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Tangier Island, Virginia Shoreline Management Plan for the West Coast of the Uppards

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Shoreline Management Plan for the West Coast of the Uppards

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EXECUTIVE SUMMARY

Tangier Island is located in the northwestern portion of Virginia's Chesapeake Bay in Accomack County just south of the Virginia-Maryland border. The area known as Tangier Island is now made up of three separate islands: the main residential area called the Town of Tangier, Port Isobel Island east of the town, and a marsh island north of the town now known as the Uppards. The research for this management plan assesses the physical and hydrodynamic setting in the vicinity of the west coast of the Uppards shoreline as it relates to erosion, loss of land, and the potential for SAV protection.

Design concepts for shore protection address shoreline processes, client goals, and the degree of protection desired. The theory used to develop the Uppards West Coast Shoreline Management Plan is Headland Control. Potential breakwater/beach fill configurations were assessed using the Model SEB, empirical data from other installations, and existing shore geomorphology. The goals of the plan are to reduce overall erosion, protect SAV, and prevent breaching in areas of concern.

Geomorphic evolution is the response of coastal lands and bottoms to the processes of sea level rise, local wind/wave climate and tidal currents. Tangier Island and the string of islands to the north in Maryland have been diminished in size and extent over the years as a direct result of these processes. At the last low stand about 15,000 years ago, sea level was 300 feet lower, and this island chain was an upland interfluve between southward flowing streams that are now the Chesapeake Bay to the west and Tangier Sound to the east. At one time, this island chain was continuous; today it is fragmented, and the island masses have been reduced significantly by shore erosion.

Much of Tangier, including the Uppards Island, is marsh with only a few sand ridges that represent the upland areas. The shoreline around the Uppards varies in nature due, in part, to varying fetch exposures. The west shore has higher erosion rates because it faces the open Chesapeake Bay while the east shore of the Uppards has a much lesser fetch across the shallows of Tangier Sound and is protected by Port Isobel from larger waves to the southeast resulting in less dramatic shore change. The Uppards'shoreline is very irregular and exists as a series of headlands and embayments at varying scales. The large embayments have beaches where sand extends from below MLW to a berm feature on top of the marsh. The eroding marsh face extends into the very nearshore as peat/clay substrate. The nearshore shelf has a series of shore parallel sand bars especially off the northern half of the west shore of the Uppards.

The hydrodynamic assessment showed that the west coast of the Uppards is exposed to a bimodal wind/wave climate with a net northern component and west and southwest modifying components. This is important when designing the configuration of the shore protection system. Sea level rise is important as well. Relative sea level has been rising at various rates in Tangier's vicinity but has averaged about 1 ft/100 years over the past several thousand years. However, the recent tidal update for much of the Bay shows an increase of almost twice that rate over the last 20 years.

Utilizing geo-rectified aerial photography from 1938, 1960, 1987, and 2001, shoreline change rates were determined along the Uppards. Shoreline change rates vary but are all erosional except for areas around the north end where sand bars come and go. In the area of concern between baseline stations 4000 and 4600, the rates of erosion have increased with time. Using the rate calculated from the 1938 to 2001 shorelines for station 4000, 16 ft/yr, the 400 ft marsh isthmus width between the shoreline and Toms Gut would breach in about 25 years. This would essentially break the Uppards in two and accelerate the defragmentation of the island mass. By assuming a linear rate of shoreline change, the position of the shoreline was projected 10, 20, 30, 40, 50, and 60 years into the future based on the rates calculated between the 1938 and 2001 shorelines. The smaller oxbow tidal channel at Station 4000 would breach in about 15 years. Typically, these smaller channels fill with sand and maintain some type of shoreline continuity. However, if a "permanent" tidal channel is formed and maintains itself, island breaching, as previously discussed, may accelerate.

Headland Control enhances existing shore points and/or create headland features so that a state of static equilibrium is reached in the adjacent embayments. Several erosion resistant points of marsh shore have developed over time; their apexes occur at about station 1800, 3400, 5600 and 6850. Stone breakwaters (structures 1, 2, 4, and 5) would be placed offshore of these marsh headlands. These are headland breakwaters except for 2 and 4 which are headland composites with breakwater/spurs connected by a sill. The overall headland features include beach and dune creation as well with associated grass plantings. The shore in between would be allowed to evolve (erode) into static equilibrium. More closely spaced headland breakwaters, structures 6, 7, and 8, are proposed to address the Uppards' north end erosion. Along with structure 5, these would create provide a continuous beach and dune system across the north end of the Uppards. The potential breech into Toms Gut is partially addressed by structures 2 and 4 but will require an additional headland breakwater to complete the shore protection. With structure 3 in place, continuous shore protection with beach and dunes would exist along about 3,000 ft of coast.

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1 INTRODUCTION

Tangier Island is located in the northwestern portion of Virginia's Chesapeake Bay in Accomack County (Figure 1). It is about 9 nautical miles (nm) from the Eastern Shore of Virginia mainland and 12 nm from the western shore (Northumberland County) and just south of the Virginia-Maryland border. The area known as Tangier Island is now made up of three separate islands: the main residential area called the Town of Tangier, Port Isobel Island east of Tangier, and a marsh island north of Tangier now known as the Uppards (Figure 2).

Geomorphic evolution as it pertains to the coastal region and, in particular, Chesapeake Bay is the response of coastal lands and bottoms to the processes of sea level rise, wind/wave climate and tidal currents. Tangier Island and the string of islands to the north have been diminished in size and extent over the years as a direct result of these processes. At one time, this island chain was continuous; today it is fragmented, and the island masses have been reduced significantly by shore erosion. Marine resources such as wetlands, clams, oysters, submerged aquatic vegetation (SAV), and the numerous benthic communities respond to the evolution of their respective substrates. In the case of SAV, their decline in the area between Tangier and Goose Islands has been significant, and probably due, in part, to the loss of the "landbridge" between the two islands over time. Wave and current activity has increased in the gap potentially causing greater sedimentation in the lee of the islands over time. Both of these trends have an adverse impact to existing SAV and their ability to colonize and expand.

The ongoing erosion of the marsh island north of Tangier, known as the Uppards, will continue to reduce the "protection" afforded existing SAV by the island mass and further expose the east shoals to wind/wave action from the northwest, west and even southwest conditions. Stopping this erosive trend would, at the least, maintain the present shore position. A stone seawall, similar to the one protecting the sewage treatment plant and airport, would stop erosion, but may be or flanked if severe erosion occurs. Although good for shore protection, a continuous stone wall does not have intrinsic habitat value. Headland breakwaters with beach fill also can provide shore protection with the added benefit of habitat creation and enhancement, particularly beaches and dunes. In order to define the limits and effectiveness of shore protection for the Uppards, a Shoreline Management Plan was developed to provide a conceptual shore plan and cost estimates.

The Plan addresses design parameters and potential impacts for structural modifications through shoreline change and wave climate analyses. These analyses were performed for the Uppard's west-facing Chesapeake Bay shoreline by determining rates and patterns of shore change and the distribution of wave energy along the reach. Also included are the potential impacts from storms and storm surge. The wave climate analysis also provides data necessary to determine such breakwater system parameters as breakwater length, height, beach planform, and rock size.

The research for the Plan assesses the physical and hydrodynamic setting in the vicinity of the Uppards shoreline as it relates to erosion, loss of land, and the potential for SAV protection using some type of wave barrier (*i.e.* breakwaters). Three study components address these goals: 1) site assessment, 2) wave climate analysis, and 3) structural recommendations. The site assessment has several sub-tasks including historical shoreline morphologic assessment and determination of rates of change, and a site survey. The wave climate analysis utilizes wind/wave modeling as well as bay formation modeling. Likely, the final plan will involve the installation of headland breakwaters and beach fill so the recommendations will include cost estimates. These elements will provide information necessary for the shoreline management plan and support the current research effort being conducted by the University of Maryland by Dr. Evamaria Koch. Collectively, the two efforts will provide the U.S. Army Corps of Engineers with sufficient research results to address the potential use of breakwaters in this vicinity for SAV restoration/preservation.

2 METHOD

2.1 Geo-Referencing and Photo Mosaics

Recent and historic aerial photography was used to estimate, observe, and analyze past shoreline positions and trends involving shore evolution for Tangier Island. Some of the photographs were available in fully geographically referenced (georeferenced) digital form, but most were scanned and georectified for this project.

Aerial photos from the VIMS Shoreline Studies Program and the SAV archives were aquired. The years included 1938, 1960, 1987 and 2001. High level black and white aerials were available for 1938 and 1960, and color aerials were obtained for 1987 and 2001. The 2001 imagery was already processed and mosaicked by the SAV Program at VIMS. The aerials for the remaining flight lines were processed and mosaicked by the VIMS Shoreline Study Program.

The images were scanned as tiffs at 600 dpi and converted to ERDAS IMAGINE (.img) format. They were georectified to a reference mosaic, the 1994 Digital Orthophoto Quarter Quadrangles (DOQQ) from the United States Geological Survey (USGS). The original DOQQs were in MrSid format but were converted into .img format as well. The software of choice for georeferencing and mosaicking was ArcView 3.3 which included Image Analyst, IMAGINE image support, Legend Tool, MrSid image support, Spatial Analyst, TIFF 6.0 image support, and projection extensions. The digitizing was performed using ESRI ArcMap.

Ground control points were created to register all aerial photos to the reference images. These are points that mark features found in common on both the reference images and in the original scanned tiffs that are being georeferenced. While in ArcView, the 1994 DOQQs and the scanned tiffs were displayed, and a control point shapefile was created. To maintain an accurate registration without too much warp and twist in the images, it was necessary to distribute the control points evenly. This can be challenging in areas with little development. Good examples of control points are permanent features such as manmade features and stable natural landmarks. The standard in this project was from eight to sixteen control points for each aerial image with a root mean square error (RMS) under 3 for each. In order to increase accuracy of the georectification, three observed control points were established at select road intersections in the Town of Tangier. See section 2.3 for more information on survey methodology.

Once the individual images were geo-rectified to the corresponding DOQQs, the mosaic tool in ArcView was used to create an aerial mosaic of the entire study area for each year. The final mosaics are in .img format. In ArcMap, heads-up digitizing with the mosaics in the background was used to delineate shoreline segments representing marsh or beach. These data were labeled as such in the attribute table of the shapefile for each year. In areas where the shoreline was not clearly delineated, the location was estimated based on the experience of the digitizer.

2.2 Shoreline Rate of Change

A custom Arcview extension called "shoreline" (VHB, 2000) was used to analyze shoreline rate of change. A shore parallel landward baseline is drawn, and the extension creates equally-spaced transects along the baseline and calculates distance from the baseline at that location to each year's shoreline. The output from the extension are perpendicular transects of a length and interval specified by the user. The extension provides the transect number, the distance from beginning baseline to each transect, and the distance from the baseline to each digitized shoreline in an attribute table. The attribute table is exported to a spreadsheet, and the distance of the digitized shoreline from the arbitrary baseline are used to determine the rates of change.

This extension is useful on relatively straight shorelines. However, in areas that have unique shoreline morphology, such as creek mouths and spits, the data created from this extension may not provide an accurate representation of shoreline change and should be manually checked for accuracy.

2.3 Shore Survey

A shoreline and nearshore survey was performed along approximately 12,000 feet of Uppards coast in the summer of 2003. Trimble 4700 Real-Time Kinematic Global Positioning System (RTK-GPS) was used to acquire the shore data. The 4700 receiver utilizes dual-frequency, real-time technology to obtain centimeter accuracy in surveying applications. Two benchmarks, Point A and Point C, were set with 2-hr occupations. These data were processed through the National Geodetic Survey's On-line Positioning User Service (OPUS). All the survey data were based on these benchmarks. Based on Points A and C, average measured horizontal and vertical error ranged from 0.04 to 1.4 inches for the survey. The horizontal projection for the data is U.S. State Plane, Virginia South, meters, NAD83; the vertical datum is NAVD88, meters, Geoid99. The survey includes the following elements:

1. Edge of shoreline vegetation, beaches and peat scarps;
2. Mean High Water (MHW) and Mean Low Water (MLW), survey extends to approx. the -3 ft MLW contour;
3. Existing beach and marsh bayward of the primary dune crest and/or sand overwashes.

The data were converted to survey feet, MLLW in order to plot with the U.S. Army Corps of Engineers' bathymetric survey. NAVD88 is 1.38 ft above MLLW (tidal epoch 1960-1978); this information was calculated from a tidal benchmark at Tangier's airport (Pilot 1979, PID#FW1702).

Vertical and oblique aerial imagery was acquired on 14 August 2003 and 29 December 2003. The December photos were taken to document any shore changes due to the passage of Hurricane Isabel in September 2003. The photos provide the basis for delineating shoreline features and position.

2.4 Hydrodynamic Setting and Coastal Processes

As part of the Shoreline Management Plan development, the incoming wave climate was evaluated using RCPWAVE and wind data from Patuxent Naval Air Station. To quantify the wave climate acting upon Tangier's shoreline, the local wind climate was evaluated. Presently, the closest, long-term wind data set exists at Patuxent Naval Air Station (Table 1). The general wind field evaluation was used to generate a corresponding wave field of significant wave conditions directed toward Mathews shore across Chesapeake Bay following procedures developed by Sverdrup and Monk (1947) and Brietsneider (1966) as modified by Kiley (1980).

The wind field evaluation and effective fetch as well as bathymetric contours and storm surge are input to the SMB computer model to calculate wave height, period, and length for a suite of wind speeds at the project offshore boundary. In this case, wind speeds of 10 to 100 mph at 6-10 mph increments were used. Specified storm surges ranged from 2 to 9 ft. Offshore, the wind and wave direction were assumed the same. However, at about -15 ft MLW, the waves enter the nearshore shoaling region and must be evaluated using a hydrodynamic wave refraction model. The predicted wave heights and periods for the three subject directions (northeast, east, and southeast) are used as input to the hydrodynamic model, RCPWAVE.

RCPWAVE is a linear wave propagation model designed by the USACE (Ebersole *et al.*, 1986) for engineering purposes. The model is a 2-D steady-state, finite-difference model that simulates wave propagation over a bathymetric grid outside the surfzone. It computes changes in wave characteristics that result naturally from refraction, shoaling, and diffraction over complex topography. The Coastal Engineering Design and Analysis System (CEDAS v.2.01) created by Veri-Tech incorporates RCPWAVE into the Nearshore Evolution MOdeling System or NEMOS which is a set of codes that operates as a system to simulate the long-term planform evolution of the beach in response to imposed wave conditions, coastal structures, and other engineering activities. The use of RCPWAVE to model the hydrodynamics at Tangier assumes that only the offshore bathymetry affects wave transformation; the application does not include the effects of tidal currents.

A detailed nearfield bathymetric grid for the purpose of ascertaining littoral processes along the Uppards shoreline was created. The grid (Figure 3) of the study region was created using the Corps of Engineers bathymetric survey of 2003 and VIMS Shoreline Studies Program's beach and nearshore survey. RCPWAVE takes a simulated incident wave condition at the seaward boundary of the grid and allows it to propagate shoreward across the nearshore bathymetry. Waves also tend to become smaller over shallower bathymetry and remain larger over deeper bathymetry. Upon entering shallow water, waves are subject to refraction, in which the direction of wave travel changes with decreasing depth in such a way that wave crests tend to become parallel to the depth contours. Irregular bottom topography can cause waves to be refracted in a complex way and produce variations in the wave height and energy along the coast.

