Inlet Hazard Area Boundaries, 2025 Update:

Science Panel Recommendations to the North Carolina Coastal Resources Commission

August 1, 2025

NC Coastal Resources Commission's Science Panel on Coastal Hazards
& NC Division of Coastal Management

NORTH CAROLINA
Department of Environmental Quality

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NC Coastal Resource Commission's July 2016 Scope of Work for the Science Panel

The CRC presented three tasks to the Science Panel:

1) Develop inlet shoreline change rate calculation methodology.
2) Re-evaluate points along the oceanfront shoreline where inlet processes are the dominant influence over shoreline position.
3) Present results at CRC meeting.

NC Coastal Resource Commission's April 2022 Scope of Work for the Science Panel

1) Building upon prior Science Panel work and reports, perform 5-year re-evaluation of Inlet Hazard Area (IHA) methods and boundaries incorporating data collected since the 2019 study.
2) Evaluate end-point and linear regression methods, and consider alternative methods for calculating oceanfront shoreline change rates.
3) Present draft report(s), including proposed IHA boundaries and erosion rates, in summer 2024.

Current Science Panel Members

Dr. Reide Corbett (East Carolina University); Dr. Andrea Hawkes (University of NC at Wilmington); Dr. Joseph Long (University of NC at Wilmington); Dr. Jesse McNinch (USACE); Dr. Laura Moore (University of NC at Chapel Hill, Science Panel Chair); Dr. Brad Murray (Duke University); Dr. Martin Posey (University of NC at Wilmington); Mr. Spencer Rogers (NC Sea Grant retired); and Mr. Greg "Rudi" Rudolph (Carteret County Shore Protection Office retired).

Acknowledgements

This report is the result of a close collaborative effort between the current North Carolina Coastal Resources Commission's (CRC) Science Panel and the Division of Coastal Management (DCM). The Science Panel members provided their coastal processes and inlet knowledge and experience and guided the development of the final methodology used. The DCM, led by Mr. Ken Richardson, performed all statistical analyses, created the maps and figures, and prepared the first draft of the report. His efforts were supported by the DCM staff, including Mr. Mike Lopazanski, and Mr. Tancred Miller.

This report builds on the reports and work carried out by former Science Panel members Mr. Steve Benton (DCM retired); Mr. Bill Birkemeier (USACE Field Research Facility retired, former Science Panel Chair); Dr. Bill Cleary (UNC Wilmington emeritus); Mr. Kevin Conner, PE (USACE); Mr. Tom Jarrett, PE (Coastal Planning and Engineering); Dr. Dave Mallinson (East Carolina University); Dr. Margery Overton (former Science Panel chair, NC State University); Dr. Charles "Pete" Peterson (UNC Chapel Hill Institute for Marine Science); Dr. Stan Riggs (East Carolina University); Dr. Tony Rodriguez (UNC Chapel Hill Institute for Marine Science); Mr. Spencer Rogers (NC Sea Grant); Dr. Beth Sciaudone, PE (NC State University); Dr. Greg Williams, PE (USACE Wilmington District retired); and Dr. Rob Young (Western Carolina University). The authors also express their gratitude to former members of the Science Panel who were involved in the early consideration of inlet hazard designation: Dr. Walter Barnhardt (US Geological Survey); Dr. John Fisher (former Science Panel chairperson, NC State University emeritus); Dr. Orrin Pilkey (Duke University emeritus); and Dr. John Wells (Virginia Institute of Marine Science).

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Executive Summary

The initial Inlet Hazard Areas in North Carolina were established in 1979, recognizing the dynamic nature of shorelines near inlets compared to those along the oceanfront. The innovative methodology at the time used the historical migration of inlet-facing shorelines (the shorelines located between the two islands on either side; hereafter referred to as 'inlet shorelines') to define IHAs. Subsequent research revealed that, in addition to inlet migration, fluctuations in the ocean shoreline position near inlets pose a significant threat to development. Over the past forty years, some inlets have undergone substantial changes. Certain inlets like Mad Inlet, Old Topsail Inlet, and New/Corncake Inlet have closed completely with little chance of reopening. Others, such as New Topsail and Shallotte Inlets, have shifted beyond the original IHA boundaries.

In 2004, the Science Panel on Coastal Hazards initiated efforts to develop the IHA methodology, leading to initial recommendations in 2010, followed by an update in 2019 and the current update, which the Science Panel started working on in 2024. Each proposed update incorporates new data collected since the most recent prior study and involves review and consideration of the prior methodology used to define IHAs, with modifications made as deemed necessary.

Inlet shorelines and oceanfront shorelines near inlets exhibit distinct behaviors compared to oceanfront shorelines unaffected by inlets. While inherently dynamic and characterized by local uniqueness, inlets in North Carolina can generally be categorized as either *migrating* in the direction of net alongshore sand transport, or *non-migrating*. Migrating inlets are characterized by rapidly changing inlet shorelines, which often undergo cumulative, long-term change at a pace that can be significantly faster (by an order of magnitude or more) than oceanfront shorelines distant from inlets. For instance, New Topsail Inlet has been steadily migrating southward at a rate of approximately 90 feet per year since the 1930s. Similarly, Mason Inlet experienced a notable southward shift of 365 feet per year before it was relocated and stabilized in 2002.

In the vicinity of both migrating and non-migrating inlets, shoreline positions exhibit pronounced fluctuations, shifting between periods of relatively rapid erosion and accretion over timescales of years to decades. Inlets can widen and narrow in response to changes in wave height and storms, equating to fluctuations in the positions of inlet shorelines. In addition, movements in the primary ebb-tide channel across the subaqueous ebb-tidal delta (or 'offshore bar') often cause fluctuations on both inlet and near-inlet oceanfront shorelines. Shorelines on one side of an inlet tend to erode while shorelines on the other side accrete, with the pattern reversing when the ebb channel shifts from one side of the delta to the other.

Because inlets and their shorelines are highly variable through space and time as described above, the existing vegetation line (EVL) in inlet-affected areas is also highly variable through space and time. This makes the EVL an unreliable, often misleading, indicator of long-term erosion trends and hazards in inlet-affected areas. Basing setbacks on the EVL in inlet-affected areas, then, can lead to construction of buildings and infrastructure within the envelope of fluctuating shoreline positions. Thus, **a key conclusion of this report, which is consistent with prior recommendations of the Science Panel, is that accurately identifying hazard areas associated with fluctuations in shoreline position near inlets requires measuring from the landward-most position of all vegetations lines for the period of study – a composite line we call the Hybrid Vegetation Line (HVL) – rather than from the EVL**. For this reason, the Science Panel strongly recommends and advocates for measuring setbacks from the HVL in IHAs. The HVL line is analogous to the Pre-Project Vegetation Line (formerly called Static Vegetation Line), currently employed where beach nourishment has occurred) in that it is a fixed line and based on an historical vegetation line.

To best capture risk associated with the rapid annual to decadal shoreline changes associated with inlets, the Science Panel reviewed and refined the IHA Method (IHAM). This modified approach echoes the CRC's Ocean Erodible Area (OEA) mapping method, which establishes minimum and maximum setbacks and the landward extent of the OEA by measuring from either the EVL or the pre-project line. The IHAM methodology includes risk lines calculated in the same way as the oceanfront minimum (30 times the erosion rate) and maximum (90 times the erosion rate) setbacks, except that the risk lines are measured from the HVL instead of the EVL or Pre-Project Vegetation Line.

Because shorelines in the vicinity of inlets behave differently than shorelines farther away from inlets, shoreline erosion rates are measured, and applied, differently near inlets:

- The time period for analysis is selected for each inlet individually, based on the available imagery and timing of changes to the inlet system that affect inlet dynamics, including relevant management actions.

- The alongshore boundary of the IHA is identified by an increase in shoreline change variability compared to adjacent oceanfront shoreline that is less influenced by inlets.

The maps in this report present the Panel's recommended IHA Boundaries for each of the developed inlets. Because inlet fluctuations make the EVL a poor indicator of future conditions, the proposed boundaries are delineated relative to the HVL.

The Science Panel on Coastal Hazards recommends the CRC consider updating subsequent IHA boundaries every five years, to coincide with updates to oceanfront shoreline erosion rates and OEA boundaries. This 2025 report is submitted as an update of the 2010 and 2019 Science Panel recommendations and reports.

1.0 Introduction

Tidal inlets are important and ever-changing components of barrier island coasts. They serve various functions, including connecting the ocean to inland bodies of water, fostering habitat, aiding navigation, enhancing water quality, and supporting recreational activities. Inlets are extremely dynamic, and their characteristics fluctuate over time. They may open and close, become narrower or wider, and/or shift position over time. Inlet width, in particular, can fluctuate rapidly at daily to annual time scales. This causes inlet shorelines to change position at much faster rates than oceanfront shorelines distant from inlets. For example, in 2013-14, Tubbs Inlet between Sunset Beach and Ocean Isle Beach widened by a factor of three from approximately 560 feet to more than 1700 feet. The inlet has since been narrowing, moving toward its previous width. These changes in inlets occur in response to sand supply, storms, sea level, geological control, tidal currents, tidal channels, and shifting tidal deltas. While all inlets possess unique characteristics that change over time, they can generally be classified based on their dynamics, some tend to migrate in one general direction along the coastline, while others do not exhibit a cumulative alongshore migration.

- *Migrating inlets*. Some inlets move alongshore in response to the prevailing alongshore current and sand transport, persistently accreting on one side and forcing the opposite inlet shoreline to erode. Inlet migration rates vary with wave conditions. Despite a prevailing direction of migration, in some cases, inlet migration may temporarily reverse direction. Inlet shorelines at migrating inlets exhibit very rapid long-term change. For example, New Topsail Inlet has been migrating south at approximately 90 feet per year since the 1930s. Mason Inlet was migrating at 365 feet per year before it was relocated and stabilized in 2002. The presence and rate of inlet migration is affected by natural processes, inlet closures, dredging, beach nourishments, and engineered structures. At the time of this report only Old Topsail and Drum Inlets are considered actively migrating.
- *Non-migrating inlets*. Most of the NC inlets are not actively migrating but have fluctuated around the same general location for decades to centuries. These inlets remain in the same general location because: 1) the net alongshore sediment transport rate is small relative to the rate that tidal currents transport sand; 2) a feature in the underlying geology, such as relict river channel, limits migration; and/or 3) maintenance dredging and engineering structures prevent inlet migration.

In addition to the rapid changes in shoreline position around inlets, the oceanfront shorelines near inlets are subject to much higher short-term (annual to decadal) multi-year patterns of shoreline erosion and accretion than oceanfront shorelines more distant from inlets. These oceanfront shorelines are inlet influenced, and fluctuations are most often caused by shifts in the alignment of the main tidal channel through the ebb-tidal delta or offshore bar. As the main tidal channel of an inlet naturally shifts from one side of the inlet to the other, oceanfront shorelines near the inlet erode on one side while shorelines on the opposite side build seaward. When the channel shifts in the opposite direction as the result of a storm or gradually over a period of years to decades, the eroding shoreline recovers and the accumulation on the other side is lost. An inlet's offshore shoals can also cause near-inlet accretion features along the oceanfront. For migrating inlets, the oceanfront shoreline zones experiencing inlet-related fluctuations migrate alongshore with the inlet, though the fluctuations can be less pronounced than for non-migrating inlets.

Although these fluctuations generally do not contribute to the long-term (many decades) erosion rate, they can pose considerable threat to coastal development because shorelines that appear stable or accretional when development occurs can shift to an erosional phase in subsequent years or decades.

This report describes methods to identify areas where inlet processes are the dominant influence on shoreline change rates due to factors like inlet migration, fluctuations in width and depth, and near-inlet oceanfront variability.

One way to appreciate just how dynamic inlets are is to examine their movement through time. While difficult to show in a print report, it is easy to visualize online using the historic inlet atlas animation developed by North Carolina Sea Grant and available using the following link:

https://ncseagrant.ncsu.edu/shifting-shorelines-inlet-atlas/

1.1 Establishment of Inlet Hazard Areas and Updates

The establishment of Areas of Environmental Concern (AECs) as authorized under the NC Coastal Area Management Act (CAMA) of 1974 (Article 7, Part 3 - G.S. § 113A-113) forms the foundation of the North Carolina CRC's permitting program for regulating coastal development. Rules define the AEC, which includes three components: 1) Ocean Erodible; 2) Inlet Hazard; and 3) Unvegetated Beach (15A NCAC 07H.0304). The IHA AEC is defined as locations that "are especially vulnerable to erosion, flooding and other adverse effects of sand, wind, and water because of their proximity to dynamic ocean inlets."[1]

The IHA maps in use today are based on analysis by Priddy and Carraway (1978). They utilized aerial photographs spanning 1940 through 1977 to analyze 23 inlets, of which 19 are still active.

[1] North Carolina Administrative Code (NCAC), Title 15A, Chapter 7, Sub-Chapter H .0304(2)

The number of photos at each inlet ranged from 6 to 32. Measurements were made on the photos themselves with a spatial resolution of 300 feet alongshore. A shoreline change rate was computed using both linear and quadratic equations to determine the best-fit shoreline change rate for each inlet. A landward limit to the IHA was established at the point where the 1% chance that shoreline position would exceed the defined hazard area at any time within the decade (1978-1988). At inlets where the regression methods could not be used, the IHA boundaries were established by using the methods of Fisher (1962, 1967) to map previous inlet territory. IHA boundaries were not designated for Masonboro Inlet, Drum Inlet, the southwestern side of Ocracoke Inlet, and Oregon Inlet because they were excluded from requirements listed in the NC Coastal Plan (NC Department of Natural Resources and Community Development, 1977). The IHAs developed for the 19 developed inlets in the study by Priddy and Carraway were presented to the CRC as IHA boundary recommendations and adopted in 1979. Minor amendments followed in 1981.

In 1998, the CRC Science Panel on Coastal Hazards identified the need to update the methodology for defining the IHA (Oct 21, 1998, Science Panel meeting minutes) and in their short-term recommendations to the CRC (Fisher, 1999) stated:

> *"Inlet Hazard Areas are coastal zones that are especially vulnerable to migration, erosion, flooding, and other adverse effects of sand, wind, and water because of their proximity to dynamic tidal inlets. Each of North Carolina's inlets is unique and there are distinct differences in the history and behavior of inlets in different coastal compartments of the state. Current Inlet Hazard Areas are based upon original studies conducted over twenty years ago. The Inlet Hazard Areas need revision to incorporate updated knowledge.*
>
> *The Panel recommends that the delineation of the Inlet Hazard Areas be revised after a review of site-specific studies of each inlet by a group of experts. The hazard zone delineation shall consider such factors as previous inlet territory, structurally weak areas along migration pathways, unusually low and narrow sections of barriers prone to breaching, external influences such as jetties and channelization, and increased erosion extending along adjacent shorelines."*

Later research has shown that in addition to inlet migration addressed in the original IHA analysis, the fluctuations in the ocean shoreline adjacent to the inlet have also been a significant threat to development (Cleary, 1999). After 46 years some of the inlets significantly changed. Three of the tidal inlets (Mad, Old Topsail and New/Corncake Inlets) from the 1978 study have closed naturally, while Shallotte, New Topsail, Bear, Barden, Bogue and Hatteras Inlets have moved significantly or completely outside the limits of the original IHA boundaries. Little River Inlet, located in South Carolina just over the SC/NC border has since been stabilized and no longer requires an IHA for the NC side.

In 2004, the Science Panel on Coastal Hazards began working on revising the IHA methods leading to initial recommendations by DCM to the CRC in 2010. This effort stalled after extensive public comment, in part because existing IHA rules were perceived as being overly restrictive in the larger redefined areas. Public comments on the 2010 draft also questioned the increased IHA size and raised concerns that inlet risk within the IHA varied considerably. The Science Panel, DCM and CRC have agreed that IHA rules should be revised to better accommodate the oceanfront expansions proposed in the latest draft maps.

In 2010, the Panel crafted initial draft IHAs for each of the established inlets. However, public feedback highlighted shortcomings, notably that the existing IHA regulations were ill-suited for the significantly expanded delineated regions. Moreover, there was no presentation of proposed regulatory amendments to accompany the updated boundary drafts. Criticisms also arose regarding the enlarged scope of the 2010 drafts and the notable variability in inlet risk within these areas. By contrast, the Ocean Erodible Area (OEA) portion of the Ocean Hazard Area (OHA), when delineated as a simple shoreline box, resembles the IHA. Nonetheless, the erosion rates published within the OHA pinpoint relatively heightened risks nearer to the shoreline. This initiative was ultimately postponed as the CRC, DCM staff, and Science Panel redirected their resources and efforts to prioritize the completion of the 2010 Terminal Groin Study,[2] 2011 Oceanfront Erosion Rate study,[3] 2012 NC Session Law 2012-202 Areas of Environmental Concern (AEC) study[4], and the 2015 NC Sea Level Rise study[5].

In 2016, the Science Panel on Coastal Hazards was again asked by the Coastal Resources Commission to develop an updated methodology to delineate IHAs. That report presented the new methodology, the IHA Method (IHAM), and recommended revised IHA boundaries for the ten active and developed tidal inlets in North Carolina. The inlets considered include Tubbs, Shallotte, Lockwood Folly, Carolina Beach, Masonboro, Mason, Rich, New Topsail, New River, and Bogue Inlets (**Figure 1**). The Cape Fear River entrance (Cape Fear Inlet) and Beaufort Inlet were not included in the 2016 study because they are separately managed in the State Ports Inlet Management AEC. The shorelines adjacent to Brown's, Bear, Barden, Drum, Ocracoke, Hatteras and Oregon inlets are publicly owned, with a low potential for future development. Thus, they were not included in this report.

[2] 2010 Coastal Resources Commission Terminal Groin Study, mandated by Session Law 2009-479
[3] 2011 Long-Term Average Annual Erosion Rate and Setback Factor Update Study
[4] 2014 Inlet Management Study
[5] 2016 NC Sea Level Rise Assessment Report: 2015 Update to the 2010 Report and 2012 Addendum

It wasn't until 2019 that the CRC finally approved the Science Panel's updated report. However, the implementation of the new boundaries faced setbacks, including prolonged public hearings, local government workshops, and the onset of the COVID-19 Pandemic. Consequently, the 2019 update was put on hold until the CRC could resume in-person meetings. As the CRC resumed consideration of the 2019 report it was nearly time to update both inlet and oceanfront erosion rates. In April 2022, the CRC formally requested the Science Panel to collaborate with Division Staff in updating the boundaries, incorporating new data collected since the 2019 proposal.

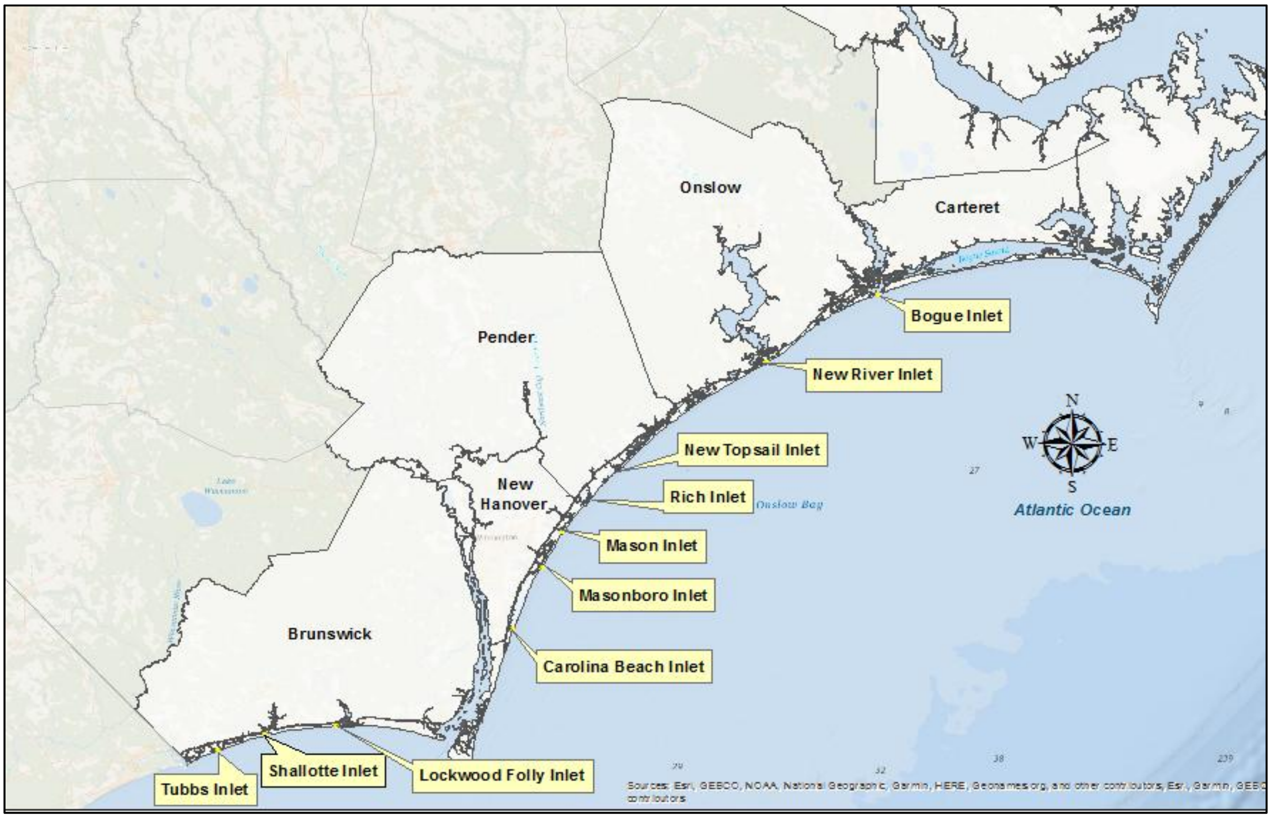

Figure 1. *Study areas include Tubbs, Shallotte, Lockwood Folly, Carolina Beach, Masonboro, Mason, Rich, New Topsail, New River, and Bogue Inlets. At least one side of each inlet is developed.*

A significant portion of stakeholder input regarding the 2010 IHA draft revolved around a common question: "*Does the level of risk remain consistent across all areas within the designated boundaries*?" Thus, in 2016 when the Panel resumed work on updating IHAs, the Panel devised the IHAM to delineate the IHA and establish two risk lines, akin to the CRC's OEA mapping. These risk lines are calculated like the minimum (30 times erosion rate) and maximum (90 times erosion rate) setbacks along the oceanfront but instead of being measured from the EVL, they were measured from the HVL, which represents the landward-most position of all vegetation lines for the period of study. Unlike the oceanfront where the EVL can serve as a reliable indicator of long-term erosion trends, fluctuations in the vegetation-line location near inlets undermines its utility as a management tool in these areas. For this reason, the panel concluded that the EVL lacks dependability as a feature from which setbacks can be measured, and to better capture the dynamic fluctuations near inlets should be measured from the HVL.

In November 2018, the NC CRC's Science Panel delivered revised IHA boundaries to the Commission. Subsequently, in February 2019, the CRC approved the updated boundaries, initiating a sequence of public hearings and workshops with local governments and stakeholders. This timeline underwent an extension to allow additional time for public and local government feedback. However, the onset of the COVID-19 Pandemic brought all public meetings to a halt, and the process of updating boundaries was once again on hold.

In 2019, the Science Panel also recommended re-evaluating boundaries and methodologies every five years, aligning with routine updates on oceanfront erosion rates. When discussions on the IHA were renewed in 2023, stakeholders urged the Commission to heed this recommendation. They sought an update to the 2019 proposal, considering new data and conditions, such as the completion in April 2022 of the terminal groin at Shallotte Inlet, Ocean Isle Beach, and any potential method adjustments deemed necessary. Despite the 2019 proposal not being enacted, DCM Staff supported the suggestion, given the unforeseen delay and upcoming oceanfront erosion study scheduled for 2024-2025. In April 2023, after thorough consideration, the CRC asked the Panel to reassess boundaries and methodologies in sync with the forthcoming oceanfront erosion rate study.

In line with the findings of the 2016 study, the current Science Panel on Coastal Hazards reaffirms the use of 30- and 90-Year Risk Lines for delineating IHAs at each inlet. Furthermore, the Panel concludes that the EVL does not reflect the fluctuating nature of inlet and inlet-adjacent shorelines. Instead, the Panel proposes employing the HVL for setback measurements, because it captures the landward-most position of the vegetation line during the period of observation, and thus represents the landward limit of the envelope across which vegetation lines fluctuate. The HVL is a fixed line, akin to a Pre-Project Vegetation line, established prior to the completion of large-scale beach nourishment projects exceeding 300,000 cubic yards[6]. The current panel also reviewed the IHA methodology, finding previously used methods sound, and identifying an improvement on the approach to delineating alongshore boundaries (see Methods).

[6] North Carolina Administrative Code (NCAC), Title 15A, Chapter 7, Sub-Chapter H .0305(6)

1.2 Report Organization

This report is organized into four chapters with three appendices; Chapter 1 provides an introduction and historical perspective; Chapter 2 describes the methodology used; Chapter 3 describes the analysis and the recommended IHA for each inlet, and; Chapter 4 provides recommendations.

Acronyms used in the report are listed in Appendix A. Appendix B lists definitions for key terms. Appendix C provides maps for each proposed IHA, which duplicate the IHA maps provided in Chapter 3 but are larger (11 x 17 inch).

Two terms used frequently throughout the report that are important to highlight are:

"**Existing Vegetation Line" (EVL)** which is defined as the current field-determined vegetation line.

"Hybrid Vegetation Line" (HVL) which is defined as the landward-most position of all vegetation lines throughout the study period (which varies by inlet), and serves as the reference point for measuring the landward extent of the IHA.

2.0 Inlet Hazard Area Methodology (IHAM)

The IHAM emerged from extensive collaboration between the North Carolina Division of Coastal Management (DCM) and the Coastal Resources Commission's (CRC) Science Panel on Coastal Hazards. This method applies a set of statistical and analytical procedures for drafting the IHAs. The key procedures of the IHAM:

1) Identify and collect aerial imagery that captures historic coastal conditions, selecting images from periods not affected by recent storms or beach nourishment projects.

2) Establish the Hybrid Vegetation Line (HVL), which represents the landward-most position of all vegetation lines throughout the study period. It is critical to use the HVL instead of the EVL (as in the OEAs) because the EVL cannot capture the variability in vegetation line, and therefore shoreline position, that puts development at risk in inlet-affected areas.

3) Use GIS software to digitize and analyze historical shoreline positions from aerial imagery and other geospatial datasets. Apply the USGS Digital Shoreline Analysis System (DSAS) to calculate long-term average annual shoreline change rates by establishing transects perpendicular to the shoreline and performing statistical linear regression on multiple shoreline datasets.

4) Compute the IHA alongshore boundaries.
    a. Compute the standard deviation (STD) of shoreline position, at each transect alongshore. Use the IHAM from the 2010 and 2019 reports, hereafter referred to as "STD-increase," to identify the initial, approximate IHA alongshore boundaries representing the extent of inlet influence along the shoreline. Standard deviation in shoreline position is higher near inlets and typically decreases moving away from inlets. Using STD-increase, the alongshore boundary of an IHA is determined as the location where the STD starts to increase. The initial approximate IHA alongshore boundaries identified by the STD-increase approach are used only as the inlet-ward limits for calculation of the 'grand average' oceanfront standard deviation, which is 15 meters (or 49.2 feet) and used in methods b and c below.

    b. Apply the STD Threshold Method (STD > 15-m). Using this approach, moving toward each inlet, the alongshore boundary of the IHA corresponds to the transect at which the local standard deviation first rises above the grand average standard deviation of 15 m.

c. STD Slope Threshold Method (STD Δ > 1-ft). This approach compares the differences in standard deviation between each adjacent pair of transects–a measure of the alongshore rate of change (or slope) of standard deviation. Moving toward each inlet, the alongshore boundary of the IHA corresponds to the first transect at which this alongshore difference in standard deviation rises above a value of 1 ft (0.3 m), which is the average difference between all pairs of transects sufficiently distant from inlets for inlet influences to be negligible. The idea behind this approach is to identify the alongshore boundary of the plateau of relatively low values typical for non-inlet-influenced transects. This approach most reliably determines the extent of shoreline where inlet influence is dominant and is the default approach applied at most inlets (**Table 1**).

5) Calculate the 30- and 90-Year Risk Lines by multiplying the smoothed erosion rates by 30 and 90, respectively, and measuring those distances landward from the HVL. The 90-Year Risk Line is then used to define the landward boundary of the IHA. This methodology mirrors the approach used along the oceanfront within the OEA, where comparable calculations, measured from the appropriate vegetation line, are used to determine minimum and maximum setback distances and to delineate the landward extent of the OEA.

6) Review draft IHA boundaries for special circumstances requiring adjustment to IHA boundaries. As an additional check, compare the draft alongshore IHA boundaries arising from steps 1-5 with imagery to identify any site-specific factors or inlet behaviors that indicate the need for further consideration and adjustment.

We note that the datasets used in the analyses are in mixed units; some are in meters and others are in feet. For this reason, when identifying thresholds, we used the nearest round number whether in meters or feet (e.g., STD >15 m and STD Δ > 1-ft).

Table 1 lists the methods used to identify the IHA boundary for each side of each inlet.

Table 1. *Methods used to identify the IHA boundary for each side of each inlet.*

Inlet	Type	IHA Method N/E Side of Inlet	IHA Method S/W Side of Inlet	Landward IHA Boundary (N/E Side)	Landward IHA Boundary (S/W Side)
Tubbs	non-migrating	STD Δ > 1-ft	STD Δ > 1-ft	90-YRL + Riprap	90-YRL
Shallotte	non-migrating	STD Δ > 1-ft	STD Δ > 1-ft	90-YRL	90-YRL
Lockwood Folly	non-migrating	STD > 15-m	STD > 15-m	90-YRL	90-YRL
Carolina Beach	non-migrating	STD Δ > 1-ft	*	90-YRL	90-YRL
Masonboro	non-migrating	*	#	90-YRL	90-YRL
Mason	non-migrating	STD Δ > 1-ft	STD Δ > 1-ft	90-YRL	90-YRL
Rich	non-migrating	STD Δ > 1-ft	*	90-YRL	90-YRL
New Topsail	migrating	*	STD Δ > 1-ft	90-YRL	90-YRL
New River	non-migrating	STD Δ > 1-ft	**	90-YRL	n/a
Bogue	non-migrating	**	STD Δ > 1-ft	n/a	90-YRL

** No alongshore boundary is identified because Masonboro and Lea-Hutaff Islands are undeveloped, and STD is > 15 m along the entire island length, so the entire island is included in the recommended IHA.*
*** No alongshore boundary is identified because Onslow Beach and Bear Islands are undeveloped, publicly owned lands.*
 # The north/east side of Masonboro Inlet features a weir jetty, operational for approximately 60 years, which defines the alongshore boundary (see Section 3.5 for details).

2.1 Aerial Imagery Selection

Orthorectified and georeferenced imagery served as the foundation for mapping shorelines and vegetation lines. Georeferenced imagery, like orthorectified imagery, involves the process of aligning aerial or satellite images with real-world geographic coordinates. However, unlike orthorectification, which corrects for terrain relief, sensor orientation, and camera tilt, georectification primarily focuses on aligning the image with a known map projection and coordinate system. Georectified imagery allows for accurate spatial referencing and integration with other geographic data layers in GIS (Geographic Information Systems) applications, enabling precise spatial analysis, mapping, and visualization, especially for low-relief settings, such as along barrier island coastlines.

In selecting imagery for this study, priority was given to accessible data that had not been affected by storm events or beach nourishment projects within one year of the photo collection date. This approach was taken to ensure consistency and minimize potential outliers in the analysis. However, avoiding oceanfront shoreline data influenced by beach nourishment projects is becoming particularly challenging in North Carolina, as these engineering practices have become increasingly common and frequent in recent years. Additionally, pre-1970 aerial images, especially those predating Hurricane Hazel in 1954, were notably scarce compared to the more abundant post-1970 data. This scarcity of older imagery further complicated efforts to find suitable historical reference points for the study. North Carolina Department of Transportation's (DOT) Photogrammetry Unit served as the primary source of imagery collected between 1970 and 2000, while post-2000 imagery originated from a variety of sources: US Army Corps of Engineers (USACE); US Geological Survey (USGS); National Oceanic and Atmospheric Administration (NOAA); US National Agricultural Imagery Program (NAIP); NC 911 Board coastal imagery; or oceanfront county data (Brunswick, Dare, Onslow, Pender, and New Hanover).

2.2 Establish the Hybrid-Vegetation Line (HVL)

Currently, the EVL serves as the primary feature from which new construction setbacks are measured. This vegetation line can be useful for assessing long-term erosion patterns along the coastline, providing a valuable benchmark for understanding gradual changes. However, it falls short in capturing the dynamic and potentially rapid fluctuations that occur near inlets. In these areas, natural processes such as tidal currents, waves, and sediment transport, and engineering practices can cause substantive changes in the vegetation line on the timescale of days, months and years, making the EVL less reliable as a sole indicator of erosional trends.

To overcome this limitation, the HVL was devised as a more reliable indicator of the range of short-term variation. The HVL represents the landward-most position of the vegetation line at each inlet over the period of study and is therefore composed of segments from different years/dates (**Figures 2a & b**).

***Figure 2a**. The Hybrid-Vegetation (red line) represents the landward-most position of the vegetation line (green lines) during the period of study and is therefore a composite line, composed of segments from different dates. This example illustrates HVL at Lockwood Folly Inlet, Holden Beach.*

Figure 2b*. The Hybrid-Vegetation (red line) at Lockwood Folly Inlet, Oak Island.*

2.3 Mapping Shorelines

DCM's continually growing database of oceanfront and inlet shorelines facilitated this study. The majority of the shorelines used in the development of the IHA boundaries presented in this report, were mapped using historic orthophotography (Section 2.1) to digitize the wet-dry line (**Figure 3**). For the purposes of analyzing long-term shoreline change rates in NC, the wet-dry line can be considered a useful proxy for the Mean High Water (MHW) line. Two studies carried out by DCM (Limber et al., 2007a; 2007b) indicated that the LiDAR-derived MHW line could be used interchangeably with the wet-dry shorelines in North Carolina. Three of the shorelines included in this study represent the location of MHW directly because they were derived from LiDAR (1997 and 2004), or NOS T-Sheets (either from the 1930s or 1940s).

Although some shoreline data exist prior to 1970, this study focuses on the period from 1970 to the most recent available dataset (2022). This timeframe was chosen primarily because imagery from the North Carolina Department of Transportation (NC DOT) is extremely limited or absent before 1970 at most inlet locations, making earlier shoreline positions less reliable for consistent analysis. In addition, early shoreline positions (1930-1940) were heavily influenced by changes and uncertainties in inlet hydrodynamics associated with the construction and maintenance dredging of the Atlantic Intracoastal Waterway (AIWW), especially in the southern portion of the State.

To reduce the effects of outliers, efforts were made to avoid using shorelines derived from imagery collected immediately after or within one year of major storms or beach nourishment projects. However, it is important to acknowledge that because the scale and frequency of the beach nourishment projects in North Carolina have been steadily increasing, it is increasingly difficult to identify imagery that reflects unnourished conditions.

Following these data selection guidelines yields 17-33 shoreline positions for analysis at each inlet.

Figure 3. *Interpretation of the "wet-dry" shoreline (black dashed line) using orthophotography.*

2.3.a Casting transects (25-meter spacing)

Shoreline positions along oceanfront areas and inlets were assessed using a series of numbered transects perpendicular to the shore spaced at 25-meter (82-foot) intervals. To ensure a consistent shoreline-perpendicular orientation and spacing, transects were extended from an onshore baseline (**Figure *4***). This alignment followed the overall positional trend of shoreline locations, particularly where inlet shorelines curve away from the oceanfront. This is a commonly-used approach that best captures shoreline change in a consistent manner where alongshore shoreline shape varies. At each intersection between shorelines and transects, shoreline change rates and additional statistical measures were computed using the US Geological Survey's (USGS) Digital Shoreline Analysis System (DSAS) (Thieler et al., 2009) in conjunction with ESRI's ArcGIS.

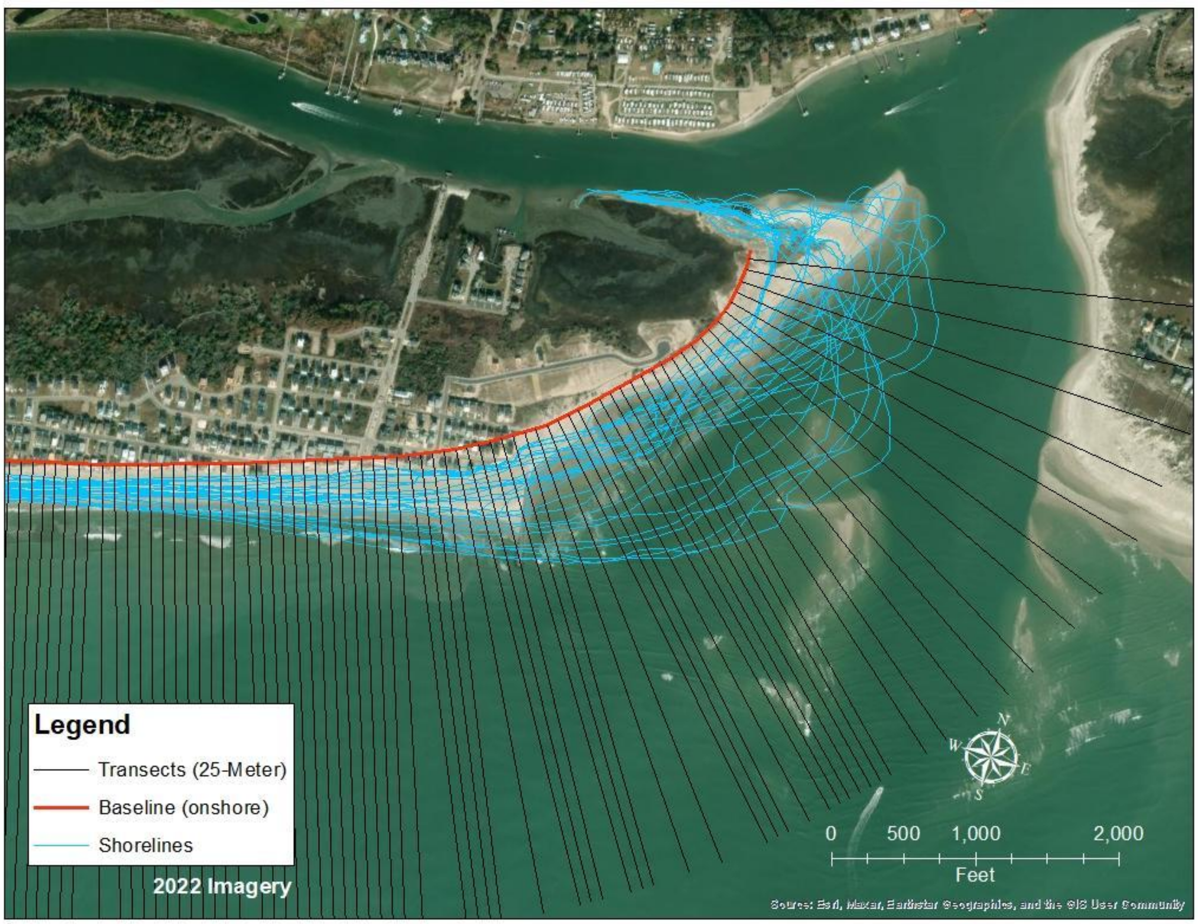

Figure 4. *This example illustrates transects (black lines) spaced 25 meters apart from an onshore baseline (red line). The baseline aligns with the overall trend of the shorelines (indicated by blue lines), resulting in transects that are generally perpendicular to the shorelines.*

As in this study, future update studies should involve reassessing baselines and transects, recasting them as needed to ensure that any newly added shorelines in subsequent analyses.

2.3.b Computing Shoreline Change Rates: Least Squares Regression

Since 1979, the Division of Coastal Management has been calculating long-term oceanfront shoreline change (erosion/accretion) rates using the end-point method, which relies on assessing positional rates of change between the earliest and most recent shorelines at each transect. One shortfall associated with the end-point method is that it doesn't account for fluctuations in shoreline position between the beginning and ending time point. Given the rapidly fluctuating position of inlet shorelines and oceanfront shorelines near inlets, the end-point method does not accurately quantify long-term trends. Consequently, for this study, least squares regression, a preferred and commonly used statistical approach to analyzing shoreline change, which incorporates the full range of information available from multiple shorelines, was employed instead of the end point method (Thieler et al., 2009).

Least squares regression is a method of estimating the coefficients of the linear regression model. It minimizes the sum of the squared differences (residuals) between the observed values and the values predicted by the model. In the context of shoreline change analysis, regression is a statistical method to analyze the relationship between two or more variables to better understand how one variable such as time, affects another variable such as shoreline position or erosion/accretion rates.

In shoreline change analysis, the objective is to find the line that best fits the data by minimizing the sum of the squared errors, which involves fitting a straight line to the data points that represent shoreline positions at different time intervals (**Figure 5**). This line represents the "best fit" to the data, meaning it minimizes the differences between the observed shoreline positions and the positions predicted by the line.

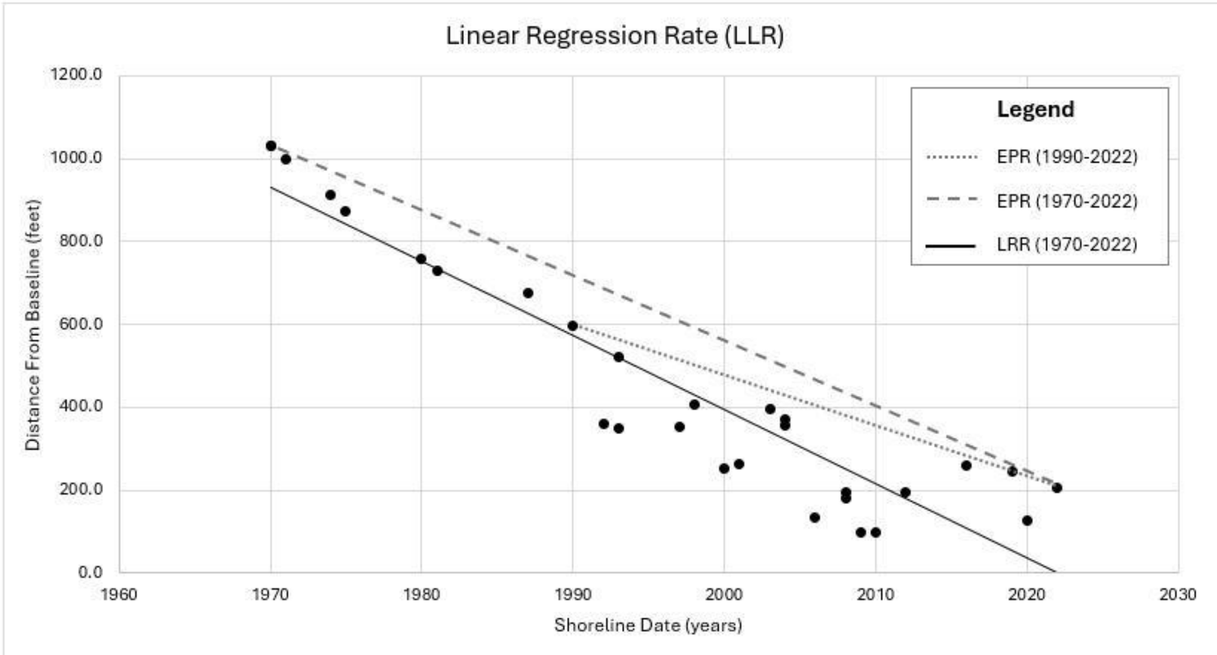

***Figure 5**. Relative shoreline position as a function of time (circles). The slope of the best fit dashed black line is the linear regression rate (LRR) of shoreline change (in this case, it is eroding at 18 feet per year). For comparison, the solid black line illustrates the end-point rate measured between 1970 and 2022 (eroding at 16 feet per year). In this example, the end-point rate does not account for the period of erosion between 1990 and 2010.*

Once the line is fitted to the data, various parameters can be calculated, such as the slope of the line, which indicates the rate of change of shoreline position over time. This method allows quantification of trends in shoreline change over specified periods of time.

Least squares regression is preferred in studies involving dynamic systems because it captures the overall trend in shoreline movement over time, including gradual changes and fluctuations, which may not be adequately captured by simpler methods like the end-point method.

The benefits of this approach include (Dolan et al., 1991), that the method:

- Incorporates all datasets that meet criteria for analysis
- Accounts for and averages across changes in trend over time
- Is purely computational
- Is an accepted and widely employed statistical approach
- Is easy to employ

Linear regression has been used in all IHA update studies (2010, 2019 and 2025). Once computed, the least squares regression rate was then smoothed using a 17-transect running-average algorithm for each transect alongshore. This smooths the alongshore variation in the shoreline change rate and follows the computation methodology historically employed for North Carolina's oceanfront shoreline rate studies since 1979.

Smoothing the raw shoreline data removes high-frequency variations, thereby highlighting the underlying trends and patterns. For example, smoothing effectively filters out the influences of short-term small-scale phenomena such as beach cusps, small sand waves, and the landward migrating portions of offshore bar systems (**Figure 6**).

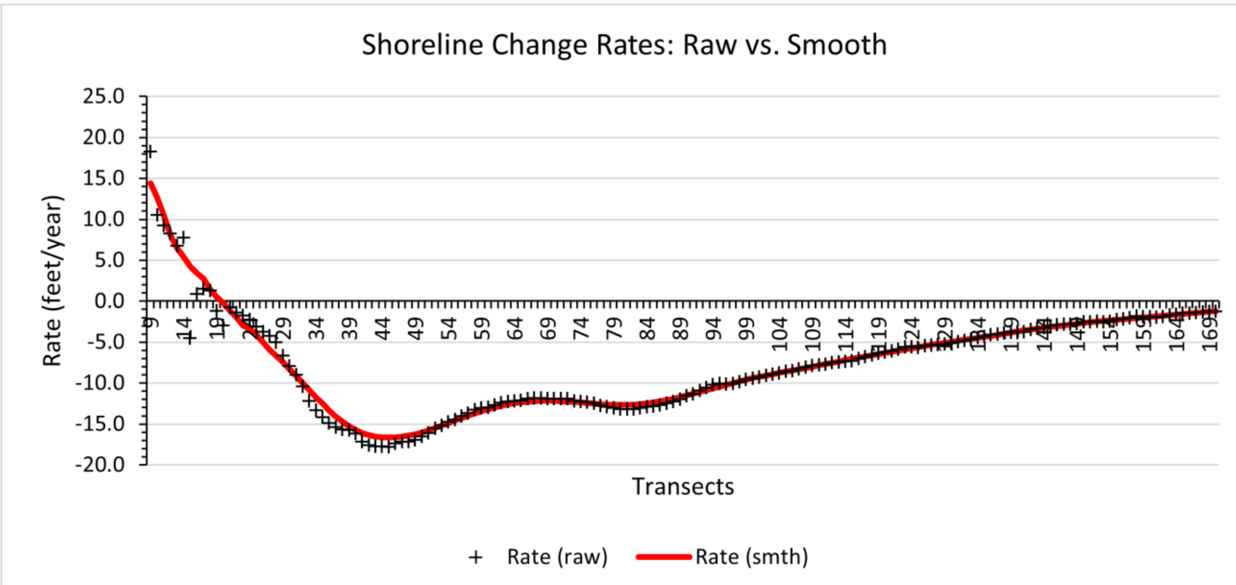

Figure 6. *Illustrates raw and smoothed shoreline change rates.*

Distinctive shoreline features characterized by regularly spaced protrusions and indentations along the coastline (**Figure 7**), including beach cusps, can vary significantly in size, ranging from approximately 5 feet to 5,000 feet, and their lifespan can vary from days for smaller features to seasons or even years for larger sand waves. These variations are documented in studies such as those by Dolan and Ferm (1968) and Davis (1978).

Figure 7. *This image illustrates examples of beach cusps and nearshore sandbars relative to transects.*

Similarly, offshore bars are submerged or partially submerged ridges of sand or gravel that form parallel to the shoreline. They typically extend to lengths around ~300 feet, with migration and attachment rates varying over time, spanning from seasons to years (Davis, 1978). These features influence shoreline cusping and are constantly shifting.

While smoothing effectively removes short-term variations from the data (i.e., beach cusps), it's important to note that larger, longer-lived features such as capes, which may have significant implications for coastal dynamics, are not affected by this process. These details underscore the importance of understanding the specific characteristics and behaviors of different shoreline features when analyzing oceanfront and inlet data.

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 or moving average,” this technique consists of averaging at least 17 transects (approximately 0.25

miles of shoreline given the 25 m spacing) to determine an average ("smoothed" value) for each transect in the study area. Each transect's value is calculated by averaging the shoreline change rate in that transect (the ninth in the "window" of 17 transects) with the shoreline change rates for the 8 transects on either side. This spatially averaged value is the "smoothed rate." As the algorithm nears the last transect within an inlet, the number of transects used in the average is decreased by two (dropping one from each side of the centered transect calculation) until the last transect is reached. The last value is calculated by taking the weighted average using the last two transects.

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

R_s *= smoothed rate*

T_1 *= erosion rate at last transect adjacent to the inlet*

T_2 *= erosion rate at second to last transect adjacent to inlet*

This methodology is consistent with methods used in each oceanfront shoreline change analysis since 1979. The use of smoothed data ensures a more uniform representation of shoreline conditions at the scale of interest.

2.4 Using Standard Deviation (STD) of Shoreline Position to Identify the Alongshore IHA Boundary

The alongshore IHA boundary marks the point along the oceanfront shoreline where inlet-related processes exert more influence on shoreline position relative to processes influencing oceanfront shorelines more distant from inlets. Because shorelines near inlets tend to exhibit greater dynamism compared to more distant stretches, delineating this boundary necessitates a nuanced approach. The approach described here relies primarily on analyzing the standard deviation of shoreline positions (**Figure 8**), which offers insights into the magnitude of shoreline variability, essentially, the degree of back-and-forth movement at each transect. This methodology provides a comprehensive assessment of how inlet-related processes influence the coastal landscape and identifies the transition zone where the impact of an inlet becomes increasingly dominant.

In the 2019 update study, the Panel recommended that future studies continue evaluating the IHAM and consider possible alternative approaches that could enhance the method's overall effectiveness. This recommendation is included in the CRC's charge to the Panel. In addition, public comments following the 2019 study brought to light concerns that the prior standard deviation method, while useful for identifying where inlets begin to influence shoreline position, falls short in delineating where inlet influence on shoreline dynamics is dominant. Concerns were also expressed regarding possible subjectivity in the process of selecting the alongshore transect designated as the IHA boundary. To address the prior panel's recommendations and these public concerns, the current Science Panel evaluated a variety of alternative approaches to using the increase in standard deviation (STD-increase) to identify the alongshore IHA boundary.

When considering modifications to the methodology, the Panel had two main objectives. First, to develop a refined method that reliably identifies where inlets exert a "dominant" influence on shoreline position, effectively filtering out variability arising from oceanfront influences. Second, to develop a refined methodology that ensures identification of alongshore boundaries relies as exclusively as possible on computational analyses with limited subjectivity or dependence on the choice of parameters used in the analysis technique.

In the following three subsections we describe the refined approach used to identify the IHA boundaries presented in this report. The refined approach involves identifying initial, approximate IHA boundaries using the 2019 approach, and then refining these boundaries using two new approaches that also rely on the standard deviation in shoreline position.

Figure 8. *This map highlights the greater variability in shoreline position near inlets compared to farther away.*

2.4.a Using the Standard Deviation (STD) to Identify Initial, Approximate Alongshore IHA Boundaries: STD-increase

Below, we use **Figure 9** to illustrate the approach (STD-increase) to identifying IHA boundaries used in the 2019 report, which is used herein to identify initial, approximate location where inlet influence becomes dominant. **Figure 9** is a plot of the alongshore variation in the standard deviation spanning the length of an island, with inlets located on both the left and right sides and the oceanfront in between. For each inlet, a plot such as this, along with the actual data (**Table 2**), served as the starting point for identifying where the transition from oceanfront to inlet begins when approaching an inlet.

In **Figure 9**, transects 27 and 296 (marked by vertical dashed red lines) indicate where the trend in standard deviation starts to consistently increase as one moves toward the inlet. To the left of transect 27 and right of transect 296, shoreline processes are influenced by the inlets, whereas the area between these transects tends to be dominated by oceanfront processes. The 2010 and 2019 IHA studies used this technique as the primary method for identifying the alongshore IHA boundary, except where the Science Panel agreed to modifications based on specific criteria (such as engineering practices or underlying geology) that justified a shift in boundary location.

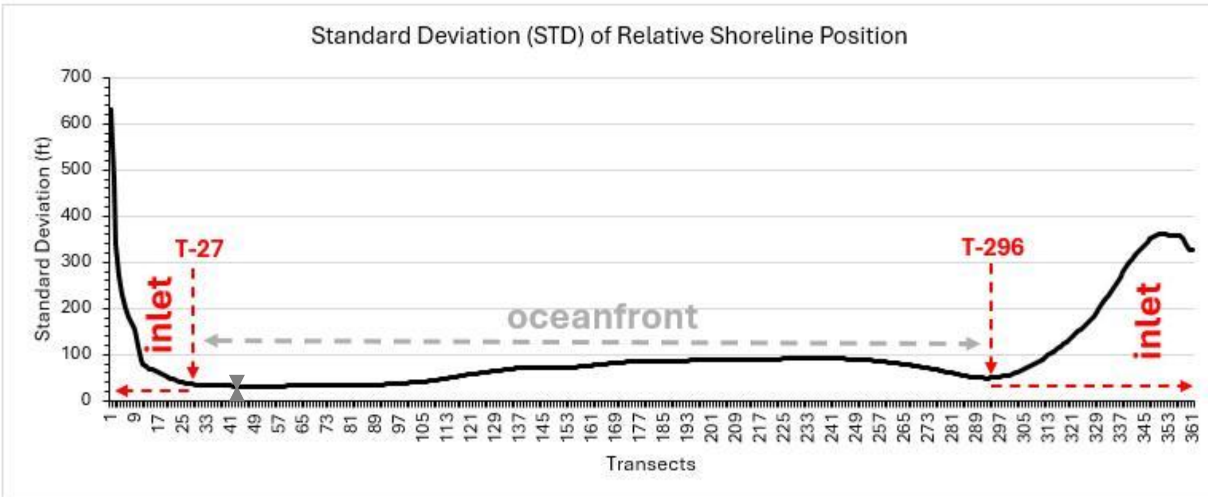

Figure 9. *This graph illustrates an example of the standard deviation of shoreline position plotted relative to the transect numbers. The vertical dashed lines at transect 27 (left) and transect 296 (right) show where standard deviation starts to increase approaching the inlet. For the purposes of this study, the area between the transects is considered "oceanfront."*

Table 2. *This table illustrates an example of using the increase in standard deviation (STD-increase) to define the IHA alongshore boundary. Moving from the oceanfront towards the inlet, standard deviation starts to consistently increase at transect 296, defining it as the IHA alongshore boundary. It should be noted that transect 295 is technically where the increase starts, however, this is the end of a decrease, which is why transect 296 marks the beginning of the continual increase.*

Transect ID	STD
289	14.87
290	14.70
291	14.65
292	14.61
293	14.48
294	14.24
295	13.89
296	**14.12**
297	14.45
298	14.99
299	15.42
300	15.76
301	16.47
302	17.49
303	18.49
304	19.46
305	20.37
306	21.25
307	22.04
308	22.94
309	23.82
310	24.75
311	25.57

2.4.b Using Standard Deviation (STD) of Shoreline Position to Identify the Alongshore IHA Boundaries: STD > 15 m

To apply the STD threshold approach, we first compute an oceanfront grand average standard deviation (14.7 meters) and a grand median standard deviation (15.01 meters) across all shorelines outside of the initial, approximate IHA boundaries identified using the approach described in 2.4a. Given that the mean and the median are similar, we rounded this value – hereafter referred to as the STD threshold – to 15 meters (49.2 feet). Where the standard deviation first exceeds this threshold of 15 meters approaching an inlet, the variability in shoreline position exceeds the typical variability in shoreline position in adjacent oceanfront areas, suggesting that inlet processes are the dominant influence on shoreline position (**Table 3**). The first transect where STD exceeds 15 meters (STD > 15 m) approaching an inlet from the oceanfront is then identified as the IHA boundary where this approach is applied.

Table 3. *This table illustrates an example of using the 15-M standard deviation (STD) threshold method to define the IHA alongshore boundary. Moving from the oceanfront towards the inlet, the 15-meter threshold is exceeded at transect-216; thus, defining it as the IHA alongshore boundary.*

Transect ID	STD
204	12.78
205	12.66
206	12.55
207	12.52
208	12.86
209	12.91
210	13.31
211	13.27
212	13.28
213	13.78
214	14.21
215	14.59
216	**15.05**
217	15.35
218	16.07
219	16.63
220	17.46
221	18.64

Oceanfront → **Inlet**

Although this modification to the 2019 methodology is easily automated, the output still requires expert interpretation of the results and an understanding of the data and inlet processes that are unique at each location, which can affect each data set. Unlike the strict application of the standard deviation method as described in Section 2.4.a, in which the area on the plot can generally be identified, this modified method does not always result in a clear visual interpretation of the standard deviation.

2.4.c Using Standard Deviation (STD) of Shoreline Position to Identify the Alongshore IHA Boundaries: Slope Threshold (STD Δ > 1-ft)

The STD Slope (or first-derivative; STD Δ > 1-ft) method employs alongshore differences (Δ) between consecutive points (neighboring transects). This more nuanced approach identifies the location where the standard deviation starts to increase substantially relative to the oceanfront shoreline distant from inlets. The grand average Δ for oceanfront shoreline transects distant from inlets (defined as those outside of the initial, approximate IHA described in Section 2.4.a) in the studied regions is 0.94 ft, which is rounded to 1 ft. Moving alongshore toward an inlet, the transect where Δ first exceeds 1ft is identified as the IHA alongshore boundary when applying this approach. Compared to the STD >15 m method, the STD Δ > 1-ft method involves the following additional steps:

1. Calculate the average oceanfront standard deviation Δ (0.94 ft, rounded up to 1.0 ft.) for all oceanfront shoreline areas outside of the initial, approximate IHA alongshore boundaries.

2. Smooth the raw standard deviation data using a 17-point running average using the same procedure applied in the smoothing of the shoreline change data. (Smoothing improves the ability to identify the location where the Δ between neighboring transects starts to increase substantially relative to the oceanfront standard deviation Δ.)

3. Calculate the standard deviation differences, or Δs, between neighboring transects starting at each island's midway point and moving toward the inlet at either end.

4. Moving from the middle of each island toward the inlet, identify the first transect for which the standard deviation difference exceeds 1.0 (STD Δ > 1-ft). This indicates where shoreline position variability starts to increase substantially relative to average oceanfront shoreline variability (**Table 4**). This transect where STD Δ first exceeds 1.0 is identified as the alongshore boundary of the IHA when applying this approach.

Table 4. *This table illustrates an example of using the STD Slope Threshold (STD Δ > 1-ft) method to define the IHA alongshore boundary. Moving from the oceanfront towards the inlet, the threshold value of 1.0 is exceeded at transect-296, defining it as the IHA alongshore boundary.*

Transect ID	STD	STD Δ
289	50.51	-0.59
290	49.92	-0.43
291	49.49	-0.27
292	49.22	-0.02
293	49.20	0.28
294	49.48	0.52
295	50.00	0.78
296	50.78	**1.03**
297	51.82	1.23
298	53.05	1.42
299	54.46	1.60
300	56.06	1.78
301	57.84	1.98
302	59.82	2.19
303	62.01	2.43
304	64.44	2.78
305	67.22	3.06
306	70.28	3.30
307	73.58	3.58
308	77.16	3.84
309	81.01	4.00
310	85.01	4.09
311	89.10	4.12

Oceanfront

Inlet

This method is easily automated and quantitatively objective. For this reason, the Panel used this as the default method for identifying alongshore IHA boundaries.

2.4.d Using STD Approaches in Combination to Identify the Final Alongshore IHA Boundaries

The current study uses the methodology applied in the 2010 and 2019 studies (now referred to as the STD-increase method) as the initial step in applying two new methods, the STD Threshold method (STD > 15 m) and the STD Slope Threshold method (STD Δ > 1-ft), to identify the alongshore locations where inlet processes begin to dominantly influence shoreline position. The new methods achieve the Panel's two objectives: reducing subjectivity (and dependence on analysis-parameter choices) in boundary selection and relying more on computational outputs that can be easily automated. In some locations, two of the methods identified the same transect.

The STD Δ > 1-ft method serves as the primary approach for identifying the alongshore IHA boundaries presented in this report. The two exceptions to the application of the STD Δ > 1-ft are explained and justified in the text provided in the inlet section of the report. As with previous studies, no computational method can completely eliminate the need for adjustments based on special circumstances (e.g., presence of an engineered structure).

2.5 The 30- and 90-Year Risk Lines

The hazard risk varies within the IHA. To identify areas at greater risk, the 30- and 90-Year Risk Lines were developed based on the inlet-shoreline erosion rates. It should be noted that these lines are calculated no differently than how current oceanfront and inlet minimum and maximum setbacks are determined, or how the landward boundary of the OEA is calculated, multiplying 30 and 90 times the erosion setback factor based on shoreline change rates, with a minimum rate of change of 2 feet of erosion/year. The only difference between them is that the IHA boundary is measured from the HVL, while setbacks and the OEA boundary are not.

The 90-Year Risk Line defines the landward extent of the IHA. It is measured landward from the HVL along each transect. The line is calculated as 90 times the shoreline erosion rate (LRR), with a minimum applied rate of -2 feet per year if the shoreline is eroding at a lower rate or accreting. The 30-Year Risk Line is an intermediate line that defines a higher level of risk closer to the shoreline. It is computed similarly to the 90-Year Risk Line, but by using a multiplier of 30 and measured relative to the HVL.

2.6 Refining the Draft IHA Boundaries

In most cases, the methods described above worked well, requiring no additional modifications. However, as Priddy and Carraway (1978) and Overton and Fisher (2004) found in their studies, defining an IHA for some inlets may potentially require additional refinements based on how well the computed IHA fits the unique character of an inlet. This is not surprising considering that the STD Threshold and STD Slope Threshold methods are based only on historic shoreline positions, assume uniformly erodible material and assume that past shoreline changes can be used to estimate future shoreline behaviors. These are usually, but not always, good assumptions. Some of the issues considered in this, and previous studies are:

- the stabilizing impact of engineering activities including the AIWW;
- areas with low measured erosion due to local geomorphology and underlying geology;
- locations within an inlet where the minimum erosion rate of 2 feet per year was considered unrealistic (i.e., due to sandbag structures);
- migrating, low-elevation, ephemeral swash bars, which overly magnify the dynamic nature of the inlet and unrealistically impact the 30- and 90-Year Risk Lines, and;
- instances where the break in the standard deviation separating inlet influence from the oceanfront was not clear or occurred too close to the inlet based on other observations of coastal change (i.e., Masonboro and Lea-Hutaff Islands).

After the computed draft alongshore IHA boundaries were refined to address issues such as those listed above, a working group[7] of the Science Panel visually compared the full suite of computed and refined draft IHA boundaries with the time-series of satellite imagery and aerial photography available on Google Earth. In this review step, the working group sought to identify any site-specific factors or inlet behaviors indicating the need for further consideration and possible adjustment. As a result of this process, changes to the Mason Inlet and Rich Inlet IHA boundaries were identified as necessary and incorporated into the final report (see individual inlet sections for details).

[7] Joseph W. Long, Ph. D, Spencer Rogers, Greg “Rudi” Rudolph, and NCDCM staff (Ken Richardson)

3.0 Inlet Hazard Area Recommendations

This chapter delineates the IHA recommendations for each inlet. In each section, the history of the inlet is first briefly described. The relevant analysis details of the IHAM and any modifications are then outlined for each side of the inlet. Maps locating the Panel's recommended IHA for each side of the inlet are presented. Larger scale copies of these maps can be found in Appendix C, and online at the NC Division of Coastal Management website (nccoastalmanagement.net). In addition, historic inlet change videos can be accessed via the Shifting Shoreline: Inlet Atlas (https://ncseagrant.ncsu.edu/shifting-shorelines-inlet-atlas/), via the timelapse tool (https://earthengine.google.com/timelapse/), or by site specific inlet (https://www.youtube.com/playlist?list=PLsJngra3Sf4GLh2FmBRRuAUPmSGJfsOXc).

3.1 Tubbs Inlet

Tubbs Inlet is a relatively small migrating inlet that was recognized on early 1700's maps. Throughout much of its early history the inlet migrated westward along an 8,600-foot pathway, at a rate between 50 and 65 feet per year. The inlet was closed in 1969 and then in January 1970 reopened 3,200 feet further eastward to a position that approximated its 1938 location (**Figure 10**). Following relocation, the inlet began migrating eastward toward Ocean Isle, but the rate of migration has varied.

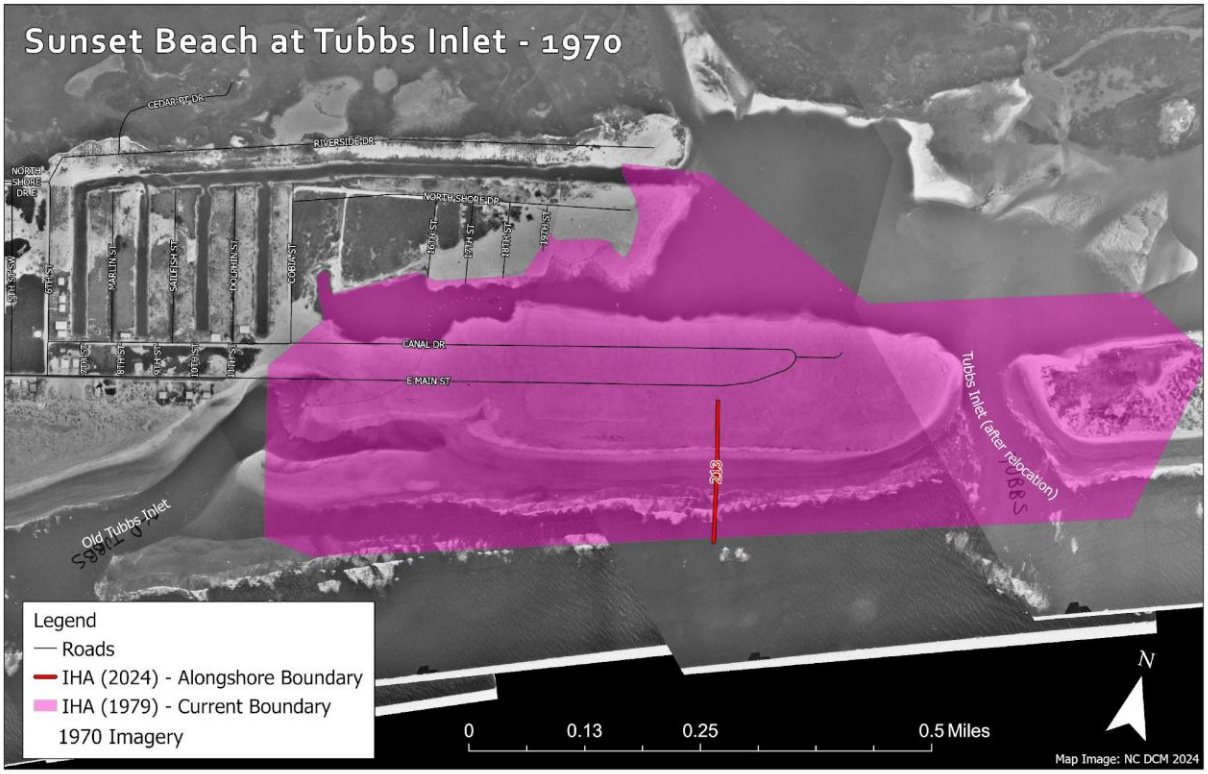

Figure 10. *This map illustrates conditions at Sunset Beach (Tubbs Inlet) in 1970 relative to the current IHA (est. 1979), the 2024 IHA alongshore boundary limit (red line) at transect-213, and Old Tubbs Inlet (left) and relocated Tubbs Inlet (right). This map image provided for reference purposes only as 1970 data were not used in this analysis.*

Causes of the migration reversal are complex, making the inlet difficult to predict. Around the time of relocation feeder channels behind both sides of the inlet were altered by dredging for land development. Other sections of the channels connecting to the AIWW shoaled and became hydraulically less efficient. More recently the inlet's migration may have been influenced by the construction of the dual navigation jetties at Little River Inlet, then 4 miles to the southwest, and the natural closing of Mad Inlet in 1997, then 3 miles to the southwest. The inlet shoreline can be considered at least widely fluctuating and may be establishing a migration to the northeast.

