FINAL REPORT

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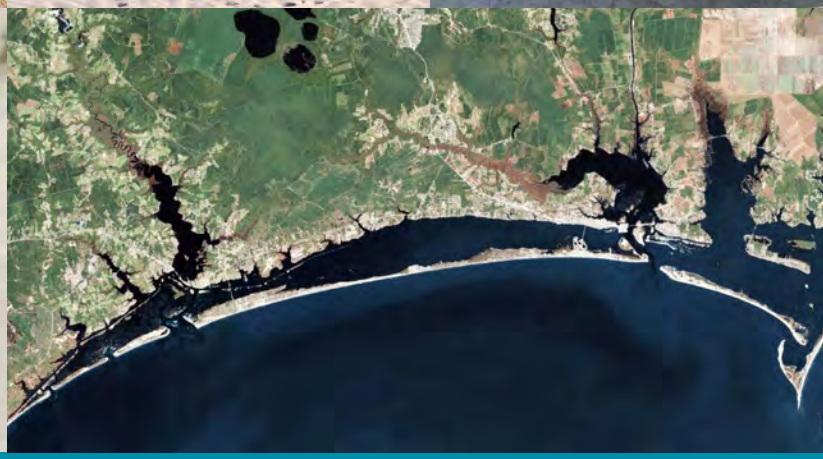

Bogue Banks Beach
and Nearshore Mapping Program

September 2012

moffatt & nichol

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Executive Summary

Comprehensive surveying of the Bogue Banks shoreline began in 1999 to develop the Bogue Banks Beach Restoration Project. In Spring 2004, the Bogue Banks Beach and Nearshore Mapping Program was initiated to assess beach conditions and form strategies for future beach nourishment projects. Bear Island was added to the program in October 2004 and Shackleford Banks was added in May 2005. Currently, surveys are performed annually during each spring/summer timeframe along all three islands. In addition, after large storm events surveying is performed along Bogue Banks to assess damages. The most recent regular survey was completed during spring 2012 (March and April 2012) by Geodynamics. For this evaluation, the spring 2012 survey was compared with the spring/summer 2011 (May and June 2011) survey. The survey data was used to compute shoreline change at +1.1 ft NAVD88 which is designated as Mean High Water (MHW) and volume change above MHW, -5 ft NAVD88 (wading depth), -12 ft NAVD88 (outer bar), -20 ft NAVD88, and -30 ft NAVD88.

Key statistics were computed for defined regions along the Bogue Banks shoreline, Bear Island, and Shackleford Banks between the 2011 and 2012 survey profiles including;

JUNE 2011 v. APRIL 2012	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Banks Oceanfront (1-112)	128,393	-37.0	-6.8	-871,672	-9.5	-1,219,951	-15.1	-1,933,825	-24.3	-3,119,687	-19.7	-2,529,892
Bogue Banks County Project (9-76)	88,094	-36.5	-7.2	-636,490	-7.8	-685,153	-11.7	-1,035,102	-23.2	-2,044,361	-11.8	-1,039,124
Bear Island (1-18)	16,500	-1.4	-3.3	-53,765	-5.1	-83,737	0.2	3,922	-0.9	-14,673	0.8	13,296
Shackleford Banks (1-24)	46,001	-20.1	-6.1	-281,642	-8.0	-365,768	-12.5	-573,413	-10.3	-473,835	-14.7	-677,093

Key statistics for individual reaches along Bogue Banks were as follows:

JUNE 2011 v. APRIL 2012	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	4.3	-0.4	-2,923	-5.6	-41,637	-26.9	-199,903	-32.7	-243,370	-29.6	-219,935
Emerald Isle-West (9-25)	22,344	-20.7	-5.0	-111,449	-6.1	-137,356	-11.8	-264,467	-18.6	-414,633	-6.1	-136,680
Emerald Isle-Central (26-36)	15,802	-37.8	-6.3	-99,667	-6.0	-94,201	-8.9	-139,918	-23.4	-369,599	-9.8	-154,303
Emerald Isle-East (37-48)	13,220	-26.4	-7.5	-99,396	-10.0	-132,365	-11.6	-153,682	-22.6	-298,270	-12.2	-160,697
Indian Beach-Salter Path (49-58)	12,850	-43.7	-8.2	-105,632	-9.5	-122,411	-12.8	-163,958	-26.0	-334,048	-11.9	-153,274
Pine Knoll Shores-West (59-65)	9,063	-46.4	-7.6	-68,625	-5.2	-47,394	-8.5	-76,886	-24.4	-220,746	-12.5	-113,255
Pine Knoll Shores-East (66-76)	14,815	-55.6	-10.2	-151,720	-10.2	-151,426	-15.9	-236,192	-27.5	-407,065	-21.7	-320,915
Atlantic Beach (77-102)	26,176	-43.1	-7.3	-190,162	-14.3	-373,650	-20.3	-530,856	-28.7	-750,155	-43.7	-1,144,341
Fort Macon State Park (103-112)	6,691	-65.0	-6.3	-42,097	-17.9	-119,510	-25.1	-167,964	-12.2	-81,801	-18.9	-126,493
Beaufort Inlet (113-116)	2,000	23.9	5.1	10,159	16.3	32,534	16.7	33,466	14.4	28,766	10.2	20,497
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

It is apparent there has been significant shoreline recession along Bogue Banks and significant volumetric losses along the beach profiles over the past year. This is largely due to the impact of Hurricane Irene. Shoreline recession attributed to the direct impact of Hurricane Irene was minimal due to the reshaping of the beach from the storm. Much of the material eroded from the dune was deposited along the beachface, keeping the shoreline position relatively stable. However, in the months after the storm, shoreline recession greatly increased, likely because of the large volume losses in storm protection below MHW seen as a result of the storm. Volume losses during Hurricane Irene were significantly large. Despite quiescent weather the remainder of the year, Bogue Banks did not see much in terms of recovery from the storm but rather saw continued volume losses, especially above MHW with some minor recovery above

-12 ft NAVD88. Overall, approximately 1,000,000 cy of material was lost from the county project above -12 ft NAVD88 over the past year while approximately 1,900,000 cy was lost along the entire oceanfront. All reaches experienced significant erosion, including Atlantic Beach and Fort Macon which had just recently been nourished. The losses which occurred during the past year have been broken down into the losses from Hurricane Irene (June 2011-September 2011) and the time period following the storm (September 2011-April 2012). These statistics are presented below.

JUNE 2011 v. IRENE	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	8.5	-4.1	-30,297	-10.1	-75,280	-18.6	-138,201	-5.2	-38,663	13.7	101,935
Emerald Isle-West (9-25)	22,344	-5.5	-4.4	-98,004	-10.0	-222,862	-25.9	-579,219	-21.9	-489,290	-2.2	-48,471
Emerald Isle-Central (26-36)	15,802	-0.7	-3.4	-53,055	-5.2	-81,696	-13.7	-216,386	-27.2	-429,866	-6.7	-106,286
Emerald Isle-East (37-48)	13,220	-3.8	-3.5	-45,723	-9.3	-122,432	-11.9	-157,073	-18.8	-249,104	1.3	17,312
Indian Beach-Salter Path (49-58)	12,850	-2.4	-5.5	-70,567	-10.4	-133,830	-18.4	-235,939	-30.3	-389,783	-6.7	-86,084
Pine Knoll Shores-West (59-65)	9,063	6.4	-3.6	-32,250	-3.8	-34,590	-11.3	-102,188	-32.8	-297,329	-16.2	-147,017
Pine Knoll Shores-East (66-76)	14,815	15.5	-2.6	-38,432	-0.5	-7,258	-7.6	-112,555	-20.6	-304,670	-5.3	-77,848
Atlantic Beach (77-102)	26,176	6.8	-6.0	-156,328	-7.5	-197,552	-13.9	-362,678	-15.1	-395,857	-18.8	-490,869
Fort Macon State Park (103-112)	6,691	-41.1	-7.8	-52,480	-18.0	-120,558	-7.2	-48,058	12.2	81,416	24.2	162,104
Beaufort Inlet (113-116)	2,000	-88.3	0.5	952	-11.5	-23,020	-29.6	-59,154	-40.3	-80,600	-43.0	-86,054
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reach Length	Weighted Avg	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total
County Project (9-76)	88,094	0.8	-3.8	-338,030	-6.8	-602,668	-15.9	-1,403,361	-24.5	-2,160,042	-5.1	-448,393
Oceanfront (1-112)	128,393	0.3	-4.5	-577,135	-7.8	-996,059	-15.2	-1,952,298	-19.6	-2,513,146	-5.3	-675,223

IRENE v. APRIL 2012	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	-4.2	3.7	27,374	4.5	33,644	-8.3	-61,703	-27.5	-204,707	-43.3	-321,870
Emerald Isle-West (9-25)	22,344	-15.2	-0.6	-13,445	3.8	85,506	14.1	314,752	3.3	74,656	-3.9	-88,209
Emerald Isle-Central (26-36)	15,802	-37.1	-2.9	-46,612	-0.8	-12,505	4.8	76,468	3.8	60,267	-3.0	-48,017
Emerald Isle-East (37-48)	13,220	-22.6	-4.1	-53,673	-0.8	-9,933	0.3	3,391	-3.7	-49,166	-13.5	-178,010
Indian Beach-Salter Path (49-58)	12,850	-41.3	-2.7	-35,065	0.9	11,419	5.6	71,981	4.3	55,735	-5.2	-67,190
Pine Knoll Shores-West (59-65)	9,063	-52.8	-4.0	-36,376	-1.4	-12,804	2.8	25,302	8.5	76,583	3.7	33,761
Pine Knoll Shores-East (66-76)	14,815	-71.1	-7.6	-113,288	-9.7	-144,168	-8.3	-123,636	-6.9	-102,395	-16.4	-243,066
Atlantic Beach (77-102)	26,176	-49.9	-1.3	-33,834	-6.7	-176,098	-6.4	-168,178	-13.5	-354,298	-25.0	-653,472
Fort Macon State Park (103-112)	6,691	-23.9	1.6	10,383	0.2	1,048	-17.9	-119,906	-24.4	-163,217	-43.1	-288,596
Beaufort Inlet (113-116)	2,000	112.2	4.6	9,207	27.8	55,554	46.3	92,620	54.7	109,366	53.3	106,551
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reach Length	Weighted Avg	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total
County Project (9-76)	88,094	-37.3	-3.4	-298,459	-0.9	-82,485	4.2	368,259	1.3	115,680	-6.7	-590,731
Oceanfront (1-112)	128,393	-37.3	-2.3	-294,537	-1.7	-223,892	0.1	18,473	-4.7	-606,542	-14.4	-1,854,669

Bear Island appears to have been affected most above MHW and above -5 ft NAVD88, showing a significant loss of material from the beachface down to -5 ft NAVD88, that appears to be deposited near the offshore bar. Shackleford Banks also appears to have been impacted significantly by Hurricane Irene. Profile plots show clear erosion of the primary dune in almost half of the transects. Losses to the beachface down to the elevation of the outer bar are apparent as well.

In addition, calculations were performed to estimate the amount of material remaining on the beach in excess of the baseline nourishment condition established by the Phase I, Phase II, and Phase III components of the Bogue Banks Beach Restoration Project. It was determined reaches within the Phase I and Phase III projects still contain more sand than was originally in place after the earlier baseline projects with 110% and 148% , respectively. It should be noted that the Pine Knoll Shores East reach, within Phase I project, is approaching the 50% of remaining fill threshold with only 65% currently remaining. The Phase II reach contains only 87% of the sand in place after earlier projects. Within the Phase II project there has been a

hotspot which, historically, has shifted back and forth between transect 32 in Emerald Isle Central and transect 44 in Emerald Isle East. Of the two reaches within the Phase II project area, Emerald Isle East contains the least amount of original fill material at only 35%. While there is evidence of the hotpost drifting into Emerald Isle Central, that reach currently contains sufficient reserve material (135%) and would benefit from material placed in Emerald Isle East due to perceived westerly sediment transport across the region. The hotspot project for Emerald Isle East, which was previously in the planning stages, has now been expanded to include portions of Emerald Isle West and Pine Knoll Shores which experienced large amounts of erosion due to Hurricane Irene. It is expected that material will be placed on the beach in these areas during winter 2012-2013.

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1.0 Objective

The Bogue Banks Beach and Nearshore Mapping Program (BBBNMP) is sponsored by Carteret County and formally began in June 2004 as a continuation of a monitoring program initiated in 1999 for assessing beach conditions and forming strategies for the Bogue Banks Beach Restoration Project (Phases I, II, and III). Bear Island was first surveyed and added to the BBBNMP in October 2004 while Shackleford Banks was added in May 2005. Since May 2005, surveys along Bogue Banks, Bear Island, and Shackleford Banks have been performed annually during each spring/summer timeframe. In addition, Bogue Banks is also surveyed after large storm events to quantify damage done to the beach and augment the municipalities' FEMA reimbursement request for beach nourishment. The most recent regular survey was completed during spring 2012 (March and April 2012) by Geodynamics LLC (Geodynamics). This report documents the data sources, methods, and results of a survey evaluation performed to compare the spring 2012 survey with a previous survey performed in spring/summer 2011.

2.0 Summary of Previous Work

Previous beach monitoring studies performed by Coastal Science & Engineering (CSE) between 2004 and 2007 were reviewed to gain an understanding of previous survey methods, associated coastal analysis, and observed trends (Note: UNC-IMS completed the 2003 work). Each year, comparisons along Bogue Banks were made to an initial survey performed in 1999, providing some long-term analysis. Bear Island and Shackleford Banks were added to the monitoring effort in 2004 and 2005 respectively. Each year, surveys for these regions were compared to the initial surveys in 2004 and 2005 to provide long-term analysis results. In addition, at Bogue Banks, Bear Island, and Shackleford Banks, comparisons were made each year to the previous year's survey, providing insight into sand movement within a single year. **Table 1** and **Table 2** show the long-term and short-term volume changes over the various reaches of shoreline included in the BBBNMP.

Table 1. Long-term Volume Change (Previous Studies)

	Dune to -4' NGVD				Dune to -11' NGVD				Dune to -15' NGVD			
	June 1999-June 2004	June 1999-May 2005	June 1999-May 2006	June 1999-May 2007	June 1999-June 2004	June 1999-May 2005	June 1999-May 2006	June 1999-May 2007	June 1999-June 2004	June 1999-May 2005	June 2004-May 2006	June 2004-May 2007
Reach	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy
Bogue Inlet-Channel	-	-	-	-	-	-	-	-	-	-	115,528	-
Bogue Inlet-Ocean	185,872	250,657	-25,335	33,023	-268,237	395,676	99,426	147,797	-	-	-	-
Emerald Isle-West	420,971	963,253	739,518	899,412	723,052	1,321,780	1,072,208	1,185,131	-	-	685,012	1,783,395
Emerald Isle-Central	604,558	675,135	586,251	661,490	874,031	1,002,184	742,535	781,223	-	-	-11,291	1,194,915
Emerald Isle-East	700,213	670,766	640,656	685,168	965,114	963,911	803,382	946,483	-	-	-20,827	1,335,655
Indian Beach/Salter Path	856,179	829,318	681,474	783,473	1,361,192	1,290,983	1,035,738	1,155,522	-	-	-178,053	1,744,153
Pine Knoll Shores-West	329,308	305,689	226,660	403,726	398,891	526,330	357,306	680,649	-	-	87,624	1,135,995
Pine Knoll Shores-East	500,958	392,759	315,186	781,720	650,158	576,150	399,946	1,072,778	-	-	-190,587	1,796,876
Atlantic Beach	-10,721	931,032	661,520	558,278	136,193	1,902,206	1,305,619	1,194,947	-	-	1,661,386	2,358,100
Fort Macon	-196,301	15,679	23,930	36,932	-184,943	287,847	179,302	221,169	-	-	695,424	558,157
Beaufort Inlet	-	-	-	-	-	-	-	-	-	-	-	-
County Project	3,412,182	3,836,920	3,189,745	4,214,989	4,972,437	5,681,337	4,411,116	5,821,785	-	-	371,879	8,990,990
Entire Oceanfront	3,390,495	5,034,288	3,849,860	4,843,223	4,655,450	8,267,067	5,995,463	7,385,699	-	-	2,728,689	11,907,247
Bear Island	-	-	-	-	-	-	-	-	-	-	-	-
Shackleford Banks	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Short-term Volume Change (Previous Studies)

	Dune to -4' NGVD				Dune to -11' NGVD				Dune to -15' NGVD			
	Dec 2003-June 2004	June 2004-May 2005	May 2005-May 2006	May 2006-May 2007	Dec 2003-June 2004	June 2004-May 2005	May 2005-May 2006	May 2006-May 2007	Dec 2003-June 2004	June 2004-May 2005	May 2005-May 2006	May 2006-May 2007
Reach	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy
Bogue Inlet-Channel	-9,809	10,792	42,160	-26,182	-24,465	20,639	131,171	-7,147	-17,943	18,389	-	103,996
Bogue Inlet-Ocean	46,594	13,918	-204,216	58,358	-8,041	626,020	-299,980	48,372	-	-	-235,915	-52,942
Emerald Isle-West	54,586	542,282	-223,735	159,894	153,489	598,728	-249,571	112,922	147,494	807,600	-122,588	82,591
Emerald Isle-Central	11,253	70,577	-88,885	75,240	80,919	128,154	-259,649	38,688	70,888	238,146	-249,437	50,782
Emerald Isle-East	35,498	-29,447	-41,418	44,512	60,434	-1,204	-177,539	143,100	37,466	86,866	-127,967	130,604
Indian Beach/Salter Path	350,295	-43,495	-128,931	101,999	651,819	-85,523	-234,853	119,783	649,217	6,703	-184,756	103,996
Pine Knoll Shores-West	45,812	-8,333	-66,901	177,066	39,306	146,225	-149,924	323,343	26,129	233,908	-146,284	400,836
Pine Knoll Shores-East	45,904	-83,525	-97,553	466,534	67,286	-59,354	-197,027	672,831	11,741	-44,338	-146,248	563,500
Atlantic Beach	123,250	942,289	-269,512	-103,242	65,826	1,766,014	-596,587	-110,672	-63,325	2,189,434	-528,048	-274,554
Fort Macon	8,783	255,147	-13,739	17,087	-42,921	473,780	-84,893	33,818	-94,922	792,583	-14,647	151,211
Beaufort Inlet	41,514	85,619	-22,410	-11,428	85,574	448,098	-56,020	-4,905	103,219	1,035,861	-	-
County Project	543,349	448,059	-647,422	1,025,245	1,053,253	727,025	-1,268,564	1,410,668	942,935	1,328,884	-977,280	1,332,309
Entire Oceanfront	721,977	1,659,414	-1,134,889	997,448	1,068,117	3,592,840	-2,250,025	1,382,186	784,689	4,310,901	-1,755,890	1,156,024
Bear Island	-	-29,705	-162,365	-105,930	-	-135,310	-139,170	-343,295	-	11,980	-64,820	-471,975
Shackleford Banks	-	-	-450,401	-74,356	-	-	-686,685	55,122	-	-	-665,033	270,338

3.0 Survey Methods and Data Sources

Most recently, Geodynamics conducted a survey of Shackleford Banks, Bear Island, and Bogue Banks in March and April 2012. The profile lines and origins used in previous studies were also used for the most recent survey for ease of comparison. **Figure 1** and **Figure 2** show the location of the profile lines and origins applied by Geodynamics for the surveying. Two transects were added near Beaufort Inlet (112B) and Bogue Inlet (117B) in 2008 to better track sand movement near the inlets. The established profile lines and origins will be used in all future survey periods. As shown, lines were stationed from west to east along Bogue Banks and east to west along Bear Island and Shackleford Banks. The survey data was provided in ASCII (xyz), Excel (xyz), Shapefile (GIS), and ISRP (BMAP) formats allowing for compatibility with multiple programs. The survey was referenced in NAD 1983 State Plane North Carolina (feet) with a vertical datum of NAVD 1988.

