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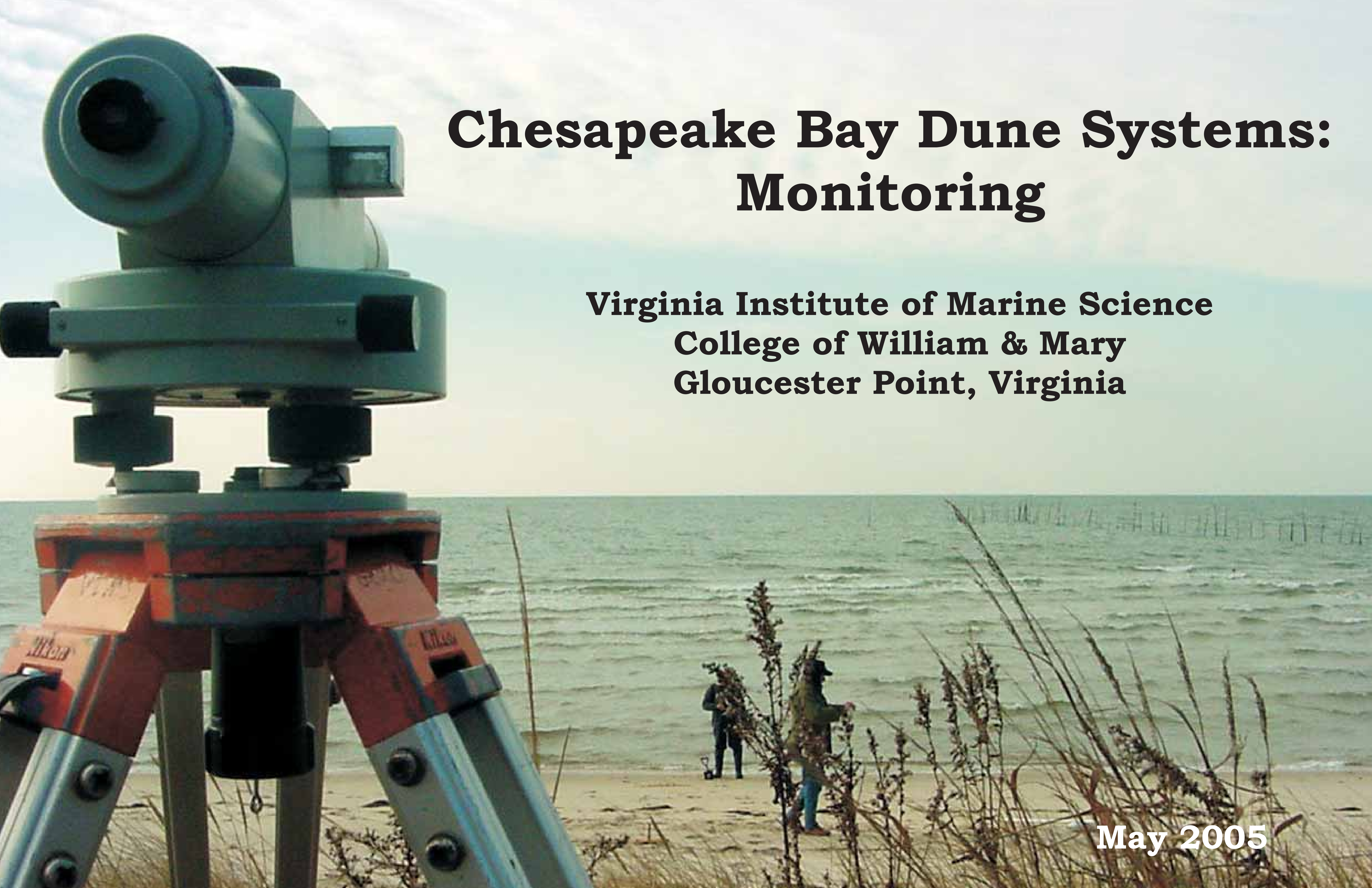

May 2005

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Final Report

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1 Introduction

1.1 Background and Purpose

Dune systems of the Commonwealth of Virginia are considered a unique and valuable natural resource. The primary dune and beach components of existing dune systems are protected under the Coastal Primary Sand Dune and Beaches Act (Act). Until 1998, the exact extent of existing dune systems in the Chesapeake Bay was unknown as was the relationship between primary and secondary dunes. At that time, a study entitled "Chesapeake Bay Dune Systems: Evolution and Status" was initiated (Hardaway *et al.*, 2001). The goals of that study were to locate, classify, and enumerate the existing jurisdictional dunes and dune fields within eight localities listed in the Act (Figure 1-1). All report figures are located in Appendix A. These include the cities of Hampton, Norfolk, Virginia Beach, and the counties of Accomack, Mathews, Lancaster, Northampton and Northumberland.

Results of that study indicated the variable nature of dune systems around Chesapeake Bay in terms of shoreline change and developmental pressures. In order to better understand these issues, this present study resolved to develop a Bay-wide monitoring program of selected dune sites. This program characterizes the seasonality of dune resources, performs biological assessments, and analyzes historical shoreline change for selected dune fields (with emphasis on secondary dunes). In addition, this study will define adjacent dune ecosystems that complement functions of coastal primary dunes (secondary dunes and dune fields). Also, a preliminary study was conducted at the Church Neck dune site to investigate shallow ground water movement and associated inorganic nitrogen concentrations within a primary dune setting on Virginia's Eastern Shore.

This project is aimed at developing an understanding of detailed beach and dune change. During the course of this monitoring, Hurricane Isabel impacted the coastal plain of Virginia and significantly altered almost all Bay shorelines to one degree or another in September 2003. This is particularly true of shorelines facing north, east, and south since the winds shifted as the storm passed. This event provided an opportunity to measure the changes to natural dune systems around the Bay due to the storm as well as their recovery after the event.

1.2 Chesapeake Bay Dune Systems

1.2.1 Geographic Extent

The distribution of dunes varies around Chesapeake Bay. Hardaway *et al.* (2001) found that the occurrence of Bay dunes is due, in part, to three main factors: 1) morphologic opportunity (*i.e.*, relatively stable setting), 2) abundant sand supply in the littoral transport system, and 3) conducive onshore wind/wave climate. Deposited sand must remain above a stable backshore to allow dune vegetation to become established. Each dune that has been documented by Hardaway *et al.* (2001) has its own history of change -- both growth and decay. Many miles of natural dunes have been altered by development and many have been created due to man's influence. In fact, dunes around the Chesapeake Bay estuarine system in the localities within the Act encompass only about 40 miles of shoreline (Hardaway *et al.*, 2001). This is about 0.4% of the total Bay shore making it a rare shore type.

The Chesapeake Bay geography allows us to group dune sites into three main regions. The Eastern Shore, Southern Shore, and the Western Shore. These three regions are subject to similar wind and wave climates. However, the previous study also showed that dune morphology varies significantly within each region.

1.2.2 Classification

In Hardaway *et al.* (2001), a Chesapeake Bay dune classification system was developed. This classification is based on parameters that are unique to certain dune systems and have a basis in dune field evolution, vegetative zones, lateral and vertical extent of primary and secondary dune, and anthropogenic impacts. The system was developed for use as a management tool. Dune classes can be used to guide shoreline development decisions, shoreline management strategies, and restoration goals.

The dune classification system is three tiered (Figure 1-2). The primary tier characterizes the level or type of human involvement in the dune system. These three categories (Natural, Man-Influenced, or Man-Made) reflect how the state of the dune is most impacted. The second tier in the classification (A to G) are the parameters most influential in defining the status of a given dune system. Parameter values within each second tier category define a range of limits or characteristics for each category. Categories A, B and C relate to the nature of the impinging wave climate at a given site while categories D, E, and F relate to geologic parameters.

Exposure (A) is a qualitative assessment of the wave exposure and wave climate across open water. Wave impact, particularly during storms, is the dominant natural process driving shoreline erosion and sediment transport along the Bay coasts. Bay Influenced (A.1) is somewhere between the Open Bay exposure (A.2) and Riverine exposure (A.3). Generally, A.1 sites have fetches of 5-10 nautical miles (nm); A.2 have fetches of >10 nm; and A.3 have fetches of <5 nm. Hardaway *et al.* (2001) suggested that, the large elevations and dune-field widths of the dunes along the open bay coast of Virginia Beach are a function of abundant sand supply and long fetch to the storm dominant northwest, north, and northeast wind-wave fields. In contrast, the areas of more limited fetch in the riverine environments of Lancaster County that face the milder southerly wind-wave climate have only modest dunes. The high percentage of open bay dune shoreline (85%) is a function of sand supply and more aggressive wind and wave climates (enhanced wave runup) combining with geomorphic opportunities for beach/dune development. Riverine sources of sand are relatively low, and reduced wave periods result in less runup potential to form and maintain beach berms which are the foundation for dune development.

Shore Orientation (B) is the direction the main dune shore faces according to eight points on the compass. Shoreline exposure to dominant directions of wind-waves is a component of fetch and wave climate as well as aeolian processes that assist in dune growth, development, and decay.

Nearshore Gradient (C) controls wave refraction and shoaling which effect the nature of wave approach and longshore transport as well as onshore/offshore transport. The presence or absence of bars will indicate the relative amount of nearshore sediment available for transport.

The Morphologic Setting (D) indicates the dune form and is significant in the genesis of a particular dune site. Aerial images were used to determine and classify the nature of the

Morphologic Setting. Four basic categories were developed including: 1) Isolated dunes, 2) Creek mouth barrier dune/spit, 3) Spit and 4) Dune fields. Morphological Settings 1 and 4 are distinguished only by shore length (*i.e.* Morphologic Setting 1 < 500 ft and Morphologic Setting 4 > 500 ft) as an arbitrary boundary. These categories were subdivided to reflect the nature of the setting into four subcategories. These include: 1) Pocket, 2) Linear, 3) Shallow Bay, and 4) Salient.

The morphology of Chesapeake Bay dune sites shows that 72% or almost 29 miles of dune coast are dune fields (Hardaway *et al.*, 2001). The long, continuous coast of Norfolk and Virginia Beach have the longest per-site average. The isolated dunes in Lancaster appear to result from human influence. The creek mouth dune sites in Mathews are a reflection of the coastal morphology since they occur along natural coasts.

The Relative Stability (E) or state of a dune site was very subjective. This parameter is a value judgement as to the overall present and future integrity, of a particular site. If the site had wave cut scarps along the primary dune face and/or was actively moving landward (overwash), it was termed Land Transgressive/Erosional (E.3). If the backshore/dune face had only a slight gradient with stabilizing vegetation it was stable (E.1) and possibly even accretionary (E.2). It is common for all three states to occur within one site. Where one end may be eroding, sand is transported across the central area (stable) and is deposited at the downdrift end.

The situation may be seasonal within isolated dune sites as the beach/dune shifts back and forth. Accreting shorelines, which offer the potential for dune expansion, account for only 8% of the total dune shore length while 44 % are eroding. This might infer that dune shorelines are on the decline. However, characterization of the overall condition of the dune site is the objective of this parameter. The true measure of a dune site's stability requires more detailed analysis of shore change.

The underlying substrate (F) is a general category used for describing the type of sediment the dune resides on and against. Two broad categories were chosen -- marsh and upland. Marsh substrates, which include creek mouths and bottoms, are usually low regions where storm surges can easily penetrate, inundate, and force sand landward in the form of washovers. Upland substrates usually rise up and create a "backstop" for landward moving sand masses under storm attack. This could help explain the relatively high frequency of upland sites that are man-influenced since development often occupies the "high ground". In fact, man-influenced upland dune shorelines have a greater frequency of occurrence than dunes against natural uplands.

If the site was not Natural (1) (*i.e.* Man-influenced, 2, or Man-made, 3), then the nature of man's impact was determined by type of modification. The shore structures include Groins (G.1), Revetments and Bulkheads (G.2), Breakwaters (G.3), Jetties (G.4), and Beach Fill (G.5). The degree of impact which any given structure or combination of structures had on the local dune feature was not always clear. It was qualitatively assessed as having an influence on dune development. The Relative Stability (E) relates in part to whether man's influence was erosive (destructive) or accretionary/stable (constructive).

1.2.3 Dune Site Measurements

Each dune has several slope breaks that are common to one another, yet given site specific conditions, make it unique. By analyzing the slope break relationships (*i.e.* primary dune crest elevation, primary dune width, secondary dune elevation, etc.) the nature of the dune features can be related, at least semi-quantitatively, to the geographic occurrence and, eventually, to the environmental setting (Figure 1-3).

The results of this analysis for Bay dunes by Hardaway *et al.* (2001) led to the characterization of "growth components". The primary dune will grow when it 1) is in a relatively stable setting, 2) has an abundance of sand in the littoral/shore system, and 3) has an onshore wind field climate capable of transporting sand from a broad beach/backshore to the dune face.

Primary dune elevations are highest in Virginia Beach, Norfolk, and Hampton. The dunes in these "metropolitan" localities possess all three components and may be enhanced by various beach nourishment projects. At the same time, developmental pressures are perhaps the greatest in these same three localities. In fact, all of the dune sites in Norfolk are man-influenced.

Primary dune heights become smaller as the three growth components decrease in magnitude. Lancaster, with the lowest average primary dune elevations, has the most riverine primary dunes which are relatively small and are sometimes little more than vegetated sand berms. The extreme range of primary dune crest elevations of 16.5 feet MLW for Virginia Beach and 4.6 feet MLW for Lancaster indicate the variation in magnitude of the growth components around Chesapeake Bay.

1.3 Hurricane Isabel

Hurricane Isabel made landfall along the southeast coast of North Carolina on September 18, 2003. At one time, the storm was a Category 5 on the Safir-Simpson scale. It had been downgraded to a Category 2 before it made landfall (Figure 1-4). By the time it impacted the Chesapeake Bay, it was a minimal Category 1. However, in addition to being in the "right front" quadrant of the advancing hurricane, southeastern Virginia experienced east and east-southeast winds which have the greatest potential to transport water into Chesapeake Bay and its Virginia tributaries.

The extent of coastal flooding during a storm depends largely on both the background astronomical tide and the surge generated by the storm's high winds and low atmospheric pressure. Together, surge and astronomical tide combine to form a "storm tide." Storm-tide flooding is maximized when the storm surge and a rising tide reach their peak at the same time. The SLOSH Model (Figure 1-5) depicts the maximum predicted surge levels around the Bay. However, it may have under-predicted certain areas, particularly up the rivers. Measured storm impacts would seem to indicate higher surges than then model predicted.

The hurricane of 1933, widely known as the "storm of the century" for Chesapeake Bay, generated a storm surge in Hampton Roads of 5.84 feet, more than a foot higher than the 4.76 ft storm surge recorded for Hurricane Isabel. Yet many long-time Tidewater residents say that the high-water marks left by Isabel equaled or exceeded those of the 1933 storm (Boon, 2003).

An analysis of sea-level records shows that Isabel's coastal flooding matched that of the August 1933 storm due to the long-term increase in sea level in Hampton Roads (Boon, 2003). Data from a tide monitoring station at Sewells Point show that sea level in tidewater Virginia rose

1.35 feet between August 1933 and September 2003. Based on storm surge and astronomical tide, the 1933 hurricane storm surge exceeded Isabel's by more than a foot. Its surge also occurred at the beginning of spring tides while Isabel's surge occurred in the middle of a neap tide. However, the increase in sea level at Hampton Roads in the seventy years between the two storms was enough to boost Isabel's storm tide to within an inch and a half of the level experienced during the 1933 storm (Boon, 2003).

Additional storm data was obtained by an Acoustic Doppler Current Profiler (ADCP) which was deployed in 28 ft of water offshore of VIMS at Gloucester Point. The instrument provided a quantitative record of the hurricane's impact on lower Chesapeake Bay. Data from the ADCP showed that Isabel created a 7-foot storm tide topped by 6-foot waves. At the height of the storm, wave crests were passing over the instrument once every 5 seconds, and the storm was forcing the entire flow of the York River upstream at a rate of 2 knots. Because Isabel was so large, its winds, waves, and surge affected the Bay for an abnormally long time. The ADCP data showed that storm conditions persisted in the Bay for nearly 12 hours and that wave-driven currents were strong enough to mobilize bottom sediments even at the instrument’s depth, increasing water turbidity by a factor of two to three compared to fair-weather conditions (VIMS, 2003).

Weather data provided by instruments atop VIMS' Byrd Hall showed that maximum sustained winds on the campus reached 65 mph, with 90-mph gusts. The barometer bottomed out at 29.2 inches, with a rainfall accumulation of about 2.2 inches (VIMS, 2003).

Around the Bay, similar impacts were recorded by tide gauges (Figure 1-6). The location and records of six tide gauges indicate the widespread flooding that occurred due to the storm. In the lower Bay, the Sewells Point, Chesapeake Bay Bridge Tunnel, and Kiptopeke gauges survived the storm, and they indicated a total water level above MLLW at the peak of the storm of 8 ft, 7.5 ft, and 6.5 ft, respectively. This is between 4 to 5 ft above normal. The tide was running higher than normal for the day before the storm and the two days after at these locations. In fact, on the day after the storm at Sewells Point, the lowest tide was higher than the predicted high tide of 2.5 ft.

At Gloucester Point on the York River, the tide gauge stopped recording at 8.5 ft MLLW and failed to record the peak water level of the storm. Both the Lewisetta and Windmill Point gauges showed an extended period of flooding at 2 ft above normal high tide. In all locations throughout the Bay, tides were above normal for 2 days after the storm.

2 Methods

2.1 Monitoring Site Selection

Monitoring sites for seasonal surveys were selected using the following criteria**:**

a. Presence of a secondary dune
b. Near or adjacent to developmental pressures (existing or potential)
c. Reasonable land access for surveys
d. General geographical distribution around Bay localities.
e. Research stability (*i.e.* State land)

A total of 9 sites were selected for seasonal surveys which were conducted spring and fall for 4 years and after significant storm events (Figure 2-1). Site information is located in Table 2-1. Site parameters based on the classification scheme discussed in section 1.2.2 of this report are shown in Table 2-2. A listing of available monitoring information is shown in Table 2-3.

Site MA3: Chesapeake/Bavon Beach, Mathews County. This site represents a linear dune field that has faced developmental pressures for the past 20 years.

Site LN39: Near Mosquito Point, Lancaster County. This site is a relatively natural dune field that has developed near the mouth of the Rappahannock River around a salient feature. It has two shoreline exposure components - riverine and Bay influenced.

Site NH10: Just north of Silver Beach, Northampton County. This Bay site is part of a dune field that is both natural and man-influenced.

Site NH17: Floyd’s Farm on Savage Neck, Northampton County. This site transitions along a natural spit and includes a primary dune only. The adjacent land use is agricultural, but the shore a block to the north has been developed. Potential exists for shoreline hardening and subsequent downdrift impacts in the near future. This site also was chosen for groundwater analysis.

Site NH51: Pond Drain, Northampton County. A Department of Conservation and Recreation natural site with an extensive dune field and no potential for development except for on adjacent properties.

Site NL42: Smith Point, Northumberland County. This site has an extensive dune field and is significantly impacted by the Little Wicomico River mouth jetties and a few groins. Development is presently occurring across secondary dunes at this site.

Site NL58: East side of Hack Creek, Northumberland County. This dune field site has been impacted by jetties at Hack Creek and by a few groins, but the upland is undeveloped.

Site NL 59: West side of Hack Creek, Northumberland County. This dune field has elements of primary and primary/secondary dunes that are in transition and are being impacted by development and significantly impacted by groins and Hack Creek jetties.

Site VB4: First Landing State Park, Virginia Beach. This site is a relatively natural dune field site that also has an oceanic influence. Development has occurred on secondary dunes on adjacent properties.

Table 2-1. Information on the dune monitoring sites.

Dune Site No.	Location^		Dune Shore Length (feet)	Tide Range (feet)	Primary Dune Site?	Secondary Dune Site?	Ownership
	Easting (feet)	Northing (feet)					
MA3	2,647,500	368,050	4,290	2.3	Yes	Yes	Private
LN39-1	2,619,050	471,800	600	1.3	Yes	No	Private
LN39-2	2,619,050	471,800	900	1.3	Yes	Yes	Private
NH10	2,736,760	431,420	1,410	1.8	Yes	Yes	Private
NH17	2,731,590	411,450	960	1.9	Yes	No	Private
NH51	2,727,070	322,410	10,000	2.6	Yes	Yes	Public
NL42	2,652,500	572,400	3,690	1.2	Yes	Yes	Private
NL58	2,630,450	589,550	950	1.2	Yes	Yes	Private
NL59	2,629,200	590,300	1,680	1.2	Yes	Yes	Private
VB4	2,716,250	223,550	5,550	2.8	Yes	Yes	Public

^Virginia State Plane South, NAD1927

Table 2-2. Dune monitoring site parameters.

Dune Site No.	Type	Fetch Exposure	Shoreline Direction of Face	Nearshore Gradient		Morphologic Setting		Relative Stability *	Underlying Substrate	Structure
MA3	Man-Inf	Open Bay	East	Shallow	bars	Dune Field	Linear	Stable	Upland	Dune
LN39-1	Natural	River, Bay-inf	South	Steep	no bars	Dune Field	Salient	Erosion	Upland	
LN39-2	Natural	River	West	Steep	no bars	Dune Field	Salient	Accrete	Upland	
NH10	Natural	Open Bay	West	Medium	bars	Dune Field	Linear	Stable	Upland	
NH17	Natural	Open Bay	Northwest	Medium	bars	Dune Field	Linear	Stable	Upland	
NH51	Natural	Open Bay	Southwest	Steep		Dune Field	Linear	Stable	Upland	
NL42	Man-Inf	Open Bay	East	Medium		Dune Field	Linear	Stable	Upland	Jetty/Groin
NL58	Man-Inf	Open Bay	Northeast	Medium	bars	Dune Field	Linear	Stable	Upland	Groin
NL59	Man-Inf	Open Bay	Northeast	Medium	bars	Dune Field	Linear	Stable	Upland	Groin
VB4	Natural	Open Bay	Northwest	Steep	bars	Dune Field	Linear	Accrete	Upland	

*Stability is relative to the original dune report by Hardaway *et al.* (2001).

Table 2-3. Dune monitoring site information available.

Site	Survey Dates	Low-Level Aerial Photography Dates	Historical Aerial Photography
MA3	19Jan2001, 4Sep2001, 5Jul2002, 15Oct2002, 27Mar2003, 2Oct2003, 14Jul2004, 8Dec2004	24Oct2001, 25Jun2003, 24Sep2003	1937, 1953, 1960, 1968, 1979, 1982, 1994, 2002
LN39	15Feb2001, 28Aug2001, 21Mar2002, 31Oct2002, 24Jun2003, 14Oct2003, 23Aug2004, 7Dec2004	24Oct2001, 15Aug2003, 25Sep2003,	1937, 1959, 1977, 1982, 1994, 2002
NH10	1Mar2001, 19Sep2001, 4Jun2002, 16Dec2002, 10Jun2003, 23Dec2003, 12Jul2004, 22Dec2004	24Oct2001, 25Jun2003, 14Jan2004, 26Oct2004	1938, 1949,1989,1992, 1994, 2002
NH17	24Jan2001, 20Sep2001, 4Jun2002, 16Dec2002, 10Jun2003, 23Dec2003, 12Jul2004, 21Dec2004	24Oct2001, 25Jun2003, 14Jan2004, 26Oct2004	1938, 1949,1989,1992, 1994, 2002
NH51	26Apr2001, 19Sep2001, 4Jun2002, 16Dec2002, 11Jun2003, 18 Nov2003, 15Jul2004, 21Dec2004	24Oct2001, 25Jun2003, 14Jan2004, 26Oct2004	1938, 1949,1989,1992, 1994, 2002
NL42	5Apr2001, 12Sep2001, 21Mar2002, 31Oct2002, 24Jun2003, 14Oct2003, 7Jul2004, 7Dec2004	13Dec2000, 24Oct2001, 15Aug2003, 25Sep2003	1937, 1953,1961, 1969, 1994, 2002
NL58	23Mar2001, 23Aug2001, 5Mar2002, 10Dec2002, 26Jun2003, 3Oct2003, 6Jul2004, 6Dec2004	24Oct2001, 15Aug2003, 25Sep2003	1937, 1953, 1969, 1994, 2002
NL59	23Mar2001, 23Aug2001, 5Mar2002, 10Dec2002, 26Jun2003, 3Oct2003, 7Jul2004, 6Dec2004	13Dec2000, 24Oct2001, 15Aug2003, 25Sep2003	1937, 1953, 1969, 1994, 2002
VB4	8Mar2001, 13Sep2001, 4Jun2002, 18Dec2002, 14Apr2003, 4Nov2003, 15Jul2004, 22Dec2004	24Oct2001, 25Jun2003, 24Sep2003, 26Oct2004	1937, 1960, 1962, 1970, 1976, 1980, 1985, 1987, 1994, 2002

2.2 Field Surveys

2.2.1 Profiles and Site Measurements

Several cross-shore profiles with benchmarks were established at each site. Each surveyed transect used the crest of the primary dune as the horizontal control and mean low water (MLW) as the vertical control. The MLW line is indirectly obtained from water level measurements. The water level position and elevation are checked in the lab against measured tidal elevations (at the nearest NOAA tide station) and time of day to establish MLW for the profile.

At each survey, cross-sectional profiles, ground photos, and sediments were taken. These data were used to determine the changes at each site biannually. The two dimensional data are represented in an Excel spreadsheet. This data was analyzed using the Beach Morphology and Analysis Program (BMAP) (Veritech, 2004). From the profile data, the position of mean high water (MHW) was used to track changes at the site through time. The changes at MHW can be a good indicator of average rates of shoreline change, but they do not always reflect the overall changes at the site in the dune or beach face. Volume also was calculated from the profile data in cubic yards (cy) per foot, which when multiplied by the distance between profiles, yielded volume changes in cy. Therefore, volume analysis only accounts for the shoreline between the profiles and not the entire dune site. For this analysis, the cross-sectional beach was broken into two sections, the beach face between mean low water (MLW) and MHW, and the area above MHW. The elevation of MHW for each site is listed in Table 2-1 as the tide range.

Several other components of the dune profile, as shown in Figure 1-3, were included in the cross-sectional profiles taken at each site on each date. All data is shown in Appendix B. Care was taken to measure the same dune and beach system components during each survey period. Each site has a continuous sand feature that extends from the offshore landward that consists of a 1) nearshore region seaward of MLW; 2) an intertidal beach, berm and backshore region, the latter of which may be vegetated, between MLW and base of primary dune; 3) a primary dune from bayside to landside including the crest and foredune where present; and 4) a secondary dune region where present. All profiles extended beyond MLW (seaward) to the back of the primary dune (landward). If a secondary dune was present at the site, the back or landward extent of the secondary dune was not always reached, but the crest was always surveyed. The dimensions, including lateral position and the elevation of various profile components were calculated from the data. These include:

A = Distance between Secondary Dune Crest to Back of Secondary Dune
B = Distance between Secondary Dune Crest to Back of Primary Dune
C = Distance between Primary Dune Crest to Back of the Primary Dune
D = Distance between Primary Dune Crest to MLW (E + F + G)
E = Distance between Primary Dune Crest to Front of Primary Dune
F = Distance between Front of Primary Dune to Beach Berm
G = Distance between Beach Berm to MLW
H= Distance between the Primary Dune Crest and the Toe
L = Distance between Crest of Primary Dune to Back of Secondary Dune (A + B + C)
T = Elevation of Toe of the beach
U = Elevation of Back of Secondary Dune
V = Elevation of Secondary Dune Crest
W = Elevation of Back of Primary Dune
X = Elevation of Primary Dune Crest
Y = Elevation of Front of Primary Dune
Z = Elevation of Beach Berm

2.2.2 Sediments

The sedimentology of the study area is based on both active processes as well as the underlying geology of the region. Sorting and winnowing of the sediments by the littoral currents and waves occurs continuously in the nearshore region at the sites, and erosion can expose outcrops of material deposited long ago.

Sediment samples were taken along select profile lines, at the sites. Certain morphologic regions were sampled. Base of Dune (BOD) samples represent the area of the beach that is influenced by aeolian transport and run-up from occasional storm events. Sediments were also taken at the Secondary Dune Crest (2DC), Back Base of Primary Dune (BBPD), Primary Dune Crest (PDC), BERM (sometimes an upper and lower berm), midbeach (MB), TOE, and offshore (OS). The toe of the beach is located at the break in slope between the beach face and the nearshore region. It is sometimes evidenced by a distinct change in sediment type. The results of the sediment data analysis are located in Appendix C.

A grain size determination on each of the site's samples was performed by wet sieving a homogenous sample to separate sands from the fine silts and clays. The water and fines, which were collected in the settling tube, were stirred and allowed to settle for a specific amount of time (which was determined by Stoke's Law). A pre-determined amount is pipetted out. The water was dried out of the sample, and the sediment was weighed. The sands and gravels, left in the sieve, were dried and separated, then weighed. From this, the gravel, sand, silt and clay ratio was determined for that particular sample. For finer fractionization of the sands, a settling tube was used. The Rapid Sand Analyzer (RSA) is a large tube filled with water over which a balance is set. The sand was placed onto the surface of the water and allowed to settle onto a weighing pan. The balance is controlled by a computer, which records the weights as the individual grains of sand land on the weigh pan. This data was converted to the statistical and graphical output, all based on Stoke's Law.

The data from the grain size determination and the RSA analysis were combined to determine the mean, median, sorting, skewness, and kurtosis as defined by Folk (1980) for the entire sample. This is accomplished with a Matlab program that determines the graphic statistics of each sample in phi. A phi vs millimeter chart is shown in Appendix C.

The grain size distribution of beach and dune sands generally varies across-shore and, to a lesser degree, alongshore as a function of the mode of deposition. The coarsest sand particles usually are found where the backwash meets the incoming swash in a zone of maximum turbulence at the base of the subaerial beach; here the sand is abruptly deposited creating a step or toe. Just offshore, the sand becomes finer. Another area of coarser particle accumulation is the berm crest, which is sometimes coincident with last high tide or mean high water where the runup deposits all grain sizes as the swash momentarily stops before the backwash starts. The dune and backshore generally contain the finest particles because deposition here is limited by the wind's ability to entrain and move sand (Bascom, 1959; Stauble *et al*., 1993). This is typical of estuarine beaches in Chesapeake Bay (Hardaway *et al.*, 1991).

The sorting of sediments can be described by the Inclusive Graphic Standard deviation (Folk, 1980). The spread of the grain size distribution about the mean defines the concept of sorting. Well-sorted sands will have a frequency distribution curve that is sharp-peaked and narrow with a value smaller than 0.5 phi; this means only a few size classes are present (Friedman and Sanders, 1978). Poorly-sorted sediments are represented by most size classes in the sample. Poorly sorted samples have numbers larger than 1 phi.

2.2.3 Biology

Primary dunes were delineated, where possible, into foredune, crest, and trough. These features must be defined on a site-specific basis as they are dictated by local morphology at the time of sample station establishment. The trough is generally defined as the area landward of the back toe of the crest to the seaward toe of the secondary dune (if present) or upland scarp.

Three randomly selected but permanently established plots for the foredune, crest, and trough along the transect line were established for each sampling transect. The herbaceous layer was sampled using tenth of a square meter plots to determine stem density and percent cover by species. Distances follow the contour of the dunes.

Secondary dunes were sampled randomly within a 66 foot swath with the transect line as the mid point. The number of samples was dependent upon the depth (seaward to landward) of the dune field. The transect that began at the seaward toe of the secondary dune is divided into ten meter intervals. The first random number denoted the length down the transect within the specific ten meter interval. The second random number denoted the perpendicular distance from the transect line. Even numbers for the second random number required movement to the right (facing landward); odd numbers required movement to the left.

Three strata were sampled at each profile– herbaceous, shrub, and tree. The herbaceous strata were assessed using tenth of a meter (0.3 ft) plots to determine stem density and percent cover by species. The shrub strata assessment quantified stem density by species within the 66 foot diameter. Tree stem density was determined using a bitterlich. All data is published in Appendix D.

2.2.4 Ground Water

This portion of the study was conducted from March-August, 2002 at site NH17. Grain size analysis was conducted on a single 4.5 m core collected from the foredune region utilizing an impact driving method (Starr and Ingleton, 1992) and from a 4.3 m auger hole within the immediate upland region above the bluff. Discrete samples, typically on the order of 10 cm intervals, were collected from the core and auger hole to provide a general description of site sediment characteristics. Grain size was determined by wet sieve and pipette analysis (Folk, 1980). Saturated horizontal hydraulic conductivity (K_h) was determined from monitoring wells using a slug test procedure that accounted for unconfined aquifer and partial aquifer penetration conditions (Bouwer and Rice, 1976).

Six monitoring wells were installed along a single transect perpendicular to the shoreline in order to measure lateral head variation and collect water samples. Wells were installed with a hand auger and constructed of 5.1 cm diameter schedule 40 polyvinyl chloride (PVC) casing with 0.025 cm slotted PVC screen. Well screen lengths were 91 cm in length except for the interidal beach monitoring well that had a 61 cm screen length. The well annulus around the screen was backfilled with gravel while the remaining annulus was backfilled with native sand and sealed with granular bentonite. Monitoring well and land topography elevations, relative to a standard reference point, were determined by differential leveling techniques. Water levels were measured during each site visit with a hand operated water level indicator and pressure transducers (5 minute intervals) were utilized for extended studies.

Water samples for chemical analysis were collected on several occasions from monitoring wells along the transect. Three well volumes of water were removed by peristaltic pump prior to sample collection. Samples were collected in Nalgene sample containers and placed on ice during transport to the laboratory. Samples were filtered with 0.45 mm membrane filters prior to analysis. Ammonium was determined by a modified phenate method (Strickland and Parsons 1972). Nitrite was determined spectrophotometrically by diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediamine to form an azo dye (U.S. EPA Method 354.1). Nitrate was determined after reduction to nitrite by CU-Cd columns (U.S. EPA Method 353.3). In addition to nutrient analysis, ground water temperature, salinity and dissolved oxygen levels were measure during each site visit with an YSI 85 unit.

2.3 Reach Assessment

A shore reach is defined as a segment of shoreline where littoral processes mutually interact. Subreaches are sets within larger reach segments. Reach boundaries can be defined by natural features such as tidal creeks, large embayments or headlands. Man made structures such as bulkheads, revetments, groins and particularly jetties can create hard boundaries.

2.3.1 Historical and Recent High-Level Aerial Photos

Aerial photos from VIMS's Shoreline Studies and Submerged Aquatic Vegetation (SAV) Programs, United States Geological Survey (USGS), Hampton Roads Planning District Commission (HRPDC), and Virginia Base Mapping Program (VBMP) archives were acquired. The 1994 imagery was already processed and mosaicked by USGS, while the 2002 imagery was processed and mosaicked by VBMP. 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 orthorectified to a reference mosaic, the 1994 Digital Orthophoto Quarterquadrangles (DOQQ) from USGS. The original DOQQs were in MrSid format but were converted into .img format as well. ERDAS Orthobase image processing software was used to orthographically correct the individual flightlines using a bundle block solution. Camera lens calibration data was matched to the image location of fiducial points to define the interior camera model. Control points from 1994 USGS DOQQ images provide the exterior control, which is enhanced by a large number of image-matching tie points produced automatically by the software. A minimum of four ground control points were used per image, allowing two points per overlap area. The exterior and interior models were combined with a 30-meter resolution digital elevation model (DEM) from the USGS National Elevation Dataset (NED) to produce an orthophoto for each aerial photograph. The orthophotographs that cover each USGS 7.5 minute quadrangle area were adjusted to approximately uniform brightness and contrast and were mosaicked together using the ERDAS Imagine mosaic tool to produce a one-meter resolution mosaic also in an .img format.

To maintain an accurate match with the reference 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 maximum root mean square (RMS) error allowed was 3 for each block.

Once the aerial photos were orthorectified and mosaicked, the shorelines were digitized in ArcMap with the mosaics in the background to help delineate and locate the shoreline which was an approximation to MHW. MHW was often defined as the location of the last high water or the "wetted perimeter" on the beach sand. In areas where the shoreline was not clearly delineated on the aerial photography, the location was estimated based on the experience of the digitizer. Digitizing the shoreline brings in, perhaps, the greatest amount of potential error because of the problems of image clarity and definition of shore features. The final format of the shorelines is as a shapefile. One shapefile was produced for each year that was mosaicked. In areas where the shoreline was not clearly delineated on the aerial photography, the location was estimated based on the experience of the digitizer.

2.3.2 Recent Low-Level Aerial Photos

Recent color aerial photography was acquired to help estimate, observe, and analyze shoreline changes before and after hurricane Isabel for the nine dune monitoring sites. The dates these aerials were flown range from June 25, 2003 to October 26, 2004. The images were scanned as tiffs at 600 dpi. All sites were georectified to a reference mosaic, the 2002 Digital Orthophotos from the Virginia Base Mapping Program (VBMP). The VBMP aerial photography is divided into a series of orthophoto tiles and is stored in a Virginia south, state plane projection, in feet. The aerial photo tiles from VBMP for each site were mosaicked and reprojected to a UTM zone 18 north projection, in meters.

The Georeferencing Tool from ESRI's ArcMap GIS software was used to georeference the images. This method requires ground control points to register the aerial photography to the reference images. These are points that mark features found in common on both the reference images and on the aerial photographs that are being georeferenced. Control points were distributed evenly to maintain an accurate registration without too much warp and twist in the images. This can be challenging in areas with little development or at sites with severe storm damage. Good examples of control points are permanent features such as manmade features and stable natural landmarks with low to no elevation. The standard in this project was to achieve an average root mean square (RMS) error of 10 or less for each image.

In the first step of the process, the reference image and each scanned aerial photograph are roughly aligned so that their common points can be identified. Then, with the aid of the Georeferencing tool, ground control points were added until the location of the aerial photograph closely matches the location of the reference image. When an acceptable correspondence is achieved, the aerial photograph was saved as a rectified image. Finally, all the rectified images were then mosaicked using the mosaic tool in ERDAS Imagine and the shorelines digitized as described above. These shorelines were based on a single point in time and are based on water levels visible on the photos. They may not directly match the profile data taken at the site.

2.3.3 Rate of Shoreline Change

An Arcview extension called "shoreline" was used to analyze shoreline rate of change. A straight, approximately shore parallel baseline was drawn landward of the shorelines. 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 the beginning of the 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 distances of the digitized shoreline from the baseline are used to determine the rates of change. The rates of change are summarized as mean or average rates and standard deviations for each baseline.

Shoreline change rates are based on aerial imagery taken at a particular point in time. We have attempted to portray the same shoreline feature for each date along the coast of each monitoring site. Every 100 feet along each baseline on each plate, the rate of change was calculated. The mean or average rate for each site is calculated with the long-term rate determined between 1937 and 2003 or 2004 depending on the latest date available. These rates are averaged over the subreach and may not match the trends at individual profiles. The short time frame between the low-level aerial photography tends to exaggerate rates of shoreline change. The total average and standard deviation (Std Dev) for the entire data set of individual rates is also given. The standard deviation shows the relative spread of values about the mean or average. Larger standard deviation values relative to the mean indicates a wider scatter of erosion rates about the mean while lower standard deviation values indicate erosion rates are concentrated near the mean (*i.e.* all the rates calculated for the entire plate were similar). When short time frames are used to determine rates of shoreline change, shore alterations may seem amplified. The rates based on short-time frames can modify the overall net rates of change.

It is very important to note that this extension is only useful on relatively straight shorelines. In areas that have unique shoreline morphology, such as creek mouths and spits, the data collected by this extension may not provide an accurate representation of true shoreline change. The shore change data was manually checked for accuracy. However, where the shoreline and baseline are not parallel, the rates may not give a true indication of the rate of shoreline change.

3 Site MA3

3.1 Reach Assessment

Site MA3 is located near the southern end of Mathews County on the Chesapeake Bay (Figure 3-1). It features an open bay coast classified as Man-Influenced Linear Dune Field (secondary dunes). The current land use is residential and includes the Chesapeake Shores and Bavon Beach communities. Approximately 45 homes are situated on the Bay side of a low neck of land that becomes an island during northeasters. The shoreline along the study site is a Bay barrier system with dunes, beach and nearshore bar system.

The study site is about 4,300 ft long and is set within a larger reach that extends from Dyer Creek on the north to Deep Creek on the south which is today about 7,500 ft. The MA3 shoreline has an historic erosion rate of about -1.6 ft/yr (Byrne and Anderson, 1978). In 1852, old charts show a series of islands along the coast that extended across the north and south ends of the study site. These islands were probably marshy in nature. By 1942, the islands had disappeared, and the shore position had actually advanced along the southern half of MA3 (Byrne and Anderson, 1978).

These southernmost shorelines in Mathews County at New Point Comfort have had dramatic shifts in shore position. New Point Comfort Lighthouse, completed in 1805, became an island in the 1850s when Deep Creek breached. The island has since receded leaving the lighthouse completely stranded in Chesapeake Bay.

The shoreline in 1937 imagery shows a sandy coast with numerous offshore bars and a few remnant marsh headlands (Figure 3-2-1). The land use was agricultural with two houses located near the shore about mid-way along the study site. A fairly large pond was entrapped by a sandy barrier at the south boundary of the site. A large amount of sand was eroded by 1953 as the shore became straighter as two marsh headlands, whose slower rate of erosion, began to effect the shore morphology. By 1960, shoreline retreat had reduced the size of the pond by 90%. Land use was still basically agricultural, but more roads had been built and a few more coastal cottages can be seen. A road now extended to the north end of the point. The physical boundaries of the site were defined by a marsh headland on the north and south. Obliquely attached sand bars still controlled the beach planform, and SAV could be seen in the bar troughs offshore. It is difficult to ascertain the extent of dunes at that time although there was sufficient beach width to support them.

Aerial imagery in 1968 (Figure 3-2-2) and low oblique aerials in 1973 show the development of a fairly continuous dune ridge along the entire site. Behind it was a low landward sloping sandy terrace - the old overwash. About 10 cottages had been built along this sandy chenier which had areas of vegetation and bare zones. The vegetation was most likely dune plants which may have been the initiation of areas of secondary dune development. Most of the agricultural areas had reverted to woods.

In 1994 (Figure 3-2-3), approximately 35 cottages were present along the shore. Linear dune ridges had developed along the north end of the site as well as on a large beach salient located about 1,000 ft from the south bounding marsh headland. The area between the salient and the north end dune ridges was a relatively thin beach with little of no fore dune vegetation. The shoreline directly across from the main entrance to Chesapeake Shores had the narrowest beach, a trend which continues today. The areas in front of and between the cottages had evolved as secondary dune features.

In 2002, the Chesapeake Shores and Bavon Beach coast were geomorphically diverse alongshore. Linear foredunes had become established and advanced in response to a lack of storm activity behind shoreline salients that are controlled in part by attached oblique sand bars. The central area between the two salients remained a “hotspot”. The large beach salient identified in 1987 had been reduced in size and extent. Dune fencing had been used along much of the shore, particularly along the northern portion, in order to advance the foredune feature.

Overall shore change (Figure 3-2-3) indicates that the southern portion of the Bavon Beach coast reach is eroding quickly. However, the section of coast where the residential communities are located has become more stable since 1937 as the shoreline sits between two marsh headland.

3.2 Field Surveys

Eight profiles along about 900 ft of shoreline were established along the Chesapeake Shores/Bavon Beach coast to represent the alongshore variability in beach/dune planform and secondary dune morphology (Figure 3-1). Profile MA3-1, located on the north end, is set within a slight embayment created by beach salients, and Profile MA3-2 is on a beach salient. The general line of cottages is about 90 feet landward of the primary dune leaving the secondary dune feature relatively unaffected. Dune fencing occurs at both these transects and each shows significant beach and/or dune accretion between the two profile dates, 19 January 2001 and 27 March 2003 which is the profile date taken before Hurricane Isabel (Figure 3-3). Profile MA3-3 is located in a transitional area where the cottages are about 50 feet from the primary dune which is restricting the secondary dune area but allows a slight accretion of the base of the dune.

Profiles MA3-4, MA3-5 and MA3-6 (Figure 3-3) are within the chronic “hotspot” that occurs between two beach salients about 500 feet apart. Once again, these beach features are controlled, in part, by the position of attachment of the offshore bar system. Profile MA3-4 initially had beach face recession, but overall it has increased in beach width and a new dune was beginning to form. Both MA3-5 and MA3-6 had beach accretion between 2001 and 2003. The position of the cottage line varies within this region more as a function of order of construction and varies between 50 and 5 feet from the primary dune crest.

The south half of the study area is represented by Profiles MA3-7 and MA3-8 (Figure 3-3). Here the cottage line is farther from the primary dune and the secondary dune features tend to be higher and wider than the coast to the north. At profile MA3-7, slight changes were noted across the beach face, but at MA3-8, the beach face has generally eroded, but a new dune has formed since 2001 and the nearshore bar has grown.

Over the course of the monitoring program, the subaerial beach or the beach face generally was accretionary (Table 3-1). Above MHW, the beach was also accretionary except for the period after Hurricane Isabel when significant dune erosion occurred. These volumetric changes are reflected in the net change in four years of data between January 2001 and December 2004 (Figure 3-4). Profiles MA3-1, 3-2, 3-4, and 3-5 had relatively little change in the primary dune and significant backshore and beach face growth. Profiles MA3-3 and 3-6 lost their original primary dune but still accreted at the backshore and beach face. MA3-7 lost both its primary and secondary dune and width from the backshore and beach face. MA3-8's dune was not impacted, but backshore and beach face width was reduced over the course of the monitoring project. These variations in response to the same wind, wave, and storm conditions are the result of the location of nearshore bars.

The measured data help determine the stability of the site and it's response to storm events (Appendix B). The backshore width (F) increased on most profiles through the monitoring period indicating an accreting system. This corresponded to an increased distance between the dune crest and the toe of the beach (H). Profiles MA3-3 and 3-8 were the exceptions. At the same time, an overall drop in the primary dune crest elevations (X) occurred. One of the interesting features of the site as a whole is the elevated position of the beach toe (T). Most of the profiles are about 1 ft above MLW except for Profile MA3-5 which is not elevated. The intertidal beach area is generally elevated due to an abundant sand volume in the littoral system and the position of the nearshore bars. Significant SAV beds also exist along the site. They sit between the bars and act to slow sediment transport in that region.

Additional information collected at each site included ground photography, sediments, and vegetation characterization. The history of the site at MA3-7 over the course of the monitoring project is shown in Figure 3-5. Photos are taken from different vantage points making direct comparison difficult. However, the same walkover can be seen in each photo. This section of the site had a wide beach and a gently sloping dune face when monitoring began in 2001. As the years progressed, the backshore width was reduced and the dune face began to scarp. Even before Hurricane Isabel impacted this shore, these dunes were eroding. The storm completely removed the dunes at the site and exposed an old cottage foundation where the MA3-7 benchmark was located. Grain size (Appendix C) changed little over the course of the monitoring project. It follows the general characterization of bay beaches with the coarsest sand at the berm, midbeach and the toe and the finer-grained material in the dune and nearshore. The grain sizes were fairly consistent between May 2002 and March 2003 survey dates.

Table 3-1. Volume change on the beach face and above MHW.

Time Period	Volume Change (cy)	
	Beach Face^	Above MHW^
Jan 2001-Sep 2001	+98	+416
Sep 2001-May 2002	+306	+469
May 2002-Oct 2002	+125	-169
Oct 2002-Mar 2003	+217	-14
Mar 2003-Jul 2004*	+74	-1,142
Jul 2004-Dec 2004	-50	+637

^Beach Face is defined as between 0 ft MLW and +2.3 ft MLW; MHW is defined as +2.3 ft MLW
*All profiles were not surveyed Post Isabel so the total site volume cannot be calculated for the October 2003 survey.

3.3 Hurricane Isabel Impacts

Hurricane Isabel impacts were significant. Storm surge readings at Sewells Point and Gloucester Point were +8 ft MLLW. Maximum wrack line meaurements at the site were about 9 ft. Wind-generated wave action at the site ranged the whole spectrum from northeast to southeast and south as the storm progressed across the Virginia coastal plain. Low-level georectified aerial photography at MA3 before and after Hurricane Isabel show that most of the shoreline retreated during the storm (Figure 3-6). However, the location and direction of the nearshore bars effected how the various sections of the shore were impacted. At this site, the low-level photos and the on-the-ground monitoring show differing results. This is a result of when the data were taken and difficulty in interpreting the position of MHW in the post-Isabel photos.

Five profiles have all three periods of pre- post- and recovery: MA3-1, MA3-2, MA3-4, MA3-5 and MA3-8. Profiles MA3-3, MA3-6, and MA3-7 were not surveyed immediately after Hurricane Isabel. Impacts of Isabel varied along the length of the project site. The northern section, MA3-1 and MA3-2, had the primary dune material carried landward to fill the tough and seaward to widen the upper beach (Figure 3-7). The recovery shows the primary dune redeveloping at about the same location as the pre-storm dunes with a wider beach/backshore and foredune development. The sequence of events are seen clearly in ground photos (Figure 3-8). The residents had installed new fence and did some intermittent dune grass plantings after the storm.

The middle section, MA3-4 and MA3-5 had similar impacts (Figure 3-7). The primary dune at MA3-4 was impacted to the extent that the dune face was scarped and the foredune that had accreted since 2001 was eroded. A wide beach was left after the storm. The "hot spot" of the site is typified by MA3-5 where the primary dune was flattened to fill the adjacent trough and widen the beach. Recovery shows the beach/berm positions to have remained fairly constant since the post-storm shift. A new primary dune appears to be developing very near the pre-storm position at MA3-5. A widened backshore has provided the opportunity for foredune development on both profiles (Figure 3-9).

While profiles MA3-6 and 3-7 were not profiled, they had large impacts to their dunes (Figure 3-10). The southern part of the project shore is MA3-8. It had a large foredune pre-Isabel which was eroded out with a consequent increase in beach width (Figure 3-7). However, the foredune has not grown at the same rate as those on the northern end of the site and the beach face and upper beach have eroded. The recovery period does shows a significant foredune re-vegetation (Figure 3-11).

The rates of change at MHW on the profiles (Table 3-2) show that the system was accreting before the hurricane impacted the region and that the site was relatively unaffected by the storm in the short-term. The shore change for the reach show large variations along the coast before and after the storm (Figure 3-12), but the long-term change (1937-2003) was relatively unaffected by these large variations. Table 3-3 shows the calculated rate of shoreline change for the MA3 reach. The rates of change were decreasing between 1937 and 2002. The end point rate of change between 1937 and 2002 was -2.3 ft/yr. The short time span between the 2002 through 2003 dates lead to large, exaggerated rates of shoreline change particularly after Hurricane Isabel. However, overall, these dates have little effect on the end point long-term rate between 1937 and post-Isabel 2003 which had an erosion rate of -2.8 ft/yr. Interestingly, the long-term rate of change was decreasing as the shoreline became more stable between the two marsh headlands. This matches the trend of accretion shown in the short-term profile data.

Table 3-2. Average rate of change at MHW in feet per year at each profile at site MA3 before Hurricane Isabel and over the complete period of monitoring.

Profile Number	Average Rate of Change at MHW (ft/yr)	
	Jan 2001-Mar 2003 Pre-Hurricane Isabel	Jan 2001-Dec 2004 Overall
1	+6.0	+2.6
2	-0.1	+3.1
3	+1.3	-0.2
4	+0.6	+5.1
5	+4.4	+4.7
6	+3.2	-0.6
7	-3.0	-3.6
8	-4.8	-4.3
Average	**1.0**	**0.9**

Table 3-3. Historic and recent average rates of shoreline change determined from aerial photography.

Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-1953	-7.6	14.2
1953-1968	-1.5	2.4
1968-1982	-0.8	3.2
1982-1994	-0.2	3.1
1994-2002	0.9	5.4
2002-June 25, 2003	-15.6	12.4
June 25, 2003-September 25, 2003	-71.6	47.3
1937-September 25, 2003	**-2.8**	**3.7**

4 Site LN39

4.1 Reach Assessment

Site LN39 is located near Mosquito Point on the Rappahannock River in Lancaster County (Figure 4-1). The site consists of shorelines on either side of the sandy salient. One shore faces westward up the Rappahannock River while the other side faces eastward toward the open Bay. The current land use is residential, but the site occurs as a broad sandy salient with low secondary dune field. The site is somewhat Man-Influenced by shoreline hardening both up and downriver of the site.

In 1937, Mosquito Point was a broad natural sandy spit trending northwest/southeast with a truncated distal end (Figure 4-2-1). A small entrapped pond occurred at the upland/spit boundary. At the end of the larger spit, a large salient occurred on the southwest side, and a shore spit appendage trended northeast from the northeast side. The sand supply for the spit appears to have come from long-term erosion of the high sandy upland banks upriver where the historic erosion rate was -1.5 to -2.0 ft/yr (Byrne and Anderson, 1978). Land use was mainly agricultural at that time. The spit morphology is controlled by sand supply, tidal currents, and the impinging wave climate. The latter parameter has two components, a river component from the southwest and northwest and a Bay component from the east.

By 1959, a road had been built to the end of the spit, and what appears to be a bulkhead was built across the distal end of the spit (Figure 4-2-1). The impact of this shore structure was to separate the end of the spit into a river salient and a creek spit. The downriver end of the salient had retreated upriver adjacent to the bulkhead and the creek spit had turned more northward into Mosquito Creek and had become longer. In the area of the study site, the salient had well-developed dune vegetation.

By 1977, the creek spit had disappeared with the material either going ashore or leaving the site to become a shoal in the creek (Figure 4-2-1). Groins were added just inside the creek shore and possibly more bulkheading occurred on the end of the main spit. The salient grew larger on the upriver side but remained blunted on the downriver side partially due to the impact of the adjacent shore hardening and the impinging Bay waves. By 1982, the downriver side of the salient had moved further upriver as groins were built on the river side at the end of the main spit. A channel had been cut across the creek shoal to the shore for easier boat access (Figure 4-2-2).

The downriver side of the spit in 1994 had formed an embayment from the salient point or cusp and the downriver shore structures (Figure 4-2-2). The upriver end feathers into the upland banks. In 2002, the embayment had become more pronounced as the Bay-facing shore eroded and the upriver side accreted (Figure 4-2-2). The salient is an odd sand form both in appearance and history. The upriver side has a low primary dune feature, and the downriver side has a higher primary dune feature, due in part, possibly to longer period Bay waves and associated higher runup potential. The area behind these primary dunes is a secondary dune field that appears as a series of low linear ridges trending northwest/southeast that were primary dunes in the past.

4.2 Field Surveys

Two profiles were established to represent each side of the salient spit feature, bay and river exposure, respectively (Figure 4-1). LN39-1 is on the bay shore, and LN39-2 is the river profile. A secondary dune field exists at LN39-2, but at LN39-1 the linear ridges are truncated by the primary dune so there is no secondary dune feature identified.

Profile LN39-1 showed a cut and fill change between Feb 15, 2001 and Aug 28, 2001 where the lower beach face had moved onto the upper beach widening the upper beach berm (Figure 4-3). The following interval showed accretion on the backshore and beach face as well as the possible development of a foredune. However, by October 2002, the shore at MHW had eroded about 35 ft. At profile LN39-2, an increase in sand volume occurred across the entire beach zone through the monitoring period of 2001-2003. Then net change between 2001 and 2004 at each profile indicated severe erosion and upriver movement of LN39-1 with associated beach, backshore, and dune growth at LN39-2 (Figure 4-4).

The measured data help determine the stability of the site and it’s response to storm events (Appendix B). The general trends indicated by the profile data are measured in the site data. The distance from the primary dune crest to the back of the primary dune (C) decreased 4 ft at LN39-1 while increasing 27 ft at LN39-2 through the length of the monitoring period. At LN39-2, the 27 ft increase accounts for both a riverward movement of the dune crest by 14 ft and a widening of the entire dune landward of 13 ft. At the same time, the elevation of the dune crest (X) had decreased by 1 ft at LN39-1 but remained the same at LN39-2. The same general trend is evident in the backshore width (F). It narrowed at LN39-1 but increased in width at LN39-2. The location and elevation of the beach berm (E+F, Z) and the toe of the beach (H, T) varied depending on wind/wave conditions. At times, the elevation of the toe was -2 ft below MLW to 1 ft above.

Additional information collected at each site included ground photography, sediments, and vegetation characterization. The history of the site at LN39-1 over the course of the monitoring project is shown in Figure 4-5. Photos show a wide backshore in the beginning of the monitoring program. This narrows through time, and by October 2002, the backshore was very close to the edge of the dune vegetation. However, the June 2003 photo showed that during the summer the backshore had widened and recolonization of the backshore with dune vegetation was beginning. The hurricane wiped out most of the dune and the vegetation at this site, but once again, the following summer, the vegetation was beginning to grow on the wide flat backshore. The winter 2004 profile showed the loss of the backshore as the subaerial beach came almost to the edge of the dune vegetation. Grain size (Appendix C) changed little over the course of the monitoring project. It followed the general characterization of bay beaches with the coarsest sand and gravel at midbeach and the toe and the finer-grained material in the dune. Over half of the sample taken in the erosional nearshore at profile LN39-1 was gravel. Mean grain size was fairly consistent over the course of the monitoring program except for the beach berm at profile LN39-2 which became finer after the hurricane.

4.3 Hurricane Isabel Impacts

Low-level aerial photos show the movement of the shoreline due to the hurricane (Figure 4-6). Significant landward movement of about 40 ft occurred along the Bay-facing shoreline and slight accretion occurred on the upriver section. Profile data shows that LN39-1 eroded about 32 ft and profile LN39-2 accreted 25 ft at MHW (Figure 4-7). Over the entire monitoring period, LN39-1 was eroding and the hurricane accelerated the rate of erosion (Table 4-1). The reverse was true of LN39-2. It was accreting before the hurricane, and after the hurricane, the rate of accretion at MHW accelerated. The storm tide range at Windmill Point near LN39 was 3.5 ft MLLW.

At LN39-2, the dune vegetation was unaffected by the storm (Figure 4-8). By December 2004, a wide platform had accreted along this section of shore on which grass had not grown yet, but likely will next summer. At LN39-1, the dune vegetation was recolonizing the backshore before the hurricane (Figure 4-9). After the storm, much of the dune vegetation was covered by sand that had over-washed during the storm. It was able to regrow in the recovery period helping to stabilize the dune. At the far end of the monitoring site where the natural dune site forms an embayment with the bulkheaded shore, significant erosion occurred leading to the loss of trees during the storm.

Rates of shoreline change using the historical shorelines were not calculated for this site because too much change makes a baseline difficult to place. Figure 4-10 shows the shorelines and where the rates of change were calculated manually. The long-term rates reflect the how the salient has changed over time. The distal end of the salient, that has moved upriver over time and is represented by Transect 1, shows large erosion rates. Both Transects 2 and 3 are accreting at about the same long-term rate. At Transect 4, where the accreting dune ties into the eroding upland banks, the change is variable; but overall, little net shore change occurred between 1937 and 2003.

Table 4-1. Average rate of change at MHW in feet per year at each profile at site LN39 before Hurricane Isabel and over the complete period of monitoring.

Profile Number	Average Rate of Change at MHW (ft/yr)	
	Feb 2001-Jun 2003 Pre-Hurricane Isabel	Feb 2001-Dec 2004 Overall
1	–7.8	-11.4
2	+3.3	+8.0

5 Site NH10

5.1 Reach Assessment

Site NH10 lies just north of Silver Beach on the Bay in Northampton County (Figure 5-1). The study site is about 1,400 feet long and extends across a large, lawned, residential lot and an adjacent wooded lot to the north. A small intermittent drainage runs through the upland bank and beach of the wooded section. The site is set within a larger shore reach defined by the limits of Occohannock Neck which extends from Occohannock Creek and Nassawadox Creek. A subreach of this site extends from Battle Point to Silver Beach. Battle Point and Silver Beach have evolved into headland features due to shoreline hardening over the years.

The adjacent upland along NH10 is 10 to12 feet above MLW and is composed mainly of sandy strata (Hardaway *et al*., 2004). The dune field narrows toward the south and terminates just north of Silver Beach. A groin exists on the south boundary of the study site. The dune field at the site is composed of a primary dune at each end with primary and secondary dunes in the middle. NH10 is part of a larger littoral cell with a relatively abundant sand volume occupying the beach and nearshore region. Like much of the bayside coast of Northampton County, there is an abundance of sand in the nearshore bar system.

The historic erosion rate between 1851 and 1942 was -5.7 ft/yr (Byrne and Anderson, 1978). However, more recent net shoreline changes between 1938 to 2002 show little change at the study site (Figure 5-2). Both north and south of the study site, shoreline retreat increases at historic rates until Silver Beach and Battle Point where fairly recent shoreline hardening renders shoreline change rates to zero.

Utilizing aerial imagery from VIMS' archives, a more detailed progression of change was published in Hardaway *et al.* (2004). Smaller scale photos of the entire reach are shown in Figure 5-2. Aerial imagery in 1949 shows a wider beach along the project area and adjacent shoreline (Figure 5-2-1). A small patch of "dune" backshore vegetation existed about mid-site just south of an upland drainage ditch. Oblique aerial imagery from 1972 shows the site with a narrow backshore and narrow patchy dunes against a vertically exposed fastland bank (Hardaway *et al.*, 2004). By 1989, the beach had widened, and the dune field had begun to mature (Figure 5-2-1). Sand accreted up and over the upland bank adjacent to the lawned lot. Several groins were installed by the mid-1990s and may have contributed to a widening of the beach/backshore region (Figure 5-5-2).

Over time, this system has evolved into a nodal point where historic erosion is slight. This could be attributed to its fortunate position along the larger reach as well as local effects of upland drainages. Another cause could be a decrease in offshore gradient which suggests more sand storage and wave attenuation due to a significant offshore bar series. This subreach of shoreline has had little overall change in nearshore bar morphology through time. In the central area of the reach, the bars are at their widest. This corresponds to the most stable shore section of the beach as well as the location of the dune monitoring site. An additional dune site exists just north of NH10 (Hardaway *et al.*, 2004). However, it is a remnant of a previously larger site and is not nearly as stable as NH10 probably due to shore hardening to the north.

5.2 Field Surveys

Three profiles were selected to depict the varying alongshore topography at the site as it ranges from a primary dune (NH10-1) and transitions (NH10-2) toward a primary and secondary (NH10-3) morphology (Figure 5-1). The primary dune crest elevation decreases northward from 15 ft above MLW at the southern end of the site to less than 10 ft above MLW at the northern end of the site (Figure 5-3). Between March 2001 and June 2003, all three profiles accreted with profile NH10-1 and 10-2 showing significant foredune growth. Nearshore bars play a significant role in stabilizing this system.

Volume calculations between the profiles show that, in general, both the beach face between MLW and MHW and the backshore/dune above MHW was accreting (Table 5-1). This site was impacted by Hurricane Floyd in 1999 and between 2001-2003 this site was likely recovering from this event by rebuilding its dune. Between June and December 2003, Hurricane Isabel impacted the region, but little volumetric change occurred at the profiles. However, in the recovery period between December 2003 and July 2004, the beach face lost sand while the dune continued to accrete. In fact, the net profile plots showing the profile cross-sections on March 1, 2001 and December 22, 2004 show large overall seaward accretion at profiles NH10-1 and 10-2 (Figure 5-4). Profile NH10-3 showed growth in the upper backshore and dune but it lost beach width on the lower backshore and beach face.

The measured data help determine the stability of the site and it's response to storm events (Appendix B). For instance, at NH10-3, the primary dune crest moved seaward 4 ft after the hurricane, but the dune elevation had already been increasing over the course of the monitoring period, 0.5 ft overall (X). At both NH10-2 and 10-3, the front base of the primary dune moved seaward 6 ft and 10 ft, respectively (E). However, while the elevation of the front base of the primary dune (Y) increased at both NH10-1 and 10-2, it decreased slightly at NH10-3. At NH10-1 and 10-3, the distance to MLW generally increased over the course of the monitoring program (D). The distance and elevation to MLW and the toe of the beach are not coincident at NH10 due to the movement of the nearshore bars. In fact, the elevation of the toe (H) is highly variable sometimes as much as 2 ft above MLW. This is particularly true of NH10-2 after Hurricane Isabel.

Additional information collected at each site included ground photography, sediments, and vegetation characterization. The history of the site at NH10-2 over the course of the monitoring project is shown in Figure 5-5. Photos show seasonal variations in the dune vegetation as it colonizes the backshore in the summer and retreats during the winter. In both June 2003 and July 2004, the vegetation is close to the beach berm indicating accretion of the dune seaward. Of note also is the nearshore attached bar shown in December 2003 during a particularly low tide. These bars control the morphology of the site. Grain size (Appendix C) changed little over the course of the monitoring project. It follows the general characterization of bay beaches with the coarsest sand and gravel at midbeach, toe, and nearshore with midbeach being the coarsest, and the finer-grained material in the dune.

Table 5-1. Volume change on the beach face and above MHW.

Time Period	Volume Change (cy)	
	Beach Face^	Above MHW^
Mar 2001-Sep 2001	+44	+14
Sep 2001-Jun 2002	+37	+74
Jun 2002-Dec 2002	+21	+59
Dec 2002-Jun 2003	+25	-24
Jun 2003-Dec 2003	+155	+244
Dec 2003-Jul 2004	-192	+40
Jul 2004-Dec 2004	+73	-17

^Beach Face is defined as between 0 ft MLW and +1.8 ft MLW; MHW is defined as +1.8 ft MLW

5.3 Hurricane Isabel Impacts

Low-level vertical aerial photography taken before Hurricane Isabel in June 2003, after Isabel in January 2004, and in October 2004 show how the storm impacted this dune site (Figure 5-6). The dune site boundary and profile locations are shown for reference. These photos indicate significant southerly sand transport along this shore reach due to the hurricane and little change at the site. The beach face and backshore actually accreted due to Hurricane Isabel. The beach and dune profiles support this (Figure 5-7) as post-Isabel accretion occurred on all three profiles. Profile NH10-2 not only had beach and backshore accretion but also had a wider and higher primary dune crest after the storm. The ground photos taken before and after the hurricane show little change at NH10-1 and 10-3 (Figure 5-8). No tide gauge is close to this site; however, the projected storm tide range was about 3.5 ft above MLLW.

The average rates of shoreline change for the entire subreach were calculated using the orthorectified historical and recent aerial photography described in Section 5.1 as well as the low-level georectified aerial photography shown in Figure 5-6. The baseline used is also shown in Figure 5-6. The results are shown in Figure 5-9 and Table 5-2. The alongshore rates of change due to Hurricane Isabel are within the range of the historic rates of change. In fact, the overall average rate of change is relatively stable between 1938 and 2004.

The rate of shoreline change at MHW over the course of the monitoring period also was determined from the field data (Table 5-3). Before Hurricane Isabel, the net change in the position of MHW was positive at NH10-1, no net change at profile NH10-2, and negative or landward change at profile NH10-3. This resulted in a net change of 0 for the entire site. However, over the course of the entire monitoring period, it would appear that Hurricane Isabel had a positive effect on the southern section of the reach as the average rate of change increased to about +2 ft/yr. The northern section of the site had only a slightly larger erosion rate at MHW. For the entire site, what was stable with no net change became slightly accretionary.

Table 5-2. Historic and recent average rates of shoreline change determined from aerial photography.

Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1938-1949	-4.3	1.0
1949-1989	0.1	0.4
1989-1994	-2.8	4.8
1994-2002	0.4	3.5
2002-June 25, 2003	-1.4	10.8
June 25, 2003-January 14, 2004	-9.2	12.1
January 14, 2004-October 26, 2004	-3.2	13.0
1938-October 26, 2004	**-0.8**	**0.3**

Table 5-3. Average rate of change at MHW in feet per year at each profile at site NH10 before Hurricane Isabel and over the complete period of monitoring.

Profile Number	Average Rate of Change at MHW (ft/yr)	
	Mar 2001-Jun 2003 Pre-Hurricane Isabel	Mar 2001-Dec 2004 Overall
1	+0.9	+2.1
2	0.0	+2.0
3	-0.8	-1.2
Average	**0.0**	**1.0**

6 Site NH17

6.1 Reach Assessment

Site NH17 is located on the Floyd Farm in Northampton County (Figure 6-1). It is an open bay shoreline which extended approximately 960 feet between profiles NH17-1 and NH17-4. Profiles NH17-1 through NH17-3 are clearly on the mainland attached portion of a much larger spit that includes two other dune sites as identified in the Hardaway *et al.* (2001). NH17-4 is located in the transitional zone between the spit and the regular shoreline/upland bank. These dune sites are separated by short stretches of non-vegetated spit (sand only). The entire spit is almost a mile long and is unnamed. For the purposes of discussion, it will be referred to as Vaucluse Spit.

Vaucluse Spit lies within a larger reach defined by Westerhouse Creek on the north and Hungars Creek on the south. Here the curvilinear shoreline is oriented almost north - south. This reach represents the southern two-thirds of the Church Neck bayshore. Historic erosion is about -0.7 ft/yr but varies to the north and south at +1.6 ft/yr and +1.4 ft/yr, respectively (Byrne and Anderson, 1978).

NH17 represents the shore attached section of Vaucluse Spit where a strong southerly littoral transport system has "fed" the growth of the spit. However, in 1938, the distal end of a shore salient was about 3,000 ft south of the project site (Figure 6-2-1). This area of spit development occurs as the shoreline turns from a north-northeast/south-southwest strike to a more north/south strike. A large offshore shoal with a north-northeast/south-southwest bearing ran off and down the Bay and extended into the Hungars Creek ebb shoal complex. Another similar but smaller offshore shoal occurred to the north just south of Westerhouse Creek. Significant SAV beds had developed in the lee of these shoal features. By 1949, the salient became a shore-attached spit which migrated alongshore for another 3,000 ft (a rate of approximately +175 ft/yr).

A 1949 aerial photo shows that a new spit feature had developed in front of the project site (Figure 6-2-1). This spit was shore attached about 1,500 ft north of the study site and extended along shore about 2,000 ft and several hundred feet offshore. It appeared to be the downdrift result of the small spit and shoal complex seen to the north in 1938. This subreach had been a zone of shear and significant sediment transport and deposition over the years. Both of these previous spits eventually welded to the shoreline. A small salient had formed alongshore at the study site in the lee of a spit shown in 1955 (not depicted in report) aerial photography. This salient is now the present day north end of the study site and of Vaucluse Spit.

In 1972, oblique aerial imagery showed that the distal end of Vaucluse Spit had migrated about 1,000 ft to the south. A narrow tidal creek bordered by wetlands had developed along the lee side between the spit and the mainland. A primary dune feature ran the length of the spit from just north of the study site southward. The older 1937/55 spit to the south had migrated ashore and existed as a series of vegetated (dune) arched salients with tidal creeks and marshes. By 1989, Vaucluse Spit was about 4,000 ft long with intermittent patches of dune and washover. The north boundary was located at the study site (Figure 6-2-1).

Vaucluse Spit grew 1,300 ft in length between 1989 and 2002, a rate of 100 ft/yr (figure 6-2-2). This progradation of the Spit has protected the mainland coast from severe storm wave attack. The mobile sand spit and nearshore bar systems not only influenced the impinging wave climate and shore change but also created and altered nearshore habitat of SAV. Today, Vaucluse Spit is about 5,500 ft long and firmly attached at the project site. The coast to the north is developing significant offshore bars, shoals and some shore attached salient features which are all pointing to the south. SAV beds, lee side marshes and dunes have come and gone over the years in this highly active littoral system.

