STOCKTON UNIVERSITY
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Hereford Inlet, Cape May County, March 10, 1991, seven years prior to the initial NJ State and municipally funded beach restoration. Bird habitat consisted of four large intertidal shoals situated between the 123rd Street groin in Stone Harbor and the rock revetment protecting North Wildwood. 25 years and 4.8 million cubic yards of beach restoration later, nesting habitat had expanded into a 7,500 foot long spit extending to a point south of the third shoal in the photo.

An Analysis of Thirty Years' Study of Sand Redistribution and Shoreline Changes in New Jersey's Four Coastal Counties Raritan Bay, the Atlantic Ocean Coast, and Delaware Bay Fall 1986 Through Fall 2016

VOLUME 1 of 4 INTRODUCTION & MONMOUTH COUNTY

Prepared for:
New Jersey Department of Environmental Protection
Division of Coastal Engineering
1510 Hooper Avenue, Toms River, New Jersey 08753

Prepared by:
Stockton University Coastal Research Center
30 Wilson Avenue, Port Republic, NJ 08241

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VOLUME 1 of 4 INTRODUCTION & MONMOUTH COUNTY

Prepared by:
Dr. Stewart Farrell
Kim McKenna, Steven Hafner,
Brad Smith, Crist Robine, Holly Pimpinelli
Nick DiCosmo, Christie Tracey, Irina Beal
Alex Ferencz, Marcus Gruver, and Mat Suran

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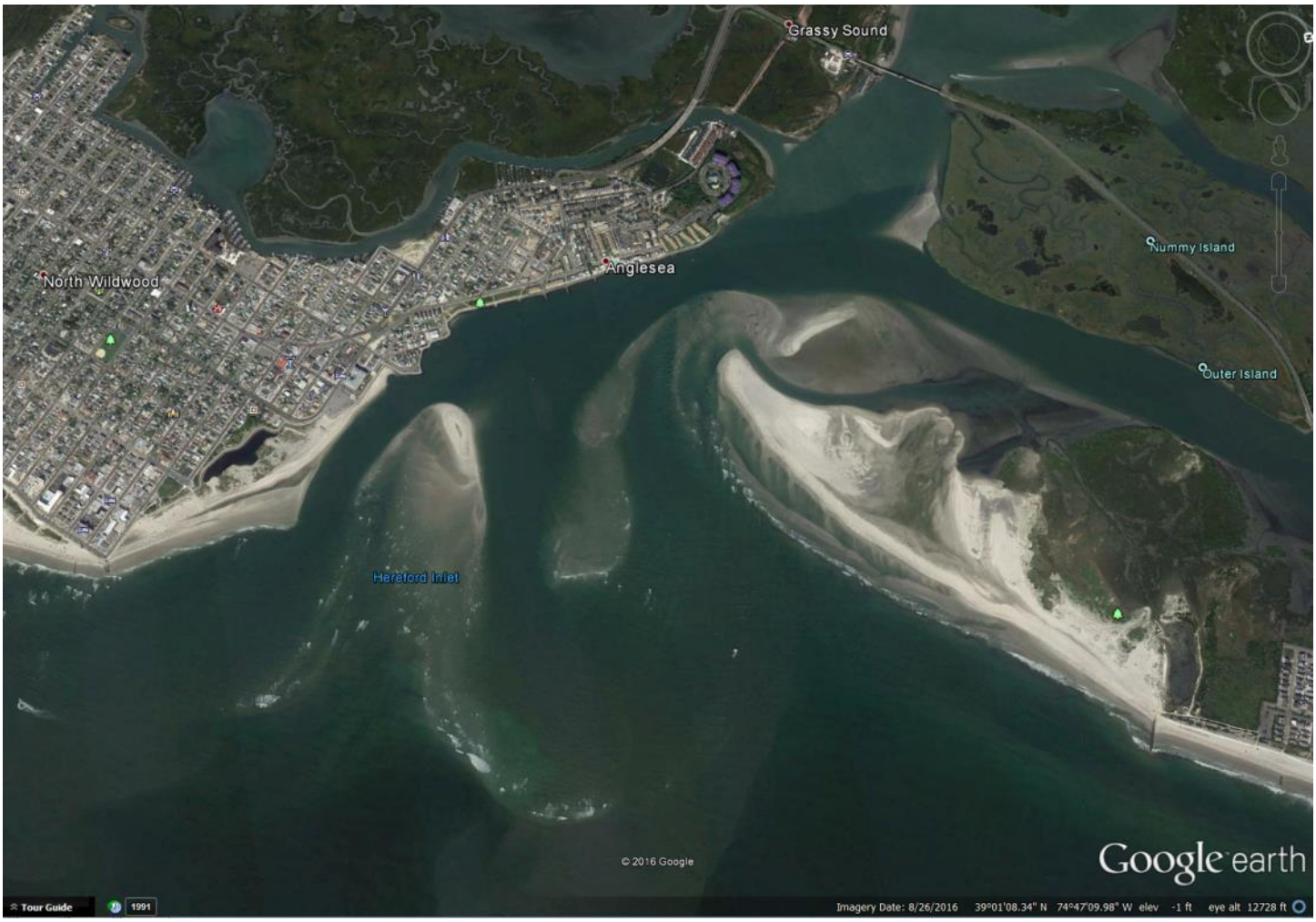

Figure 1. August 26, 2016 aerial view of Hereford Inlet adjusted to approximate the cover photo dated 1991. The multiple beach restoration efforts by both Federal and NJ State agencies in cooperation with the Borough of Stone Harbor has had the secondary result of restoring over 7,000 feet of bird nesting habitat as a sand spit developed adjacent to the 123rd Street groin in Stone Harbor. Sand elevation enhancements to the spit in 2015 resulted in extraordinary nesting success that year. The overwash fan in the mid-section of the spit resulted from Northeast Storm Jonas in January 2016.

Thirty years have passed since the New Jersey Department of Environmental Protection (NJDEP) initially authorized the New Jersey Beach Profile Network (NJBPN) project in 1986. While there are multiple examples where extensive changes in shoreline configuration have occurred, the Hereford Inlet example was chosen because of the cause and effect relationship between extensive beach management projects and natural wildlife habitat generation that resulted from those projects. By 1991, beach deterioration in Stone Harbor on Seven-Mile Island in Cape May County had produced total loss of the upland dune and vegetated surface of Stone Harbor Point. Large intertidal shoals existed, but useful nesting habitat was limited (cover photo). Projects in 1998, 2003, 2011 and 2013 (following Hurricane Sandy) placed 4.819 million cubic yards of sand on the oceanfront beaches of Stone Harbor. Subsequent littoral transport of sand to the south produced the changes by

2016 (shown above). Similar examples exist at Corson's Inlet, mid-beach in Ocean City, Brigantine, and at the south end of the Island Beach State Park in Ocean County. Northerly sand transport, derived from the material placed between Sea Bright and Long Branch in Monmouth County since 1995, has enhanced the Sandy Hook National Seashore by over 3.4 million cubic yards of sand. This report quantifies the changes, both positive and negative, observed at the 107 survey locations along the New Jersey Raritan Bay, Atlantic oceanfront, and lower Delaware Bay shorelines. Its goal is to provide a review of the past three decades and provide science-based guidance for future management decisions.

STORMS:

The first major storm to impact the New Jersey coastal zone during the NJBPN surveying era was the 1992 northeaster. An analysis of subsequent beach profile survey data indicated a four-year time span for natural recovery, via cross-shore transport, to restore the amount of beach sand that was removed during that event. The winter northeast storms in 1998 helped solidify federal involvement in shore protection projects along many areas of the Jersey shoreline. Other storms that caused either county- or state-wide coastal changes were: Mother's Day Northeaster 2008; Veteran's Day Northeaster 2009; Hurricane Irene 2011; Hurricane Sandy 2012; October Northeaster 2015; Northeaster January 2016-Jonas; and Tropical Storm Hermine 2016. Hurricane Sandy was the most devastating to the state's coastal zone, relocating over 14 million cubic yards of berm/dune sand, and reinforced the need for high dunes and wide beaches for shoreline protection (CRC, 2012; Barone, McKenna, and Farrell, 2014; McKenna, Farrell, and Gebert, 2016). The first serious storm since Hurricane Sandy occurred January 22-24, 2016 (Jonas) and resulted in a federal disaster declaration largely due to unexpected levels of tidal flooding in Cape May County (FEMA, 2016).

SHORE PROTECTION:

By the mid-1990s, Ocean City, Cape May City, and several communities in Monmouth County had partnered with the state and US Army Corps of Engineers (USACE) to commence beach nourishment projects with great success; providing a better level of shore protection and improving all forms of economic growth and real estate value enhancement. Federal partnerships expanded in the early 2000s to include Seven-Mile Island, Brigantine and Absecon Island, Long Beach Island, and Ludlam Island.

SHORELINE MANAGEMENT ENDEAVORS SINCE HURRICANE SANDY:

The Philadelphia and New York US Army Corps Districts answered the call for help following Hurricane Sandy, and with the Congressional authorization of PL 113-2 (Disaster Relief Appropriations Act of 2013) the funds were made available to restore all federally-authorized shore protection projects to design specifications with 100% Federal funding. Work started in mid-2013 and continued into 2015 at previously authorized, but unconstructed projects such as Ludlam Island in Cape May County and within the Allenhurst, Deal, and Elberon segments of Monmouth County. PL 113-2 funds were utilized to complete Long Beach Island (Beach Haven to Holgate) in 2016.

The USACE returned to beach fill maintenance mode in 2016-2017 and completed projects at Seven Mile Island (Avalon and Stone Harbor in Cape May County) and Absecon Island (Atlantic City, Ventnor, Margate and Longport). Maintenance projects are expected in Brigantine as well as in Cape May City. Repair work on the Ludlam Island project commenced following January 2016 northeast storm (Jonas).

2015-2016

The shoreline change values listed throughout this report represent the calculated difference in horizontal distance of the zero (NAVD88) elevation position from one beach profile to another. Advances seaward are positive and retreats landward are negative. Each number shown below is the average change for all the sites in each county. This set of data shows the influence of the January 2016 northeast storm and other events that led to a universal decline in sand volume and a shoreline retreat. The summer of 2016 allowed a net increase in sand volume which exceeded the loss in all but Atlantic County for sand volume and Cape May County for shoreline position recovery. The 18-month changes were substantially negative in Atlantic County, yet positive

in the other three. Beach restoration work was influential in Monmouth (Deal, Elberon) and in Cape May County (Ludlam Island). Work was also in progress on Long Beach Island in 2016 as well.

Table 1. Annual County-Averaged Volume & Shoreline Changes

Sand Volume Changes at the NJ Oceanfront

	S 15 – F 15 [$yds^3/ft.$]	F 15 – S 16 [$yds^3/ft.$]	S 16 – F 16 [$yds^3/ft.$]	S 15 – F 16 [$yds^3/ft.$]
Monmouth County	**6.00**	**-10.97**	**22.90**	**17.87**
Ocean County	**14.95**	**-1.60**	**28.53**	**41.38**
Atlantic County	**-14.14**	**-13.77**	**4.42**	**-22.16**
Cape May County	**32.80**	**-5.54**	**7.57**	**35.63**

Shoreline Position Shifts Landward (-) or Seaward (+) at the NJ Oceanfront

	S 15 – F 15 [ft.]	F 15 – S 16 [ft.]	S 16 – F 16 [ft.]	S 15 – F 16 [ft.]
Monmouth County	**-7.39**	**-20.51**	**42.04**	**14.15**
Ocean County	**19.08**	**-15.67**	**38.60**	**42.02**
Atlantic County	**27.63**	**-1.77**	**-15.04**	**-44.44**
Cape May County	**58.99**	**-22.16**	**16.36**	**53.19**

Currently Margate and Longport are scheduled to be completed in 2017. Northern Ocean County (Manasquan Inlet to Island Beach State Park) is also scheduled for major shoreline enhancement. This project has been the subject of high-stakes litigation as oceanfront owners seek to prevent the work, alleging property rights issues related to private ownership to the mean high tide line on the beach. The most recent court hearing was completed in March 2017 in Ocean County Superior Court where multiple homeowners from Bay Head, Point Pleasant Beach and Mantoloking sought injunction against the project in those communities. The judge's decision is pending, but the project is scheduled to commence south of the area of contention in Ortley Beach. The three Wildwood communities are under final design by the Philadelphia District. Once completed, all New Jersey oceanfront municipalities will be included in federal shore protection projects within the purview of either the Philadelphia District or the New York District.

Local efforts have largely focused on repairing dune damage using front end loading or bulldozing capabilities. Dune planting and public access programs remain with local communities working down to the level of individual owner options to improve their dune protection.

Challenges remain as individuals and a few communities continue to object to oceanfront sand placement which adds material that was never previously within the coastal zone to the beaches. Litigation is moving slowly to adjudicate solutions to these issues, but in the long-term view, there are looming changes to coastal habitation that must be faced, if not by this generation, certainly by the next several. Major state and federal projects have gone to completion and been exposed to a few storm events since Hurricane Sandy. These efforts tend to

greatly reduce wave damage on the oceanfront, but tidal flooding continues to take its toll on bayside properties and local infrastructure. NOAA (National Oceanographic & Atmospheric Administration) projections on sea level rise by 2100 range from 0.9 ft. minimum to a game changing 3.9 ft. vertically. The latter value puts 50% of the NJ coastal zone properties in the water every high tide, with an exponential rise in storm damage.

ACKNOWLEDGEMENTS

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INTRODUCTION:

The New Jersey Beach Profile Network (NJBPN) project was instituted following storm damages experienced during Hurricane Gloria in 1985 to provide local and regional information on coastal zone changes and is designed to document seasonal and storm-related damage assessments of the New Jersey shoreline. New Jersey Department of Environmental Protection (NJDEP) and Coastal Research Center (CRC) personnel selected the original sites for surveys during a fall 1986 reconnaissance examination from Sandy Hook to Cape May Point. The objective was that every municipality would have one survey site with additional sites placed where conditions dictated. A few years later sites were installed at each tidal inlet margin to more closely follow the relatively rapid changes observed initially. Over the years, sites were moved a few dozen feet as development introduced obstacles along a few original profile transects, and most recently a new site was added at the most northerly beach access at Sandy Hook National Seashore to better track the vast quantity of sand moving into this natural area.

Each survey site was visited annually starting in the fall of 1986. Semiannual visits, each spring and fall, began in 1994 following the passage of New Jersey Public Law 93. The program was expanded to take surveys every spring following the winter northeasters and in the fall following summer beach accretion. The information collected consists of photographs of the beach/dune system at each site, a topographic profile of the dune, beach and seafloor to a minimum depth of 15-18 ft, and field notes on significant geologic or manmade changes. Construction activity is noted and necessary information regarding quantity and duration of such activity is gathered. The field data are used to generate graphical cross section plots, which can be used for comparison across the width of the active coastal zone. The cross section is also used to calculate sand volume and shoreline position changes.

In this 30-year report each site was subjected to an analysis of trends in shoreline position and sand volume to allow both quantitative and visual portrayals of the patterns of change. This provides us the ability to point to natural events or individual efforts that may have altered the overall trend that appears in the data.

NEW JERSEY COASTAL ZONE:

The New Jersey coast is defined through a system of spits, headlands, barrier islands/tidal inlets. The northern coast in Monmouth County is a headland beach (a bluff of older geologic sedimentary units) that erodes during serious storm events. Long-term erosion of the headland created two barrier spits; one to the north from Long Branch (Sandy Hook), and the other to the south from Bay Head (Mantoloking to Barnegat Inlet). To the south of Barnegat Inlet, barrier islands comprise the remainder of the NJ coastline where individual islands are separated from the mainland by a series of bays and tidal lagoons, and by each other through a series of structured and non-structured tidal inlets. The general geomorphological relationship among the coastal features between Sandy Hook and Barnegat Inlet was detailed by Fisher (1967). Individual barrier islands have a different and unrelated origin as sea level rose, and as storms, tides, and waves reworked sand from continental shelf deposits that formed the barrier island chain south of Barnegat Inlet. Hicks (1953) showed that the dark, denser minerals present in beach sand still had Monmouth County traits on Long Beach Island, but from Little Beach Island south to Cape May City, the sand was finer, with different dark minerals (magnetite/illmenite) from the northern beaches (glauconite, zircon and garnet). This pattern has been observed

in the sand supplies found 2-3 mi offshore that are tapped for the shore protection material added to the present beaches. Sand mined offshore for Monmouth County beaches is coarser with garnet and zircon as heavy minerals, while sand mined offshore for Ludlam Island contained finer sands and was dominated with magnetite as the primary accessory mineral.

New Jersey Beach Profile Network

Monmouth County

Raritan Bay and Sandy Hook to Manasquan Inlet

NJBPN Profile #'s 187 - 256

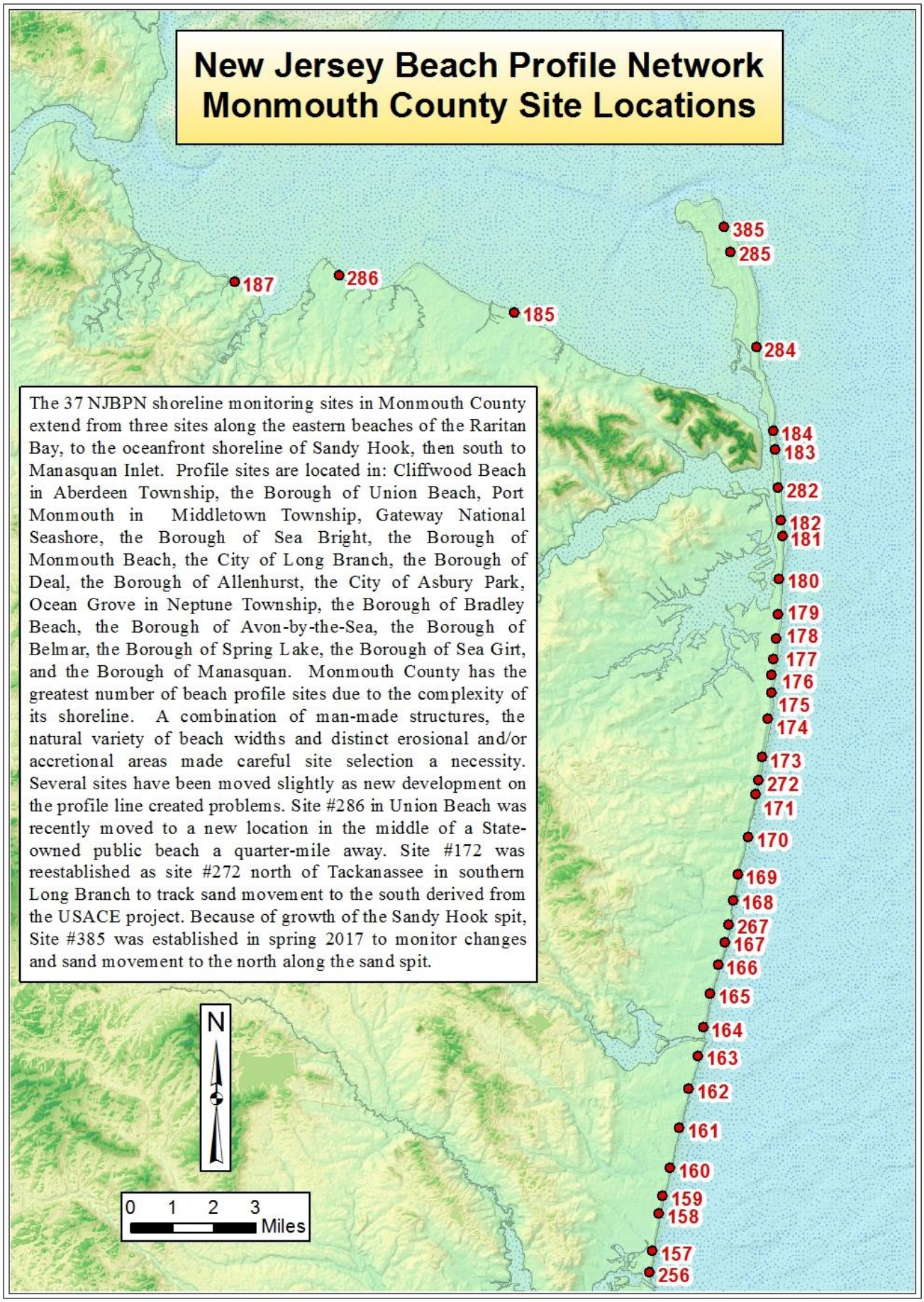

Figure 2. Locations of the 37 NJBPN profile sites in Monmouth County, NJ.

Monmouth County Summary

Thirty years ago, the Monmouth County shoreline was sand starved and severely depleted except for Sandy Hook. In fact, storms frequently threatened to sever the entire Sandy Hook spit from Sea Bright, turning the park into a northern barrier island. The sites picked along the Raritan Bay coast were all erosional with the best site located at a new county park at Cliffwood Park Beach. The Sea Bright shoreline was one with small pocket sand beaches retained at individual rock groins while between groins the beach was wet to the massive rock seawall and at many places at low tide. Long Branch, Elberon, and Deal were similarly rock coasts with tiny pocket beaches retained by the groins. Between Allenhurst and the Manasquan Inlet sand beaches were present, but were narrow, steep and suffered wave overwash into Ocean Avenue that runs parallel to the shoreline.

The situation dramatically shifted from 1994 through 2001 when the New York District of the US Army Corps of Engineers (USACE) commenced the massive Monmouth County Shore Protection Project (Sea Bright to Manasquan). Initially split into two phases, one from Sandy Hook National Seashore south to Long Branch, and the other from Asbury Park south to Manasquan Inlet. Loch Arbor, Allenhurst, Deal and Elberon did not participate in the initial effort, but reconsidered following Hurricane Sandy. Sandy inflicted considerable damage along the Monmouth County shoreline devastating Raritan Bay communities with extreme flooding and intense locally generated storm waves, while the Monmouth oceanfront was over-run in many locations due to narrowed beach widths and a lack of robust dunes. Belmar, Avon-By-The-Sea and Asbury Park had no dunes at all and Manasquan, Sea Girt, Ocean Grove and Spring Lake's dunes were of variable width/elevation. Even the Sea Bright seawall did not protect the municipality from Sandy's wrath. Flooding from the Navesink and Shrewsbury Estuaries combined with wave overtopping of the seawall exposed many properties to damage. The gap in the seawall at the municipal center of Sea Bright was practically the death of the business district. Long Branch escaped major damage due to its location at 27 to 28 ft. elevation on the sedimentary bluff that was armored by rock and steel sheet pile walls. The pedestrian boardwalk was destroyed from the West End north to Morris Avenue as wave run-up reached to 30-foot levels above sea level.

Following Sandy, Congress authorized restoration work complete with groin modifications plus storm water system changes funded at 100% federal money under PL 113-2 (Disaster Relief Appropriations Act of 2013). Work continued in 2013 and 2014 to finish all segments originally constructed (2.1 million cu. yds. - $25.6 million) placed between Sea Bright and Monmouth Beach. Long Branch received 3.3 million cu. yds. ($40.1 million), Asbury Park to Manasquan was enhanced with the placement of 2.3 million cu. yds. ($43.6 million). During 2015 the final phase of the Monmouth County shore protection project got underway with the placement of sand along the Loch Arbor, Allenhurst and Deal shoreline. Work wrapped up northward late in 2016 into Long Branch through the Elberon section (3.5 mi) leading to Lake Takanassee and the original project beaches beginning at West End Avenue (4.45 million cubic yards and $38 million dollars).

The USACE undertook multiple efforts in restoration, spending $36.9 million placing 875,000 cubic yards of new sand along the Keansburg Raritan Bay shoreline. The Port Monmouth work involved 3,000 feet of shoreline and a half-million cubic yards of new sand plus a western groin to hold the sand and a new, longer fishing pier at the Spy House Museum. In Union Beach, work in the design phases was reevaluated following Sandy via the Limited Re-evaluation Report that is currently underway and being conducted with non-federal partners, NJDEP and Borough of Union Beach, NJ. This project includes levees, floodwalls, tide gates, pump stations, and a dune and beach program. All these efforts are 100% federally funded under Public Law 113-2.

Looking back over the 30-year study interval, the 27 Monmouth County oceanfront beach survey sites averaged a net gain of 113.72 yds^3/ft. in sand volume combined with a shoreline advance average of 218 ft. This represents a great deal of money, but the work provides a vast quantity of sand (15,298,524 cubic yards) to this section of the coastal system.

Individual Profile Site Descriptions

Cliffwood Park, Aberdeen (Site 187):
This is a small county park, established shortly before surveying commenced in 1986. The shoreline faces north, northeast into Raritan Bay and is subject to a significant wave fetch across the bay. Hurricane Sandy transported the entire dune landward into the parking and access areas for the park. Stability had returned since the spring of 2014 and continued through 2016 with a sand volume loss of -1.07 yds^3/ft. and a 6.3-foot shoreline retreat. There were no dramatic changes to either the quantity of sand in the system or the position of the zero elevation (shoreline) in 18 months. Thirty years of surveying results in a sand volume change of -25.44 yds^3/ft. and a shoreline retreat of 111 ft. This is a considerable loss to this small park beach amounting to about 1.0 yds^3/ft. of sand per year and a 3-foot shoreline retreat each year.

Beach Street, Union Beach (Site 286):
The Union Beach site is now located in the middle of the municipal bathing beach on Raritan Bay. The site was moved to provide more meaningful data on bay beach changes. Hurricane Sandy pushed sand landward beyond the parking lot, but did not severely affect the shoreline position. During 2013, Union Beach funded sand placement from Amboy Aggregates in the amount of 14,000 cubic yards by truck. Over the past 18 months this beach lost 5.63 yds^3/ft. and had a shoreline retreat of 11.2 ft. The planning and design effort on the part of the New York District Corps of Engineers is still in process to enhance this entire coastal segment. The 30-year analysis is not too relevant because of the revetment construction 15 years ago combined with the relocation of the profile site to a bathing beach site in 2009 yields a sand volume change of just 2.0 yds^3/ft. and a 7-foot shoreline retreat over 7 years.

Bay Shore Waterfront Park, Port Monmouth #(Site 185):
The easternmost site along the Monmouth County Raritan Bay shoreline is positioned west of Highlands and Atlantic Highlands at a Monmouth County Park site dedicated to an historic building dating to the revolution. Significant shore rehabilitation work preceded Hurricane Sandy and served to absorb some of the impact. The New York District Corps of Engineers concluded pumping approximately a half-million cubic yards of sand onto 3,000 feet of the Port Monmouth shoreline adding a 150 yds^3/ft. sand volume addition to the beach. This project includes a new, longer fishing pier and a rock groin on the west end to retain the bulge in the sand shoreline now present. The 142.11 yds^3/ft. sand volume reported as a result of the spring 2014 to fall 2014 survey documents this project. Minor losses between project completion and the spring of 2015 continued into the fall of 2016 with -4.15 yds^3/ft. in sand loss combined with a shoreline retreat of 1.2 ft. The USACE project dominates the changes observed over the past 30 years with 66.22 yds^3/ft. in sand volume gain and a 163-foot shoreline advance. Regular episodes of retreat in this shoreline position occurred between 1986 and 2014, but were totally mitigated by the USACE project. The sand volume placed during the project was over twice the calculated 30-year comparison indicating just how much long term retreat occurred.

North Beach, Sandy Hook National Seashore (Site 385):
This site was established in 2016 to improve the coverage of shoreline and sand volume changes occurring within the Sandy Hook National Seashore at the northern extent of public access approximately 3,500 ft. north of the Gunnison Beach site. The site has been surveyed, but no comparisons exist to report until next year. The goal is to gain better information with regard to sediment accumulation at Sandy Hook as a result of littoral transport from the USACE beach project which extends to the entrance gate of the National Seashore.

Gunnison Beach, Sandy Hook National Seashore (Site 285):
The Gunnison Beach site on Sandy Hook National Seashore is positioned near the base of the spit that changes most rapidly. Gains in sand volume continued over the past 18 months with 25.28 yds^3/ft. added to the profile accompanied by a shoreline retreat of 2.5 ft. This beach has grown wider almost every year since the NY District Corps of Engineers started its massive shore protection project in 1995. This review only extends back to the 1994 establishment date for the National Seashore sites, but the changes observed since the establishment 21 years ago was 232.53 yds^3/ft. in added sand with a 564-foot shoreline advance. The rate of advance

increased rapidly following the initial beach restoration work in 1994-1995, meaning that the littoral transport to the north was extremely important to this sand volume gain.

Parking Lot E, Sandy Hook National Seashore (Site 284):
This public bathing beach was selected because it was located in the middle of Sandy Hook and represented both a public use area and an easy access point to conduct surveys. Since spring 2015 this site has gained 10.56 yds^3/ft accompanied by a 51.4 ft shoreline retreat. This was the result of rapid erosion between spring 2015 and fall 2015 (-49.4 ft.) continuing into the spring of 2016 (-38.7 ft.). In the following six months, the site experienced a partial recovery with a 36.7 ft shoreline advance. The 21-year history at this location was one where the shoreline advanced 48 ft as the sand volume grew by 131.11 yds3/ft.

Highlands Beach, Sandy Hook National Seashore (Site 184):
This was initially the northernmost coastal site in Monmouth County, but data supported the need to add the two sites on Sandy Hook since it was clear that losses south at site 184 were being deposited along the National Seashore beaches. Sand volumes declined during 2015, but the 2016 comparisons showed a gain that cut the net loss to -13.46 yds^3/ft. while the shoreline retreated 54.9 ft. The 30-year history saw 77.57 yds^3/ft in sand volume increases with a 206-foot shoreline advance, all due to the NY District's coastal enhancement project.

Evaluating only these four cross sections show that over the past 21 years the Sandy Hook National Seashore shoreline between the entrance gate and Gunnison Beach has gained 3,445,514 cubic yards of sand all derived from the NY District beach restoration project between Long Branch and the National Seashore entrance. This amounts to 138.45 cubic yards of sand deposited on each of the 24,886 feet between Via Ripa (site183) and Gunnison Beach (site 285). Even more sand lies north of the Gunnison Beach site expanding the Sandy Hook spit extensively. This was the motivation for adding the new site some 3,200 feet further north from Gunnison.

Via Ripa, Sea Bright (Site 183):
This northern Sea Bright location lies just south of the bridge to Atlantic Highlands across the entrance into the Shrewsbury and Navesink Estuaries. The Federal project added 43.1 yds^3/ft. to the beach producing a shoreline position almost equal to pre-Sandy conditions. During this study interval, the beach gained 50.34 yds^3/ft. as the summer 2016 gain added 52.21 yds^3/ft. The shoreline advanced 135 feet due to large sand accumulation. The 30-year history showed a sand volume gain (105 yds^3/ft) while the shoreline advanced 311 feet.

Shrewsbury Way, Sea Bright (Site 282):
Stability exists at this site that differs from most other Sea Bright locations in that the profile had 116% of the original beach nourishment sand quantity present as of April 2012. The USACE restored this site to original specifications by 2014. Since then the sand volume declined by 13.46 yds^3/ft and the shoreline retreated 55 ft. The 30-year history saw 309.51 yds^3/ft in sand volume increase with a 402-foot shoreline advance.

Sea Bright Public Beach, Sea Bright (Site 182):
The Public Beach location was purchased by the State 29 years ago and converted into a public bathing area with some off-street parking. This beach contained 98% of the initial Federal project's fill material as of fall 2011. No dune existed other than grass growing at the toe of the rock seawall. As of the fall of 2016, this site had lost just 1.78 yds^3/ft accompanied by an 18.5-foot shoreline retreat to a condition equaling the pre-Sandy shoreline and sand volume situation. The thirty-year history was one of 166.14 yds^3/ft sand volume gain with a 436-foot shoreline advance.

Municipal Beach, Sea Bright (Site 181):
The barrier spit widens here to include commercial businesses on both sides of Ocean Avenue plus parking for the beach. However, no rock seawall extended across a gap at the municipal beach. The federal project replaced the losses suffered from Hurricane Sandy. The past 18 months showed 29.18 yds^3/ft in sand volume loss with a 40.foot shoreline retreat by fall 2016. The 30-year history has 79.86 yds^3/ft in sand volume

increases with a 176-foot shoreline advance. The storm damage has been addressed with structural additions across the gap left years ago in the rock seawall.

Sunset Court, Sea Bright (Site 180):
The location north of Cottage Road (site 179) maintained 45% of the initial sand volume placed in 1999. The repeated deposition of maintenance material at Cottage Road moved north through this location. There was no dune, other than grass here and there among the rocks of the seawall. Repeated quantities of sand have been placed to the south aiding this location's stability. The past 18 months saw sand volume loss of 22.1 yds^3/ft with a shoreline retreat of 27.5 ft. The thirty-year history included sand volume gain of 122.16 yds^3/ft with a 238-foot shoreline advance.

Cottage Road, Monmouth Beach (Site 179):
The Cottage Road location has been the "Hot Spot" erosion area in an otherwise very successful Federal beach restoration project. Immediately south of this site a massive stone groin was privately built decades ago and acts to restrict sand movement north from the beach fronting a 19th Century private beach club. The groin obviously serves its intended purpose, but to the detriment of the Federal beach project's durability just north of the groin. The Cottage Road site commenced losing sand as soon as it was completed. Losses were replaced in 1997, 1999, 2001, and a modest sand volume was added in 2010 from dredging the Shrewsbury River. Just prior to Sandy, construction of the 2012 phase of the beach fill had started at this location and was moving northward. The post-storm survey in late March 2013 showed even more loss at the low tide line. By October 2013, restoration had occurred where the berm was regenerated at elevation 10.0 ft. and extended 500 ft. from the seawall at that elevation. The spring to fall 2013 survey comparison found a shoreline advance of 293 ft due to the placement of 201.44 yds^3/ft of new sand. During 2014, the site lost 72.41 yds^3/ft and the shoreline retreated 133 ft. In the 2014 to 2015 interval the site lost 16.31 yds^3/ft net on two of three seasonal profiles with modest sand volume losses. During the past 18 months the site has lost sand at every survey interval totaling 55.89 yds^3/ft with a shoreline change totaling 29 feet of shoreline movement landward. The thirty-year history was net positive in the amount of 109.31 yds^3/ft in sand volume and a 312-foot shoreline advance largely because prior to the USACE project, the site had ocean water at the rocks at low tide.

Monmouth Beach Club, Monmouth Beach (Site 178):
The Valentine Street site is located on the premises of the venerable Monmouth Beach Club with the survey starting point in the landward segment of the timber deck overlooking the seawall. Destroyed by Sandy, this site has been rebuilt and the sand replaced to the initial federal project specifications. Sand placement between March and October of 2013 was an impressive 181.20 yds^3/ft with a 231 ft shoreline advance seaward. Over the past 18 months the site has lost 31.72 yds^3/ft while the shoreline retreated 48 ft. The 30-year history finds 132.12 yds^3/ft in sand volume gains with a 263 ft shoreline advance. The rock groin impounds a significant wedge of sand to its south side making this site a bit more stable.

Ocean Avenue, Long Branch (Site 177):
This site was once a USO non-commissioned officer's beach recreation area for Fort Monmouth personnel. Presently part of the Seven-Presidents Park system belonging to Monmouth County, this site saw severe erosion during Sandy, followed by further losses offshore as some sand moved landward by March 2013. Over the past 18 months the sand volume gained 6.17 yds^3/ft and the shoreline retreated 26.5 ft. The thirty-year history saw 117.90 yds^3/ft in sand volume gains with a 280 ft shoreline advance, all due to federal beach nourishment.

Seven Presidents Park, Long Branch (Site 176):
This site was converted into open parkland space 32 years ago with the purchase of all commercial and private buildings near the waterfront. The area has 25 ft dunes with several prominent gaps to allow public easy access to the beach. The Federal project was completed here in 1999 and 74% of the initial sand placed was still present in October 2011. The site was restored after Sandy and the past 18 months have allowed a 14.26 yds^3/ft

sand volume gain and a 15.5 ft shoreline advance. The 30-year history is defined by a 152.54 yds^3/ft sand volume gain and a 287 ft shoreline advance.

Broadway Avenue, Long Branch (Site 175):
The Broadway Avenue site is located within the Federal project and as of fall 2011, retained 79% of the as-built sand volume. The vertical steel wall that was installed years ago was overtopped during Hurricane Sandy. The beach was restored by late 2013 and within the last 18 months there were gains in sand volume (48.29 yds^3/ft) and 106-foot shoreline retreat. Sand loss was particularly severe at this site, but the 30-year history was one where the sand volume increased by 104.65 yds^3/ft and the shoreline advanced 246 ft seaward.

Morris Avenue, Long Branch (Site 174):
This site is positioned at the old Long Branch beachfront along the former Ocean Avenue that is now a pedestrian walkway. Sandy removed the boardwalk at the top of the bluff above the rock seawall. The USACE restored the beach width by late 2013 and over the past 18 months, a sand volume loss (-47.09 yds^3/ft) accompanied an 81.6-foot shoreline retreat, similar to that observed at Broadway Avenue. The thirty-year comparison showed 97.91 yds^3/ft gain in sand volume with a 272 ft shoreline advance.

West End Avenue, Long Branch (Site 173):
Located near the southern end of the Federal Phase I Monmouth County beach restoration project, this Long Branch site consists of a rock revetment that protects the base of the bluff and a pedestrian boardwalk positioned at the edge of the bluff some 15 ft above the revetment. In 1999, the initial beach replenishment was completed and provided a 250 ft wide beach, but did not include a dune. Hurricane Sandy demolished the boardwalk, but the site was restored by 2013. The added bonus of the latest fill is that for the first time the beach project extends south through Elberon, Deal, and Allenhurst completing the entire developed county shoreline. Over the past 18 months the site lost 46.87 yds^3/ft and the shoreline retreated 74 ft. Over thirty years the sand volume increased by 90.94 yds^3/ft while the shoreline advanced 185 ft seaward.

Lake Takanassee (805 Ocean Avenue), Long Branch (Site 272):
The Lake Takanassee site was established in 2010 as a replacement for former site 172 that was abandoned due to encroaching development. This is the northernmost "estuary lake" along the Monmouth County shoreline and, like the others has a fresh water drainage system constricted at the shoreline by a bay-mouth barrier. It was necessary to relocate the profile to the south, further from the condominium's parking lot retaining bulkhead, so the post-Sandy cross sections appear to be dramatically different in backshore orientation and elevation. This is real and unavoidable. This site was later restored with a fresh water discharge system along the south side of the breach into the lake created by Hurricane Sandy so that the lake is no longer subject to tidal flow. The last 18 months have seen a 210.34 yds^3/ft as the latest work concluded by the USACE. The shoreline advanced by 246 feet as new sand was pumped into the site. There is no 30-year history at this site since the original site was vacated years ago and only recently re-established.

Pullman Avenue, Elberon (Site 171):
The single cross section located in Elberon at Pullman Avenue demonstrated the susceptibility of even the high bluff located here (28 ft NAVD88) to major erosion from the storm surge and waves generated by Hurricane Sandy. The rock revetment and timber wall account for about 40% of the bluff height and were unaffected. Deposition during Sandy occurred offshore where 24.40 yds^3/ft of beach and bluff material was deposited. The scour at the base of the rock revetment protecting this coast was extensive taking sand to -10 ft elevations (as recorded with the Jan 13, 2013 survey 2.5 months later). Since then sand moved back landward, first by the spring 2013 survey back to the pre-Sandy elevations, then by the fall 2013 survey, depositing a dry sand beach over half way up the revetment adding 17.14 yds^3/ft of new material and creating the best "beach" ever recorded at this location since 1986. The shoreline advanced 49 feet, generating a dry beach at the rock revetment at an elevation of 8.75 ft. This new deposit was 220 ft wide and unprecedented for this site. The bluff erosion during Sandy seems to be the plausible sand source generating a beach. In the past 18 months the

USACE project passed through the site adding 258.6 yds^3/ft in new sand volume creating a 388-foot shoreline advance. This change is amazing to behold and is the essential extent of the change seen over the past 30 years.

Roosevelt Avenue, Deal (Site 170):
The Roosevelt Avenue site is located north of the Deal sewage pumping station built in 1906 at the base of the sedimentary bluff. It is essentially a three-story building with just the top story presented at the end of Roosevelt Avenue. South of this street is a series of private homes built on the bluff with a decent sand beach seaward of the bluff edge. North of Roosevelt Avenue there is essentially no dry beach between closely-spaced groins. Site 170 has a 26-year history of a wet beach against the rocks. Occasional offshore bars have migrated to the shoreline yielding a temporary dry beach less than 25 ft in width. Hurricane Sandy's waves over-topped the rock wall and scoured deeply into the soil, fill debris (bricks etc.) and bluff sediments. Since Sandy, the beach sand that was removed from the base of the rock revetment and carried offshore slowly returned so that the spring 2013 survey closely matched the pre-Sandy condition. More sand moved landward over the summer season so that by October 2013 a dry beach was present at the base of the rocks. This condition slowly deteriorated as sand moved offshore in 2014. The site lost 18.77 yds^3/ft and the zero elevation shoreline retreated 54 ft. The beach was still present, but wet at high tide. The USACE project arrived during the 2015-2016 interval adding 191.59 yds^3/ft in sand volume and an advance in the shoreline of 309 ft. This change occurred between the spring and fall of 2016 and is the extent of profile volume and shoreline change over the past 30 years.

Darlington Avenue, Southern Deal (Site 169):
Deal is divided from Allenhurst by a massive boxed pair of groins that retain all sand on the Allenhurst beach, letting none past to the north. The Darlington Avenue site is about a mile north into Deal and was picked because there was a pocket beach centered at Darlington Avenue extending several blocks in either direction. The sediment bluff, once exposed 25 years ago had been armored by individual property owners over time with timber bulkhead "seawalls". The beach varied little over time. Hurricane Sandy exposed the older sedimentary bluff to an extent not seen in decades. The private structures were no match for the storm. Individual owners repaired the extensive damage to their bluff protection once again concealing the sedimentary deposits from inspection. This site did gain sand as the federal project got underway with 241.39 yds^3/ft added during the spring to fall 2015 interval. The net change was a sand volume gain of 231.44 yds^3/ft accompanied by a 350 ft shoreline advance. Since the first interval of surveys during the subsequent 18 months included the USACE efforts, the net gain was very positive (+218.01 yds^3/ft) and the shoreline advanced seaward by 296 ft as the project adjusted to wave conditions. The latest survey period, spring 2016 to fall 2016, saw a 9.2 yds^3/ft sand volume loss and a 14 ft shoreline retreat.

Corlies Avenue, Allenhurst (Site 168):
The site 168 at Allenhurst sits on top of an old concrete wall that drops vertically to the sand beach. There is a wooden walk elevated above the road just landward of the concrete wall. The boardwalk is 20 ft above sea level about 100 ft from the low tide line on the beach. Loch Arbor has only a two-block shoreline with half a public beach and half in private ownership. There has been a long history of storm waves washing through the private beach club into Deal Lake (located about 2,000 ft to the south). This occurred as the road across the "estuary" lake was still closed months after Hurricane Sandy. Deal Lake is the largest of the now-closed stream estuaries along the Monmouth County shoreline. It was mapped as open to tidal flow as late as 1880, but had closed by 1889. There was no paved road across the bay mouth sand bar until after 1920 according to the earliest aerial photography. There is a sizable, functioning weir and boxed flume that carries freshwater seaward to drain the lake, though sand spilled into the lake at the seaward end. This site was not included in prior phases of the Federal project, but over the past 13 years material bypassed the large terminal groin in Asbury Park and enhanced this small reach. In the past 18 months since the USACE completed this southernmost piece of the final phase of beach restoration in Monmouth County the site lost 1.53 yds^3/ft as the shoreline retreated 15 ft. The 30-year history shows 117.66 yds^3/ft in sand volume gains with a 149 ft shoreline advance, all due to the USACE project effort.

Seventh Avenue and Third Avenue, Asbury Park (Sites 267 & 167):
The Federal project beach in Asbury Park had no dune, but the added sand matched the elevation of the boardwalk. The beach at site 267 lost 39.61 yds^3/ft as a result of Sandy while 27.56 yds^3/ft were deposited offshore out to 915 ft from the reference point. The shoreline retreated 81 ft in the process. By the fall of 2013, the shoreline had advanced 27 ft with 17.79 yds^3/ft returned to the beach. The USACE provided an additional 92.68 yds^3/ft generating a 115 ft shoreline advance. Since Sandy the site lost 24.13 yds^3/ft as the shoreline retreated 74 ft. Over the 30-year history of this location the sand volume increased by 104.20 yds^3/ft and the shoreline advanced 167 ft due to the beach fill.

At site 167 on Third Avenue, the same process repeated with a Hurricane Sandy storm loss of 29.66 yds^3/ft from the beach, an 84 ft shoreline retreat and sand moved well offshore beyond 17.6 ft depths (NAVD88). By October 2013 26.98 yds^3/ft had returned to the beach as 42.62 yds^3/ft migrated onshore or to the south from the storm deposits seaward. The shoreline advanced 68 ft. By the fall of 2014 the added sand amounted to 60.39 yds^3/ft and the shoreline advanced 35 ft seaward as a result of the ACOE project. Since Sandy the beach lost 21.35 yds^3/ft in sand volume as the shoreline retreated 37 ft. The thirty year history saw 93.76 yds^3/ft in sand volume added to the site with a 163-foot shoreline advance.

Ocean Pathway, Ocean Grove (Site 166):
Following Hurricane Sandy, Ocean Grove had severe damage to the beach and boardwalk focused south of Main Street. At Ocean Pathway the dune remained as did the large, open, but roofed seating area seaward of the boardwalk. The dune remained with the instrument monument about 1.5 ft from the scarp. By the fall of 2013 22.65 yds^3/ft had recovered on the beach as 28.69 yds^3/ft migrated landward (the shoreline advanced 60 ft in the process). The 2014 activity added 35.79 yds^3/ft in new sand producing a 13 ft shoreline advance. Between spring 2015 and fall 2016, there was a sand volume loss of 5.13 yds^3/ft and a minor shoreline retreat of 4 ft. The 30-year history of this site was one of 93.08 yds^3/ft increase in sand volume accompanied by a 134 ft shoreline advance.

McCabe Avenue, Bradley Beach (Site 165):
The McCabe Avenue site had some damage from Hurricane Sandy, but fared better than most locations. The recovery deposit present in the April 2013 cross section amounted to 7.09 yds^3/ft that was attributed to placement of overwash deposits extracted from the upland areas. Following the Federal work in 2014, the site gained 75.40 yds^3/ft and the shoreline advanced 34 ft. Between 2015-2016 the site lost sand (-5.79 yds^3/ft) and a 33 ft shoreline retreat. The 30-year history showed a sand volume gain of 107.37 yds^3/ft accompanied by a 217 ft shoreline advance seaward.

Sylvania Avenue, Avon by the Sea (Site 164):
Avon has one site located at Sylvania Avenue where Hurricane Sandy damage to the boardwalk was extensive and extended to the structures adjacent to the boardwalk. Sand lost from the beach was carried inland. The recovered overwash material was pushed back onto the beach by the June survey date in 2013 producing most of the recovery evidenced. Little farther recovery occurred between June and September 2013. The Federal effort added 99.16 yds^3/ft and a 108 ft shoreline advance seaward. Over the past 18 months the beach sand volume decreased by 4.20 yds^3/ft and the shoreline retreated 14 ft. The past 30 years saw a beach sand volume gain of 81.64 yds^3/ft with a shoreline advance of 138 feet.

5th Avenue and 18th Avenue, Belmar (Sites 163 & 162):
Belmar has two survey sites, one at 18th Avenue and the second at 5th Avenue near Shark River Inlet. The Belmar beach has a boardwalk between it and Ocean Avenue that suffered damage but was still largely present. Sand was washed into Ocean Avenue during the storm. The erosion is defined by the April 2013 survey data with some deep scour and offshore deposition in evidence at site 163, but there was less scour at site 162 and deposition offshore. Sand recovery was vigorously pursued in moving the overwash deposition back to the beach and appears to have contributed to the overall recovery prior to the Federal work in 2014. Since the 5th

Ave. site (site 163) is extra wide due to the presence of the Shark River Inlet south jetty that traps the sand carried in the longshore current, the Federal project did not add significant sand to this site. This is shown in the 30-year review where the sand volume increased by 26.11 yds^3/ft, by far the smallest value for all of the Monmouth County oceanfront. The 30-year shoreline advanced just 23 ft. The past 18 months saw a sand volume change of -9.61 yds^3/ft and a shoreline retreat of 4 ft. The 18th Ave. site (site 162) was augmented by vertical deposition raising the beach berm 2-3 ft across its entire width. The sand volume added was 66.17 yds^3/ft producing a 76 ft shoreline advance. The past 18 months saw a sand volume loss of 7.60 yds^3/ft with a shoreline retreat of 8 ft. The 30-year history displays a sand volume change of 67.48 yds^3/ft and a shoreline advance of 127 ft.

Brighton Avenue and Salem Avenue, Spring Lake (Sites 161 & 160):
The Spring Lake dunes, developed decades ago landward of the boardwalk, proved instrumental in the destruction of the boardwalk the entire length of Spring Lake during Hurricane Sandy. Waves rushed under the boardwalk, hit the dunes and were directed upward with great force. This action lifted the timber boardwalk sections off the concrete supports and where the dune breached, these sections were pushed into Ocean Avenue as a vast array of debris. By late 2014, the boardwalk was rebuilt on its original concrete supports and the Federal project provided 40.47 yds^3/ft in new sand at Brighton Ave. and 32.29 yds^3/ft at Salem Ave. Each shoreline position advanced 76 and 42 ft, respectively. Brighton Ave. gained 51.67 yds^3/ft over the 18 months after Sandy as the shoreline advanced 32 ft, while Salem Avenue gained 31.74 yds^3/ft and the shoreline advanced 5 ft.

Between spring 2015 and fall 2016, the Brighton Avenue site gained 4.64 yds^3/ft in sand volume while Salem Ave. gained 15.18 yds^3/ft. The two shoreline positions retreated, Brighton by 31 ft and Salem by 11 ft. So, since Hurricane Sandy restoration occurred both Spring Lake profile sites have accumulated an additional 50 yds^3/ft. The 30-year history was one where Brighton Ave. gained 91.26 yds^3/ft and Salem gained 65.32 yds^3/ft The two shoreline positions advanced 157 ft and 94 ft respectively.

New York Avenue and Trenton Avenue, Sea Girt (Sites 159 & 158):
Sea Girt is divided into two parts, each with a profile site. The New York Avenue site 159, represents northern Sea Girt where a shore-parallel Ocean Avenue allows vehicles to park at the boardwalk with easy public access. Homes exist across Ocean Avenue. Here there were incipient dunes built since Hurricane Irene in 2011, which were totally erased by Sandy. New York Avenue lost 69.52 yds^3/ft from the beach and nearshore. By the April 2013 a new dune had been placed on the beach using sand recovered from inland with a wider base, but about the same height. Deposition offshore amounted to 16.36 yds^3/ft that was documented 936 ft seaward from the reference monument. Clearly the majority of the sand was further seaward because by September 2013, 39.16 yds^3/ft had returned to the beach producing an 86 ft advance in the zero elevation position. During 2014 the Federal project provided 23.81 yds^3/ft advancing the shoreline 107 ft as of fall 2014. During the past 18 months this site lost sand (-12.73 yds^3/ft) as the shoreline retreated 44 ft. The 30-year history showed that this site gained 79.76 yds^3/ft and the shoreline advanced 187 ft.

The southern site at Trenton Avenue typifies the coastal bluff with homes on top and a wide, reasonably high dune mostly developed landward of the boardwalk that protected the bluff face from erosion and kept the Hurricane Sandy overwash out of the street ends. The Trenton Avenue street end was damaged by wave action because the paving extended to the boardwalk allowing the waves to reach the end of street construction. This site saw a sand volume loss of 25.82 yds^3/ft and a shoreline retreat of 30 ft over the past 18 months. The site gained 117.94 yds^3/ft in sand volume accompanied by a 233 ft shoreline advance over the past 30 years.
A major Wreck Pond project has been implemented at this “estuary lake” entrance located between Spring Lake and Sea Girt with a goal to enhance water quality in the fresh water section of the drainage basin and preserve the incursion of salt water into the “estuary” portion of the water body as part of habitat restoration. This new structure may influence sand distribution in its vicinity.

Riddle Way and Pompano Avenue, Manasquan (Sites 157 & 256):
Manasquan is located at the southern limit of the NY District's massive Monmouth County beach restoration project and positioned just north of the Manasquan Inlet. Prior to the Federal project, the Borough had established a small dune system seaward of the paved promenade that is in front of the oceanfront homes. This was primarily in response to the December 1992 northeast storm that damaged the community. There are two cross sections in Manasquan. Following Sandy, no promenade remained at Pompano Avenue (site #56) with tiny remnant dunes present seaward of the asphalt promenade at Riddle Way (site 157). A ridge of excavated sand had been built along the alignment of the promenade at the south end of the Borough Beach. At Riddle Way the dune was all but removed, but the promenade surface remained intact. The dune provided 11.24 yds^3/ft of sand to the beach during the storm, but the beach lost and additional 13.75 yds^3/ft as the offshore added 59.07 yds^3/ft. The shoreline retreated 24 feet. By the fall of 2014 the USACE had added 94.17 yds^3/ft in new sand advancing the shoreline 92 ft seaward. However, there is still only a minimal dune just seaward of a fence line located at the edge of the promenade pavement. This site gained 3.25 yds^3/ft with a 19 ft shoreline retreat over the next 18 months all in small survey increments. Between 2015 and the fall of 2016 Riddle Way lost 22.28 yds^3/ft in sand volume with a 53 ft shoreline retreat. The 30-year history at Riddle Way displays a 78.26 yds^3/ft sand volume gain accompanied by a 150 ft shoreline advance.
At the Pompano Avenue (site 256) Hurricane Sandy removed the dune as well as the entire promenade with most of the sand transported inland. A huge bar appeared offshore (59.36 yds^3/ft deposited). Since April 2013 only 12.80 yds^3/ft has returned to the beach, but 32.27 yds^3/ft of that deposit has moved elsewhere either landward or toward the Manasquan Inlet. The USACE placed 82.26 yds^3/ft at this site generating a 113 ft shoreline advance, but there was no significant dune present along the rebuilt promenade. Between spring 2014 and fall 2015 the site gained 14.03 yds^3/ft with a 37 ft shoreline retreat. In the following 18 months, the site gained in sand volume (47.30 yds^3/ft) and the shoreline advanced (56 ft). This site tends to have a positive response to minor and moderate northeast storms due to sand capture by the inlet jetties during the northeast wave approach direction. This site has a 21-year survey history with the sand volume gaining 136.11 yds^3/ft as the shoreline advanced 199 ft.

The computation of the change to the beach/dune sand volume out to a depth of 16 feet of water is obtained by directly comparing the initial 1986 survey with the fall survey completed in 2016. The shoreline position is determined by the horizontal displacement of the point where the profile line crosses the zero elevation horizontal elevation. Seaward advance means that the zero elevation shifted seaward on the most recent beach profile. Retreat is defined by a landward shift in the zero elevation crossing point. Since the entire Monmouth County oceanfront shoreline was subject to the NY District's Shore Protection Project commencing in 1995, finishing in 2016 in Elberon, all sites show positive sand volume gains and shoreline advances due to the effects of the project adding sand obtained from offshore. Sand was transported north into Sandy Hook National Seashore in vast quantities with the north Belmar site only site NOT receiving direct sand placement, because sand capture by the Shark River jetties had already developed a 600-foot wide beach. However, this site did gain over 25 yds^3/ft. of sand.

INSTRUCTIONS FOR USING THE GRAPHICAL ILLUSTRATIONS PROVIDING INFORMATION ON EACH OF THE 107 NEW JERSEY COASTAL SITES DEVELOPED SINCE 1986 (OR A MORE RECENT ESTABLISHMENT DATE)

1. The initial page for each survey location is a photograph showing the beach condition as it existed during the fall survey season of 2016.
2. The second page is a pair of beach photographs showing the comparison from the fall survey season of 2015 with the corresponding view taken during the survey season completed in the fall of 2016 with descriptive comments below the two photographs.
3. The third page is the cross section plot for the site showing the most recent four surveys dating from spring 2015, fall 2015, spring 2016 and fall 2016 accompanied with a text description of pertinent changes to the dune, beach or offshore segment.
4. The fourth page is a shoreline position and sand volume trend analysis showing each fall survey since the profile was established in 1986 or a later date for some sites. The bars represent annual shoreline position changes and sand volume gain or loss combined with a pair of lines showing the cumulative effect of the annual change data. Major projects always appear the year they are constructed and subsequent years of change that follow.
5. The fifth page is a presentation of all profile surveys at the specific site color-coded by date of survey. Initial surveys are plotted in blue, shifting green, then yellow, finally to orange and red colors for the most recent years. The plots show the evolution of the profiles over the complete 30-years of measured data, with the ability to see the dramatic impact of major beach restoration efforts as a significant alteration to the pattern. Colors progressing from blue to red in the seaward direction indicate an accretional pattern and colors progressing from blue to red in the landward direction indicate an erosional pattern. The thick black line displays the mean profile shape, which is calculated by taking the average of all measured profiles from each site.
6. The sixth and final page shows a pair of aerial photographs paired with a cross-section plot of the site. The aerial photographs are composed of a historical aerial from around the year 1995 and a more recent aerial from around the year 2015 (exact years are indicated on the plot). The cross-section plot displays the profile view of the site from the same years as displayed in the aerial photographs and both the plots and aerials are set to the same distance scale. This figure shows the change over time at each profile site as presented by an aerial image comparison and a cross-sectional comparison. Combining these two different means of data presentation allows for changes in topographic features, vertical elevations, and shoreline positions to be displayed simultaneously in the same figure.

Figure 3. Cliffwood Beach Park looking west along the toe of the dunes. Storm debris marks recent activity, but the beach was fairly stable.

NJBPN 187 – Beach Park, Cliffwood Beach

Figures 4a & 4b. This is the westernmost NJBPN site located on Raritan Bay. The photograph on the left shows the beach along the toe of the dune November 13, 2015 while the right-hand picture was taken looking east on the beach October 19, 2016. This beach has retreated very slowly over the three decades of study, but the total amount of retreat is almost 120 ft documented since 1986. The site needs an influx of sand deposited on the beachface slope to sustain the dunes and prevent erosion from cutting into the reserve sand supplies for this open space shoreline segment.

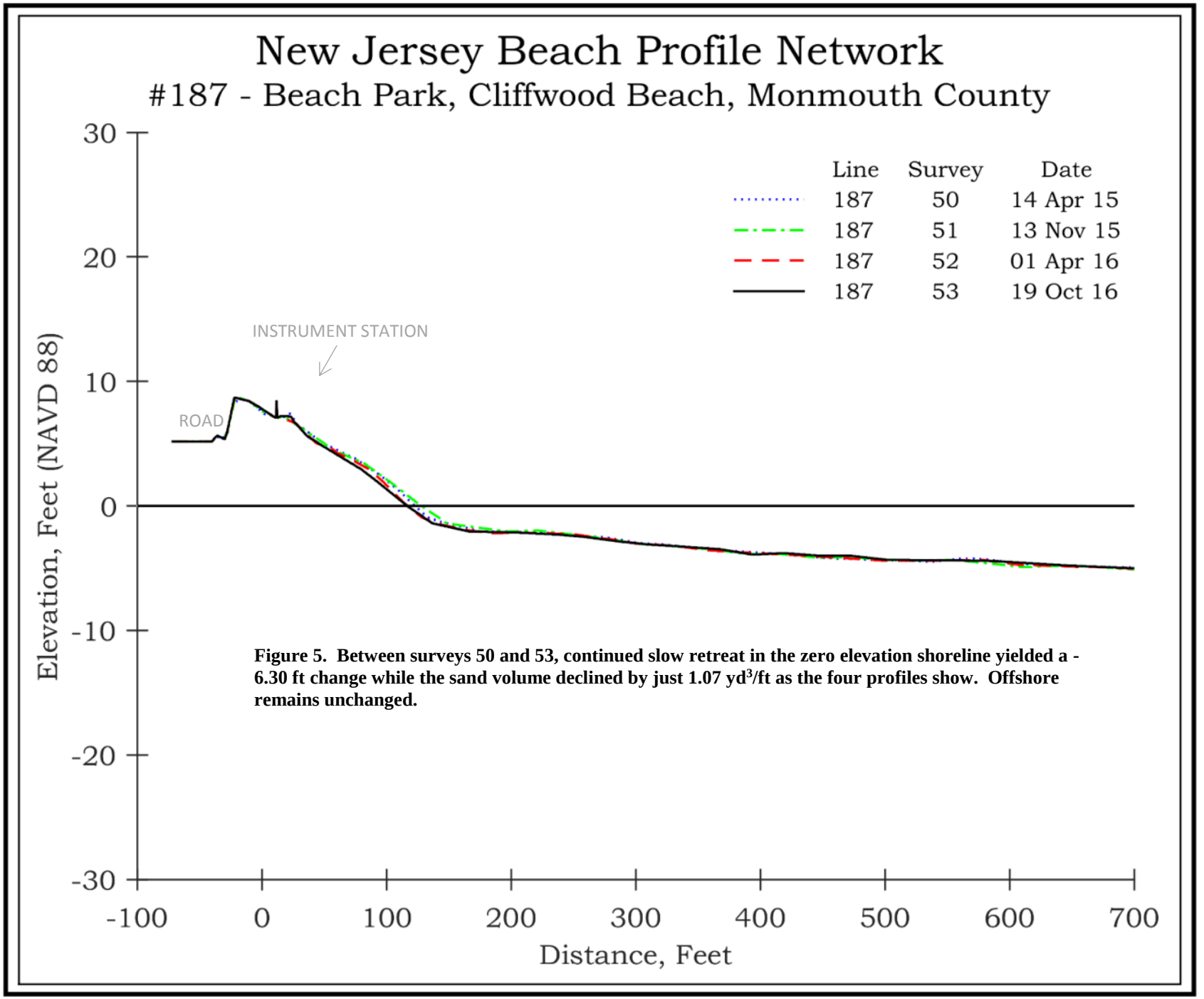

Figure 5. Between surveys 50 and 53, continued slow retreat in the zero elevation shoreline yielded a -6.30 ft change while the sand volume declined by just 1.07 yd^3/ft as the four profiles show. Offshore remains unchanged.

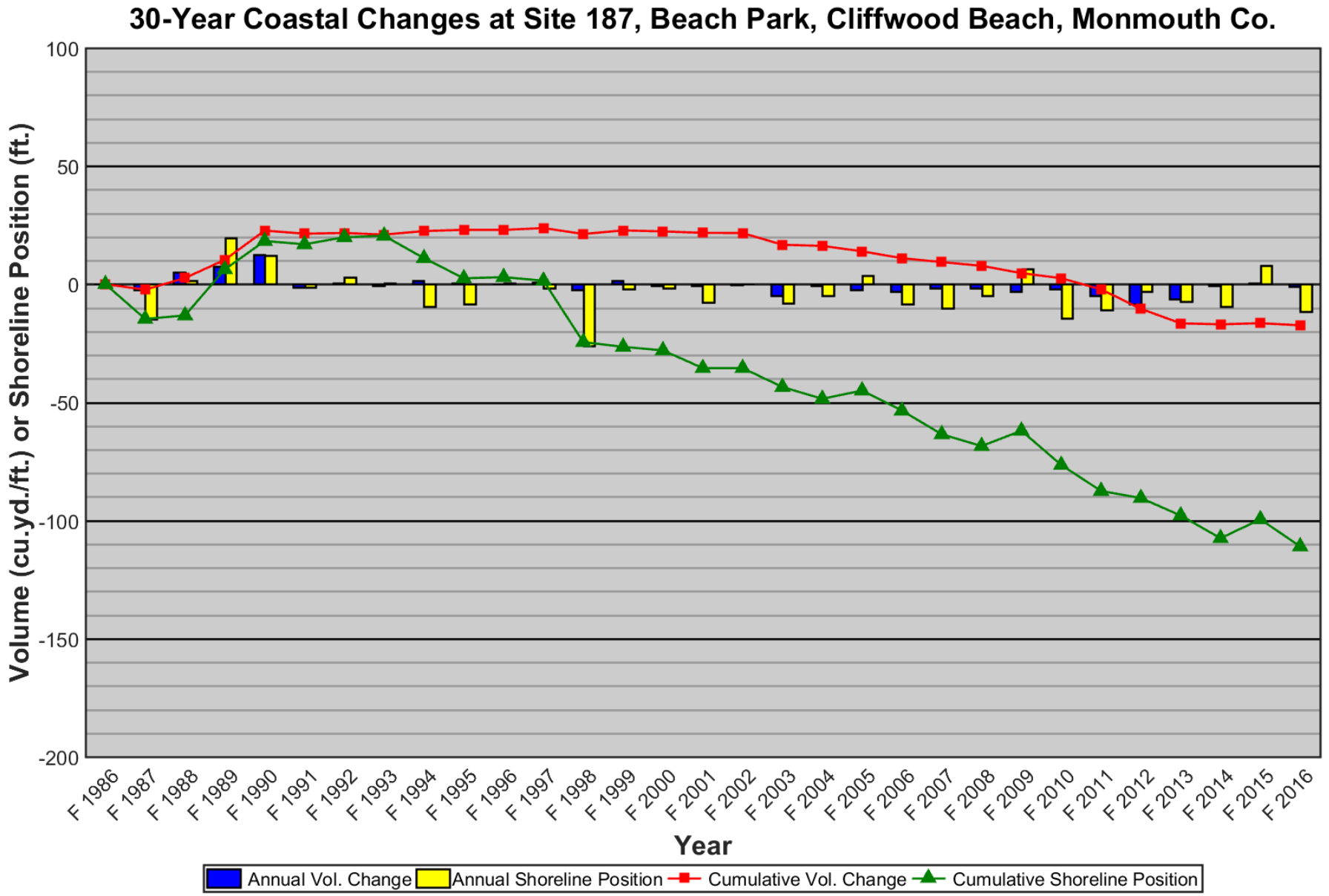

Figure 6. Thirty-year trend analysis for Cliffwood Beach Park. The sand volume grew with a 1989 influx to build a dune system and remained constant for a decade. The recent trend is negative up to 2012 (Hurricane Sandy), followed by stability. The shoreline has retreated about 130 ft since the 1993 maximum position seaward.

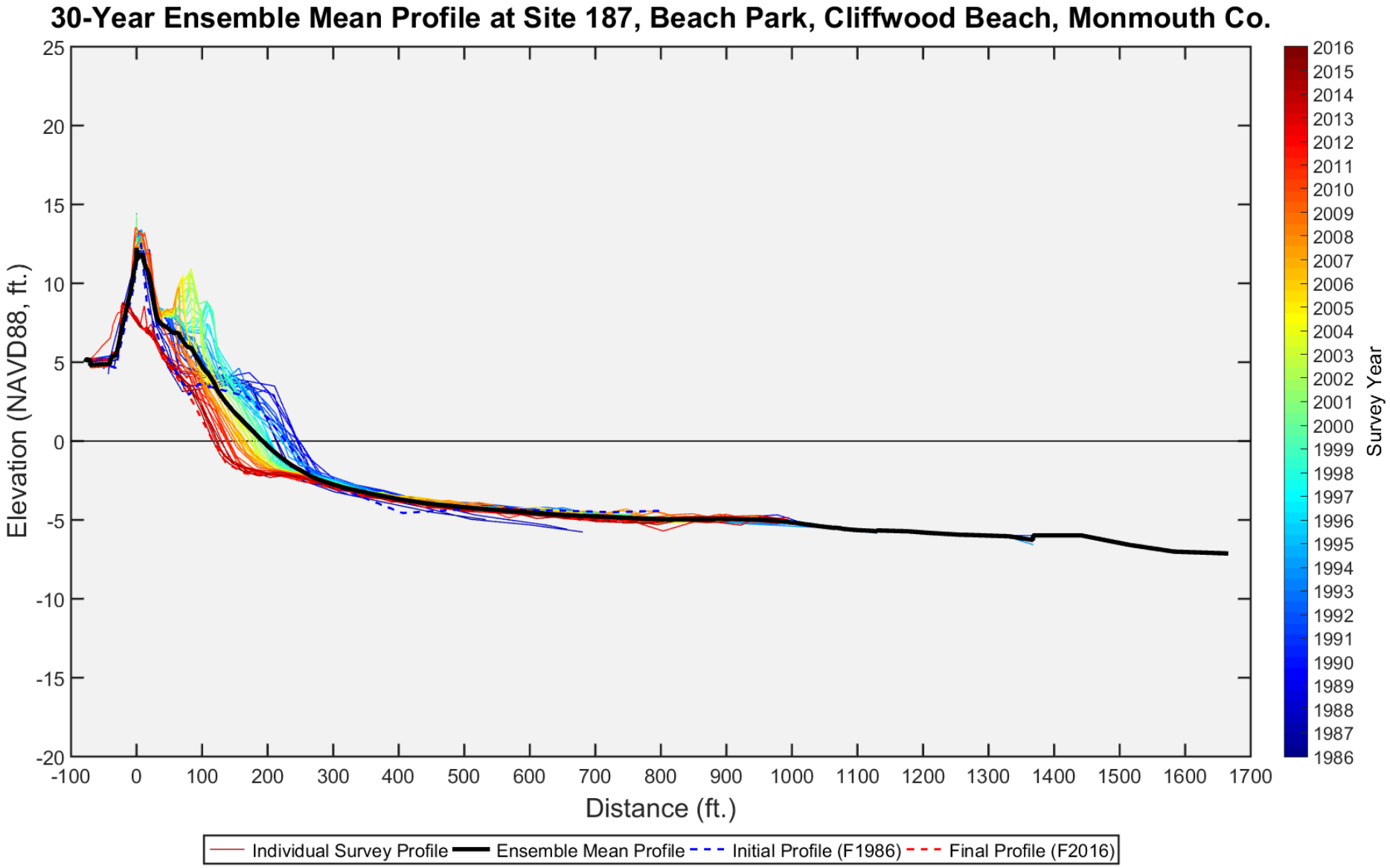

Figure 7. An ensemble plot of all profile cross sections since 1986 demonstrates two important trends. One, the Raritan Bay floor does not change over time since the majority of the profile lines seem to lay on top of each other and do not vary much from the mean. Two, the beach face has undergone slow, but consistent retreat over the past 30 years as displayed by the uniform color shift from the blue lines (early surveys) through the green lines (surveys from the mid-1990's) into the orange and red lines (surveys from the 2000's). The consistent shoreline retreat is displayed quite dramatically in this figure.

#187 - Beach Park, Cliffwood Beach, Aberdeen Township, Monmouth County

Comparison of 1995 to 2015

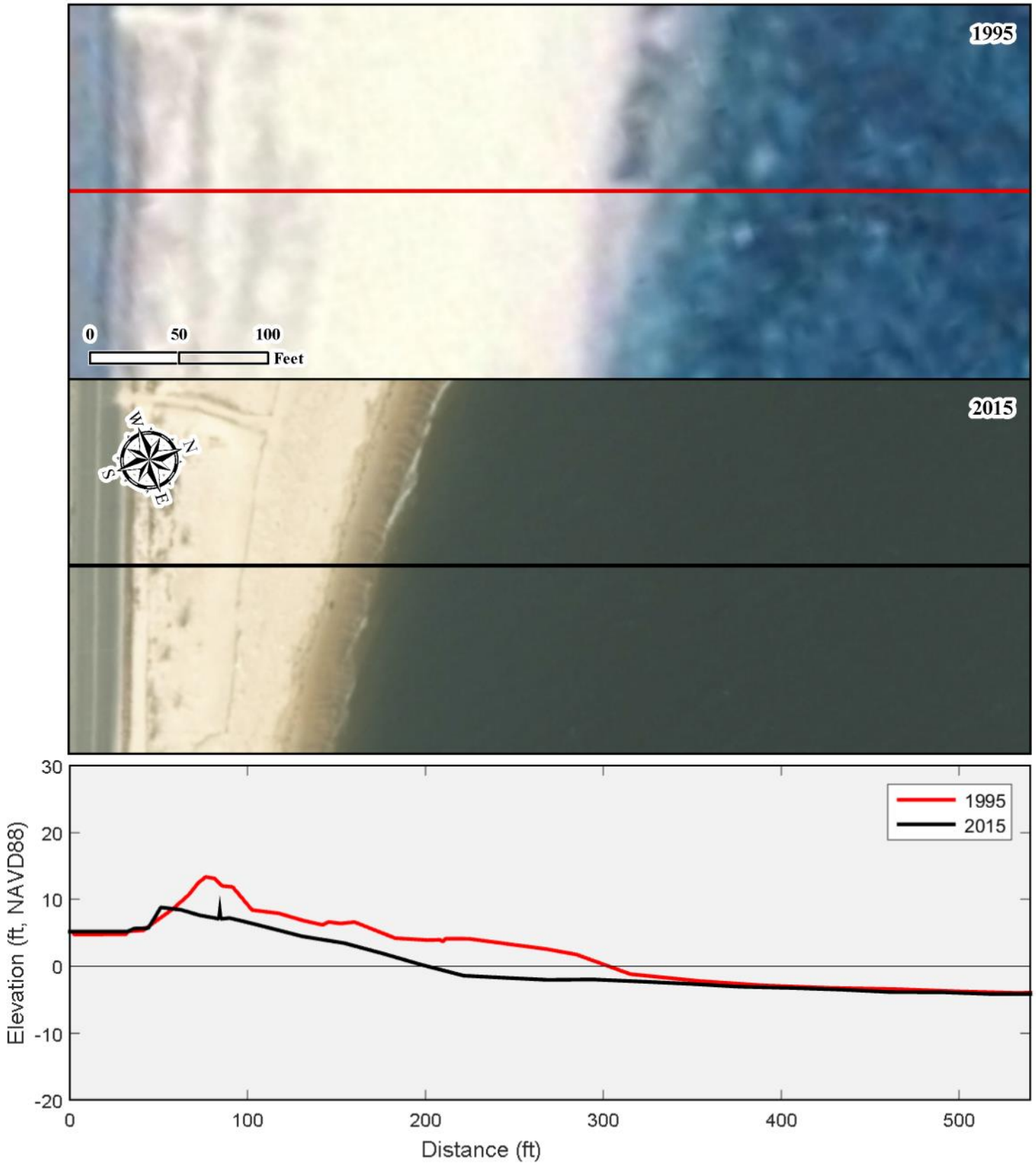

Figure 8. The shoreline retreat is evident at this site from the pictures and the two cross sections above. No new sand has been provided to the site over time since 1989

Figure 9. Public bathing beach in Union Beach looking east toward the rock revetment. The original site was further east by 500 to 600 ft.

NJBPN 286 – Beach Street, Union Beach

Figure 10a & 10b. This site was moved to the public bathing beach in 2009. The photograph on the left shows the shoreline on November 13, 2015 with a storm ridge in place to help resist wave attack. In 2014, 14,000 cubic yards of sand were added to the beach to provide a better facility for Union Beach. The photo on the right shows the adjustment in beach width two years following the municipality's in efforts in replacing lost sand as of October 19, 2016. A New York District USACE design for Union Beach will address flooding, long-term erosion as well as beach enhancement when it goes to construction.

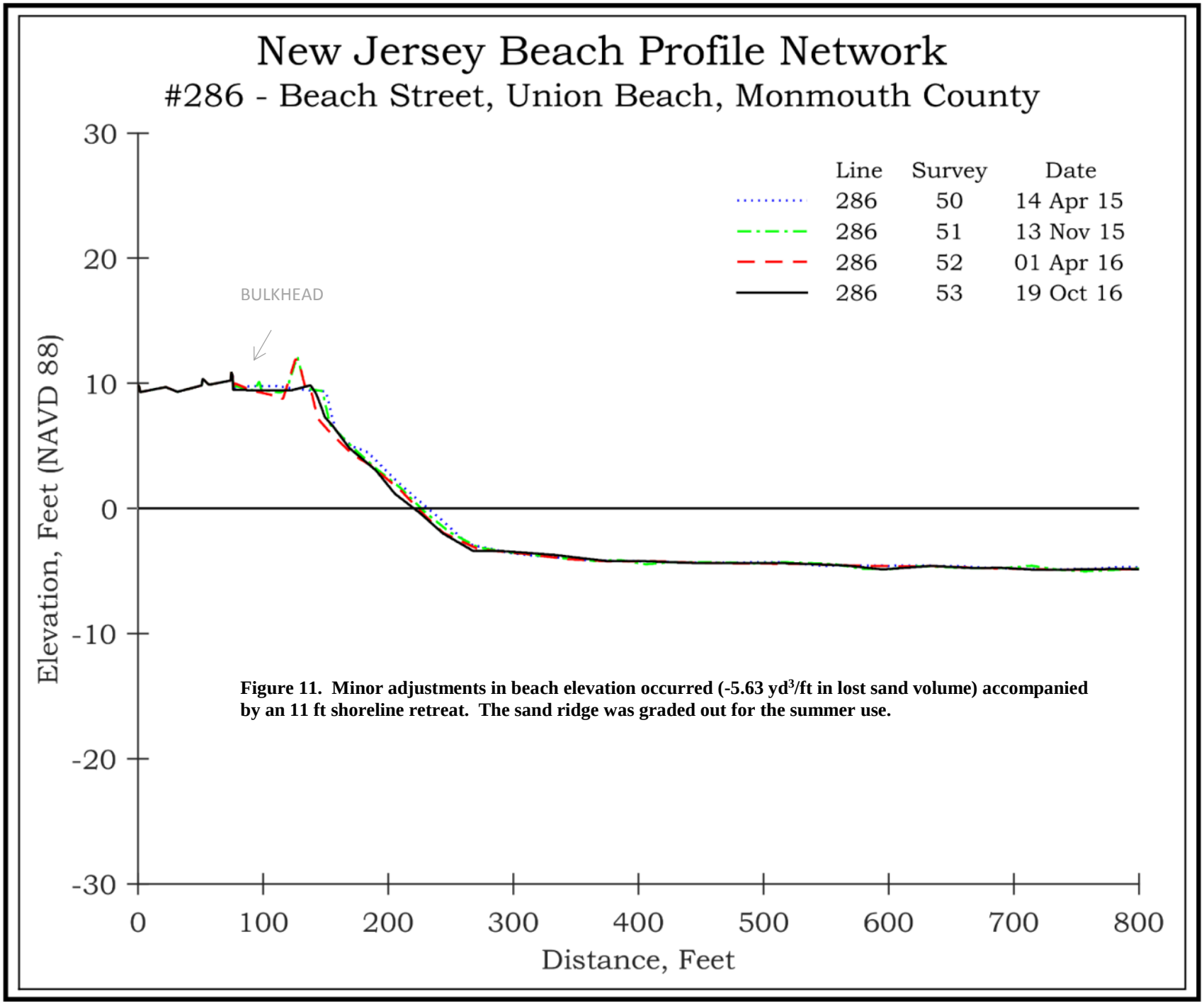

Figure 11. Minor adjustments in beach elevation occurred (-5.63 yd^3/ft in lost sand volume) accompanied by an 11 ft shoreline retreat. The sand ridge was graded out for the summer use.

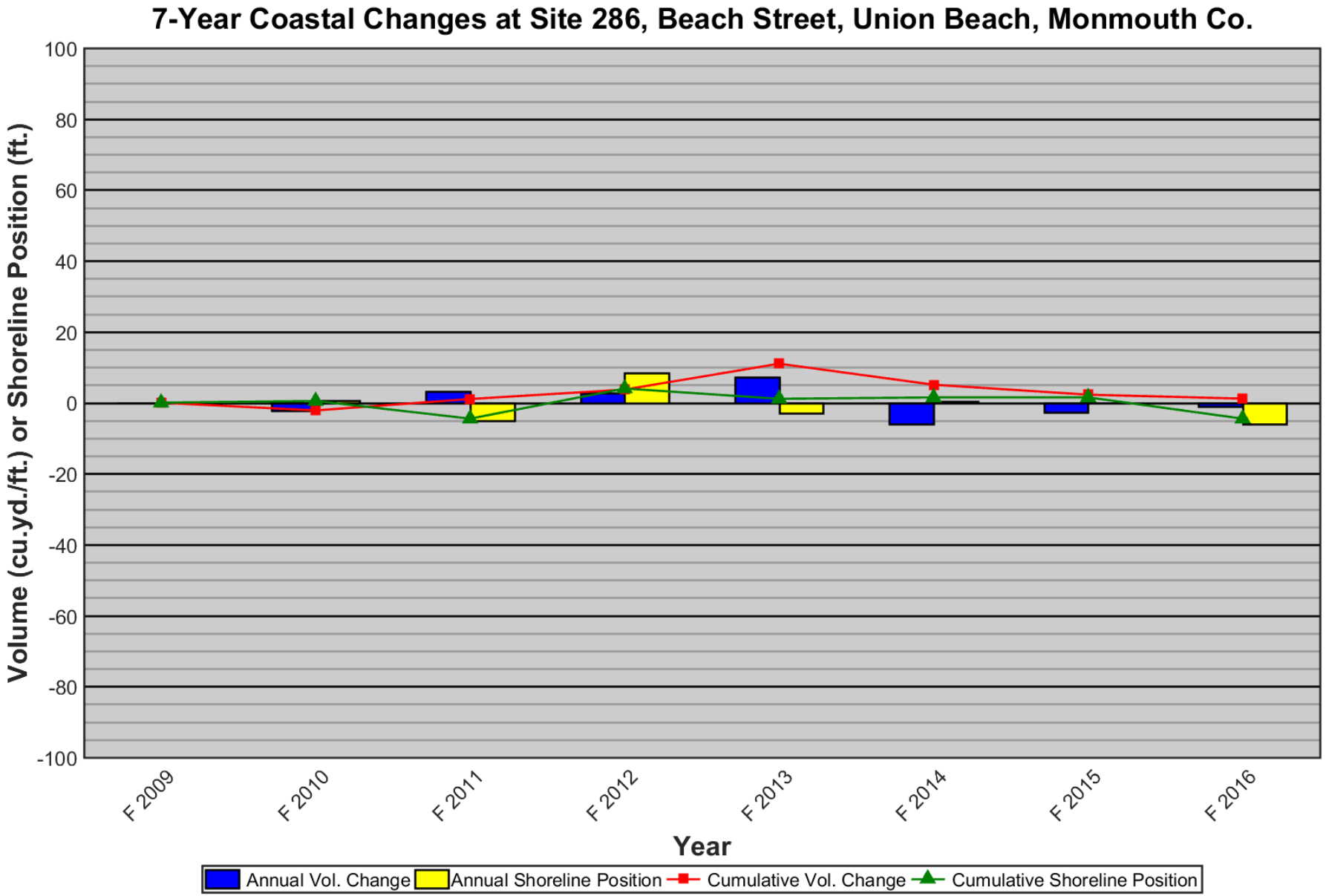

Figure 12. The Union Beach site was relocated 0.25 mi to the north of the original location in 2009 due to a project that armored the upland edge of the beach with stone. The shift was done in order to avoid the immediate effect of a hard structure while measuring the littoral processes in the area. Changes at the site are, on average, minimal and the site can be considered relatively stable. About 7 yds^3/ft of sand was added to the site in 2013 (following Hurricane Sandy) and since this addition, the site has experienced slow volume loss and a slow shoreline retreat of about 5 ft by the year 2016.

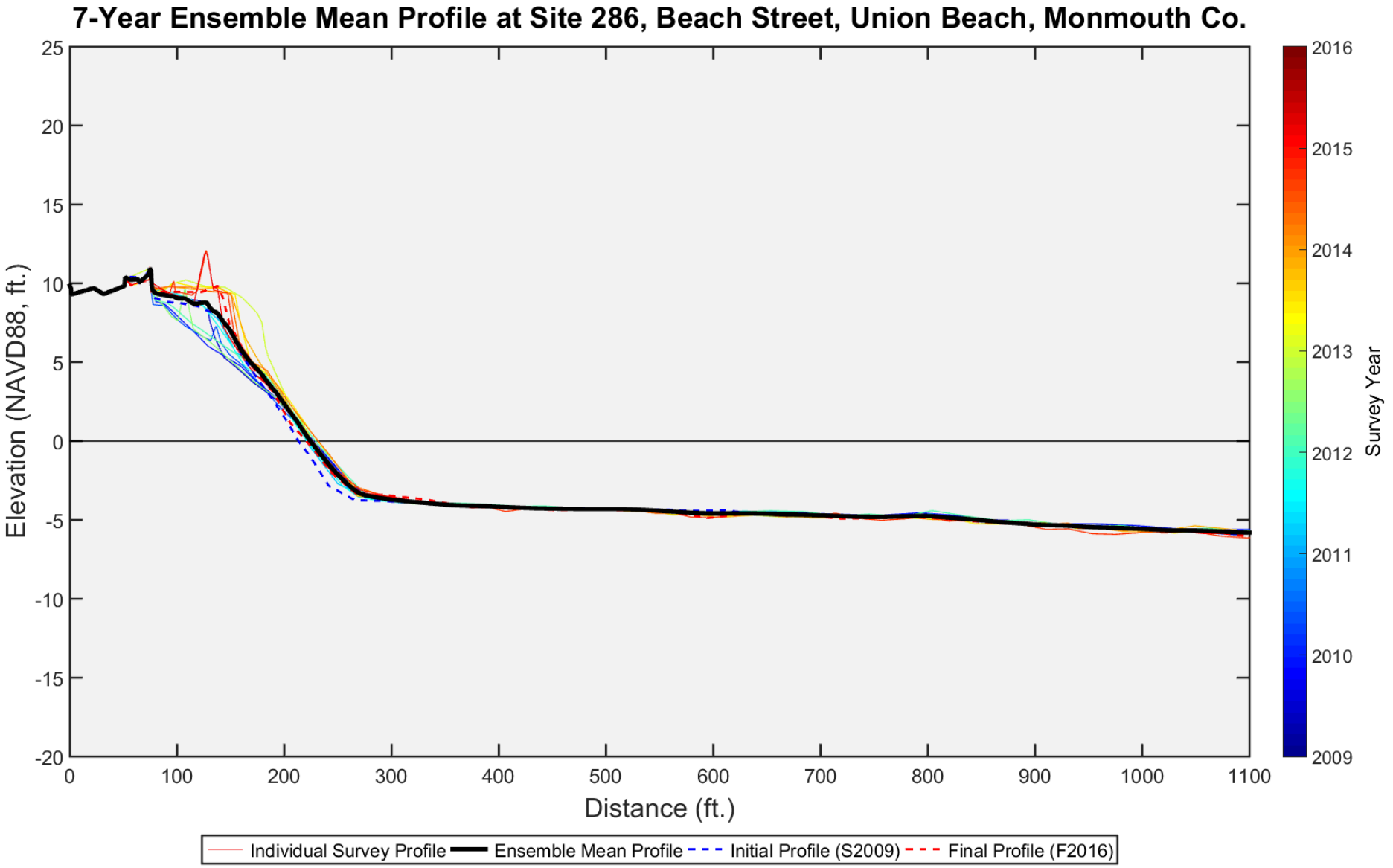

Figure 13. The observable changes are quite minimal over the 7 year existence of this profile line. The majority of the changes occurred above elevation 0 ft NAVD88 in the foreshore and dune area. The changes in this area are represented by an overall positive beach volume change and the recently added sand has generated a small, which is visible in the year 2016 (dark red). This figure also shows little to no elevation change in the offshore and reinforces the consistency in elevation of the Raritan Bay floor that is typical of all three sites.