When the existing IHA boundary was established in 1979, shortly after the inlet was relocated, there was not enough data at the time to forecast how natural processes and adjacent shorelines would respond to the inlet's relocation, so the IHA boundary was simply mapped to encompass both the new and former locations of the inlet that were identified through historical imagery (https://ncseagrant.ncsu.edu/shifting-shorelines-inlet-atlas/).

3.1.a Sunset Beach side of Tubbs Inlet

Tubbs and Mad Inlets were presumed to have had a combined influence on making Sunset Beach one of a few accreting islands in North Carolina (Cleary & Marden, 1999). The northeastward migrating spit on Sunset Beach retreated 1,100 feet around 2013 but was quickly recovering by 2017. In the area near the inlet at the end of East Main Street and Canal Drive, continual accretion, erosion, and shoaling occur. Erosion control structures such as sandbags, riprap, and bulkheads are used to harden the shoreline for the purpose of protecting infrastructure and property. Currently, there are no oceanfront erosion control structures, and no history of beach nourishment at Sunset Beach.

Because of the relocation and the dredging of feeder channels behind both Sunset Beach and Ocean Isle for land development around the time of the inlet relocation, 1970 and 1971 data were excluded, and only shoreline data after 1971 (starting with 1981 data) were used in the analyses (**Figure 11**). The HVL at Sunset Beach is determined using 1981, 1993, 1998, 2003 and 2004 vegetation lines (**Figure 14**).

Applying the STD Δ > 1 threshold identifies the alongshore IHA boundary at transect 213 (**Figure 13**). The landward IHA boundary was defined using the 90-Year Risk Line starting at transect 213 and moving in the direction of the inlet until reaching transect 222; where the boundary is then extended from the 90-Year Risk Line approximately 300 feet to the riprap along the backbarrier shoreline where erosion has been persistent and is influenced by inlet processes and the hydrodynamic fluctuations between Jinks Creek and the inlet (**Figure 15**).

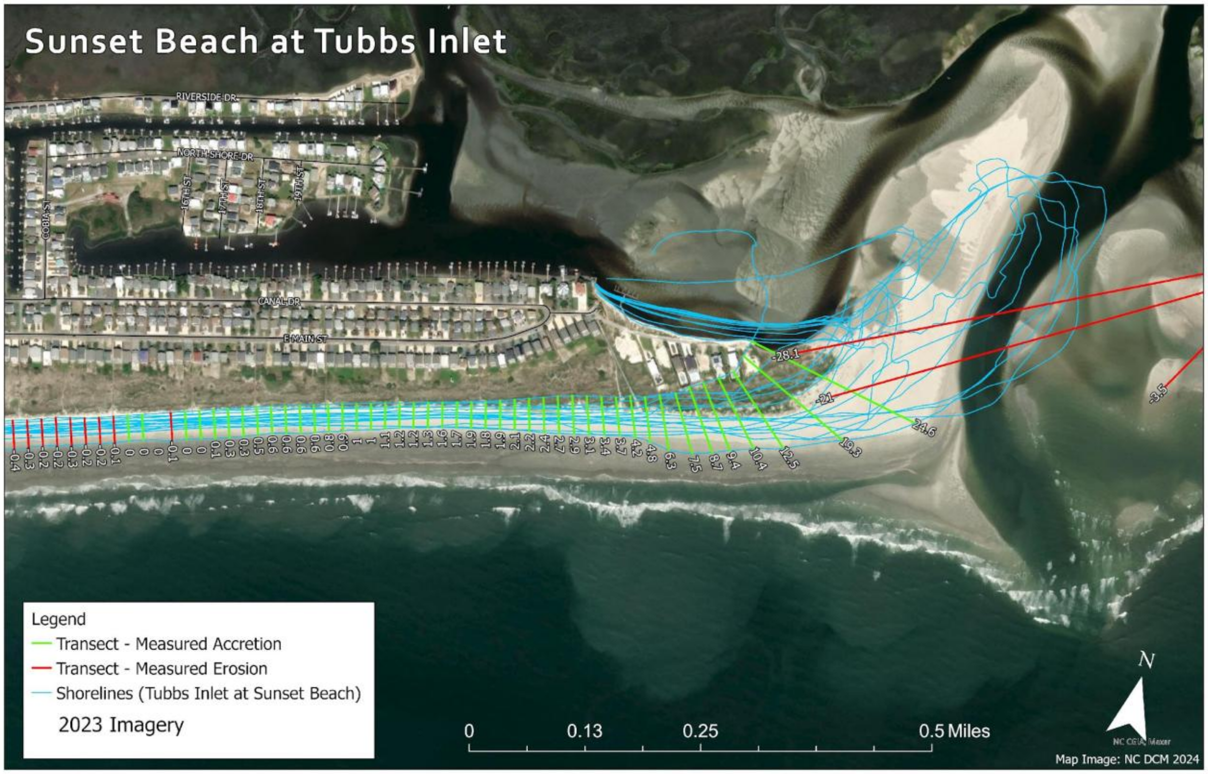

Figure 11. *Tubbs Inlet at Sunset Beach. Shorelines included in the analysis: 1981, 1992, 1993, 1997, 1998, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2022 shown relative to transects used to measure shoreline change rates.*

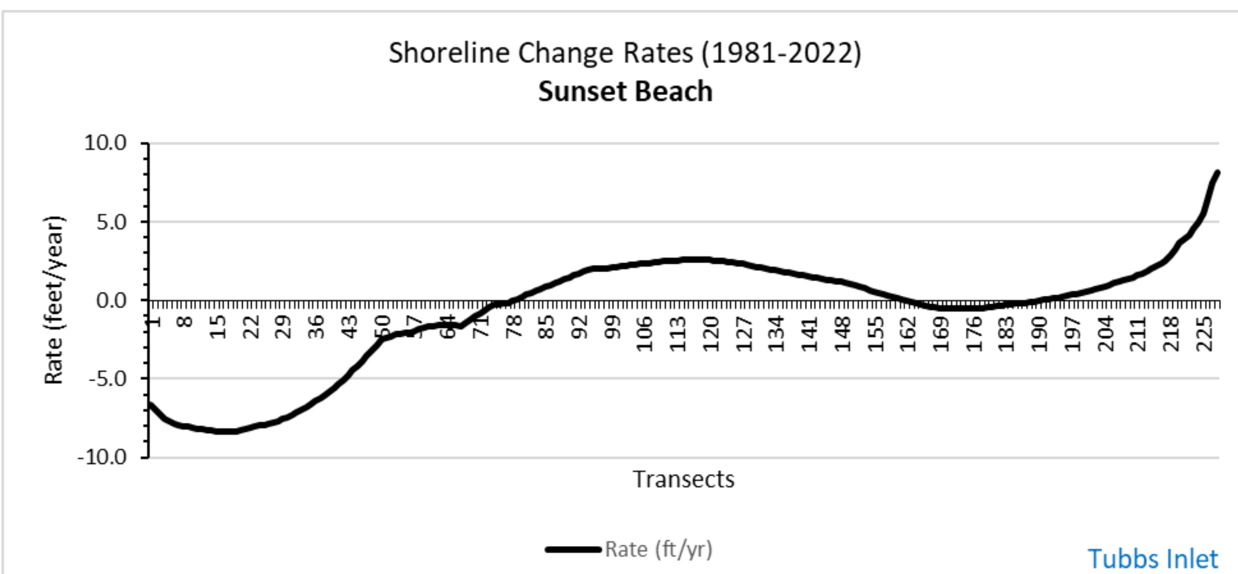

Figure 12. *Shoreline change rates (ft/yr) at Sunset Beach from 1981 to 2022: Negative values indicate erosion, while positive values indicate accretion.*

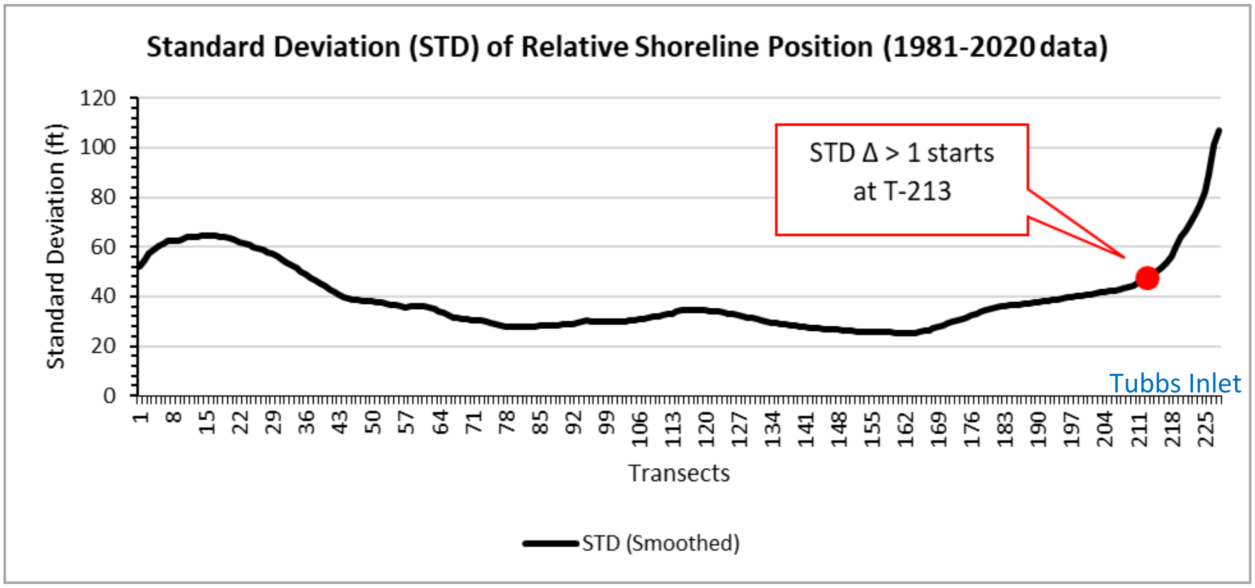

Figure 13. *Using the standard deviation of relative shoreline position data at Tubbs Inlet-Sunset Beach and applying the STD Δ > 1 threshold method, transect 213 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet.*

Figure 14. *Tubbs Inlet at Sunset Beach. Vegetation Lines mapped: 1981, 1992, 1993, 1998, 2003, 2004, 2009, 2010, 2012, 2016, 2020, 2022. Vegetation line segments making up the HVL within the updated IHA: 1981, 1993, 1998, 2003, 2004.*

Figure 15. *Tubbs Inlet at Sunset Beach: Updated IHA boundary in relation to transect 213 (alongshore IHA boundary), HVL, 30- and 90-Year Risk Lines, and current (1979) IHA boundary.*

3.1.b Ocean Isle side of Tubbs Inlet

Since relocation, Tubbs Inlet has been migrating toward Ocean Isle at a highly irregular rate. The inlet shoreline has been armored with sandbags, which have served to temporarily reduce erosion rates and limit further structural damage and loss of property. Farther to the northeast, the ocean shoreline has accreted following the relocation (**Figures 17 and 18**). The shoreline and vegetation data for Ocean Isle at Tubbs inlet are shown in **Figures 16 and 19**.

The HVL within the 2024 IHA includes 1980, 1981, and 1993 vegetation lines (**Figure 19**). Applying the STD Δ > 1 threshold, identifies the alongshore IHA boundary at transect 27 (**Figure 18**). The landward IHA boundary was defined using the 90-Year Risk Line starting at transect 27 and moving in the direction of the inlet (**Figure 20**).

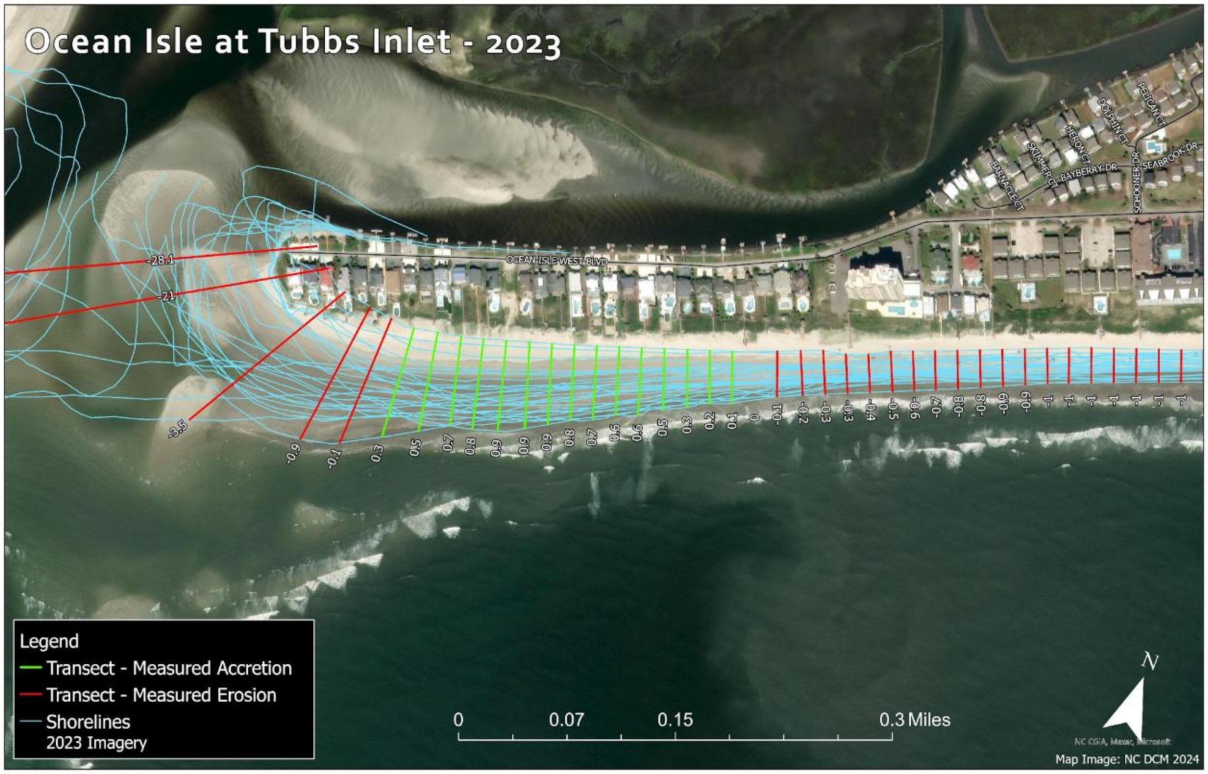

Figure 16. *Tubbs Inlet at Ocean Isle. Shorelines included in the analysis: 1970, 1971, 1974, 1975, 1980, 1981, 1987, 1990, 1992, 1993, 1997, 1998, 2000, 2001, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2022 shown relative to transects used to measure shoreline change rates.*

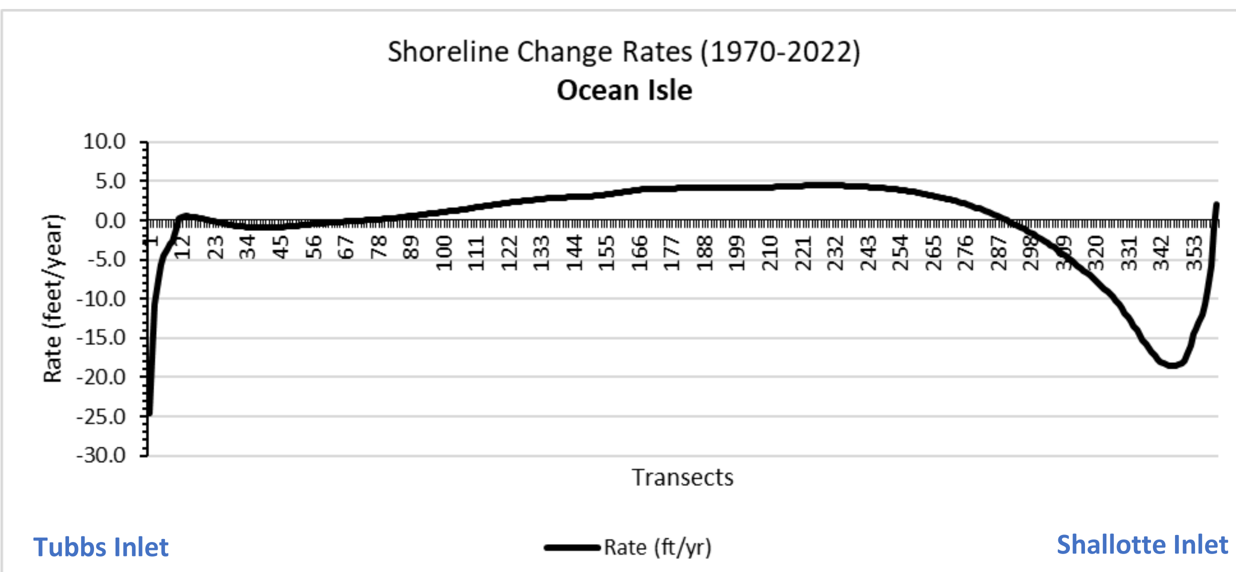

Figure 17. *Shoreline change rates (ft/yr) at Ocean Isle from 1970 to 2022: Negative values indicate erosion, while positive values indicate accretion.*

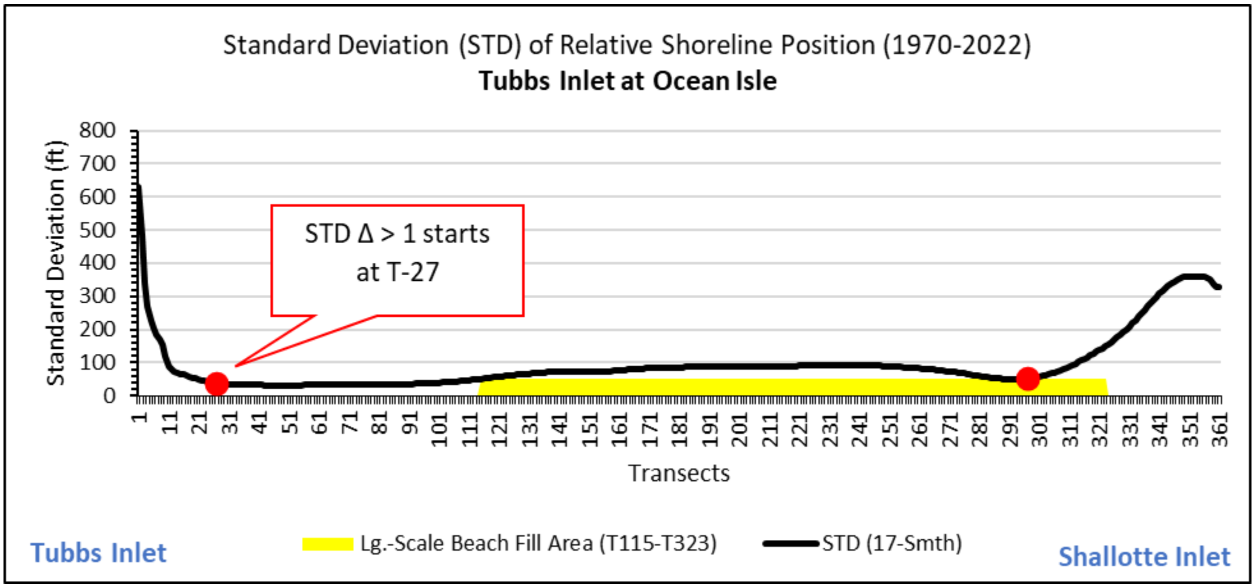

Figure 18. *Using the standard deviation of relative shoreline position data at Tubbs Inlet-Ocean Isle and applying the STD Δ > 1 threshold method, transect 27 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

Figure 19. *Tubbs Inlet at Ocean Isle. Vegetation Lines mapped: 1970, 1971, 1974, 1975, 1980, 1981, 1987, 1990, 1992, 1993, 1998, 2000, 2001, 2003, 2004, 2009, 2010, 2012, 2016, 2020, 2022. Vegetation line segments making up the HVL within the updated IHA: 1980, 1981, 1993.*

Figure 20. *Tubbs Inlet at Ocean Isle: Updated IHA boundary in relation to transect 27 (alongshore IHA boundary), HVL, 30- and 90-Year Risk Lines, and current (1979) IHA boundary.*

3.2 Shallotte Inlet

Shallotte Inlet, charted as early as 1672, has fluctuating inlet shorelines. Seismic data from the nearshore area indicates the inlet is a permanent feature related to the paleo-channel of the ancestral Shallotte River. Since 1938 the throat position of the ebb (main) channel has shifted within a 900 feet wide corridor. Although the position of the ebb channel within the throat has not changed appreciably, its seaward portion across the ebb-tidal delta has shifted widely, approximately 13,000 feet across the offshore shoal.

The historic reorientation and repositioning of the outer bar channel from the southwest to the southeast facilitated changes in the shape of the ebb-tidal delta and its effect on the adjacent oceanfront shorelines. Since the late 1960's the ebb channel has generally been aligned in an SE-ESE direction, which has favored the accretion along the Holden Beach shoulder that has led to the bulbous shape of the western end of the island. By contrast, during the same interval, the Ocean Isle oceanfront shoreline has experienced chronic long-term erosion.

When the Shallotte Inlet ebb channel orientation is positioned towards Holden Beach, the updrift shoulder of Ocean Isle experiences erosion (and vice versa). The bulbous shape of Holden Beach shoreline has been present since 1974. If the ebb channel becomes more westerly, then this accreted sand is expected to erode. Ocean Isle had the same bulbous shape between 1938 and 1958 before the ebb channel shifted and caused erosion at the eastern end of Ocean Isle. If the ebb channel once again re-orients itself toward Ocean Isle, the bulbous shape will return to Ocean Isle, and Holden Beach will erode.

In 2001, the US Army Corps of Engineers constructed a beach nourishment project along 17,000 feet of Ocean Isle Beach extending west from Shallotte Boulevard. Material used to construct the project was obtained from a borrow area in Shallotte Inlet that extended from near the AIWW, seaward to approximately the 17-foot depth contour. In essence, the borrow area created a new ebb channel oriented perpendicular to the adjacent shorelines. The location of the Shallotte Inlet channel was based on historic positions and alignments of the inlet's ocean bar channel, which seemed to have positive impact on the east end of Ocean Isle Beach. The Shallotte Inlet borrow area has been used to provide sand for periodic nourishment of Ocean Isle.

3.2.a Ocean Isle Beach side of Shallotte Inlet

Among the inlets analyzed in this study, the east end of Ocean Isle at Shallotte Inlet and within the limits of the 2024 IHA has experienced the greatest loss of property (approximately 286 platted lots), fifty-eight (58) homes and approximately 1-mile of surfaced road due to persistent erosion between 1970 and 2023 (**Figures 21 and 22**).

Although the channel's midpoint has been relatively stable since 1938, the shoulders of both Ocean Isle Beach and Holden Beach have experienced lengthy cycles of erosion and accretion. The impact of Hurricane Hazel in 1954 caused the reorientation of the channel to move in a more easterly direction, which made Ocean Isle Beach experience accelerated erosion, and since the 1970's, erosion has remained persistent.

Figure 21. *This map illustrates existing structures (green dots), and structures lost to erosion (houses indicated by red x-marks and roads indicated by red lines) relative to conditions in 1970. Based on an inventory between 1970 and 2023, 58 structures and approximately 286 platted parcels and one mile of surfaced road within the 2024 IHA have been lost or relocated because of erosion.*

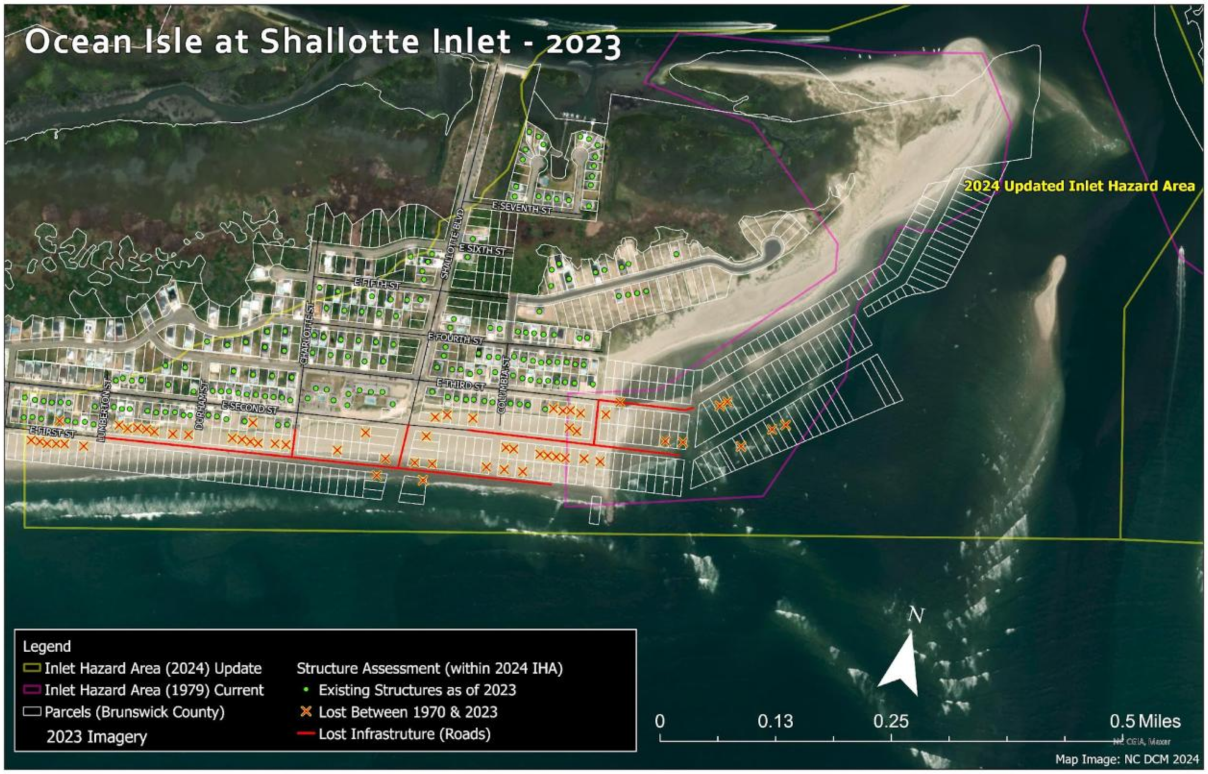

Figure 22. *This map illustrates existing structures (green dots), and structures lost to erosion (houses indicated by red x-marks and roads indicated by red lines) relative to conditions in 2023. Based on an inventory for the period between 1970 and 2023, 58 structures and approximately 286 platted parcels and one mile of surfaced road within the 2024 IHA have been lost or relocated as a result of erosion. Currently, there are 185 structures within the 2024 IHA.*

Over the years, various strategies have been employed to combat the erosion at Shallotte Inlet (**Figures 23 and 24**). Efforts included beach nourishment projects, where large amounts of sand were placed on the beach in hopes of restoring the shoreline and providing a buffer against further erosion. However, the temporary nature of this solution became apparent as the newly added sand was quickly eroded away.

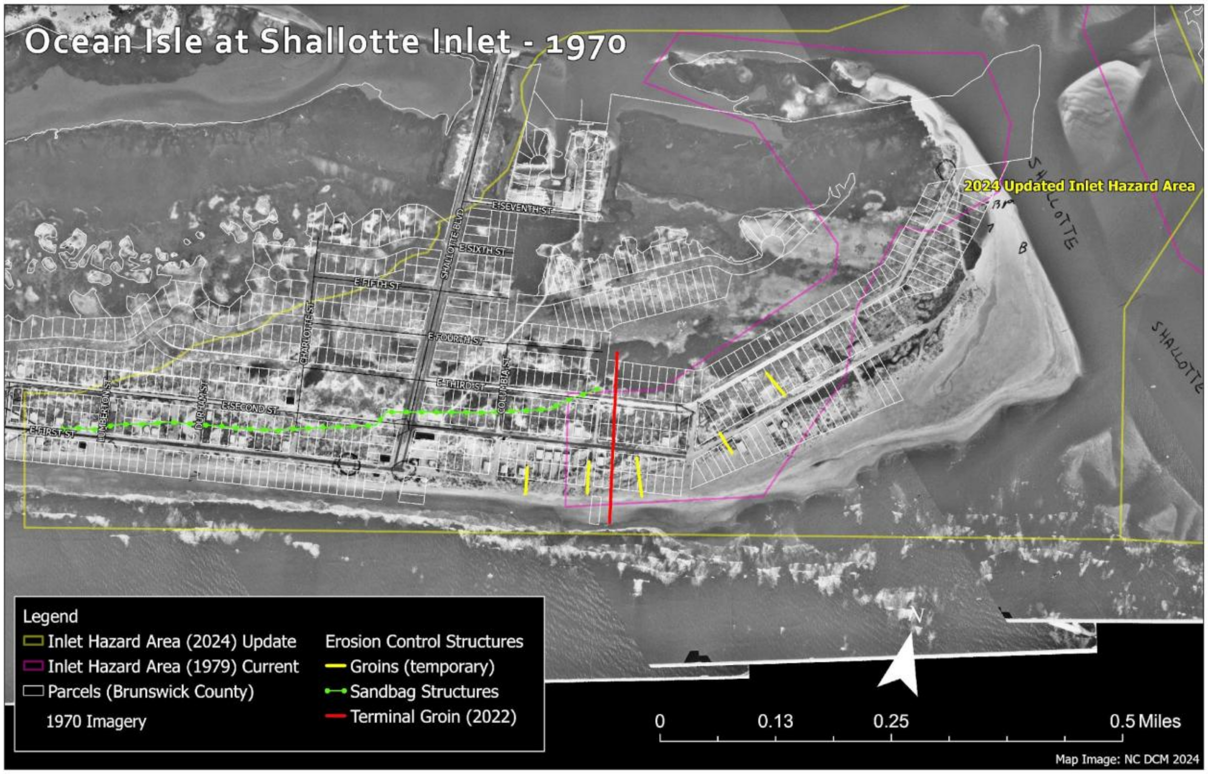

Figure 23. *This map illustrates conditions in 1970 relative to the variety of erosion control structures applied in efforts to stabilize the shoreline. Small temporary groins (shore-perpendicular yellow lines) were installed before 1992 followed by sandbag structures (green dotted line) over the course of time, until construction of the terminal groin (red line) was completed in 2022.*

Figure 24. *This map illustrates conditions in 2023 relative to the variety of erosion control structures applied in efforts to stabilize the shoreline. Small temporary groins (shore-perpendicular yellow lines) were installed before 1992 followed by sandbag structures (green dotted line) over the course of time, until construction of the terminal groin (red line) was completed in 2022.*

While not intended to be a long-term solution, a series of temporary groins were constructed before 1992 to trap sand and help stabilize the shoreline. These structures ultimately proved to be ineffective and short-lived. For property owners adjacent to Shallotte Inlet, sandbag structures have historically become the last line of defense, providing short-term protection. Numerous sandbag revetments have been constructed along the 5,000 feet of developed shoreline adjacent to the inlet. Closest to the inlet the beach road is now 4th Street, 1st through 3rd Streets having been eroded.

Recognizing the need for a more permanent solution, the Town Ocean Isle Beach completed construction of a 500-foot granite boulder terminal groin. The groin was designed to serve as a long-lasting barrier to erosion, with hopes of holding the shoreline in place and protecting the vulnerable east end of Ocean Isle. While the terminal groin represents an ambitious and costly effort, its effectiveness remains to be seen, as more time is needed to fully assess its impact on erosion patterns and shoreline stability (**Figures 25 and 26**).

Figure 25. *This image captures the inlet shoreline at the terminal groin as it appeared on February 23, 2023. Post-construction, the inlet beach is wide, and the terminal groin, located in the middle left of the photo, is mostly covered. A newly built road and ongoing construction are visible in the mid-center of the image. Photo source: Town of Ocean Isle Beach, NC.*

Figure 26. *This image captures the inlet shoreline at the terminal groin as it appeared on June 25, 2024. Since 2023 (Figure 35), erosion on the inlet side of the groin has resulted in continued landward movement of the shoreline, exposing the groin's anchor, and approaching the vegetation in front of the new development. Photo source: NC DCM and DWR.*

The terminal groin is expected to affect shoreline stability immediately to its west by eventually reducing erosion and retaining sediment; however, the eastern side, adjacent to the inlet, will continue to be significantly influenced by the dynamic processes of the inlet. This area will likely experience varying degrees of erosion and sediment deposition, making it challenging to predict long-term outcomes. Therefore, a longer period of observation is necessary to fully assess the overall performance and effectiveness of the structure in stabilizing the shoreline. Additionally, ongoing, detailed monitoring is crucial, especially at the landward terminus of the structure, where persistent shoreline erosion continues to be a concern.

Applying the STD Δ > 1 threshold identifies the alongshore IHA boundary at transect 296 (**Figure 29**). The landward IHA boundary was defined using the 90-Year Risk Line starting at transect 296 and moving in the direction of the inlet (**Figure 30**). After the 90-Year Risk line intersects the Atlantic Intracoastal Waterway (hereafter referred to as the Intracoastal Waterway, or ICW), the IHA stays within the ICW and incorporates the adjacent spit.

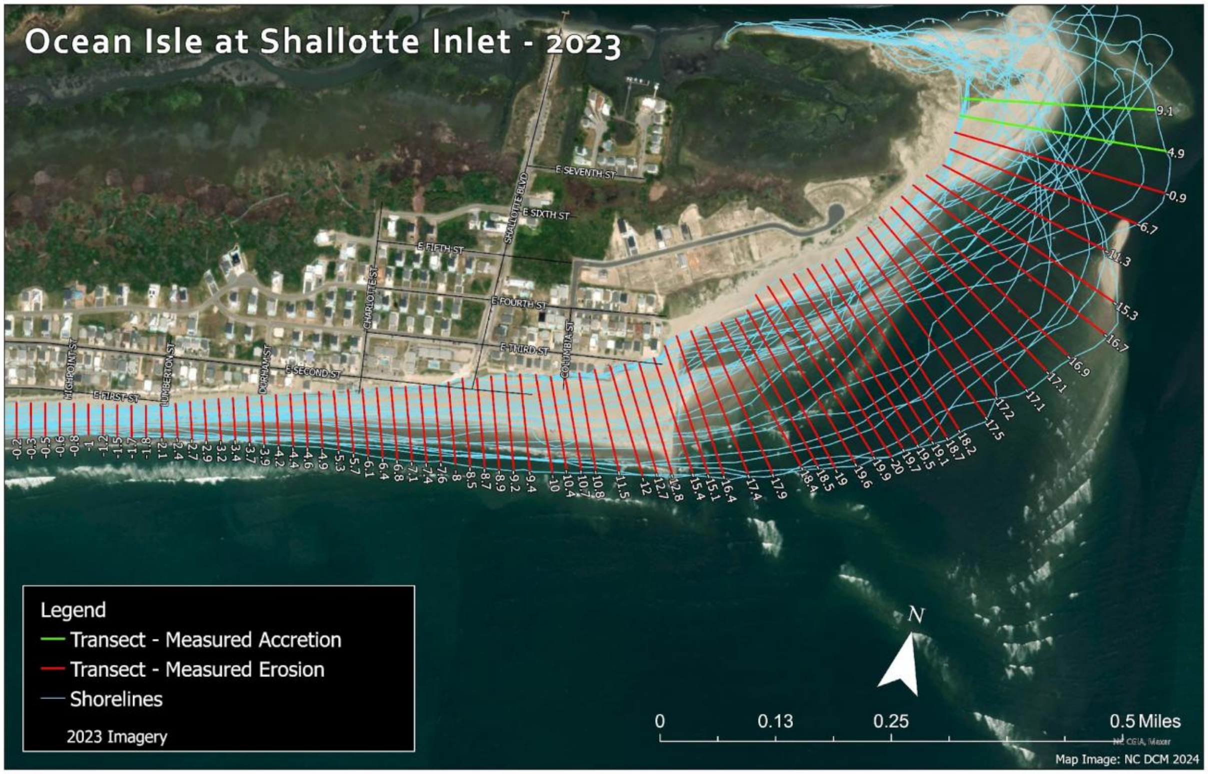

Figure 27. *Shallotte Inlet at Ocean Isle. Shorelines included in the analysis: 1970, 1971, 1974, 1975, 1980, 1981, 1987, 1990, 1992, 1993, 1997, 1998, 2000, 2001, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2022 shown relative to transects used to measure shoreline change rates.*

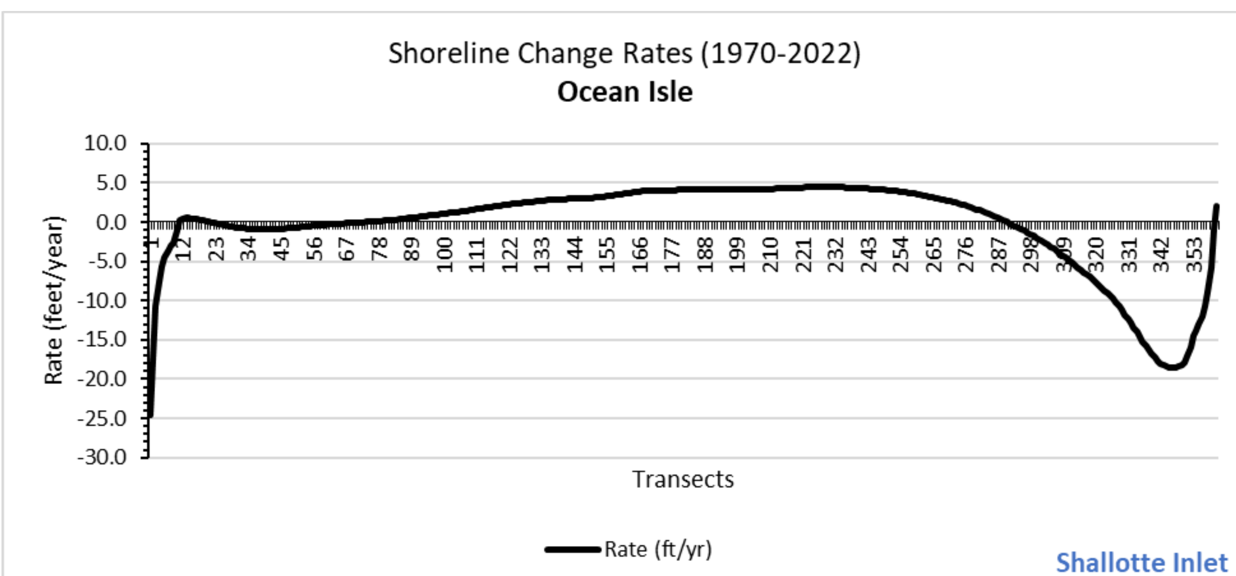

Figure 28. *Shoreline change rates (ft/yr) at Ocean Isle from 1970 to 2022: Negative values indicate erosion, while positive values indicate accretion.*

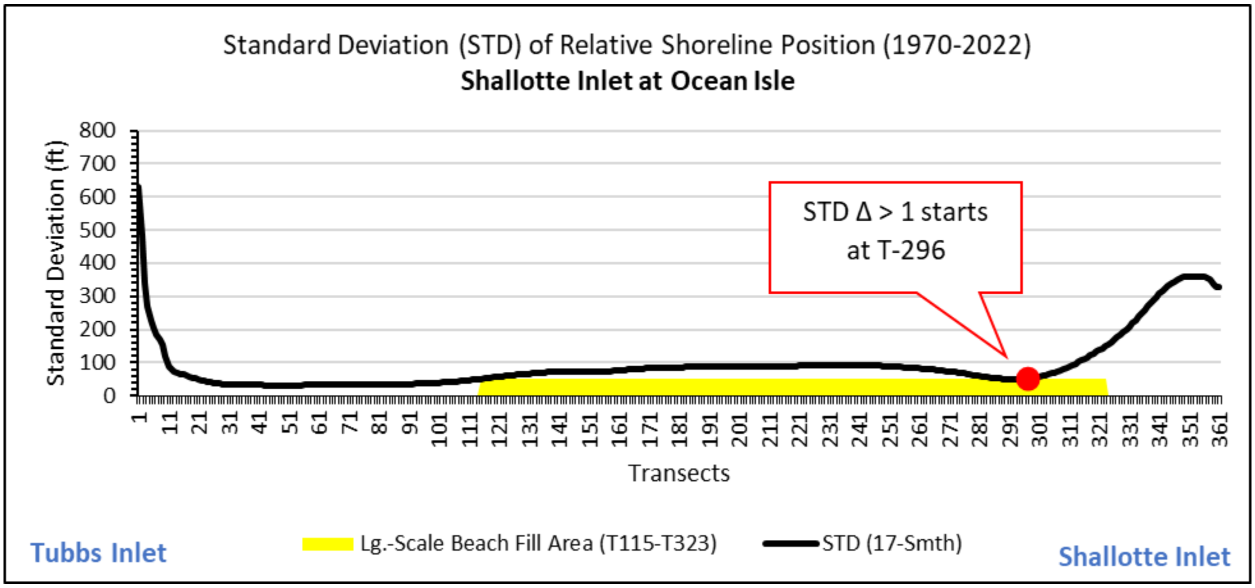

Figure 29. *Using the standard deviation of relative shoreline position data at Tubbs Inlet-Ocean Isle and applying the STD Δ > 1.0 threshold method, transect-296 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

Figure 30. *Shallotte Inlet at Ocean Isle. Vegetation Lines mapped: 1970, 1974, 1975, 1980, 1981, 1987, 1990, 1992, 1993, 1998, 2000, 2001, 2003, 2004, 2008, 2009, 2010, 2012, 2016, 2020, 2022. Vegetation line segments making up the HVL: 2000, 2001, 2003, 2004, 2008, 2009, 2010, 2012, 2020, 2022.*

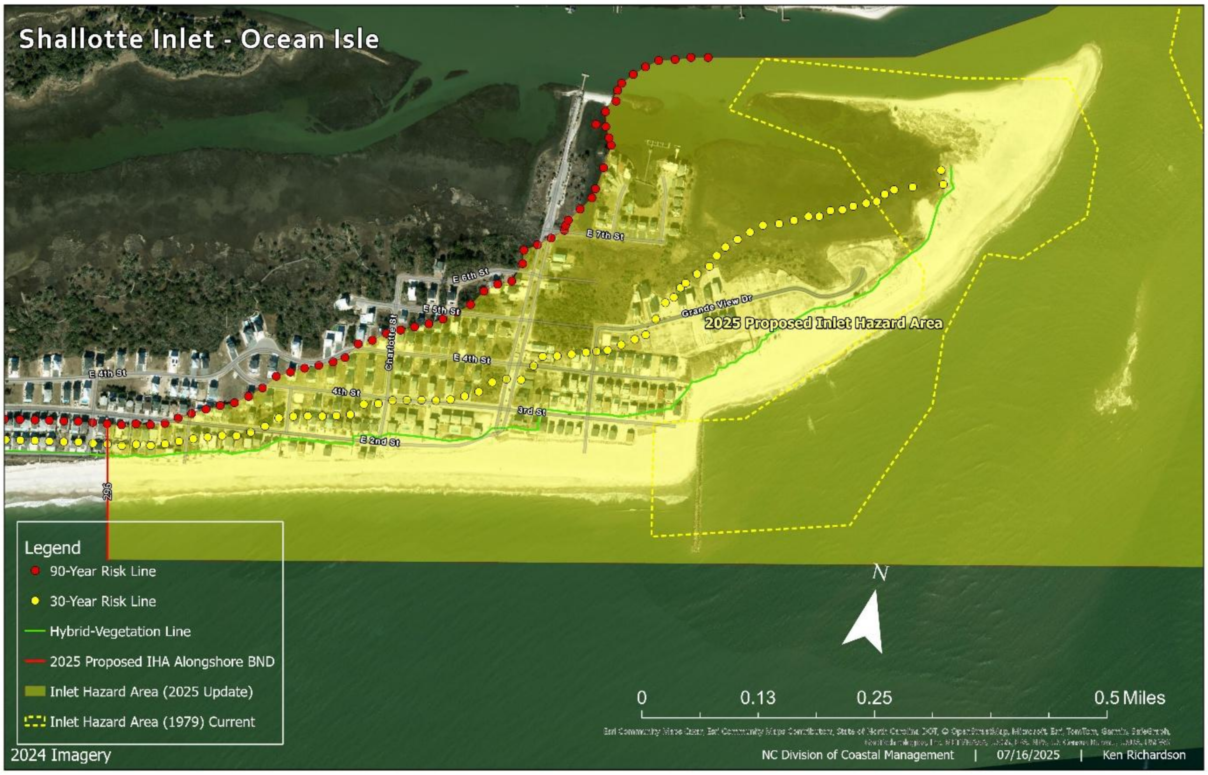

Figure 31. *Shallotte Inlet at Ocean Isle: Updated IHA boundary in relation to transect-296 (alongshore IHA boundary), HVL, 30- and 90-Year Risk Lines, and current (1979) IHA boundary.*

3.2.b Holden Beach side of Shallotte Inlet

The Holden Beach side of Shallotte Inlet has experienced overall length accretion with some episodic short-term erosion. The extreme swing in the offshore ebb channel resulted in the net accretion along more than a mile of near-inlet shoreline on Holden Beach. For property owners, this has resulted in no need for costly interventions to stabilize the shoreline or experience loss of properties due to erosion. This accretional phase began in the 1970s when the inlet's ebb channel aligned closer to the Holden Beach shoreline, which could be attributed to a possible underestimation of the IHA's landward boundary in the area immediately adjacent to the inlet. This prolonged cycle underscores the intricate and dynamic interaction between natural processes and the evolving morphology of the inlet, where consistent sediment deposition has gradually pushed the shoreline seaward.

The observed changes are significant because they occurred well before any human interventions (beach nourishment) were implemented. Aerial imagery from the 1970s to the early 2000s vividly captures this natural accretion process, offering a clear visual record of the shoreline's progressive seaward movement, with relatively minor shoreline losses. These changes demonstrate the inlet's dynamic nature, where natural forces have favored accretion over erosion for an extended period. The implications of this trend are profound, as they suggest that the inlet's current behavior is a product of long-standing natural inlet cycles rather than more recent human interventions.

In 2002, to offset coastal erosion along its oceanfront shoreline, the Town of Holden Beach completed its first major beach nourishment project, subsequently followed by six additional projects over the next thirteen years (Holden Beach, 2015). These efforts were strategically aimed at stabilizing the shoreline while affording added protection against storm damage. However, it's important to note that none of these projects were conducted within the area identified by the Panel's 2024 IHA boundary proposal. Due to the ongoing accretion that began nearly thirty years before beach nourishment practices started, the island's west end simply did not require beach nourishment. The fact that this area has never been nourished is crucial for understanding the long-term sediment dynamics and shoreline stability near the inlet, and that this gain over time began long before beach nourishment practices.

Sediment transport within inlet areas is subject to continuous and unpredictable changes due to the complex interaction of wave energy, wind direction, tidal fluctuations, and the constantly shifting bathymetric and hydrographic features of the inlet. This makes sediment transport highly variable and difficult to predict with accuracy. Initial studies by the USACE in 1973 indicated that the net longshore sediment transport around Holden Beach predominantly moved from west to east, reflecting the prevailing wave and current patterns of that period. However, later studies starting in the early 1980s, such as those by Miller (1983), suggest a shift, with net longshore sediment movement now occurring from east to west.

The Panel agreed that the current lengthy cycle of accretion along the inlet-ocean shoreline within the proposed IHA is largely driven by inlet dynamics rather than being an isolated result of alongshore sediment transport from areas that have undergone beach nourishment. Aerial imagery analysis provides compelling evidence of this, showing accretion occurring between 1970 and pre-2002, before beach nourishment efforts began. In contrast, post-2000 imagery reveals that the more recent realignment of the ebb channel, those accretion areas have been eroding.

It is important to recognize that these accretional gains are very likely not permanent, based on the fluctuations observed on oceanfront shorelines adjacent to other North Carolina inlets and an understanding of inlet processes. The dynamic nature of the inlet means that a reversal, initiating a cycle of erosion, is an inevitable part of the natural process. Although the reach of inlet influences on the shoreline's position can be estimated, accurately predicting when this shift might occur and forecasting a timeline of accretion-erosion cycles is far more complex.

The shoreline and vegetation data for the Holden Beach side of Shallotte Inlet are shown in **Figures 32 and 35**. The HVL within the IHA is a composite of 1970, 1981, 1992, 1993 vegetation lines.

Applying the STD Δ > 1 threshold identifies the alongshore IHA boundary at transect-144 (**Figure 34**). The landward IHA boundary was defined using the 90-Year Risk Line starting at transect 144 and moving in the direction of the inlet. Where the end of the HVL intersects the marsh (landward side of Holden Beach), the IHA boundary is extended across the marsh to intersect the ICW (**Figure 36**).

Figure 32. *Shallotte Inlet at Holden Beach. Shorelines included in the analysis: 1970, 1981, 1992, 1993, 1997, 1998, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2022.*

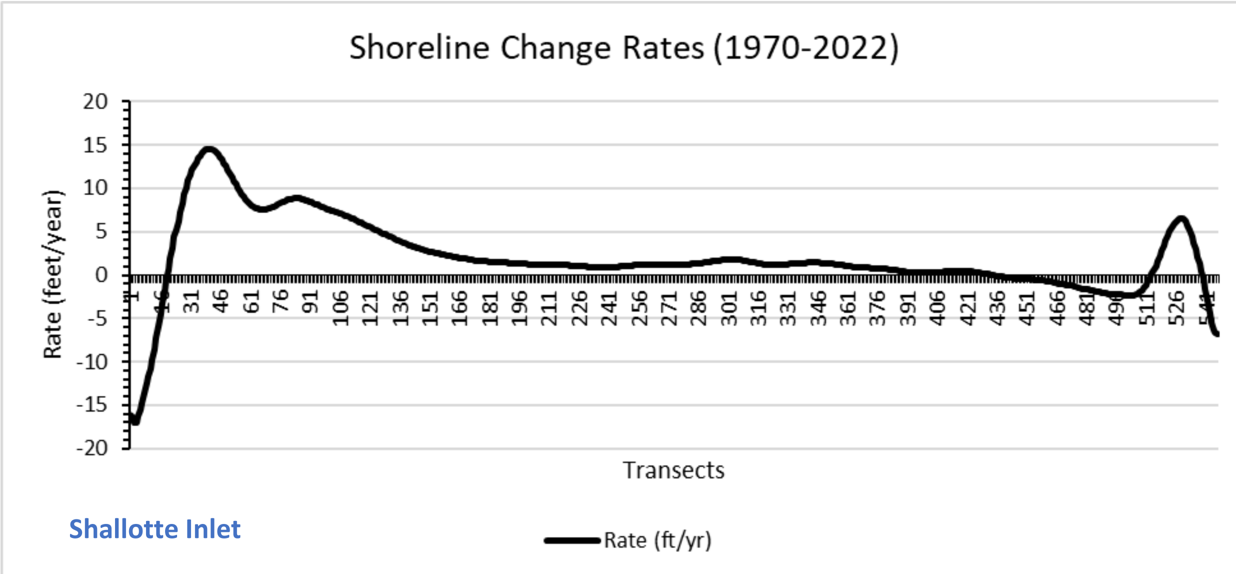

Figure 33. *Shoreline change rates (ft/yr) at Holden Beach from 1970 to 2022. Negative values indicate erosion, while positive values indicate accretion.*

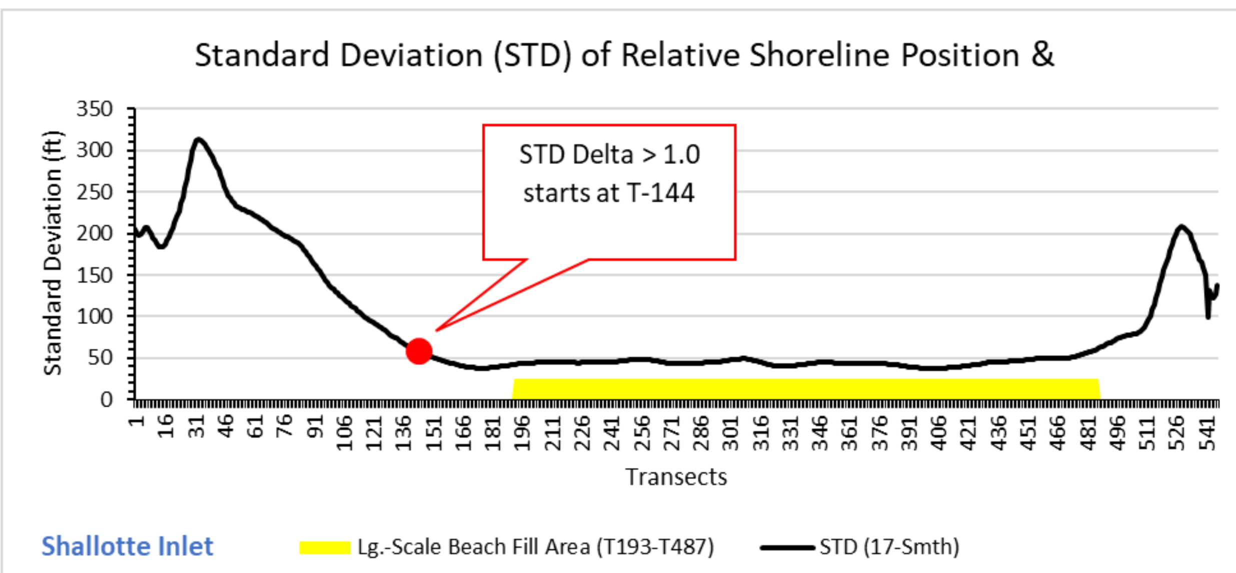

Figure 34. *Using the standard deviation of relative shoreline position data at Shallotte Inlet-Holden Beach and applying the STD Δ > 1.0 threshold method, transect 144 (red point) is identified as the alongshore IHA boundary. This transect is where the standard deviation difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

Figure 35. *Shallotte Inlet at Holden Beach. Vegetation Lines mapped: 1970, 1981, 1992, 1993, 1998, 2003, 2004, 2008, 2009, 2010, 2012, 2016, 2020, 2022. Vegetation line segments making up the HVL: 1970, 1981, 1992, 1993.*

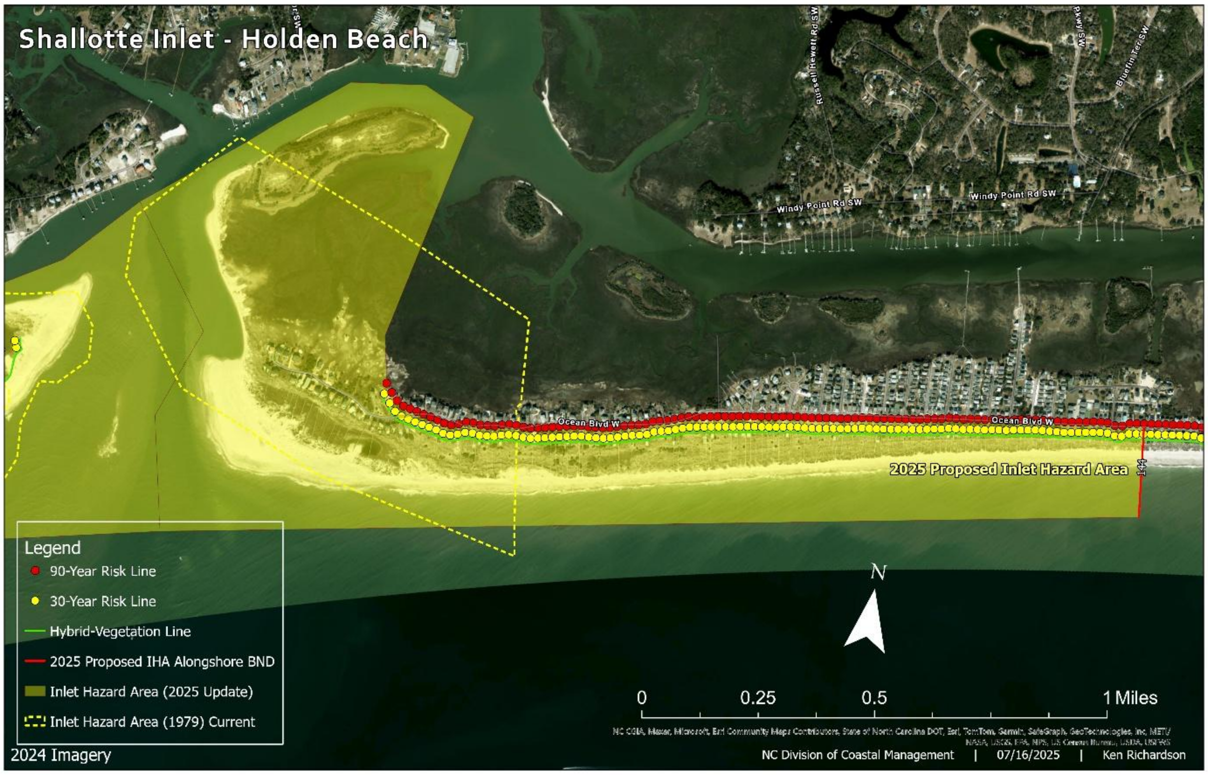

Figure 36. *Shallotte Inlet at Holden Beach: Updated IHA boundary in relation to transect-144 (alongshore IHA boundary), HVL, 30- and 90-Year Risk Lines, and current (1979) IHA boundary.*

3.3 Lockwood Folly Inlet

The oceanfront shorelines adjacent to Lockwood Folly Inlet, like those of nearby Shallotte Inlet, experience wide swings in position. Lockwood Folley Inlet was charted as early as 1672. Seismic data from the inner-continental shelf suggests the inlet is a permanent feature related to the paleo-channel of the ancestral Lockwood Folly River that extends across the hard bottom-dominated shoreface. Since 1938 the throat position of the ebb channel has shifted east and west within a 420 feet wide corridor. Although the throat segment of the ebb channel has been confined to a relatively narrow zone, the outer segment of the channel has migrated to the southwest and the southeast across a 7,250 feet wide length of the oceanfront shorelines. Because of the complex pattern of movement of the ebb channel across the outer bar, the symmetry of the ebb delta has continually been altered as has the protective wave-sheltering effect of the shoals on the ocean shorelines.

The contrasting patterns of change along the Holden Beach and Oak Island oceanfront shorelines directly reflect the influence of the ebb channel's position, its alignment and the attendant shape changes of the ebb-tidal delta. In general, the predominant historic southeasterly alignment of the ebb channel has promoted much of the long-term chronic erosion along Holden Beach involving hundreds of feet of shoreline retreat and by contrast the hundreds of feet of progradation along Oak Island.

Lockwood Folly Inlet is an authorized Federal shallow-draft navigation project. The navigation channel is periodically maintained by dredging.

3.3.a Holden Beach side of Lockwood Folly Inlet

Shoreline and vegetation data between 1971 and 2022 illustrate the effects on the shoreline of low-elevation swash bars consistently welding onto the ocean shoreline near the inlet. The shoreline more distant from the inlet has been eroding (**Figures 37 and 38**). Sandbag revetments have been installed to armor roads and houses along 2,000 feet of developed shoreline adjacent to the inlet.

The shoreline and vegetation data for the Holden Beach side of Lockwood Folly Inlet are shown in **Figures 37 and 40**. The HVL is comprised of vegetation lines from 1993, 1998, 2003, 2004, 2008, 2009, 2010, 2012, 2020, 2021 (**Figure 40**). Because the STD $\Delta > 1$ boundary would not include the area where homes were lost as recently as the early 90s (as well as in 70s and 80s), the boundary identified with the STD > 15-m boundary is used instead. This yields an alongshore IHA boundary at transect 478 (**Figure 39**). Notably this is the same transect that would have been identified using the previously applied STD increase approach, lending further confidence to this transect as the most appropriate boundary. The landward IHA boundary was defined using the 90-Year Risk Line starting at transect 478 and moving in the direction of the inlet. Where the HVL ends and at the last 90-Year Risk Line point adjacent to the inlet, the IHA boundary is extended across approximately 250 feet to intersect the ICW (**Figure 41**).

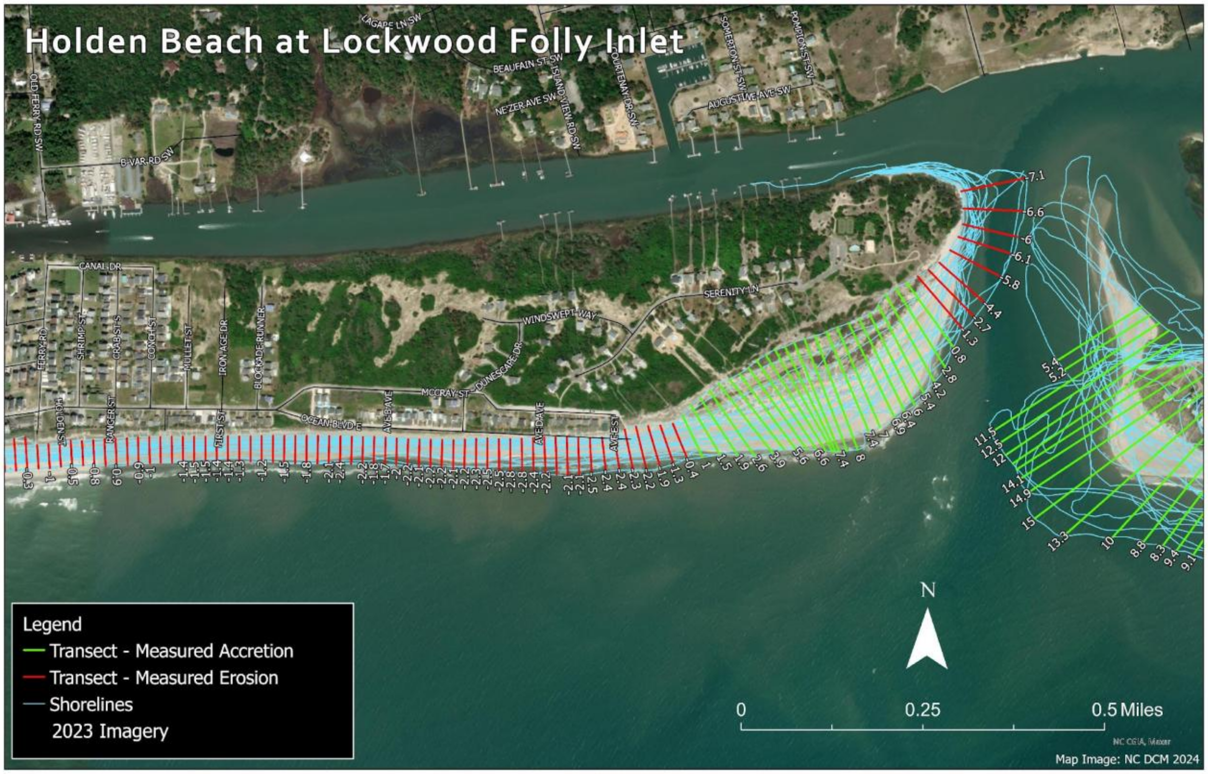

Figure 37. *Lockwood Folly Inlet at Holden Beach. Shorelines included: 1971, 1978, 1988, 1993, 1997, 1998, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2021, 2022.*

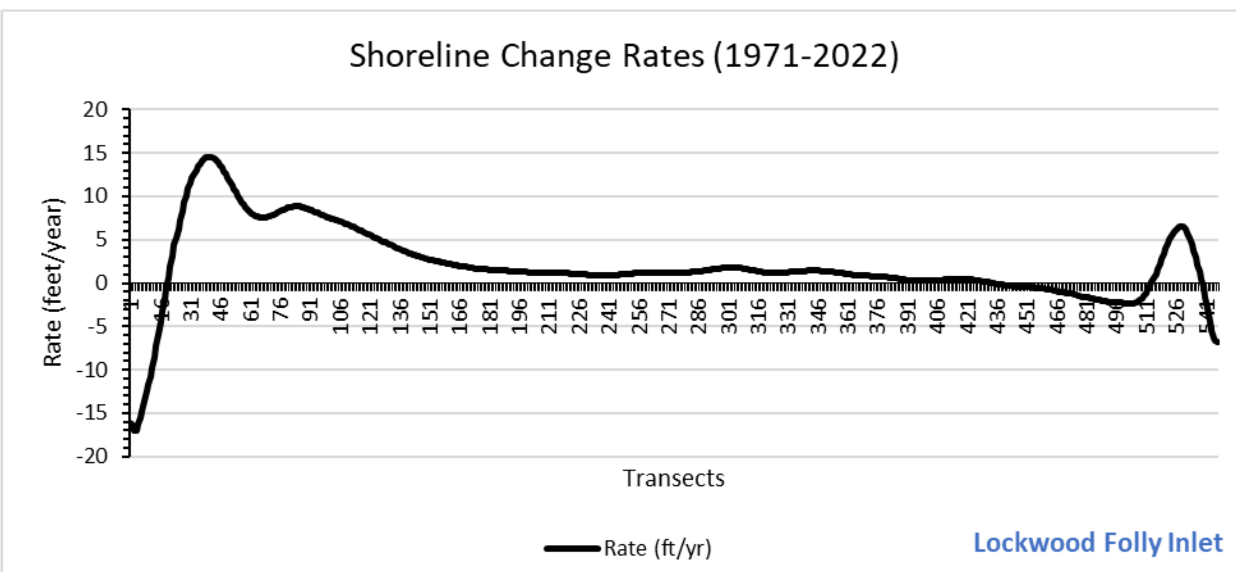

Figure 38. *Shoreline change rates (ft/yr) at Ocean Isle from 1971 to 2022: Negative values indicate erosion, while positive values indicate accretion.*

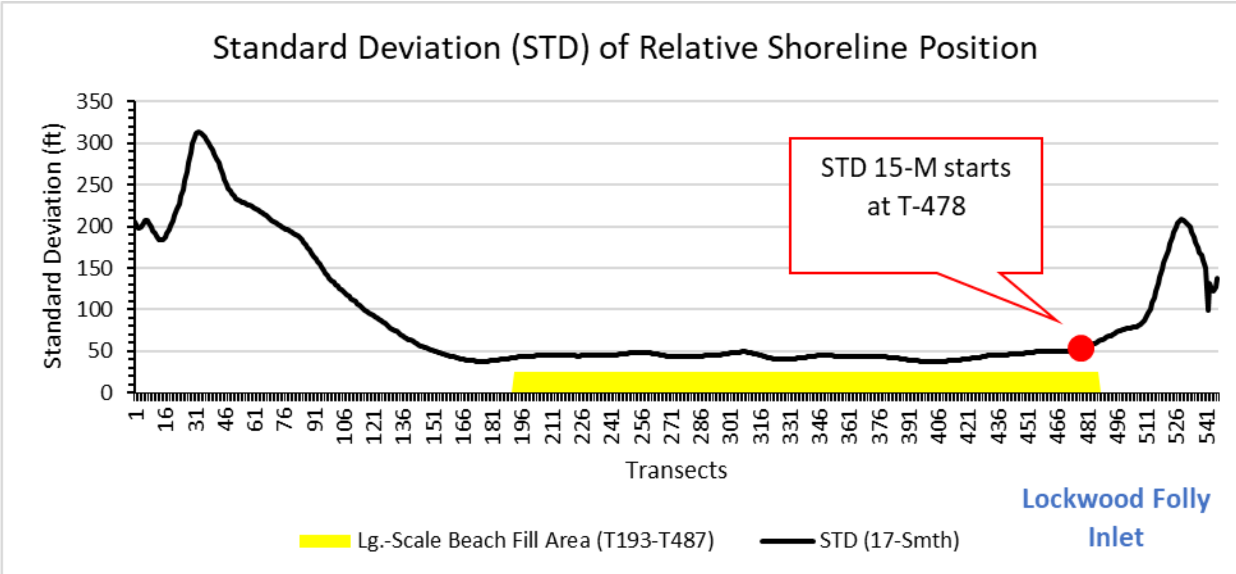

Figure 39. *Using the standard deviation of relative shoreline position data at Lockwood Folly Inlet-Holden Beach and applying the STD 15-m threshold method, transect-478 (red point) is identified as the alongshore IHA boundary. This transect is where the STD exceeds 15 meters moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

Figure 40. *Lockwood Folly Inlet at Holden Beach. Vegetation Lines mapped: 1971, 1978, 1988, 1993, 1998, 2003, 2004, 2008, 2009, 2010, 2012, 2016, 2020, 2021, 2022. Vegetation line segments making up the HVL: 1993, 1998, 2003, 2004, 2008, 2009, 2010, 2012, 2020, 2021.*

Figure 41. *Lockwood Folly Inlet at Holden Beach: Updated IHA boundary in relation to transect-478 (alongshore IHA boundary), HVL, 30- and 90-Year Risk Lines, and current (1979) IHA boundary.*

3.3.b Oak Island side of Lockwood Folly Inlet

The Oak Island shoreline has been significantly affected by wide fluctuations in the inlet's ocean ebb channel. Oak Island experienced severe erosion between 1974 to 1984 (Cleary and Marden, 1999) causing building failures and relocations, partial loss of the loop road, and the construction of various erosion control structures. Analysis of longer-term data (1971-2016) demonstrates the shoreline's recovery resulting in extensive long-term accretion. Some of the lots that previously lost buildings were redeveloped after 2000. Several of the new houses that were threatened by a local shift in the ebb channel in 2014-2016 were armored with sandbags. Shoreline and vegetation data for the Oak Island side of Lockwood Folly Inlet are shown in **Figures 42 and 45**.