Several steps were taken by Geodynamics to ensure the most accurate survey data. The spring 2012 survey represents a continuation of previous surveys conducted for the Carteret County Shore Protection Office using high-density singlebeam sonar and topographic survey of Bogue Banks. This survey meets the requirements specified in the NOS (National Ocean Service) Hydrographic Surveys Specifications and Deliverables (April, 2007), the OCS (Office of Coast Survey) Field Procedures Manual for Hydrographic Surveying (June 2008) and the criteria for Navigation and Dredging Support Hydrographic Surveys as outlined in the U.S. Army Corps of Engineers Hydrographic Surveying Manual, EM 1110-2-1003 (EM 1110-2-1003 January 2002). The following sections will discuss the singlebeam (bathymetric) and topographic data acquisition including its associated equipment, quality control procedures, and data processing.

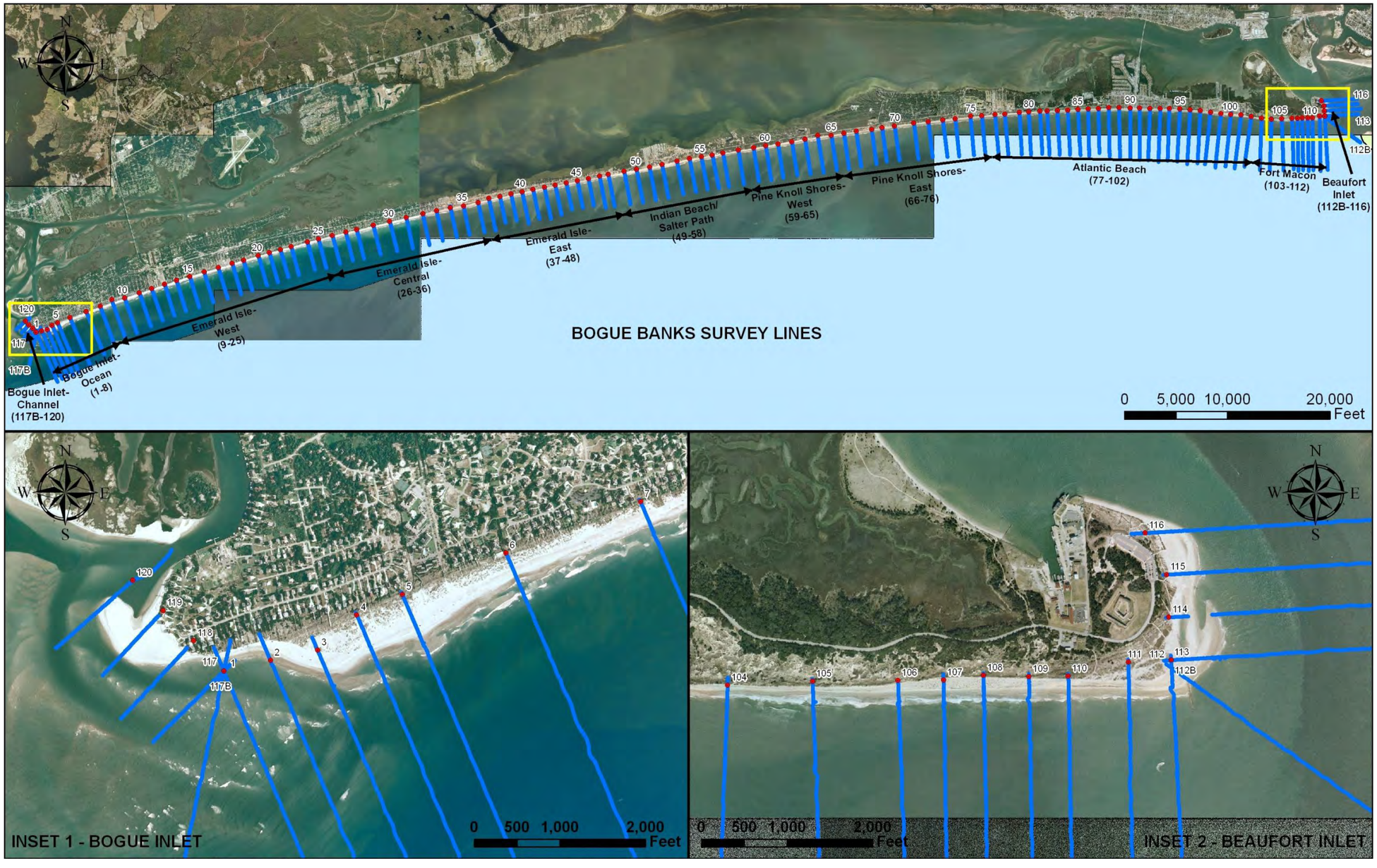


Figure 1. BBBNMP Profile Line Locations – Bogue Banks

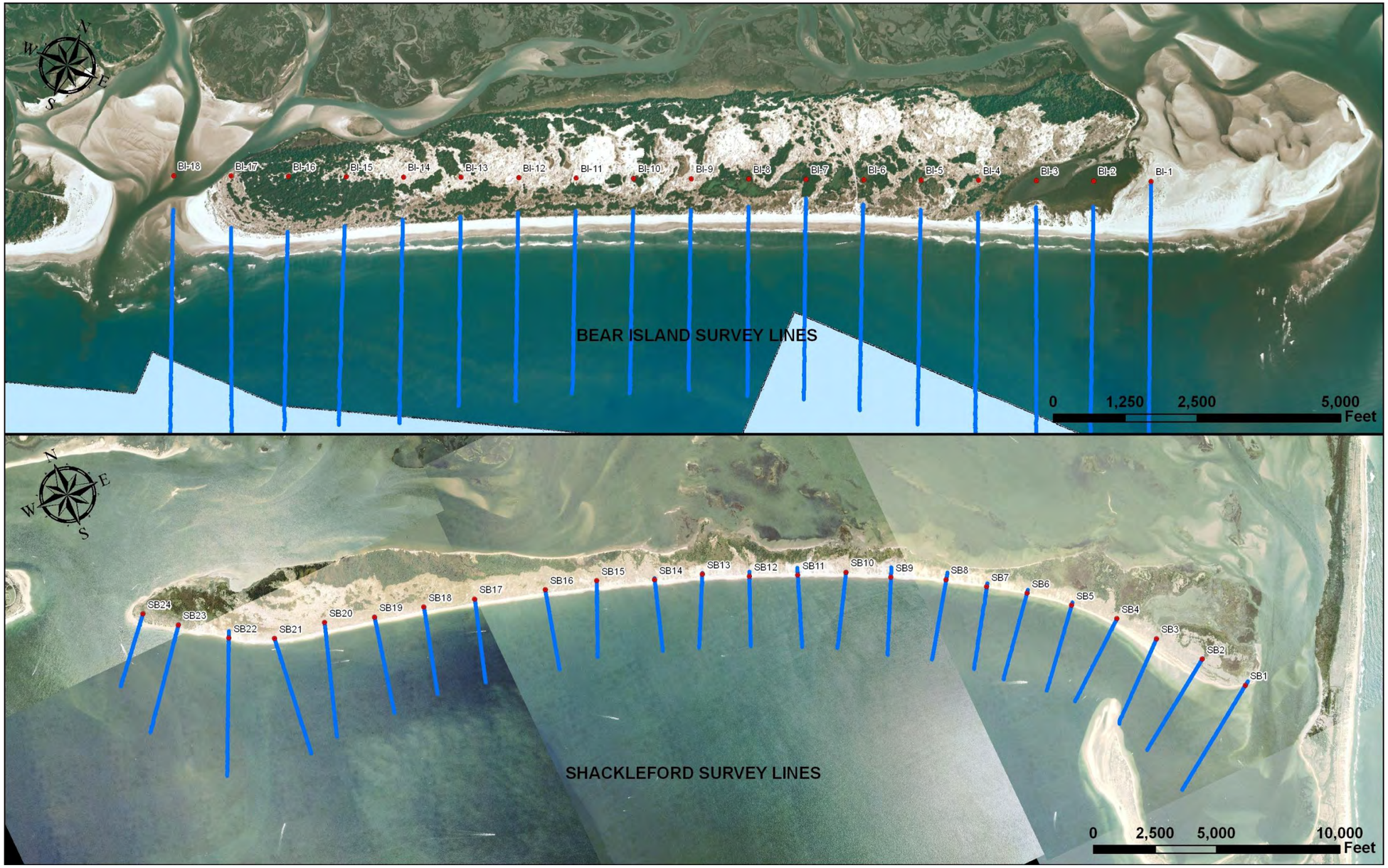


Figure 2. BBBNMP Profile Line Locations – Bear Island and Shackleford Banks

3.1 Singlebeam (Bathymetric) Data Acquisition and Processing

The following sections discuss the equipment, quality controls, sounding corrections, and data processing associated with the singlebeam data acquisition.

3.1.1 Singlebeam Survey Equipment, Hardware, and Software

The R/V Echo served as the survey platform for singlebeam data acquisition (**Figure 3**). The R/V Echo is designed to be a vessel of opportunity for shallow water inshore and coastal ocean mapping. The R/V Echo is a 21 ft Cape Fear Catamaran with through-hull and pole-mount singlebeam sonar capability. The vessel is powered by a 140 hp four-stroke engine mounted on a jack plate to enable ultra shallow water data collection. Data acquisition computers are housed within the water-tight console and are powered through an onboard battery bank. This vessel represents the state-of-the-art in modern hydrographic surveying. The hardware systems inventory for the R/V Echo is shown in **Table 3**.

Figure 3. The R/V Echo Hydrographic Survey Platform Setup

Table 3. Singlebeam Hardware Systems Inventory

	R/V Shoals		
	Hardware	**Manufacturer**	**Model**
Horizontal Control	RTK Radio Modem	Pacific Crest	PDL LPB
	RTK Radio Antenna	Pacific Crest	n/a
	GPS Antenna	Trimble	Zephyr
	Cellular Internet Card	UT Starcom	UT 175
	GPS Receiver	Trimble	5700
	POS MV	Applanix	Wavemaster
Vertical Control	RTK Radio Modem	Pacific Crest	PDL LPB
	RTK Radio Antenna	Pacific Crest	n/a
	GPS Antenna	Trimble	Zephyr
	Cellular Internet Card	UT Starcom	UT 175
	GPS Receiver	Trimble	5700
	POS MV	Applanix	Wavemaster
Echo Sounding	2 Transducers	Airmar	SMSW200-4a
	ODOM CV100	ODOM	CV100
	Operator Station	CCS-inc	FPC-6920
Attitude Positioning	Inertial Motion Unit (IMU)	Applanix	Wavemaster
	Position Compute System (PCS)	Applanix	Wavemaster
	Primary GPS Antenna (port)	Trimble	Zephyr
	Secondary GPS Antenna	Trimble	Zephyr
Sound Velocity	Sound Profile Velocimeter	AML Oceanographic	Minos X SV&P

The vertical control for singlebeam data acquisition was provided by three basestations and a combination of VRS and RTK-GPS. They are: the North Carolina Geodetic Surveys' Virtual Reference Station "NCBE" located on Pivers Island, NC, "IMS Base" located at the UNC-IMS building in Morehead City, NC, and benchmark "Westport" located in Emerald Isle, NC. A repeater was also used to extend radio corrections. Station NCBE utilizes a Trimble NETR5 GNSS (Global Navigation Satellite System) receiver to collect and broadcast corrections to roving users via an internet connection.

Horizontal positioning and vessel attitude for singlebeam data was provided by the Applanix Positioning for Marine Vessels (POS/MV Wavemaster) systems and was corrected using Inertially-Aided Real-Time Kinematic (IARTK) technology. This system provides roll and pitch accuracy to 0.01°, heading to 0.02° (with a 2 m antenna baseline), heave accuracy to 5 cm or 5% (whichever is greater).

The AML Oceanographic Minos X SV&P sound velocimeter was used during the survey in order to obtain accurate sound velocity profiles throughout the survey area. Unlike traditional Conductivity, Temperature, and Depth (CTD) sensors, velocimeters measure sound speed directly using "time of flight" technology, automatically compensating for pressure, salinity, and temperature. The system comprises a sound velocity probe attached to the data collector where the survey technician logs the sound velocity profile data as the probe is deployed.

An Odom CV100 singlebeam sonar system was used to acquire singlebeam bathymetry data during the survey. The CV100 system operates at frequencies in the 200 kHz band; ideal for

shallow depths (<40 m). The transducer forms a 4 degree beam. With an operational depth range from <30 cm to 600 m and a ping rate up to 20 Hz, the CV100 is ideal for shallow water surveys.

The software systems inventory for singlebeam data acquisition and processing is presented in **Table 4**.

Table 4. Singlebeam Software Systems Inventory

	Software	Version
Data Acquisition	HYPACK	2012
	POSView	3.4
Data Processing	HYPACK	2012
	POSPac MMS	5.2

The HYPACK software suite was used during survey preparation in order to create profile lines plans. The initial line plan was created in accordance with the Carteret County Shore Protection Office beach profile monitoring stations established in 1999. Survey lines were extended to a length of 5000 ft from the baseline as per the official SOW. HYPACK was also used during the survey to collect singlebeam bathymetric data and topographic data.

The POSView software by Applanix was used with the POS MV system. The software provides a tightly-coupled integration of the attitude measurements recorded by the IMU and the position measurements recorded by the GPS. POSView allowed the survey technician to monitor the attitude and positioning accuracy throughout the survey. POSView logged a POSPac True Heave file which contains the Kalman filtered heave for further post-mission attitude processing.

HYPACK was subsequently used to manipulate and process both singlebeam bathymetric data and topographic data once it was collected. The Singlebeam Editor in HYPACK was used to import, clean, and thin the data. Upon cleaning, the *Export* module was used to export the data into a specific format. The post-processed POSPac file was integrated with the singlebeam data in HYPACK single beam editor.

The POSPac MMS (mobile mapping solution) software by Applanix was used to post-process attitude and navigation data collected in POSView. By post-processing the attitude and navigation data stored in the POSPac data file with a logged GPS observable file from the basestation, common artifacts of RTK-GPS can most often be eliminated and the overall accuracy of the attitude and navigation can be increased.

3.1.2 Singlebeam Quality Control

All survey line planning was completed in HYPACK. Survey line spacing was based on previous surveys of Bogue Banks with extensions per USACE specification. Survey lines were extended to reach a 5000 ft distance offshore from the start of the profile or baseline.

At the start of each survey day, a series of pre-survey protocols were run to aide in quality control and to determine any possible errors/issues prior to surveying. A temporary benchmark located at Geodynamics headquarters in Morehead City, NC was checked daily. The GAMS

parameters and POS/MV installation parameters located under the installation settings of the POS/MV were all checked each day prior to enabling Ethernet logging of POSPac data.

All singlebeam and topographic data acquisition were completed using HYPACK *Survey* software. Data acquisition was performed at vessel speeds of approximately 3 - 7 knots. The HYPACK data acquisition software produced a constantly-updated OTF (On-The-Fly) data matrix, which allowed for real-time monitoring of the data coverage. Data displays in HYPACK *Survey* were used to monitor all survey parameters and the quality of data being recorded.

Sound velocity profiles were acquired routinely and when the survey vessel moved to a different location within the survey area. Each successive sound velocity cast was assessed and used to determine the need for additional casts.

3.1.3 Corrections to Echo Soundings

The vessel offsets were measured with respect to the ship's reference point, located at the top center of the Inertial Motion Unit (IMU). The vessel offsets were then entered into POSView to ensure an accurate merging of the IMU data with the singlebeam data.

The Applanix POS/MV unit was setup to receive phase-differential RTK position offsets from the GPS base station at NCBE Pivers Island. This configuration allowed the POS/MV to integrate sub-meter positional solutions with highly-accurate vessel attitude positions obtained from the IMU. When the GPS Azimuth Measurement Subsystem (GAMS) was online, positional solutions were being received from 5 or more satellite fixes with a Positional Dilution of Precision (PDOP) equal to or less than 3. When these conditions were not satisfied, the GAMS solution becomes dormant. GAMS continues to track satellites while in this state, but does not process the phase-differential corrections. A calibration of the GAMS system was conducted at the start of survey off Bogue Banks, NC following the auto-start procedure laid out in the POS/MV V4 Installation and Operation Guide. The GAMS parameters in the setup menu were initially set to zero, with the exception of the heading calibration threshold which was set to 0.500°. The vessel then made aggressive figure-8 maneuvers until the GAMS solution came online and the values in the parameter setup menu were automatically updated.

Dynamic draft is the summation of the static draft and settlement and squat corrections, and is a required corrector for the echo soundings. Dynamic draft was accounted for in the echo soundings by using RTK-GPS. The ellipsoid-based vertical corrections received from the VRS network provided the survey vessel with an accurate real-time elevation based on the vessels position in the water. This worked to factor out the static draft, settlement, and squat of the survey vessel.

Sound speed profiles were taken at the start of each survey day, and again throughout the day as warranted by the survey area and water mass properties. Sound velocity profiles were acquired routinely and when the survey vessel moved to a different location in the survey area. Each successive sound velocity cast was assessed and used to determine the need for additional casts. A total of 28 sound velocity profiles where taken during the survey which greatly exceeds the standard set forth in the USACE Hydrographic Manual. A comparison of the sound velocity

profiles was conducted in order to determine sound speed variations in different parts of the survey area.

RTK-based tidal measurements were continuously recorded throughout the survey by HYPACK Survey. The GPS height determined by the POS/MV was integrated into the raw singlebeam sonar data in the HYPACK data acquisition software by integrating the post-processed POSPac Smoothed Best Estimate of Trajectory (SBET) file. After importing the raw singlebeam data in HYPACK, the GPS tide was merged with the heave such to provide accurate tidal corrections and remove heave.

3.2 Topographic Data Acquisition and Processing

The following sections discuss the equipment, quality controls, sounding corrections, and data processing associated with the topographic data acquisition.

3.2.1 Topographic Survey Equipment, Hardware, and Software

A Trimble 5700 RTK-GPS rover backpack system was used to acquire topographic data during the survey. The Trimble 5700 RTK-GPS receiver integrates GPS observables with real-time VRS network corrections to provide a centimeter-level position and elevation. The RTK-GPS data is output from the 5700 receiver at 10 Hz to the Panasonic Toughbook U1 data acquisition tablet PC. A Kawasaki Mule and a Yamaha ATV is used to transport personnel between profiles (**Figure 4**).

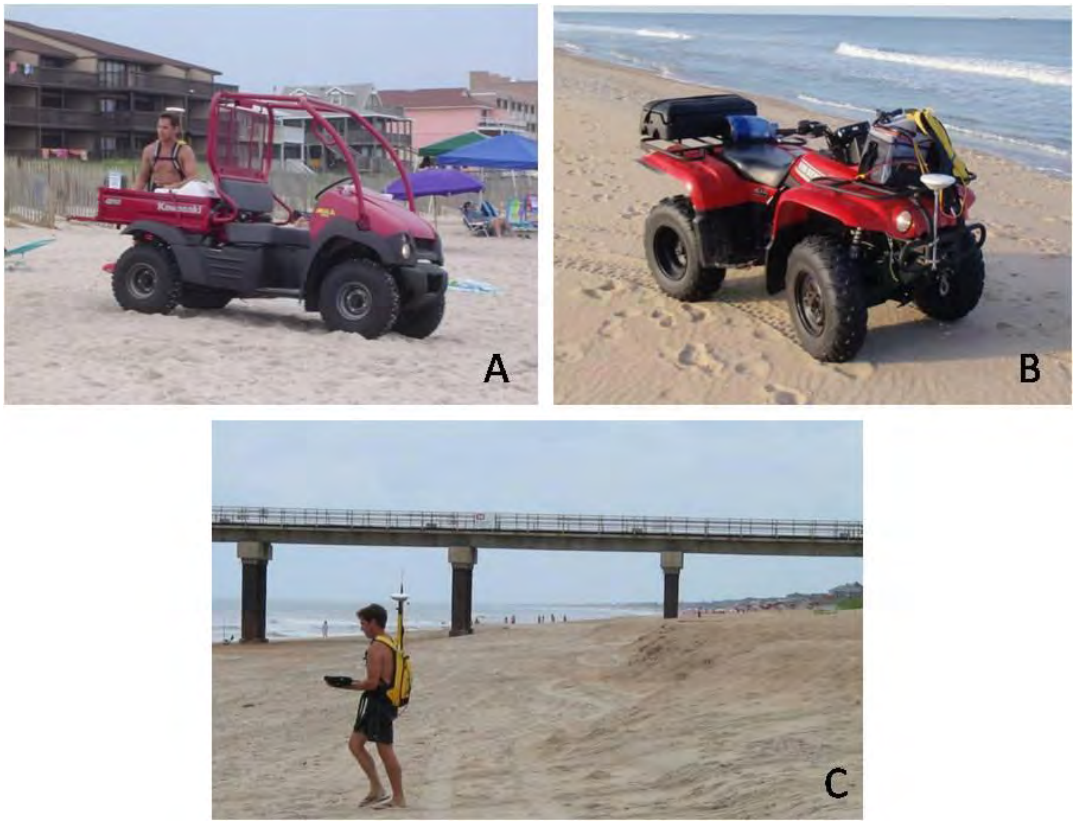


Figure 4. The (A) Kawasaki Mule, (B) Yamaha ATV, and (C)Trimble 5700 RTK-GPS Rover Backpack

The hardware systems inventory for topographic data collection is presented in **Table 5**.