This section of shoreline has a history of growth and change due to the movement of large amount of sands through the area (Figure 6-2-2). The boundaries of the dune sites and other habitat are in constant motion as they are part of a continuous beach/dune system that is broken by intermittent washovers and peat exposures. Potential shoreline development to the north would likely reduce erosion rates locally if the shorelines are hardened, but it also may negatively impact downdrift shores by reducing sand supply.

6.2 Field Surveys

Four profiles were established to represent different alongshore sub-morphologic units and they all begin along the top slope of the upland bank (Figure 6-3). NH17-1 crosses a very narrow creek, the primary dune and beach, and continues into the Bay. NH17-2 goes down the bank, across a wet swale, over the primary dune and beach, and into the Bay. NH17-3 crosses a dry swale, over the primary dune and beach and into the Bay. NH17-4 runs from the bank to the back of the primary dune, over the primary dune and beach, and into the Bay. The tidal creek, wet swale, and dry swale are a small watershed with a southward dipping "thalwag" gradient. The spit is welding to the shore from north to south along the study site. The top and face of the upland bank are covered in sand and are stable and protected by the spit. A wide disparity in the alongshore dune field morphology exists from the crest both landward and seaward. Once again, a significant series of sand bars occur across the nearshore region.

Profile data show significant accretion between Jan 2001 and Jun 2003 (Figure 6-3) particularly in the middle and on the northern end of the site at profiles NH17-2 through NH17-4. Significant foredunes had developed on these profiles in front of the primary dune. Volume calculations (Table 6-1) confirm these accretionary trends. Above MHW, significant accretion occurred particularly in the winter of 2001-2002. Only a few instances of negative volume change occurred on the beach face. Figure 6-4 shows the net change between 2001 and 2004. This site has seen tremendous growth on the beach face and in the backshore and primary dune regions. This could be the result of dune rebuilding in the wake of two events, Hurricane Floyd, which had a greater impact on the Eastern Shore than Hurricane Isabel. It also could be the result of the beginnings of a new salient/spit forming off of Floyd's Farm as the present day Vaucluse Spit begins to weld to the shoreline.

The measured data help determine the stability of the site and it's response to storm events (Appendix B). At this site, no changes occurred behind the primary dune. The primary dune increased in width by 17 ft at profile NH17-3 when the distance to the front base of primary dune (E) increased. The width of the backshore (F) decreased during that same time on NH17-3 likely due to the growth of a foredune that appears to be wind-induced. Supporting this is that the elevation of the front of the primary dune (Y) increased 1 ft, 0.5 ft, 1 ft, and 2.5 ft at NH17-1, 17-2, 17-3, and 17-4, respectively. Also, the primary dune crest elevation (X) changed by about +0.5 ft on all four profiles.

Additional information collected at each site included ground photography, sediments, and vegetation characterization. The history of the site at NH17-1 over the course of the monitoring project is shown in Figure 6-5. Photos show a great deal of submerged aquatic vegetation detritus on the beach during the summer. This detritus helps stabilize the beach and allows for dune growth. Little change in the dune itself occurs even after Hurricane Isabel impacted this shore in September 2003. However, an event did occur during the fall/winter of 2004 which affected the shore because the dune face is scarped and the backshore appears to be lower and flatter. Grain size (Appendix C) changed little over the course of the monitoring project. It follows the general characterization of bay beaches with the coarsest sand and gravel at midbeach and the toe and the finer-grained material in the dune and nearshore. Mean grain size at each sample location was very consistent between the September 2001 and July 2004 monitoring period.

Table 6-1. Volume change on the beach face and above MHW.

Time Period	Volume Change (cy)	
	Beach Face^	Above MHW^
Jan 2001-Sep 2001	-27	+114
Sep 2001-Jun 2002	+272	+490
Jun 2002-Dec 2002	-73	+65
Dec 2002-Jun 2003	+69	+167
Jun 2003-Dec 2003	+150	+164
Dec 2003-Jul 2004	-27	+47
Jul 2004-Dec 2004	+102	+42

^Beach Face is defined as between 0 ft MLW and +1.9 ft MLW; MHW is defined as +1.9 ft MLW

6.3 Hurricane Isabel Impacts

Low-level georectified aerial photography indicates the impact of Hurricane Isabel on the NH17 coast (Figure 6-6). Little change occured at the site, but erosion was occurring north of the site at the new development which did not exist in 2002. Incidentally, the bayside vegetation was removed from the upland prior to the hurricane. Storm tide levels are estimated to have been about 4.5 ft MLLW. At profile NH17-1 and 17-2 (Figure 6-7), little change occurred on the beach face or upper backshore, but the foredune did grow as elevated water levels pushed sand inland. Profiles NH17-3 and NH17-4 at the more northern end of the site showed significant accretion across the whole profile from the foredune to MLW. The ground photos before and after the hurricane at profiles NH17-2 and 17-4 showed a wider backshore and no impact to the dune due to the storm (Figure 6-8). In fact, foredune accretion is seen in the December 2003 photos. Once again, the nearshore attached bars control the morphology of this site.

The rate of shoreline change at MHW was calculated before Hurricane Isabel and over the entire monitoring period (Table 6-2). This site is accreting rapidly; the hurricane slowed growth at MHW at profile NH17-1 but increased it at profiles NH17-2 and 3. Overall, the average rate of change for the site was about +1.5 ft/yr. The rate of historic and recent change based on digitized shorelines show that the long-term end point rate (1938-2004) along much of the reach is close to zero (Figure 6-9). In fact, averaged over the whole shoreline (Table 6-3), the average rate of change is -1 ft/yr.

Table 6-2. Average rate of change at MHW in feet per year at each profile at site NH10 before Hurricane Isabel and over the complete period of monitoring.

Profile Number	Average Rate of Change at MHW (ft/yr)	
	Jan 2001-Jun 2003 Pre-Hurricane Isabel	Jan 2001-Dec 2004 Overall
1	+2.2	+0.9
2	+0.5	+1.0
3	+0.5	+3.0
4	+2.2	+1.9
Average	**1.4**	**1.7**

Table 6-3. Historic and recent average rates of shoreline change determined from aerial photography.

Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1938-1949	16.6	14.4
1949-1989	-5.1	4.9
1989-1994	-3.3	6.9
1994-2002	0.9	3.6
2002-June 25, 2003	-10.8	11.8
June 25, 2003-January 14, 2004	-21.9	17.6
January 14, 2004-October 26, 2004	-16.0	8.7
1938-October 26, 2004	**-1.0**	**1.4**

7 Site NH51

7.1 Reach Assessment

This study site is set within a shore reach that extends from Old Plantation Creek to the Kiptopeke State Park and associated old ferry pier and offshore concrete ship breakwaters. A large subreach within this area extends from Elliotts Creek to Picketts Harbor Road (Figure 7-1). At one time, a large dune field appears to have extended between Elliotts Creek and Picketts Harbor (called Picketts Hole in Madison's 1807 map of Bay, Stephenson and McKee, 2000). Presently, the north end of this field has fragmented, and the main dune field extends northward from Picketts Harbor, past Pond Drain (mid-way), to where the shore intersects with a high northwest/southeast trending upland ridge, a distance of about 10,000 feet. The study site for this project extends from just south of Pond Drain southeastward for about 2,000 feet. The site lies entirely within the Department of Conservation and Recreation's (DCR) Natural Area.

Historic erosion along the study site between 1888 and 1942 was about -2.3ft/yr (Byrne and Anderson, 1978). Pond Drain and its intermittent inlet was a feature on 1863 boat sheets. Its shore morphology has not changed significantly. The upland ridge that Pond Drain bisects is a linear feature averaging about 25 feet MLW high and is 10 ft higher than the landward bounding plain. This upland ridge appears to be the northern extension of Butlers Bluff. Its southeastern boundary is the shoreline at Picketts Harbor and the much larger bayside scarp that is also about 25 ft MLW. This scarp runs up the bayside Eastern Shore for some distance and is oriented about north-northeast/south-southwest. This 3-way intersection is also the boundary of the Occohannock Formation. The Butlers Bluff Formation is very sandy strata whose west boundary is the bayside scarp. The dune field of site NH51 goes back to the upland ridge (Hardaway *et al*., 2004).

The whole coast is largely a headland controlled, in part, by underlying geology and extensive offshore bars. These bars are both shore parallel and oblique and appear to control beach processes and transport. The hydrodynamics and littoral processes are complex and are a blend of bay and ocean generated wave climate. Northwest and southwest winds and abundant sand supply favor foredune formation along much of the reach.

In 1938, aerial imagery showed a protruding shore with a headland south of Pond Drain (Figure 7-2-1). The shoreline turned to the east toward the upland ridge north of Picketts Harbor. A series of "foredunes" could be seen within the boundaries of the protuberance. The hump was a shore planform salient that appeared coincident with attached nearshore bars. By 1949, the hump had smoothed out somewhat and elongated along into a more vegetated foredune sequence. The foredunes were distinguished by what appeared to be grasses; whereas, the older ridge had a line of intermittent trees and shrubs. The foredune extended south from Pond Drain about 4,500 ft and north about 1,000 ft.

In 1989, the position of the shoreline at and adjacent to Pond Drain had advanced seaward with an associated recession northward toward Elliotts Creek (Figure 7-2-1). This appeared to a be a cut and fill sequence with erosion of the northern subreach providing material for advancement to south (Hardaway *et al*., 2004). This advance had provided the beach and backshore width for expansion of the linear foredune which is now well established and extends to Picketts Harbor. The recession had destroyed the semi-continuous dune feature that once extended to Old Plantation Creek. The foredunes north of Pond Drain had been reduced to about 500 ft alongshore.

In the 1990s (Figure 7-2-2), shore salients could be seen where offshore bars attached obliquely to the coast and were particularly obvious in the 2002 digitized shoreline. Today, three isolated dunes occur along the northern subreach to Old Plantation Creek (Hardaway *et al*., 2004). The foredune sequence south of Pond Drain is well established, but erosion of the dune face is prevalent several hundred feet south of Pond Drain. Foredunes have increased to the north behind beach salients that are controlled, in part, by the extensive offshore sand bars.
Overall, a "nodal point" (zero crossing point) exists just south of Picketts Harbor Road (Figure 7-2-2). South of that point, erosion occurs until Kiptopeke. North of that point, accretion exists at Pond Drain.

7.2 Field Surveys

Three profiles were established across the DCR property (Figure 7-1). In order to adequately portray this reach, two or three profiles were needed south at Picketts Harbor Road; however, permission could not be obtained from the private land owner. Profile NH51-1 is generally representative of the primary dune field in front of the established secondary features (Figure 7-3). Profile NH51-3 is in the active erosional zone adjacent to Pond Drain where the primary dune narrows to the pioneer tree zone, and NH51-2 is a transitional cross-section. The back base of the primary dune is 55ft and 51ft from the primary dune on NH51-1 and NH51-2, respectively. These profiles represent a more established area of the linear dune feature, and NH51-2 rests comfortably behind a beach salient controlled by an attached, oblique offshore bar. NH51-3 has a narrower but higher primary dune feature. Overall, this study site covers the more erosive end of the Pond Drain subreach.

Little or no measured change has occurred landward of the primary dune crest (Figure 7-3). Initially, between April and September 2001, an increase in beach width between MHW and MLW occurred at NH51-1 and NH51-2. Sea rocket and *Ammophila* had advanced across the widened backshore and helped establish an upper berm feature on those profiles. However, since that time until June 2003, the beach face at NH51-1 and 51-2 has both eroded and accreted, and the backshore was generally erosional. Profile NH51-3 has shown a loss of the lower berm and beach face. These profiles have a steeper dune/beach face probably due to intermittent erosional events. Over the course of the entire monitoring period (Figure 7-4), the dune face and backshore have eroded at NH51-1, but the beach face has accreted. At NH51-2, the overall primary dune crest height is higher, but the lower backshore just above MHW has eroded while the beach face has accreted. Generally, profile NH51-3 has eroded.

These trends are supported by the volume of sand calculations on the beach face and above MHW (Table 7-1). Generally, net losses occurred particularly during Hurricane Isabel. However, the beach rebounded to about the same volumes.

The measured data help determine the stability of the site and it's response to storm events (Appendix B). Little change occurred landward of the primary dune at this site. The distance to the front base of the primary dune (E) from the primary dune crest decreased on profiles NH51-1 and 51-2, while the elevation of the front base of the primary dune (Y) increased indicating erosion of the dune. At NH51-3, E increased while Y decreased. The backshore width (F) was reverse, increasing on profiles NH51-1 and 51-2 but decreasing on NH51-3. The distance from the primary dune crest to the toe of the beach (H), increased on all profiles. The elevation of the toe (T) is generally below MLW at this site probably due to the lack of nearshore bar attachment which affect the position of the toe on the other sites in Northampton County. The interpretation of a secondary dune in the study area is difficult because of the variable ridge and swale topography landward of the primary dune along the shore reach since this was an area of significant accretion over the long-term. The variability of the primary dune height and width alongshore conveys to the secondary dune ridges when the shore advances and the primary dune becomes a secondary dune.

Additional information collected at each site included ground photography, sediments, and vegetation characterization. The history of the site at NH51-2 over the course of the monitoring project is shown in Figure 7-5. Photos show dune colonization of the foredune in 2001 and 2002. However erosion in the winter/spring of 2002-03 eroded the backshore and dune face at NH10-2. Following the hurricane, the November 2003 photo shows the sand stacked up against the dune on which dune grass began to re-grow in the summer of 2004. Grain size (Appendix C) changed little over the course of the monitoring project. It follows the general characterization of bay beaches with the coarsest sand and gravel at midbeach and the toe and the finer-grained material in the dune and nearshore. Little gravel occurs at this site and mean grain size is very consistent across the whole profile over the entire monitoring program, about 1.5 phi.

Table 7-1. Volume change on the beach face and above MHW.

Time Period	Volume Change (cy)	
	Beach Face^	Above MHW^
Mar 2001-Sep 2001	-760	-2,169
Sep 2001-Jun 2002	-298	-426
Jun 2002-Dec 2002	-30	+57
Dec 2002-Jun2 003	+56	-97
Jun 2003-Dec 2003	-1,546	-5,975
Dec 2003-Jul 2004	+1,650	+5,161
Jul 2004-Dec 2004	+447	-250

^Beach Face is defined as between 0 ft MLW and +2.6 ft MLW; MHW is defined as +2.6 ft MLW

7.3 Hurricane Isabel Impacts

Low-level georectified aerial photography indicates the impact of Hurricane Isabel on the NH51 coast (Figure 7-6). The most noticeable change along the shoreline is the change in direction of the drainage. The change in direction from exiting northwest to southwest is the result of increased sand transport to the south shifting it alongshore. The beach itself appears to be wider. The straighter edge of vegetation in January 2004 indicates that scarping of the dune which occurred during the storm. The profile data supports these trends (Figure 7-7). Significant erosion of the dune face occurred, but the beach face, generally between MHW and MLW, accreted. The storm surge at Kiptopeke State Park near this site was 6.5 ft MLLW. The ground photos before and after the hurricane show that the dune scarping occurred before the hurricane (Figure 7-8). In June 2003, the dune at NH51-1 was already scarped. The storm did appear to widen the beach and push sand up against the dune. This sand was beginning to be recolonized by dune vegetation in the summer of 2004. Overall, at MHW, the average rate of change was mostly negative particularly before the hurricane (Table 7-2). After the hurricane, the erosion rate slowed probably, due to the influx of sand from erosion of the dune face and alongshore sand transport.

The long-term rates of change show significant variation along the shoreline (Figure 7-9). The nodal point for change occurs at about station 800 on the shore change baseline. North of that point, accretion had occurred historically creating large positive rates of shoreline change (Table 7-3). The positive rate of change had generally been decreasing, and the reach eventually became erosional. The rates of change due to the storm were large, but well within the historical range of change for this site. In fact, during the recovery period from Hurricane Isabel accretion of the shore occurred. Overall end point change is positive, but that is not considered indicative of the more recent trends as indicated by the profile data.

Table 7-2. Average rate of change at MHW in feet per year at each profile at site NH51 before Hurricane Isabel and over the complete period of monitoring.

Profile Number	Average Rate of Change at MHW (ft/yr)	
	Mar 2001-Jun 2003 Pre-Hurricane Isabel	Mar 2001-Dec 2004 Overall
1	+0.2	+0.3
2	+0.5	-0.7
3	-4.8	-2.4
Average	**-1.4**	**-0.9**

Table 7-3. Historic and recent average rates of shoreline change determined from aerial photography.

Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1938-1949	6.0	3.1
1949-1989	3.0	2.2
1989-1994	-2.8	6.9
1994-2002	0.8	3.3
2002-June 25, 2003	-18.9	8.2
June 25, 2003-January 14, 2004	-14.4	16.6
January 14, 2004-October 26, 2004	6.7	19.5
1938-October 26, 2004	2.3	1.8

8 Site NL42

8.1 Reach Assessment

Site NL42 is located just south of Smith Point along the Chesapeake Bay shoreline (Figure 8-1). The study site is set within a larger shore reach that extends from the Little Wicomico River entrance and associated stone jetties in the north to Taskmakers Creek in the south. A smaller subreach of the northern half extends from Smith Point down to Gaskins Pond, a distance of about 10,500 ft. The dune field within the boundaries of site NL42 is about 3,700 ft in length. More specific information on the overall reach can be found in Hardaway *et al.* (2001). This is an Open Bay site with fetch exposure to the northeast (Smith Island), east (Tangier Island) and southeast of about 12nm, 11nm, and 25nm, respectively.

Smith Point area is a large spit that has formed over the centuries as the result of sediment transport down Northumberland's shore on the Potomac River and up it's shore along the Bay. The Little Wicomico River inlet was several thousand feet north and west of its present position until the 1930s when jetties were built to hold the new inlet position at the apex of Smith Point. Historic erosion along the NL42 study site is about -2.6 ft/yr (Byrne and Anderson, 1978), but that doesn't tell the tale of this highly dynamic estuarine coast.

Aerial imagery on March 29, 1937 (Figure 8-2-1) shows the Smith Point Jetties during construction. The channel was dredged and material placed upriver, closing off the old inlet. The south shoreline (NL42) was a long irregularly-shaped salient with two protrusions along the shore, a large one to the south and a smaller one to north which together formed one feature. A series of sparsely vegetated "foredunes" can be seen across a broad sandy spit with a reciprocal morphologic planform to the shoreline. The spit is over 1,000 ft wide before abutting the Little Wicomico River where that shore is characterized with tidal marsh fringes. The shoreline against the south side of the Smith Point jetties extended over 300 ft seaward relative to the shore attachment on the north side of the Smith Point jetties. Beyond the large sandy salient shore of NL42, the coast southward consisted of a continuous beach and backshore system until Taskmakers Creek with only two small tidal creeks at Gaskins Pond and Owens Pond (Hardaway *et al.*, 2001). Two intermittent drains from two unnamed ponds just north of Gaskins also were present. A large partially-vegetated, hooked spit protruded southward across Taskmakers Creek. These beaches were narrow creek mouth barriers especially at Owens Pond.

By 1953 and through 1961, the large protruding salient resided further south, and the shoreline toward the jetties had receded and become more linear (Figure 8-2-1). The shoreline against the jetties had advanced farther seaward on both sides with the south side maintaining the larger advance. The protruding salient shore planform appears to mimic offshore sand bars. The coast to the south was still mostly continuous until Taskmakers Creek, but Owens Pond had been jettied (wood), and the creek mouth barrier had gotten very narrow allowing numerous washovers and was migrating westward. The hooked spit across Taskmaker Creek was gone, rotated in part westward and closing off the mouth of the Northeast Branch, converting it into an intermittently open saltwater pond (Hardaway *et al.*, 2001).

In 1969, there were two distinct protruding salients (the south one being larger) along NL42 with the curvilinear embayment formed between the two receding and intersecting the earlier foredune (Figure 8-2-2). Vegetated foredunes appear to have formed following the coast along the backshore terrace of each salient feature and along the sand fillet against the south jetty. Groins appear along the coast to the south as evidenced by small shore protuberances with a slight northward transport expression.

Oblique aerial photography in 1978 shows that an access road had been built down the middle of the NL42 spit. Two protuberances, a large one on the south and smaller one on the north, had become well established. In 1994, the salients were still in about the same positions. The shoreline to the south had become bulkheaded and groined, and the creek mouth barrier across Owens Pond was gone. Sand had migrated and filled small bays on the creek's west side to form small pocket beaches. Sand bars sit in what was once the Owens Pond (Hardaway *et al.*, 2001). In 2002, the largest salient had groins up to it, and the smaller salient had developed into two (Figure 8-2-2). The shore structures were constructed in response to the erosion occurring on the southern end of the site.

8.2 Field Surveys

Four profiles were established along NL42 (Figure 8-1) and represent different morphologic areas of the spit. Profile NL42-1 is located near the south jetty, an historic area of shore flux. It presently has an erosive primary dune face with little backshore region. The distance to Profile NL42-2 is long due to unavailable property owners. Profile NL42-2 crosses a shore salient while Profile NL42-3 is in the adjacent shallow embayment. Profile NL42-4 is within the southern groin field, a direct man-influenced shore. These subreaches are morphologically different but constitute the dune field that was generally categorized as a linear dune field.

NL42-1 and NL42-4 have been profiled since April 2001 (Figure 8-3). Profiles NL42-2 and NL42-3 were not established until September 2001. The shore at NL42-1 was relatively stable except for an episode of accretion in 2002 and subsequent erosion in 2003 before the hurricane. NL42-2 generally was erosional between 2001 and 2003. NL42-3 had periods of erosion and accretion. Shore change was significant on NL42-4 across the backshore, berm, and toe section of the profile demonstrating some seasonal flux within the groin field. Net volume change has been mostly erosional for both the beach face and the backshore/dune areas except for the period encompassing Hurricane Isabel (Table 8-1). A great deal of sand was eroded from the lower beach and beach face and overwashed into the dune area. Overall net change has been significantly erosional through the entire period of dune monitoring (Figure 8-4).

The measured data help determine the stability of the site and it's response to storm events (Appendix B). The primary dune was lost at profiles NL42-1 and 42-4 due to the storm and the distance from the primary dune crest to the front of the primary dune (E) decreased at profiles NL42-2 and 42-3. The elevation of the toe of the beach (T) at this site is generally well below MLW.

Additional information collected at each site included ground photography, sediments, and vegetation characterization. The history of profiles NL42-1 and NL42-2 over the course of the monitoring project is shown in Figures 8-5 and 8-6. Photos show that NL42-1 is generally erosional since the dune vegetation extends only to the dune crest and trees occur in the backshore/subaerial beach. Vegetation is sparse at NL42-2; however, it tends to expand during the summer. During the storm, the sand went completely over the dune vegetation at the most seaward side of the site. Grain size (Appendix C) changed little over the course of the monitoring project. It follows the general characterization of bay beaches with the coarsest sand and gravel at midbeach and the toe and the finer-grained material in the dune. The nearshore has over 50% gravel.

Table 8-1. Volume change on the beach face and above MHW.

Time Period	Volume Change (cy)	
	Beach Face^	Above MHW^
Sep 2001-Mar 2002	-216	-288
Mar 2002-Oct 2002	+63	-125
Oct 2002-Jun 2003	-190	-160
Jun 2003-Oct 2003	-333	+750
Oct 2003-Jul 2004	-269	-309
Jul 2004-Dec 2004	-16	-260

^Beach Face is defined as between 0 ft MLW and +1.2 ft MLW; MHW is defined as +1.2 ft MLW

8.3 Hurricane Isabel Impacts

The dune site was partially sheltered from northerly wind-driven waves, but as Hurricane Isabel passed westward, the winds shifted to the east, then southeast, and finally south which impacted the entire dune field. The estimated storm tide level was about 3.5 ft MLLW; this does not include the wave action which extended the reach of the surge and pushed sand up higher on the beach. The low level georectified aerial photos before and after the hurricane (Figure 8-7) indicate significant shore recession along most of the NL42 shoreline. Only one section of shoreline was stable during the hurricane and that was between stations1000-1400. Salients at stations 1500 and 1800 were significantly eroded. The southern end of the reach was particularly affected.

Survey data along the site show that Isabel over-topped the primary dune and moved the beach face landward. The position of the primary dune shifted landward and upward on the profiles along the dune field coast where it has remained through the recovery period (Figure 8-8). NL42-2 indicates a seaward shift of the primary dune crest; however, that is a function of where the primary dune crest was originally defined. In the field it was difficult to discern a half foot rise over 50 ft. Likely the position of the primary dune crest was actually closer to the water than indicated. Landward shifts where about 50 ft, 35 ft, 10 ft, and 40 ft for NL42-1, NL42-2, NL42-3, and NL42-4, respectively. MHW shifted landward as well. Shore change on NL42-4 is interesting in that all the updrift groins were detached from the shoreline during the storm, and the large pre-storm sand fillet against the adjacent groins were eroded and carried landward (Figure 8-9). Before the hurricane, the average rate of shoreline change at MHW was -2.3 ft/yr. However, overall, the hurricane increased the rate of shoreline change to -4.5 ft/yr with profile NH42-4 being the hardest hit (Table 8-2).

Shore change was highly variable along this reach between 1937 and 2003 (Figure 8-10), but it was generally erosional. The rate of change due to the hurricane was very large – probably exaggerated by the short time frame. Overall the end point change averaged over the entire shore reach was just about -1 ft/yr (Table 8-3).

Table 8-2. Average rate of change at MHW in feet per year at each profile at site NL42 before Hurricane Isabel and over the complete period of monitoring.

Profile Number	Average Rate of Change at MHW (ft/yr)	
	Sep 2001-Jun 2003 Pre-Hurricane Isabel	Sep 2001-Dec 2004 Overall
1	-0.1	-1.1
2	**-4.5**	**-5.3**
3	**-1.0**	**-2.3**
4	**-3.5**	**-7.8**
Average	**-2.3**	**-4.1**

Table 8-3. Historic and recent average rates of shoreline change determined from aerial photography.

Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-1953	2.3	4.1
1953-1961	-0.4	5.6
1961-1969	-7.4	6.2
1969-1994	0.7	3.0
1994-2002	-0.1	5.7
2002-August 15,2003	-14.9	12.4
August 15, 2003-September 25, 2003	-229.6	162.3
1937-September 25, 2003	**-0.7**	**1.5**

9 Site NL58

9.1 Reach Assessment

Sites NL58 and NL59 are located on either side of Hack Creek on the Potomac River in Northumberland County. Site NL58 begins at the entrance channel to Hack Creek and extends downriver approximately 950 feet. NL59 extends from Hack Creek upriver approximately 1,680 feet. Both sites are considered Open Bay due to their long fetch exposures to the Northeast and East of over 14nm and 15nm, respectively.

Sites NL58 and NL59 are a subreach of a larger shore reach that is loosely defined by Smith Point downriver and Hull Creek upriver; a shoreline length of about 42,000 ft. This shore is primarily upland or fastland coast that is a fairly straight, slightly convex headland intermittently interrupted by tidal inlets. The subreach can be defined by Condit Pond to the west and Flag Pond to the east. Hack Creek is currently a jettied inlet that can be considered a subreach boundary which then places each site into separate, but similar, coastal compartments.

The historic erosion rate of this reach is about -4.9 ft/yr (Byrne and Anderson, 1978). The upland coast is about 10 to 15 ft above MLW with a historic annual eroded sediment load of 1.9 cy/ft/yr. Presently, the shoreline along NL58 consists of a relatively wide sandy beach and dune system that is controlled by a groin field. These groins are of the 60 ft x 60 ft design and extend from Hack Creek downriver past the site for another 1,000 ft**.**

Site NL58 is a creek mouth barrier like many other dune sites along this reach of shoreline (Figure 9-2-1). Eroding fastland provides copious sand for littoral transport both along and offshore. The many offshore bars and creek mouth shoals are evidence of this. Alongshore moving sands get trapped within a tidal creek's shoals as well as move landward across low drainages often covering marsh complexes associated with the tidal creek. Hack Creek is such a system. Generally, the net movement of littoral sands is downriver with a dominant onshore/offshore component and frequent reversals.

The nearshore region is relatively broad and contains a series of extensive offshore sand bars. These bars are generally shore parallel and run alongshore well beyond the boundaries of the site. Several distinct bars have continuously existed offshore of Hack Creek which indicates the relative abundance of sandy material. Hack Creek's ebb shoal interrupts the nearest bar feature and acts to control littoral processes in the immediate area.

Historical and recent aerial imagery show the general evolution of the subject coast (Figure 9-2-1). A relatively wide beach existed in 1937 along both sites, and Hack Creek was still a natural feature with extensive shoals, both ebb and flood. The extent of site NL58 can been seen in the imagery, and the dune field extended a long way downriver. The coast was dominated by farmland, marshland, and woodland, and featured no development. By 1953, 10 to 12 cottages had been built just downriver of Vir-Mar Landing. Although the houses cannot be seen, a road had been built into the area south of NL58 so it's likely development existed. However, Hack Creek and its adjacent shores were still relatively natural with no groins installed to date. The creek mouth barrier appeared relatively stable.

In 1969, no groins had yet been built across NL58, and Hack Creek had not been jettied (Figure 9-2-1). However, groins had been installed at the first cottage downriver of Hack Creek in response to development along the uplands toward Vir-Mar Landing. The downriver extent of the dune field had diminished. An erosional dune scarp can be seen at the site along with foredune formation near Hack Creek. The dune field appeared to have secondary dune features as evidenced by numerous pine and live oak trees.

In 1987, approximately 12 groins were added across NL58, and Hack Creek had been jettied on either side with wood structures (photo not shown). An ebb shoal jet was created by the jetties which may have a localized effect on the impinging wave climate. By 1994, the seaward edge of the site had stabilized and resembled the general dune morphology in 2002 (Figure 9-2-2). The groins control littoral processes making the site generally stable.

9.2 Field Surveys

At this site, dune morphology transitions alongshore and across shore. Three zones were identified, and a representative profile was established in each (Figure 9-1). Profile NL58-1 represents the low primary dune section nearest Hack Creek. NL58-2 is "mid-site" and features a primary and secondary dune feature. NL58-3 is positioned on the downriver one-third of the site. This section of shore appeared to have a primary dune with a foredune feature. However, upon analysis, the profile resembles one of a secondary dune due to vegetation. This may be the result of the area being subject to perpetual shear causing difficulty in forming a stable primary dune feature.

Profile data taken between March 2001 and June 2003 show that the site becomes less stable downriver of Hack Creek (Figure 9-3). NL58-1 was very stable during that time frame; NL58-2 had variable movement in the beach face and backshore and even slight dune crest accretion; and NL58-3 was erosional. Net change between 2001 and 2004 was generally erosional at NL58-2 and NL58-3; however, NL58-1 remained stable and even had some primary dune crest elevation growth (Figure 9-4). Volume calculations (Table 9-1) show that the site was generally erosional on the beach face and above MHW except during the Hurricane Isabel recovery period when eroded material was redeposited on the beach. Much of this reach's sand budget is within the nearshore region out to 500 feet or more. Figure 9-3 shows one or two bar sets. These bars may feed the beach and nearshore during calm periods as well as act as wave buffers and sand sinks during storm events.

The measured data help determine the stability of the site and it's response to storm events (Appendix B). The distance from the primary dune crest to the toe of the beach (H) decreased at profiles NL58-1 and 58-2, but increased at profile NL58-3. The elevation of the toe of the beach (T) is generally below MLW because the nearshore bars are detached from the beach. The primary dune crest elevation (X) increased at profile NL58-1 by over 1 ft, remained stable at NL58-2, but decreased slightly at NL58-3.

Additional information collected at each site included ground photography, sediments, and vegetation characterization. The history of the site at NL58-3 over the course of the monitoring project is shown in Figure 9-5. The first photo in March 2001 shows that the dune at this site was recovering from an erosional event since the dune had been scarped at some point, but now the dune vegetation is expanding into the foredune area. Between 2001 and 2003 when the hurricane occurred, the beach and dune was fairly stable, but the storm significantly scarped the dune. The slope of the dune face scarp is decreasing, but vegetation has not taken hold at this site. Grain size (Appendix C) changed little over the course of the monitoring project. It follows the general characterization of bay beaches with the coarsest sand and gravel at midbeach and the toe and the finer-grained material in the dune and nearshore. Little change in mean grain size at each sample site occurred during the monitoring period.

Table 9-1. Volume change on the beach face and above MHW.

Time Period	Volume Change (cy)	
	Beach Face^	Above MHW^
Mar 2001-Aug 2001	-124	-501
Aug 2001-Mar 2002	+9	-44
Mar 2002-Dec 2002	-15	-45
Dec 2002-Jun 2003	-11	+34
Jun 2003-Oct 2003	-115	-677
Oct 2003-Jul 2004	+108	+540
Jul 2004-Dec 2004	-8	-59

9.3 Hurricane Isabel Impacts

Hurricane Isabel impacts were generated by a storm surge of at least 4 ft MLLW, as measured at Lewisetta, and wind-driven waves originated from the north and east. Wave height estimates onshore from measured wrack lines were 3 to 4 ft. Low-level aerial photos show that the entire shoreline receded significantly due to Hurricane Isabel (Figure 9-6). Dune scarping occurred along the length of the sites as evidenced by the relatively straight line of vegetation along the backshore. At profiles NL58-1, the beach face was relatively stable, but the backshore and dune face eroded due to the elevated water levels (Figure 9-7). At NL58-2, the beach, backshore and dune eroded. The little increase in dune height that occurred between 2001 and 2003 was eroded. The dune at NL58-3 was not overtopped, but the dune face and beach were significantly eroded. A large amount of the change that occurred during the storm was recouped in the recovery period. Before the hurricane, the average rate of change at MHW was relatively small over the entire site at only +0.3 ft/yr (Table 9-2). Over the entire monitoring period, including the hurricane, the site became erosional site at -0.6 ft/yr. Figure 9-8 shows the photos before and after the hurricane at NL58-2. The hurricane scarped the dune and then pushed sand up against the dune. The backshore and beach face appeared to be lower in the summer of 2004.

The rates of shoreline change along this reach of shore was relatively small historically (Figure 9-9). In fact, overall, the rates of change were slowing as shore structures stabilized the shoreline. The hurricane generated rates of change that were extremely large, but the overall net change between 1937 and 2003 was only -1 ft/yr (Table 9-3).

Table 9-2. Average rate of change at MHW in feet per year at each profile at site NL58 before Hurricane Isabel and over the complete period of monitoring.

Profile Number	Average Rate of Change at MHW (ft/yr)	
	Mar 2001-Jun 2003 Pre-Hurricane Isabel	Mar 2001-Dec 2004 Overall
1	0.6	-0.3
2	+2.0	-0.6
3	-1.8	-0.8
Average	**0.3**	**-0.6**

Table 9-3. Historic and recent average rates of shoreline change determined from aerial photography.

Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-1953	-1.9	0.8
1953-1969	-1.6	1.0
1969-1994	0.3	0.7
1994-2002	0.2	1.6
2002-August 15,2003	-4.4	9.2
August 15, 2003-September 25, 2003	-192.5	98.1
1937-September 25, 2003	**-1.0**	**0.2**

10 Site NL59

10.1 Reach Assessment

Site NL59 is the updrift, upriver component of the dune field adjacent to Hack Creek (Figure 10-1). It shares a similar site setting and history as NL58. Portions of this dune field occur as a creek mouth barrier across Black Pond but much of it abuts the adjacent fastland. The present status is a dune field controlled in large part by the existing groin field. NL59 tends to widen downriver toward Black Pond and Hack Creek and feathers out upriver toward Condit Pond.

In 1937, the reach where NL59 presently exists had a wide beach, and occurred on a washover into Black Pond and was adjacent to Hack Creek (Figure 9-2-1). No development existed along this stretch of coast. In 1953, residential development existed upriver of the site, but no groins existed, and by 1969, a dirt road was built across the Black Pond washover to a house perched on a high back dune feature (Figure 9-2-1). This probably effectively dammed the pond. Given the historic erosion rate, it can be conjectured that the upland coast existed as a vertically exposed and actively eroding fastland bank.

Oblique aerial photos taken in 1976 show that the shoreline between Hack Creek and Condit Pond had not become more developed, but numerous groins (approximately 34) had been installed along the entire reach, possibly in preparation for future development. Between 1960 and 1976, these groins had accreted enough sand to create a wide beach and primary dune field. The upper part of the previously eroding fastland can be seen in the imagery. The accreted beach and dune field extended from Hack Creek to within about 1,000 ft of Condit Pond. Hack Creek inlet had a single groin/jetty built on the upstream shore.

In 1994, development had been minimal, but the groins were still maintaining the beach and dune field (Figure 9-2-2). The dune field was still fairly low and narrow with no apparent secondary dune development. By 1997 (photo not shown), a wider more robust dune had developed, and more cottages can be seen along the upland. The beach zone was fairly straight along the dune field. In 2002, the beach was intermittently wide and narrow, and the dune was correspondingly erosional along the dune face (Figure 9-2-2). Unlike the nearshore bar fields at NL42, MA3 and NH10, there is a shore parallel trough that separates the first bar from the beach.

10.2 Field Surveys

Three profiles were established to represent different morphologic subunits of the dune field (Figure 10-1). NL59-1 represents the primary dune only section, NL59-2 represents a short transitional section, and NL59-3 reflects the primary and secondary dune relationship.

Profile NL59-1 had variable change between 2001 and 2003, but it was generally erosional (Figure 10-2). Profile NL59-2 was generally stable except for one episode of erosion between March and August 2001. NL59-3 was stable except for slight erosion of its upper backshore/dune face. The offshore bars can be seen in the profiles. At this site, the beach toe is well below MLW (Figure 10-2). Overall net change at the site between 2001 and 2004 had been erosional including the loss of the primary dune at profile NL59-3 (Figure 10-3).

The measured data help determine the stability of the site and it's response to storm events (Appendix B). Profile NL59-1 had an increase to the base of the primary dune (E) during the course of the monitoring which corresponded with an increase in the elevation of the base of the primary dune (Y). The dune was scarped during the storm, but it rebounded quickly. Conversely, at NL59-2, the distance to the base of the primary dune (E) was decreasing and the backshore width (F) increasing indicating landward movement of the dune face. Primary dune crest elevations (X) were fairly stable until the hurricane wiped out the dune at NL59-3.

Additional information collected at each site included ground photography, sediments, and vegetation characterization. The history of the site at NL59-3 over the course of the monitoring project is shown in Figure 10-4. Photos show that slight recession of the dune was occurring as there was no seaward extension of dune grasses and the vegetation ends on the dune face. The hurricane significantly widened and flattened the beach, but by July 2004, the backshore had steepened and grass was beginning to grow on it. Grain size (Appendix C) changed little over the course of the monitoring project. It follows the general characterization of bay beaches with the coarsest sand and gravel at midbeach and the toe and the finer-grained material in the dune. The nearshore had significant amounts of gravel in the 2001 sample which is more than is in the NL58 samples.

Table 10-1. Volume change on the beach face and above MHW.

Time Period	Volume Change (cy)	
	Beach Face^	Above MHW^
Mar 2001-Aug 2001	-18	-170
Aug 2001-Mar 2002	+6	+12
Mar 2002-Dec 2002	-6	-54
Dec 2002-Jun 2003	-11	+19
Jun 2003-Oct 2003	-102	-497
Oct 2003-Jul 2004	+100	+348
Jul 2004-Dec 2004	-18	-31

^Beach Face is defined as between 0 ft MLW and +1.2 ft MLW; MHW is defined as +1.2 ft MLW

10.3 Hurricane Isabel Impacts

The low level photos of the Hack Creek West shoreline (Figure 10-5) show general landward movement of the shoreline due to the storm. Survey data confirms the loss of the seaward half of the primary dune face at NL59-1 and NL59-2 and the loss of the entire primary dune at NL59-3 due to Isabel (Figure 10-6). Much of this sand shifted to the beach and backshore. The following recovery period had been slow to develop a pre-Isabel profile on any transect. The pre, post- and recovery is seen in the ground imagery (Figure 10-7). The dune was scarped significantly during the storm but the sand was accumulating at the base of the dune by July 2004. Overall, the shoreline at MHW was stable both before the hurricane and over the entire period of monitoring (Table 10-2). It would appear that the hurricane did not impact the rate of shoreline change at MHW. However, the shoreline farther east than profile NL59-3, which is at about station 1300 on the baseline, has been eroding since 1937

(Figure 10-8). The groins somewhat stabilized the shore between 1994 and 2002, but by 2003 erosion was occurring along much of the shore particularly after the hurricane. The shoreline appears to be less erosional along the shoreline farther west, but overall, net change had been erosional along this reach (Table 10-3).

Table 10-2. Average rate of change at MHW in feet per year at each profile at site NL59 before Hurricane Isabel and over the complete period of monitoring.

Profile Number	Average Rate of Change at MHW (ft/yr)	
	Mar 2001-Jun 2003 Pre-Hurricane Isabel	Mar 2001-Dec 2004 Overall
1	0.3	0.3
2	0.2	-0.1
3	-0.7	-0.4
Average	**-0.1**	**-0.1**

Table 10-3. Historic and recent average rates of shoreline change determined from aerial photography.

Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-1953	0.5	0.6
1953-1969	-3.3	0.6
1969-1994	1.9	0.3
1994-2002	-0.9	1.0
2002-August 15,2003	-5.6	7.3
August 15, 2003-September 25, 2003	-171.5	78.2
1937-September 25, 2003	**-0.4**	**0.3**

11 Site VB4

11.1 Reach Assessment

Site VB4 is located within the larger shore reach defined by Cape Henry to the east and Lynnhaven Inlet to the west (Figure 11-1). The site typifies the dune-laden coast of First Landing State Park. The site is classified as a natural Open Bay dune field that is partially exposed to oceanic conditions including sea swell and northeast storm waves. Adjacent properties are Fort Story to the east and residential private properties to the west. Site VB4 is the natural reach of shoreline left between two developed coasts.

In 1937, the larger reach from Cape Henry to Lynnhaven Inlet was not developed (Figure 11-2-1). Several cross roads led to the Bay. Only two housing units can be seen, and one is at the present location of the State Park Visitor Center. The housing structures at this time were protected by what appears to be a vertical bulkhead about 200 ft long in the backshore area. The housing complex was built seaward of the primary dune or on it. The adjacent primary dunes had receded landward on the west side and may have advanced or built out on the east side. The bulkhead appears to have acted like a littoral block in this fashion indicating a movement of beach sands to the west.

Between 1960 and 1962, the shoreline had advanced across the study site by about 150 ft (Figure 11-2-1). In 1962, waves of sand can be seen moving alongshore with associated attached nearshore bars. Beach cottage development had increased significantly to the west and foredune development can be seen migrating from east to west in front of the bulkheaded area. By 1970, primary and secondary dune development can be seen across the study site and adjacent shores as the shoreline in this area continued to advance seaward (Figure 11-2-2). By 1976, the beach zone had accreted another 100 ft beyond the 1962 position as the dune system continued to advance.

Accretion continued along the site in the 1980s and 1990s (Figure 11-2-3). In 2002, a series of irregular and hummocky "secondary" dune ridges can be seen behind the primary dune (Figure 11-2-4). The cause of this shoreline movement is not clear but may be related to the ongoing beach nourishment at the City's Resort Strip on the ocean coast. The city nourishes that beach annually with between 150,000 cy and 300,000 cy of beach fill that is trucked in or by-passed from Rudee Inlet. Over time, the littoral system may have moved the material northward around Cape Henry and onto the Bay beaches.

11.2 Field Surveys

Three beach and dune profiles were established along the First Landing State Park coast (Figure 11-1). These profiles were situated to capture the area in front of the old bulkhead and housing complex (VB4-2), now the park offices, and the adjacent "updrift" and "downdrift" coasts, profiles VB4-3 and VB4-1, respectively. All three profiles were generally accretionary between March 2001 and June 2003 (Figure 11-3). In particular, VB4-3 had an significant increase in primary dune crest elevation. The nearshore bars are close to shore on all three profiles and can be seen migrating onto the beach resulting in large movement in the beach face and lower backshore (Table 11-1). Large amounts of sand moved during the hurricane, but it was returned during the recovery period. Over the entire monitoring period (Figure 11-4), VB4-1 and VB4-2 made gains in the upper backshore and primary dune face. VB4-3 had significant accretion in the primary dune crest elevation and upper backshore.

The measured data help determine the stability of the site and it's response to storm events (Appendix B). Prior to Hurricane Isabel, the primary dune crest elevation (X) tended to decrease in elevation toward the east. This could be happenstance based on the selection of profile locations or indicate that the easterly section, the updrift, is a newer feature as the shoreline advances at a slightly faster rate. Significant accretion across the entire primary dune raised the crest elevation (X) and widened the dune (E) at profile VB4-3. The elevation of the back of the primary dune (W) also increased after the storm. Secondary dune crest heights (V) were 3 ft and 5 ft higher at VB4-2 than at VB4-1 and 4-3, respectively. The position and elevation of the toe of the beach (H and T) varied probably due to the location of the nearshore bars.

Additional information collected at each site included ground photography, sediments, and vegetation characterization. The history of the site at VB4-1 over the course of the monitoring project is shown in Figure 11-5. Photos show the process of bar movement onshore as the berm builds up and is deposited against the base of the dune after the hurricane. Vegetation is expanding onto the new dune face which will help stabilize it. Grain size (Appendix C) changed little over the course of the monitoring project. It follows the general characterization of bay beaches with the coarsest sand and gravel at midbeach and the toe and the finer-grained material in the dune. Mean grain size was consistent at each sample location over the course of the monitoring program except at the toe which got finer and the nearshore which got coarser.

Table 11-1. Volume change on the beach face and above MHW.

Time Period	Volume Change (cy)	
	Beach Face^	Above MHW^
Mar 2001-Sep 2001	-619	+303
Sep 2001-Jun 2002	+375	+375
Jun 2002-Dec 2002	+662	-81
Dec 2002-Apr 2003	-38	+1,493
Apr 2003-Nov 2003	-4,033	-7,912
Nov 2003-Jul 2004	+3,474	+7,794
Jul 2004-Dec 2004	-437	-385

^Beach Face is defined as between 0 ft MLW and +2.8 ft MLW; MHW is defined as +2.8 ft MLW

11.3 Hurricane Isabel Impacts

Low-level recent aerial photos show the movement of the shoreline due to the hurricane (Figure 11-6). The nearshore attached bars control the movement of sand along the shoreline. In June 2003, a large bulge of sand on the right side of the study area was a nearshore bar in the process of attaching. During the storm, that sand moved alongshore mitigating the impact of the storm at profile VB4-3. By October 2004, another bar is in the process of attaching in the same region. Figure 11-7 shows the earliest profile taken at the site as well as the pre- and post-Hurricane Isabel and 2004 recovery data. The hurricane eroded the beach face at VB4-1 and 4-2, but sand was deposited in the backshore. At VB4-3, sand accreted across most of the profile due the storm. The pre, post, and recovery photos show that little change occurred to the dune at VB4-3 (Figure 11-8). Table 11-2 shows the average rate of change at MHW. Prior to the storm, the beach was accretionary, but due to the storm and the period following it, the overall trend of the beach is considered erosional. However, that is only the beach face. The backshore and dune accreted significantly, particularly at profile VB4-3 as shown in Figure 11-4. In fact, the long-term trend along the entire dune site is accretionary at 4.9 ft/yr change between 1937 and 2004 (Table 11-3). The hurricane had widely varying results on this overall stretch of shoreline (Figure 11-9). Some areas had positive rates of change while others had negative. In general, the rates were within the overall range of historic shoreline change.

Table 11-2. Average rate of change at MHW in feet per year at each profile at site VB4 before Hurricane Isabel and over the complete period of monitoring.

Profile Number	Average Rate of Change at MHW (ft/yr)	
	Mar 2001- Apr 2003 Pre-Hurricane Isabel	Mar 2001-Dec 2004 Overall
1	+4.6	-4.6
2	+0.8	-5.5
3	+1.5	-0.9
Average	**2.3**	**-3.7**

Table 11-3. Historic and recent average rates of shoreline change determined from aerial photography.

Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-1960	3.8	1.6
1960-1970	9.8	3.6
1970-1976	-2.7	4.5
1976-1980	8.6	4.2
1980-1985	13.3	14.2
1985-1994	8.2	3.3
1994-2002	-1.2	2.9
2002-June 25, 2003	30.2	34.5
June 25, 2003-September 25, 2003	-67.4	80.7
September 25, 2003-October 26, 2004	-18.6	15.5
1937-October 26, 2004	**4.9**	**1.3**

12 Biology Results

Vegetation sampling was conducted on twenty-five transects between the nine monitoring sites to characterize the plant communities of each site. The data is tabulated in Appendix D. Periodic monitoring of these relatively stable dunes and beaches was not considered necessary due to consistent stability of the plant community structure generally characteristic of dune and beach environments. Results show that foredunes were generally non-vegetated, but sparse communities of American beach grass (*Ammophila breviligulata*), sea rocket (*Cakile edentula*), running beach grass (*Panicum amarum*), saltmeadow hay (*Spartina patens*), and seaside spurge (*Euphorbia poligonifolia*)were enumerated. Crests were also usually dominated by the “no cover” category. The tall but clumped growth patterns of plants commonly found on primary dune crests, especially American beach grass, give the appearance of overall dense growth; however, close observation and analysis shows patchy and/ or sparse stem distributions. Where present, American beach grass averaged approximately 21 percent cover and generally was the dominant plant species. Switch grass (*Panicum virgatum*), seaside goldenrod (*Solidago sempervirens*), Japanese sedge (*Carex kobomugi*), seabeach sandwort (*Arenaria lanuginosa*), and saltmeadow hay also had areas of local dominance on dune crests.

The trough feature was not present at stations NL-42, NL-58, or NH-10. Where a trough could be defined plant density was also more sparse than it appeared and the “no cover” category again dominated. Running dune grass, saltmeadow hay, switch grass (*Panicum virgatum*), aster (*Aster sp.*), American beach grass, Japanese sedge, and bluestem (*Schizachyrium littorale*) showed local dominance.

Stations NL-42, NL-59, and NH-17 do not have secondary dunes. The herbaceous layer for those sites containing secondary dunes was again dominated by “no cover”, but contained healthy communities of American beach grass, bluestem, seaside goldenrod, saltmeadow hay, running dune grass, Japanese sedge, trumpet vine (*Campsis radicans*), dandelions (*Taraxacum officinale*), and greenbrier (*Smilax sp.*). The shrub layer was dominated by loblolly pines (*Pinus taeda*), various oaks (*Quercus sp.*), wax myrtle (*Myrica cerifera*), holly (*Ilex opaca*), and black cherry (*Prunus serotina*). LN-39 and NH-51 also had large numbers of persimmon trees (*Diospyros virginiana*) growing upon the secondary dunes. Trees generally were absent, but transects NL-58, LN-39, and NH 51 had large loblolly pines. The secondary dune at site MA-3 contains one large black cherry tree.

Post-Isabel vegetation analysis was not possible due to the geologic alteration that occurred at each monitoring site. Intensive pre-hurricane and post-hurricane sampling would have been necessary to determine changes and recovery rates of above-ground and below-ground biomass. Accurate assessments of vegetation biomass was beyond the scope of this program.

13 Ground Water Results

Sediments within the dune region at NH17 were dominated by sand sized particles which typically comprised 80-100 percent of the sediment mass. Finer sediments, predominantly clay size fractions that represented approximately 20 percent of the sediments mass, were observed interdispersed throughout the core below the one-meter depth. Most notably was a 55 cm interval that occurred between 1.8 and 2.3 meters below the dunes crest. While there were no observable peat or relatively intact organic matter observed in the core, staining indicative of organic matter was observed within portions of the core. Sediments within the immediate uplands region were dominated by sand sized particles, however, elevated clay levels at depth were noted and could denote a localized clay layer or lens. Water transmission properties of sediments within the dune system (back dune, crest and fore dune) were relatively high and representative of clean sand. The geometric mean of hydraulic conductivity within this region was 8.02 $m \cdot day^{-1}$ with individual well mean values ranging from 2.92 to 20.99 $m \cdot day^{-1}$. A greatly reduced hydraulic conductivity was measured within the clay lens influenced upland region; the measured value was less than 0.01 $m \cdot day^{-1}$.

Dune feature and representative mean water table elevations for NH17 are provided in Figure 13-1. Water table depths were on the order of 3.0 m below the lands surface in the immediate uplands, 2.7 m at the dune crest, and decreasing to 0.05 m near the front of the dune and beach region. Tidal fluctuations influenced water table elevations up to 28 cm in the fore dune-beach region, 6 cm within the dune crest and < 4 cm in the immediate upland region. Fluctuations in water table elevations resulted in complex, bi-directional shallow ground water flow patterns within the dune crest to the beach region. Calculated mean hydraulic gradients over a two-week field exercise were 0.0058 within the most shoreward fore dune region, 0.0008 from the mid-fore dune to the front of the dune, 0.0018 from the back dune swale region to the dune crest, and 0.0041 from the uplands towards the back dune swale area. A negative mean hydraulic gradient of –0.0017 indicated net movement of shallow ground water from the mid-fore dune to the dune crest region. Estimated flow velocities, based on mean gradients, hydraulic conductivities and an assumed porosity of 0.4, were on the order of 2-11 $cm \cdot day^{-1}$ from the dune region towards the Bay.

Mean physical and inorganic nitrogen water quality parameters for adjacent Bay surface water, dune system shallow ground water, and upland shallow ground water are provided in Figure 13-2 and Table 13-1, respectively. Shallow ground water salinity levels within the dune system were indicative of freshwater (psu on the order of 0.1) indicating the importance of precipitation and upland ground water discharge to the site. In contrast, shallow ground water within the beach region exhibited levels similar to Bay water suggesting that pore water drainage at low tide and vertical infiltration of Bay water during high-tide events were important controlling factors within this region. Given the relatively deep water table aquifer conditions within Virginia Eastern Shore, it would be anticipated that fresher ground water would be observed at deeper locations within the beach region. Dissolved oxygen levels, expressed as percent saturation, were extremely low (<10%) within the beach and fore dune regions; corresponding concentrations were on the order of 1 $mg \cdot L^{-1}$ or less. Dissolved oxygen concentration increased within the dune crest and swale regions.

Dissolved inorganic nitrogen (DIN) levels within the beach and front, fore dune region were on the order of 30 $\mu mol \cdot L^{-1}$ and dominated by ammonium. DIN levels increased approximately 10 fold within the upper fore dune and dune crest region and conversely were dominated by nitrate. DIN levels within both the back dune swale and immediate upland region were somewhat reduced as compared to shallow ground water within the upper fore dune and crest region. Elevated nitrate levels within the back dune, crest and upper fore dune regions are indicative of deeper, water table aquifer inputs influenced by the upgradient, upland agricultural field. The shallow, localized clay lense observed in the immediate uplands likely isolated the upland monitoring well to some degree from this enriched high nitrate ground water. It is important to note that speciation of DIN was reflective of the oxygen status of the ground water, where anoxic and hypoxic conditions favor ammonium and well-oxygenated subsurface environments favor nitrate speciation. Additionally, low oxygenated environment are more conducive to the microbial mediated processes of denitrification and ammonification.

Based on this preliminary investigation, shallow ground water flow patterns and chemistry indicates that the dune region is an area of active ground water discharge and nitrogen transformation. Therefore, a dune system may serve a role in ground water quality remediation prior to its discharge from upland landscapes that have demonstrated elevated nitrogen loadings to shallow ground water systems.

Table 13-1. Mean inorganic nitrogen water quality concentrations within adjacent Bay water, beach shallow ground water, dune system shallow ground water, and shallow groundwater in the immediate uplands. Concentrations are expressed in $\mu mol \cdot L^{-1}$. BD denotes below method detection limit.

Location Description	Well ID	NH_4^+	NO_2^-	NO_3^-	DIN
Bay water		2.9	BD	0.8	3.7
Beach	1	32.2	BD	0.1	32.3
Fore dune	2	29.5	BD	0.5	30.0
Fore dune	3	9.5	0.9	286.1	296.5
Dune crest	4	2.8	0.1	372.9	375.8
Back dune swale	5	2.4	0.1	182.8	185.3
Uplands	6	7.2	4.6	79.2	91.0

14 Discussion

Dune sites around Chesapeake Bay, like all natural systems, have an evolutionary history of development based on local and regional parameters. Dune development in the Bay is a function of the 3 “growth” parameters of 1) sand supply, 2) relative stability and 3) hydro/aerodynamic settings. If a site is or becomes stable with abundant sand available, and it is exposed to a relative strong and/or frequent energy setting, then primary dune growth will occur. With time, the primary dune will grow higher and generally wider. Further along, a foredune may develop, the embryonic stage of the next primary dune, which will grow and relegate the old primary dune to secondary dune status. This process may also go the other way as the local setting and the relative importance of the 3 “growth” parameters can change, *i.e.* reduced sand supply and more erosive.

The nine sites selected for monitoring represent a wide range of dune site settings around the Bay with an emphasis on secondary dune fields and proximity to future development. These sites feature a coastal hazard component as well as an associated coastal habitat component. Dunes are a rare feature in the Bay today and although not quantified, this is due to development along many reaches of coast. Conversely, some dune field are the result of man’s activities so the balance and tradeoffs of development and dune creation are an issue. From a coastal hazard perspective, most would agree that having a healthy dune system along their property is preferable to not having none at all. These sites were chosen because they were seemingly stable dune sites some of which were just beginning to recover from Hurricane Floyd in 1999.

Before Hurricane Isabel impacted Chesapeake Bay in 2003, several of the dune sites were actively accreting. This allowed us to view the processes at work (Figure 14-1). As SAV detritus collects along the shore, it increases the elevation of the backshore and provides a backstop for wind-blown sand. Once that happens, a dune dimple is created in the backshore. This dimple eventually becomes a dunelet as dune vegetation becomes established on it. Over time, this region of dunelets becomes a foredune which may lead to the formation of a primary dune. These processes are typical for most dune sites that have ample sand available and SAV in the offshore. Finally, some sites might accrete by other processes such as sand accumulation against a manmade structure or deposition of a berm during a storm event.

A summary table was created for all nine sites, and it includes the calculated rate of change at MHW for each profile before Hurricane Isabel and over the entire monitoring period (Table14-1). Accretionary is defined as a positive trend greater than +0.5 ft/yr; stable is defined as trends between +0.5 and -0.5 ft/yr; and erosional is defined as less than -0.5 ft/yr. The trend for the change above MHW is based on volume calculations. Also included on the table is the determination of whether or not the dune crest is increasing at each site, the average amount of change over the entire site, and the net movement in the location of the dune crest either landward or seaward.

MA3 is a secondary dune site with a low upland that is controlled by 2 marsh headlands and nearshore attached bars. The source of sand for dune development at this site is from these nearshore bars. This abundance of sand has elevated the toe of the beach such that sand is available for aeolian transport to the backshore and dune area. The residents of the local communities have enhanced this process by installing dune fencing and planting dune grasses. Dunes have existed at this site since at least 1973. When Hurricane Isabel impacted the shore in September 2003, a wide beach was left as sand was eroded from the dunes and deposited close by. The residents re-installed dune fencing to help the dunes recover. Many of the dunes are rebuilding at the same location. The storm did not impact the long-term (1937-2003) rate of shoreline change at MHW or the short-term rate based on the monitoring program. Before the storm, most of the beach was accretionary as only the southern end was eroding (Table 14-1) and the dunes were stable overall. Due to the storm, the dune crest heights decreased along the site, and the position of the crest moved seaward in most cases. The only exception to this was at profile MA3-7 which was completely removed during the storm and has not recovered.

LN39 is a unique site in the Bay where dunes have existed since at least 1937. It has both a riverine side which features a primary only dune and a bay-influenced side that has an extensive secondary dune system. It is situated on a low upland spit that has been eroding from the bay side and accreting to the river side. It’s source of sand is from both nearshore detached bars and upland bank erosion down river. Presently, the site is controlled by shore structures and the spit’s interface with the downdrift upland banks. The structures include bulkheads and groins that have been constructed on the bay side of the spit in order to address erosion at several nearby homes. The riverine side of the site has also been impacted as vegetation was clear-cut at the site (Figure 14-2); however, it did affect the coastal habitat properties of the dune. Along the site, the hurricane accelerated rates of shoreline change, both positive and negative. The net change in the position of the dune moved back 13 ft at profile LN39-1 but moved seaward 36 ft at LN39-2.

NH10 is a dune sited backed by a fastland bank. Only the middle profile has a secondary dune; the other two profiles contain only have primary dunes. A great deal of sand exists in the nearshore attached bar system. This section of shore has the widest bar system leading to the most stable beach. Generally, this reach is a nodal point inside the larger reach that has had little change. Patchy dunes have existed at this site since 1949 and 1973, but by 1989, the dune field had matured. Even today, two-thirds of the site is accreting seaward. The dune crest height has accreted about 0.5 ft over the course of the monitoring program even in the area where the beach is erosional (Table 14-1). During the hurricane, significant southerly transport allowed the beach, backshore and dune to accrete. The storm created stable beaches that have become accretionary. The site is somewhat man-influenced due to the presence of a groin at the southern end of the site.

The present day dune at NH17 developed on a spit that formed in 1955. The dunes were established by 1972. This site also has nearshore attached bars which provide a large amount of sand for dune creation. NH17 is backed by a high upland bank which has been farmed for several generations. The entire reach is slightly erosional updrift and downdrift of the dune site, but the dune site itself has been accretionary even after Hurricane Isabel impacted the shore. On average, the dune crest height has increased 0.5 ft over the course of the monitoring period (Table 14-1). However, the dune crest itself has remained in the same position. Significant foredune growth has occurred at this site which decreased the width of the backshore. This site is natural; however it has the potential to become developed. One house has been built updrift of this site since the monitoring began. The upland bank vegetation was clear cut. This section of shore eroded during Hurricane Isabel. If erosion continues, shore control structures could be emplaced which would affect the downdrift dune site.

Site NH51 is part of a larger dune system that has existed since 1807. Since that time, this system has been fragmenting. Yet, the same shore morphology has occurred at this site since 1863 and, the dunes at NH51 are shown in the 1937 aerial photography. This large headland morphology is controlled by geology, and the nearshore attached and offshore bars. The wave climate at the site is a blend of ocean and bay. The dune field sits against a high upland bank whose erosion updrift and downdrift have been a source of sand for the site. NH51 is situated north of a nodal point in the overall reach. Just north of the nodal point, accretion is occurring; however, farther north at NH51, the site is losing dune which may be part of the overall trend of fragmentation. Part of the site was stable before Hurricane Isabel, but the most northern section was erosional (Table 14-1). The overall trend at the site has been erosional both on the beach and above MHW. No net change in dune crest height has occurred, but the crests themselves have retreated several feet.

Smith Point, where NL42 is located, has been an accretionary feature through time as sand has been transported down the Potomac River and up the Bay shoreline. However, the morphology of the site has been changing since the entrance to the Little Wicomico River was stabilized in the 1930s. In addition, when several ponds breached along the more southern section of the reach, sand transport was interrupted possibly reducing the amount of sand moved along the shoreline. However, dunes have existed at NL42 since before 1937. The large protruding salients that existed at the site 30 years ago have been eroding leading to a more linear shoreline. Sand is continuing to accrete on either side of the jetties so that reach of shoreline at NL42-1 is fairly stable. The southern section of the shoreline has had many groins built in order to catch sand and create a stable shoreline. However, the shore morphology between these groins and Smith Point is equilibrating leading to the formation of an embayment between the two. Overall this site is erosional (Table 14-1). The primary dune crest has decreased by 2.3 ft in height, and dunes at two of the profiles have not recovered from Hurricane Isabel. The hurricane left many of the groins at the southern end of the site stranded (Figure 14-3).

NL58 and NL59 are similar sites that exist on either side of a tidal creek emptying into the Potomac River. Eroding fastland updrift provides the sediment necessary for dune growth. NL58 has had a dune field since 1937 which has allowed a secondary dune field to become established along sections of the shore. However, as development of the shore occurred, groins were installed along the shoreline leading to the degradation of the dune field downdrift. Groins were built at the site by 1987. Before the hurricane, the shoreline was accretionary at NL58-1 and NL58-2 while the more downdrift profile NL58-3 was erosional. Even before the monitoring program, this profile was in decline. What was originally thought to be a primary dune only site showed that it was actually a secondary dune whose primary dune had been eroded. The hurricane caused the shoreline to become erosional overall (Table 14-1) even though the overall average height of the dune increased by 0.4 ft.

Portions of NL59 are adjacent to the creek mouth barrier of Black Pond, but much of it abuts the adjacent upland. It is wider toward Hack Creek since sand tends to accumulate at the jetties. Groins were installed along the shore in the 1960s, and by 1976, these had accreted a wide enough beach for a dune to develop. Most of the site was stable over the course of the monitoring program; however, the hurricane caused the dune to become erosional decreasing primary dune height by an average of 3.2 ft (Table 14-1). Profile NL59-3 lost it's primary dune making the secondary dune the primary.

VB4 has been a dune field since at least 1937. It occurs on an accretionary stretch of shoreline where a great deal of sand is moving into the Bay from the ocean and transported around Cape Henry. It's a relatively natural area since it is a state park; however, updrift the dunes have been impacted by residential development. Sand tends to move onshore in the form of nearshore attached bars on the easternmost section of shore. This section, at VB4-3, is rapidly increasing particularly in dune crest height. Over the entire site, the average dune crest height increased by 1.7 ft (Table 14-1). Monitoring at VB4-3 has shown that the dune crest has moved landward 6 ft, but that is misleading because the dune has grown so much that the crest has moved back. Hurricane Isabel significantly impacted this region creating an overall erosional site through the course of the monitoring program. However, this is likely a temporary trend due to the size of the storm. Likely, the site will continue accreting.

The measured parameters calculated from the data collected allows us to see that the front base of the primary dune (Y) increases in elevation when a foredune is developing and when the dune is accreting in general; but it also increases when the dune is scarped and eroding so it's change is not a good indicator of dune system health. If the distance to the base of the primary dune (E) increases and the backshore width (F) decreases, then the dune is generally accreting seaward.

It was noted that beach berm position (F) and elevation (Z) can vary significantly at each profile and within each site. On the western shore of Chesapeake Bay, the results suggest that the berm varies seasonally with it being higher in fall/winter than summer. This seasonal variation is not as obvious on the eastern or southern shores. What was noted at most sites is that during the summer/fall, dune grasses tended to move seaward and colonize the dune dimples formed by the deposition of SAV detritus that is only deposited in the summer/fall.

The previously described relationship of the slope of the entire system between the primary dune crest and MLW (Hardaway *et al.*, 2001) was used again in this analysis. This relationship is calculated by dividing X by D. Previous results have shown this ratio to fluctuate around 0.1 at all dune sites around Chesapeake Bay based on the initial dune surveys performed in 1999 and 2000. Subsequent monitoring at specific sites has refined that number slightly. On the west and southern shores, the number through time has been 0.8. On the eastern shore, which tends to have a great deal of sand in the system, the number was 0.1. On the Potomac River at sites NL58 and NL59, the slopes were slightly steeper (0.17) reflects that they are a high, but narrower system. The information gleaned from this relationship might be useful in building a stable dune system.

After Hurricane Isabel, dunes began regrowing in their original locations, and this is particularly true in Mathews. Other sites like NH10 and NL17 had berms deposited during the storm and are sites where new new dunes are growing. Whereas erosional sites that had berms deposited during the storm (NH51) were subsequently eroded. The beach width at VB4 has fluctuated after the storm, but generally, the beach face is narrower while the backshore is wider.

The primary dune crest is the constant reference point for each profile. Generally, sites with low geologic underpinnings and/or facing less dominant wind/wave directions have a relatively lower primary dune crest. These include LN39, NL42, and, to some degree, NH17. The remaining sites have higher primary dune crests as a result of greater exposure to dominant wind/wave climates and higher adjacent uplands that reduce the potential for overwash.

The relationship of the primary to secondary dunes warrants discussion because, in many cases, the secondary dune(s) were once the primary dune feature. This is well documented at VB4, NH51, and NL42. It is less clear at the other sites with secondary dunes. Generally, the averaged secondary dune elevations are higher than the associated primary dune elevations at NH10, NL58, NL59, and VB4 by 2.1 ft, 0.9 ft, 2.1 ft, and 3.2 ft, respectively. NH10, VB4, and NH59 have the sand resources and a larger wind/wave climate that allows for the development of higher dunes. It has been previously documented that at these sites, what was once the primary dune has become the secondary dune. Dune heights are similar at LN39, NH51, and NL42. These trends have been similar since the beginning of the monitoring program and were not affected overall by the hurricane. Even though some height was lost at some sites, it was not enough to reverse the overall trends. MA3 had significant changes in its primary dune crest height due to the storm. Before the hurricane, the primary dune was higher than the secondary dune; however, after the hurricane, the secondary dune was higher.

Table 14-1. Summary of dune site trends before the storm, over the entire monitoring period, and above MHW.

Site	Profile Number	Site Type	Pre-Storm	Overall	Above MHW	Dune Crest Height (X)	Net Dune Crest Movement (ft)
MA3	1	Secondary	Accretionary	Accretionary		Decreasing	+1
	2	Secondary	Stable	Accretionary		Decreasing	0
	3	Secondary	Accretionary	Stable		Decreasing	+28
	4	Secondary	Accretionary	Accretionary		Stable	-3
	5	Secondary	Accretionary	Accretionary		Decreasing	+33
	6	Secondary	Accretionary	Erosional		Decreasing	+10
	7	Secondary	Erosional	Erosional		Gone	Not Recovered
	8	Secondary	Erosional	Erosional		Stable	0
	Overall		**Accretionary**	**Accretionary**	**Stable**	**-2.5 ft**	
LN39	1	Primary Only	Erosional	Erosional		Decrease	-13
	2	Secondary	Accretionary	Accretionary		Stable	+36
NH10	1	Primary Only	Accretionary	Accretionary		Stable	0
	2	Secondary	Stable	Accretionary		Increasing	0
	3	Primary Only	Erosional	Erosional		Increasing	+4
	Overall		**Stable**	**Accretionary**	**Accretionary**	**+0.5 ft**	
NH17	1	Primary Only	Accretionary	Accretionary		Increasing	0
	2	Primary Only	Accretionary	Accretionary		Increasing	0
	3	Primary Only	Accretionary	Accretionary		Increasing	0
	4	Primary Only	Accretionary	Accretionary		Increasing	0
	Overall		**Accretionary**	**Accretionary**	**Accretionary**	**+0.5 ft**	
NH51	1	Secondary	Stable	Stable		Increasing	-2
	2	Secondary	Stable	Erosional		Increasing	-3
	3	Secondary	Erosional	Erosional		Decreasing	-3
	Overall		**Erosional**	**Erosional**	**Erosional**	**0 ft**	
NL42	1	Primary Only	Stable	Erosional		Gone	Not Recovered
	2	Secondary	Erosional	Erosional		Increasing	+30
	3	Secondary	Erosional	Erosional		Increasing	-19
	4	Primary Only	Erosional	Erosional		Gone	Not Recovered
	Overall		**Erosional**	**Erosional**	**Erosional**	**-2.3 ft**	
NL58	1	Primary Only	Accretionary	Stable		Increasing	0
	2	Secondary	Accretionary	Erosional		Stable	0
	3	Primary Only	Erosional	Erosional		Decreasing	0
	Overall		**Stable**	**Erosional**	**Erosional**	**+0.4 ft**	
NL59	1	Primary Only	Stable	Stable		Decrease	-1
	2	Primary Only	Stable	Stable		Stable	0
	3	Secondary	Erosional	Stable		Gone	2nd to primary
	Overall		**Stable**	**Stable**	**Erosional**	**-3.2 ft**	
VB4	1	Secondary	Accretionary	Erosional		Increase	0
	2	Secondary	Accretionary	Erosional		Stable	0
	3	Secondary	Accretionary	Erosional		Increase	-6
	Overall		**Accretionary**	**Erosional**	**Accretionary**	**+1.7 ft**	

15 Conclusions

Shore protection is information of primary importance to this dune assessment. At all sites with both upland development and dunes, no damage occurred during Hurricane Isabel to real property (except possibly flooding which is unavoidable). Arguably, Isabel was a 50 to 100 yr storm event, depending on site location. Sites that lost sections of their primary dune but which had a secondary dune that became a primary dune after the storm were NL58/59 and NH51. This reveals the intrinsic value of secondary dunes from a coastal hazard perspective and reinforces the stated growth/stability factors of 1) stable setting, 2) sand supply and 3) conducive hydrodynamic and aerodynamic exposure.

