in earlier studies for several reasons: (1) there is a difference in the miles of shoreline analyzed (due to starting and stopping points near inlets and capes), (2) the early shoreline date used in the 1997 study (and earlier) is not the same as the one used in the 2003, 2011, and this study and; (3) changing the required minimum number of transects from 16 to 8 in the 2003 Overton and Fisher update study, and space-reduction between transects from 328 and 984 feet (100 and 300 meters) to 164 feet (50 meters) are refinements made in the blocking methodologies that may influence setback factor statistics only when comparing this and 2011, 2003 studies to earlier studies (1998, 1992, 1986, and 1980). Preliminary analysis of the data continues to show remarkable consistency with earlier updates (Table 7).

Statewide Totals Summary	**2016** Miles (% of total)	**2009** Miles (% of total)	**1998** Miles (% of total)	**1992** Miles (% of total)	**1986*** Miles (% of total)	**1980*** Miles (% of total)
Miles of Shoreline Mapped/Analyzed	**304.5**	**307.4**	**312**	**300**	**237***	**245***
Setback Factor (2 ft/yr.)	174.6 (57.3%)	190.2 (61.9%)	193 (62%)	165 (55%)	144 (61%)	149 (61%)
Setback Factor (2.5 to 5.0 ft/yr.)	67.1 (22.1%)	62.1 (20.2%)	64 (21%)	54 (18%)	43 (18%)	52 (21%)
Setback Factor (5.5 to 8.0 ft/yr.)	38.7 (12.7%)	31.5 (10.2%)	28 (9%)	30 (10%)	20 (8%)	22 (9%)
Setback Factor (>8.0 ft/yr.)	22.7 (7.4%)	20.8 (6.8%)	27 (8%)	32 (10.7%)	22 (9%)	22 (9%)
Insufficient Data	*1.4 (<0.5%)*	*2.8 (<1%)*	*0*	*19 (6%)*	*8 (4%)*	*0*

Table 7. Summary of blocked shoreline change rates (Setback Factors) for all studies. This table is an illustrative comparison of total length of oceanfront shoreline mapped and analyzed, and its calculated construction Setback Factor for each of the six studies; where sixty feet is the minimum construction setback (2 ft. x 30 = 60 ft.). Length shown in the row labeled “Setback Factor (2 ft)” is inclusive of length of all accreting sections of shoreline, and those calculated to be eroding at two feet per year or less. Where the year ends with an asterisk (*) in the table header, that total shoreline distance is less compared to others because some, or all, of the National Seashore was not mapped for that study (i.e. Shackleford Banks, Core Banks).

(*) this study did not include the entire oceanfront shoreline (Core Banks or Shackelford Banks).

South-Facing Shoreline Dates	2016 Miles (% of total)	2009 Miles (% of total)	1998 Miles (% of total)	1992 Miles (% of total)	1986* Miles (% of total)	1980* Miles (% of total)
Miles of Shoreline Mapped/Analyzed	103.7 (34.1%)	103.9	96	106.8	82	80
Setback Factor (2 ft)	76.5 (73.8%)	77.3 (74.4%)	69 (72%)	58.4 (55%)	59 (72%)	70 (82%)
Setback Factor (2.5 to 5.0 ft)	13.0 (12.5%)	13.8 (13.3%)	14 (14%)	14.4 (13%)	12 (15%)	12 (14%)
Setback Factor (5.5 to 8.0 ft)	9.5 (9.2%)	9.0 (8.7%)	9 (9%)	5.9 (6%)	3 (4%)	3 (4%)
Setback Factor (>8.0 ft)	3.9 (3.8%)	3.6 (3.5%)	5 (5%)	9 (8%)	7 (9%)	0 (0%)

Table 8. South-facing beach summary of blocked shoreline change rates (Setback Factors) for all studies. This table is an illustrative comparison of total length of shoreline mapped and analyzed, and its calculated construction Setback Factor for each of the five studies, were sixty feet is the minimum construction setback (2 ft. x 30 = 60 feet). Length shown in the row labeled "Setback Factor (2 feet)" is inclusive of length of all accreting sections of shoreline, and those calculated to be eroding at two feet per year or less. Where the year ends with an asterisk (*), in the table header, that total shoreline distance is less compared to others because some, or all, of the National Seashore was not mapped for that study (i.e. Shackleford Banks, Core Banks).

East-Facing Shorelines	2016 Miles (% of total)	2009 Miles (% of total)	1998 Miles (% of total)	1992 Miles (% of total)	1986* Miles (% of total)	1980* Miles (% of total)
Miles of Shoreline Mapped/Analyzed	200.8 (65.9%)	203.5	216	192.8	155	160
Setback Factor (2 ft)	98.3 (49.0%)	112.8 (55.4%)	124 (58%)	89 (46%)	85 (55%)	78 (49%)
Setback Factor (2.5 to 5.0 ft)	52.9 (26.3%)	48.3 (23.7%)	50 (23%)	39.9 (21%)	31 (20%)	40 (25%)
Setback Factor (5.5 to 8.0 ft)	29.7 (14.8%)	22.4 (11.0%)	19 (9%)	24.3 (13%)	17 (11%)	20 (12%)
Setback Factor (>8.0 ft)	18.5 (9.2%)	17.2 (8.5%)	22 (10 %)	23.4 (12%)	15 (10%)	23 (14%)

Barrier Island Summaries

The following graphs show oceanfront shoreline change rate data (raw, smoothed, and blocked) at each transect for all NC barrier islands. For purpose of this study and illustrating raw and smoothed with blocked data, positive rate values identify measured erosion (*positive = erosion*) while negative values represent measured accretion (*negative = accretion*). The black points, or crosshairs, are the raw data; the green and/or red lines are the smoothed data; and the bold-black line is the blocked data (setback factors). Units for the vertical axis are feet per year, and

Table 9. East-facing beach summary of blocked shoreline change rates (Setback Factors) for all studies. This table is an illustrative comparison of total length of shoreline mapped and analyzed, and its calculated construction Setback Factor for each of the five studies, where sixty feet is the minimum construction setback (2 ft. x 30 = 60 feet). Length shown in the row labeled "Setback Factor (2 feet)" is inclusive of length of all accreting sections of shoreline, and those calculated to be eroding at two feet per year or less. Where the year ends with an asterisk (*), in the table header, that total shoreline distance is less compared to others because some, or all, of the National Seashore was not mapped for that study (i.e. Shackleford Banks, Core Banks).

the horizontal axis corresponds to transect numbers.

Bird Island and Sunset Beach

Bird Island and Sunset Beach are North Carolina's southern-most beaches and considered to have low sloping south-facing beaches with approximately 3.3 miles of combined oceanfront shoreline. Sunset Beach has been naturally accreting and has not required any nourishment projects (Figure 12). Several factors have had significant influences in defining today's shoreline position; a navigation jetty constructed at Little River inlet (left side of graph), the closing of Madd inlet (transect IDs 35-40), and engineering (end of island and inlet configuration) of Tubbs Inlet prior to 1970. There was no change in blocked erosion rate factors since 2.8 miles (86.7 percent) of its shoreline resulted in measured accretion with only minor erosion (2 feet per year, or less) in the area adjacent to Tubbs Inlet for a shoreline distance equal to distance of 0.3 miles, or 11.4 percent of its oceanfront shoreline; therefore, the calculated setback factors for both Bird Island and Sunset Beach is 2 feet per year (Figures 12 & 13).

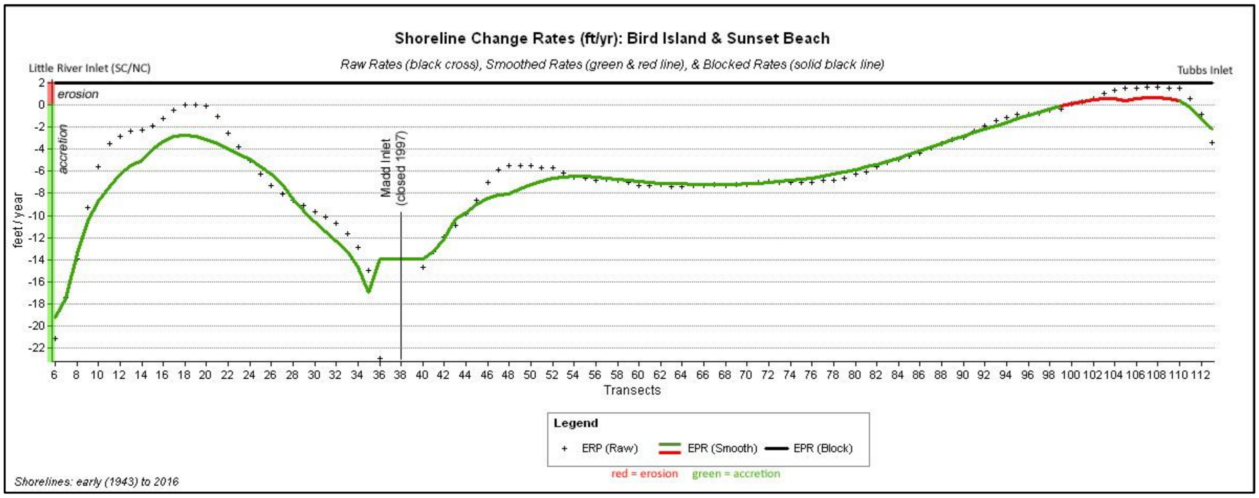

Figure 12. Bird Island and Sunset Beach shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

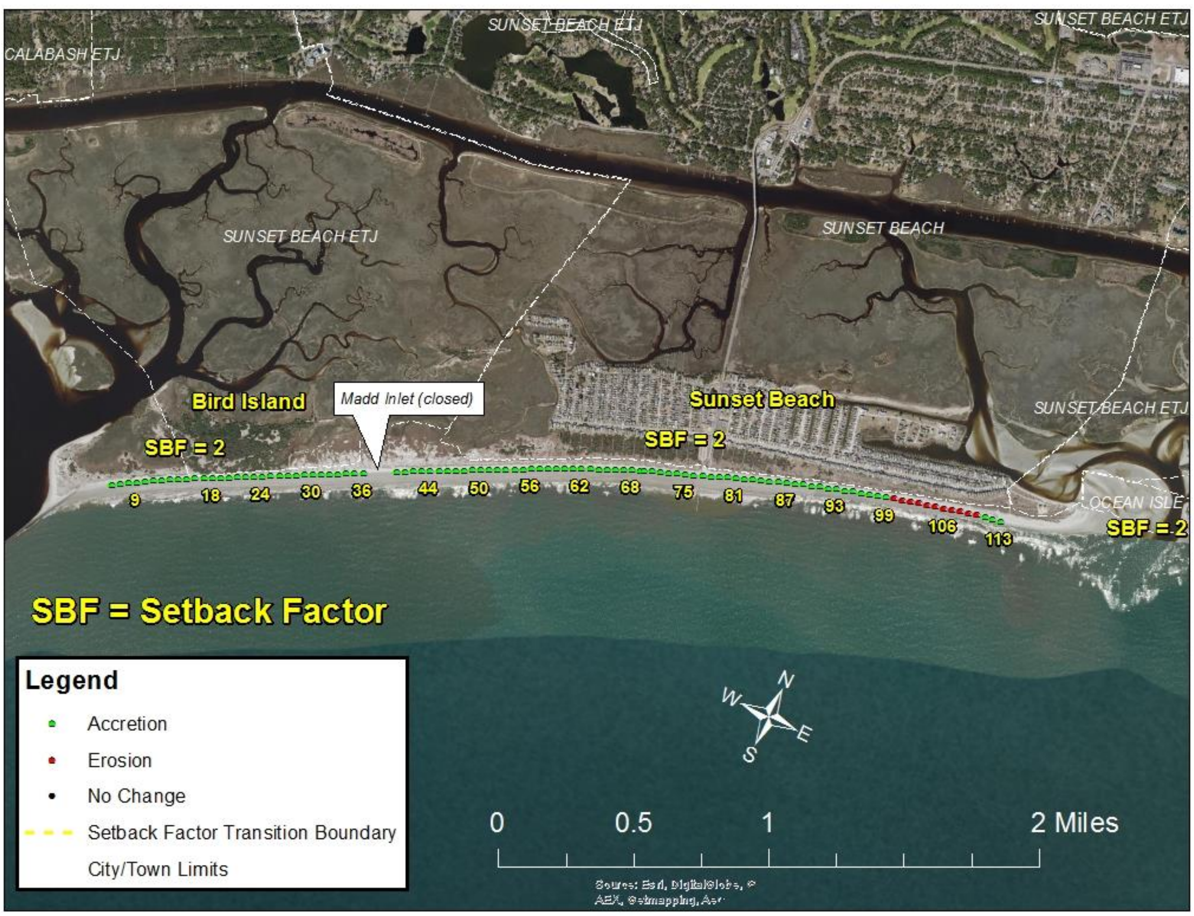

Figure 13. Bird Island & Sunset Beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Ocean Isle Beach

Ocean Isle Beach is considered low sloping and south-facing, with approximately 5.7 miles of oceanfront shoreline. Approximately 4.6 miles (80.6 percent) of this shoreline resulted in measured accretion, while 1.0 miles (18.3 percent) is eroding (Figure 14). Ocean Isle has received several nourishment projects since the 2000s which had immediate post-project influences on shoreline position, and potentially influenced degree of measured accretion. Those areas are adjacent to inlets (Tubbs and Shallotte) located on each shoulder of the barrier island. Most of the island resulted in a calculated Setback Factor of 2 feet per year, while a small portion adjacent to Shallotte Inlet continued to see factors greater than 2 (up to 5 ft./yr.) (Figure 14 and 15). Overall, Setback Factors remained the same or slightly lower compared to the 2011 study.

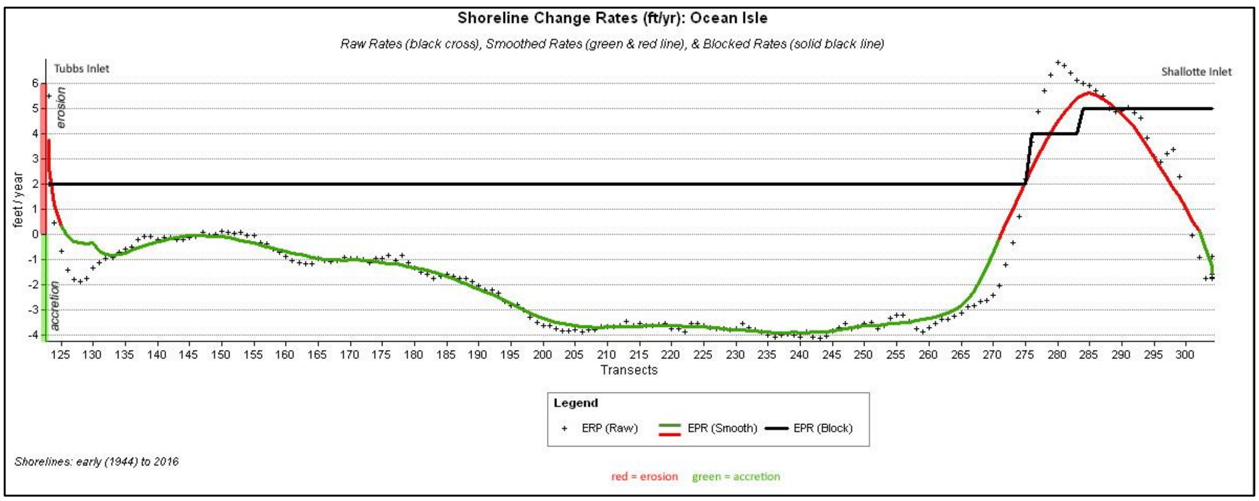

Figure 14. Ocean Isle shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

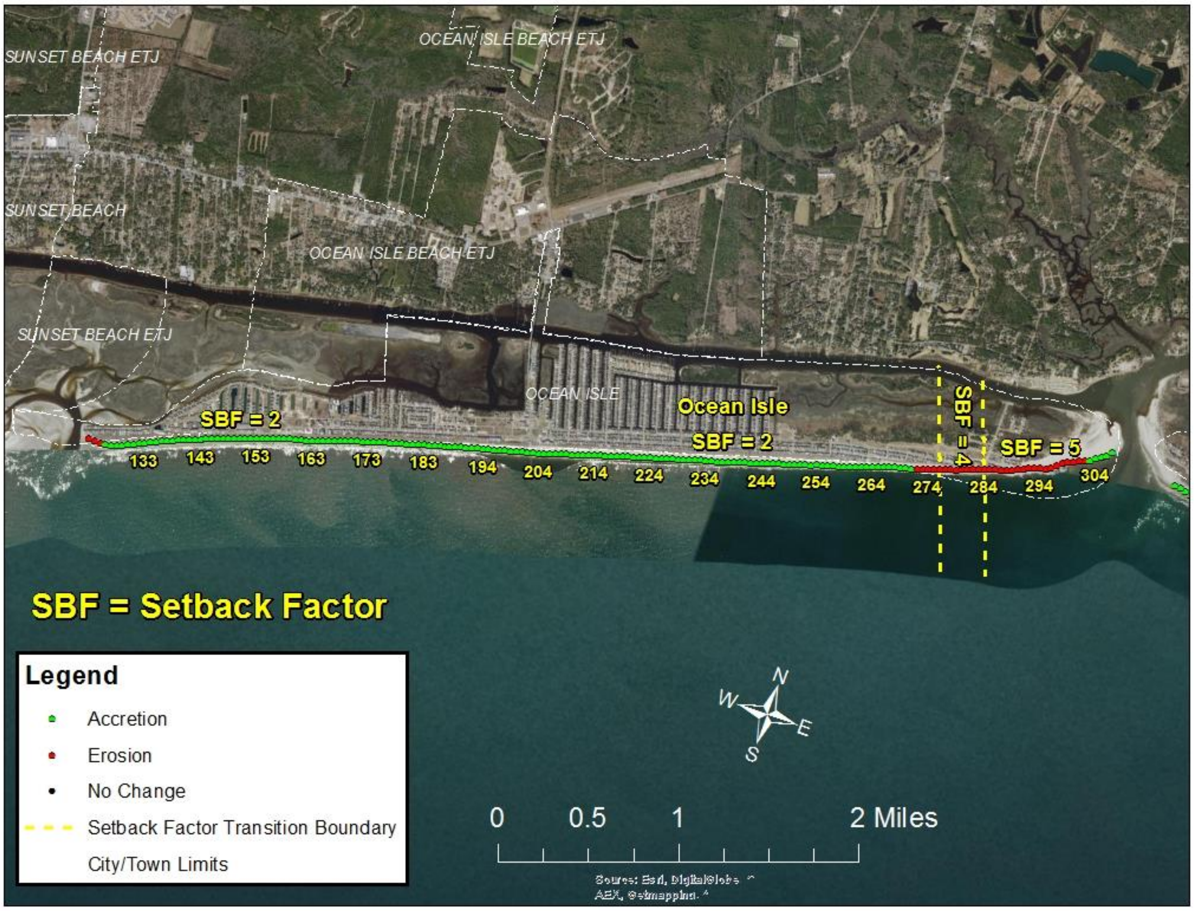

Figure 15. Ocean Isle Beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Holden Beach

Holden Beach is considered low sloping and a south-facing, with approximately 8.0 miles of oceanfront shoreline. Approximately 2.0 miles (24.8 percent) of this shoreline resulted in measured accretion, while 6.0 miles (74.8 percent) is eroding (Figure 16). Although down slightly from the 2011 study (58.9 percent), still most (54.7 percent) of the measured erosion is 2 feet per year or less. In 2017, Holden Beach placed approximately 1.3 million cubic yards of sand along four miles of its oceanfront shoreline, and it is the first project since 2006 and 2009. Although this project could have some measured influence on the next update study, this update was not influenced by recent nourishment. The area on Holden Beach with the highest erosion is adjacent to Lockwood Folly Inlet (located on right side of the graph) where setback factors transition from 2 to 6 approaching Lockwood Folly Inlet (Figures 16 & 17). Overall, where factors were two feet per year in 2011, they continue to be two, however, Setback Factors are slightly higher adjacent to Lockwood Folly Inlet (range from 2 to 6 ft./yr.).

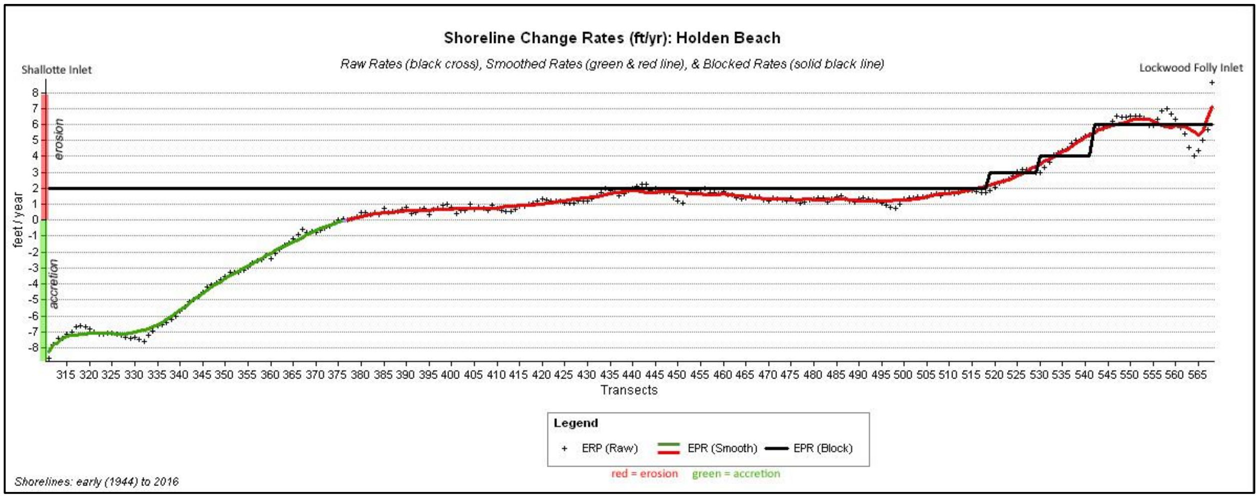

Figure 16. Holden Beach shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

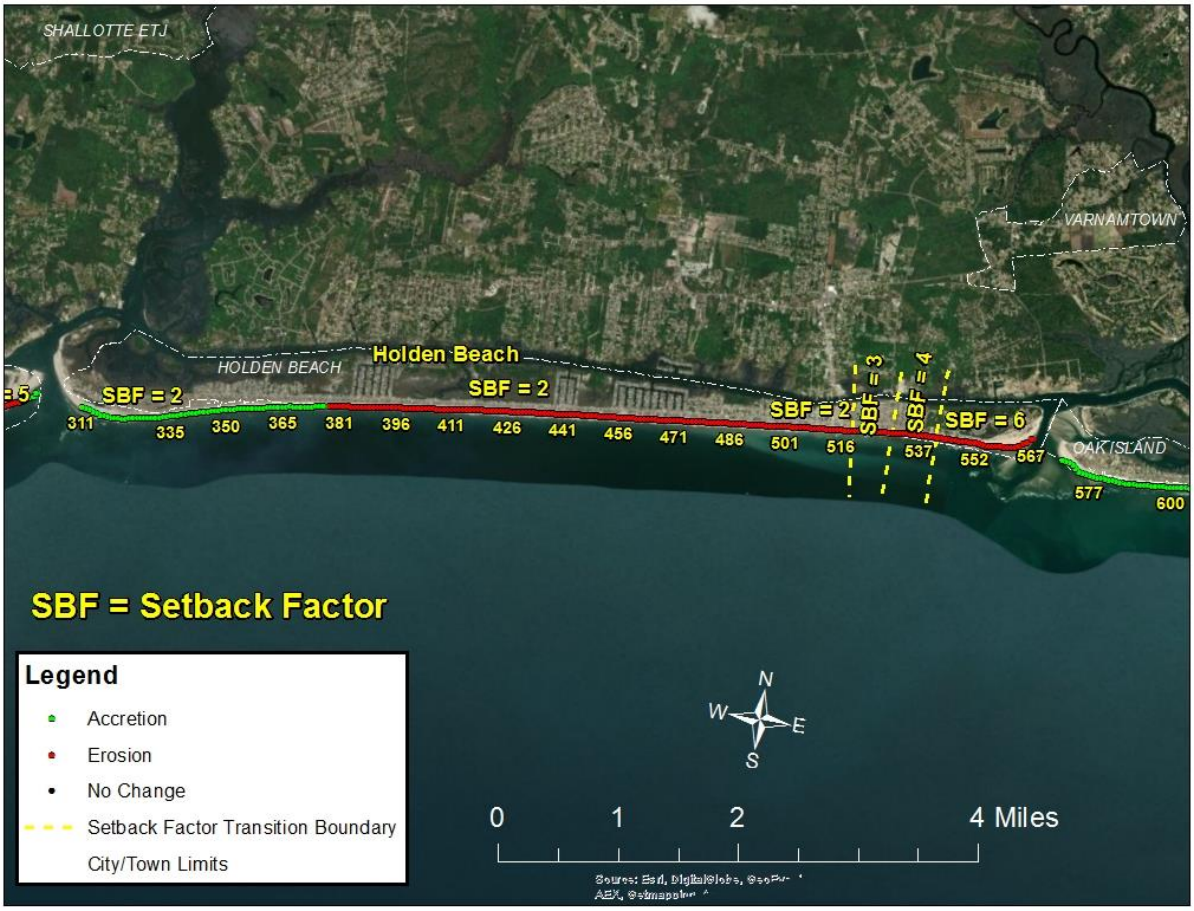

Figure 17. Holden Beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Oak Island

The Town of Oak Island has a south-facing beach with approximately 9.3 miles of oceanfront shoreline. Approximately 6.5 miles (70.7 percent) resulted in measured accretion, while the remaining 2.6 miles (28.6 percent) demonstrated measured erosion (Figure 18). Although the maximum measured erosion was 2.5 feet per year (transect # 861, near Oak Island/Caswell Beach Town limits), the average is less than 1.0 foot per year. The setback factor for the entire oceanfront shoreline is two (2) (Figure 19).

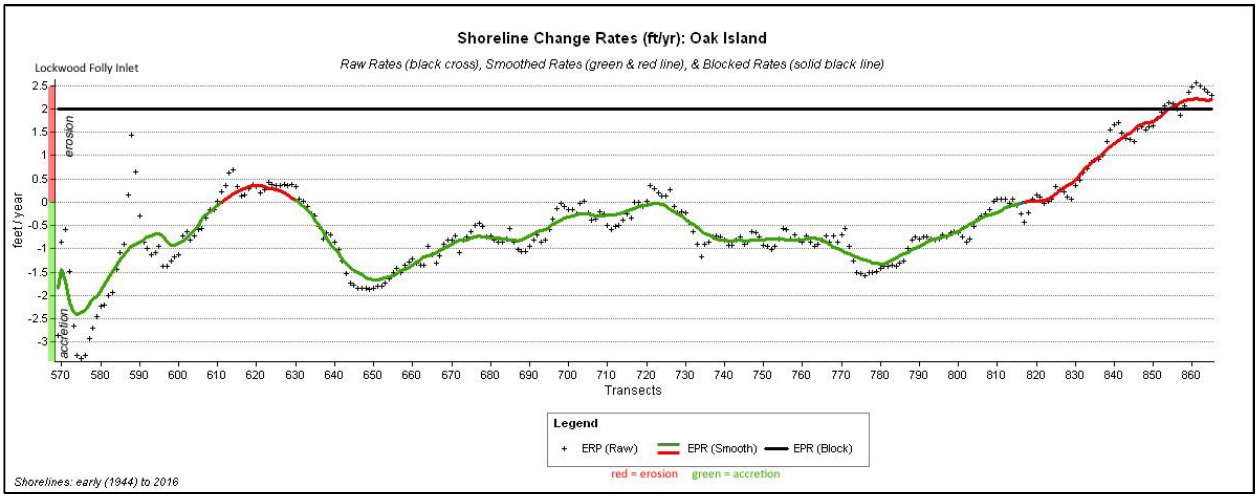

Figure 18. Oak Island shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

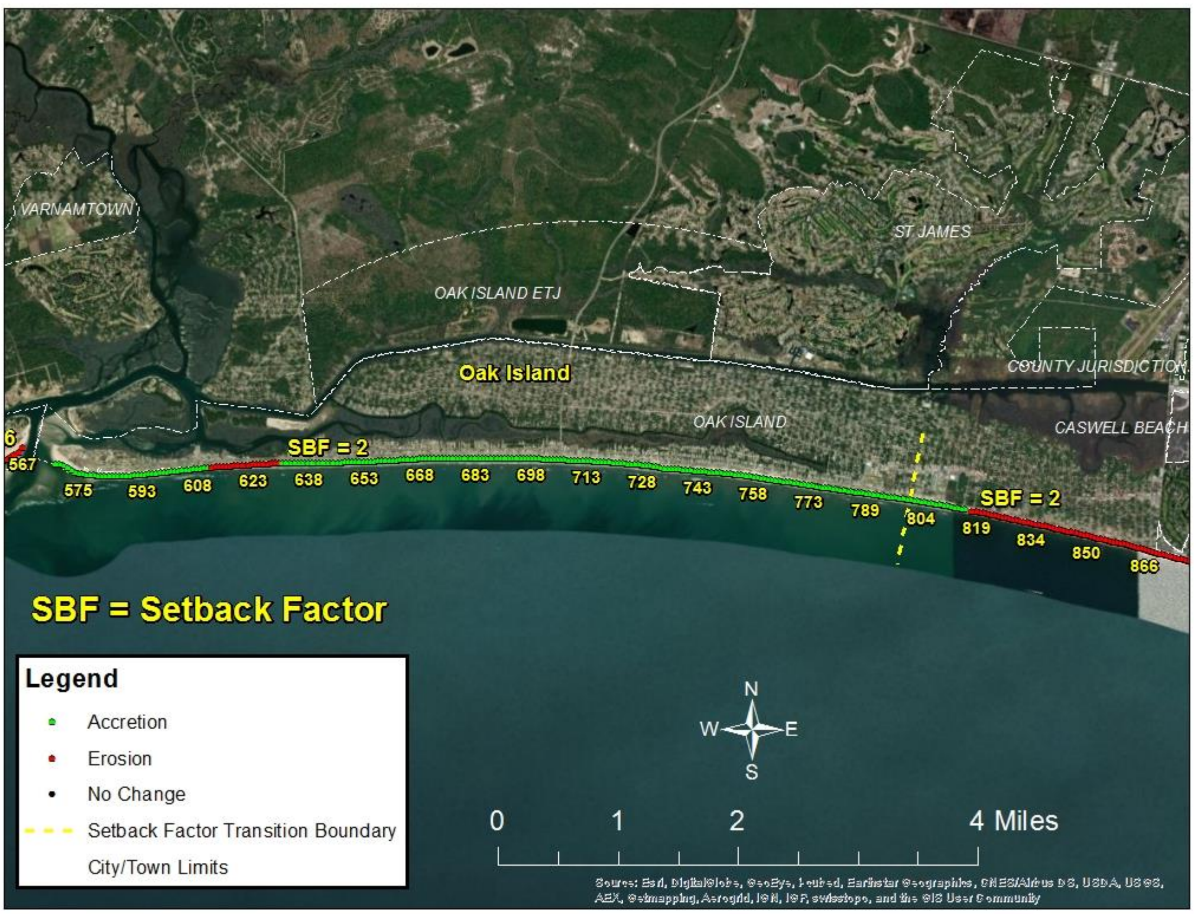

Figure 19. Oak Island. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Caswell Beach and Fort Caswell

Caswell Beach and Fort Caswell have combined oceanfront shorelines totaling 3.5 miles. Approximately 2.3 miles (65.5 percent) resulted in measured accretion, while 1.2 miles (34.5 percent) resulted in measured erosion (Figure 20). The average shoreline change rate was just under two feet per year (1.6), and the calculated setback factor is two (2) (Figure 21).

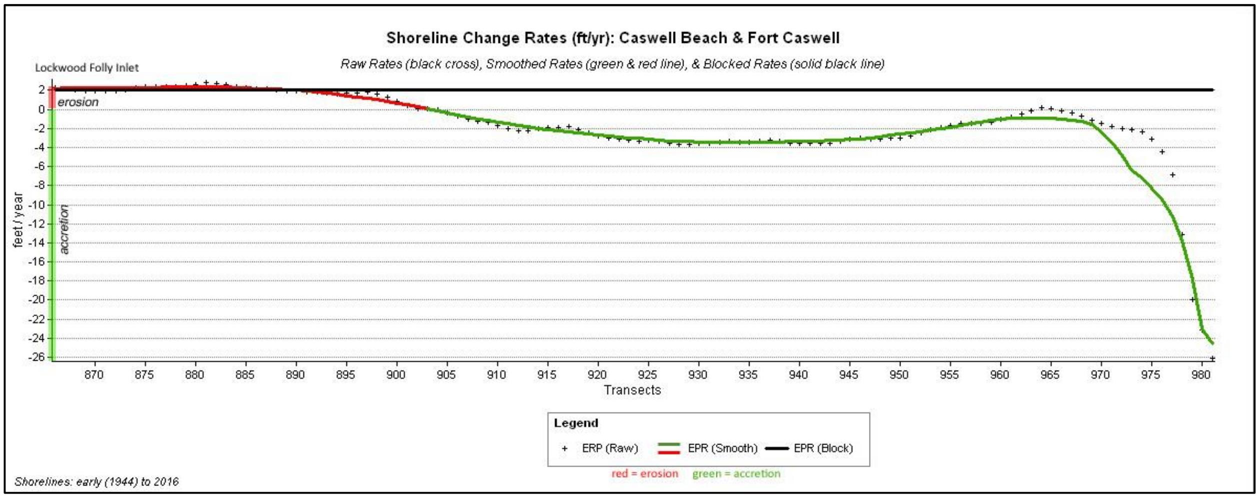

Figure 20. Caswell Beach and Fort Caswell shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

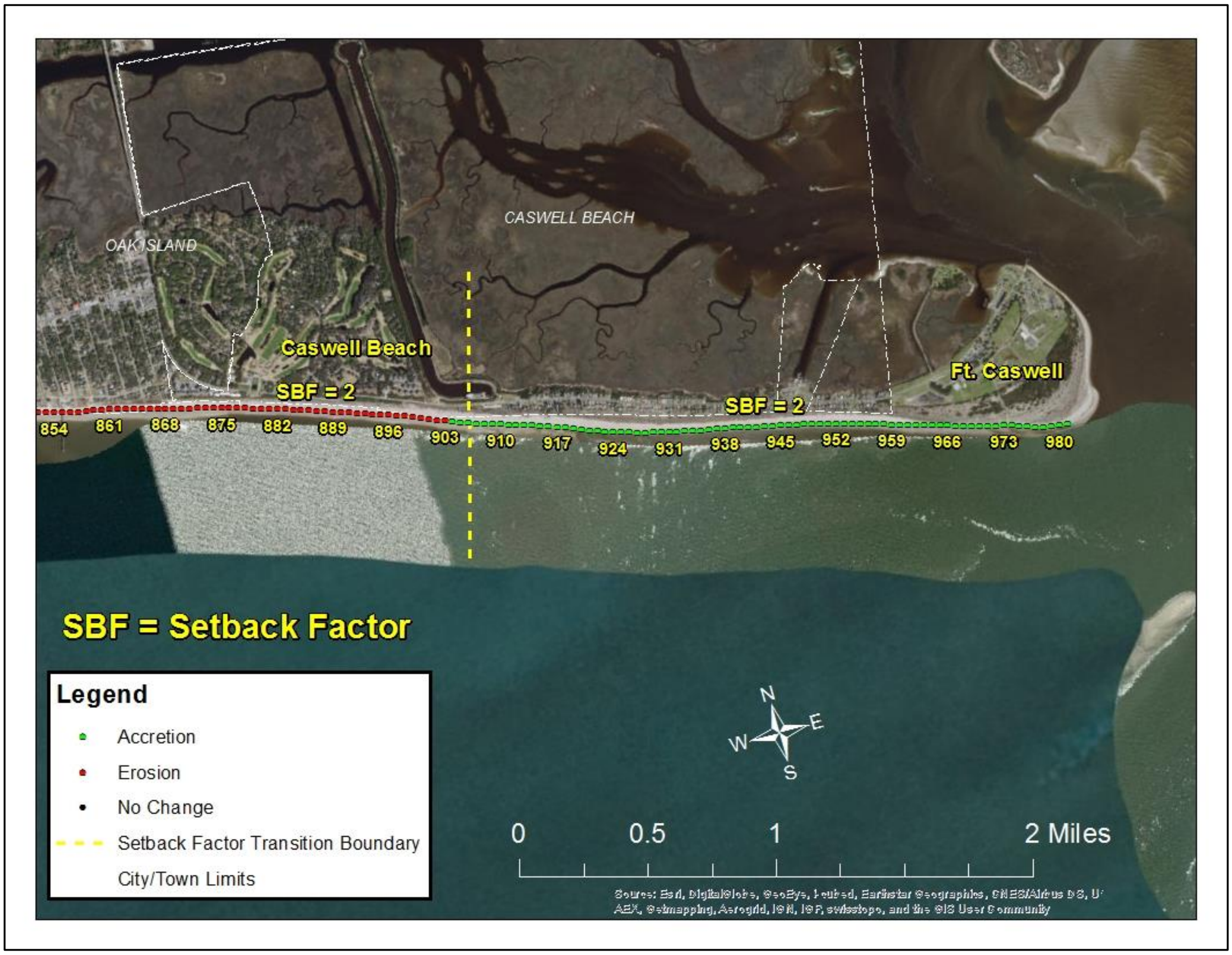

Figure 21. Caswell Beach and Fort Caswell. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Bald Head Island

Bald Head Island's "south-beach" is the last south-facing shoreline in Brunswick County just before transitioning to east-facing beaches at Cape Fear. This 3.2-mile oceanfront shoreline is the region's most dynamic, the state's second most dynamic developed shoreline, and has demonstrated consistently high erosion rates throughout all studies. However, with the completion of the terminal groin on south-beach and adjacent to the Cape Fear Inlet (near transect #985) in 2015, continued routine maintenance of beach east of the groin, and the groin field in the same region, all appear to have collectively lower rates slightly compared to previous studies for the approximate one-half mile segment of the shoreline at the west end of south-beach (average 3.4 feet per year). Overall, shoreline change rates for south-beach are generally consistent with those from earlier studies where the average erosion rate is 3.9 feet per year (Figure 22). Blocked shoreline changes rates (setback factors) ranged between 2 and 13 and averaged approximately 4 feet per year. Setback factors did decrease for approximately 0.4 miles (13.6 percent) of shoreline (adjacent to terminal groin), but this shoreline position is dominated by erosional processes and resulted in an increase in setback factors for 0.9 miles of shoreline (28.2 percent) (Figures 22 and 23).

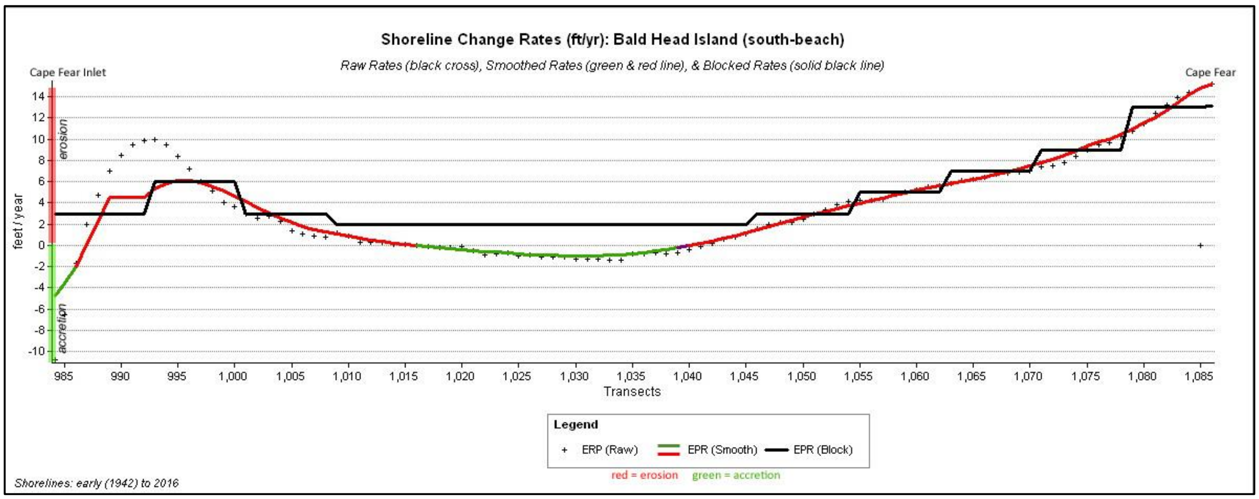

Figure 22. Bald Head Island ("south-beach") shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

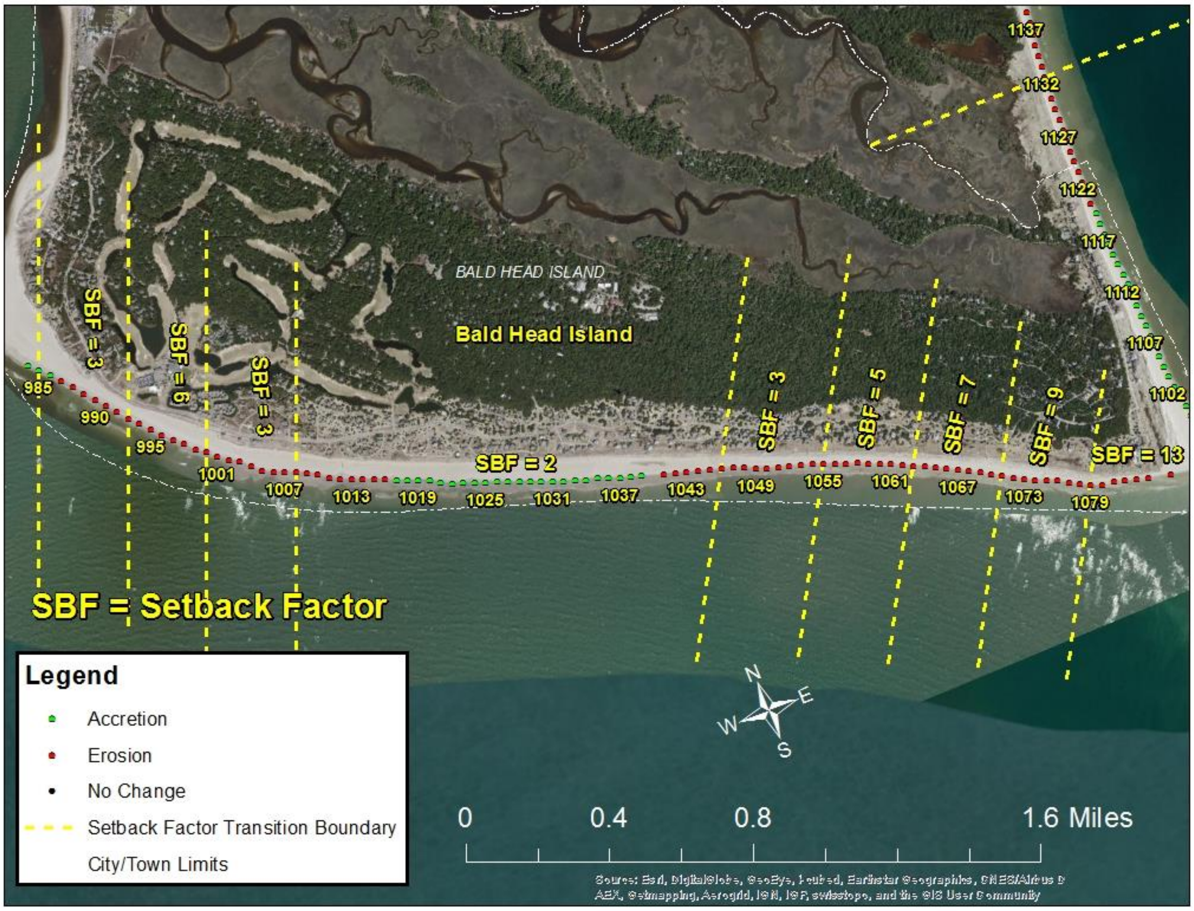

Figure 23. Bald Head Island's south-beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Moving from Bald Head Island's south beach to east beach while rounding Cape Fear the data show an erosion-accretion pivot point along the shoreline. Bald Head Island's east beach under normal conditions has been demonstrated through the data to be accretional with shoreline change rate factors equal to two feet per year, and setback factors equal to two (Figures 24 and 25).

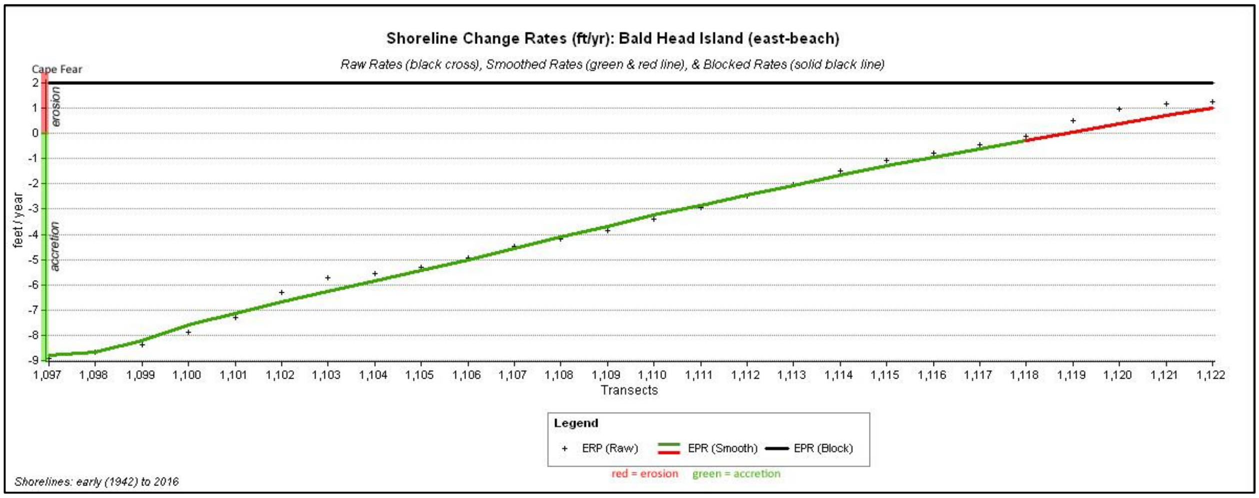

Figure 24. Bald Head Island's east-beach shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

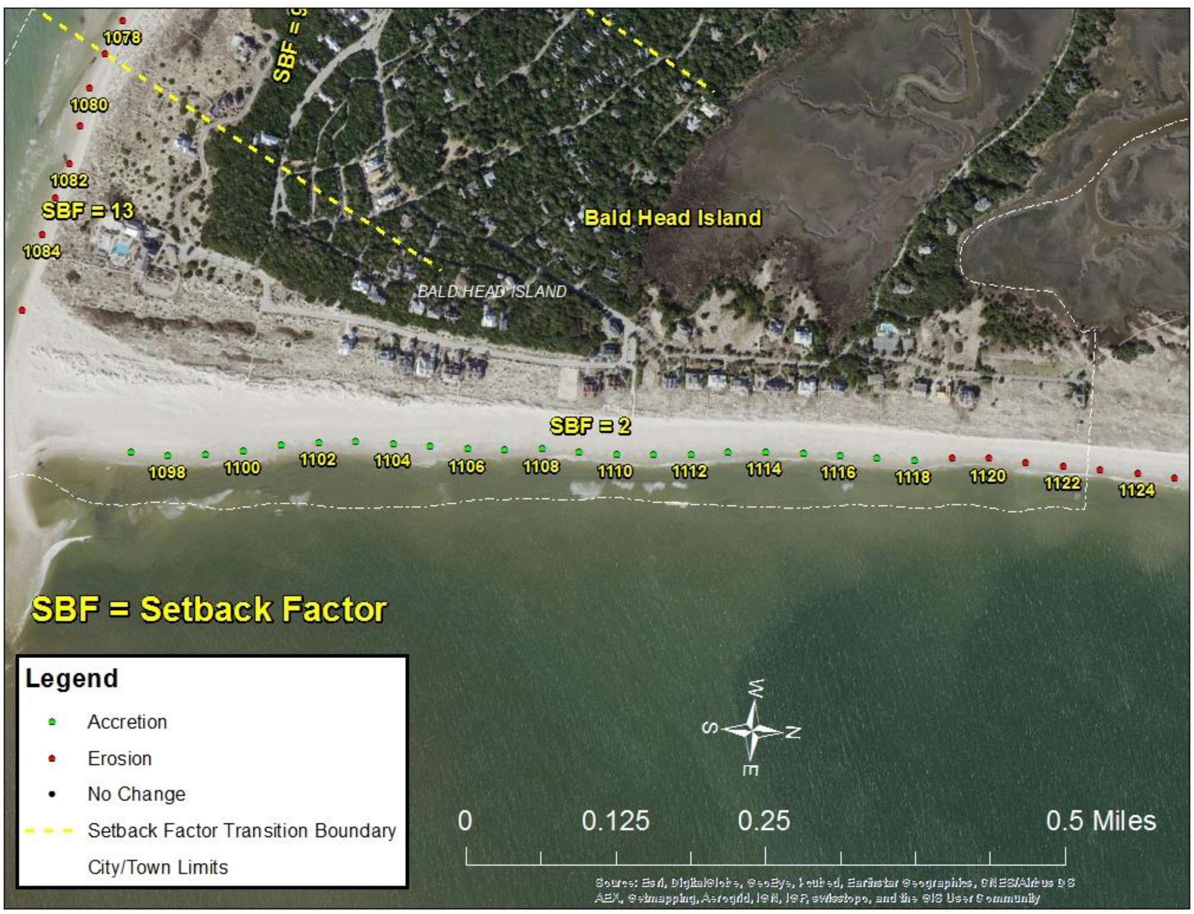

Figure 25. Bald Head Island's east-beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Zeke's Island and Fort Fisher State Park

Moving northward towards the now closed Corncake Inlet, which formally separated Bald Head and Zeke's islands, the oceanfront shoreline at Zeke's Island and Fort Fisher State Park demonstrates consistent erosional characteristics. The extent of this shoreline segment is 8.4 miles, where 3.4 miles (41.1 percent) of this shoreline demonstrates accretional characteristics, while 4.9 miles (58.9 percent) is eroding. The average shoreline change rate is less 1 foot per year (erosion) with a median rate of 2.6 feet per year (erosion), and blocked shoreline change rates (setback factors) ranging between 2 and 8 with an average 4.0 feet per year (Figures 26, 27, and 28).

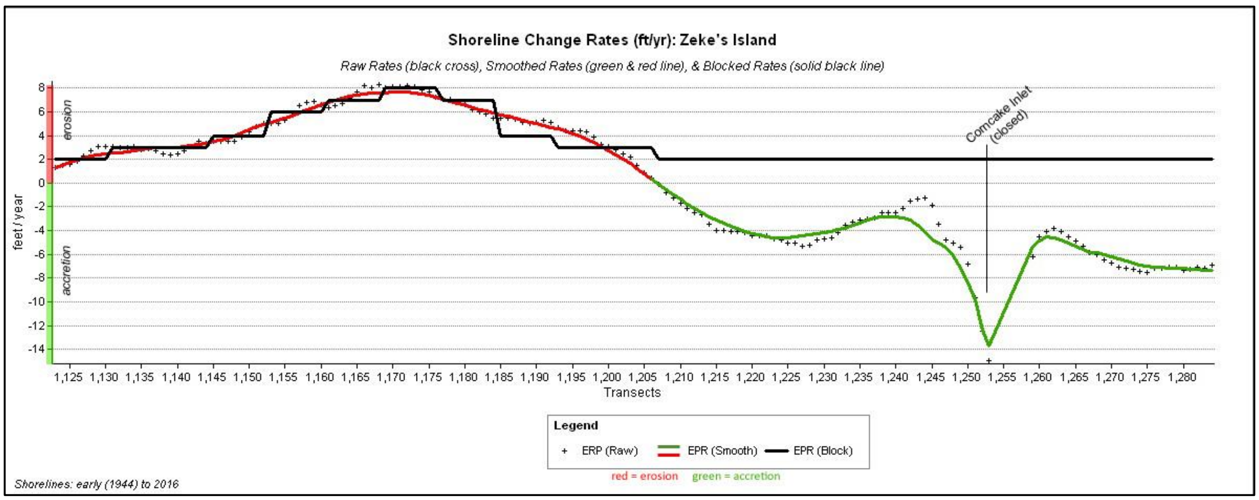

Figure 26. Zeke's Island (between Bald Head Island and Fort Fisher) shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

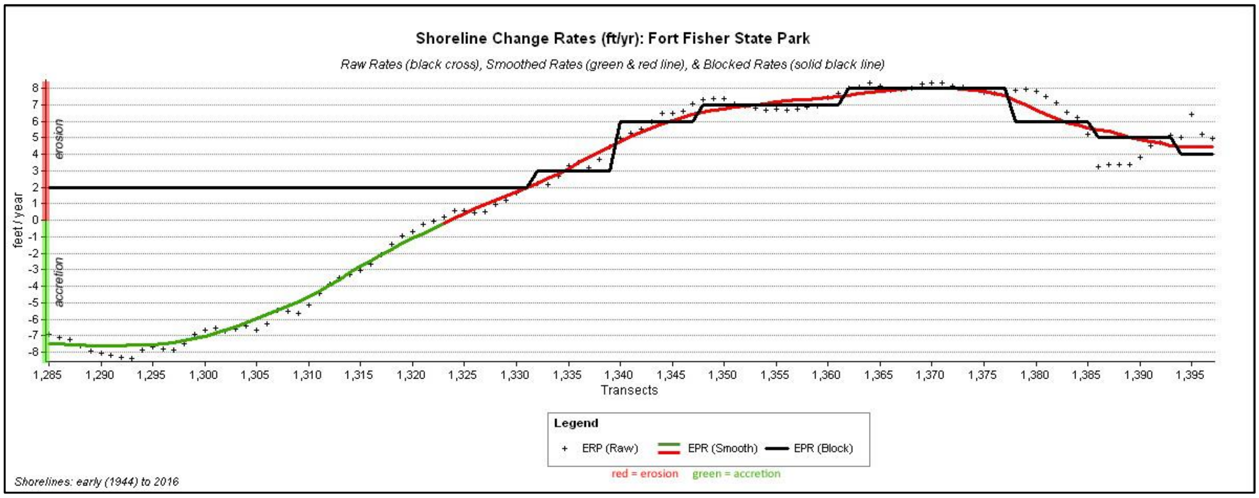

Figure 27. Fort Fisher State Park shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

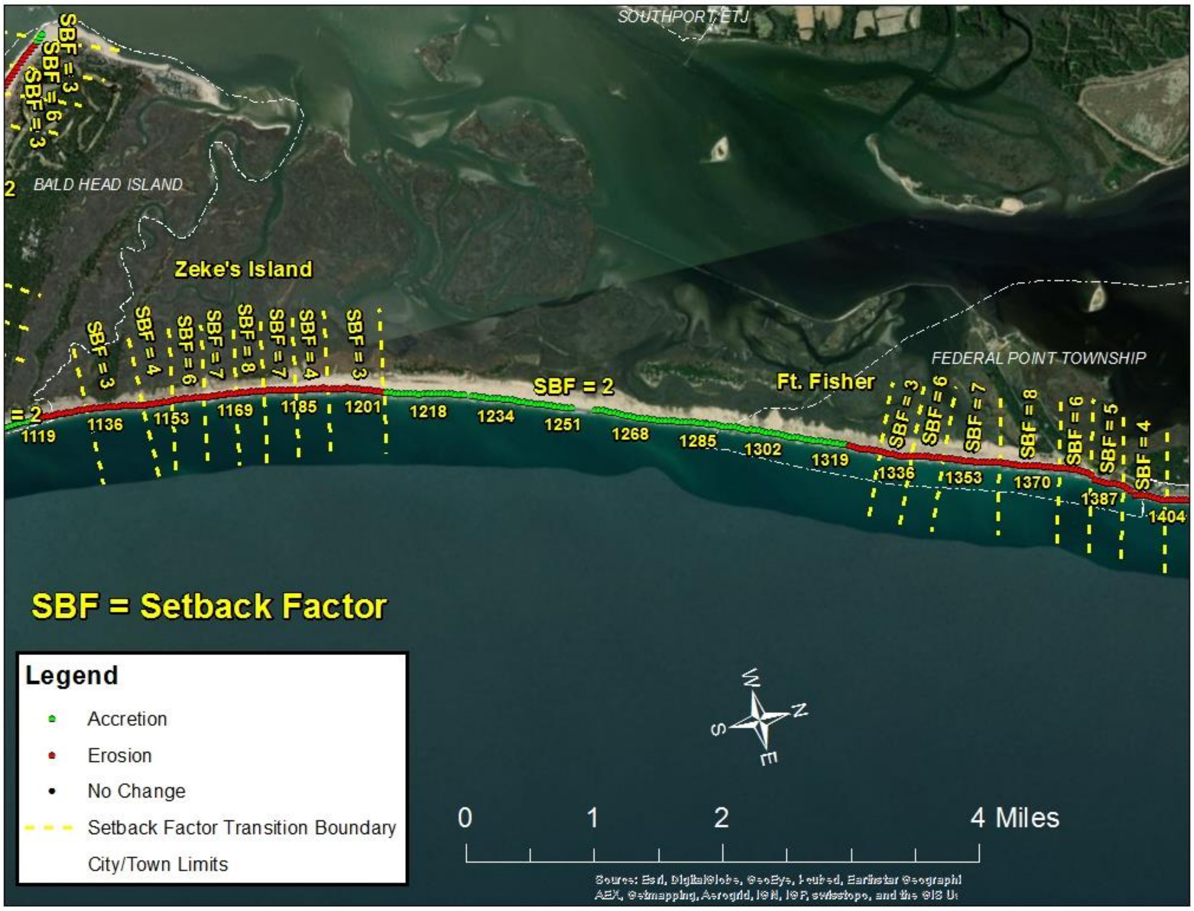

Figure 28. Zeke's Island and Fort Fisher State Park. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Kure Beach

Kure Beach is an east-facing beach with 2.9 miles of oceanfront shoreline where approximately one mile (35.1 percent) resulted in measured accretion, and the remaining 1.8 miles (63.8 percent) measured erosion (Figure 29). The highest rates at Kure beach are located adjacent to Fort Fisher State Park and the Town's limit where erosion rates peaked at 6.4 feet per year and resulted in a setback factor of four. Compared to the 2011 study, there was a slight decrease for a 500 feet section of shoreline near Fort Fisher State Park, while the remaining 2.8 miles of shoreline experienced no change in setback factor values (Figures 29 and 30).

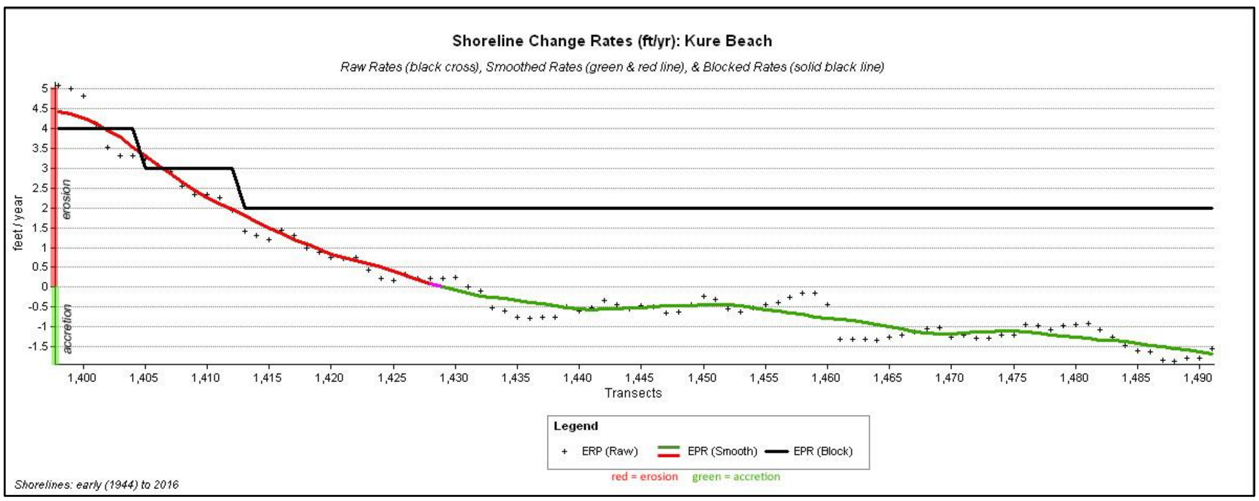

Figure 29. Kure Beach shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

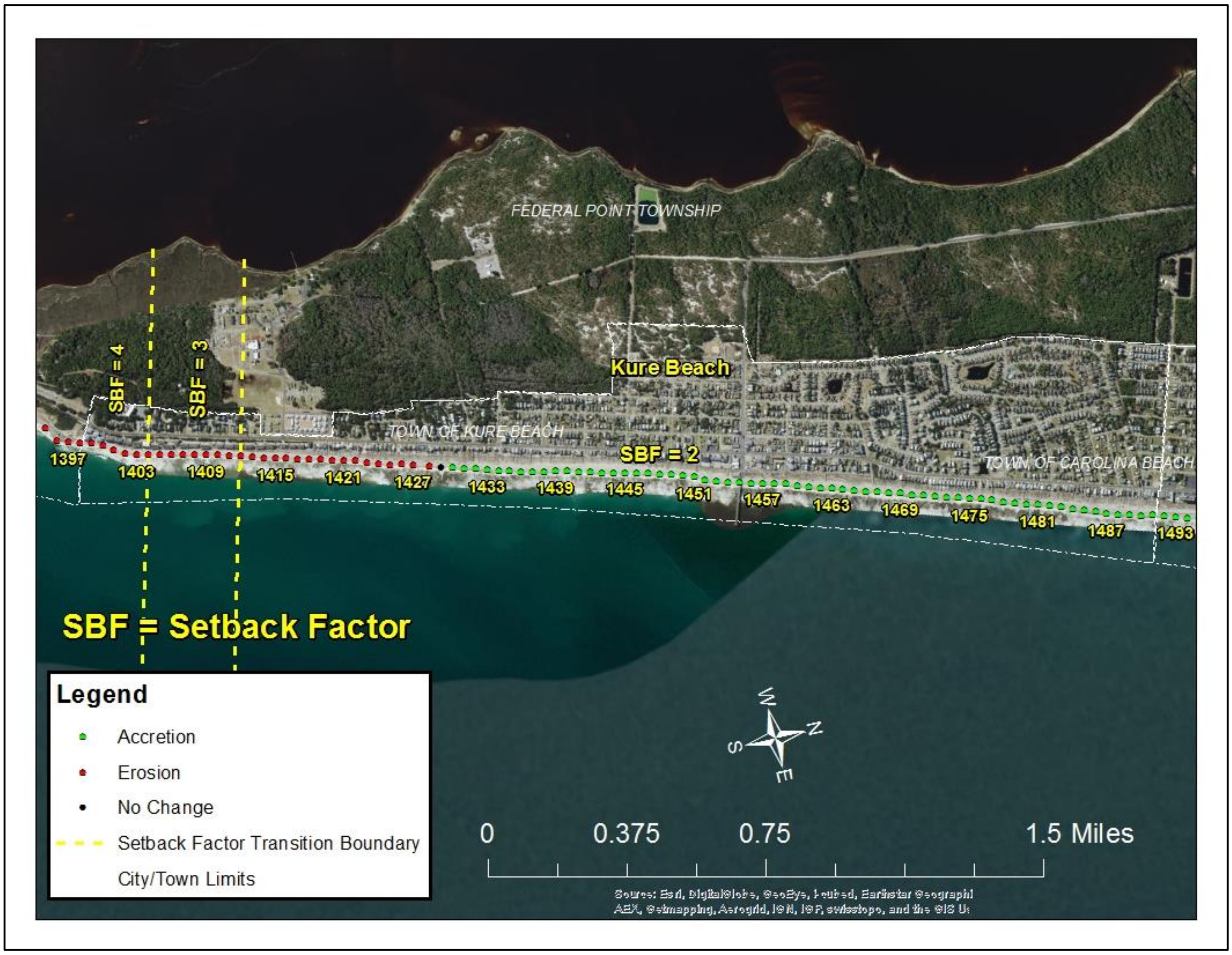

Figure 30. Kure Beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Carolina Beach

Carolina Beach is and east-facing beach with approximately four miles of oceanfront shoreline where 2.5 miles (65.1 percent) resulted in measured accretion, while the remaining 1.3 miles (34.1 percent) resulted in measured erosion. The average blocked erosion rate at Carolina Beach is 2.5, however, for most of the developed shoreline, the setback factor is 2. (Figure 31 and 32).

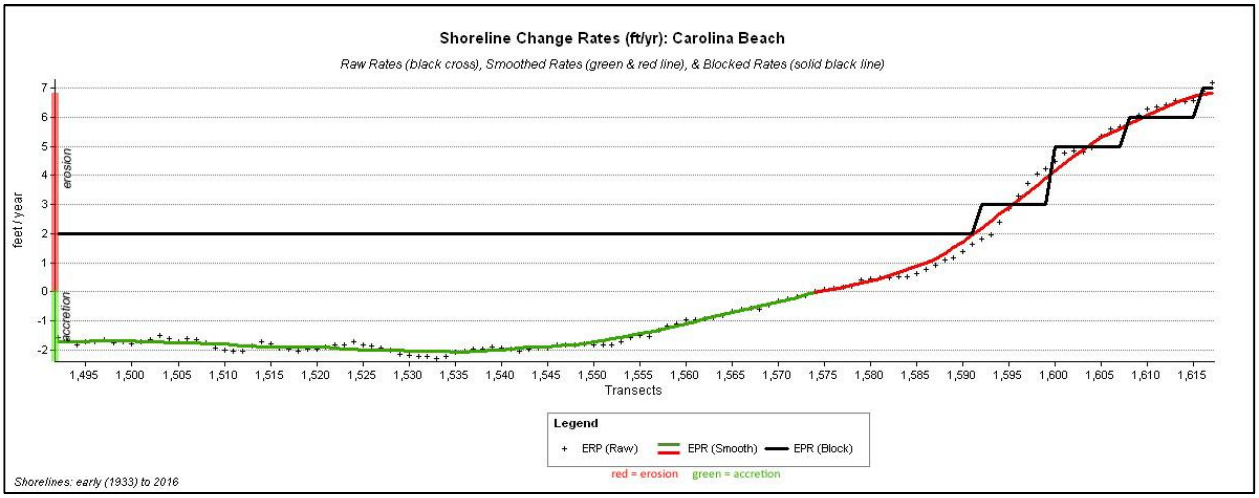

Figure 31. Carolina Beach shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

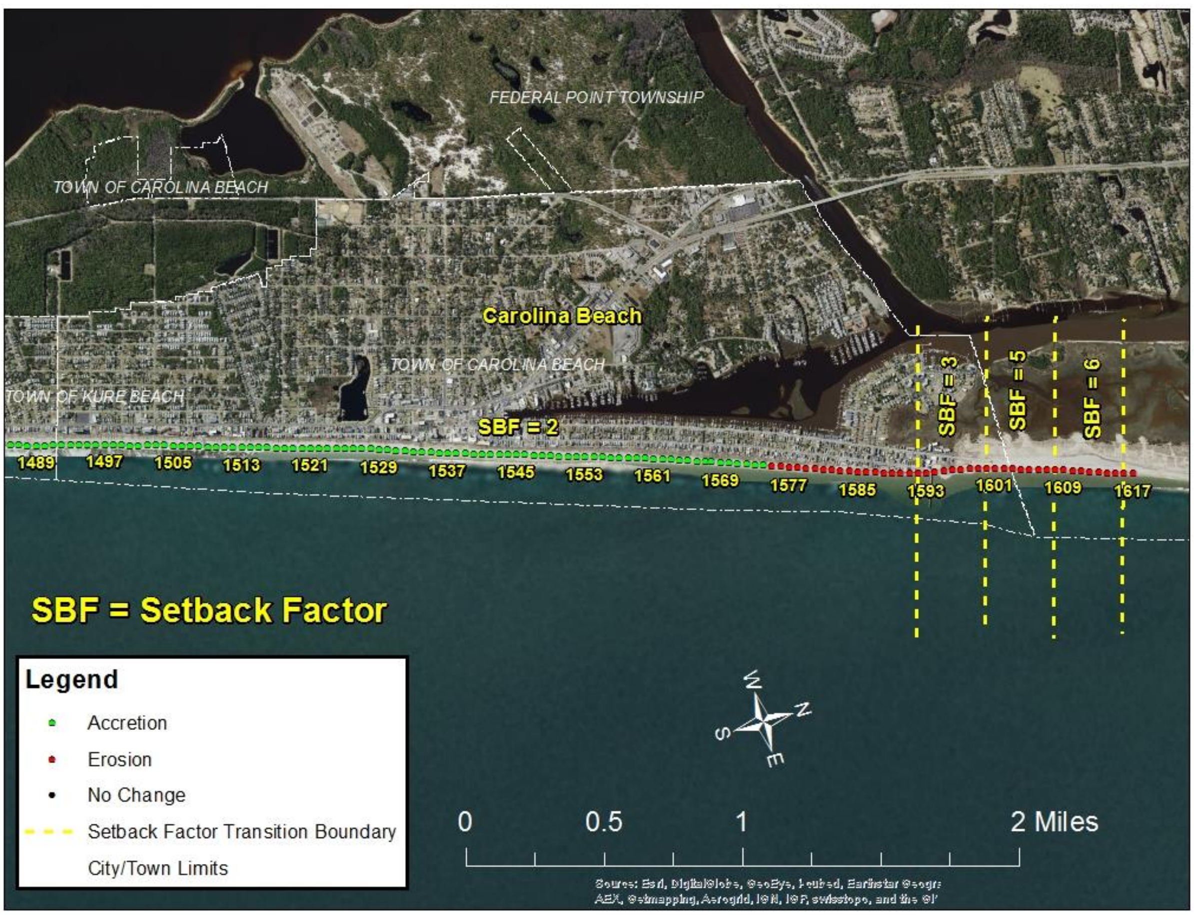

Figure 32. Carolina Beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Masonboro Island

Masonboro Island is an undeveloped barrier island. Its oceanfront shoreline is east facing and extends 7.8 miles with Carolina Beach inlet on its southern end (left side on the graph) and Masonboro inlet on its northern flank (right side on the graph). Approximately 7.7 miles (98.4 percent) of its shoreline resulted in measured erosion, while the remaining 0.1 miles (1.6 percent) resulted in measured accretion. The area with measured accretion is adjacent to the rock navigation jetty at Masonboro inlet where the fillet is regularly maintained; thus, artificially reducing shoreline change. The average blocked erosion rate at Masonboro Island is 7.0 feet per year, the maximum is 14 feet per year, and the minimum is two feet per year (Figure 33 and 34). The highest erosion factor occurs on the end adjacent to Carolina Beach Inlet.

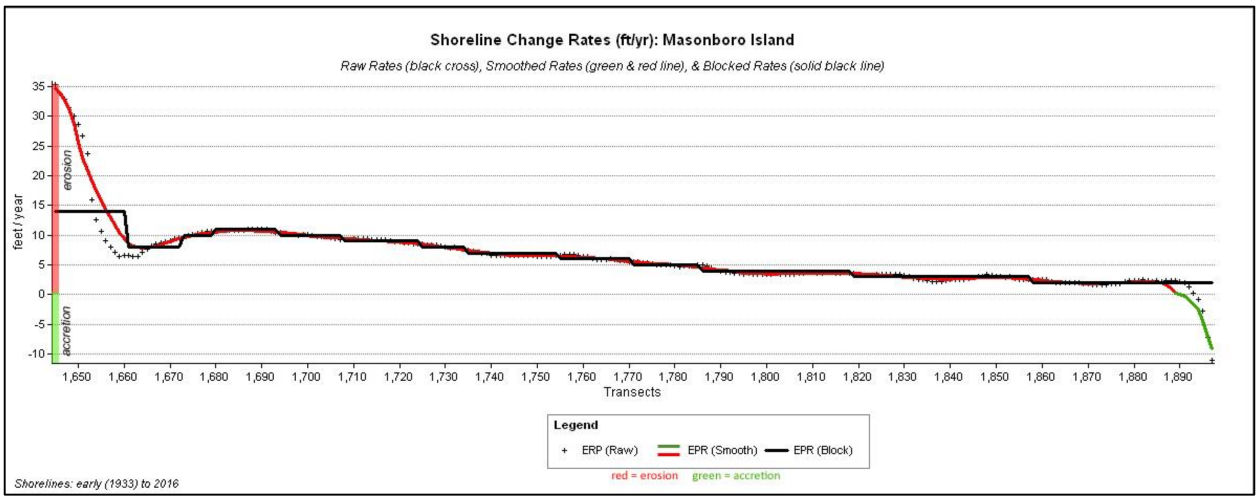

Figure 33. Masonboro Island Bird Island and Sunset Beach shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

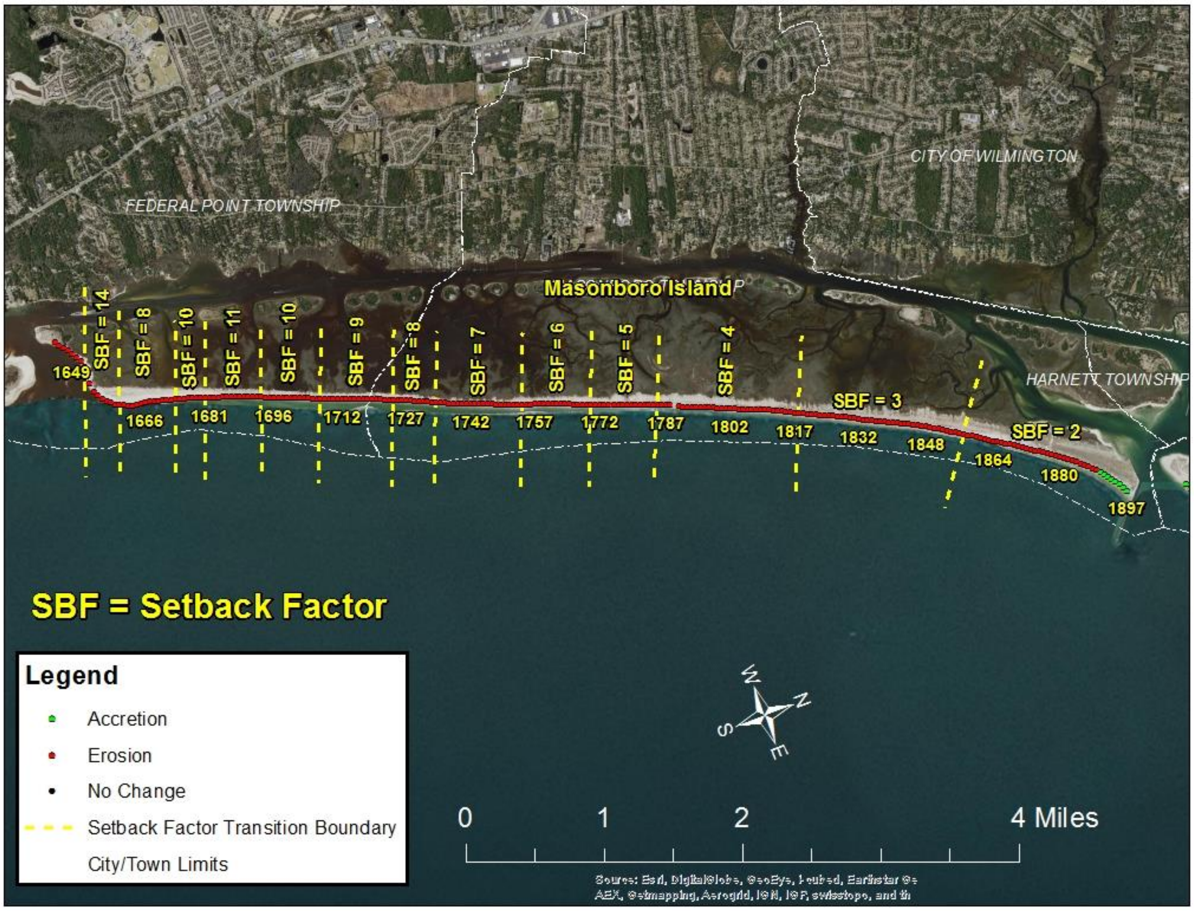

Figure 34. Masonboro Island. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Wrightsville Beach

Wrightsville Beach has approximately 4.5 miles of oceanfront shoreline, is east-facing, and flanked by two inlets (Masonboro and Mason). Masonboro Inlet is hardened with two rock navigational jetties (one on each side). Wrightsville Beach is routinely maintained as part of a USACE Storm Damage Reduction project. As a result, approximately 4.0 miles (95.6 percent) of its shoreline resulted in measured accretion, while the remaining 0.1 miles (2.2 percent) resulted in measured erosion. The average, maximum, and minimum blocked erosion rate at Wrightsville Beach is two feet per year (Figure 35 and 36). There is a data gap because the early shoreline reflects a time (1933) when Moore's Inlet was open.