Table 1. Summary wind data from hourly occurrences between 1973 and 2001 at Patuxent Naval Air Station.

		WIND DIRECTION								
Wind Speed (mph)	**Mid Range (mph)**	**South**	**South west**	**West**	**North west**	**North**	**North east**	**East**	**South east**	**Total**
< 5	3	8025* 3.3+	5797 2.4	6521 2.6	7855 3.2	32727 13.3	5603 2.3	4985 2.0	4976 2.0	76489 31.0
5-10	8	15248 6.2	13059 5.3	12328 5.0	12571 5.1	15859 6.4	12329 5.0	9441 3.8	12009 4.9	102844 41.7
10-20	15	8338 3.4	10154 4.1	8404 3.4	12065 4.9	10152 4.1	5173 2.1	3424 1.4	5743 2.3	63453 25.7
20-30	25	210 0.1	334 0.1	504 0.2	1528 0.6	667 0.3	224 0.1	73 0.0	80 0.0	3620 1.5
30-40	35	12 0.0	13 0.0	29 0.0	78 0.0	44 0.0	12 0.0	11 0.00	2 0.00	201 0.1
40-60	50	0 0.00	1 0.00	0 0.00	3 0.00	1 0.00	1 0.00	1 0.00	0 0.00	7 0.00
Total		31833 12.9	29358 11.9	27786 11.3	34100 13.8	59450 24.1	23342 9.5	17935 7.3	22810 9.2	246614 100.0

2.5 Standard Equilibrium Bay Modeling

The integration of the wave climate analysis with the shore planform analysis is shown as a three-step procedure in Figure 4. The Standard Equilibrium Bay (SEB) model is an empirical procedure developed by Hsu *et* al. (1989) to describe pocket beach stability. It is used to model potential shore configurations that result when Headland Control is utilized as the primary shore erosion control strategy. This strategy employs stone structures (possibly combinations of breakwaters, sills and revetments) along existing headland features to begin the process of long-term shoreline equilibration. The wind field for a typical bay site depicts the direction of the annual significant wind and the design storm wind. Wave height (H) and period (T) are predicted at a point offshore of the project site by SMB. The wind and wave directions are assumed to be the same. SMB output is used for input into RCPWAVE and the associated bathymetric grid. RCPWAVE models wave attenuation accross the nearshore region and the output wave parameters, height and angle (H and α), are chosen at the appropriate area of the proposed breakwater project. Wave angle drives the beach planform calculations from SEB. The upper beach berm is modified by the design storm condition.

Detailed beach planform analysis is depicted in Figure 5. The tangential section of a pocket beach becomes approximately parallel with the dominant impinging wave crests. The tangential section is the first to form in shoreline/pocket beach evolution. The spiral section forms last and will deviate most until dynamic equilibrium is attained. Pocket embayment prediction works best for coasts with a unidirectional wave climate. Along coasts with two (bimodal) or more (omnidirectional) directions of wind/wave influence, the sandy embayed shoreline will fluctuate with changing wind/wave fields, particularly during storms as shown in Figure 4.

The relationship between four specific headland breakwater system parameters were investigated by Hardaway *et al.* (1991) for 35 breakwater embayments around Chesapeake Bay. Referring to Figure 4, these parameters include breakwater crest length (L_B), bay gap (G_B), backshore beach width (B_M), and embayment indentation (M_b). The midbay backshore beach width and backshore elevation are important design parameters because they set the size of the minimum protective beach zone in the headland breakwater system. This beach dimension often drives the bayward encroachment that is required for a particular shore protection design. Linear regression analyses were best for the relationship of M_b:G_B with a correlation coefficient of 0.892. The ratio of these two parameters is about 1:1.65 and can be used as a general guide in siting the breakwater system for preliminary analysis then detailed bay shape using the SEB model can be done. Stable relationships for M_b and G_B are not valid for transitional bay/breakwater segments because interfacing the main headland breakwater system with adjacent shores becomes very site specific.

2.6 Plan Development

Design concepts must not only address the shoreline processes and client goals but also the degree of protection desired. The concept of a design storm condition will dictate the initial costs and expected performance of any proposed structures. Personnel at VIMS worked in coordination with the U.S. Army Corps of Engineers, Norfolk District to assess preliminary designs.

The conceptual design includes the following elements related to established tidal datums:

1. Baseline with horizontal and vertical control;
2. Planview with existing conditions and proposed design;
3. Typical cross-sections with existing conditions and proposed design;
4. Structure positions and dimensions.
5. Cost Estimate
6. Permitting restrictions

The theory used to develop the Uppards West Coast Shoreline Management Plan is Headland Control. Potential breakwater/beach fill configurations were assessed using the Model SEB, empirical data from other installations, and existing shore geomorphology. The goals of the plan are:

1) Reduce overall erosion
2) Protect SAV
3) Prevent breaching in areas of concern

3 RESULTS and DISCUSSION

3.1 Physical Setting

3.1.1 Geomorphology and Historic Shore Change

Tangier Island is at the distal end of a chain of Chesapeake Bay islands that extend from Bloodsworth Island in Maryland to South Marshall, Smith, and, finally, Tangier in Virginia (Figure 6). Many other smaller islands make up this Chesapeake Bay archipelago. These islands were once a more continuous feature when sea level was lower. At the last low stand about 15,000 years ago, sea level was 300 feet lower, and this island chain was an upland interfluve between southward flowing streams that are now the Chesapeake Bay to the west and Tangier Sound to the east. Since then, relative sea level has been rising at various rates but has averaged about 1 ft per 100 years over the past several thousand years. However, the recent tidal update for much of the Bay shows an increase of almost twice that rate over the last 20 years.

As sea level rose and flooded the ancestral Bay and its tributaries, the Bay coast began to recede by the process known as shoreline erosion. Shoreline erosion became more dominant as the estuary widened and fetch distances increased. Early maps show the more continuous nature of the Bloodsworth to Tangier Archipelago. The 1877 US Coast Survey Chart No. 33 shows that Tangier and the Uppards were basically connected to Goose Island (Figure 7). The land bridge between Goose Island and Tangier Island reportedly served as a wave barrier and protected the east side from direct Bay wave attack and allowed SAV to flourish. By the turn of the Century, further fragmentation can be seen (Figure 8).

More “recent” shoreline change was measured by VIMS using aerial imagery taken in 1938, 1960, 1987 and 2001. Shoreline types were denoted marsh or beach since these two sediments erode differently. Marsh substrate is much more resistant to erosion, and it erodes much more unevenly than low fastland or sediment banks with the same fetch exposure (Figure 9).

In 1938, the west coast of Tangier Island was very irregular, particularly the Uppards shoreline (Figure 10). A small marsh island occurred at the northwest end of the Uppards. A larger island just south of there was separated from the main island by a tidal channel. The present day channel from the Bay into the Town of Tangier did not exist. The shore zone had many tidal marsh channels, many of which are connected to the eastern drainages. Several pocket beaches existed, but no significant sand accumulation occurred at the Uppards.

By 1960, the small marsh island to the north had disappeared. The larger island was no longer completely separated from the mainland and had been reduced by half (Figure 11). Sand was filling in the small tidal marsh channels to the north. With the islands gone, sand could move more easily northward along the coast, and a beach/bar began forming on the north end of the Uppards. The navigational channel into Tangier from the west did not exist so the Uppards was still part of the residential island of Tangier.

Aerial imagery in 1987 shows dramatic changes to the coast (Figure 12). The area of the marsh island and headland on the northern part of the Uppards was sheared away. The west coast of the Uppards was fairly straight. Sand bars existed along the coast, and a large “rooster tail” spit/bar had formed off the north end toward the east. The navigation channel into Tangier had been well established. It was built in 1957 and some of the dredge material was placed on the Uppards.

The 2001 aerial imagery shows the west coast of the Uppards has once again developed into a more irregular shoreline with headlands and embayments (Figure 13). The position of the headlands are in the approximate reaches of past headland features of 1937 and 1960. The “rooster tail” spit/bar of 1987 has welded onto the northeast side of the island and encapsulated a tidal pond. Sand dunes have developed as well. The area about mid-way along the coast is presently an area of concern (AOC) since the Bay shoreline is only about 400 ft from an interior salt pond called Toms Gut. The meandering tidal channel entering Toms Gut from the southwest at about Station 4000 (Figure 14) is only 150 ft from the 2001 Bay coast.

A summary of shore positions and shoreline change rates at the Uppards is provide in Figure 14. Shoreline change rates vary but are all erosional except for areas around the north end where sand bars and spits have come and gone through time. In the AOC between baseline stations 4000 and 4600, the rates of erosion have increased with time. Using the rate calculated from the 1938 to 2001 shorelines for station 4000, 16 ft/yr, the 400 ft marsh isthmus between the shoreline and Toms But would breach in about 25 years. This would essentially break the Uppards in two and accelerate the defragmentation of the island mass. Mills *et al.* (2003) came to the same conclusion. In fact, they predict that the entire Uppards Island will be gone by the year 2100.

By assuming a linear rate of shoreline change, the position of the shoreline was projected 10, 20, 30, 40, 50, and 60 years into the future based on the rates calculated between the 1938 and 2001 shorelines using the End Point Rate (EPR) method (Fenster *et. al*, 1993) (Figure 15). The majority of the island was based on rates calculated using Baseline 1. However, the north end of the island used Baseline 2 in order to adequately express the change in shore position from the northern exposure. However, these rates are somewhat misleading in that much change has occurred on the north end of the Uppards since 1938. The shoreline had accreted significantly between 1938 and 1960, but by 1987 had eroded to approximately the 1938 position. Since the rates of change are calculated using the EPR method, this accretion and subsequent erosion are not reflected in the 1938-2001 rate. The rates also show that the small oxbow tidal channel near Toms Gut would breach in about 15 years. Typically, these smaller channels fill with sand and maintain some type of shoreline continuity. However, if a “permanent” tidal channel is formed and maintains itself, island breaching, as previously discussed, may accelerate.

Figure 16 shows the projected shoreline configurations at 10, 20, 30, 40, 50 and 60 years. These data are based on the linear rate of shore change presented in Figure 15 and are the result of the authors’ experience in shore morphologic evolution. The disintegration of the marsh islands to the north in Maryland was also used to model the proposed prediction of shore position in the future.

3.1.2 Present Geomorphology

Much of Tangier, including the Uppards Island, is marsh with only a few sand ridges that represent the upland areas. On the Uppards, only two sand ridges occur near the north end. A complex of tidal marsh channels and bays lies within the shore boundary of the Uppards. As shoreline erosion has proceeded over the years these channels are breached often resulting in dramatic patterns of shore change. The shoreline around the Uppards varies in nature due, in part, to varying fetch exposures. The west shore has higher erosion rates because it faces the open Chesapeake Bay while the east shore of the Uppards has a much lesser fetch across the shallows of Tangier Sound and is protected by Port Isobel from larger waves to the southeast resulting in less dramatic shore change. It is also within the Tangier Sound shallows that important SAV occur.

Today the shoreline along the west shore of the Uppards occurs as a low eroding marsh coast. The shoreline is very irregular and exists as a series of headlands and embayments at varying scales (Figure 17). The large embayments have beaches where sand extends from below MLW to a berm feature on top of the marsh. The sandy berm is fairly continuous along the west shore, and the increase in elevation allows a change in vegetation including salt bushes. The eroding marsh face extends into the very nearshore as peat/clay substrate. The nearshore shelf has a series of shore parallel sand bars especially off the northern half of the west shore of the Uppards.

Large storm events can significantly alter coastal geomorphology. The passage of Hurricane Isabel in September 2003 severely impacted shores all around the Chesapeake Bay. In addition to being in the "right front quadrant" of the advancing hurricane, the Virginia portion of Chesapeake Bay experienced winds from the northeast, east and east-south-east which accentuates storm surge. While wind/waves from these directions do not directly impact the western shore of the Uppards, the large storm surge allowed water to cover much of the island increasing the reach of the waves all around the island. The magnitude of the storm surge, about 8 ft MLLW, was close to that of the 1933 hurricane, the local "storm of record." Figure 18 depicts the pre and post hurricane shoreline of the west coast of the Uppards. These photo mosaics are not rectified images so changes are only qualitative. Of note is the change in direction of the inlet to the pond on the north end of the Island. Also important is that washover has occurred into the oxbow in the AOC indicating that breaching may be sooner than modeled in Figure 15.

3.2 Hydrodynamic Setting

3.2.1 Hydrodynamic Setting

Tangier Island has a mean tide of 1.4 ft with a diurnal range of 1.7 ft. Relative sea level has risen 0.3 ft since the last tidal epoch (1960-1978). The west coast of the Uppards which has a north/south orientation has effective fetch (U.S. Army Corps of Engineers, 1984) exposures to the northwest, west, and southwest of 25 nautical miles (nm), 17 nm, and 26 nm, respectively (Figure 18). Storm surge frequencies according to Boon *et al.* (1978) are 5.5 ft, 6.2 ft, 6.9 ft and 7.6 ft MLW for the 10, 25, 50 and 100 year return intervals.

3.2.2 Wave Climate

The wave climate impacting the west coast of Tangier is forced by the frequency and duration of winds. Three primary wind directions effect the Uppards coast; they are, the northwest, west and southwest. However, north and south wind-driven waves will also have some impact even though they generally run normal to the coast. These two ancillary directions may amplify or moderate the main three directions impacting the coast. This is particularly true of the north wind which has the highest total frequency as seen in Table 1. Clearly the north and northwest components dominate over the south and southwest. Westerly wind-wave crest lines approach basically parallel to the coast. Selected results from our RCPWAVE analysis are shown in Figures 20, 21, and 22. The modeled wave height contours with wave direction arrows are shown for the input parameters listed in Table 2. The plots show how the wave height contours change with the bathymetry as the wave moves toward the shore. Also depicted are the directional arrows of the wave. The arrows are not indicative of wave height, only direction.

In general, the west coast of the Uppards is exposed to a bimodal wind/wave climate with a net northern component as per the wind frequency. This is important when designing the configuration of the shore protection system. Wind-wave height patterns from the northwest and southwest show alternating "bands" of reduced and enhanced wave heights in the nearshore region oriented in the direction of wave propagation. The wind/wave height patterns from the west show a slight increase more or less uniformly along the nearshore region perhaps as a response to shoaling.

Wave direction vectors from the west are fairly uniform and shore normal whereas wave vectors from the northwest and southwest are more irregular in direction in the nearshore. Wave vectors have similar patterns as they enter the main harbor to Tangier. Waves propagating around the north end of the Uppards show a significant shearing pattern from each wind/wave direction particularly the southwest and west.

Table 2. Selected input wave conditions to RCPWAVE.

Surge Level (ft MLLW)	Wind Speed (mph)	Direction	Wave Height (H) (ft)	Period (T) (seconds)
2	25	Northwest	3.2	4.3
2	25	West	2.6	3.9
2	25	Southwest	2.9	4.1
4	35	Northwest	3.9	4.8
4	35	West	3.2	4.4
4	35	Southwest	3.6	4.6
6	50	Northwest	5.1	5.5
6	50	West	4.3	5.0
6	50	Southwest	4.7	5.3

3.3 Shoreline Management Plan

3.3.1 Conceptual Plan Design

Headland Control attempts to enhance existing shore points and/or create headland features so that a state of static equilibrium is reached in the adjacent embayments. Several erosion resistant points of marsh shore have developed over time; their apexes occur at about station 1800, 3400, 5600 and 6850 (refer to Figure 14). Net wave approach is from the northwest along most of the coast except across the north end.