Numerous examples of man's influence occur along some shore reaches that have had a positive and sometimes negative effect. In fact, man-influenced upland dune shorelines have a greater frequency of occurrence than dunes against natural uplands. At NL59 a beach and dune would not have developed except for the groin field installation. Other sites are enhanced by man's intervention such as at MA3 where sand fencing and dune grass plantings have helped enhance the protective dune. Partial impacts such as the updrift areas of NH10 and NL42 are degraded due to groins, but NL42 may not have existed as extensively had it not been for the Smith Point jetties. Future impacts are a potential at NH17 which may face problems if structures placed updrift reduce the sand supply. The take home message is that shoreline management plans should recognize the importance of dunes and beaches and incorporate them in long-term strategies.

The future prospects for the monitoring sites varied based on long-term evolutionary trends. Sites MA8, NH10, NH17, VB4 will continue to accrete. Site LN39 is unique with erosion of its bay side feeding the riverine side causing a basic cut and fill scenario. Dune sites in the process of decay are NH51 and NL42 which are affected by both natural causes and man's influence, respectively. The dune sites on either side of Hack Creek, NL58-59 are probably in a state of equilibrium, at least in the short term for the next 10 years or so.

Contradictory results of data analysis show the complexity of each individual system. Dune sites are quite resilient to storm attack and generally recover quickly. However, when monitoring the response of a system to a large event, timing is important. The aerial photos don't always match the on ground data because of the rapidity of change in the system both during the storm and in the recovery phase. By December 2003, some of the beach/dune systems monitored were already in the recovery phase for the profiles. If the sites were surveyed in September or October 2003, the hurricane damage was evident.

The presence of nearshore bars add to the stability of a site but also result in highly mobile systems which are difficult to categorize. The nearshore attached bars are the deciding factor for stability. They provide the protection needed for the backshore and make sand available for aeolian transport necessary for dune creation.

As seen at NH17, a dune system may serve a role in ground water quality remediation prior to its discharge from upland landscapes that have demonstrated elevated nitrogen loadings into shallow ground water systems. Future directions for a continued ground water study at this site include: (1) refine the spatial scale of study (vertical) to support multidimensional modeling efforts so as to be able to define deeper ground water flow patterns and nitrogen transport patterns, (2) make direct measurements of nitrogen reduction processes occurring within the dune system and identify organic carbon sources that serve to fuel these processes, and (3) conduct a comparative study down-gradient from a low impact land use.

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Appendix A
Report Figures

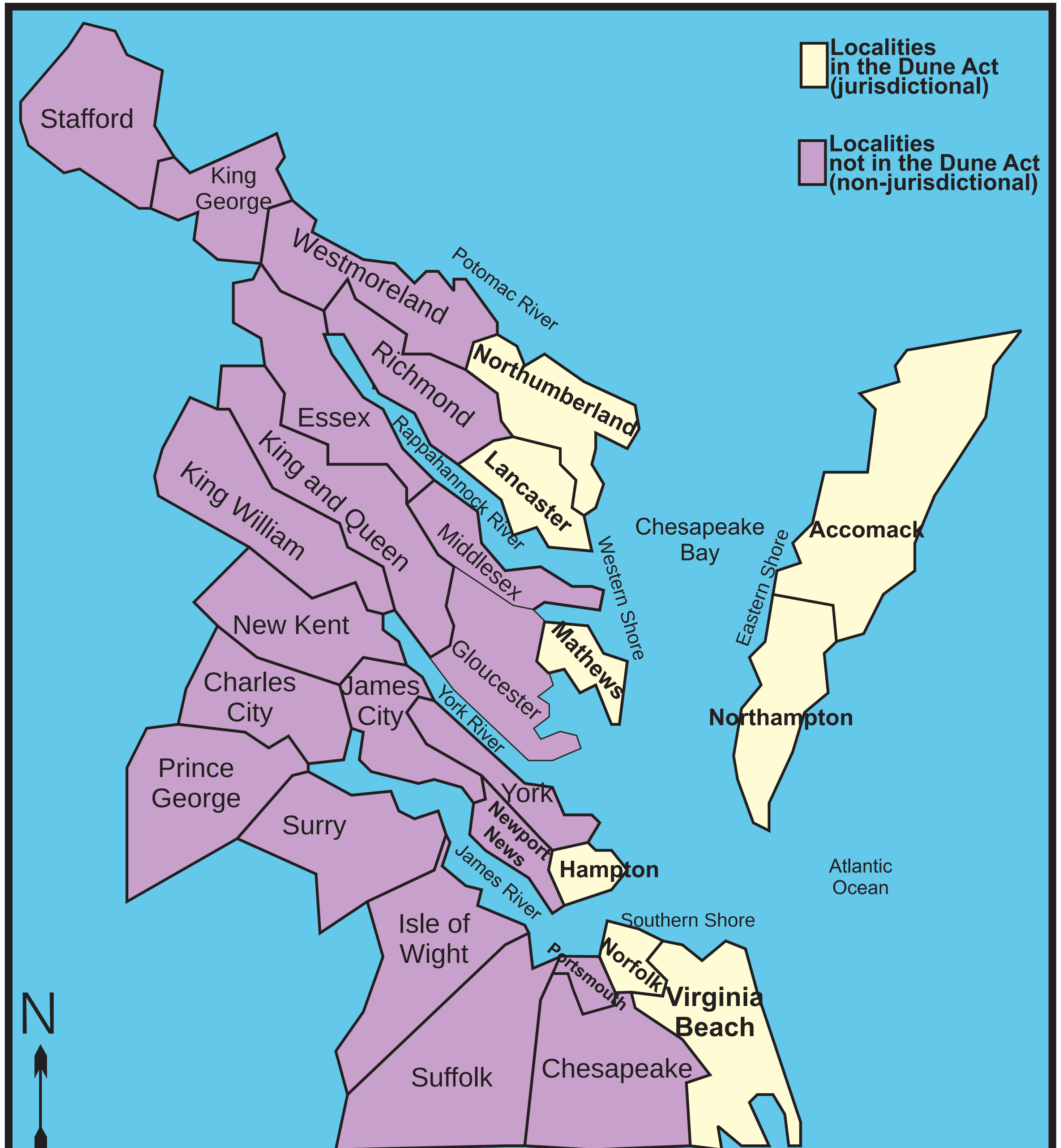


Figure 1-1. Location of localities in the Dune Act with jurisdictional and non-jurisdictional localities noted.

Dune Classification System

I. Natural | **II. Man Influenced** | **III. Manmade**

A. Exposure: fetch
1. Riverine, Bay Influenced
2. Open Bay
3. Riverine

B. Shore Orientation (faces)
1. North
2. Northeast
3. East
4. Southeast
5. South
6. Southwest
7. West
8. Northwest

C. Nearshore Gradient
(to the 6 ft contour)
1. 0 to 1,000 ft
2. 1,000 to 3,000 ft
3. >3,000 ft
   1. Extensive Bars
   2. No Bars

D. Morphologic Setting
1. Isolated <500 ft alongshore
   1. Pocket
   2. Linear
   3. Shallow Bay
   4. Salient
2. Creek Mouth Barrier/Spit
3. Spit
4. Dune Field >500 ft alongshore
   1. Pocket
   2. Linear
   3. Shallow Bay (curvilinear)
   4. Salient (point)

E. Relative Stability
1. Stable
2. Accretionary
3. Land Transgressive/Erosional

F. Geologic Underpinnings
1. Marsh
2. Upland

G. Structure/Fill
1. **Groin**
2. **Revetment/Bulkhead**
3. **Breakwater**
4. **Jetty**
5. **Beach Fill**

Figure 1-2. Classification system for Chesapeake Bay dune systems.

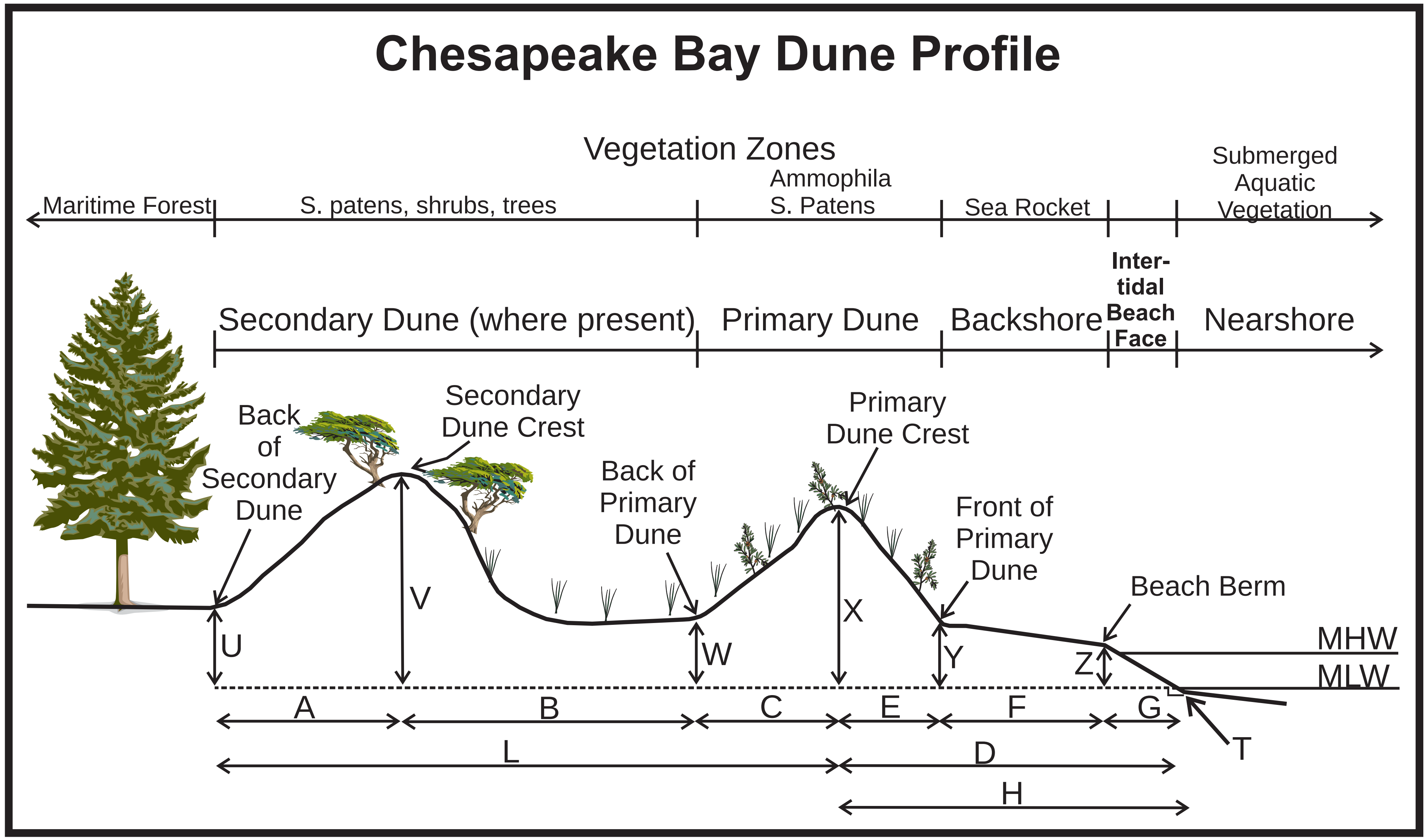


Figure 1-3. Typical profile of a Chesapeake Bay dune system with measured parameters indicated.

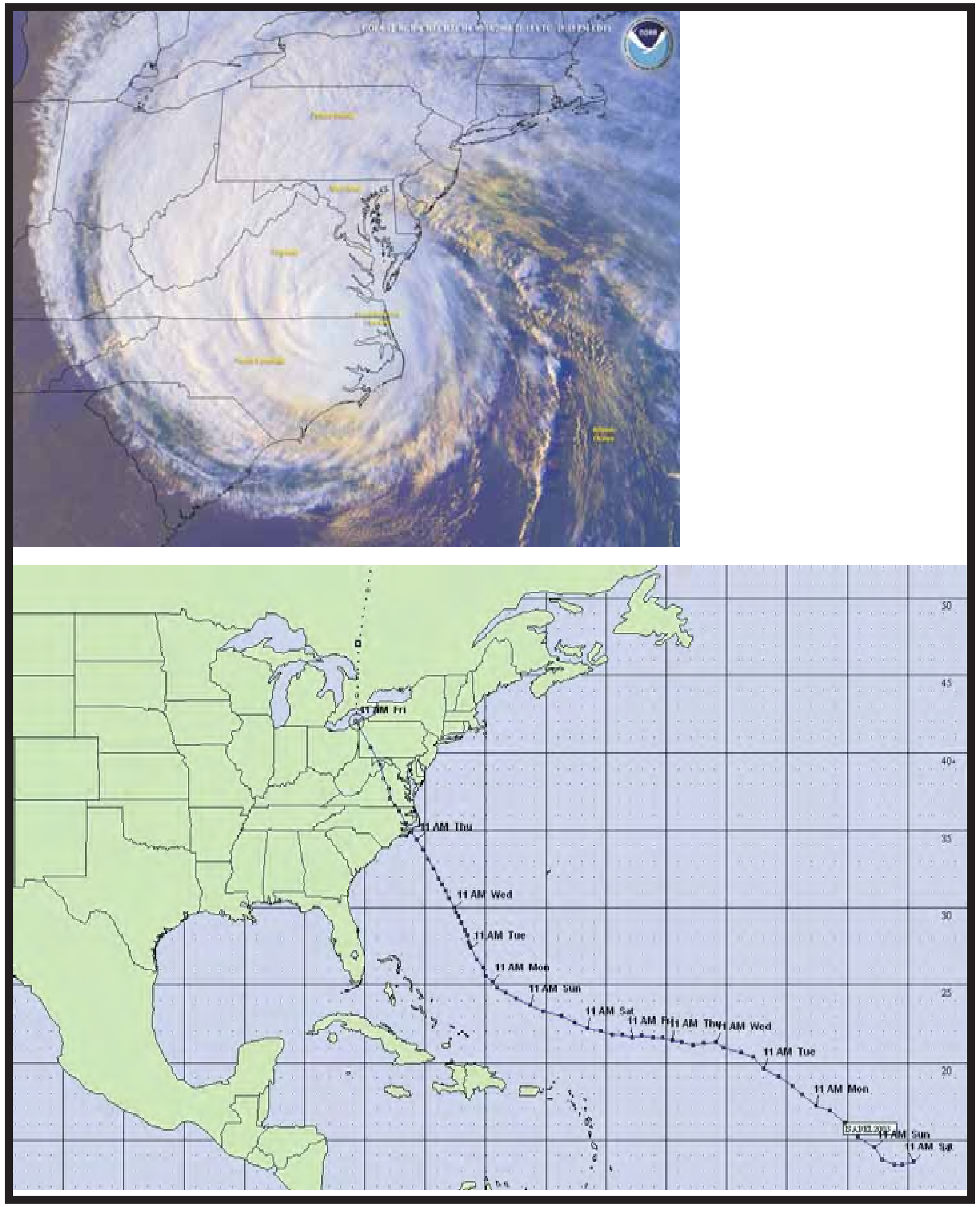


Figure 1-4. Hurricane Isabel photo at landfall and storm track from the National Hurricane Center.

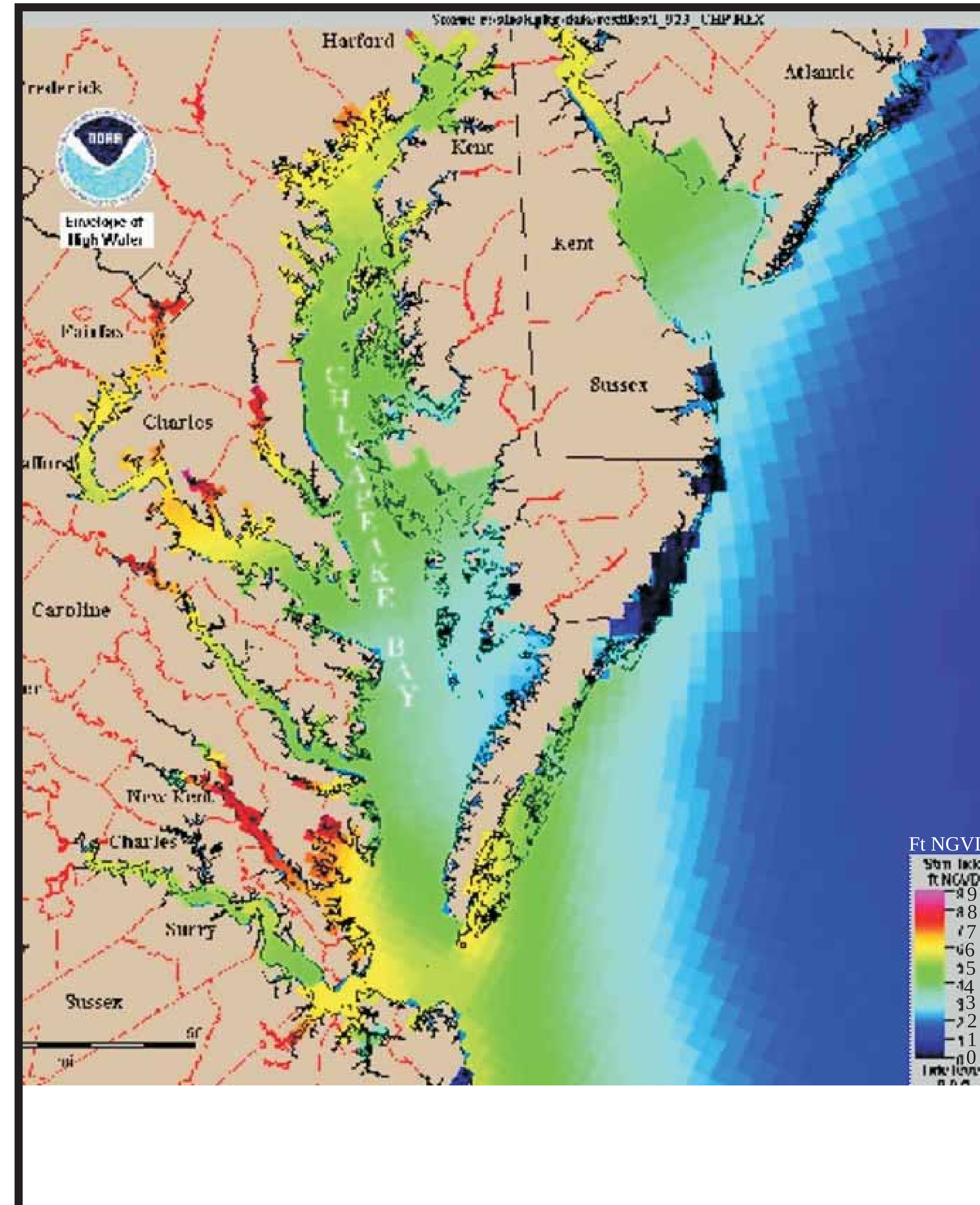


Figure 1-5. NOAA's slosh model storm surge prediction graphic.

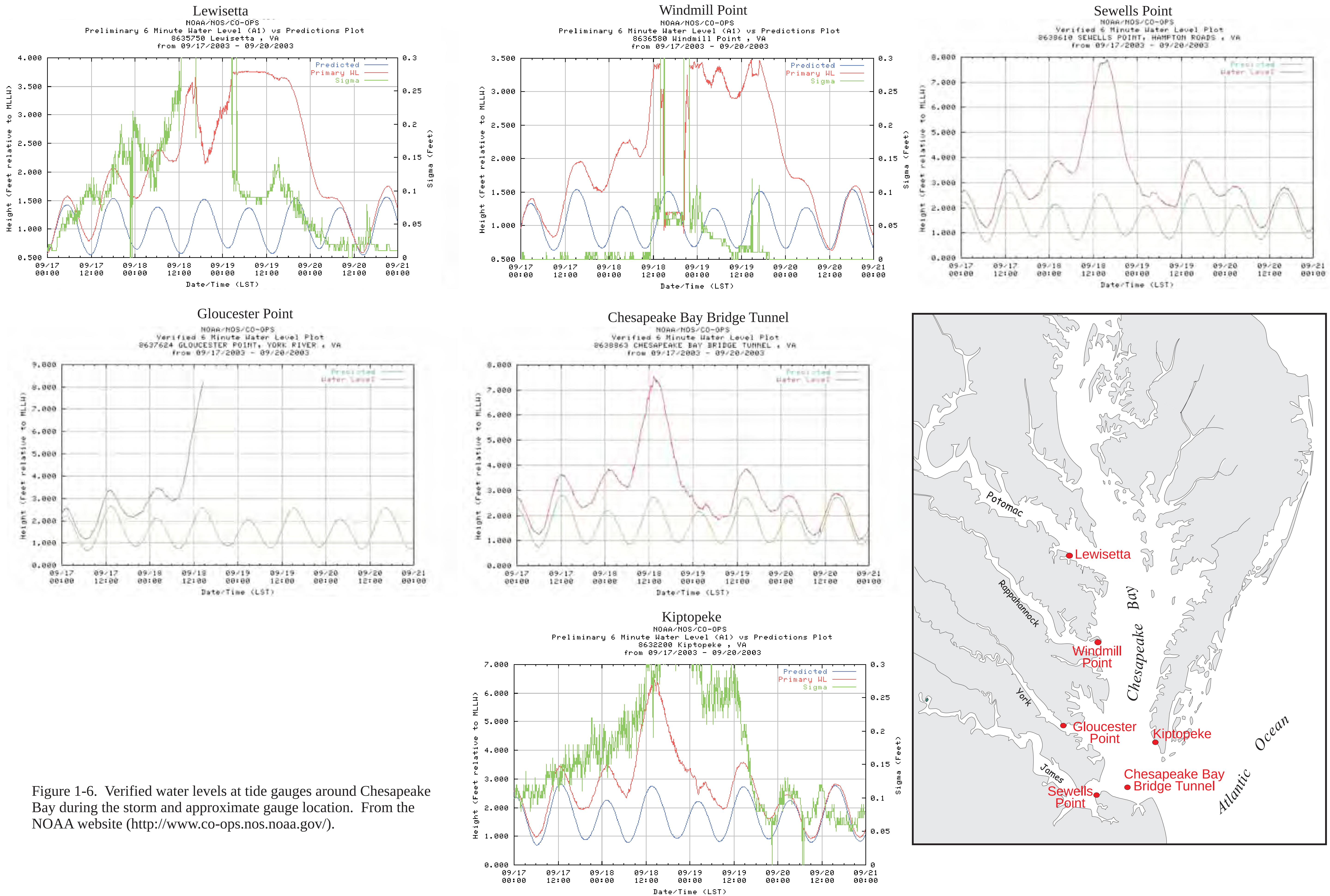


Figure 1-6. Verified water levels at tide gauges around Chesapeake Bay during the storm and approximate gauge location. From the NOAA website (http://www.co-ops.nos.noaa.gov/).

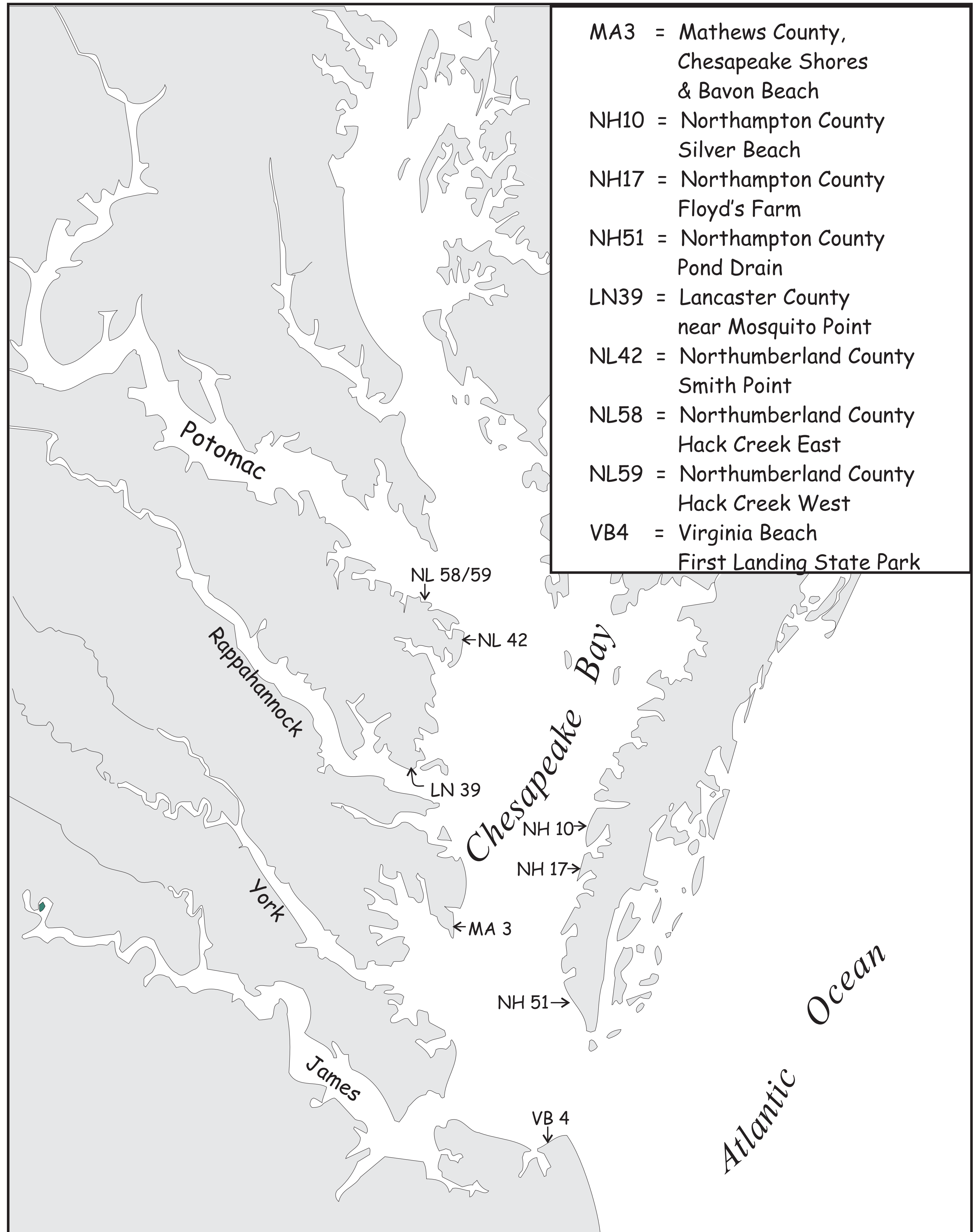


Figure 2-1. Location of dune monitoring sites.

Figure 3-1. Location of site Ma3 in Mathews County with approximate position of cross-shore beach profiles.

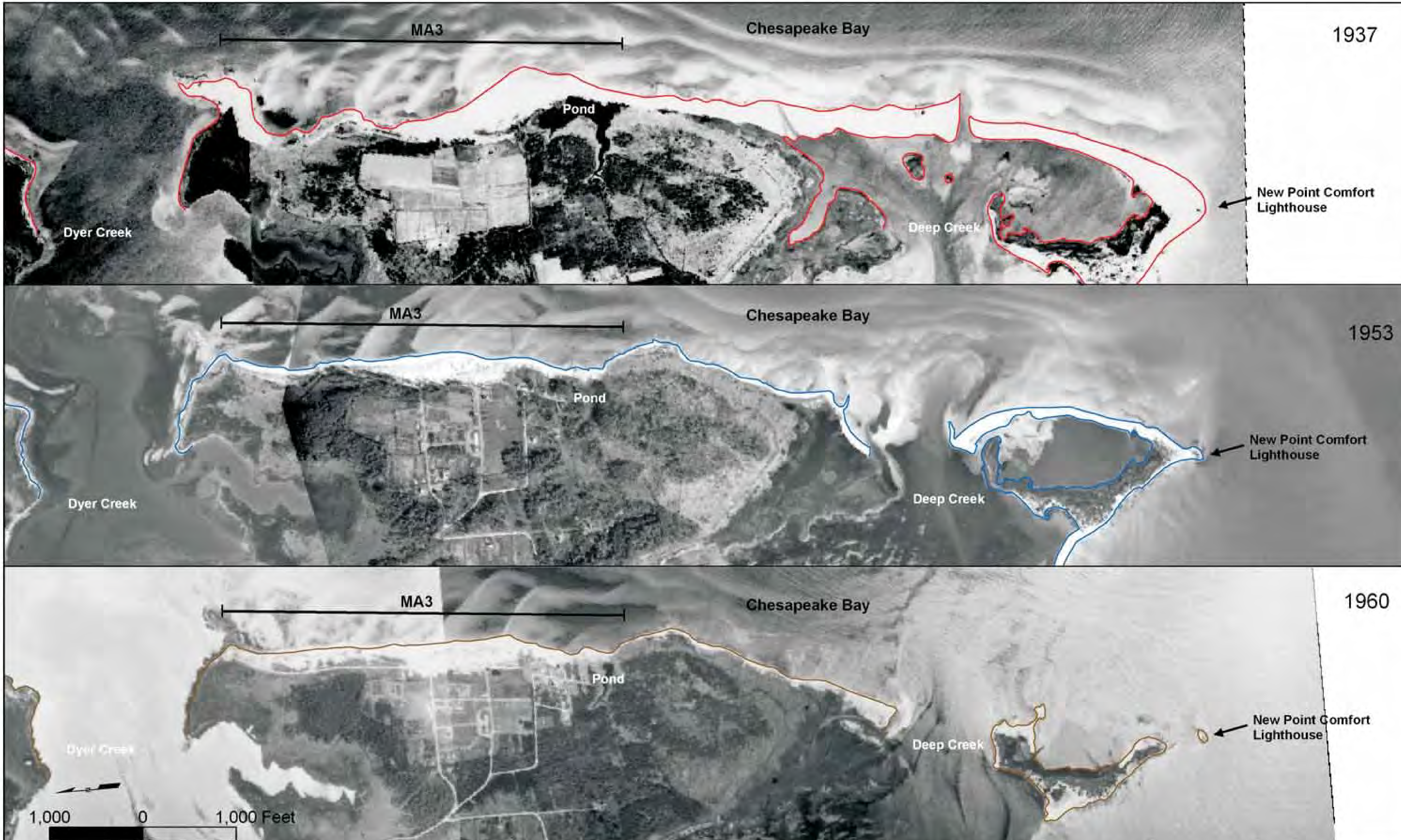


Figure 3-2-1. High -level orthorectified aerial photography of the Bavon coast and MA3 taken in 1937, 1953, and 1960.

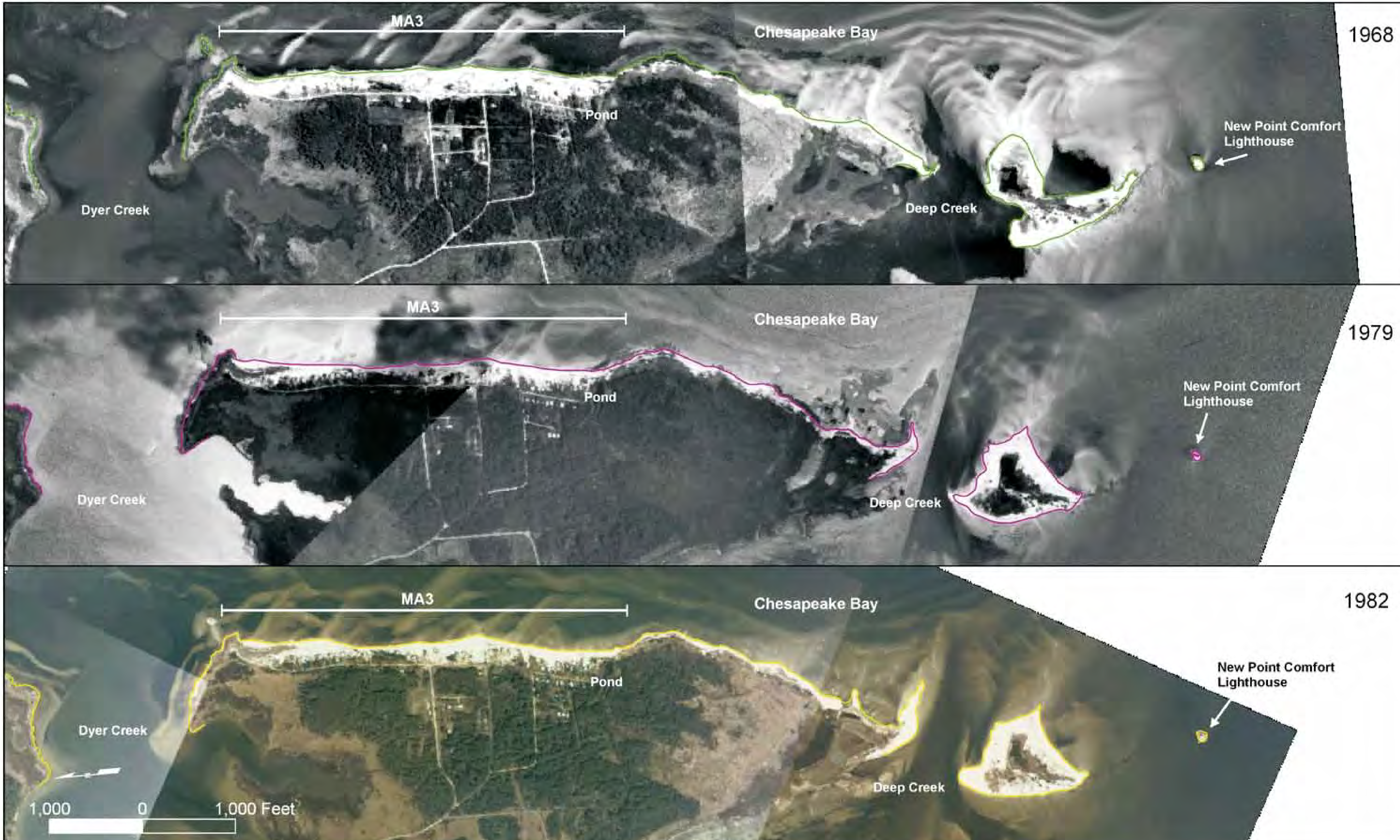


Figure 3-2-2. High -level orthorectified aerial photography of the Bavon coast and MA3 taken in 1968, 1979, and 1982.

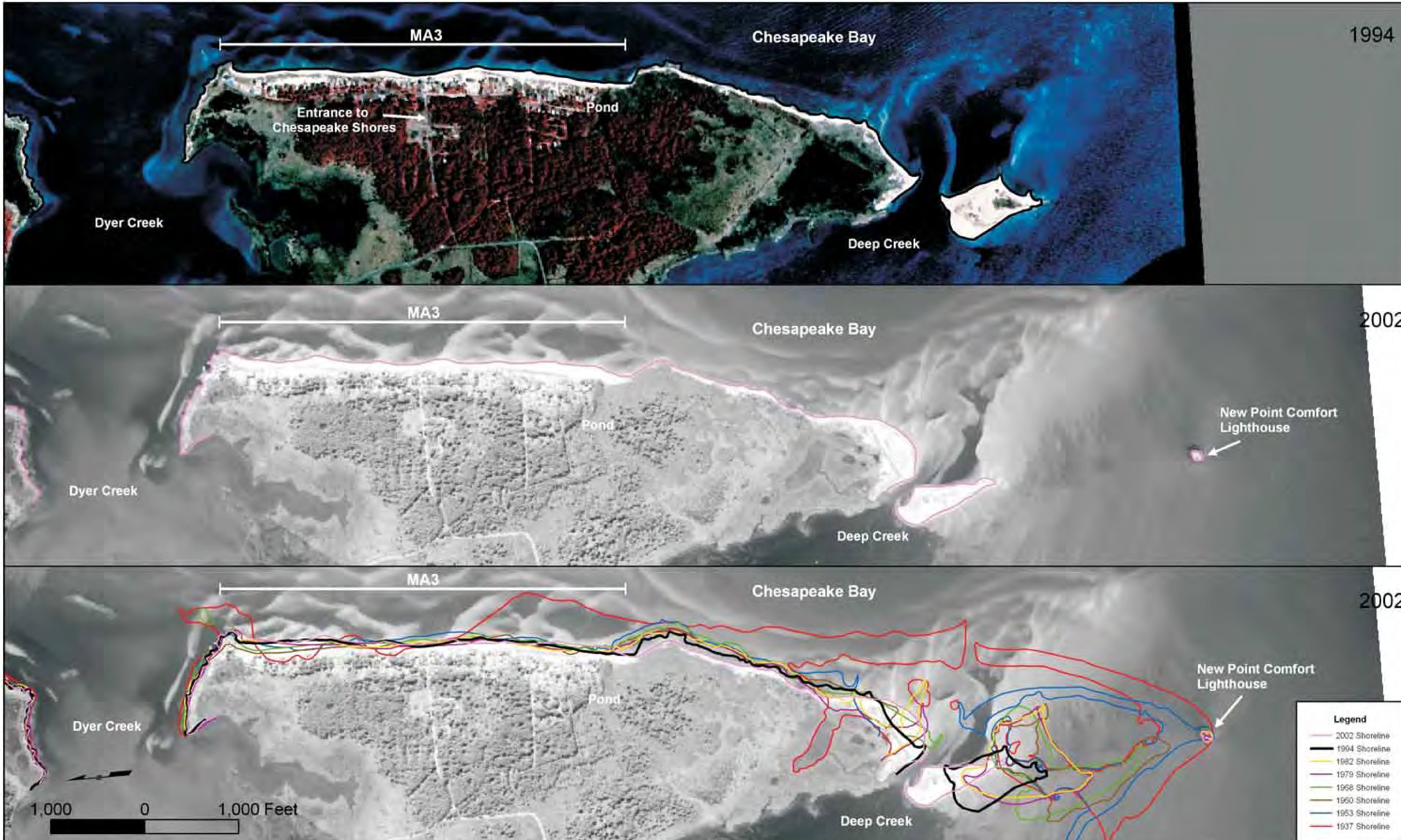


Figure 3-2-3. High-level orthorectified aerial photography of the Bavon coast and MA3 taken in 1994 and 2002 as well as the 2002 photo and all the digitized shorelines.

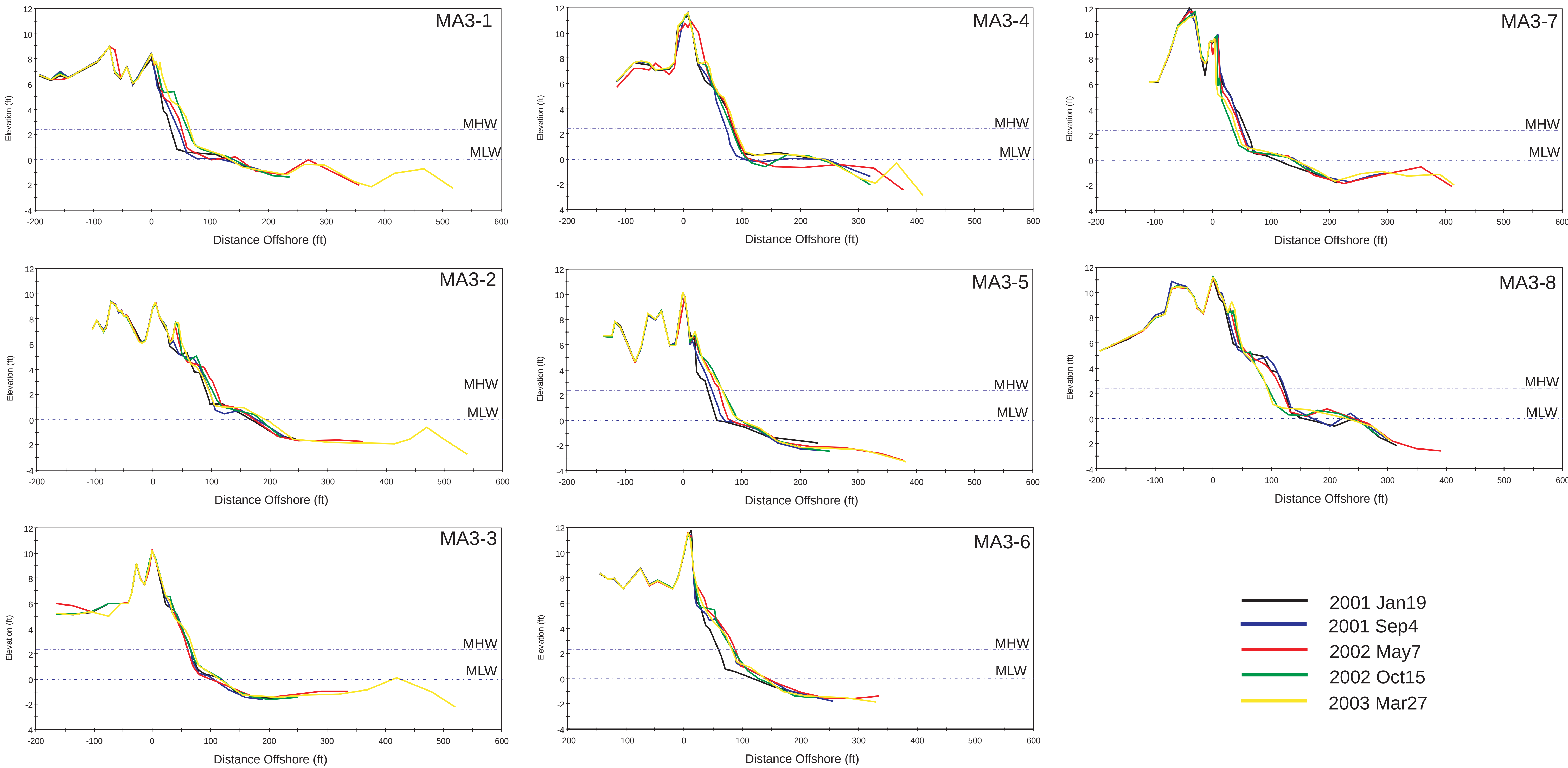


Figure 3-3. Profile plot comparisons for the eight profiles at MA3 between January 2001 and March 2003.

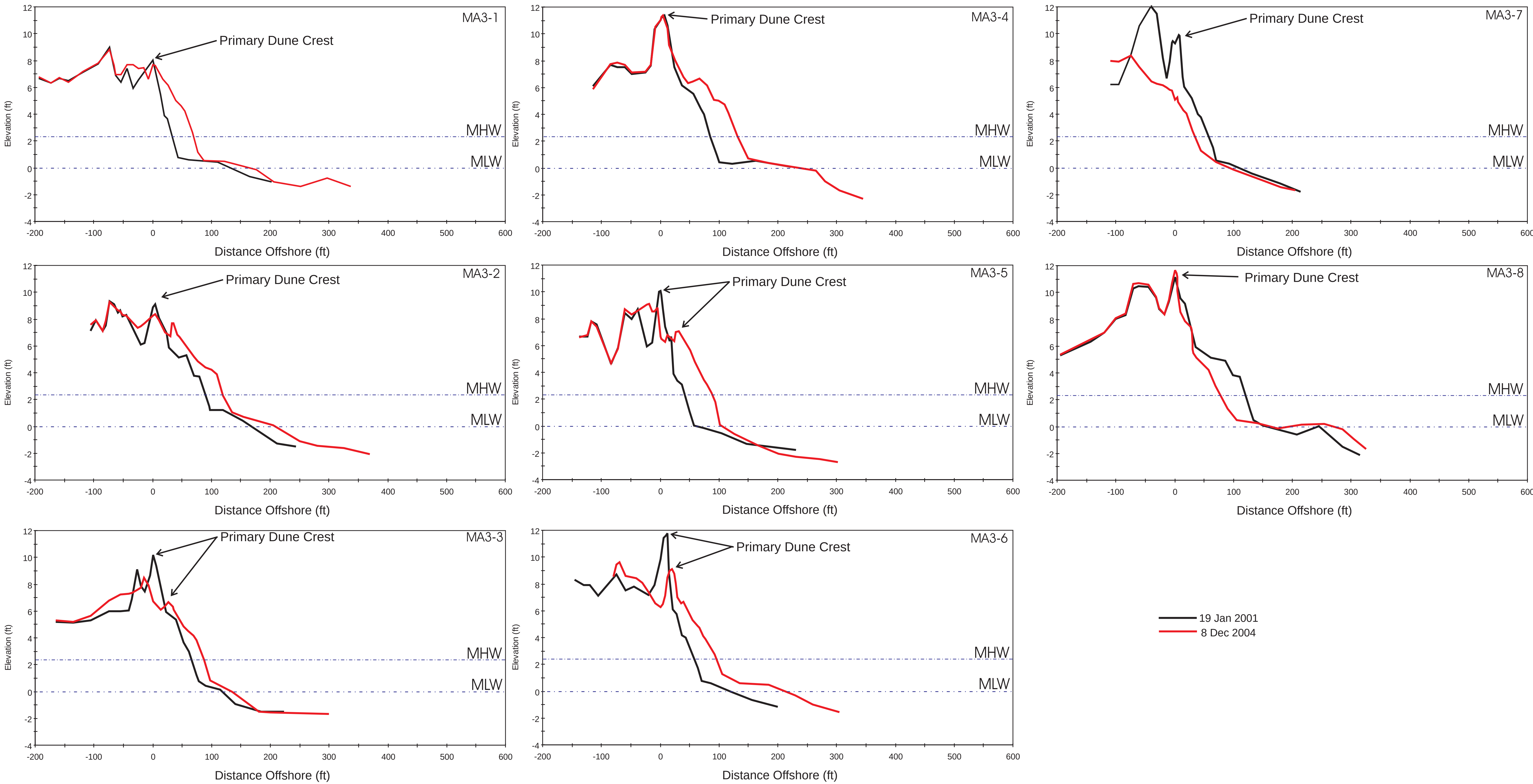


Figure 3-4. Net profile change between January 2001 and December 2004.

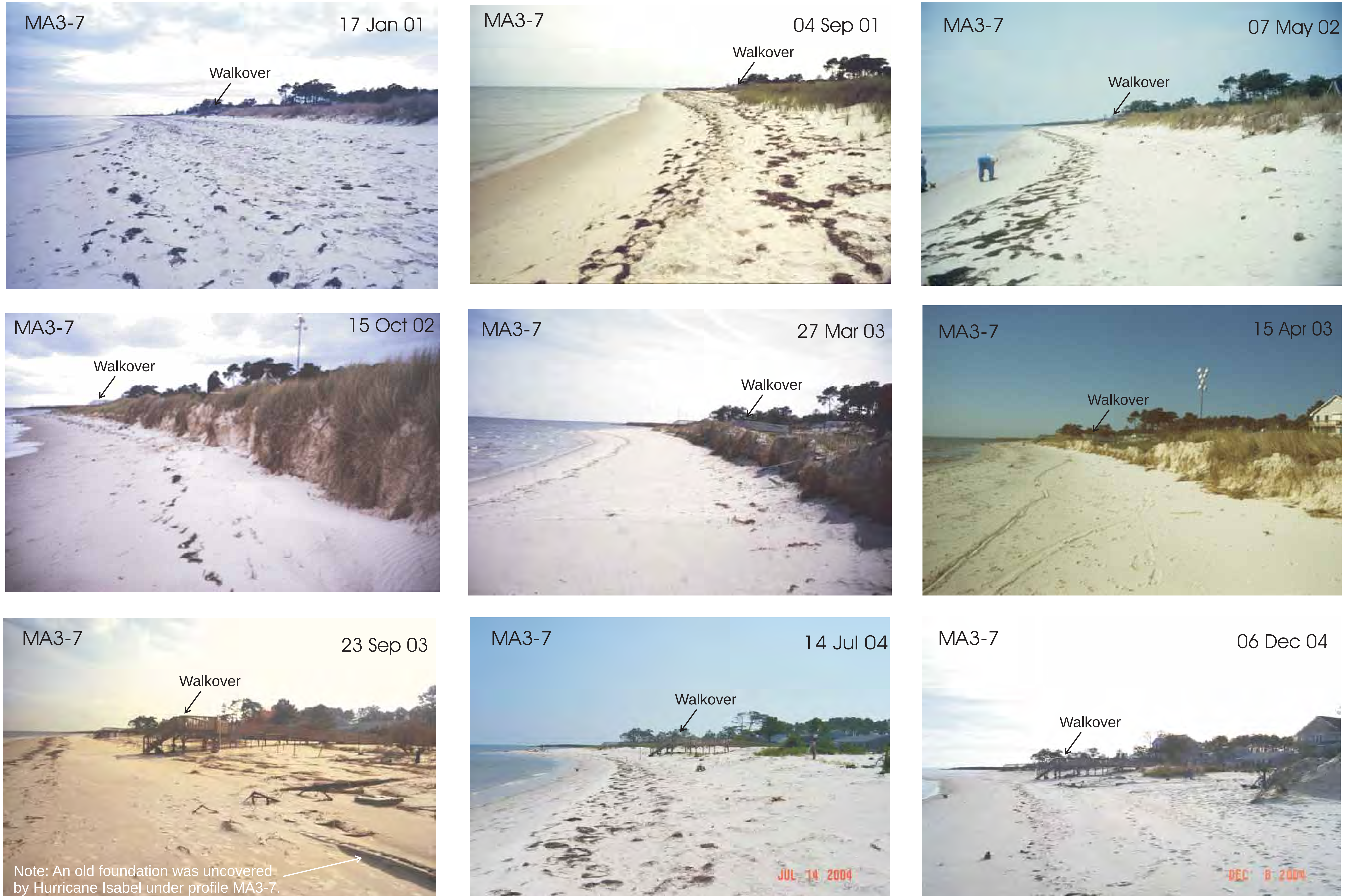


Figure 3-5. Recent ground photos at profile MA3-7 over the course of the monitoring program.

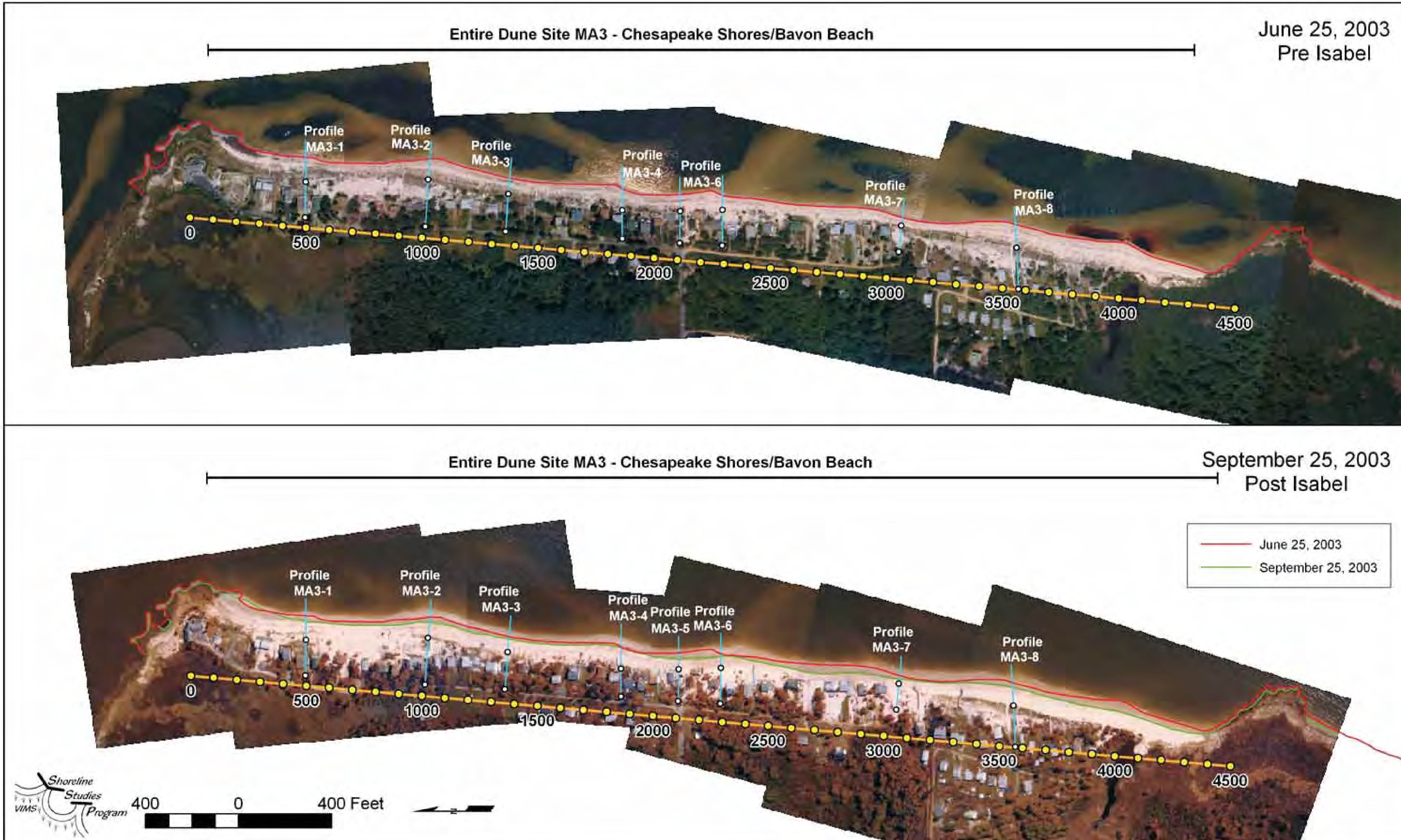


Figure 3-6. Low-level pre and post hurricane Isabel georectified aerial photography.

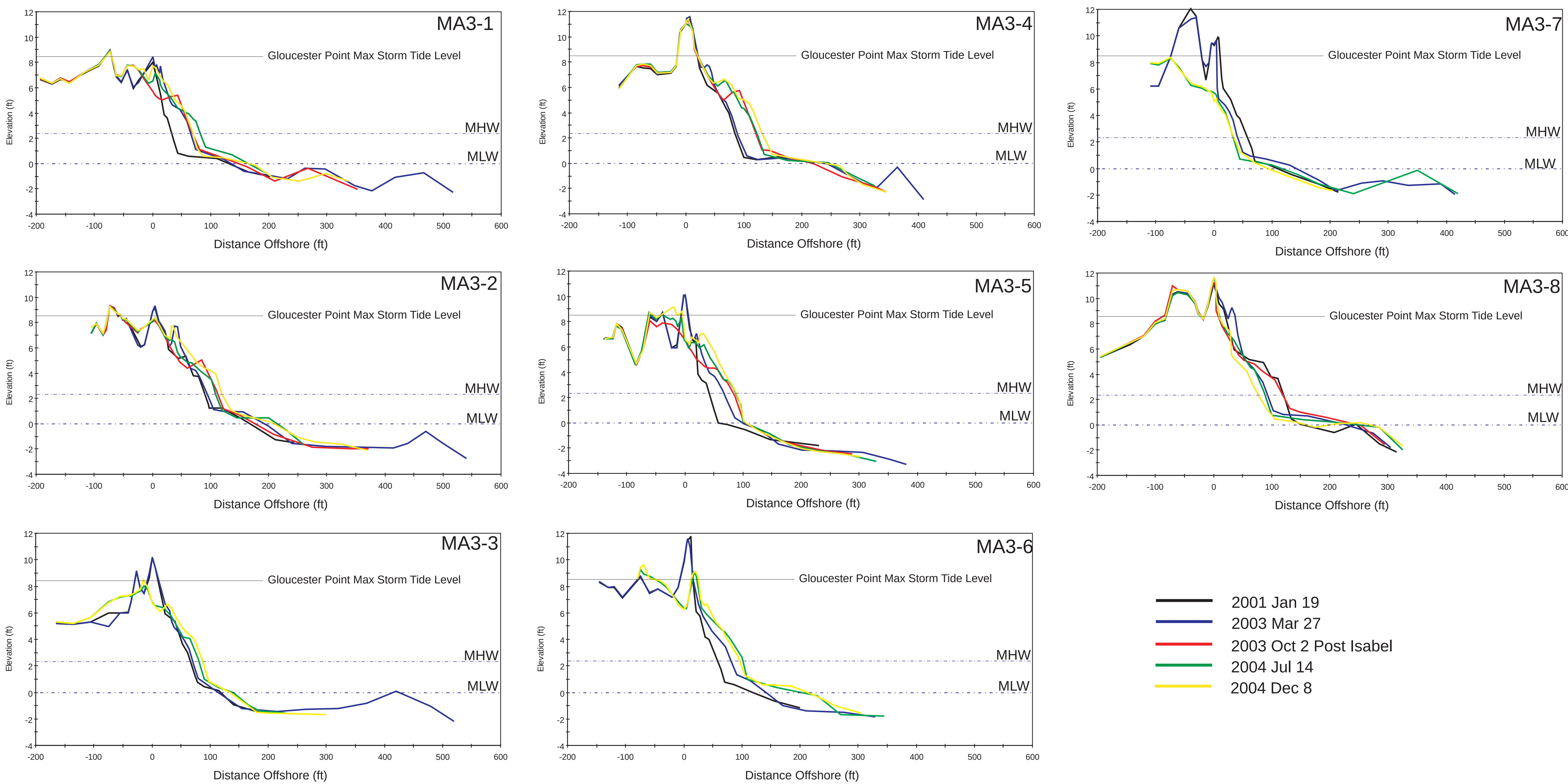


Figure 3-7. Profile plot comparisons for the eight profiles at MA3 showing the first survey taken at the site, the profile taken before Hurricane Isabel, after the hurricane and in 2004.

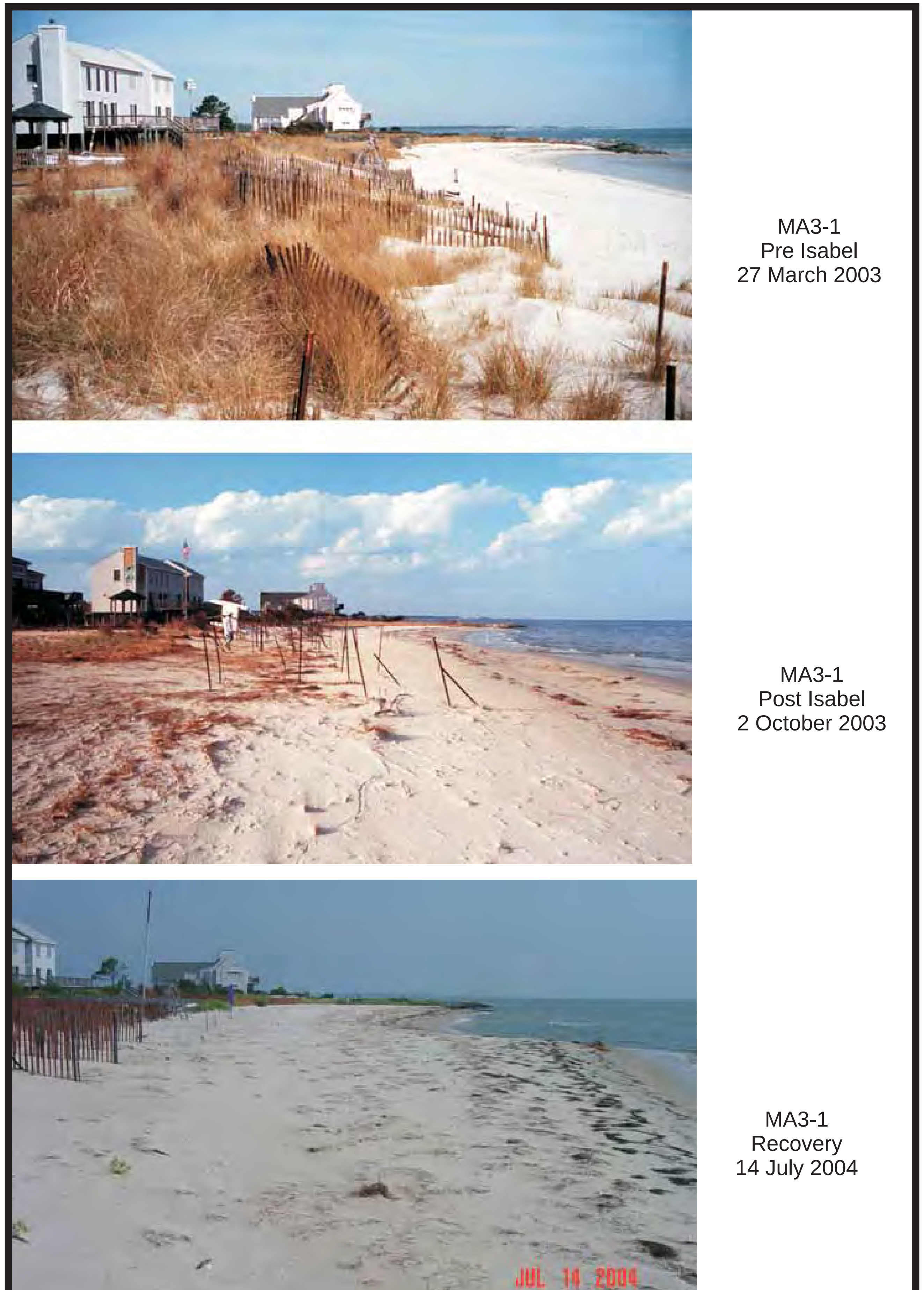


Figure 3-8. Ground shots taken before Hurricane Isabel, after Isabel and 10 months after the storm at MA3-1.

Figure 3-9. Ground shots taken before Hurricane Isabel, after Isabel and 10 months after the storm at MA3-4.

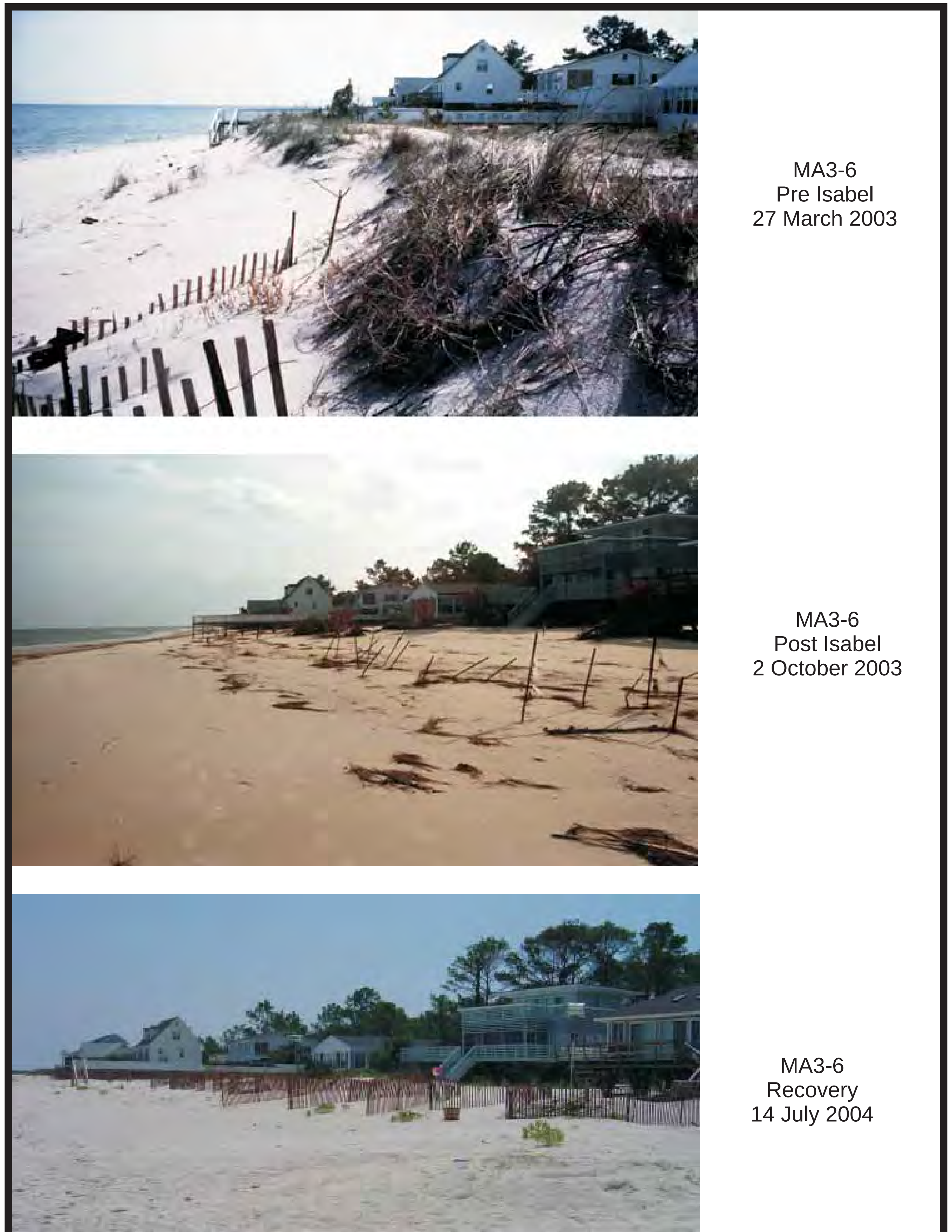


Figure 3-10. Ground shots taken before Hurricane Isabel, after Isabel and 10 months after the storm at MA3-6.

Figure 3-11. Ground shots taken before Hurricane Isabel, after Isabel and 10 months after the storm at MA3-8.

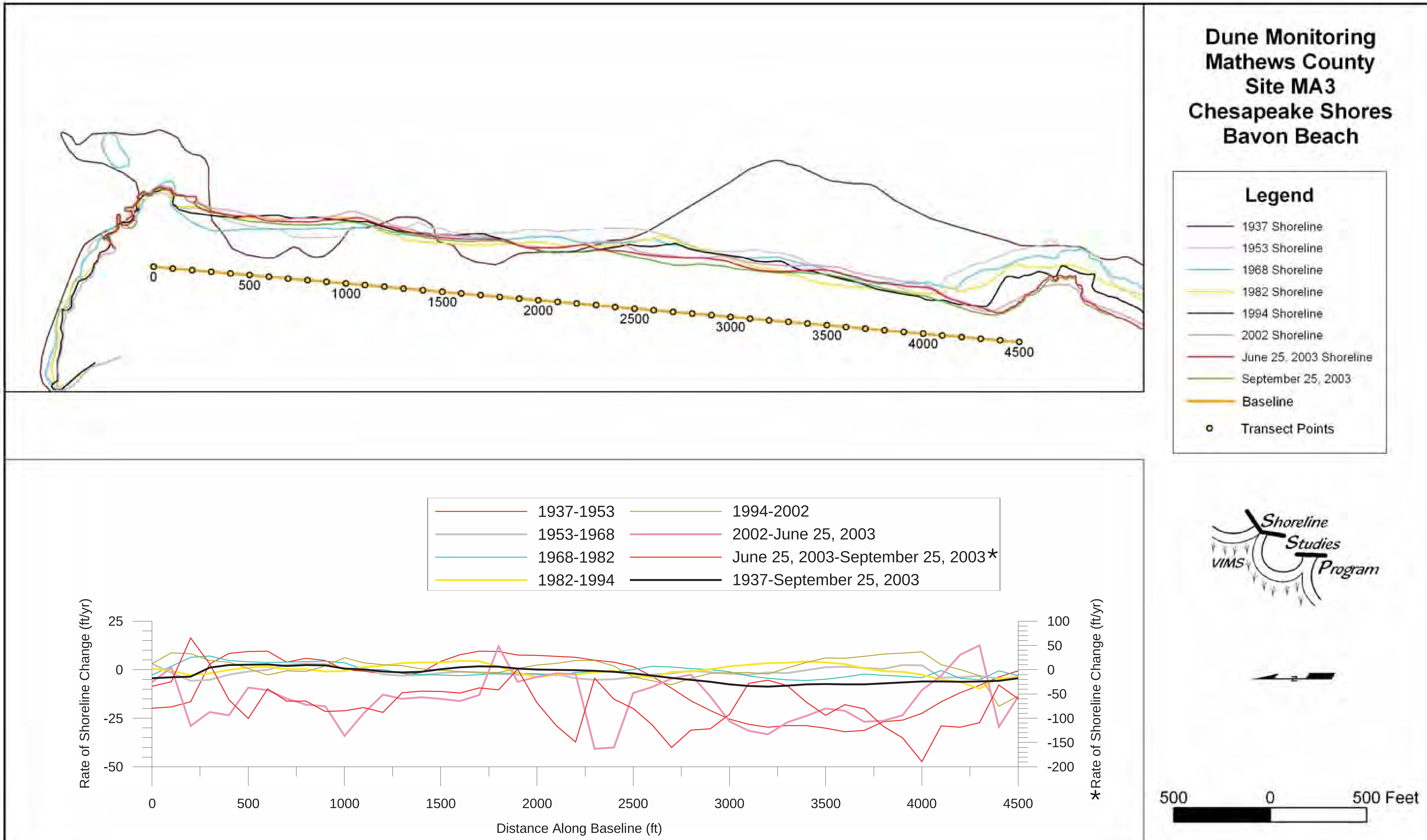


Figure 3-12. Rate of shoreline change calculated from shorelines digitized from rectified aerial photos.