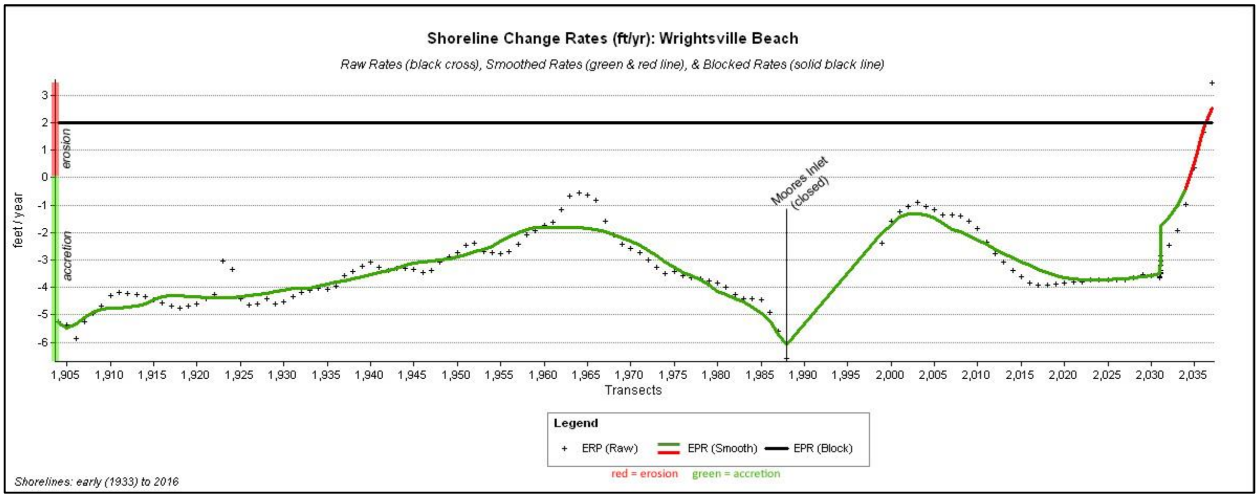

Figure 35. Wrightsville Beach shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

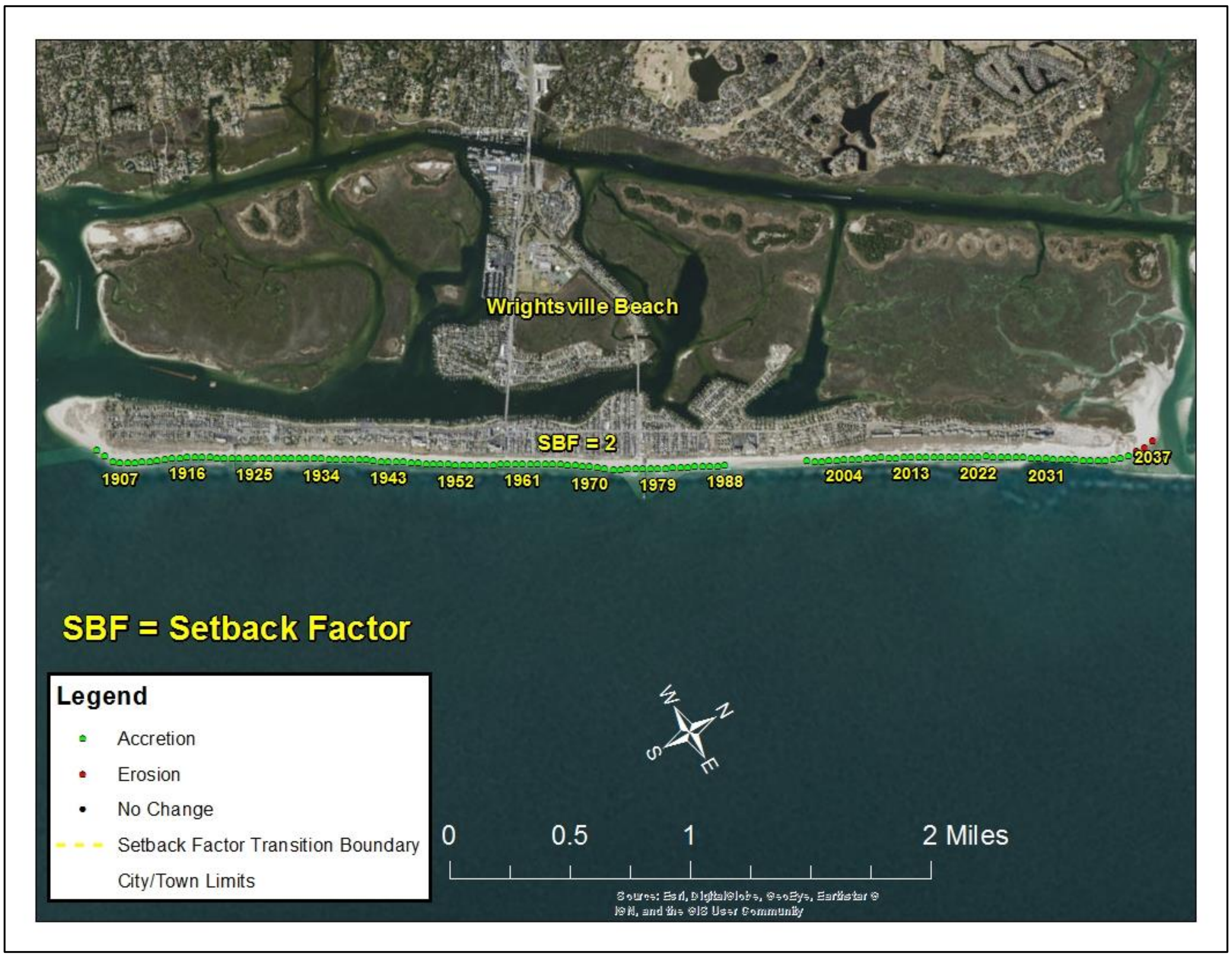

Figure 36. Wrightsville Beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Figure Eight Island

Figure Eight Island has approximately 3.6 miles of oceanfront shoreline, is east facing, and flanked by two inlets (Mason and Rich). Approximately 3.6 miles (100 percent) of its shoreline resulted in measured accretion. Erosion was minimized, and accretion measured high as a direct result of beach nourishment. The setback factor for all of Figure Eight Island's oceanfront is two feet per year (Figure 37 and 38).

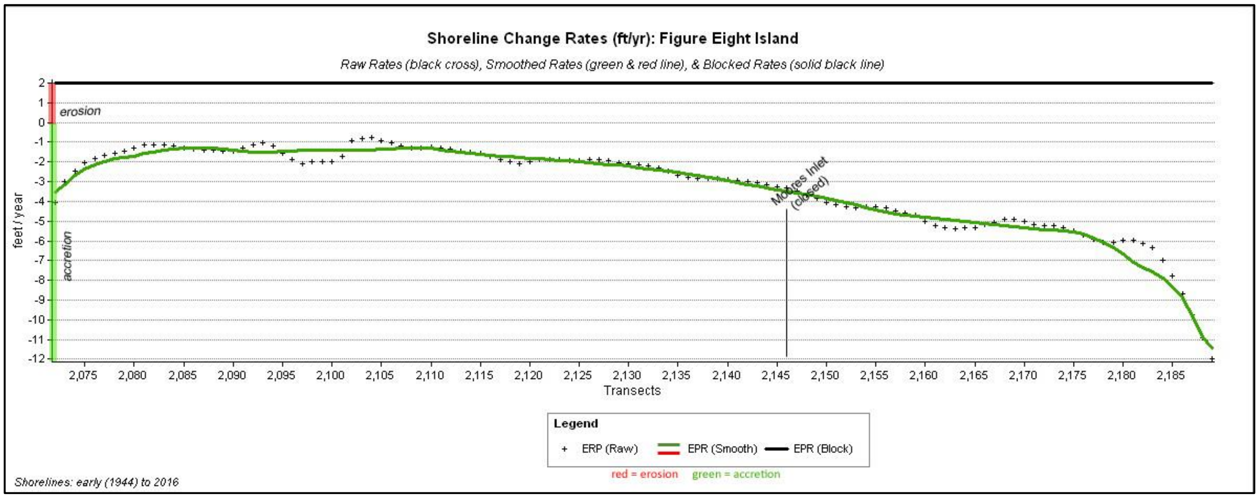

Figure 37. Figure Eight Island shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

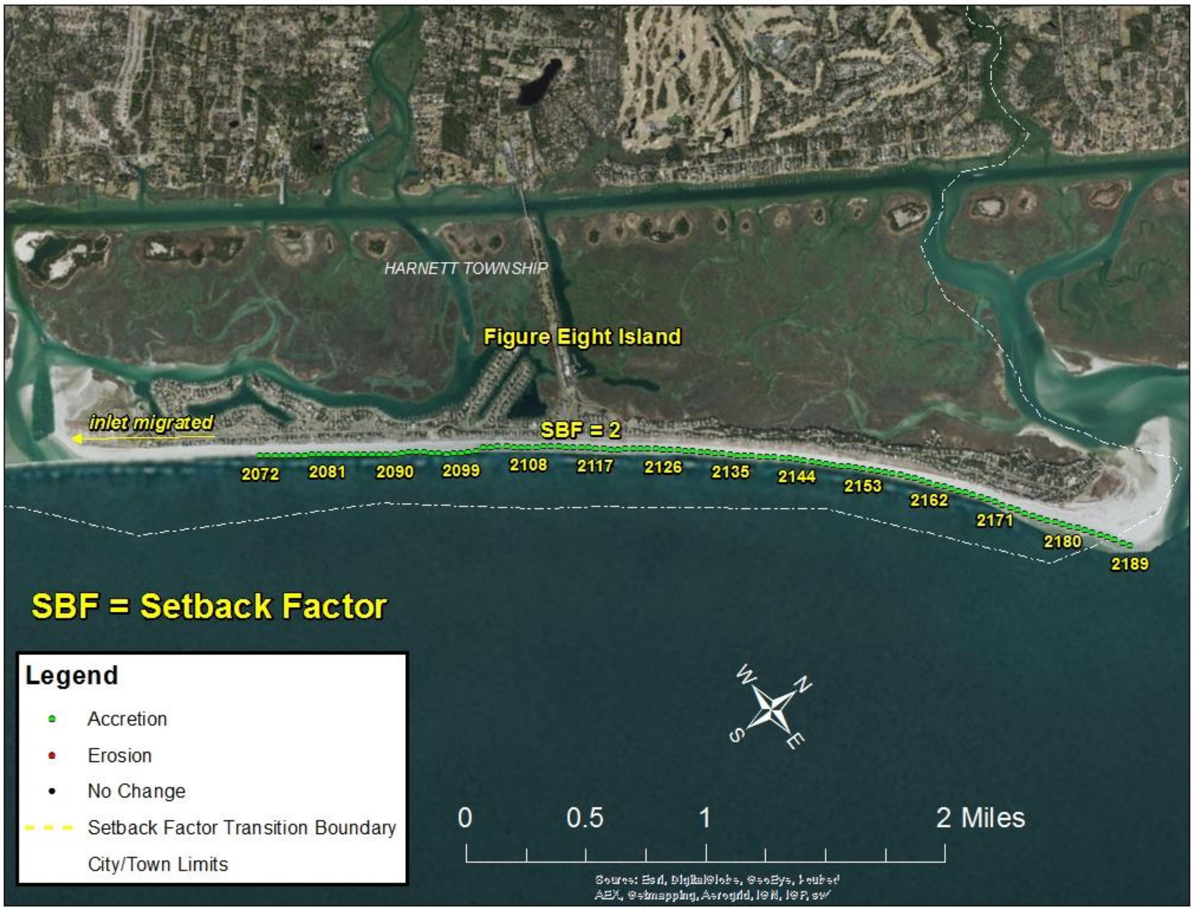

Figure 38. Figure Eight Island. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Lea-Hutaff Island

Lea-Hutaff Island has approximately 3.6 miles of oceanfront shoreline, is east-facing, and flanked by two inlets (Rich and New Topsail). Nearly all its oceanfront shoreline, 3.2 miles (89 percent) resulted in measured erosion characterized as eroding based on results, while the remaining 0.8 miles (22 percent) contains a data gap because of the closure of Old Topsail Inlet, which once separated Lea and Hutaff Islands. The average blocked erosion rate is 9.0 feet per year, the maximum is 10.0 feet per year near New Topsail Inlet (Figure 39 and 40).

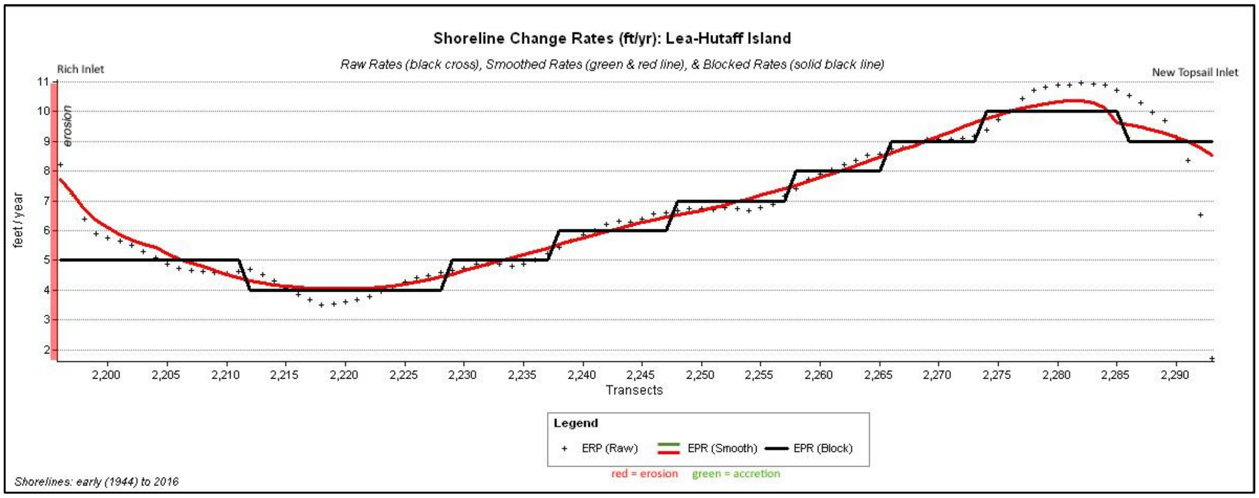

Figure 39. Lea-Hutaff Island shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

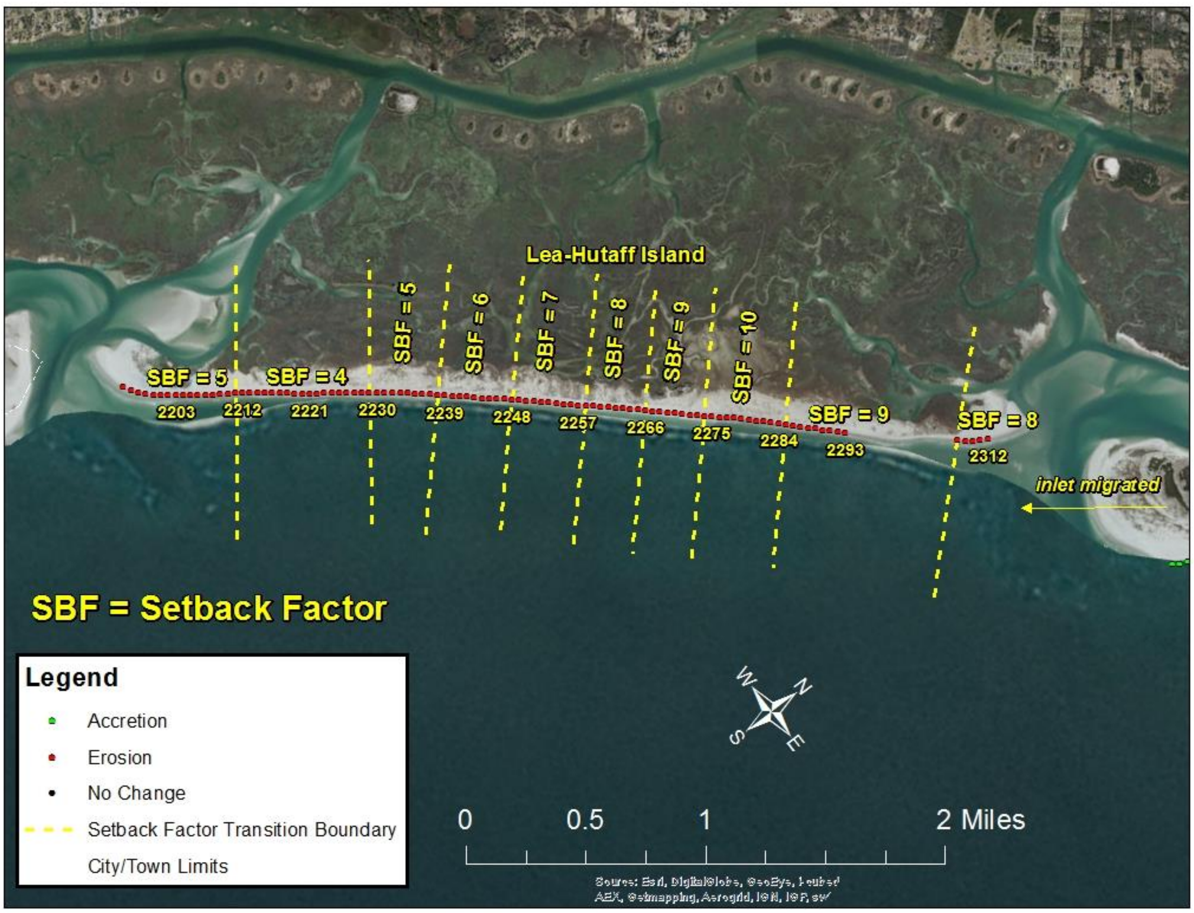

Figure 40. Figure Eight Island. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Topsail Beach

Topsail Island has approximately 22 miles of oceanfront shoreline and is an east-facing barrier island flanked by two inlets (New Topsail and New River). Topsail Beach makes up 28.1 percent (4.8 miles) of its shoreline, Surf City 27.3 percent (6.0 miles), and North Topsail Beach 50.1 percent (11.1 miles).

Approximately 3.9 miles (85.1 percent) of Topsail Beach's ocean shoreline resulted in measured accretion, while 0.5 mile (12.2 percent) resulted in measured erosion. The Town's most recent large-scale beach nourishment project was completed in 2011, which likely reduced actual erosion and increased accretion rates. The average shoreline change rate is 3.6 feet per year (accretion), and the blocked shoreline change rate (Setback Factor) is two feet per year (Figure 41 and 42).

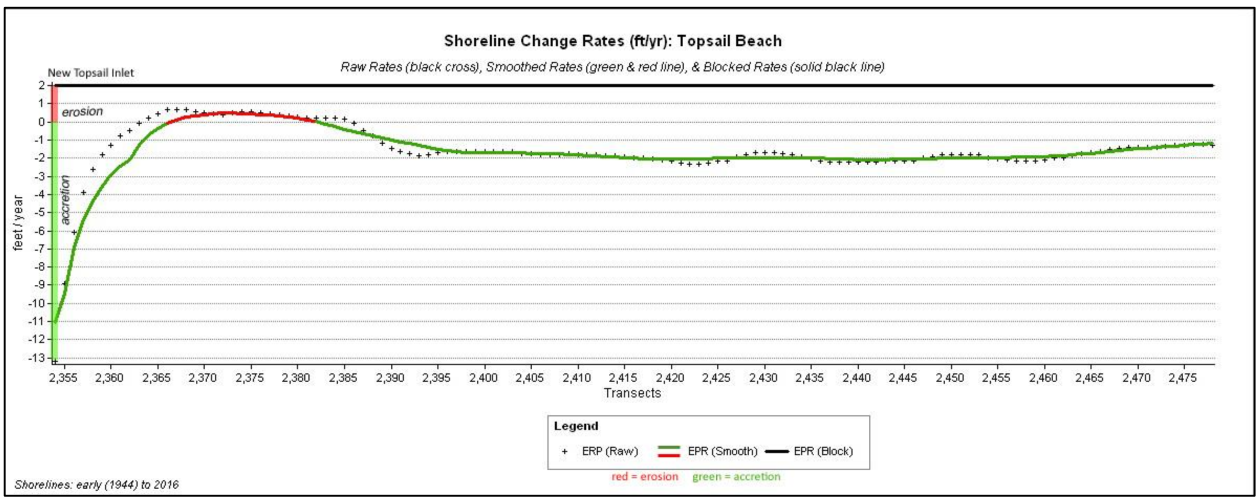

Figure 41. Topsail Beach. shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

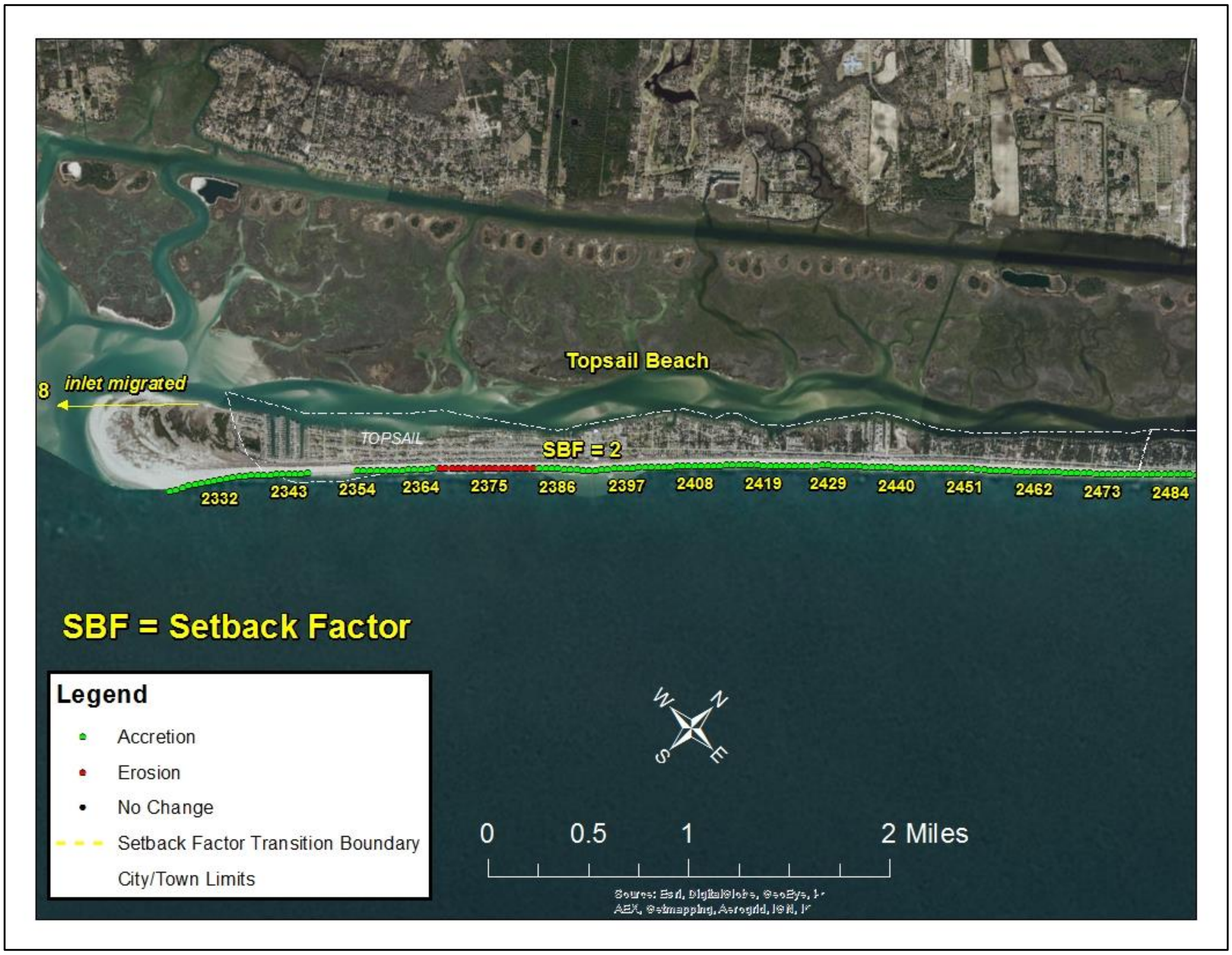

Figure 42. Topsail Beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Surf City

At Surf City, approximately 4.9 miles (82.3 percent) of its shoreline resulted in measured accretion, while 0.9 mile (15.1 percent) resulted in measured erosion. The average shoreline change rate is less than 1 foot per year (accretion), and the blocked shoreline change rate (Setback Factor) is two feet per year (Figure 43 and 44).

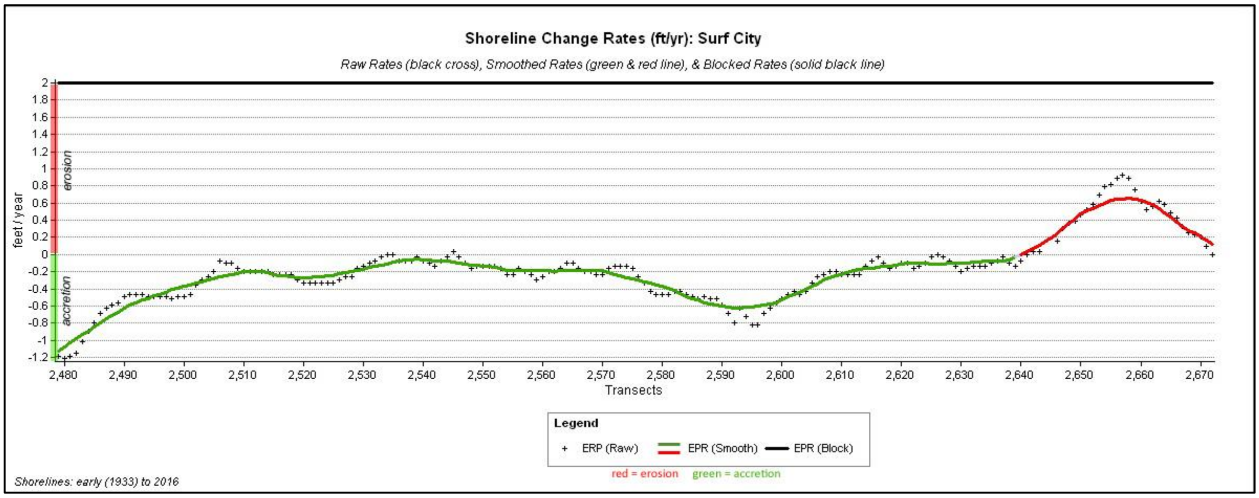

Figure 43. Surf City shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

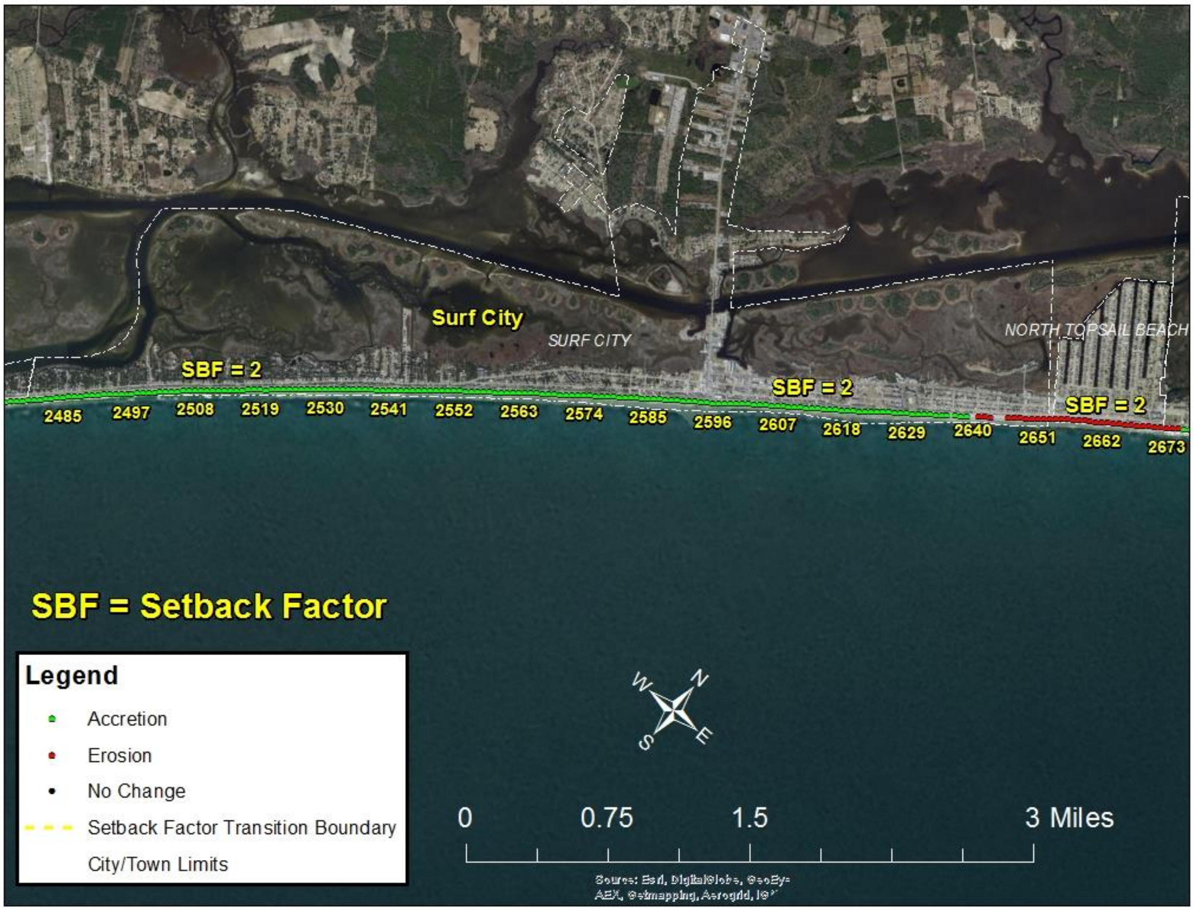

Figure 44. Surf City. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

North Topsail Beach

At North Topsail Beach, approximately 9.3 miles (83.8 percent) of its shoreline resulted in measured erosion, while 1.7 miles (15.4 percent) resulted in measured accretion. The average shoreline change rate is 1.1 feet per year (erosion), and most of the Town's shoreline (7.4 miles) resulted in a blocked shoreline change rate (setback factor) equal to 2.0 feet per year, and a setback factor equal to 3 for a segment of shoreline nearing New River Inlet (Figure 45 and 46). The area adjacent to New River Inlet has experienced the highest erosion, however, the setback factor is equal to 2 feet per year because existing rules (15A NCAC 07H.0304) require that the setback factor immediately adjacent to an Inlet Hazard Area (IHA) be applied throughout the IHA.

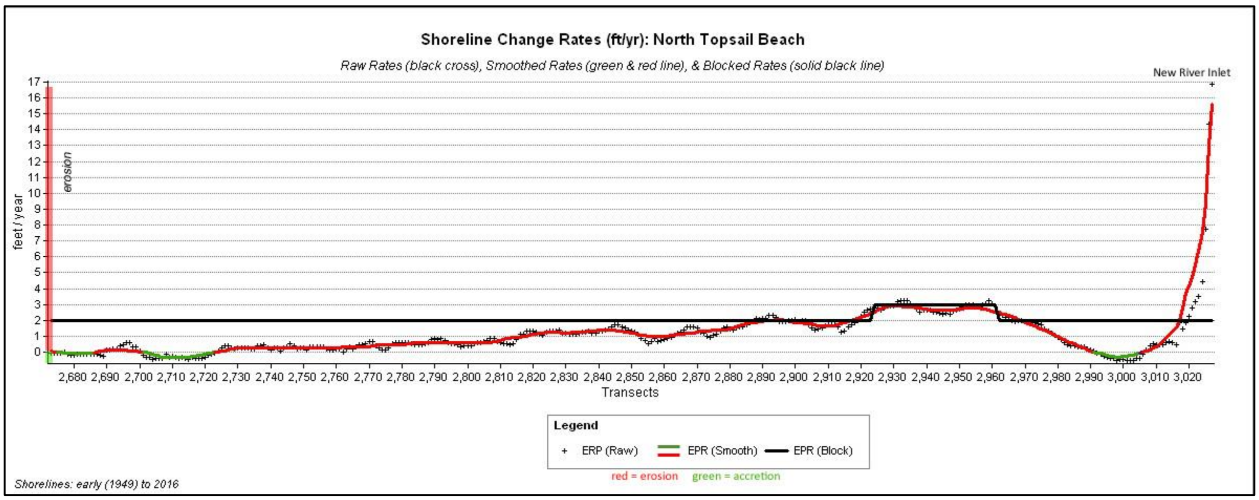

Figure 45. North Topsail Beach shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

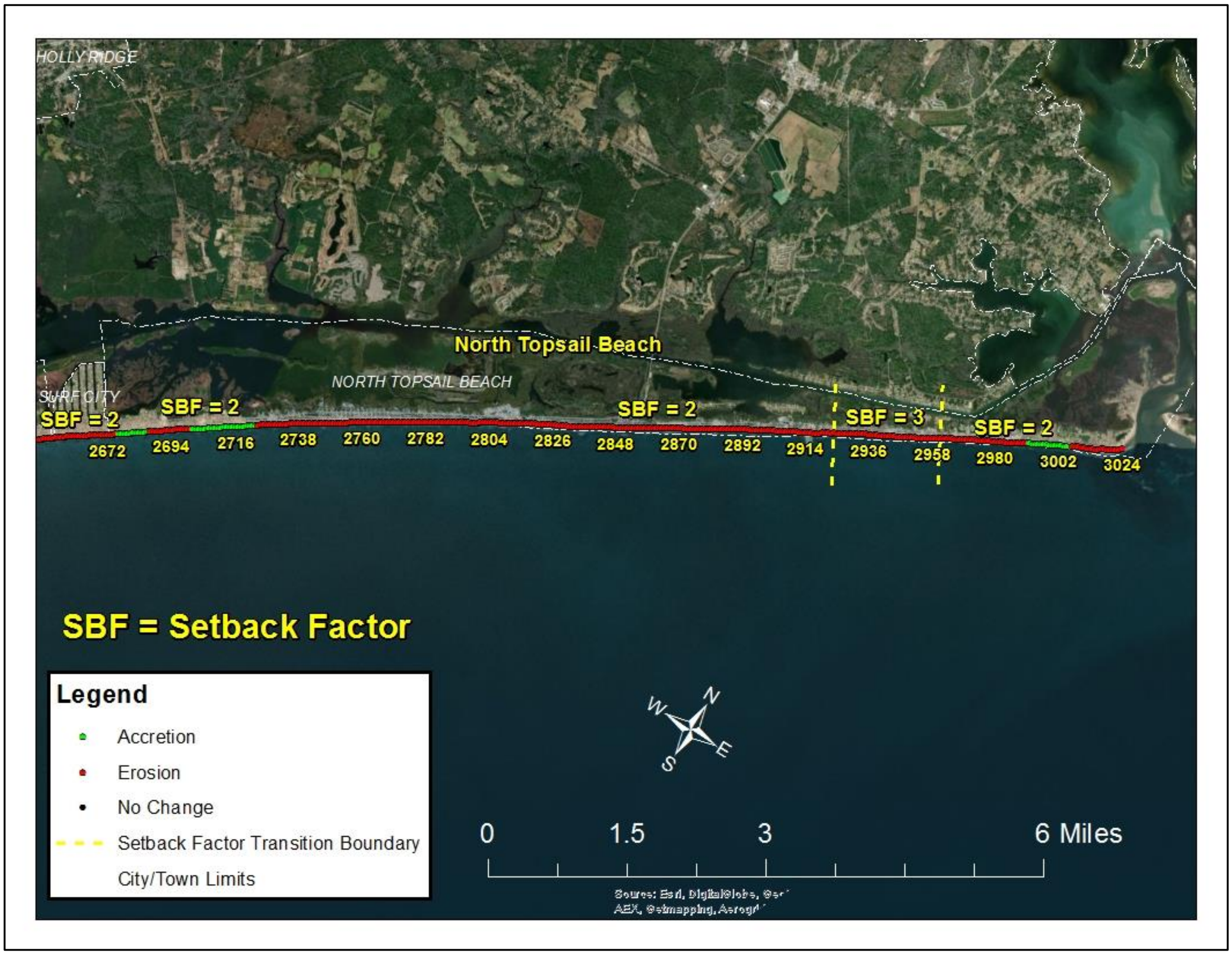

Figure 46. North Topsail Beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Onslow Beach

Onslow Beach has approximately 7.3 miles of oceanfront shoreline and is east-facing. Approximately 6.1 miles (83.5 percent) of its shoreline resulted in measured erosion, while 0.8 miles (11.4 percent) resulted in measured accretion. The average blocked erosion rate is 5 feet per year, the maximum is 11 feet per year, and the minimum is two feet per year (Figure 47 and 48). Rates for Onslow Beach were calculated using a 2017 shoreline, and not 2016, because there was a data gap in the 2016 shoreline.

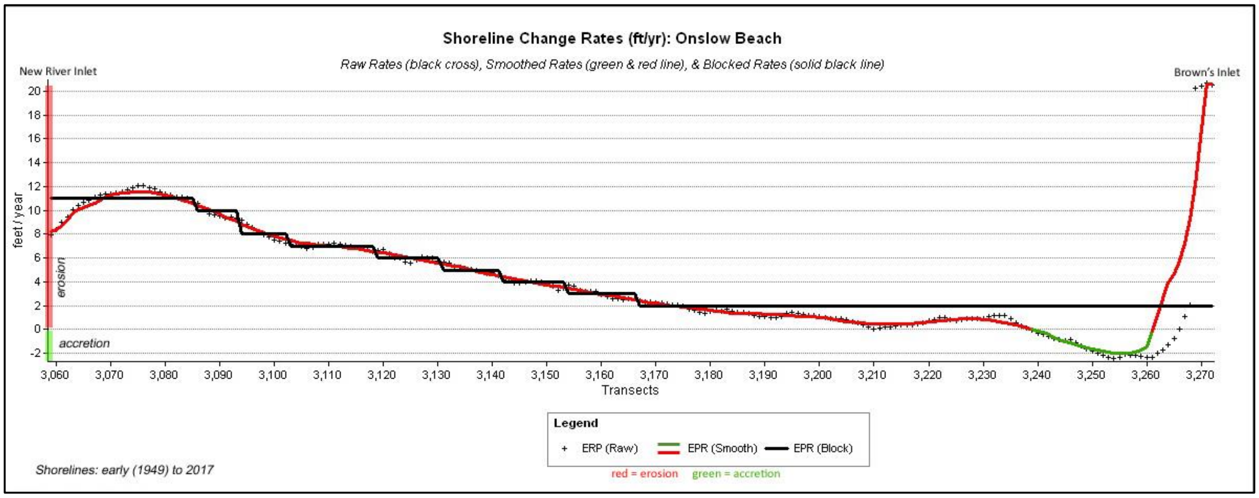

Figure 47. Onslow Beach shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

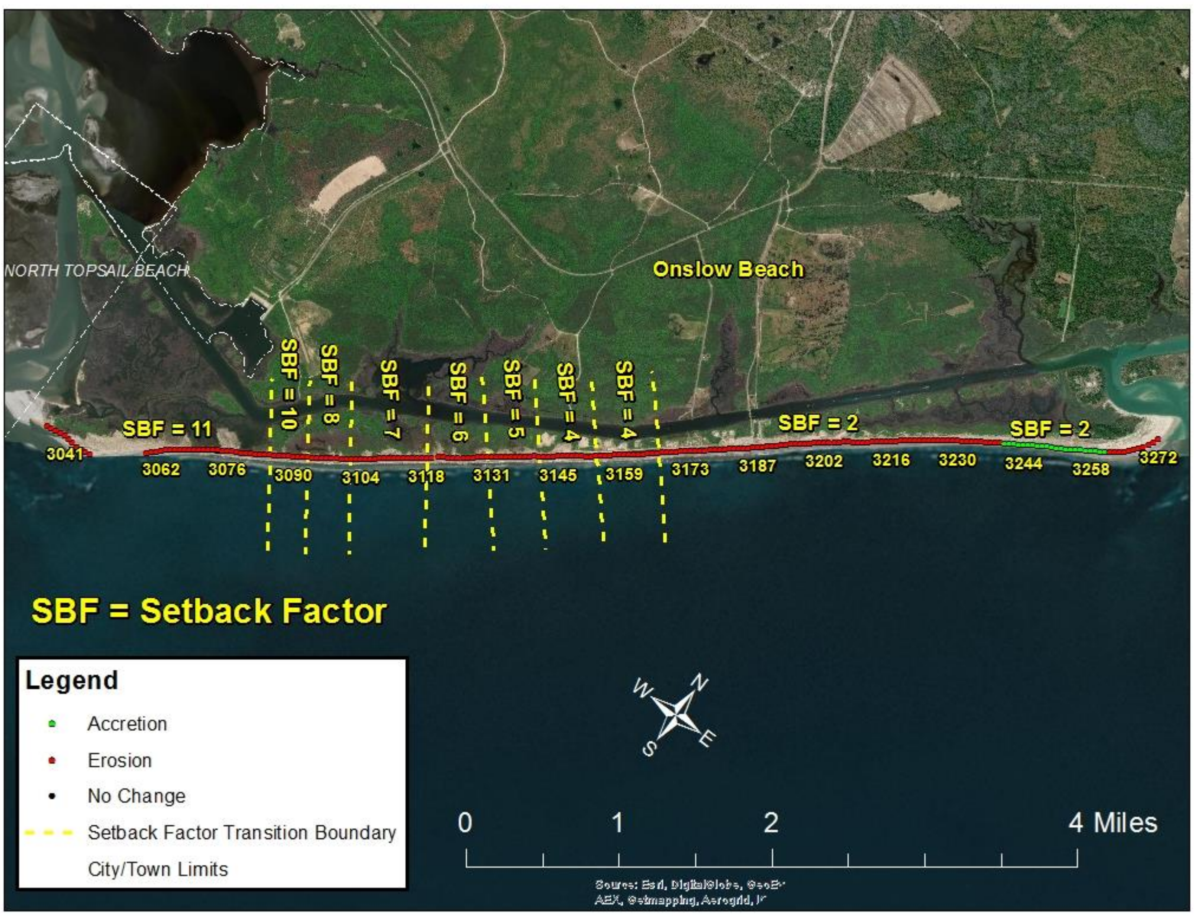

Figure 48. Onslow Beach. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Brown's Island

Brown's Island is an undeveloped barrier island and marks the transition point, moving up the coast from Cape Fear to Cape Lookout, where the beach begins facing a southerly direction. This island's oceanfront shoreline is approximately 3.3 miles long, with approximately 3.1 miles (94.3 percent) of shoreline with measured erosion, while 0.1 mile (3.8 percent) resulted in measured accretion. The average shoreline change rate is 3.5 feet per year (erosion), and blocked shoreline change rate (setback factor) is 4.0 feet per year (Figure 49 and 50).

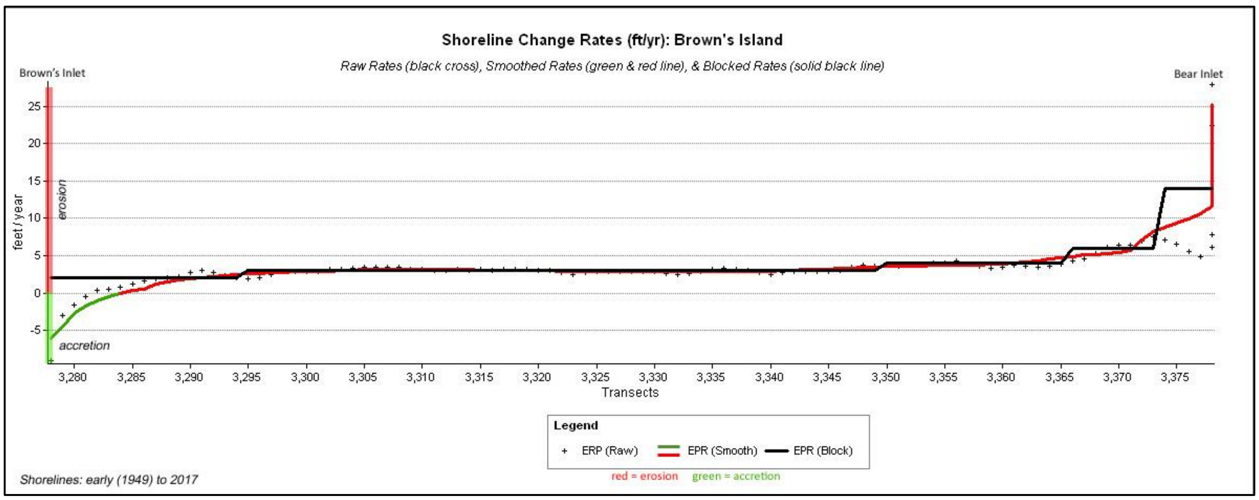

Figure 49. Brown's Island shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

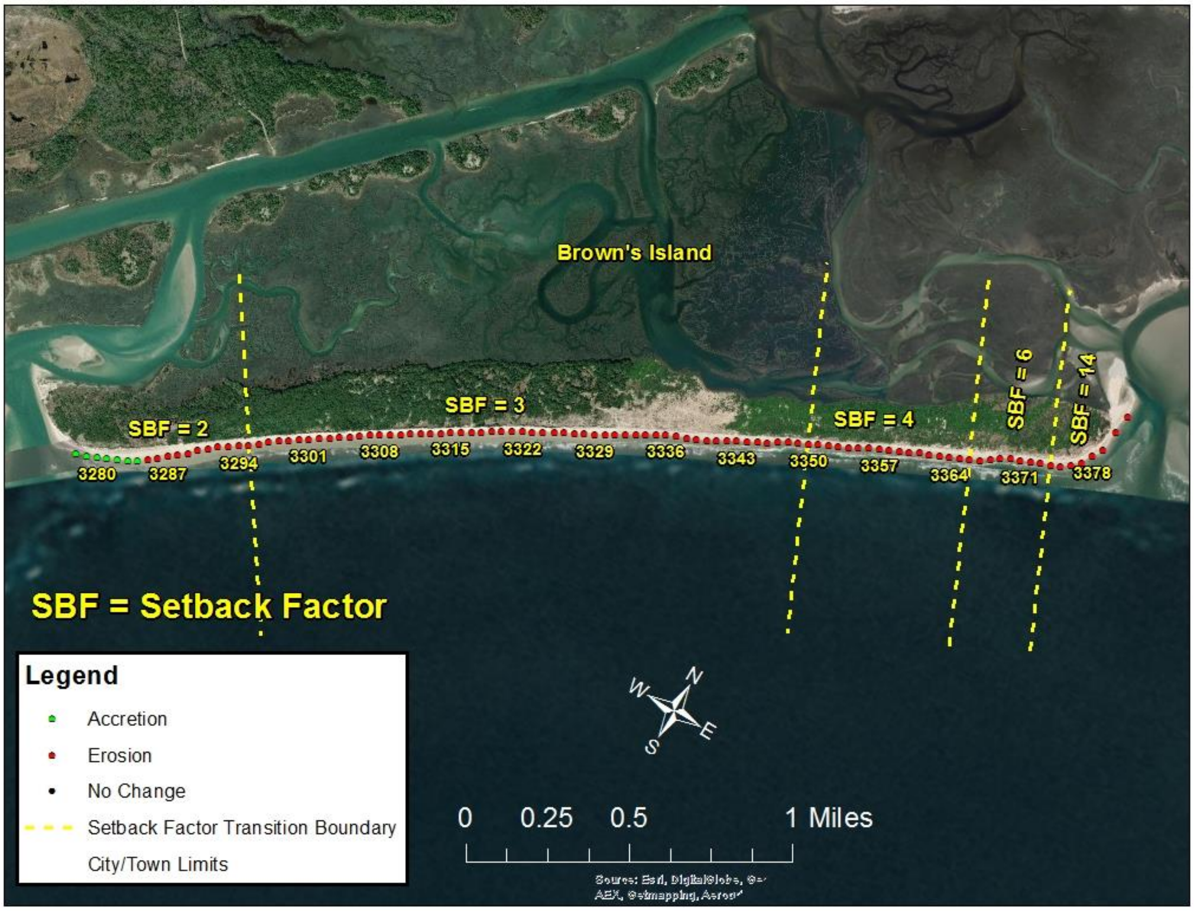

Figure 50. Brown's Island. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Bear Island (Hammocks Beach State Park

Bear Island (Hammocks Beach State Park) is an undeveloped south facing barrier island with approximately 3.0 miles of oceanfront shoreline. Approximately 2.4 miles (78.6 percent) of its shoreline resulted in measured erosion, while 0.6 of a mile (21.4 percent) resulted in measured accretion. The average shoreline change rate is less than 1 foot per year (accretion), and the blocked shoreline change rate (setback factor) is 3 feet per year, the maximum is 4.5 feet per year, and the minimum is two feet per year (Figure 51 and 52).

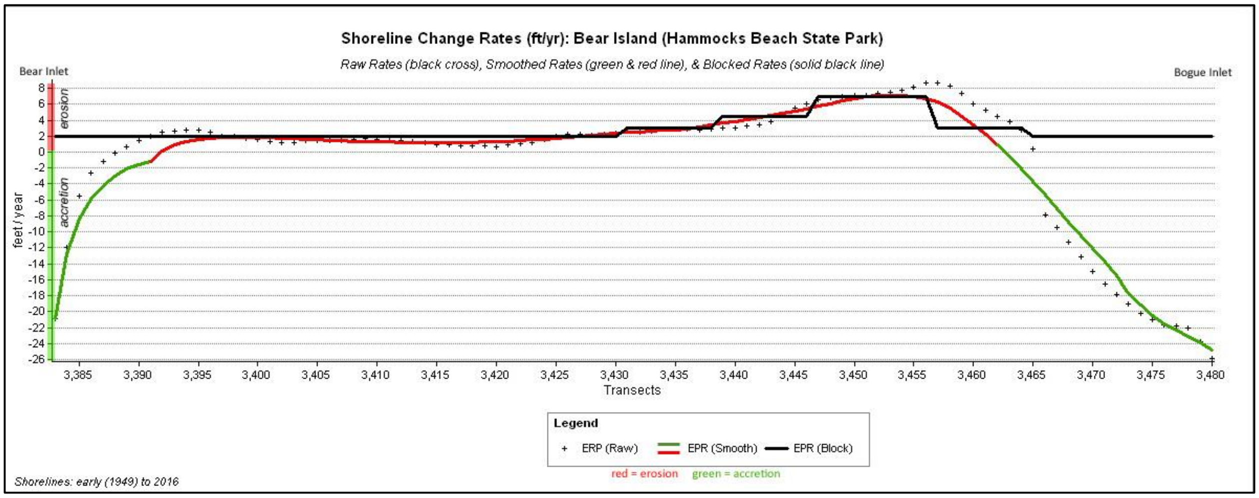

Figure 51. Bear Island shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

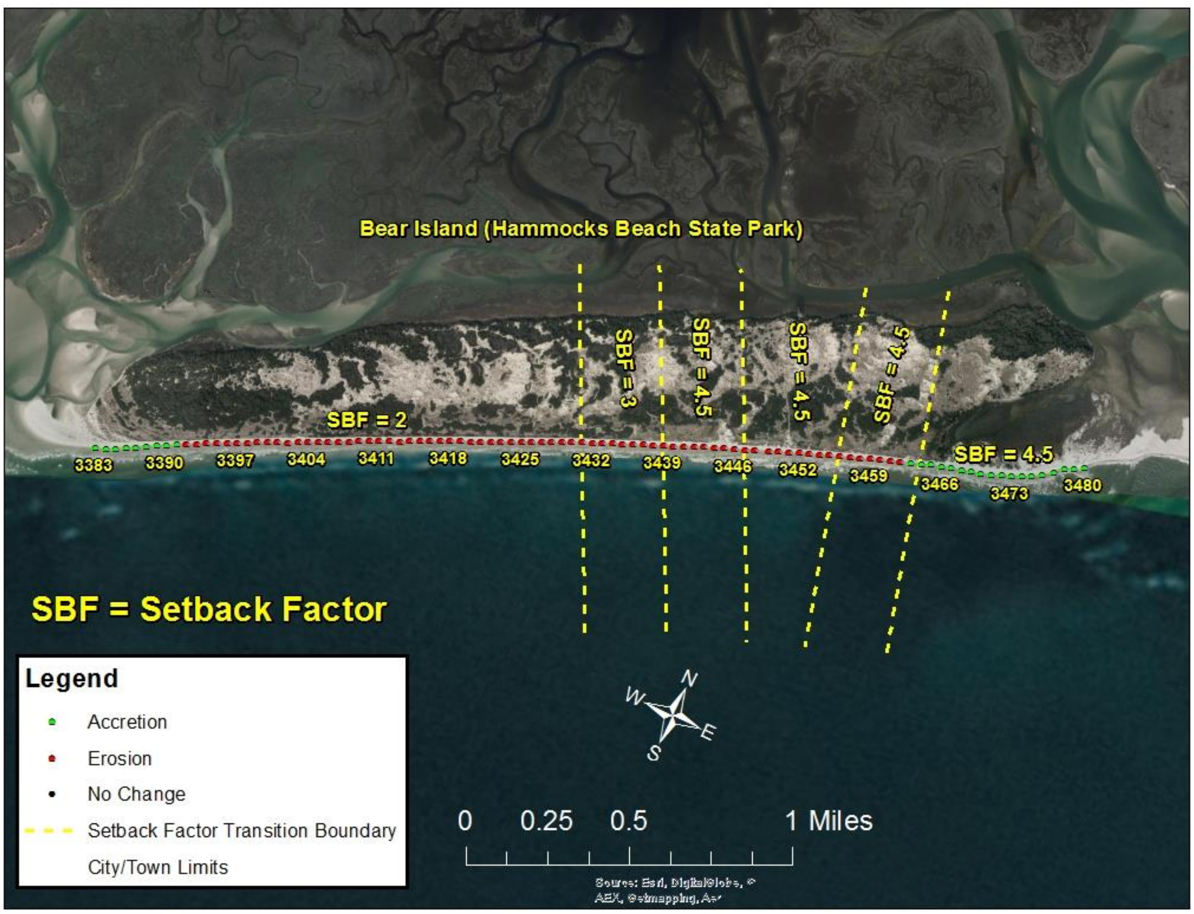

Figure 52. Bear Island. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Emerald Isle

Bogue Banks is a south-facing barrier island with nearly 25 miles of oceanfront shoreline and is comprised of five townships and a state park. Emerald Isle makes up approximately 11.2 miles (49 percent) of its shoreline, Indian Beach 1.7 miles (approximately 7 percent), Salter Path 0.8-mile, Pine Knoll Shores 4.8 miles (19.2 percent), and Atlantic Beach and Fort Macon State Park 6.1 miles (24.4 percent). It is also flanked by two inlets (Bogue and Beaufort).

At Emerald Isle, approximately 7.7 miles (69.1 percent) of its ocean shoreline resulted in measured accretion, while 3.4 miles (30.1 percent) resulted in measured erosion. The average shoreline change rate is 0.3 feet per year (accretion), the blocked shoreline change rate (setback factor) is 2.0 feet per year for all Emerald Isle's oceanfront (Figure 53 and 54).

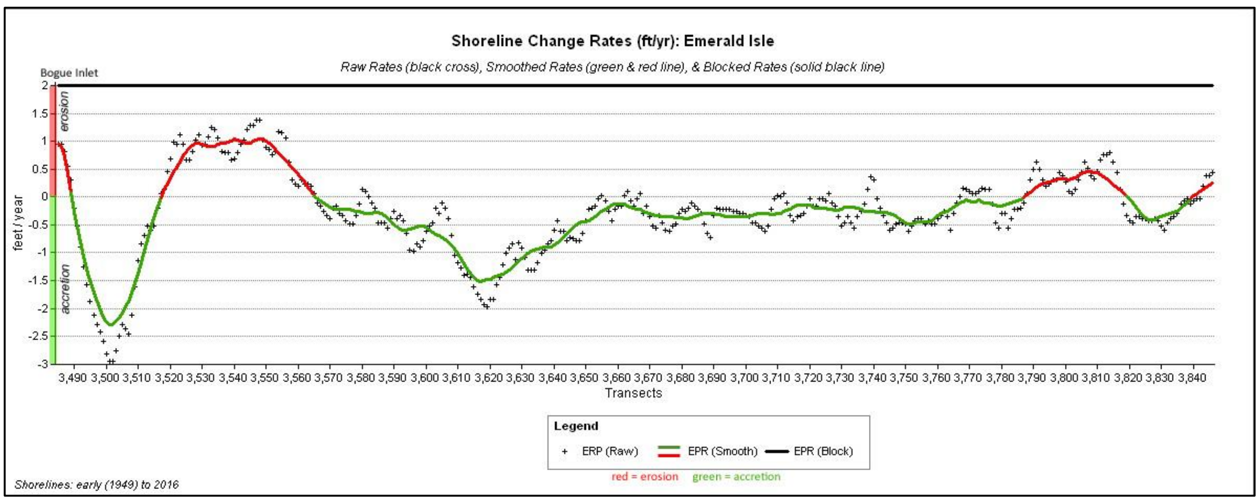

Figure 53. Emerald Isle shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

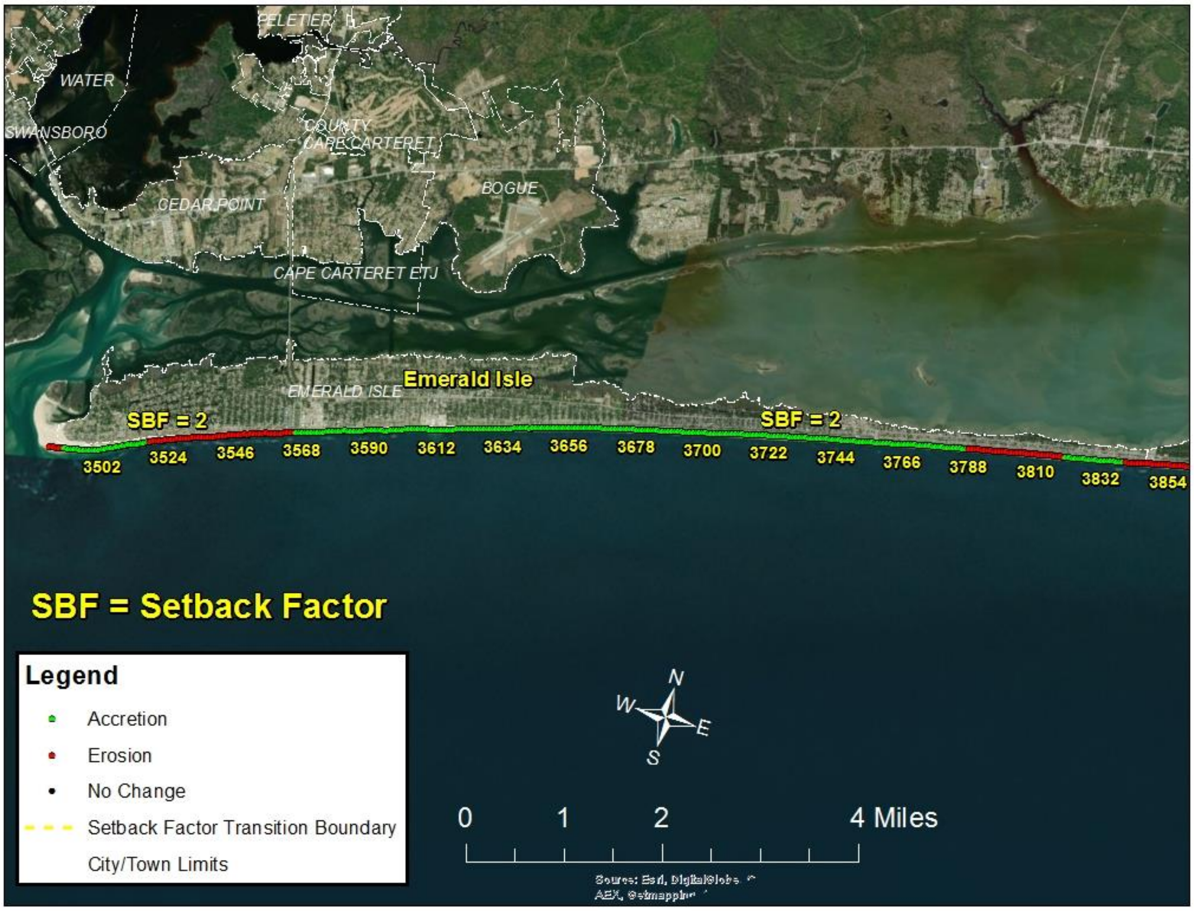

Figure 54. Emerald Isle. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Indian Beach & Salter Path

At Indian Beach, approximately 1.7 miles (100 percent) of its shoreline resulted in measured erosion, while no accretion was measured. Although erosion was measured, the average is less than 1 foot per year, and the blocked shoreline change rate (setback factor) is 2 feet per year for all Indian Beach (Figure 55 and 56).

At Salter Path, approximately 100 percent (0.8 mile) of its shoreline resulted in measured erosion (less than two feet per year). The average blocked shoreline change rate is two feet per year (Figure 55 and 56).

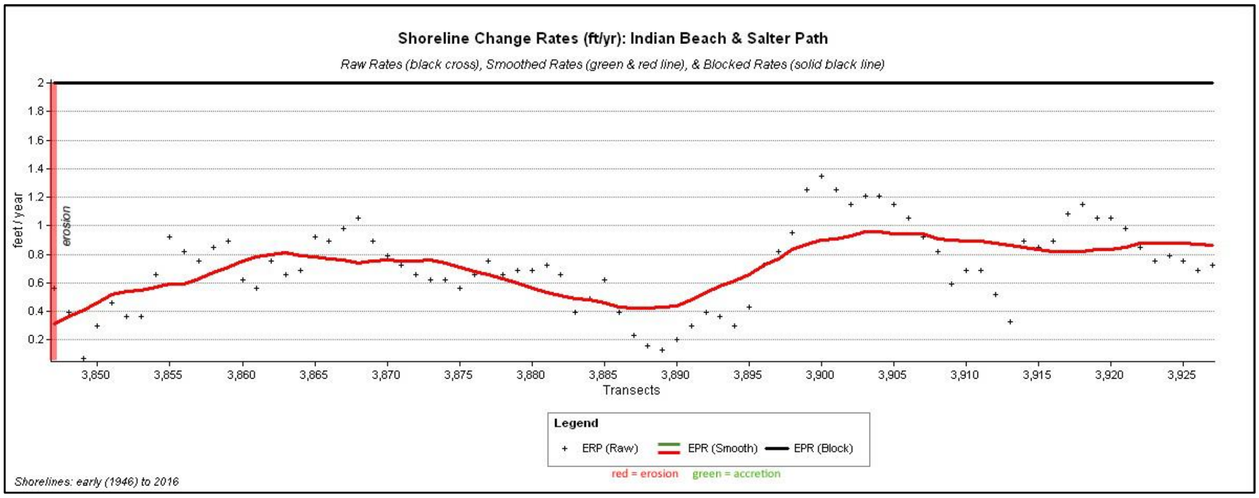

Figure 55. Indian Beach and Salter Path shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

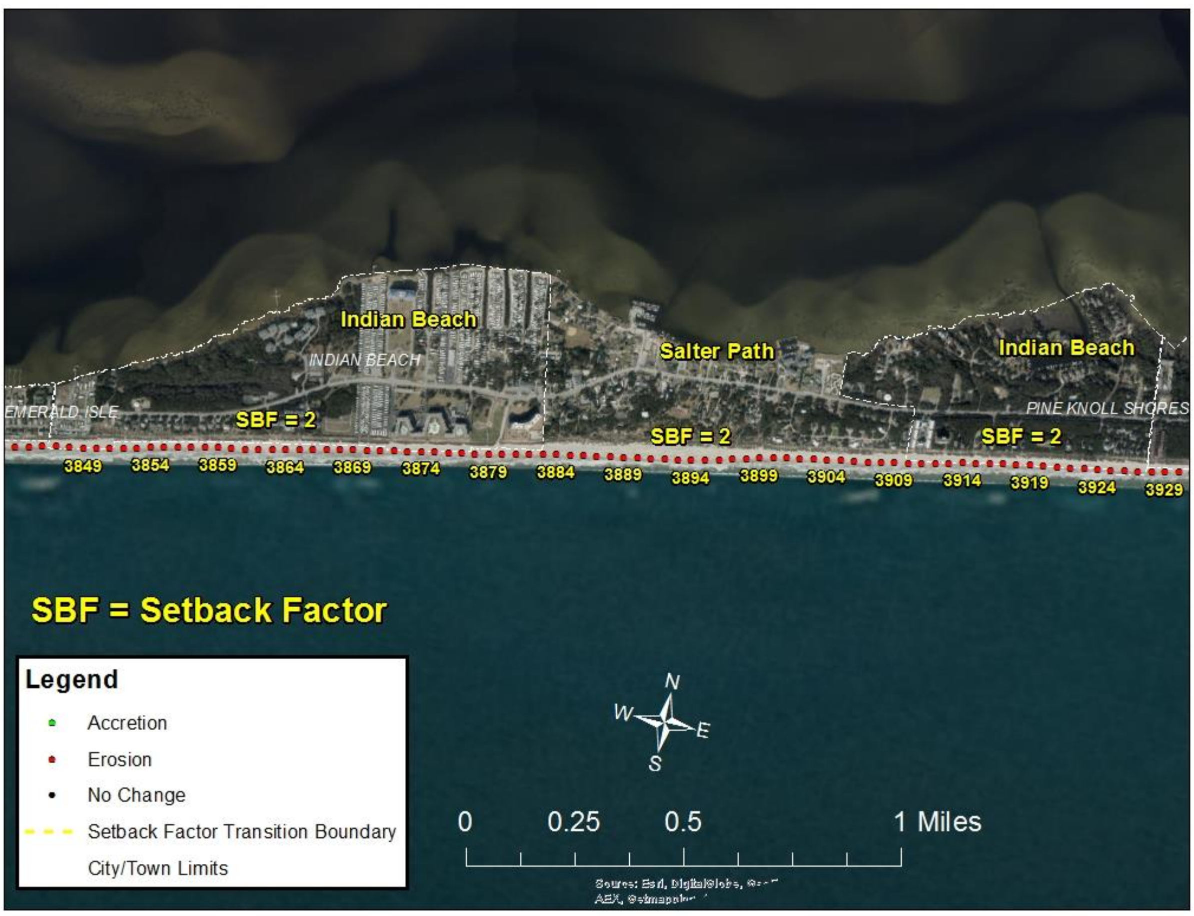

Figure 56. Indian Beach and Salter Path. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Pine Knoll Shores

At Pine Knoll Shores, approximately 3.5 miles (72.9 percent) of its shoreline resulted in measured erosion, while 1.1 miles (23.9 percent) resulted in measured accretion. The average shoreline change rate is less than 1 foot per year (erosion), and the blocked shoreline change rate is two feet per year (Figure 27).

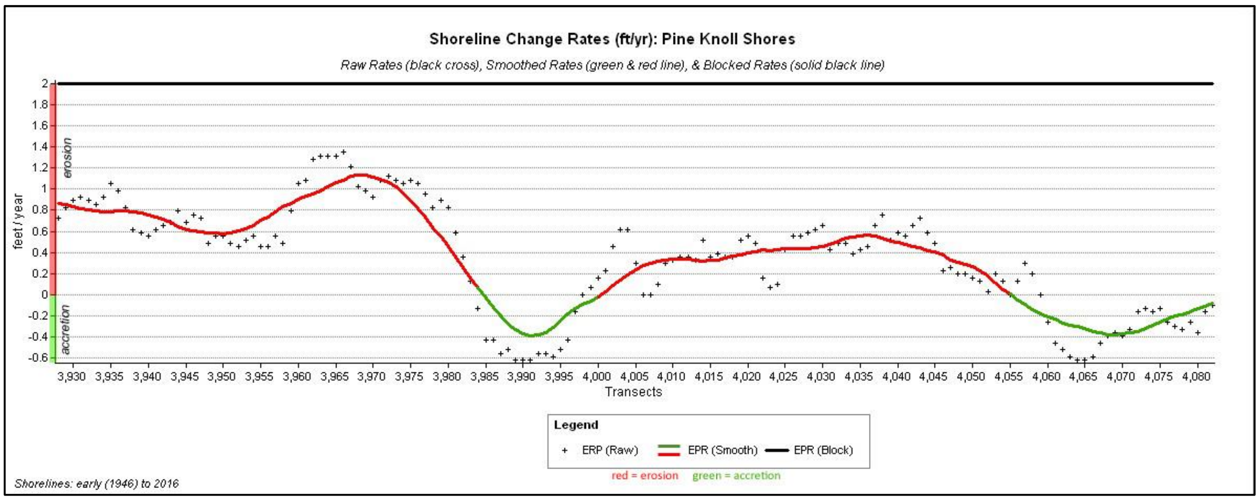

Figure 57. Pine Knoll Shores shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

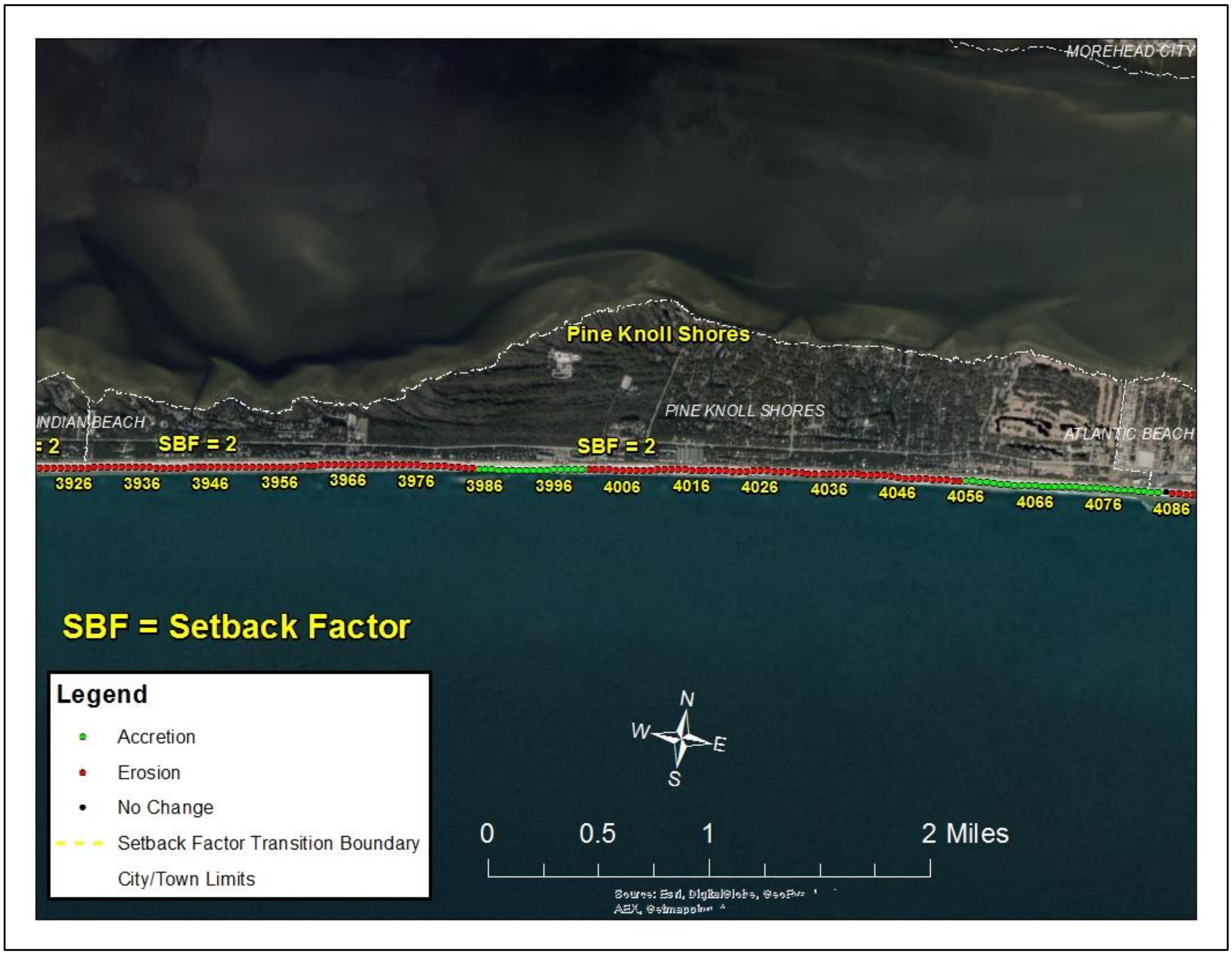

Figure 58. Pine Knoll Shores. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Atlantic Beach and Fort Macon State Park

At Atlantic Beach and Fort Macon, approximately 5.1 miles (84.2 percent) of its shoreline resulted in measured accretion, while 0.9 miles (15.3 percent) resulted in measured erosion. Both shorelines receive regular beach fill because of maintaining Morehead City Port channel (Beaufort Inlet), which significantly reduces erosion rates and artificially increased accretion. blocked shoreline change rate (setback factor) is two feet per year for all Atlantic Beach and Fort Macon (Figure 27).

