FINAL REPORT

Bogue Banks Beach
and Nearshore Mapping Program

November 2016

moffatt & nichol

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

carteret county Shore protection office protectthebeach.com

Executive Summary

Comprehensive beach 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 codified to continue assessing 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 the 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 annual survey was completed during spring/summer 2016 by Geodynamics. For this evaluation, the spring/summer 2016 survey was compared with the spring/summer 2015 survey to assess the changes in the beach occurring over the past year. 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 (approximate closure), and -30 ft NAVD88 (offshore). This allows a detailed review of the shoreline and active profile performance since the 2014 monitoring report.

Key statistics for individual reaches along Bogue Banks along with the entire oceanfront shoreline were as follows:

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (Transects 1-11)	11,488	22.3	3.9	45,054	4.0	46,320	1.0	11,368	2.5	28,296	0.0	-13
Emerald Isle-West (Transects 12-25)	18,288	5.6	1.9	34,721	1.1	20,350	-3.4	-62,725	4.1	74,453	2.6	48,444
Emerald Isle-Central (Transects 26-36)	15,802	-9.3	-1.6	-25,259	4.4	68,985	-2.8	-45,006	7.4	116,759	4.3	67,978
Emerald Isle-East (Transects 37-48)	13,220	5.6	-0.8	-10,033	-0.8	-10,673	-7.3	-96,674	-0.7	-8,979	-5.0	-65,902
Indian Beach-Salter Path (Transects 49-58)	12,850	9.8	0.4	5,449	5.6	71,648	-3.3	-42,345	4.1	52,626	-1.0	-12,633
Pine Knoll Shores (Transects 59-76)	23,878	-5.3	-0.7	-17,468	4.4	104,089	-1.6	-37,740	1.4	32,403	-2.5	-58,862
Atlantic Beach (Transects 77-102)	26,176	-4.8	0.1	1,923	-3.1	-79,892	-9.2	-241,055	-7.6	-200,189	-14.5	-380,813
Fort Macon State Park (Transects 103-112)	6,691	34.0	8.3	55,572	14.9	99,369	28.3	189,340	31.9	213,470	31.5	210,807
Beaufort Inlet (Transects 112B-116)	2,000	33.3	5.3	10,661	8.9	17,840	0.0	-43	4.4	8,840	11.0	21,989
Bogue Inlet-Channel (Transects 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
Oceanfront (Transects 1-112)	**128,393**	**3.0**	**0.7**	**89,960**	**2.5**	**320,195**	**-2.5**	**-324,837**	**2.4**	**308,839**	**-1.5**	**-190,994**

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

The Bogue Banks oceanfront shoreline experienced an overall average seaward advancement at MHW of 3.0 ft over the past year. However, patterns of seaward advancement and landward recession fluctuated greatly over the entire shoreline. Volumetrically, there was a dominant trend of volume losses above -12 ft NAVD88 and volume gains above -20 ft NAVD88 due to the flattening and seaward movement of the offshore bar in Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores. Atlantic Beach displayed the largest volume losses above -12 ft NAVD88 which were not captured offshore. Fort Macon experienced a gain in volume, due to the nourishment event which placed 150,000 cy between Transects 104 and 107 and eastward littoral transport which produced volume gains in areas nearest the terminal groin.

This year's analysis also included an assessment of the change in position of the base of the dune along Bogue Banks, which was performed using shore parallel survey lines collected in 2015 and 2016 by driving the survey ATV along the base of the dune. The difference in position at each transect was calculated and plotted to determine any trends in movement along the oceanfront shoreline. An average seaward movement of approximately 5.6 ft was calculated over the entire shoreline. It should be noted that the accuracy of the dune base position surveyed is highly subjective and based on surveyor interpretation. Other methods for tracking this feature are being investigated.

Key statistics calculated for Bear Island were as follows:

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bear Island (Transects 1-18)	16,500	-35.5	-4.8	-79,097	-7.2	-119,276	-9.9	-162,690	-2.5	-41,551	-5.3	-86,714

Bear Island experienced a moderate amount of shoreline recession at MHW over the past year as well as an overall loss in material above all elevations. Profile plots show that the western end of the island experienced erosion above all elevations from Transects 12 – 18 while the eastern end of the island exhibited alternating patterns of erosion and accretion in which some of the onshore losses of material were captured offshore at lower elevations.

Key statistics calculated for Shackleford Banks were as follows:

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Shackleford Banks (Transects 1-19)	39,459	-8.3	-1.2	-70,481	-1.9	-120,901	1.5	-75,484	0.5	-134,985	5.2	26,314
Shackleford Banks (Transects 20-23)	6,542	-80.6	-10.7	-67,979	-38.7	-284,435	-94.2	-681,487	-123.7	-914,900	-132.7	-976,518
Shackleford Banks (Transects 1-24)	46,001	-21.9	-3.0	-138,459	-8.8	-405,335	-16.5	-756,971	-22.8	-1,049,885	-20.7	-950,204

The majority of the island (Transects 1-19) experienced minor landward recession of the shoreline at MHW and minor volume losses above -12 ft NAVD88 (approximately 75,484 cy). The remaining transects along the western end of Shackleford Banks (Transects 20-23) experienced significant landward recession of the shoreline at MHW and substantial losses in volume of approximately 681,487 cy. Profile plots show significant erosion of the dunes and beachface in the transects located adjacent to Beaufort Inlet. This behavior is not unexpected given the location of the deep draft channel being directly adjacent to this area of Shackleford Banks and the recent history of significant erosion. The combination of the deep draft channel hydraulics, episodic dredging and shoaling, as well as barrier island morphology make this a very dynamic area. The remainder of the island experienced minor losses in comparison with some accretion on the eastern end of the island.

Carteret County is currently in the final stages of developing a programmatic Environmental Impact Statement (EIS) which would essentially outline the nourishment needs (quantity, location, and timeframe) and sediment resources for Bogue Banks for the next 50 years and be used to obtain a permit to cover these activities. The annual monitoring efforts will decide the exact timing and extents of future nourishment projects by tracking the average profile volume in each management reach as compared to nourishment triggers that define the minimum profile volumes required to provide an equal level of protection along the Bogue Banks shoreline. Assessment of current conditions compared to the nourishment triggers defined in the Master Beach Nourishment Plan (engineering portion of the EIS) was completed as part of this report. The following table indicates that all management reaches currently contain average profile volumes above their individual nourishment triggers as well as the island wide average trigger of 233 cy/ft. Using historical erosion rates (background and storm), it would appear that based on the current volumes, the next nourishment action may be needed within 3-5 years if there is a period of above normal storm activity. Otherwise, the next nourishment action is not expected for 7-12 years.

Reach (Profiles)	Management Reach Length (ft)	2016 Volume Above -12 ft NAVD88 (cy)	Nourishment Trigger (cy)
Bogue Inlet (1-11)	11,488	320	235
Emerald Isle West (12-25)	18,288	311	266
Emerald Isle Central (26-36)	15,802	295	211
Emerald Isle East (37-48)	13,220	267	221
Indian Beach/Salter Path (49-58)	12,850	278	224
Pine Knoll Shores (59-76)	23,878	252	211
Atlantic Beach (77-102)	26,176	313	254
TOTAL	**121,702**		
AVERAGE		**290**	**233**
		weighted	weighted

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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 the 1999 monitoring program initiated for assessing beach conditions. The program's primary purpose centered on forming strategies for the Bogue Banks Beach Restoration Project or County Project (Phases I, II, and III). The monitoring program was initiated along Bogue Banks and expanded to include Bear Island in October 2004. The inclusion of Shackleford Banks occurred later in May 2005. Since May 2005, surveys along Bogue Banks, Bear Island, and Shackleford Banks have been performed annually during the spring/summer timeframe. In addition, surveys occur for Bogue Banks after large storm events to quantify shoreline and volume changes and to augment the municipalities' FEMA reimbursement request for beach nourishment. The most recent annual survey occurred during the spring and summer of 2016 and was performed by Geodynamics LLC (Geodynamics). This report documents the data sources, methods, and results of a survey evaluation performed to compare the spring/summer 2016 survey with a previous survey performed in spring/summer 2015.

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: University of North Carolina Institute of Marine Sciences completed the 2003 work). Each year, comparisons along Bogue Banks were made to an initial survey performed in 1999, providing for 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 other 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 2-1** and **Table 2-2** show the long-term and short-term volume changes over the various reaches of shoreline included in the BBBNMP.

Table 2-1. Long-term Volume Change (Previous Studies: 2004-2007)

	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 2-2. Short-term Volume Change (Previous Studies: 2004-2007)

	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

For analysis from 2008 – 2015, please refer to the annual reports prepared by Moffatt & Nichol.

3.0 Survey Methods and Data Sources

Most recently, Geodynamics conducted a survey of Shackleford Banks, Bear Island, and Bogue Banks in March through May 2016. The profile lines and origins used in previous studies were also used for the most recent survey for ease of comparison. **Figure 3-1** and **Figure 3-2** 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. 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 references the NAD 1983 State Plane North Carolina (feet) horizontal datum and the NAVD 1988 vertical datum.

Several steps were taken by Geodynamics to ensure the most accurate survey data. The spring/summer 2016 survey represents a continuation of previous surveys conducted for the Carteret County Shore Protection Office using high-density singlebeam sonar and topographic equipment. The 2016 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 discuss the singlebeam (bathymetric) and topographic data acquisition including the associated equipment, quality control procedures, and data processing requirements.

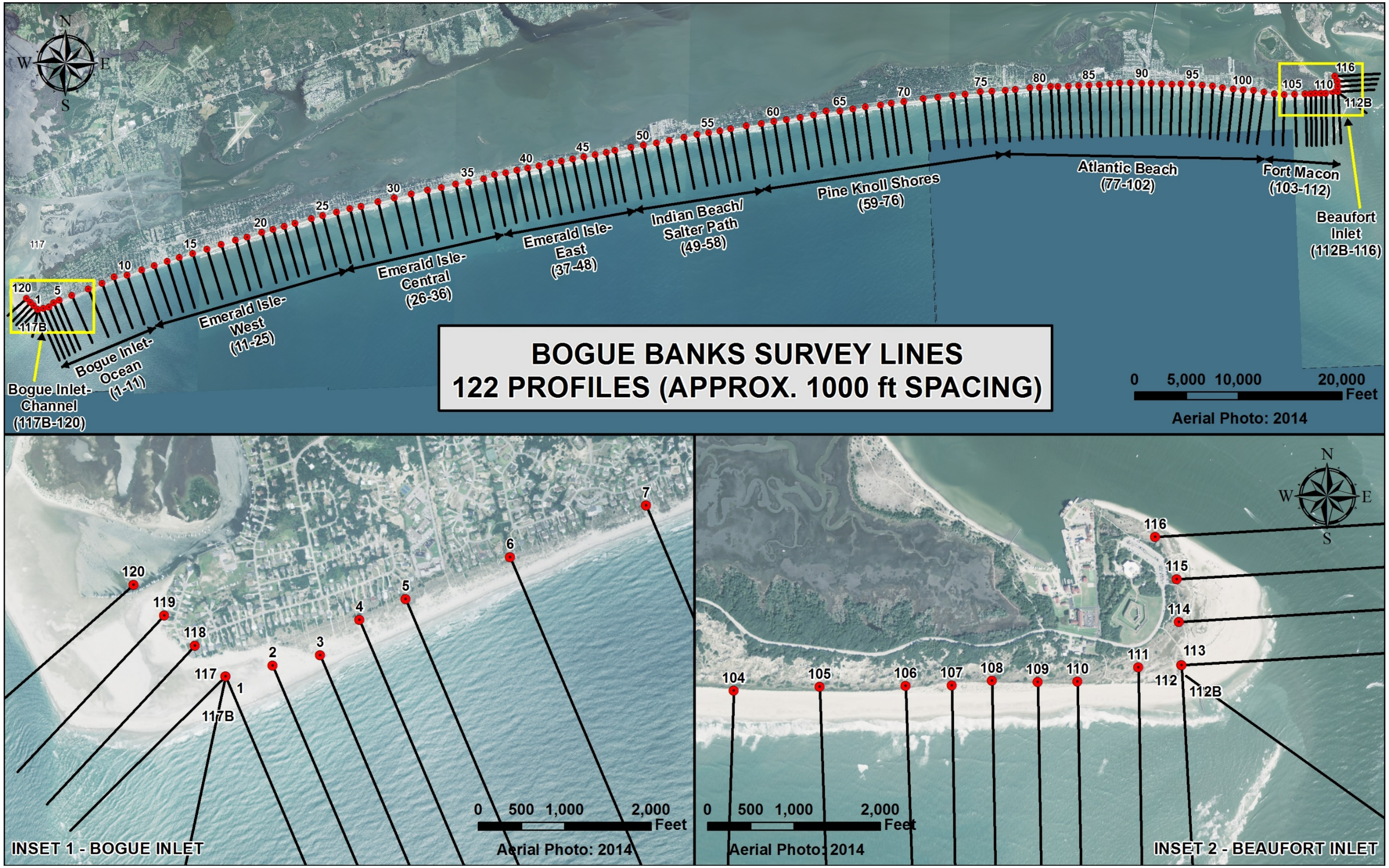


Figure 3-1. BBBNMP Profile Line Locations – Bogue Banks

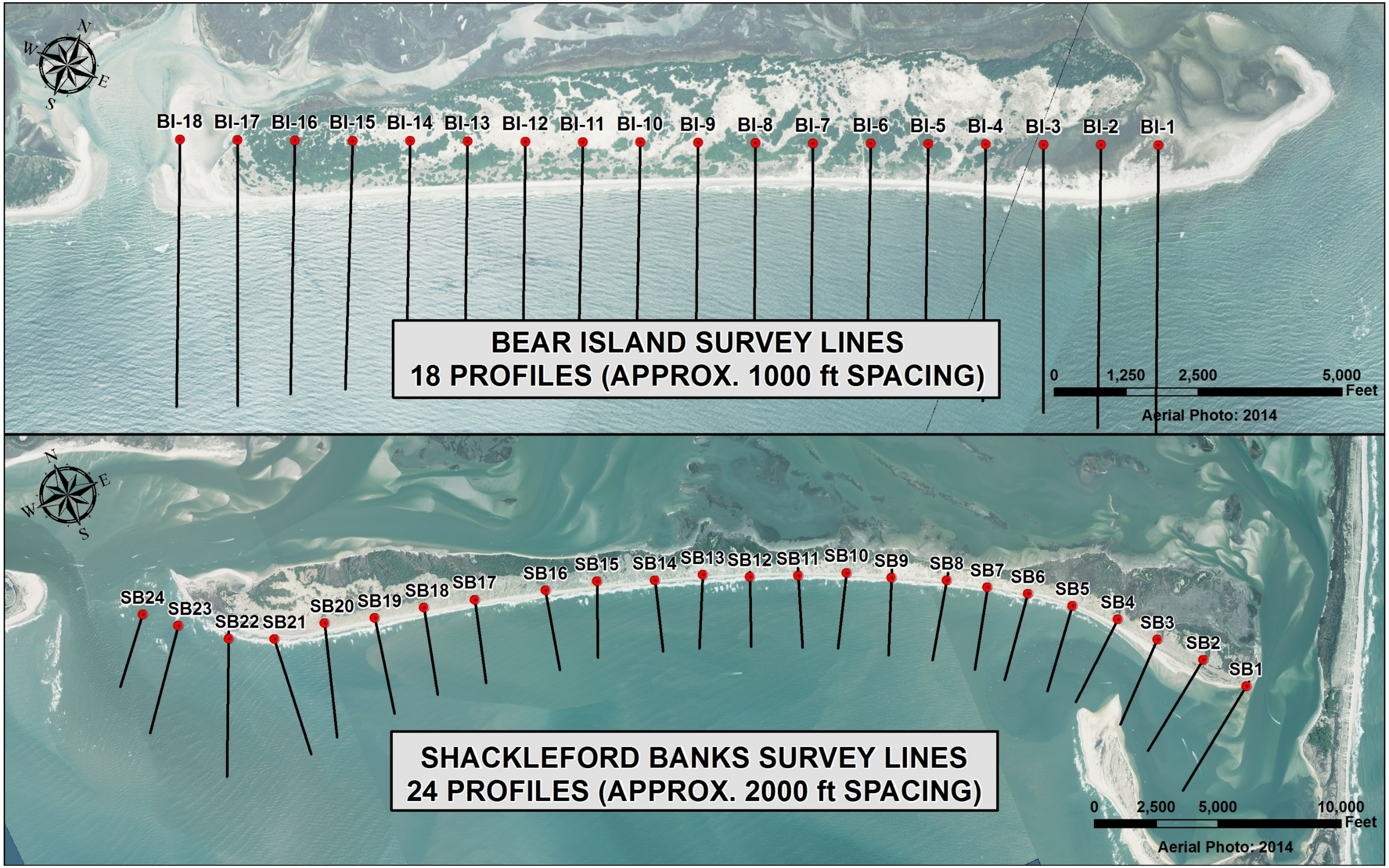


Figure 3-2. BBBNMP Profile Line Locations – Bear Island and Shackleford Banks

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 3-3**). 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 R/V Echo specifications are presented in Table 3-1 and the hardware systems inventory for the R/V Echo is shown in **Table 3-2**.

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

Table 3-1. R/V Echo Vessel Specifications

Dimensions:	21' x 9' x 1.2'
USCG:	Designated Research Vessel
Flag	U.S.
Registry:	North Carolina
Official Number:	NC 7341 DT
Tonnage:	1
Lab Space:	1 Open Concole Operator Station
Max Speed:	30 Knots
Min. Survey Speed:	2.5 Knots
Propulsion:	1 x 140 HP Suzuki 4-Stroke Outboard Motor - 2011
Auxillary Power:	24v DC Battery Banks & 12V DC Parallel Battery Banks
Fuel Capacity:	60 Gallons
GPS:	Simrad
Sounder:	Lowrance StructureScan
Compass:	n/a
Radar:	n/a
Autopilot:	n/a
VHF:	Icom 25 watt
Cellular Phone:	iPhone 6s
Internet:	Verizon JetPack 4G LTE

Table 3-2. R/V Echo Hardware Systems Inventory

	Hardware	Manufacturer	Model
Horizontal & Vertical Control	RTK Radio Modem	Trimble	TDL 450H
	RTK Radio Antenna	Pacific Crest	n/a
	GPS Antenna	Trimble	Zephyr
	Cellular Internet	Verizon	Jetpack
	POS MV	Applanix	Wavemaster
Echo Sounding	StructureScan	Simrad	1.7.0
	ODOM CV100	ODOM	CV100
	Operator Station	CCS-inc	FPC-04649
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 SVP-X

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 3-3**.

Table 3-3. Singlebeam Software Systems Inventory

	Software	Version
Data Acquisition	HYPACK	2014
	POSView	8.1
	Odom eChart	1.4
Data Processing	HYPACK	2015
	SeaCast	3.6
	ArcView	3.4
	ArcGIS	10.3
	POSPac MMS	7.1
	Matlab	2013b

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/WM 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.

ArcGIS and ArcView GIS are complete Geographic Information Systems (GIS) software packages. All survey area maps, coverage extents, and final chart products were created using ArcGIS 10.2.

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 - 10 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/WM unit was setup to receive phase-differential RTK position offsets from the GPS base station at NCBE Pivers Island. This configuration allowed the POS Computer System (PCS) to integrate decimeter positional solutions with highly-accurate vessel attitude and positions obtained from the IMU and dual GNSS receivers. The PCS software computes velocity, roll, pitch, and true heading from the accelerometer and gyro outputs. These sensed accelerations and rates of rotation are calculated into measurements of velocity, heading, and track of the vessel through complex algorithms. For improved heading, the GPS Azimuth Measurement Subsystem (GAMS) limited the amount of noise in the vertical measurements, correcting for heading by aligning two fixed GPS antennas. Using a Kalman filter, this heading is combined with the Dynamic Heading Alignment, a method that uses data supplied by the IMU and GPS receivers to calculate heading, enabling heading accuracies between 0.05° and 0.1° RMS.

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/WM 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 any influences obtained from the wave conditions.

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 R7 RTK-GPS rover backpack system was used to acquire topographic data during the survey. The Trimble R7 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 R7 receiver at 10 Hz to the Panasonic Toughbook CF-U1 data acquisition tablet PC. A Yamaha ATV is used to transport personnel between profiles as well as collect tie-lines along morphological breaks on shore (**Figure 3-4**).

Figure 3-4. Yamaha ATV Used For Topographic Data Acquisition and Transportation

Table 3-4 provides the hardware systems inventory for topographic data collection.

Table 3-4. Topographic Hardware Systems Inventory

Hardware	Manufacturer	Model
Acquisition PC	Panasonic	FZ-M1 Tablet
GPS Receiver	Trimble	R7
GPS Antenna	Trimble	Zephyr 2
Internet	Verizon	Jetpack

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 R7 RTK-GPS system. The topographic rover received and integrated the differential corrections from the VRS station and RTK-GPS for centimeter-level positioning.

Table 3-5 presents the software systems inventory for topographic data collection.

Table 3-5. Topographic Software Systems Inventory

	Software	Version
Data Acquisition	HYPACK	2015
	GNSS Internet Radio	1.4.11
Data Processing	HYPACK	2015
	ArcGIS	10.3
	Microsoft Excel	2012

The HYPACK software suite was used during survey preparation in order to create profile line 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 to meet specific project requirements. 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. Microsoft Excel was used to format data columns specific to the client's needs.

All survey area maps, coverage extents, and final chart products were created using ArcGIS, a complete Geographic Information Systems (GIS) software package.

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 were 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 previous profile data for a quick in-field QA-QC check.

A series of shore parallel topographic lines were acquired between stationed topo/bathy profile transects along Bogue Banks. Approximately 4 survey lines collected from a calibrated all-terrain vehicle (ATV) were acquired and geocoded at the dune base, above/ below any noticeable berm (or open beach in absence of feature) and above/below the anticipated MHW contour. The goal of collecting these data is to calculate any deviation in the dune base over time, to improve digital elevation modeling of the beach face and to extract a more accurate MHW contour.

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 2012a, 08 section 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 3-5**). 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.

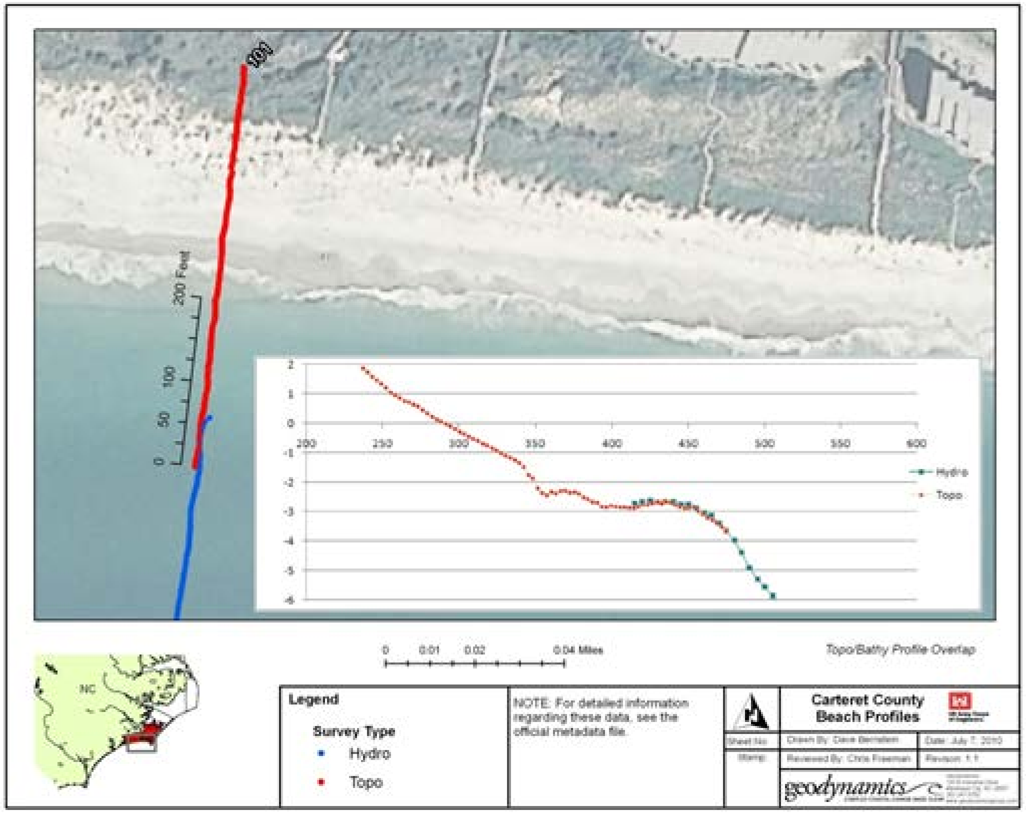


Figure 3-5. Example of Topographic and Bathymetric Data Overlap in Surfzone

3.5 Survey Data Acquisition Timeline

The most recent set of survey data was collected by Geodynamics during March through May of 2016. The Shackleford Banks survey was completed on March 8, 2016. Bear Island was surveyed on March 16, 2016. The Bogue Banks survey, due to weather, was performed over a longer range of dates from March 8, 2016 to May 16, 2016. The date used for the Bogue Banks profiles for this report is May 16, 2016, when a large portion of the surveying was completed.

The previous set of annual survey data, used for comparison in this report, was also collected by Geodynamics during March through June of 2015. The Shackleford Banks survey was completed on March 9-10, 2015. Bear Island was surveyed on June 4, 2015. The Bogue Banks survey, due to weather, was performed over a longer range of dates from April 6, 2015 to June 2, 2015. The date used for the Bogue Banks profiles for this report is May 20, 2015, when a large portion of the surveying was completed.

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 2015 and spring/summer

2016 beach profiles being used for the comparison were then formatted and imported into BMAP. Using BMAP, two indicators of shoreline change were calculated for each transect.

First, the 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 2015 and spring/summer 2016 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 (years) between survey dates. This allows an equivalent comparison of shoreline migration rates occurring between different time periods. 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 2015 and spring/summer 2016 profile data. The MHW shoreline position contour was extracted from the spring/summer 2015 and spring/summer 2016 DEMs and plotted on aerials. These figures are presented in **Appendix A**.

Second, representative volume changes were calculated at each transect between the spring/summer 2015 and the spring/summer 2016 surveyed conditions. 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 occurs 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 (years) 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 represent changes in the amount of material in the dune system and on the subaerial beach. These areas are highly influenced by storm activity. Volume comparisons for portions of the profiles above -5 ft NAVD88, an approximate wading depth, represent changes in the recreational beach area. 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 4-1** presents a graphic showing the various calculation lenses.

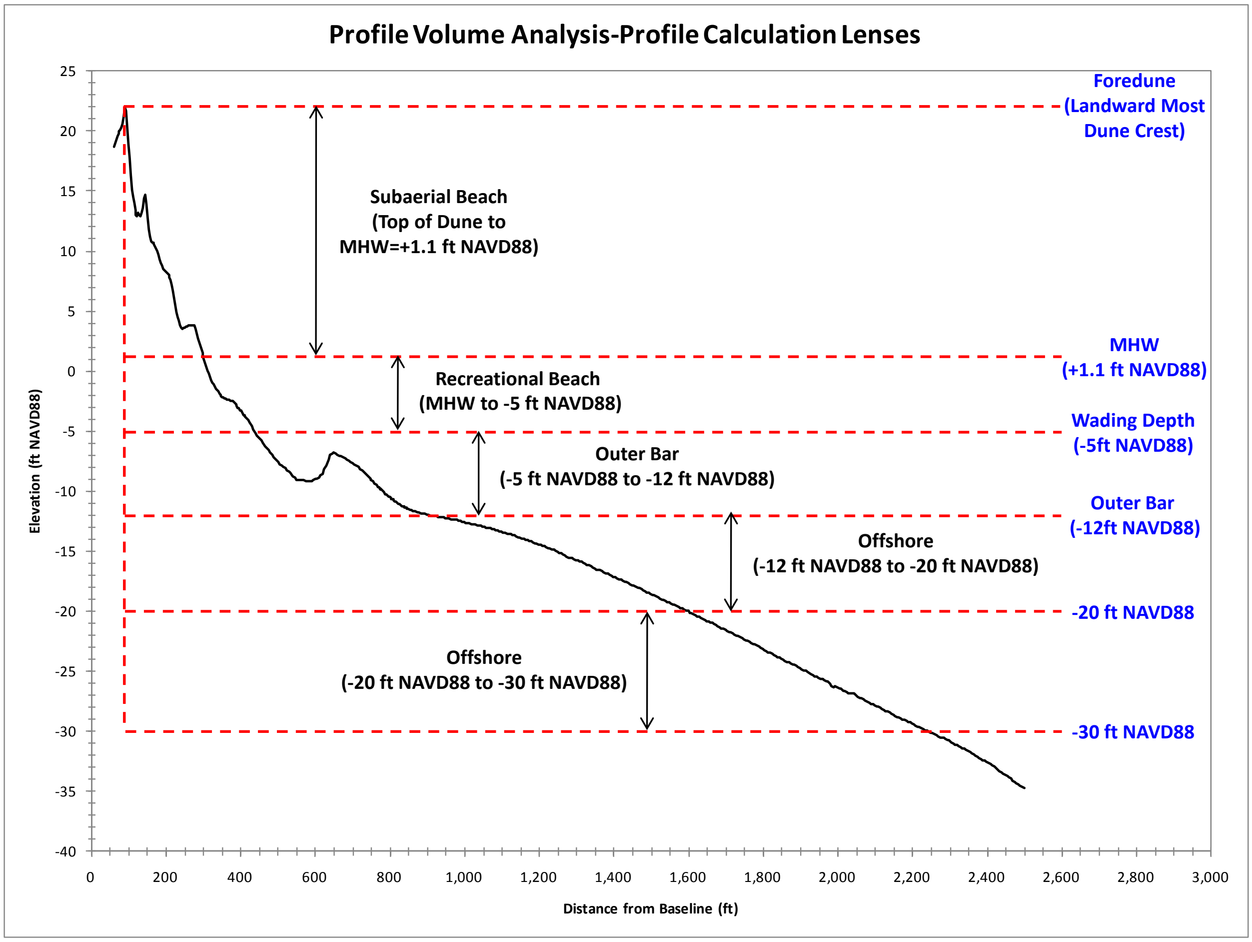


Figure 4-1. Profile Volume Calculation Lenses

Furthermore, an assessment of the change in position of the base of the dune along Bogue Banks was performed using shore parallel survey lines collected in 2015 and 2016 by driving the survey ATV along the base of the dune. The difference in position at each transect was calculated and plotted to determine any trends in movement along the oceanfront shoreline.

Finally, in accordance with the Master Beach Nourishment Plan, a preliminary assessment of current conditions of the beach compared to the new nourishment triggers was completed as part of this report. The assessment utilized historical erosion rates to estimate the potential time remaining until the next nourishment action may be necessary.

5.0 Discussion of Annual Surveying Evaluation

This section discusses key events in the past year which influence the results of the annual analysis (i.e. nourishment projects, storms, etc.), updated development of background erosion rates to include the 2016 survey, annual shoreline and volume change trends (2015 – 2016), statistical analysis of long-term trends (2008 - 2016), and the current status of the beach as it relates to the Master Beach Nourishment Plan nourishment triggers.

It should be noted that annual monitoring is now being performed in accordance with the Master Beach Nourishment Plan which involves a slight adjustment of the shoreline reaches previously established for monitoring. **Table 5-1** shows the changes that will be made in Bogue Inlet – Ocean, Emerald Isle – West, and Pine Knoll Shores. Bogue Inlet – Ocean has become slightly larger while Emerald Isle – West has lost a few transects. Pine Knoll Shores – West and Pine Knoll Shores – East are now combined into one management reach.

Table 5-1. Master Beach Nourishment Plan Management Reaches

OLD MONITORING REACHES:		NEW MANAGEMENT REACHES:	
Reach (Profiles)	**Length (ft)**	**Reach (Profiles)**	**Length (ft)**
Bogue Inlet-Ocean (1-8)	7,432	Bogue Inlet (1-11)	11,488
Emerald Isle-West (9-25)	22,344	Emerald Isle West (12-25)	18,288
Emerald Isle-Central (26-36)	15,802	Emerald Isle Central (26-36)	15,802
Emerald Isle-East (37-48)	13,220	Emerald Isle East (37-48)	13,220
Indian Beach-Salter Path (49-58)	12,850	Indian Beach/Salter Path (49-58)	12,850
Pine Knoll Shores-West (59-65)	9,063	Pine Knoll Shores (59-76)	23,878
Pine Knoll Shores-East (66-76)	14,815		
Atlantic Beach (77-102)	26,176	Atlantic Beach (77-102)	26,176
Fort Macon (103-112)	6,691	Fort Macon (103-112)	6,691

5.1 Key Events During the Reporting Period

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

5.1.1 Storm Events

Wave data from the NDBC Masonboro Inlet-Station 41110 buoy was downloaded for the period of time from the 2015 survey through August 2015 when the Onslow Bay buoy was reinstated after being offline since January 2015. Then, wave data from the NDBC Onslow Bay – Station 41159 was downloaded for August 2015 through May 2016. The wave data was then plotted in order to analyze storm activity which may have impacted the study area. **Figure 5-1** shows the location of the buoys while **Figure 5-2** and **Figure 5-3** present a plot of the wave heights during the reporting period. The 2015 Atlantic hurricane season (June 2015 – November 2015) was relatively mild with only Tropical Storm Ana (May 2015) and Hurricane Joaquin (October 2015) impacting the east coast. Offshore significant wave heights exceeded 10 ft only three times during the season. The winter storm season (December 2015 – May 2016) was slightly more active.

Winter storm Jonas impacted the east coast in January 2016 followed by multiple winter storms in February 2016 causing wave heights to exceed 14 ft on four occasions during the season.

Figure 5-1. Onslow Bay (Sta 41159) & Masonboro Inlet (Sta 41110) Buoy Locations

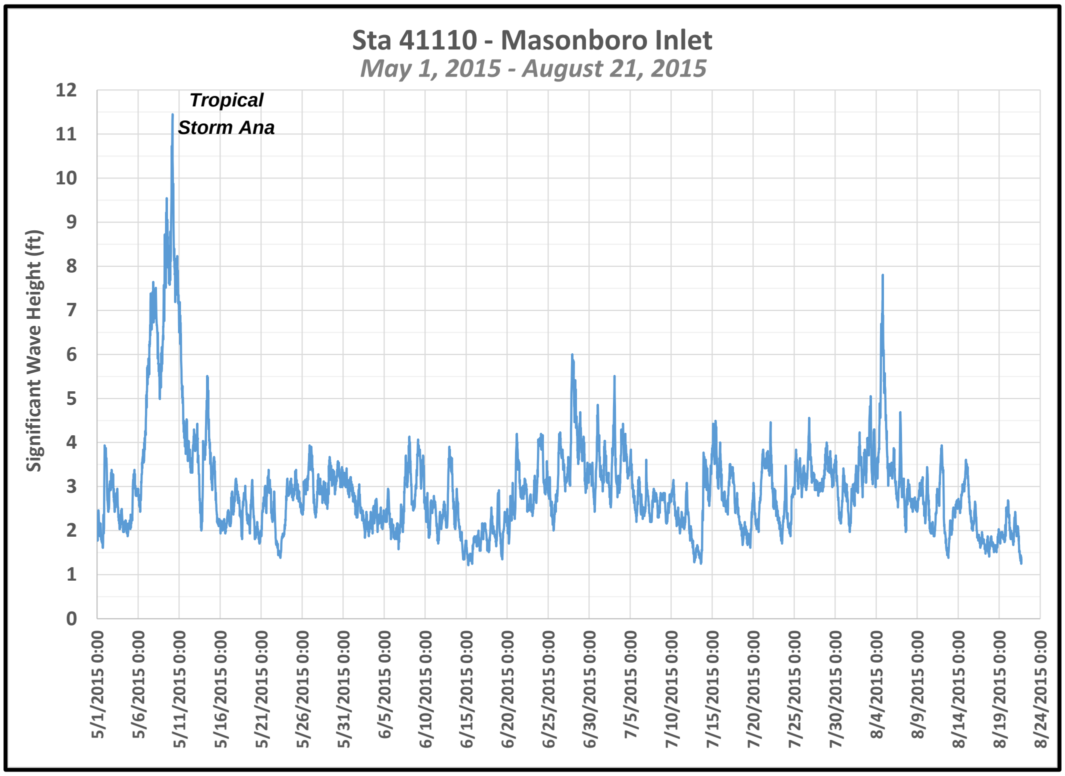


Figure 5-2. Masonboro Inlet – Station 41110 Wave Height

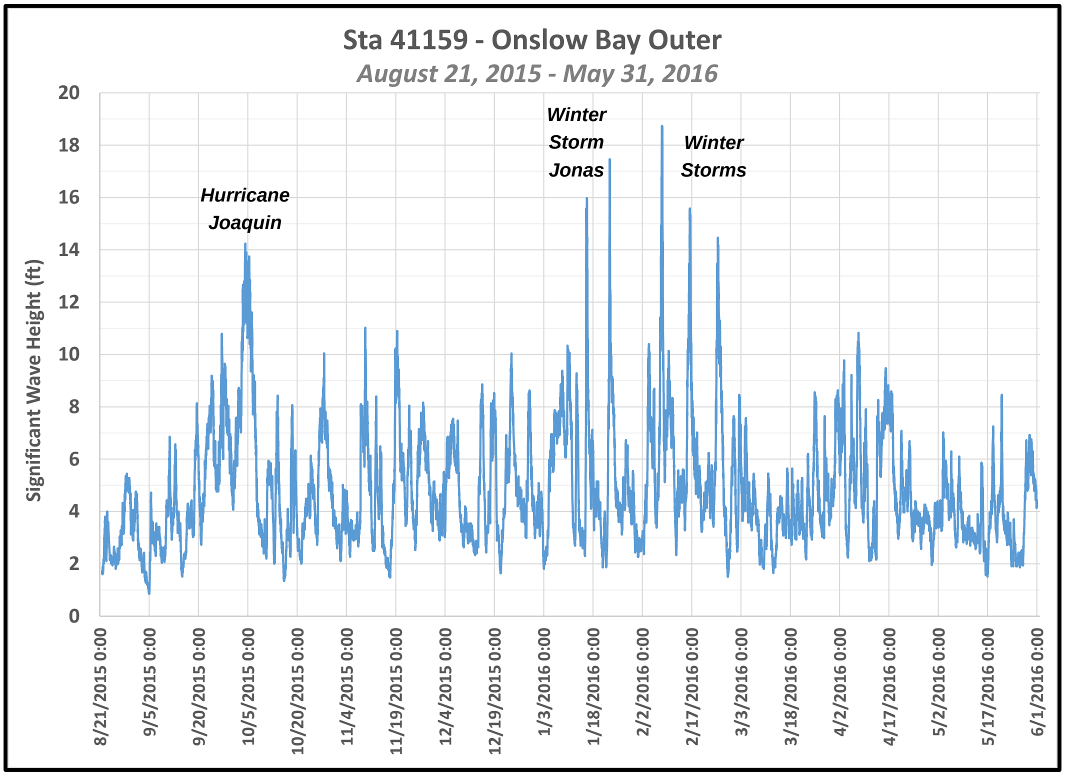


Figure 5-3. Onslow Bay Outer-Station 41159 Wave Height

5.1.2 Nourishment Events

Marinex Construction left a pipeline on the bottom of the Beaufort Inlet seafloor the previous summer while conducting maintenance work at the Morehead City Harbor. This work included a pipeline dredge that delivered sand to scows/barges; and the scows were subsequently towed offshore to the nearshore berm and dumped. The pipe was buried during the Fall 2015 months by shoal material; and in order to retrieve the submerged pipeline, Marinex Construction removed approximately 150,000 cubic yards of sand laying on top of the pipe and additional material the USACE funded to be excavated from December 1-12, 2015. All dredged shoal material was placed along the beach at Fort Macon approximately between Transects 104 and 107 (approximately 2,500 ft) as depicted in **Figure 5-4**.

Figure 5-4. Fort Macon Nourishment Dredge and Placement Locations

5.2 Determination of Background Erosion Rates for Bogue Banks (1999 – 2016)

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. This report updates the background erosion rates previously calculated to include the newest 2016 survey. First, the beach nourishment volumes were documented for the period of time from the initial Bogue Banks Restoration Project in 2002 through 2016. The Bogue Banks area has undergone extensive beach nourishment throughout the duration of the monitoring effort as part of the County Project, the USACE Section 933 Project, USACE Dredge Disposal Projects, and post-storm FEMA work. **Table 5-2** and **Table 5-3** summarize the nourishment projects in the study area since initiation of the monitoring program.

Table 5-2. Nourishment Volumes by Project & Management Reach

Year	Project	Management Reach	Nourishment Volume (cy)
2002	County Phase 1	Pine Knoll Shores	1,276,586
2002	County Phase 1	Indian Beach/Salter Path	456,994
2002	USACE Disposal	Fort Macon	209,348
2003	County Phase 2	Emerald Isle - Central	1,016,946
2003	County Phase 2	Emerald Isle - East	850,780
2004	USACE Section 933	Indian Beach/Salter Path	582,735
2004	USACE Section 933	Pine Knoll Shores	116,547
2004	FEMA Post Isabel	Emerald Isle - Central	57,408
2004	FEMA Post Isabel	Emerald Isle - East	98,592
2005	Brandt Island Pump Out	Atlantic Beach	2,390,000
2005	USACE Disposal	Fort Macon	530,729
2005	County Phase 3	Bogue Inlet - Ocean	173,919
2005	County Phase 3	Emerald Isle - West	516,949
2007	USACE Section 933	Pine Knoll Shores	507,939
2007	FEMA Post Ophelia	Emerald Isle - West	304,037
2007	FEMA Post Ophelia	Emerald Isle - Central	114,942
2007	FEMA Post Ophelia	Emerald Isle - East	229,468
2007	FEMA Post Ophelia	Indian Beach/Salter Path	319,113
2007	FEMA Post Ophelia	Pine Knoll Shores	262,276
2007	USACE Disposal	Fort Macon	184,828
2008	AIWW Tangent B Disposal	Pine Knoll Shores East	148,393
2011	USACE Disposal	Atlantic Beach	799,504
2011	USACE Disposal	Fort Macon	547,196
2013	FEMA Post Irene	Emerald Isle - West	198,190
2013	FEMA Post Irene	Emerald Isle - Central	83,635
2013	FEMA Post Irene	Emerald Isle - East	367,965
2013	FEMA Post Irene	Pine Knoll Shores	315,221
2014	USACE Disposal	Atlantic Beach	522,518
2014	USACE Disposal	Fort Macon	585,067
2015	USACE Disposal	Fort Macon	150,000
TOTAL			***13,917,825***

Table 5-3. Total Nourishment Volumes by Management Reach

Management Reach (Transects)	Nourishment Volume (cy)
Bogue Inlet - Ocean (1-11)	173,919
Emerald Isle West (12-25)	1,019,176
Emerald Isle Central (26-36)	1,272,931
Emerald Isle East (37-48)	1,546,805
Indian Beach/Salter Path (49-58)	1,358,842
Pine Knoll Shores (59-76)	2,626,962
Atlantic Beach (77-102)	3,712,022
Fort Macon (103-112)	2,207,168
TOTAL	***13,917,825***

Second, historical volume changes above -12 ft NAVD88 (typical vertical extent of nourishment placement) were documented from 1999 through 2016. The volume changes were established by adding the annual volume changes calculated by M&N since 2008 to the volume changes from 1999-2007 calculated in the 2007 monitoring report (CSE 2007). **Table 5-4** shows the computed volume change (including nourishments) above -12 ft NAVD88 from 1999-2016 for the defined management reaches.

Table 5-4. Volume Change by Reach Above -12 ft NAVD88

Reach (Transects)	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) (2012-2013)	Volume Change (cy) (2013-2014)	Volume Change (cy) (2014-2015)	Volume Change (cy) (2015-2016)	Volume Change (cy) (1999-2016)
Bogue Inlet-Ocean (Transects 1-11)	362,928	-300,153	210,104	-110,684	-2,766	-270,969	190,178	51,969	-28,850	11,368	113,126
Emerald Isle-West (Transects 12-25)	970,000	-25,922	34,719	-79,827	4,583	-193,402	310,178	111,906	120,098	-62,725	1,189,608
Emerald Isle-Central (Transects 26-36)	940,707	136,125	38,910	-161,290	1,206	-139,918	238,243	-1,999	102,953	-45,006	1,109,931
Emerald Isle-East (Transects 37-48)	786,998	-18,603	-134,995	-120,185	56,038	-153,682	446,124	26,034	15,048	-96,674	806,104
Indian Beach/Salter Path (Transects 49-58)	1,155,522	-116,245	-118,761	-118,078	55,234	-163,958	-44,355	58,729	115,676	-42,345	781,419
Pine Knoll Shores (Transects 59-76)	1,753,427	-57,452	-53,514	-162,946	-81,597	-313,077	385,385	-66,012	81,633	-37,740	1,448,107
Atlantic Beach (Transects 77-102)	1,194,947	27,172	-106,720	-11,803	750,462	-530,856	59,686	573,232	-64,358	-241,055	1,650,706
Fort Macon State Park (Transects 103-112)	221,169	-137,402	-151,048	-46,357	595,792	-167,964	-79,760	436,823	-361	189,340	860,232
Total	**7,385,698**	**-492,480**	**-281,305**	**-811,170**	**1,378,951**	**-1,933,825**	**1,505,678**	**1,190,683**	**341,840**	**-324,837**	**7,959,233**

To calculate the background erosion rate, the documented nourishment volumes were subtracted from total volume changes above -12 ft NAVD88 between 1999 and 2016 and annualized over the 17 year time period. **Table 5-5** shows the average annual background erosion rates for each management reach of the Bogue Banks oceanfront. The average background erosion rate for the entire Bogue Banks shoreline is approximately -2.73 cy/ft/yr. This result is slightly higher than the rate calculated for the 2015 monitoring report, indicating some minor erosion has occurred during the 2015-2016 monitoring period. It is important to note that Atlantic Beach, Fort Macon and Emerald Isle – East continue to have the highest erosion rates.