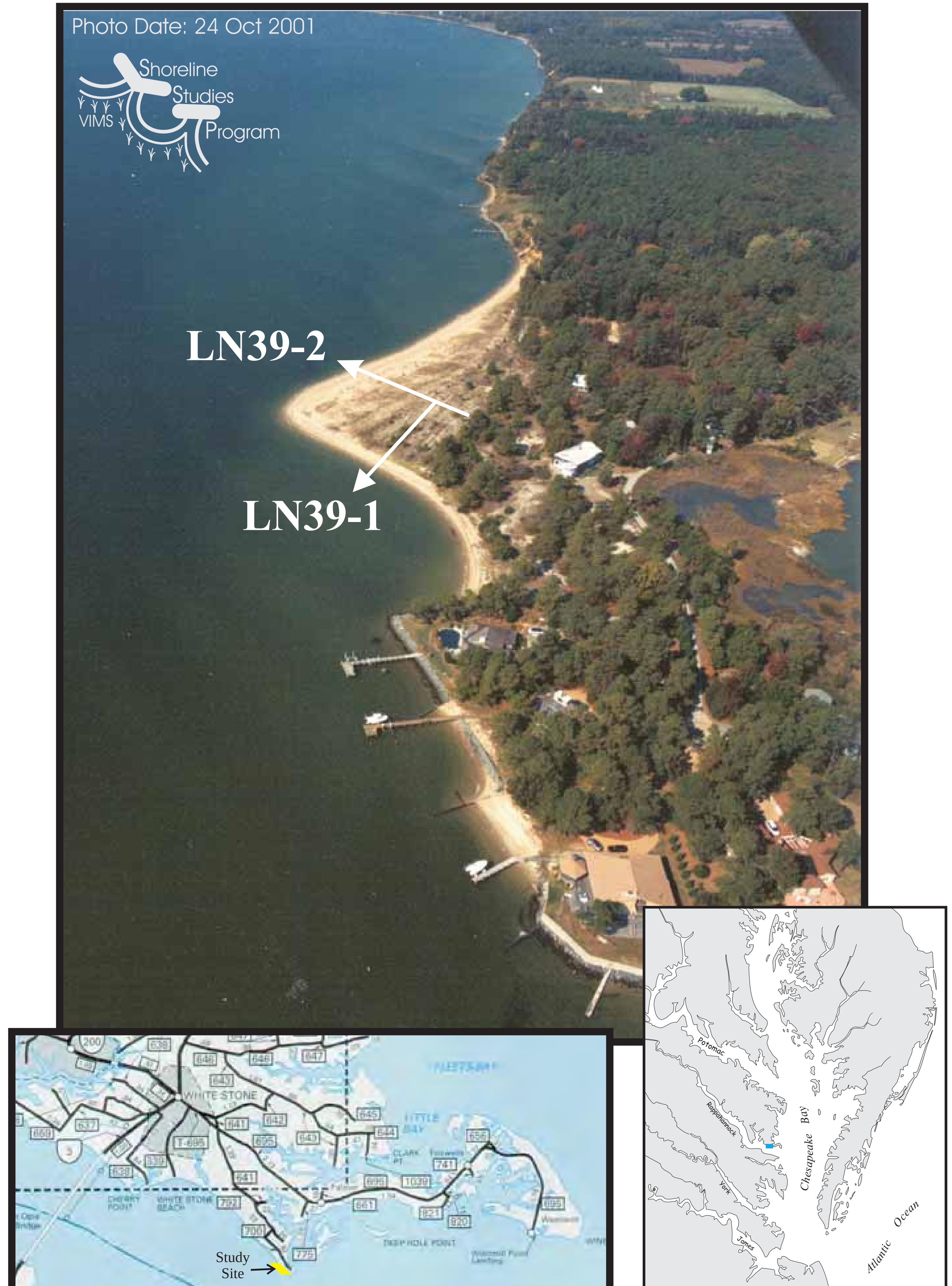


Figure 4-1. Location of site LN39 in Lancaster County with approximate position of cross-shore beach profiles.

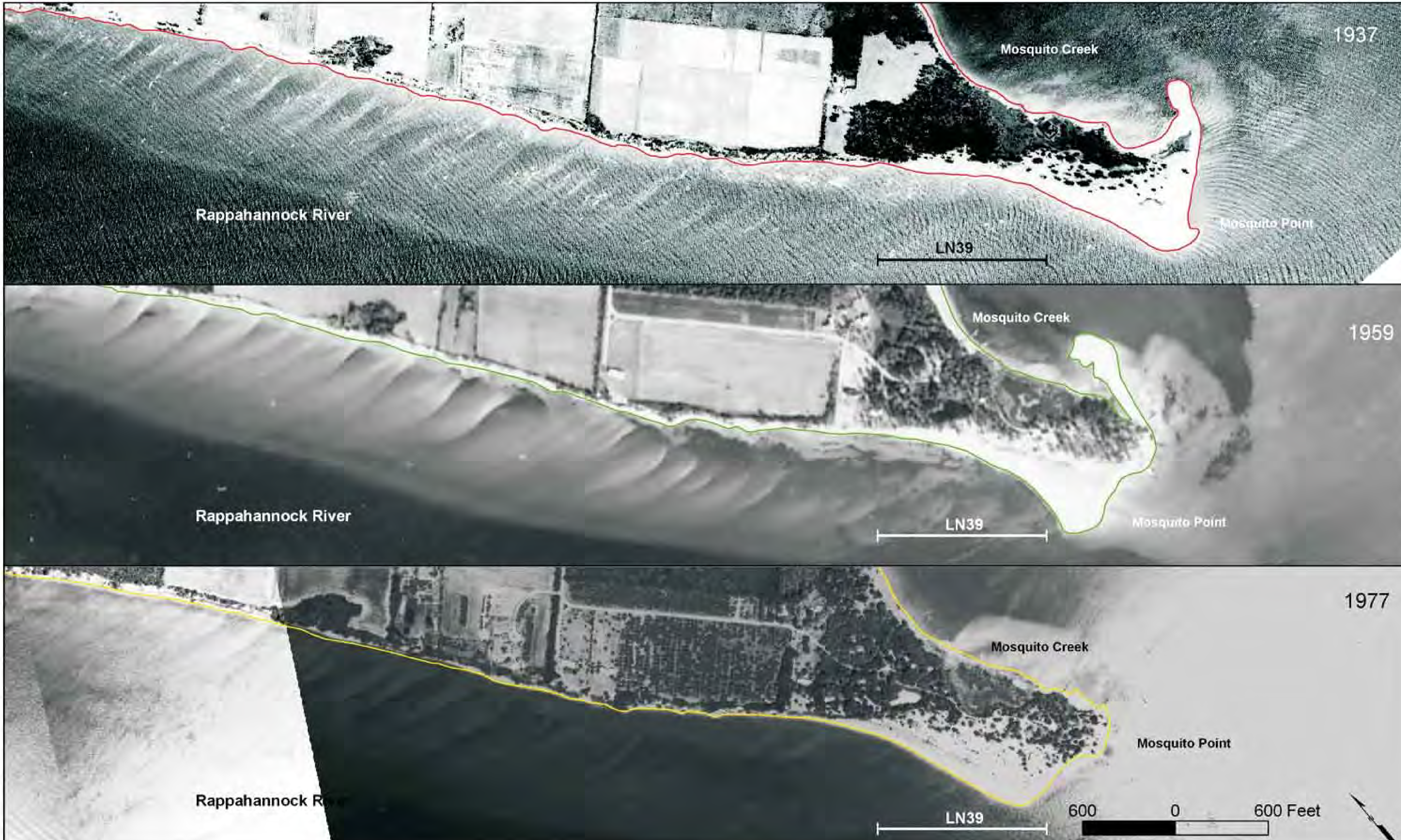


Figure 4-2-1. High-level orthorectified aerial photography of Mosquito Point coast and LN39 taken in 1937, 1959, and 1977.

Figure 4-2-2. High-level orthorectified aerial photography of Mosquito Point coast and LN39 taken in 1982, 1994, and 2002 as well as all the digitized shorelines.

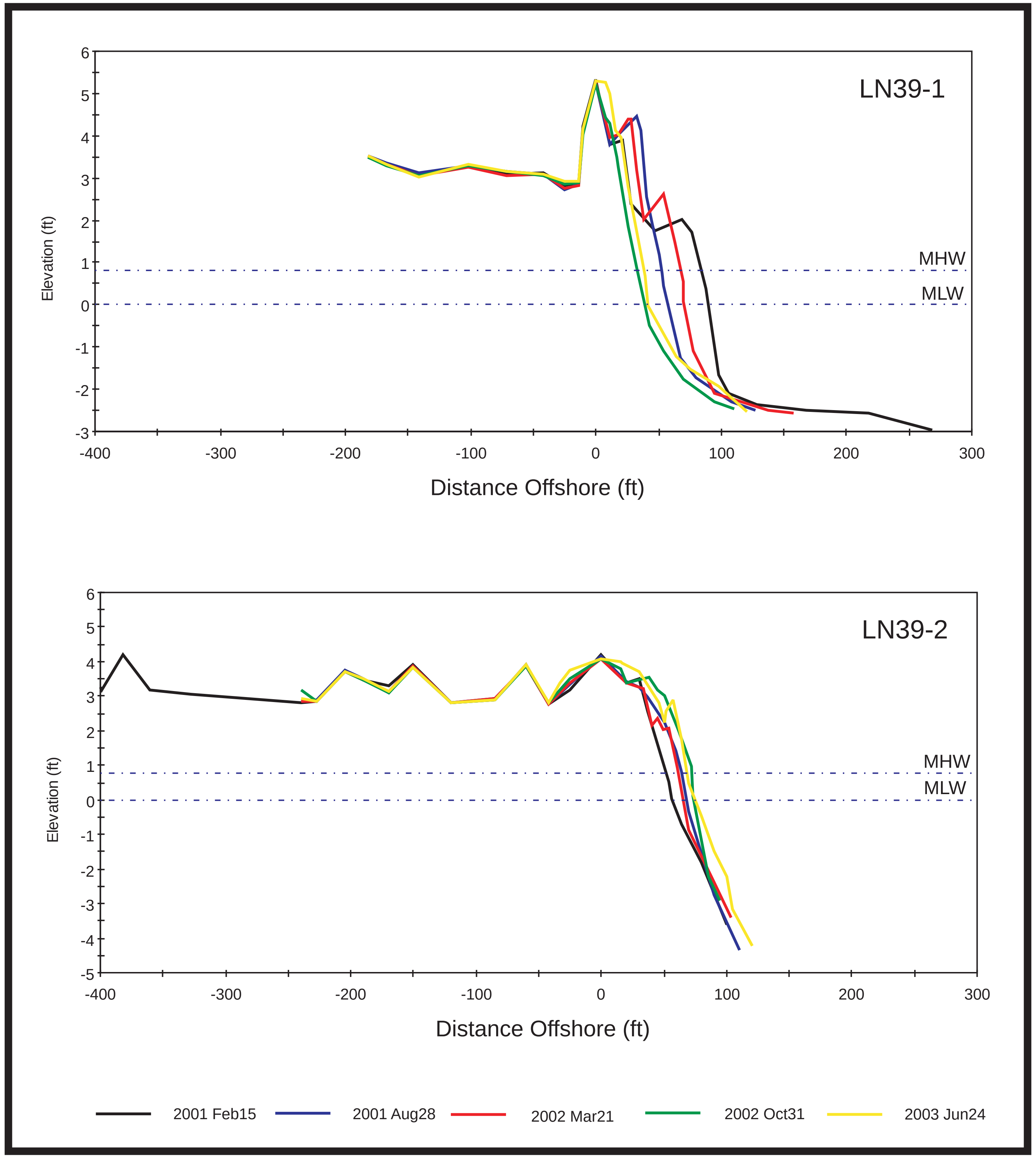


Figure 4-3. Profile plot comparisons for the two profiles at LN39 between February 2001 and June 2003.

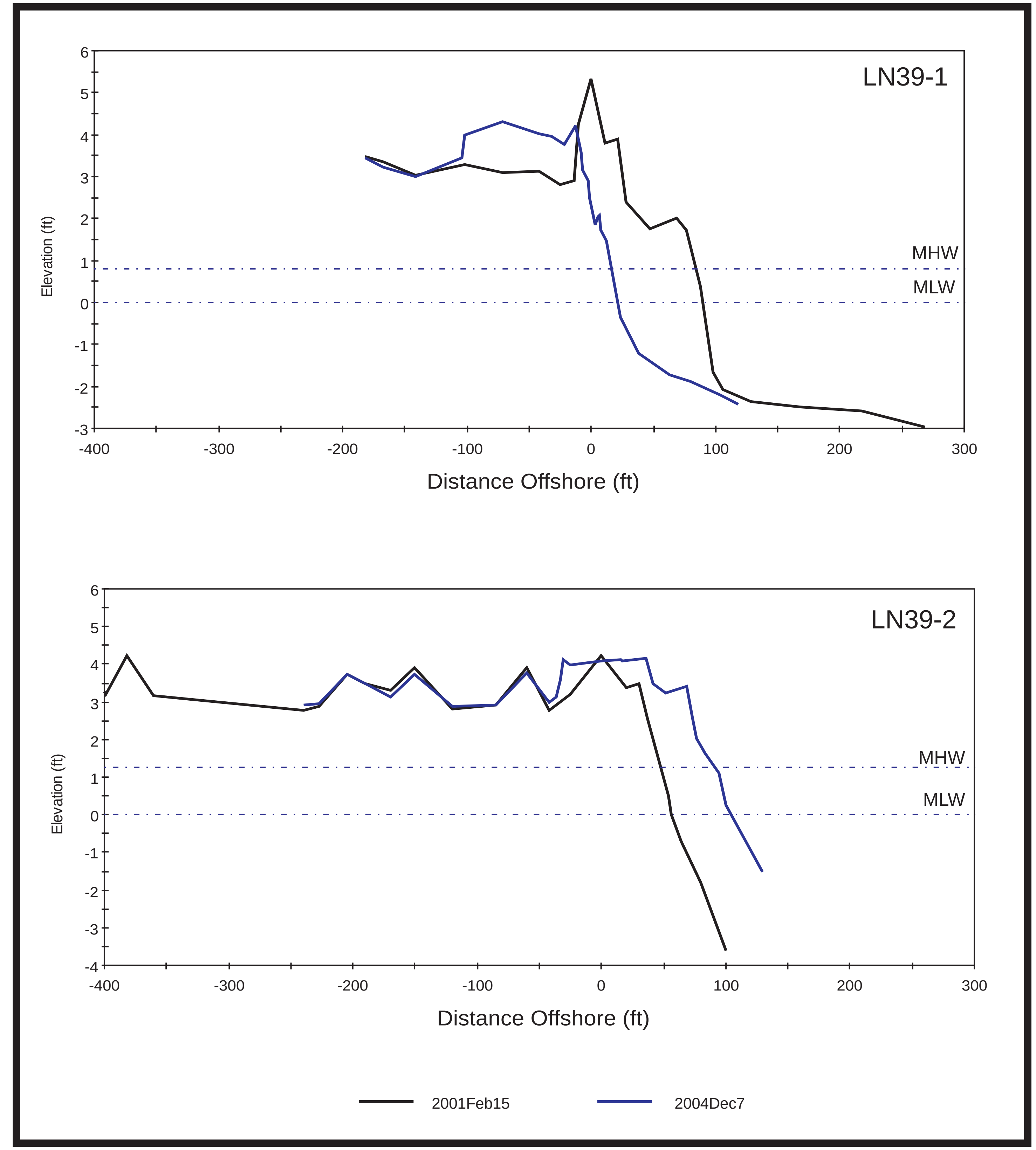


Figure 4-4. Net profile change between February 2001 and December 2004.

Figure 4-5. Recent ground photos at profile LN39-1 over the course of the monitoring program.

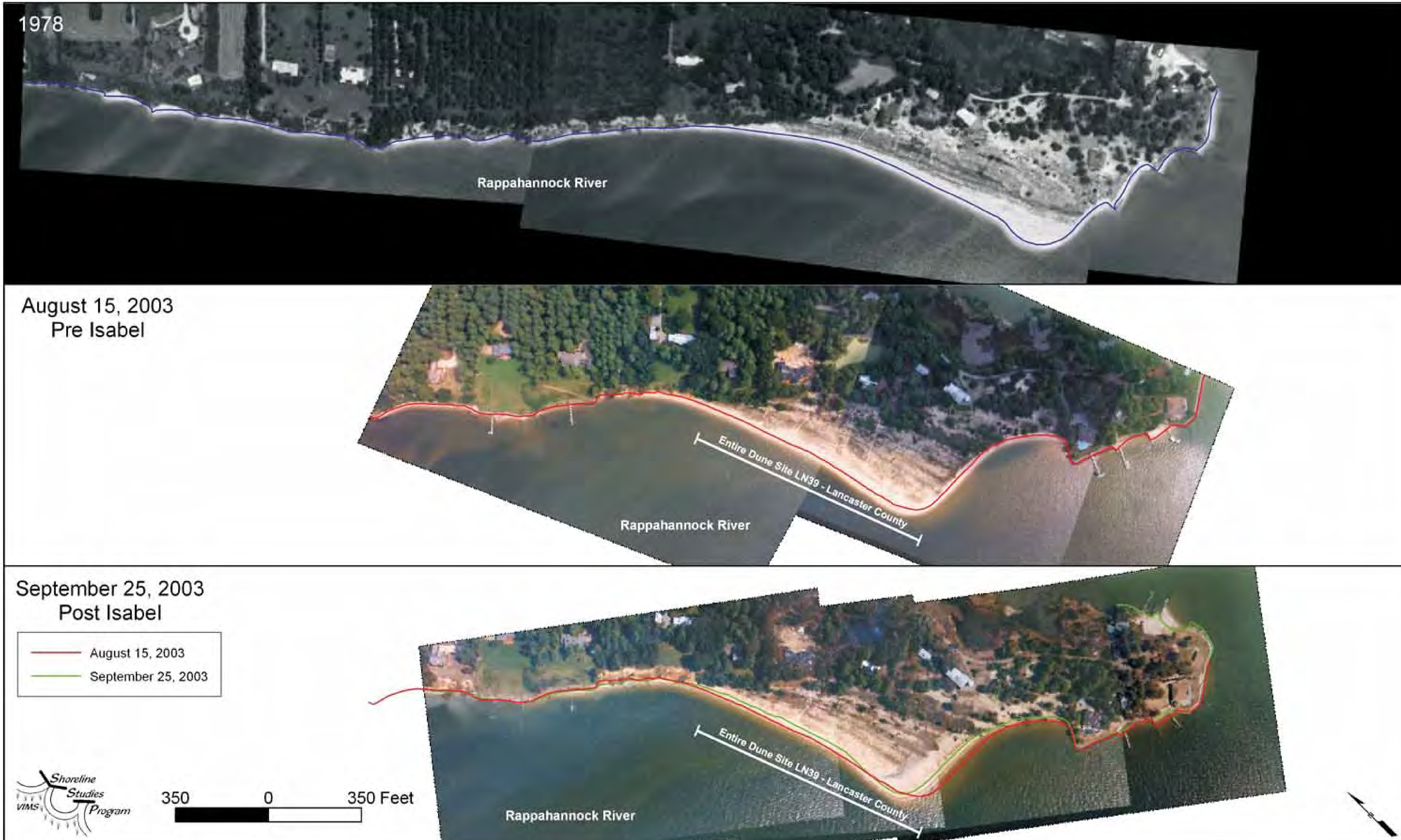


Figure 4-6. Low-level 1978, and pre and post Hurricane Isabel georectified aerial photography.

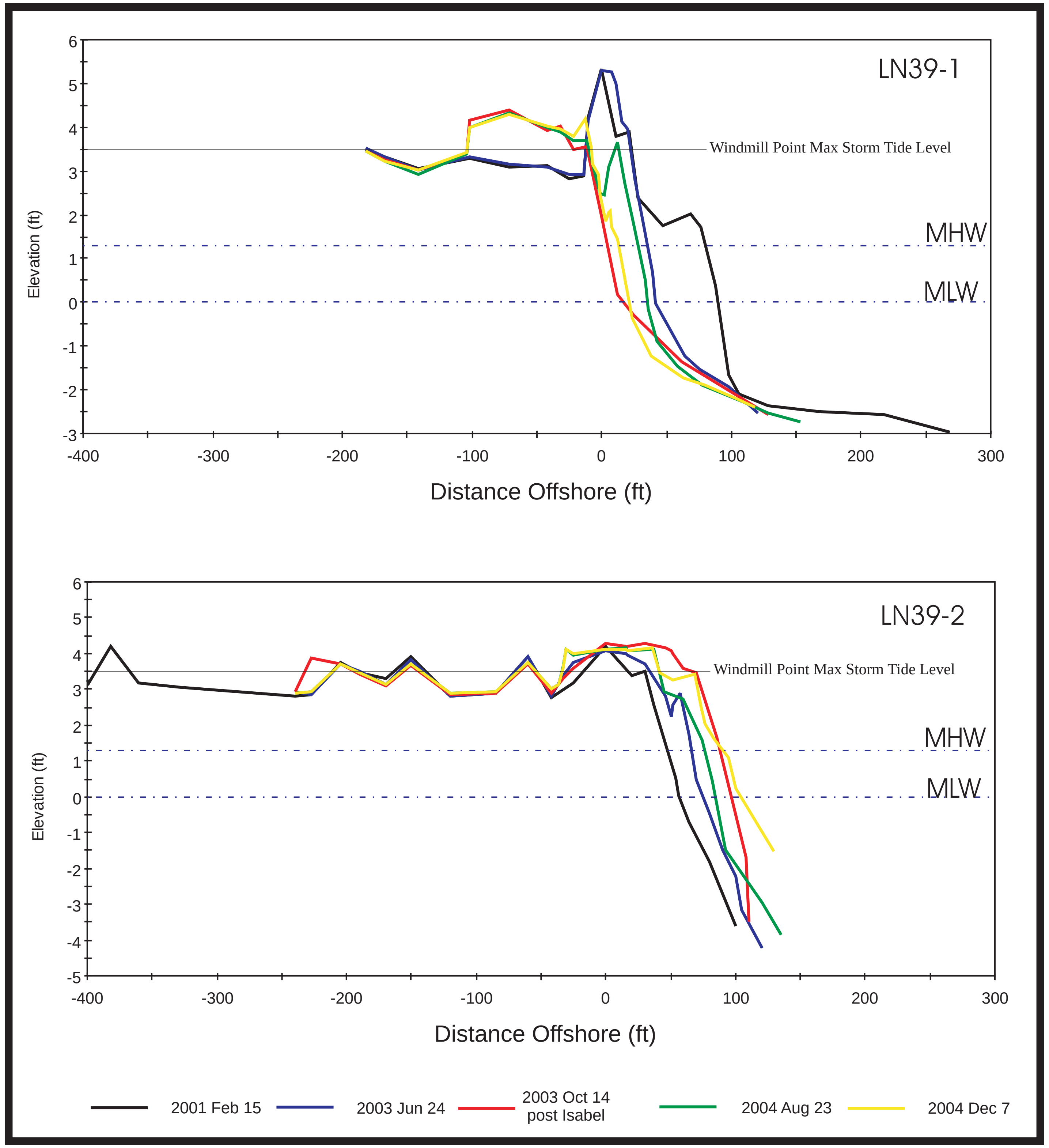
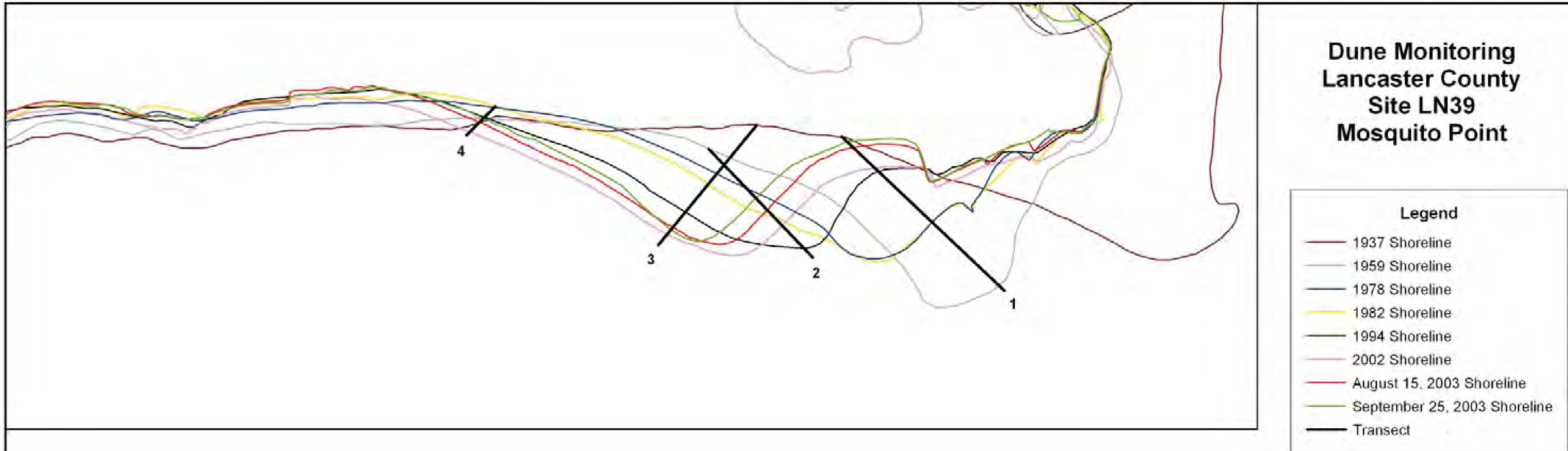


Figure 4-7. Profile plot comparisons for the two profiles at LN39 showing the first survey taken at the site, data taken before Hurricane Isabel, after the hurricane and in 2004.

Figure 4-8. Ground photos at LN39-2 taken before and after the hurricane and in 2004.

Figure 4-9. Ground photos at LN39-1 before and after the hurricane and in 2004.



Transect 4

Span	Rate (ft/yr)
1937-1959	-0.7
1959-1978	-2.4
1978-1982	-1.0
1982-1994	3.6
1994-2002	7.3
2002-Aug2003	-38.4
Aug2003-Sep2003	-80.4
1937-Sep2003	**-0.3**

Transect 3

Span	Rate (ft/yr)
1937-1959	5.5
1959-1978	3.1
1978-1982	9.2
1982-1994	8.6
1994-2002	10.1
2002-Aug2003	-26.8
Aug2003-Sep2003	55.4
1937-Sep2003	**5.8**

Transect 2

Span	Rate (ft/yr)
1959-1978	8.2
1978-1982	38.8
1982-1994	10.2
1994-2002	-11.0
2002-Aug2003	-62.3
Aug2003-Sep2003	-229.7
1959-Sep2003	**5.4**

Transect 1

Span	Rate (ft/yr)
1959-1978	-13.8
1978-1982	0.6
1982-1994	-17.4
1994-2002	-1.9
2002-Aug2003	-82.9
Aug2003-Sep2003	-114.8
1959-Sep2003	**-13.4**

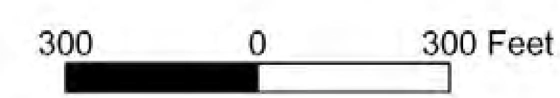


Figure 4-10. Rate of shoreline change calculated from shorelines digitized from rectified aerial photos.

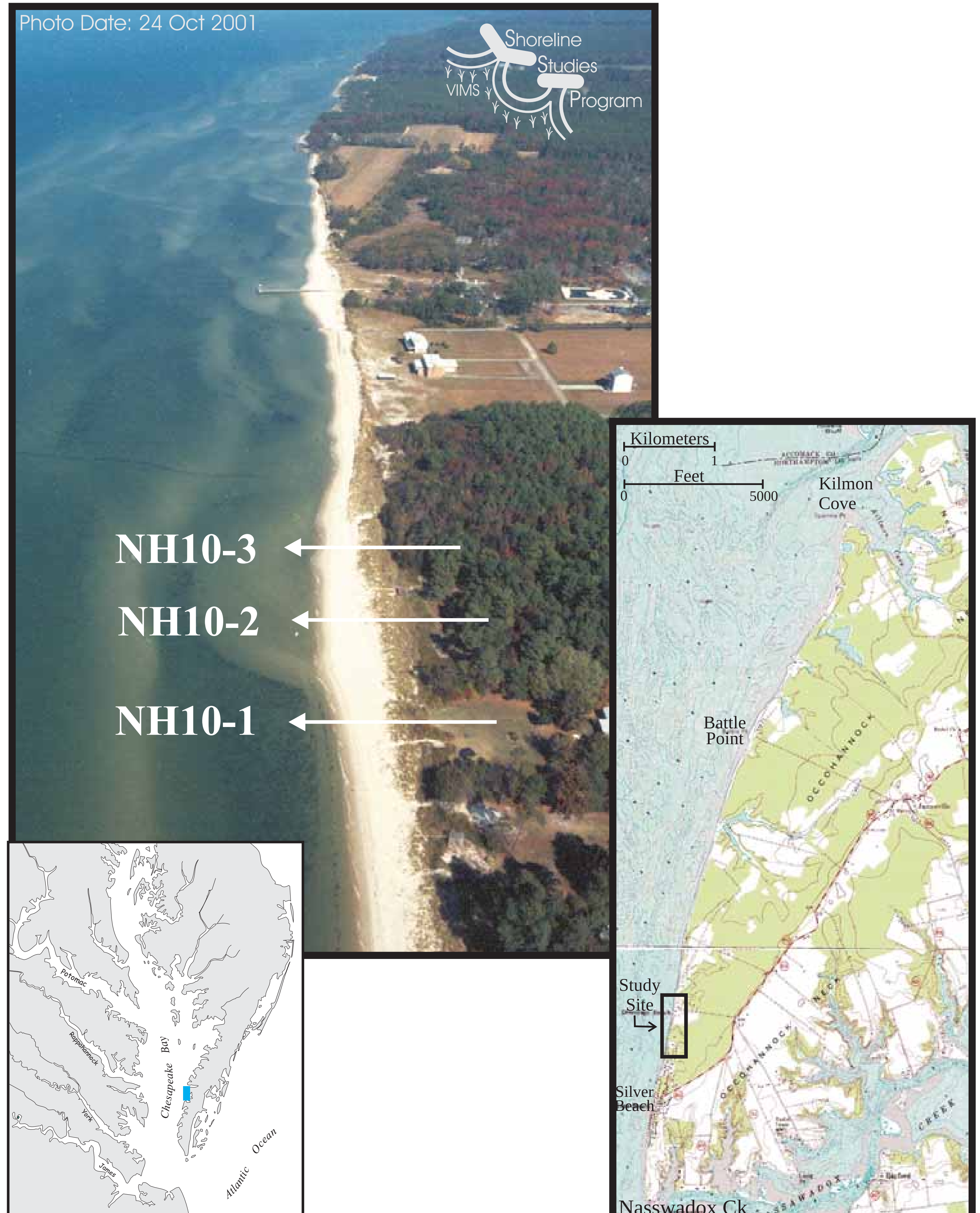


Figure 5-1. Location of site NH10 in Northampton County with approximate position of cross-shore beach profiles

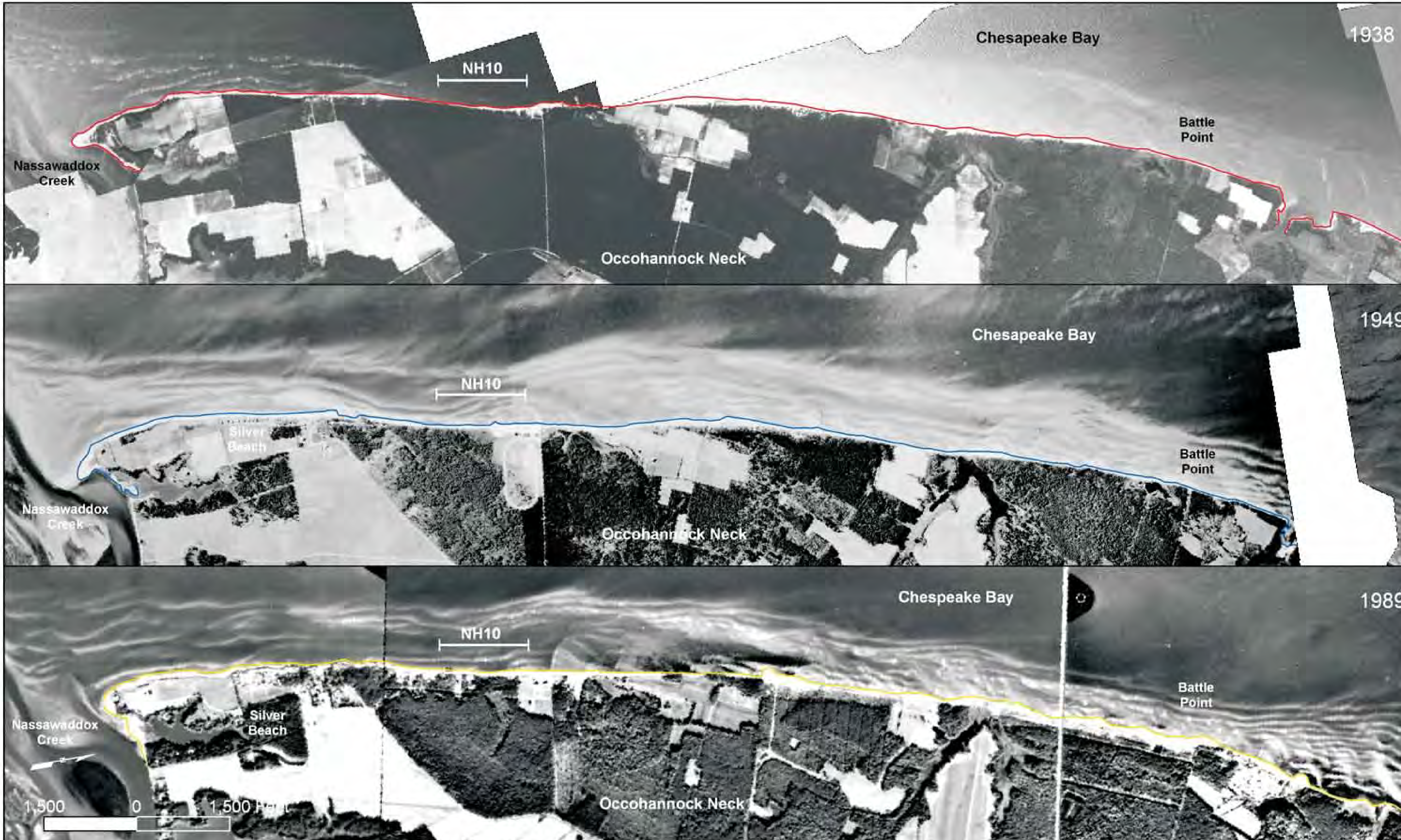


Figure 5-2-1. High-level orthorectified aerial photography of Occohannock Neck and NH10 taken in 1938, 1949, and 1989.

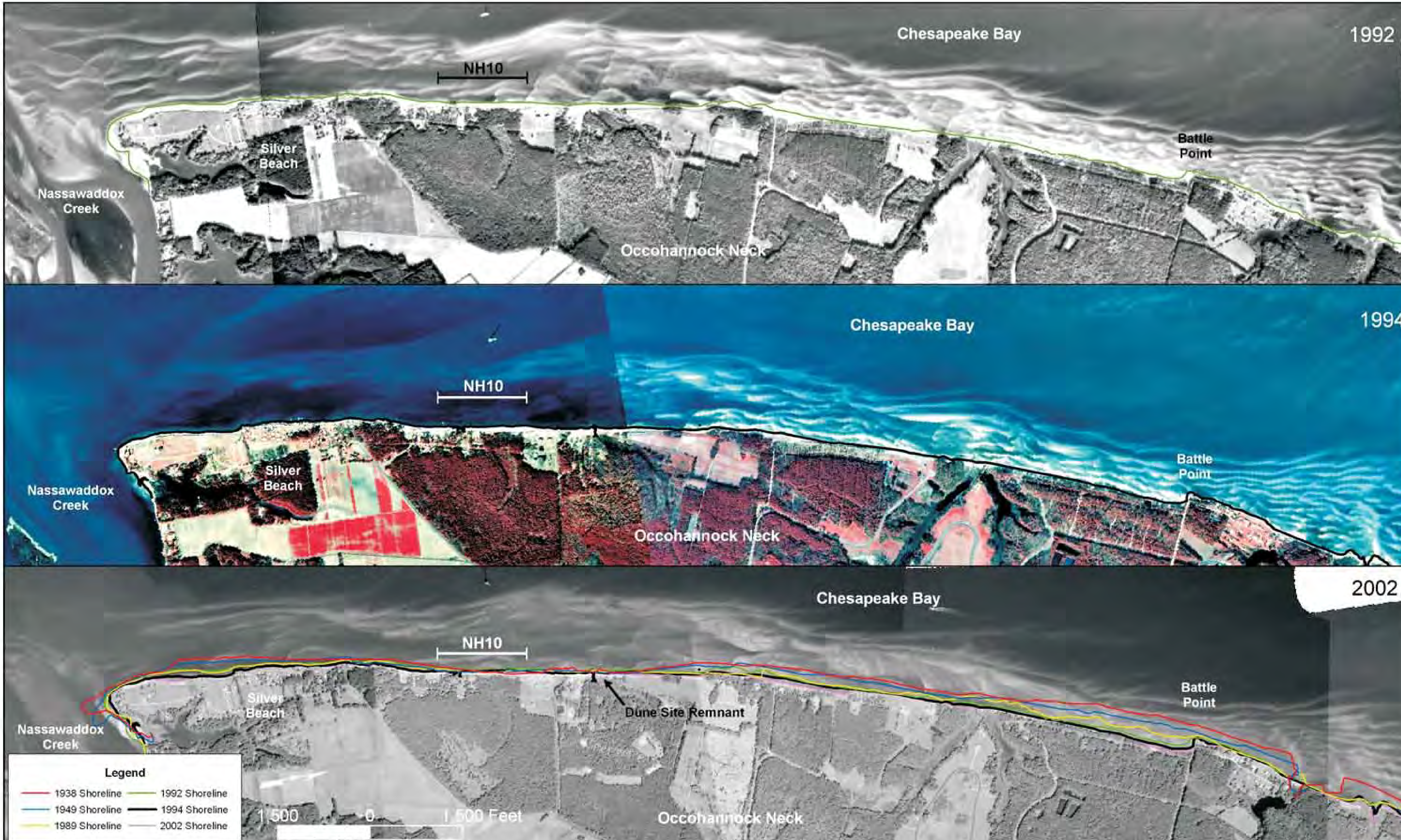


Figure 5-2-2. High-level orthorectified aerial photography of Occohannock Neck and NH10 taken in 1992, 1994, and 2002 as well as all the digitized shorelines.

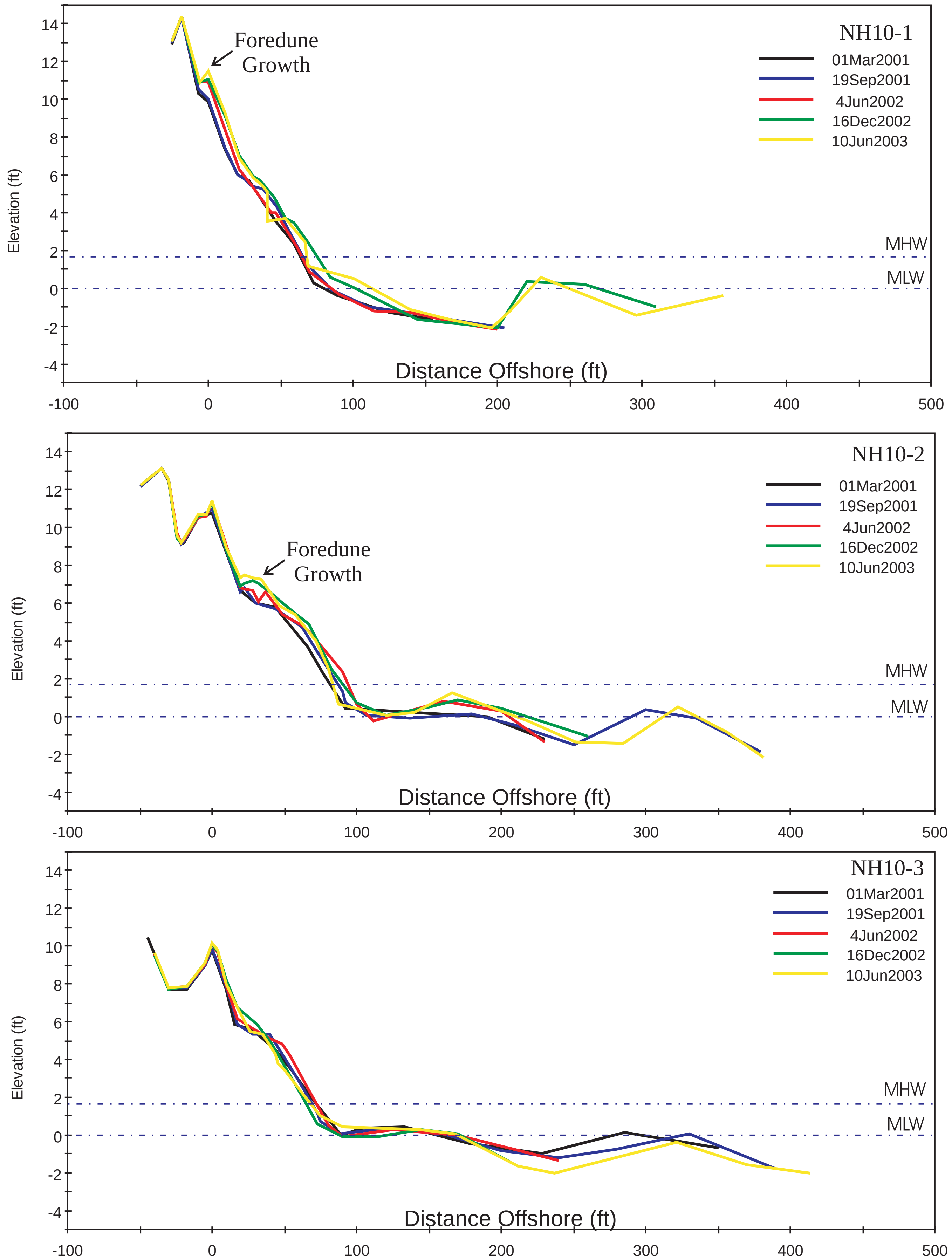


Figure 5-3. Profile plot comparisons for the three profiles at NH10 between March 2001 and June 2003.

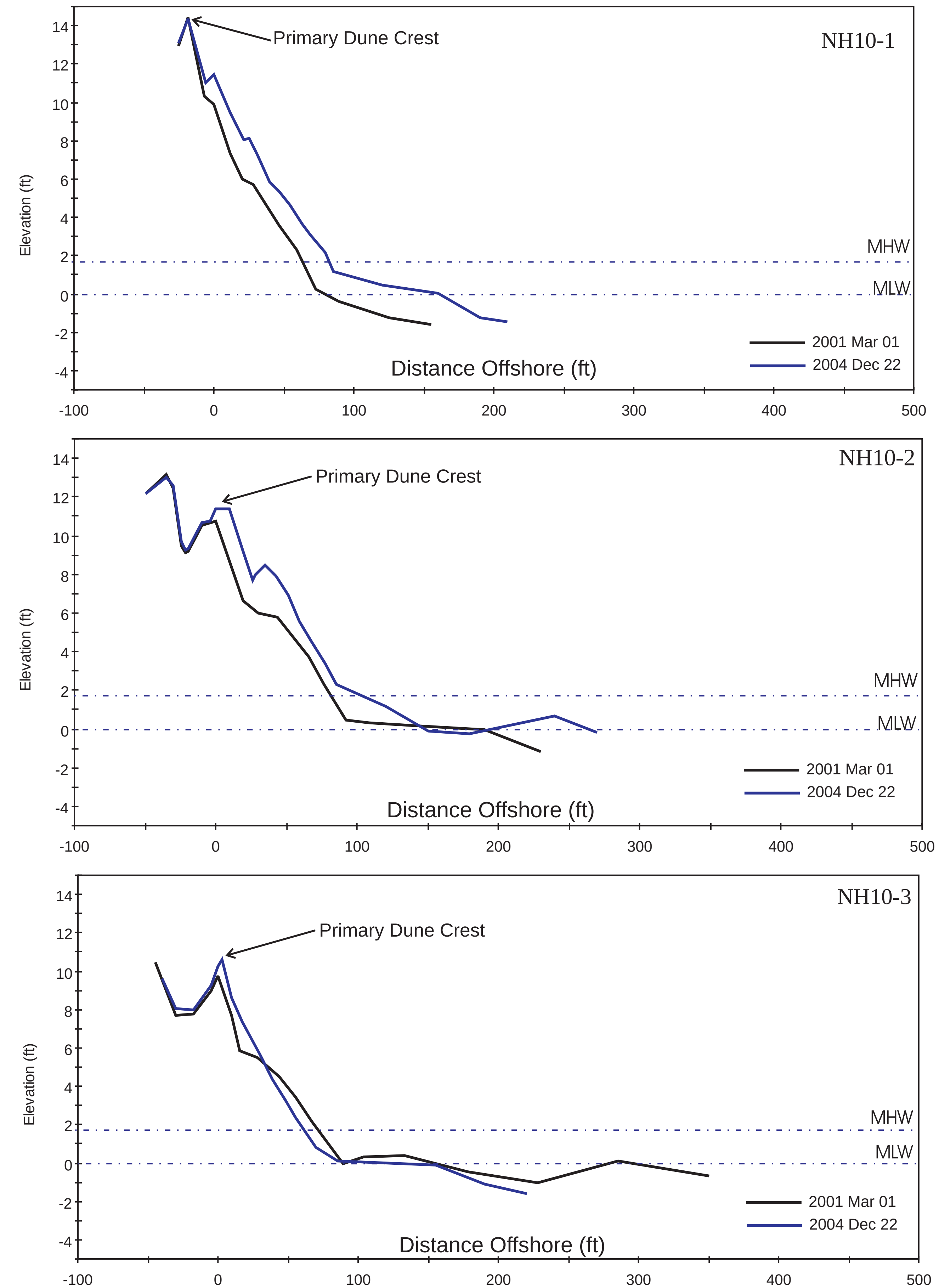
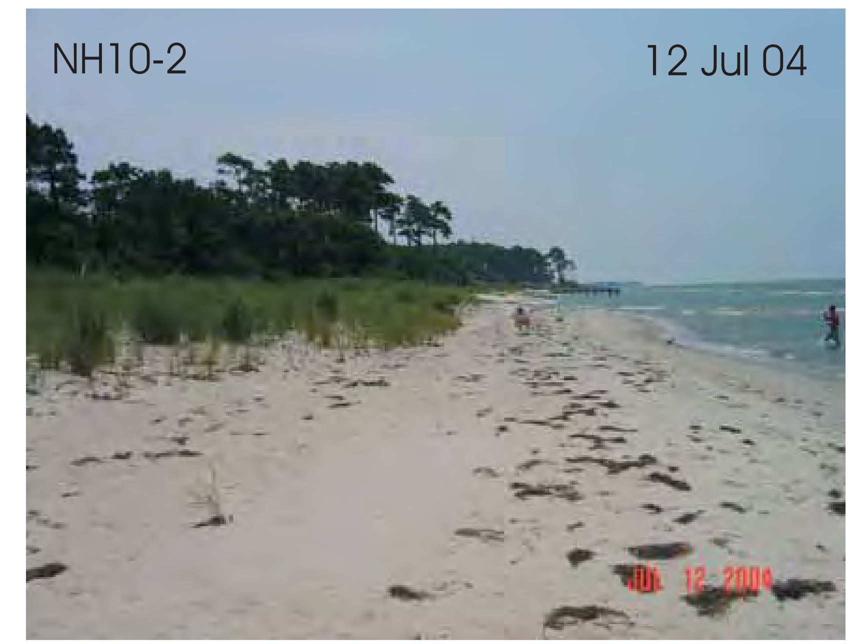


Figure 5-4. Net profile change at NH10 between March 2001 and December 2004.



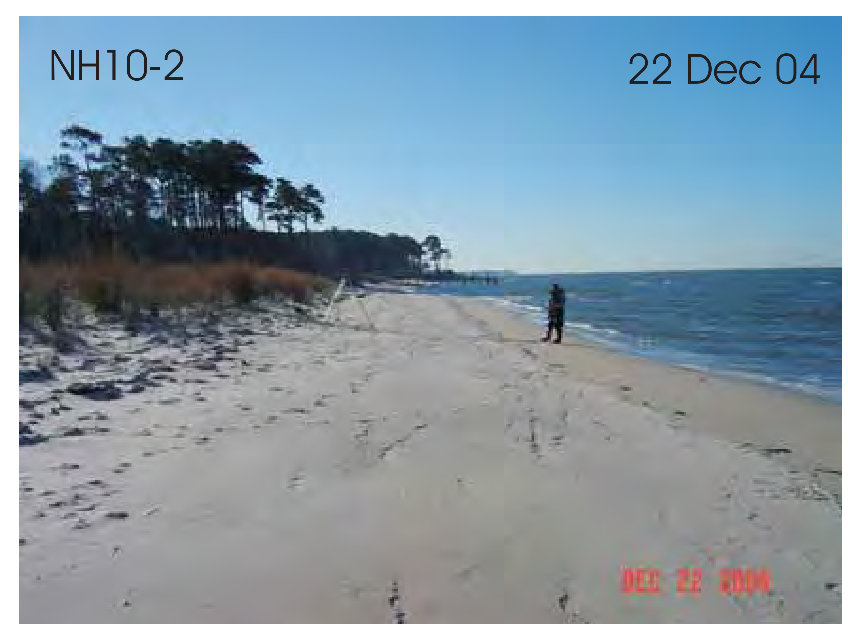


Figure 5-5. Recent ground photos at profile NH10-2 over the course of the monitoring program.

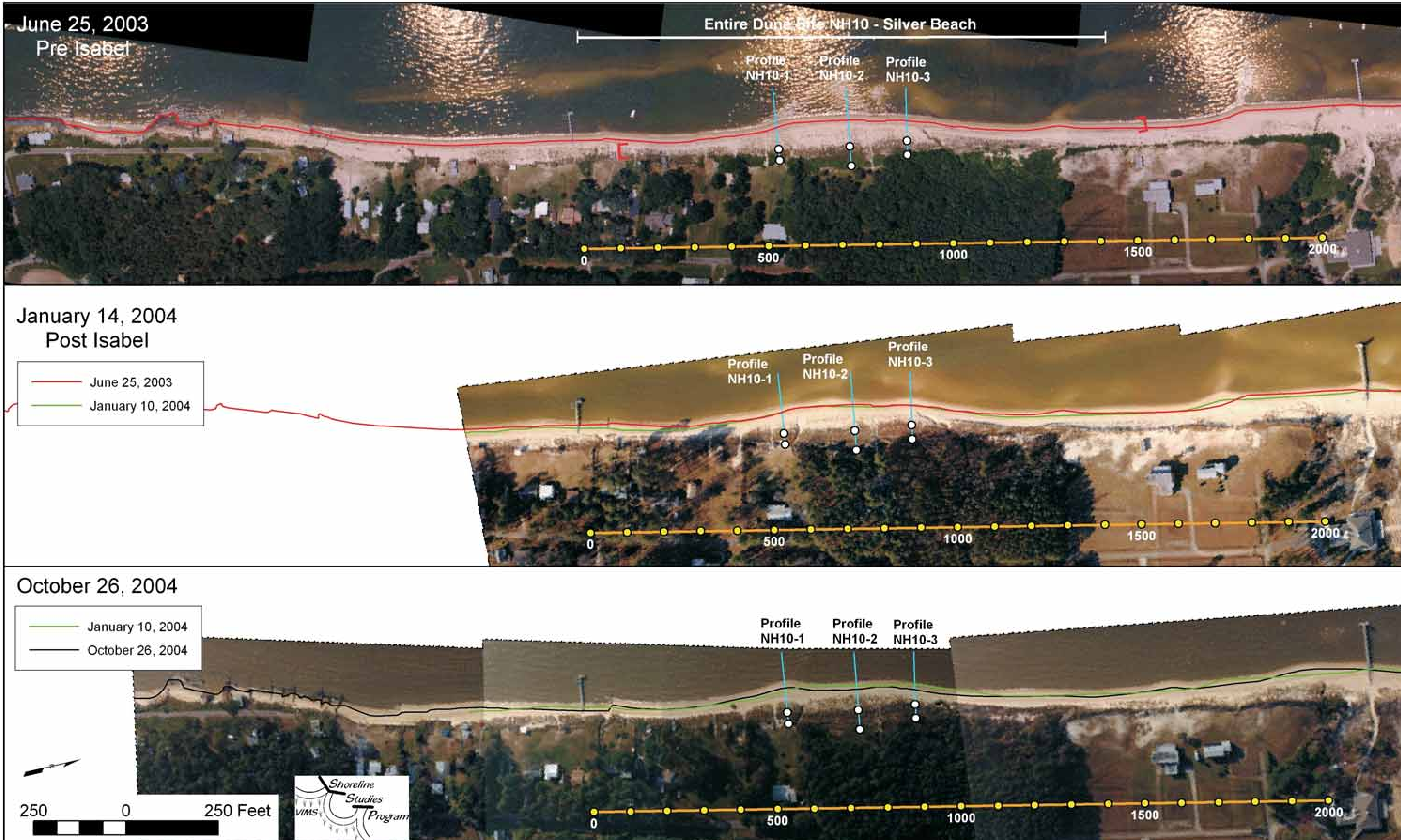


Figure 5-6. Low-level pre and post Hurricane Isabel and October 2004 georectified aerial photography.

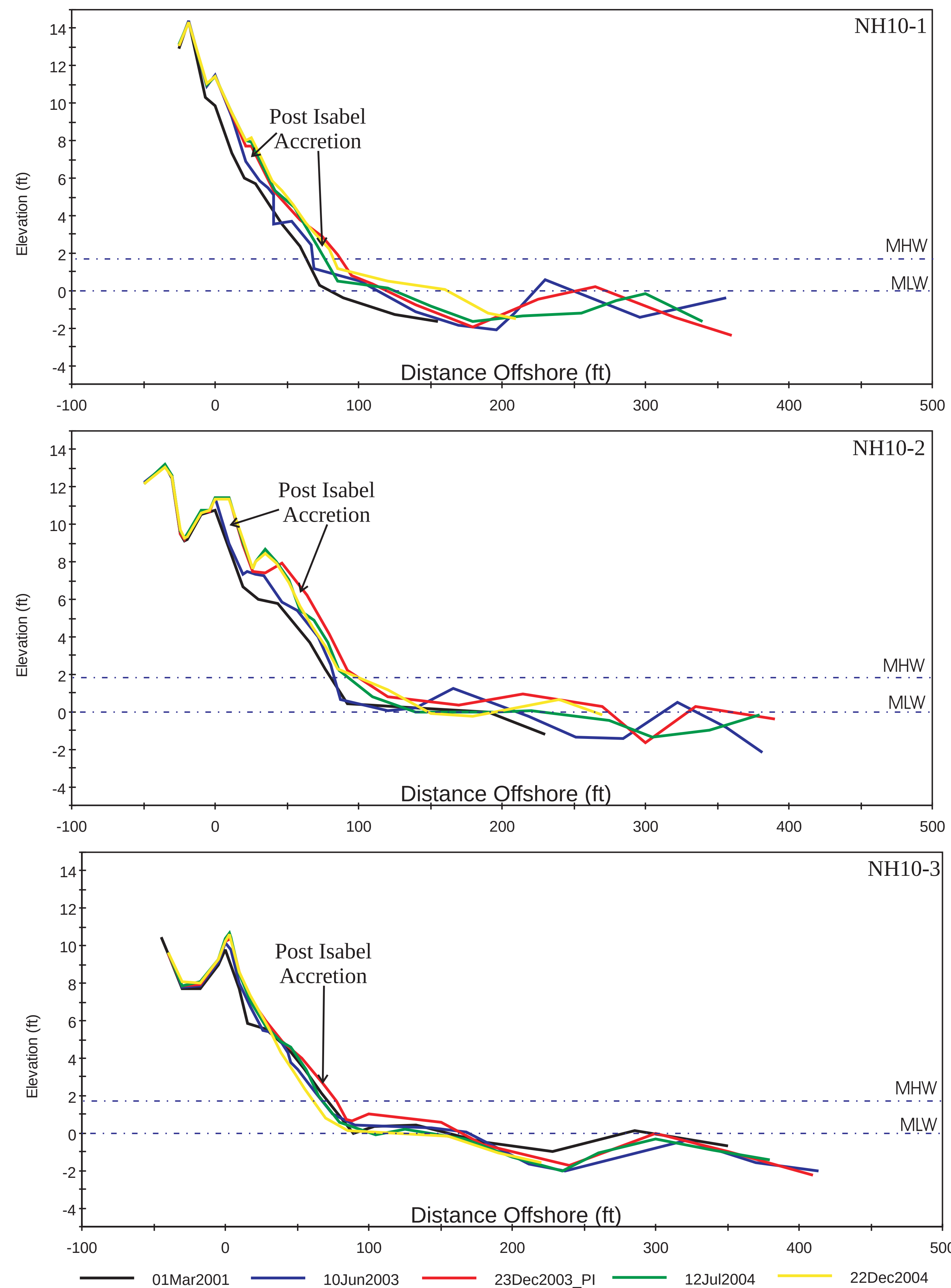


Figure 5-7. Profile plot comparisons for the three profiles at NH10 showing the first survey taken at the site in March 2001, data taken before and after Hurricane Isabel and in 2004.

Figure 5-8. Ground photos at NH10-1 and 10-3 before and after the hurricane and in 2004.

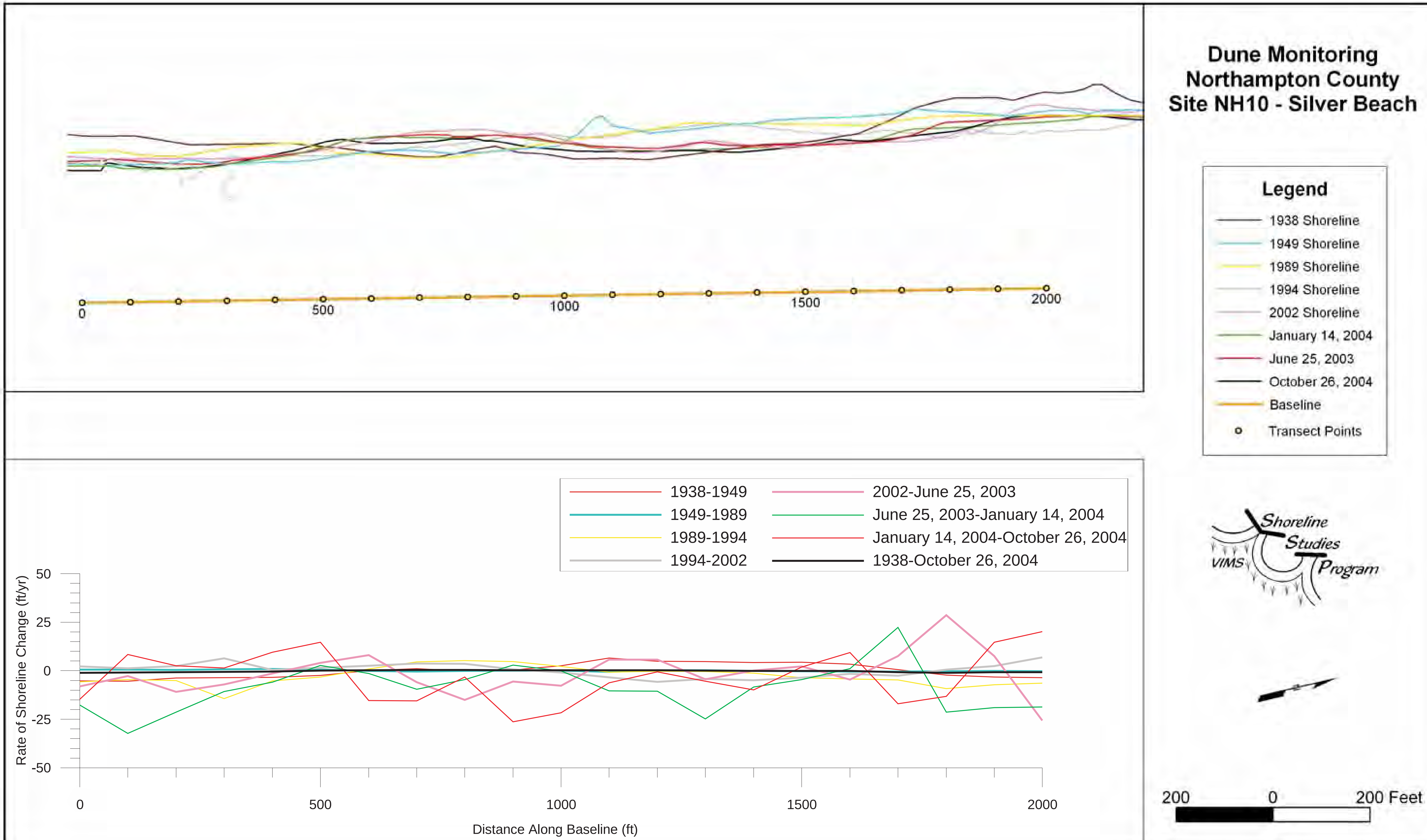


Figure 5-9. Rate of shoreline change calculated from shorelines digitized from rectified aerial photos.

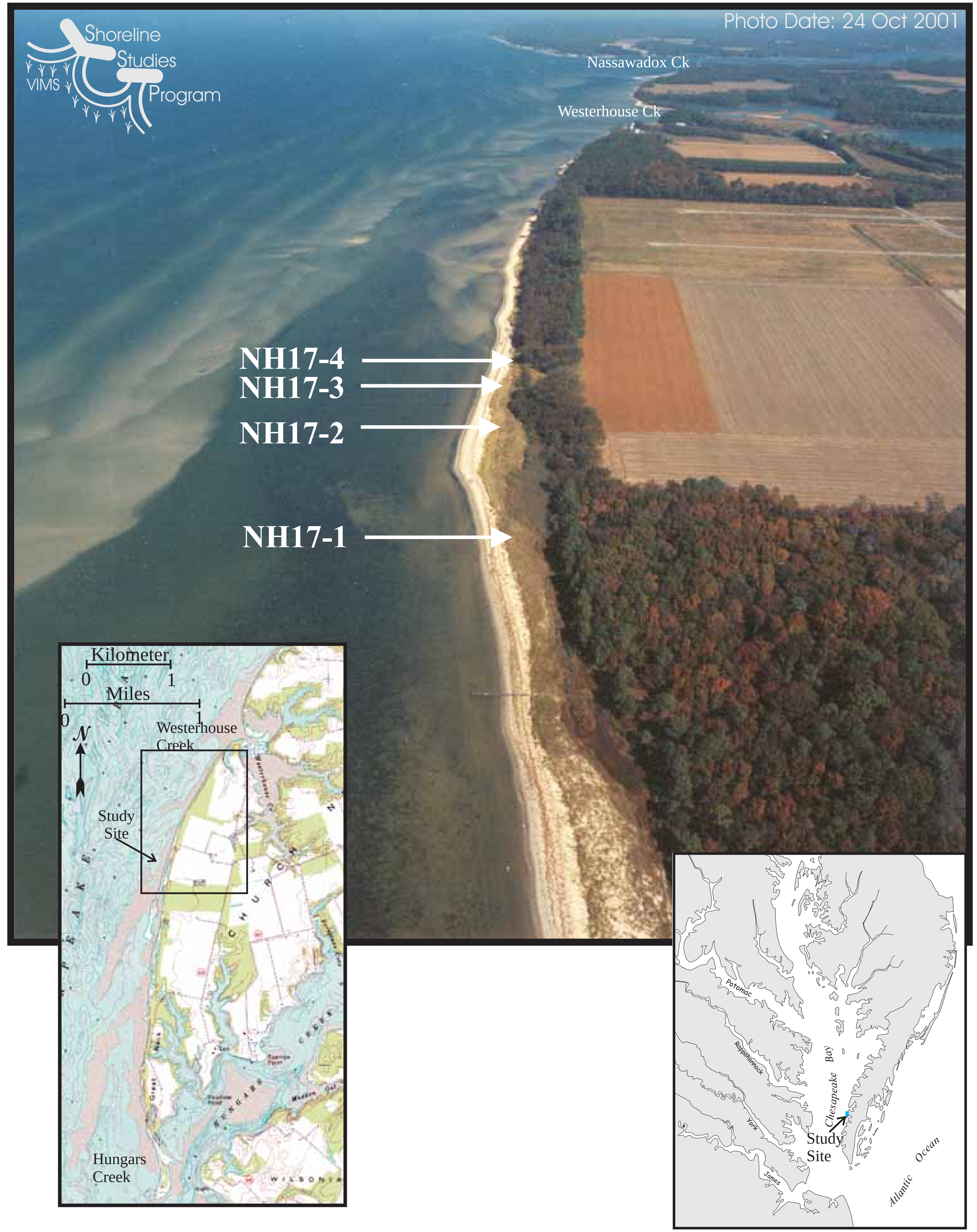


Figure 6-1. Location of site NH17 in Northampton County with approximate position of cross-shore beach profiles.

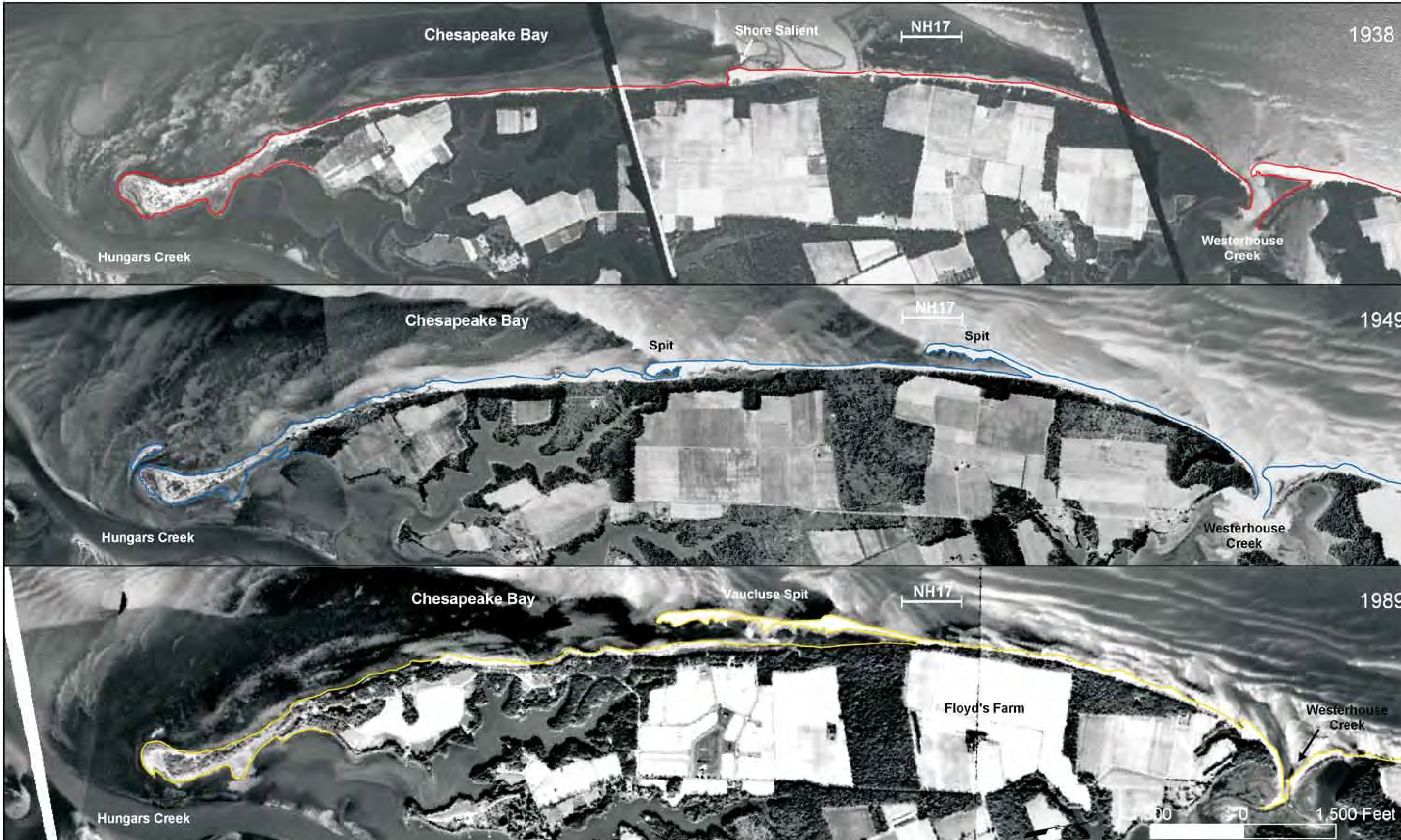


Figure 6-2-1. High-level orthorectified aerial photography of Floyd's Farm and NH17 taken in 1938, 1949, and 1989.

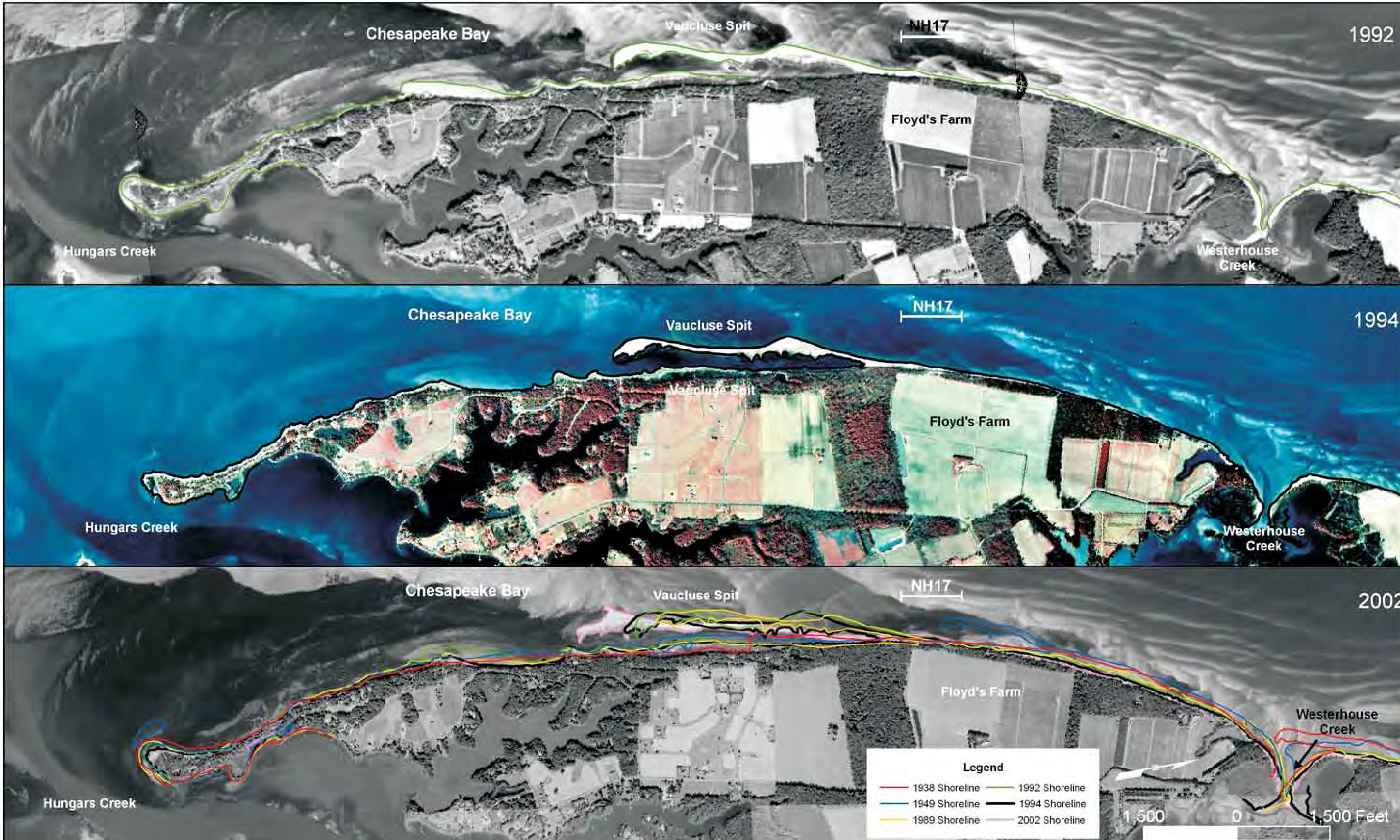


Figure 6-2-2. High-level orthorectified aerial photography of Floyd's Farm and NH17 taken in 1992, 1994, and 2002 as well as all the digitized shorelines.