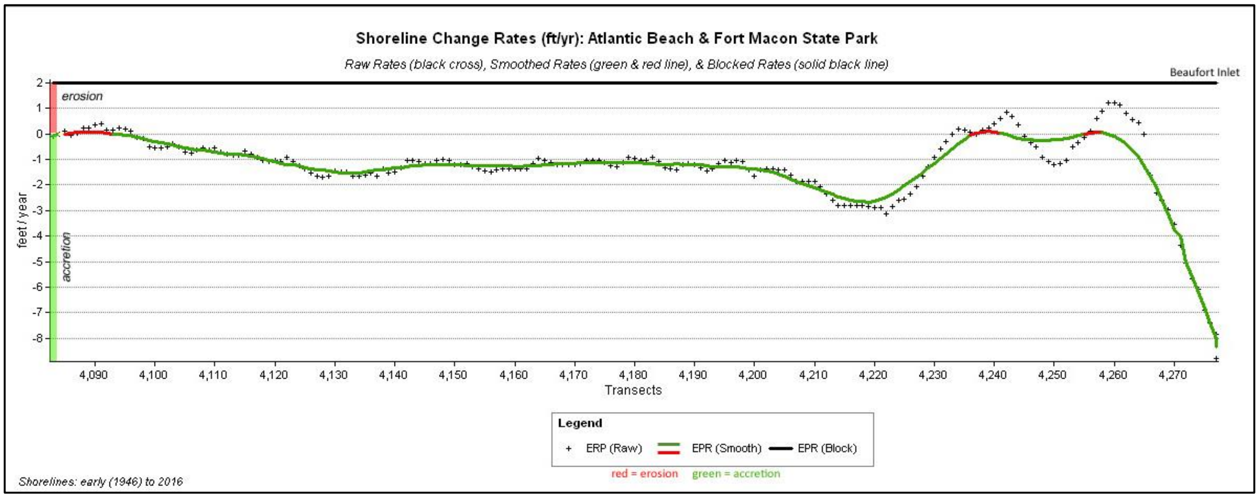

Figure 59. Atlantic Beach and Fort Macon State Park shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

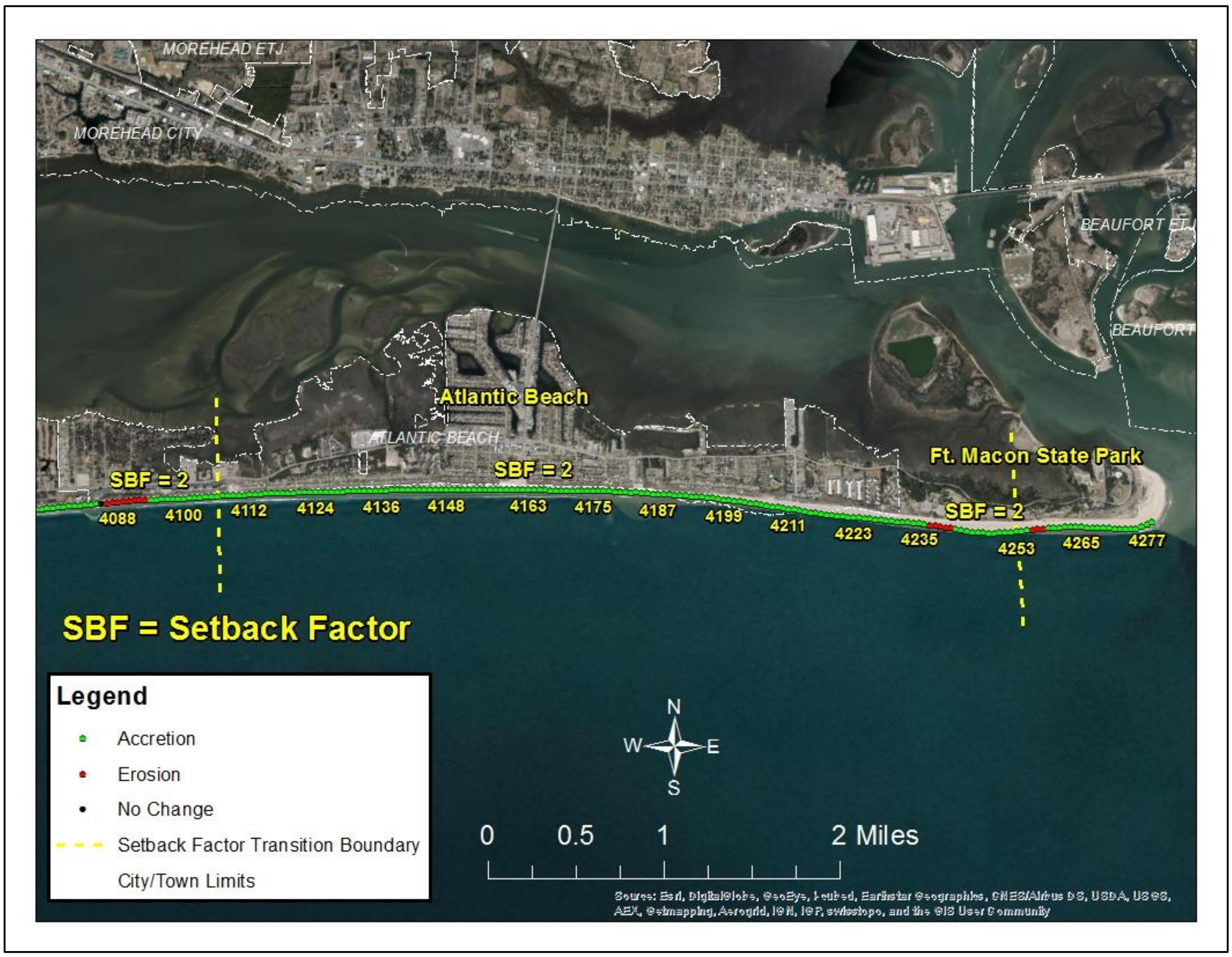

Figure 60. Atlantic Beach and Fort Macon State Park. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Shackleford Banks

Shackleford Banks is an undeveloped south-facing barrier island with approximately 8.1 miles of oceanfront shoreline and is flanked by two inlets (Beaufort and Barden). Approximately 6.4 miles (79 percent) of its shoreline resulted in measured erosion, while 1.7 miles (21 percent) resulted in measured accretion. Although the shoreline adjacent to Beaufort Inlet has been eroding at significant rates in recent years, the 2016 shoreline is nearing the same location as the early shoreline (1946); although small, still resulting in measured accretion. The average shoreline change rate is 2.7 feet per year (erosion), and blocked rate (setback factor) is 4.0 feet per year (Figure 61 and 62).

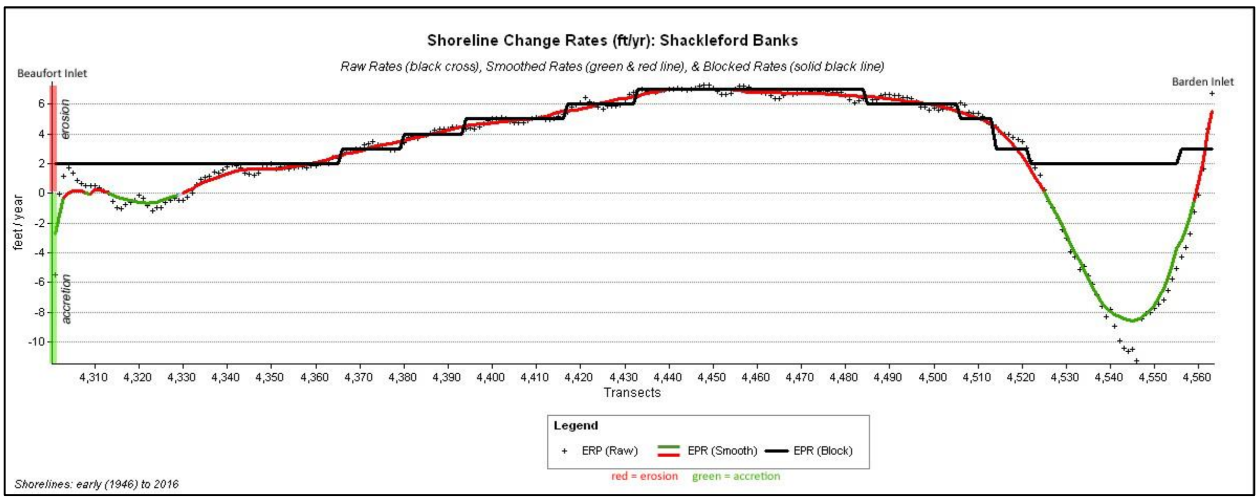

Figure 61. Shackleford Banks shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

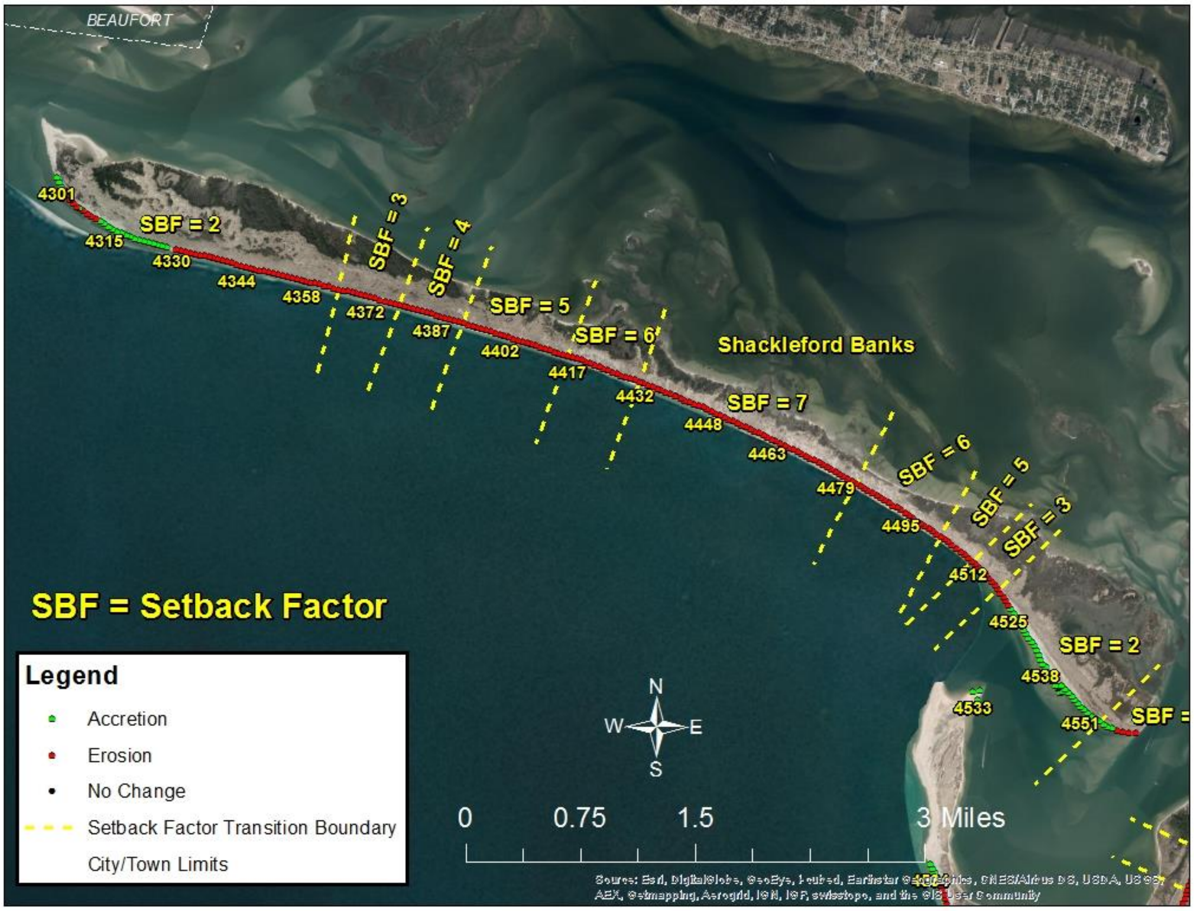

Figure 62. Shackleford Banks. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Cape Lookout

At Cape Lookout starting at Barden Inlet moving towards the point at the cape is an undeveloped south-facing portion of the Core Banks, with approximately 2.4 miles of oceanfront shoreline. Approximately 2.0 miles (83.1 percent) of its shoreline resulted in measured erosion, while 0.3 of a mile (15.6 percent) resulted in measured accretion. The average shoreline change rate is 5.3 feet per year (erosion), and 6.0 feet per year blocked rate (setback factor) (Figure 63 and 64).

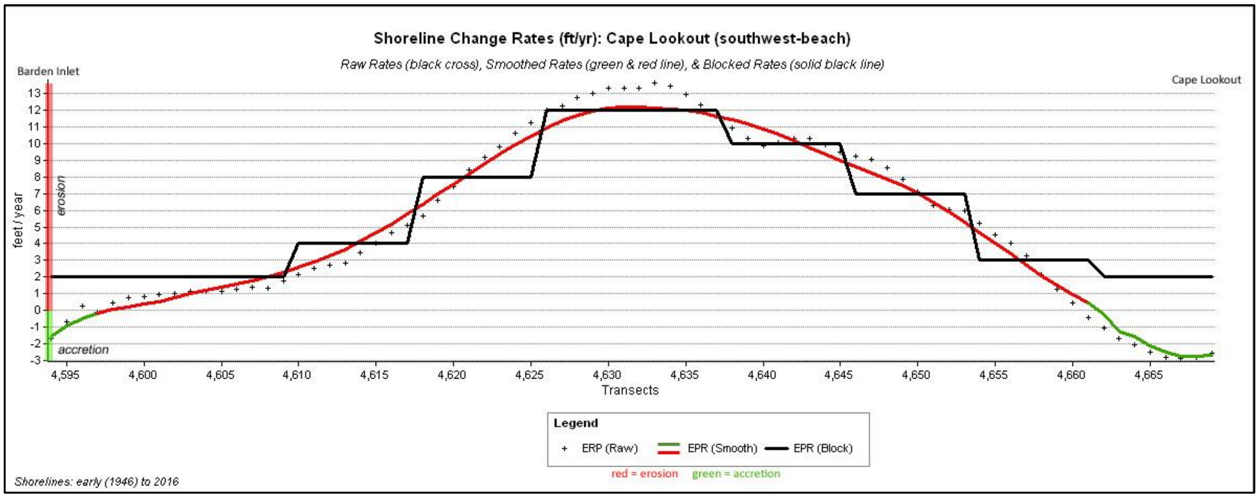

Figure 63. Cape Lookout shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

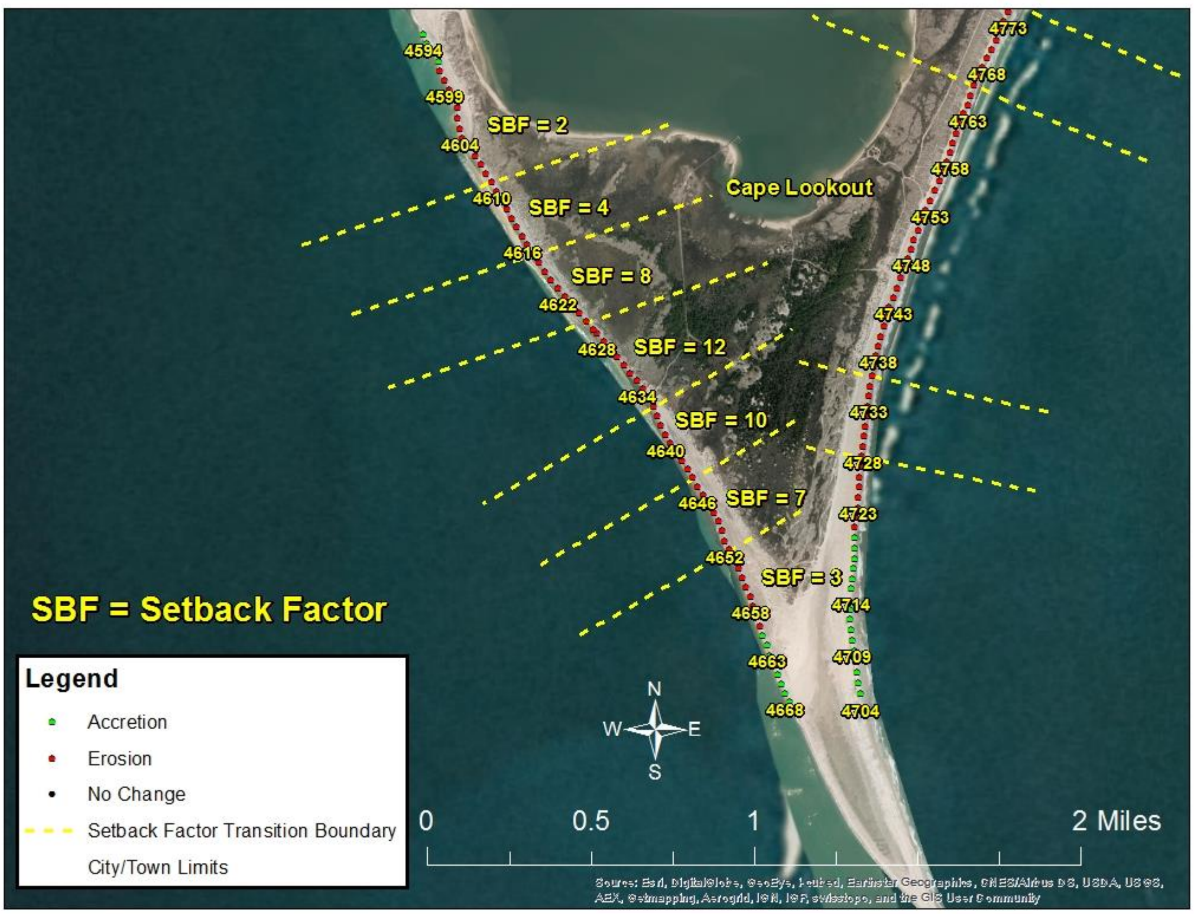

Figure 64. Cape Lookout (south-west beach). Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Cape Lookout starting at the point at the cape and moving towards Drum Inlet is an undeveloped east facing portion of the Core Banks with approximately 20.9 miles of oceanfront shoreline. Approximately 18.2 miles (87.1 percent) of its shoreline resulted in measured erosion, while 2.1 miles (10.2 percent) resulted in measured accretion. The average shoreline change rate is 4.3 feet per year (erosion), and blocked rate (setback factor) is 5.0 feet per year (Figure 65 and 66).

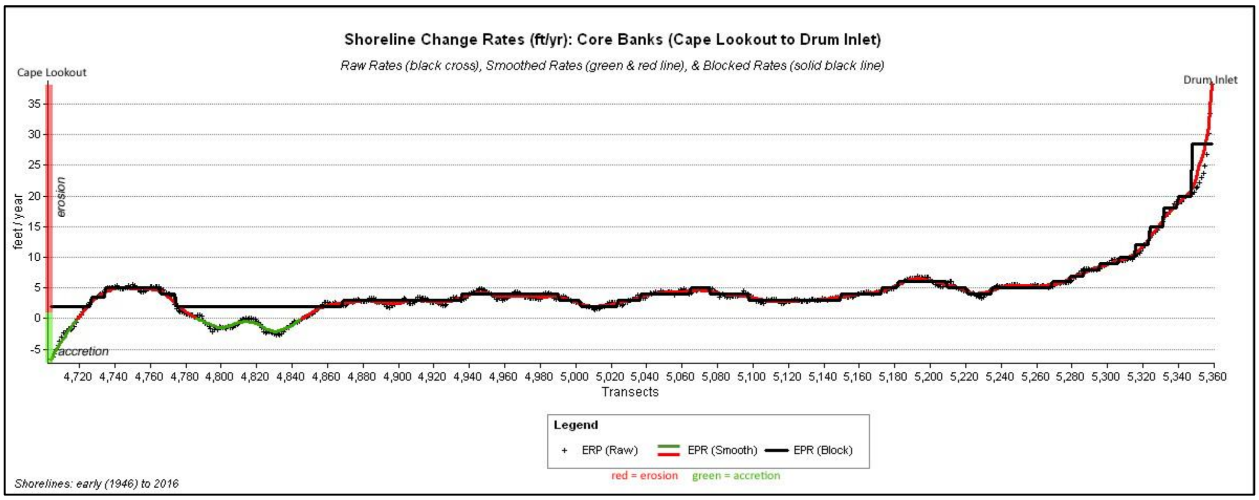

Figure 65. Cape Lookout to Drum Inlet shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

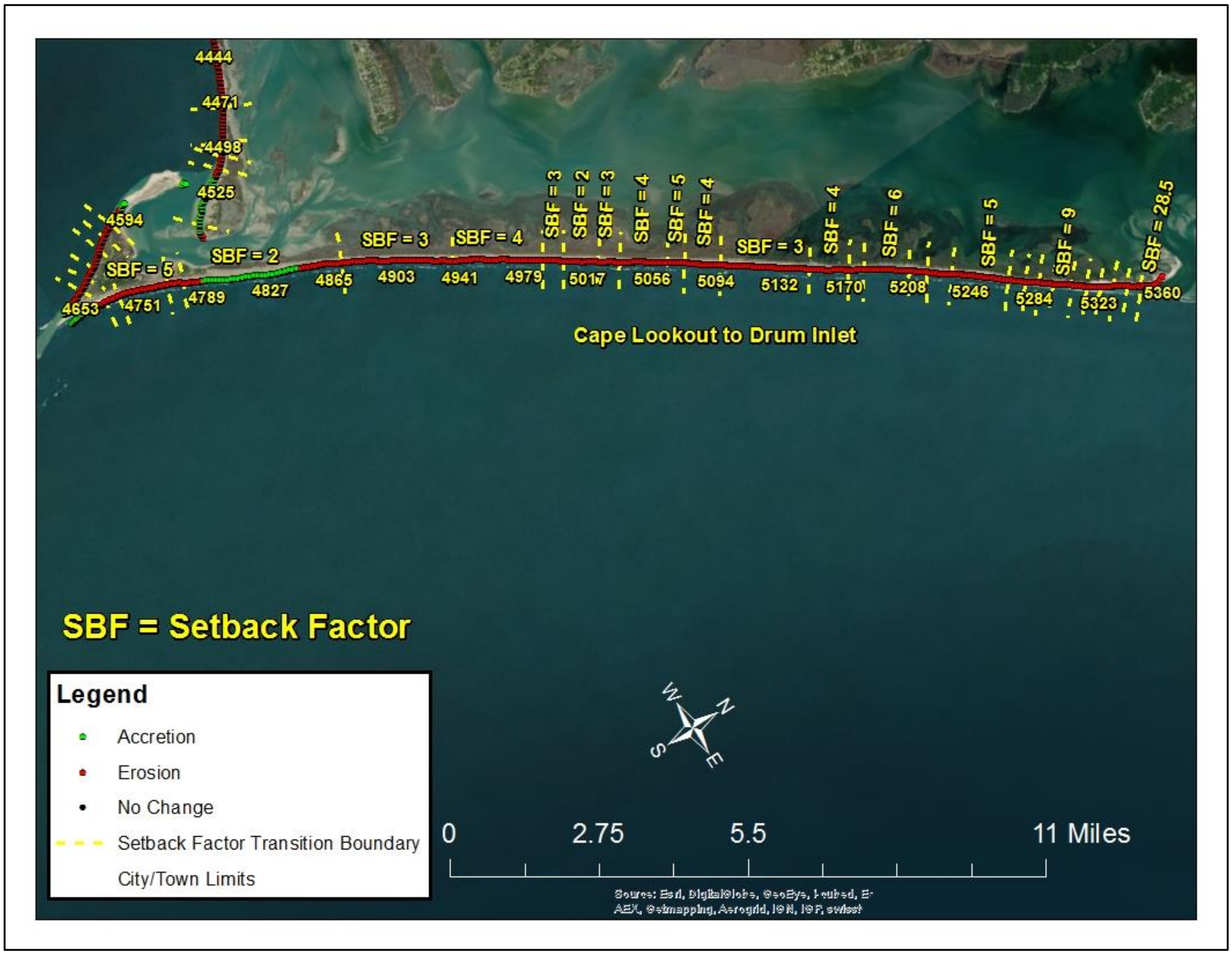

Figure 66. Cape Lookout to Drum Inlet. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Core Banks from Drum Inlet to Ocracoke Inlet is the remaining undeveloped east-facing portion of the Core Banks with approximately 21.5 miles of oceanfront shoreline. Approximately 18.8 miles (91.8 percent) of its shoreline resulted in measured erosion, while 1.4 miles (7.1 percent) resulted in measured accretion. The average shoreline change rate is 4.8 feet per year, and average blocked rate (setback factor) is 5.0 feet per year, ranging from 5 to 12 (Figure 67 and 68).

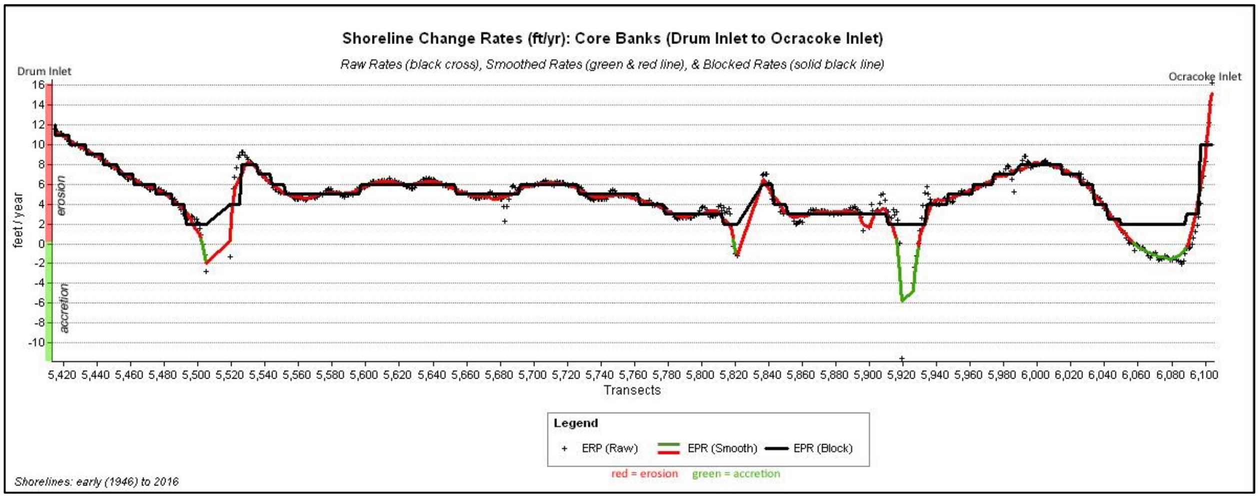

Figure 67. Core Banks (Drum Inlet to Ocracoke Inlet) shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

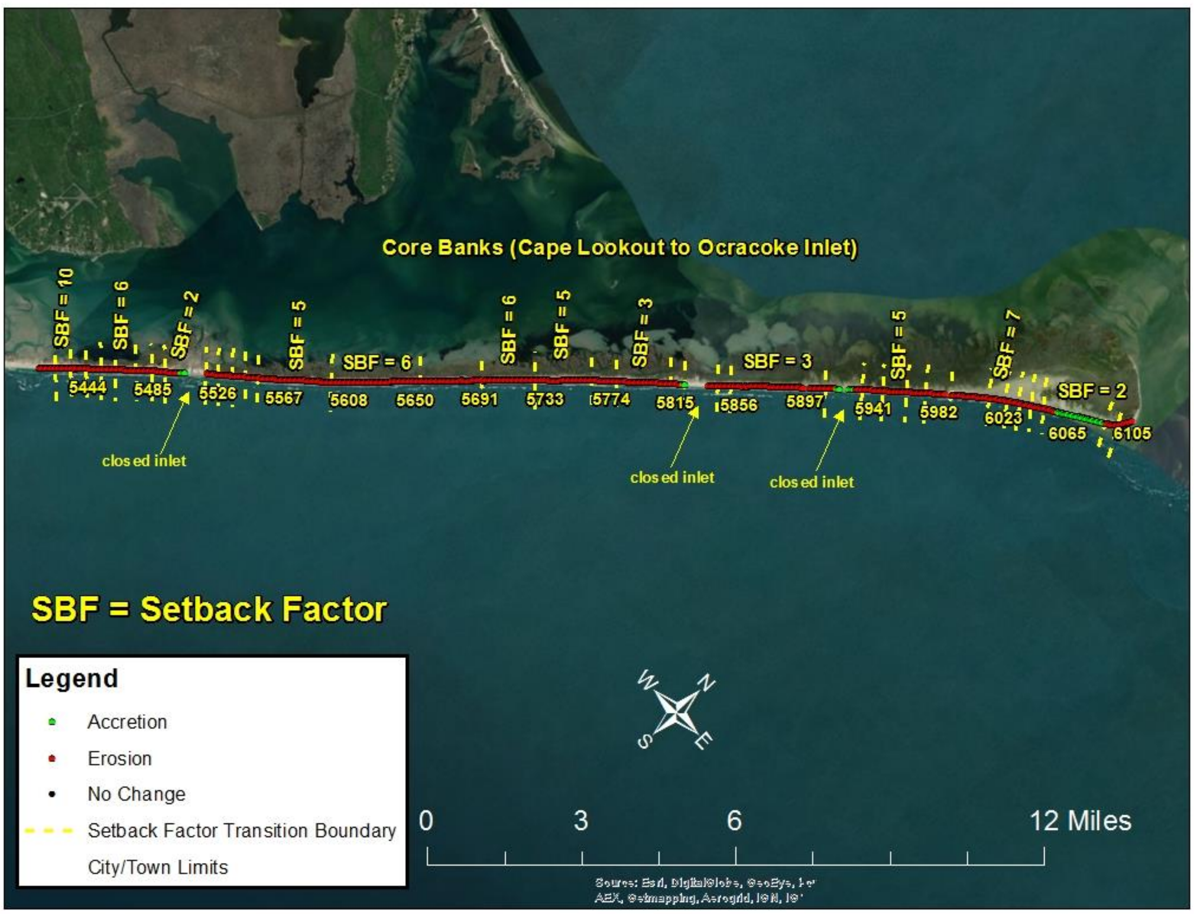

Figure 68. Core Banks (Drum Inlet to Ocracoke Inlet). Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Ocracoke Island

Ocracoke Island marks the transitional point from east to south facing beaches moving south to north approaching Cape Hatteras. Ocracoke's oceanfront is undeveloped, and its shoreline is approximately 16.3 miles in length. Approximately 11.5 miles (70.9 percent) of its shoreline resulted in measured erosion, while 4.2 miles (26.1 percent) resulted in measured accretion. The average shoreline change rate is 3.2 feet per year, and average blocked rate (setback factor) is 4.0 feet per year, ranging between (Figure 69 and 70).

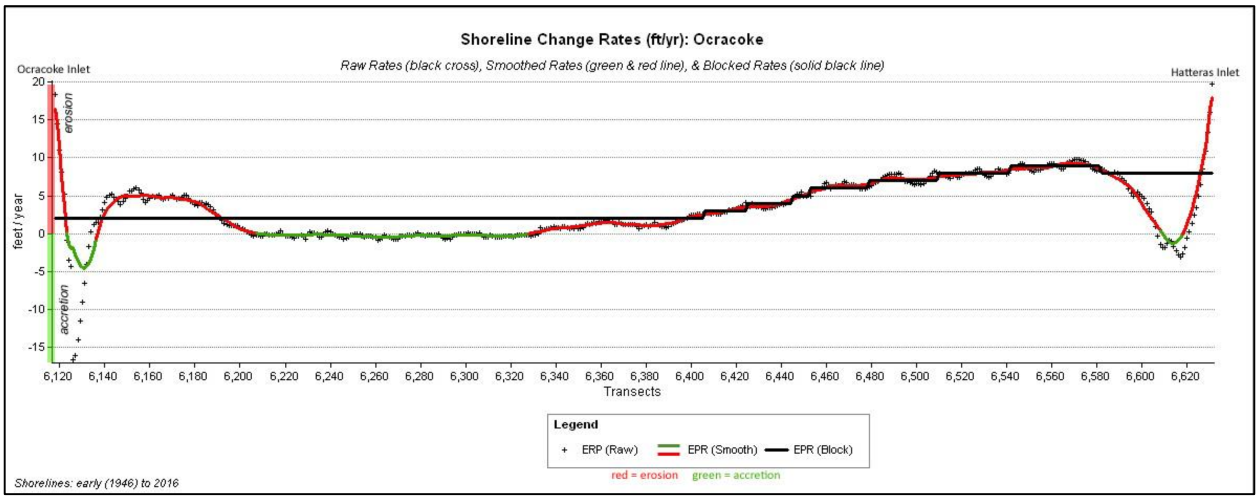

Figure 69. Ocracoke Island shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

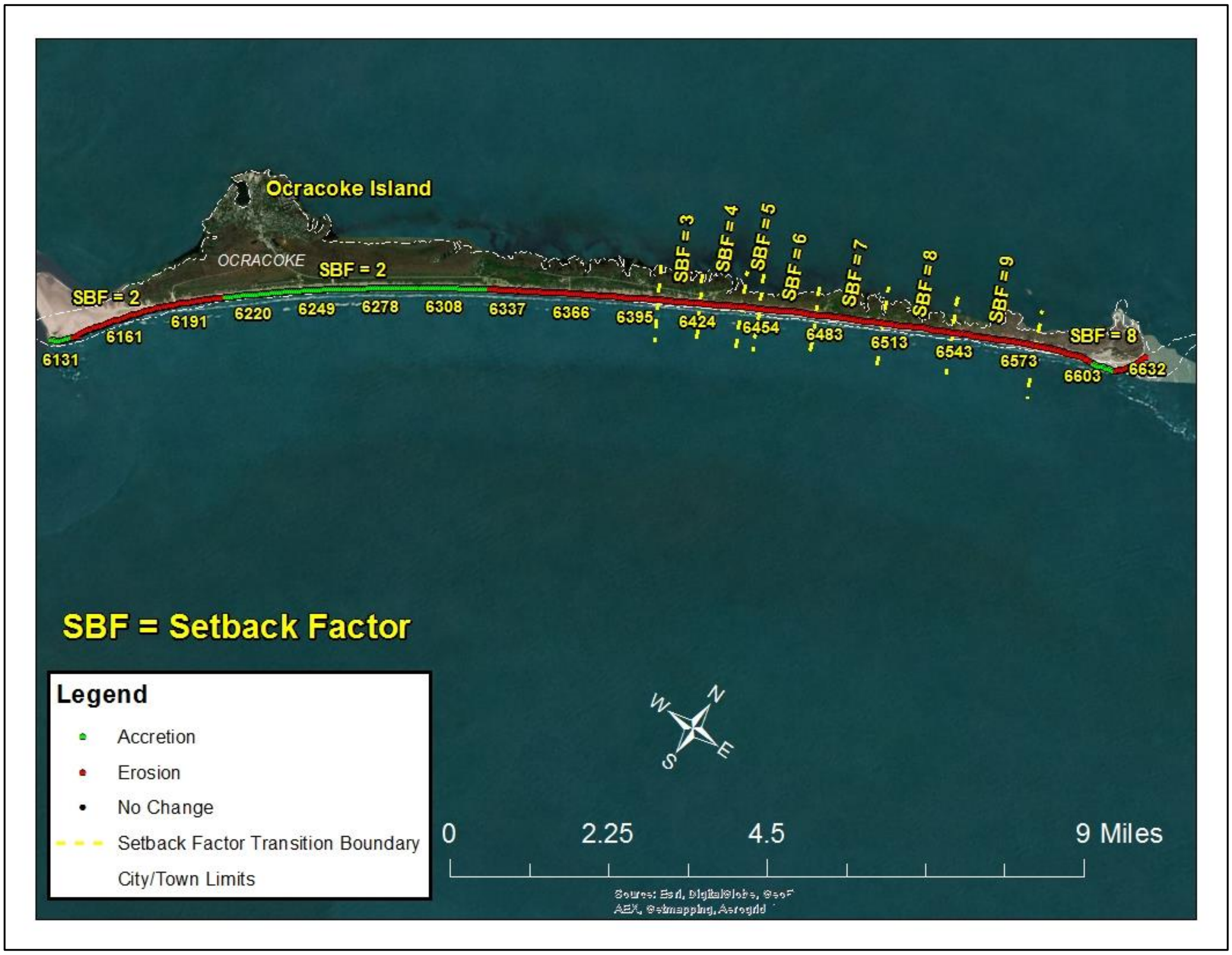

Figure 70. Ocracoke Island. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Cape Hatteras

Hatteras from Ocracoke Inlet to Cape Hatteras (includes Hatteras Village) has a south-facing shoreline and is approximately 12.9 miles in length. Approximately 6.8 miles (53.6 percent) of its shoreline resulted in measured erosion, while 5.4 miles (42.5 percent) resulted in measured accretion. The average shoreline change rate is 8.2 feet per year (erosion), and average blocked rate (setback factor) is 4 feet per year, ranging between 2 and 12 feet per year. (Figure 71 and 72).

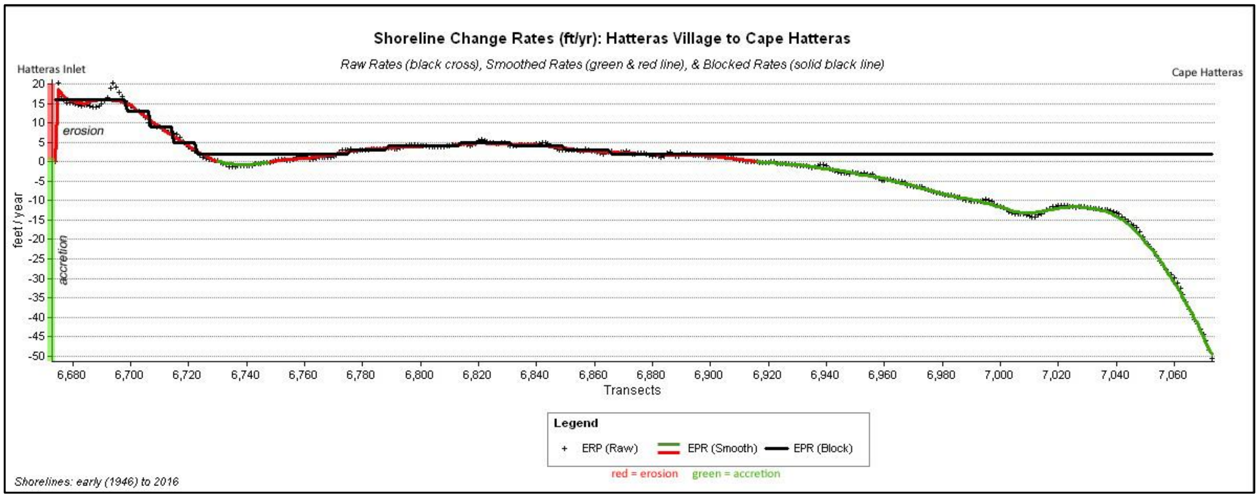

Figure 71. Cape Hatteras (at Hatteras Village) shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

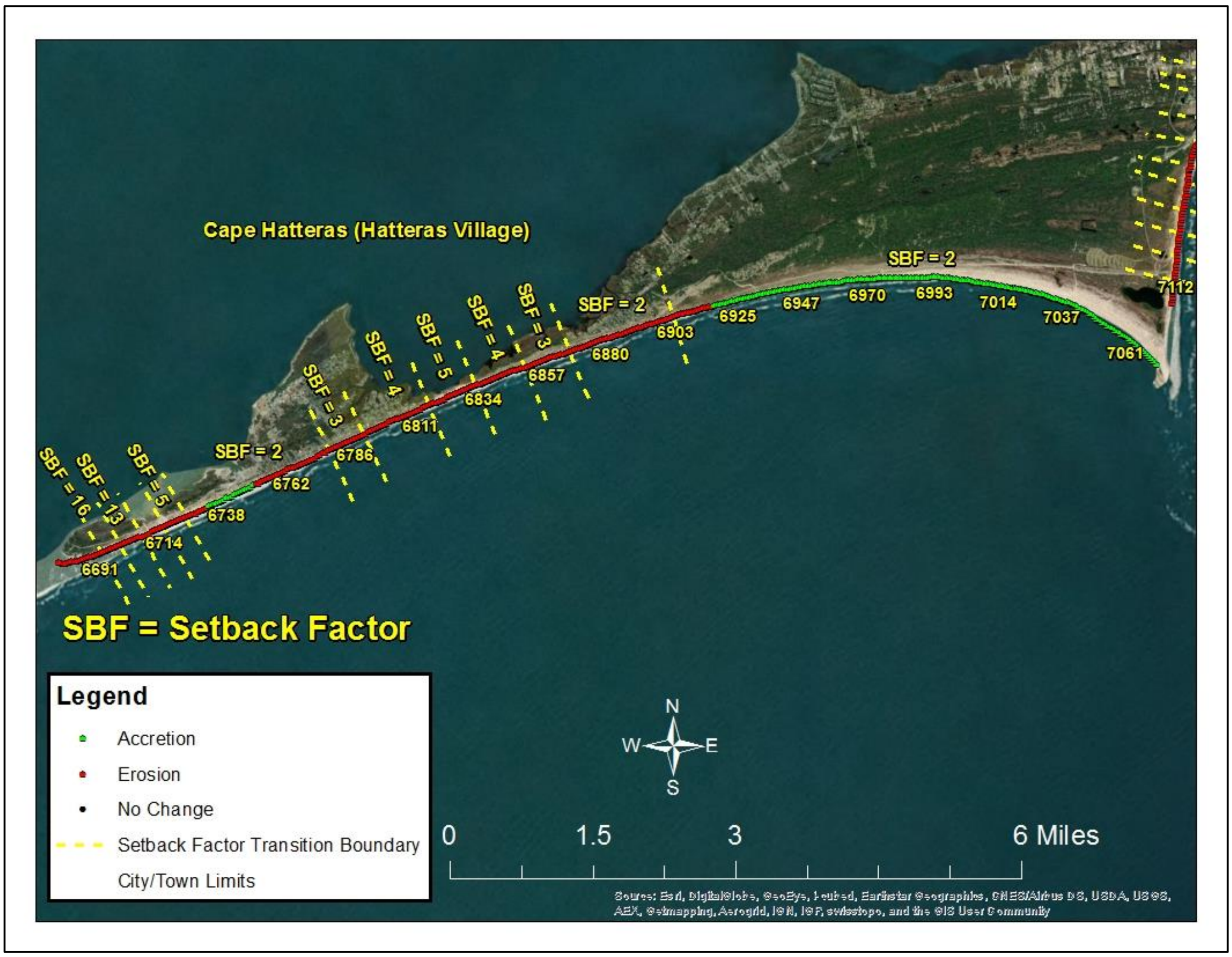

Figure 72. Cape Hatteras (at Hatteras Village). Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Cape Hatteras and Buxton

At the Outer Banks from Cape Hatteras to Buxton, the oceanfront shoreline is on an east-facing beach with a combined length of approximately 5.3 miles. This entire segment of shoreline segment resulted in measured erosion with an average shoreline change rate of 8.3 feet per year, and 8.0 feet per year average blocked rate (setback factor). Setback factors range between 3.0 and 12.0 (Figure 73 and 74).

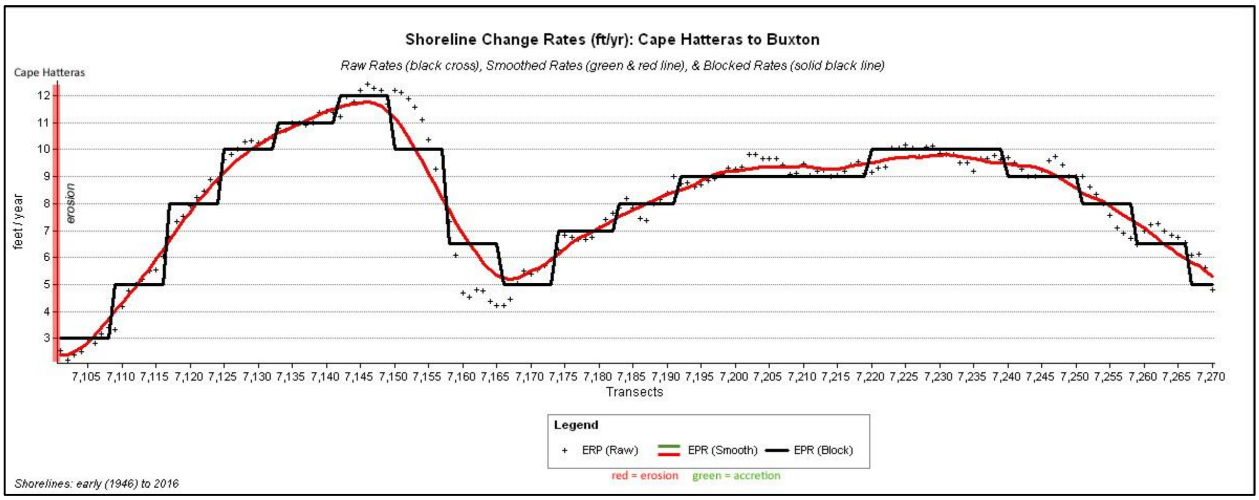

Figure 73. Cape Hatteras and Buxton shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

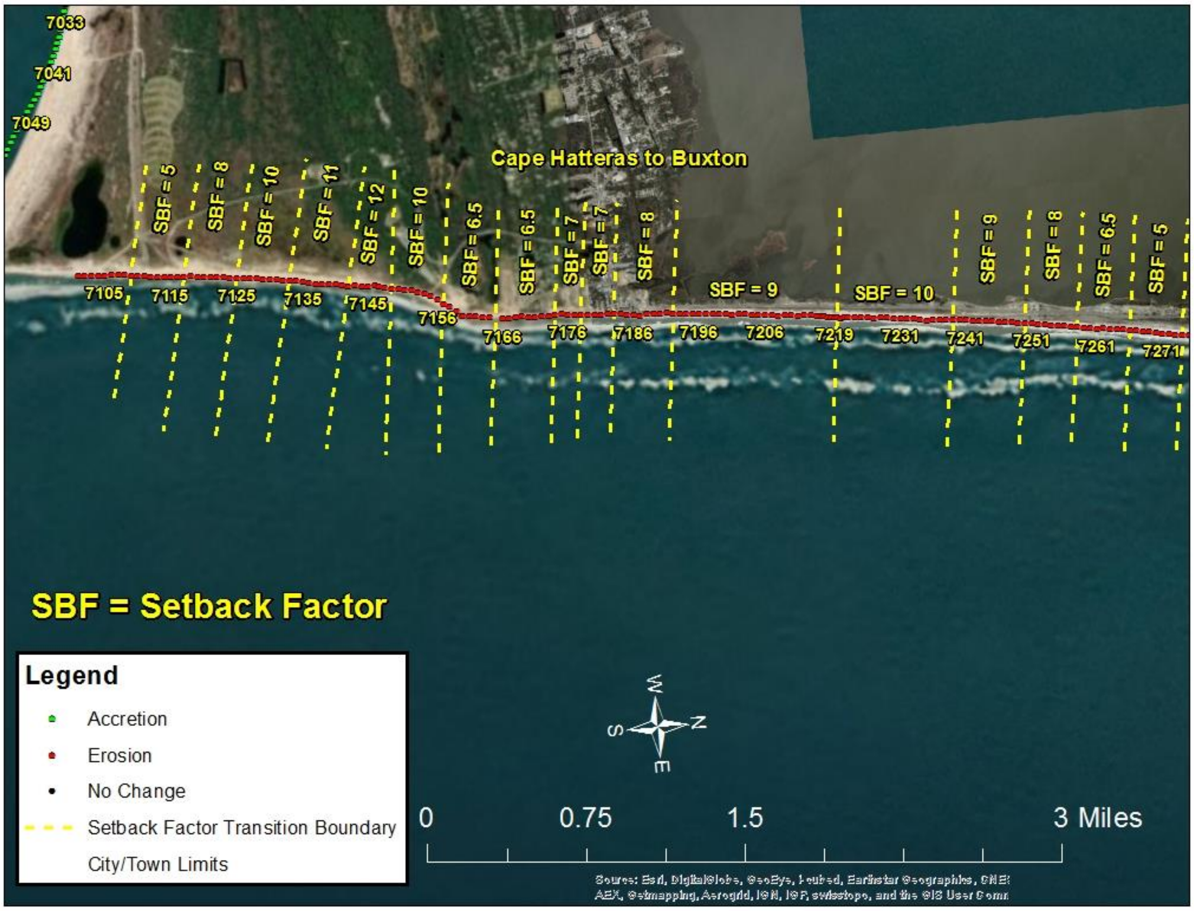

Figure 74. Cape Hatteras to Buxton. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

National Seashore (Outer Banks at Avon)

The shoreline segment adjacent to Avon is approximately 4.9 miles in length, and approximately 4.0 miles (82.4 percent) of Avon's shoreline resulted in measured erosion, while the remaining 0.8 miles (17.6 percent) resulted in measured accretion. The average shoreline change rate is 2.4 feet per year (erosion), and the average blocked rate is 3.0 feet per year, with a range between 2 and 6 feet per year (Figure 75 and 76).

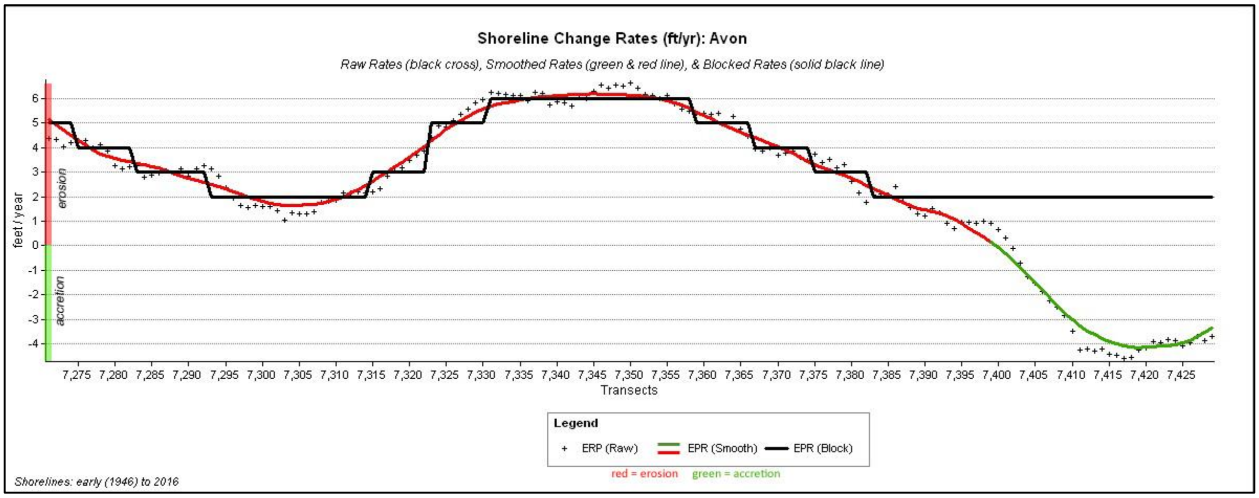

Figure 75. Avon shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

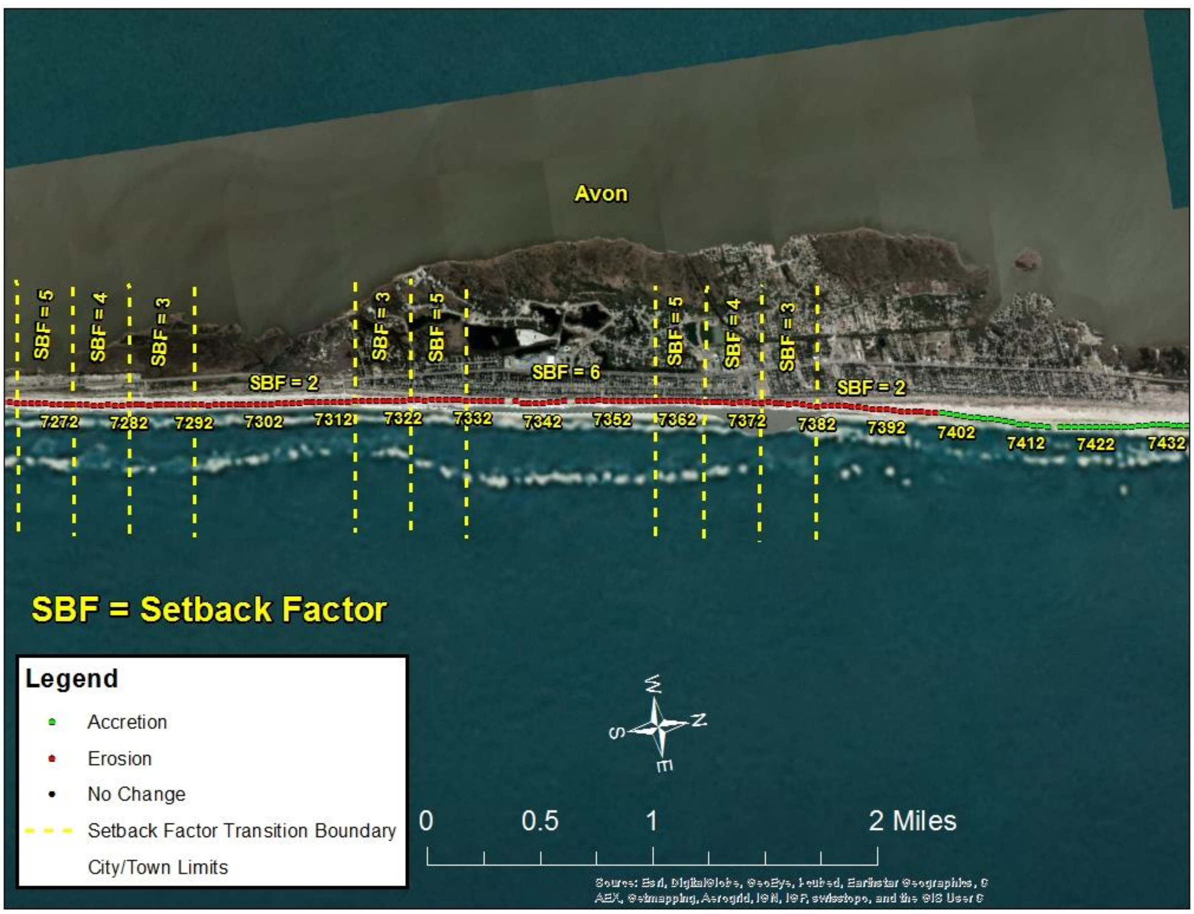

Figure 76. Avon. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

National Seashore (Outer Banks between Avon and Salvo)

The area along the National Seashore between Avon and Salvo has an east-facing beach with approximately 11.2 miles of ocean shoreline. Approximately 8.5 miles (75.8 percent) of this shoreline resulted in measured erosion, while the remaining 2.7 miles (24.2 percent) of shoreline resulted in measured accretion. The average shoreline change rate is 1.9 feet per year (erosion), and the average blocked rate (setback factor) is 3.0 feet per year, with a range between 2.0 and 6.0 feet per year (Figure 77 and 78).

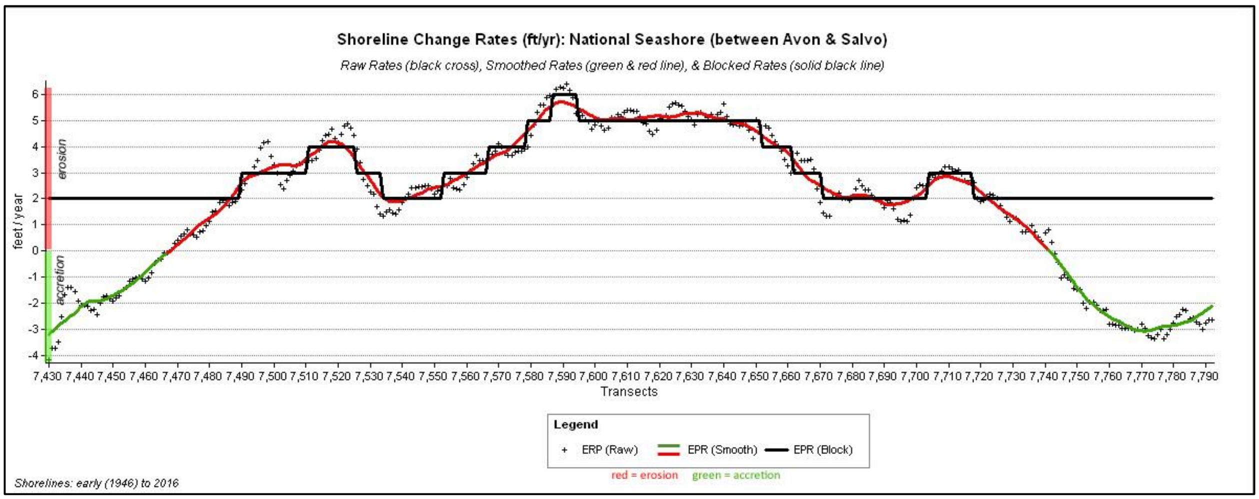

Figure 77. National Seashore between Avon and Salvo shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

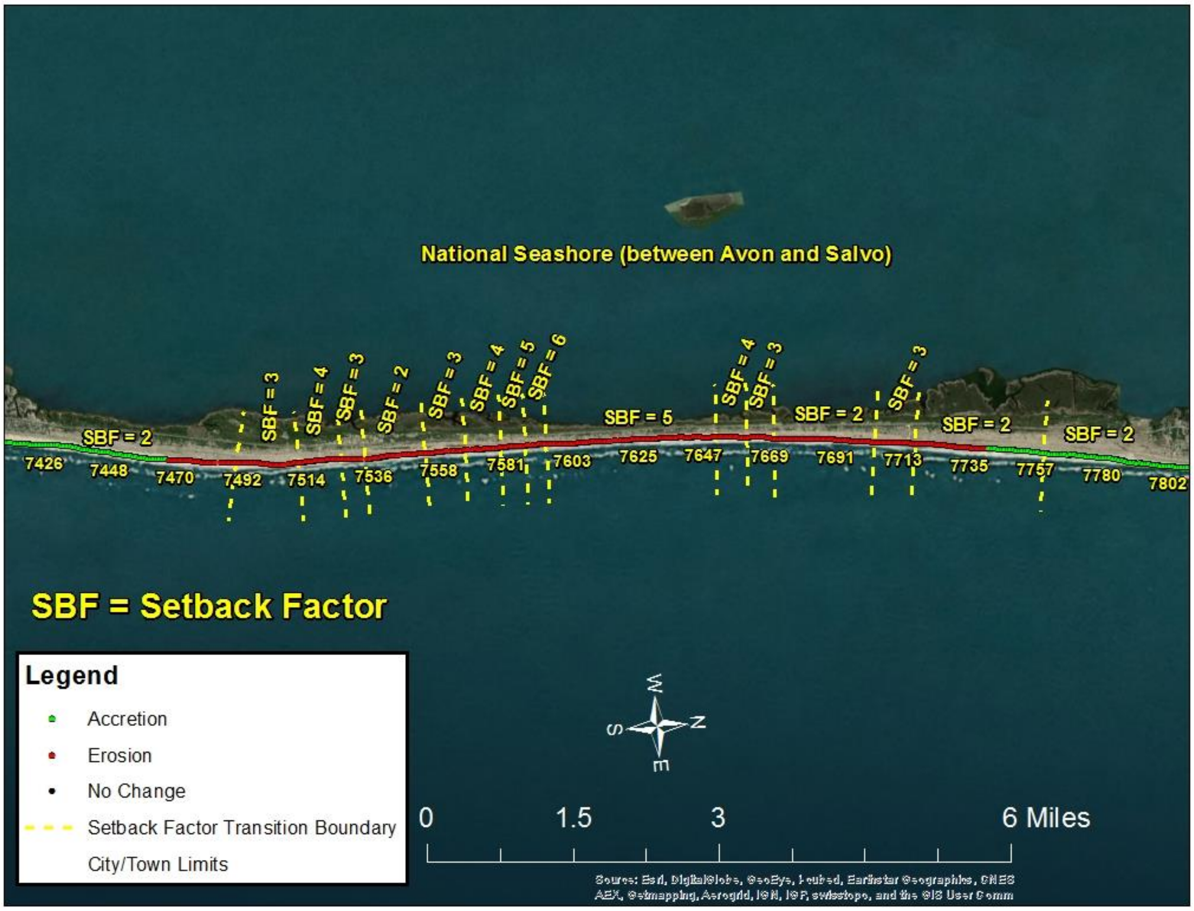

Figure 78. National Seashore between Avon and Salvo. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Salvo to Rodanthe

The area along the National Seashore at Salvo and Rodanthe has an east-facing beach with approximately 6.5 miles of ocean shoreline. Approximately 4.9 miles (76.2 percent) of this shoreline resulted in measured erosion, while the remaining 1.5 miles (22.9 percent) of shoreline resulted in measured accretion. The average shoreline change rate is 5.3 feet per year (erosion), and the average blocked rate (setback factor) is 6.0 feet per year, with a range between 2.0 and 13.0 feet per year (Figure 79 and 80).

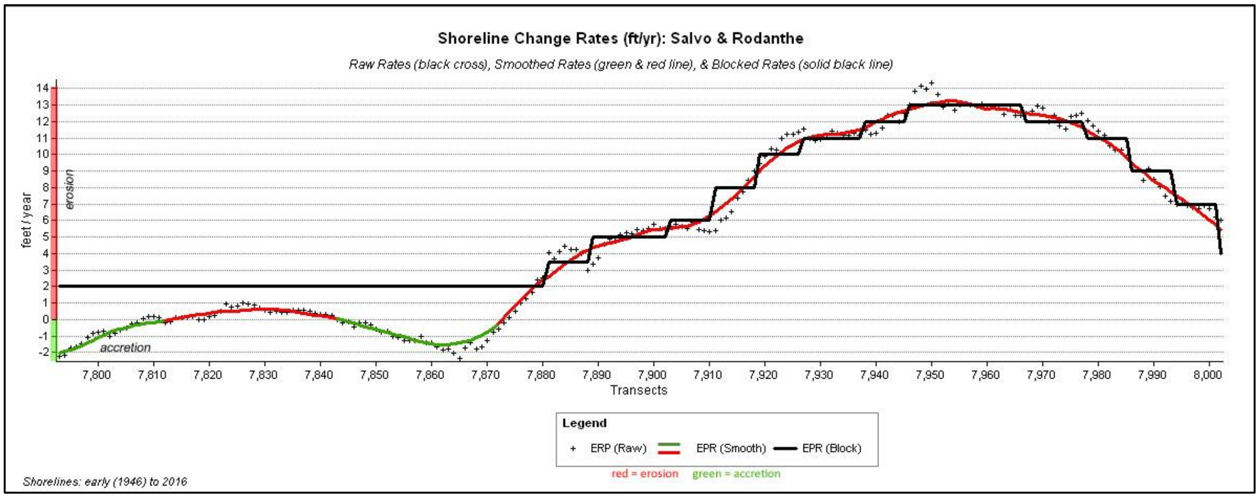

Figure 79. Salvo to Rodanthe shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

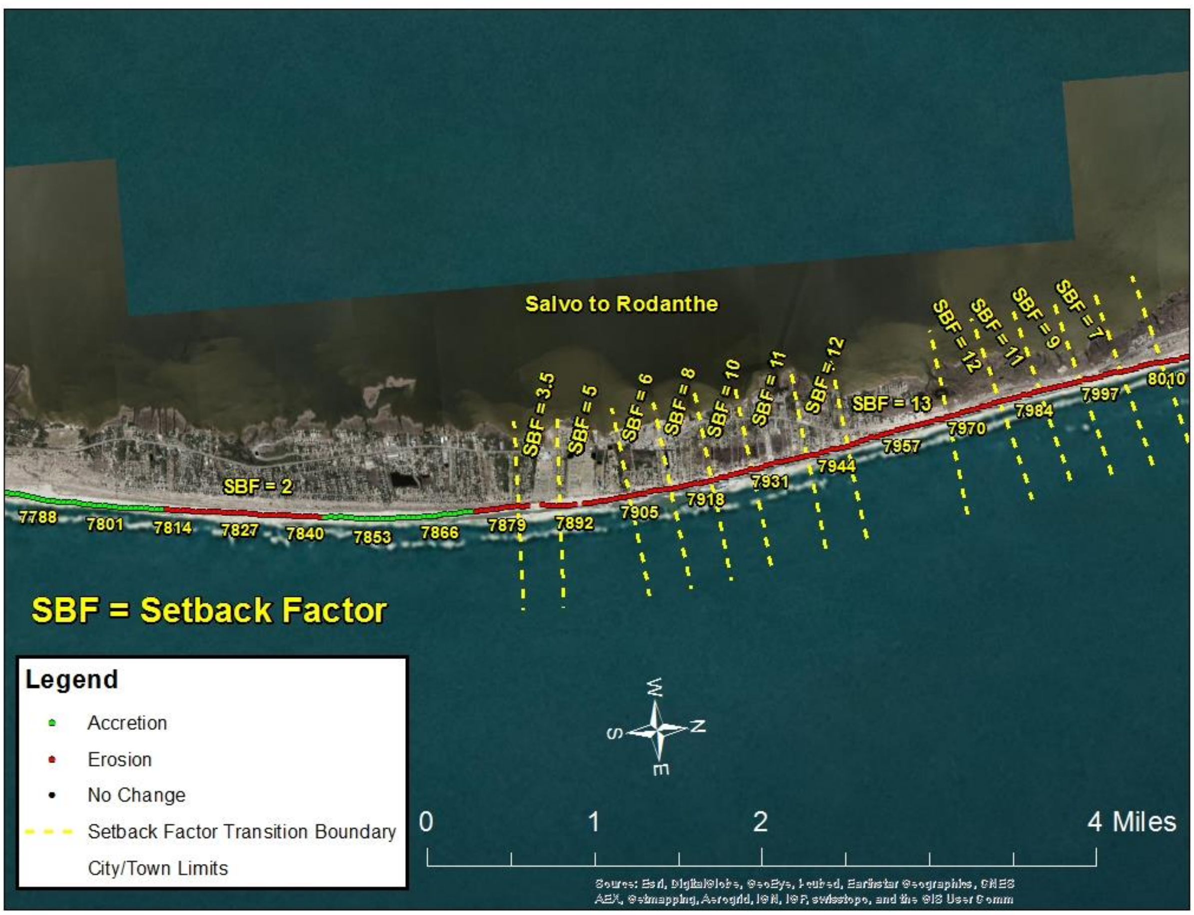

Figure 80. Salvo to Rodanthe. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

National Seashore between Rodanthe and Oregon Inlet (Pea Island)

At the Outer Banks from Rodanthe to Oregon Inlet, or Pea Island National Seashore, is an east-facing beach with approximately 10.8 miles of oceanfront shoreline. Approximately 9.1 miles (85 percent) of this shoreline resulted in measured erosion, while the remaining 1.6 miles (14.7 percent) resulted in measured accretion. The average shoreline change rate is 5.8 feet per year, and the average blocked rate (setback factor) is 7.0 feet per year with a range between 2 and 22 feet per year (Figure 81 and 82).

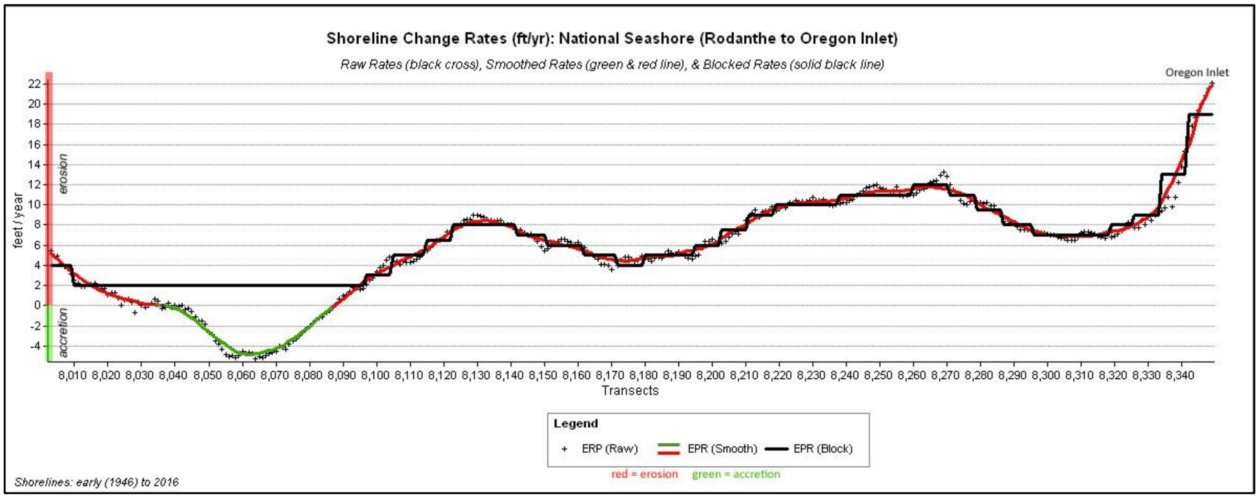

Figure 81. National Seashore between Rodanthe and Oregon Inlet (Pea Island) shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

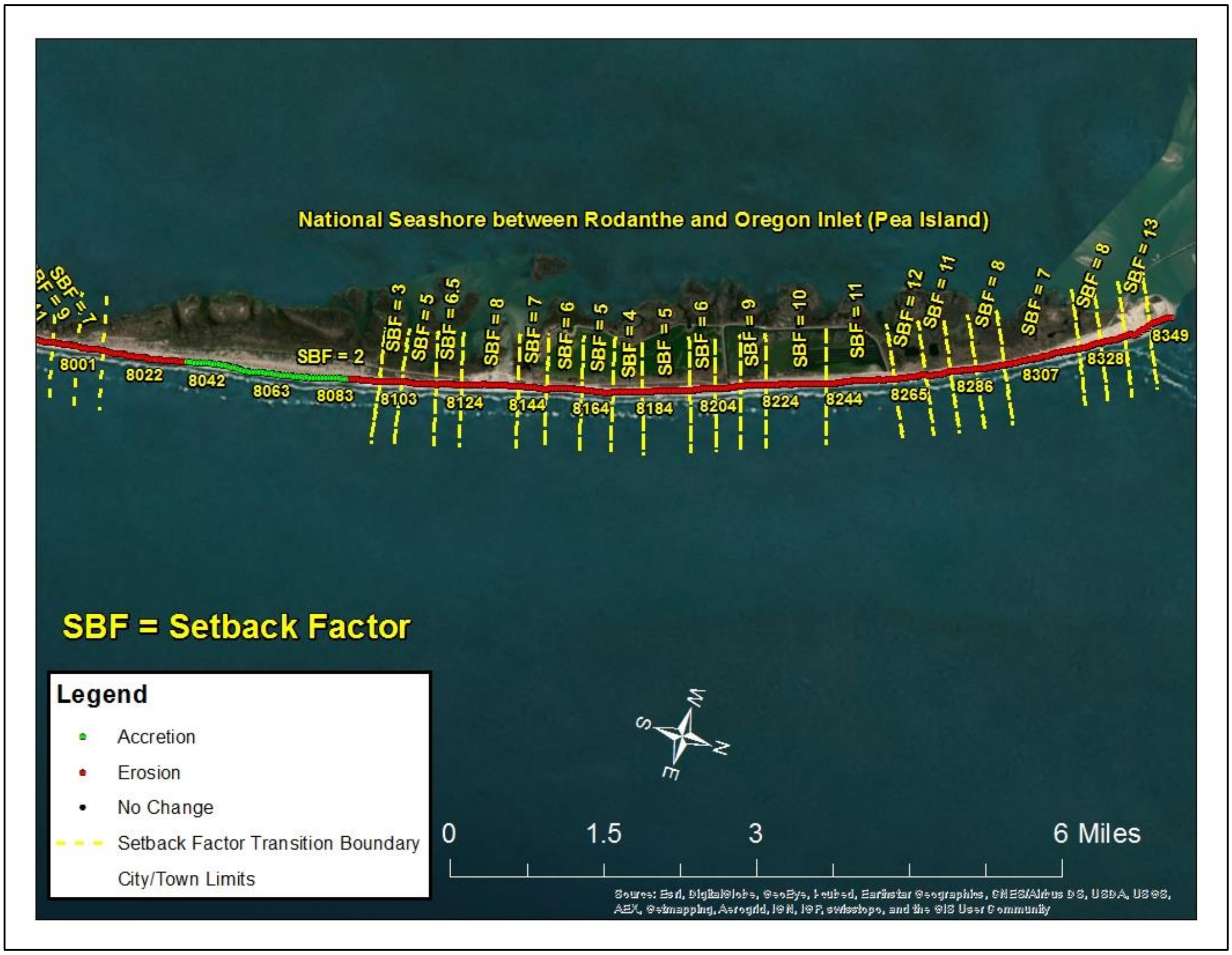

Figure 82. National Seashore between Rodanthe and Oregon Inlet (Pea Island). Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

National Seashore between Oregon Inlet and Nags Head (Boddie Island)

The National Seashore from Oregon Inlet to Nags Head (includes Boddie Island) has an east-facing shoreline and is approximately 4.6 miles long. Approximately 4.2 miles (90.7 percent) of this shoreline resulted in measured erosion, while the remaining 0.4 of a mile (9.3 percent) of shoreline resulted in measured accretion. The average shoreline change rate is 6.7 feet per year (erosion), and the average blocked rate is 8.0 feet per year with a range between 2 and 11 feet per year (Figure 83 and 84).

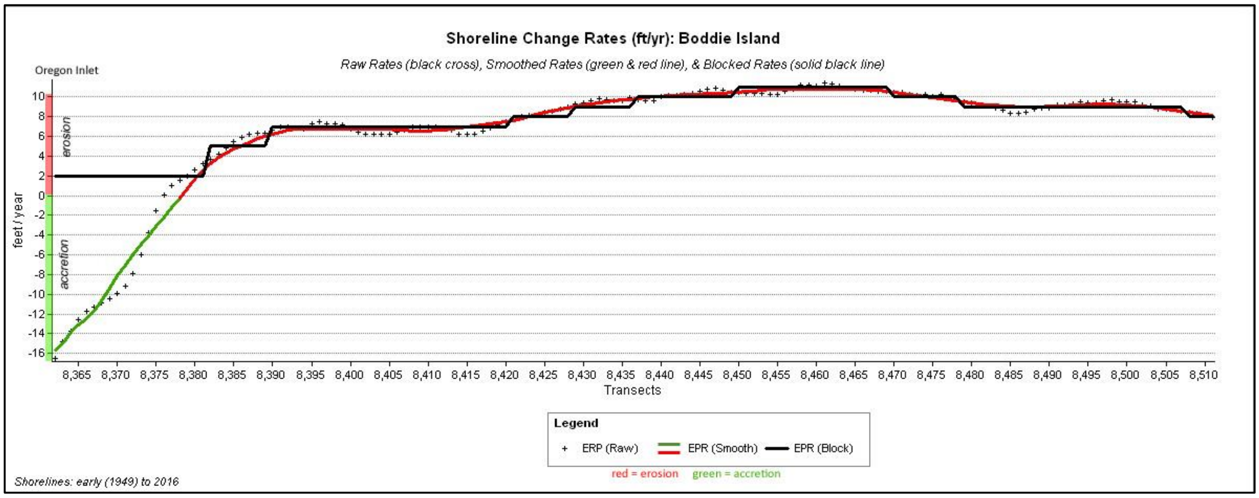

Figure 83. National Seashore between Oregon Inlet and Nags Head (Pea Island) shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

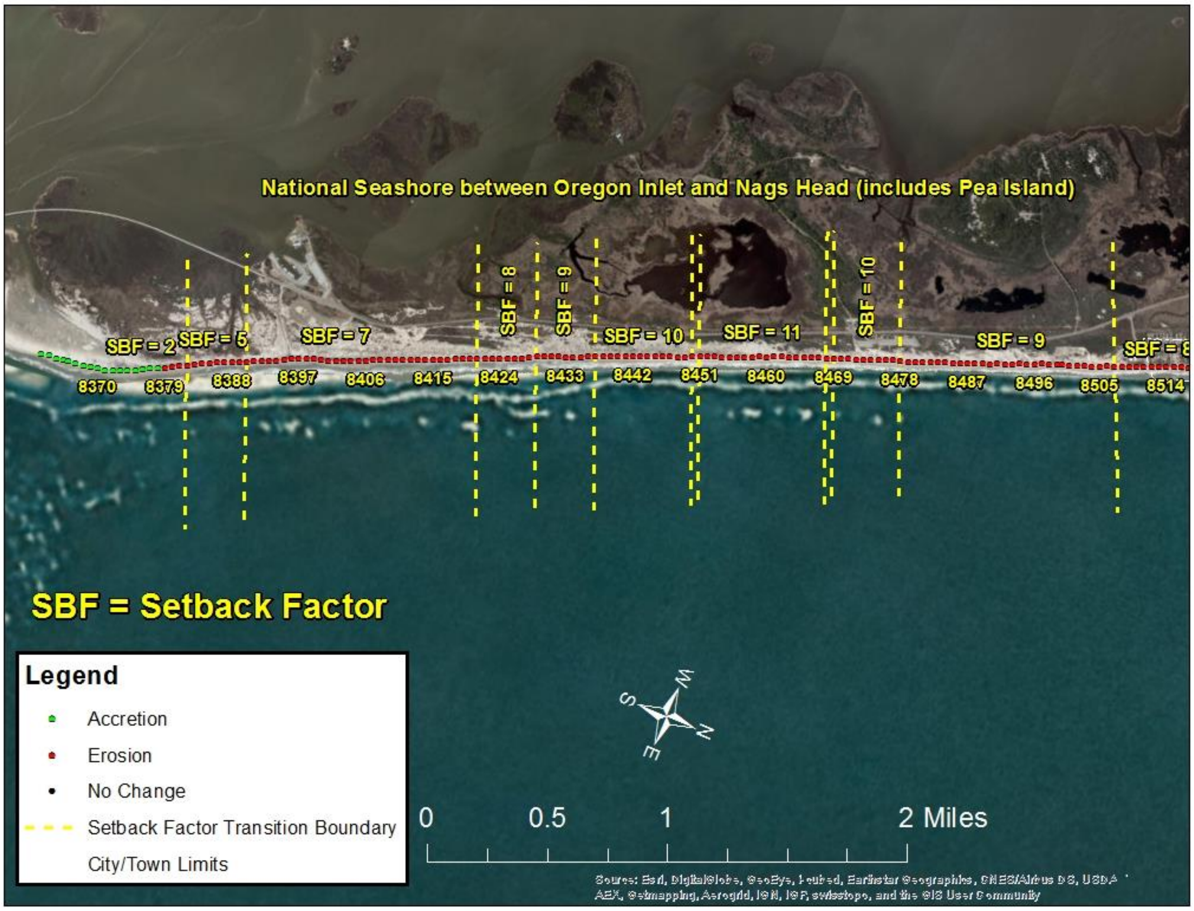

Figure 84. National Seashore between Oregon Inlet and Nags Head (Pea Island). Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Nags Head

Nags Head has an east-facing beach and its shoreline is approximately 11.2 miles long. Nearly all 11.2 miles (99.7 percent) of this shoreline resulted in measured erosion. Although the average shoreline change rate is less than 1 foot per year (erosion), the average blocked rate (setback factor) is 3 feet per year with a range between 2 and 8 feet per year (Figure 85 and 86).