Table 5. Topographic Hardware Systems Inventory

Hardware	Manufacturer	Model
Acquisition PC	Panasonic	Atom CF-U1
GPS Receiver	Trimble	5700
GPS Antenna	Trimble	Zephyr
Internet Con. (imbedded Gobi)	Qualcomm	HS-USB 250D

The vertical and horizontal control for topographic data acquisition was provided by three basestations and a combination of VRS and RTK-GPS. They are the North Carolina Geodetic Surveys' Virtual Reference Station "NCBE" located on Pivers Island, NC, "IMS Base" located at the UNC-IMS building in Morehead City, NC, and benchmark "Westport" located in Emerald Isle, NC. A repeater was also used to extend radio corrections. Station NCBE utilizes a Trimble NETR5 GNSS (Global Navigation Satellite System) receiver to collect and broadcast corrections to roving users via an internet connection.

Horizontal and vertical positioning for topographic data was acquired by a Trimble 5700 RTK-GPS system. The topographic rover received and integrated the differential corrections from the VRS station and RTK-GPS for centimeter-level positioning.

The software systems inventory for topographic data collection is presented in **Table 6**.

Table 6. Topographic Software Systems Inventory

	Software	Version
Data Acquisition	HYPACK	2012
	GNSS Internet Radio	1.4.11
	VZAccess Manager (Verizon/Quick link)	6.9.0
Data	HYPACK	2012

The HYPACK software suite was used during survey preparation in order to create profile lines plans. The initial line plan was created in accordance with the Carteret County Shore Protection Office beach profile survey lines. Survey lines were extended to a length of 5000 ft offshore from the baseline as per the official SOW. HYPACK was also used during the survey to collect topographic data. Phase-differential RTK corrections from NCBE were received by using an imbedded Gobi card accompanied with Verizon Access Manager and GNSS Internet Radio.

HYPACK was subsequently used to manipulate and process the topographic data. The Singlebeam Editor in HYPACK was used to import, clean, and thin the data.

3.2.2 Topographic Quality Control

All survey line planning was completed in HYPACK. The planned survey line spacing was dictated by the Carteret County Shore Protection Office Beach Profile Project. Survey lines were typically oriented parallel to the shoreline (note: lines were changed from Coastal Science and Engineering's 1999-2007 azimuths due to inconsistent data acquisition in 2008). Each

topographic mapping system was tested prior to each survey day. Surveyors verified line files, data acquisition rates, masking angles, and software / hardware setup.

At the start of each survey day, a series of pre-survey protocols were run to aide in quality control and to determine any possible errors/issues prior to surveying. Benchmarks located at the Geodynamics office were checked and quality assessed prior to surveying each day. Each surveyor's rod and backpack antenna draft ware checked and input in the survey software.

All topographic data acquisition was completed using the HYPACK Survey software. Data acquisition was performed by walking as upright as possible while following the planned survey line. The surveyor constantly monitored the GPS status, off-line value, distance from baseline, and overall morphology along the profile. The HYPACK data acquisition software produced a constantly updated OTF data matrix, which allowed for real-time monitoring of the data coverage as well. To ensure ample topographic data overlap with the hydrographic data, the surveyor would plot the targets acquired during the surfzone hydrographic survey. These targets indicated how far the surveyor needed to go down the profile and into the surfzone. Upon completion of a survey day, all data was thoroughly reviewed and various profiles overlaid on 2010 profile data for a quick in-field QA-QC check.

3.3 Vertical and Horizontal Control

The vertical datum for this survey is the North American Vertical Datum of 1988 (NAVD88). Soundings were reduced to NAVD88 from ellipsoid heights in HYPACK by integrating the local Geoid 2003 model.

The horizontal datum for the final data product is the North Carolina State Plane Zone 3200, Feet. Horizontal control was derived using Real Time Kinematic (RTK) or VRS-RTK positioning. The North Carolina Geodetic Surveys' Virtual Reference Station "NCBE" located on Pivers Island, NC provided position and elevation as well as the multiple RTK-GPS basestations.

3.4 Merging Topographic and Bathymetric Data

Upon processing the individual hydrographic and topographic data sets in HYPACK, the datasets are merged, resulting in one edited HYPACK file per profile line. Each profile line is then thoroughly inspected for topo/bathy overlap, landward and seaward data extents, and consistency with previous profile data.

Rigorous QA-QC assessments are performed on the final topo-bathy profiles in order to ensure the highest quality data. Topographic data, in the less variable dune areas, is overlaid with the previous years' data and the horizontal and vertical alignment is evaluated. The topo-bathy profiles are examined one-by-one to review the overlap of topographic and hydrographic data to guarantee reliable surfzone data (**Figure 5**). The entire topo-bathy profile is then compared to the same profile from a previous years' dataset to assess the overall quality and consistency of the profile data.

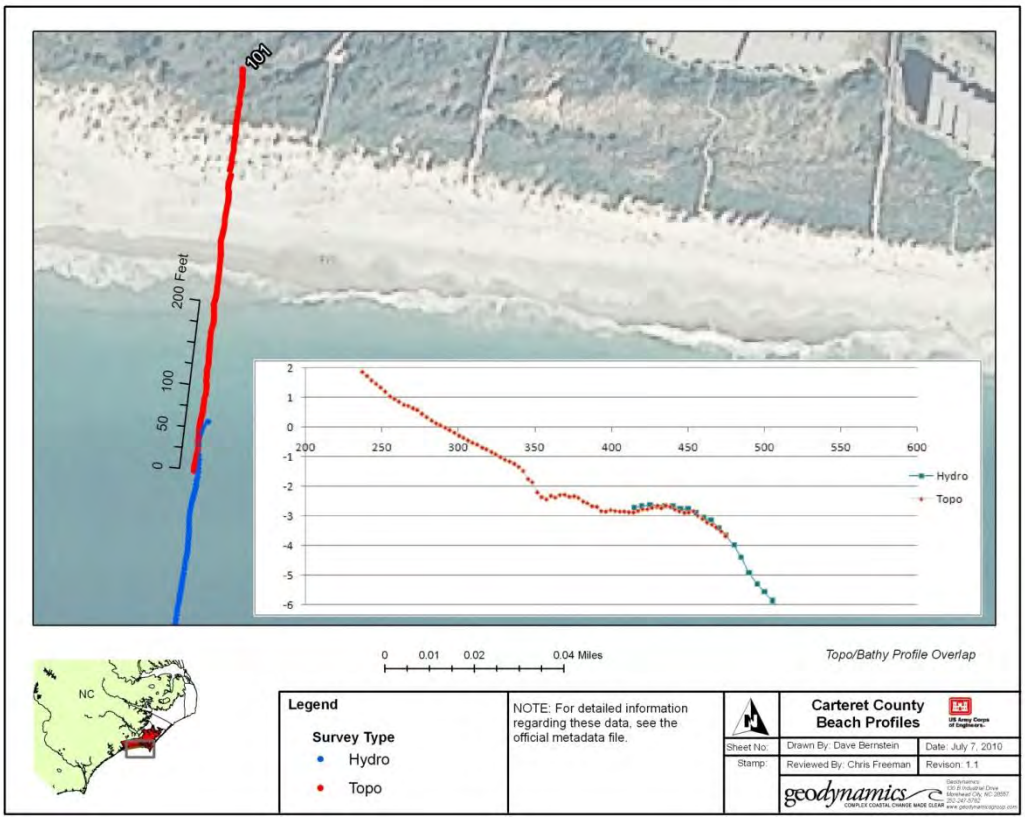


Figure 5. Example of Topographic and Bathymetric Data Overlap in Surfzone

3.5 Survey Data Acquisition Timeline

The most recent survey data was collected by Geodynamics during March and April of 2012. The Shackleford Banks survey was done on March 19, 2012 through March 20, 2012. For this report, March 20, 2012 was used as the survey date for all profile lines on Shackleford Banks. Bear Island surveys were performed on March 29, 2012 and April 3, 2012. For this report, April 3, 2012 was used as the survey date for all profile lines on Bear Island. The Bogue Banks survey, due to weather, was performed over a longer range of dates from March 23, 2012 to April 13, 2012. The date used for the Bogue Banks profiles for this report is April 11, 2012 when a majority of the data was collected.

The previous set of regular survey data, used for comparison in this report, was also collected by Geodynamics during May and June of 2011. The Shackleford Banks survey was done on May 9, 2011 through May 12, 2011. For this report, May 10, 2011 was used as the survey date for all profile lines on Shackleford Banks. Bear Island surveys were performed on June 14, 2011 and June 15, 2011. For this report, June 15, 2011 was used as the survey date for all profile lines on Bear Island. The Bogue Banks survey, due to weather, was performed over a longer range of dates. A portion of the survey was performed from May 10, 2011 through May 12, 2011, while the remainder of the survey was performed from June 6, 2011 through June 17, 2011. The date used for the Bogue Banks profiles for this report is June 1, 2011 which is between the two survey periods.

4.0 Survey Evaluation Methods

Survey comparisons and respective analysis were performed using Beach Morphology Analysis Package (BMAP). BMAP is a program developed by the USACE to analyze morphologic and dynamic properties of beach profiles.

All survey data sources were imported into ArcGIS, in xyz format, and displayed to compare the coverage of each set of data. Excel files containing the spring/summer 2011 and spring 2012 beach profiles being used for the comparison were then formatted and imported into Beach Morphology Analysis Package (BMAP). Using BMAP, two indicators of shoreline change were calculated for each transect.

First, change in shoreline position at mean high water (MHW), which was defined as +1.1 ft NAVD88 (based on NOAA tidal benchmark at Morehead City-equivalent to previously computed elevation of +2.1 ft NGVD29), was calculated at each transect between the spring/summer 2011 and spring 2012 profiles. The resulting value represents the shoreline change (ft) over the time period between surveys. The shoreline change rate (ft/yr) was then calculated by dividing by the amount of time between survey dates in order to better compare changes between different time periods.

Then, representative volume changes were calculated at each transect between spring/summer 2011 and spring 2012. Volume changes were calculated for five different extents in order to better understand the processes occurring onshore and offshore of the Bogue Banks beach area. Calculations included volume change above MHW (+1.1 ft NAVD88-equivalent to +2.1 ft NGVD29), above -5 ft NAVD88 (wading depth/recreational beach-equivalent to -4 ft NGVD29), above -12 ft NAVD88 (outer bar-equivalent to -11 ft NGVD29), above -20 ft NAVD88, and above -30 ft NAVD88. Upon inspection of recent survey data, it appears the depth of closure is somewhere between -20 ft NAVD88 and -30 ft NAVD88 (likely closer to -20 ft NAVD88). For those profiles which did not extend to -30 ft NAVD88, volume calculations were performed above -30 ft out to the extent of the shortest survey. As with the shoreline change, the results represent volume change (cy/ft) over the period of time between surveys. The volume change rate (cy/ft/yr) was then calculated by dividing by the amount of time between survey dates in order to better compare changes between different time periods. In addition, the volume changes were converted to cumulative changes over the entire shoreline. This was done by applying the average end area method to the unit volume changes (cy/ft) and unit volume change rates (cy/ft/yr) computed at each transect and summing the total volume changes over the entire shoreline. The resulting value indicated the total loss or gain of material between survey periods based on the applicable profile extents. It should be noted that the uncertainty in the hydrographic portion of the survey is approximately 0.11 ft. If this uncertainty is applied along the portion of the profile between the seaward side of the outer bar (approximately 1300 ft offshore) and a depth of -30 ft NAVD88 (approximately 2850 ft offshore) along all 128,393 ft of oceanfront shoreline, this lends itself to an uncertainty of approximately ±811,000 cy.

Volume changes calculated for portions of the profiles above MHW are representative of changes in the amount of material in the dune system and on the subaerial beach. These areas are highly influenced by the impact of storm activity. Volume comparisons for portions of the profiles above -5 ft NAVD88, which is an approximate wading depth, are representative of

changes in the portion of the beach used for recreation. Volume comparisons above -12 ft NAVD88 help to track sand movement to and from the outer sand bar and are ultimately used in decision making for future beach nourishment projects. Volume comparisons above -20 ft NAVD88 allow for the tracking of sand movement offshore while reducing the amount of uncertainty associated with the survey data by eliminating changes beyond this depth related to the vertical margin of uncertainty in the hydrographic survey data. Finally, volume comparisons above -30 ft NAVD88 allow the complete tracking of sand movement offshore. However, hydrographic survey measurement accuracy may impact these calculations. This is a comprehensive way to assess the impact of storm activity on the subaerial beach and dune system as well as track the movement of sand offshore and quantify total gains and losses in the entire system. **Figure 6** presents a graphic showing the various calculation lenses.

Figure 6. Profile Volume Calculation Lenses

Finally, FEMA beach maintenance calculations were done based on a baseline nourishment condition consisting of the post-nourishment surveys from Phase I (2002), Phase II (2003), and Phase III (2005) of the Bogue Banks Beach Restoration Project. Profile volumes above -12 ft NAVD88 (equal to previously utilized elevation of -11 ft NGVD29) from spring 2012 were compared to profile volumes above -12 ft NAVD88 from the post-fill surveys. The amount of remaining fill was computed by subtracting the amount of fill placed in the restoration project from the volume change calculated between the post-nourishment surveys and 2012.

For visual reference, a Digital Elevation Model (DEM) was created by Geodynamics using Surfer, a 3D surface mapping software package, for both the spring/summer 2011 and spring 2012 profile data. The MHW shoreline position contour was extracted from the spring/summer 2011 and spring 2012 DEMs and plotted on aerials. The post-Irene MHW contour was also plotted for reference. These figures are presented in **Appendix A**.

5.0 Discussion of Periodic Surveying Evaluation

This section will discuss long-term background erosion rates, recent events (i.e. nourishment projects, storms, etc.), overall shoreline trends, regional shoreline trends, and beach maintenance analysis. Plots of the shoreline and volume changes from spring/summer 2011 and spring 2012, at each transect, for Bogue Banks, Bear Island, and Shackleford Banks are presented in **Appendix B**. Profile comparison plots for individual transects, which include the spring/summer 2011, post-Irene (September 2011) and spring 2012, are presented in **Appendix C**. The computed shoreline changes and volume changes at each individual transect for the time periods being covered are tabulated in **Appendix D**.

5.1 Determination of Background Erosion Rate for Bogue Banks

Due to the numerous nourishment projects which have taken place along Bogue Banks since the monitoring program was initiated in 1999, it is important to determine a background erosion rate without nourishment from which to compare the performance of the various projects and to develop long-term trends in volume losses/gains. Therefore, the historical volume changes above -12 ft NAVD88 and beach nourishment volumes were documented. The Bogue Banks area has undergone extensive beach nourishment throughout the duration of the monitoring effort as part of the Bogue Banks Beach Restoration Project, the USACE Section 933 Project, USACE Dredge Disposal Projects, and some post-storm FEMA work. **Table 7** and **Table 8** summarize the nourishment projects in the study area since the monitoring program was initiated. It should be noted that these tables differ slightly from previous reports due to in depth research regarding the Bogue Banks nourishment history which revealed a few discrepancies, mostly due to discrepancies in reported contracted versus in-place nourishment volumes.

Table 7. Nourishment Volumes by Project

Project	Reach	Year	In-Place Volume (cy)
County Phase 1	Pine Knoll Shores - East & West	2002	1,276,586
County Phase 1	Indian Beach/Salter Path	2002	456,994
USACE Disposal	Fort Macon	2002	209,348
County Phase 2	Emerald Isle - East & Central (berm)	2003	1,743,788
County Phase 2	Emerald Isle - East & Central (dune)	2003	123,938
USACE Section 933	Indian Beach/Salter Path & Pine Knoll Shores - West	2004	699,282
FEMA Post Isabel	Emerald Isle - East & Central	2004	156,000
Brandt Island Pump Out	Atlantic Beach	2005	2,390,000
USACE Disposal	Fort Macon	2005	530,729
County Phase 3	Emerald Isle - West	2005	690,868
USACE Section 933	Pine Knoll Shores - East & West	2007	507,939
FEMA Post Ophelia	Emerald Isle, Pine Knoll Shores, & Indian Beach/Salter Path	2007	1,229,836
USACE Disposal	Fort Macon	2007	184,828
AIWW Tangent B Disposal	Pine Knoll Shores East	2008	148,393
USACE Disposal	Atlantic Beach	2011	799,504
USACE Disposal	Fort Macon	2011	547,196
		Total	**11,695,229**

Table 8. Nourishment Volumes by Reach

Reach	Nourishment Volume (cy)
Bogue Inlet - Ocean	59,272
Emerald Isle - West	935,633
Emerald Isle - Central & East	2,368,136
Indian Beach/Salter Path	1,358,842
Pine Knoll Shores	2,311,741
Atlantic Beach	3,189,504
Fort Macon	1,472,101
Total	**11,695,229**

To calculate the background erosion rate, nourishment volumes were subtracted from total volume changes above -12 ft NAVD88 between a baseline survey taken in 1999 and the spring 2012 survey. The volume changes were established by adding the yearly volume changes calculated by M&N since 2008 to the volume changes from 1999-2007 calculated in the 2007 monitoring report (CSE 2007). **Table 9** shows the computed volume change (including nourishments) above -12 ft NAVD88 from 1999-2012 for the defined reaches.

Table 9. Volume Change by Reach Above -12 ft NAVD88

Reach	Volume Change (cy) (1999-2007)	Volume Change (cy) (2007-2008)	Volume Change (cy) (2008-2009)	Volume Change (cy) (2009-2010)	Volume Change (cy) (2010-2011)	Volume Change (cy) (2011-2012)	Volume Change (cy) (1999-2012)
Bogue Inlet-Ocean	147,797	-218,444	169,134	-82,982	-28,440	-199,903	-212,839
Emerald Isle West	1,185,131	-107,631	75,690	-107,529	30,257	-264,467	811,451
Emerald Isle Central & East	1,727,705	117,522	-96,085	-281,475	57,244	-293,600	1,231,310
Indian Beach/ Salter Path	1,155,522	-116,245	-118,761	-118,078	55,234	-163,958	693,714
Pine Knoll Shores	1,753,427	-57,453	-53,514	-162,946	-81,597	-313,077	1,084,840
Atlantic Beach	1,194,947	27,172	-106,720	-11,803	750,462	-530,856	1,323,201
Fort Macon State Park	221,169	-137,402	-151,048	-46,357	595,792	-167,964	314,190
Total	**7,385,698**	**-492,481**	**-281,305**	**-811,170**	**1,378,951**	**-1,933,825**	**5,245,869**

Table 10 shows the average annual background erosion rates for each reach of the Bogue Banks oceanfront. The average background erosion rate for the entire Bogue Banks shoreline is approximately -3.9 cy/ft/yr. This result is slightly higher than similar calculations completed in previous years, likely in response to Hurricane Irene in August 2011.

Table 10. Average Annual Background Erosion Rates (1999-2012)

Reach	Length (ft)	Volume Change Above -12 ft NAVD88 (cy) (1999-2012)	Nourishment Volume (cy)	Background Erosion (cy)	Average Annual Background Erosion Rates (cy/ft/yr)
Bogue Inlet-Ocean	7,432	-212,839	59,272	-272,111	-2.82
Emerald Isle West	22,344	811,451	935,633	-124,182	-0.43
Emerald Isle Central & East	29,022	1,231,310	2,368,136	-1,136,826	-3.01
Indian Beach/Salter Path	12,850	693,714	1,358,842	-665,128	-3.98
Pine Knoll Shores	23,878	1,084,840	2,311,741	-1,226,901	-3.95
Atlantic Beach	26,176	1,323,201	3,189,504	-1,866,303	-5.48
Fort Macon State Park	6,691	314,190	1,472,101	-1,157,911	-13.31
Total	**128,393**	**5,245,869**	**11,695,229**	**-6,449,360**	**-3.86**

5.2 Key Events During the Reporting Period

Beach changes are greatly influenced by natural and engineering processes. This section describes key events that occured during the reporting period that likely had an impact on shoreline change as well as profile volume gains and losses.

