FINAL REPORT FOR 2013
ON THE CHANGES SEEN ON THE OCEANFRONT BEACHES
IN
THE BOROUGH OF MANTOLOKING, OCEAN COUNTY, NEW JERSEY
FOCUSED ON THE IMPACTS OF HURRICANE SANDY

View looking west across Stephens Place towards Route 35 taken on October 1, 2013 following Sandy debris removal and sand excavation for dune and beach restoration. One year after Hurricane Sandy ravaged our coastline and displaced thousands from their homes, significant progress is being achieved to clean up and restore the communities and shorelines hardest hit by the storm but much work remains to rebuild all the damaged property. Here the home to the right is newly finished construction while several adjacent lots remain vacant following debris removal.

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Annual Report for 2013
To
The Borough of Mantoloking
On the
Oceanfront Municipal Shoreline

Executive Summary:

The year following Hurricane Sandy has seen a steady transformation of a community devastated by the storm's impact to one of renewal. Efforts to clean up and remove storm debris progressed towards construction to rebuild and strengthen properties and infrastructure damaged by Sandy in a more resilient manner. Dune/beach system restoration efforts occurred in earnest combined with initial natural recovery to return the beach configuration to as near pre-storm conditions as possible in the year following Sandy. In addition several property owners at the northend extended a rock seawall from Bay Head onto their properties as a dune core to enhance protection from future storm events.

Planning continues to construct a steel bulkhead within the dune footprint using funding from NJ Department of Transportation (NJ DOT) to primarily protect RT 35 and prevent a repeat of the devastating dune breach experienced at Herbert Street during Sandy. The US Army Corps of Engineers (USACE) plans for a flood and coastal storm damage reduction project from Manasquan Inlet to Barnegat Inlet continue to progress towards construction. Under P.L. 113-2 2013 Disaster Relief Appropriations Act (Hurricane Sandy) this project was determined to be eligible for funds as an authorized but unconstructed project. To begin the process towards initiation and completion of initial construction $1,050,000 was authorized to complete the necessary steps towards initial construction that include the Limited Reevaluation Report and Project Partnership Agreement. This project is critical to ensuring the Borough's dune and beach system is resilient enough to protect the community during future major storm events. Communities with similar projects completed prior to Sandy experienced significantly less storm damage from waves and storm surge.

The winter 2013 storm season was relatively mild with one moderate storm event named "Saturn" impacting the Jersey coast. Winter storm Saturn tracked up the east coast for several days from March 4 - 7, 2013. On March 5, 2013 the winter northeaster moved north along the New Jersey coast and caused significant beach erosion. Sand volume losses were focused near 1117 Ocean Avenue and at the southern beach for a net loss this winter of 51,698 cubic yards (CY) of sand. Weather patterns in the spring transitioned to calmer wind and wave conditions favorable for natural sand recovery. Natural beach building and continued recovery efforts resulted in a net gain of 49,822 CY of sand over the spring months, essentially restoring the winter losses. Favorable conditions for natural recovery continued through the summer months into the fall that further enhanced restoration efforts. The Borough shoreline gained 110,922 CY of sand over the summer months with another 107,455 CY gained during the fall. For 2013 the Borough's oceanfront shoreline recovered an impressive 216,500 CY of sand through natural processes and restoration efforts although much of sand remained offshore.

Beach Monitoring Program Methodology:

In 1993 the Borough of Mantoloking requested that the CRC design and establish a beach-monitoring program to provide information on coastal zone management issues within the municipality. Five sites were selected based on a variety of criteria including accessibility, prior history of data collection, uniformity in spacing between sites and providing a typical representation of the surrounding dune and beach conditions. These same five sites have been monitored by the CRC on a quarterly schedule over the last 20 years, ensuring a continuous and coherent data set, which provides the Borough with a valuable resource tool when determining coastal management issues. The following is a list of the selected sites and locations:

- Mant-1: Beach access path at Carrigan Place
- Mant-2: Beach access path at 1041 Ocean Avenue
- Mant-3: 1117 Ocean Avenue (NJBPN site #153)*

- Mant-4: Princeton Avenue street end
- Mant-51: Beach access path at 1543 Ocean Avenue**

* 1117 Ocean Avenue was established on private land in 1986 for the New Jersey Beach Profile Network
** Replaced Mant-5 formerly located on private property at 1547 Ocean Ave.

This monitoring program is intended to provide municipal officials with a periodic review of shoreline stability, dune erosion or accretion and monitor changes to the vegetation and sand collecting systems installed by individual property owners. This together with the official fall annual dune walk along the entire municipal oceanfront gives a good review of the changes occurring from both engineering activities and natural causes. The Coastal Research Center completed the quarterly surveys for 2013 on the following dates:

Winter	Survey #83	March 27, 2013
Spring	Survey #84	May 29, 2013
Summer	Survey #85	September 20, 2013
Fall	Survey #86	December 13, 2013

The winter survey followed the only significant northeast storm in 2013 winter storm "Saturn" that moved off the Jersey coast on March 5, 2013 causing modest beach erosion. Remaining surveys in 2013 all showed recovery as the restoration process continued along with natural recovery. Table 1 below shows the fall shoreline and sand volume changes at the five monitoring locations. Shoreline changes are measured in feet while sand volume changes are in cubic yards per foot. Individual profile changes are averaged with adjacent sites and multiplied by the distance between sites to determine a net cell volume change. Total volume change for the Borough is determined by summing the net cell volume changes.

Table 1
Fall 2013 Shoreline & Sand Volumes Changes
September 20, 2013 to December 13, 2013

Profile Number	Shoreline Change (feet)	Volume Change (yds^3/ft)	Avg.Volume Change (yds^3/ft)	Distance Between (feet)	Net Volume Change (yds^3)
Northern Municipal Boundary					
			-8.384	294	-2,465
Mant-1	-23	-8.38			
			2.211	3,033	6,706
Mant-2	-23	12.81			
			11.003	2,584	28,432
Mant-3	-27	9.20			
			15.055	2,789	41,987
Mant-4	-15	20.91			
			13.680	2,164	29,602
Mant-51	-27	6.45			
			6.450	495	3,193
Southern Municipal Boundary					
			Total Volume Change =		**107,455**

During fall 2013 an early storm event with 72 hrs of 30 plus knot onshore winds around October 10th generated waves that eroded the beach, flattened the berm and scoured the nearshore, sand was transferred offshore to the bar system. The losses of the berm lead to a retreat in the shoreline positions and beach width at each site. Despite the onshore losses most of the sites actually showed modest net sand volume gains as the sand accumulation offshore offset the beach losses. While only

the Carrigan Place beach had a net sand volume loss. The net change for the fall was a gain of 107,455 CY of sand as material moved into the offshore survey coverage area that offset the onshore beach erosion and loss of the summer berm.

Table 2 below is designed to show just the sand volume changes above the zero elevation datum. The North American Vertical Datum of 1988 lies between low and high tide. Here the change in dune volume is added to the change on the beach. These changes do include any sand moved back onto the beach following work to remove sand washed inland onto streets and other places were access to it was physically possible. The 604,321 CY of sand lost during Sandy is the sand quantity needed to return the Borough beach/dune system to its September 20, 2012 condition. The table below shows the volume of sand that has returned to the beach and dune system since Sandy.

Table 2
Beach and Dune Recovery since Hurricane Sandy between December 12, 2012 and December 13, 2013

Profile Number	Shoreline Change (feet)	Volume Change (yds^3/ft)	Avg.Volume Change (yds^3/ft)	Distance Between (feet)	Net Volume Change (yds^3)
Northern Municipal Boundary					
			7.438	294	2,187
Mant-1	-28	7.44			
			19.368	3,033	58,742
Mant-2	-28	31.30			
			31.964	2,584	82,594
Mant-3	-28	32.63			
			27.008	2,789	75,325
Mant-4	-19	21.39			
			18.754	2,164	40,583
Mant-51	-52	16.12			
			16.121	495	7,980
Southern Municipal Boundary					
			Total Volume Change =		**267,410**

In the year following Sandy the beach and dune system has recovered 267,410 CY of sand. This volume does not include offshore gains or the nearshore shore parallel bar formation. The majority of this sand was placed in reconstruction of the dune configuration. This represents recovery of 44% of the sand volume lost from the beach/dune system during Sandy. Unfortunately, the rapid pace of dune reconstruction has resulted in an unconsolidated sand barrier less resistant than a naturally formed feature. Prior to Sandy the landward crest and slope was heavily vegetated from years of formation and stability while the seaward slope frequently eroded during storms largely consisted of unconsolidated sands and rapidly eroded during storm events.

The storm resistance of an unconsolidated sand barrier depends on its height to resist wave run-up during the storm; its width at the toe to withstand the rate of erosion during the storm (Sandy eroded at a 10 to 12 feet per hour rate); and a wide beach so waves must break out on the beach and lose energy before encountering the dune. Vegetation counts a little, but on a man-made dune, the roots do not bind the entire structure together because they are planted on the crest and seaward slope after construction and not develop vertically over time as the dune grows upward.

The US Army Corps of Engineers designed beach restoration project would provide essential storm protection to the Northern Ocean County coast. A 22-foot dune is essential to resist a repeat

performance with significant beach width required to absorb wave energy prior to impacting the dune. The larger native dune configuration that was in place south of Albertson Avenue put in place across the entire Mantoloking oceanfront with a beach width of at least 150 feet to the high tide line and maintained at that width, would diminish the impact of subsequent storms on the public infrastructure and to private development.

Mantoloking Quarterly Shoreline Changes:

Table 3 below catalogue the individual profile site sand volume changes and shoreline position movements over the four quarters of study. Each volume calculation compares the indicated survey with the previous one and sums the areas of accumulation and erosion across the entire profile line in cubic yards of sand per foot of beachfront. The advance or retreat in the shoreline position is measured at the intersection of the individual survey line and the zero datum elevation point on the profile. This is the North American Vertical Datum of 1988, which lies between mean low and mean high tide.

Table 3
2013 Quarterly Municipal
Profile Volume Change

Profile Number	Winter 12/12-3/27 (yds^3/ft)	Spring 3/27-5/29 (yds^3/ft)	Summer 5/29-9/20 (yds^3/ft)	Fall 9/20-12/13 (yds^3/ft)
Mant-1	5.97	3.89	3.27	-8.38
Mant-2	9.06	-7.14	12.86	12.81
Mant-3	-43.95	31.73	32.66	9.20
Mant-4	19.88	-19.55	-4.15	20.91
Mant-51	-12.12	16.49	-5.44	6.45
Net Beach Volume Change	-51,698 yds^3	49,822 yds^3	110,922 yds^3	107,455 yds^3

The sum of the four seasonal volume changes across the municipal beachfront was a net gain of 216,501 cubic yards of material restored this year following Sandy. The only loss was concentrated in the winter quarter influenced by winter storm "Saturn". The last three quarters showed modest natural recovery combined with anthropogenic related restoration efforts. Spring and summer recovery added sand onshore that restored the dune configuration and a summer beach berm by September 2013. An early fall event around October 10th generated 72 hours of 30 plus knot onshore winds that flattened and eroded the summer beach berm and reduced the beach width. Sand was transferred offshore where additional material accumulated from beyond the survey envelope for an overall net gain despite the onshore losses.

Table 4 below shows the shoreline position and net volume changes from September 20, 2013 a month before Sandy to December 13, 2013 one year following Sandy. Shoreline changes are given in feet while individual volume changes are expressed in cubic yards per foot of linear shoreline. Individual volume changes are averaged with adjacent volume changes then multiplied by the distance between sites to determine a net cell volume change in cubic yards. A summation of the net cell volumes provides a total volume change for the Borough's oceanfront shoreline.

Table 4
Shoreline and Sand Volume Changes
Pre-Sandy to One-Year Post-Sandy
September 20, 2012 and December 13, 2013

Profile Number	Shoreline Change (feet)	Volume Change (yds^3/ft)	Avg.Volume Change (yds^3/ft)	Distance Between (feet)	Net Volume Change (yds^3)
Northern Municipal Boundary					
			-33.343	294	-9,803
Mant-1	-73	-33.34			
			-25.328	3,033	-76,820
Mant-2	-31	-17.31			
			-15.467	2,584	-39,967
Mant-3	-49	-13.62			
			-9.701	2,789	-27,056
Mant-4	-17	-5.78			
			-13.561	2,164	-29,346
Mant-51	-33	-21.34			
			-21.341	495	-10,564
Southern Municipal Boundary					
			Total Volume Change =		**-193,555**

One year following Sandy the Borough's shoreline and offshore region remains 193,555 CY of sand below the pre-Sandy conditions on September 20, 2012. Shoreline positions remain at a deficit of between 17 to 73 feet as much of the sand that returned to the beach was used towards restoring the dune ridge. The overall beach width remained narrow after a temporary seasonal development of a summer berm was eroded during the fall months. Each site remained with a net sand deficit one year following Sandy but an accumulation of sand offshore on the bar system and reconstruction of the dune has reduced the net sand deficit volumes that resulted from Sandy by approximately 55%.