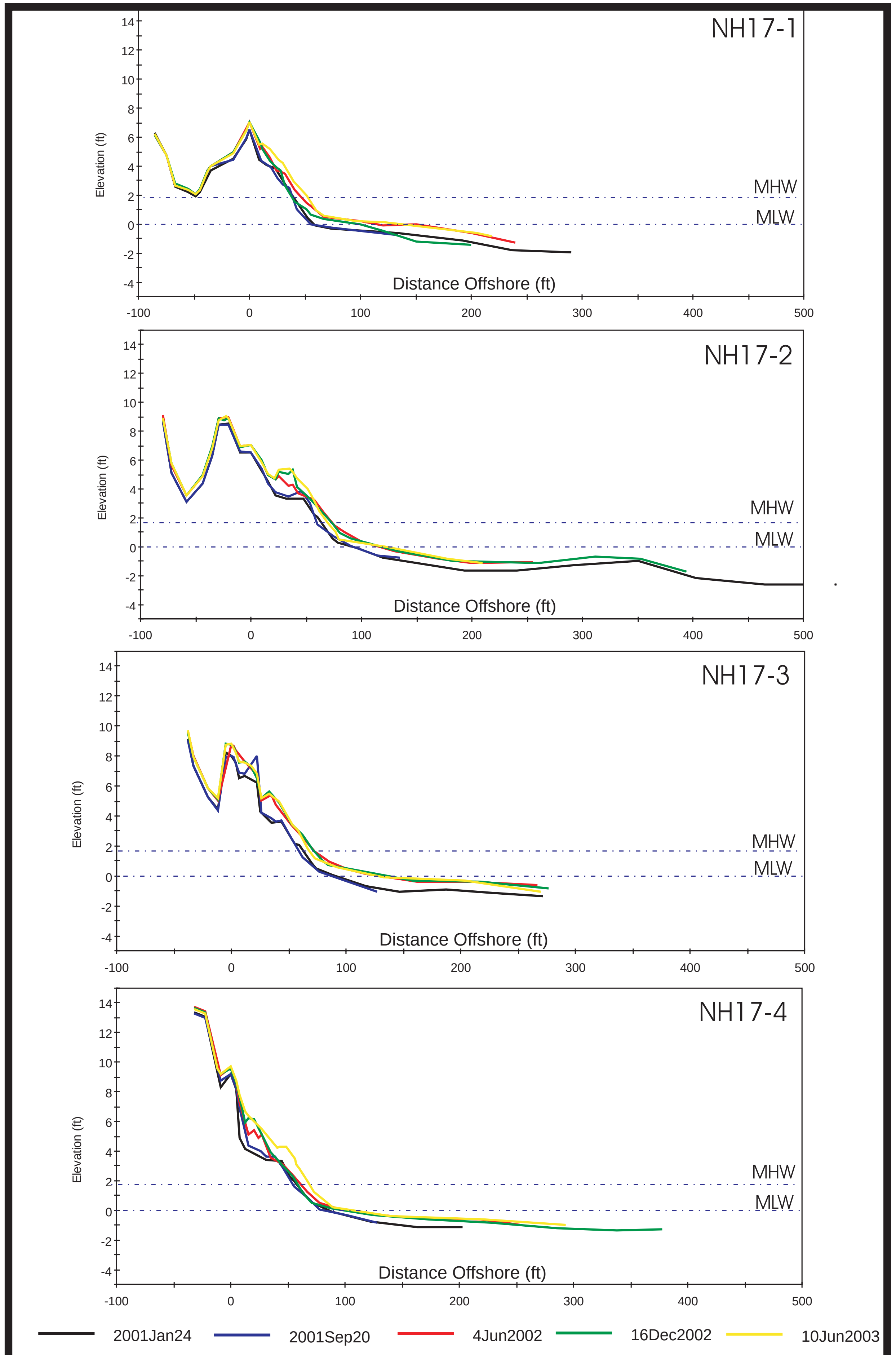


Figure 6-3. Profile plot comparisons for the three profiles at NH17 between January 2001 and June 2003.

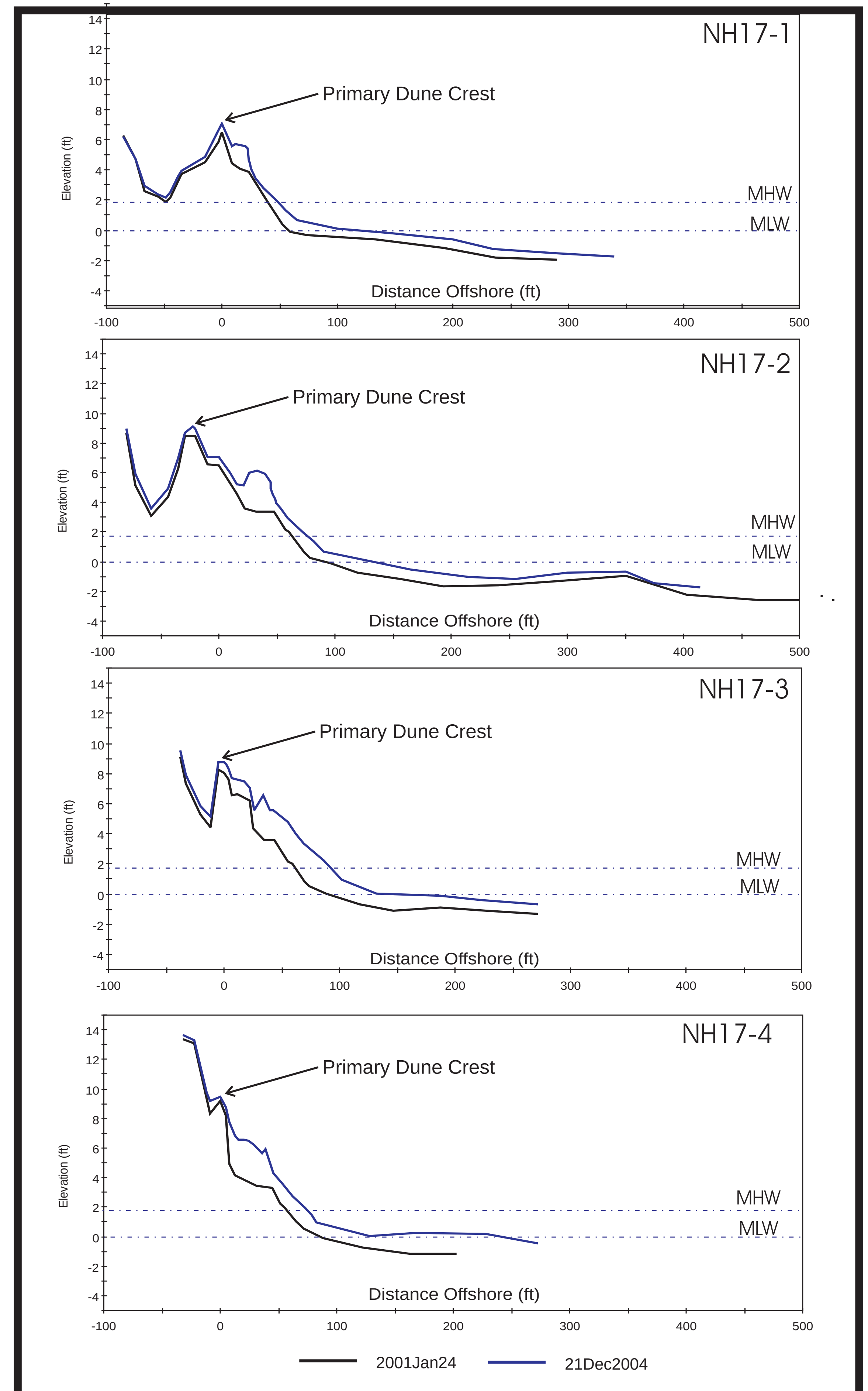


Figure 6-4. Net profile change at NH17 between January 2001 and December 2004.

Figure 6-5. Recent ground photos at profile NH17-1 over the course of the monitoring program.

Figure 6-6. Low-level pre and post Hurricane Isabel and October 2004 georectified aerial photography.

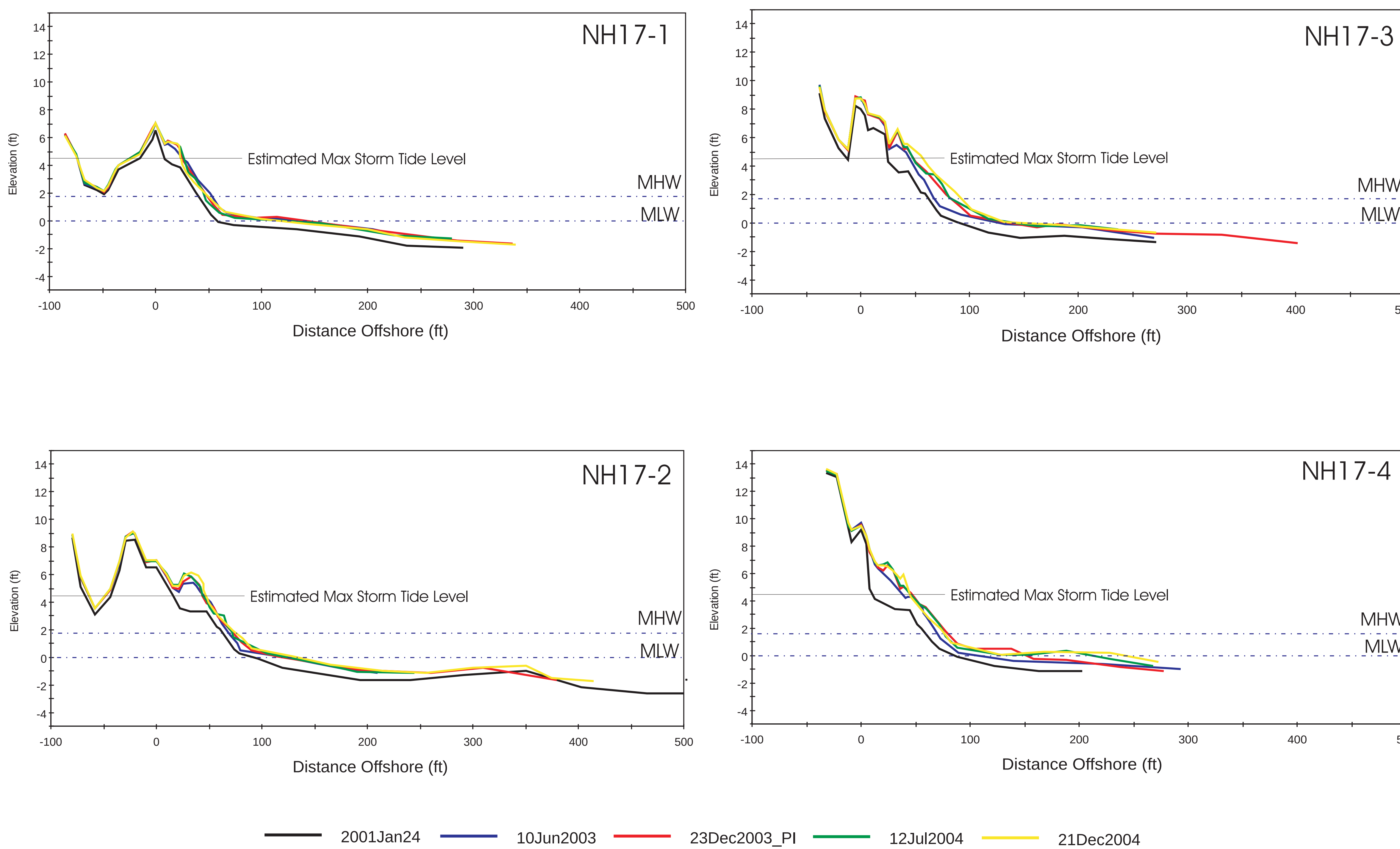


Figure 6-7. Profile plot comparisons for the four profiles at NH17 showing the first survey taken at the site in January 2001, the data taken before and after the hurricane, and in 2004.

Figure 6-8. Ground photos at NH17-2 and 17-4 before and after the Hurricane and in 2004.

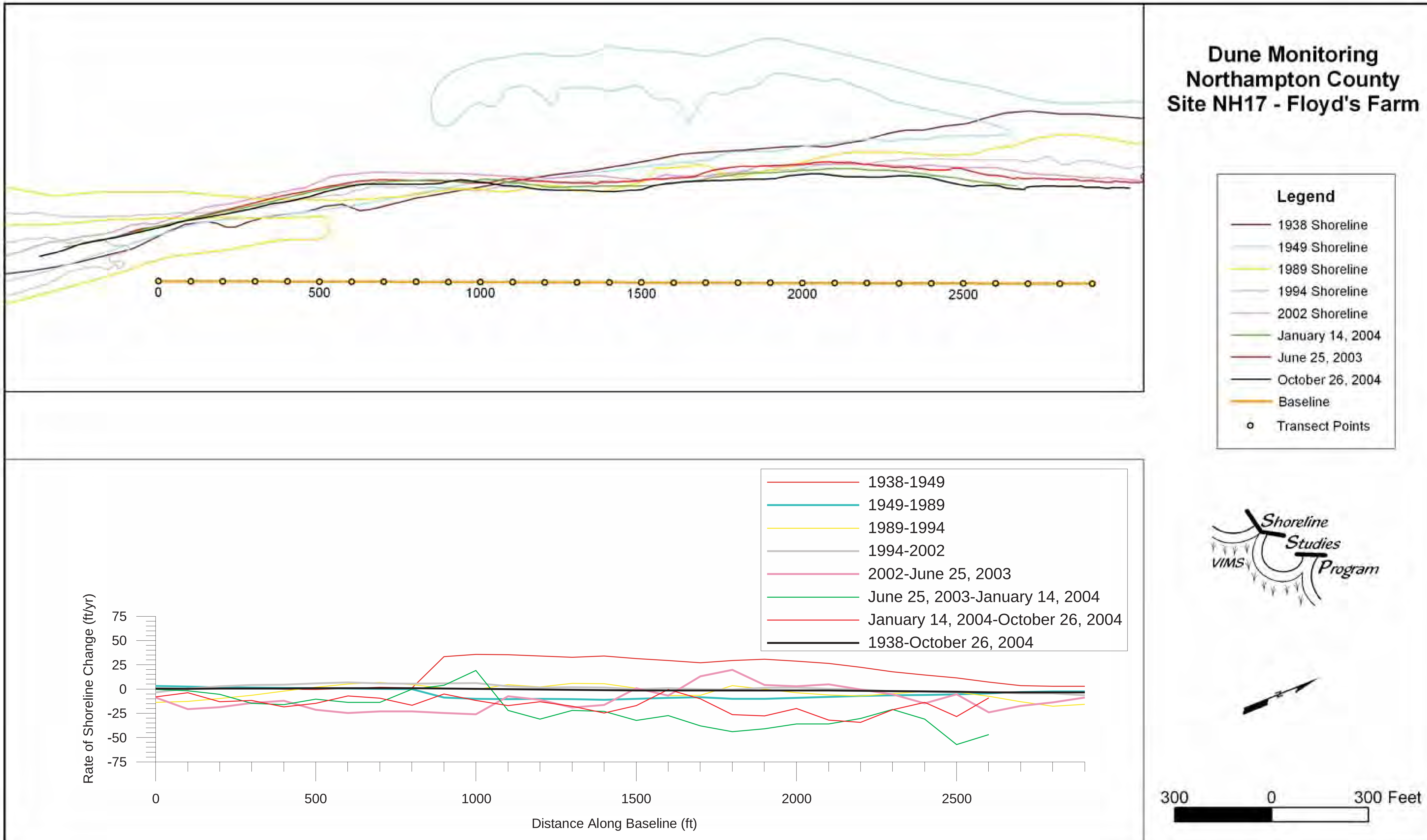


Figure 6-9. Rate of shoreline change calculated from shorelines digitized from rectified aerial photos.

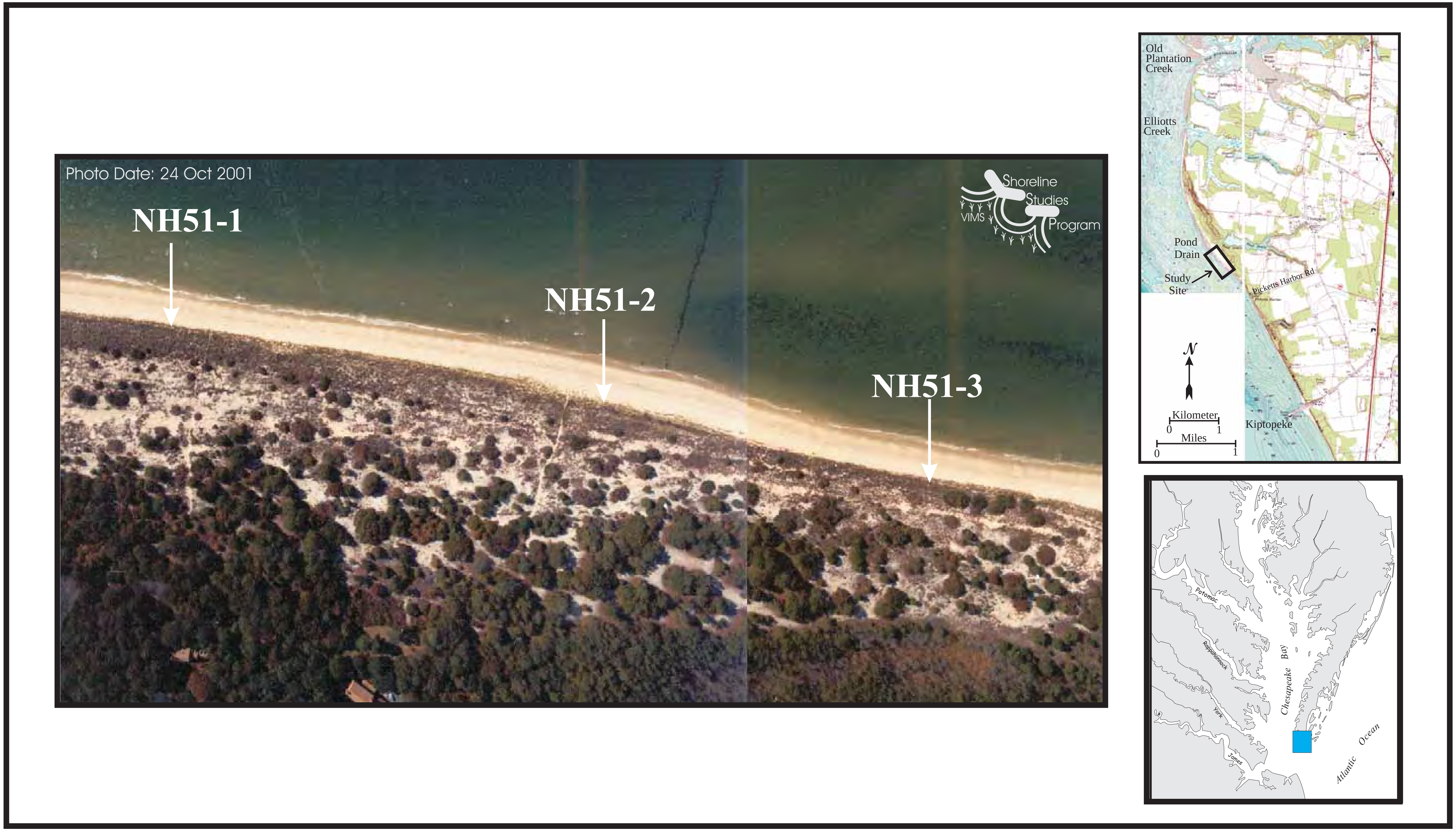


Figure 7-1. Location of site NH51 in Northampton County with approximate position of cross-shore beach profiles.

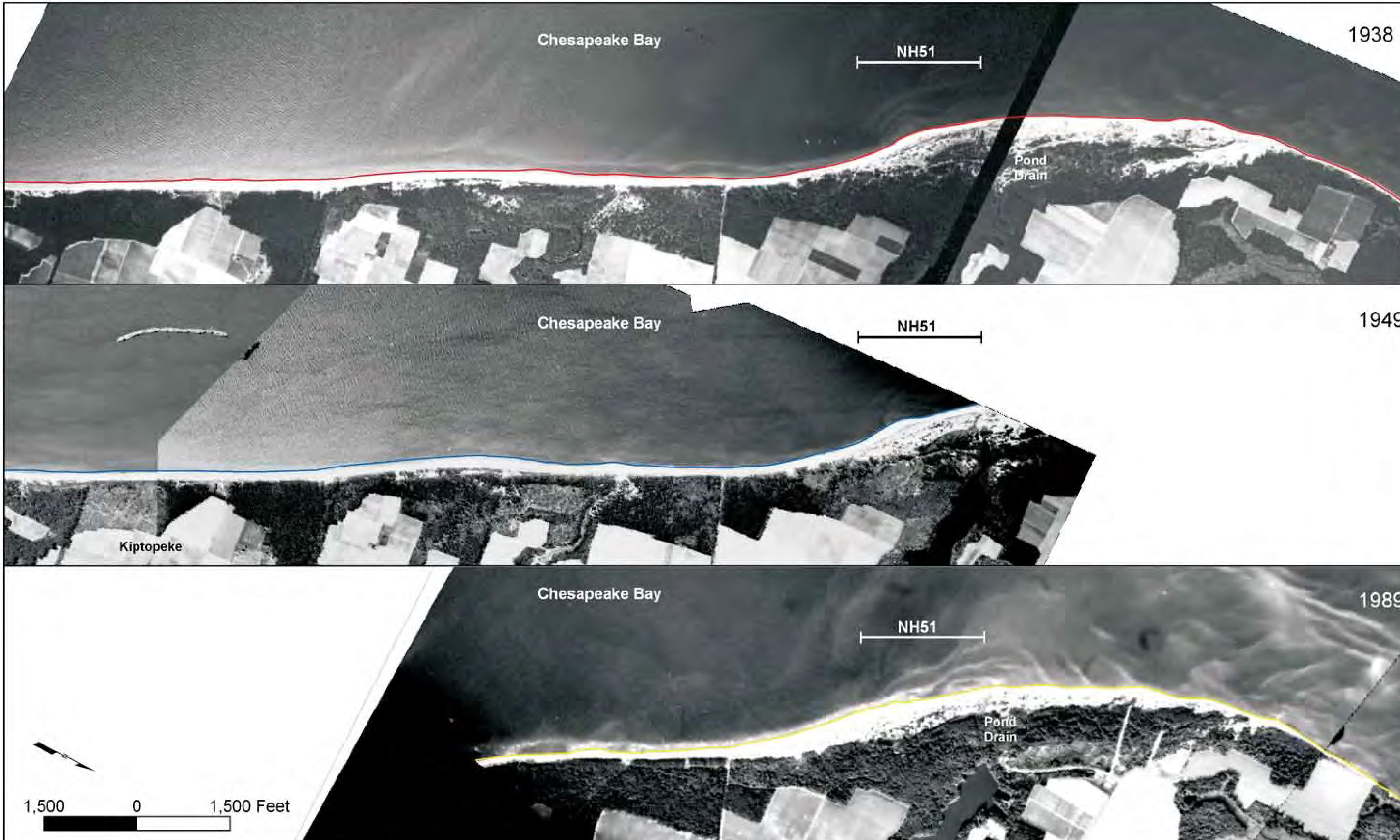


Figure 7-2-1. High-level orthorectified aerial photography of Pond Drain and NH51 taken in 1938, 1949, and 1989.

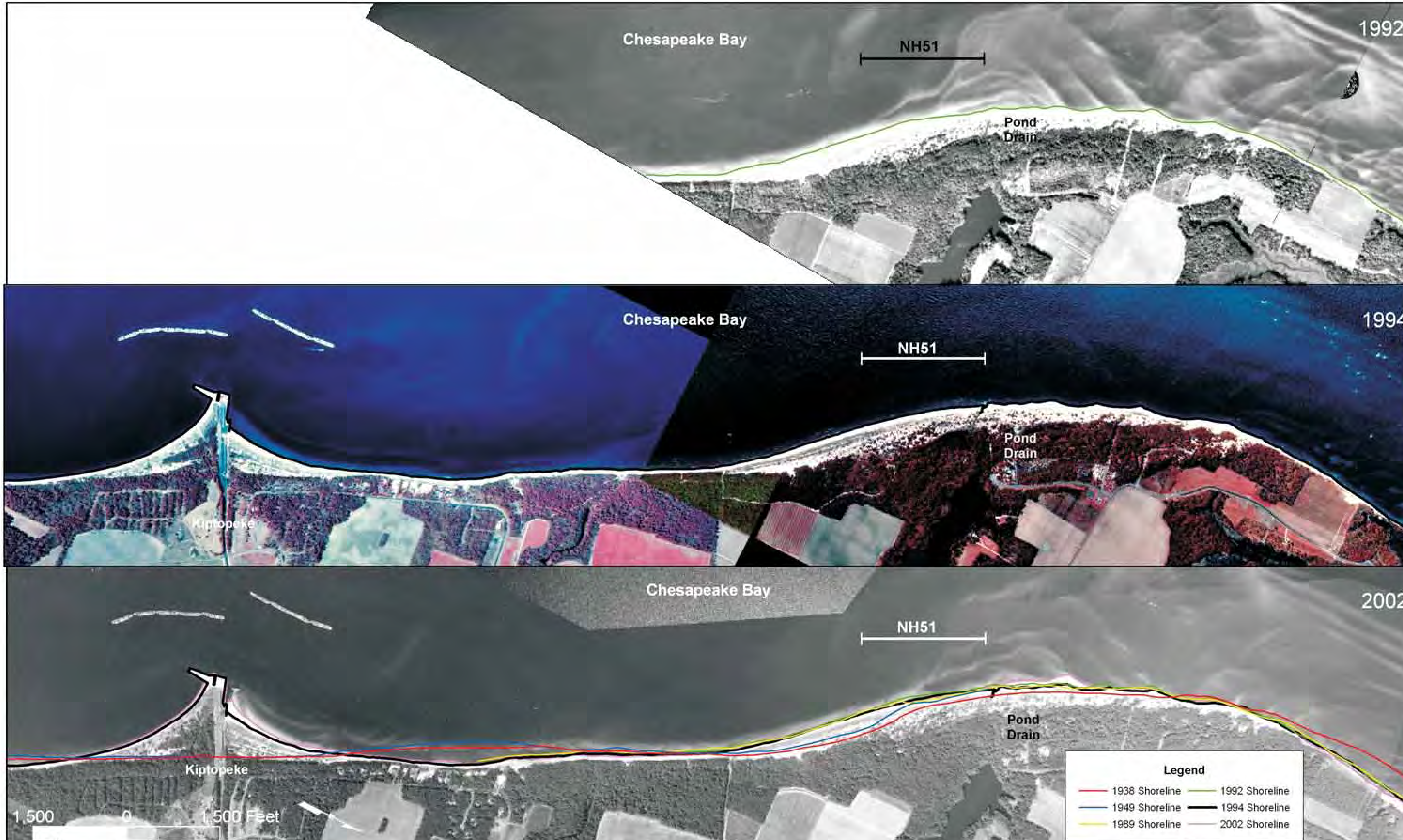


Figure 7-2-2. High-level orthorectified aerial photography of Pond Drain and NH51 taken in 1992, 1994, and 2002 as well as all the digitized shorelines.

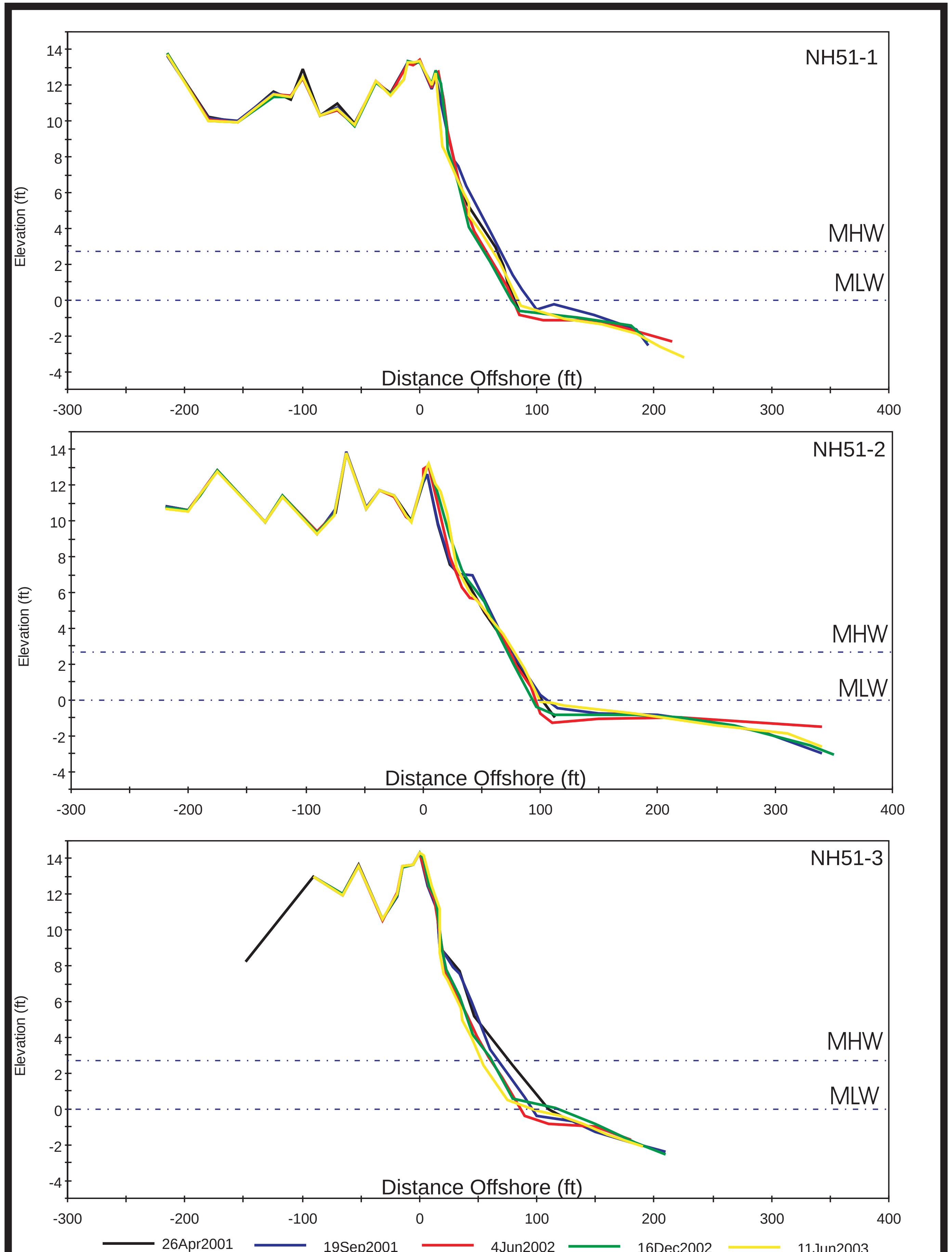


Figure 7-3. Profile plot comparisons for the three profiles at NH51 between April 2001 and June 2003.

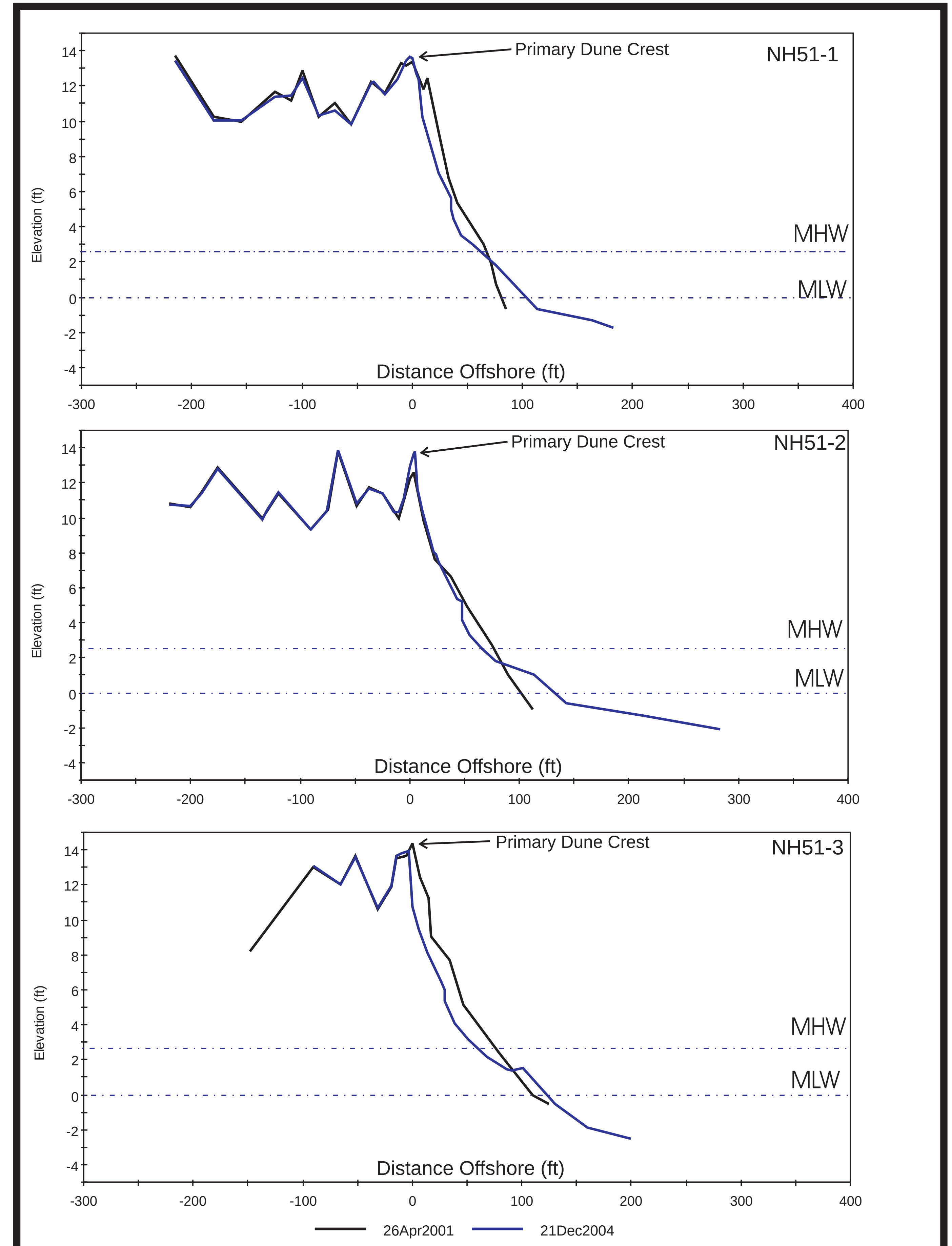


Figure 7-4. Net profile change at NH51 between April 2001 and December 2004.

Figure 7-5. Recent ground photos at profile NH51-2 over the course of the monitoring program.

Figure 7-6. Low-level pre and post Hurricane Isabel and October 2004 georectified aerial photography.

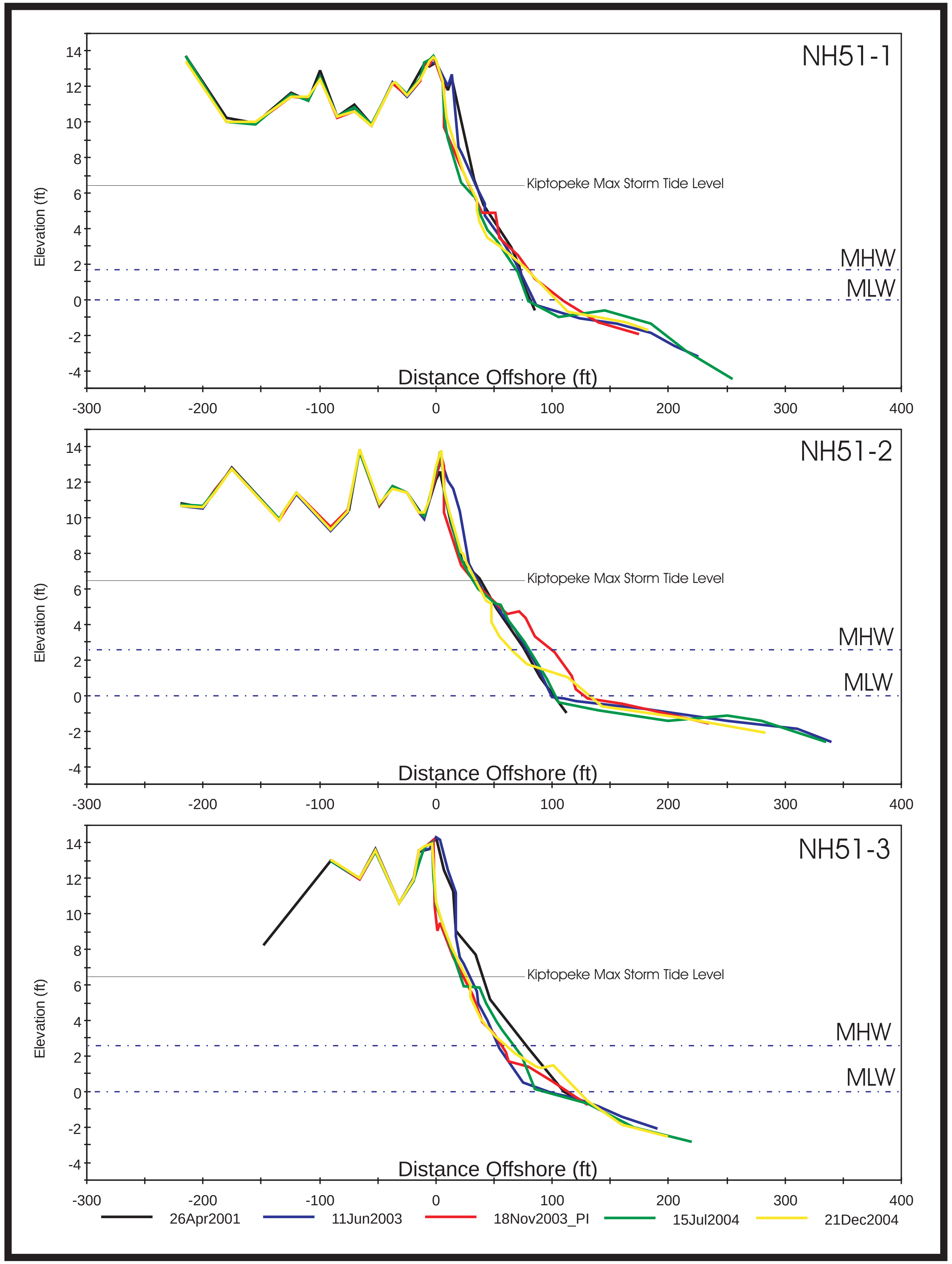


Figure 7-7. Profile plot comparisons for the three profiles at NH51 showing the first survey taken at the site in April 2001, data taken before and after the hurricane, and in 2004.

Figure 7-8. Ground photos at NH51-1 before and after the hurricane and in 2004.

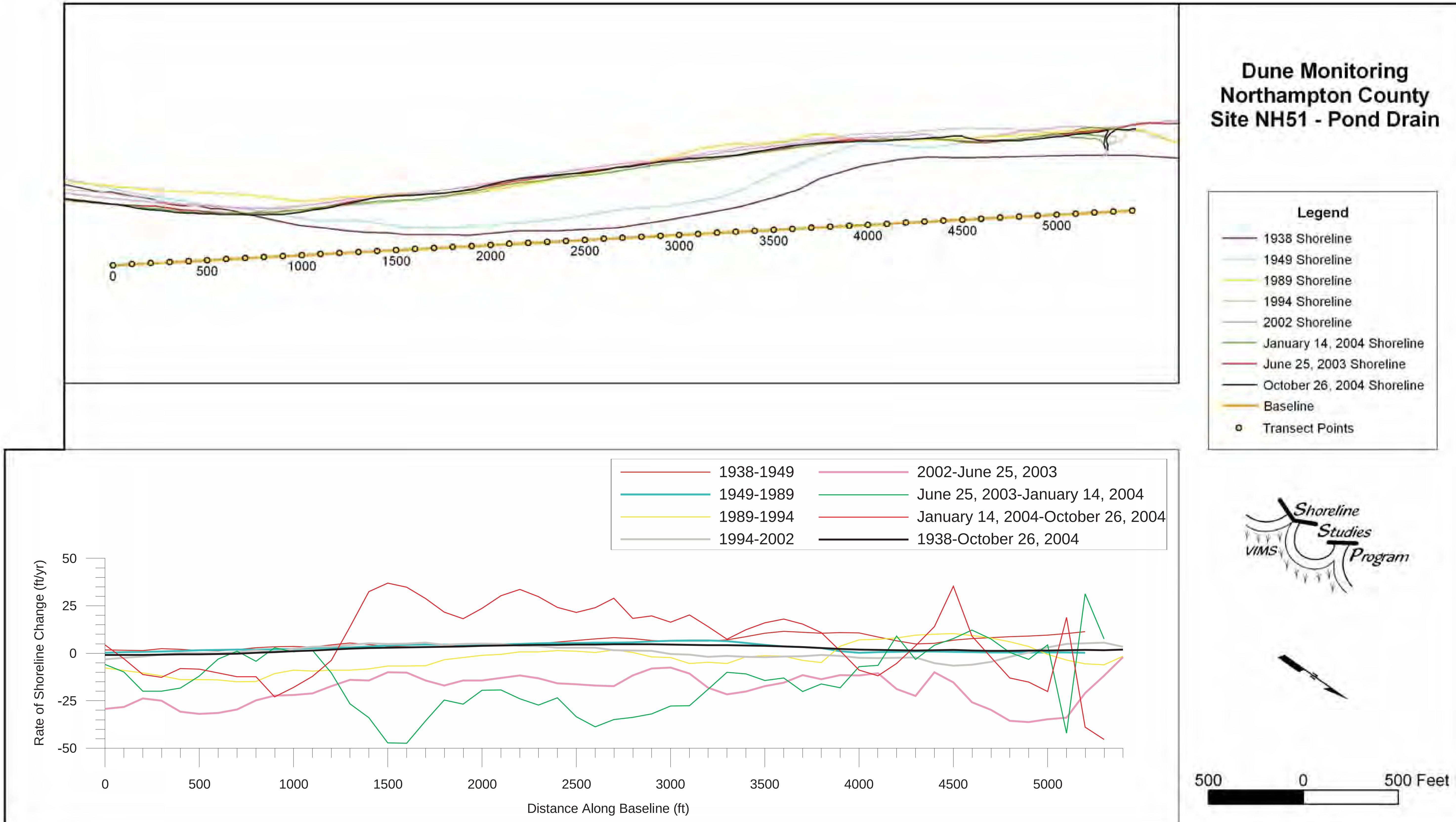


Figure 7-9. Rate of shoreline change calculated from shorelines digitized from rectified aerial photos.

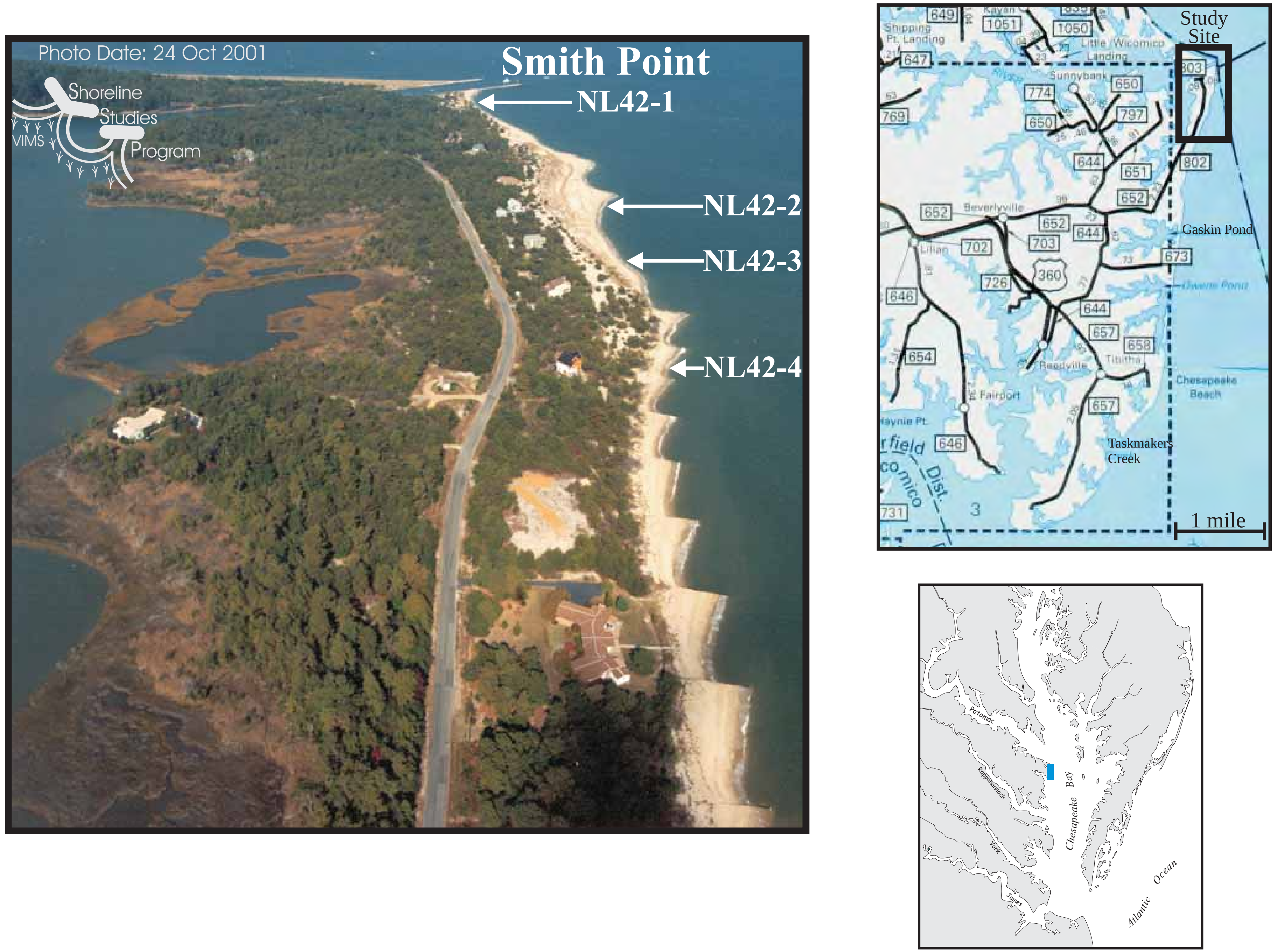


Figure 8-1. Location of site NL42 in Northumberland County with approximate position of cross-shore beach profiles.

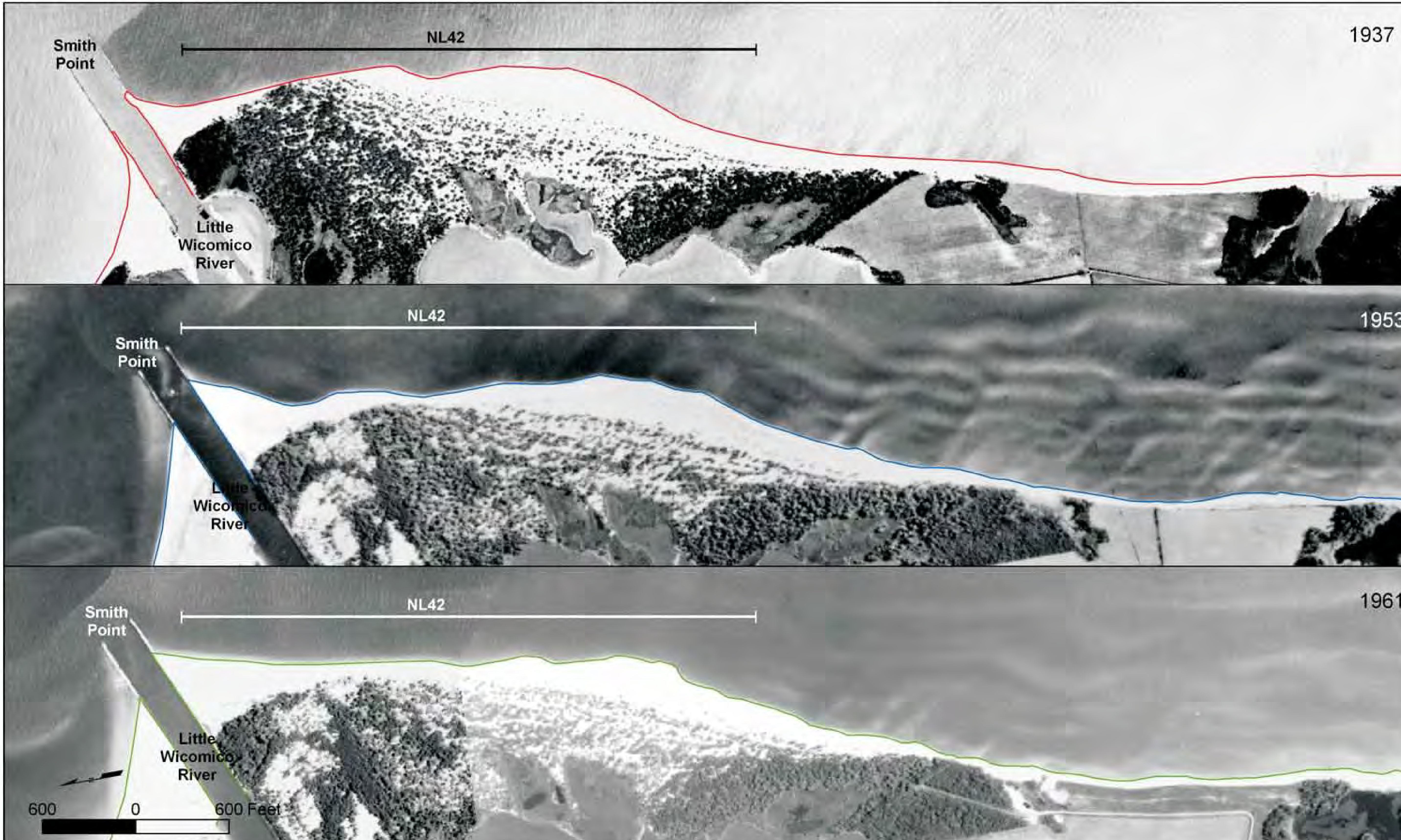


Figure 8-2-1. High-level orthorectified aerial photography of Smith Point and NL42 taken in 1937, 1953, and 1961.

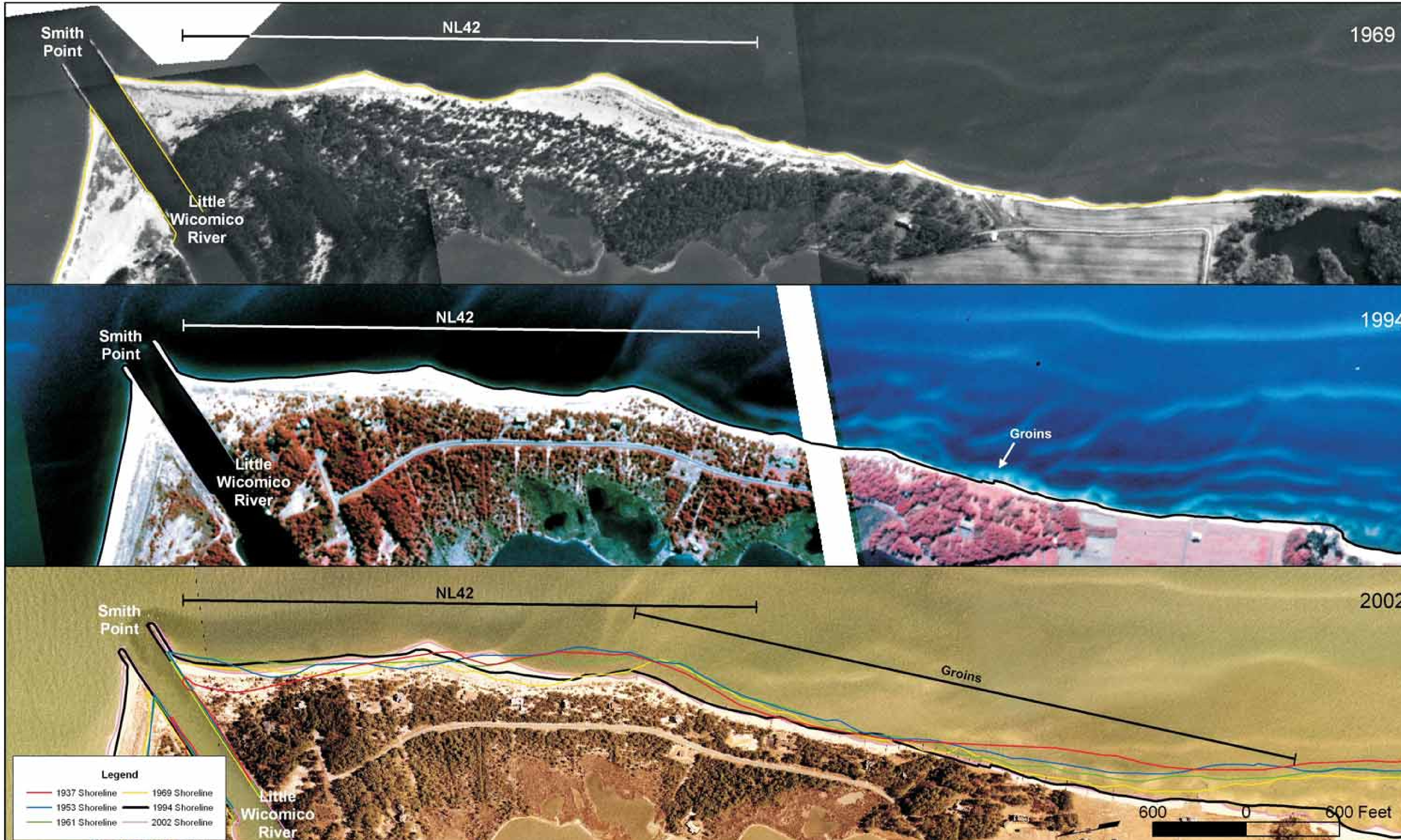


Figure 8-2-2. High-level orthorectified aerial photography of Smith Point and NL42 taken in 1969, 1994, and 2002 as well as all the digitized shorelines.

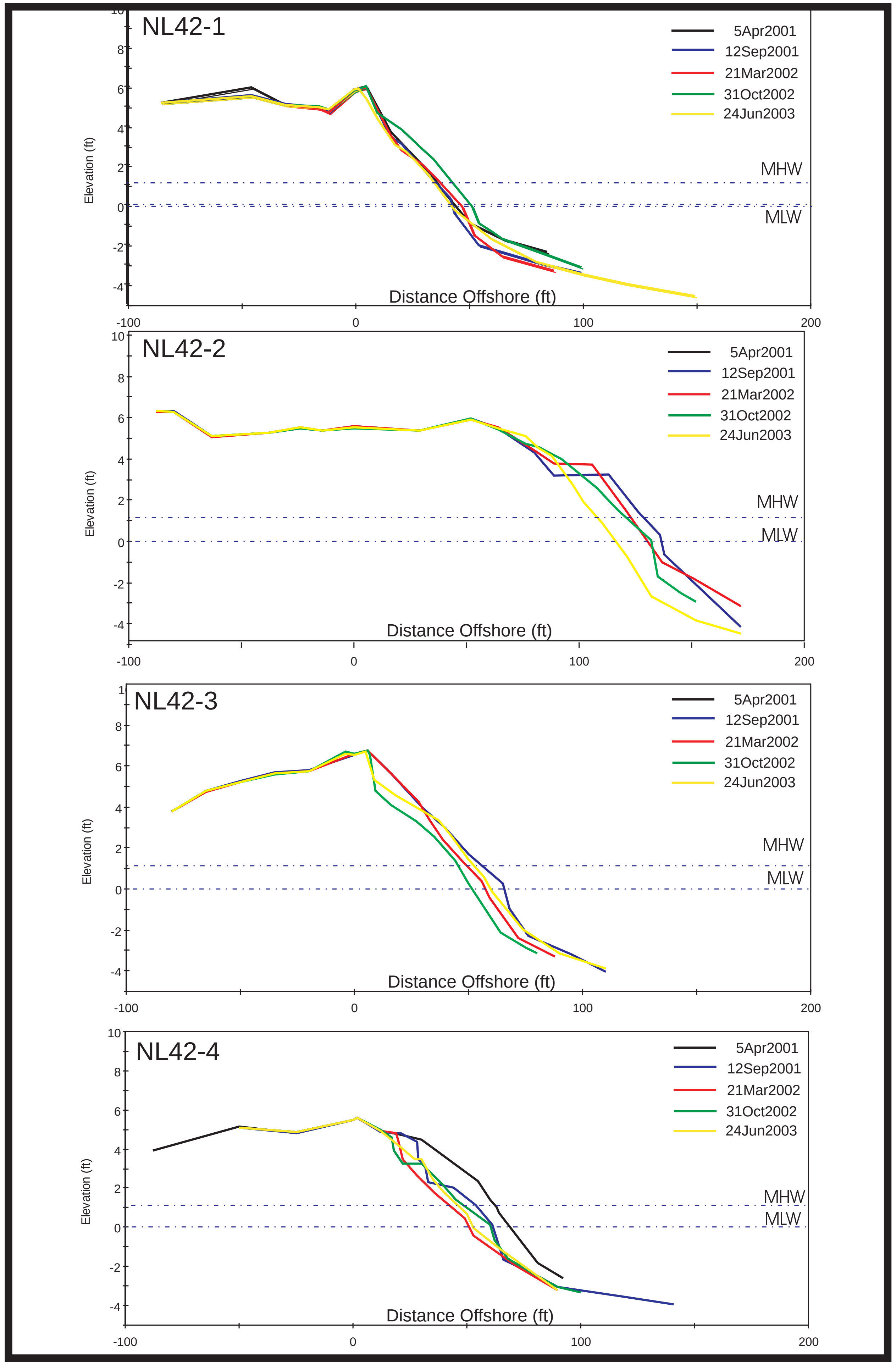


Figure 8-3. Profile plot comparisons for the four profiles at NL42 between April/September 2001 and June 2003.

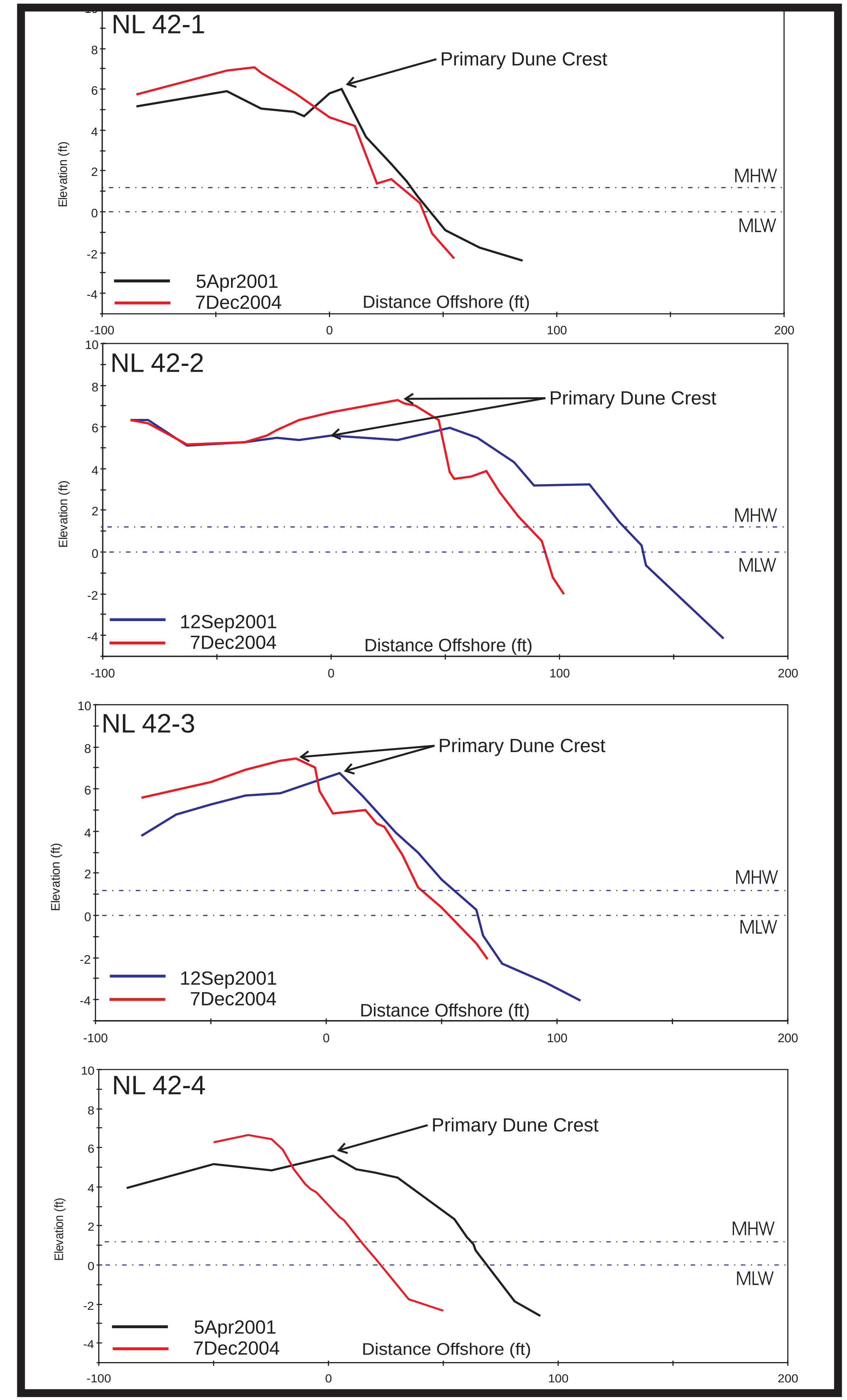


Figure 8-4. Net profile change at NL42 between April/September 2001 and December 2004.

Figure 8-5. Recent ground photos at profile NL42-1 over the course of the monitoring program.

Figure 8-6. Recent ground photos at profile NL42-2 over the course of the monitoring program.

Figure 8-7. Low-level pre and post Hurricane Isabel georectified aerial photography.

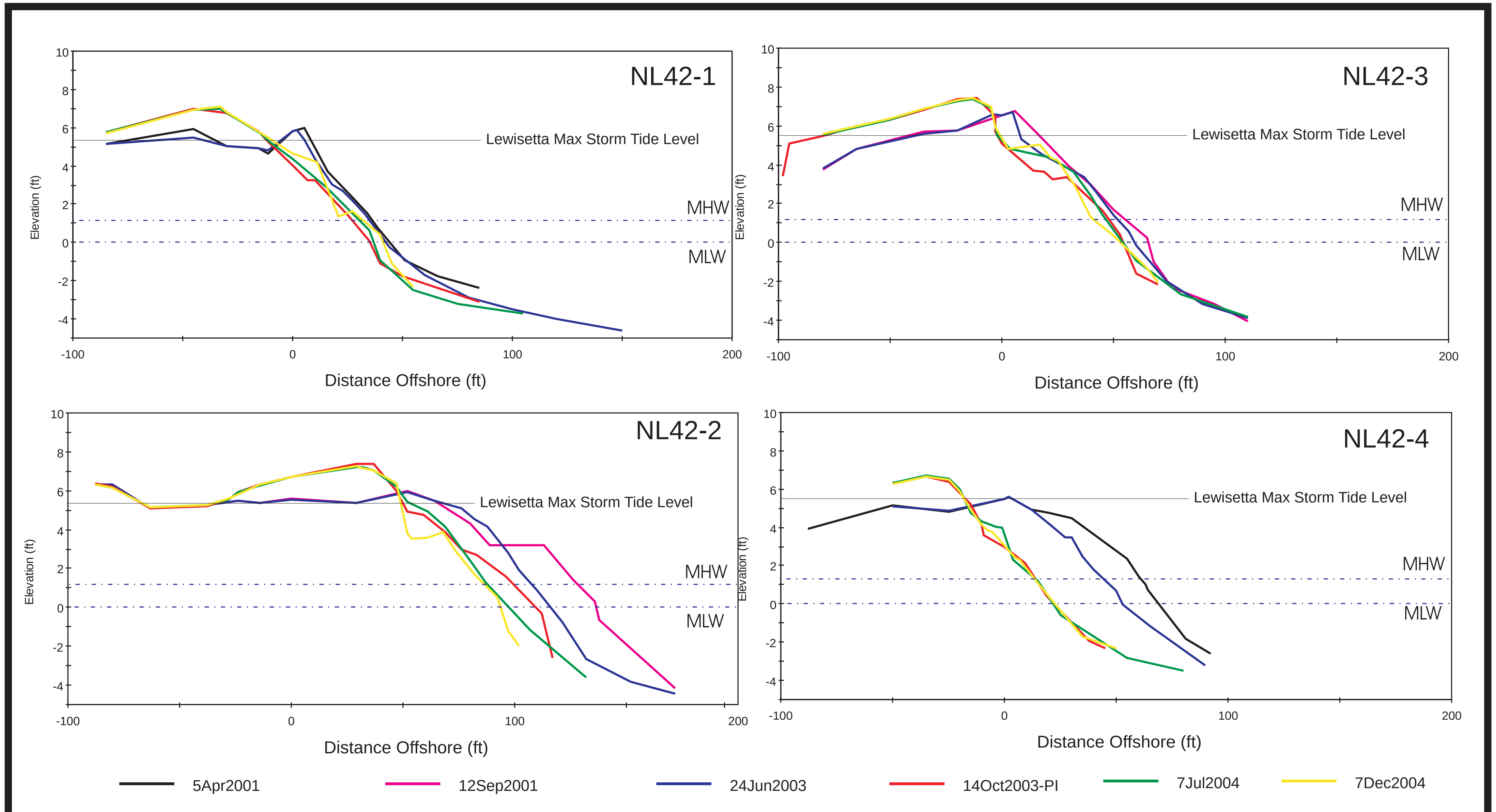


Figure 8-8. Profile plot comparisons for the four profiles at NL42 showing the first survey taken at the site in April/September 2001, data taken before and after the hurricane, and in 2004.

Figure 8-9. Ground shots taken at NL42-3 before and after the hurricane and in 2004.