The HVL is comprised of 1971, 1987, 1988, 1990, 1993, 2016, and 2021 vegetation lines (**Figure 45**). Applying the STD 15-mthreshold identifies the IHA alongshore boundary at transect 81, whereas the STD Δ > 1identifies the boundary at transect 49 (for comparison, STD increase suggests that inlet influence extends to at least transect 86). An accretionary dune feature exists centered around transect 63 and the visible associated landward shift in the HVL ends at transect

66. For these reasons, Transect 81 is recommended as the IHA boundary to include the accretionary dunes influenced by the inlet, which are not captured by the STD Δ > 1 threshold (**Figure 43**). The recommended landward IHA boundary is the 90-Year Risk Line extending into the ICW (**Figure 46**).

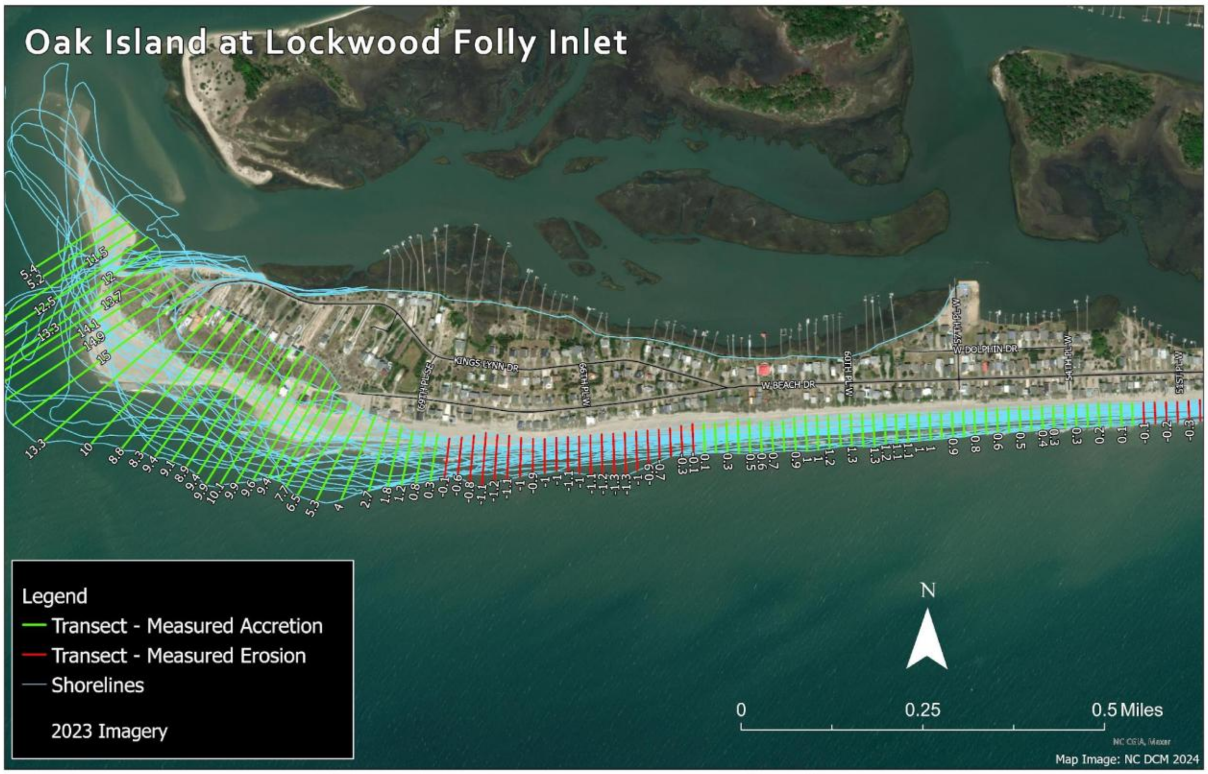

Figure 42. *Lockwood Folly Inlet at Oak Island, shorelines analyzed: 1970, 1971, 1974, 1975, 1978, 1979, 1980, 1987, 1988, 1990, 1993, 1998, 2000, 2003, 2004, 2008, 2009, 2010, 2012, 2016, 2020, 2021.*

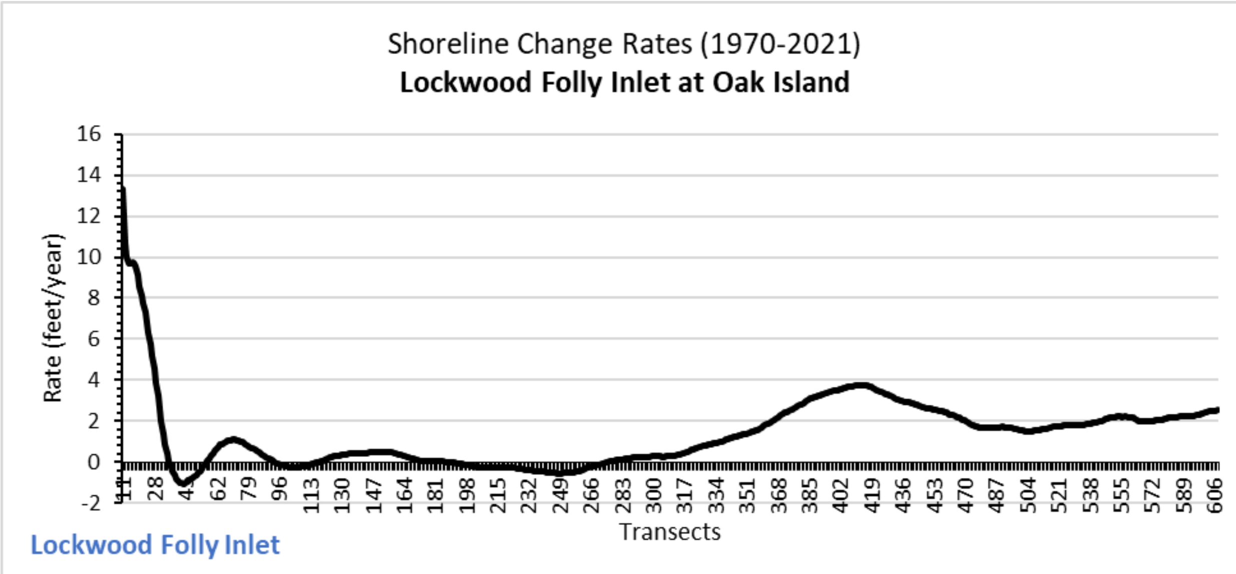

Figure 43. *Shoreline change rates (ft/yr) at Ocean Isle from 1970 to 2021: Negative values indicate erosion, while positive values indicate accretion.*

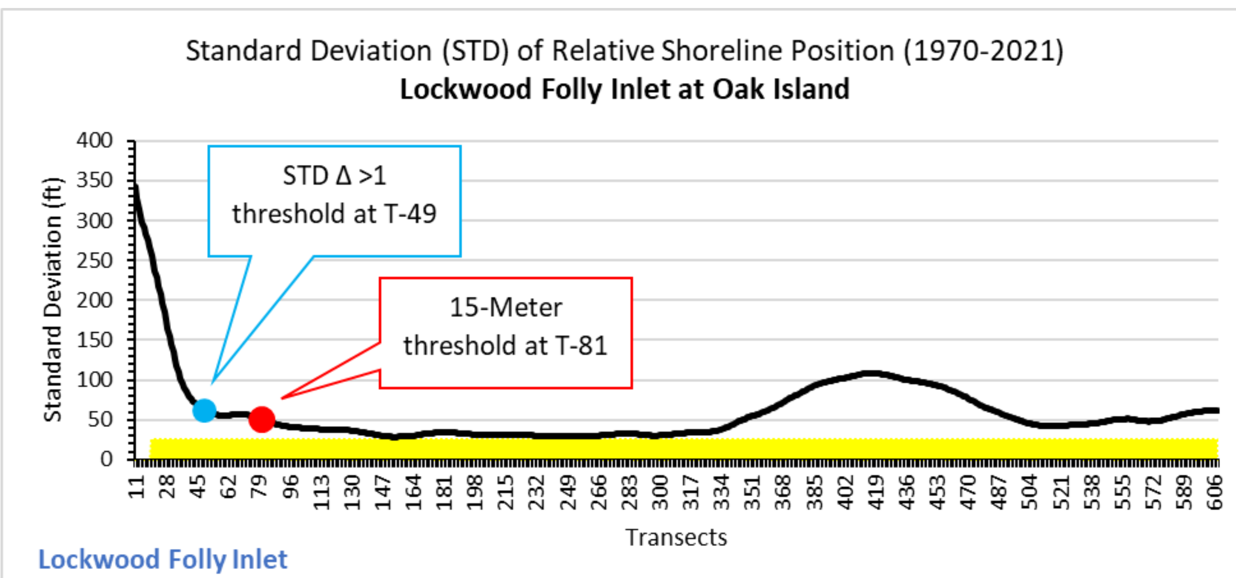

Figure 44. *Using the standard deviation of relative shoreline position data at Lockwood Folly Inlet-Oak Island and applying the STD 15-m threshold method, transect 81 (red point) is identified as the alongshore IHA boundary. This transect is where the standard deviation threshold exceeds 15 meters (49.2 ft) moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

Figure 45. *Lockwood Folly Inlet at Oak Island. Vegetation Lines mapped: 1971, 1974, 1975, 1978, 1979, 1980, 1987, 1988, 1990, 1993, 1998, 2000, 2003, 2004, 2008, 2009, 2010, 2012, 2016, 2020, 2021. Vegetation line segments making up the HVL: 1971, 1987, 1988, 1990, 1993, 2016, 2021.*

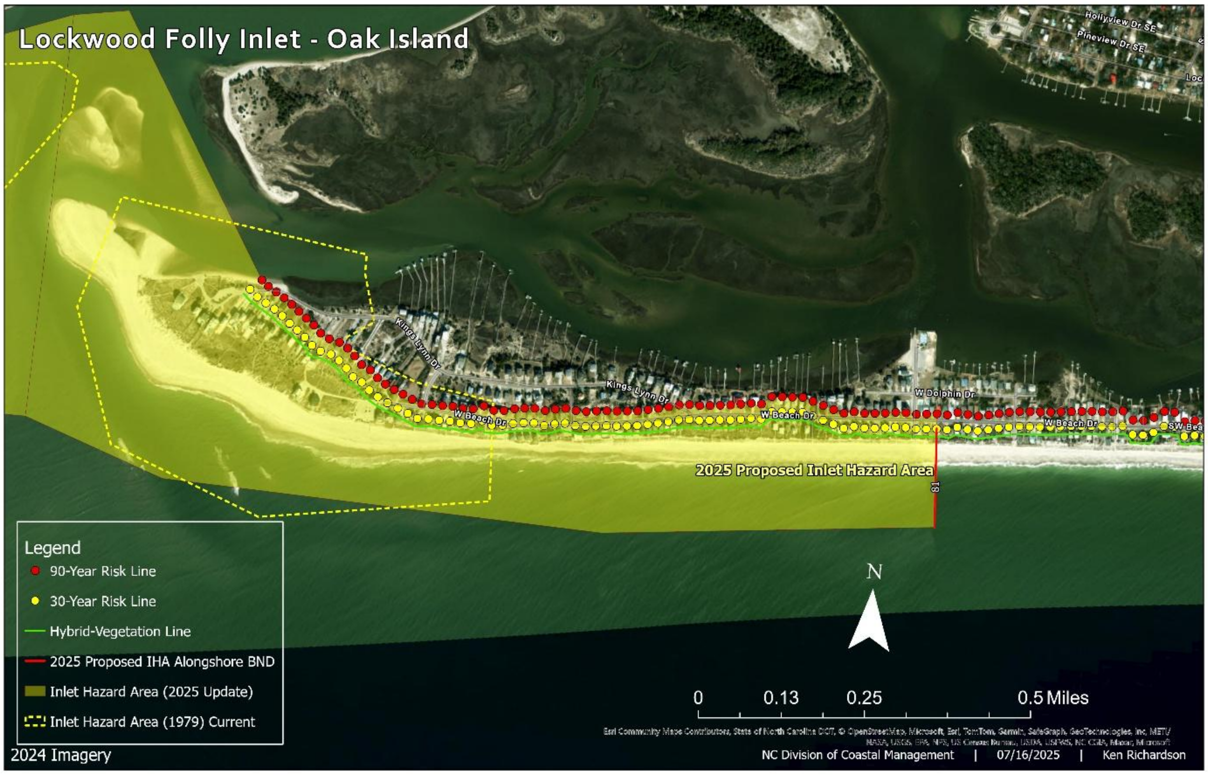

Figure 46. *Lockwood Folly Inlet at Oak Island: Updated IHA boundary in relation to transect 81 (alongshore IHA boundary), HVL, 30- and 90-Year Risk Lines, and current (1979) IHA boundary.*

3.4 Carolina Beach Inlet

Carolina Beach Inlet was opened by private interests in 1952, at a location approximately 7,500 feet northeast of the Town of Carolina Beach. The inlet was opened along the closure zone of the former Sugarloaf Inlet, a short-lived inlet of the late 19th Century. Carolina Beach Inlet is an authorized Federal shallow-draft navigation project that connects the open ocean and the ICW through a short, narrow and relatively deep navigation channel. The inlet also provides a connection to the Cape Fear River across the mainland via Snows Cut. Since the 1970s, a designated borrow area has been regularly used as a borrow source for a US Army Corps of Engineers beach nourishment project along sections of Carolina Beach. During the past 50 years the inner and outer segments of the main channel have shifted toward Masonboro Island as much as 475 feet. After the opening of the inlet, the adjacent oceanfront shorelines along both Carolina Beach and Masonboro Island began to erode at rapid rates that ultimately led to a significant landward offset of Carolina Beach. As part of the US Army Corps of Engineers project a rock revetment was constructed to protect the northern 1,800 feet of development. The chronic erosion was related to the reduced rate of sand bypassing at the inlet as the ebb-tidal delta continued to impound sand. The reduced rate of bypassing also severely impacted updrift Masonboro Island, where the oceanfront has retreated approximately 500 feet since 1962.

3.4.a Carolina Beach side of Carolina Beach Inlet

Vegetation and shoreline data for the Carolina Beach side of Carolina Beach Inlet are shown in **Figures 47 and 50**. Analysis of shoreline data from 1971 to 2021 shows long-term accretion along the oceanfront with erosion measured adjacent to the inlet channel (**Figures 47 and 48**), though these findings are influenced by a shore-parallel granite rock structure, routine beach nourishment and maintenance dredging activities at Carolina Beach Inlet. Applying the STD Δ > 1 threshold, identifies the alongshore IHA boundary at transect 2119 (**Figure 49**). Note that inlet influence to the south of this transect is limited by the existing rock structure. The landward IHA boundary was defined using the 90-Year Risk Line starting at transect 2119 and moving in the direction of the inlet. From the last 90-Year Risk Line point adjacent to the inlet, the IHA boundary is extended to intersect the ICW (**Figure 51**).

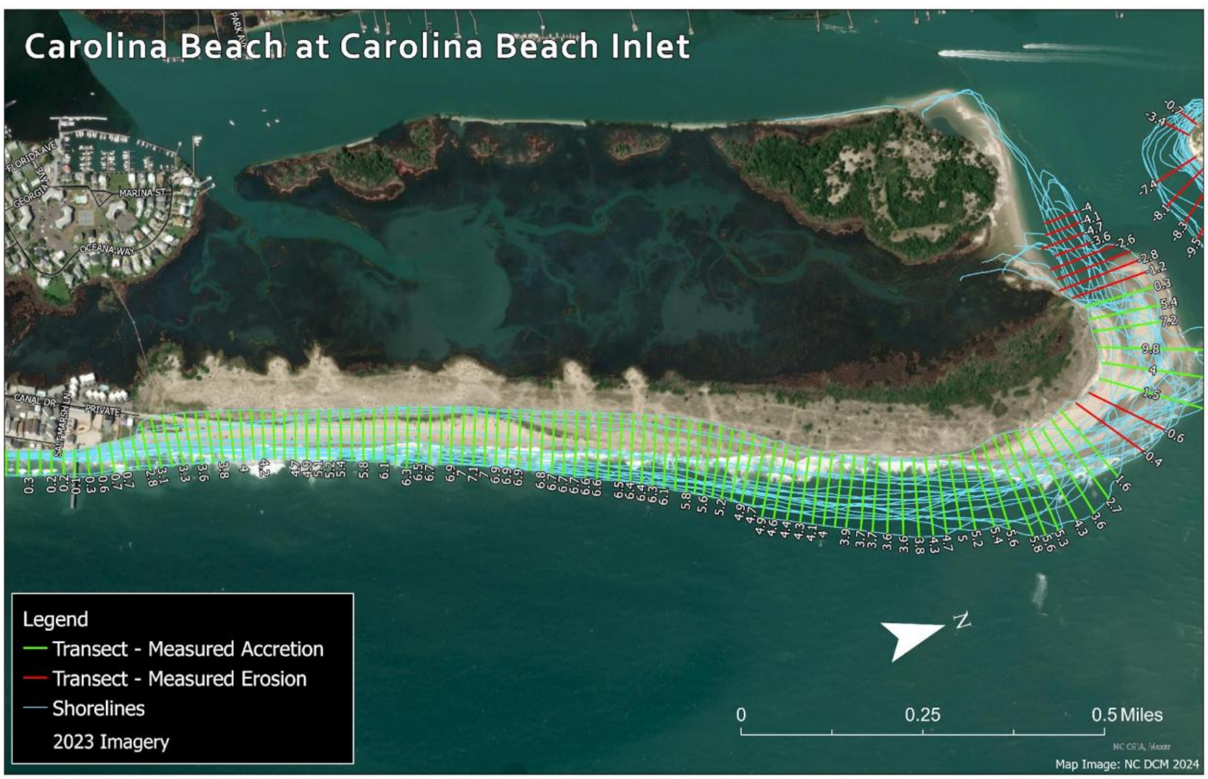

Figure 47. *Carolina Beach Inlet at Carolina Beach. Shorelines included in the analysis: 1971, 1973, 1974, 1977, 1984, 1992, 1997, 1998, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2021.*

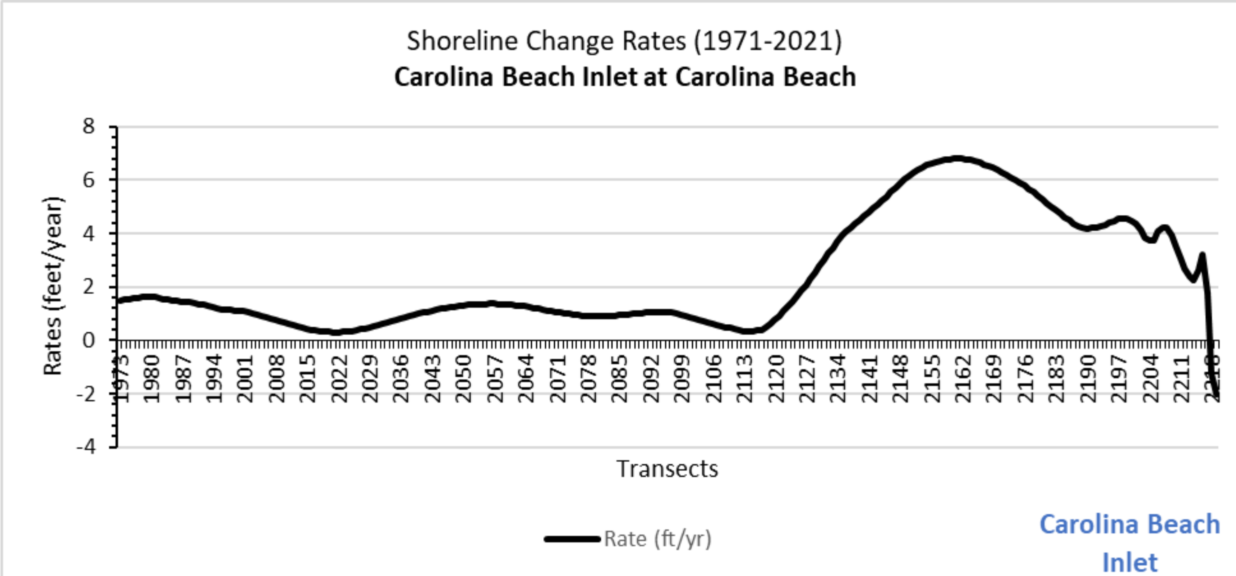

Figure 48. *Shoreline change rates (ft/yr) at Carolina Beach from 1970 to 2021: Negative values indicate erosion, while positive values indicate accretion.*

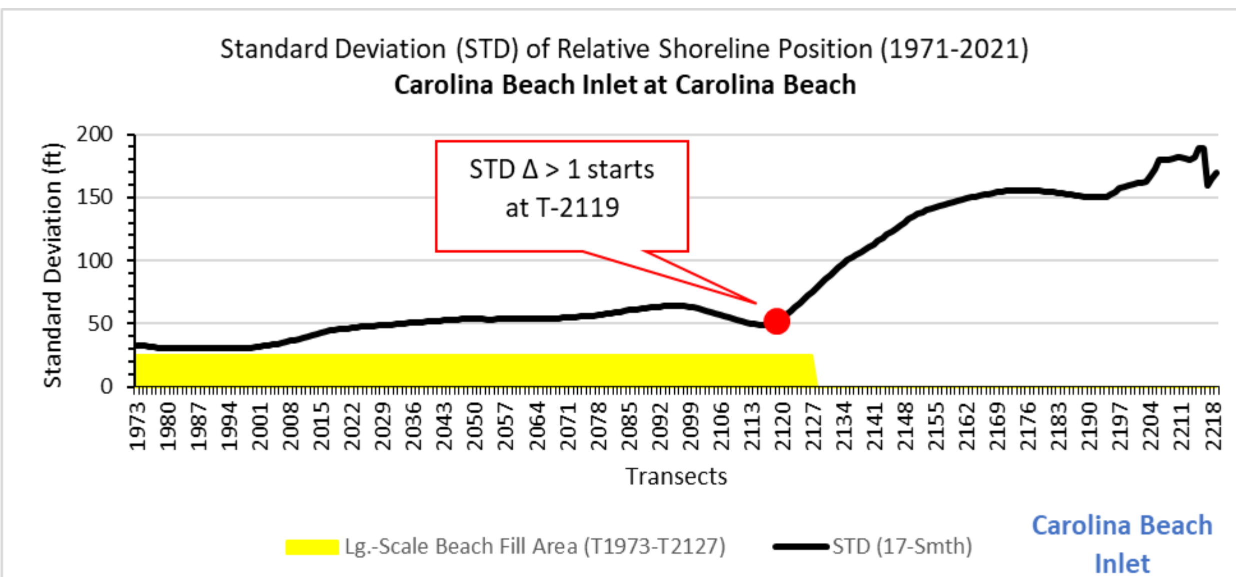

Figure 49. *Using the standard deviation of relative shoreline position data at Carolina Beach Inlet – Carolina Beach, and applying the STD Δ > 1.0 threshold method, transect 2119 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

Figure 50. *Carolina Beach Inlet at Carolina Beach. Vegetation Lines mapped: 1971, 1974, 1977, 1984, 1992, 1998, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2021. Vegetation line segments making up the HVL: 1971, 1974, 1977, 1984, 1992, 1998, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2012.*

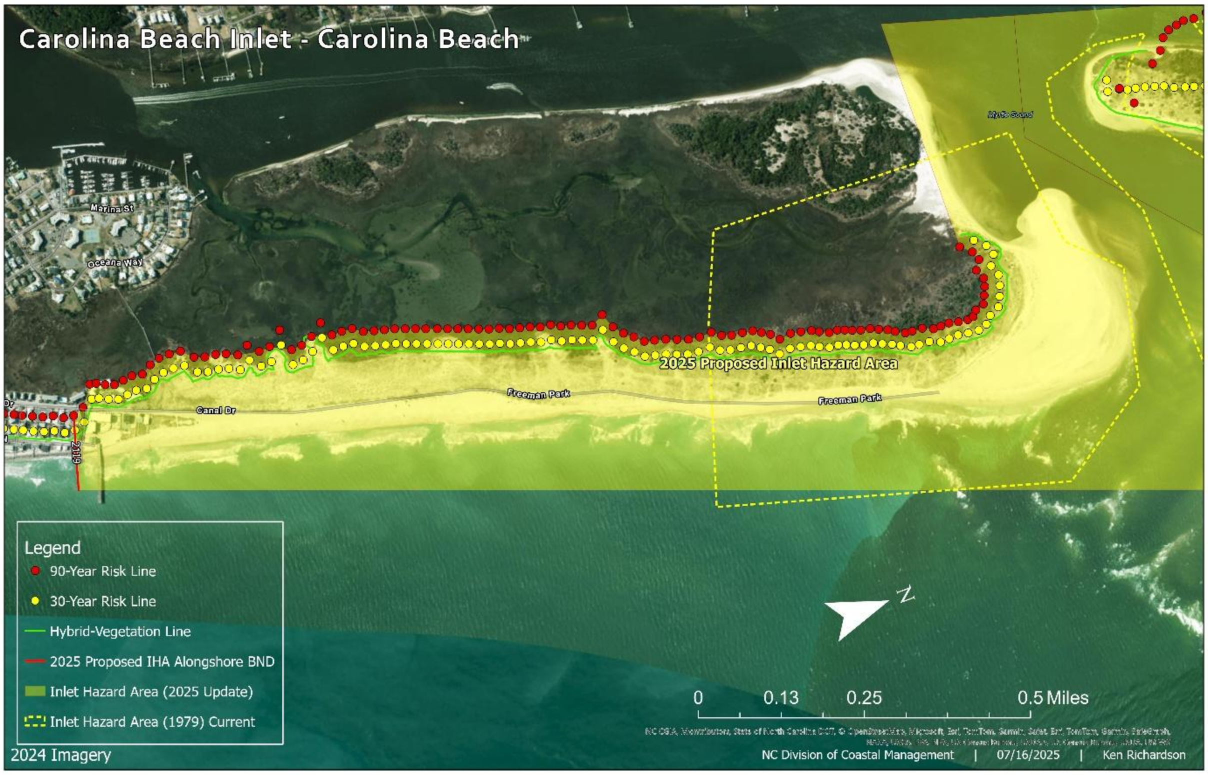

Figure 51. *Carolina Beach Inlet at Carolina Beach HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

3.4.b Masonboro Island side of Carolina Beach Inlet

Carolina Beach Inlet is bordered on the north by uninhabited Masonboro Island, a narrow, low-lying and dynamic barrier island characterized by extensive overwash, a 1954 breach during Hurricane Hazel, and a wide backbarrier marsh. The entire island is affected by both Carolina Beach Inlet and Masonboro Inlet to the north. This can be seen in the vegetation and shoreline data shown in **Figures 52, 53, 54, and 55**, which illustrate the high rates of erosion occurring within Carolina Beach Inlet and along most of the oceanfront. Erosion is a consequence of sediments not bypassing the Masonboro Inlet jetties from the north.

The standard deviation in shoreline position was examined along the Masonboro Island oceanfront and determined to be high everywhere, with the lowest value at transect 382 and increasing values from there toward each inlet (**Figure 58**). In addition, measured erosion across the island is high; mean = -6.9 feet/year, median = -8.6 feet/year, and maximum = -22.9 feet/year except at the north end of the island in an area that is within the depositional fillet of and protected by the Masonboro Inlet south jetty (**Figure 57**). Based on that finding and considering that the 90-Year Risk Line falls into the backbarrier marsh, the recommended IHA extends along the entire length of Masonboro Island (**Figures 59 and 60**).

Figure 52. *Carolina Beach Inlet at Masonboro Island. Shorelines included in the analysis: 1971, 1974, 1977, 1984, 1992, 1997, 1998, 2000, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2021.*

Figure 53. *Carolina Beach and Masonboro Inlets at Masonboro Island. Vegetation Lines mapped: 1971, 1974, 1977, 1984, 1992, 1998, 2000, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020. Vegetation line segments making up the HVL: 1974, 1977, 1984, 1998, 2000, 2002, 2003, 2004, 2006, 2008, 2010, 2012, 2016, 2020, 2021.*

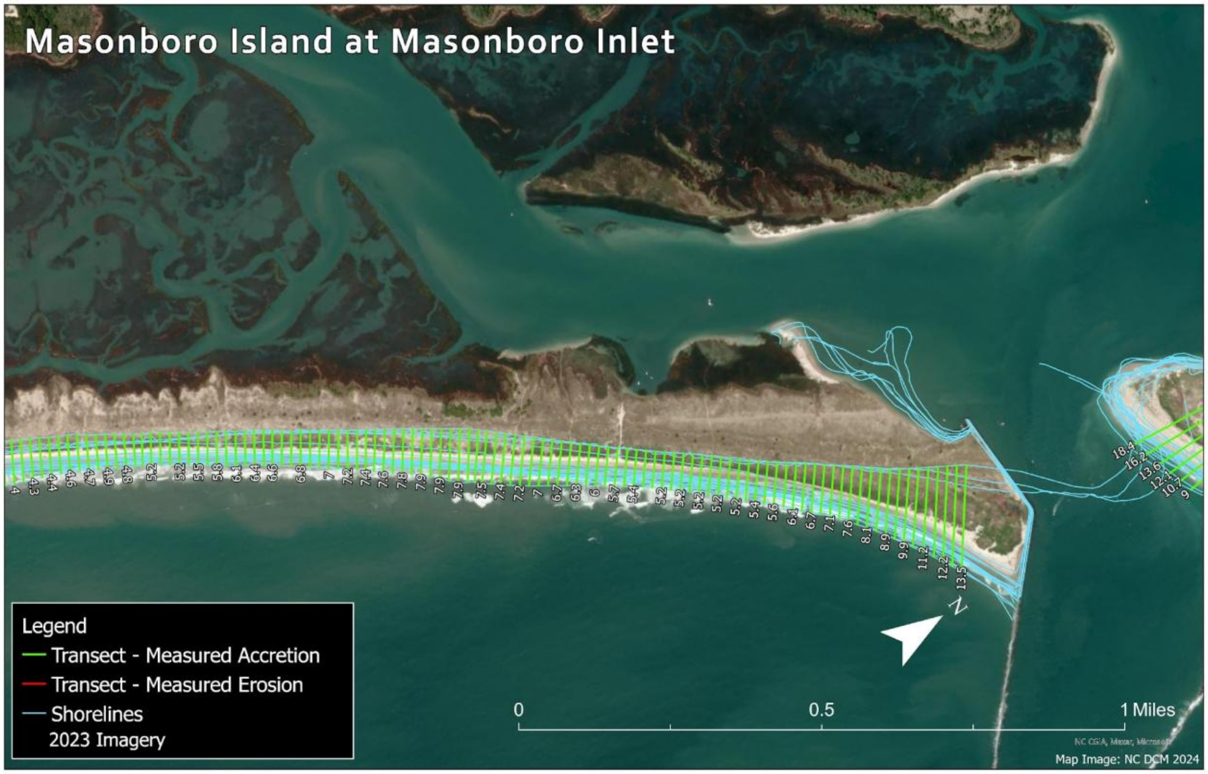

Figure 54. *Masonboro Inlets at Masonboro Island. Shorelines included in the analysis: 1971, 1974, 1977, 1984, 1992, 1997, 1998, 2000, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2021.*

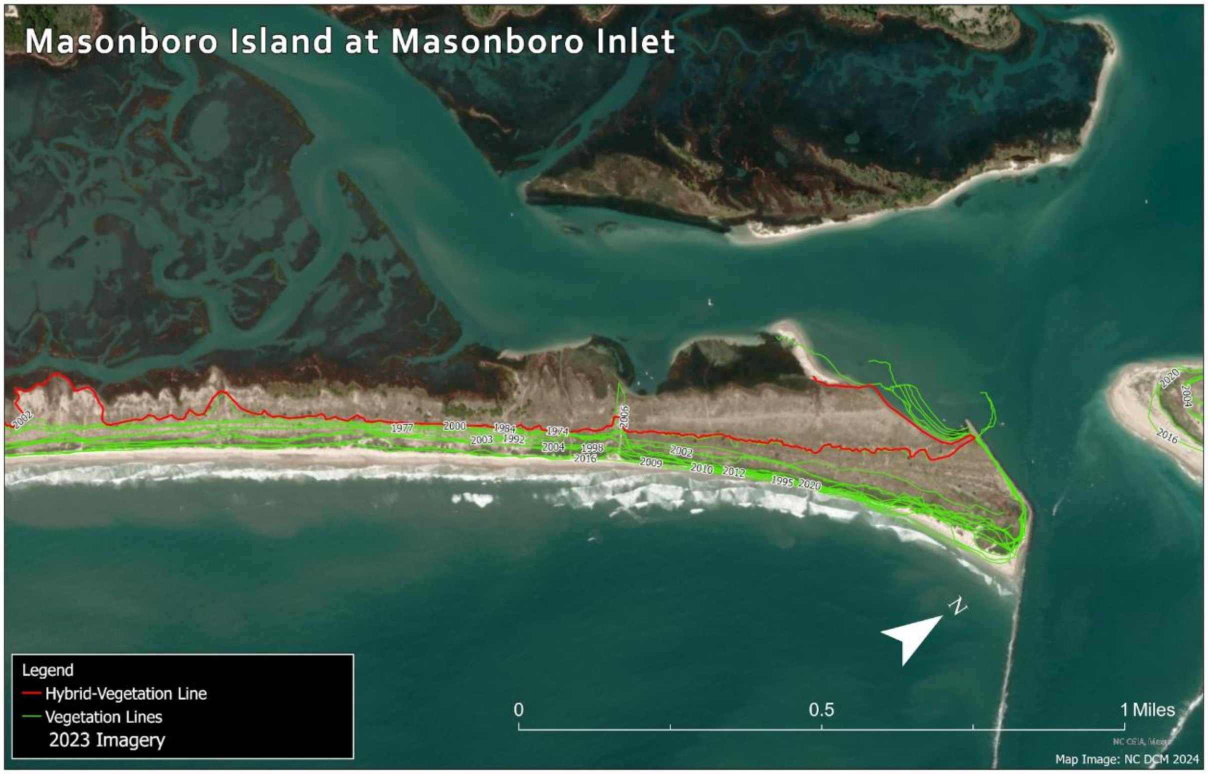

Figure 55. *Carolina Beach and Masonboro Inlets at Masonboro Island. Vegetation Lines mapped: 1971, 1974, 1977, 1984, 1992, 1998, 2000, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2021. Vegetation line segments making up the HVL: 1974, 1977, 1984, 1998, 2000, 2002, 2003, 2004, 2006, 2008, 2010, 2012, 2016, 2020, 2021.*

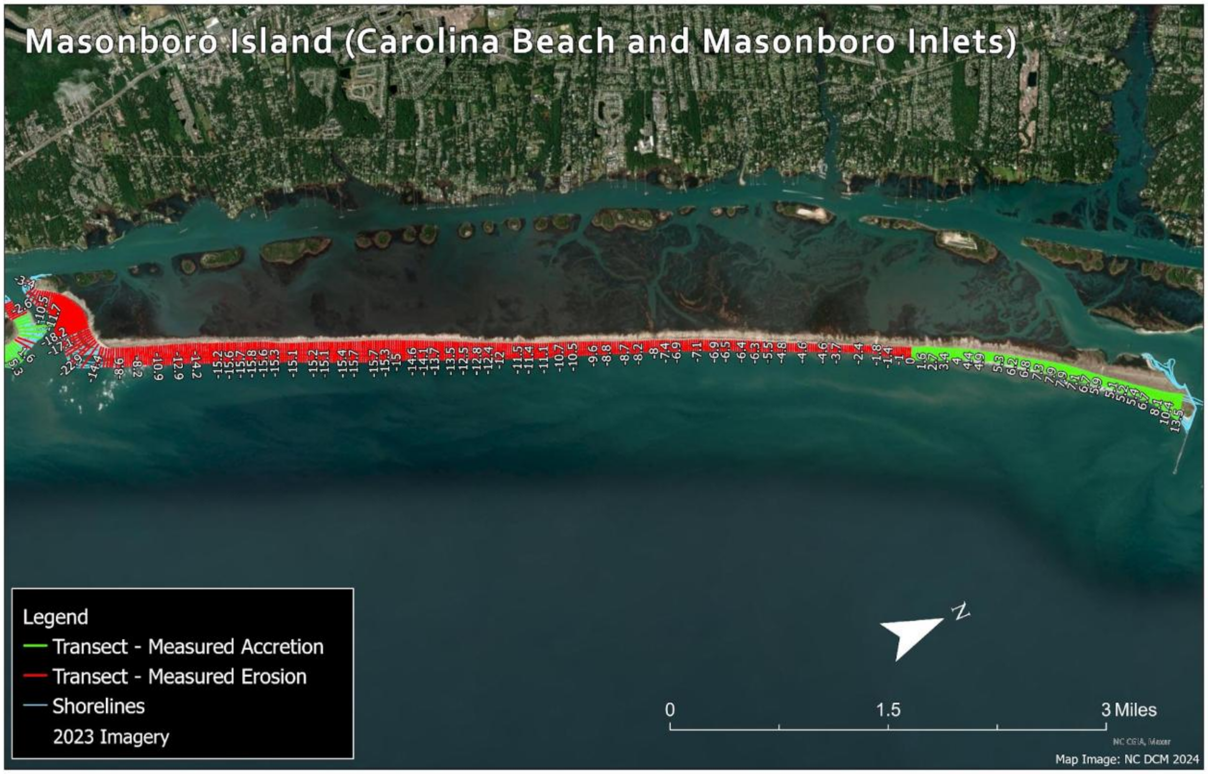

Figure 56. *Carolina Beach and Masonboro Inlets at Masonboro Island. Shorelines included in the analysis: 1971, 1974, 1977, 1984, 1992, 1997, 1998, 2000, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2020, 2021.*

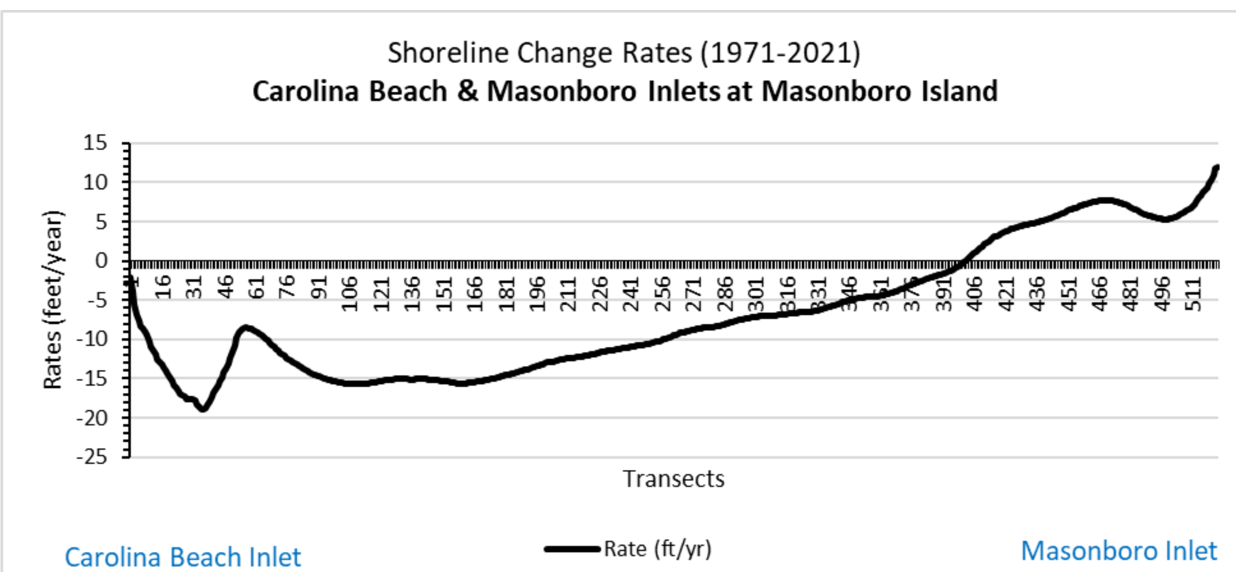

Figure 57. *Shoreline change rates (ft/yr) at Sunset Beach from 1971 to 2021: Negative values indicate erosion, while positive values indicate accretion.*

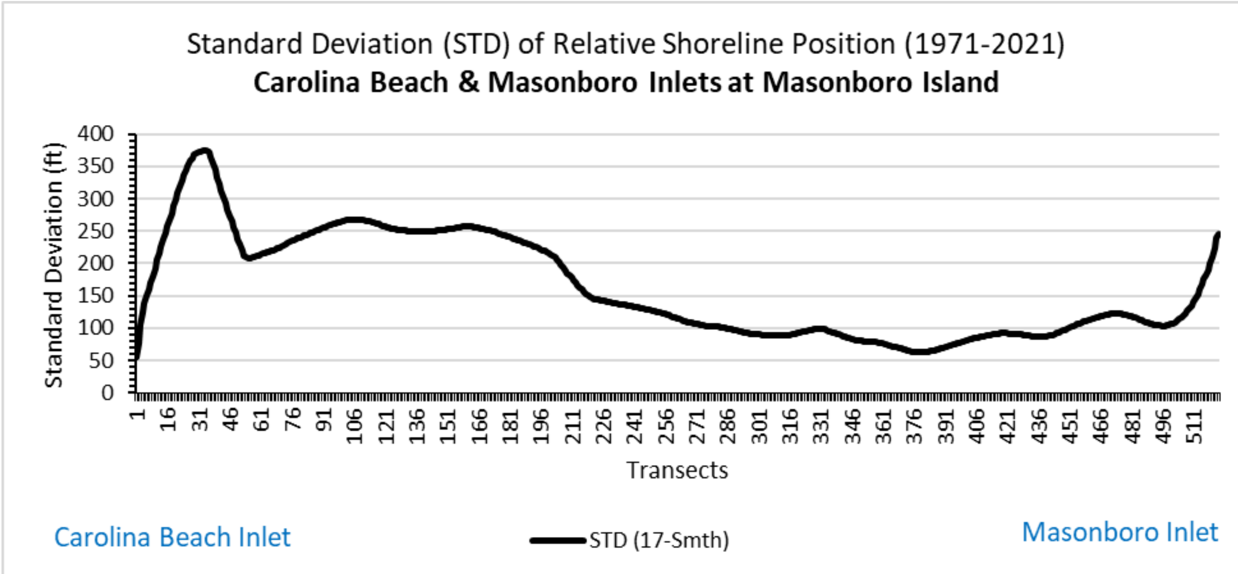

Figure 58. *Masonboro Island standard deviation of relative shoreline position. Because both Carolina Beach Inlet (left) and Masonboro Inlet (right) influence Masonboro Island's entire shoreline, the recommended IHA includes Masonboro Island in its entirety.*

Figure 59. *Carolina Beach Inlet at Masonboro Island HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

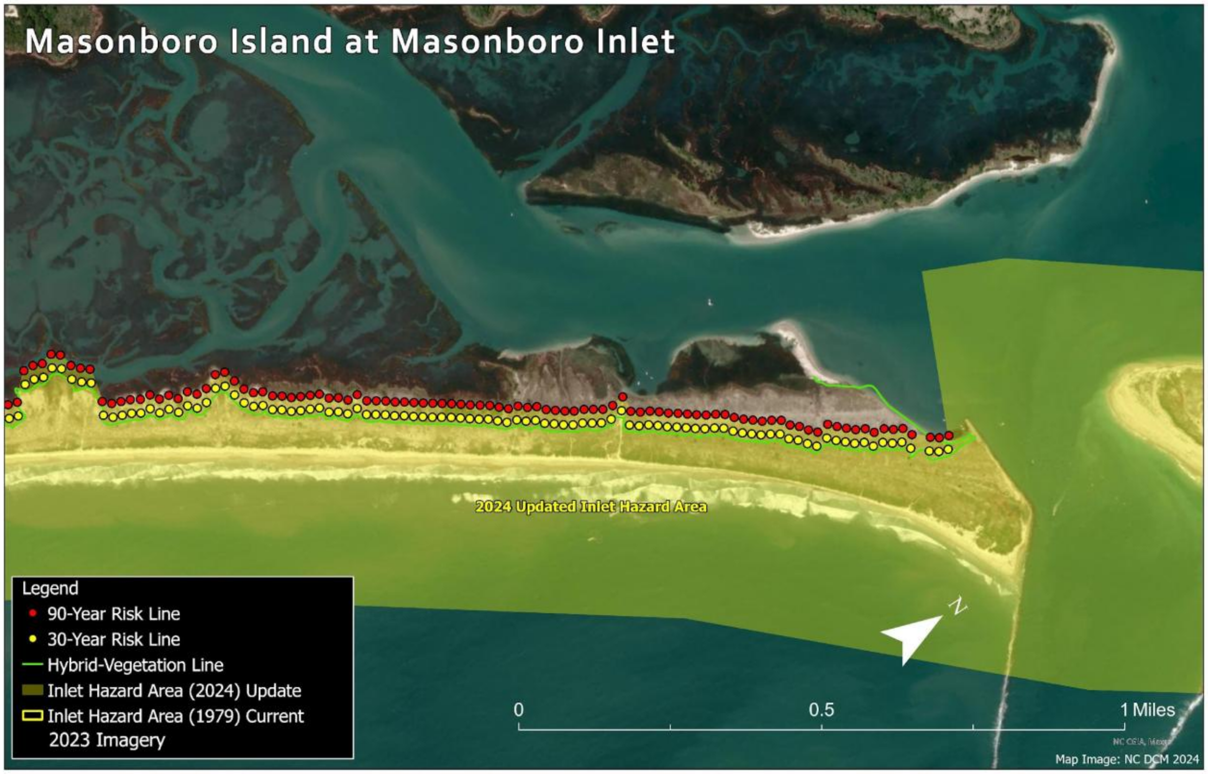

Figure 60. *Masonboro Inlet at Masonboro Island HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

3.5 Masonboro Inlet

Masonboro Inlet is a migrating inlet that is now stabilized. It was documented on historic charts from 1733 and likely opened in a storm in the early 1700s approximately 7,650 feet northeast of its current location. Since completion of the ICW (ca. 1930) the inlet and the tidal basin have been modified by a variety of projects on Wrightsville Beach designed to mitigate the oceanfront erosion, dredge and landfill along the sound and improve navigation. In May 1950, a navigation project was authorized by Congress that proposed the construction of a 14-foot deep by 400-foot-wide channel across the ebb-tidal delta flanked by twin jetties and a series of access channels to the ICW. A single northern weir-jetty was completed in 1966. The south jetty was constructed in 1981.

In the first decade after construction, the north jetty trapped sand extending at least a mile north of the jetty with up to 400 feet of accretion near the jetty. Since then, the low weir has stabilized the ocean shoreline changes by allowing excess sand from the north to be transported inside the jetty, preventing additional entrapment north of the jetty.

The Wrightsville Beach Storm Damage Reduction Project (dune and beach nourishment), completed in 1965, initially involved the placement of approximately 3.0 million cubic yards of material along the oceanfront, extending from the weir-jetty northward to the closure zone of Moore's Inlet, approximately 2.5 miles north. Since that time an additional 13 million cubic yards of beach fill has been used to renourish the oceanfront beach north of the accretion caused by the jetty. Sand accumulating in the inlet area and adjacent navigation channels is periodically dredged for nourishment to the north, backpassed onto Wrightsville Beach and less frequently bypassed to the south onto Masonboro Island as mitigation for the jetty system.

Following construction of the north jetty, the north end of Masonboro Island experienced rapid oceanfront erosion as the sheltered inlet shoreline rapidly migrated north, narrowing the inlet and eventually eroding the inlet shoreline on Wrightsville Beach. By the initiation of construction of the south jetty, erosion threatened the street at the south end of Wrightsville Beach. The shifting navigation channel threatened to undermine sections of the new north jetty. Those changes initiated plans to complete the other half of the originally designed twin jetties.

Construction of the south jetty in 1980 trapped sand on the northern oceanfront of Masonboro Island, reversing the rapid erosion that followed construction of the north jetty. Within the next decade, the fillet created south of the new jetty accreted over 420 feet and eventually stabilized. The fillet has stabilized at least 3000 feet of Masonboro Island shoreline immediately south of the jetty.

Construction of the south jetty simultaneously blocked the sand transport driving the migration of the northern tip of the island and navigation channel. After sand transport from the south was terminated, the remaining primary sand transport into the inlet was over the weir in the north jetty. That reversed the prior erosion on the Wrightsville Beach inlet shoreline inside the jetties. Over the decade following construction of the south jetty, the tip of the island accreted more than 1300 feet into the inlet. The spit eventually interfered with the navigation channel alignment and threatened to undermine the south jetty. In 1996 the US Army Corps of Engineers began removing the southern 400 feet of spit. The material is now regularly removed for beachfill in Wrightsville Beach or jetty mitigation on Masonboro Island.

Since construction of the second jetty, the ebb-tidal delta has enlarged, extended seaward and steepened. The emplacement of the jetties and the consequent increase in the tidal prism has increased sediment entrapment within the ebb-tidal delta and along the fillets. The twin jetties have cut off all natural bypassing across the inlet. The only bypassing is by the irregular dredging to Masonboro Island. Although several thousand feet of ocean shoreline on the north end of Masonboro Island has accreted or stabilized due to the fillet of the south jetty, the end of natural bypassing and the limited volume of dredged mitigation bypassing has accelerated erosion on much of the rest of the island.

3.5.a Masonboro Island side of Masonboro Inlet

As discussed in Section 3.4b, the Masonboro Island side of Masonboro Inlet is included in the island-wide recommended IHA for Masonboro Island. The northern tip of Masonboro Island was removed by dredging after the construction of the south jetty in 1980. The jetty now armors the entire inlet shoreline.

3.5.b Wrightsville Beach side of Masonboro Inlet

After the north jetty construction caused an initial accretion, the ocean shoreline has been relatively stable since the 1970s for more than a mile north of the structure. Prior to construction of the north jetty and beach nourishment in 1965, the NC General Assembly declared the oceanfront dunes and beach, including all sand trapped by the jetty, were state-owned. Construction of the south jetty in 1980 reversed the previous northward migration of the inlet.

Shoreline and vegetation data for Wrightsville Beach at Masonboro Inlet are shown in **Figures 61 and 64**. Applying STD $\Delta > 1$ would identify transect 21 as the alongshore IHA boundary, (**Figure 63**). However, the standard deviation between this transect and the jetty reflects persistent shoreline accretion since the jetty was emplaced in 1966 rather than rapid shoreline fluctuations associated with inlet dynamics. For this reason, and because the alongshore system has equilibrated in the time since emplacement of the north jetty in 1966, the approximate terminus point of the north inlet jetty, which coincides with transect 11, is proposed as the IHA alongshore boundary. The 30- and 90-Year Risk Lines are within the north jetty inlet shoreline (**Figure 65**). The landward boundary of the IHA extends from the end of the 90-Year Risk Line to the small concrete rip-rap on the backbarrier shoreline.

Figure 61. *Masonboro Inlet at Wrightsville Beach. Shorelines included: 1973, 1974, 1977, 1984, 1992, 1995, 1997, 1998, 2000, 2002, 2003, 2004, 2006, 2009, 2010, 2012, 2016, 2020.*

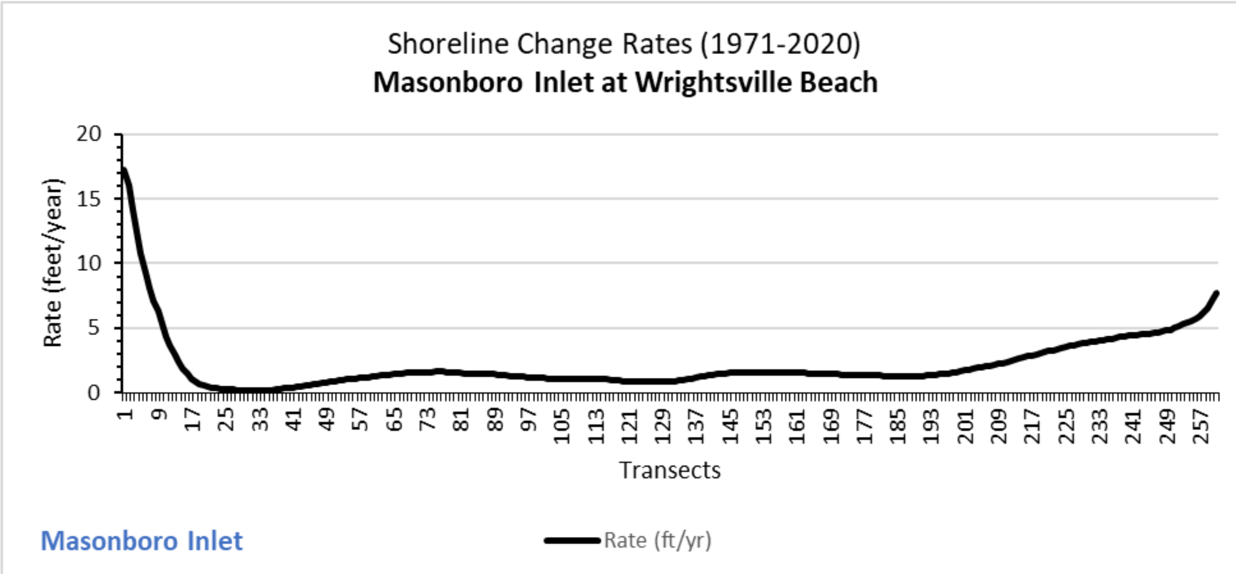

Figure 62. *Shoreline change rates (ft/yr) at Wrightsville Beach from 1970 to 2020: Negative values indicate erosion, while positive values indicate accretion.*

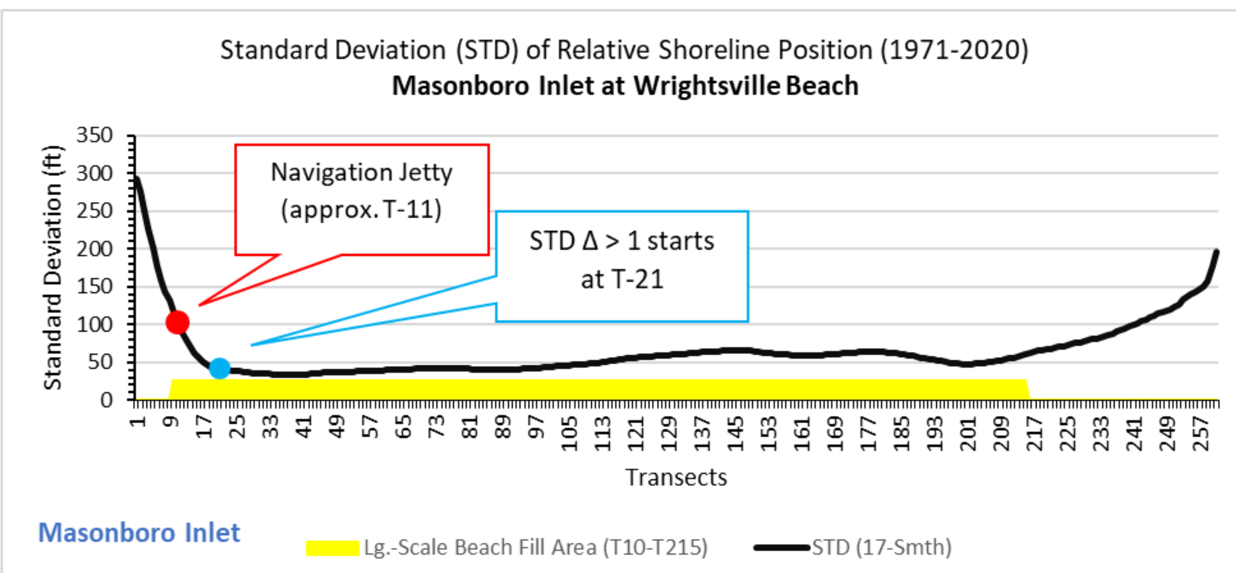

Figure 63. *Using the standard deviation of relative shoreline position data at Masonboro Inlet-Wrightsville Beach and applying the STD Δ > 1.0 threshold method, transect-21 (blue point) can be interpreted as the potential alongshore IHA boundary; however, based on navigational jetties influence on the adjacent shoreline (north side), the jetty (red point at approximately transect-11) was identified as the alongshore IHA boundary.*

Figure 64. *Masonboro Inlet at Wrightsville Beach. Vegetation Lines mapped: 1992, 1995, 1998, 2000, 2002, 2003, 2004, 2006, 2009, 2010, 2012, 2016. Vegetation line segments making up the HVL: 1992, 1998, 2000, 2002, 2003, 2004, 2009, 2010, 2020.*

Figure 65. *Masonboro Inlet at Wrightsville Beach HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

3.6 Mason Inlet

Mason Inlet is a small migrating system that opened in the early 1880s 1.8 miles northeast of its current location. The rate of inlet migration varied over decadal scales and there have been short-term reversals in the migration direction. During the period between 1974 and 1997 the inlet migrated southward 3,600 feet, at an average rate of 160 feet per year. Actual rates have ranged from 6 and 310 feet per year with the highest rates coinciding with significant shoaling of both the channel and within the backbarrier area. In 1997 the inlet threatened buildings on the north end of Wrightsville Beach, and the southern inlet shoreline was hardened with a large geotextile tube revetment, which remains in place. Infilling of sound-side channels stemmed from the migration of the inlet and the associated juxtaposition of the flood-tidal delta and Mason Creek. The near closure of Mason Creek, the primary channel connection to the ICW, led to a dramatic reduction of the tidal prism and accelerated the migration rate. Both oceanfront shorelines near the inlet also fluctuate.

In 2002, the inlet was relocated approximately 2,800 feet to the northeast on Figure Eight Island. Since that time the inlet location and feeder channels have been maintained by periodic dredging, which has maintained the increased tidal prism and slowed the natural migration rate. Easements and permits for the present inlet maintenance agreements expire in 2031.

During the period from the mid-1960s to the early 1980s, the planform of the updrift oceanfront shoreline along Figure Eight Island was concave seaward. The bulbous nature of the shoreline near the inlet reflected the positive influence of the relatively large ebb-tidal delta whose wave-sheltering effect extended approximately 5,000 feet updrift on Figure Eight Island. The overlapping ebb platform protected and frequently nourished the shoreline with the attachment of large swash bars. During the 1970s, progradation extended and widened the beach by 300 feet. As migration continued, the zone of bar attachment also shifted southward. The former shoreline reaches that had accreted began to rapidly erode as the barrier lengthened and the planform changed accordingly. The erosion hot-spot is currently located approximately 3,500 feet northeast of the inlet where beach nourishment and sandbag revetments have been placed.

3.6.a Wrightsville Beach side of Mason Inlet

The shoreline and vegetation data for the Wrightsville Beach side of Mason Inlet are shown in **Figures 66 and 69**. The analysis was conducted under two scenarios: (1) the full dataset from 1970–2020, and (2) data from 2003–2020, focusing solely on post-relocation conditions following the inlet's 2002 relocation. When considering the full dataset, while the inlet shoreline consistently migrated toward Wrightsville Beach, the oceanfront shoreline near Shell Island Resort remained generally stable and accretional due to pre-relocation inlet influences. However, the post-2002 analysis highlights significant erosion as the oceanfront shoreline adjusted to the relocated inlet's stabilized position. Consequently, post-2002 data were utilized to delineate the alongshore IHA boundary, while the 1970–2020 data informed long-term erosion rate calculations. These trends are further shaped by routine beach nourishment and maintenance dredging activities at Mason Inlet.

The HVL within the 2024 IHA includes segments of 1971, 1987, 2002, 2003, 2006, and 2010 vegetation lines (**Figure 69**). Applying STD $\Delta > 1$ identifies the alongshore IHA boundary at transect 249 (**Figure 68**). The landward IHA boundary was defined using the 90-Year Risk Line starting at transect 249 and moving in the direction of the inlet until reaching the last 90-Year Risk Line point, then the boundary follows the tidal creek until reaching the inlet (**Figure 70**).

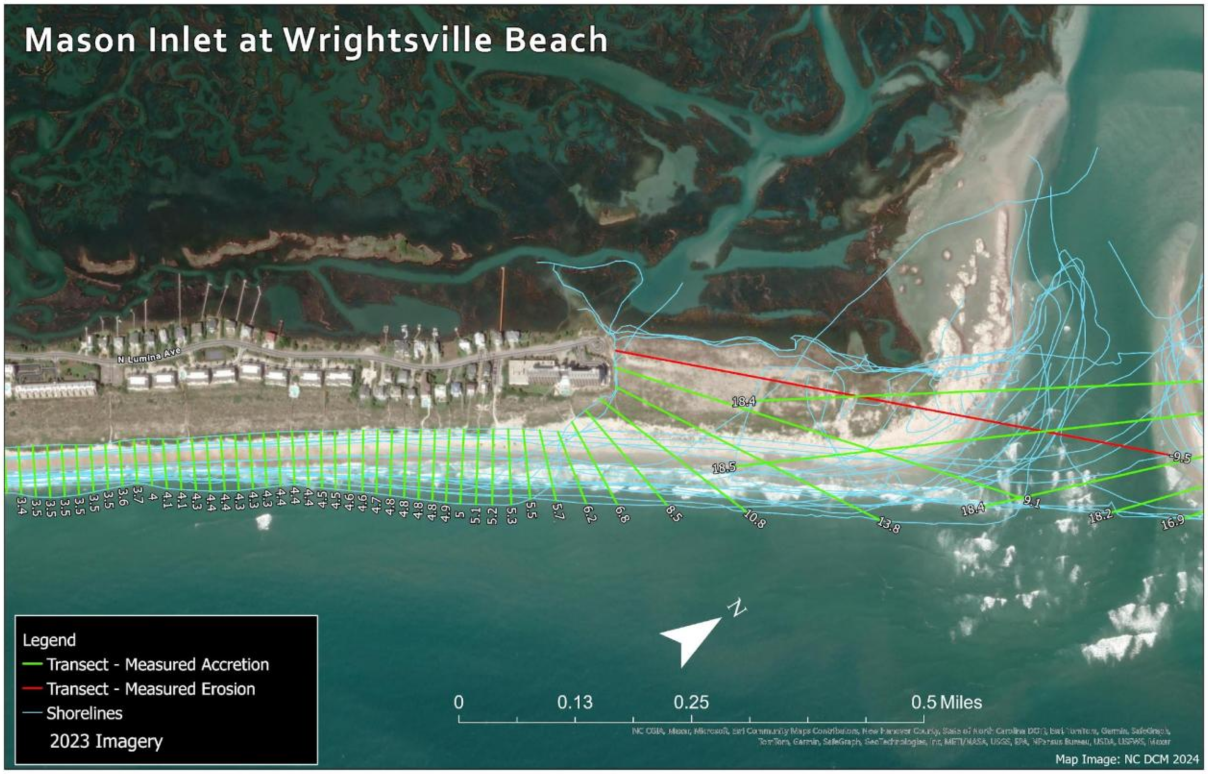

Figure 66. *Mason Inlet at Wrightsville Beach. Shorelines included: 1971, 1973, 1977, 1987, 1992, 1997, 1998, 2002, 2003, 2004, 2006, 2009, 2010, 2012, 2016, 2019, 2020.*

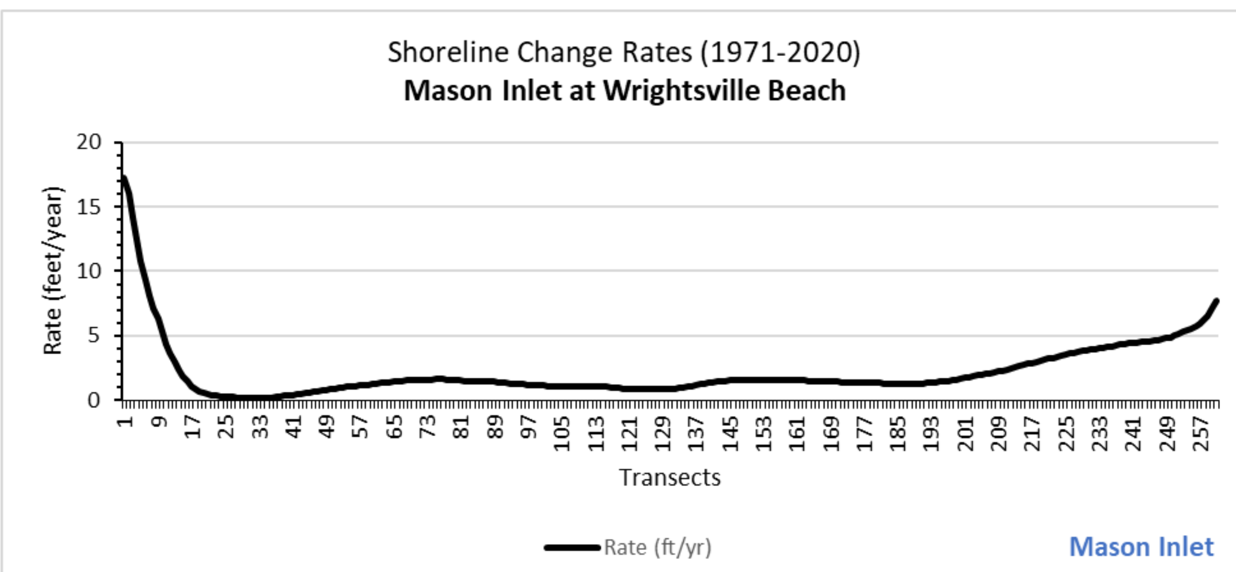

Figure 67. *Shoreline change rates (ft/yr) at Wrightsville Beach from 1971 to 2020: Negative values indicate erosion, while positive values indicate accretion.*

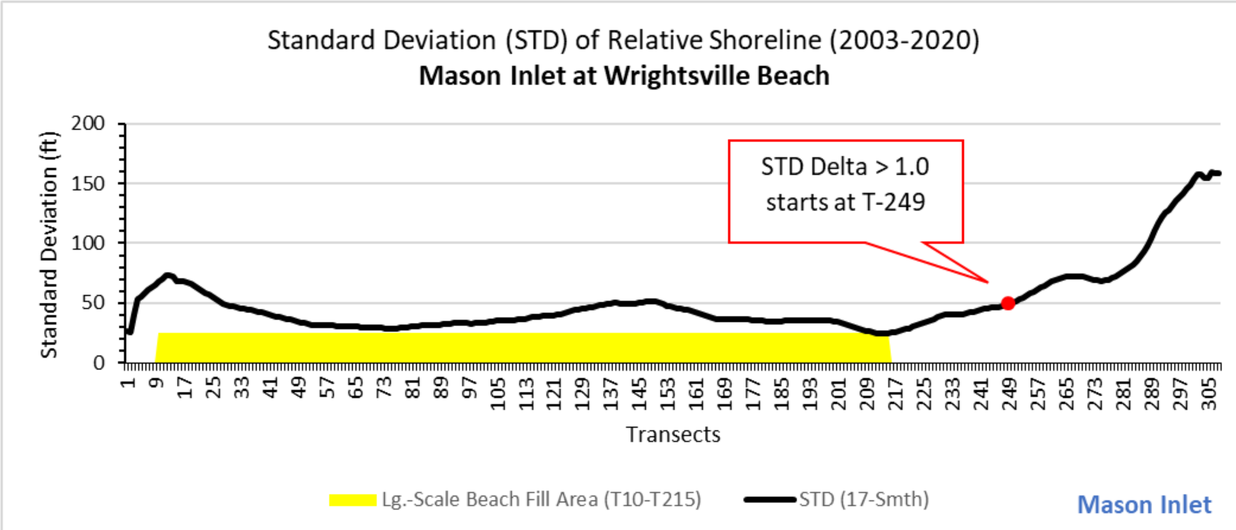

Figure 68. *Using the standard deviation of relative shoreline position data (2003-2020) at Mason Inlet-Wrightsville Beach and applying the STD Δ > 1.0 threshold method, transect-249 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

Figure 69. *Mason Inlet at Wrightsville Beach. Vegetation Lines mapped: 1971, 1977, 1987, 1992, 1998, 2002, 2003, 2004, 2006, 2009, 2010, 2012, 2016, 2019, 2020. Vegetation line segments making up the HVL: 1971, 1987, 2002, 2003, 2006, and 2010.*

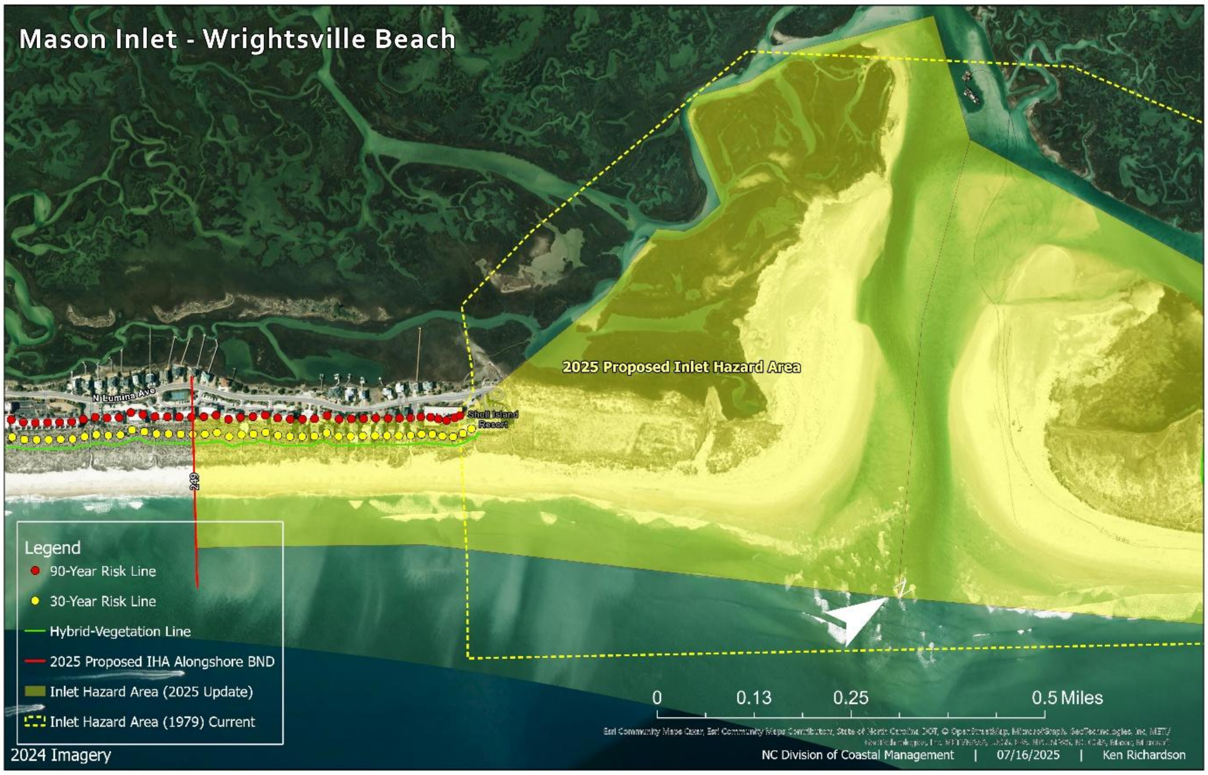

Figure 70. *Mason Inlet at Wrightsville Beach HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

3.6.b Figure Eight Island side of Mason Inlet

Like the Wrightsville Beach side of Mason Inlet, post-2002 data were used to identify the alongshore IHA boundary, while all data (1970-2020) were used to calculate the long-term shoreline change and calculate 30 and 90-Year Risk Lines. Shoreline and vegetation data for the Figure Eight Island side of Mason Inlet are presented in **Figures 80 and 83**. Analysis of shoreline data shows long-term accretion from 1970 to 2020 (**Figures 80 and 81**) with measured erosion between transects 14 and 27. These findings are influenced by routine beach nourishment and maintenance dredging activities at Mason Inlet. As with the Wrightsville Beach side of the inlet, the data used in the analysis reflects the ongoing inlet maintenance and nourishment projects. If these management actions change, the inlet processes and therefore IHA boundaries will change. The HVL is based on the 1971, 1977, 1998, 2002, 2004 and 2012 vegetation lines (**Figure 83**). Applying STD Δ > 1 identifies the alongshore IHA boundary at transect 42 (**Figure 82**). The landward IHA boundary follows the 90-Year Risk Line, starting at transect 42 and continuing towards the inlet until the last 90-Year Risk Line point, where it is extended across the marsh to meet the tidal creek (**Figure 84**).