5.2.1 Storm Events

Hurricane Irene made landfall at Cape Lookout, NC on August 27, 2011. All of the beaches overseen by the Carteret County Shore Protection Office fall within 30 miles of the hurricane's landfall point. As a direct result of the hurricane, the beaches of Bogue Banks, including all reaches of the County and local municipality sponsored (non-federal) engineered beach project, experienced erosion of the incipient and primary frontal dunes with significant profile volume loss above -12 ft NAVD88. The federal government declared Hurricane Irene as a federal disaster within Carteret County, and FEMA Category A through G public assistance was authorized on August 31, 2011.

Geodynamics conducted a post-storm survey on Bogue Banks in September 2011 immediately following the passage of Hurricane Irene. The survey data was used to perform a post-storm assessment of the Bogue Banks engineered beaches and provide FEMA with a volume of sand loss above -12 ft NAVD88 which would be eligible for reimbursement (M&N, 2011). The post-storm survey data was compared to the June 2011 survey taken as part of the annual monitoring effort. **Table 11** shows the losses calculated in the post-storm report from Hurricane Irene.

Table 11. Bogue Banks Regional Shoreline and Volume Change Statistics (June 2011 – September 2011 Comparison)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	8.5	-4.1	-30,297	-10.1	-75,280	-18.6	-138,201	-5.2	-38,663	13.7	101,935
Emerald Isle-West (9-25)	22,344	-5.5	-4.4	-98,004	-10.0	-222,862	-25.9	-579,219	-21.9	-489,290	-2.2	-48,471
Emerald Isle-Central (26-36)	15,802	-0.7	-3.4	-53,055	-5.2	-81,696	-13.7	-216,386	-27.2	-429,866	-6.7	-106,286
Emerald Isle-East (37-48)	13,220	-3.8	-3.5	-45,723	-9.3	-122,432	-11.9	-157,073	-18.8	-249,104	1.3	17,312
Indian Beach-Salter Path (49-58)	12,850	-2.4	-5.5	-70,567	-10.4	-133,830	-18.4	-235,939	-30.3	-389,783	-6.7	-86,084
Pine Knoll Shores-West (59-65)	9,063	6.4	-3.6	-32,250	-3.8	-34,590	-11.3	-102,188	-32.8	-297,329	-16.2	-147,017
Pine Knoll Shores-East (66-76)	14,815	15.5	-2.6	-38,432	-0.5	-7,258	-7.6	-112,555	-20.6	-304,670	-5.3	-77,848
Atlantic Beach (77-102)	26,176	6.8	-6.0	-156,328	-7.5	-197,552	-13.9	-362,678	-15.1	-395,857	-18.8	-490,869
Fort Macon State Park (103-112)	6,691	-41.1	-7.8	-52,480	-18.0	-120,558	-7.2	-48,058	12.2	81,416	24.2	162,104
Beaufort Inlet (113-116)	2,000	-88.3	0.5	952	-11.5	-23,020	-29.6	-59,154	-40.3	-80,600	-43.0	-86,054
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reach Length	Weighted Avg	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total
County Project (9-76)	**88,094**	**0.8**	**-3.8**	**-338,030**	**-6.8**	**-602,668**	**-15.9**	**-1,403,361**	**-24.5**	**-2,160,042**	**-5.1**	**-448,393**
Oceanfront (1-112)	128,393	0.3	-4.5	-577,135	-7.8	-996,059	-15.2	-1,952,298	-19.6	-2,513,146	-5.3	-675,223

*Notes: 1. Due to the dynamic nature of Bogue Inlet, shoreline and volume calculations were not performed

The nor'easter season was fairly inactive and very similar to the previous year. Wave data indicates only a couple of instances where offshore wave heights reached 14 feet. This is relatively calm compared to other years which have seen some larger nor'easter events where offshore wave heights reached as high as 25 feet, with multiple events of waves over 16 feet.

5.2.2 Nourishment Events

There were no nourishment events during the June 2011 to April 2012 time period. It should be noted that the post-Irene nourishment project is currently being planned and material is scheduled to be placed on the beach in Emerald Isle and Pine Knoll Shores during winter 2012-2013.

5.3 Regional Shoreline and Volume Trends

Key statistics were calculated to quantify the average shoreline and volume changes for each individual shoreline reach as well as the entire shoreline. The computed statistics include average shoreline change, average volume change, and cumulative volume change (e.g. total volume of material lost or gained along a section of shoreline). A summary of the resulting statistics for the reporting period comparison are presented in **Table 12** through **Table 14**. Evaluation of the computed statistics will take into account volume changes computed for portions of the profile above MHW (+1.1 ft NAVD88), above -5 ft NAVD 88, above -12 ft NAVD88, above -20 ft NAVD88, and above -30 ft NAVD88 in order to better understand onshore and offshore processes. Since each reach consists of a different length of shoreline, a weighted average for unit shoreline change (ft) and unit volume change (cy/ft) at each transect was calculated for the Bogue Banks Oceanfront and County Project based on the length of each reach.

Table 12. Bogue Banks Regional Shoreline and Volume Change Statistics (Summer 2011 – Spring 2012 Comparison)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	4.3	-0.4	-2,923	-5.6	-41,637	-26.9	-199,903	-32.7	-243,370	-29.6	-219,935
Emerald Isle-West (9-25)	22,344	-20.7	-5.0	-111,449	-6.1	-137,356	-11.8	-264,467	-18.6	-414,633	-6.1	-136,680
Emerald Isle-Central (26-36)	15,802	-37.8	-6.3	-99,667	-6.0	-94,201	-8.9	-139,918	-23.4	-369,599	-9.8	-154,303
Emerald Isle-East (37-48)	13,220	-26.4	-7.5	-99,396	-10.0	-132,365	-11.6	-153,682	-22.6	-298,270	-12.2	-160,697
Indian Beach-Salter Path (49-58)	12,850	-43.7	-8.2	-105,632	-9.5	-122,411	-12.8	-163,958	-26.0	-334,048	-11.9	-153,274
Pine Knoll Shores-West (59-65)	9,063	-46.4	-7.6	-68,625	-5.2	-47,394	-8.5	-76,886	-24.4	-220,746	-12.5	-113,255
Pine Knoll Shores-East (66-76)	14,815	-55.6	-10.2	-151,720	-10.2	-151,426	-15.9	-236,192	-27.5	-407,065	-21.7	-320,915
Atlantic Beach (77-102)	26,176	-43.1	-7.3	-190,162	-14.3	-373,650	-20.3	-530,856	-28.7	-750,155	-43.7	-1,144,341
Fort Macon State Park (103-112)	6,691	-65.0	-6.3	-42,097	-17.9	-119,510	-25.1	-167,964	-12.2	-81,801	-18.9	-126,493
Beaufort Inlet (113-116)	2,000	23.9	5.1	10,159	16.3	32,534	16.7	33,466	14.4	28,766	10.2	20,497
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reach Length	Weighted Avg	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total
County Project (9-76)	88,094	-36.5	-7.2	-636,490	-7.8	-685,153	-11.7	-1,035,102	-23.2	-2,044,361	-11.8	-1,039,124
Oceanfront (1-112)	128,393	-37.0	-6.8	-871,672	-9.5	-1,219,951	-15.1	-1,933,825	-24.3	-3,119,687	-19.7	-2,529,892

*Note: Due to the dynamic nature of Bogue Inlet, shoreline and volume calculations were not performed

Table 13. Bear Island Shoreline and Volume Change Statistics (Summer 2011 – Spring 2012 Comparison)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bear Island (1-18)	16,500	-1.4	-3.3	-53,765	-5.1	-83,737	0.2	3,922	-0.9	-14,673	0.8	13,296

Table 14. Shackleford Banks Shoreline and Volume Change Statistics (Spring 2011 – Spring 2012 Comparison)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Shackleford Banks (1-24)	46,001	-20.1	-6.1	-281,642	-8.0	-365,768	-12.5	-573,413	-10.3	-473,835	-14.7	-677,093

It is apparent from **Table 12** that there has been significant recession of the Bogue Banks shoreline and significant volumetric losses along the beach profiles over the past year. This is largely due to the impact of Hurricane Irene (see **Table 11**). However, despite quiescent weather the remainder of the year, Bogue Banks did not see much in terms of recovery from the storm but rather saw continued shoreline recession and volume losses, especially above MHW with some minor recovery above -12 ft NAVD88. **Table 15** shows the changes which occurred between Hurricane Irene and the April 2012 survey.

Table 15. Bogue Banks Regional Shoreline and Volume Change Statistics (September 2011-April 2012)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	-4.2	3.7	27,374	4.5	33,644	-8.3	-61,703	-27.5	-204,707	-43.3	-321,870
Emerald Isle-West (9-25)	22,344	-15.2	-0.6	-13,445	3.8	85,506	14.1	314,752	3.3	74,656	-3.9	-88,209
Emerald Isle-Central (26-36)	15,802	-37.1	-2.9	-46,612	-0.8	-12,505	4.8	76,468	3.8	60,267	-3.0	-48,017
Emerald Isle-East (37-48)	13,220	-22.6	-4.1	-53,673	-0.8	-9,933	0.3	3,391	-3.7	-49,166	-13.5	-178,010
Indian Beach-Salter Path (49-58)	12,850	-41.3	-2.7	-35,065	0.9	11,419	5.6	71,981	4.3	55,735	-5.2	-67,190
Pine Knoll Shores-West (59-65)	9,063	-52.8	-4.0	-36,376	-1.4	-12,804	2.8	25,302	8.5	76,583	3.7	33,761
Pine Knoll Shores-East (66-76)	14,815	-71.1	-7.6	-113,288	-9.7	-144,168	-8.3	-123,636	-6.9	-102,395	-16.4	-243,066
Atlantic Beach (77-102)	26,176	-49.9	-1.3	-33,834	-6.7	-176,098	-6.4	-168,178	-13.5	-354,298	-25.0	-653,472
Fort Macon State Park (103-112)	6,691	-23.9	1.6	10,383	0.2	1,048	-17.9	-119,906	-24.4	-163,217	-43.1	-288,596
Beaufort Inlet (113-116)	2,000	112.2	4.6	9,207	27.8	55,554	46.3	92,620	54.7	109,366	53.3	106,551
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reach Length	Weighted Avg	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total
County Project (9-76)	88,094	-37.3	-3.4	-298,459	-0.9	-82,485	4.2	368,259	1.3	115,680	-6.7	-590,731
Oceanfront (1-112)	128,393	-37.3	-2.3	-294,537	-1.7	-223,892	0.1	18,473	-4.7	-606,542	-14.4	-1,854,669

According to **Table 15**, almost all of the shoreline recession evident between the Summer 2011 and Spring 2012 surveys in **Table 12** occurred after Hurricane Irene. The beach protection lost during Hurricane Irene has likely been the cause of increased recession of the shoreline. In addition, another 300,000 cy of material was lost above MHW since the hurricane, likely due to decreased storm protection. Profile plots in **Appendix C** show a large loss of sand between MHW and +5 ft NAVD88. It appears that this material has been captured by the system above -12 ft NAVD88 and some of the losses between -12 ft NAVD88 and -20 ft NAVD88 from the Hurricane Irene have possibly started to move back onshore given the minor volume gains seen above -12 ft NAVD88 after the hurricane. However, the continued losses above -30 ft NAVD88 points to the fact that the material deposited during Hurricane Irene out past -20 ft NAVD88 may be lost to the system for good.

It is important to note that not all of the transects within Atlantic Beach and Fort Macon were surveyed after Hurricane Irene, therefore it is hard to determine an exact amount of material lost from the hurricane itself and the amount lost after the hurricane. Regardless, it is evident that Hurricane Irene had a large impact on these areas which had just been nourished the previous winter.

Bear Island, which was not surveyed post-storm, appears to have been affected most above MHW and above -5 ft NAVD88. Profile plots in **Appendix C** show a significant loss of material from the beachface down to -5 ft NAVD88, which appears to be deposited near the offshore bar.

Shackleford Banks also appears to have been impacted significantly by Hurricane Irene. Profile plots in **Appendix C** show clear erosion of the frontal dune in almost half of the transects. Losses to the beachface and down to the elevation of the outer bar are apparent as well.

Figure 7 and **Figure 8** display the trends seen in **Table 12** through **Table 14** with bar plots of the average unit volume changes and cumulative volume changes at each reach. Apparent from these figures is the significant losses seen over the entire study area with the exception of the Beaufort Inlet reach. It is likely that material from Atlantic Beach and Fort Macon was pushed over or around the terminal groin during the storm, causing accretion of the east facing beach in Beaufort Inlet.

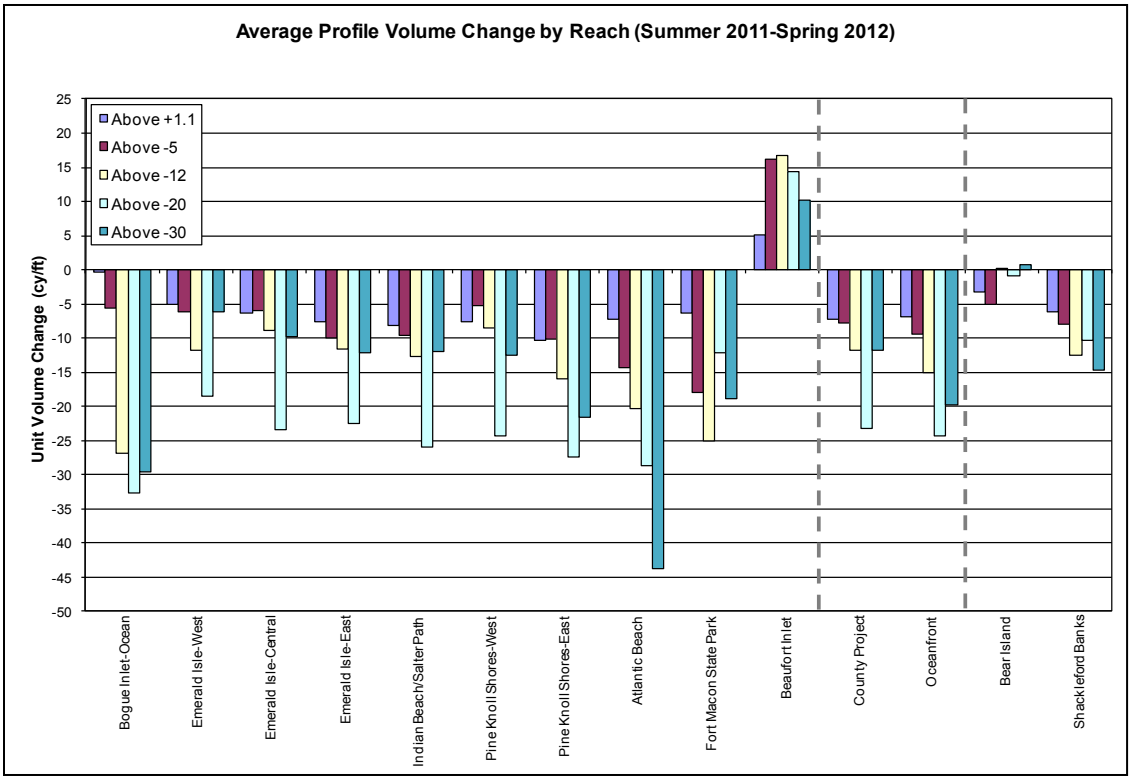


Figure 7. Average Unit Volume Change by Reach

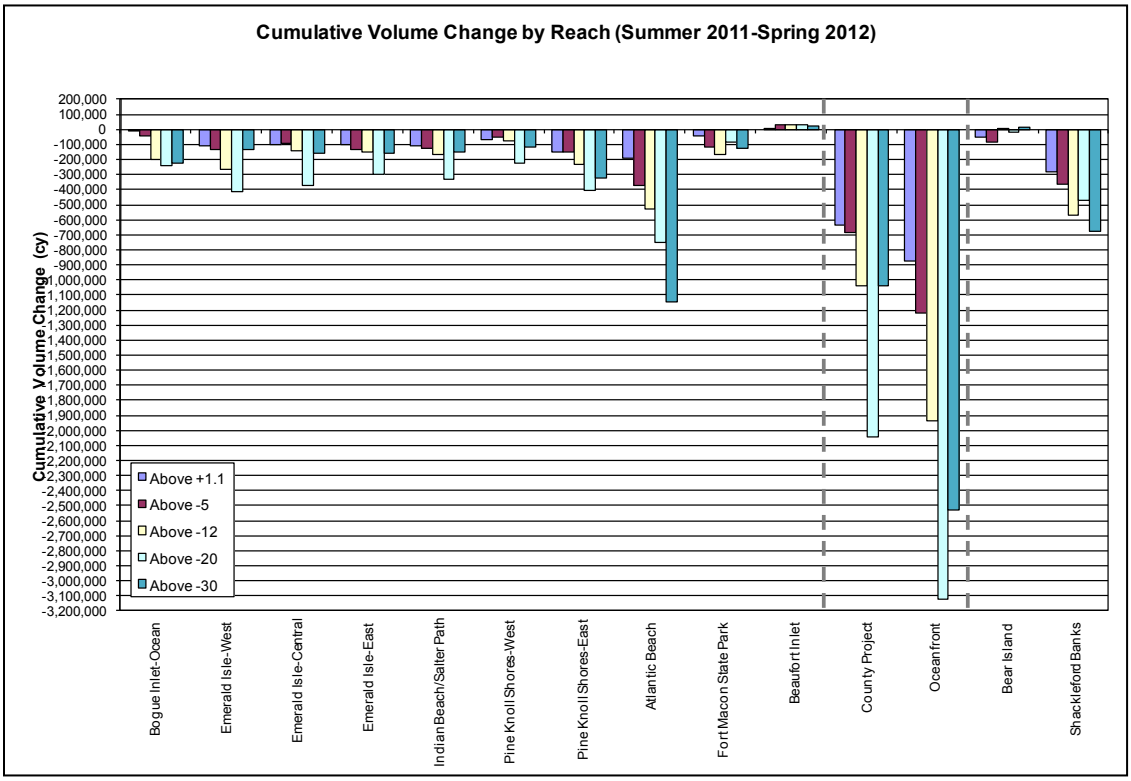


Figure 8. Cumulative Volume Change by Reach

A target minimum volume for each profile from the foredune (landward most crest of the primary dune) to the outer bar (above -12 ft NAVD88) was established at 225 cy/ft during the formulation of the Bogue Banks Beach Restoration Project. **Figure 9** displays the average profile volume to the outer bar per transect within each reach of shoreline for 2008 - 2012. Values displayed in the graph are tabulated in **Table 16**.

As shown in **Figure 9**, Emerald Isle East and Pine Knoll Shores (East and West) are the closest to the minimum target of 225 cy/ft. While all three areas are rapidly approaching the 225 cy/ft threshold, Emerald Isle East has the least material remaining from the original restoration project and is thus in the greatest need of nourishment (see FEMA calculations in **Section 5.6**). Pine Knoll Shores East is also closing in on having less than half of the original restoration project fill remaining (see **Section 5.6**). It should be noted that a post-Irene nourishment project is currently being planned for areas of Emerald Isle and Pine Knoll Shores which would place sand on the beach during winter 2012-2013. What was originally planning to be a smaller hotspot project to utilize this year's planned USACE hopper project to place sand in the Emerald Isle hotspot area from the Morehead City Harbor Federal Navigation Project, has now expanded to a full post-storm renourishment aided by funds from FEMA.