Profile Site Descriptions:

Each site was surveyed four times in 2013, cross-section plots with each of the four surveys are included for each site. In addition an annual comparison was provided to show the changes from September 2012 one-month prior to Sandy to December 2013 to show recovery progress to pre-storm conditions. Photos from each site provide a visual record of changes during the year. A sand volume change trend chart was included for each site to show the seasonal and annul trends from 2002 through 2013.

- **Mant-1 Carrigan Place**

Mant-1 is located at the seaward end of Carrigan Place, along the municipal beach access path between the private residential properties at #911 and #915 East Avenue. Carrigan Place is located about 500 feet south of the Bay Head – Mantoloking boundary. The profile reference location is a fire hydrant located along the west curb of East Avenue. The cross-section includes the road and beach access path on the landward dune toe between the oceanfront homes.

Hurricane Sandy's waves reduce the dune to essentially the elevation of the berm. Sand was pushed landward and buried the fire hydrant on the west side of East Avenue. The net sand volume losses attributed to Sandy onshore and offshore was 70.25 yds^3/ft. Natural recovery and anthropogenic activities restored much of the dune and beach losses from Sandy in 2013. One year following Sandy the beach and dune configuration mimic the pre-Sandy conditions though offset landward approximately 30 feet.

Winter storm Saturn in early March scoured the beachface and nearshore moving sand offshore to the shore parallel bar system. Efforts to restore the dune ridge following Sandy had progressed over the winter months adding width and height with a crest elevation at nearly 14 feet. Sand from the offshore bar system pushed landward during the spring as weather, wind and wave patterns produced favorable conditions for beach building. Sand welded to the beachface pushed landward under the spring wave climate to form a new berm. Construction on the dune core that extended the rock seawall south from Bay Head continued through the spring. Over the summer more sand moved onshore and developed a typical summer beach berm under the summer wave climate. Installation of the rock seawall was completed and dune restoration efforts restored the dune width and crest elevation to the pre-Sandy conditions. During the fall and extended period of onshore winds in October generated storm wave conditions that eroded the beach, flattened the summer berm and dragged sand offshore. The dune system remained intact but by December 13, 2013 the beach was extremely narrow providing little storm protection as the winter storm season approached.

Efforts to restore the section of shoreline have been partially successful returning nearly half (53%) of the sand volume loss during Sandy. The shoreline position in December 2013 remained 73 feet landward of its pre-storm position while the net volume was still 33.34 yds^3/ft. of sand below the pre-Sandy conditions. The sand volume loss was spread across the seaward dune slope, beachface and nearshore.

1a. March 27, 2013

1c. December 13, 2013

1b. May 29, 2013

Photographs 1a to 1c all show views to the south.

Photograph 1a shows the beach following initial recovery from Sandy. Modest natural recovery and restoration efforts had reestablished a small barren dune ridge and narrow dry beach by March 27, 2103.

View 1b shows the post-Sandy efforts to extend the rock seawall south from Bay Head to this region on May 29, 2013. The dune ridge was excavated for placement of the rocks to enhance the dunes resistance to breaches during future storms.

View 1c Taken on December 13, 2013 following an early snowfall and completion of the dune restoration efforts. The snow line nicely delineates the high tide line. A year following Sandy the dry beach width is still extremely narrow that will allow storm waves and surge to easily impact the seaward dune toe. A wider beach is needed to enhance dune system stability.

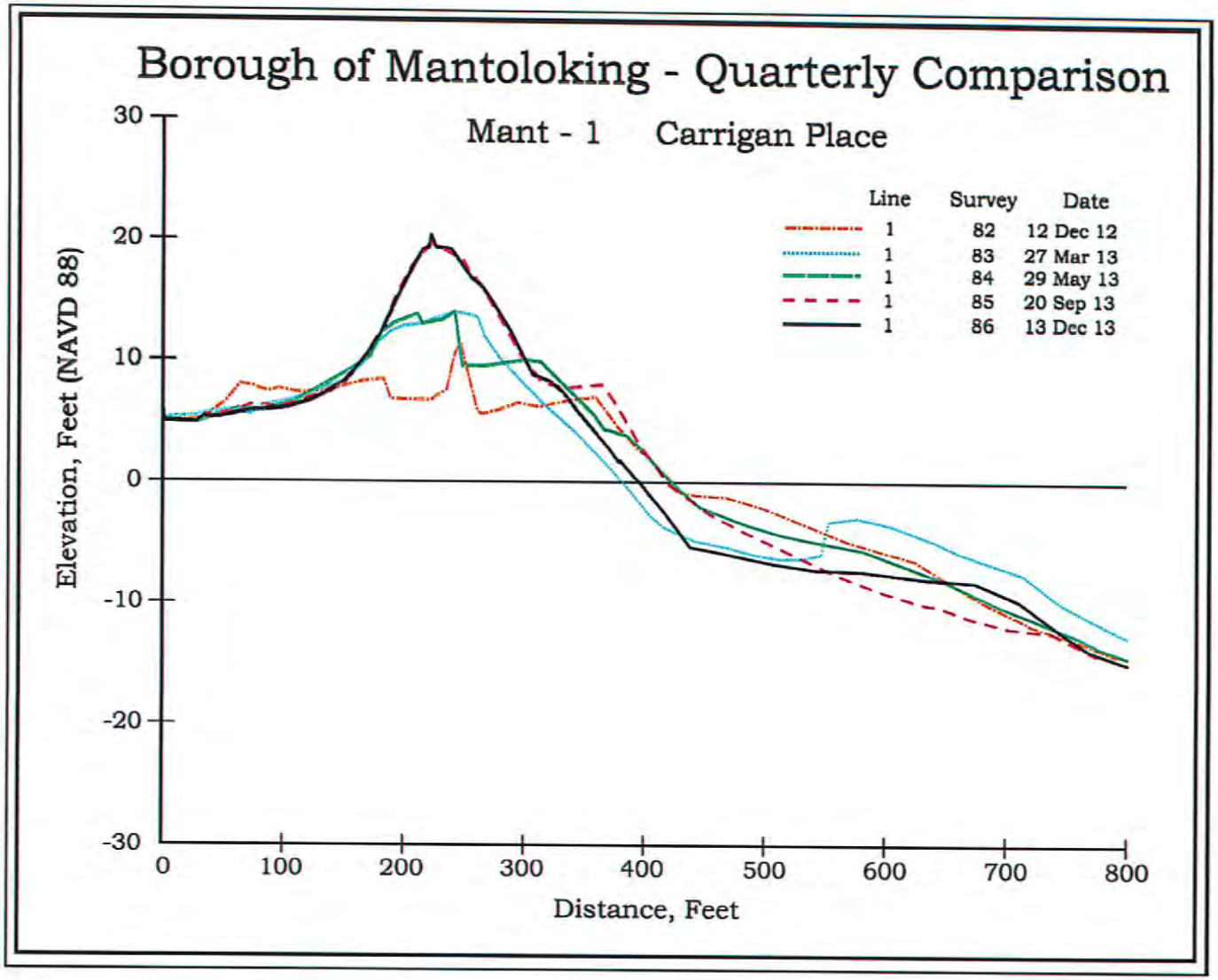


Figure 1a: The quarterly shoreline trend illustrates an overall decrease in shoreline width over the 5 quarters. There was an overall shoreline change of -28.30 feet. The dune crest drastically increased in width and elevation from Survey 82 and then remained relatively stable between Survey 85 and Survey 86. The beach width eroded following development of a seasonal beach berm during the summer.

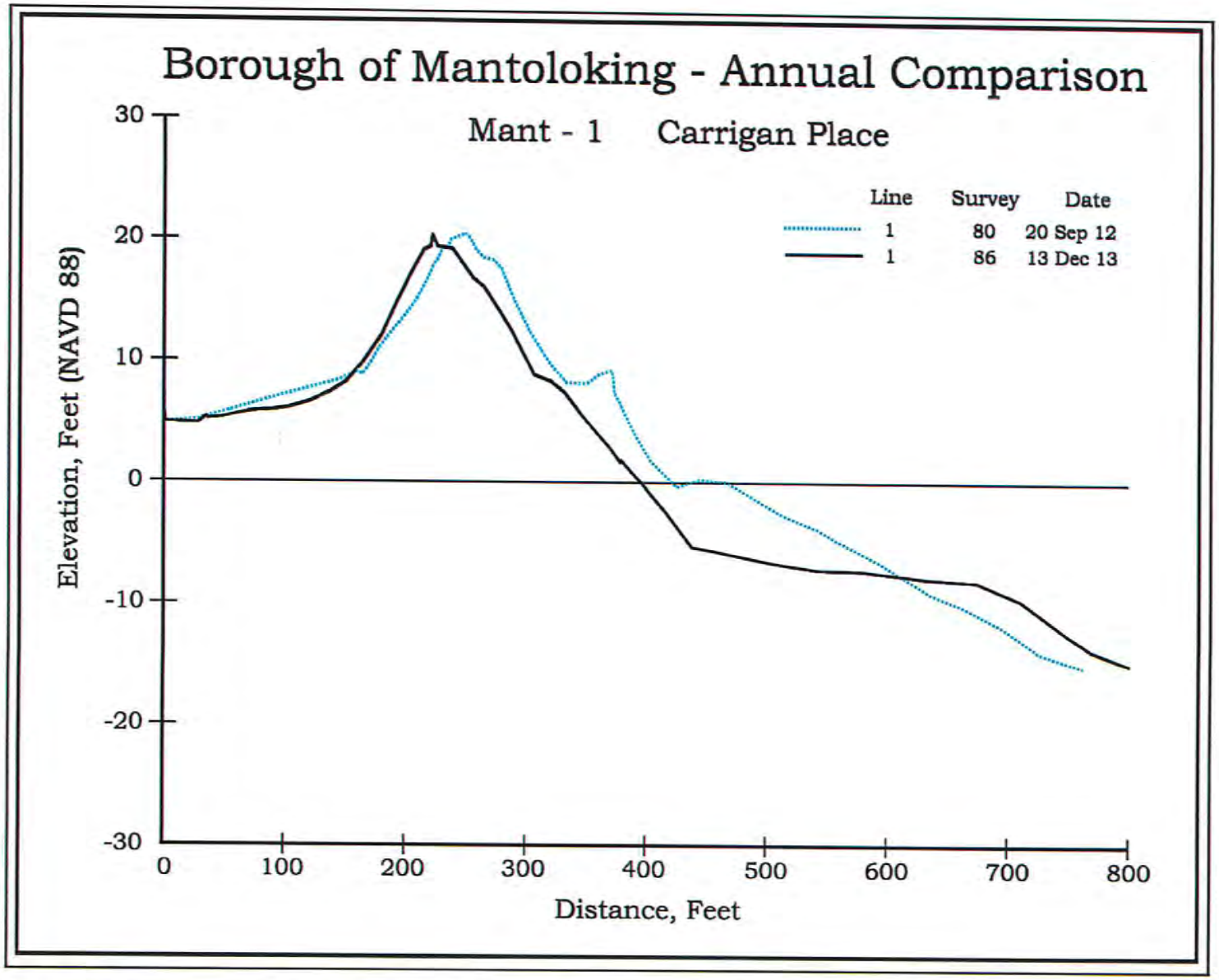


Figure 1b: The analysis from survey 80 to 86 for Carrigan Place showed an overall decrease in width with the dune and beach configuration shifted landward about 30-40 feet. There was a total loss of 72.65 feet in shoreline width and reduced berm. Sand was shifted offshore to the profile limits. The total volume change is a loss of 33.34 cubic yard/feet.