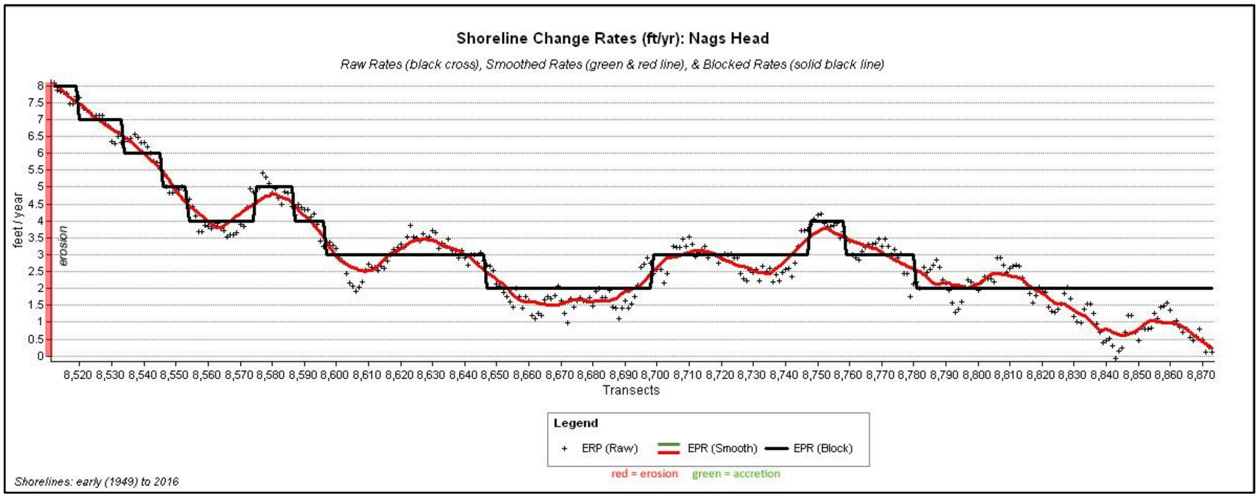

Figure 85. Nags Head shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

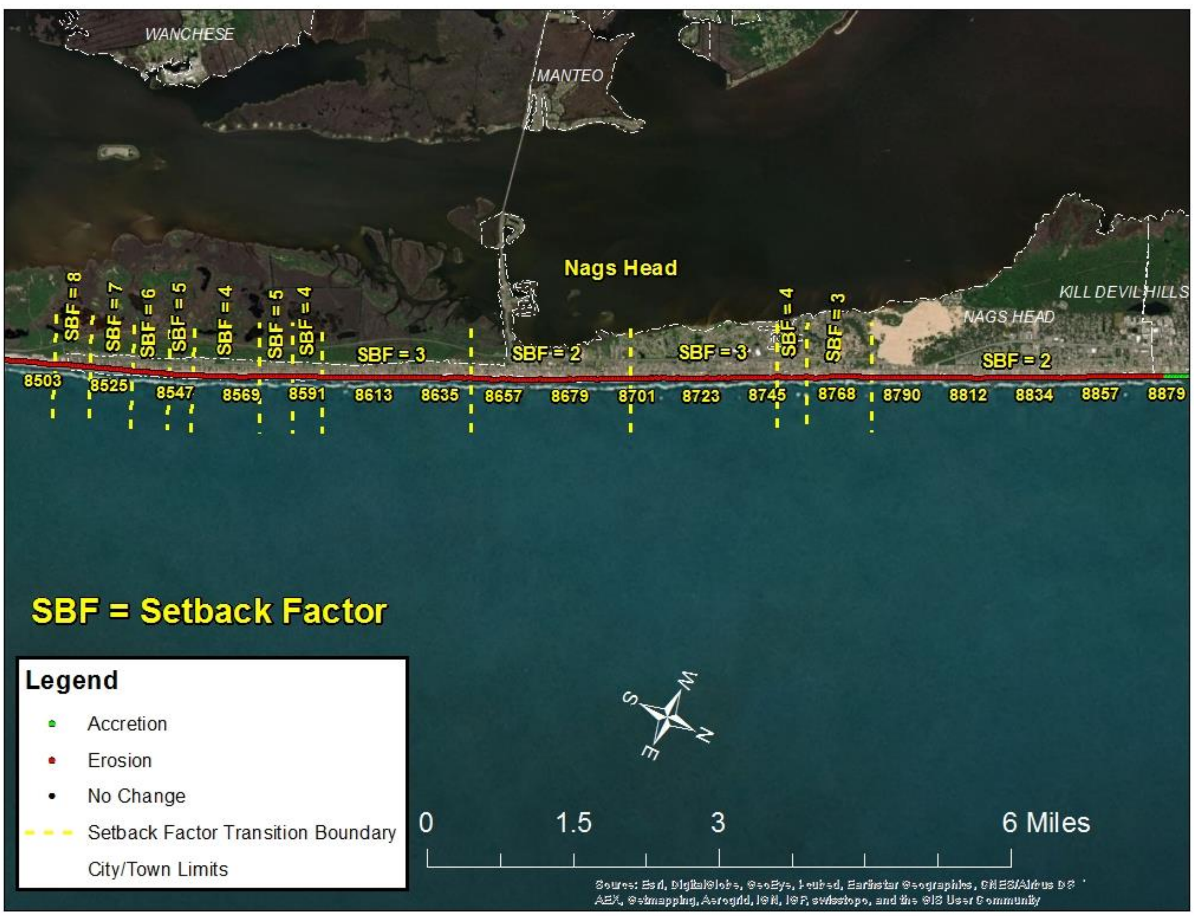

Figure 86. Nags Head. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Kill Devil Hills

Kill Devil Hills has an east-facing beach and its shoreline is approximately 4.7 miles long. Approximately 2.7 miles (56.9 percent) of its ocean shoreline resulted in measured erosion, and 1.9 miles (40.5 percent) resulted in measured accretion. The average shoreline change rate is less than 1 foot per year (erosion), and the average blocked rate is 2.0 feet per year with a range between 2 and 4 feet per year (Figure 87 and 88).

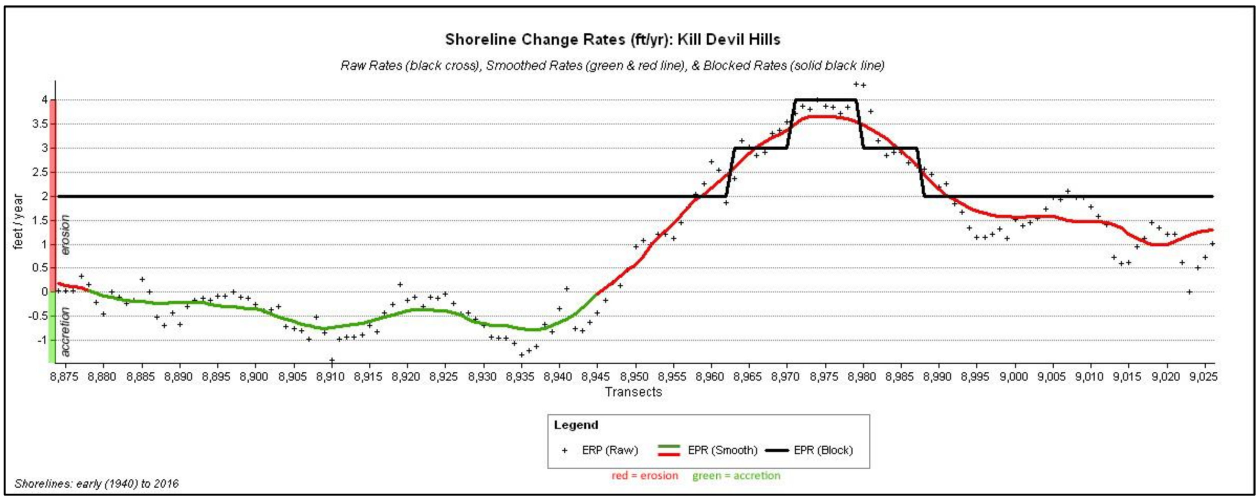

Figure 87. Kill Devil Hills shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

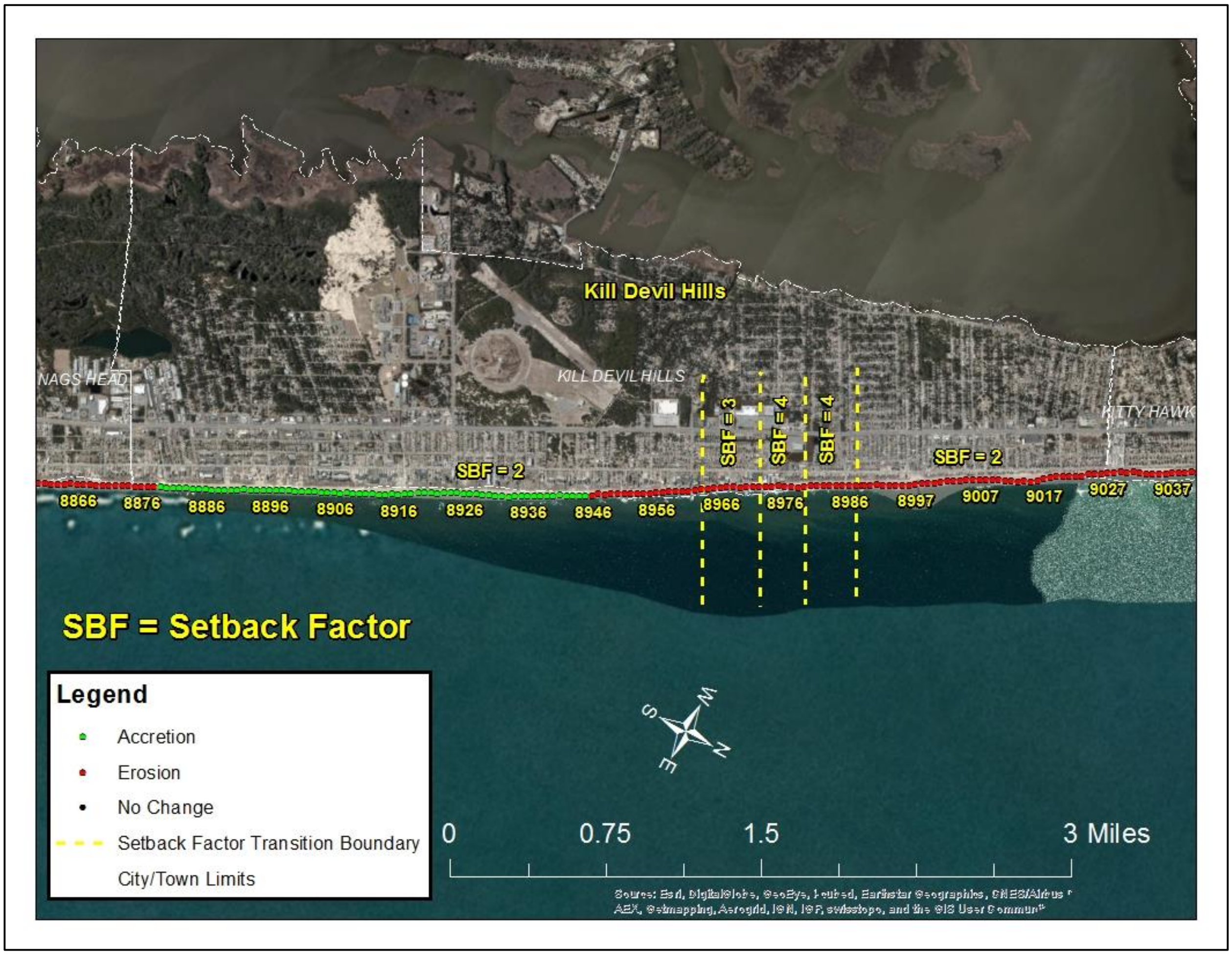

Figure 88. Kill Devil Hills. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Kitty Hawk

Kitty Hawk has an east-facing beach and its shoreline is approximately 3.5 miles long that resulted in measured erosion for the entire length. The average shoreline change rate 2.2 feet per year (erosion), and the average blocked rate (setback factor) is 2.0 feet per year with a range between 2 and 3 feet per year (Figure 89 and 90).

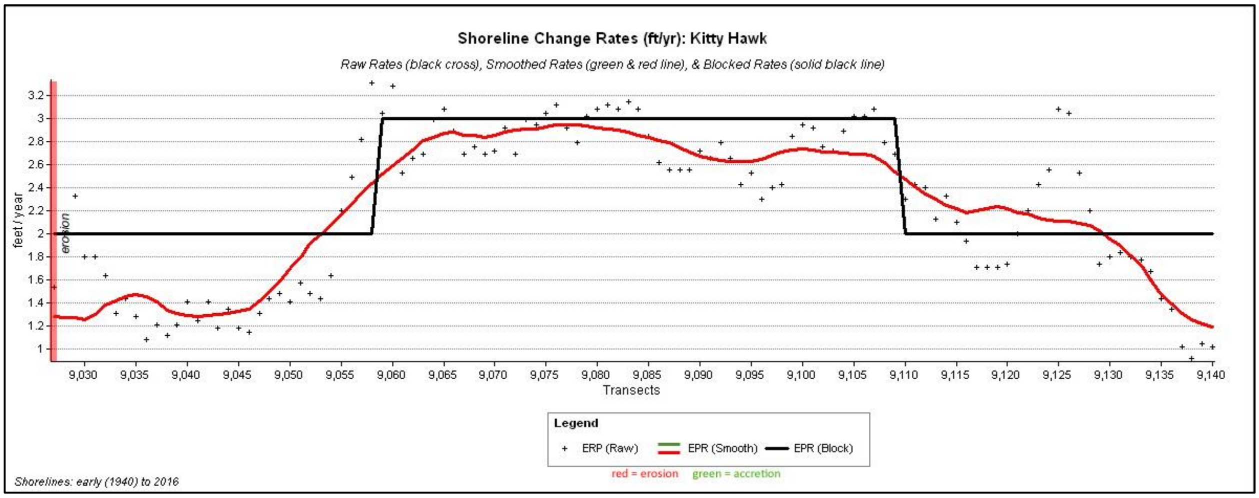

Figure 89. Kitty Hawk shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

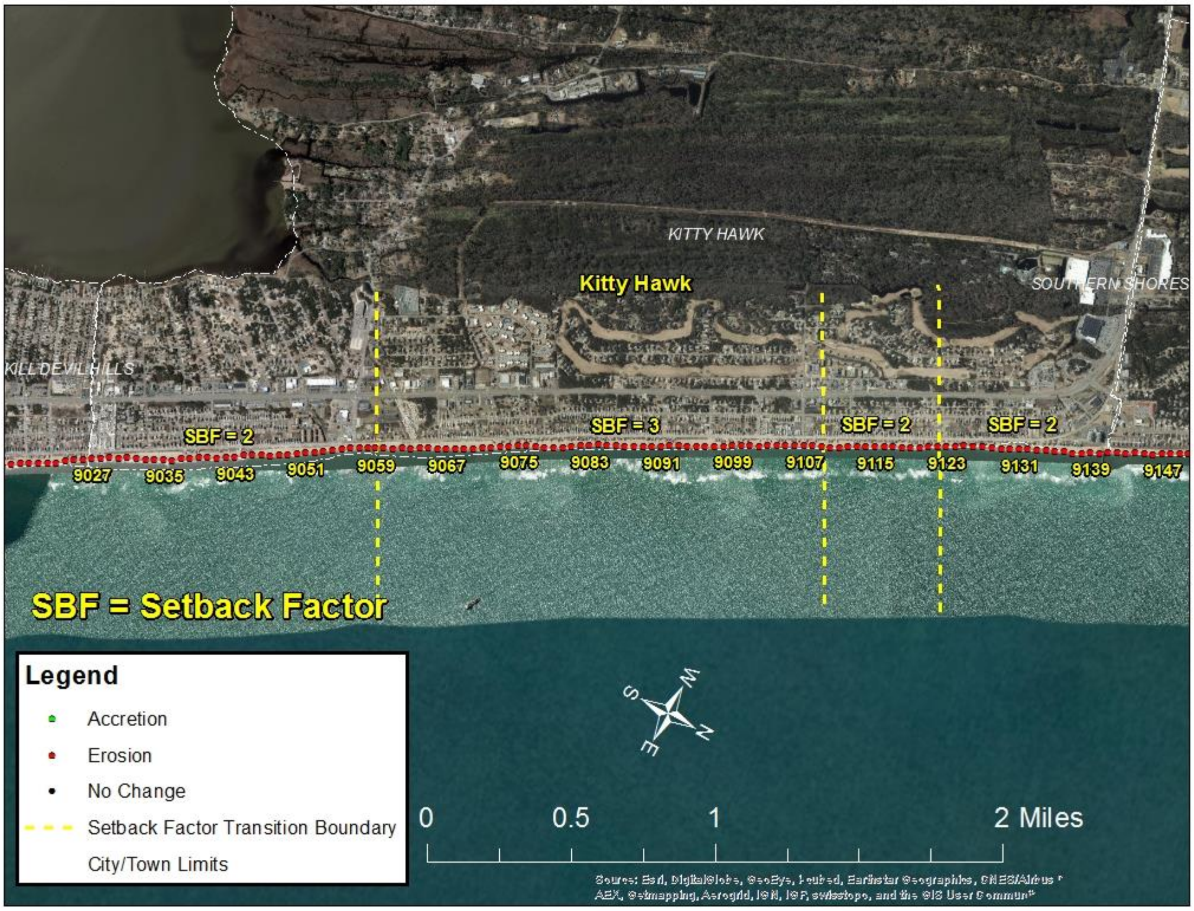

Figure 90. Kitty Hawk. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Southern Shores

Southern Shores has an east-facing beach and its shoreline is 4.5 miles long. Approximately 4.0 miles (88 percent) of it shoreline resulted in measured erosion, while the remaining 0.5 mile (11 percent) resulted in measured accretion. The average shoreline change rate 0.5 feet per year (erosion), and the blocked rate (setback factor) is 2.0 feet per year for Southern Shore's entire ocean shoreline (Figure 91 and 92).

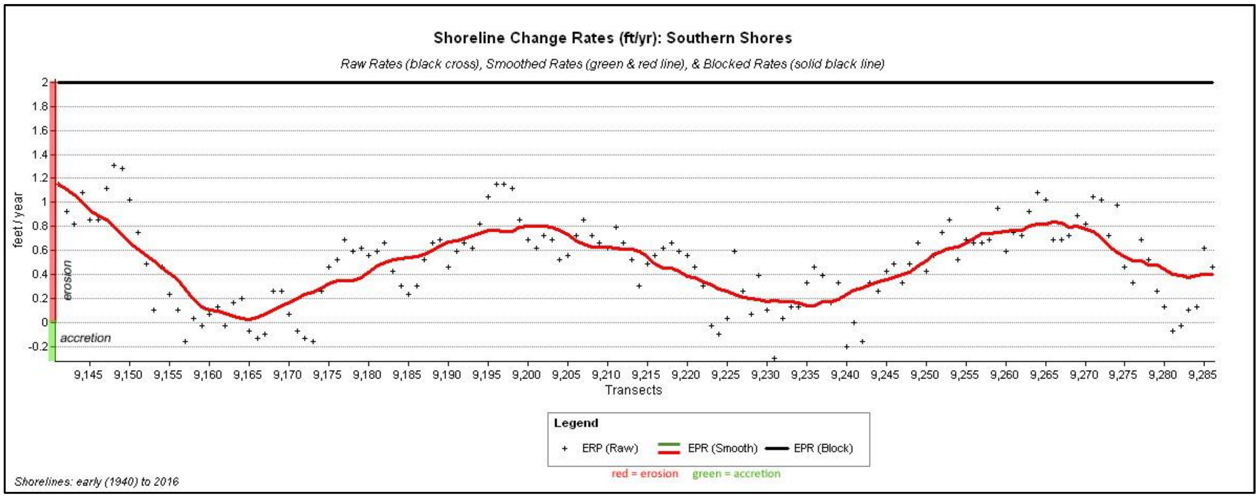

Figure 91. Southern Shores shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

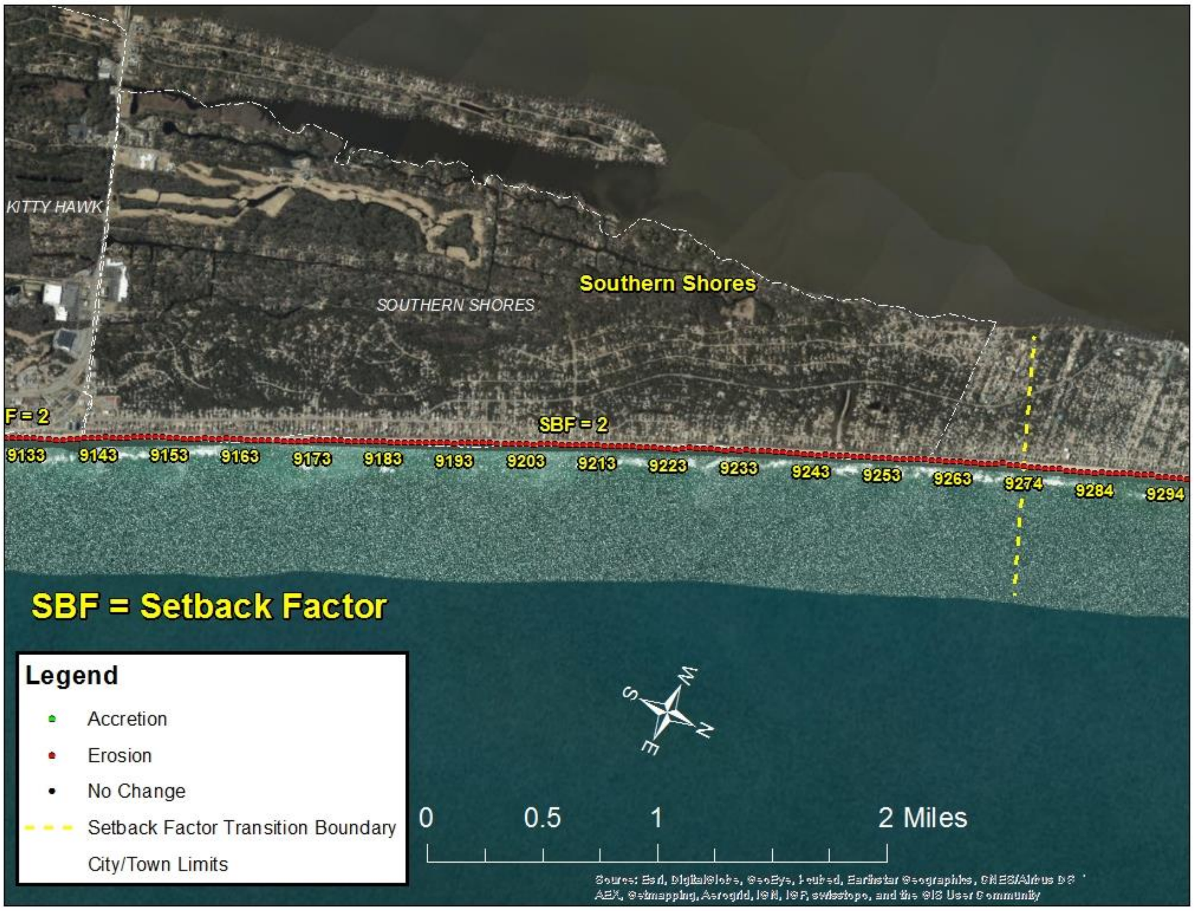

Figure 92. Southern Shores. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Duck

Duck has an east-facing beach and its shoreline is 1.8 miles long. Approximately 1.1 miles (64.4 percent) of it shoreline resulted in measured erosion, while the remaining 0.6 mile (33.9 percent) resulted in measured accretion. The average shoreline change rate is less than 0.5 feet per year (erosion), and the blocked rate (setback factor) is 2.0 feet per year for Duck's entire ocean shoreline (Figure 93 and 94).

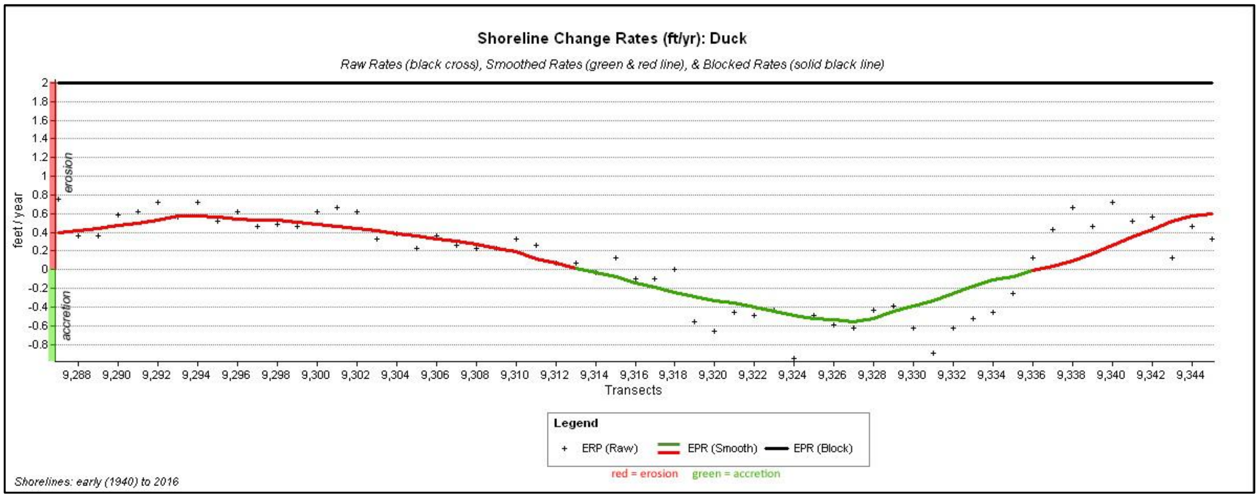

Figure 93. Duck shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

Figure 94. Duck. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Corolla

Corolla has an east-facing beach and its shoreline is 15.1 miles long. Approximately 13.6 miles (90.1 percent) of it shoreline resulted in measured erosion, while the remaining 1.5 mile (9.9 percent) resulted in measured accretion. The average shoreline change rate less than 1.3 feet per year (erosion), and the blocked rate (setback factor) is 2.0 feet per with a range between 2 and 4 feet per year (Figure 95 and 96).

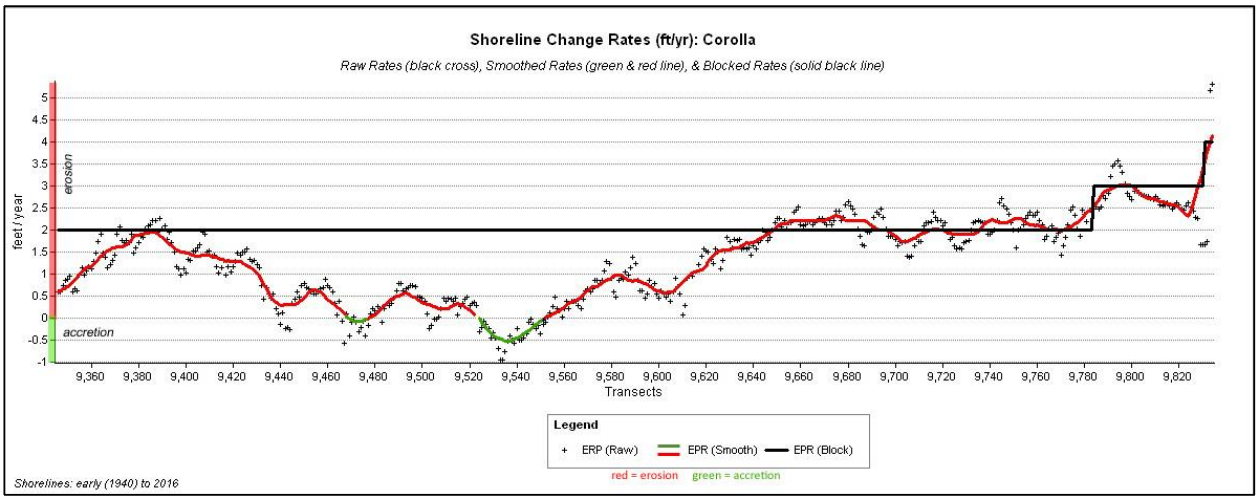

Figure 95. Corolla shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

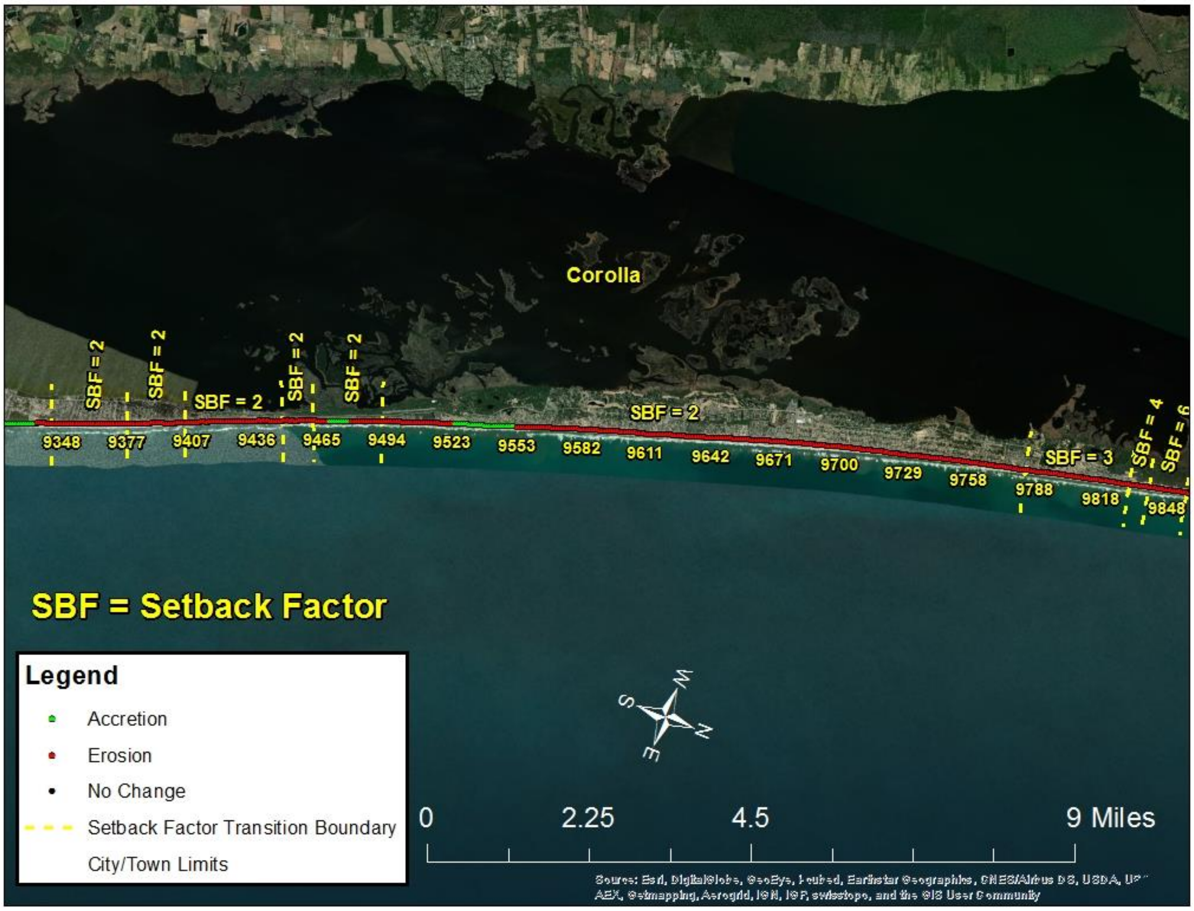

Figure 96. Corolla. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

Corolla to NC-VA State Line

The northern-most section of NC's ocean shoreline extends from Corolla to the NC-VA State line. This segment of shoreline is 10.9 miles in length. Approximately 8.1 miles (53.8 percent) of the shoreline resulted in measured erosion, while 2.7 miles (18.3 percent) of this shoreline resulted in measured accretion. The average shoreline change rate is 3.8 feet per year (erosion), and the average blocked rate (setback factor) is 5 feet per year, with a range between 2 and 8 feet per year (Figure 97 and 98).

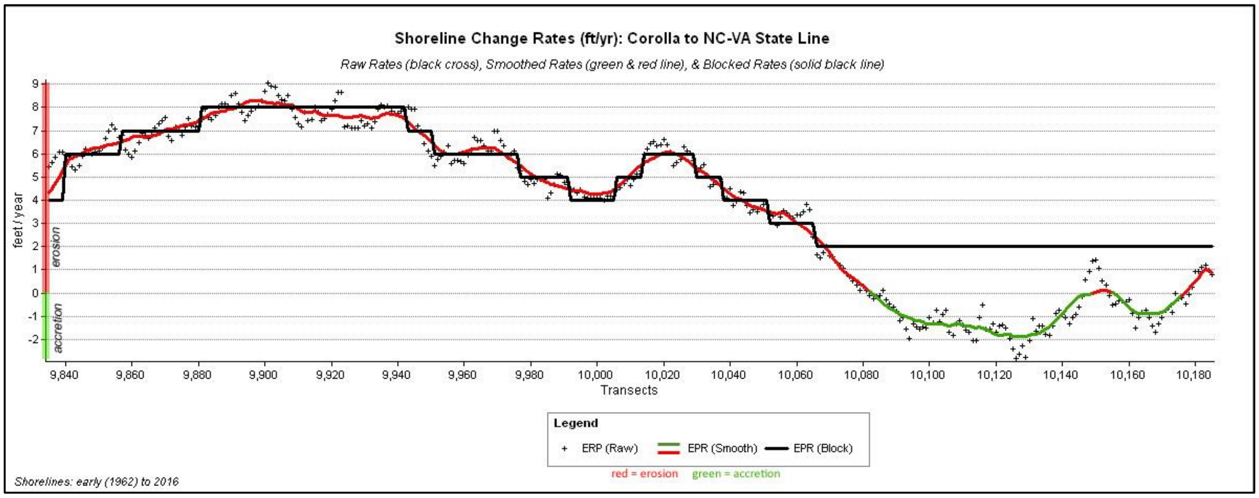

Figure 97. Corolla to NC-VA State line shoreline change rates and blocked rates (setback factors). Black-points represent all (erosion and accretion) raw rates; smoothed rates are represented by the solid green (accretion) and red (erosion) line; and the solid black line represents blocked rates (setback factors).

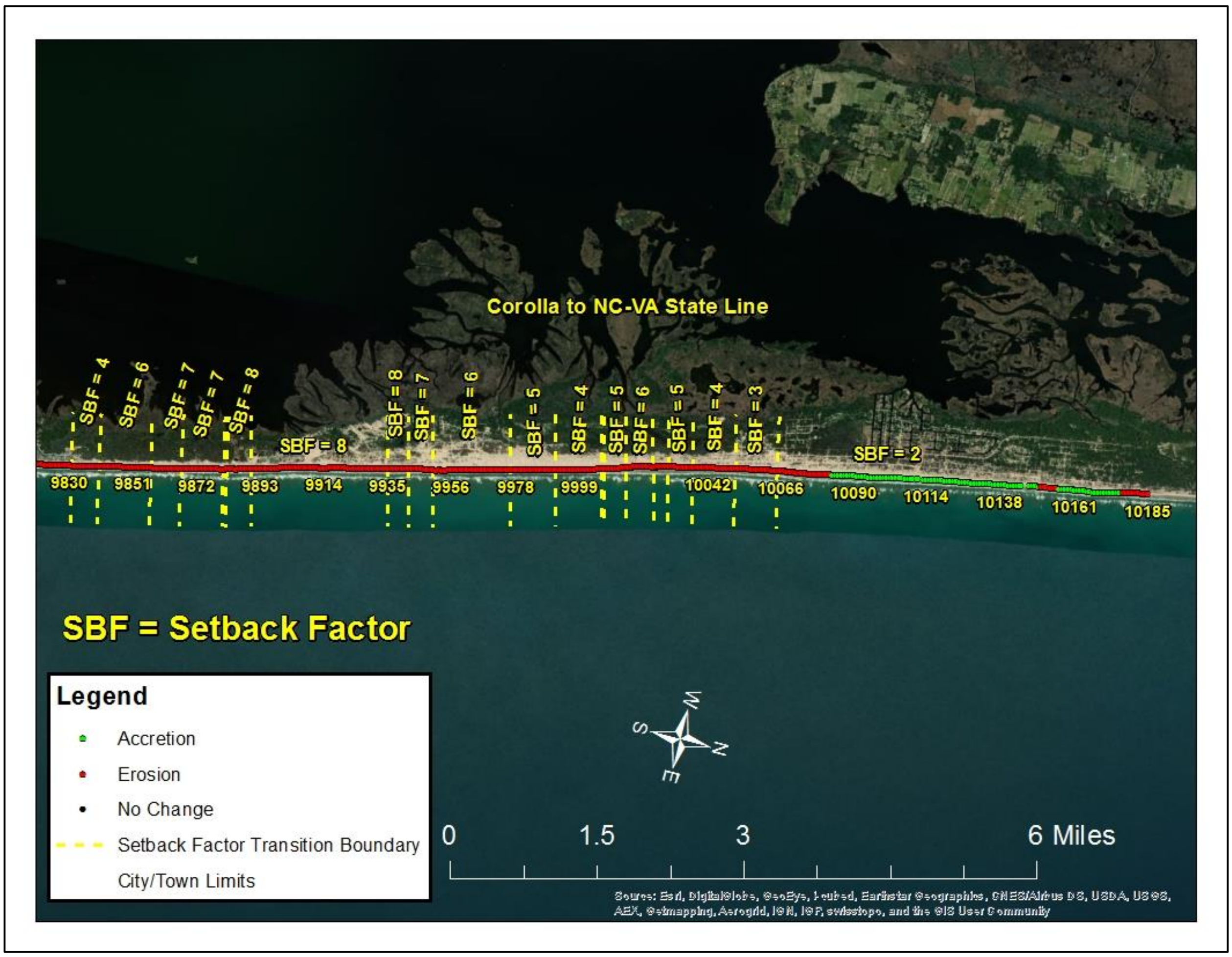

Figure 98. Corolla to NC-VA State line. Points represent transect-shoreline intersections on the 2016 shoreline; and number labels correspond to graph's x-axis transect numbers.

SUMMARY

Setback Factors and shoreline change rates south of Cape Lookout were generally consistent with those calculated in previous studies, and although some locations north of Cape Lookout resulted in slightly higher rates than were calculated in the previous study (NC DCM, 2011), they are still consistent overall when compared to the collective results from all studies. Given that most oceanfront communities now have experience with nourishing some portion of their beach on at least one occasion, it is important to emphasize that where "accretion" is measured, there is a distinct chance that while this does serve to reduce storm damage and maintain a healthy public beach, long-term beach nourishment does artificially lower actual erosion rates, and may not be the result of natural accretion.

For nearly forty years, the State has calculated oceanfront shoreline change rates using the end-point method using two shorelines (early and current). Although this method can serve to measure long-term trends, it does not always include significant short-term changes like those currently being experienced on the shoulder of Shackleford Banks adjacent to Beaufort Inlet. In preparations for the next update study in 2024, the Division of Coastal Management will compare alternative methods that incorporate multiple shorelines.

This report, data, and maps, will be made available for download and viewing on the Division's website:

https://deq.nc.gov/about/divisions/coastal-management

or, Internet browser key word search "NC DCM"

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APPENDIX A: Oceanfront Setback Factors & Average Annual Long-Term Shoreline Change Rate Maps