Figure 80. Mason Inlet at Figure Eight Island. Shorelines included in the analysis: 1971, 1973, 1977, 1987, 1992, 1997, 1998, 2002, 2003, 2004, 2006, 2009, 2010, 2012, 2016.

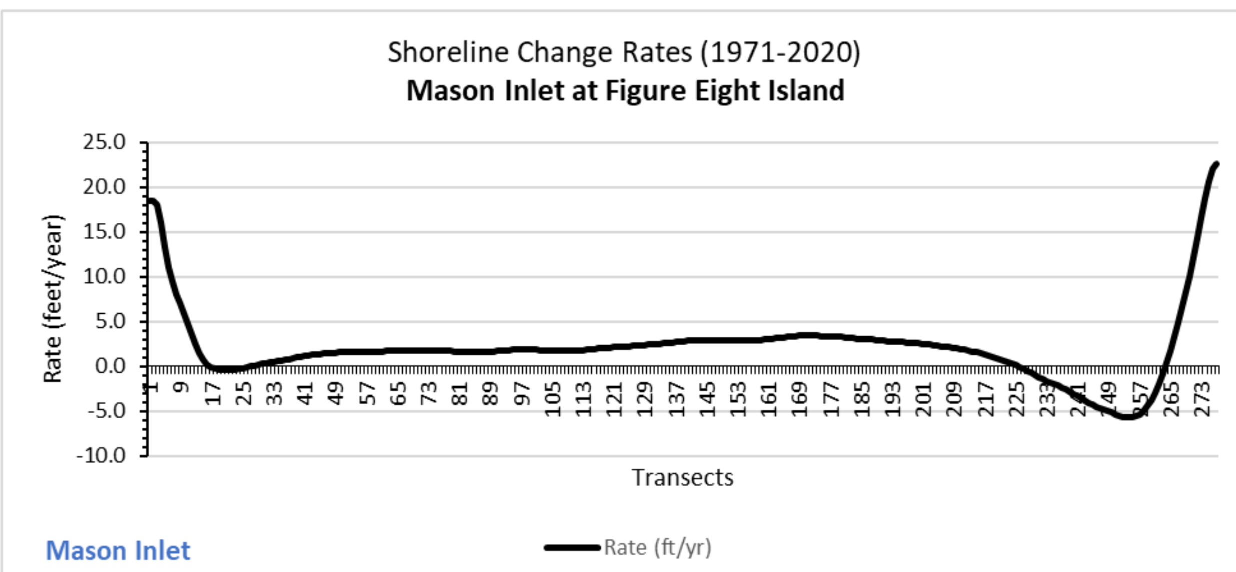

Figure 81. Shoreline rates (ft/yr) at Figure Eight from 1971 to 2020: Negative values indicate erosion, while positive values indicate accretion.

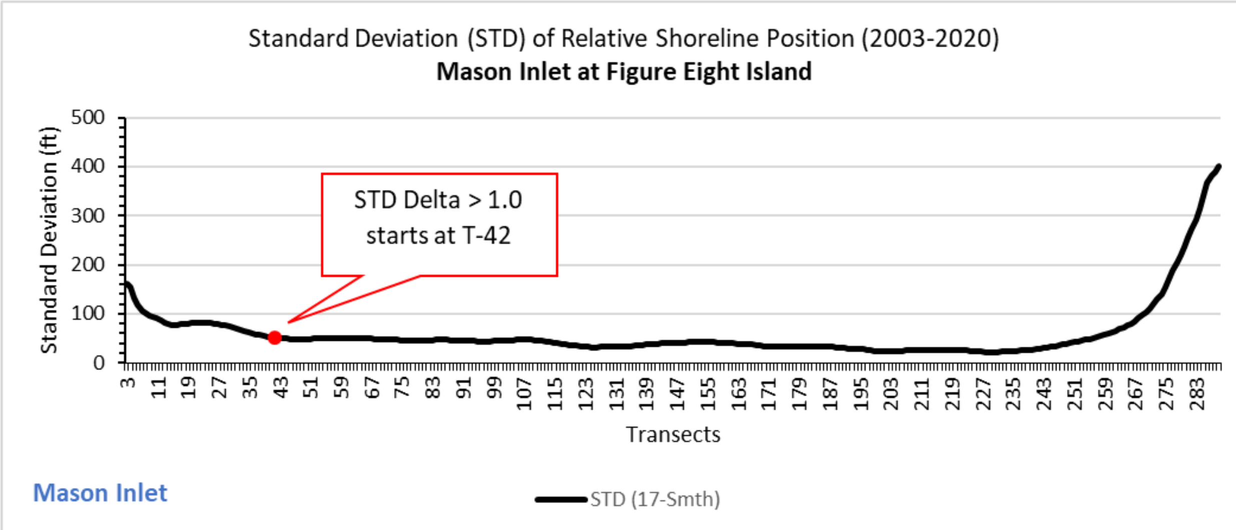

Figure 82. *Using the standard deviation of relative shoreline position data (2003-2020) at Tubbs Inlet-Ocean Isle and applying the STD Δ > 1.0 threshold method, transect 42 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

Figure 83. *Mason Inlet at Figure Eight Island. Vegetation Lines mapped: 1971, 1977, 1987, 1992, 1998, 2002, 2003, 2004, 2006, 2009, 2010, 2012, 2016, 2020. Vegetation line segment(s) making up the Hybrid-Vegetation Line: 1971, 1977, 1998, 2002, 2004 and 2012.*

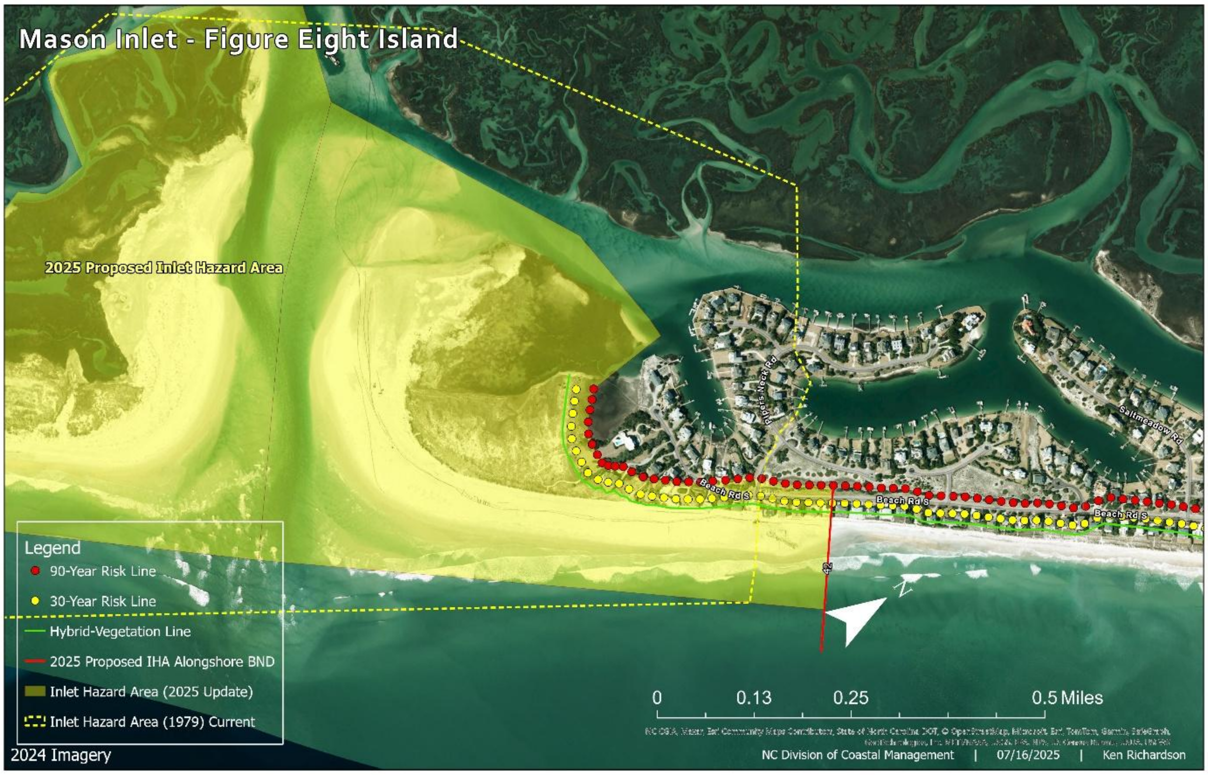

Figure 84. *Map of Mason Inlet at Figure Eight Island HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

3.7 Rich Inlet

Rich Inlet drains a bar-built estuary and adjacent Futch Creek. Both oceanfront shorelines near the inlet fluctuate widely. The inlet has been identified on charts dating from the 1700s. Its origin is related to an incised paleo-channel. The inlet has been relatively stable during the past 80 years as determined by the length of its migration pathway (1,500 feet) when compared to the inlet's width (1,800-4,000 feet). Migration rates and direction have been highly variable. The inlet's variability is directly related to the continual and often rapid (NE or SW) reorientation and repositioning of the offshore ebb channel. As the ebb channel deflects across the offshore shoal, the ebb-tidal delta's position, shape and areal extent are continually changing. Channel deflection episodes have caused the adjacent barrier shorelines to erode or prograde, as the wave-sheltering effect of the ebb-tidal delta has decreased or increased with the size and shape of the ebb-tidal delta.

In late 1994 a major ebb-tidal breaching event occurred that led to a 1,200 feet northeasterly repositioning of the inlet and a 3,800 feet northeasterly movement of the bar channel. The dramatic shift altered the "breakwater effect" along Figure Eight Island that was previously afforded by the ebb-tidal delta during the previous 50 years. Additionally, the zone of swash bar attachment shifted to the northeast.

The chronic oceanfront erosion that ensued (1997-2012) along the northern 3,000 feet of the Figure Eight Island shoreline ranged from 100 to 580 feet and averaged approximately 280 feet. Due to the poor performance of the nourishment efforts used to mitigate the erosion, an 1,800 feet-long reach was eventually armored with sandbags. In October 2004, both the throat and bar channel segments shifted to the southwest and by June 2012, the throat segment migrated 950 feet at an average rate of 120 feet per year. By contrast, the outer bar channel segment shifted southwest 2,700 feet at a rate of 330 feet per year between 2011 and 2012; the highly asymmetric ebb-tidal delta provided a significant wave-sheltering effect that promoted shoreline progradation that averaged 90 feet.

Additionally, the 2012 breaching event that repositioned the ebb channel 2,530 feet to the northeast provided the downdrift bypassing of a large volume of sand. This bypassing caused large swash bars to attach to Figure Eight Island by 2015, which in turn caused the ocean shoreline to prograde an average of 190 feet. Since 2012, the ebb channel has deflected 940 feet to the northeast and reconfigured the ebb-tidal delta. By 2016, the ebb channel within the throat migrated 820 feet back to the southwest, which led to the erosion of 280 feet of shoreline along the Figure Eight Island side of Rich's Inlet.

3.7.a Figure Eight Island at Rich

The shoreline and vegetation data for Figure Eight Island at Rich Inlet are shown in **Figures 85 and 88**. Analysis of shoreline data from 1971 to 2020 shows long-term erosion along the oceanfront from transect 225 to transect 263 (average is -3.3, mean is -3.4, maximum is -5.7 feet/year); while accretion was measured within the inlet as a result of regular spit formation (**Figures 85 and 86**). The HVL for the area within the IHA is comprised of segments from 1984, 1998, 2002, 2006, 2009, 2010, 2012, 2016 vegetation lines (**Figure 88**). Applying STD Δ > 1 identifies transect 225 as the IHA alongshore boundary (**Figure 87**). The 90-Year Risk line is recommended as the landward limit of the IHA then extending to intersect Beach Road. (**Figure 89**).

Figure 85. *Rich Inlet at Figure Eight Island. Shorelines included: 1971, 1973, 1977, 1980, 1984, 1992, 1997, 1998, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2019, 2020.*

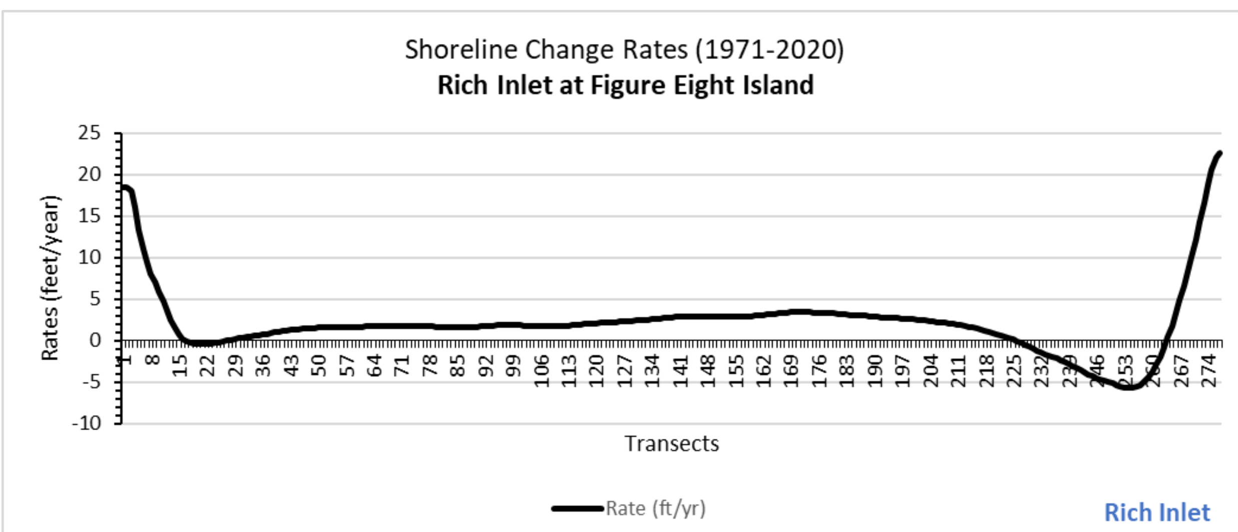

Figure 86. *Shoreline change rates (ft/yr) at Figure Eight from 1971 to 2020: Negative values indicate erosion, while positive values indicate accretion.*

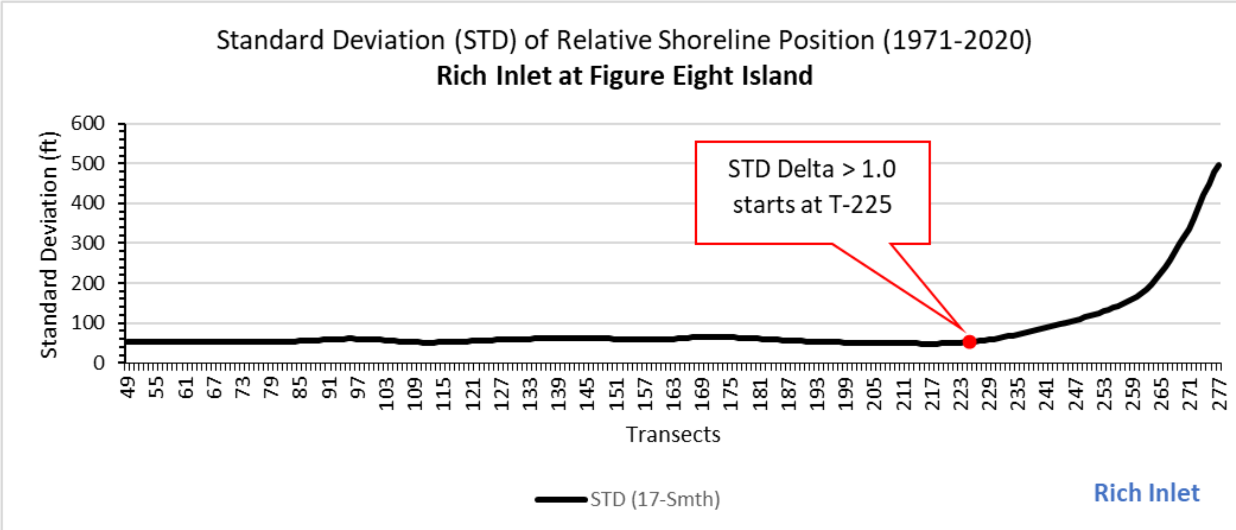

Figure 87. *Using the standard deviation of relative shoreline position data at Tubbs Inlet-Ocean Isle and applying the STD Δ > 1.0 threshold method, transect 225 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet.*

Figure 88. *Rich Inlet at Figure Eight Island. Vegetation Lines mapped: 1971, 1977, 1980, 1984, 1992, 1998, 2002, 2003, 2004, 2006, 2009, 2010, 2012, 2016, 2020. Vegetation line segments making up the HVL: 1984, 1998, 2002, 2006, 2009, 2010, 2012, 2016.*

Figure 89. *Rich Inlet at Figure Eight Island HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

3.7.b Lea-Hutaff Island side of Rich Inlet

The Lea and Hutaff Islands (also known as Coke and No-Name Islands) were joined in 1997 by the closure of Old Topsail Inlet. The resulting Lea-Hutaff Island is strongly influenced by the adjacent Rich and New Topsail Inlets. The shoreline and vegetation data are shown in **Figures 90 and 93**. Similar to Masonboro Island, the standard deviation of relative shoreline position and erosion rates are high for most of the island (**Figures 90, 91 and 92**); standard deviation average is 167, median is 150, high is 502 and lowest is 110 feet; erosion rate average is -8.4, median is -8.6, high is -17.6 and lowest is -2.6 feet/year. Based on their narrow and low-lying topography, lack of dune ridges and regular and extensive overwash (**Figure 94**), the Panel recommends that the boundary of the IHA include the entire island (**Figure 95**).

Figure 90. *Shorelines included in the analysis: 1971, 1973, 1974, 1976, 1980, 1984, 1992, 1995, 1997, 1998, 2000, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2019, 2020, 2021.*

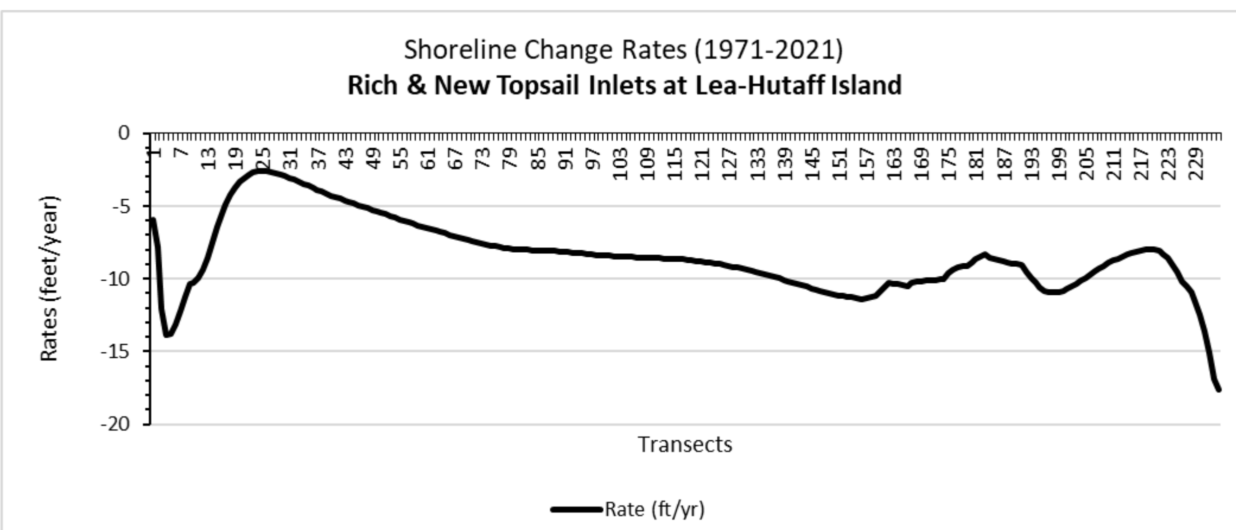

Figure 91. *Shoreline change rates (ft/yr) at Lea-Hutaff Island from 1971 to 2020: Negative values indicate erosion, while positive values indicate accretion.*

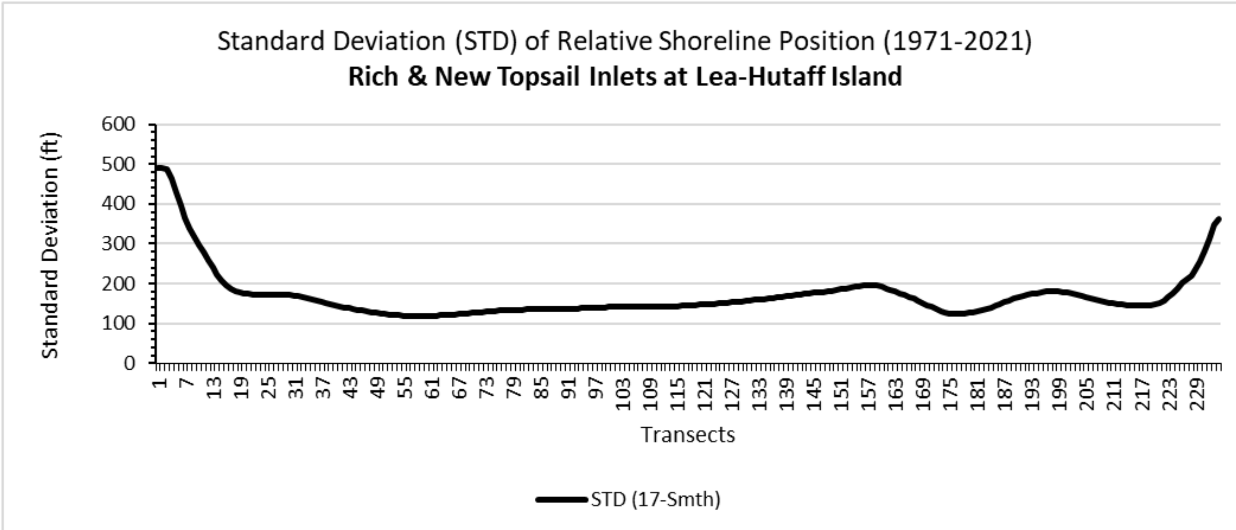

Figure 92. *IHA alongshore boundaries were not identified using standard deviation of relative shoreline position data at Rich & New Topsail Inlets-Lea-Hutaff Island due to combined inlet influences on the island.*

Figure 93. *Rich and New Topsail Inlets at Lea-Hutaff Island. Vegetation Lines mapped: 1971, 1973, 1974, 1976, 1980, 1984, 1992, 1995, 1997, 1998, 2000, 2004, 2006, 2008, 2009, 2010, 2012, 2016, 2019, 2020, 2021. Vegetation line segments making up the HVL: 1998, 2000, 2004, 2010, 2012, 2016, 2020, 2021.*

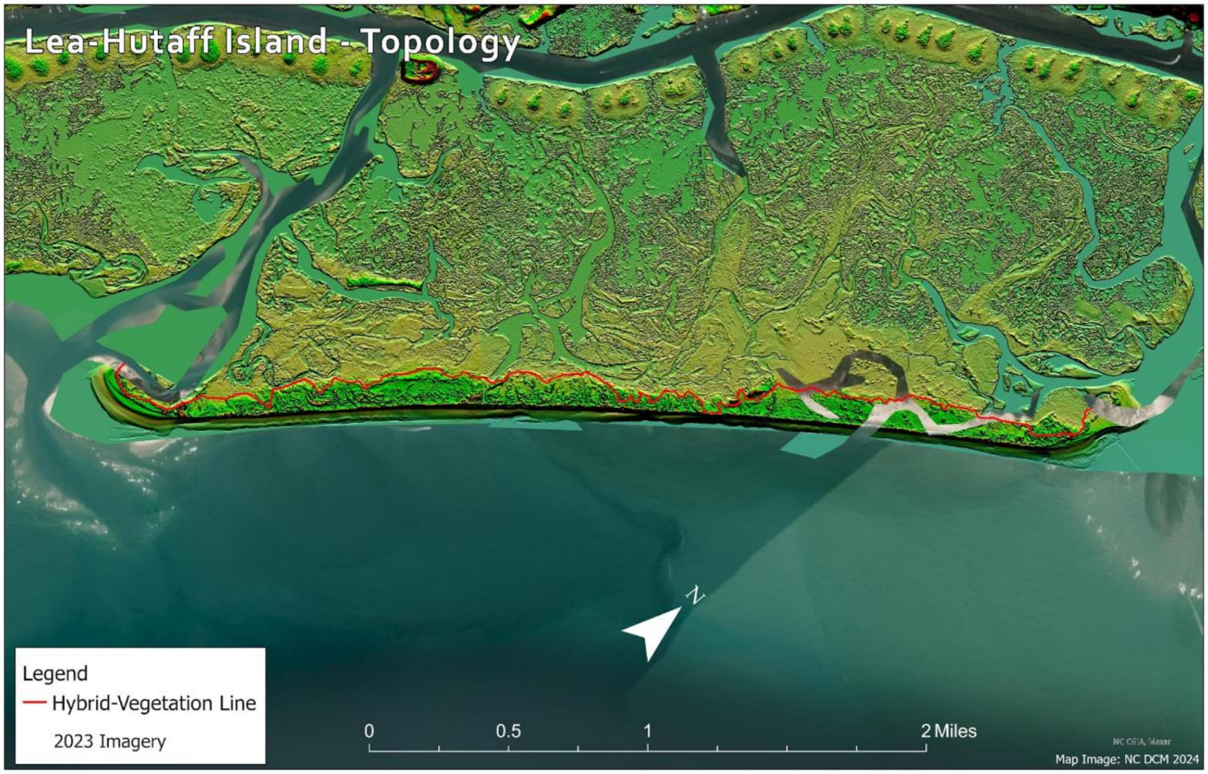

Figure 94. *This map image of Lea-Hutaff Island highlights the existing topography in relation to the HVL. The island's low elevation makes it highly vulnerable to overwash during storm events, which has pushed the vegetation lines to the island's estuarine shoreline or close to it.*

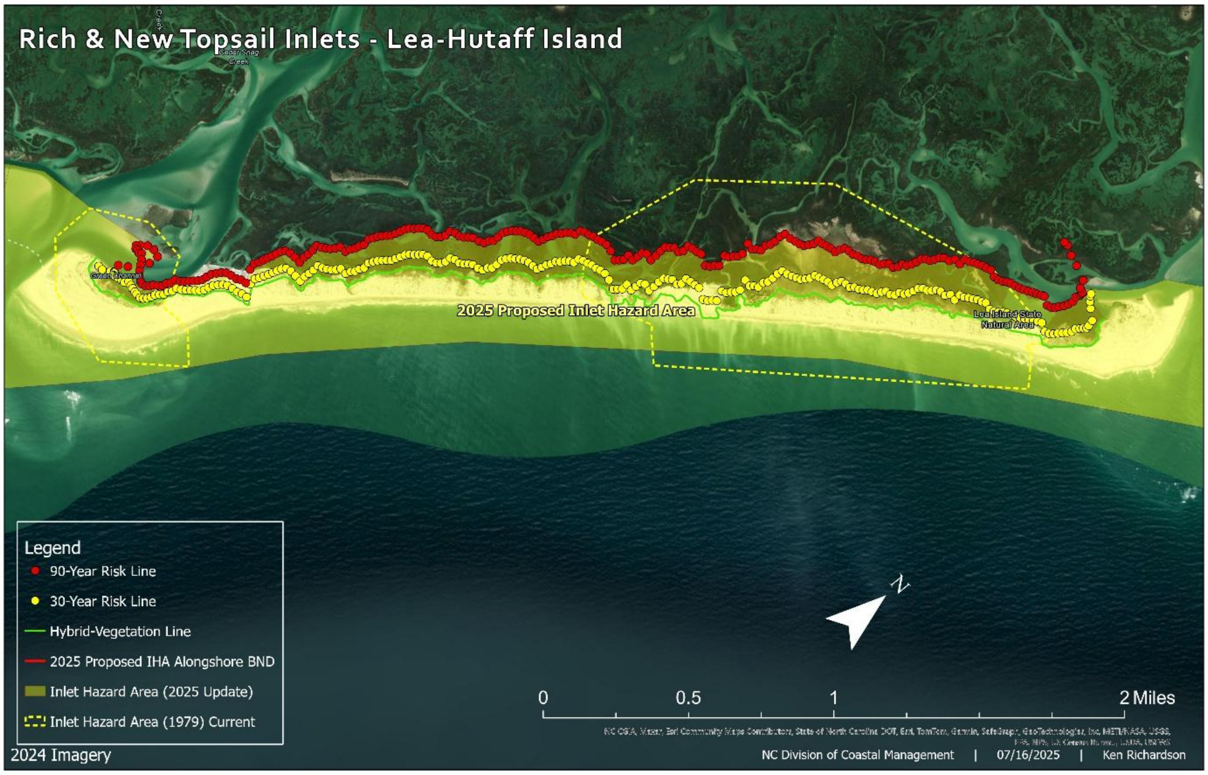

Figure 95. *Rich and New Topsail Inlets at Lea-Hutaff Island HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

3.8 New Topsail Inlet

New Topsail Inlet is historically the most persistently migrating inlet in North Carolina, having migrated 6.2 miles to the southwest. The earliest land grants record the existence of New Topsail Inlet as early as 1726. Between 1938 and 2009, the ebb channel within the throat migrated 6,300 feet to the southwest at an average rate of 90 feet per year. Migration direction and rates were highly variable. More recently, between 2010 and 2014 the channel reversed its migration direction and shifted 590 feet toward Topsail Beach at an average rate of 150 feet per year. By August 2016, the ebb channel had been repositioned an additional 1,000 feet to the northeast during a breaching event in the offshore channel.

The inlet's minimum width has fluctuated considerably from 1,000 feet (1984) to 2,300 feet (1995). The mean inlet minimum width for the past 70 years was 1,600 feet. It typically narrows due to spit growth on both shoulders, which often marks a shift in the migration direction. Cyclical deflection and reorientation of the offshore ebb channel has occurred numerous times since

1938. Reorientation of the channel is due to storm-related ebb delta breaching events, which result in sand bypassing to Topsail Beach.

The inlet-related variables that control shoreline change patterns are the migration direction and rate, the channel alignment across the offshore ebb platform and the attendant shape of the ebb tidal delta. The planform of Topsail Beach curves seaward near the inlet, due to the attachment of swash bars that perpetuate this maximum accretion zone as the inlet migrates to the southwest. During the period between 1949 and 1962, the inlet migrated southward 180 feet, at a rate of 14 feet per year. As a result, the zone of maximum accretion (swash bar attachments) incrementally shifted toward the inlet approximately 3,500 feet. As migration occurred, the planform of the trailing shoreline was altered as erosion commenced along the former zone of maximum progradation.

3.8.a Lea-Hutaff Island side of New Topsail Inlet

As discussed in Section 3.7.b above, this area is included in the island-wide proposed IHA for Lea-Hutaff Island (**Figure 95**).

3.8.b Topsail Beach side of New Topsail Inlet

The shoreline and vegetation data for Topsail Beach at New Topsail Inlet are shown in **Figures 96 and 99**. New Topsail Inlet's rapid southward migration reduces erosion risks on the north side of the inlet. Since a migration reversal is unlikely, in such cases it is recommended to limit the inlet analysis to the most recent 30 years. For the Topsail Beach side of New Topsail Inlet, the computation of the HVL used the full record (1971-2021) on the oceanfront but was limited to an approximate 30-year data record (1991-2016) within the inlet because of the rapid migration (**Figure 99**). Due to erosion caused by Hurricanes Bertha and Fran (1996), the inlet HVL is defined primarily by the year 2000 vegetation line (Figure 226). It is recommended that this 30-year adjustment should be reevaluated during each IHA update. If the inlet continues to migrate, the IHA is expected to move south with the inlet.

Applying STD $\Delta > 1$ identifies the alongshore IHA boundary at transect 33 (**Figure 98**). The landward IHA boundary follows the 90-Year Risk Line, starting at transect 33 and continuing towards the inlet until the last 90-Year Risk Line point, where it is extended to meet the Topsail Sound (**Figure 100**).

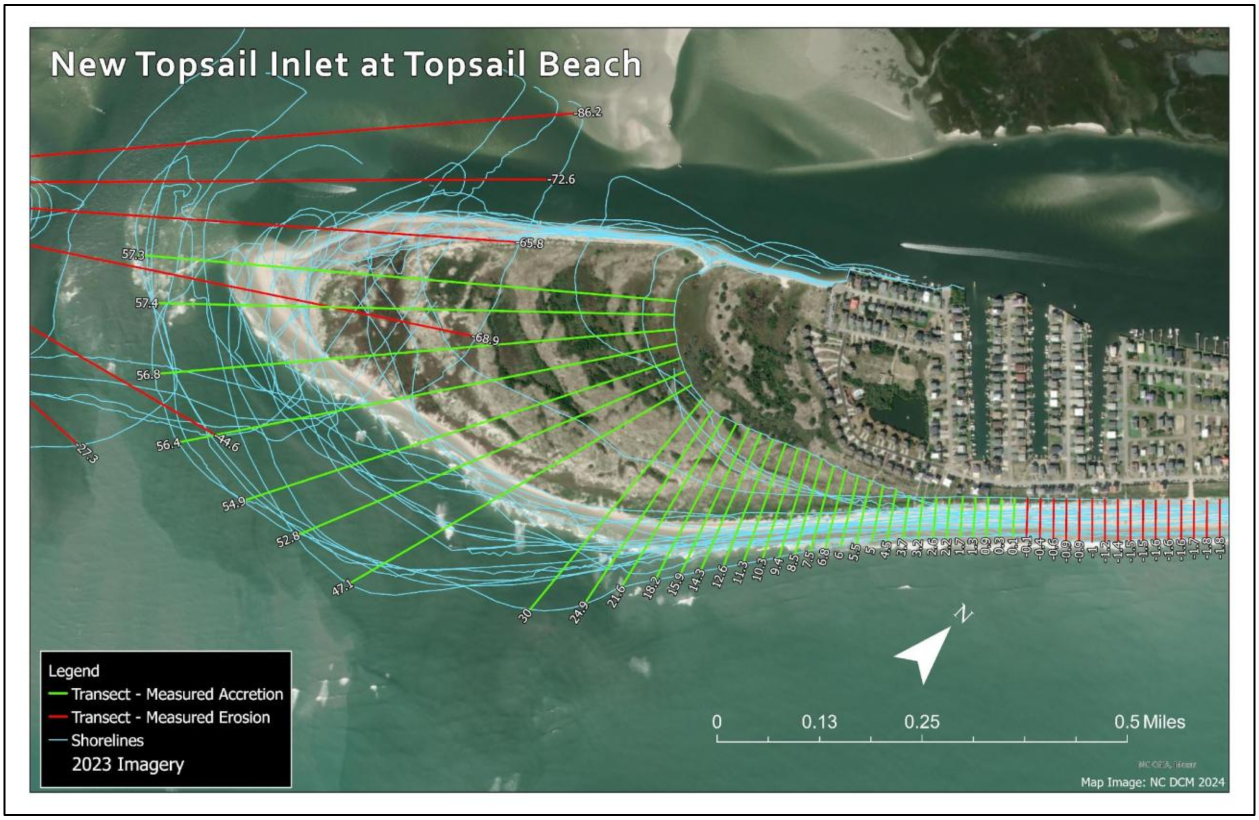

Figure 96. *New Topsail Inlet at Topsail Beach Shorelines included: 1971, 1973, 1974, 1976, 1984, 1992, 1995, 1997, 1998, 2000, 2003, 2004, 2006, 2008, 2009, 2010, 2011, 2012, 2016, 2019, 2020, 2021.*

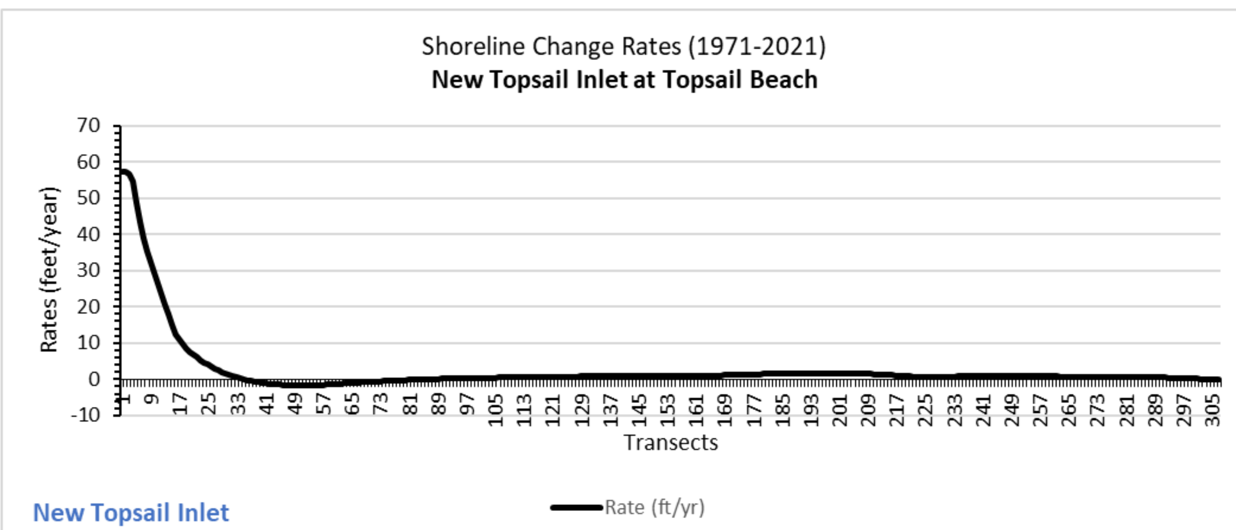

Figure 97. *Shoreline change rates (ft/yr) at Topsail Beach from 1971 to 2021: Negative values indicate erosion, while positive values indicate accretion.*

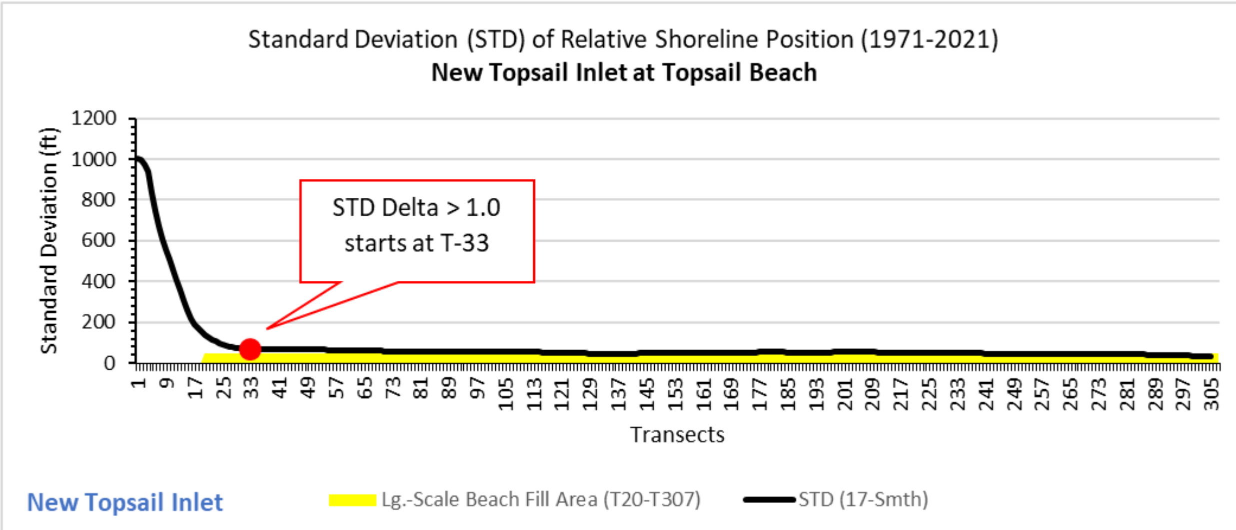

Figure 98. *Using the standard deviation of relative shoreline position data at New Topsail Inlet-Topsail Beach and applying the STD Δ > 1.0 threshold method, transect 33 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

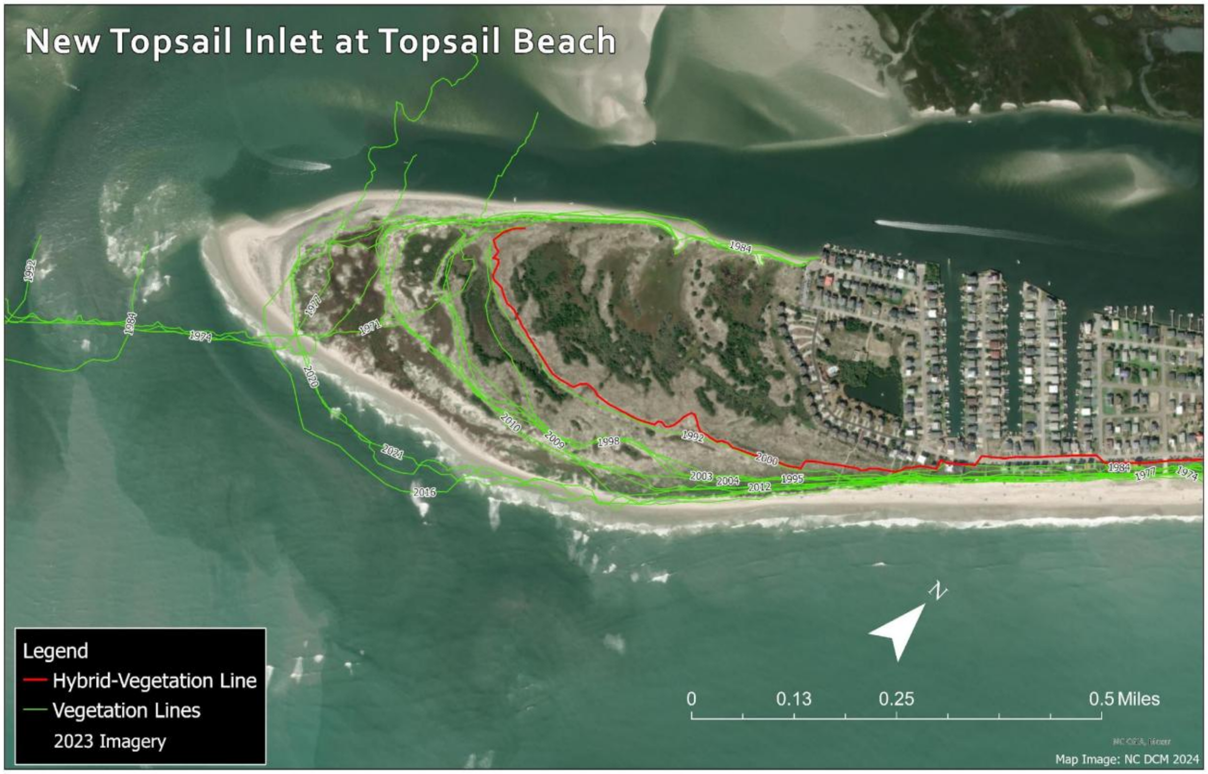

Figure 99. *New Topsail Inlet at Topsail Beach. Vegetation Lines mapped: 1971, 1974, 1977, 1984, 1992, 1995, 1997, 1998, 2000, 2003, 2004, 2008, 2009, 2010, 2011, 2012, 2016, 2019, 2020, 2021. To account for the inlet's rapid migration, the HVL within the inlet was based on a ~30-year period (1991-2021); all vegetation lines were considered on the oceanfront.*

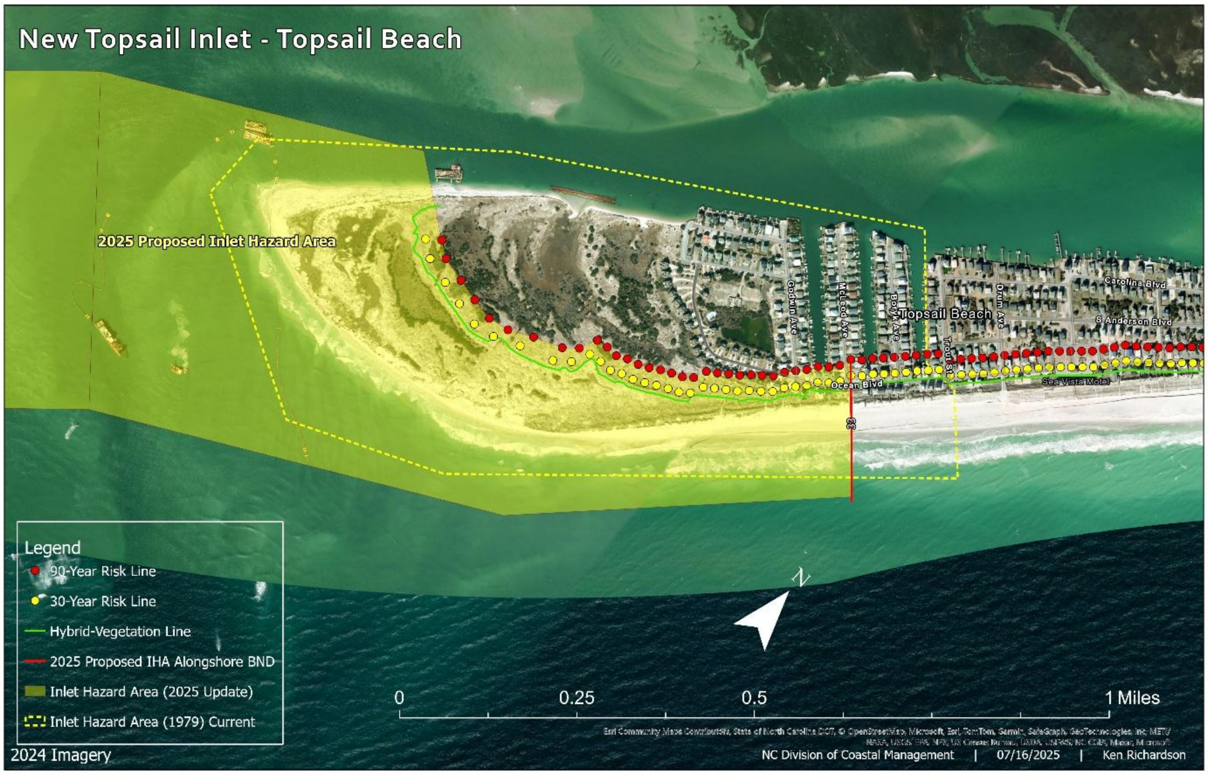

Figure 100. *New Topsail Inlet at Topsail Beach: Updated IHA boundary in relation to transect-33 (alongshore IHA boundary), HVL, 30- and 90-Year Risk Lines, and current (1979) IHA boundary.*

3.9 New River Inlet

New River Inlet is a migrating inlet that drains New River and the adjacent estuaries. Its origin is related to the location of the incised paleo-channel of New River. Although navigation channel improvements within the marsh occurred between 1885-1940, the inlet was basically unmodified when major system-wide modifications began in 1940. The US Army Corps of Engineers excavated a channel, 6-foot depth by 90 feet wide extending 2.3 miles from the IICW to the inlet gorge. Concurrently the ebb channel was relocated approximately 1,700 feet to the northeast of its 1938 position. The new hydraulic connections substantially increased the tidal prism and the retention capacity of the ebb-tidal delta. The inlet is an authorized Federal shallow-draft navigation channel which, along with the access channel, has been periodically maintained since 1963. Side-cast dredging of the bar channel began in 1964.

Between 1945 and 1962, the inlet migrated 490 feet to the southwest at an average rate of 29 feet per year. From 1962 to 1974, the inlet shifted 530 feet southwest at an average rate of approximately 41 feet per year. During the following period (1974-1990) the inlet migrated 120 feet southward at approximately 7 feet per year. During this period, the orientation of the outer bar channel caused the ebb-tidal delta to be offset to the southwest. During this period the North Topsail Beach oceanfront prograded an average of 180 feet. However, the inlet configuration changed as the outer bar channel shifted to an ESE-SE alignment. As a result, the ebb-tidal delta shifted toward Onslow Beach and the former accretion zone began to erode at rapid rates. During the past 25 years, chronic erosion has been the norm along the North Topsail Beach shoreline while the inlet has migrated southward 140 feet, at a rate of approximately 9 feet per year. Sandbag revetments now armor more than 3,000 feet of the developed shoreline near and on the inlet.

In an effort to mitigate the erosion along the oceanfront shoreline, the ebb channel was realigned by dredging in 2013 to a near shore-normal alignment in order to cause a reconfiguration of the ebb-tidal delta and to restore the breakwater effect it once afforded end of North Topsail Beach in the 1980's. Beach nourishment was placed on the shoreline at that time but was eroded rapidly near the inlet.

Only the North Topsail Beach side of New River Inlet is considered here as the Onslow Beach side of the inlet is owned and operated by the US Marine Corps Base, Camp Lejeune.

3.9.a North Topsail Beach side of New River Inlet

Shoreline and vegetation data for the North Topsail Beach side of New River Inlet are presented in **Figures 101 and 104**. Analysis of shoreline data between 1971 and 2020 show a trend of long-term erosion, with a median of -3.6, average of -4.3, and maximum of -16.1 feet/year (**Figures 101 and 102**); and it is expected that without sandbag structures adjacent to property along New River Inlet Road, erosion rates would be higher. The HVL is a composite of 1971, 1974, 1998, 2016, 2020, 2021 vegetation lines (**Figure 104**). Applying STD $\Delta > 1$ identifies the alongshore IHA boundary at transect 1353 (**Figure 103**). The landward IHA boundary follows the 90-Year Risk Line, starting at transect 1353 and continuing towards the inlet until the last 90-Year Risk Line point, where it is extended across the marsh and tidal creeks to intersect New River Inlet (**Figure 104**).

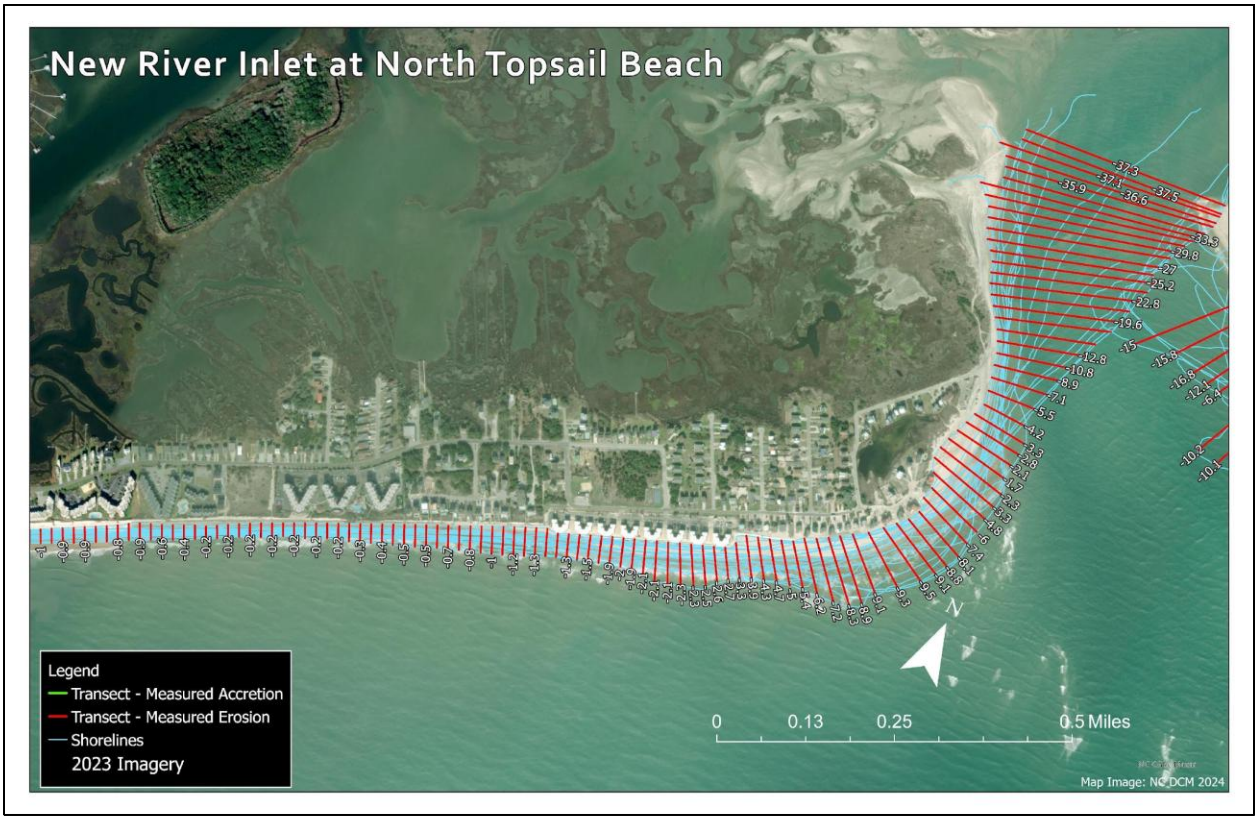

Figure 101. *New River Inlet at North Topsail Beach. Shorelines included: 1971, 1973, 1974, 1977, 1984, 1992, 1995, 1997, 1998, 2000, 2003, 2004, 2006, 2009, 2010, 2012, 2016, 2019, 2020, 2021.*

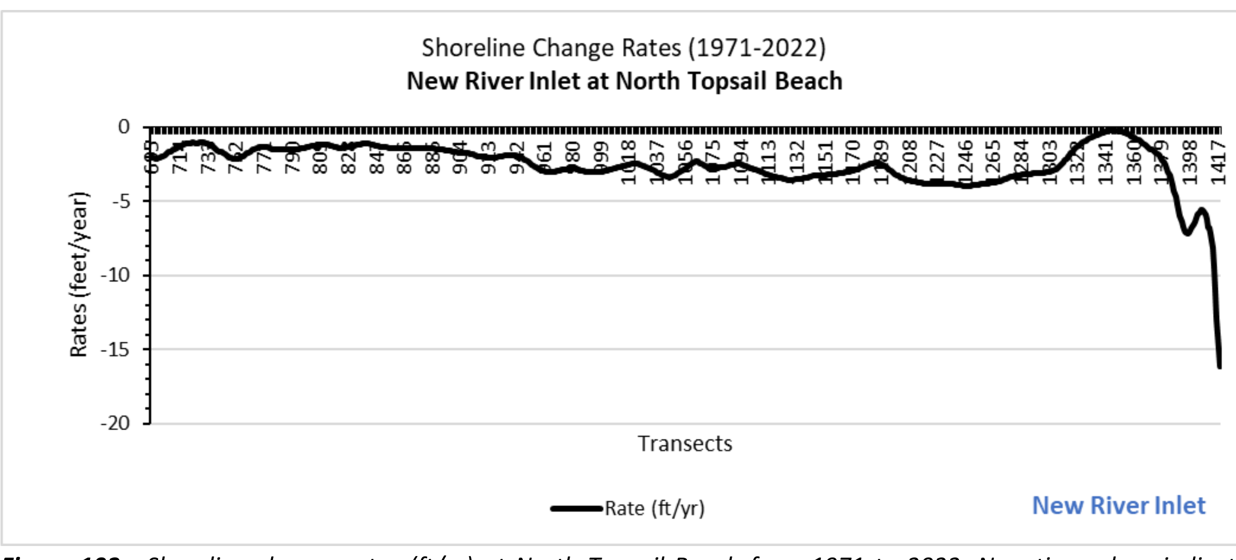

Figure 102. *Shoreline change rates (ft/yr) at North Topsail Beach from 1971 to 2022: Negative values indicate erosion, while positive values indicate accretion.*

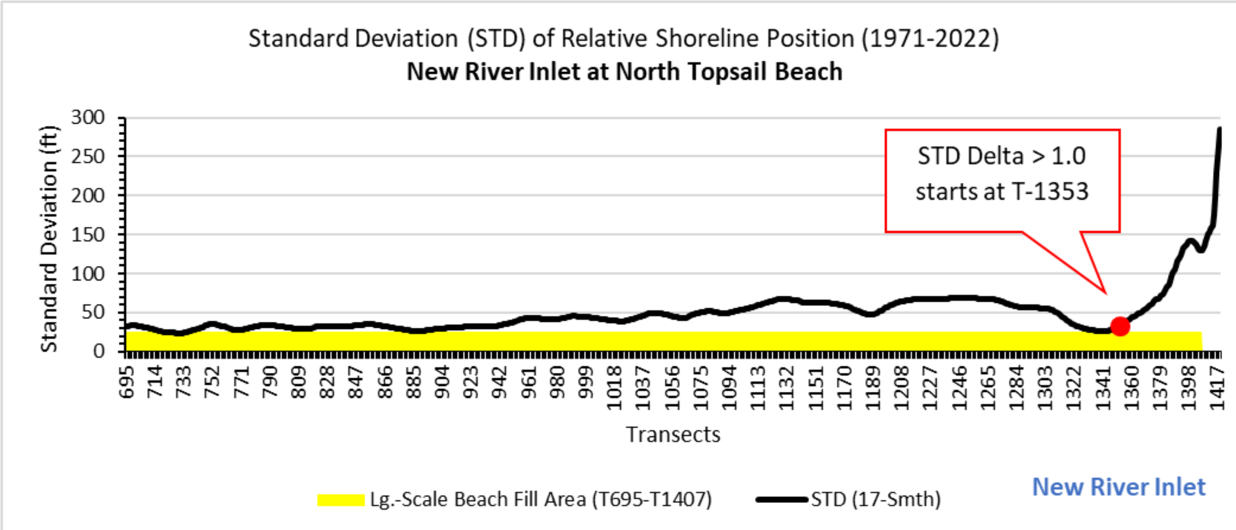

Figure 103. *Using the standard deviation of relative shoreline position data at New River Inlet-North Topsail Beach and applying the STD Δ > 1.0 threshold method, transect 1353 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

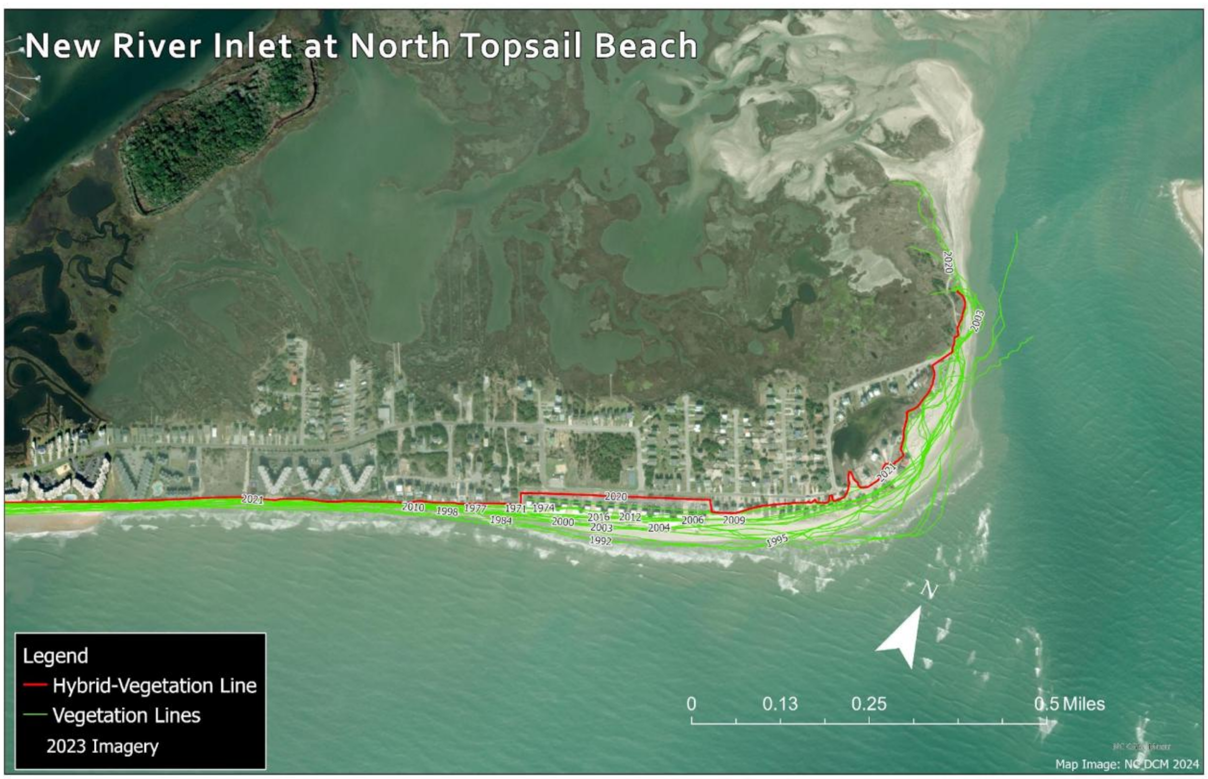

Figure 104. *New River Inlet at North Topsail Beach. Vegetation Lines mapped: 1971, 1974, 1977, 1984, 1992, 1995, 1998, 2000, 2003, 2004, 2006, 2009, 2010, 2012, 2016, 2019, 2020, 2021 and; vegetation line composite segments making up the HVL: 1971, 1974, 1998, 2016, 2020, 2021.*

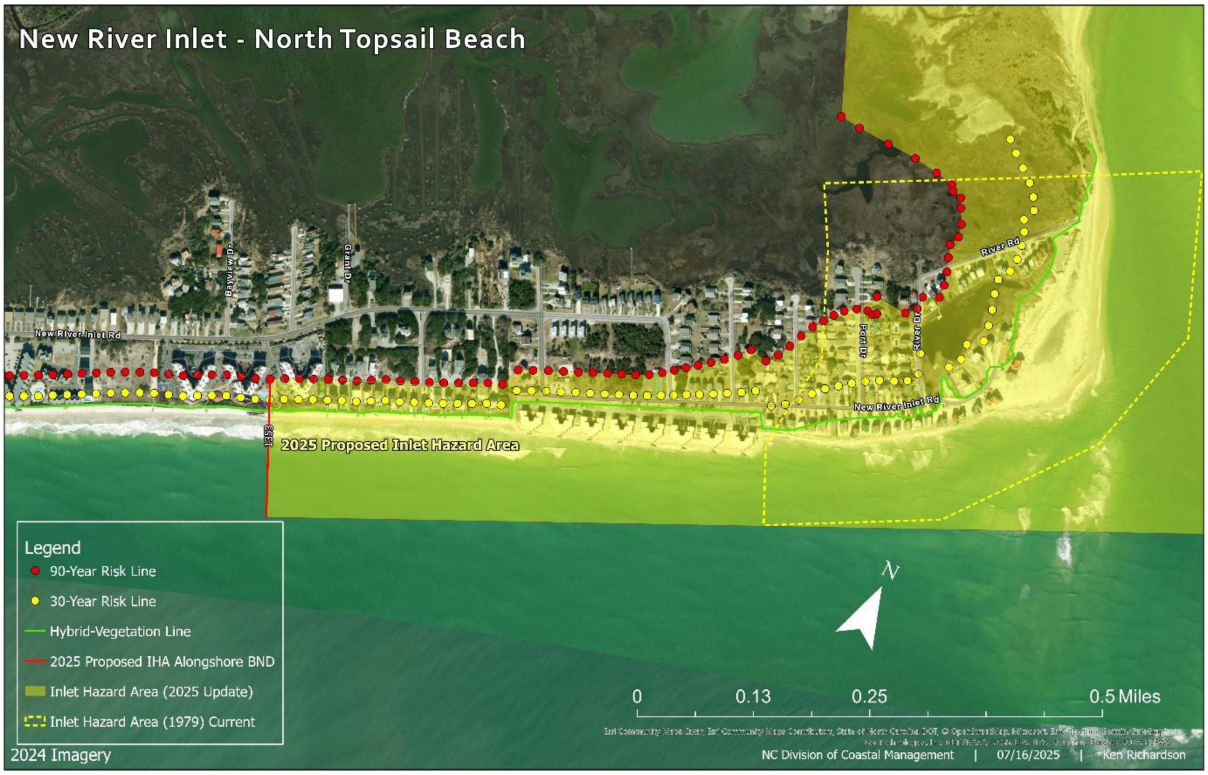

Figure 105. *New River Inlet-North Topsail Beach HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

3.10 Bogue Inlet

Bogue Inlet has been open continuously and in the same general location since the first map of coastal North Carolina was produced in 1585. Bogue Inlet is one of the larger inlets in southeastern North Carolina and drains an expansive estuary as well as the White Oak River Basin. The general inlet floodway is stable, and its position is controlled by the ancestral location of White Oak River. The inlet width and both ocean shorelines near the inlet have fluctuated widely during the study period.