Table 5-5. Average Annual Background Erosion Rates (1999 - 2016)

Reach (Transects)	Length (ft)	Volume Change Above -12 ft NAVD88 (cy) (1999-2016)	Nourishment Volume (cy)	Background Erosion (cy)	Average Annual Background Erosion Rates (cy/ft/yr)
Bogue Inlet-Ocean (Transects 1-11)	11,488	113,126	173,919	-60,793	-0.31
Emerald Isle-West (Transects 12-25)	18,288	1,189,608	1,019,176	170,432	0.55
Emerald Isle-Central (Transects 26-36)	15,802	1,109,931	1,272,931	-163,000	-0.61
Emerald Isle-East (Transects 37-48)	13,220	806,104	1,546,805	-740,701	-3.30
Indian Beach/Salter Path (Transects 49-58)	12,850	781,419	1,358,842	-577,423	-2.64
Pine Knoll Shores (Transects 59-76)	23,878	1,448,107	2,626,962	-1,178,855	-2.90
Atlantic Beach (Transects 77-102)	26,176	1,650,706	3,712,022	-2,061,316	-4.63
Fort Macon State Park (Transects 103-112)	6,691	860,232	2,207,168	-1,346,936	-11.84
Total	**128,393**	**7,959,233**	**13,917,825**	**-5,958,592**	**-2.73**

5.3 Bogue Banks Shoreline and Volume Change Analysis (2015 – 2016)

This section discusses the results of the shoreline and volume change analysis for the defined management reaches along Bogue Banks (see **Figure 3-1**). Key statistics were calculated to quantify average shoreline and volume changes for individual management reaches as well as the entire oceanfront shoreline for Bogue Banks. 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). 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.

For reference, **Appendix B** contains plots of the shoreline and volume changes from the spring/summer 2015 and the spring/summer 2016 surveys at each transect along Bogue Banks. **Appendix C** presents profile comparison plots for individual transects for the spring/summer 2015 and the spring/summer 2016 surveys. Where applicable, the Irene post-fill profiles (February/March 2013) are also plotted for comparison. Lastly, **Appendix D** provides the computed shoreline changes and volume changes measured at each individual transect in tabular format.

5.3.1 Bogue Inlet

The Bogue Inlet region is comprised of an oceanfront area along the western terminus of Bogue Banks which covers Transects 1 through 11 (Bogue Inlet – Ocean) and an area along the eastern side of Bogue Inlet covering Transects 117 through 120 (Bogue Inlet – Channel) (see **Figure 3-1**). **Table 5-6** presents a summary of average shoreline and volume changes occurring between 2015 and 2016 for the Bogue Inlet region.

Table 5-6. Average Shoreline and Volume Change for Bogue Inlet (2015 - 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (Transects 1-11)	11,488	22.3	3.9	45,054	4.0	46,320	1.0	11,368	2.5	28,296	0.0	-13
Bogue Inlet-Channel (Transects 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

As shown in **Table 5-6**, the Bogue Inlet-Ocean region shoreline experienced seaward advancement at MHW and volumetric gains above all elevations. **Figure 5-5** displays the unit volume change at each transect for the Bogue Inlet-Ocean region. As can be seen, the transect adjacent to Bogue Inlet experienced large fluctuations in volume change while the eastern portion of the reach experienced a more stable pattern of minor volume gains.

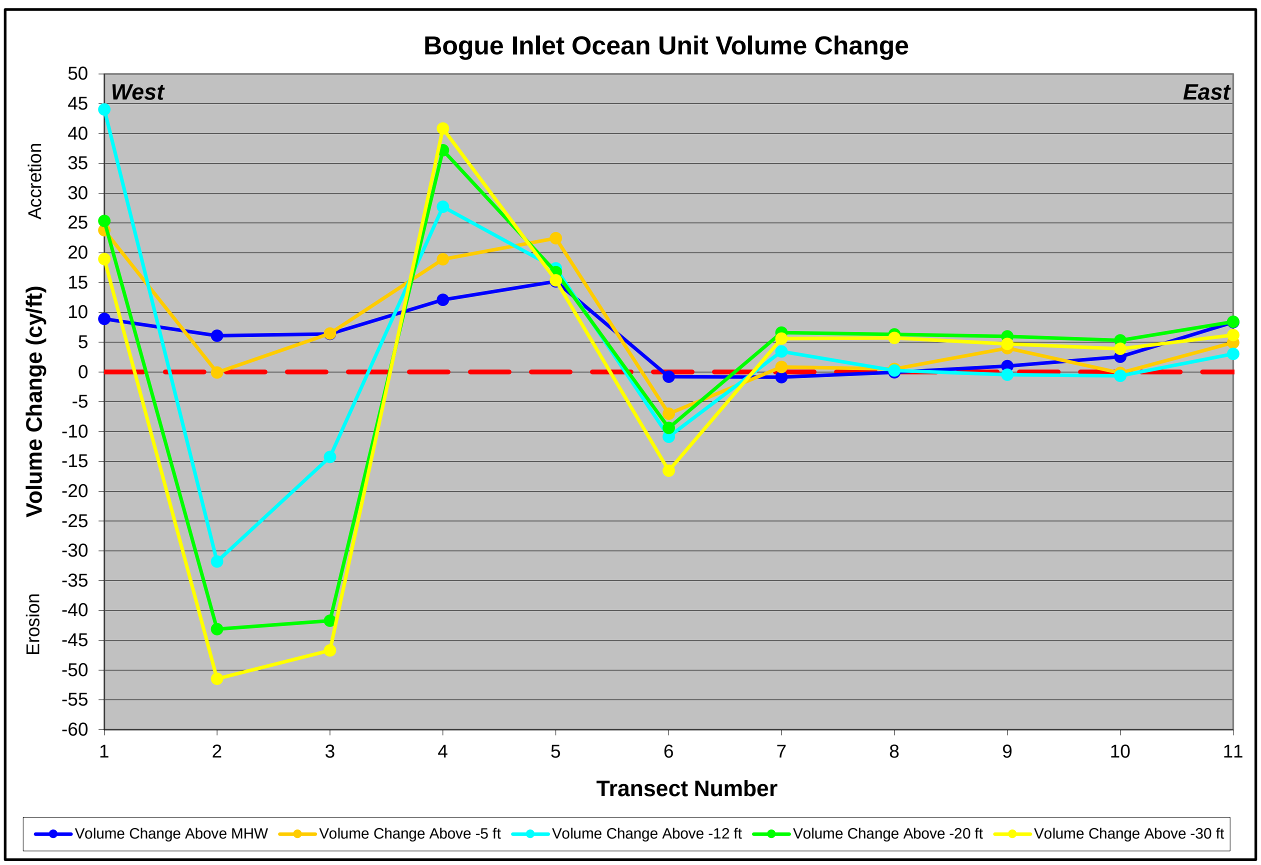


Figure 5-5. Bogue Inlet Ocean Unit Volume Change (2015 - 2016)

The Bogue Inlet-Channel region is highly dynamic due to the inlet. The location of dry land changes so frequently that profiles along Bogue Inlet often do not line up properly from year to year. Therefore, analytical calculations were not performed at Transect 117 through 120.

However, upon investigation of the profile plots in **Appendix C**, it appears that that there has been some eastward migration of Bogue Inlet channel. In June 2016, Geodynamics conducted a topographic and hydrographic survey to assess conditions at the Point. Based on this survey, it appears that approximately 380 ft exist between the edge of the current channel location and the boundary of the "safe box" which was determined as part of the Master Beach Nourishment Plan (see **Figure 5-6**). When compared with a similar survey taken in June 2015, the channel appears to have moved approximately 40 ft to the east between April 2014 and June 2015.

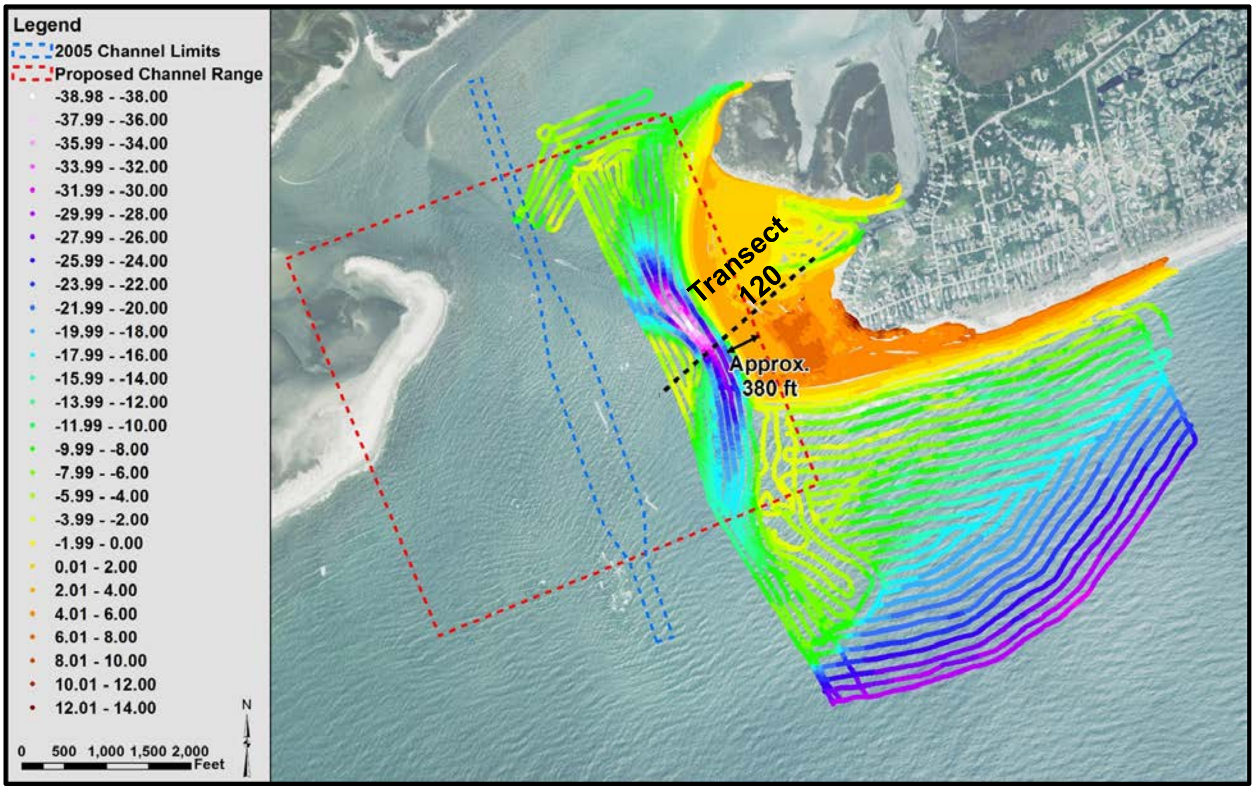


Figure 5-6. Bogue Inlet Channel Survey - June 2016 (Geodynamics)

Figure 5-7 shows an example profile (Transect 120) from Bogue Inlet which displays the eastward migration of the channel bank toward The Point between 2015 and 2016.

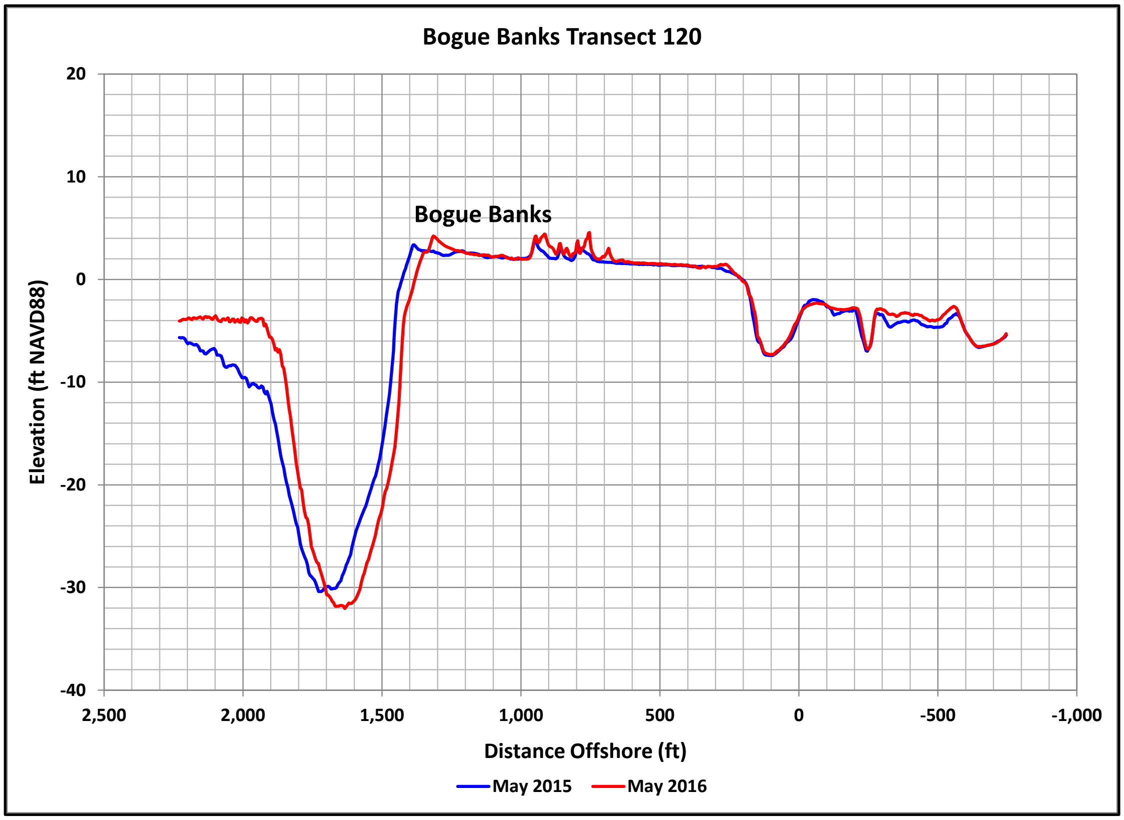


Figure 5-7. Example Bogue Inlet Transect

5.3.2 Emerald Isle

The Emerald Isle region covers Transects 12 through 48 of the Bogue Banks shoreline and is divided into three management reaches (see **Figure 3-1**): 1) Emerald Isle – West (Transects 12-25), 2) Emerald Isle – Central (Transects 26-36), and 3) Emerald Isle – East (Transects 37-48). Since monitoring began in 1999, this area has received a total of 3.84 million cy of nourishment material as a result of the County Project and FEMA post-storm work (Isabel, Ophelia, and Irene). **Table 5-7** presents a summary of average shoreline and volume changes occurring between 2015 and 2016 for the Emerald Isle management reaches.

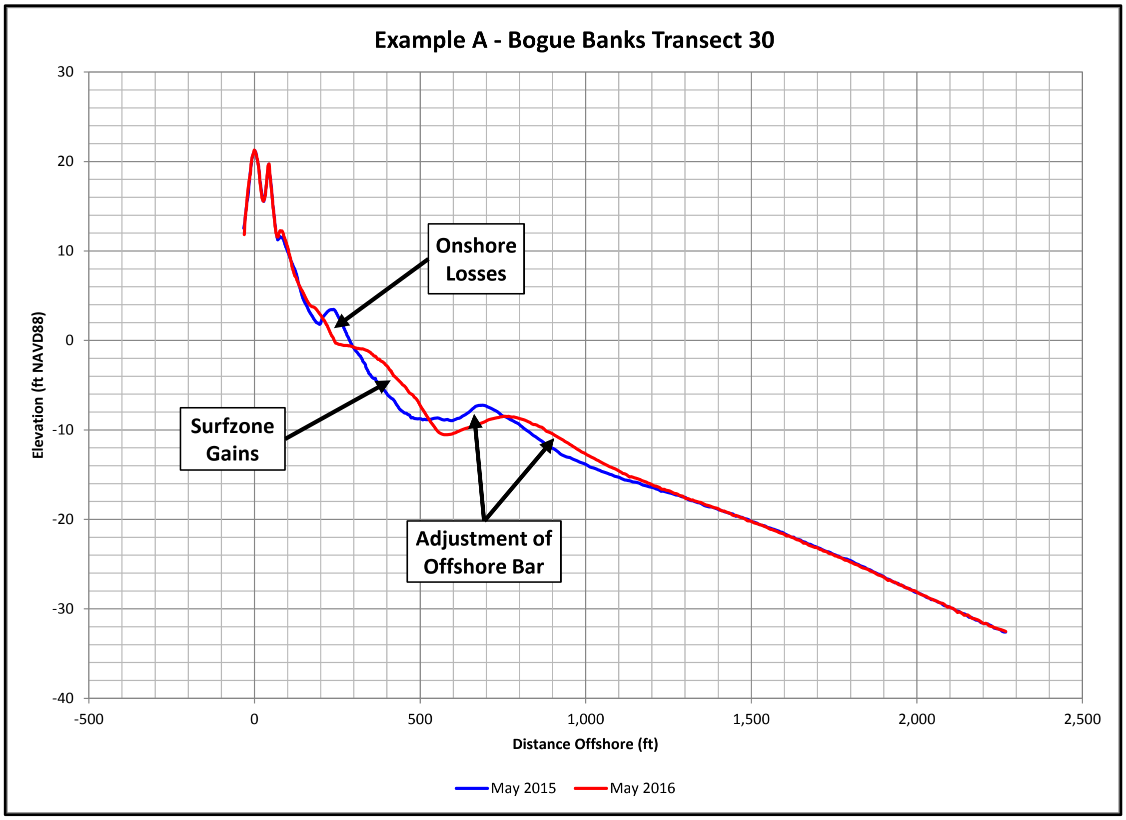
Table 5-7. Average Shoreline and Volume Change for Emerald Isle (2015 - 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Emerald Isle-West (Transects 12-25)	18,288	5.6	1.9	34,721	1.1	20,350	-3.4	-62,725	4.1	74,453	2.6	48,444
Emerald Isle-Central (Transects 26-36)	15,802	-9.3	-1.6	-25,259	4.4	68,985	-2.8	-45,006	7.4	116,759	4.3	67,978
Emerald Isle-East (Transects 37-48)	13,220	5.6	-0.8	-10,033	-0.8	-10,673	-7.3	-96,674	-0.7	-8,979	-5.0	-65,902
Emerald Ise - Total (Transects 12-48)	47,310	0.6	0.0	-571	1.7	78,662	-4.3	-204,405	3.9	182,233	1.1	50,520

Shoreline change at MHW showed a mixed response throughout the reaches of Emerald Isle with landward recession in Emerald Isle – Central and seaward advancement in Emerald Isle – West and Emerald Isle - East. Profile plots in **Appendix C** show profile behavior in Emerald Isle –

Central where material from MHW has been pulled offshore and deposited in the surfzone between MHW and the outer bar (see **Figure 5-8**, Example A). Meanwhile, profiles in Emerald Isle – West and Emerald Isle – East show behavior where material from the surfzone has been pushed onshore to MHW (see **Figure 5-8**, Example B).

Volumetrically, **Table 5-7** indicates that all three management reaches in Emerald Isle experienced volume losses above -12 ft NAVD88 (-204,405 cy). However, Emerald Isle gained material overall above -20 ft NAVD88 (182,233 cy), indicating that the material lost above -12 ft NAVD88 has been captured offshore above -20 ft NAVD88. The profile plots in **Appendix C** show that there has been an adjustment in the offshore bar where it has flattened and extended slightly further offshore, causing the losses above -12 ft NAVD88 and the gains above -20 ft NAVD88 (see **Figure 5-8**, Examples A and B).



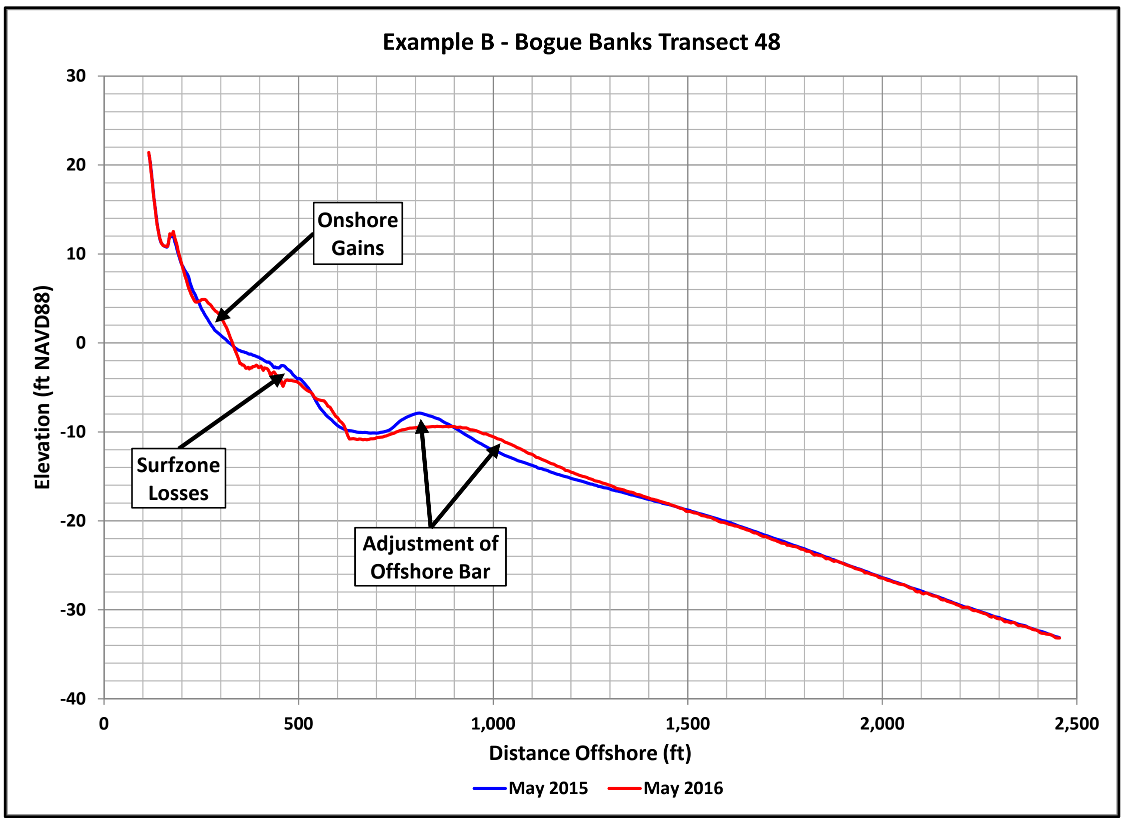


Figure 5-8. Example Profiles – Emerald Isle

Figure 5-9 displays the unit volume change at each transect above the five elevations analyzed. As can be seen, alternating erosion and accretion patterns throughout the Emerald Isle region. Emerald Isle – East experienced mostly erosion with the largest pocket of erosion located in between Emerald Isle – Central and Emerald Isle – East, an area that has historically been a hotspot. Meanwhile, Emerald Isle – West experienced mostly accretion as is typical with this reach.

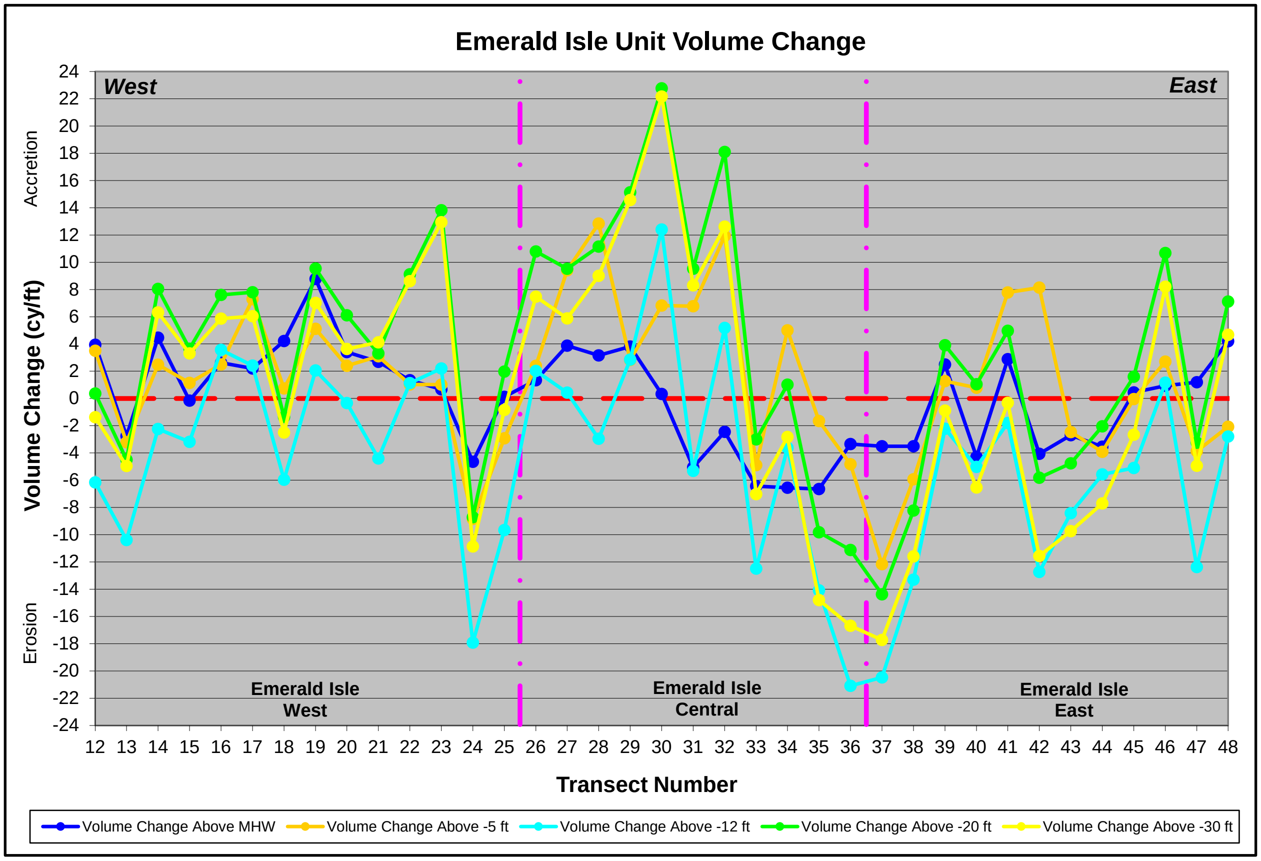


Figure 5-9. Emerald Isle Unit Volume Change (2015 - 2016)

5.3.3 Indian Beach/Salter Path

The Indian Beach/Salter Path region covers Transects 49 through 58 of the Bogue Banks shoreline and is defined as a single management reach (see **Figure 3-1**). Since monitoring efforts began in 1999, this area has received 1.36 million cy of nourishment material from the County Project, USACE Section 933, and FEMA post-storm work (Ophelia). **Table 5-8** presents a summary of average shoreline and volume changes occurring between 2015 and 2016 for the Indian Beach/Salter Path region.

Table 5-8. Average Shoreline and Volume Change for Indian Beach/Salter Path (2015 - 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Indian Beach-Salter Path (Transects 49-58)	12,850	9.8	0.4	5,449	5.6	71,648	-3.3	-42,345	4.1	52,626	-1.0	-12,633

Shoreline change at MHW in the Indian Beach/Salter Path area showed a seaward advancement of approximately 9.8 ft between the last two surveys, indicating material being pushed onshore from the surfzone. Profile plots in **Appendix C** show that material has been pushed onshore at a majority of the transects (see **Figure 5-10**).

As with Emerald Isle, **Table 5-8** indicates that Indian Beach/Salter Path experienced volume losses above -12 ft NAVD88 (-42,345 cy) and volume gains above -20 ft NAVD88 (53,626 cy), indicating that the material lost above -12 ft NAVD88 has been captured offshore above -20 ft NAVD88. The profile plots in **Appendix C** show that there has been an adjustment in the offshore bar where it has flattened and extended slightly further offshore, causing the losses above -12 ft NAVD88 and the gains above -20 ft NAVD88 (see **Figure 5-10**).

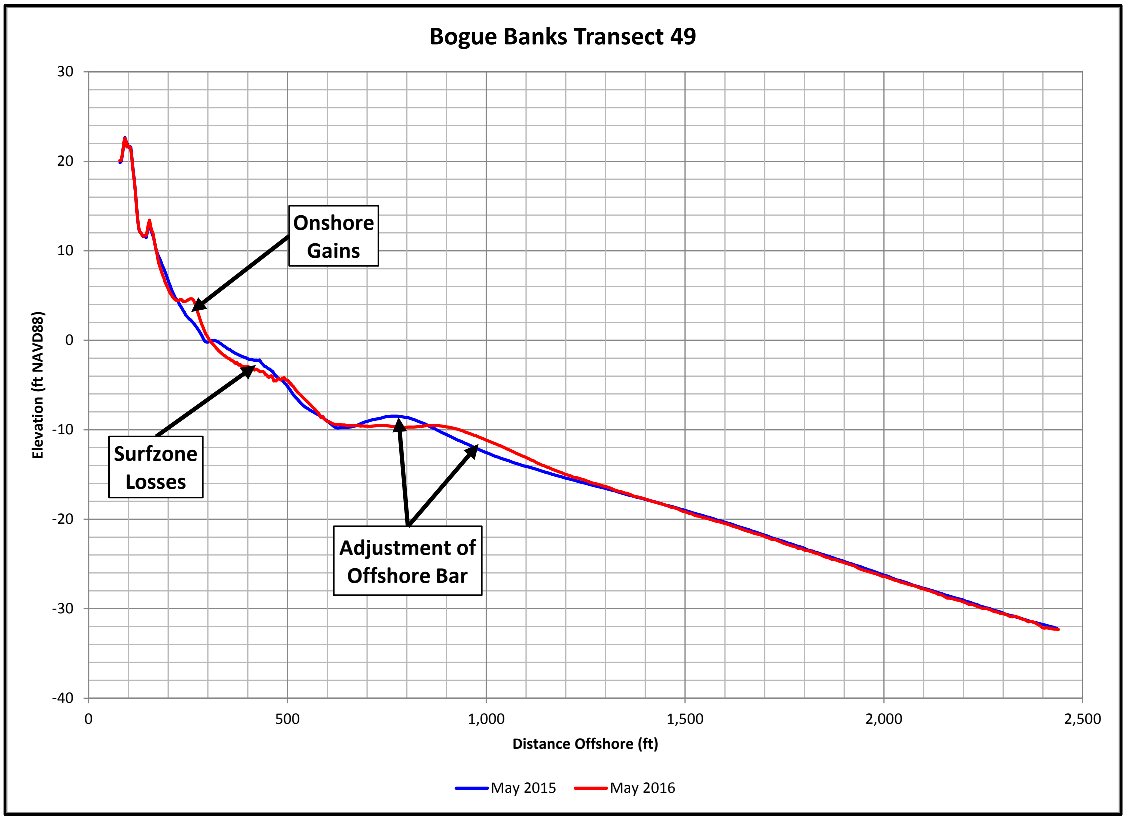


Figure 5-10. Example Profile – Indian Beach/Salter Path

Figure 5-11 displays the unit volume change at each transect for the Indian Beach/Salter Path region. As can be seen, the western portion of the reach was slightly more accretional than transects in the eastern portion of the reach.

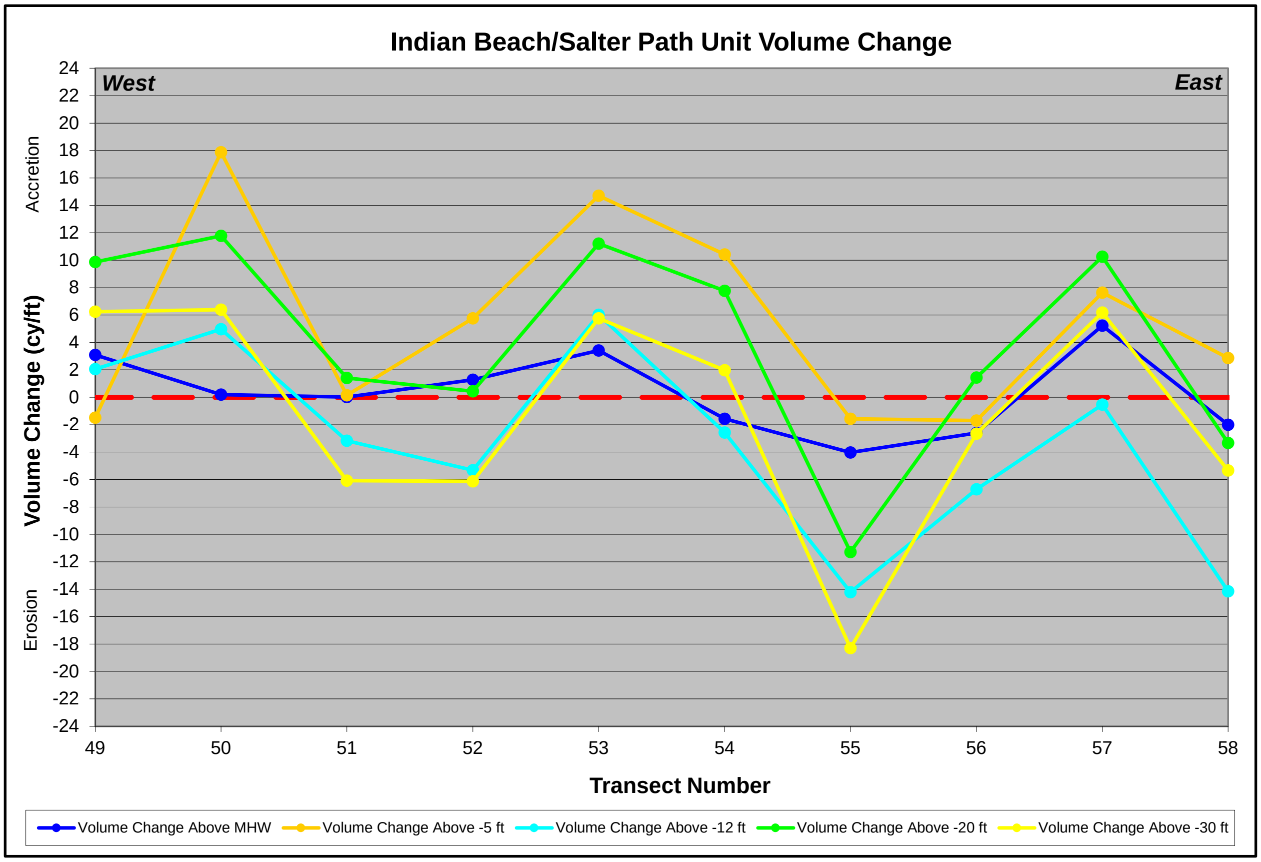


Figure 5-11. Indian Beach/Salter Path Unit Volume Change (2015 - 2016)

5.3.4 Pine Knoll Shores

The Pine Knoll Shores region covers Transects 59 through 76 of the Bogue Banks shoreline and is defines as a single management reach (see **Figure 3-1**). Since monitoring efforts began in 1999, the Pine Knoll Shores area has received 2.63 million cy of nourishment material as a result of the County Project, USACE Section 933, and FEMA post-storm work (Ophelia and Irene). **Table 5-9** presents a summary of average shoreline and volume changes occurring between 2015 and 2016 for the Pine Knoll Shores region.

Table 5-9. Average Shoreline and Volume Change for Pine Knoll Shores (2015 - 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Pine Knoll Shores (Transects 59-76)	23,878	-5.3	-0.7	-17,468	4.4	104,089	-1.6	-37,740	1.4	32,403	-2.5	-58,862

Shoreline change at MHW showed overall landward recession of the shoreline at MHW in Pine Knoll Shores. The shoreline change plot in **Appendix B** and profile plots in **Appendix C** indicate that shoreline behavior actually fluctuated throughout the reach with some areas of seaward advancement and some areas of landward recession.

As with Emerald Isle and Indian Beach/Salter Path, **Table 5-9** indicates that Pine Knoll Shores experienced volume losses above -12 ft NAVD88 (-37,740 cy) and volume gains above -20 ft

NAVD88 (32,403 cy), indicating that the material lost above -12 ft NAVD88 has been captured offshore above -20 ft NAVD88. The profile plots in **Appendix C** show that there has been an adjustment in the offshore bar where it has flattened and extended slightly further offshore, causing the losses above -12 ft NAVD88 and the gains above -20 ft NAVD88. Profile plots also show a significant gain in material just landward of the offshore bar in at a majority of transects (see **Figure 5-12**).

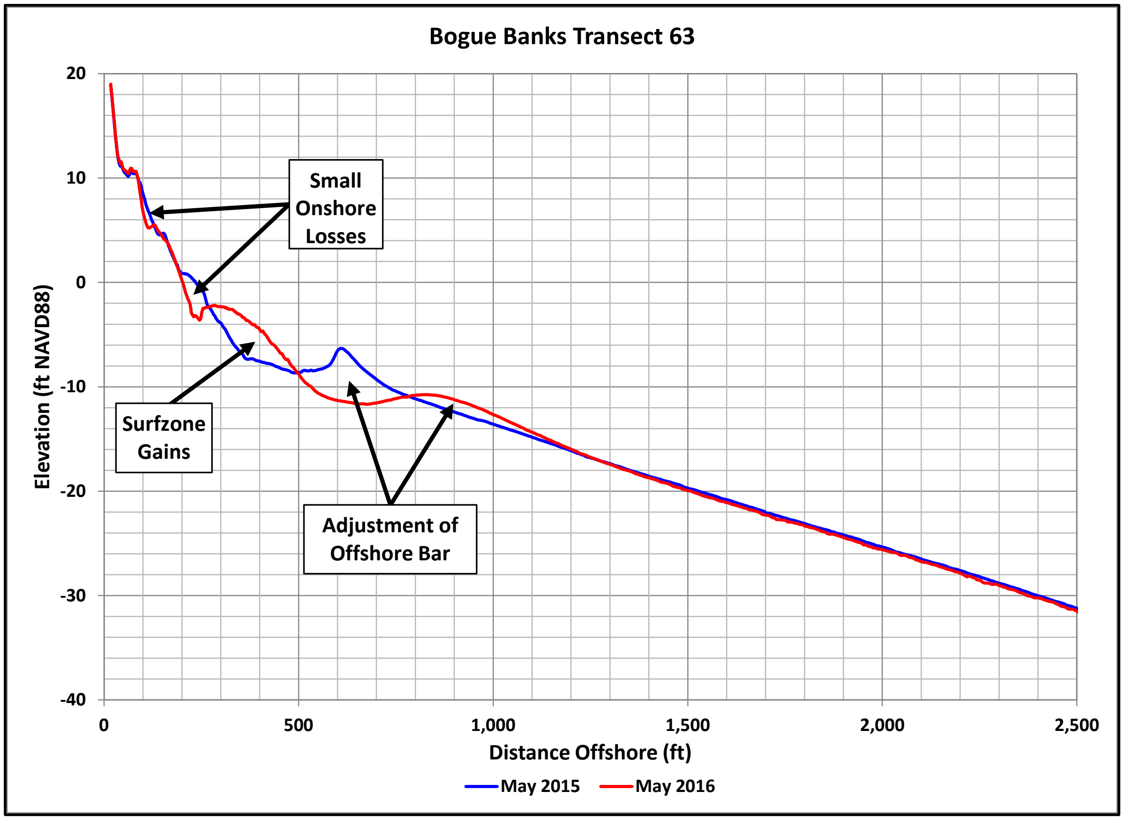


Figure 5-12. Example Profile – Pine Knoll Shores

Figure 5-13 displays the unit volume change at each transect for the Pine Knoll Shores region. As can be seen, the western portion of Pine Knoll Shores appears to have experienced larger losses than the eastern portion. However, alternating volume gains and losses are present throughout the management reach.

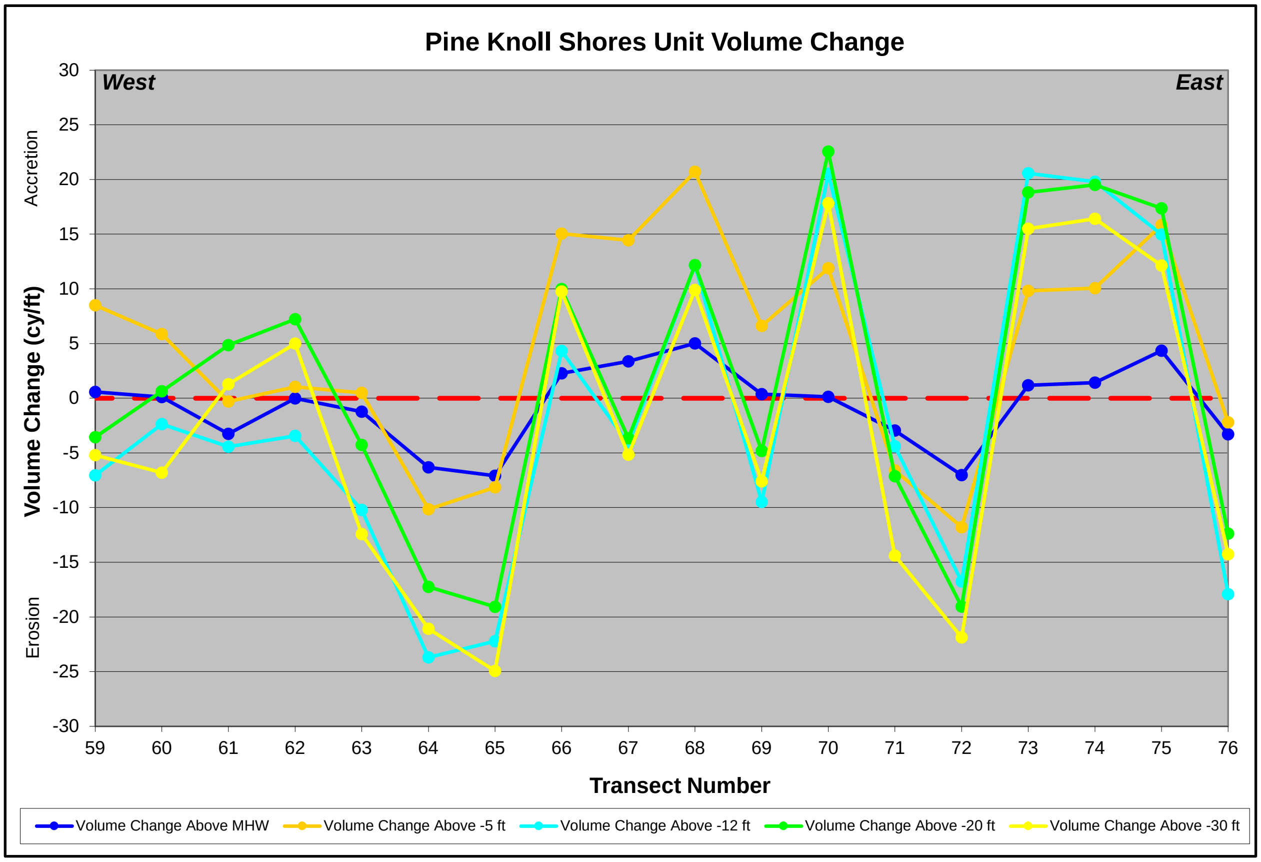


Figure 5-13. Pine Knoll Shores Unit Volume Change (2015 - 2016)

5.3.5 Atlantic Beach

The Atlantic Beach region covers Transects 77 through 102 of the Bogue Banks shoreline and is defined as a single management reach (see **Figure 3-1**). Since monitoring began in 1999, the area has received 3.71 million cy of nourishment material from the Brandt Island Pump Out and USACE dredge disposal. **Table 5-10** presents a summary of average shoreline and volume changes occurring between 2015 and 2016 for the Atlantic Beach region.

Table 5-10. Average Shoreline and Volume Change for Atlantic Beach (2015 - 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Atlantic Beach (Transects 77-102)	26,176	-4.8	0.1	1,923	-3.1	-79,892	-9.2	-241,055	-7.6	-200,189	-14.5	-380,813

Atlantic Beach experienced an overall shoreline recession at MHW of approximately -4.8 ft over the past year. The shoreline change plot in **Appendix B** and profile plots in **Appendix C** show that transects closest to the inlet experienced the largest losses. However, there were some pockets of seaward advancement of the shoreline at MHW.