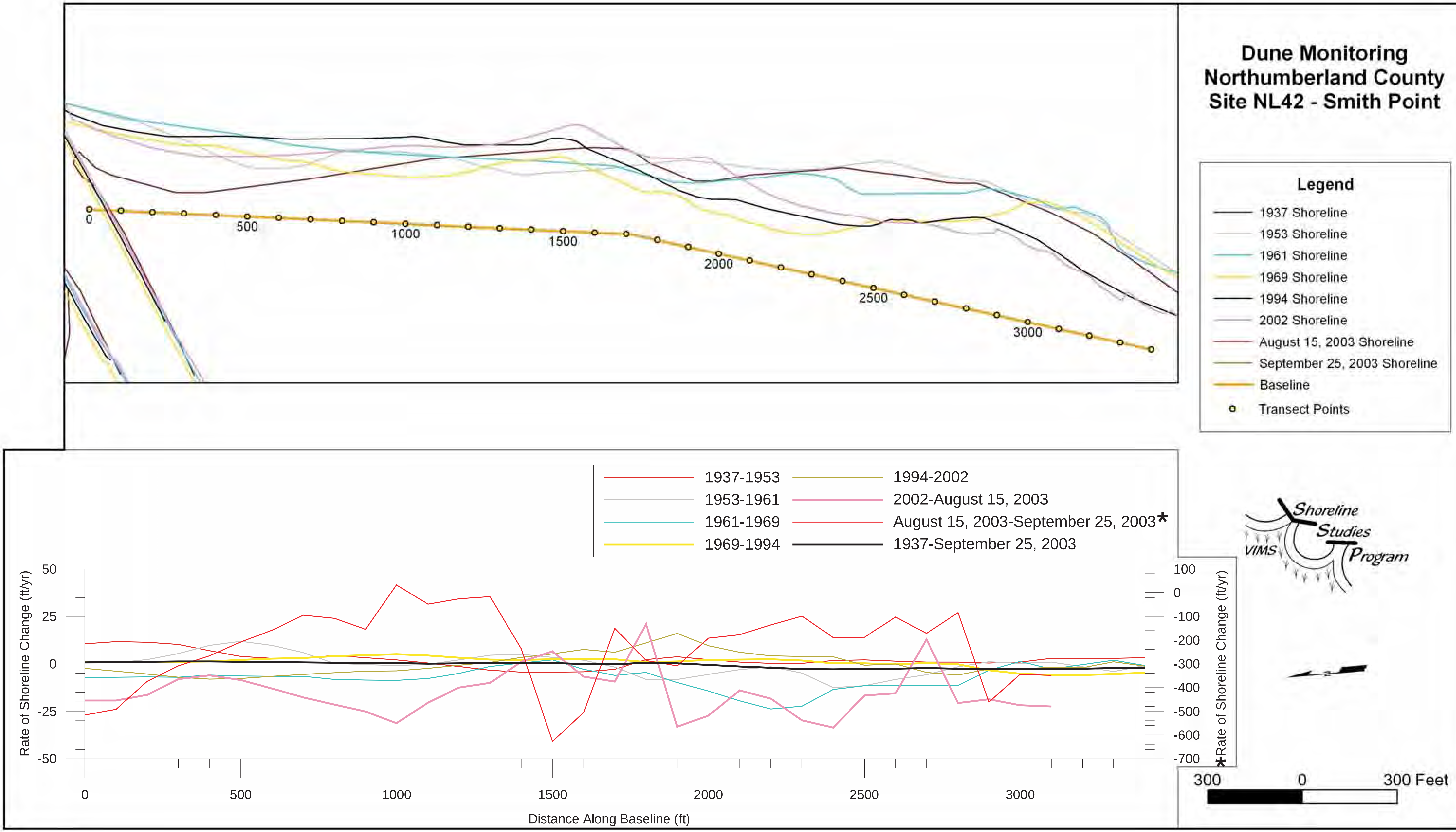
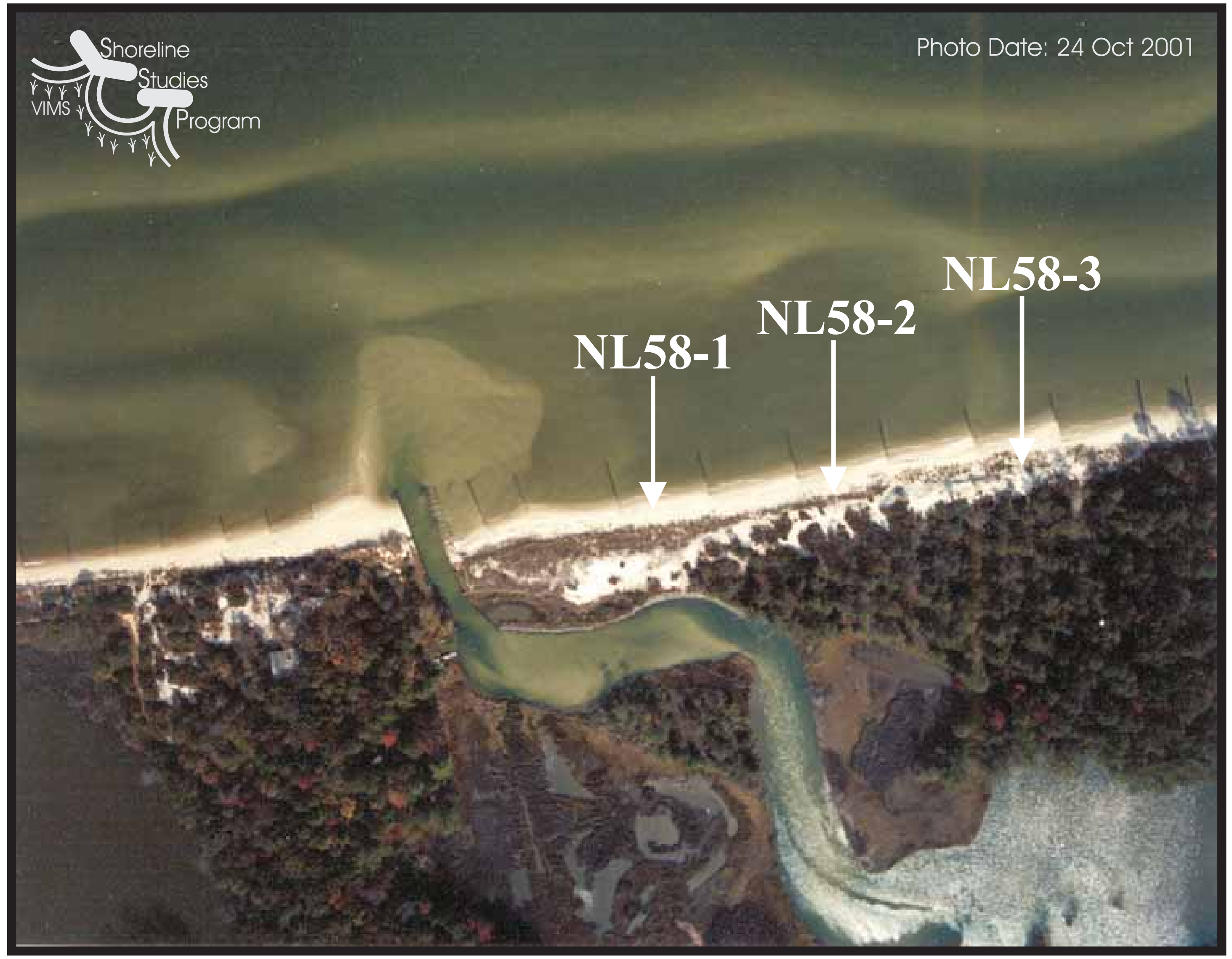
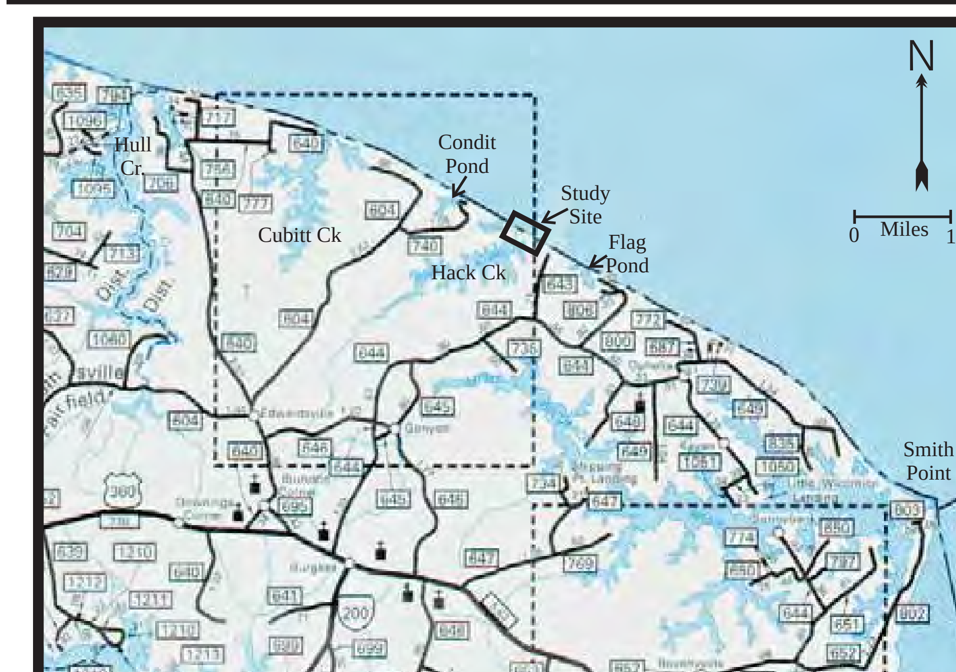


Figure 8-10. Rate of shoreline change calculated from shorelines digitized from rectified aerial photos.





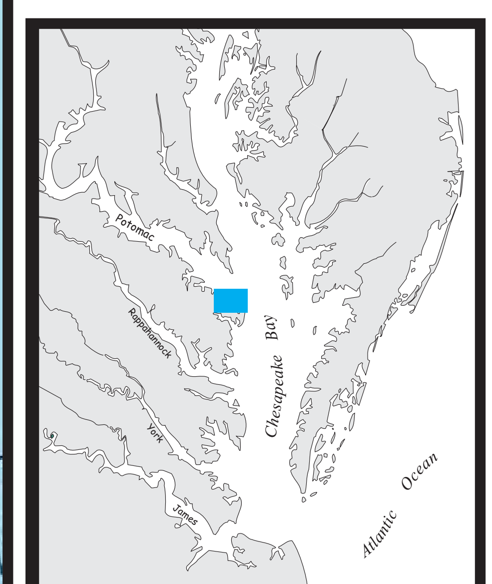


Figure 9-1. Location of site NL58 in Northumberland County with approximate position of cross-shore beach profiles.

Figure 9-2-1. High-level orthorectified aerial photography of Hack Creek and NL58/59 taken in 1937, 1953, and 1969.

Figure 9-2-2. High-level orthorectified aerial photography of Hack Creek and NL58/59 taken in 1994 and 2002 as well as all the digitized shorelines.

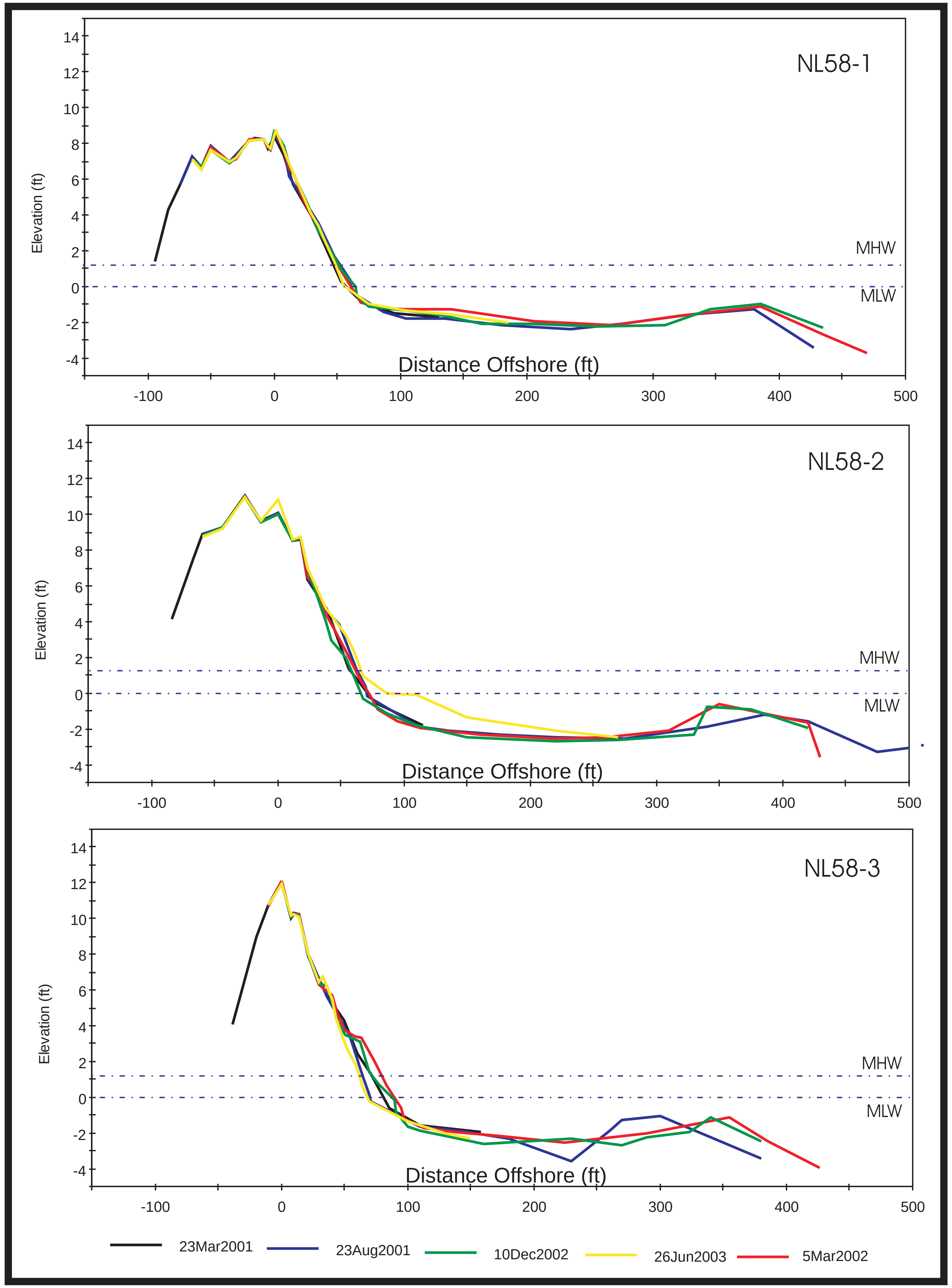


Figure 9-3. Profile plot comparisons for the three profiles at NL58 between March 2001 and June 2003.

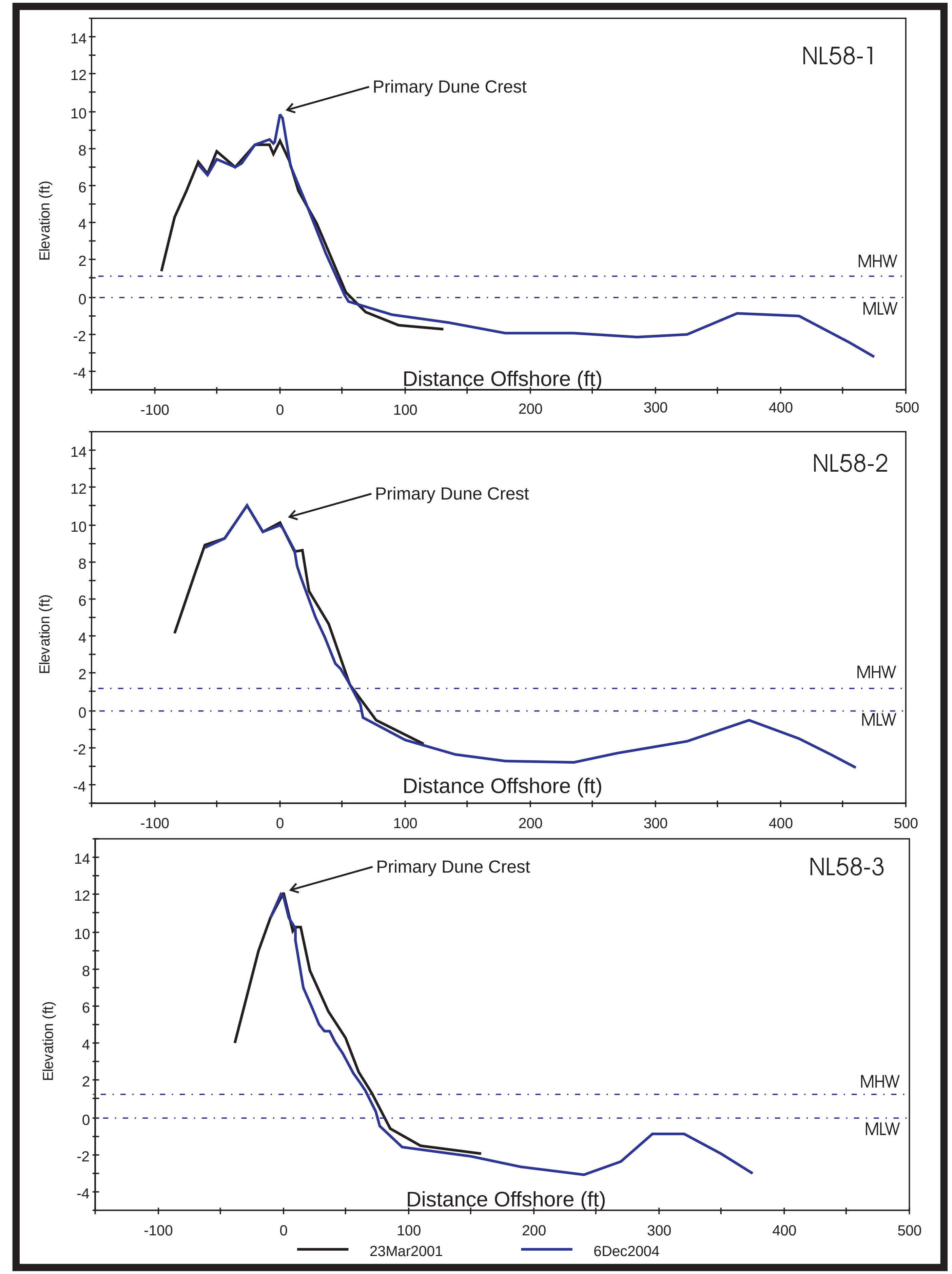


Figure 9-4. Net profile change at NL58 between March 2001 and December 2004.

Figure 9-5. Recent ground photos at profile NL58-3 over the course of the monitoring program.

Figure 9-6. Low-level pre and post Hurricane Isabel georectified aerial photography.

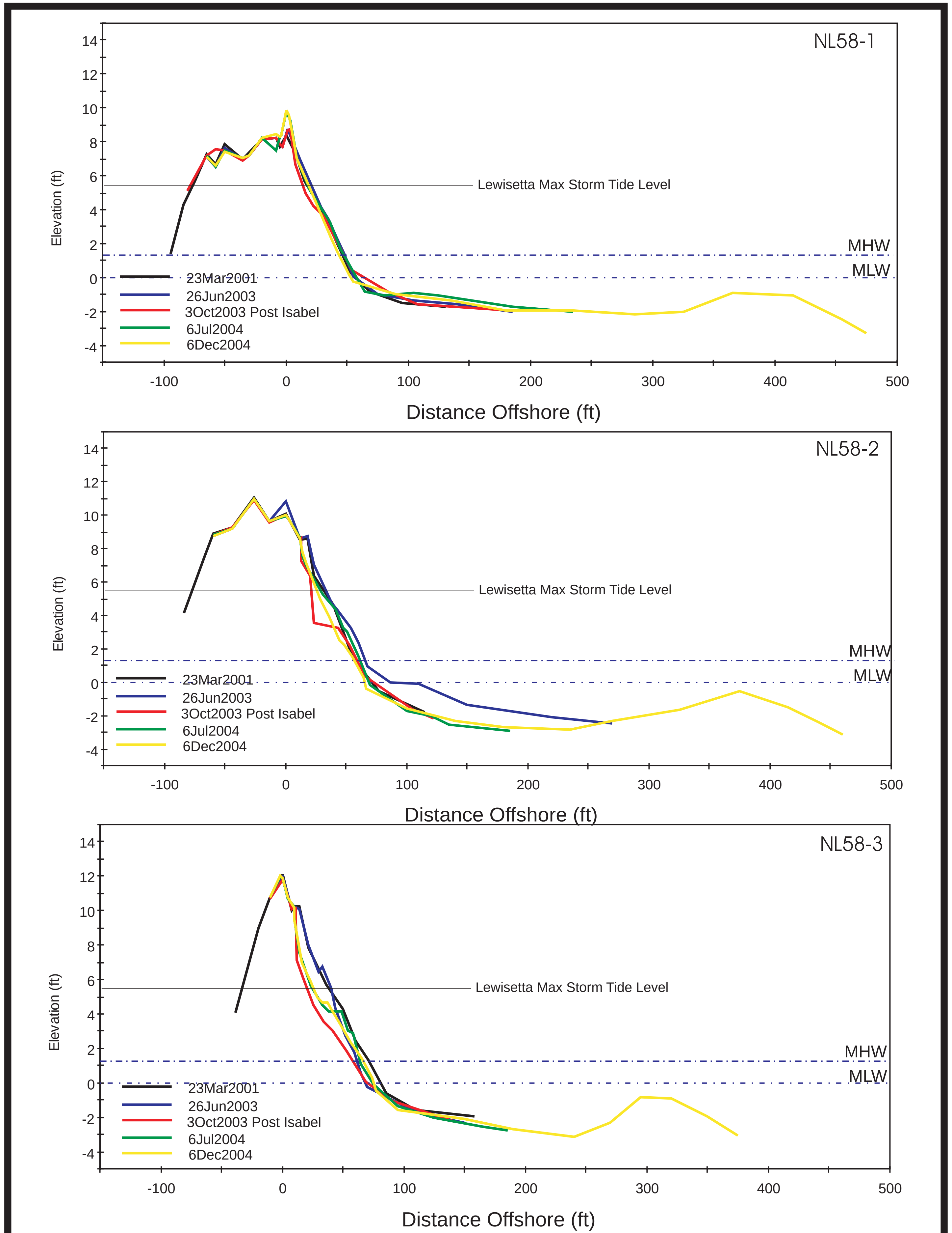


Figure 9-7. Profile plot comparisons for the three profiles at NL58 showing the first survey taken at the site in March 2001, data taken before and after the hurricane and in 2004.

Figure 9-8. Ground photos at NL58-2 before and after the hurricane and in 2004.

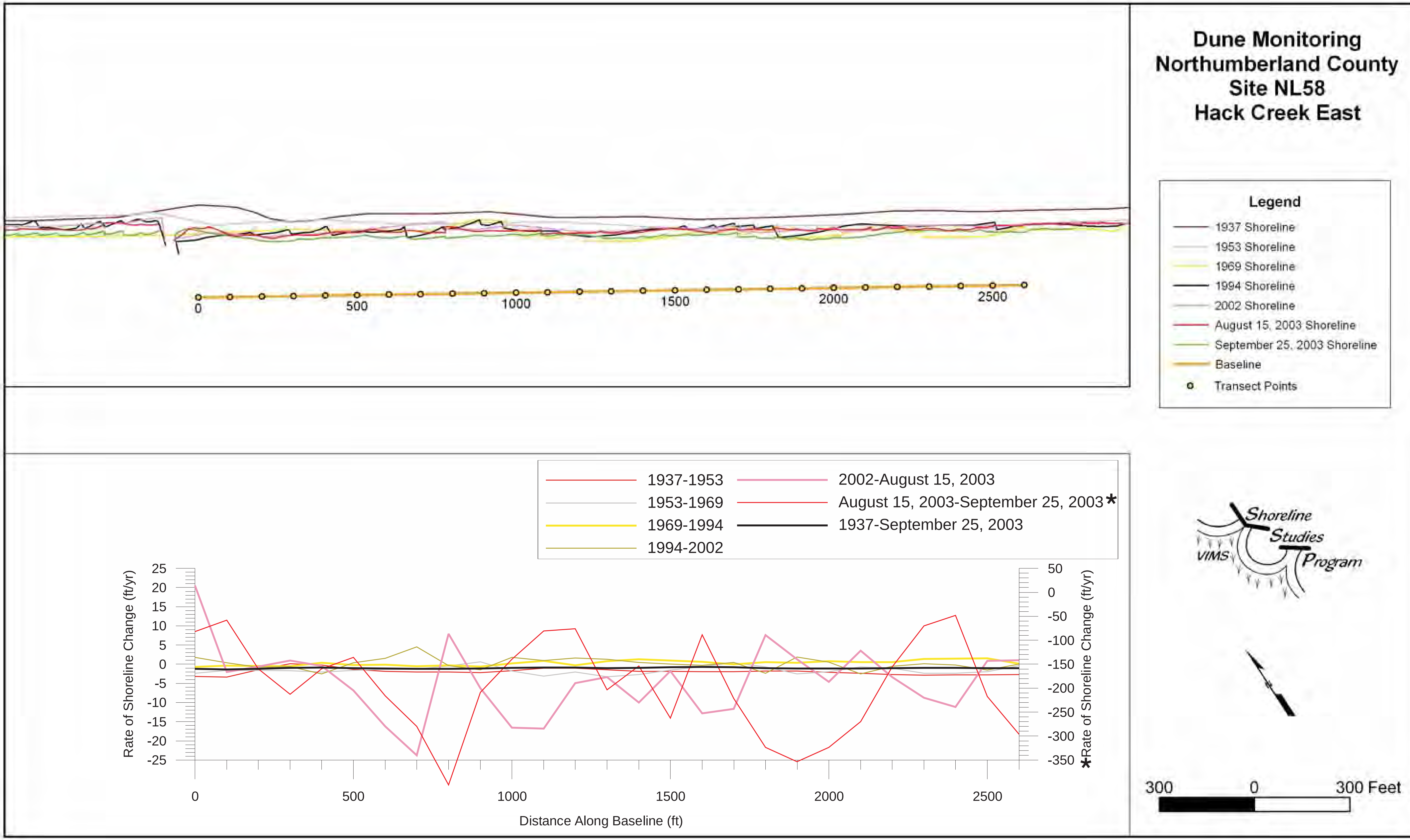
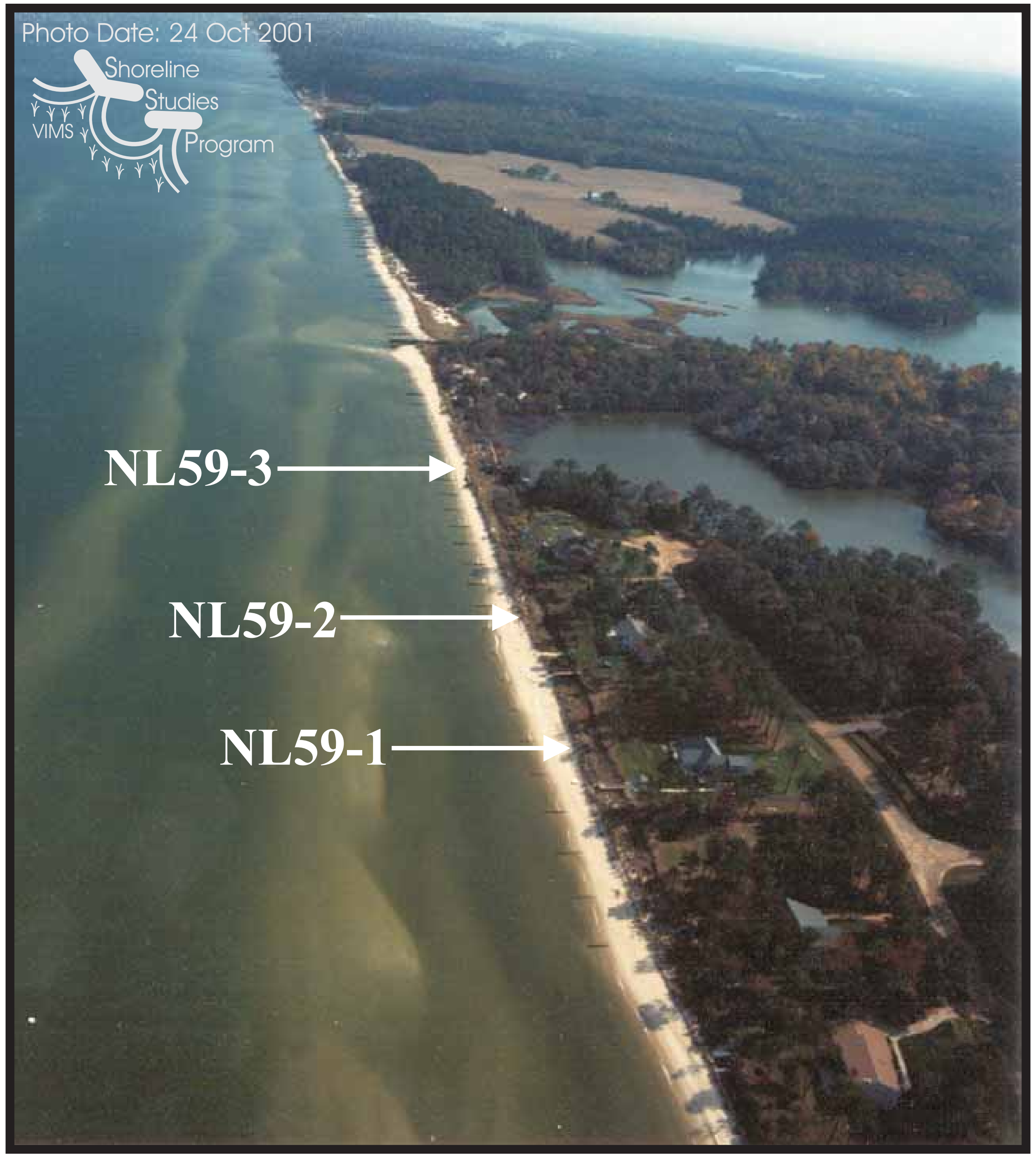


Figure 9-9. Rate of shoreline change calculated from digitized shorelines from rectified aerial photos.



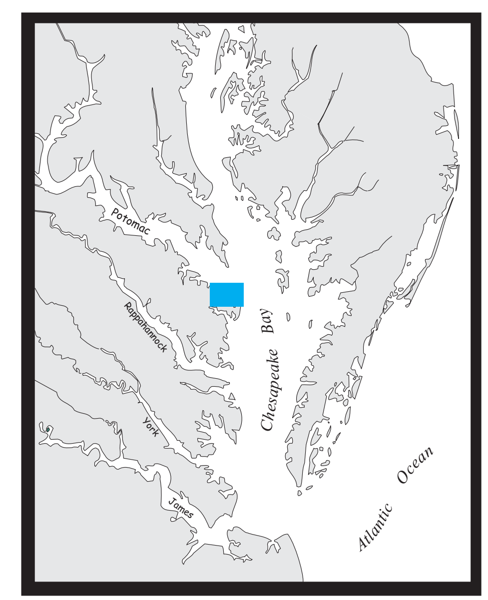


Figure 10-1. Location of site NL59 in Northumberland County with approximate position of cross-shore beach profiles.

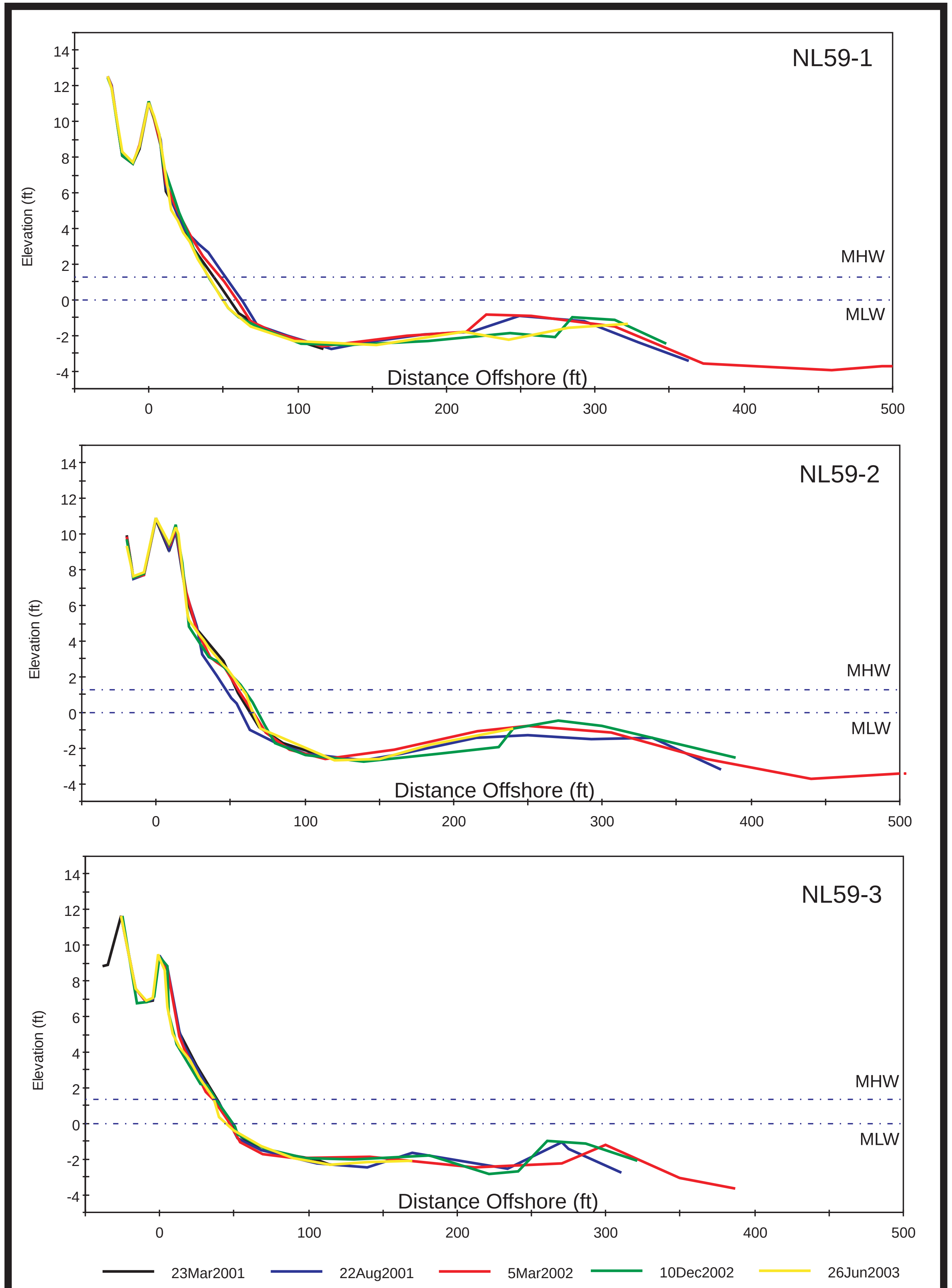


Figure 10-2. Profile plot comparisons for the three profiles at NL59 between March 2001 and June 2003.

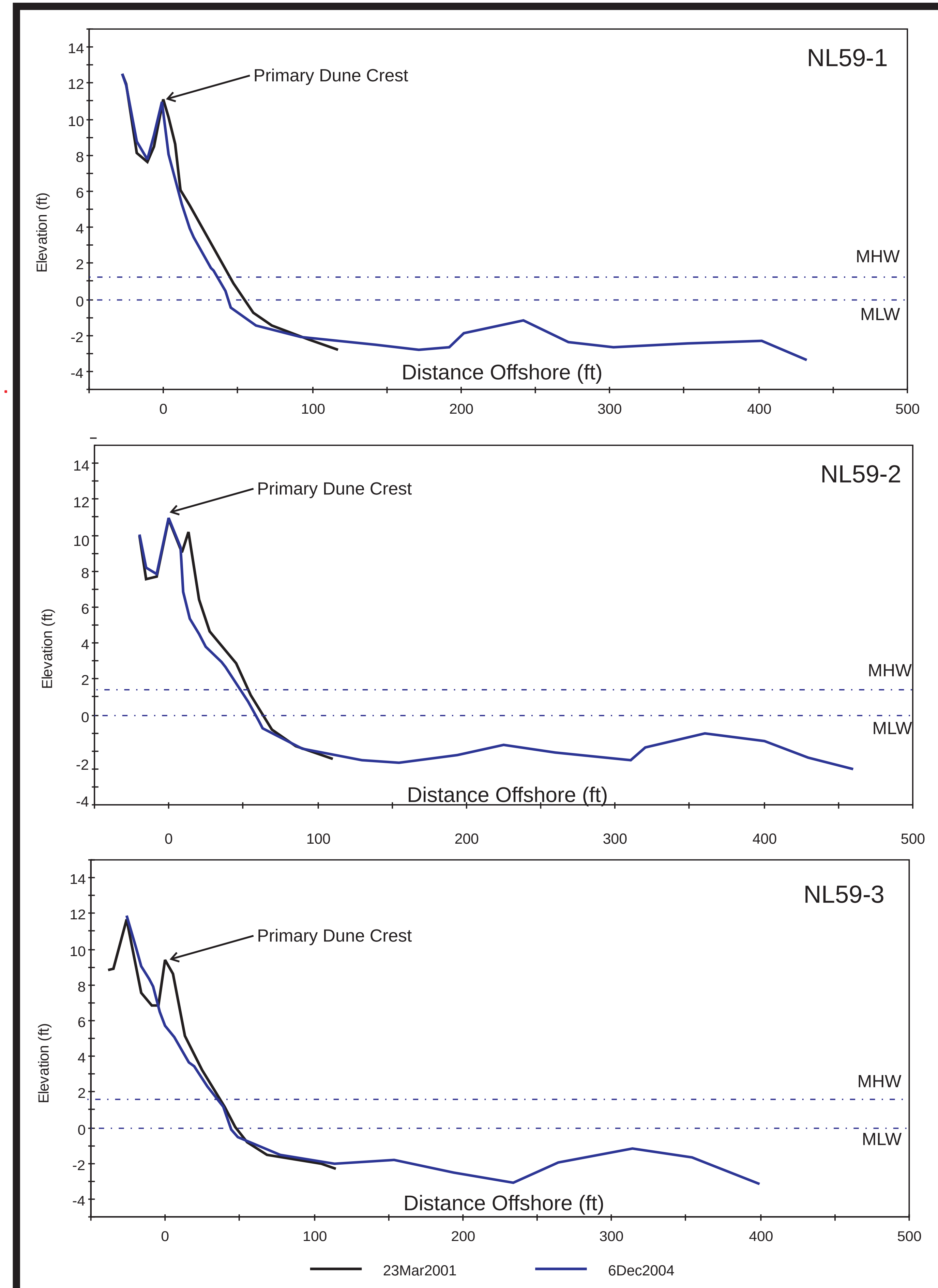


Figure 10-3. Net profile change at NL59 between March 2001 and December 2004.

Figure 10-4. Recent ground photos at profile NL59-3 over the course of the monitoring program.

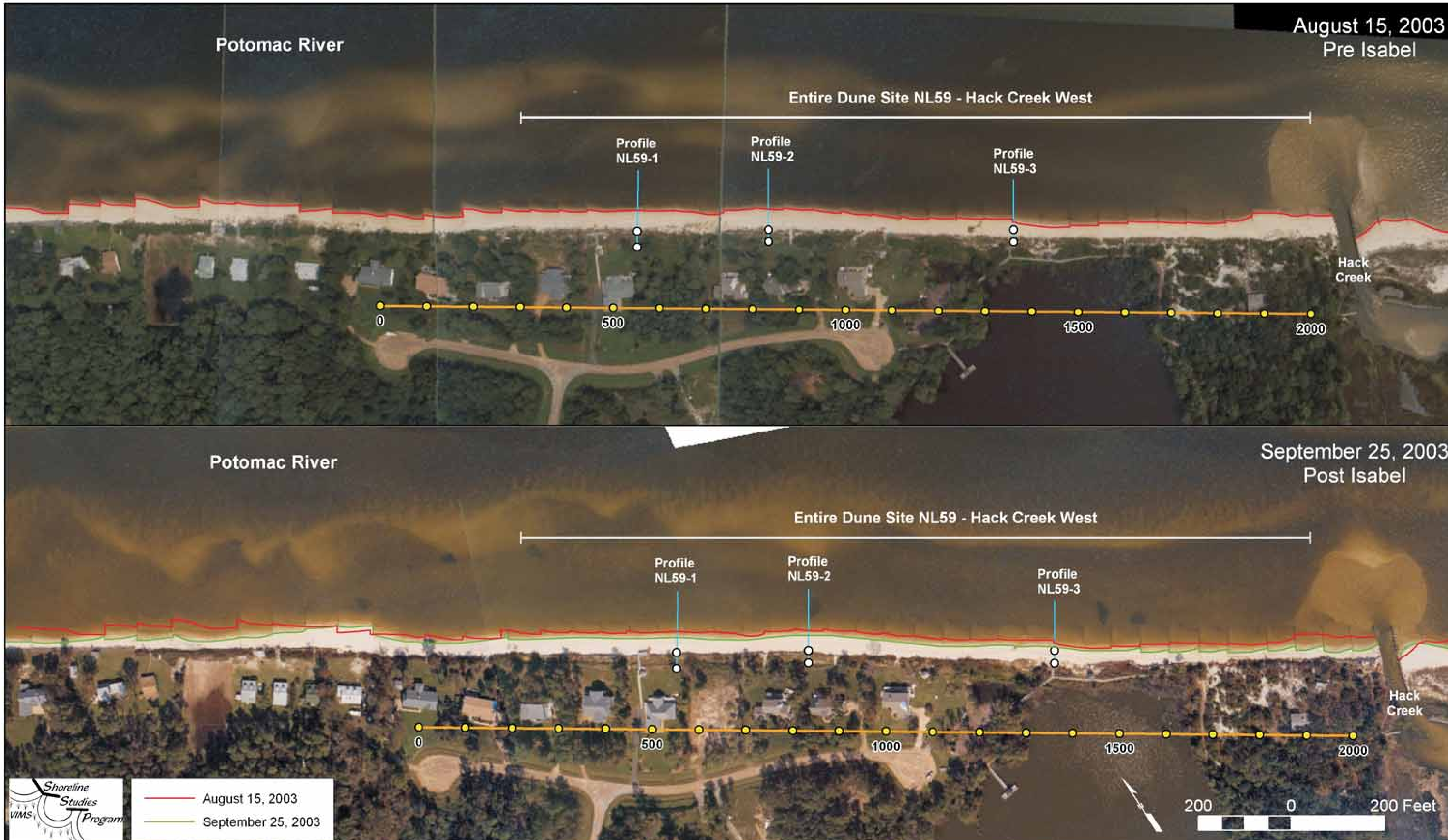


Figure 10-5. Low-level pre and post Hurricane Isabel georectified aerial photograhpy.

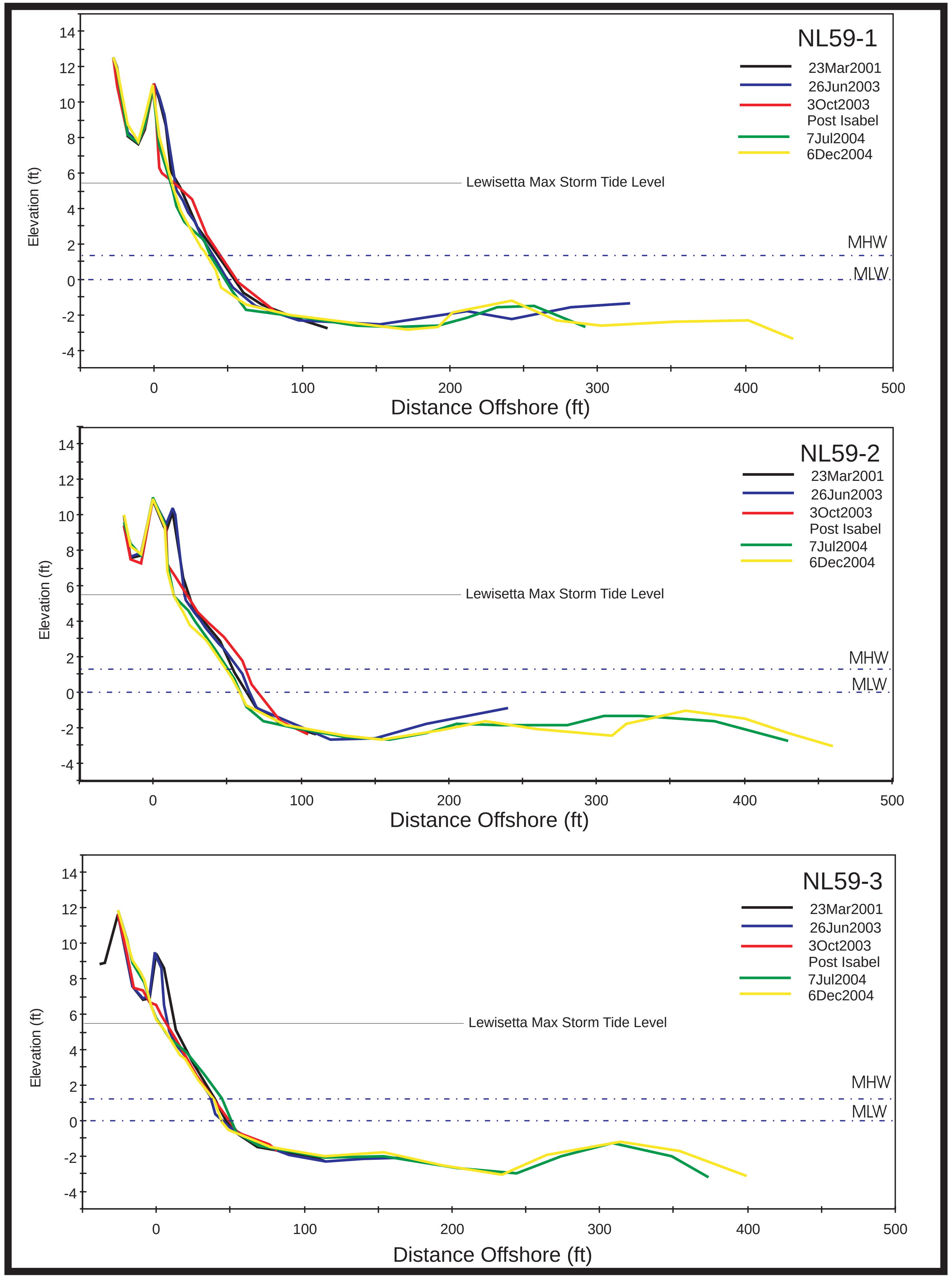


Figure 10-6. Profile plot comparisons for the three profiles at NL59 showing the first survey taken at the site in March 2001, data taken before and after the hurricane and in 2004.

Figure 10-7. Ground photos at NL59-1 before and after the Hurricane and in 2004.

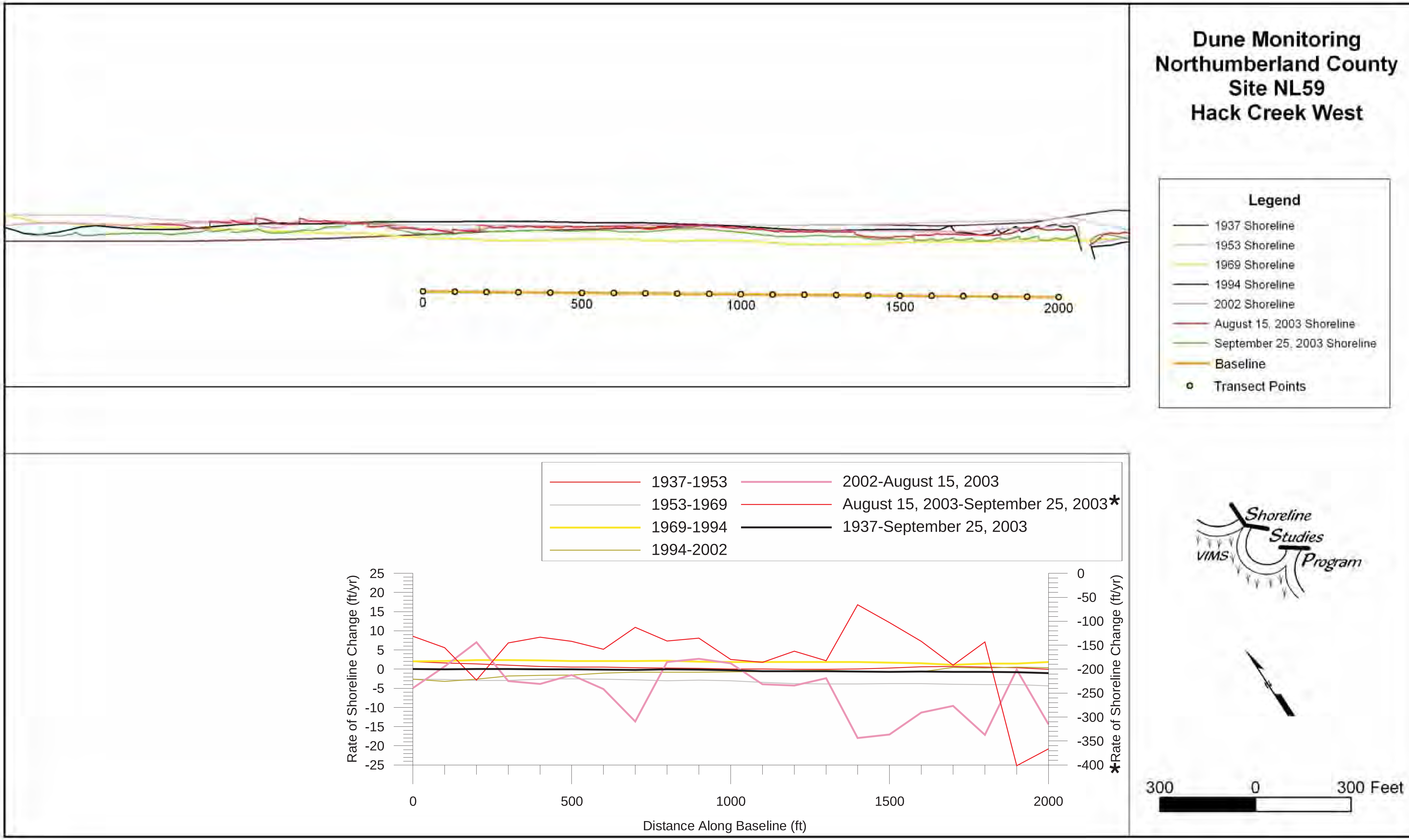


Figure 10-8. Rate of shoreline change calculated from shorelines digitized from rectified aerial photos.

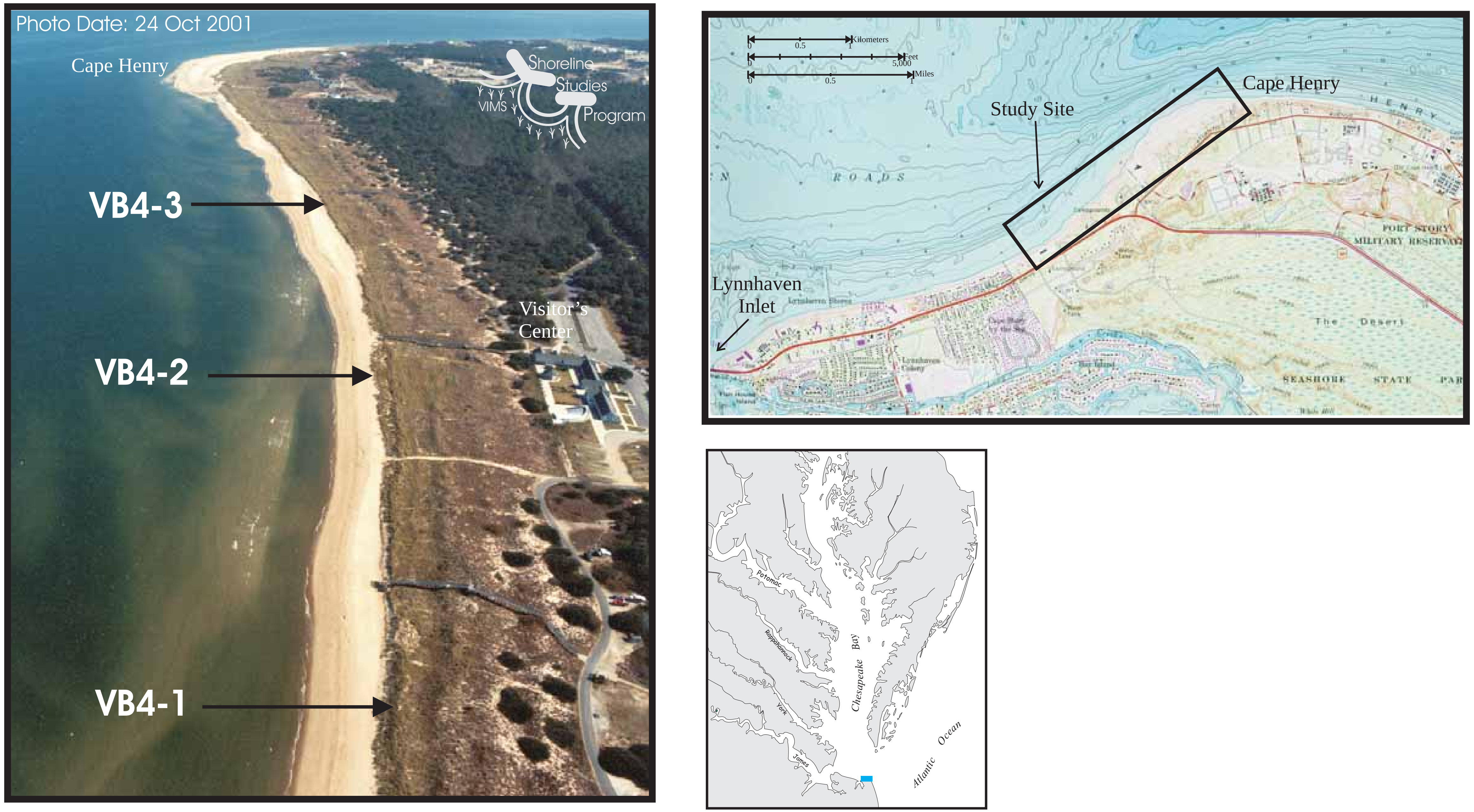


Figure 11-1. Location of site VB4 in Virginia Beach with approximate position of cross-shore beach profiles.

Figure 11-2-1. High-level orthorectified aerial photography of First Landing State Park and VB4 taken in 1937, 1960, and 1962.

Figure 11-2-2. High-level orthorectified aerial photography of First Landing State Park and VB4 taken in 1970, 1976, and 1980.

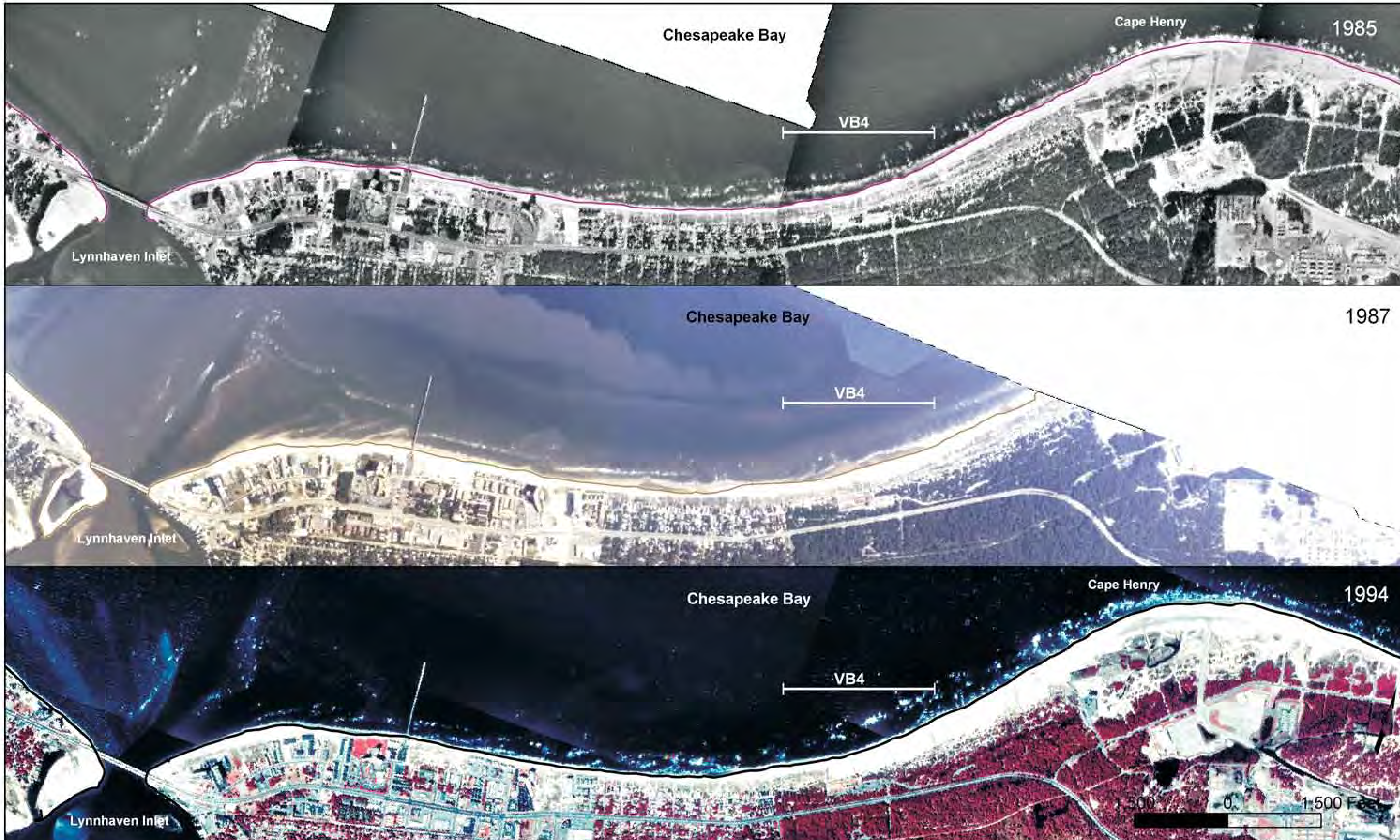


Figure 11-2-3. High-level orthorectified aerial photography of First Landing State Park and VB4 taken in 1985, 1987, and 1994.

Figure 11-2-4. High-level orthorectified aerial photography of First Landing State Park and VB4 taken in 2002 as well as all the digitized shorelines.

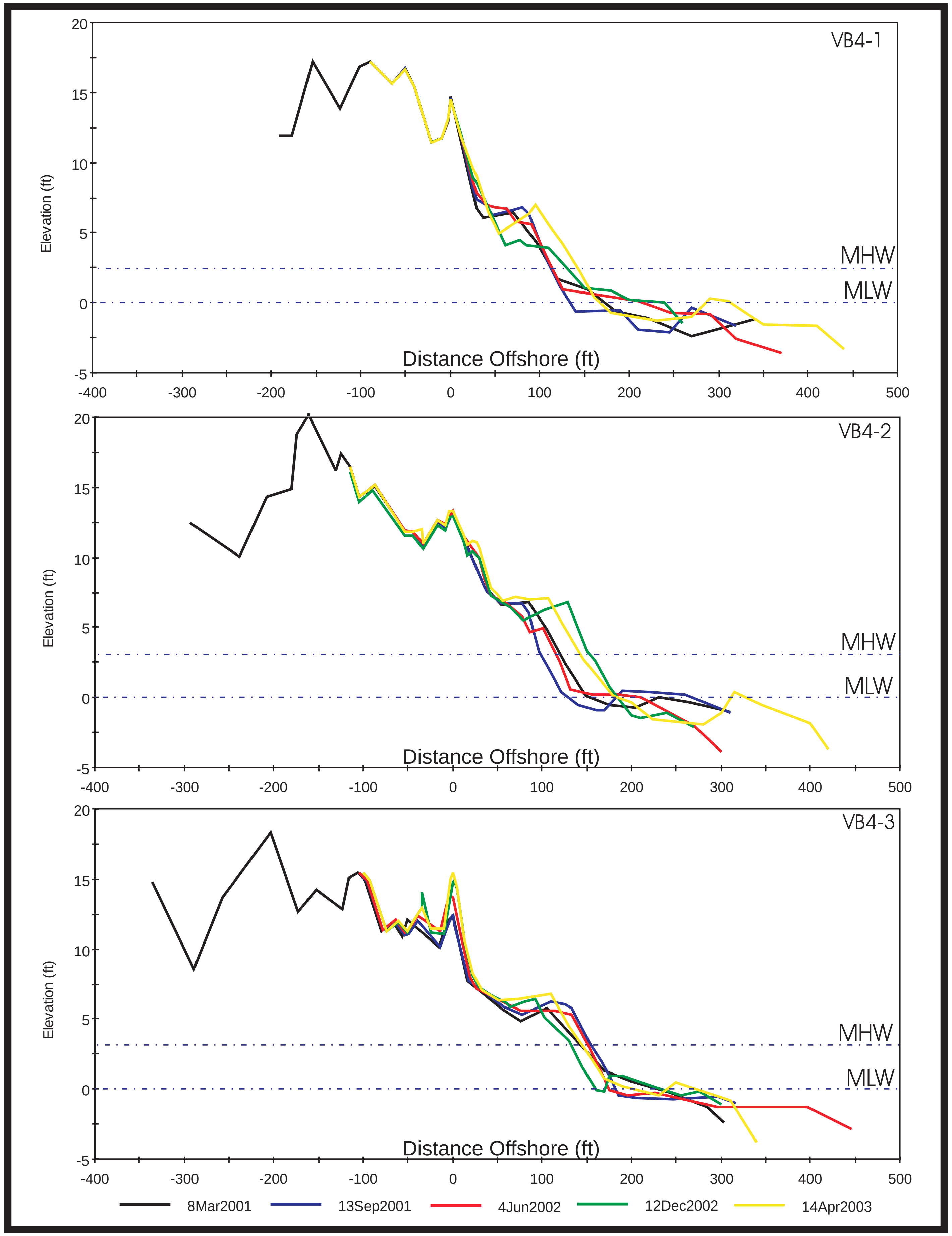


Figure 11-3. Profile plot comparisons for the three profiles at VB4 between March 2001 and April 2003.

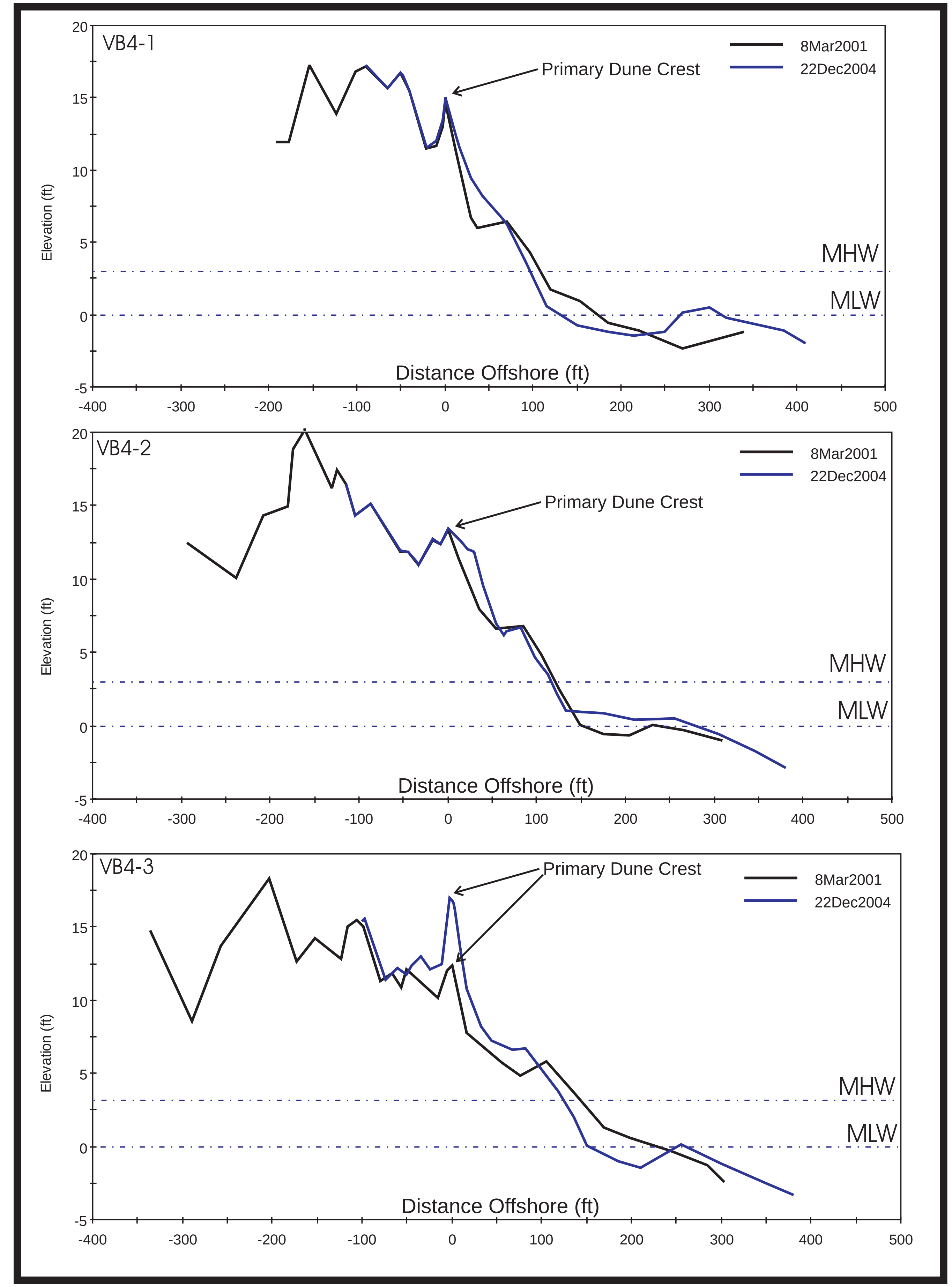


Figure 11-4. Net profile change at VB4 between March 2001 and December 2004.

Figure 11-5. Recent ground photos at profile VB4-1 over the course of the monitoring program.

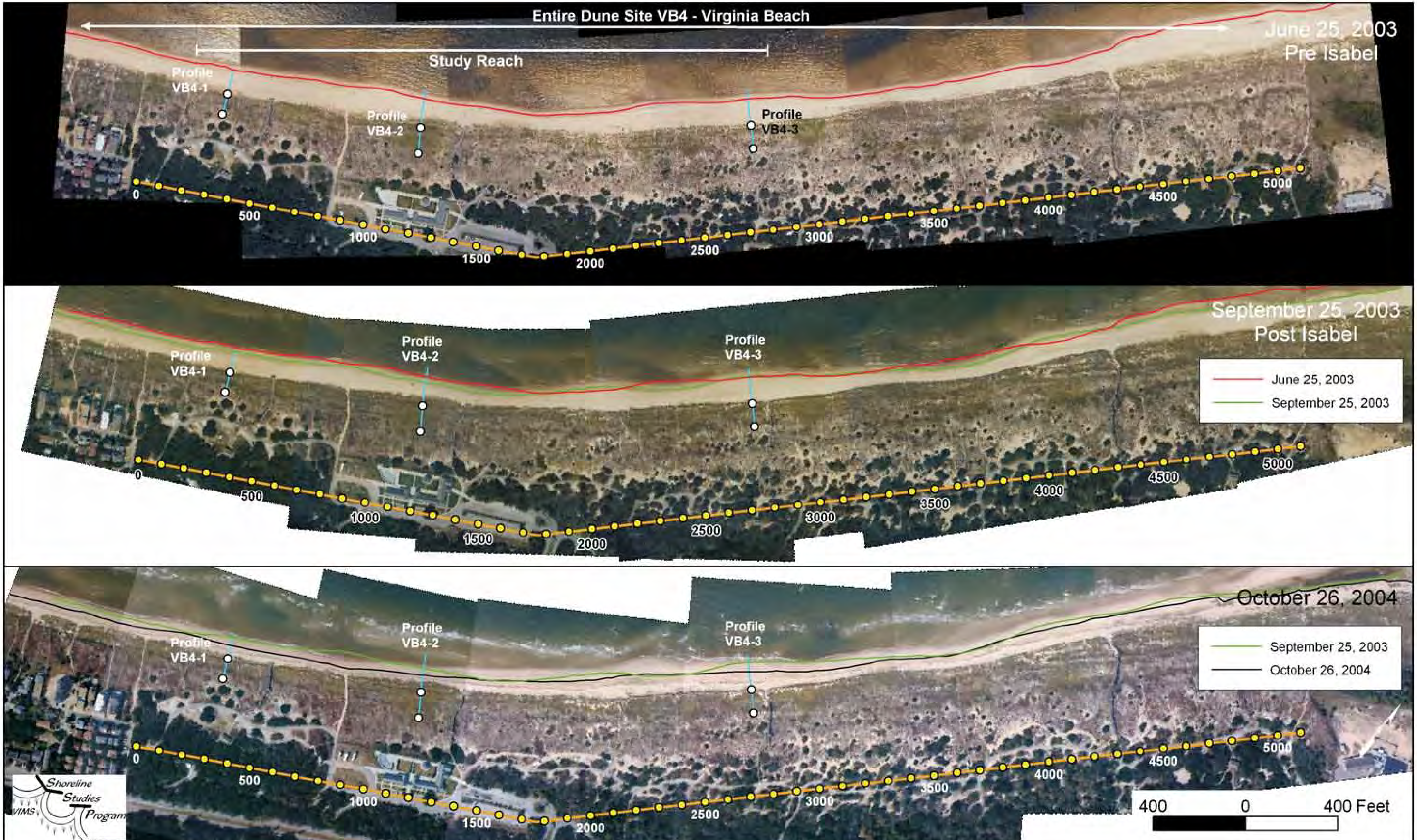


Figure 11-6. Low-level pre and post Hurricane Isabel georectified aerial photography.

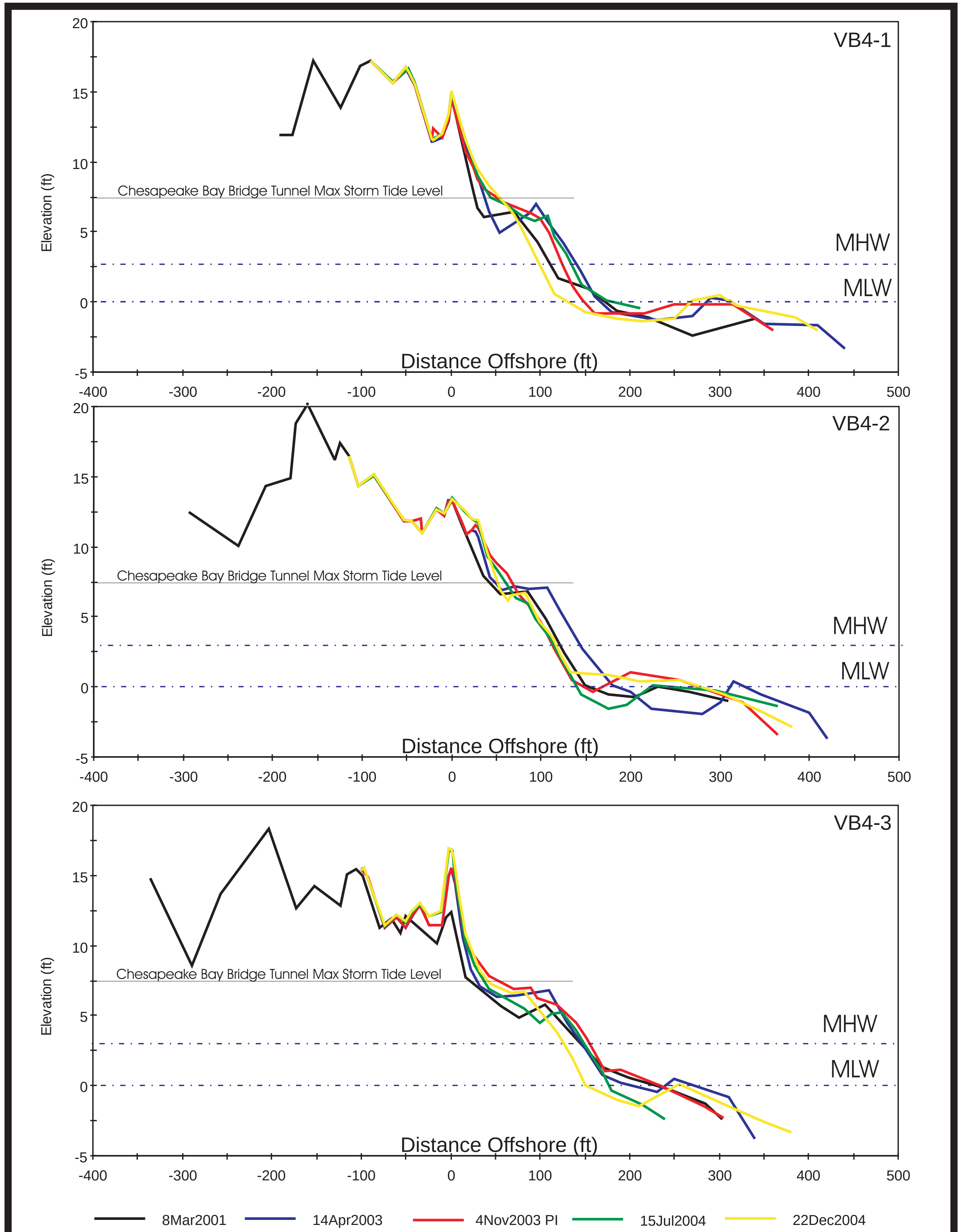


Figure 11-7. Profile plot comparisons for the three profiles at VB4 showing the first survey taken at the site in March 2001, data taken before and after the hurricane and in 2004.

Figure 11-8. Ground photos at VB4-3 before and after the hurricane and in 2004.