During the past 70 years the inlet's width ranged from 3,800 to 8,300 feet and averaged 6,200 feet; depths in the ebb channel have fluctuated between 16 and 30 feet. The main offshore ebb channel is highly unstable and has a history of rapid migration along its 10,200-foot-long pathway. The migration rate and direction have varied considerably.

The orientation and position of the ebb platform channel have changed repeatedly. During the past 50 years, the outer bar channel has generally been aligned in a southeast-to-south-southwest orientation. The channel movement and orientation, coupled with the migration of the landward segments of the channel, have dictated much of the change along both the inlet and oceanfront shorelines. Breaching of the ebb-tidal delta has led to rapid repositioning of the ebb channel. The most dramatic natural realignment event occurred between October 1938 and July 1949 when the ebb channel was repositioned approximately 3,000 feet east of its 1938 position. A similar but smaller-scale event occurred in the mid-1970s. Between 2000 and 2010 approximately 1,500 feet of the Emerald Isle side inlet shoreline was armored with sandbag revetments.

In March 2005, the ebb channel was artificially relocated approximately 3,200 feet westward to mitigate the chronic erosion along the Bogue Banks inlet shoreline. Between October 2006 and April 2014, the ebb channel migrated toward Bogue Banks a net distance of 1,400 feet, and subsequently shifted westward 380 feet. The average eastward migration rate was 150 feet per year.

The inlet variables that control the behavior of the oceanfront shorelines are the position and alignment of the ebb channel, which ultimately dictate the shape of the ebb-tidal delta. The symmetry of the outer bar in turn controls its breakwater and natural nourishment effects along the adjacent oceanfront shorelines. The natural coastwise progradation that has occurred along Bogue Banks during various periods is directly attributable to the easterly migration of the ebb channel and the changing shape of the ebb-tidal delta. By contrast, the historic recession along Bear Island has reflected the negative influence of the ebb channel as it tracked eastward toward Bogue Banks. Since 1946, the US Army Corps of Engineers has maintained a 3.1-mile-long, 6.5-foot-deep channel connecting the inlet to the ICW.

3.10.a Emerald Isle side of Bogue Inlet

Shoreline and vegetation data for the Emerald Isle side of Bogue Inlet are presented in **Figures 106 and 109**. Analysis of shoreline data from 1971 and 2022 shows long-term accretion (**Figures 106 and 107**), though these findings are influenced by routine beach nourishment and channel realignment activities at Bogue Inlet. The HVL is a composite of 1971, 1976, 1987, 1992, 2006, 2009, 2010, 2012 vegetation lines (**Figure 109**). Applying STD $\Delta > 1$ identifies the alongshore IHA boundary at transect 75 (**Figure 108**). The landward IHA boundary follows the 90-Year Risk Line, starting at transect 75 and continuing towards the inlet until the last 90-Year Risk Line point, where it follows the remaining 300 feet of Inlet Road, then intersecting the creek adjacent to the U.S Coast Guard Base at Emerald Isle, then intersecting Bogue Sound (**Figure 110**).

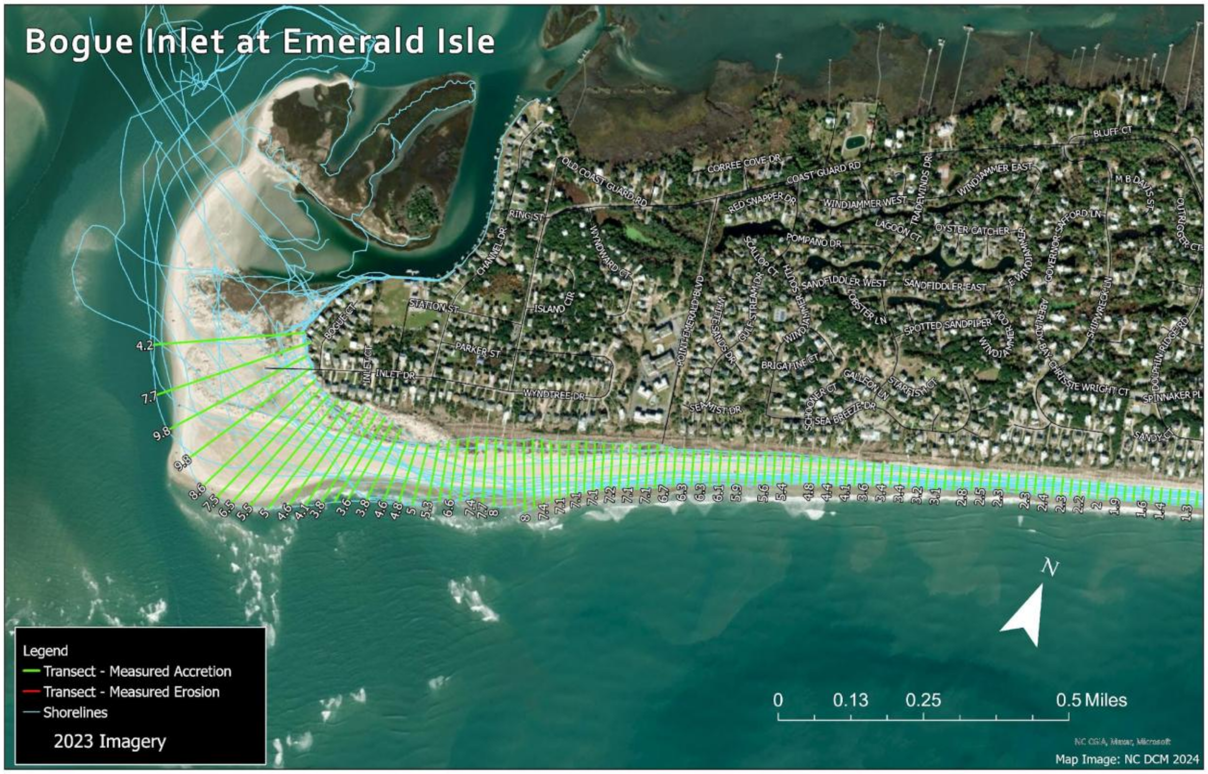

Figure 106. *Shorelines included in the analysis: 1971, 1973, 1976, 1987, 1992, 1997, 1998, 2003, 2004, 2006, 2009, 2010, 2012, 2016, 2020, 2022.*

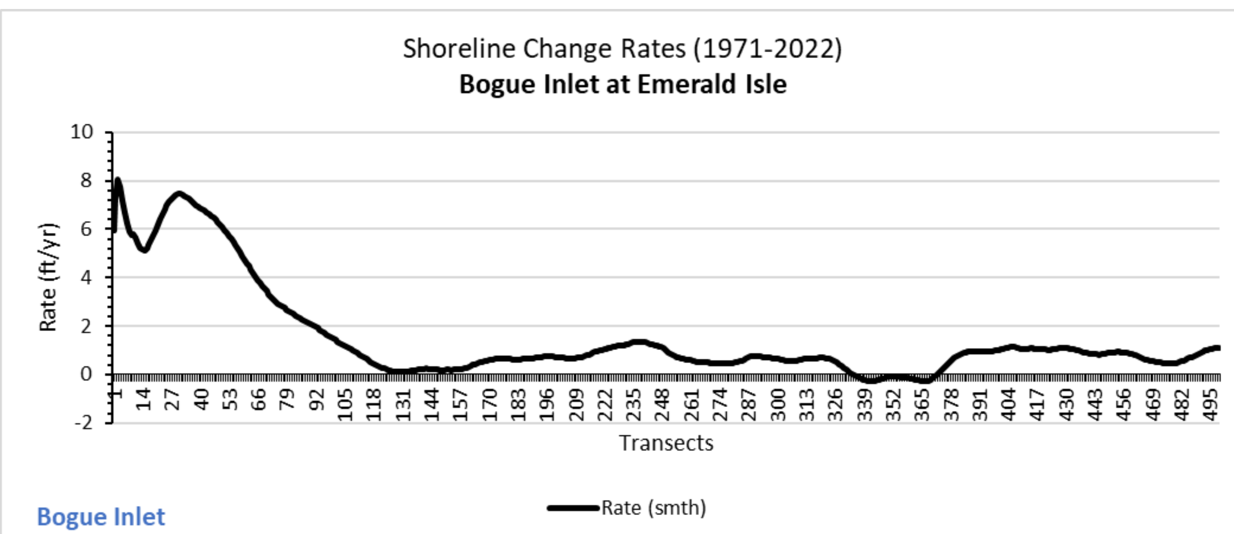

Figure 107. *Shoreline change rates (ft/yr) at Emerald Isle from 1971 to 2022: Negative values indicate erosion, while positive values indicate accretion.*

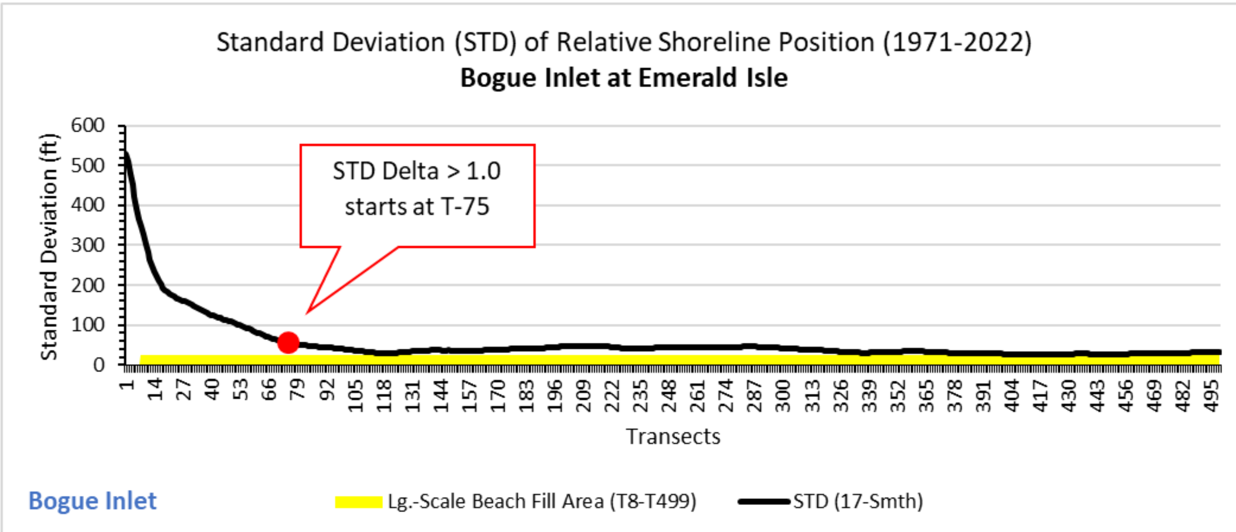

Figure 108. *Using the standard deviation of relative shoreline position data at Bogue Inlet-Emerald Isle and applying the STD Δ > 1.0 threshold method, transect 75 (red point) is identified as the alongshore IHA boundary. This transect is where the difference (Δ) between neighboring transects exceeds 1.0 moving towards the inlet. The area highlighted in yellow indicates location of large-scale beach nourishment and subsequent maintenance projects.*

Figure 109*. Bogue Inlet at Emerald Isle. Vegetation Lines mapped: 1971, 1976, 1987, 1992, 1998, 2003, 2004, 2006, 2009, 2010, 2012, 2016, 2020, 2022, and; vegetation line composite segments making up the HVL: 1971, 1976, 1987, 1992, 2006, 2009, 2010, 2012.*

Figure 110. *Bogue Inlet at Emerald Isle HVL and the recommended IHA boundary with the 30- and 90-Year Risk Lines.*

4.0 Recommendations

The Inlet Hazard Area Method (IHAM) outlined and applied here is an objective methodology for calculating inlet shoreline change rates and for delineating the Inlet Hazard Areas (IHA) and areas within the IHA at greatest risk of experiencing inlet related erosion. The proposed IHA boundaries in this report have been developed for the 10 developed Inlets in North Carolina using the updated IHA approach described.

Since the Science Panel on Coastal Hazards began work on updating the Inlet Hazard Area in 2004, a goal was to devise hazard and management approaches using the present line of stable dune vegetation. The Panel believes floating vegetation line has been an effective reference boundary for Ocean Erodible Areas and building setback standards since adopted in 1979 in areas outside of inlet influence. While desirable for continuity for multiple oceanfront hazards, repeated efforts to apply the floating vegetation line within IHAs have proven unsuccessful. As inlet shorelines fluctuate in position, the floating vegetation lines move seaward during accretionary periods. An accreting shoreline and a seaward position of the vegetation line might seem to suggest low risk. However, accretion tends to be followed by rapid erosion, so that a seaward position of the floating vegetation line actually indicates heightened risk to come. Because shoreline fluctuations tend to be in opposite phases on either side of an inlet, methods that might seem to reasonably define the IHA risk based on a floating (present-day) vegetation line on one side of an inlet actually result in a boundary on the other side of the inlet that either excessively over or under-estimates the hazard. Using the Hybrid Vegetation Line (HVL) as defined in this report, instead of a floating vegetation line, to define IHAs resolves this problem. Because the use of a the HVL provides a measurement approach that most reliably and accurately accounts for fluctuations in inlet shorelines, the Panel strongly recommends basing IHA landward boundaries and building setbacks on the HVL as described and applied in this report.

Given the potential for conditions at inlets to rapidly fluctuate over both the short- and long-term, the Science Panel on Coastal Hazards recommends that the CRC consider updating the IHA every five years to include new shoreline and vegetation line data. We recommend the five-year time frame to coincide with the oceanfront erosion rate and Ocean Erodible Area updates.

References

Benton, S.B., Bellis, C.J., Knisel, J.M., Overton, M.F., Fisher, J.S., 2004, 1998 long-term average annual erosion rate update: Methods report (March 18). NC Division of Coastal Management, NC Coastal Resources Commission Information Item, April 28, 2004, 23 pp.

Cleary, W.C. and Marden, T.P., 1999, Shifting shorelines: A pictorial atlas of North Carolina inlets. NC Sea Grant publication UNC-SG-99-04, 51 pp.

Coastal Resources Commission, 1997, Charge of the Science Panel on Coastal Hazards. Memorandum CRC-763a, NC Division of Coastal Management., August 20, 2 pp.

Coastal Resources Commission's Science Panel on Coastal Hazards & NC Division of Coastal Management, 2019, Inlet Hazard Area Boundary Update: Science Panel Recommendations to the North Carolina Coastal Resources Commission. Memorandum CRC-763a, NC Division of Coastal Management., February 12.

Dolan, R., Fenster, M.S. and Holme, S.J., 1991, Temporal Analysis of Shoreline Recession and Accretion, Journal of Coastal Research, 7(3), 723-744

DCM, 2000, Meeting minutes of the CRC Science Panel on Coastal Hazards. NC Division of Coastal Management, March 6, 2000, 5 pp.

DCM, 2002, Meeting minutes of the CRC Science Panel on Coastal Hazards. NC Division of Coastal Management, February 18, 3 pp.

DCM, 2004, Meeting minutes of the CRC Science Panel on Coastal Hazards. NC Division of Coastal Management, November 3, 12 pp.

DCM, 2016, Coastal Erosion Study. NC Division of Coastal Management, February 12.

Fisher, J.J., 1967, Development Patterns of Relict Beach Ridges, Outer Banks Barrier Chain, North Carolina. Unpublished Dissertation (PhD), University of North Carolina at Chapel Hill, 254 pp.

Fisher, J.J., 1962, Geomorphic expressions of former inlets along the Outer Banks of North Carolina. Unpublished Thesis (MS), University of North Carolina at Chapel Hill,125 pp.

Fisher, J.S., 1999, CRC Science Panel on Coastal Hazards short-term recommendations. Memorandum CRC-838, NC Division of Coastal Management, May 4, 6 pp.

Genz, A.S., Fletcher, C.H., Dunn, R.A., Frazer, L.N., and Rooney, J.J., 2007. The predictive accuracy of shoreline change rate methods and alongshore beach variation on Maui, Hawaii. Journal of Coastal Research, 23(1), 87–105.

Holden Beach: Annual Beach Monitoring Report. Applied Technology & Management (ATM), October, 2015.

Limber, P.W., List, J.H., Warren, J.D., 2007a, Applications of a LiDAR-derived mean high-water shoreline in North Carolina. Proceedings of Coastal Zone 07, Portland, OR, July 22-26. 5 pp.

Limber, P.W., List, J.H., Warren, J.D., 2007b, using topographic LiDAR to delineate the North Carolina shoreline in Kraus N.C. and Rosati J.D. (eds.), Coastal Sediments ’07 volume three: Proceedings of the sixth international symposium on coastal engineering and science of coastal sediment processes, May 13-17, New Orleans, LA, p. 1837-1850.

NC Department of Natural Resources and Community Development, 1977, The North Carolina Coastal Plan. October, 205 pp.

Overton, M. F. and J. S. Fisher, “North Caroline Shoreline Change Update Study”, prepared for the Division of Coastal Management, DENR, April 2003.

Overton, M.F. and Fisher, J.S., 2004, Methodology for the analysis of shoreline change for the purpose of delineating the Inlet Hazard Area. Prepared for the NC Division of Coastal Management, December 13, 3 pp.

Priddy, L.J. and Carraway, R., 1978, Inlet hazard areas: The final report and recommendations to the Coastal Resources Commission. Prepared by the NC Division of Marine Fisheries Technical Services Section, NC Department of natural Resources and Community Development., September, 60 pp.

Rogers, S.M., 2015, Personal Communication, Science Panel and CRAC presentations.

Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L., and Ergul, A., 2009, Digital Shoreline Analysis System (DSAS) version 4.0 – An ArcGIS Extension for Calculating Shoreline Change: U.S. Geological Survey Open-File Report 2008-1278., updated for version 4.3

Warren, J.D., 2008, Inlet hazard area policy recommendations. NC Division of Coastal Management memo CRC 08-48, November 6, 2 pp.

Warren, J.D. and Richardson, K.R., 2009, Inlet Hazard Boundary Update: Recommendations to the North Carolina Coastal Resources Commission. NC Division of Coastal Management document CRC 09-05.

Appendix A: List of Acronyms

AEC	Area of Environmental Concern
AIWW	Atlantic Intracoastal Waterway
CAMA	NC Coastal Area Management Act of 1974
CRC	NC Coastal Resources Commission
CSC	NOAA Coastal Services Center
DCM	NC Division of Coastal Management
DOT	Department of Transportation
DSAS	Digital Shoreline Analysis System
EVL	Existing Vegetation Line
EP	End-Point (Shoreline Change Rate Methodology)
GIS	Geographic Information System
GS	General Statute
HVL	Hybrid-Vegetation Line
IHA	Inlet Hazard Area
IHAM	Inlet Hazard Area Method
LiDAR	Light Detection and Ranging
LRR	Linear Regression (Shoreline Change Rate Methodology)
MLW	Mean Low Water
MHW	Mean High Water
NC	North Carolina
NCAC	NC Administrative Code
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
OEA	Ocean Erodible Area
T-sheet	Topographic Sheet
US	United States
USGS	US Geological Survey

30-YRL 30-Year Risk Line

90-YRL 90-Year Risk Line

Appendix B: Definition of Key Terms

End-Point (EPR) Shoreline Change Rates: This shoreline change rate is calculated by measuring the distance between two shorelines (early and current) and dividing by the time period. This method has been used on the oceanfront since 1979.

Hybrid-Vegetation Line (HVL): This line represents the landward-most position of all vegetation lines at each inlet. The Hybrid-Vegetation Line is most often a composite containing landward-most segments from multiple vegetation lines, or at some locations, may represent only a single date.

Inlet Hazard Area (IHA): Is an Area of Environmental Concern (AEC) defined in NC's Coastal Resource Commission's Rules (15A NCAC 07H. 0304). These 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. Current rules define this area as extending 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 (15A NCAC 07H. 0304 (2)).

Least Squares Regression (Linear Regression - LRR) Shoreline Change Rates: Shoreline change rates are calculated using multiple shorelines. A linear regression rate-of-change statistic is determined by fitting a least-squares regression line to all shoreline points for a transect. The regression line is placed so that the sum of the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate is the slope of the line. The method of linear regression includes these features: (1) All the data are used, regardless of changes in trend or accuracy; (2) the method is purely computational; (3) the calculation is based on accepted statistical concepts; and (4) the method is easy to employ (Dolan et al., 1991). However, the linear regression method is susceptible to outlier effects and tends to underestimate the rate of change relative to other statistics, such as EPR (Dolan et al., 1991; Genz et al., 2007). In conjunction with the linear regression rate, the standard error of the estimate (LSE), the standard error of the slope with user-selected confidence interval (LCI), and the R-squared value (LR2) are reported. Linear Regression was used to calculate inlet shoreline change rates.

Migrating Inlets: Some inlets move alongshore in response to the prevailing alongshore current and sand transport, persistently accreting on one side and forcing the opposite inlet shoreline to erode. Inlet migration rates vary with wave conditions. Despite a prevailing direction of migration, in some cases, inlet migration may temporarily reverse direction. Inlet shorelines at migrating inlets exhibit very rapid long-term change. For example, New Topsail Inlet has been migrating south at ~90 feet per year since the 1930s. Mason Inlet was migrating at 365 feet per year before it was relocated and stabilized in 2002. The presence and rate of inlet migration is affected by natural processes, inlet closures, dredging, beach nourishments, and engineered structures. At the time of this report only Old Topsail and Drum Inlets are considered actively migrating.

Non-migrating Inlets*:* Most of the NC inlets are not actively migrating but have fluctuated around the same general location for decades to centuries. These inlets remain in the same general location because: 1) the net alongshore sediment transport rate is small relative to the rate that tidal currents transport sand; 2) a feature in the underlying geology, such as relict river channel, limits migration; and/or 3) maintenance dredging and engineering structures prevent inlet migration.

Ocean Erodible Area (OEA): The OEA is an Area of Environmental Concern (AEC) defined in NC's Coastal Resource Commission's Rules (15A NCAC 07H. 0300). 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 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 120 feet landward from the first line of stable and natural vegetation (15A NCAC 07H. 0304 (1)).

Standard Deviation (STD): is a measure of how spread out data points are from their average value (mean). It essentially quantifies the typical distance between data points and the mean of the dataset. A higher standard deviation indicates that the data (shorelines) are more dispersed, while a lower standard deviation suggests they are clustered closer to the mean.

STD Threshold Method (STD > 15-m): Using this approach, moving toward each inlet, the alongshore boundary of the IHA corresponds to the transect at which the local standard deviation first rises above the grand average standard deviation of 15 m.

STD Slope (or first-derivative; STD Δ > 1-ft): This method employs alongshore differences (Δ) in standard deviation between consecutive transects. This more nuanced approach identifies the location where the standard deviation starts to increase substantially relative to the oceanfront shoreline distant from inlets. Moving alongshore toward an inlet, the transect where Δ first exceeds 1ft is identified as the IHA alongshore boundary when applying this approach.

Transects: These measurements lines are spaced 25 meters (82.03 feet) apart and cast perpendicular to the general trend in orientation observed of all shorelines collectively. Transects are used when calculating shoreline change rates at specific locations. Transects were cast using GIS and the US Geological Survey's Digital Shoreline Analysis System (DSAS).

Vegetation Lines: Vegetation lines were interpreted as the First Line of Stable and Natural Vegetation (*FLSNV*). Although a few were mapped in the field using a mapping grade GPS, most vegetation lines were digitized using Geographic Information Systems (GIS) and orthorectified imagery.

Appendix C: Proposed Inlet Hazard Area Maps

Figure C1. Proposed Inlet Hazard Area at Tubbs Inlet (Sunset Beach).

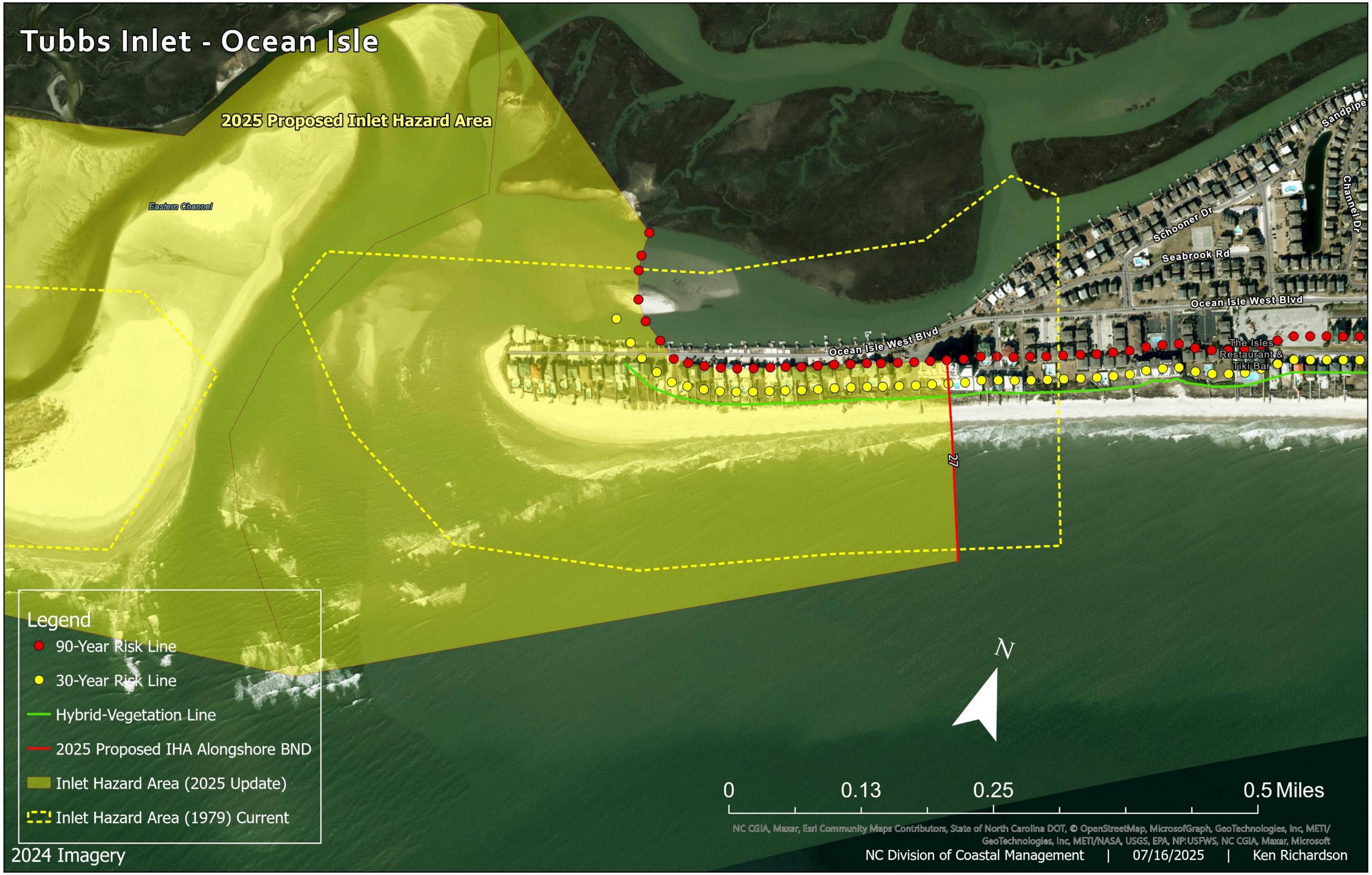

Figure C2. Proposed Inlet Hazard Area at Tubbs Inlet (Ocean Isle Beach).

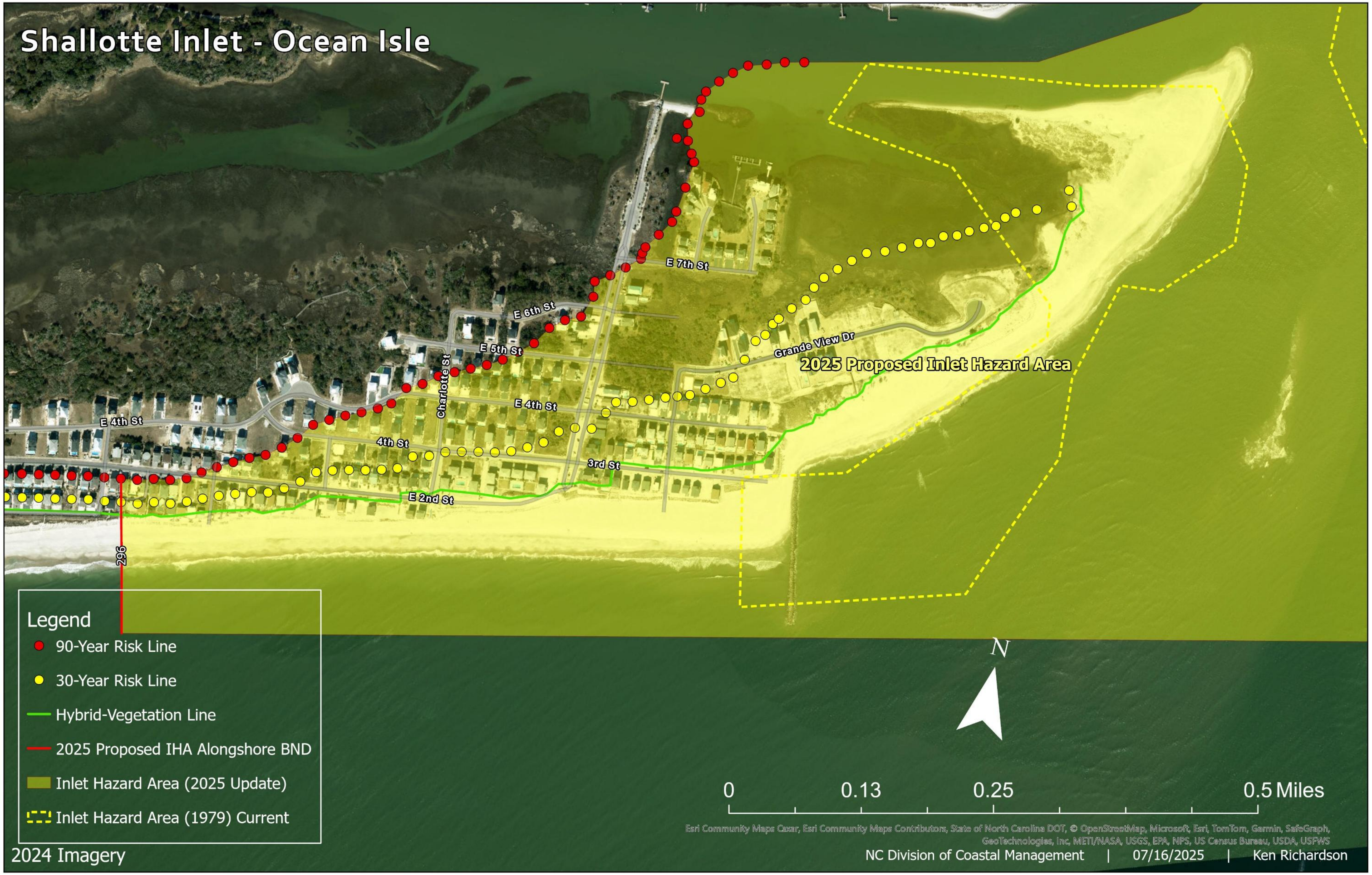

Figure C3. Proposed Inlet Hazard Area at Shallotte Inlet (Ocean Isle).

Figure C4. Proposed Inlet Hazard Area at Shallotte Inlet (Holden Beach).

Figure C5. Proposed Inlet Hazard Area at Lockwood Folly Inlet (Holden Beach).

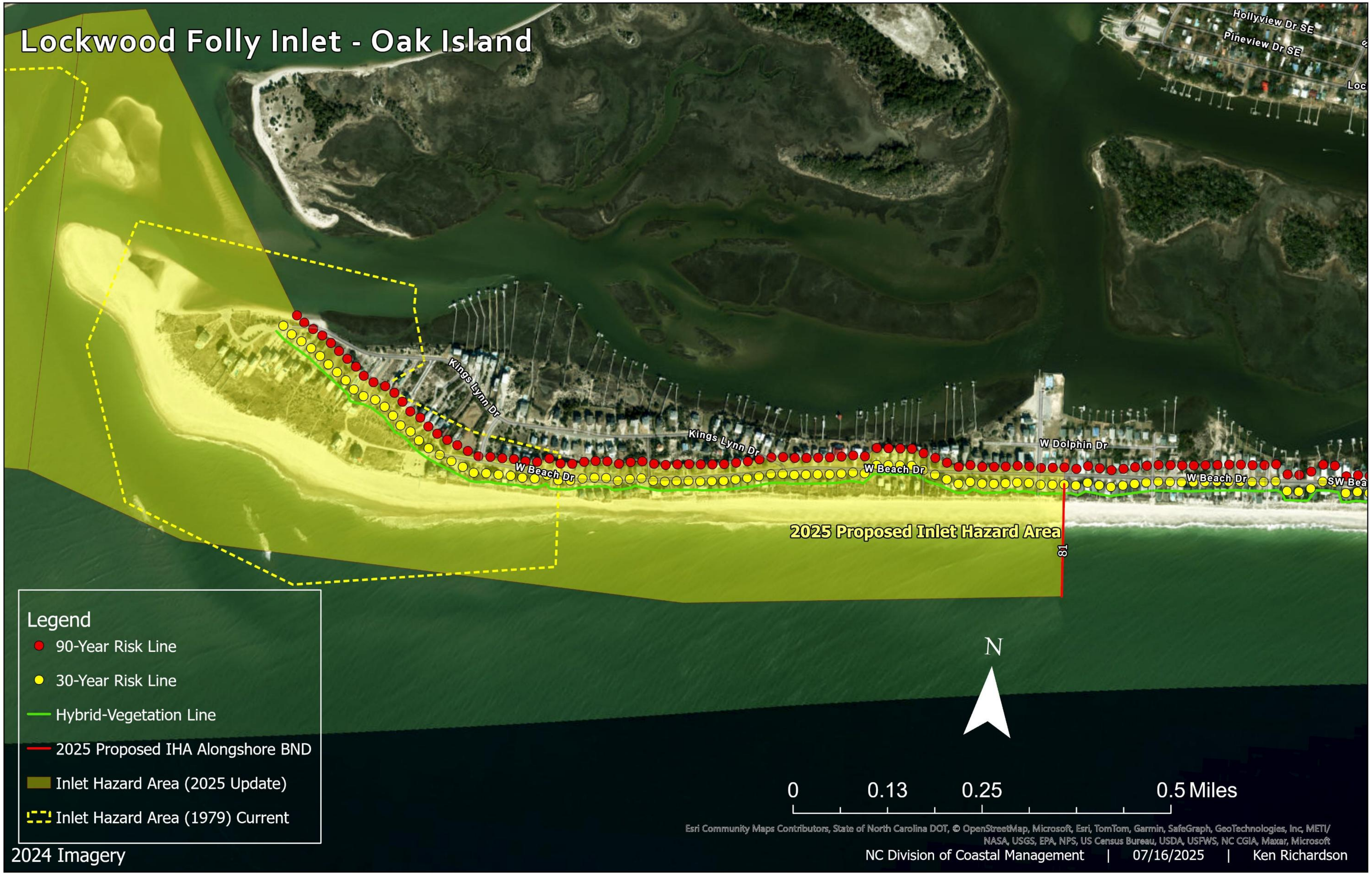

Figure C6. Proposed Inlet Hazard Area at Lockwood Folly Inlet (Oak Island).

Figure C7. Proposed Inlet Hazard Area at Carolina Beach Inlet (Carolina Beach).

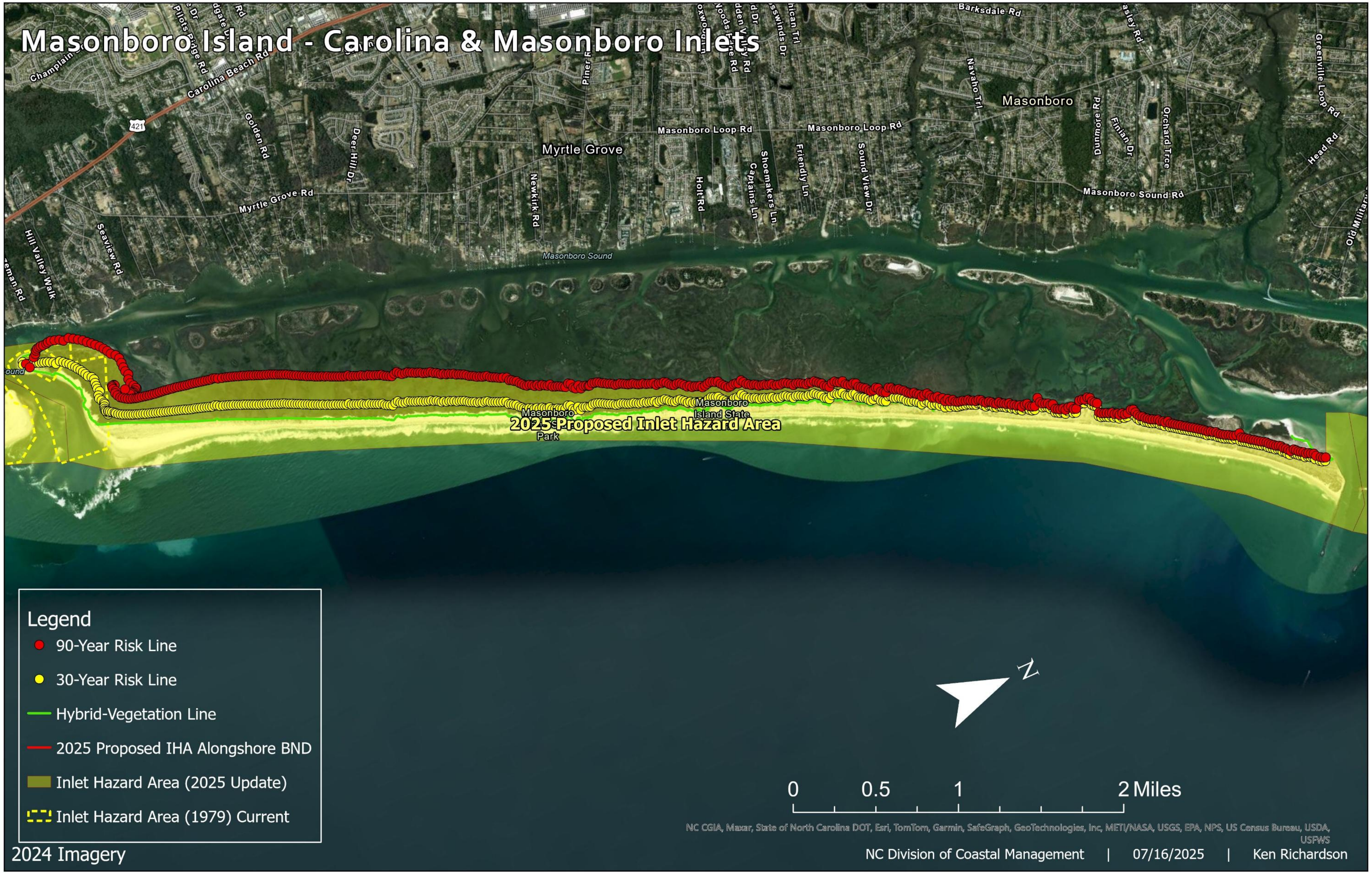

Figure C8. Proposed Inlet Hazard Area at Carolina Beach Inlet (Masonboro Island).

Figure C9. Proposed Inlet Hazard Area at Masonboro Inlet (Wrightsville Beach).

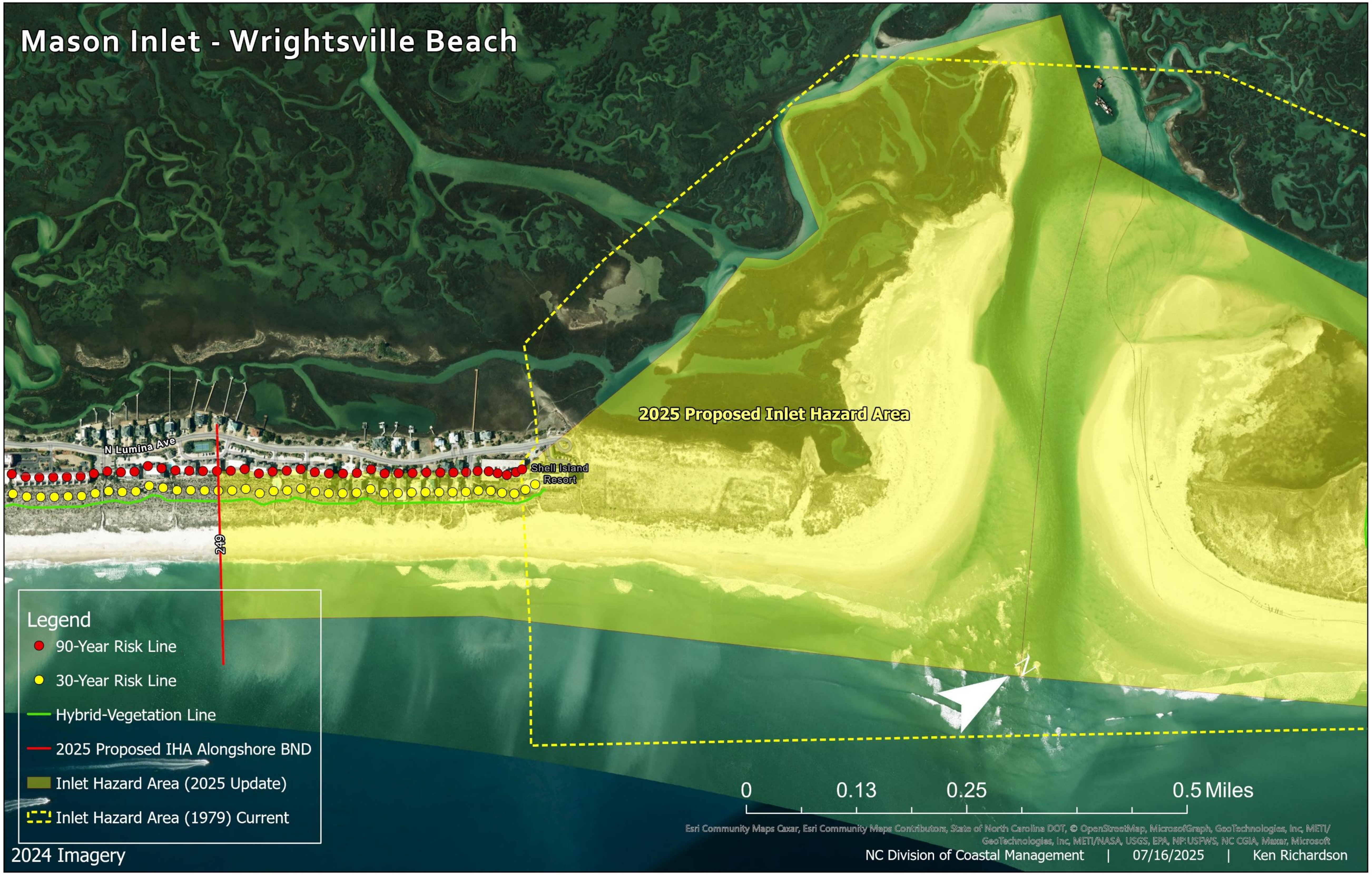

Figure C10. Proposed Inlet Hazard Area at Mason Inlet (Wrightsville Beach).

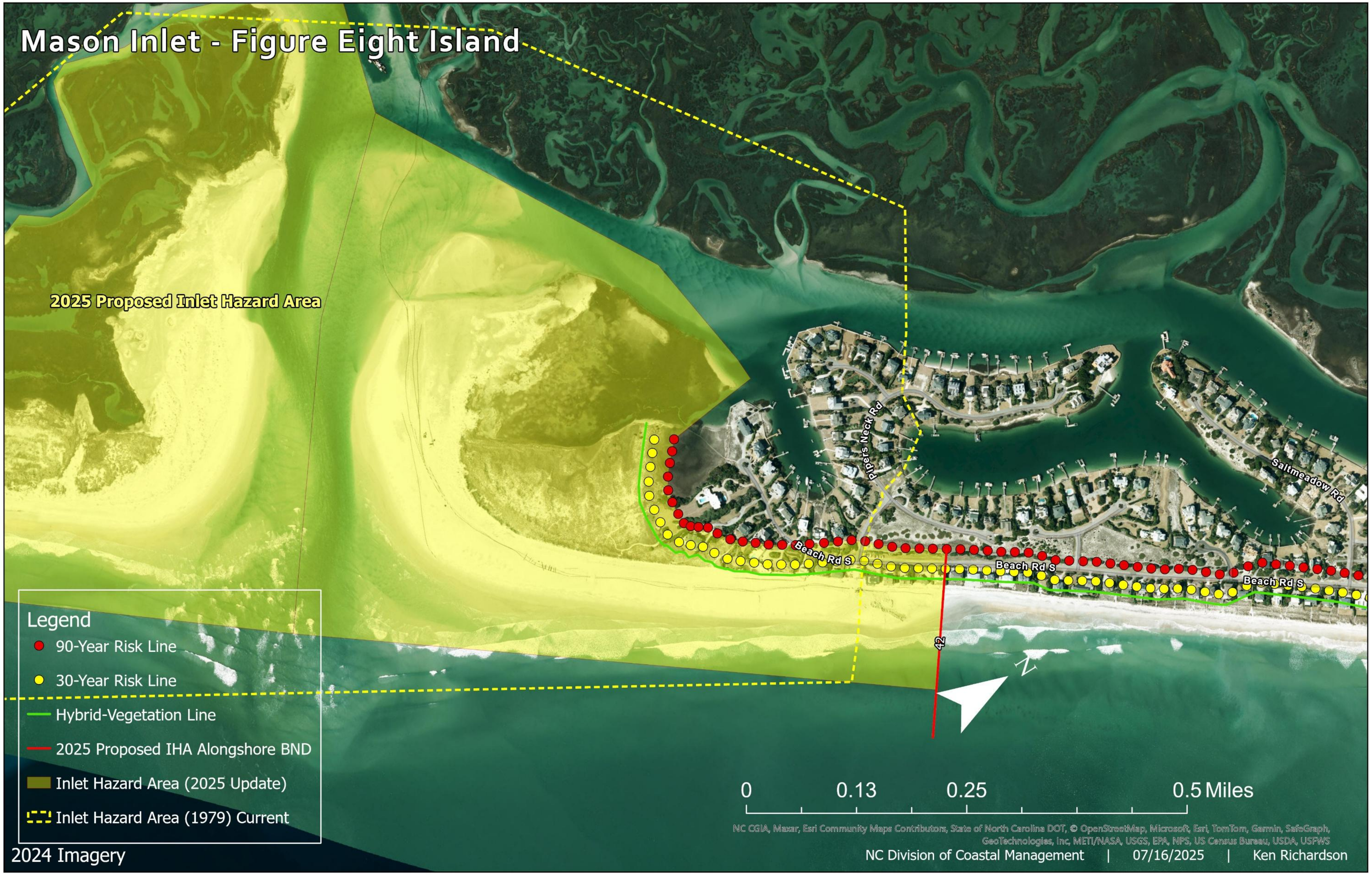

Figure C11. Proposed Inlet Hazard Area at Mason Inlet (Figure Eight Island).

Figure C12. Proposed Inlet Hazard Area at Rich Inlet (Figure Eight Island).

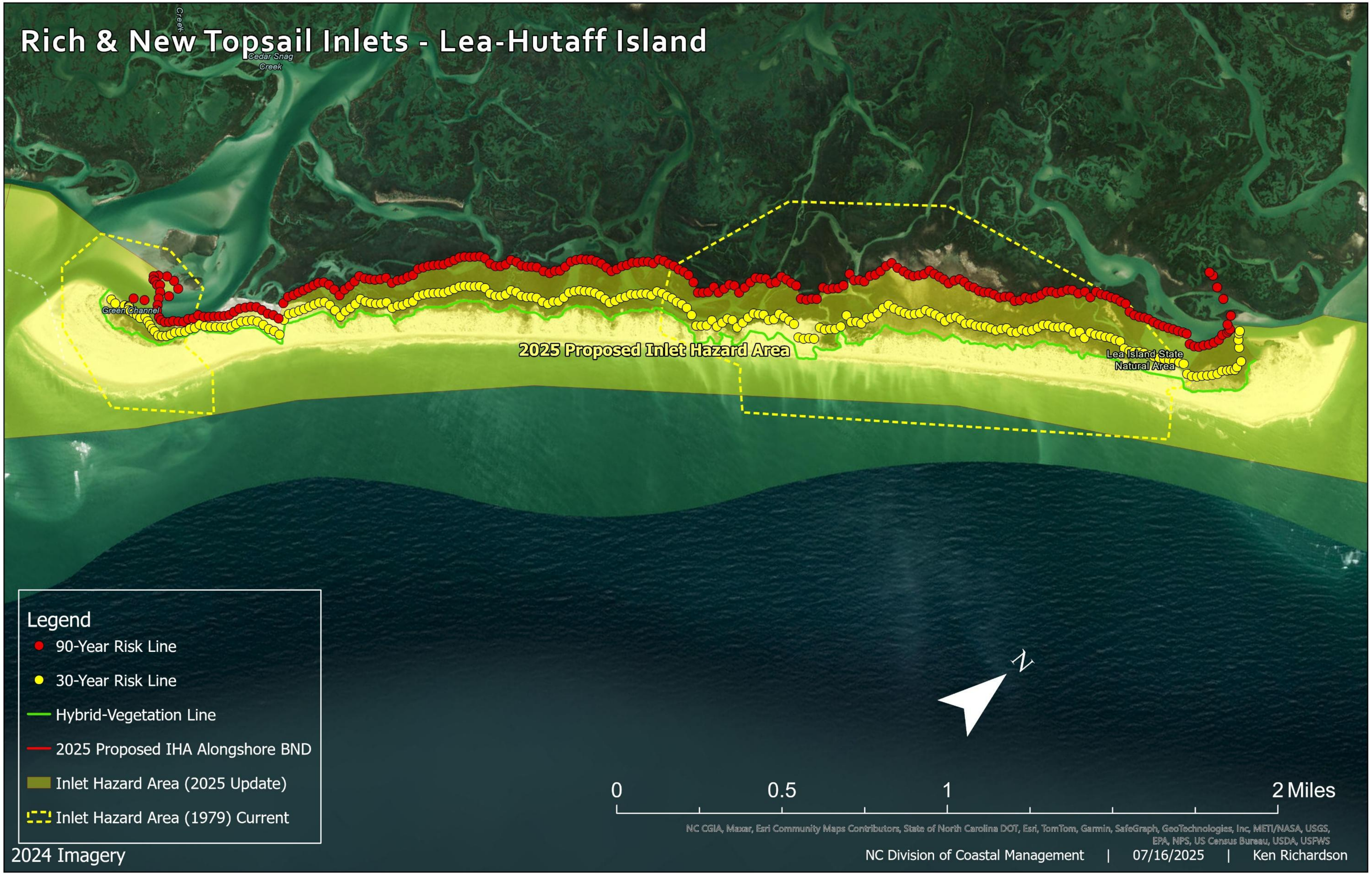

Figure C13. Proposed Inlet Hazard Area at Rich & New Topsail Inlets (Lea-Hutaff Island).

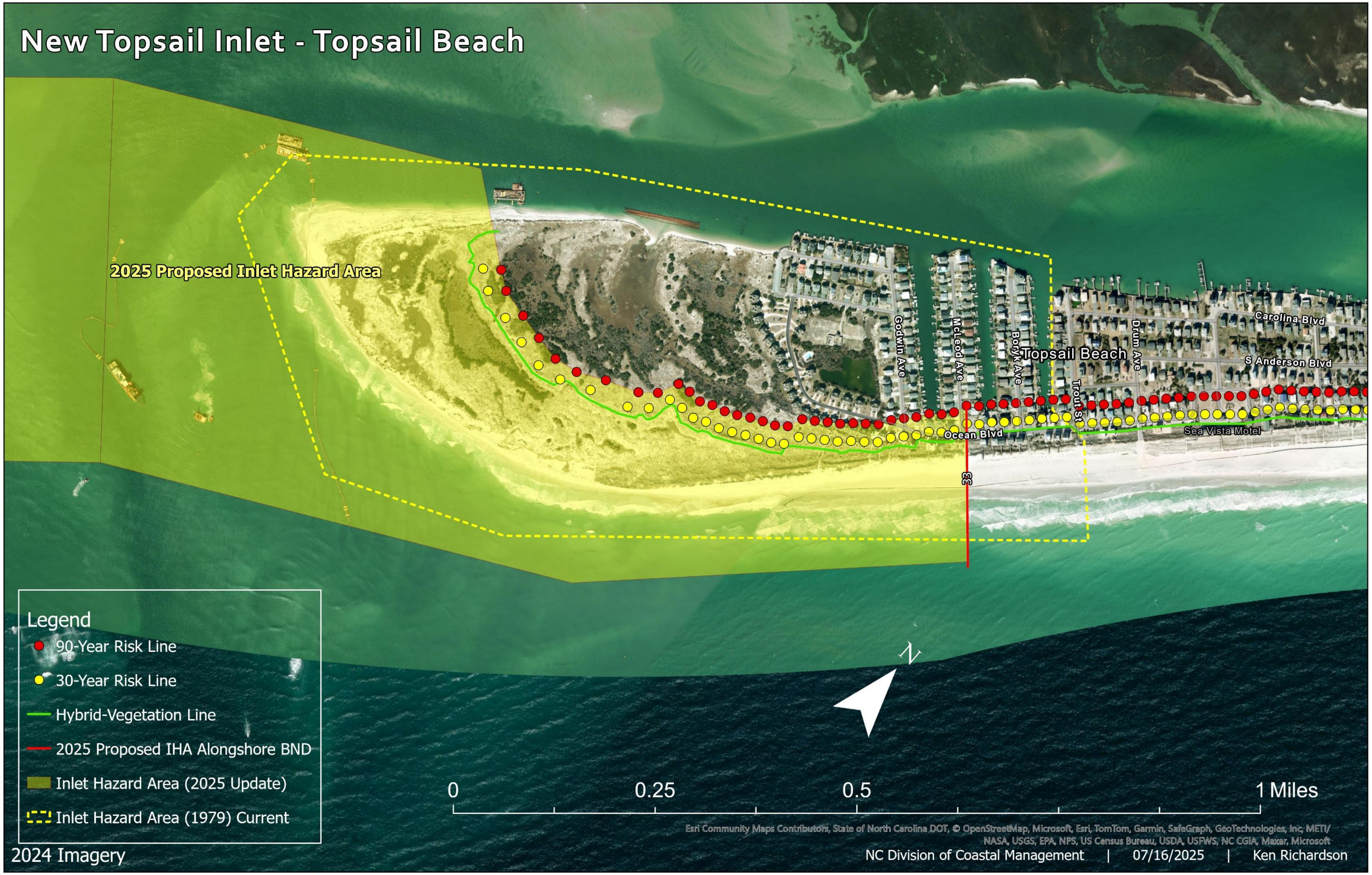

Figure C14. Proposed Inlet Hazard Area at New Topsail Inlet (Topsail Beach).

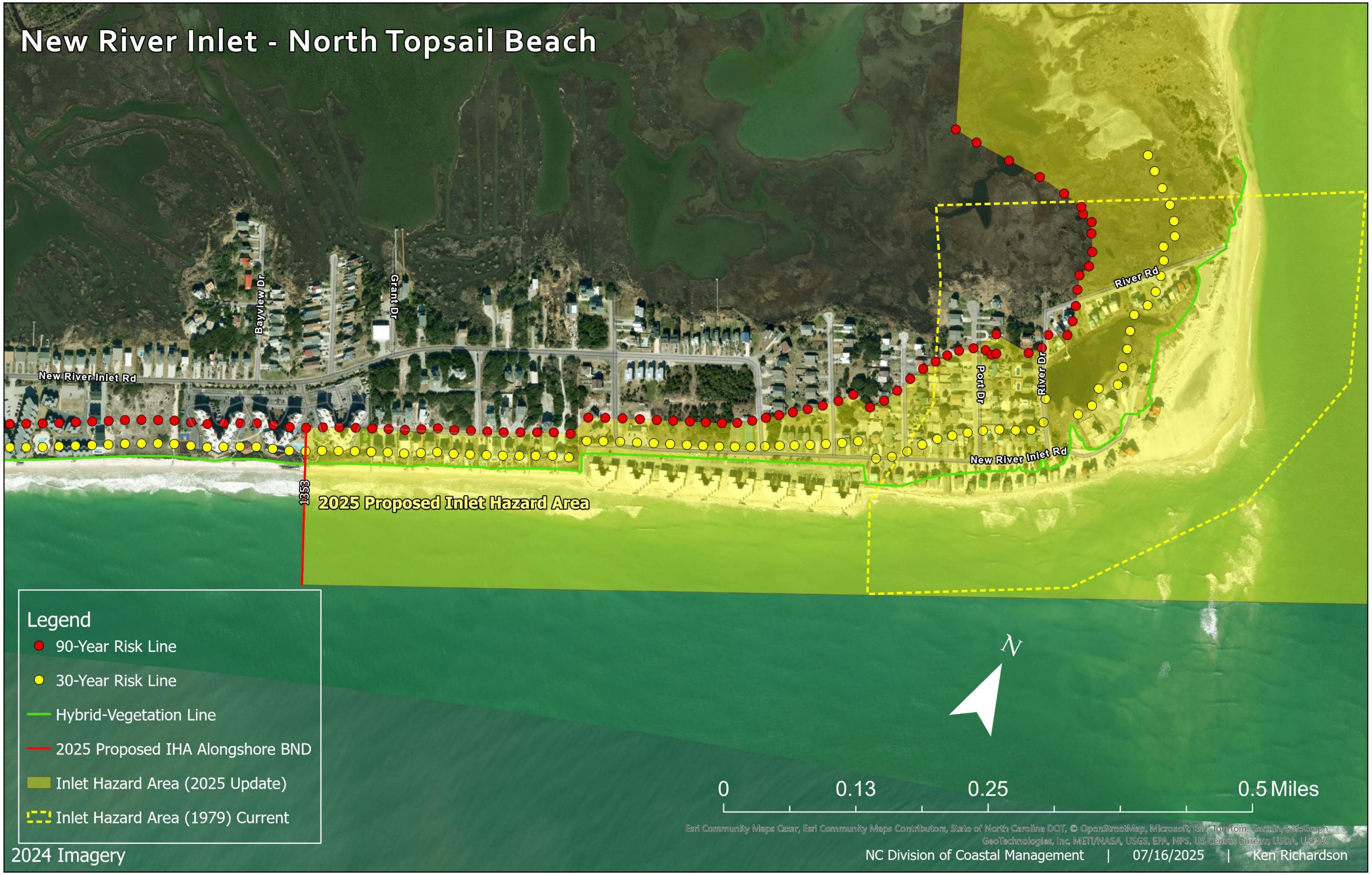

Figure C15. Proposed Inlet Hazard Area at New River Inlet (North Topsail Beach).

Figure C16. Proposed Inlet Hazard Area at Bogue Inlet (Emerald Isle).

Appendix D: Time Series Inlet Image

Figure D1. Tubbs Inlet at Sunset Beach in 1981, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 213 (red line).

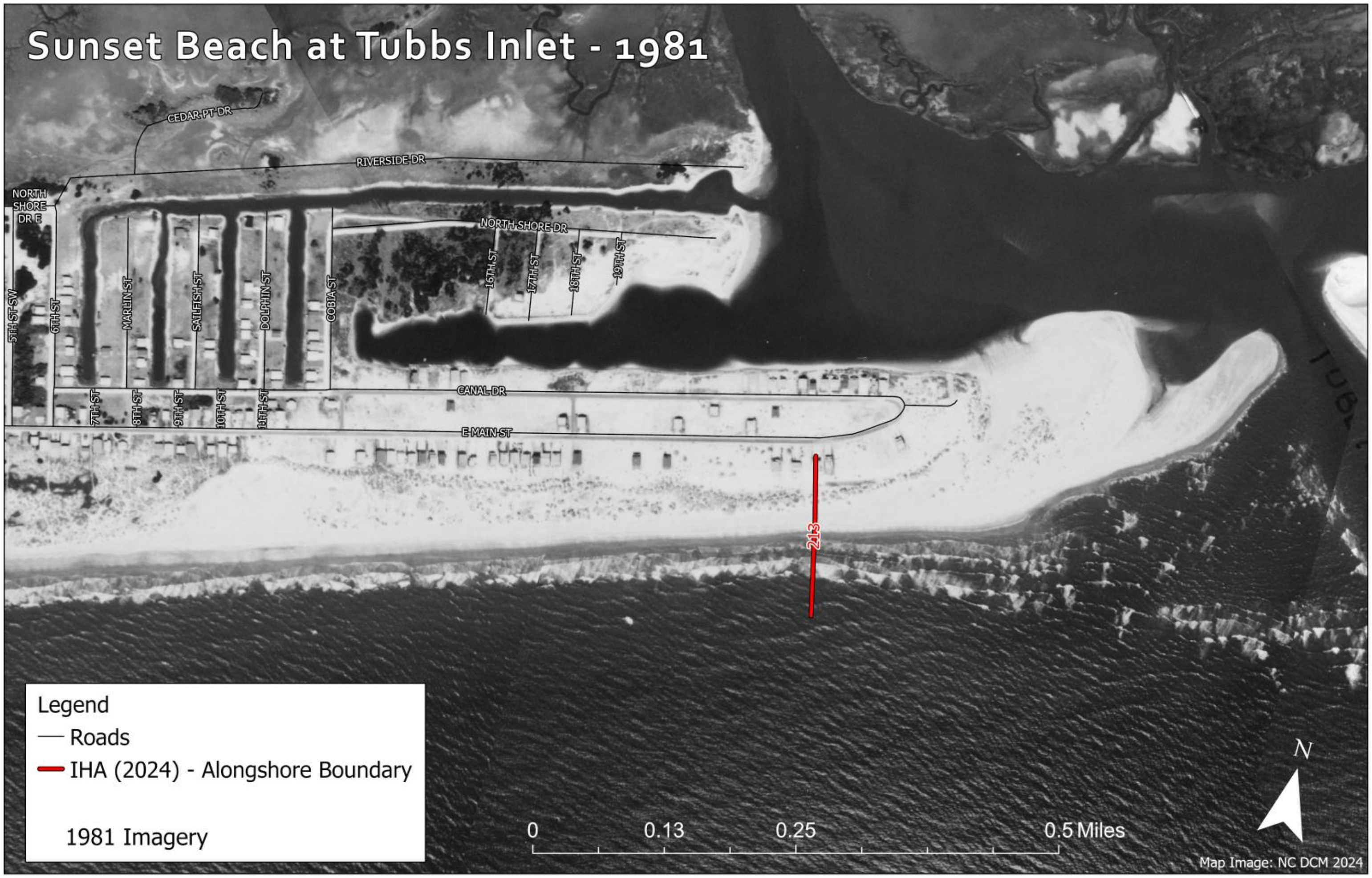

Figure 1. Tubbs Inlet at Sunset Beach in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 213 (red line).

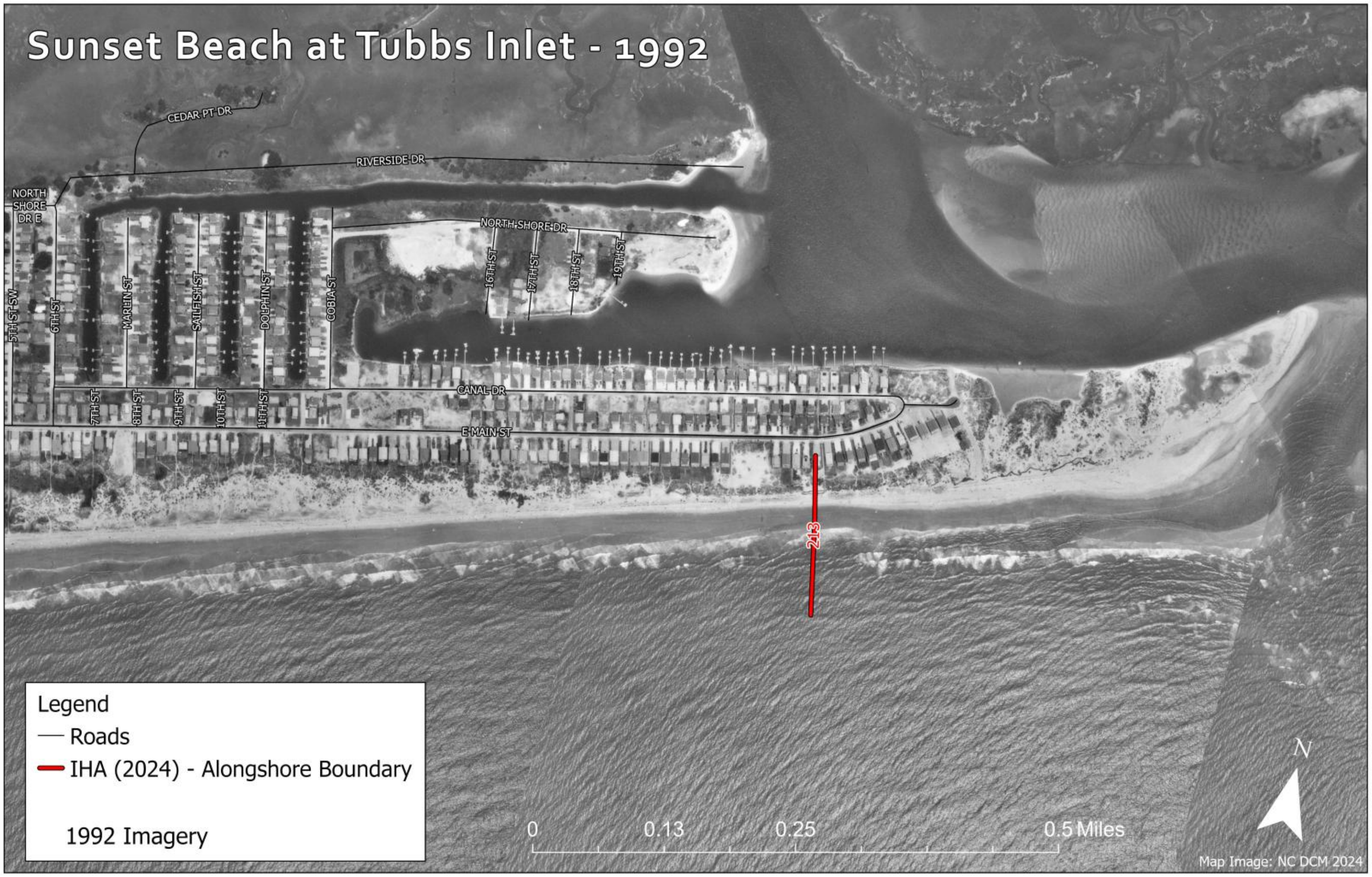

Figure 2. Tubbs Inlet at Sunset Beach in 1998, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 213 (red line).

