FINAL REPORT FOR 2016
ON THE CONDITION OF THE MUNICIPAL OCEANFRONT BEACHES
THE BOROUGH OF AVALON, CAPE MAY COUNTY, NEW JERSEY

Photo above was taken two days after a January 2016 northeast storm named Jonas. Its impact on the north end of the Avalon shoreline is visible with exposed rocks at 11th Street. Waves overtopped the jetty scouring the beach along the south margin. The water reached the dune toe other places, but fortunately did little serious damage. (photo by Ted Kingston for the CRC).

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March 2017

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ANNUAL REPORT FOR 2016 - TO THE BOROUGH OF AVALON
ON THE
CONDITION OF THE MUNICIPAL BEACHES

Introduction:

The Stockton University Coastal Research Center (CRC) has continued the Avalon municipal shoreline monitoring effort that initially began back in 1984. This annual report provides the results and analyses from the fall 2015 to fall 2016 survey datasets of that program. Discussed are the long term performances of the 2015 beach nourishment project, winter storm Jonas, the 2016 sand back-pass project and the 2nd annual Townsend's Inlet bathymetry survey.

Avalon is a contrast in extremes between beach environments. From the chronic armored erosional hotspot along the northern oceanfront, to the rapidly accretive southern beach/dune system that comprise the finest example of a mature maritime coastal forest on New Jersey's developed coastal barrier islands. Seven-Mile Island is one of the more stable NJ barrier islands, but proximity to Townsends Inlet has resulted in the northernmost part of the island suffering chronic erosion. Northeast exposure here is significant, because of the seaward offset across the inlet from Ludlam Island. There is a storm-related cost to being "Cooler by a Mile". This offset between Sea Isle City and Avalon puts the Avalon northern beaches at an angle to severe exposure to northeast storm winds and waves that directly impact the Avalon shoreline adjacent to Townsends Inlet. Wave-generated sand transport consistently moves large volumes of sand south and to an extent offshore. Efforts to combat this chronic erosion and provide shore protection to this region include repetitive beach nourishment projects, extensions to the inlet jetty, installation of a nearshore submerged breakwater and the construction of a timber bulkhead and rock revetment between 8th Street and 17th Street, all completed since famous Easter (March) northeaster of 1962.

In contrast, the shoreline segment south of 30th Street has directly benefited from longshore currents moving sand south from the north end "hotspot". Beaches from 32nd Street to 56th Street support a 100 acre tract of highly developed dunes and beaches. In this region the dunes can reach over 1000 feet in width, with crest elevations of 50 feet, while beaches up to 300 feet wide continue to accumulate sand and support further dune growth. This accretive shoreline provides the community with stable shore protection, excellent natural habitats and most recently a source of sand to help combat repetitive sand loss on the engineered beach through sand back-passing.

During the summer of 2015, Avalon undertook its own restoration of the north end engineered beach. This project followed the 2013 USACE (US Army Corps of Engineers) emergency maintenance due to impacts from Hurricanes Irene and Sandy, when the USACE placed a reported 336,359 cubic yards (CY) of sand on the engineered beach. The 2013 project, rapidly eroded after winter storm Saturn and a series of smaller storms impacted the Jersey shore. With no federal funding available Avalon undertook a massive project on its own to restore the severely eroded federal project beach. The 2015 project placed 740,000 cubic yards of sand, dredged from Townsends Inlet, to between 9th and 23rd Streets to restore the federal beach design.

Unfortunately, early fall storms beginning in October 2015 almost immediately began to erode the new project beach berm. Winter storms including Jonas, had a significant impact on Cape May County's beaches, eventually resulting in a limited federal disaster declaration. In Avalon, the engineered beach was severely eroded. The seaward dune slopes were cut landward by the storm events, leaving steep vertical scarps in several locations up to 15 feet high from the dune crest to the beach. By March 2016, the project beach berms had been essentially removed by storm erosion. Project sand was carried offshore and longshore away from the project area.

To restore safe beach access and shore up storm protection the Borough undertook another sand back-pass project during spring 2016. The project was completed by June in time for the start of the summer season. This

newest and 4th round of sand back-pass projects by the Borough harvested and placed approximately 50,000 cy of sand from the northern borrow zone transferred to the engineered beach.

Monitoring Program:

The CRC monitored the ten oceanfront cross sections four times in 2016 on a seasonal timeline. These surveying activities continue a monitoring program dating back to 1981. The five northern sites are located within the engineered beach project area while the southern five sites cover the accretional region including the natural exclusion area and sand back-passing borrow zones. Monitoring provides details on natural sediment movement along the Borough's Atlantic shoreline and surveying has continued through multiple beach restoration projects starting in 1987 with a local/state sponsored project that gathers data for project performance evaluation. Each topographic beach profile starts at a fixed reference position landward of the dune. The repetitive surveys for each profile include changes to the dune, beach and nearshore.
The following is a list of quarterly studies included in this report and the dates of the surveys:

- Survey 134 December 21 & 22, 2015; 4th Quarter
- Survey 136 March 7 & 8, 2016; 1st Quarter
- Survey 137 June 13 - 20, 2016; 2nd Quarter
- Survey 138 September 8 & 9, 2016; 3rd Quarter
- Survey 139 December 19 & 23, 2016; 4th Quarter

**Note: Survey 135 post-storm (Jonas) was included as a separate sub-section below*

Winter Storm Jonas & Storm Impacts:

The El Nino winter weather pattern that started in 2015 and continued into 2016 generated a series of northeast storm events. Fall 2015 storm losses removed -412,858 cy of sand from the engineered beach berm and beachface slope, based on the 4-month post fill survey conducted in November 2015 using the 200-foot spaced engineered beach baseline station sites. Nearshore gains of 48,879 cy of sand south of 17th Street partially offset the loss for a net initial 4-month project area loss of -363,980 cy of sand.

Winter storm Jonas that struck the Jersey shore on January 26, 2016. Sustained onshore winds topped 50 mph with gusts exceeding 60 mph and affected the coast for over 24 hours. Jonas occurred at a time of lunar spring astronomical tides that combined with the storm surge and resulted in record coastal flooding in many of the coastal communities in Cape May County. This extreme storm surge combined with battering waves generated by Jonas produced extensive beach and dune erosion along Cape May County beaches.

In Avalon, the engineered project beach berm was severely impacted for a second time in less than 6 months following construction. The Avalon engineered beach suffered a net loss of -75,787 cubic yards of sand from Jonas. Erosion removed much of the summer project sand that remained on the beach following the October 2015 storm event. Severe erosion of the beaches between 10th Street through 17th Street caused between 62 to 89 feet of shoreline retreat with severe loss of berm width and height. The flattening of the beach allowed storm waves and surge to cut into the seaward dune toe. Table 1 on the following page shows the volume and shoreline position losses from the storm along the engineered beaches. The Borough did not request the CRC to conduct a survey (#135) of the southern beaches following Jonas, survey #135 only included the five sites within the engineered beach.

Successive storms in February and March continued to erode, flatten and lower the beach elevation resulting in extensive dune erosion along the engineered beach. Southern beaches were also flattened and lowered in elevation by the storm waves but the dunes remained unaffected. Only three of the ten Borough monitoring sites showed net sand gains over the winter months. The net sand volume change for the Avalon oceanfront beaches was a loss of -213,286 cubic yards (cy) of sand. The worst hit beaches were the sites at 12th and 17th Streets that lost -31.22 yds^3/ft. and -33.58 yds^3/ft. of sand respectively with 78th Street also suffering significant sand volume loss (-34.78 yds^3/ft.).

Table 1
Oceanfront Shoreline and Volume Changes
Jonas Storm Changes to Engineered Beach

Profile Number	Shoreline Change (feet)	Volume Change (yds^3/ft)	Avg.Volume Change (yds^3/ft)	Cell Distance (feet)	Net Volume Change (yds^3)
8th Street Jetty					
			7.173	500	3,587
AV-9	-9	7.17			
			-12.437	840	-10,447
AV-12	-89	-32.05			
			-25.306	1400	-35,428
AV-17	-62	-18.57			
			-12.221	1680	-20,530
AV-23	-8	-5.88			
			-9.264	1400	-12,969
AV-28	-31	-12.65			
Total Volume Change for Oceanfront Beaches in cubic yards =					-75,787

Summary of Sand Back-passing Projects:

As of June 2016, the Borough of Avalon has undertaken 4 rounds of sand back-passing projects. The initial pilot project in 2006, moved 58,000 cy of sand from the beaches between 31st and 68th Streets back to the northern zone of erosion. After evaluation of the pilot project a second project started in February 6, 2012, completed March 5, 2012 with 63,956 cy of sand moved to the erosional shoreline between 12th and 21st Streets.

The third back-passing project commenced in late February 2014, and was scheduled to be completed prior to the shorebird nesting season in early spring. To ensure the construction activity did not interfere with potential arriving shorebirds in the mid-island natural area /exclusion zone only the northern borrow zone was utilized for this project. This effort moved 50,097 cy of sand within a 6 week window utilizing 1,544 truckloads of sand excavated from the borrow zone and hauled to the engineered beach.

The Borough's fourth sand back-passing program, initiated during the spring of 2016, was completed by the June 14th survey. Sand was harvested from the northern borrow zone located between 40th Street and 32nd Street. Sand harvesting on the beach was limited to the intertidal zone between the high tide line (HTL) to mean low water (MLW). This restricted sand harvesting from the beach above 4 feet NAVD 88 and below -2.25 feet NAVD88. Surveys conducted in March, prior to sand harvesting indicated an estimated 58,800 cy of sand available within the designated borrow zone. Sand placement was focused on two erosional hotspot regions along the engineered beach. The southern placement occurred from 23rd Street and tapered to existing conditions just north of 20th Street. North end placement started just south of 15th Street tapering to existing conditions at 9th Street. Project design was to establish a 50-foot wide beach berm at approximately 7 feet NAVD 88 elevation within the placement areas with a 20:1 slope to MLW.

Two quarterly lines run through the project placement area, line AV-12 is within the northern placement area while AV-23 is within the southern placement area, while AV-35 is in the northern borrow zone. The June 2016 survey shows the project specifications were effectively achieved at both placement monitoring sites. This project truck haul information indicates approximately 50,000 cy of sand was harvested and placed during 2016. Monitoring of the quarterly sites within the engineered project area provide an estimate of project performance while AV-35 will give an indication of natural recovery rates in the harvest zone.

Table 2 below compares the shoreline and onshore volume changes for each of the five Borough oceanfront beach profiles within the engineered beach project area from the first quarter (March 8, 2016 pre back-pass) to second quarter (June 15, 2016 post back-pass) to estimate the volume of sand retained from the 2016 sand back pass project. The net volume change is calculated by averaging the adjacent profile volume changes and multiplying by the distance between profiles. The total sand volume change for the Avalon engineered beach was calculated from the summation of the net changes over the project area.

Table 2
Oceanfront Shoreline and Volume Changes
Engineered Beach Onshore Changes
March 8, 2016 to June 15, 2016

Profile Number	Shoreline Change (feet)	Volume Change (yds³/ft)	Avg.Volume Change (yds³/ft)	Cell Distance (feet)	Net Volume Change (yds³)	Cumulative Volume Change (yds³)
8th Street Jetty						
			-4.500	500	-2,250	-2,250
AV-9	-13	-4.50				
			3.500	840	2,940	690
AV-12	36	11.50				
			9.690	1400	13,566	14,256
AV-17	-10	7.88				
			12.455	1680	20,924	35,180
AV-23	48	17.03				
			13.545	1400	18,963	54,143
AV-28	42	10.06				

Total Volume Change for Oceanfront Beaches in cubic yards = 54,143

The sand back-pass project added sand directly to sites AV-12 (11.50 yds^3/ft.) and AV-23 (17.03 yds^3/ft.). Using just these two locations to calculate the sand volume placed within the southern (873 feet) and northern (1725 feet) placement zones indicates gains of 14,867 cy and 19,838 cy of sand respectively for a net sand placement of 34,705 cy of sand. With pre-construction surveys conducted in March 2016 and post-construction surveys completed in June 2016 this leaves nearly a three-month construction window during which sand was hauled and placed. During this window, waves and currents undoubtedly re-worked the sand placed and re-distributed sand across the adjacent engineered beaches. Using all five profile sites within the engineered beach and the changes onshore to redefine the sand volume change, indicates that 54,143 cubic yards of sand accumulated on the engineered beach by the completion of the project.

The five sites yielded a net onshore sand volume gain associated with significant shoreline position advances at three of the five sites (AV-12, AV-23 & AV-28). Although the shoreline position at 17th Street did not advance there was an increase in beach elevation and formation of a dry recreational berm 60 feet in width seaward of the dune toe not directly associated with the project efforts. The 9th Street site was outside the project limits with no indication of sand accumulation in this region from the project area. This indicates during the construction window sand was moving longshore in a southerly direction. Although, also outside the project placement area the 28th Street beach did show significant sand accumulation onshore forming a wider dry recreational beach. Sand sources for natural development of the beach berm here may have been derived both from cross-shore transport of sand to the beach and thru longshore drift from the project area to this region.

As the 2016 back-pass project proceeded the CRC was asked to survey the USACE monitoring lines within the project placement area. These additional lines were surveyed at the start of the project and immediately

following construction. Comparison of the USACE lines pre & post project survey data was done using ArcGIS. Digital Elevation Models were created for each survey and then those surfaces compared for elevation and volume changes. The results are shown below in Figure 1.

Avalon, New Jersey
2016 Sand Back Passing Project Placement Area
Elevation & Volume Change Analysis
April 2016 to June 2016

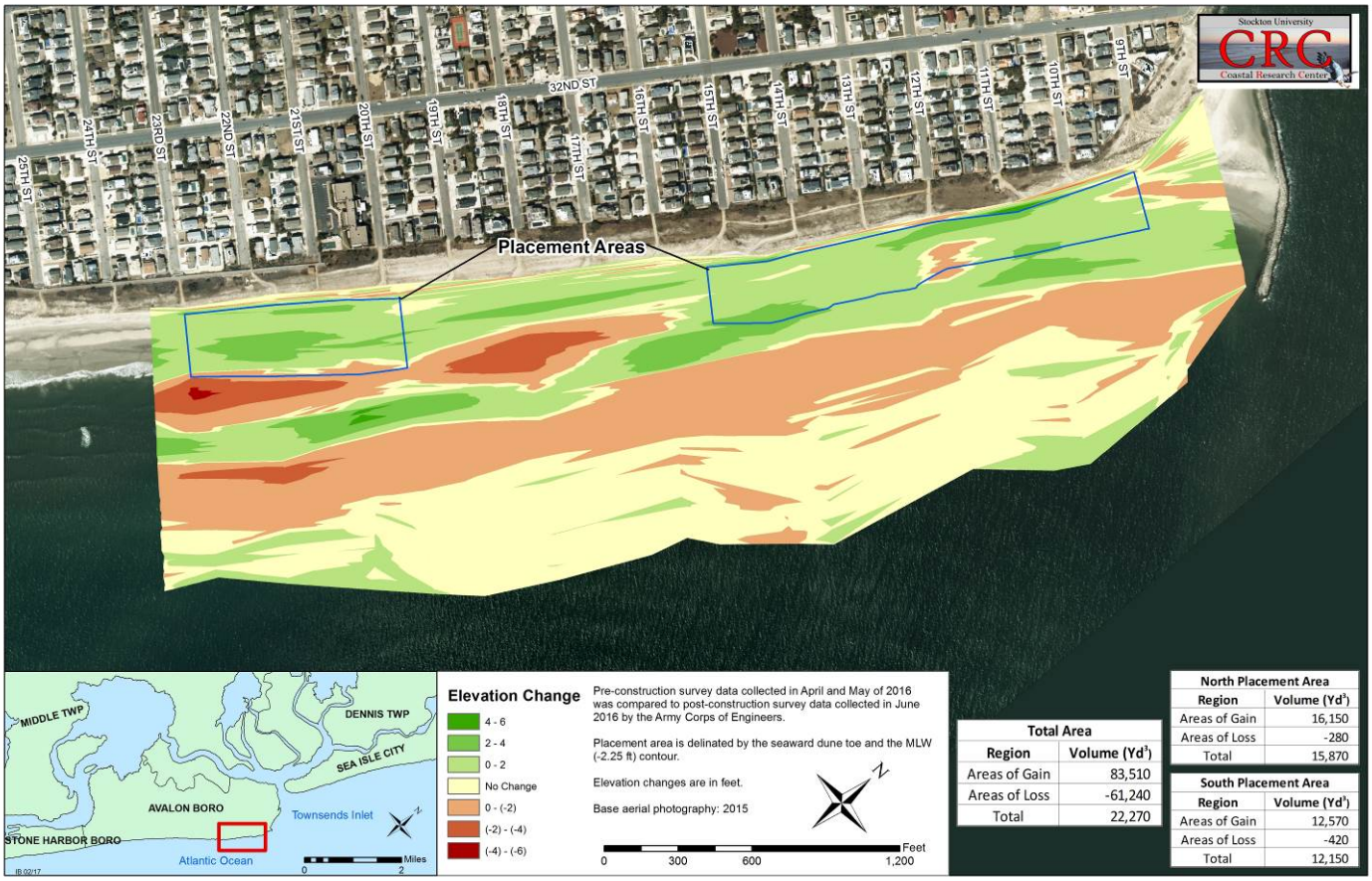

Figure 1 – The elevation and volume change map above shows the results of sand placement during the 2016 sand back-passing project. Green areas represent regions of elevation gains, orange elevation loss while yellow essential regions of no change. The southern (23rd to 20th Streets) and northern (15th to 9th Streets) placement zones are delineated by the blue irregular polygon shapes. Volume changes were calculated for the survey area and within each placement area.