In order to address Goal 1, reducing overall erosion, the first step is to place stone breakwaters (structures 1, 2, 4, and 5) offshore of these marsh headlands (Figure 22A-C). These are headland breakwaters except for #4 which is a headland composite with breakwater/spurs connected by a sill. The overall headland features include beach and dune creation as well with associated grass plantings. Rocks and beach material will be brought in by barge. Sand may also be obtained from dredging of adjacent navigational channel. See typical cross-sections for detail Figure 23. The shore in between would be allowed to evolve (erode) into static equilibrium

Goal 2 requires stopping the north end erosion which is addressed by more closely spaced headland breakwaters in addition to the steps taken for Goal 1. Structures 6, 7, and 8 are proposed headland breakwaters. Along with structure 5, these would create provide a continuous beach and dune system across the north end of the Uppards.

Goal 3 requires addressing the main AOC, the potential breech into Toms Gut. This is partially addressed by structures 2 and 4 but will require an additional headland breakwater to complete the shore protection required to fulfill Goal 3. Thus, the addition of structure 3 as shown in Figure 22B. With structure 3 in place, continuous shore protection with beach and dunes would exist along about 3,000 ft of coast.

The full plan provides total shore protection along most of the Uppards west except for areas between structures 4 and 5 and between structures 1 and 2. These areas would evolve (erode) toward an equilibrium planform as shown. Structure 1 resides in front of an existing dredge material disposal are.

The dune is required to keep beach sand from being overwashed onto the marsh. This might allow the beach to move inland as well and reduce the breakwater and headland effect. The dune is portrayed at +8 ft MLLW which is just above the 100 year storm surge level. A lower dune can be applied, but the potential overwash consequences should be assessed in term of cost and effectiveness. Damage to the dune may need to be repaired after severe storm events such as the recent Hurricane Isabel.

Potential impacts to the littoral sediment transport system would be similar to the natural coast with its series of headlands and pocket bays that have developed over time. Some sandy material will enter proposed embayments and some will migrate around the structures. The northernmost unit will shelter the adjacent coast and perhaps allow some sand accumulation in its lee. The eroding east coast of the Uppards will still be exposed northeasters. Continuing the project around the north point and down the east coast is an option, but this might more directly impact existing SAV beds.

3.3.2 Conceptual Cost Estimate

The preliminary cost estimate for the conceptual plan is portrayed using four different scenarios (Table 3 and 4). Table 5 presents a summary cost estimate of the various components of the proposed plan. The breakwater height required for long-term shore protection is proposed to be +4 ft MLLW. Breakwaters at +4ft MLLW are equal to or higher than the salt bush berm and should provide adequate support for the proposed beach and dune systems. However, there is the reality of sea level rise which has doubled over the last 20 years. Therefore, a +5 ft MLLW breakwater height option is presented for costing.

Sand is a primary component in developing the shore protection plan. The source will significantly affect cost. Two scenarios are given - one with borrowed sand barged in and the other with dredge material from the Tangier Island entrance channel. The required marsh and dune grasses are the same in each of the four options. Other ancillary costs may include mobilization/demobilization and certain site work requirements; these are not included.

Option A1
Breakwaters at +4 ft MLLW with borrowed sand $5,458,736

Option A2
Breakwaters at +4 ft MLLW with dredged sand $3,537,736

Option B1
Breakwaters at +5 ft MLLW with borrowed sand $5,802,716

Option B2
Breakwaters at +5 ft MLLW with dredged sand $3,881,716

Table 3. Cost estimate of rock for proposed structures for the west coast of the Uppards.

Structure Number	Structure Type	Rock Crest Length (ft)	Calculated Length (ft)	Elevation +4 ft MLLW		Elevation +5 ft MLLW	
				Tons per foot	Tonnage at +4 ft MLLW	Tons per foot	Tonnage at +5 ft MLLW
1	BW	400	415	10	4,150	11.8	4,897
2	BW/spur	300	315	10	3,150	11.8	3,717
	sill	300	300	7.5	2,250	7.5	2,250
	BW/spur	300	315	10	3,150	11.8	3,717
3	BW	360	375	10	3,750	11.8	4,425
4	BW/spur	250	265	10	2,650	11.8	3,127
	sill	650	650	7.5	4,875	7.5	4,875
	BW/spur	200	215	10	2,150	11.8	2,537
5	BW	300	315	10	3,150	11.8	3,717
6	BW	160	175	10	1,750	11.8	2,065
7	BW	220	235	10	2,350	11.8	2,773
8	BW	300	315	10	3,150	11.8	3,717
Total					**36,525**		**41,817**

Table 4. Cost estimate for sand and plants needed to complete the proposed management plan.

Structure Number	**Structure Type**	**Shore Length (ft)**	**Sand (cy/ft)**	**Sand Needed (cy)**	**Alongshore Footage of Needed Plants (ft)**	**Area Covered by Plants (sq. ft)**
1	BW	400	17	6,800	75	30,000
2	BW/spur	400	17	6,800	75	30,000
	sill	300	17	5,100	110	33,000
	BW/spur	300	17	5,100	75	22,500
3	BW	800	17	13,600	75	60,000
4	BW/spur	500	17	8,500	75	37,500
	sill	650	17	11,050	110	71,500
	BW/spur	300	17	5,100	75	22,500
5	BW	450	17	7,650	75	33,750
6	BW	400	17	6,800	75	30,000
7	BW	400	17	6,800	75	30,000
8	BW	750	17	12,750	75	56,250
Total				**96,050**		457,000
					2.25 plants/sq. ft	**1,028,250 plants**

Table 5. Complete cost estimate for the entire west coast of Uppards management plan.

Rock		Tonnage	Cost per Ton ($)	Total Cost ($)
	Elev. +4 ft MLLW	36,525	65	2,374,125
	Elev. +5 ft MLLW	41,817	65	2,718,105
Sand	Amount (cy)	Cost per cy ($)	Site	Total Cost ($)
	96,050	30	Borrow	2,881,500
		10	Dredge	960,500
Plants	Number of Plants	Cost per Plant ($)		Total Cost ($)
	203,111	1		203,111

4 SUMMARY

The Shore Management Plan as presented will provide long-term shore protection along the Uppards west coast. The proposed plan may be phased depending on the highest priority goal. Sea level rise will become a more important factor with time. A plan to add to the breakwaters and sand to the beach/dune system should be adhered to with certain planview and elevational benchmarks. Also, erosion of the east side of the Uppards is occurring but at a much lesser rate relative to the west coast. A shore plan for that coast should be considered in future efforts.

Acknowledgments

The 1877 and 1984 charts were downloaded from the Office of Coast Survey's website (http://nauticalcharts.noaa.gov).

5 REFERENCES

Boon, J.D, C.S. Welch, H.S. Chen, R.J. Lukens, C.S. Fang and J.M. Zeigler. 1978. A storm surge study: Volume I. Storm surge height-frequency analysis and model prediction for Chesapeake Bay. Spec. Rept. 189 in Applied Mar. Sci. and Ocean Engineering, Virginia Institute of Marine Science, Gloucester Point, VA, 155 pp.

Bretschneider, C.L. 1966. Wave generation by wind, deep and shallow water. In: Estuary and Coastline Hydrodynamics, A.T. Ippen (Ed.), McGraw-Hill, New York, chap. 3, p. 133-196.

Ebersole,B.A., M.A. Cialone, and M.D. Prater, 1986. RCPWAVE- A Linear Wave Propagation Model for Engineering Use. U.S. Army Corps of Engineers Report, CERC-86-4, 260 pp.

Fenster, M.S., R. Dolan, and J.F. Elder, 1993. A new method for predicting shoreline positions from historical data. *J. Coastal Res*., **9**(1), 147-171.

Hardaway, Jr., C.S., G. R. Thomas, and J. -H. Li, 1991. Chesapeake Bay Shoreline Study: Headland Breakwaters and Pocket Beaches for Shoreline Erosion Control. Special Report in Applied Marine Science and Ocean Engineering No. 313. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Hsu J.R.C., R. Silvester and Y.M. Xia, 1989. Generalities on static equilibrium bays. *Coastal Engineering*, **12**: 353-369.

Kiley, K. 1980. Estimates of bottom water velocities and associated with gale wind generated waves in the James River, Virginia. Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, VA.

Mills, W.B., P.E., C.-F. Chung, and K. Hancock, 2003. Predictions of relative sea level change and shoreline erosion over the 21st Century on Tangier Island, Virginia. Contract Report by Tetra Tech, Inc., Lafayette, California.

Sverdrup, H.U. and W.H. Munk. 1947. Wind sea, and swell: Theory of relations for forecasting. U.S. Navy Hydrographic Office Publ. No. 601.

U. S. Army Corps of Engineers, 1984. Shore Protection Manual. Coastal Engineering Research Center.

VHB, 2000. Vanasse Hangen Brustlin, Inc., 477 McLaws Circle; Suite 1, Williamsburg, Virginia 23185

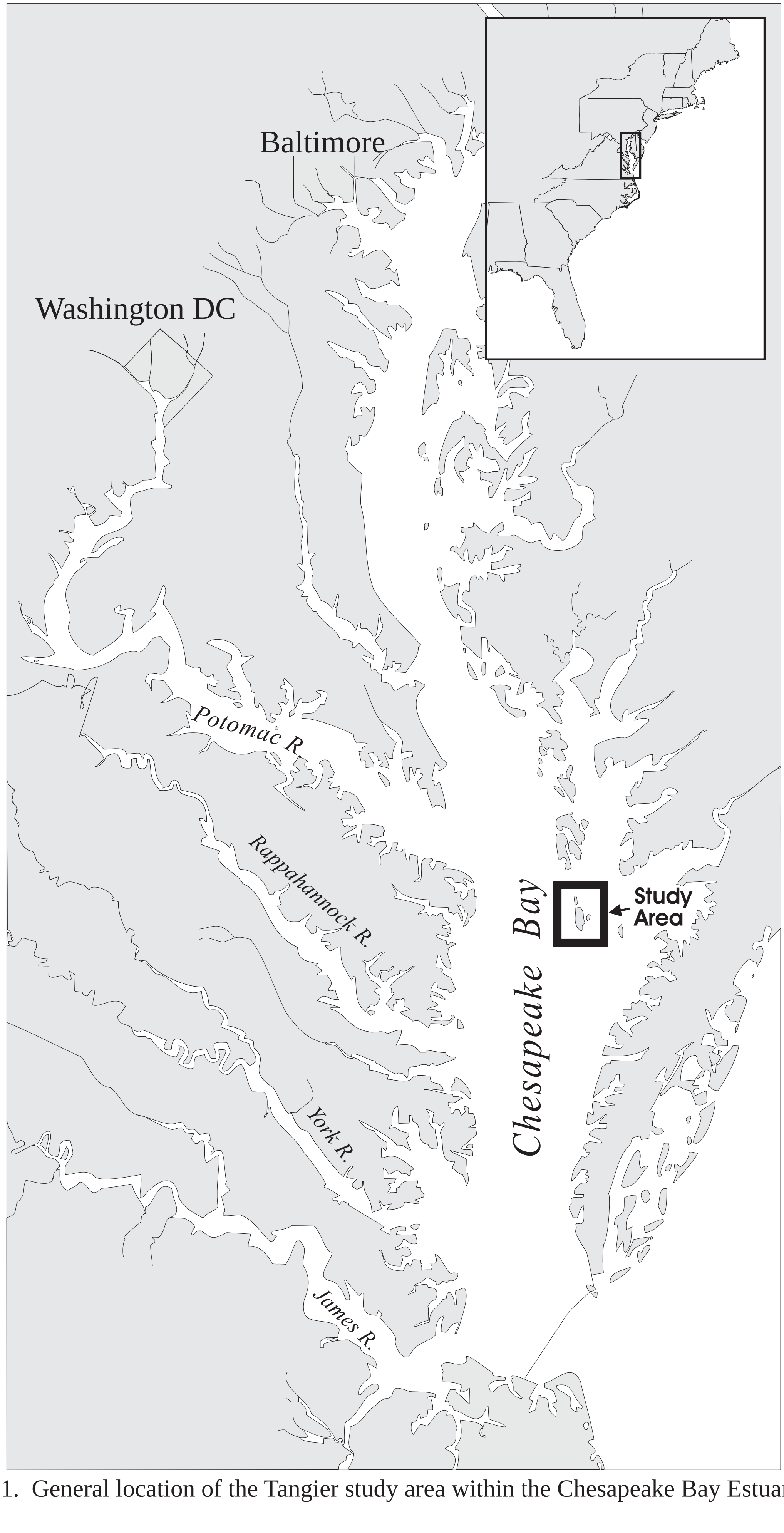


Figure 1. General location of the Tangier study area within the Chesapeake Bay Estuarine System.

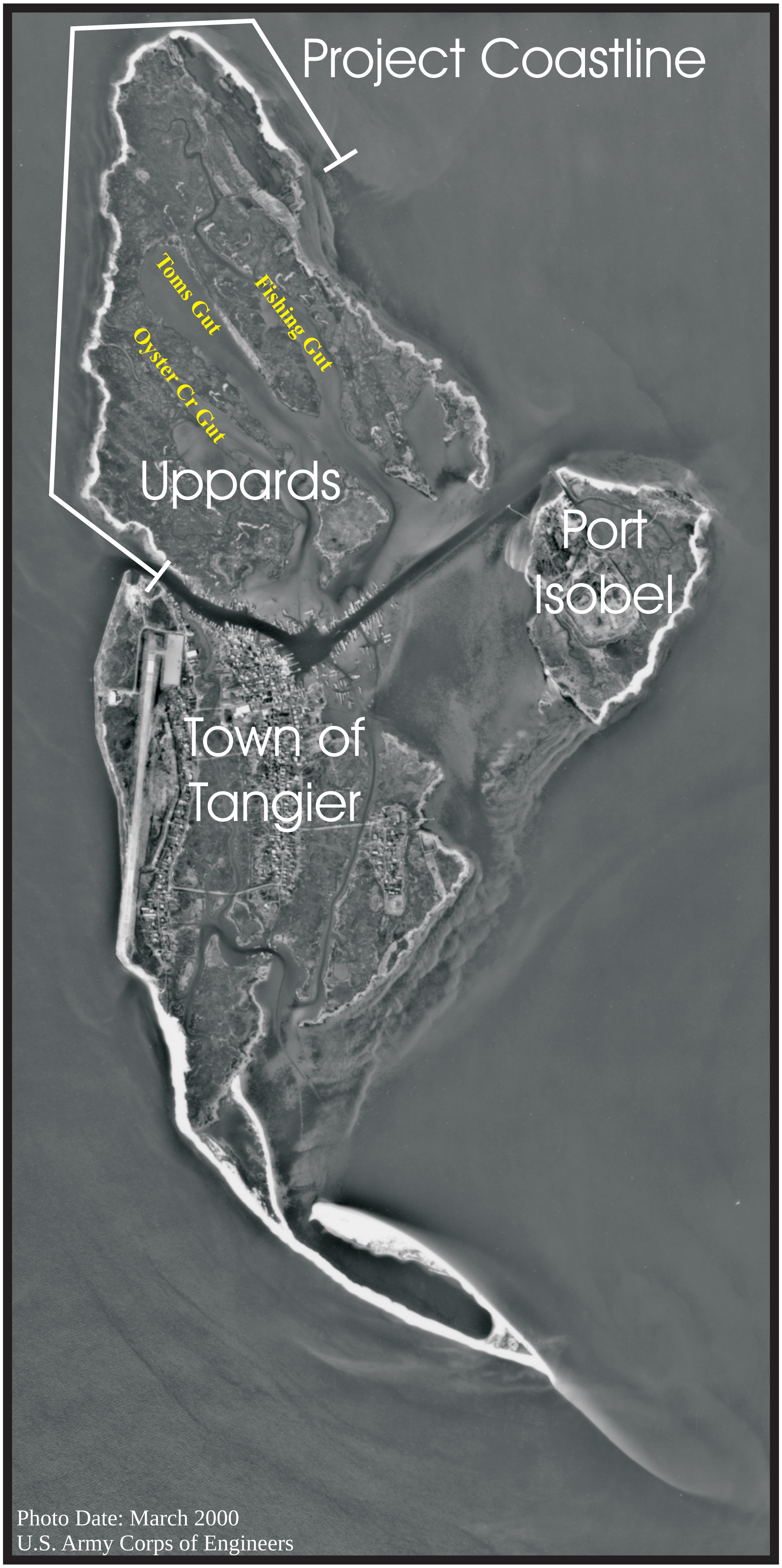


Figure 2. Location of specific project coastline.