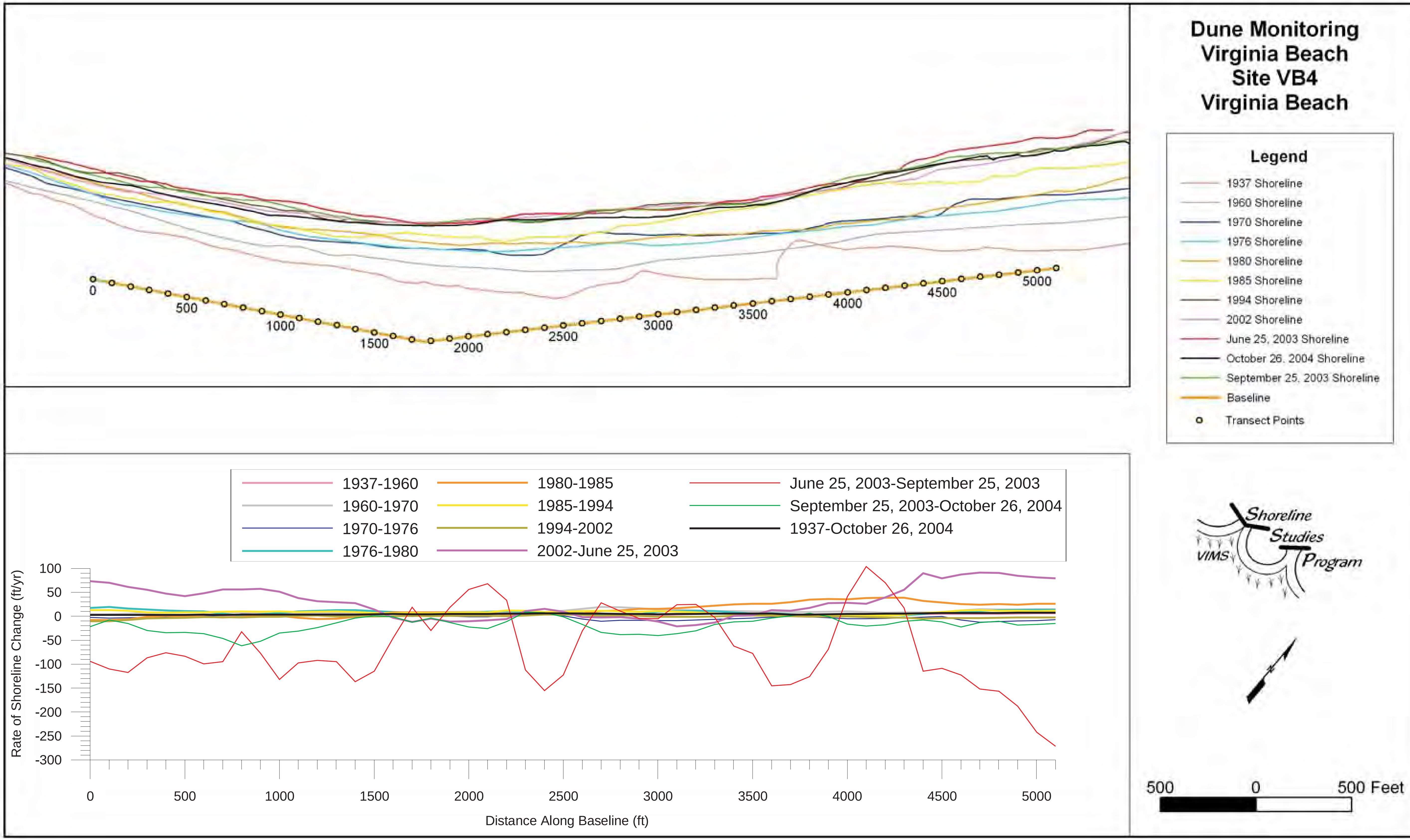


Figure 11-9. Rate of shoreline change calculated from shorelines digitized from rectified aerial photos.

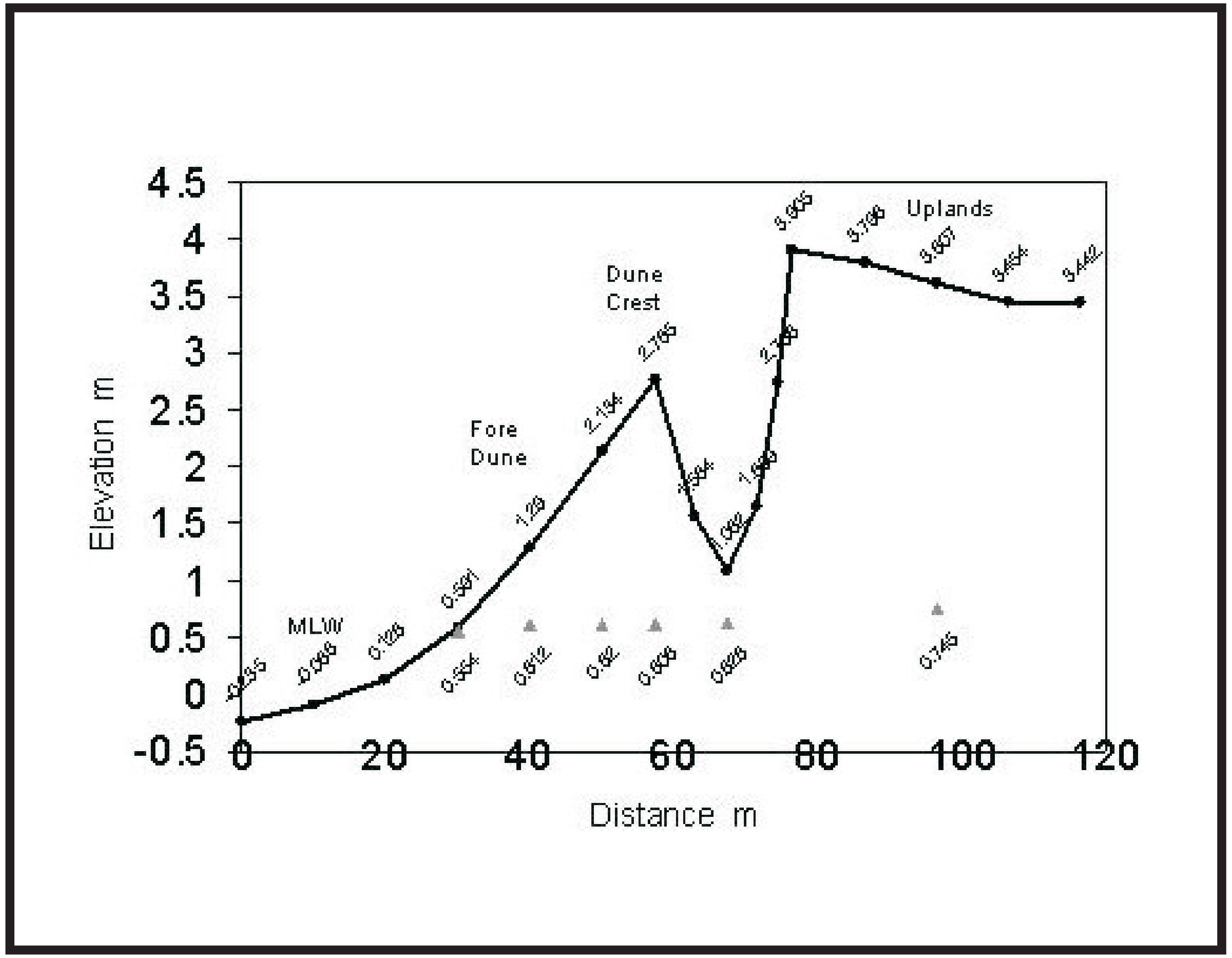


Figure 13-1. Dune feature elevations and mean water table elevations (▲) for the time period 7/18/2002-8/2/2002 based on 5 minute interval data.

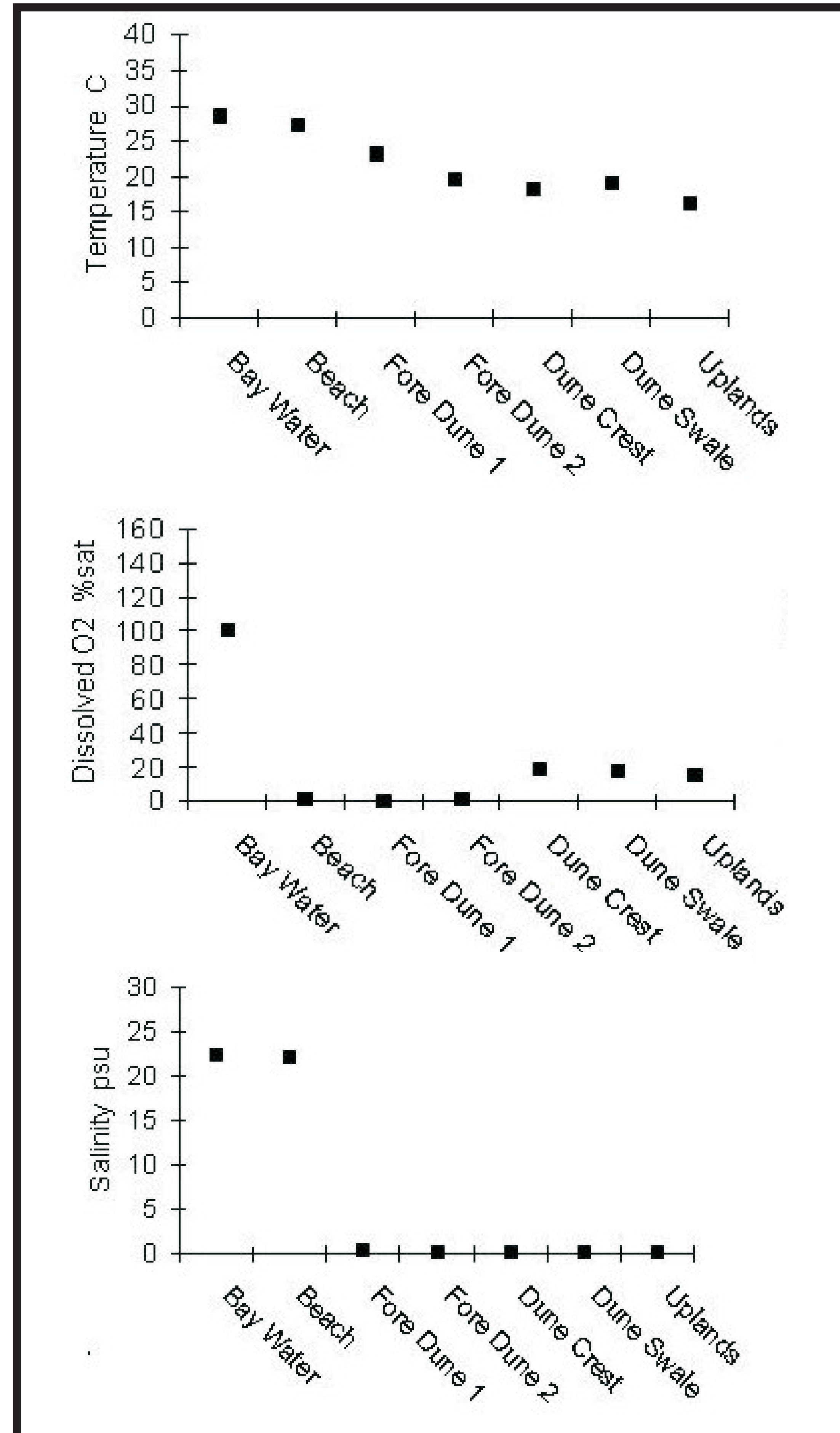


Figure 13-2. Mean physical water quality measured during site visits.

Figure 14-1. Dune formation processes at Nh10. A dune dimple forms close the high water line on SAV detritus and accumulates wind-blown sand allowing dune vegetation to grow into a dunelet. Over time, the area where the dunelets occur become a foredune.

Figure 14-2. Clear-cutting of the dune vegetation at Ln39.

Figure 14-3. Impact of Hurricane Isabel on Nl42's structures.

Appendix B
Measured Parameters

MA3 LN39 NH10 NH17 NH51 NL42 NL58 NL59 VB4

Mathews Dune Horizontal Measurements

Locality	SITE	Profile No.	DATE	Horizontal Measurements							
				Secondary System		Primary System					
				Extent from Crest		Extent from Crest			Extent from…		
				to Back of 2nd Dune (Feet)	to Back of Primary Dune (Feet)	to Back of Primary Dune (Feet)	to MLW (Feet)	to Front of Primary Dune (Feet)	Front of Primary to Beach Berm (Feet)	Beach Berm to MLW (Feet)	Primary Crest to Toe (Feet)
				A	B	C	D	E	F	G	H
MA	3	1	19-Jan-01	10.7	10	33	89	20	5	64	43
MA	3	1	4-Sep-01	10.7	10	33	77	10	21	46	60
MA	3	1	7-May-02	10.7	10	33	57	5	41	11	60
MA	3	1	15-Oct-02	10.7	10	33	99	21	21	57	71
MA	3	1	27-Mar-03	10.7	10	33	94	30	29	35	75
MA	3	1	2-Oct-03	21	-	-	-	-	-	63	-
MA	3	1	14-Jul-04	21	26	12	120	14	58	48	88
MA	3	1	8-Dec-04	21	26	10	122	26	28	68	76
MA	3	2	19-Jan-01	30	35	25	161	23	52	86	93
MA	3	2	4-Sep-01	30	35	25	169	40	35	94	102
MA	3	2	7-May-02	30	35	25	168	44	53	71	112
MA	3	2	15-Oct-02	30	35	24	180	45	36	99	107
MA	3	2	27-Mar-03	31	34	24	185	45	39	101	101
MA	3	2	2-Oct-03	30	32	28	170	39	41	90	117
MA	3	2	14-Jul-04	30	32	28	210	54	43	113	115
MA	3	2	8-Dec-04	30	32	28	202	41	62	99	130
MA	3	3	19-Jan-01	14	14	13	117	23	38	56	78
MA	3	3	4-Sep-01	14	14	13	106	23	25	58	80
MA	3	3	7-May-02	14	14	13	99	23	32	44	71
MA	3	3	15-Oct-02	14	14	13	119	23	31	65	75
MA	3	3	27-Mar-03	14	14	13	113	23	41	49	80
MA	3	3	2-Oct-03	-	-	-	-	-	-	-	-
MA	3	3	14-Jul-04	20	30	4	120	4	44	72	70
MA	3	3	8-Dec-04	18	30	14	104	9	39	56	70
MA	3	4	19-Jan-01	42	48	32	218	30	37	151	93
MA	3	4	4-Sep-01	42	48	32	98	38	14	46	83
MA	3	4	7-May-02	67	23	32	108	39	23	46	85
MA	3	4	15-Oct-02	42	48	32	103	42	11	50	88
MA	3	4	27-Mar-03	42	48	32	224	39	22	163	98
MA	3	4	2-Oct-03	49	41	29	209	60	30	119	127
MA	3	4	14-Jul-04	42	48	25	247	56	54	137	135
MA	3	4	8-Dec-04	42	48	29	236	42	70	124	146
MA	3	5	19-Jan-01	45	15	21.6	59.7	24.4	14	21.3	59.4
MA	3	5	4-Sep-01	45	15	21.6	71.7	28.4	14	29.3	73.4
MA	3	5	7-May-02	45	15	21.6	83.7	28.4	32.3	23	78.4
MA	3	5	15-Oct-02	45	15	21.6	100.7	30.4	31.3	39	90.4
MA	3	5	27-Mar-03	45	15	21.6	100.7	35.4	32	33.3	87.4
MA	3	5	2-Oct-03	57	-	-	-	-	-	28.3	-
MA	3	5	14-Jul-04	64	21	31.7	70.3	14.3	39.7	16.3	70
MA	3	5	8-Dec-04	63	21	31.7	70.3	27	21	22.3	70
MA	3	6	19-Jan-01	70	55	30	108	12	22	74	61
MA	3	6	4-Sep-01	70	55	31	131	11	38	82	79
MA	3	6	7-May-02	70	55	31	134	23	44	67	88
MA	3	6	15-Oct-02	70	55	31	117	16	41	60	81
MA	3	6	27-Mar-03	70	55	27.5	132.5	25.5	39	68	83.5
MA	3	6	2-Oct-03	-	-	-	-	-	-	-	-
MA	3	6	14-Jul-04	5	75	18	184	12	50	122	92
MA	3	6	8-Dec-04	8	70	22	195	14	43	138	85
MA	3	7	19-Jan-01	55	27	20	103	9	29	65	64
MA	3	7	4-Sep-01	55	27	20	134	14	14	106	53
MA	3	7	7-May-02	55	27	20	132	11	22	99	54
MA	3	7	15-Oct-02	55	27	20	131	2	20	109	38
MA	3	7	27-Mar-03	55	27	17	136	2	27	107	46
MA	3	7	2-Oct-03	-	-	-	-	-	-	-	-
MA	3	7	14-Jul-04	-	-	-	-	-	-	98	-
MA	3	7	8-Dec-04	-	-	-	-	-	-	75	-
MA	3	8	19-Jan-01	58	45	17	152	35	76	41	134
MA	3	8	4-Sep-01	58	45	17	172	42	62	68	134
MA	3	8	7-May-02	58	45	17	240	44	50	146	120
MA	3	8	15-Oct-02	58	45	17	232	48	38	146	111
MA	3	8	27-Mar-03	58	45	17	227	52	33	142	103
MA	3	8	2-Oct-03	48	55	16	245	29	43	173	131
MA	3	8	14-Jul-04	58	45	17	245	24	47	174	100
MA	3	8	8-Dec-04	58	45	17	268	28	30	210	90

* NOTE:TOE/STEP elevated above MLW

Mathews Dune Vertical Measurements

Locality	SITE	Profile No.	DATE	Vertical Measurements						
				Secondary System		Primary System				
				Elevation of...		Elevation of...				
				Back of 2nd Dune (Feet MLW)	2nd Dune Crest (Feet MLW)	Back of Primary Dune (Feet MLW)	Dune Crest (Feet MLW)	Front of Primary Dune (Feet MLW)	Beach Berm (Feet MLW)	Toe (Feet MLW)
				U	V	W	X	Y	Z	T
MA	3	1	19-Jan-01	6.4	7.4	5.9	8.0	3.9	3.6	0.8*
MA	3	1	4-Sep-01	6.5	7.4	6.0	8.5	5.7	4.0	0.5
MA	3	1	7-May-02	6.4	7.33	6.07	8.46	7.5	3.3	0.95
MA	3	1	15-Oct-02	6.4	7.4	6	8.45	5.4	4.1	1.4
MA	3	1	27-Mar-03	6.4	8.94	6	7.38	4.6	3.37	1.12
MA	3	1	2-Oct-03	6.4	8.9	-	-	-	5.41	1
MA	3	1	14-Jul-04	6.4	8.9	6.3	7.2	5.6	3.38	1.31
MA	3	1	8-Dec-04	6.4	8.9	6.5	7.2	6.2	4.22	1.16
MA	3	2	19-Jan-01	7.1	8.6	6.1	9.1	5.9	3.7	1.2
MA	3	2	4-Sep-01	7.1	8.6	6.1	9.2	5.1	4.2	0.2
MA	3	2	7-May-02	7.0	9.2	6.11	9.18	5.86	4.2	1.16
MA	3	2	15-Oct-02	7.1	9.2	6.11	9	5.8	5.2	1.48
MA	3	2	27-Mar-03	7.1	9.2	6.11	9.3	6	3.09	1.14
MA	3	2	2-Oct-03	7.0	8.9	7.2	8.1	6.1	5.04	1.9
MA	3	2	14-Jul-04	7.0	8.9	7.3	8.3	6.6	3.47	1.05
MA	3	2	8-Dec-04	7.0	8.9	7.4	8.3	6.7	7.8	1.03
MA	3	3	19-Jan-01	6.0	9.1	7.5	10.2	5.0	3.0	0.8
MA	3	3	4-Sep-01	6.0	9.2	7.5	10.1	5.3	4.4	0.5
MA	3	3	7-May-02	6.1	9.19	7.5	10.26	5.02	5.4	0.93
MA	3	3	15-Oct-02	6.0	9.2	7.5	10.4	5.39	4.8	1.27
MA	3	3	27-Mar-03	6.0	9.19	7.5	10.19	5.3	5.4	1.03
MA	3	3	2-Oct-03	-	-	-	-	-	-	-
MA	3	3	14-Jul-04	6.0	8.1	7.5	6.3	4.1	4.06	1.01
MA	3	3	8-Dec-04	6.0	8.5	7.5	6.67	4.6	3.85	0.83
MA	3	4	19-Jan-01	6.1	7.7	7.1	11.4	6.2	4.0	0.5
MA	3	4	4-Sep-01	6.1	7.7	7.1	11.6	6.2	4.6	0.3
MA	3	4	7-May-02	5.7	7.1	6.68	10.46	6.3	3.23	1.6
MA	3	4	15-Oct-02	6.2	7.1	7.2	11.59	5.9	5.43	0.89
MA	3	4	27-Mar-03	6.2	7.7	7.2	11.59	7.5	3.74	0.57
MA	3	4	2-Oct-03	5.8	7.8	7.2	11.3	8.0	5.8	1.05
MA	3	4	14-Jul-04	5.8	7.9	7.2	11.2	8.1	3.7	0.72
MA	3	4	8-Dec-04	5.8	10.53	7.2	11.4	8.2	4.14	0.7
MA	3	5	19-Jan-01	4.6	8.7	5.9	10	3.7	3.1	0
MA	3	5	4-Sep-01	4.6	8.7	5.9	10.1	4.7	3.7	-0.1
MA	3	5	7-May-02	4.6	8.7	5.93	10.06	5.4	2.6	0
MA	3	5	15-Oct-02	4.6	8.7	5.9	10.07	5.2	3.8	0
MA	3	5	27-Mar-03	4.6	8.7	5.9	10.2	5.2	2.52	0.39
MA	3	5	2-Oct-03	4.6	7.6	-	-	-	3.18	0.06
MA	3	5	14-Jul-04	4.6	8.2	5.9	6.3	4.2	2.81	0.03
MA	3	5	8-Dec-04	4.6	9.1	6.3	6.9	4.8	3.12	0.08
MA	3	6	19-Jan-01	8.3	8.7	7.2	11.6	6.1	4	0.8
MA	3	6	4-Sep-01	8.4	8.8	7.1	11.4	5.8	4.4	-0.2
MA	3	6	7-May-02	8.4	8.72	7.77	11.33	6.41	3.7	1
MA	3	6	15-Oct-02	8.4	8.75	7.2	11.19	5.71	5.5	0.7
MA	3	6	27-Mar-03	8.4	8.75	7.2	11.61	5.78	4.6	1.32
MA	3	6	2-Oct-03	-	-	-	-	-	-	-
MA	3	6	14-Jul-04	8.4	9.26	6.34	6.34	6.2	4.03	0.98
MA	3	6	8-Dec-04	8.4	9.47	6.4	9.11	6.9	3.86	1.25
MA	3	7	19-Jan-01	6.2	12	6.7	9.9	6	3.8	0.5
MA	3	7	4-Sep-01	6.2	11.9	7.7	9.9	5.8	4.6	1.2
MA	3	7	7-May-02	7.7	11.79	7.63	9.82	5.63	4	0.7
MA	3	7	15-Oct-02	7.8	10.67	7.71	9.89	5.9	3.7	1.17
MA	3	7	27-Mar-03	7.8	10.6	7.67	9.7	6.02	3.65	1.22
MA	3	7	2-Oct-03	-	-	-	-	-	-	-
MA	3	7	14-Jul-04	-	-	-	-	-	4.2	0.72
MA	3	7	8-Dec-04	-	-	-	-	-	4.07	1.26
MA	3	8	19-Jan-01	7	10.4	8.4	11.2	5.9	3.7	0.5
MA	3	8	4-Sep-01	7	10.7	8.4	11.3	5.5	4.3	0.9
MA	3	8	7-May-02	6.96	10.37	8.29	11.3	5.99	4.5	2.04
MA	3	8	15-Oct-02	7.02	10.49	8.38	11.22	5.45	4.4	0.94
MA	3	8	27-Mar-03	7.01	10.45	8.37	11.3	5.19	3.38	1.12
MA	3	8	2-Oct-03	6.9	11	8.3	11.2	6.5	5.1	1.3
MA	3	8	14-Jul-04	6.9	10.3	8.2	11.5	7	4.36	0.76
MA	3	8	8-Dec-04	6.9	10.7	8.2	11.6	7.3	4.23	1.34

* NOTE:TOE/STEP elevated above MLW

Lancaster Dune Measurements

Locality	SITE	Profile No.	DATE	Horizontal Measurements							
				Secondary System		Primary System					
				Extent from Crest		Extent from Crest			Extent from…		
				to Back of 2nd Dune (Feet)	to Back of Primary Dune (Feet)	to Back of Primary Dune (Feet)	to MLW (Feet)	to Front of Primary Dune (Feet)	Front of Primary to Beach Berm (Feet)	Beach Berm to MLW (Feet)	Primary Crest to Toe (Feet)
				A	B	C	D	E	F	G	H
LN	39	1	15-Feb-01	-	-	14	90	11	57	22	98
LN	39	1	28-Aug-01	-	-	14	56	11	34	11	67
LN	39	1	21-Mar-01	-	-	14	72	11	43	18	78
LN	39	1	31-Oct-02	-	-	14	40	14	4	22	43
LN	39	1	24-Jun-03	-	-	14	41	14	6	21	39
LN	39	1	14-Oct-03	-	-	11	29	12	-	-	23
LN	39	1	23-Aug-04	-	-	9	50	15	10	25	57
LN	39	1	7-Dec-04	-	-	10	33	15	4.5	13.5	36
LN	39	2	15-Feb-01	25	35	25	58	20	17	21	64
LN	39	2	28-Aug-01	25	18	42	70	20	39	11	90
LN	39	2	21-Mar-01	25	18	42	66	20	34	12	69
LN	39	2	31-Oct-02	25	18	42	74	20	31	23	72
LN	39	2	24-Jun-03	25	18	42	76	50	2	24	70
LN	39	2	14-Oct-03	25	18	72	67	30	10	27	68
LN	39	2	23-Aug-04	25	22	75	47	0	29	18	55
LN	39	2	7-Dec-04	25	22	74	68	5	27.5	35.5	64

Locality	SITE	Profile No.	DATE	Vertical Measurements						
				Secondary System		Primary System				
				Elevation of...		Elevation of...				
				Back of 2nd Dune (Feet MLW)	2nd Dune Crest (Feet MLW)	Back of Primary Dune (Feet MLW)	Dune Crest (Feet MLW)	Front of Primary Dune (Feet MLW)	Beach Berm (Feet MLW)	Toe (Feet MLW)
				U	V	W	X	Y	Z	T
LN	39	1	15-Feb-01	-	-	2.9	5.3	3.8	1.7	-2.1
LN	39	1	28-Aug-01	-	-	2.9	5.3	3.8	1.9	-1.3
LN	39	1	21-Mar-01	-	-	2.8	5.3	4.0	2.6	-1.1
LN	39	1	31-Oct-02	-	-	2.9	5.2	4.4	3.3	-0.5
LN	39	1	24-Jun-03	-	-	2.9	5.3	4.1	4.0	-0.1
LN	39	1	14-Oct-03	-	-	3.5	3.6	1.8	-	0.2
LN	39	1	23-Aug-04	-	-	3.7	3.7	2.5	3.6	-0.9
LN	39	1	7-Dec-04	-	-	3.8	4.2	1.8	2.1	-0.4
LN	39	2	15-Feb-01	2.9	3.9	2.8	4.2	3.4	2.6	-0.7
LN	39	2	28-Aug-01	2.9	3.9	2.8	4.2	3.4	1.4	-2.8
LN	39	2	21-Mar-01	2.9	3.9	2.8	4.1	3.4	2.1	-0.8
LN	39	2	31-Oct-02	2.9	3.9	2.9	4.1	3.4	3.0	1.0
LN	39	2	24-Jun-03	2.9	3.9	2.9	4.1	2.9	2.6	0.5
LN	39	2	14-Oct-03	2.9	3.7	2.9	4.3	3.6	3.4	-0.2
LN	39	2	23-Aug-04	2.9	3.8	3.0	4.1	4.1	2.1	-1.5
LN	39	2	7-Dec-04	2.9	3.8	3.0	4.1	3.5	3.4	0.3

Northampton Dune Measurements

Locality	SITE	Profile No.	DATE	Horizontal Measurements							
				Secondary System		Primary System					
				Extent from Crest		Extent from Crest			Extent from…		
				to Back of 2nd Dune (Feet)	to Back of Primary Dune (Feet)	to Back of Primary Dune (Feet)	to MLW (Feet)	to Front of Primary Dune (Feet)	Front of Primary to Beach Berm (Feet)	Beach Berm to MLW (Feet)	Primary Crest to Toe (Feet)
				A	B	C	D	E	F	G	H
NH	10	1	1-Mar-01	-	-	7	96	11	54	31	91
NH	10	1	19-Sep-01	-	-	7	102	11	45	46	86
NH	10	1	4-Jun-02	-	-	7	102	11	77	14	133
NH	10	1	16-Dec-02	-	-	7	120	11	66	43	102
NH	10	1	10-Jun-03	-	-	7	131	11	60	60	87
NH	10	1	23-Dec-03	-	-	7	137	12	81	44	113
NH	10	1	12-Jul-04	-	-	7	140	12	68	60	103
NH	10	1	22-Dec-04	-	-	7	176	12	75	89	103
NH	10	2	1-Mar-01	-	16	19	184	19	47	118	92
NH	10	2	19-Sep-01	-	16	19	107	19	43	45	108
NH	10	2	4-Jun-02	-	16	19	108	19	45	44	100
NH	10	2	16-Dec-02	-	16	19	218	19	48	151	100
NH	10	2	10-Jun-03	-	16	19	208	19	121	68	87
NH	10	2	23-Dec-03	-	16	19	274	25	39	210	92
NH	10	2	12-Jul-04	-	16	19	138	25	34	79	86
NH	10	2	22-Dec-04	-	16	19	146	25	43	78	85
NH	10	3	1-Mar-01	-	-	30	89	16	39	34	89
NH	10	3	19-Sep-01	-	-	30	90	17	30	43	89
NH	10	3	4-Jun-02	-	-	30	88	17	37	34	67
NH	10	3	16-Dec-02	-	-	17	87	18	23	46	90
NH	10	3	10-Jun-03	-	-	17	168	17	33	118	90
NH	10	3	23-Dec-03	-	-	21	159	24	40	95	76
NH	10	3	12-Jul-04	-	-	21	98	24	28	46	76
NH	10	3	22-Dec-04	-	-	21	117	26	19	72	81

Locality	SITE	Profile No.	DATE	Vertical Measurements						
				Secondary System		Primary System				
				Elevation of...		Elevation of...				
				Back of 2nd Dune (Feet MLW)	2nd Dune Crest (Feet MLW)	Back of Primary Dune (Feet MLW)	Dune Crest (Feet MLW)	Front of Primary Dune (Feet MLW)	Beach Berm (Feet MLW)	Toe (Feet MLW)
				U	V	W	X	Y	Z	T
NH	10	1	1-Mar-01	-	-	12.94	14.4	10.34	3.56	0.26
NH	10	1	19-Sep-01	-	-	13.02	14.36	10.52	4.32	1.34
NH	10	1	4-Jun-02	-	-	13.07	14.38	10.95	0.86	-1.21
NH	10	1	16-Dec-02	-	-	13.05	14.37	10.91	3.47	0.56
NH	10	1	10-Jun-03	-	-	13.09	14.37	10.89	3.71	-1.16
NH	10	1	23-Dec-03	-	-	13.04	14.36	11.01	2.87	0.78
NH	10	1	12-Jul-04	-	-	13.14	14.34	10.99	3.52	0.52
NH	10	1	22-Dec-04	-	-	13.07	14.33	11.05	3.07	1.14
NH	10	2	1-Mar-01	-	13.14	9.19	10.75	6.66	3.72	0.46
NH	10	2	19-Sep-01	-	13.16	9.25	11.01	6.57	4.75	0.06
NH	10	2	4-Jun-02	-	13.12	9.38	11.37	6.8	4.73	0.62
NH	10	2	16-Dec-02	-	13.12	9.42	11.36	6.9	4.88	0.71
NH	10	2	10-Jun-03	-	13.16	9.46	11.4	7.37	4.03	0.65
NH	10	2	23-Dec-03	-	13.13	9.49	11.45	7.47	6.19	2.18
NH	10	2	12-Jul-04	-	13.18	9.52	11.45	7.56	4.86	2.22
NH	10	2	22-Dec-04	-	13.04	9.34	11.37	7.66	4.51	2.32
NH	10	3	1-Mar-01	-	-	7.73	9.76	5.87	3.41	-0.05
NH	10	3	19-Sep-01	-	-	7.76	9.76	5.83	4.52	0.04
NH	10	3	4-Jun-02	-	-	7.77	10.09	6.13	4.15	2.39
NH	10	3	16-Dec-02	-	-	7.83	10.06	6.72	5.09	-0.11
NH	10	3	10-Jun-03	-	-	7.86	10.2	6.78	3.41	0.4
NH	10	3	23-Dec-03	-	-	7.9	10.39	5.97	2.69	1.67
NH	10	3	12-Jul-04	-	-	7.86	10.48	5.69	3.42	0.54
NH	10	3	22-Dec-04	-	-	7.98	10.63	5.61	3.21	0.13

Northampton Dune Measurements

Locality	SITE	Profile No.	DATE	Horizontal Measurements: Secondary System, Extent from Crest: to Back of 2nd Dune (Feet) A	to Back of Primary Dune (Feet) B	Primary System, Extent from Crest: to Back of Primary Dune (Feet) C	to MLW (Feet) D	to Front of Primary Dune (Feet) E	Extent from…: Front of Primary to Beach Berm (Feet) F	Beach Berm to MLW (Feet) G	Primary Crest to Toe (Feet) H
NH	17	1	1-Mar-01	-	-	45	60	9	29	22	59
NH	17	1	19-Sep-01	-	-	45	56	11	25	20	55
NH	17	1	4-Jun-02	-	-	45	111	10	31	70	55
NH	17	1	16-Dec-02	-	-	45	97	9	23	65	51
NH	17	1	10-Jun-03	-	-	45	33	9	31	7	60
NH	17	1	23-Dec-03	-	-	45	143	9	29	105	62
NH	17	1	12-Jul-04	-	-	45	109	9	29	71	50
NH	17	1	21-Dec-04	-	-	45	109	9	38.5	61.5	65
NH	17	2	1-Mar-01	-	-	24	111	10	70	31	99
NH	17	2	19-Sep-01	-	-	24	112	10	63	39	135
NH	17	2	4-Jun-02	-	-	24	137	10	76	51	104
NH	17	2	16-Dec-02	-	-	24	137	10	74	53	110
NH	17	2	10-Jun-03	-	-	24	142	10	72	60	97
NH	17	2	23-Dec-03	-	-	24	141	10	76	55	108
NH	17	2	12-Jul-04	-	-	24	143	10	74	59	93
NH	17	2	21-Dec-04	-	-	24	150	10	83	57	110
NH	17	3	1-Mar-01	-	-	12	90	25	34	31	74
NH	17	3	19-Sep-01	-	-	12	89	26	18	45	62
NH	17	3	4-Jun-02	-	-	12	130	26	26	78	73
NH	17	3	16-Dec-02	-	-	12	133	26	36	71	80
NH	17	3	10-Jun-03	-	-	12	126	42	16	68	73
NH	17	3	23-Dec-03	-	-	12	134	43	17	74	100
NH	17	3	12-Jul-04	-	-	12	139	43	25	71	82
NH	17	3	21-Dec-04	-	-	12	131	43	26	62	102
NH	17	4	1-Mar-01	-	-	9	85	13	42	30	72
NH	17	4	19-Sep-01	-	-	9	82	16	30	36	78
NH	17	4	4-Jun-02	-	-	9	102	16	34	52	78
NH	17	4	16-Dec-02	-	-	9	100	13	41	46	71
NH	17	4	10-Jun-03	-	-	9	110	13	47	50	73
NH	17	4	23-Dec-03	-	-	9	153	16	44	93	105
NH	17	4	12-Jul-04	-	-	9	128	16	44	68	78
NH	17	4	21-Dec-04	-	-	9	128	16	50	62	83

Locality	SITE	Profile No.	DATE	Vertical Measurements: Secondary System, Elevation of...: Back of 2nd Dune (Feet MLW) U	2nd Dune Crest (Feet MLW) V	Primary System, Elevation of...: Back of Primary Dune (Feet MLW) W	Dune Crest (Feet MLW) X	Front of Primary Dune (Feet MLW) Y	Beach Berm (Feet MLW) Z	Toe (Feet MLW) T
NH	17	1	1-Mar-01	-	-	2.19	6.50	4.46	2.10	-0.09
NH	17	1	19-Sep-01	-	-	2.37	6.53	4.37	2.49	0
NH	17	1	4-Jun-02	-	-	2.39	7.01	5.16	2.35	1.25
NH	17	1	16-Dec-02	-	-	2.08	7.02	5.34	2.69	0.99
NH	17	1	10-Jun-03	-	-	2.09	7.01	5.49	2.98	0.93
NH	17	1	23-Dec-03	-	-	2.55	7.00	5.40	3.20	0.45
NH	17	1	12-Jul-04	-	-	2.59	7.01	5.65	3.00	1.21
NH	17	1	21-Dec-04	-	-	2.52	7.03	5.55	1.92	0.67
NH	17	2	1-Mar-01	-	-	4.37	8.5	6.53	2.05	0.25
NH	17	2	19-Sep-01	-	-	4.4	8.44	6.57	3.03	-0.58
NH	17	2	4-Jun-02	-	-	4.89	8.95	6.95	2.33	1
NH	17	2	16-Dec-02	-	-	4.93	8.87	6.92	2.42	0.55
NH	17	2	10-Jun-03	-	-	4.91	8.93	6.94	3.69	1
NH	17	2	23-Dec-03	-	-	4.9	8.93	7.01	3.05	0.5
NH	17	2	12-Jul-04	-	-	4.95	8.95	6.98	3	1.45
NH	17	2	21-Dec-04	-	-	4.93	8.95	7.03	1.94	0.65
NH	17	3	1-Mar-01	-	-	4.43	8.04	4.33	2.03	0.5
NH	17	3	19-Sep-01	-	-	4.39	8.00	4.2	3.69	1.28
NH	17	3	4-Jun-02	-	-	5.07	8.76	5.05	3.43	1.59
NH	17	3	16-Dec-02	-	-	5.13	8.73	4.91	2.72	0.99
NH	17	3	10-Jun-03	-	-	5.15	8.81	4.96	3.01	1.18
NH	17	3	23-Dec-03	-	-	5.15	8.85	5.25	3.5	0.45
NH	17	3	12-Jul-04	-	-	5.15	8.82	5.3	3.42	1.74
NH	17	3	21-Dec-04	-	-	5.15	8.73	5.57	3.39	0.93
NH	17	4	1-Mar-01	-	-	8.34	9.18	4.12	1.98	0.52
NH	17	4	19-Sep-01	-	-	8.72	9.18	4.36	2.9	0.08
NH	17	4	4-Jun-02	-	-	9.12	9.64	5.14	3.1	0.51
NH	17	4	16-Dec-02	-	-	9.18	9.58	5.9	2.29	0.5
NH	17	4	10-Jun-03	-	-	9.17	9.73	6.7	2.8	1.21
NH	17	4	23-Dec-03	-	-	9.15	9.55	6.6	3.6	0.4
NH	17	4	12-Jul-04	-	-	9.16	9.52	6.59	3.43	1.42
NH	17	4	21-Dec-04	-	-	9.21	9.5	6.57	2	0.93

Northampton Dune Measurements

Locality	SITE	Profile No.	DATE	Horizontal Measurements							
				Secondary System		Primary System					
				Extent from Crest		Extent from Crest			Extent from…		
				to Back of 2nd Dune (Feet)	to Back of Primary Dune (Feet)	to Back of Primary Dune (Feet)	to MLW (Feet)	to Front of Primary Dune (Feet)	Front of Primary to Beach Berm (Feet)	Beach Berm to MLW (Feet)	Primary Crest to Toe (Feet)
				A	B	C	D	E	F	G	H
NH	51	1	26-Apr-01	55	45	55	82	33	8	41	85
NH	51	1	19-Sep-01	55	45	55	94	30	10	54	80
NH	51	1	4-Jun-02	55	45	55	80	37	10	33	75
NH	51	1	16-Dec-02	55	45	55	77	23.5	9	44.5	85
NH	51	1	11-Jun-03	55	50	55	79	13.2	39.9	25.9	86
NH	51	1	18-Nov-03	55	45	53	112	9	44	59	141
NH	51	1	15-Jul-04	55	45	53	82	24	30	28	82
NH	51	1	21-Dec-04	55	45	53	105	26	31	48	115
NH	51	2	26-Apr-01	25	17	51	98	20	29	49	109
NH	51	2	19-Sep-01	25	17	51	105	23	16	66	112
NH	51	2	4-Jun-02	25	17	53	91	28	24	39	105
NH	51	2	16-Dec-02	25	17	53	89	28	19	42	92
NH	51	2	11-Jun-03	25	17	53	94	23.4	19.6	51	95
NH	51	2	18-Nov-03	25	17	52.5	122.5	3	69.5	50	115.5
NH	51	2	15-Jul-04	25	17	48	102	21	55	26	105
NH	51	2	21-Dec-04	25	17	48	132	11	55	66	143
NH	51	3	26-Apr-01	96	20	32	111	17	-	-	110
NH	51	3	19-Sep-01	96	20	32	98	17	-	-	90
NH	51	3	4-Jun-02	96	20	32	87	23	26	38	110
NH	51	3	16-Dec-02	96	20	32	120	23	11	86	90
NH	51	3	11-Jun-03	96	20	32	98	21	23	54	120
NH	51	3	18-Nov-03	96	20	31	115	2	39	74	63
NH	51	3	15-Jul-04	96	20	29	100	27	33	40	88
NH	51	3	21-Dec-04	96	20	29	126	32.4	21.6	72	163

Locality	SITE	Profile No.	DATE	Vertical Measurements						
				Secondary System		Primary System				
				Elevation of...		Elevation of...				
				Back of 2nd Dune (Feet MLW)	2nd Dune Crest (Feet MLW)	Back of Primary Dune (Feet MLW)	Dune Crest (Feet MLW)	Front of Primary Dune (Feet MLW)	Beach Berm (Feet MLW)	Toe (Feet MLW)
				U	V	W	X	Y	Z	T
NH	51	1	26-Apr-01	9.9	12.9	9.9	13.3	6.8	3.0	-0.6
NH	51	1	19-Sep-01	10.0	12.5	9.8	13.3	7.8	3.7	-0.6
NH	51	1	4-Jun-02	10.0	12.4	9.8	13.5	5.5	3.8	0.7
NH	51	1	16-Dec-02	10.0	12.5	9.8	13.3	8.5	6.5	-0.6
NH	51	1	11-Jun-03	10.0	12.5	9.8	13.4	12.7	3.7	-0.3
NH	51	1	18-Nov-03	10.0	12.5	9.8	13.7	9.7	4.9	-1.3
NH	51	1	15-Jul-04	9.9	12.6	9.9	13.7	6.6	3.3	-0.1
NH	51	1	21-Dec-04	10.02	12.43	9.8	13.55	7.09	3	-0.69
NH	51	2	26-Apr-01	9.36	13.82	10.66	12.6	7.6	4.91	-0.96
NH	51	2	19-Sep-01	9.28	13.85	10.73	12.59	7.36	6.97	-0.47
NH	51	2	4-Jun-02	9.4	13.79	10.67	13.09	6.33	4.57	-1.29
NH	51	2	16-Dec-02	9.34	13.78	10.69	13.23	7.25	5.48	-0.41
NH	51	2	11-Jun-03	9.31	13.79	10.7	13.24	7.41	5.44	-0.12
NH	51	2	18-Nov-03	9.47	13.75	10.71	13.51	10.3	4.38	0.35
NH	51	2	15-Jul-04	9.34	13.76	10.78	12.71	7.86	3.06	-0.4
NH	51	2	21-Dec-04	9.32	13.85	10.8	12.92	10.36	2.51	-0.58
NH	51	3	26-Apr-01	8.2	13.63	10.63	14.33	9.04	-	0
NH	51	3	19-Sep-01	8.2	13.59	10.61	14.34	9.15	-	0.68
NH	51	3	4-Jun-02	8.2	13.6	10.57	14.36	7.54	4.1	-0.86
NH	51	3	16-Dec-02	8.2	13.56	10.61	14.3	7.8	6.32	0.44
NH	51	3	11-Jun-03	8.2	13.59	10.61	14.34	7.56	3.96	-0.37
NH	51	3	18-Nov-03	8.2	13.55	10.62	14.17	9.03	3.95	1.7
NH	51	3	15-Jul-04	8.2	13.52	10.62	14.01	5.95	3.48	0.12
NH	51	3	21-Dec-04	8.2	13.56	10.65	13.95	5.98	3.14	-1.87

Northumberland Dune Measurements

Locality	SITE	Profile No.	DATE	Horizontal Measurements							
				Secondary System		Primary System					
				Extent from Crest		Extent from Crest			Extent from…		
				to Back of 2nd Dune (Feet)	to Back of Primary Dune (Feet)	to Back of Primary Dune (Feet)	to MLW (Feet)	to Front of Primary Dune (Feet)	Front of Primary to Beach Berm (Feet)	Beach Berm to MLW (Feet)	Primary Crest to Toe (Feet)
				A	B	C	D	E	F	G	H
NL	42	1	5-Apr-01	-	-	16.5	40.5	10.5	11	19	45.5
NL	42	1	12-Sep-01	-	-	16.2	37.8	10.8	5	22	49.8
NL	42	1	21-Mar-02	-	-	16.2	41.8	10.8	14	17	47.8
NL	42	1	31-Oct-02	-	-	16.2	46.8	4.8	20	22	49.8
NL	42	1	24-Jun-03	-	-	13	41	15	10	16	42
NL	42	1	14-Oct-03	-	-	-	-	-	-	26	-
NL	42	1	7-Jul-04	-	-	-	-	-	-	14	-
NL	42	1	7-Dec-04	-	-	-	-	-	-	21	-
NL	42	2	5-Apr-01	-	-	-	-	-	-	-	-
NL	42	2	12-Sep-01	-	25	63	136	89	24	23	172
NL	42	2	21-Mar-02	-	25	63	130	89	32	9	151
NL	42	2	31-Oct-02	-	25	63	132	72	36	24	135
NL	42	2	24-Jun-03	-	25	63	116	76	26	14	121.3
NL	42	2	14-Oct-03	-	25	100	73	15	31	27	80
NL	42	2	7-Jul-04	-	25	95	66	21	28	17	75
NL	42	2	7-Dec-04	-	25	93	64	25	19	20	67
NL	42	3	5-Apr-01	-	-	-	-	-	-	-	-
NL	42	3	12-Sep-01	45	15	26	60	24	10	26	62
NL	42	3	21-Mar-02	45	15	26	51	28	5	18	66
NL	42	3	31-Oct-02	45	15	26	46	3	18	25	59
NL	42	3	24-Jun-03	45	15	25	55	3.5	28.5	23	69
NL	42	3	14-Oct-03	-	-	39	65	10	30	25	64
NL	42	3	7-Jul-04	-	-	37	67	17	36	14	73
NL	42	3	7-Dec-04	-	-	37	66	16	30	20	78
NL	42	4	5-Apr-01	-	-	27	67	18	35	55	79
NL	42	4	12-Sep-01	-	-	27	60	19	23	18	64
NL	42	4	21-Mar-02	-	-	27	49	18	8	23	51
NL	42	4	31-Oct-02	-	-	27	58	15	13	30	66
NL	42	4	24-Jun-03	-	-	27	51	18.5	9.5	23	48
NL	42	4	14-Oct-03	-	-	-	-	-	-	22	-
NL	42	4	7-Jul-04	-	-	-	-	-	-	22	-
NL	42	4	7-Dec-04	-	-	-	-	-	-	28.5	-

Locality	SITE	Profile No.	DATE	Vertical Measurements						
				Secondary System		Primary System				
				Elevation of...		Elevation of...				
				Back of 2nd Dune (Feet MLW)	2nd Dune Crest (Feet MLW)	Back of Primary Dune (Feet MLW)	Dune Crest (Feet MLW)	Front of Primary Dune (Feet MLW)	Beach Berm (Feet MLW)	Toe (Feet MLW)
				U	V	W	X	Y	Z	T
NL	42	1	5-Apr-01	-	-	4.7	6.0	3.7	2.4	-0.9
NL	42	1	12-Sep-01	-	-	4.7	5.9	3.4	3.1	-2.0
NL	42	1	21-Mar-02	-	-	4.7	5.9	3.5	2.0	-1.5
NL	42	1	31-Oct-02	-	-	4.8	6.0	4.6	2.3	-0.9
NL	42	1	24-Jun-03	-	-	4.8	5.9	3.0	2.2	-0.2
NL	42	1	14-Oct-03	-	-	-	-	-	3.2	-1.1
NL	42	1	7-Jul-04	-	-	-	-	-	1.9	-2.5
NL	42	1	7-Dec-04	-	-	-	-	-	1.4	-1.1
NL	42	2	5-Apr-01	-	-	-	-	-	-	-
NL	42	2	12-Sep-01	-	6.3	5.1	5.6	3.2	3.2	-0.7
NL	42	2	21-Mar-02	-	6.3	5.2	5.6	3.7	1.5	-1.8
NL	42	2	31-Oct-02	-	6.3	5.2	5.5	4.8	2.6	-1.7
NL	42	2	24-Jun-03	-	6.3	5.3	5.5	5.1	1.9	-0.8
NL	42	2	14-Oct-03	-	6.3	5.2	7.4	4.8	2.7	-5.6
NL	42	2	7-Jul-04	-	6.3	5.2	7.2	5.4	2.3	-1.1
NL	42	2	7-Dec-04	-	6.3	5.2	7.3	3.7	2.9	-1.2
NL	42	3	5-Apr-01	-	-	-	-	-	-	-
NL	42	3	12-Sep-01	3.8	5.7	5.8	6.8	3.9	3.0	-1.0
NL	42	3	21-Mar-02	3.8	5.6	5.8	6.7	3.4	2.4	-2.4
NL	42	3	31-Oct-02	3.8	5.6	5.8	6.8	4.8	3.3	-2.9
NL	42	3	24-Jun-03	3.8	5.6	5.8	6.7	5.3	3.4	-2.0
NL	42	3	14-Oct-03	-	-	5.2	7.4	5.0	3.3	-1.6
NL	42	3	7-Jul-04	-	-	6.3	7.4	4.8	2.4	-0.9
NL	42	3	7-Dec-04	-	-	6.4	7.4	4.8	2.9	-1.3
NL	42	4	5-Apr-01	-	-	4.8	5.6	4.8	2.4	-1.8
NL	42	4	12-Sep-01	-	-	4.8	5.6	4.8	2.0	-1.7
NL	42	4	21-Mar-02	-	-	4.86	5.62	4.4	2.65	-0.4
NL	42	4	31-Oct-02	-	-	4.87	5.62	4.61	3.25	-1.58
NL	42	4	24-Jun-03	-	-	4.85	5.57	4.15	3.45	0.71
NL	42	4	14-Oct-03	-	-	-	-	-	2.97	0.42
NL	42	4	7-Jul-04	-	-	-	-	-	3.99	-0.58
NL	42	4	7-Dec-04	-	-	-	-	-	3.73	-1.73

Northumberland Dune Measurements

Locality	SITE	Profile No.	DATE	Horizontal Measurements							
				Secondary System		Primary System					
				Extent from Crest		Extent from Crest			Extent from…		
				to Back of 2nd Dune (Feet)	to Back of Primary Dune (Feet)	to Back of Primary Dune (Feet)	to MLW (Feet)	to Front of Primary Dune (Feet)	Front of Primary to Beach Berm (Feet)	Beach Berm to MLW (Feet)	Primary Crest to Toe (Feet)
				A	B	C	D	E	F	G	H
NL	58	1	23-Mar-01	-	-	2.5	57	15	15	27	92
NL	58	1	23-Aug-01	-	-	2.5	58	12	23	23	87
NL	58	1	5-Mar-02	-	-	2.5	60	12	33	15	68
NL	58	1	10-Dec-02	-	-	2.5	65	27	18	20	65
NL	58	1	26-Jun-03	-	-	3.2	57	29	13	15	74
NL	58	1	3-Oct-03	-	-	2	63	23	7	33	53
NL	58	1	6-Jul-04	-	-	6	59	29	7	23	56
NL	58	1	6-Dec-04	-	-	1.5	55	31	12	12	56
NL	58	2	23-Mar-01	61	13	13	61	24	15	22	80
NL	58	2	23-Aug-01	61	13	13	61	24	25	12	71
NL	58	2	5-Mar-02	61	13	13	72	31	25	16	79
NL	58	2	10-Dec-02	61	13	13	66	24	18	24	60
NL	58	2	26-Jun-03	61	13	13	85	24	32	29	109
NL	58	2	3-Oct-03	61	13	13	72	12	12	48	66
NL	58	2	6-Jul-04	61	13	13	70	12	29	29	70
NL	58	2	6-Dec-04	61	13	13	67	17	19	31	67
NL	58	3	23-Mar-01	-	-	39	82	36	14	32	86
NL	58	3	23-Aug-01	-	-	39	71	36	18	17	110
NL	58	3	5-Mar-02	-	-	39	91	30	44	17	95
NL	58	3	10-Dec-02	-	-	39	89	30	40	19	100
NL	58	3	26-Jun-03	-	-	39	69	30	30	9	70
NL	58	3	3-Oct-03	-	-	39	70	13	28	29	69
NL	58	3	6-Jul-04	-	-	39	76	20	38	18	75
NL	58	3	6-Dec-04	-	-	39	77	18	30	29	94

Locality	SITE	Profile No.	DATE	Vertical Measurements						
				Secondary System		Primary System				
				Elevation of...		Elevation of...				
				Back of 2nd Dune (Feet MLW)	2nd Dune Crest (Feet MLW)	Back of Primary Dune (Feet MLW)	Dune Crest (Feet MLW)	Front of Primary Dune (Feet MLW)	Beach Berm (Feet MLW)	Toe (Feet MLW)
				U	V	W	X	Y	Z	T
NL	58	1	23-Mar-01	-	-	5.7	8.4	5.7	4.0	-1.5
NL	58	1	23-Aug-01	-	-	5.7	8.5	6.1	3.5	-1.4
NL	58	1	5-Mar-02	-	-	7.7	8.7	6.6	1.9	-0.9
NL	58	1	10-Dec-02	-	-	7.8	8.8	4.6	2.0	0.0
NL	58	1	26-Jun-03	-	-	7.8	8.8	4.1	3.4	-1.0
NL	58	1	3-Oct-03	-	-	7.7	8.7	5.0	3.7	0.4
NL	58	1	6-Jul-04	-	-	7.4	9.8	5.1	3.2	0.2
NL	58	1	6-Dec-04	-	-	8.3	9.8	5.2	2.3	-0.2
NL	58	2	23-Mar-01	4.2	11.1	9.6	10.1	6.4	4.7	-0.5
NL	58	2	23-Aug-01	4.2	11.0	9.5	10.1	6.5	3.8	-0.2
NL	58	2	5-Mar-02	4.2	10.99	9.6	10.0	5.9	2.1	-0.9
NL	58	2	10-Dec-02	4.2	11.0	9.6	10.0	7.0	3.0	0.9
NL	58	2	26-Jun-03	4.2	11.0	9.6	10.9	7.0	3.3	1.0
NL	58	2	3-Oct-03	4.2	10.9	9.6	10.0	6.5	3.5	0.3
NL	58	2	6-Jul-04	4.2	11.0	9.6	9.9	6.0	4.3	-0.2
NL	58	2	6-Dec-04	4.2	11.0	9.6	10.0	6.0	3.9	-0.4
NL	58	3	23-Mar-01	-	-	4.0	12.1	5.7	4.3	-0.6
NL	58	3	23-Aug-01	-	-	4.0	12.0	5.6	3.5	-1.7
NL	58	3	5-Mar-02	-	-	4.0	12.09	4.63	2.01	-0.7
NL	58	3	10-Dec-02	-	-	4.0	11.97	4.25	3.08	-1.6
NL	58	3	26-Jun-03	-	-	4.0	11.96	6.48	1.78	-0.2
NL	58	3	3-Oct-03	-	-	4.0	11.84	7.1	3.04	0.0
NL	58	3	6-Jul-04	-	-	4.0	11.85	6.9	2.87	-0.1
NL	58	3	6-Dec-04	-	-	4.0	11.87	6.9	3.42	-1.6

Northumberland Dune Measurements

Locality	SITE	Profile No.	DATE	Horizontal Measurements							
				Secondary System		Primary System					
				Extent from Crest		Extent from Crest			Extent from…		
				to Back of 2nd Dune (Feet)	to Back of Primary Dune (Feet)	to Back of Primary Dune (Feet)	to MLW (Feet)	to Front of Primary Dune (Feet)	Front of Primary to Beach Berm (Feet)	Beach Berm to MLW (Feet)	Primary Crest to Toe (Feet)
				A	B	C	D	E	F	G	H
NL	59	1	23-Mar-01	-	-	11	56	11	27	18	60
NL	59	1	22-Aug-01	-	-	11	63	11	29	23	73
NL	59	1	5-Mar-02	-	-	11	61	11	25	25	68
NL	59	1	10-Dec-02	-	-	11	50	20	21	9	60
NL	59	1	26-Jun-03	-	-	11	50	19	14	17	68
NL	59	1	3-Oct-03	-	-	11	54	4	22	28	82
NL	59	1	7-Jul-04	-	-	10	47	17	18	12	61
NL	59	1	6-Dec-04	-	-	10	43	19	14	10	46
NL	59	2	23-Mar-01	-	-	8	64	27	18	19	69
NL	59	2	22-Aug-01	-	-	8	59	27	14	18	64
NL	59	2	5-Mar-02	-	-	8	66	27	38	1	90
NL	59	2	10-Dec-02	-	-	8	70	22	35	13	73
NL	59	2	26-Jun-03	-	-	8	66	22.4	21.6	22	70
NL	59	2	3-Oct-03	-	-	8	71	12	36	23	86
NL	59	2	7-Jul-04	-	-	8	59	15	27	17	75
NL	59	2	6-Dec-04	-	-	8	58	15	23	20	63
NL	59	3	23-Mar-01	9	17	9	47	13	12	22	55
NL	59	3	22-Aug-01	9	17	9	46	16	7	23	52
NL	59	3	5-Mar-02	9	17	9	49	13	23	13	54
NL	59	3	10-Dec-02	9	17	8	52	15	17	20	52
NL	59	3	26-Jun-03	9	17	8	45	14	7	24	41
NL	59	3	3-Oct-03	9	-	-	-	-	-	36	-
NL	59	3	7-Jul-04	9	-	-	-	-	-	30	-
NL	59	3	6-Dec-04	9	-	-	-	-	-	23	-

Locality	SITE	Profile No.	DATE	Vertical Measurements						
				Secondary System		Primary System				
				Elevation of...		Elevation of...				
				Back of 2nd Dune (Feet MLW)	2nd Dune Crest (Feet MLW)	Back of Primary Dune (Feet MLW)	Dune Crest (Feet MLW)	Front of Primary Dune (Feet MLW)	Beach Berm (Feet MLW)	Toe (Feet MLW)
				U	V	W	X	Y	Z	T
NL	59	1	23-Mar-01	-	-	7.6	11.1	6.1	3.0	-0.7
NL	59	1	22-Aug-01	-	-	7.6	11.1	6.3	2.7	-1.4
NL	59	1	5-Mar-02	-	-	7.7	11.2	6.5	2.4	-1.2
NL	59	1	10-Dec-02	-	-	7.6	11.2	4.9	1.2	-1.0
NL	59	1	26-Jun-03	-	-	7.7	11.1	4.4	2.3	-1.5
NL	59	1	3-Oct-03	-	-	7.7	11.1	6.3	4.5	-1.8
NL	59	1	7-Jul-04	-	-	7.7	10.9	7.5	2.2	-1.7
NL	59	1	6-Dec-04	-	-	7.8	10.9	8.1	1.7	-0.4
NL	59	2	23-Mar-01	-	-	7.7	10.9	4.7	2.9	-0.8
NL	59	2	22-Aug-01	-	-	7.7	10.9	4.8	2.1	-1.0
NL	59	2	5-Mar-02	-	-	7.7	10.9	4.6	0.1	-2.1
NL	59	2	10-Dec-02	-	-	7.8	10.9	4.8	1.5	-0.7
NL	59	2	26-Jun-03	-	-	7.9	10.9	5.2	2.7	-0.9
NL	59	2	3-Oct-03	-	-	7.3	10.9	7.4	3.1	-1.6
NL	59	2	7-Jul-04	-	-	7.7	11.0	5.4	2.4	-1.6
NL	59	2	6-Dec-04	-	-	7.8	10.9	5.4	2.7	-0.7
NL	59	3	23-Mar-01	8.9	11.7	6.8	9.4	5.1	3.2	-0.8
NL	59	3	22-Aug-01	8.9	11.7	6.8	9.4	4.4	3.4	-0.9
NL	59	3	5-Mar-02	8.9	11.7	6.9	9.34	4.91	1.34	-1.0
NL	59	3	10-Dec-02	8.9	11.7	6.8	9.37	4.41	2.16	-0.6
NL	59	3	26-Jun-03	8.9	11.7	9.9	9.47	4.32	1.54	0.3
NL	59	3	3-Oct-03	8.9	11.7	-	-	-	4.58	-0.7
NL	59	3	7-Jul-04	8.9	11.7	-	-	-	3.83	-0.7
NL	59	3	6-Dec-04	8.9	11.7	-	-	-	3.46	-0.6

Virginia Beach Dune Measurements

Locality	SITE	Profile No.	DATE	Horizontal Measurements							
				Secondary System		Primary System					
				Extent from Crest		Extent from Crest			Extent from…		
				to Back of 2nd Dune (Feet)	to Back of Primary Dune (Feet)	to Back of Primary Dune (Feet)	to MLW (Feet)	to Front of Primary Dune (Feet)	Front of Primary to Beach Berm (Feet)	Beach Berm to MLW (Feet)	Primary Crest to Toe (Feet)
				A	B	C	D	E	F	G	H
VB	4	1	8-Mar-01	15	40	10	170	25	45	100	185
VB	4	1	13-Sep-01	15	40	10	132	30	58	44	140
VB	4	1	4-Jun-02	15	40	10	217	37	54	126	125
VB	4	1	12-Dec-02	15	40	10	239	37	73	129	150
VB	4	1	14-Apr-03	15	40	10	168	42	53	73	160
VB	4	1	4-Nov-03	15	37	10	149	39	60	50	146
VB	4	1	15-Jul-04	15	38	10	178	44	64	70	146
VB	4	1	22-Dec-04	15	38	11	129	41	50	38	115
VB	4	2	8-Mar-01	79	128	33	150	35	50	65	149
VB	4	2	13-Sep-01	79	128	33	130	33	52	45	122
VB	4	2	4-Jun-02	79	128	33	192	43	43	106	183
VB	4	2	12-Dec-02	79	128	33	183	29	99	55	175
VB	4	2	14-Apr-03	79	128	33	181	50	58	73	180
VB	4	2	4-Nov-03	79	128	33	146	50	36	60	134
VB	4	2	15-Jul-04	79	128	33	139	52	30	57	130
VB	4	2	22-Dec-04	79	128	33	273	54	26	193	133
VB	4	3	8-Mar-01	28	90	16	230	16	90	124	164
VB	4	3	13-Sep-01	28	90	14	185	18	115	52	166
VB	4	3	4-Jun-02	28	90	14	177	19	113	45	275
VB	4	3	12-Dec-02	28	90	15	163	9	118	36	255
VB	4	3	14-Apr-03	28	90	15	206	18	127	61	165
VB	4	3	4-Nov-03	28	89	11	238	23	187	28	250
VB	4	3	15-Jul-04	28	89	11	185	26	101	58	170
VB	4	3	22-Dec-04	28	89	11	158	32	86	40	250

Locality	SITE	Profile No.	DATE	Vertical Measurements						
				Secondary System		Primary System				
				Elevation of...		Elevation of...				
				Back of 2nd Dune (Feet MLW)	2nd Dune Crest (Feet MLW)	Back of Primary Dune (Feet MLW)	Dune Crest (Feet MLW)	Front of Primary Dune (Feet MLW)	Beach Berm (Feet MLW)	Toe (Feet MLW)
				U	V	W	X	Y	Z	T
VB	4	1	8-Mar-01	15.6	16.8	11.7	14.7	7.9	6.4	-0.6
VB	4	1	13-Sep-01	15.6	16.7	11.7	14.6	7.4	6.4	-0.6
VB	4	1	4-Jun-02	15.6	16.6	11.7	14.6	7.3	5.6	0.9
VB	4	1	12-Dec-02	15.6	16.7	11.7	14.5	7.6	4.0	1.0
VB	4	1	14-Apr-03	15.6	16.6	11.8	14.5	8.0	4.2	0.4
VB	4	1	4-Nov-03	15.6	16.4	11.7	14.5	7.9	5.0	-0.8
VB	4	1	15-Jul-04	15.6	16.7	12.0	14.9	7.5	4.7	1.3
VB	4	1	22-Dec-04	15.6	16.5	12.1	15.1	8.3	3.6	0.6
VB	4	2	8-Mar-01	10.1	20.2	11.0	13.3	8.0	6.8	0.0
VB	4	2	13-Sep-01	10.1	20.2	10.9	13.2	7.5	6.1	0.4
VB	4	2	4-Jun-02	10.1	20.2	11.0	13.3	7.3	5.1	0.5
VB	4	2	12-Dec-02	10.1	20.2	10.6	13.0	7.2	6.8	-1.3
VB	4	2	14-Apr-03	10.1	20.2	11.1	13.3	7.3	7.3	0.1
VB	4	2	4-Nov-03	10.1	20.2	11.0	13.3	6.7	6.1	0.4
VB	4	2	15-Jul-04	10.1	20.2	11.0	13.5	8.3	6.1	-0.5
VB	4	2	22-Dec-04	10.1	20.2	11.0	13.4	6.9	6.7	1.0
VB	4	3	8-Mar-01	12.8	15.4	10.2	12.3	7.7	5.8	1.1
VB	4	3	13-Sep-01	12.8	15.4	10.2	12.4	7.8	5.8	-0.5
VB	4	3	4-Jun-02	12.8	15.4	11.3	13.7	8.0	5.8	-0.1
VB	4	3	12-Dec-02	12.8	15.4	11.1	14.3	10.4	5.1	-0.1
VB	4	3	14-Apr-03	12.8	15.4	11.3	14.5	8.3	6.8	0.7
VB	4	3	4-Nov-03	12.8	15.4	12.3	15.6	9.6	5.8	0.9
VB	4	3	15-Jul-04	12.8	15.4	12.4	16.8	8.5	5.2	1.0
VB	4	3	22-Dec-04	12.8	15.4	12.5	16.8	8.2	3.8	0.01

Appendix C
Sediment Analysis Results

MA3	LN39	NH10	NH17	NH51	NL42	NL58	NL59	VB4

Mathews Sediment Data

Date	Site	Sample #	Description	Total Sample Statistics							
				%Total	%Total	%Total	Graphic Measures				
				Gravel	Sand	Mud	Mean	Median	Std Dev	Skewness	Kurtosis
4-Sep-03	MA3	7-8	Secondary Dune Crest	0.00	97.99	2.01	2.10	2.19	0.67	5.02	50.11
7-May-02	MA3	7-8	Secondary Dune Crest	0.00	100.00	0.00	2.05	2.06	0.30	1.00	8.30
27-Mar-03	MA3	7-8	Secondary Dune Crest	0.00	99.97	0.03	1.93	2.06	0.51	-2.83	19.86
14-Jul-04	MA3	7-8	Secondary Dune Crest	0.00	100.00	0.00	2.11	2.19	0.23	0.41	3.22
8-Dec-04	MA3	7-8	Secondary Dune Crest	0.00	100.00	0.00	1.96	2.06	0.33	-2.68	29.06
4-Sep-03	MA3	7-6	Back Base of Primary Dune	0.00	97.53	2.47	2.19	2.31	1.02	2.71	18.50
7-May-02	MA3	7-6	Back Base of Primary Dune	0.00	98.40	1.60	2.16	2.19	0.77	6.34	47.72
27-Mar-03	MA3	7-6	Back Base of Primary Dune	1.24	98.67	0.09	1.55	2.06	0.67	-4.90	48.69
14-Jul-04	MA3	7-6	Back Base of Primary Dune	0.00	100.00	0.00	1.87	2.06	0.51	-2.01	11.77
8-Dec-04	MA3	7-6	Back Base of Primary Dune	0.05	99.82	0.13	1.87	1.94	0.45	0.22	39.87
4-Sep-03	MA3	7-7	Primary Dune Crest	0.00	99.25	0.75	1.62	2.19	1.10	0.12	9.80
7-May-02	MA3	7-7	Primary Dune Crest	0.00	99.20	0.80	2.13	2.19	0.56	8.75	90.54
27-Mar-03	MA3	7-7	Primary Dune Crest	0.00	99.88	0.12	2.25	2.19	0.46	1.08	3.92
14-Jul-04	MA3	7-7	Primary Dune Crest	0.00	100.00	0.00	2.13	2.19	0.36	-2.87	30.57
8-Dec-04	MA3	7-7	Primary Dune Crest	0.00	99.86	0.14	2.08	2.19	0.42	2.74	53.10
4-Sep-03	MA3	7-1	Front Base of Primary Dune	0.00	98.63	1.37	2.02	2.06	0.61	6.84	65.12
7-May-02	MA3	7-1	Front Base of Primary Dune	0.00	99.10	0.90	1.78	2.06	0.85	0.77	16.36
27-Mar-03	MA3	7-1	Front Base of Primary Dune	0.00	99.98	0.02	1.96	2.06	0.35	-5.79	48.64
14-Jul-04	MA3	7-1	Front Base of Primary Dune	0.00	100.00	0.00	2.23	2.19	0.31	0.93	5.47
8-Dec-04	MA3	7-1	Front Base of Primary Dune	0.00	99.74	0.26	1.98	2.06	0.27	-0.35	3.22
4-Sep-03	MA3	7-2	Berm	0.00	99.12	0.88	2.33	2.31	0.54	8.12	83.21
7-May-02	MA3	7-2	Berm	0.00	99.50	0.50	0.86	1.19	0.96	1.12	10.89
27-Mar-03	MA3	7-2	Upper Berm	0.00	99.90	0.10	1.96	1.94	0.32	0.73	4.99
14-Jul-04	MA3	7-2	Upper Berm	0.00	100.00	0.00	2.10	2.19	0.44	-3.43	25.84
8-Dec-04	MA3	7-2	Berm	0.00	99.90	0.10	2.12	2.19	0.28	1.00	42.92
4-Sep-03	MA3	7-3	Midbeach	0.00	99.23	0.77	2.01	1.94	0.58	7.28	72.93
7-May-02	MA3	7-3	Midbeach	0.00	97.90	2.10	1.93	1.94	0.86	5.77	40.12
27-Mar-03	MA3	7-3	Midbeach	0.00	99.93	0.07	1.65	1.69	0.41	0.27	3.70
14-Jul-04	MA3	7-3	Midbeach	0.00	100.00	0.00	2.07	2.06	0.28	-1.18	21.82
8-Dec-04	MA3	7-3	Midbeach	0.00	99.41	0.59	1.93	2.06	0.60	3.54	51.26
4-Sep-03	MA3	7-4	Toe	11.68	87.33	0.99	-0.78	0.44	1.86	-0.26	4.32
7-May-02	MA3	7-4	Toe	0.20	99.00	0.80	1.74	2.06	0.67	1.31	36.59
27-Mar-03	MA3	7-4	Toe	0.00	100.00	0.00	1.22	1.44	0.69	-0.14	1.96
14-Jul-04	MA3	7-4	Toe	1.29	98.47	0.24	0.74	1.19	0.90	-0.23	15.31
8-Dec-04	MA3	7-4	Toe	3.64	96.10	0.26	0.37	1.81	1.32	-1.22	6.98
4-Sep-03	MA3	7-5	Nearshore	0.00	98.49	1.51	2.14	2.31	0.84	2.99	28.38
7-May-02	MA3	7-5	Nearshore	0.00	98.80	1.20	2.12	2.19	0.63	7.00	64.42
27-Mar-03	MA3	7-5	Nearshore	0.00	99.33	0.67	2.15	2.19	0.30	5.35	92.13
14-Jul-04	MA3	7-5	Nearshore	0.00	99.76	0.24	1.31	2.44	1.15	-2.30	10.57
8-Dec-04	MA3	7-5	Nearshore	0.00	99.32	0.68	2.16	2.31	0.67	3.05	38.57