Using the USACE lines to determine the retained placement volume in each zone yields the following results. Within the southern zone 20th to 23rd Street areas of gain totaled 12,570 cy of sand while in the northern zone 9th to 15th Street areas of gain totaled 16,150 cy of sand or a net of 28,720 cy of sand. This represents 57% of the reported 50,000 cy of sand hauled during the project or a 43% initial project loss rate. Expanding the analysis to include the beach between placement areas and nearshore gains only, yields a larger gain of 83,510 cy of sand. Immediate losses in the offshore region in this same area were 61,240 cy of sand indicating some of this larger sand gain likely moved cross-shore towards the beach with the calmer spring wave climate. The net volume change for the entire survey area was a gain of 22,270 cy of sand. Without detailed project surveys to cover placement and sand harvesting volumes, reliance is on an accurate volume estimate based on truck loads. Delivered and counted during the project.

The CRC surveys would indicate a rapid loss of sand occurred during the project interval or inconsistency in those reported sand volumes hauled during the project. AV-35 was the only CRC profile within the northern borrow zone with pre and post construction data. Survey results showed -36.35 yds^3/ft. of sand removed from the harvest zone. Additional project before and after survey data was provided by Mott, McDonald to estimate

the sand quantity harvested from the borrow zone. These excavation volume change results are shown in figure 2 below the "Borrow Area: Elevation Change Map" for the 2016 project using this data set.

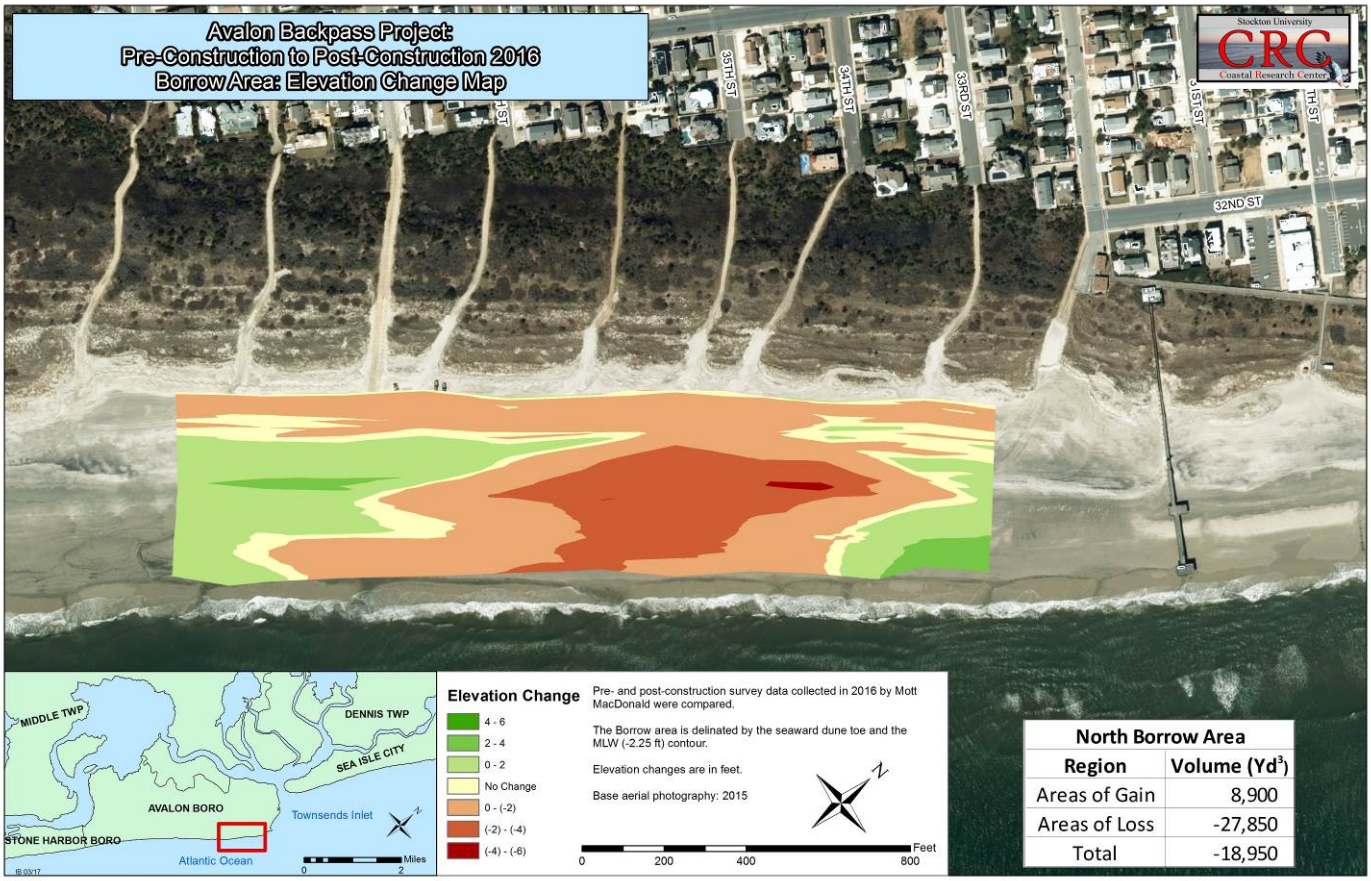

Figure 2. Above is an elevation change map comparing pre and post construction survey data collect by Mott MacDonald along the northern borrow zone beach in 2016 for the Avalon sand back-pass project. Orange and reds show areas of lower elevation (excavation) while the greens are zones of elevation gain (sand accumulation). Yellow areas are regions of no elevation change.

The beach borrow zone elevation change map shows sand excavation was focused from 33rd Street south to 38th Street. A modest elevation loss seen on the upper beach was likely background changes and not related to the project. Additional background changes occurred at the north and south edges of the borrow zones where a modest accumulation of sand added elevation as the spring 2016 wave climate during the project favored natural beach building in this region. The comparison analysis shows approximately -27,850 cy of sand was removed from the excavated region of the northern borrow zone. This volume correlates with the approximate 28,000 cy placement volume CRC pre and post construction USACE survey analysis indicate was deposited during project within the two placement zones. The reported haul volume which was 50,000 cy of sand harvested from this region, fact that indicates an astounding 44% sand recharge rate while the project was ongoing. This accretion rate in the borrow area is nearly identical to the 43% loss rate shown in the placement zone during the project. This survey data strongly suggests that the truck-haul sand volume is likely accurate and that the natural processes at work along the Avalon beachfront are very efficient and always active.

Rapid erosion removed the project berm over the summer at AV-12 (northern placement zone) but at AV-23 (southern placement area) sand accumulated onshore. No sand accumulated at AV-9, indicating the source of sand accumulation at AV-23 was longshore transport from the northern placement zone. This zone continues to be the focus of rapid erosion rates making placement and retention of small sand volumes problematic even in the short term as experienced during and following the 2016 project.

Oceanfront beaches were surveyed quarterly to depict both seasonal and annual changes, erosional and recovery rates and to assist in storm damage assessments and project performance assessments. During the sand back-pass project, each of the five engineered beach cross sections (9th to 28th Streets) were surveyed prior to sand placement and as the work was completed to estimate sand volumes placed. Winter started seriously in January 2016 ushering in a northeast storm named Jonas followed two weeks later with a second smaller event. There were no east coast hurricanes in 2016 that directly impacted the Jersey shore, with post-tropical storm (Hurricane Matthew) occurring in October as a multi-day event with modest wind velocities, but having substantial beach erosion impacts. Table 3 below shows the individual profile site trends in sand volume change by quarter for 2016.

Table 3
2016 Oceanfront Beach Profile
Quarterly Sand Volume Changes

Profile Number	Winter 12/15 - 3/16 (yds^3/ft)	Spring 3/16 - 6/16 (yds^3/ft)	Summer 6/16 - 9/16 (yds^3/ft)	Fall 9/16 - 12/16 (yds^3/ft)
8th Street Jetty				
AV-9	58.04	-31.98	-14.41	-5.66
AV-12	-31.22	-13.2	-28.78	-28.13
AV-17	-33.58	-26.64	6.25	-32.15
AV-23	26.08	-8.82	38.69	-41.59
AV-28	-9.27	-15.02	5.72	-2.49
AV-35	6.11	-47.4	32.83	20.47
AV-44	-14.19	-5.31	-9.87	15.59
AV-58	-18.32	22.98	13.57	-10.02
AV-70	-17.4	22.42	-5.77	-21.72
AV-78	-34.78	13.55	1.5	22.02
Quarterly Volume Change (yds^3) =	**-213,286**	**-80,398**	**111,973**	**-142,408**

The net seasonal total sand volume change along the Avalon oceanfront shoreline during 2016 was a substantial loss of -324,119 cy nearly offsetting the gain of 404,468 cy in 2015. In 2015, Great Lakes pumped 740,000 cubic yards of sand onto the engineered beach, unfortunately, a northeast storm in early October 2015 removed nearly 27% of the placed sand from the beaches south of 11th Street leaving approximately 537,577 cy of the project sand remaining in place. Additional losses occurred between October and December 2015.

This erosional trend continued through the winter of 2016 resulting in a net volume loss of -213,286 cy of sand. Erosion occurred both along the southern beaches and on the engineered beach but with two odd anomalies where a significant volume of sand accumulated at 9th Street (58.04 $yds^3/ft.$) and 23rd Street (26.08 $yds^3/ft.$).

The erosional trend continued but slowed during the spring for a net volume loss of -80,398 cy of sand. Early natural beach recovery occurred on the southern beaches while erosion was focused along the northern engineered beach and at 35th Street were sand harvesting occurred as part of the spring 2016 back-passing project. Over the summer months, natural sand recovery and beach building processes dominated and resulted in a net volume gain of 111,973 cy of sand. The focus of this summer gain occurred from 17 Street south, while the northern beaches continued to erode. Along the engineered beach, rapid erosion returned over the fall, while the northern borrow zone for the spring back-pass project continued to recover sand. The net volume change was a loss of -142,408 cy of sand during fall 2016.

Table 4 below shows the fourth quarter changes at each profile location following the fall 2016 seasonal changes. Shoreline position changes (zero datum NAVD88) are measured in feet. Profile volume changes were averaged with adjacent sites to calculate an average volume change then multiplied by the distance between sites to determine a net cell volume change in cubic yards. Summation of each cell volume change provides the total change in sand volume for the Avalon oceanfront beaches during the fourth quarter.

Table 4
2016 Oceanfront Beach Profile
Fourth Quarter Sand Volume Change

Profile Number	Shoreline Change (feet)	Volume Change (yds^3/ft)	Avg.Volume Change (yds^3/ft)	Cell Distance (feet)	Net Volume Change (yds^3)	
8th Street Jetty						
			-5.660	500	-2,830	-2,830
AV-9	-17	-5.66				
			-16.895	840	-14,192	-17,022
AV-12	-38	-28.13				
			-30.140	1400	-42,196	-59,218
AV-17	-51	-32.15				
			-36.870	1680	-61,942	-121,159
AV-23	-38	-41.59				
			-22.040	1400	-30,856	-152,015
AV-28	12	-2.49				
			-2.490	2025	-5,042	-157,058
AV-35	8	20.47				
			18.030	2510	45,255	-111,802
AV-44	56	15.59				
			2.785	3925	10,931	-100,871
AV-58	-21	-10.02				
			-15.870	3360	-53,323	-154,194
AV-70	-14	-21.72				
			0.150	2240	336	-153,858
AV-78	41	22.02				
			22.020	520	11,450	-142,408
Total Volume Change for Oceanfront Beaches in cubic yards =					-142,408	

Fall 2016 fourth quarter changes were again dominated by an October event. The summer season came to an end with a near miss by Hurricane Hermine over the extended Labor Day weekend. Weather forecasts were ambivalent in their calls for retrograde movements of Hermine back to the west that had all of the NJ and Delaware coastal officials on edge until it finally continued northeastward out of the region. The path did generate waves that flattened Jersey beaches and sand was moved seaward by the storm activity. A two week period of persistent onshore winds began September 28 and continued through October 10th with winds peaking to 36 mph. Hurricane Matthew began to develop in late September moving north through the Caribbean and

over Cuba. It continued its path north into the Atlantic Ocean and up the Florida coast. On October 8, it made landfall in South Carolina as a Category 1 hurricane with winds of 75 mph and emerged off the North Carolina coast. As it pulled away from the coast, Matthew began to undergo an extra-tropical transition to become post-tropical on October 9, while situated to the east of the Outer Banks. The remnants persisted, finally dissipating on October 10 as it merged with another low over Atlantic Canada. Along Jersey's coast, this resulted in heavy rain, minor flooding, steady onshore winds and significant waves causing beach erosion that continued until October 10, 2016. November through December was dominated by offshore winds and a calmer wave climate.

The early fall season wave climate caused significant beach erosion at the north end engineered beaches that are particularly exposed and vulnerable to northeast onshore wave impacts. The erosional "hotspot" from 12th Street through 23rd Street suffered the worst erosion and volume losses, with -152,015 cy of sand removed in the fourth quarter. Shoreline positions retreated from 38 to 51 feet in this region. Despite the loss of sand along the engineered beach, recovery continued in the northern borrow zone, with significant sand volume gains at 35th and 44th Streets, totaling 56,187 cy of sand, essentially the volume harvested in spring 2016 for the back-pass project. The net fall 2016 volume change for the Borough's oceanfront beaches was a loss of -142,408 cy of sand. Shoreline position changes reflected these volume changes that ranged from -51 feet of retreat at 17th Street to a 56-foot shoreline advance at 44th Street.

Early fall storm events have become a fairly regular occurrence starting with Hurricane Sandy in 2012. These storms expose summer nourishment projects conducted in 2013, 2014, 2015 and again in 2016 to erosion even before the winter storm season typically reves up in late fall. This reduced the projects stability and longevity beyond the anticipated level had the beach more time to compact to a more resilient feature before weathering repetitive storm events. In light of this emerging climate pattern, the need for a continued accelerated supply of sand feeding the system to stabilize the erosional "hotspot" has become apparent. This rate of required sand supply can be addressed through more frequent and robust back-pass efforts and hopefully natural inlet sand bypassing. However, the recent erosion rate suggests the current federal project maintenance volumes and intervals have been insufficient to keep pace with the accelerated rate of sand loss caused by this increased storm frequency and intensity during early fall since Sandy.

Table 5 on the following page shows the annual volume change for 2016. Individual profile shoreline position changes (zero datum) are presented in feet while the profile sand volume change is expressed in cubic yards per foot. A net cell volume was calculated by averaging the adjacent profile volume changes multiplied by the cell distance. A cumulative sand volume change for the Borough's oceanfront beaches was derived by the summation of the net cell volume changes.