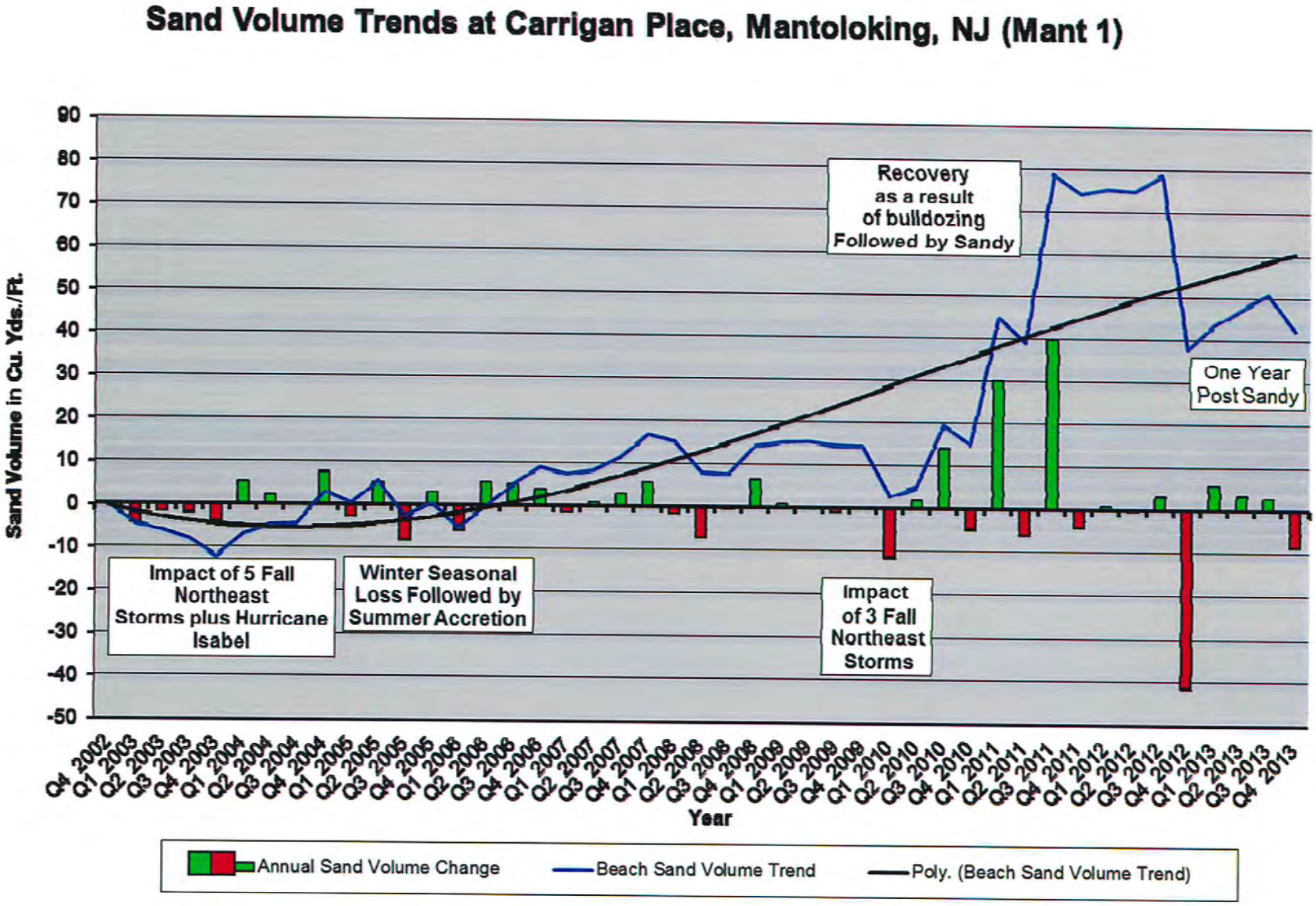


Figure 1. The quarterly sand volume trends show early impact of storms in 2003 and 2006, followed by loss in 2009. 2011 was an excellent year for accumulation with the net increase at Carrigan Place of almost 80 yds^3/ft. maintained over 5 quarters. Both natural and dune bulldozing appear to have had an impact. Then Hurricane Sandy cut the gain by half. This location is still ahead of where it started with the 4th quarter of 2013 as recovery from Sandy continued during 2013.

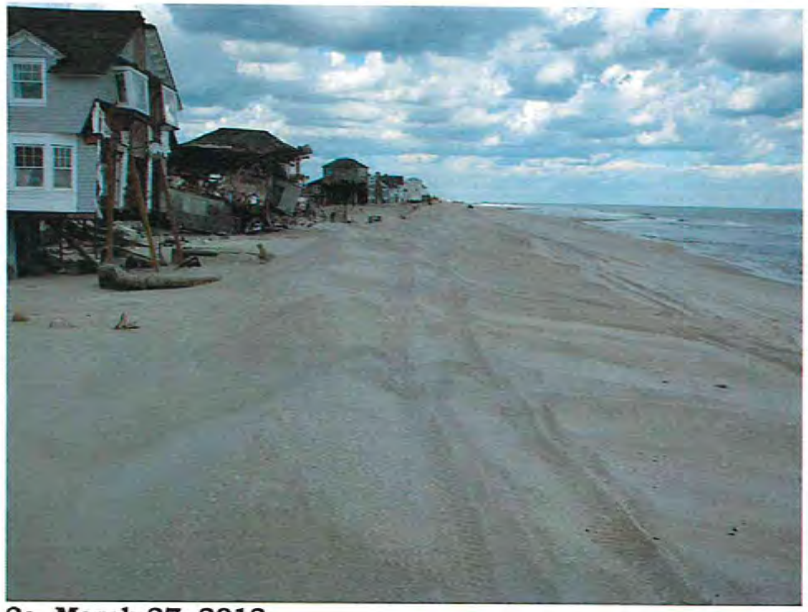
- **Mant-2 #1041 Ocean Avenue**

Mant-2 is located along Ocean Avenue on the municipal beach access path between the private residences at #1039 and #1041 Ocean Avenue. The site location was selected because of its position approximately midway between Carrigan Place and the pre-existing New Jersey Beach Profile Network site located at #1117 Ocean Avenue and it has public accessibility. The profile starts at a reference location at a monument located midway along the access path.

Hurricane Sandy's surge and storm waves flattened the beach and dune system at this location and caused major damage to oceanfront homes. The net profile volume loss attributed to Sandy was 72.69 yds^3/ft. of sand. Within a month following Sandy nearly 22 yds3.ft of sand had returned to the beach through natural recovery and initial restoration activities.

On March 5, 2013 winter storm Saturn tracked up the New Jersey coast as a strong nor'easter. Its waves scoured the beachface and nearshore seafloor, sand was dragged offshore to form a large shore parallel bar. This spring weather patterns developed that favored landward cross-shore transport and beach building. Sand moved from the bar system to the beach and welded to the beachface that lead to development of a beach berm. In addition sand was added to the dune ridge that increased the width and crest height. Summer beach building continued as sand pushed onshore. The wave climate moved the sand higher up the beachface slope to the seaward dune toe. Additional sand was added to the dune ridge expanding the width and elevation.

Despite the natural spring and summer beach building and restoration activity the dune and beach configuration remained well below the pre-Sandy conditions. The nearshore had a deep scour trough while offshore a large wedge of sand formed a new bar system. Erosion pushed the shoreline position 31 feet landward of the pre-Sandy position but the offshore deposit partially offset and reduced these onshore sand volume losses. The site remains 17.31 yds^3/ft. of sand below the pre-Sandy volume. This represents a return of nearly 75 % of the loss sand but nearly half (31.3yds^3/ft.) of that volume is contained in the offshore bar system. As conditions allow this sand should push back onshore.



2a. March 27, 2013

2c. December 13, 2013

2b. September 20, 2013

Photographs 2a to 2c. All views are to the north taken along the seaward dune toe.

Photograph 2a. shows homes devastated by Sandy still in post storm condition. Massive structural damage occurred as storm waves and surge demolished buildings. Efforts to stabilize the beach and clean up debris were underway but the process would continue most of the year.

View 2b. Dune restoration continued throughout the spring and summer with upland material mixed with overwashed sand hauled back to the beach. Natural sand recovery was limited over the summer with development of a narrow beach seaward of the dune system. The severely damaged homes were removed by September 20, 2013.

View 2c. By December 13, 2013 dune restoration work had rebuilt a sizable barrier but no vegetation or dune fence was yet installed. The beach remained narrow that exposes the seaward slope to potential storm wave run up and erosion.

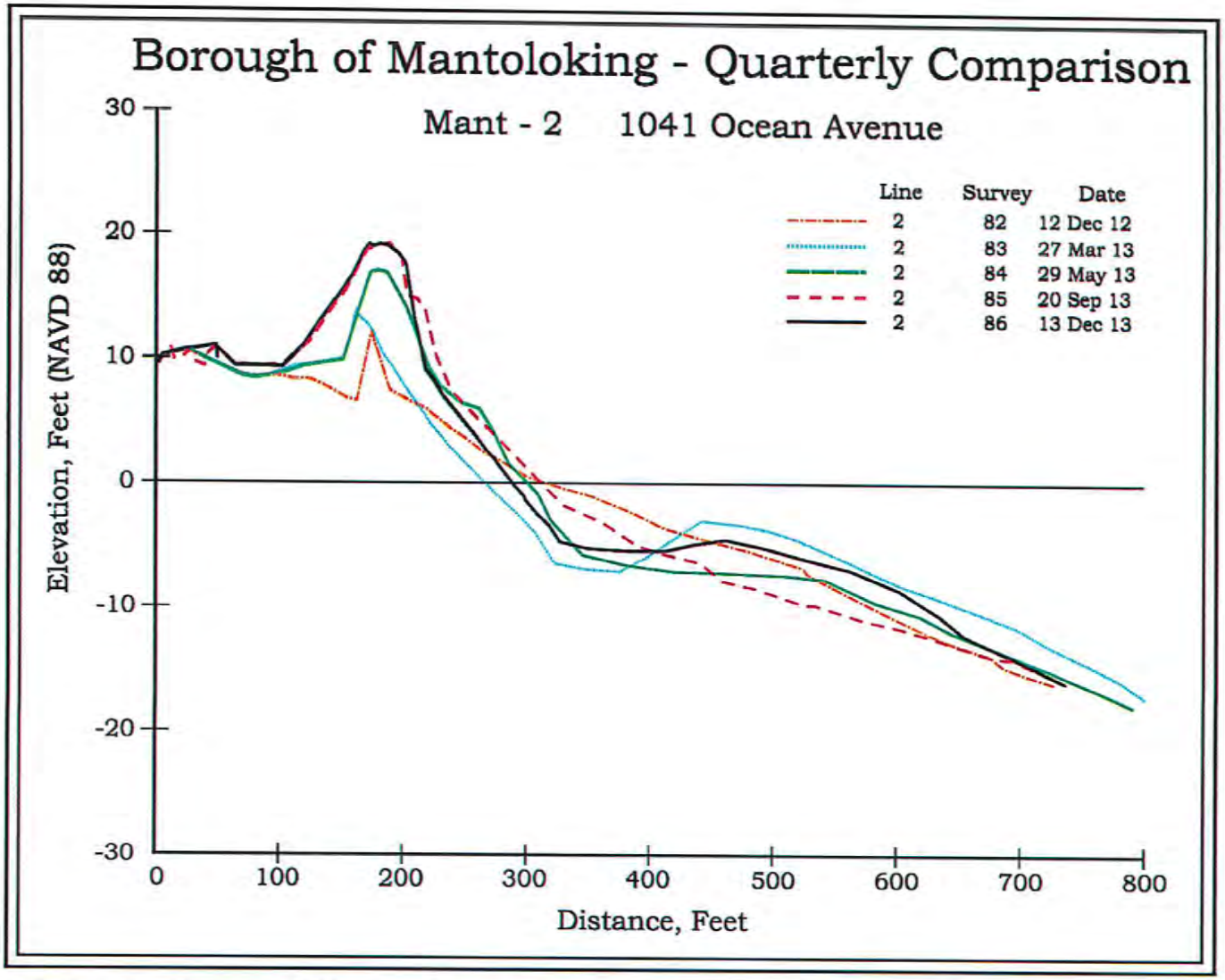


Figure 2a: Quarterly shoreline changes at 1041 Ocean Avenue shows an overall decrease in shoreline width over the 5 quarters. The shoreline position retreated landward -28 feet. The volume change over the 5 quarters resulted in a gain of 31.30 cubic yard/feet. The dune crest drastically increased in width and elevation from Survey 82 and then remained relatively stable at about 20 feet NAVD 88 between Survey 85 and Survey 86.