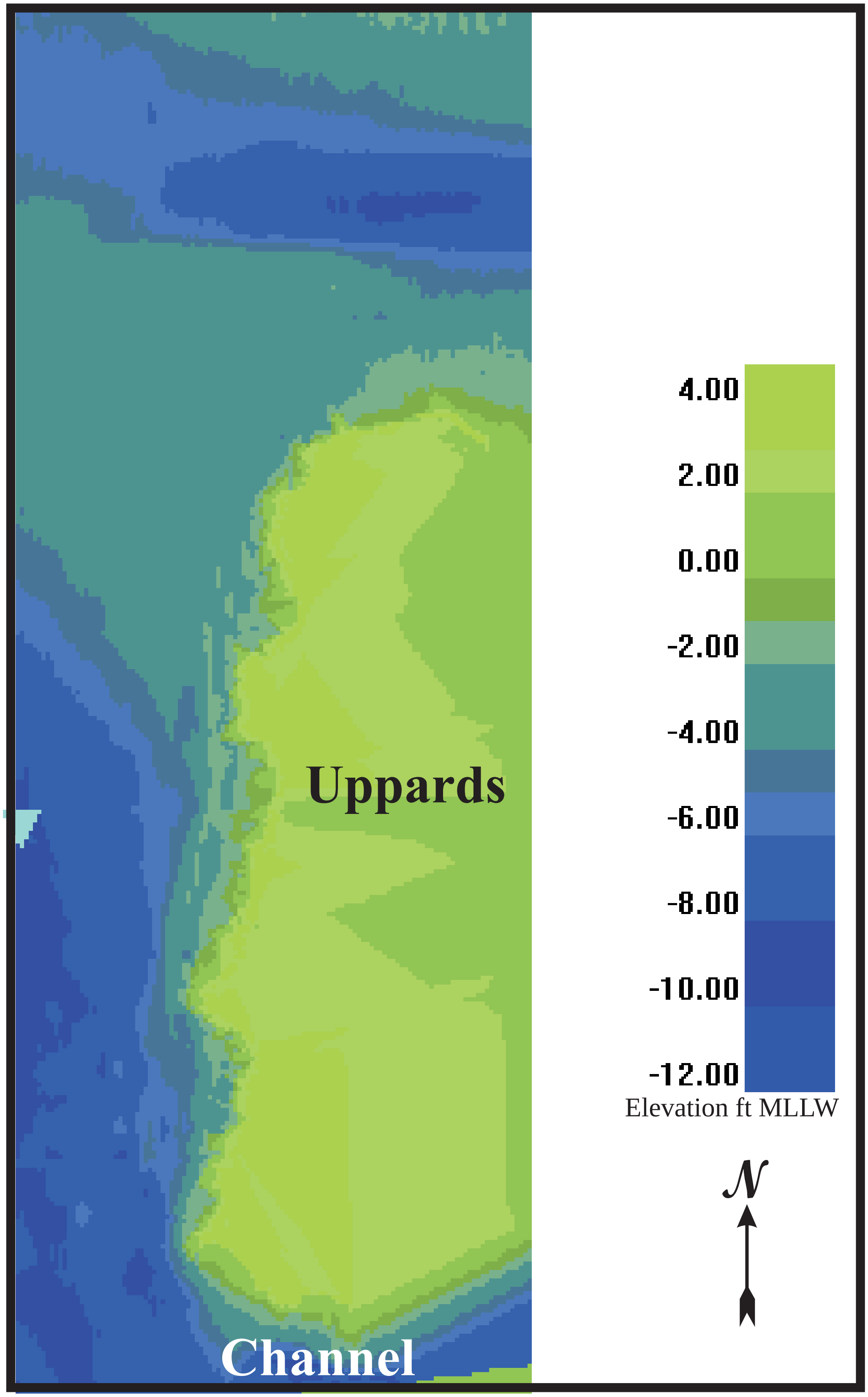


Figure 3. RCPWAVE grid of the Uppards created from VIMS Shoreline Studies Program beach/marsh and nearshore survey and the U.S. Army Corps of Engineers bathymetric survey, Summer 2003.

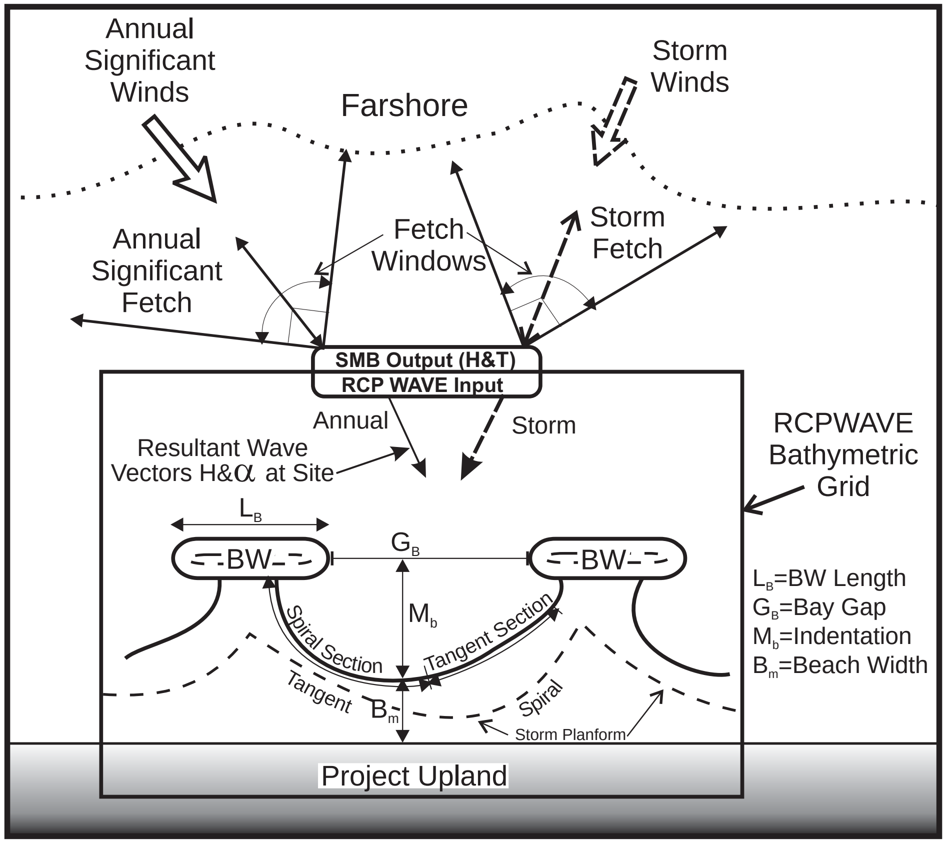


Figure 4. Parameters related to wind/wave generation (SMB), nearshore wave refraction (RCPWAVE), and beach planform prediction (SEB).

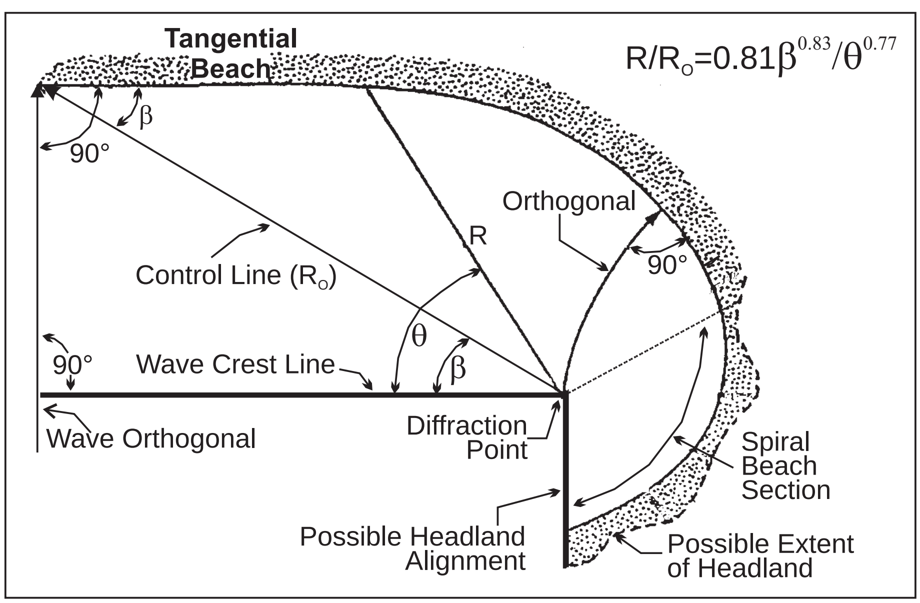


Figure 5. Parameters of the Static Equilibrium Bay (after Hsu *et al*., 1989).

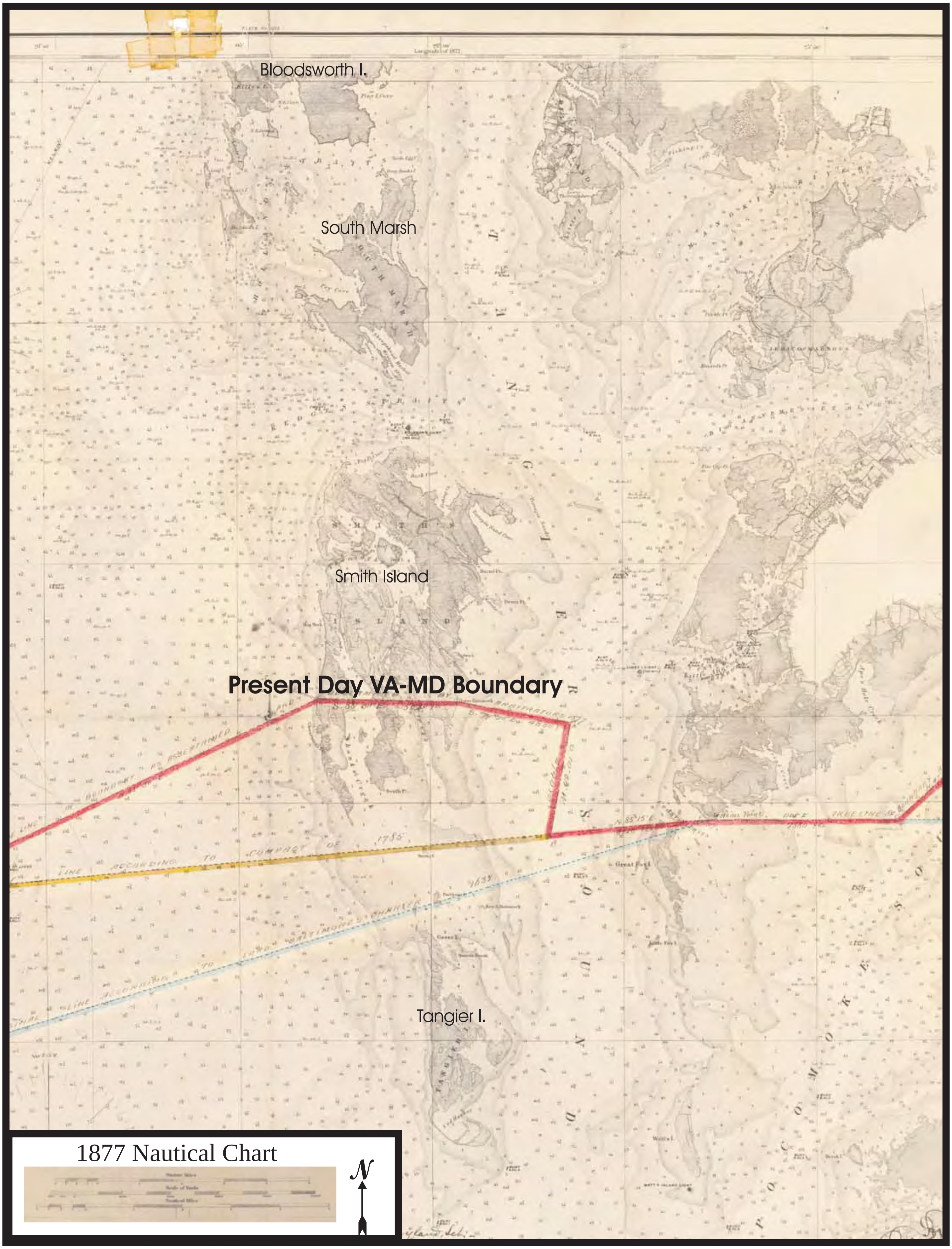


Figure 6. An 1877 nautical chart showing the extent of the Chesapeake Bay chain of islands.

Figure 7. An enlargement of the 1877 nautical chart showing the extents of Tangier and Goose Islands.