Volumetrically, Atlantic Beach experienced a fairly large loss in material above -12 ft NAVD88 (-241,055 cy) that was not balanced with a gain in material above -20 ft NAVD88 as with the other reaches. Profile plots in **Appendix C** show erosion of onshore and surfzone material along with a deflated offshore bar (see **Figure 5-14**).

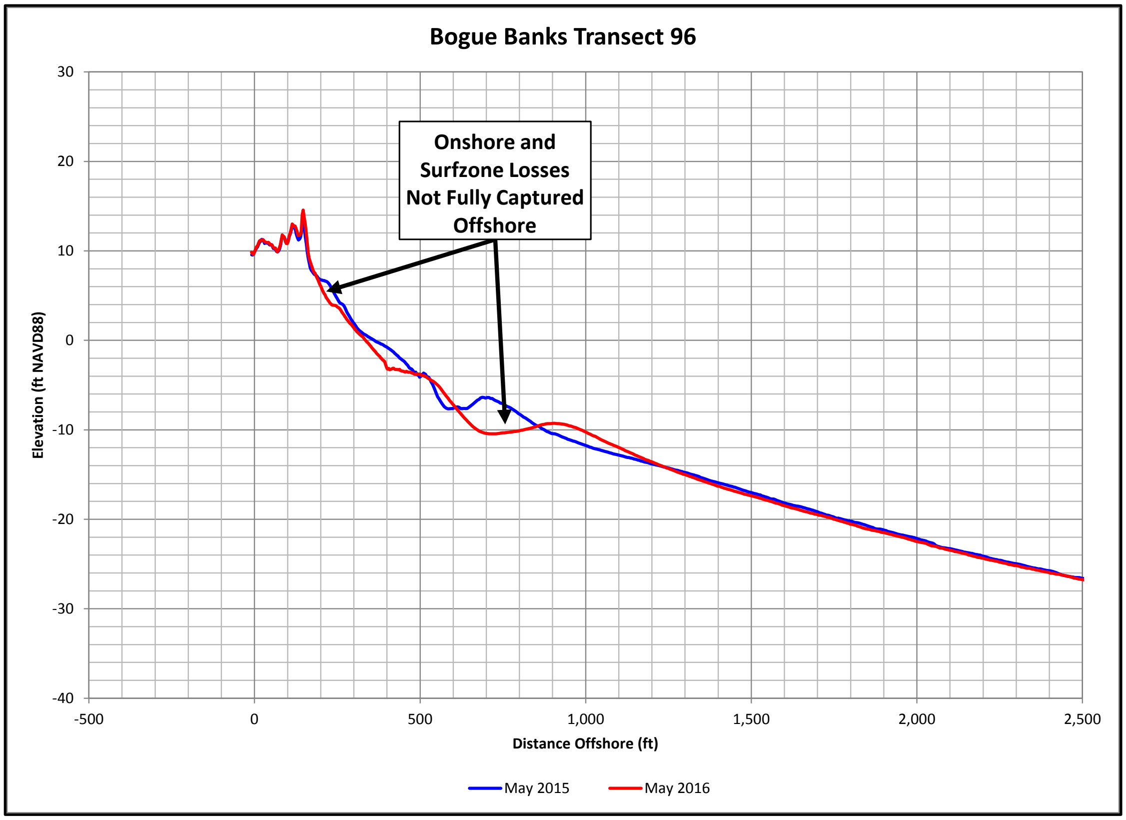


Figure 5-14. Atlantic Beach Example Profile

Figure 5-15 displays the unit volume change for each transect in the Atlantic Beach region. As can be seen, the reach experienced mostly losses with the exception of Transect 78. The magnitude of loss alternates back and forth across the reach.

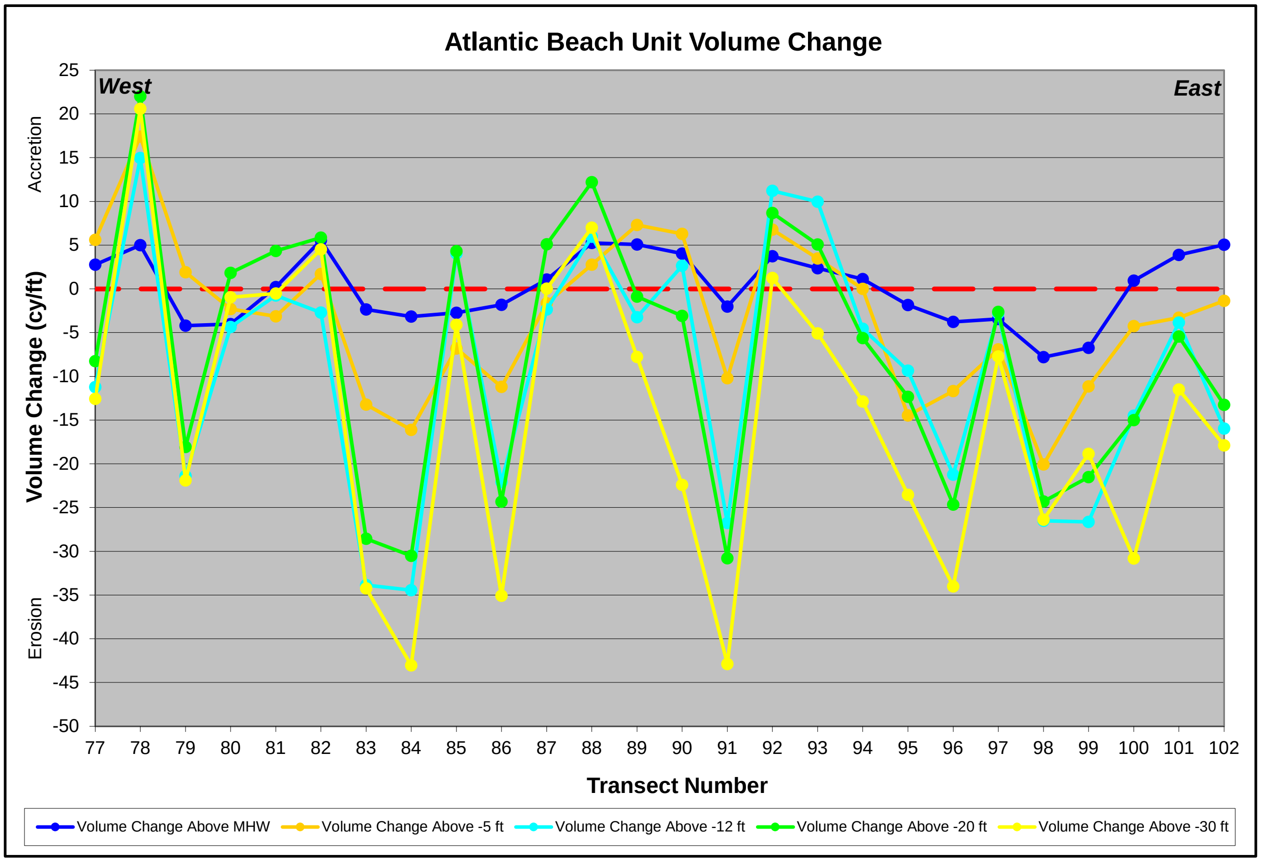


Figure 5-15. Atlantic Beach Unit Volume Change (2015 - 2016)

5.3.6 Fort Macon State Park

The Fort Macon State Park region covers Transects 103 through 112 of the Bogue Banks shoreline and is defined as a single management reach (see **Figure 3-1**). Since monitoring began in 1999, this region has received 2.21 million cy of nourishment material from USACE Inner Harbor Dredging Disposal. Most recently, 150,000 cy of material was placed on Fort Macon in December 2015 in conjunction with activities to uncover a pipeline which had been left in the channel and covered due to shoaling. **Table 5-11** presents a summary of average shoreline and volume changes occurring between 2015 and 2016 for the Fort Macon State Park region.

Table 5-11. Average Shoreline and Volume Change for Fort Macon State Park (2015 - 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Fort Macon State Park (Transects 103-112)	6,691	34.0	8.3	55,572	14.9	99,369	28.3	189,340	31.9	213,470	31.5	210,807

Fort Macon experienced an overall seaward advancement of the shoreline at MHW. This is due to the 150,000 cy of material placed between Transects 104 and 107 in addition to accretion experienced adjacent to the terminal groin due to eastward littoral transport of material toward Beaufort Inlet.

Volumetrically, the reach experienced a gain in material of 189,340 cy above -12 ft NAVD88. Calculations show that Transects 104 – 107, where material was placed, gained approximately 113,440 cy of material, indicating some of the nourishment material has already been transported from the placement location. **Figure 5-16** displays the unit volume change for each transect in the Fort Macon region. As can be seen, the majority of transects in the reach experienced volume gains. Placement between Transect 104 – 107 is evident as well as the gains directly adjacent to the terminal groin.

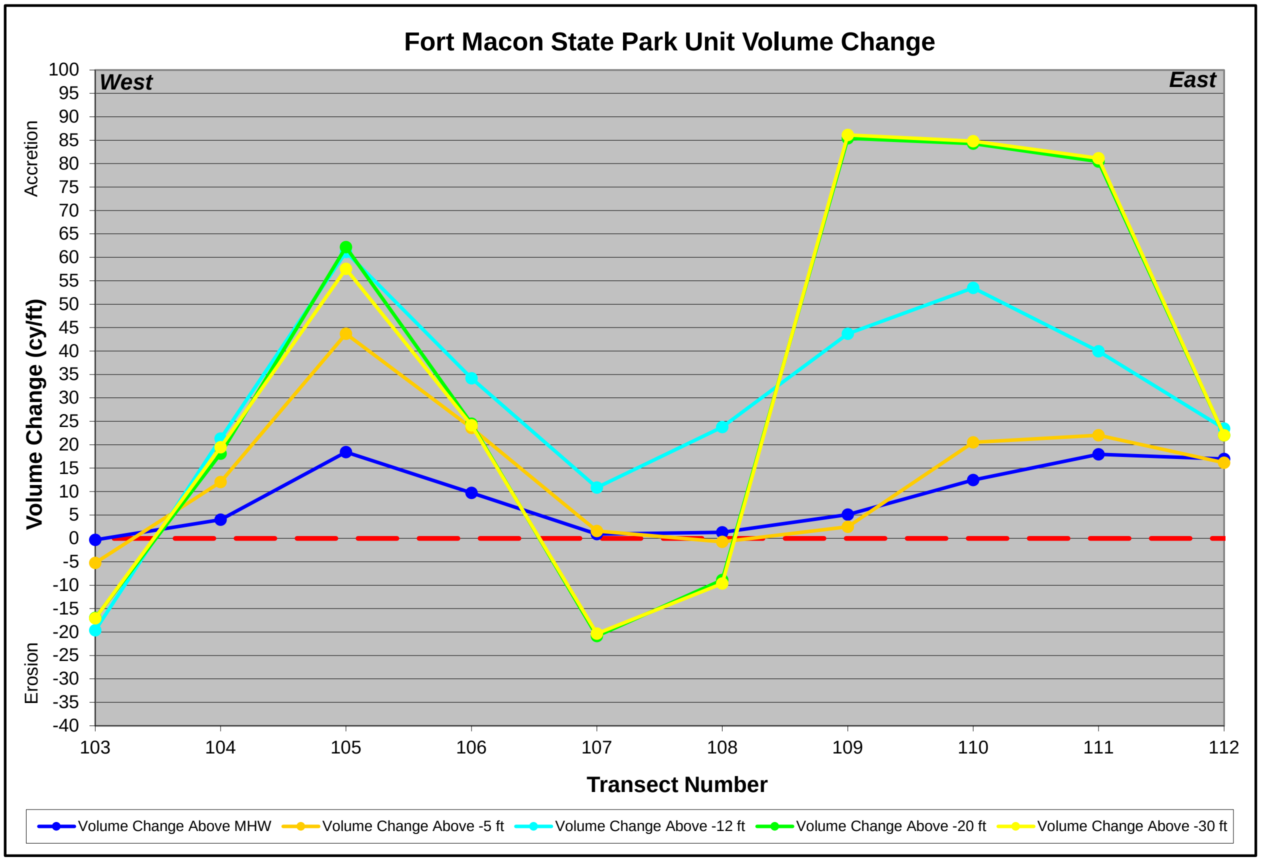


Figure 5-16. Fort Macon State Park Unit Volume Change (2015 - 2016)

5.3.7 Beaufort Inlet

The Beaufort Inlet region is comprised of an area along the western side of Beaufort Inlet which covers Transects 112B through 116. **Table 5-12** presents a summary of average shoreline and volume changes occurring between 2015 and 2016 for the Beaufort Inlet region.

Table 5-12. Average Shoreline and Volume Change for Beaufort Inlet (2015 - 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Beaufort Inlet (Transects 112B-116)	2,000	33.3	5.3	10,661	8.9	17,840	0.0	-43	4.4	8,840	11.0	21,989

Table 5-12 shows a significant seaward advancement of the shoreline at MHW in the Beaufort Inlet region. However, upon inspection of the profile plots in **Appendix C**, it appears that there

was a large amount of seaward advancement at Transect 112B which is responsible for a majority of the average accretion.

Volume changes at Beaufort Inlet show mostly gains in material with only a minor loss above -12 ft NAVD88. **Figure 5-17** displays the unit volume change at each transect in the Beaufort Inlet region. As can be seen, the mouth of the inlet experienced the largest gains, especially at Transect 112B, while the more interior portions of the inlet experienced erosion.

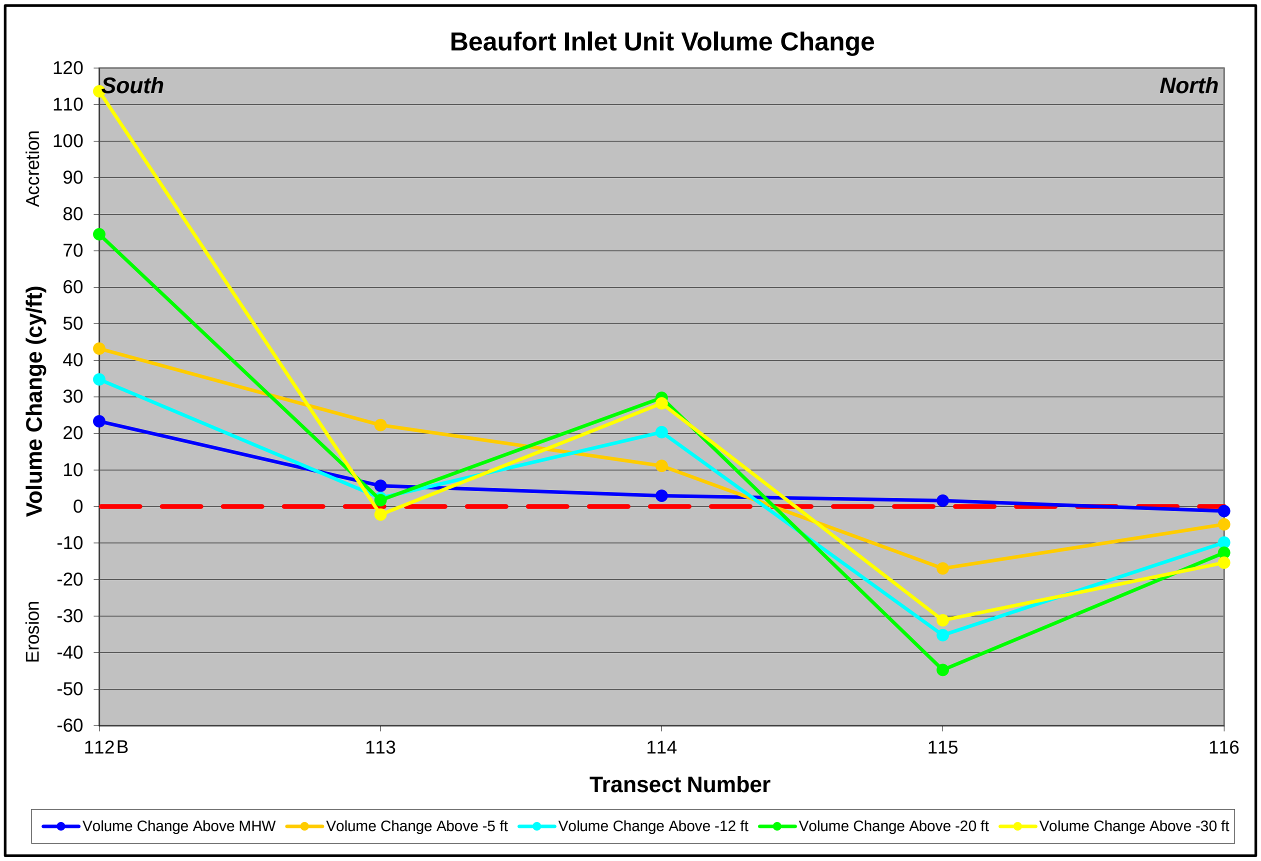


Figure 5-17. Beaufort Inlet Unit Volume Change (2015 - 2016)

In May 2015, the USACE performed a condition survey of the Morehead City Harbor navigation channel. **Figure 5-18** presents the results of the survey. Apparent from this figure is the submerged "toe" of Shackleford Banks along the eastern side of the channel. Also of importance is a more shallow feature cutting through the middle of the stretches of deep water. This feature was also detected in the profile plot of Transect 112B (at approximately 3,000 ft offshore) along with another shallow feature approximately 1,300 ft offshore (see **Figure 5-19**, Example A). It appears that the shallow feature at 3,000 ft has deepened since the 2015 survey (most likely due to dredging). The channel alignment inside the inlet appears to have been fairly stable over the last year as shown in Transect 114 (see **Figure 5-19**, Example B).

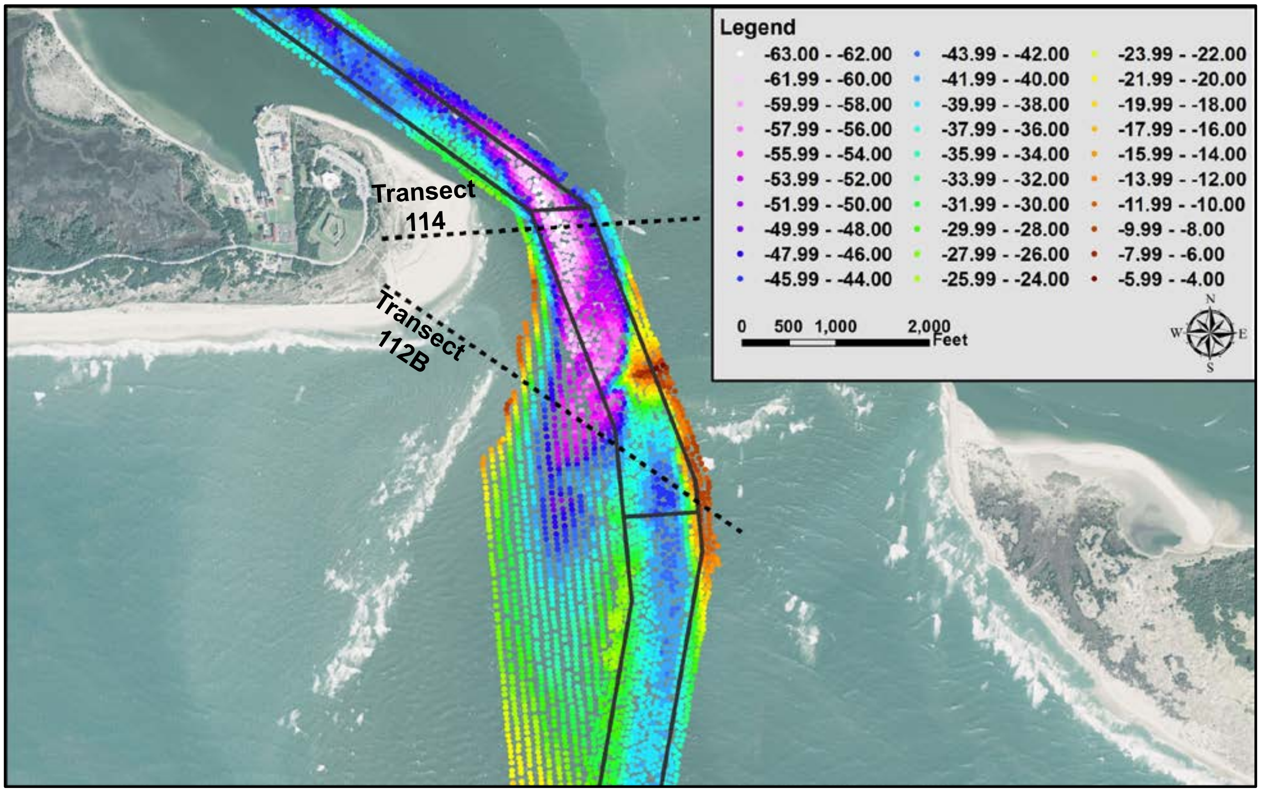
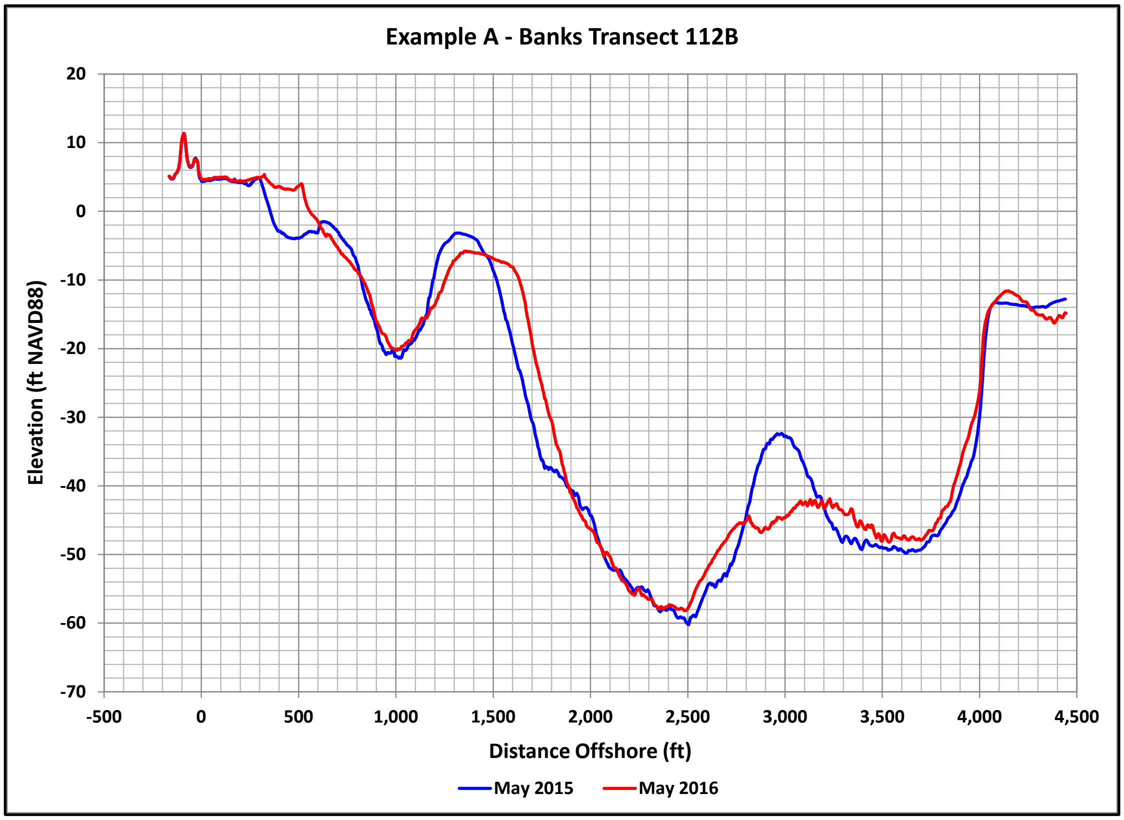


Figure 5-18. USACE Morehead City Harbor Navigation Channel Survey – July 2016 (USACE)



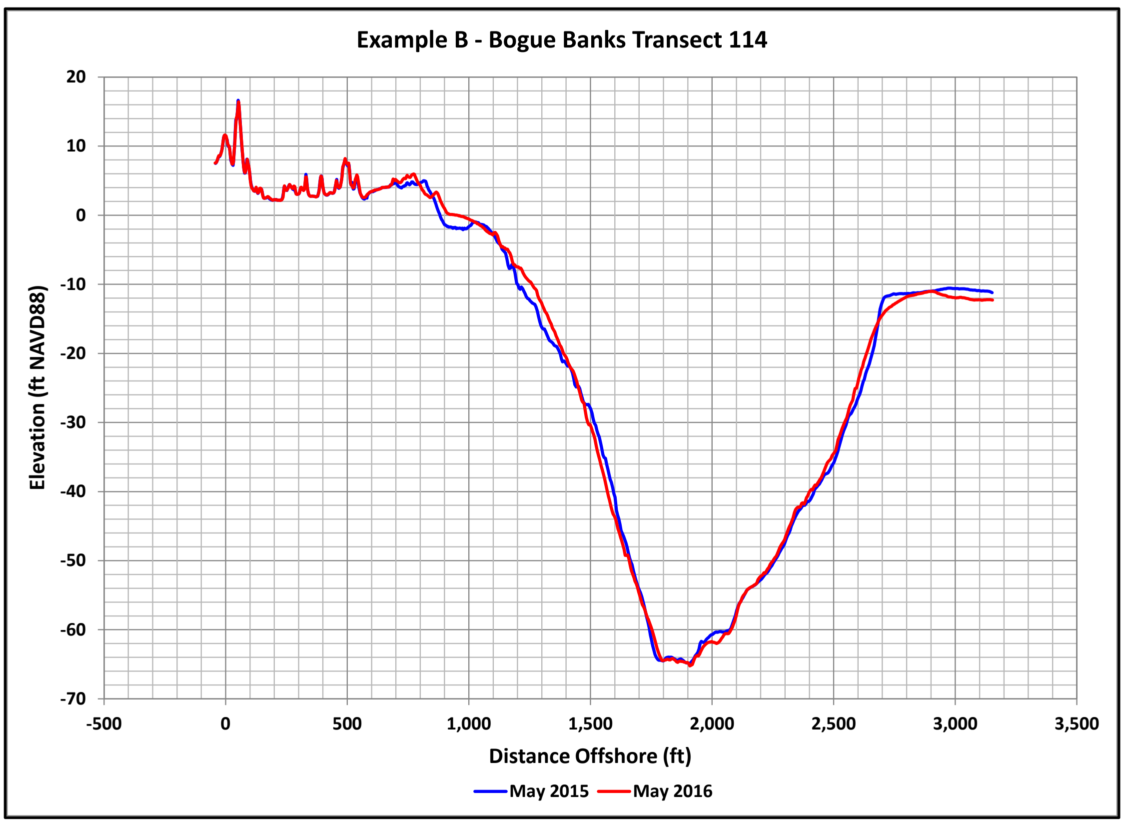


Figure 5-19. Example Beaufort Inlet Transects

5.3.8 Bogue Banks Summary

Table 5-13 provides a summary of the shoreline and volume changes along Bogue Banks as presented in the previous sections along with average and total oceanfront values. For Bogue Banks, since each reach consists of a different length of shoreline, the calculations provide a weighted average for unit shoreline change (ft) and unit volume change (cy/ft) along the Bogue Banks oceanfront. The weighted average also accounts for differences in the shoreline length between each transect.

Table 5-13. Bogue Banks Shoreline and Volume Change Statistics (2015 – 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (Transects 1-11)	11,488	22.3	3.9	45,054	4.0	46,320	1.0	11,368	2.5	28,296	0.0	-13
Emerald Isle-West (Transects 12-25)	18,288	5.6	1.9	34,721	1.1	20,350	-3.4	-62,725	4.1	74,453	2.6	48,444
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Emerald Isle-East (Transects 37-48)	13,220	5.6	-0.8	-10,033	-0.8	-10,673	-7.3	-96,674	-0.7	-8,979	-5.0	-65,902
Indian Beach-Salter Path (Transects 49-58)	12,850	9.8	0.4	5,449	5.6	71,648	-3.3	-42,345	4.1	52,626	-1.0	-12,633
Pine Knoll Shores (Transects 59-76)	23,878	-5.3	-0.7	-17,468	4.4	104,089	-1.6	-37,740	1.4	32,403	-2.5	-58,862
Atlantic Beach (Transects 77-102)	26,176	-4.8	0.1	1,923	-3.1	-79,892	-9.2	-241,055	-7.6	-200,189	-14.5	-380,813
Fort Macon State Park (Transects 103-112)	6,691	34.0	8.3	55,572	14.9	99,369	28.3	189,340	31.9	213,470	31.5	210,807
Beaufort Inlet (Transects 112B-116)	2,000	33.3	5.3	10,661	8.9	17,840	0.0	-43	4.4	8,840	11.0	21,989
Bogue Inlet-Channel (Transects 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
Oceanfront (Transects 1-112)	**128,393**	**3.0**	**0.7**	**89,960**	**2.5**	**320,195**	**-2.5**	**-324,837**	**2.4**	**308,839**	**-1.5**	**-190,994**

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

Table 5-13 indicates that the Bogue Banks oceanfront shoreline experienced an overall average seaward advancement at MHW of 3.0 ft over the past year. However, patterns of seaward advancement and landward recession fluctuated greatly over the entire shoreline as is apparent in the shoreline change plot in **Appendix B**. Volumetrically, there was a dominant trend of volume losses above -12 ft NAVD88 and volume gains above -20 ft NAVD88 due to the flattening and seaward movement of the offshore bar in Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores. Atlantic Beach displayed the largest volume losses above -12 ft NAVD88 which were not captured offshore. Fort Macon experienced a gain in volume, due to the nourishment event which placed 150,000 cy between Transects 104 and 107 and eastward littoral transport which produced volume gains nearest the terminal groin.

Figure 5-20 and **Figure 5-21** display the trends seen in **Table 5-13** with bar plots of the average unit volume changes and cumulative volume changes at each management reach for Bogue Banks. Apparent from these figures is the losses experienced above -12 for a majority of the reaches and the gain in material at Fort Macon from the nourishment project.

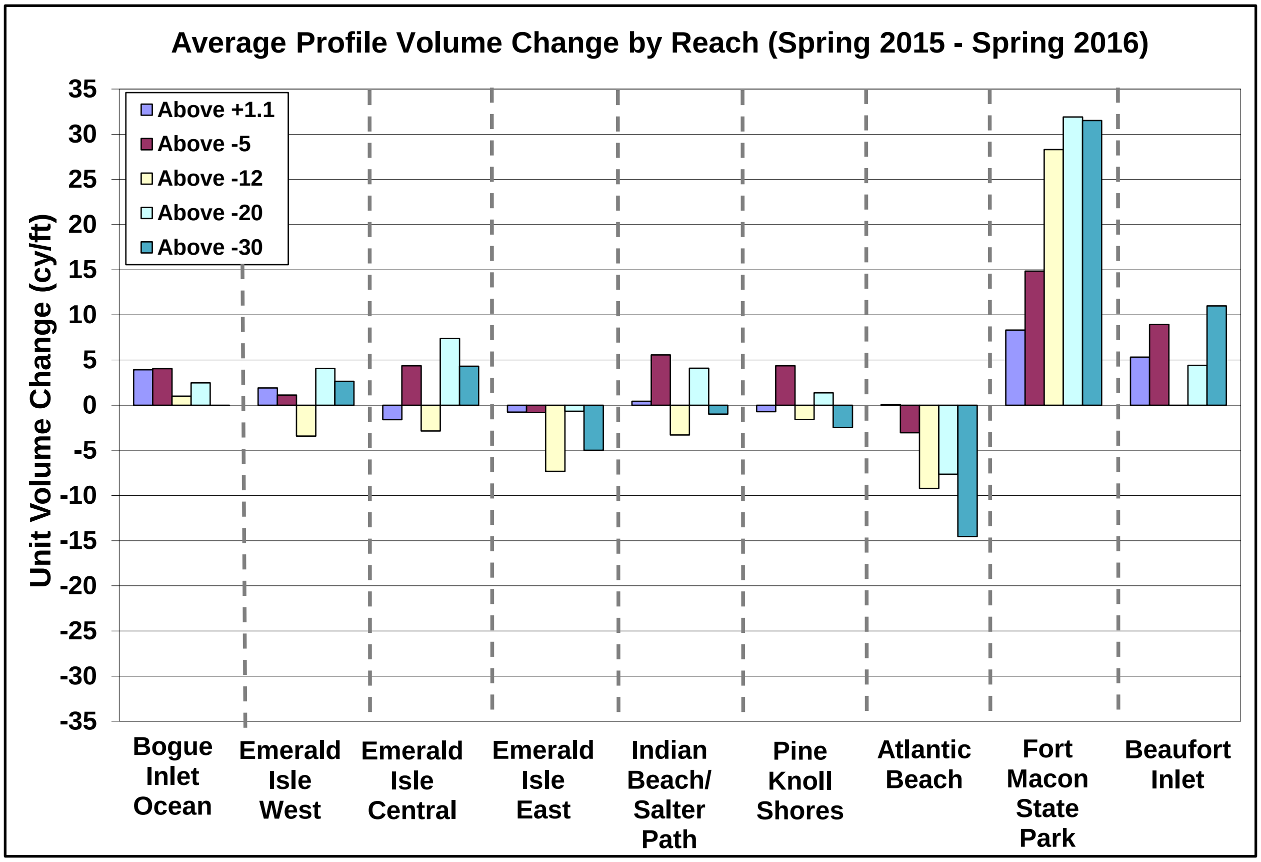


Figure 5-20. Average Unit Volume Change By Reach (2015 – 2016)

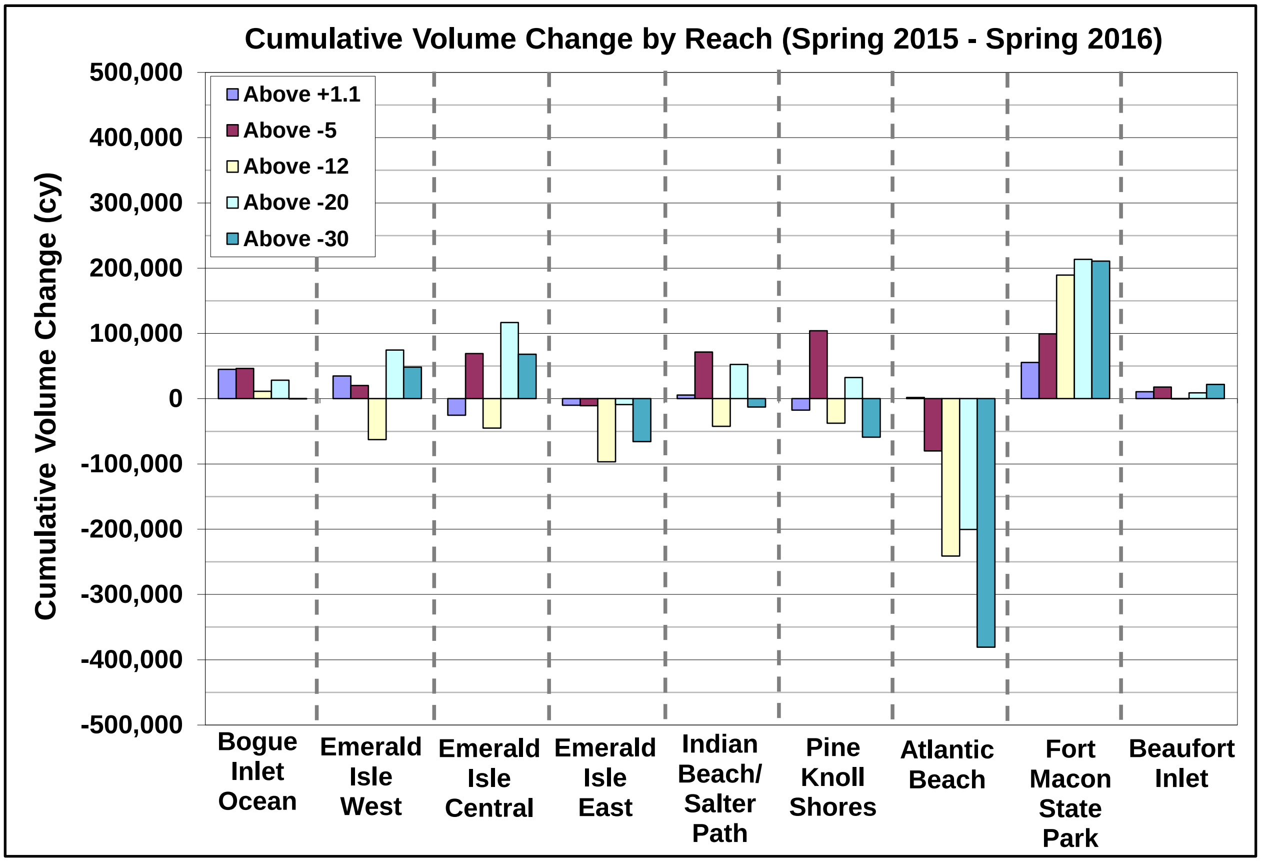


Figure 5-21. Cumulative Volume Change By Reach

This year's analysis also included an assessment of the change in position of the base of the dune along Bogue Banks, which was performed using shore parallel survey lines collected in 2015 and 2016 by driving the survey ATV along the base of the dune. The difference in position at each transect was calculated and plotted to determine any trends in movement along the oceanfront shoreline. **Figure 5-22** presents the results of this analysis. An average seaward movement of approximately 5.6 ft was calculated over the entire shoreline. It should be noted that the accuracy of the dune base position surveyed is highly subjective due to surveyor interpretation. Other methods for tracking this feature are being investigated.

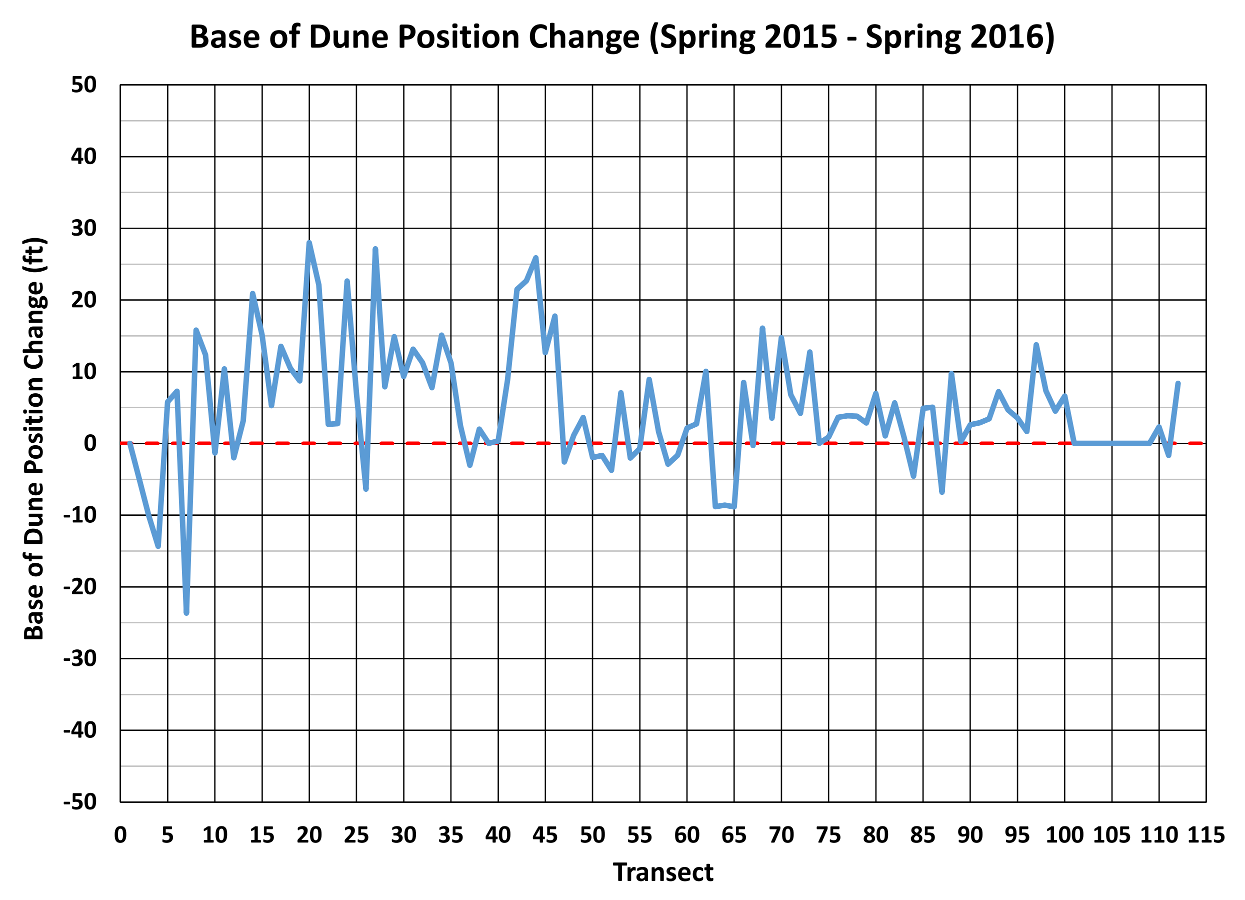


Figure 5-22. Base of Dune Position Change

5.4 Bear Island Shoreline and Volume Change Analysis (2015 – 2016)

This section discusses the results of the shoreline and volume change analysis for Bear Island. Key statistics were calculated to quantify average shoreline and volume changes for including average shoreline change, average volume change, and cumulative volume change (e.g. total volume of material lost or gained along a section of shoreline). 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.

For reference, **Appendix B** contains plots of the shoreline and volume changes from the spring/summer 2015 and the spring/summer 2016 surveys at each transect along Bear Island. **Appendix C** presents profile comparison plots for individual transects for the spring/summer 2015 and the spring/summer 2016 surveys. **Appendix D** provides the computed shoreline changes and volume changes measured at each individual transect in tabular format.

Bear Island contains 18 transects spaced 1000 ft apart. **Table 5-14** presents a summary of average shoreline and volume changes occurring between 2015 and 2016 for the Bear Island region.

Table 5-14. Average Shoreline and Volume Change for Bear Island (2015 - 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bear Island (Transects 1-18)	16,500	-35.5	-4.8	-79,097	-7.2	-119,276	-9.9	-162,690	-2.5	-41,551	-5.3	-86,714

Bear Island experienced a moderate amount of shoreline recession at MHW over the past year, as shown in **Table 5-14**. Volumetric calculations indicate an overall loss in material above all elevations. **Figure 5-23** displays the unit volume change at each transect on Bear Island. As can be seen, the western end of the island experienced mostly erosion above all elevations while the eastern end of the island had alternating patterns of erosion and accretion.