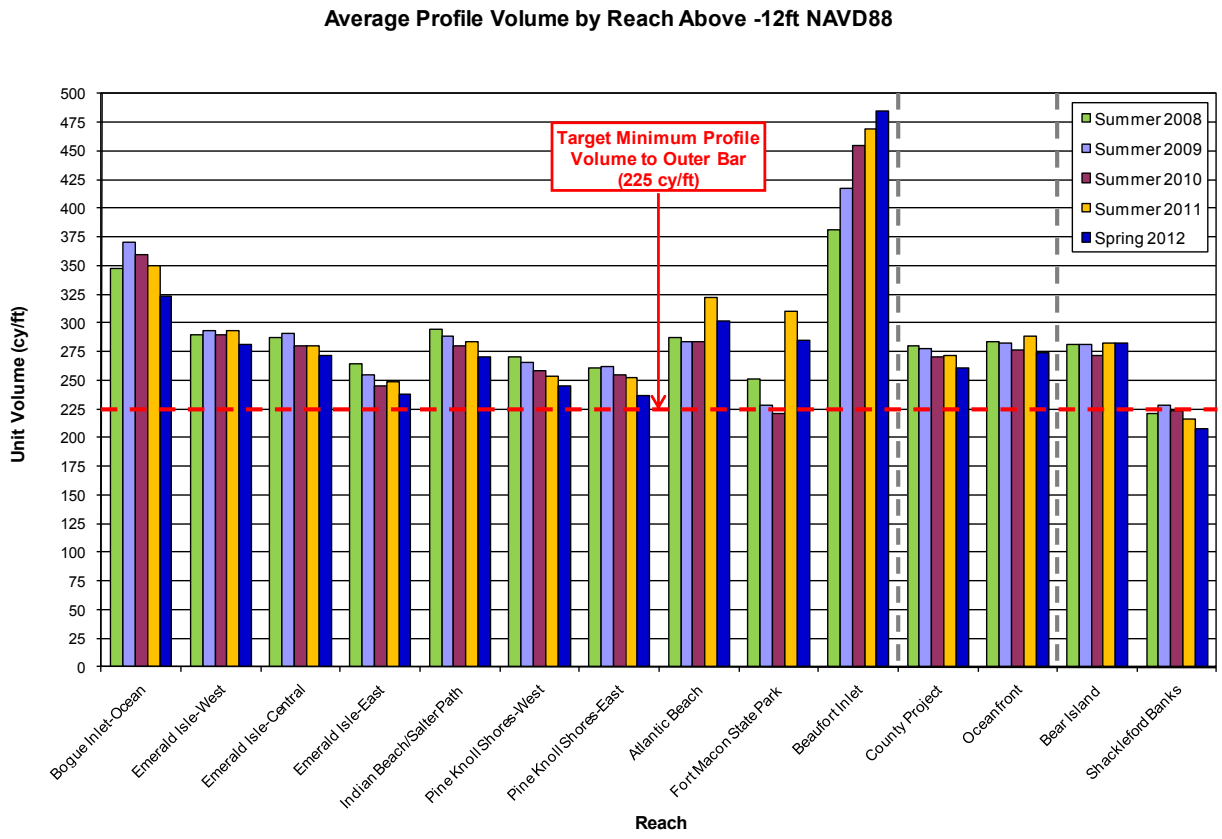


Figure 9. Average Profile Volume From Foredune to Outer Bar by Reach

Table 16. Average Profile Volume From Foredune to Outer Bar by Reach

Reach	July 2008	June 2009	June 2010	June 2011	April 2012
Bogue Inlet-Channel (117-120)	N/A	N/A	N/A	N/A	N/A
Bogue Inlet-Ocean (1-8)	348	371	359	350	323
Emerald Isle-West (9-25)	290	294	289	293	282
Emerald Isle-Central (26-36)	288	291	280	281	272
Emerald Isle-East (37-48)	265	255	245	249	238
Indian Beach/Salter Path (49-58)	294	289	280	284	271
Pine Knoll Shores-West (59-65)	270	265	258	253	245
Pine Knoll Shores-East (66-76)	261	262	255	253	237
Atlantic Beach (77-102)	287	284	283	322	302
Fort Macon State Park (103-112)	251	229	222	311	286
Beaufort Inlet (113-116)	382	418	455	469	485
County Project	280	278	271	272	260
Oceanfront	284	282	276	289	274
Bear Island (1-18)	282	281	272	282	282
Shackleford Banks (1-24)	221	229	223	216	207

5.4 Local Shoreline and Volume Trends

Local shoreline trends are discussed below for the defined regions of Bogue Banks as well as Bear Island and Shackleford Banks (**Figure 1**). A summary of the information in **Table 12** through **Table 14** and **Appendix B** has been created for each region of study.

5.4.1 Emerald Isle

The Emerald Isle region covers Transects 9 through 48. Since monitoring began in 1999, Emerald Isle has received a total of 3.3 million cy of nourishment material as a result of the Bogue Banks Beach Restoration Project and FEMA post-storm work (Isabel and Ophelia). A summary of average shoreline and volume changes between 2011 and 2012 for the Emerald Isle region are presented in **Table 17**. For comparison, a summary of average shoreline and volume changes from Hurricane Irene are presented in **Table 18**.

Table 17. Average Shoreline and Volume Change for Emerald Isle (2011-2012)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Emerald Isle-West (9-25)	22,344	-20.7	-5.0	-111,449	-6.1	-137,356	-11.8	-264,467	-18.6	-414,633	-6.1	-136,680
Emerald Isle-Central (26-36)	15,802	-37.8	-6.3	-99,667	-6.0	-94,201	-8.9	-139,918	-23.4	-369,599	-9.8	-154,303
Emerald Isle-East (37-48)	13,220	-26.4	-7.5	-99,396	-10.0	-132,365	-11.6	-153,682	-22.6	-298,270	-12.2	-160,697

Table 18. Average Shoreline and Volume Change for Emerald Isle (Hurricane Irene)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Emerald Isle-West (9-25)	22,344	-5.5	-4.4	-98,004	-10.0	-222,862	-25.9	-579,219	-21.9	-489,290	-2.2	-48,471
Emerald Isle-Central (26-36)	15,802	-0.7	-3.4	-53,055	-5.2	-81,696	-13.7	-216,386	-27.2	-429,866	-6.7	-106,286
Emerald Isle-East (37-48)	13,220	-3.8	-3.5	-45,723	-9.3	-122,432	-11.9	-157,073	-18.8	-249,104	1.3	17,312

Shoreline change at MHW showed considerable recession at all reaches of Emerald Isle, most of which occurred after Hurricane Irene due to decreased beach protection. Hurricane Irene only accounted for 26%, 2%, and 14% of the shoreline change over the past year at Emerald Isle West, Central, and East respectively. Volumetrically, **Table 17** indicates that all reaches of Emerald Isle experienced a loss in sand above all elevations. While there has been some minor recovery in the area above lower elevations, evident by the larger losses above -12 ft NAVD and -20 ft NAVD88 from Hurricane Irene seen **Table 18** than over the whole year as seen in **Table 17**, the beach as a whole lost a large amount of sand due to Hurricane Irene in all three reaches. The profile plots in **Appendix C** show a large amount of erosion between 0 and +5 ft NAVD88. It appears that while some material has been pushed back onto the beach in an attempt to restore the berm to a pre-storm elevation a much greater amount of material has been pulled offshore and deposited along the beachface between 0 and -10 ft NAVD88 (example transect 25). The plots also show movement further offshore of the bar.

As mentioned in previous reports, the Emerald Isle East portion of the Phase II project has been in need of nourishment. Historically, the hotspot has drifted between transect 44 in Emerald Isle East and transect 32 in Emerald Isle Central, shifting slightly westward over the past few years. The current survey evaluation indicates the hotspot has shifted back to Emerald Isle East between transects 40 and 44. In addition, there was a large amount of erosion from transect 23 in Emerald Isle West to transect 30 in Emerald Isle Central, along with some additional localized erosion activity in Emerald Isle West.

A post-storm renourishment project is currently being planned for winter 2012-2013 to restore areas of the beach damaged most during Hurricane Irene. The previously intended Emerald Isle East hotspot project has been enlarged to encompass some localized erosion that occurred in Emerald Isle West, as well, due to the hurricane. Emerald Isle East has been in need of nourishment over the past few years due to the hotspot as well as having the smallest remainder of sand from the original Bogue Banks Restoration Project nourishment project (currently only 35%).

Figure 10 displays the unit volume change at each transect above the five elevations that were analyzed.

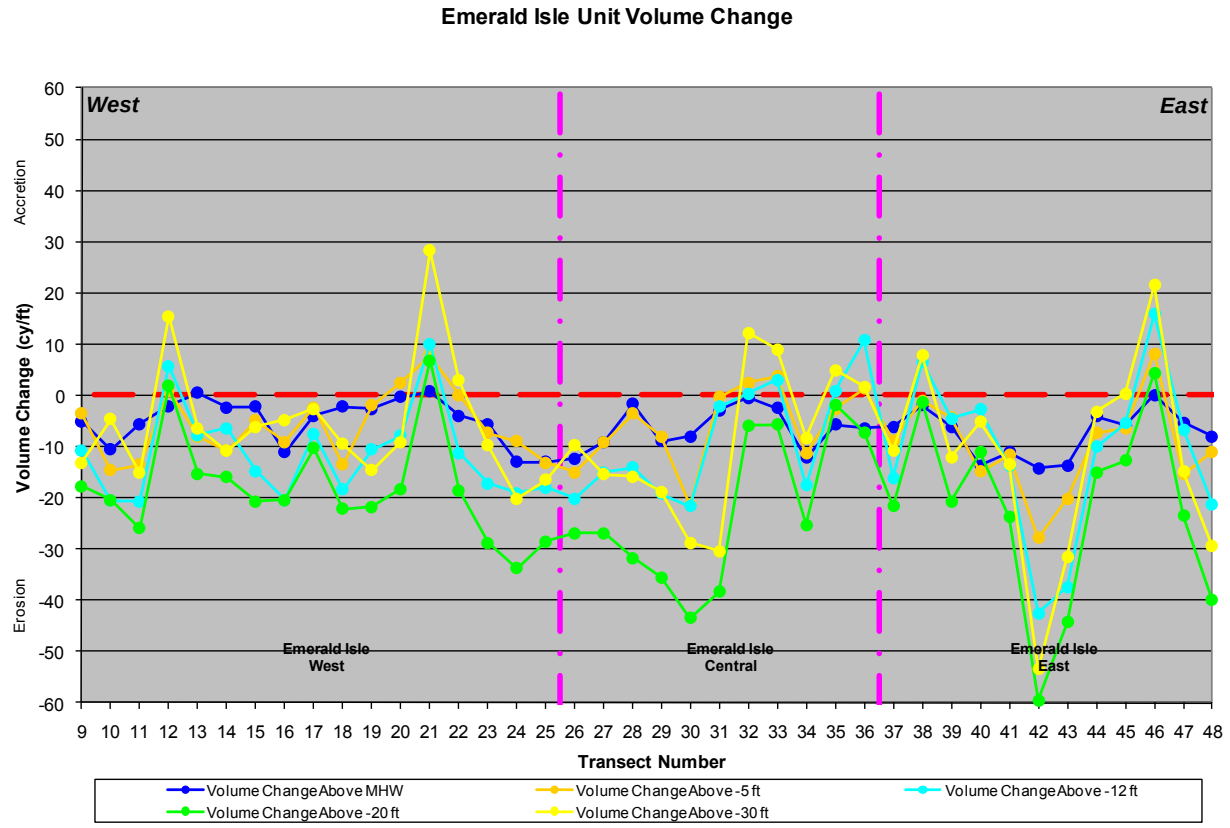


Figure 10. Emerald Isle Unit Volume Change (2011 - 2012)

5.4.2 Indian Beach/Salter Path

The Indian Beach region covers Transects 49 through 58. Since monitoring efforts began in 1999, this region has received 1.36 million cy of nourishment material from the Bogue Banks Beach Restoration Project, USACE Section 933, and FEMA post-storm work (Ophelia). A summary of average shoreline and volume changes between 2011 and 2012 for the Indian Beach/Salter Path region are presented in **Table 19**. For comparison, a summary of average shoreline and volume changes from Hurricane Irene are presented in **Table 19**.

Table 19. Average Shoreline and Volume Change for Indian Beach/Salter Path (2011-2012)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Indian Beach-Salter Path (49-58)	12,850	-43.7	-8.2	-105,632	-9.5	-122,411	-12.8	-163,958	-26.0	-334,048	-11.9	-153,274

Table 20. Average Shoreline and Volume Change for Indian Beach/Salter Path (Hurricane Irene)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Indian Beach-Salter Path (49-58)	12,850	-2.4	-5.5	-70,567	-10.4	-133,830	-18.4	-235,939	-30.3	-389,783	-6.7	-86,084

As with Emerald Isle, shoreline change in the Indian Beach/Salter Path area showed significant recession of approximately 44 ft between the last two surveys, most of this occurring post-storm (approximately 94%) due to the decreased beach protection offshore from the hurricane. Profile plots in **Appendix C** show a continued pattern of erosion between 0 and +5 ft NAVD88, with some slight restoration of the berm and the remaining material being pushed offshore between 0 and -10 ft NAVD88. The plots also indicate that the bar in this area remains further offshore than in previous surveys. Volumetrically, **Table 19** indicates that the Indian Beach/Salter Path area lost material above all elevations over the past year. However, as with Emerald Isle, there has been some minor recovery above lower elevations, evident by the larger losses above -12 ft NAVD and -20 ft NAVD88 from Hurricane Irene seen **Table 20** than over the whole year as seen in **Table 19**, with continued losses above MHW. **Figure 11** displays the unit volume change at each transect for the Indian Beach/Salter path region.

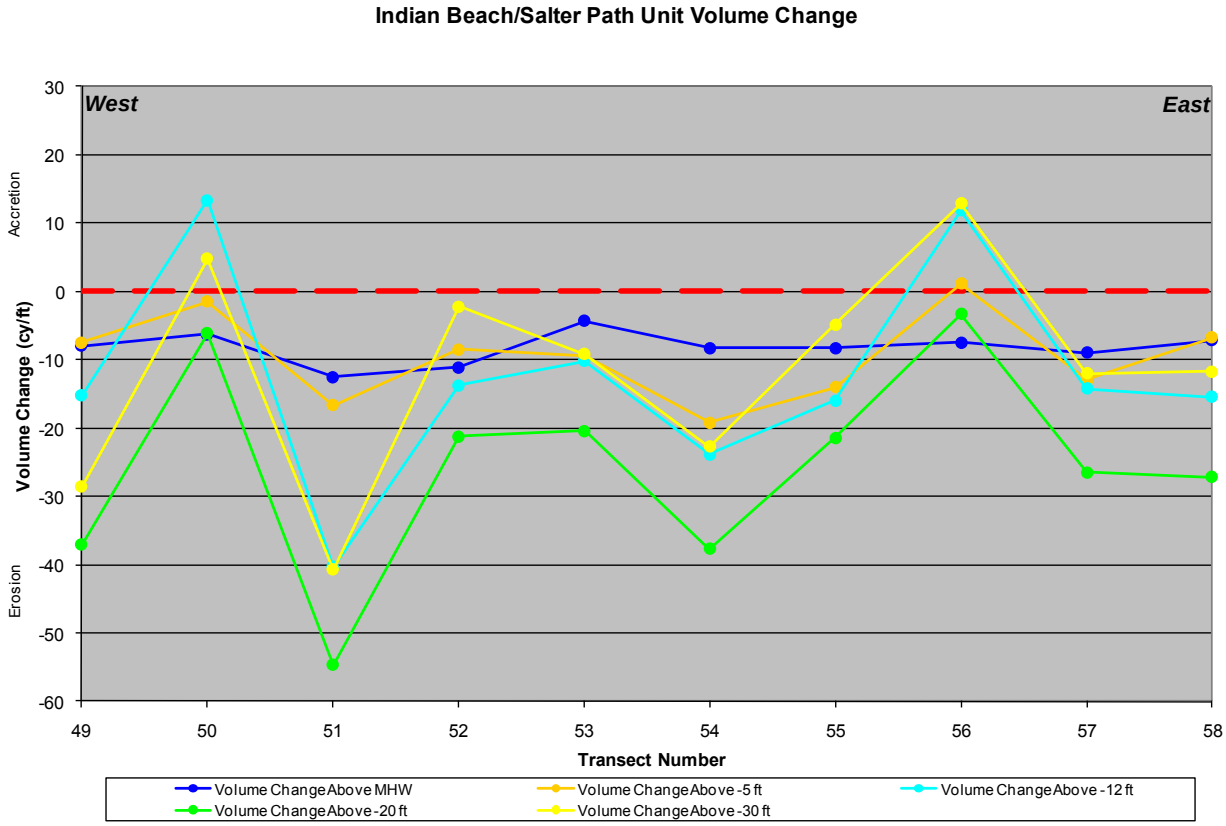


Figure 11. Indian Beach/Salter Path Unit Volume Change (2011 - 2012)

5.4.3 Pine Knoll Shores

The Pine Knoll Shores region covers Transects 59 through 76. Since monitoring efforts began in 1999, the Pine Knoll Shores region has received 2.31 million cy of nourishment material as a result of the Bogue Banks Beach Restoration Project, USACE Section 933, and FEMA post-storm work (Ophelia). A summary of average shoreline and volume changes between 2011 and 2012 for the Pine Knoll Shores region are presented in **Table 21**. For comparison, a summary of average shoreline and volume changes from Hurricane Irene are presented in **Table 22**.

Table 21. Average Shoreline and Volume Change for Pine Knoll Shores (2011-2012)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Pine Knoll Shores-West (59-65)	9,063	-46.4	-7.6	-68,625	-5.2	-47,394	-8.5	-76,886	-24.4	-220,746	-12.5	-113,255
Pine Knoll Shores-East (66-76)	14,815	-55.6	-10.2	-151,720	-10.2	-151,426	-15.9	-236,192	-27.5	-407,065	-21.7	-320,915

Table 22. Average Shoreline and Volume Change for Pine Knoll Shores (Hurricane Irene)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Pine Knoll Shores-West (59-65)	9,063	6.4	-3.6	-32,250	-3.8	-34,590	-11.3	-102,188	-32.8	-297,329	-16.2	-147,017
Pine Knoll Shores-East (66-76)	14,815	15.5	-2.6	-38,432	-0.5	-7,258	-7.6	-112,555	-20.6	-304,670	-5.3	-77,848

The Pine Knoll Shores shoreline showed significant recession at MHW between the last two surveys. All of this occurred after Hurricane Irene. The region actually saw a slight seaward movement of the shoreline as a result of the hurricane as seen in **Table 22**. This was due to sand from erosion of the incipient dune being deposited along the beachface. Volumetrically, Pine Knoll Shores lost material above all elevations over the past year. While Pine Knoll Shores West showed some slight recovery above lower elevations, Pine Knoll Shores East saw continued loss of material above all elevations after the hurricane. This is shown in **Table 21** and **Table 22** where the losses for Pine Knoll Shores West from Hurricane Irene above -12 ft NAVD88 and -20 ft NAVD88 are greater in **Table 22** than **Table 21** whereas the losses for Pine Knoll Shores East above these elevations are smaller in **Table 22** than **Table 21**. Profile plots in **Appendix C** show similar trends to Emerald Isle and Indian Beach/Salter path with even more pronounced erosion from 0 to +5 ft NAVD88. **Figure 12** displays the unit volume change at each transect for the Pine Knoll Shores region. The post-Irene renourishment project scheduled for winter 2012 will also place sand in the Pine Knoll Shores area.