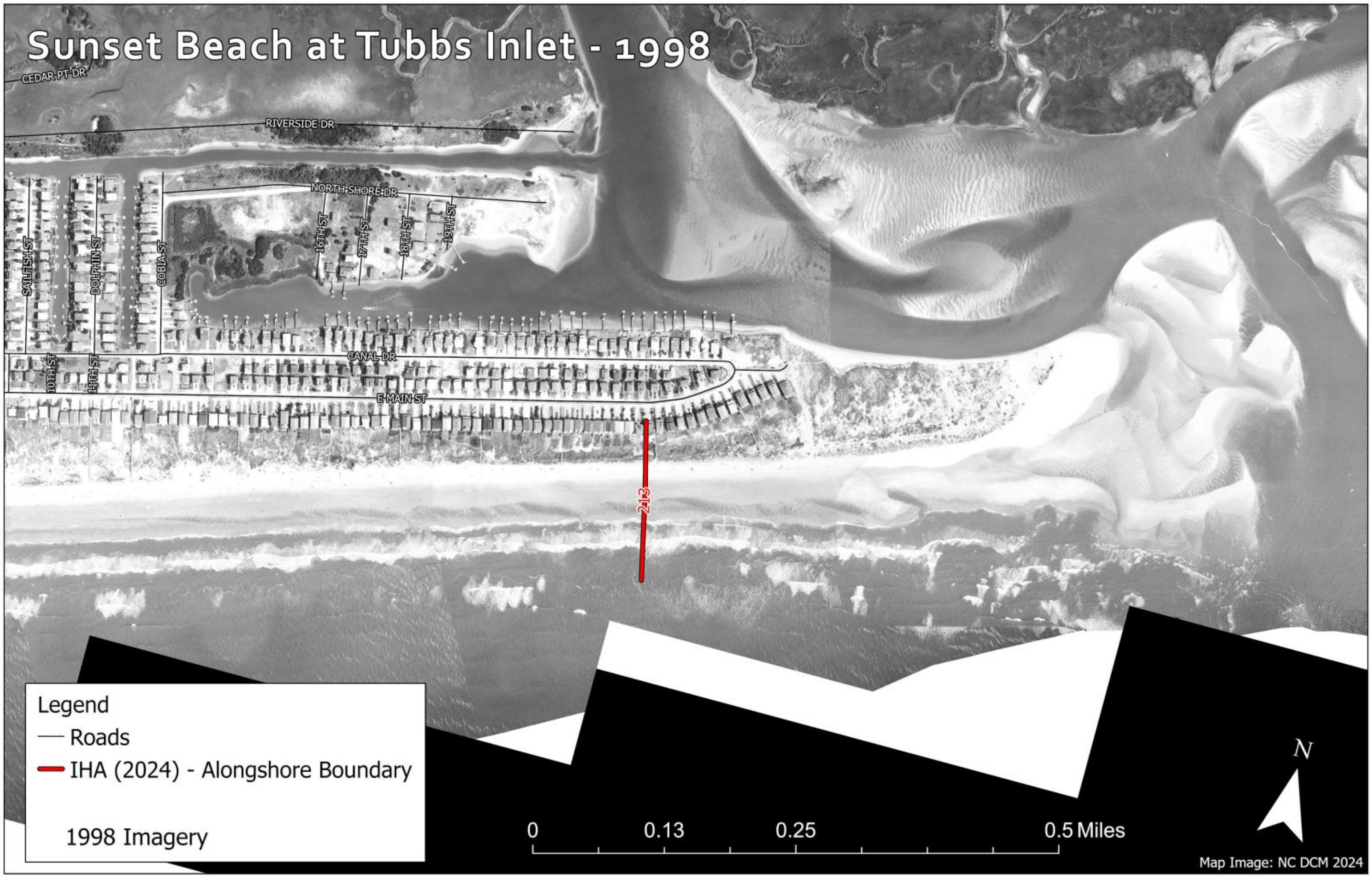

Figure 3. Tubbs Inlet at Sunset Beach in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 213 (red line).

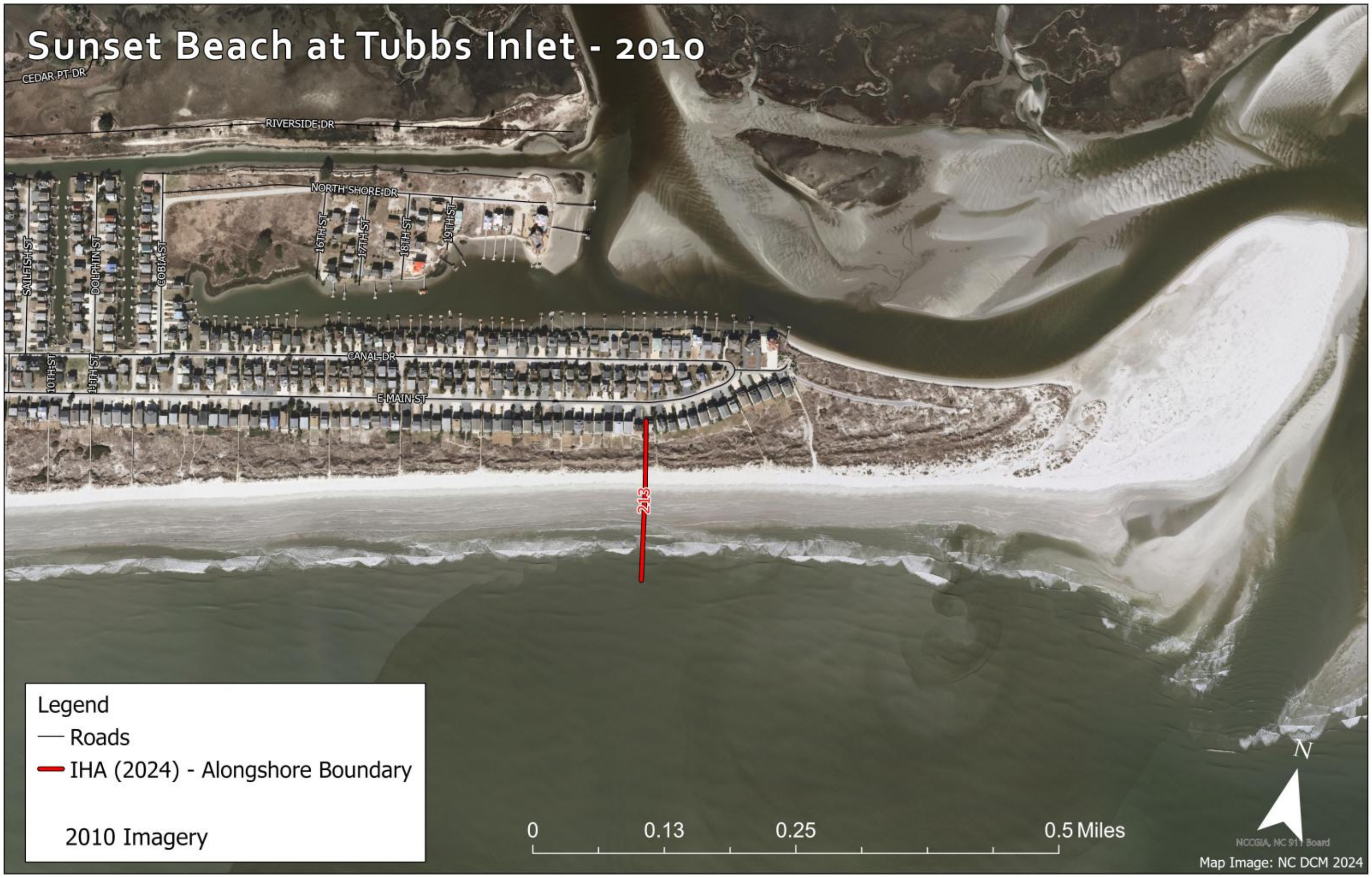

Figure 4. Tubbs Inlet at Sunset Beach in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 213 (red line).

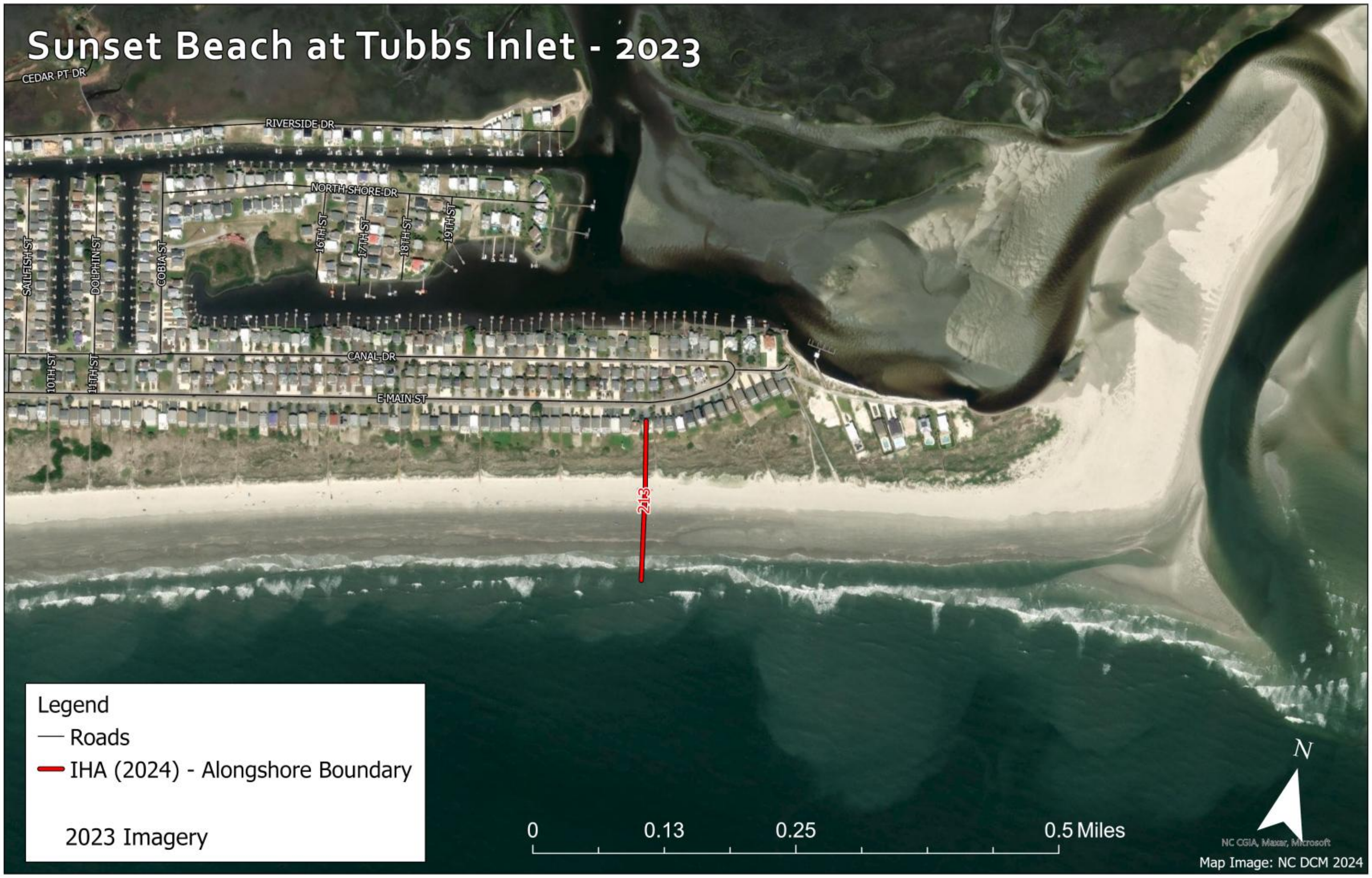

Figure D6. Tubbs Inlet at Ocean Isle in 1970, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 27 (red line).

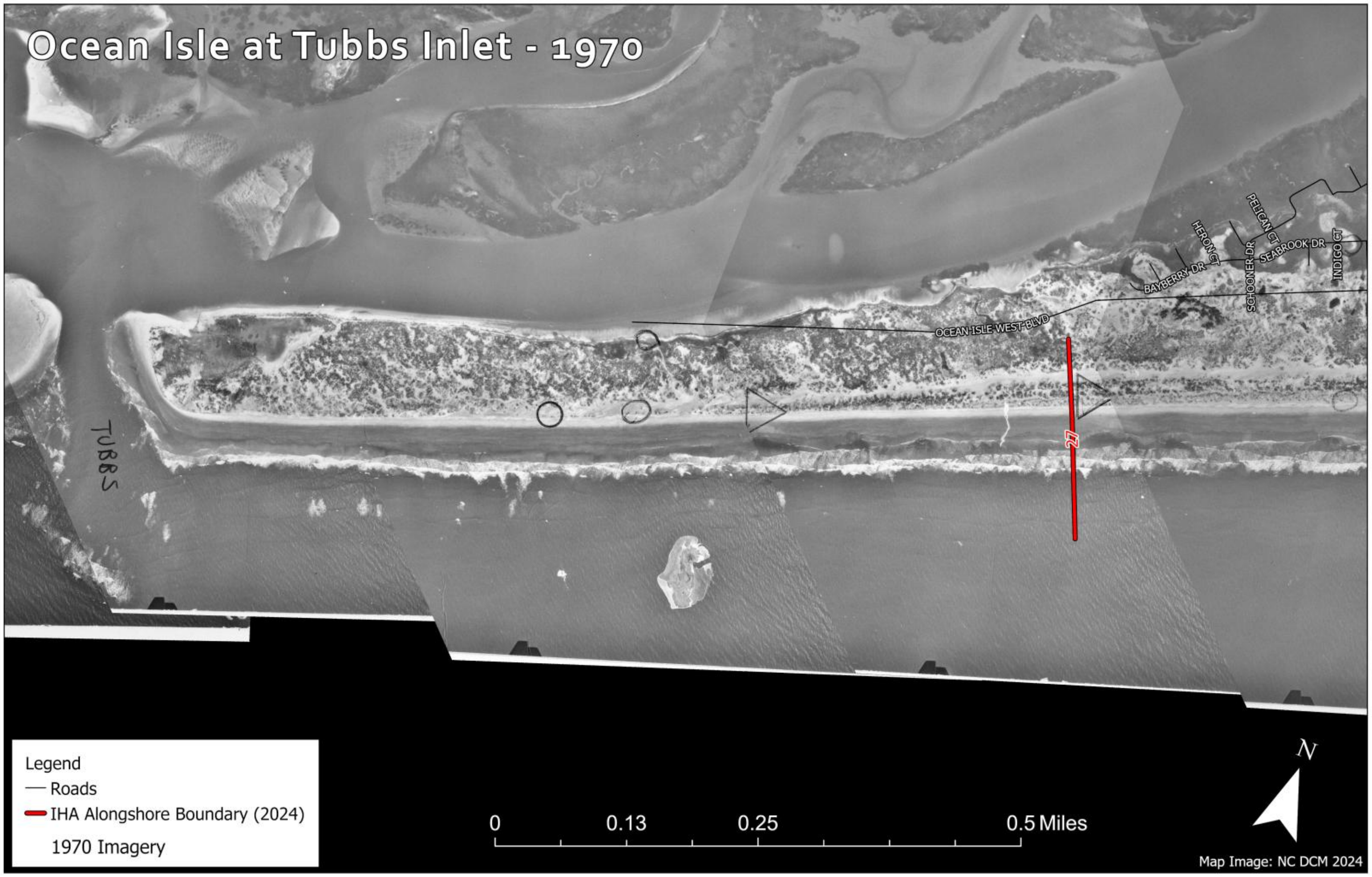

Figure D7. Tubbs Inlet at Ocean Isle in 1981, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 27 (red line).

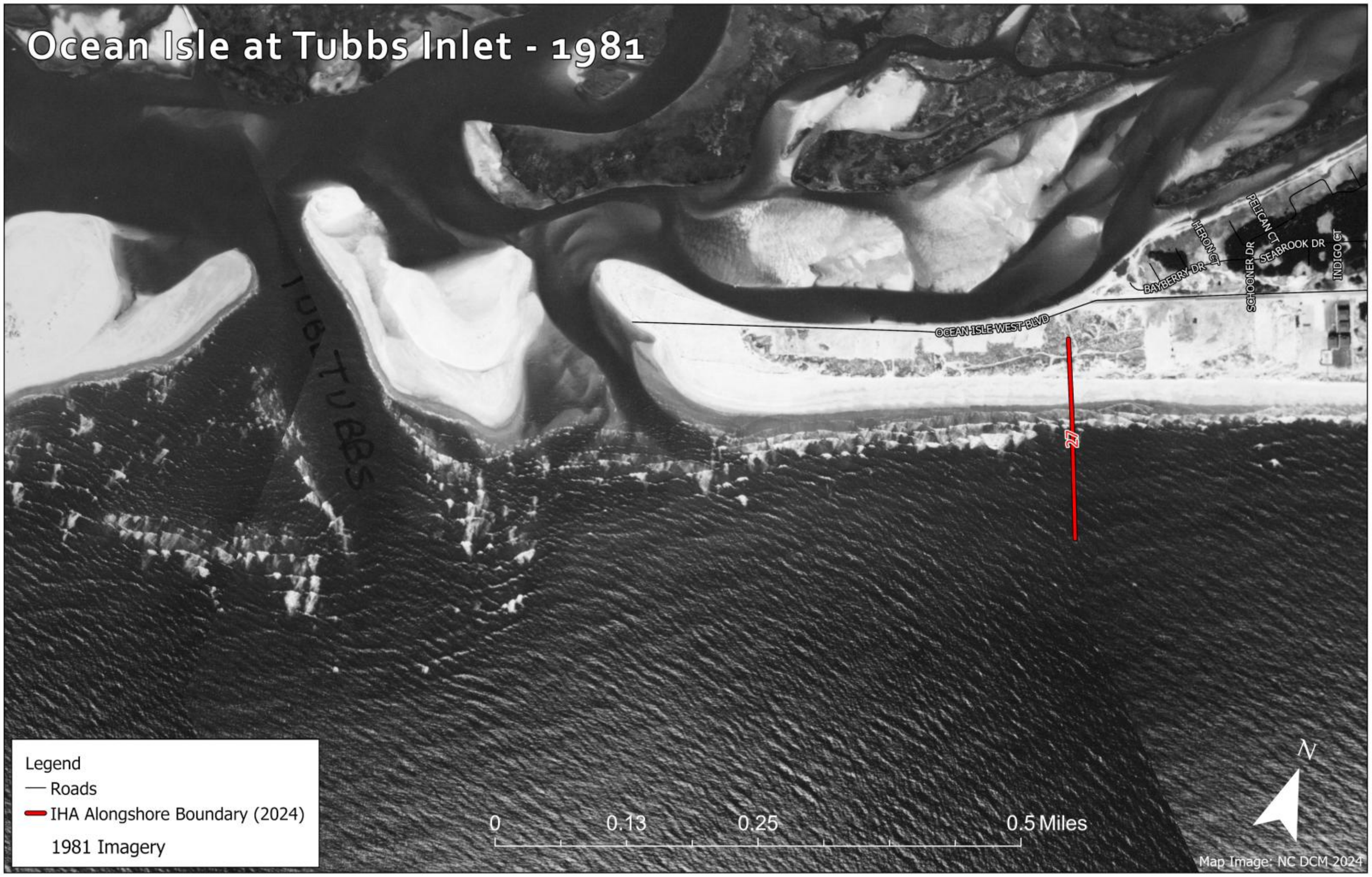

Figure D8. Tubbs Inlet at Ocean Isle in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 27 (red line).

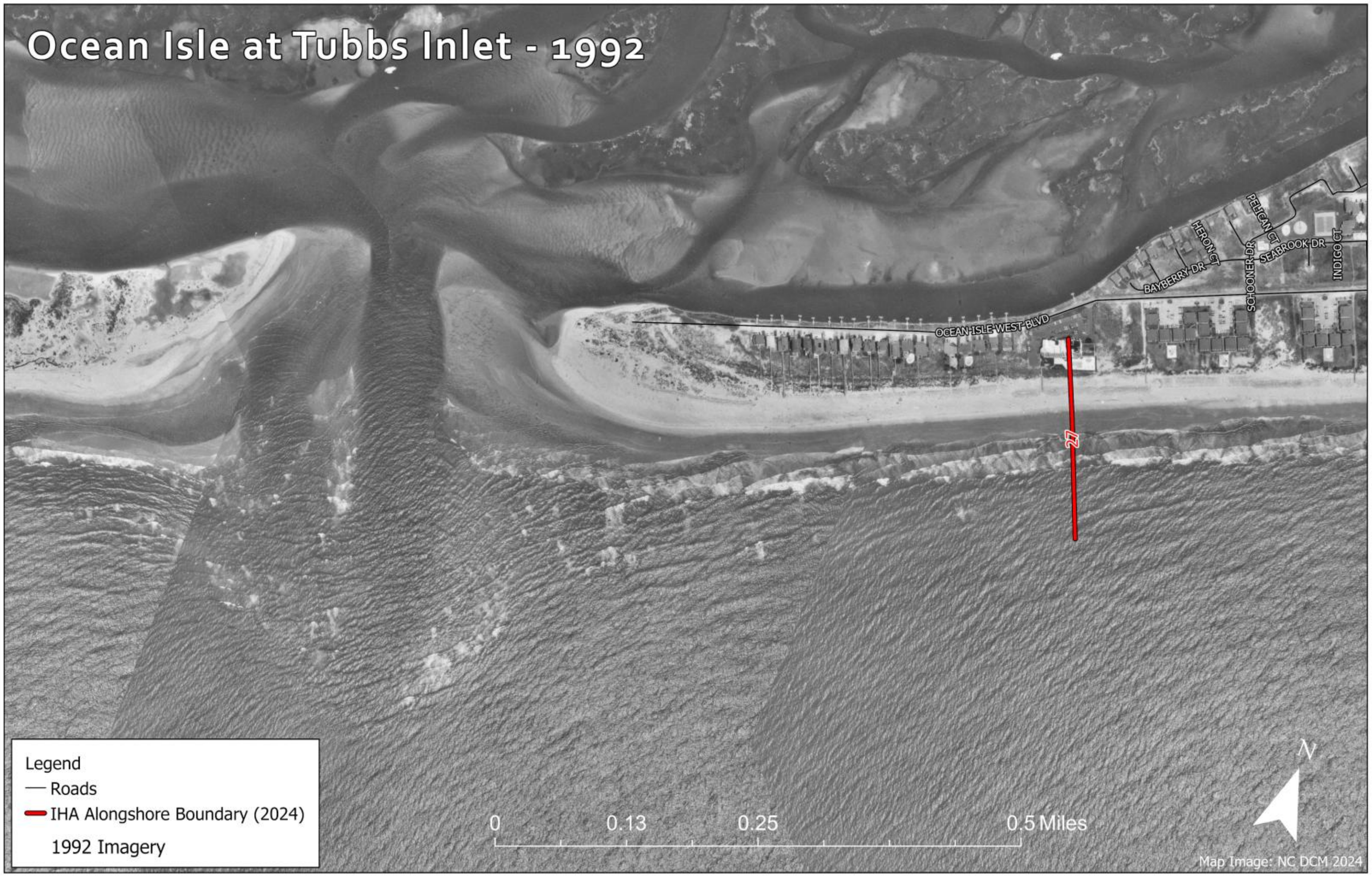

Figure D9. Tubbs Inlet at Ocean Isle 1998, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 27 (red line).

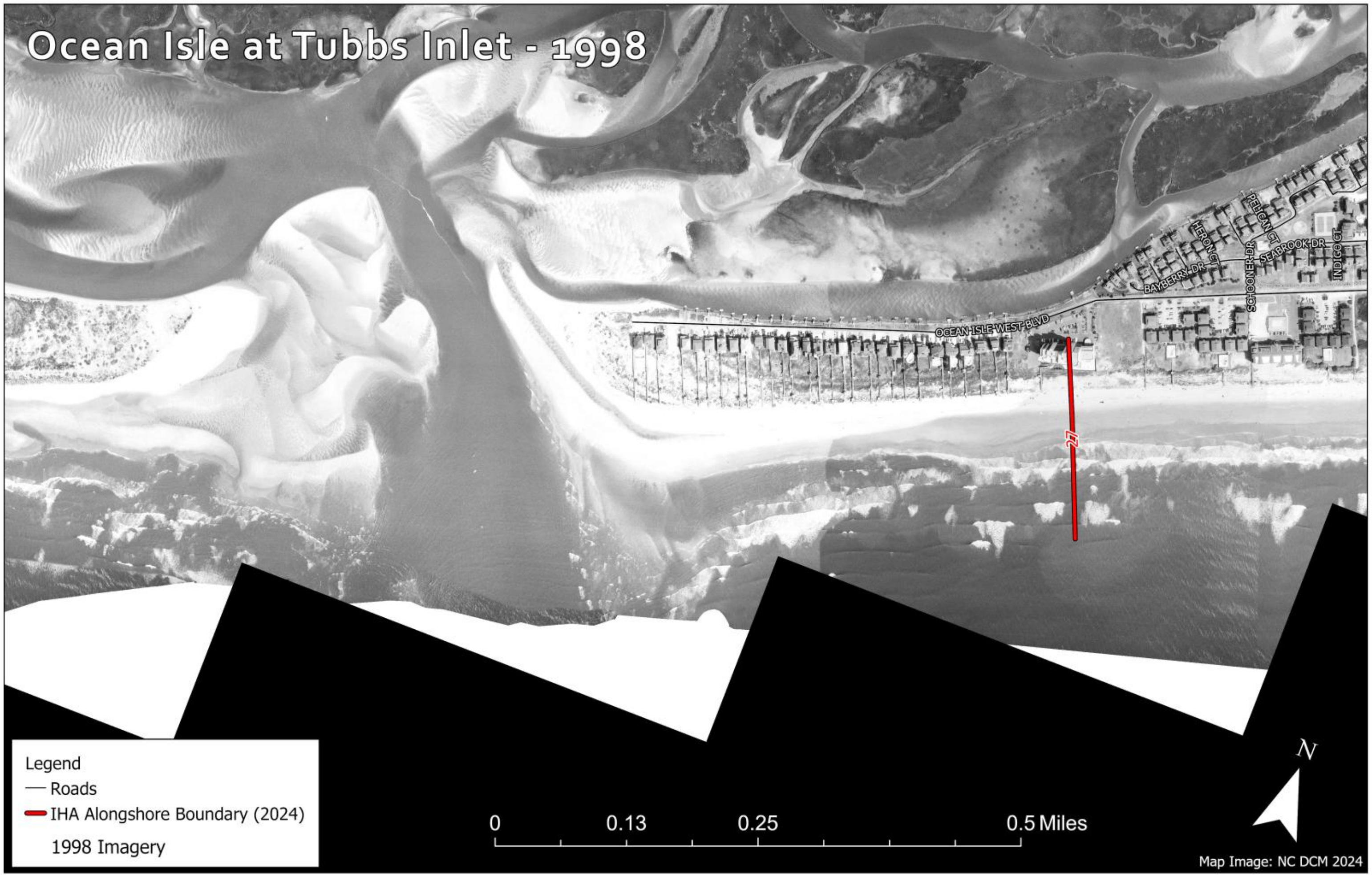

Figure D10. Tubbs Inlet at Ocean Isle in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 27 (red line).

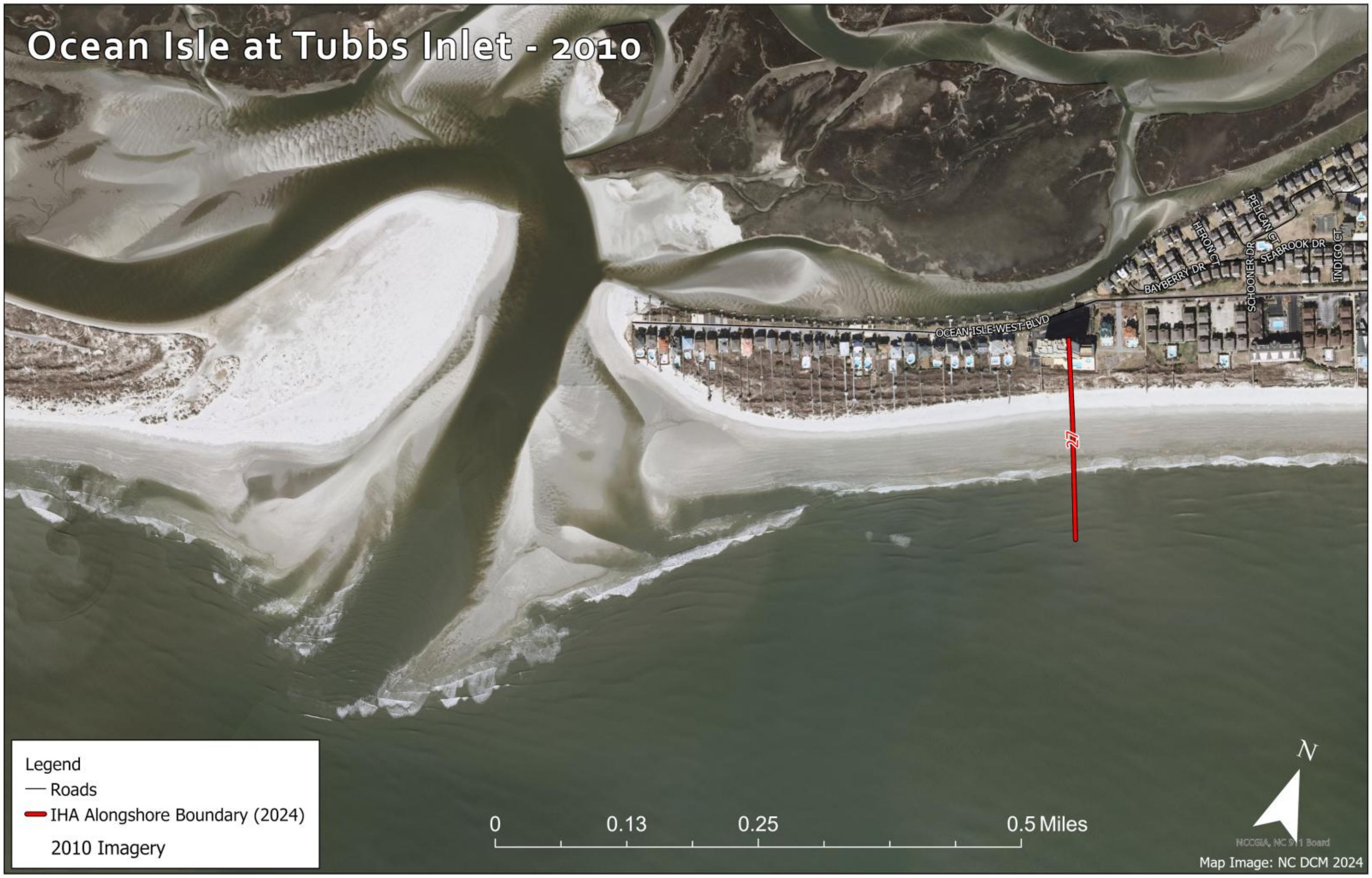

Figure D11. Tubbs Inlet at Ocean Isle in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 27 (red line).

Figure D12. Tubbs Inlet at Ocean Isle in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 27 (red line).

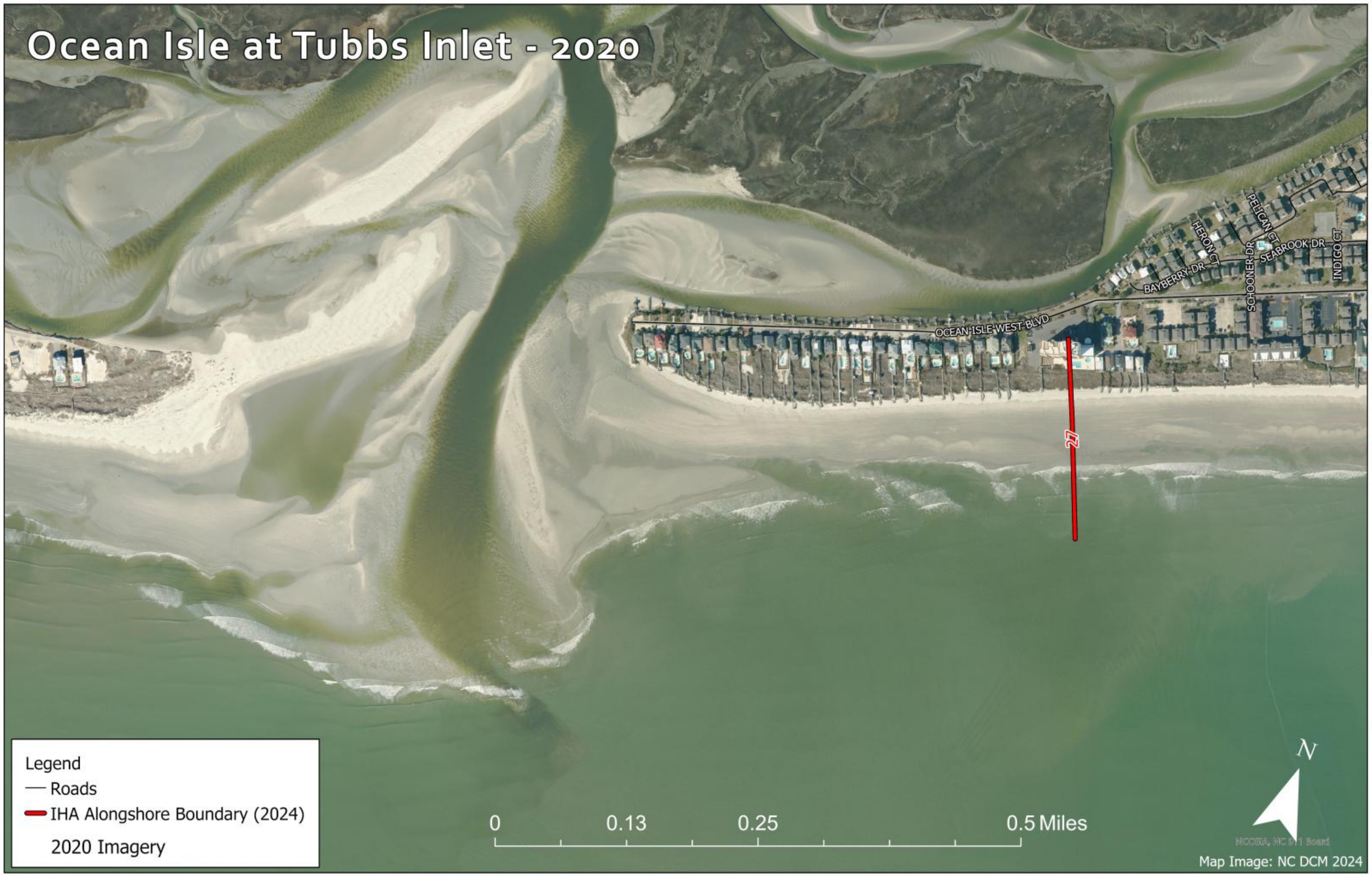

Figure D13. Tubbs Inlet at Ocean Isle in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 27 (red line).

Figure D14. Shallotte Inlet at Ocean Isle in 1970, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 296 (red line).

Figure D15. Shallotte Inlet at Ocean Isle in 1981, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 296 (red line).

Figure D16. Shallotte Inlet at Ocean Isle in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 296 (red line).

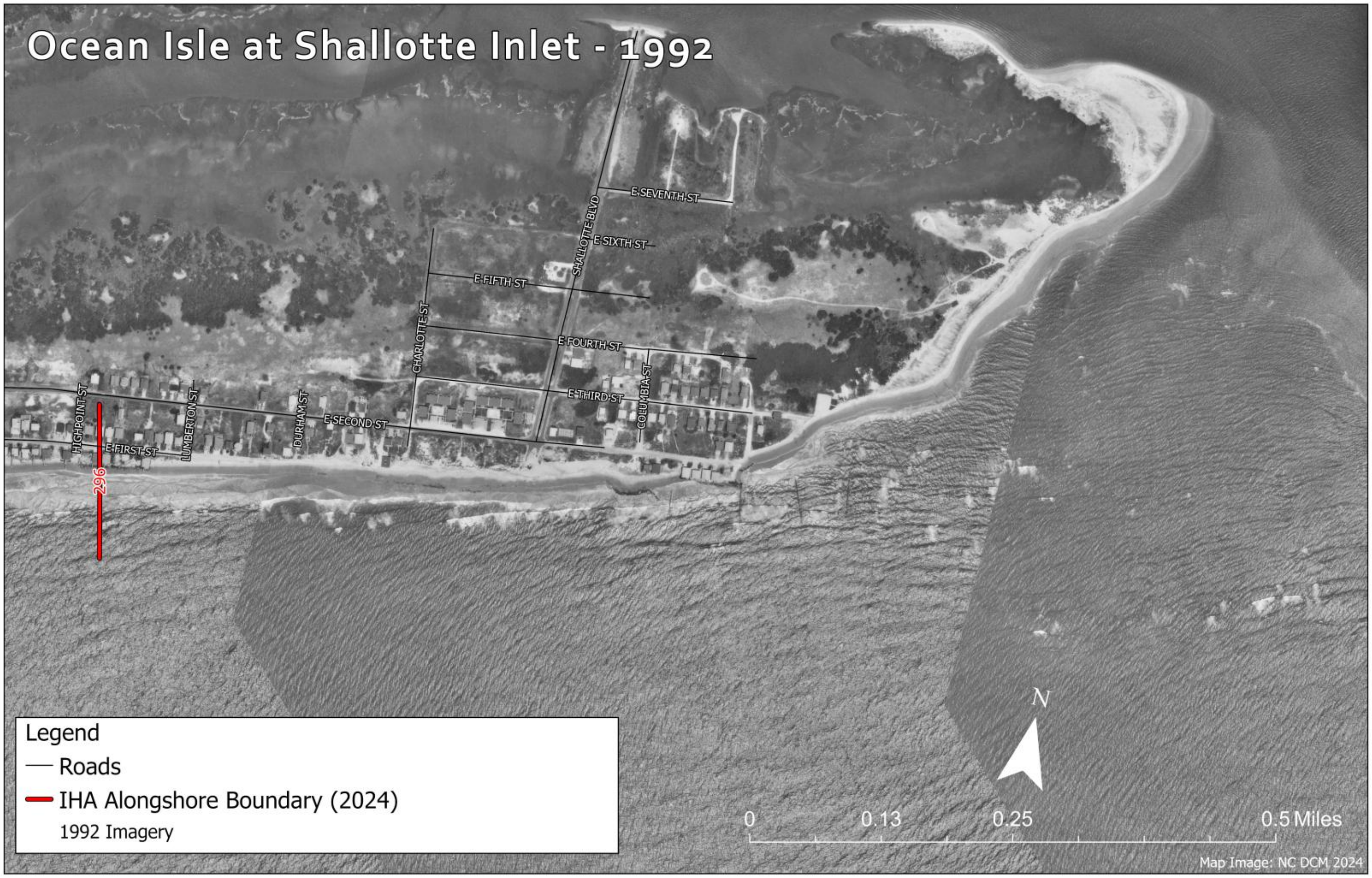

Figure D17. Shallotte Inlet at Ocean Isle in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 296 (red line).

Figure D18. Shallotte Inlet at Ocean Isle in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 296 (red line).

Figure D19. Shallotte Inlet at Ocean Isle in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 296 (red line).

Figure D20. Shallotte Inlet at Ocean Isle in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 296 (red line).

Figure D21. Shallotte Inlet at Holden Beach in 1954, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image). This image show conditions less than a month after Hurricane Hazel where a significant breach and overwash can be seen. This photo is included for reference only, as 1954 data were not used in the analysis.

Figure D22. Shallotte Inlet at Holden Beach in 1958, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image). This image shows natural recovery over the course of four years following the breach and overwash associated with Hurricane Hazael. This photo is included for reference only as 1958 data were not use in the analysis.

Figure D23. Shallotte Inlet at Holden Beach in 1970, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image). Shoaling along the oceanfront can be observed and is caused by inlet's ebb channel orientation along the shoreline.

Figure D24. Shallotte Inlet at Holden Beach in 1981, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image). Note the bulbous area of accretion along the shoreline caused by the inlet's ebb channel orientation. This illustrates an accreting beach 21 years before the installation of the first major beach nourishment project.

Figure D25. Shallotte Inlet at Holden Beach in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image), shows significant changes. Although the prominent accretion area is less noticeable due to short-term erosion and the growth of vegetation, the ebb channel along the shoreline remains visible. Additionally, gradual longshore accretion toward the alongshore IHA boundary is ongoing, indicating continued shoreline changes in this dynamic environment.

Figure D26. Shallotte Inlet at Holden Beach in 1993, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image). Although the prominent accretion area is less noticeable due to short-term erosion and the growth of vegetation, the ebb channel along the shoreline remains visible. Additionally, gradual longshore accretion toward the alongshore IHA boundary is still occurring, indicating ongoing shoreline changes in this dynamic environment.

Figure D27. Shallotte Inlet at Holden Beach in 1998, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image), shows significant accretion. Here, the prominent accretion area is more noticeable as the ebb channel continues to remain along the shoreline. Additionally, gradual longshore accretion toward the alongshore IHA boundary is still occurring, indicating ongoing shoreline changes in this dynamic environment without any influences of beach nourishment.

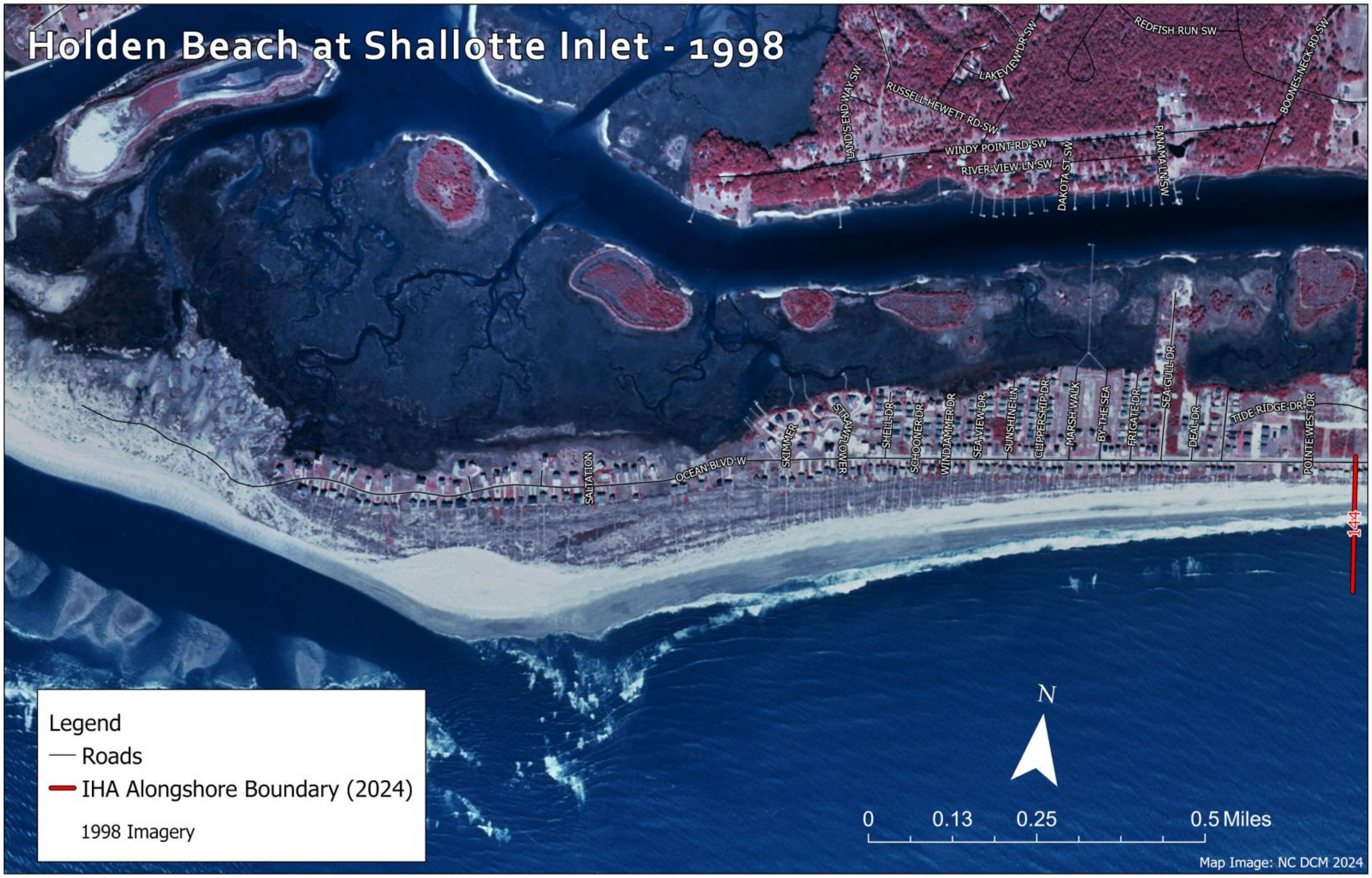

Figure D28. Shallotte Inlet at Holden Beach in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image).

Figure D29. Shallotte Inlet at Holden Beach in 2012, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image).

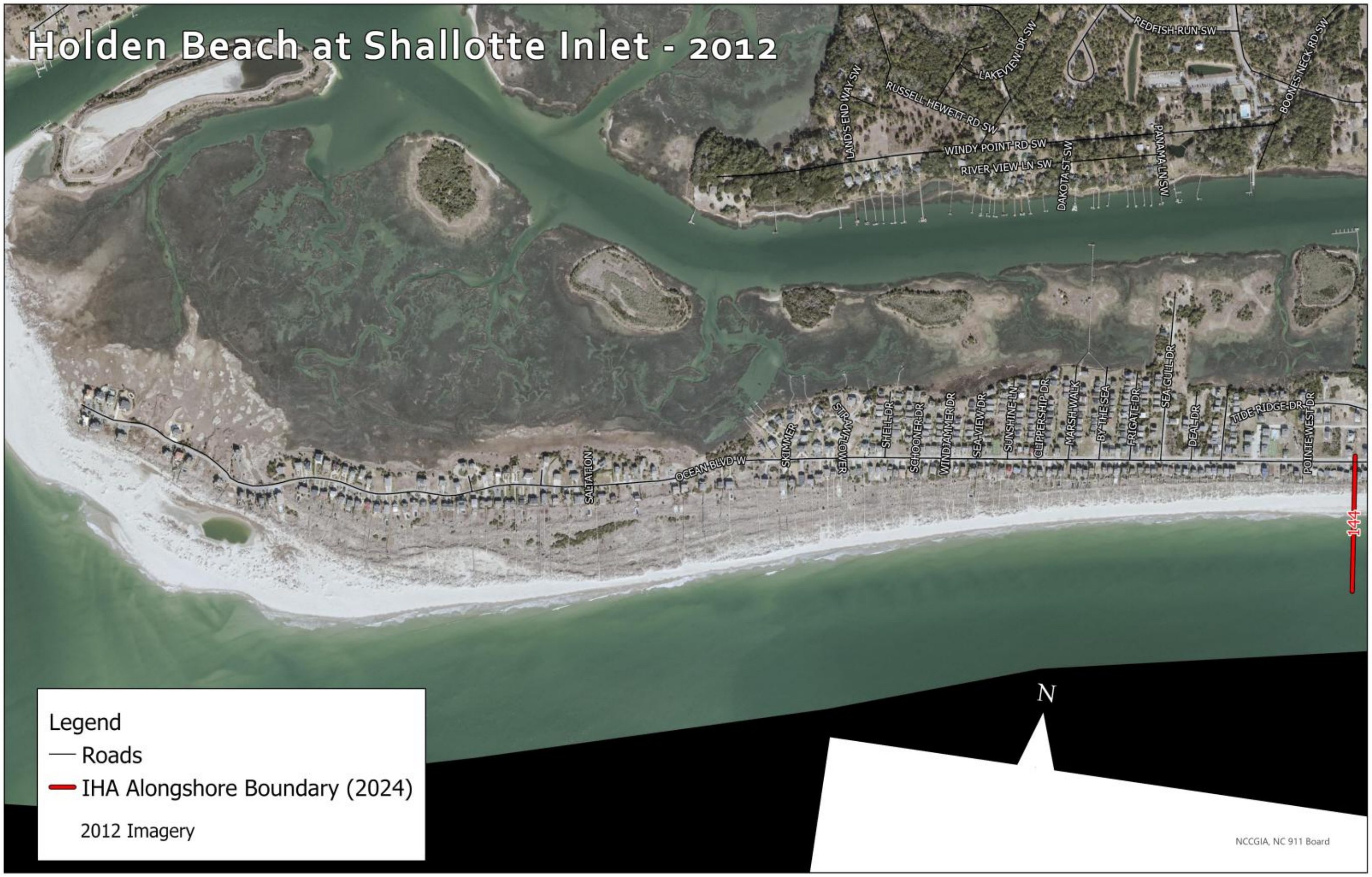

Figure D30. Shallotte Inlet at Holden Beach in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image).

Figure D31. Shallotte Inlet at Holden Beach in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image).

Figure D32. Shallotte Inlet at Holden Beach in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 144 (marked by the red line on the right edge of the image).

Figure D33. Lockwood Folly Inlet at Holden Beach in 1971, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 478 (red line).

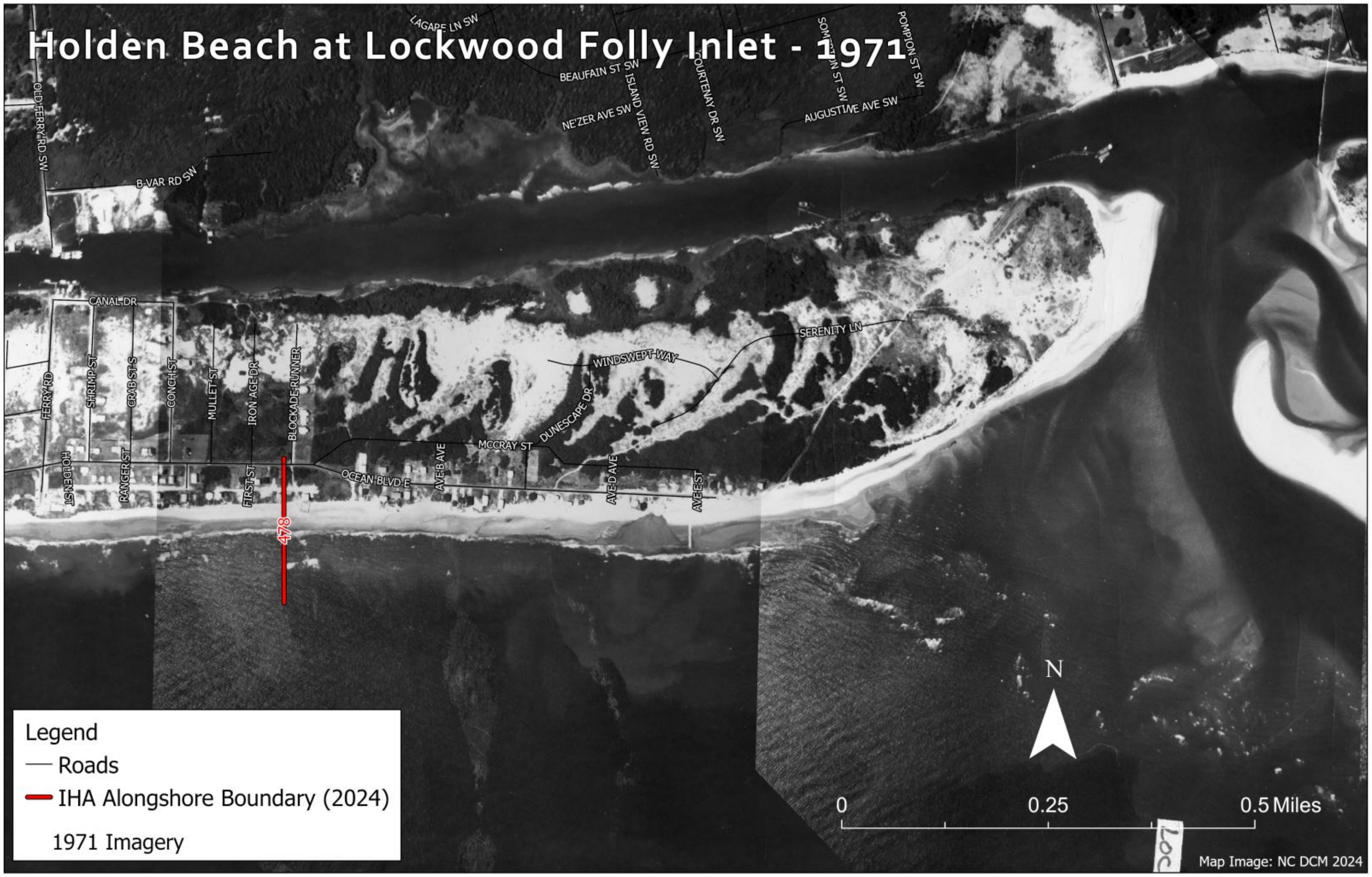

Figure D34. Lockwood Folly Inlet at Holden Beach in 1978, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 478 (red line).

Figure D35. Lockwood Folly Inlet at Holden Beach in 1988, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 478 (red line).

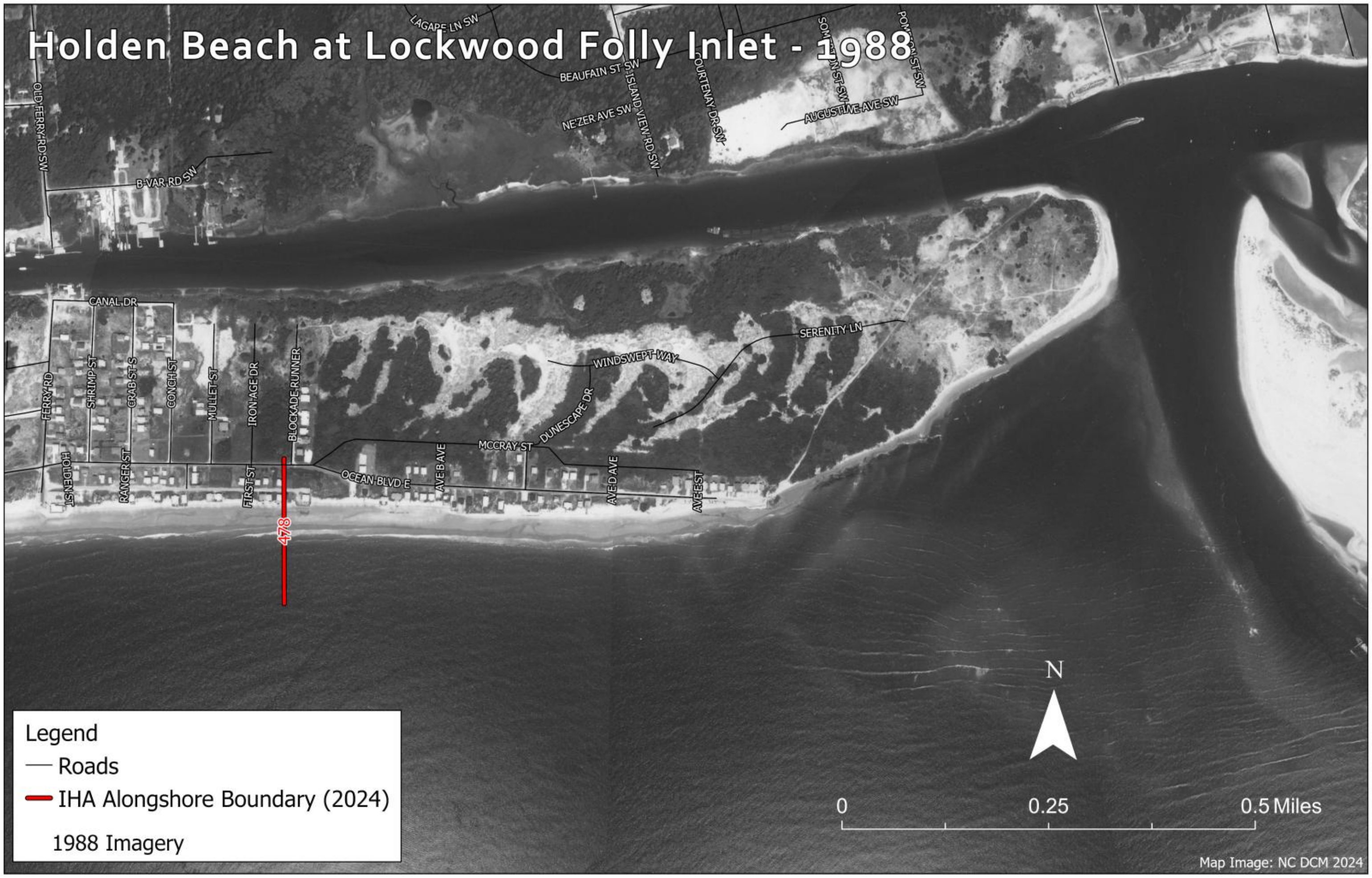

Figure D36. Lockwood Folly Inlet at Holden Beach in 1993, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 478 (red line).

Figure D37. Lockwood Folly Inlet at Holden Beach in 1998, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 478 (red line).

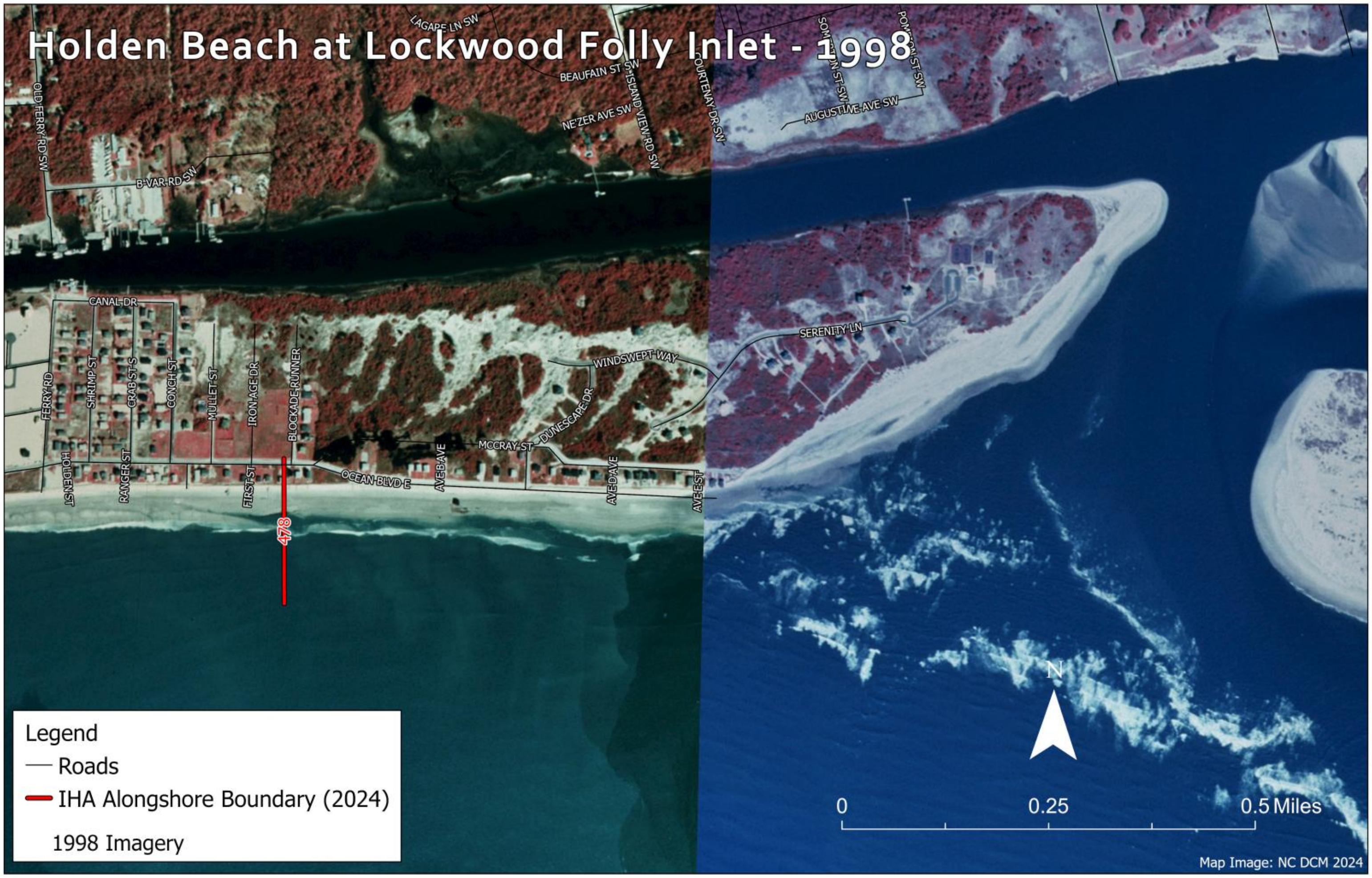

Figure D38. Lockwood Folly Inlet at Holden Beach in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit transect 478 (red line).

Figure D39. Lockwood Folly Inlet at Holden Beach in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 478 (red line).

Figure D40. Lockwood Folly Inlet at Holden Beach in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 478 (red line).

Figure D41. Lockwood Folly Inlet at Holden Beach in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 478 (red line).

Figure D42. Lockwood Folly Inlet at Oak Island in 1971, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D43. Lockwood Folly Inlet at Oak Island in 1978, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D44. Lockwood Folly Inlet at Oak Island in 1988, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D45. Lockwood Folly Inlet at Oak Island in 1993, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D46. Lockwood Folly Inlet at Oak Island in 1998, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D47. Lockwood Folly Inlet at Oak Island in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D48. Lockwood Folly Inlet at Oak Island in 2012, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D49. Lockwood Folly Inlet at Oak Island in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D50. Lockwood Folly Inlet at Oak Island in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D51. Lockwood Folly Inlet at Oak Island in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 81 (red line).

Figure D52. Carolina Beach Inlet at Carolina Beach in 1971, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 2119 (red line).

Figure D53. Carolina Beach Inlet at Carolina Beach in 1974, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 2119 (red line).

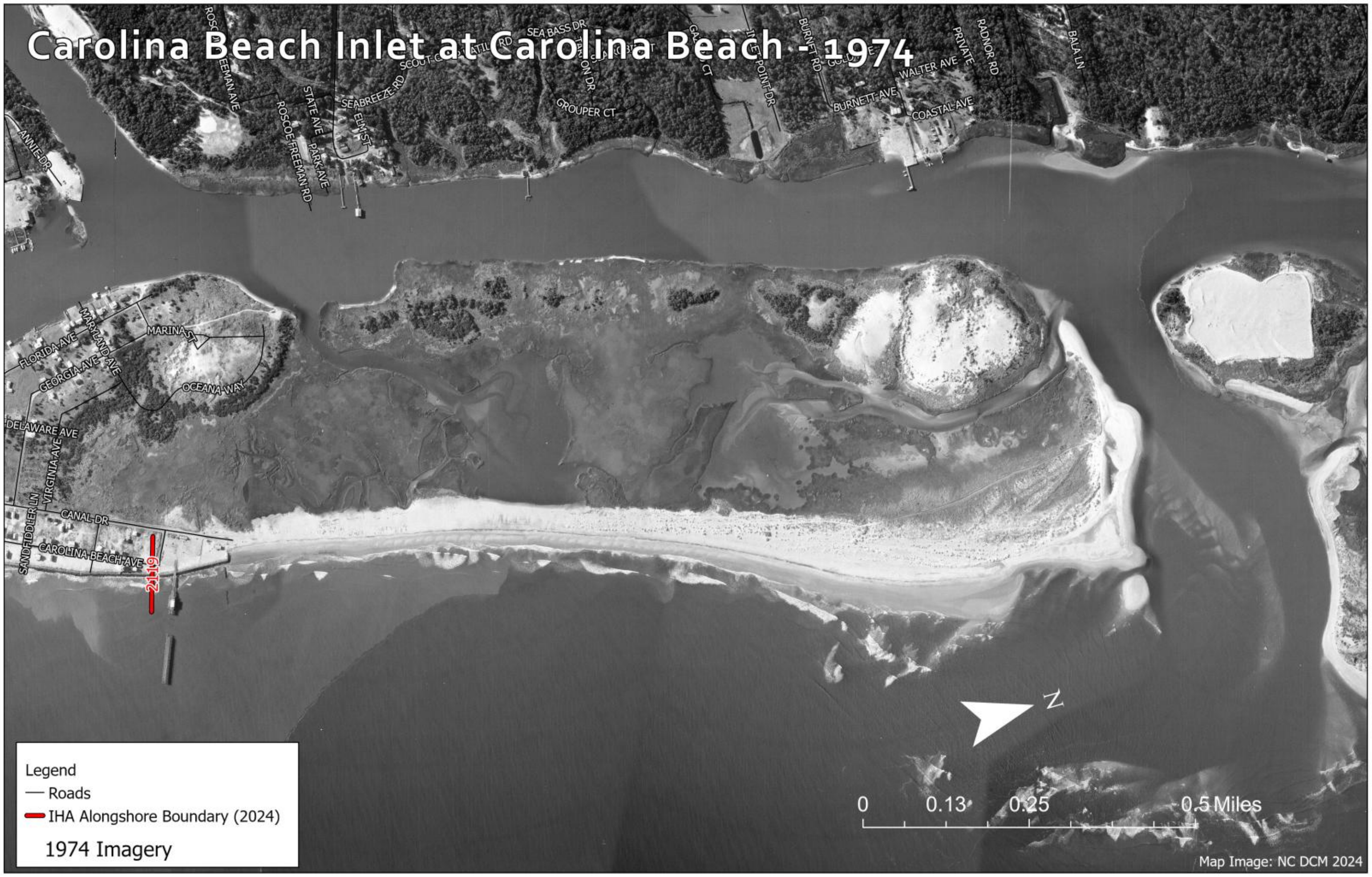

Figure D54. Carolina Beach Inlet at Carolina Beach in 1977, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 2119 (red line).

Figure D55. Carolina Beach Inlet at Carolina Beach in 1984, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 2119 (red line).

Figure D56. Carolina Beach Inlet at Carolina Beach in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 2119 (red line).

Figure D57. Carolina Beach Inlet at Carolina Beach in 1998, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 2119 (red line).

Figure D58. Carolina Beach Inlet at Carolina Beach in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 2119 (red line).

Figure D59. Carolina Beach Inlet at Carolina Beach in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 2119 (red line).

Figure D60. Carolina Beach Inlet at Carolina Beach in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit transect 2119 (red line).

Figure D61. Carolina Beach Inlet at Carolina Beach in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 2119 (red line).

Figure D62. Carolina Beach Inlet at Masonboro Island in 1971.

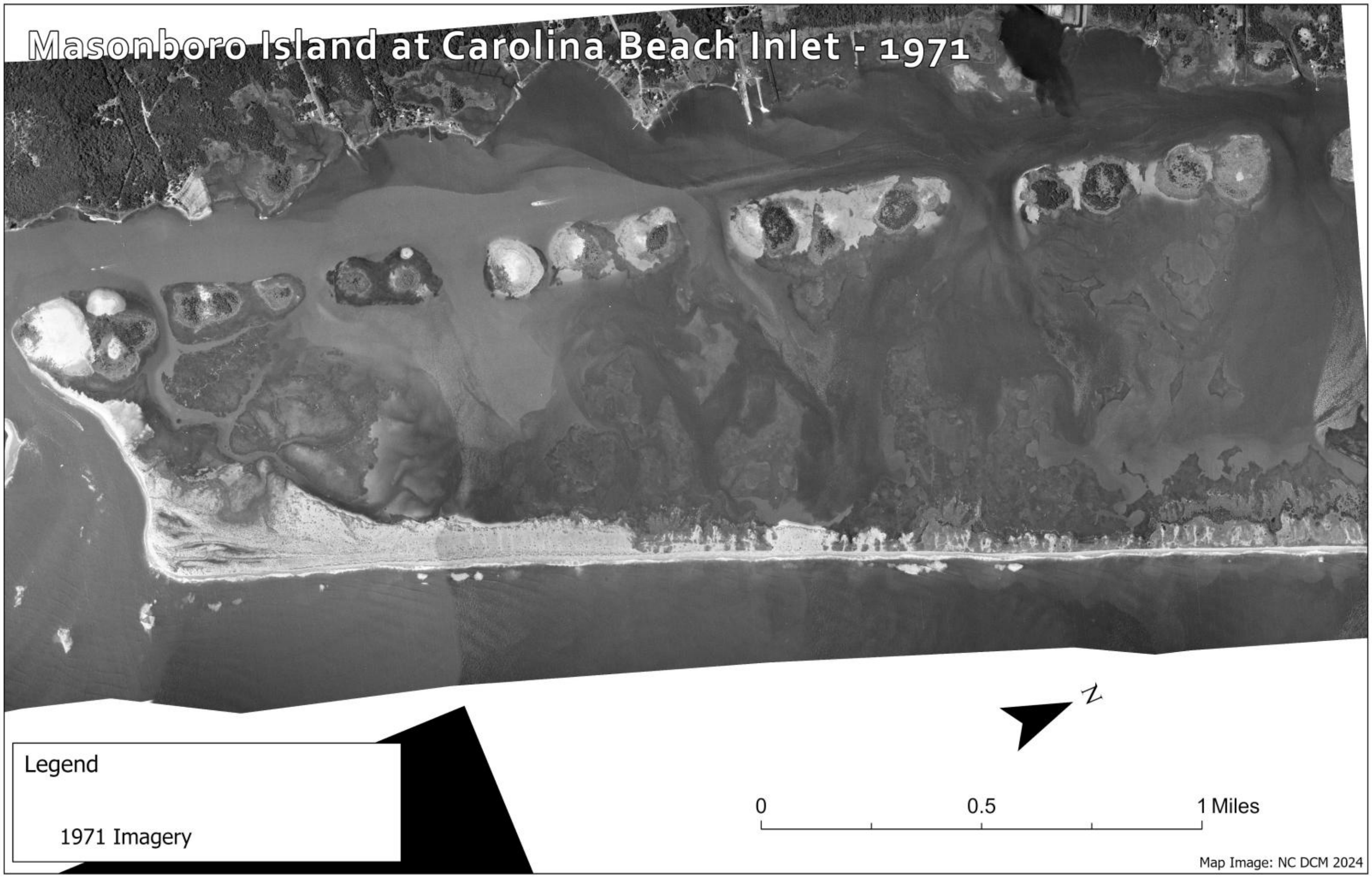

Figure D63. Carolina Beach Inlet at Masonboro Island in 1984.