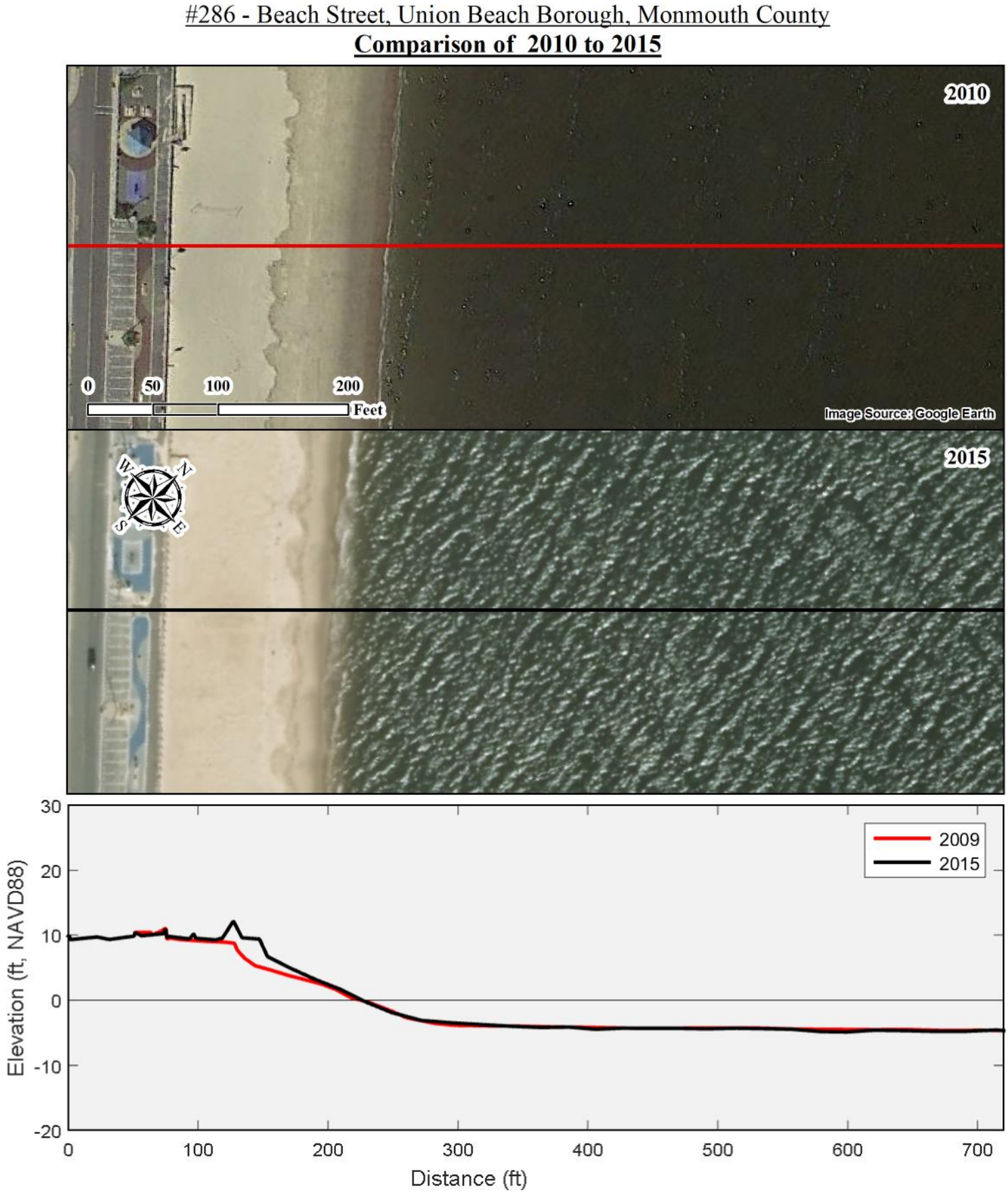

Figure 14. Between 2009 and 2015 the new site location has gained a more substantial dune but other observable changes have been minimal.

Figure 15. View to the west along the toe of the new dune field at the Bay Shore Park showing the expanse of beach now present as a result of the USACE project at this site.

NJBPN 185 – Spy House Museum, Port Monmouth


Figure 16a & 16b. This site is an exceptional example of the effect produced by an ambitious project completed by October 2014 by the USACE. The rubble-rich erosional scarp in at the uplands edge was cleaned up and a new dune installed combined with a much wider beach and a new fishing pier extending into the bay. The sand ridge in the left photograph (November 13, 2015) was graded out and by October 19, 2016 (right photograph) the broad expanse of sand beach was a remarkable improvement over the 2013 situation.

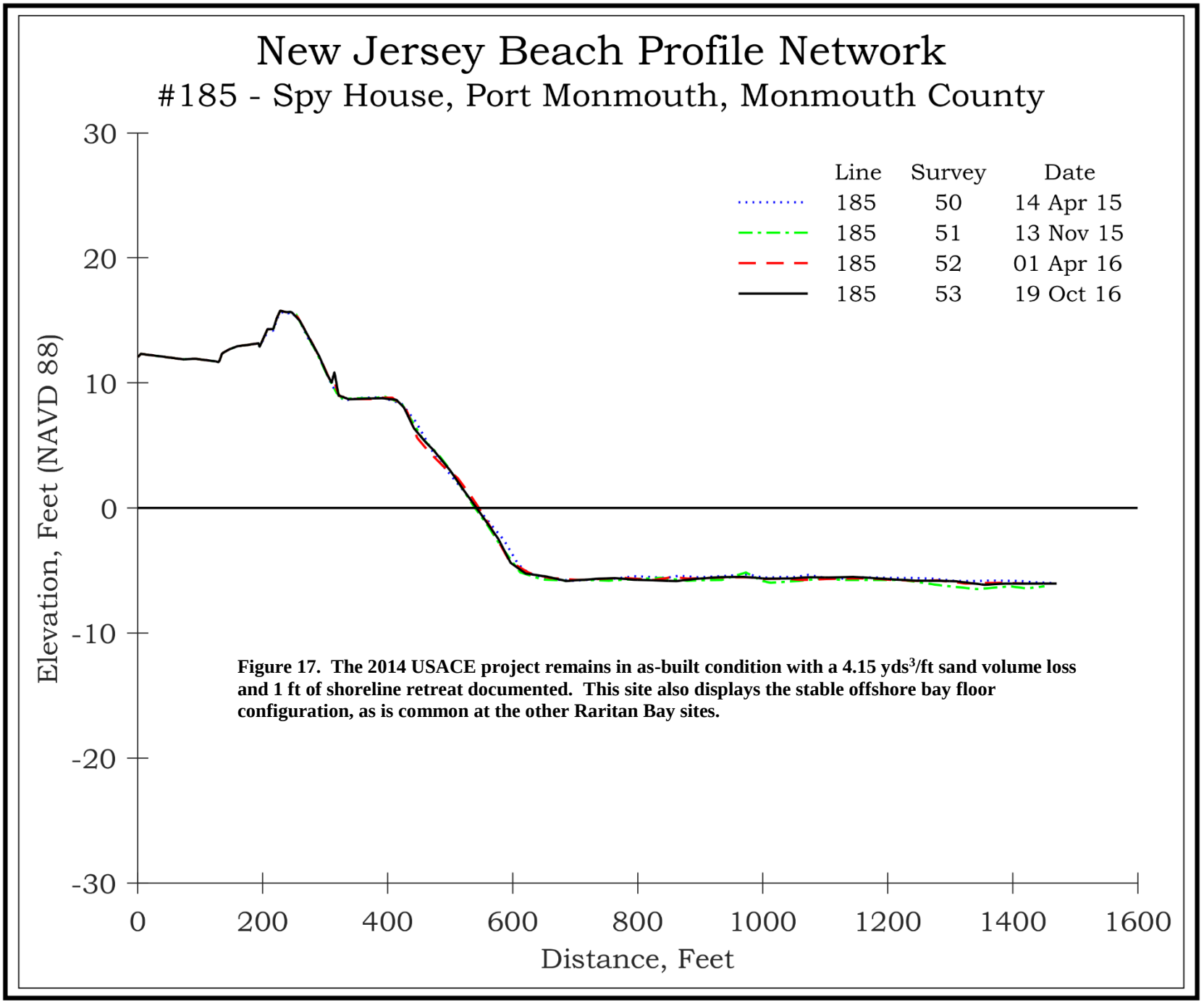

Figure 17. The 2014 USACE project remains in as-built condition with a 4.15 yds^3/ft sand volume loss and 1 ft of shoreline retreat documented. This site also displays the stable offshore bay floor configuration, as is common at the other Raritan Bay sites.

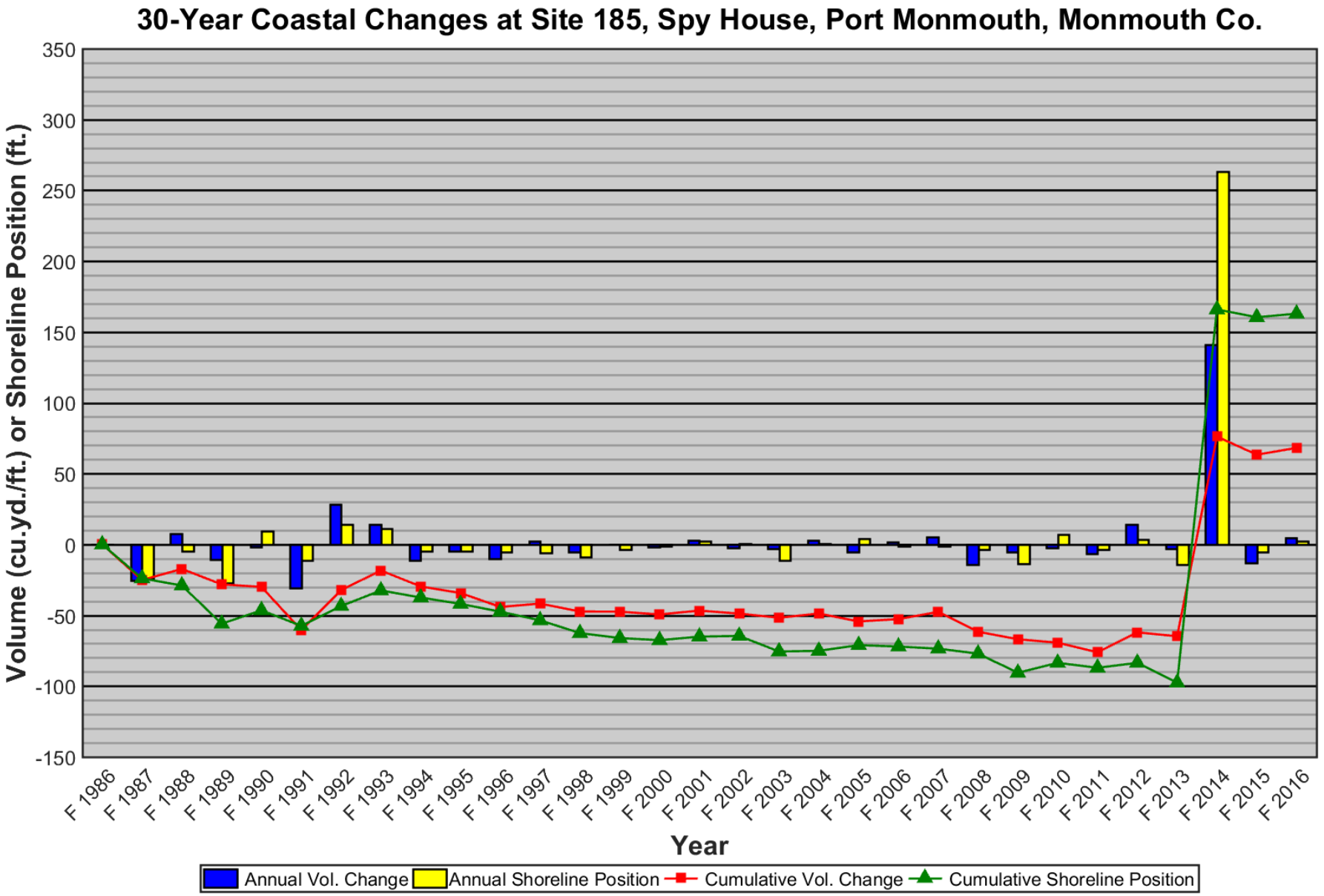

Figure 18. Site 185 is the easternmost profile site along the Raritan Bay coast. Slow loss in sand volume combined with shoreline retreat ultimately resulted in a USACE project at this location in 2014. The new shoreline position is about 160 ft seaward of the original 1986 location and about 260 ft seaward of the 2013 position. The sand volume increased by almost yds^3/ft of beach as well.

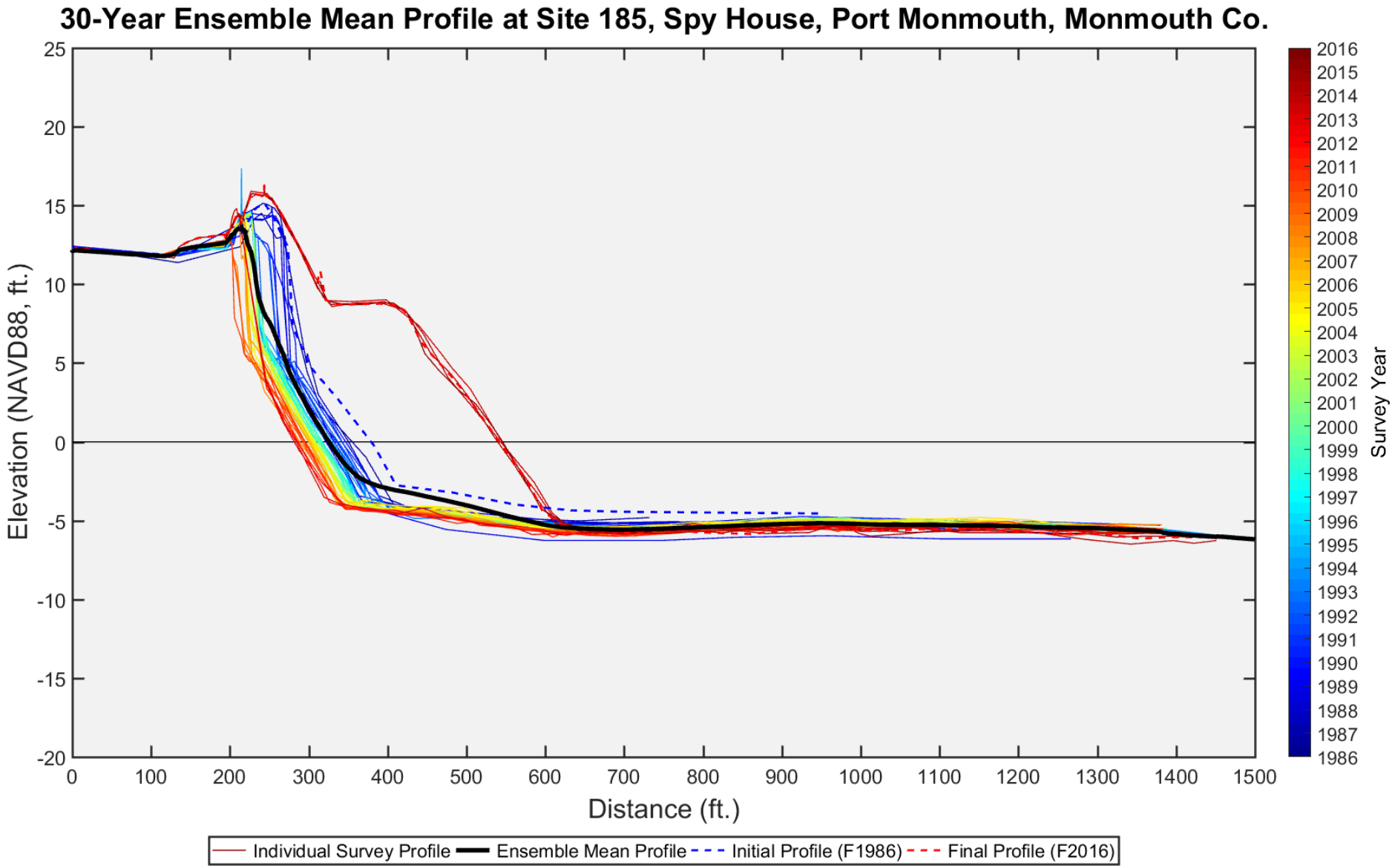

Figure 19. Site 185 was enhanced in 2015 with a USACE beach restoration project that added 200 ft to the shoreline as a new beach/dune system. The latest profile plots show the new beach in place while the earlier cross sections demonstrate the recessional nature of this shoreline over time making the USACE project necessary. The offshore segment continues the theme of little change in Raritan Bay floor elevations.

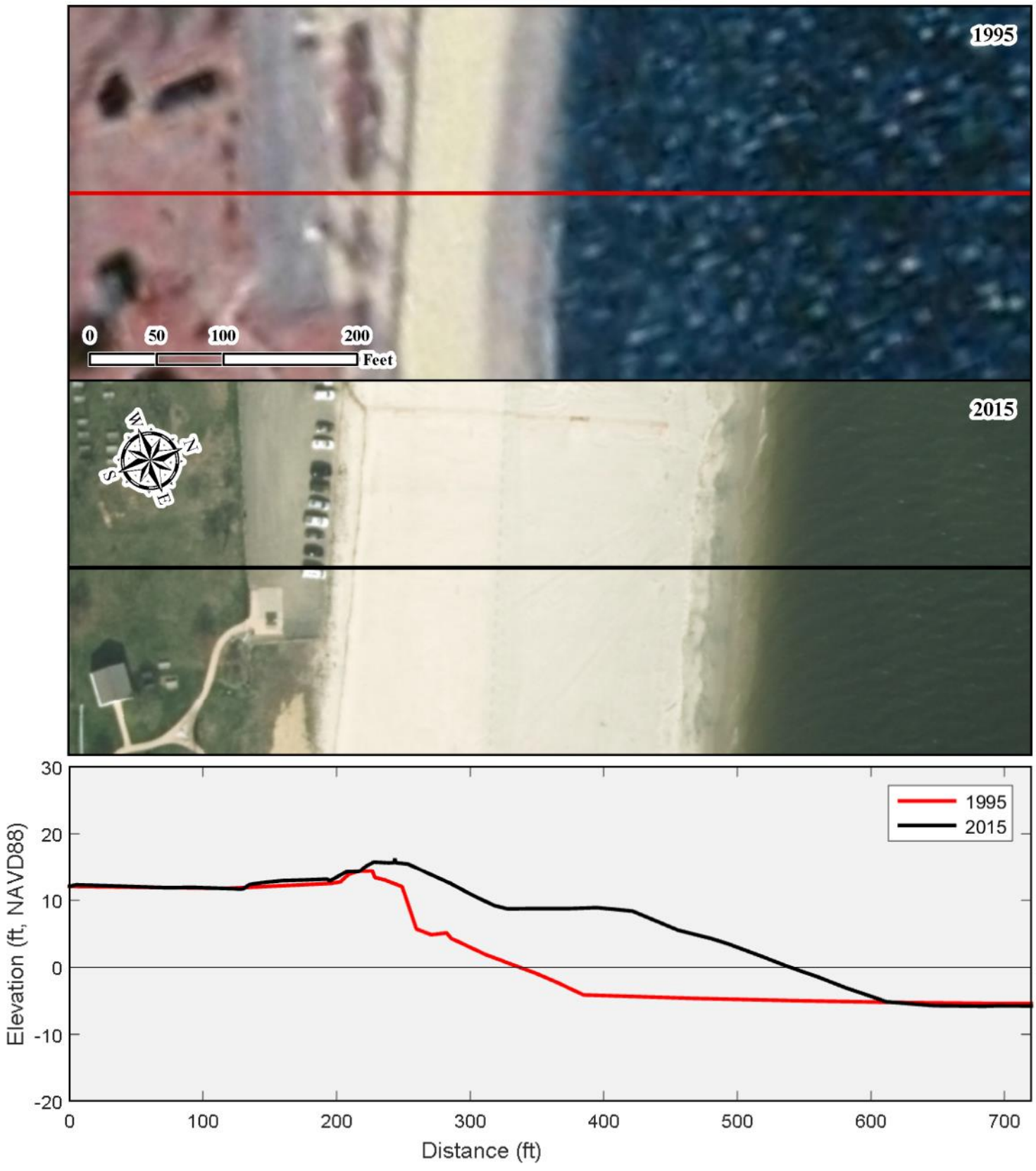

Figure 20. The dramatic difference from 1995 to 2015, as displayed in this figure, is completely due to a USACE project that occurred in 2014-2015 and provided a much-enhanced shoreline.

Figure 19. This view looks north toward the tip of Sandy Hook from the new profile location 3,500 ft north of Gunnison Beach. The site is the final public access point to the beach without traveling further north along the sand. The goal is to evaluate sand transport along the National Seashore coastline more completely.

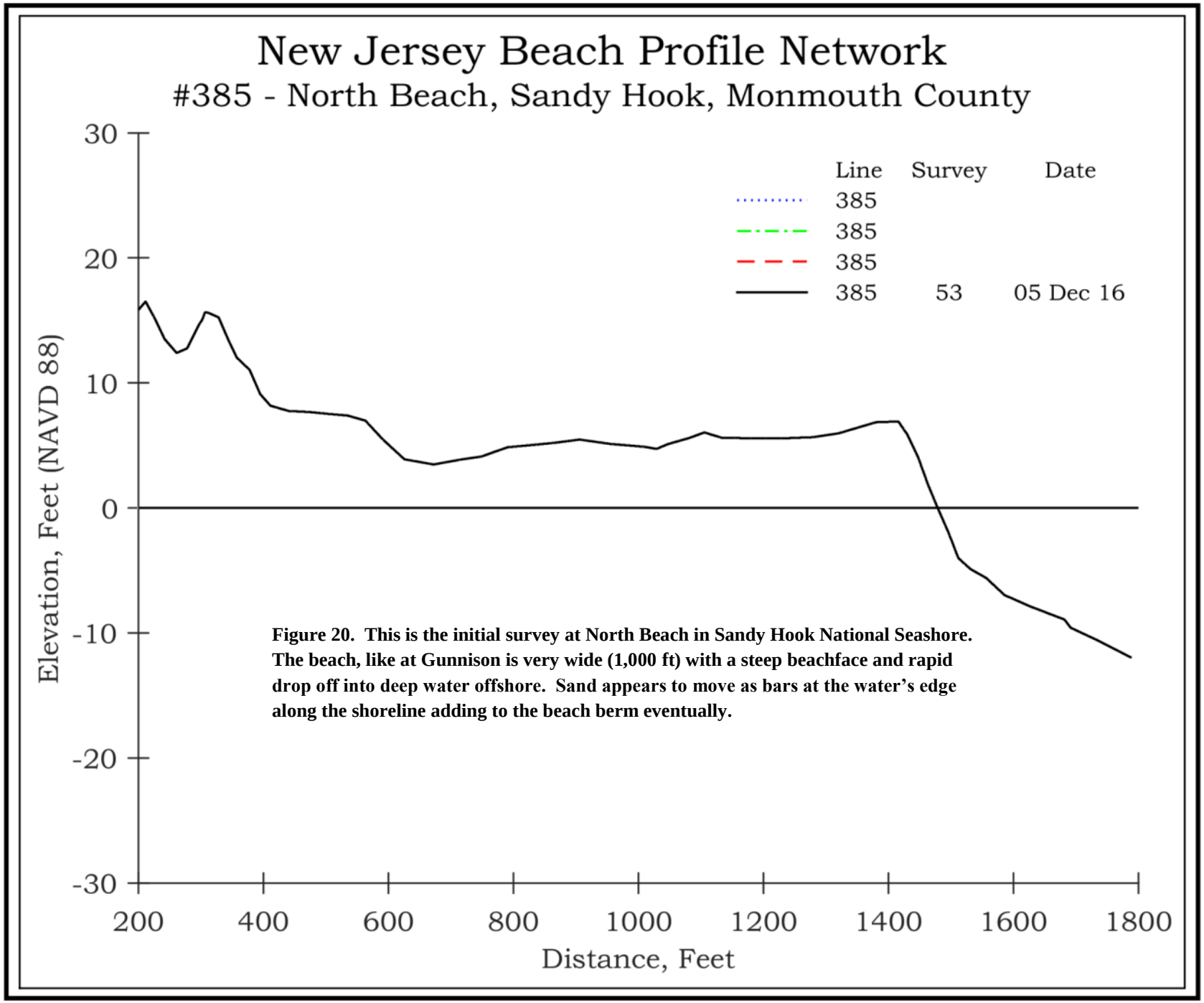

Figure 20. This is the initial survey at North Beach in Sandy Hook National Seashore. The beach, like at Gunnison is very wide (1,000 ft) with a steep beachface and rapid drop off into deep water offshore. Sand appears to move as bars at the water's edge along the shoreline adding to the beach berm eventually.

#385 - North Beach, Sandy Hook, Monmouth County

Comparison of 1995 to 2016

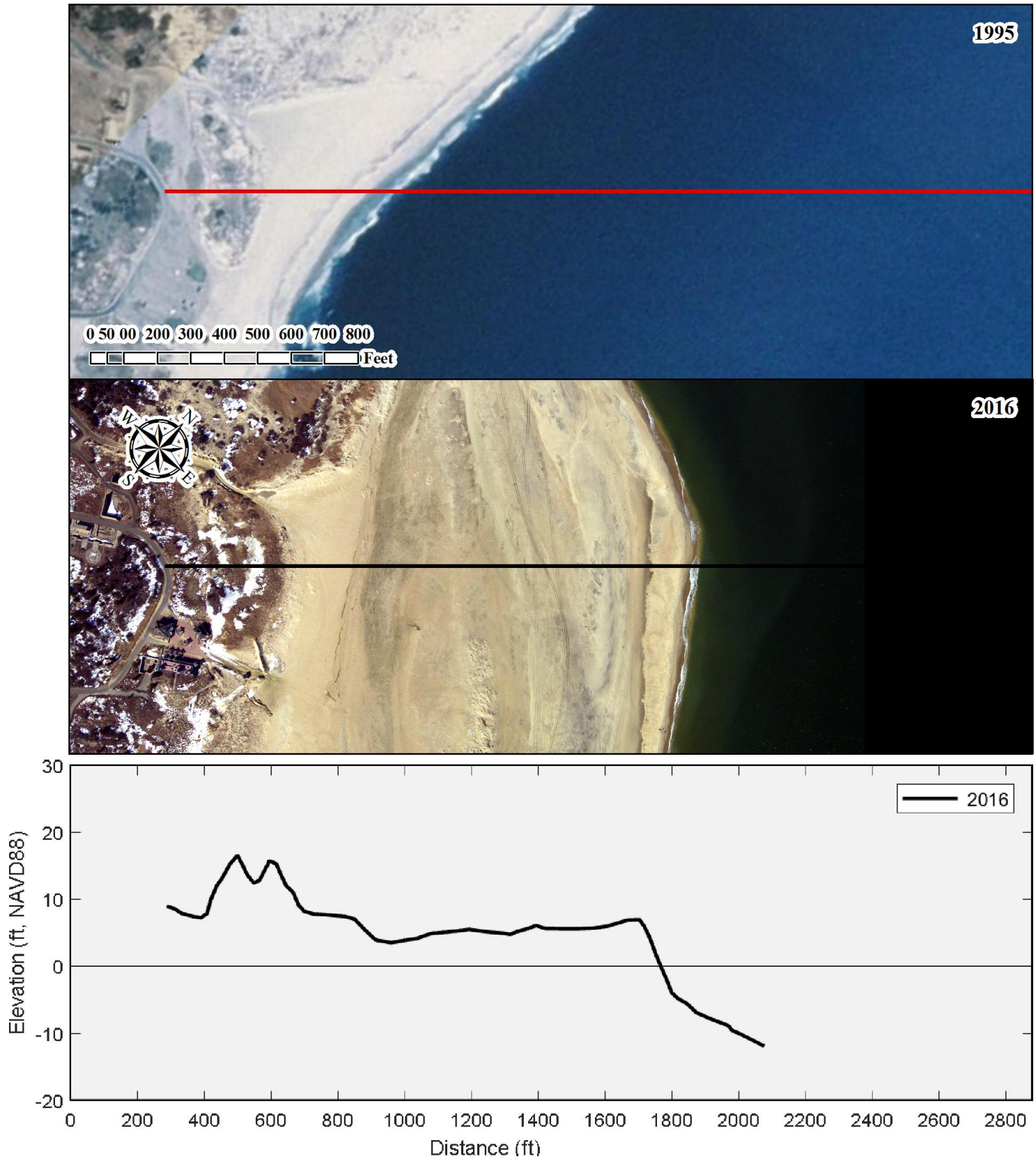

Figure 21. The aerial comparison in this figure from the year 1995 to 2016 displays a large growth in beach width and a large positive shoreline change of almost 1,000 ft. This site was established in 2016, so data can only be presented as a cross-section plot for the year 2016. The large growth in beach width may be attributed to the northward directed alongshore transport of beach fill material, as has been displayed at site 285, which is located just to the south of site 385.

Figure 22. The expanse of the Gunnison beach cannot be presented in just one picture, but this view across the outer low dunes to the beach provides some perspective to the width of the site. The dry sand beach is over 1,500 ft in width and grows wider every year.

NJBPN 285 – Gunnison Beach, Sandy Hook National Seashore


Figure 22a & 22b. This was the northernmost ocean NJBPN site along the Sandy Hook National Seashore until 2016 when a new site was added 3,500 ft north to capture additional data on shoreline advances along this park coastline. This site has shown advances in the berm position since 1999. The photograph on the left shows the Dec. 7, 2015 beach looking north; on the right is the same view from the toe of the dune Dec. 5, 2016. A single picture cannot grasp the enormity of this section of beach over 1,500 ft in width from the edge of the dune grass. However, the aerial views below provide a sense of scale.

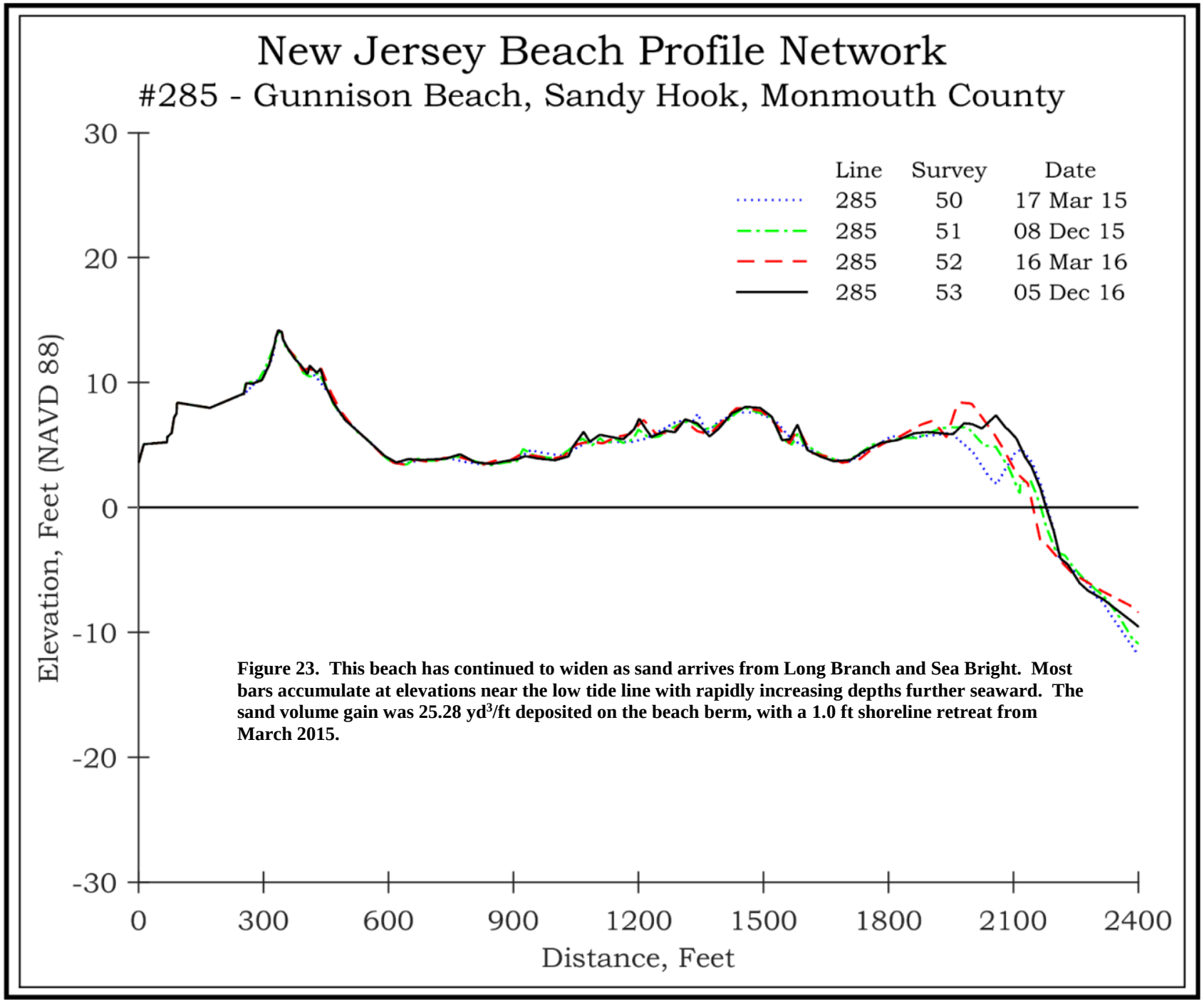

Figure 23. This beach has continued to widen as sand arrives from Long Branch and Sea Bright. Most bars accumulate at elevations near the low tide line with rapidly increasing depths further seaward. The sand volume gain was 25.28 yd^3/ft deposited on the beach berm, with a 1.0 ft shoreline retreat from March 2015.

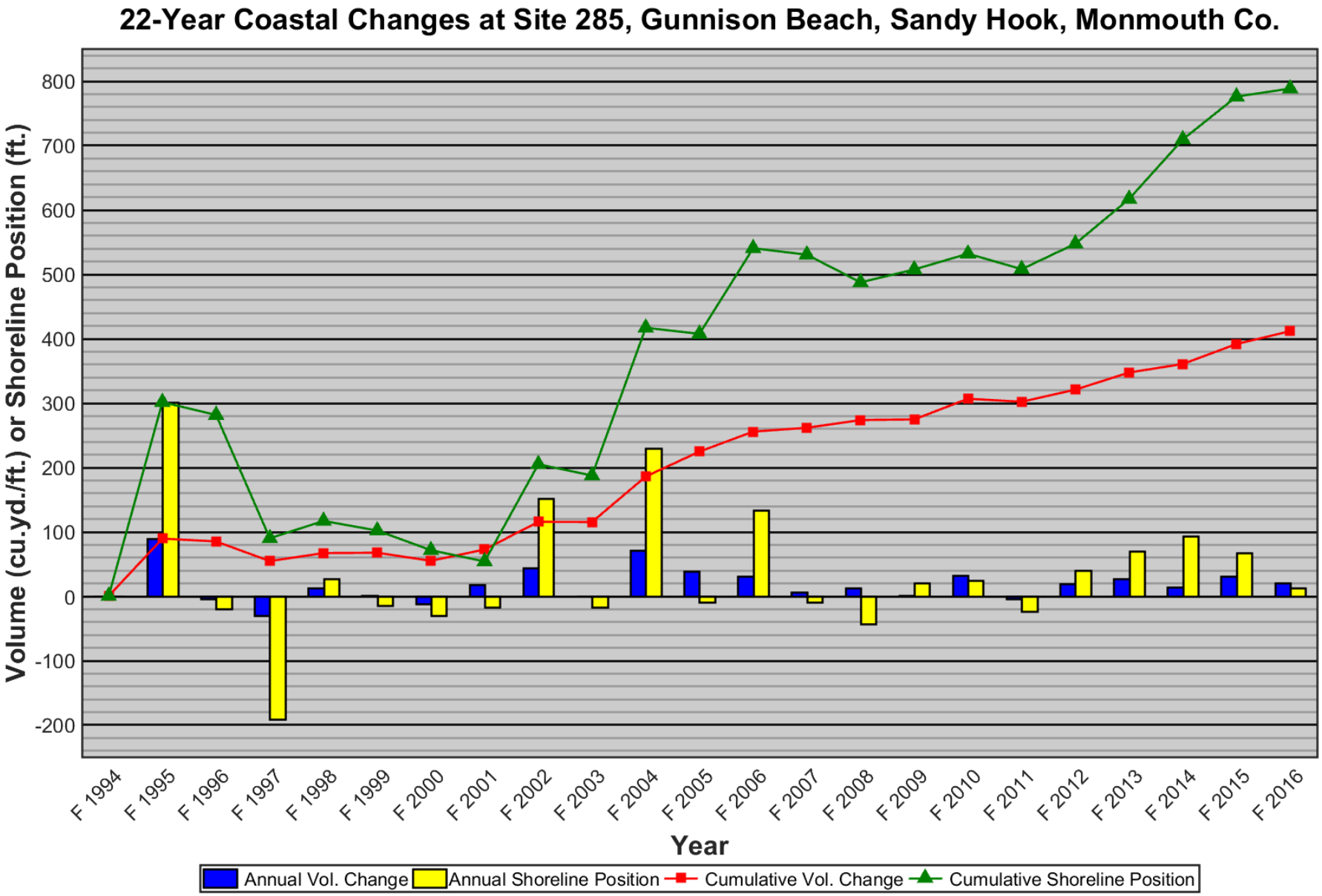

Figure 24. The initial change at this location established in 1994, prior to the commencement of beach work by the NY District USACE consisted of one extensive shoreline advance followed by steady more modest changes until 2001 when a progressive expansion of both the width of the beach and growth in sand volume present took place extending to 2016. The net gain in sand volume was just over 300 yds^3/ft of beach combined with an almost 800 ft shoreline advance in 22 years.

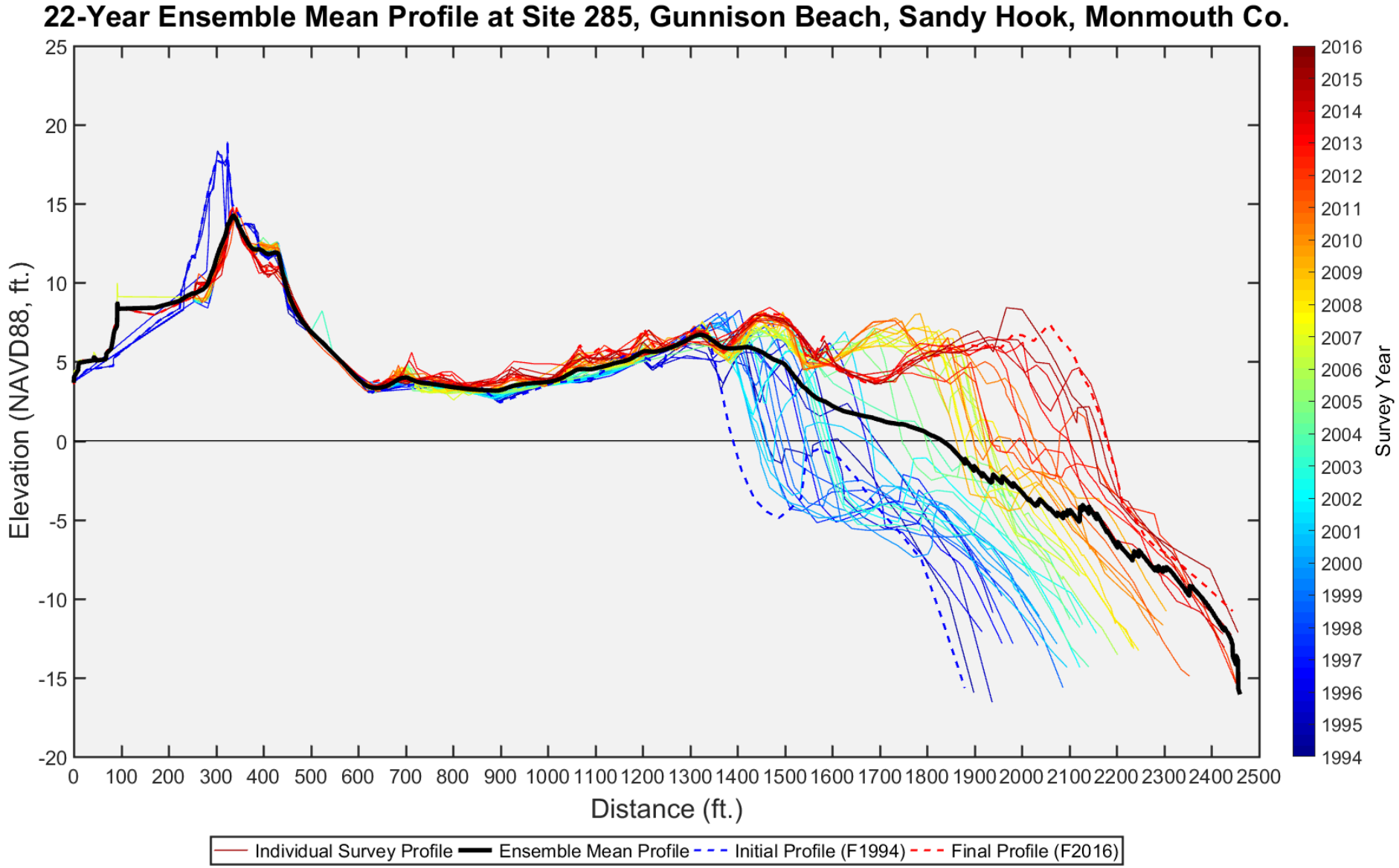

Figure 25. The array of 22 years of survey cross sections at this site demonstrate a steady shoreline advance that exploded in the mid 1990's following the USACE Monmouth County shore protection project that started in 1995. Littoral transport has moved sand north along the National Seashore coastline to this site showing in vertical profile what is illustrated in Figure 24 above quantitatively and below in Figure 26 in aerial photographs. The site experienced a positive (seaward) shoreline change of approximately 750 ft from the year 1994 to 2016 .

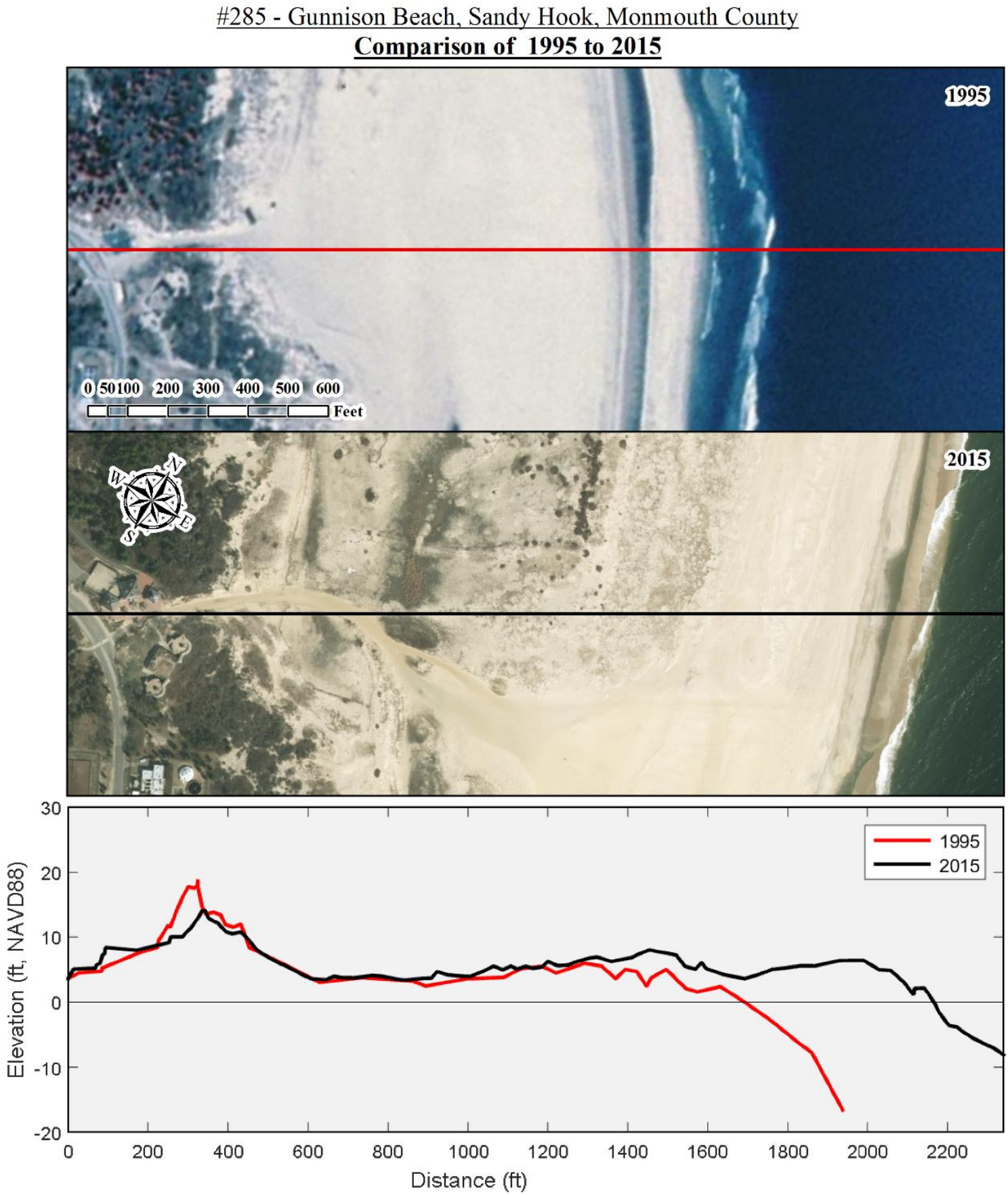

Figure 26. Sand derived from the federal project south of the National Seashore area has moved up the coast and added considerably to this shoreline's width. The shoreline has moved 500 ft seaward filling in the seafloor originally at 15 to 20 ft depths. This represents a very large sand volume derived from the Monmouth County Phase I fill.

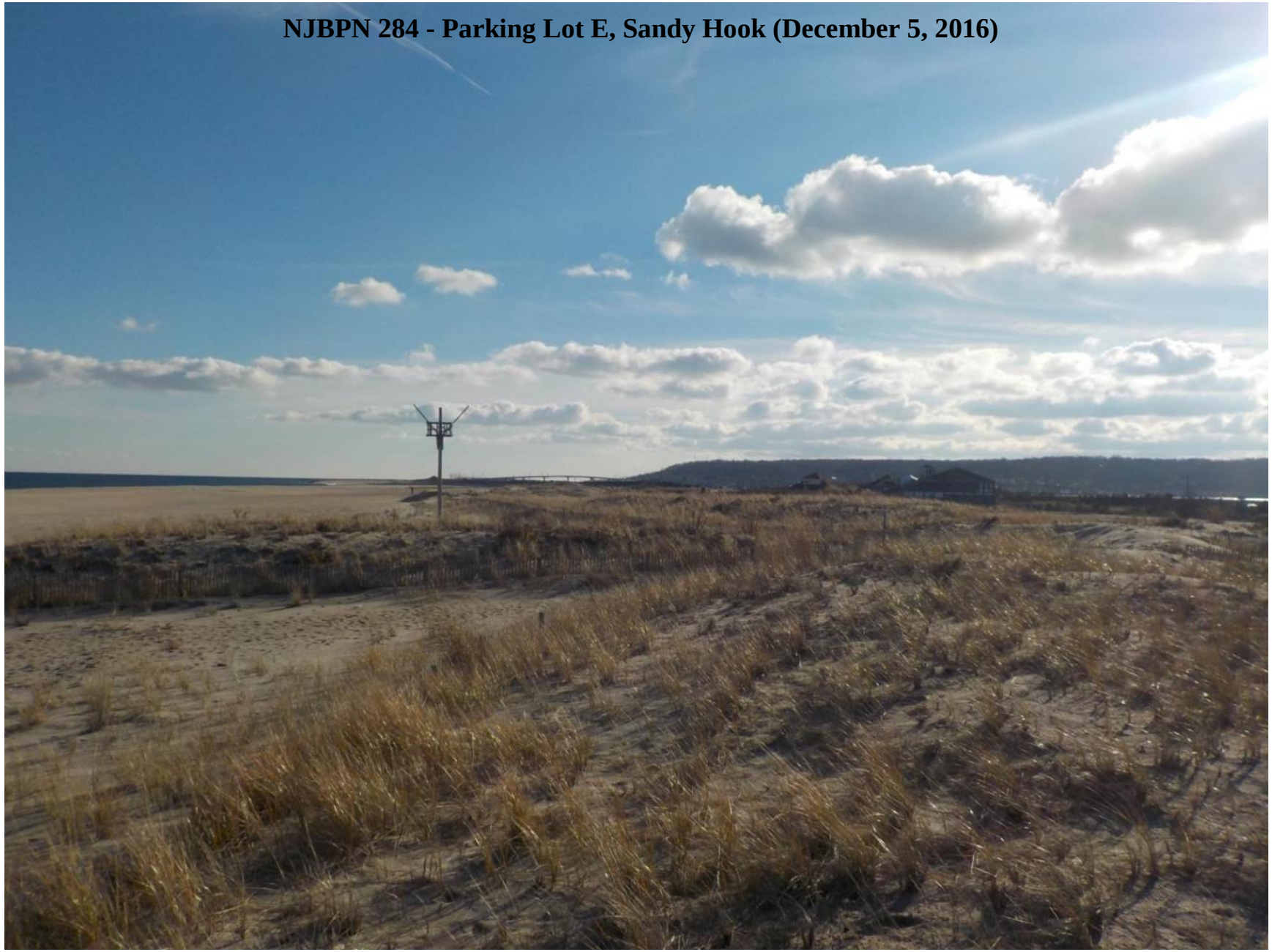

Figure 27. View to the south at Parking Lot E at Sandy Hook National Seashore close to the edge of the dune grass. The site has expanded in beach width due to the placement of offshore material to the south in Monmouth County.

NJBPN 284 – Parking Lot E, Sandy Hook National Seashore


Figure 28a & 28b. On the left is a beach picture from December 12, 2015 looking north along the seaward toe of the dune grass. The similar view on December 5, 2016 shows the gentle dune slope onto the dry beach and the extent of beach width at this site.

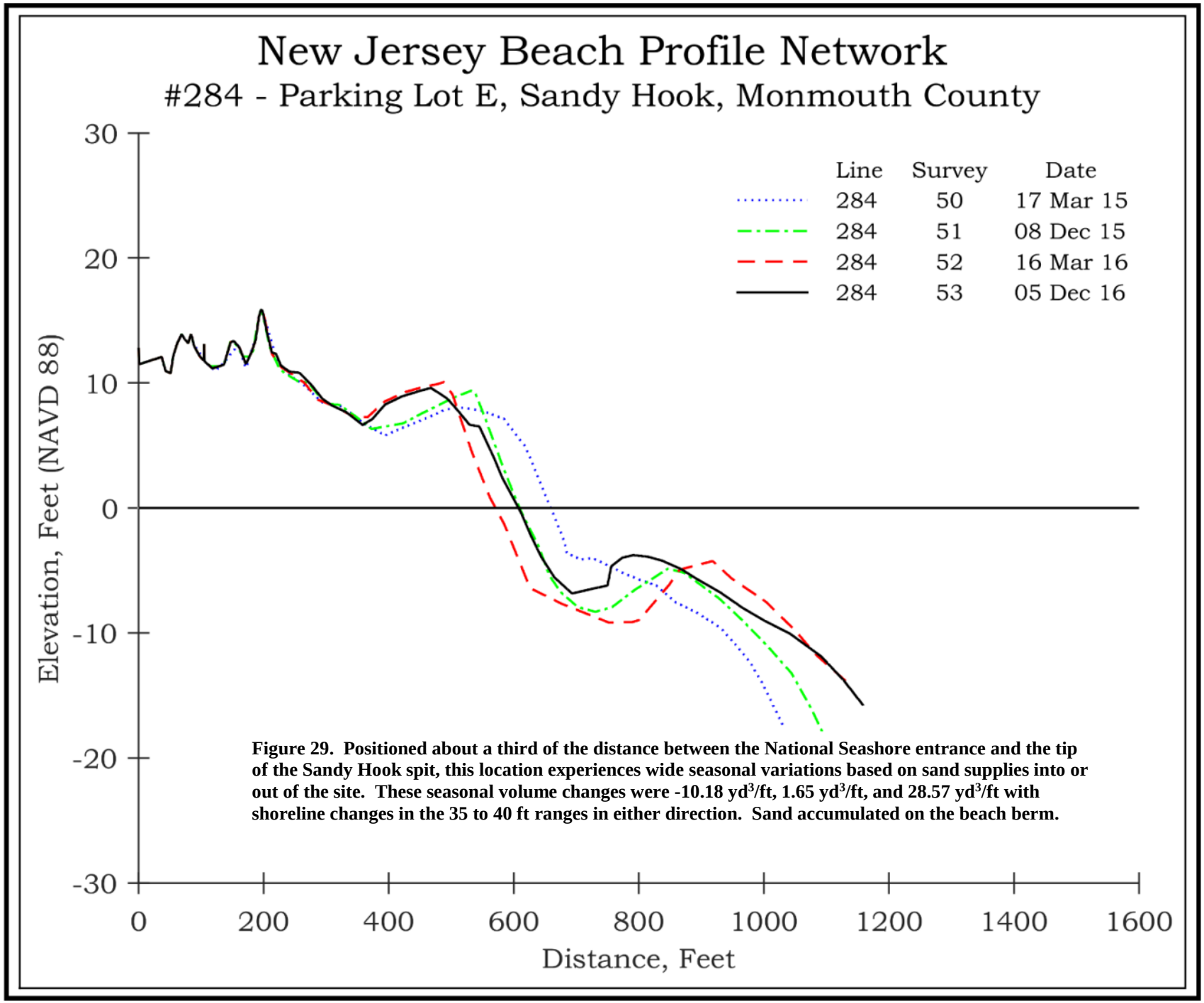

Figure 29. Positioned about a third of the distance between the National Seashore entrance and the tip of the Sandy Hook spit, this location experiences wide seasonal variations based on sand supplies into or out of the site. These seasonal volume changes were -10.18 yd^3/ft, 1.65 yd^3/ft, and 28.57 yd^3/ft with shoreline changes in the 35 to 40 ft ranges in either direction. Sand accumulated on the beach berm.

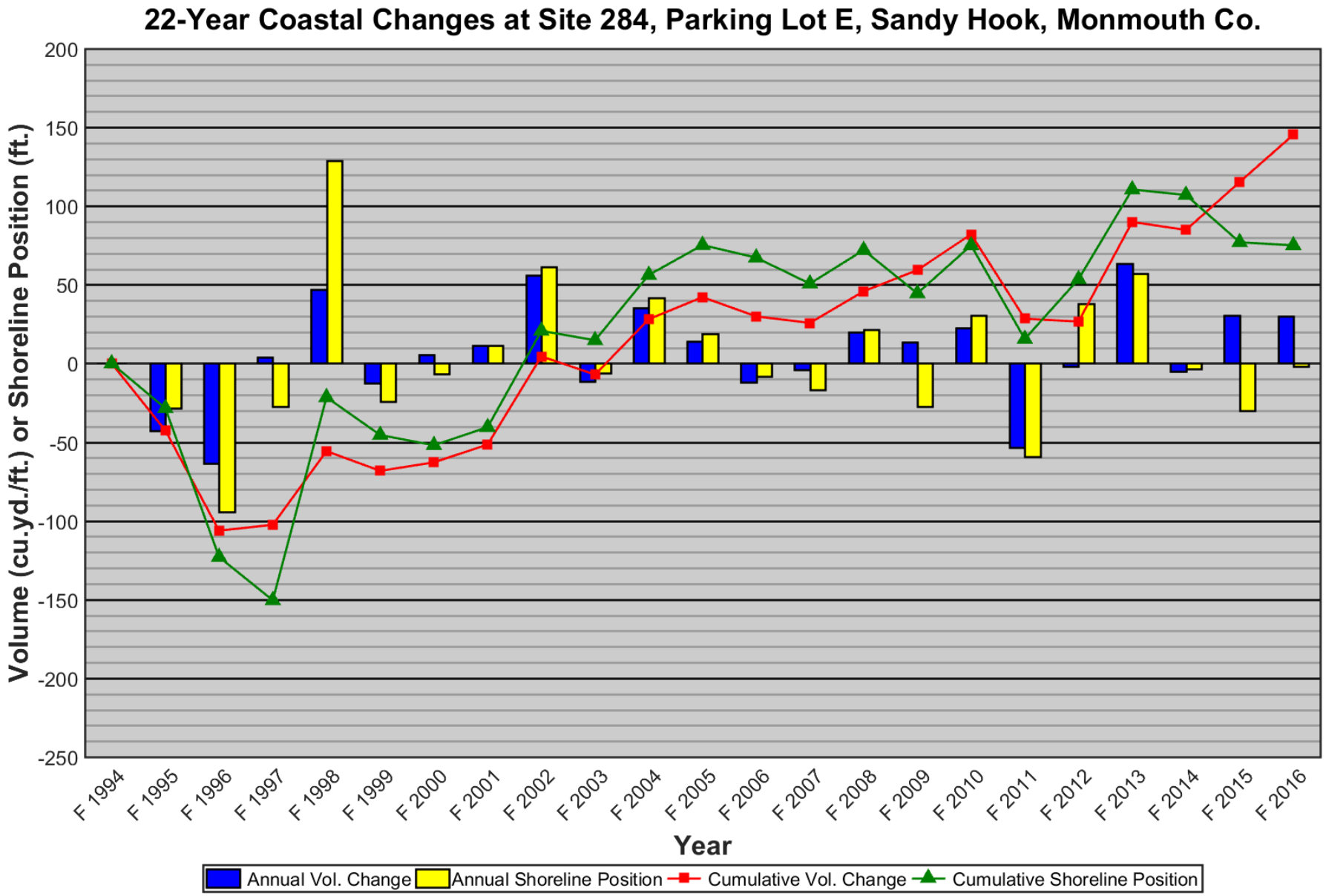

Figure 30. A similar pattern of irregular shoreline changes remaining slightly negative by 2001 shifted steadily to a positive trend after 2002. A significant loss in 2011 was the only point of retreat with a net sand volume gain of 145 yds^3/ft and a shoreline advance of 75 ft since 1994. The trend is for sand to pass through this location on its way farther north.

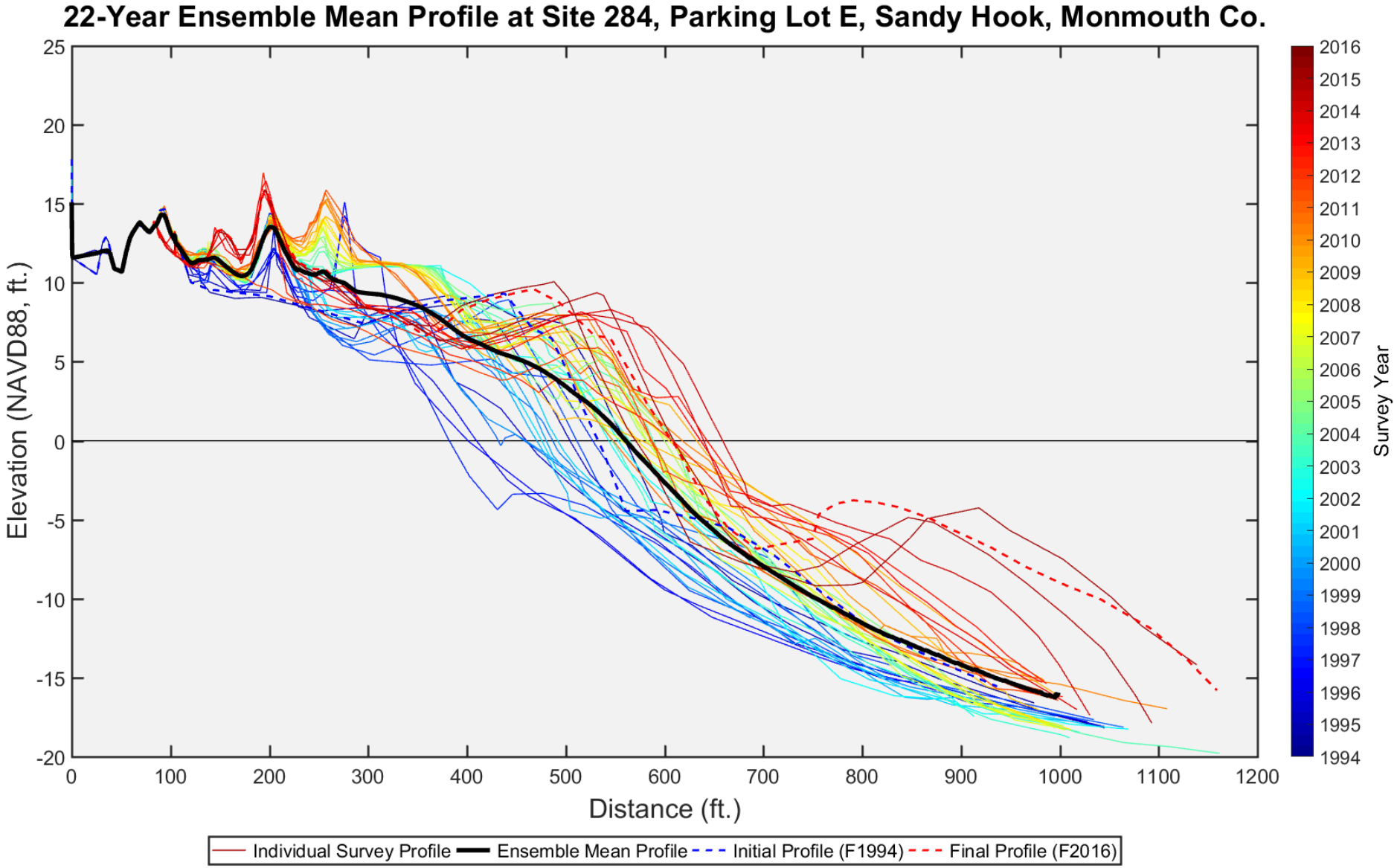

Figure 31. The mid-National Seashore coastline also advanced seaward over 22 years since the site was established, but at a slower pace and less consistently as some times the shoreline retreated landward of prior locations. Here the mean profile position essentially bisects the envelope of all changes.

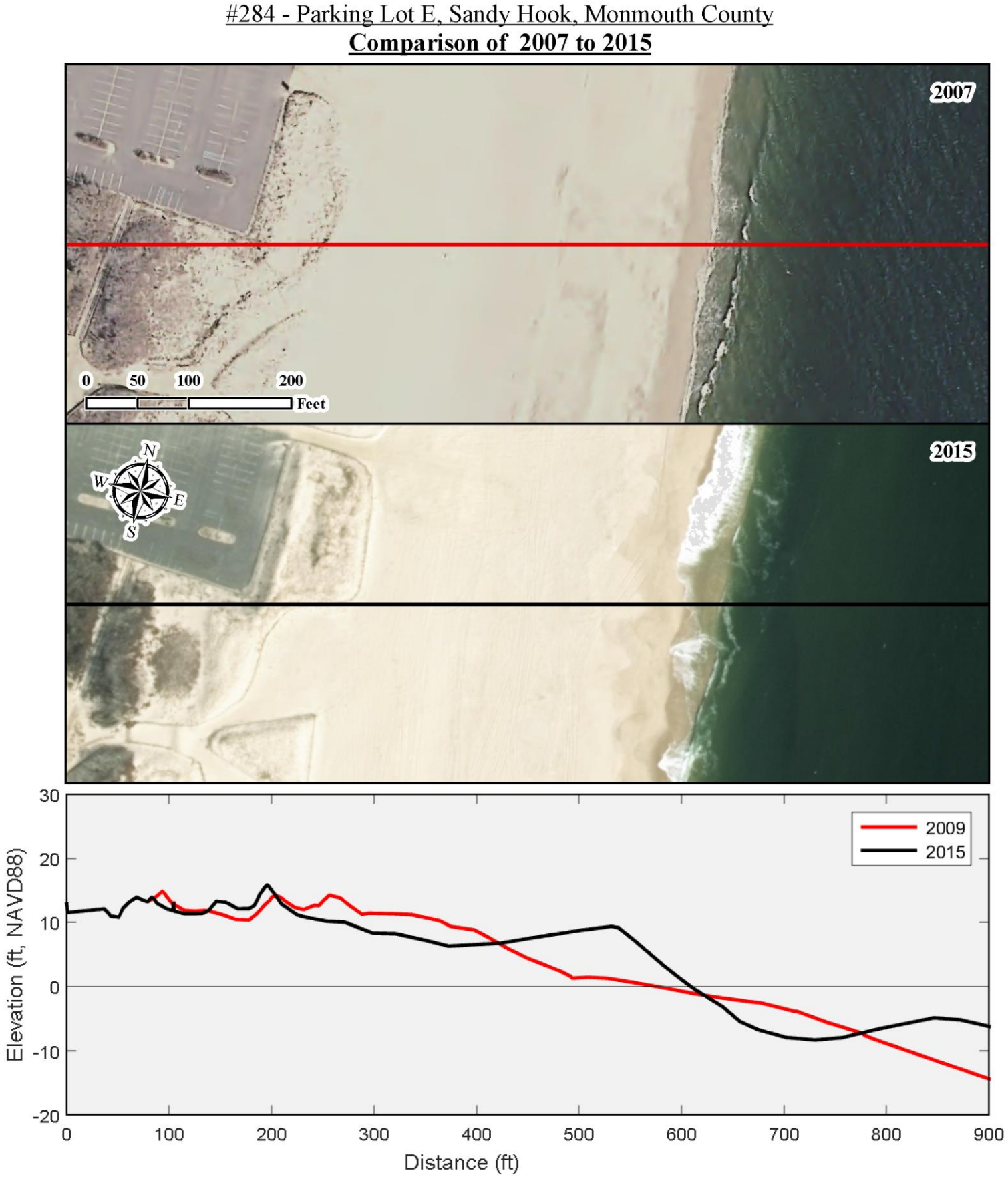

Figure 32. While the shoreline position has not changed too dramatically, the beach sand volume has increased all due to sand migration north along the Monmouth County shoreline from the federal shore protection project.

Figure 33. View to the south at the point where Route 36 crosses the Shrewsbury/Navesink Estuary entrance to Atlantic Highlands. This beach has remained in decent condition since 1995 as sand moved north through the site.

NJBPN 184 – Highlands Beach, Sandy Hook National Seashore


Figure 34a & 34b. Site 184 is located near the entrance to the Sandy Hook National Seashore and has experienced a gain in sand volume since the start of the federal shore protection project back in 1995. The left view was taken December 8, 2015 following a northeast storm eroding the beach. The December 5, 2016 view on the right shows sand recovery and a wider beach.

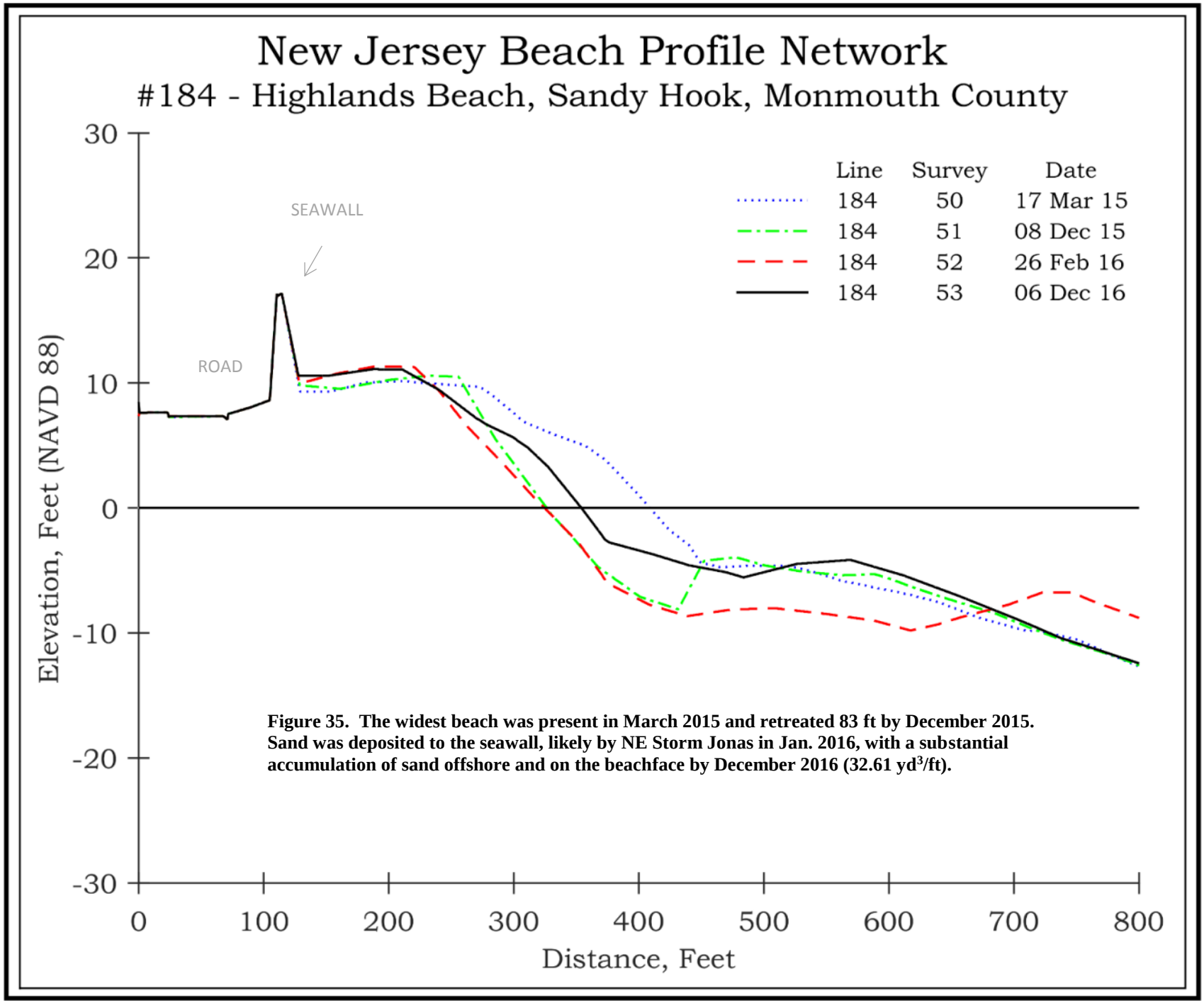

Figure 35. The widest beach was present in March 2015 and retreated 83 ft by December 2015. Sand was deposited to the seawall, likely by NE Storm Jonas in Jan. 2016, with a substantial accumulation of sand offshore and on the beachface by December 2016 (32.61 yd^3/ft).

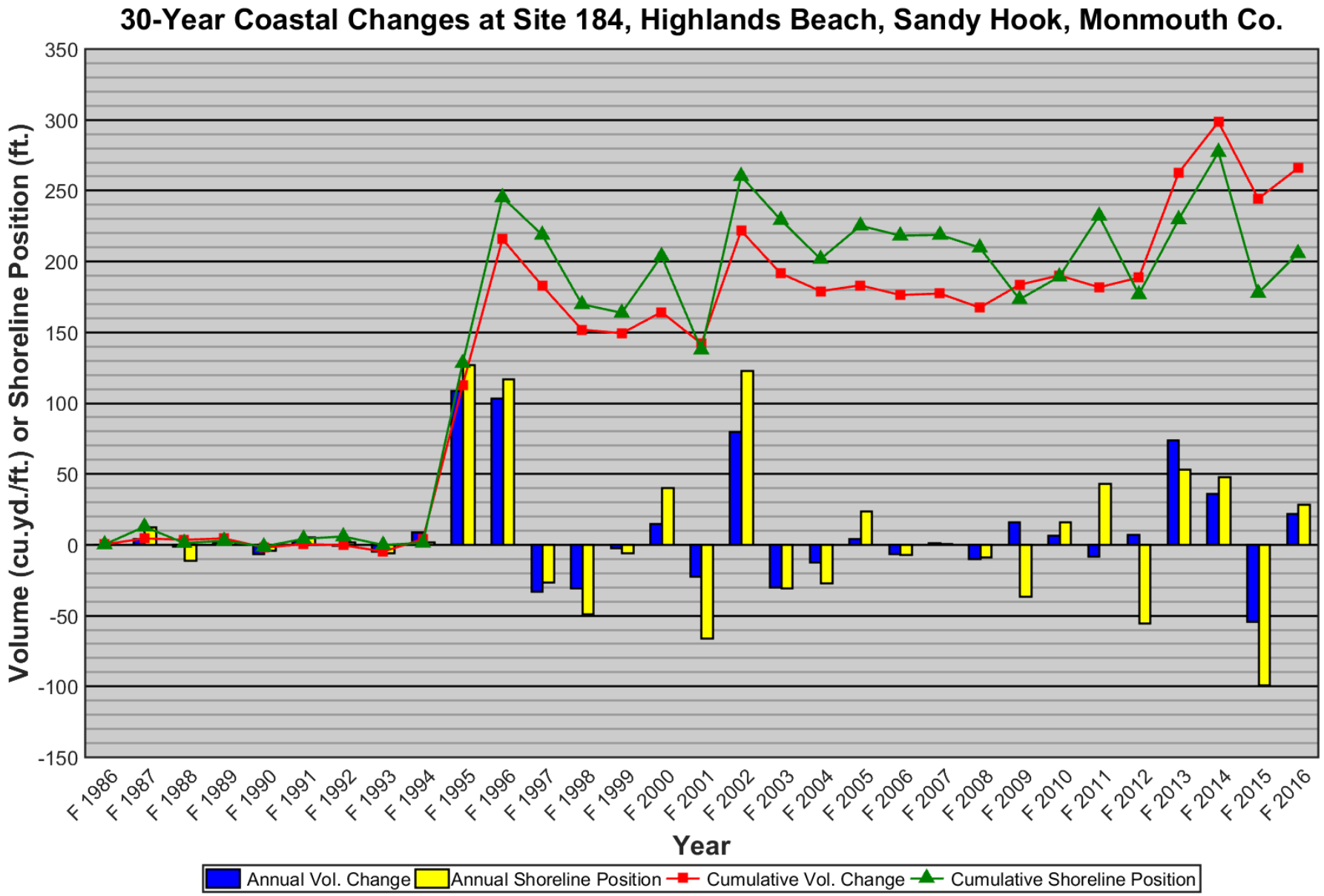

Figure 36. The pattern above showing minimal changes until the onset of the USACE project in 1995 is typical of most other Monmouth County sites moving south from here. The addition of about 265 yds^3/ft of beach produced a 205 ft shoreline advance. Maintenance occurred in 2002 and after Sandy in 2013.

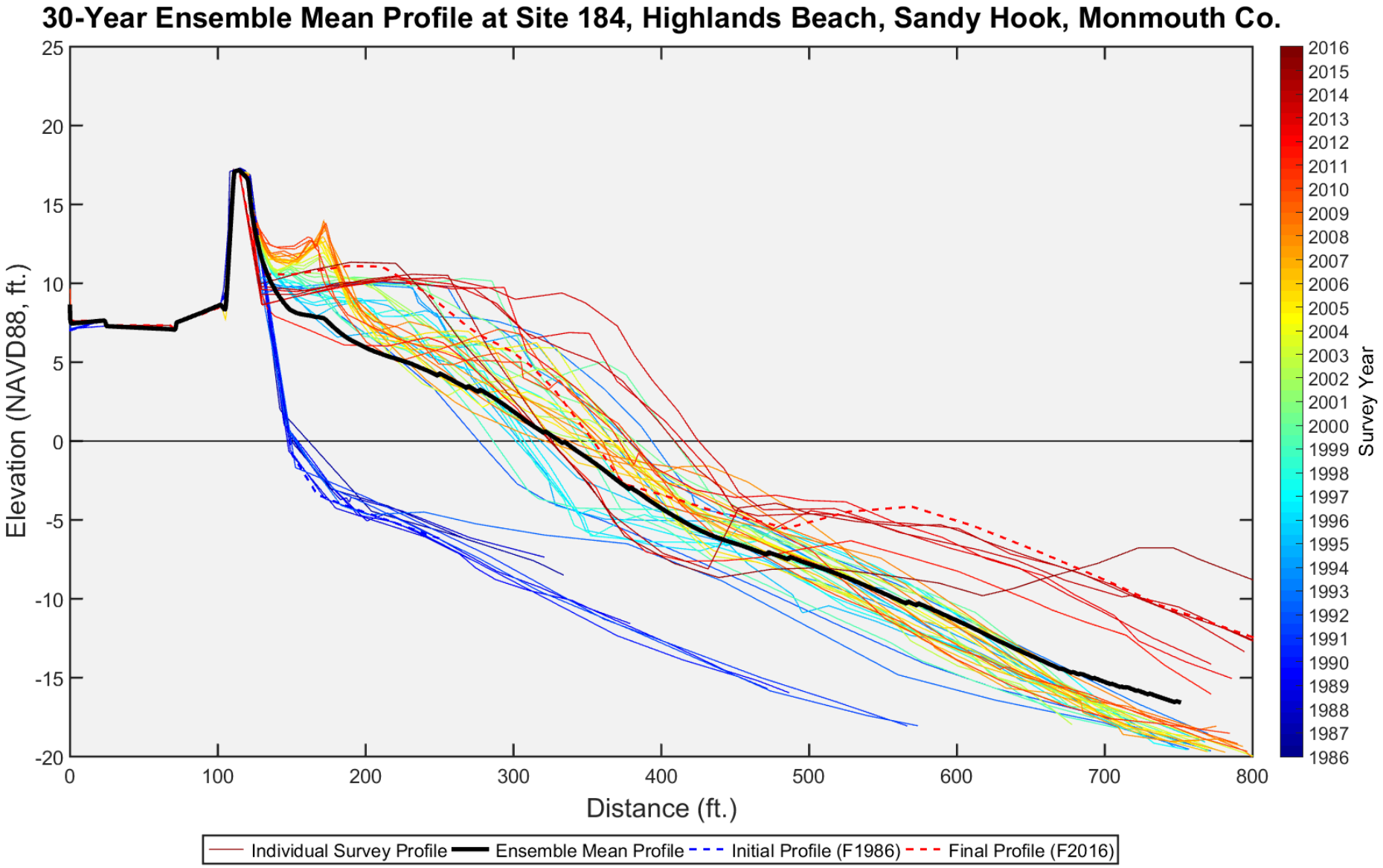

Figure 37. The Sea Bright beaches including this site at the National Seashore entrance all exhibit early profile conditions with little or no sand at the base of the rocks above the zero elevation position. Starting in 1995, the USACE project added 150 ft of beach width and raised the sand elevation to 8.5 ft as seen in the large shift in the position of the plotted cross sections by the mid 1990s. Since the project, the variation in profile shape has been considerable as sand moved north into the National Seashore. Maintenance shows in the latest profiles where the shoreline has advanced still further seaward.

#184 - Highlands Beach, Sandy Hook, Monmouth County

Comparison of 1995 to 2015

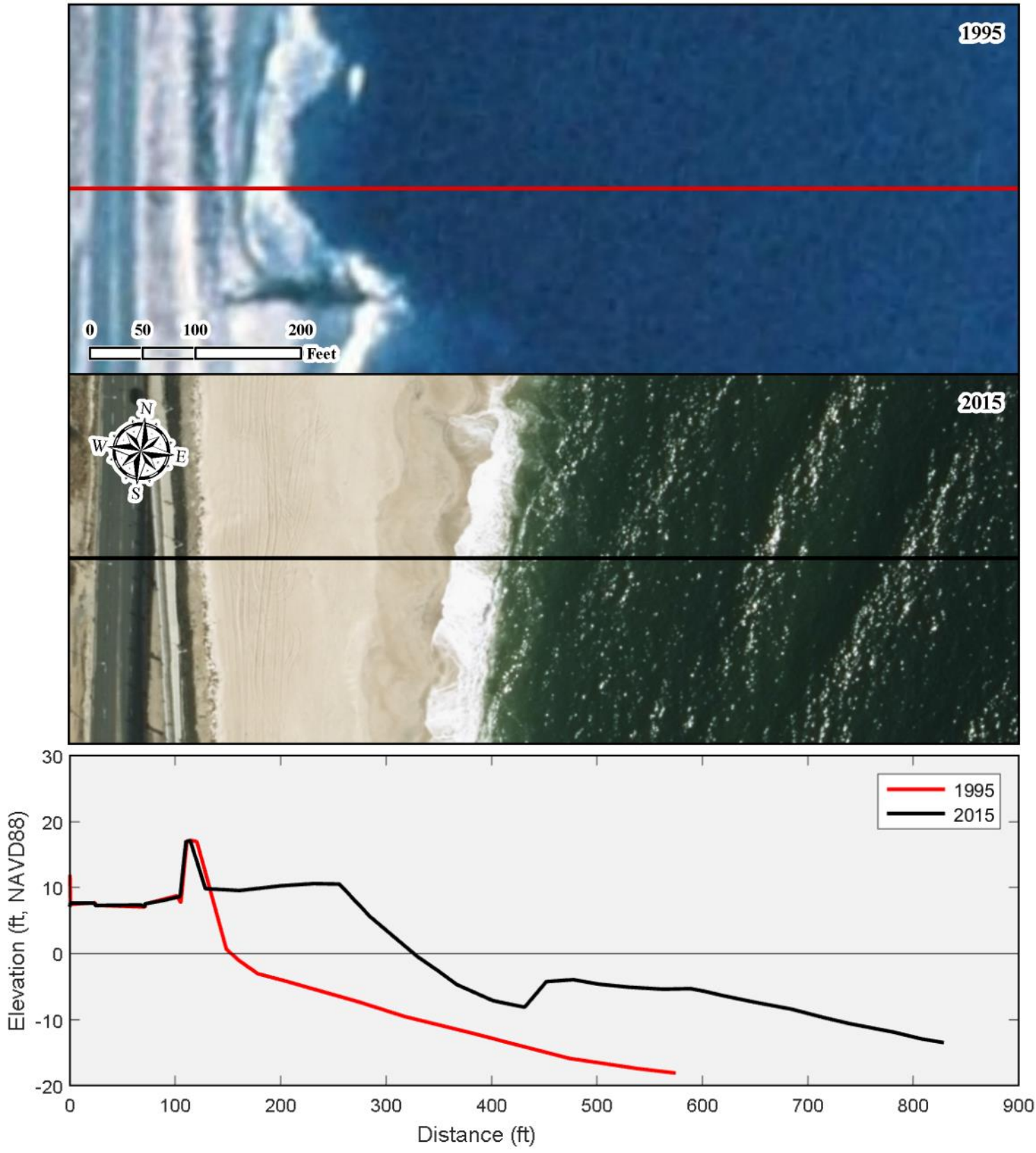

Figure 38. The federal project ended near this site and the effect was to generate a massive beach seaward of the rock seawall where water washed up onto the rocks directly in 1995.

Figure 39. Looking north along the dune crest at Via Ripa Street in Sea Bright. This site has not varied in either sand volume or shoreline position very much over time.

NJBPN 183 – Via Ripa Street, Sea Bright


Figure 40a & 40b. This site is near the northern limit of the initial Federal shore protection. The left side (Sept. 16, 2015) shows growth in the dune grass since sand was added to the site in 2014. The right view within the dune shows a stable beach as of December 6, 2016.

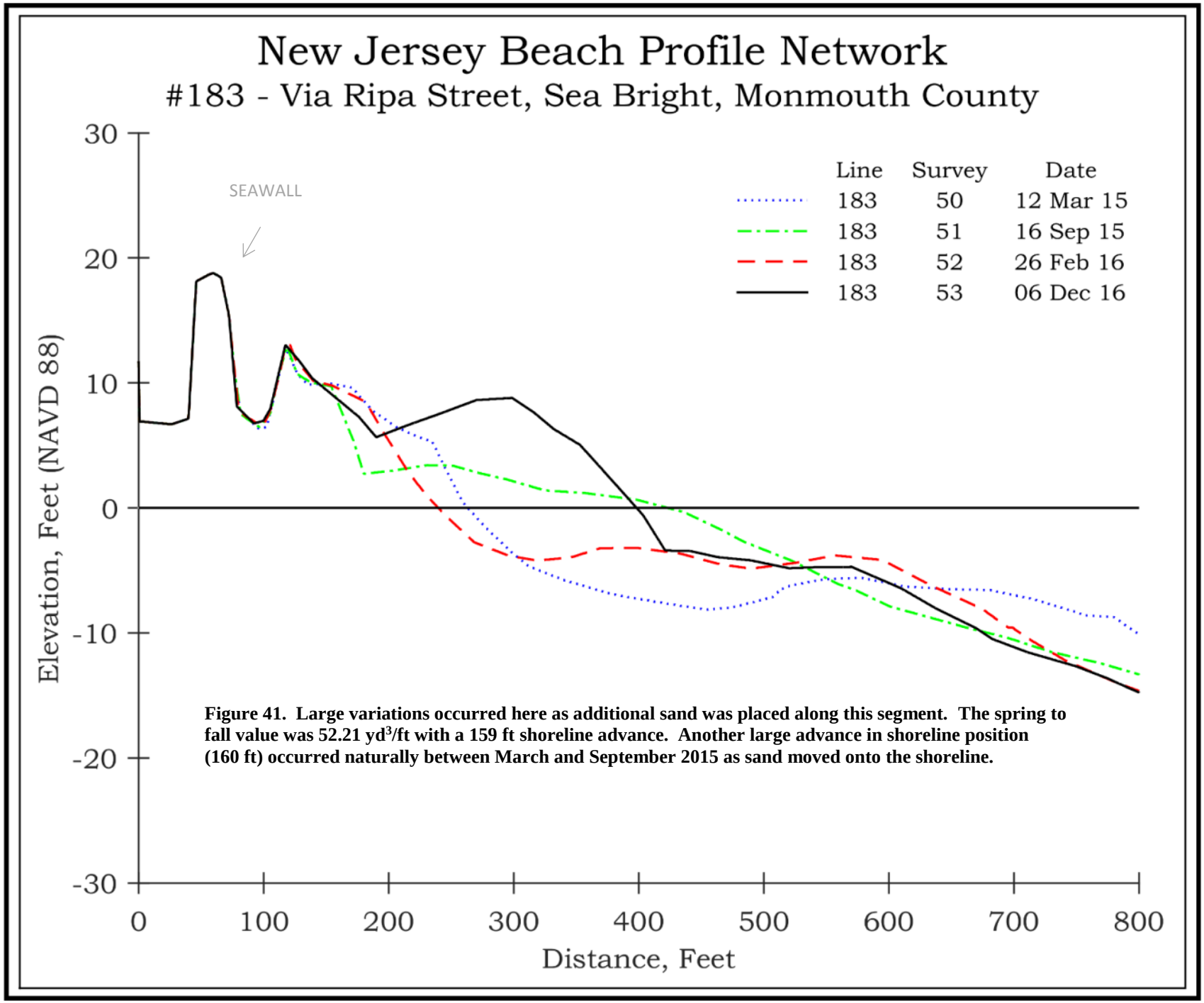

Figure 41. Large variations occurred here as additional sand was placed along this segment. The spring to fall value was 52.21 yd^3/ft with a 159 ft shoreline advance. Another large advance in shoreline position (160 ft) occurred naturally between March and September 2015 as sand moved onto the shoreline.