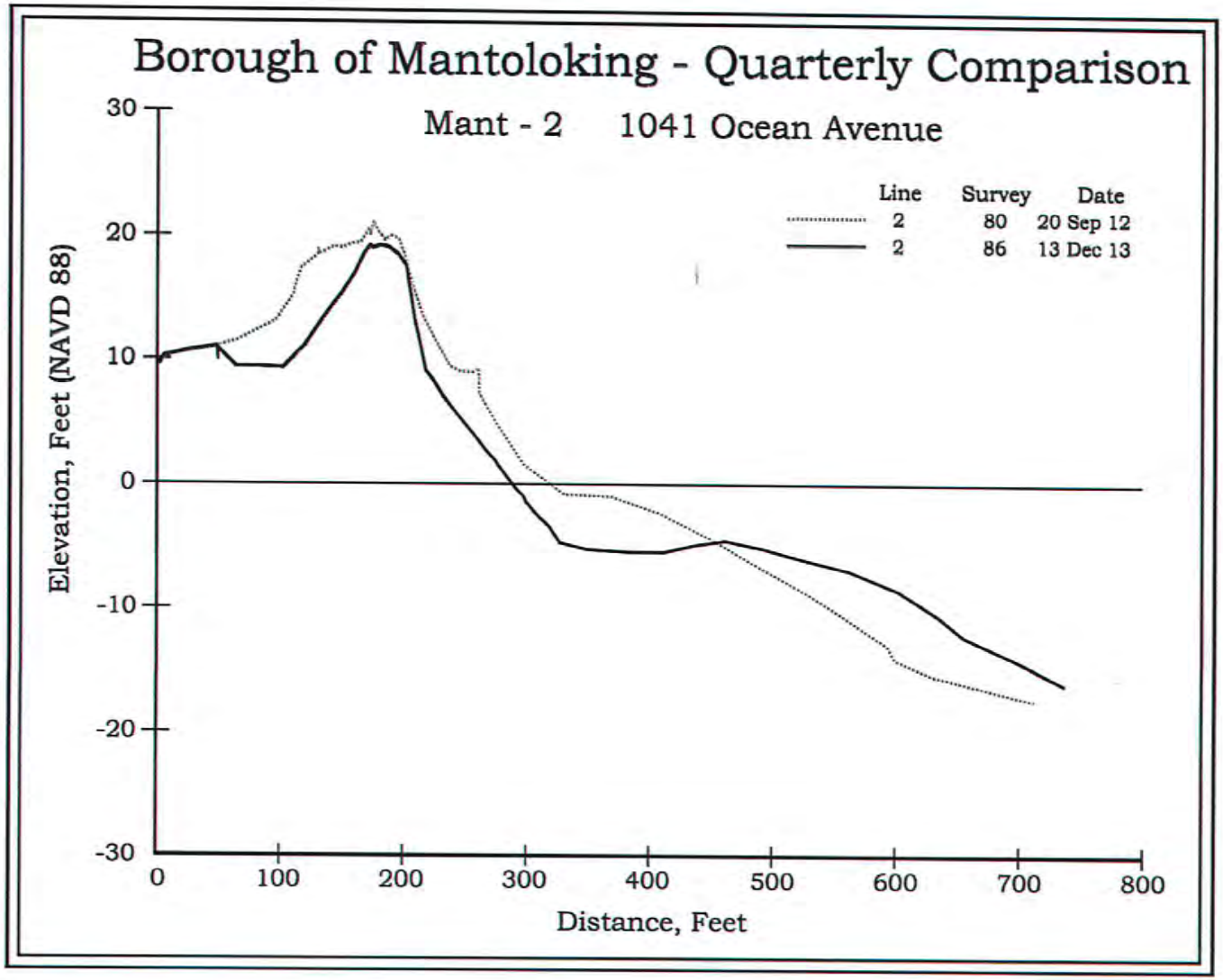


Figure 2b: From September 2012 to December 2013, 1041 Ocean Avenue experienced an overall loss of 31 feet in beach width. The site showed a sizable loss of sand from the back dune, dune crest, and fore dune area. All of these changes resulted in a net loss of 17.31 cubic yard/feet for 2013.

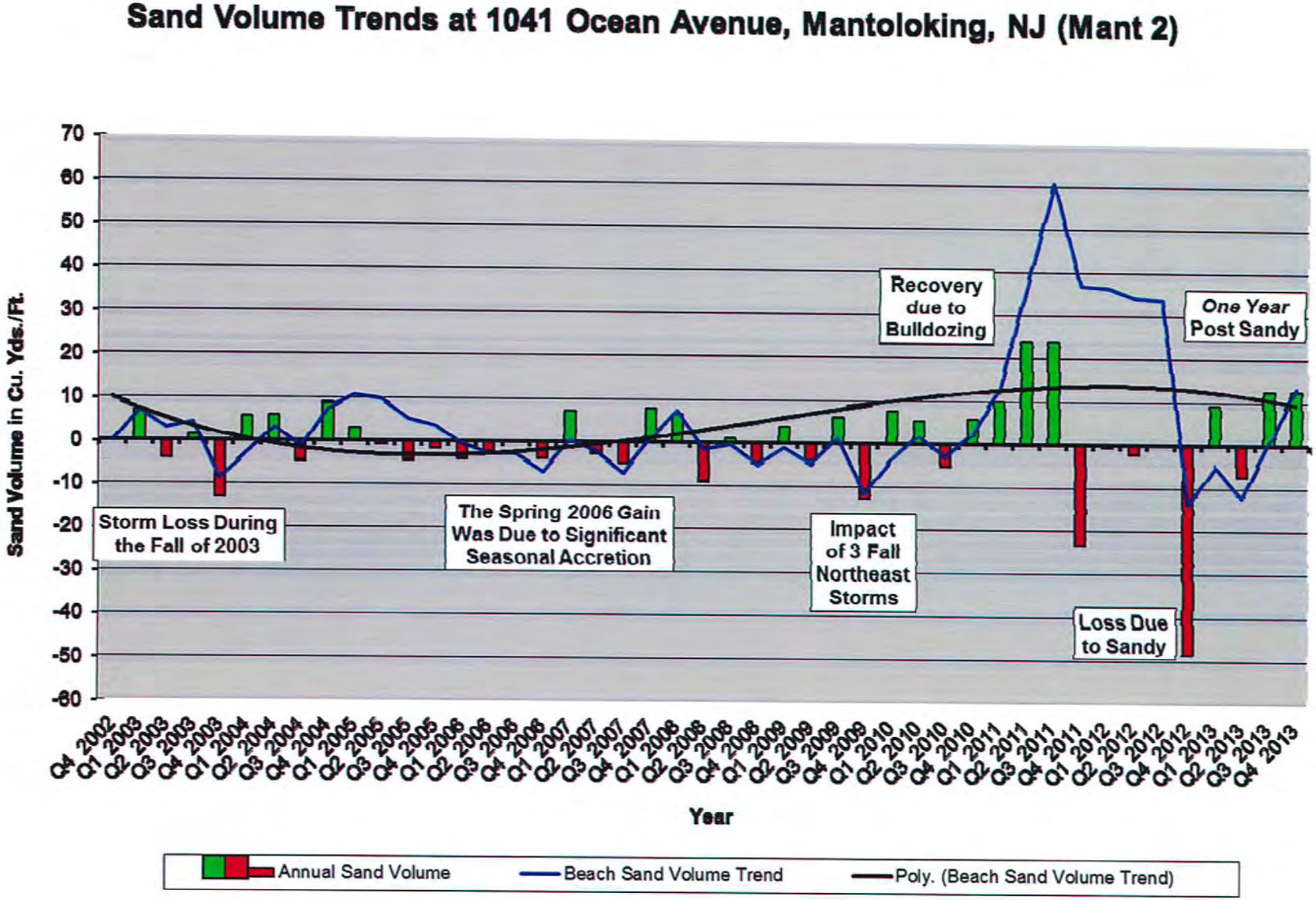


Figure 2. Quarterly sand volume changes since 2002 show modest annual or quarterly changes until 2011 when sand accretion commenced leading to a net increase of 60 yds³/ft. at the site. A loss late in 2011 was doubled by the impact of Hurricane Sandy. In 2013 three quarters of recovery restored less than 50% of the sand eroded during Sandy.

- **Mant-3 #1117 Ocean Avenue**

The third Borough monitoring site is located on private property at #1117 Ocean Avenue. This site originally established in 1986 is part of the State of New Jersey's coastal monitoring program (NJBPN). The site was later included in the beach-monitoring program in Mantoloking because of the pre-existing data collected for the State at this location. The profile line was set along the home's dune walkover to minimize damage to the dune vegetation. Positioned nearly in the center of the municipal shoreline, this site has proven to be vulnerable to dune erosion over the years.

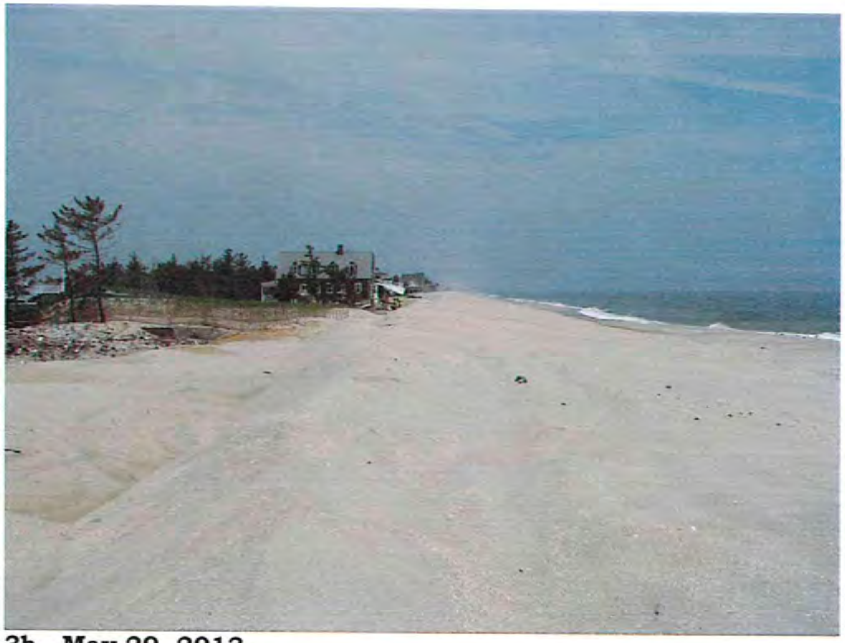
Hurricane Sandy's surge and storm waves caused massive damage in this region as the beach/dune system failed and a full breach occurred. The beach and dune were flattened and overwash carried sand across the highway into the bay. At Herbert Street just south of this site storm waves and surge obliterated the beach and dune opening a temporary inlet. Efforts by the USACE and NJDOT closed the inlet by early November that allowed beach and dune system restoration activity, debris clean up and reconstruction to begin. The net sand volume losses attributed to Sandy was 131.97 $yds^3/ft.$ of sand at this site.

By December 12, 2012 a small dune ridge was reestablished as the beach began to recovery both naturally and through restoration activities. Unfortunately, winter storms including Saturn scoured deep into the beachface and nearshore. Sand was swept offshore where a bar formation developed, additional sand was added to the dune crest and seaward slope. By spring sand began to move landward from the offshore bar and additional sand was added to the dune ridge increasing the width and elevation. Beach building continued through the summer both naturally as sand moved cross-shore to the beachface from offshore forming a typical summer recreational beach berm and mechanically as sand was recovered from the bay and returned to the beach and dune system. Restoration efforts again added sand to the dune expanding the overall width and elevation but still below pre-Sandy conditions. During the fall erosion flattened the summer beach berm and scoured the beachface and nearshore. Sand was transferred approximately a hundred feet offshore forming a new shore parallel sand bar and shallow platform.

By December 2013 the overall dune width and elevation have not been fully restored to the pre-Sandy configuration. The elevation of the dune crest was at approximately 18.5 feet NAVD88, which remains below the 20 feet NAVD88 crest elevation prior to Sandy while the volume in the landward slope is 35.44 $yds^3/ft.$ of sand below the pre-Sandy configuration. In addition to the diminished dune the beach was much narrower, with no developed berm, a scour trough nearshore and the shoreline position is 49 feet landward of the pre-Sandy position. Offshore a huge sand bar is positioned to move landward once favorable conditions prevail. The huge volume of sand offshore contained in the bar (49.69$yds^3/ft.$) partially offset the losses onshore for a net deficit of 13.62 $yds^3/ft.$ of sand below the pre-Sandy configuration and conditions. Restoration efforts and natural processes have returned nearly 90% of the sand volume lost during Sandy to this site although much of the sand remained offshore.