Table 5
Oceanfront Beach Profile
2016 Annual Sand Volume Change

Profile Number	Shoreline Change (feet)	Volume Change (yds^3/ft)	Avg.Volume Change (yds^3/ft)	Cell Distance (feet)	Net Volume Change (yds^3)	
8th Street Jetty						
			6.990	500	3,495	3,495
AV-9	-53	6.99				
			-47.235	840	-39,677	-36,182
AV-12	-158	-101.46				
			-93.760	1400	-131,264	-167,446
AV-17	-142	-86.06				
			-35.960	1680	-60,413	-227,859
AV-23	65	14.14				
			-2.405	1400	-3,367	-231,226
AV-28	31	-18.95				
			-18.950	2025	-38,374	-269,600
AV-35	41	10.74				
			0.370	2510	929	-268,671
AV-44	-62	-10.00				
			-0.600	3925	-2,355	-271,026
AV-58	39	8.80				
			-5.560	3360	-18,682	-289,708
AV-70	8	-19.92				
			-10.260	2240	-22,982	-312,690
AV-78	18	-0.60				
			-0.600	520	-312	-313,002
Total Volume Change for Oceanfront Beaches in cubic yards =					-313,002	

A direct comparison between surveys conducted in December 2015 with those in December 2016 show an annual loss of -313,002 cy of sand derived largely from the northern engineered beaches. This contrasts with the 2015 annual gain of 442,786 cy of sand along the Avalon oceanfront beaches following the Borough's restoration efforts that added 740,000 cy of sand to the system by July 2015. As a result, the net volume gain to the system after two years is only 129,784 cy of sand. Following the 2015 nourishment project the engineered beach suffered an initial loss of -363,980 cy of sand, from July 2015 to November 2015. The net loss from the engineered beach in 2016 was -269,600 cy despite the addition of approximately 50,000 cy through sand back-passing. These results indicate a net volume loss of -633,580 cy of sand from the engineered beach within 17 months of the 2015 beach nourishment project.

In comparison, by December 2014 the engineered beach had lost 100% of the 2013 USACE project fill volume of 336,359 cy of sand plus an additional loss of -383,685 cy of sand for a total loss of -720,044 cy of sand eroded from the engineered beaches in just 22 months. This loss was entirely replaced at Borough expense during the 2015 nourishment project.

Avalon's north end is susceptible to erosion even during modest and moderate storm events due to its orientation to the northeast and prevailing southerly longshore currents that moves sand rapidly away from the engineered beaches. The USACE completed construction in 2016 of a massive nourishment project for southern Ocean City and all of Ludlam Island. This project introduced over 4 million cubic yards of offshore sand into the nearshore littoral system. Introduction of this sand never previously present on any historical beach into the system will dramatically alter the rate of sediment entering Townsends Inlet potentially restoring

natural sand bypassing rates to Avalon. Of the approximately 3.2 million cubic yards destined to be deposited on Ludlam Island, NJ coastal processes guarantee that about half will make its way south to Townsends Inlet over time. This process is being followed and the second iteration of the inlet review appears in its own chapter towards the end of this report.

Individual Site Review:

This section describes the changes documented at each of the cross-section locations. In general, for 2016 winter and fall losses overshadowed the Borough's 2016 sand-backpassing project designed to partially restore severely eroded beaches along the engineered beach. The Borough's sand back-passing project completed in late spring harvested sand from a borrow zone defined between 31st Street and approximately 38th Street then transferring the sand to improve beach conditions at the erosional hotspots near 23rd Street to 20th Street and 15th Street to 10th Street. Unfortunately, erosion during the fall of 2016 removed most of the project sand from these zones. Six-months following this sand back-pass project the borrow zone beaches had fully recovered the harvested sand volume.

AV-9 - Ninth Street

In 2015, beach conditions at the north end had deteriorated rapidly requiring the Borough of Avalon to undertake a full scale beach restoration project, 159.22 yds^3/ft. of new sand was placed at 9th Street. Unfortunately, subsequent rapid erosion continued removing berm width and moving the zero datum elevation shoreline position landward 212 feet by December, 2015. The sand volume removed amounted to -122.46 yds^3/ft. or approximately 75% of the sand placed six months earlier.

Winter storms in 2016 including Jonas continued to erode this section of shoreline. Storm waves overwashed the beach and reached the dune toe but did little damage other than flatten the beach berm. By March, the shoreline position had retreated 19 feet. During the same time frame a large wedge of sand accumulated nearshore resulting in a large natural net volume gain of 58.04 yds^3/ft. of sand.

Located near the 2016 backpass project taper, 9th Street did not receive any direct sand placement. Erosion continued through spring, removing -31.98 yds^3/ft. of sand by June 20. Over the summer months, an additional -14.41 yds^3/ft. of sand was lost. The nearshore slope was scoured while onshore sand accumulated along the foredune fence throughout 2016. Erosion rates slowed in fall with a net loss of -5.66 yds^3/ft. of sand removed from the beachface slope. The annual change was a modest gain of 6.99 yds^3/ft. of sand focused offshore while the shoreline position retreated 53 feet for the year.

1a. January 26, 2016

1b. June 13, 2016

1c. January 20, 2017

Photographs 1a to 1c. 9th Street view to the south.

Photograph 1a shows the beach and seaward dune slope immediately following winter storm Jonas. The dry beach is very narrow with wrack material deposited at the dune toe indicating storm wave run-up reached the fence line. The fence remained intact and little damage was suffered.

View 1b taken on June 13 follows the 2016 Sand Backpass project. Although no sand was directly placed here aeolian accumulation along the seaward dune toe has nearly buried the fence line.

View 1c Northeast storms continued to slowly erode and flatten the beach berm but the foredune continued to accumulate aeolian sand throughout 2016. Storm wave sheltering from the 8th Street jetty helps this minimal beach width at 9th Street protect the foredune while south at 10th Street erosion has exposed the rock revetment.

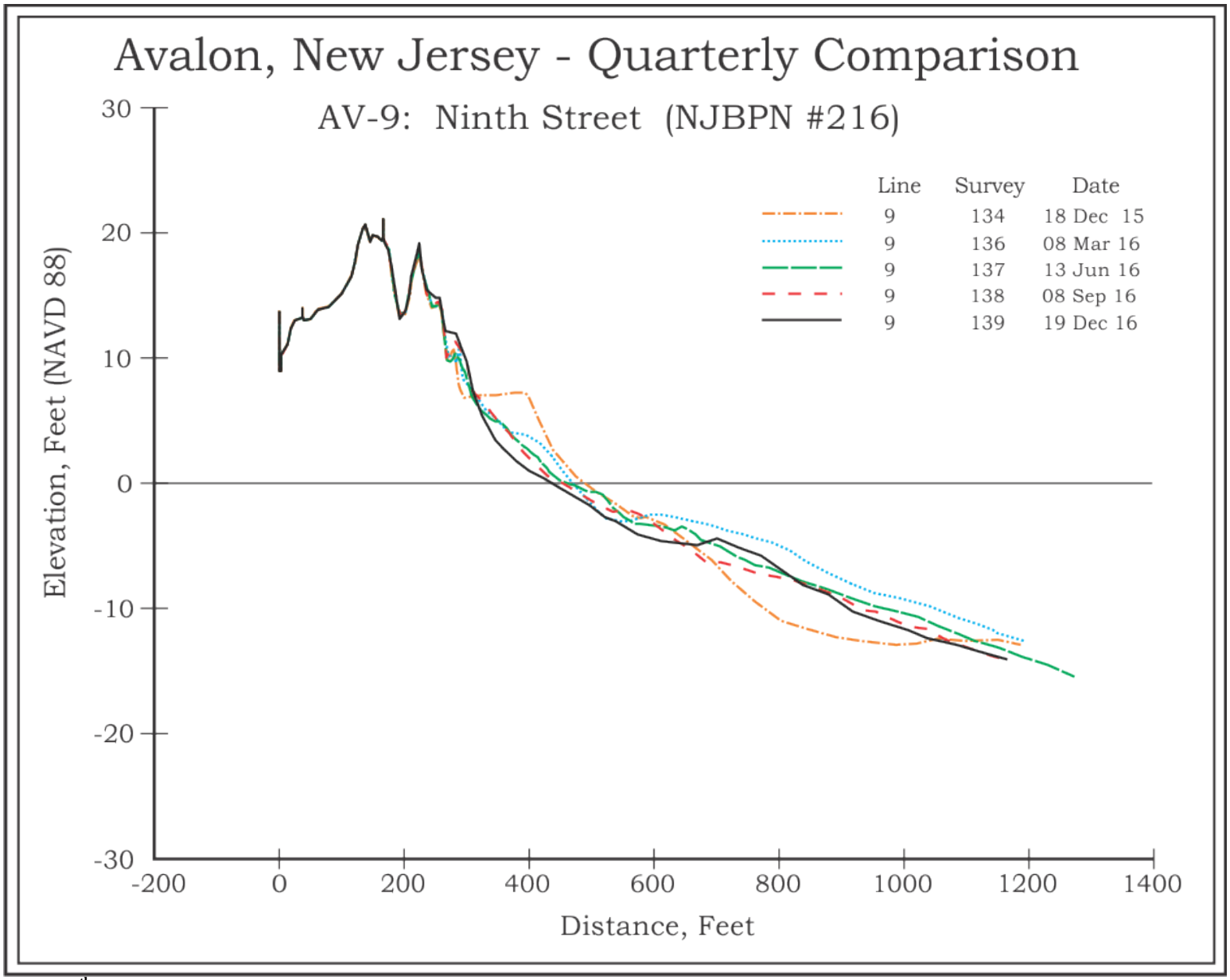

Figure 3. At 9th Street the four quarterly surveys combined with the December 2015 annual survey demonstrate steady erosion of the beach berm and beachface slope while the foredune continued to accumulate sand. Offshore following an initial influx of sand the seafloor was slowly scoured over the remainder of 2016. Rapid erosion since the Avalon 2015 nourishment project placed 159.22 yds^3/ft. of sand advancing the shoreline position 300 feet has returned conditions to nearly pre-project configuration. Pockets of sand accumulation on the foredune and offshore resulted in an annual volume gain of 6.99 yds^3/ft. despite 53 feet of shoreline position retreat and 80 feet of recreational berm width lost.

AV-12 - Twelfth Street

The Borough's 2015 beach nourishment project added 209.12 yds^3/ft. in new sand to this site and restored the recreational beach berm. Erosion following the project removed -95.59 yds^3/ft. of sand, with 159 feet of shoreline retreat in the first six-months. Winter storms in 2016 did moderate damage to this beach, cutting into the berm and seaward dune slope. Winter storm Jonas removed -32.05 yds^3/ft. of sand from this site resulting in 90 feet of shoreline position retreat. Erosion of the seaward dune slope cut a 10-15 foot high scarp from the crest to beach. The rock revetment in this location remained buried, but rocks were exposed at 11th Street.

During the spring of 2016 the Borough's sand backpass project moved material to this location. The onshore change at this site from March to June was a gain of 11.50 yds^3/ft. of sand and a shoreline position advance of 36 feet. A narrow 50 foot wide beach berm was established in time for summer recreational use and the seaward dune slope scarp partially restored to allow safer beach access. Even though the project restored a modest beach overall the site continued to erode for a net loss of -13.20 yds^3/ft. of sand from nearshore.

The erosional trend continued through the summer and fall with an additional -28.78 yds^3/ft. of sand removed by September 9, 2016 and -28.13 yds^3/ft. of sand lost during the fall. All the project sand was removed from the beach and dune cut landward while the nearshore was scoured. A 15 foot high dune scarp was left from the dune crest to the exposed rock revetment. The net volume loss for 2016 was -101.46 yds^3/ft. of sand with 158 feet of shoreline retreat. There was no evidence of cross-shore sand movement offshore indicating longshore currents continue to be the dominant force effecting sediment transport in this region. Exposure of this shoreline to approaching waves from the northeast combined with the longshore rapid movement of sand to the south continues to make this region an erosional hotspot.

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2a. January 26, 2016

2c. December 18, 2016

2b. June 13, 2016

Photographs 2a to 2c. 12th Street Views to the south.

Photograph 2a shows 12th Street following winter storm Jonas. The beach is narrow and the berm was flattened. The seaward dune slope was cut landward by storm waves, leaving a 15 foot high scarp. A narrow dry strip of sand remained where the seaward dune toe had extended to prior to Jonas. No rocks were exposed following Jonas at this site.

View 2b was taken in June following the sand back pass project project. The beach remains relatively narrow but sand added has raised the berm elevation. Sand was added to the dune restoring a more gradual seaward slope and safer access to the beach.

View 2c was taken December 18th following a series of storm events that started in September with tropical storm Hermine. During the fall waves cut away at the beach and dune. The access pathway was destroyed leaving a scarp in the seaward dune slope, exposing the revetment rocks buried below, with essentially no dry beach remaining.

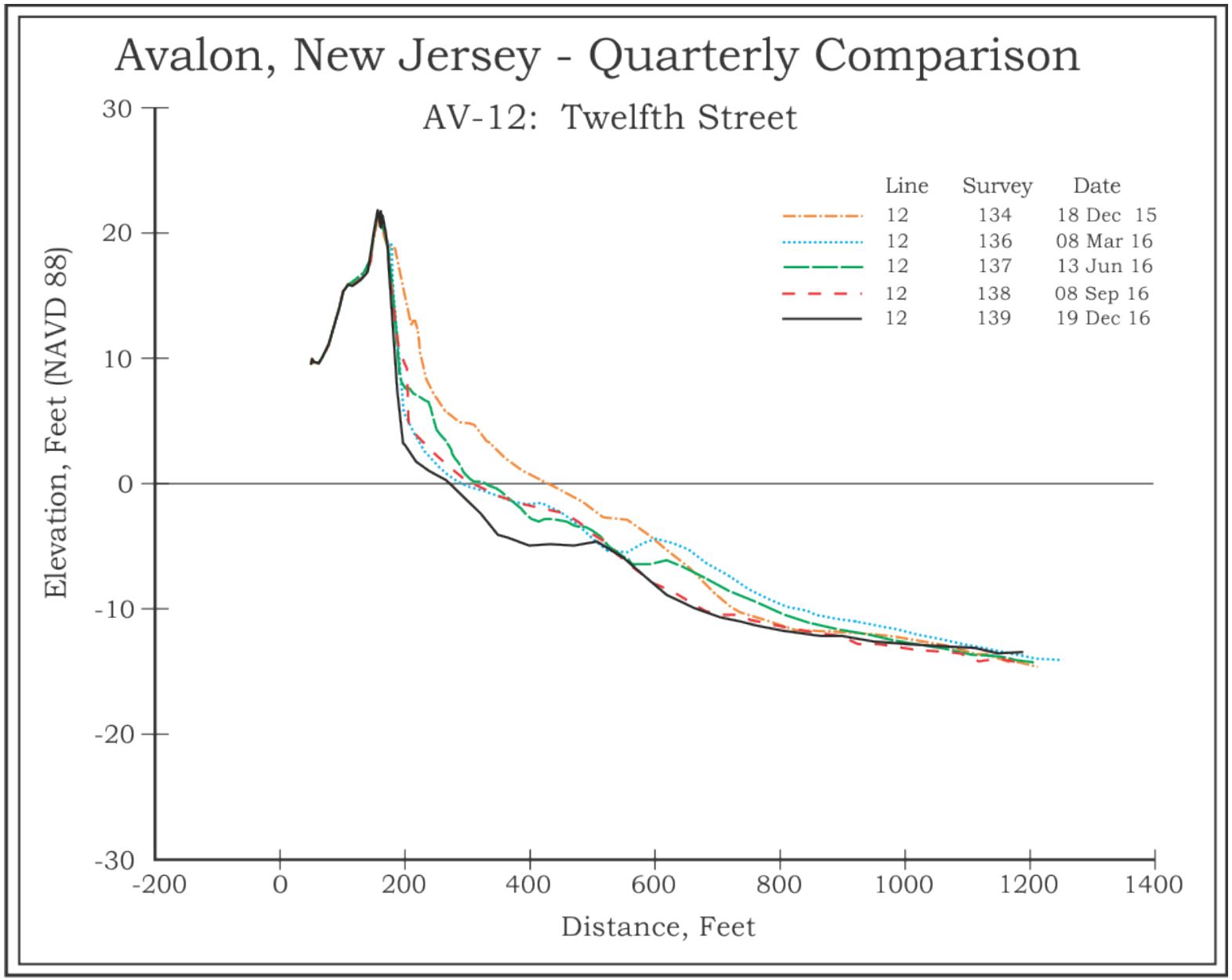

Figure 4. The first quarter of 2016 shows the eroded state of the site following winter storms with a steep dune scarp dropping straight down from the crest to the rocks. By June the berm was partailly restored following sand back passing. Following the project the shoreline has retreated and sand was scoured from the dune, beach and nearshore, no sand accumulation occurred anywhere along the profile. The annual changes for 2016 was 158 feet of shoreline retreat and a net loss of 101.46yds^3/ft. of sand, losses occurred from the seaward dune crest to 700 feet offshore, near the profile limits.

AV-17 - Seventeenth Street

The profile is located at the southern terminus of a rock revetment which continues north to 8th Street, at this location no exposure was noted in 2016. The 2015 Borough nourishment project added 125.13 yds^3/ft. with a 231-foot shoreline advance. Within six months the beach configuration flattened out with a loss of -46.75 yds^3/ft. of sand as the shoreline position retreated 71 feet. Affects from winter storm Jonas, that struck the coast in January 2016, removed an additional -18.57 yds^3/ft. of sand and another 62 feet of shoreline retreat.