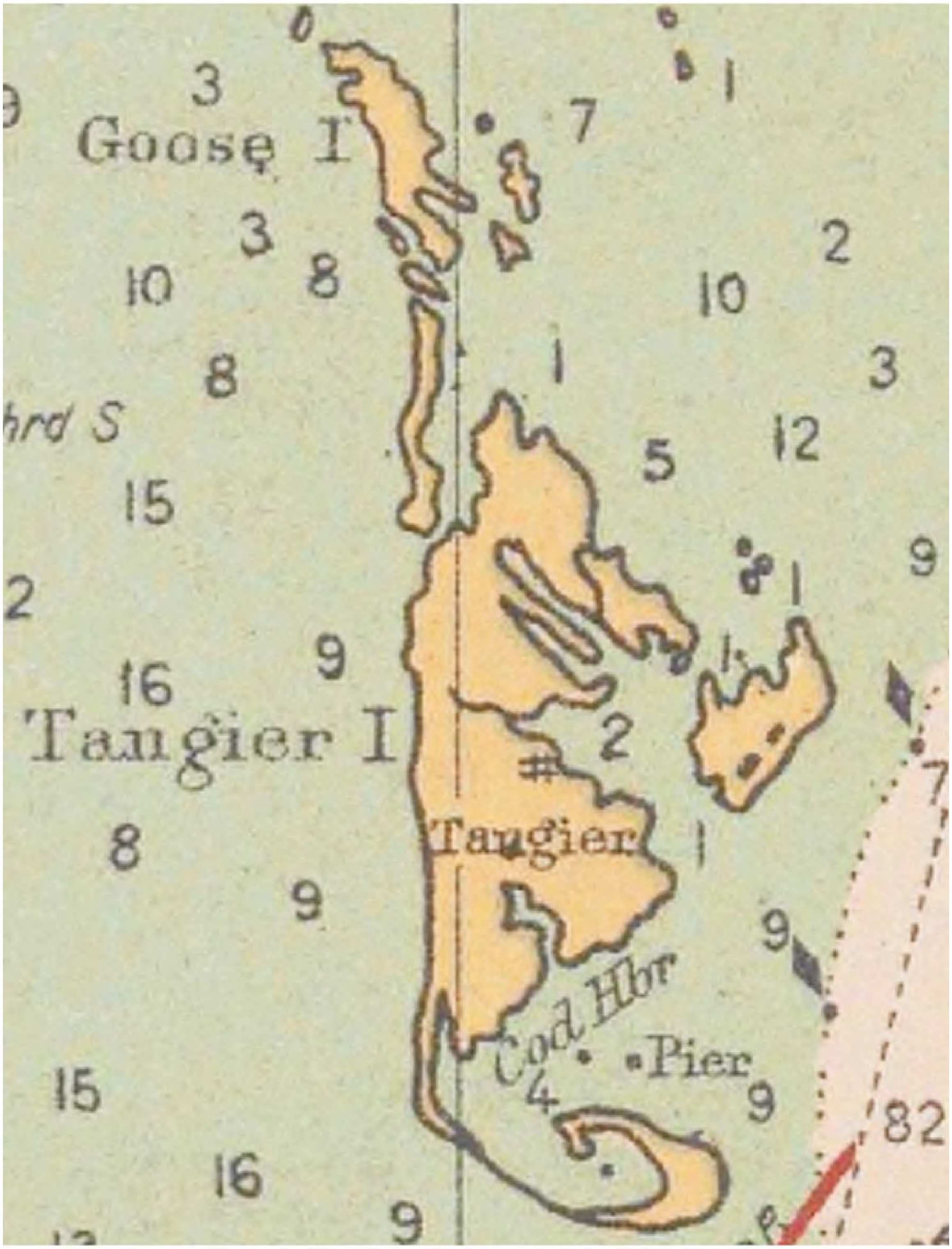
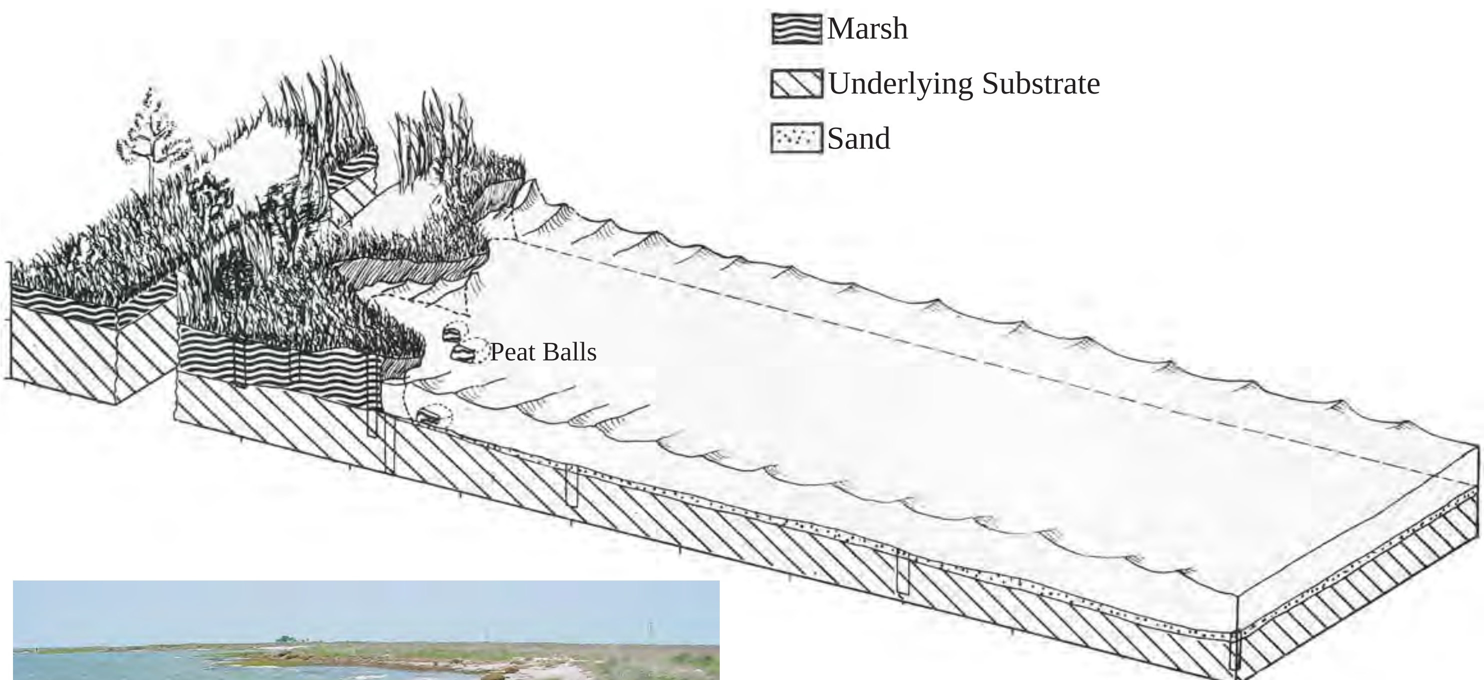


Figure 8. A 1914 nautical chart showing the reduced extent of the Chesapeake Bay chain of islands.



Also note the sandy salt bush berm that occurs along much of the coast.

Peat Boulder

Figure 9. Graphic depicting marsh erosion and photos taken at the Uppards. Note the large peat boulder in the lower photo that has been reworked by wave action after eroding then carried onto the marsh shore terrace by storm waves.

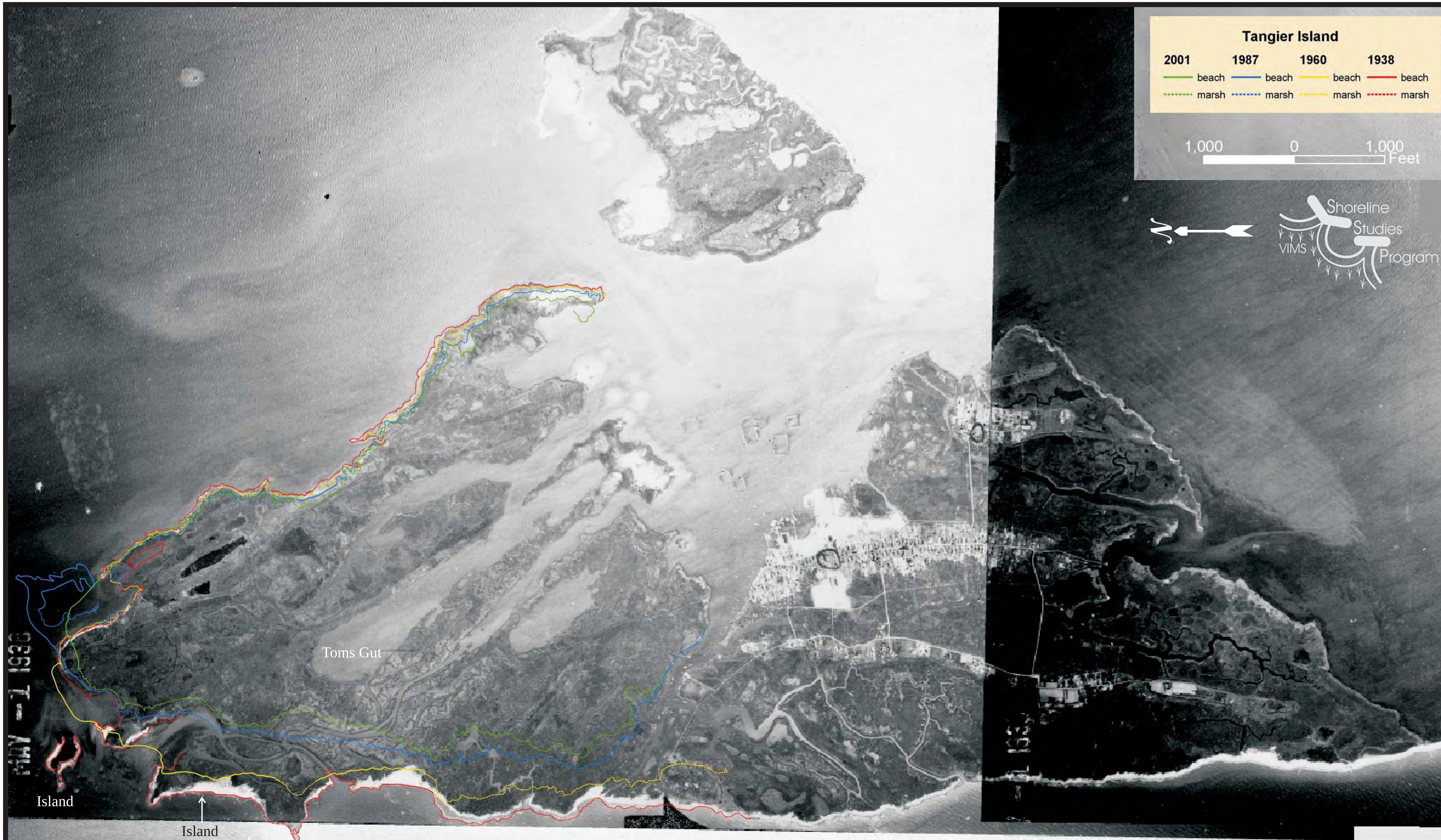


Figure 10. Geo-rectified 1938 imagery of Tangier Island.

Figure 11. Geo-rectified 1960 imagery of Tangier Island.

Figure 12. Geo-rectified 1987 imagery of Tangier Island.

Figure 13. Geo-rectified 2001 imagery of Tangier Island.

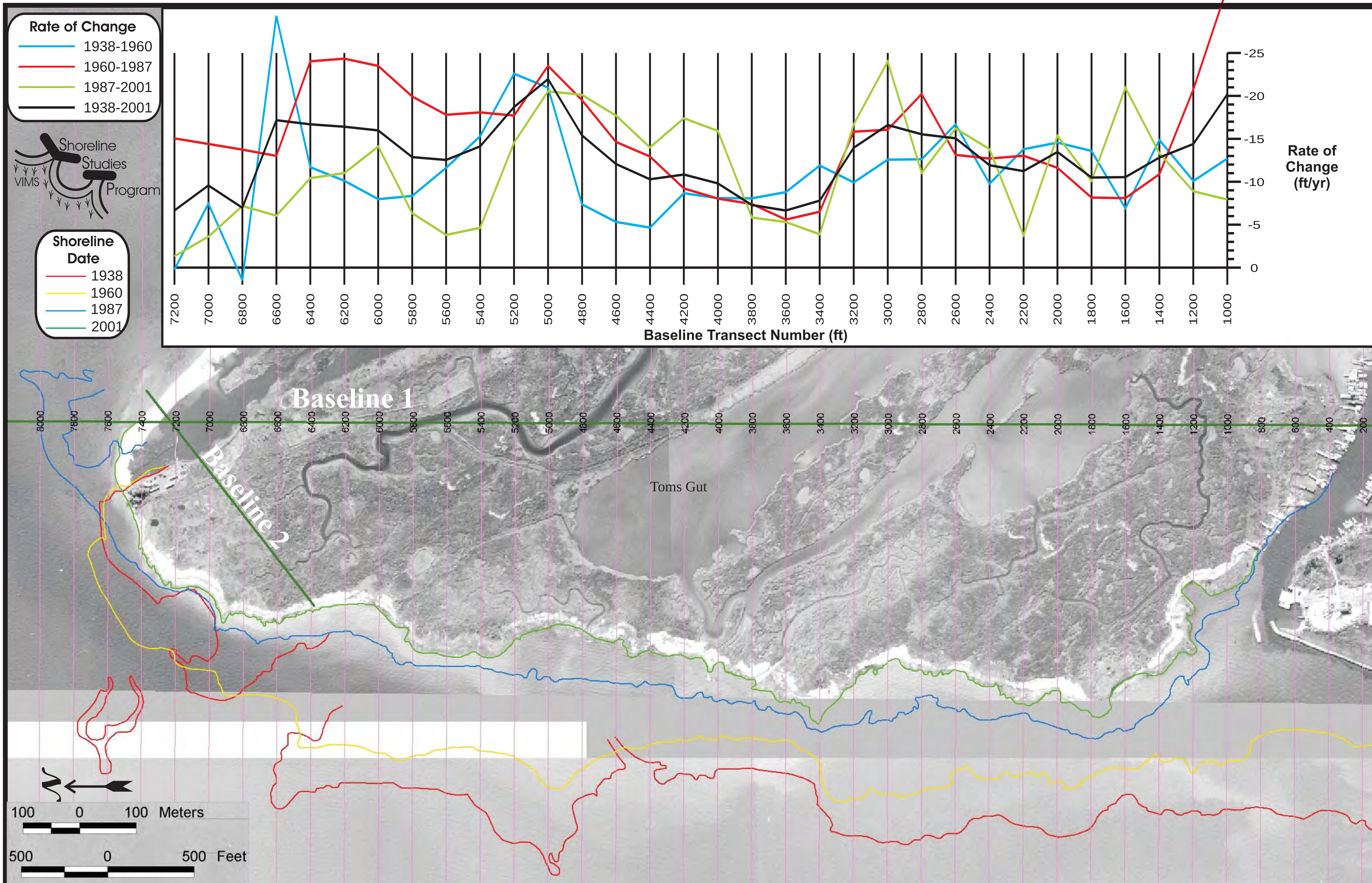


Figure 14. Historical shoreline positions along the Uppards shoreline with rate of change calculated.