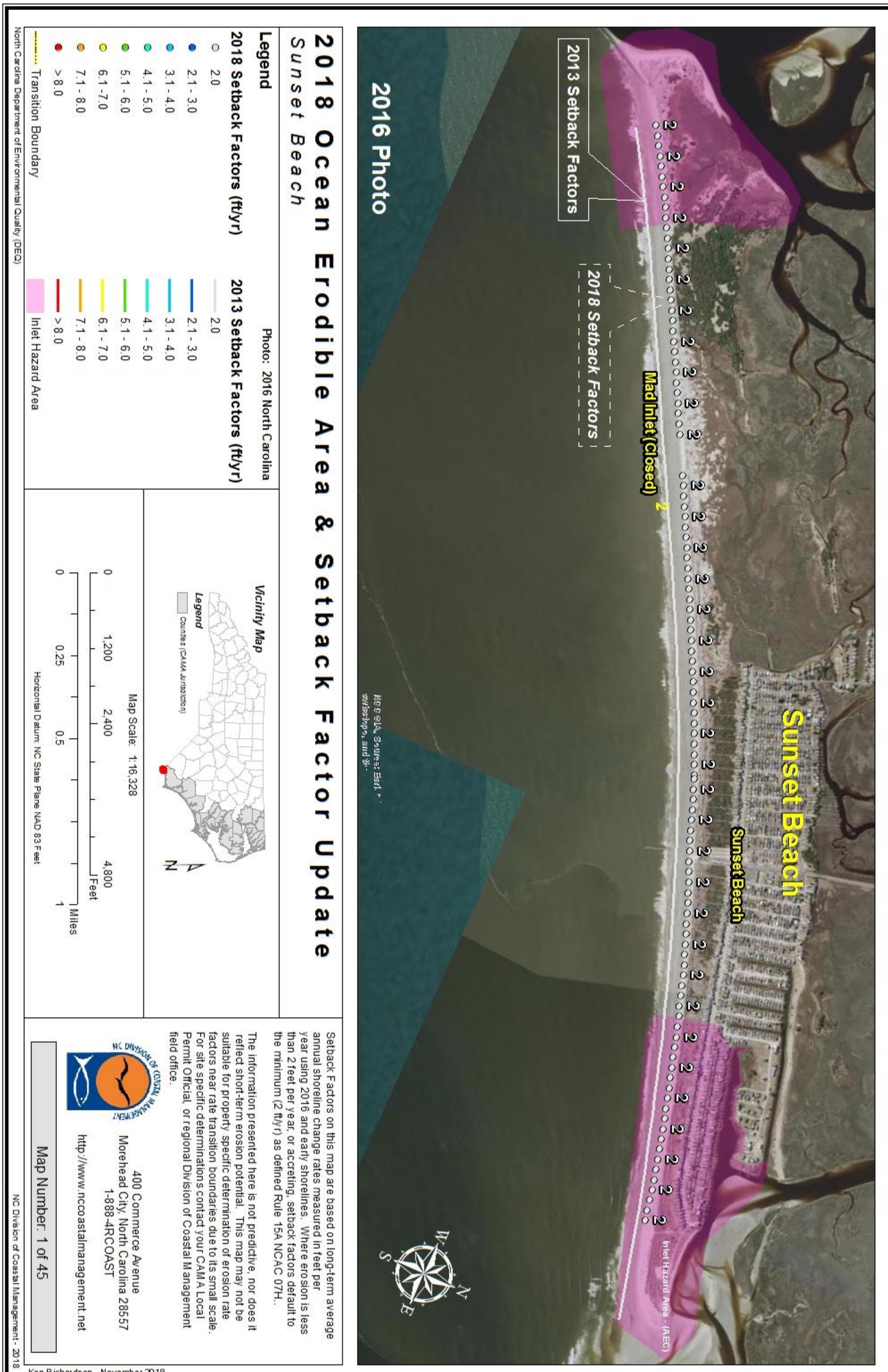

Figure A 1. Sunset Beach & Bird Island Setback Factors

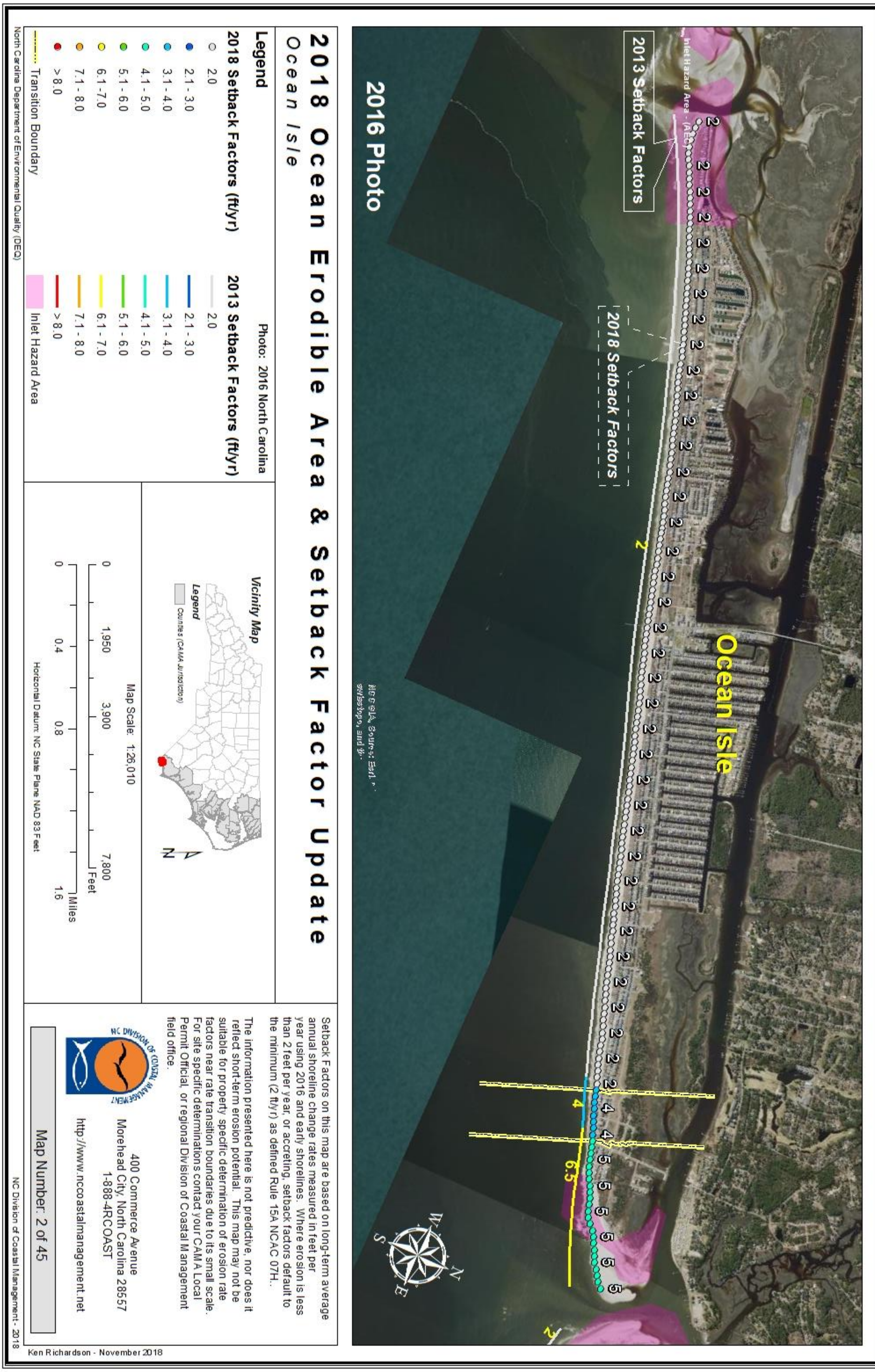

Figure A 2. Ocean Isle Setback Factors

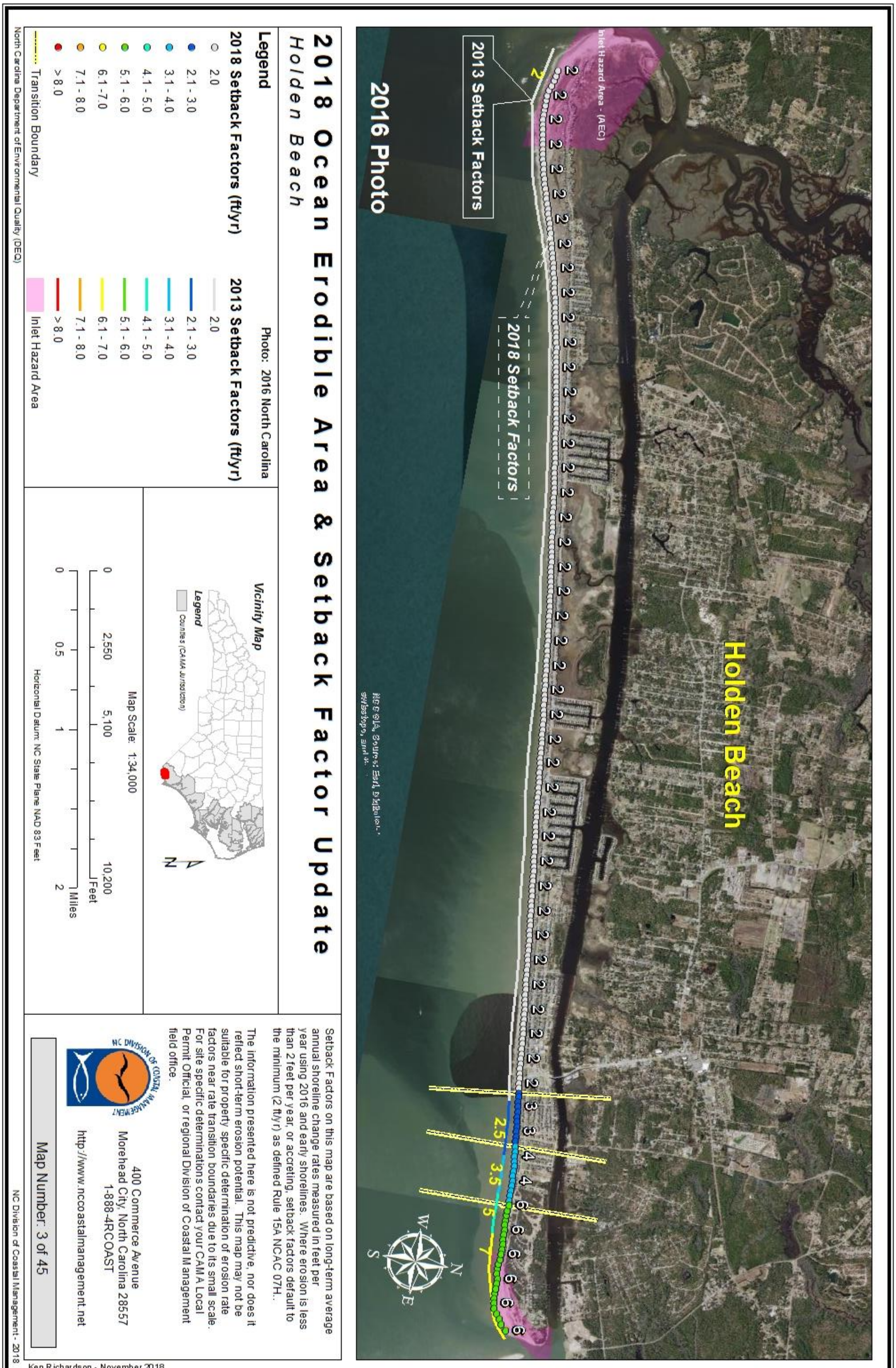

Figure A 3. Holden Beach Setback Factors

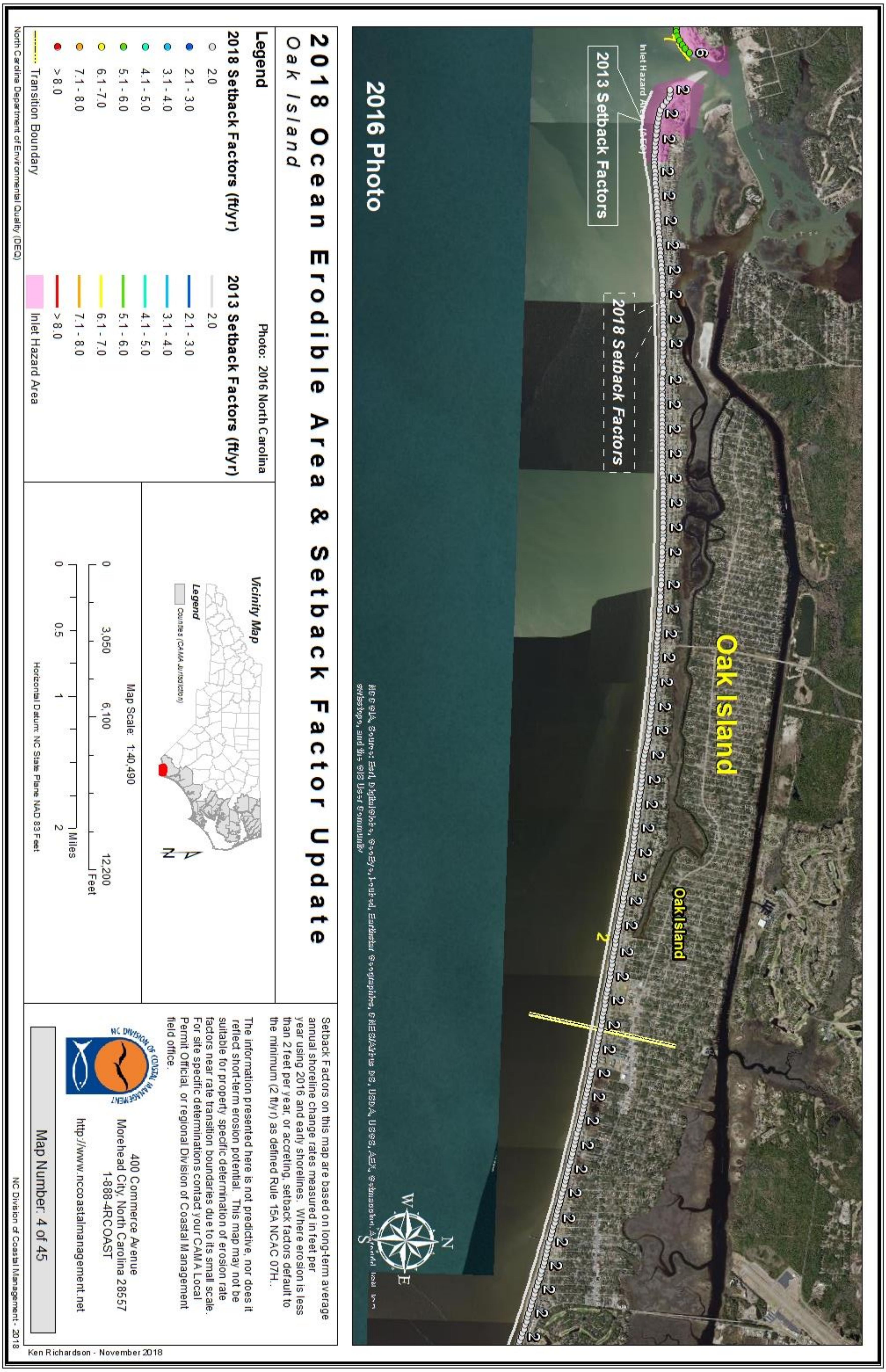

Figure A 4. Oak Island Setback Factors

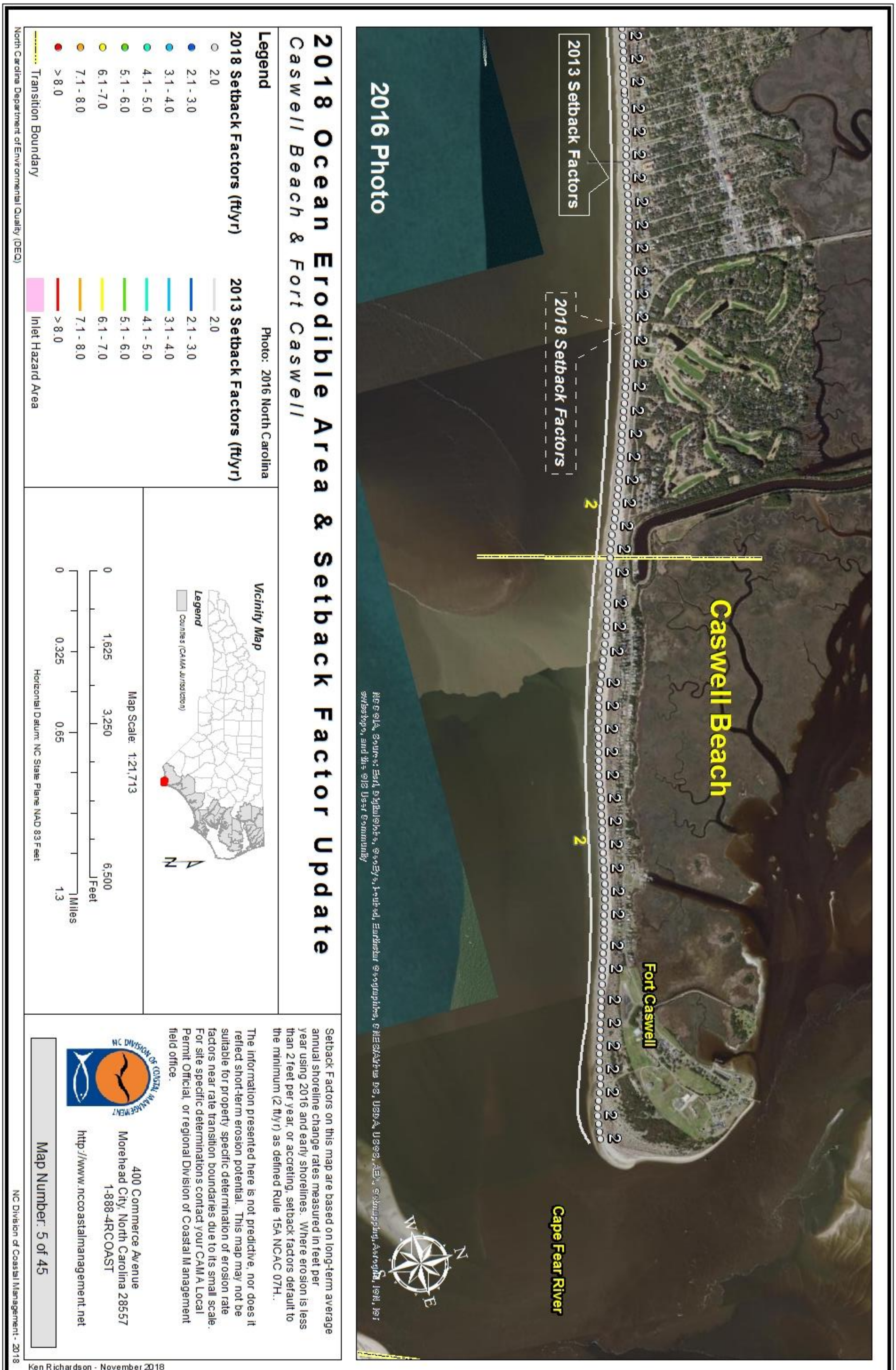

Figure A 5. Caswell Beach & Fort Caswell Setback Factors

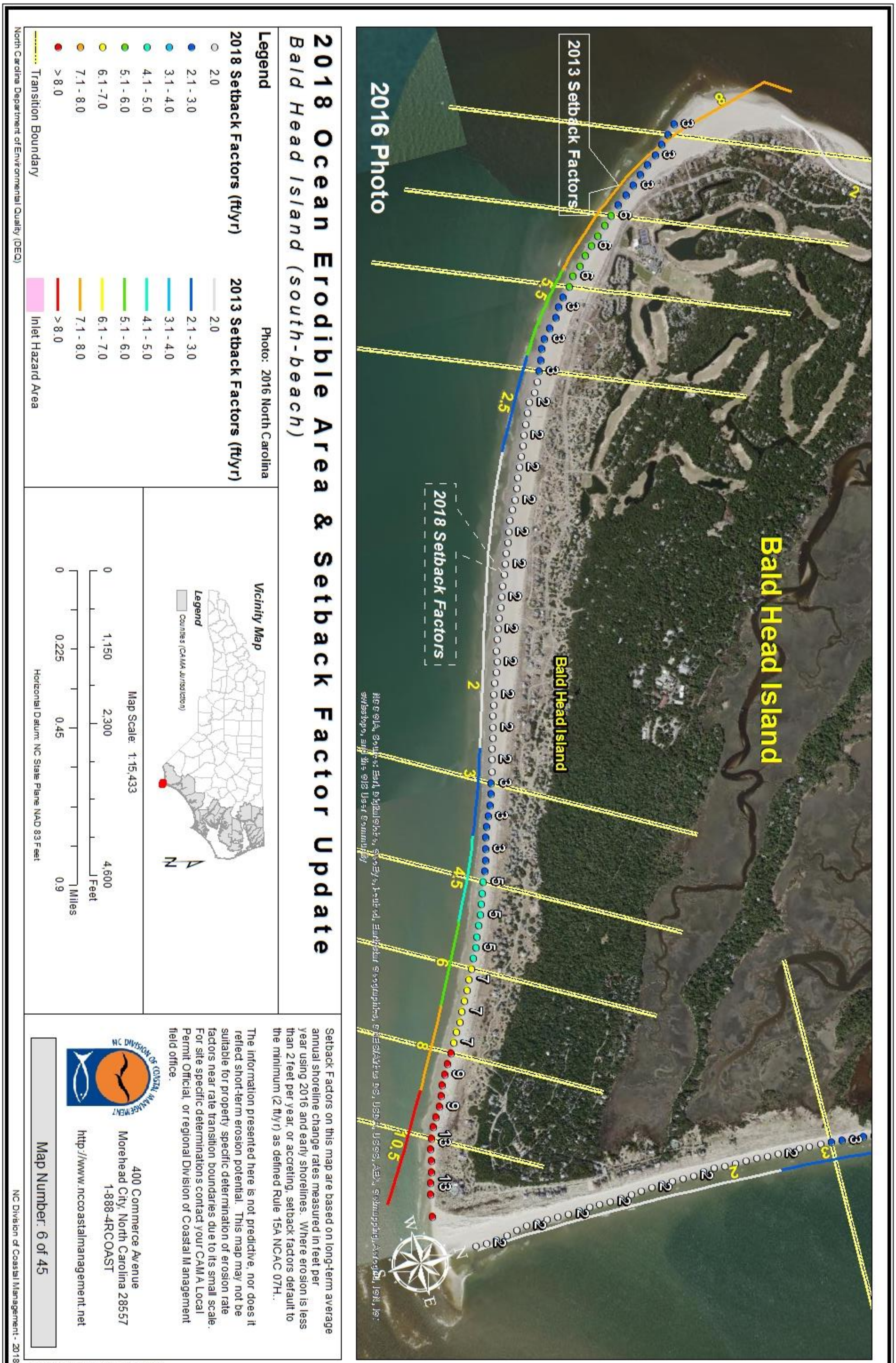

Figure A 6. Bald Head Island (south-beach) Setback Factors

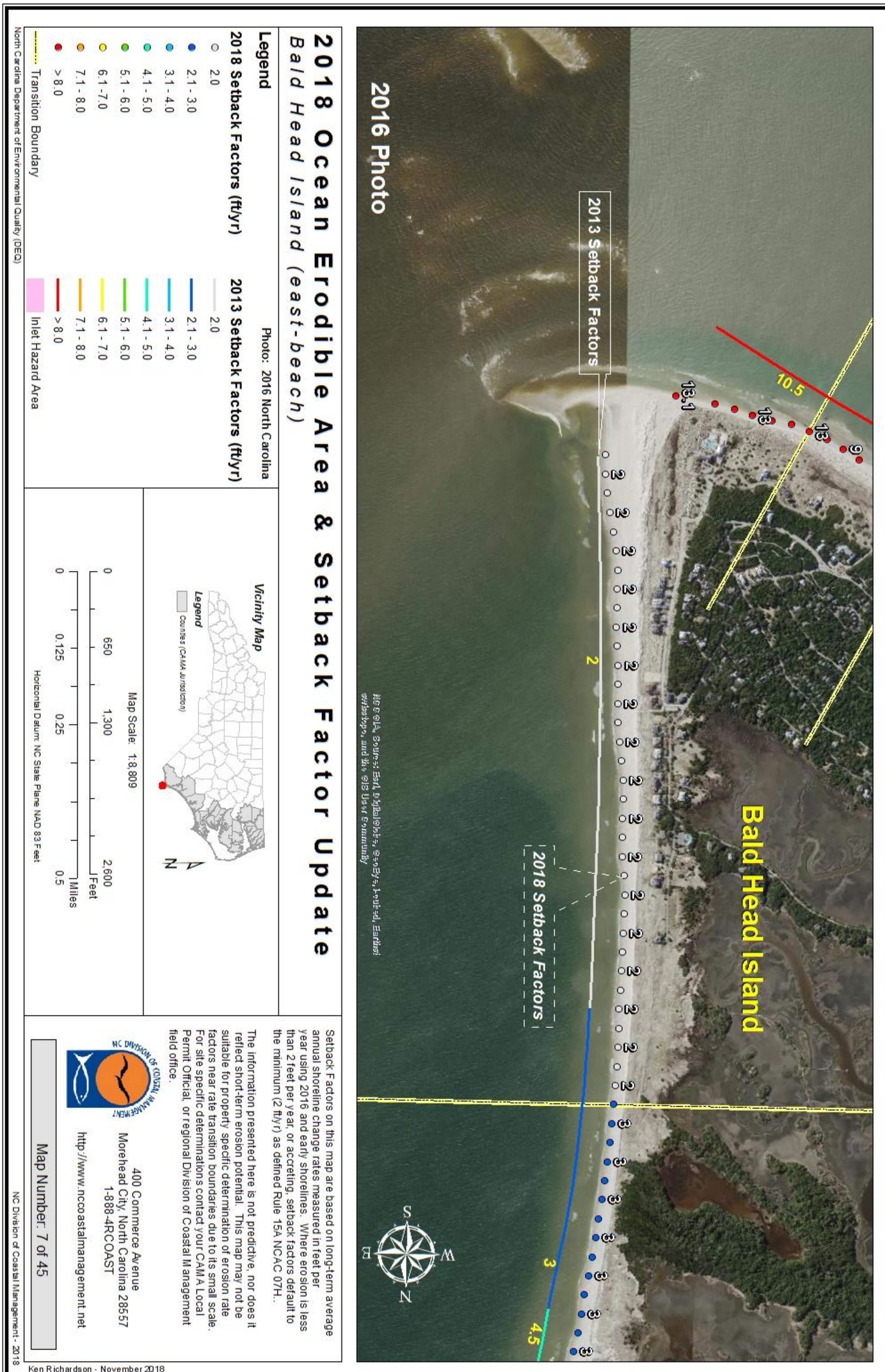

Figure A 7. Bald Head Island (east-beach) Setback Factors

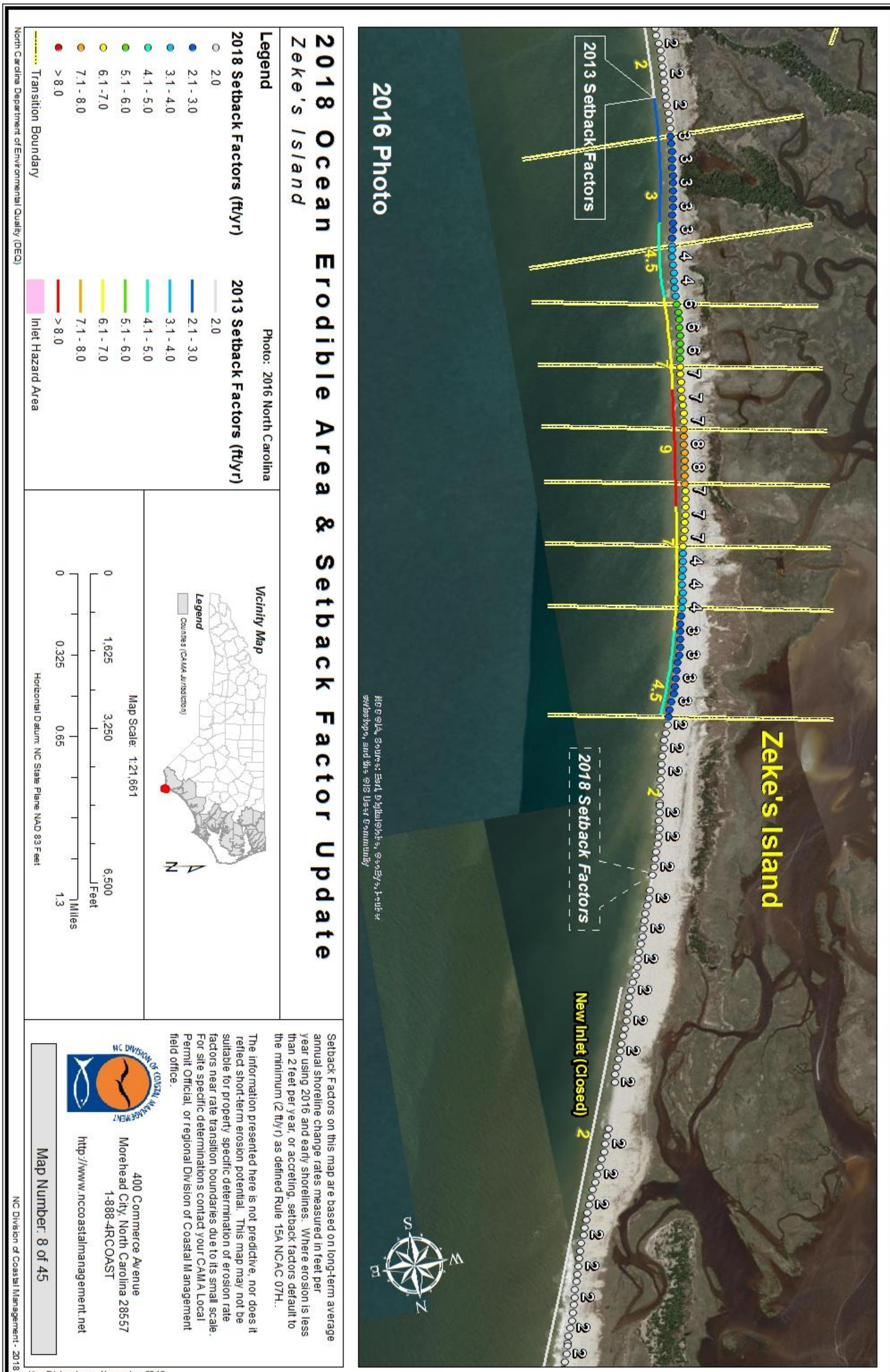

Figure A 8. Zeke's Island Setback Factors

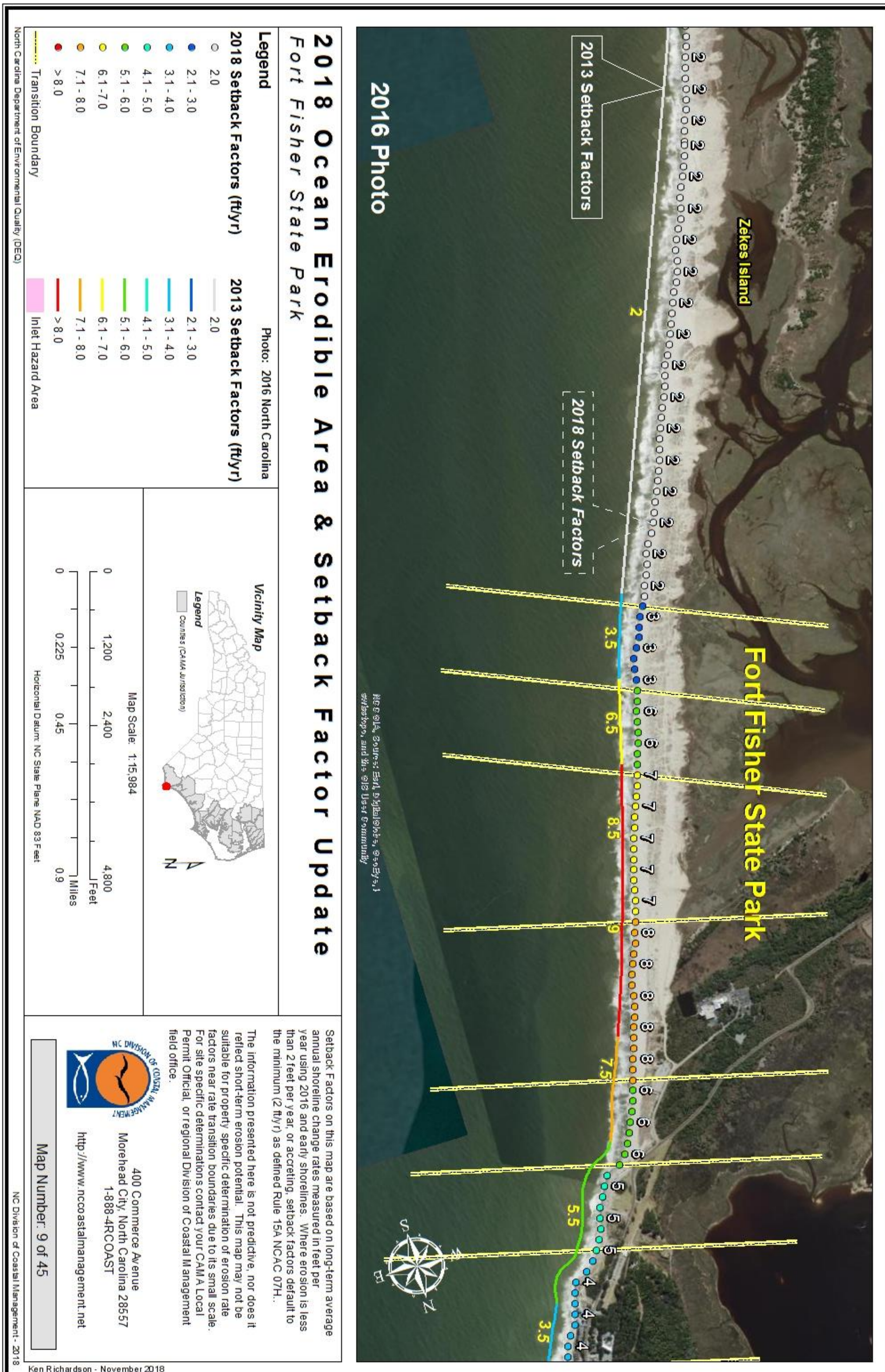

Figure A 9. Fort Fisher State Park Setback Factors

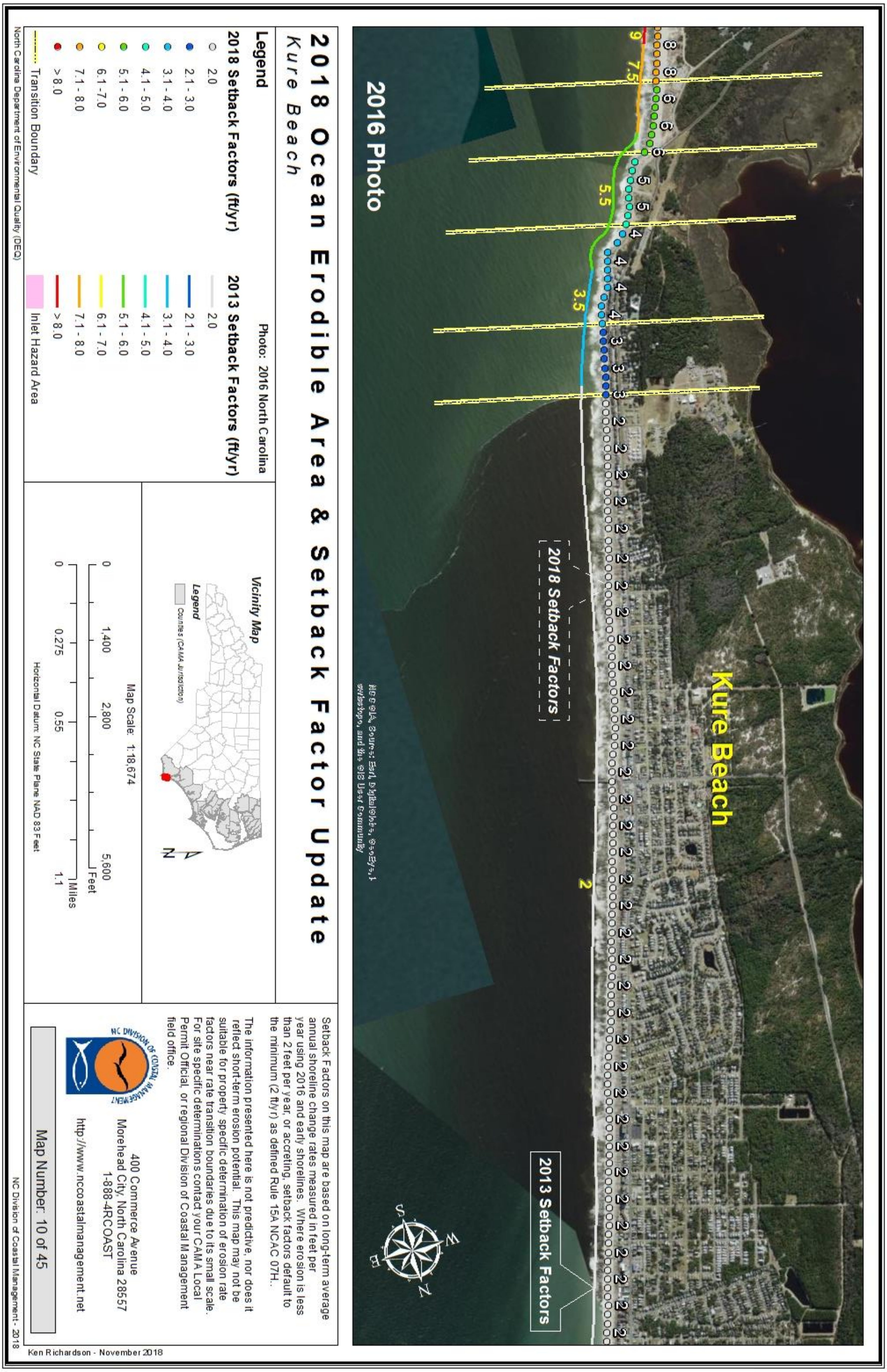

Figure A 10. Kure Beach Setback Factors

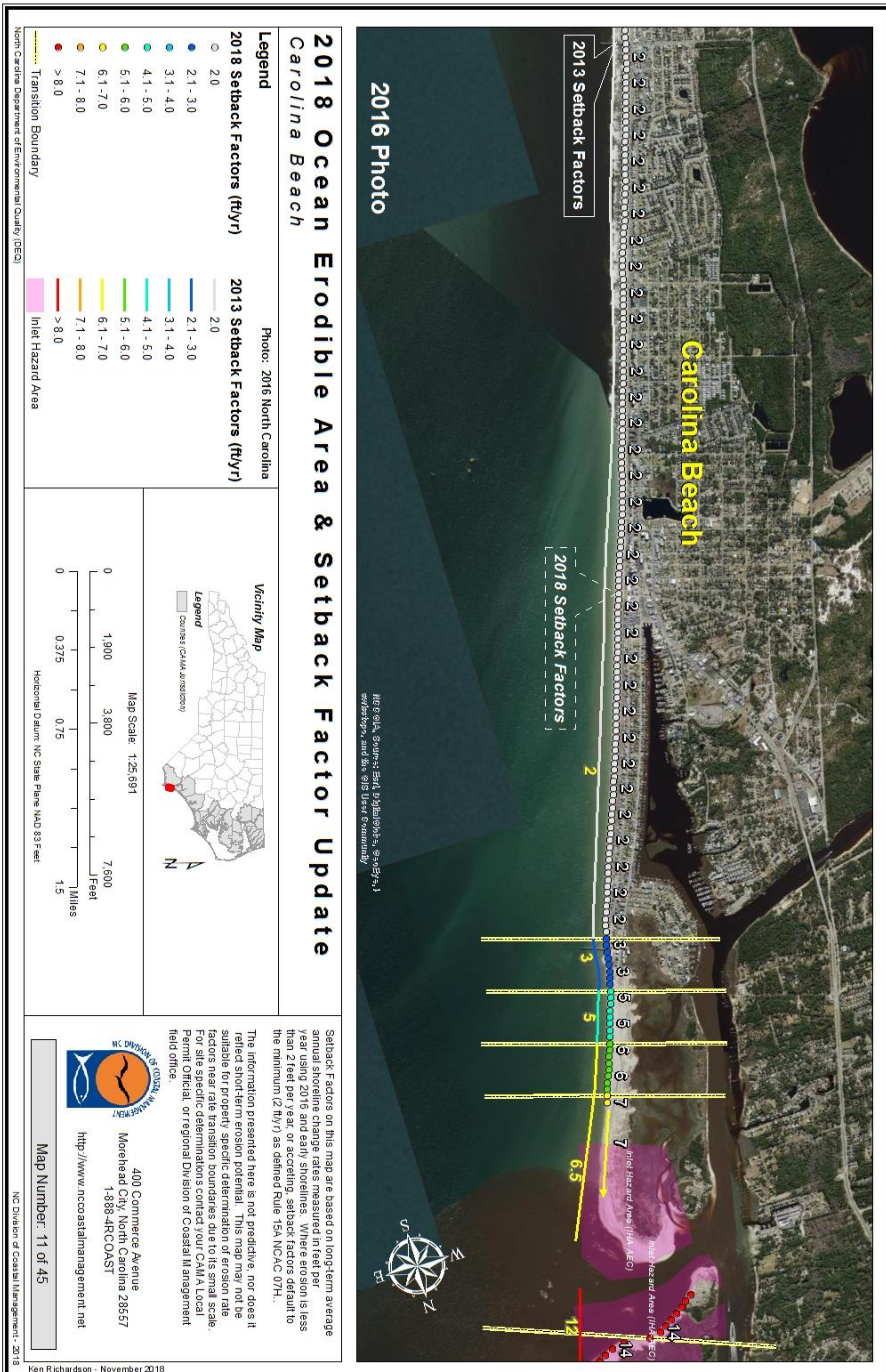

Figure A 11. Carolina Beach Setback Factors

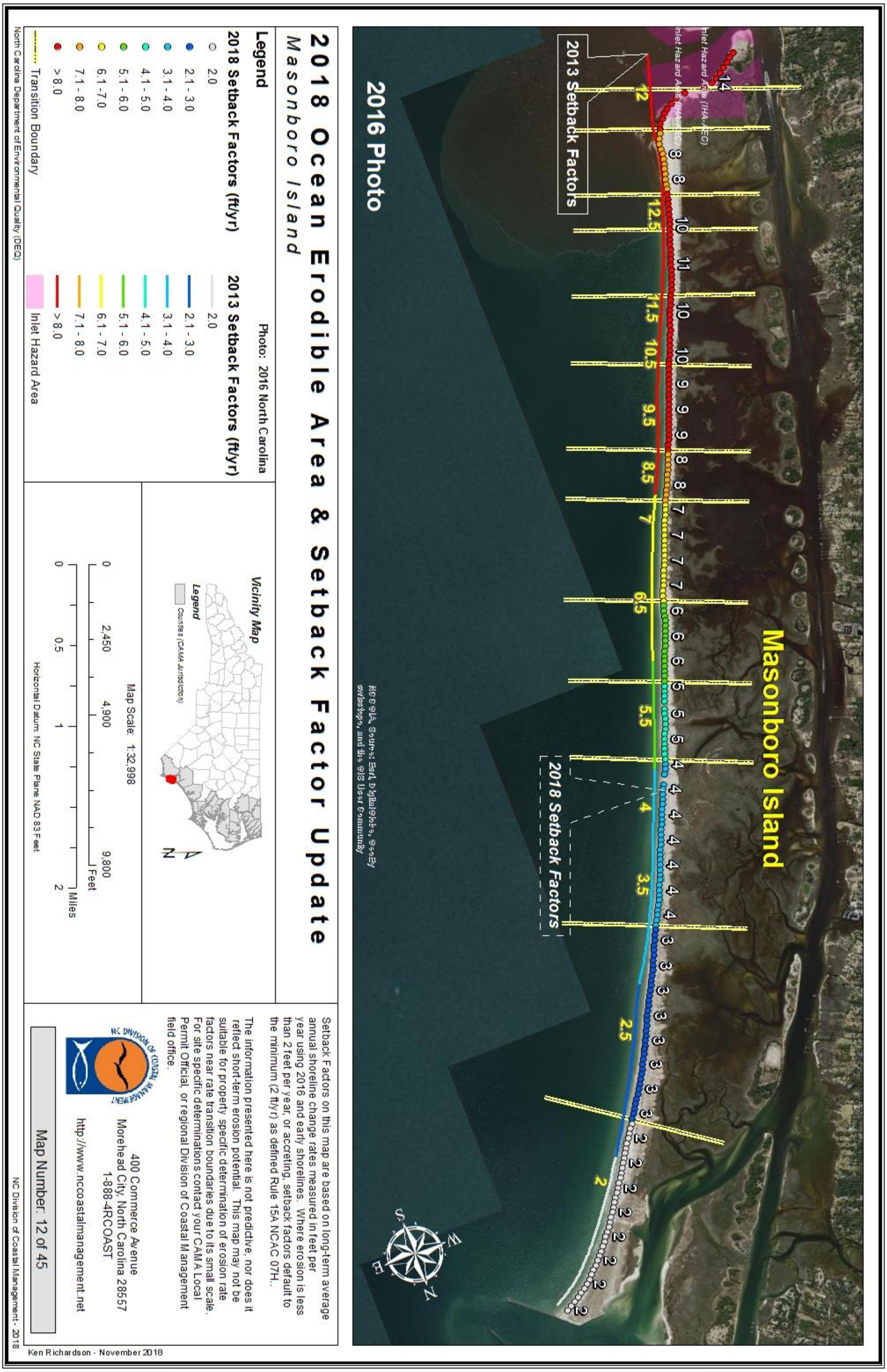

Figure A 12. Masonboro Island Setback Factors

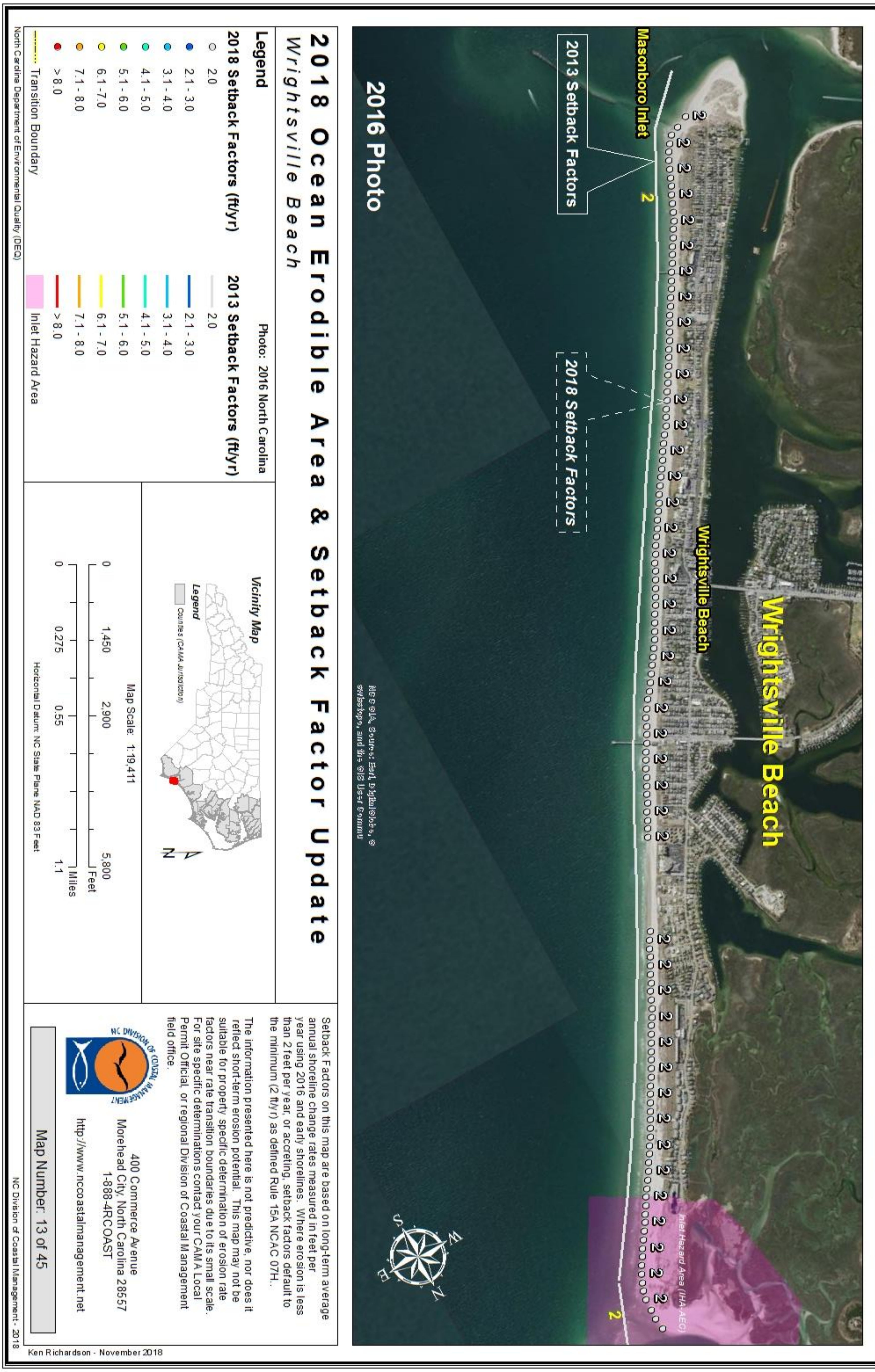

Figure A 13. Wrightsville Beach Setback Factors

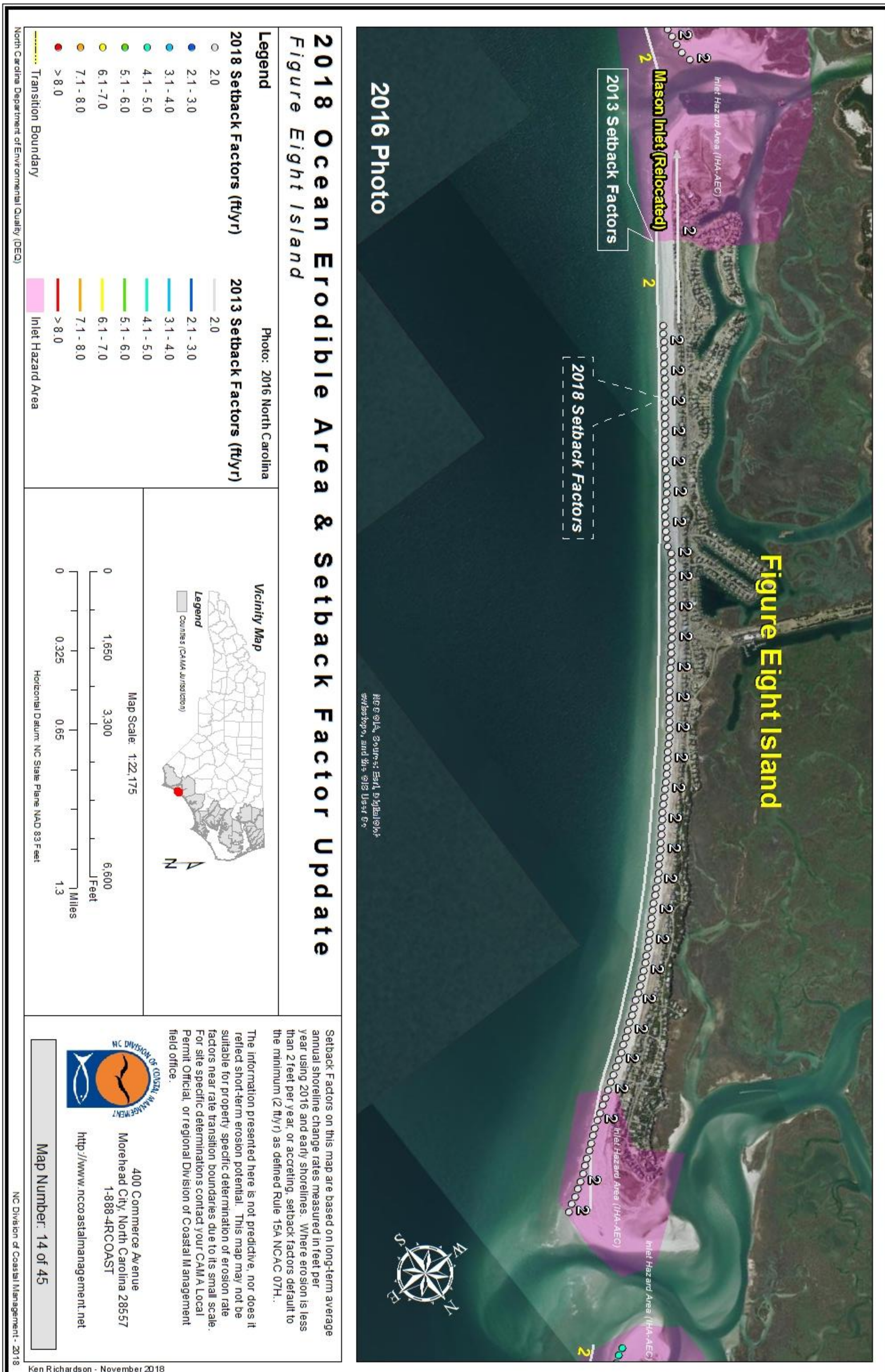

Figure A 14. Figure Eight Island Setback Factors

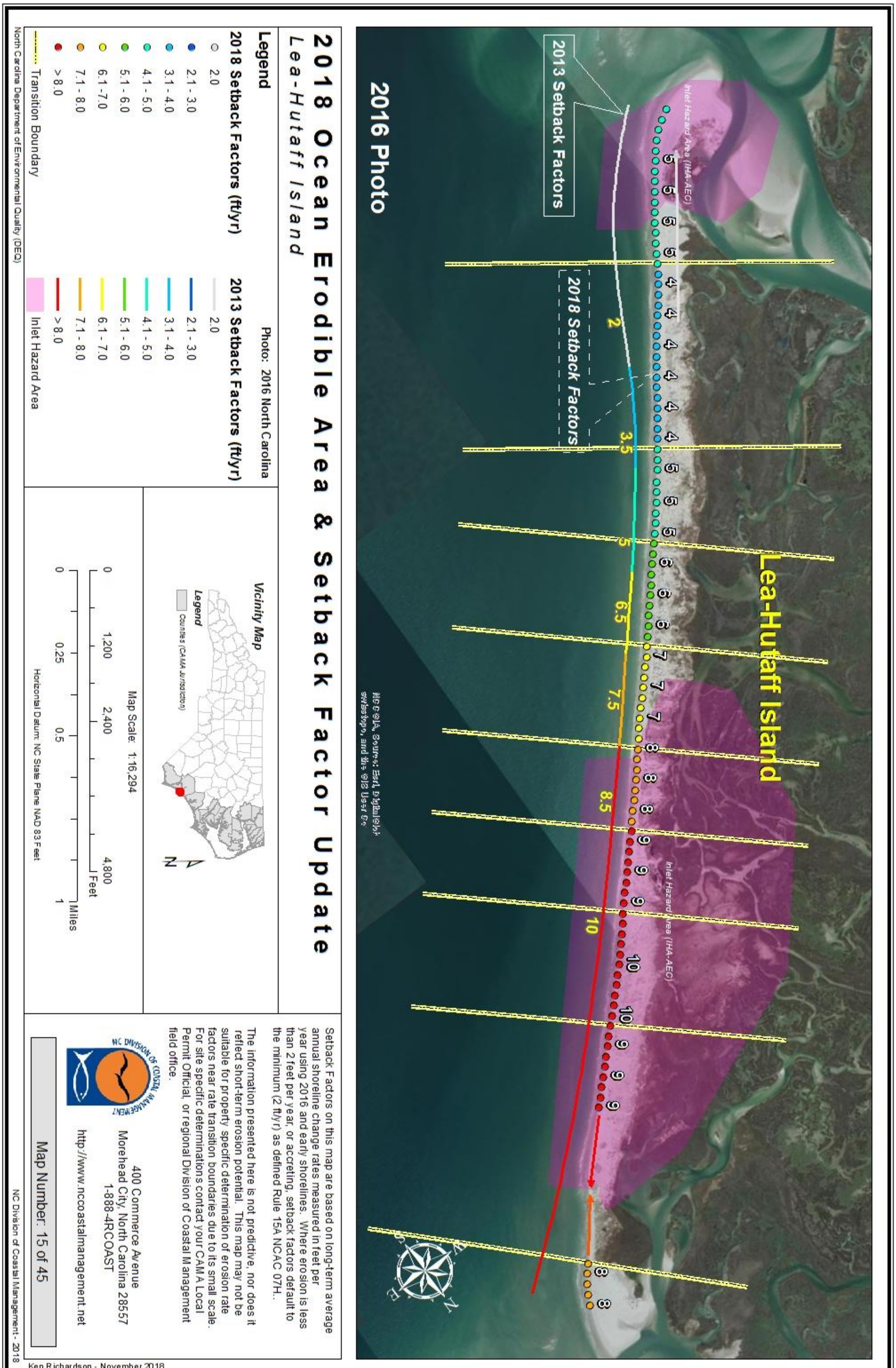

Figure A 15. Lea-Hutaff Island Setback Factors

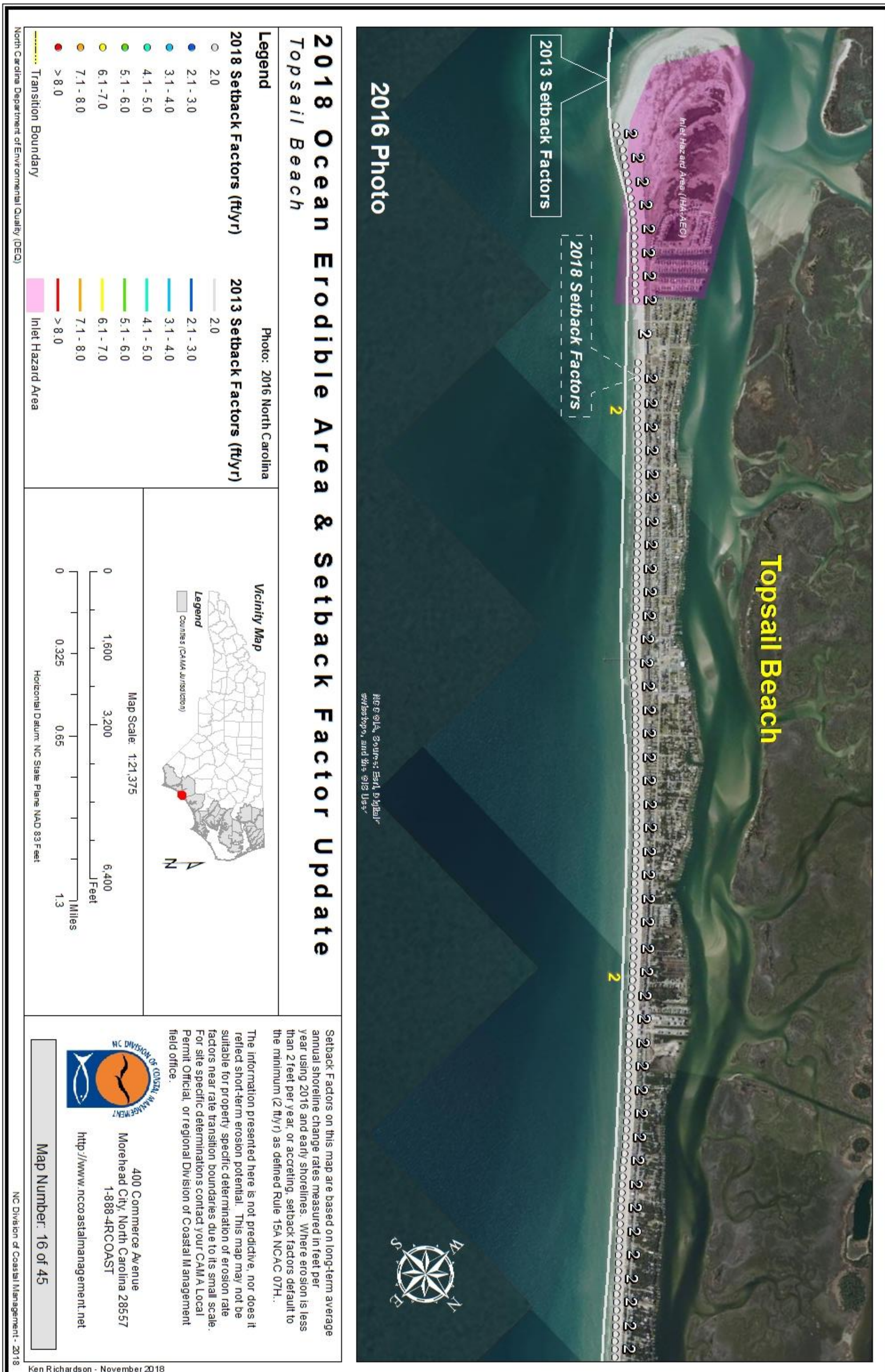

Figure A 16. Topsail Beach Setback Factors

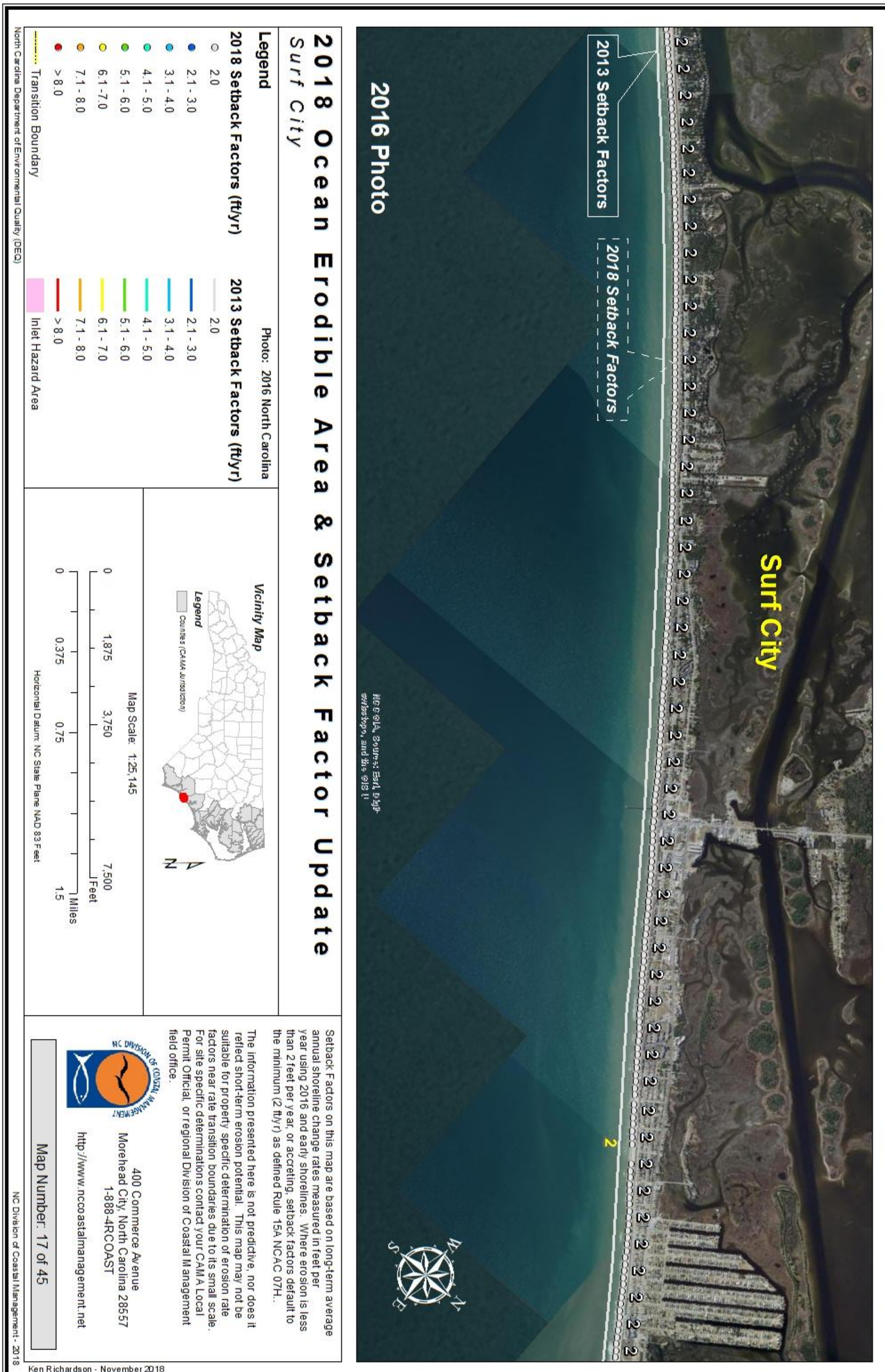

Figure A 17. Surf City Setback Factors

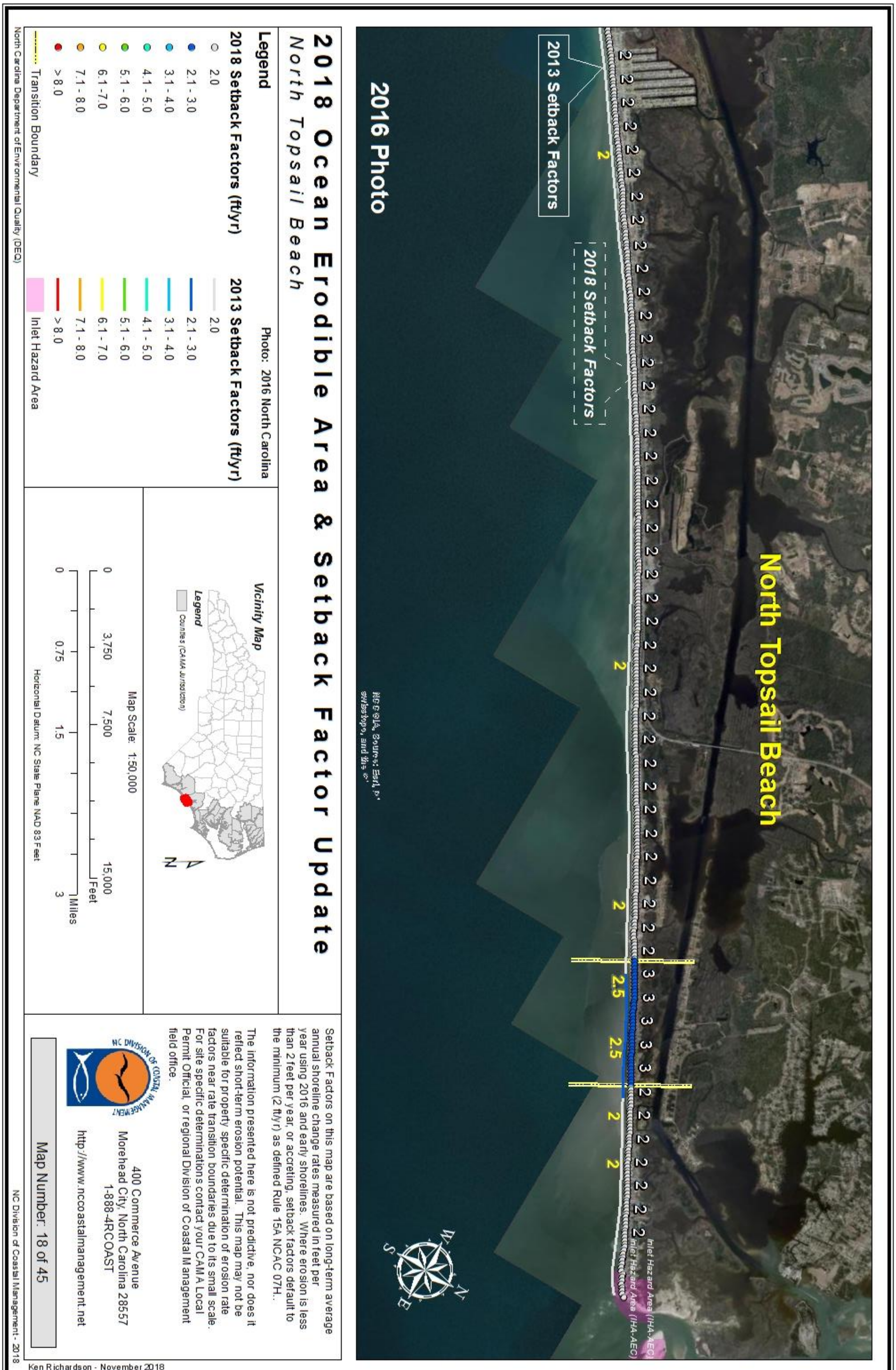

Figure A 18. North Topsail Beach Setback Factors

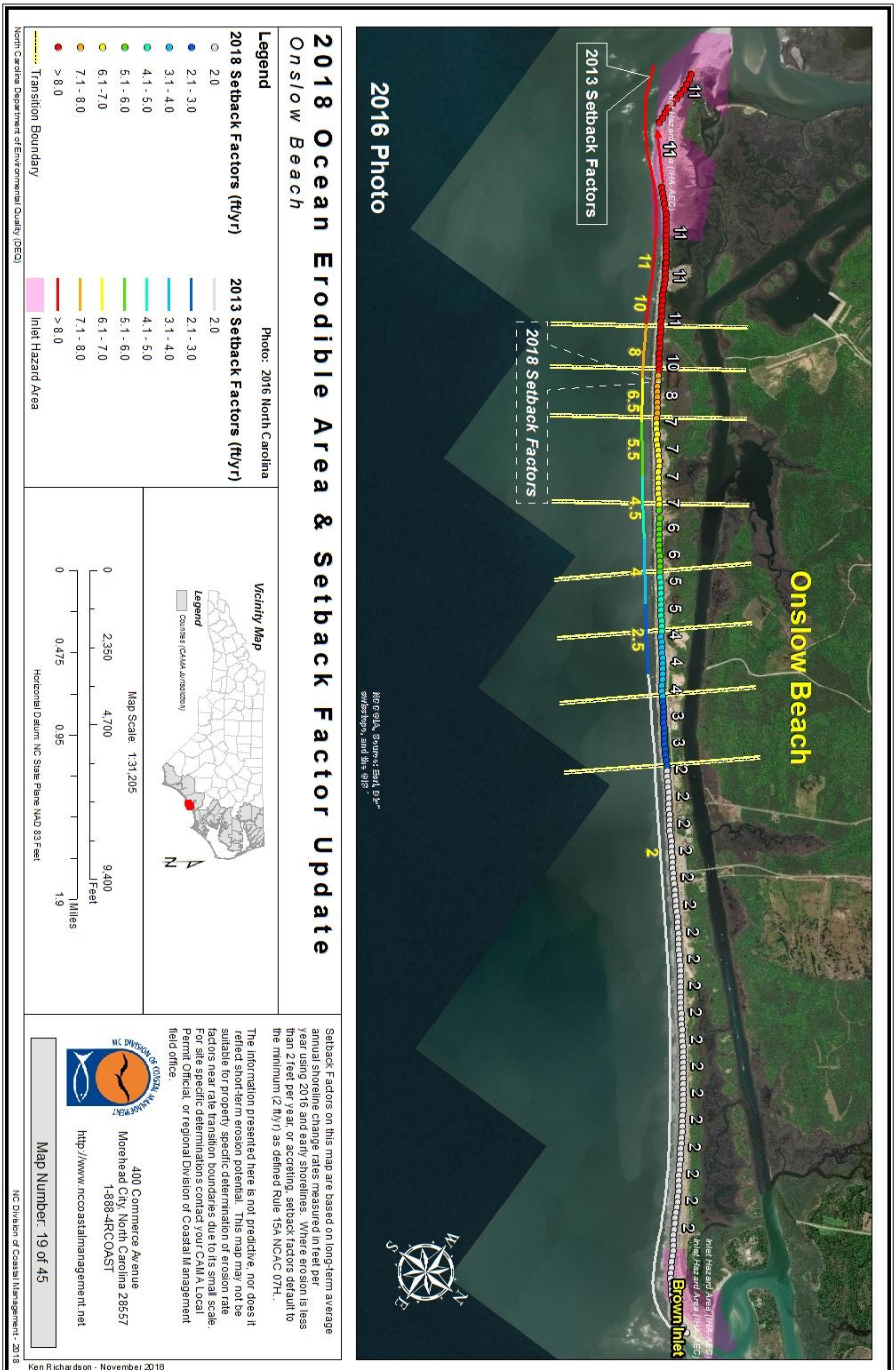

Figure A 19. Onslow Beach Setback Factors

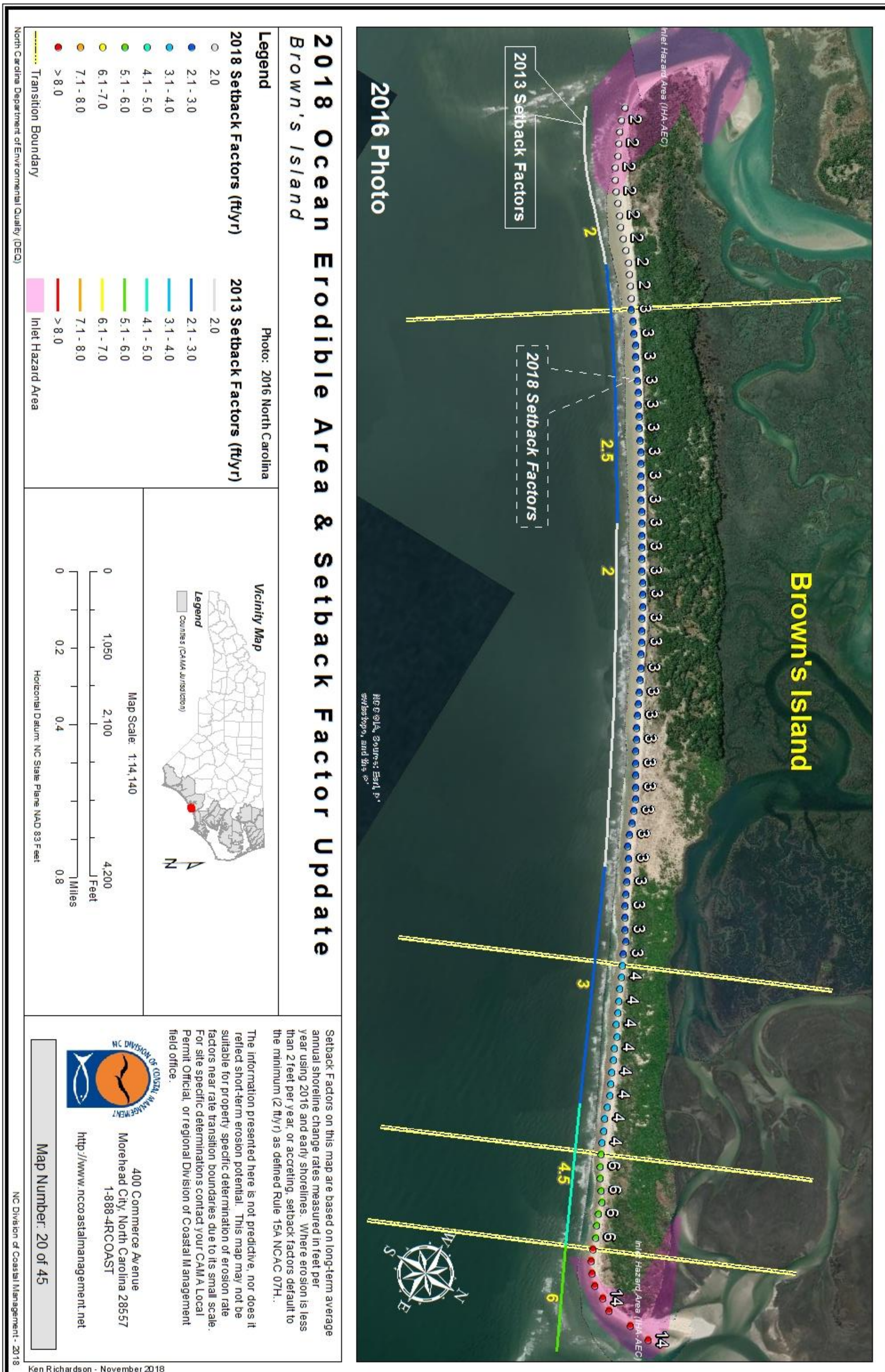

Figure A 20. Brown's Island Setback Factors

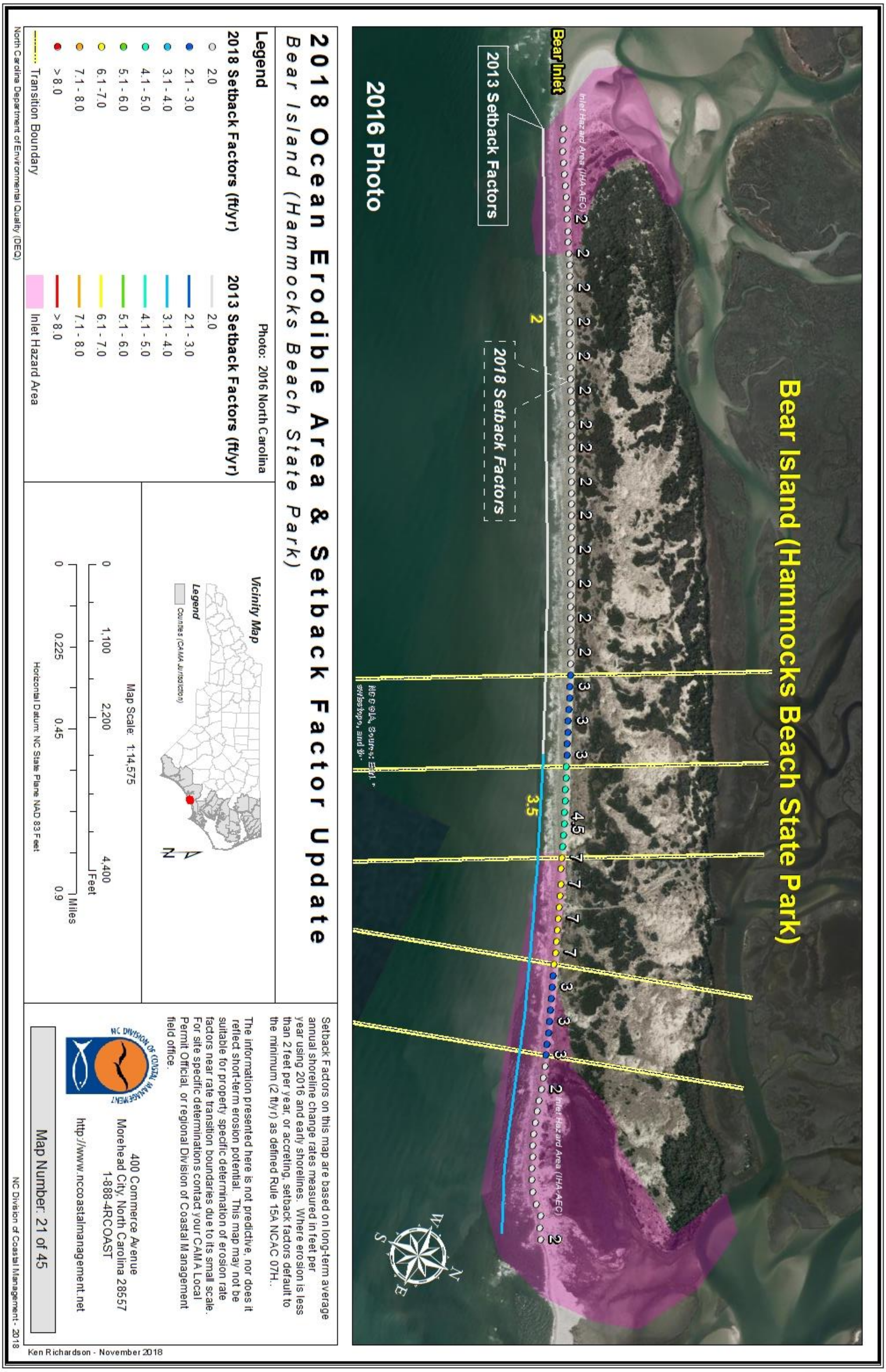

Figure A 21. Bear Island (Hammocks Beach State Park) Setback Factors

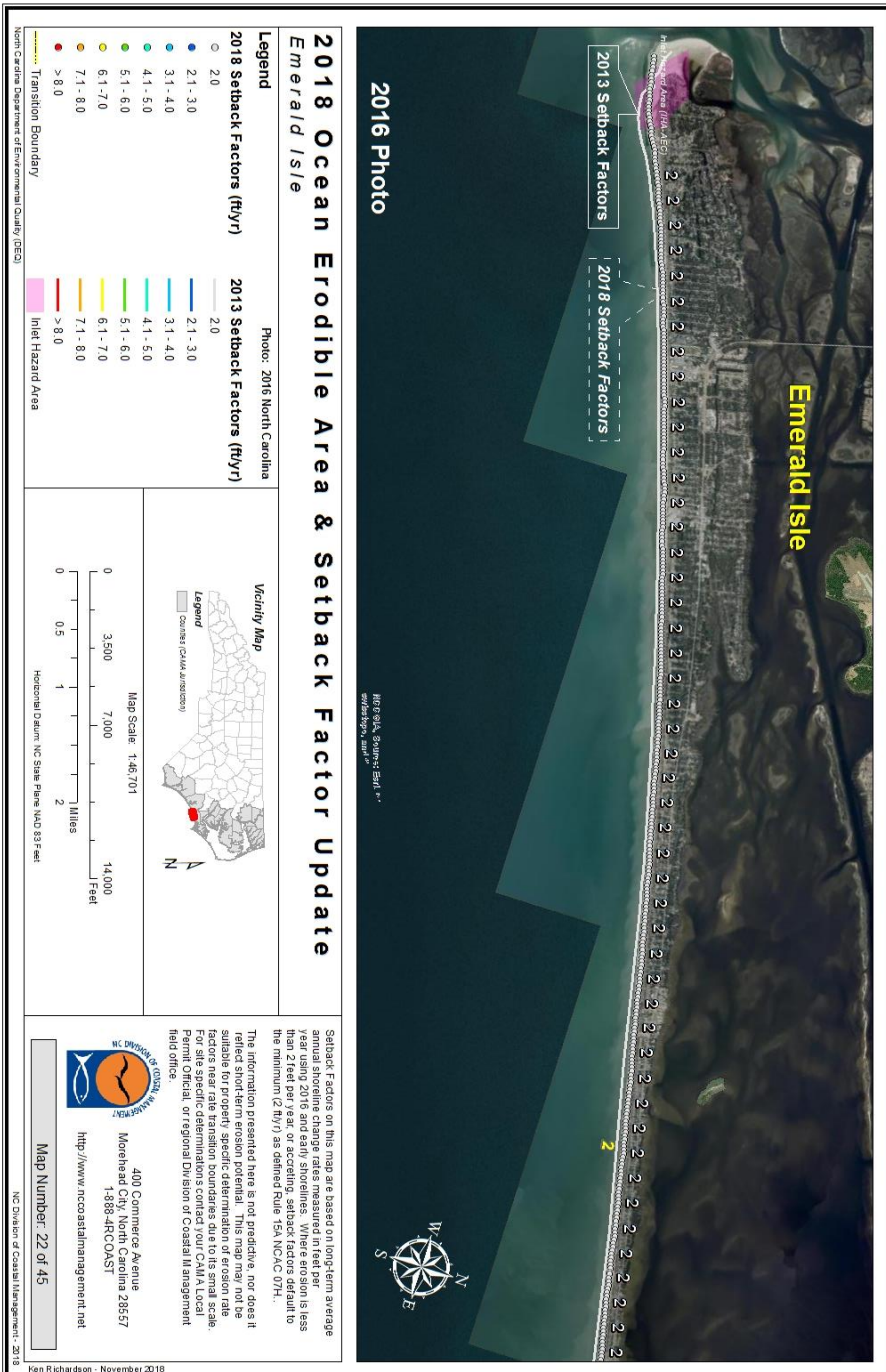

Figure A 22. Emerald Isle Setback Factors

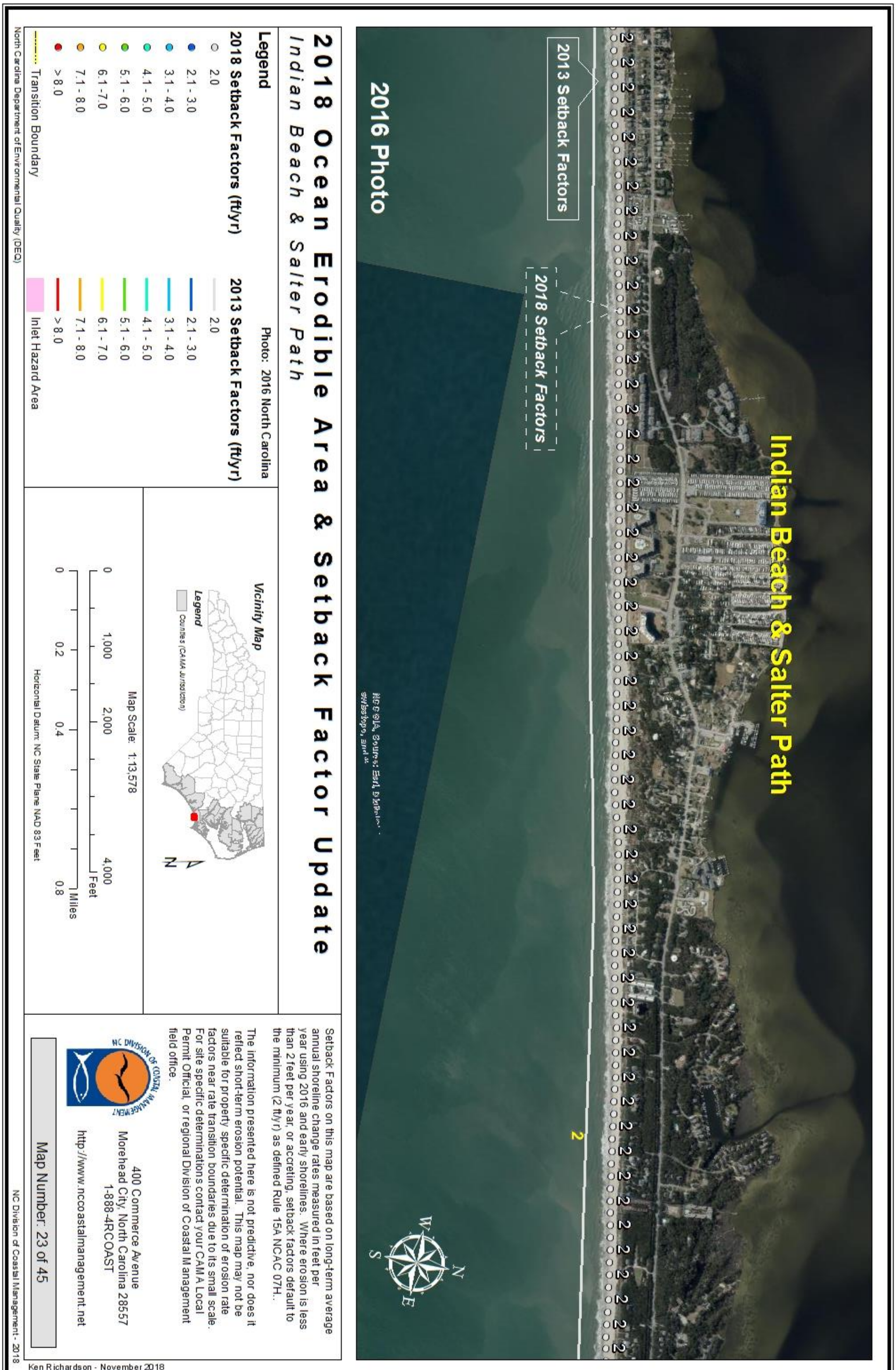

Figure A 23. Indian Beach & Salter Path Setback Factors

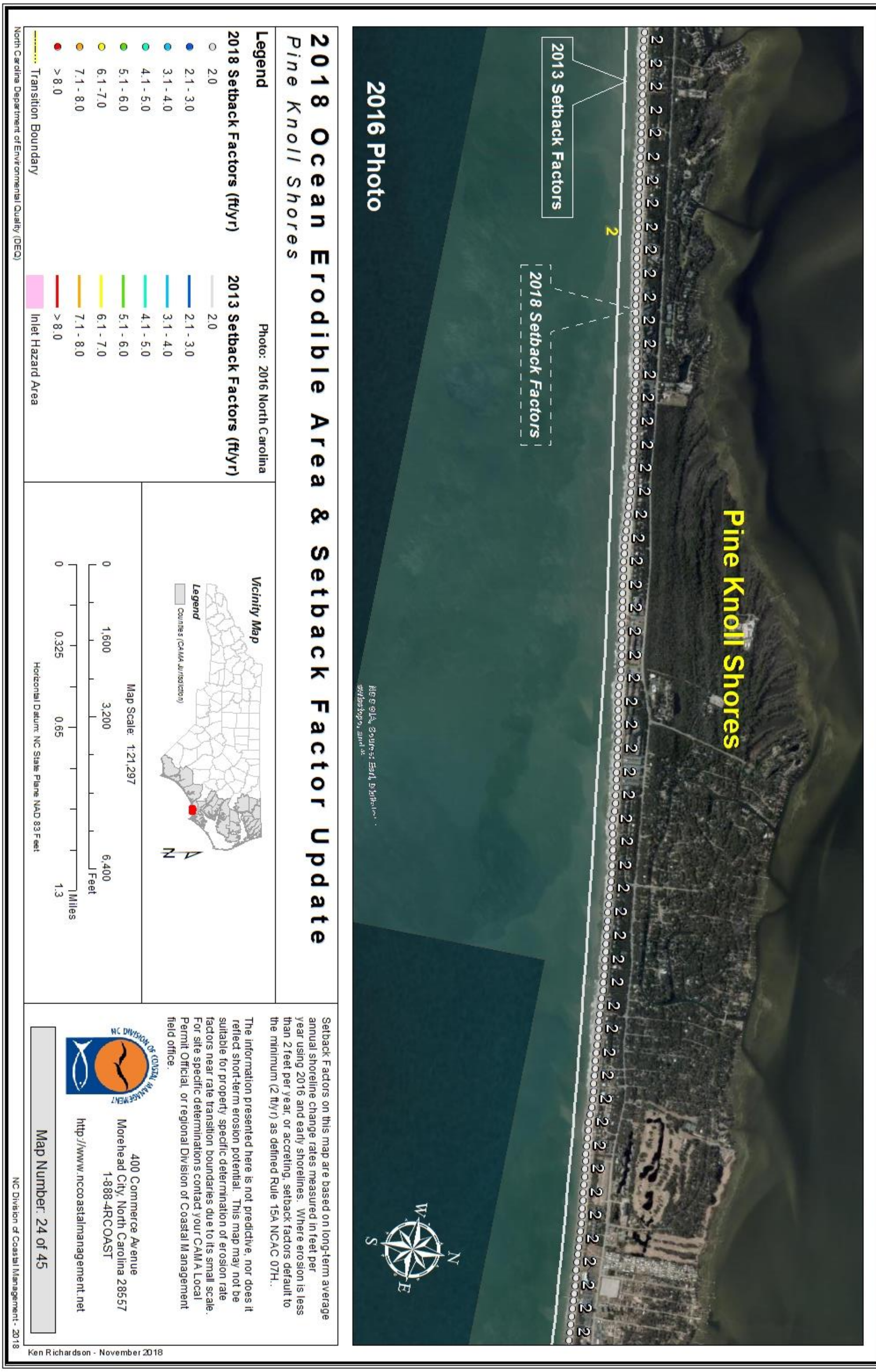

Figure A 24. Pine Knoll Shores Setback Factors

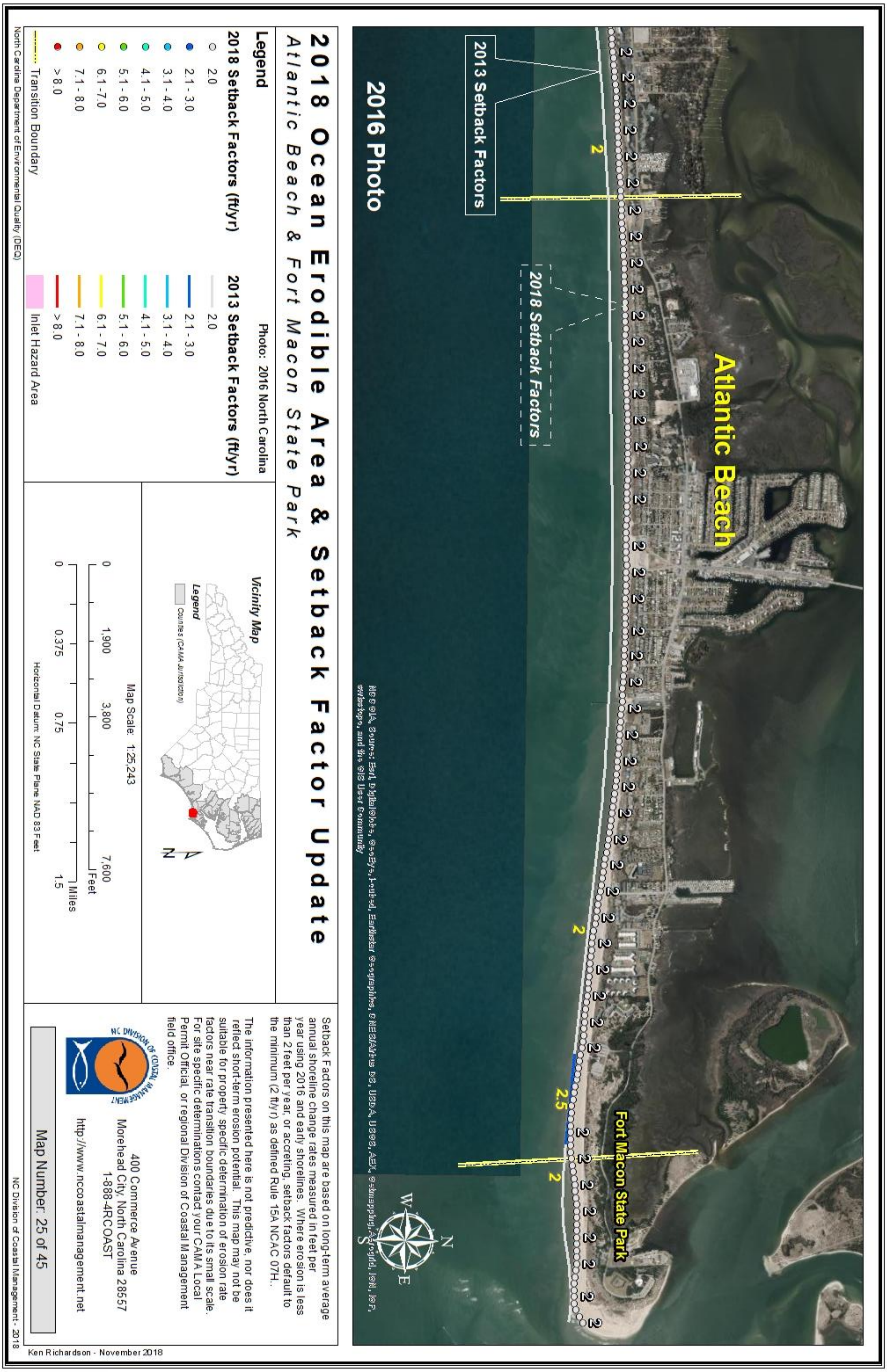

Figure A 25. Atlantic Beach & Fort Macon State Park Setback Factors

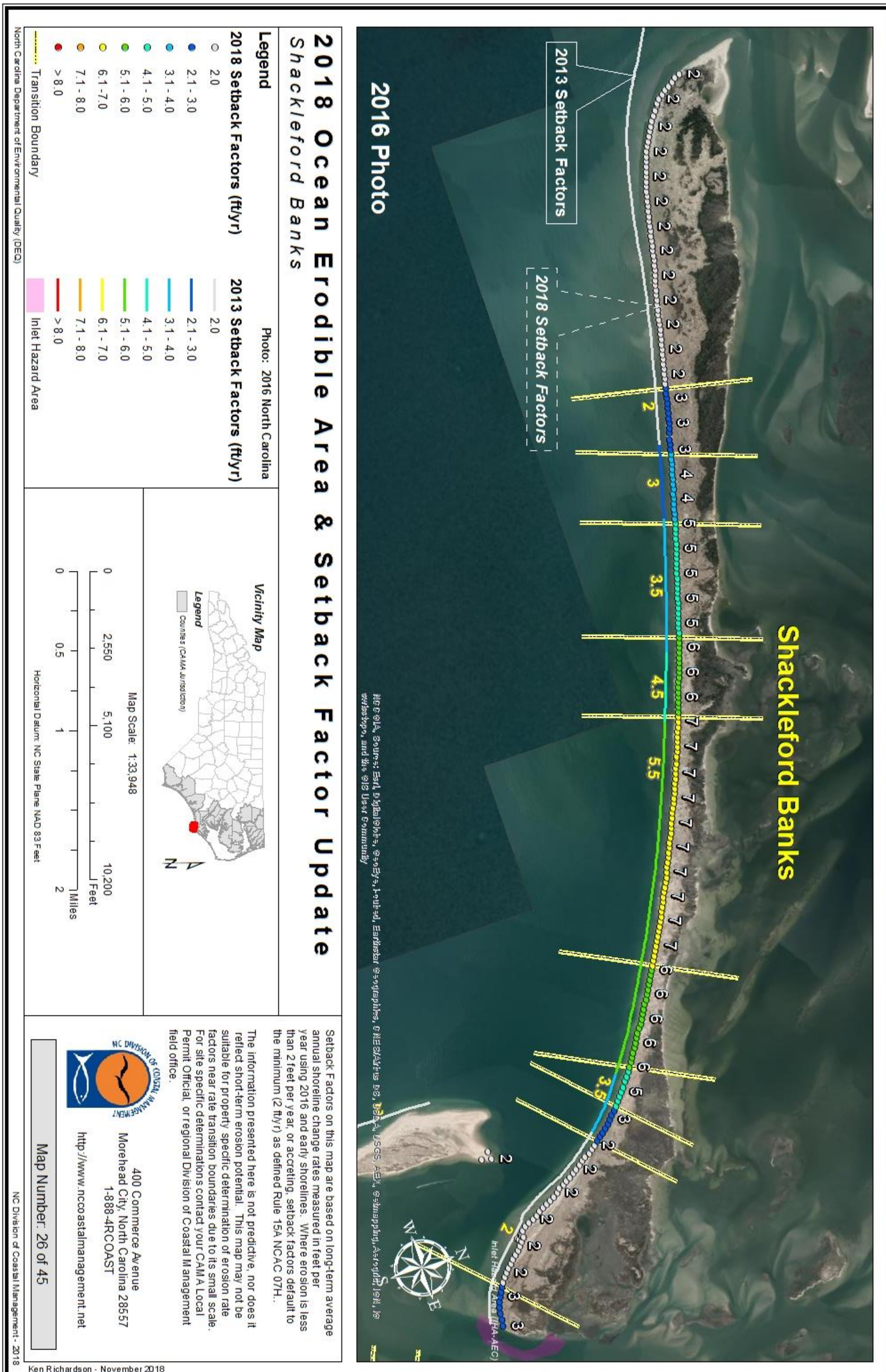

Figure A 26. Shackleford Banks Setback Factors

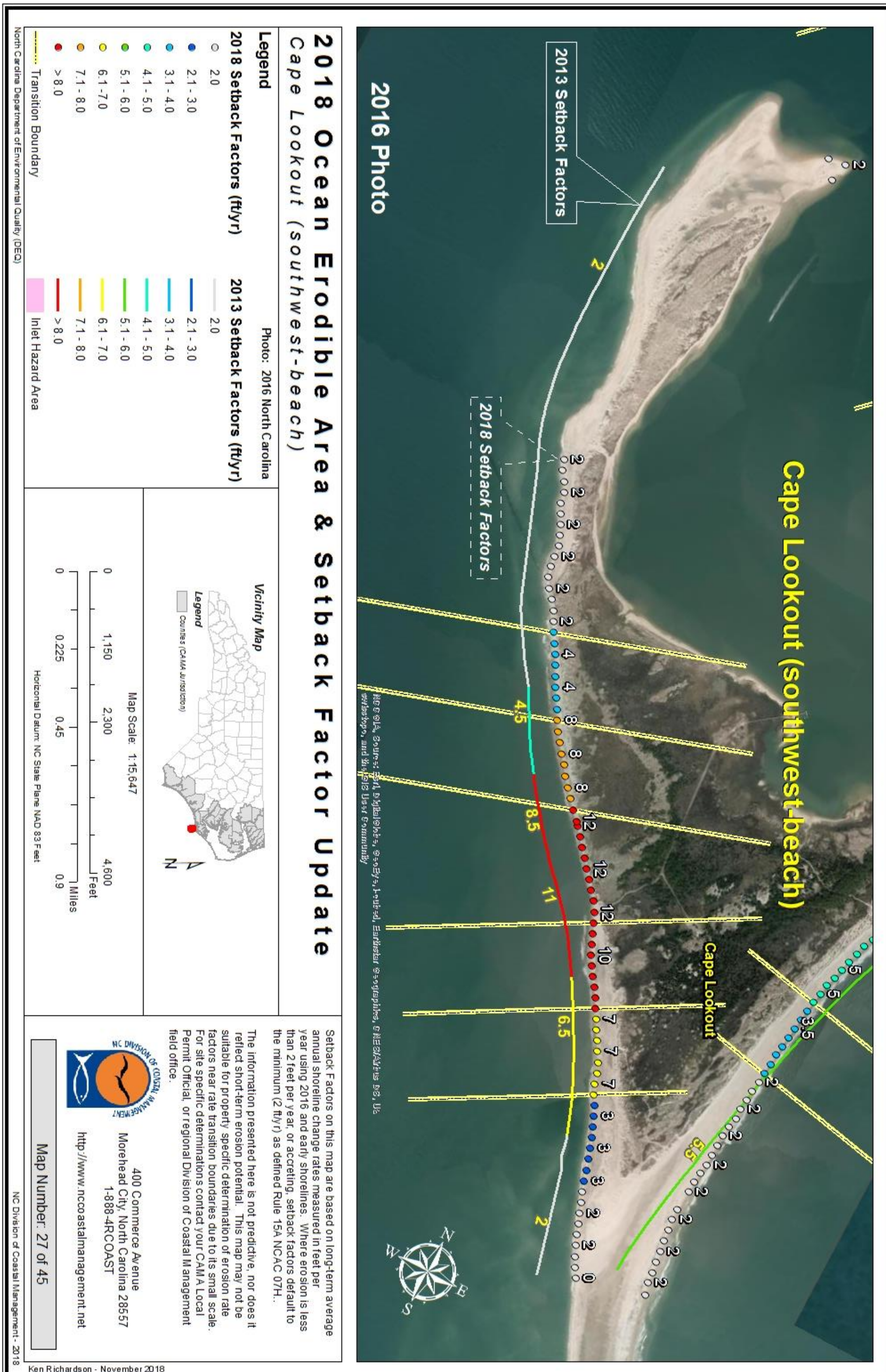

Figure A 27. Cape Lookout (southwest-beach) Setback Factors

Figure A 28. Core Banks (Cape Lookout to Drum Inlet)

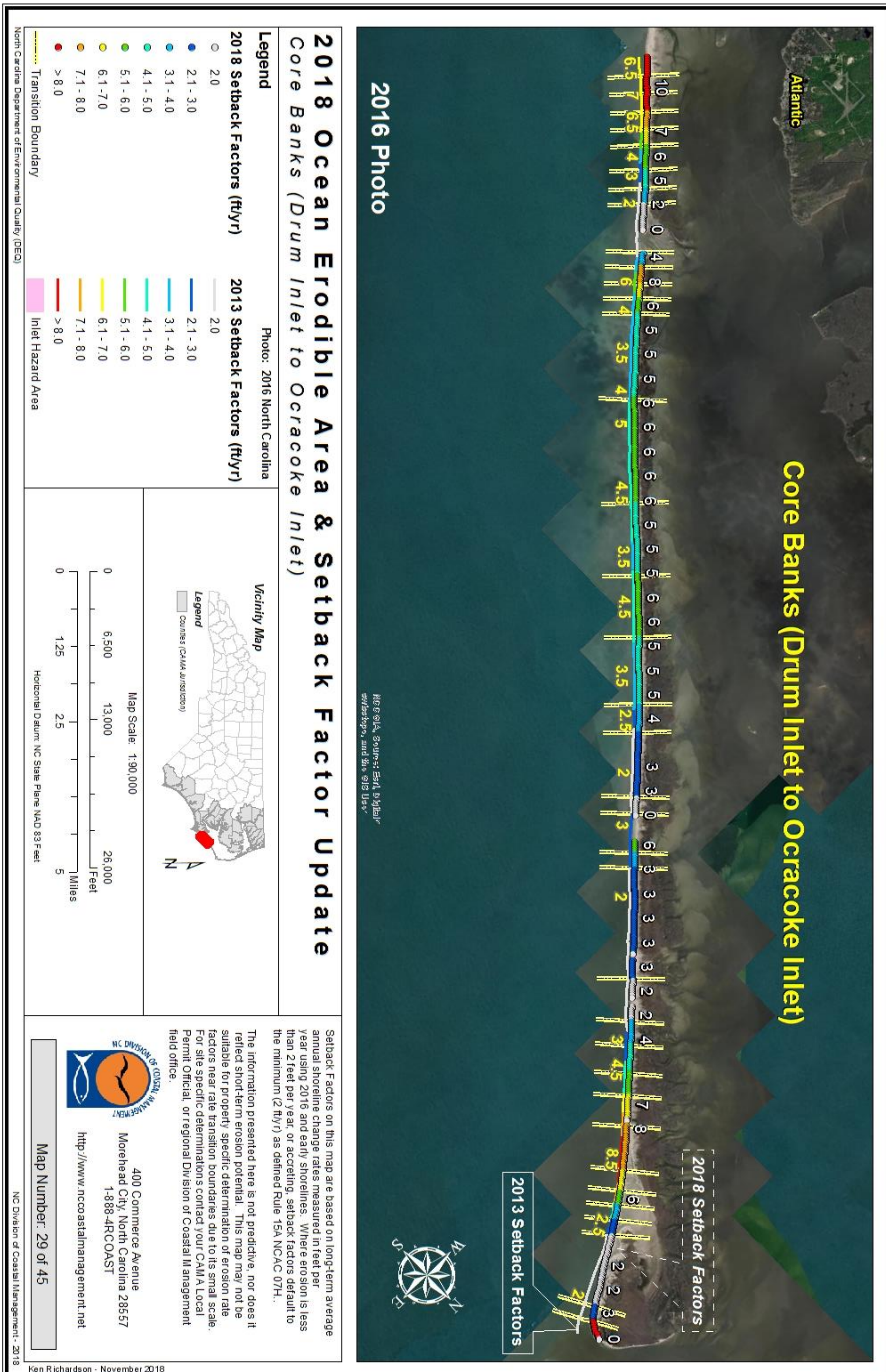

Figure A 29. Core Banks (Drum Inlet to Ocracoke Inlet)