By March 2016, winter storms had eroded the remaining project beach berm and scoured the nearshore seafloor. A narrow flattened strip of sand remained seaward of the dune toe that had suffered minor scarping along the foredune toe during the storms. The net volume change over the winter was a loss of -33.58 yds^3/ft. of sand.

This site is located just south of the northern sand placement zone identified for the sand backpass project as between 9th to 15th Streets but indirectly received sand through natural longshore transfer of material. This process added 7.88 yds^3/ft. of sand to the beach. Sand accumulated on the berm and along the foredune toe. This beach berm deposit was eroded away by September 8 following the offshore passage of Hurricane Hermine. Beach erosion and nearshore scouring continued through the fall resulting in a net loss of -32.15 yds^3/ft. of sand with 51 feet of shoreline retreat. Although the beach eroded, the foredune toe continued to accumulate aeolian sand. Net change for 2016 was a volume loss of -86.06 yds^3/ft. of sand with 142 feet of shoreline position retreat from December 2015 to December 2016.

3a. January 26, 2016

3b. June 13, 2016

3c. December 18, 2016

Photographs 3a to 3c. 17th Street, view to the south.

Photograph 3a shows the low narrow dry beach at 17th Street following winter storm Jonas. Storm wave run-up reached the foredune toe and fence line scouring a small scarp along the toe and deposited wrack material. Wave energy in this region was not sufficient to cause damage to the fence.

View 3b the sand backpass project in spring added sand here, the beach elevation was raised and the dune slope restored. Beach width supported summer recreational activity and provided a source of sand for continued aeolian sand accumulation on the foredune.

View 3c shows the impact of storms in fall 2016 that reduced the beach berm width and elevation. The dune system here was spared erosion with aeolian sand accumulation continuing on the foredune.

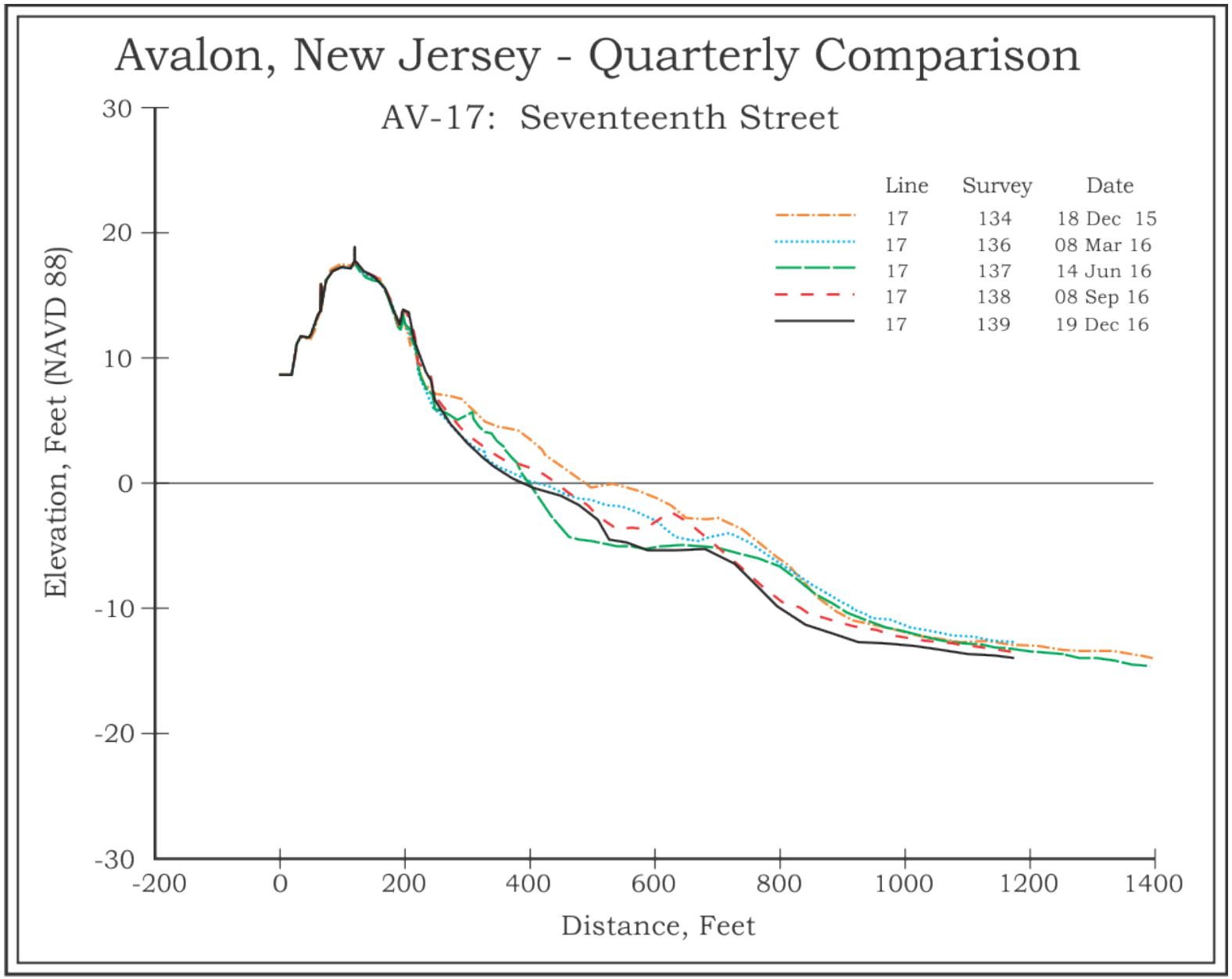

Figure 5. The five surveys document continued retreat following the 2015 Avalon Borough maintenance effort. Initially sand was scoured from the nearshore and beachface slope cutting the beach berm landward towards the dune toe. Sand backpassing efforts during the spring temporarily restored a 50-foot wide recreational beach berm for summer while nearshore scouring continued. Beach erosion resumed over the summer and continued into the fall with seafloor scouring removing sand to the outer profile limits. Subsequent adjustments resulted in an annual net volume -86.06 yds^3/ft. of sand along with a 142-foot shoreline position retreat from December 2015 to December 2016.

AV-23 - Twenty Third Street

The 23rd Street cross section is located seaward of the Avalon boardwalk near the southern end of the engineered beach and federal project. Sand placement in July 2015 created an extensive berm as 123.36 yds^3/ft. in new sand was added. The shoreline advanced 216 feet in the process. Extremely rapid erosion during the fall resulted in the loss of 75.65 yds^3/ft. and a 192-foot shoreline retreat by December 2015. Winter storm Jonas and smaller events continued to erode the beach and cut into the seaward dune slope leaving a 10 foot high scarp from the crest to the beach. The pipeline was exposed to the dune as the beach was flattened and the shoreline retreated landward. Although sand was stripped from the beach it was transferred cross-shore and accumulated nearshore and further offshore. Additional sand moved longshore from the erosional northern beaches and accumulated here offshore, resulting in a net volume gain of 26.08yds^3/ft. of sand.

Sand backpassing placed sand directly on this site during the spring restoring a 100-foot wide beach berm. Sand was also pushed up against the dune scarp partially restoring the seaward slope to allow for safe beach access. The project added 17.03 yds^3/ft. of sand to the beach and advanced the shoreline positon 48 feet. While sand was being placed onshore seafloor scouring took place nearshore and offshore offsetting the gains onshore resulting in a net loss of -8.82 yds^3/ft. of sand from March to June 2016.

Over the summer, a large wedge of sand moved onto the profile. Sand accumulated from the seaward dune toe across the beach and beachface slope to the nearshore where a large shore parallel bar developed. This sand was likely eroded from the northern beaches then transferred south on longshore currents. The net volume gain was 38.69 yds^3/ft. of sand that raised the recreational beach berm two feet and advanced the shoreline position 57 feet.

Fall 2016 saw an erosional trend return to all of the engineered beach sites with an increase in storm activity. Waves and currents eroded the beachface slope and nearshore seafloor that flattened and removed a well-developed nearshore sand bar. Storm waves and surges were not severe enough to overtop the developed summer beach berm that protected the seaward dune toe from any additional damage a thin veneer of sand was also lost further offshore. The net result was 38 feet of shoreline retreat with -41.59 yds^3/ft. of sand removed from September to December 2016. Cumulative seasonal changes still resulted in a net volume gain of 14.14 yds^3/ft. of sand and a 65-foot shoreline position advance despite the significant fourth quarter losses. This site benefited both directly and indirectly from the backpass through sand placement and natural sand accumulation as sand eroded from the northern beaches was transferred south through this location. Unfortunately, these gains are likely temporary and as the northern beaches further erode and become sand starved the erosional progression will translate south towards this site.

4a. January 26, 2016

4b. June 13, 2016

4c. December 18, 2016

Photographs 4a to 4c. 23rd Street, views to the north.

Photograph 4a shows the dune erosion at this site caused by winter storm Jonas. The storm outfall pipeline (distance) is exposed to the dune and the beach is flattened and narrow.

View 4b was taken immediately following sand placement during the backpass project. The storm pipeline is now partially buried again as the restored beach extends to the outfall end. Sand also accumulated along the toe of the dune scarp.

View 4c was taken in late fall, this site continued to accumulate sand following completion of sand backpassing. The dune slope has been partially restored through natural aeolian processes and the beach berm elevation was raised. The beachface slope eroded over the fall exposing more of the pipeline.

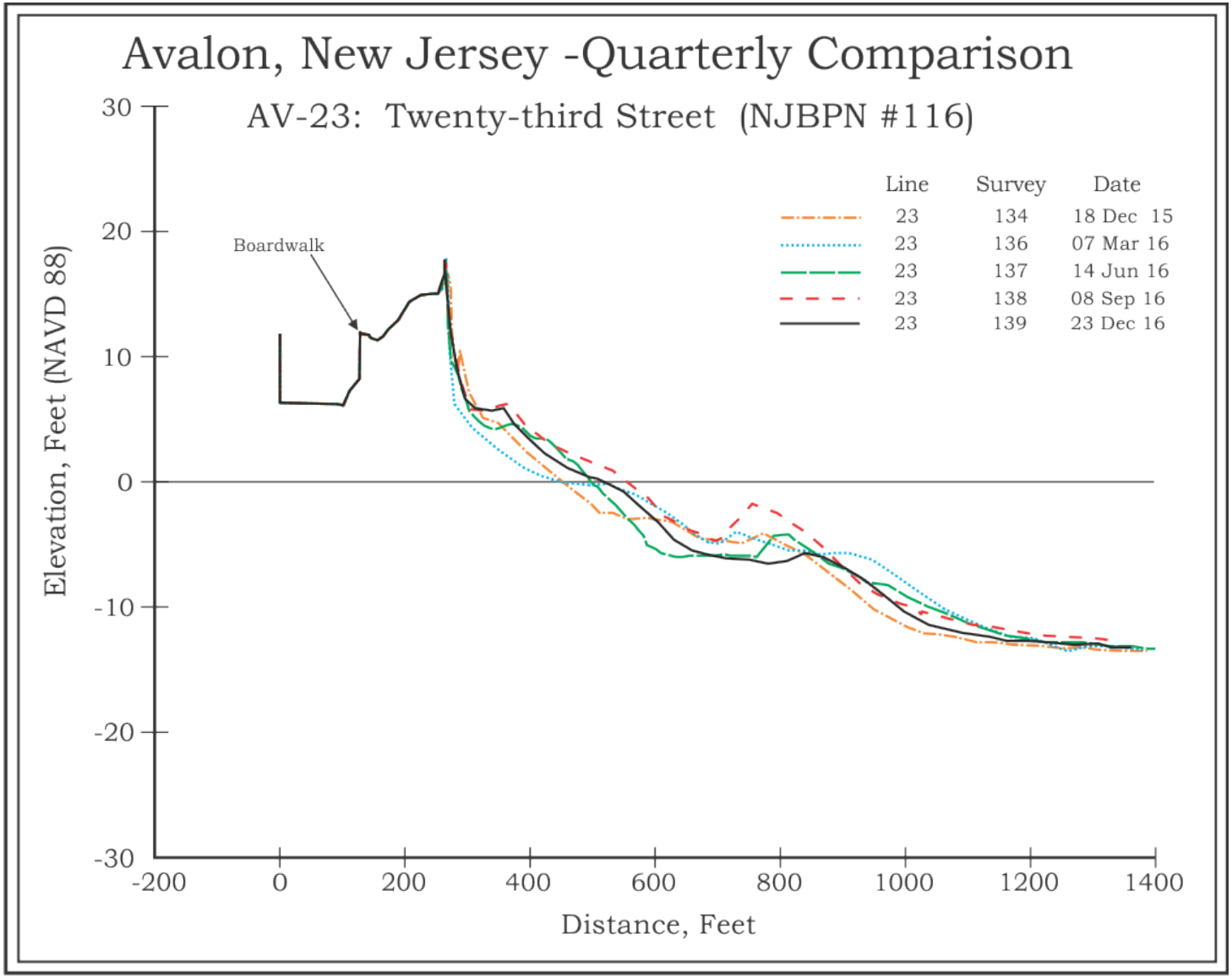

Figure 6. The five profiles show the significant variation in beach configurations in 2016. Winter storms combined to initially erode the beach and seaward dune slope leaving a vertical scarp 10 feet high and removing the dry recreational beach berm. During the spring, the 2016 backpass project restored a 100 foot-wide beach berm and partially restored the seaward dune slope, allowing for safe access to the beach. Natural sand recovery continued here through the summer, elevating the beach berm nearly two feet as sand accumulated nearshore and on the beachface slope then pushed onshore during the favorable summer wave climate. During the fall, the dry beach provided a source for aeolian sand that accumulated on the seaward dune slope. Early fall storm events began to erode the beachface slope and scour the nearshore seafloor, flattening a significant shore parallel sand bar that had developed over the summer. The net result for the year was a significant shoreline position advance of 65 feet with the addition of 14.14 yds^3/ft. of sand.

AV-28 - Twenty Eighth Street

The 28th Street location is situated in a transition position along the barrier island between an erosional zone to the north and accretional area to the south. This site typically benefits from predominant longshore current transport of sand south from the north end erosional beaches. Although included in the federal project scope this beach typically has not received sand during the USACE maintenance projects. The 2015 Avalon beach maintenance did not directly place any sand on this location either, nor did the 2016 sand backpass project. Following the 2015 project this site gained 46.66 yds^3/ft. from July to December, accompanied by a 42-foot shoreline advance seaward. The magnitude of the sand volume increase is an example of the influx of sand from the erosional beaches to the north.

Winter storm Jonas cut into the beach and seaward dune slope leaving a 4-6 high vertical scarp from the foredune crest to the beach with nearshore scouring, the shoreline retreated 31 feet and the beach lost -12.65 yds^3/ft. of sand. Modest offshore gains reduced the net winter loss to -9.27 yds^3/ft. of sand from December 2015 to March 2016. During the spring, the erosional trend continued for a net loss of -15.02 yds^3/ft. of sand. Sand accumulated on the beachface slope restoring a low berm ridge but the nearshore seafloor was scoured offsetting the gains onshore.

Sand continued to push onshore during the summer adding sand to the beach and along the dune toe, offshore sand moved landward forming a nearshore bar. Net change was a gain of 5.72yds^3/ft. of sand. Through the fall sand continued to move landward and pushed higher onto the upper beach building a typical summer beach berm but in late December, sand also accumulated along the seaward dune toe. Further offshore sand was removed resulting in a modest net volume loss of -2.49yds^3/ft. of sand, more typical of predominant cross-shore sediment movement. By the end of the year, the beach berm width and elevation was at its peak position, resulting in a shoreline position advance of 31 feet, but losses offshore and from the dune resulted in a net volume loss of -18.95 yds^3/ft. of sand.

5a. January 26, 2016

5b. June 15, 2016

5c. December 23, 2016

Photographs 5a to 5c. 28th Street, views to the north.

Photograph 5a was taken just after winter storm Jonas. The beach was flattened and narrowed with a 4-6 foot scarp cut into the seaward dune slope.

View 5b shows the 28th Street beach following the sand backpass project. No sand was added this far south, but subsequently, evidence points to some sand migrating to this location.

View 5c is a view December 23, 2016. Sand has accumulated naturally on the beach berm and along the seaward dune toe nearly restoring the damage from Jonas.