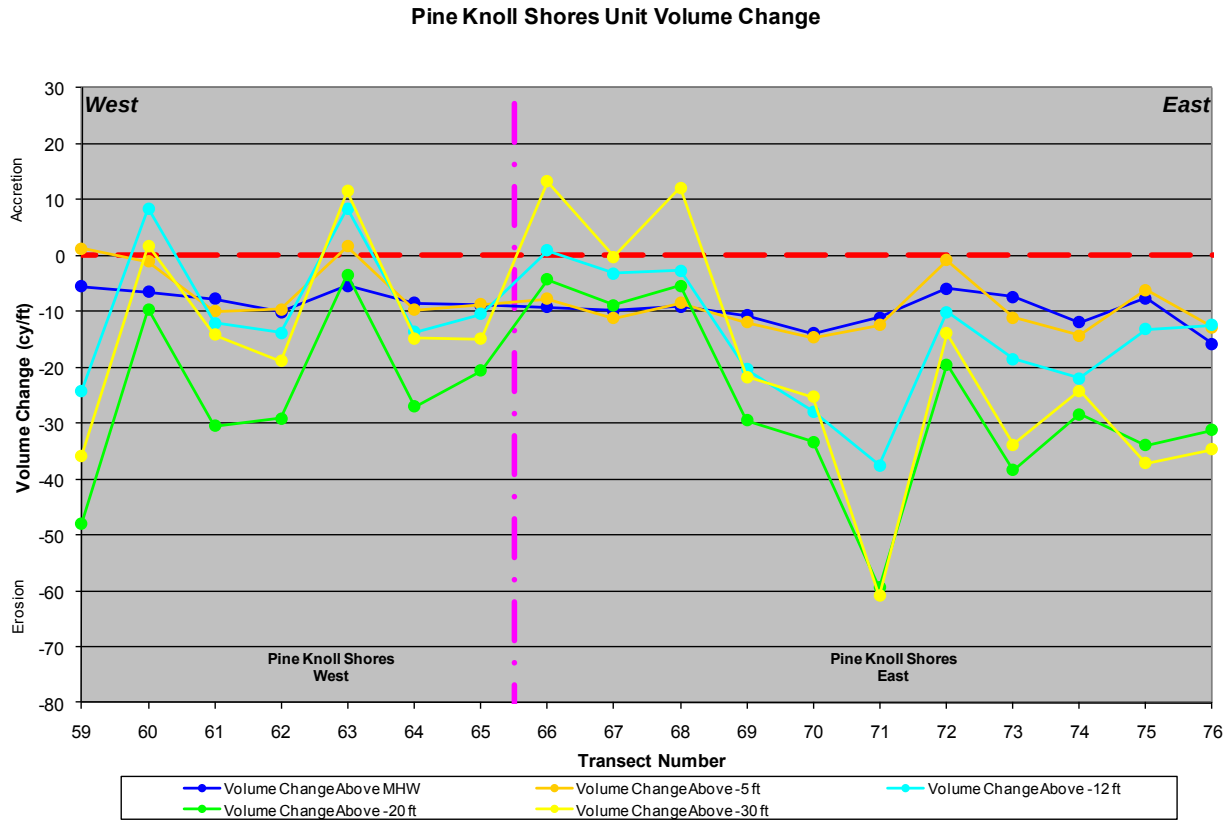


Figure 12. Pine Knoll Shores Unit Volume Change (2011 - 2012)

5.4.4 Atlantic Beach

The Atlantic Beach region covers Transects 77 through 102. Since monitoring began in 1999, the region has received 3.19 million cy of nourishment material from the Brandt Island Pump Out and USACE dredge disposal. Most recently, approximately 800,000 cy of material was placed on Atlantic Beach in winter 2010-2011 as Year 1 of the USACE Interim Operation Plan for the Morehead City Harbor Federal Navigation Project. A summary of average shoreline and volume changes between 2011 and 2012 for the Atlantic Beach region are presented in **Table 23**. For comparison, a summary of average shoreline and volume changes from Hurricane Irene are presented in **Table 24**.

Table 23. Average Shoreline and Volume Change for Atlantic Beach (2011-2012)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Atlantic Beach (77-102)	26,176	-43.1	-7.3	-190,162	-14.3	-373,650	-20.3	-530,856	-28.7	-750,155	-43.7	-1,144,341

Table 24. Average Shoreline and Volume Change for Atlantic Beach (Hurricane Irene)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Atlantic Beach (77-102)	26,176	6.8	-6.0	-156,328	-7.5	-197,552	-13.9	-362,678	-15.1	-395,857	-18.8	-490,869

As with other reaches, Atlantic Beach saw a large amount of shoreline recession over the past year. Since the reach was not surveyed at every transect after Hurricane Irene, it is difficult to tell how much was due to the storm and how much recession occurred after the storm. While post-storm surveys were completed at transects 80, 85, 90, 95, 100, and 102, only two profiles within the nourishment area were surveyed post-storm (transects 90 and 100). Profile plots in Appendix C show significant recession of the shoreline from the storm at transect 100 while they show minimal recession at MHW at transect 90. Volumetrically, the reach lost a significant amount of sand between 2011 and 2012. The fact that the nourishment project had just been completed prior to the storm likely accelerated the losses as the profile had not yet reached equilibrium. Approximately 531,000 cy of material has been lost above -12 ft NAVD88, which would constitute much of the nourishment project. Profile plots in **Appendix C** show significant erosion of the beach nourishment material. Much of this likely came from the storm itself. **Figure 13** displays the unit volume change for each transect in the Atlantic Beach region. The most notable erosion occurs within the extents of the nourishment project which extended from transect 90 to 102 with the exception of an area around transects 94-97 which has not been historically nourished and also is near the historically perceived nodal point.

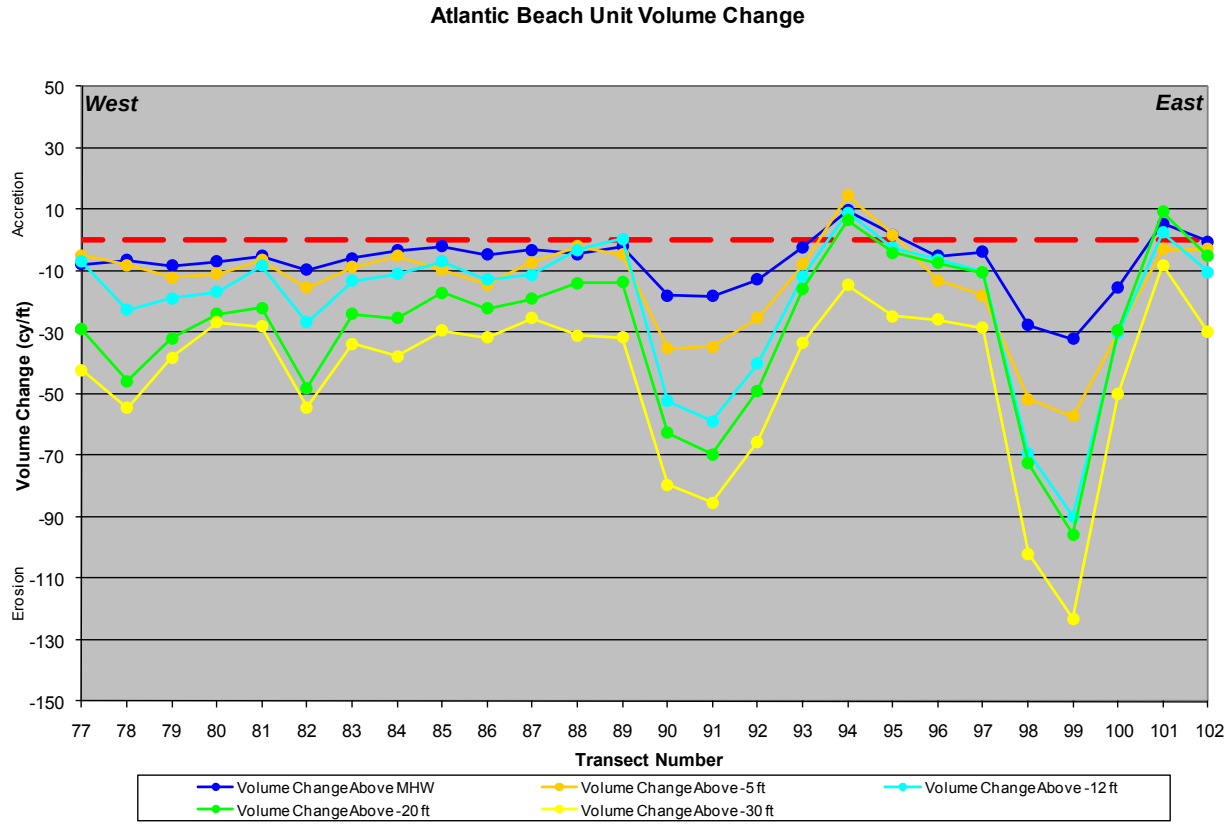


Figure 13. Atlantic Beach Unit Volume Change (2011 - 2012)

5.4.5 Fort Macon State Park

The Fort Macon State Park region covers Transects 103 through 112. Since monitoring began in 1999, this region has received 1.47 million cy of nourishment material from USACE Inner Harbor Dredging Disposal. Most recently, 547,000 cy of material was placed on Fort Macon

from November 2010 to April 2011 as part of the Year 1 USACE Interim Operation Plan for the Morehead City Harbor Federal Navigation Project. A summary of average shoreline and volume changes between 2011 and 2012 for the Fort Macon State Park region are presented in **Table 25**. For comparison, a summary of average shoreline and volume changes from Hurricane Irene are presented in **Table 26**.

Table 25. Average Shoreline and Volume Change for Fort Macon State Park (2011-2012)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Fort Macon State Park (103-112)	6,691	-65.0	-6.3	-42,097	-17.9	-119,510	-25.1	-167,964	-12.2	-81,801	-18.9	-126,493

Table 26. Average Shoreline and Volume Change for Fort Macon State Park (Hurricane Irene)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Fort Macon State Park (103-112)	6,691	-41.1	-7.8	-52,480	-18.0	-120,558	-7.2	-48,058	12.2	81,416	24.2	162,104

Like Atlantic Beach, Fort Macon saw a large amount of shoreline recession due to the coincidence of the nourishment project and Hurricane Irene. Fort Macon was also not surveyed at every transect after the storm so it is also difficult to determine whether the source of the recession was mostly the storm itself or not. Fort Macon saw a loss in the volume of material above all elevations. Profile plots in **Appendix C** show a large amount of the nourishment material has been eroded since the 2011 survey. Approximately 168,000 cy of the 596,000 cy placed on the beach has been lost above -12 ft NAVD88 (material moving eastward from Atlantic Beach is likely helping mitigate perceived losses in the Fort Macon area). **Figure 14** displays the unit volume change at each transect in the Fort Macon State Park region. It is apparent that some of the nourishment material lost from Atlantic Beach and western Fort Macon has likely been transported eastward toward the terminal groin which has helped stabilize the beach in that immediate area.

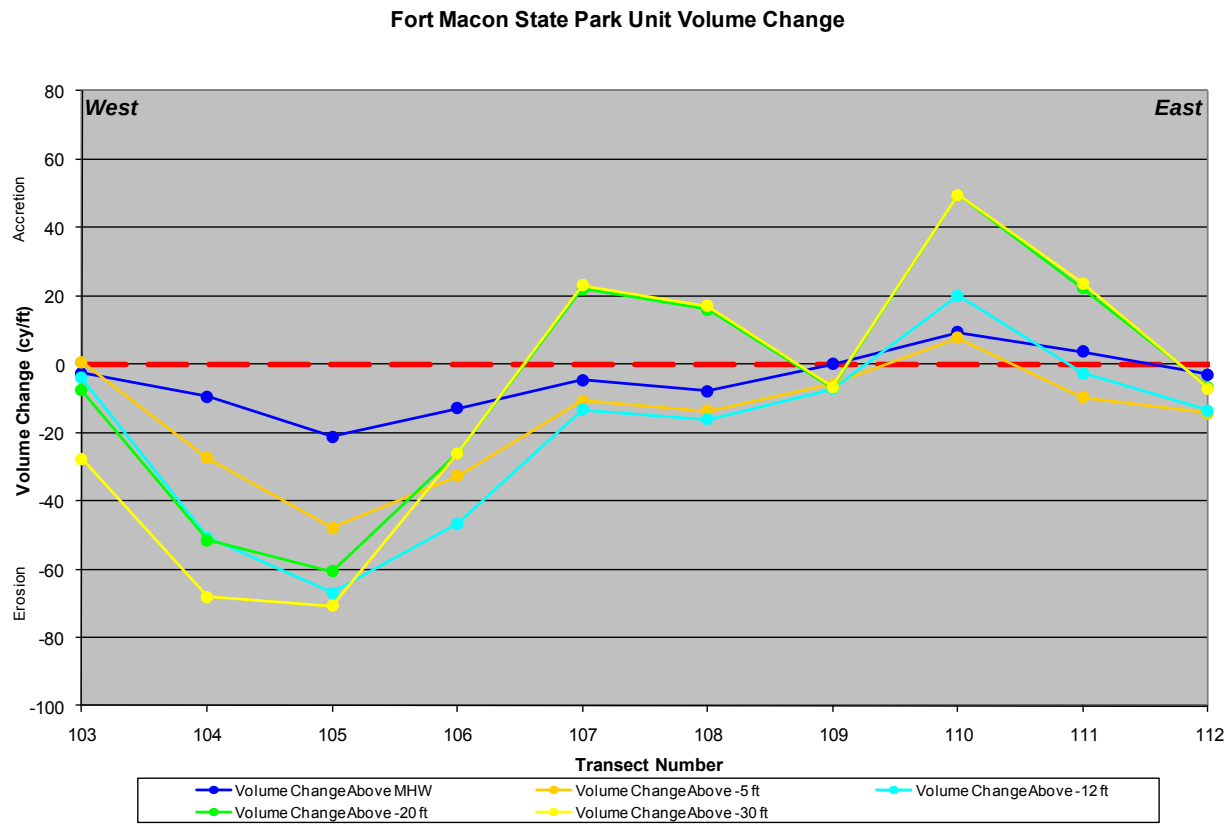


Figure 14. Fort Macon State Park Unit Volume Change (2011 - 2012)

5.4.6 Bogue Inlet

The Bogue Inlet region is comprised of an area along the oceanfront which covers Transects 1 through 8 and an area along the eastern side of Bogue Inlet covering Transects 117 through 120. A summary of average shoreline and volume changes between 2011 and 2012 for the Bogue Inlet region are presented in **Table 27**. For comparison, a summary of average shoreline and volume changes from Hurricane Irene are presented in **Table 28**.

Table 27. Average Shoreline and Volume Change for Bogue Inlet (2011-2012)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	4.3	-0.4	-2,923	-5.6	-41,637	-26.9	-199,903	-32.7	-243,370	-29.6	-219,935
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*Note: Due to the dynamic nature of Bogue Inlet, shoreline and volume calculations were not performed

Table 28. Average Shoreline and Volume Change for Bogue Inlet (Hurricane Irene)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	8.5	-4.1	-30,297	-10.1	-75,280	-18.6	-138,201	-5.2	-38,663	13.7	101,935
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*Note: Due to the dynamic nature of Bogue Inlet, shoreline and volume calculations were not performed

This region is highly dynamic due to the inlet. This can be seen in the survey evaluation plots in **Appendix B** and the profiles presented in **Appendix C**. Due to the quickly changing seaward extents of the shoreline located along the Bogue Inlet-Channel region, analytical calculations were not performed at transect 117 through 120. The location of dry land changes so frequently that profiles along Bogue Inlet do not line up appropriately from year to year. However, upon investigation of the profile plots in **Appendix C**, it appears that the area nearest the throat of the inlet (transects 117 and 117B) was impacted most by Hurricane Irene. Locations within the inlet appear to have been shielded from the storm. Although also dynamic, calculations were able to be performed for the Bogue Inlet-Ocean region, which saw major impacts from the storm nearest the inlet with the entire reach experiencing volume loss over the past year. **Figure 15** displays the unit volume change at each transect for the Bogue Inlet Ocean region.

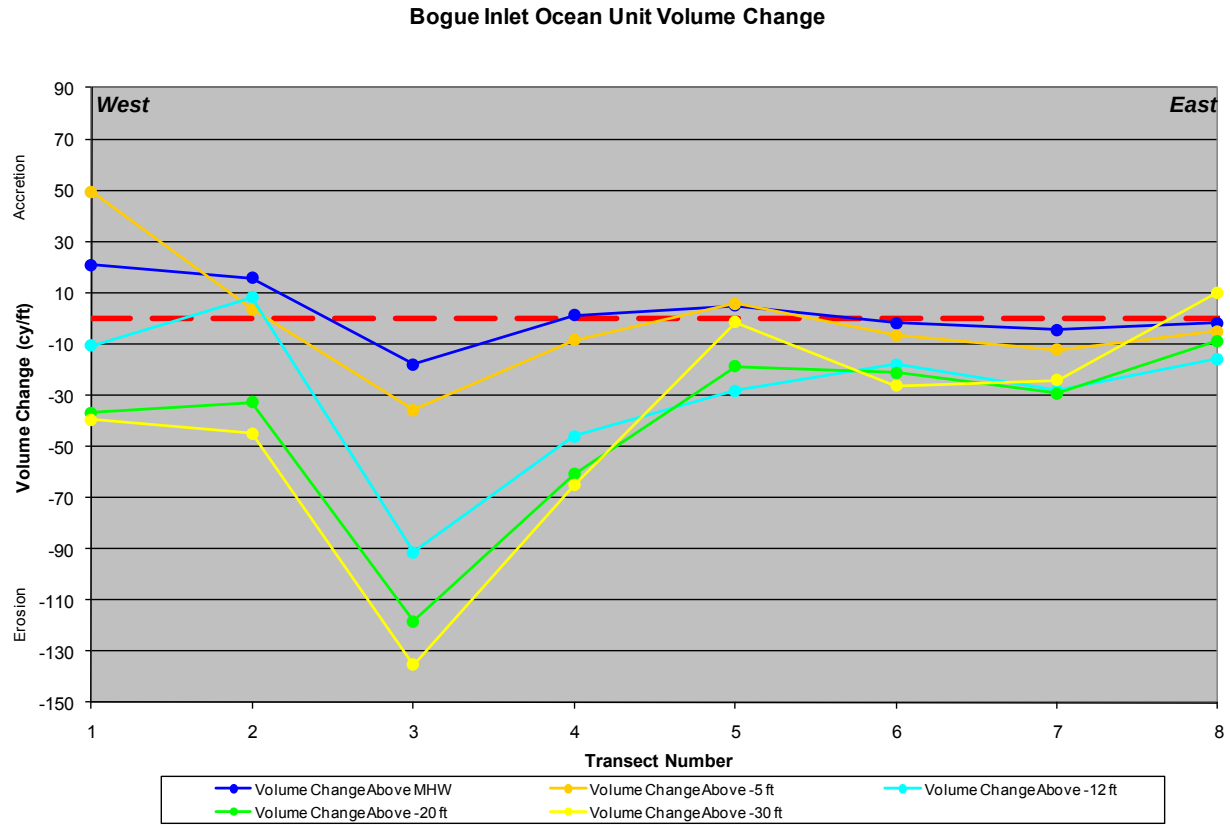


Figure 15. Bogue Inlet Ocean Unit Volume Change (2011 - 2012)

5.4.7 Beaufort Inlet

The Beaufort Inlet region is comprised of an area along the western side of Beaufort Inlet which covers Transects 113 through 116. A summary of average shoreline and volume changes between 2011 and 2012 for the Beaufort Inlet region are presented in **Table 29**. For comparison, a summary of average shoreline and volume changes from Hurricane Irene are presented in **Table 30**. It should be noted that only one profile was surveyed post-Irene (Transect 114).

Table 29. Average Shoreline and Volume Change for Beaufort Inlet (2011-2012)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Beaufort Inlet (113-116)	2,000	23.9	5.1	10,159	16.3	32,534	16.7	33,466	14.4	28,766	10.2	20,497

Table 30. Average Shoreline and Volume Change for Beaufort Inlet (Hurricane Irene)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Beaufort Inlet (113-116)	2,000	-88.3	0.5	952	-11.5	-23,020	-29.6	-59,154	-40.3	-80,600	-43.0	-86,054

Shoreline and volume changes at Beaufort Inlet showed slight accretion over the past year above all elevations. It is likely that material from the Atlantic Beach and Fort Macon nourishment has been transported eastward to Beaufort Inlet, with the help of Hurricane Irene. Profiles for this region can be seen in **Appendix C**. The shoreline configuration in this area is highly dynamic due to the inlet. **Figure 16** displays the unit volume change at each transect in the Beaufort Inlet region.