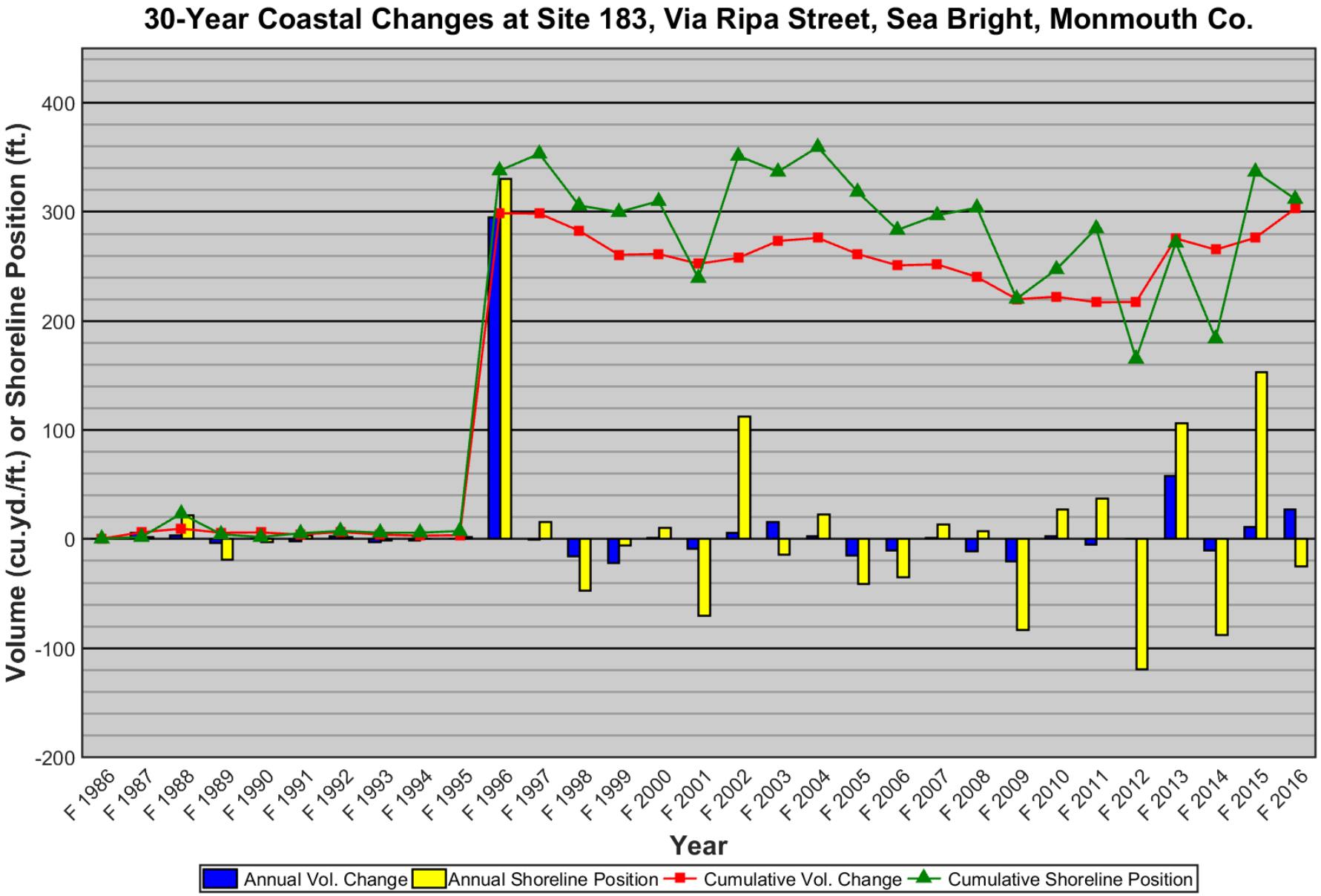

Figure 42. The pattern is one where the sand supply has varied by no more than 100 yds^3/ft of beach over 21 years since the beach fill was first completed in 1996. Maintenance occurred in 2002 and again in 2015 and overall, the site has remained very stable.

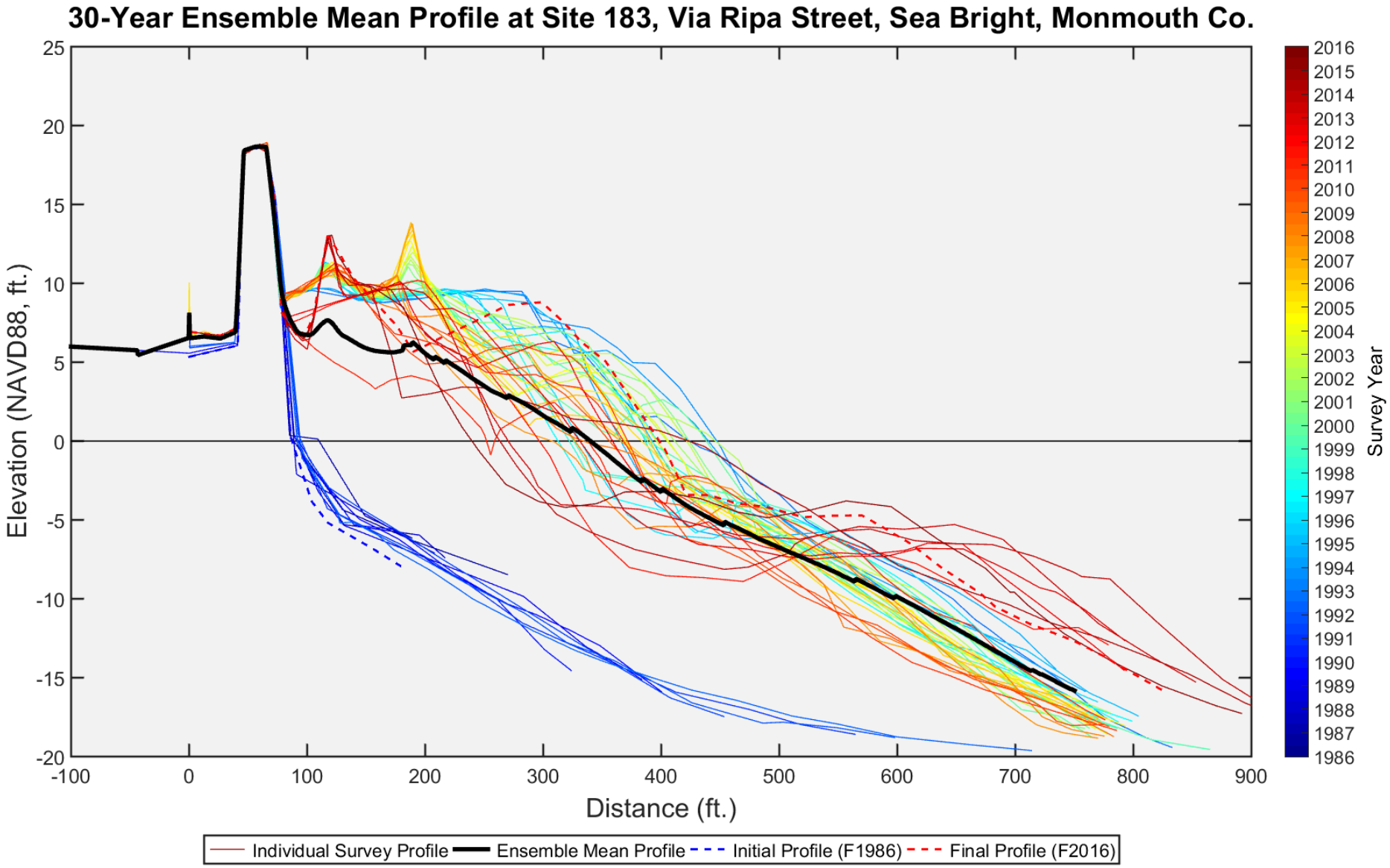

Figure 43. Via Ripa Street was another site with no sand seaward of the seawall above zero elevation NAVD88. The USACE project greatly enhanced this beach and the envelope of change is a bit smaller than site 184 to the north, but remains at or near the design specifications.

#183 - Via Ripa Street, Sea Bright Borough, Monmouth County

Comparison of 1995 to 2015

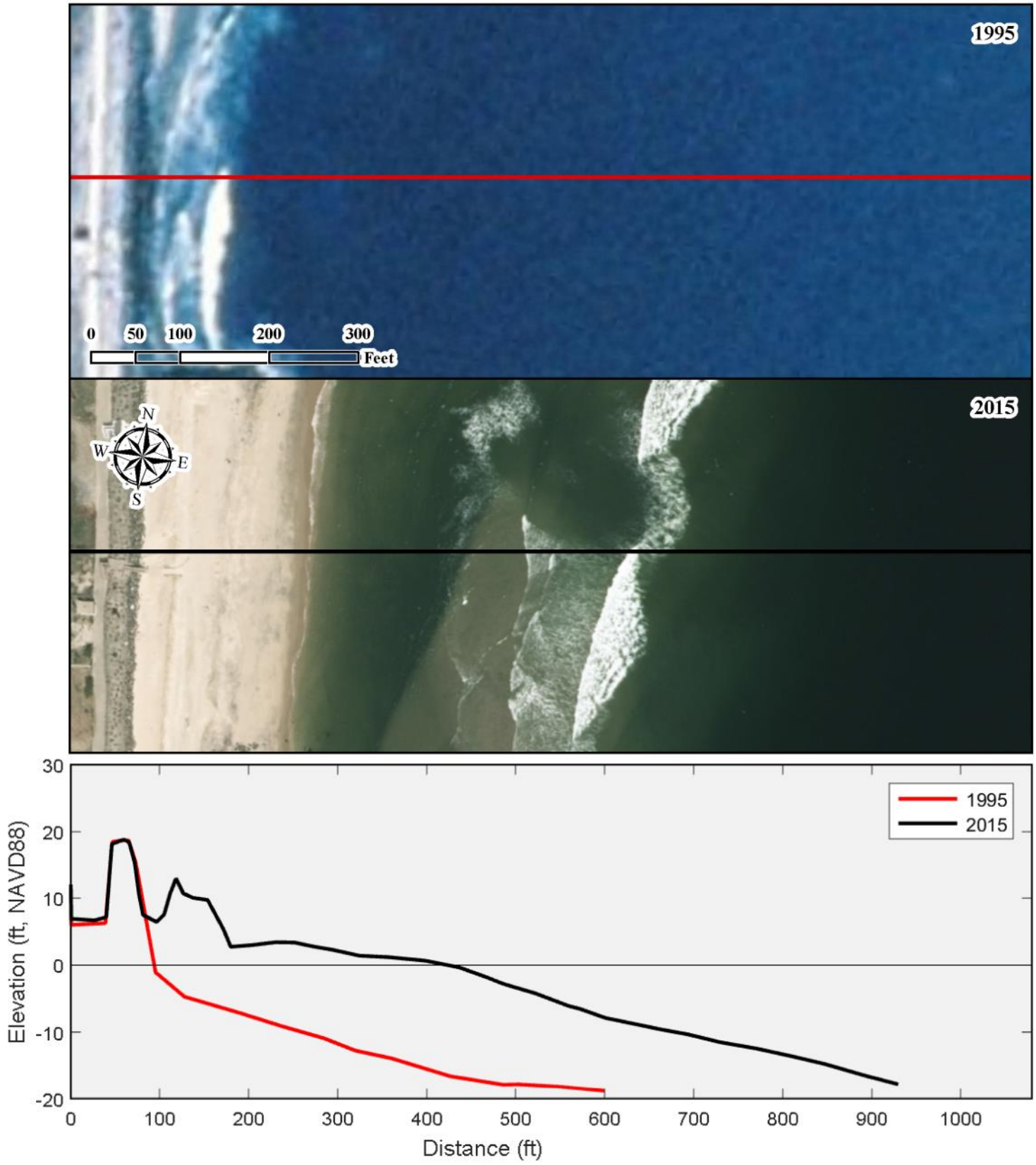

Figure 44. This was a second site where, prior to the shore protection project, there was no sand beach at the base of the seawall

Figure 45. Looking south along the dune crest at Shrewsbury Way in Sea Bright. This site has maintained beach width and shoreline position since Hurricane Sandy.

NJBPN 282 – Shrewsbury Way, Sea Bright


Figure 46a & 46b. The left view shows the restoration of this project design cross section a year after completion (September 16, 2015) with the similar view taken December 6, 2016 (right) that demonstrates no dramatic changes.

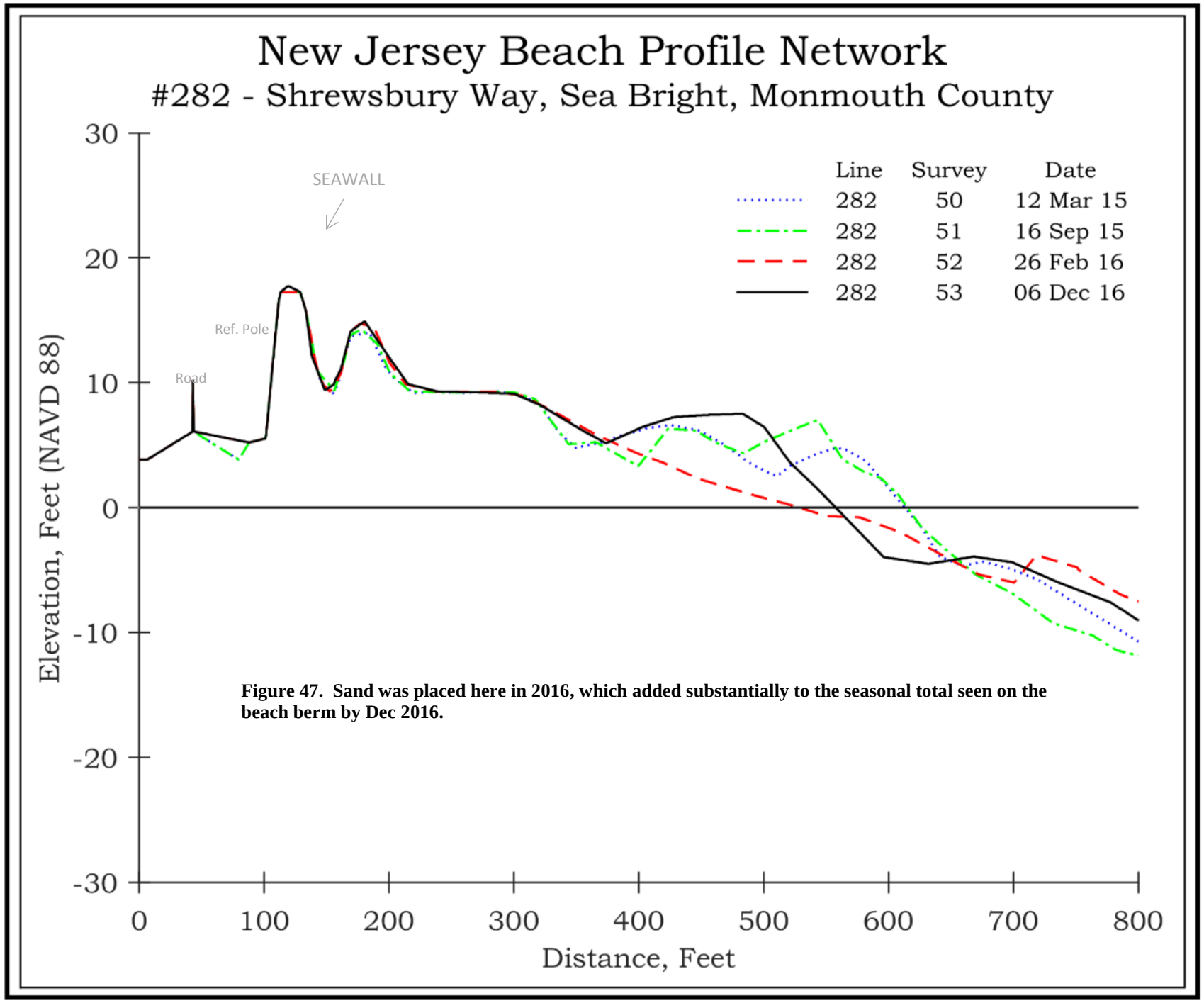

Figure 47. Sand was placed here in 2016, which added substantially to the seasonal total seen on the beach berm by Dec 2016.

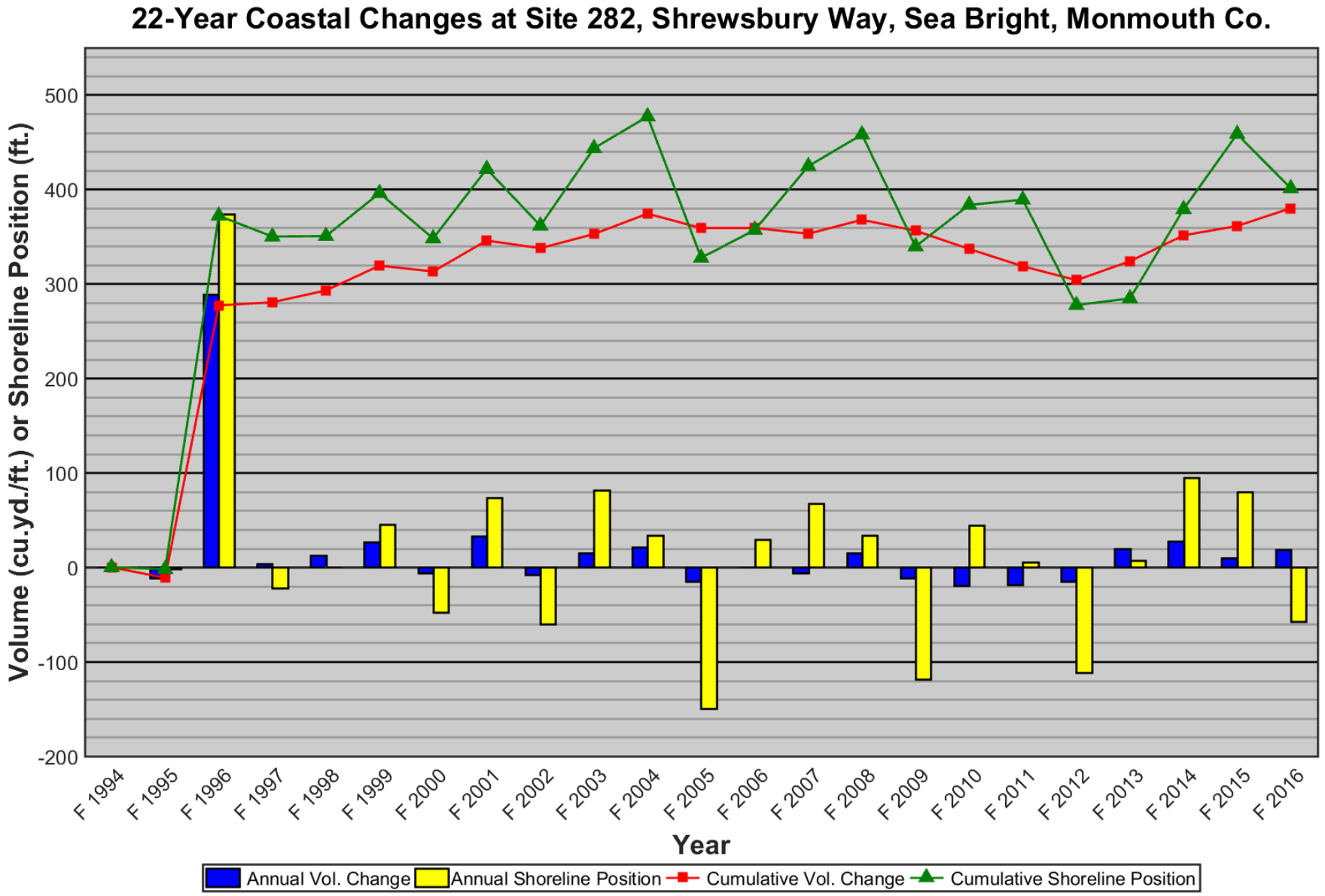

Figure 48. Established just prior to the Monmouth County project, there is a shorter interval prior to sand placement in 1996. This site had the distinction of being the most accretive of any of the Monmouth County sites. It has remained at over 100% of initial sand placement volume regardless of local events, including Hurricane Sandy, since inception. 290 yds^3/ft of sand was placed in 1996 and in 2004, 2008 and 2016 the percentage of sand retained was 133% of the initial volume, with a final shoreline change of about 400 ft.

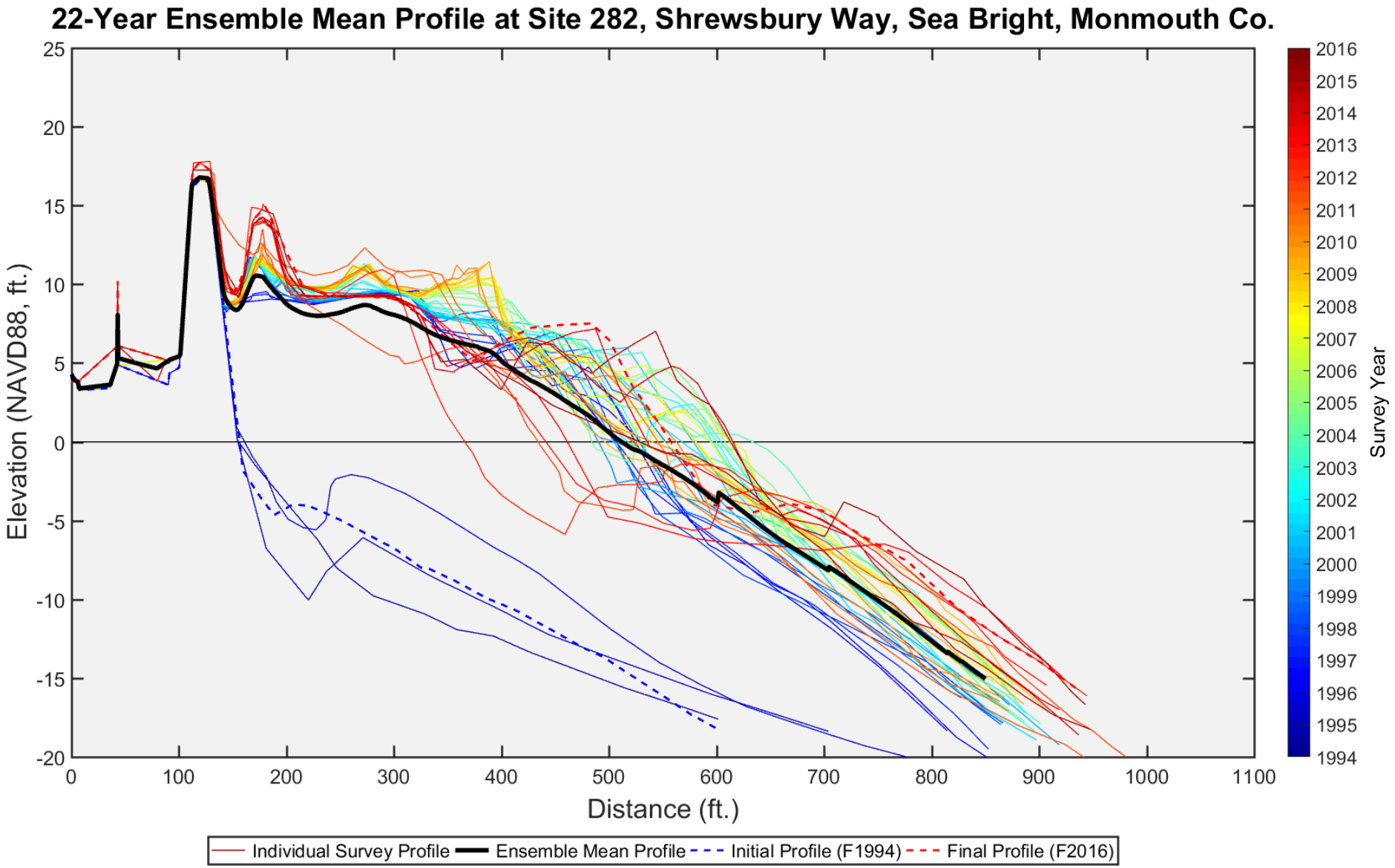

Figure 49. Since this site was established in a gap in the original survey locations, there are fewer pre-USACE project surveys. This site displays minimal variation in profile shape after the project fill in 1996 and retains an equilibrium sand volume approximating the design cross sections specifications. Volumes at this site have remained above the placement sand volumes since the initial project was completed in 1996.

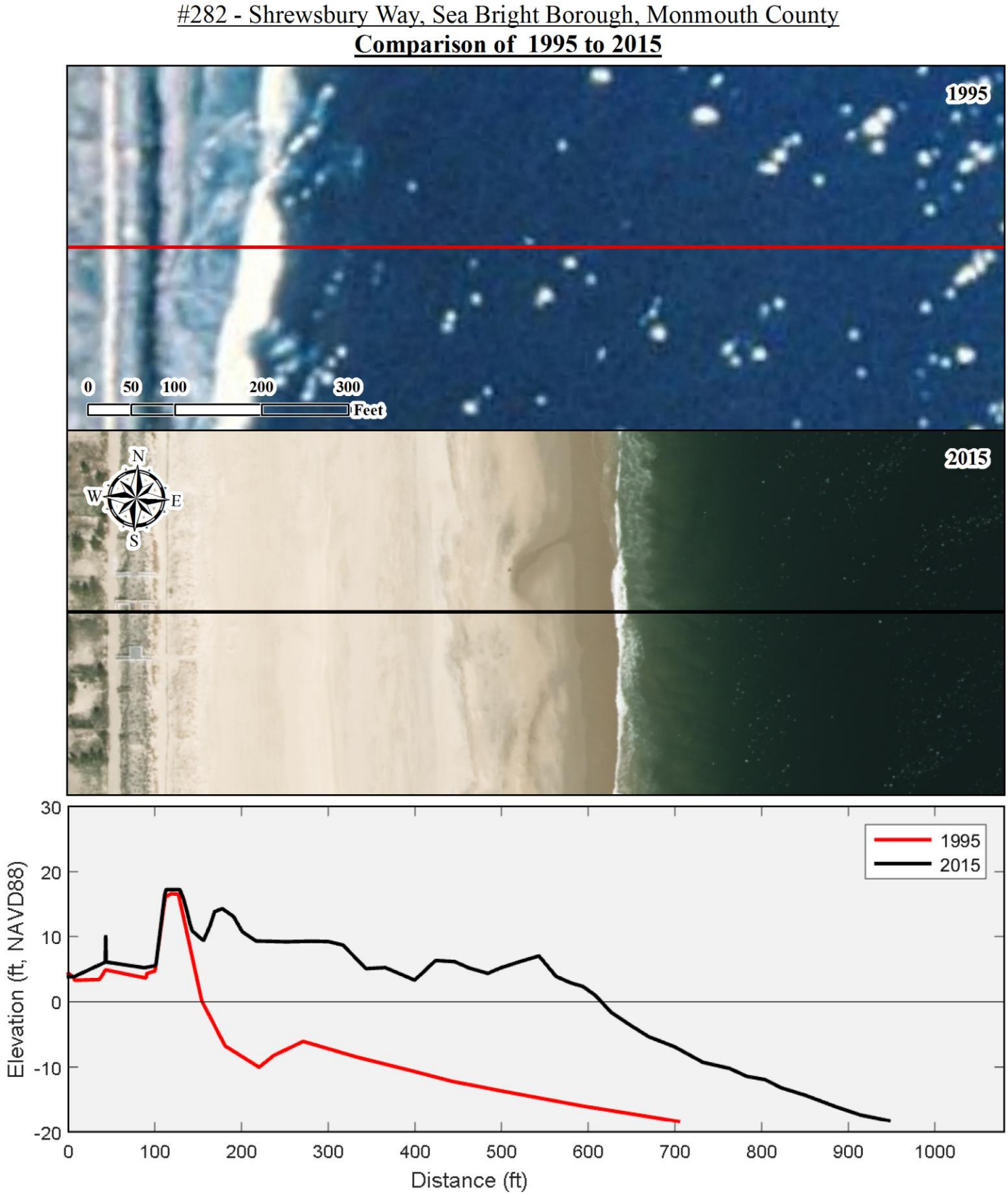

Figure 50. No beach existed at Shrewsbury Way in 1995. Following the federal project in 1996 the zero elevation shoreline moved about 500 ft seaward and a dune developed on the profile.

Figure 51. View to the north along the upper beachface at the public beach in Sea Bright. This site was severely impacted by Sandy and has recovered.

NJBPN 182 – Public Beach, Sea Bright

Figure 52a & 52b. The dune redeveloped following the 2014 beach restoration and by Sept. 16, 2015 was well vegetated with a wide, dry sand beach seaward shown by the view to the north including the fencing that defines the property line (left photo). By December 2, 2016 (right photo) the beach was a bit narrower, but within design limits as to width and sand volume.

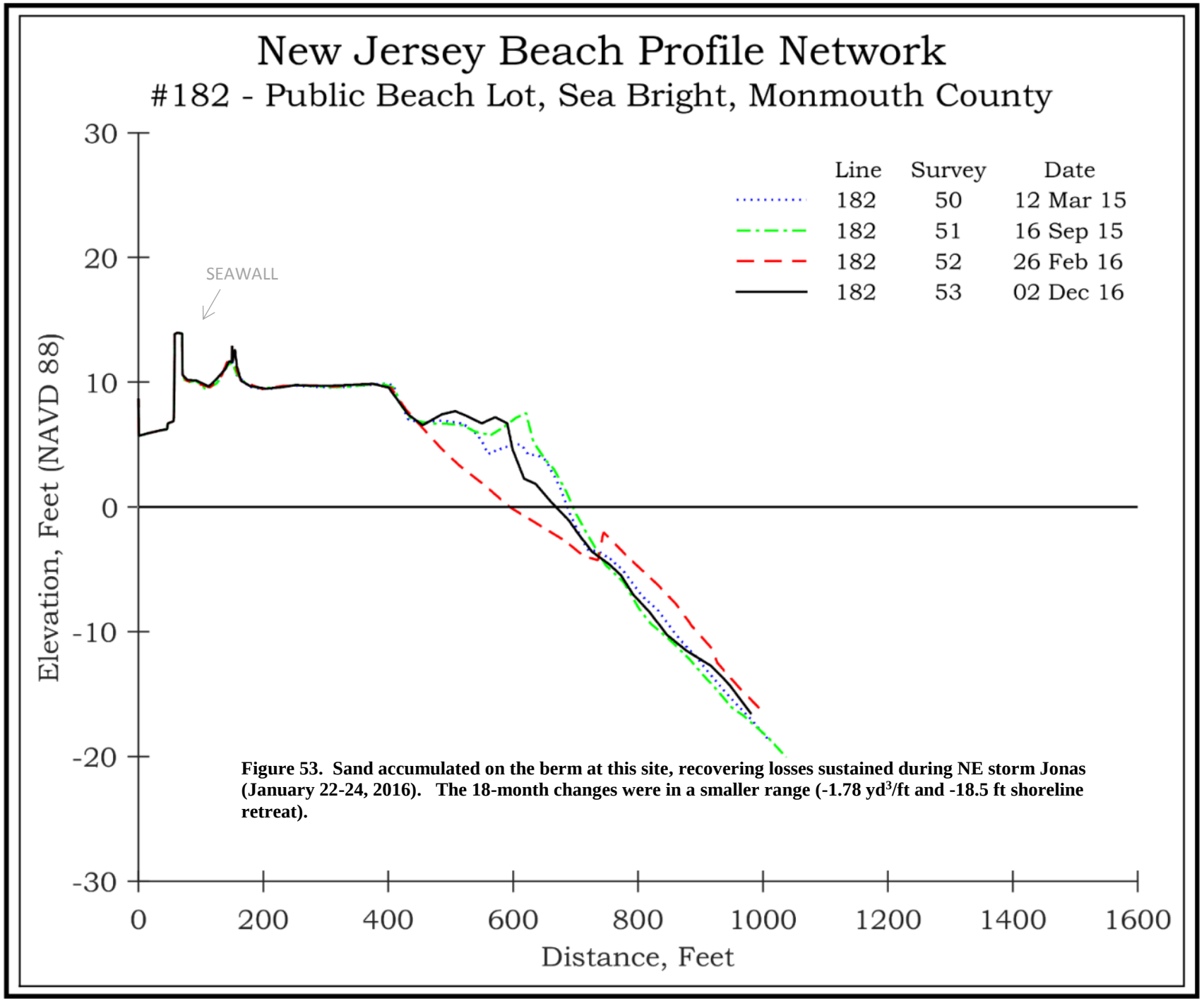

Figure 53. Sand accumulated on the berm at this site, recovering losses sustained during NE storm Jonas (January 22-24, 2016). The 18-month changes were in a smaller range (-1.78 yd^3/ft and -18.5 ft shoreline retreat).

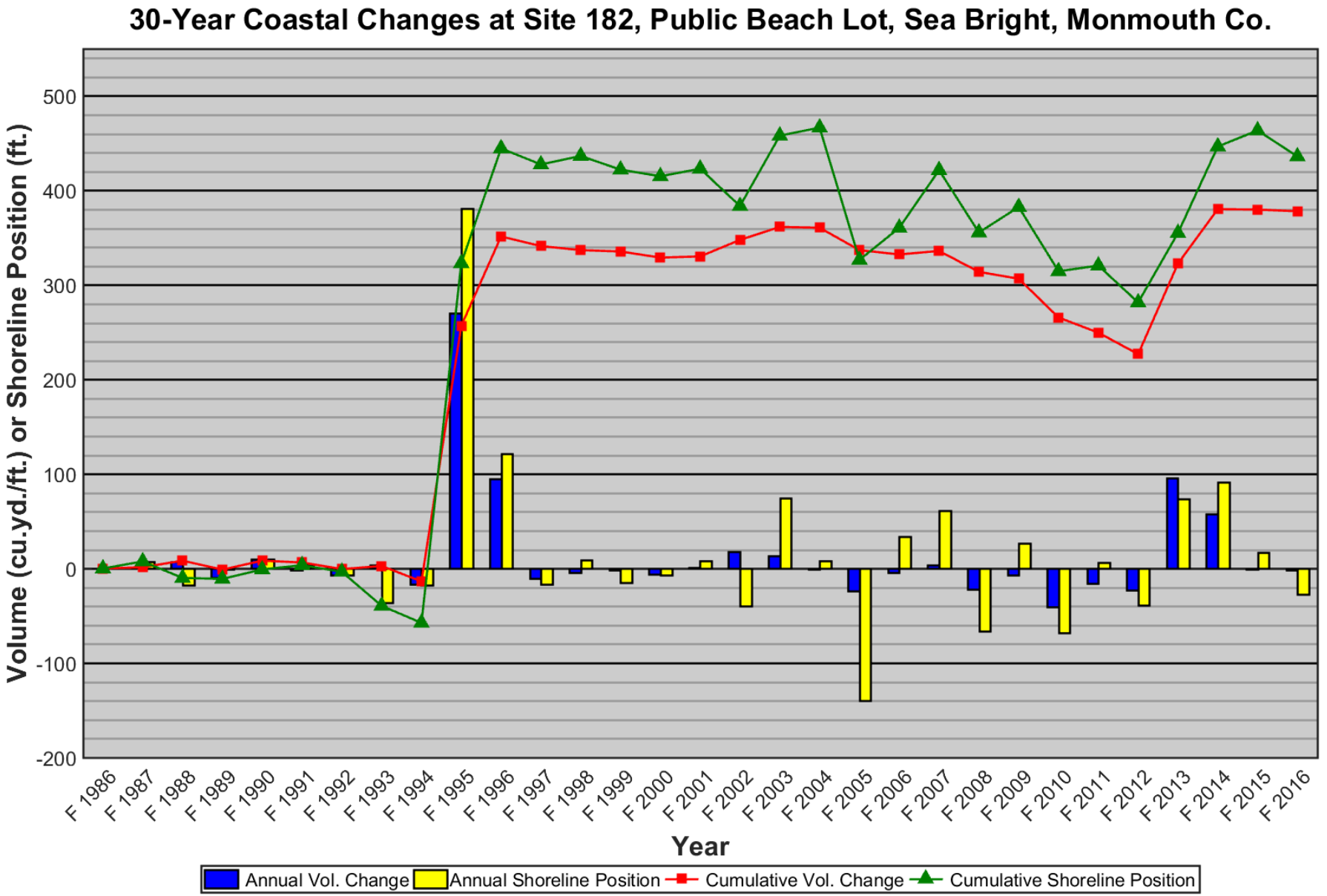

Figure 54. This site received sand in 1995 and maintained a steady consistency over the next decade. Loss commenced in 2005 so that by 2012 the site was slightly below the sand volume placed in 1995. Restoration in 2013 brought the cumulative sand volume to about 380 yds^3/ft and a shoreline change of almost 440 ft seaward from 1986 to 2016.

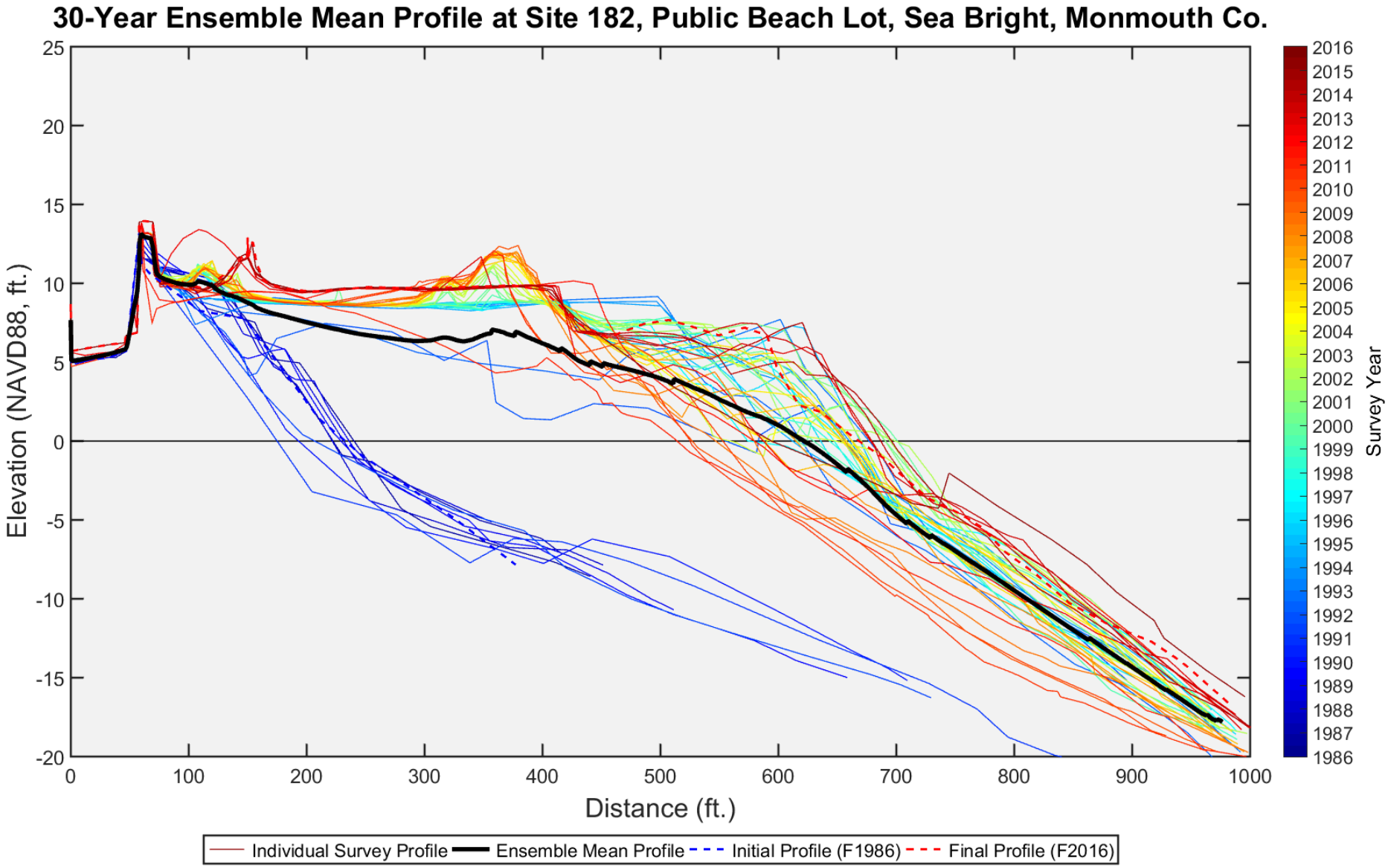

Figure 55. The public beach in Sea Bright also retains a stable sand volume over time. The early plots show sand on the beach seaward of the wall extending about 100 ft from the base of the wall. The USACE project improved this condition by adding an average of 450 ft to this distance. The recent maintenance fill shows as red cross sections restoring the width from the 2006-07 era conditions.

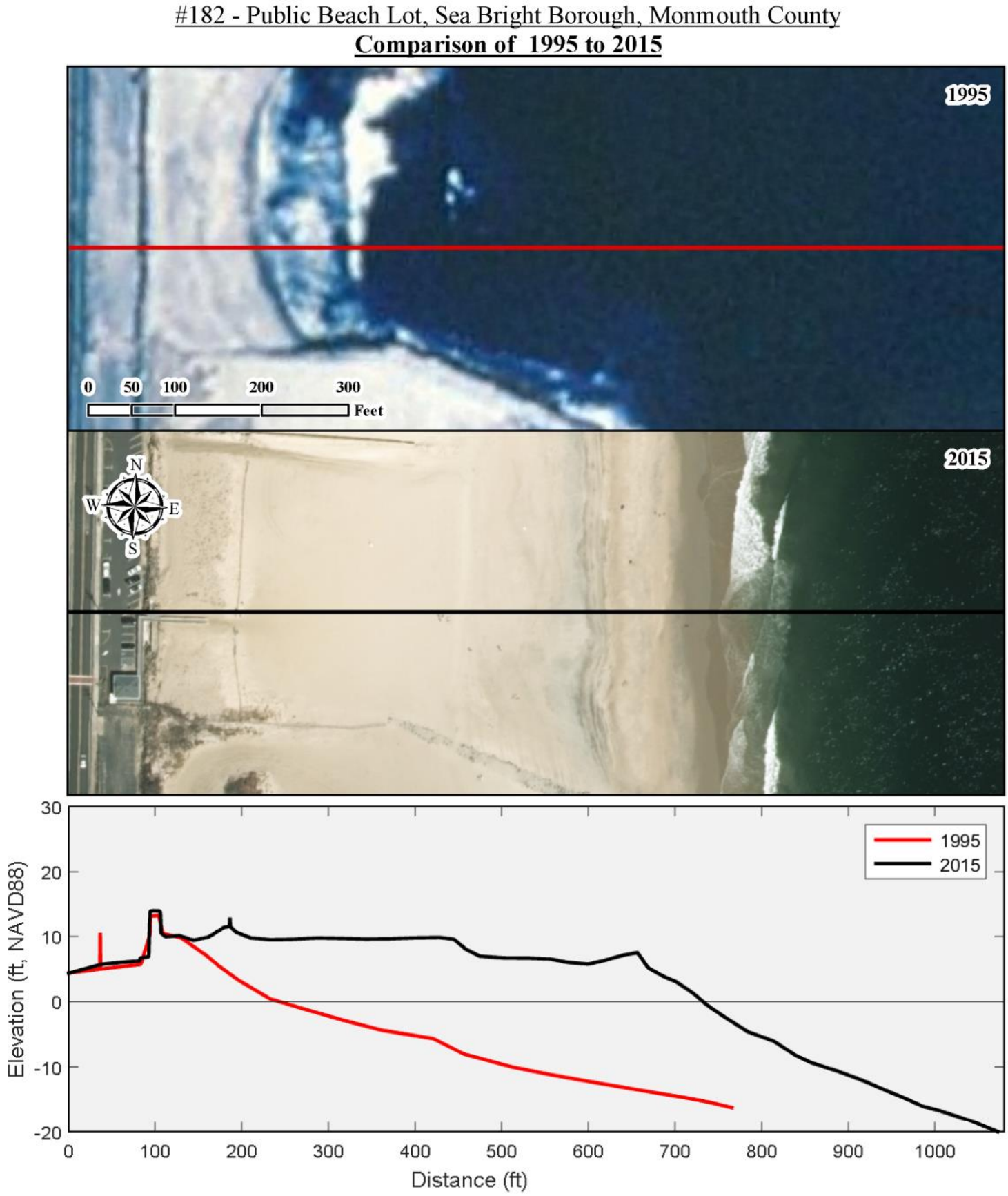

Figure 56. The change due to the federal project is extremely evident in this figure in which the end of the 1995 cross-section in 16 ft of water lies approximately at the shoreline (or zero elevation) position of the 2015 cross-section. This displays a shoreline change of about 500 ft in 20 years.

Figure 57. The Sea Bright municipal beach was badly damaged during Hurricane Sandy largely due to the gap in the seawall that allowed direct wave entry into the business district.

NJBPN 181 – Municipal Beach, Sea Bright

Figure 58a & 58b. The view one year following beach maintenance after Sandy (left photo taken Dec. 3, 2015) shows the wide dry beach seaward of the new dunes and the deck and access ramp to the beach. As of December 2, 2016 (right photo) the beach was in similar condition with a storm ridge of sand on the beach created to impede wave action.

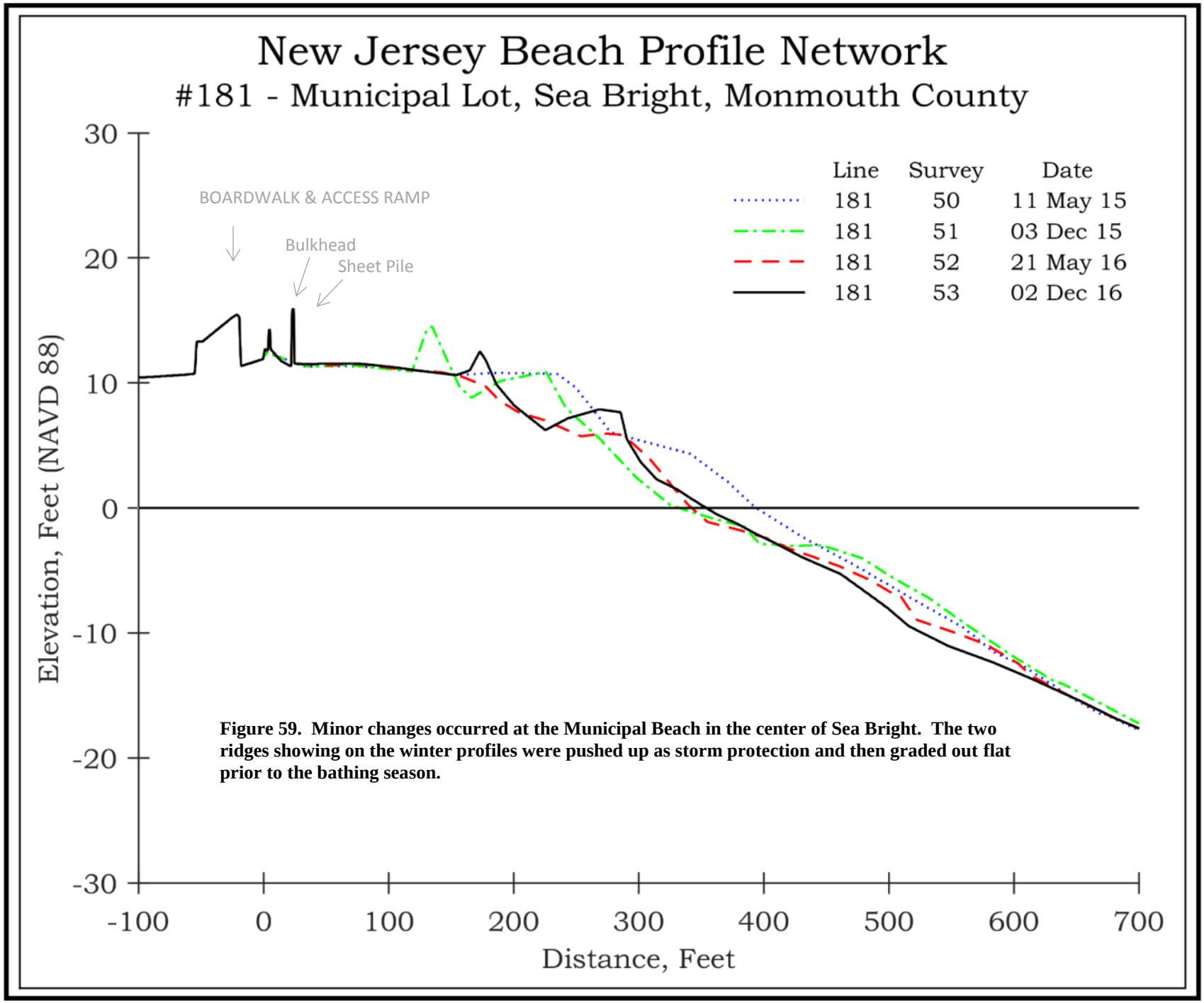

Figure 59. Minor changes occurred at the Municipal Beach in the center of Sea Bright. The two ridges showing on the winter profiles were pushed up as storm protection and then graded out flat prior to the bathing season.

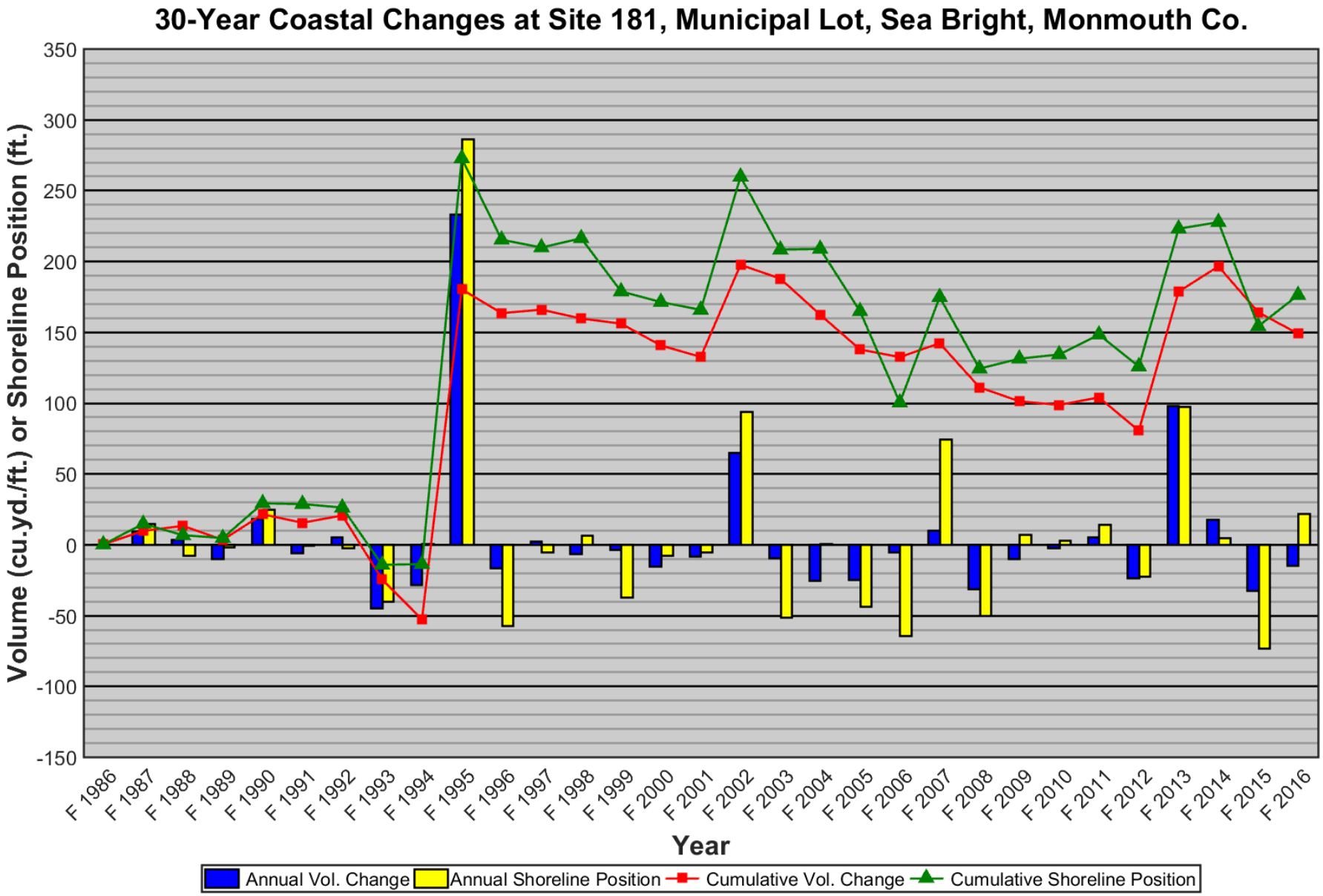

Figure 60. The municipal beach in the business district of Sea Bright suffered slow sand loss rates bouncing back in 2002 and in 2013 after maintenance work added more material. As of 2016 the site retained 84% of the initial sand placement volume.

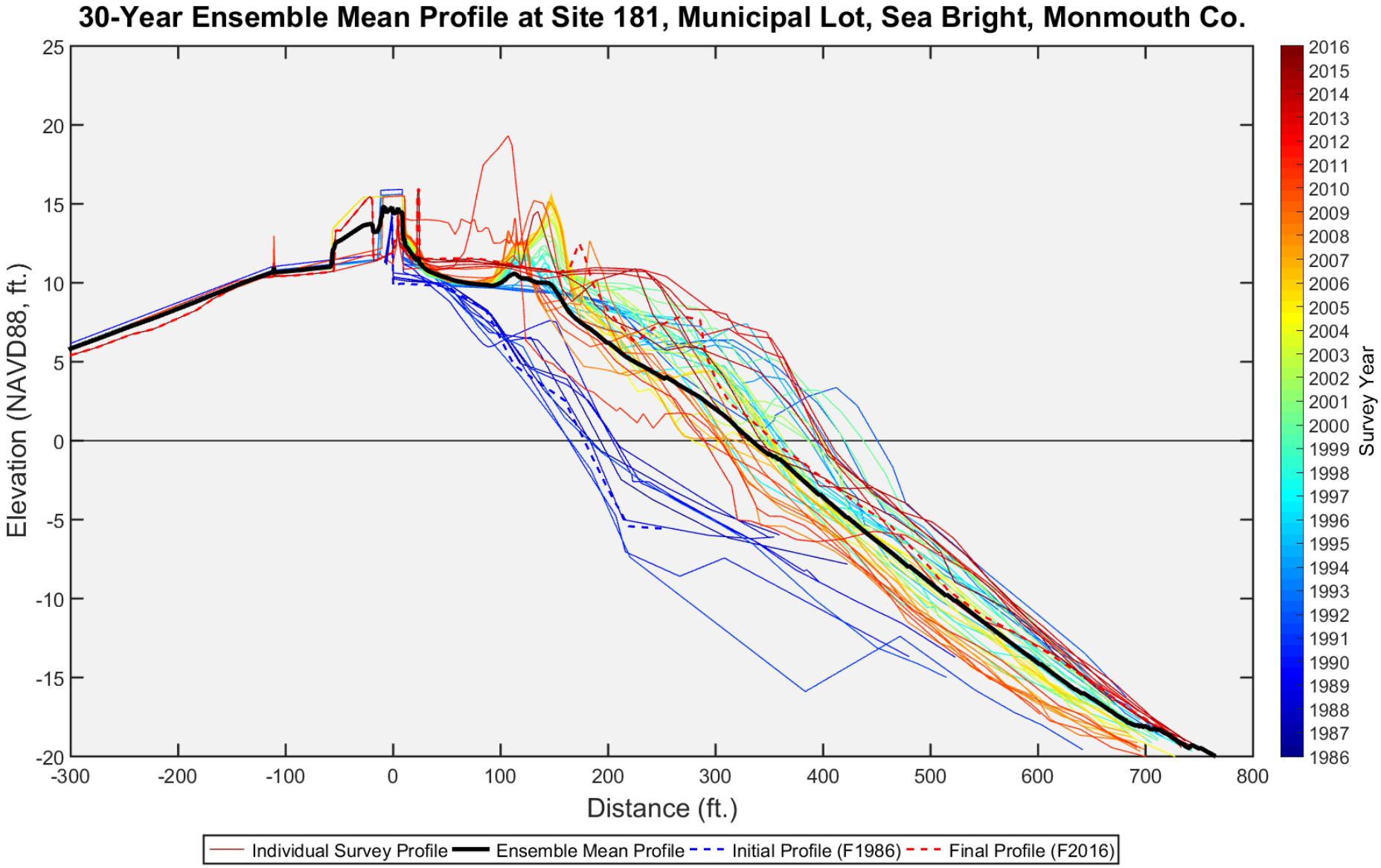

Figure 61. The municipal bathing beach originally had a narrow sand shoreline that the USACE project enhanced by 200 ft in width. The envelope of cross-sections since the project show variability and slow retreat followed most recently by the Hurricane Sandy restoration effort.

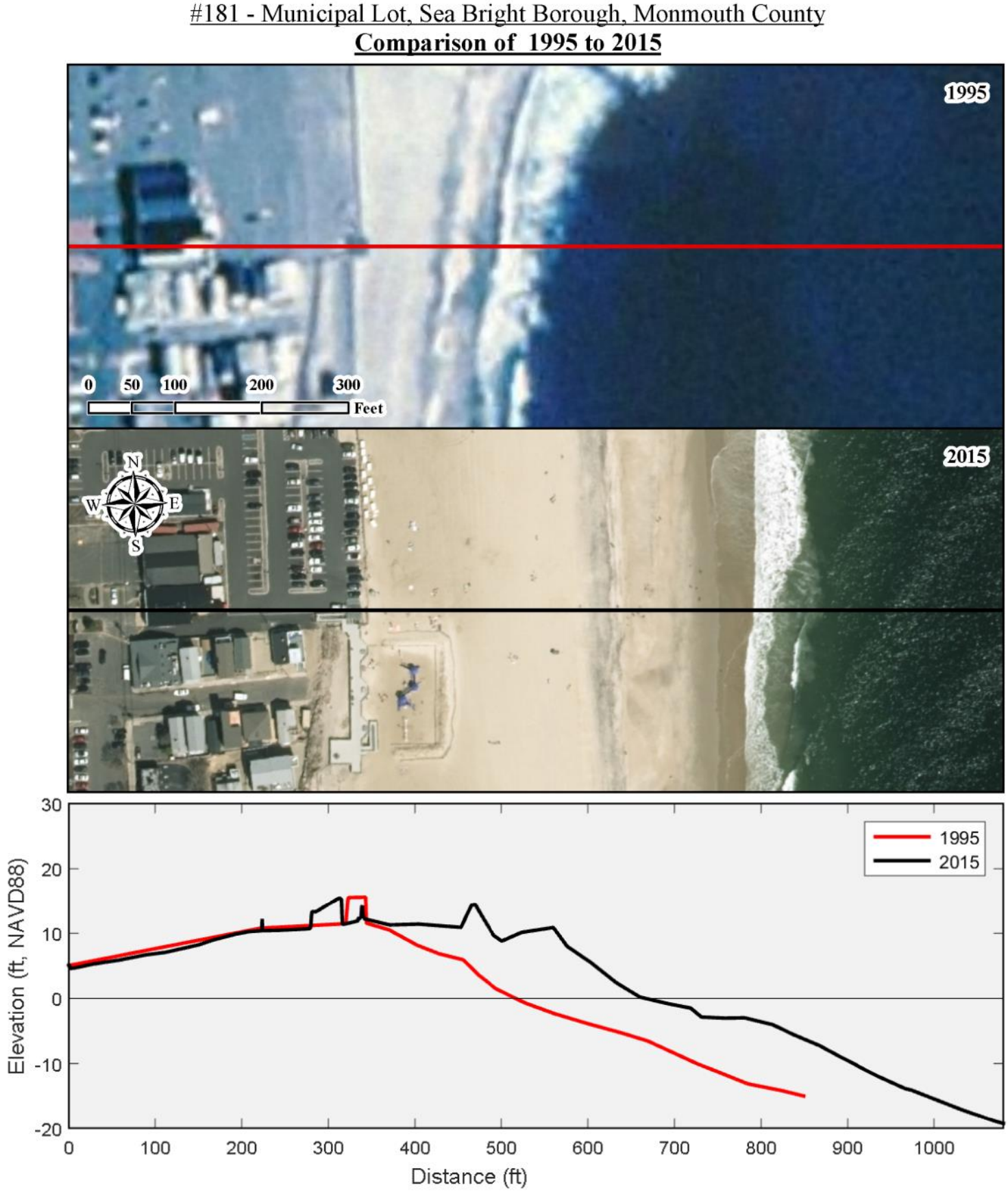

Figure 62. This figure shows that the public beach also saw a major increase in beach width due to the federal project.

Figure 63. View to the south along the crest of a dune developed seaward of the seawall in Sea Bright.

NJBPN 180 – Sunset Court, Sea Bright

Figure 64a & 64b. The restoration by the USACE had been completed in the left photo taken December 24, 2015 for 2 years, with the addition of 101.64 yds^3/ft to the profile's cross-section. A small dune was added by the summer of 2014 and has grown substantially since. The seaward slope was planted with dune grasses, and some grass has established naturally out on the dry beach seaward of the dune (right photo taken December 2, 2016).

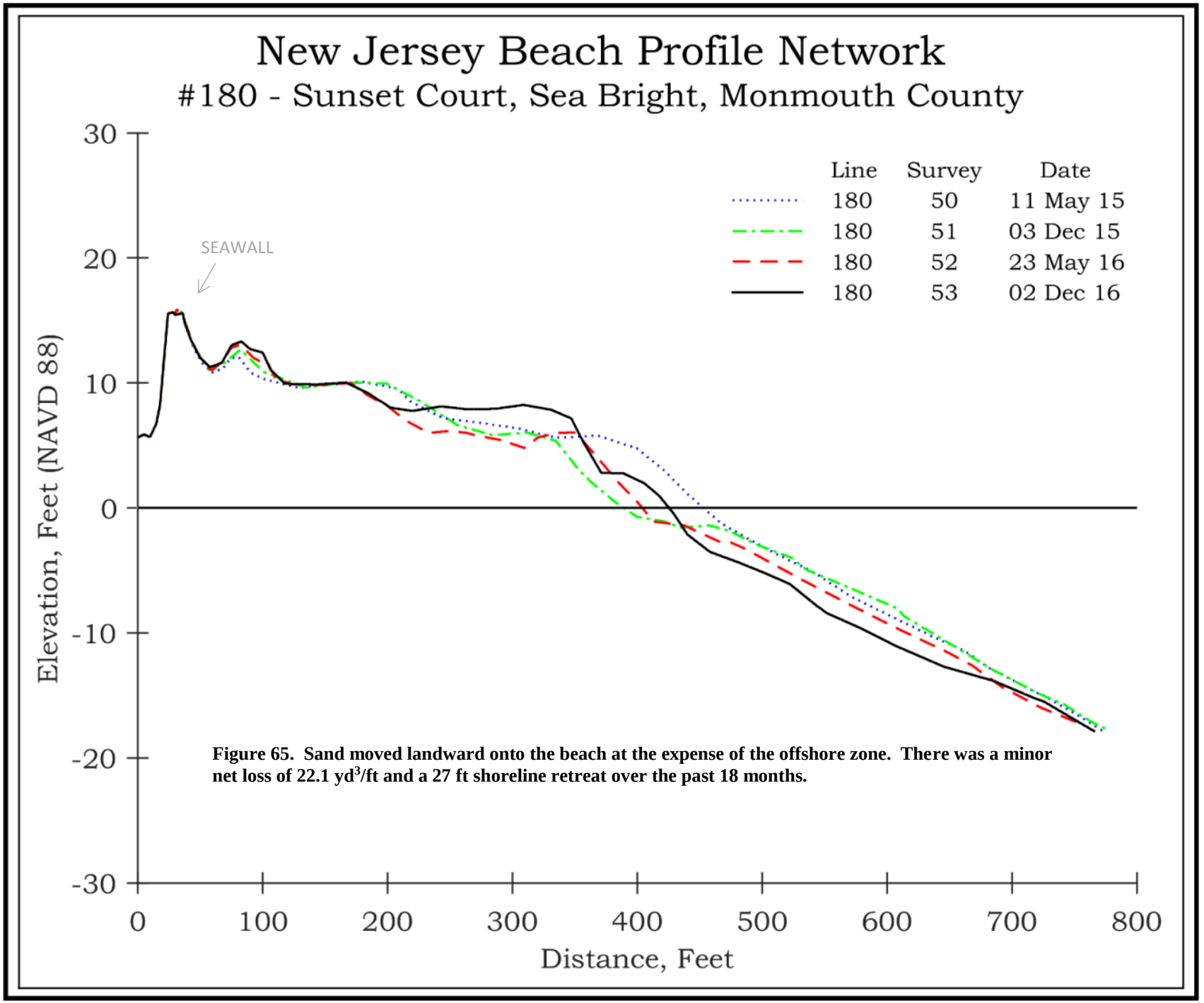

Figure 65. Sand moved landward onto the beach at the expense of the offshore zone. There was a minor net loss of 22.1 yd^3/ft and a 27 ft shoreline retreat over the past 18 months.

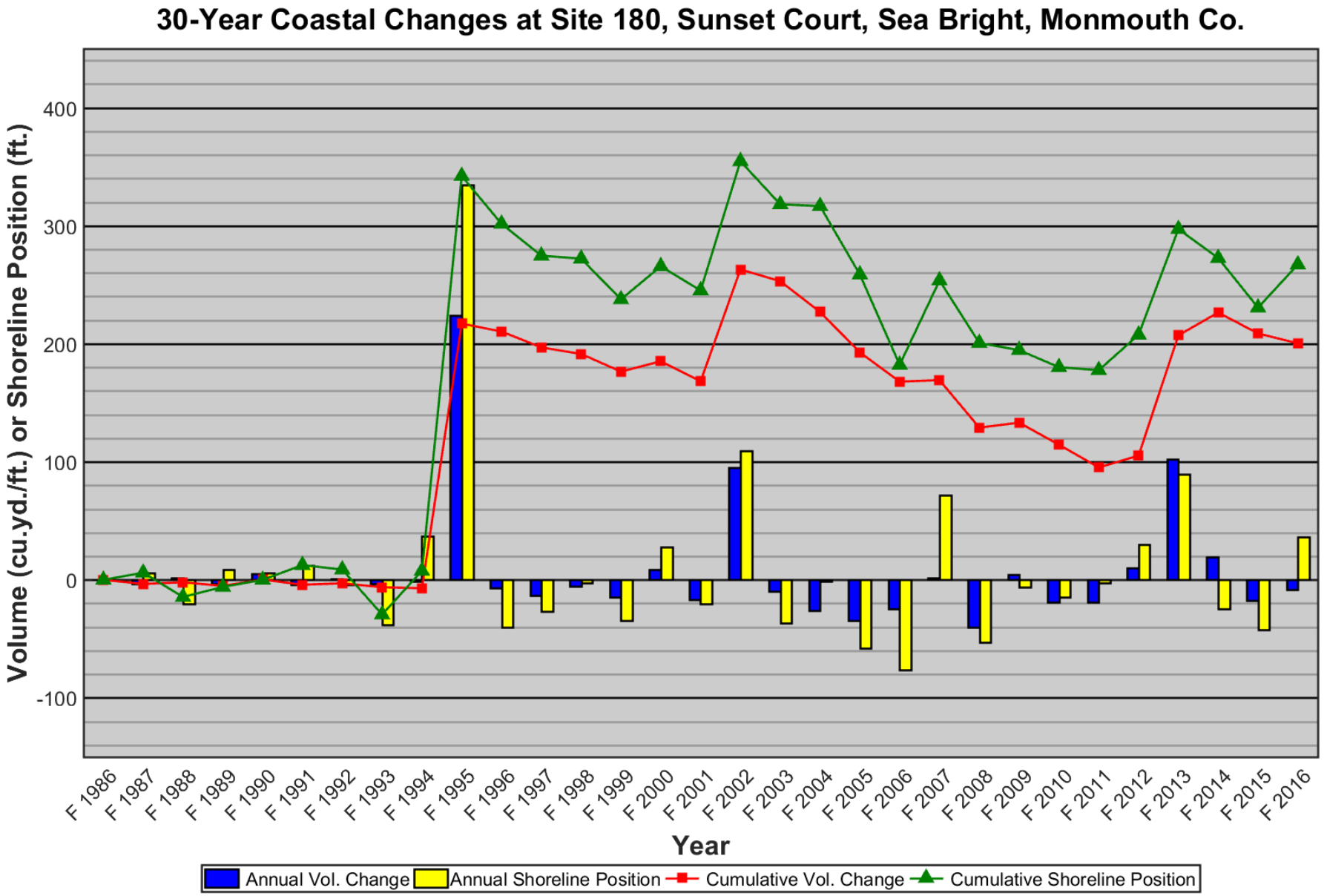

Figure 66. Moving south along the coastline and into Sea Bright, the rate of sand loss shows an increase as compared to sites to the north. The 2002 and 2013 maintenance efforts, however, were able to bring the site back to initial positions and sand volumes.

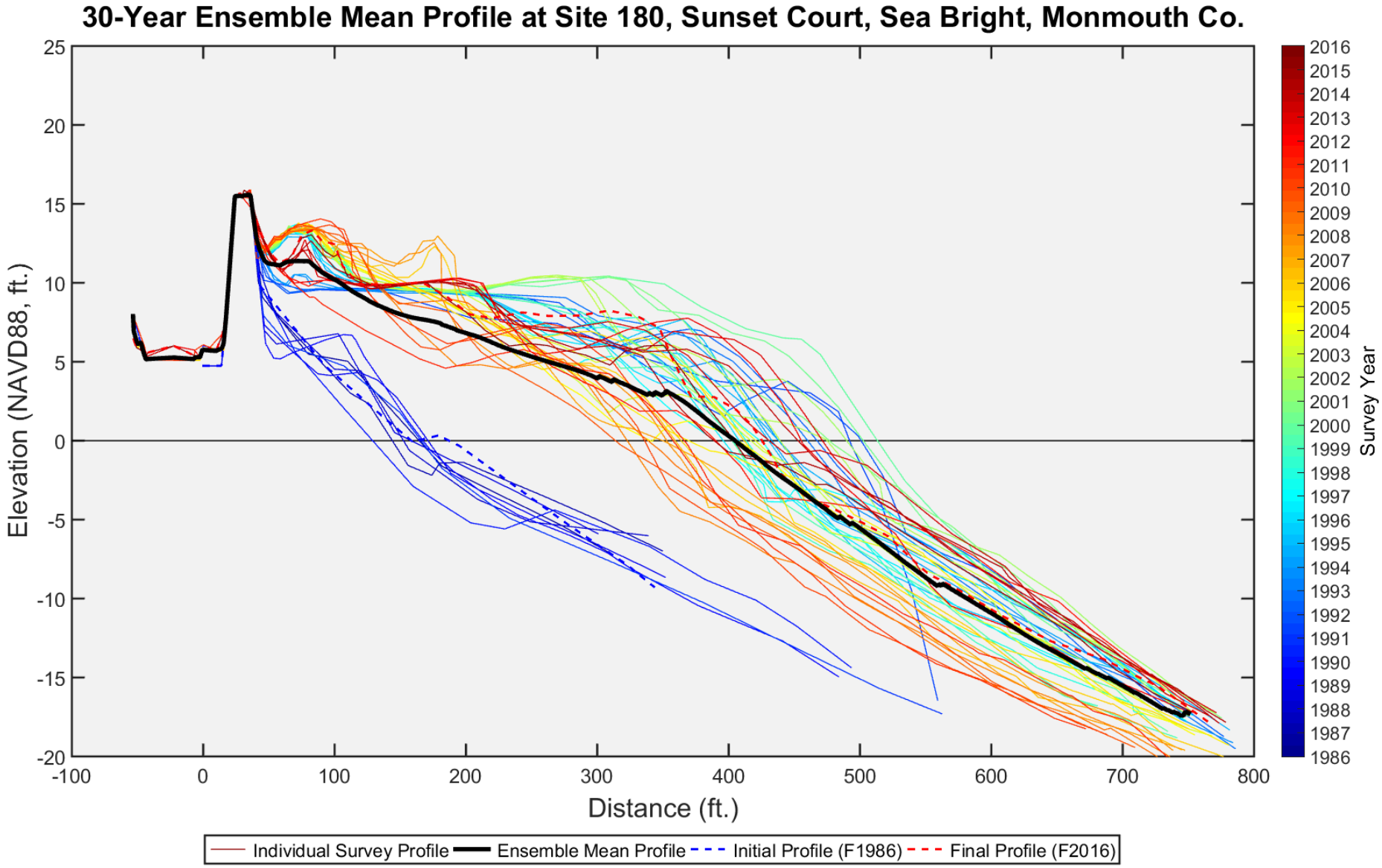

Figure 67. The beach at Sunset Court was extremely narrow and often wet to the rocks prior to the USACE project. Subsequently the project lost material over time until the post-Sandy restoration effort was completed.

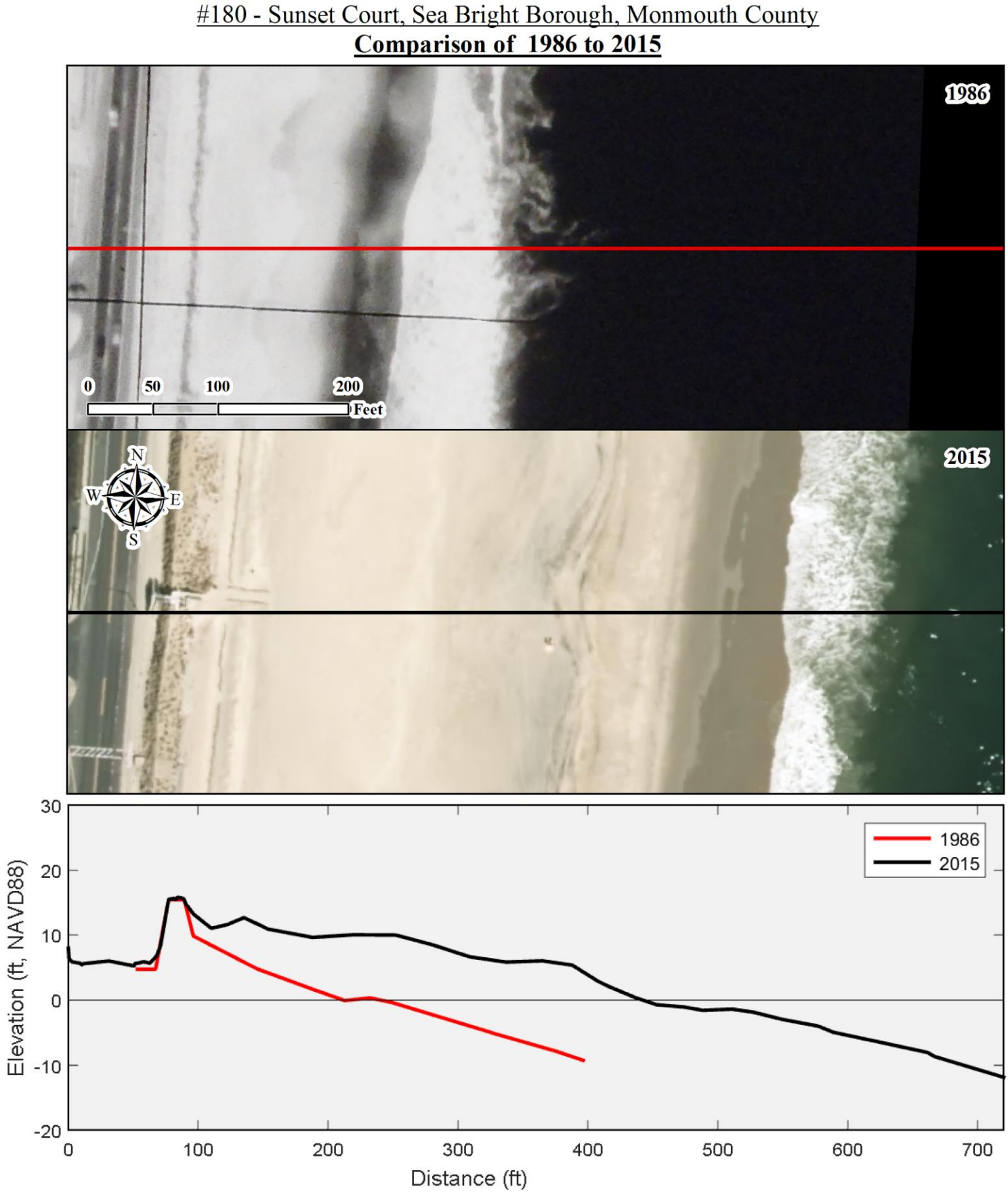

Figure 68. A narrow low beach has become much wider due a 200 ft shoreline advance that was a result of the federal shore protection project.

Figure 69. View of site 179 from the top of the seawall looking northeast. Prior to any beach fill, the low tide still reached the rocks. The dune was restored as well as the design beach following Hurricane Sandy.

NJBPN 179 – Cottage Road, Monmouth Beach


Figure 70a & 70b. This site has the worst erosion history of any site in Monmouth County. The left photograph Dec. 3, 2015 shows the situation 2 years after the completed work by the USACE. On the right, the existing beach has narrowed further with a single straight line of snow fencing in place between the rocks and the dune on site as of Dec. 2, 2016.

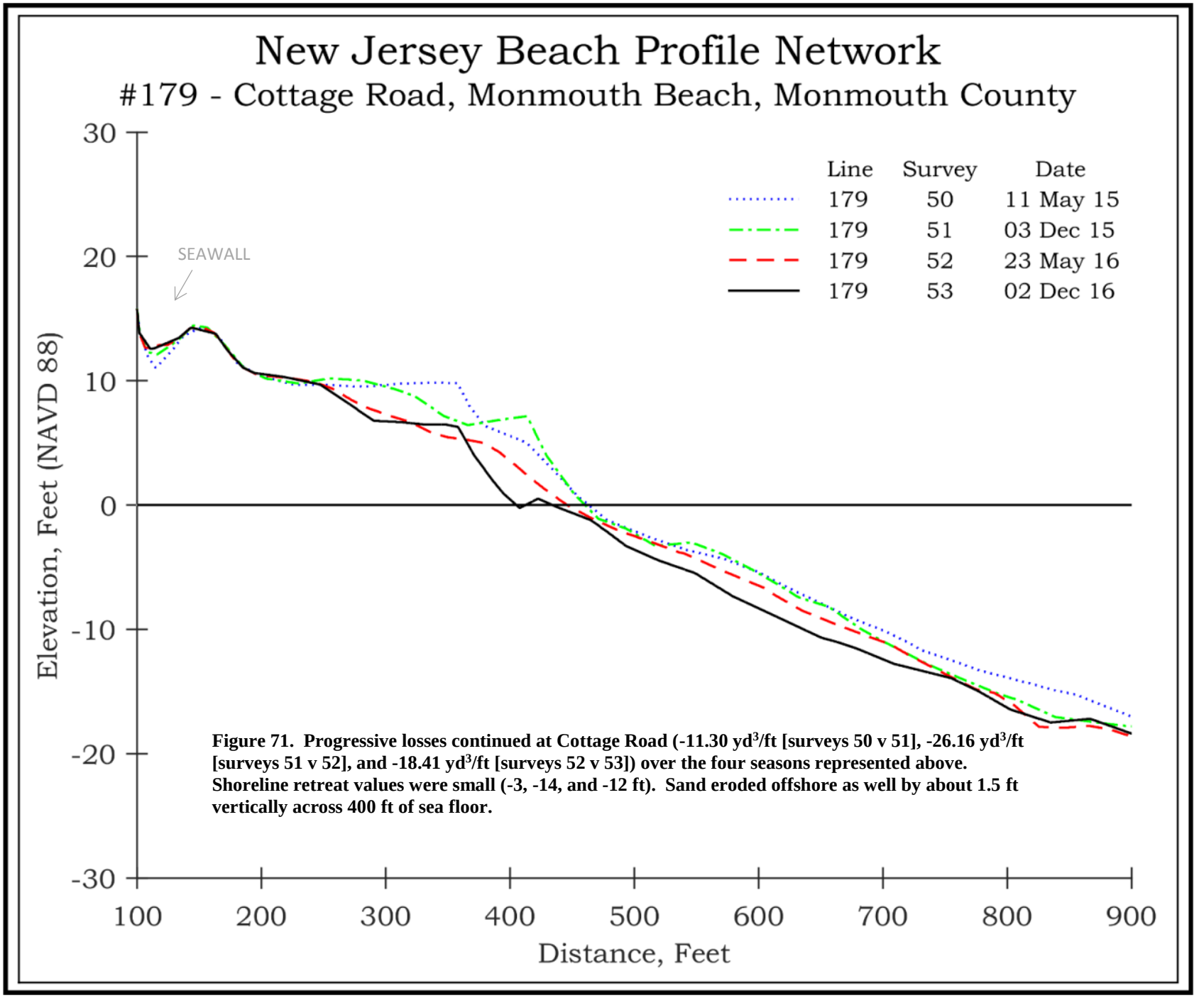

Figure 71. Progressive losses continued at Cottage Road (-11.30 yd^3/ft [surveys 50 v 51], -26.16 yd^3/ft [surveys 51 v 52], and -18.41 yd^3/ft [surveys 52 v 53]) over the four seasons represented above. Shoreline retreat values were small (-3, -14, and -12 ft). Sand eroded offshore as well by about 1.5 ft vertically across 400 ft of sea floor.

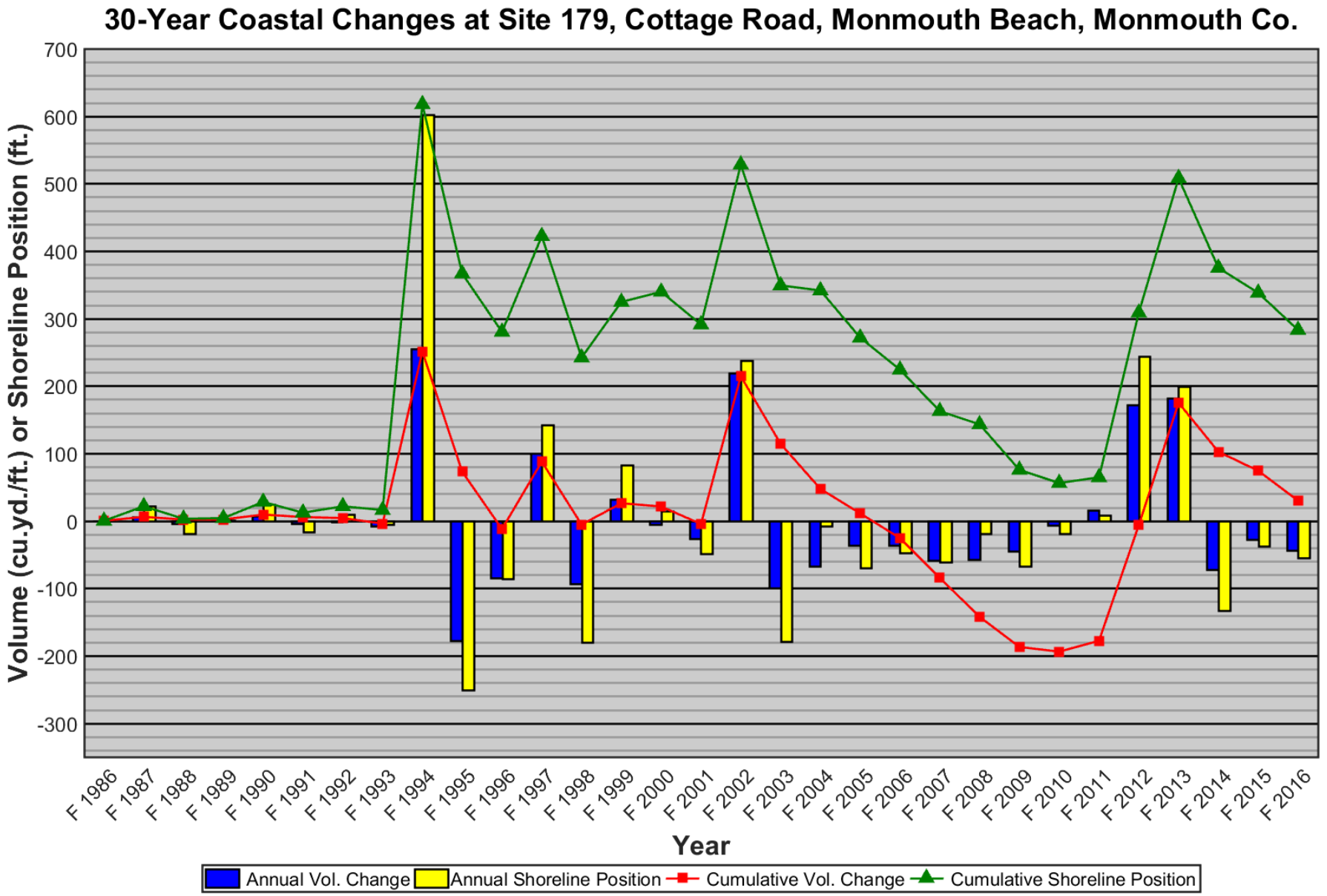

Figure 72. Between site 180 and Cottage Road, the sand loss rate rapidly increases to a point where the two restoration efforts barely held the line for more than a year each. By 2010 sand loss had reached almost 200 yds^3/ft, which is almost equal to the original quantity placed. Since the Sandy maintenance effort, the site continues to lose sand at a rate leading to 2016 values almost matching the sand volume present in 1986. The shoreline position displays an overall negative trend, but is still almost 300 ft seaward of the original 1986 position. There have been multiple smaller maintenance efforts using Shrewsbury River dredged sand as well.