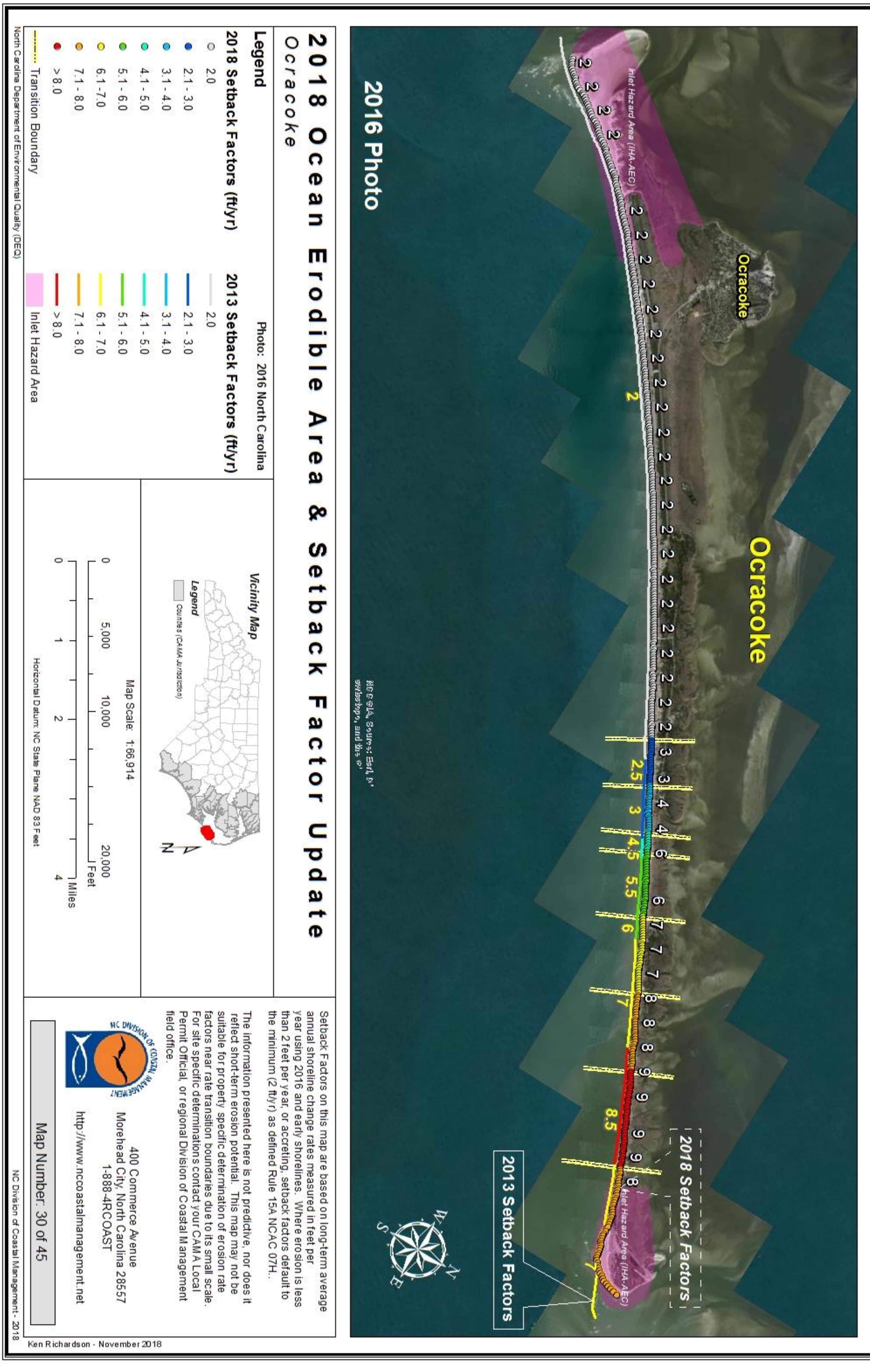

Figure A 30. Ocracoke Setback Factors

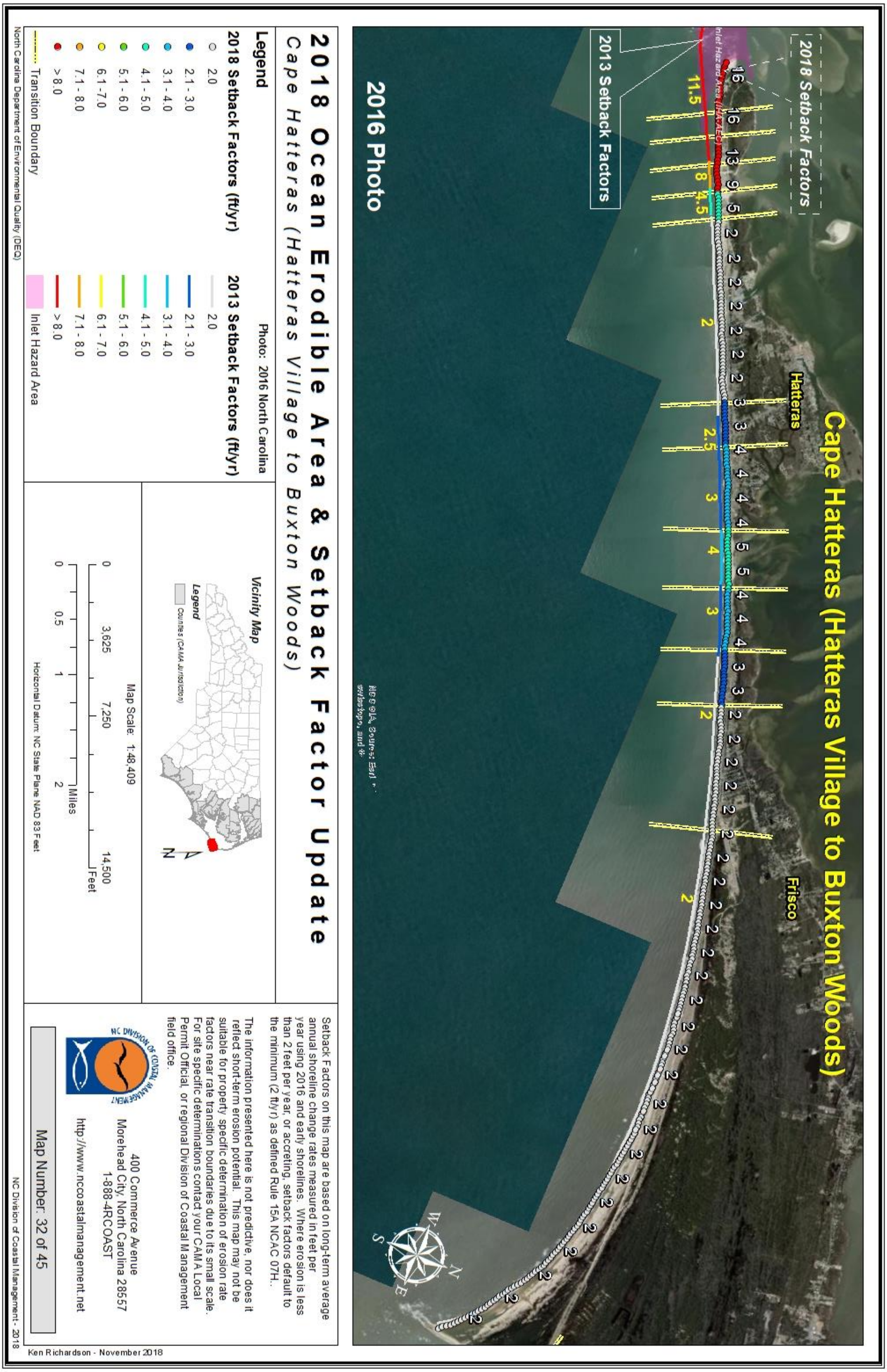

Figure A 31. Cape Hatteras (Hatteras Village to Cape) Setback Factors

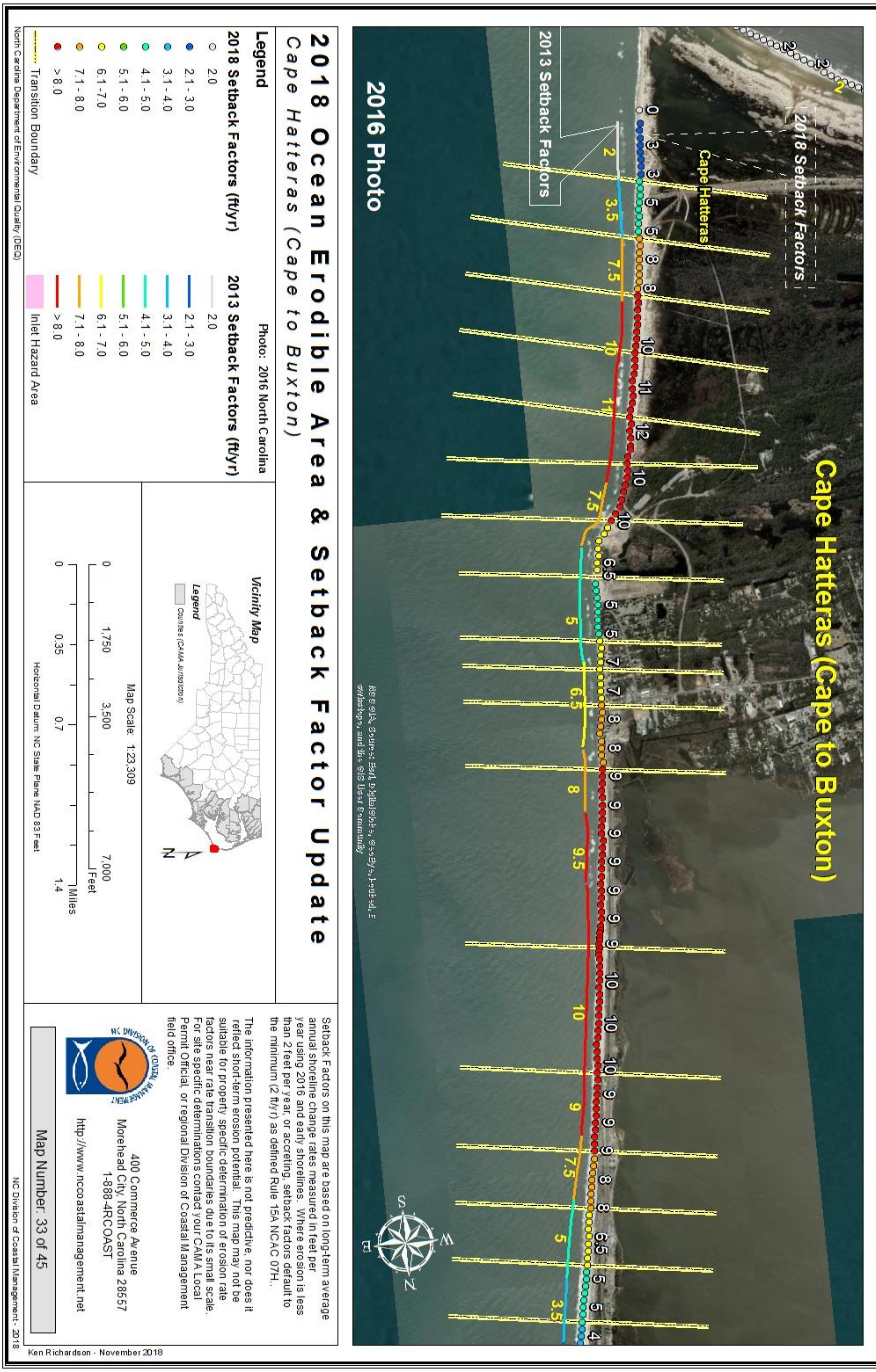

Figure A 32. Cape Hatteras (Cape to Buxton) Setback Factors

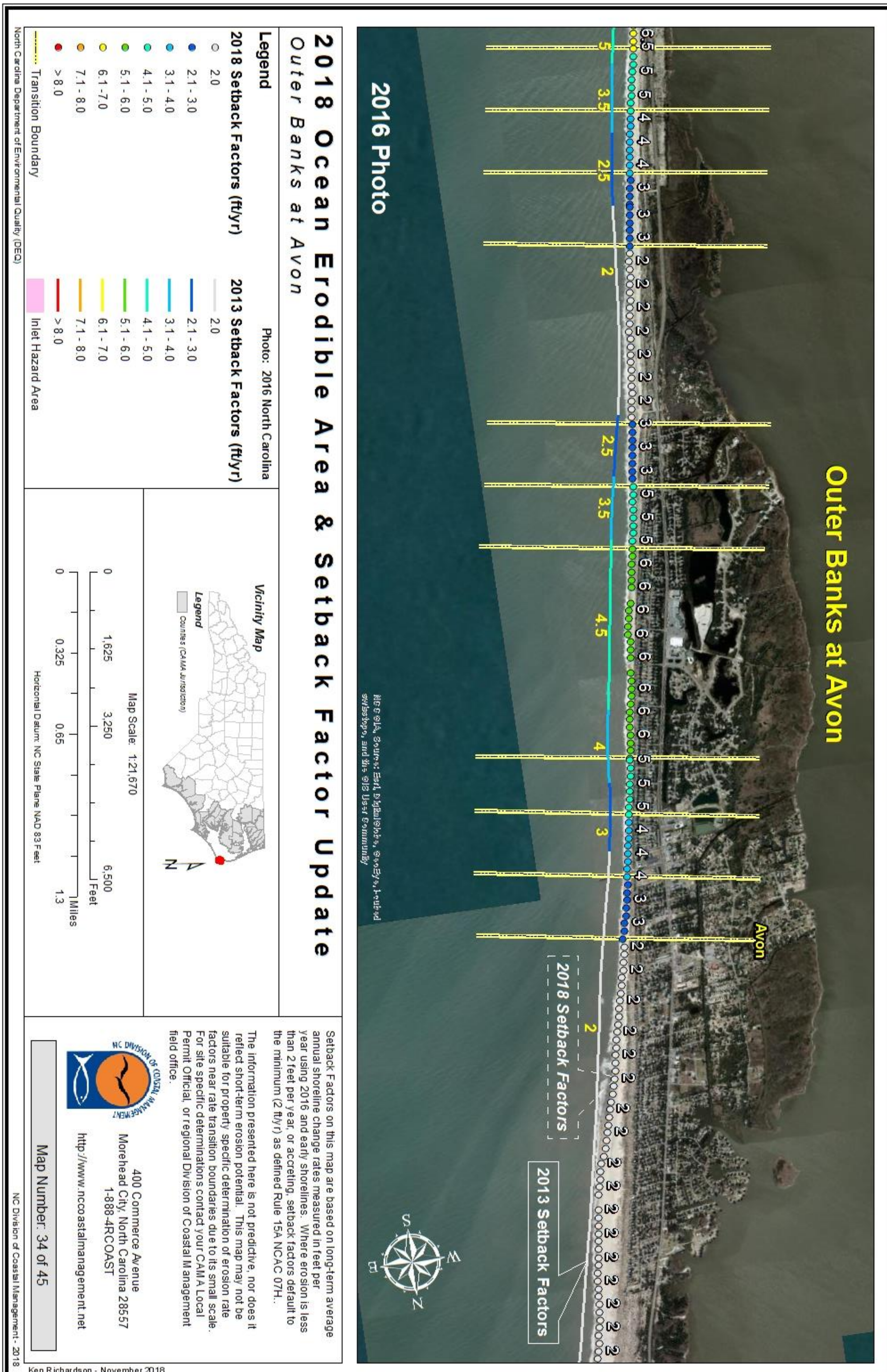

Figure A 33. Outer Banks at Avon

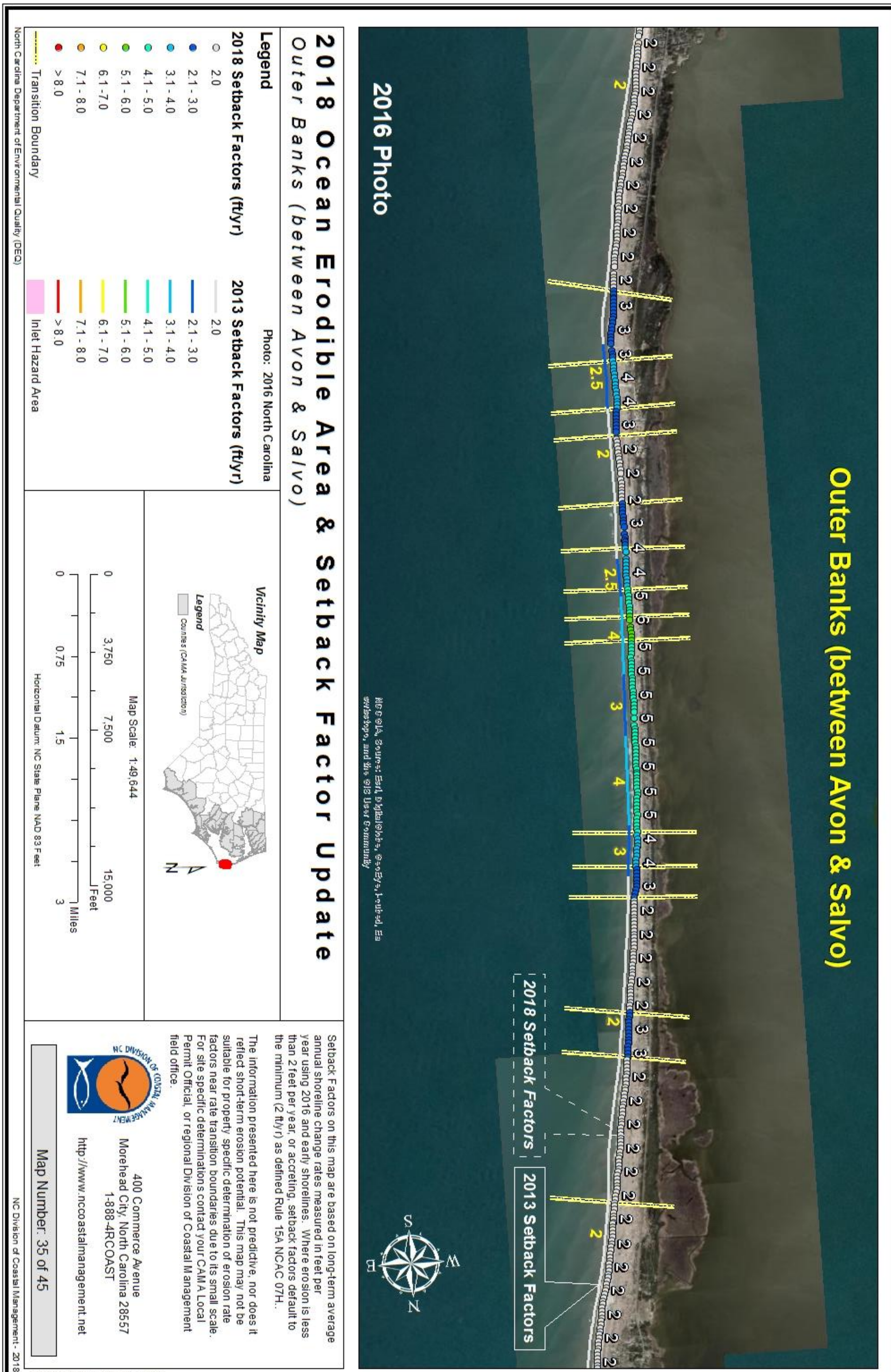

Figure A 34. Outer Banks (between Avon and Salvo) Setback Factors

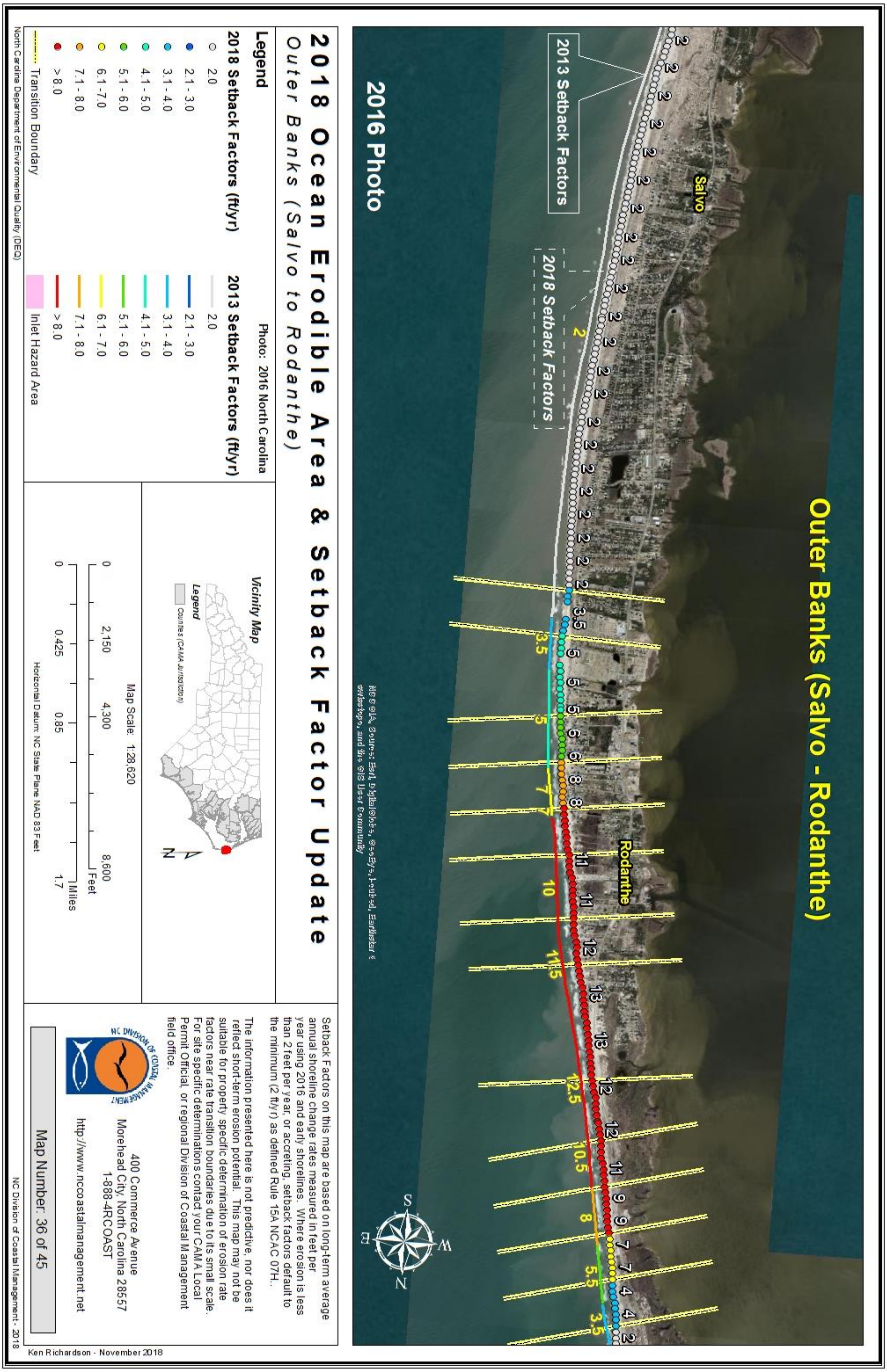

Figure A 35. Outer Banks at Salvo and Rodanthe Setback Factors

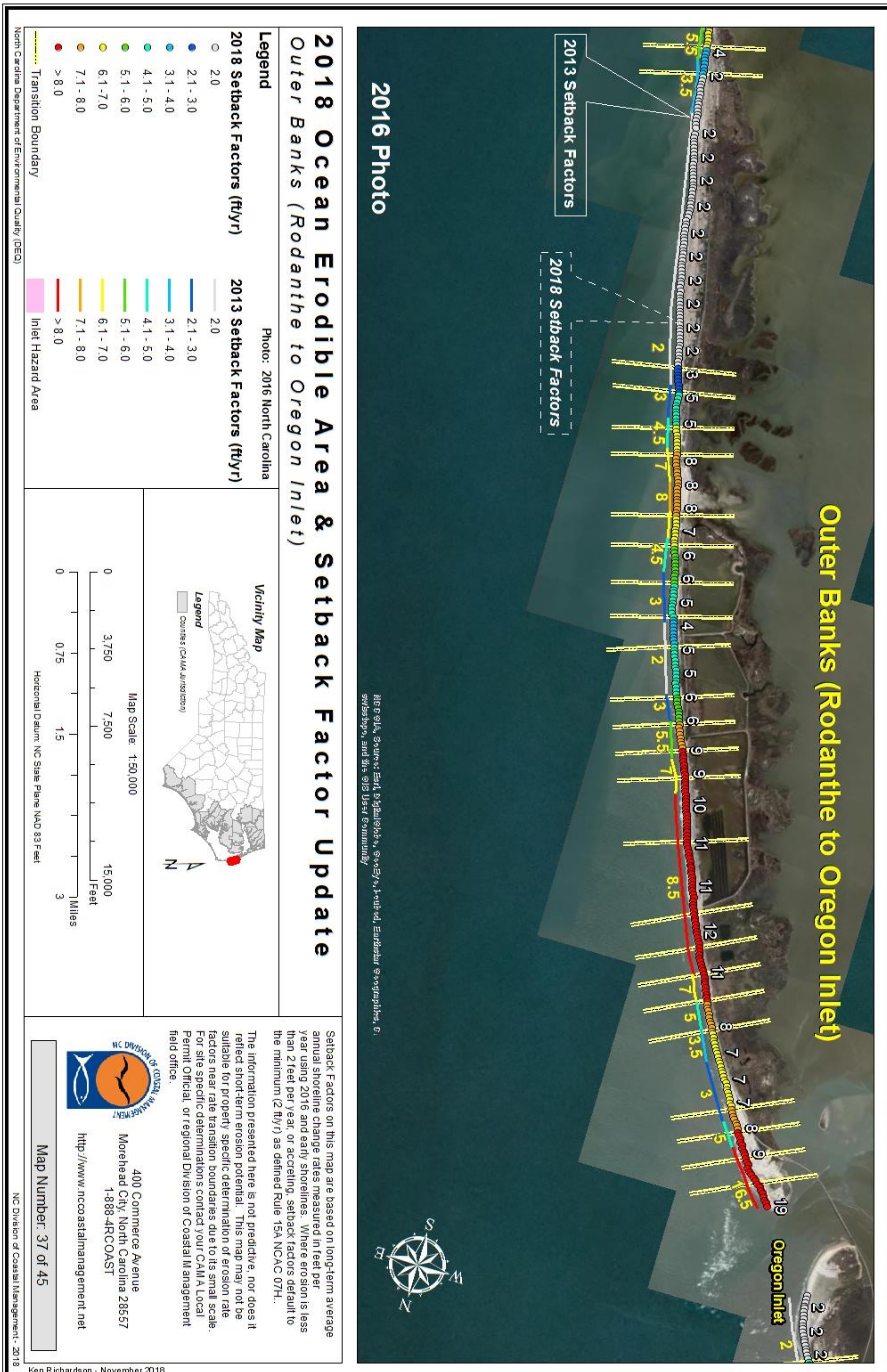

Figure A 36. Outer Banks between Rodanthe and Oregon Inlet (Pea Island) Setback Factors

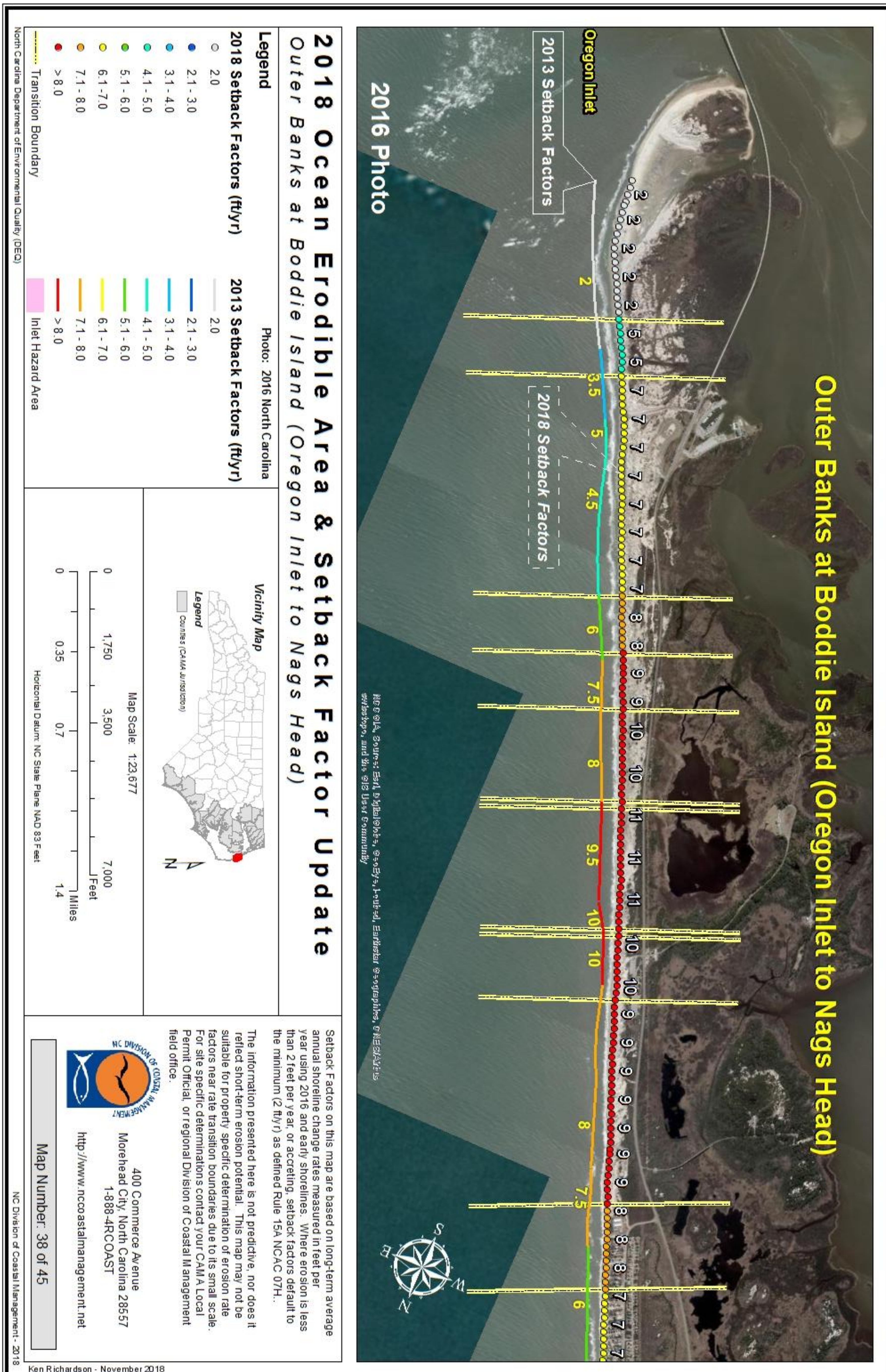

Figure A 37. Outer Banks at Boddie Island Setback Factors

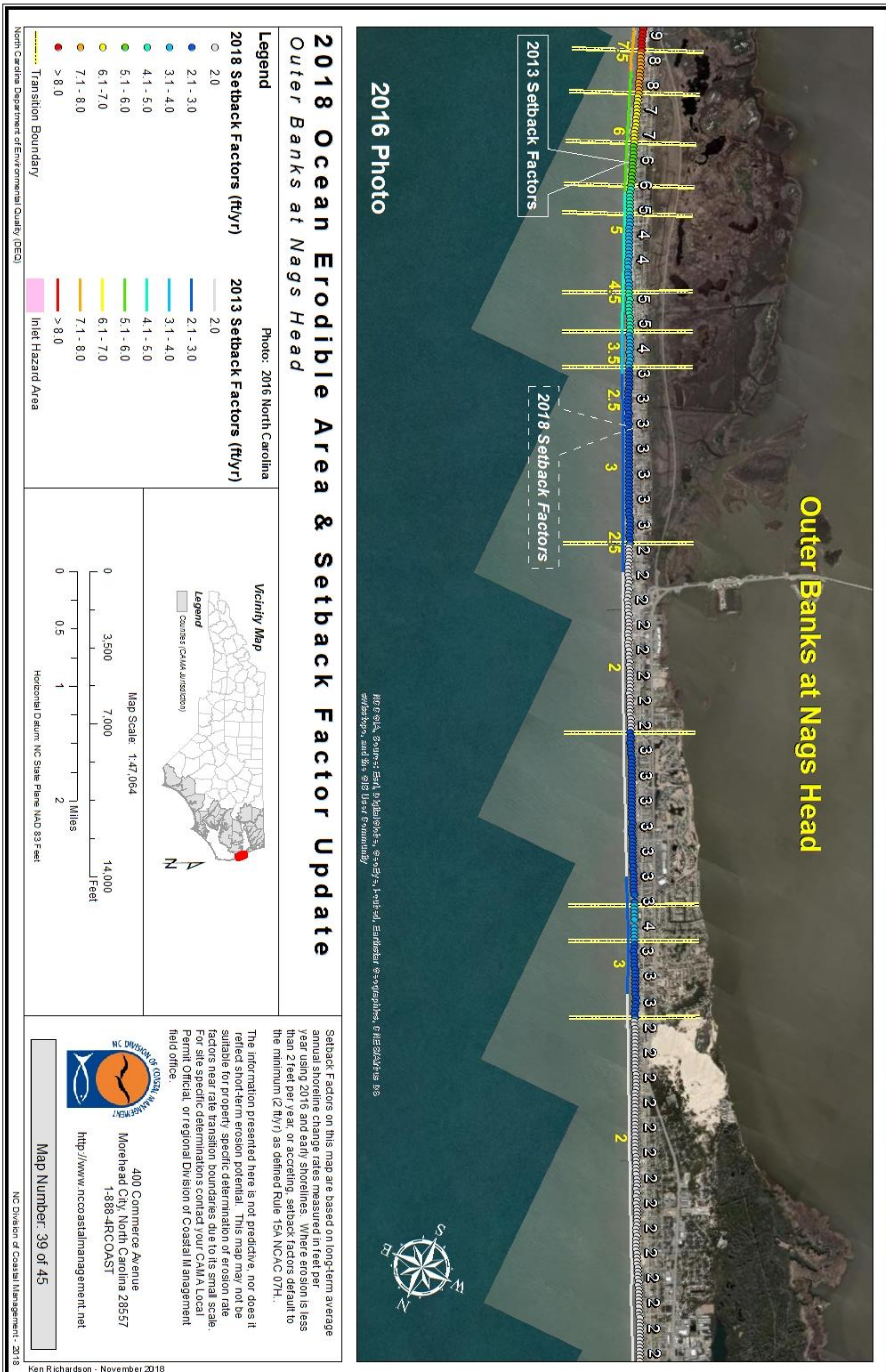

Figure A 38. Outer Banks at Nags Head Setback Factors

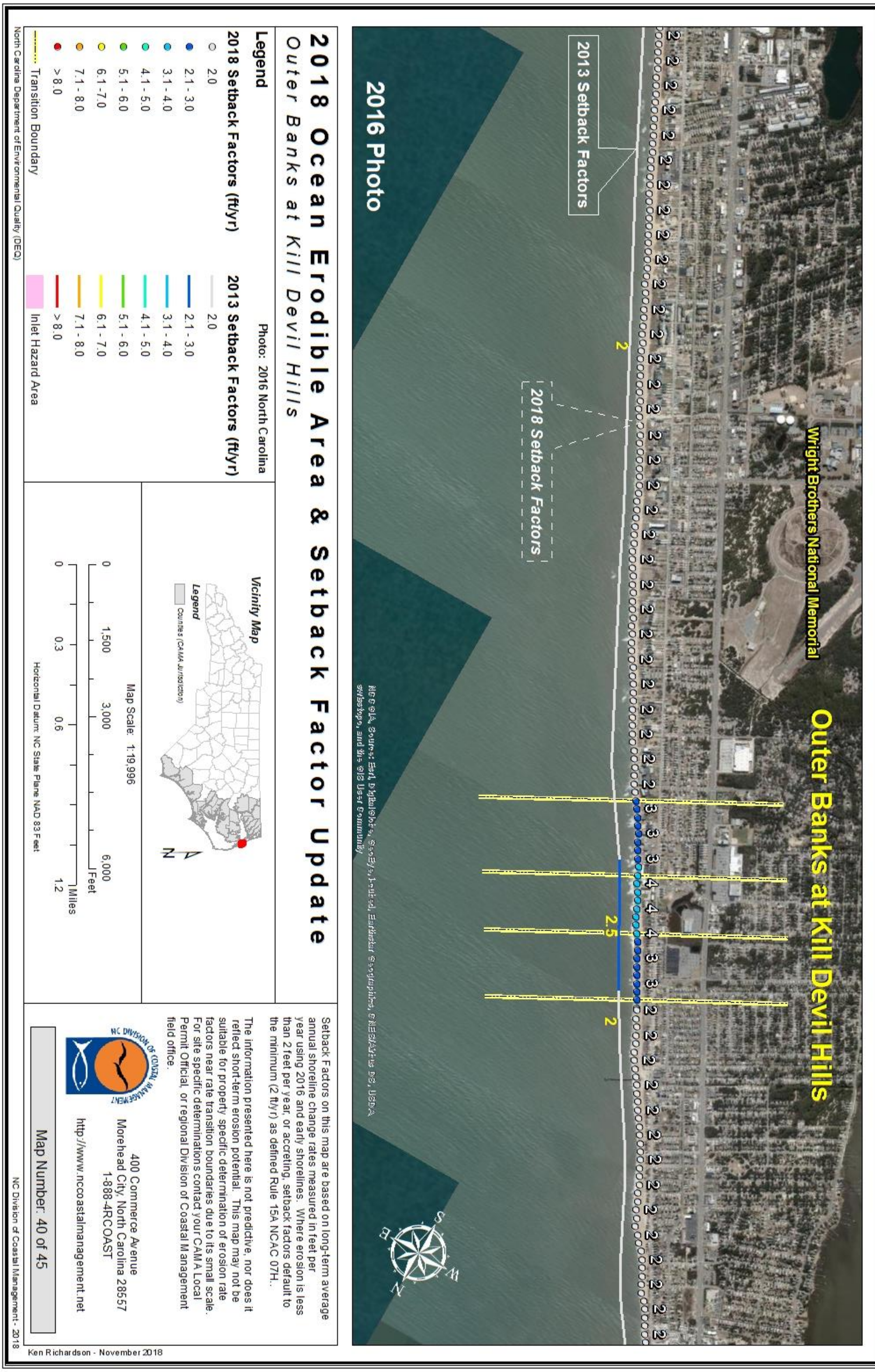

Figure A 39. Outer Banks at Kill Devil Hills Setback Factors

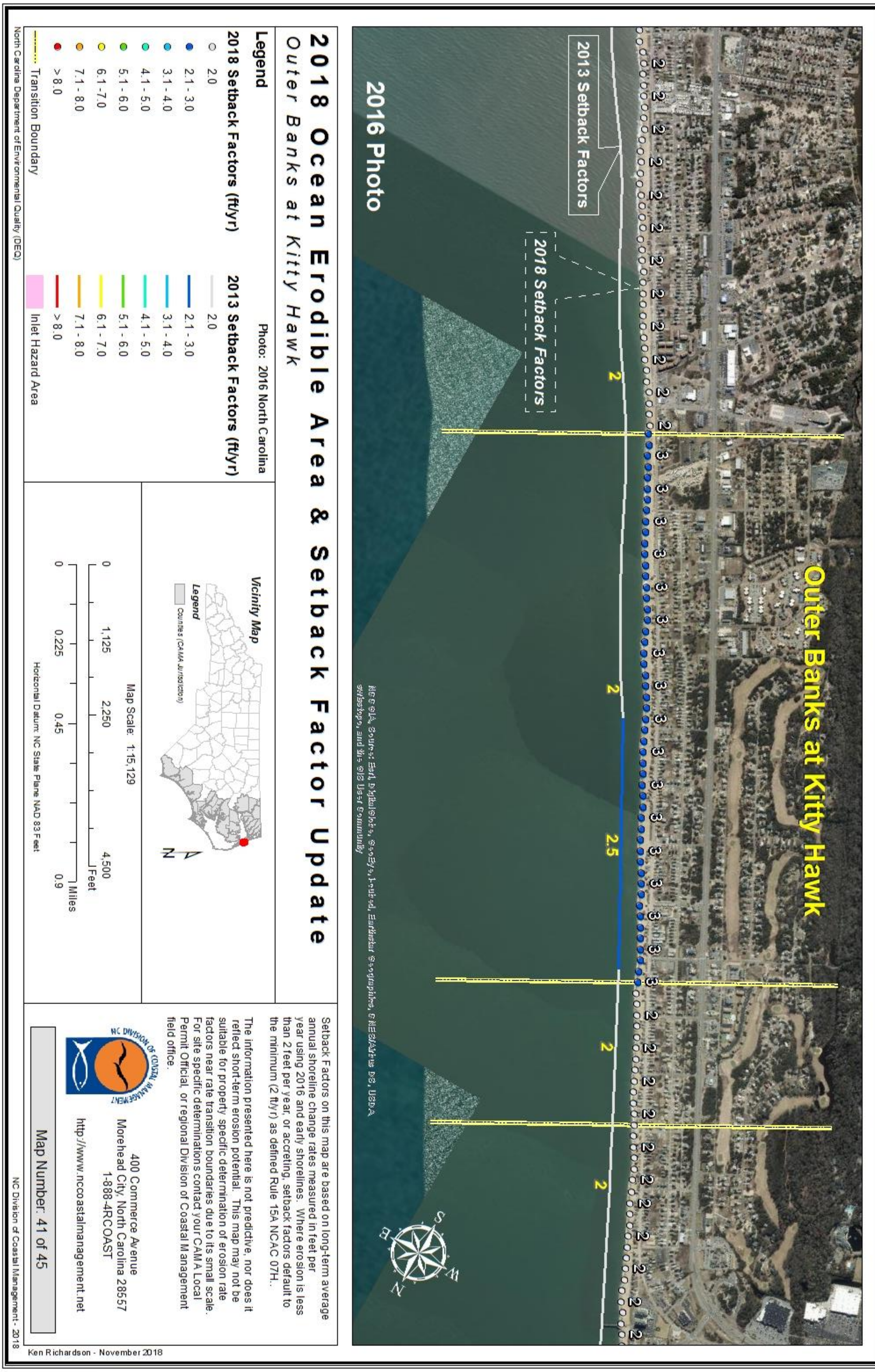

Figure A 40. Outer Banks at Kitty Hawk Setback Factors

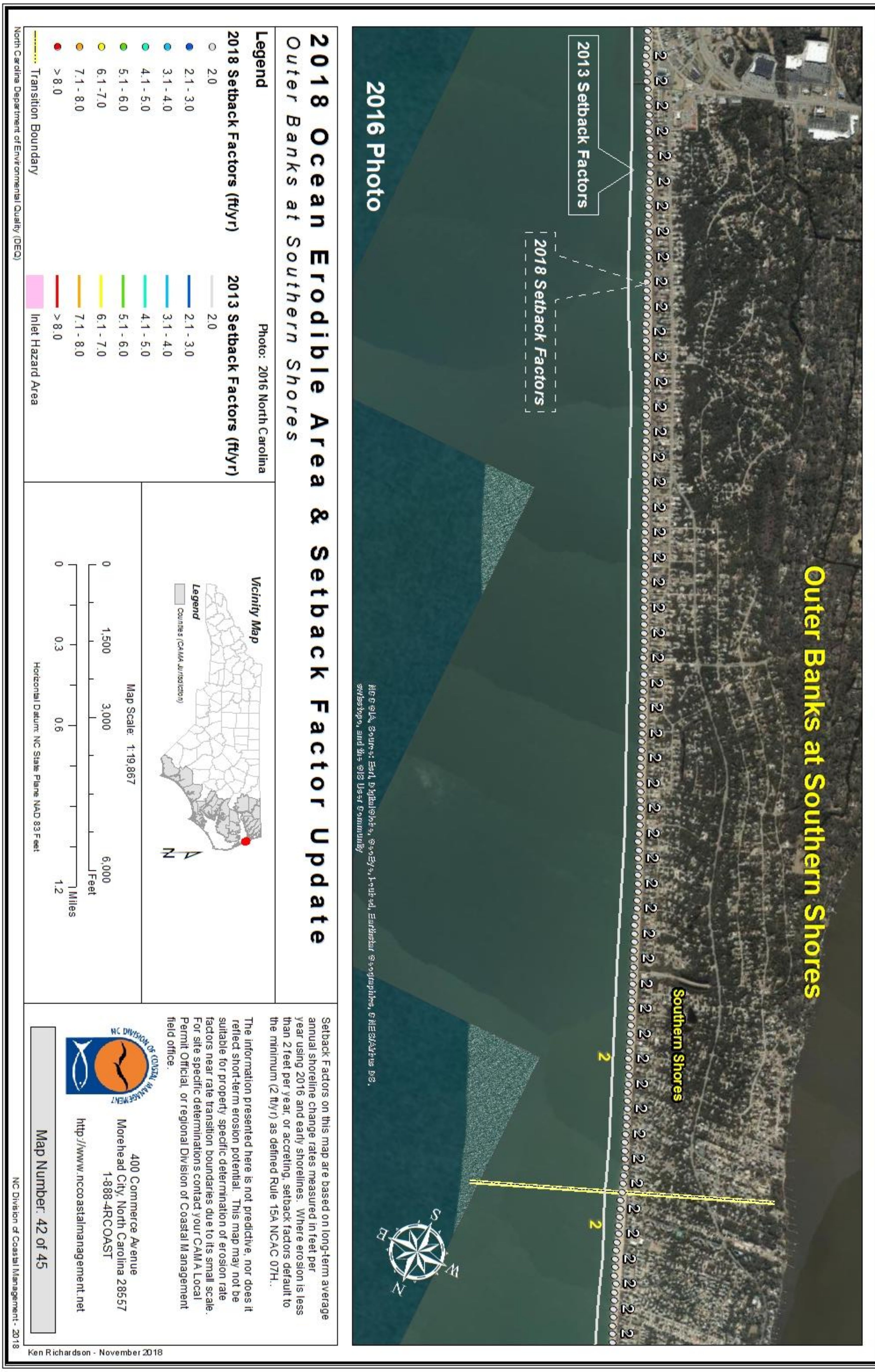

Figure A 41. Outer Banks at Southern Shores Setback Factors

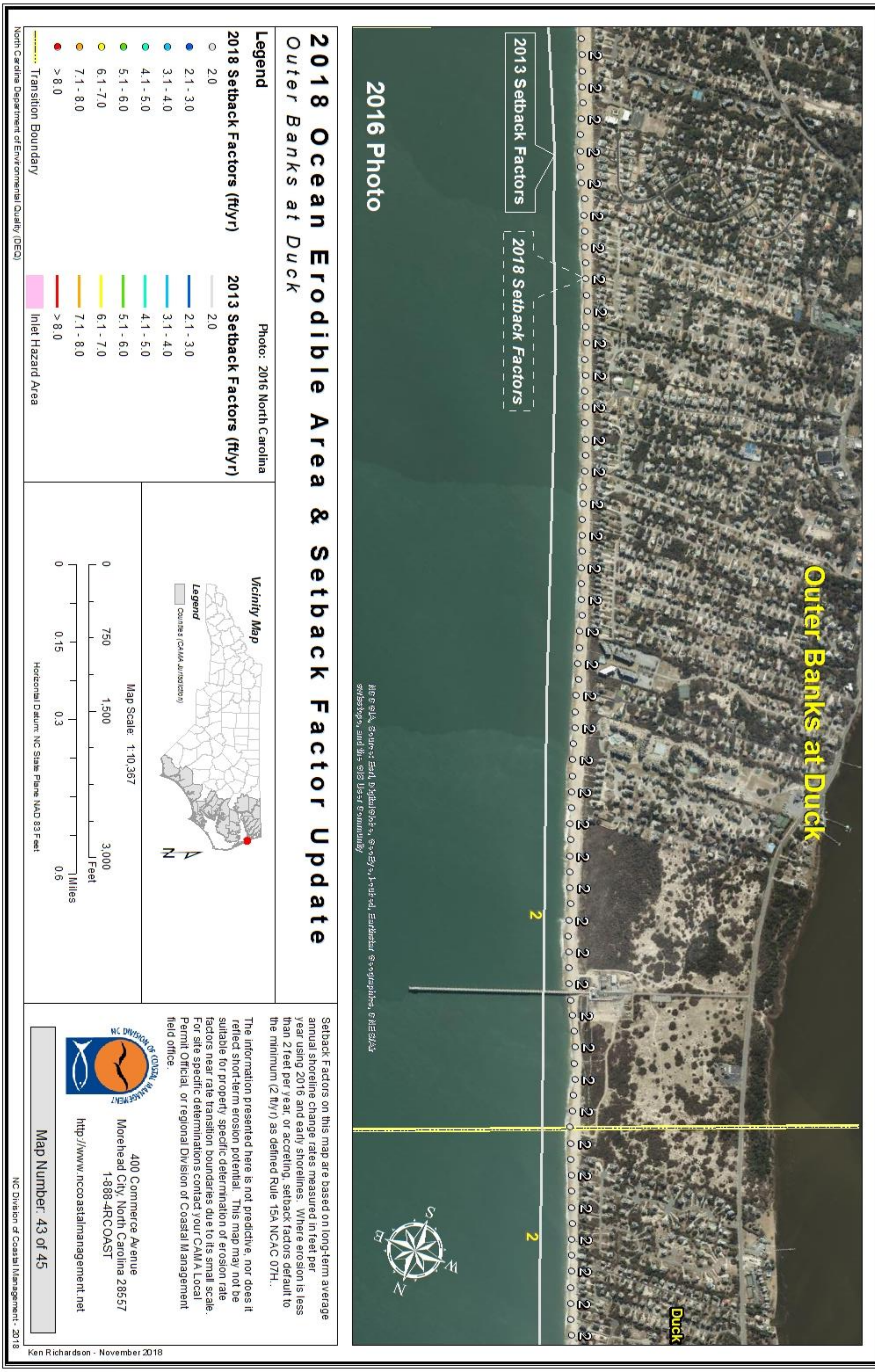

Figure A 42. Outer Banks at Duck Setback Factors

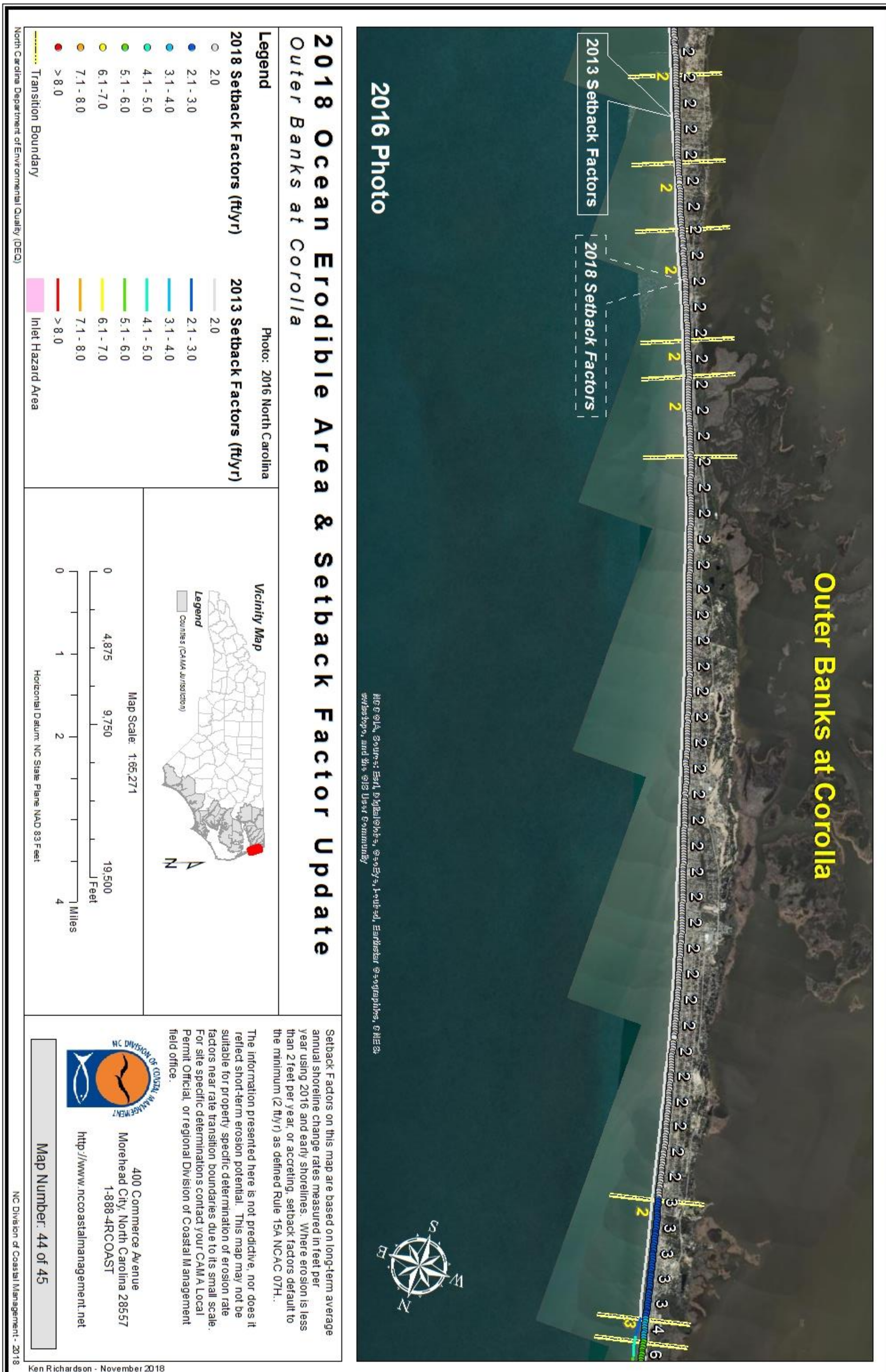

Figure A 43. Outer Banks at Corolla Setback Factors

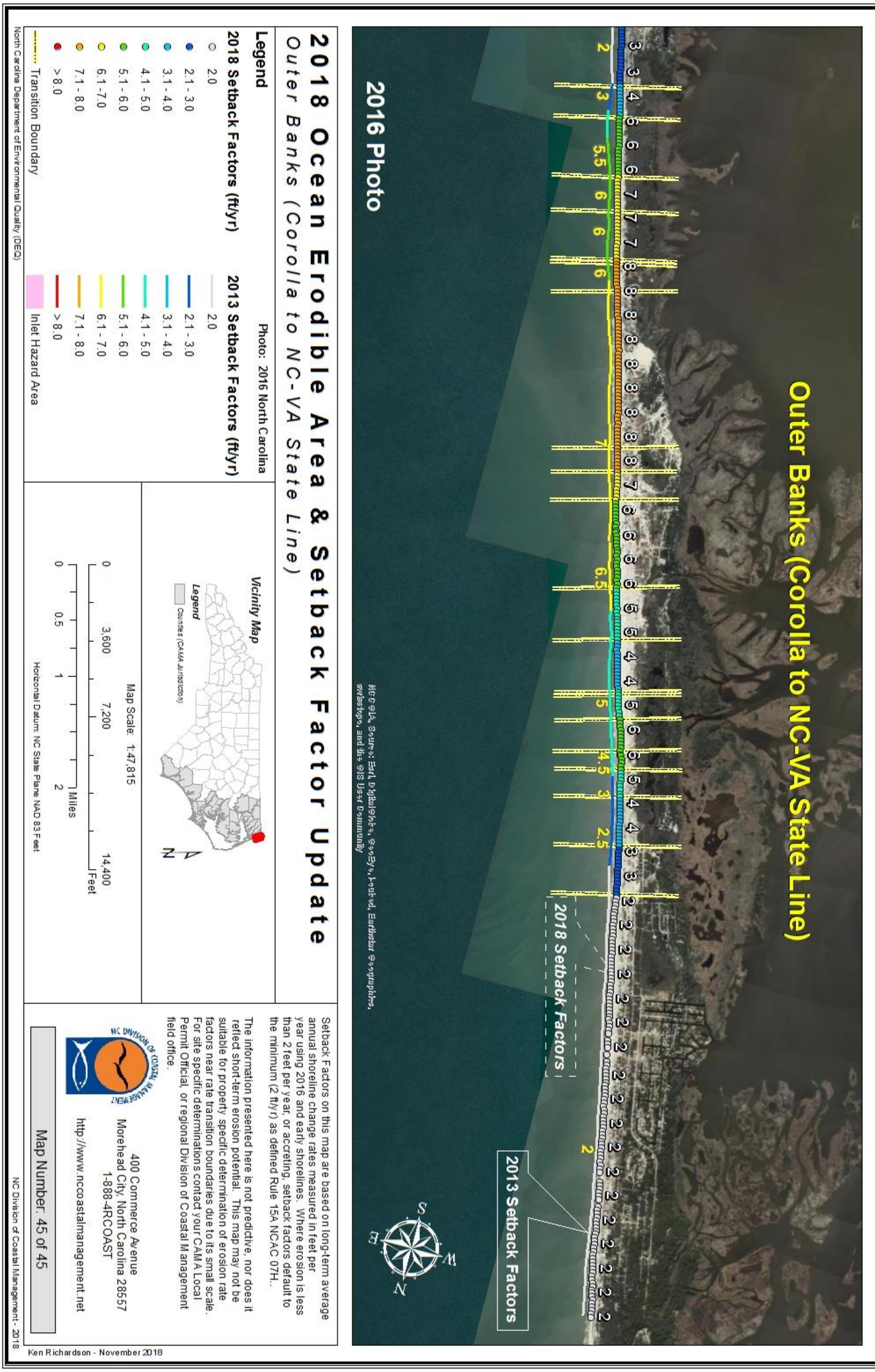

Figure A 44. Outer Banks at Corolla to NC-VA State Line Setback Factors

APPENDIX B: Comparision of Average Annual Long-Term Shoreline Change Rates from 2003, 2011, and 2018 Update Studies Using Early Shoreline and 1998, 2009, and 2016 Shorleines

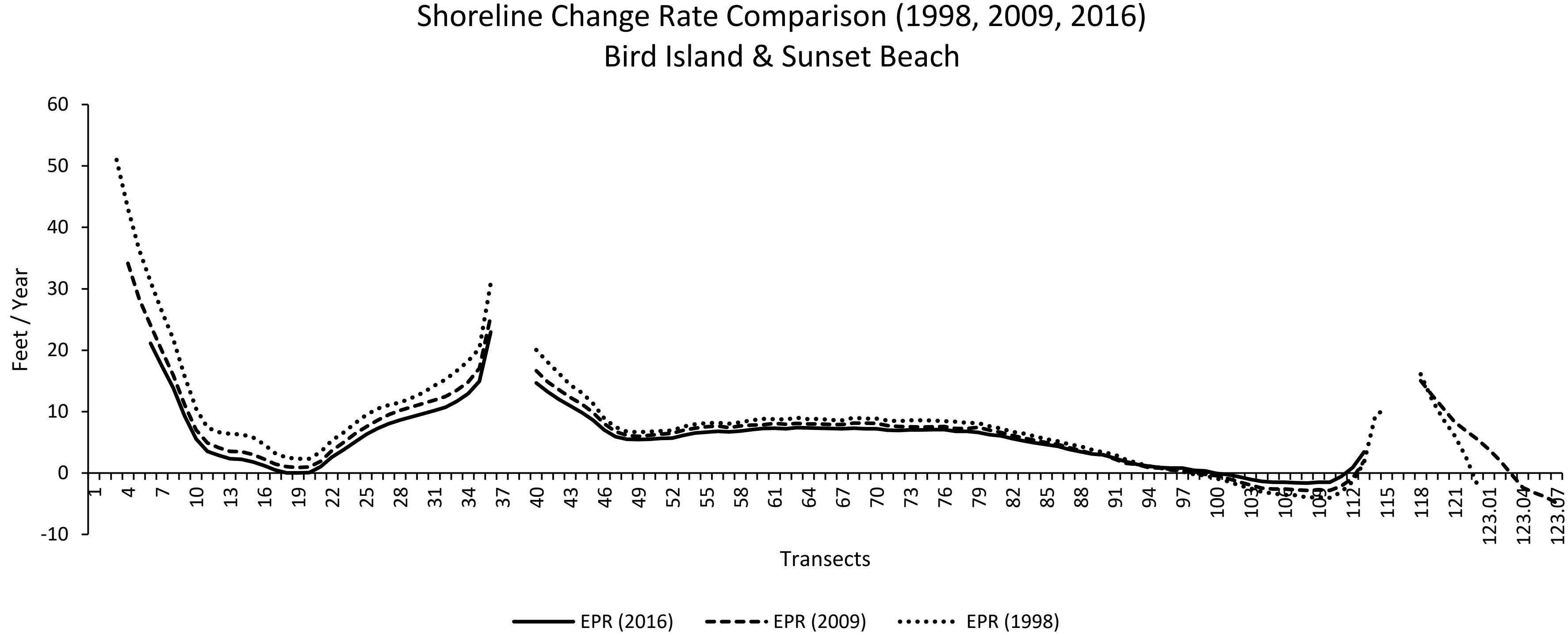

Figure B1. Shoreline change rate comparison at Sunset Beach using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented west to east, Little River Inlet of left-side, Madd Inlet (now closed) at transects 35-40 and Tubbs Inlet or right-side. Transect numbers correspond to those labeled on map in the results summary section.

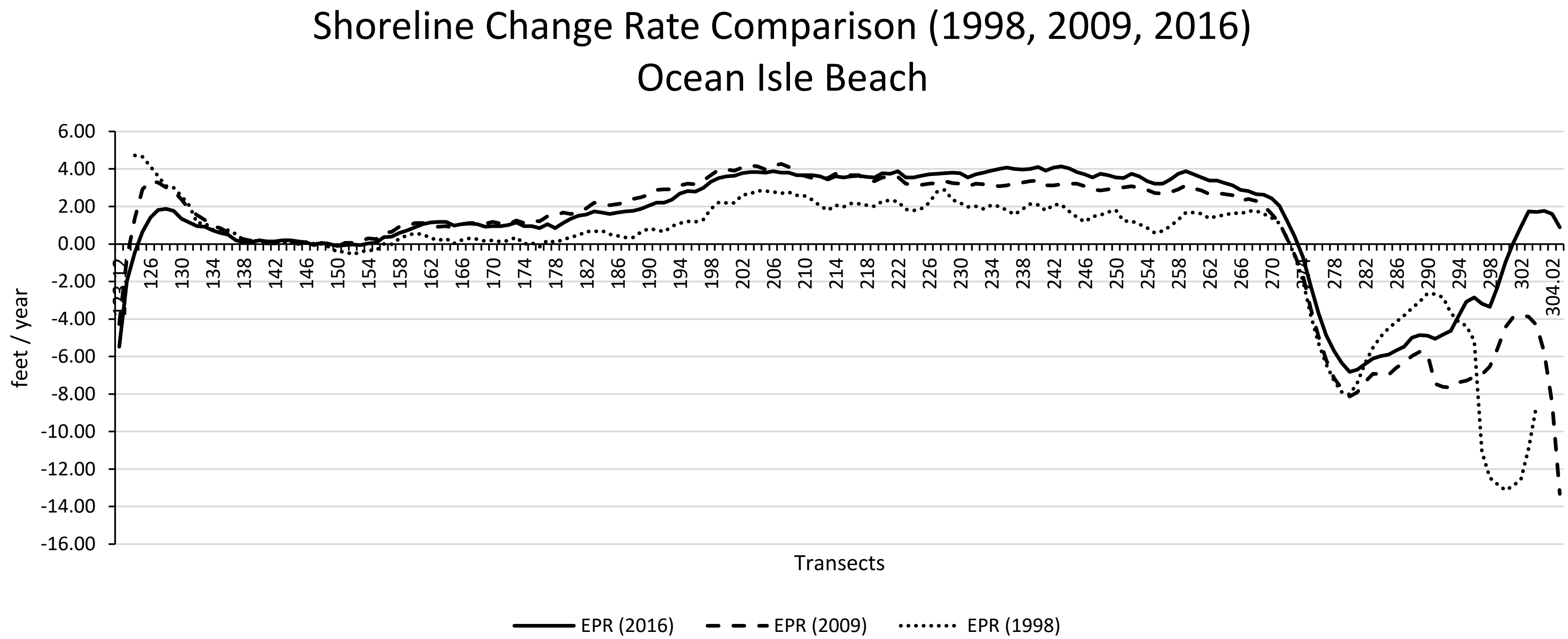

Figure B2. Shoreline change rate comparison at Ocean Isle using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented west to east, Tubbs Inlet on graph's lest side, Shallotte Inlet on right-side. Transect numbers correspond to those labeled on map in the results summary section.

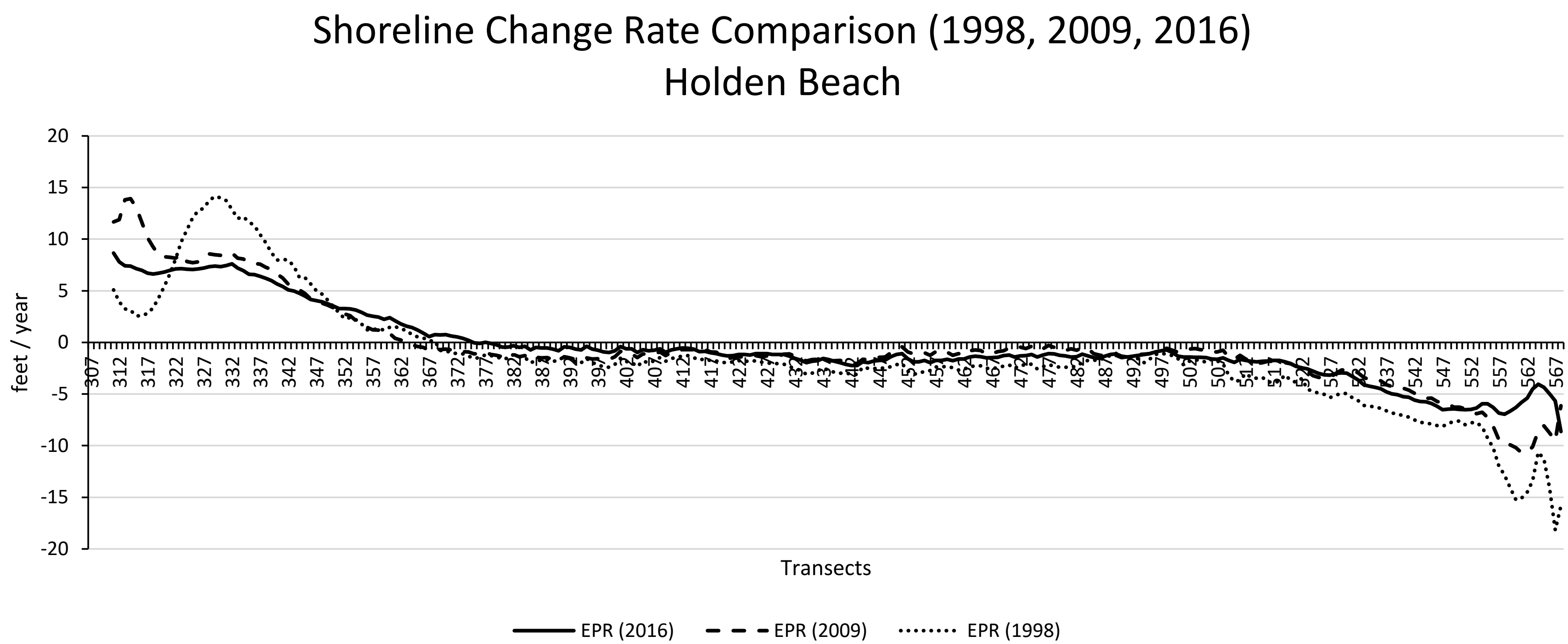

Figure B3. Shoreline change rate comparison at Holden Beach using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented west to east with Shallotte Inlet on left-side and Lockwood Folly Inlet on right-side. Transect numbers correspond to those labeled on map in the results summary section.

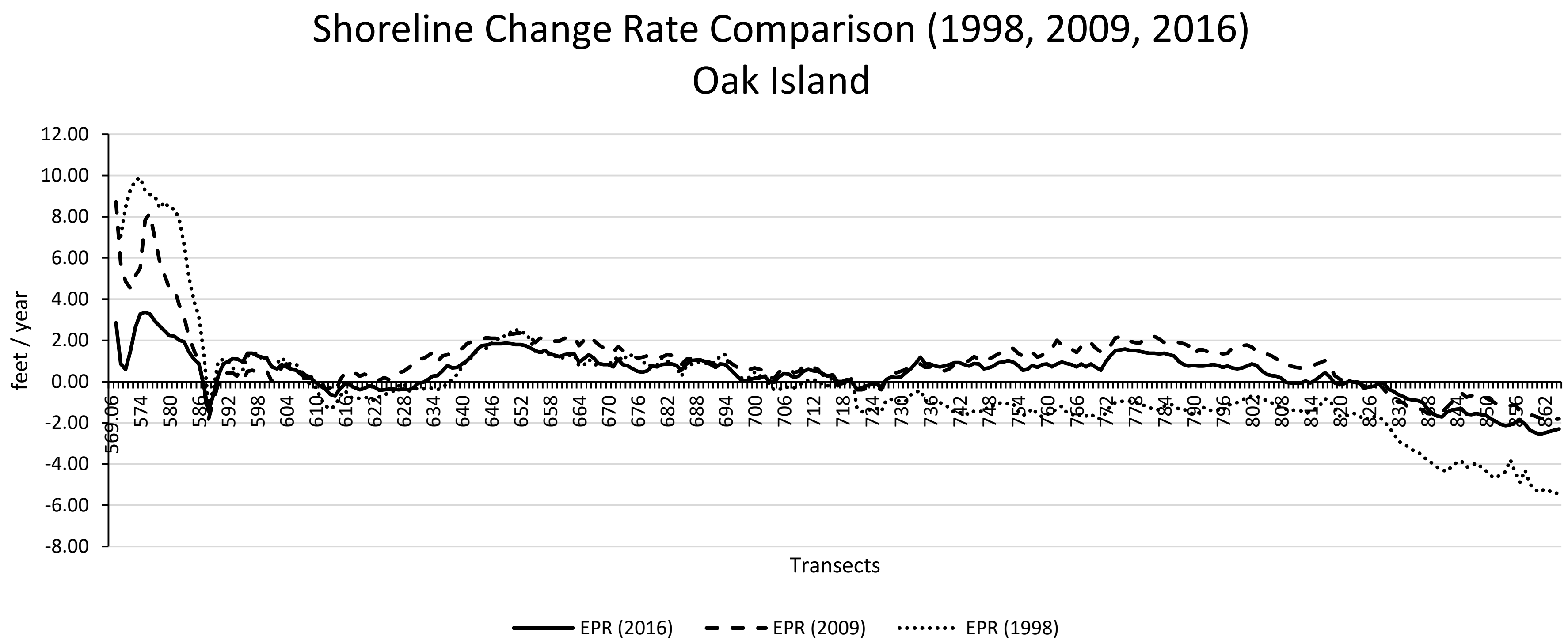

Figure B4. Shoreline change rate comparison at Oak Island using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from west to east with Lockwood Folly Inlet on left-side and Oak Island-Caswell Beach Town Limits on right-side. Transect numbers correspond to those labeled on map in the results summary section.

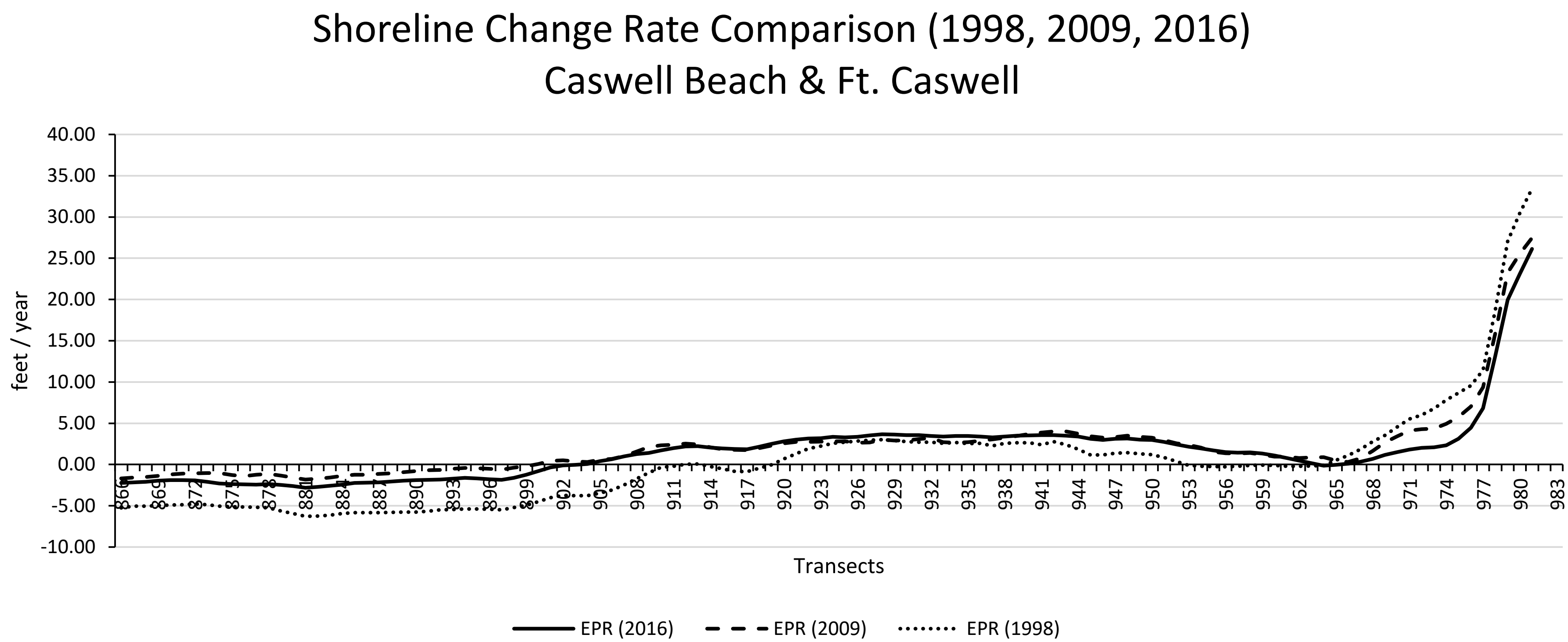

Figure B5. Shoreline change rate comparison at Caswell Beach and Fort Caswell using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from west to east with Oak Island-Caswell Beach Town Limits on left-side and Cape Fear Inlet on right-side. Transect numbers correspond to those labeled on map in the results summary section.

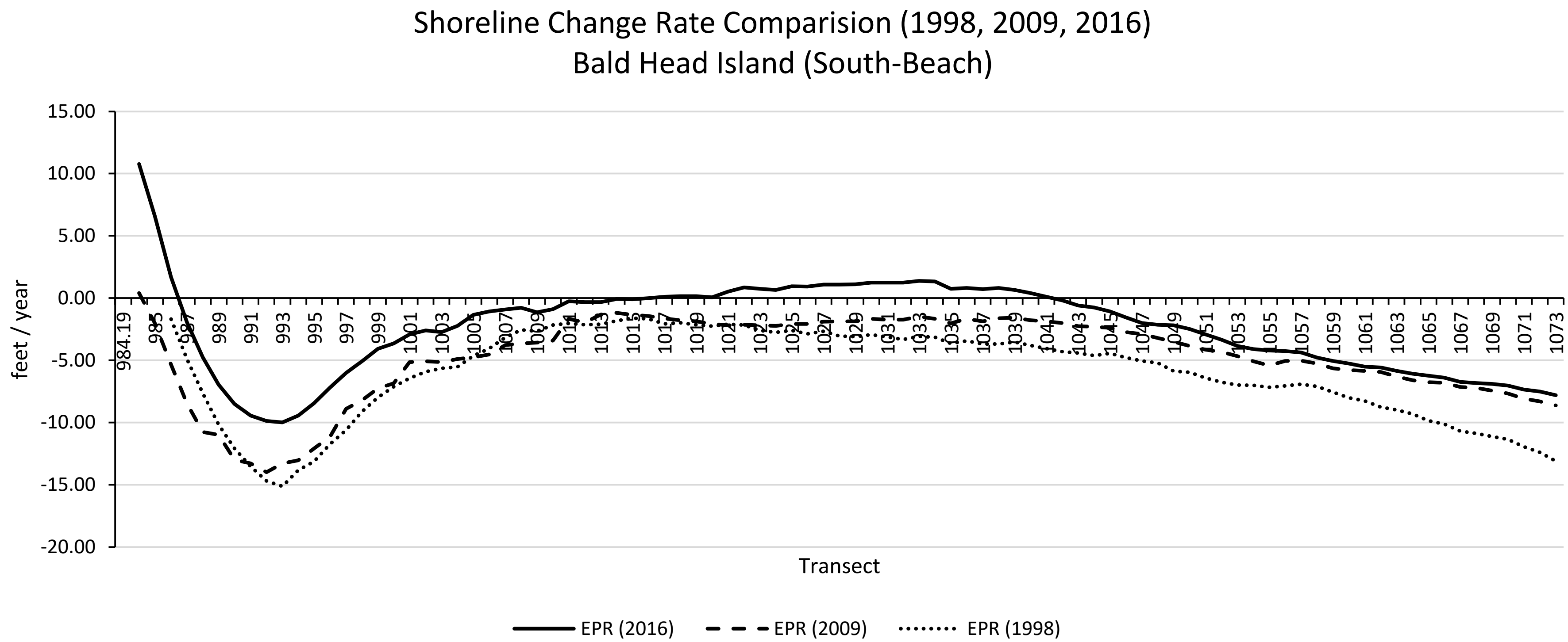

Figure B6. Shoreline change rate comparison at Bald Head Island (south-beach) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented with Cape Fear Inlet on graph's left-side and Cape Fear on south-beach on right-side. Transect numbers correspond to those labeled on map in the results summary section.

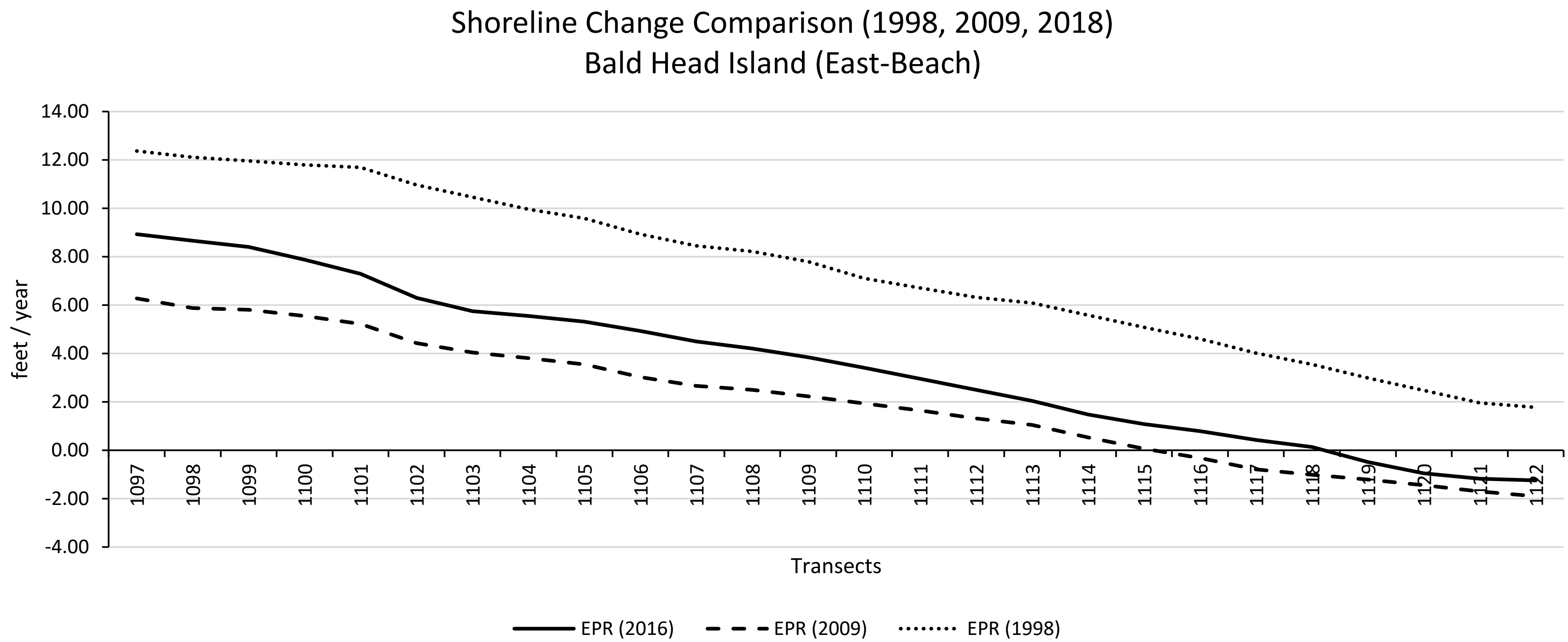

Figure B7. Shoreline change rate comparison at Bald Head Island (east-beach) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented with Cape Fear on left-side and Bald Head Island limits on right-side. Transect numbers correspond to those labeled on map in the results summary section.