Date	Site	Sample #	Description	Total Sample Statistics							
				%Total	%Total	%Total	Graphic Measures				
				Gravel	Sand	Mud	Mean	Median	Std Dev	Skewness	Kurtosis
28-Aug-01	LN39	1-6	Back Base of Primary Dune	5.46	93.20	1.35	-0.55	-0.06	1.19	-0.15	6.11
24-Jun-03	LN39	1-6	Back Base of Primary Dune	1.04	98.11	0.85	0.76	1.06	0.94	-0.02	7.43
28-Aug-01	LN39	1-7	Primary Dune Crest	0.00	98.97	1.03	1.32	1.31	0.49	1.50	10.42
24-Jun-03	LN39	1-7	Primary Dune Crest	0.00	99.41	0.59	1.39	1.44	0.59	1.57	6.58
28-Aug-01	LN39	1-1	Base of Dune/Edge of Vegetation	1.89	97.11	1.00	-0.04	0.06	1.23	1.96	12.39
24-Jun-03	LN39	1-1	Edge of Vegetation	1.28	98.72	0.00	0.54	0.94	1.19	0.20	4.29
28-Aug-01	LN39	1-2	Beach Berm	0.86	98.36	0.78	0.52	0.69	0.91	2.40	26.52
24-Jun-03	LN39	1-2	Beach Berm	0.00	99.88	0.12	1.31	1.44	0.59	-0.66	9.42
28-Aug-01	LN39	1-3	Midbeach	7.13	91.71	1.15	-0.15	1.31	1.47	-0.31	9.90
24-Jun-03	LN39	1-3	Midbeach	0.38	99.62	0.00	0.77	1.06	0.82	0.43	6.44
28-Aug-01	LN39	1-4	Toe	20.40	78.33	1.28	-1.48	-0.06	1.71	-0.26	4.47
24-Jun-03	LN39	1-4	Toe	18.22	81.75	0.03	-1.46	-0.44	1.34	-0.75	3.14
28-Aug-01	LN39	1-5	Nearshore	56.56	42.57	0.87	-2.79	-3.11	2.29	0.65	2.27
28-Aug-01	LN39	2-6	Back Base of Primary Dune	0.00	99.21	0.79	0.94	1.06	0.85	4.35	35.36
24-Jun-03	LN39	2-6	Back Base of Primary Dune	0.63	99.32	0.05	1.05	1.31	0.89	0.10	6.88
28-Aug-01	LN39	2-7	Primary Dune Crest	9.68	88.81	1.52	-0.74	0.44	1.50	-0.06	9.01
24-Jun-03	LN39	2-7	Primary Dune Crest	2.72	97.19	0.09	-0.07	0.44	1.05	-0.69	4.87
28-Aug-01	LN39	2-1	Front Bace of Primary Dune	1.43	97.08	1.49	0.48	0.94	1.01	1.31	20.77
24-Jun-03	LN39	2-1	Front Bace of Primary Dune	0.44	99.56	0.00	0.19	0.19	0.66	0.77	8.63
14-Oct-03	LN39	2-1	Front Bace of Primary Dune	1.59	98.41	0.00	0.47	1.06	0.82	-1.84	9.63
23-Aug-04	LN39	2-1	Front Bace of Primary Dune	4.38	95.62	0.00	0.02	0.81	1.01	-1.97	8.52
28-Aug-01	LN39	2-2	Upper Berm	2.29	97.15	0.56	0.32	0.94	0.91	-0.93	18.72
24-Jun-03	LN39	2-2	Upper Berm	0.00	99.86	0.14	0.69	0.81	0.73	1.15	4.95
28-Aug-01	LN39	2-3	Beach Berm	10.70	88.58	0.72	-0.94	-0.06	1.65	0.24	5.52
24-Jun-03	LN39	2-3	Beach Berm	11.55	88.43	0.02	-1.06	-0.44	1.16	-1.06	4.41
14-Oct-03	LN39	2-2	Beach Berm	2.59	97.41	0.00	0.24	0.94	0.91	-2.76	13.63
23-Aug-04	LN39	2-2	Beach Berm	1.83	97.58	0.59	0.28	0.81	0.96	-0.27	7.74
7-Dec-04	LN39	2-2	Beach Berm	0.00	99.86	0.14	1.21	1.31	0.46	2.94	45.37
14-Oct-03	LN39	2-3	Midbeach	5.18	94.82	0.00	-0.25	0.44	1.43	-0.44	4.33
23-Aug-04	LN39	2-3	Midbeach	0.00	99.94	0.06	0.60	0.56	0.83	1.73	6.14
7-Dec-04	LN39	2-3	Midbeach	0.17	99.73	0.10	0.74	0.94	0.64	1.26	20.29
28-Aug-01	LN39	2-4	Toe	9.24	89.17	1.59	-0.66	0.44	1.62	0.18	7.53
24-Jun-03	LN39	2-4	Toe	29.37	70.50	0.13	-1.90	-0.69	1.39	-0.17	4.24
14-Oct-03	LN39	2-4	Toe	15.07	84.72	0.21	-1.28	-0.19	1.46	-0.20	5.93
23-Aug-04	LN39	2-4	Toe	12.25	87.12	0.63	-1.05	-0.06	1.41	0.15	8.96
7-Dec-04	LN39	2-4	Toe	27.01	72.78	0.21	-1.88	-0.31	1.79	-0.11	3.08
28-Aug-01	LN39	2-5	Nearshore	7.89	90.10	2.02	-0.41	0.94	1.60	-0.19	8.10
14-Oct-03	LN39	2-5	Nearshore	3.10	96.86	0.04	-0.31	-0.06	0.92	-0.40	8.56
23-Aug-04	LN39	2-5	Nearshore	7.95	91.11	0.94	-0.50	1.06	1.59	-0.82	6.34
7-Dec-04	LN39	2-5	Nearshore	16.58	83.18	0.24	-1.23	-0.06	1.50	-0.56	4.86

Date	Site	Sample #	Description	Total Sample Statistics							
				%Total Gravel	%Total Sand	%Total Mud	Graphic Measures				
							Mean	Median	Std Dev	Skewness	Kurtosis
19-Sep-01	NH10	2-8	Secondary Dune Crest	0.00	98.34	1.65	2.08	2.06	0.60	6.90	67.10
12-Jul-04	NH10	2-8	Secondary Dune Crest	0.00	100.00	0.00	1.51	1.69	0.80	-0.24	6.17
22-Dec-04	NH10	2-8	Secondary Dune Crest	0.00	99.81	0.19	1.32	1.31	0.85	1.50	8.99
19-Sep-01	NH10	2-6	Back Base of Primary Dune	0.00	99.00	1.00	1.22	1.31	1.00	3.94	28.47
12-Jul-04	NH10	2-6	Back Base of Primary Dune	0.00	100.00	0.00	1.53	1.69	0.53	0.33	4.41
22-Dec-04	NH10	2-6	Back Base of Primary Dune	0.00	100.00	0.00	1.34	1.56	0.74	-0.30	8.11
19-Sep-01	NH10	2-7	Primary Dune Crest	0.00	97.85	2.14	1.43	1.56	1.06	2.95	20.48
12-Jul-04	NH10	2-7	Primary Dune Crest	0.00	100.00	0.00	1.59	1.69	0.44	-1.30	9.75
22-Dec-04	NH10	2-7	Primary Dune Crest	0.00	99.59	0.41	1.75	1.81	0.55	5.53	64.81
19-Sep-01	NH10	2-1	Front Base of Primary Dune	0.00	99.77	0.23	1.18	1.31	0.72	4.42	49.02
12-Jul-04	NH10	2-1	Front Base of Primary Dune	0.00	100.00	0.00	0.79	0.81	0.61	-0.04	3.06
22-Dec-04	NH10	2-1	Front Base of Primary Dune	0.00	99.55	0.45	1.32	1.31	0.65	5.16	50.06
19-Sep-01	NH10	2-2	Beach Berm	0.00	99.36	0.64	-1.61	-0.31	1.86	0.09	3.71
12-Jul-04	NH10	2-2	Beach Berm	0.00	100.00	0.00	1.27	1.56	1.03	0.36	2.61
22-Dec-04	NH10	2-2	Beach Berm	0.39	99.35	0.26	0.52	0.69	0.91	1.42	13.54
19-Sep-01	NH10	2-3	Midbeach	25.55	74.03	0.41	-0.17	0.06	0.88	3.03	42.67
12-Jul-04	NH10	2-3	Midbeach	16.13	83.87	0.00	-1.27	-0.31	1.37	-0.73	3.19
22-Dec-04	NH10	2-3	Midbeach	0.00	99.61	0.39	0.33	0.19	0.86	3.33	24.39
19-Sep-01	NH10	2-4	Toe	2.44	96.98	0.58	1.56	2.06	1.03	0.28	18.67
12-Jul-04	NH10	2-4	Toe	31.42	68.57	0.01	-1.90	-0.19	2.12	0.06	2.10
22-Dec-04	NH10	2-4	Toe	20.50	79.08	0.42	-1.31	0.44	2.01	-0.38	2.90
19-Sep-01	NH10	2-5	Nearshore	1.03	97.90	1.07	1.16	1.56	1.01	1.69	20.18
12-Jul-04	NH10	2-5	Nearshore	4.94	94.61	0.45	0.48	2.06	1.41	-1.68	9.06
22-Dec-04	NH10	2-5	Nearshore	5.87	93.35	0.78	0.27	1.94	1.51	-1.20	8.34
20-Sep-01	NH17	3-6	Back Base of Primary Dune	0.00	98.86	1.15	1.93	2.19	0.75	0.61	17.69
12-Jul-04	NH17	3-6	Back Base of Primary Dune	0.53	99.03	0.44	1.89	2.19	0.60	-1.56	52.81
21-Dec-04	NH17	3-6	Back Base of Primary Dune	0.06	99.80	0.14	2.15	2.31	0.44	-1.58	40.72
20-Sep-01	NH17	3-7	Primary Dune Crest	0.00	97.72	2.28	1.45	1.69	1.01	2.43	20.42
12-Jul-04	NH17	3-7	Primary Dune Crest	0.00	99.74	0.26	2.16	2.19	0.29	0.44	5.87
21-Dec-04	NH17	3-7	Primary Dune Crest	0.06	99.80	0.14	2.15	2.31	0.44	-1.58	40.72
20-Sep-01	NH17	3-1	Front Base of Primary Dune	0.00	99.26	0.74	1.71	1.94	0.78	3.21	31.56
12-Jul-04	NH17	3-1	Old Front Base of PrimaryDune	0.00	99.98	0.02	2.18	2.19	0.39	1.47	14.61
21-Dec-04	NH17	3-1	Front Base of Primary Dune	0.00	99.52	0.48	2.17	2.31	0.55	4.06	59.01
20-Sep-01	NH17	3-2	Beach Berm	0.00	99.21	0.79	1.76	2.31	1.00	0.17	15.89
12-Jul-04	NH17	3-2	Beach Berm	2.10	97.90	0.00	0.72	1.69	1.12	-1.43	6.55
21-Dec-04	NH17	3-2	Beach Berm	0.36	99.37	0.27	1.57	1.94	0.69	0.34	28.24
20-Sep-01	NH17	3-3	Midbeach	0.00	98.88	1.12	0.30	1.31	1.70	-0.14	5.13
12-Jul-04	NH17	3-3	Midbeach	1.89	97.80	0.31	0.68	1.56	1.20	-0.59	7.31
21-Dec-04	NH17	3-3	Midbeach	0.00	99.26	0.74	1.73	2.19	0.84	1.46	23.04
20-Sep-01	NH17	3-4	Toe	4.66	94.35	0.99	-0.63	0.81	2.05	0.09	4.30
12-Jul-04	NH17	3-4	Toe	12.97	86.50	0.53	-0.92	0.19	1.85	-0.15	3.50
21-Dec-04	NH17	3-4	Toe	4.94	94.06	1.00	0.55	2.06	1.37	-1.65	11.21
20-Sep-01	NH17	3-5	Nearshore	11.49	85.68	2.83	2.37	2.31	0.36	9.72	142.34
12-Jul-04	NH17	3-5	Nearshore	0.32	95.60	4.08	2.08	2.44	1.13	2.23	16.85
21-Dec-04	NH17	3-5	Nearshore	0.00	88.74	11.26	2.64	2.81	1.29	2.46	11.79
15-Jul-04	NH51	2-8	Secondary Dune Crest	0.00	100.00	0.00	1.45	1.44	0.56	0.00	5.75
21-Dec-04	NH51	2-8	Secondary Dune Crest	0.00	99.90	0.10	1.65	1.94	0.64	-1.55	12.27
19-Sep-01	NH51	2-6	Back Base of Primary Dune	0.00	99.73	0.27	1.42	1.69	0.89	2.01	22.96
15-Jul-04	NH51	2-6	Back Base of Primary Dune	0.00	100.00	0.00	1.79	1.94	0.49	-0.16	3.27
21-Dec-04	NH51	2-6	Back Base of Primary Dune	0.00	99.75	0.25	1.60	1.81	0.61	1.94	24.77
19-Sep-01	NH51	2-7	Primary Dune Crest	0.00	99.23	0.77	1.42	1.69	0.84	1.54	22.10
15-Jul-04	NH51	2-7	Primary Dune Crest	0.19	99.81	0.00	1.97	2.19	0.51	-2.66	27.25
21-Dec-04	NH51	2-7	Primary Dune Crest	0.00	99.86	0.14	2.23	2.31	0.38	4.75	74.96
19-Sep-01	NH51	2-1	Front Base of Primary Dune	0.00	97.61	2.40	1.43	1.69	0.79	0.59	17.03
15-Jul-04	NH51	2-1	Front Base of Primary Dune	0.00	100.00	0.00	1.90	1.94	0.29	0.28	3.18
21-Dec-04	NH51	2-1	Front Base of Primary Dune	0.00	99.95	0.05	2.07	2.19	0.35	-0.32	56.11
19-Sep-01	NH51	2-2	Beach Berm	0.00	98.99	1.00	1.43	1.69	0.92	2.15	22.33
15-Jul-04	NH51	2-2	Beach Berm	0.00	100.00	0.00	1.68	1.69	0.52	1.11	6.87
21-Dec-04	NH51	2-2	Beach Berm	0.00	99.46	0.54	2.18	2.19	0.51	6.97	91.00
19-Sep-01	NH51	2-3	Midbeach	0.00	98.81	1.19	0.88	1.69	1.09	-0.40	17.16
15-Jul-04	NH51	2-3	Midbeach	0.00	100.00	0.00	1.18	1.31	0.65	0.29	4.36
21-Dec-04	NH51	2-3	Midbeach	0.00	99.54	0.46	1.72	1.94	0.67	3.39	34.39
19-Sep-01	NH51	2-4	Toe	1.74	97.52	0.74	1.43	1.69	0.92	2.23	23.09
15-Jul-04	NH51	2-4	Toe	4.53	95.47	0.00	0.12	1.31	1.23	-1.76	7.18
21-Dec-04	NH51	2-4	Toe	0.00	99.16	0.84	2.09	2.19	0.64	6.02	59.18
19-Sep-01	NH51	2-5	Nearshore	0.00	99.10	0.90	1.42	1.69	0.77	0.46	18.34
15-Jul-04	NH51	2-5	Nearshore	1.11	98.50	0.39	1.49	2.19	0.79	-2.83	42.51
21-Dec-04	NH51	2-5	Nearshore	0.00	98.99	1.01	2.31	2.31	0.65	6.35	57.37

Northumberland Sediment Data

Date	Site	Sample #	Description	Total Sample Statistics						
				%Total Gravel	%Total Sand	%Total Mud	Graphic Measures			
							Mean	Median	Std Dev	Skewness
12-Sep-01	NL42	2-8	Secondary Dune Crest	3.05	96.56	0.39	0.34	1.06	1.05	-0.47
12-Sep-01	NL42	2-6	Back Base of Primary Dune	12.71	87.07	0.21	-1.05	0.81	1.69	-1.21
7-Jul-04	NL42	2-6	Back Base of Primary Dune	0.22	96.07	3.71	0.72	0.81	0.93	3.84
7-Dec-04	NL42	2-5	Back Base of Primary Dune	2.32	96.50	1.18	0.14	0.69	0.98	-0.25
12-Sep-01	NL42	2-7	Primary Dune Crest	0.00	99.60	0.40	0.62	0.81	0.70	2.25
7-Jul-04	NL42	2-7	Primary Dune Crest	0.00	99.63	0.37	0.55	0.44	0.96	1.54
7-Dec-04	NL42	2-7	Primary Dune Crest	0.00	99.68	0.43	0.27	0.31	0.64	4.41
12-Sep-01	NL42	2-1	Front Base of Primary Dune	8.10	90.79	1.11	-1.03	-0.44	1.85	1.08
7-Jul-04	NL42	2-1	Front Base of Primary Dune	0.00	100.00	0.00	1.10	1.19	0.65	0.94
7-Dec-04	NL42	2-1	Front Base of Primary Dune	13.17	86.83	0.00	-0.99	0.31	1.40	-1.26
12-Sep-01	NL42	2-2	Beach Berm	2.54	96.68	0.78	0.12	0.69	1.00	1.17
7-Jul-04	NL42	2-2	Beach Berm	0.00	100.00	0.00	0.59	0.81	0.74	0.97
7-Dec-04	NL42	2-2	Beach Berm	0.39	99.36	0.25	-0.16	-0.19	0.79	2.98
12-Sep-01	NL42	2-3	Midbeach	13.12	86.04	0.83	-0.89	0.44	1.64	-0.18
7-Jul-04	NL42	2-3	Midbeach	4.05	95.75	0.20	-0.06	0.81	1.13	-0.74
7-Dec-04	NL42	2-3	Midbeach	6.37	93.41	0.22	-0.72	-0.19	0.99	0.36
12-Sep-01	NL42	2-4	Toe	85.08	14.51	0.41	-3.27	-3.64	1.41	3.11
7-Jul-04	NL42	2-4	Toe	34.19	65.81	0.00	-2.12	-0.06	1.94	-0.35
7-Dec-04	NL42	2-4	Toe	47.50	52.24	0.26	-2.41	-0.94	1.57	0.37
7-Jul-04	NL42	2-5	Nearshore	53.92	46.08	0.00	-2.69	-3.11	1.78	0.47
23-Aug-01	NL58	2-8	Secondary Dune Crest	0.00	99.27	0.74	1.40	1.44	0.89	1.36
6-Jul-04	NL58	2-8	Secondary Dune Crest	0.00	99.87	0.13	1.02	1.06	0.55	0.56
6-Dec-04	NL58	2-8	Secondary Dune Crest	0.19	99.41	0.40	1.16	1.19	0.78	1.10
23-Aug-01	NL58	2-6	Back Base of Primary Dune	0.00	99.84	0.16	1.47	1.44	0.63	0.98
6-Jul-04	NL58	2-6	Back Base of Primary Dune	0.06	99.94	0.00	0.78	0.81	0.55	0.87
6-Dec-04	NL58	2-6	Back Base of Primary Dune	0.00	99.80	0.20	0.96	0.94	0.57	1.78
23-Aug-01	NL58	2-7	Primary Dune Crest	0.00	99.12	0.88	1.48	1.44	0.74	2.81
6-Jul-04	NL58	2-7	Primary Dune Crest	0.00	98.72	1.28	1.00	0.94	0.65	1.93
6-Dec-04	NL58	2-7	Primary Dune Crest	0.00	99.46	0.54	0.95	0.94	0.71	3.18
23-Aug-01	NL58	2-1	Front Base of Primary Dune	0.00	100.00	0.00	0.82	0.81	0.50	0.74
6-Jul-04	NL58	2-1	Front Base of Primary Dune	0.00	100.00	0.00	0.88	0.94	0.43	1.24
6-Dec-04	NL58	2-1	Front Base of Primary Dune	0.00	99.75	0.25	1.08	1.19	0.50	-0.12
23-Aug-01	NL58	2-2	Beach Berm	0.00	99.82	0.18	0.84	0.94	0.58	2.35
6-Jul-04	NL58	2-2	Beach Berm	0.00	100.00	0.00	0.97	0.94	0.55	2.27
6-Dec-04	NL58	2-2	Beach Berm	0.00	100.00	0.00	1.13	1.19	0.37	0.82
23-Aug-01	NL58	2-3	Midbeach	1.58	98.39	0.03	0.00	0.44	0.89	-0.17
6-Jul-04	NL58	2-3	Midbeach	0.00	100.00	0.00	0.85	0.81	0.36	2.74
6-Dec-04	NL58	2-3	Midbeach	0.00	99.71	0.29	0.49	0.56	0.57	2.22
23-Aug-01	NL58	2-4	Toe	1.01	98.85	0.14	-0.32	0.94	1.59	-0.66
6-Jul-04	NL58	2-4	Toe	3.06	96.94	0.00	-0.27	0.06	0.90	-0.44
6-Dec-04	NL58	2-4	Toe	9.23	89.97	0.80	-0.71	0.19	1.22	-0.87
23-Aug-01	NL58	2-5	Nearshore	8.66	90.72	0.63	0.02	0.19	0.82	1.30
6-Jul-04	NL58	2-5	Nearshore	3.57	96.20	0.23	0.24	0.94	1.21	-0.89
7-Jul-04	NL59	2-6	Back Base of Primary Dune	0.00	99.76	0.24	1.22	1.31	1.01	0.25
6-Dec-04	NL59	2-5	Back Base of Primary Dune	2.11	97.55	0.34	0.83	1.56	0.98	-1.41
7-Jul-04	NL59	2-7	Primary Dune Crest	0.00	100.00	0.00	1.50	1.44	0.81	1.01
6-Dec-04	NL59	2-6	Primary Dune Crest	0.87	98.88	0.25	1.40	1.81	0.96	-0.37
22-Aug-01	NL59	2-1	Front Base of Primary Dune	0.00	99.21	0.79	1.14	1.31	0.79	1.27
7-Jul-04	NL59	2-1	Front Base of Primary Dune	0.00	100.00	0.00	1.01	1.06	0.89	0.06
6-Dec-04	NL59	2-1	Front Base of Primary Dune	0.00	100.00	0.00	1.21	1.19	0.59	1.55
22-Aug-01	NL59	2-2	Beach Berm	0.63	99.34	0.03	1.09	1.19	0.57	-1.59
7-Jul-04	NL59	2-3	Beach Berm	0.97	99.03	0.00	1.09	1.31	0.88	-0.34
6-Dec-04	NL59	2-2	Beach Berm	0.00	99.97	0.03	1.06	1.06	0.50	1.74
22-Aug-01	NL59	2-3	Midbeach	0.00	99.93	0.07	0.92	0.94	0.63	2.08
6-Dec-04	NL59	2-3	Midbeach	0.06	99.94	0.00	0.65	0.69	0.56	2.05
22-Aug-01	NL59	2-4	Toe	24.70	75.00	0.30	-4.14	-3.84	-	-
7-Jul-04	NL59	2-4	Toe	38.41	61.47	0.12	-2.00	-0.06	1.83	-0.07
6-Dec-04	NL59	2-4	Toe	27.90	72.10	0.00	-1.66	-0.19	1.63	-0.42
22-Aug-01	NL59	2-5	Nearshore	26.31	72.92	0.77	-1.53	0.19	2.22	0.09
7-Jul-04	NL59	2-5	Nearshore	1.09	98.01	0.90	1.29	1.69	1.04	0.10

Virginia Beach Sediment Data

Date	Site	Sample #	Description	Total Sample Statistics							
				%Total Gravel	%Total Sand	%Total Mud	Graphic Measures				
							Mean	Median	Std Dev	Skewness	Kurtosis
13-Sep-01	VB4	2-8	Secondary Dune Crest	0.00	96.60	3.40	1.84	1.94	1.01	3.60	21.65
15-Jul-04	VB4	2-8	Secondary Dune Crest	0.00	99.82	0.18	1.16	1.31	0.79	-0.42	3.72
22-Dec-04	VB4	2-8	Secondary Dune Crest	0.00	99.47	0.53	0.97	1.06	0.88	2.55	20.11
13-Sep-01	VB4	2-6	Back Base of Primary Dune	0.00	98.93	1.07	1.68	1.94	0.72	2.31	29.18
15-Jul-04	VB4	2-6	Back Base of Primary Dune	0.00	99.97	0.03	1.27	1.44	0.61	-0.28	3.53
22-Dec-04	VB4	2-6	Back Base of Primary Dune	0.00	98.11	1.89	1.33	1.44	1.11	3.41	20.63
13-Sep-01	VB4	2-7	Primary Dune Crest	0.00	98.50	1.49	1.72	1.81	0.67	5.30	48.43
15-Jul-04	VB4	2-7	Primary Dune Crest	0.00	99.92	0.08	1.64	1.94	0.55	-0.63	4.35
22-Dec-04	VB4	2-7	Primary Dune Crest	0.00	99.29	0.71	1.68	1.94	0.61	-0.42	5.71
13-Sep-01	VB4	2-1	Front Base of Primary Dune	0.00	98.07	1.93	1.54	1.69	0.78	4.76	39.12
15-Jul-04	VB4	2-1	Front Base of Primary Dune	0.00	100.00	0.00	1.04	1.44	0.82	-0.90	4.43
22-Dec-04	VB4	2-1	Front Base of Primary Dune	0.00	99.66	0.34	1.11	1.06	0.67	3.21	30.36
13-Sep-01	VB4	2-2	Beach Berm	0.00	98.45	1.55	1.09	1.31	0.87	3.54	30.01
15-Jul-04	VB4	2-2	Beach Berm	0.00	99.87	0.13	1.72	1.94	0.60	0.98	16.42
22-Dec-04	VB4	2-2	Beach Berm	0.00	99.70	0.30	1.42	1.56	0.63	1.61	18.30
13-Sep-01	VB4	2-3	Midbeach	0.00	98.34	1.66	0.99	1.06	0.88	5.13	40.24
15-Jul-04	VB4	2-3	Midbeach	0.00	99.68	0.32	2.22	2.19	0.42	8.66	116.67
22-Dec-04	VB4	2-3	Midbeach	3.12	96.81	0.07	-0.28	-0.06	0.91	-0.39	7.84
13-Sep-01	VB4	2-4	Toe	12.70	85.65	1.66	-0.91	0.19	1.74	0.13	5.94
15-Jul-04	VB4	2-4	Toe	1.30	98.37	0.33	0.42	0.94	1.14	-0.10	7.64
22-Dec-04	VB4	2-4	Toe	1.54	97.87	0.59	-0.09	-0.06	1.09	1.85	15.80
13-Sep-01	VB4	2-5	Nearshore	0.00	98.25	1.75	1.99	2.44	0.95	0.98	23.70
15-Jul-04	VB4	2-5	Nearshore	25.43	74.29	0.28	-1.71	1.81	2.47	-0.87	2.09
22-Dec-04	VB4	2-5	Nearshore	0.00	99.14	0.86	2.22	2.31	0.60	5.27	56.48

Appendix D
Vegetation Data

Foredune Vegetation Analysis | Crest Vegetation Analysis | Trough Vegetation Analysis | Secondary Dune Vegetation Analysis

Foredune Vegetation Analysis

Locality	Site No.	Profile No.	Date	Plot	Foredune Plot % Cover: No cover	American Beach Grass	Saltmeadow Hay	Running Dune Grass	Seaside Spurge	Phrag	Sea Rocket	Foredune Plot Stem Density: American Beach Grass	Saltmeadow Hay	Running Dune Grass	Seaside Spurge	Phrag	Sea Rocket
MA	3	8	19-Jun-01	1	99.0	1.0						2.0					
MA	3	8	19-Jun-01	2	90.0	10.0						6.0					
MA	3	8	19-Jun-01	3	92.0	8.0						8.0					
MA	3	5	19-Jun-01	1	95.0	5.0						10.0					
MA	3	5	19-Jun-01	2	100.0												
MA	3	5	19-Jun-01	3	100.0												
MA	3	2	19-Jun-01	1	97.0	3.0						2.0					
MA	3	2	19-Jun-01	2	85.0	15.0						13.0					
MA	3	2	19-Jun-01	3	95.0	5.0						6.0					
				MEAN	94.8	6.7	0.0	0.0	0.0	0.0	0.0	6.7					
LN	39	1	17-Aug-01	1	100.0												
LN	39	1	17-Aug-01	2	100.0												
LN	39	1	17-Aug-01	3	100.0												
LN	39	2	17-Aug-01	1	100.0												
LN	39	2	17-Aug-01	2	100.0												
LN	39	2	17-Aug-01	3	100.0												
				MEAN	100.0												
NL	58	1	23-Aug-01	1	0.0												
NL	58	1	23-Aug-01	2	0.0												
NL	58	1	23-Aug-01	3	0.0												
NL	58	2	23-Aug-01	1	100.0												
NL	58	2	23-Aug-01	2	68.0		25.0	7.0					73.0	4.0			
NL	58	2	23-Aug-01	3	100.0												
NL	58	3	23-Aug-01	1	60.0	40.0						47.0					
NL	58	3	23-Aug-01	2	85.0	15.0						11.0					
NL	58	3	23-Aug-01	3	95.0	5.0						5.0					
				MEAN	56.4	20.0	25.0	7.0	0.0	0.0	0.0	21.0	73.0	4.0	0.0	0.0	0.0
NL	59	1	23-Aug-01	1	100.0												
NL	59	1	23-Aug-01	2	100.0												
NL	59	1	23-Aug-01	3	100.0												
NL	59	2	23-Aug-01	1	0.0												
NL	59	2	23-Aug-01	2	0.0												
NL	59	2	23-Aug-01	3	0.0												
NL	59	3	23-Aug-01	1	0.0												
NL	59	3	23-Aug-01	2	0.0												
NL	59	3	23-Aug-01	3	0.0												
				MEAN	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NL	42	1	12-Sep-01	1	0.0												
NL	42	1	12-Sep-01	2	0.0												
NL	42	1	12-Sep-01	3	0.0												
NL	42	2	12-Sep-01	1	100.0												
NL	42	2	12-Sep-01	2	94.0			4.0	2.0					1.0	1.0		
NL	42	2	12-Sep-01	3	100.0												
NL	42	3	12-Sep-01	1	0.0												
NL	42	3	12-Sep-01	2	0.0												
NL	42	3	12-Sep-01	3	0.0												
NL	42	4	12-Sep-01	1	0.0												
NL	42	4	12-Sep-01	2	0.0												
NL	42	4	12-Sep-01	3	0.0												
				MEAN	24.5	0.0	0.0	4.0	2.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0
VB	4	1	05-Oct-01	1	90.0	10.0						4.0					
VB	4	1	05-Oct-01	2	100.0												
VB	4	1	05-Oct-01	3	100.0												
VB	4	2	05-Oct-01	1	75.0	5.0		20.0				3.0		4.0			
VB	4	2	05-Oct-01	2	98.0			2.0						1.0			
VB	4	2	05-Oct-01	3	53.0	12.0		35.0				12.0		9.0			
VB	4	3	05-Oct-01	1	0.0												
VB	4	3	05-Oct-01	2	0.0												
VB	4	3	05-Oct-01	3	0.0												
				MEAN	57.3	9.0	0.0	19.0	0.0	0.0	0.0	6.3	0.0	4.7	0.0	0.0	0.0
NH	10	2	12-Oct-01	1	100.0												
NH	10	2	12-Oct-01	2	100.0												
NH	10	2	12-Oct-01	3	100.0												
NH	10	3	12-Oct-01	1	0.0												
NH	10	3	12-Oct-01	2	0.0												
NH	10	3	12-Oct-01	3	0.0												
				MEAN	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH	17	2	12-Oct-01	1	85.0	15.0						14.0					
NH	17	2	12-Oct-01	2	100.0												
NH	17	2	12-Oct-01	3	100.0												
NH	17	3	12-Oct-01	1	100.0												
NH	17	3	12-Oct-01	2	85.0	15.0						12.0					
NH	17	3	12-Oct-01	3	90.0	10.0						9.0					
				MEAN	93.3	13.3	0.0	0.0	0.0	0.0	0.0	11.7	0.0	0.0	0.0	0.0	0.0
NH	51	1	30-Oct-01	1													
NH	51	1	30-Oct-01	2													
NH	51	1	30-Oct-01	3													
NH	51	2	30-Oct-01	1	100.0												
NH	51	2	30-Oct-01	2	100.0												
NH	51	2	30-Oct-01	3	37.0	60.0					3.0	56.0					2.0
NH	51	3	30-Oct-01	1													
NH	51	3	30-Oct-01	2													
NH	51	3	30-Oct-01	3													
				MEAN	79.0	60.0	0.0	0.0	0.0	0.0	3.0	56.0	0.0	0.0	0.0	0.0	2.0

Crest Vegetation Analysis

Locality	Site No.	Profile No.	Date	Plot No.	Crest Plot % Cover															Crest Plot Stem Density													
					No cover	American Beach Grass	Saltmeadow Hay	Running Dune Grass	Seaside Spurge	Phrag	Buttonweed	Seabeach Sandwort	Dune bean	Aster General	Blue Stem	Switch Grass	Trumpet Vine	Japanese Sedge	Goldenrod	American Beach Grass	Saltmeadow Hay	Running Dune Grass	Seaside Spurge	Phrag	Buttonweed	Seabeach Sandwort	Dune bean	Aster General	Blue Stem	Switch Grass	Trumpet Vine	Japanese Sedge	Goldenrod
MA	3	8	19-Jun-01	1	70.0	30.0														22.0													
MA	3	8	19-Jun-01	2	62.0	38.0		2.0												18.0		1.0											
MA	3	8	19-Jun-01	3	85.0	15.0														24.0													
MA	3	5	19-Jun-01	1	96.0	3.0		1.0												4.0		1.0											
MA	3	5	19-Jun-01	2	95.0	1.0		4.0												2.0		3.0											
MA	3	5	19-Jun-01	3	90.0	5.0		5.0												8.0		5.0											
MA	3	2	19-Jun-01	1	48.0	50.0		1.0						1.0						39.0		1.0						2.0					
MA	3	2	19-Jun-01	2	84.0	15.0		1.0												17.0		1.0											
MA	3	2	19-Jun-01	3	92.0	7.0								1.0						10.0								4.0					
				MEAN	80.2	18.2	0.0	2.3	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
LN	39	1	17-Aug-01	1	95.0				0.0		5.0												2.0		2.0								
LN	39	1	17-Aug-01	2	90.0							10.0														1.0							
LN	39	1	17-Aug-01	3	100.0																												
LN	39	2	17-Aug-01	1	100.0		0.0														1.0												
LN	39	2	17-Aug-01	2	21.0	50.0	25.0		4.0											23.0	26.0		8.0										
LN	39	2	17-Aug-01	3	30.0	50.0	20.0													25.0	23.0												
				MEAN	72.7	50.0	15.0	0.0	2.0	0.0	5.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	16.7	0.0	5.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NL	58	1	23-Aug-01	1	70.0	25.0	1.0	4.0												20.0	2.0	3.0											
NL	58	1	23-Aug-01	2	60.0	40.0														15.0													
NL	58	1	23-Aug-01	3	97.0		3.0														16.0												
NL	58	2	23-Aug-01	1	100.0			0.0														1.0											
NL	58	2	23-Aug-01	2	99.0			1.0														2.0											
NL	58	2	23-Aug-01	3	100.0																												
NL	58	3	23-Aug-01	1	100.0																												
NL	58	3	23-Aug-01	2	100.0																												
NL	58	3	23-Aug-01	3	100.0																												
				MEAN	91.8	32.5	2.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.5	9.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NL	59	1	23-Aug-01	1	90.0	5.0											5.0			4.0											1.0		
NL	59	1	23-Aug-01	2	100.0																												
NL	59	1	23-Aug-01	3	100.0																												
NL	59	2	23-Aug-01	1	100.0																												
NL	59	2	23-Aug-01	2	100.0																												
NL	59	2	23-Aug-01	3	100.0																												
NL	59	3	23-Aug-01	1	100.0																												
NL	59	3	23-Aug-01	2	100.0																												
NL	59	3	23-Aug-01	3	100.0																												
				MEAN	98.9	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
NL	42	1	12-Sep-01	1	98.0	2.0														2.0													
NL	42	1	12-Sep-01	2	100.0																												
NL	42	1	12-Sep-01	3	100.0																												
NL	42	2	12-Sep-01	1	85.0			15.0														3.0											
NL	42	2	12-Sep-01	2	100.0																												
NL	42	2	12-Sep-01	3	100.0																												
NL	42	3	12-Sep-01	1	86.0		2.0	12.0													7.0	6.0											
NL	42	3	12-Sep-01	2	72.0		25.0	3.0													35.0	2.0											
NL	42	3	12-Sep-01	3	90.0		10.0														19.0												
NL	42	4	12-Sep-01	1	100.0																												
NL	42	4	12-Sep-01	2	80.0		20.0														41.0												
NL	42	4	12-Sep-01	3	97.0			3.0														1.0											
				MEAN	92.3	2.0	14.3	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	25.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VB	4	1	05-Oct-01	1	96.0	2.0		2.0												2.0		1.0											
VB	4	1	05-Oct-01	2	65.0	35.0														32.0													
VB	4	1	05-Oct-01	3	95.0	5.0														3.0													
VB	4	2	05-Oct-01	1	55.0	15.0		20.0										10.0		10.0		9.0										4.0	
VB	4	2	05-Oct-01	2	53.0	7.0												40.0		9.0												23.0	
VB	4	2	05-Oct-01	3	90.0	10.0														4.0													
VB	4	3	05-Oct-01	1	100.0																												
VB	4	3	05-Oct-01	2	97.0	3.0														9.0													
VB	4	3	05-Oct-01	3	10.0	90.0														63.0													
				MEAN	73.4	20.9	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0	16.5	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0
NH	10	2	12-Oct-01	1	90.0	10.0														9.0													
NH	10	2	12-Oct-01	2	92.0	8.0														3.0													
NH	10	2	12-Oct-01	3	72.0	5.0	3.0									20.0				7.0	11.0									7.0			
NH	10	3	12-Oct-01	1	69.0	12.0	15.0	4.0												9.0	22.0	3.0											
NH	10	3	12-Oct-01	2	50.0	30.0	5.0												15.0	27.0	13.0												1.0
NH	10	3	12-Oct-01	3	92.0		5.0	3.0													8.0	2.0											
				MEAN	77.5	13.0	7.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	15.0	11.0	13.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	1.0
NH	17	2	12-Oct-01	1	43.0	40.0	5.0									12.0				41.0	20.0									5.0			
NH	17	2	12-Oct-01	2	49.0	50.0													1.0	47.0													1.0
NH	17	2	12-Oct-01	3	50.0	40.0	7.0						3.0							30.0	12.0						1.0						
NH	17	3	12-Oct-01	1	96.0	2.0	2.0													1.0	2.0												
NH	17	3	12-Oct-01	2	83.0	15.0	2.0													15.0	2.0												
NH	17	3	12-Oct-01	3	70.0	30.0														28.0													
				MEAN	65.2	29.5	4.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	12.0	0.0	0.0	1.0	27.0	9.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	5.0	0.0	0.0	1.0
NH	51	1	30-Oct-01	1	74.0	12.0	9.0												5.0	8.0	16.0												2.0
NH	51	1	30-Oct-01	2	100.0																												
NH	51	1	30-Oct-01	3	88.0	1.0	9.0							2.0						1.0	16.0							3.0					
NH	51	2	30-Oct-01	1	100.0																												
NH	51	2	30-Oct-01	2	75.0	25.0														22.0													
NH	51	2	30-Oct-01	3	62.0	15.0	20.0										3.0			20.0	61.0										2.0		
NH	51	3	30-Oct-01	1	56.0	2.0	40.0	2.0												2.0	146.0	3.0											
NH	51	3	30-Oct-01	2	90.0		2.0	1.0						5.0	2.0						2.0	1.0						5.0	2.0				
NH	51	3	30-Oct-01	3	81.0		1.0							10.0	8.0						1.0							4.0	3.0				
				MEAN	80.7	11.0	13.5	1.5	0.0	0.0	0.0	0.0	0.0	5.7	5.0	0.0	3.0	0.0	5.0	10.6	40.3	2.0	0.0	0.0	0.0	0.0	0.0	4.0	2.5	0.0	2.0	0.0	2.0

Trough Vegetation Analysis

Trough Plot % Cover

Locality	Site No.	Profile No.	Date	Plot	No cover	American Beach Grass	Saltmeadow Hay	Running Dune Grass	Seaside Spurge	Phrag	Buttonweed	Aster General	Blue Stem	Switch Grass	Trumpet Vine	Japanese Sedge	Goldenrod	Sea Oats	Horseweed	Dandelion	Lazy Daisy	Rabbit Tobacco	Virginia Creeper	Unknown
MA	3	8	19-Jun-01	1	84.0	10.0	5.0																	1.0
MA	3	8	19-Jun-01	2	87.0	10.0	3.0																	
MA	3	8	19-Jun-01	3	75.0	25.0																		
MA	3	5	19-Jun-01	1	64.0	25.0		1.0												10.0				
MA	3	5	19-Jun-01	2	79.0	5.0		1.0												15.0				
MA	3	5	19-Jun-01	3	88.0	10.0														2.0				
MA	3	2	19-Jun-01	1	93.0	5.0	2.0																	
MA	3	2	19-Jun-01	2	89.0	10.0	1.0																	
MA	3	2	19-Jun-01	3	96.0	2.0	2.0																	
				MEAN	83.9	11.3	2.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0	0.0	1.0
LN	39	1	17-Aug-01	1	65.0									35.0										
LN	39	1	17-Aug-01	2	100.0																			
LN	39	1	17-Aug-01	3	74.0	1.0			0.0		20.0			5.0										
LN	39	2	17-Aug-01	1	67.0	5.0	3.0		5.0												15.0	5.0		
LN	39	2	17-Aug-01	2	75.0		3.0	1.0			5.0								4.0		10.0	2.0		
LN	39	2	17-Aug-01	3	91.0		1.0	0.0			5.0	3.0												
				MEAN	78.7	3.0	2.3	0.5	2.5	0.0	10.0	3.0	0.0	20.0	0.0	0.0	0.0	0.0	4.0	0.0	12.5	3.5	0.0	0.0
NL	58	1	23-Aug-01	1	0.0																			
NL	58	1	23-Aug-01	2	0.0																			
NL	58	1	23-Aug-01	3	0.0																			
NL	58	2	23-Aug-01	1	0.0																			
NL	58	2	23-Aug-01	2	0.0																			
NL	58	2	23-Aug-01	3	0.0																			
NL	58	3	23-Aug-01	1	0.0																			
NL	58	3	23-Aug-01	2	0.0																			
NL	58	3	23-Aug-01	3	0.0																			
				MEAN	0.0																			
NL	59	1	23-Aug-01	1	0.0																			
NL	59	1	23-Aug-01	2	0.0																			
NL	59	1	23-Aug-01	3	0.0																			
NL	59	2	23-Aug-01	1	0.0																			
NL	59	2	23-Aug-01	2	0.0																			
NL	59	2	23-Aug-01	3	0.0																			
NL	59	3	23-Aug-01	1	91.0		1.0	3.0															5.0	
NL	59	3	23-Aug-01	2	85.0			15.0																0.0
NL	59	3	23-Aug-01	3	90.0			10.0																0.0
				MEAN	29.6	0.0	1.0	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
NL	42	1	12-Sep-01	1	0.0																			
NL	42	1	12-Sep-01	2	0.0																			
NL	42	1	12-Sep-01	3	0.0																			
NL	42	2	12-Sep-01	1	0.0																			
NL	42	2	12-Sep-01	2	0.0																			
NL	42	2	12-Sep-01	3	0.0																			
NL	42	3	12-Sep-01	1	0.0																			
NL	42	3	12-Sep-01	2	0.0																			
NL	42	3	12-Sep-01	3	0.0																			
NL	42	4	12-Sep-01	1	0.0																			
NL	42	4	12-Sep-01	2	0.0																			
NL	42	4	12-Sep-01	3	0.0																			
				MEAN	0.0																			
VB	4	1	5-Oct-01	1	69.0	20.0	5.0	1.0																5.0
VB	4	1	5-Oct-01	2	53.0	2.0	5.0					40.0												
VB	4	1	5-Oct-01	3	76.0	3.0	1.0					15.0						5.0						
VB	4	2	5-Oct-01	1	8.0											90.0	2.0							
VB	4	2	5-Oct-01	2	25.0	5.0										70.0								
VB	4	2	5-Oct-01	3	68.0	2.0										30.0								
VB	4	3	5-Oct-01	1	93.0	7.0																		
VB	4	3	5-Oct-01	2	72.0	20.0	8.0																	
VB	4	3	5-Oct-01	3	97.0	3.0																		
				MEAN	62.3	7.8	4.8	1.0	0.0	0.0	0.0	27.5	0.0	0.0	0.0	63.3	2.0	5.0	0.0	0.0	0.0	0.0	0.0	5.0
NH	10	2	12-Oct-01	1	0.0																			
NH	10	2	12-Oct-01	2	0.0																			
NH	10	2	12-Oct-01	3	0.0																			
NH	10	3	12-Oct-01	1	0.0																			
NH	10	3	12-Oct-01	2	0.0																			
NH	10	3	12-Oct-01	3	0.0																			
				MEAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH	17	2	12-Oct-01	1	98.0		1.0										1.0							
NH	17	2	12-Oct-01	2	100.0																			
NH	17	2	12-Oct-01	3	100.0																			
NH	17	3	12-Oct-01	1	0.0																			
NH	17	3	12-Oct-01	2	0.0																			
NH	17	3	12-Oct-01	3	0.0																			
				MEAN	49.7	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH	51	1	30-Oct-01	1	0.0																			
NH	51	1	30-Oct-01	2	0.0																			
NH	51	1	30-Oct-01	3	0.0																			
NH	51	2	30-Oct-01	1	91.0		4.0					5.0												
NH	51	2	30-Oct-01	2	64.0		2.0	2.0					60.0											
NH	51	2	30-Oct-01	3	1.0		5.0					4.0	90.0											
NH	51	3	30-Oct-01	1	65.0							5.0	30.0											
NH	51	3	30-Oct-01	2	85.0							10.0	5.0											
NH	51	3	30-Oct-01	3	94.0							5.0			1.0									
				MEAN	44.4	0.0	3.7	2.0	0.0	0.0	0.0	5.8	46.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Trough Plot Stem Density

Locality	Site No.	Profile No.	Date	Plot	American Beach Grass	Saltmeadow Hay	Running Dune Grass	Seaside Spurge	Phrag	Buttonweed	Aster General	Blue Stem	Switch Grass	Trumpet Vine	Japanese Sedge	Goldenrod	Sea Oats	Horseweed	Dandelion	Lazy Daisy	Rabbit Tobacco	Virginia Creeper	Unknown
MA	3	8	19-Jun-01	1	12.0	4.0																	1.0
MA	3	8	19-Jun-01	2	14.0	2.0																	
MA	3	8	19-Jun-01	3	26.0																		
MA	3	5	19-Jun-01	1	22.0		1.0												1.0				
MA	3	5	19-Jun-01	2	5.0		1.0												2.0				
MA	3	5	19-Jun-01	3	9.0														1.0				
MA	3	2	19-Jun-01	1	9.0	12.0																	
MA	3	2	19-Jun-01	2	21.0	3.0																	
MA	3	2	19-Jun-01	3	4.0	7.0																	
				MEAN	13.6	5.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	1.0
LN	39	1	17-Aug-01	1									12.0										
LN	39	1	17-Aug-01	2																			
LN	39	1	17-Aug-01	3	2.0			3.0		19.0			6.0										
LN	39	2	17-Aug-01	1	6.0	8.0		11.0												1.0	12.0		
LN	39	2	17-Aug-01	2		10.0	2.0			14.0								1.0		1.0	5.0		
LN	39	2	17-Aug-01	3		5.0	1.0			7.0	2.0												
				MEAN	4.0	7.7	1.5	7.0	0.0	13.3	2.0	0.0	9.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	8.5	0.0	0.0
NL	58	1	23-Aug-01	1																			
NL	58	1	23-Aug-01	2																			
NL	58	1	23-Aug-01	3																			
NL	58	2	23-Aug-01	1																			
NL	58	2	23-Aug-01	2																			
NL	58	2	23-Aug-01	3																			
NL	58	3	23-Aug-01	1																			
NL	58	3	23-Aug-01	2																			
NL	58	3	23-Aug-01	3																			
				MEAN																			
NL	59	1	23-Aug-01	1																			
NL	59	1	23-Aug-01	2																			
NL	59	1	23-Aug-01	3																			
NL	59	2	23-Aug-01	1																			
NL	59	2	23-Aug-01	2																			
NL	59	2	23-Aug-01	3																			
NL	59	3	23-Aug-01	1		5.0	2.0															2.0	
NL	59	3	23-Aug-01	2			18.0																2.0
NL	59	3	23-Aug-01	3			23.0																2.0
				MEAN	0.0	5.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0
NL	42	1	12-Sep-01	1																			
NL	42	1	12-Sep-01	2																			
NL	42	1	12-Sep-01	3																			
NL	42	2	12-Sep-01	1																			
NL	42	2	12-Sep-01	2																			
NL	42	2	12-Sep-01	3																			
NL	42	3	12-Sep-01	1																			
NL	42	3	12-Sep-01	2																			
NL	42	3	12-Sep-01	3																			
NL	42	4	12-Sep-01	1																			
NL	42	4	12-Sep-01	2																			
NL	42	4	12-Sep-01	3																			
				MEAN																			
VB	4	1	5-Oct-01	1	18.0	9.0	1.0																1.0
VB	4	1	5-Oct-01	2	4.0	12.0					19.0												
VB	4	1	5-Oct-01	3	3.0	2.0					13.0						3.0						
VB	4	2	5-Oct-01	1											36.0	1.0							
VB	4	2	5-Oct-01	2	5.0										30.0								
VB	4	2	5-Oct-01	3	2.0										12.0								
VB	4	3	5-Oct-01	1	8.0																		
VB	4	3	5-Oct-01	2	19.0	16.0																	
VB	4	3	5-Oct-01	3	4.0																		
				MEAN	7.9	9.8	1.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0	26.0	1.0	3.0	0.0	0.0	0.0	0.0	0.0	1.0
NH	10	2	12-Oct-01	1																			
NH	10	2	12-Oct-01	2																			
NH	10	2	12-Oct-01	3																			
NH	10	3	12-Oct-01	1																			
NH	10	3	12-Oct-01	2																			
NH	10	3	12-Oct-01	3																			
				MEAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH	17	2	12-Oct-01	1		3.0										1.0							
NH	17	2	12-Oct-01	2																			
NH	17	2	12-Oct-01	3																			
NH	17	3	12-Oct-01	1																			
NH	17	3	12-Oct-01	2																			
NH	17	3	12-Oct-01	3																			
				MEAN	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH	51	1	30-Oct-01	1																			
NH	51	1	30-Oct-01	2																			
NH	51	1	30-Oct-01	3																			
NH	51	2	30-Oct-01	1		7.0					4.0												
NH	51	2	30-Oct-01	2		3.0	2.0					22.0											
NH	51	2	30-Oct-01	3		6.0					2.0	32.0											
NH	51	3	30-Oct-01	1							4.0	17.0											
NH	51	3	30-Oct-01	2							4.0	8.0											
NH	51	3	30-Oct-01	3							7.0			1.0									
				MEAN	0.0	5.3	2.0	0.0	0.0	0.0	4.2	19.8	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Secondary Dune Vegetation Analysis

Locality	Site No.	Profile No.	Date	Random Plot Locatior			Secondary Dune Plot % Covei																			
							Herbs																			
				No.	Distance Landward (m)	Distance Laterally (m)	No cover	American Beach Grass	Saltmeadow Hay	Running Dune Grass	Phrag	Buttonweed	Dune Bean	Aster General	Blue Stem	Trumpet Vine	Japanese Sedge	Goldenrod	Sea Oats	Horseweed	Dandelion	Lazy Daisy	Cyperus haspan	Greenbrier	Moss Unknown	Unknown
MA	3	8	19-Jun-01	1	4.85	1.7	98.0		2.0																	
MA	3	8	19-Jun-01	2	0.05	1.4	64.0	5.0	1.0							30.0										
MA	3	8	19-Jun-01	3	5.4	4.3	0.0									100.0										
MA	3	5	19-Jun-01	1	6.6	1.9	68.0	20.0						2.0							10.0					
MA	3	5	19-Jun-01	2	1.4	1.6	68.0	25.0															7.0			
MA	3	5	19-Jun-01	3	6.3	4.6	100.0																			
MA	3	2	19-Jun-01	1	0.5	2.5	95.0	5.0																		
MA	3	2	19-Jun-01	2	4.9	2.4	99.0			1.0																0.0
						MEAN	74.0	13.8	1.5	1.0	0.0	0.0	0.0	2.0	0.0	65.0	0.0	0.0	0.0	0.0	10.0	0.0	7.0	0.0	0.0	0.0
LN	39	1	17-Aug-01	1	2.1	8.6	85.0		5.0	7.0		3.0														
LN	39	1	17-Aug-01	2	7	0.23	92.0		3.0			5.0														
LN	39	1	17-Aug-01	3	6.2	3	90.0					10.0														
LN	39	1	17-Aug-01	4	4	5	96.0													4.0						
LN	39	1	17-Aug-01	5	6.9	8.7	97.0		3.0																	
LN	39	2	17-Aug-01	1	5.4	9.6	82.0			1.0		12.0										5.0				
LN	39	2	17-Aug-01	2	1	4	100.0		0.0																	
LN	39	2	17-Aug-01	3	6.9	8.6	99.0															1.0				
LN	39	2	17-Aug-01	4	2.2	9.9	88.0		0.0	5.0		4.0								3.0						
						MEAN	92.1	0.0	2.2	4.3	0.0	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	3.0	0.0	0.0	0.0	0.0
NL	58	1	23-Aug-01	1	0	0																				
NL	58	1	23-Aug-01	2	0	0																				
NL	58	1	23-Aug-01	3	0	0																				
NL	58	2	23-Aug-01	1	8.2	7.8	85.0																	15.0		
NL	58	2	23-Aug-01	2	3.4	9.2	100.0																			
NL	58	3	23-Aug-01	1	0	0																				
NL	58	3	23-Aug-01	2	0	0																				
NL	58	3	23-Aug-01	3	0	0																				
						MEAN	92.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0
NL	59	1	23-Aug-01	1	0	0																				
NL	59	1	23-Aug-01	2	0	0																				
NL	59	1	23-Aug-01	3	0	0																				
NL	59	2	23-Aug-01	1	0	0																				
NL	59	2	23-Aug-01	2	0	0																				
NL	59	2	23-Aug-01	3	0	0																				
NL	59	3	23-Aug-01	1	0	0																				
NL	59	3	23-Aug-01	2	0	0																				
NL	59	3	23-Aug-01	3	0	0																				
						MEAN																				
NL	42	1	12-Sep-01	1	0	0																				
NL	42	1	12-Sep-01	2	0	0																				
NL	42	1	12-Sep-01	3	0	0																				
NL	42	2	12-Sep-01	1	0	0																				
NL	42	2	12-Sep-01	2	0	0																				
NL	42	2	12-Sep-01	3	0	0																				
NL	42	3	12-Sep-01	1	0	0																				
NL	42	3	12-Sep-01	2	0	0																				
NL	42	3	12-Sep-01	3	0	0																				
NL	42	4	12-Sep-01	1	0	0																				
NL	42	4	12-Sep-01	2	0	0																				
NL	42	4	12-Sep-01	3	0	0																				
						MEAN																				
VB	4	1	5-Oct-01	1	14.9	8.9	71.0		3.0	25.0			1.0													
VB	4		5-Oct-01	2	1.5	5.3	93.0		3.0																	4.0
VB	4	2	5-Oct-01	1	29	5	43.0	20.0	28.0	4.0							5.0									
VB	4		5-Oct-01	2	5.6	8	68.0		2.0								30.0									
VB	4		5-Oct-01	3	1.4	2.6	70.0	5.0	10.0					5.0			10.0									
VB	4	3	5-Oct-01	1	7.7	8.2	85.0		15.0																	
VB	4		5-Oct-01	2	3.8	7.8	89.0	7.0		4.0																
VB	4		5-Oct-01	3	9.97	4	5.0								95.0											
VB	4		5-Oct-01	4	5.3	0.04	93.0	2.0		2.0									3.0							
						MEAN	68.6	8.5	10.2	8.8	0.0	0.0	1.0	5.0	95.0	0.0	15.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
NH	10	2	12-Oct-01	1	3.4	7.1	82.0	18.0	0.0																	
NH	10	3	12-Oct-01	1	0	0																				
						MEAN	82.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH	17	2	12-Oct-01	1	0	0																				
NH	17	3	12-Oct-01	1	0	0																				
						MEAN																				
NH	51	1	30-Oct-01	1	3.7	4.1	89.0			10.0				1.0												
NH	51	1	30-Oct-01	2	9.4	5.4	93.0		5.0	2.0																
NH	51	1	30-Oct-01	3	0.3	8	68.0	15.0	0.0	2.0				5.0											10.0	
NH	51	1	30-Oct-01	4	6.7	4.3	59.0		1.0						40.0											
NH	51	1	30-Oct-01	5	5.1	7.8	55.0							5.0	30.0			10.0								
NH	51	2	30-Oct-01	1	9.3	4.2	100.0																			
NH	51	2	30-Oct-01	2	3.8	6.8	93.0			2.0				5.0												
NH	51	2	30-Oct-01	3	8.8	3.1	95.0							5.0												
NH	51	2	30-Oct-01	4	5.9	6	100.0																			
NH	51	2	30-Oct-01	5	1.5	5.6	100.0																			
NH	51	3	30-Oct-01	1	6.9	8.6	70.0								30.0											
						MEAN	83.8	15.0	2.0	4.0	0.0	0.0	0.0	4.2	33.3	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0

Secondary Dune Vegetation Analysis

Locality	Site No.	Profile No.	Date	Random Plot Location			Secondary Dune Plot Stem Density: Herbs																	
				No.	Distance Landward (m)	Distance Laterally (m)	American Beach Grass	Saltmeadow Hay	Running Dune Grass	Phrag	Buttonweed	Dune Bean	Aster General	Blue Stem	Trumpet Vine	Japanese Sedge	Goldenrod	Sea Oats	Horseweed	Dandelion	Lazy Daisy	Cyperus haspan	Greenbrier	Unknown
MA	3	8	19-Jun-01	1	4.85	1.7		3.0																
MA	3	8	19-Jun-01	2	0.05	1.4	4.0	2.0																
MA	3	8	19-Jun-01	3	5.4	4.3																		
MA	3	5	19-Jun-01	1	6.6	1.9	15.0						1.0							4.0				
MA	3	5	19-Jun-01	2	1.4	1.6	18.0															22.0		
MA	3	5	19-Jun-01	3	6.3	4.6																		
MA	3	2	19-Jun-01	1	0.5	2.5	5.0																	
MA	3	2	19-Jun-01	2	4.9	2.4			2.0															1.0
						MEAN	10.5	2.5	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	22.0	0.0	1.0
LN	39	1	17-Aug-01	1	2.1	8.6		9.0	4.0		4.0													
LN	39	1	17-Aug-01	2	7	0.23		3.0			3.0													
LN	39	1	17-Aug-01	3	6.2	3					4.0													
LN	39	1	17-Aug-01	4	4	5													1.0					
LN	39	1	17-Aug-01	5	6.9	8.7		9.0																
LN	39	2	17-Aug-01	1	5.4	9.6			2.0		15.0										6.0			
LN	39	2	17-Aug-01	2	1	4		1.0																
LN	39	2	17-Aug-01	3	6.9	8.6															1.0			
LN	39	2	17-Aug-01	4	2.2	9.9		1.0	4.0		5.0								2.0					
						MEAN	0.0	4.6	3.3	0.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	3.5	0.0	0.0	0.0
NL	58	1	23-Aug-01	1	0	0																		
NL	58	1	23-Aug-01	2	0	0																		
NL	58	1	23-Aug-01	3	0	0																		
NL	58	2	23-Aug-01	1	8.2	7.8																	1.0	
NL	58	2	23-Aug-01	2	3.4	9.2																		
NL	58	3	23-Aug-01	1	0	0																		
NL	58	3	23-Aug-01	2	0	0																		
NL	58	3	23-Aug-01	3	0	0																		
						MEAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
NL	59	1	23-Aug-01	1	0	0																		
NL	59	1	23-Aug-01	2	0	0																		
NL	59	1	23-Aug-01	3	0	0																		
NL	59	2	23-Aug-01	1	0	0																		
NL	59	2	23-Aug-01	2	0	0																		
NL	59	2	23-Aug-01	3	0	0																		
NL	59	3	23-Aug-01	1	0	0																		
NL	59	3	23-Aug-01	2	0	0																		
NL	59	3	23-Aug-01	3	0	0																		
						MEAN																		
NL	42	1	12-Sep-01	1	0	0																		
NL	42	1	12-Sep-01	2	0	0																		
NL	42	1	12-Sep-01	3	0	0																		
NL	42	2	12-Sep-01	1	0	0																		
NL	42	2	12-Sep-01	2	0	0																		
NL	42	2	12-Sep-01	3	0	0																		
NL	42	3	12-Sep-01	1	0	0																		
NL	42	3	12-Sep-01	2	0	0																		
NL	42	3	12-Sep-01	3	0	0																		
NL	42	4	12-Sep-01	1	0	0																		
NL	42	4	12-Sep-01	2	0	0																		
NL	42	4	12-Sep-01	3	0	0																		
						MEAN																		
VB	4	1	5-Oct-01	1	14.9	8.9		4.0	15.0			1.0												
VB	4		5-Oct-01	2	1.5	5.3		8.0																1.0
VB	4	2	5-Oct-01	1	29	5	16.0	34.0	2.0							3.0								
VB	4		5-Oct-01	2	5.6	8		5.0								20.0								
VB	4		5-Oct-01	3	1.4	2.6	4.0	12.0					3.0			6.0								
VB	4	3	5-Oct-01	1	7.7	8.2		44.0																
VB	4		5-Oct-01	2	3.8	7.8	6.0		2.0															
VB	4		5-Oct-01	3	9.97	4								37.0										
VB	4		5-Oct-01	4	5.3	0.04	1.0		1.0									1.0						
						MEAN	6.8	17.8	5.0	0.0	0.0	1.0	3.0	37.0	0.0	9.7	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
NH	10	2	12-Oct-01	1	3.4	7.1	17.0	3.0																
NH	10	3	12-Oct-01	1	0	0																		
						MEAN	17.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH	17	2	12-Oct-01	1	0	0																		
NH	17	3	12-Oct-01	1	0	0																		
						MEAN																		
NH	51	1	30-Oct-01	1	3.7	4.1			7.0				1.0											
NH	51	1	30-Oct-01	2	9.4	5.4		7.0	2.0															
NH	51	1	30-Oct-01	3	0.3	8	9.0	1.0	1.0				5.0											
NH	51	1	30-Oct-01	4	6.7	4.3		1.0						11.0										
NH	51	1	30-Oct-01	5	5.1	7.8							4.0	12.0			1.0							
NH	51	2	30-Oct-01	1	9.3	4.2																		
NH	51	2	30-Oct-01	2	3.8	6.8			1.0				5.0											
NH	51	2	30-Oct-01	3	8.8	3.1							3.0											
NH	51	2	30-Oct-01	4	5.9	6																		
NH	51	2	30-Oct-01	5	1.5	5.6																		
NH	51	3	30-Oct-01	1	6.9	8.6								7.0										
						MEAN	9.0	3.0	2.8	0.0	0.0	0.0	3.6	10.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Secondary Dune Vegetation Analysis

Locality	Site No.	Profile No.	Date	Random Plot Location			Secondary Dune Plot Stem Density															2nd Dune Plot Stem Density	
							Shrubs															Trees	
				No.	Distance Landward (m)	Distance Laterally (m)	Loblolly Pine	Short Needle Pine	Black Locust	Wax Myrtle	Groundsel	Persimmon	Sweetgum	Red Cedar	Oak General	Live Oak	American Holly	Seashore Elder	Mexican Tea	Black Cherry	Unknown	Loblolly Pine	Black Cherry
MA	3	8	19-Jun-01	1	4.85	1.7																	
MA	3	8	19-Jun-01	2	0.05	1.4																	
MA	3	8	19-Jun-01	3	5.4	4.3																	
MA	3	5	19-Jun-01	1	6.6	1.9	4.0			1.0										13.0			
MA	3	5	19-Jun-01	2	1.4	1.6	3.0			3.0										7.0			
MA	3	5	19-Jun-01	3	6.3	4.6	4.0													5.0			1.0
MA	3	2	19-Jun-01	1	0.5	2.5														2.0			
MA	3	2	19-Jun-01	2	4.9	2.4	2.0		1.0											2.0			
						MEAN	3.3	0.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.0	0.0	1.0
LN	39	1	17-Aug-01	1	2.1	8.6																	
LN	39	1	17-Aug-01	2	7	0.23	4.0					1.0											
LN	39	1	17-Aug-01	3	6.2	3	5.0					4.0	1.0							1.0			
LN	39	1	17-Aug-01	4	4	5	7.0					8.0	1.0							3.0			
LN	39	1	17-Aug-01	5	6.9	8.7	12.0							3.0						14.0			
LN	39	2	17-Aug-01	1	5.4	9.6	21.0			1.0	3.0			4.0									
LN	39	2	17-Aug-01	2	1	4	26.0					40.0		3.0						3.0			
LN	39	2	17-Aug-01	3	6.9	8.6	20.0			3.0	1.0	22.0		1.0						3.0		1.0	
LN	39	2	17-Aug-01	4	2.2	9.9	18.0				1.0	3.0		2.0						1.0			
						MEAN	14.1	0.0	0.0	2.0	1.7	13.0	1.0	2.6	0.0	0.0	0.0	0.0	0.0	4.2	0.0	1.0	0.0
NL	58	1	23-Aug-01	1	0	0																	
NL	58	1	23-Aug-01	2	0	0																	
NL	58	1	23-Aug-01	3	0	0																	
NL	58	2	23-Aug-01	1	8.2	7.8	3.0	1.0							16.0		1.0				1.0	1.0	
NL	58	2	23-Aug-01	2	3.4	9.2	5.0	2.0							21.0		1.0				1.0	6.0	
NL	58	3	23-Aug-01	1	0	0																	
NL	58	3	23-Aug-01	2	0	0																	
NL	58	3	23-Aug-01	3	0	0																	
						MEAN	4.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	18.5	0.0	1.0	0.0	0.0	0.0	1.0	3.5	0.0
NL	59	1	23-Aug-01	1	0	0																	
NL	59	1	23-Aug-01	2	0	0																	
NL	59	1	23-Aug-01	3	0	0																	
NL	59	2	23-Aug-01	1	0	0																	
NL	59	2	23-Aug-01	2	0	0																	
NL	59	2	23-Aug-01	3	0	0																	
NL	59	3	23-Aug-01	1	0	0																	
NL	59	3	23-Aug-01	2	0	0																	
NL	59	3	23-Aug-01	3	0	0																	
						MEAN																	
NL	42	1	12-Sep-01	1	0	0																	
NL	42	1	12-Sep-01	2	0	0																	
NL	42	1	12-Sep-01	3	0	0																	
NL	42	2	12-Sep-01	1	0	0																	
NL	42	2	12-Sep-01	2	0	0																	
NL	42	2	12-Sep-01	3	0	0																	
NL	42	3	12-Sep-01	1	0	0																	
NL	42	3	12-Sep-01	2	0	0																	
NL	42	3	12-Sep-01	3	0	0																	
NL	42	4	12-Sep-01	1	0	0																	
NL	42	4	12-Sep-01	2	0	0																	
NL	42	4	12-Sep-01	3	0	0																	
						MEAN																	
VB	4	1	5-Oct-01	1	14.9	8.9												1.0					
VB	4		5-Oct-01	2	1.5	5.3	1.0											1.0	1.0				
VB	4	2	5-Oct-01	1	29	5													1.0				
VB	4		5-Oct-01	2	5.6	8										1.0							
VB	4		5-Oct-01	3	1.4	2.6																	
VB	4	3	5-Oct-01	1	7.7	8.2										1.0		3.0	1.0				
VB	4		5-Oct-01	2	3.8	7.8										2.0		1.0	1.0				
VB	4		5-Oct-01	3	9.97	4										4.0			4.0				
VB	4		5-Oct-01	4	5.3	0.04										2.0							
						MEAN	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1.5	1.6	0.0	0.0	0.0	0.0
NH	10	2	12-Oct-01	1	3.4	7.1																	
NH	10	3	12-Oct-01	1	0	0																	
						MEAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH	17	2	12-Oct-01	1	0	0																	
NH	17	3	12-Oct-01	1	0	0																	
						MEAN																	
NH	51	1	30-Oct-01	1	3.7	4.1	1.0			6.0													
NH	51	1	30-Oct-01	2	9.4	5.4				3.0		15.0											
NH	51	1	30-Oct-01	3	0.3	8				6.0		12.0											
NH	51	1	30-Oct-01	4	6.7	4.3	2.0			6.0		13.0											
NH	51	1	30-Oct-01	5	5.1	7.8	4.0			11.0		4.0		2.0	1.0							1.0	
NH	51	2	30-Oct-01	1	9.3	4.2				8.0		37.0		1.0						1.0			
NH	51	2	30-Oct-01	2	3.8	6.8	1.0			9.0		8.0		1.0									
NH	51	2	30-Oct-01	3	8.8	3.1	5.0			1.0		11.0			6.0		2.0						
NH	51	2	30-Oct-01	4	5.9	6	8.0			4.0		2.0			2.0		2.0			2.0			
NH	51	2	30-Oct-01	5	1.5	5.6	7.0			5.0		1.0			7.0		3.0						
NH	51	3	30-Oct-01	1	6.9	8.6	4.0			3.0		2.0			2.0					1.0			
						MEAN	4.0	0.0	0.0	5.6	0.0	10.5	0.0	1.3	3.6	0.0	2.3	0.0	0.0	1.3	0.0	1.0	0.0