3a. December 19, 2012

3c. December 13, 2013



3b. May 29, 2013

Photographs 3a to 3c. All views are to the north from the approximate dune toe location at 1117 Ocean Avenue.

Photograph 3a shows the conditions on December 19, 2012 just two months following Sandy. Early efforts to stabilize the shoreline required use of upland sand evident by the distinct orange color. Several damaged homes remain in place awaiting debris removal and restoration.

View 3b. By May 29, 2013 the severely damaged homes and debris was removed while beach restoration efforts continued. Sand washed overland to the bay during the storm breach was excavated and transferred back to the beach to enhance the dune and beach restoration efforts.

View 3c. By December 13, 2013 the dune ridge was restored but without fencing or plantings. The beach remained extremely narrow leaving the dune ridge vulnerable to wave run up and erosion.

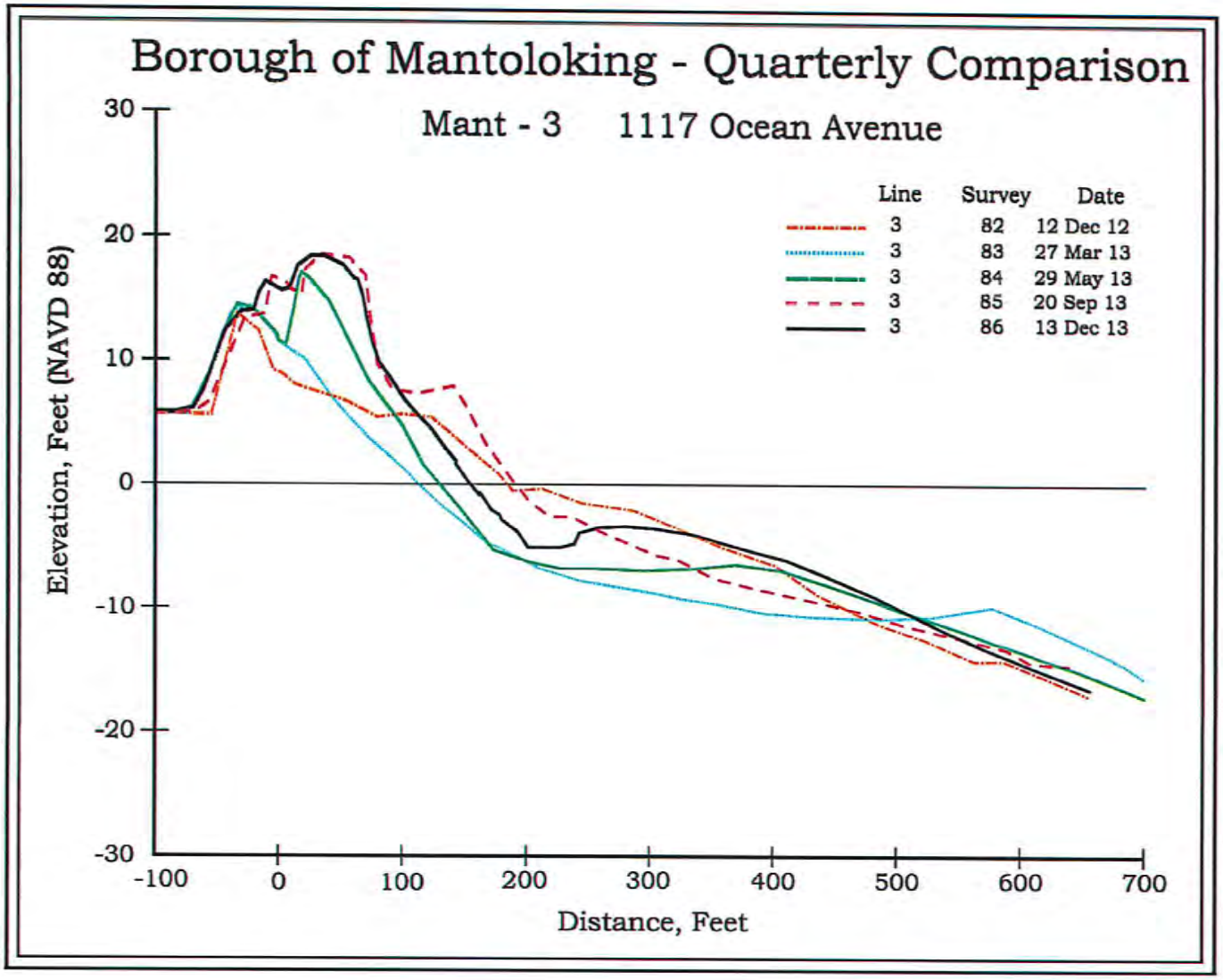


Figure 3a: Quarterly shoreline changes at site 1117 Ocean Avenue shows an overall shoreline change of -28.15 feet in 2013. This negative change of shoreline width is coupled with a positive growth of dune crest height and width. The growth of dune height and width has been relatively steady since survey 82. The beach experienced a net volume increase of 32.630 cubic yard/feet in 2013.

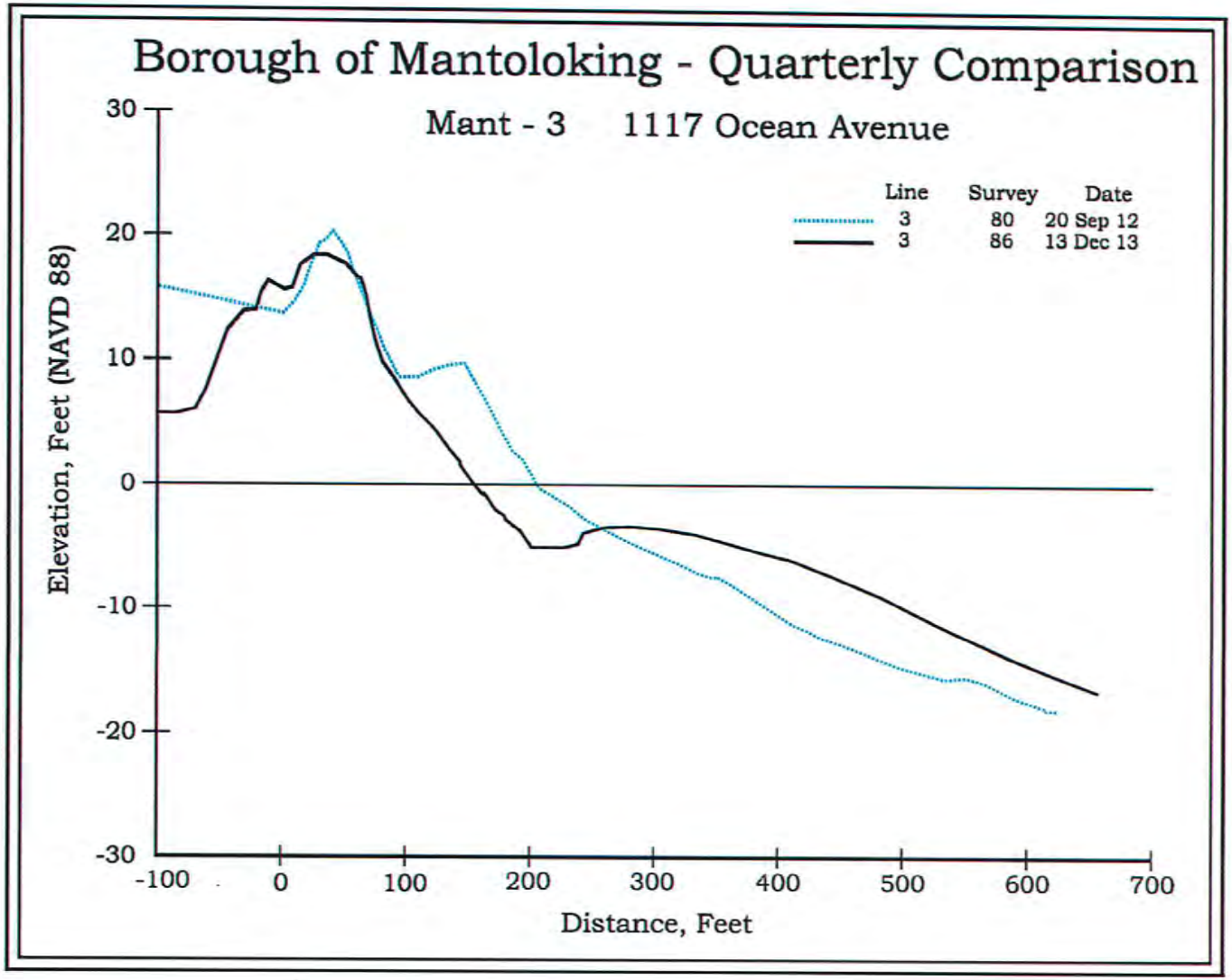


Figure 3b: A comparison of the September 2012 data to the more recent December 2013 data indicates substantial shoreline erosion and deposition of sand offshore. The beach experienced a loss of -49 feet of shoreline width and a net loss of -13.62 cubic yard/feet.

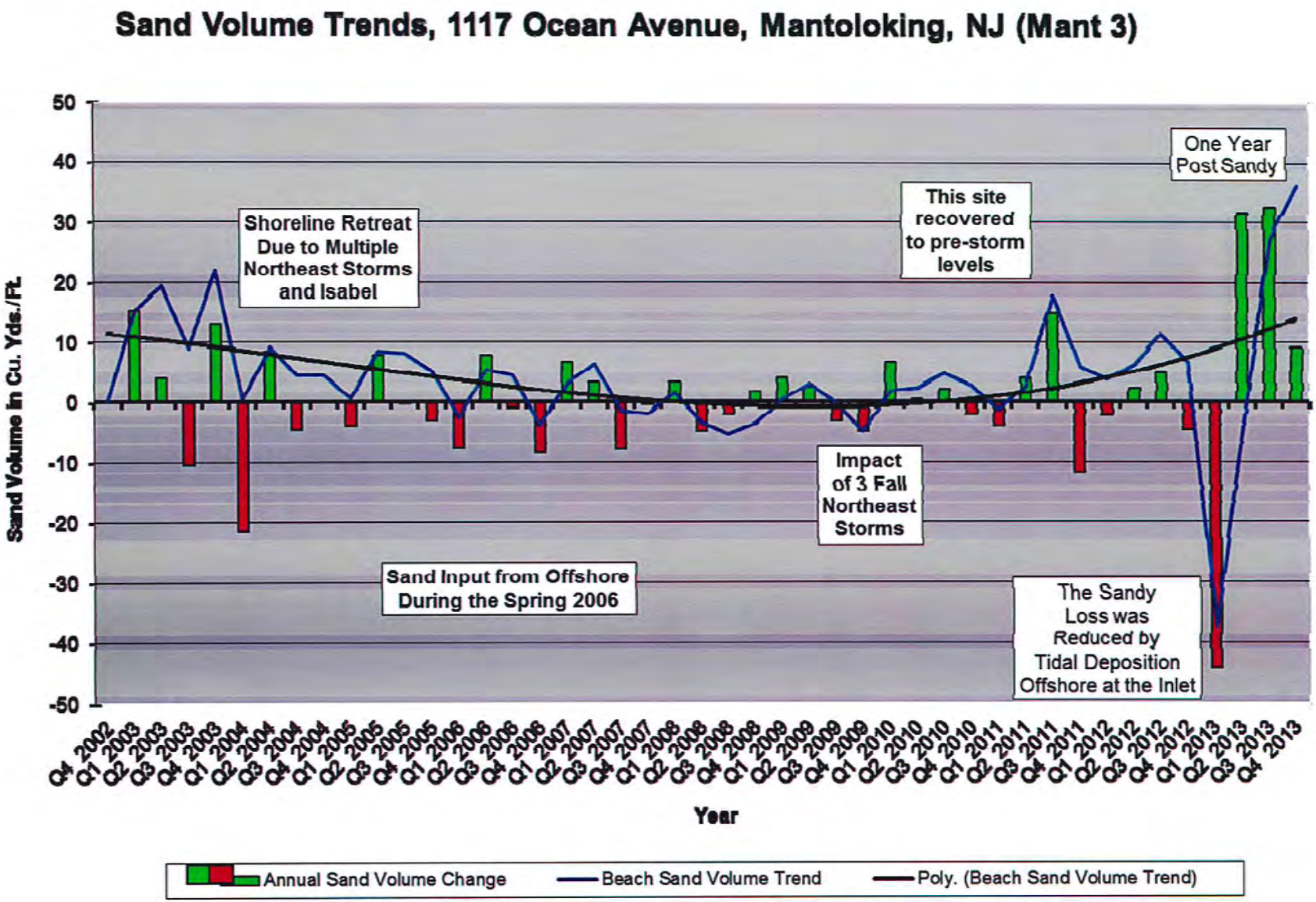


Figure 3. Located in the middle of the Borough shoreline, this site has always seemed vulnerable to erosion because the dune was the narrowest of the five sites with a thin crest at 20 feet elevation. Hurricane Irene eroded landward of the crest in 2011, and the sand volume pushed back did replace the volume lost to that Hurricane. Sandy powered through the properties on the ocean and destroyed the homes behind and on either side of the profile monument. Sand was hauled back to the location. The immediate post-Sandy loss was -131.97 yds^3/ft. By December the loss was -87.67 yds^3/ft. on the beach/dune system but due to sand deposited offshore became reduced to 46.27 yds^3/ft. Recovery efforts and natural processes have restored much of the net sand volume lost from Sandy in 2013 but much of that recovered sand volume remains offshore.