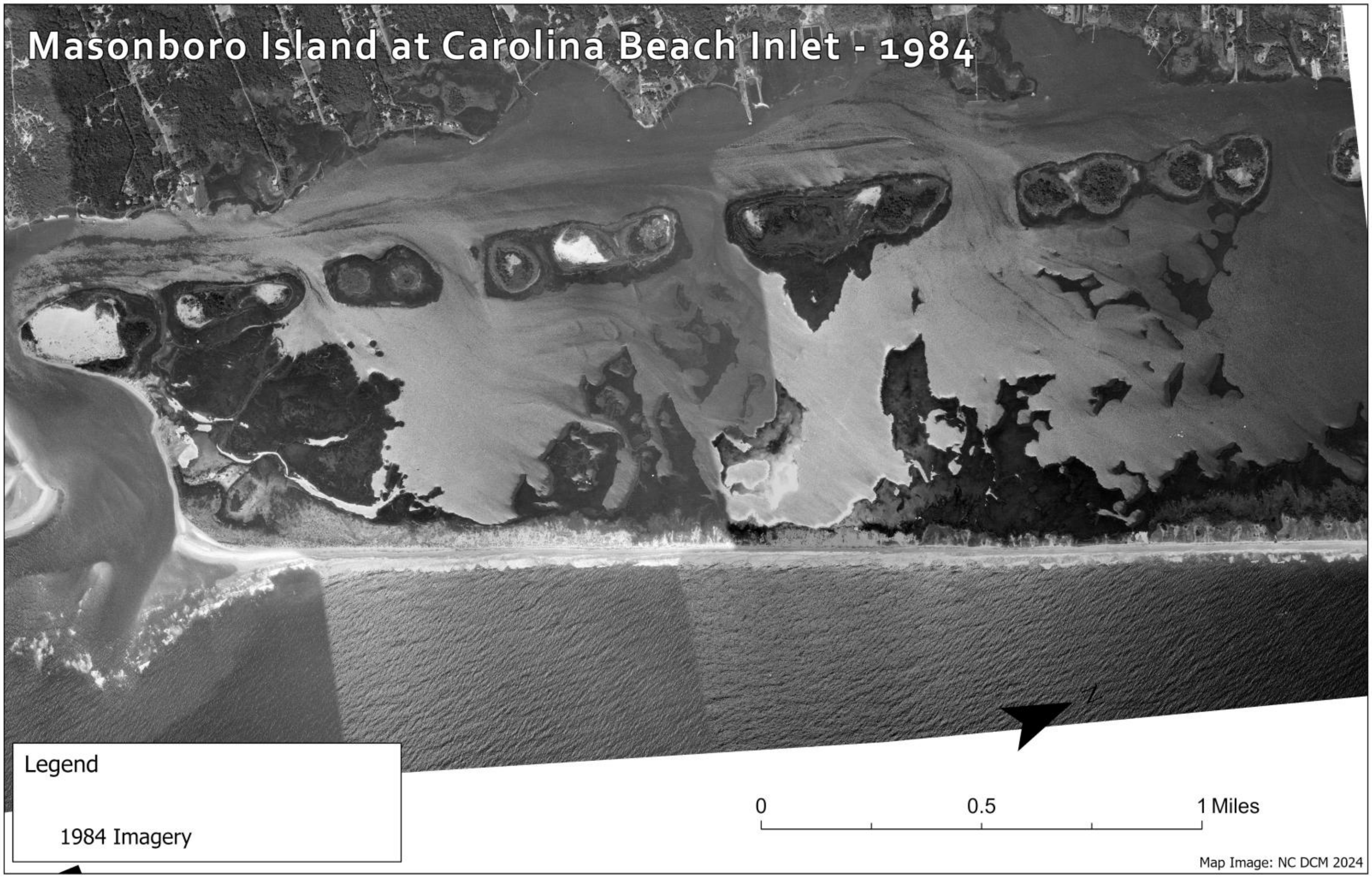

Figure D64. Carolina Beach Inlet at Masonboro Island in 1993.

Figure D65. Carolina Beach Inlet at Masonboro Island in 1998.

Figure D66. Carolina Beach Inlet at Masonboro Island in 2010.

Figure D67. Carolina Beach Inlet at Masonboro Island in 2020.

Figure D68. Carolina Beach Inlet at Masonboro Island in 2023.

Figure D69. Masonboro Inlet at Masonboro Island in 1974.

Figure D70. Masonboro Inlet at Masonboro Island in 1977.

Figure D71. Masonboro Inlet at Masonboro Island in 1984.

Figure D72. Masonboro Inlet at Masonboro Island in 1998.

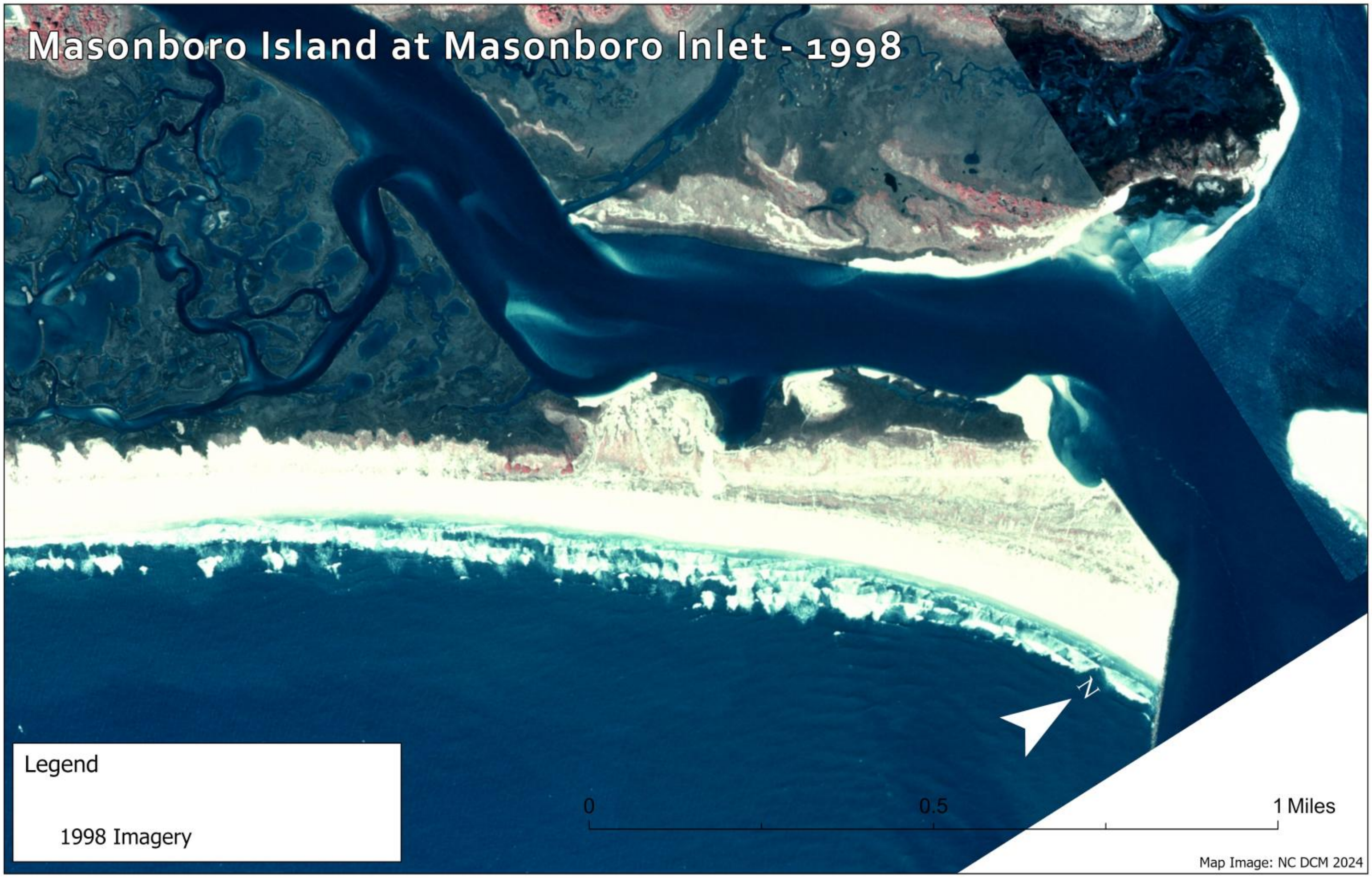

Figure D73. Masonboro Inlet at Masonboro Island in 2010.

Figure D74. Masonboro Inlet at Masonboro Island in 2020.

Figure D75. Masonboro Inlet at Masonboro Island in 2023.

Figure D76. Masonboro Inlet at Wrightsville Beach in 1974, shown relative to the 2024-2025 alongshore IHA boundary limit at the navigation jetty (red line).

Figure D77. Masonboro Inlet at Wrightsville Beach in 1977, shown relative to the 2024-2025 alongshore IHA boundary limit at the navigation jetty (red line).

Figure D78. Masonboro Inlet at Wrightsville Beach in 1984, shown relative to the 2024-2025 alongshore IHA boundary limit at the navigation jetty (red line).

Figure D79. Masonboro Inlet at Wrightsville Beach in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit at the navigation jetty (red line).

Figure D80. Masonboro Inlet at Wrightsville Beach in 2001, shown relative to the 2024-2025 alongshore IHA boundary limit at the navigation jetty (red line).

Figure D81. Masonboro Inlet at Wrightsville Beach in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at the navigation jetty (red line).

Figure D82. Masonboro Inlet at Wrightsville Beach in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at the navigation jetty (red line).

Figure D83. Masonboro Inlet at Wrightsville Beach in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit at the navigation jetty (red line).

Figure D84. Masonboro Inlet at Wrightsville Beach in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at the navigation jetty (red line).

Figure D85. Mason Inlet at Wrightsville Beach in 1971, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit at transect 249 (red line).

Figure D86. Mason Inlet at Wrightsville Beach in 1977, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit at transect 249 (red line).

Figure D87. Mason Inlet at Wrightsville Beach in 1987, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit at transect 249 (red line).

Figure D88. Mason Inlet at Wrightsville Beach in 1992, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit at transect-249 (red line).

Figure D89. Mason Inlet at Wrightsville Beach in 1998, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit at transect-249 (red line).

Figure D90. Mason Inlet at Wrightsville Beach in 2002, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit at transect 249 (red line).

Figure D91. Mason Inlet at Wrightsville Beach in 2010, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit at transect 249 (red line).

Figure D92. Mason Inlet at Wrightsville Beach in 2016, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit at transect-249 (red line).

Figure D93. Mason Inlet at Wrightsville Beach in 2023, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit at transect 249 (red line).

Figure D94. Mason Inlet at Figure Eight Island (right) in 1971, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit (red line).

Figure D95. Mason Inlet at Figure Eight Island (right) in 1977, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit (red line).

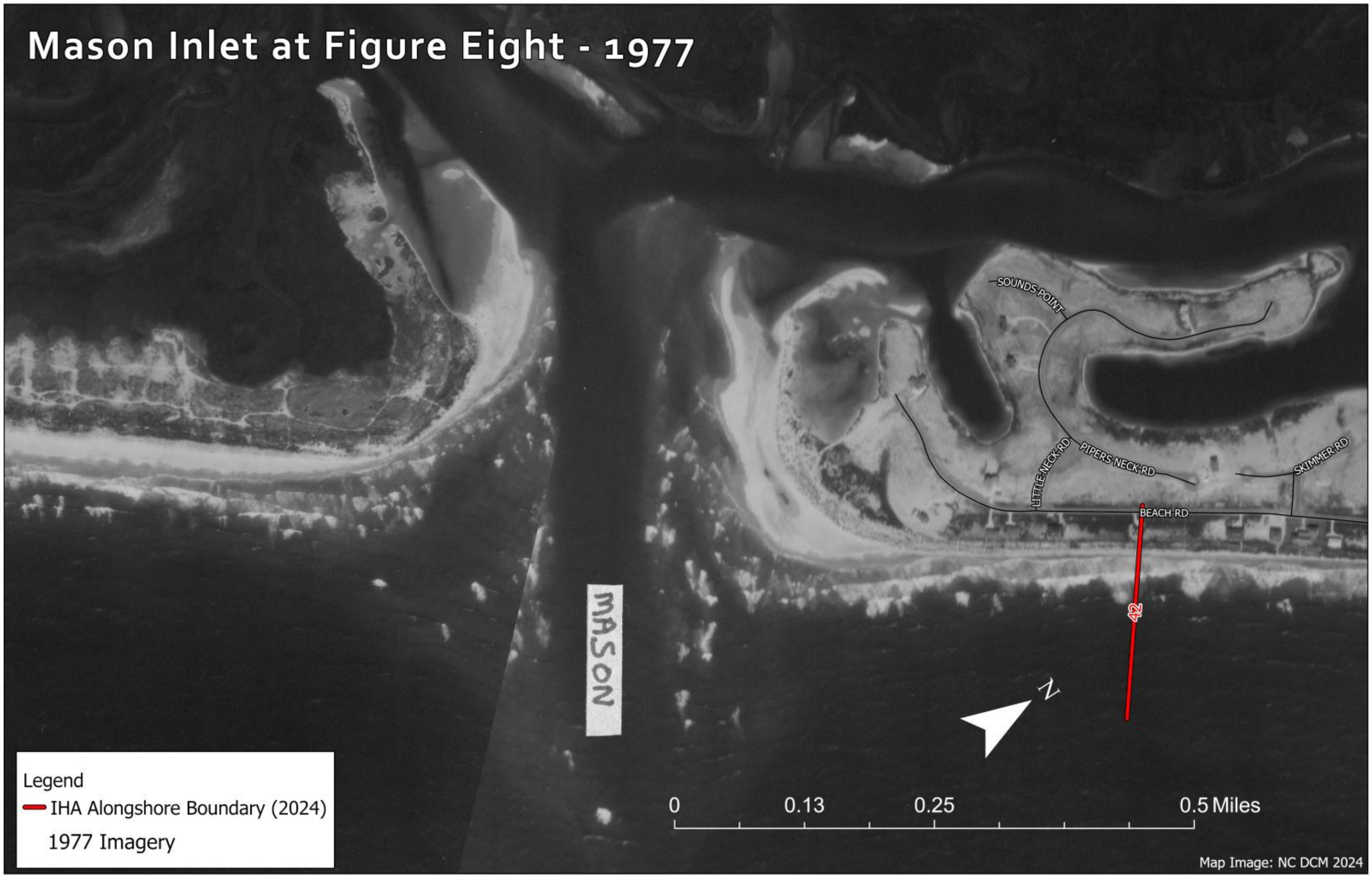

Figure D96. Mason Inlet at Figure Eight Island in 1992, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit (red line).

Figure D97. Mason Inlet at Figure Eight Island in 1998, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit (red line).

Figure D98. Mason Inlet at Figure Eight Island in 2002, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit (red line).

Figure D99. Mason Inlet at Figure Eight Island in 2010, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit (red line).

Figure D100. Mason Inlet at Figure Eight Island in 2016, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit (red line).

Figure D101. Mason Inlet at Figure Eight Island in 2020, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit (red line).

Figure D102. Mason Inlet at Figure Eight Island in 2023, shown relative to the Science Panel's 2024-2025 alongshore IHA boundary limit (red line).

Figure D103. Rich Inlet at Figure Eight Island in 1938, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line). This image is provided for reference only as 1938 data were not used in this study.

Figure D104. Rich Inlet at Figure Eight Island in 1958, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line). This image is provided for reference only as 1958 data were not used in this study.

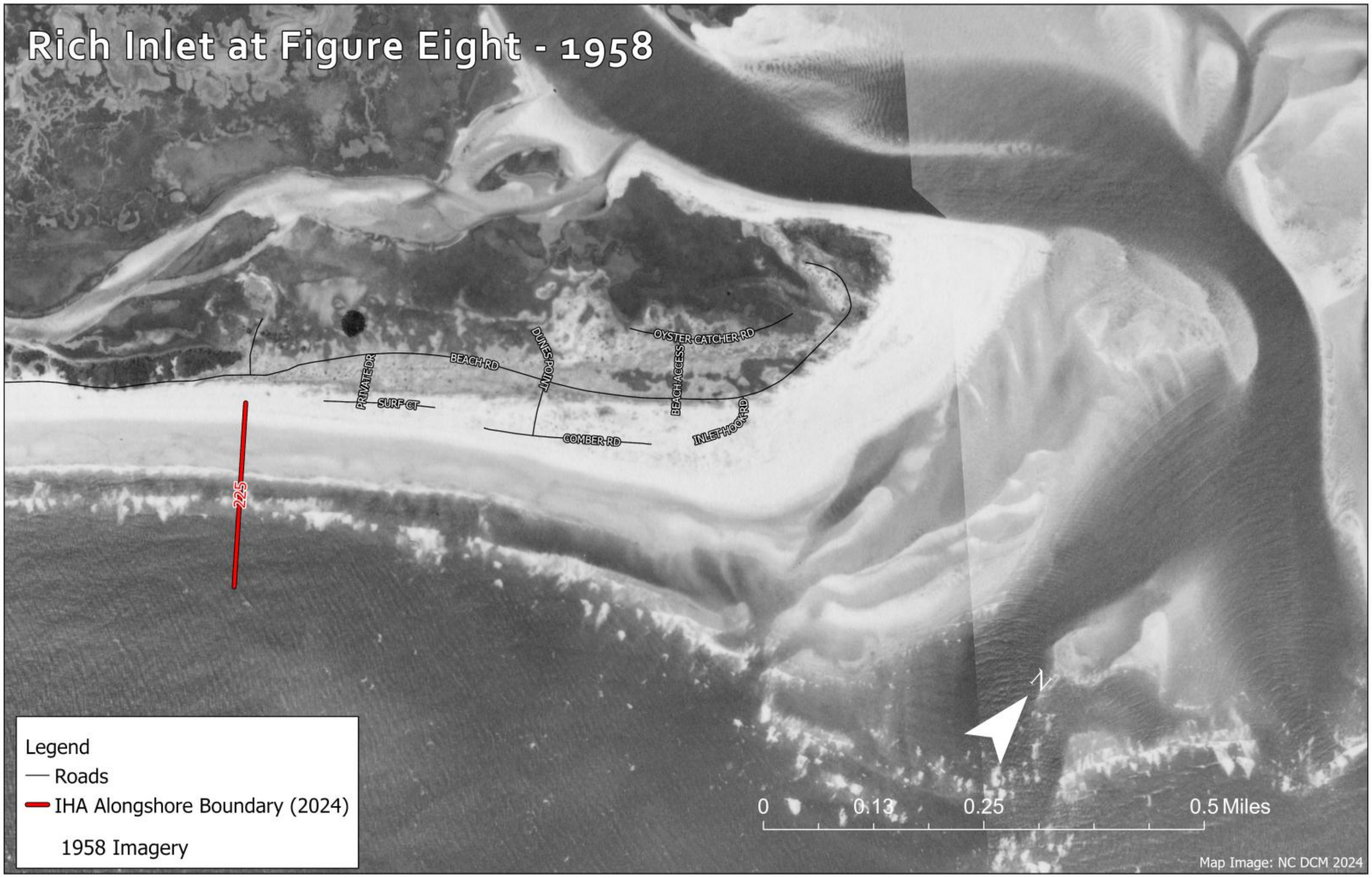

Figure D105. Rich Inlet at Figure Eight Island in 1980, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line).

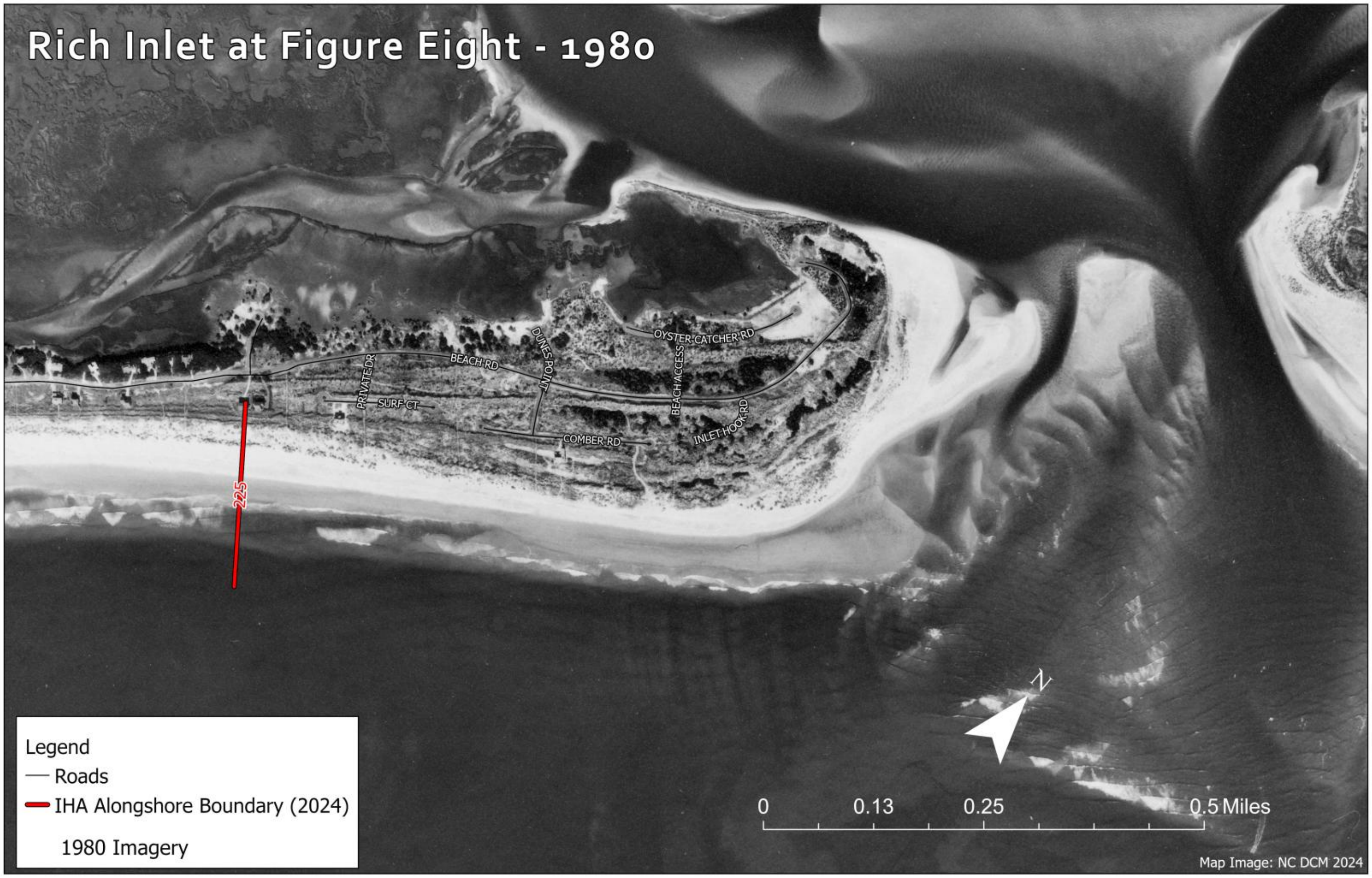

Figure D106. Rich Inlet at Figure Eight Island in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line).

Figure D107. Rich Inlet at Figure Eight Island in 1998, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line).

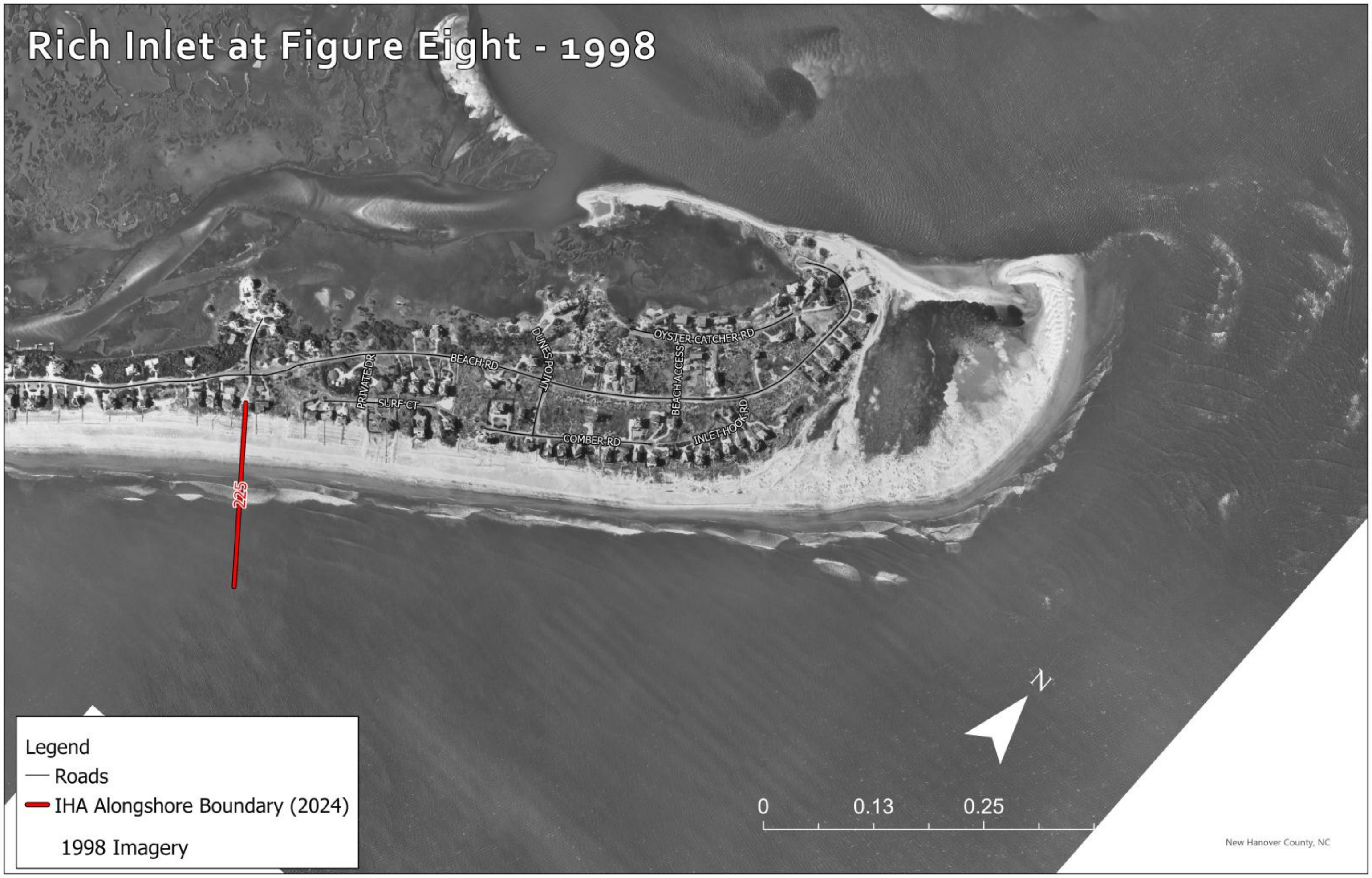

Figure D108. Rich Inlet at Figure Eight Island in 2002, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line).

Figure D109. Rich Inlet at Figure Eight Island in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line).

Figure 110. Rich Inlet at Figure Eight Island in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line).

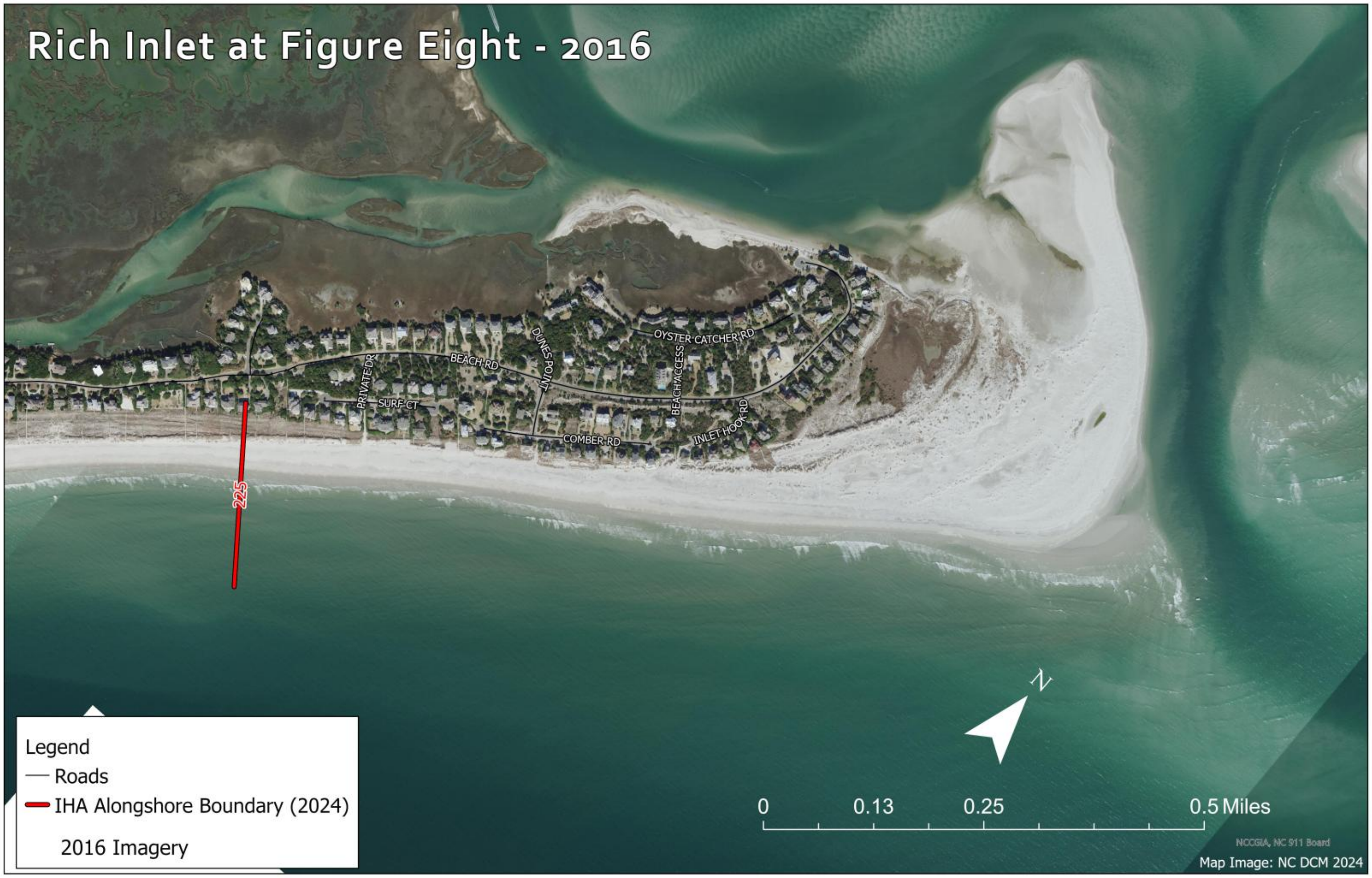

Figure D111. Rich Inlet at Figure Eight Island in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line).

Figure D112. Rich Inlet at Figure Eight Island in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 225 (red line).

Figure D113. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 1971, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

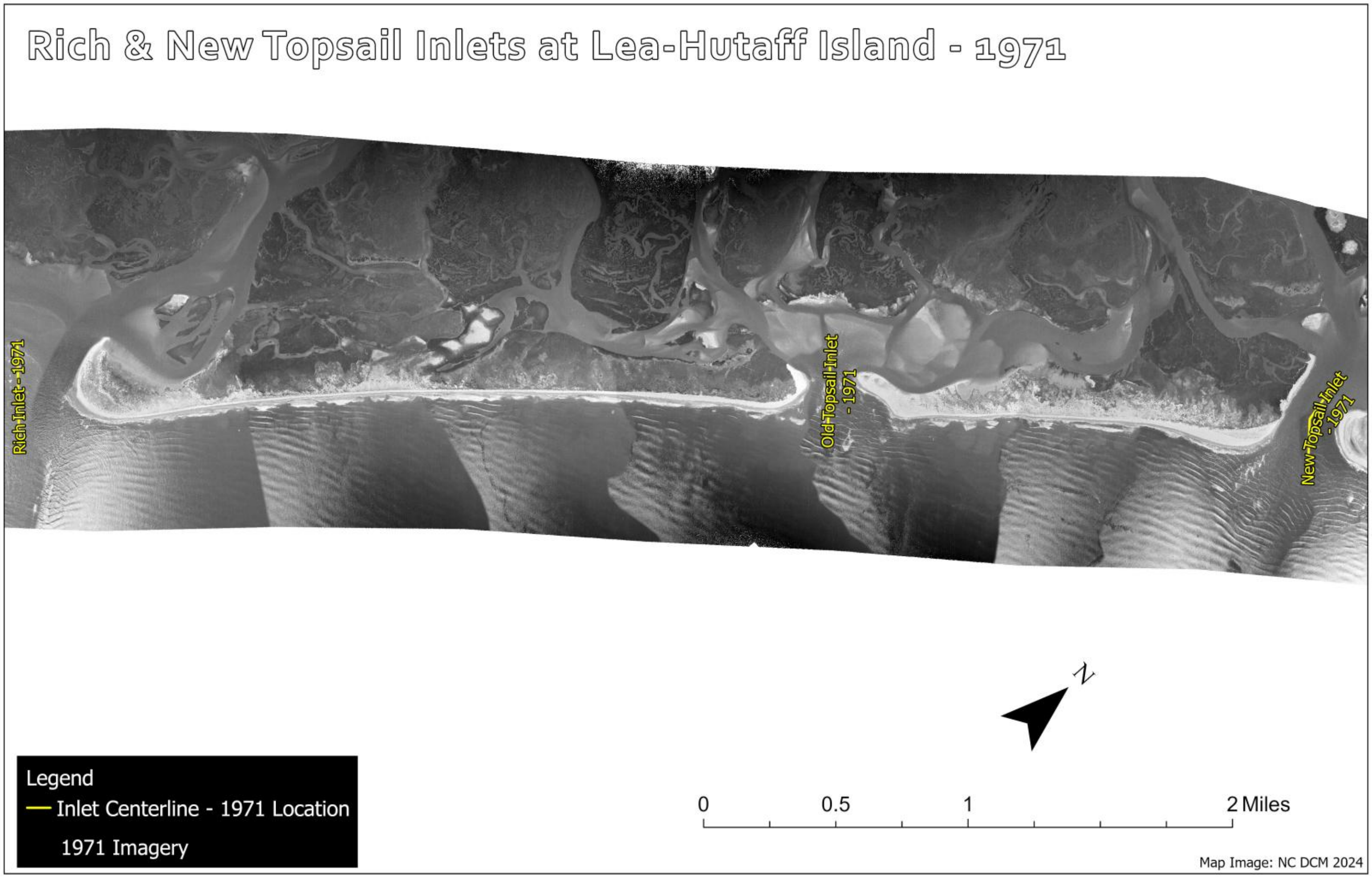

Figure D114. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 1974, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

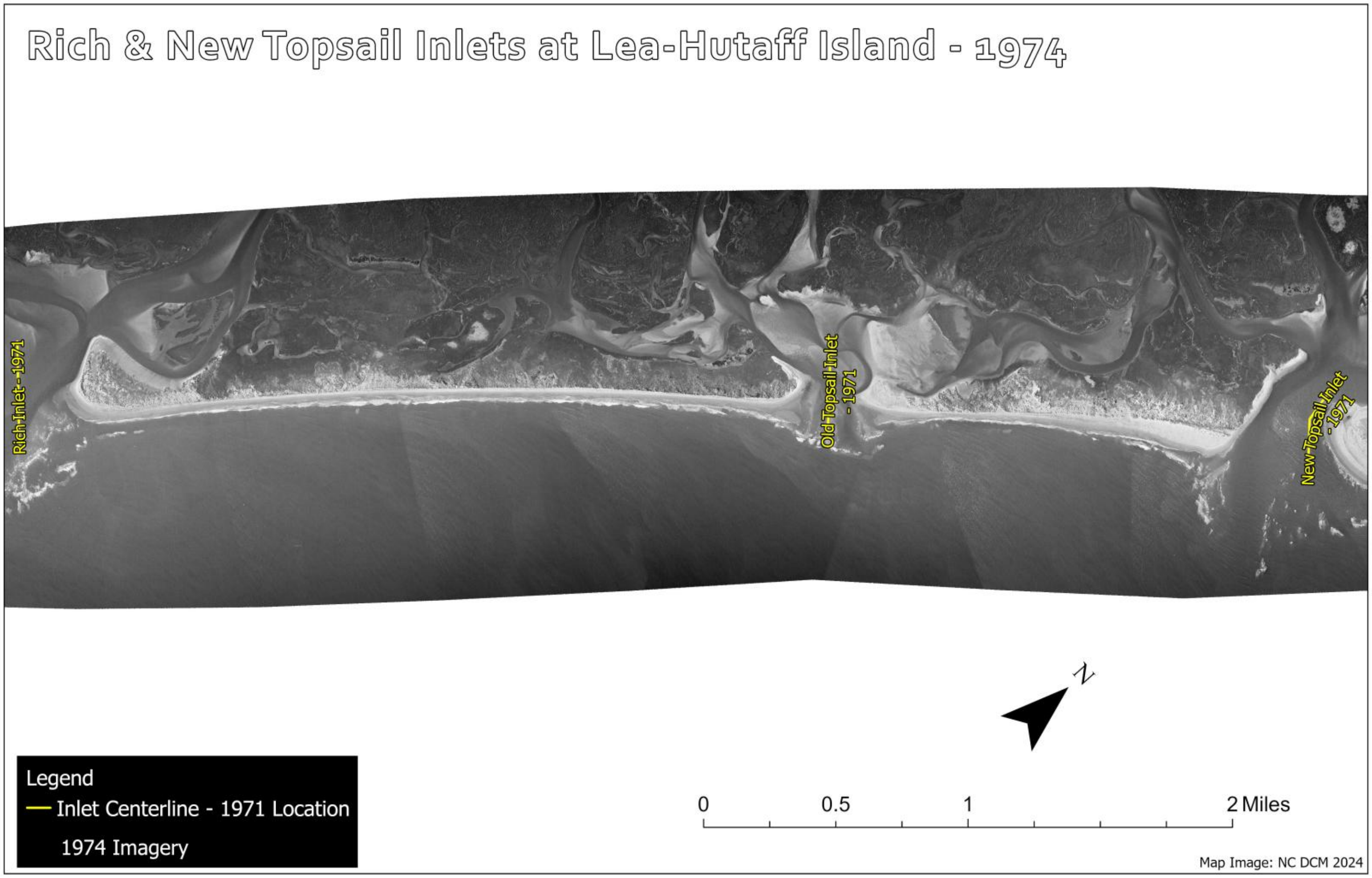

Figure D115. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 1977, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

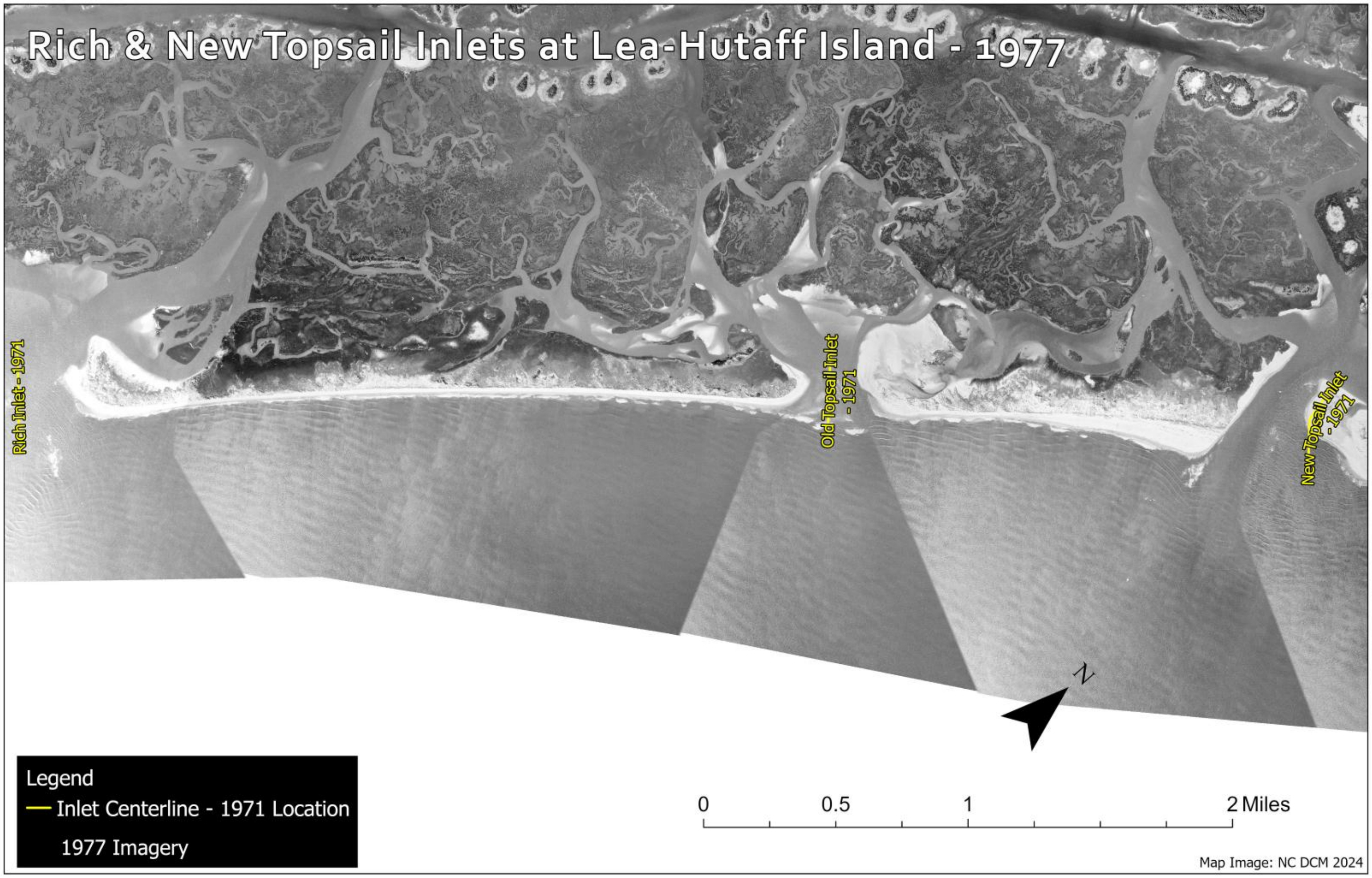

Figure D116. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 1984, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

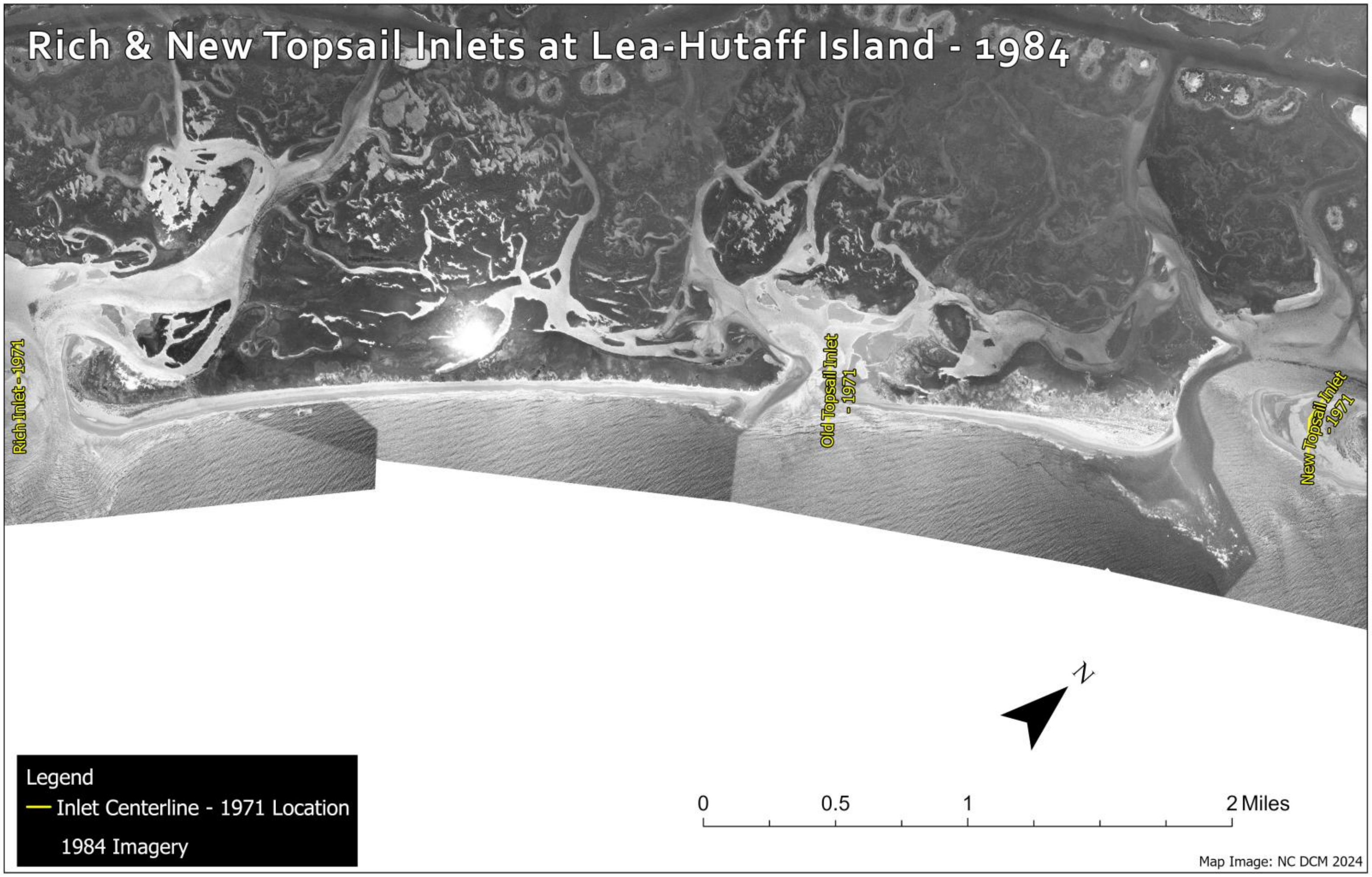

Figure D117. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 1992, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

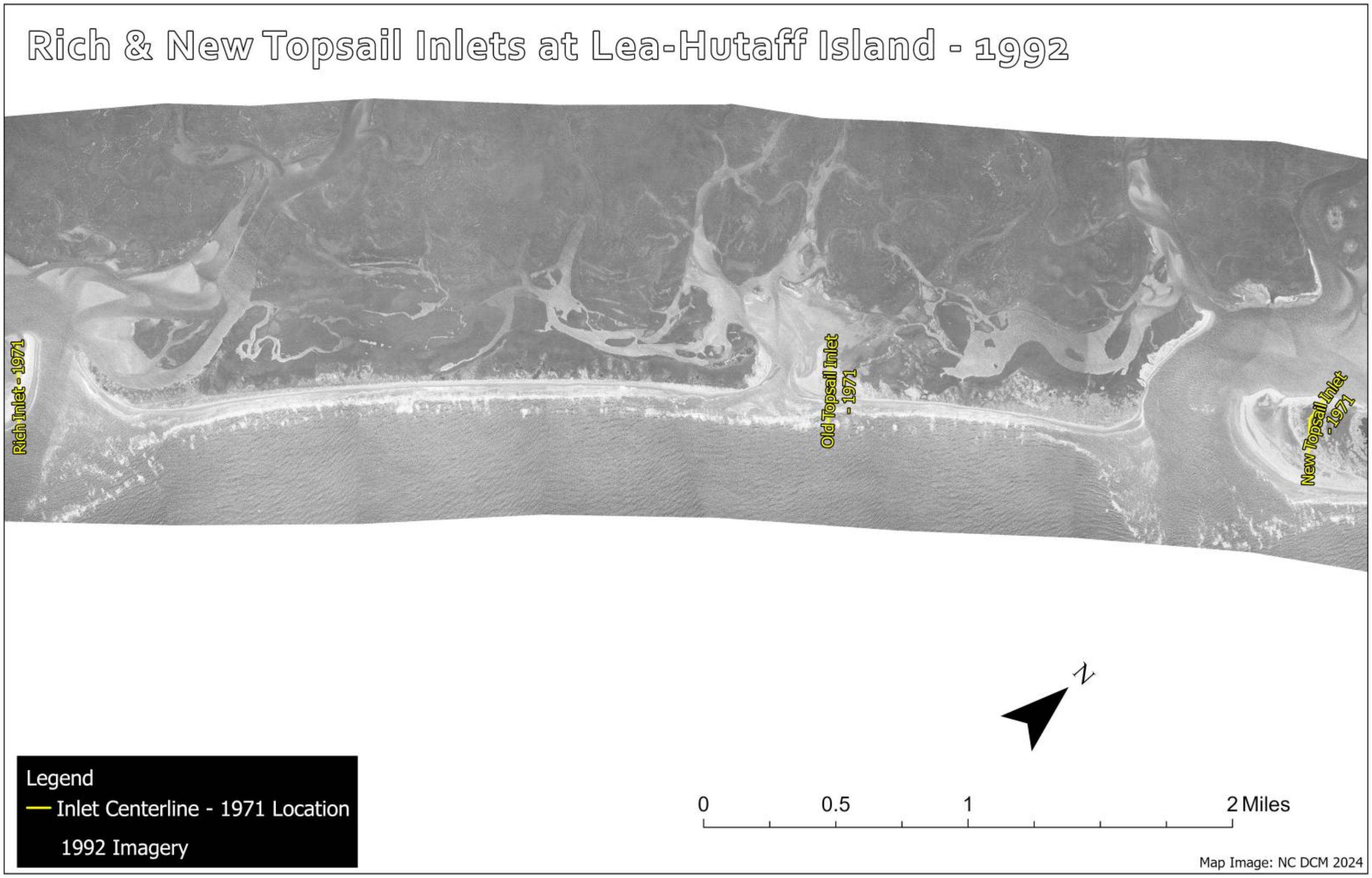

Figure D118. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 1995, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

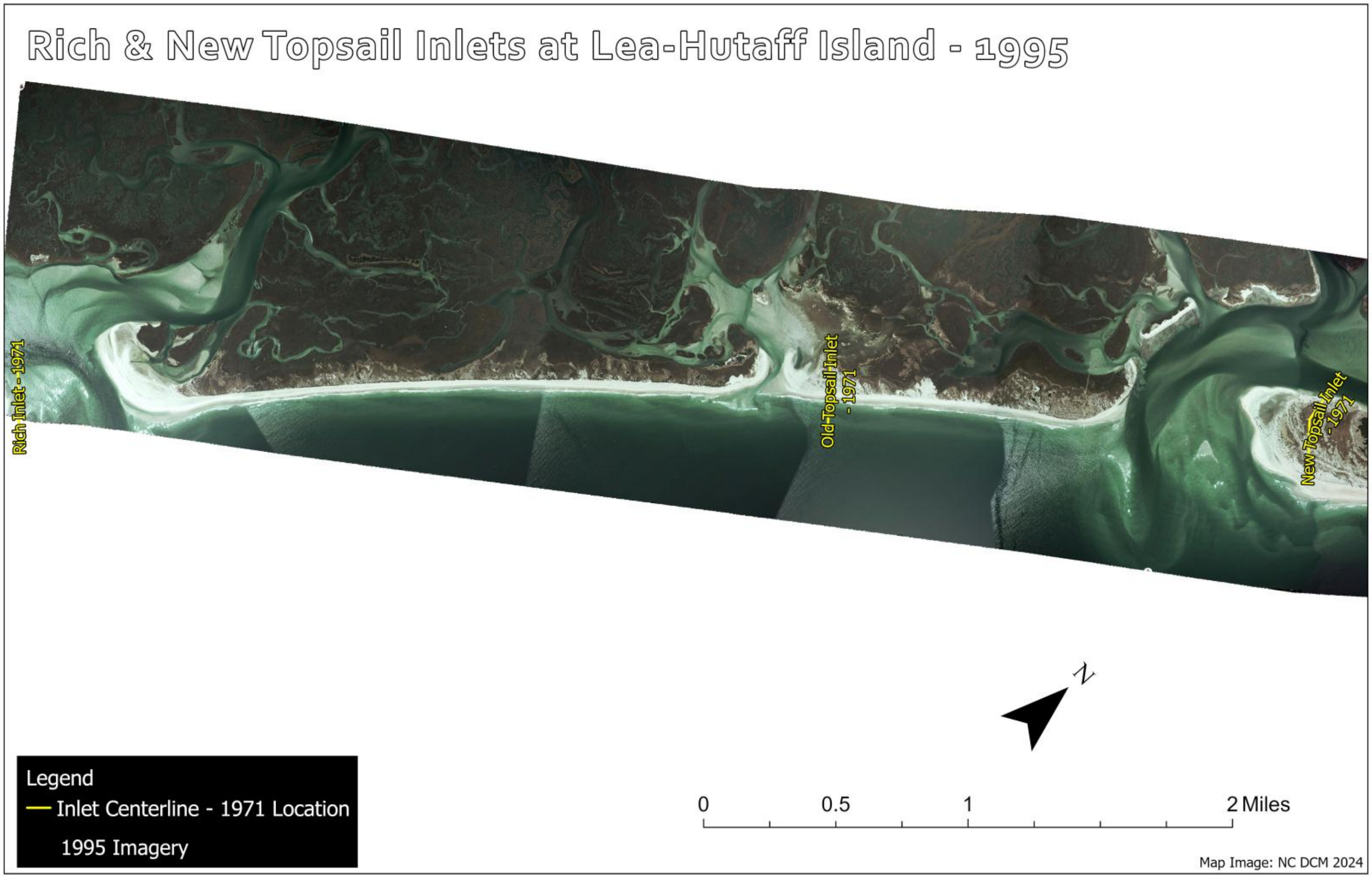

Figure D119. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 1998, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

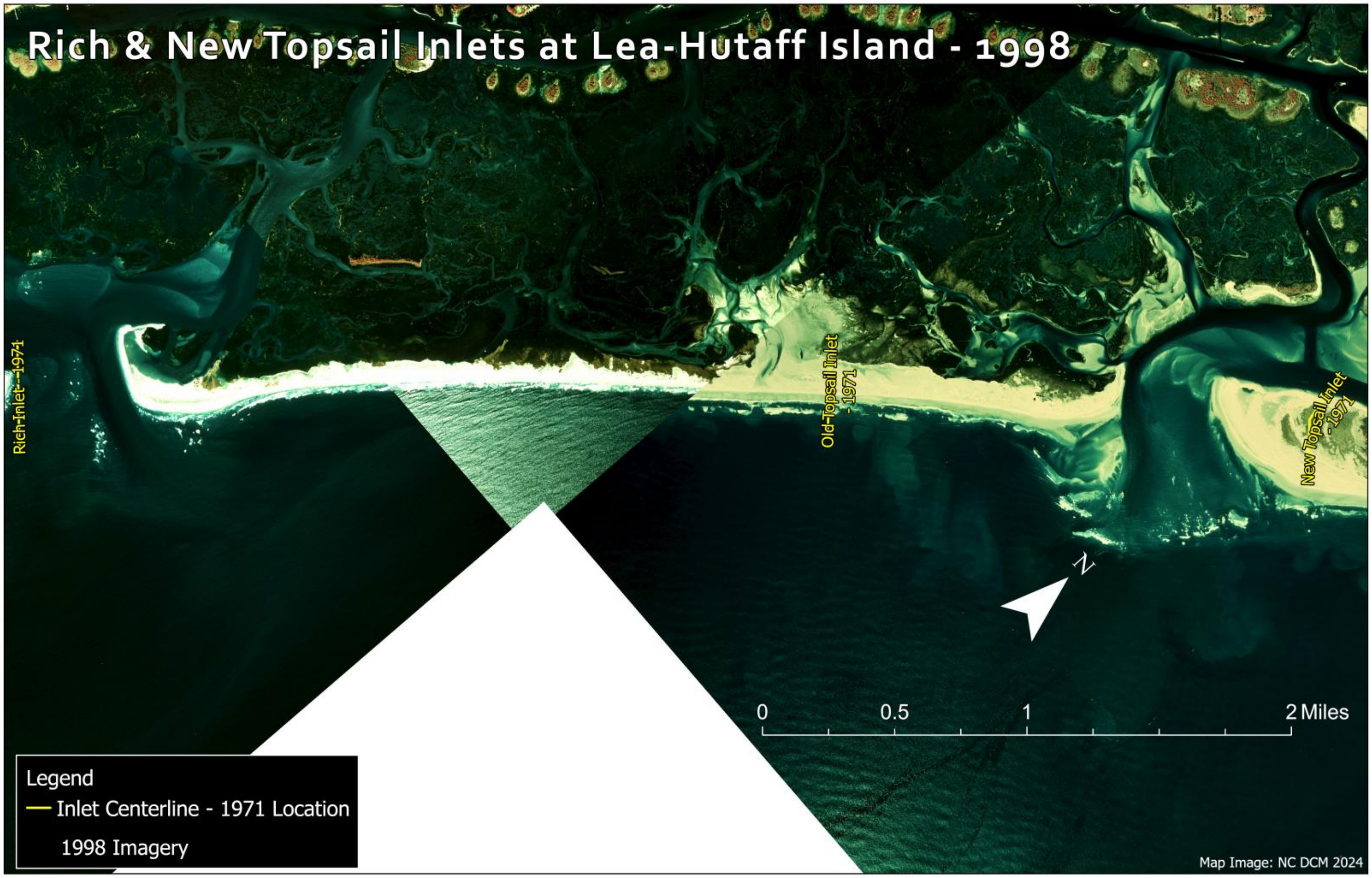

Figure D120. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 2000, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

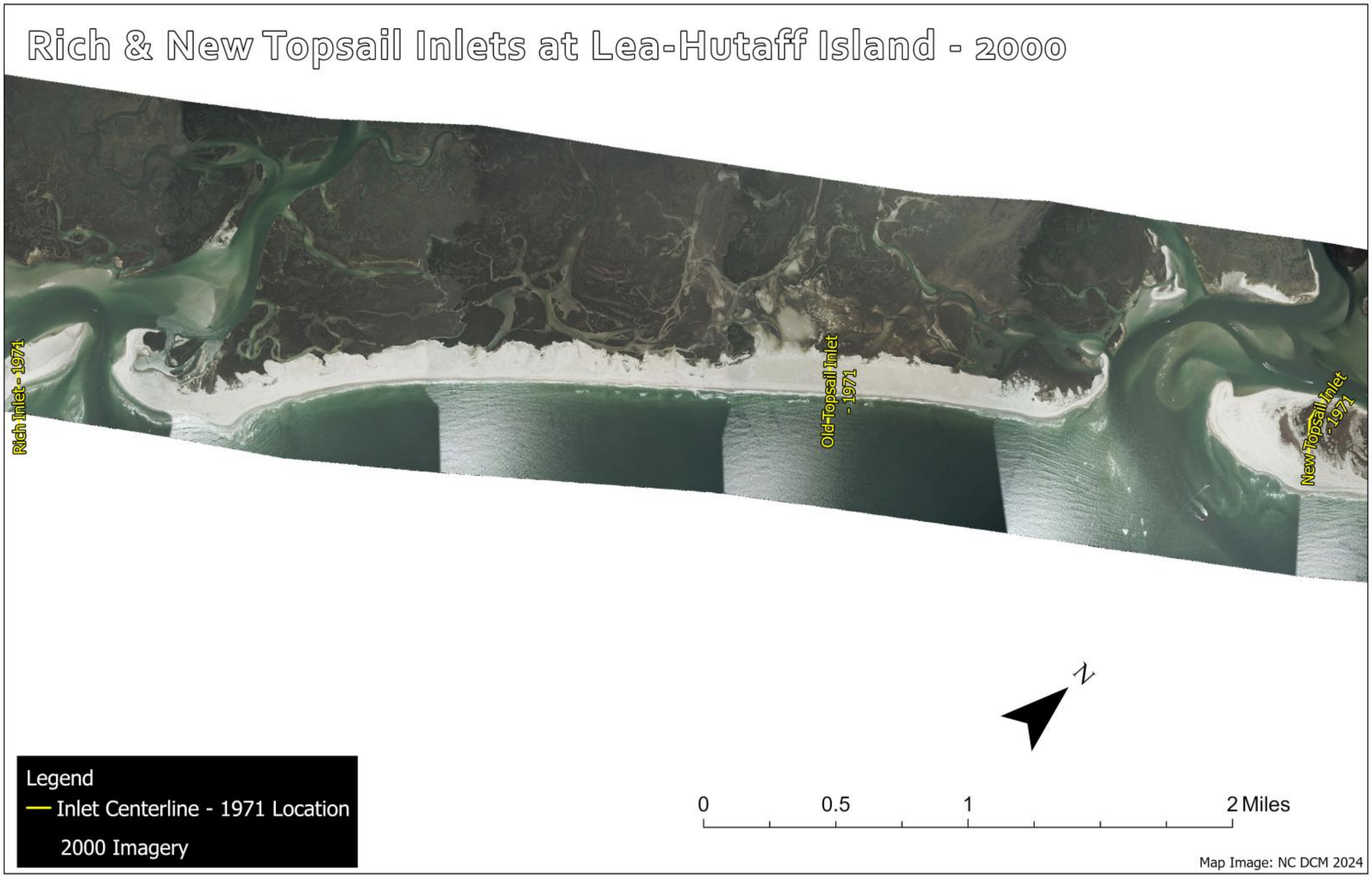

Figure D121. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 2012, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

Figure D122. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 2016, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

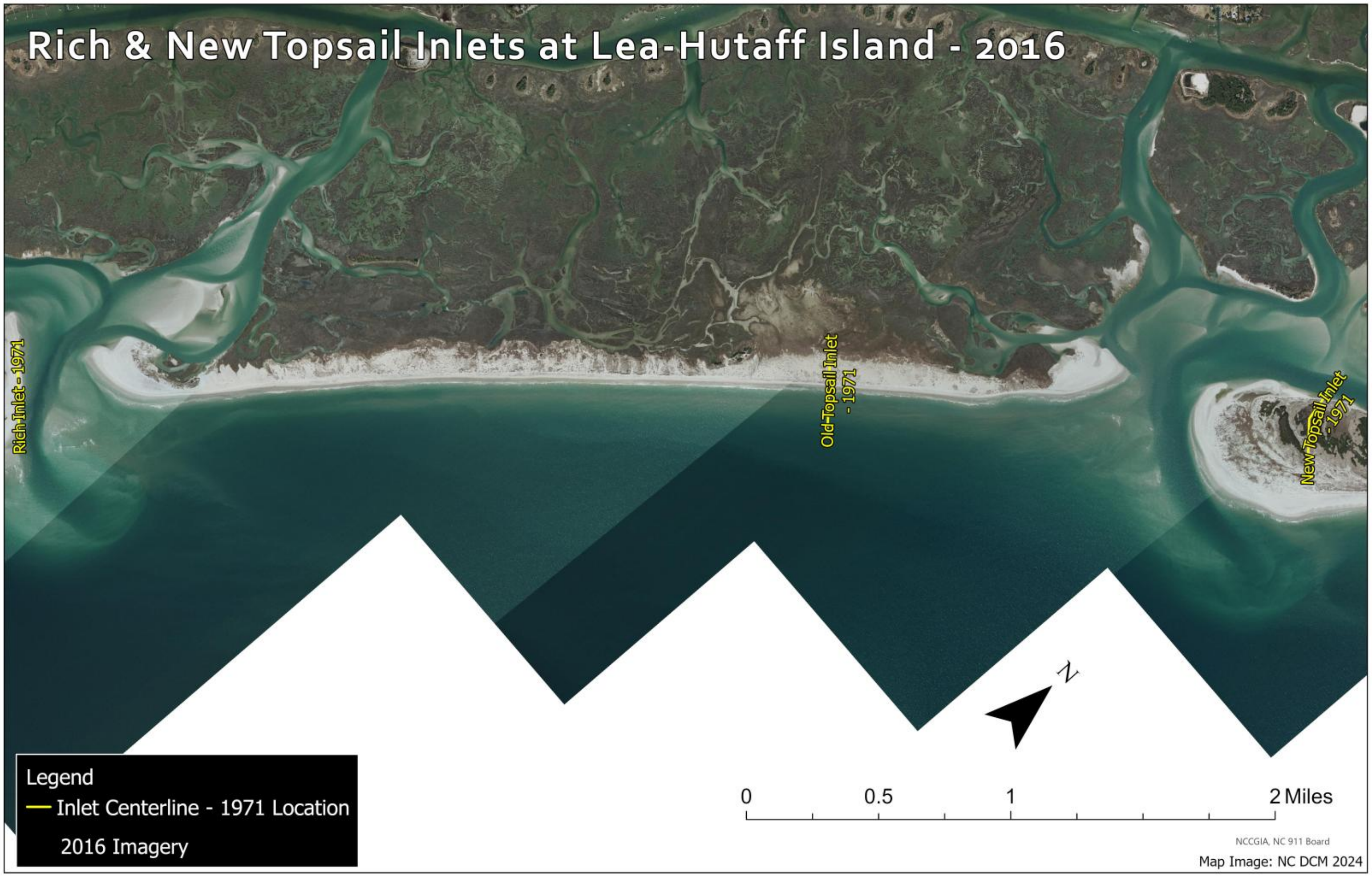

Figure D123. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 2020, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

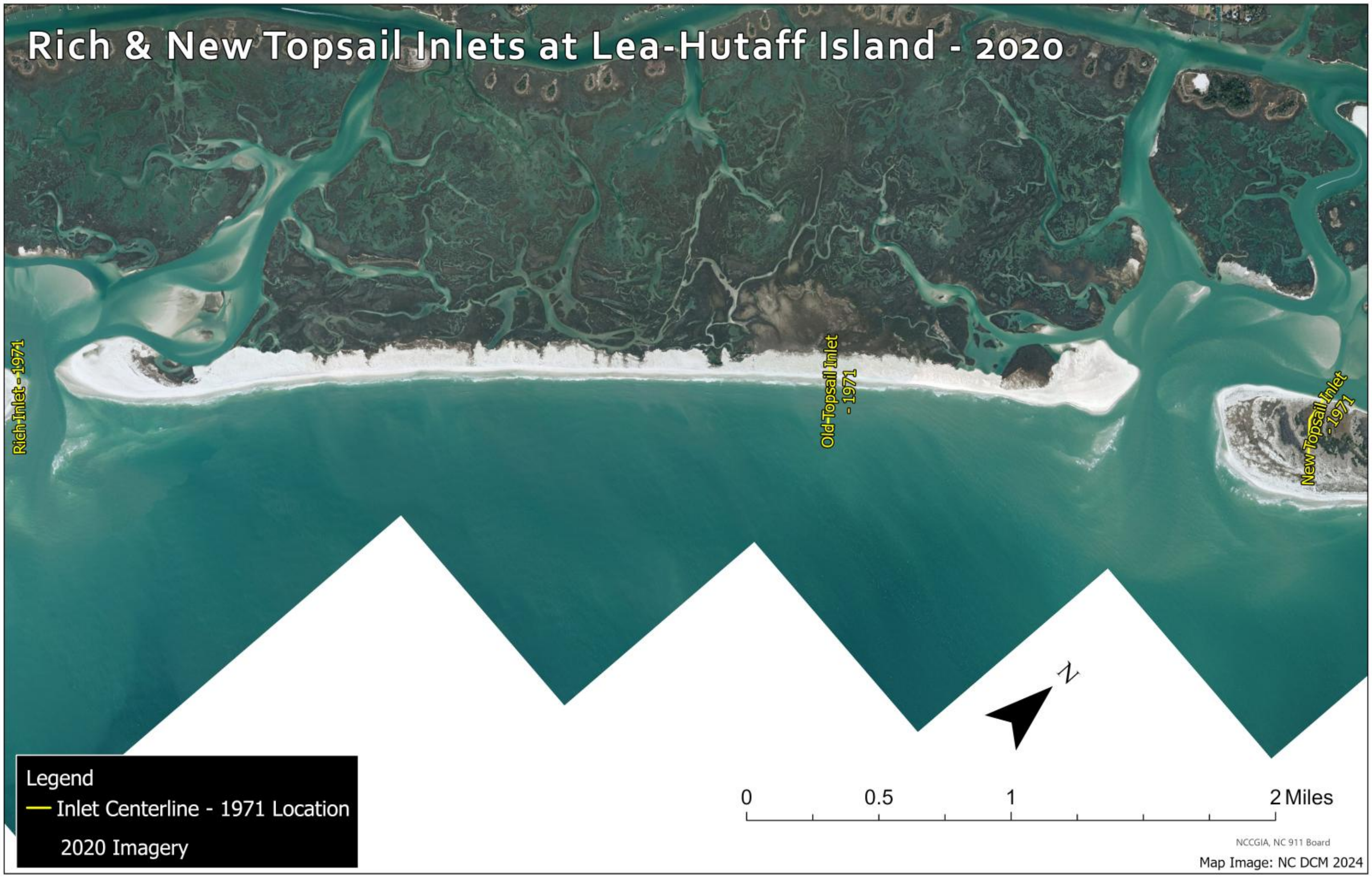

Figure D124. Rich (left) and New Topsail (right) Inlets at Lea-Hutaff Island in 2023, shown relative to 1971 inlet channel centerlines at Rich, Old Topsail (closed in 1998), and New Topsail Inlets.