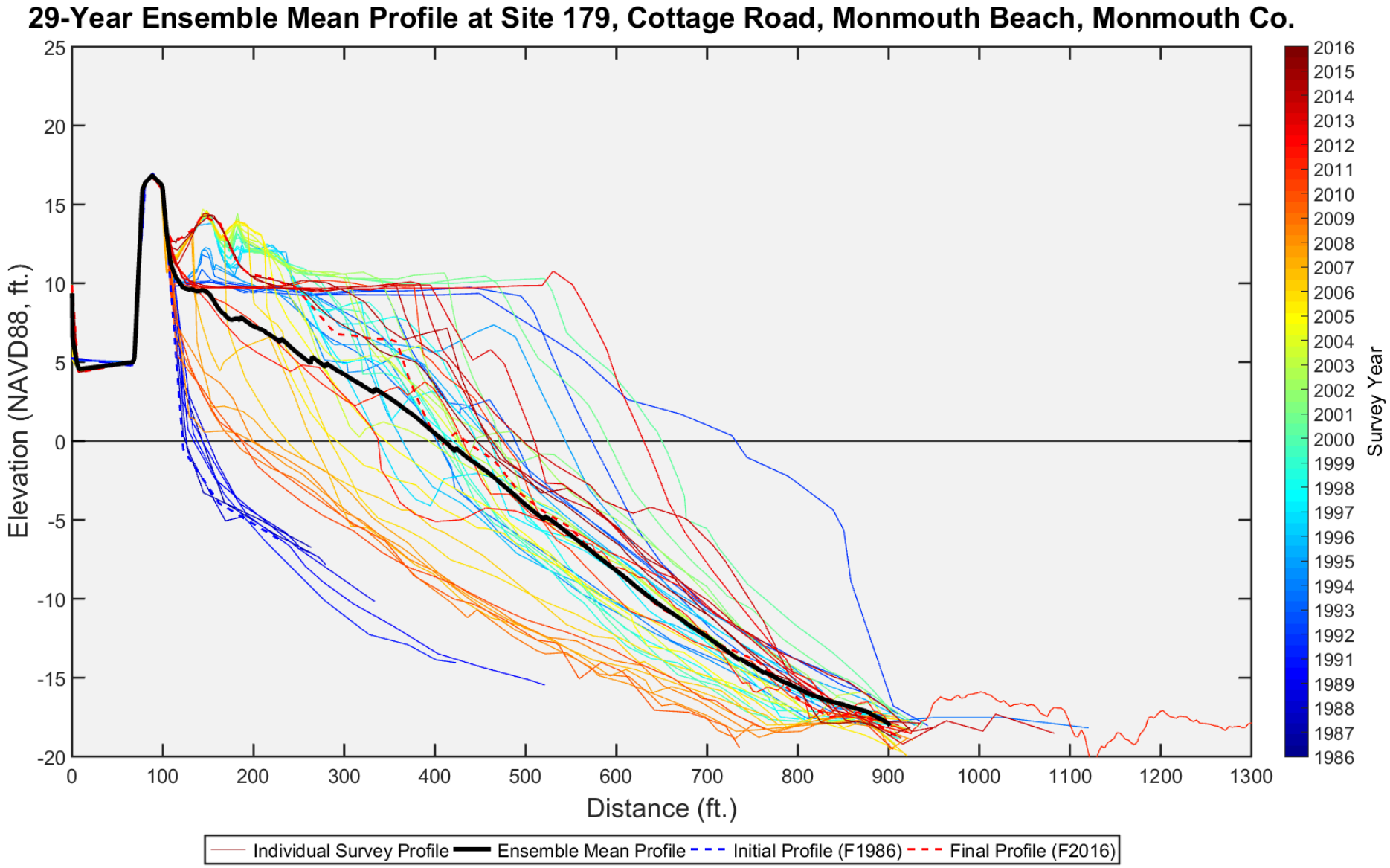

Figure 73. The issues plaguing the Cottage Road site are evident in the scatter of cross sections compared to other Sea Bright locations. Initially there was no beach above the zero elevation on many occasions. The initial USACE beach fill shows as a huge wedge of sand extending to a point 900 feet seaward of the reference position. Retreat occurred in spite of repeated minor repair efforts and the site was almost back to the pre-project status by the years of 2007 to 2008. The post-Sandy restoration shows as a massive addition of new sand (farthest seaward red line) followed by continued retreat to the red dashed line that represents the most recent survey profile.

#179 - Cottage Road, Monmouth Beach Borough, Monmouth County

Comparison of 1986 to 2015

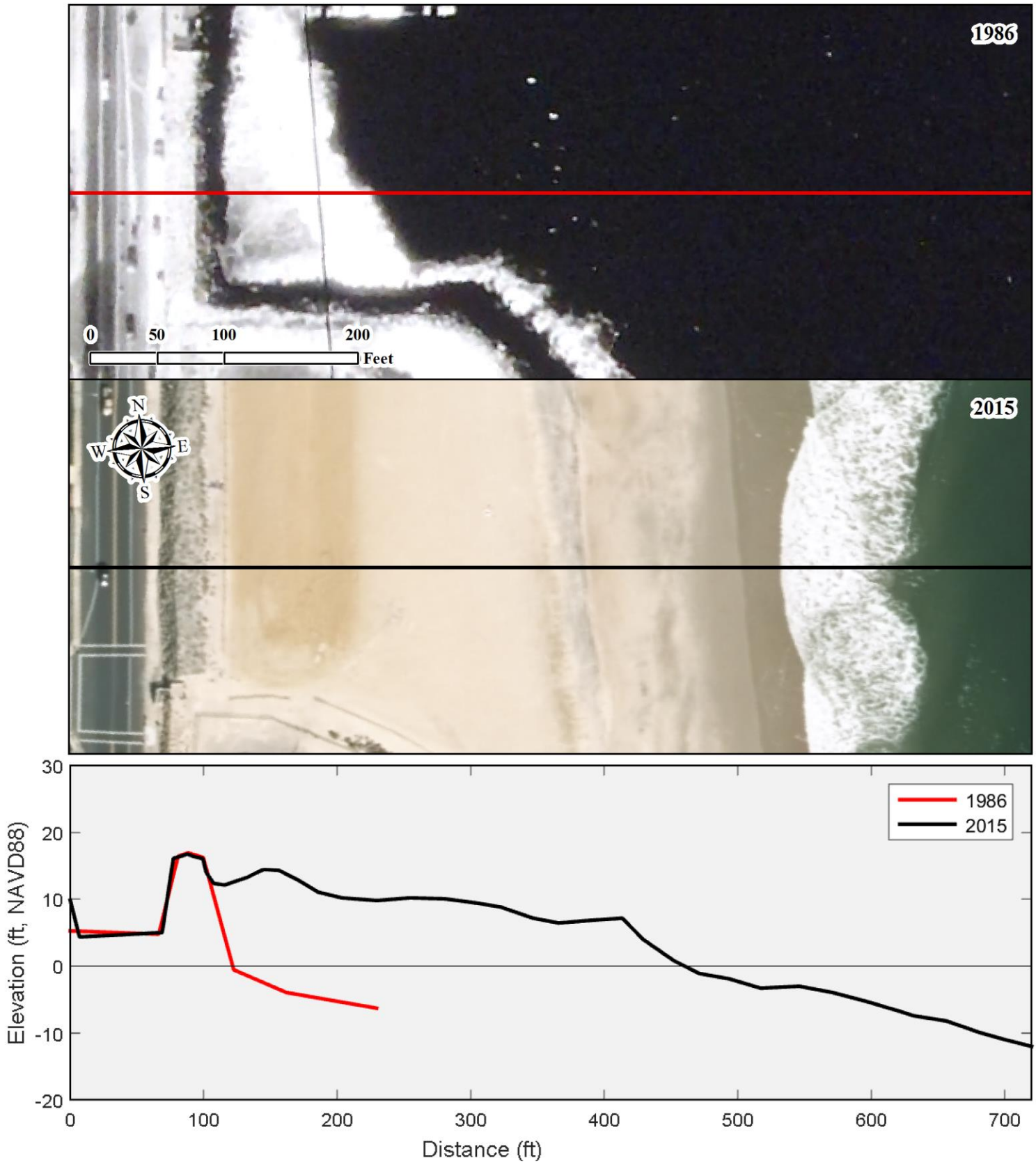

Figure 74. Seawater was directly at the seawall prior to the federal project. Today the shoreline position lies 350 feet seaward of its 1986 location. The site loses sand to the northerly littoral transport system at the greatest rate found anywhere in Monmouth County. There is a major rock groin immediately south of the profile site acting to restrict sand from moving north onto this beach segment.

Figure 75. The dry beach at the toe of the beach grass on the dune. This site was moved slightly following reconstruction after Hurricane Sandy.

NJBPN 178 – Monmouth Beach Club, Monmouth Beach

Figure 76a & 76b. The left photo taken December 3, 2015 shows the results of the USACE work to restore the project to design specifications 2 years following completion. To the right, the beach was steeper a year later without the sand ridge in place for the winter by December 20, 2016.

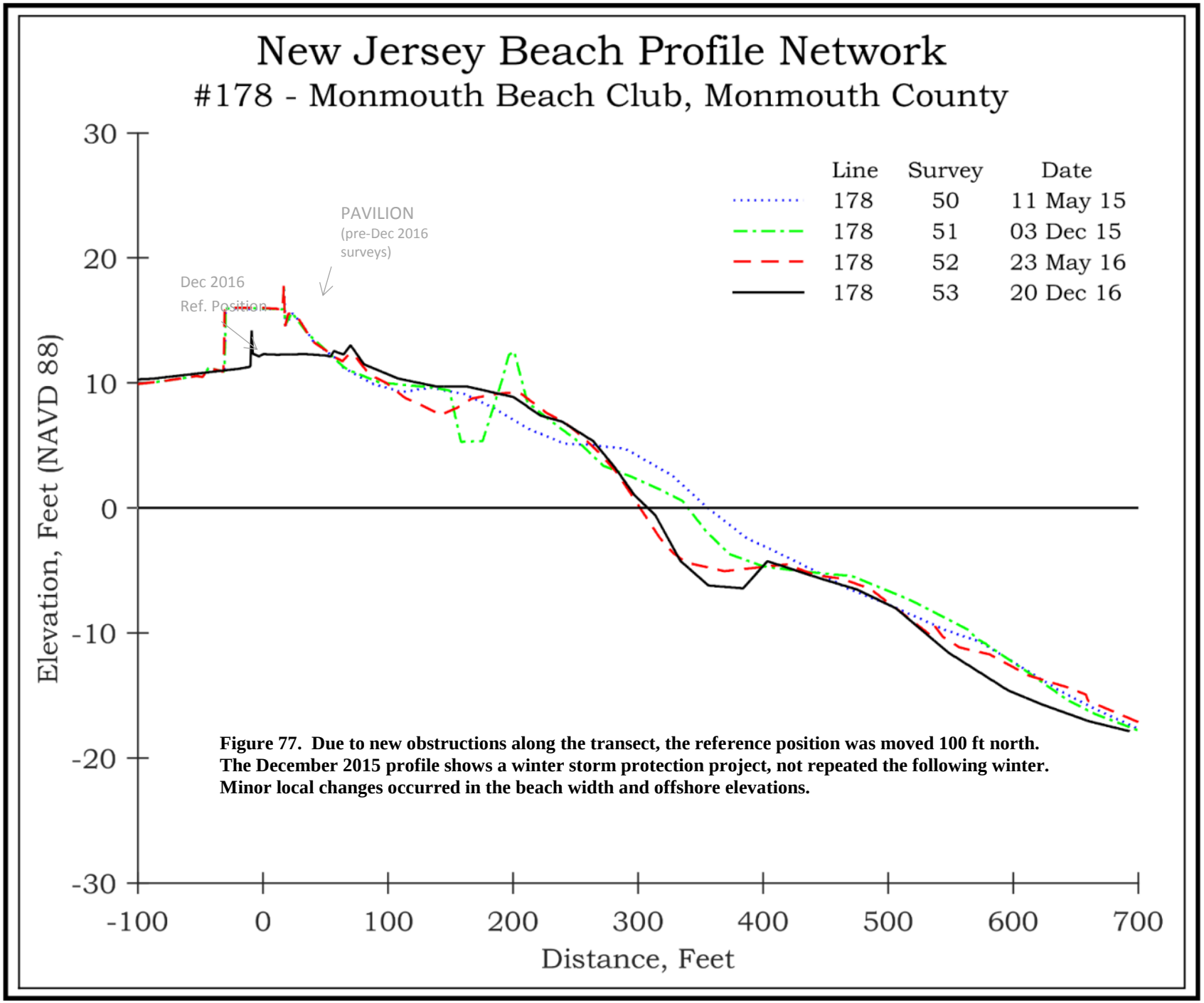

Figure 77. Due to new obstructions along the transect, the reference position was moved 100 ft north. The December 2015 profile shows a winter storm protection project, not repeated the following winter. Minor local changes occurred in the beach width and offshore elevations.

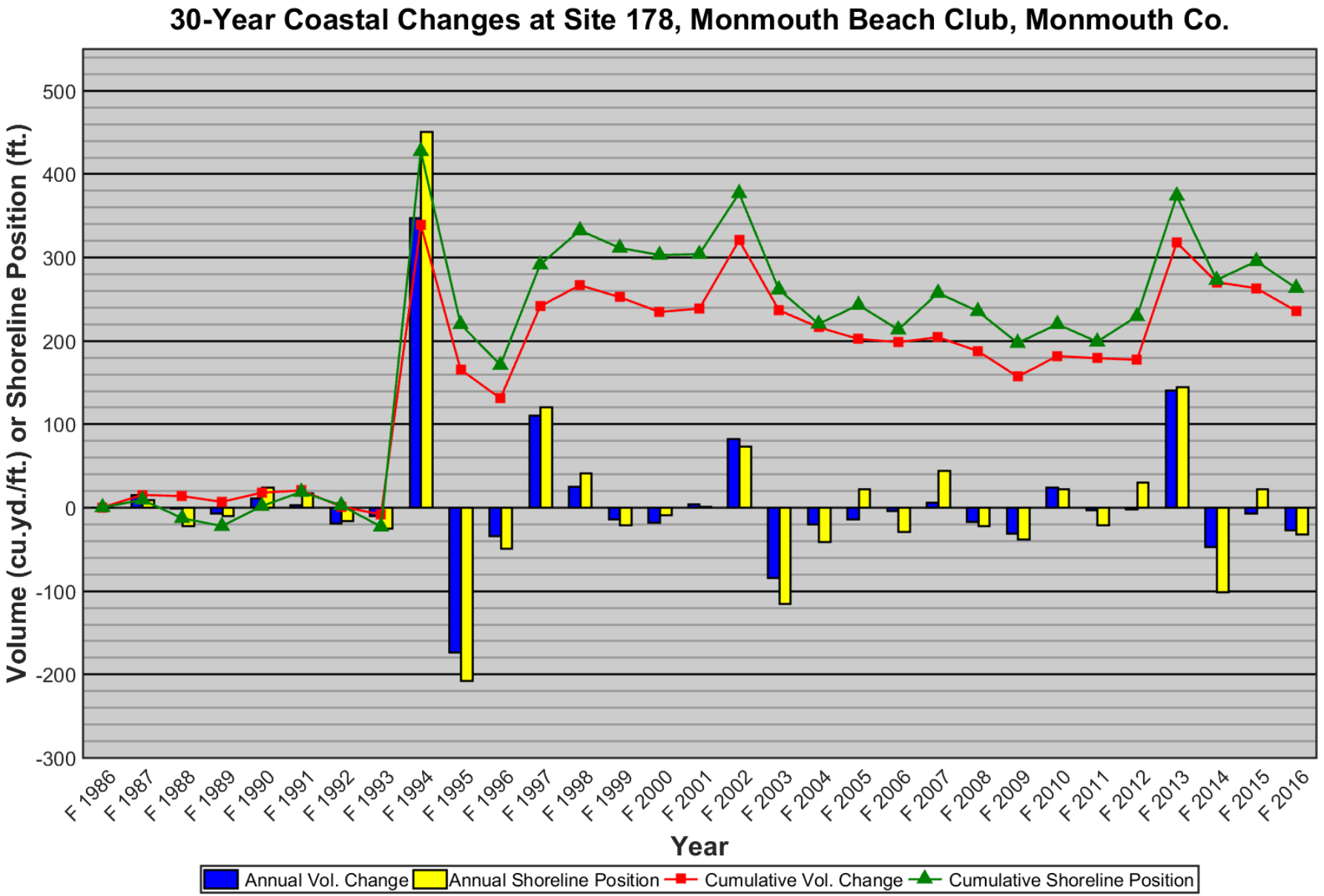

Figure 78. Immediately on the south side of the large groin established for the benefit of the Monmouth Beach Club, the sand supply remains far more consistent over time. Long term sand residence times exceed 38% of initial volume after 15 years and one maintenance in 2002. Four years after the 2013 placement effort the beach retained 70% of the added sediment.

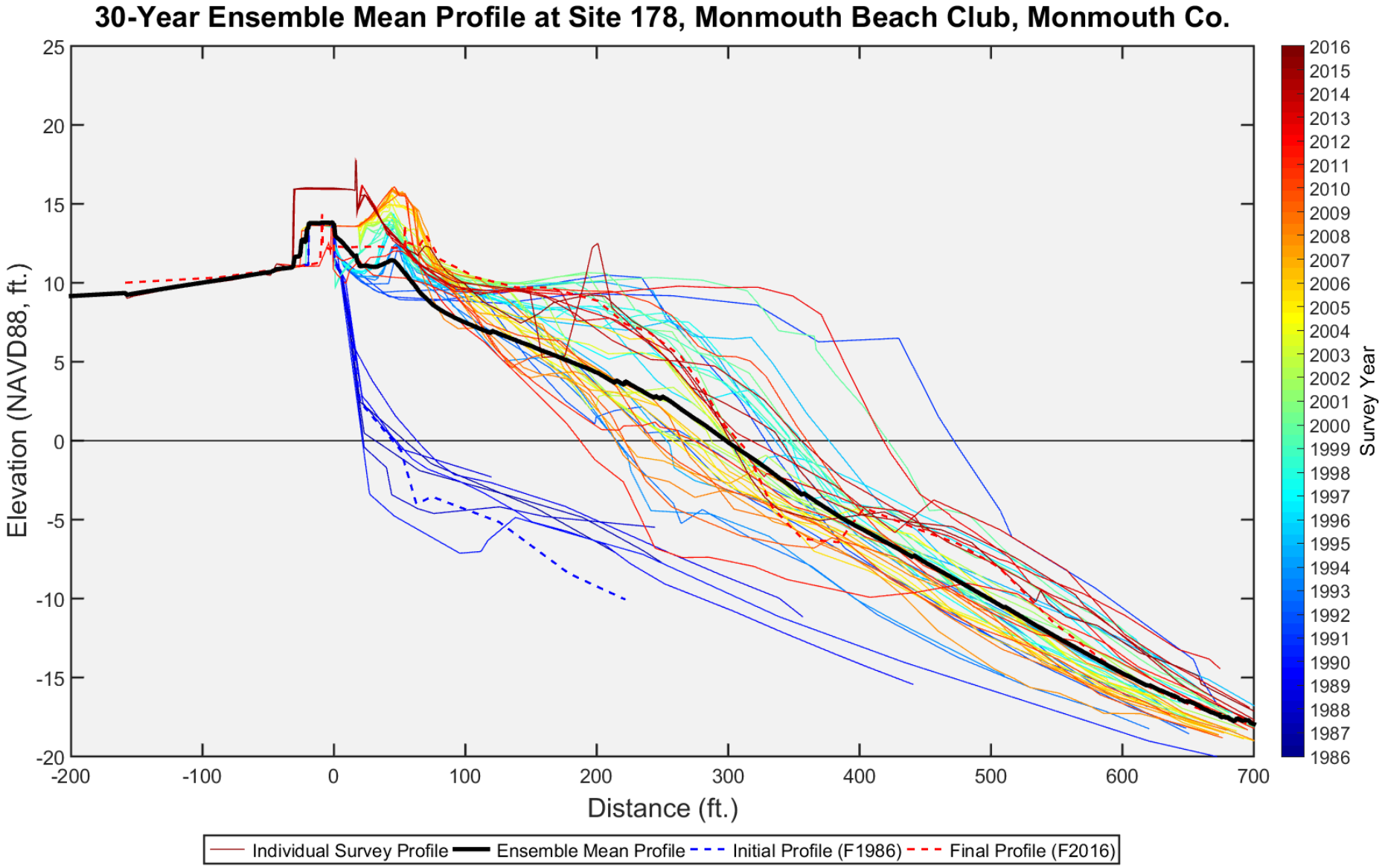

Figure 79. In contrast to Cottage Road (site 179), this site presents a more compact envelope of change indicating that greater beach stability exists. The rock groin built years ago to provide a beach for the Monmouth Beach Club remains as a barrier to northerly sand transport today. Initially there was some sand at the site, but presently the beach is wide and provides good protection.

#178 - Monmouth Beach Club, Monmouth Beach Borough, Monmouth County

Comparison of 1986 to 2015

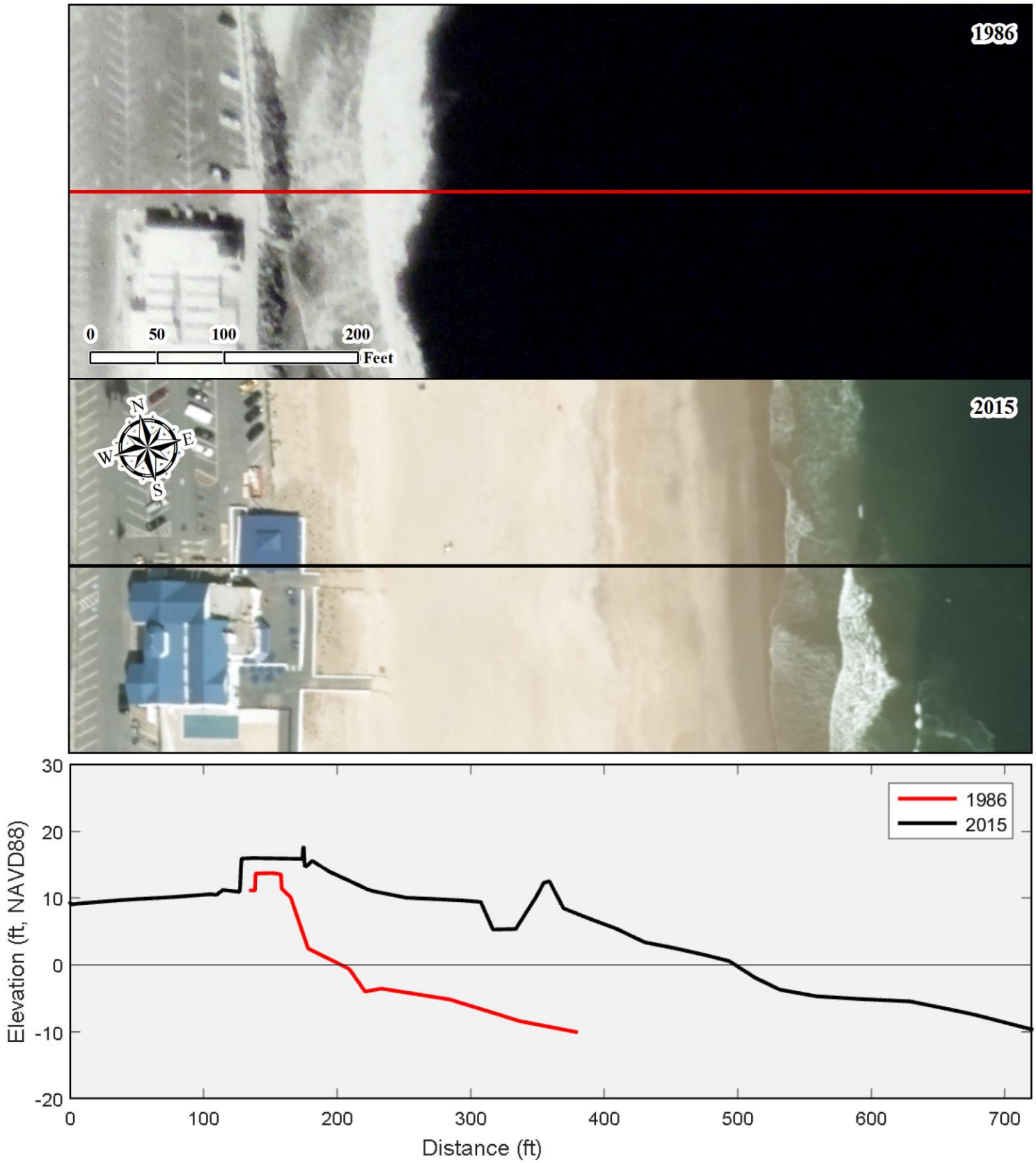

Figure 80. This site had little beach seaward of the rock seawall in 1986. Twenty years later in 2015, the shoreline has moved about 300 ft seaward and the added 300 ft of beach above the zero elevation has increased the protective capability of the site.

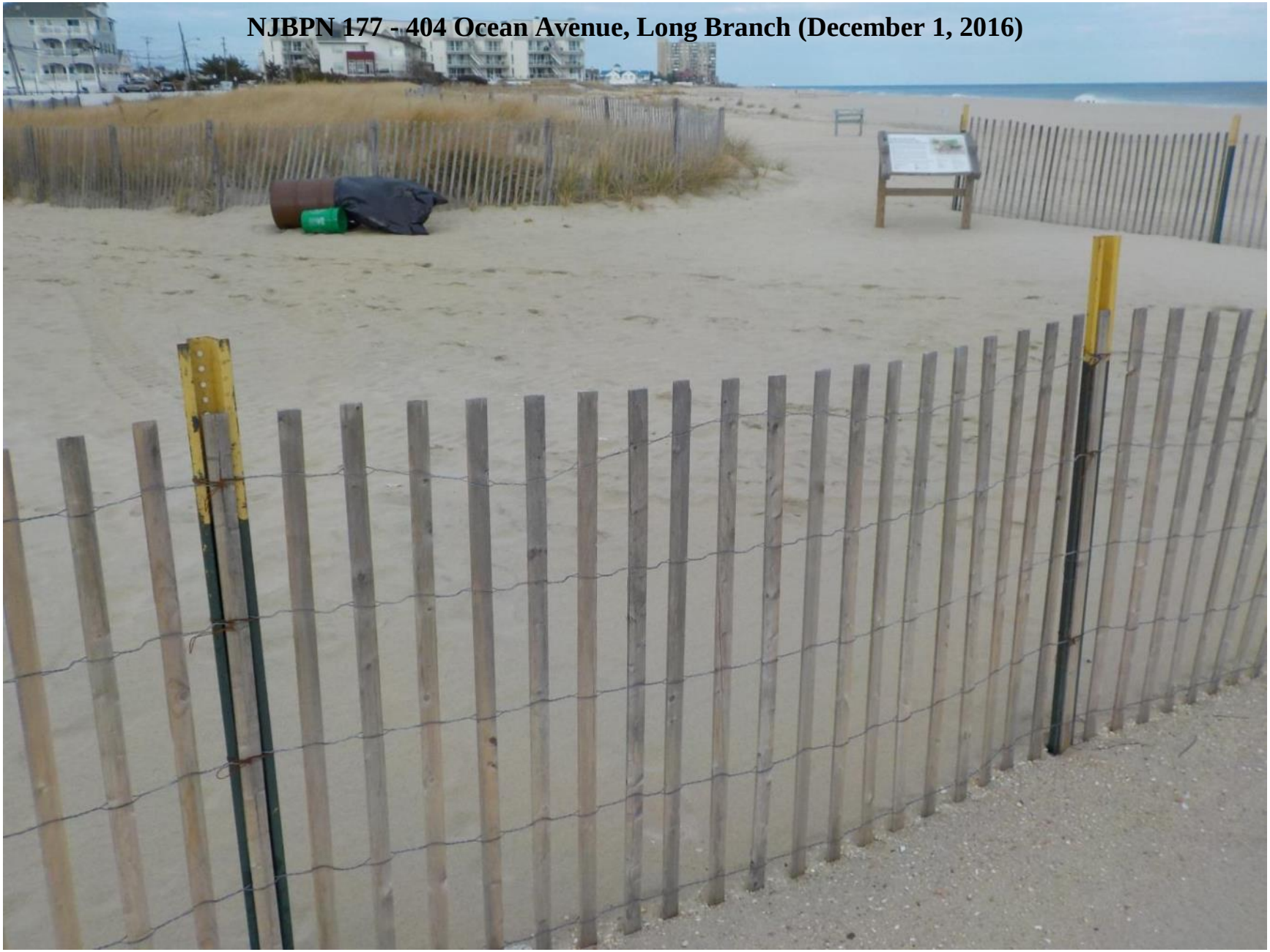

Figure 81. View to the north along the seaward dune toe at 404 Ocean Avenue. Now in public hands, this site was once part of the Fort Monmouth holdings.

NJBPN 177 – 404 Ocean Avenue, Long Branch


Figure 82a & 82b. The left photo was taken December 3, 2015 following the addition of 123.04 yds^3/ft on the beach after the arrival of the USACE to complete the northern segment of their project. By December 1, 2016 the beach was similar but a little narrower.

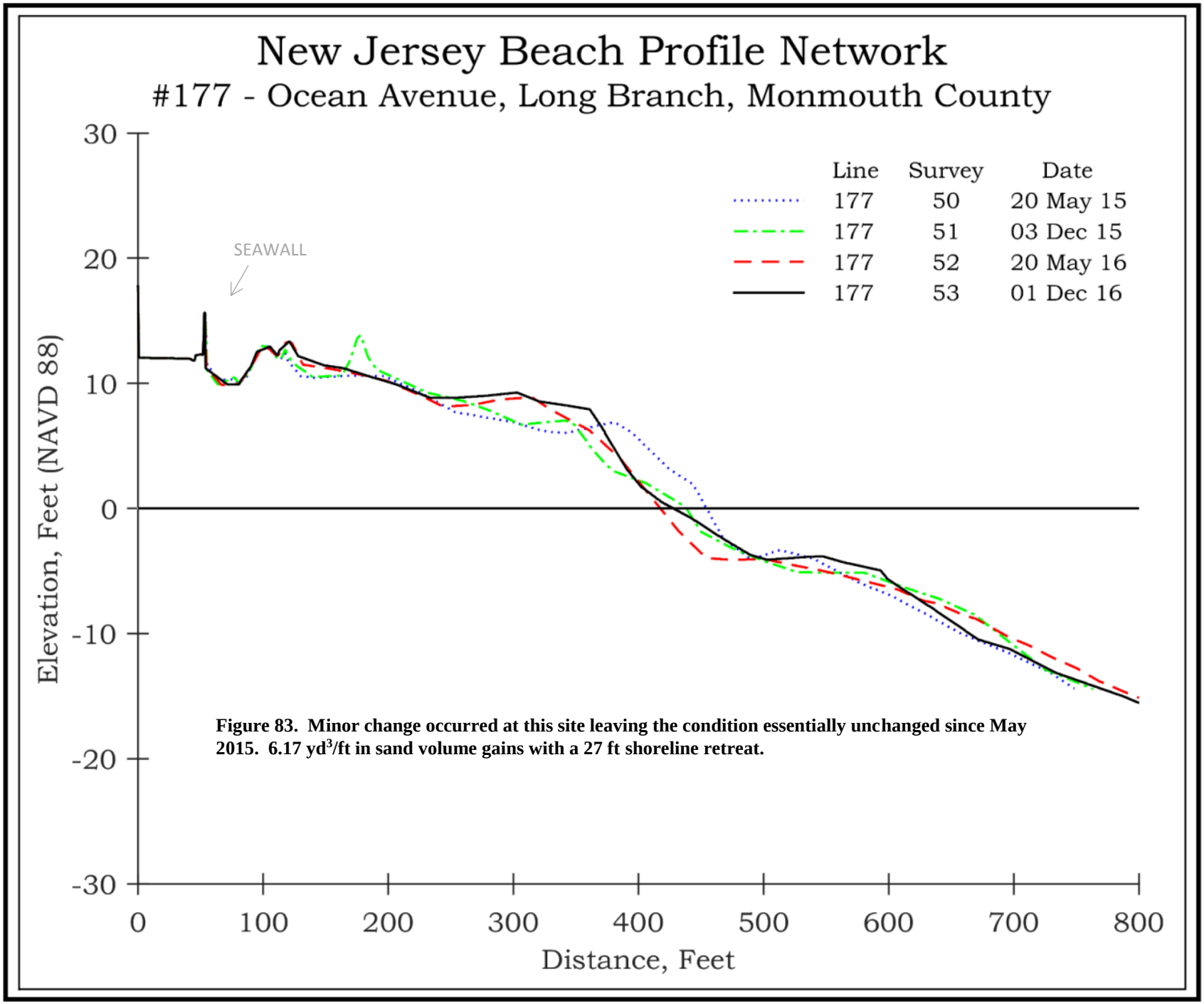

Figure 83. Minor change occurred at this site leaving the condition essentially unchanged since May 2015. 6.17 yd^3/ft in sand volume gains with a 27 ft shoreline retreat.

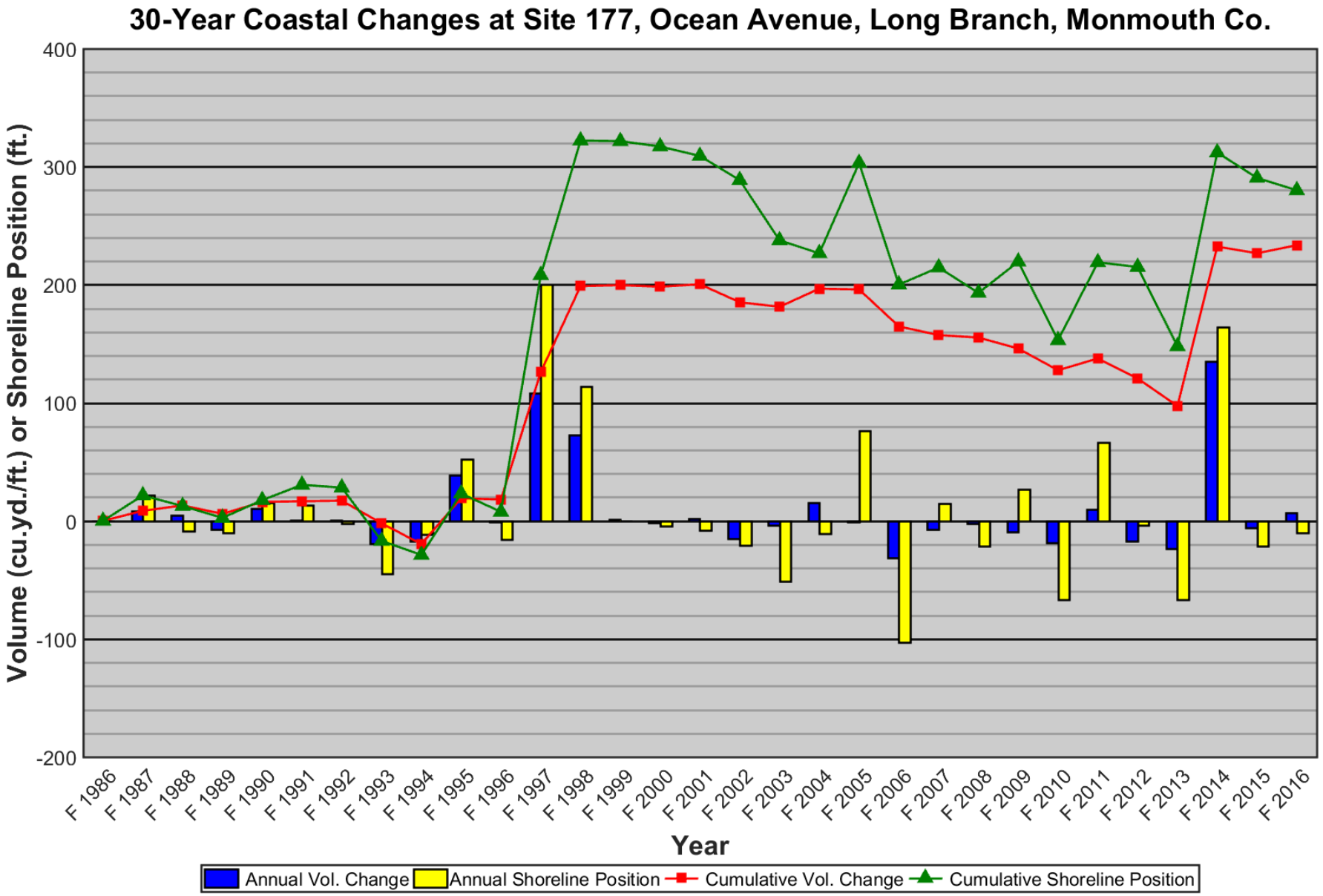

Figure 84. Beach stability was relatively normal at this location with maintenance efforts in 2014 showing a return to initial project shoreline positions and sand volume. As of 2016 the sand volume present was 120% of the 1998 placement volume, but the shoreline receded by about 40 ft. In terms of the initial shoreline position in 1986, however, the shoreline has moved about 280 ft seaward.

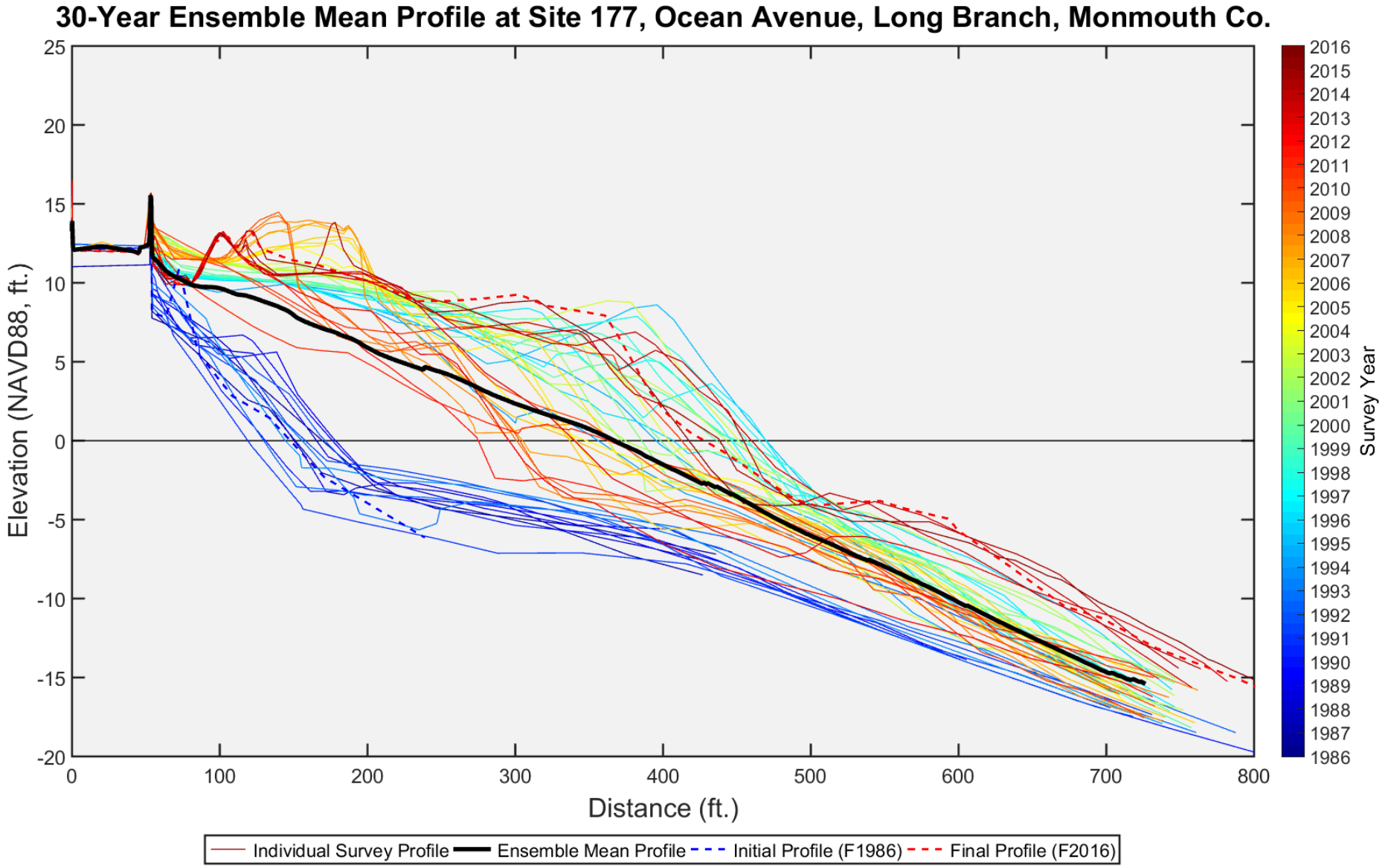

Figure 85. Moving into Long Branch, the original beach profile assumes a more normal configuration, although quite narrow. The USACE project provided a far wider beach with modest levels of shoreline retreat over 15 years before the site was restored following Hurricane Sandy.

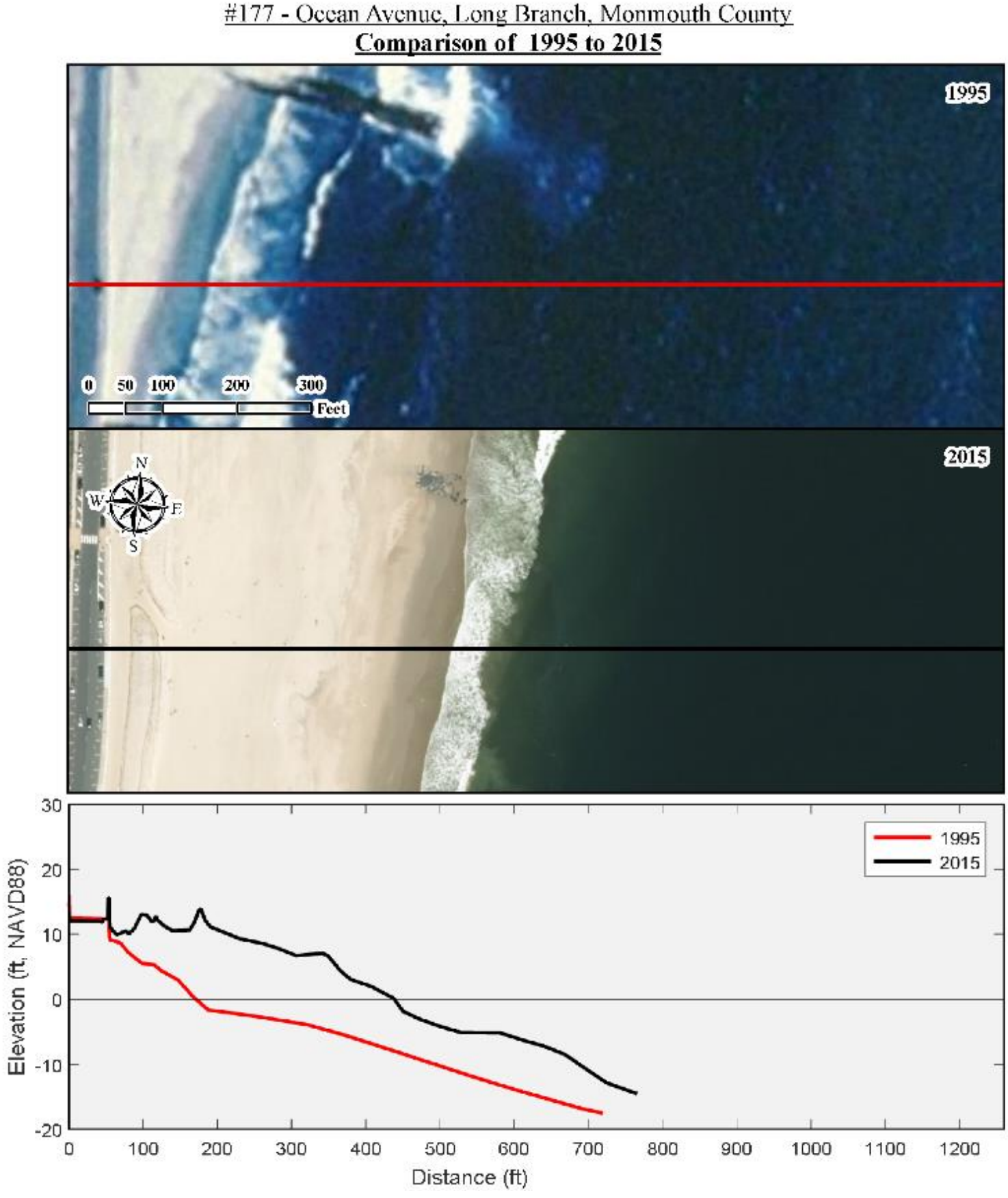

Figure 86. Sand added to this site has created a wider beach over 20 years. The added sand and increased beach width has increased the protective capability of the site and put the road at less risk of inundation.

Figure 87. North view along the seaward dune toe at the Seven Presidents Park in Long Branch. Established prior to the NJBPN work, this park was once developed properties, all removed except for the headquarters building.

NJBPN 176 – Seven President's Park, Long Branch

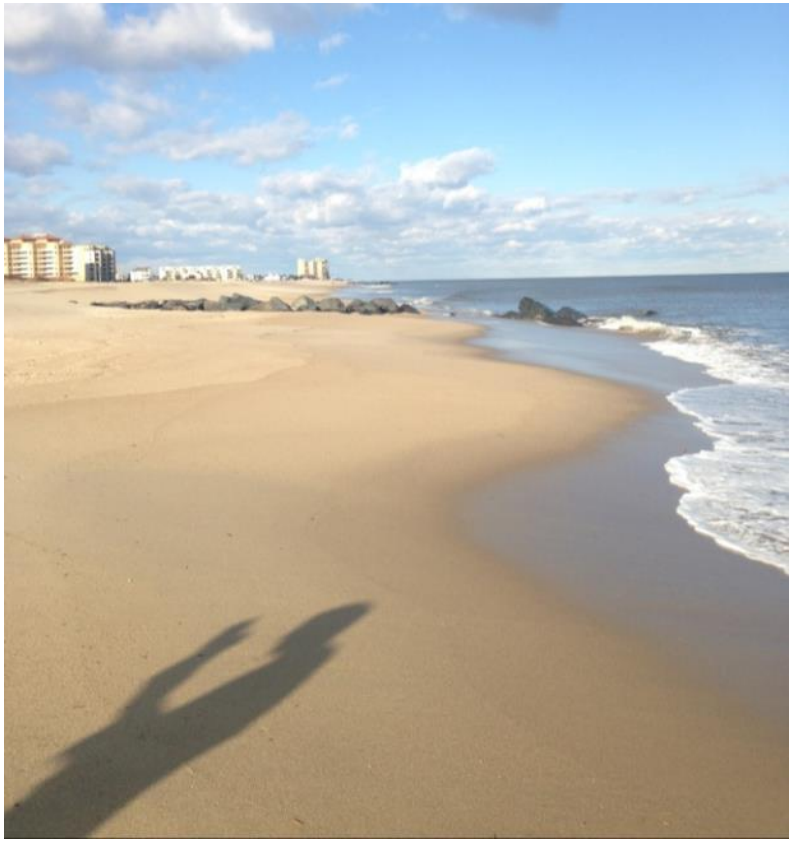

Figure 88a & 88b. This site is a popular recreational park with a partial ridge of 25 ft elevation dunes. By survey 48, the sand volume increased by 115.73 yds^3/ft as a result of USACE work (November 18, 2014). The left photograph was taken December 3, 2015 and shows the tips of the groin rocks exposed on the beach. By December 1, 2016 (right photo) a small scarp had occurred, but the rocks were a bit less exposed.

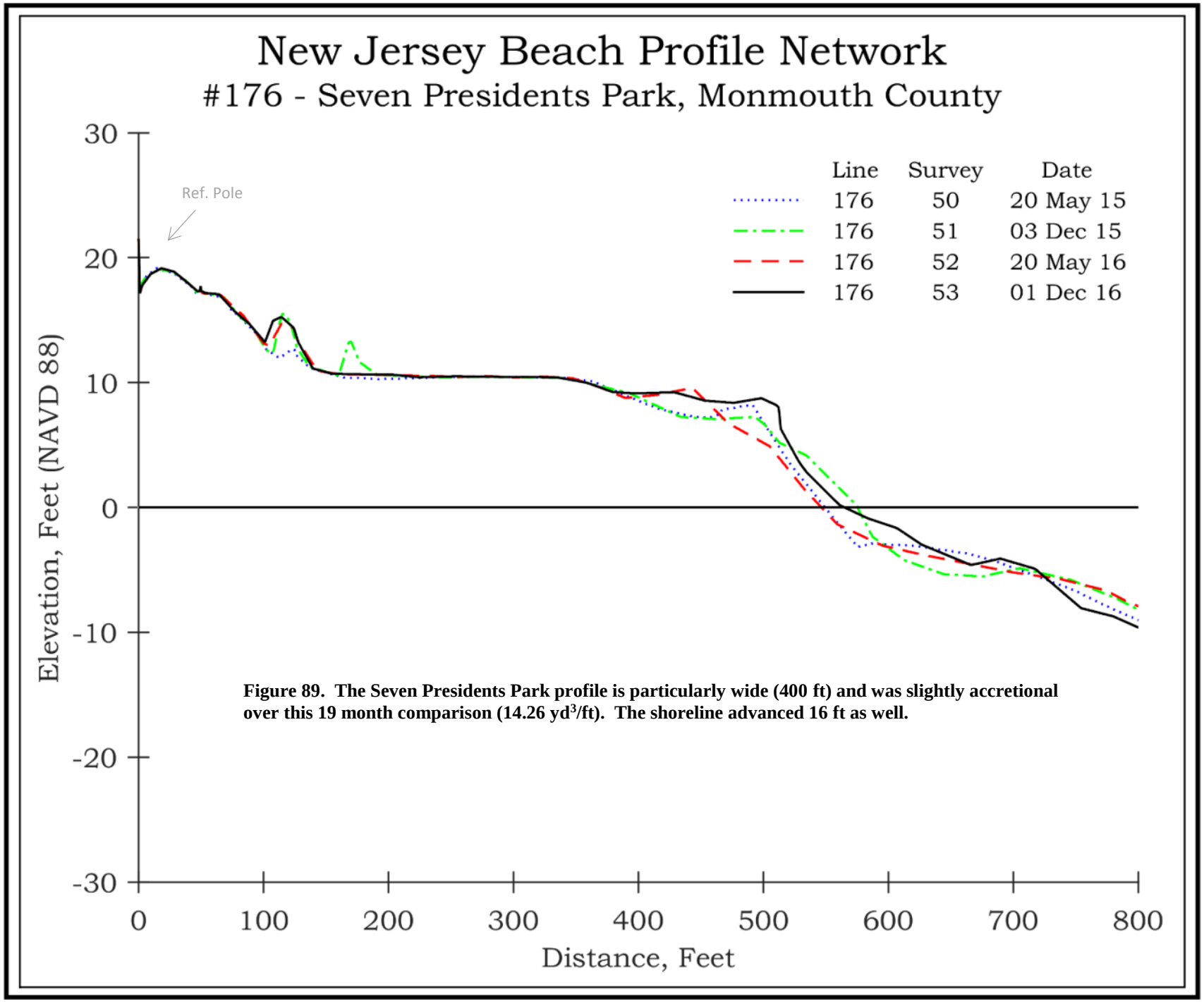

Figure 89. The Seven Presidents Park profile is particularly wide (400 ft) and was slightly accretional over this 19 month comparison (14.26 yd^3/ft). The shoreline advanced 16 ft as well.

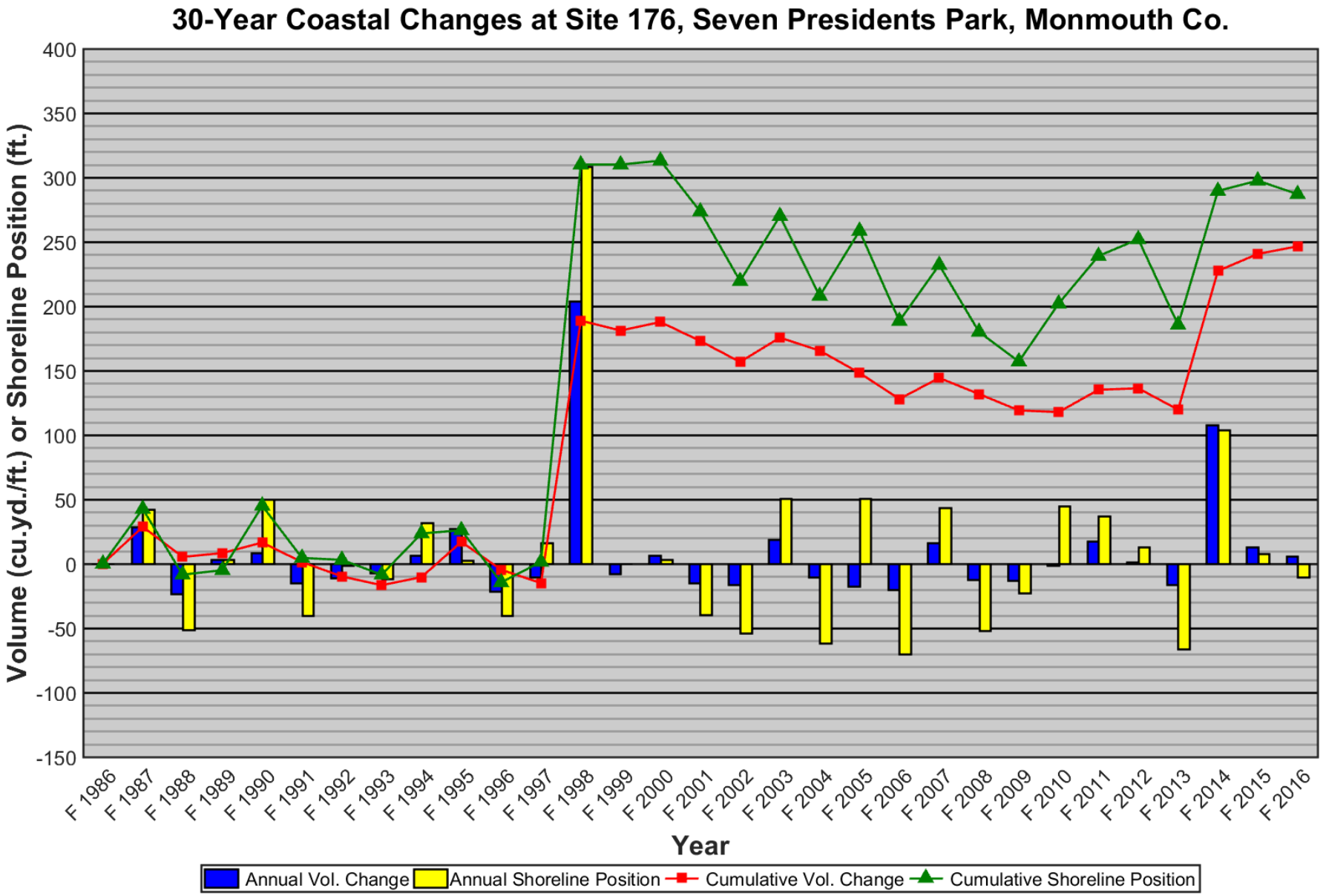

Figure 90. The park beach has very high seasonal use, but has been quite stable since 1997 showing just one major enhancement in 2014. Current sand volumes exceed the initial placement volume from 1997 by about 55 yds^3/ft of beach.

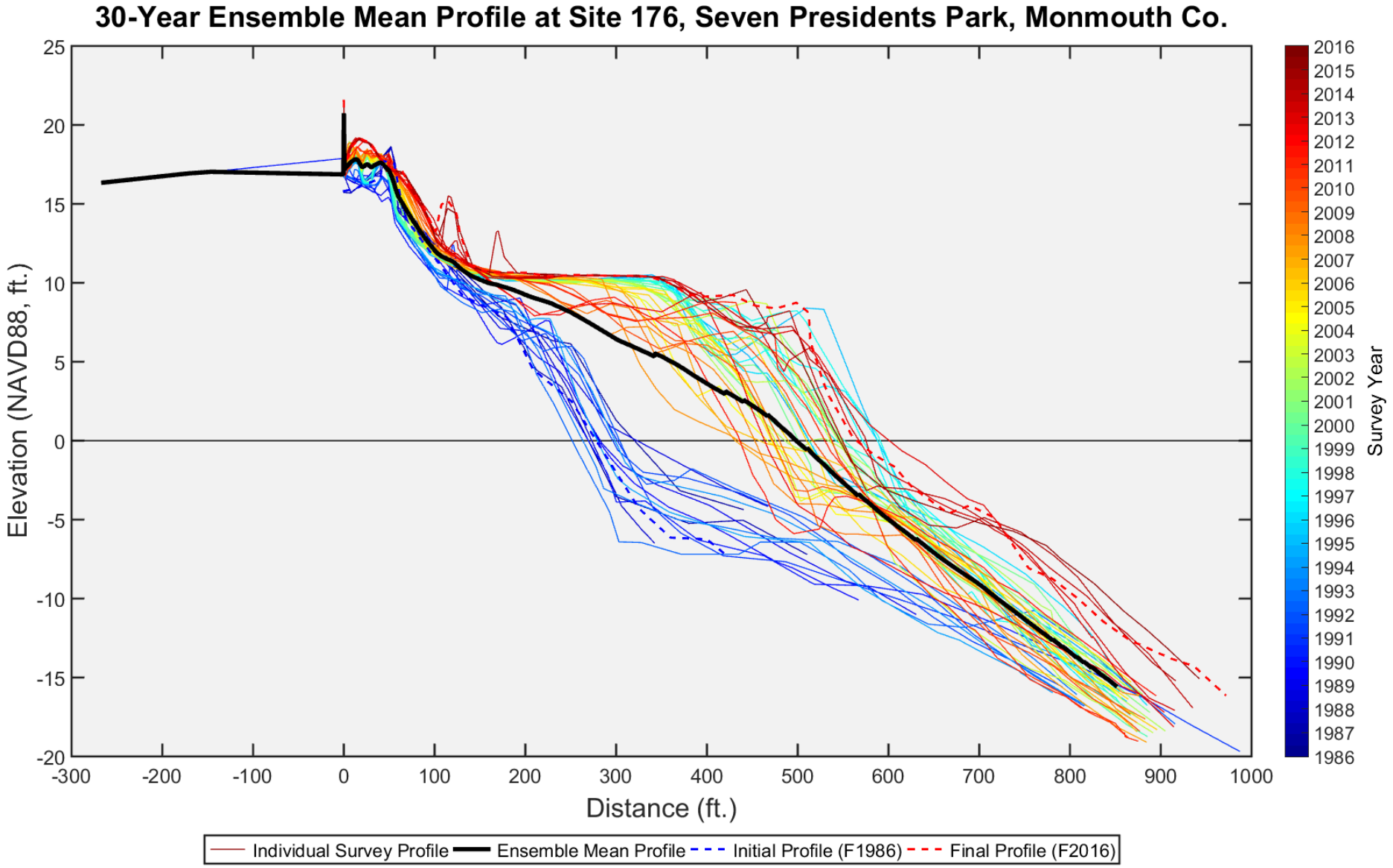

Figure 91. The park beach was fairly consistent prior to the USACE project, but was far wider following the work. The envelope of beach sand volume change was quite small compared to other sites indicating a measure of stability. Retreat did occur between 1998 and 2007, but maintained a decent level of protection.

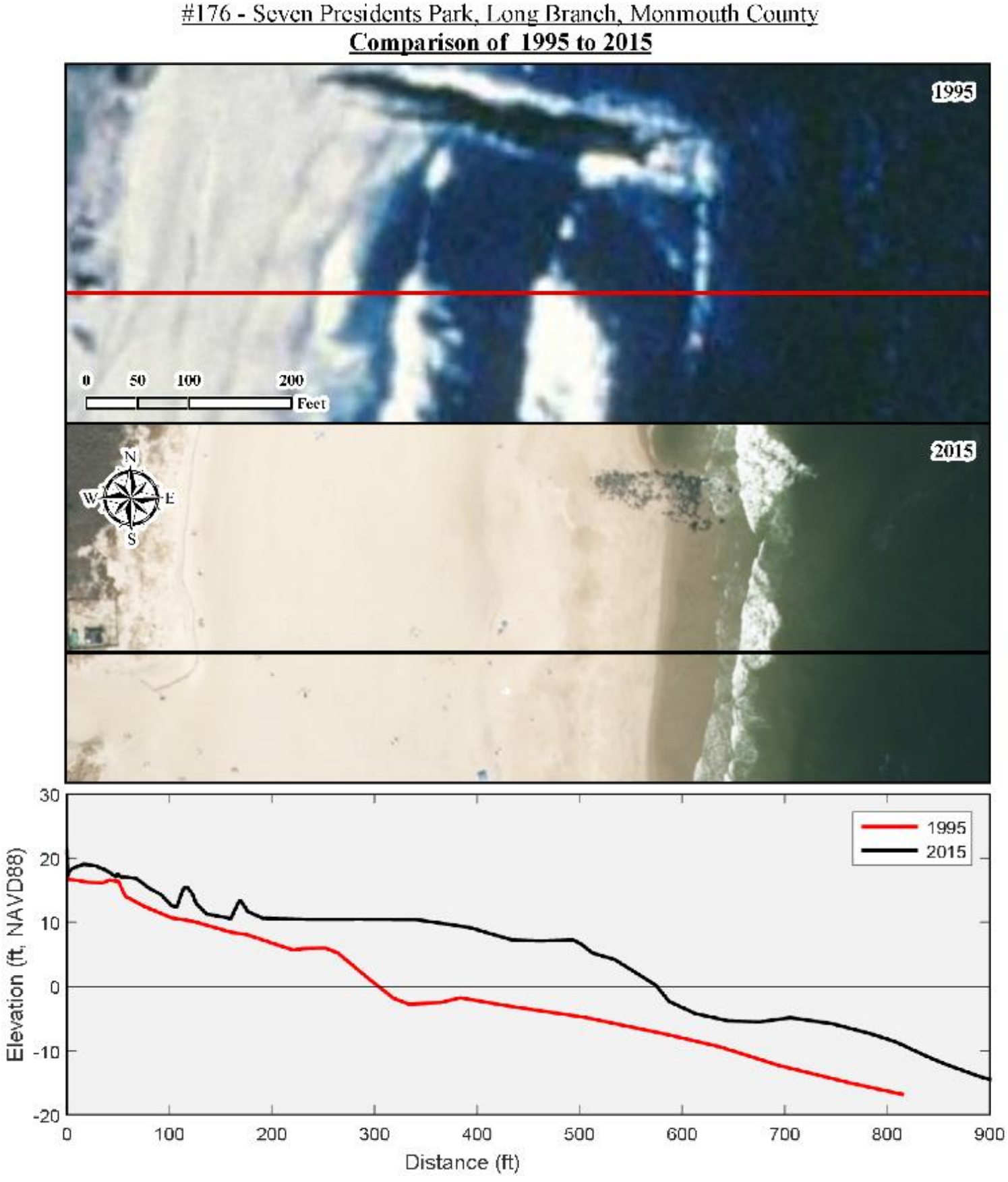

Figure 92. At the County Park, the beach width increase has meant a much greater public use capacity, so that presently the parking lot is the limit on visitors on summer weekends, and not the beach area available.

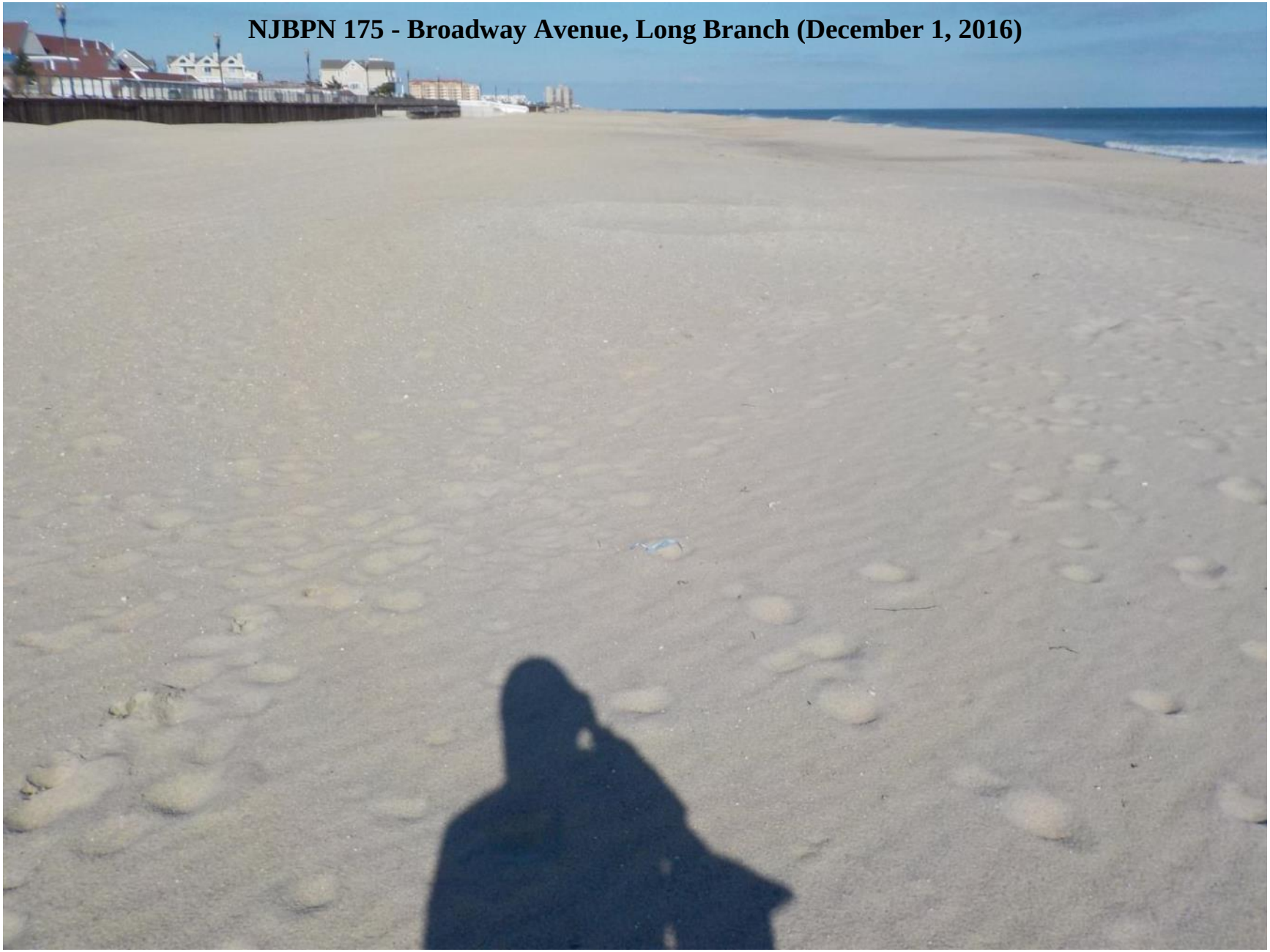

Figure 93. The Long Branch bluff is protected by a steel sheet pile wall dating back over 70 years. The sand placement provides a wide, dry protective and excellent recreational beach in spite of no dune development.

NJBPN 175 – Broadway Avenue, Long Branch


Figure 94a & 94b. The left photograph taken December 15, 2015 shows the beach 18 months following the USACE project completion at this location. By December 11, 2016 (right photo) the beach was narrower, but still wider relative to the rock groins originally exposed following Sandy.

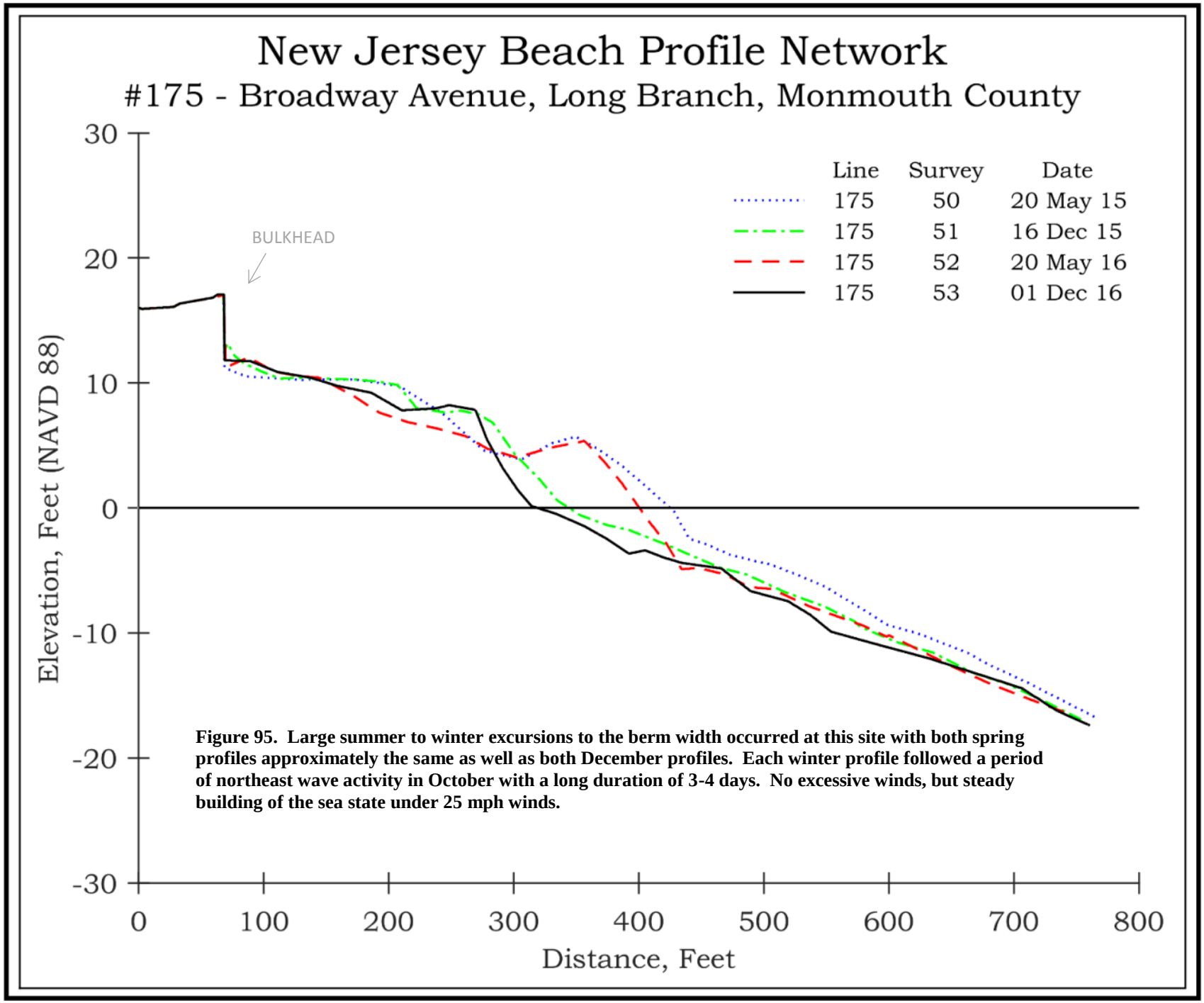

Figure 95. Large summer to winter excursions to the berm width occurred at this site with both spring profiles approximately the same as well as both December profiles. Each winter profile followed a period of northeast wave activity in October with a long duration of 3-4 days. No excessive winds, but steady building of the sea state under 25 mph winds.

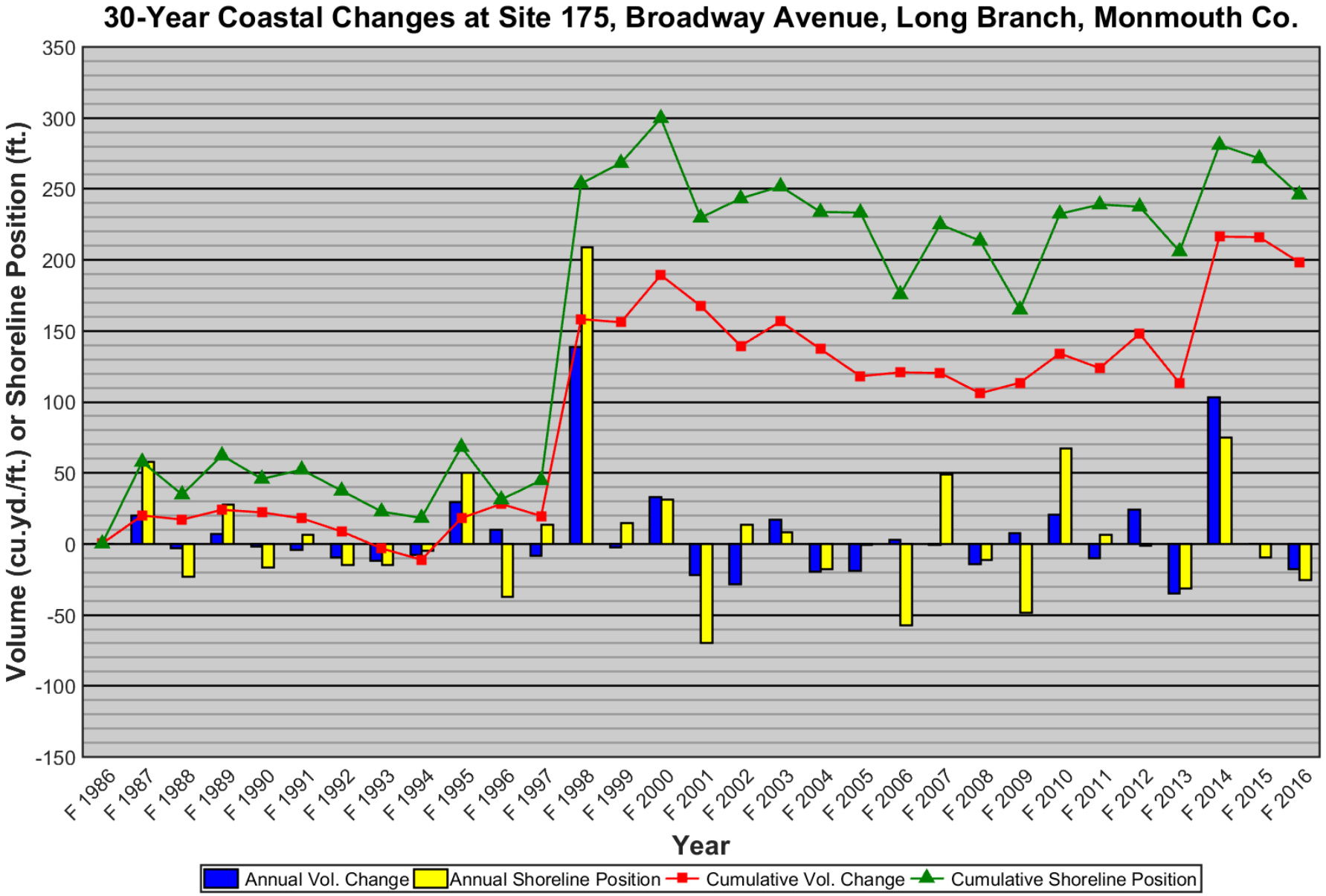

Figure 96. The Broadway Avenue site did acquire a modest sand volume between 1986 and 1998 when the initial federal beach project was complete. Since the project in 1998, the only maintenance work required occurred in 2014 after Sandy.

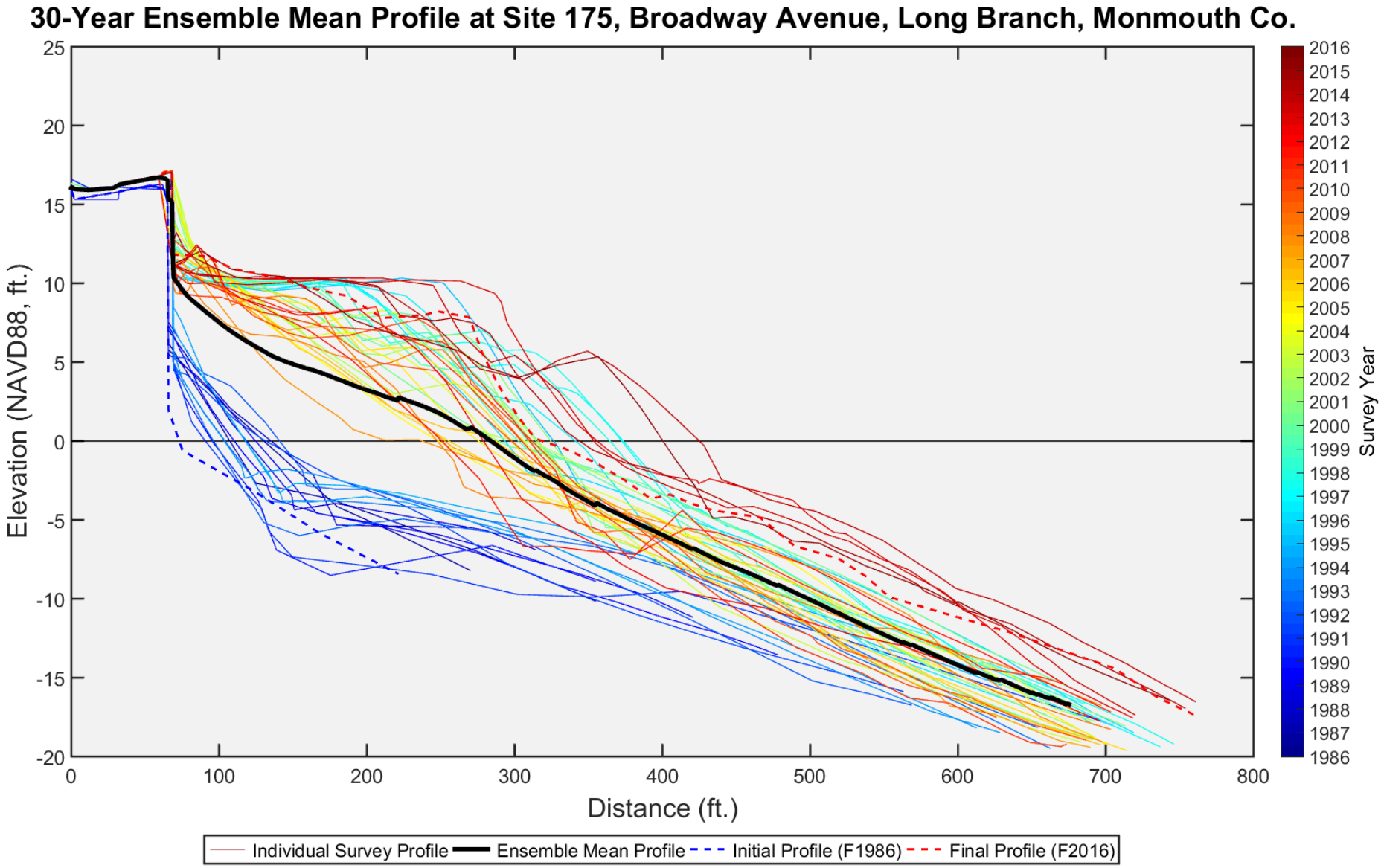

Figure 97. The beach at Broadway was under 100 ft wide prior to the USACE project. The berm provided vastly improved the recreational quality and storm protection.

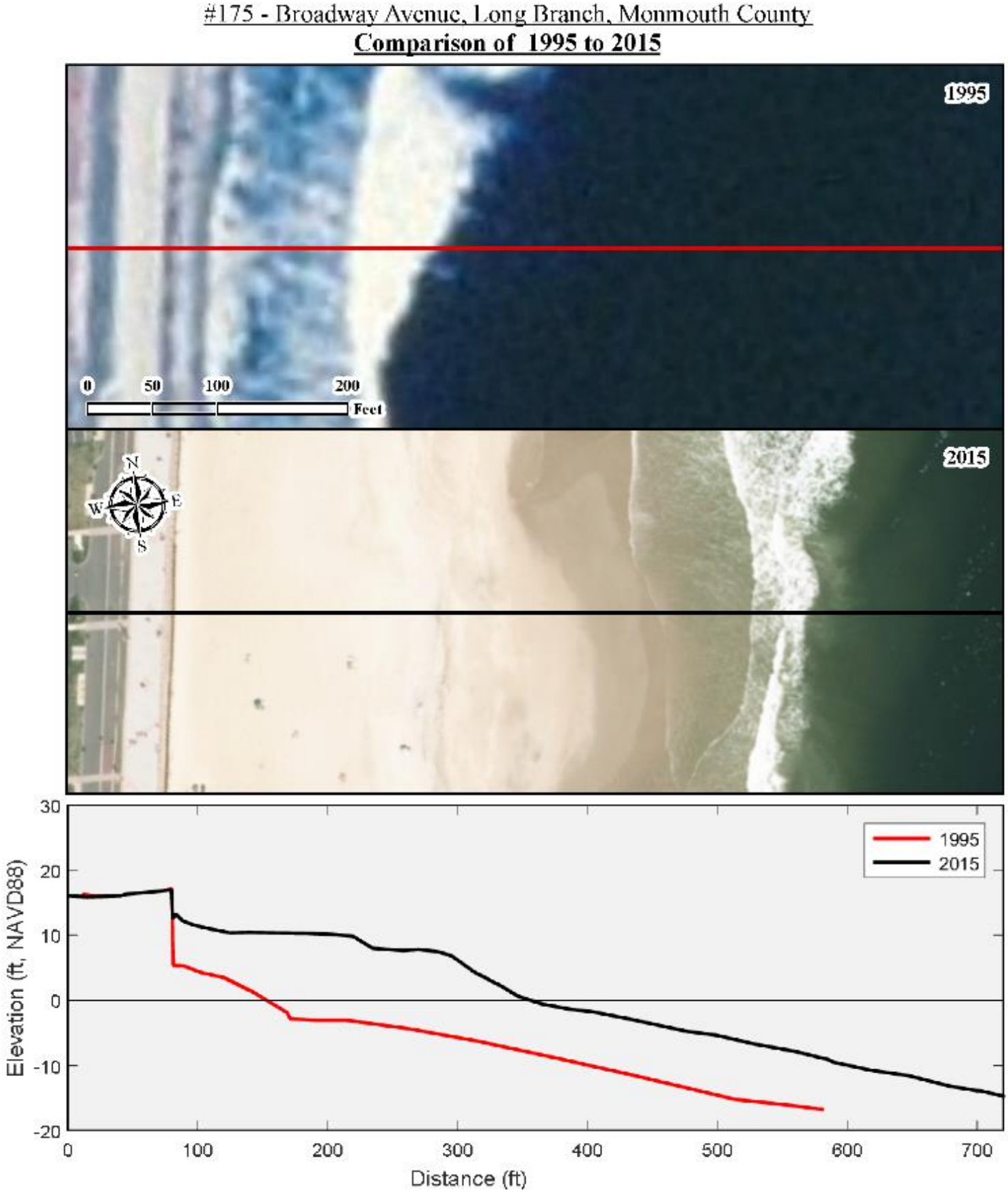

Figure 98. The Long Branch beach was available for bathing use in 1995, but presently is a far superior attraction due to the federal project. A 200 ft shoreline advance over 20 years has made a big difference.

Figure 99. Hurricane Sandy exposed the rock revetment, eroded the bluff above, and damaged the boardwalk. The beach and pedestrian walk were replaced since Hurricane Sandy and remain in good shape.

NJBPN 174 – Morris Avenue, Long Branch


Figure 100a & 100b. The Federal project, completed in 2014, resulted in a wider beach. The left photo (taken December 15, 2015) shows a new bulkhead to protect the roadway. By December 1, 2016 (right photo), the beach was still significantly wider than it was following Hurricane Sandy. The beach remains in good condition.

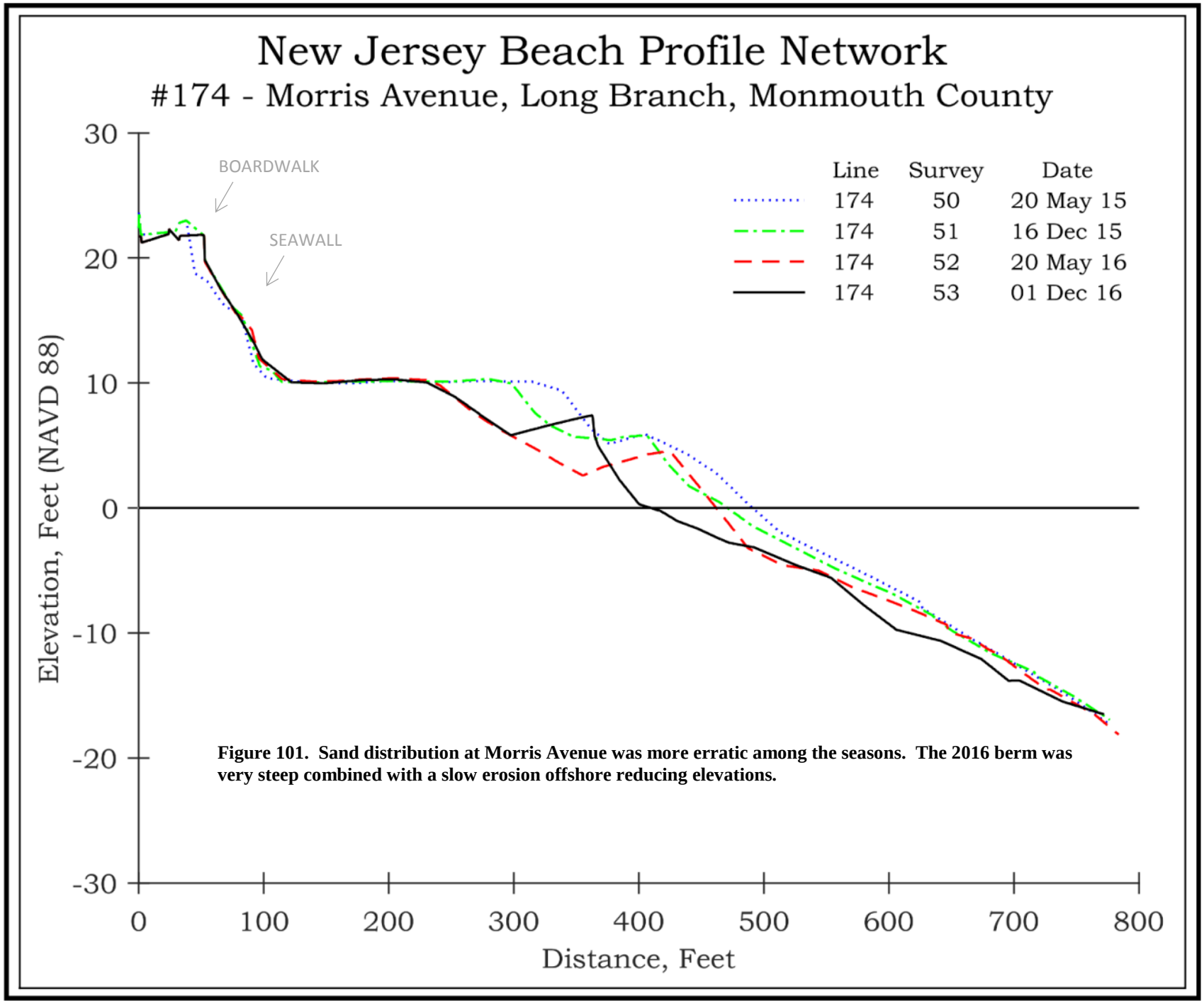

Figure 101. Sand distribution at Morris Avenue was more erratic among the seasons. The 2016 berm was very steep combined with a slow erosion offshore reducing elevations.