- **Mant-4 Princeton Avenue**

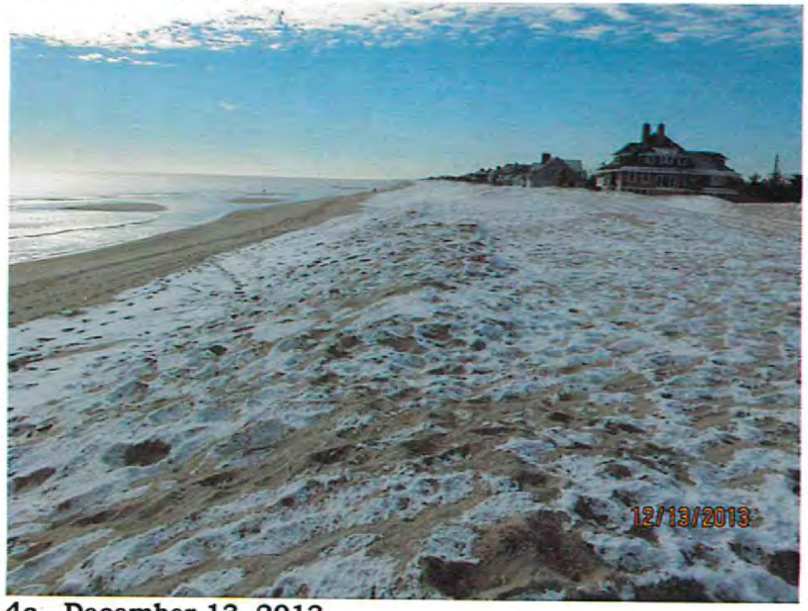
The Mant-4 beach profile is located at the seaward end of Princeton Avenue along the municipal dune walkover. This site was selected for the beach monitoring program in the Borough due to its location approximately midway between the #1117 and #1543 Ocean Avenue sites, and for its easy accessibility. Of special interest is the history of erosional problems associated with the vertical access shaft for the Ocean County Utilities Authority (OCUA) sewage discharge line, located on the seaward dune slope, adjacent to the profile line. Following the 1992 northeast storm Mantoloking installed individual geo-textile bags filled with sand around the street end and the access shaft into the municipal utility line.

Hurricane Sandy completely removed the dune and severely eroded the beach so that the street pavement simply ended at a continuation of that elevation out onto the dune's position, then down to the beach. The breach caused a significant overwash to cascade into the Borough at this street-end opening. A volume loss of 76.32 $yds^3/ft.$ of sand was attributed to Sandy at this location.

By December 12, 2012 restoration efforts had constructed a narrow dune ridge but the beach remained at a significantly diminished elevation. During the winter the beachface suffered additional wave scour and formed a nearshore trough. Sand accumulated a few hundred feet offshore formed a nearshore bar and shallow platform. Sand was added to the seaward and landward dune slopes. By spring the weather patterns and wave climate favored landward cross-shore sand transport, sand was added to the beachface and seaward dune slope. Beach building continued during the summer, sand that welded to the beachface was pushed higher up the slope by the gentle summer wave climate to form a summer recreational beach berm. Additional sand was added to the seaward dune slope and crest. During the fall the beachface eroded and the summer berm was flattened by a strong onshore system but the seaward dune slope remained intact. Sand was transferred offshore forming a nearshore bar.

A year following Sandy the overall dune width and elevation are well below the pre-Sandy configuration. The December 2013 dune elevation approached 18 feet NAVD 88 while the Pre-Sandy dune crest approached nearly 22 feet NAVD88. A comparison of the pre-Sandy dune configuration to the December 2013 dune conditions showed the landward dune slope and volume remained at a deficit of 23.86 $yds^3/ft.$ of sand. The beach width was narrower but offshore sand deposition partially offset the onshore deficits for a net loss of just 5.78 $yds^3/ft.$ of sand one year following Sandy. Although over 90% of the sand loss during Sandy has returned to the profile nearly 30 $yds^3/ft.$ or 50% of this sand remained well offshore on the bar. Under favorable conditions this sand should begin to move landward this spring.

4a. December 19, 2012



4c. December 13, 2013

4b. May 29, 2013

Photographs 4a to 4c. All views are to the south at Princeton Avenue.

Photograph 4a shows the conditions on December 19, 2012 damaged and devastated homes await restoration and debris removal while upland material (darker color) was being hauled to the site to stabilize the shoreline.

View 4b By May 29, 2013 additional sand has been returned to the beach for the upland overwash. Repairs have begun on the damaged home but debris from the devastated property remained.

View 4c Dune restoration efforts had rebuilt the dune ridge but it remained barren as of December 13, 2013. The beach is extremely narrow leaving the seaward dune slope vulnerable to wave run up and erosion.

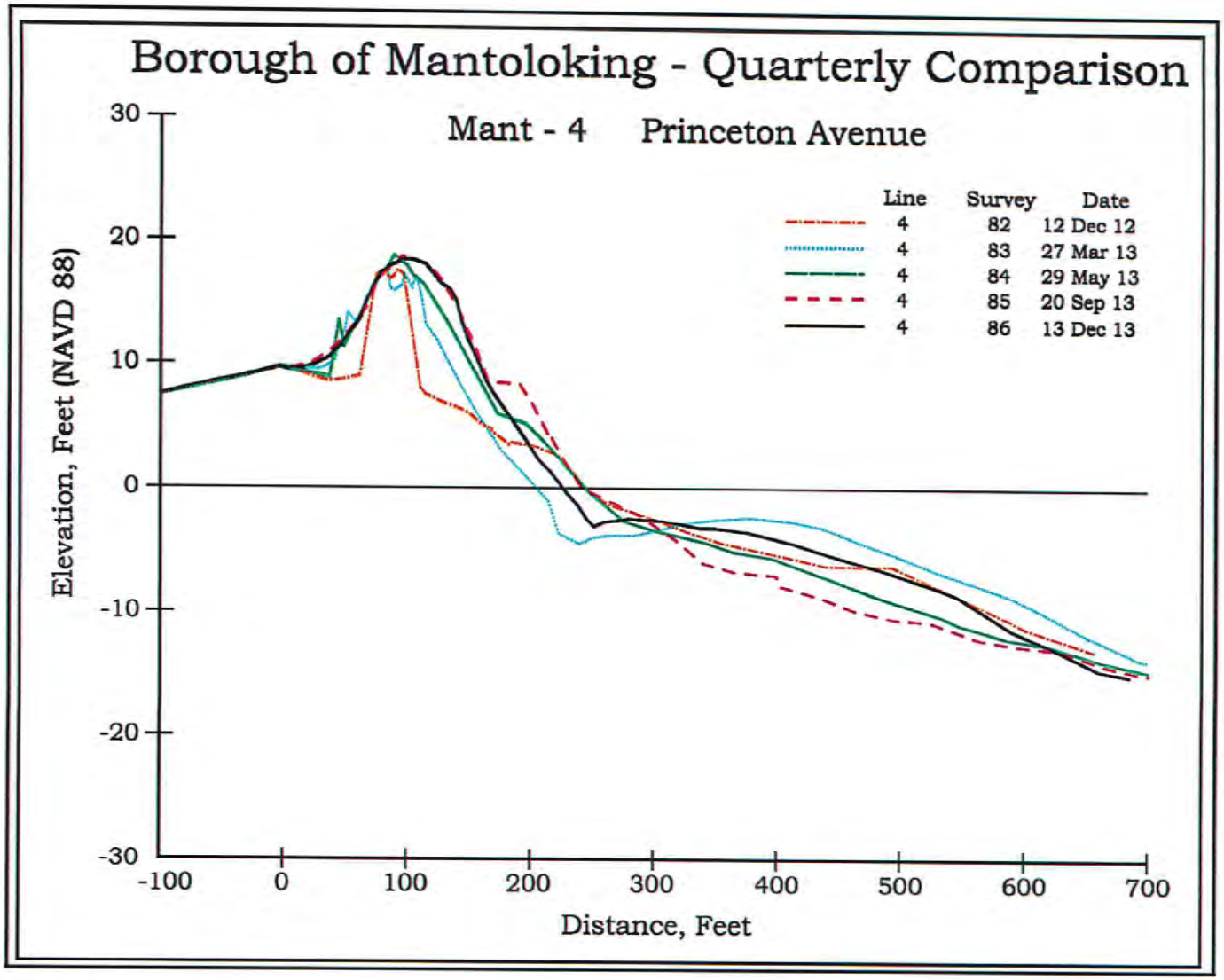


Figure 4a: The quarterly analysis of Princeton Avenue shows continued accretion on the dune from Survey 82 to Survey 86. There was a negative overall shoreline change of -18.93 feet. The Princeton site also experienced an overall increase in sand volume by 21.39 cubic yard/feet as sand was added to the beach and moved landward from offshore.

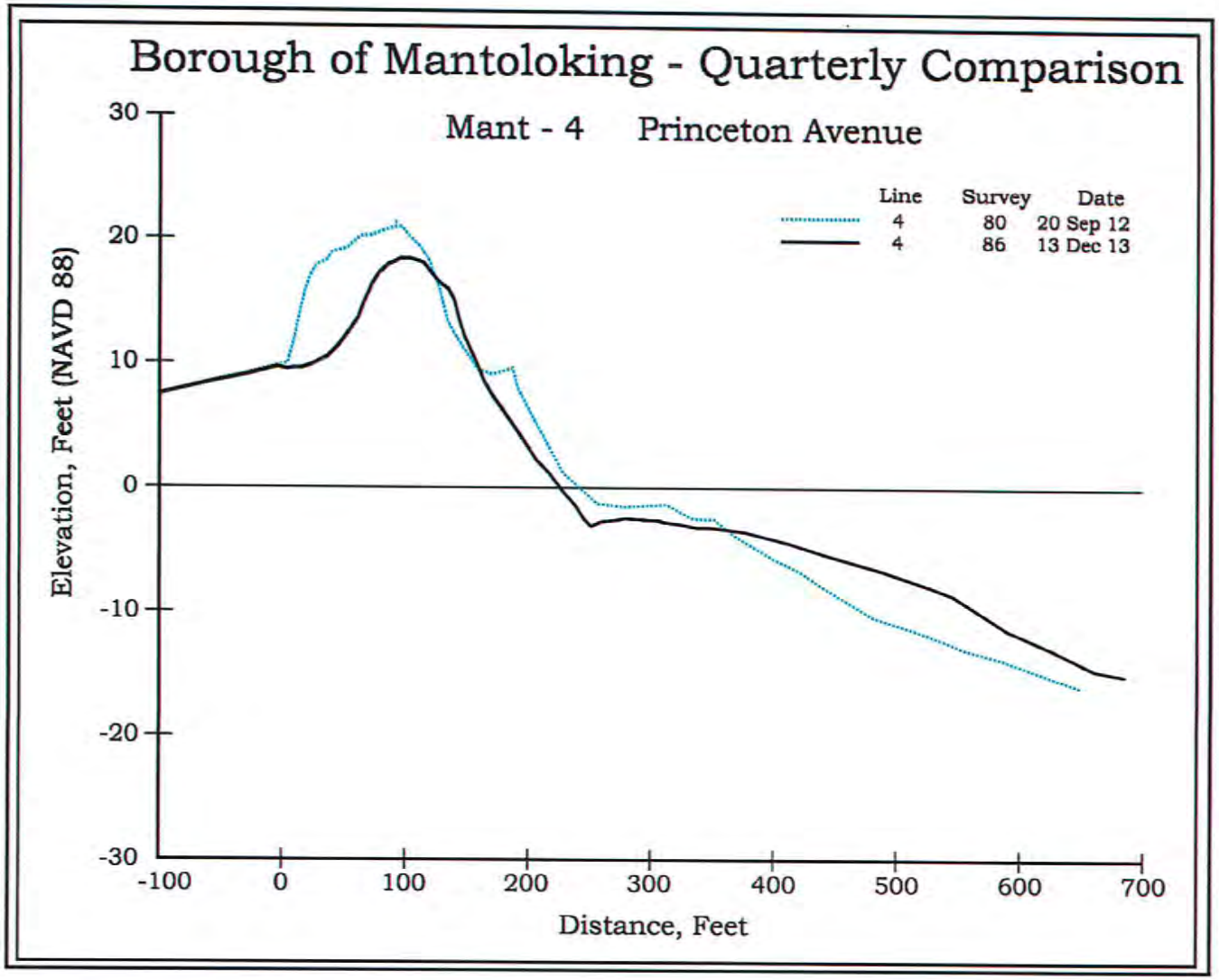


Figure 4b: One year following Sandy the Princeton Avenue beach, dune crest and back dune area configuration remained well below the dune/beach configuration surveyed prior to Sandy. The beach also remained extremely narrow. The beach remained at a loss of -17 feet in shoreline width and a volume loss of -5.78 cubic yard/feet to the pre-Sandy conditions as a significant accumulation offshore partially offset the onshore losses.