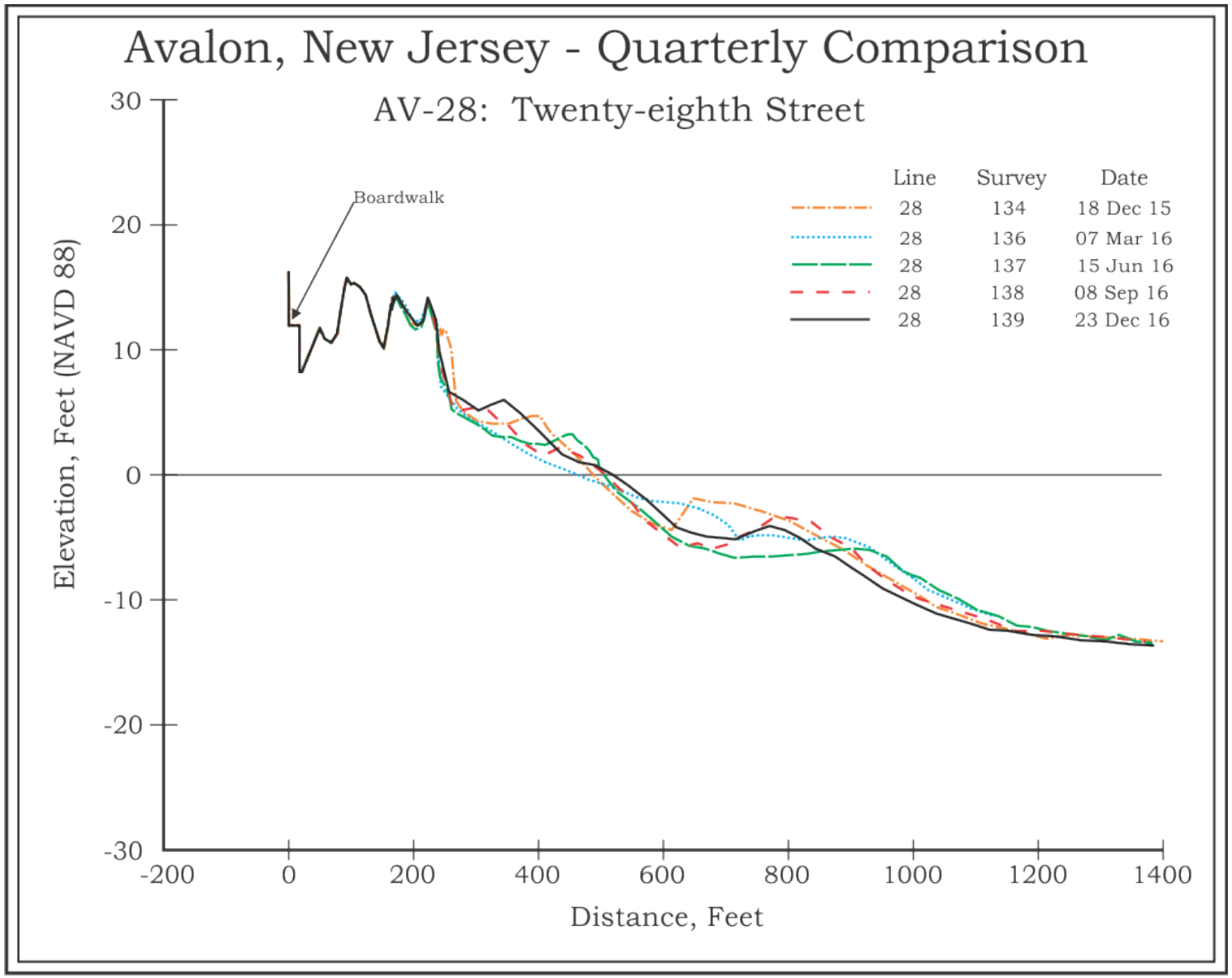

Figure 7. This site suffered dune and beach erosion as a result of winter storm in 2016. The seaward dune slope was cut into a vertical scarp, beach berm was flattened, nearshore scoured and sand transferred offshore. Positioned south of the vast majority of maintenance fill efforts, this site gains sand natural as those to the north lose material, consequently, it was not included in the 2016 backpass effort. Natural spring and summer beach building processes restored a summer recreational beach berm. Sand continued to feed onto the beach through fall 2016 and the beach berm built higher onto the upper beach with aeolian sand partially restoring the seaward dune slope. The net change for the year was a 31-foot seaward advance in the shoreline position with a volume loss of -18.95 yds^3/ft. of sand, as offshore losses offset onshore gains.

AV-35 - Thirty Fifth Street

This site has shown steady growth since monitoring at this location commenced. Growth has been through natural processes as no beach restoration sand has ever been deposited directly on this site. The beach has steadily accreted sand since the initial 1987 beach nourishment project added sand to the northern engineered beach. Sand accumulation has been so dramatic here that the current primary dune marks approximately the old shoreline position in 1987. As a result of this remarkable natural accumulation of sand this section of shoreline was designated as the northern borrow zone for sand backpassing projects.

Initially sand eroded from the beach as winter storm Jonas and the winter wave climate flattened the beach berm but did no damage to the dune system. The June survey shows results of sand harvesting for the 2016 sand backpass project. This region was again designated the primary borrow zone to avoid potential disturbance to the southern exclusion zone. The harvest zone is evident in the profile plot on the lower beach with up to three feet of material excavated vertically along approximately 200 feet of the profile. Comparison of the winter to spring surveys show 36.35 yds^3/ft. of sand was harvested from this site. Harvesting sand to MLW pulled the zero datum shoreline position landward 206 feet from March to June.

Natural recovery occurred rapidly over the summer months, longshore and cross-shore sediment transport supplied sand from the northern beaches and offshore while the summer wave climate moved sand onto this shoreline. By September, the pre-harvesting shoreline position was restored, advancing seaward 197 feet in just three months through the natural beach building process. Within three months 57% of the sand volume (20.74 yds^3/ft.) harvested from the beach was restored onshore building a summer beach berm 200 feet wide seaward of the dune toe.

Through fall 2016 sand continued to accumulate onshore and nearshore. By December 19th the excavation area was completely filled with an excess of material forming a 320-foot wide beach berm at elevation 5ft. NAVD88, six feet vertically above the post-harvest excavation beach grade. Another 16.65 yds^3/ft. of sand was added the beach bringing the accumulated volume onshore following harvesting to 37.39 yds^3/ft. of sand, or 103% of the sand volume excavated just six months earlier. This rapid natural recovery again demonstrated the incredible resiliency of this section of shoreline and viability of harvesting sand from this region to extend the interval between major nourishment cycles at the north end. The annual sand volume change was despite sand harvesting was a net gain of 10.74 yds^3/ft. sand with 41 feet of shoreline position advancement. The extensive beach width also supported continued dune growth throughout the year even with sand harvesting.

6a. January 27, 2016

6b. June 15, 2016

6c. December 23, 2016

Photographs 6a to 6c. 35th Street, views to the north.

Photograph 6a shows the conditions following winter storm Jonas and before sand backpassing commenced. The beach was flattened by the storm, wrack debris provides evidence that storm waves reached the toe but did no damage.

View 6b photo taken in June 2016 shows deposition around a new row of fence as the process of dune growth continues. A wet runnel on the lower beach (distance) demarks the region of sand harvesting during the 2016 sand backpass project.

View 6c was taken approximately 6-months following sand harvesting. The beach elevation and width have fully recovered and the dune fence continued to trap aeolian sand from the wide beach.

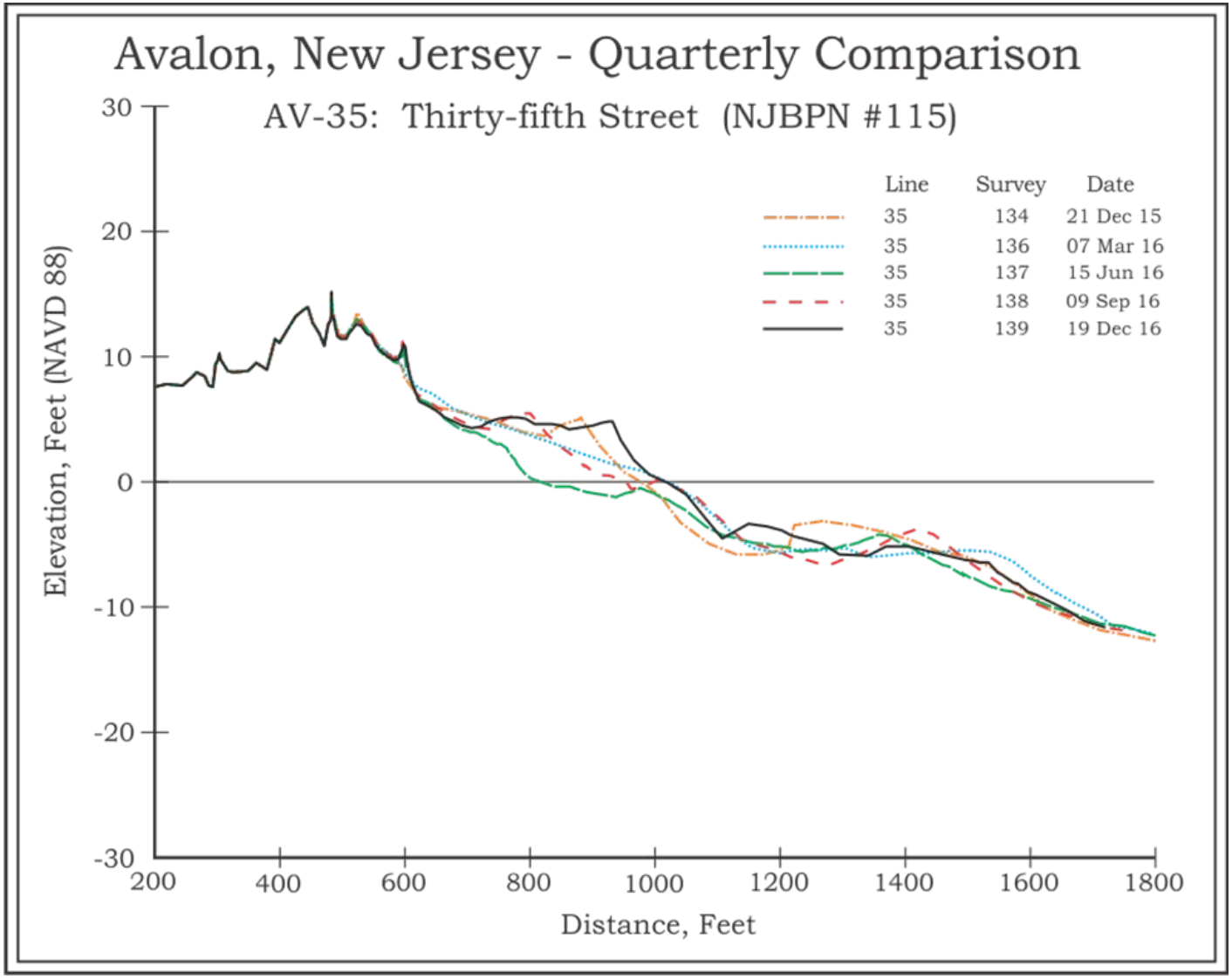

Figure 8. 35th Street is located near the center of the northern borrow zone. Winter storms in 2016 had flattened the beach berm but sufficient sand remained in place to harvest for the 2016 backpass project. The June profile (#137) shows the excavation immediately following sand harvesting. By September 9th, approximately three-months following sand harvesting the beach berm had recovered through natural processes. After six-months full recovery had occurred with development of a higher and wider beach berm than the year before harvesting. Despite sand harvesting, the net profile changes for the year was a volume gain of 10.74 yds^3/ft. of sand with 41 feet of shoreline position advancement, demonstrating the incredible resilience of this section of shoreline.

AV-44 - Forty Fourth Street

This site is located within the exclusion zone and in the Avalon "High Dune Area" comprised of over 100 acres of premier coastal dunes along the New Jersey shoreline. The dune system is a 1,000-foot wide zone that extends seaward from the 50-foot elevation primary dune along Dune Drive and is populated by multiple ridges of lower elevation that have accumulated and expanded quickly over many decades as the beach rapidly accreted seaward. The sand feeding this expansion has come from the northend erosional zone. The sites natural exclusion zone primarily was established to preserve habitat for endangered and threatened shorebirds. As a result and despite the abundance of available sand accumulating in this region annually no sand has been harvested from this region during the Borough's multiple sand back-passing programs including 2016.

During the winter of 2016 the beach berm was flattened and nearshore scoured resulting in a net loss of 14.19 yds^3/ft. of sand. Through spring and summer natural beach building processes pushed sand higher onto the upper beach restoring a narrower recreational beach berm, as the berm built higher the shoreline the beachface slope steepened pulling the shoreline position landward. The new berm position still provided over 100 feet of dry beach seaward of the dune toe. Offshore sand moved landward partially filling the deep nearshore scour trough cut over the winter. By fall, waves from early storm events had reduced the beach berm elevation, but the sand was only spread across the beachface slope helping to maintain the wider beach but with a flattened configuration. Nearshore the wide trough continued to persist as sand slowly moved landward. The fourth quarter showed modest sand recovery with 15.59 yds^3/ft. of sand added to the system and 56 feet of shoreline position advance. Though positive, this influx of sand did not completely offset the winter losses, resulting in a net annual modest volume loss of -10 yds^3/ft. of sand, with 62 feet of shoreline retreat as the beach berm configuration had not yet fully redeveloped.

7a. December 21, 2015

7b. June 20, 2016

7c. December 19, 2016

Photographs 7a to 7c. 44th Street, views to the north.

Photograph 7a is a view northeast across the foredune area and beach. Located within the exclusion zone rapid dune growth still occurs without dune fencing as the region continues to accumulate sand and the dune expands seaward through natural aeolian processes.

View 7b is the same view in June, vegetation has colonized the seaward slope as this foredune continues to expand. The dry wide beach is roped off for nesting shorebirds.

View 7c is a view to the south in December 2016 showing the wide dry beach continues to accumulate sand supporting foredune development and expansion of the system seaward onto the upper beach.

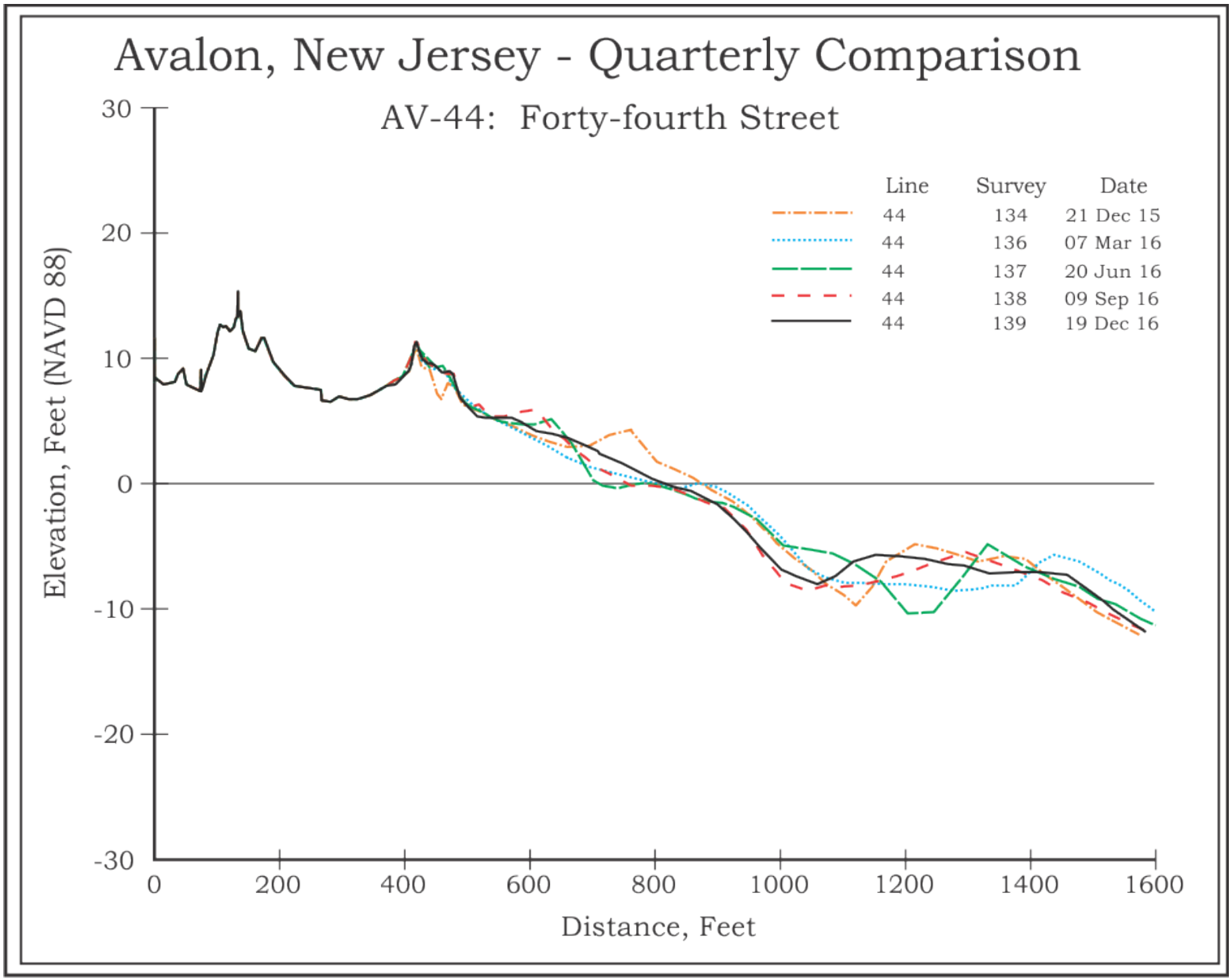

Figure 9. Following winter storm Jonas and the winter wave climate the beach berm was flattened and the nearshore scoured. Over the rest of the year sand accumulated nearshore, on the beach and in the dune but at a slower rate than seen at 35th Street. As a result, the storm losses experienced over the winter persisted with a net volume loss of 10 yds^3/ft. of sand and 62 feet of shoreline retreat. Fourth quarter results are encouraging that this net lingering storm loss would be fully recovered in 2017 with the absence of any significant storm events, as the site gained 15.59 yds^3/ft. of sand advancing the shoreline seaward 56 feet from September to December 2016.