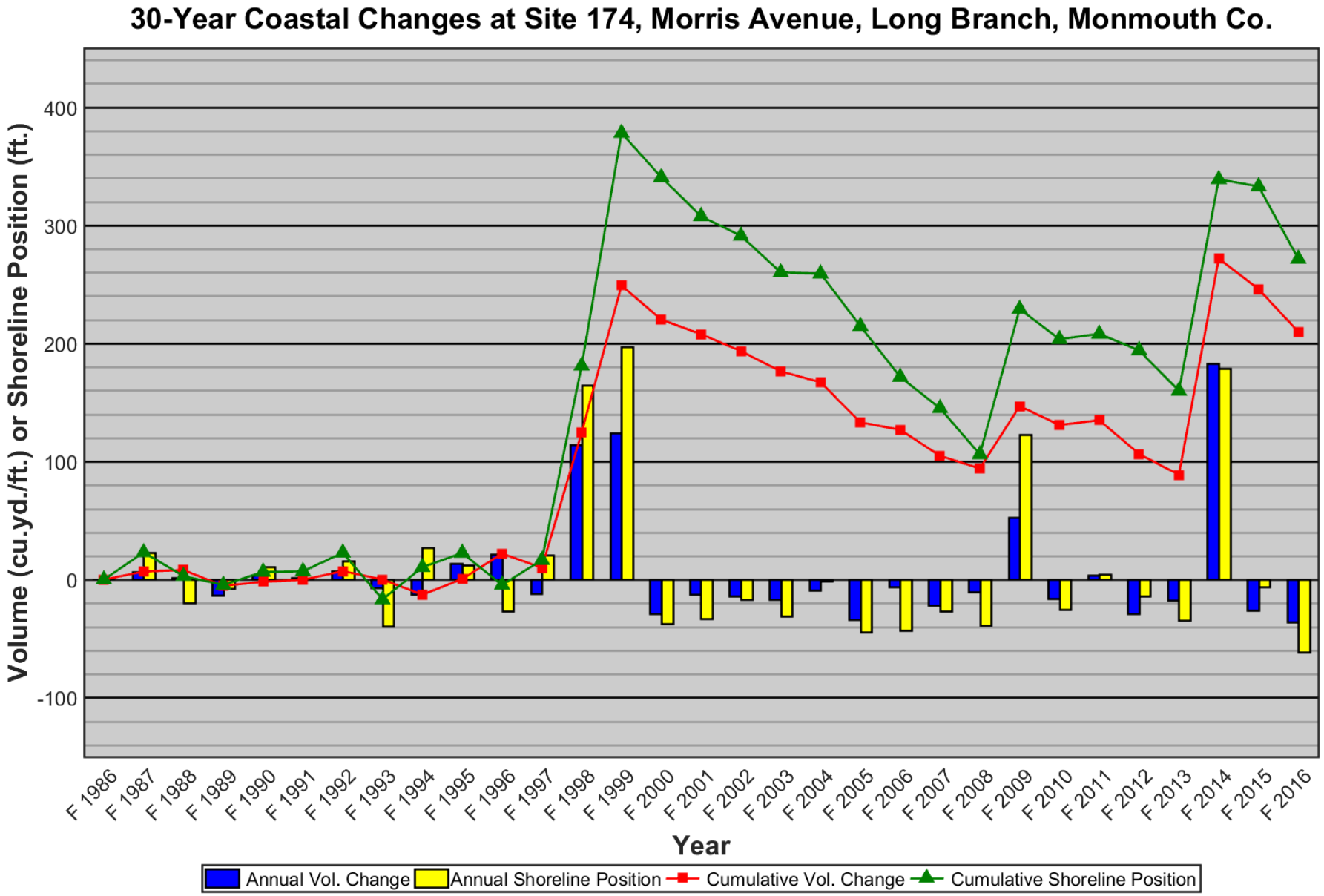

Figure 102. Morris Avenue is within a mile of the initial ending point for sand placement going south in Phase I. Since there was relatively little sand supply moving north into Long Branch from Elberon, the loss rate increased toward the southern end of the fill project. Progressive loss appears to define the trend during the times between successive maintenance efforts by the USACE.

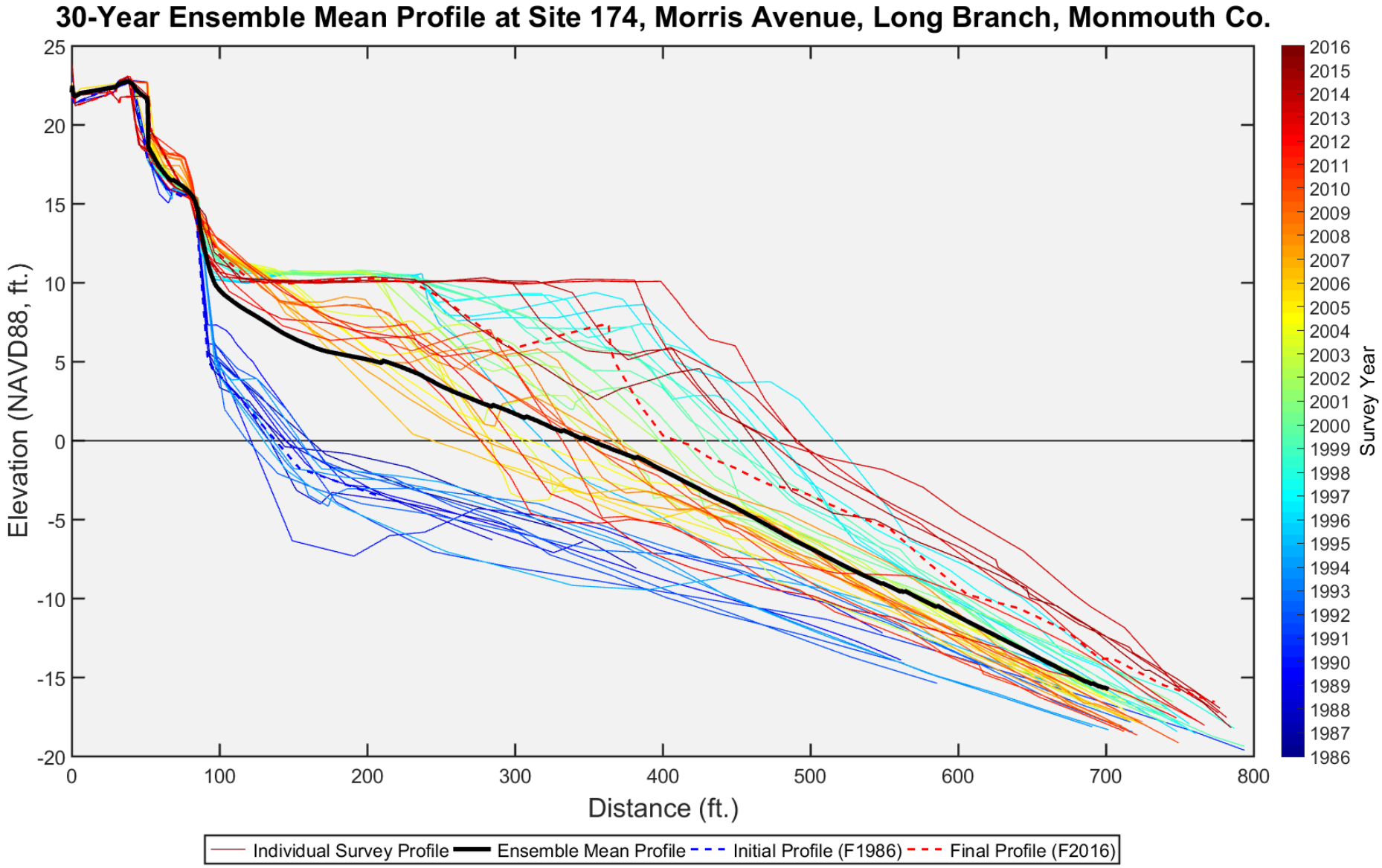

Figure 103. During the 1980s, the Long Branch beach was about 60 ft wide between the rocks and zero elevation position (or shoreline). The site exhibits a wider range of shoreline positions because of its location to the federal beach fill, which initially ended a mile to the south.

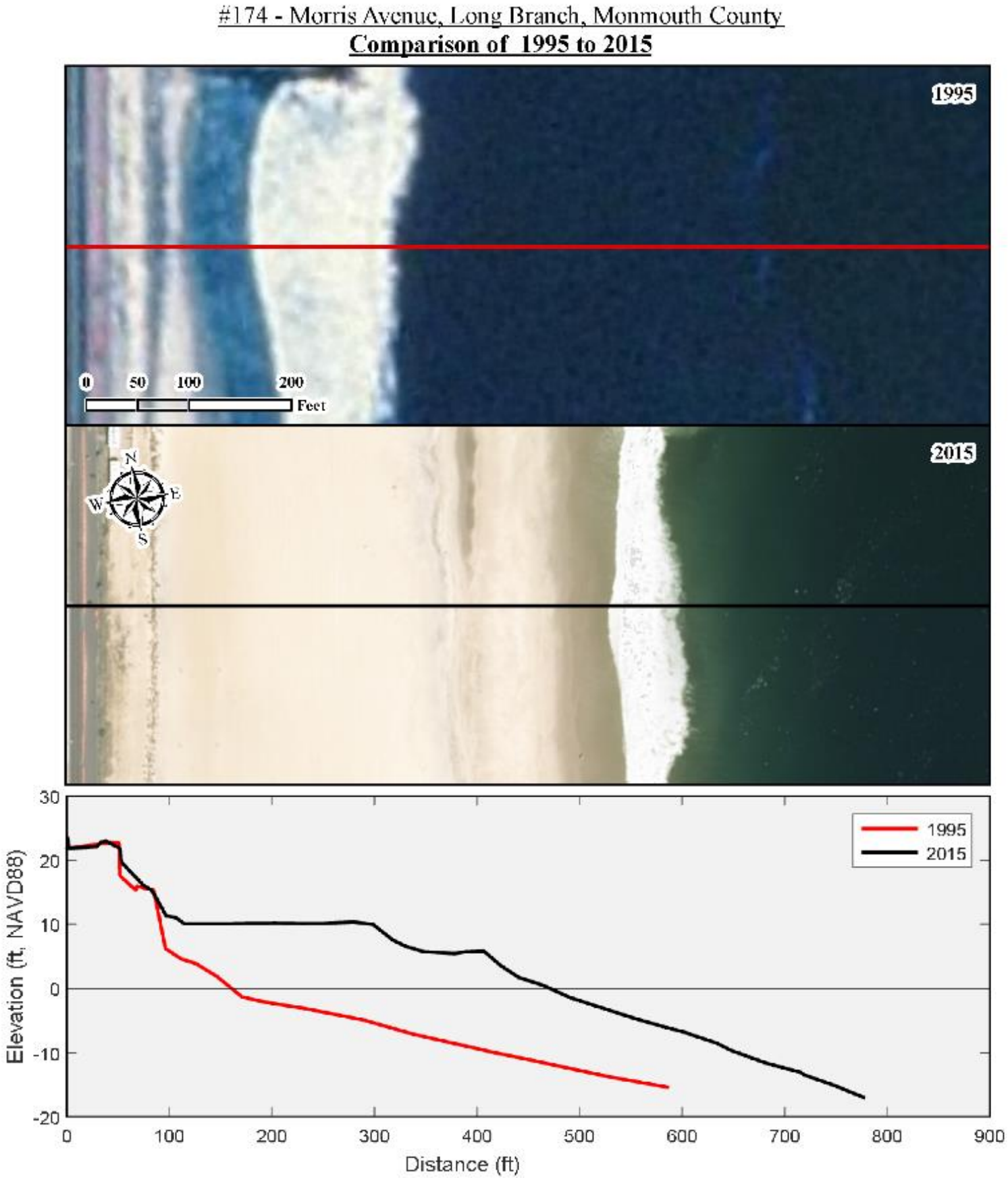

Figure 104. The narrow Long Branch beach at Morris Avenue has become about 320 feet wider since 1995.

Figure 105. View north on the beach at West End Avenue, Long Branch. This beach has had difficulty in maintaining its USACE design width over time. Perhaps the completion of the Allenhurst to Elberon section can supply the sand to this site, which was previously lacking.

NJBPN 173 – West End Avenue, Long Branch

Figure 106a & 106b. This site is located near the original southern limit of the federal beach nourishment project. The December 16, 2015 (left photo) view shows a minor scarp in the beach, but a bar welding onto the shoreline just at the toe of the scarp (tan color to the sand). By November 28, 2016 (right photo), the beach was of uniform slope with a wide low tide terrace present to the water's edge.

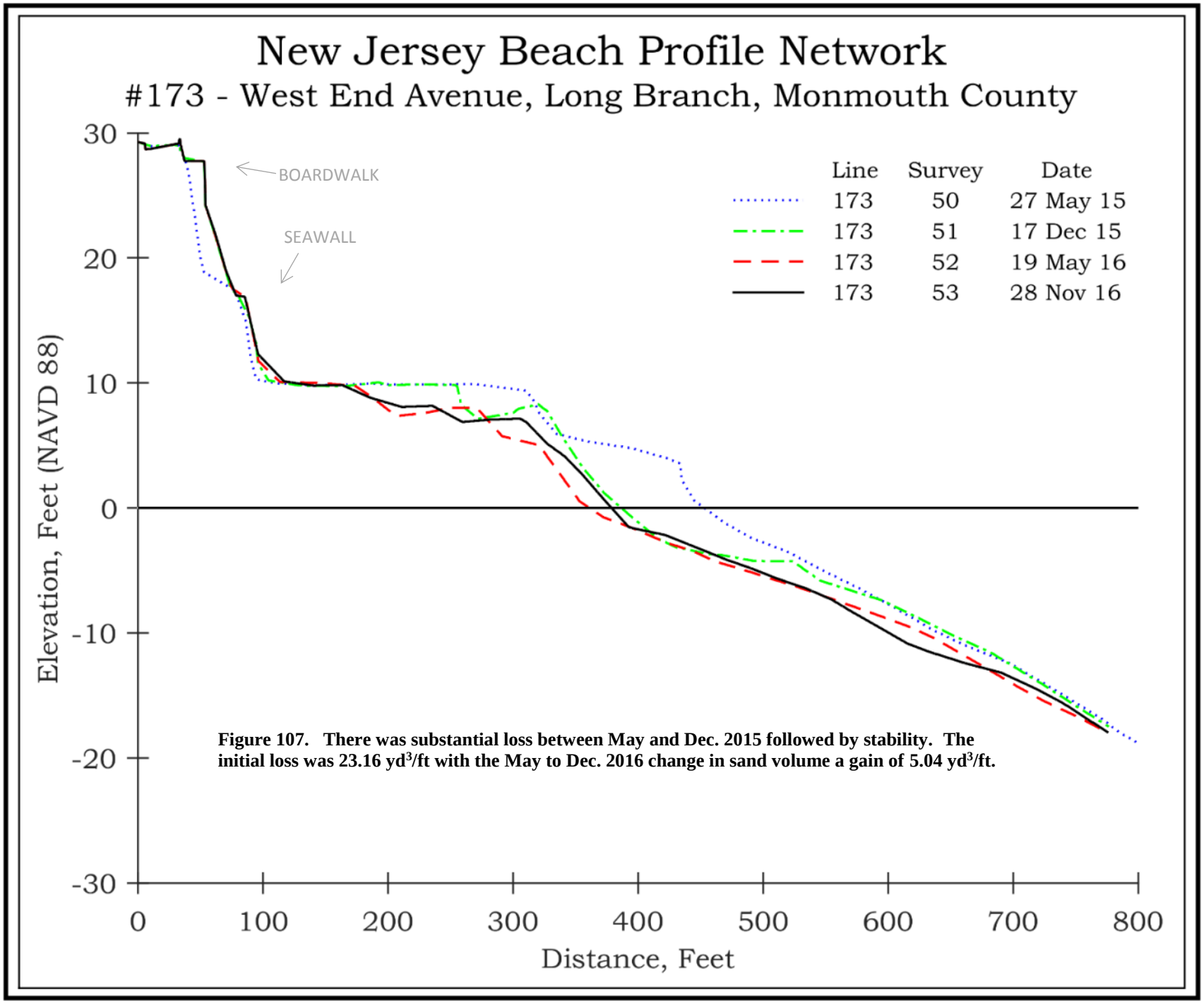

Figure 107. There was substantial loss between May and Dec. 2015 followed by stability. The initial loss was 23.16 yd^3/ft with the May to Dec. 2016 change in sand volume a gain of 5.04 yd^3/ft.

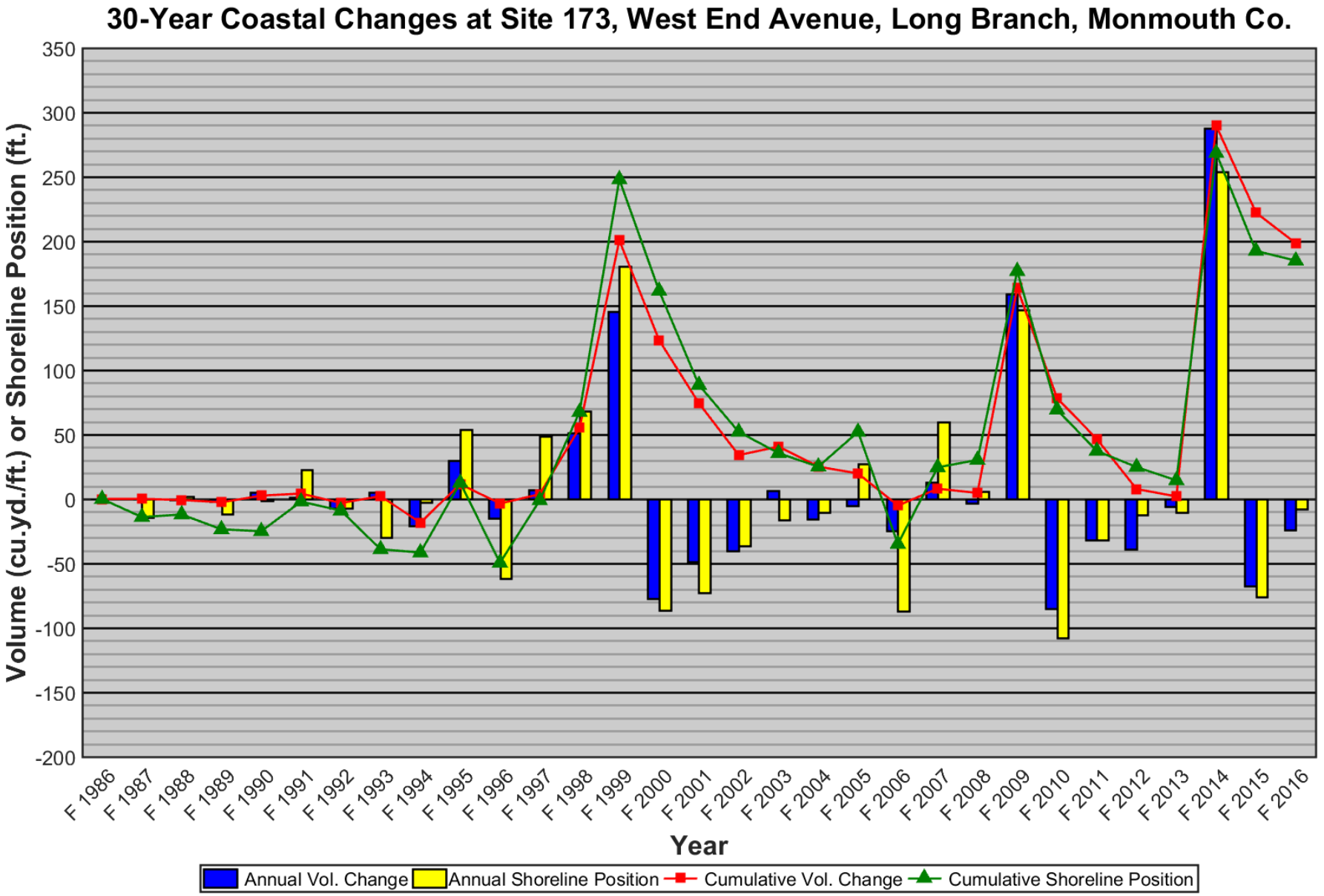

Figure 108. West End Avenue was essentially at the southern end of the Phase I project and the sand loss rate shows the impact of pronounced littoral transport to the north with no sand supply coming to this location from farther south. The project was completed in 1999, but the site was 75% depleted by 2002. Restored in 2009, the site was back to initial conditions by 2012. The 2014, post-Sandy effort has experienced a loss of about 100 yds^3/ft thus far, but now that Phase III of the project is complete, the rate of loss may decline dramatically.

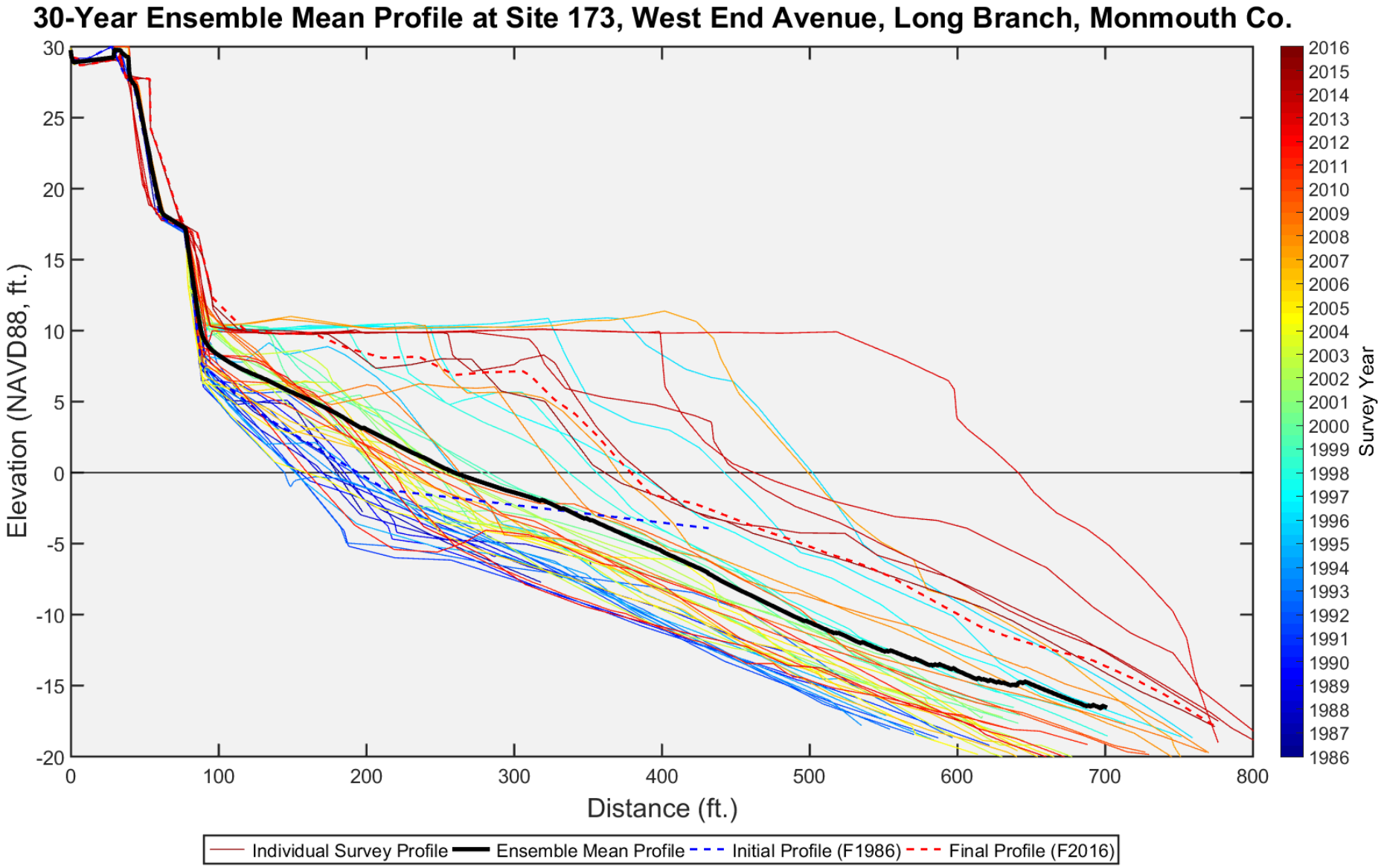

Figure 109. West End Avenue was within a 1,000 ft of the southern limit of sand placement in 1997. This allowed "end-effect" losses because sand preferentially moved north from here producing the range of retreat shown. This is the only site where the post-project beach eroded landward to become equivalent with pre-project beach configurations. The immediate post-Sandy restoration profile was truly amazing in comparison. Retreat continues to the point where the red dashed line from the fall of 2016 survey is about half way back to the original configuration.

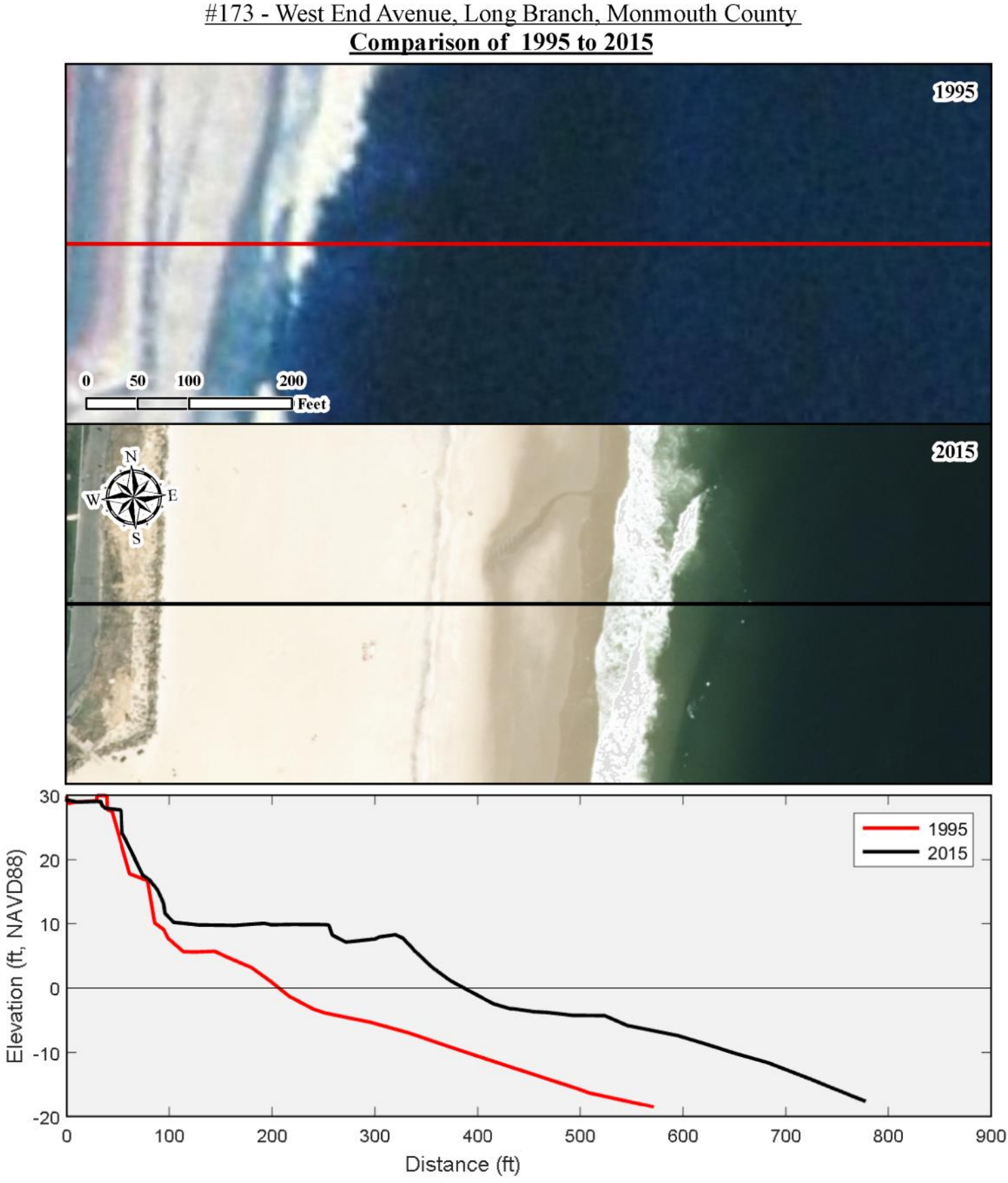

Figure 110. West End Avenue was at the southern terminus of the federal project until 2016 and frequently saw major sand losses with associated shoreline retreat. Recent work completing the Allenhurst to Long Branch segment (Phase III) will mitigate these losses.

Figure 111. This new site was put in place after the original location site was destroyed by development in a location just north of Lake Takanassee. Breached open by Hurricane Sandy, a new flume to drain the lake has been completed and the beach restored.

NJBPN 272 – 805 Ocean Ave, Long Branch


Figure 112a & 112b. This site, established in 2010, is located on the northeastern edge of Lake Takanassee and within a groin compartment. On the left (Dec. 17, 2015) the beach extends about 200 ft from the instrument station. The USACE restoration effort extended to the south into Elberon during 2014 and by December 21, 2016 the beach was completed between Allenhurst and Long Branch. The wave activity had cut a scarp in the new berm creating a wider nearshore terrace seaward.

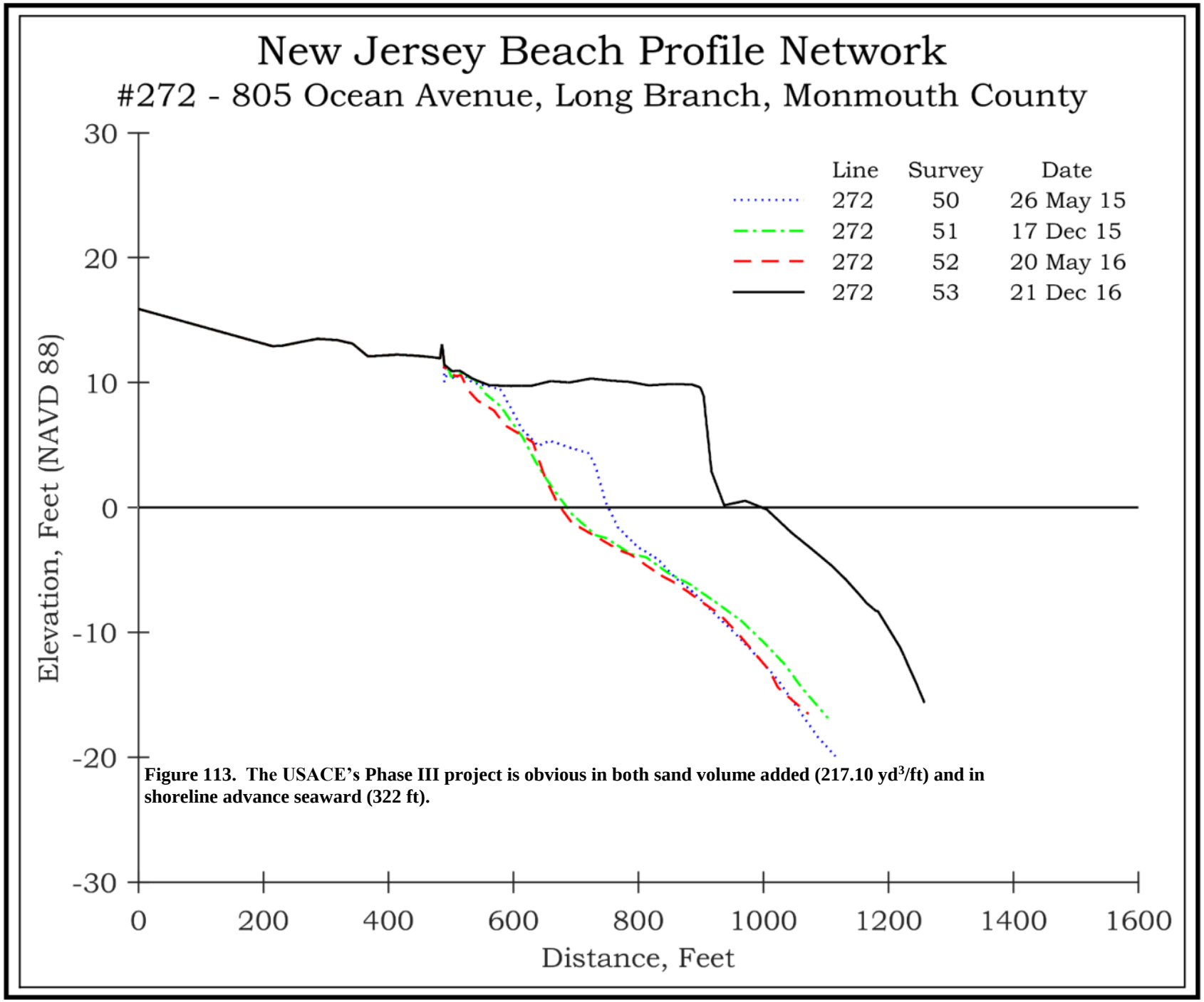

Figure 113. The USACE's Phase III project is obvious in both sand volume added (217.10 yd^3/ft) and in shoreline advance seaward (322 ft).

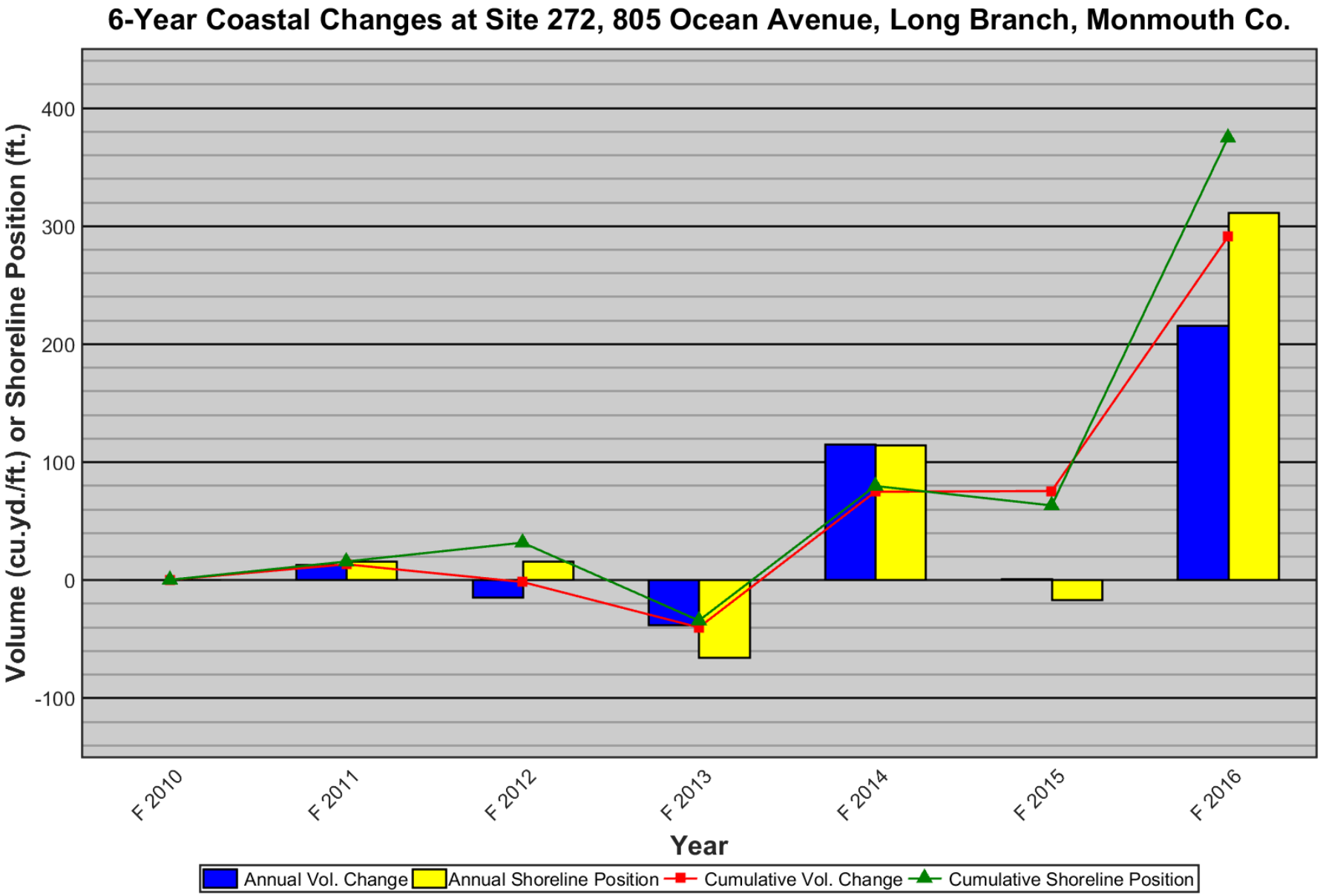

Figure 114. This site was lost to development years ago and recently re-established as a means to follow the inception of the third phase in this USACE project at a site near Lake Takanassee. The 2016 jump in both shoreline and sand volume are evidence that the Phase III work was completed by fall 2016. A modest sand volume arrived during the post-Sandy restoration effort as well in 2014.

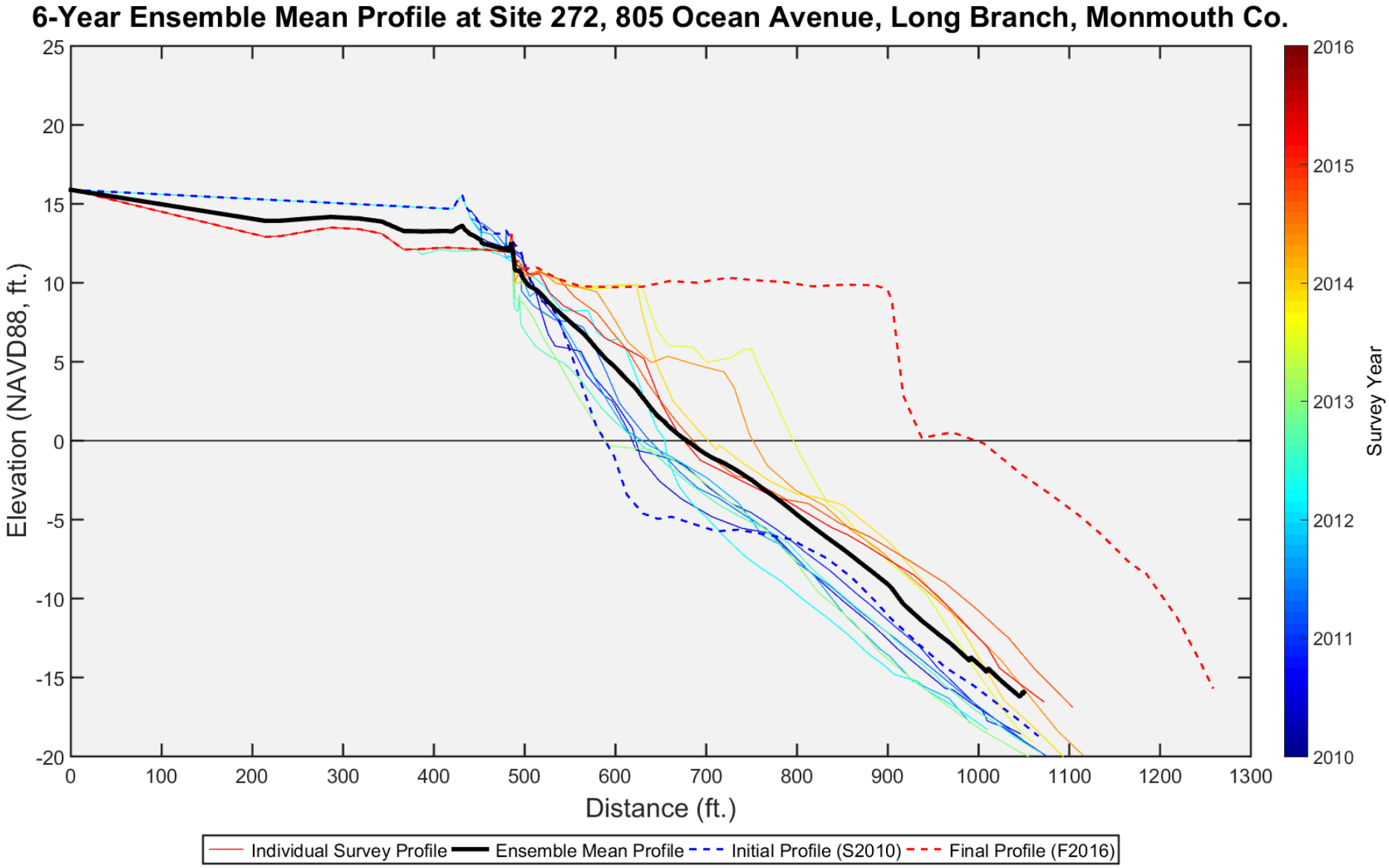

Figure 115. This site was re-established further south than the original site 172 that was actually paired with site 173 because of the shoreline contrast that previously existed at West End Avenue in Long Branch. The Phase III work between Allenhurst and Elberon was completed in 2016 and shows at the most recent cross section (dashed red line).

#272 - 805 Ocean Avenue, Long Branch, Monmouth County

Comparison of 2010 to 2015

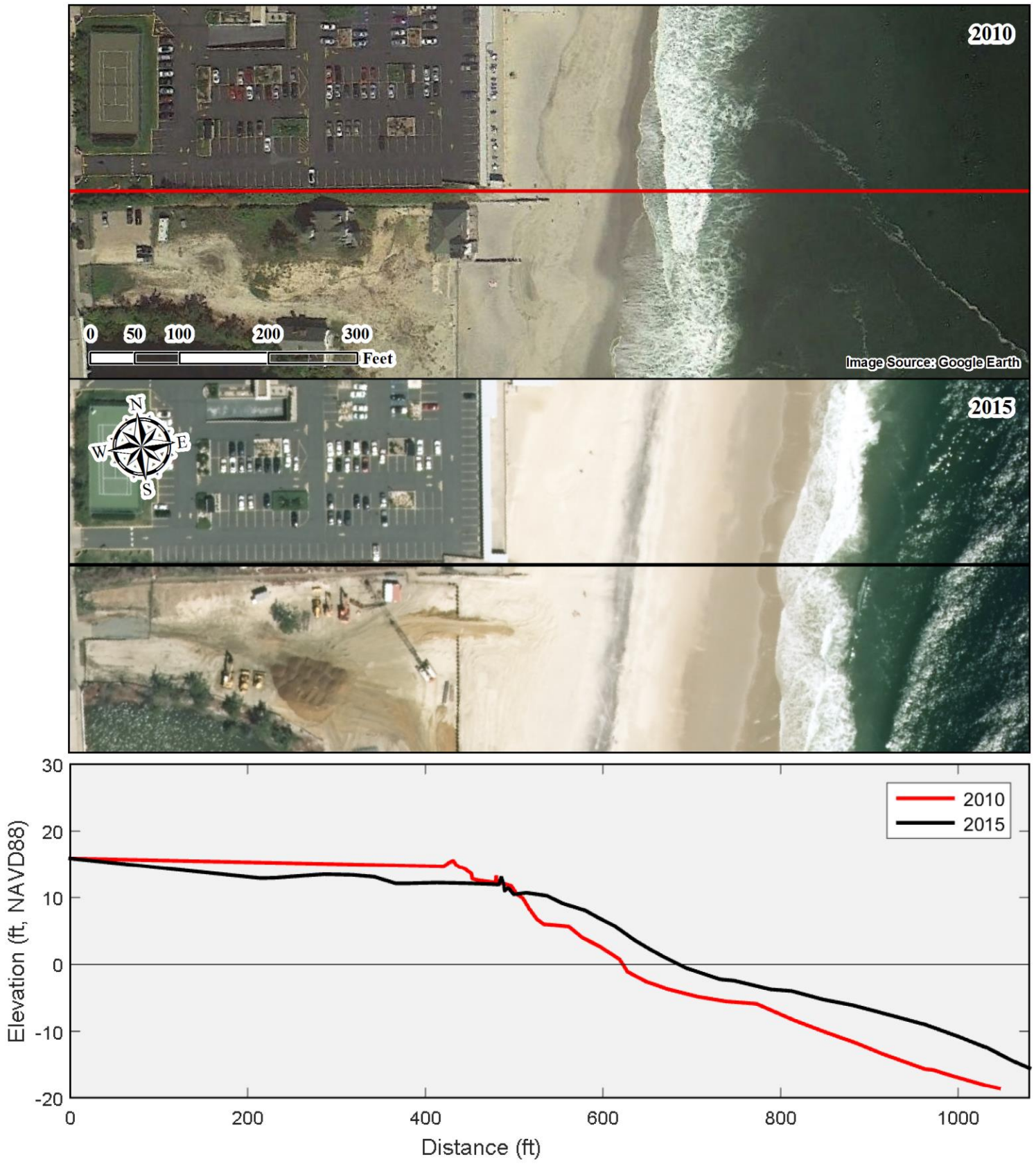

Figure 116. This site was recently added as the development at the shoreline allowed access to a site just north of Lake Takanassee. The federal project just reached completion as of fall 2016, as evident in Figure 113. No photography earlier than April, 2016 is known to exist so the change due to the federal project cannot be displayed as of now.

Figure 116. The USACE project beach was nearly complete at Pullman Ave. in the fall of 2016. This exact location would have been over 250 ft into the ocean a year earlier. This site seldom had a dry sand beach prior to the project. The entire profile beyond the toe of the rock revetment was subaqueous.

NJBPN 171 – Pullman Avenue, Elberon

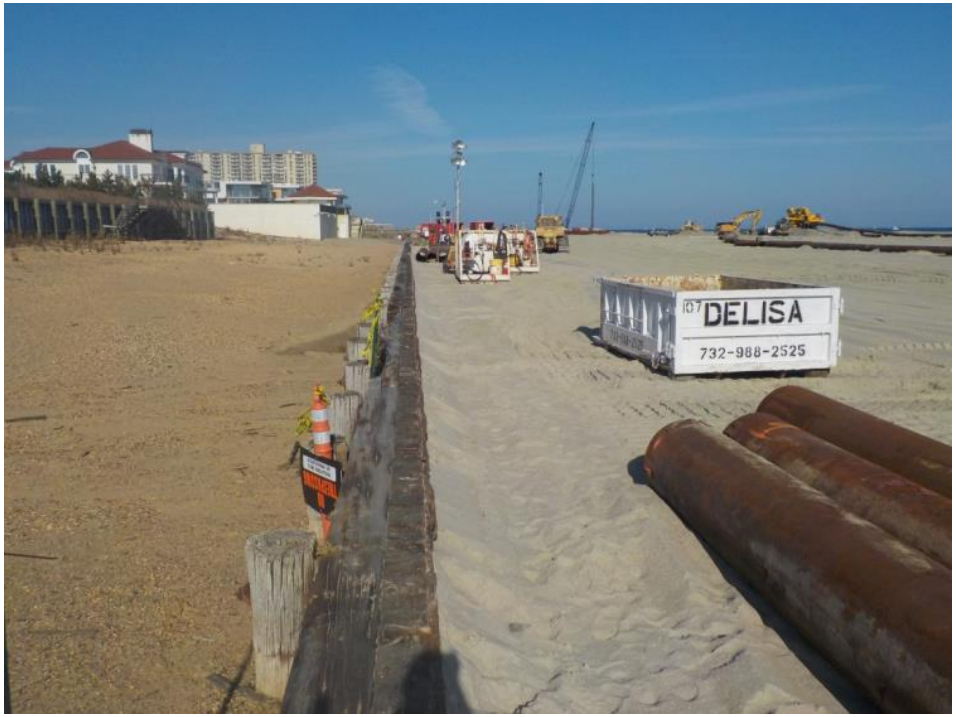

Figure 117a & 117b. This site is located on the highest point along the bluff shoreline and erosion of the bluff sediment generated a dry beach after Sandy that remained through December 16, 2015 (left photo). By November 28, 2016 (right photo), the USACE was finishing up the Phase III beach project as can be seen with the pipeline still in place. The new beach is 400 ft wider than the old on, making the picture comparison dramatically different.

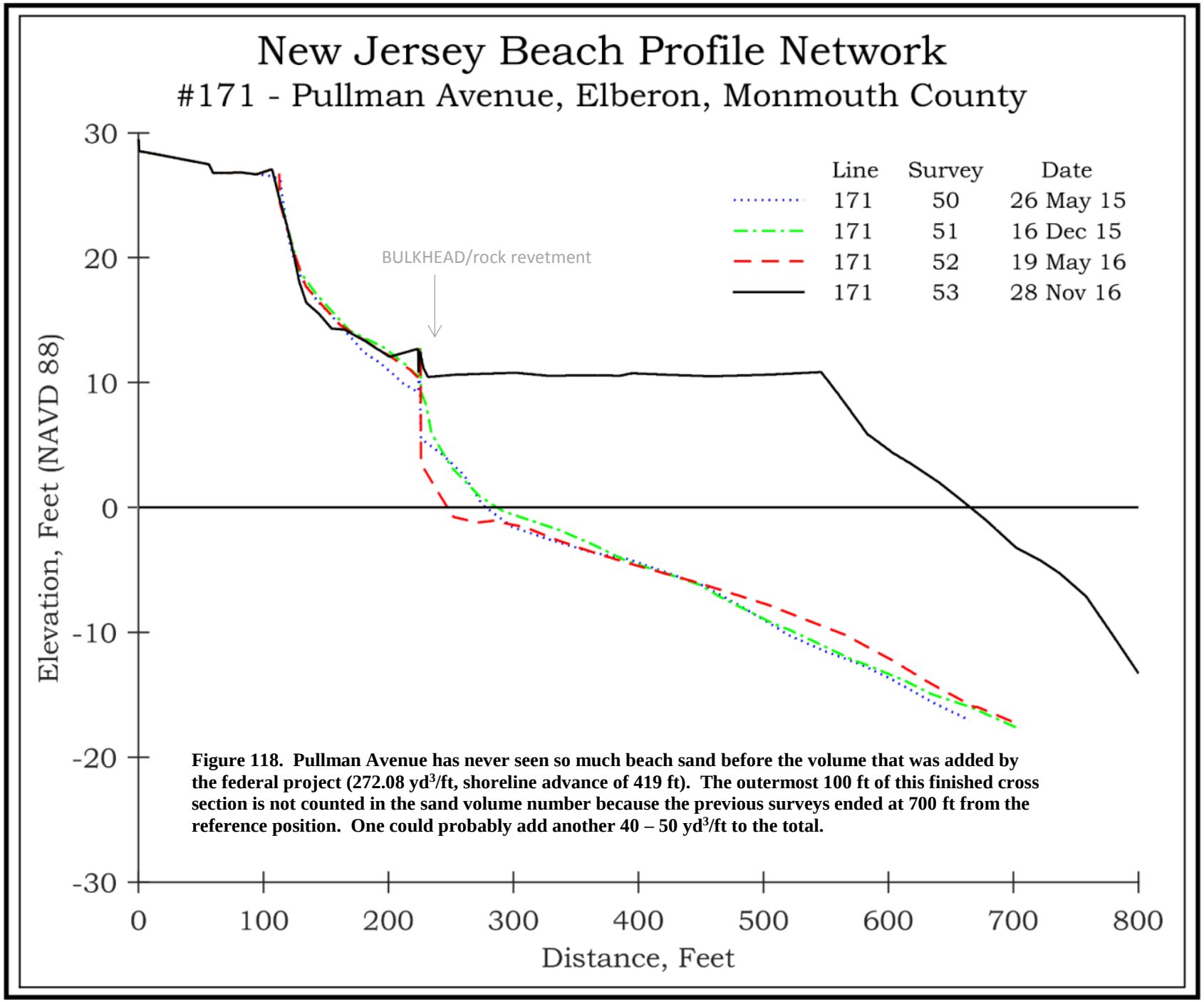

Figure 118. Pullman Avenue has never seen so much beach sand before the volume that was added by the federal project (272.08 yd^3/ft, shoreline advance of 419 ft). The outermost 100 ft of this finished cross section is not counted in the sand volume number because the previous surveys ended at 700 ft from the reference position. One could probably add another 40 – 50 yd^3/ft to the total.

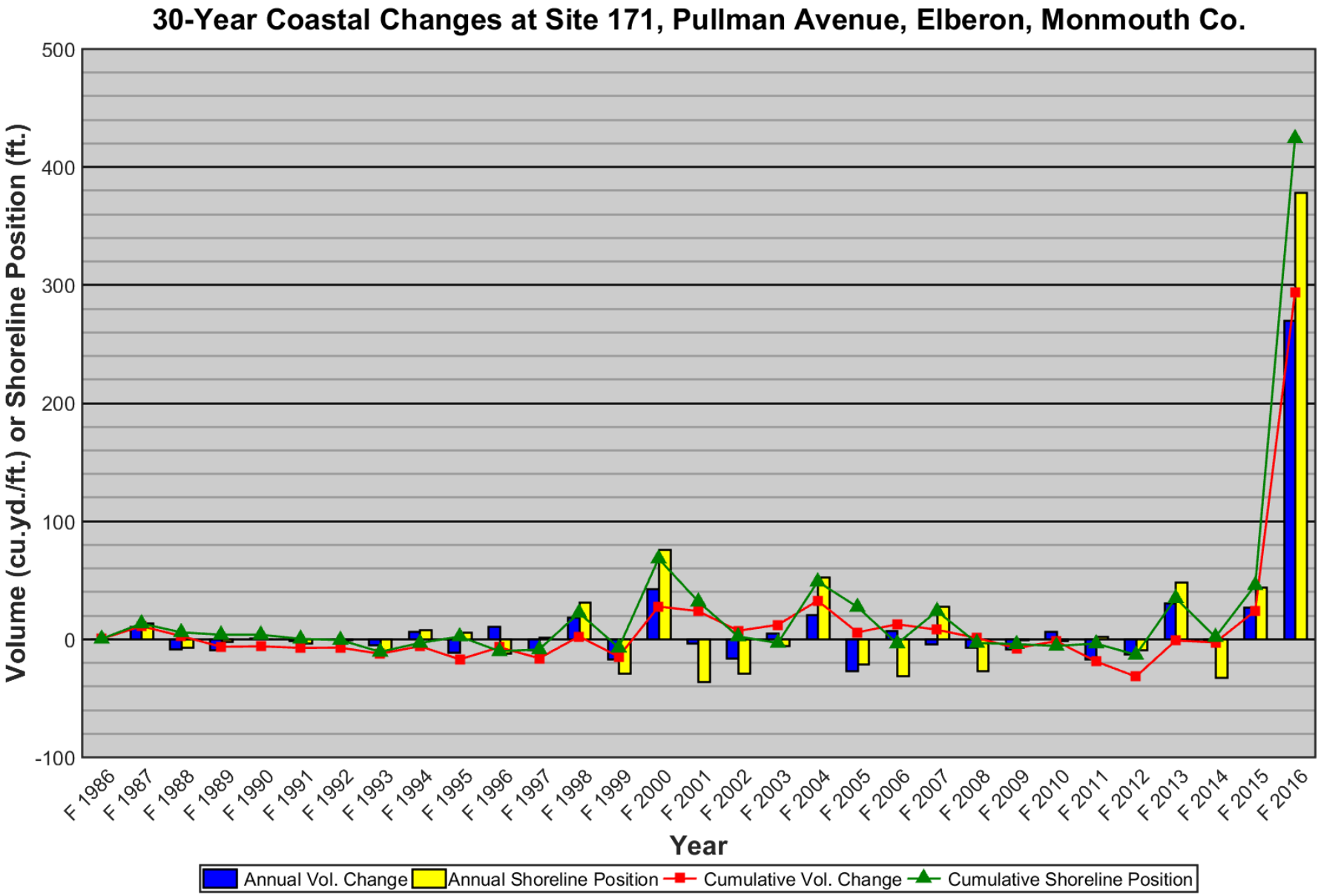

Figure 119. The long term trend shows five positive shoreline spikes with three accompanied by sand volume increases. The 2013 spike was due to sand eroded directly from the upper bluff during Sandy and distributed into the swash zone to create a dry beach for the first time since 2004. The impact of the USACE project in 2016 is quite obvious.

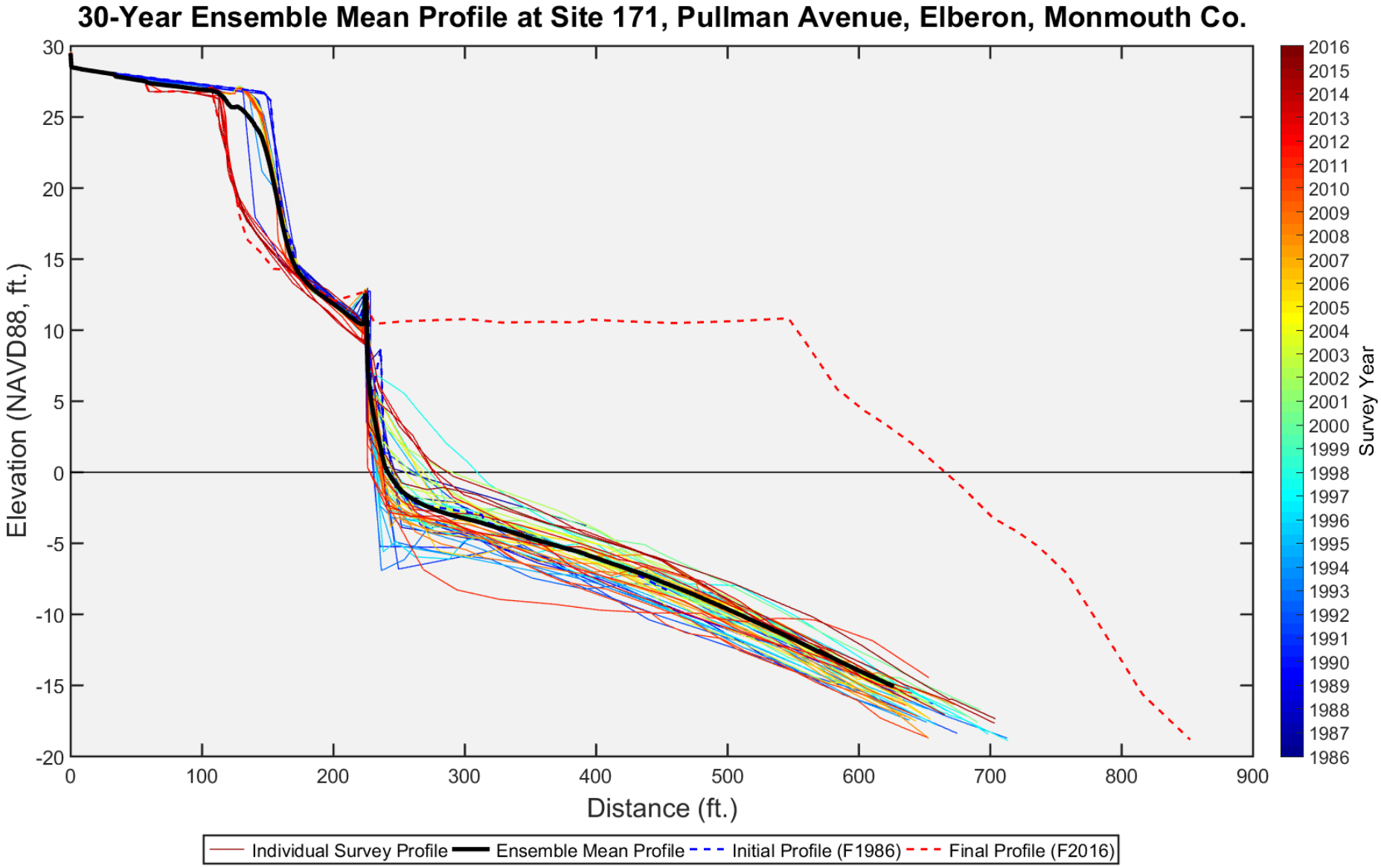

Figure 120. The lower bluff was fully armored with steel sheet pile plus large rock revetment protection. The upper 18 ft was not protected, but had avoided any erosion until Hurricane Sandy cut a 50 ft slice out of the bluff sediments. Occasionally a wet sand beach presented itself at low tide and rarely a dry sand beach existed at the base of the revetment until the fall 2016 profile cross section which represents the completed USACE project at this site.

#171 - Pullman Avenue, Elberon Borough, Monmouth County

Comparison of 1995 to 2015

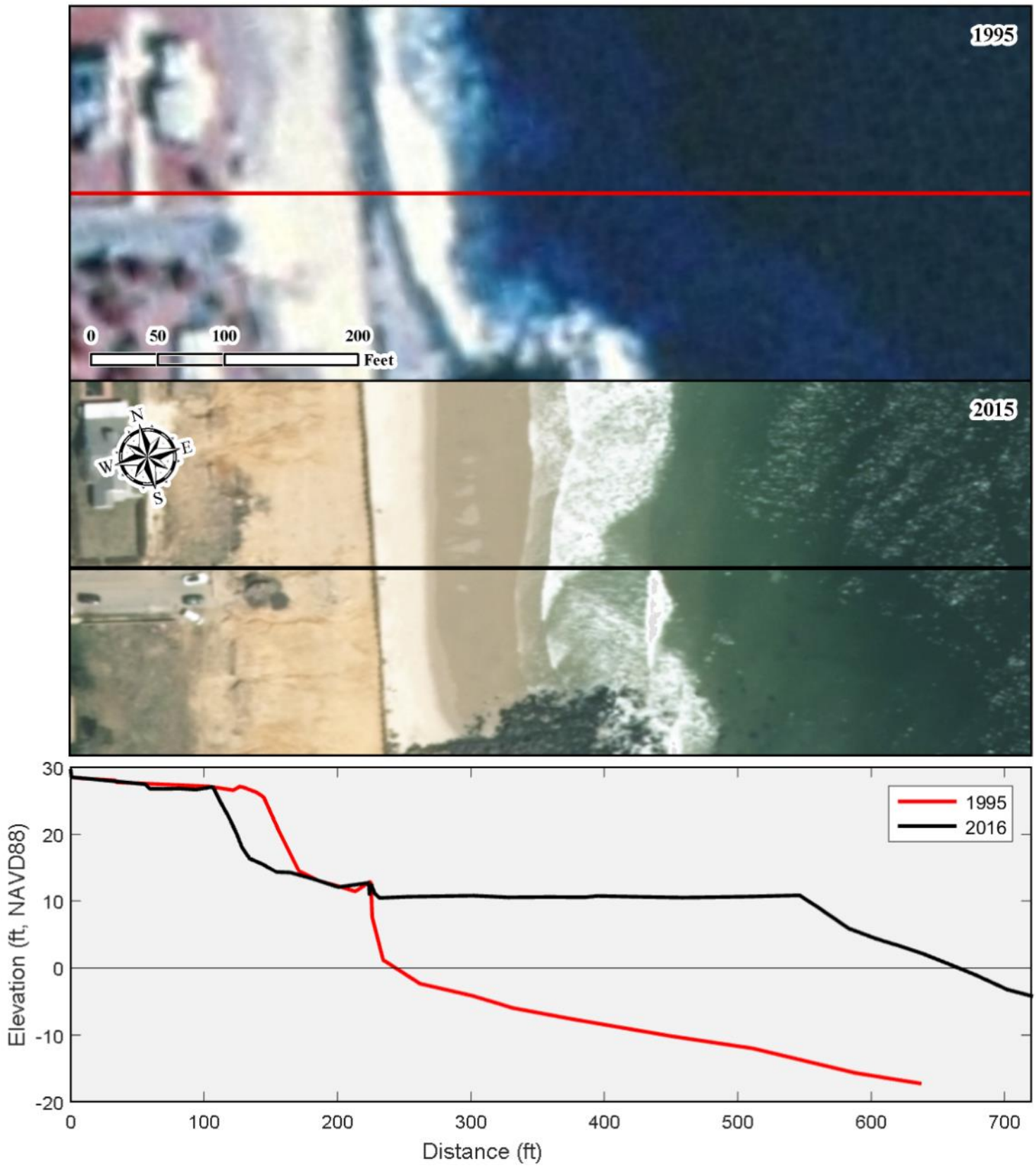

Figure 121. Sand placement reached this site by the fall of 2016, and therefore the aerial photograph available does not show the full extent of this recent work by the New York District USACE. A 400 ft shoreline advance turns a site with water at the rock revetment at nearly all tidal stages to a wide sand beach. Great protection, but very little recreational use expected.

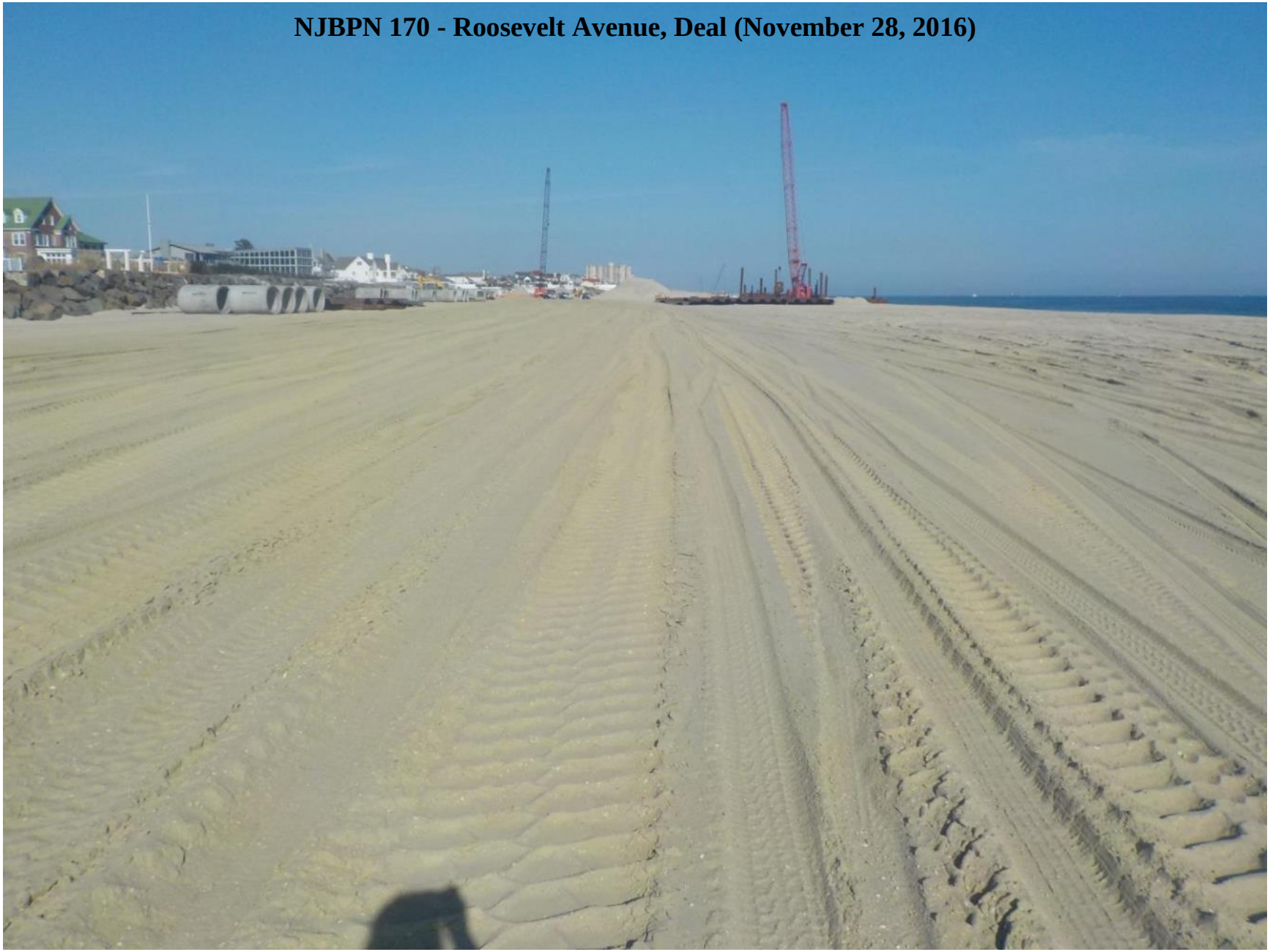

Figure 122. View to the north on the new USACE beach at Roosevelt Avenue, Deal. This site would have been 200 ft into the ocean a year earlier. This site seldom had a dry sand beach prior to the project. The entire profile beyond the toe of the rock revetment was subaqueous.

NJBPN 170 – Roosevelt Avenue, Deal

Figure 123a & 123b. This profile is located between two rock groins that limit sediment movement. Prior to 2016, this area had never received sand from direct beach nourishment. The photo on the left (taken December 4, 2015) shows what little sand accumulated above low tide in the compartment between groins. By November 28, 2016 the USACE contractor was finishing up the beach and the point where the photographer took the shot would have been 300 ft into the ocean a year earlier.

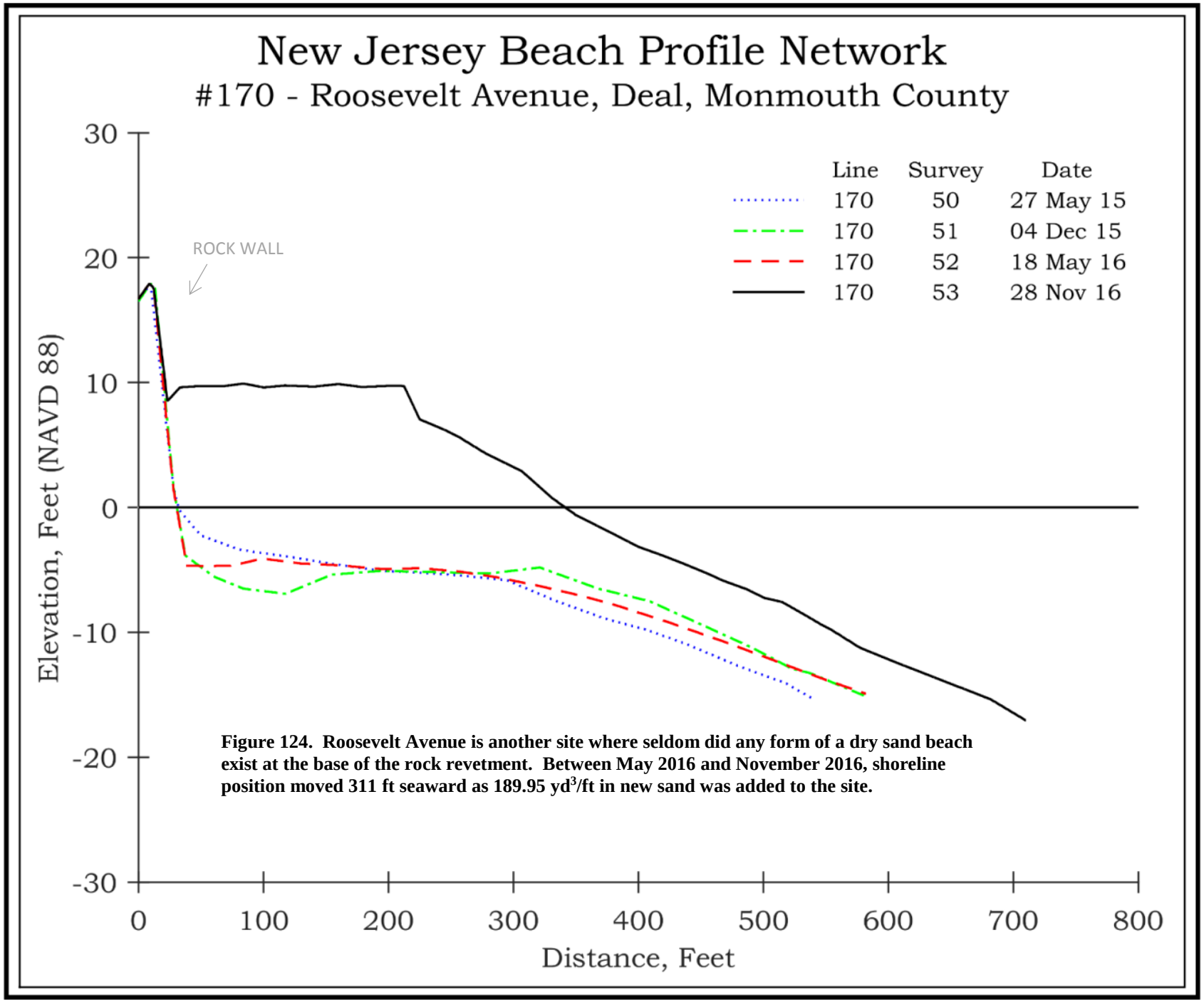

Figure 124. Roosevelt Avenue is another site where seldom did any form of a dry sand beach exist at the base of the rock revetment. Between May 2016 and November 2016, shoreline position moved 311 ft seaward as 189.95 yd^3/ft in new sand was added to the site.

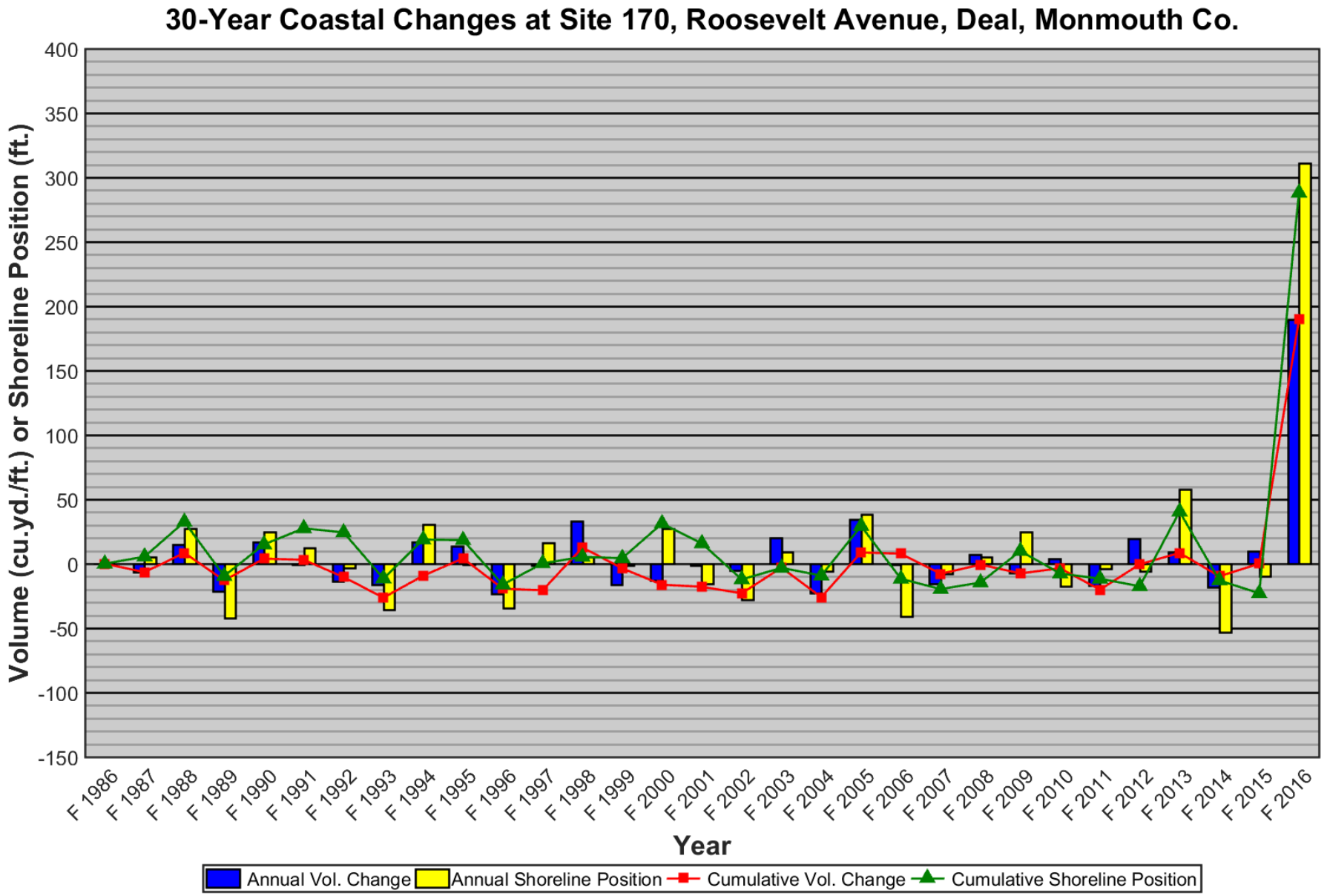

Figure 125. The Roosevelt Avenue site was one seldom having any type of wet or dry sand beach until 2005 and again after Sandy in 2013. Now the beach extends 300 ft from the rocks, which were once the only shoreline feature present.

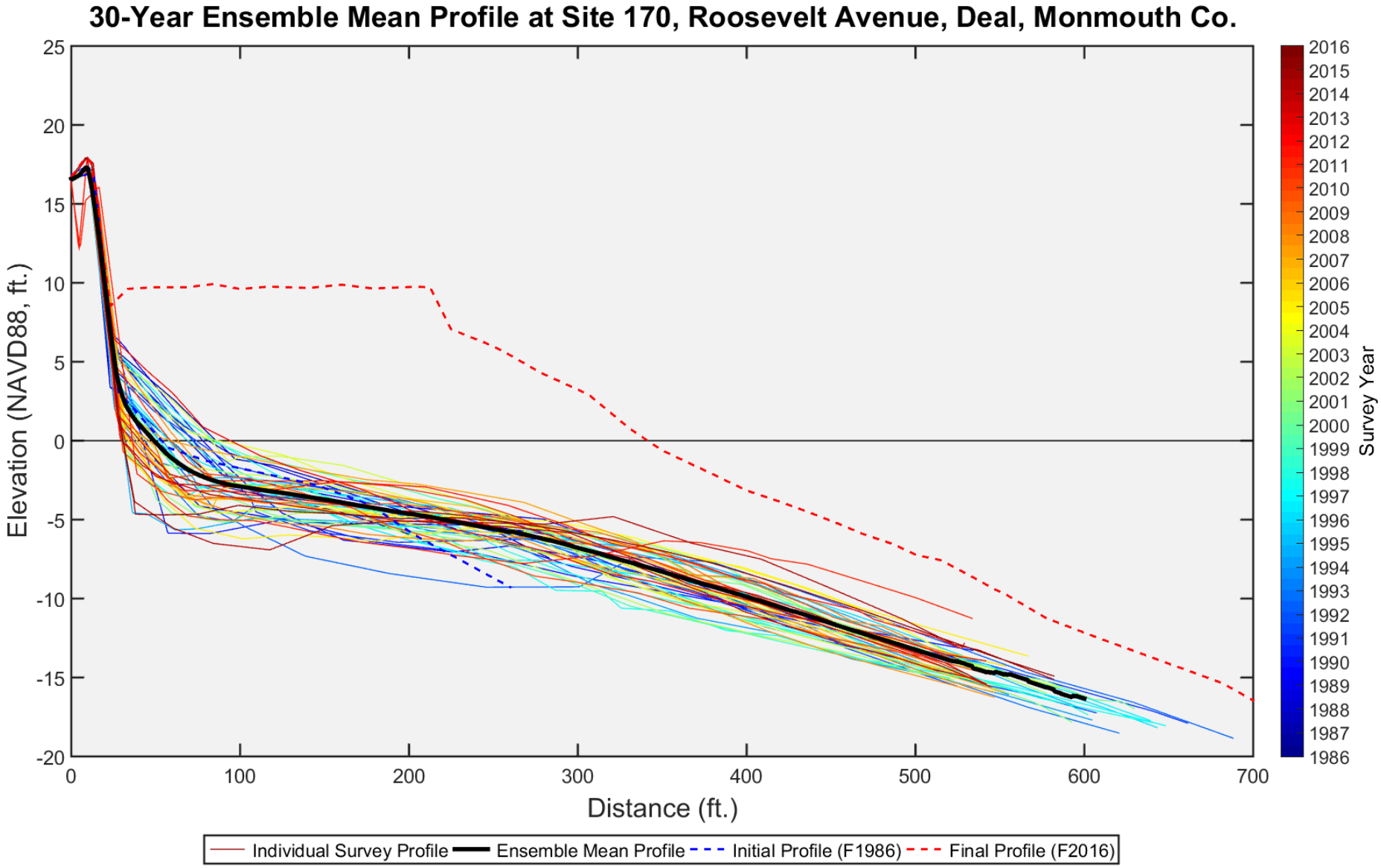

Figure 126. Roosevelt Avenue was another Deal site without a sand beach at the base of the rock revetment. Occasionally sand would create a wet beach at low tide, but frequently the beach profile started in the water. The fall 2016 cross-section defines the change to the last 30 years of beach surveys at this location.

#170 - Roosevelt Avenue, Deal Borough, Monmouth County

Comparison of 1995 to 2015

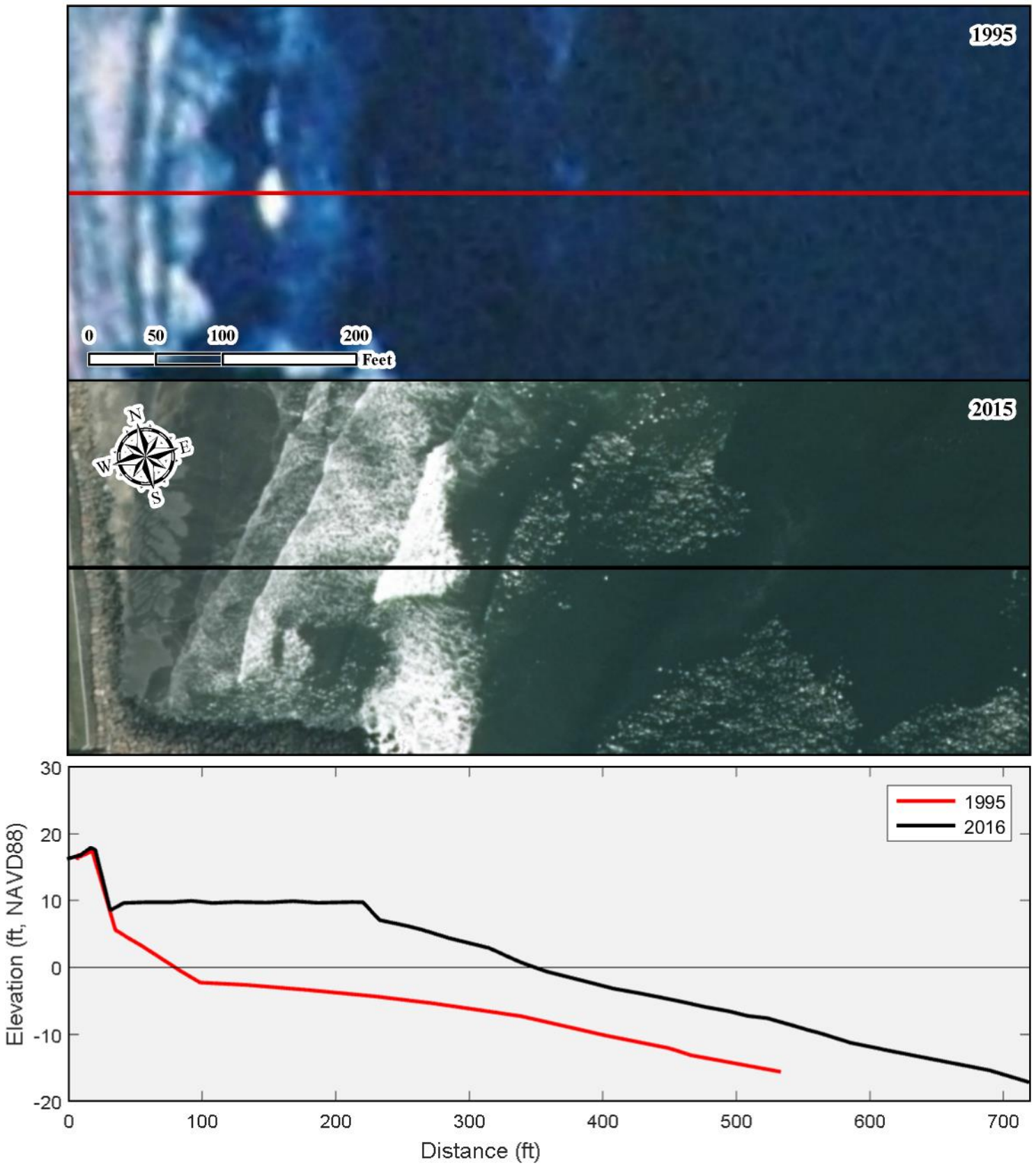

Figure 127. The fall 2016 profile cross-section displays the effect of the recently completed USACE work versus the past history of water at the rock toe.

Figure 128. Looking north from the top edge of the bluff at Darlington Avenue, Deal over a year following sand placement the site. New bulkhead construction followed Hurricane Sandy. The beach is about 50 ft narrower than as finished, but the sand volume is nearly the same.

NJBPN 169 – Darlington Avenue, Deal

Figure 129a & 129b. The Darlington site had a small sub-aerial beach contained between two larger groins. The upland bluff was eroded significantly during Sandy and material was added to the beach. By November 30, 2015 (left) the USACE project was underway adding dramatically to the beach with additional groin work in progress as well. By November 27, 2016 the beach was adjusted to the greater sand volume and about at the same level of material present.