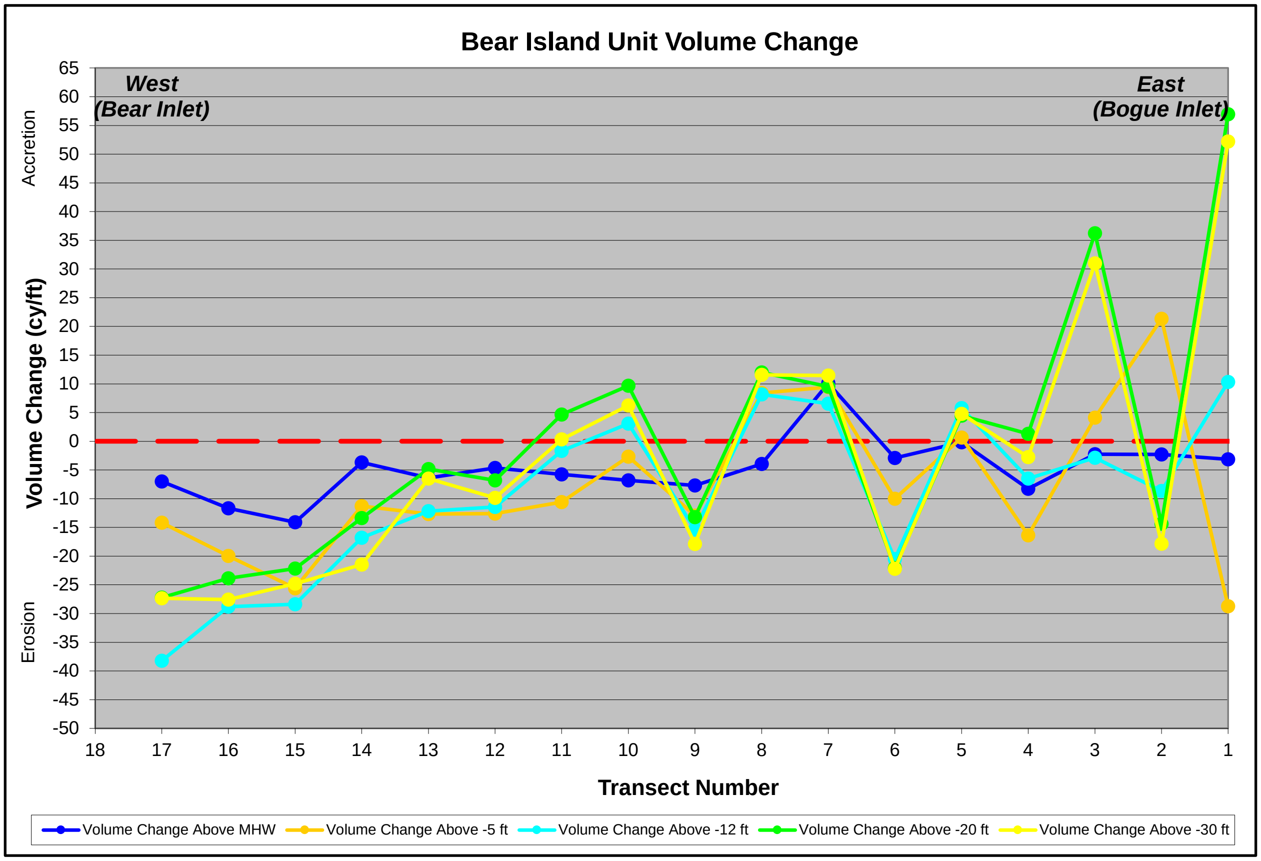
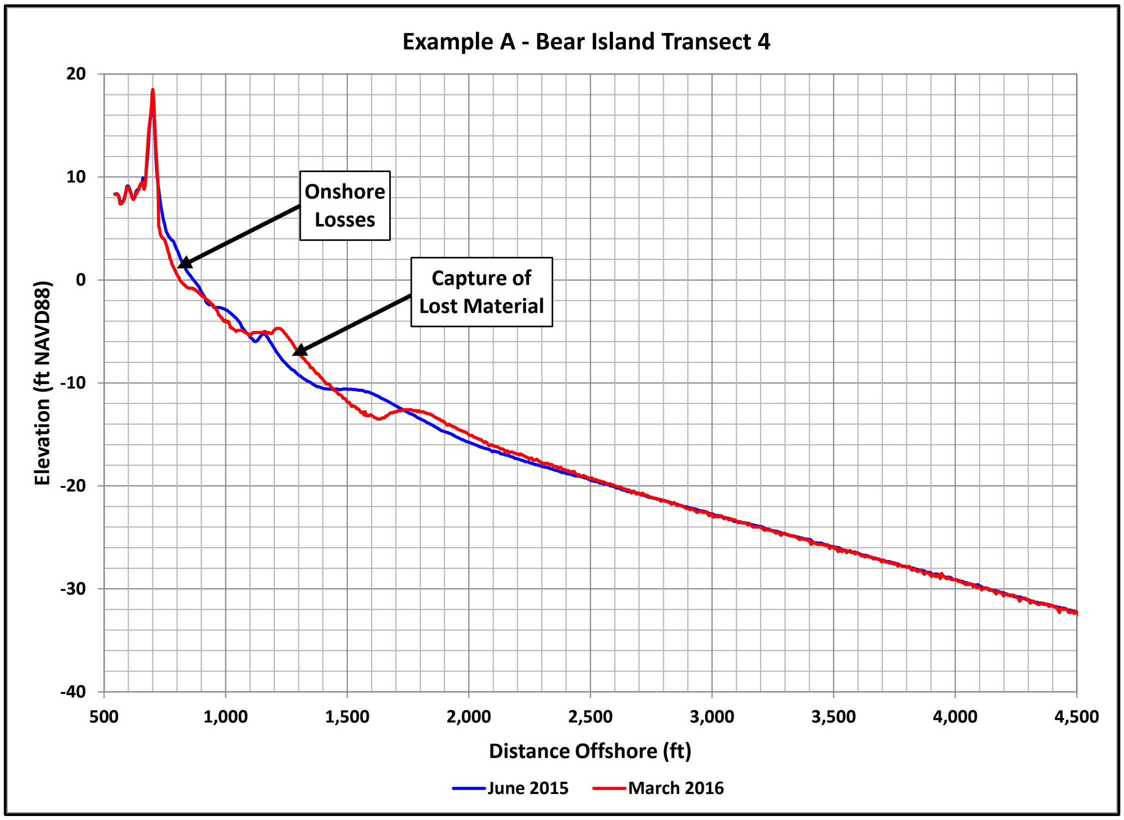


Figure 5-23. Bear Island Unit Volume Change (2015 - 2016)

Figure 5-24 presents example profiles from Bear Island showing typical profile behavior at the eastern end of the island where onshore losses were captured offshore (see Example A) while the profiles on the western end of the island exhibited onshore losses which were not captured offshore (see Example B).



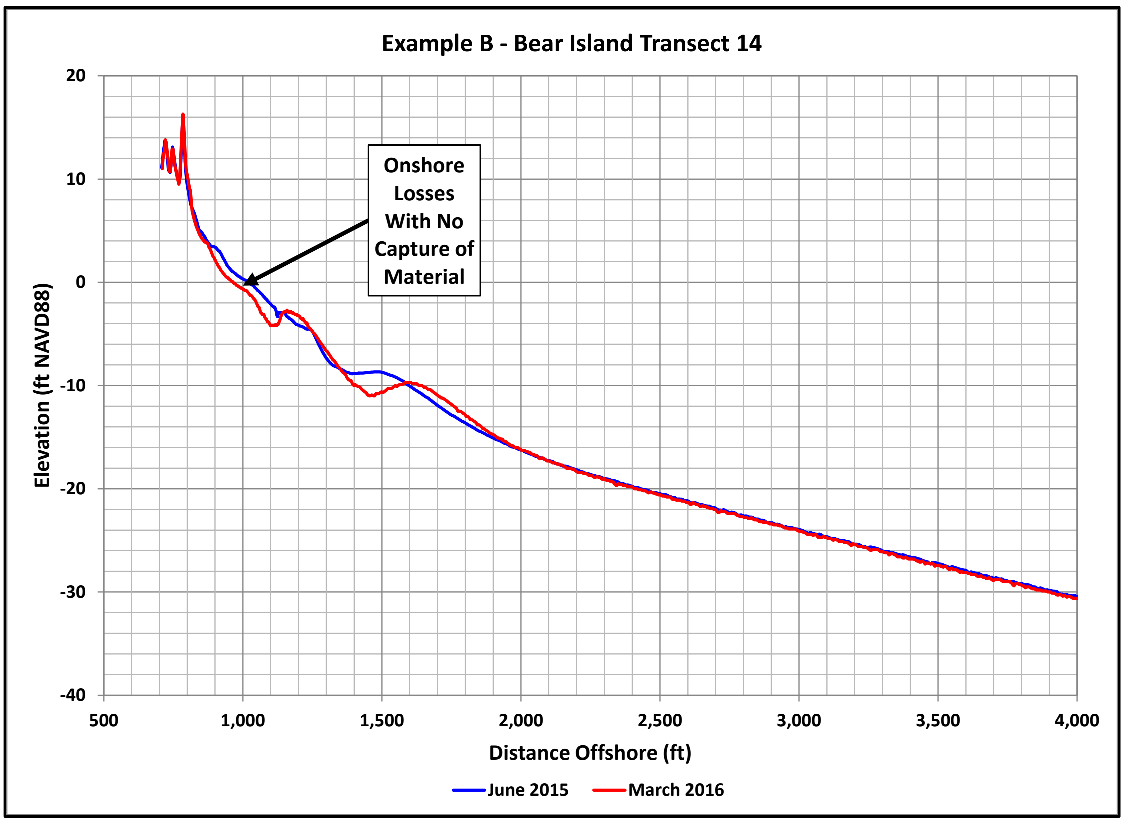


Figure 5-24. Bear Island Example Profiles

5.5 Shackleford Banks Shoreline and Volume Change Analysis (2015 – 2016)

This section discusses the results of the shoreline and volume change analysis for Shackleford Banks. Key statistics were calculated to quantify average shoreline and volume changes for including average shoreline change, average volume change, and cumulative volume change (e.g. total volume of material lost or gained along a section of shoreline). 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.

For reference, **Appendix B** contains plots of the shoreline and volume changes from the spring/summer 2015 and the spring/summer 2016 surveys at each transect along Shackleford Banks. **Appendix C** presents profile comparison plots for individual transects for the spring/summer 2015 and the spring/summer 2016 surveys. **Appendix D** provides the computed shoreline changes and volume changes measured at each individual transect in tabular format.

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 island. **Table 5-15** presents a summary of average shoreline and volume changes occurring between 2015 and 2016 for the Shackleford Banks region. Due to the erosional behavior of the western end of the island which began in 2010, statistics for the island have been divided between Transects 1-19 and 20 – 23. It should be noted that Transect 24 no longer contains any dry land and was therefore not included in the statistical analysis.

Table 5-15. Average Shoreline and Volume Change for Shackleford Banks (2015 - 2016)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Shackleford Banks (Transects 1-19)	39,459	-8.3	-1.2	-70,481	-1.9	-120,901	1.5	-75,484	0.5	-134,985	5.2	26,314
Shackleford Banks (Transects 20-23)	6,542	-80.6	-10.7	-67,979	-38.7	-284,435	-94.2	-681,487	-123.7	-914,900	-132.7	-976,518
Shackleford Banks (Transects 1-24)	46,001	-21.9	-3.0	-138,459	-8.8	-405,335	-16.5	-756,971	-22.8	-1,049,885	-20.7	-950,204

Table 5-15 indicates Transects 1 – 19, which comprise most of the island, experienced minor landward recession of the shoreline at MHW. The remaining transects along Shackleford Banks (20-23) experienced significant landward recession of the shoreline at MHW. Profile plots in **Appendix C** show significant erosion of the dunes and beachface for these transects.

Volumetrically, Transects 1-19 experienced minor erosion above -12 ft NAVD88 (approximately 75,484 cy). The remaining transects along Shackleford Banks (20-23) experienced significant losses in volume of approximately 681,487 cy. As mentioned previously, significant erosion of the dunes and beachface is apparent in the profile plots in **Appendix C**. **Figure 5-25** displays the unit volume change at each transect on Shackleford Banks. It is evident from this figure that the majority of the loss on Shackleford Banks was located at Transects 20 through 23, adjacent to Beaufort Inlet. This behavior is not unexpected given the location of the deep draft channel being directly adjacent to this area of Shackleford Banks and the recent history of significant erosion. The combination of the deep draft channel hydraulics, episodic dredging and shoaling, as well as barrier island morphology make this a very dynamic area. The remainder of the island experienced minor losses in comparison with some accretion on the eastern end of the island.

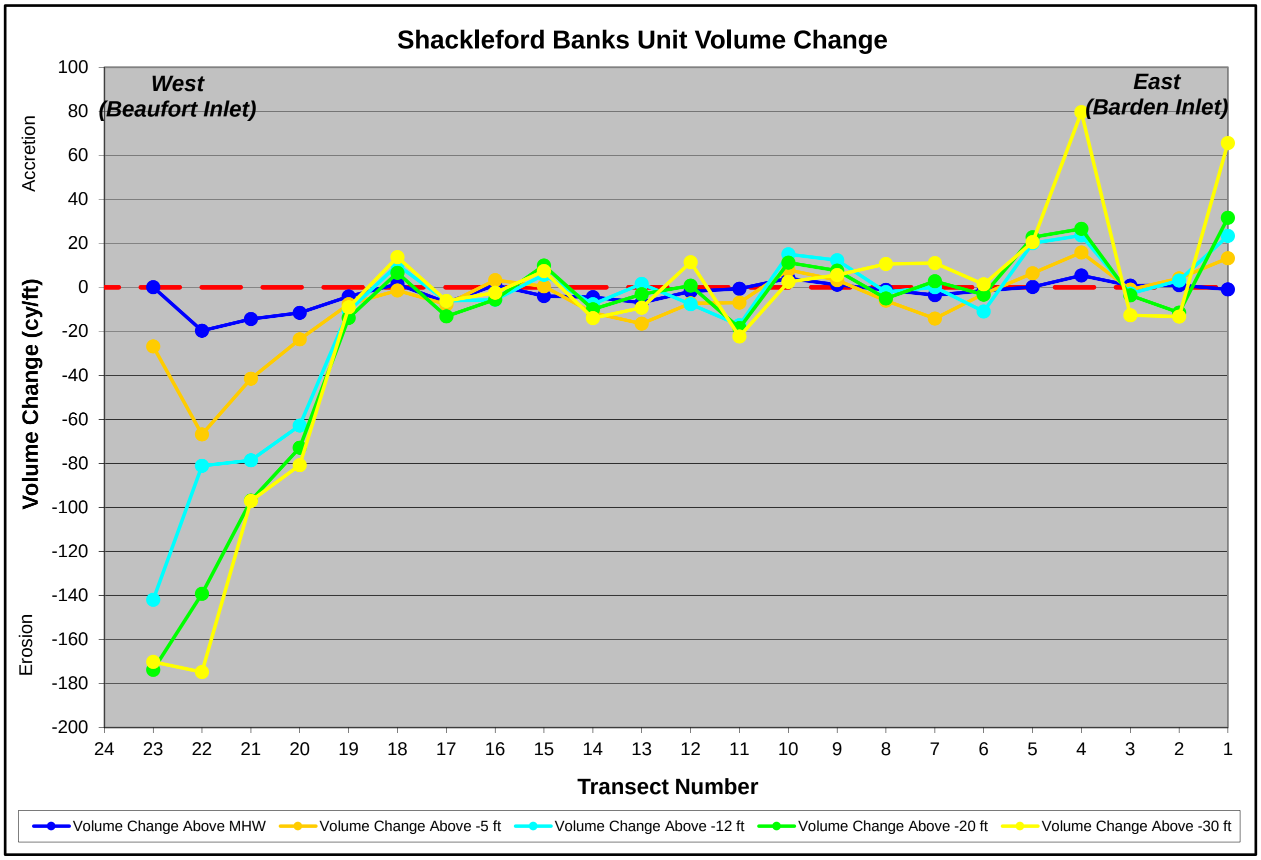
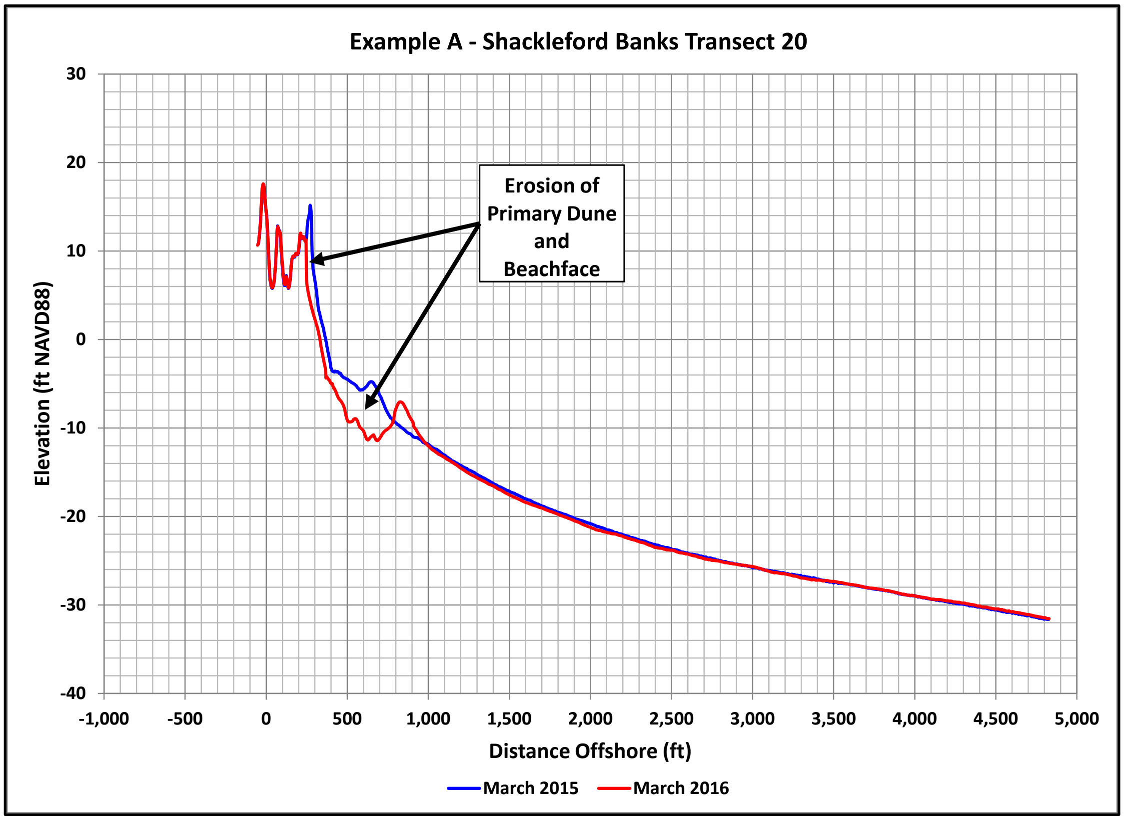


Figure 5-25. Shackleford Banks Unit Volume Change (2015 – 2016)

Figure 5-26 presents example profiles from Shackleford Banks showing extreme erosion of the dune and beachface at the western end of the island (see Example A) while the remainder of the island exhibited a fairly stable dune and beachface with only a slight adjustment of the offshore bar (see Example B).



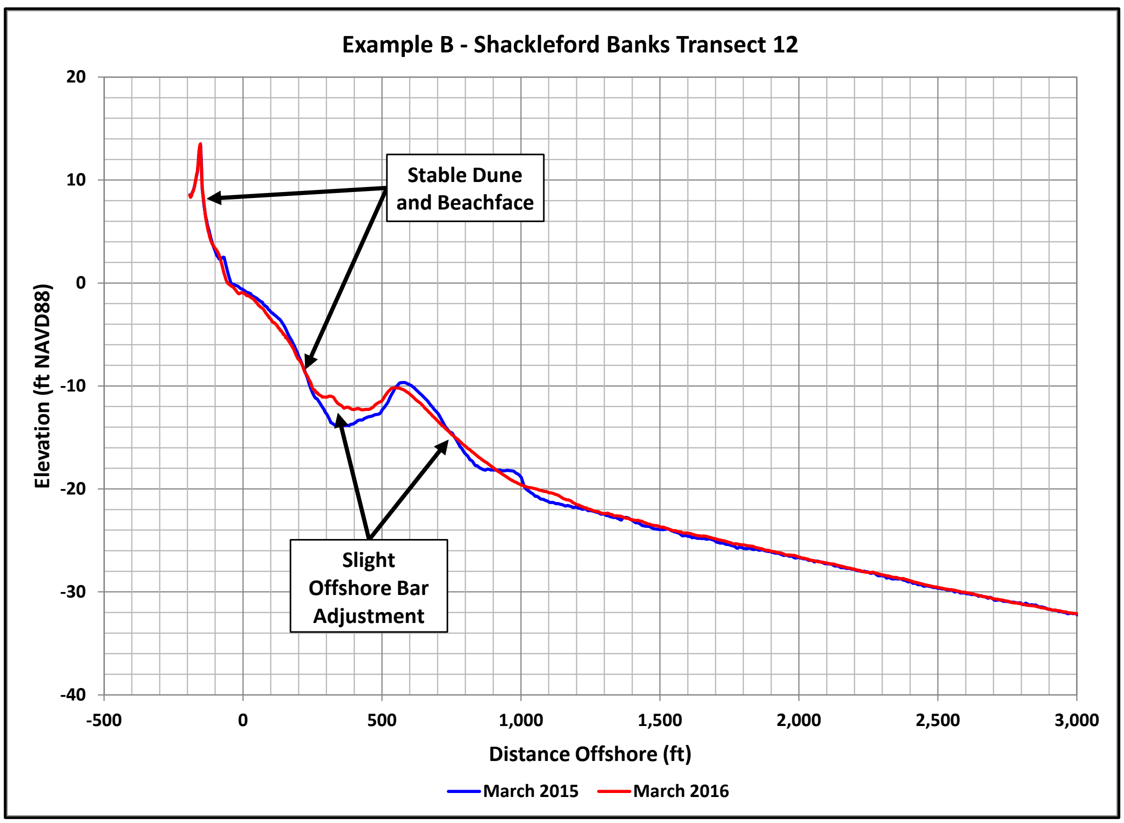


Figure 5-26. Shackleford Banks Example Profiles

5.6 Statistical Analysis of Recent Volume Change Trends (2008 – 2016)

Using the eight most recent high quality survey datasets (2008-2016), statistical analyses were performed to determine if any long-term trends in ocean front behavior are visible for Bogue Banks, Bear Island, and Shackleford Banks. The average volume change per year and standard deviation was calculated for each transect using the volume changes from the current monitoring report along with the six previous reports (M&N 2009, 2010, 2011, 2012, 2013, 2014, and 2015). In areas where nourishment occurred, the amount of nourishment material was subtracted out in order to determine trends in beach change without the effects of the nourishment. For reference, **Appendix E** tabulates the statistical analysis of long-term trends.

5.6.1 Bogue Banks

To determine the longterm trends along Bogue Banks, annual volume changes from the monitoring reports were averaged at each transect. Nourishments within the time period from 2008 -2016 (Post-Irene - February/March 2013 and MCH Maintenance Dredging in 2011, 2014, 2015) were subtracted out of the total volume change 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 5-27** shows the mean volume change with nourishment and **Figure 5-28** shows the mean volume change with the nourishment subtracted out from 2008-2016. In comparison of the two figures, the hotspots along Emerald Isle and Pine Knoll Shores are very visible as well as the increased erosion rates in Atlantic Beach and Fort Macon when nourishment effects are subtracted out.

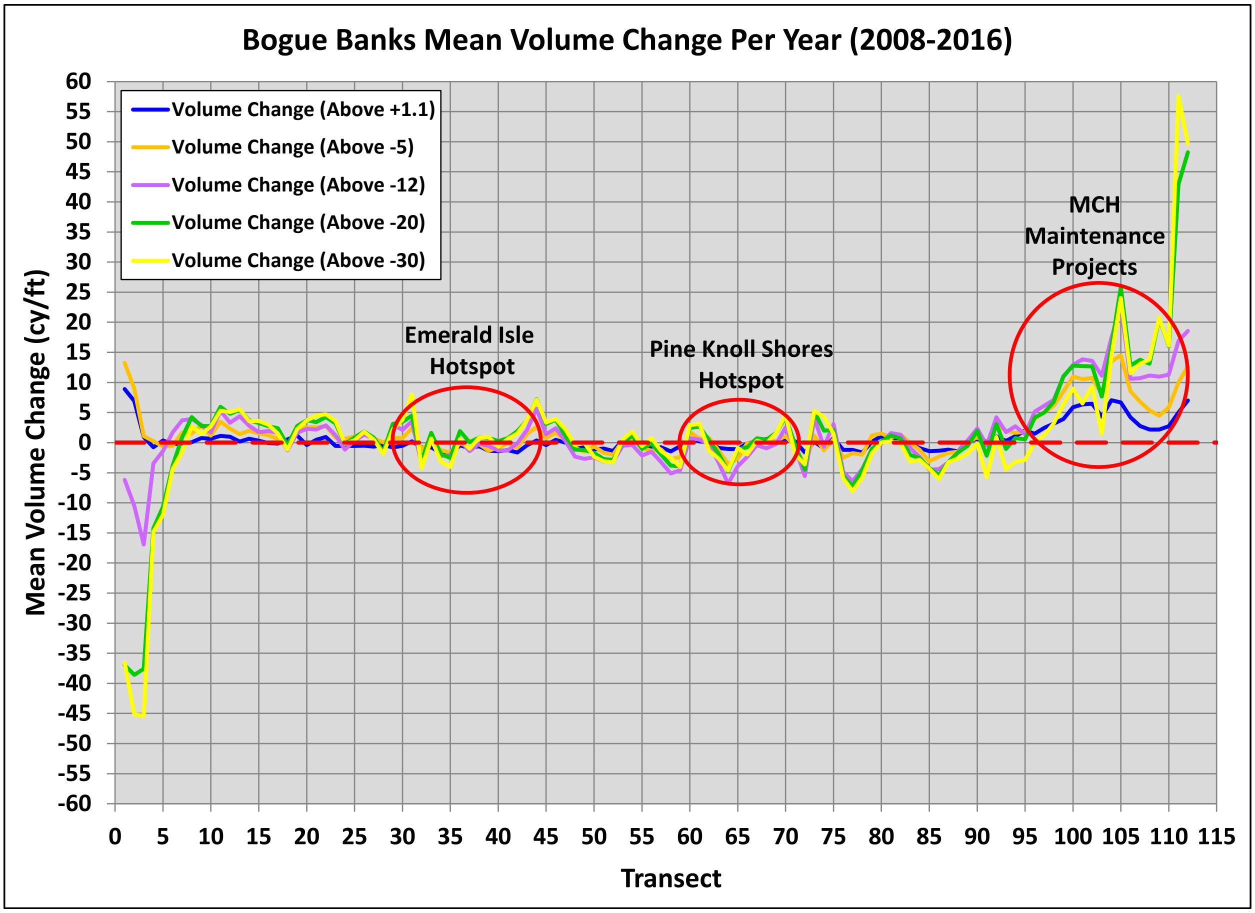


Figure 5-27. Bogue Banks Mean Volume Change (With Nourishment)

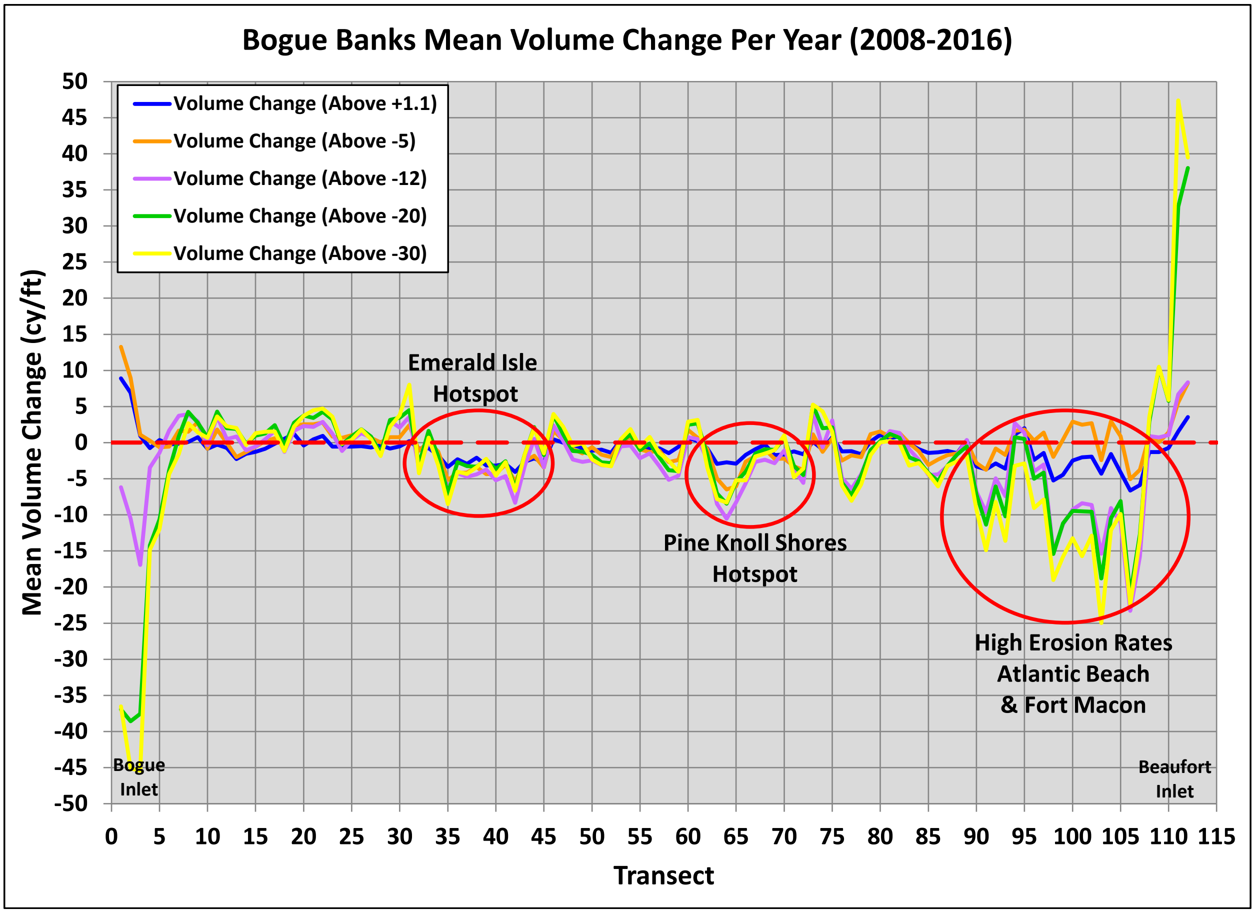


Figure 5-28. Bogue Banks Mean Volume Change (Without Nourishment)

The standard deviations of the average annual volume change (without nourishment) were also calculated for each referenced elevation included in the analysis. **Figure 5-29** through **Figure 5-33** shows the mean volume change per year with standard deviation bars at plus and minus one standard deviation for each of the referenced elevations.

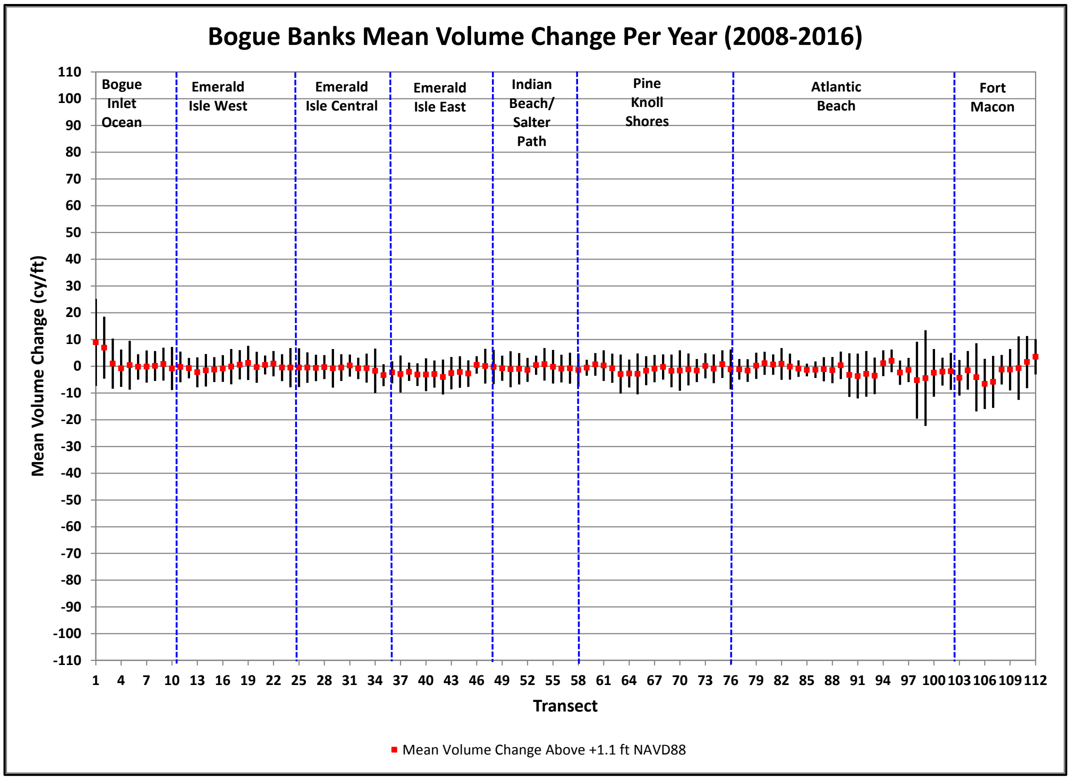


Figure 5-29. Bogue Banks Statistical Analysis of Volume Change Above +1.1 ft NAVD88

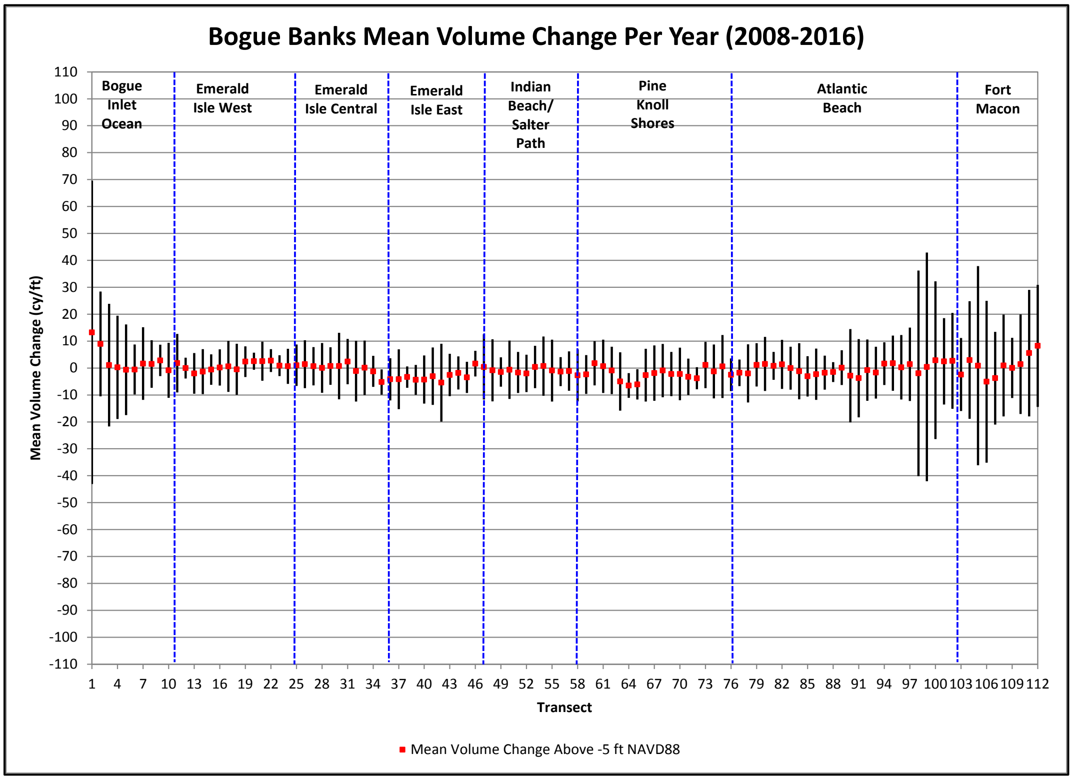


Figure 5-30. Bogue Banks Statistical Analysis of Volume Change Above -5.0 ft NAVD88

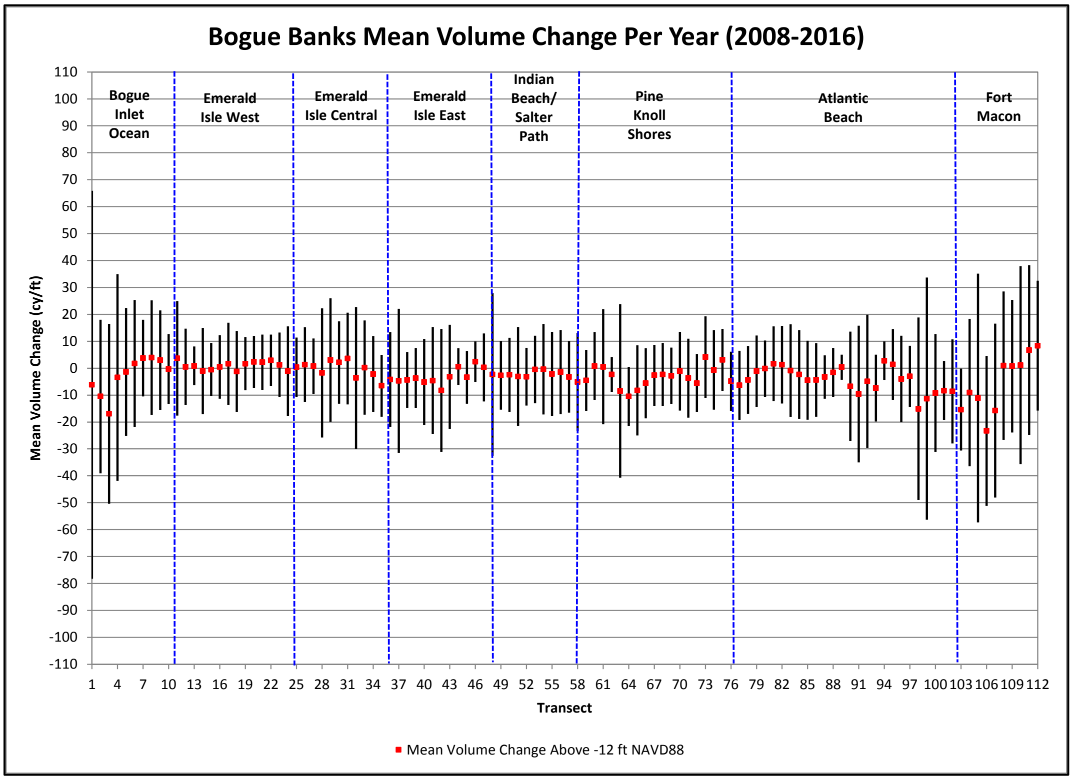


Figure 5-31. Bogue Banks Statistical Analysis of Volume Change Above -12.0 ft NAVD88

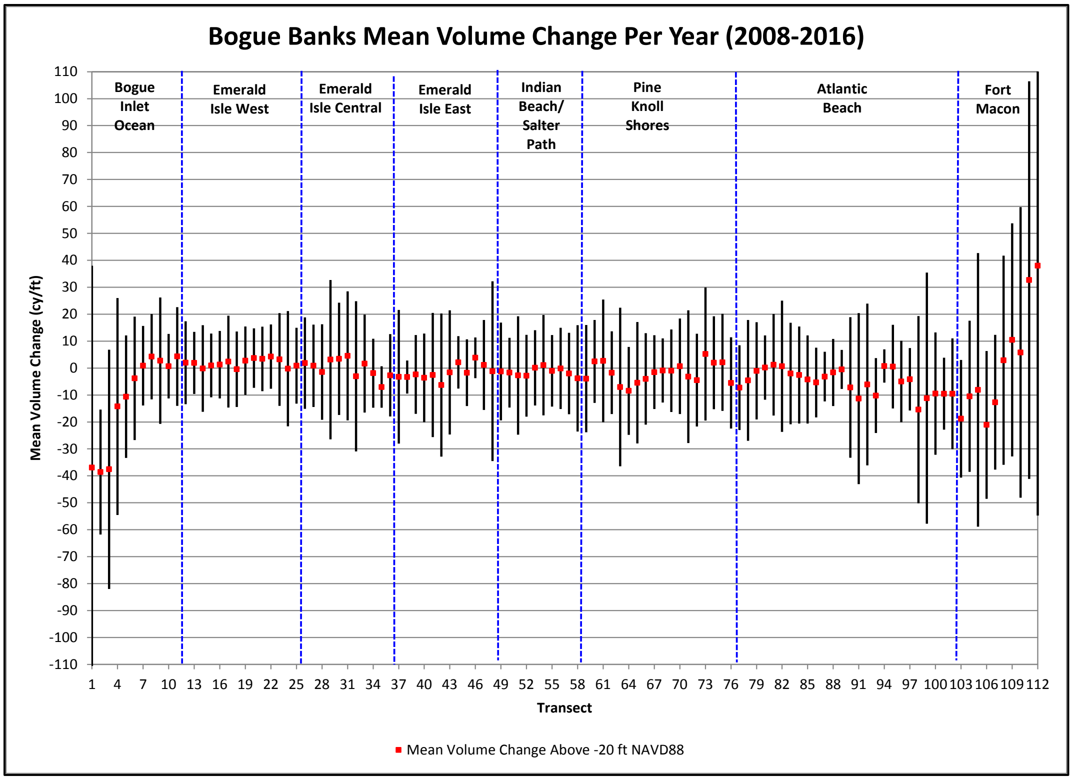


Figure 5-32. Bogue Banks Statistical Analysis of Volume Change Above -20.0 ft NAVD88

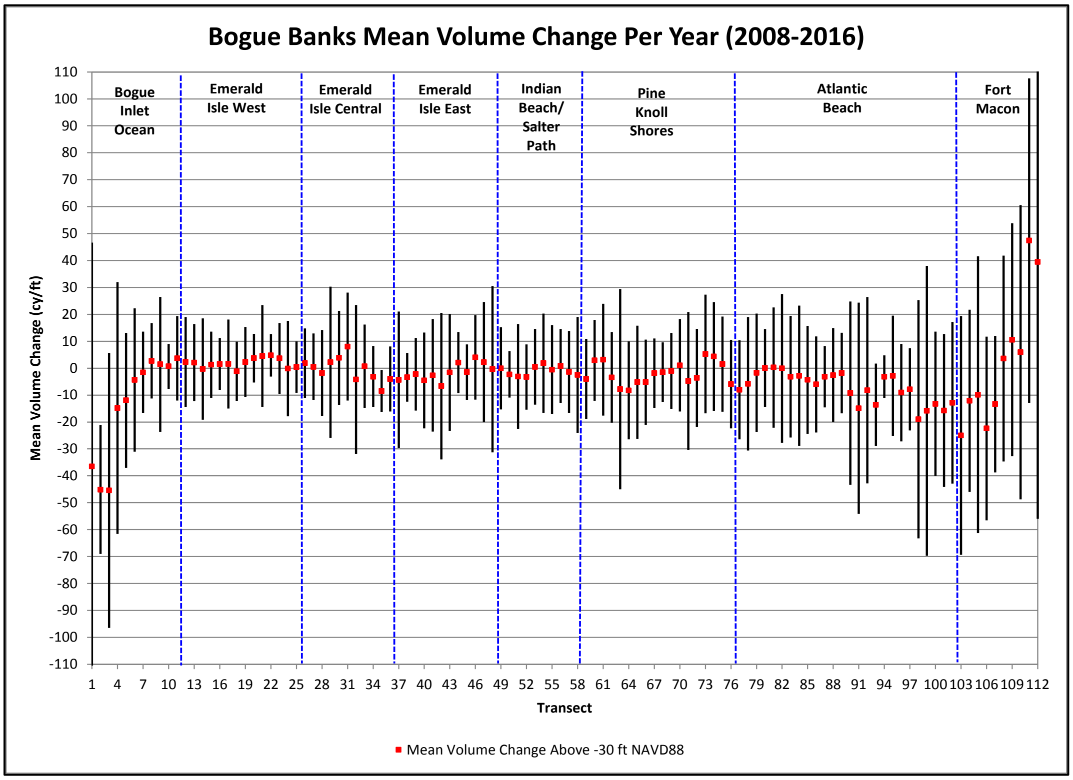


Figure 5-33. Bogue Banks Statistical Analysis of Volume Change Above -30.0 ft NAVD88

The variability in volume change increases with depth especially above MHW, -5 ft NAVD88, and -12 ft NAVD88. This is intuitive since the majority of sand movement historically happens in the subaerial profile with large fluctuations in the offshore bar position. 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 there is not a large amount of additional sand movement at these lower depths. Also important is the standard deviation is much larger on either end of the island, as would be expected given the inlet effect on each end of the island. Changes near the inlets often fluctuate significantly each year. As more datasets are collected, average long-term trends will become more apparent.

5.6.2 Bear Island

To determine the longterm volume change trends along Bear Island, the average annual volume change rate was calculated at each transect based on changes calculated for the monitoring reports from 2008 to 2016. **Figure 5-34** shows the mean volume change per year from 2008-2016. Large changes near Bogue Inlet are very apparent.