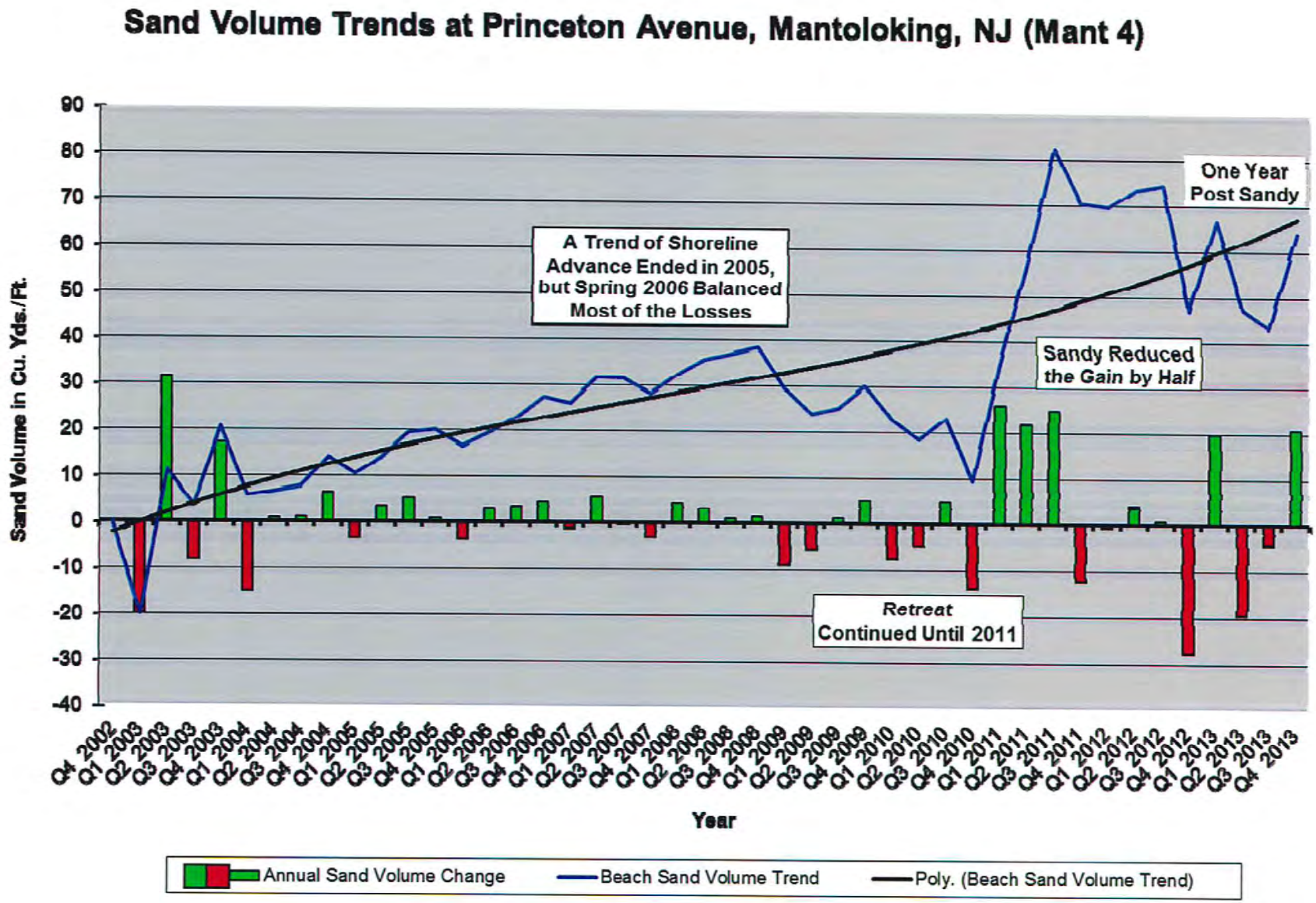


Figure 4. This site was repeatedly defended due to the presence of the MUA sewer line discharge pipeline that crosses the beach into the sea. Sand volume slowly gained over six years since 2002 only to decline nearly to the starting sand volume by late 2010. 2011 and early 2012 produced a sizable sand volume increase of 65 cubic yards of sand per foot of beachfront. Sandy reduced this gain by half. In 2013 sand recovery was focused on the first and fourth quarter with 50% offshore, this gain was partially offset by net losses during the spring and summer quarters.

- **Mant-51 #1543 Ocean Avenue**

This monitoring site was initially located on private property between the homes at #1547 and #1549 Ocean Avenue. Because of its proximity to the border with Brick Township, this location became the final site for the Borough monitoring program. A profile line was established along the southern property line of #1547 Ocean Avenue with a reference location at the landward dune toe. During 2005, the site was moved to the public access pathway between #1543 and #1539 Ocean Avenue because of accessibility issues on private property at the previous site location. The shift in the line's location was 202 feet to the north.

The dune system along the southern 1,500 feet of Mantoloking is the widest and highest in the municipality. Homes are set back to the natural toe of the back slope of the dune. In November 2010, the dune was 180 feet wide at the toe and 90 feet along the crest with an elevation of 23 feet NAVD 88. These dunes are among the best seen along the Northern Ocean County developed shoreline.

Hurricane Sandy's storm surge and fierce waves impacted the dune toe almost immediately as the ocean surge inundated the narrow beach rapidly allowing near continuous erosion throughout the storm. As a result over half the dune volume above the 10.0-foot elevation (NAVD88) was eroded away, but the dune elevation landward of the 24-foot crest elevation at the site remained above 20 feet in spite of the significant erosion and prevented overwash. This sacrifice of the dune width allowed the homes to survive without any wave impact or wave-produced flooding landward into the Borough. Water did flow landward down the Albertson Ave public access pathway, but not in volumes seen to the north. Although Sandy losses here were less than at the other Borough locations the storm volume losses were still substantial, 53.41 $yds^3/ft.$ of sand.

Over the winter months the beachface and nearshore was scoured by waves with sand transferred to the bar offshore. Some sand was bulldozed onto the seaward dune slope. During the spring sand move landward from offshore and welded to the beachface pushed up the slope to develop a beach berm. Sand was again pushed up the seaward slope to restore the slope configuration. Sand continued to move onshore during the summer adding beach width and raising the beach berm elevation. Again sand was pushed up the seaward dune slope to restore some of the Sandy losses. During the fall the beach eroded and the beach berm was flattened during the October event but the seaward dune slope remained intact, the resulting beach was extremely narrow. Sand was transferred offshore and reformed the bar system.

A year following Sandy the dune configuration has not been fully restored and the beach elevation and width is still below the pre- Sandy conditions (-44.74 $yds^3/ft.$). Sand accumulated offshore reducing the net loss to 21.34 $yds^3/ft.$ of sand. The gains represent approximately 40% of the sand volume losses during Sandy.

5a. December 19, 2012

5c. December 13, 2013

5b. May 29, 2013

Photographs 5a to 5c. All views are to the south from 1543 Ocean Ave.

Photograph 5a shows the conditions on December 19, 2012 two months following Sandy. The dune at 1543 Ocean Ave lost nearly a third of its overall width and volume during Sandy but the dune remained intact and prevented overwash and breaching. With a wider beach than the northern and mid Borough beaches bulldozing sand from the beach berm to the dune toe was possible and initiated to repair the dune scarp.

View 5b continued periodic bulldozing of sand from the berm restored the seaward dune slope configuration to mimic pre-Sandy conditions by the end of May 2013.

View 5c By December 2013 the dune rebuilding efforts had restored the full dune width but no plantings or fences were installed. The summer berm eroded leaving a narrow beach.

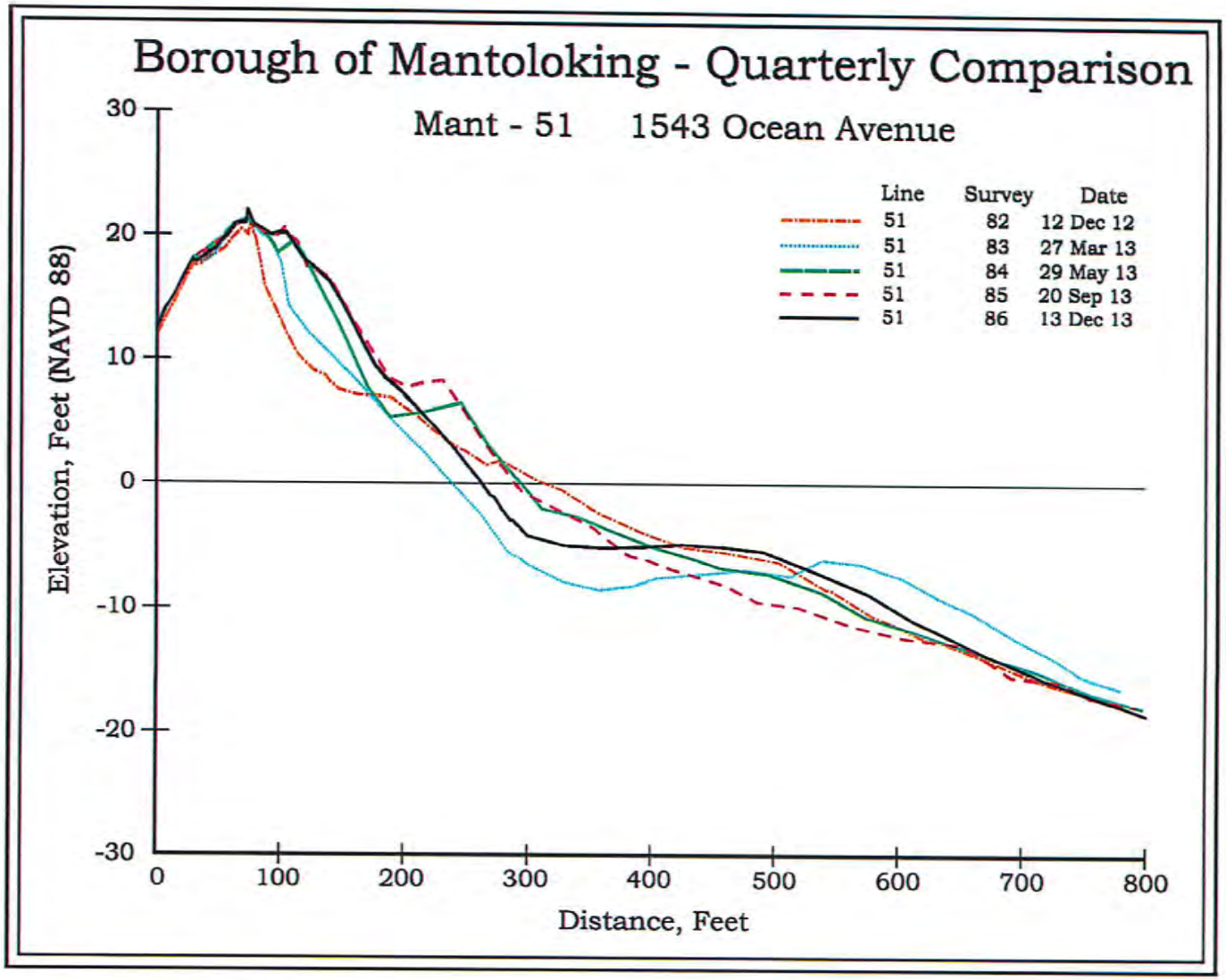


Figure 5a: The quarterly analysis of the cross section of site 1543 Ocean Avenue reveals consistent accretion on the dune from survey 82 to Survey 86. There was a total volume increase of 16.12 cubic yard/feet of sand. However, there was a net shoreline position retreat of 52 feet.