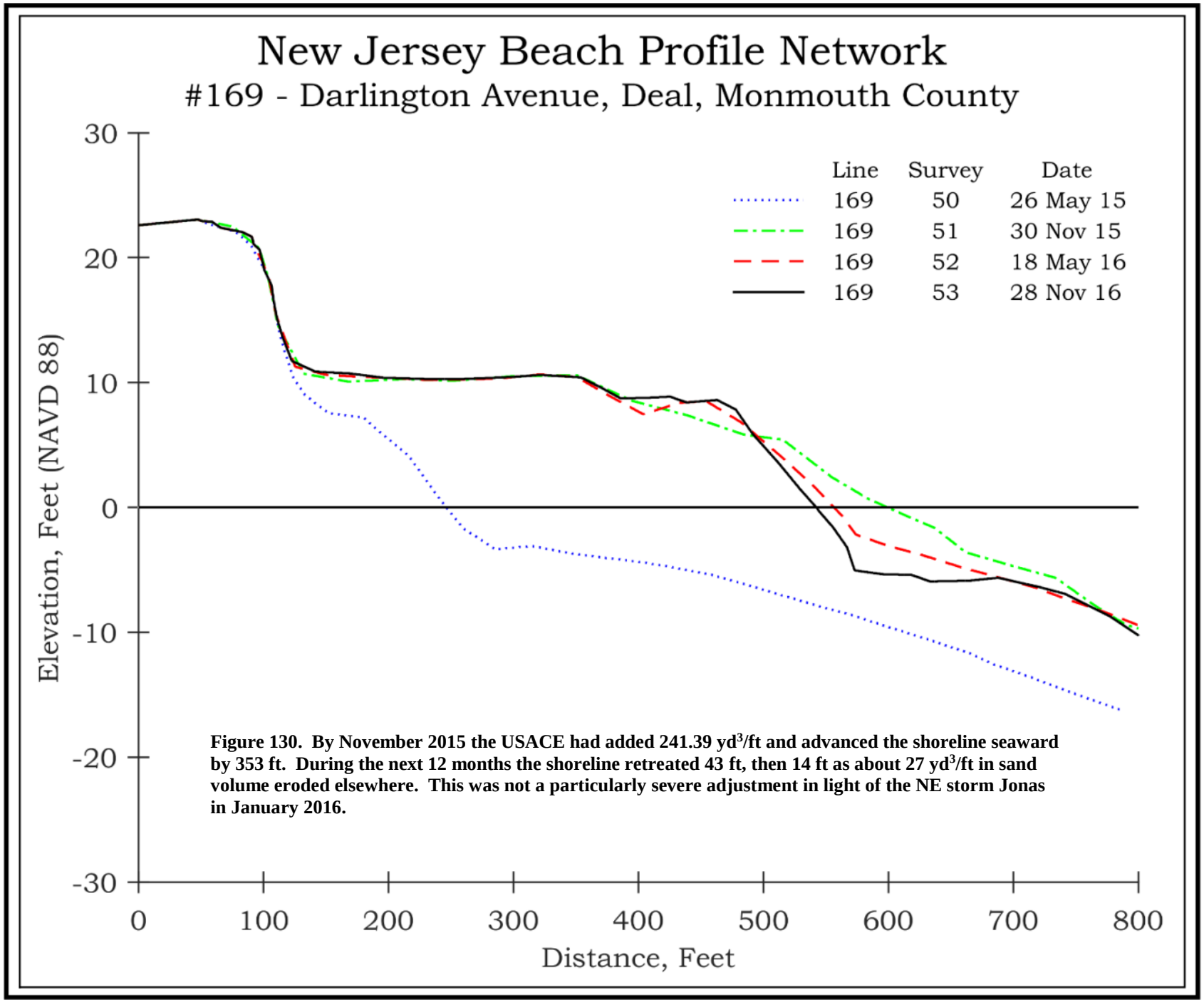

Figure 130. By November 2015 the USACE had added 241.39 yd^3/ft and advanced the shoreline seaward by 353 ft. During the next 12 months the shoreline retreated 43 ft, then 14 ft as about 27 yd^3/ft in sand volume eroded elsewhere. This was not a particularly severe adjustment in light of the NE storm Jonas in January 2016.

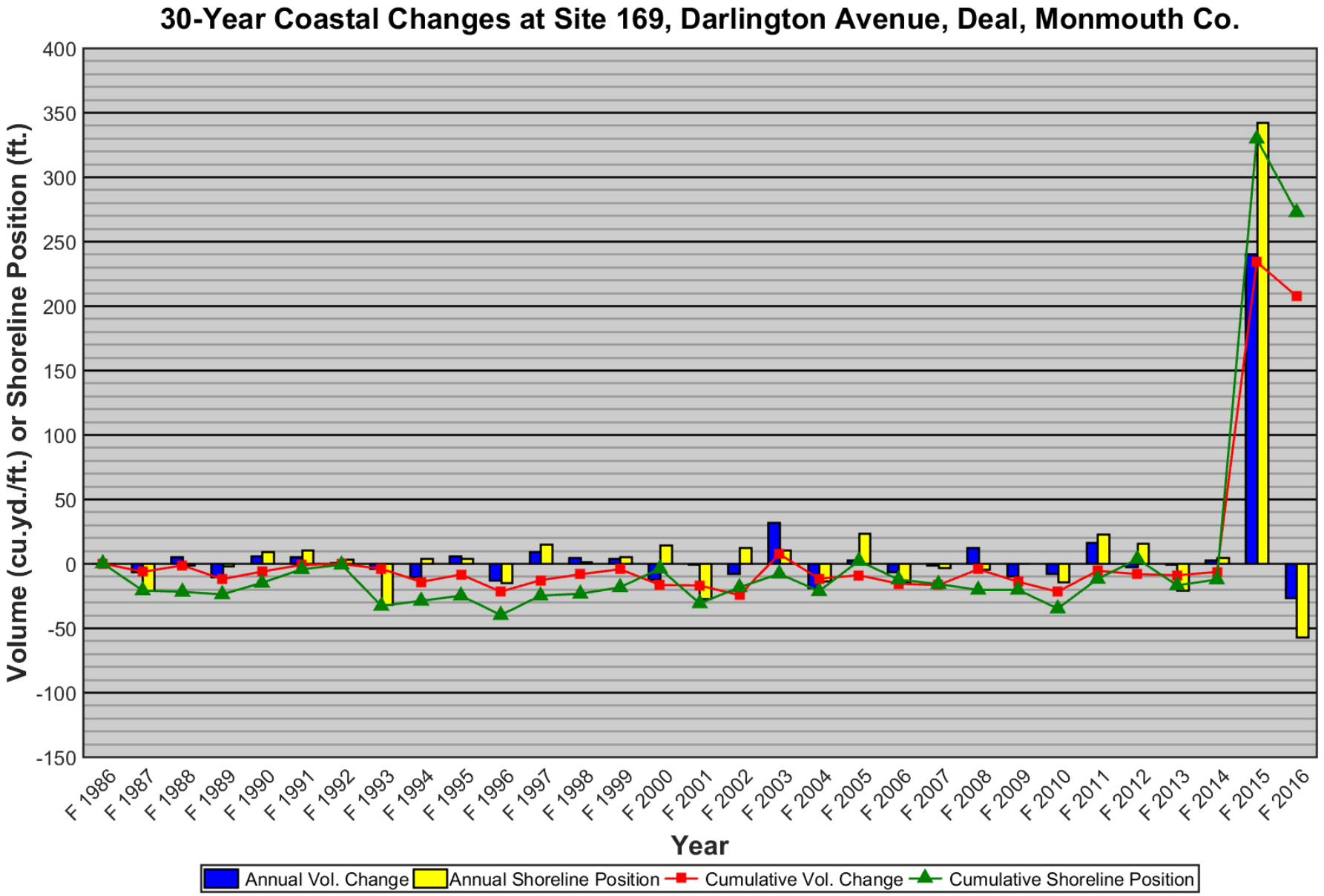

Figure 131. The Darlington Avenue site remained around the initial sand volume condition with a 25 ft average shoreline retreat until 2014. The USACE project extended the shoreline seaward by 340 ft as 240 yds^3/ft of sand was added. Minor loss occurred between 2015 and 2016.

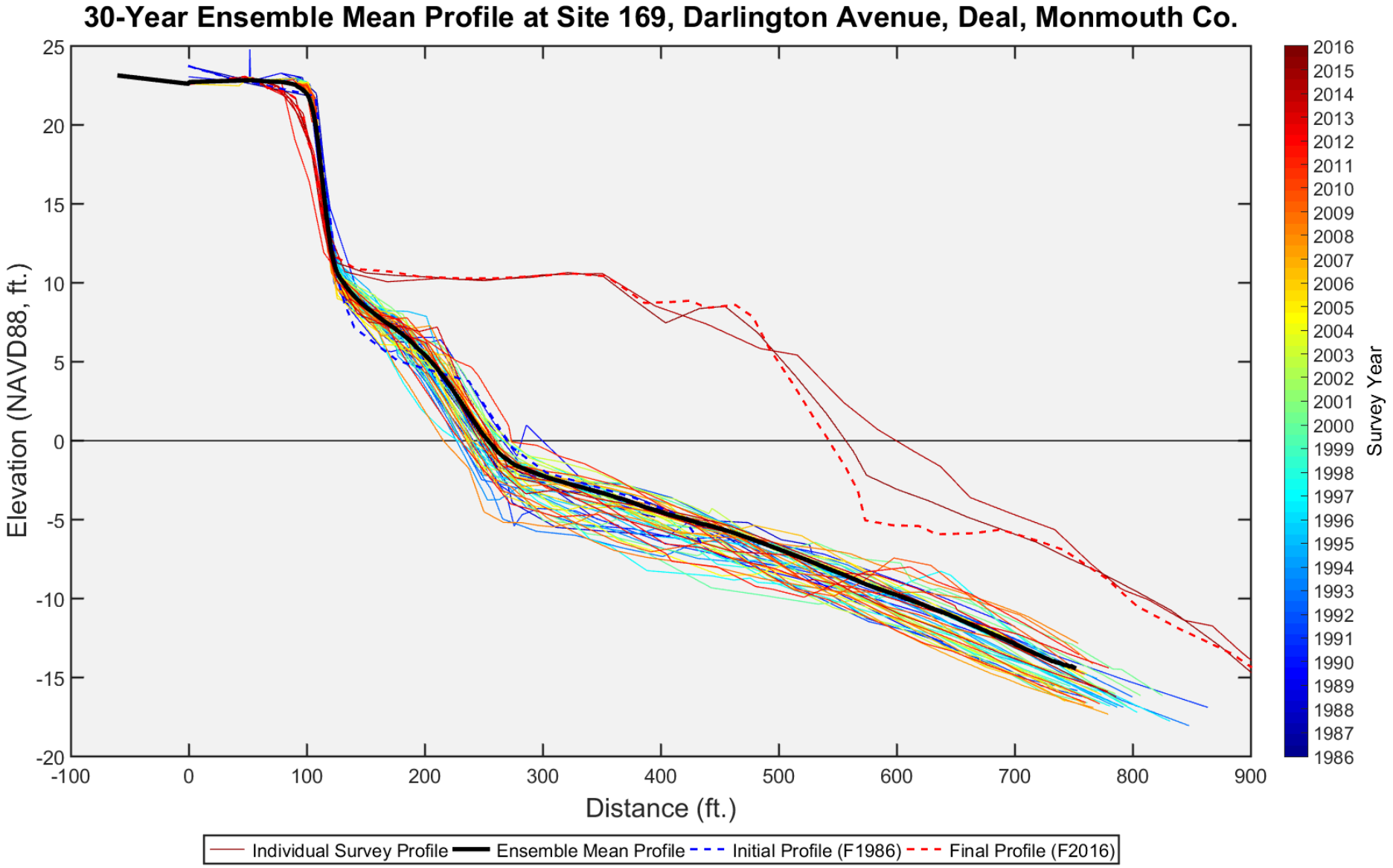

Figure 132. Darlington Avenue was a Deal survey site with a dry sand beach located at the base of an unarmored segment of bluff. Sandy cut into the older sediments as well as destroyed private bulkheads along this segment. The USACE project reached here by the fall of 2015 so three surveys have been performed since project completion. The previous beach configuration was a tight envelope of change indicating that the sand here was basically trapped between adjacent rock groins.

#169 - Darlington Avenue, Deal Borough, Monmouth County

Comparison of 1995 to 2016

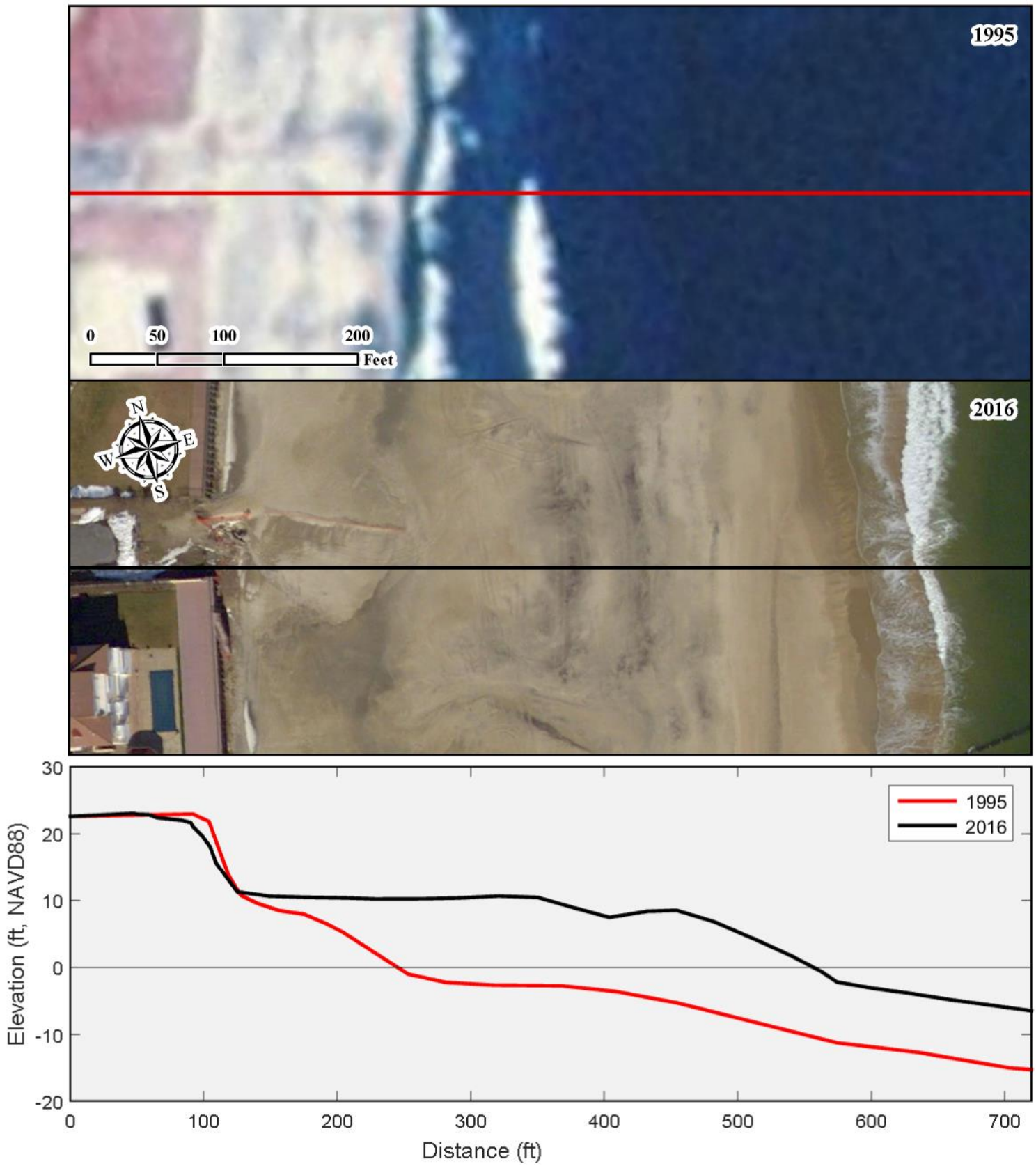

Figure 133. The Phase III work had been completed at Darlington Avenue, as is evident in the 2016 aerial photograph. The aerial and cross-section comparison from 1995 to 2016 shows that the beach width was increased by more than 300 ft over 21 years.

Figure 134. The beach berm in Allenhurst looking south along the winter storm ridge pushed up as "protection". This measure works to keep water and debris off the main beach during minor to moderate storms, but is not so effective during a major event.

NJBPN 168 – Corlies Avenue, Allenhurst

Figure 135a & 135b. This site in Allenhurst also represents the shoreline conditions for Loch Arbor's 2-block shoreline. Here an old concrete wall protects the sedimentary bluff. The left photograph shows conditions as of November 30, 2015 after the federal project was completed. By November 21, 2016 the wide beach remained present, protected by a massive groin complex at the Deal border.

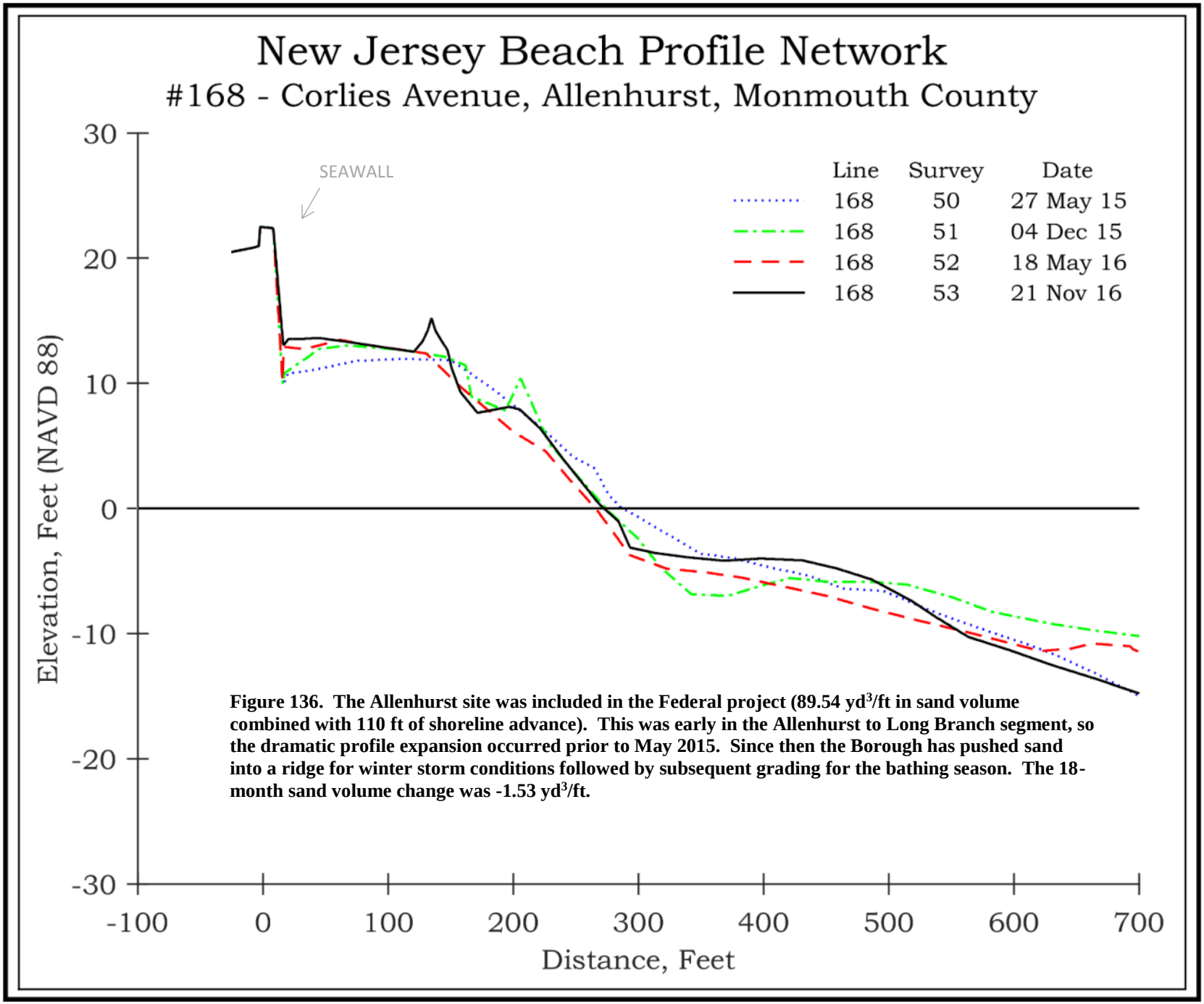

Figure 136. The Allenhurst site was included in the Federal project (89.54 yd^3/ft in sand volume combined with 110 ft of shoreline advance). This was early in the Allenhurst to Long Branch segment, so the dramatic profile expansion occurred prior to May 2015. Since then the Borough has pushed sand into a ridge for winter storm conditions followed by subsequent grading for the bathing season. The 18-month sand volume change was -1.53 yd^3/ft.

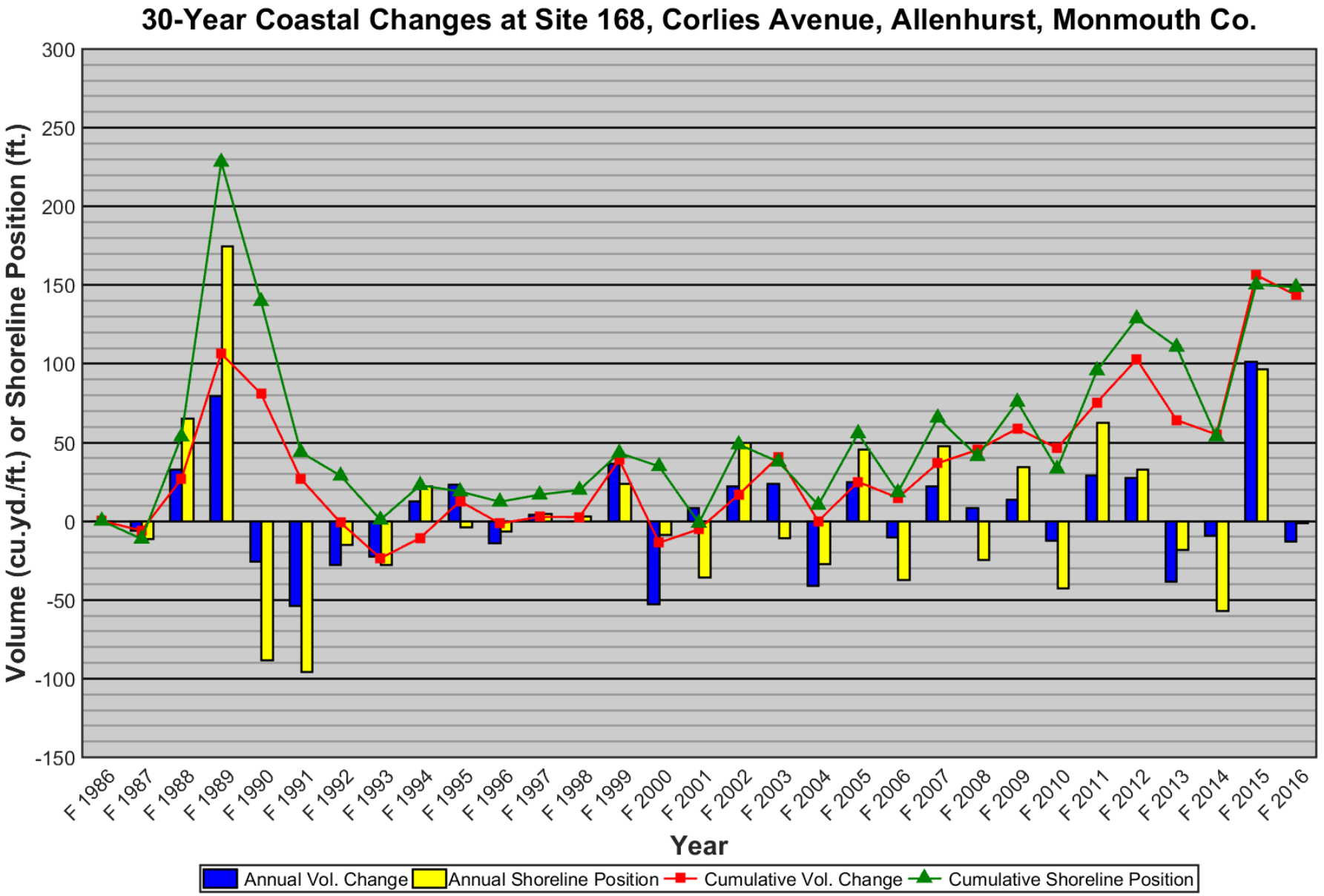

Figure 137. An early sand placement project created a wider beach at the profile site, but was not extended between Asbury Park and Deal. That sand spread laterally leaving a modest increase in sediment present. A small amount of material escaped from the Asbury federal project segment (Phase II), and in 2015 the USACE project added over 100 yds^3/ft of sand.

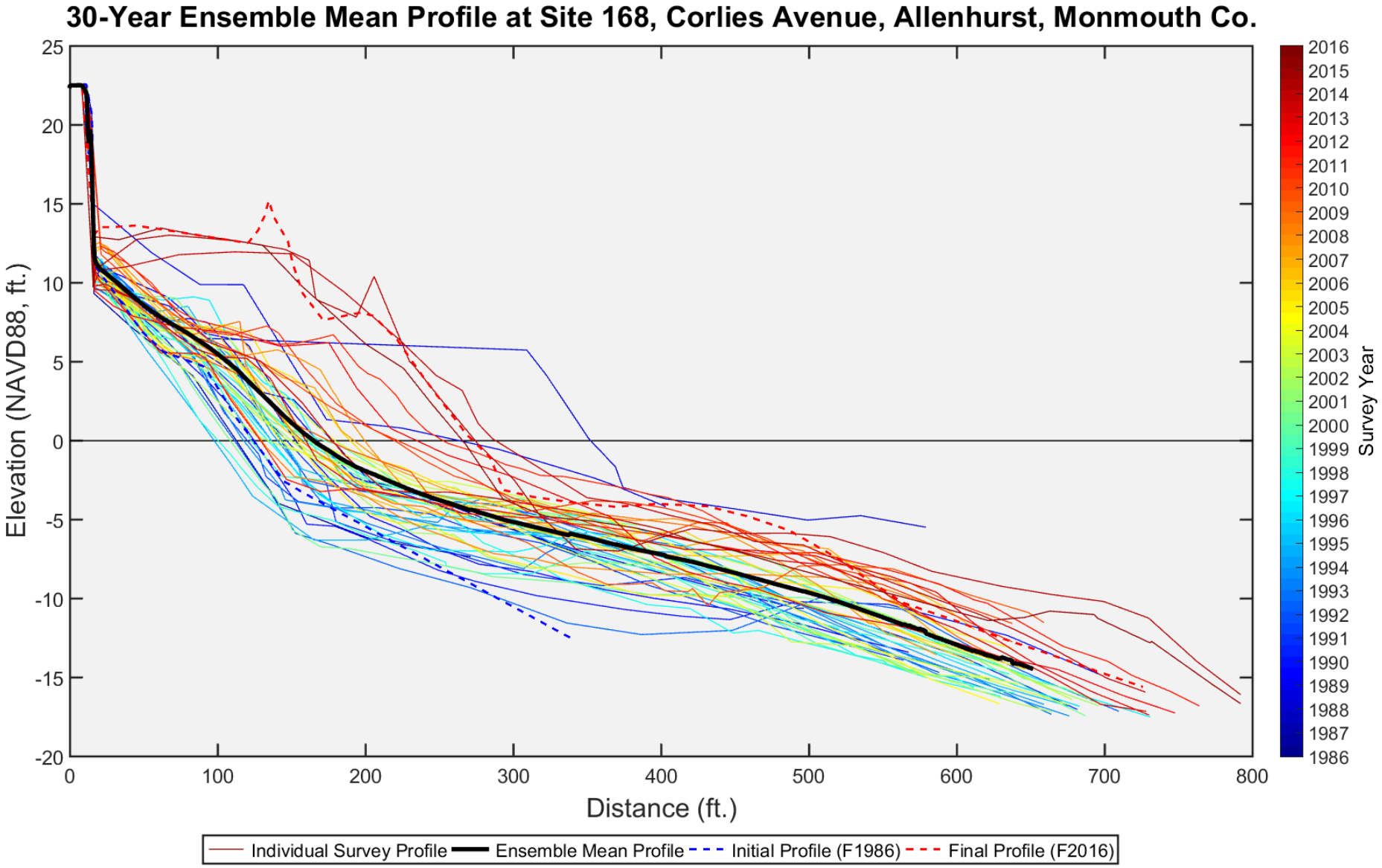

Figure 138. Allenhurst has had a varied history with one early beach project that shows above as a major berm extending seaward to the 400 ft distance. The pre-USACE beach was quite narrow and backs up to a vertical concrete wall defending the sedimentary bluff at this site. The cluster of orange and yellow profile lines are showing that the Phase II work that ended in Asbury Park did very slowly leak sand north to add somewhat to the Allenhurst/Loch Arbor beachfront. The red profile lines show the results of direct sand placement during the Phase III USACE work effort.

#168 - Corlies Avenue, Allenhurst Borough, Monmouth County

Comparison of 1995 to 2015

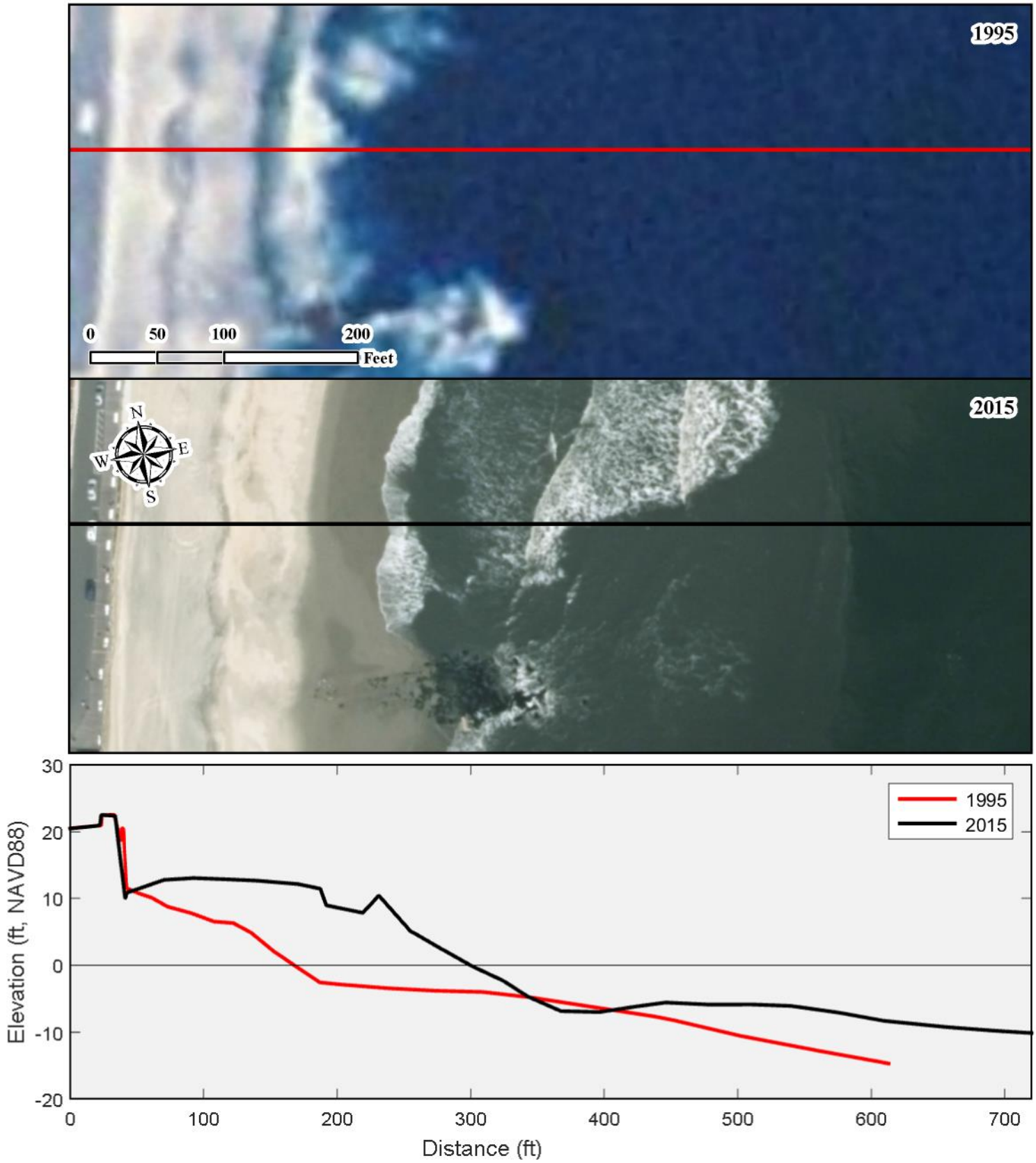

Figure 139. The Allenhurst beach had received a minor sand influx derived from losses to the Asbury Park segment (Phase II) completed in 1999. Some sand was pumped onto the site in 2015 generating the contrast shown above.

Figure 140. View to the north along the Asbury Park boardwalk looking at the wide, dry beach in the fall of 2016.

NJBPN 267 – 7th Avenue, Asbury Park


Figure 141a & 141b. This site is the northernmost site included in the Federal shore protection's southern project segment (Phase II). The left photo (taken on November 30, 2015) shows the completed Federal project two years later that added 92.68 yds^3/ft and produced a 100 ft shoreline advance. By November 21, 2016, conditions remained similar, but without the pushed-up winter storm ridge of sand in the mid-beach area.

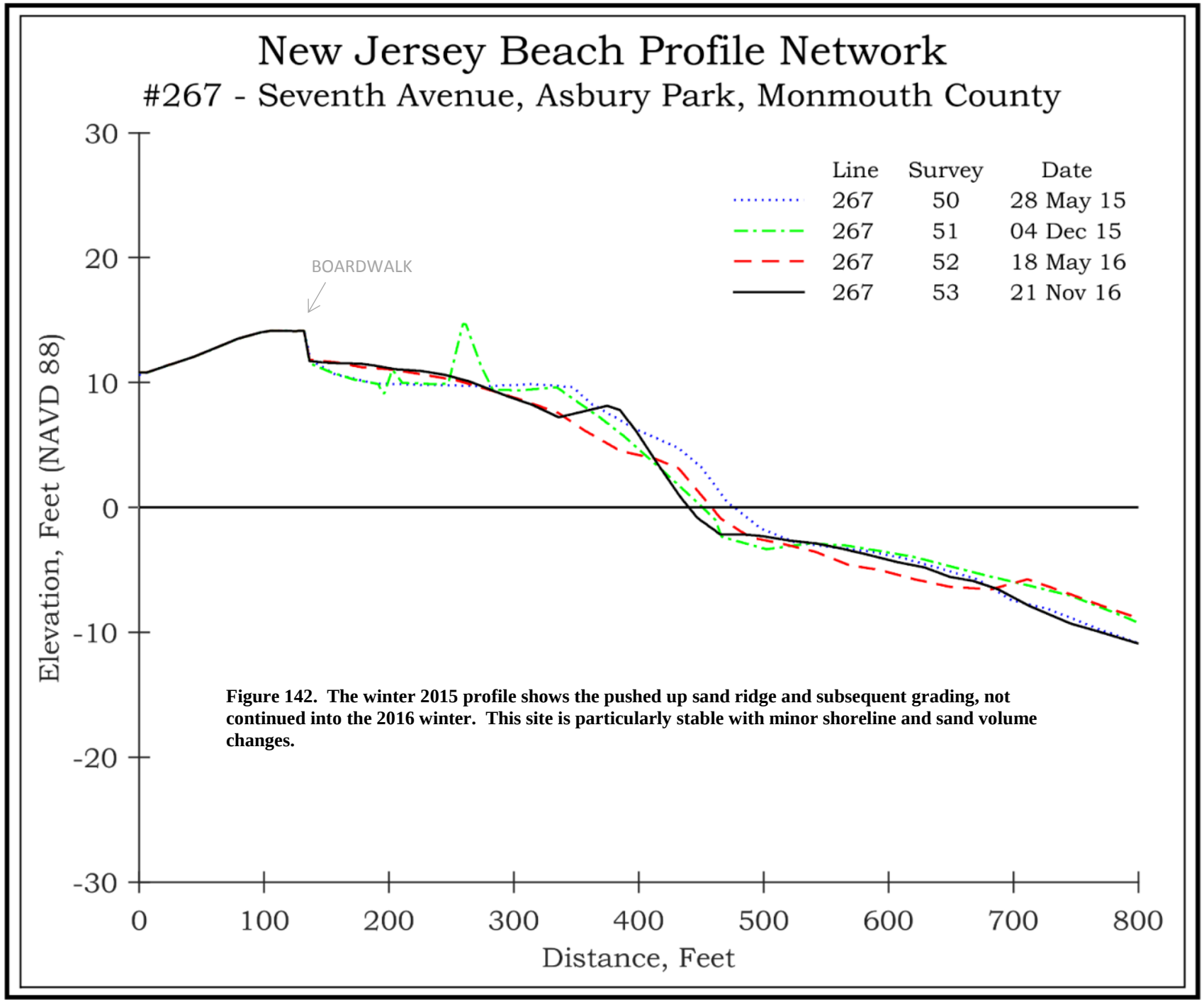

Figure 142. The winter 2015 profile shows the pushed up sand ridge and subsequent grading, not continued into the 2016 winter. This site is particularly stable with minor shoreline and sand volume changes.

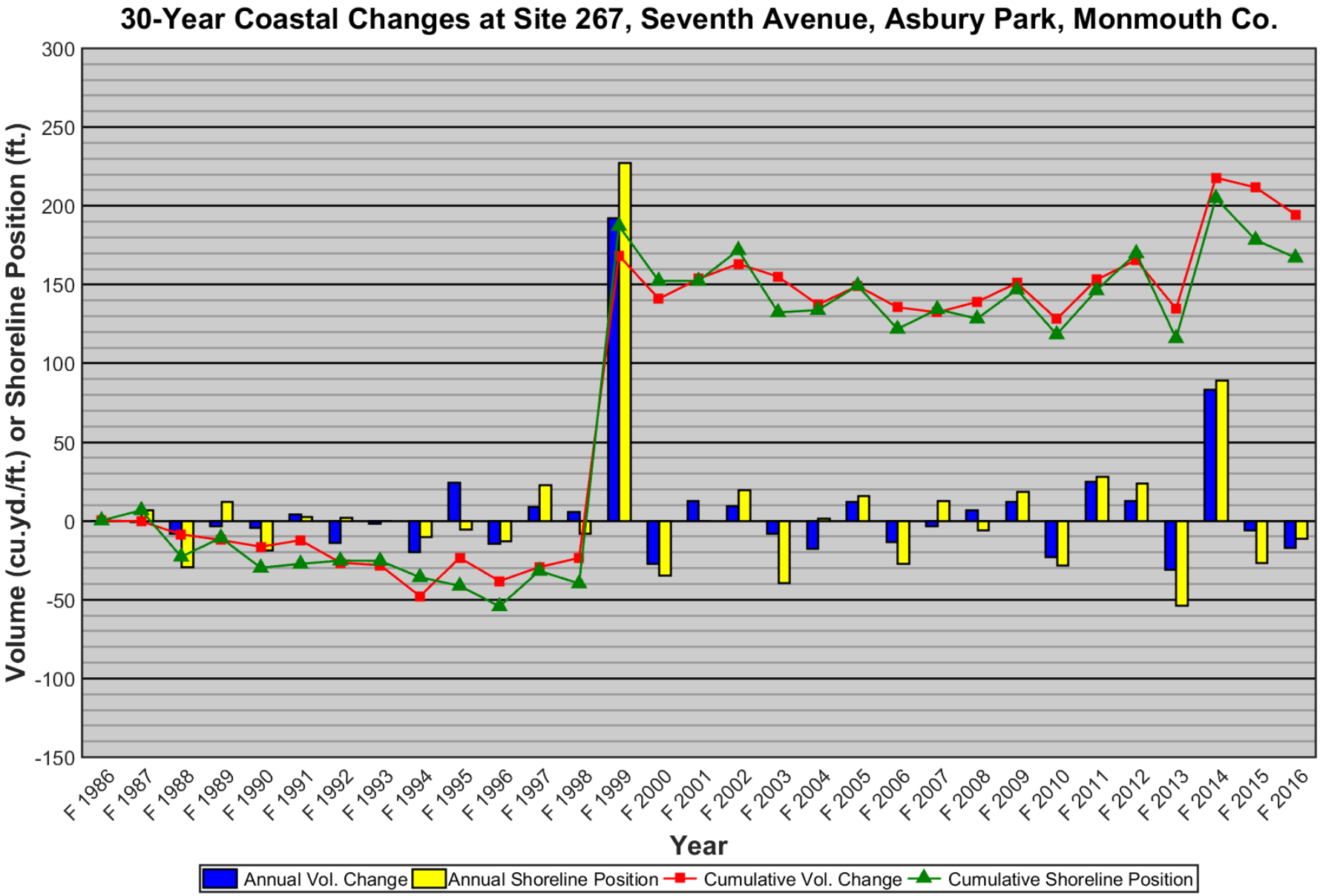

Figure 143. Asbury Park's northern beach was rather stable over the 13 years between the initial fill in 1999 and Hurricane Sandy. The recovery sand in 2014 returned the shoreline and sand volume conditions slightly above the initial project amounts.

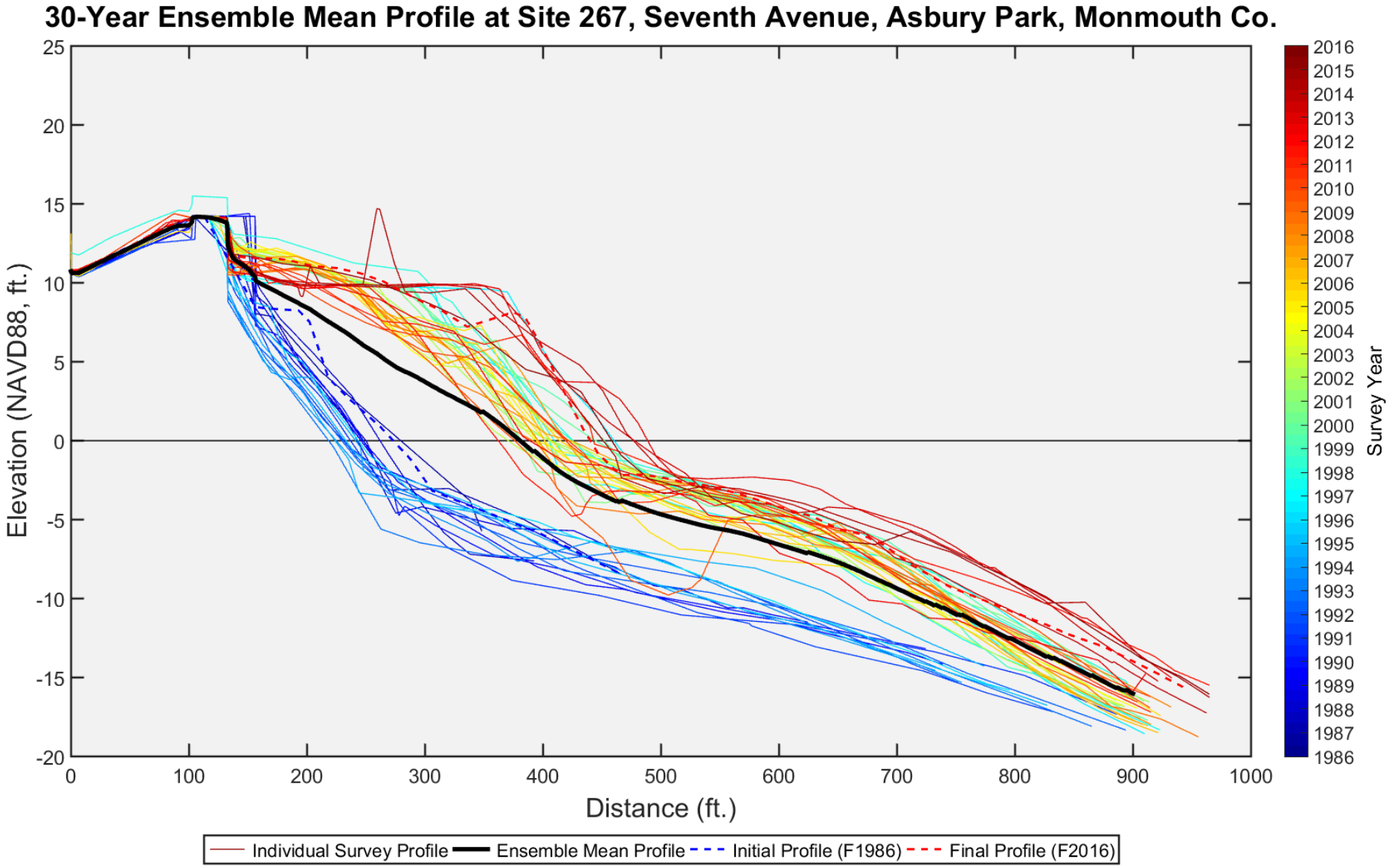

Figure 144. Asbury Park has always been categorized by a dry sand beach that did not change much over the 1986-1996 time interval. The USACE project in 1999 tripled the beach width and the site remained fairly stable over the next 15 years.

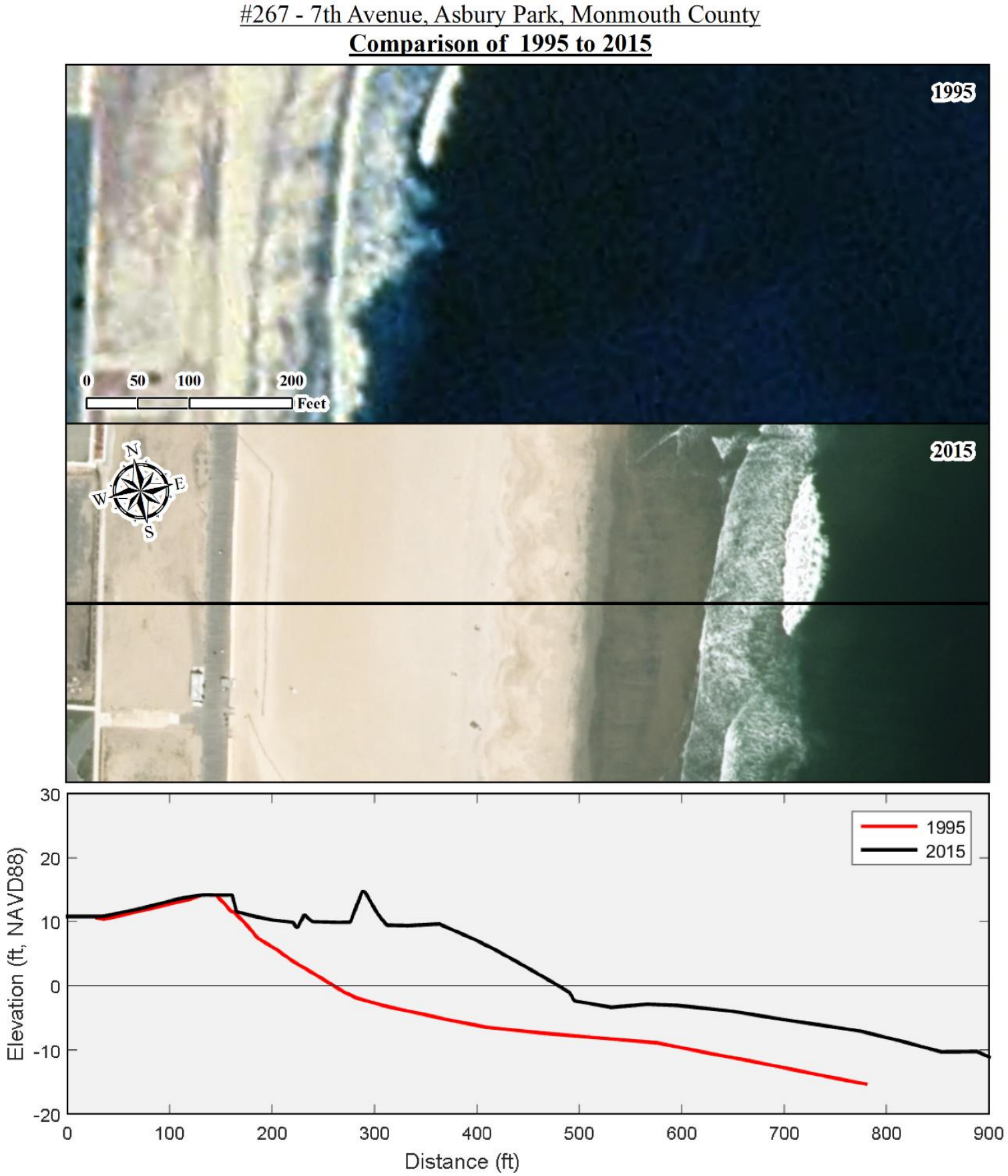

Figure 145. Sand added to the Asbury Park beach did improve the shore protection benefits by 200 ft in spite of no dune being built in Asbury.

Figure 146. View looking north from 3rd Avenue in Asbury Park showing the iconic Paramount Hall. Groins are exposed in the surf zone, but the beach remains in good shape.

NJBPN 167 – 3rd Avenue, Asbury Park


Figure 147a & 147b. The USACE work added the berm as more sand accumulated offshore as of survey 48. The December 4, 2015 view on the left shows the restored beach year later. By November 21, 2016, very little additional change had occurred and the project remains in good shape.

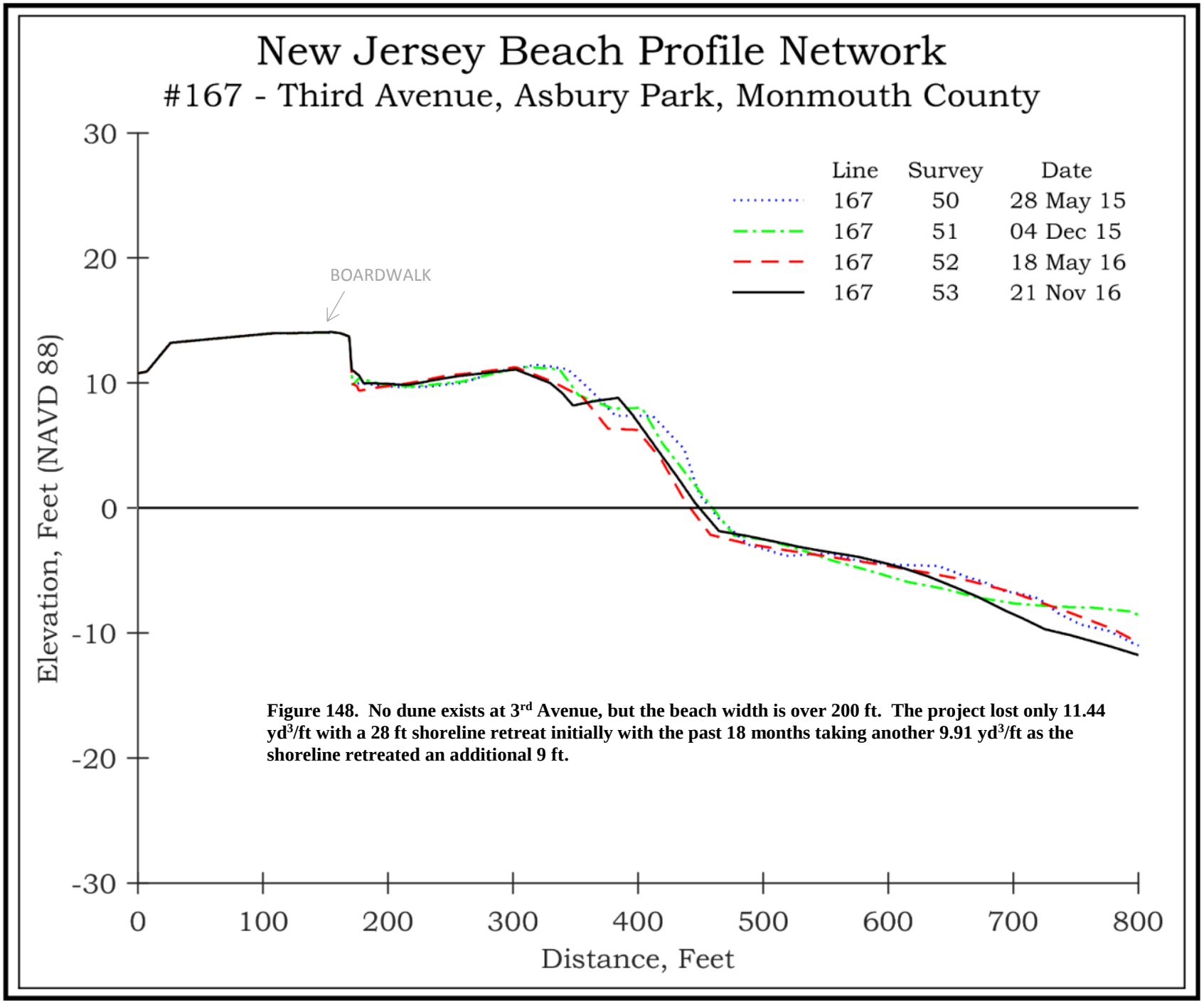

Figure 148. No dune exists at 3rd Avenue, but the beach width is over 200 ft. The project lost only 11.44 yd^3/ft with a 28 ft shoreline retreat initially with the past 18 months taking another 9.91 yd^3/ft as the shoreline retreated an additional 9 ft.

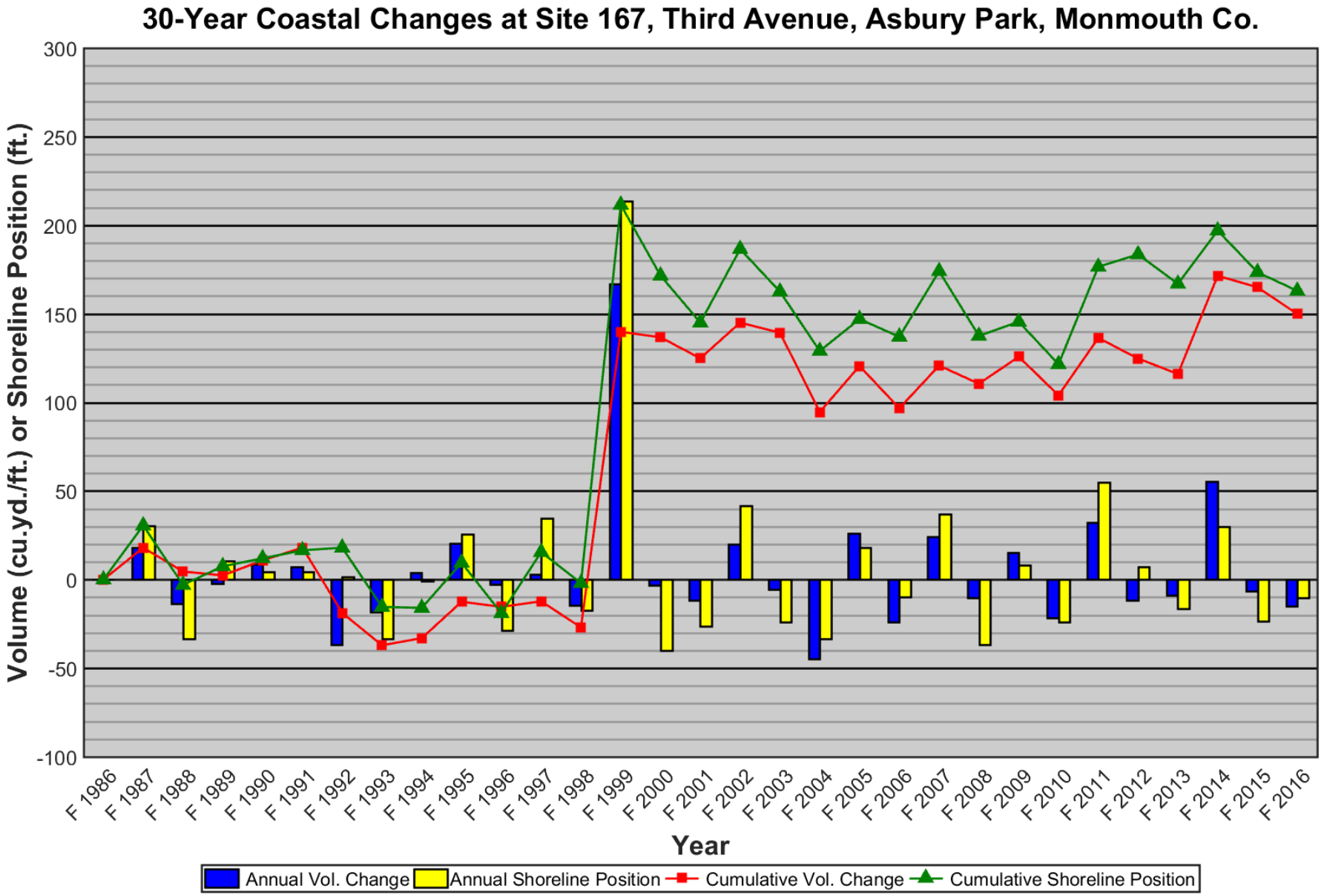

Figure 149. This site was also very stable following the initial sand placement in 1999. The post-Sandy maintenance returned the sand volume to slightly more than the initial placement volume in 1999, while the shoreline ended up retreating 55 ft farther landward from 2014 to 2016.

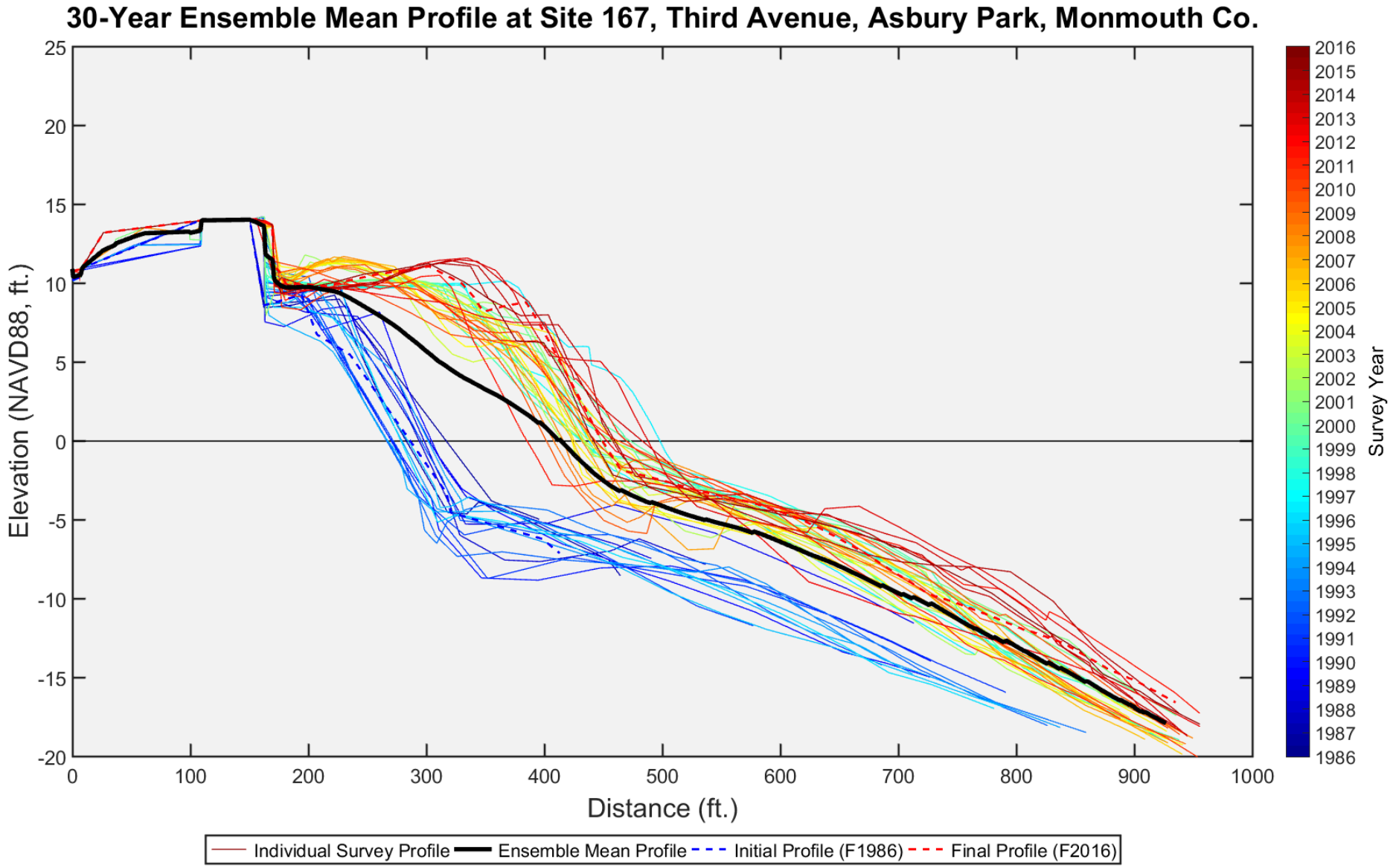

Figure 150. The 3rd Avenue beach in Asbury Park was also tripled in width by the USACE project and remained relatively stable after project completion. Both groups of cross-sections comprise a tight envelope of change.

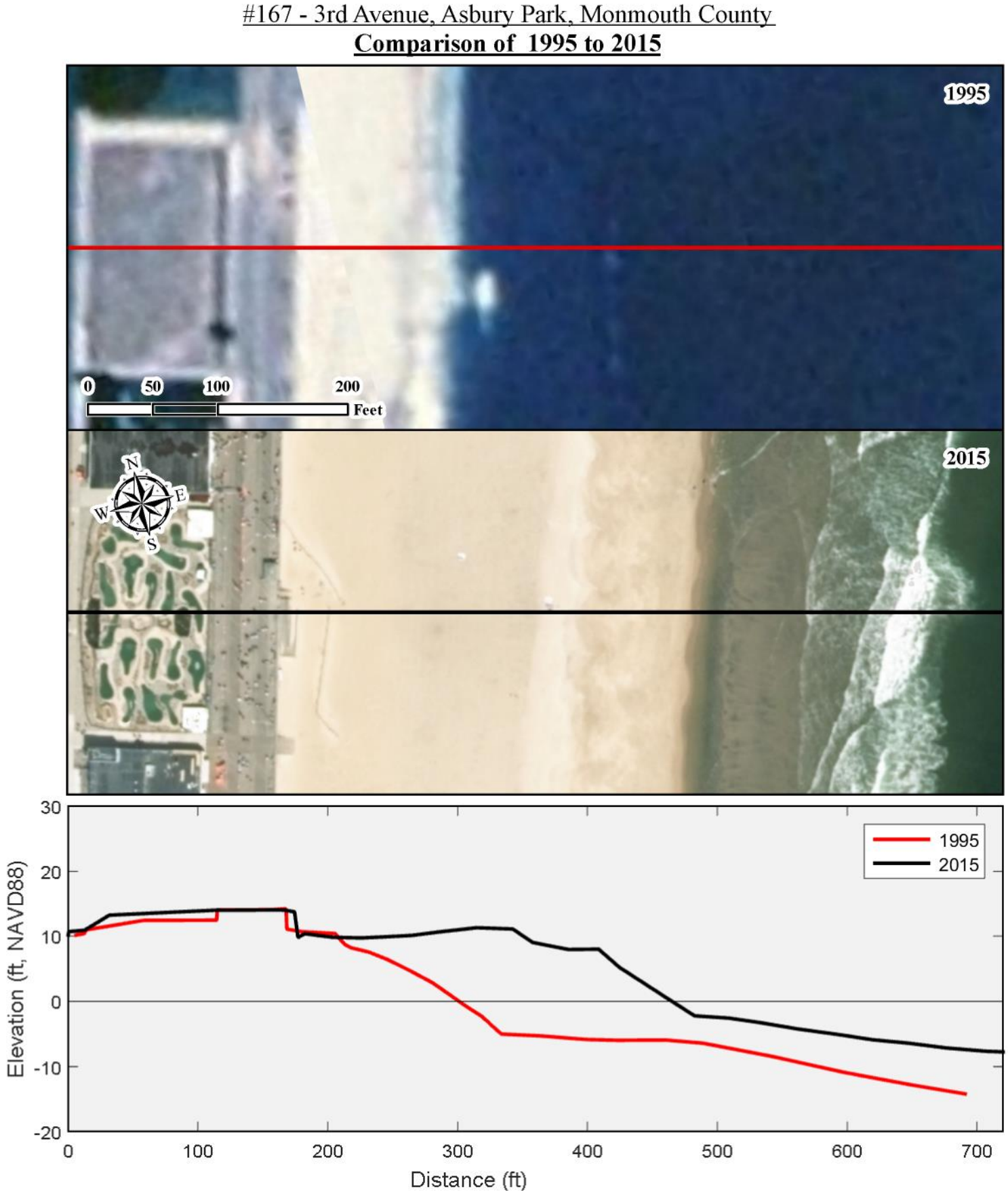

Figure 151. The middle Asbury Park shoreline widened by 186 ft due to the federal project, however, no dune was ever built.

Figure 152. Looking north along the dune toe in Ocean Grove where the dune just barely survived Hurricane Sandy. Restored in width, the site is in good shape.

NJBPN 166 – Ocean Pathway, Ocean Grove

Figure 153a & 153b. The sand volume added during 2014 amounted to 35.79 yds^3/ft with a 12 ft shoreline advance. A year later on December 4, 2015 the beach remained in good shape with minor shoreline retreat (left). On the right (November 21, 2016) the sand volume grew by a modest amount indicating that the site was quite stable and even accretional.

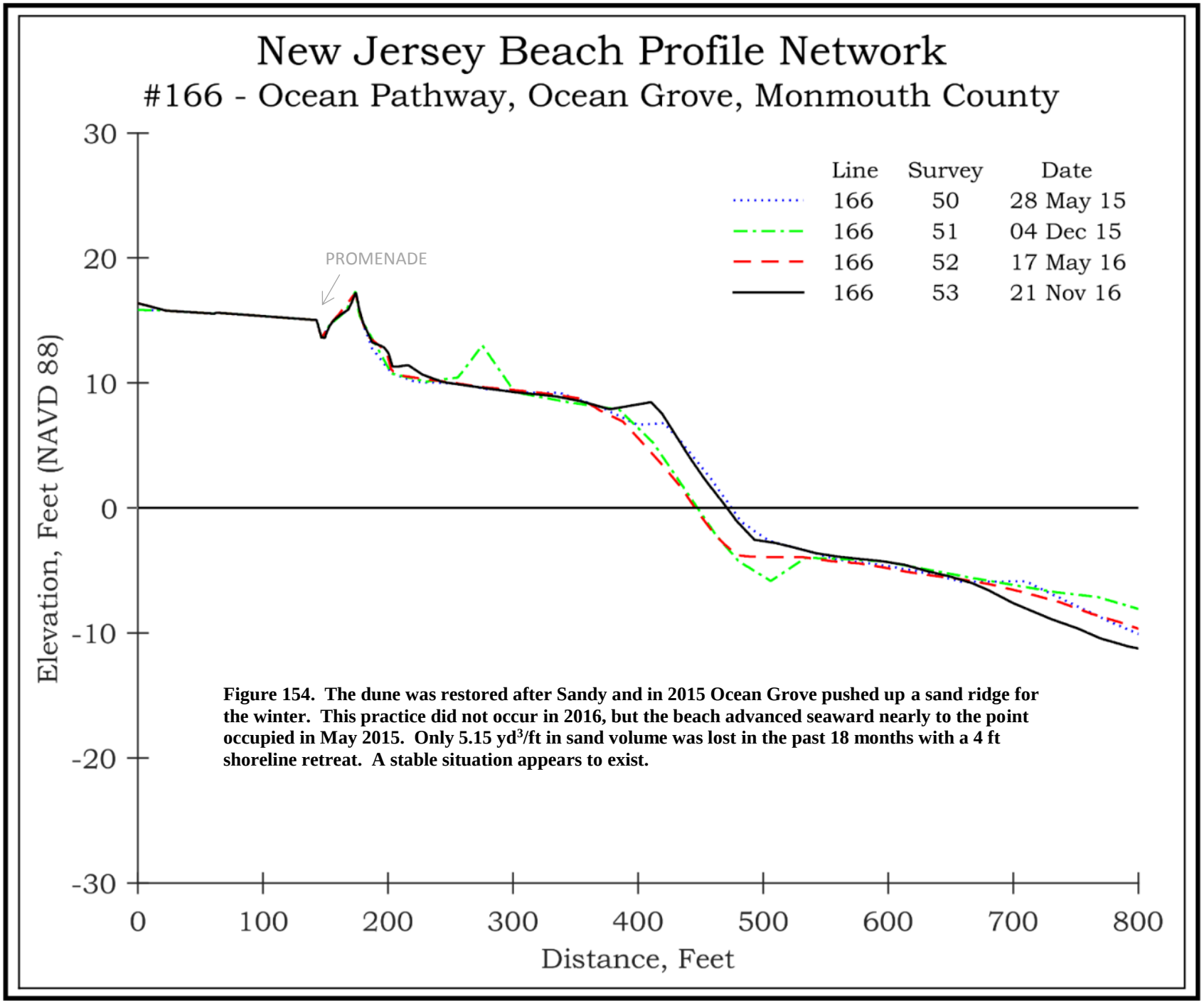

Figure 154. The dune was restored after Sandy and in 2015 Ocean Grove pushed up a sand ridge for the winter. This practice did not occur in 2016, but the beach advanced seaward nearly to the point occupied in May 2015. Only 5.15 yd^3/ft in sand volume was lost in the past 18 months with a 4 ft shoreline retreat. A stable situation appears to exist.

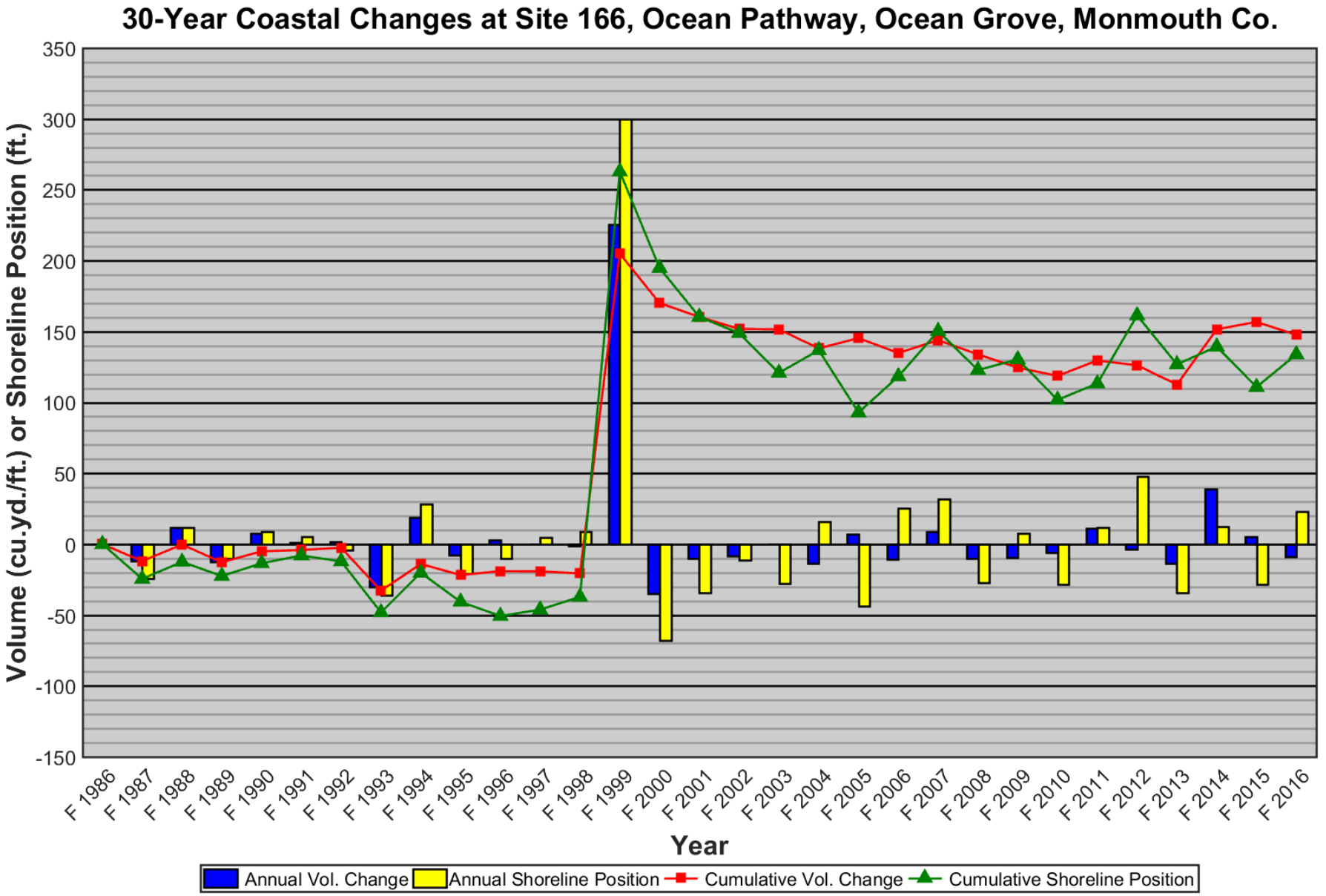

Figure 155. Ocean Grove maintained a relatively stable beachfront. This site was saved by the dune during Sandy, but there was little left of it. The long term trend reduced the sand supply to 51% of what was initially placed. Post-storm maintenance brought that value up to 71% of the initial sand volume placed.

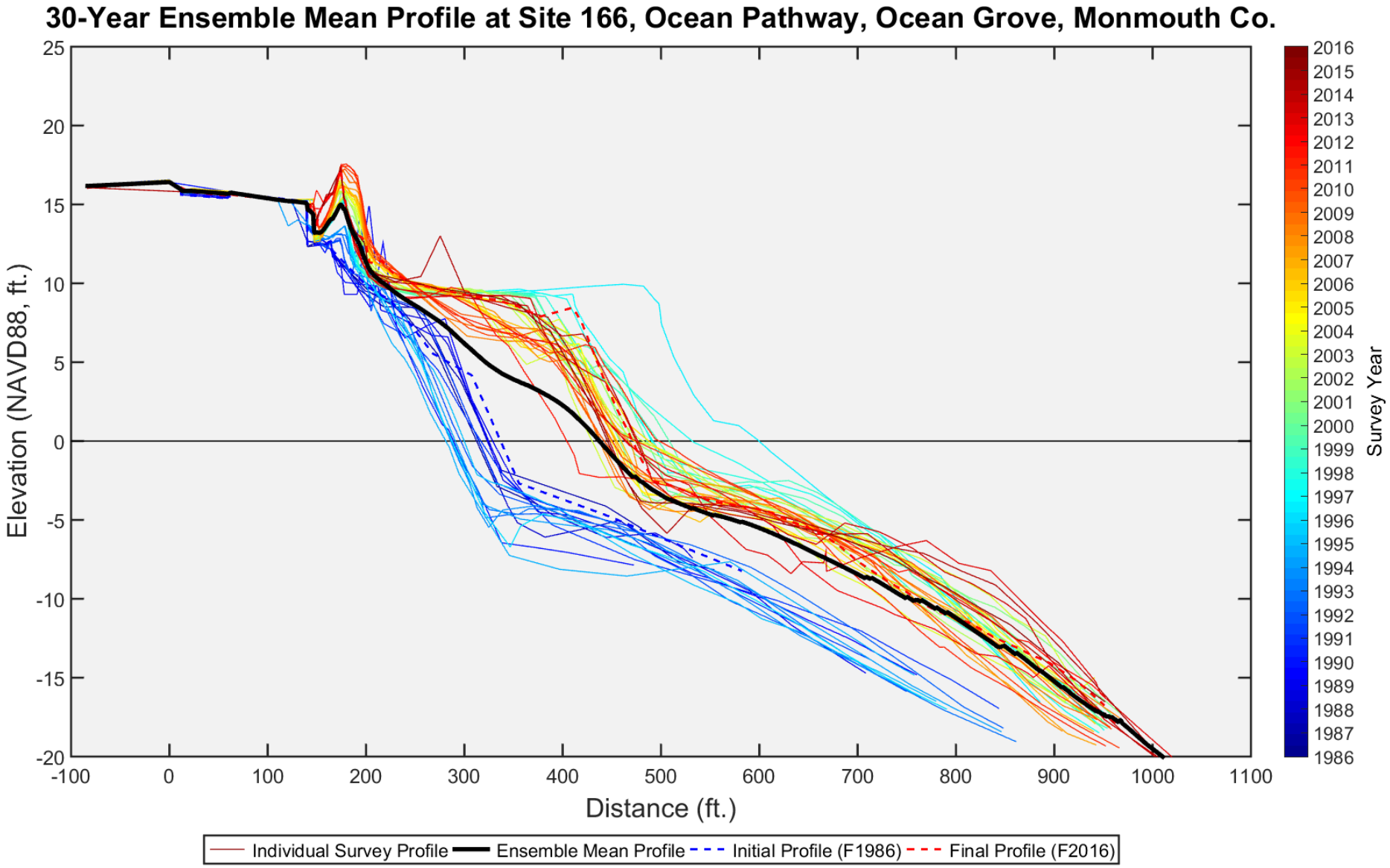

Figure 156. Ocean Grove's beach was narrow and quite steep but was tripled in width by the USACE project. Some retreat occurred initially (green profile lines) from the initial placement sand volume, which was not equaled during restoration following Hurricane Sandy (red lines).

#166 - Ocean Pathway, Ocean Grove Borough, Monmouth County

Comparison of 1995 to 2015

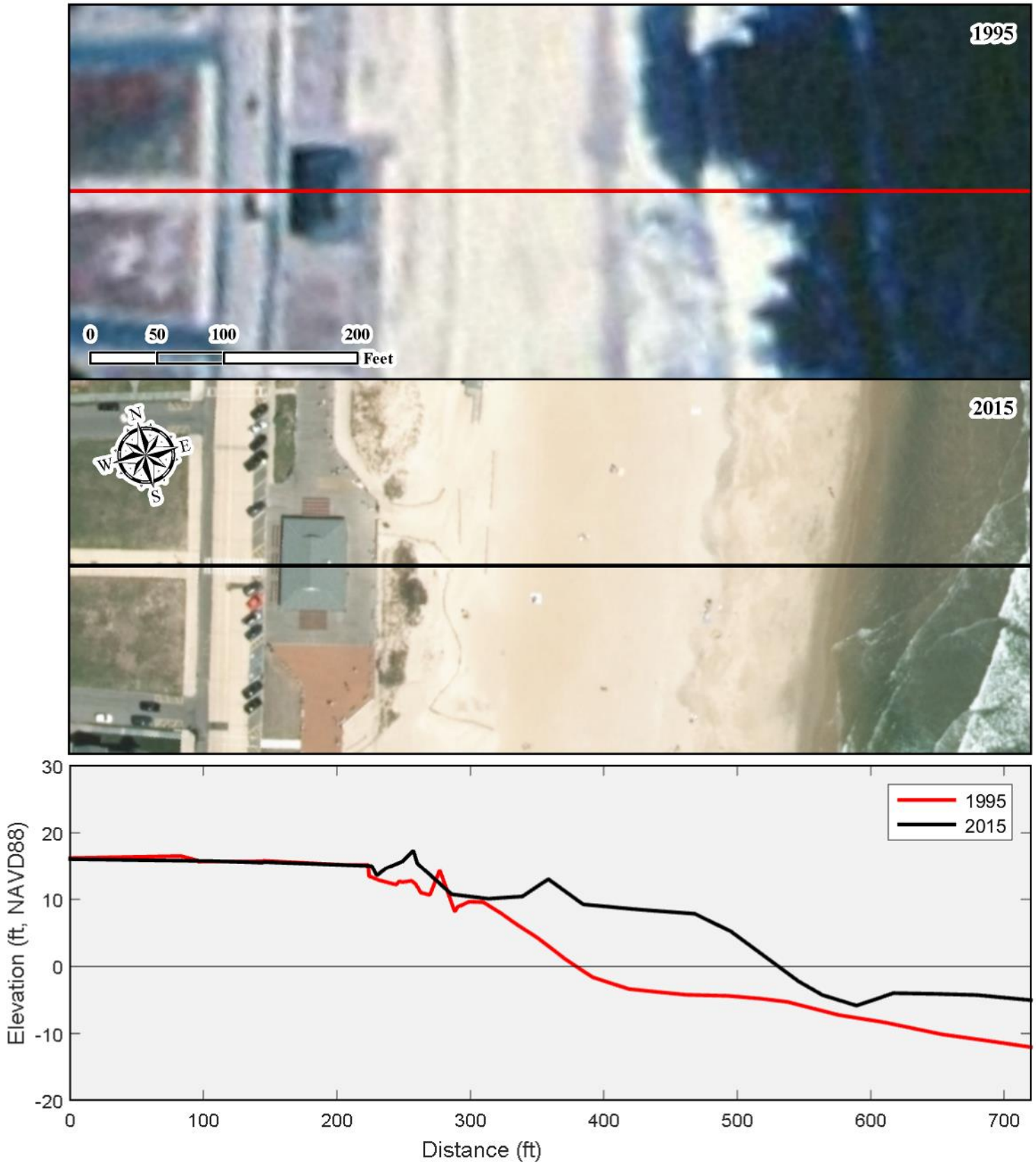

Figure 157. Ocean Grove was enhanced with a 160 ft wider beach following the initial beach restoration effort.

Figure 158. Looking north along the seaward dune toe in Bradley Beach, NJ. The beach width is at the design distance and the dune is beginning to regrow after Sandy.

NJBPN 165 – McCabe Avenue, Bradley Beach

Figure 158a & 158b. The beach and fencing was restored as of December 2014 adding elevation to the beach if not much width. By December 3, 2015 (left) a small dune zone had been established and the beach retained most of the applied material. The November 17, 2016 survey date found more sand deposited among the dune plants while the beach was a few feet narrower (right photo).

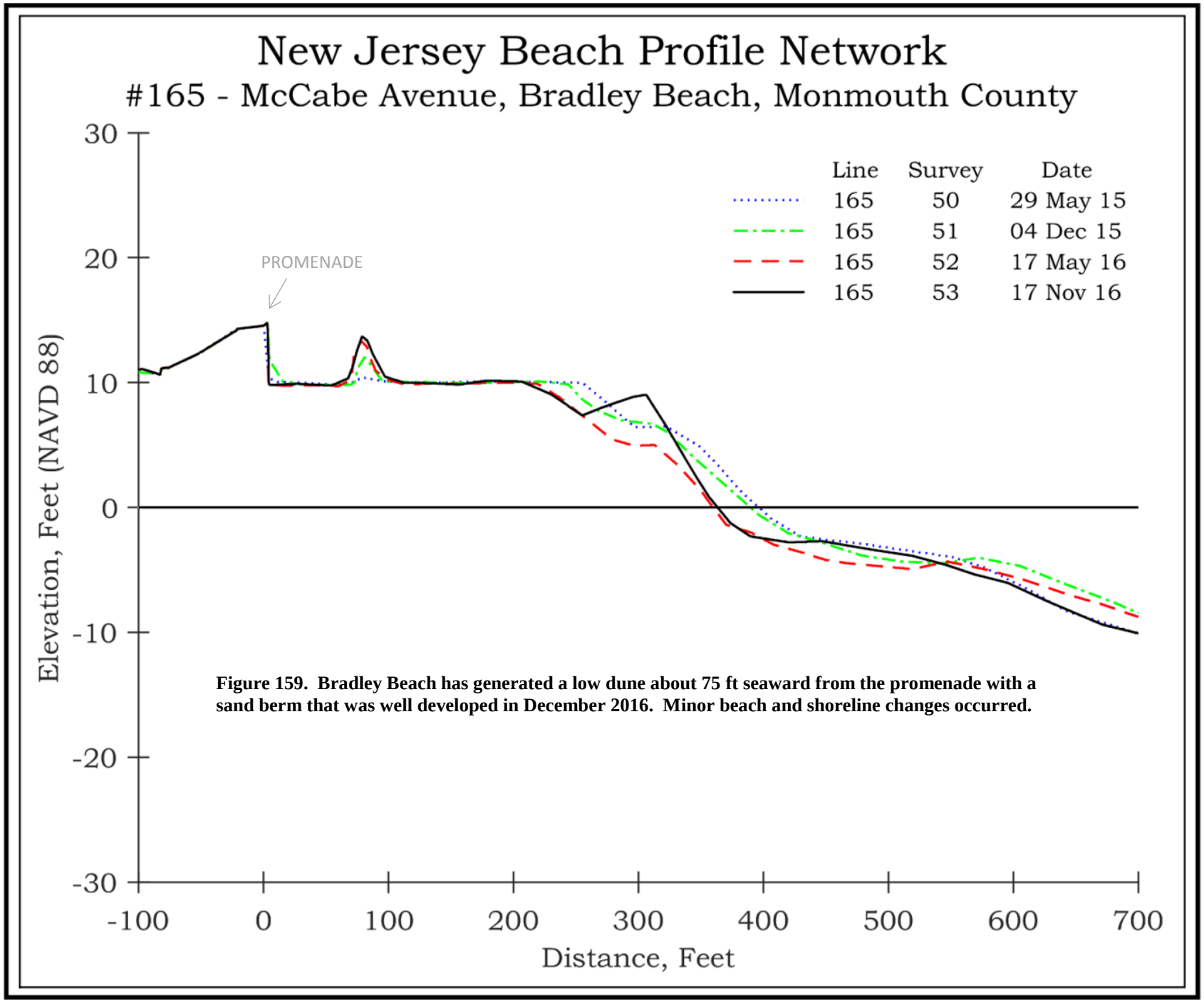

Figure 159. Bradley Beach has generated a low dune about 75 ft seaward from the promenade with a sand berm that was well developed in December 2016. Minor beach and shoreline changes occurred.