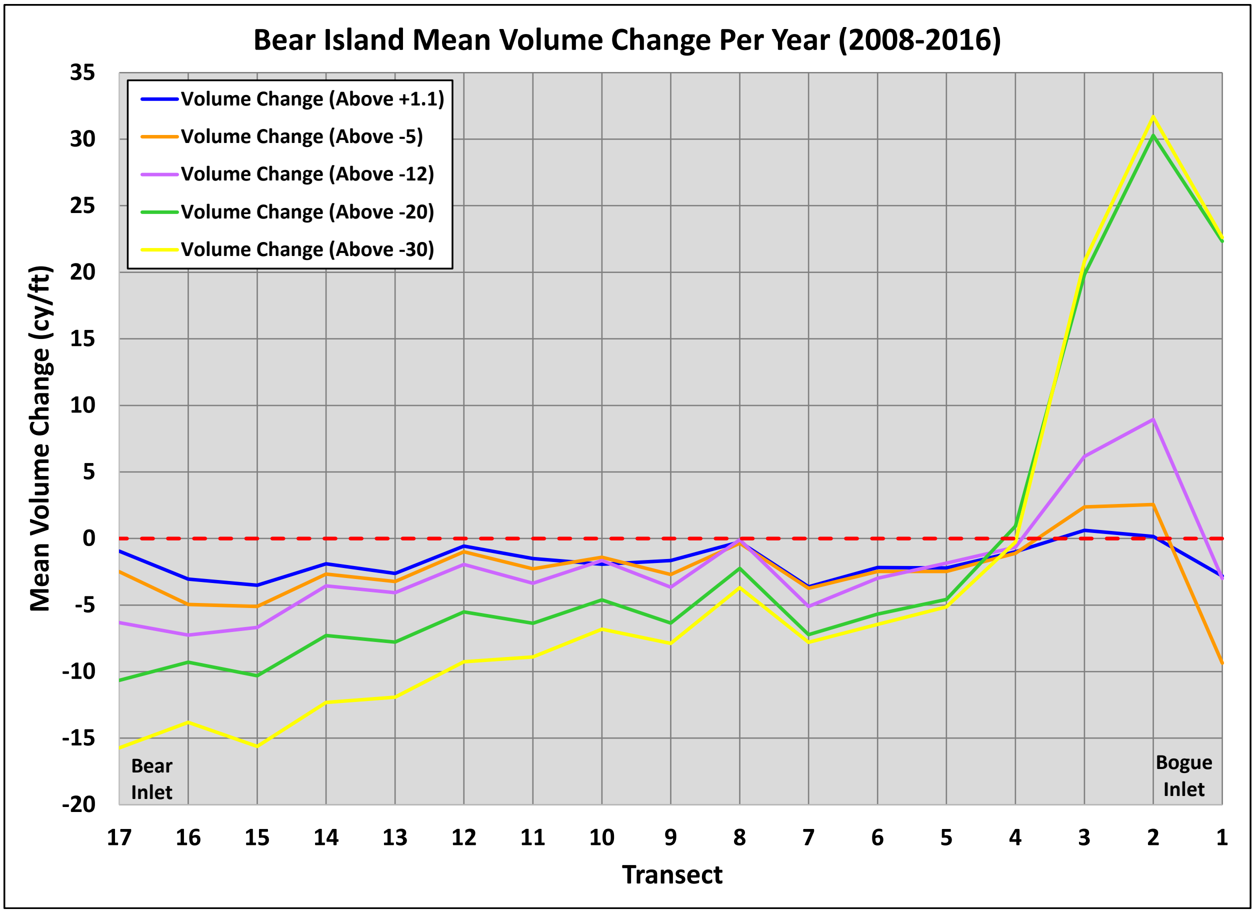


Figure 5-34. Bear Island Mean Volume Change

The standard deviations of the average annual volume change per year were also calculated for each referenced elevation included in the analysis. **Figure 5-35** through **Figure 5-39** shows the mean volume change per year with standard deviation bars at plus and minus one standard deviation for each of the referenced elevations.

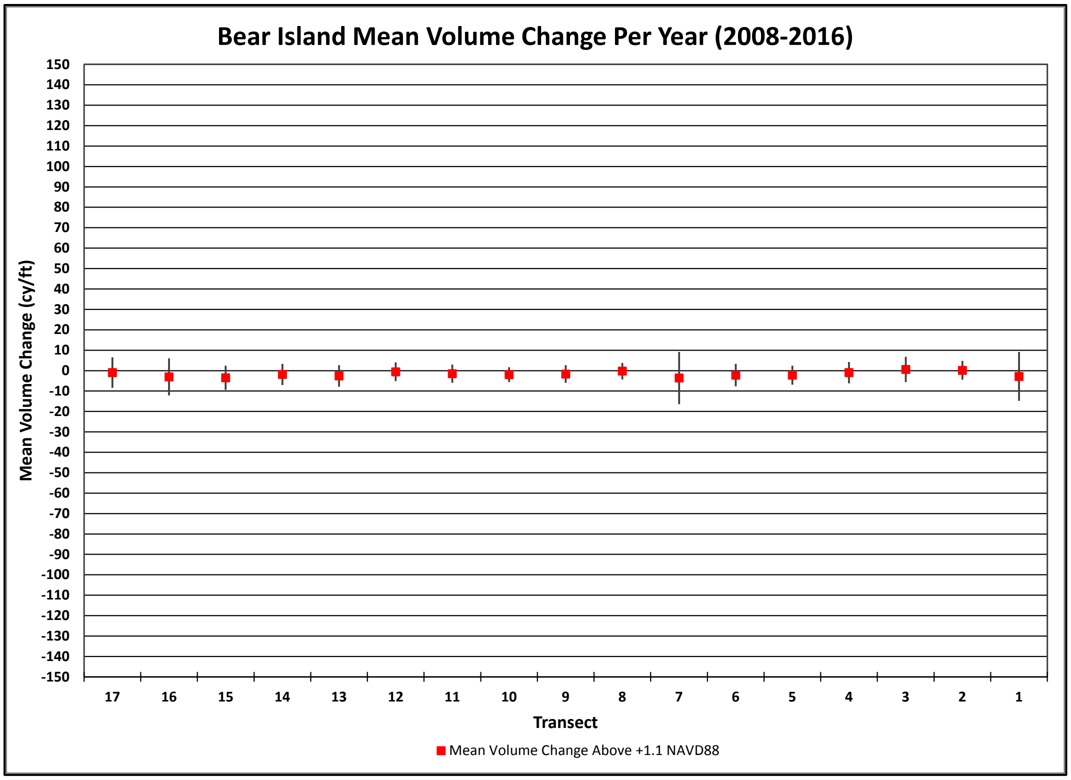


Figure 5-35. Bear Island Statistical Analysis of Volume Change Above +1.1 ft NAVD88

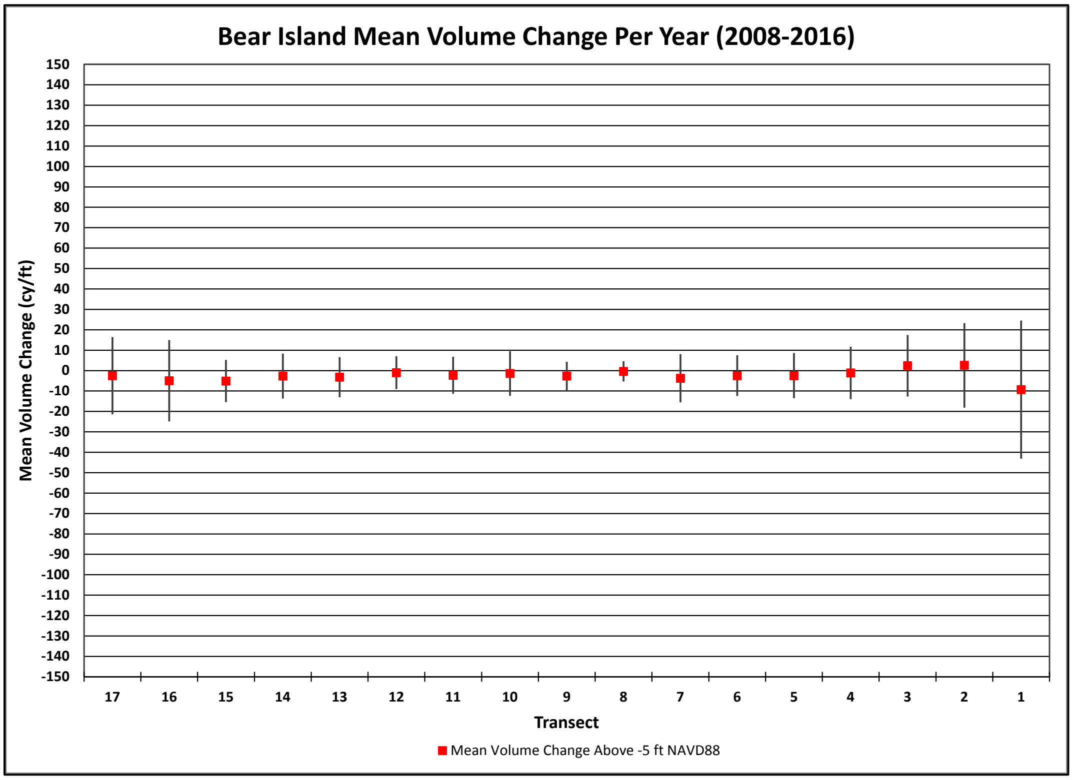


Figure 5-36. Bear Island Statistical Analysis of Volume Change Above -5.0 ft NAVD88

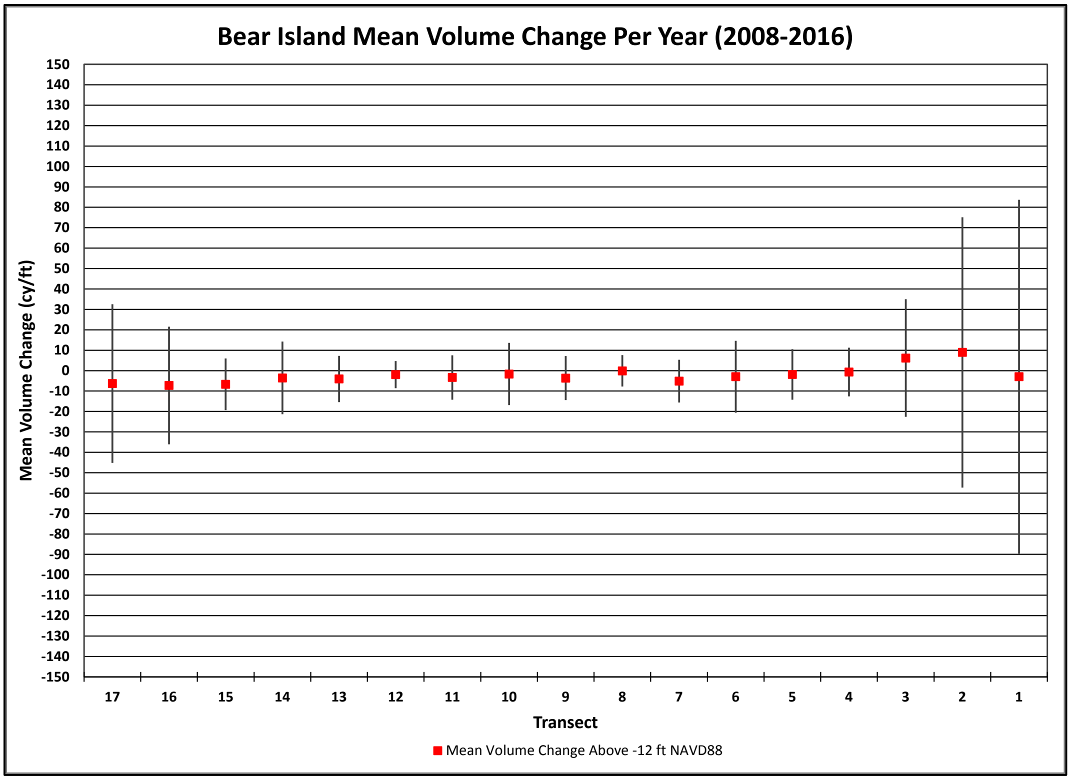


Figure 5-37. Bear Island Statistical Analysis of Volume Change Above -12.0 ft NAVD88

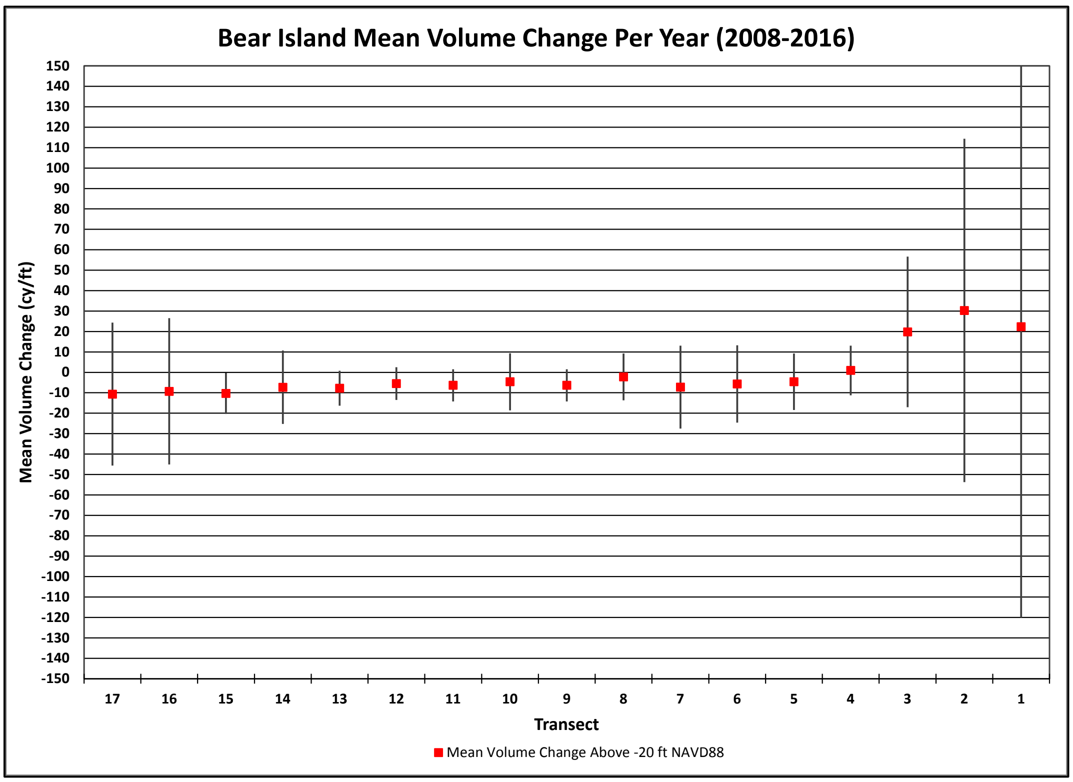


Figure 5-38. Bear Island Statistical Analysis of Volume Change Above -20.0 ft NAVD88

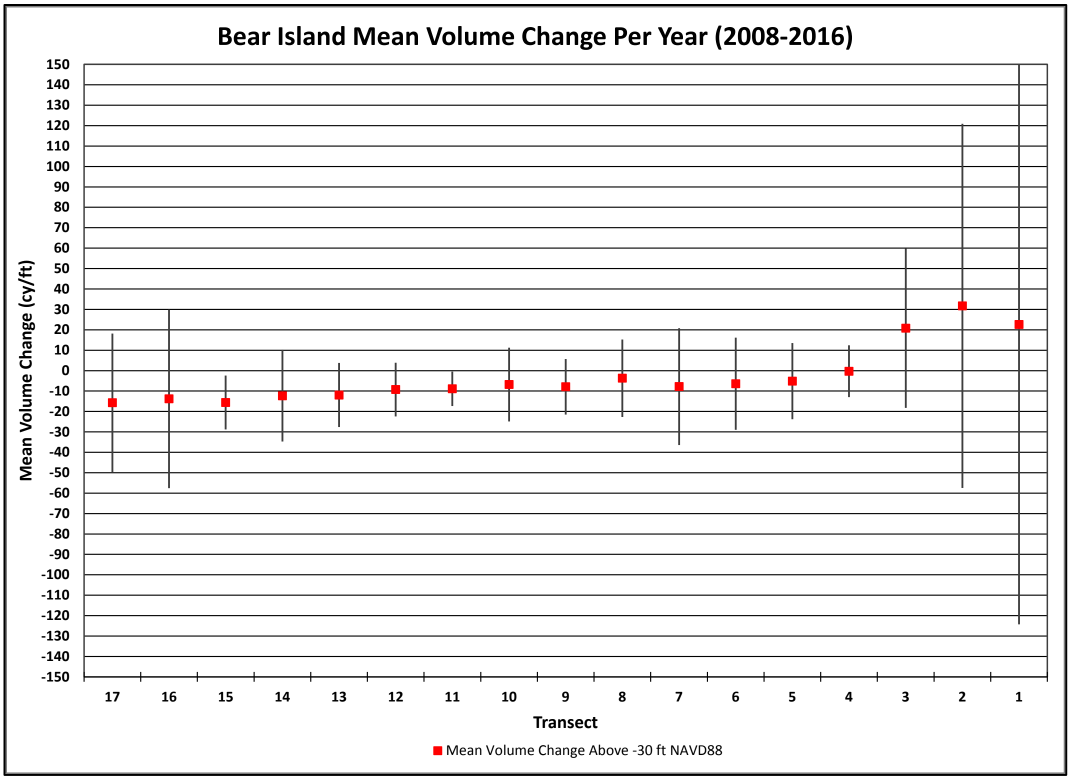


Figure 5-39. Bear Island Statistical Analysis of Volume Change Above -30.0 ft NAVD88

5.6.3 Shackleford Banks

To determine the longterm volume change trends along Shackleford Banks, the average annual volume change rate was calculated at each transect based on changes calculated for the monitoring reports from 2008 to 2016. **Figure 5-40** shows the mean volume change per year from 2008-2016. Large changes near Beaufort Inlet are very apparent.

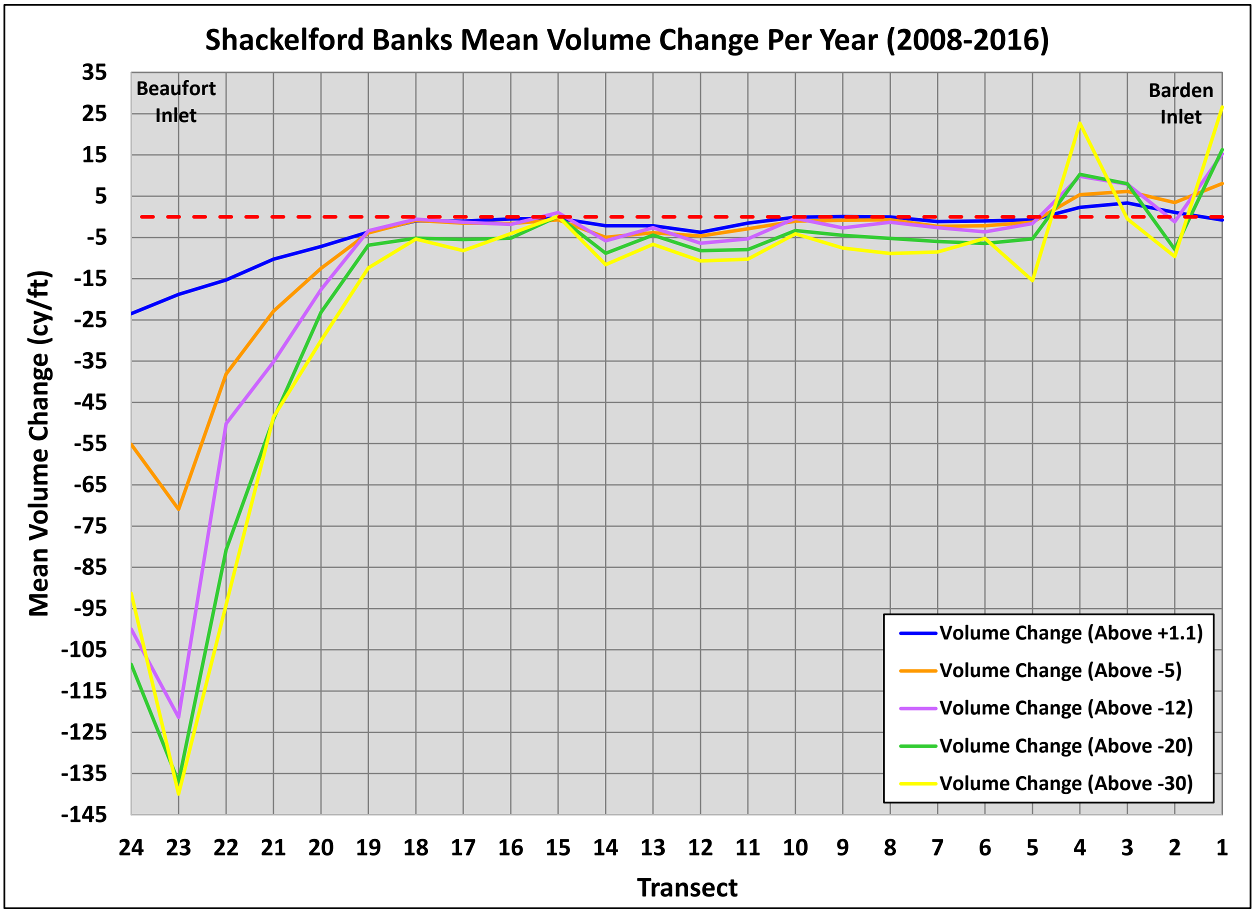


Figure 5-40. Shackleford Banks Mean Volume Change

The standard deviations of the average annual volume change were also calculated for each referenced elevation included in the analysis. **Figure 5-41** through **Figure 5-45** shows the mean volume change per year with standard deviation bars at plus and minus one standard deviation for each of the referenced elevations.

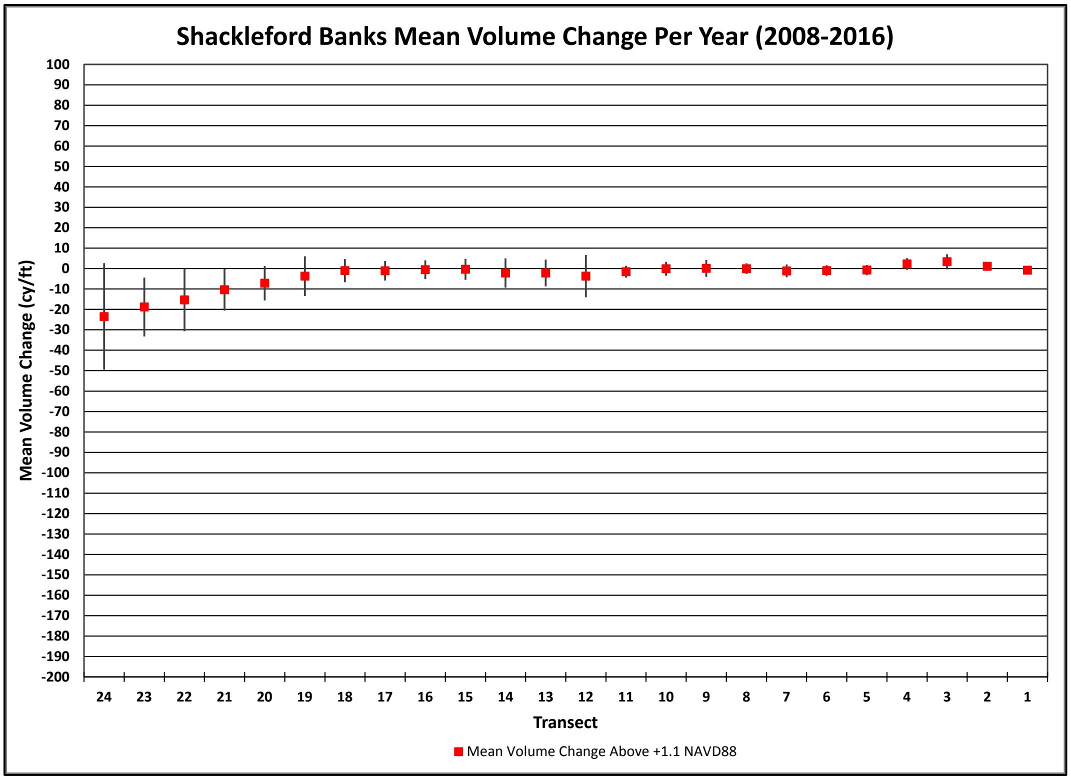


Figure 5-41. Shackleford Banks Statistical Analysis of Volume Change Above +1.1 ft NAVD88

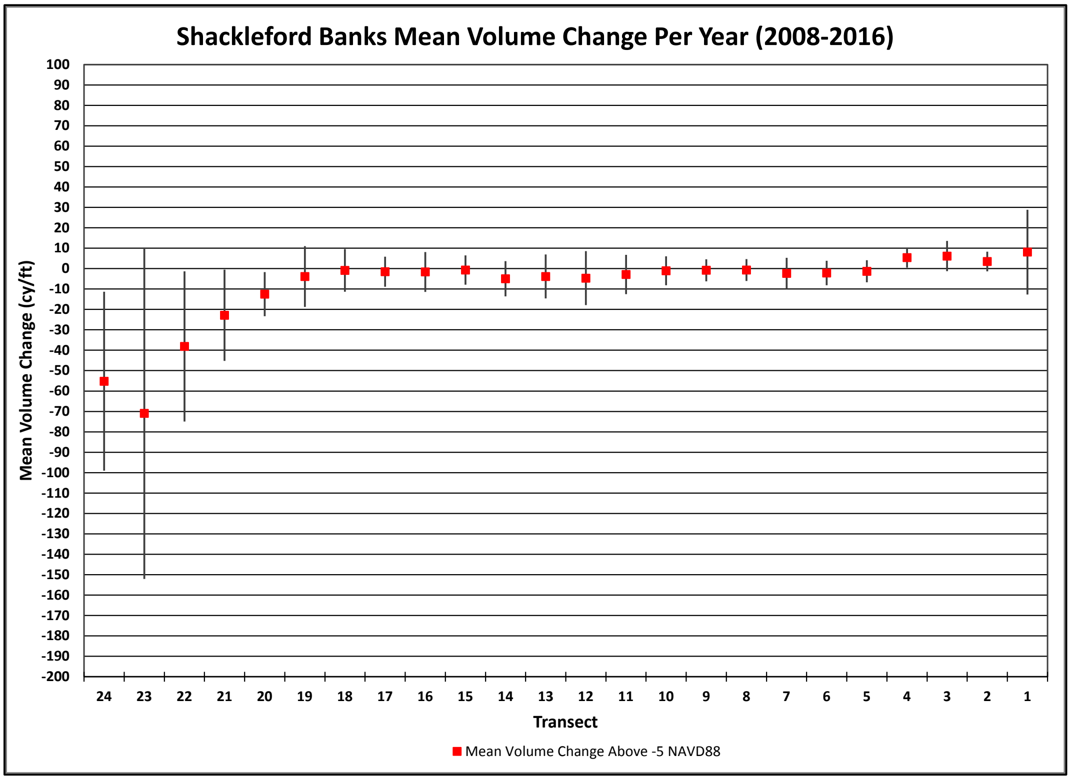


Figure 5-42. Shackleford Banks Statistical Analysis of Volume Change Above -5.0 ft NAVD88

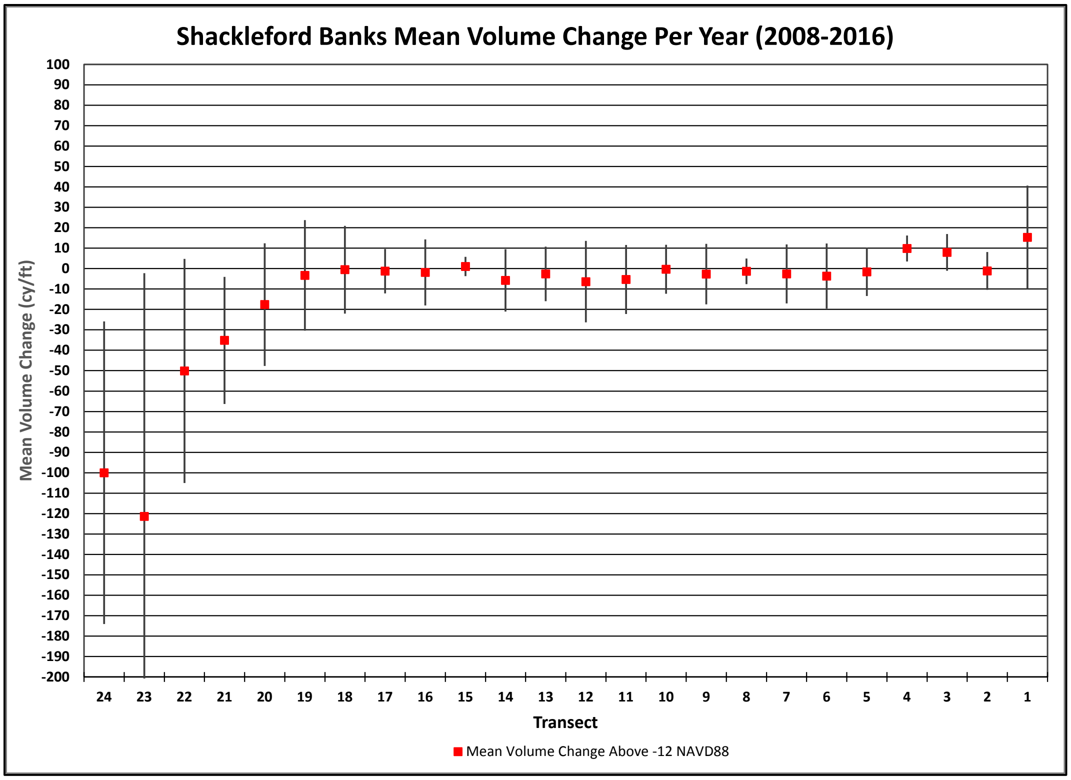


Figure 5-43. Shackleford Banks Statistical Analysis of Volume Change Above -12.0 ft NAVD88

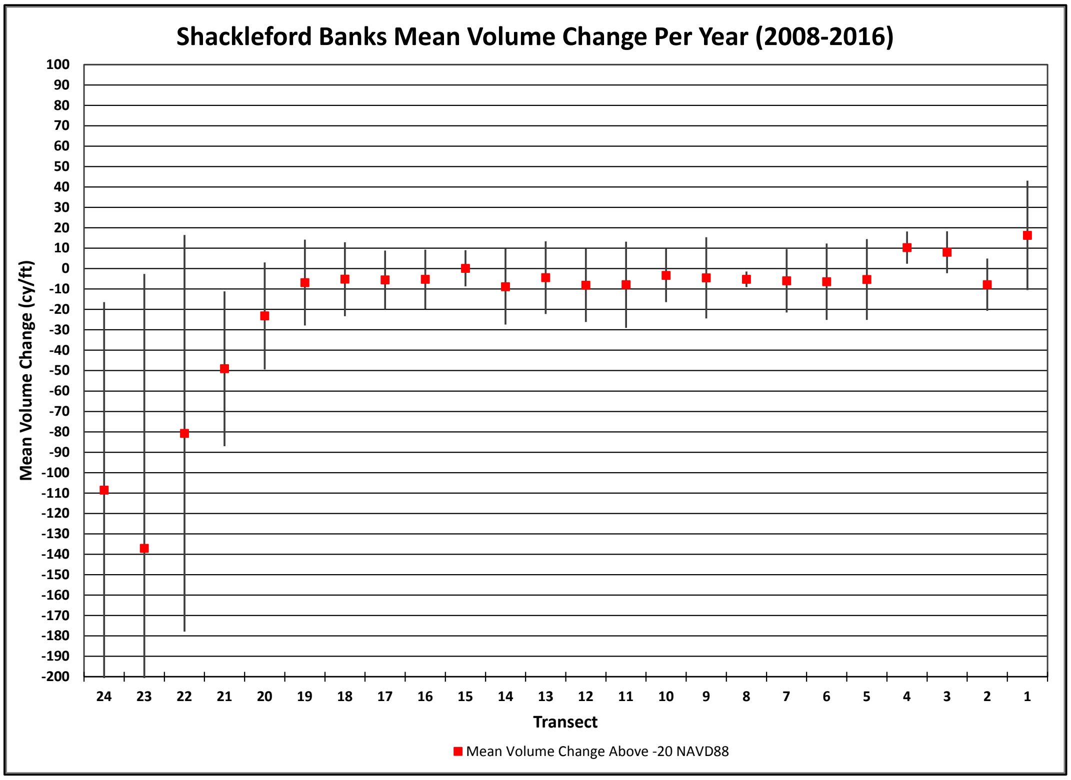


Figure 5-44. Shackleford Banks Statistical Analysis of Volume Change Above -20.0 ft NAVD88

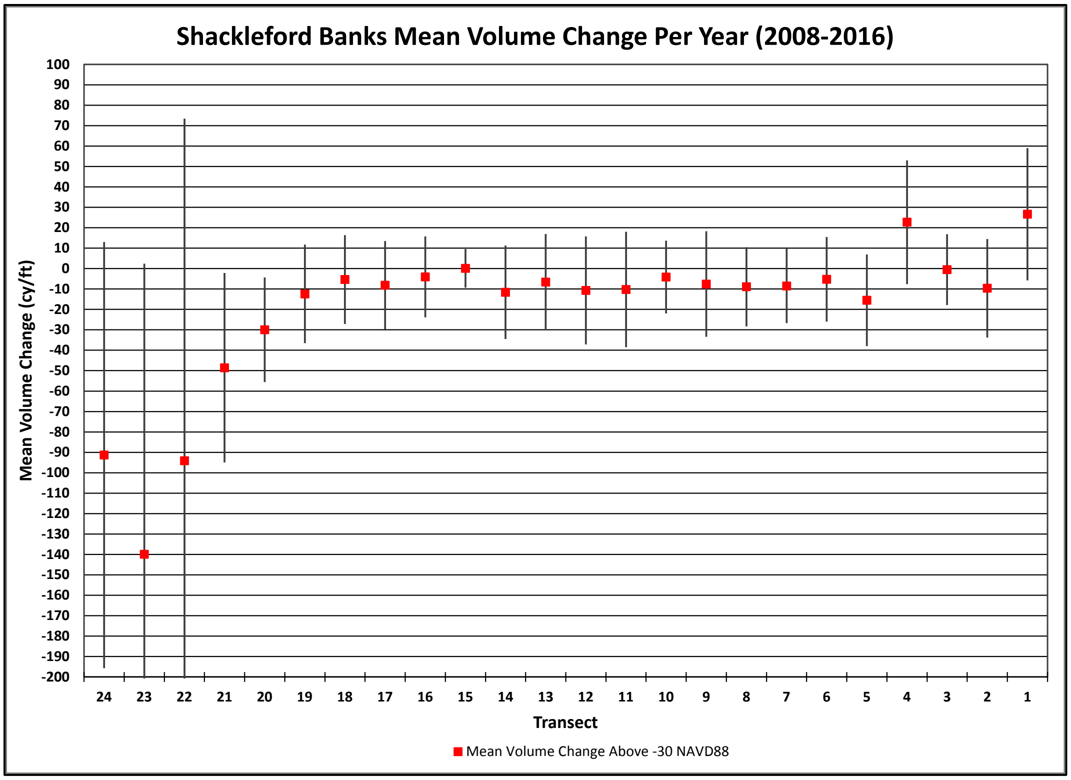


Figure 5-45. Shackleford Banks Statistical Analysis of Volume Change Above -30.0 ft NAVD88

5.7 Bogue Banks Master Beach Nourishment Plan Incorporation

Carteret County is currently in the final stages of developing a programmatic Environmental Impact Statement (EIS) which would essentially outline the nourishment needs (quantity, location, and timeframe) and sediment resources for Bogue Banks for the next 50 years. One environmental permit, obtained from review of the EIS, would be available to cover all nourishment actions for the next 50 years, eliminating the time-consuming process of permitting each individual project and allowing for placement of sand as needed. The annual monitoring efforts will decide the exact timing and extents of future nourishment projects by tracking the average profile volume in each management reach as compared to nourishment triggers that define the minimum profile volumes required to provide an equal level of protection along the Bogue Banks shoreline.

5.7.1 Profile Volumes and Nourishment Triggers

As part of the Master Beach Nourishment Plan, volumetric triggers for each management reach, based on the profile volume from the foredune (landward most crest of primary dune) to the outer bar (above -12 ft NAVD88), were determined to provide equal protection along the Bogue Banks oceanfront. Based on the engineering analysis and historical and expected future funding levels, it was determined that Carteret County would be able to maintain protection from a 25-yr storm event. Detailed SBEACH modeling (1-D cross-shore) was used to determine the amount of material above -12 ft NAVD88 that is needed to provide a 25-yr event level of protection in each management reach. This is different for each reach depending on existing dune height, berm width, offshore slope, etc. **Table 5-16** presents the management reaches and nourishment triggers along with the current average profile volume. As can be seen, each reach has a slightly different volume trigger, with an island wide weighted average of 233 cy/ft.

Table 5-16. Current Profile Volumes and Nourishment Triggers

Reach (Profiles)	Management Reach Length (ft)	2016 Volume Above -12 ft NAVD88 (cy)	Nourishment Trigger (cy)
Bogue Inlet (1-11)	11,488	320	235
Emerald Isle West (12-25)	18,288	311	266
Emerald Isle Central (26-36)	15,802	295	211
Emerald Isle East (37-48)	13,220	267	221
Indian Beach/Salter Path (49-58)	12,850	278	224
Pine Knoll Shores (59-76)	23,878	252	211
Atlantic Beach (77-102)	26,176	313	254
TOTAL	121,702		
AVERAGE		290	233
		weighted	weighted

Figure 5-46 displays the average profile volume to the outer bar within each management reach for 2008 – 2016 along with the nourishment triggers. As can be seen, all management reaches currently contain average profile volumes above the nourishment triggers.

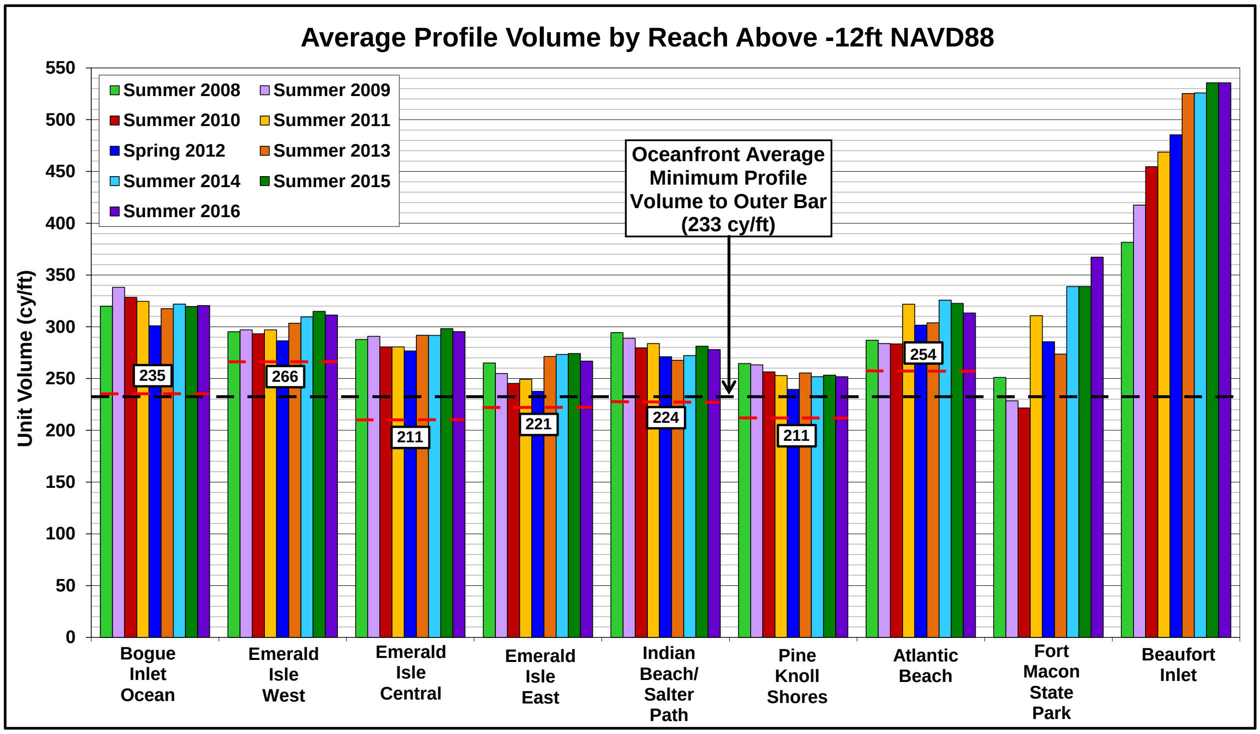


Figure 5-46. Profile Volumes and Nourishment Triggers

5.7.2 Estimation of Years Remaining Until Next Nourishment

The engineering portion of the Master Beach Nourishment Plan included statistical analysis of historical profile volume changes using an Excel add-on software called Crystal Ball. One component of the detailed Crystal Ball analytical analysis is the ability to assign confidence intervals to the future nourishment projections. This was used to determine the number of years until the next nourishment might be required based on the most recent 2016 survey data and historical erosion rates. **Table 5-17** presents the estimates of the remaining time until the new nourishment triggers are realized within each reach based on various confidence intervals. It appears the first nourishments will be required in a 7-12 year range under average conditions (see 50%, 55%, and 60% confidence intervals). However, if a period of above normal storm activity were to impact the area, these estimates could go down to 3-5 years (see 70%, 75% and 85% confidence intervals).

Table 5-17. Years Remaining Until Nourishment

Reach (Profiles)	Management Reach Length (ft)	-12 ft 2016 Volume (cy)	Preliminary -12 ft Trigger (cy)	Volume Remaining (cy)	Years to 25 yr Trigger 50%	Years to 25 yr Trigger 55%	Years to 25 yr Trigger 60%	Years to 25 yr Trigger 65%	Years to 25 yr Trigger 70%	Years to 25 yr Trigger 75%	Years to 25 yr Trigger 85%
Bogue Inlet (1-11)	11,488	320	235	85	22	13	10	8	6	5	4
Emerald Isle West (12-25)	18,288	311	266	45	131	131	131	71	27	16	8
Emerald Isle Central (26-36)	15,802	295	211	84	53	43	26	19	14	11	8
Emerald Isle East (37-48)	13,220	267	221	46	10	8	6	5	5	4	3
Indian Beach/Salter Path (49-58)	12,850	278	224	54	11	9	7	6	5	4	3
Pine Knoll Shores (59-76)	23,878	252	211	41	12	9	7	6	5	4	3
Atlantic Beach (77-102)	26,176	313	254	59	9	8	7	6	5	5	4
TOTAL	**121,702**										
AVERAGE		**290**	**233**	**59**	**35**	**31**	**28**	**17**	**10**	**7**	**5**
		weighted	weighted								

6.0 Summary

Comprehensive beach 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 codified to continue assessing 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 the 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 annual monitoring survey was completed during spring/summer 2016 by Geodynamics. For this evaluation, the spring/summer 2016 survey was compared with the spring/summer 2015 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 (offshore).

Key statistics for individual reaches along Bogue Banks along with the entire oceanfront shoreline were as follows:

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (Transects 1-11)	11,488	22.3	3.9	45,054	4.0	46,320	1.0	11,368	2.5	28,296	0.0	-13
Emerald Isle-West (Transects 12-25)	18,288	5.6	1.9	34,721	1.1	20,350	-3.4	-62,725	4.1	74,453	2.6	48,444
Emerald Isle-Central (Transects 26-36)	15,802	-9.3	-1.6	-25,259	4.4	68,985	-2.8	-45,006	7.4	116,759	4.3	67,978
Emerald Isle-East (Transects 37-48)	13,220	5.6	-0.8	-10,033	-0.8	-10,673	-7.3	-96,674	-0.7	-8,979	-5.0	-65,902
Indian Beach-Salter Path (Transects 49-58)	12,850	9.8	0.4	5,449	5.6	71,648	-3.3	-42,345	4.1	52,626	-1.0	-12,633
Pine Knoll Shores (Transects 59-76)	23,878	-5.3	-0.7	-17,468	4.4	104,089	-1.6	-37,740	1.4	32,403	-2.5	-58,862
Atlantic Beach (Transects 77-102)	26,176	-4.8	0.1	1,923	-3.1	-79,892	-9.2	-241,055	-7.6	-200,189	-14.5	-380,813
Fort Macon State Park (Transects 103-112)	6,691	34.0	8.3	55,572	14.9	99,369	28.3	189,340	31.9	213,470	31.5	210,807
Beaufort Inlet (Transects 112B-116)	2,000	33.3	5.3	10,661	8.9	17,840	0.0	-43	4.4	8,840	11.0	21,989
Bogue Inlet-Channel (Transects 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
Oceanfront (Transects 1-112)	**128,393**	**3.0**	**0.7**	**89,960**	**2.5**	**320,195**	**-2.5**	**-324,837**	**2.4**	**308,839**	**-1.5**	**-190,994**

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

The Bogue Banks oceanfront shoreline experienced an overall average seaward advancement at MHW of 3.0 ft over the past year. However, patterns of seaward advancement and landward recession fluctuated greatly over the entire shoreline. Volumetrically, there was a dominant trend of volume losses above -12 ft NAVD88 and volume gains above -20 ft NAVD88 due to the flattening and seaward movement of the offshore bar in Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores. Atlantic Beach displayed the largest volume losses above -12 ft NAVD88 which were not captured offshore. Fort Macon experienced a gain in volume, due to the nourishment event which placed 150,000 cy between Transects 104 and 107 and eastward littoral transport which produced volume gains nearest the terminal groin.

This year's analysis also included an assessment of the change in position of the base of the dune along Bogue Banks, which was performed using shore parallel survey lines collected in 2015 and

2016 by driving the survey ATV along the base of the dune. The difference in position at each transect was calculated and plotted to determine any trends in movement along the oceanfront shoreline. An average seaward movement of approximately 5.6 ft was calculated over the entire shoreline. It should be noted that the accuracy of the dune base position surveyed is highly subject to surveyor interpretation. Other methods for tracking this feature are being investigated.