Figure D125. New Topsail Inlet at Topsail Beach in 1971, shown relative to the 2024-2025 alongshore IHA boundary limit at transect-33 (red line).

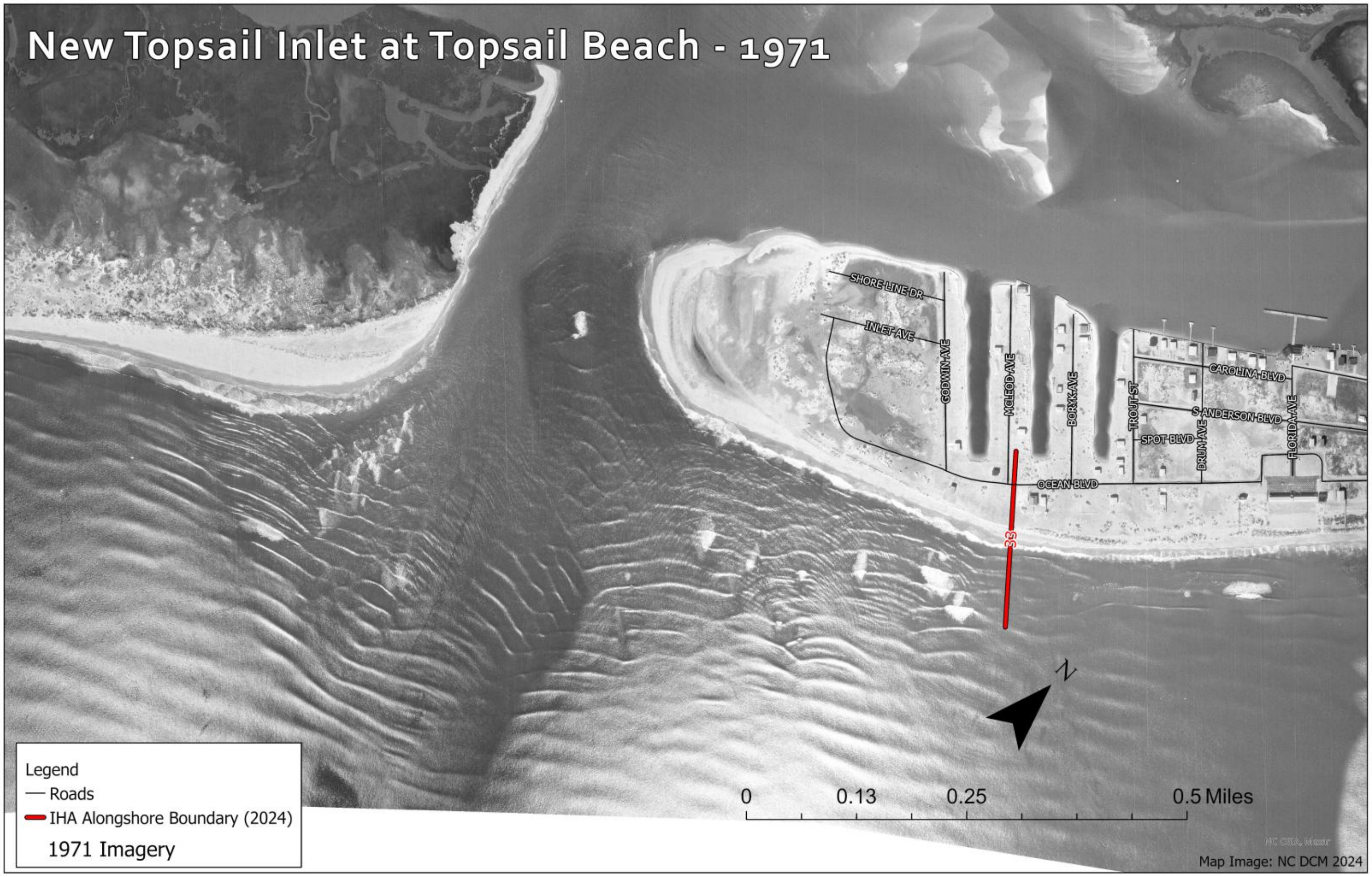

Figure D126. New Topsail Inlet at Topsail Beach in 1974, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

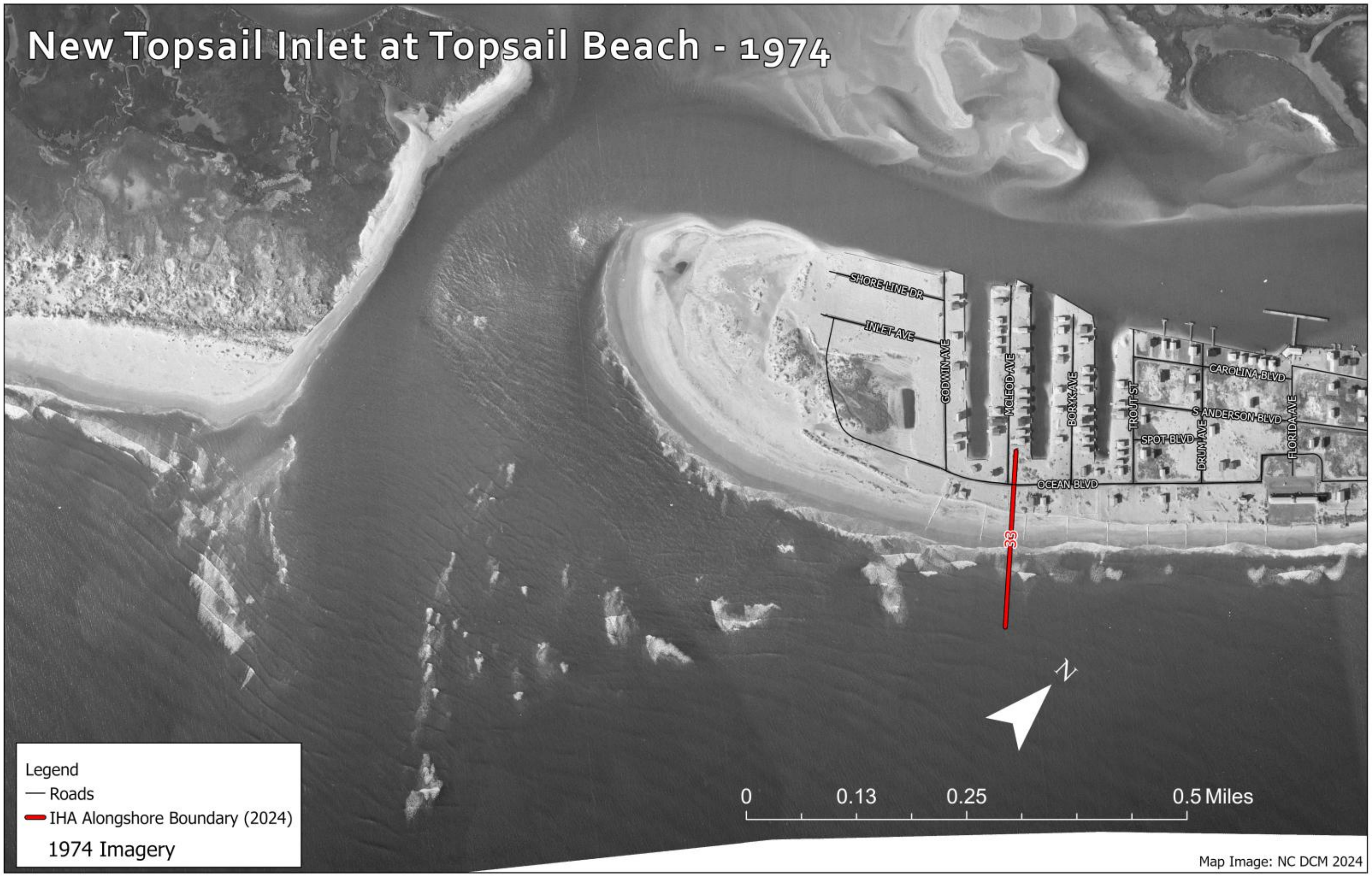

Figure D127. New Topsail Inlet at Topsail Beach in 1977, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

Figure D128. New Topsail Inlet at Topsail Beach in 1984, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

Figure D129. New Topsail Inlet at Topsail Beach in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

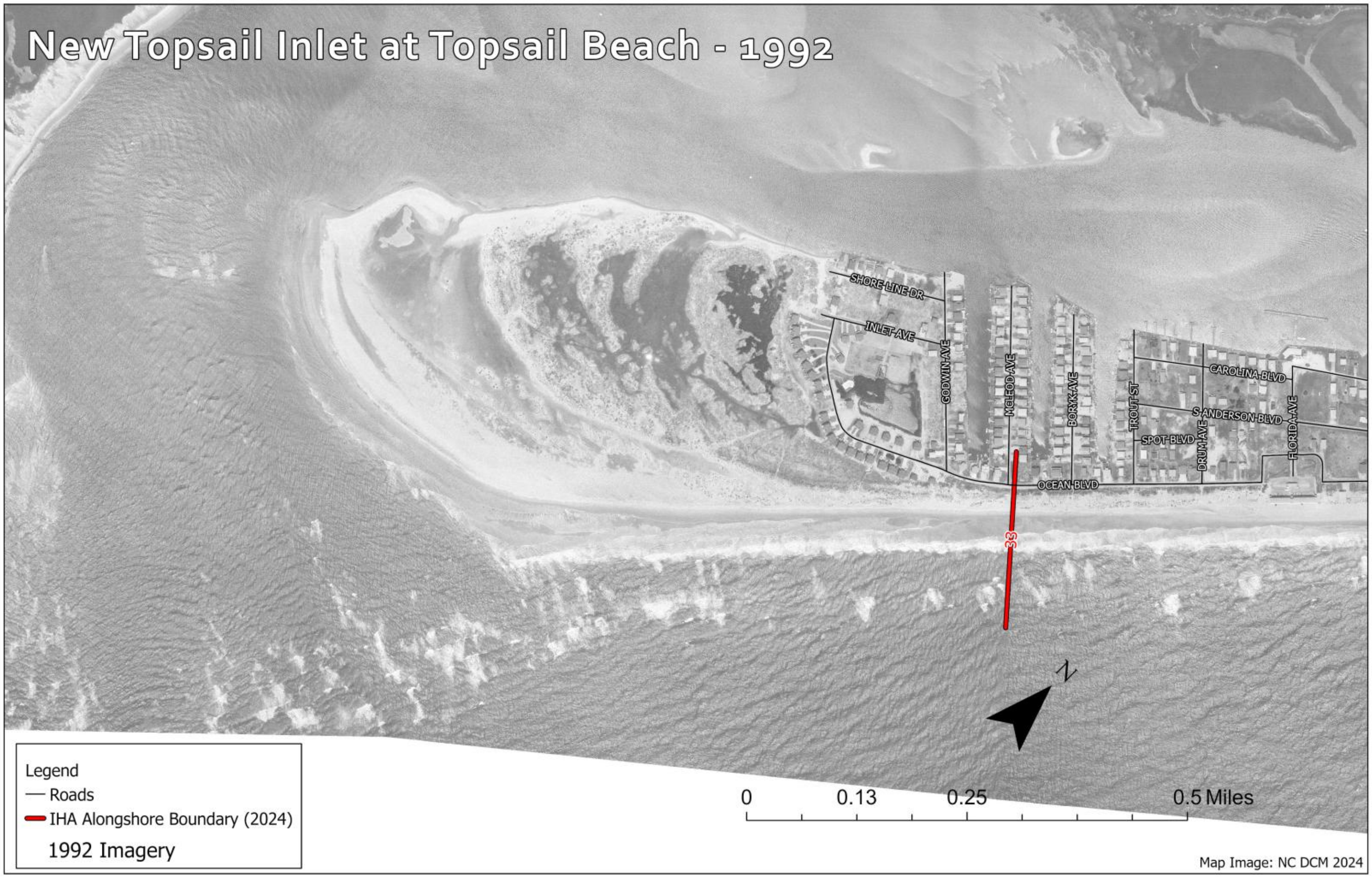

Figure D130. New Topsail Inlet at Topsail Beach in 1995, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

Figure D131. New Topsail Inlet at Topsail Beach in 2000, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

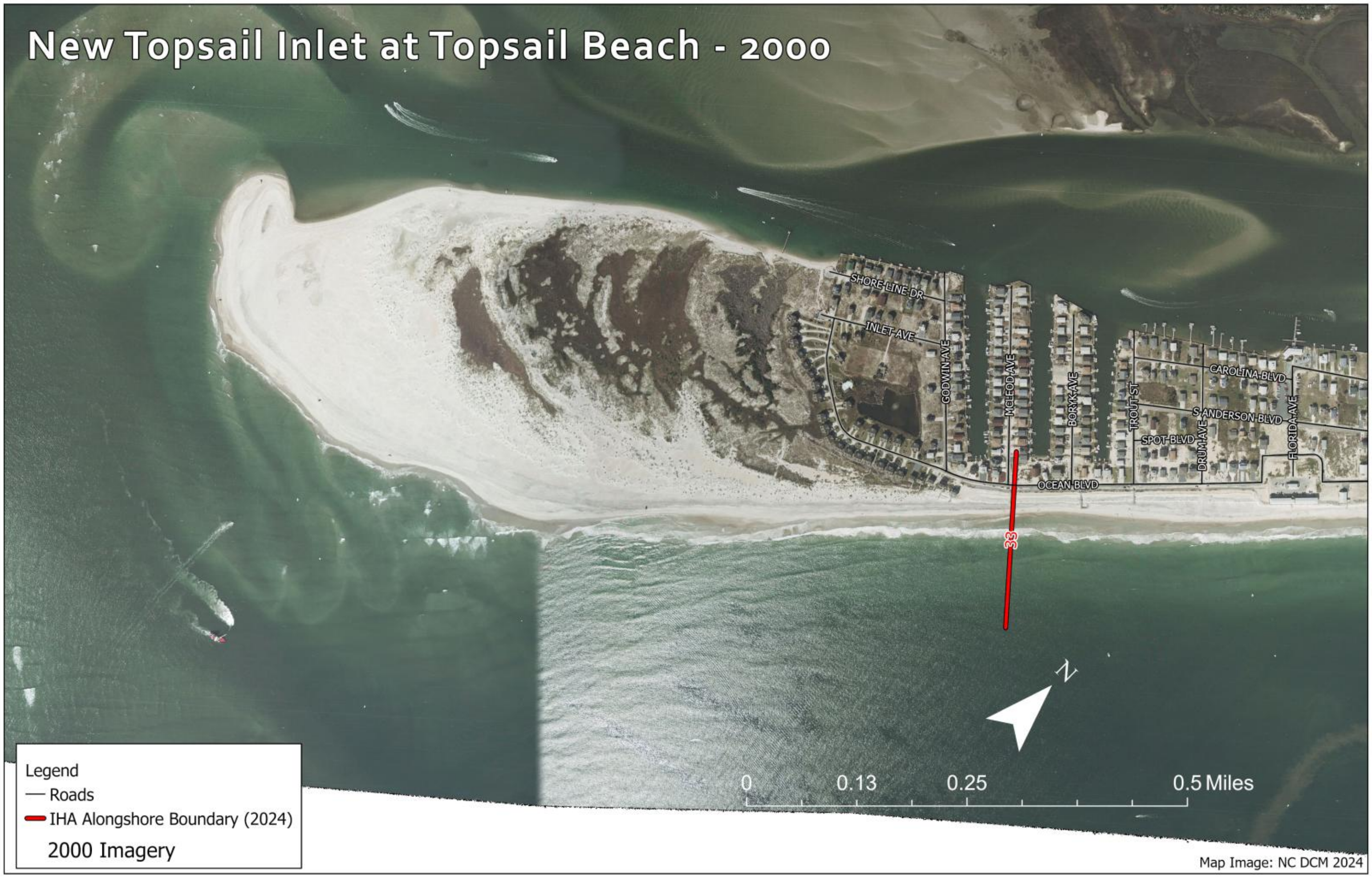

Figure D132. New Topsail Inlet at Topsail Beach in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

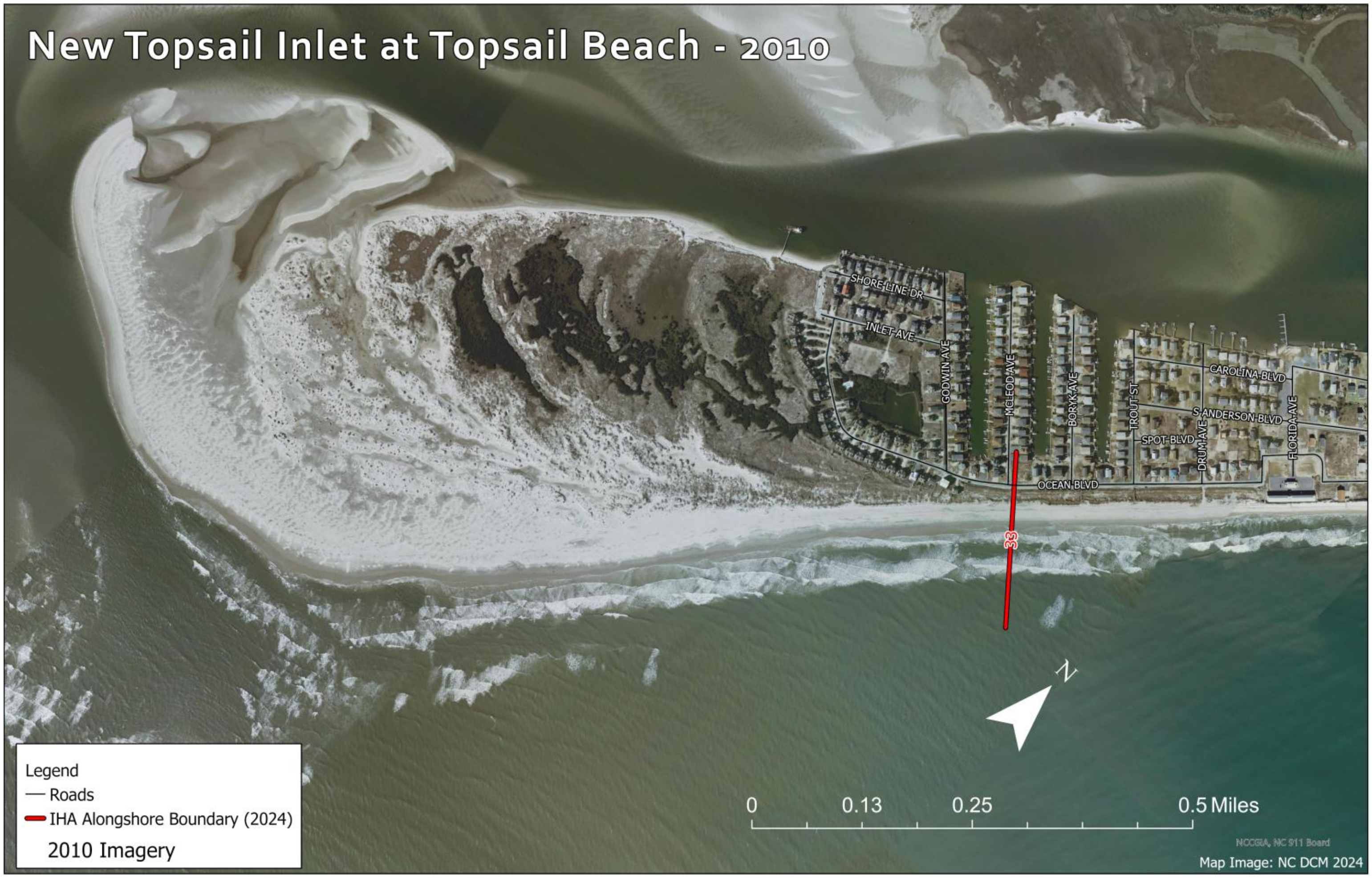

Figure D133. New Topsail Inlet at Topsail Beach in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

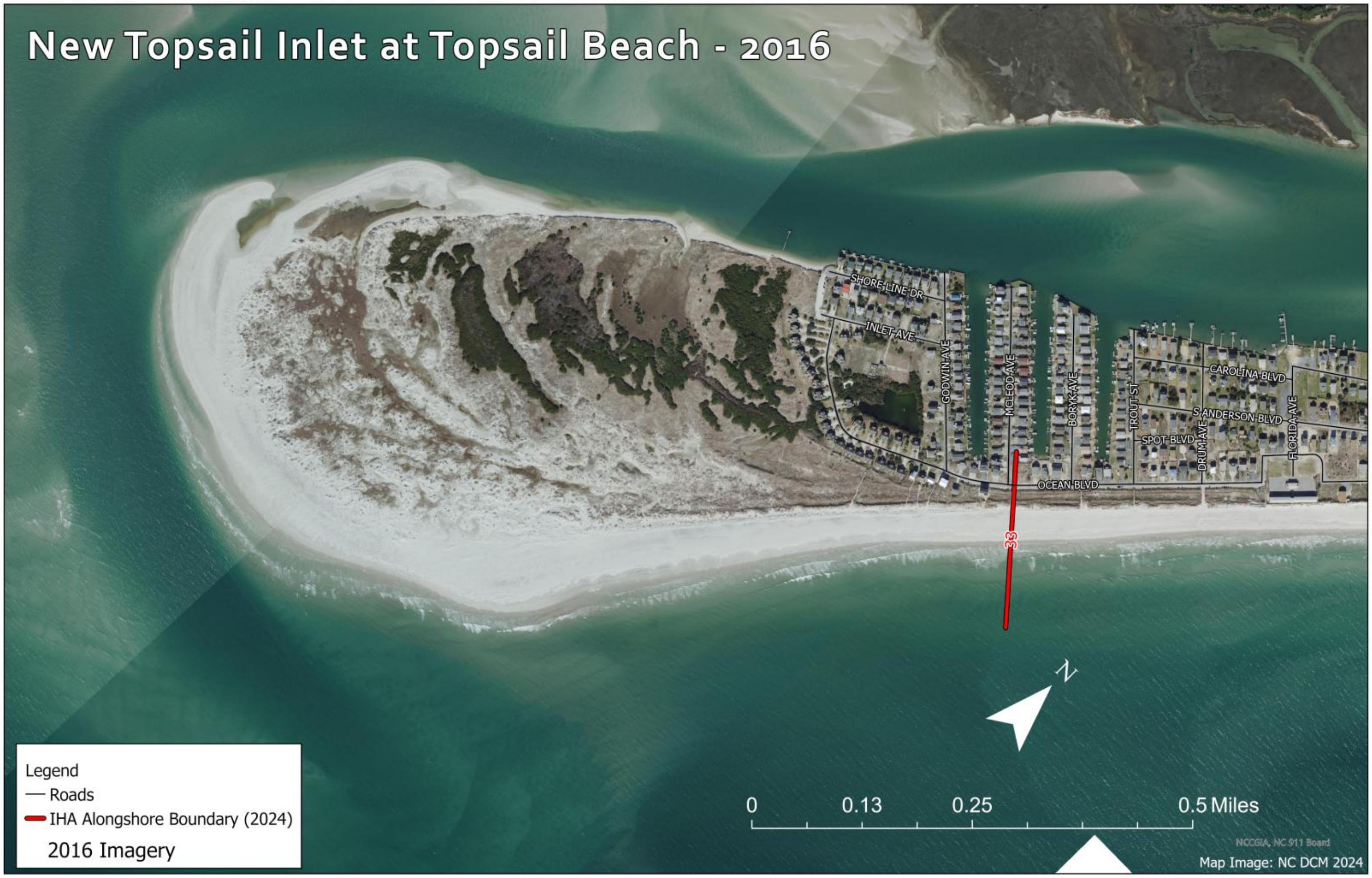

Figure D134. New Topsail Inlet at Topsail Beach in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

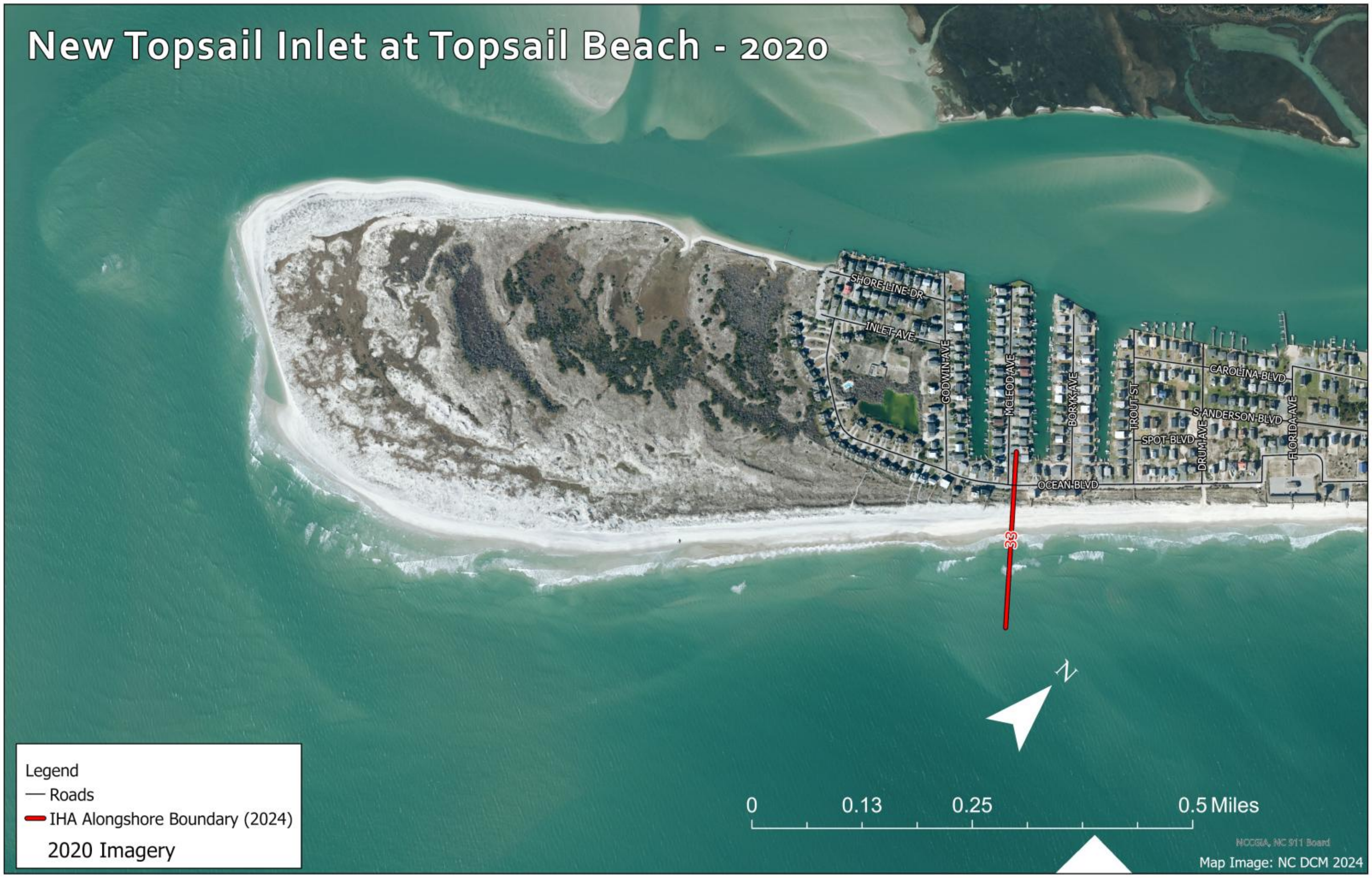

Figure D135. New Topsail Inlet at Topsail Beach in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 33 (red line).

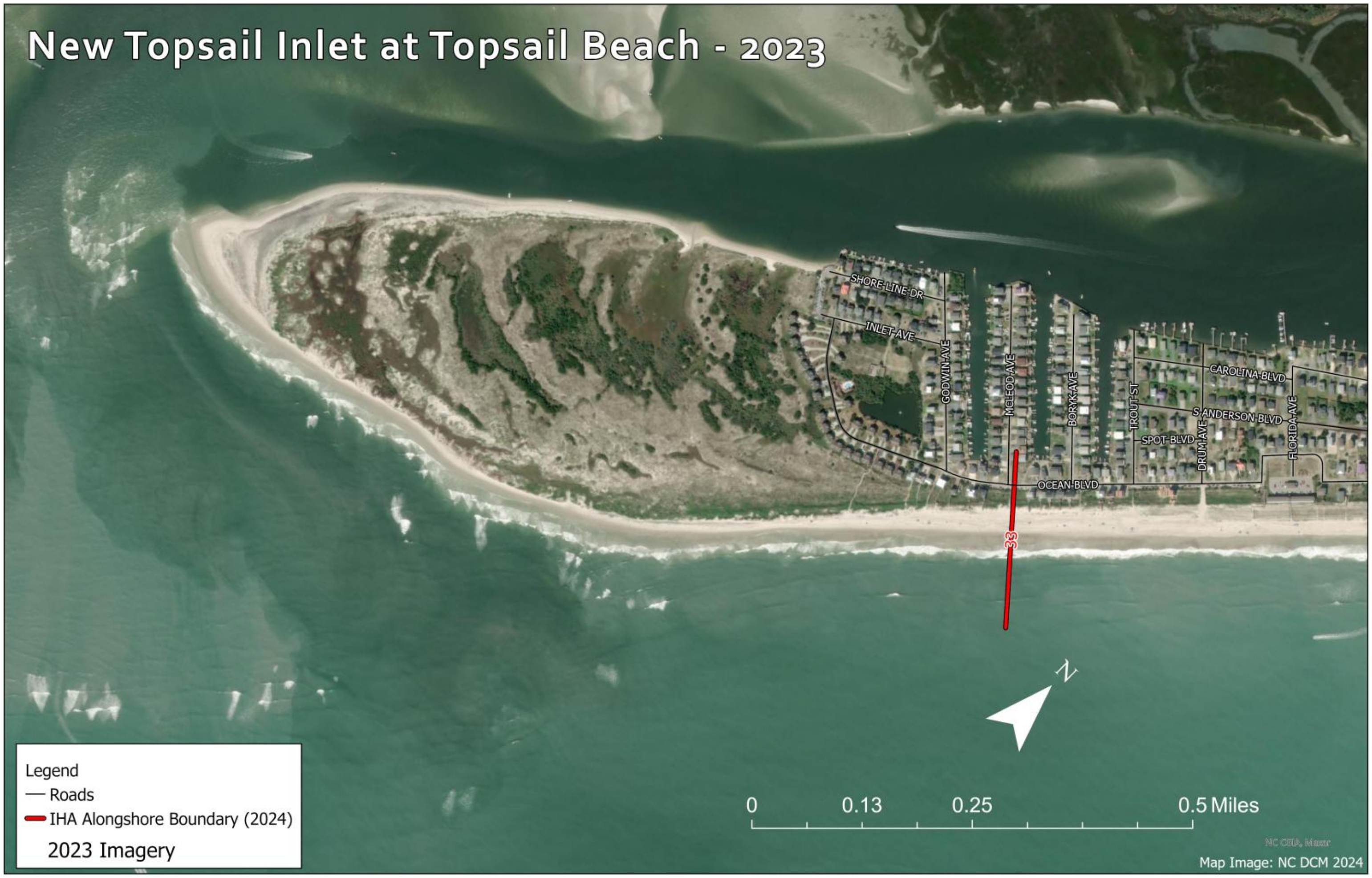

Figure D136. New River Inlet at North Topsail Beach in 1971, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

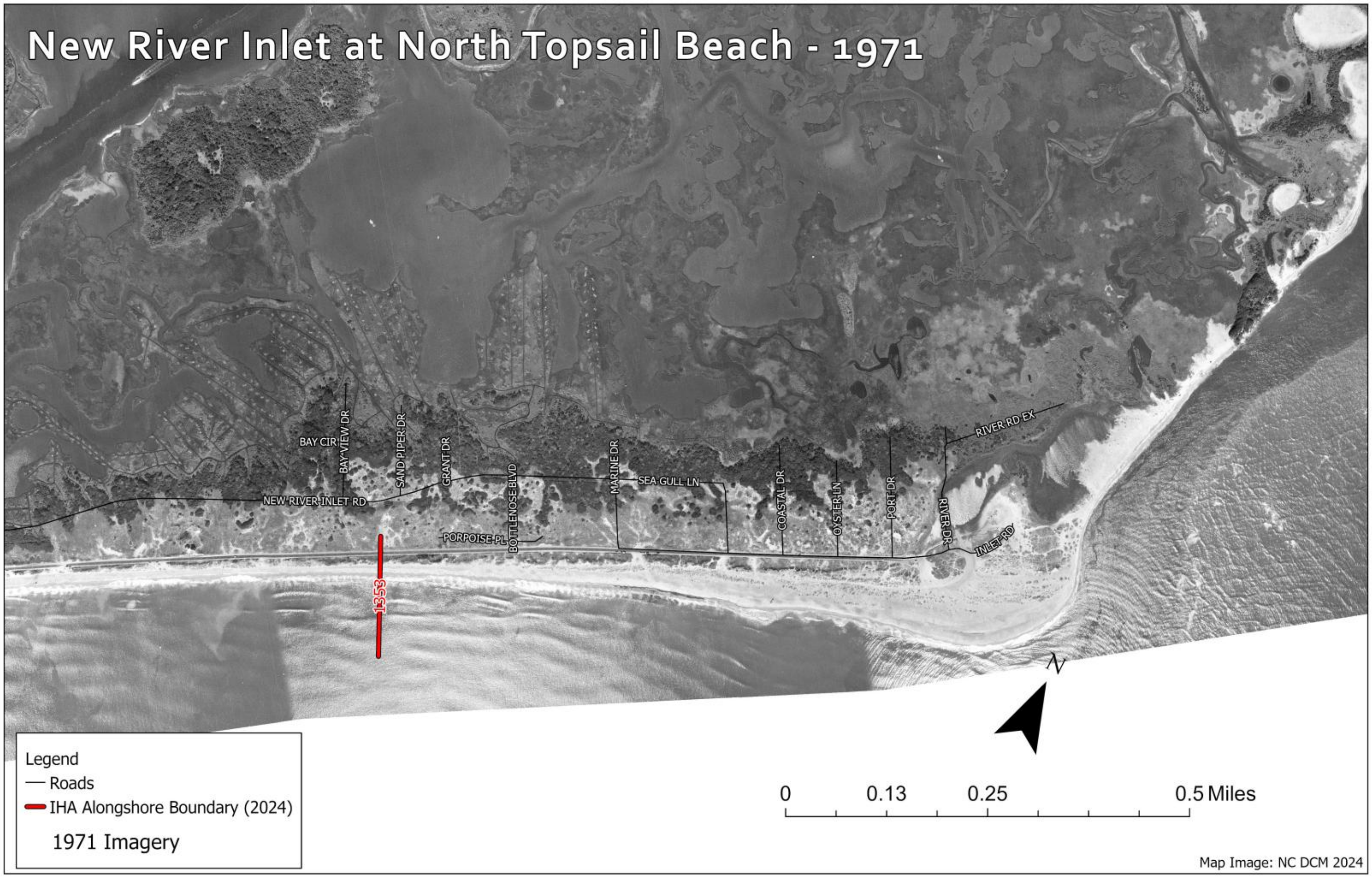

Figure D137. New River Inlet at North Topsail Beach in 1974, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

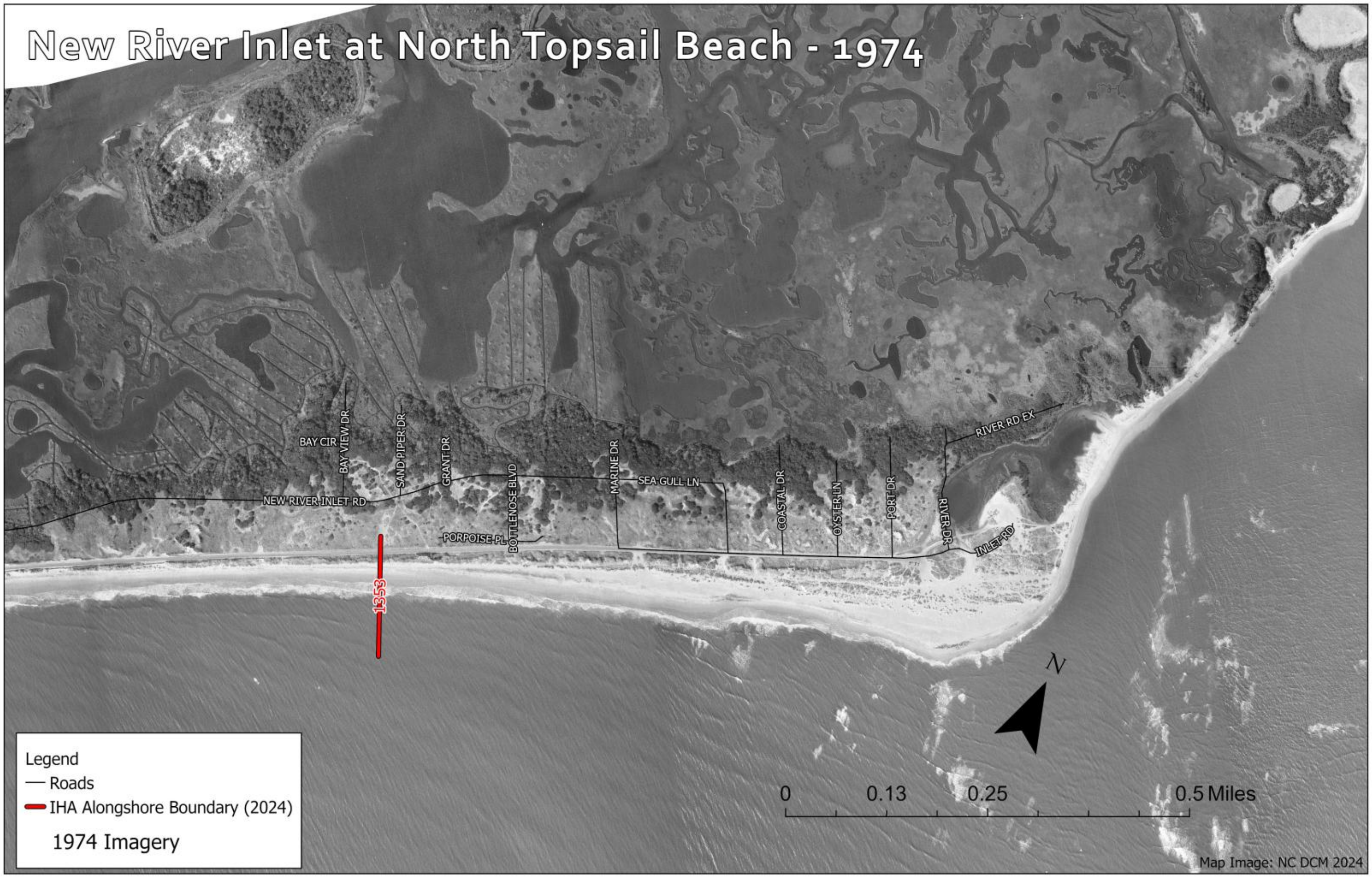

Figure D138. New River Inlet at North Topsail Beach in 1977, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

Figure D139. New River Inlet at North Topsail Beach in 1984, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

Figure D140. New River Inlet at North Topsail Beach in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

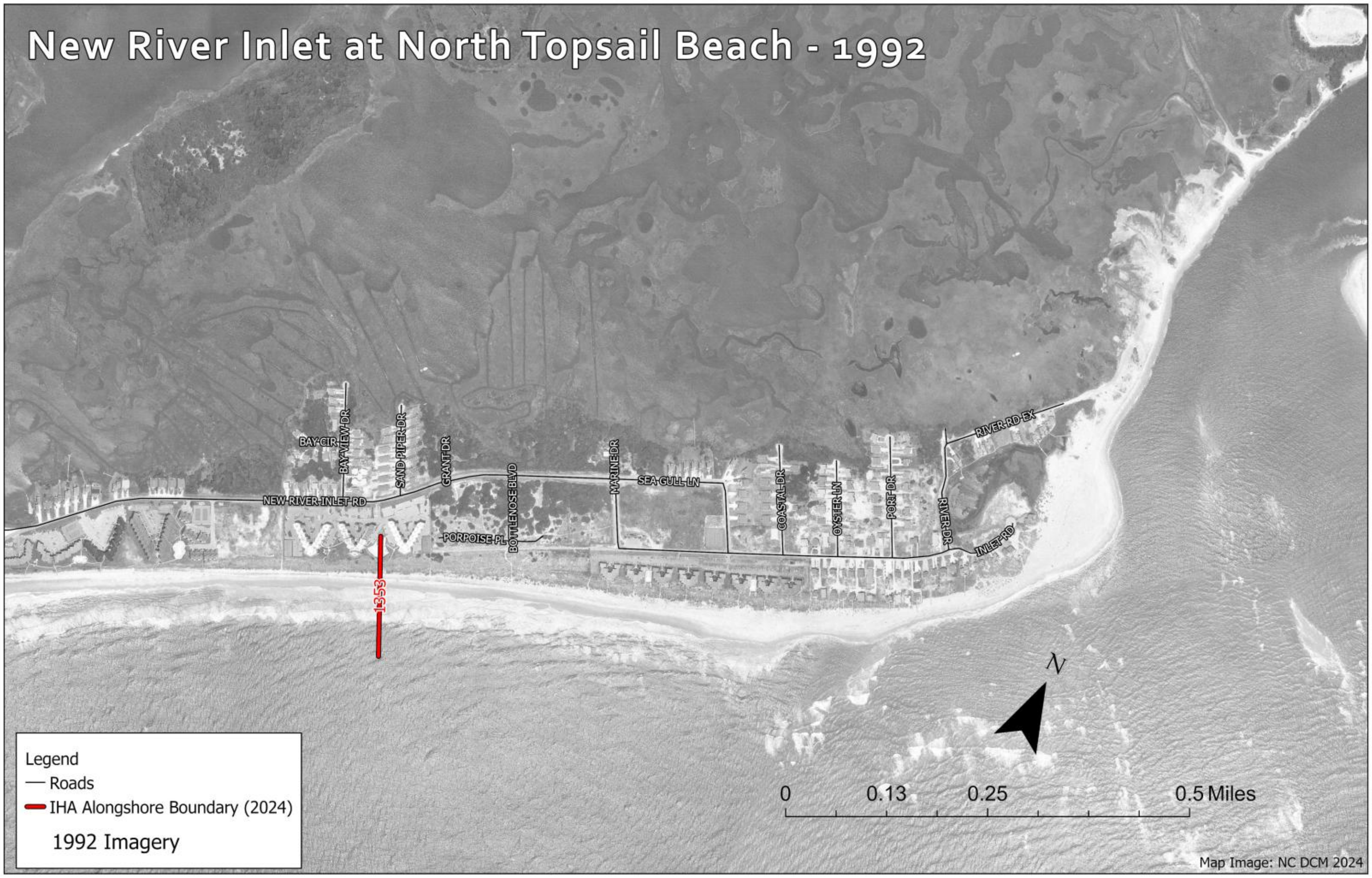

Figure D141. New River Inlet at North Topsail Beach in 1993, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

Figure D142. New River Inlet at North Topsail Beach in 1995, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

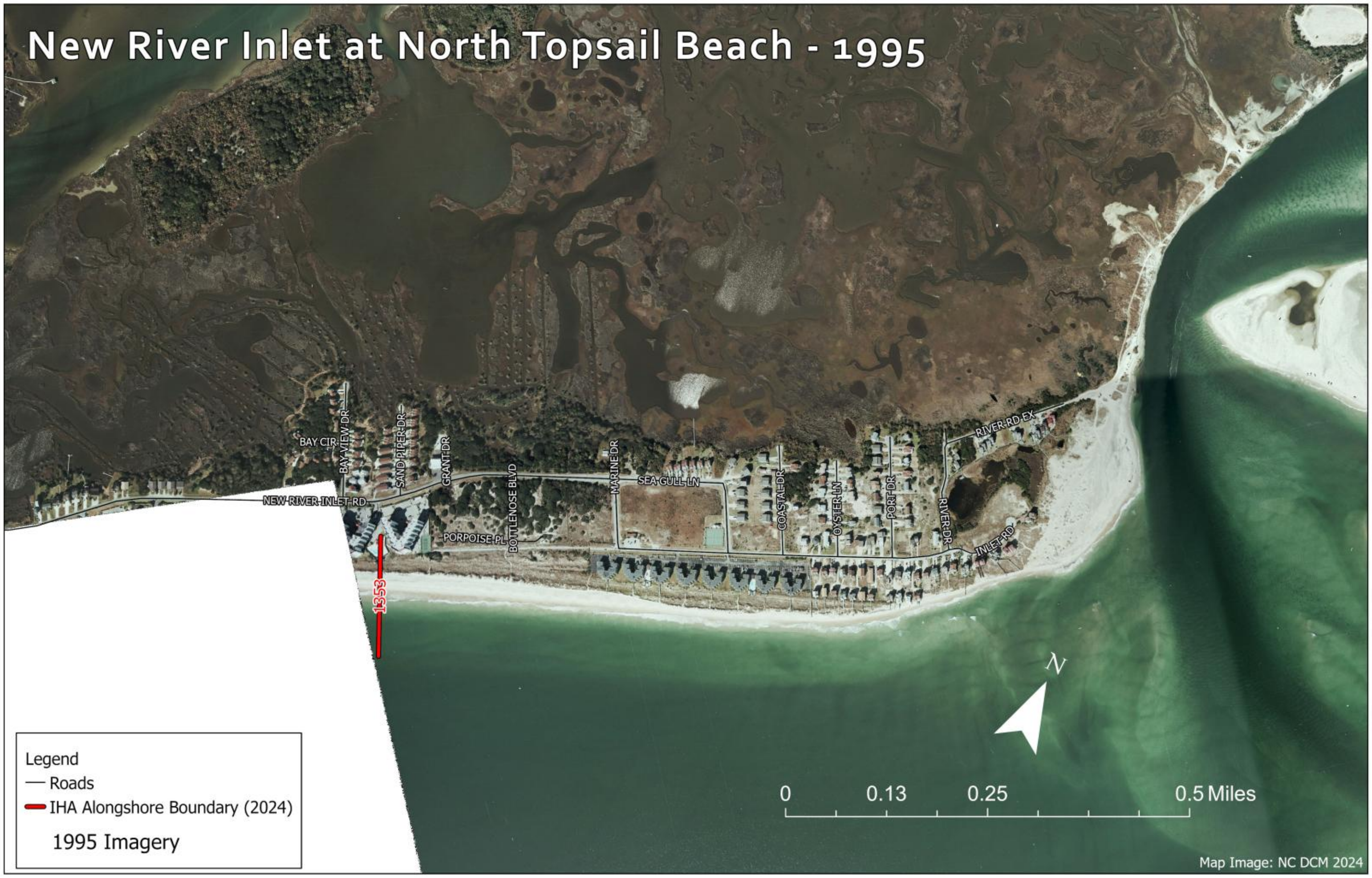

Figure D143. New River Inlet at North Topsail Beach in 1998, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

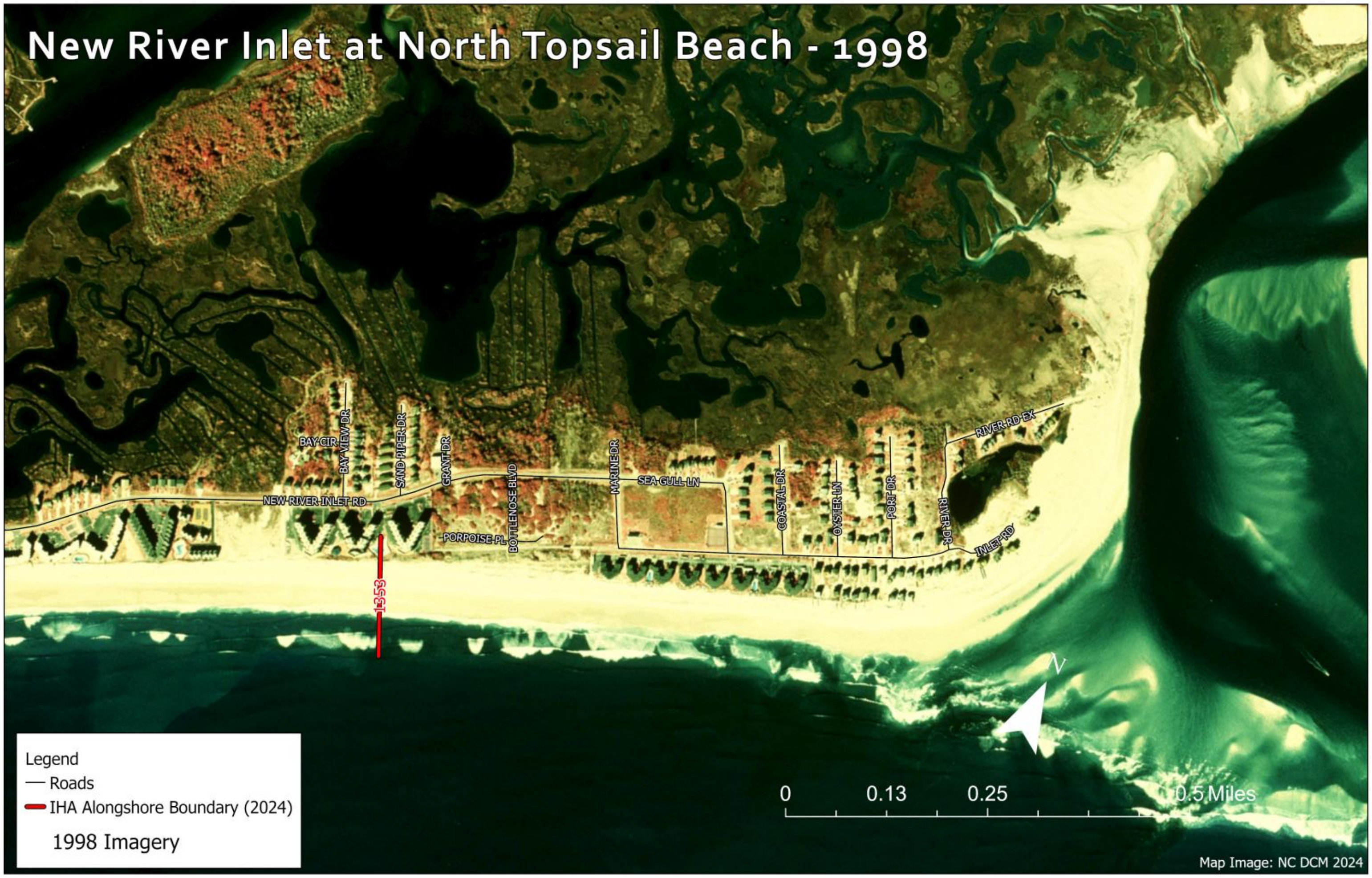

Figure D144. New River Inlet at North Topsail Beach in 2000, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

Figure D145. New River Inlet at North Topsail Beach in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

Figure D146. New River Inlet at North Topsail Beach in 2012, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

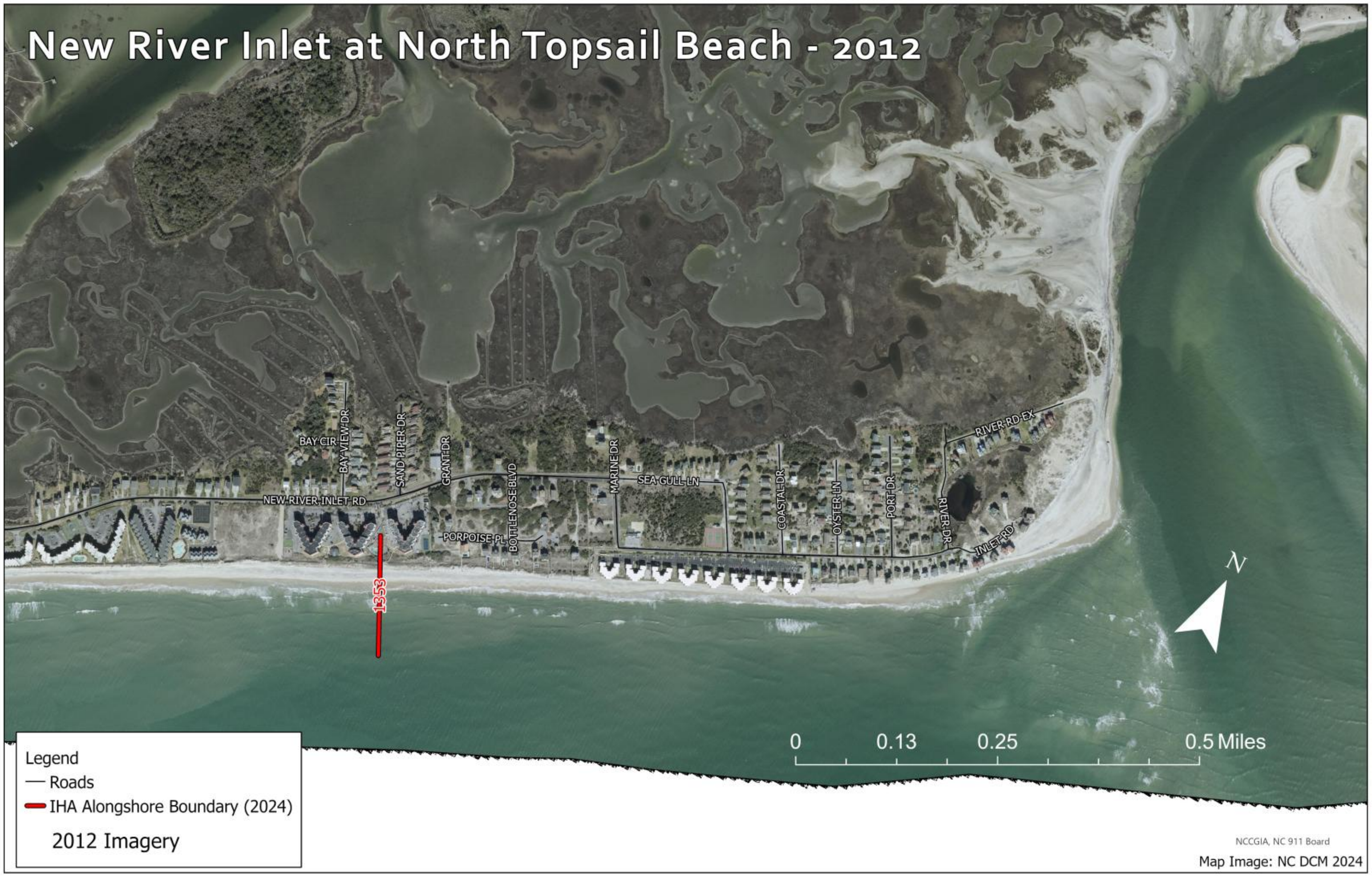

Figure D147. New River Inlet at North Topsail Beach in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

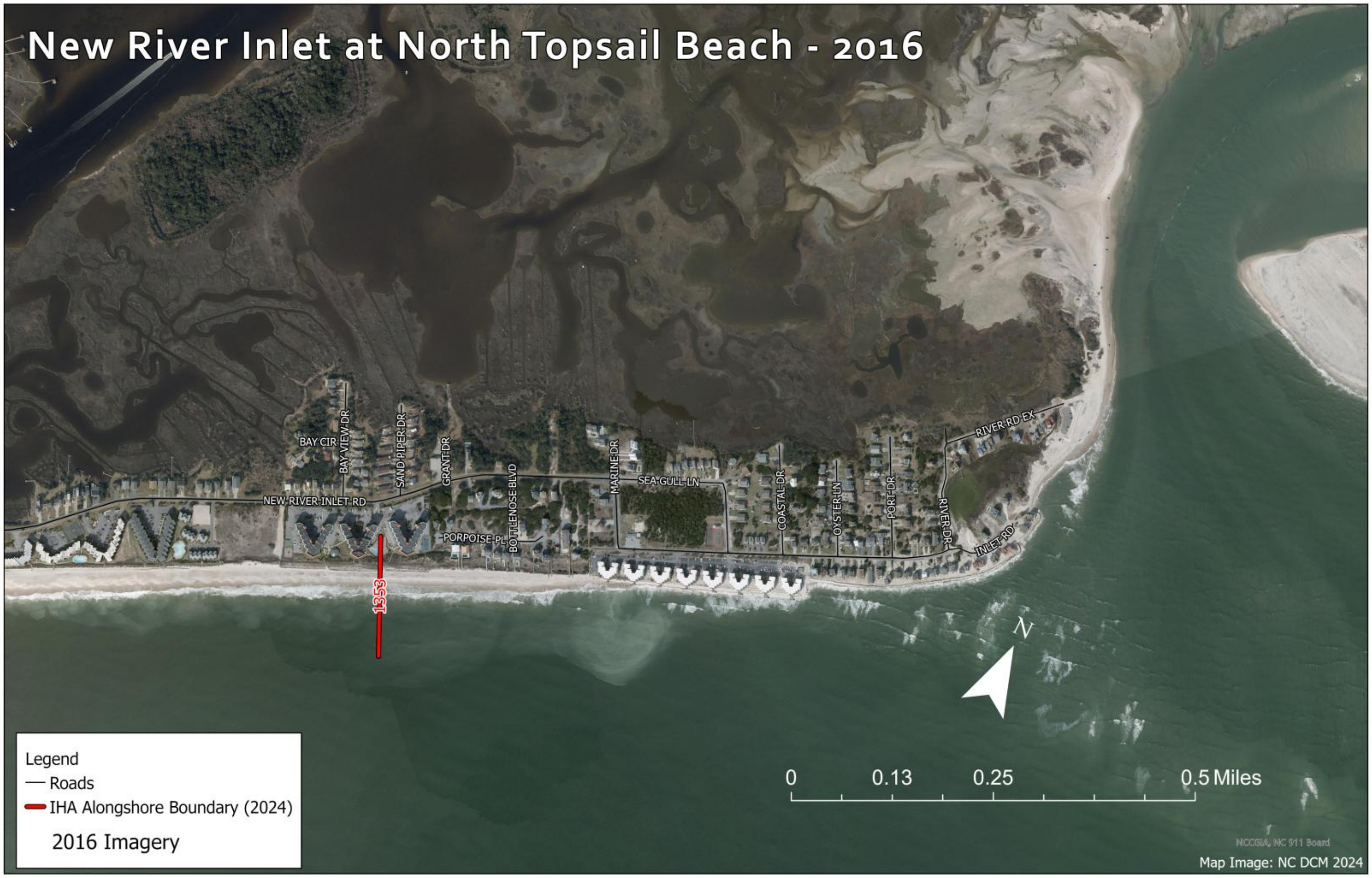

Figure D148. New River Inlet at North Topsail Beach in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

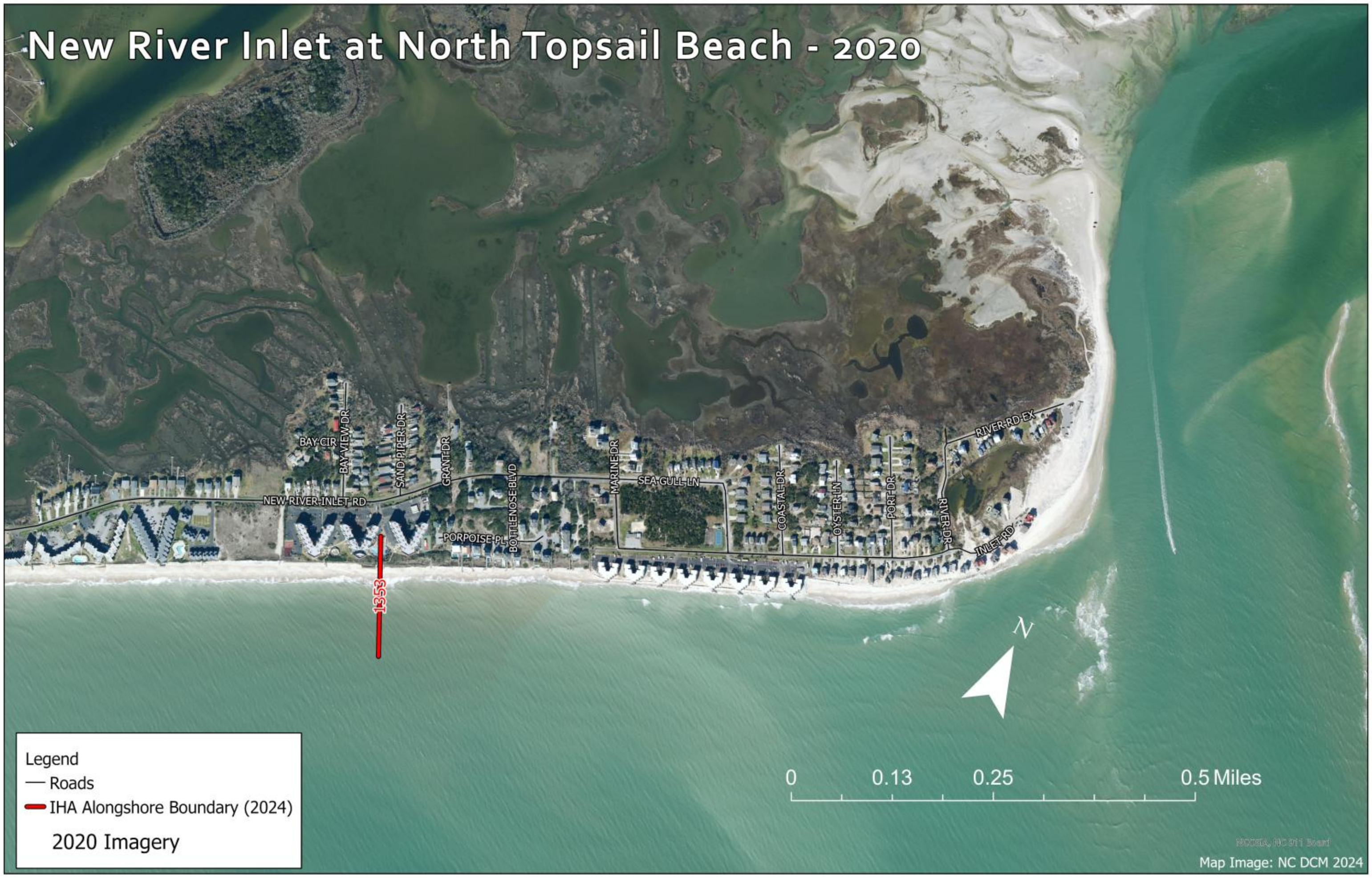

Figure D149. New River Inlet at North Topsail Beach in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 1353 (red line).

Figure D150. Bogue Inlet at Emerald Isle in 1938, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 75 (red line). This map image is for reference only as 1938 data were not used in analysis.

Figure D151. Bogue Inlet at Emerald Isle in 1958, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 75 (red line). This map image is for reference only, as 1958 data were not used in analysis.

Figure D152. Bogue Inlet at Emerald Isle in 1971, shown relative to the 2024-2025 alongshore IHA boundary limit at transect 75 (red line).

Figure D153. Bogue Inlet at Emerald Isle in 1976, shown relative to the 2024-2025 alongshore IHA boundary limit transect 75 (red line).

Figure D154. Bogue Inlet at Emerald Isle in 1987, shown relative to the 2024-2025 alongshore IHA boundary limit transect 75 (red line).

Figure D155. Bogue Inlet at Emerald Isle in 1992, shown relative to the 2024-2025 alongshore IHA boundary limit transect 75 (red line).

Figure D156. Bogue Inlet at Emerald Isle in 1998, shown relative to the 2024-2025 alongshore IHA boundary limit transect 75 (red line).

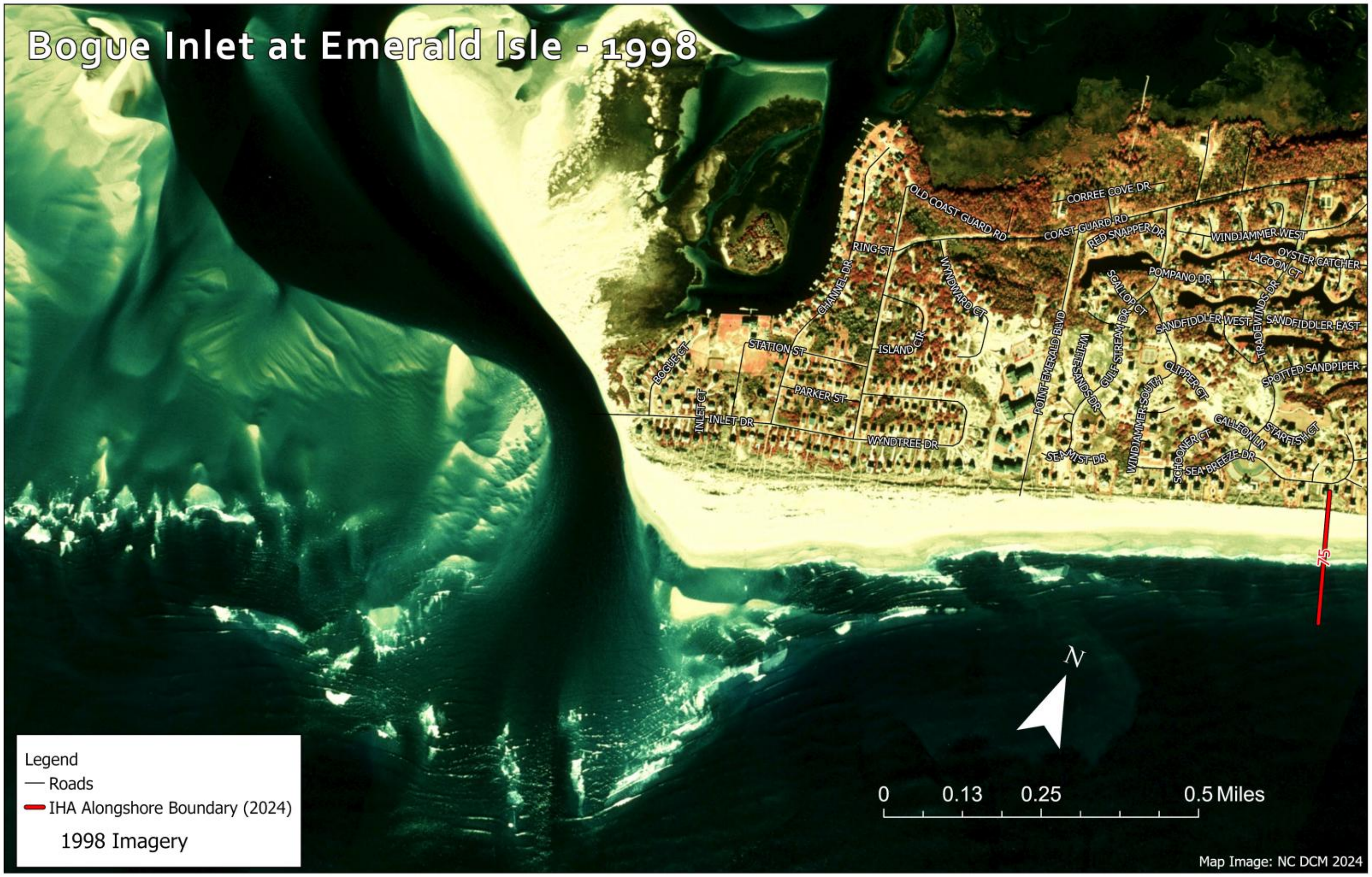

Figure D157. Bogue Inlet at Emerald Isle in 2010, shown relative to the 2024-2025 alongshore IHA boundary limit transect 75 (red line).

Figure D158. Bogue Inlet at Emerald Isle in 2016, shown relative to the 2024-2025 alongshore IHA boundary limit transect 75 (red line).

Figure D159. Bogue Inlet at Emerald Isle in 2020, shown relative to the 2024-2025 alongshore IHA boundary limit transect 75 (red line).

Figure D160. Bogue Inlet at Emerald Isle in 2023, shown relative to the 2024-2025 alongshore IHA boundary limit transect 75 (red line).

North Carolina Division of Coastal Management
400 Commerce Avenue | Morehead City, NC 28557 | phone: 252-515-5400
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