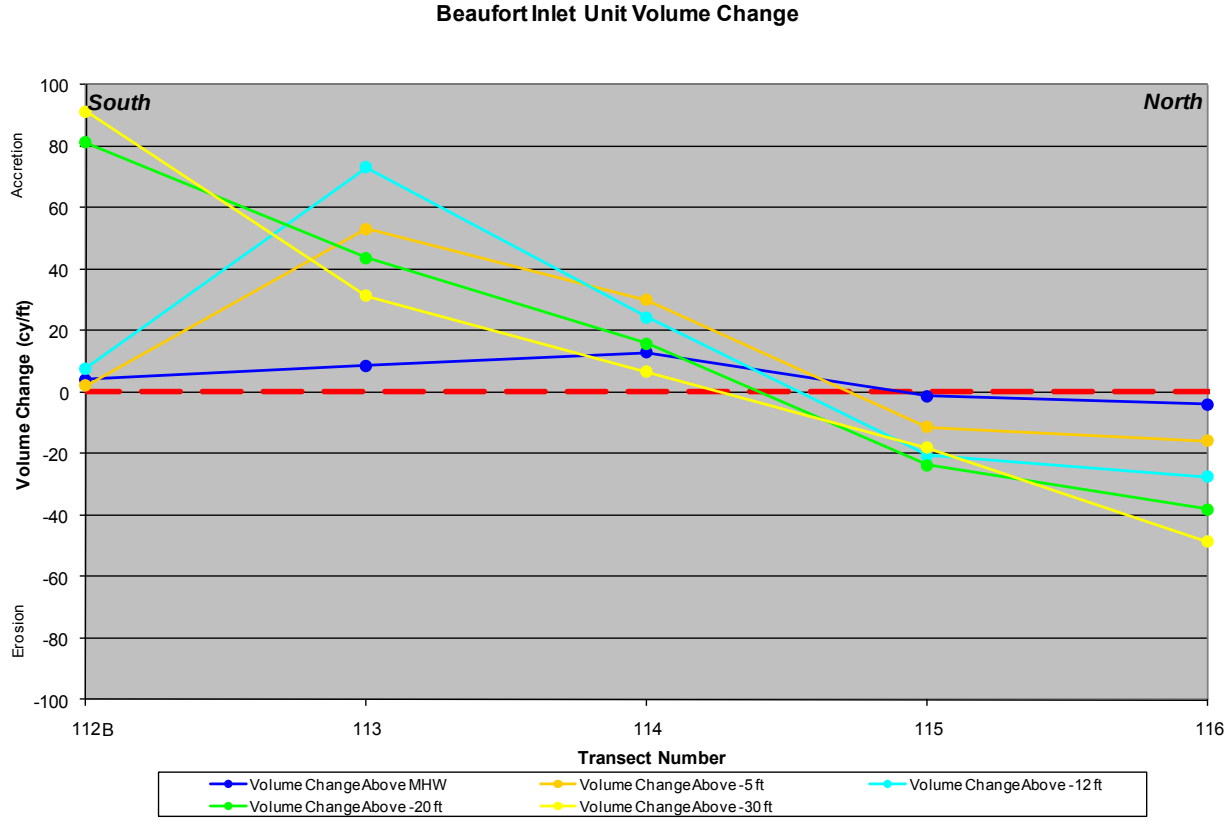


Figure 16. Beaufort Inlet Unit Volume Change (2011 - 2012)

5.4.8 Bear Island

Bear Island contains 18 transects spaced 1000 ft apart. A summary of average shoreline and volume changes between summer 2011 and spring 2012 for the Bear Island region are presented in **Table 31**.

Table 31. Average Shoreline and Volume Change for Bear Island

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bear Island (1-18)	16,500	-1.4	-3.3	-53,765	-5.1	-83,737	0.2	3,922	-0.9	-14,673	0.8	13,296

Bear Island appears to have fared well during the course of the year and likely during Hurricane Irene, showing a slight recession of shoreline position and minor overall losses in the volume of sand above MHW and -5 ft NAVD88 but a slight gain in material above -12 ft NAVD88. Upon looking at the volume change plots in **Appendix B** and profile plots in **Appendix C**, it is apparent that the majority of profiles saw just a minor loss of material along the beachface. While there is a pattern of consistent erosion along western and central portions of the island, the large volume gain at transect 2 offsets most of the erosion seen in the other transects. Volume gain near Bogue Inlet was also evident in the previous survey evaluation. It is possible that the dynamic movements of Bogue Inlet are responsible for the accretion seen at the eastern end of Bear Island. It is thought that the channel has been naturally realigning to the east of its current position, causing the ebb shoal material to weld to the eastern end of Bear Island. **Figure 17** displays the unit volume change at each transect on Bear Island. Profiles from Transect 18 only contained elevations below MHW and therefore were not included in the analysis.

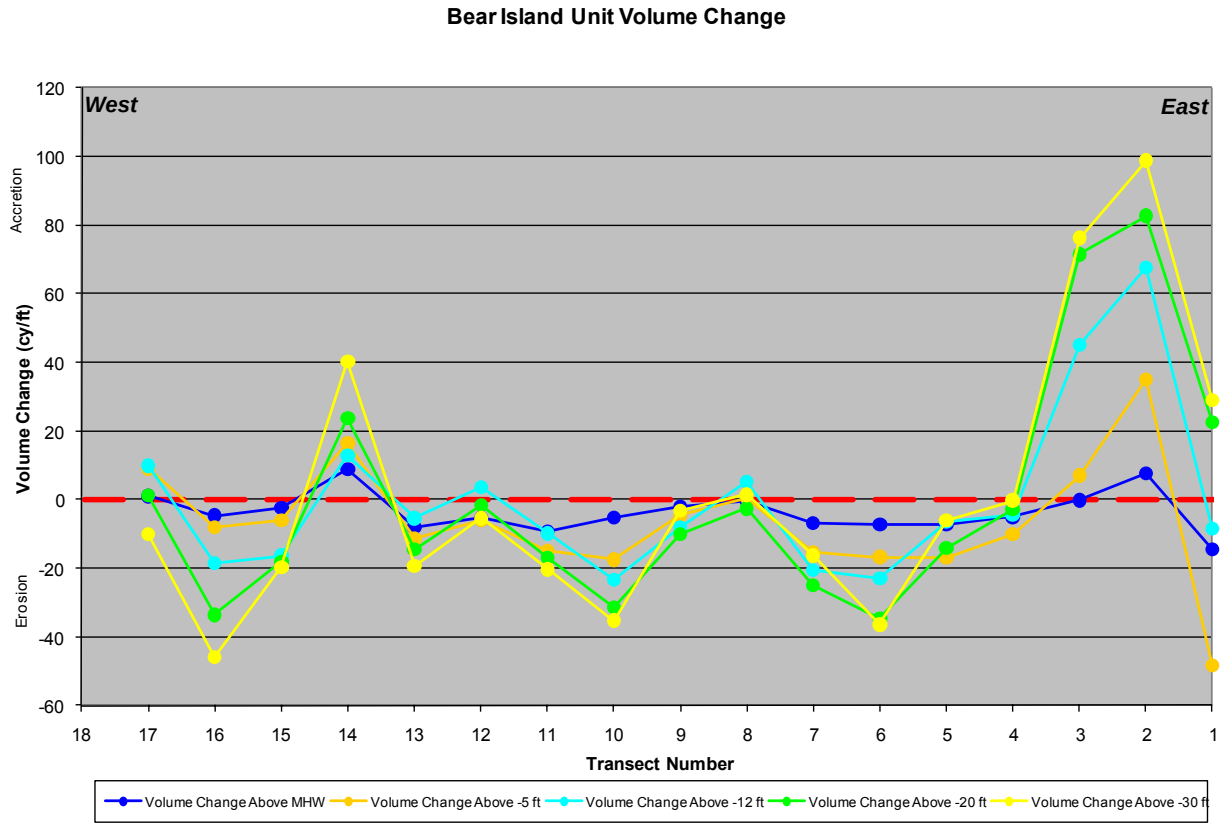


Figure 17. Bear Island Unit Volume Change (2011 - 2012)

5.4.9 Shackleford Banks

Shackleford Banks is comprised of 24 transects and is a natural shoreline, receiving no nourishment. As a result, varying accretion and erosion occurs along the shoreline. A summary of average shoreline and volume changes between 2011 and 2012 for the Shackleford Banks region are presented in **Table 32**.

Table 32. Average Shoreline and Volume Change for Shackleford Banks

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Shackleford Banks (1-24)	46,001	-20.1	-6.1	-281,642	-8.0	-365,768	-12.5	-573,413	-10.3	-473,835	-14.7	-677,093

Shackleford Banks showed shoreline recession at MHW along with volumetric losses above all elevations considered. Upon looking at the volume change plots in **Appendix B** and profile plots in **Appendix C**, it is evident the many of the dunes were impacted by Hurricane Irene, eroding the primary dune in almost half of the transects. Erosion continued down the beachface to approximately -10 ft NAVD88. **Figure 18** displays the unit volume change at each transect on Shackleford Banks.

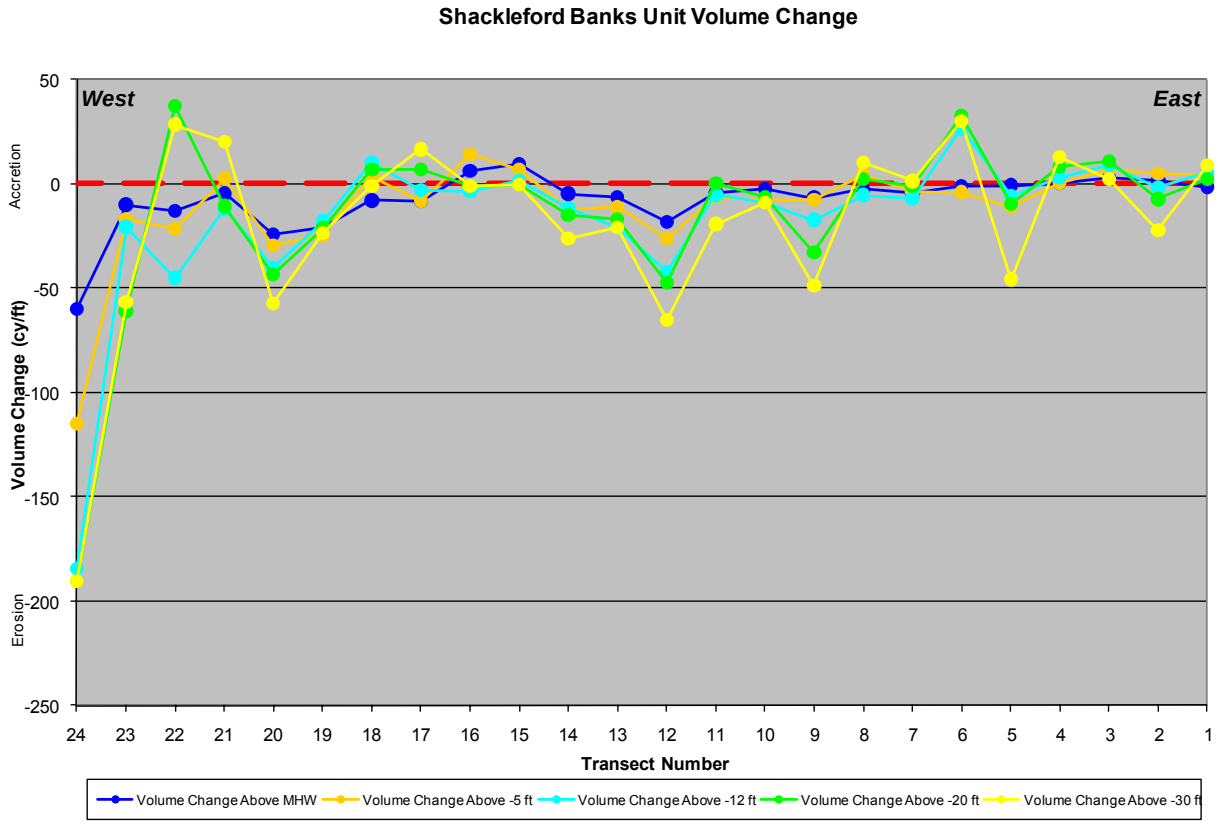


Figure 18. Shackleford Banks Unit Volume Change (2011 – 2012)

5.5 Statistical Analysis of Recent Volume Change Trends

Using the five most recent high quality survey datasets (2008-2012), statistical analyses were performed to determine if any long-term trends in the Bogue Banks oceanfront behavior are beginning to appear. The average volume change per year was calculated using the volume changes from the current monitoring report along with the three previous reports (M&N 2009 2010, and 2011). The recent nourishment (winter 2010-2011) in Atlantic Beach and Fort Macon was subtracted out at each transect based on an average cubic yard per foot placed along each reach of beach in order to determine the background erosion rate. Therefore, these numbers are subject to some uncertainty since the same amount of nourishment was likely not placed at each transect. **Figure 19** shows the mean volume change with the nourishment subtracted out. While Hurricane Irene appears to have worsened the long term average erosion along the entire beach, hotspots and Emerald Isle and Pine Knoll Shore are still visible.

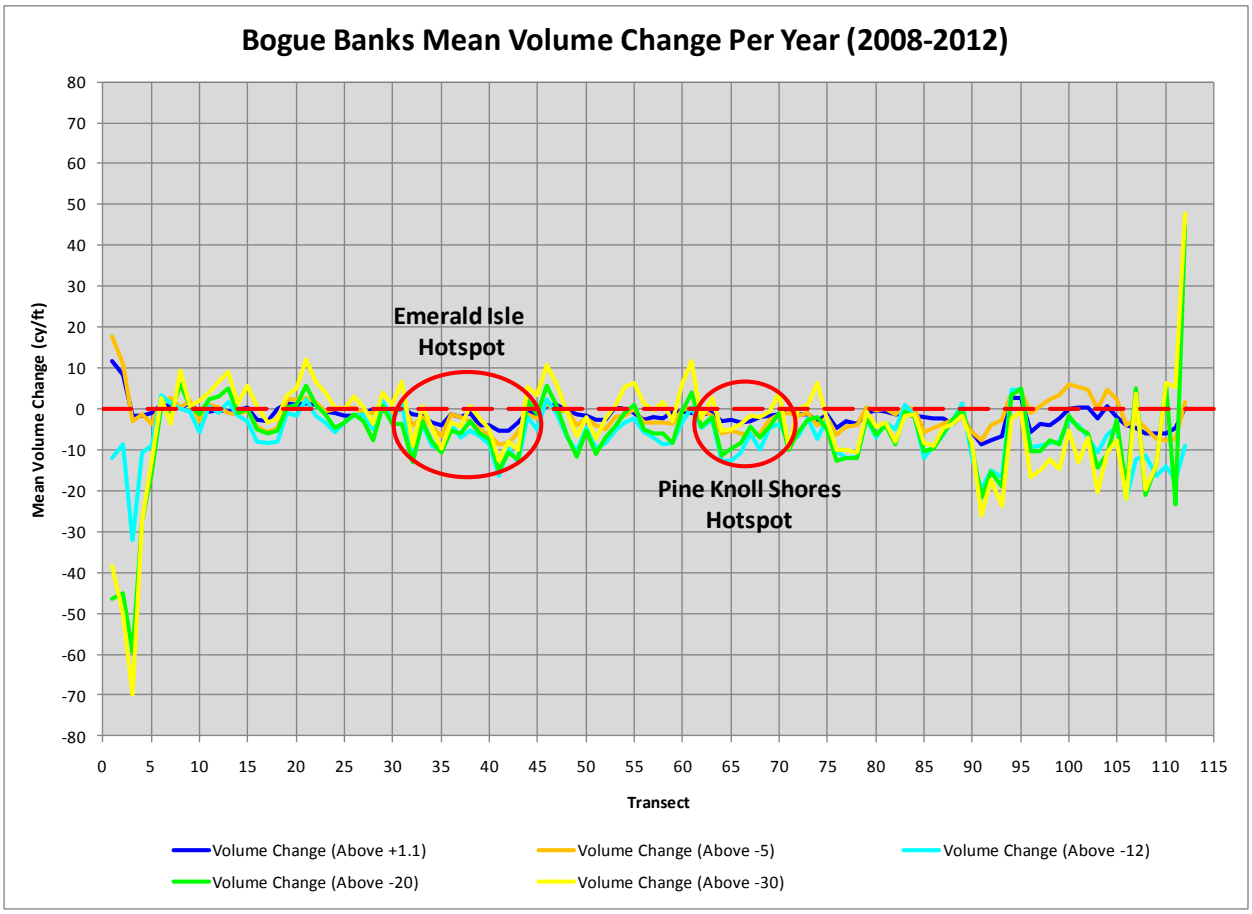


Figure 19. Bogue Banks Mean Volume Change (Without Nourishment)

The standard deviation of the mean volume change per year were also calculated. **Figure 20** through **Figure 24** shows the mean volume change per year with standard deviation bars at plus or minus one standard deviation for each of the elevations above which volume change was calculated.