Key statistics calculated for Bear Island were as follows:

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bear Island (Transects 1-18)	16,500	-35.5	-4.8	-79,097	-7.2	-119,276	-9.9	-162,690	-2.5	-41,551	-5.3	-86,714

Bear Island experienced a moderate amount of shoreline recession at MHW over the past year as well as an overall loss in material above all elevations. Profile plots show that the western end of the island experienced erosion above all elevations from Transects 12 – 18 while the eastern end of the island exhibited alternating patterns of erosion and accretion in which some of the onshore losses of material were captured offshore at lower elevations.

Key statistics calculated for Shackleford Banks were as follows:

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Shackleford Banks (Transects 1-19)	39,459	-8.3	-1.2	-70,481	-1.9	-120,901	1.5	-75,484	0.5	-134,985	5.2	26,314
Shackleford Banks (Transects 20-23)	6,542	-80.6	-10.7	-67,979	-38.7	-284,435	-94.2	-681,487	-123.7	-914,900	-132.7	-976,518
Shackleford Banks (Transects 1-24)	46,001	-21.9	-3.0	-138,459	-8.8	-405,335	-16.5	-756,971	-22.8	-1,049,885	-20.7	-950,204

The majority of the island (Transects 1-19) experienced minor landward recession of the shoreline at MHW and minor volume losses above -12 ft NAVD88 (approximately 75,484 cy). The remaining transects along the western end of Shackleford Banks (Transects 20-23) experienced significant landward recession of the shoreline at MHW and substantial losses in volume of approximately 681,487 cy. Profile plots show significant erosion of the dunes and beachface in the transects located adjacent to Beaufort Inlet. This behavior is not unexpected given the location of the deep draft channel being directly adjacent to this area of Shackleford Banks and the recent history of significant erosion. The combination of the deep draft channel hydraulics, episodic dredging and shoaling, as well as barrier island morphology make this a very dynamic area. The remainder of the island experienced minor losses in comparison with some accretion on the eastern end of the island.

Carteret County is currently in the final stages of developing a programmatic Environmental Impact Statement (EIS) which would essentially outline the nourishment needs (quantity, location, and timeframe) and sediment resources for Bogue Banks for the next 50 years and be used to obtain a permit to cover these activities. The annual monitoring efforts will decide the exact timing and extents of future nourishment projects by tracking the average profile volume in each management reach as compared to nourishment triggers that define the minimum profile volumes required to provide an equal level of protection along the Bogue Banks shoreline. Assessment of current conditions compared to the nourishment triggers defined in the Master Beach Nourishment Plan (engineering portion of the EIS) was completed as part of this report. The following table indicates that all management reaches currently contain average profile volumes above their individual nourishment triggers as well as the island wide average trigger of 233 cy/ft. Using historical erosion rates (background and storm), it would appear that based on the current volumes, the next nourishment action may be needed within 3-5 years if there is a period of above normal storm activity. Otherwise, the next nourishment action is not expected for 7-12 years.

Reach (Profiles)	Management Reach Length (ft)	2016 Volume Above -12 ft NAVD88 (cy)	Nourishment Trigger (cy)
Bogue Inlet (1-11)	11,488	320	235
Emerald Isle West (12-25)	18,288	311	266
Emerald Isle Central (26-36)	15,802	295	211
Emerald Isle East (37-48)	13,220	267	221
Indian Beach/Salter Path (49-58)	12,850	278	224
Pine Knoll Shores (59-76)	23,878	252	211
Atlantic Beach (77-102)	26,176	313	254
TOTAL	**121,702**		
AVERAGE		**290**	**233**
		weighted	weighted

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.