AV-58 - Fifty Eighth Street

The 58th Street site has shown a long term accretional trend over the monitoring history. This site lies at the southern margin of the Avalon high dune area and natural area exclusion zone. Currently, 350 feet of dune width protects oceanfront properties in this region. With an additional 300 feet of beach width to support dune growth shore protection continues to be enhanced.

From December 2015 to March 2016 the winter wave climate and winter storm Jonas combined to erode the beach and flatten the beach berm. Some sand was pushed landward to the dune toe with additional eroded sand pulled lower onto the beachface slope and carried offshore resulting in a net volume loss of -18.32 yds^3/ft. of sand.

Spring wave climate favored beach building processes and offshore sand moved landward and onto the beachface slope. This early season addition of sand raised the lower beach elevation a foot, the shoreline position advanced seaward 26 feet with the addition of 22.98 yds^3/ft. of sand to the profile. With a gentle summer wave climate more sand moved landward and onshore, beach building processes accelerated restoring the wider and higher summer beach berm. The site continued to accumulate sand with an additional 13.57 yds^3/ft. of sand added through longshore and cross-shore sediment movement. However, by the end of the fall, several modest storm events had caused minor erosion on the beachface slope, the net result was a modest loss of -10.02 yds^3/ft. of sand. Overall, the site continued the long term accretive trend, with 8.80 yds^3/ft. of sand added to the profile and a 39-foot shoreline position advance.

8a. December 21, 2015

8b. June 20, 2016

8c. December 19, 2016

Photographs 8a to 8c. 58th Street, views to the south along the seaward dune toe.

Photograph 8a illustrates the broad expanse of the dry beach that extends seaward from the edge of the dune grass. The wide beach supports continued dune growth as evident by the new foredune accumulation of sand along the zig zag fence row.

View 8b is a view looking south in June across the wide, dry beach with the accretional seaward foredune continuing to develop. This wide beach provides extensive area for seasonal recreational activities.

View 8c shows the December 2016 dry beach and dunes. Despite a several fall storm events that caused erosion on the north end, this section of shoreline with its wide beach continued to support dune growth.

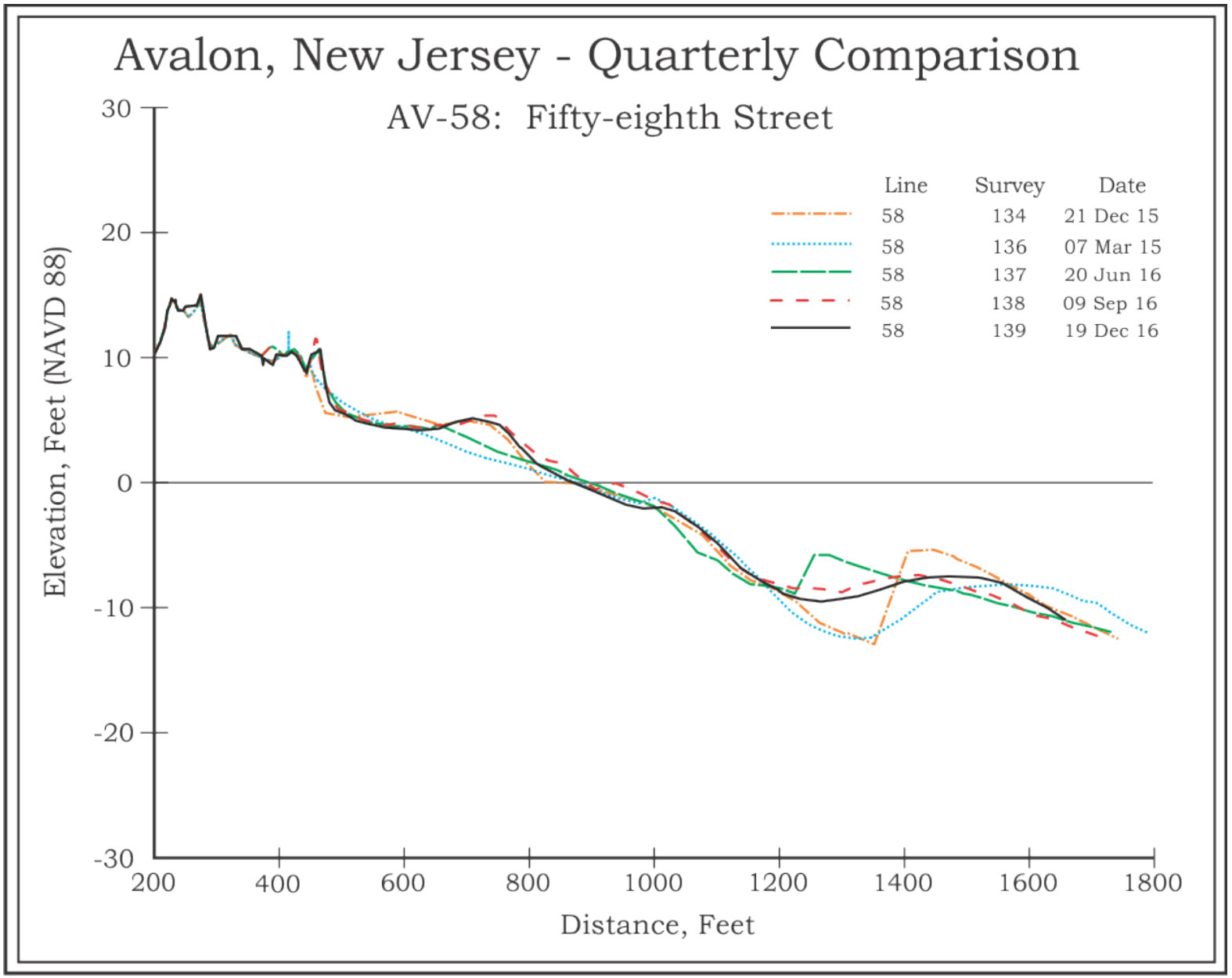

Figure 10. Winter storm Jonas surge and waves eroded the beach and flattened the beach berm. Over the spring season, sand moved towards the shoreline and onto the beach, starting the process of natural beach building. This process continued through summer and fall restoring the beach configuration to nearly the same as prior to Jonas. The foredune feature continued to accumulate sand all year further expanding the dune system onto the upper beach. Annual changes this year amounted to a shoreline position advancement of 39 feet with the addition of 8.80 yds^3/ft. of sand.

AV-70 - Seventieth Street

The 70th Street dune has continued to expand by the end of 2016 the cross section was nearly 270 feet wide with a crest elevation of 16 feet NAVD88 seaward of the development. Since 1998, an aeolian process derived from sand on the wide dry recreational beach area has supported growth. Repeated fencing installation over the past 18 years has driven the seaward expansion of the dune. The wider beaches in this region not only support continued dune growth but provide a potential source of sand for future sand backpassing projects, this location was last utilized during the 2014 project. This site has remained stable to slightly accretive and is located just north of the Stone Harbor section taper of the 2003 Seven-Mile Island Shore Protection Project.

From December 2015 to March 2016 the beach berm and beachface slope were severely eroded. Winter storm waves flattened the beach and carried sand to the nearshore, the offshore bar moved further seaward. The winter losses were 30 feet of shoreline retreat with -17.40 yds^3/ft. of sand removed from the profile. Spring wave climate was favorable for early beach building. The offshore bar moved landward and sand pushed onshore. Cross-shore and longshore sand movement added 22.42 yds^3/ft. of sand to the site, fully restoring the winter sand volume deficit.

Sand continued to push onshore during the summer months, building a higher recreational beach berm that mimicked the December 2015 configuration seen prior to Jonas, including the shoreline position. Unfortunately, the nearshore slope was scoured and the bar crest elevation flattened resulting in a modest sand volume loss of -5.77 yds^3/ft. of sand over the summer season. With the fall season, a pattern of modest storm events developed, the beachface slope and berm absorbed the wave energy allowing the foredune to continue to grow, while the nearshore slope was scoured. The result was a loss of -21.72 yds^3/ft. of sand from September 9th to December 19, 2016. Annual changes reflex these fourth quarter losses, predominantly offshore on the bar and nearshore for a net volume loss of -19.92 yds^3/ft. of sand, despite a modest shoreline position advance of eight feet.

9a. December 21, 2015

9c. December 19, 2016

9b. June 19, 2016

Photographs 9a to 9c. 70th Street, views to the south along the dune toe.

Photograph 9a shows the dune toe and beach conditions at the end of December 2015. The fence has accumulated sand and is nearly buried. The wide dry beach supports continued dune growth both as a source of sand and as a wave buffer.

View 9b shows a near identical view with the a new fence installed and the old fence all but buried following the winter and spring seasons.

View 9c shows the view to the south along the same fencing placed earlier in the year. By December 2016 it is half buried as dune growth continued.

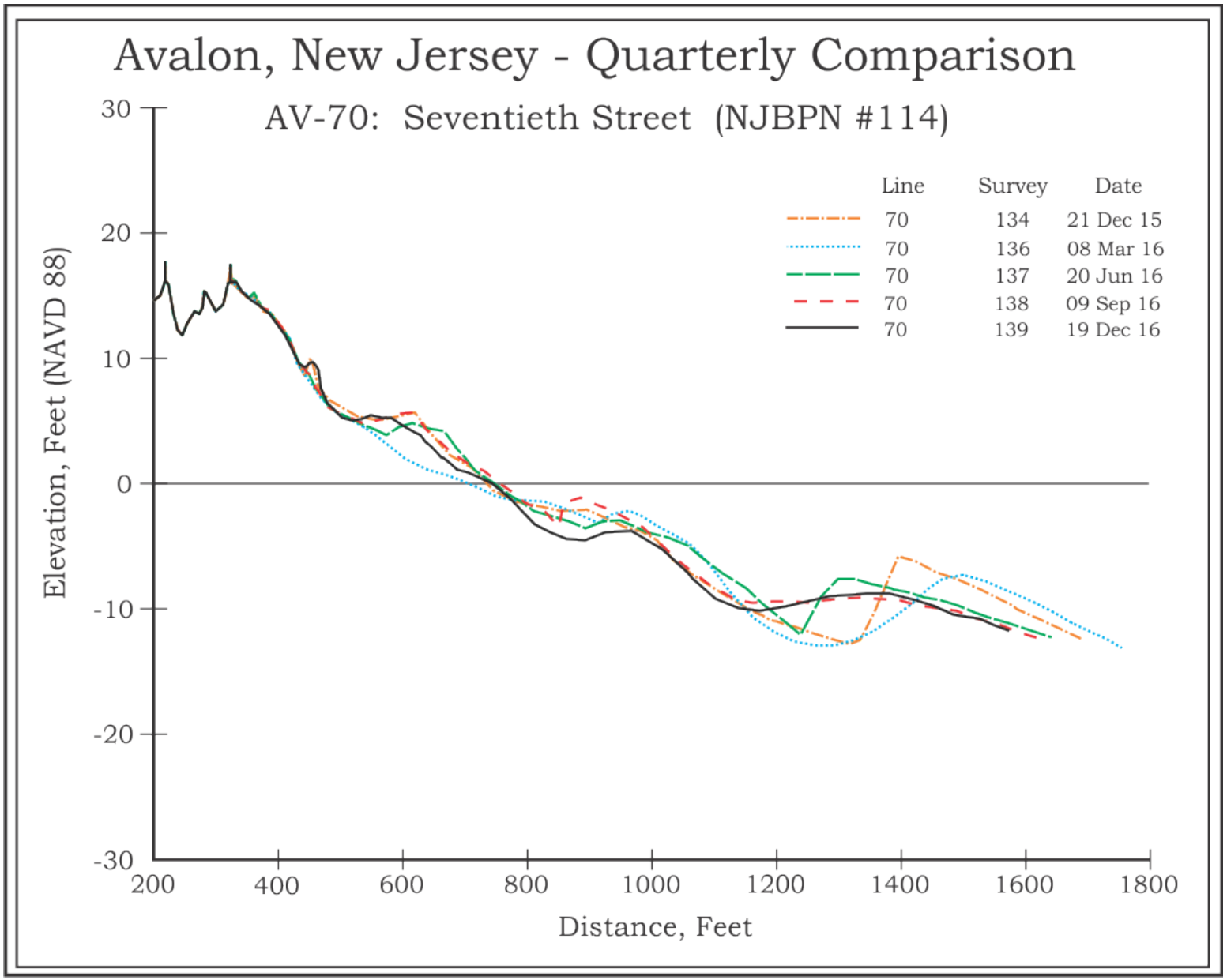

Figure 11. Winter storm Jonas and the winter wave climate completely eroded the beach berm present in December 2015. Sand accumulated nearshore and the offshore bar moved seaward. By June, sand had already begun to move back onshore and the bar had migrated landward. Over the summer, sand pushed higher onto the beach fully restoring the beach berm as sand continued to move cross-shore onto the beach. Erosion returned in the fall, waves cut into the beachface slope and beach berm while scouring the nearshore. The net change for the year was a modest shoreline position advance of 8 feet but the nearshore scouring and loss of the offshore bar removed -19.92 yds^3/ft. of sand from the site.

AV-78 - Seventy Eighth Street

This site is located near the boundary with Stone Harbor and is within the placement taper for the Stone Harbor federal nourishment project. However, this site did not receive sand directly during the last nourishment cycle. The dune system is narrower in this region, currently the dune is approximately 200 feet wide with a maximum crest elevation of 18 feet. As a result of commercial development's encroachment (110 feet) on the landward dune slope the dune system is narrower than the sites to the north.

This beach also suffered the same winter pattern of erosion seen at the site to the north. The beach berm was eroded and the flattened. Here though the narrower beach width did not fully absorb the storm wave energy before reaching the dune toe. The dune fence was damaged and 20 feet of the toe removed. Nearshore the slope was scoured and the offshore bar system moved seaward 100 feet. The net winter volume loss was -34.78 $yds^{3/}$ft. of sand.

With spring, the wave climate became more favorable for summer beach building processes landward cross-shore movement transferred sand onshore building a beach berm. The profile gained 13.55 yds^3/ft. of sand as natural recovery partially restored the winter losses. Beach building processes continued through the summer season as sand pushed higher onto the beach, forming a typical summer recreational beach berm. Summer sand volume gain was modest (1.5 yds^3/ft.) typical of cross-shore sediment transfer as sand moved from offshore to the beach**.** Sand continued to move landward from offshore over the fall with additional sand moving into the nearshore region resulting in a net volume gain of 22.02 yds^3/ft. of sand. The net annual volume loss of -0.60 yds^3/ft. of sand indicate cross-shore processes dominated changes through 2016 at this location, onshore the zero datum shoreline position advanced 18 feet.

10a. December 21, 2015

10c. December 19, 2016

10b. June 19, 2016

Photographs 10a to 10c. 78th Street, views to the north.

Photograph 10a shows the dune and beach from near the beach access path. Sand has accumulated along the seaward fence line and the beach elevation and width are more typical of late summer/early fall.

View 10b shows June view from the dune toe slope to the north, a new line of fence post have been installed and the beach recently groomed for the summer season.

View 10c was taken in late December 2016 in the same direction looking north from the seaward dune crest. The dune fence installed in June has accumulated sand with a wide dry beach to support continued growth.