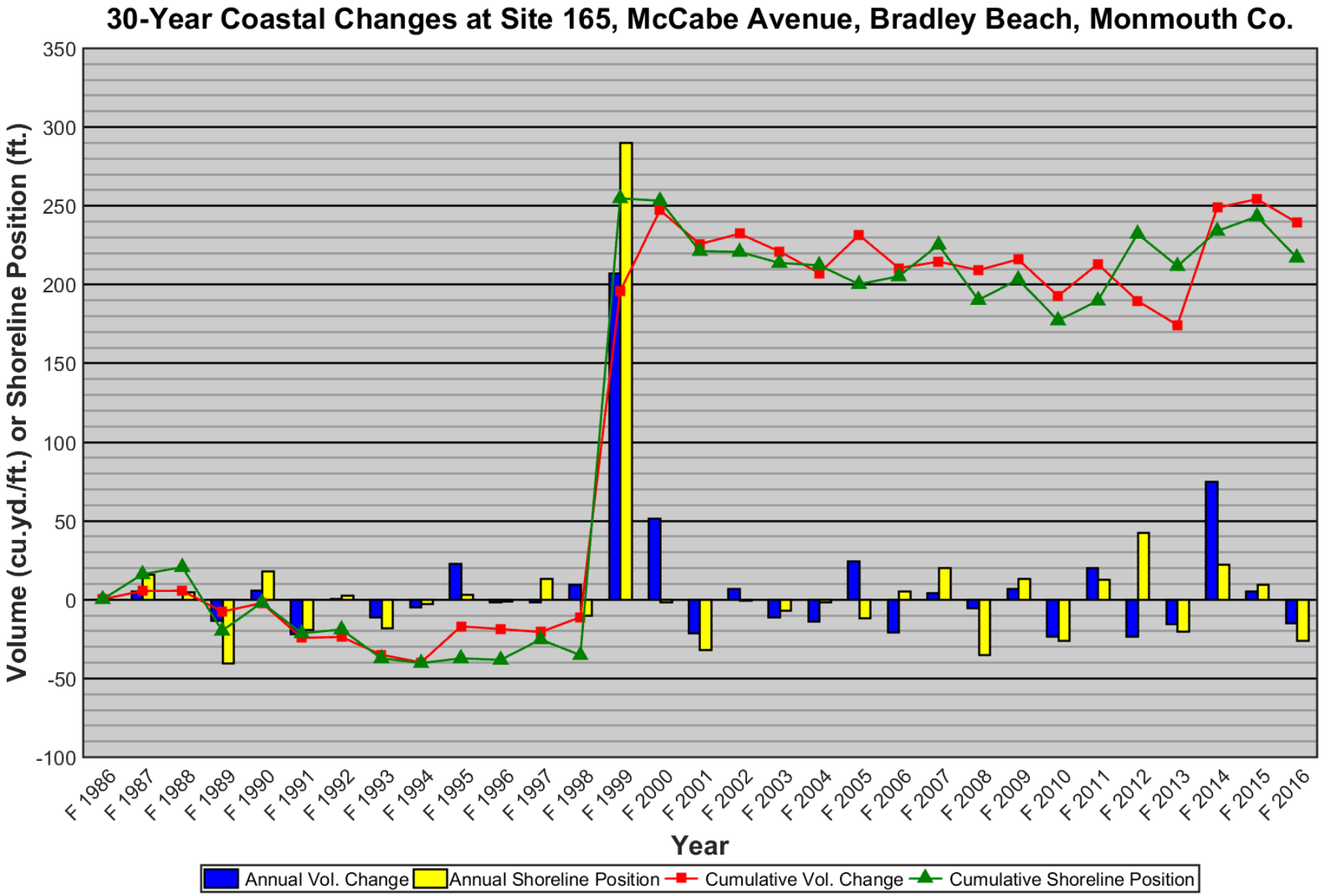

Figure 160. The McCabe Avenue location displayed shoreline retreat from the maximum shoreline position of 255 ft seaward of the original shoreline in 1999 to a minimum value 175 ft seaward of the original shoreline in 2010. Post-Sandy recovery moved both the sand volume and the shoreline position seaward (about 240 yds^3/ft more sand than in 1986 and about 215 ft seaward of 1986).

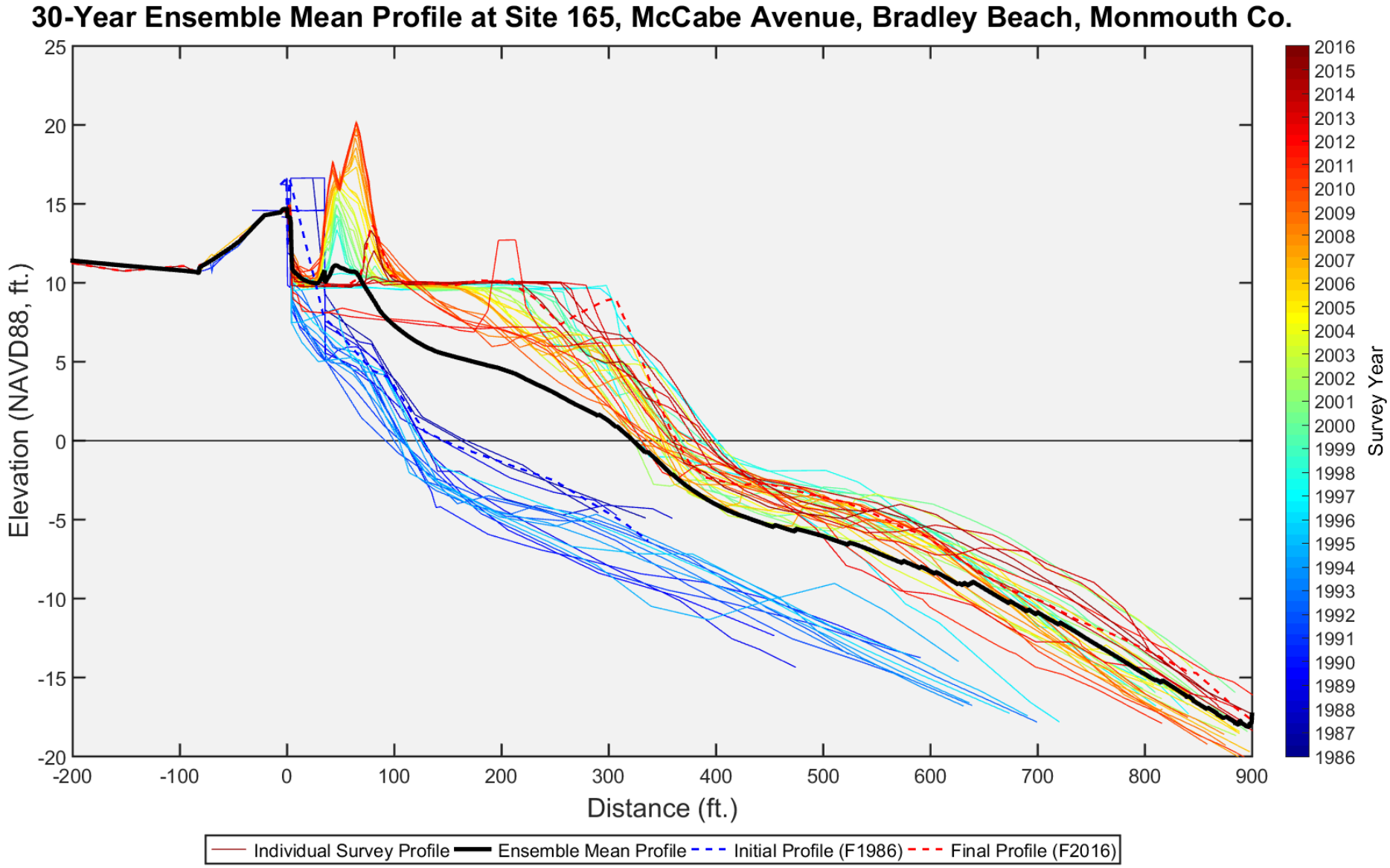

Figure 161. Bradley Beach moved its boardwalk off the sand beach and up onto the grass strip between Ocean Avenue and the bulkhead providing about 40 ft of additional beach area. The USACE project added four times the sand volume and allowed a significant dune to be developed over years of time (note the progressive array of colors on the dune profile that range from green to yellow to orange and finally red).

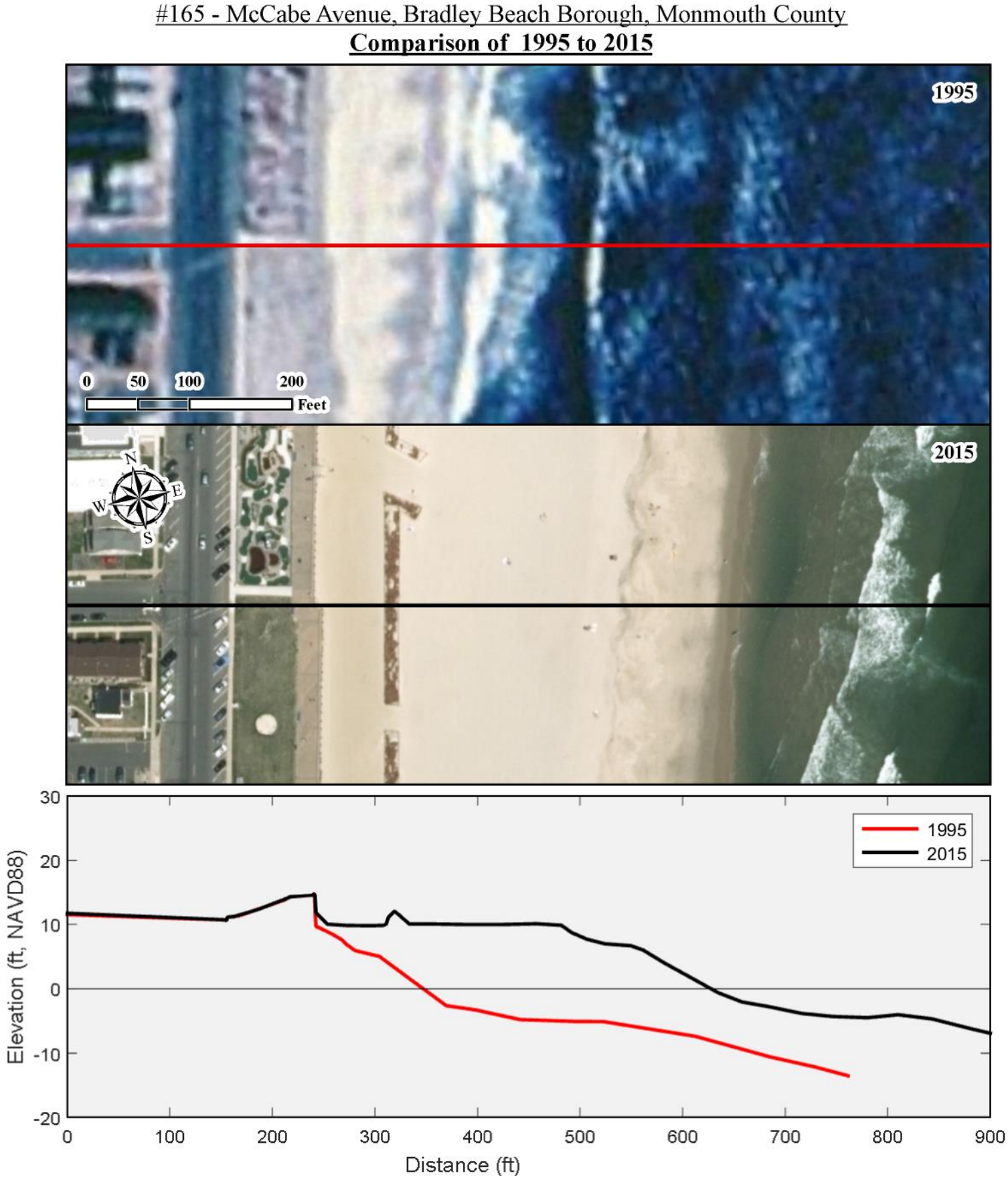

Figure 162. The beach is now 300 ft wider with a small protective dune in place.

Figure 163. Looking north in Avon-By-The-Sea from the crest of the winter storm ridge pushed up to better defend against storms.

NJBPN 164 – Sylvania Avenue, Avon-by-the Sea

Figure 164a & 164b. This site is located north of the Shark River inlet. By December 4, 2015, the groin appears to be offshore beyond the wave breaker zone (extreme right edge of the left photo). A year later on November 17. 2016 the beach seaward of the winter storm ridge was quite wide and stable (right photo).

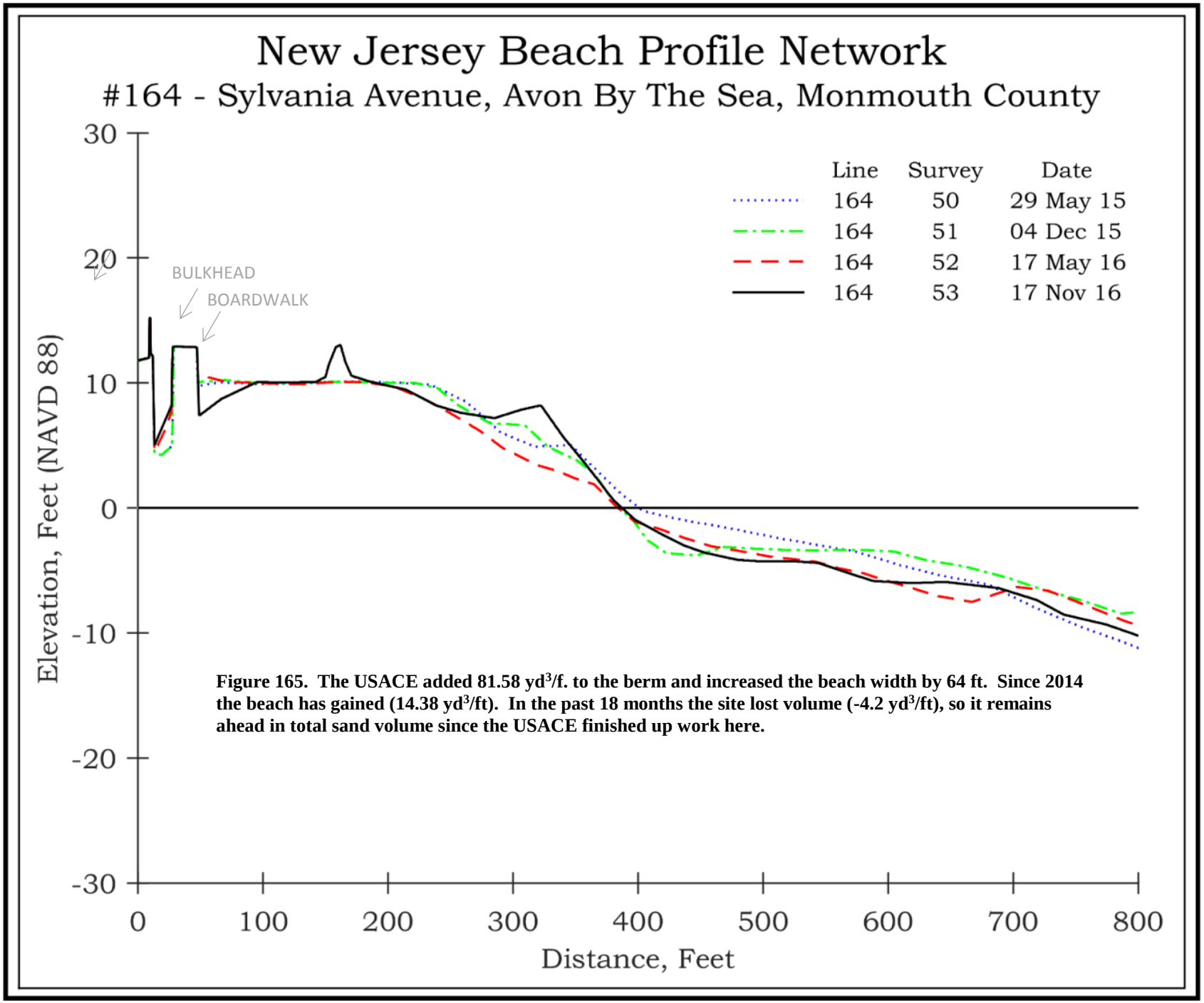

Figure 165. The USACE added 81.58 yd^3/f. to the berm and increased the beach width by 64 ft. Since 2014 the beach has gained (14.38 yd^3/ft). In the past 18 months the site lost volume (-4.2 yd^3/ft), so it remains ahead in total sand volume since the USACE finished up work here.

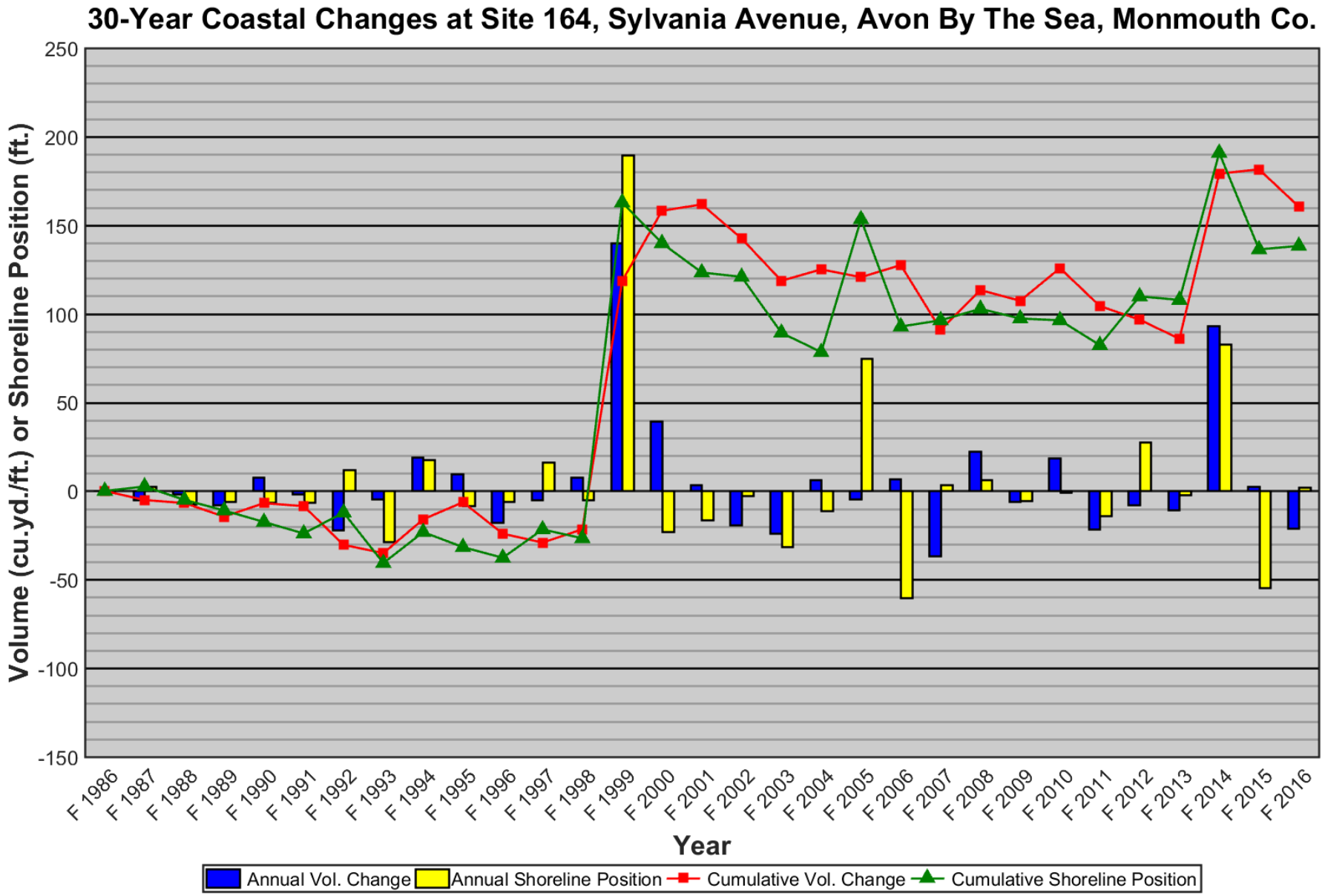

Figure 166. Both the sand volume and shoreline position did not seem to be adversely affected by the proximity to the Shark River Inlet reducing sand supplies arriving at the site. Sand does preferentially accumulate on the south side of the south jetty in Belmar. The 2014 maintenance effort put the sand volume ahead of what was initially placed in 1999.

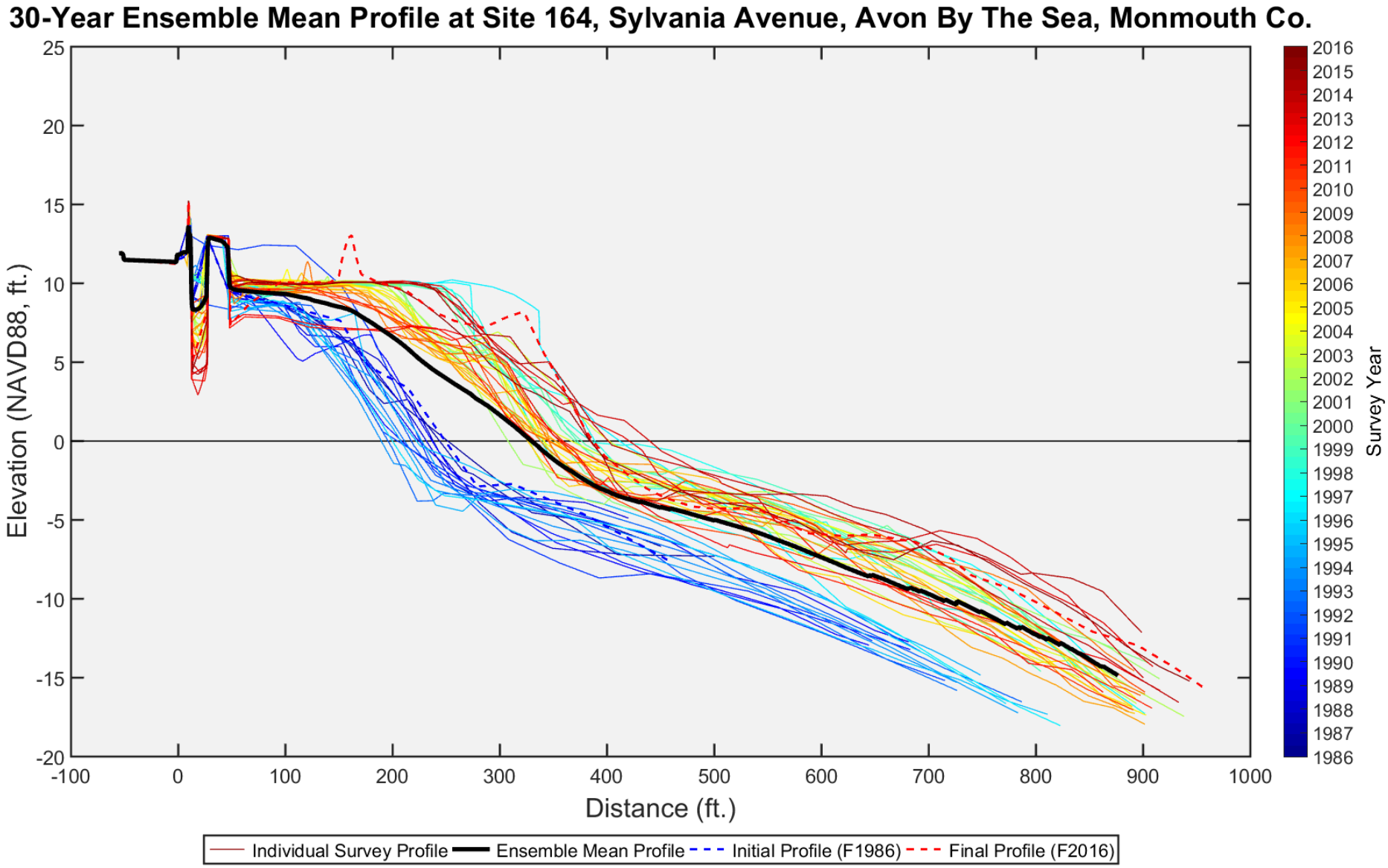

Figure 167. The Avon beach was more than doubled in width by the USACE project and remained relatively stable over time.

#164 - Sylvania Avenue, Avon-by-the-Sea Borough, Monmouth County

Comparison of 1995 to 2015

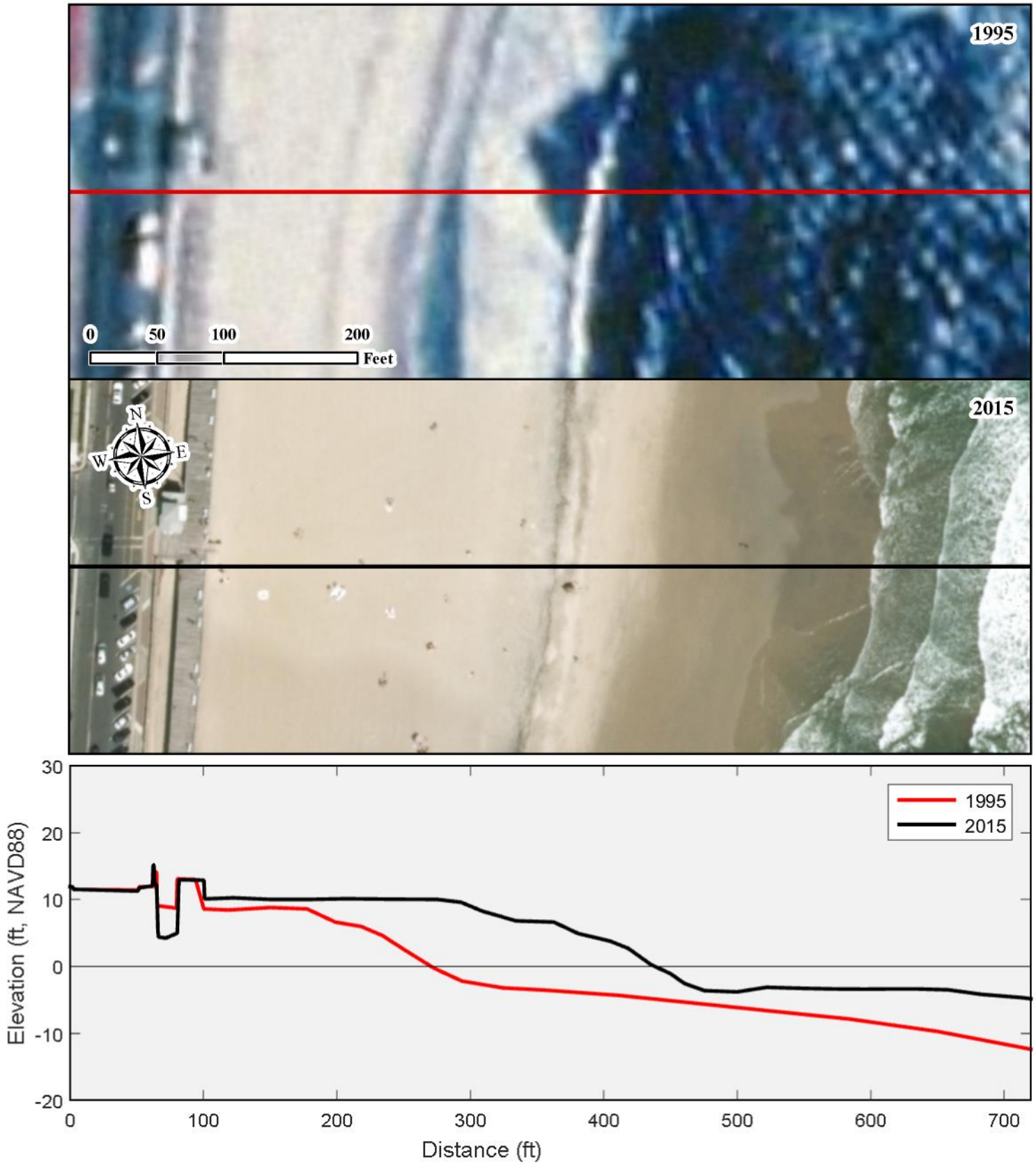

Figure 168. The Avon-by-the-Sea beach was wider than average prior to the federal project, but in 2015 the total beach width was 450 ft, as compared to 250 ft in 1995.

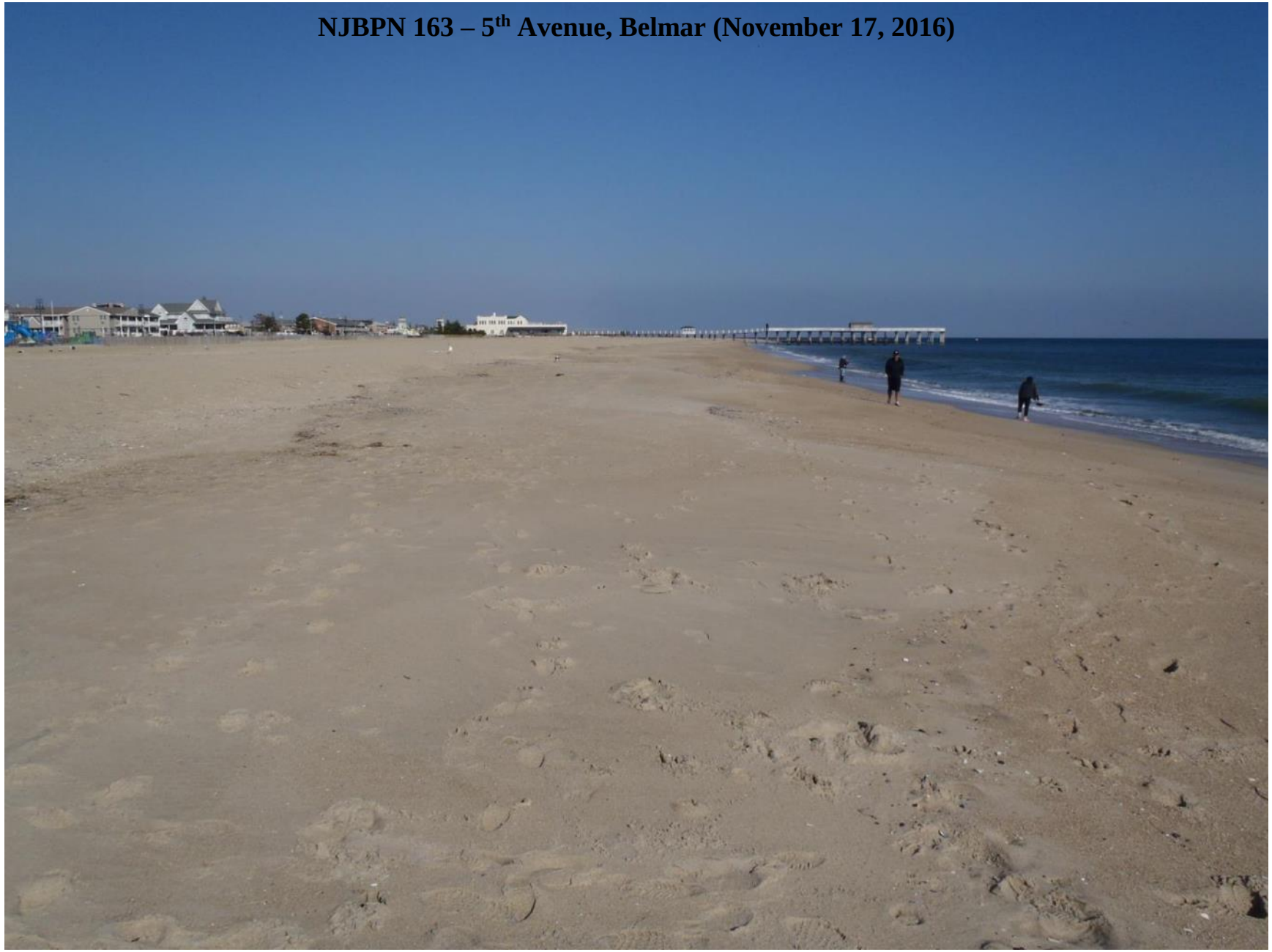

Figure 169. The north beachfront in Belmar has been wide for decades due to the sand captured by the Shark River jetties. The beach is 300 ft wide and there is a dune.

NJBPN 163 – 5th Avenue, Belmar

Figure 170a & 170b. The December 4, 2015 view on the left shows the beach in relationship to the pier at the inlet. The November 17, 2016 view on the right shows almost the same perspective. There is a dune now guarded by two rows of snow fencing but dune grass has yet to be planted.

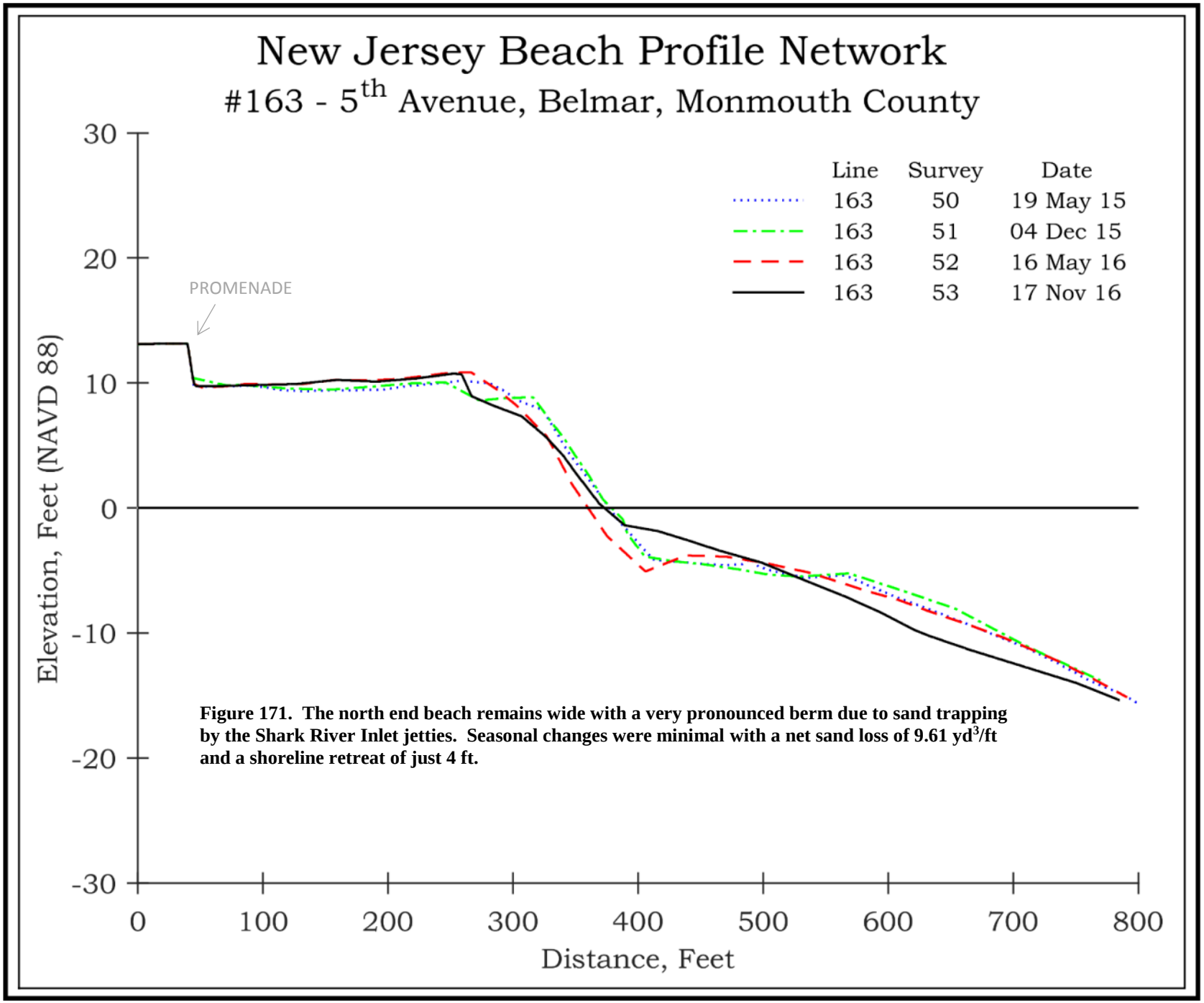

Figure 171. The north end beach remains wide with a very pronounced berm due to sand trapping by the Shark River Inlet jetties. Seasonal changes were minimal with a net sand loss of 9.61 yd^3/ft and a shoreline retreat of just 4 ft.

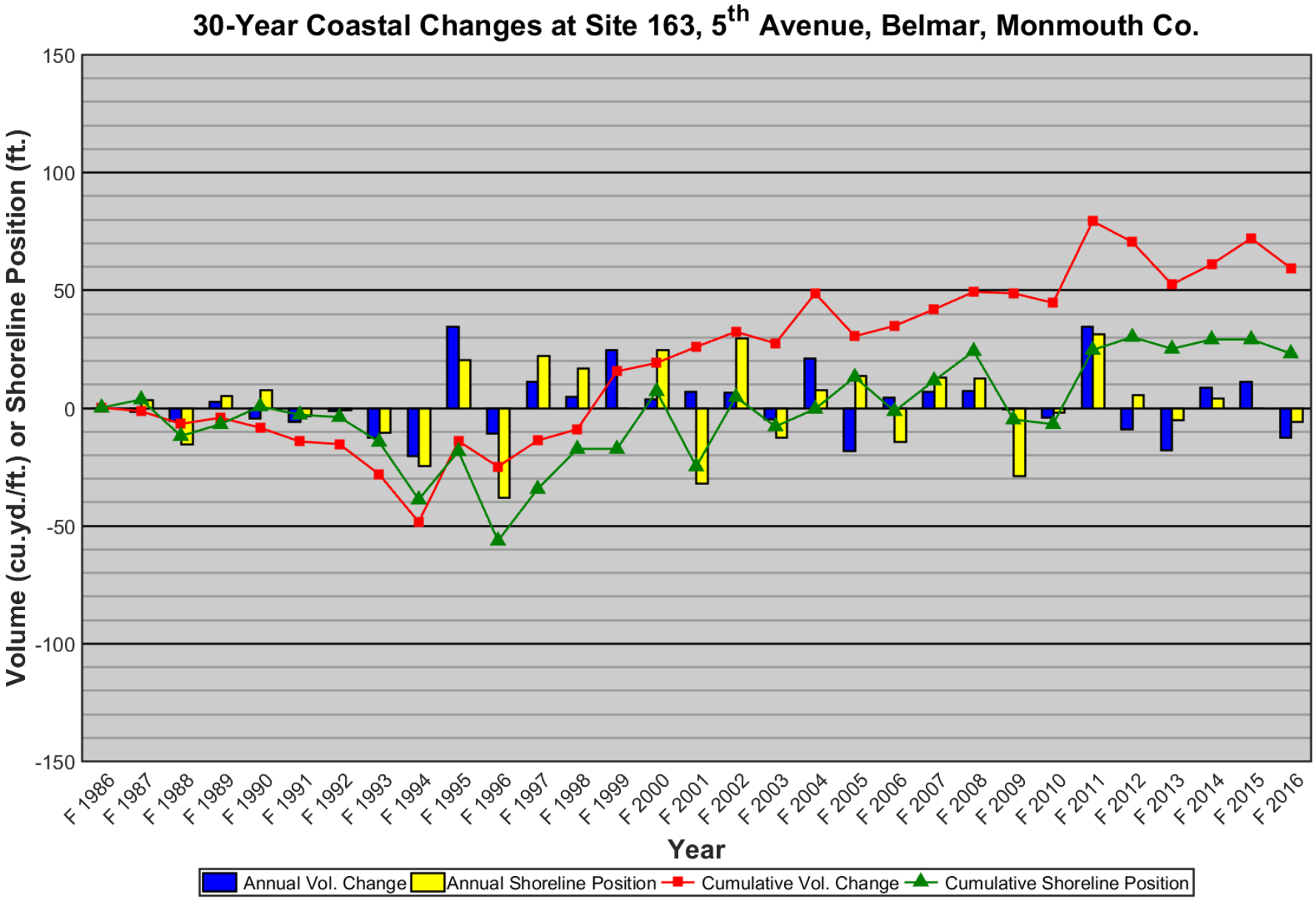

Figure 172. The past three decades have seen the slow increase in sand volume present at this site due to the influence of the USACE project starting in the late 1990's. No sand was directly placed at this site or on the beach toward the jetty north of the site. Sand migrated to the site over time, however, adding 60 yds^3/ft in net improvement. Shoreline position change did not display a definitive increasing or decreasing trend, but seemed to oscillate around zero. The net shoreline change, however, was positive and displayed a 25 ft overall seaward advance from 1986 to 2016.

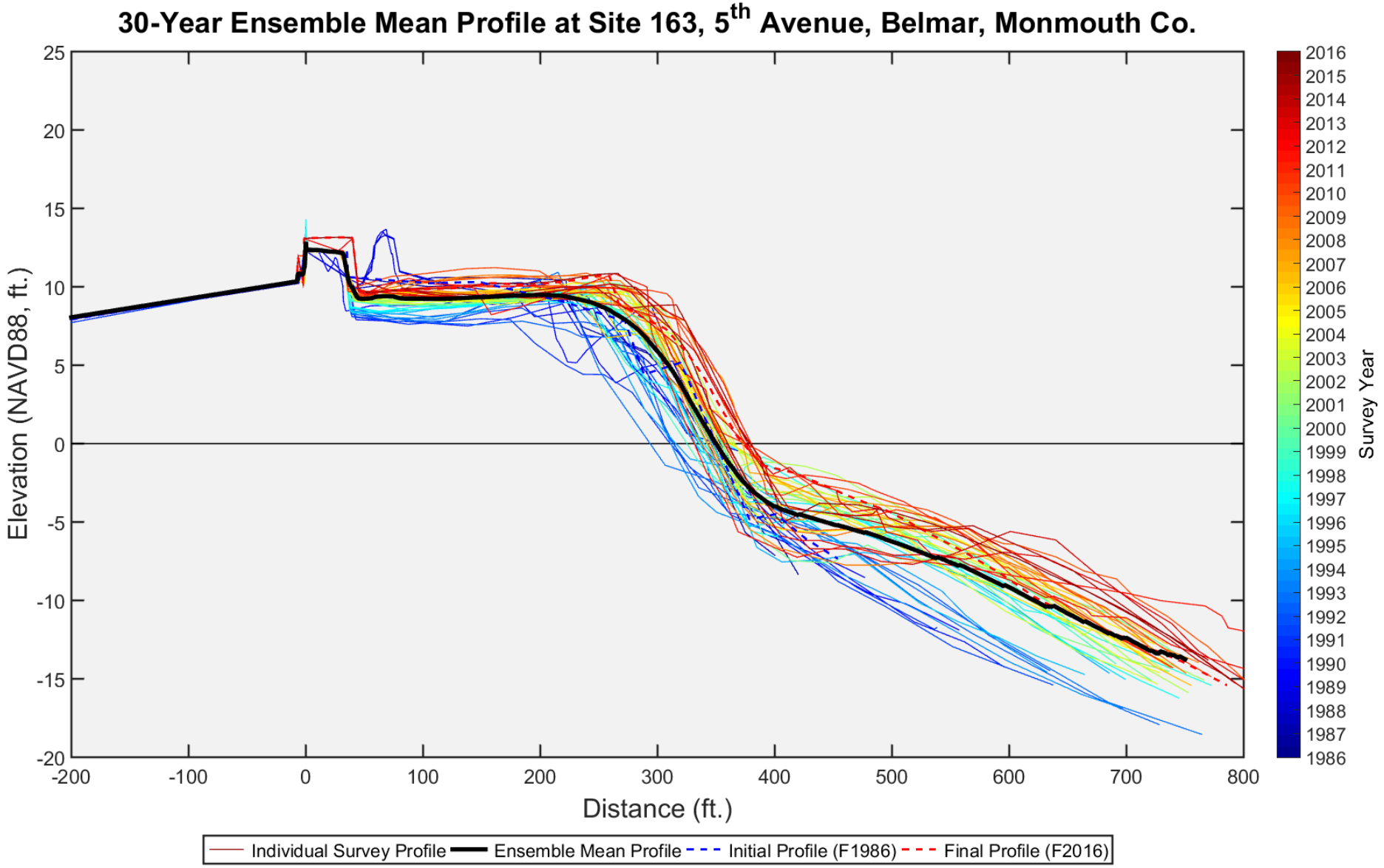

Figure 173. The gradual increase in beach width and sand volume is related to the USACE project although no direct sand placement occurred at this site and north to the Shark Rive jetty. This site is unusual along the project shoreline since it is the only site where no sand was directly placed.

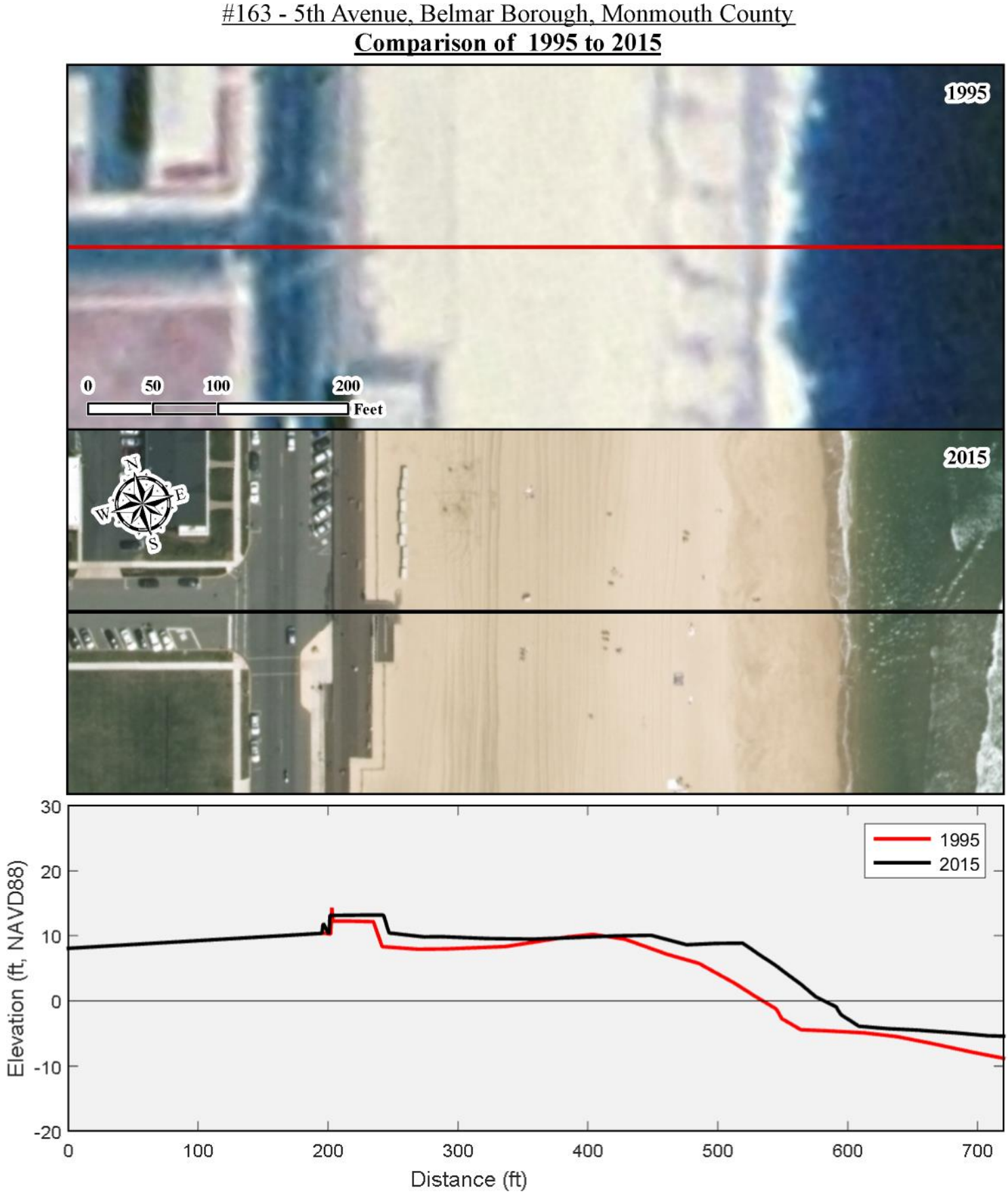

Figure 174. While never part of actual sand placement between 5th Avenue and the Shark River Inlet south jetty, this site has accumulated sand from northerly directed alongshore transport over time. The resulting shoreline change of 50 ft from 1995 to 2015, although small, is still a seaward advance.

Figure 175. View looking north at 18th Ave. Belmar from the crest of the winter storm ridge pushed up each year at this site to help defend the boardwalk from wave action. The beach width has been stable in recent time following the 2013-2014 restoration work by the USACE.

NJBPN 162 – 18th Avenue, Belmar

Figure 176a & 176b. By December 4, 2015 (left) the beach had a sand ridge pushed up to act as a winter "dune". A year later on November 17, 2016, the sand ridge was back for the coming winter (right photo). Its performance during the late January 2016 northeast storm was marginal.

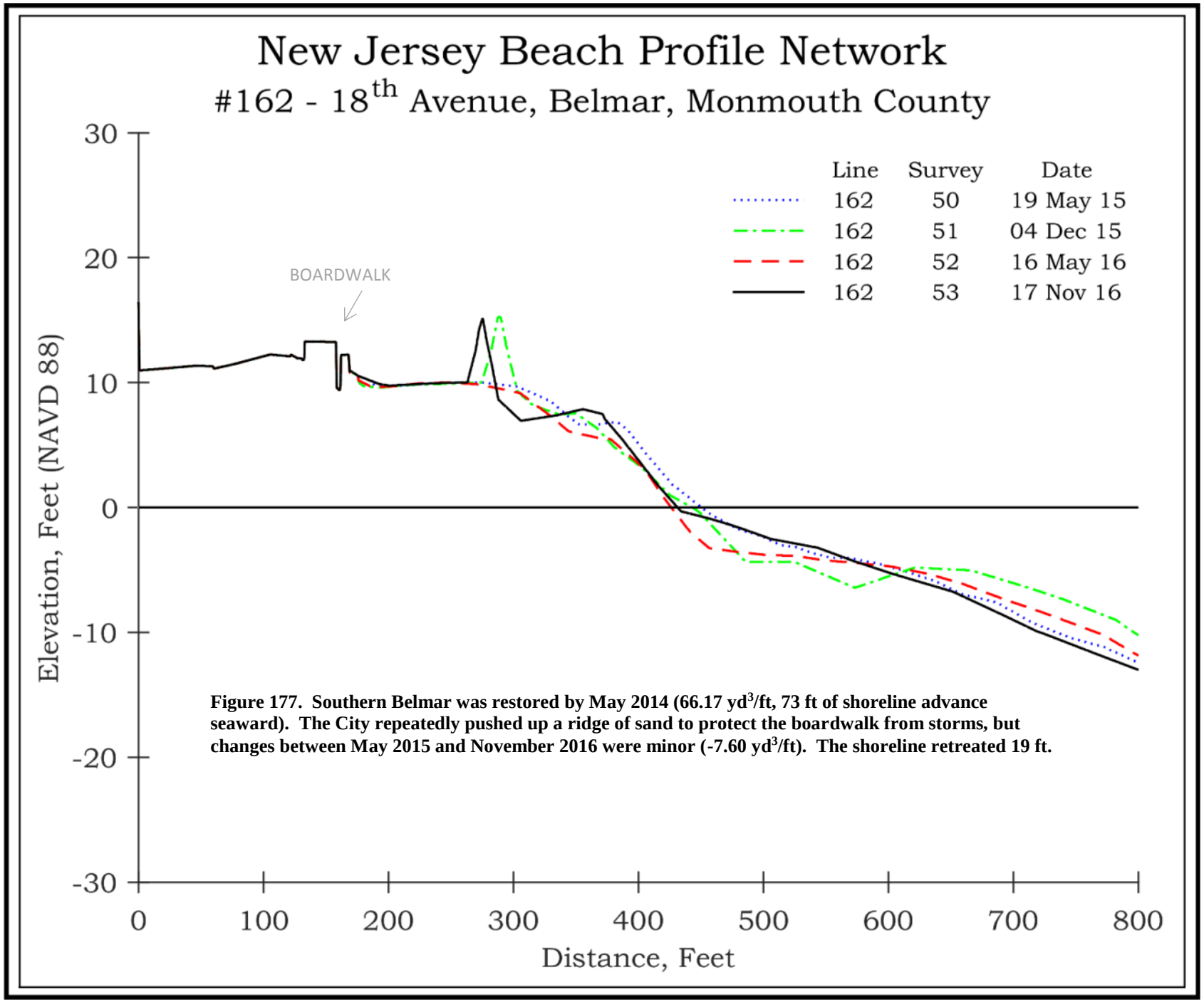

Figure 177. Southern Belmar was restored by May 2014 (66.17 yd^3/ft, 73 ft of shoreline advance seaward). The City repeatedly pushed up a ridge of sand to protect the boardwalk from storms, but changes between May 2015 and November 2016 were minor (-7.60 yd^3/ft). The shoreline retreated 19 ft.

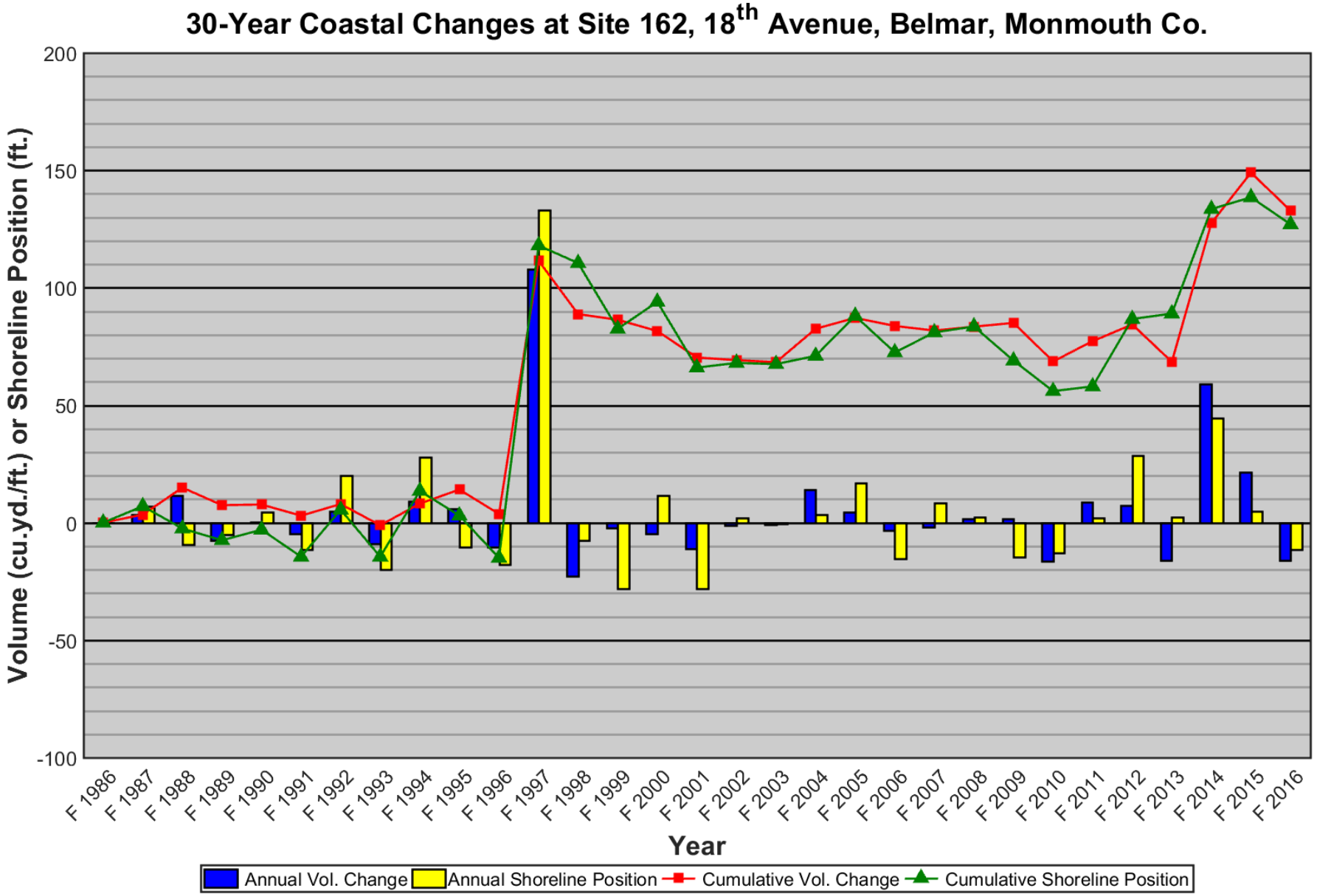

Figure 178. South Belmar beaches retreated from the 130 ft shoreline advance in 1997 to about a 55 ft advance from the original 1986 position in 2010 and 2011. Sand volume and shoreline positon both increased by about 118% from the initial fill in 1997 to the present year of 2016. The overall increase from 1997 to 2016 is due to the site being relatively stable and from the 2014 maintenance efforts.

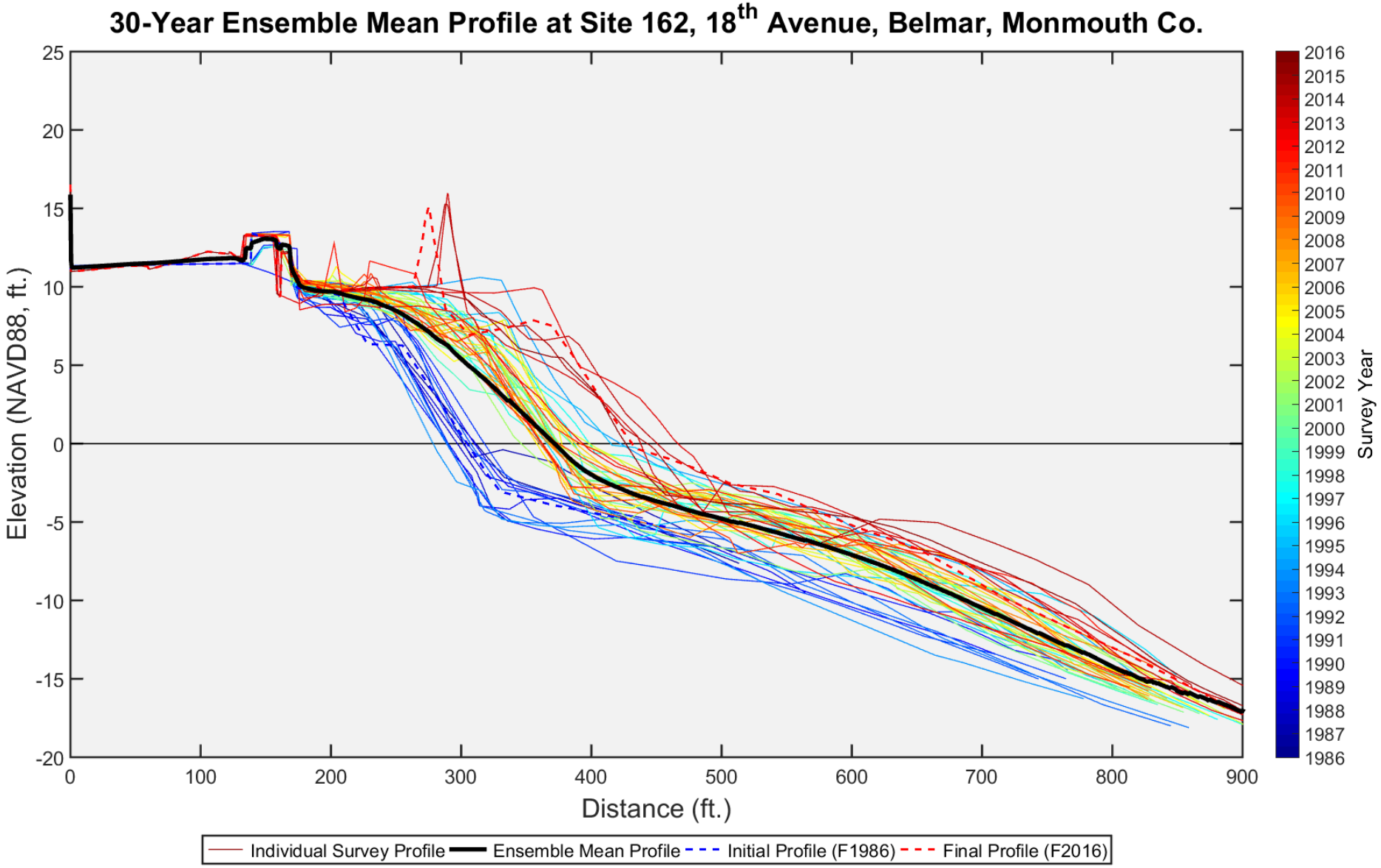

Figure 179. The USACE did place sand at 18th Avenue in Belmar, but not as much as was put on the Asbury beach. The previous beach was relatively stable while the later (2000's) profiles adjusted landward somewhat. The spikes, which look like dunes, are storm ridges pushed up in the fall for winter storm protection by the city.

#162 - 18th Avenue, Belmar Borough, Monmouth County

Comparison of 1995 to 2015

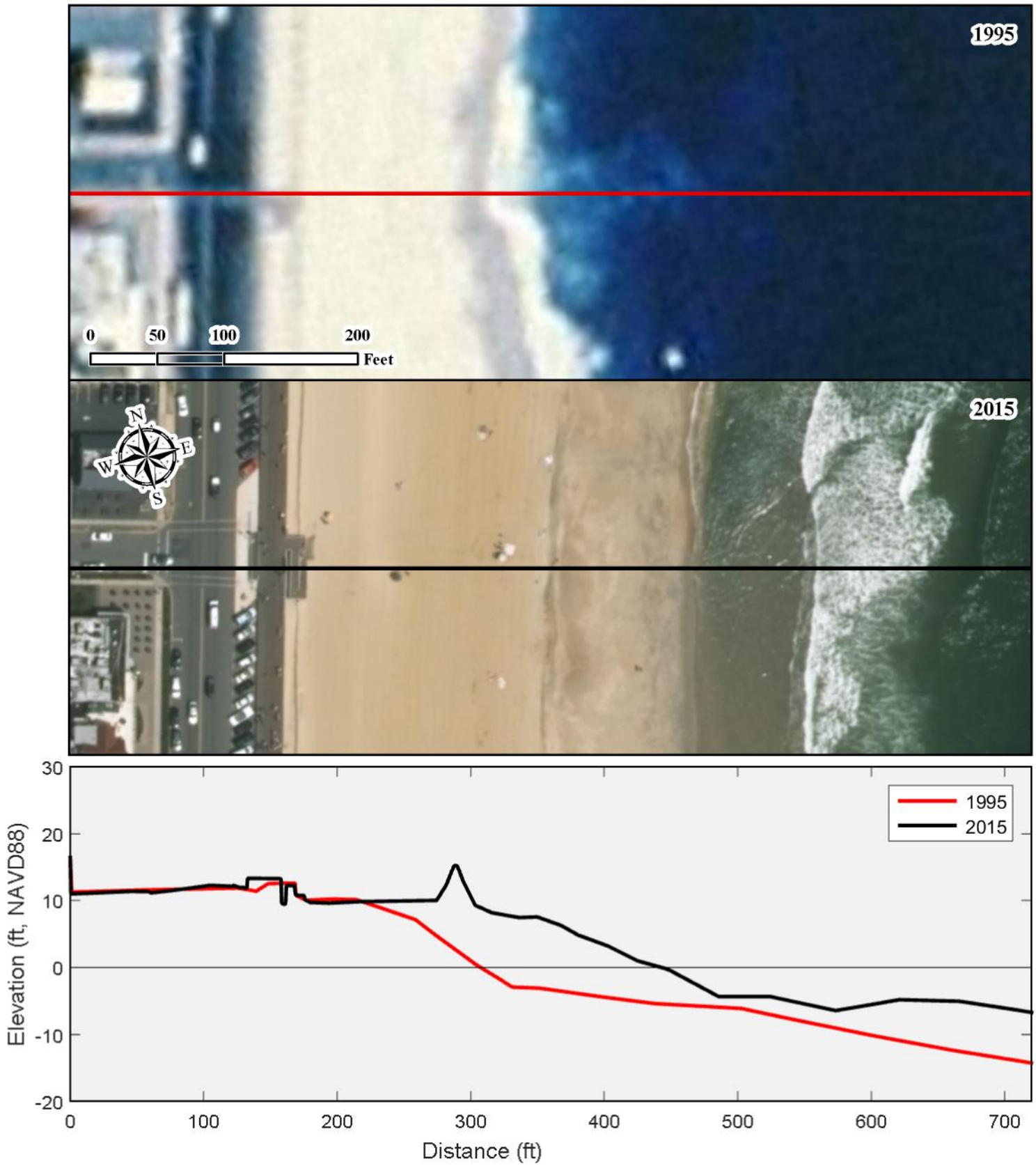

Figure 180. Southern Belmar's beaches were restored by the federal project adding about 150 ft in beach width. The spike-like dune feature was sand that was pushed up in place during the fall as added storm protection because the city has never built dunes.

Figure 181. At Brighton Avenue, Spring Lake the view to the north is from the crest of the storm ridge created each fall to help defend the boardwalk that has been destroyed twice in the past decade. Positioned as it is seaward of the dune makes wave impacts severe when they are large enough to forcefully strike the dunes. The robust concrete supports always survive, but the sections of boardwalk are lifted off and float landward or break apart.

NJBPN 161 – Brighton Avenue, Spring Lake


Figure 182a & 182b. The left view on November 29, 2015 shows the wide beach and active surf zone breaking on an offshore bar. The storm sand ridge was in place as of Nov 17, 2016 to deter waves from damaging the boardwalk structure.

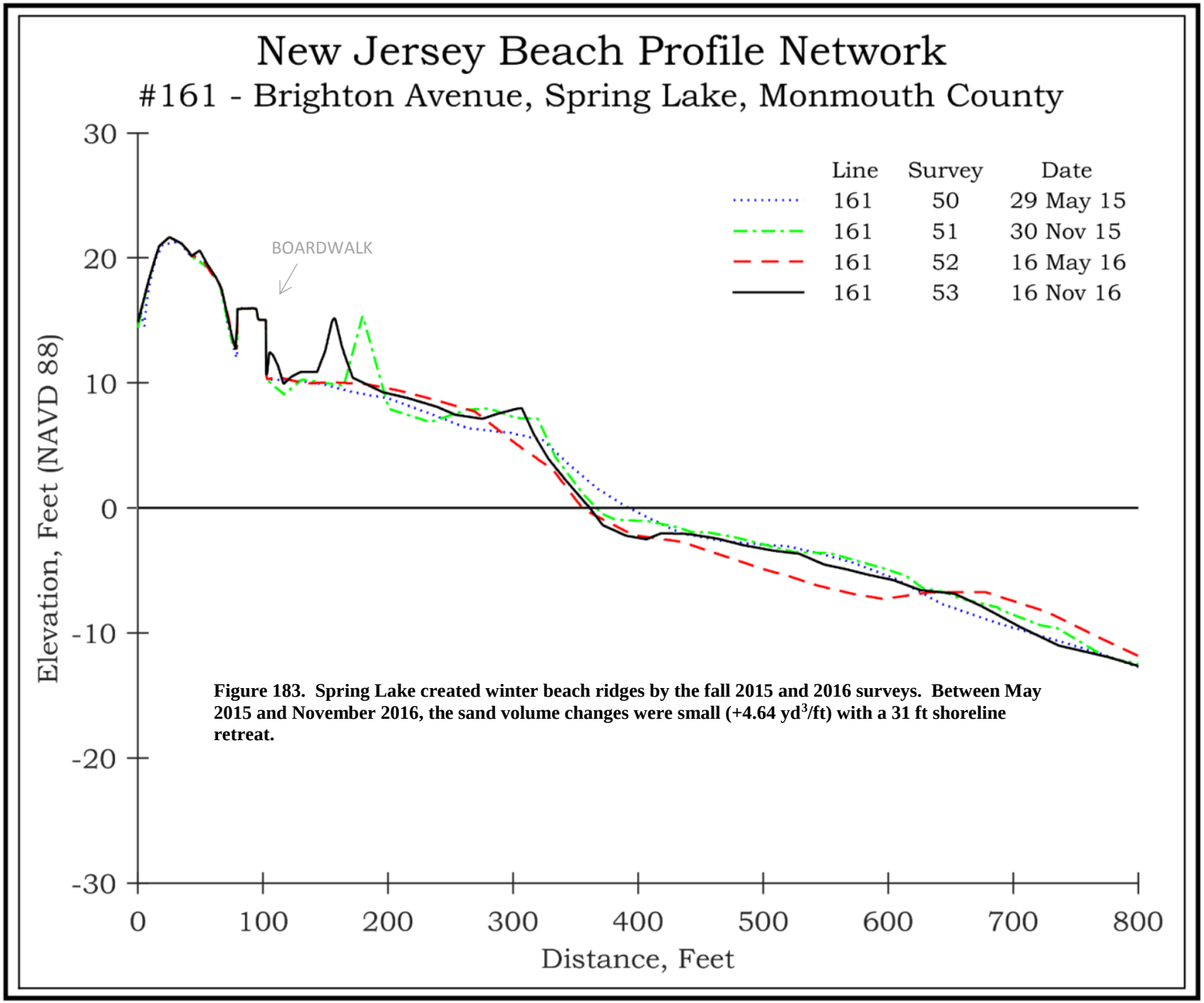

Figure 183. Spring Lake created winter beach ridges by the fall 2015 and 2016 surveys. Between May 2015 and November 2016, the sand volume changes were small (+4.64 yd^3/ft) with a 31 ft shoreline retreat.

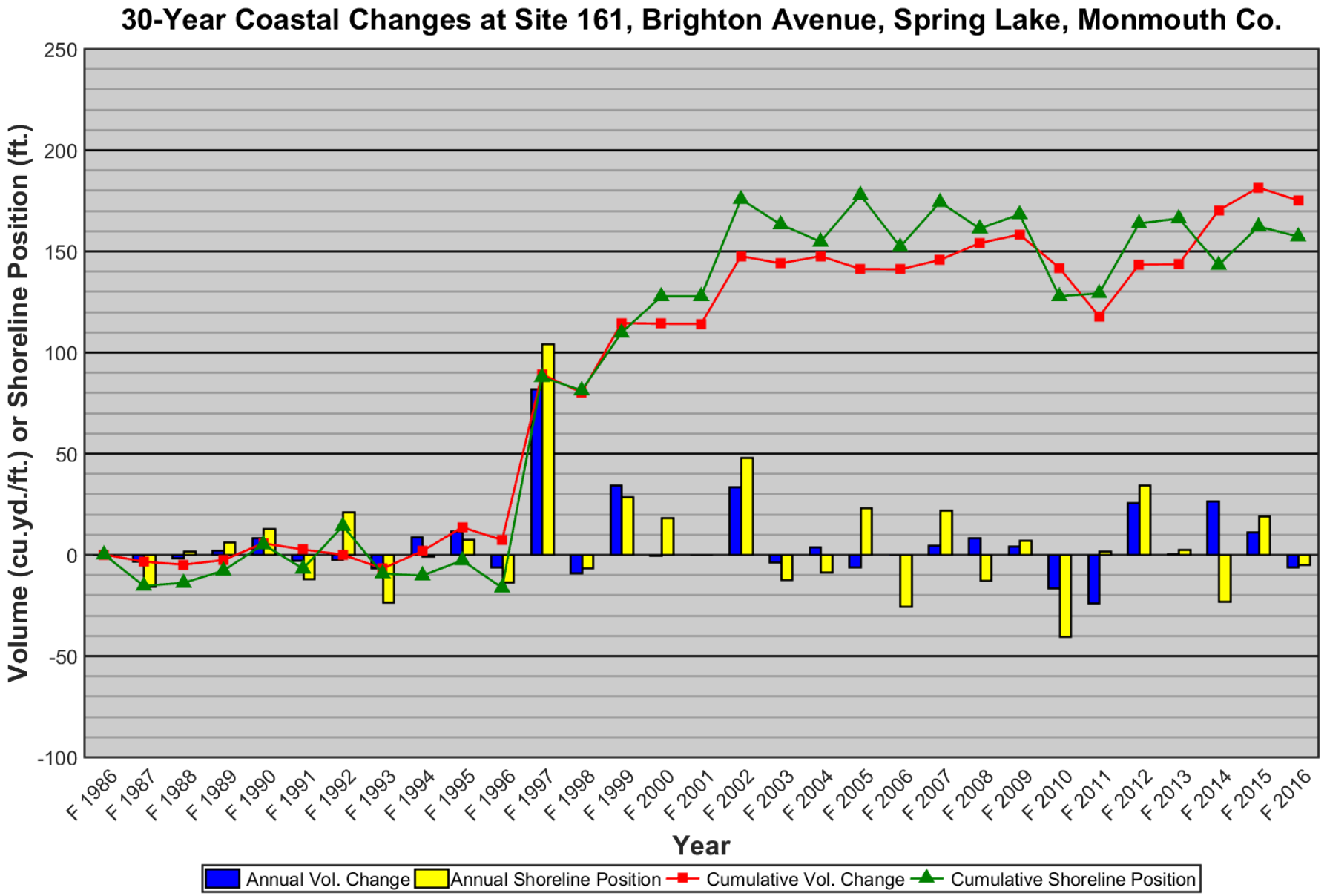

Figure 184. Site 161 was another location where the initial sand placement volume of about 80 yds^3/ft was augmented by regular accumulation resulting in a shoreline advance that peaked in both 2002 and 2005. The shoreline position oscillated around the 2002 value until a loss was experienced in both shoreline position and volume in 2010, followed by an overall increase in both from 2010 to 2016. The shoreline position in 2016 was almost 160 ft seaward of the initial 1986 location and sand volume in 2016 was 219% of that placed in 1997.

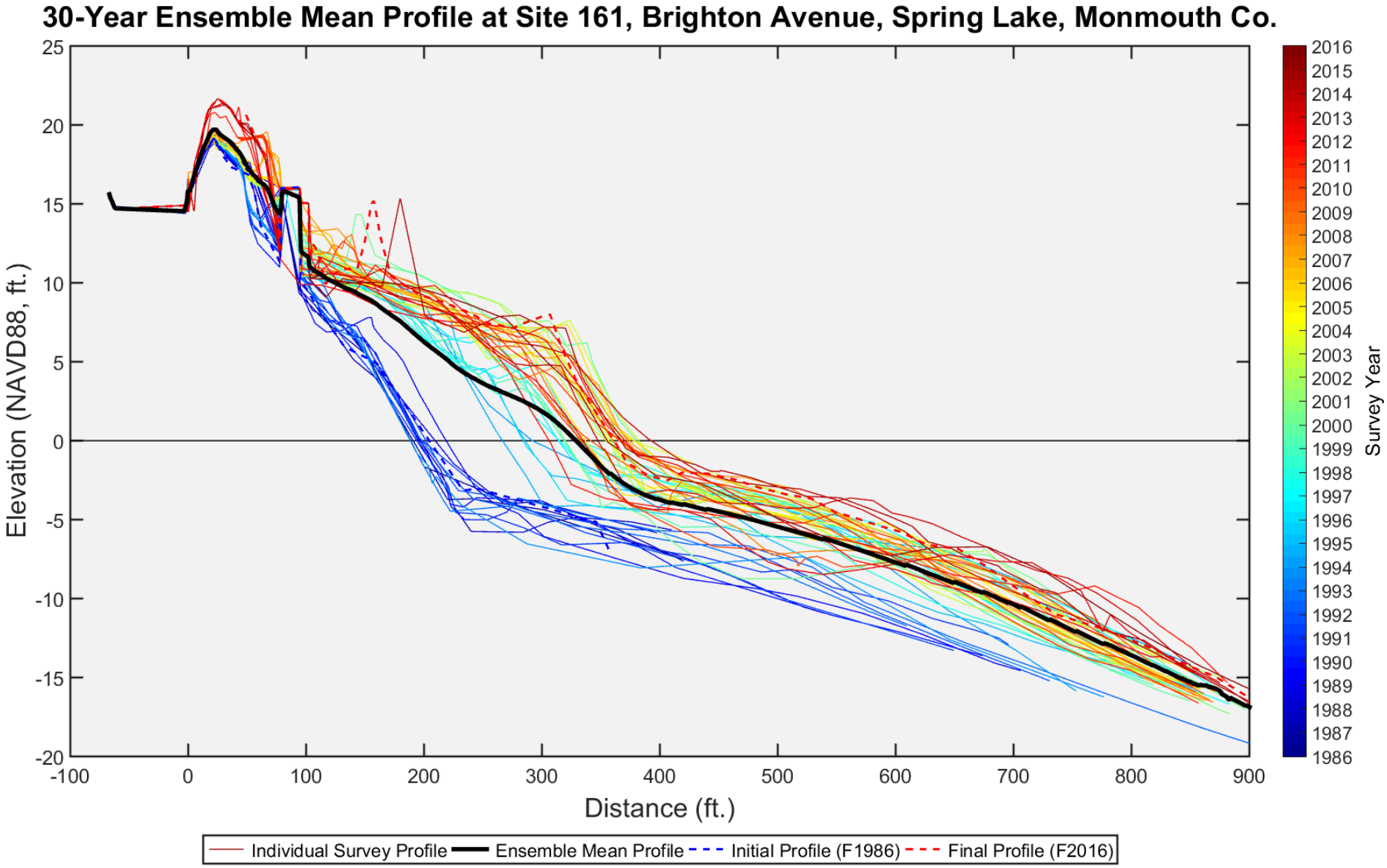

Figure 185. The Spring Lake beach prior to the USACE work was quite stable. The project added over twice the sand volume that also remained in place over time. The dune was improved following Sandy, but the boardwalk remains seaward of the dune and therefore still vulnerable to wave damage in big storms.

#161 - Brighton Avenue, Spring Lake Borough, Monmouth County

Comparison of 1995 to 2015

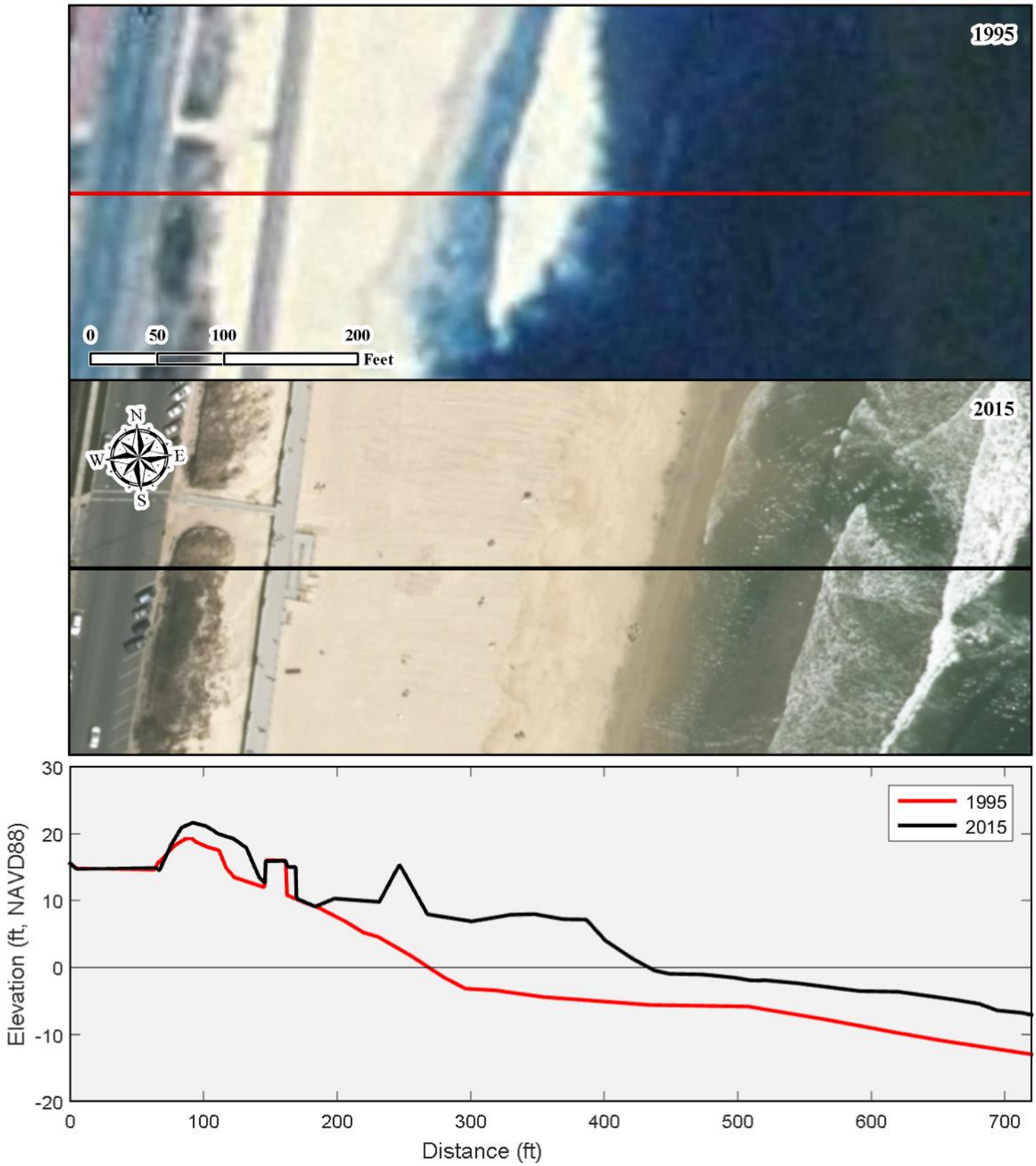

Figure 186. Dune enhancement occurred along with a 200 ft wider beach in Spring Lake. The current condition is a direct result of post-Hurricane Sandy restoration work.

Figure 187. At Salem Avenue, Spring Lake, the sand ridge is complete for the fall/winter 2016-2017. The groins are exposed, but the beach has increased in sand volume recently.

NJBPN 160 – Salem Avenue, Spring Lake

Figure 188a & 188b. The USACE completed restoration in 2014 adding 32.29 yds^3/ft of sand. The view on December 11, 2015 shows a similar beach width with the winter storm "dune" in place seaward of the boardwalk. The vegetated dune still exists landward of the boardwalk. Spring Lake re-installed the storm ridge of sand again in late 2016, which withstood the January 2016 northeast storm (Jonas).

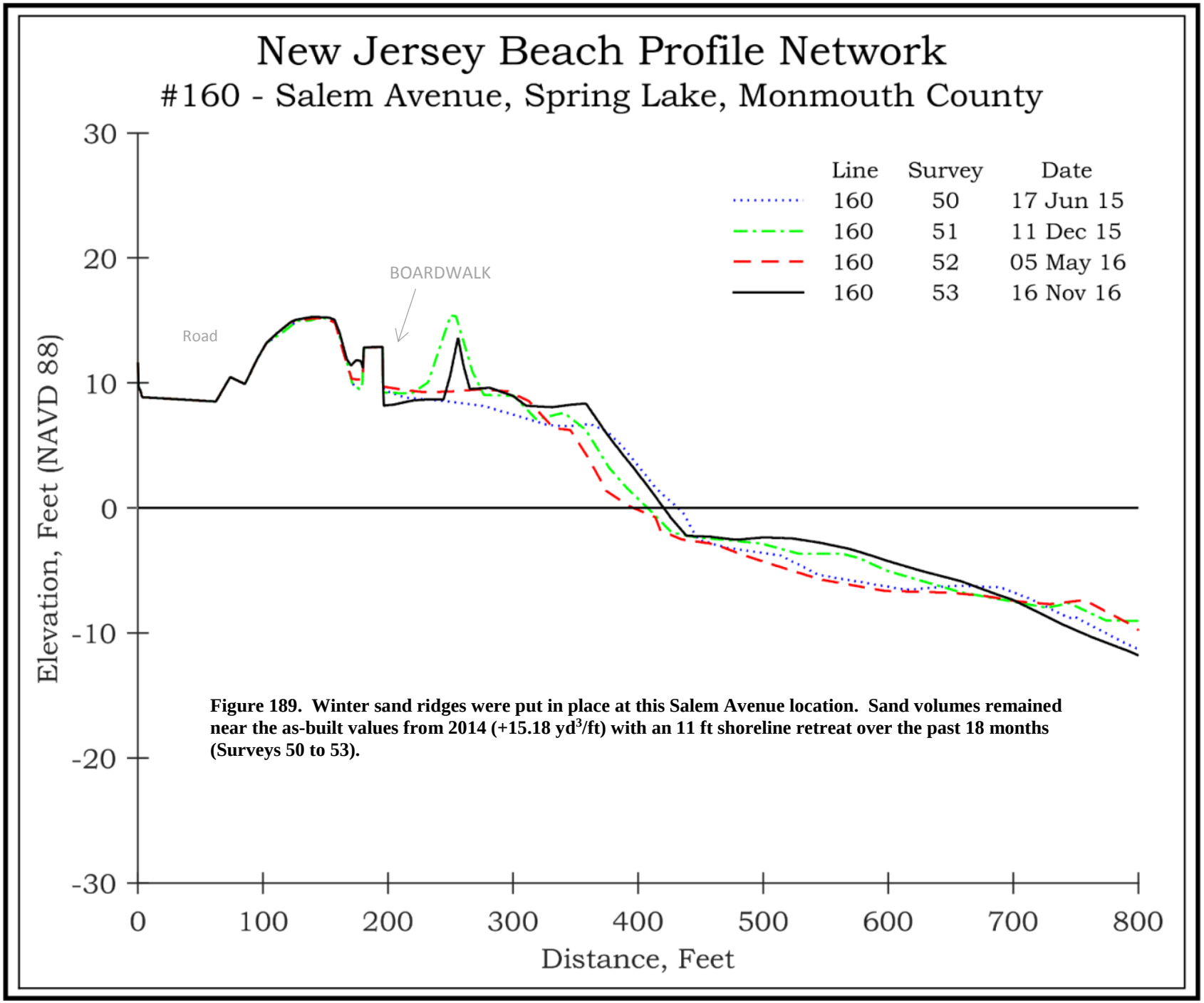

Figure 189. Winter sand ridges were put in place at this Salem Avenue location. Sand volumes remained near the as-built values from 2014 (+15.18 yd^3/ft) with an 11 ft shoreline retreat over the past 18 months (Surveys 50 to 53).

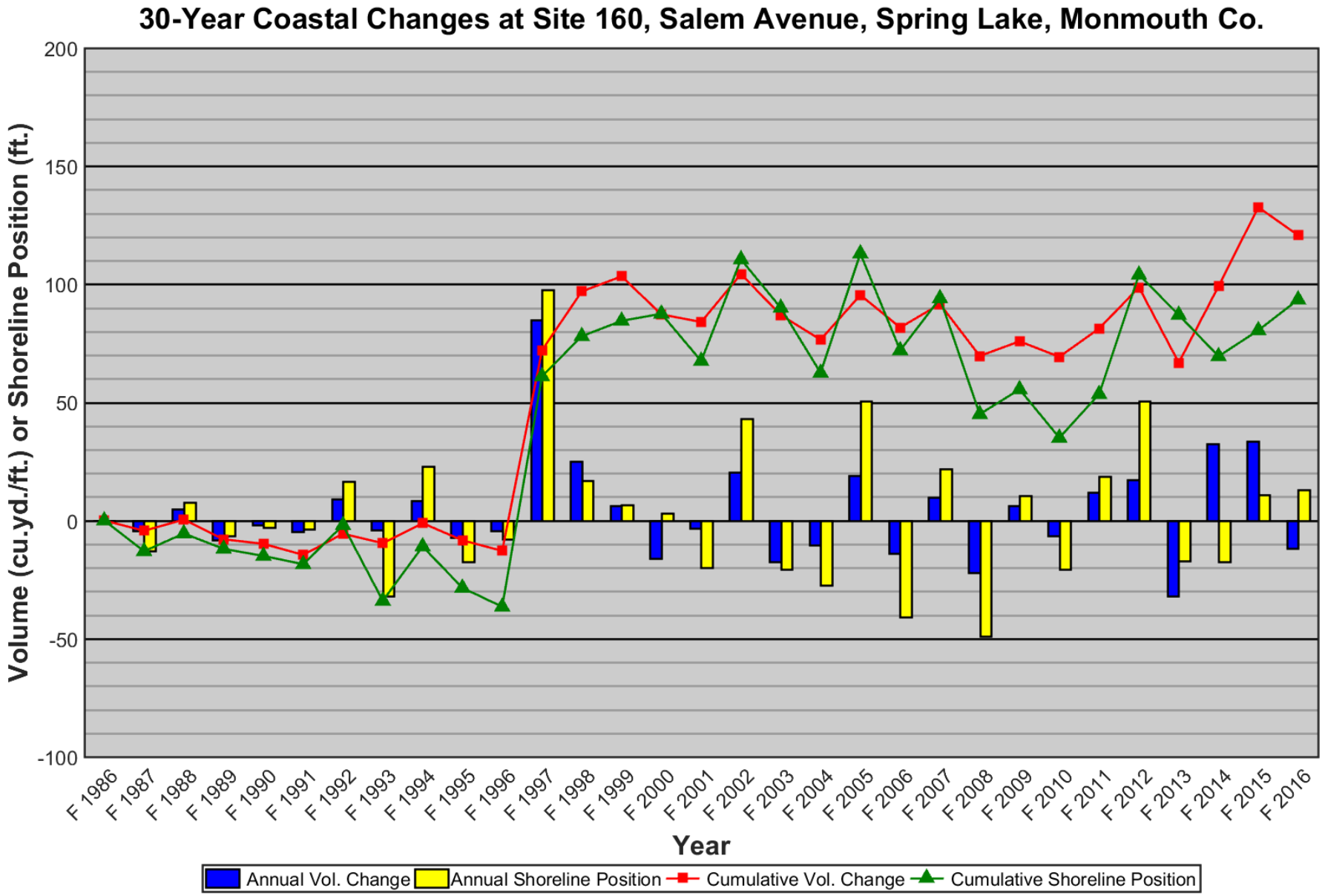

Figure 190. The shoreline at Salem Avenue oscillated around the shoreline position after the 1997 beach fill for about 10 years, until it experienced a loss of almost 50 ft in 2008. The shoreline position rebounded in 2012 and has experienced minor losses and gains since. Sand volume has remained more stable, oscillating around the initial placement volume from 1997 up until 2013 where it returned to almost the same amount from 1997. The post-Sandy recovery raised that value from about 70 yds^3/ft to 100 yds^3/ft and by 2016, the volume had increased to about 170% of the initial placement volume from 1997.