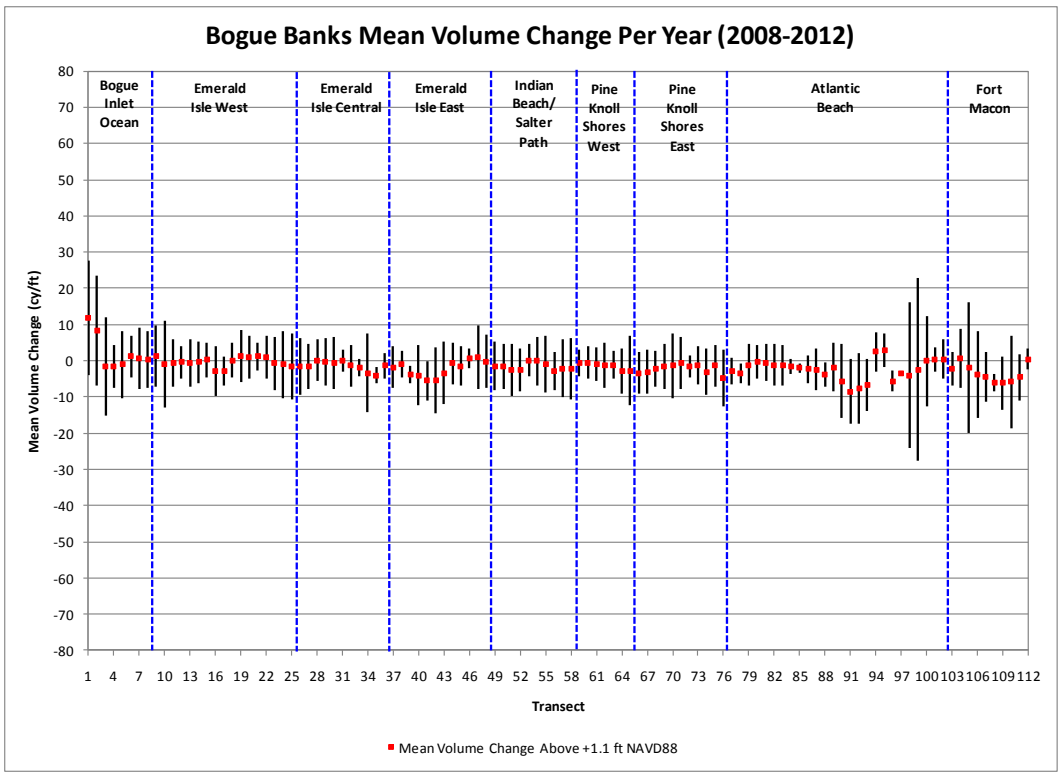


Figure 20. Statistical Analysis of Volume Change Above +1.1 ft NAVD88

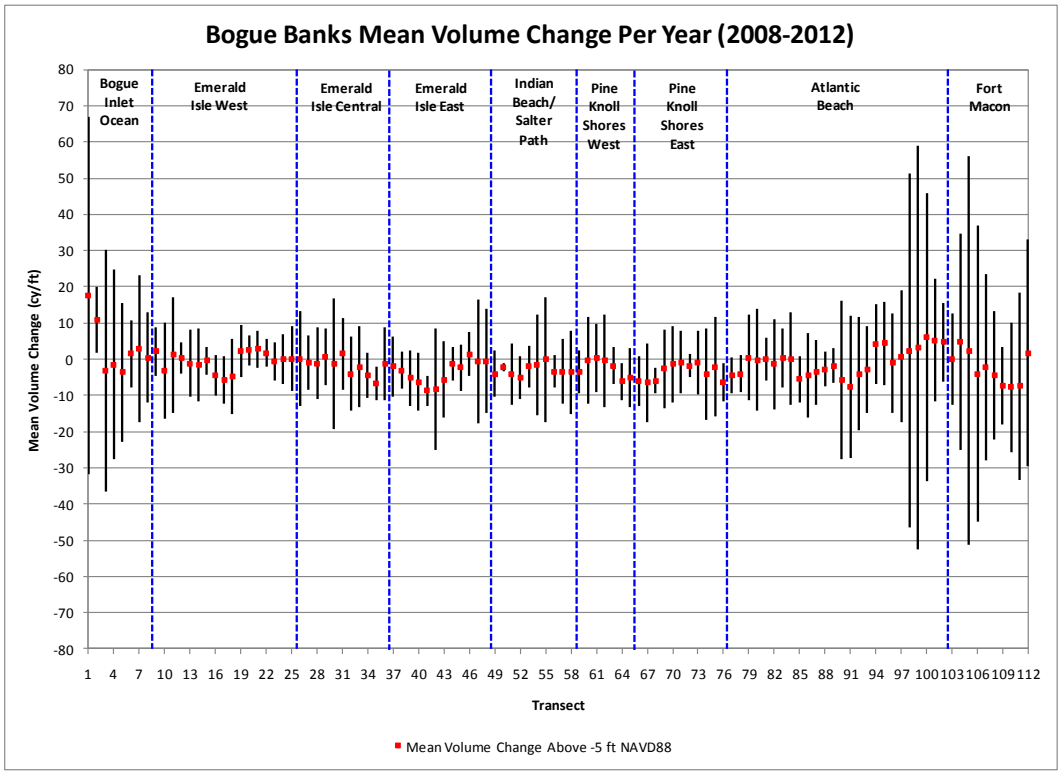


Figure 21. Statistical Analysis of Volume Change Above -5.0 ft NAVD88

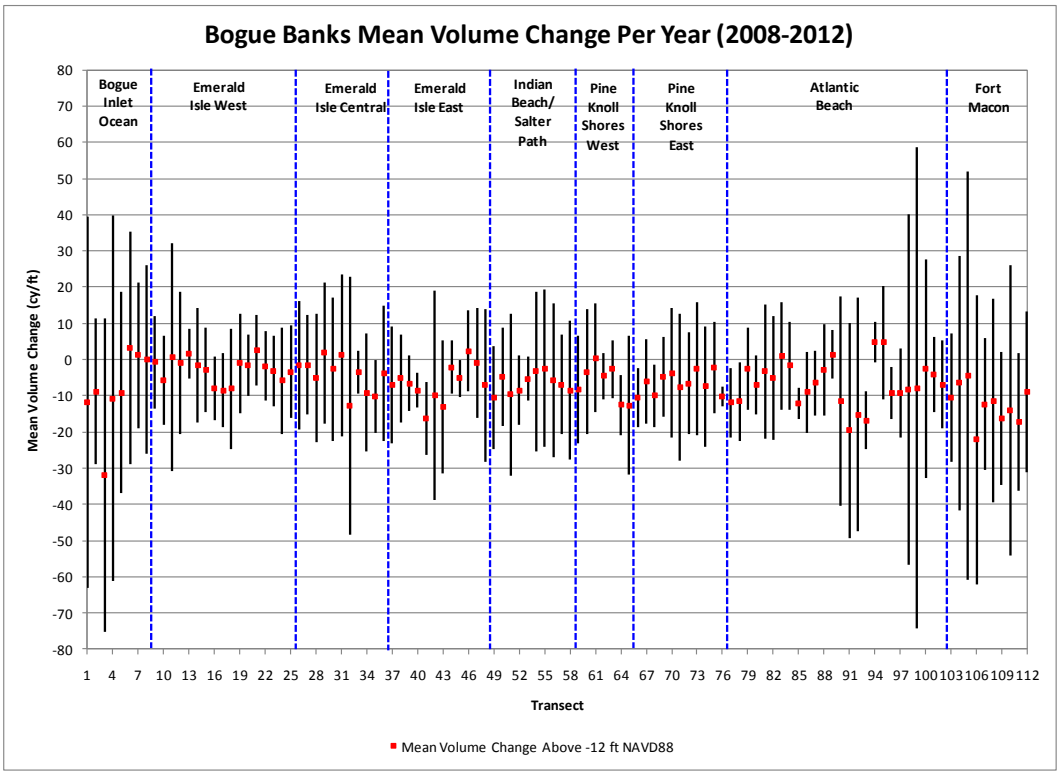


Figure 22. Statistical Analysis of Volume Change Above -12.0 ft NAVD88

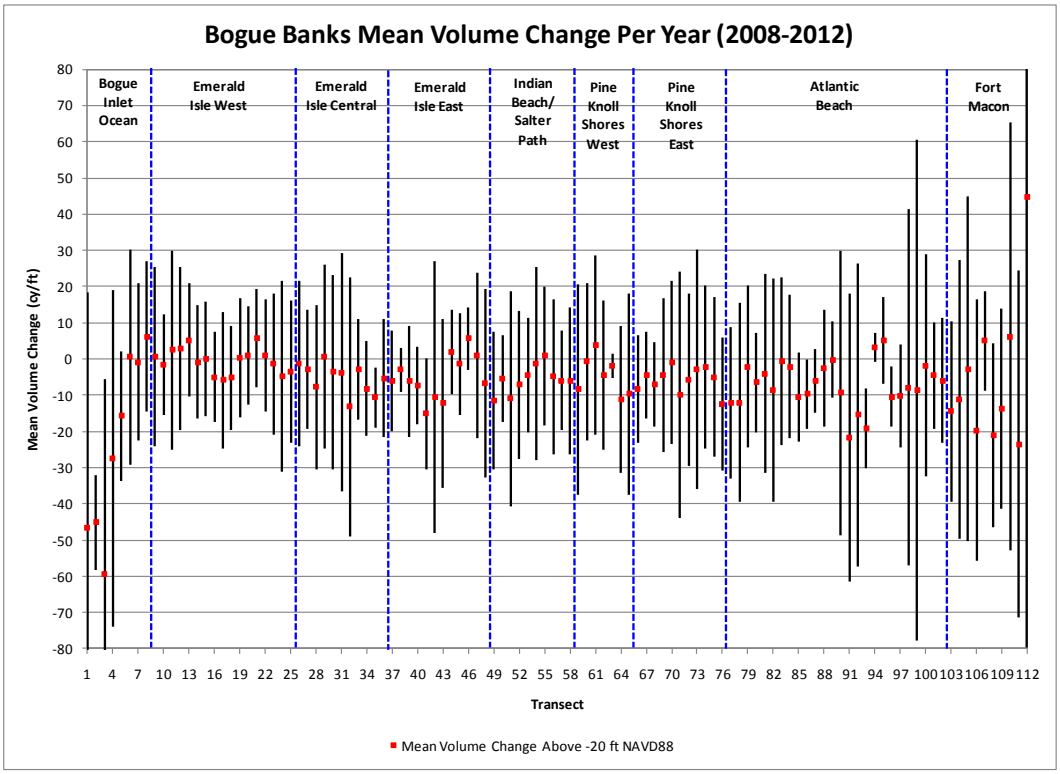


Figure 23. Statistical Analysis of Volume Change Above -20.0 ft NAVD88

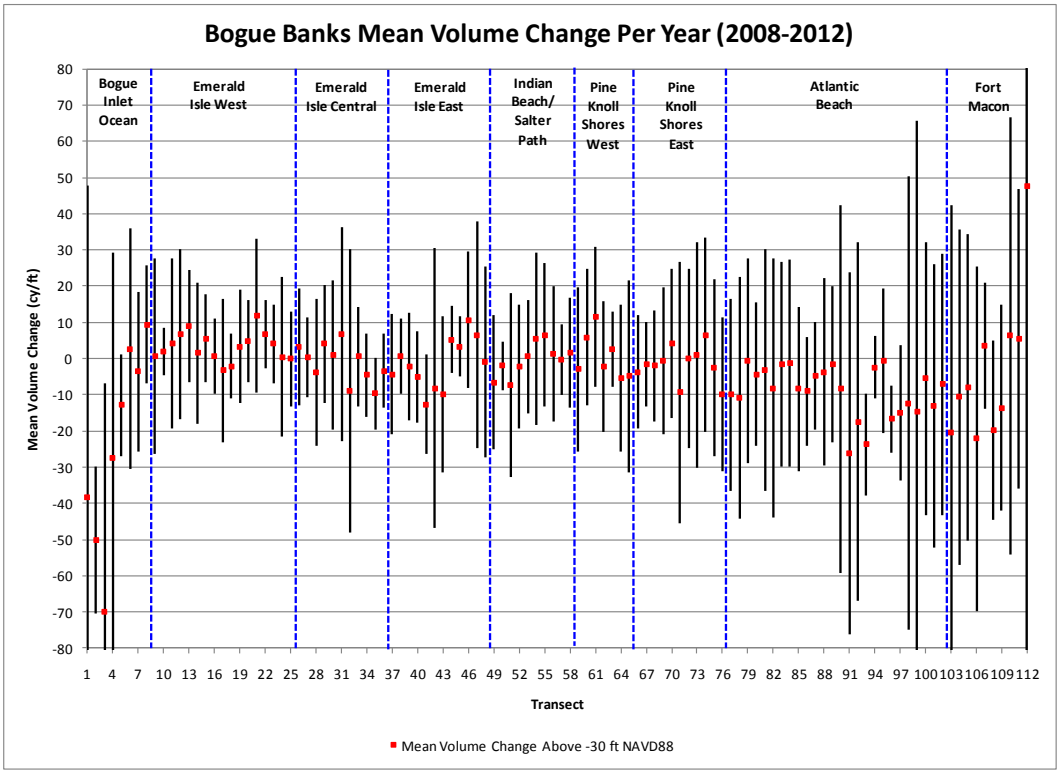


Figure 24. Statistical Analysis of Volume Change Above -30.0 ft NAVD88

The variability in volume change increases with depth especially above MHW, -5 ft NAVD88, and -12 ft NAVD88. This is intuitive based on the fact that the majority of sand movement historically happens in the subaerial beach with large fluctuations in the position of the offshore bar. The standard deviation of volume change above -20 ft NAVD88 and above -30 ft NAVD88 is not much higher than that values calculated for above -12 ft NAVD88. This implies that there is not a large amount of additional sand movement at these lower depths. Also important to note is the standard deviation is much larger on either end of the island, as would be expected given the drastic effect that the inlets have on the adjacent shoreline. Changes near the inlets often fluctuate significantly each year. As more datasets are collected, it is hoped that long-term trends will become apparent.

5.6 FEMA Beach Maintenance Analysis

Analysis was performed to calculate the amount of fill remaining from Phase I, Phase II, and Phase III of the Bogue Banks Beach Restoration Project. Using the volume change above -12 ft NAVD88 between the Phase I, Phase II, and Phase III post-nourishment surveys and the spring 2012 survey along with the amount of fill placed during Phase I, Phase II, and Phase III, the percentage of remaining fill was determined. If any reach falls below 50% of fill remaining, this area needs to be considered for nourishment. FEMA beach maintenance calculations for applicable reaches are presented in **Appendix E. Table 33** presents the results of the beach maintenance analysis.

Table 33. Percent Fill Remaining from Base Nourishment

Reach	Percent Fill Remaining	
Indian Beach/Salter Path	**170.4**	
Pine Knoll Shores West	*128.5*	**89.1**
Pine Knoll Shores East	*64.7*	
PHASE I	**110.5**	
Emerald Isle Central	*135.1*	**87.4**
Emerald Isle East	*35.1*	
PHASE 2	**87.4**	
Emerald Isle West	**152.5**	
Bogue Inlet	**87.1**	
PHASE 3	**148.1**	

The Emerald Isle East reach only contains 35% of the original fill, which is the lowest of any subunit in the County Project area. However, Emerald Isle East and Emerald Isle Central comprise the entire Phase II management reach for FEMA monitoring and maintenance which contains approximately 87% of the original fill volume. While this is still higher than the 50% remaining threshold, it is much lower than the previous year due to Hurricane Irene. This year's monitoring confirms the need for the post-Irene renourishment project, especially in Emerald Isle East, being planned for winter 2012-2013. The renourishment project will also cover a portion of Emerald Isle West, which suffered some localized erosion of the incipient dune during the hurricane, and Pine Knoll Shores which has had its eastern portion fall close to the 50% remaining fill threshold.

6.0 Summary

Comprehensive surveying of the Bogue Banks shoreline began in 1999 as a way to formulate the Bogue Banks Beach Restoration Project. In spring 2004, the Bogue Banks Beach and Nearshore Mapping Program was initiated to assess beach conditions and form strategies for future beach nourishment projects. Bear Island was added to the project in October 2004 and Shackleford Banks was added in May 2005. Surveys are performed annually during each spring/summer timeframe along all three stretches of shoreline. In addition, after large storm events, surveying is performed along Bogue Banks to assess damages. The most recent regular monitoring survey was completed during spring 2012 (March and April 2012) by Geodynamics. For this evaluation, the spring 2012 survey was compared with the spring/summer 2011 survey. The profile data were used to compute shoreline change at MHW (+1.1 ft NAVD88) and volume change above MHW, -5 ft NAVD88 (wading depth), -12 ft NAVD88 (outer bar), -20 ft NAVD88 (approximate closure), and -30 ft NAVD88.

Key statistics were computed for defined regions along the Bogue Banks shoreline, Bear Island, and Shackleford Banks between the 2011 and 2012 survey profiles including;

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Banks Oceanfront (1-112)	128,393	-37.0	-6.8	-871,672	-9.5	-1,219,951	-15.1	-1,933,825	-24.3	-3,119,687	-19.7	-2,529,892
Bogue Banks County Project (9-76)	88,094	-36.5	-7.2	-636,490	-7.8	-685,153	-11.7	-1,035,102	-23.2	-2,044,361	-11.8	-1,039,124
Bear Island (1-18)	16,500	-1.4	-3.3	-53,765	-5.1	-83,737	0.2	3,922	-0.9	-14,673	0.8	13,296
Shackleford Banks (1-24)	46,001	-20.1	-6.1	-281,642	-8.0	-365,768	-12.5	-573,413	-10.3	-473,835	-14.7	-677,093

Key statistics for individual reaches along Bogue Banks were as follows:

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	4.3	-0.4	-2,923	-5.6	-41,637	-26.9	-199,903	-32.7	-243,370	-29.6	-219,935
Emerald Isle-West (9-25)	22,344	-20.7	-5.0	-111,449	-6.1	-137,356	-11.8	-264,467	-18.6	-414,633	-6.1	-136,680
Emerald Isle-Central (26-36)	15,802	-37.8	-6.3	-99,667	-6.0	-94,201	-8.9	-139,918	-23.4	-369,599	-9.8	-154,303
Emerald Isle-East (37-48)	13,220	-26.4	-7.5	-99,396	-10.0	-132,365	-11.6	-153,682	-22.6	-298,270	-12.2	-160,697
Indian Beach-Salter Path (49-58)	12,850	-43.7	-8.2	-105,632	-9.5	-122,411	-12.8	-163,958	-26.0	-334,048	-11.9	-153,274
Pine Knoll Shores-West (59-65)	9,063	-46.4	-7.6	-68,625	-5.2	-47,394	-8.5	-76,886	-24.4	-220,746	-12.5	-113,255
Pine Knoll Shores-East (66-76)	14,815	-55.6	-10.2	-151,720	-10.2	-151,426	-15.9	-236,192	-27.5	-407,065	-21.7	-320,915
Atlantic Beach (77-102)	26,176	-43.1	-7.3	-190,162	-14.3	-373,650	-20.3	-530,856	-28.7	-750,155	-43.7	-1,144,341
Fort Macon State Park (103-112)	6,691	-65.0	-6.3	-42,097	-17.9	-119,510	-25.1	-167,964	-12.2	-81,801	-18.9	-126,493
Beaufort Inlet (113-116)	2,000	23.9	5.1	10,159	16.3	32,534	16.7	33,466	14.4	28,766	10.2	20,497
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

It is apparent that there has been significant recession of the Bogue Banks shoreline and significant volumetric losses along the beach profiles over the past year. This is largely due to the impact of Hurricane Irene. Shoreline recession due to the direct impact of Hurricane Irene was minimal due to the reshaping of the beach from the storm. Much of the material eroded from the dune was deposited along the beachface, keeping the shoreline position relatively stable. However, in the months after the storm, shoreline recession greatly increased, likely due to the large volume losses in storm protection below MHW seen as a result of the storm. Volume losses during Hurricane Irene were significantly large. Despite quiescent weather the remainder of the year, Bogue Banks did not see much in terms of recovery from the storm but rather saw continued volume losses, especially above MHW, with some minor recovery above -12 ft NAVD88. Overall, approximately 1,000,000 cy of material was lost from the county project above -12 ft NAVD88 over the past year while approximately 1,900,000 cy was lost along the entire oceanfront. All reaches experienced significant erosion, including Atlantic Beach and Fort Macon which had just recently been nourished.

Bear Island appears to have been affected most above MHW and above -5 ft NAVD88. Profile plots show a significant loss of material from the beachface down to -5 ft NAVD88, which appears to be deposited near the offshore bar. Shackleford Banks also appears to have been impacted significantly by Hurricane Irene. Profile plots show clear erosion of the primary dune in almost half of the transects. Losses to the beachface down to the elevation of the outer bar are apparent as well.

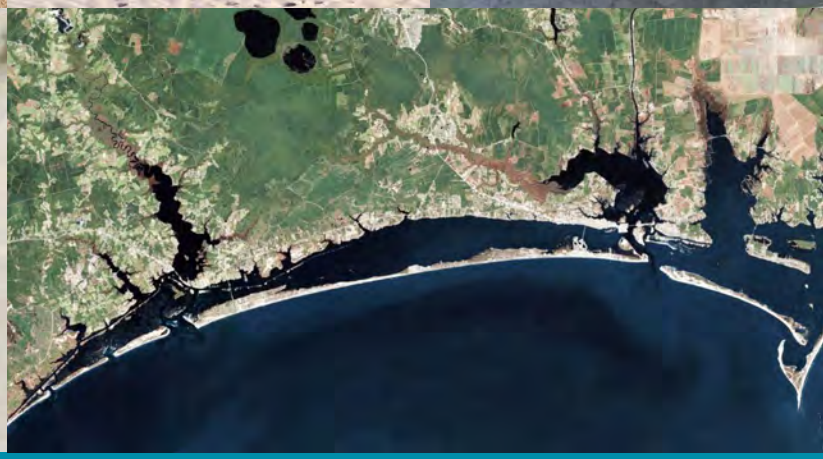
In addition, calculations were performed to estimate the amount of material remaining on the beach in excess of the baseline nourishment condition established by the Phase I, Phase II, and Phase III components of the Bogue Banks Beach Restoration Project. It was determined that reaches within the Phase I and Phase III projects still contain more sand than was originally in place after the earlier baseline projects with 110% and 148% , respectively. It should be noted that the Pine Knoll Shores East reach, within Phase I project, is approaching the 50% of

remaining fill threshold with only 65% currently remaining. The Phase II reach contains only 87% of the sand in place after earlier projects. Within the Phase II project there has been a hotspot which, historically, has shifted back and forth between transect 32 in Emerald Isle Central and transect 44 in Emerald Isle East. Of the two reaches within the Phase II project, Emerald Isle East contains the least amount of original fill material at only 35%. While there is evidence of the hotpost drifting into Emerald Isle Central, that reach currently contains sufficient reserve material (135%) and would benefit from material placed in Emerald Isle East due to perceived westerly sediment transport across the region. The hotspot project for Emerald Isle East, which was previously in the planning stages, has now been expanded to include portions of Emerald Isle West and Pine Knoll Shores which experienced large amounts of erosion due to Hurricane Irene. It is expected that material will be placed on the beach in these areas during winter 2012-2013.

As noted, there are inevitable margins of uncertainty associated with hydrographic survey data that may reduce the accuracy of volumetric change analyses. The current estimate of uncertainty in the hydrographic portion of the survey is approximately ±0.11 ft. This results in a variability along the entire Bogue Banks shoreline of roughly ±811,000 cy when taking into account the portion of the profile seaward of the outer bar (approximately 1300 ft offshore) out to a depth of -30 ft NAVD88 (approximately 2850 ft offshore). Therefore, it is essential to thoroughly review the beach and bathymetric profiles using various analytical techniques and general engineering judgment to assure that results are not falsely interpreted. Future periodic survey evaluations will continue to improve on analysis techniques so that the rich survey data sets are best utilized.





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