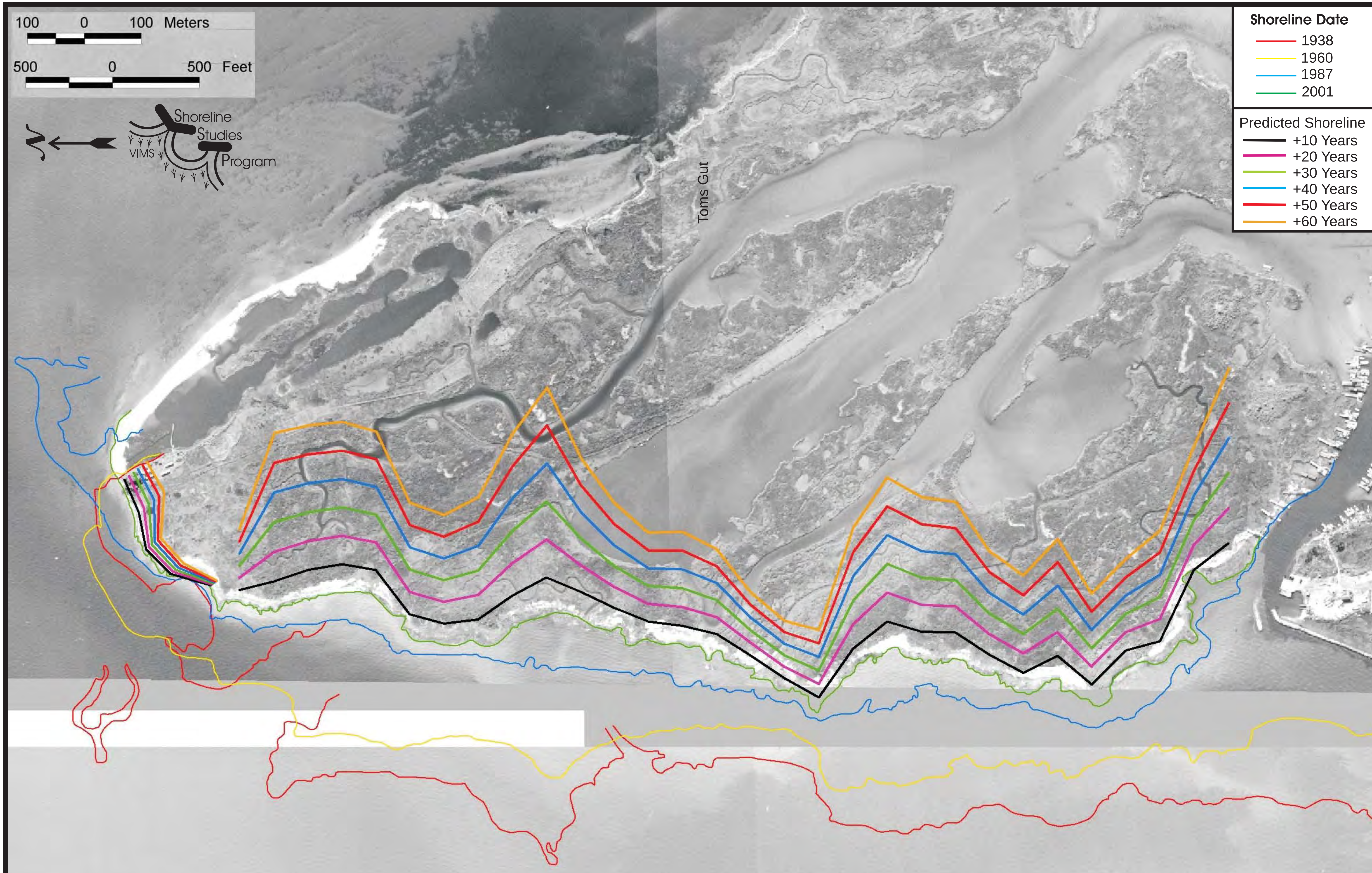


Figure 15. Historical shoreline positions and linearly interpolated shorelines using the rate of change between 1938 and 2001.

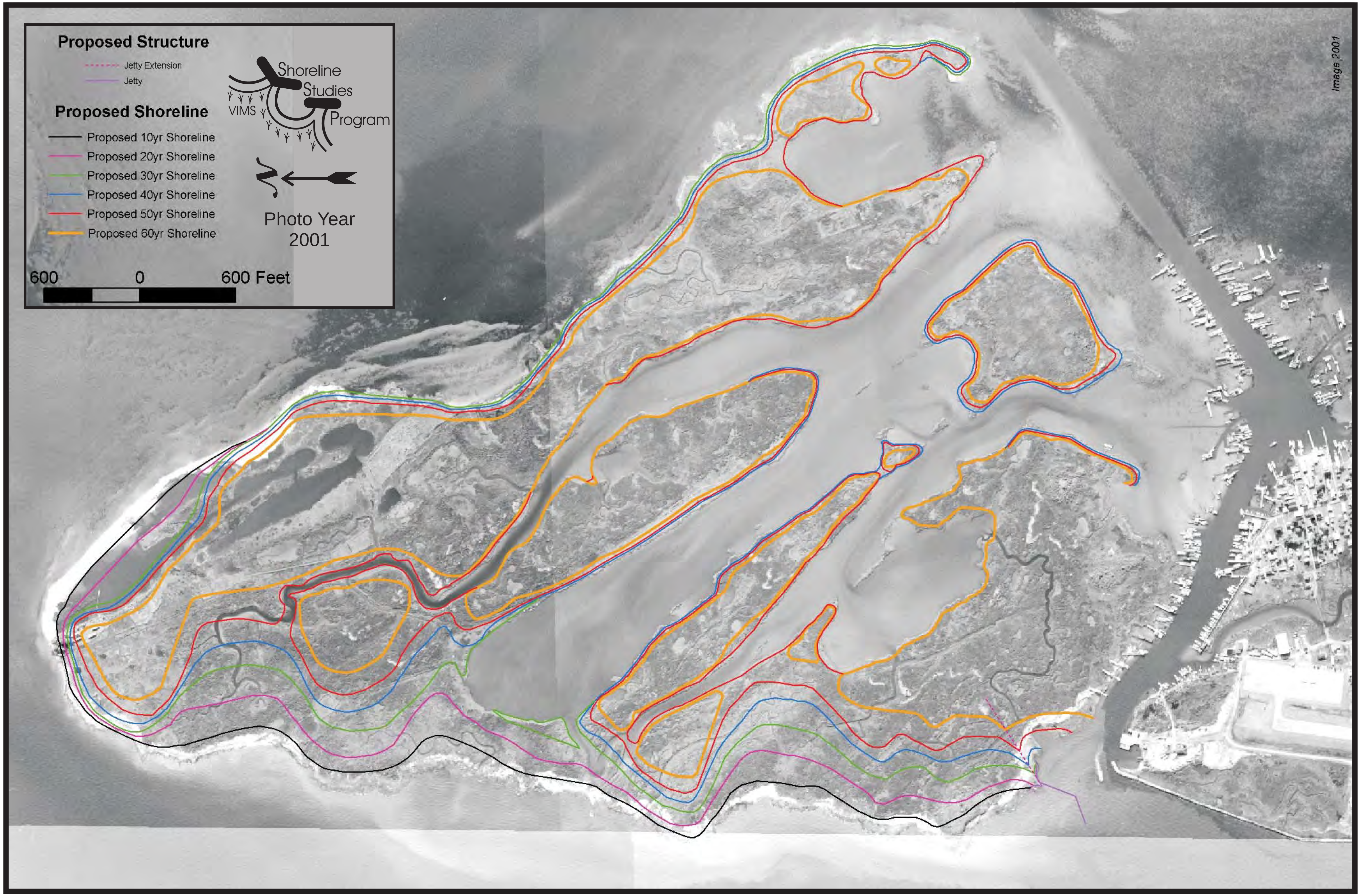


Figure 16. Projected shore positions along the Uppards for 60 years based on rates determined and shown in Figures 14 and 15.

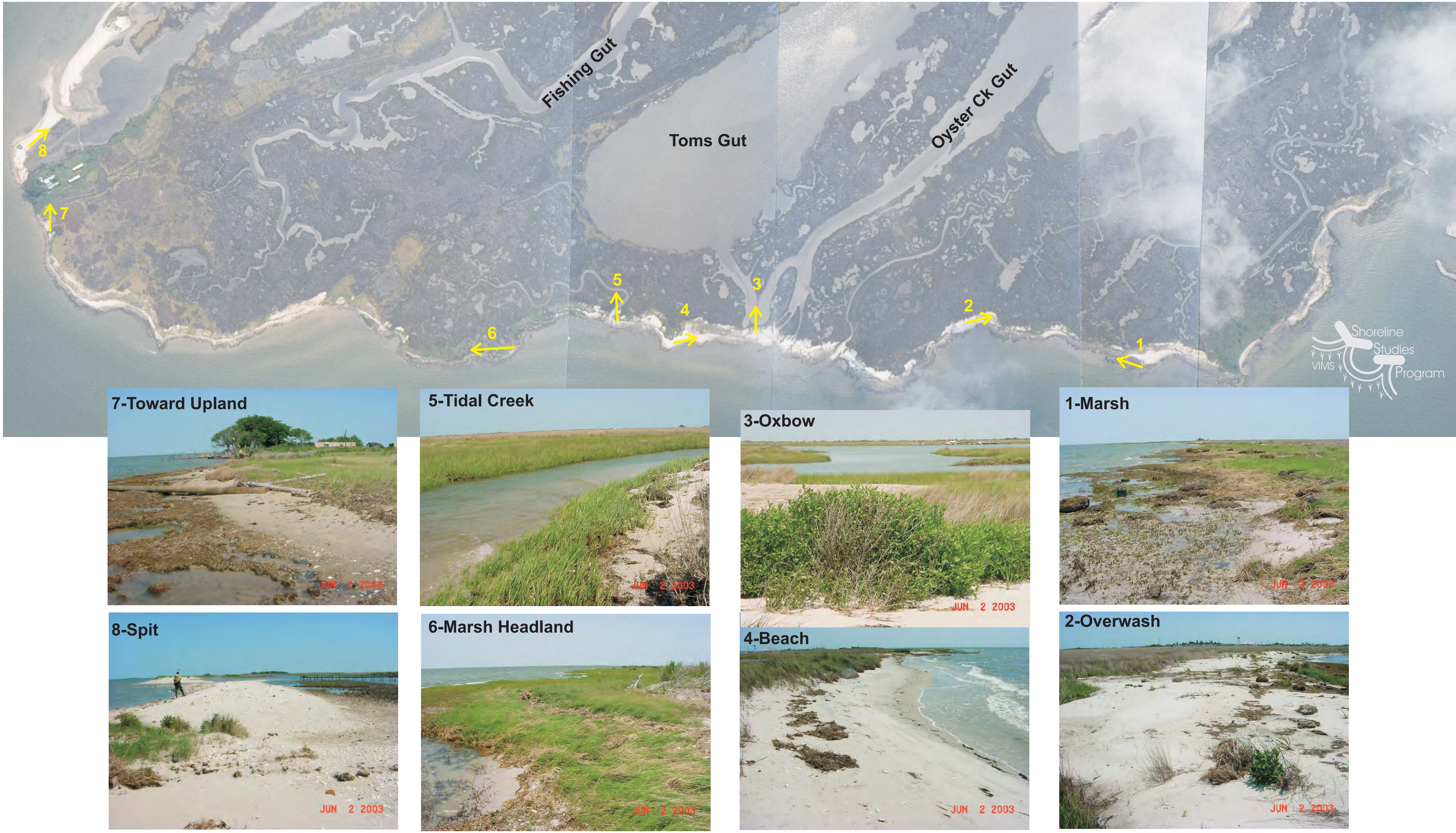


Figure 17. Non-rectified aerial photo mosaic taken 14 August 2003 showing approximate location and direction of digital ground shots take 2 June 2003 emphasizing the variability of shore types along the Uppards.

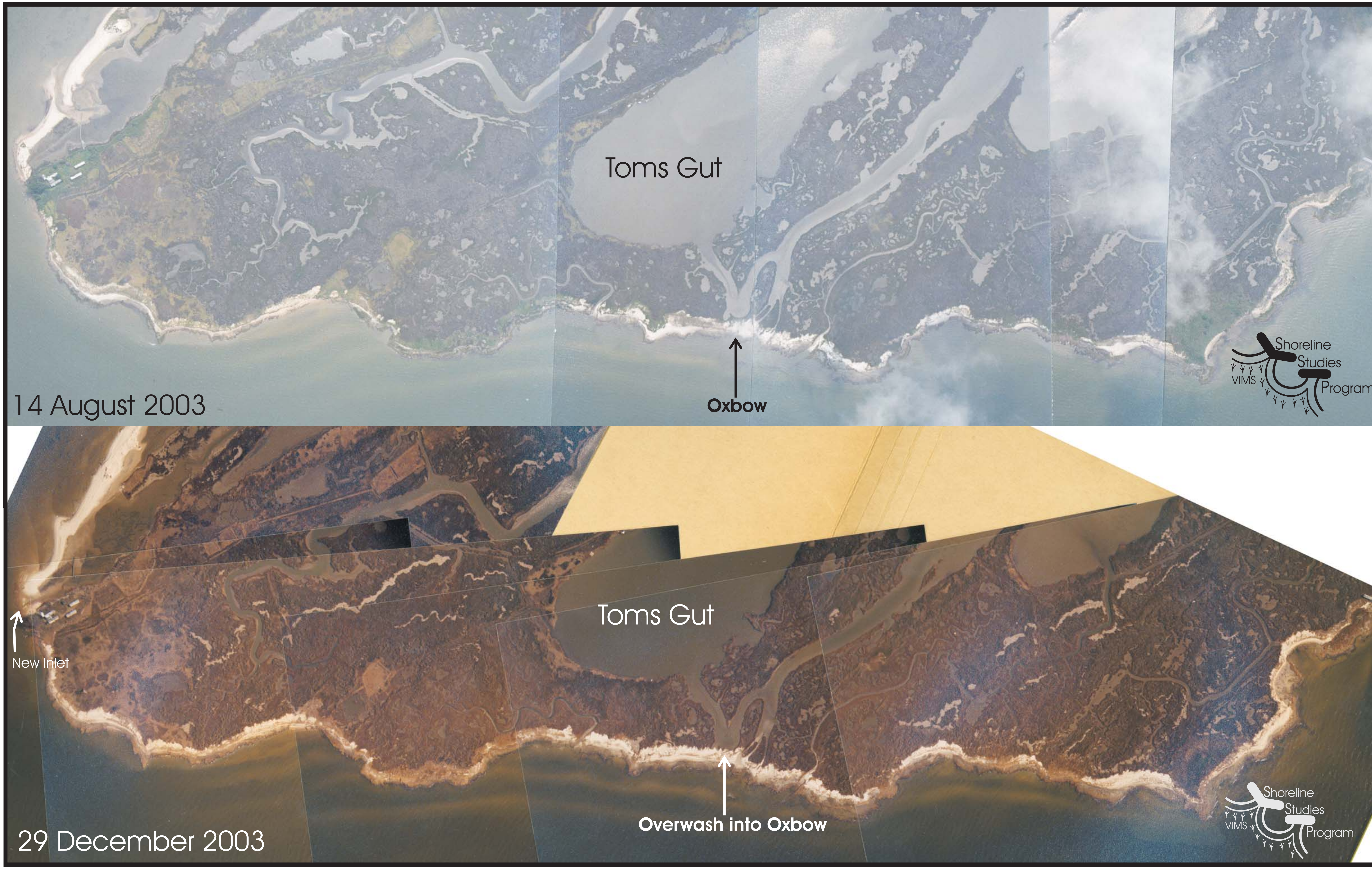


Figure 18. Non-rectified aerial photo mosaics taken before (14Sug2003) and after (29Dec2003) Hurricane Isabel showing sand movement along and on-shore.