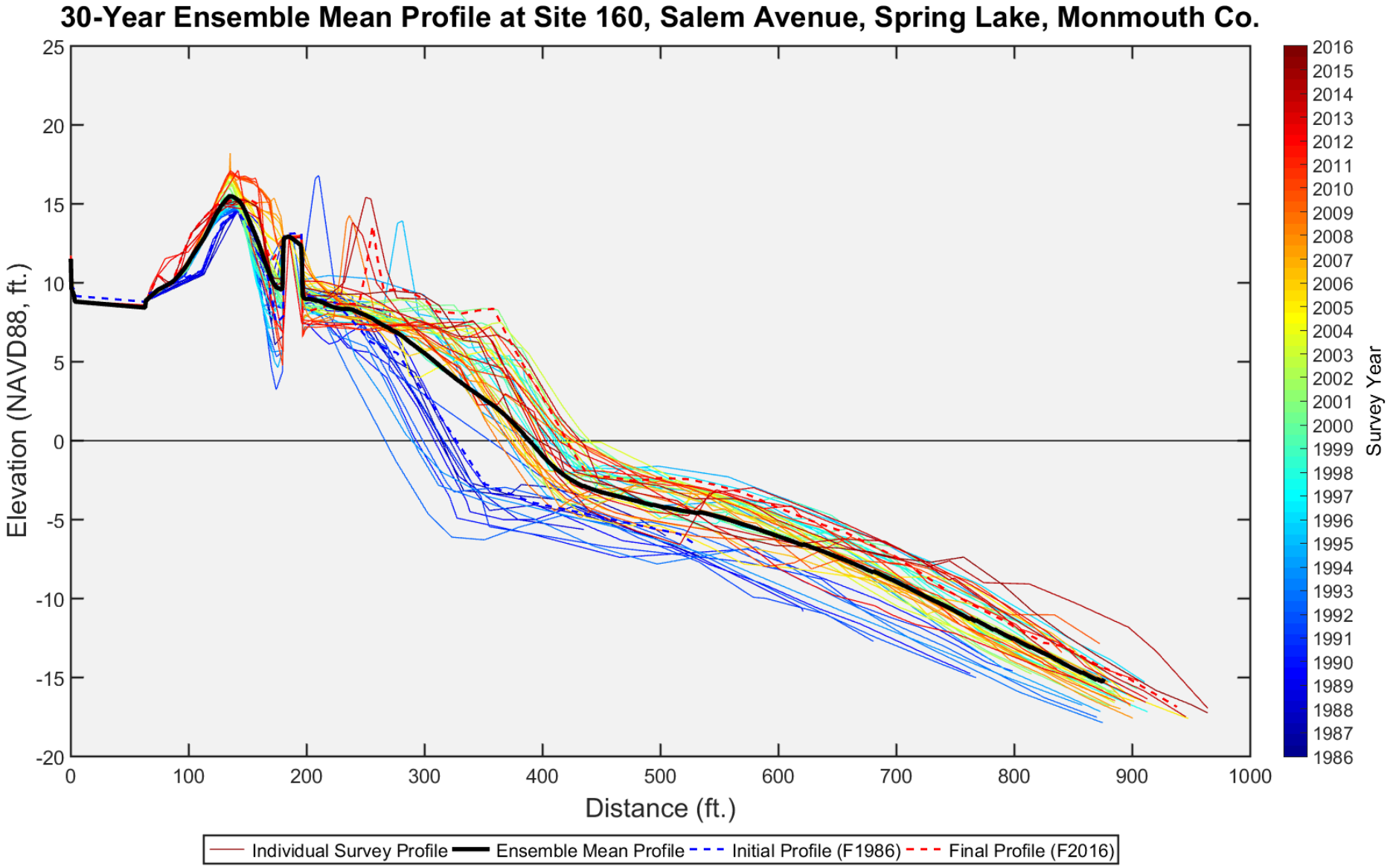

Figure 191. The second site in Spring Lake was also quite stable both before and after the USACE project. The dune was enhanced following Sandy and the borough has regularly pushed up ridges of sand as winter storm protection.

#160 - Salem Avenue, Spring Lake Borough, Monmouth County

Comparison of 1995 to 2015

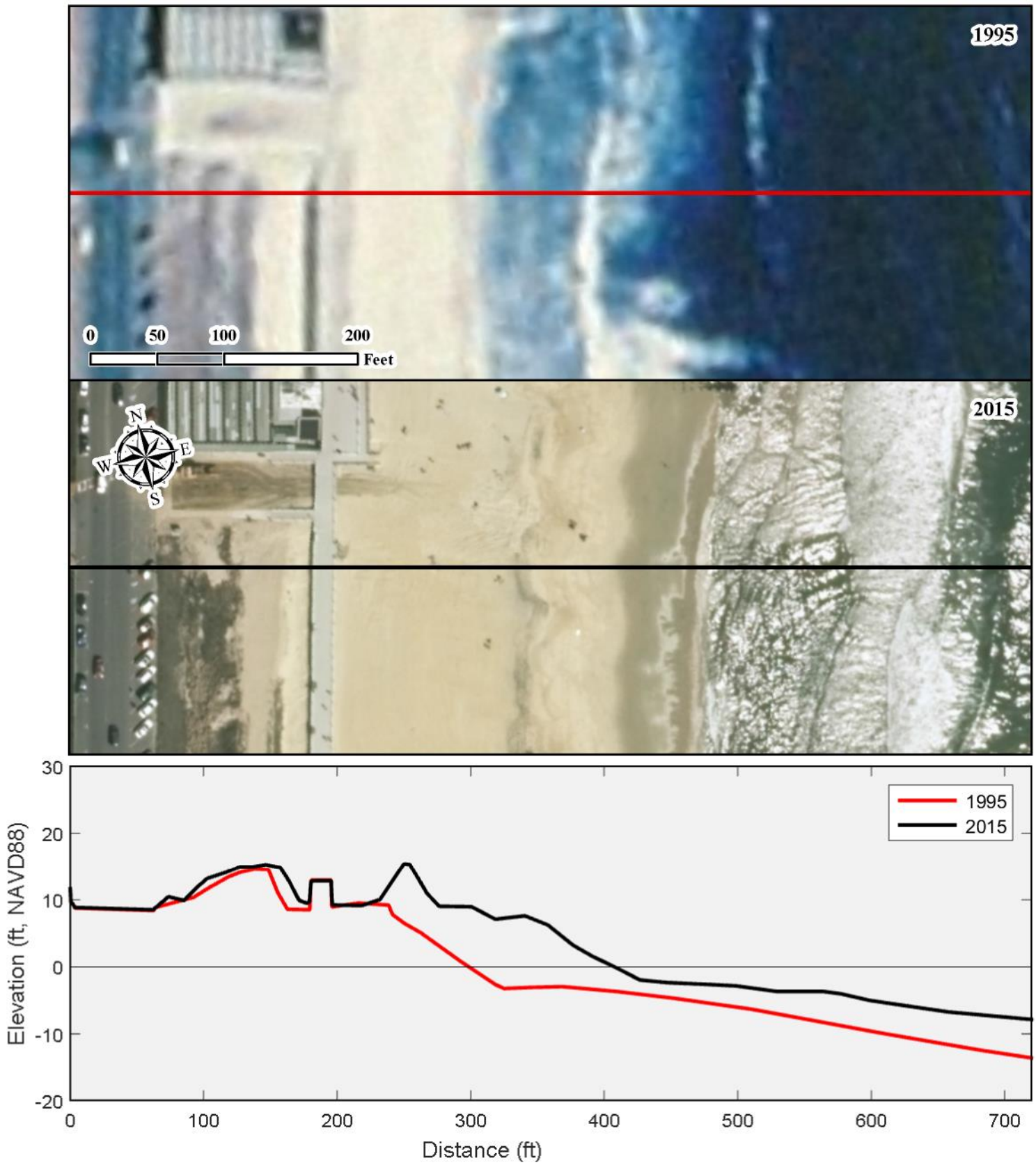

Figure 192. A similar effect as seen at site 161 was demonstrated at Salem Avenue in Spring Lake with an added ridge of sand pushed up in the fall as added storm protection for the boardwalk.

Figure 193. This northerly view in Sea Girt is at the crest of the new, post-Sandy dune on the municipal beach. This permanent feature was built instead of relying on sand pushed into place as a ridge each fall and graded out each spring.

NJBPN 159 – New York Avenue, Sea Girt


Figure 194a & 194b. Modest additions were made by the USACE during 2014 (23.81 yds^3/ft of sand added) and the beach was wider. By December 11, 2015 (left) the small dune seaward of the boardwalk has grass and gained some sand. November 16, 2016 saw a slightly larger dune and minimal change to the beach seaward of the dune.

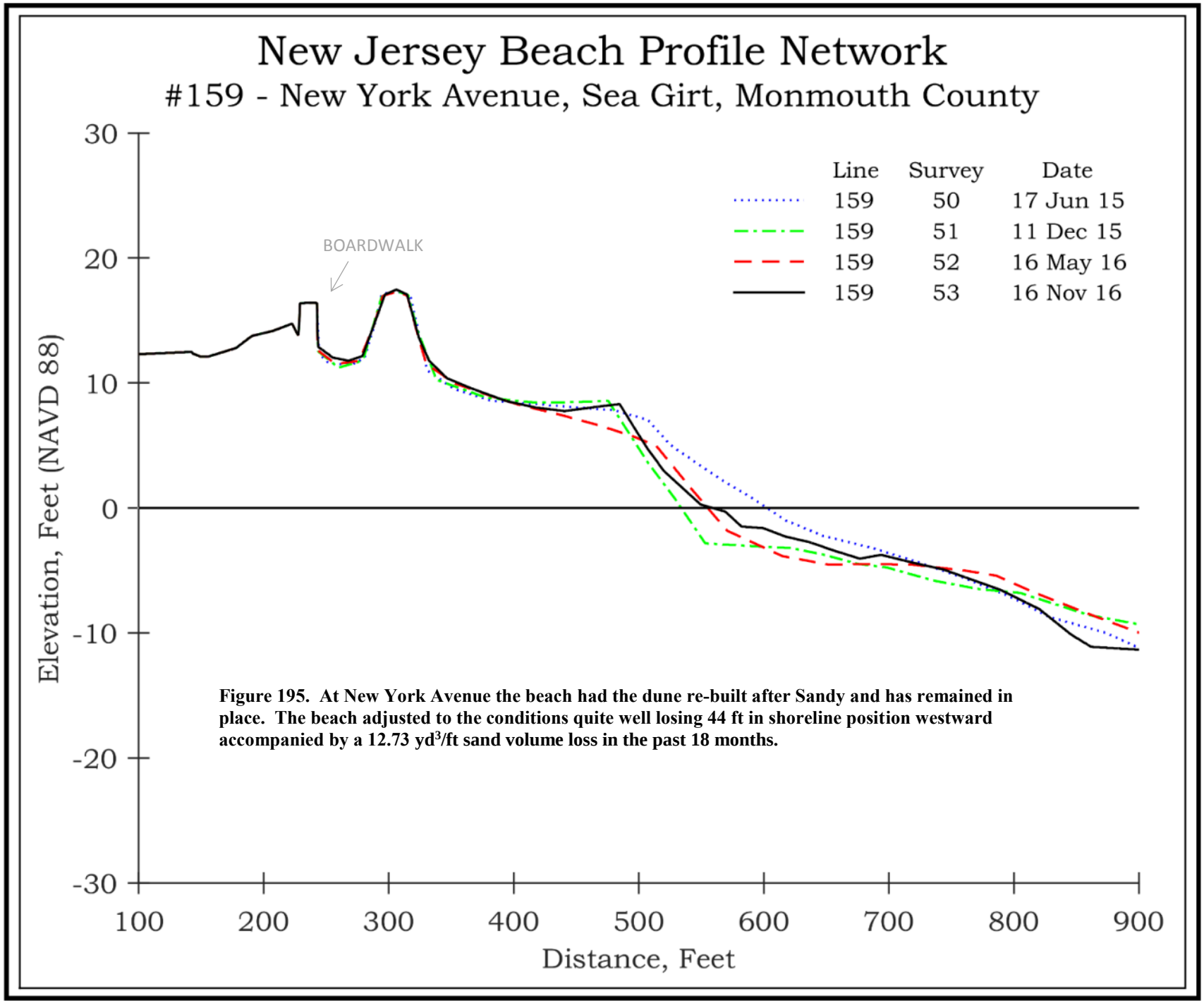

Figure 195. At New York Avenue the beach had the dune re-built after Sandy and has remained in place. The beach adjusted to the conditions quite well losing 44 ft in shoreline position westward accompanied by a 12.73 yd^3/ft sand volume loss in the past 18 months.

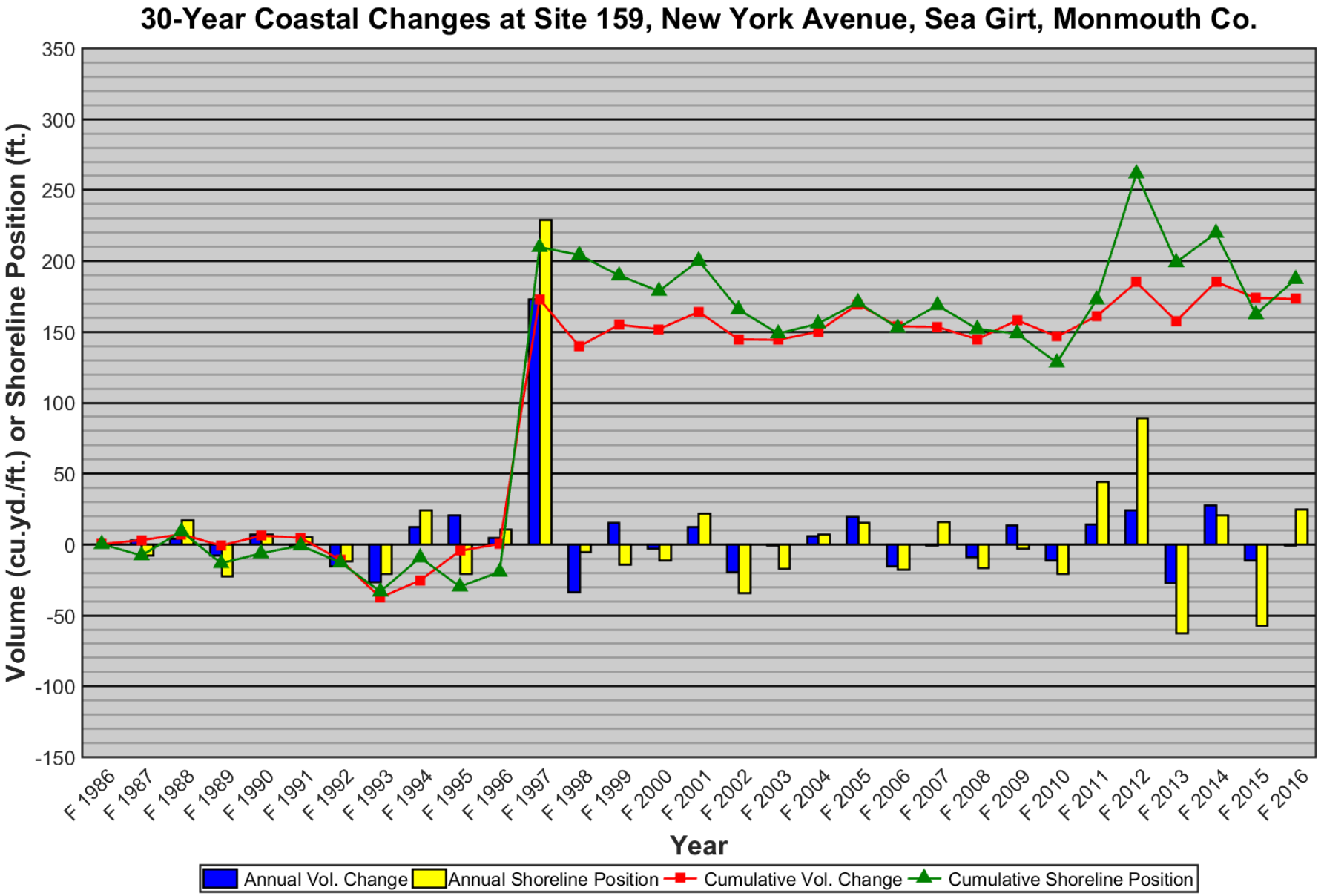

Figure 196. This location was initially completed by the USACE in 1997, adding 170 yds^3/ft to the profile that advanced the shoreline 210 ft seaward. Over the next 13 years from 1997 to 2010 the site experienced a relatively small volume loss of about 20 yds^3/ft and a larger shoreline retreat of about 80 ft. Post-Sandy maintenance provided about 25 yds^3/ft, but the change in shoreline response was significant with an almost 90 ft seaward advance in 2012. In 2016, the sand volume was about the same as the initial placement volume in 1997 and the shoreline retreated about 20 ft from post-fill shoreline position.

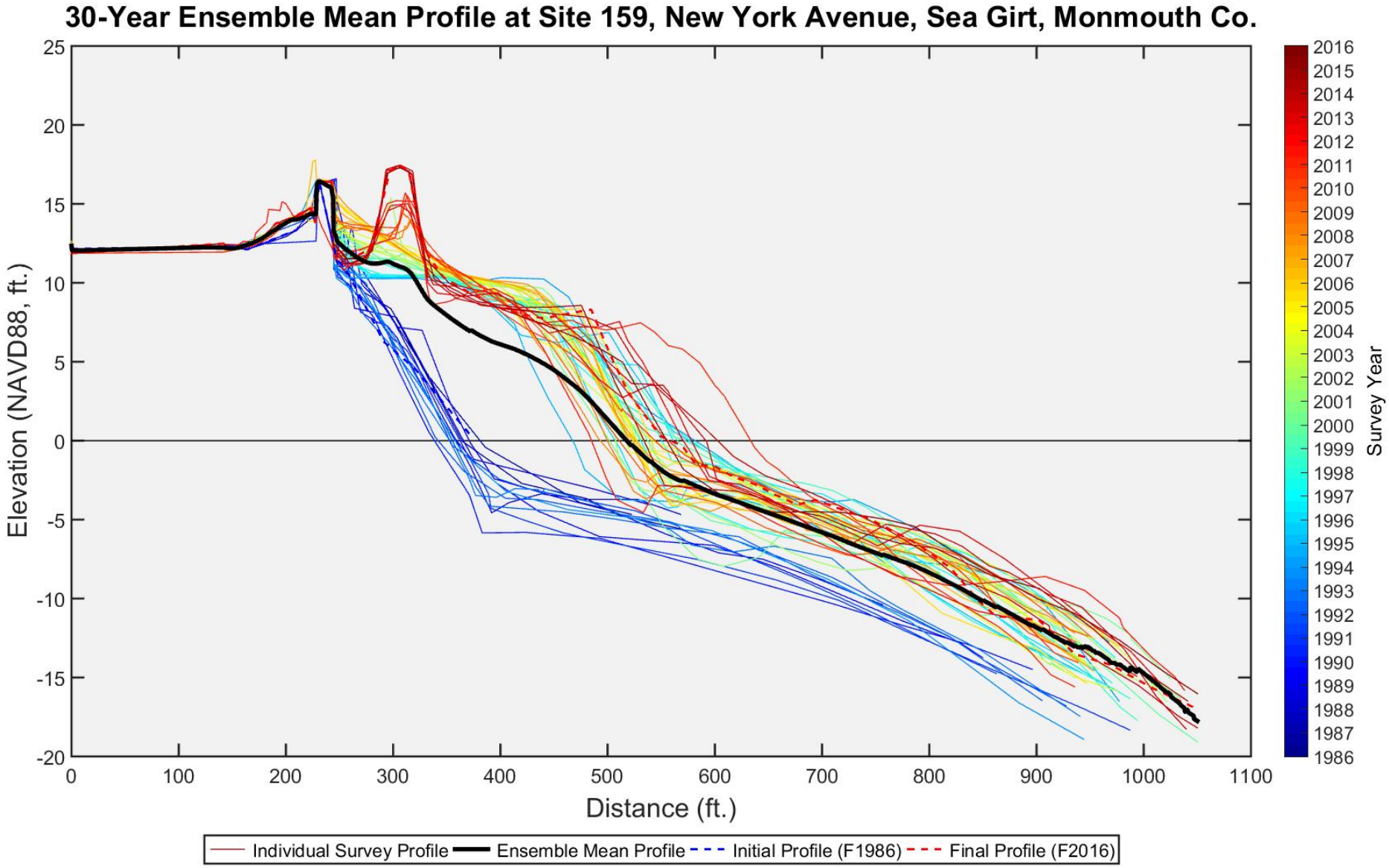

Figure 197. The Sea Girt beach was very steep prior to the USACE project. The USACE beach added considerably to the shore defense. The borough added a dune prior to Sandy that failed and was replaced with a taller feature.

#159 - New York Blvd, Sea Girt Borough, Monmouth County

Comparison of 1995 to 2015

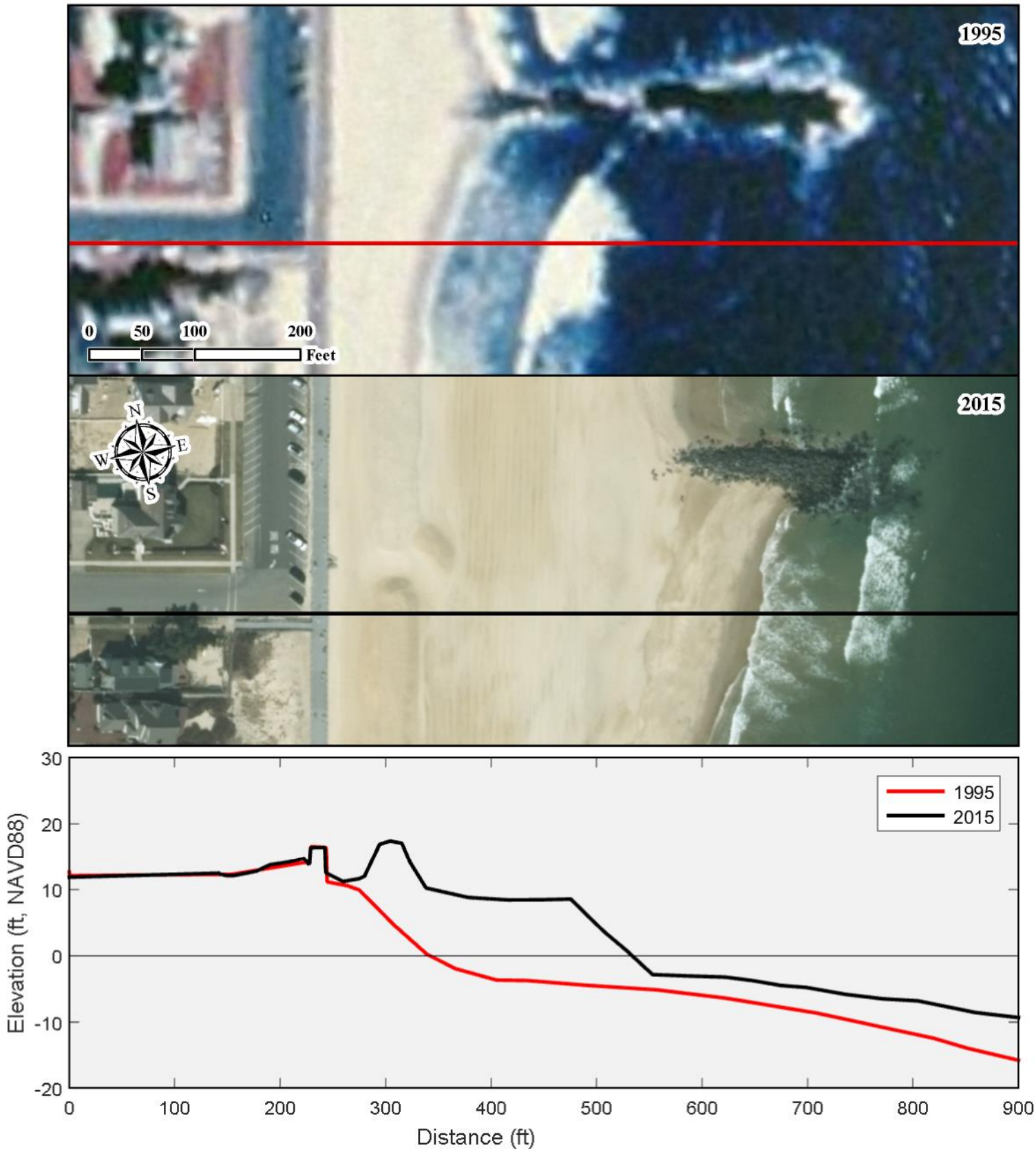

Figure 198. The boardwalk lies behind a new dune that was built to replace the old one destroyed during Hurricane Sandy. The restored beach shows in strong contrast with the profile surveyed in 1995 and displays a shoreline advance of over 200 ft.

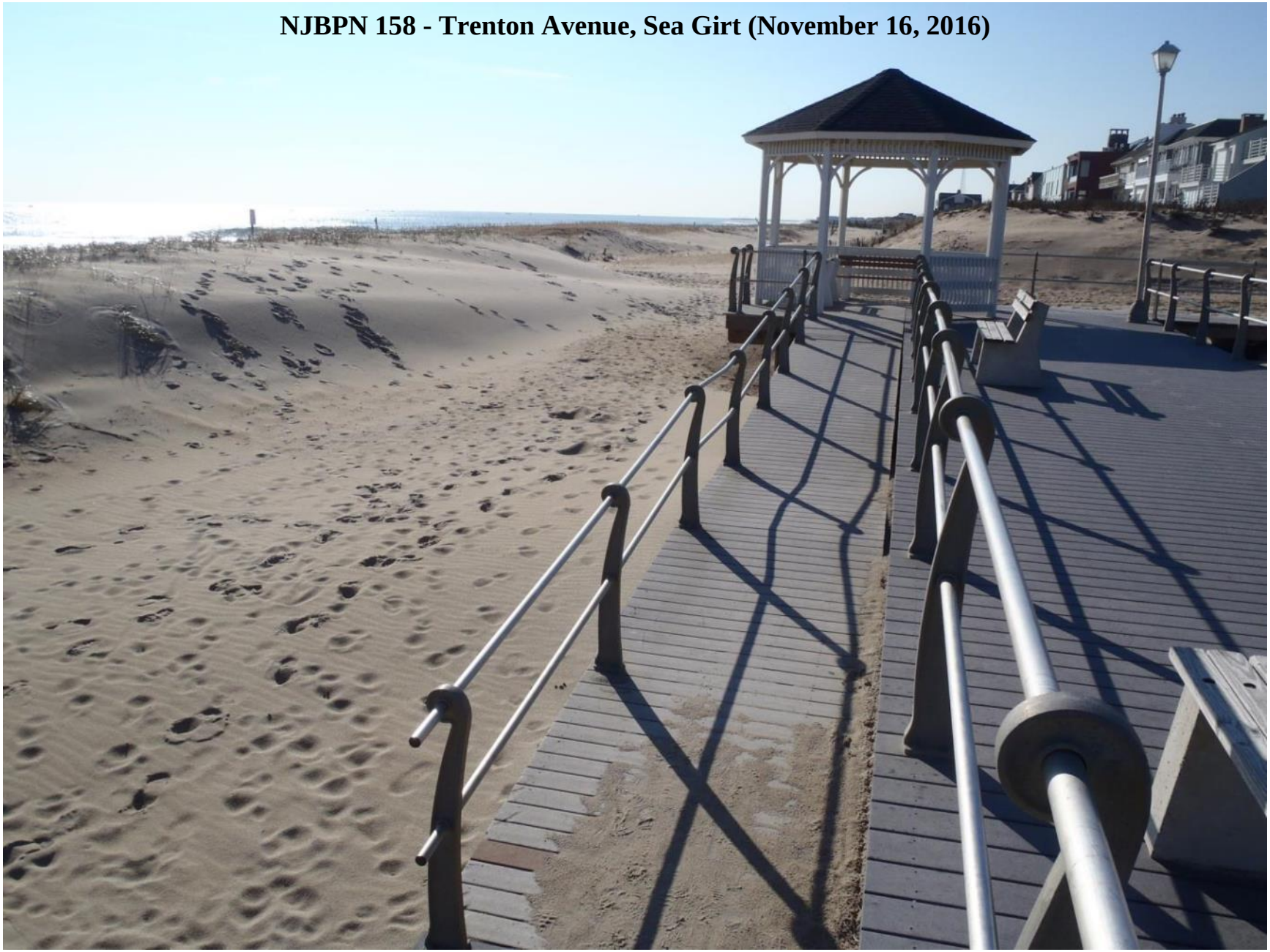

Figure 199. View to the south from Trenton Avenue, Sea Girt. The dunes provide a barrier to storm waves. Sandy did damage the gazebo, however.

NJBPN 158 – Trenton Avenue, Sea Girt

Figure 200a & 200b. Sand was added by the USACE in early 2014 and the recovered sand was molded into a dune ridge at the toe of the primary dune (left view December 11, 2015). One year later (November 16, 2016) on the right shows the sand deposited along the seaward toe of this new dune with the Manasquan Inlet jetty in the far distance to the south.

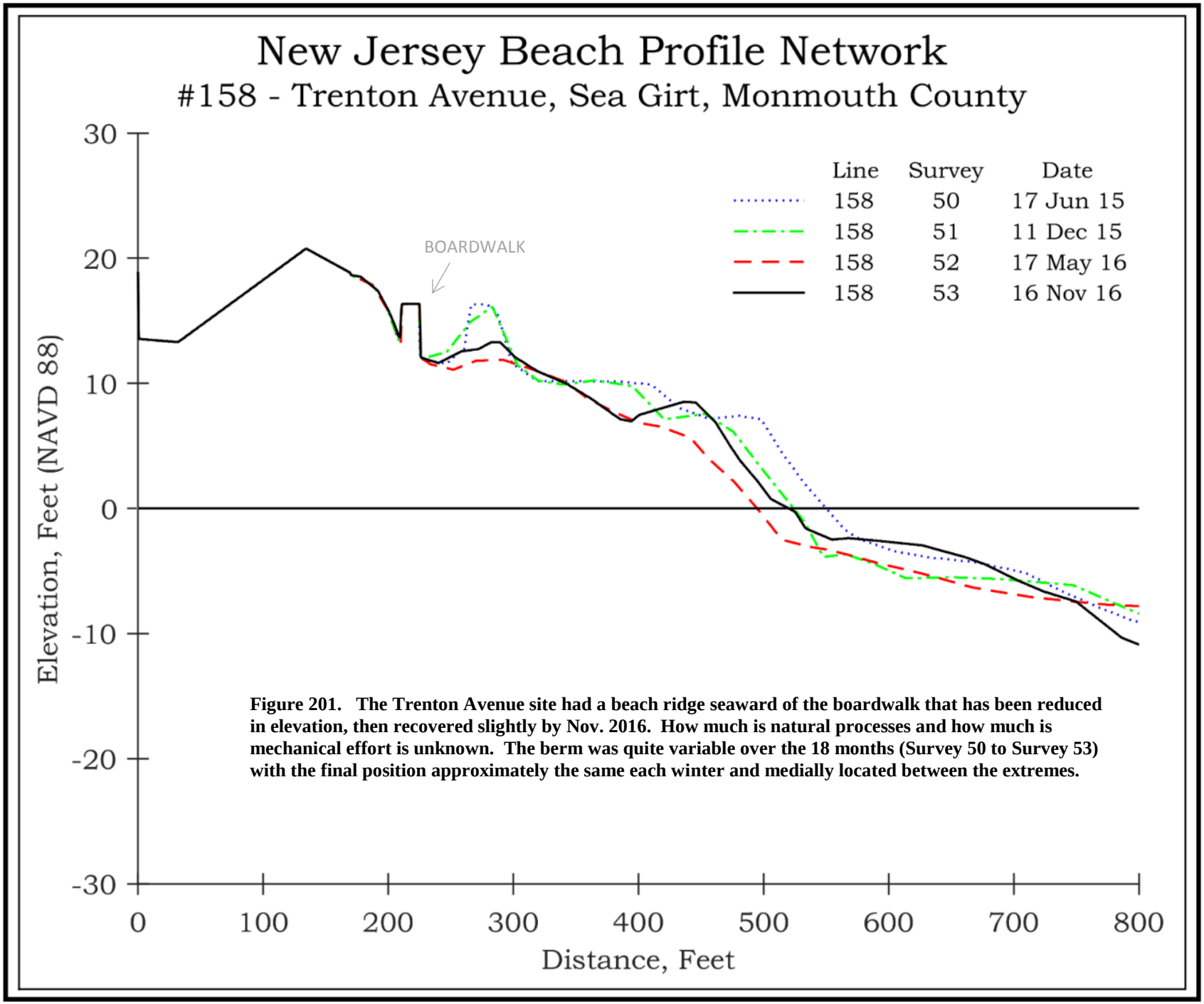

Figure 201. The Trenton Avenue site had a beach ridge seaward of the boardwalk that has been reduced in elevation, then recovered slightly by Nov. 2016. How much is natural processes and how much is mechanical effort is unknown. The berm was quite variable over the 18 months (Survey 50 to Survey 53) with the final position approximately the same each winter and medially located between the extremes.

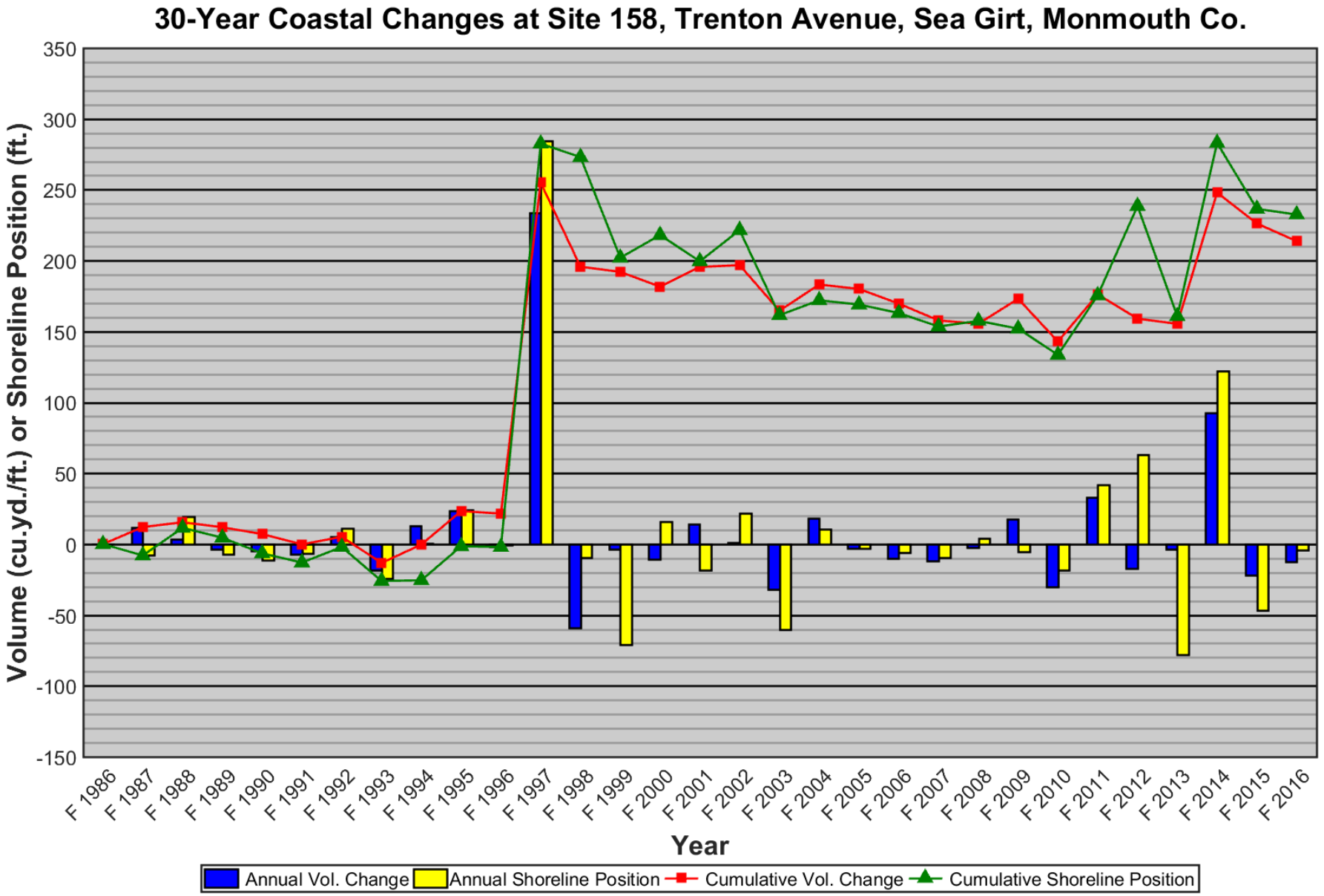

Figure 202. In 1997, a very large deposit of sand was placed at this site (about 230 yds^3/ft) which eroded down to 105 yds^3/ft by 2010. The 2014 maintenance post-Sandy shows in 2014 as a return to a sand volume of 210 yds^3/ft. The shoreline position trend followed the sand volume trend closely at this site and was almost 200 ft seaward of the initial 1986 shoreline position come 2016.

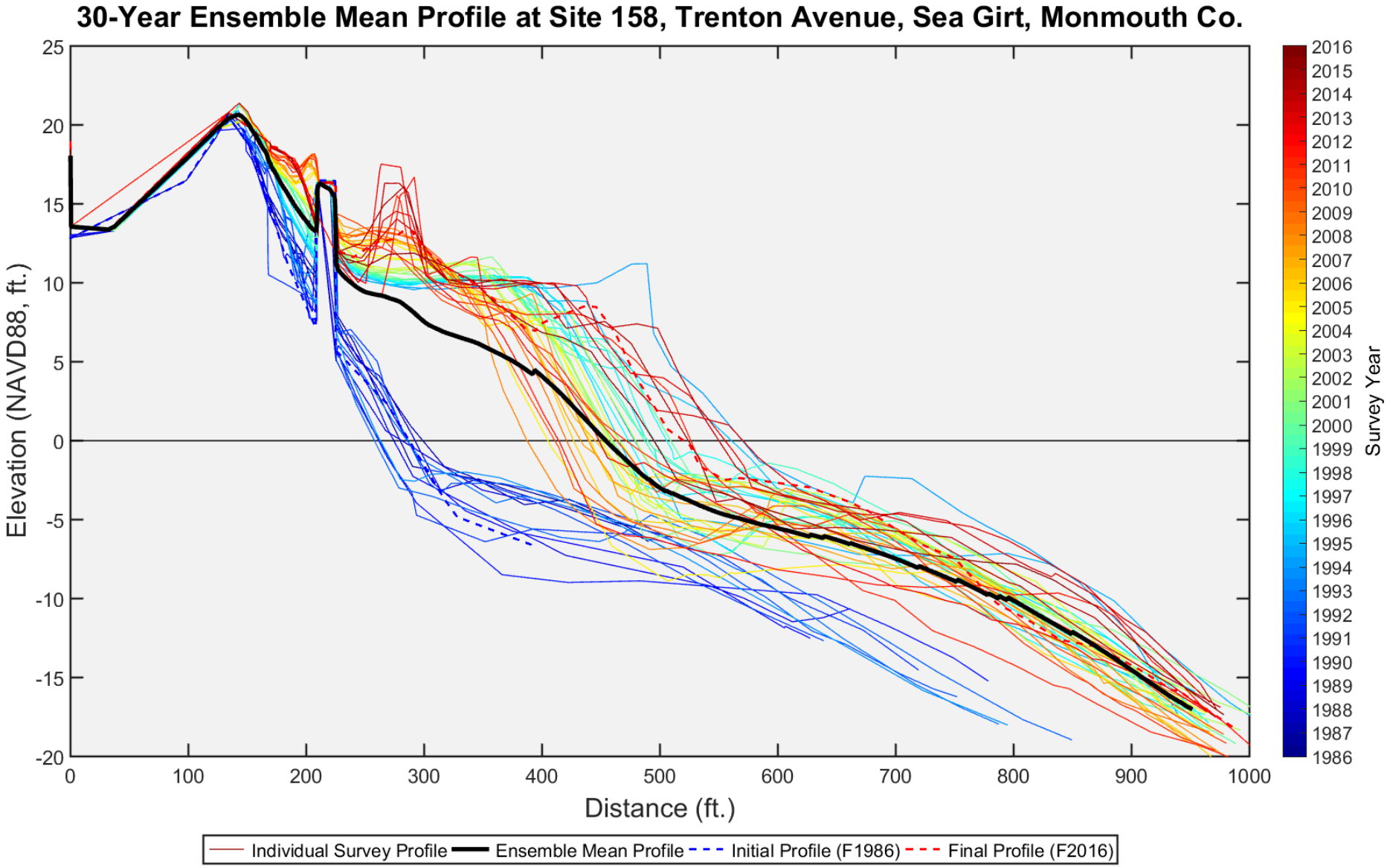

Figure 203. The pre-USACE project beach was steep and water often flowed under the boardwalk. The bluff was eroded in 1992 during a major storm. The site received abundant sand from the federal project and the site retreated over time. The post-Sandy work restored the initial beach width and added a dune seaward of the boardwalk.

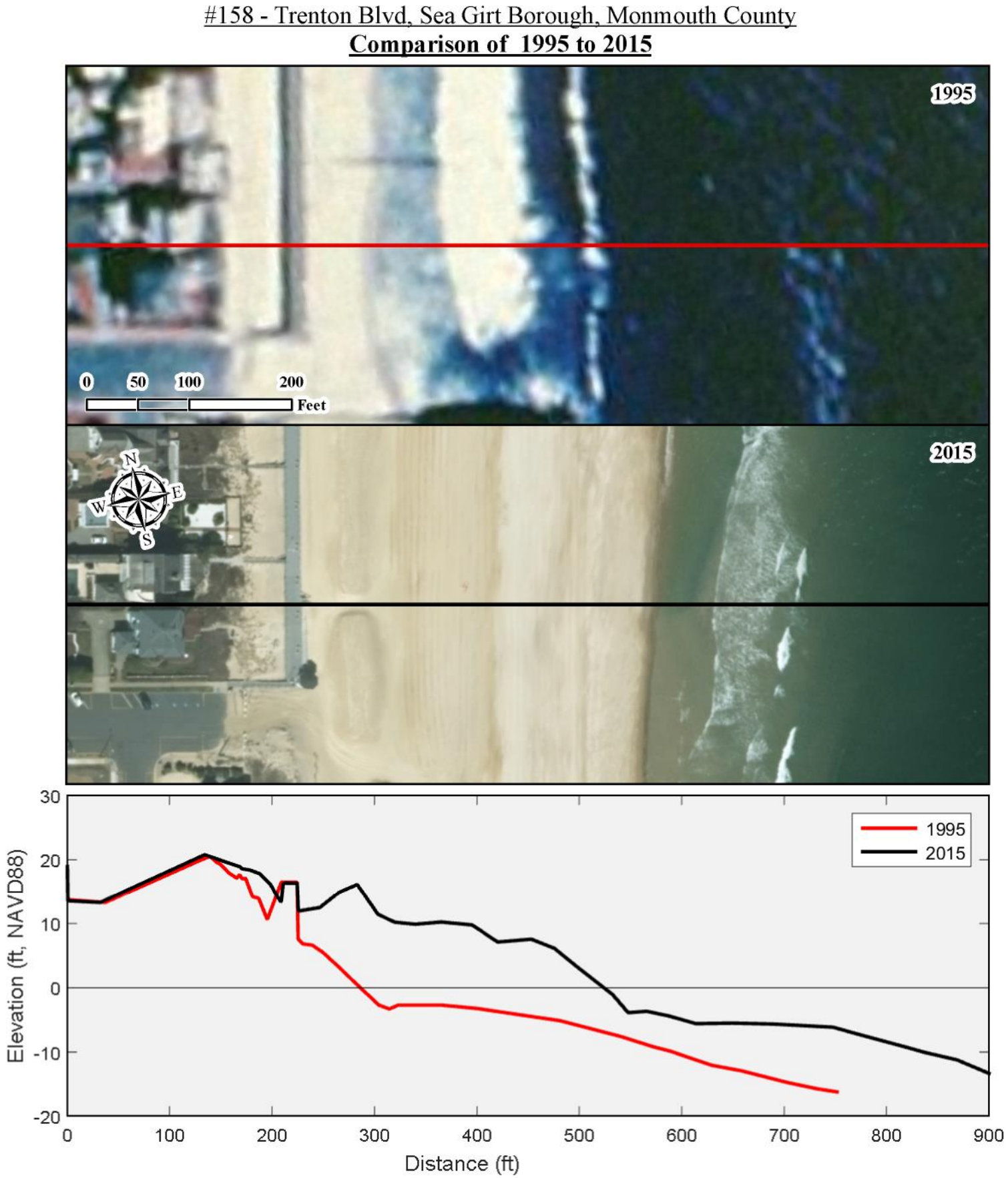

Figure 204. Sand was deposited at Trenton Avenue generating a 250 ft shoreline advance at this site.

Figure 205. Riddle Way in Manasquan shows a substantial beach behind the storm ridge pushed up for the winter waves. This view to the south is toward the inlet.

NJBPN 157 – Riddle Way, Manasquan

Figure 206a & 206b. By May 2014 the USACE had added sand to the beach, but the effort to reconstruct the dune destroyed by Sandy was minimal. A year later the left photograph (Dec. 11, 2015) shows a sand ridge of the same width that appears to be present on the beach and the sand fence has accumulated some sand. On the right in December 20, 2016, the berm rose to a winter sand ridge pushed up as wave protection, but the dune at the promenade remained minimal in size.

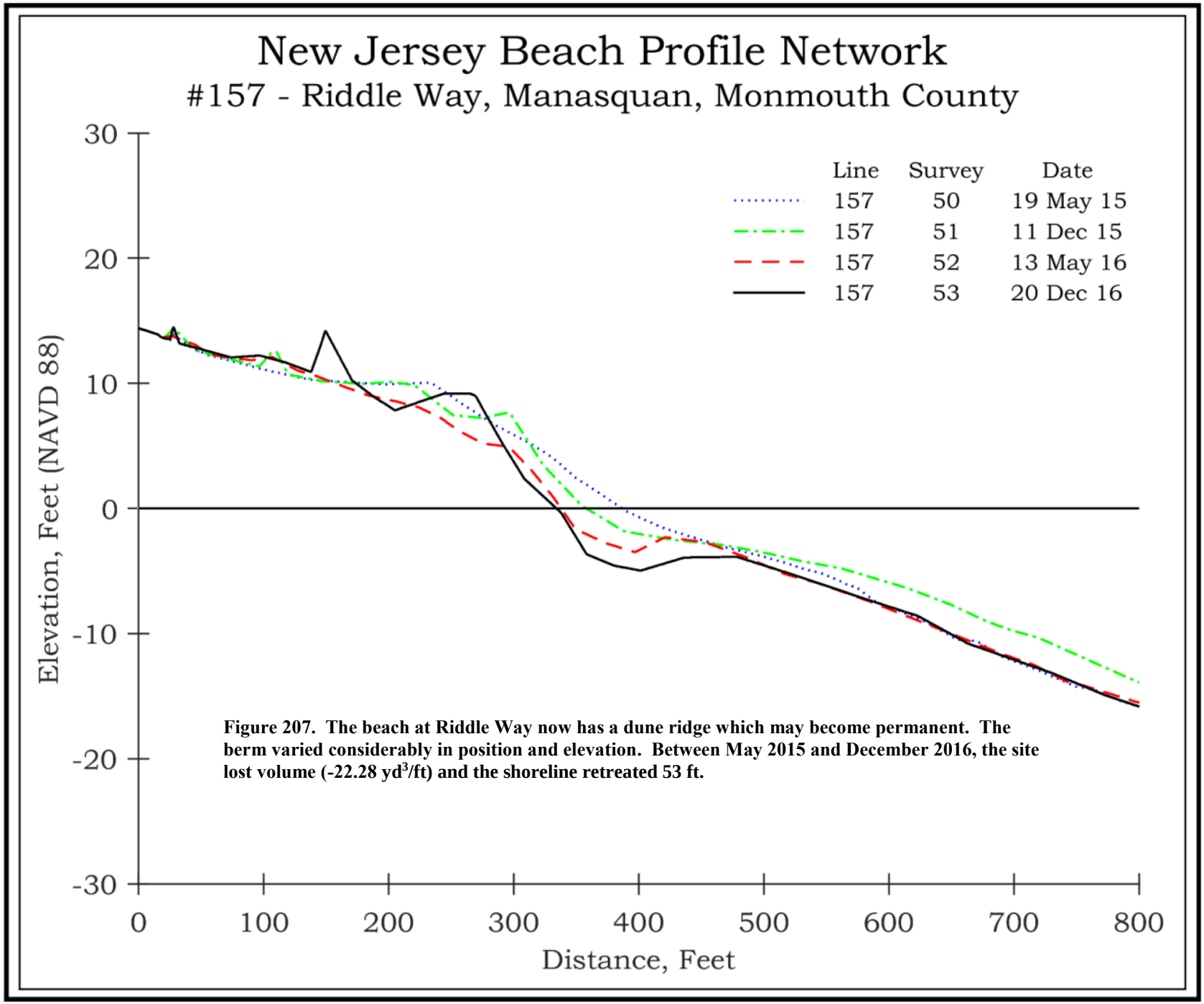

Figure 207. The beach at Riddle Way now has a dune ridge which may become permanent. The berm varied considerably in position and elevation. Between May 2015 and December 2016, the site lost volume (-22.28 yd^3/ft) and the shoreline retreated 53 ft.

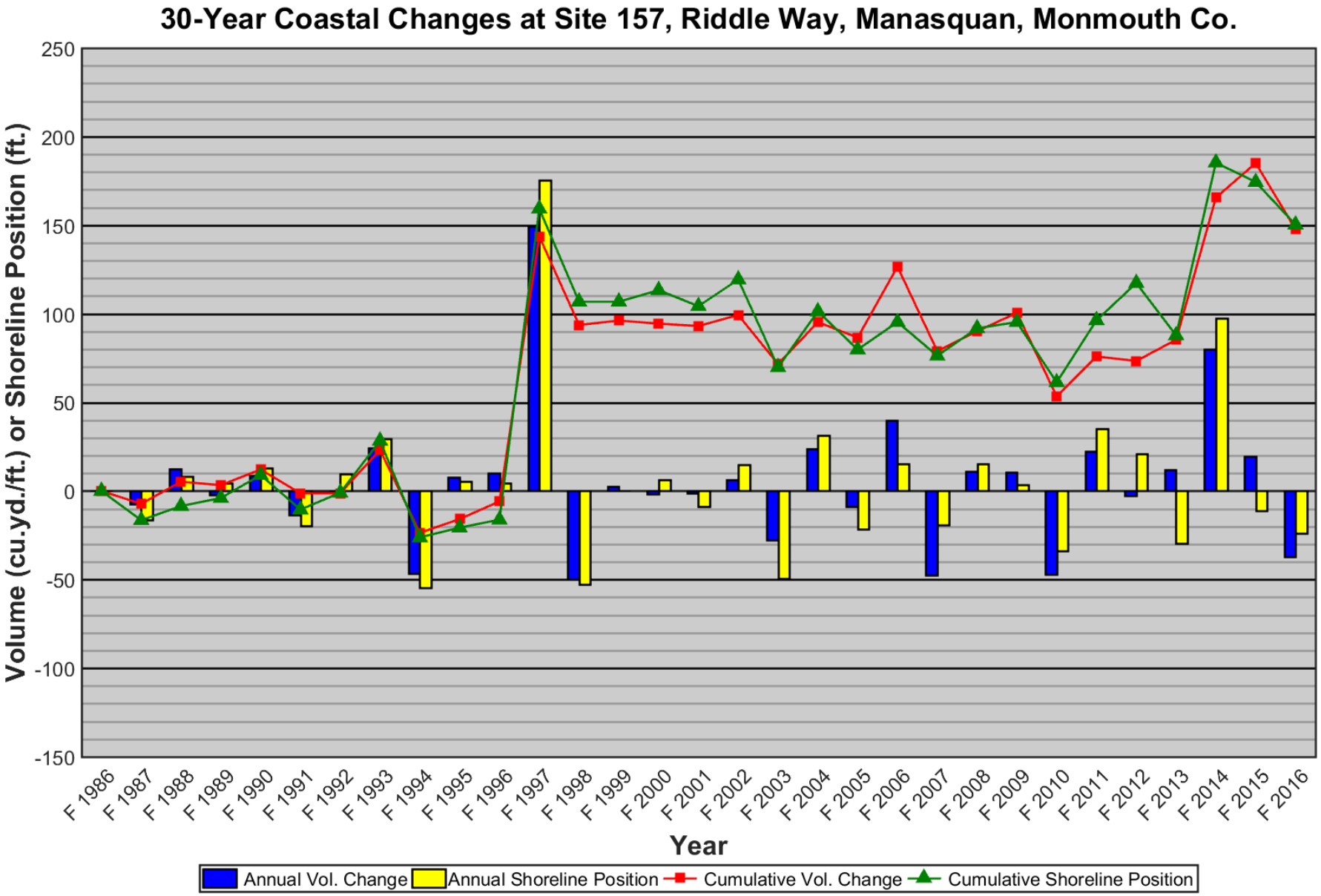

Figure 208. Riddle Way retained over 50% of the initial sand placement through Hurricane Sandy. The lower profile did allow waves to reach the homes after breaking through the dune in many places. There was a canyon-like gully cut from the promenade elevation down to First Avenue with thousands of cubic yards of sand deposited in the street. The maintenance effort in 2014 pushed the sand volume back above that initially placed in 1997.

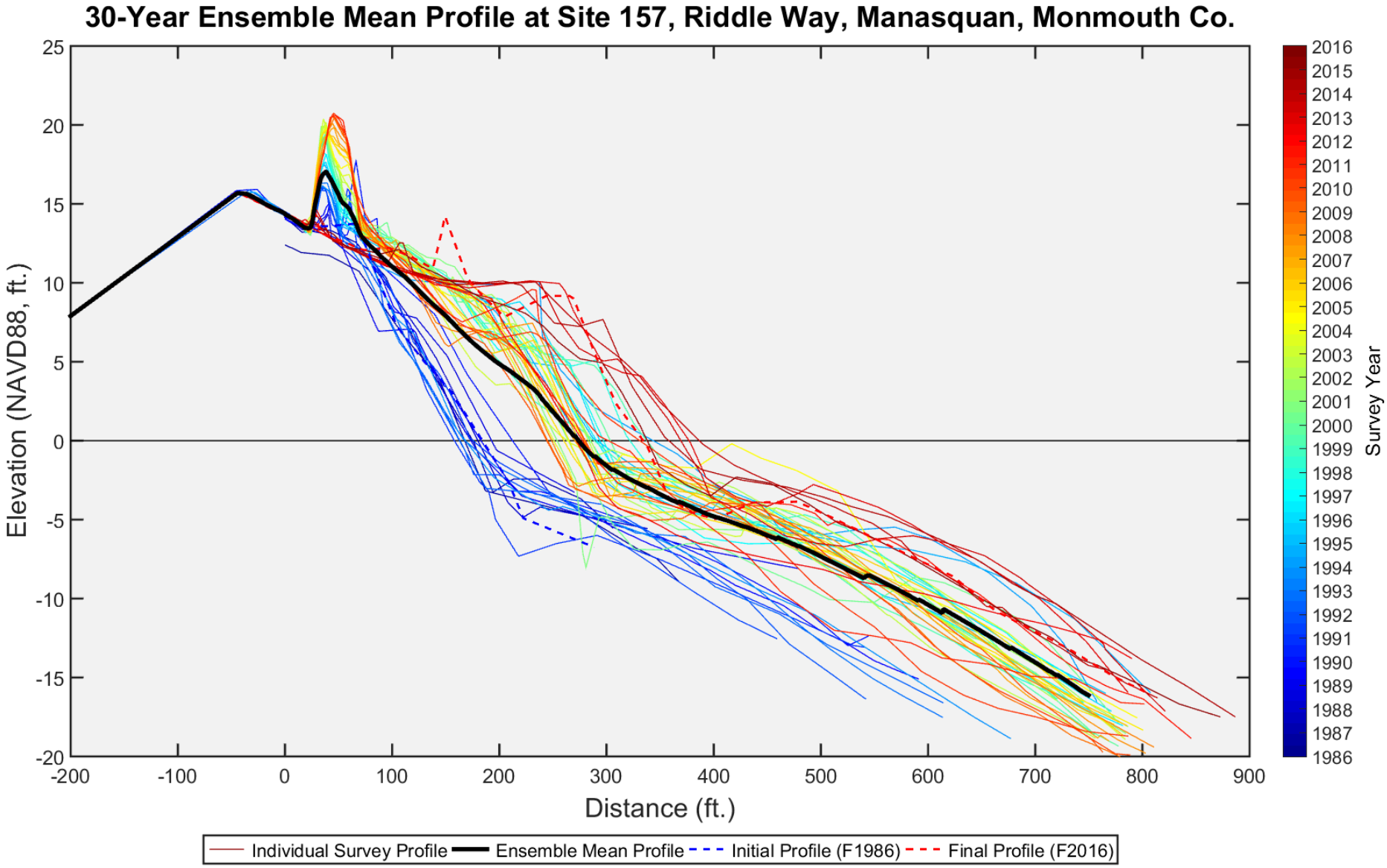

Figure 209. Riddle Way in Manasquan received sand that enhanced a steep beach providing partial protection from Sandy. The dune was never a major priority and was subject to litigation by oceanfront residents early in the project history. Sand ridges are added seasonally to protect as best they can.

#157 - Riddle Way, Manasquan Borough, Monmouth County

Comparison of 1995 to 2015

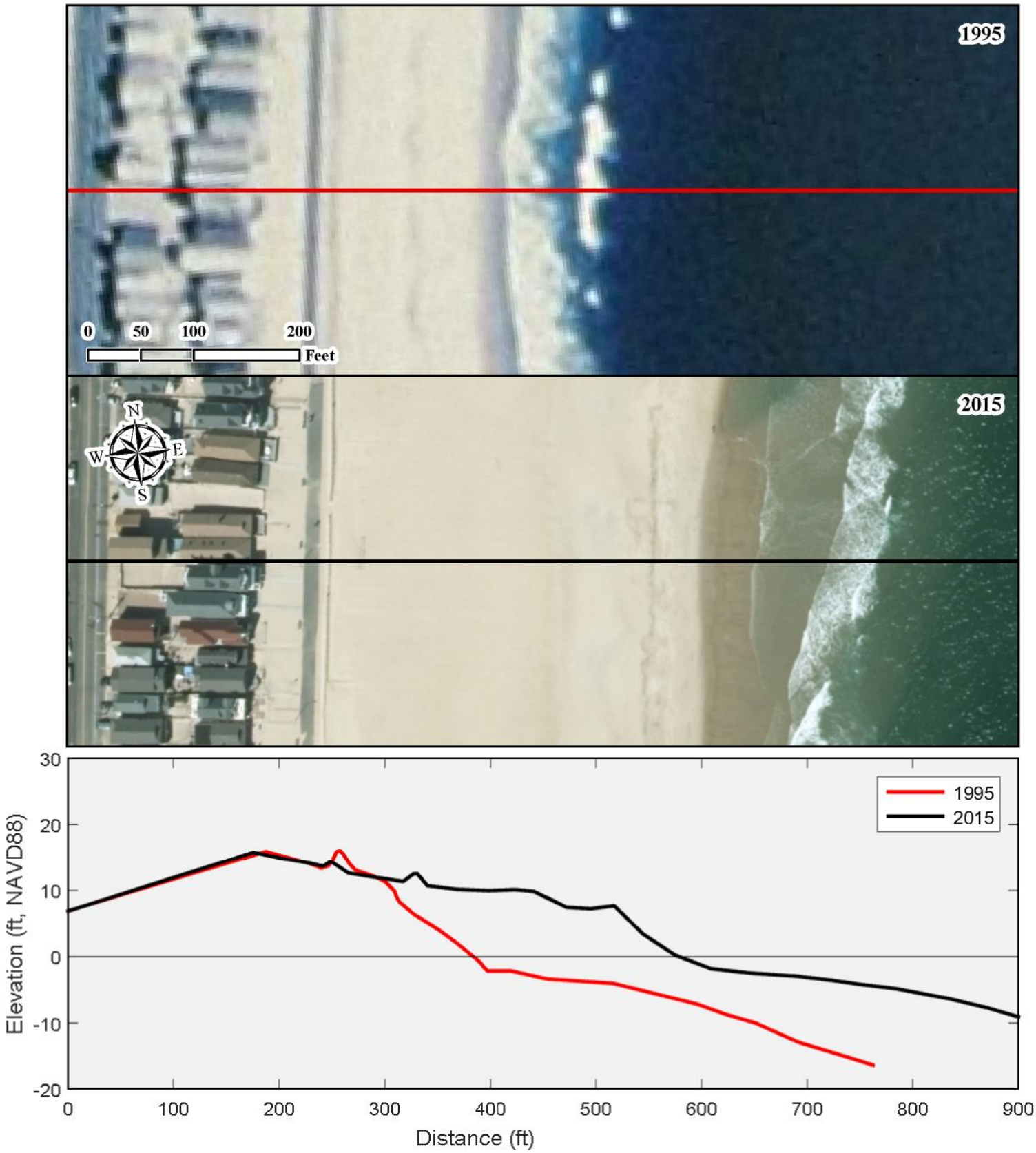

Figure 210. The homes sit on the original dune position and minimal effort has been expended to restore the dune destroyed by Hurricane Sandy and provide protection to such homes. The beach has increased in width by 180 ft.

Figure 211. View to the south at Pompano Avenue, Manasquan. This beach is close to the inlet jetty and reflects sand captured during periods of extensive northeast waves.

NJBPN 256 – Pompano Avenue, Manasquan

Figure 212a & 212b. By May of 2014 the beach had 82.26 yds^3/ft in new sand added by the USACE resulting in a 113 ft shoreline advance. The December 11, 2015 view (left photo) shows that the municipality had pushed up a sand ridge as a winter "dune". This precluded any sand building around the fence line. A year later (December 20, 2016-right photo) the 2015 sand ridge had been graded flat with a second ridge pushed up 150 ft seaward of the original feature. There is a row of sand fence at the promenade, but no real effort to promote dune development.

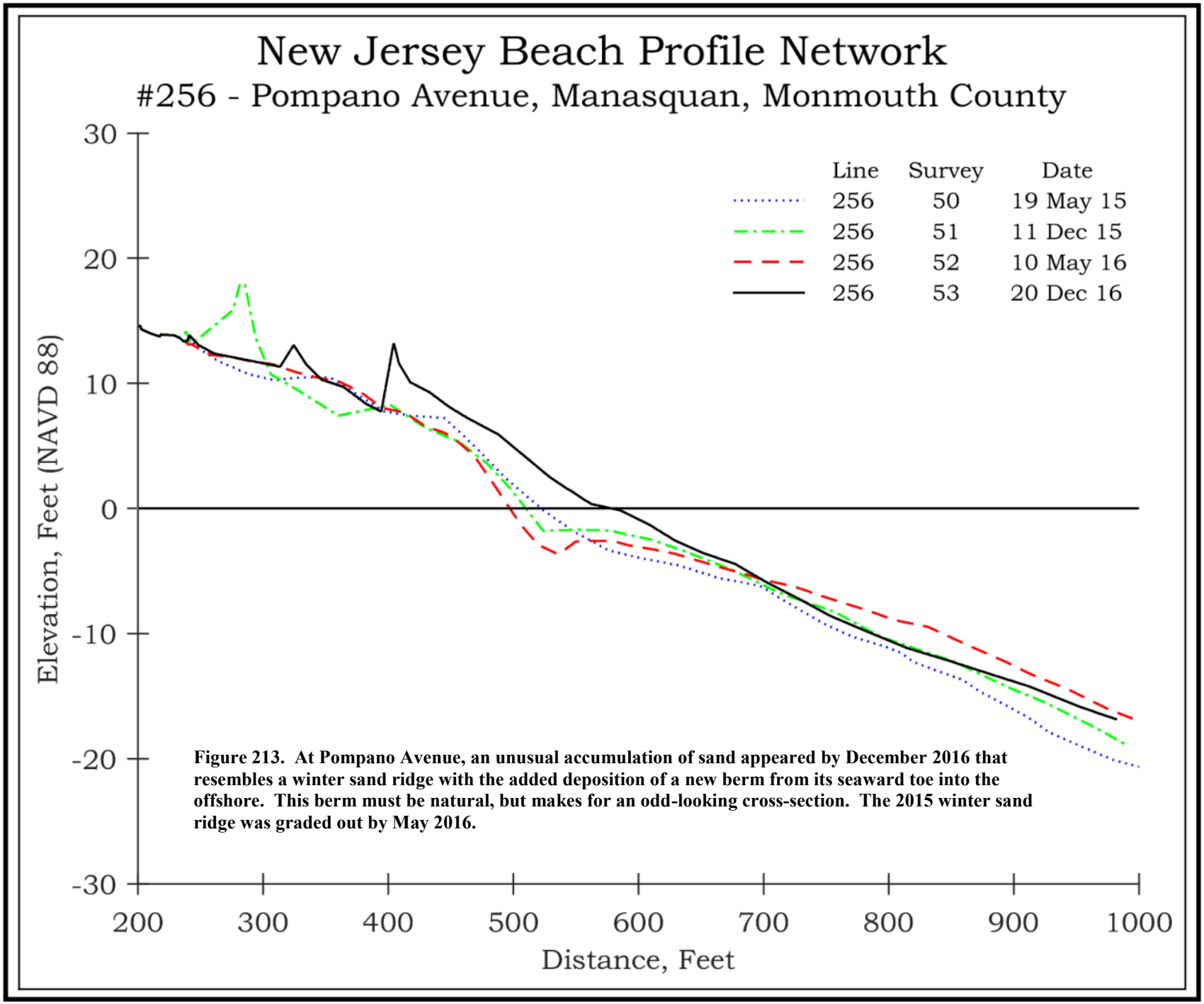

Figure 213. At Pompano Avenue, an unusual accumulation of sand appeared by December 2016 that resembles a winter sand ridge with the added deposition of a new berm from its seaward toe into the offshore. This berm must be natural, but makes for an odd-looking cross-section. The 2015 winter sand ridge was graded out by May 2016.

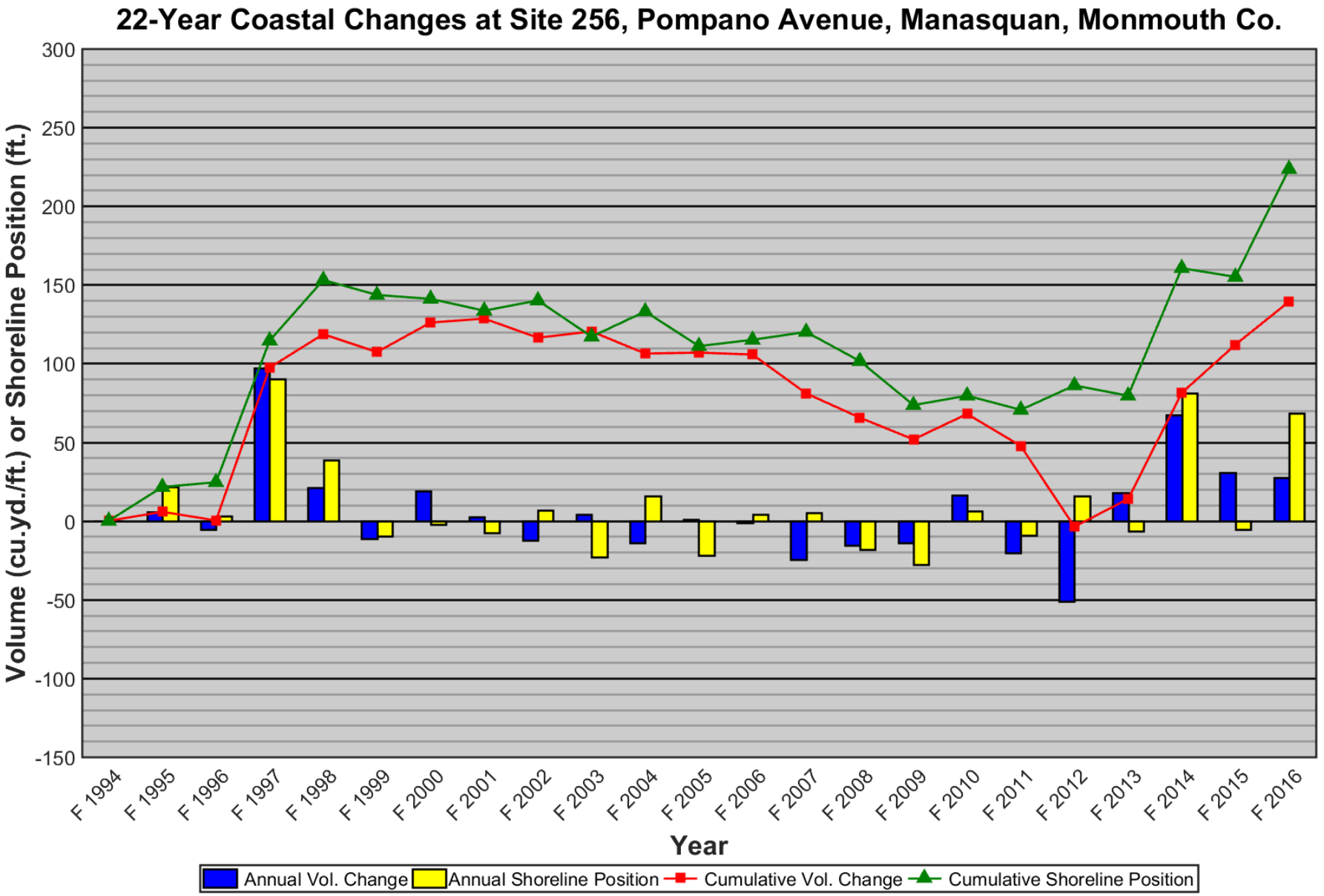

Figure 214. Established just prior to the initial beach fill by the USACE, this location suffers from a lack of sand input from the south due to the proximity to the Manasquan Inlet jetties. In 1997 100 yds^3/ft of sand were placed at the site and the volume remained stable until 2011. Hurricane Sandy removed all sand volume that was placed in 1997, with beach volumes dropping just below the initial 1986 amount. Since 2014 the trend has been quite positive yielding a net gain of 140 yds^3/ft above the initial 1986 volume.

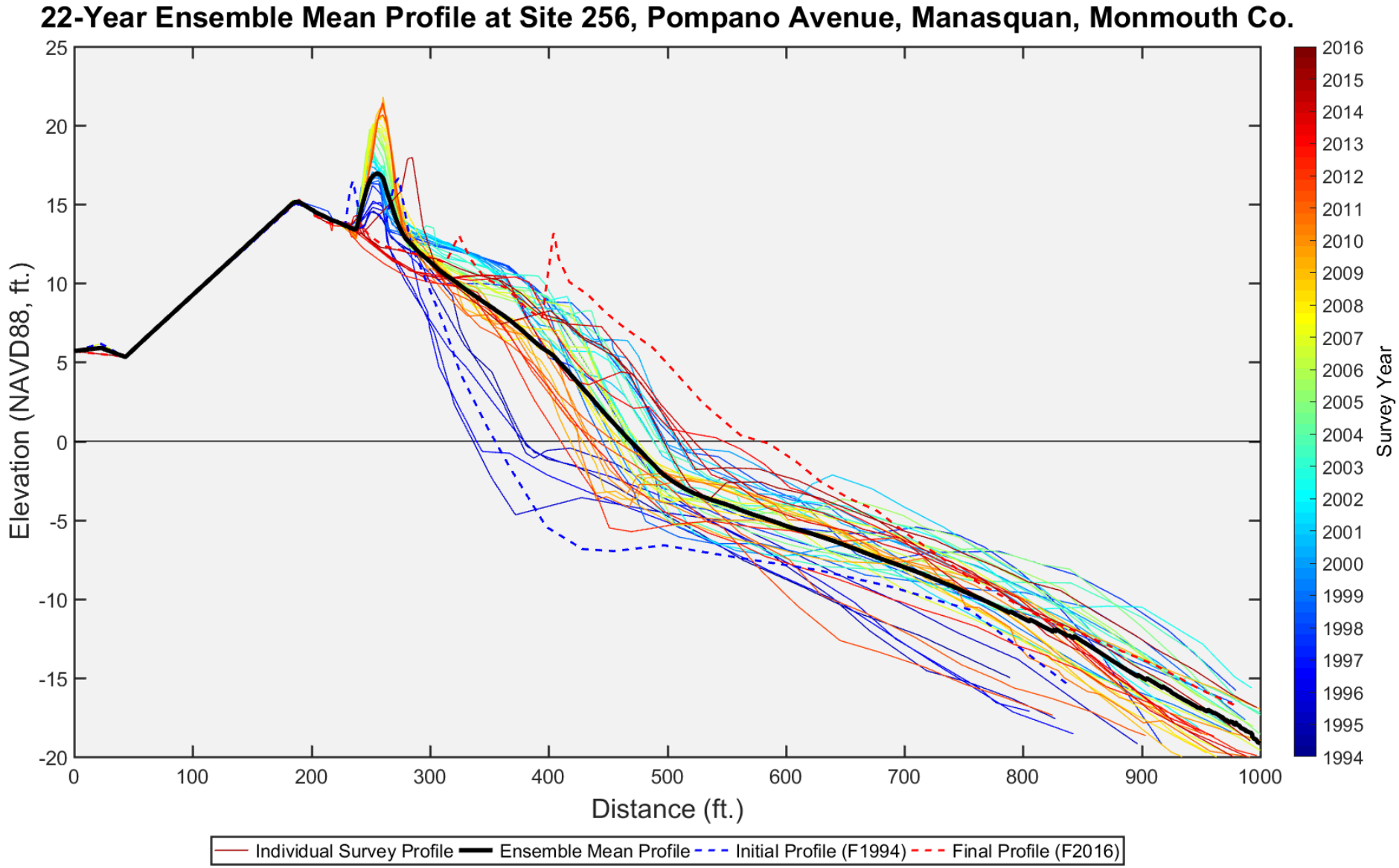

Figure 215. The southernmost profile in Monmouth County is located near Manasquan Inlet. This site received sand from the federal project, but was a difficult site in terms of stability. Hurricane Sandy removed the dune and asphalt promenade and damaged landward homes. The current beach is essentially at its 30-year maximum extent (red dashed line).

#256 - Pompano Avenue, Manasquan Borough, Monmouth County

Comparison of 1995 to 2015

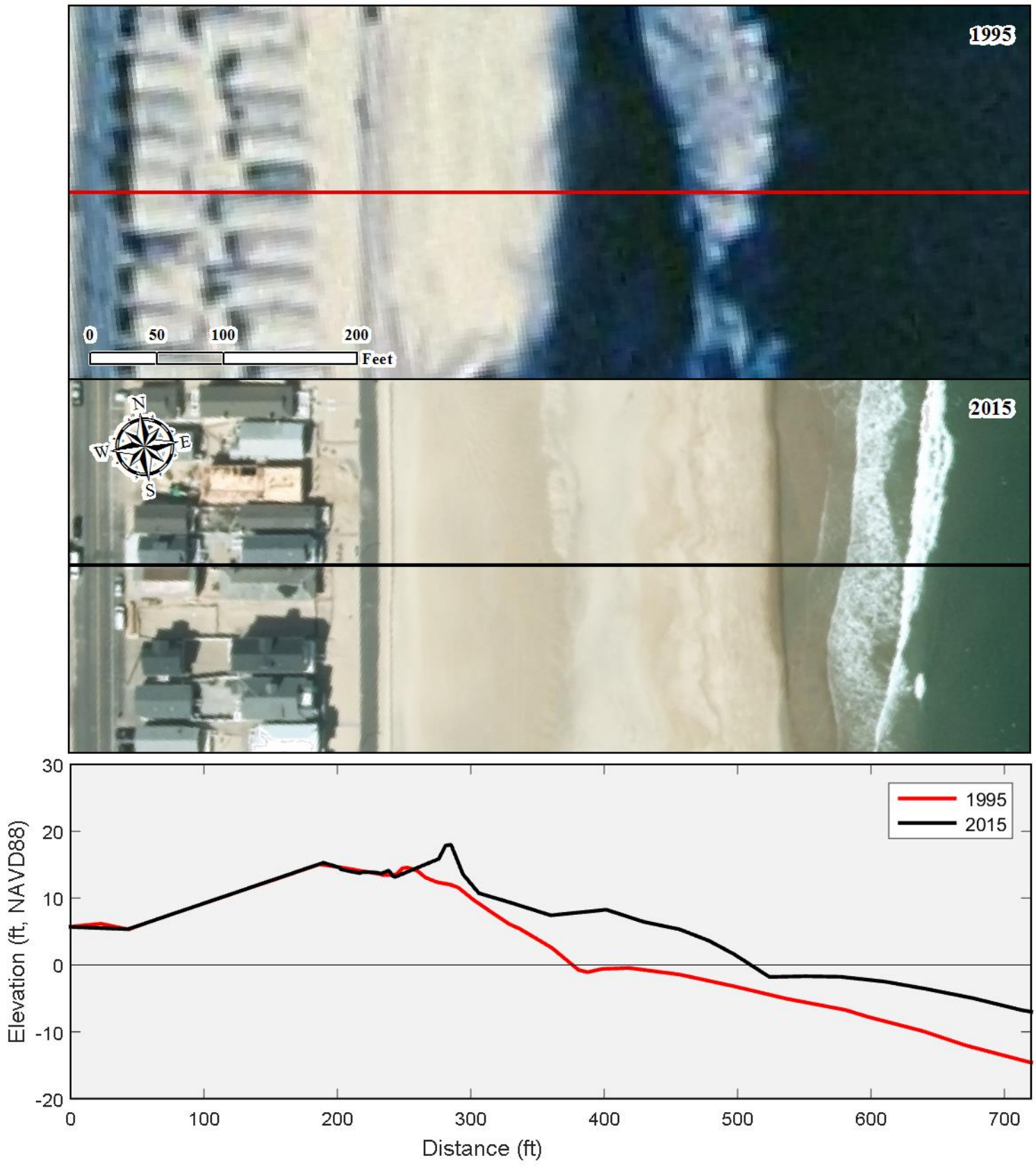

Figure 216. This beach is a few hundred feet north of the north Manasquan Inlet jetty and shows moderate variations over time.

Summary & Conclusions

The Sea Bright to Monmouth Beach segment restoration project placed 2.1 million cubic yards of sand for $25.6 million. The Long Branch phase placed 3.3 million cubic yards and cost $40.1 million. The Asbury Park to Manasquan section was completed for $43.6 million and placed 2.3 million cubic yards. Therefore, the entire Federal Shore Protection project was restored to the original design specifications. Work commenced in 2015 starting in Loch Arbor/Allenhurst and moved north into Deal, finishing in 2016 in Long Branch and joined with the Phase I project in that city.

The last section was put in place near the end of 2016 with some work added to replace sand lost during the January 2016 northeast storm (Jonas). This means that the entire Monmouth County oceanfront beach has been enhanced with offshore sand. Every one of the profile cross sections in Monmouth County shows an average of 113.72 yds^3/ft in added sand volume when the very first profile done in 1986 is directly compared to the latest one from the fall of 2016. Thirty years later the entire coastline has increased by about 219 ft in width and over 100 yds^3/ft of material has been placed between the development and the 16 ft water depth offshore. Each of the other three coastal NJ counties still have some segments without a project in place. Northern Ocean County is most vulnerable in terms of serious storm damage for the residents along that coast.

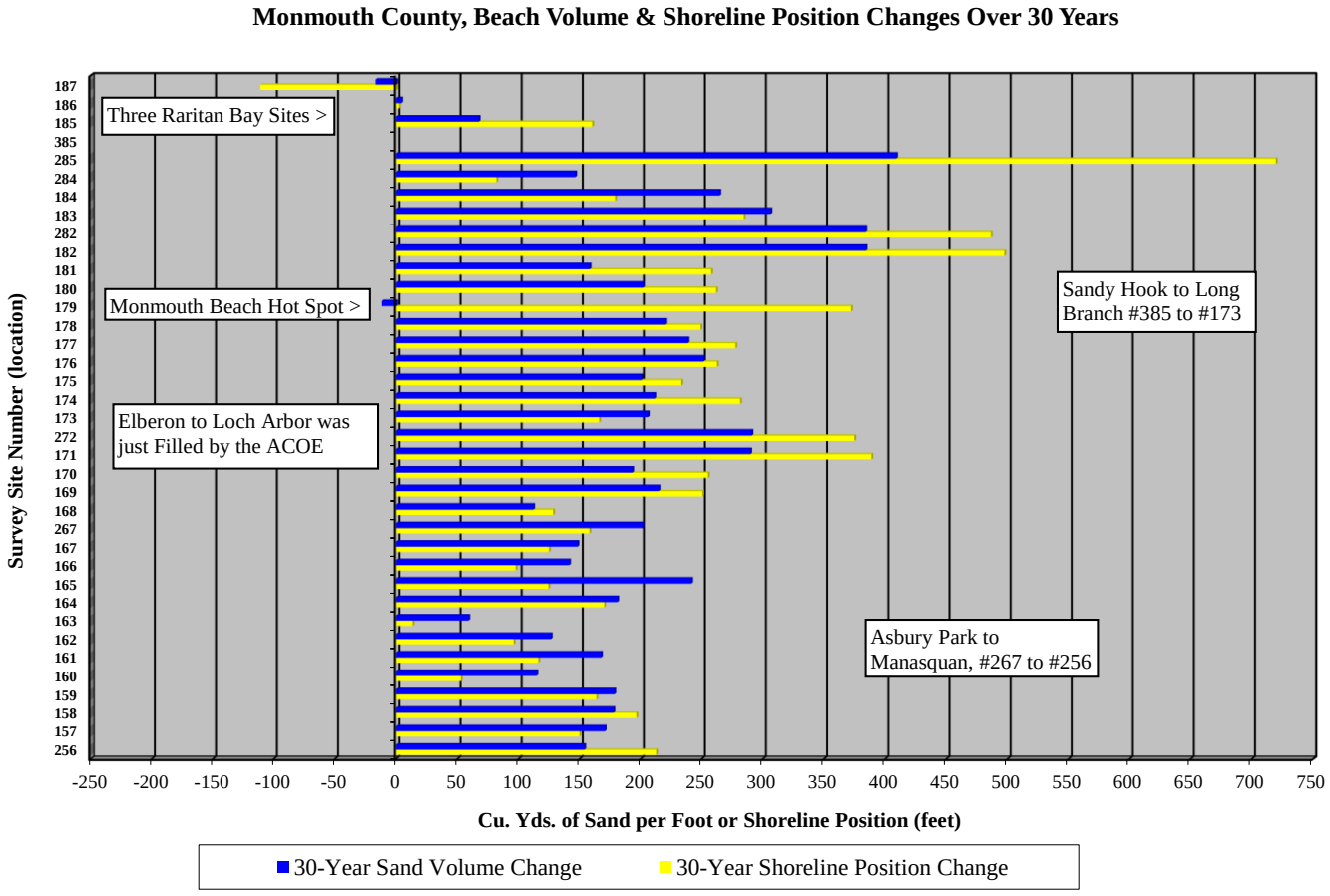

Figure 217. This summary of the cumulative changes to both shoreline position and sand volume present since 1986 shows that the Federal project has made a massive difference in both the shoreline position (+224.14 ft average) and sand volume on the beach (+194.34 yds^3/ft average) since 1995 completing the Elberon segment in 2016. The Monmouth County oceanfront has a far wider beach with a lot more sand present since NJBPN started 30 years ago.

Sand was documented as having moved north into the Sandy Hook National Seashore enhancing that shoreline by over 3.4 million cubic yards due to littoral transport from Long Branch and Sea Bright. Therefore, this project has benefitted the National Seashore in nearly the same volumetric quantities as deposited on the developed shoreline segments.

The Raritan Bay restoration took place at Port Monmouth adding a half-million cubic yards of sand at a site covered by NJBPN site 185. More sand was added at Keansburg and has been surveyed for results since placement under a separate NJDEP contract. Work continues to complete post-Sandy improvements to Union Beach by the NY District Army Corps.

The final assessment post-Sandy is that the Monmouth County shore protection project certainly saved its initial cost of $251 million dollars to build in damage averted in spite of variable levels of damage inflicted on individual communities. The composite profile plots show a general effect of this project increasing the distance between breaking storm waves and the structures by a factor between two and four times that present prior to the project. Not only were the beaches much narrower prior to the project, but the water immediately offshore was considerably deeper all of which would allow far more powerful waves to impact public and private structures on land in Monmouth County. Without this project, the Hurricane Sandy damage could easily have been doubled in the worst hit communities, and as much as five times in the least-impacted municipalities.