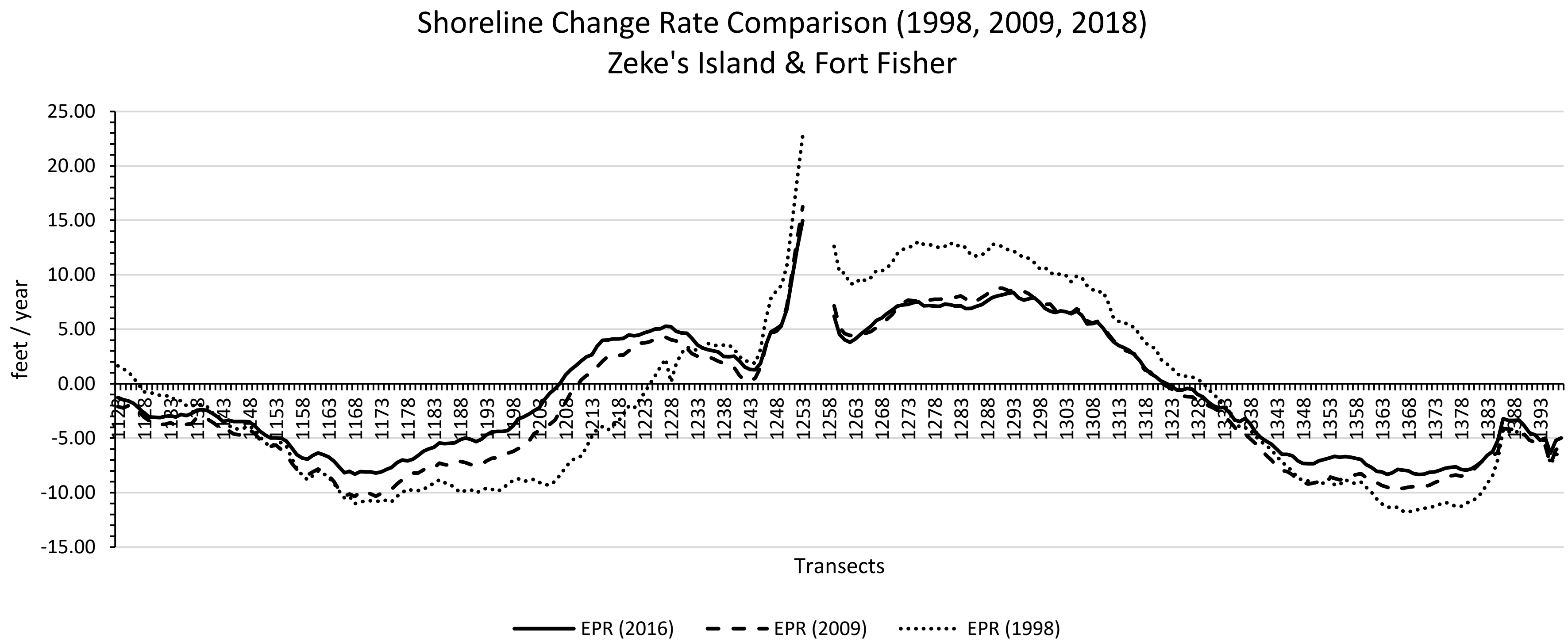

Figure B8. Shoreline change rate comparison at Zeke's Island and Fort Fisher State Park using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from south (left-side) to north (right-side). Data gap reflects former Corncake Inlet location. Transect numbers correspond to those labeled on map in the results summary section.

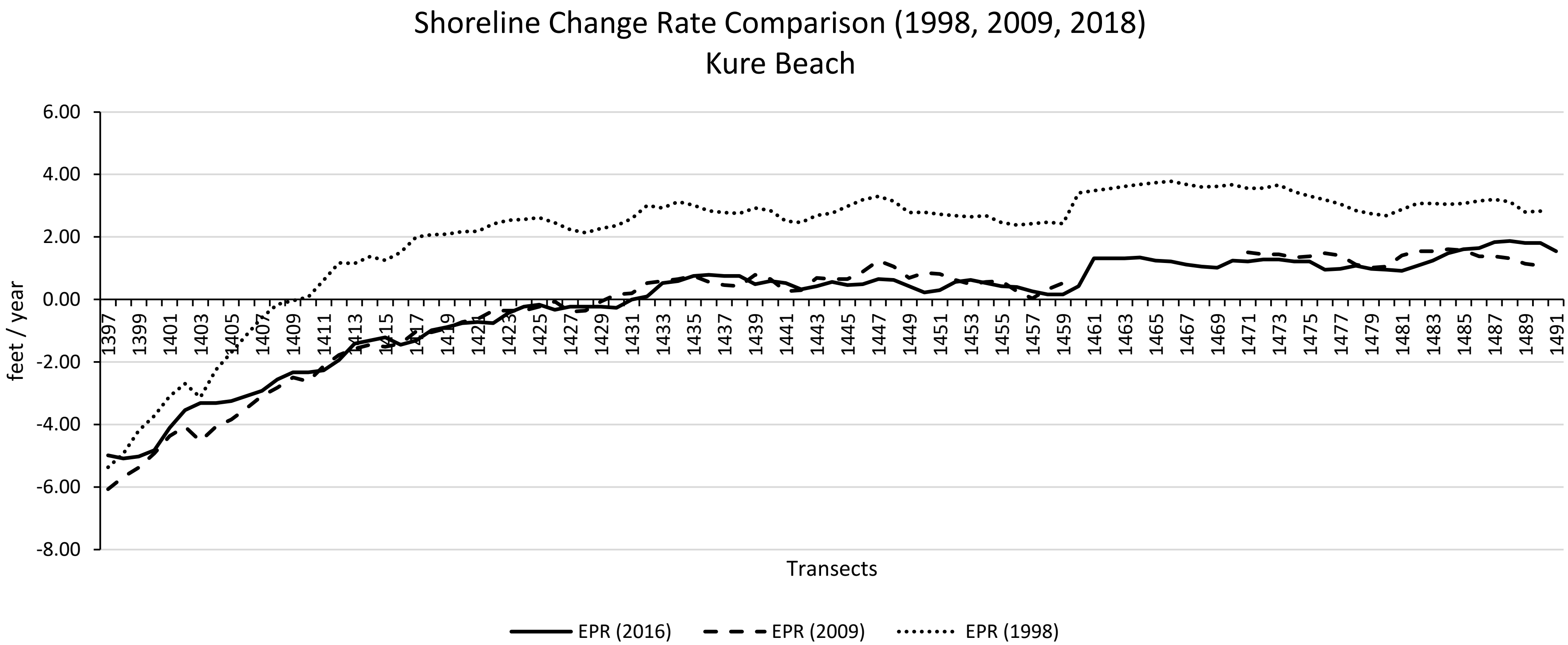

Figure 99. Shoreline change rate comparison at Kure Beach using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from south (left-side) to north (right-side) ending at Kure Beach and Carolina Beach Town Limits. Transect numbers correspond to those labeled on map in the results summary section.

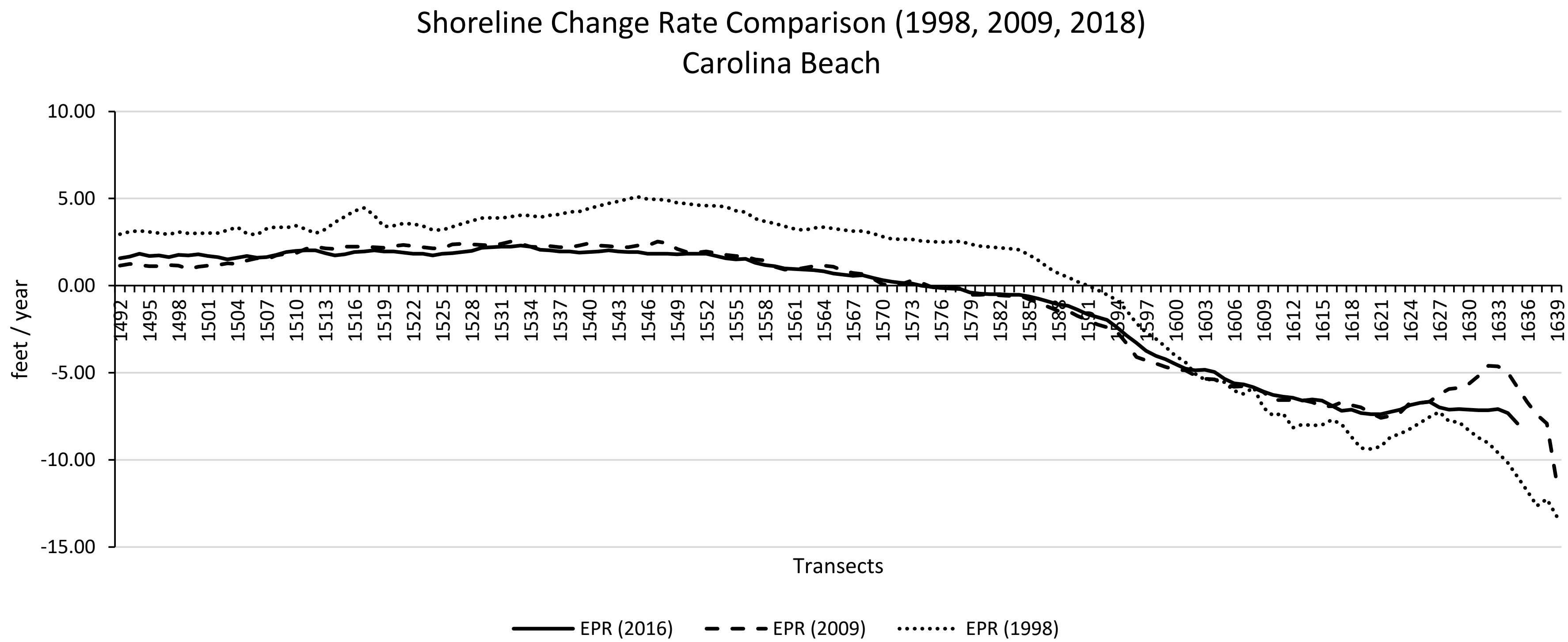

Figure B10. Shoreline change rate comparison at Carolina Beach using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from south (left-side) to north (right-side) ending at Carolina Beach Inlet. Transect numbers correspond to those labeled on map in the results summary section.

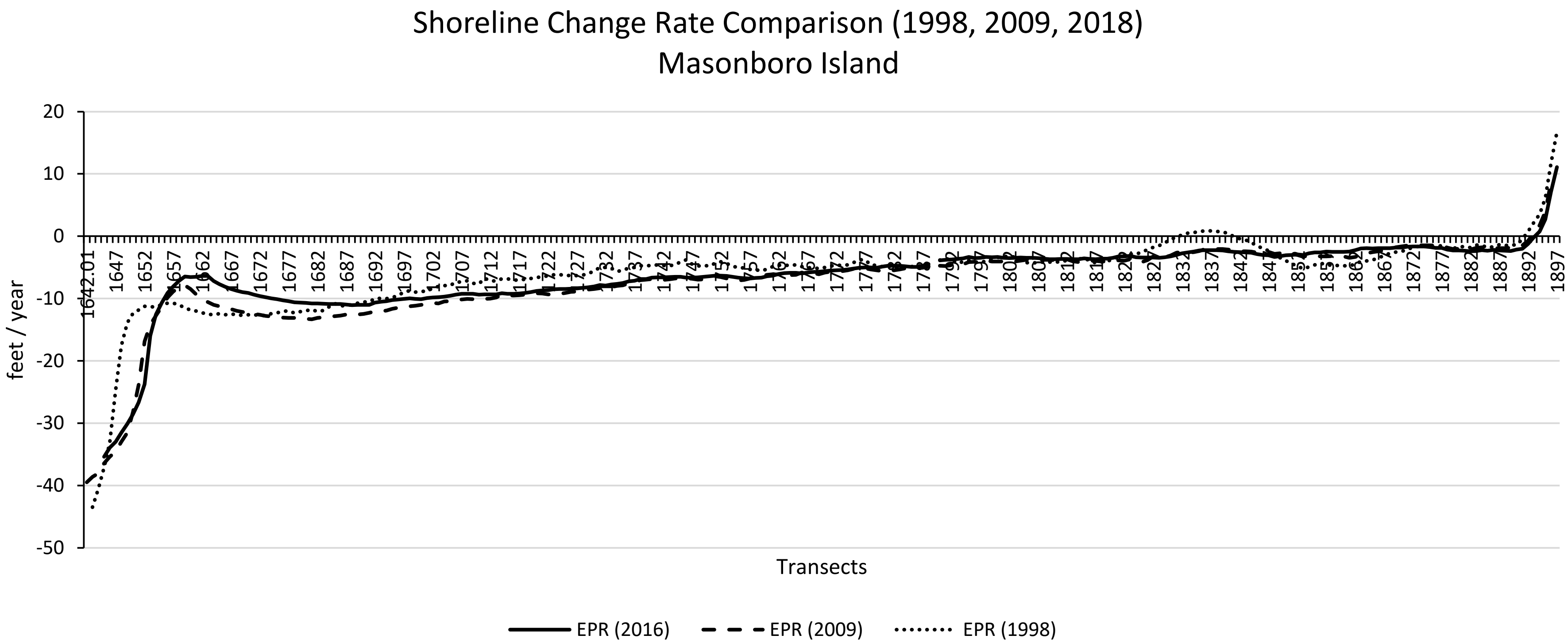

Figure B11. Shoreline change rate comparison at Masonboro Island using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Carolina Beach Inlet (graph left-side) to Masonboro Inlet (graph-right side). Transect numbers correspond to those labeled on map in the results summary section.

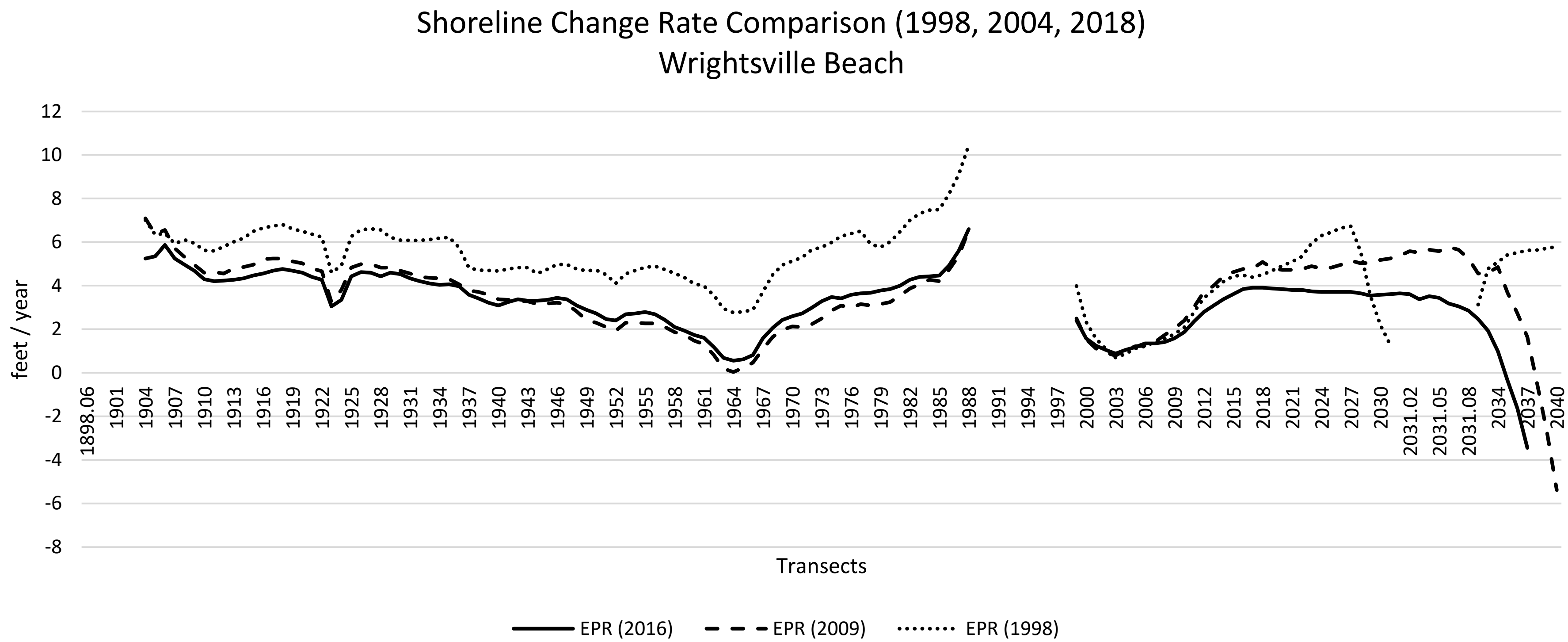

Figure B12. Shoreline change rate comparison at Wrightsville Beach using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Masonboro Inlet (graph left-side) to Mason Inlet (graph right-side). The data gap between transects 1988 and 1998 is the former location of Moore's Inlet. Transect numbers correspond to those labeled on map in the results summary section.

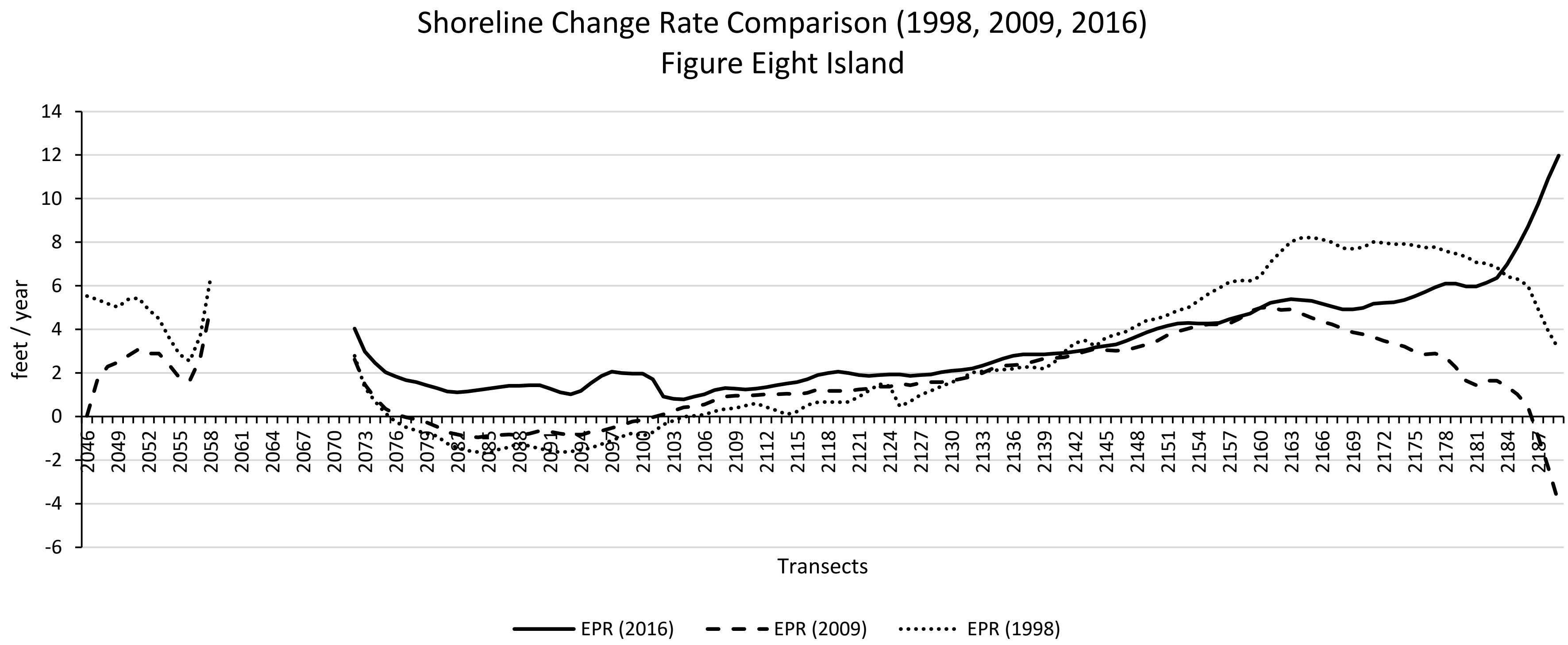

Figure B13. Shoreline change rate comparison at Figure Eight Island using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Mason Inlet (graph left-side) to Rich Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

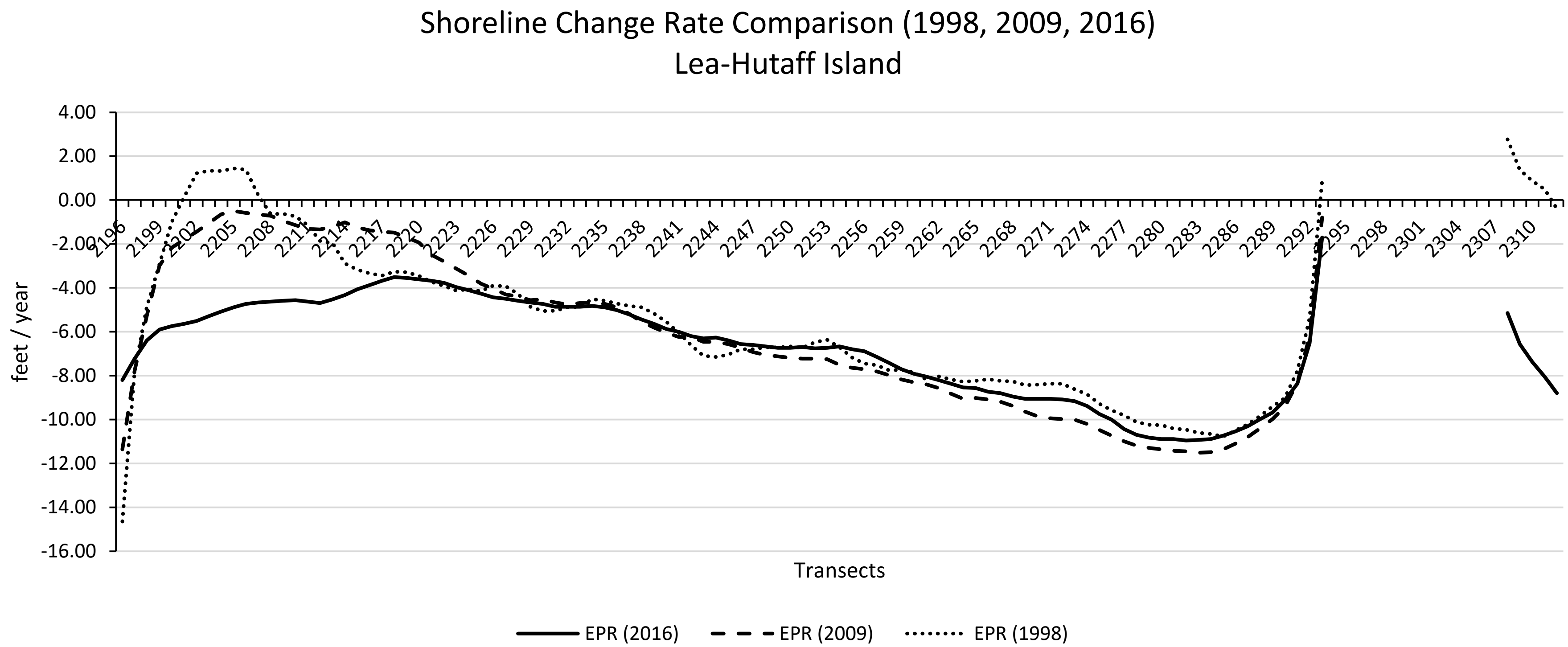

Figure B14. Shoreline change rate comparison at Lea-Hutaff Island using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Rich Inlet (graph left-side) to New Topsail Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

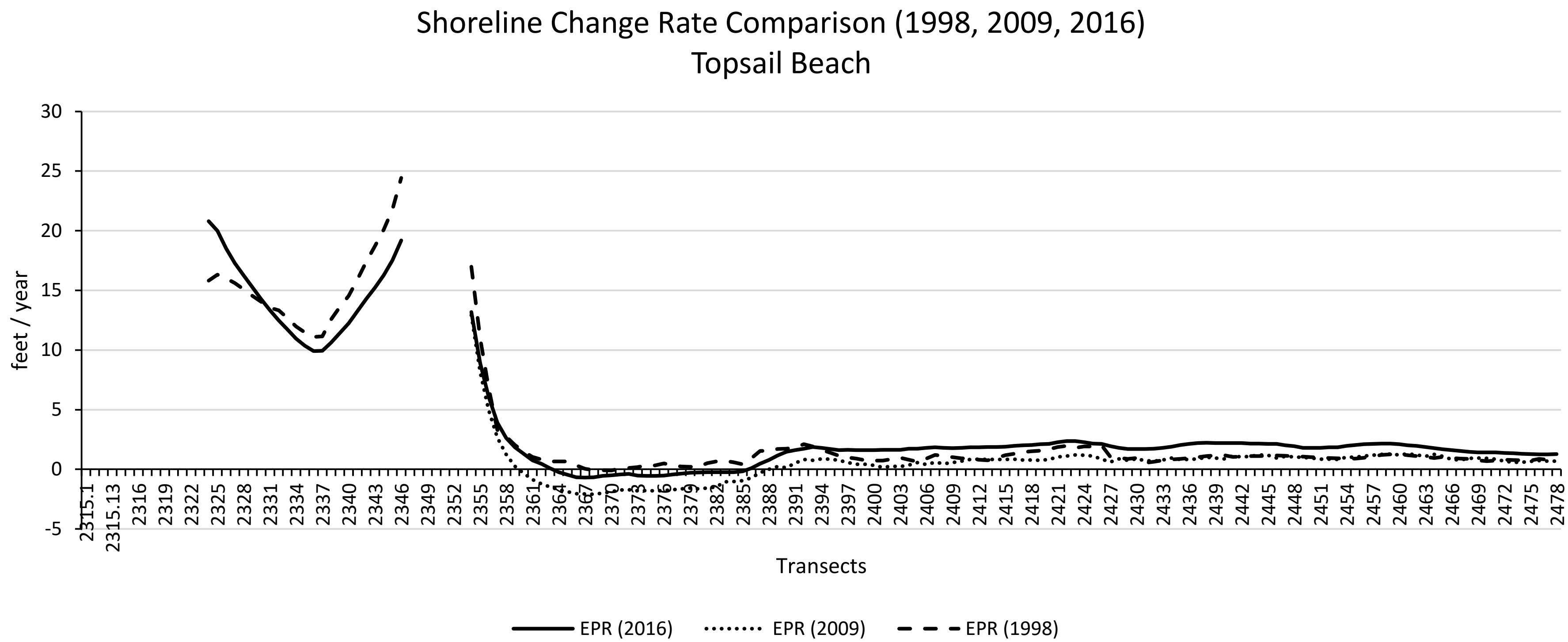

Figure B15. Shoreline change rate comparison at Topsail Beach using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from New Topsail Inlet (graph left-side) to Topsail Beach-Surf City town limits. Transect numbers correspond to those labeled on map in the results summary section.

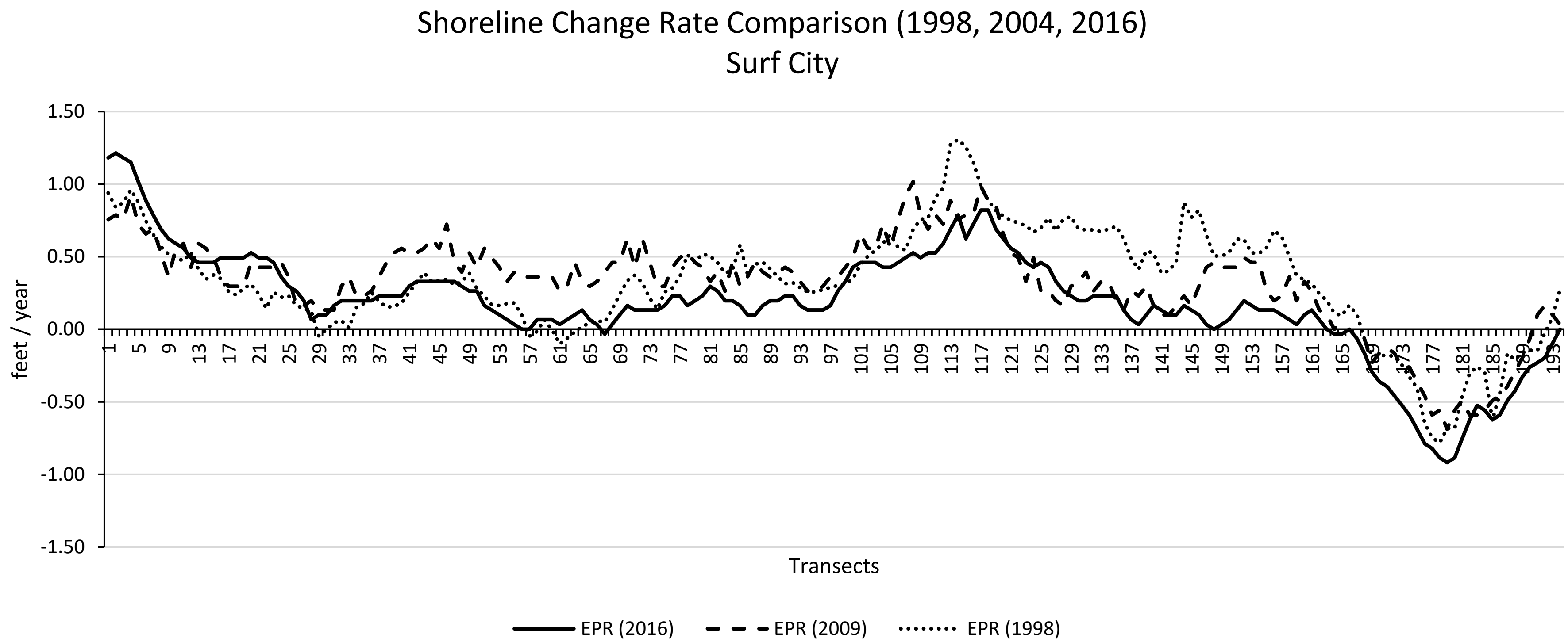

Figure B16. Shoreline change rate comparison at Surf City using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Topsail Beach-Surf City Town limits (graph left-side) to Surf City-North Topsail Beach Town limits (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

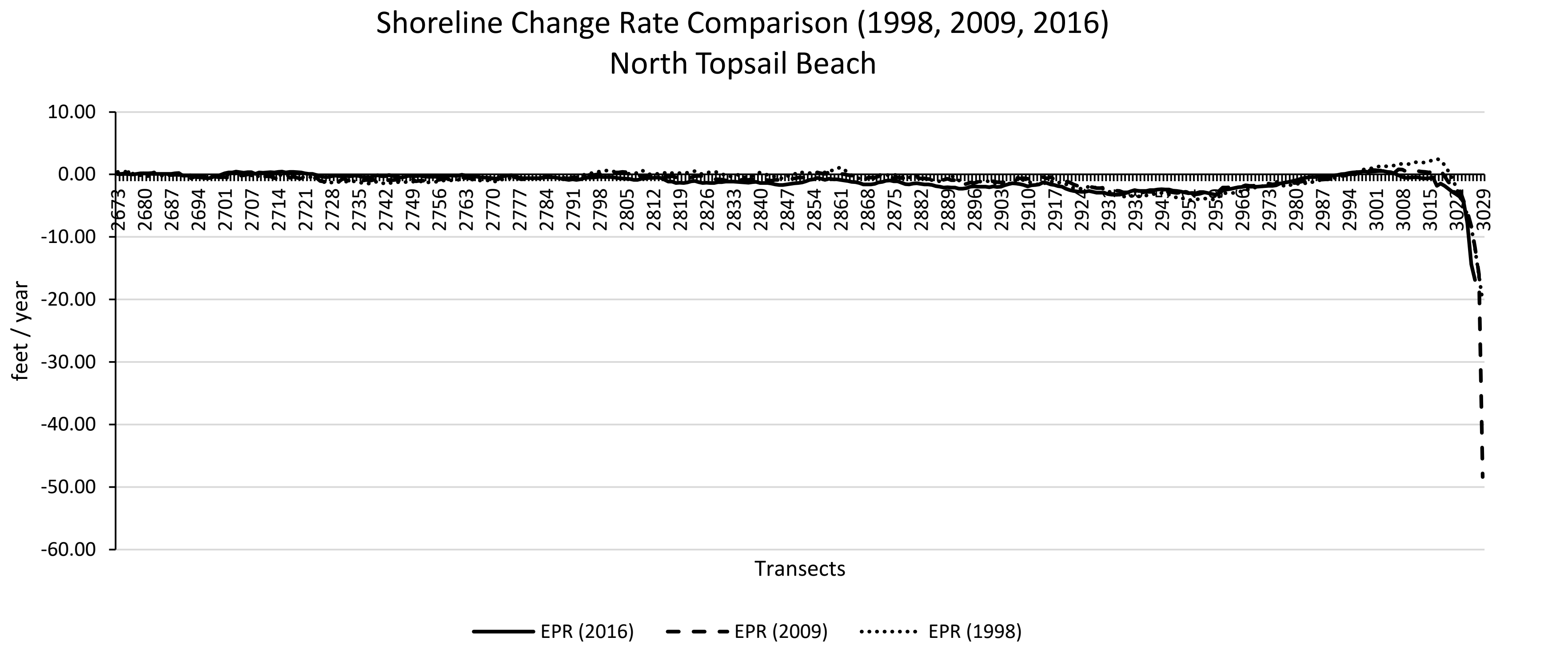

Figure B17. Shoreline change rate comparison at North Topsail Beach using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Surf City-North Topsail Beach town limits (graph left-side) to New River Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

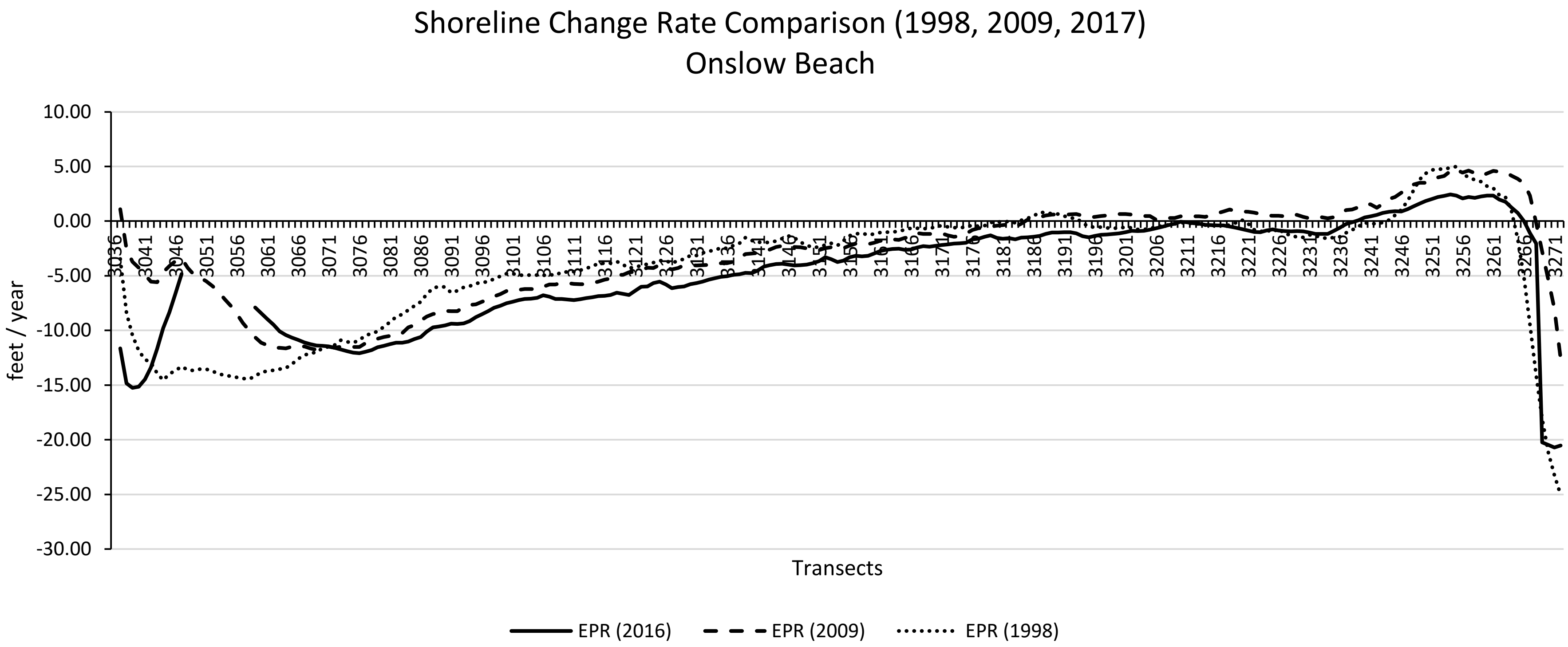

Figure B18. Shoreline change rate comparison at Onslow Beach using early shoreline and 1998, 2009, and 2017 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from New River Inlet (graph left-side) to Brown's Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

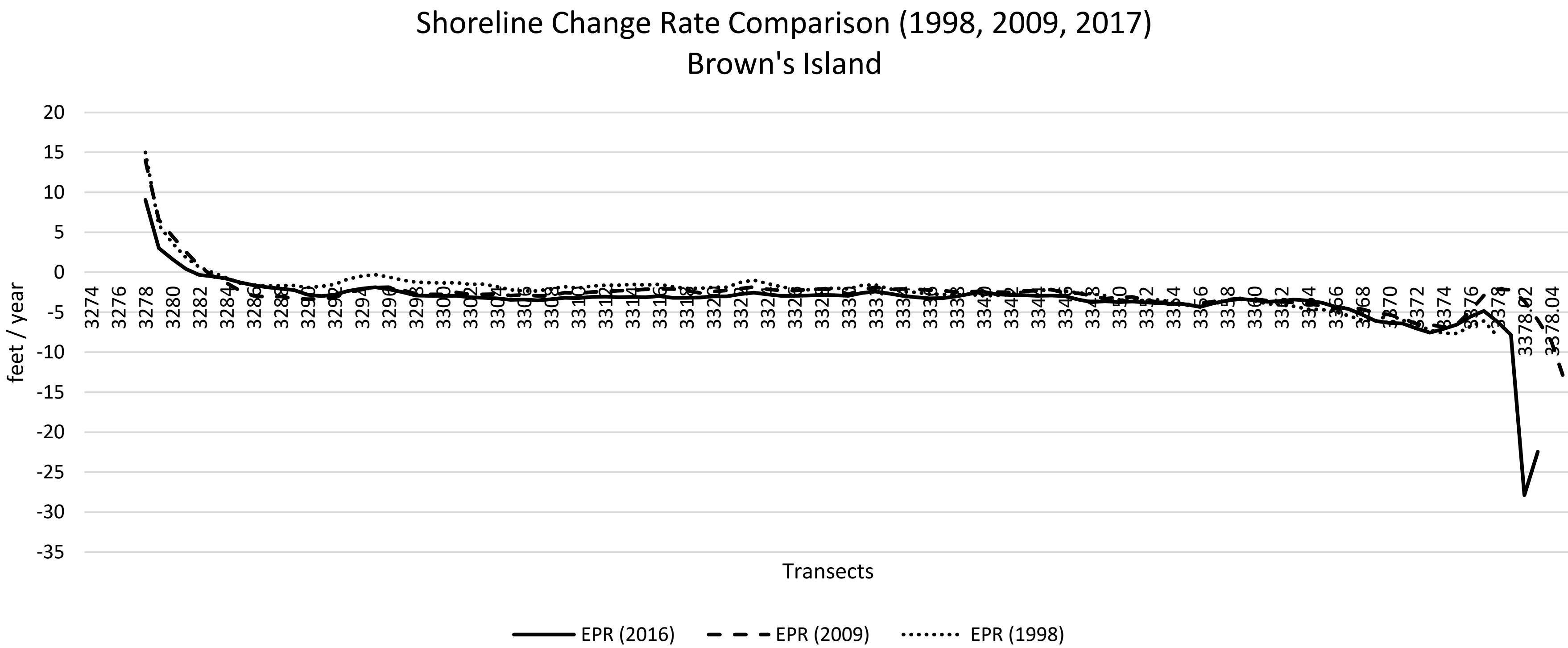

Figure B19. Shoreline change rate comparison at Brown's Island using early shoreline and 1998, 2009, and 2017 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Brown's Inlet (graph left-side) to Bear Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

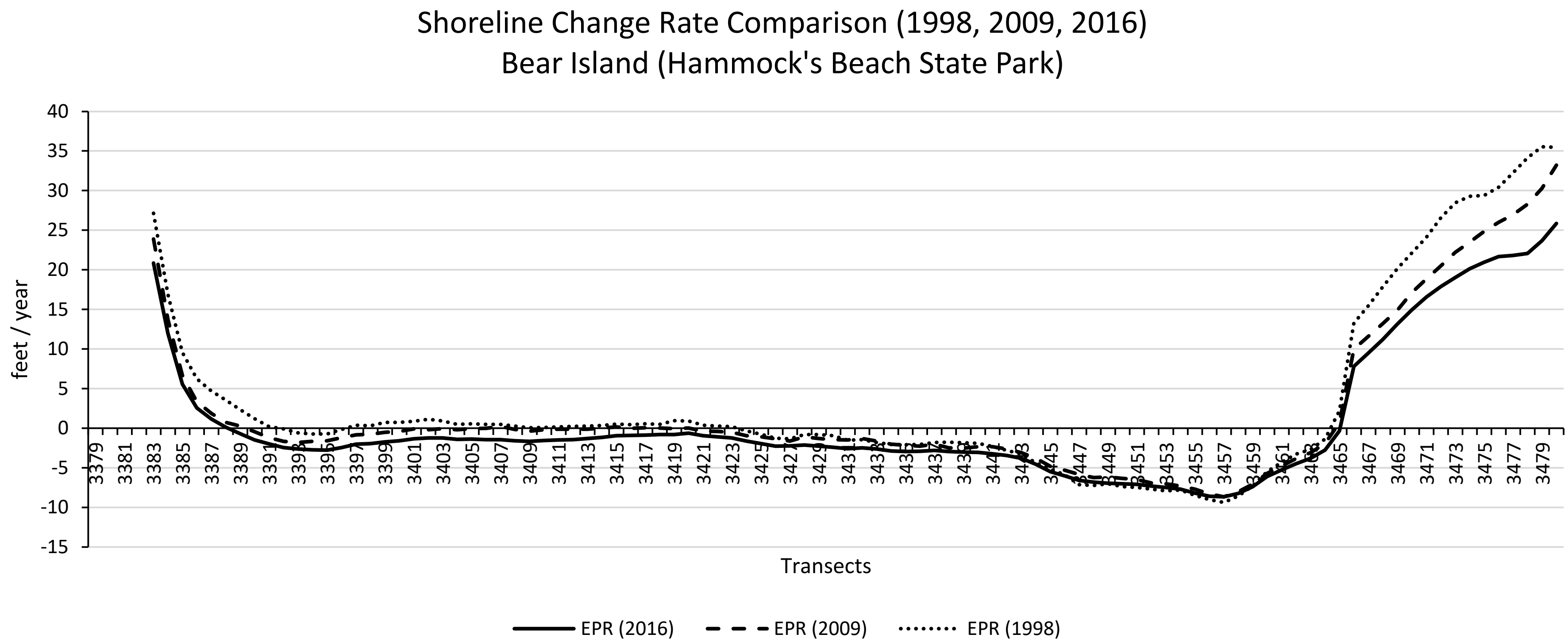

Figure B20. Shoreline change rate comparison at Bear Island (Hammocks Beach State Park) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Bear Inlet (graph right-side) to Bogue Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

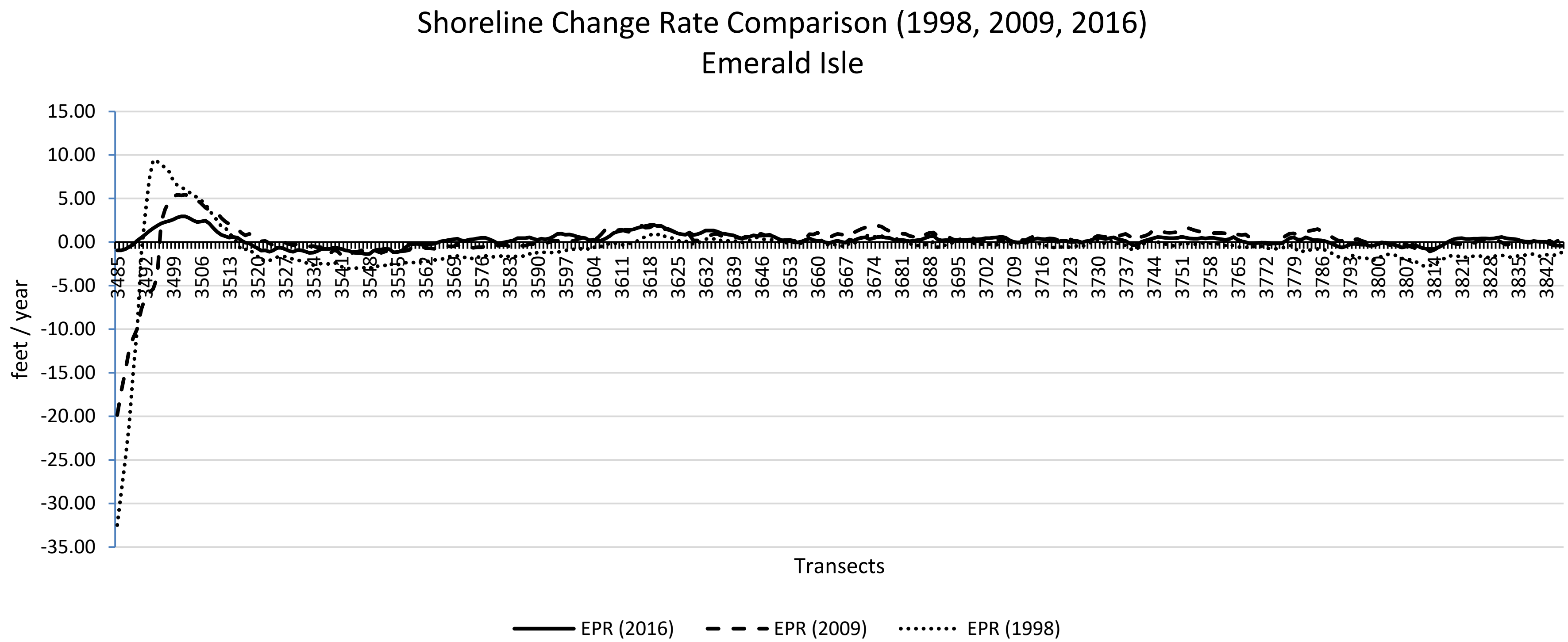

Figure B21. Shoreline change rate comparison at Emerald Isle using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Bogue Inlet (graph left-side) to Emerald Isle-Indian Beach town limits. Transect numbers correspond to those labeled on map in the results summary section.

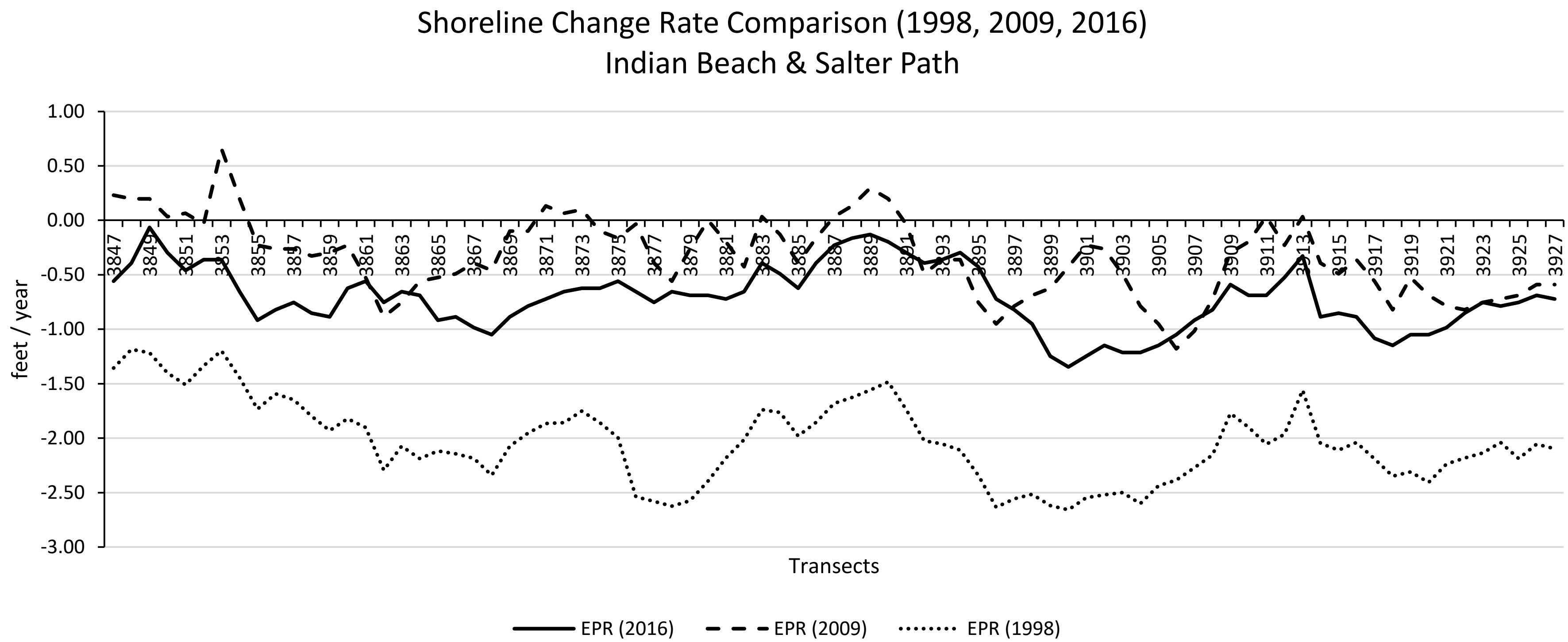

Figure B22. Shoreline change rate comparison at Indian Beach and Salter Path using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Emerald Isle-Indian Beach town limits (graph left-side) to Indian Beach-Pine Knoll Shores town limits (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

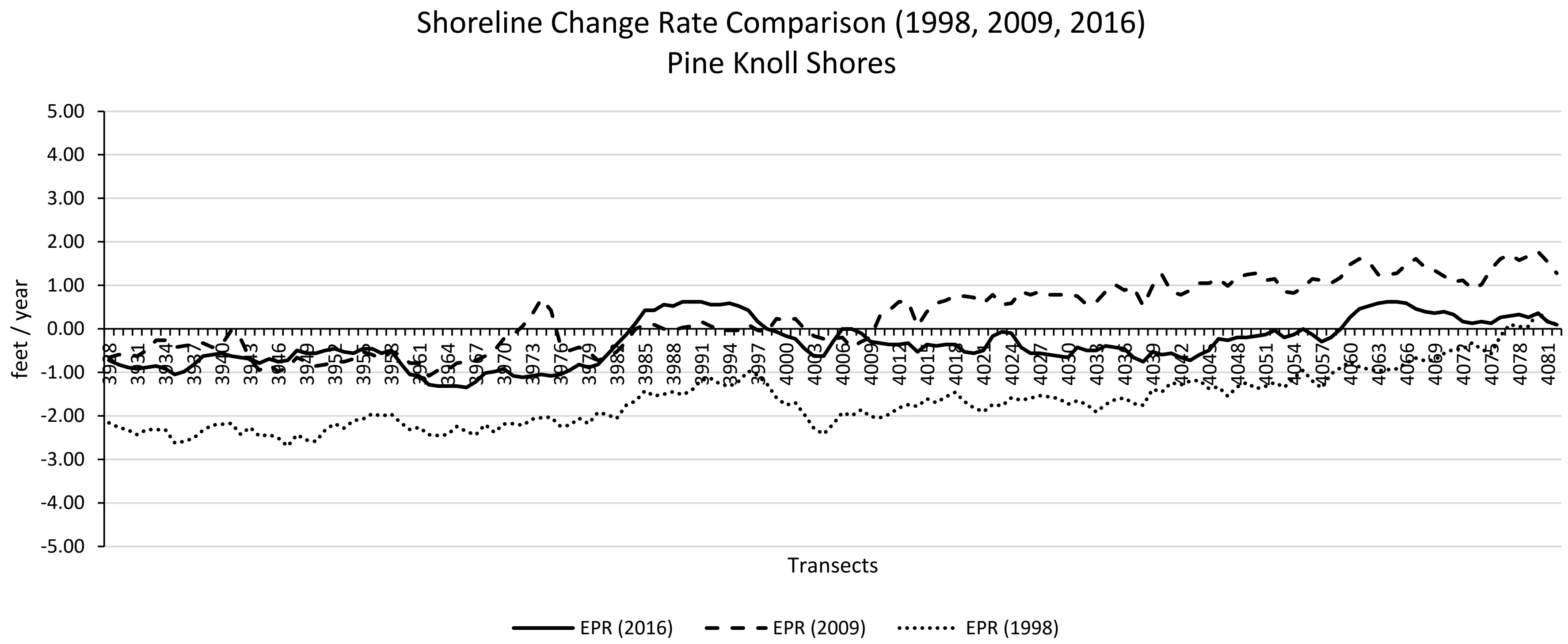

Figure B23. Shoreline change rate comparison at Pine Knoll Shores using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Indian Beach-Pine Knoll Shores town limits (graph left-side) to Pine Knoll Shores-Atlantic Beach town limits (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

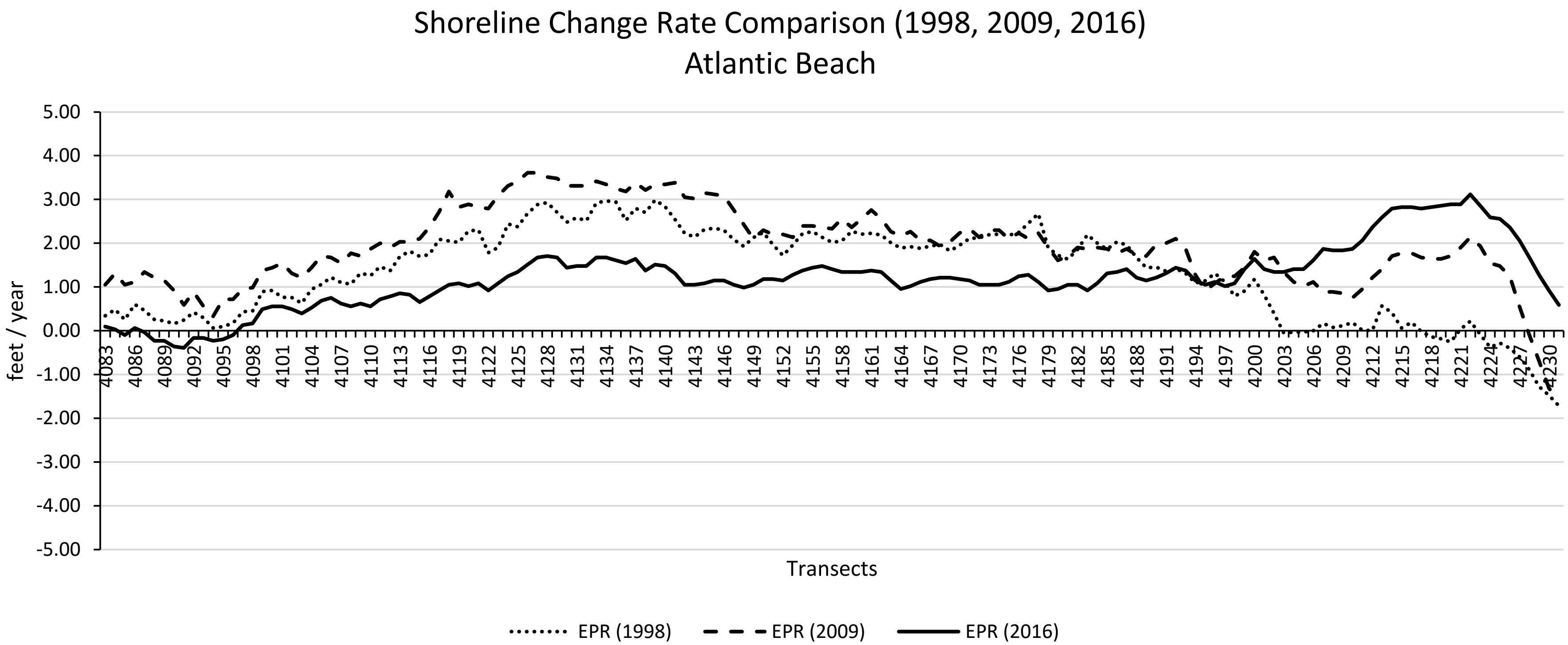

Figure B24. Shoreline change rate comparison at Atlantic Beach using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Pine Knoll Shores-Atlantic Beach town limits (graph left-side) to Fort Macon State Park (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

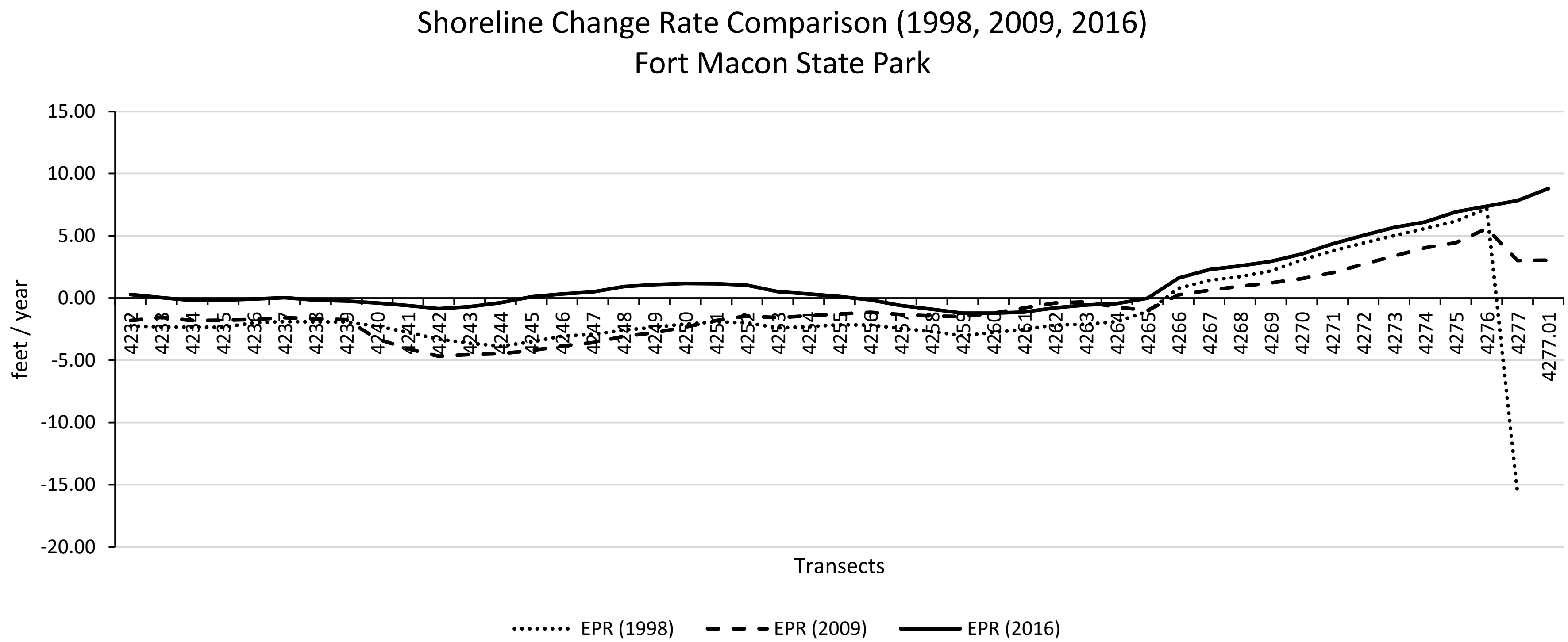

Figure B25. Shoreline change rate comparison at Fort Macon State Park using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Atlantic Beach-Fort Macon State Park boundary (graph left-side) to Beaufort Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

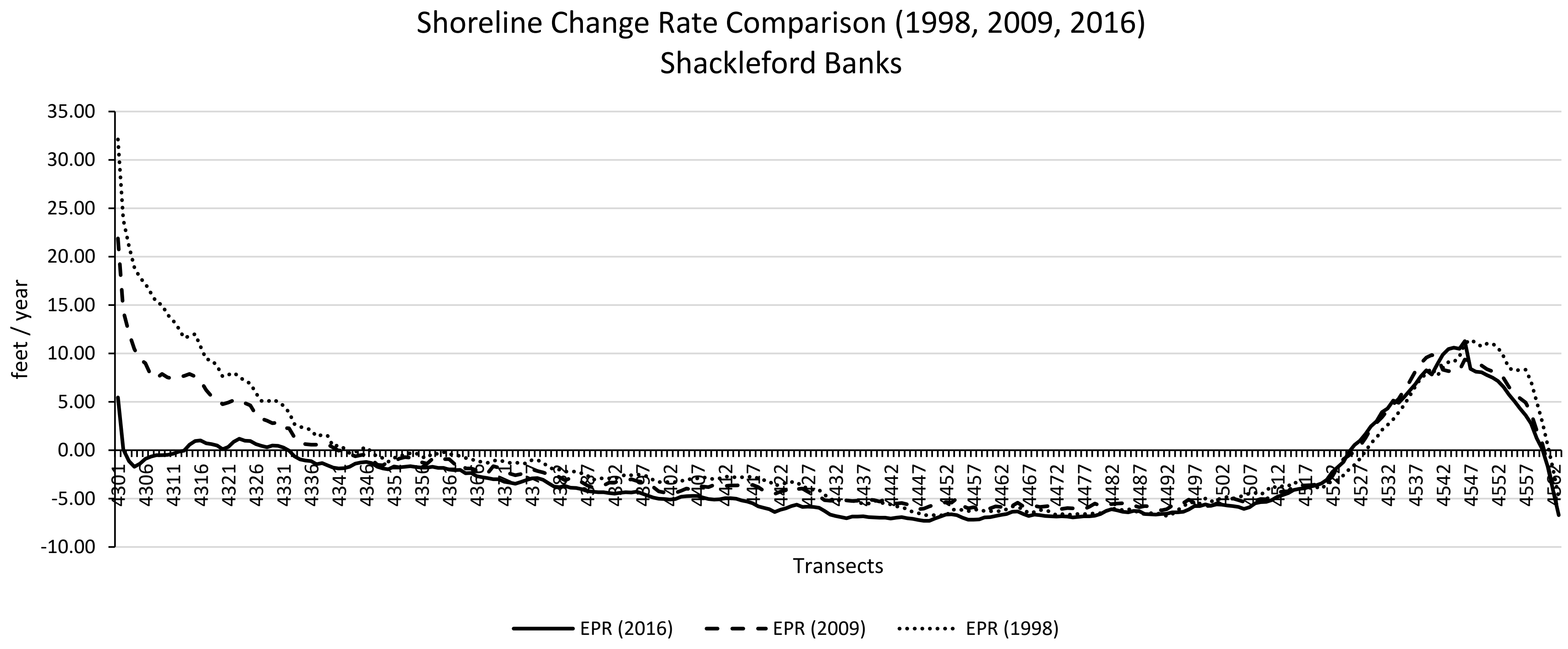

Figure B26. Shoreline change rate comparison at Shackleford Banks using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Beaufort Inlet (graph left-side) to Barden Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

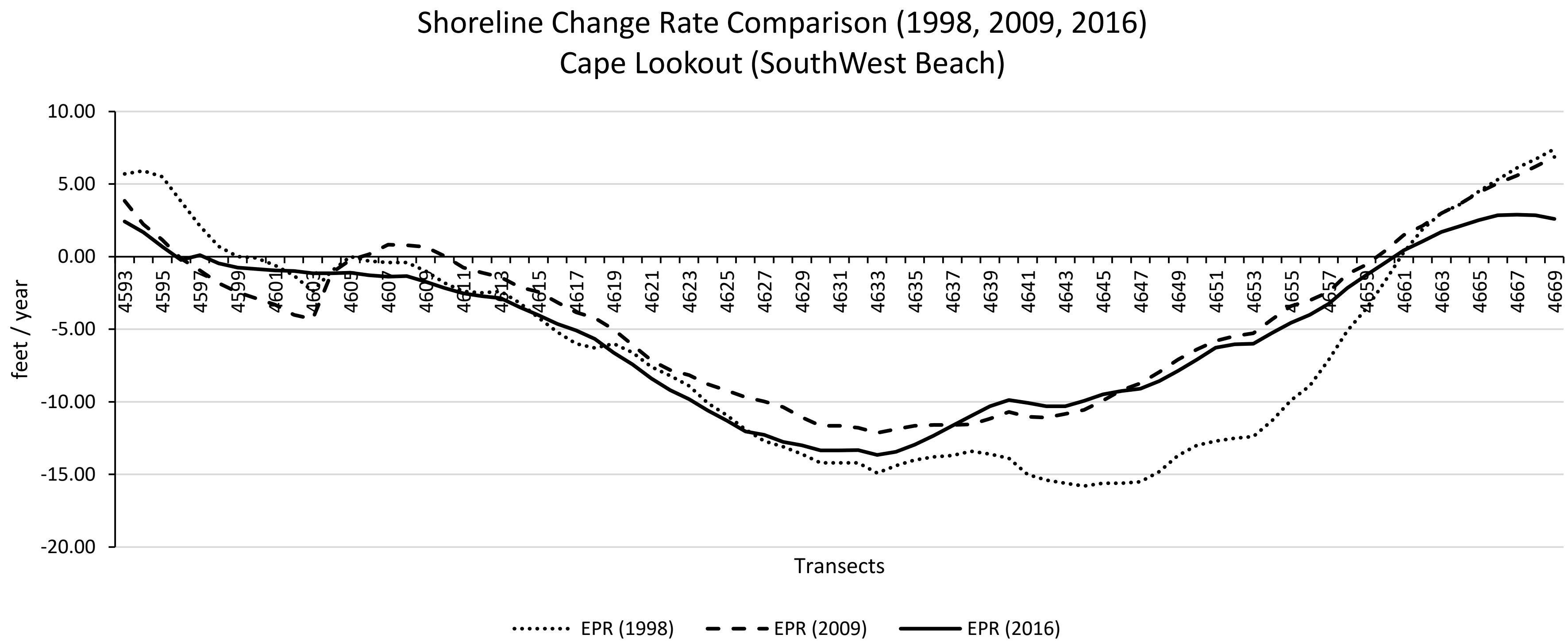

Figure B27. Shoreline change rate comparison at Cape Lookout (southwest-beach) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from Barden Inlet (graph left-side) to Cape Lookout (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

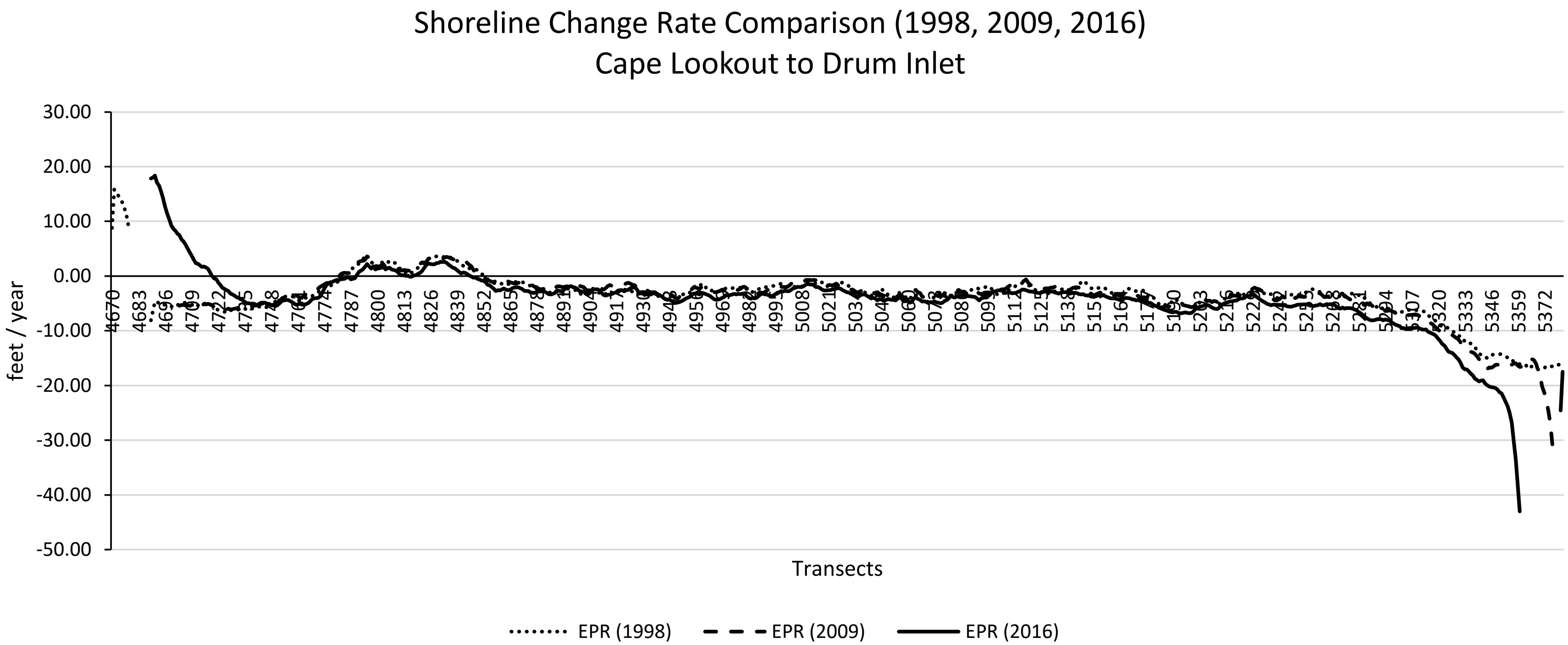

Figure B28. Shoreline change rate comparison at Core Banks (from Cape Lookout to Drum Inlet) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph is oriented from south to north, with Cape Lookout on graph's left-side, and Drum Inlet on graph's right-side. Transect numbers correspond to those labeled on map in the results summary section.

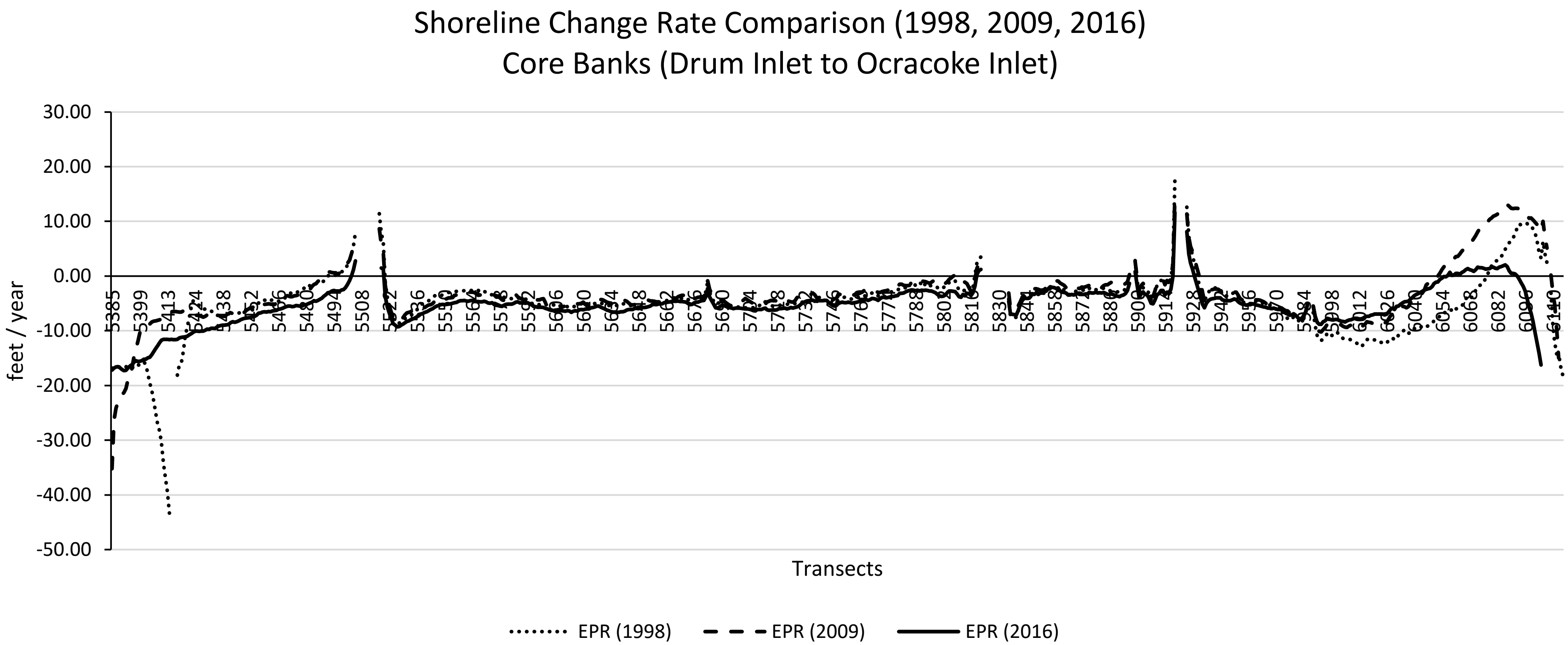

Figure B29. Shoreline change rate comparison at Core Banks (from Drum Inlet to Ocracoke Inlet) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from south to north, with Drum Inlet on left-side and Ocracoke Inlet on right-side. Data gaps represent form inlet locations. Transect numbers correspond to those labeled on map in the results summary section.