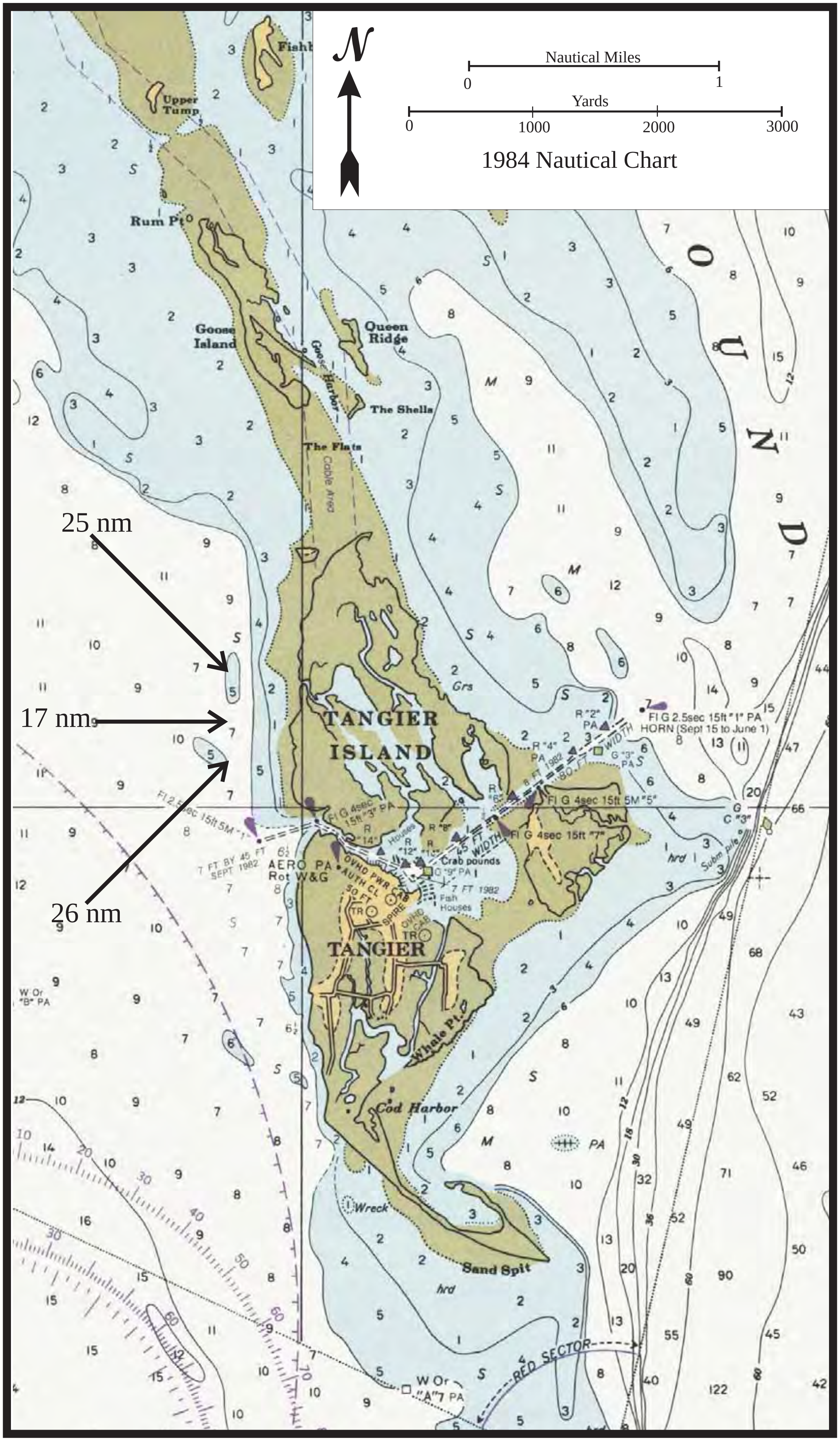


Figure 19. A 1984 nautical chart depicting the effective fetches impacting the western shore of Uppards.

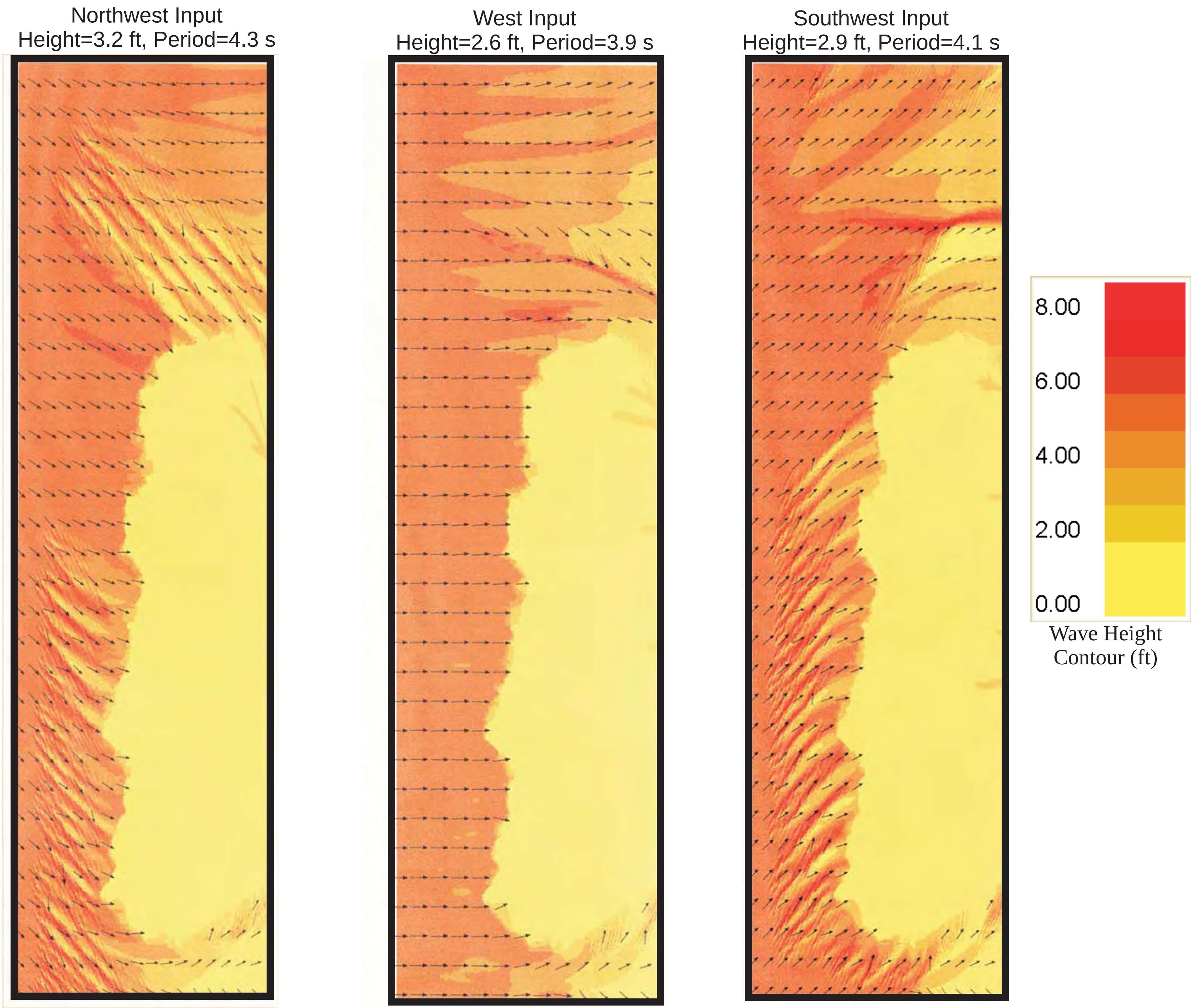


Figure 20. Modeled wave height contours with wave direction arrows using a 2 ft surge and a 25 mph wind.

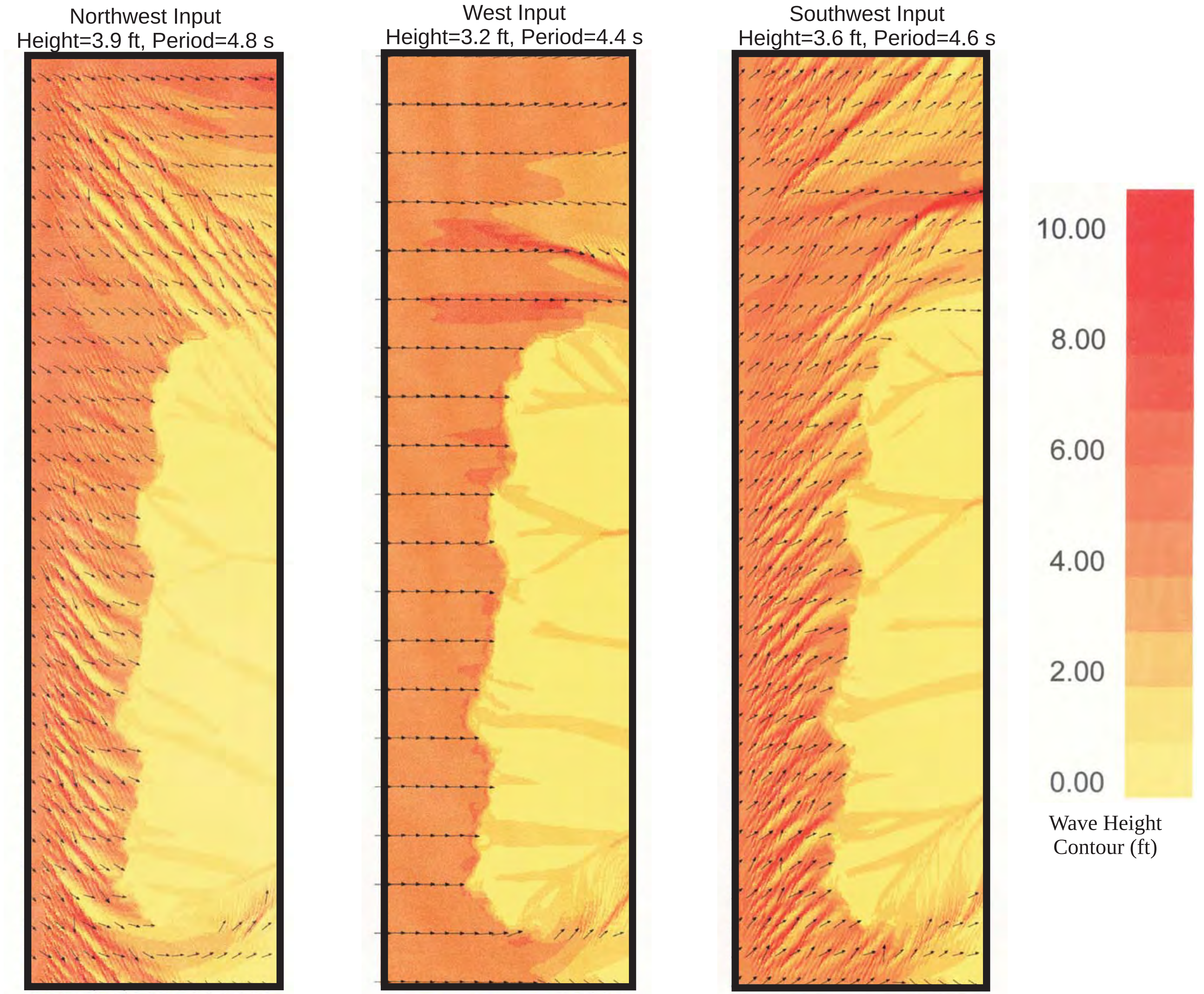


Figure 21. Modeled wave height contours with wave direction arrows using a 4 ft surge and a 35 mph wind.

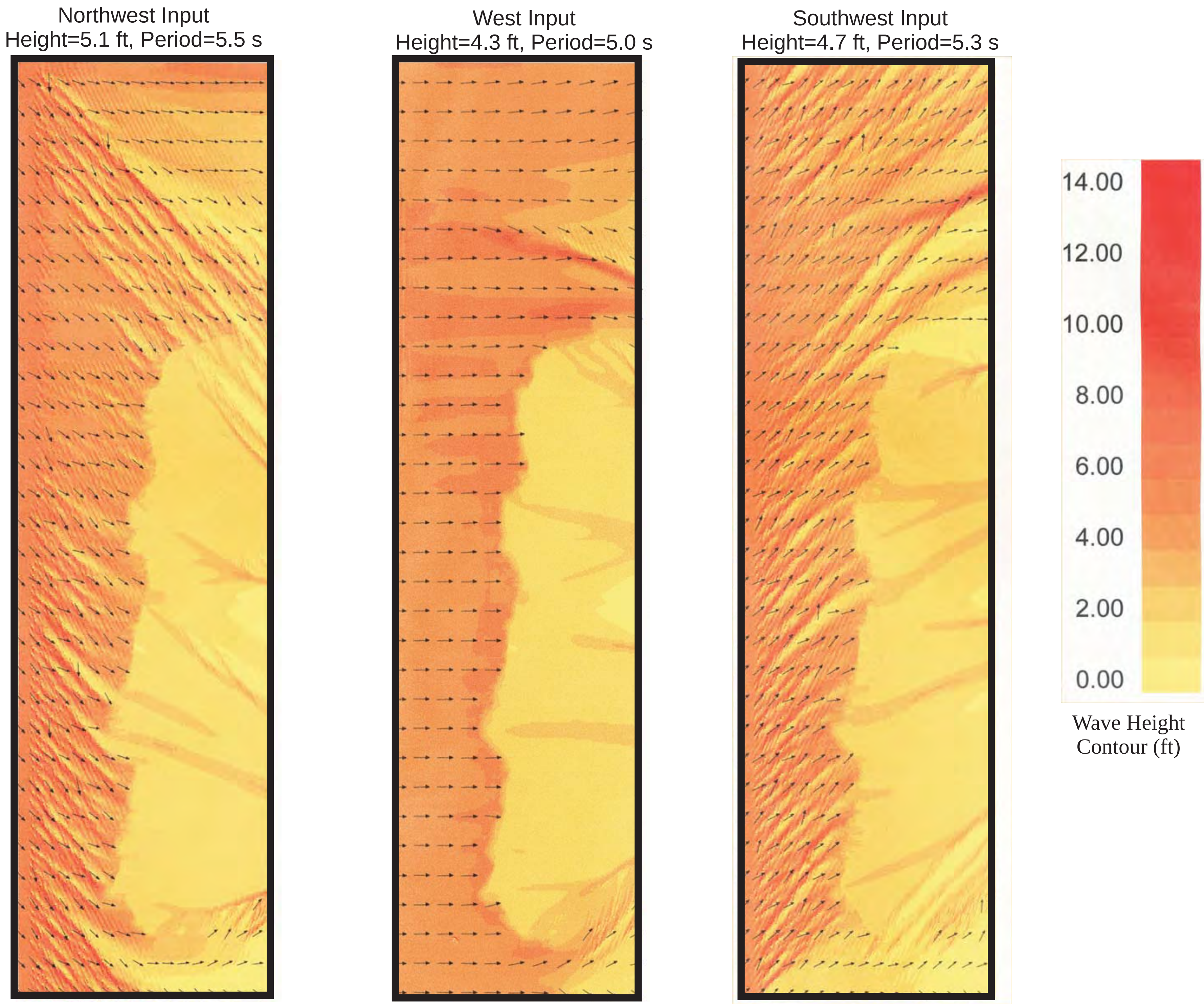


Figure 22. Modeled wave height contours with wave direction arrows using a 6 ft surge and a 50 mph wind.