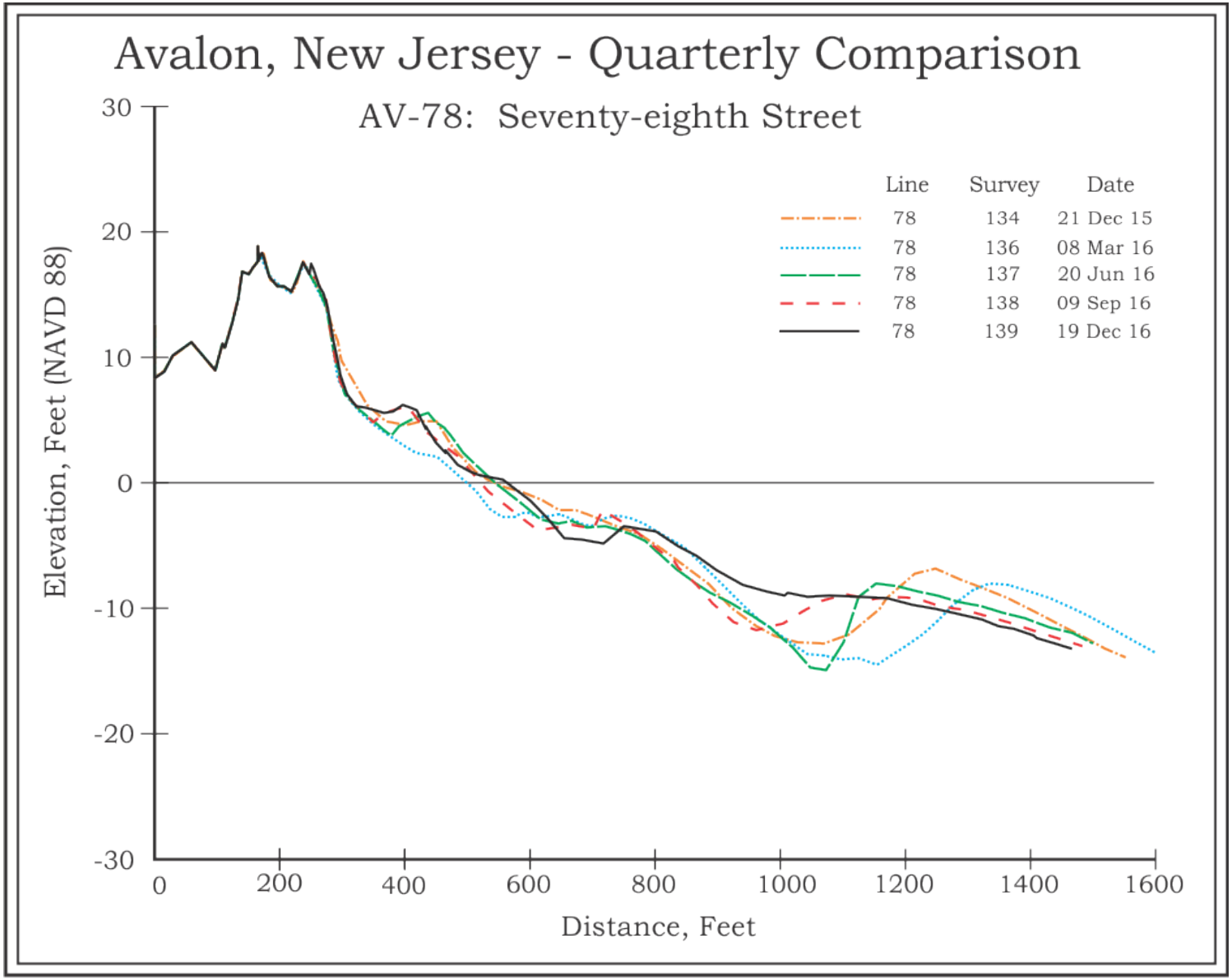

Figure 12. Following the same pattern seen to the north the winter storms and wave climate removed the beach berm but in this case the seaward dune toe was also cut back, approximately 20 feet, nearshore was scoured and the offshore bar pushed seaward. By June, the processes had reversed as sand moved landward both offshore and onshore restoring a recreational beach berm for the summer season. Over the summer sand pushed higher onto the beach and the bar migrated across the offshore trough to weld with the nearshore slope. Sand continued to move landward from offshore over the fall but waves from modest storm events scoured the nearshore while the beach berm remained intact. The net annual volume loss of -0.60 yds^3/ft. of sand indicate cross-shore processes dominated changes at this location, onshore the shoreline advanced 18 feet.

Summary of Avalon's Oceanfront Beaches:

The Borough of Avalon placed 740,000 cubic yard of sand on the beaches between 9th and 23rd Streets tapering to zero around 25th Street in 2015 in an effort to restore the engineered federal beach design. The USACE last maintenance effort was in 2013 following Hurricane Sandy. This federal maintenance effort was decimated by late 2014 with the rocks between 11th and 12th Streets again exposed. Unfortunately, the 2015 project beach suffered similar rapid erosion, starting with an odd, long-duration northeaster, that began October 4th and lasted until October 6th with winds about 25 MPH average. The next major storm event occurred January 24, 2016 named winter storm Jonas. Rated a 10-year storm, tidal flooding was significant along with storm waves and surge flattened the beach and cut scarps in the dune along the north end beaches and at 78th Street. Two weeks later another northeast event took place, also within a spring tidal cycle, and extended the attack on beaches. The engineered beach had lost -363,980 cy of sand from July 2015 to November 2015, with an additional -75,787 cy removed during the 2016 winter storms, for a net loss of -439,767 cy of sand in eight months following the 2015 nourishment.

This represents approximately 60% of the sand placement in 2015 removed within eight months of project completion. Within the erosional "hotspot" the rocks were partially exposed near 11th Street with a steep vertical cut in the dune slope up to 15 feet high from the crest to beach from about 10th through 15th Street. Additional similar dune scarping occurred near the 22nd Street outfall pipe. The project area beach berms were flattened essentially removing the elevation and width gained during the 2015 project.

Once again, Avalon faced an approaching summer season with restricted or limited beach access and reduced storm protection. To alleviate beach access concerns and improve storm protection the Borough implemented its fourth sand back-pass project. Pre-construction surveys indicated just over 58,000 cy of sand available in the northern beach borrow zone, located from 32nd to 40th Street. Approximately 50,000 cy of sand was hauled from the borrow zone to the two placement zones along the engineered beach. The southern placement area was identified from 23rd Street to 20th Street while the northern area located from 15th Street to 9th Street. A 50-foot wide project beach berm was established at approximately elevation 6.5 feet NAVD 88. Although dune restoration was not part of the project design sand was pushed up along the seaward scarp toe to improve beach access.

Unfortunately, the residence time of this sand was again shortened by storm activity. Hurricane Hermine passed nearshore over the extended Labor Day weekend, close enough to generate storm waves and strong currents along the Jersey shore. By September 8th the back-pass project beach berm had been removed within the northern area. While the southern area accumulated sand swept longshore to the south enhancing the project beach and nearshore. Additional sand swept south and onshore with initial rapid natural recovery within the project borrow area excavation zone replacing nearly half the sand removed in three months.

Fall weather patterns and wave climate continued to erode the north end federal project beaches within the erosional zone. Sand shed from this region continued to feed south. A complete recovery of the borrow area excavation zone was achieved within 5 months of the project completion through natural longshore and cross-shore processes. By December 19, 2016, the beach berm elevation actually exceeded pre-excavation elevations by up to 3 feet vertically. This region continued to demonstrate remarkable resilience to allow sustainable sand harvesting and back-passing annually as needed. Despite this recovery in the harvest area the Avalon shoreline lost a net -313,002 cy of sand in 2016. The majority of this net sand loss (86%) occurred within the erosional "hotspot" and along the engineered beach where -269,600 cy was removed, the southern shoreline accounted for an additional -43,402 cy of sand focused near 70th Street.

Oceanfront Beach Conclusion:

Avalon's north end is susceptible to erosion even during modest and moderate storm events due to its orientation to the northeast and prevailing southerly longshore currents that moves sand rapidly away from the engineered beaches. Since 2009, there has been an increase in storm frequency and intensity with the pattern shifting to begin earlier in fall. These storms expose summer nourishment projects to erosion even before the typical winter storm season starts up in late fall. Projects conducted since Sandy seem to be less stable and sand residence longevity dramatically reduced beyond levels previously observed following past projects. In light of this emerging climate pattern the need for an increased continued supply of sand feeding the system to stabilize the erosional "hotspot" has become apparent. This rate of required sand supply can be addressed through more frequent and robust sand back-pass efforts and hopefully eventually from natural inlet sand bypassing from the Ludlam Island federal beach project. However, in the short term the recent rapid erosion rate suggests the current federal project maintenance volumes and intervals have been insufficient to keep pace with the accelerated rate of sand loss caused by this increased storm frequency and intensity during early fall, especially since Sandy. The 17-month total loss of sand since completion of the July 2015 project was -633,580 cy of sand, an average annual erosion rate of -447,200 cy of sand per year.

As this report is being written Great Lakes Dock & Dredge has begun nourishment of the beaches of Stone Harbor. This is the start of a joint project with Avalon with the NJ DEP to restore beaches in both communities. The cooperative action of each Borough, NJDEP and USACE developed a unique strategy to ensure both communities continued to receive funds to restore severely eroded beaches and adequate storm protection. The federal project was threatened by a sudden reinterpretation of the Coastal Barrier Resources Act (CBRA) that has prevented federal dollars from being used despite past approvoval precedence. The new State aid agreement provides Avalon with approximately 490,000 cy of sand to repair beaches from 8th to 26th Street and an option to authorize additional sand placement during the project. With a favorable bid price of $5.15 per cubic yard and uncertainty for future federal actions as a result of the CBRA issue in Hereford Inlet it's probably prudent that Avalon go forward with that option.

Recent erosion rates on the engineered beaches have created conditions that will require over 490,000 cy of sand to fully restore the beach template to the 2017 design. A minimum placement of 650,000 cy should be considered to restore the full template design with an advance nourishment of 300,000 cy considered to increase residence time of the project berm. Hopefully, the recent increased in storm frequency will abate in the near future, but should it continue to impact the Avalon north end as it has since Sandy this advance nourishment volume will provide the Borough with a buffer and additional time to plan and coordinate its next actions.

Townsend's Inlet Bathymetric Survey:

Avalon's north end is susceptible to erosion even during modest and moderate storm events due to its orientation to the northeast and prevailing southerly longshore currents that moves sand rapidly away from the engineered beaches. There is currently little to no source to feed sand to this region to naturally replenish these erosional losses at the north end. Natural inlet sand bypassing has effectively been disrupted and limited by frequent dredging of the inlet, construction and extension of the 8th Street jetty and a lack of sand entering Townsends Inlet from Ludlum Island. Consequently, the rate of dredging has exceeded the natural replenishment rate to the ebb shoal needed for sand bypassing to occur. Additionally, the 1987 conditions for permitting sand harvesting from Townsend's Inlet required the approved borrow zone be located 1,000 feet north of the Avalon Inlet rock revetment shoreline due to resident owner complaints during the permitting process. This action insured the confinement of replenishment sand supplies back into Townsend's Inlet be positioned seaward of the extreme south end of Ludlam Island rather than more medially within the inlet entrance where northeast wave events could transfer some material toward the Avalon shoreline and eventually onto the north end beaches. Arguments need to be advanced to the

permitting agencies to re-visit this design to the official borrow zone and define a site more in harmony with the 1949 to 1978 aerial photographic history of Townsend's Inlet ebb-tidal delta shoaling patterns.

The ebb tidal shoals are the natural formation of vast reservoirs of accumulated sediment which alter nearshore wave patterns, affect inlet tidal channel structure and influence the adjacent beaches. These sediment accumulations may continue to grow with time depending upon influx of available sediments until a maximum equilibrium volume is reached that allows sand by-passing to begin from the up-drift to down-drift shoreline. Although Avalon is on the down-drift side of Townsend's Inlet this process is no longer occurring at Townsends Inlet in quantities required to naturally nourish and stabilize the north end beaches in Avalon. The ebb-tidal flow deposits sand into the ocean outside the inlet where the waves then mold the material into the typical spoon-shape shoal with the main channel located somewhere within the shoals. In the Townsend's Inlet case, the main channel lies medially with the lion's share of the shoal sand to the northeast of the channel closer to Sea Isle City. This situation has been true for several decades since beach nourishment has been using the inlet as the sand source. Dredging the material from a zone starting over 1,000 feet northeast of the Avalon shoreline has maintained this location since 1978.

The USACE completed construction of a massive nourishment project for southern Ocean City and all of Ludlam Island in 2016. This project introduced approximately 4 million cubic yards of offshore sand into the nearshore littoral system. Introduction of this sand, never previously present on any historical beach, into the system will dramatically alter the rate of sediment entering Townsend's Inlet and the ebb shoals potentially restoring natural sand bypassing rates to Avalon. The Borough approved an annual bathymetric survey of Townsend's to quantify and document this influx of sand from Ludlam Island into the inlet system process. Comparison between annual surveys will provide data to determine rates of accumulation and potential implications this deposition may have on initiating natural sand bypassing from the ebb shoals to the Avalon beaches.

Topographic and bathymetric surveys of Townsend's Inlet cover the inlet system from the southern segment of Sea Isle City to about 12th Street in Avalon back to the inlet bridge. The bathymetric data was collected using Hypack software, RTK-GPS and an Echo-Trac digital depth sounder combined on the RV Osprey, a 24-foot research vessel. Two annual surveys have been conducted starting last year as the USACE project was nearing completion and again this fall. Surveys cover both the Sea Isle City and Avalon inlet shorelines, channel and borrow zone and the entire ebb shoal system into water of under 3-foot depths at high tide. The survey lines start at the dune and cross the beach into the water using traditional land surveying methods, where the vessel continues to cover the ocean floor to depths of 30 feet offshore.

Figure 13. 1971 aerial photograph of Townsend's Inlet after construction of the 8th Ave. jetty, the rock revetment and 3 short finger groins in the inlet. The main channel lies next to the revetment with vast shoals exposed at low tide immediately northeast of the channel. Note that the seaward parts of the shoal wrap around the inlet mouth and contributed large slugs of sand to the beach lying between the jetty and 17th Street in Avalon. At this time there was a 465-foot wide vegetated dune system seaward of the end of 17th Street before reaching the dry, high tide beach. Flood tidal currents and storm wave action moved sand over the jetty into the inlet where the ebb-tidal currents carried it back out to the shoals for eventual return to the north end beach. A stable cycle of sediment was in place. The jetty was also lower in elevation and shorter so that sand did move back into the inlet from Avalon generating a feed-back loop process. Deposits of sand washed over the jetty or around it were rapidly re-positioned by the ebb-tidal currents to the offshore bar and eventually back onto the Avalon ocean beach.

Figure 13 on the previous page is an aerial photograph taken in 1971 that shows shoaling conditions and configurations ideal for sand bypassing and wave sheltering to the Avalon shoreline. This was included again in 2016 to demonstrate shoal conditions beneficial to Avalon. Sand shoals are emergent over a wide area in the ebb-tidal zone and form a crescent shape towards Avalon in this photograph. These shoal deposits have slowly disappeared due to excavation for beach restoration in both municipalities since 1978 and a diminished sand supply entering the system as the Ludlam Island beaches deteriorated. With the introduction of sand to Ludlam Island from offshore in 2015 and 2016, long shore transport from project beaches should restore larger ebb-tidal shoal deposits that may, hopefully, duplicate these pre-1978 situation.