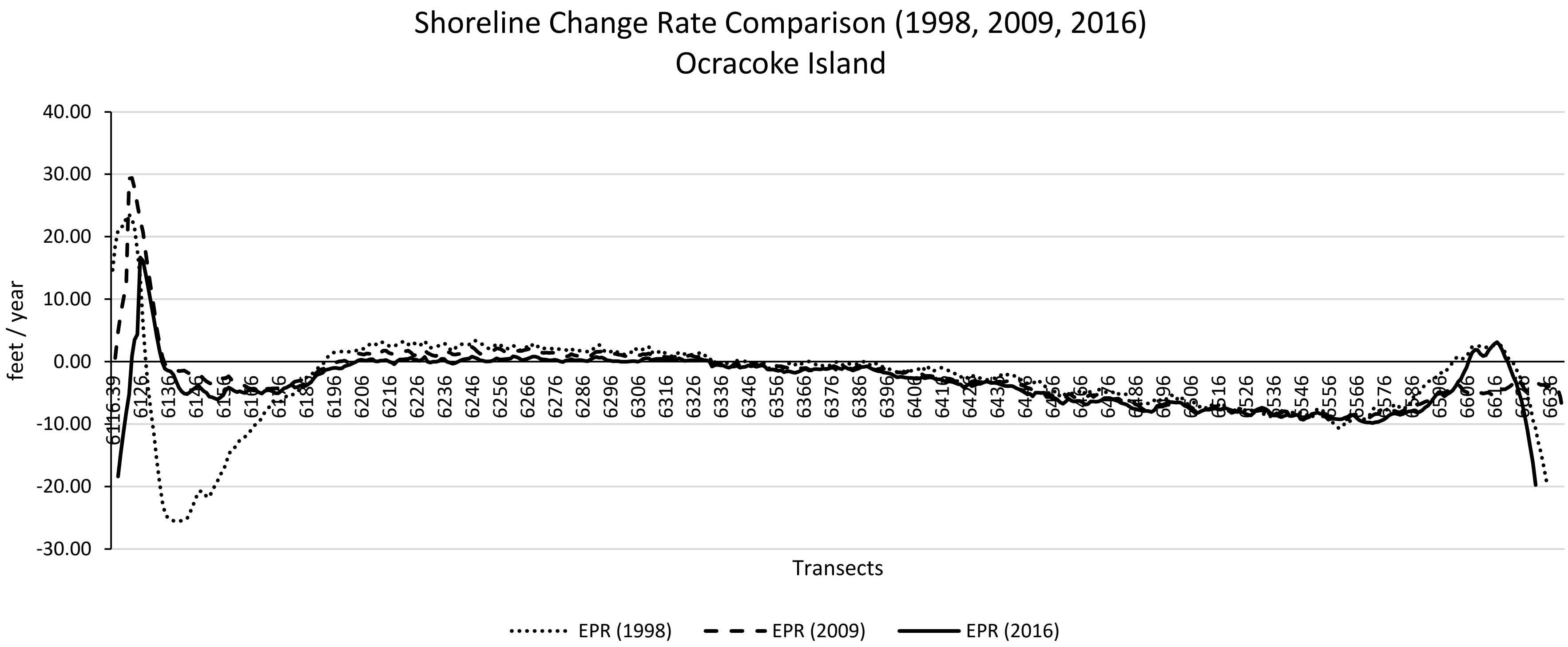

Figure B30. Shoreline change rate comparison at Ocracoke Island using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from Ocracoke Inlet (graph left-side) to Hatteras Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

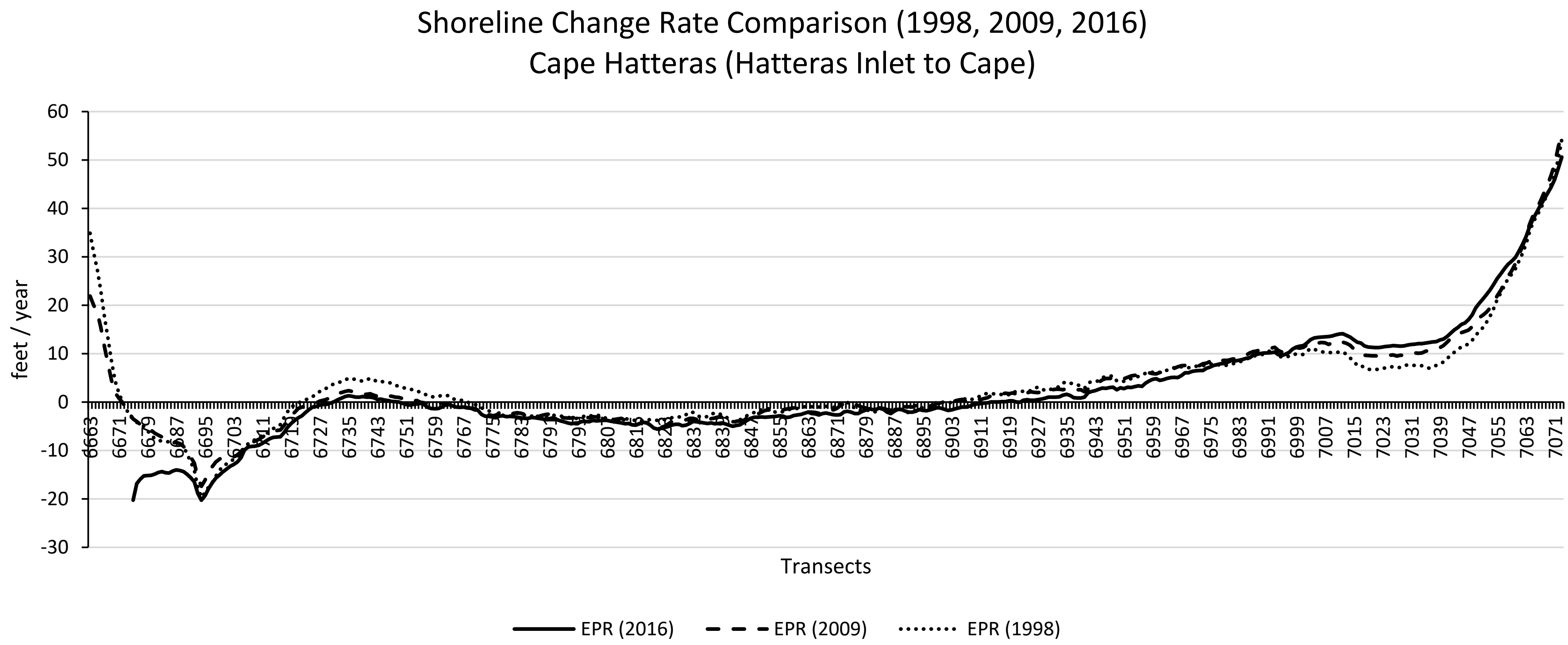

Figure B31. Shoreline change rate comparison at Cape Hatteras (from Hatteras Inlet to Cape) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from Hatteras Inlet (graph left-side) to Cape Hatteras (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

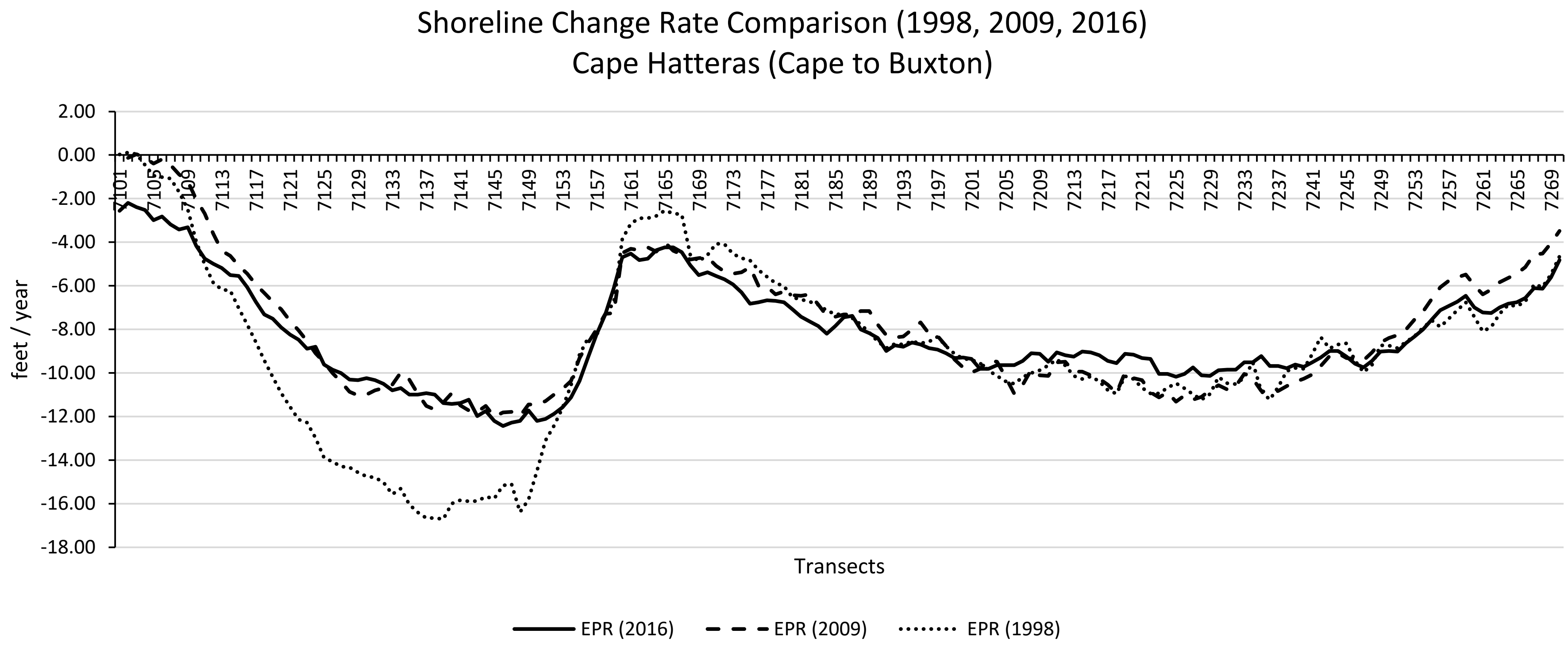

Figure B32. Shoreline change rate comparison at Cape Hatteras (from Cape to Buxton) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from Cape Hatteras (graph left-side) to north of Buxton (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

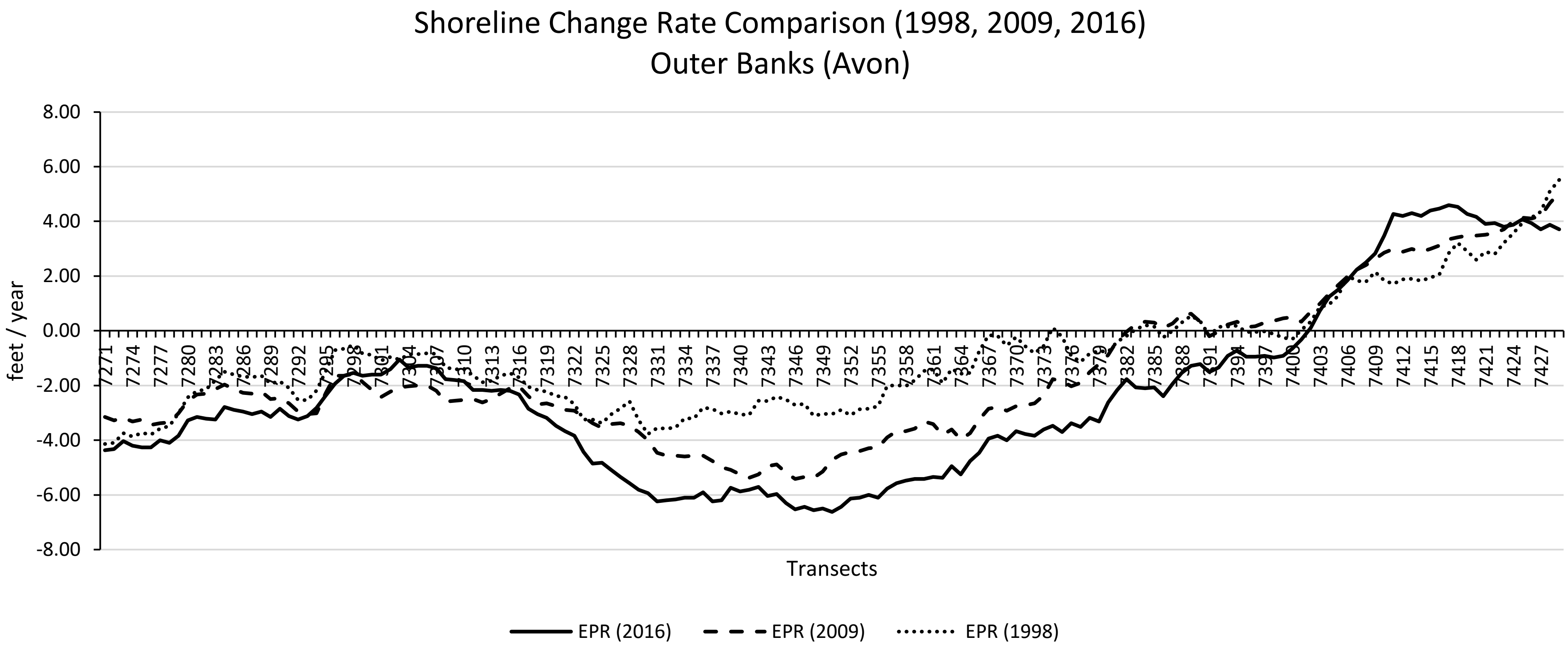

Figure B33. Shoreline change rate comparison at Outer Banks at Avon using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from south (graph left-side) to north at Avon (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

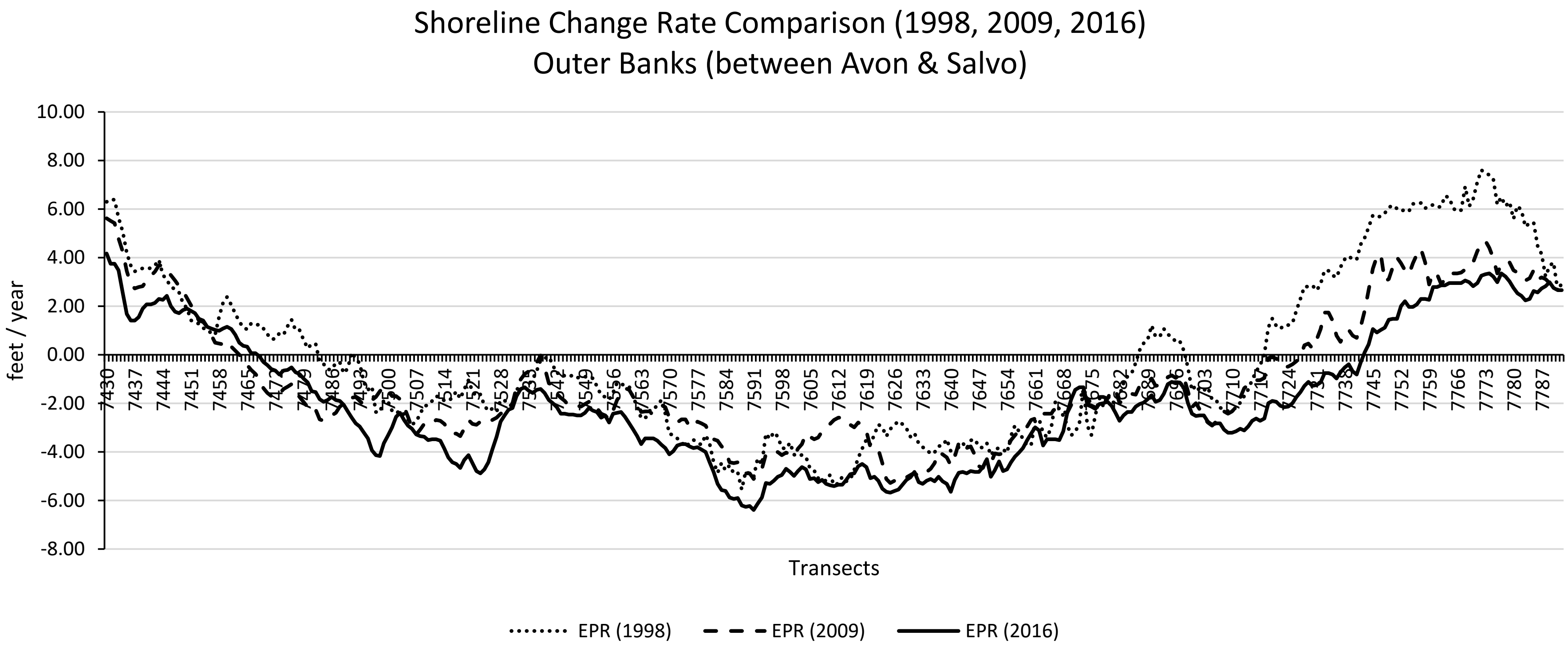

Figure B34. Shoreline change rate comparison at Outer Banks between Avon and Salvo using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from south (graph left-side) to north (graph right-side) between Avon and Salvo. Transect numbers correspond to those labeled on map in the results summary section.

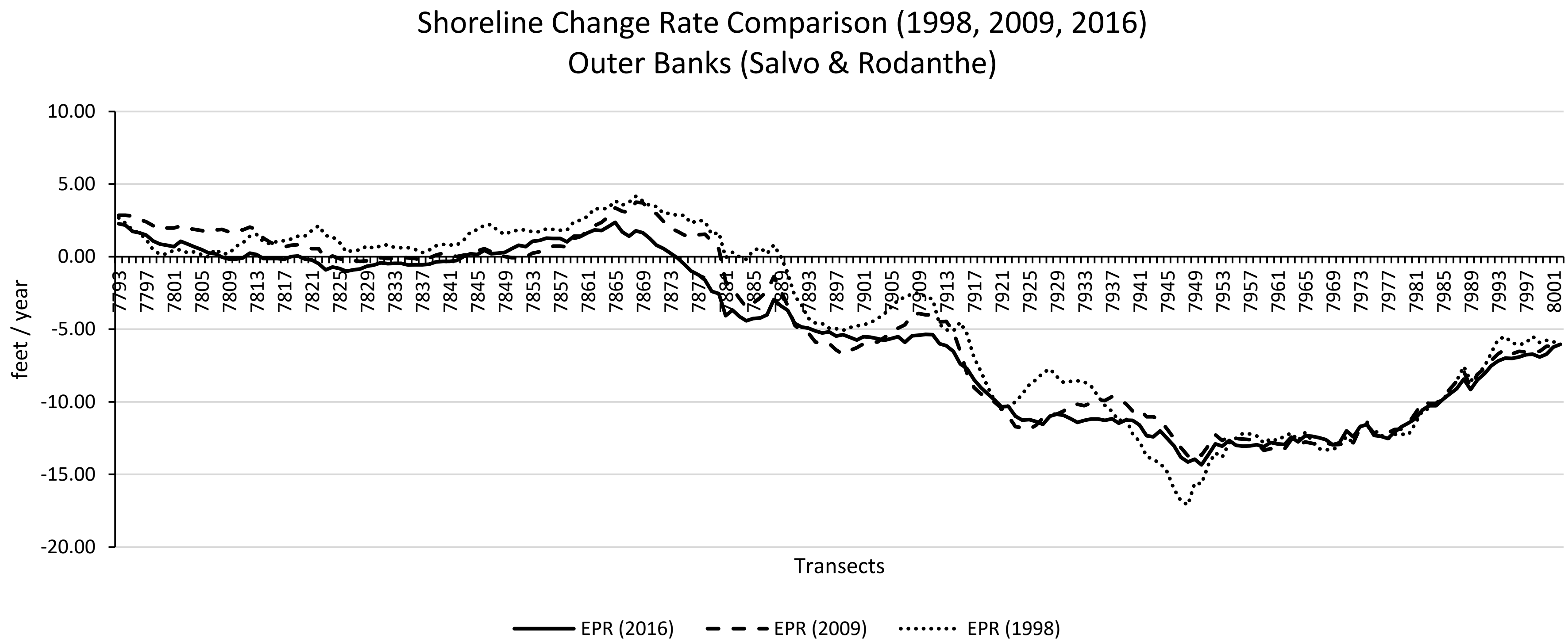

Figure B35. Shoreline change rate comparison at Outer Banks at Salvo and Rodanthe using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Graph oriented from south (left-side) to north (right-side) and includes Salvo and Rodanthe. Transect numbers correspond to those labeled on map in the results summary section.

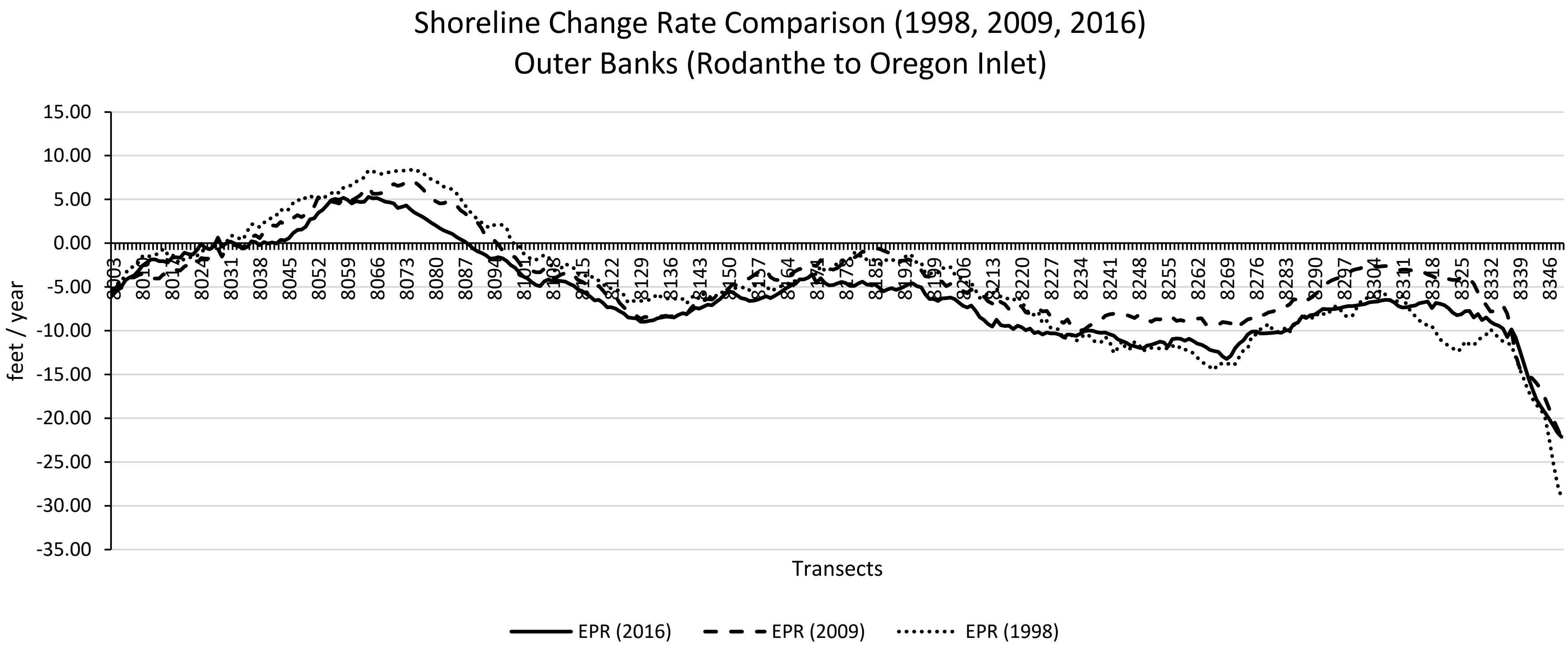

Figure B36. Shoreline change rate comparison at Outer Banks from Rodanthe to Oregon Inlet (Pea Island) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from Rodanthe (graph left-side) to Oregon Inlet (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

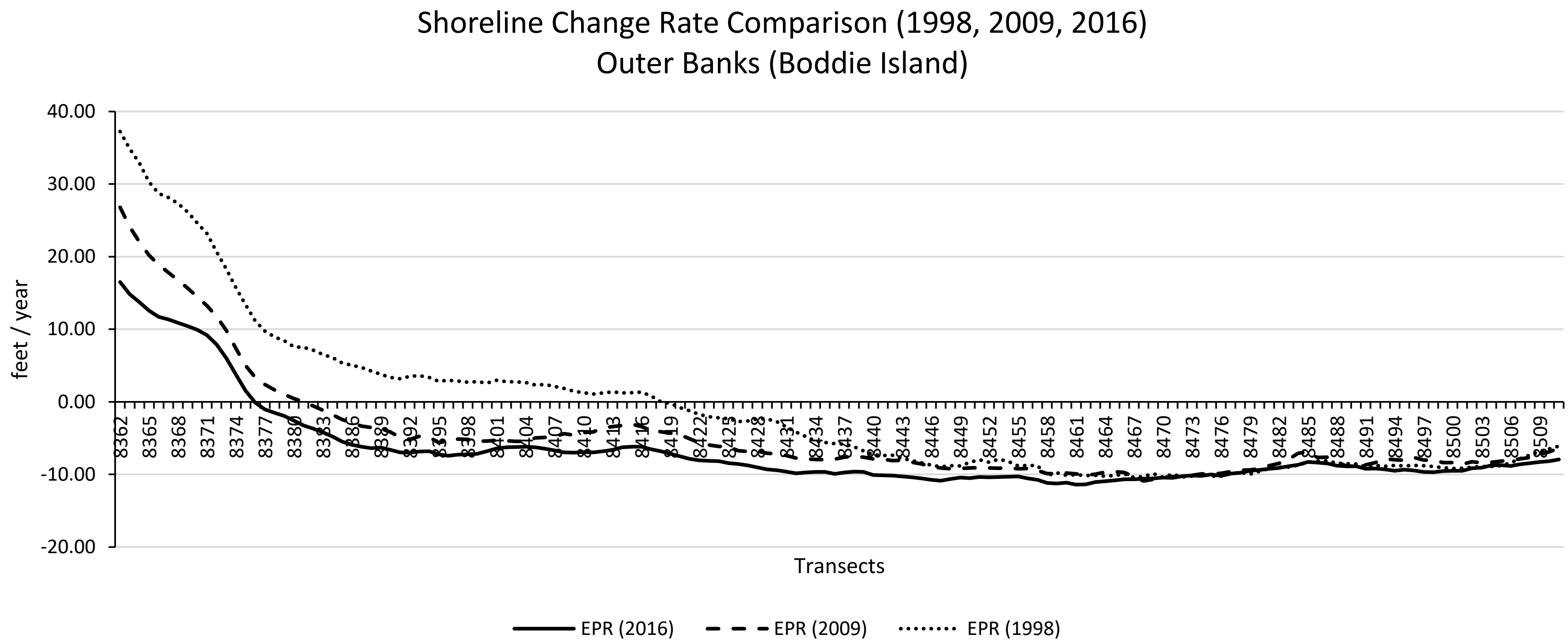

Figure B37. Shoreline change rate comparison at Outer Banks from Oregon Inlet to Nags Head (Boddie Island) using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from south (graph left-side) to north (graph right-side) and includes Boddie Island. Transect numbers correspond to those labeled on map in the results summary section.

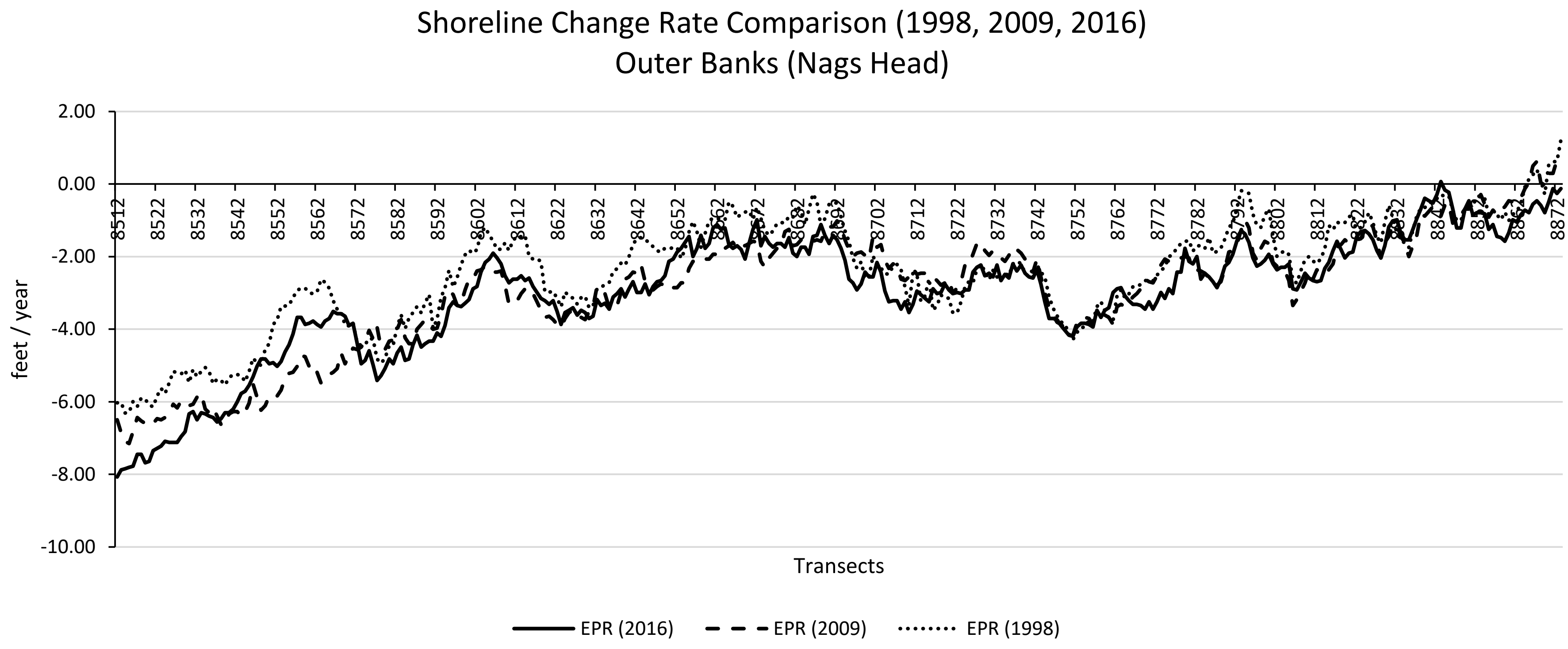

Figure B38. Shoreline change rate comparison at Outer Banks at Nags Head using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from Nag Head's southern limit (graph left-side) to its northern limit (graph right-side). Transect numbers correspond to those labeled on map in the results summary section.

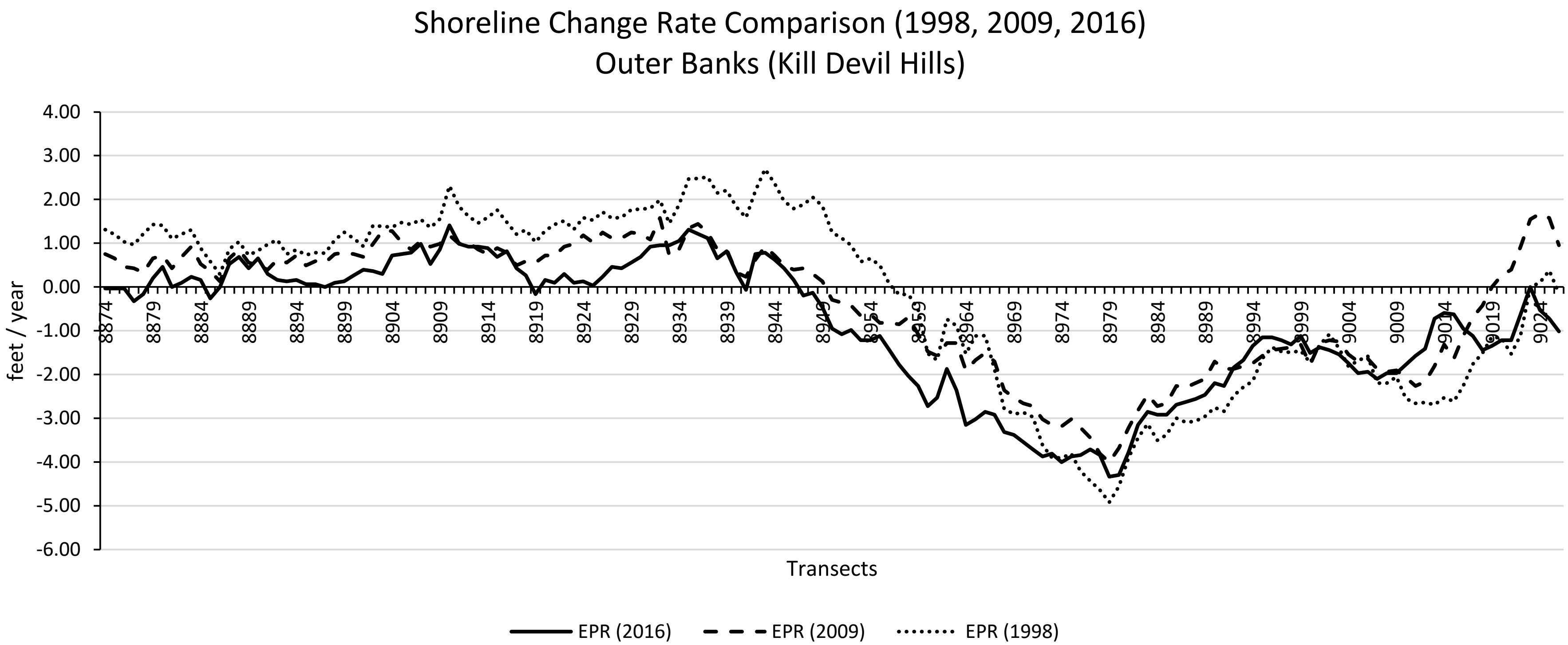

Figure B39. Shoreline change rate comparison at Outer Banks at Kill Devil Hills using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from south to north, with Nags Head-Kill Devil Hills town limits on graph's left-side and Kill Devil Hills-Kitty Hawk town limits on graph's right-side. Transect numbers correspond to those labeled on map in the results summary section.

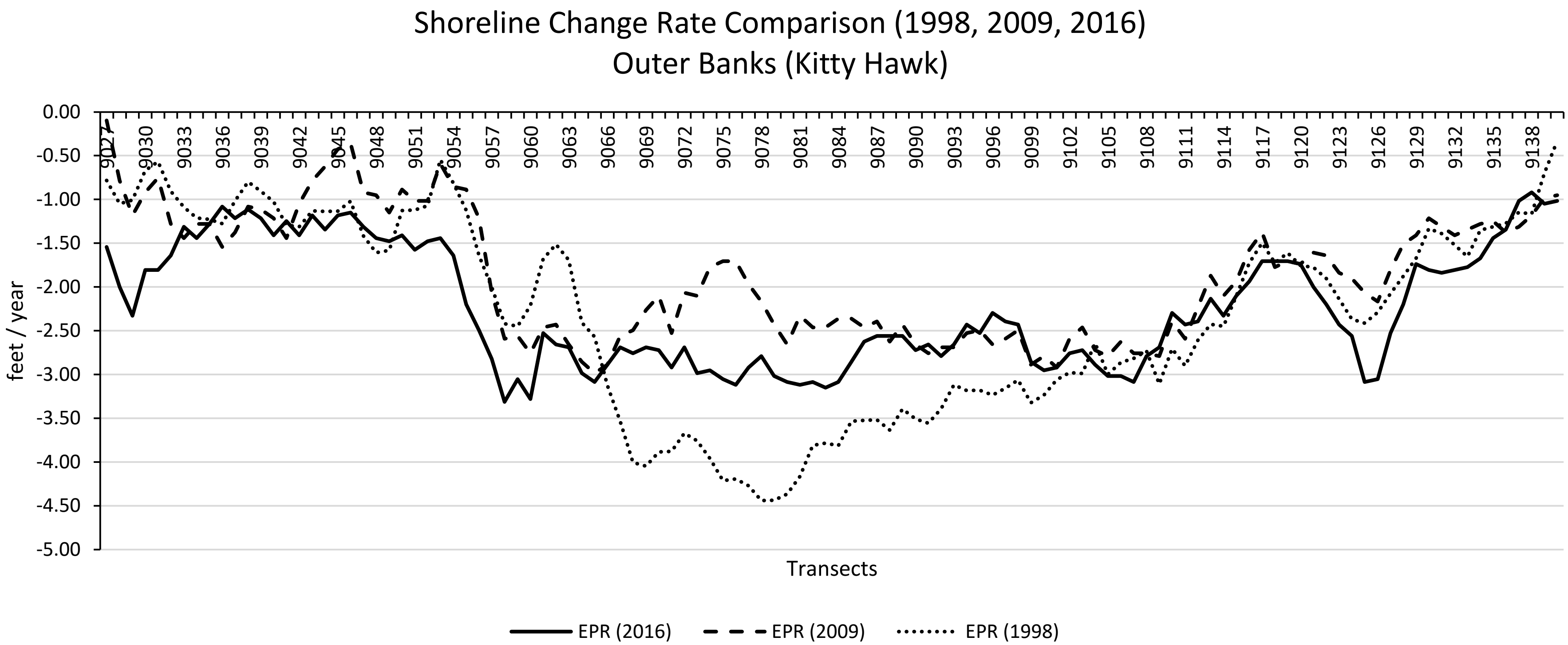

Figure B40. Shoreline change rate comparison at Outer Banks at Kitty Hawk using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from south to north, with Kill Devil Hills-Kitty Hawk town limits on graph's left-side, and Kitty Hawk-Southern Shores town limits on graph's right-side. Transect numbers correspond to those labeled on map in the results summary section.

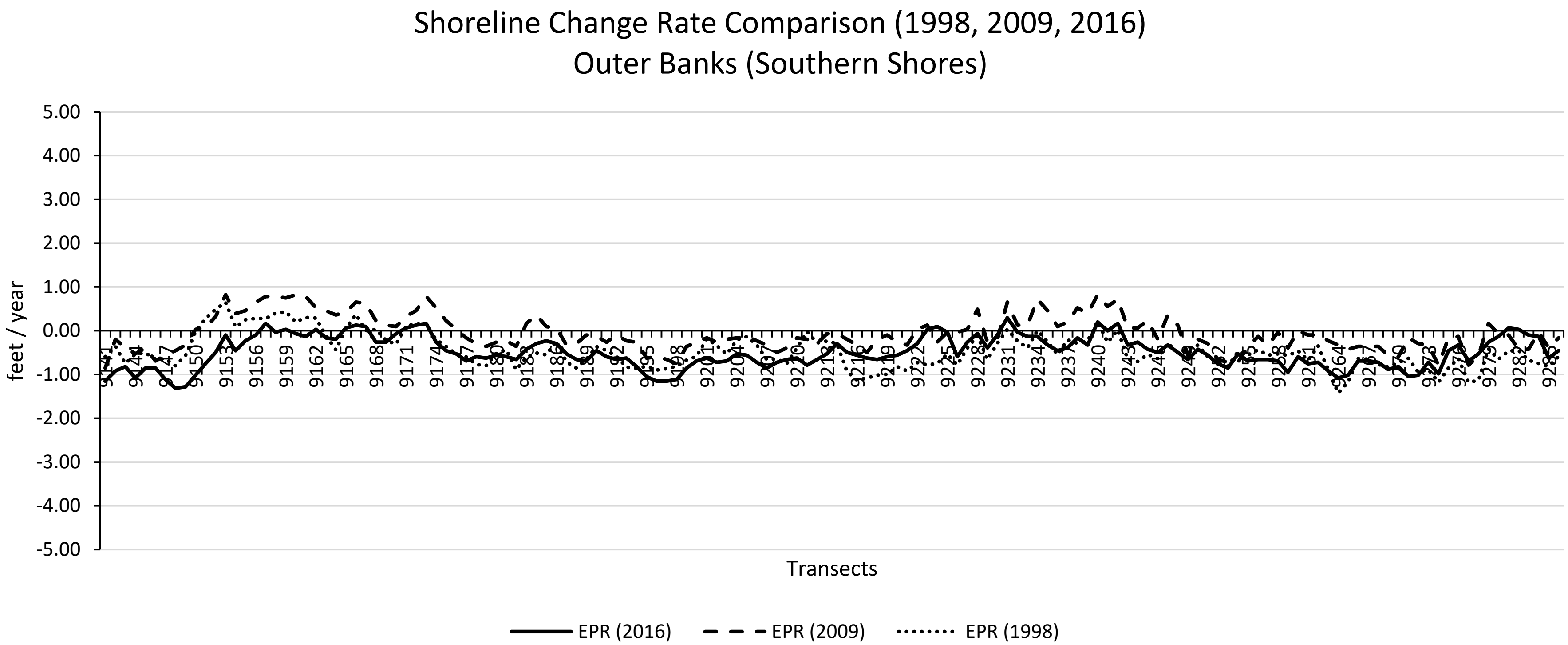

Figure B41. Shoreline change rate comparison at Outer Banks at Southern Shores using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from south to north, with Kitty Hawk-Southern Shores town limits on graph's left-side, and Southern Shores-Duck town limits on graph's right-side. Transect numbers correspond to those labeled on map in the results summary section.

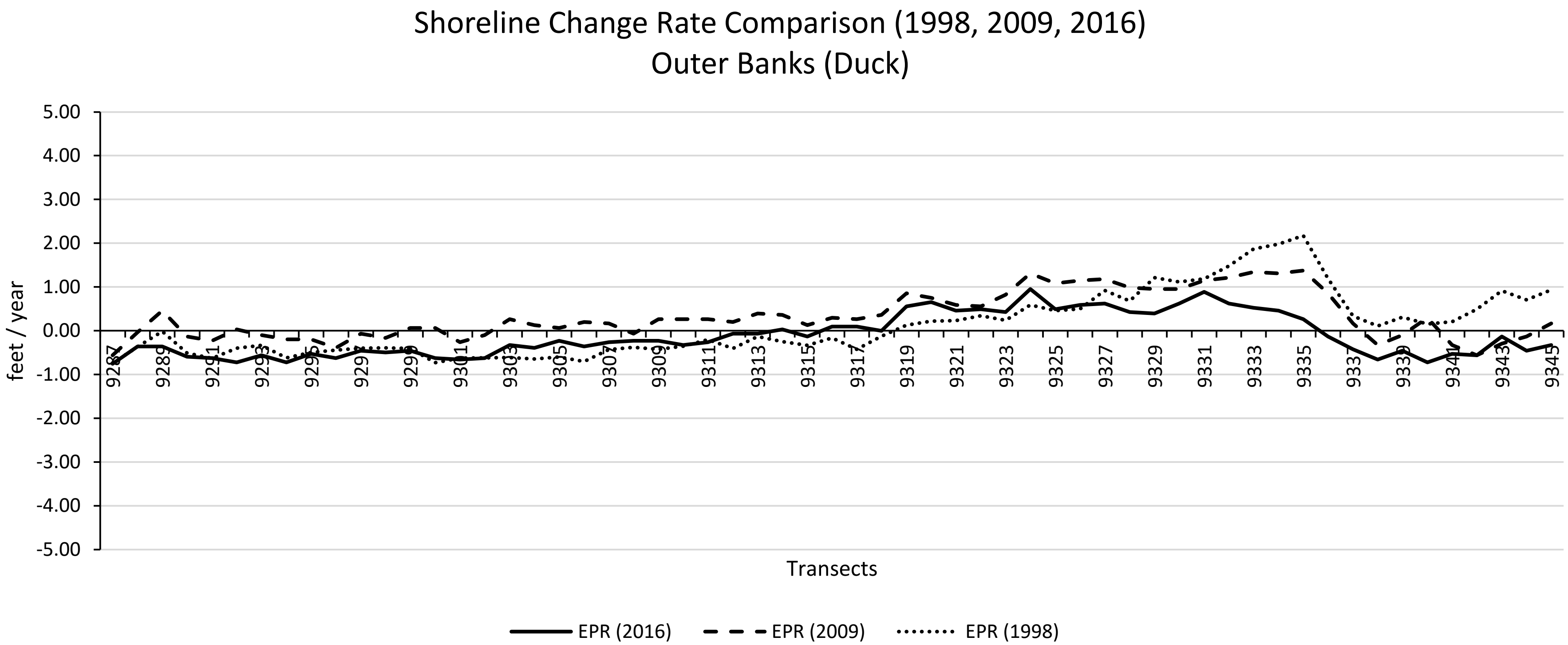

Figure B42. Shoreline change rate comparison at Outer Banks at Duck using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from south to north, with Southern Shores-Duck town limits on graph's left-side and Duck-Corolla limits on graph's right-side. Transect numbers correspond to those labeled on map in the results summary section.

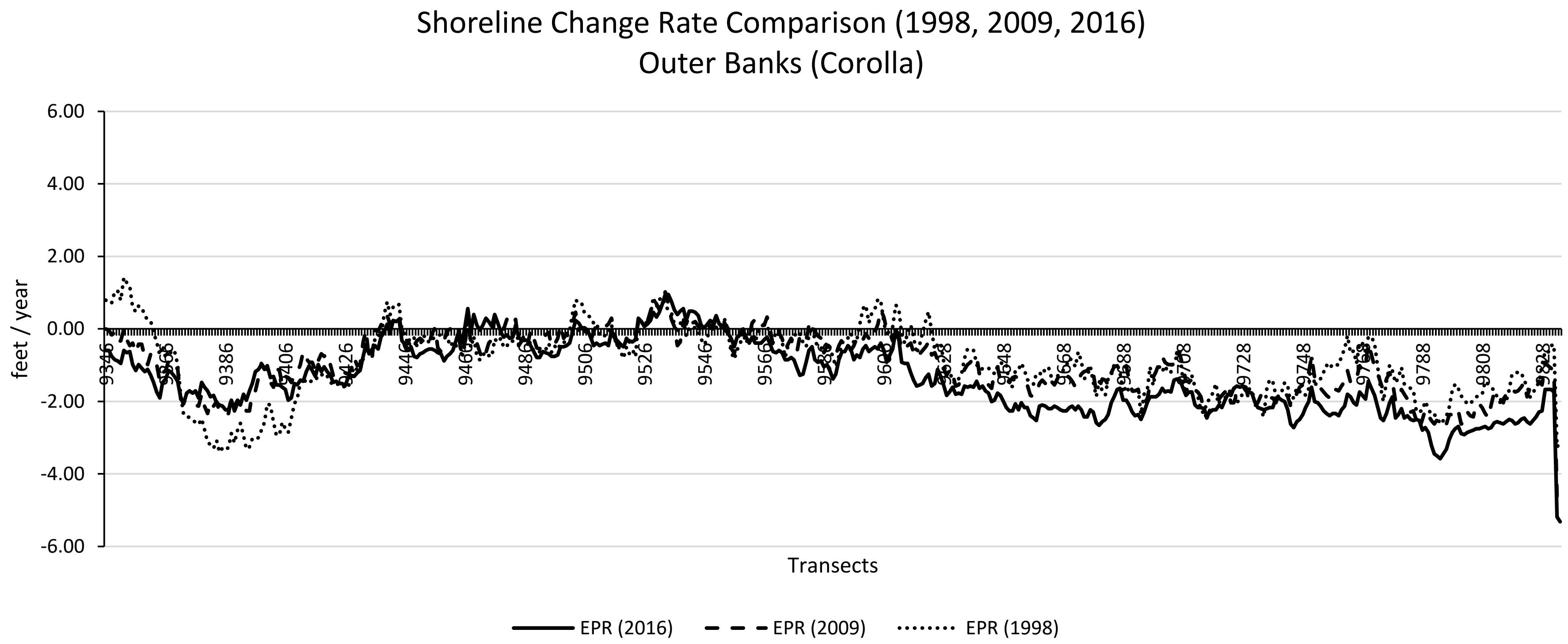

Figure B43. Shoreline change rate comparison at Outer Banks at Corolla using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from south to north, with Duck-Corolla boundary on graph's left-side, and Corolla's northern limit on graph's right-side. Transect numbers correspond to those labeled on map in the results summary section.

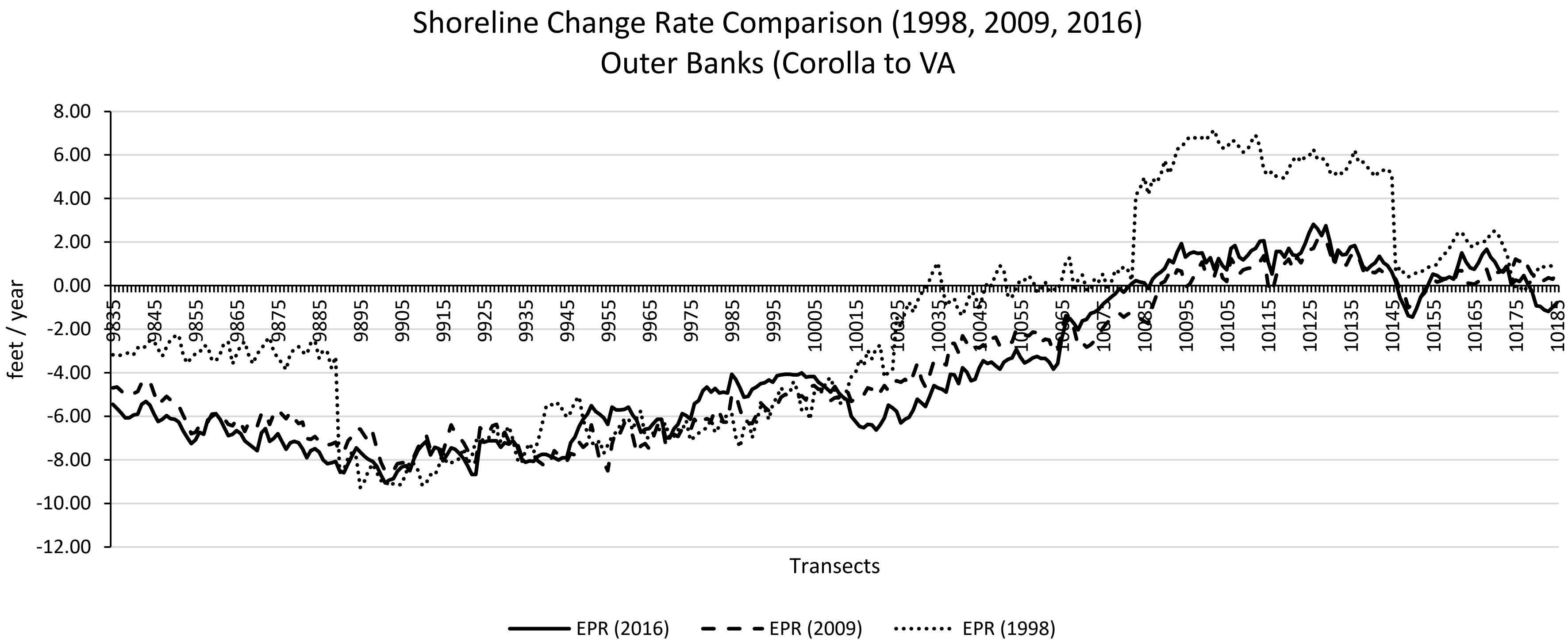

Figure B44. Shoreline change rate comparison at Outer Banks from Corolla to NC-VA State Line using early shoreline and 1998, 2009, and 2016 shorelines. On this graph, negative vales represent erosion, and positive values represent accretion. Oriented from south to north from Corolla (graph's left-side) to NC-VA state line on graph's right-side. Transect numbers correspond to those labeled on map in the results summary section.

Fiscal Analysis

North Carolina 2019 Oceanfront Setback Factors & Long-Term Average Annual Erosion Rate Update Study

2019 Draft Erosion Rates and Amendments to 15A NCAC 7H .0304(1)(a)

Prepared by

Ken Richardson
Shoreline Management Specialist
Policy & Planning Section
NC Division of Coastal Management
(252) 808-2808

February 6, 2019

Basic Information

Agency	DEQ, Division of Coastal Management (DCM) Coastal Resources Commission
Title	AREAS OF ENVIRONMENTAL CONCERN (AECS) WITHIN OCEAN HAZARD AREAS
Citation	15A NCAC 7H .0304(1)
Description of the Proposed Rule	7H.0304 defines and establishes Areas of Environmental Concern (AECs) within the Ocean Hazard Areas along the State's Atlantic Ocean shoreline. Ocean Hazard Area AECs include the Ocean Erodible Area, Inlet Hazard Area and the Unvegetated Beach Area.
Agency Contact	Ken Richardson Shoreline Management Specialist ken.richardson@ncdenr.gov (252) 808-2808 ext. 225
Authority	G.S. 113A-107; 113A-113; 113A-124
Necessity	The Coastal Resources Commission proposed amendments to 15A NCAC 7H .0304(1) reflect the five-year update of the state's oceanfront erosion rates. Erosion rates are used to establish construction setbacks for development within the Ocean Erodible Area – Areas of Environmental Concern (OEA-AEC). The proposed rule change is in the public interest as it will minimize the loss of property and human life by establishing development setbacks between oceanfront structures and the Atlantic shoreline.
Impact Summary	State government: No Local government: No Substantial impact: No Federal government: No

Summary

The Coastal Resources Commission (CRC) seeks to amend its administrative rules governing oceanfront development setbacks. Oceanfront construction setbacks are based on long-term average annual erosion rates referenced in the report "2011 Average Annual Shoreline Rate Update" (15A NCAC 7H .0304(1)(a)) adopted by the Commission May 5, 2011. The current oceanfront erosion rates were adopted by reference and became effective in 2013. The proposed amendment would update these rates using new data and analysis referenced in a new report *2019 Oceanfront and Long-term Average Annual Erosion Rate Update Study*. The purpose of updating oceanfront erosion rates is to protect life and property from hazards associated with coastal erosion.

Development sited directly adjacent to the ocean shoreline may be vulnerable to erosion and the CRC seeks to minimize the loss of property and human life by establishing 'setbacks' that specify the minimum distance between a structure and the shoreline. These updated erosion rates will be used to calculate construction setbacks and apply to property owners seeking to redevelop or construct new structures; or those needing repairs in excess of fifty percent of market value per 15A NCAC 07J.0210(1). If repairs to a structure are less than fifty percent, the owner is not required to obtain a Coastal Area Management Act (CAMA) permit.

Updating the erosion rates also keeps North Carolina in compliance with FEMA (Federal Emergency Management Administration) guidelines for the Community Rating System (CRS). These updated rates will ensure that property owners in coastal communities that participate in the National Flood Insurance Program are given fifty CRS points to maintain insurance rates at their current level. The loss of these points could increase insurance rates by up to five percent for some policyholders.

The potential economic impacts of this proposed rule change are twofold. First, although there is not an immediate positive or negative impact on CRS points for oceanfront communities, the ability to influence future FEMA CRS evaluations, and potentially increase or decrease flood insurance premiums still remains. Second, of the total oceanfront structures (8,777) that are adjacent to the Atlantic shoreline, approximately 7,579 (86.4%) will experience no change in their construction setback should they need to be rebuilt for any reason. Of the total structures, 215 (2.4%) will see reduced construction setbacks, while 983 (11.2%) will see higher construction setbacks compared to current requirements based on the 2013 update study.

Assessing the specific impact of the interaction between erosion rates and NC's setback requirements on structure values is difficult for several reasons: 1) coastal shorelines are viewed by many as desirable locations to live, and erosion hazards are often overlooked when the risks are not extreme and beach nourishment maintains a wide healthy beach (Below, Beracha, Skiba, 2015); 2) local government ordinances often include additional property boundary setbacks requirements and may restrict re-development, and; 3) there are numerous other important variables (i.e., amenities, quality of construction, size, location) that have a very important effect on property value. We believe the overall impact, if any, would be difficult to quantify accurately, and any attempt would be purely speculative.

This proposal will have no impact on Department of Transportation projects or on DCM permit income.

The proposed effective date of these rules is June 20, 2019.

Introduction and Purpose

Since 1980, the Coastal Resources Commission has updated its oceanfront erosion rates approximately once every five years with the most recent iteration effective on January 31, 2013 based on 2009 data.

The proposed erosion rates have been developed using the end-point methodology. This technique of calculating shoreline change rates is consistent with earlier studies and provides results that can be compared to those from previous studies. The end-point method uses the earliest and most current shoreline (2016) data points where they intersect at any given shore-perpendicular transect. The distance between the two shorelines (shore-transect intersect) is then divided by the time (number of years), between the two shorelines. Rates at each measured location on the shoreline are then statistically "smoothed and blocked" with neighboring transects in order to group adjacent shoreline segments that have similar rates into one shoreline segment. A "segment" of shoreline is defined as a portion of beach with statistically similar erosion rates and a minimum length of approximately 1,300 feet (400 meters). The mean erosion rate for a segment of beach serves as the ocean hazard setback factor.

Although oceanfront shorelines are in a constant state of flux, both eroding and accreting as a result of natural and engineering processes, setback factors based on calculated shoreline change rates in this latest study show similar trends to those in previous updates (see Table 1).

Statewide Totals Summary	**2016** Miles (% of total)	**2009** Miles (% of total)	**1998** Miles (% of total)	**1992** Miles (% of total)	**1986*** Miles (% of total)	**1980*** Miles (% of total)
Miles of Shoreline Mapped/Analyzed	304.5	307.4	312	300	237*	245*
Setback Factor (2 ft./yr.)	174.6 (57.3%)	190.2 (61.9%)	193 (62%)	165 (55%)	144 (61%)	149 (61%)
Setback Factors (2.5 to 5.0 ft./yr.)	67.1 (22.1%)	62.1 (20.2%)	64 (21%)	54 (18%)	43 (18%)	52 (21%)
Setback Factors (5.5 to 8.0 ft./yr.)	38.7 (12.7%)	31.5 (10.2%)	28 (9%)	30 (10%)	20 (8%)	22 (9%)
Setback Factors (>8.0 ft./yr.)	22.7 (7.4%)	20.8 (6.8%)	27 (8%)	32 (10.7%)	22 (9%)	22 (9%)
Insufficient Data	*1.4 (<0.5%)*	*2.8 (<1%)*	*0*	*19 (6%)*	*8 (4%)*	*0*

Table 1. Comparison of oceanfront setback factors from 1980 to 2016. Percentages are based on length of shoreline and its calculated setback factors, or ocean hazard setback. For example, the table row containing "Setback Factor (2 ft./yr.) is the length of oceanfront shoreline with a setback factor equal to 2. The last row labeled "Insufficient Data" show the length of shoreline where only one shoreline was available (i.e. migrating, open or closed inlets), therefore rates could not be calculated.

Statewide, the average blocked erosion rate value is3.7 feet per year, which is a slight increase (0.3 ft.) compared to the 2011 DCM update study using the 2009 shoreline (3.4 feet per year). The calculated average shoreline change rate for this 2019 study was 2.1 feet per year (erosion), and the median was 1.6 feet per year (erosion). The results are generally consistent with those of earlier erosion studies.

The main uses of the updated erosion rates will be as factors in the calculation of construction setbacks. As structures sited adjacent to the ocean shoreline may be vulnerable to erosion and water intrusion, the CRC seeks to minimize the loss of property and human life by establishing 'setbacks' that specify the minimum distance between a structure and the shoreline.

Where there is a high rate of erosion, structures must be located farther from the ocean shoreline than in locations where the shoreline is experiencing less erosion. The construction setback equations in Table 2 are used to site oceanfront development and determine the extent of the Ocean Erodible Area of Environmental Concern (OEA) - the area where there is a substantial possibility of excessive shoreline erosion. A minimum factor of two (2) is applied if the erosion rate is less than two feet per year or where the shoreline is accreting (see Table 2). The use of oceanfront setbacks based erosion rates was initially established by the Coastal Resources Commission (CRC) under the Coastal Area Management Act (CAMA) in 1979 and have be used along the coast since that time.

Construction Setback Using Minimum Setback Factor

Structure Size (square feet)	Construction Setback Equation	Minimum Setback (calculated using Setback Factor = 2 ft./yr.)
Less than 5,000	30 x Setback Factor	60
=>5,000 and < 10,000	60 x Setback Factor	120
=>10,000 and < 20,000	65 x Setback Factor	130
=>20,000 and < 40,000	70 x Setback Factor	140
=>40,000 and < 60,000	75 x Setback Factor	150
=>60,000 and < 80,000	80 x Setback Factor	160
=>80,000 and < 100,000	85 x Setback Factor	170
Greater than 100,000	90 x Setback Factor	180

Table 2. This table demonstrates an example of minimum construction setback based on structure size and minimum setback factor of 2 ft./yr.

Calculations with the new shoreline change rates show that of the 304.5 miles analyzed, 59.3 percent (180 miles) of the state's analyzed shoreline will experience no change in oceanfront setback factors while 8.5 percent (25.9 miles) of analyzed oceanfront shoreline will receive reduced setback factor values. The remaining 32.2 percent (98 miles) of analyzed shoreline will receive higher construction setback factors; however, 77 miles, nearly 79 percent, of the 98 miles is either Federal or State owned land where oceanfront development is minimal. Based on 2016 data, there are 8,777 oceanfront structures located adjacent to the Atlantic shoreline. Of these, approximately eighty-six percent (86%) of their owners will see no change in construction setback factor values, or reduced setback factors.

National Flood Insurance Rate Calculations

Calculating shoreline change rates for the purpose of updating construction setback factors every five years can affect the cost of some flood insurance premiums. Communities that regulate new development in their floodplains are eligible to participate in the National Flood Insurance Program (NFIP) qualifying for federally backed flood insurance. The Community Rating System (CRS) is an assessment tool used by the NFIP to reduce flood insurance premiums based upon action taken by a community beyond the NFIP's minimum standards for floodplain regulation. The objective of the CRS is to reward communities for current efforts, as well as to provide an incentive for new flood protection activities. Communities are classified based of the number of points they accumulate through flood preparedness activities, flood damage reduction work, and public information activities.

The reduction in flood insurance premium rates is provided according to a community's CRS classification, as shown Table 3. To reduce premiums by five percent (5%), a community must quality for five hundred (500) CRS points and be at least a Class 9 community on a class scale of one to ten (see Table 3). For each additional five hundred points, another five percent in savings is applied for communities with Special Flood Hazard Areas (SFHA). The maximum number of CRS points a community can qualify for is 4,500 with a potential savings of forty-five percent in their flood insurance premiums; these communities are considered by the U.S. Federal Emergency Management Administration (FEMA) to be Class 1.

FEMA's Community Rating System (CRS)

CRS Community Class	Points	SFHA	Non-SFHA
1	4,500	45%	10%
2	4,000	40%	10%
3	3,500	35%	10%
4	3,000	30%	10%
5	2,500	25%	10%
6	2,000	20%	10%
7	1,500	15%	5%
8	1,000	10%	5%
9	500	5%	5%
10	0	0	0

Table 3. Higher points correlate to reduced flood insurance premiums for communities with Special Flood Hazard Areas (SFHA).

The NFIP uses North Carolina's erosion rate updates to award Community Rating System (CRS) points to qualified coastal communities. FEMA's current policy allows North Carolina's oceanfront erosion rate update to account for fifty (50) CRS points only if the states erosion rates are updated once every five years. The current erosion rates, set in 2013, are due for an update in order to meet NFIP requirement. Loss of these points could potentially result in a five percent increase in flood insurance premiums depending upon the communities CRS classification.

Description of Rule Update

Rule 15A NCAC 7H .0304(1) describes Areas of Environmental Concern (AEC) within Ocean Hazard Areas (OEA). The proposed amendment will reference the updated erosion rate report and maps "North Carolina 2019 Oceanfront Setback Factors & Long-Term Average Annual Erosion Rate Update Study"

The draft amendment is located in Appendix A.

Cost or Neutral Impacts

Private Property Owners:

The oceanfront setback rules applies when oceanfront property owners are seeking a Coastal Area Management Act (CAMA) permit for construction of new a structure, or replacement of an existing structure requiring more than fifty percent (50%) repair or re-construction within the Ocean Erodible AEC. Based on analysis of the 2019 study, 7,579 (86.4%) of existing structures adjacent to the Atlantic shoreline will experience no change in its development setback factor, while 984 (11.2%) of oceanfront structures will experience an increase in construction setback factors. Table 4 depicts the number of properties affected by changes in erosion rates. Where proposed erosion rates would increase setback factors, it is worth noting that all these properties are in areas with known historically high erosion rates. "High erosion rate" is relative and considered by the NC DCM to be any rate greater than two feet per year. The highest erosion rates are primarily found in the vicinity of inlets that have not been regularly engineered for purposes of navigational safety, or erosion control (Brunswick County); and in areas where shoreline position is significantly influenced by persistent seasonal North-Easterly storms (Dare County

Analysis of the 2019 report show 984 oceanfront structures receiving an increased construction setback factor ranging from one-half a foot to three feet per year. These properties have historically had an associated high erosion rate with small fluctuations since the first study was done in 1980. These property owners could be negatively impacted by this change if their home is destroyed by more than fifty percent, and if they are unable to meet the required construction setback as measured from the first line of stable-natural vegetation. It is important to note that this does not preclude them from rebuilding should their home be destroyed as there are a number or grandfather provisions related to structure size (15A NCAC 07H .0306(a)(5)(L)) and (15A NCAC 07H .0306(a)(12).

The reference feature for measuring oceanfront development setbacks, the first line of stable and natural vegetation, is not mapped by the NC DCM since it is dynamic and can change with the frequency and severity of storms and other factors common the ocean shorelines. The location of the first line of stable and natural vegetation can also be influenced by a community's decision to construct a beach nourishment project. In time, the vegetation may respond and grow seaward with the beach, thus changing the point of reference from which the construction setback is measured. In a situation where a structure was destroyed and could not meet the construction setback, they still could potentially rebuild a structure on its original footprint and square footage if the structure meets certain grandfathering conditions (15A NCAC 07H .0306(a)(5)(L)).

Isolating or predicting the impact of state setback requirements on oceanfront property is difficult, if not impossible, since there are many statistically independent criteria that affect structure values.

To examine these types of changes, economists use hedonic price models to decompose the total structure value into measurements for individual aspects of the structure such as size, age, number of bathrooms, location, and nearby amenities. Existing research indicates that erosion risks may decrease the value of oceanfront property but that this effect is overshadowed by the much larger positive value homebuyers place on being located directly next to the ocean.[1] Our ability to analyze this change is also complicated by different local construction ordinances which typically have additional structure setback distances that are measured from points of reference not presented in this document, but can potentially limit size or placement of a proposed structure on a lot. It is true that as the erosion rate increases, construction setback increases; however, depending on size of lot and structure, local government construction requirements (lot-side and street setback) in instances of home damage exceeding 50 percent of the structure value, the property owner may still be able to repair the structure to its original size.

In the long-term, an increased setback factor may protect any existing or new structures from beach erosion. This may provide the property owners and the greater public with benefits.

As demonstrated in the following table, these impacts are not distributed equally among the oceanfront counties. Despite having the highest erosion rates, property owners in Brunswick and Dare Counties will see the most reductions in oceanfront setback factors. Although the rates are higher in these counties, it is important to note that NFIP does not consider the actual erosion rate value when they evaluate flood insurance rates. NFIP only considers that fact that the State of North Carolina did, or did not, update its erosion rates utilizing new data. NFIP requires this update to occur approximately once every five years. If the state does not, NFIP can then discredit fifty CRS points from all NC oceanfront communities with property inside a Special Flood Hazard area. On the oceanfront, these areas are defined by the Velocity Zone, or V-Zone, and vary in size based on coastal region. In some areas this zone may extend across an entire barrier island, while in others it may only contain first or second row property. NC's erosion rates are not used to delineate V-Zone boundaries.

[1]Bin, O. and Kruse J.B. "Real Estate Market Response to Coastal Flood Hazards" *Natural Hazards Review*, 7:4. 2006.; Hindsley, P. "Applying Hedonic Property Models in the Planning and Evaluation of Shoreline Management" Presented at the Coastal Society's 22nd International Conference in Wilmington North Carolina June 13, 2010.

Count of Structures Adjacent to Atlantic Shoreline & Associated Change in Erosion Rates

Location	Total Structures	No Rate Change	% No Change	Lower Rates	% Lower Rates	Higher Rates	% Higher Rates
Brunswick County	2,022	1,842	91.1%	110	5.4%	70	3.4%
New Hanover County	847	825	97.4%	11	1.2%	11	1.2%
Pender County	760	760	100%	0	0%	0	0%
Onslow County	607	558	91.9%	2	<1%	47	7.7%
Carteret County	1,257	1,256	99.9%	0	0%	1	<1%
Hyde County	0	0	100%	0	0%	0	0%
Dare County	2,539	1,750	68.9%	75	2.9%	714	28.1%
Currituck County	745	588	78.9%	16	2.1%	141	18.9%
TOTALS:	**8,777**	**7,579**	**86.4%**	**214**	**2.4%**	**984**	**11.2%**

Table 4. Count of structures adjacent to Atlantic oceanfront shoreline by county. Values represent the number of structures and percentages to demonstrate how the proposed update will influence construction setback factors for those structures. Data are based on 2016 NC 911 Orthophotos and 2018 county tax office information.

NC Department of Transportation (DOT):

Pursuant to G.S. 150B-21.4, DCM DOT permitting staff reported that the proposed amendment to 7H.0304 will not affect environmental permitting for the NC Department of Transportation. Development such as roads, parking lots, and other public infrastructure such as utilities continue to have a minimum setback factor of sixty feet (60) or thirty (30) times the shoreline setback factor (whichever is greater) as defined by 07H.0306(a)(2)(I). In the event NC DOT needs to build or maintain a road located within an Ocean Hazard AEC, DOT actions regarding the roadbed would likely be considered maintenance and repair and not affected by changes in the oceanfront setback factors

Local Government:

Public infrastructure (roads, parking lots, & utilities) have a minimum setback factor of sixty feet (60) or thirty (30) times the shoreline erosion rate (whichever is greater) as defined by 07H.0306(a)(2)(I). In the event that local governments need to replace or rebuild public infrastructure within an Ocean Hazard AEC, the proposed amendments will not change the CRC’s approach to permitting that activity.

Division of Coastal Management:

The Division of Coastal Management’s permit review process will not be changed by these amendments and DCM does not anticipate changes in permitting receipts due to the proposed action.

Benefits

Private Citizens:

Two hundred and fifteen (215) existing structures adjacent to the Atlantic shoreline will receive a reduced construction setback factor. This reduction ranges between 0.5 to 5 depending on the location of the first line of stable and natural vegetation in those areas. Although purely speculative, these properties could potentially be permitted and allowed re-development or expansion of the existing structure if new setback requirements can be met, and depending on the size of the new construction. These property owners could potentially benefit by being able to expand or re-develop their property to a greater extent possible than what is currently allowed under the existing setback factors. It is not possible to estimate the exact value of this benefit without knowing how many property owners would choose to undertake expansion or redevelopment, or knowing specifics related to construction plans; however, it is estimated that this is an overall positive net influence if compared to existing more restrictive setback requirements.

In the event that erosion rates were not updated in 2019, the loss of fifty CRS points would not have an immediate negative impact those communities listed in Table 5. However, several communities are scheduled to be reevaluated by NFIP in 2019 and 2020, and at that time could potentially benefit by having fifty points awarded as a direct result of having updated erosion rates, and potentially avoiding higher insurance premiums. Updating erosion rates alone does not guarantee a community will save five percent in premiums. However, the fifty points for updated erosion rates could make a difference for communities that are less than fifty points away from the next higher CRS classification.

Oceanfront Communities Participating in FEMA's Community Rating System Program[2]

	Community	Current CRS Class	% Discount for SFHA(1)	% Discount for Non-SFHA	CRS Points	CRS Points (-50)	*CRS Class Change if Points Lost*
1	Atlantic Beach	8	10	5	1365	*1315*	*No*
2	Carolina Beach	6	20	10	2058	*2008*	*No*
3	Caswell Beach	6	20	10	2240	*2190*	*No*
4	Duck	7	15	5	1664	*1614*	*No*
5	Emerald Isle	7	15	5	1906	*1856*	*No*
6	Holden Beach	8	10	5	1181	*1131*	*No*
7	Kill Devil Hills	6	20	10	2305	*2255*	*No*
8	Kitty Hawk	6	20	10	2116	*2066*	*No*
9	Kure Beach	8	10	5	1114	*1064*	*No*
10	Nags Head	6	20	10	2076	*2026*	*No*
11	North Topsail Beach*	*5**	25	10	*3600*	*3550*	*No**
12	Oak Island*	*7**	15	5	*2258*	*2208*	*No**
13	Ocean Isle Beach*	*8**	10	5	*2088*	*2038*	*No**
14	Pine Knoll Shores	6	20	10	2134	*2084*	*No*
15	Southern Shores	6	20	10	2153	*2103*	*No*
16	Sunset Beach*	*7**	15	5	*2109*	*2059*	*No**
17	Topsail Beach	5	25	10	2597	*2547*	*No*
18	Wrightsville Beach	7	15	5	1768	*1718*	*No*

Table 5. List of oceanfront communities participating in CRS. This table illustrates their current CRS Class, Special Flood Hazard Area (SFHA) Premium discount percentages, CRS points, and point score scenario subtracting 50 points. Based on current points, none of the listed communities would be impacted by the loss of fifty points. It should be noted that those communities identified with an asterisk (*) have an assigned CRS Class that does not correspond to their CRS Points because they did not meet FEMA's prerequisites during their last evaluation; therefore, could not be placed in the Class tier based on scored points.

[2] NFIP Flood Insurance Manual, 2018. (2018, October). October 2018 NFIP Flood Insurance Manual, Appendix F: Community Rating System. Retrieved January 23, 2019, from https://www.fema.gov, and;
Todd, Katherine. "RE: [External] RE: CRS Point Question." Message to Ken Richardson. 23 January 2019. E-mail.

Cost/Benefit Summary

Although updating rule 15A NCAC 7H .0304(1) to reference the proposed erosion rate report does not have an immediate negative or positive impact to community NFIP CRS points and Class ranking, this update does contribute to an annual cost savings for property owners living in oceanfront communities by the avoidance of a five percent (5%) increase in flood insurance rates due to the Coastal Resources Commission not updating its oceanfront setback factors. In addition, approximately 215 properties will experience reduced construction setbacks which may allow for a greater level of property development or redevelopment than under the previous setback calculations. This has an un-quantified, but positive, option value for these property owners.

References

Below, S., Beracha, E., Skiba, H. (2015). *Land Erosion and Coastal Home Values*. Journal of Real Estate Research, 37(4), 499-536.

Appendix A

DRAFT AMENDMENTS TO 15A NCAC 07H .0304 AECS WITHIN OCEAN HAZARD AREAS

15A NCAC 07H .0304 AECS WITHIN OCEAN HAZARD AREAS

The ocean hazard AECs contain all of the following areas:

(1) Ocean Erodible Area. This is the area where there exists a substantial possibility of excessive erosion and significant shoreline fluctuation. The oceanward boundary of this area is the mean low water line. The landward extent of this area is the distance landward from the first line of stable and natural vegetation as defined in 15A NCAC 07H .0305(a)(5) to the recession line established by multiplying the long-term annual erosion rate times 90; provided that, where there has been no long-term erosion or the rate is less than two feet per year, this distance shall be set at 180 feet landward from the first line of stable natural vegetation. For the purposes of this Rule, the erosion rates are the long-term average based on available historical data. The current long-term average erosion rate data for each segment of the North Carolina coast is depicted on maps entitled "North Carolina 2019 Oceanfront Setback Factors & Long-Term Average Annual Erosion Rate Update Study" ~~"2011 Long-Term Average Annual Shoreline Rate Update"~~ and approved by the Coastal Resources Commission on May 5, 2011 (except as such rates may be varied in individual contested cases or in declaratory or interpretive rulings). In all cases, the rate of shoreline change shall be no less than two feet of erosion per year. The maps are available without cost from any Local Permit Officer or the Division of Coastal Management on the internet at http://www.nccoastalmanagement.net.

(2) Inlet Hazard Area. The inlet hazard areas are natural-hazard areas that are especially vulnerable to erosion, flooding, and other adverse effects of sand, wind, and water because of their proximity to dynamic ocean inlets. This area extends landward from the mean low water line a distance sufficient to encompass that area within which the inlet migrates, based on statistical analysis, and shall consider such factors as previous inlet territory, structurally weak areas near the inlet, and external influences such as jetties and channelization. The areas on the maps identified as suggested Inlet Hazard Areas included in the report entitled INLET HAZARD AREAS, The Final Report and Recommendations to the Coastal Resources Commission, 1978, as amended in 1981, by Loie J. Priddy and Rick Carraway are incorporated by reference and are hereby designated as Inlet Hazard Areas, except for:

   (a) the Cape Fear Inlet Hazard Area as shown on the map does not extend northeast of the Bald Head Island marina entrance channel; and

   (b) the former location of Mad Inlet, which closed in 1997.

   In all cases, the Inlet Hazard Area shall be an extension of the adjacent ocean erodible areas and in no case shall the width of the inlet hazard area be less than the width of the adjacent ocean erodible area. This report is available for inspection at the Department of Environmental Quality, Division of Coastal Management, 400 Commerce Avenue, Morehead City, North Carolina or at the website referenced in Item (1) of this Rule. Photocopies are available at no charge.

(3) Unvegetated Beach Area. Beach areas within the Ocean Hazard Area where no stable natural vegetation is present may be designated as an Unvegetated Beach Area on either a permanent or temporary basis as follows:

   (a) An area appropriate for permanent designation as an Unvegetated Beach Area is a dynamic area that is subject to rapid unpredictable landform change due to wind and wave action. The areas in this category shall be designated following studies by the Division of Coastal Management. These areas shall be designated on maps approved by the Coastal Resources Commission and available without cost from any Local Permit Officer or the Division of Coastal Management on the internet at the website referenced in Item (1) of this Rule.

   (b) An area that is suddenly unvegetated as a result of a hurricane or other major storm event may be designated by the Coastal Resources Commission as an Unvegetated Beach Area for a specific period of time, or until the vegetation has re-established in accordance with 15A NCAC 07H .0305(a)(5). At the expiration of the time specified or the re-establishment of the vegetation, the area shall return to its pre-storm designation.

History Note: Authority G.S. 113A-107; 113A-107.1; 113A-113; 113A-124;

Eff. September 9, 1977;
Amended Eff. December 1, 1993; November 1, 1988; September 1, 1986; December 1, 1985;
Temporary Amendment Eff. October 10, 1996;
Amended Eff. April 1, 1997;
Temporary Amendment Eff. October 10, 1996 Expired on July 29, 1997;
Temporary Amendment Eff. October 22, 1997;
Amended Eff. July 1, 2016; September 1, 2015; May 1, 2014; February 1, 2013; January 1, 2010; February 1, 2006; October 1, 2004; April 1, 2004; August 1, 1998.