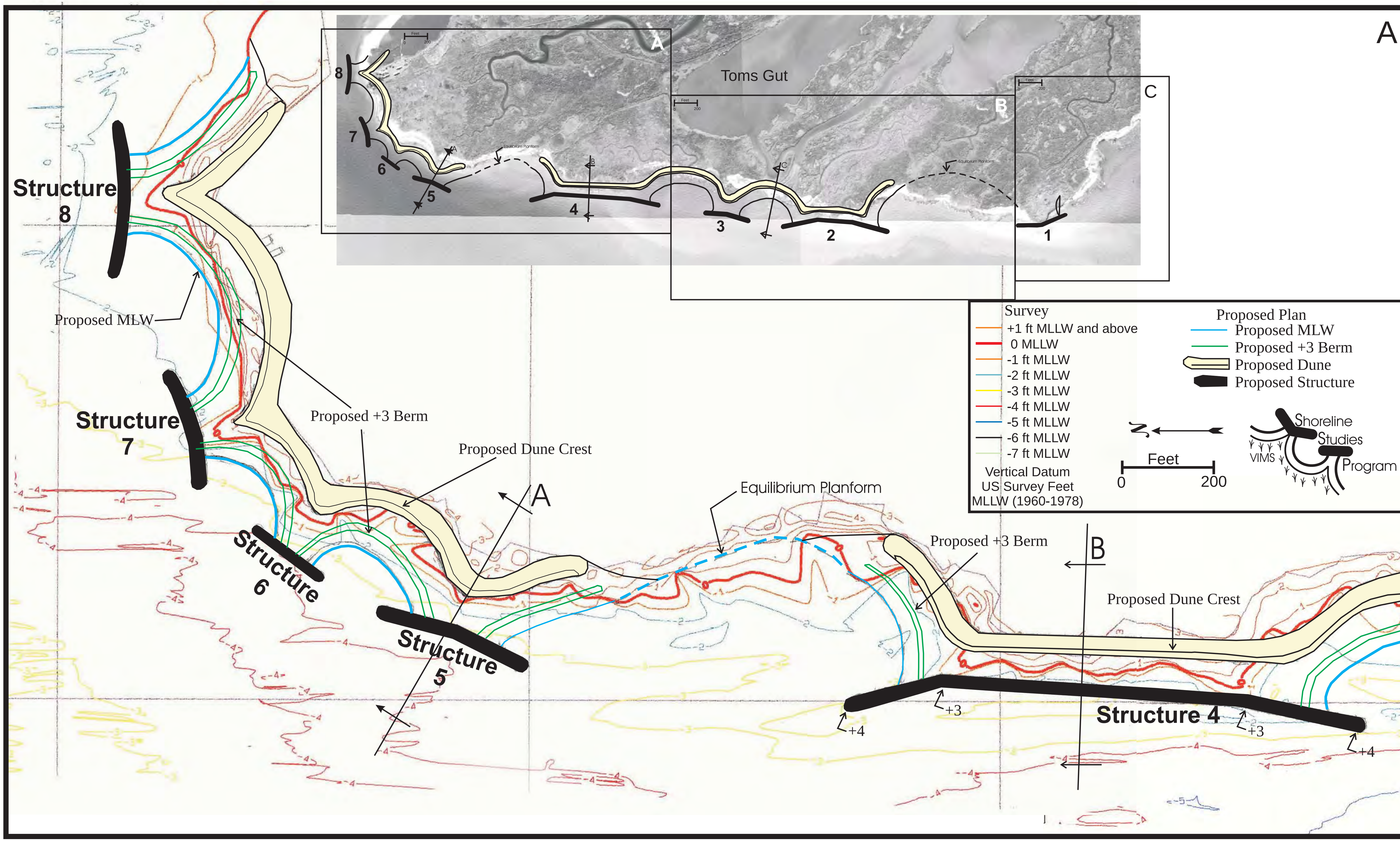


Figure 23A. Graphic depiction of the shoreline management plan for the northern section of the Uppards west coast.

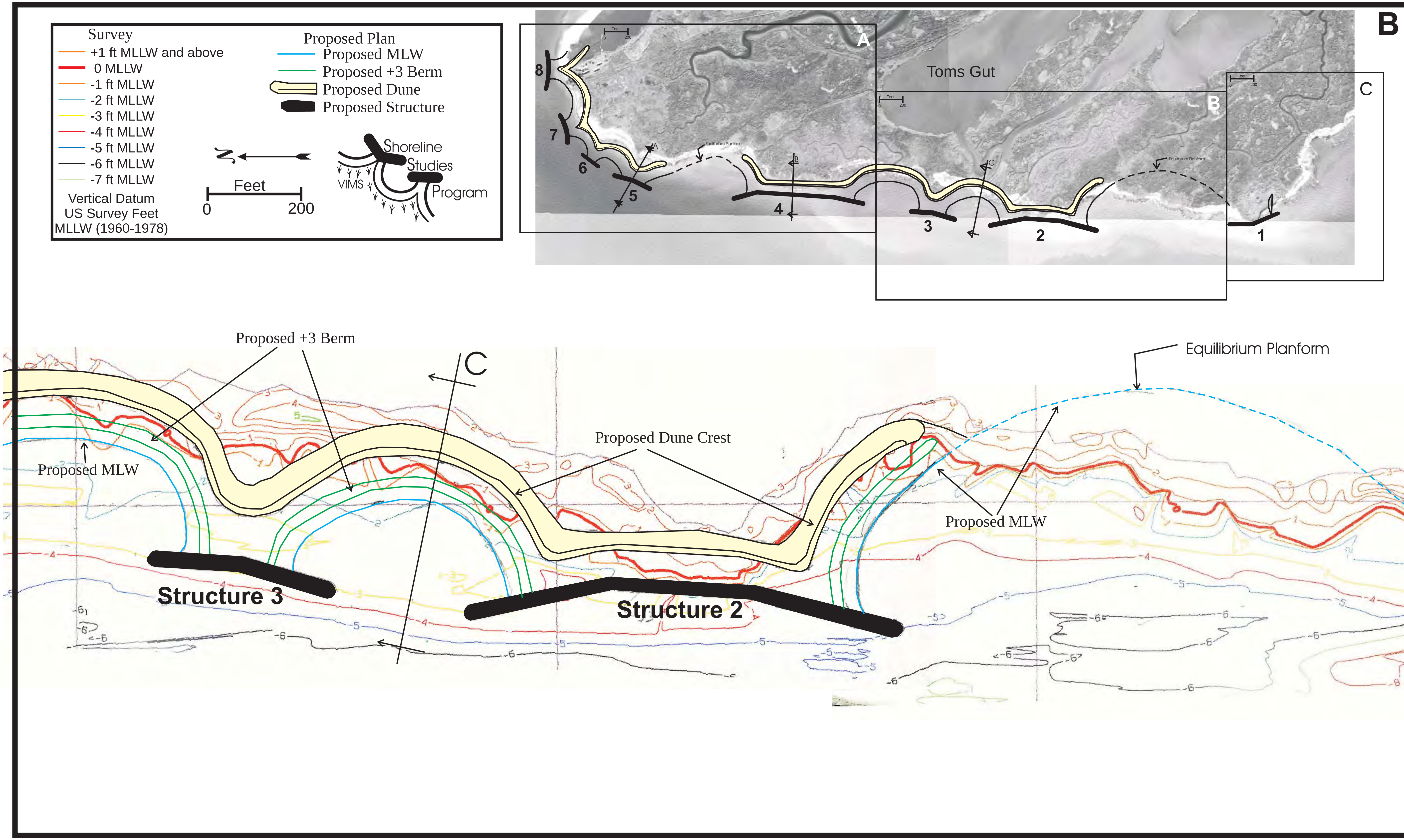


Figure 23B. Graphic depiction of the shoreline management plan for the central section of the Uppards west coast.

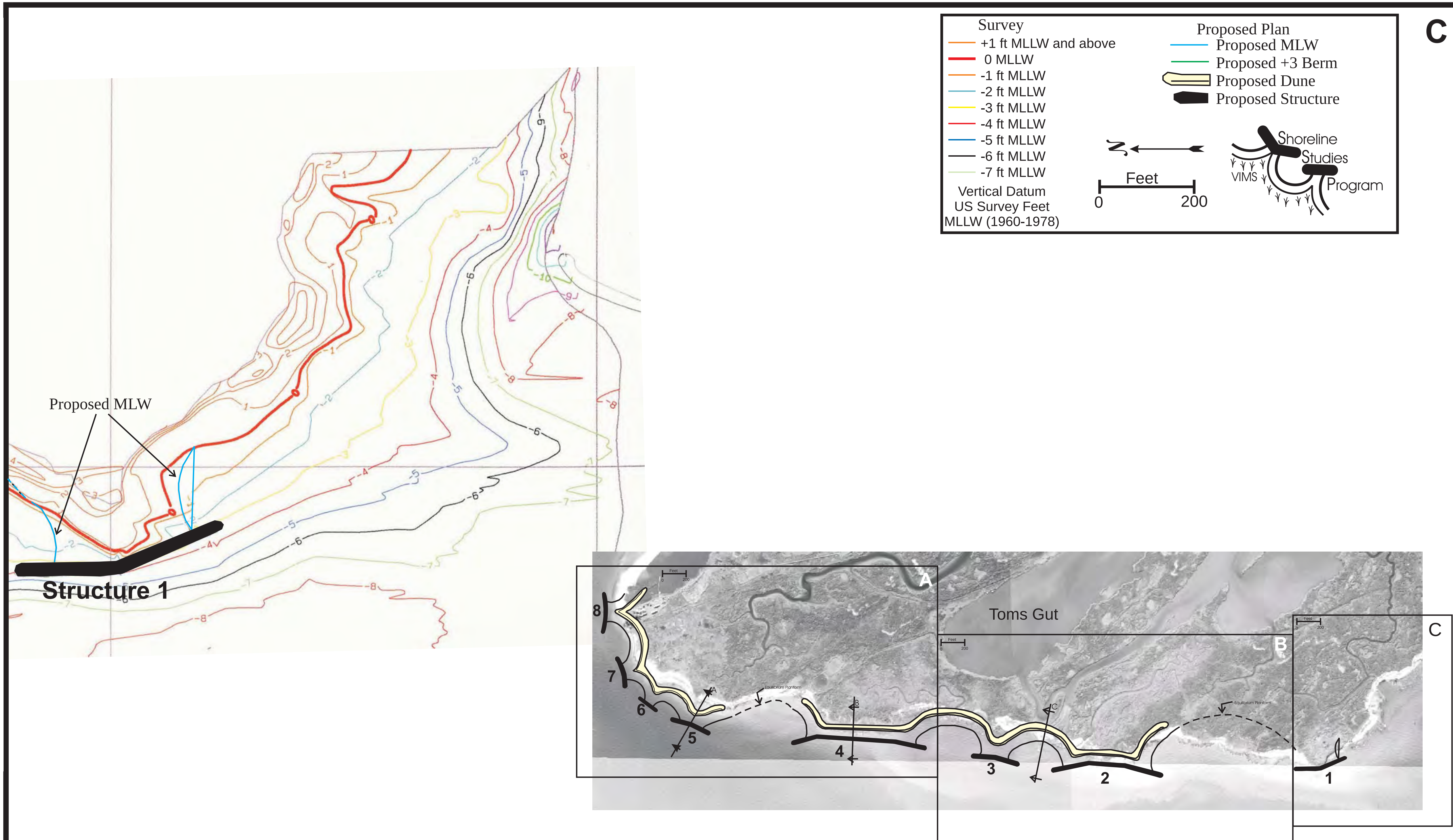


Figure 23C. Graphic depiction of the shoreline management plan for the southern section of the Uppards west coast.

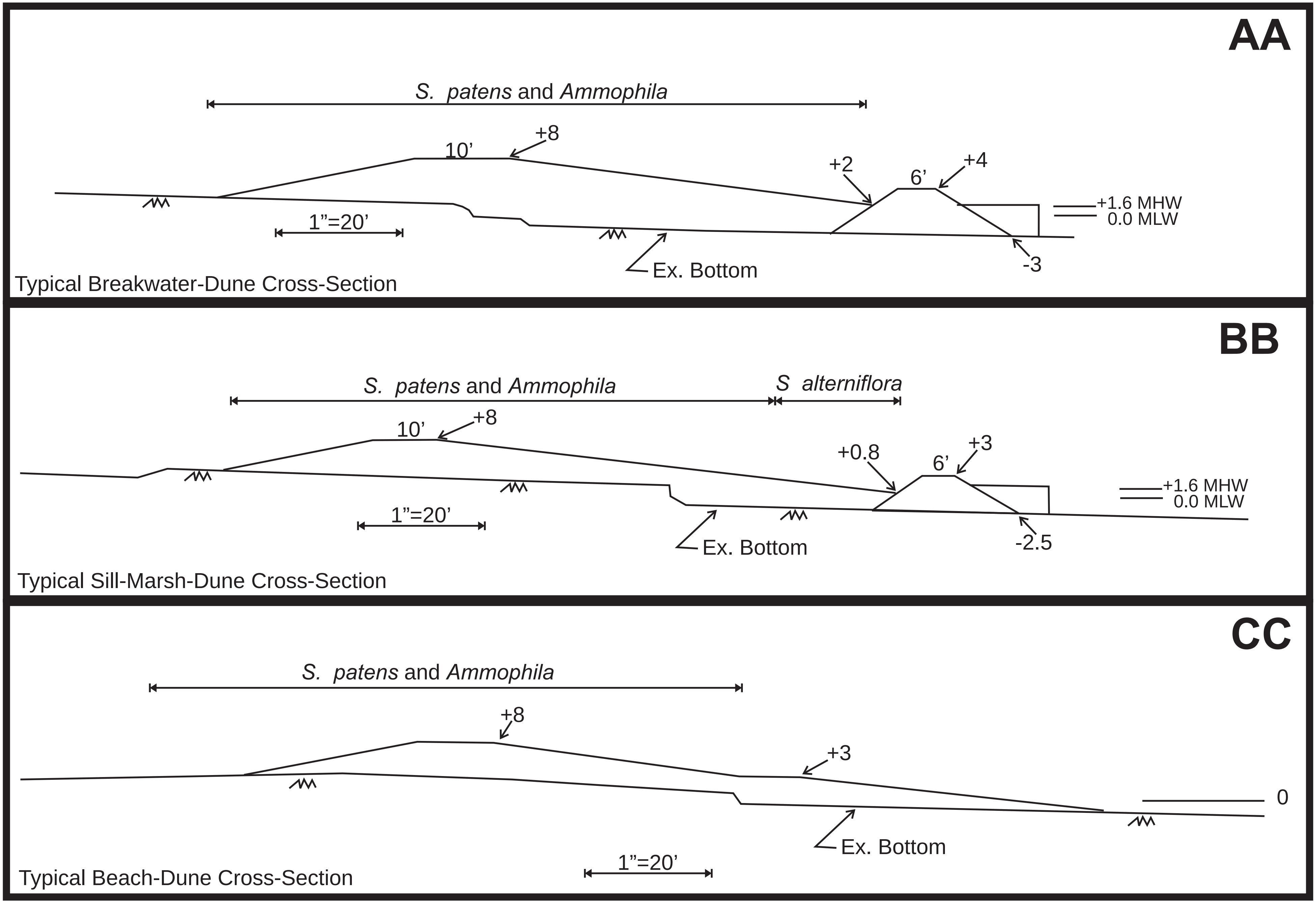


Figure 24. Typical cross-sections of proposed structures in the Uppards west coast shoreline management plan.