APPENDIX A

MHW Shoreline Plots

Figure A-1. Bogue Banks 2015 and 2016 MHW Shoreline Positions

Figure A-2. Bogue Banks 2015 and 2016 MHW Shoreline Positions

Figure A-3. Bogue Banks 2015 and 2016 MHW Shoreline Positions

Figure A-4. Bogue Banks 2015 and 2016 MHW Shoreline Positions

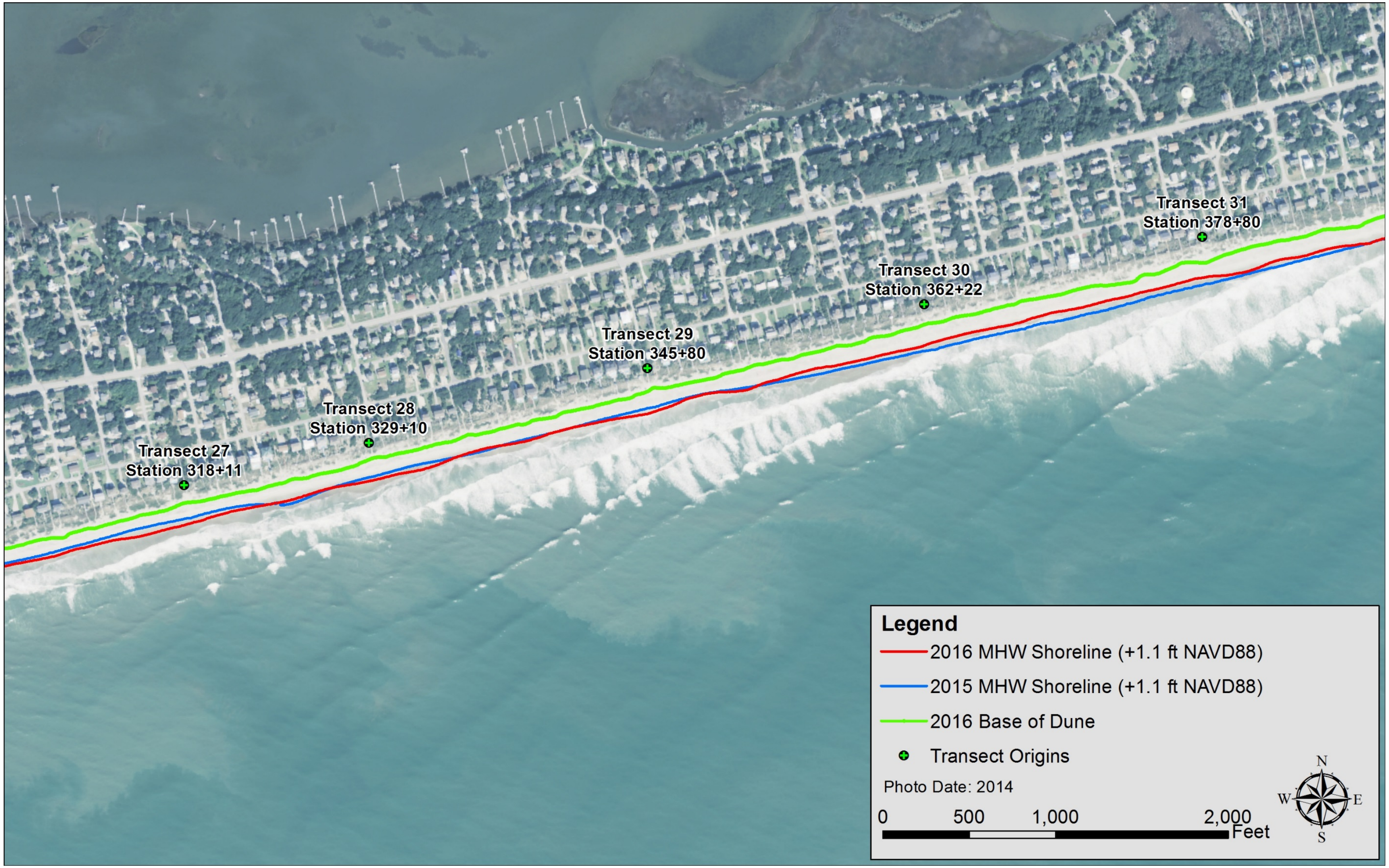


Figure A-5. Bogue Banks 2015 and 2016 MHW Shoreline Positions

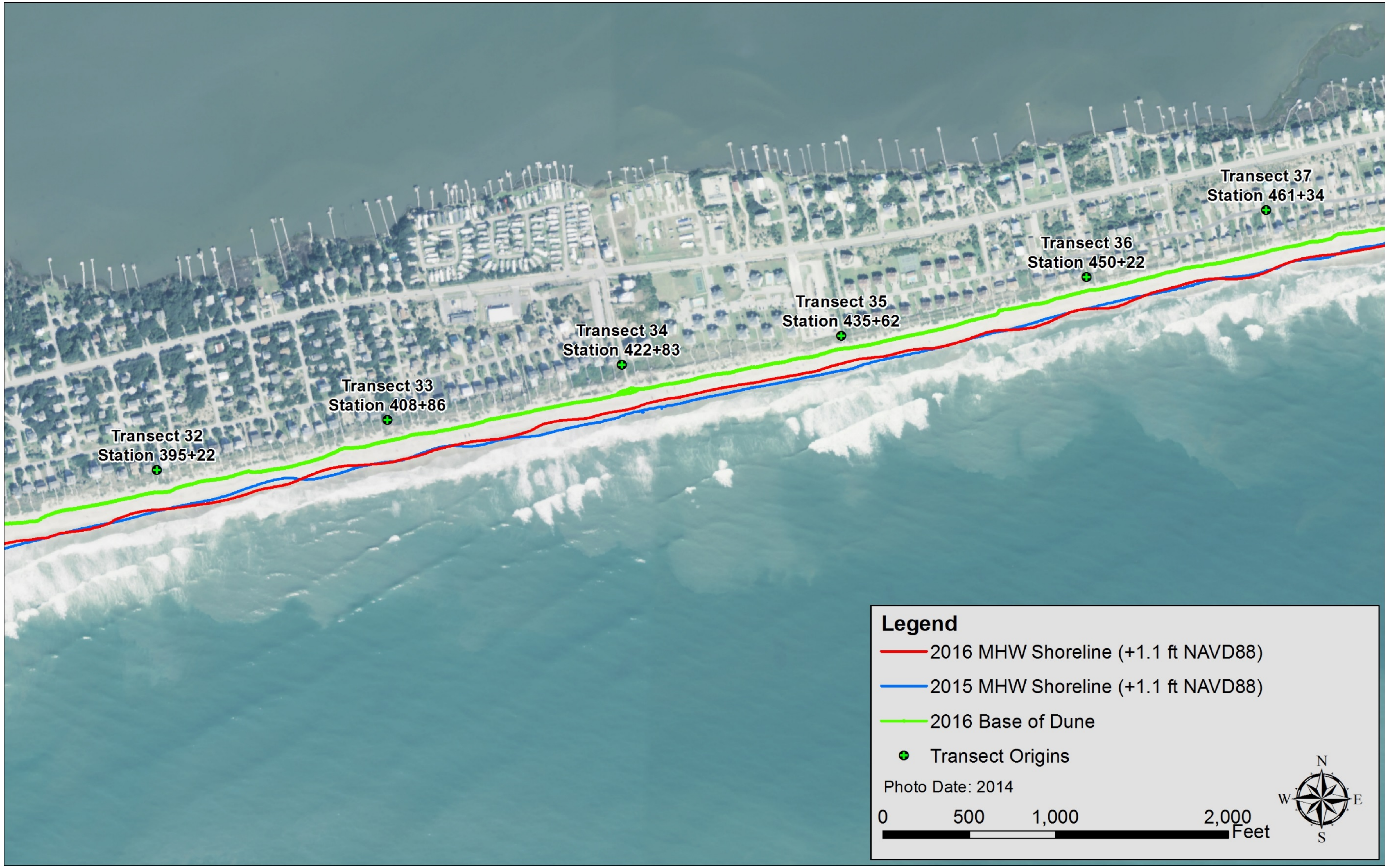


Figure A-6. Bogue Banks 2015 and 2016 MHW Shoreline Positions

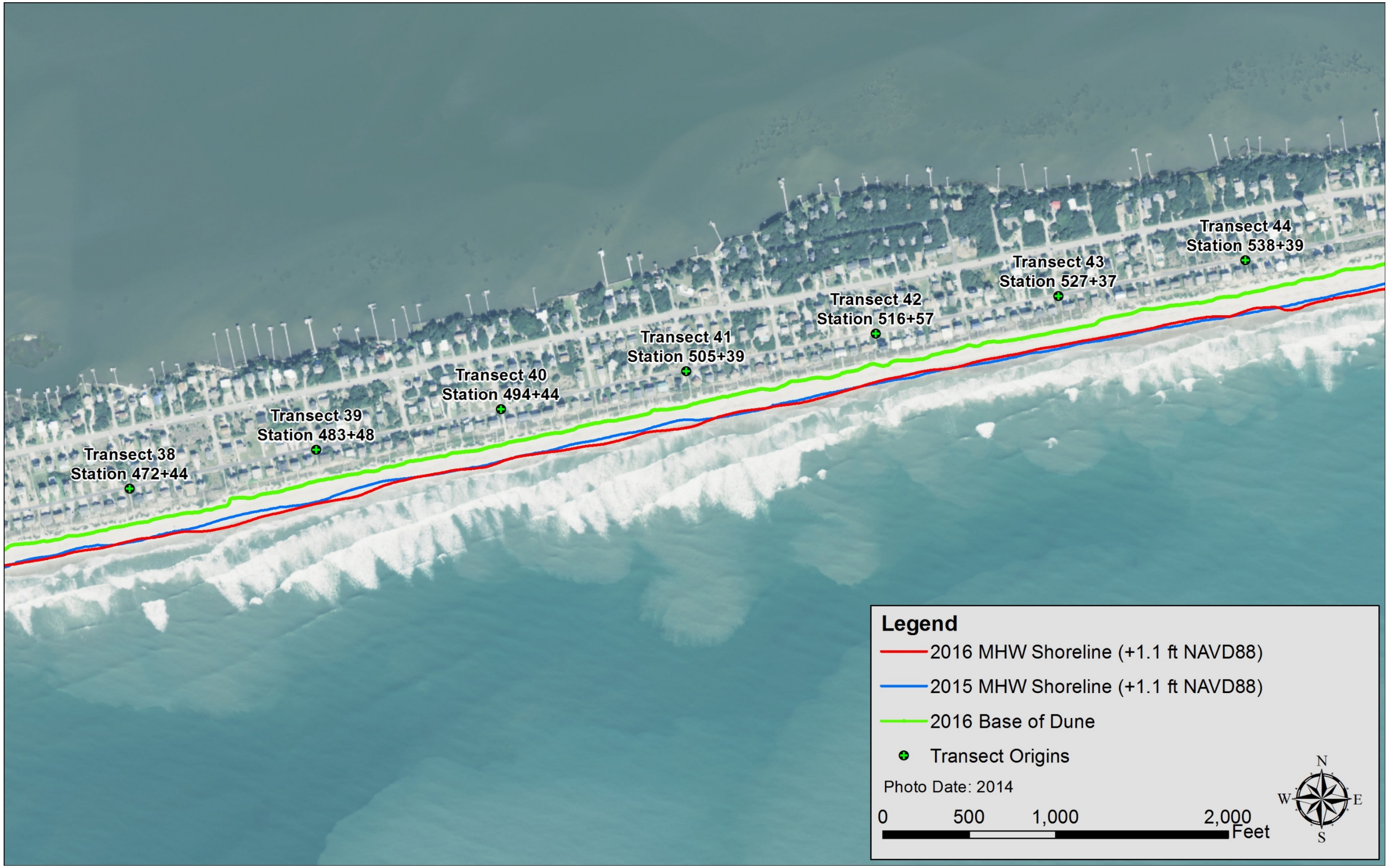


Figure A-7. Bogue Banks 2015 and 2016 MHW Shoreline Positions

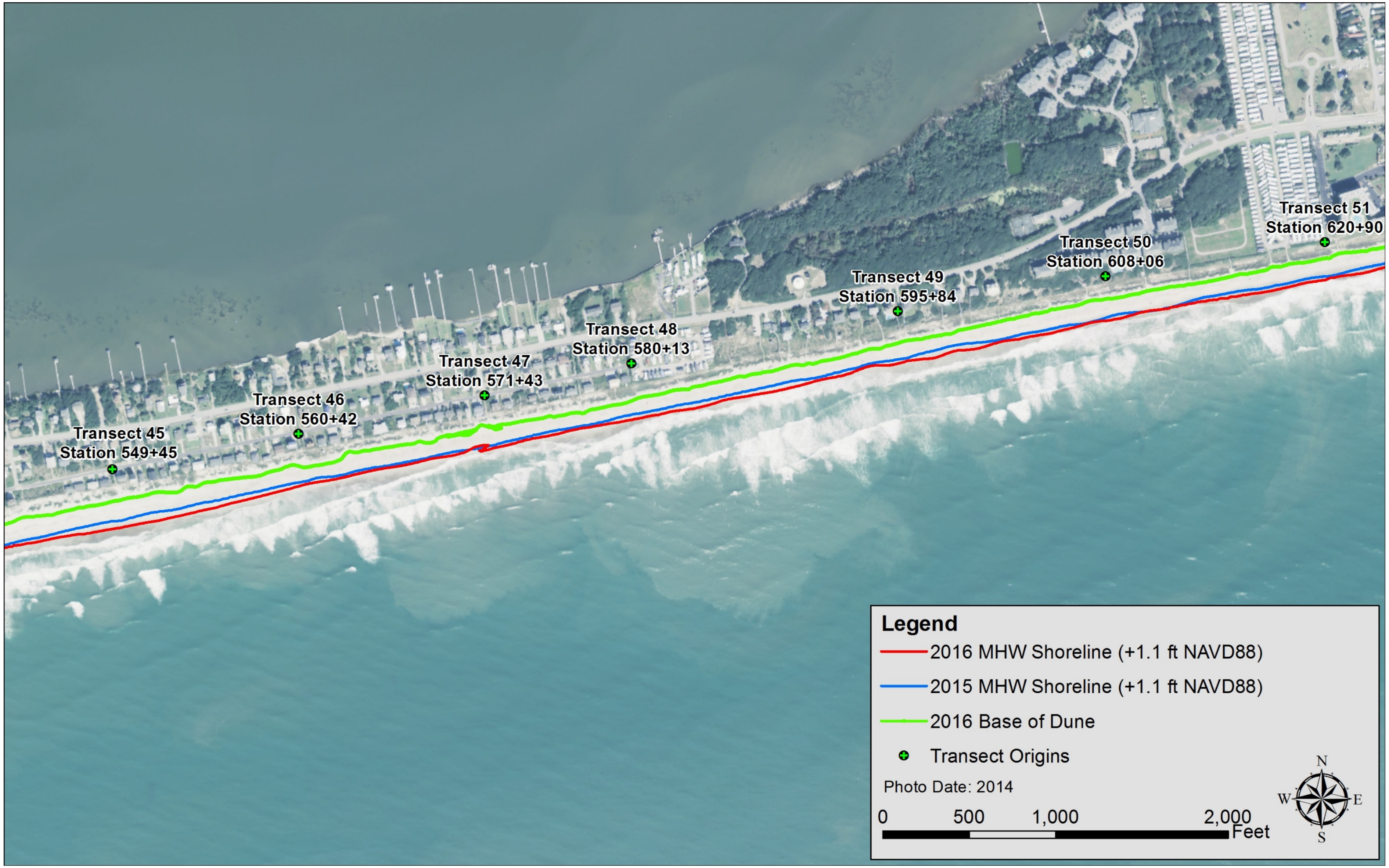


Figure A-8. Bogue Banks 2015 and 2016 MHW Shoreline Positions

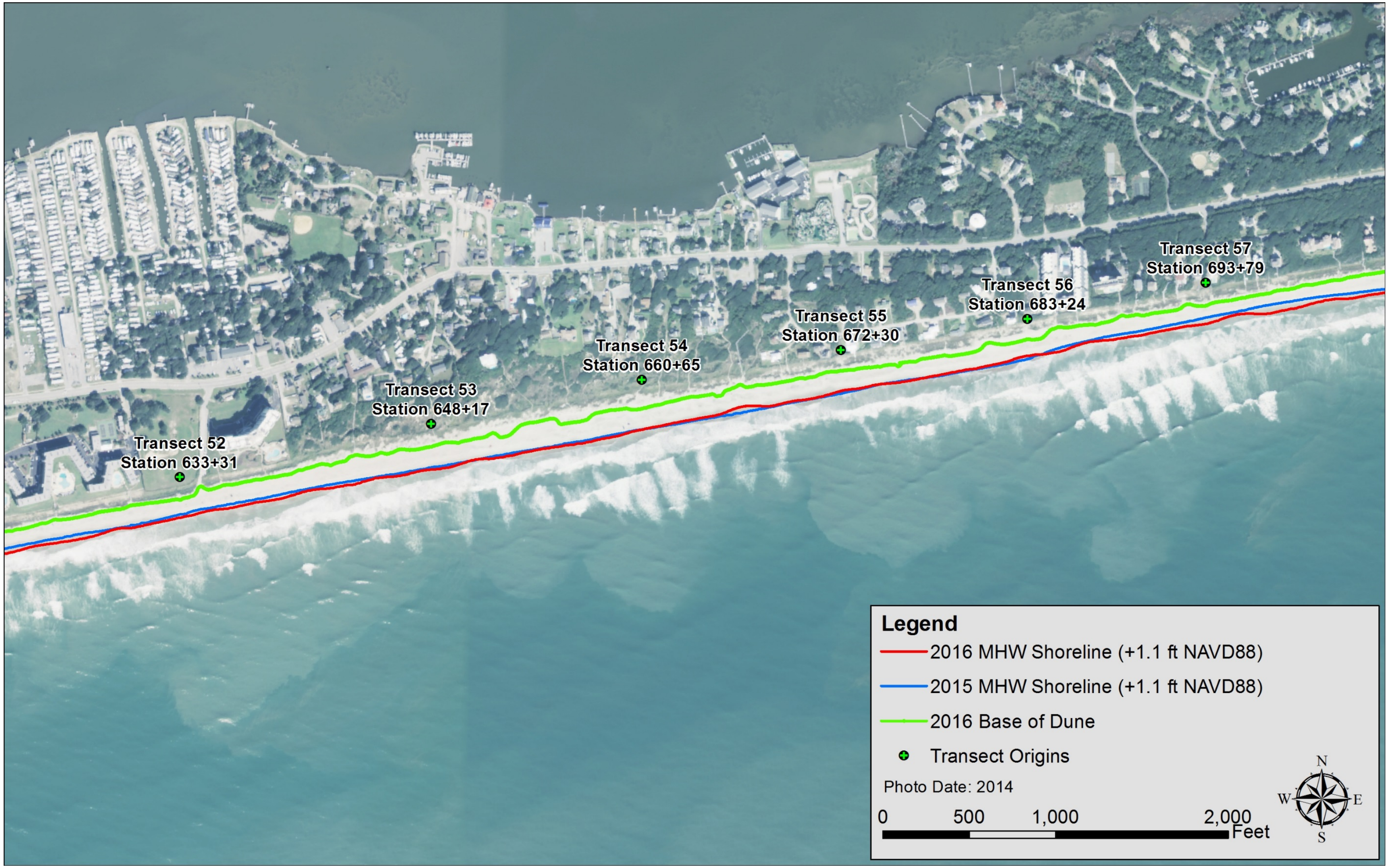


Figure A-9. Bogue Banks 2015 and 2016 MHW Shoreline Positions

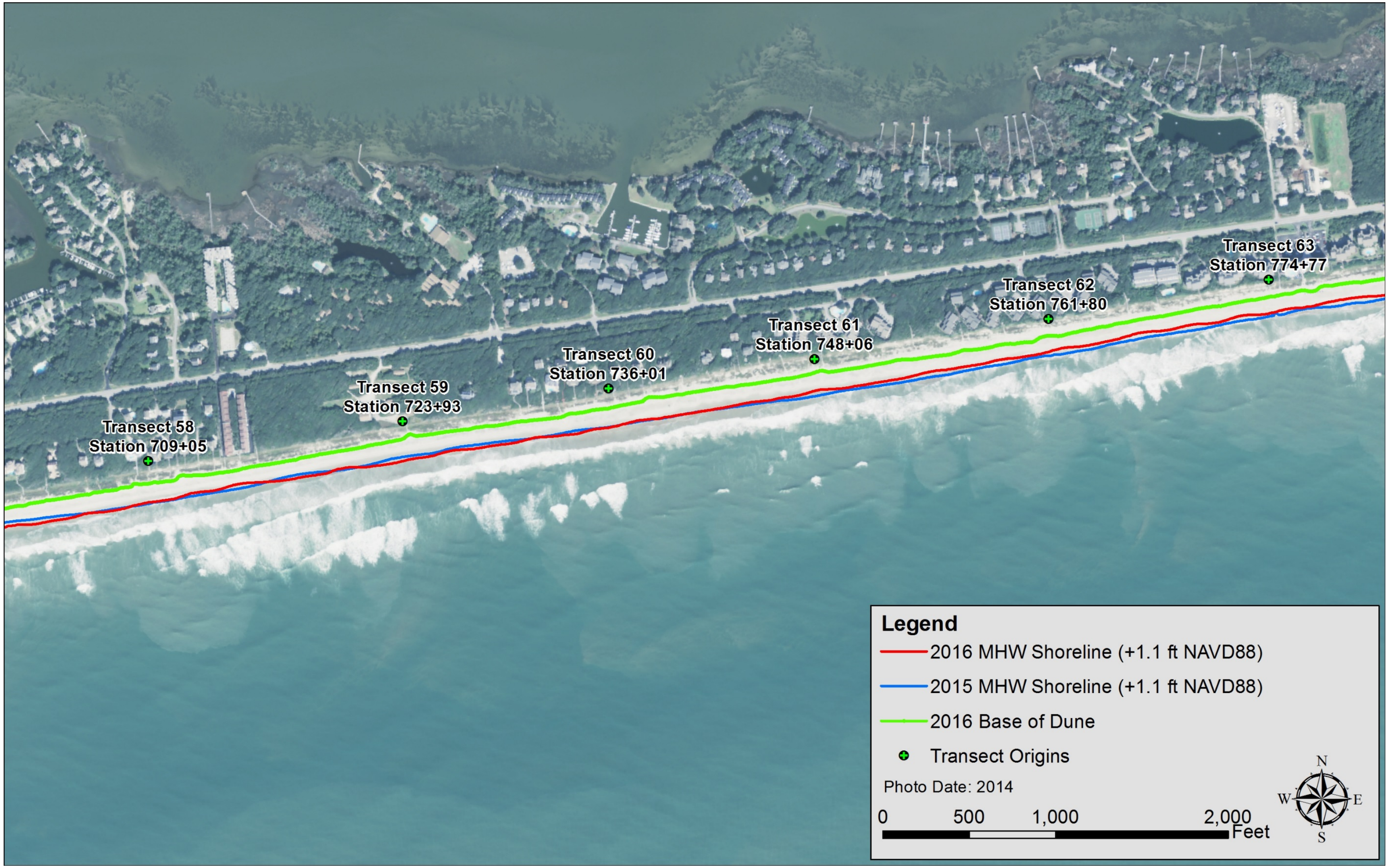


Figure A-10. Bogue Banks 2015 and 2016 MHW Shoreline Positions

Figure A-11. Bogue Banks 2015 and 2016 MHW Shoreline Positions

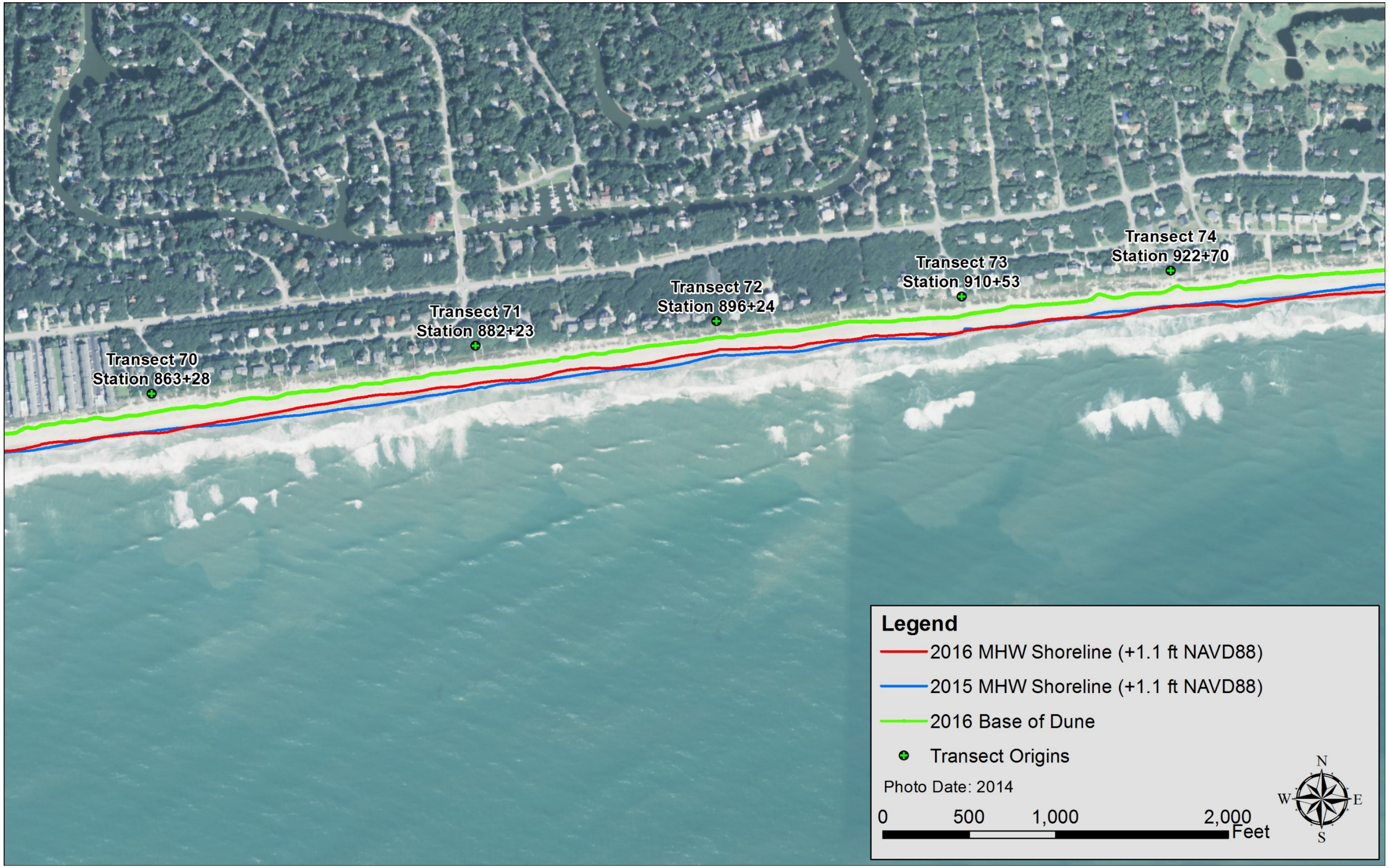


Figure A-12. Bogue Banks 2015 and 2016 MHW Shoreline Positions

Figure A-13. Bogue Banks 2015 and 2016 MHW Shoreline Positions

Figure A-14. Bogue Banks 2015 and 2016 MHW Shoreline Positions

Figure A-15. Bogue Banks 2015 and 2016 MHW Shoreline Positions

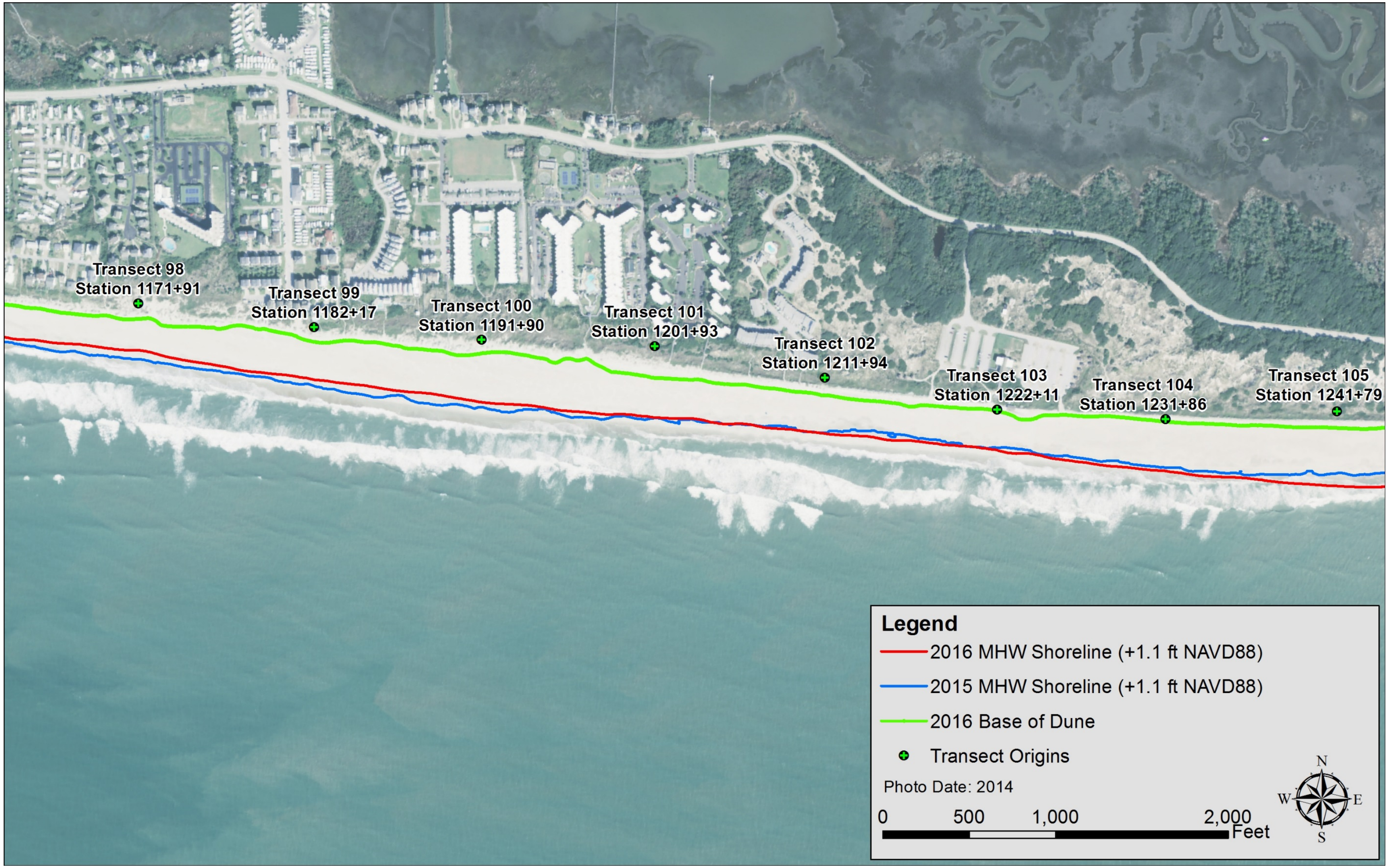


Figure A-16. Bogue Banks 2015 and 2016 MHW Shoreline Positions

Figure A-17. Bogue Banks 2015 and 2016 MHW Shoreline Positions

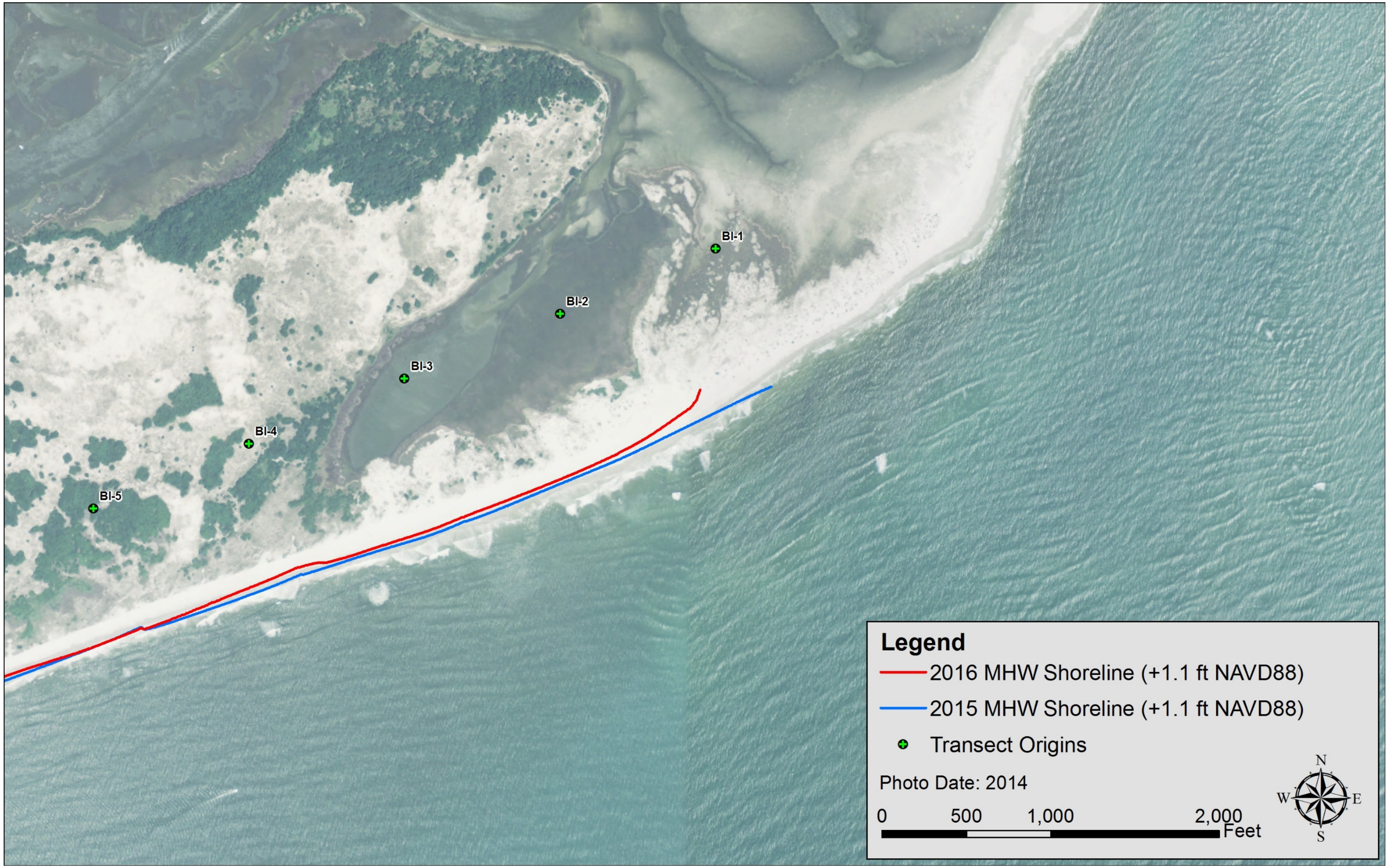


Figure A-18. Bear Island 2015 and 2016 MHW Shoreline Positions

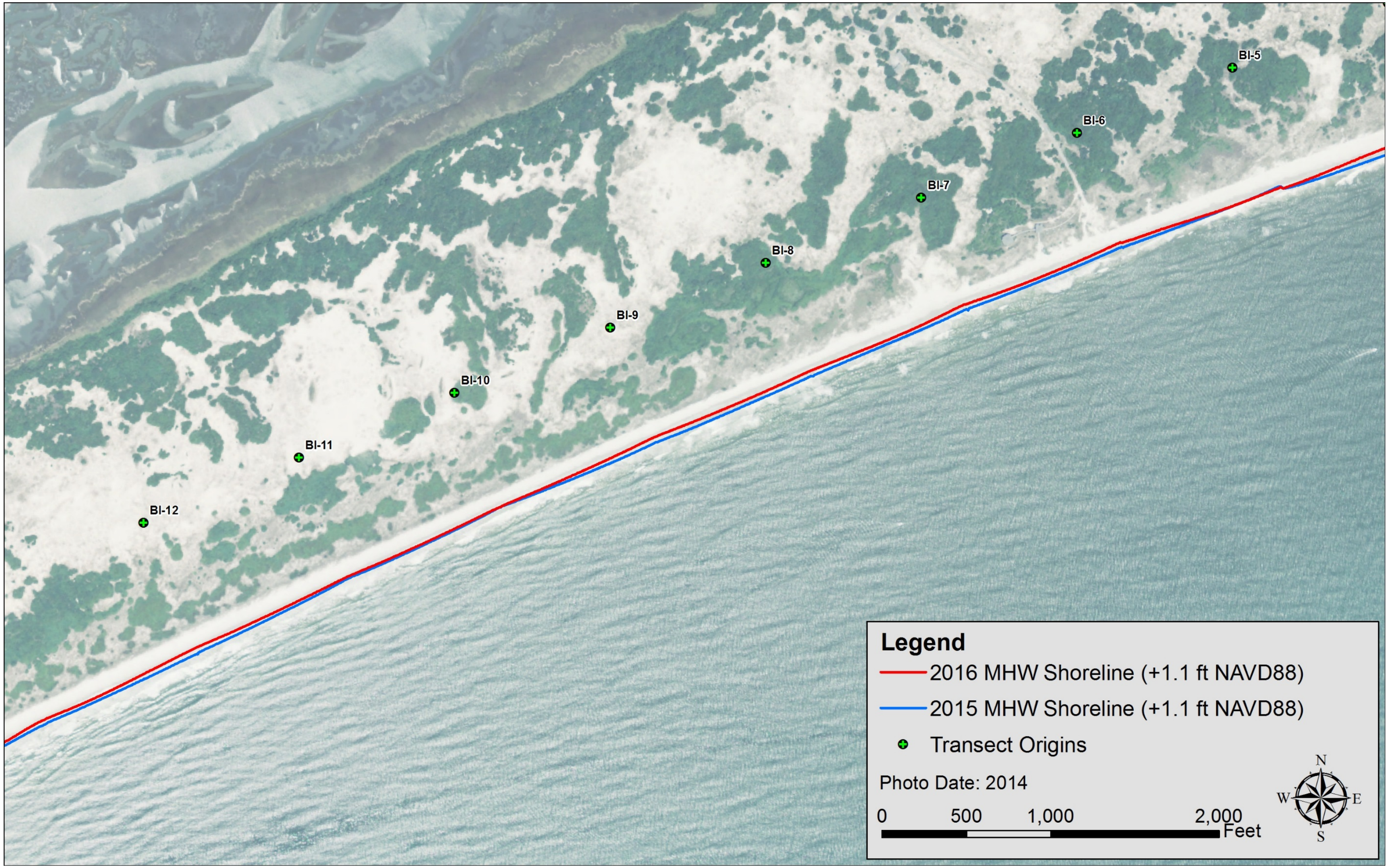


Figure A-19. Bear Island 2015 and 2016 MHW Shoreline Positions

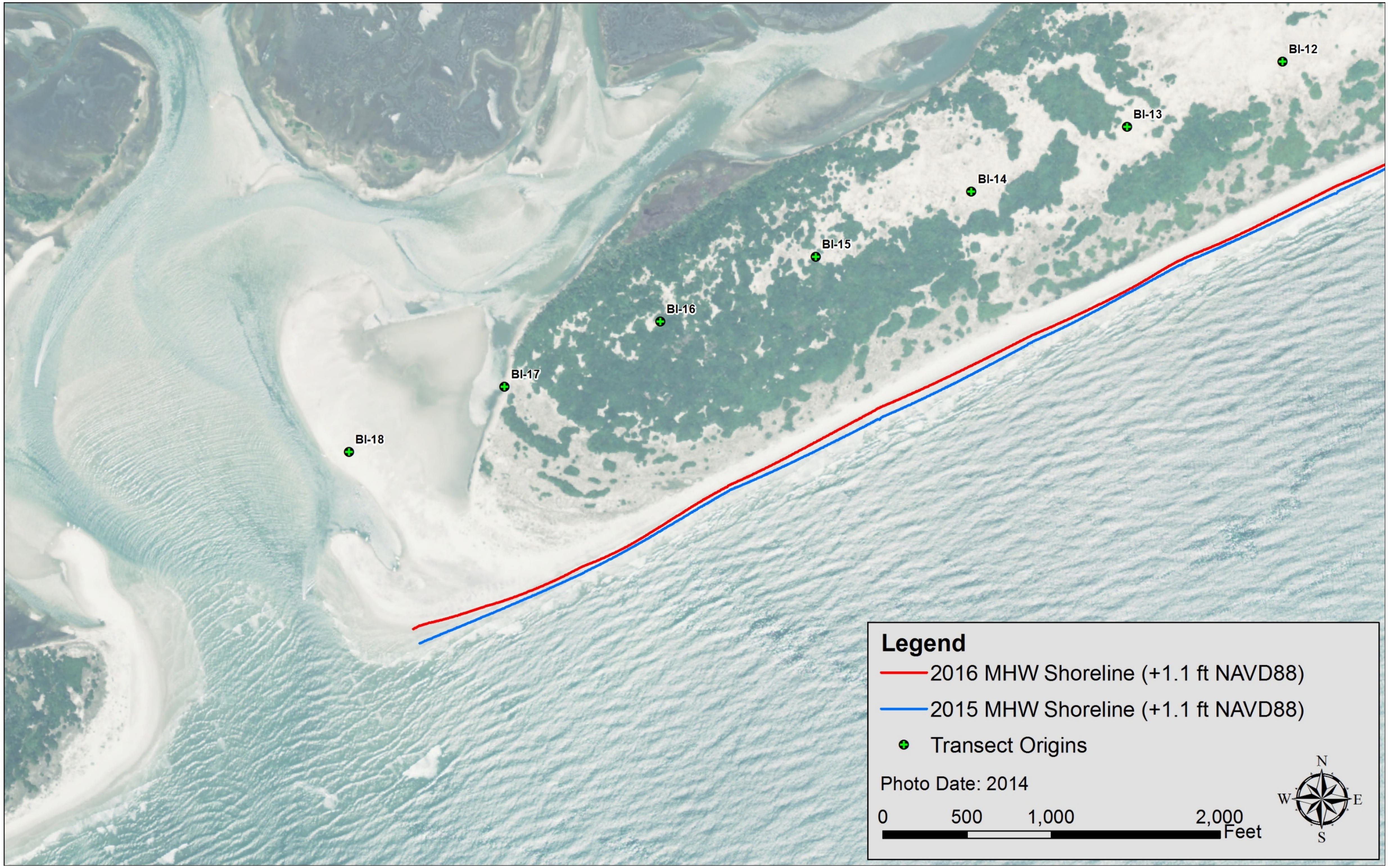


Figure A-20. 2015 and 2016 MHW Shoreline Positions

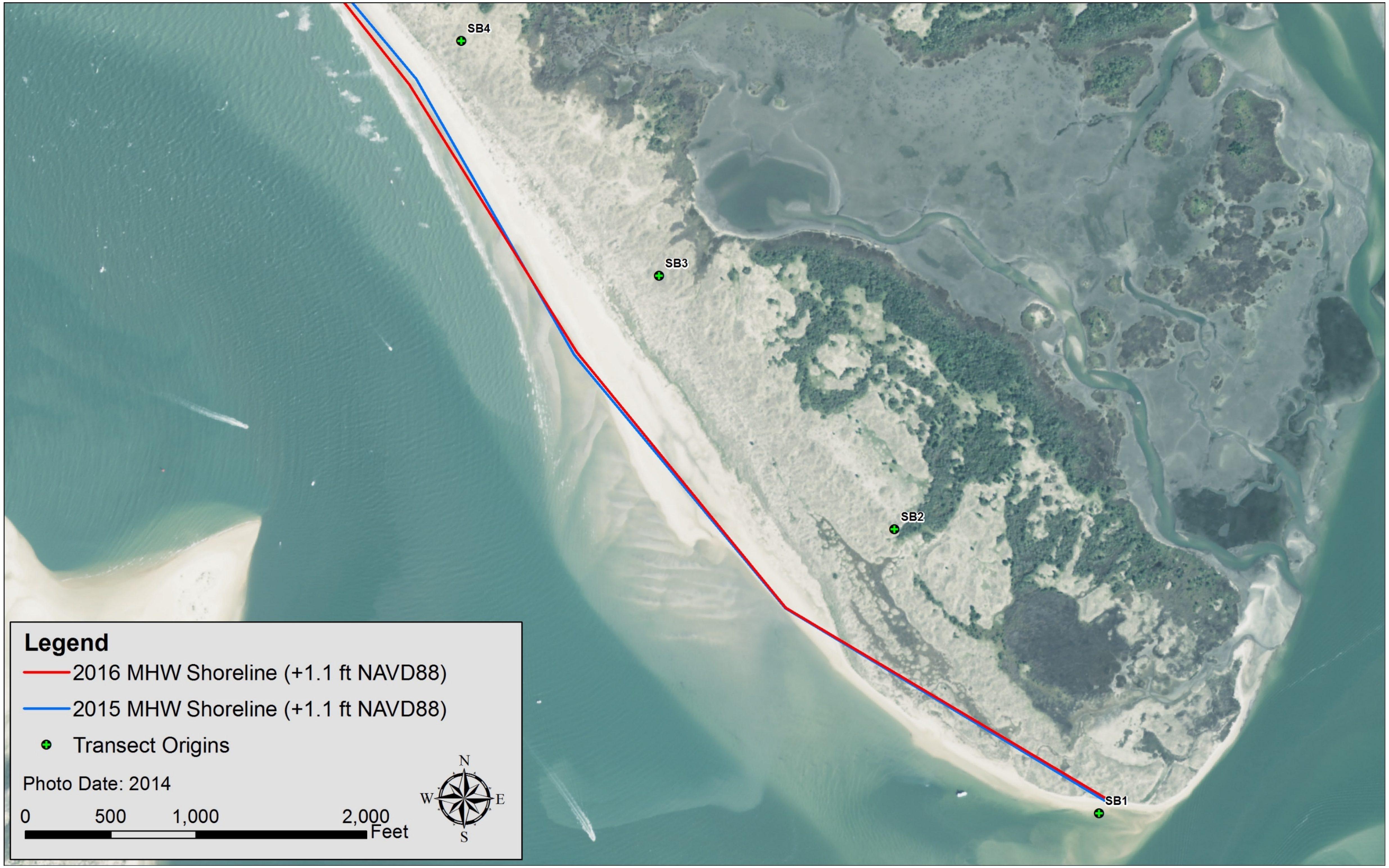


Figure A-21. Shackleford Banks 2015 and 2016 MHW Shoreline Positions

Figure A-22. Shackleford Banks 2015 and 2016 MHW Shoreline Positions

Figure A-23. Shackleford Banks 2015 and 2016 MHW Shoreline Positions

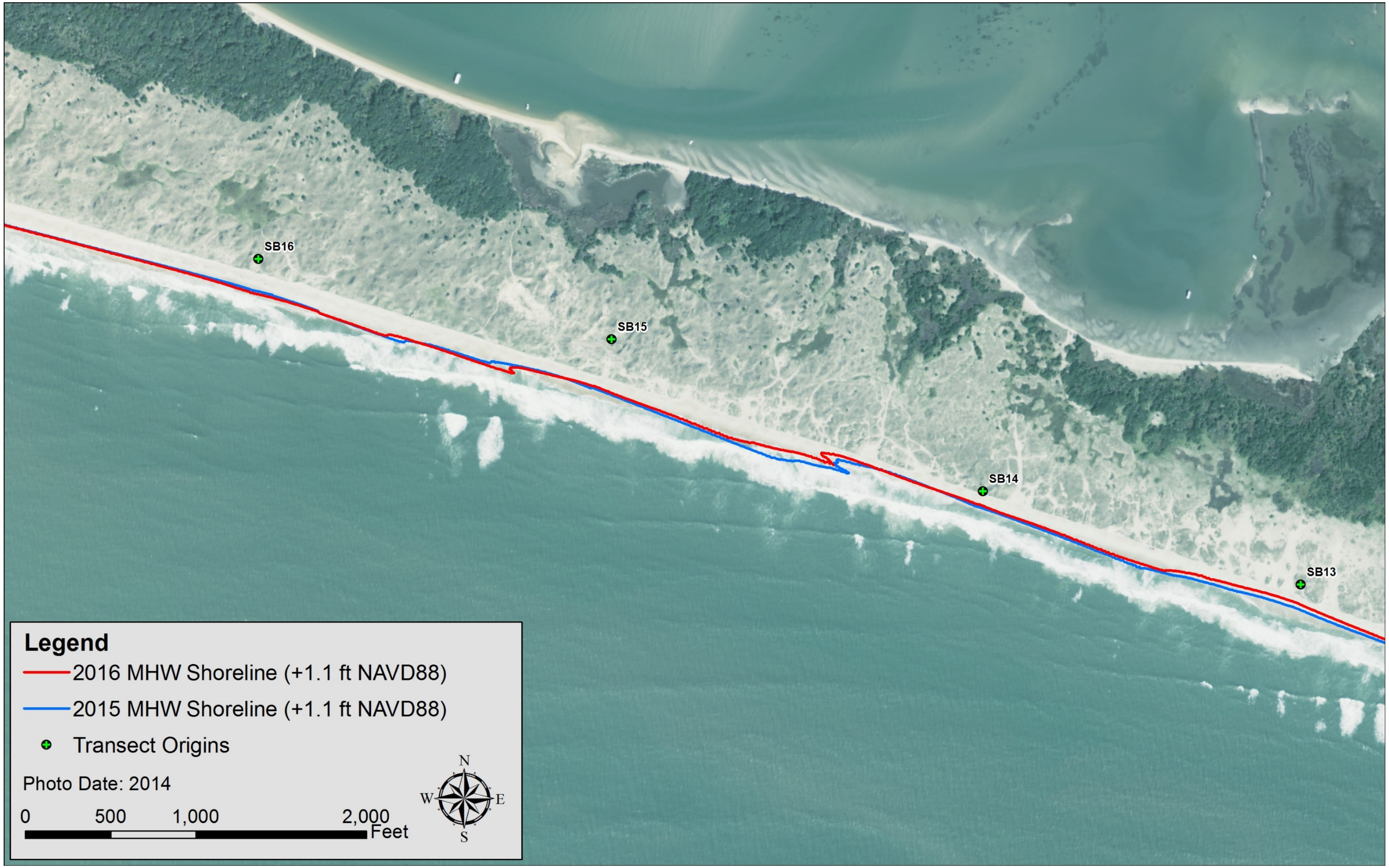


Figure A-24. Shackleford Banks 2015 and 2016 MHW Shoreline Positions

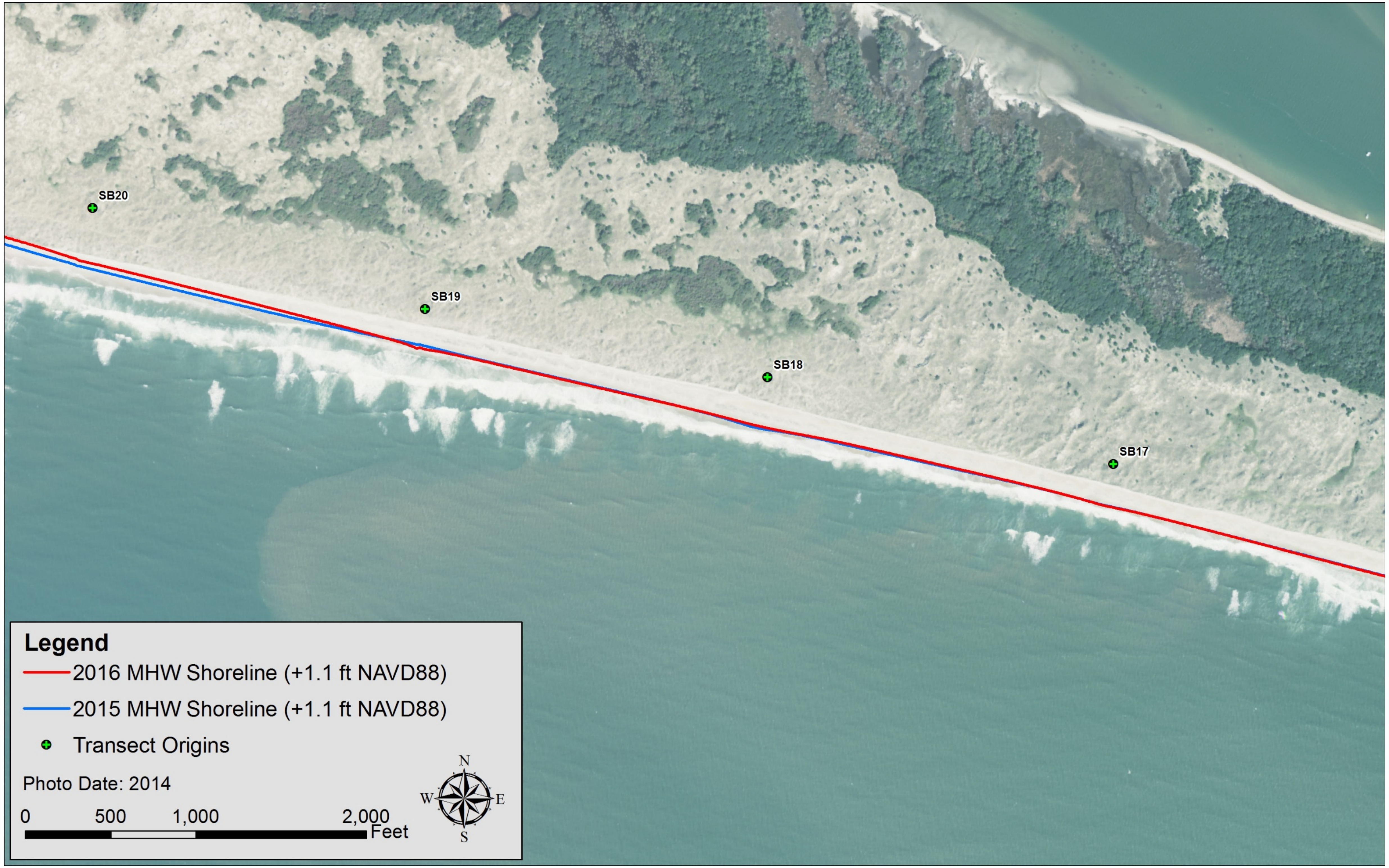


Figure A-25. Shackleford Banks 2015 and 2016 MHW Shoreline Positions

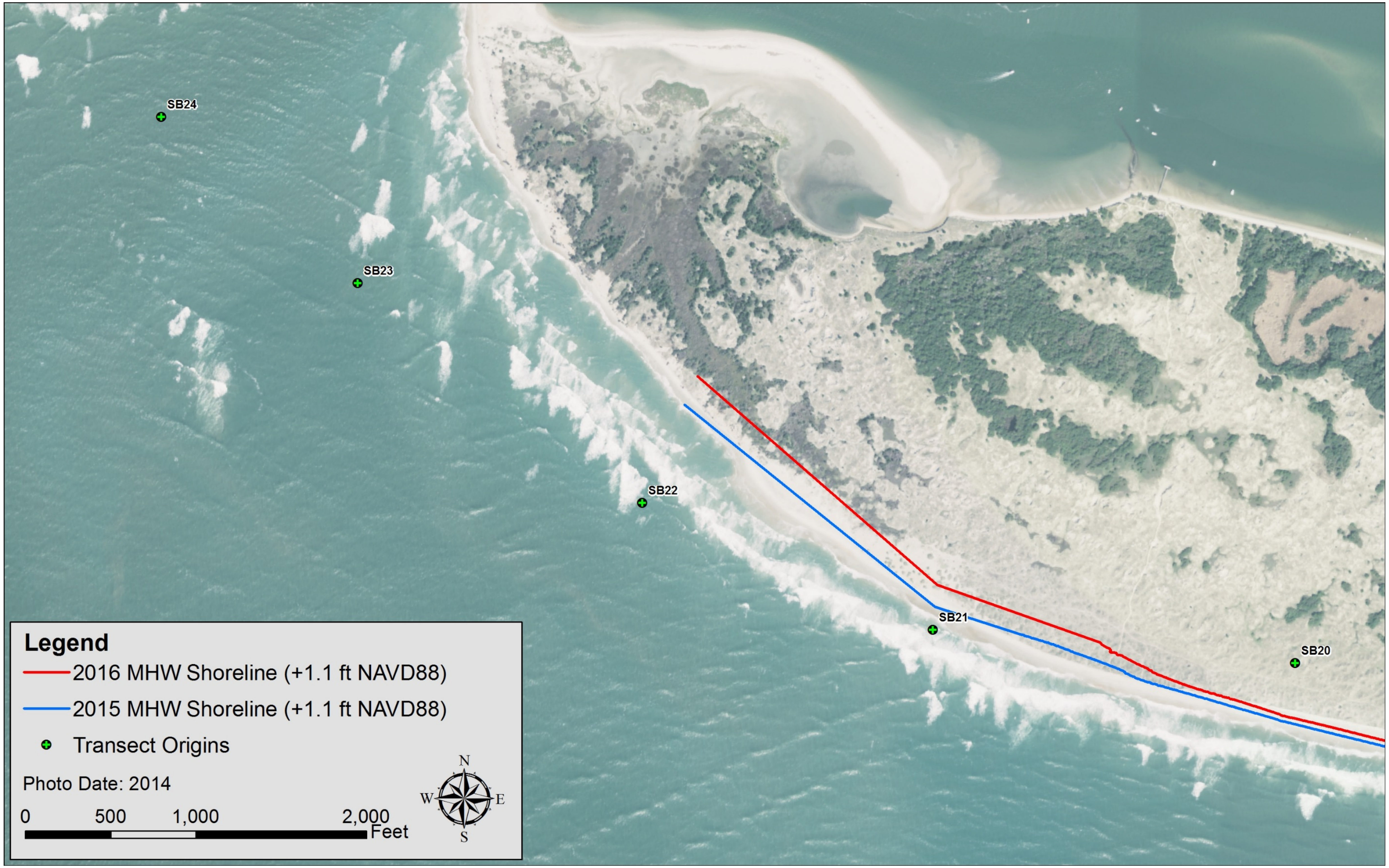


Figure A-26. Shackleford Banks 2015 and 2016 MHW Shoreline Positions

APPENDIX B

Shoreline & Volume Change Plots

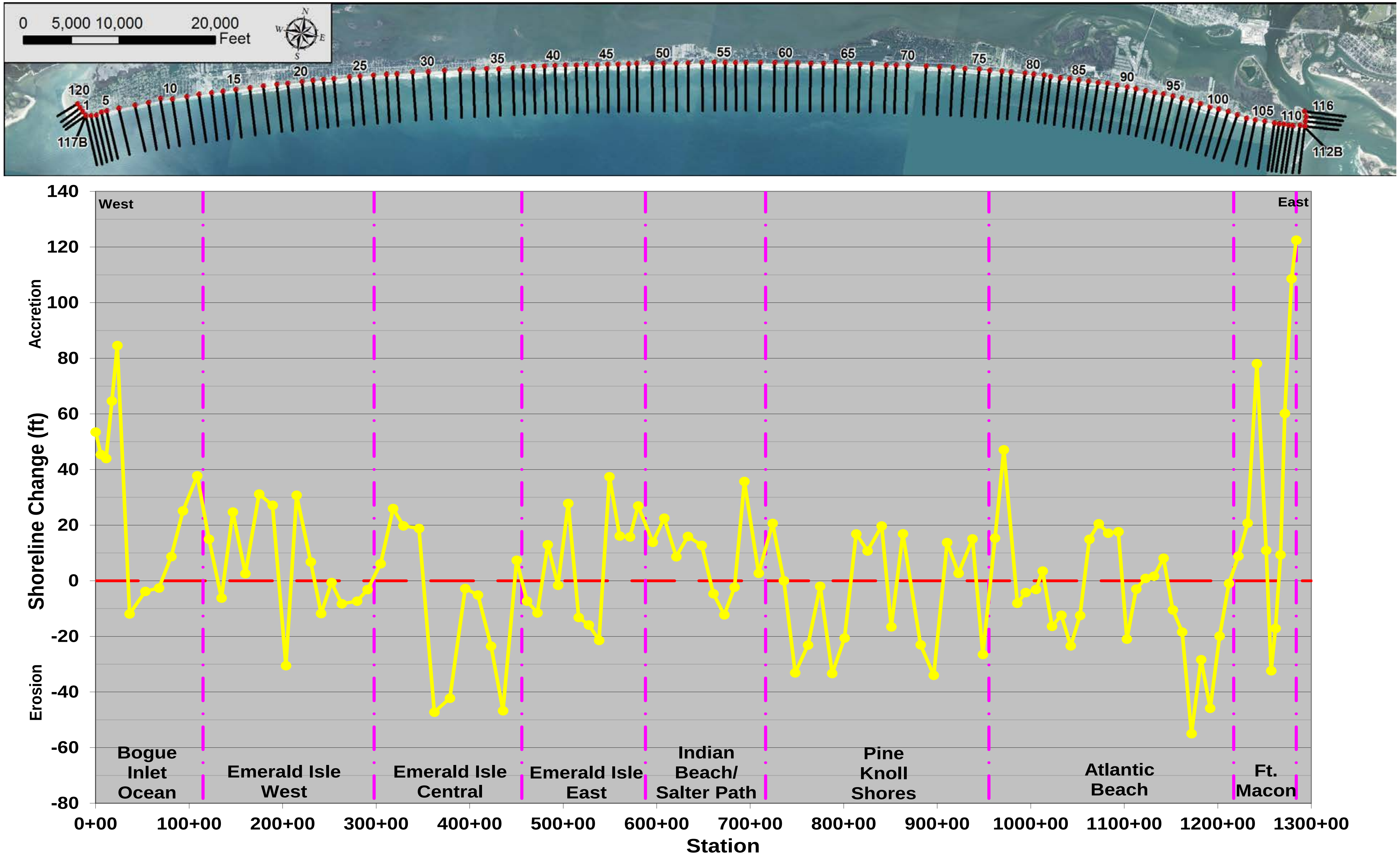


Figure B-1. Shoreline Change for Bogue Banks (2015 - 2016)

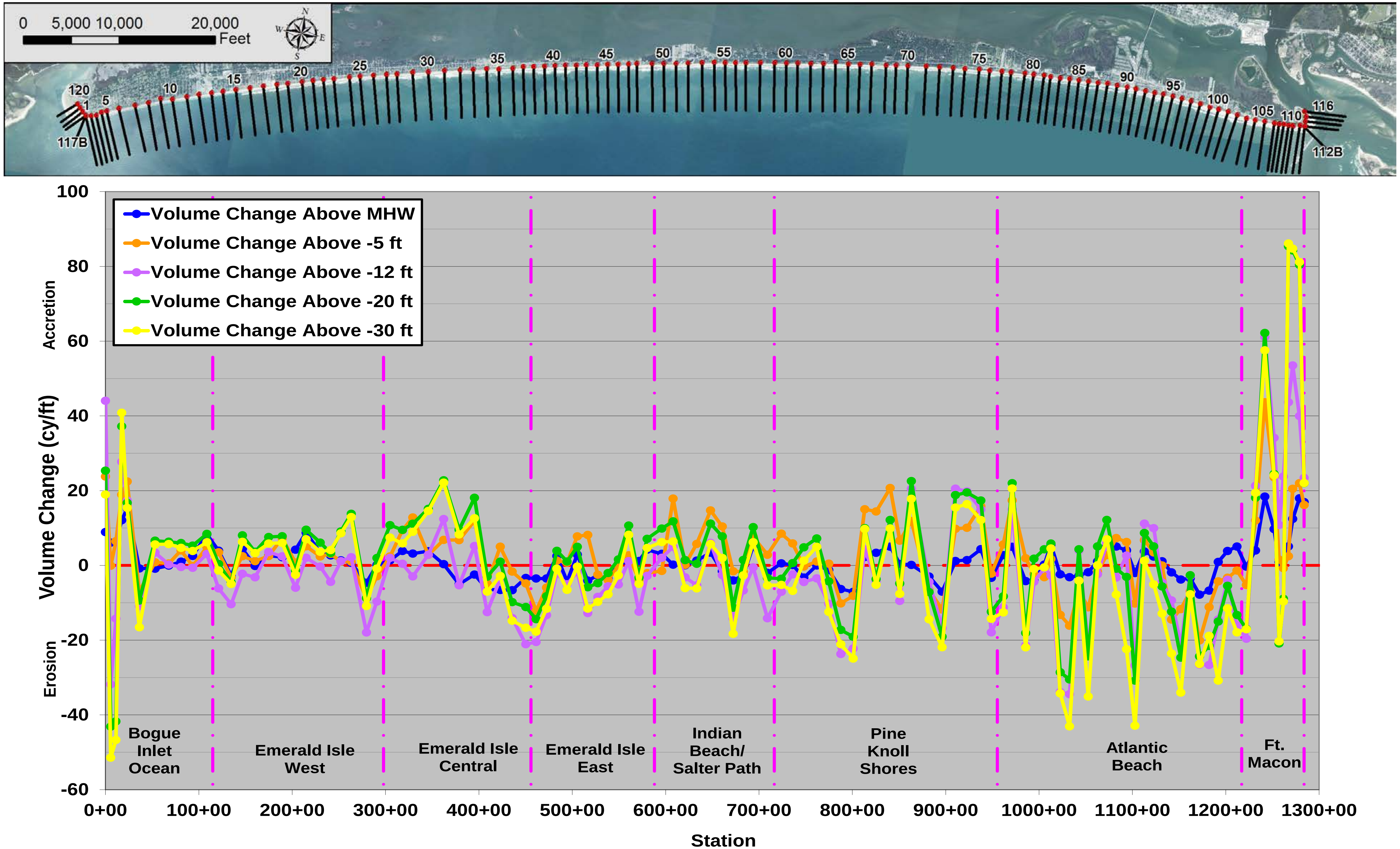


Figure B-2. Volume Change for Bogue Banks (2015 - 2016)

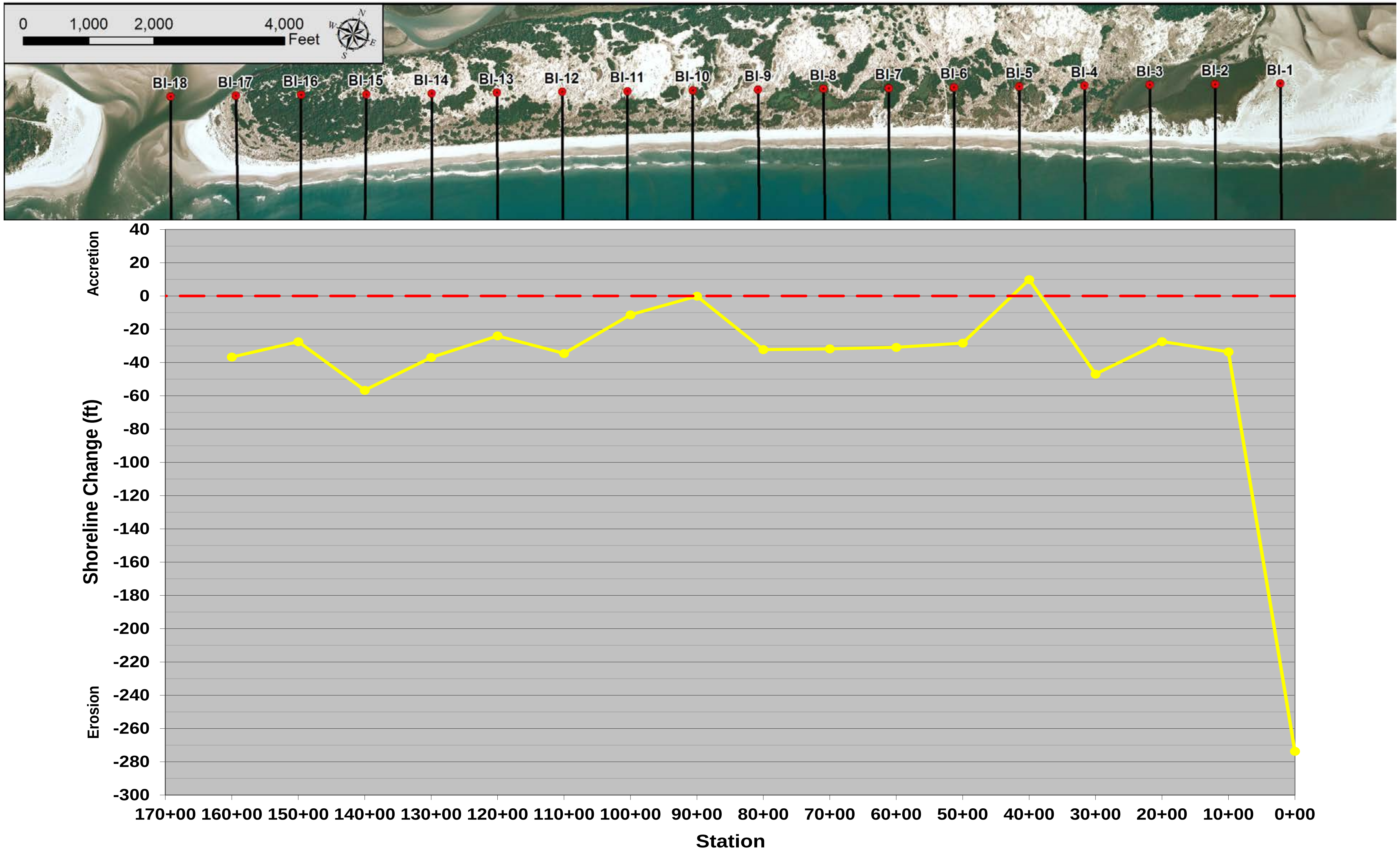


Figure B-3. Shoreline Change for Bear Island (2015 - 2016)

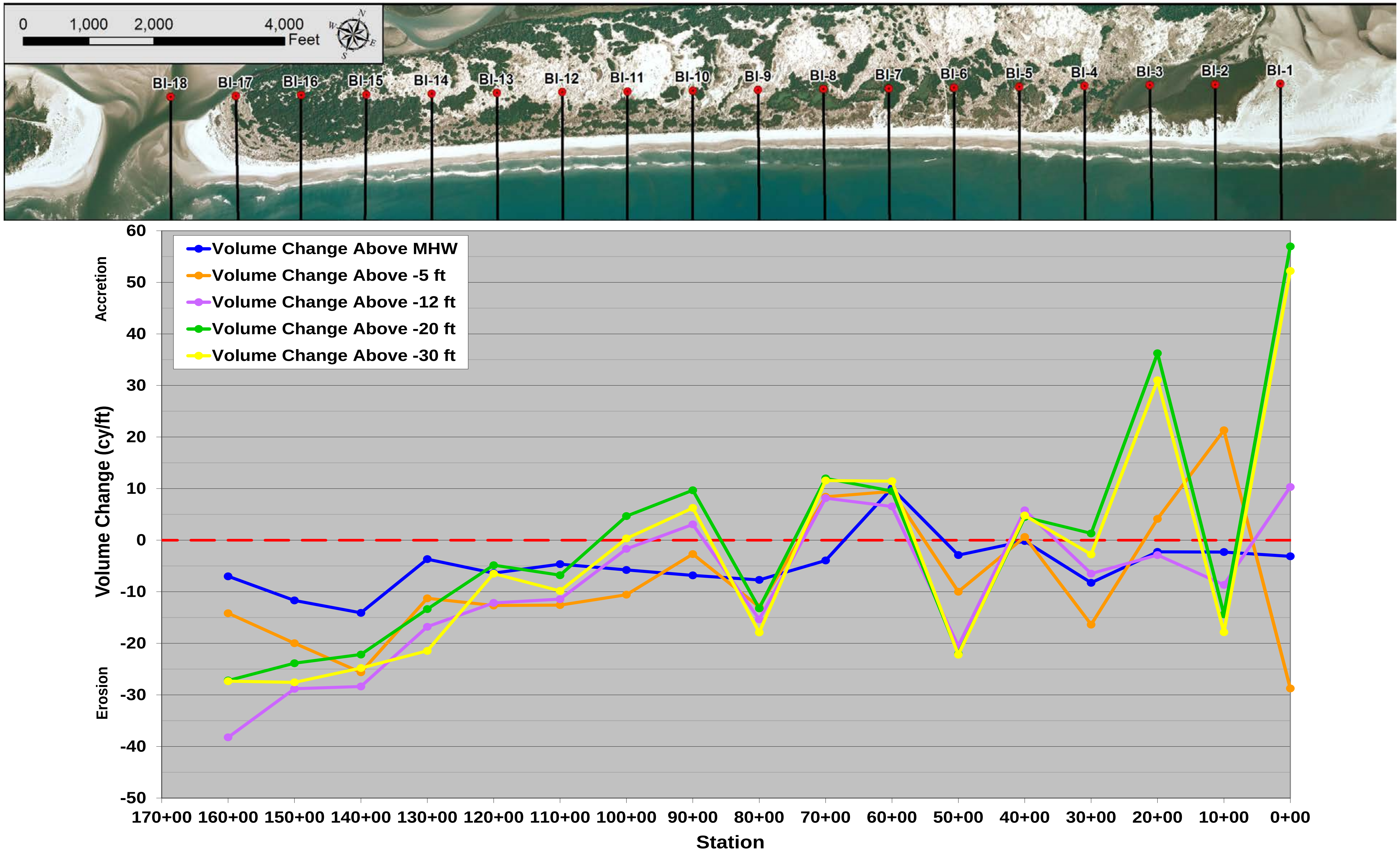


Figure B-4. Volume Change for Bear Island (2015 - 2016)

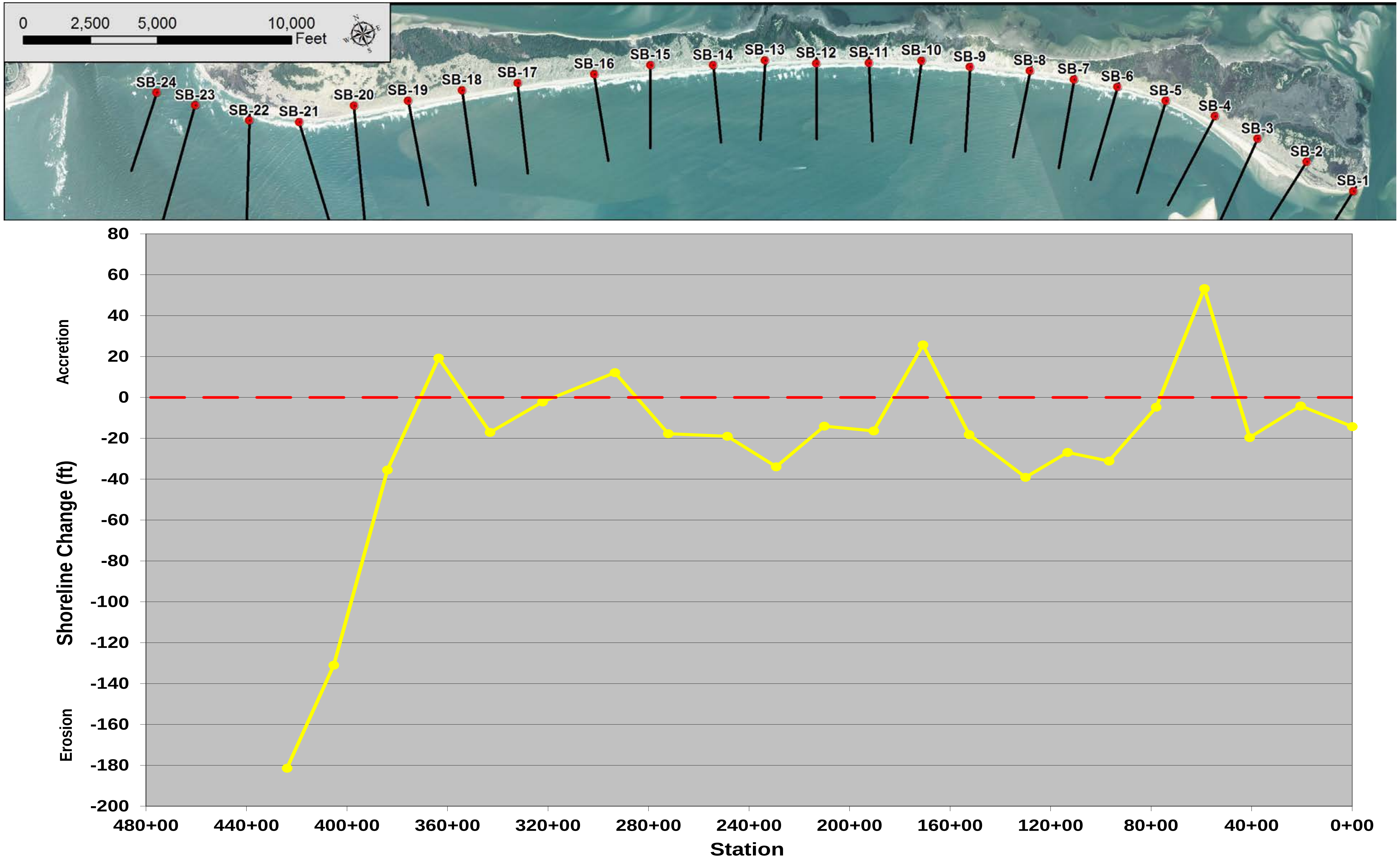


Figure B-5. Shoreline Change for Shackleford Banks (2015 - 2016)

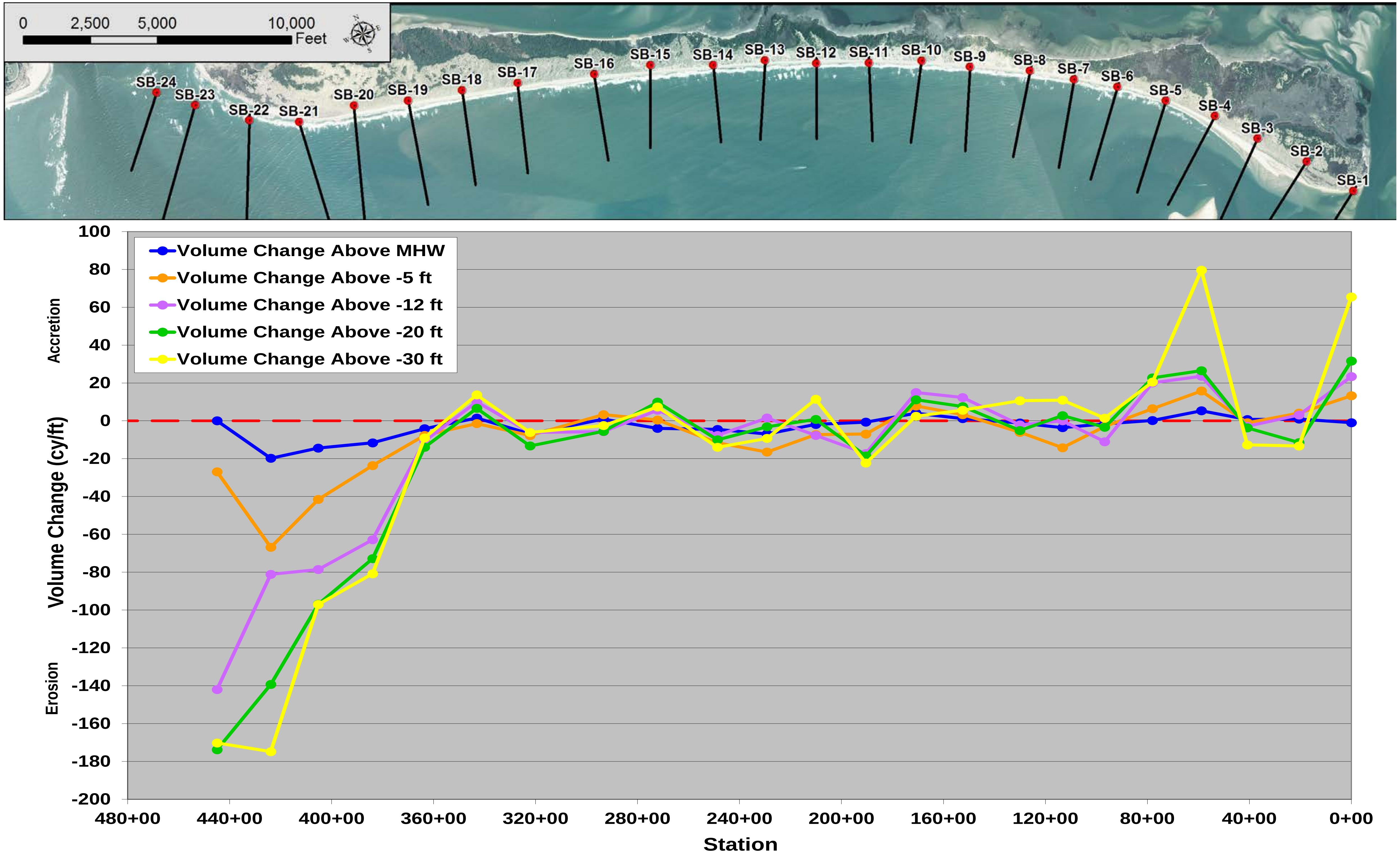


Figure B-6. Volume Change for Shackleford Banks (2015 - 2016)