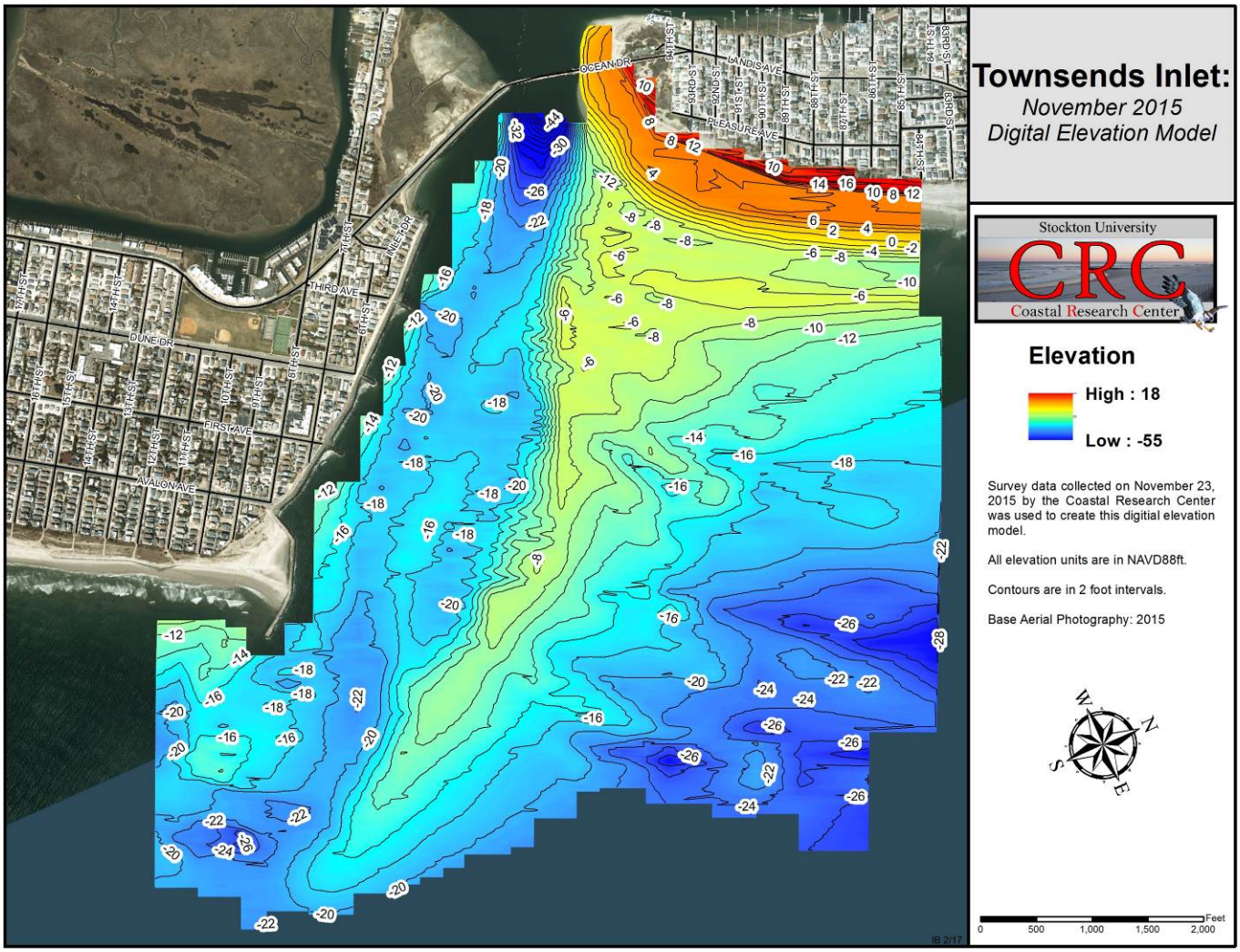

Figure 14. In the DEM above, showing elevation conditions in November 2015, red and orange colors represent higher elevations while blues are the lowest elevations, contour intervals are shown at two foot intervals. The yellow area shows the extent of the ebb shoal before sand placement was completed on Ludlam Island. The feature continues from the Sea Isle City beach seaward to the southeast tapering into deeper water beyond the 8th Street Jetty.

Figure 14 above is a digital elevation model from the November 2015 survey of Townsend's Inlet. The November 2015 survey of Townsend's Inlet, Cape May County, NJ shows the beach in Sea Isle City with the shoal system attached to the nearshore region and extending seaward along the main ebb-tidal channel of the inlet. The deep scour under the inlet bridge does not extend far out the inlet channel where depths range between 18 and -20 feet in elevation average. The elevation on the top of the shoal extending seaward is -6 to -8 feet NAVD 88 in the nearshore region gradually getting deeper over a 3,000-foot distance toward the southeast. The Borough's 2015 nourishment project used the approved borrow zone that essentially parallels the southern edge of the ebb shoal, excavation was to -20 feet NAVD88, this excavated region is still evident in the November 2015 survey. It is anticipated that the 3.4 million cubic yards of sand added to Ludlam Island will rapidly restore this shoal system to its pre-dredging conditions.

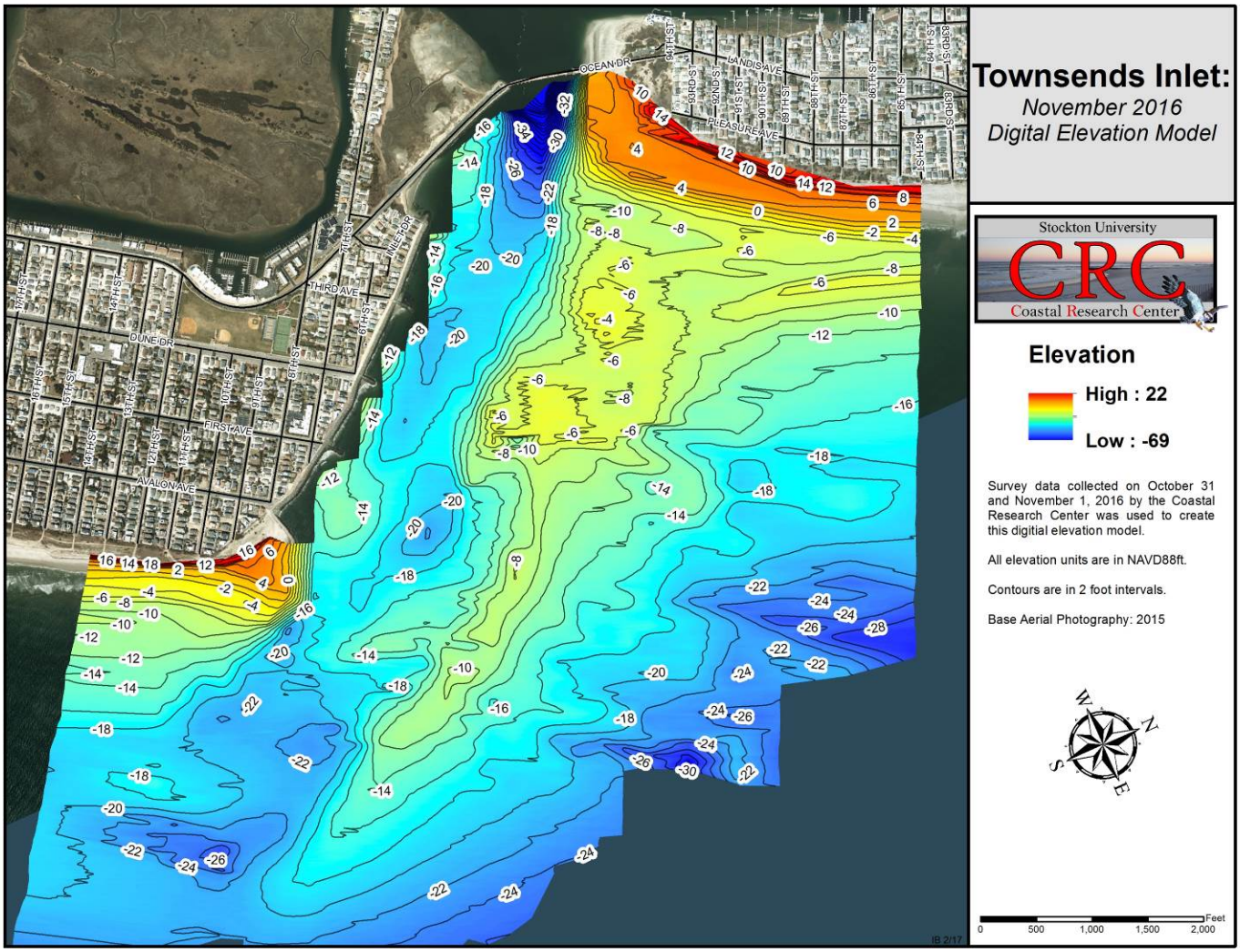

Figure 15. The DEM above, shows elevation conditions on November 1, 2016, approximately one year following the initial survey. Again red and orange colors represent higher elevations while blues are the lowest elevations, contour intervals are shown at two foot intervals. The yellow area shows the extent of the ebb shoal. Dark blue is a scour hole near the bridge, lighter blues demark the tidal channel and offshore deeper water.

Figure 15 above is a second digital elevation model from the November 2016 survey of Townsend's Inlet. The November 2016 survey of Townsend's Inlet shows a similar shape to the ebb shoal as existed in 2015. This ebb shoal system begins at the Sea Isle City beach attached to the nearshore region of the shoal, extending seaward along the main ebb-tidal channel of the inlet. The deep scour under the inlet bridge persists one year later with depths exceeding -44 feet NAVD88. This feature does not extend far out the inlet channel where average depths still range between -18 and -20 feet in elevation. The elevation on the top of the shoal extending seaward increased slightly to -4 to -6 feet NAVD 88 in the nearshore region. Along the south channel margin the dredge cut from 2015 has nearly recovered having been recharged with sand. The 3.4 million cubic yards of sand added to Ludlam Island has provided an increase source of sand to accelerate infilling of the dredge cut in a year. Towards the southeast the shoal gradually deepens over a 3,000-foot distance with a similar configuration as surveyed in 2015. Sand gains were focused on the nearshore shoal and borrow zone areas in 2016.

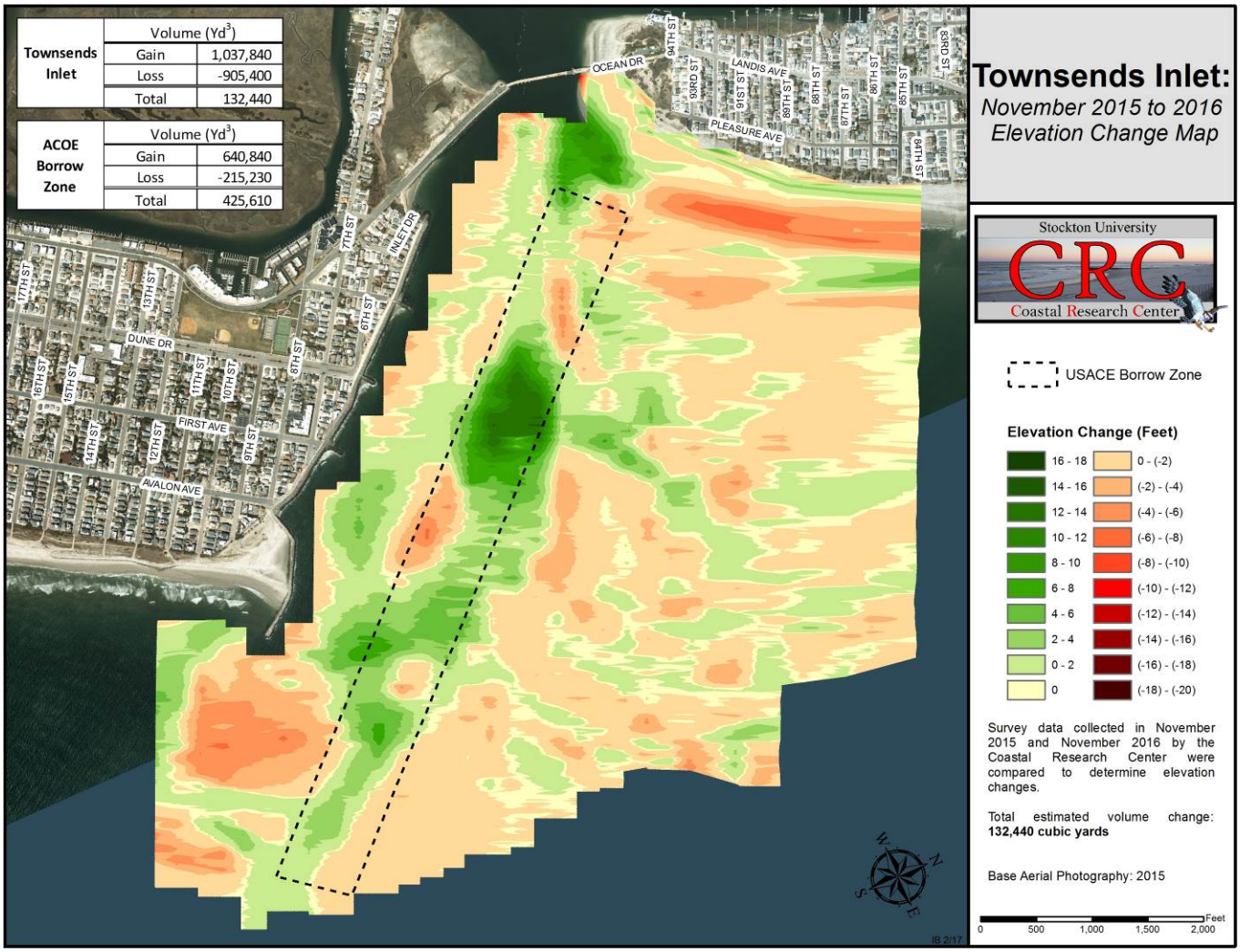

Figure 16. The map above is an elevation change map between surveys conducting November 2015 and November 2016. Green colored regions are areas of elevation gains while orange and red are regions where the elevation decreased. Yellow shaded areas are regions of no significant elevation change. The black dashed rectangle demarks the approved borrow zone used for each cycle of the federal nourishment maintenance efforts on Avalon's north end.

Figure 16 above is an elevation change map between the November 2015 and the November 2016 survey of the inlet. The map clearly shows regions of sand accumulation on the shoal and an area of loss from an extensive linear area along Sea Isle City's shoreline into the nearshore region, extending north from 93rd Street to the northern limits of the survey. A second area of loss occurred in the inlet channel mouth off Avalon seaward of the 8th Street jetty. The changes in elevations are associated with a change in sand volume. Within the borrow zone the areas of gains accumulated 640,840 cy of sand within a year. There were pockets of sand loss within the borrow zone area focused along the channel margin where -215,230 cy of sand moved away between 2015 to 2016. The net volume change within the borrow zone was a gain of 425,610 cy of sand. This exceeds the annual anticipated recharge rate of just over 300,000 cy of sand. The volume change analysis indicates that within the first year 1,037,840 cy of sand accumulated in regions throughout the inlet system. Areas of loss were significant with -905,440 cy moved mostly from the two regions of loss described above, Sea Isle City beaches and the mouth of the inlet. The net inlet change was a gain of 132,440 cy of sand.

Although the net gain was modest, it is misleading as the survey region included the anticipated erosional beaches of Sea Isle City that now contribute an increased volume of sand to the Townsend Inlet system. So the 132,440 cy of sand is an influx of sand from outside the study area that includes the erosional zone. The

areas of gain on the shoal and in the borrow zone are real totaling approximately 1 million cy of sand into the ebb shoal system in the first year of post project monitoring.

Townsend's Inlet Conclusions:

During moderate surf conditions, tidal currents and waves shape the sand into the extended southeast oriented ebb shoal depicted in the maps above. The tidal currents act to distribute sand along the axis of the feature, on the flood tide waves breaking over the entire shoal shift sand southwest toward Avalon. Ebb-tidal currents and waves act to allow sand to extend the feature seaward along its axis to a point where waning currents allow just the waves to mold the shoal around the inlet opening and set the stage to by-pass a large volume of sand to Avalon when and if a breach occurs somewhere back along the northeast axis toward the Sea Isle City beach. The main channel shifts to the new breach and this allows the detached section, however big, to be redistributed toward the Avalon shoreline. This is how inlet sand by-passing occurs.

Unfortunately, the original placement of the approved inlet borrow zone was set a thousand foot distance from the revetment rocks in Avalon. This zone was not selected as a result of inlet dynamic studies but for concerns of residents along the inlet shorelines. This zone has been used repetitively since 1987 for sand to maintain Avalon's and Sea Isle City's beaches (since 1978) and has proven counterproductive to allowing inlet bypassing to transfer sand from the Sea Isle City side of the inlet shoals to the Avalon shoreline. As the November 2015 to 2016 Elevation Change Map shows (figure 14), sand accumulates along the channel margin of the shoal recharging the borrow zone relatively quickly but repetitive dredging removes the sand before the outer limits of the ebb shoal fully form and the process of natural bypassing occurs.

One million cy of sand accumulated on the ebb shoal and surrounding inlet in 2016. This sand was largely eroded from the Sea Isle City federal project area. With just over 640,000 cy of sand added within the borrow zone footprint sufficient recharge has already occurred since Avalon's 2015 project withdrew sand. The spring 2017 project is anticipated to place 490,000 cy of sand with an option to provide additional sand.

Based on this shoal analysis it appears the necessary volume is currently available within the borrow zone and could sustain removal of 650,000 cy of sand as of November 2016. It is very likely that additional recharge has occurred over the winter months potentially increasing the available sand volume within the borrow zone. The effort to convince the USACE and the NJDEP that a re-alignment of the approved borrow zone should be made as soon as practical to maximize the potential to re-generate natural sand bypassing of the inlet's ebb-tidal shoals to Avalon.