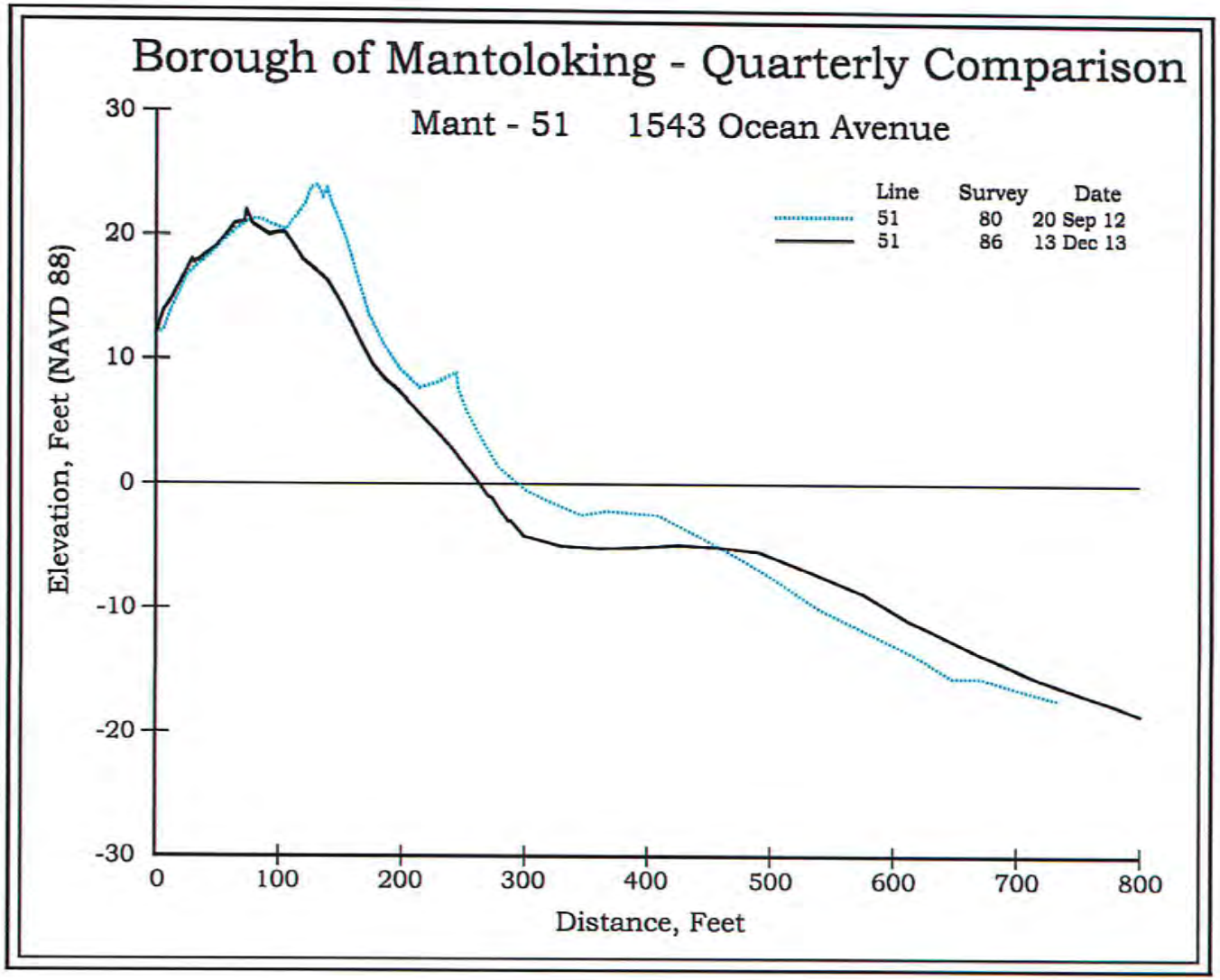


Figure 5b: Between Survey 80 and Survey 86 site 1543 Ocean Avenue experienced a total volume loss of -5.78 cubic yard/feet and a shoreline position change of -17 feet. Offshore gains partially offset the losses on the seaward dune crest and slope and from the beachface and nearshore.

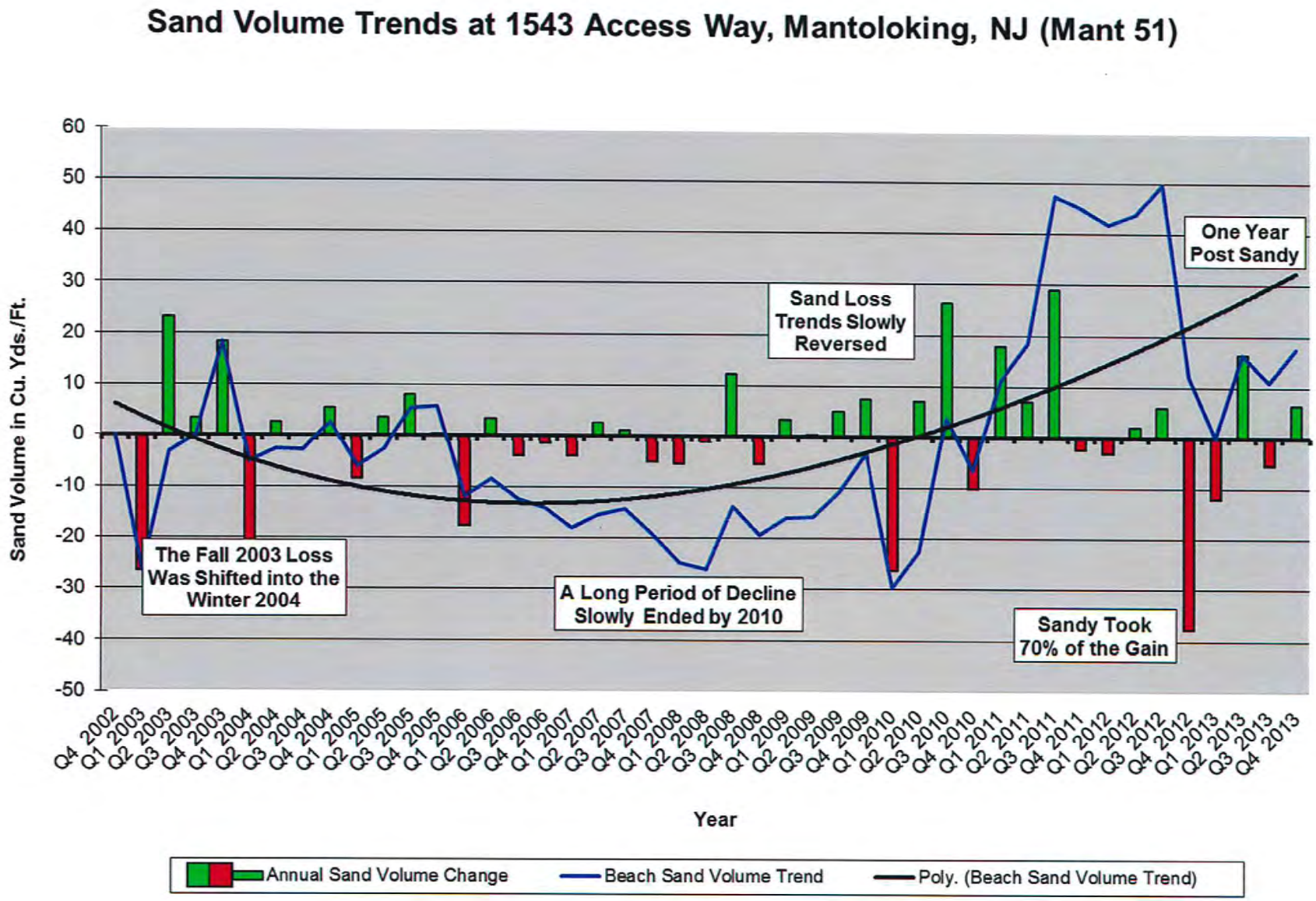


Figure 5. The highest and widest dune system in Mantoloking suffered a sand volume loss trend from 2004 to 2009. The volume of sand in the system surveyed followed the pattern elsewhere in the Borough by improving by 50 cubic yards of sand per foot of beachfront between 2010 and the 3rd quarter of 2012. Hurricane Sandy cut severely into this gain taking 70% of it either further offshore or more likely, south into Brick Township. In 2013 there was a partial recovery in the net sand volume with the largest gains in the spring and fall, much of this sand volume remained well offshore.

Conclusions:
As discussed last year the biggest contributor to the rapid rate of dune erosion and subsequent dune failure during Hurricane Sandy was the narrow beaches that lacked sufficient capability to absorb wave energy before impacting the seaward dune slope. Contrasted by wider beaches associated with the Federal shore protection projects completed on Long Beach Island where the beaches forced waves to break up to 250 feet further seaward absorbed wave energy and yielded a much lower rate of dune erosion that prevented breaches and overwash during Hurricane Sandy. The survival of lower volume dunes in Monmouth County also extends this belief that a wider beach tripping and absorbing wave energy is absolutely essential to storm protection along with a properly designed dune with sufficient elevation at its crest to stop the storm surge and storm wave overwash.

Mantoloking beaches and dunes have partially recovered from Sandy thanks to the enormous restoration efforts to recover and return sand to the beaches swept landward across island properties and into the bay during the storm. Additional sand was brought from the mainland to bolster dune ridges and provide some level of storm protection for the community. With natural sand recovery and beach building processes this spring and summer sand pushed onshore adding sand to the beach/dune system with mechanical assistance as needed to restore the seaward dune slopes.

Despite all these efforts and natural recovery the Borough's shoreline remains at a net deficit of 193,555 cubic yards of sand compared to pre-Sandy conditions. At each of the monitoring sites full recovery of the dune configuration has not yet been achieved deficient both in width and crest elevation. In addition the dune ridge consists of unconsolidated sand that is less resistant to erosion than a naturally developed dune system that would take decades to restore. The beach is narrow and at a lower elevation than before Sandy that provides little storm protection to the dune system in the event of another significant storm making landfall along the Jersey coast.

Residents near Carrigan Place extended the Bay Head rock seawall south to enhance storm protection for their properties buried in the dune to form a resistant core to storm waves. Plans continue to move forward towards installation of a steel bulkhead the length of the Borough and into neighboring communities to the south. The bulkhead would be buried in the dune footprint and provide a last defense for properties and to protect Route 35 using NJ DOT funding to prevent a repeat of the devastation caused by the breaches during Sandy. But by far the most significant development towards enhancement of the Borough's storm preparedness is the authorization of funding through the USACE to initiate and complete initial construction of a flood and coastal storm damage reduction project from Manasquan Inlet to Barnegat Inlet. This project would enhance the dune system but most importantly create a much wider beach. The wider beach would absorb storm wave energy, reduce impact on the dune system and allow the dune system to function as a barrier to storm surge breaches and wave overwash instead of absorbing the full impact of the storm wave's fury as happened during Sandy. Communities with similar projects completed prior to Sandy experienced significantly less storm damage from waves and storm surge.

Current conditions along the Borough's shoreline leave the community vulnerable to severe storm damage. Beach widths as of December 2013 ranged between 30-40 feet at reduced elevations. Beach configurations are still below pre-Sandy conditions that were shown to provide insufficient storm protection during Sandy. In the absence of the USACE project moving to construction in 2014 the Borough should consider additional sand be placed on the Borough's beaches to extend the beach width at least 100 feet seaward of the dune toe. CRC studies have documented that cross-shore sediment transport is the dominant process affecting sand distribution along the Mantoloking shoreline. As such residence times for any sand placed along the Borough's shoreline would be significantly extended and provide a significant increase to the Borough's storm preparedness.