APPENDIX C

Survey Profile Comparison Plots

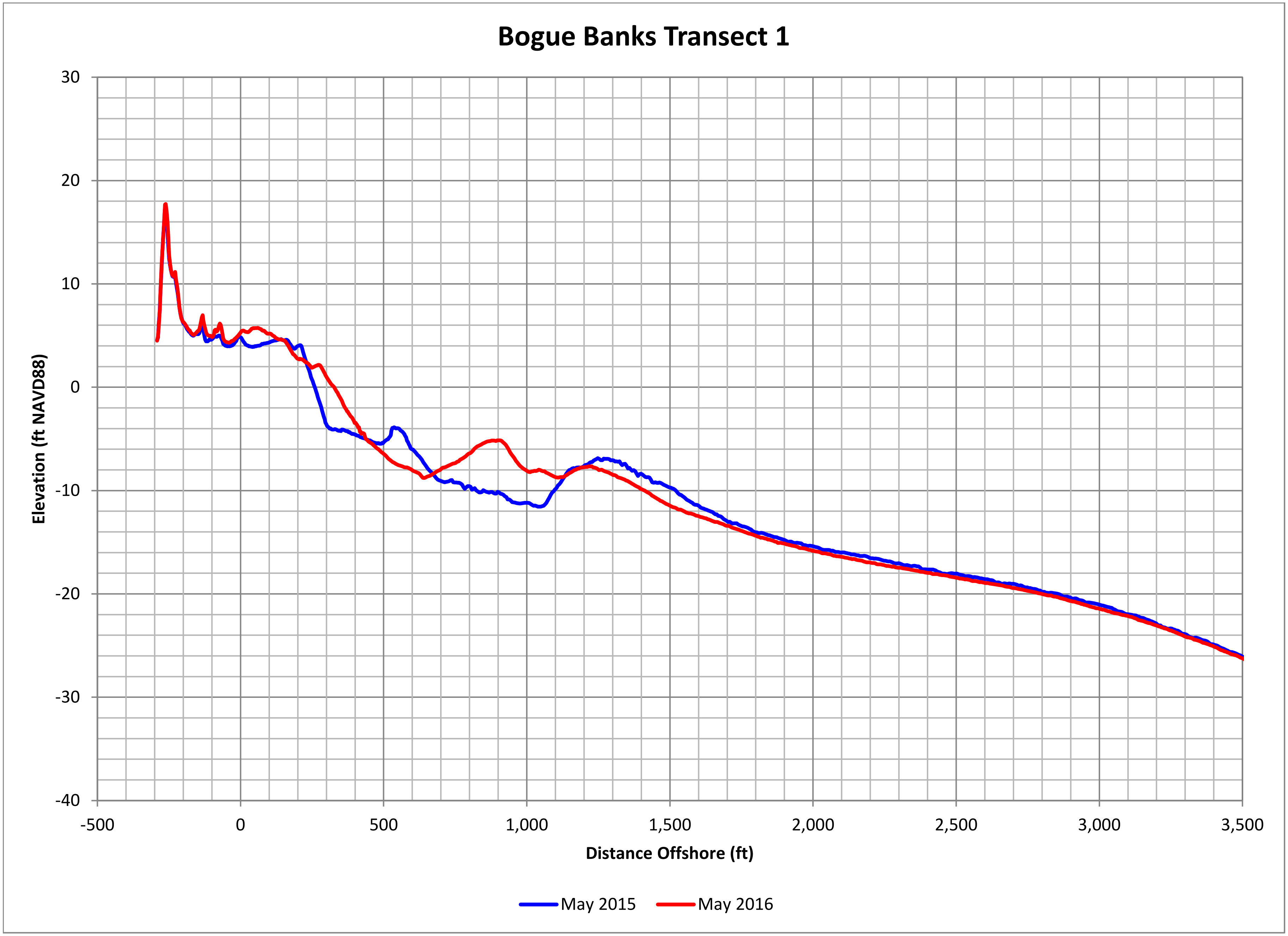


Figure C-1. Bogue Banks Profile Comparison Plot

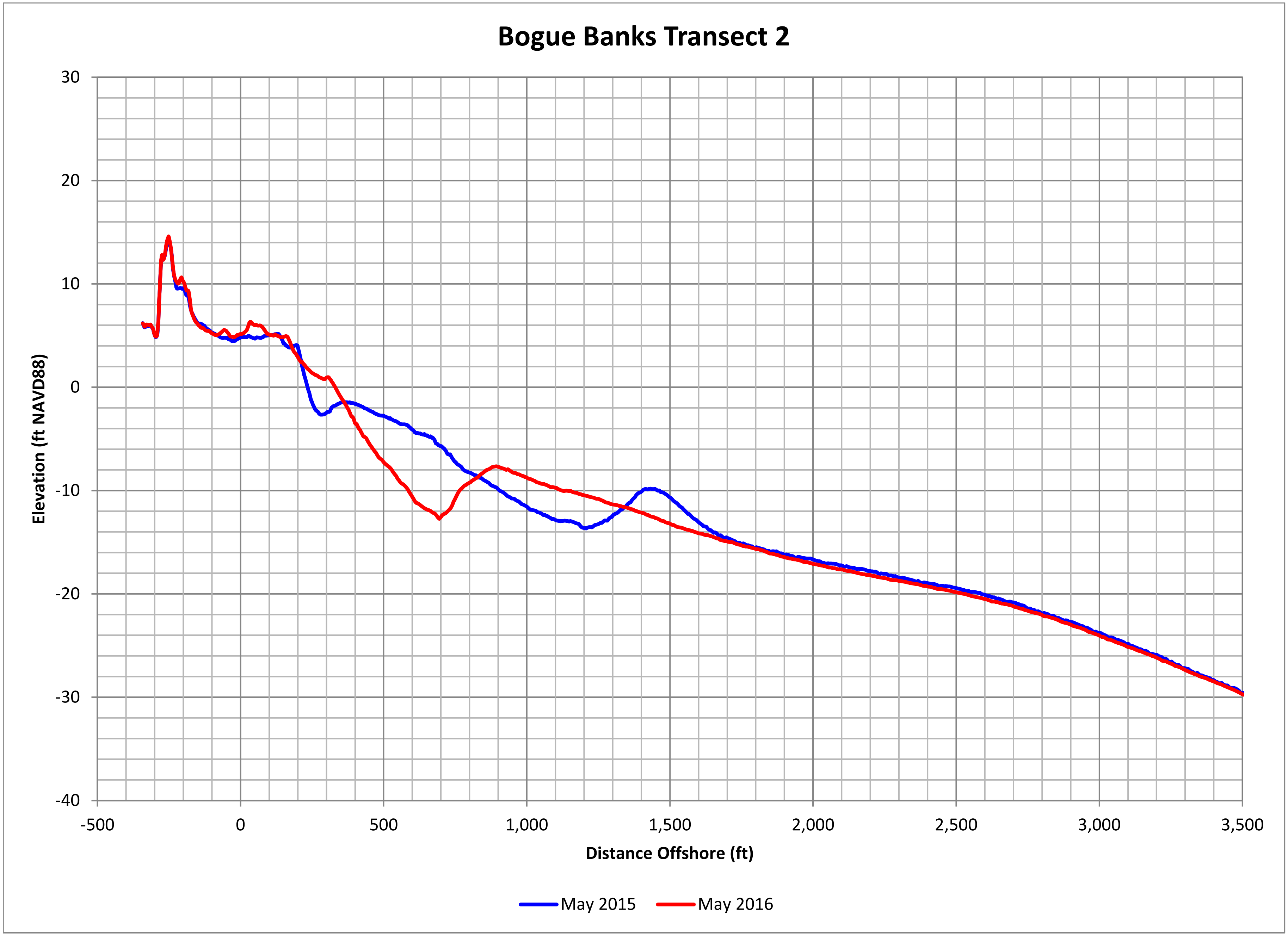


Figure C-2. Bogue Banks Profile Comparison Plot

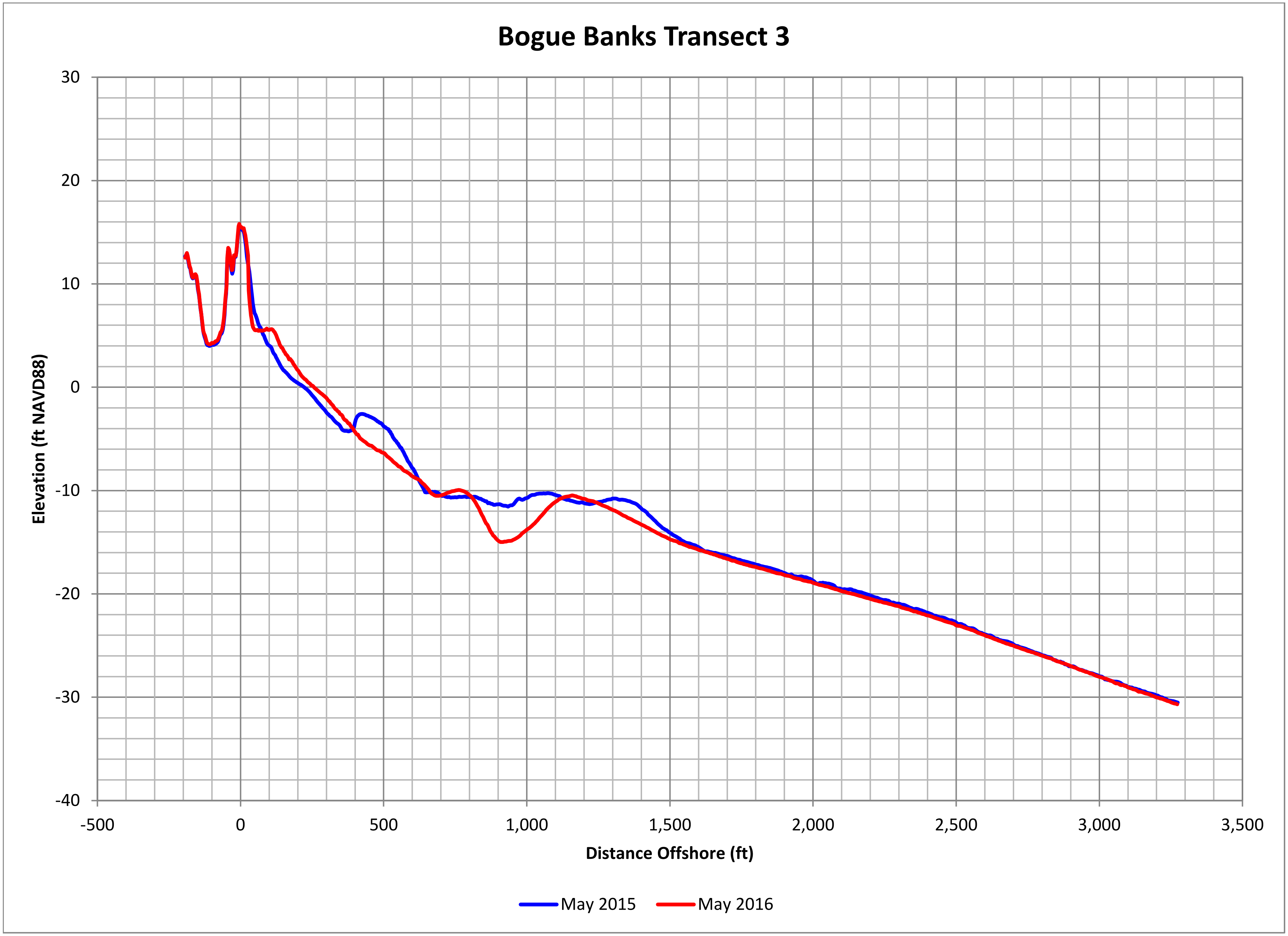


Figure C-3. Bogue Banks Profile Comparison Plot

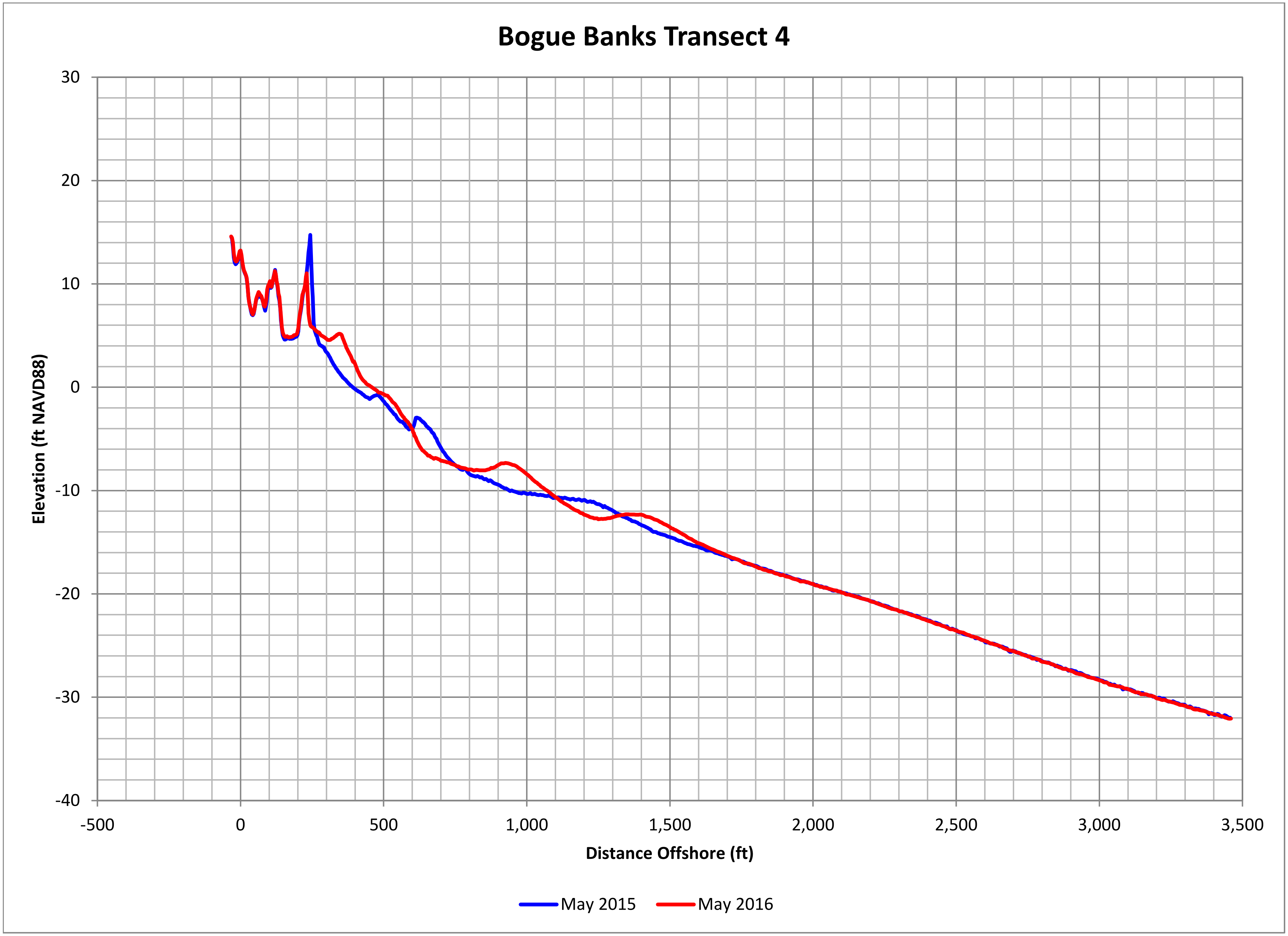


Figure C-4. Bogue Banks Profile Comparison Plot

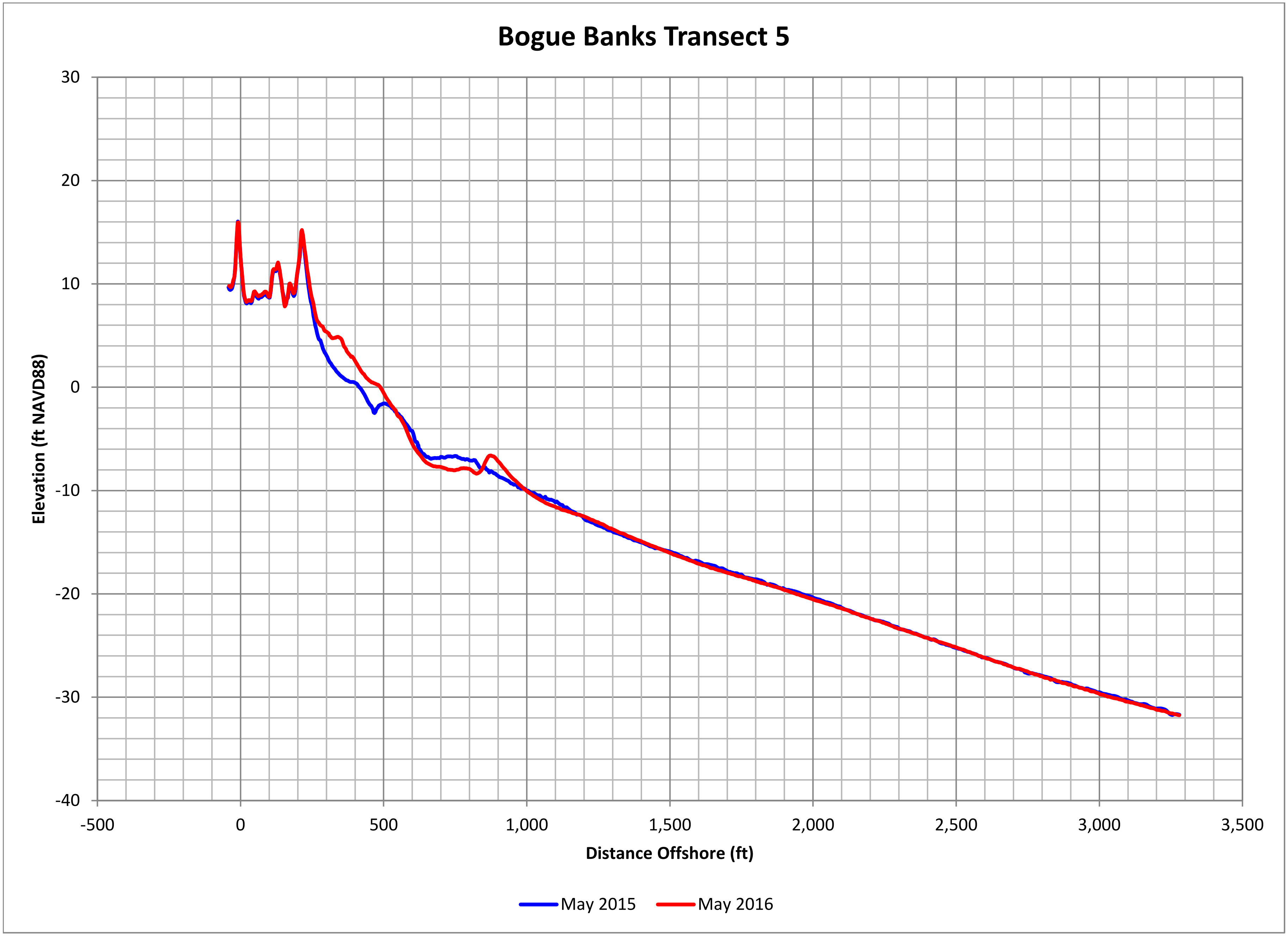


Figure C-5. Bogue Banks Profile Comparison Plot

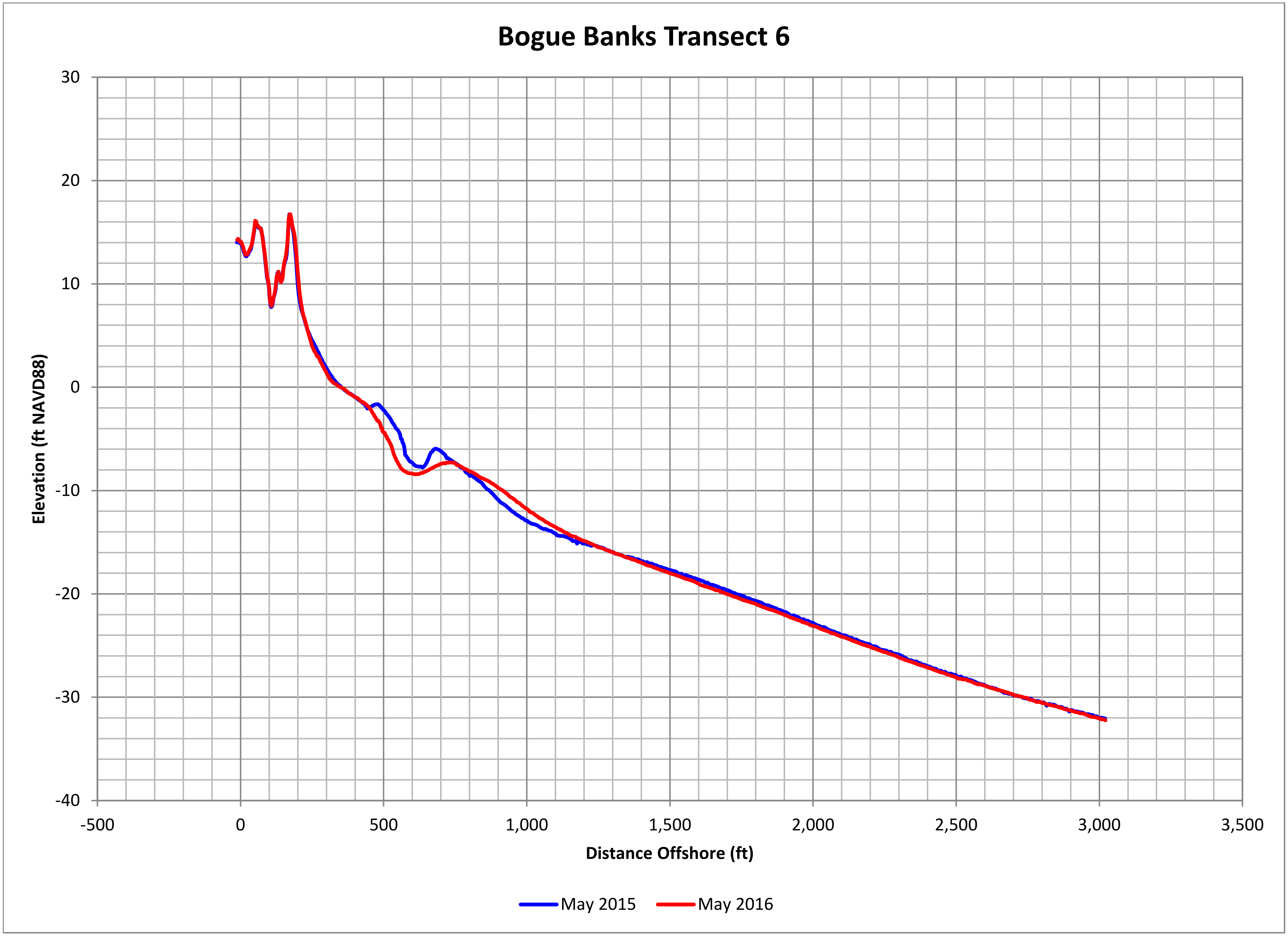


Figure C-6. Bogue Banks Profile Comparison Plot

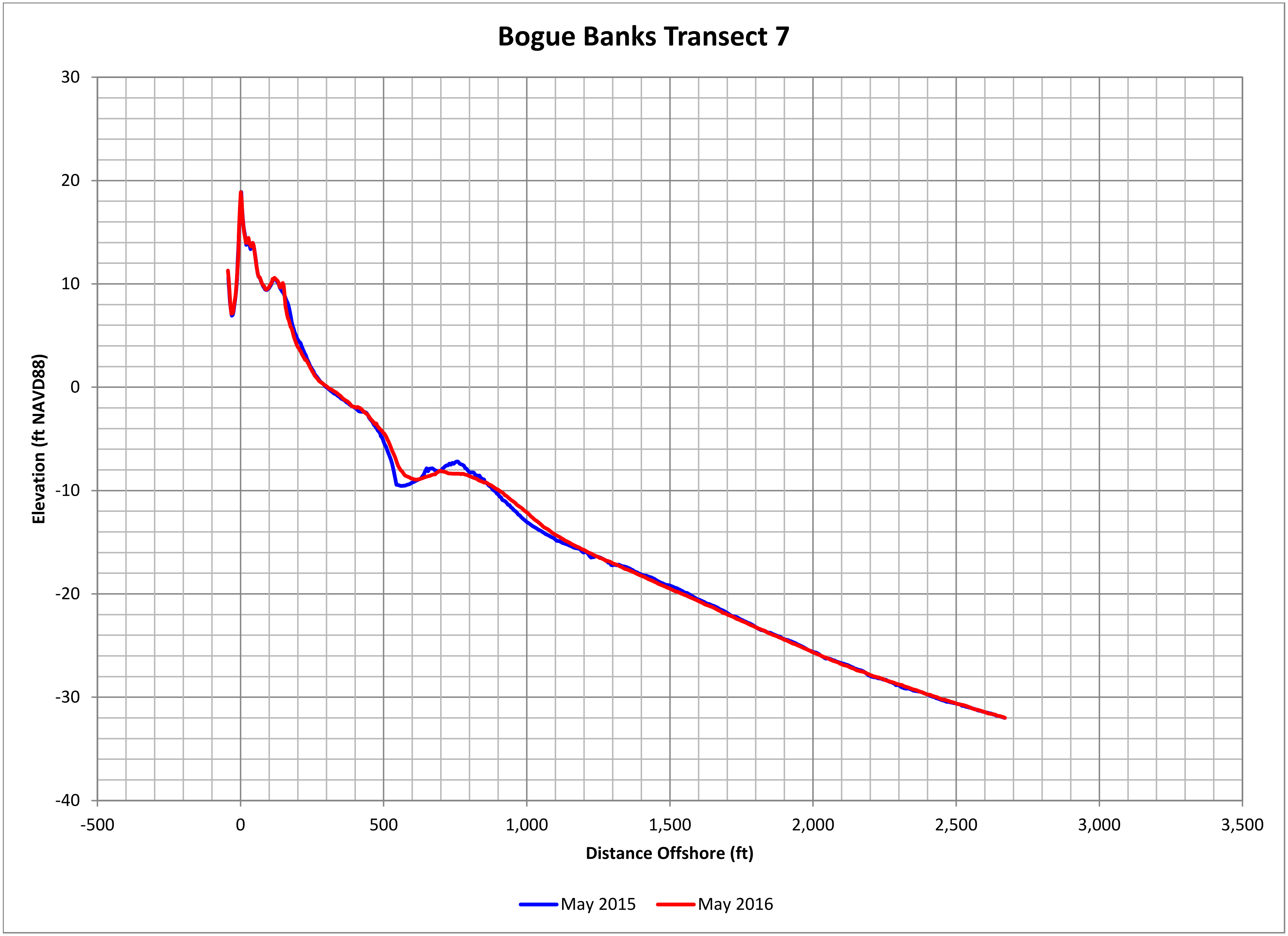


Figure C-7. Bogue Banks Profile Comparison Plot

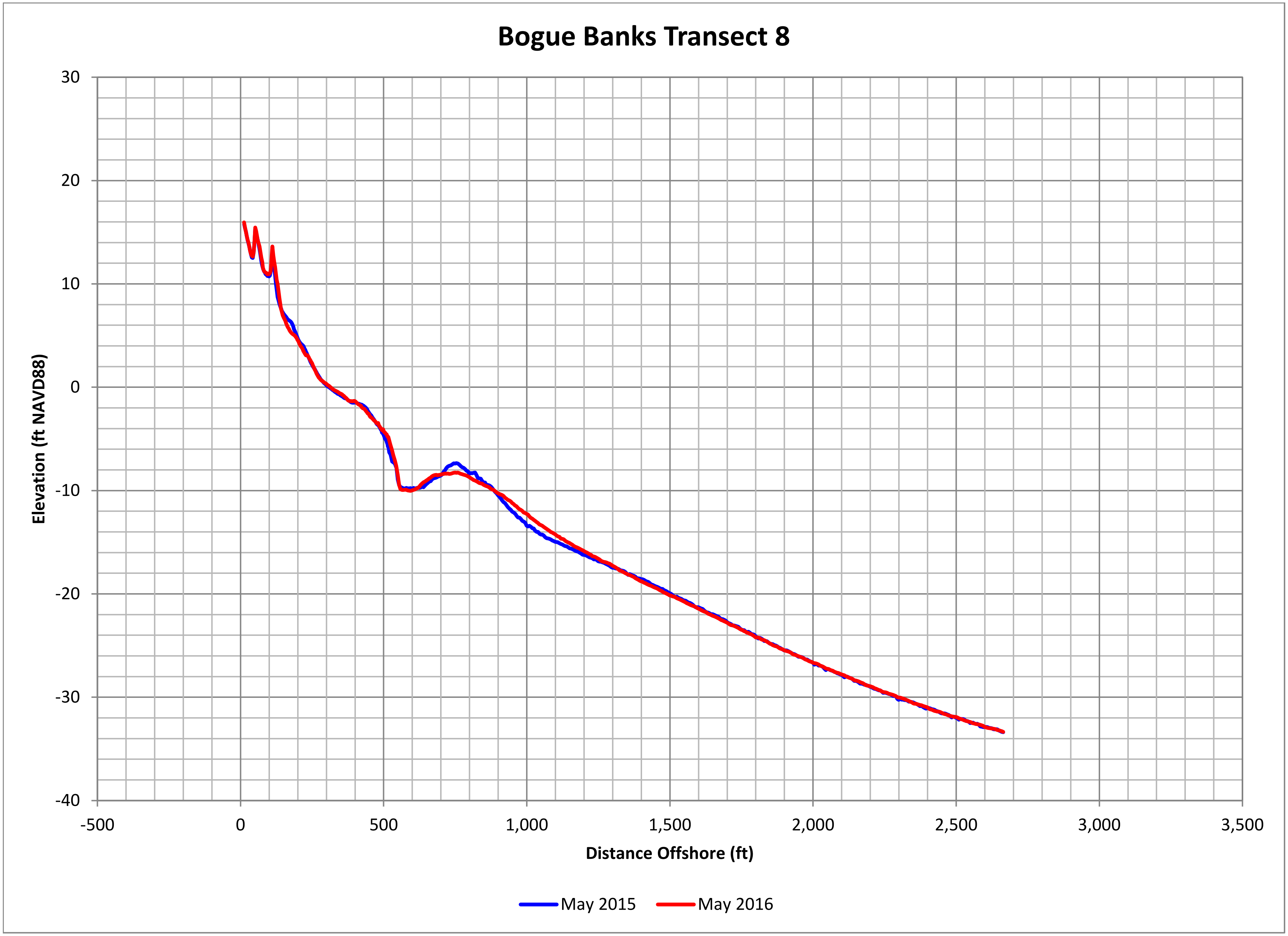


Figure C-8. Bogue Banks Profile Comparison Plot

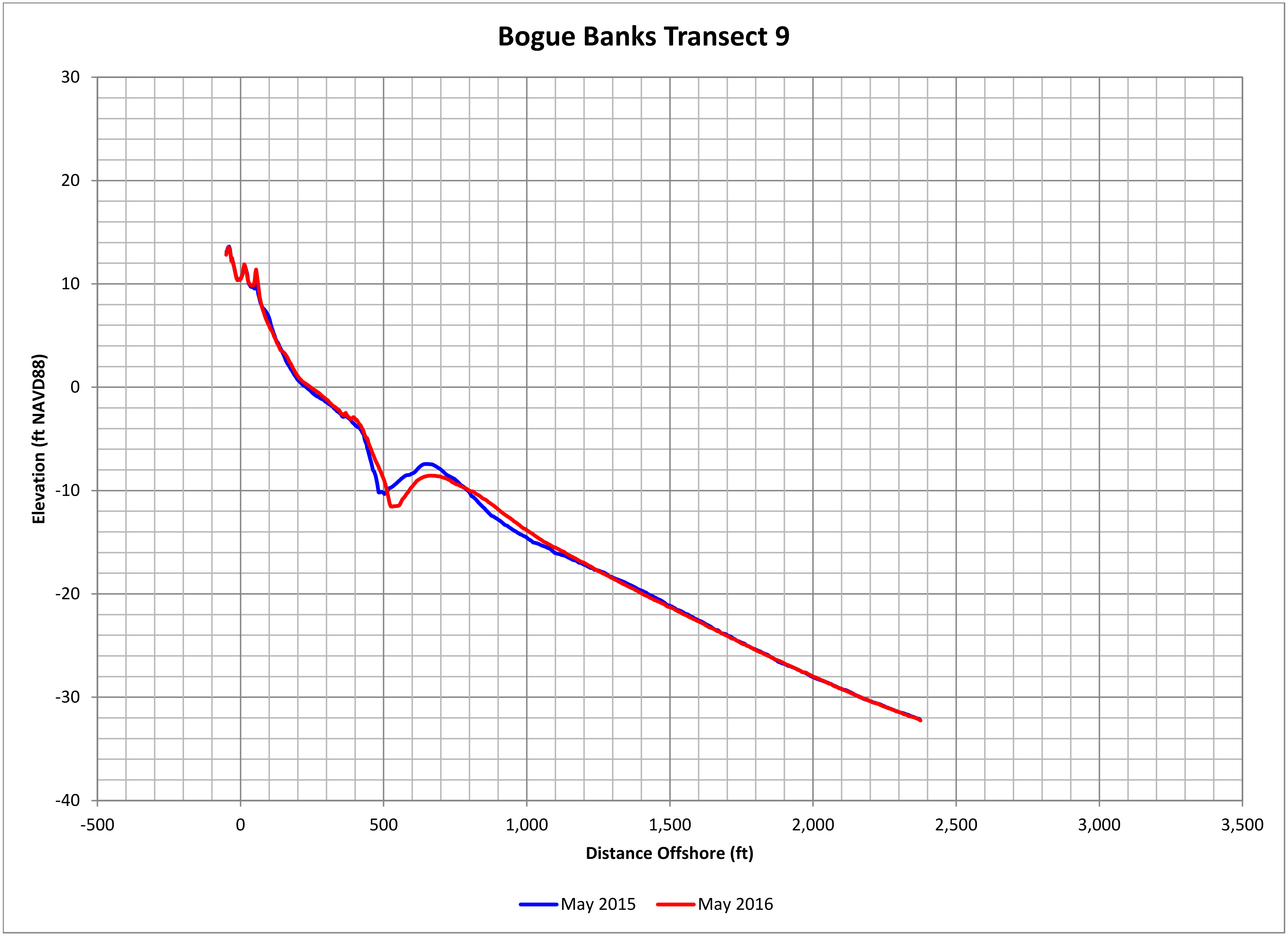


Figure C-9. Bogue Banks Profile Comparison Plot

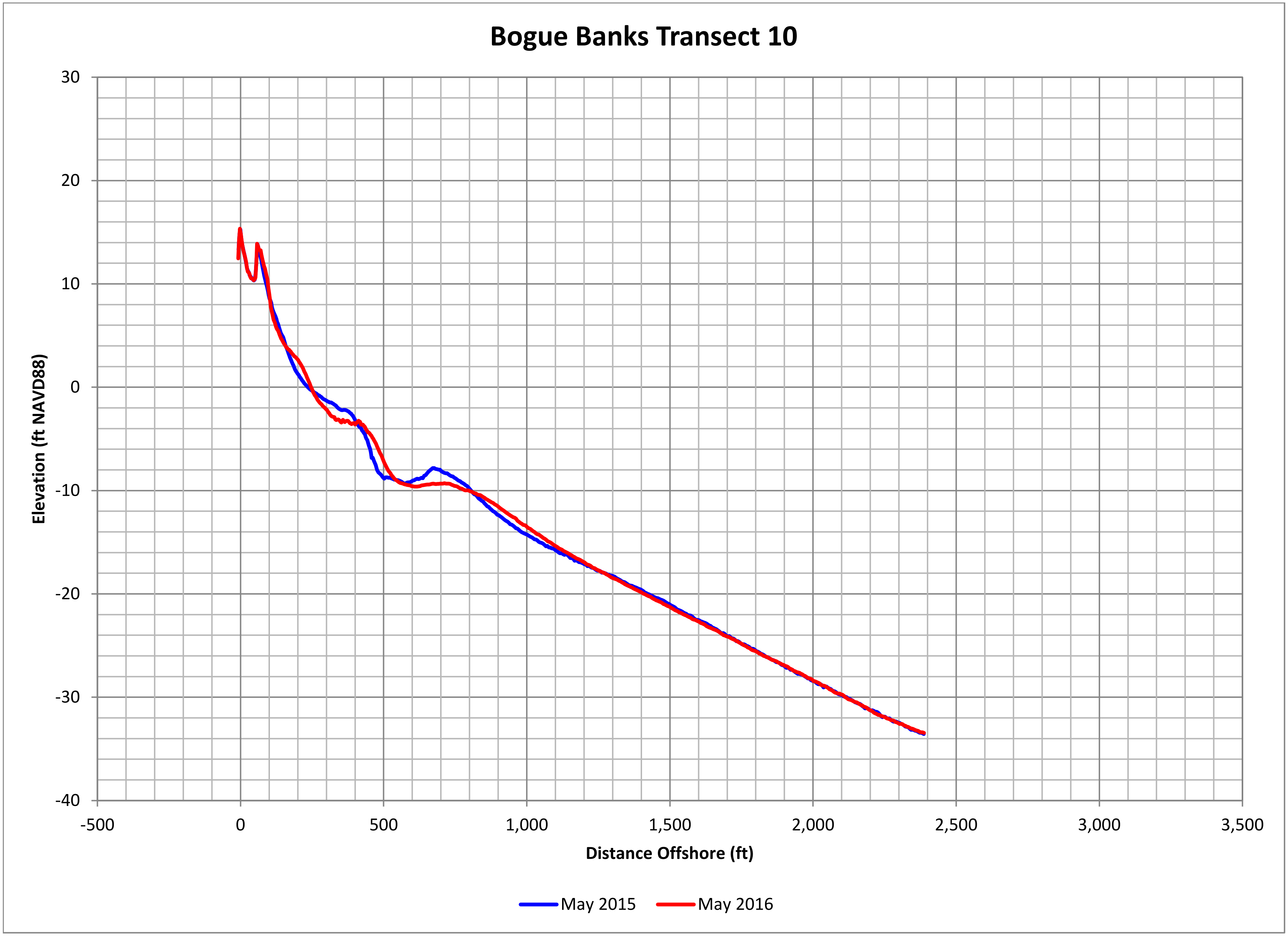


Figure C-10. Bogue Banks Profile Comparison Plot

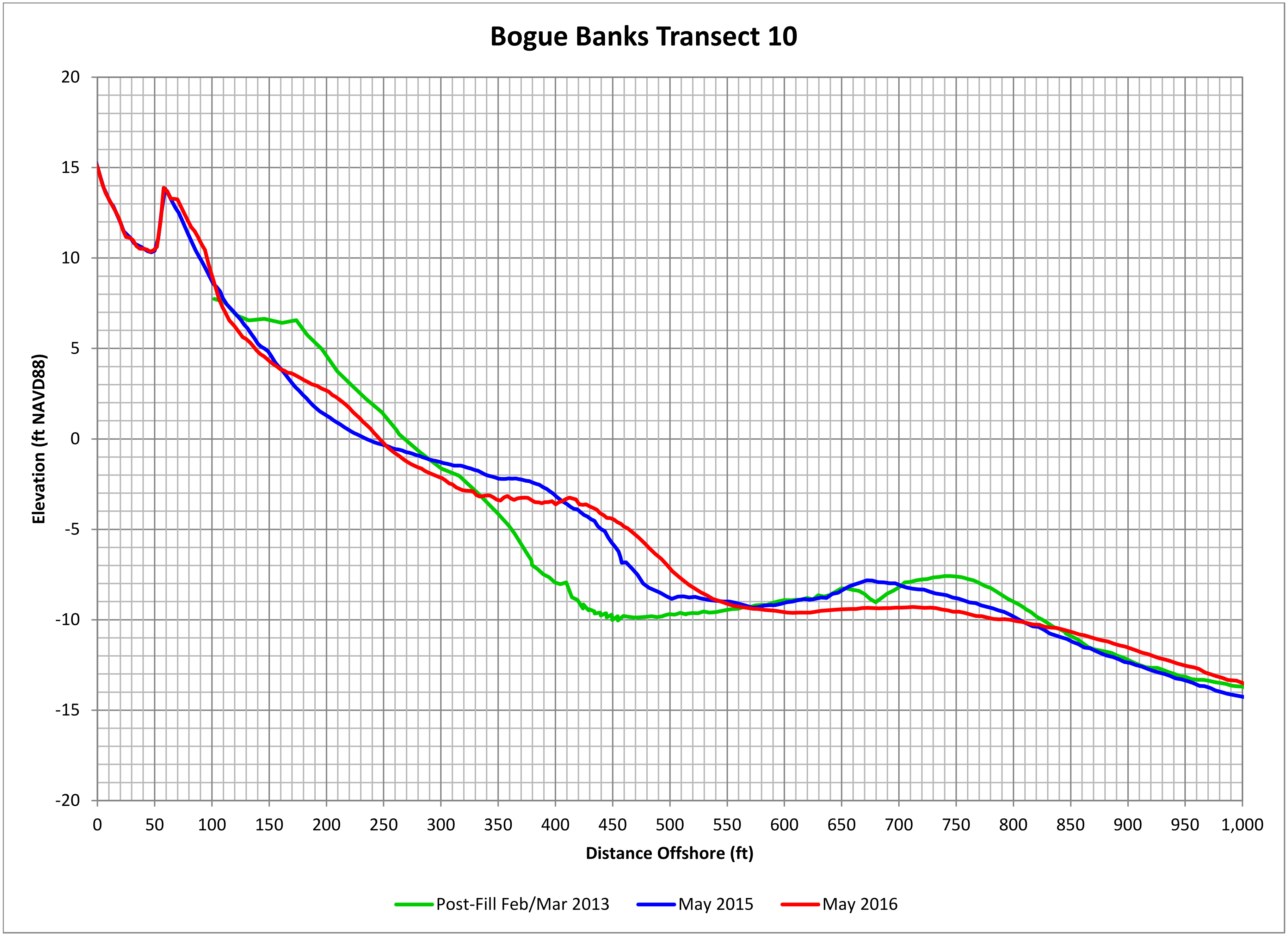


Figure C-11. Bogue Banks Profile Comparison Plot

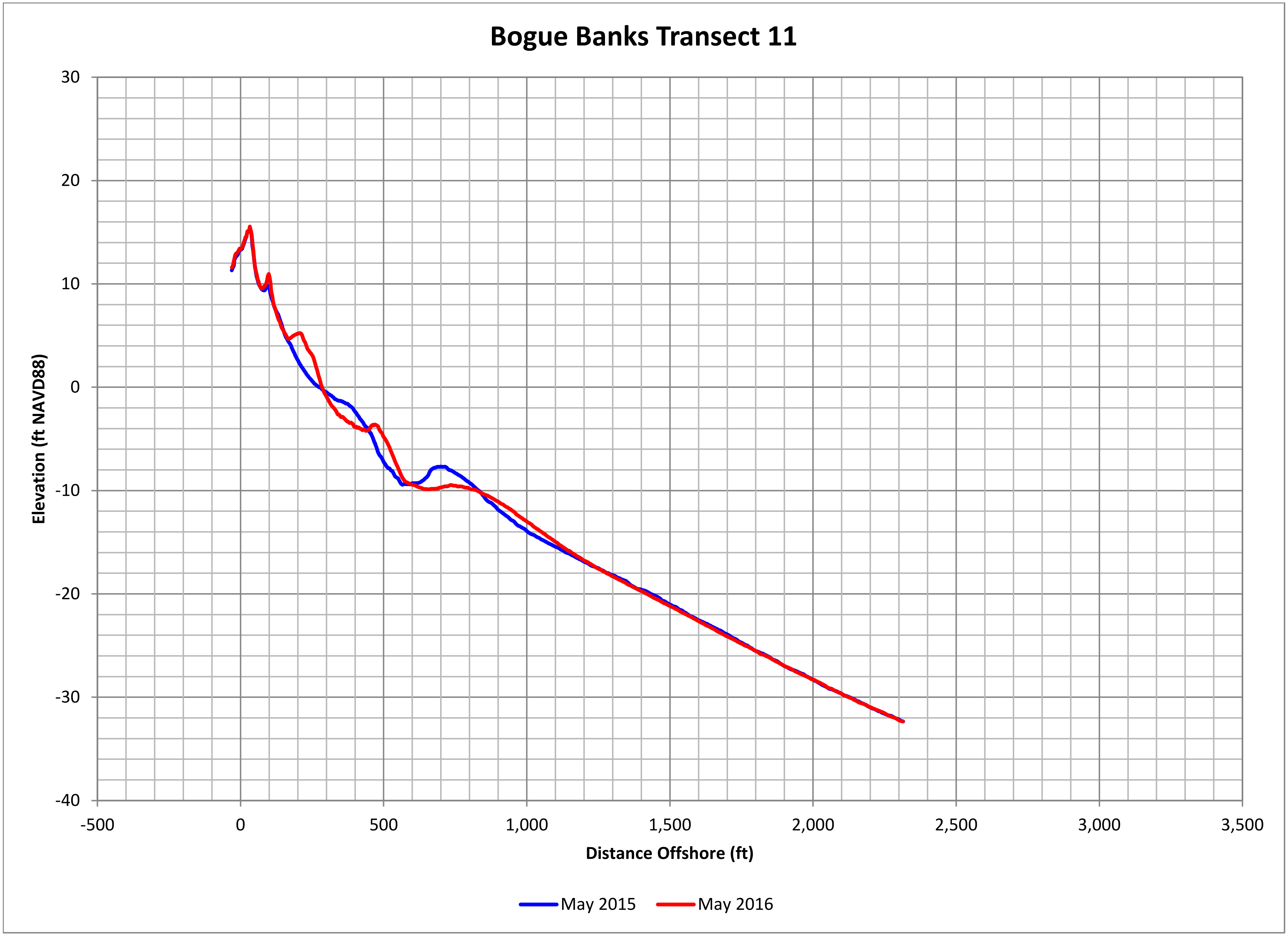


Figure C-12. Bogue Banks Profile Comparison Plot

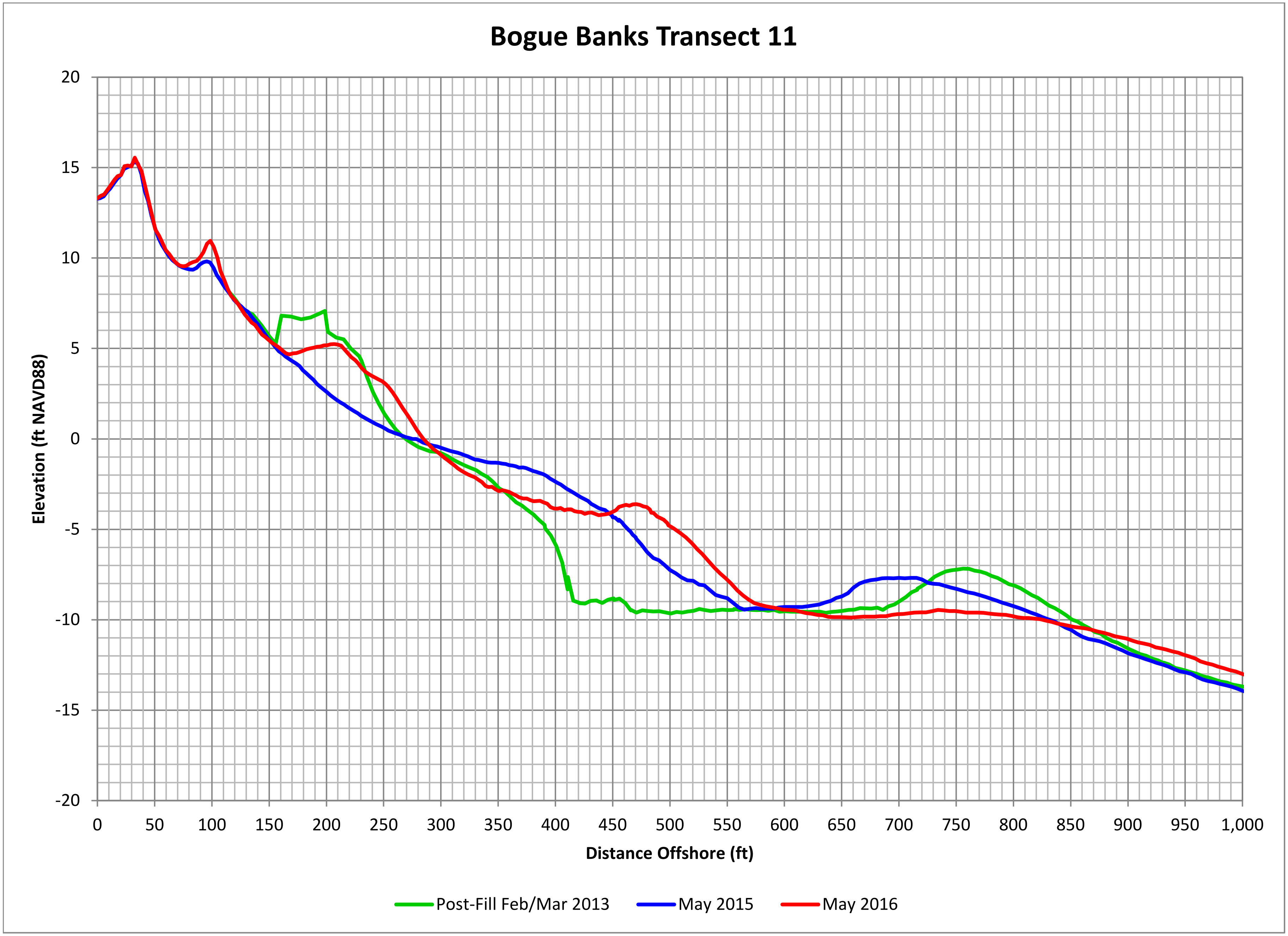


Figure C-13. Bogue Banks Profile Comparison Plot

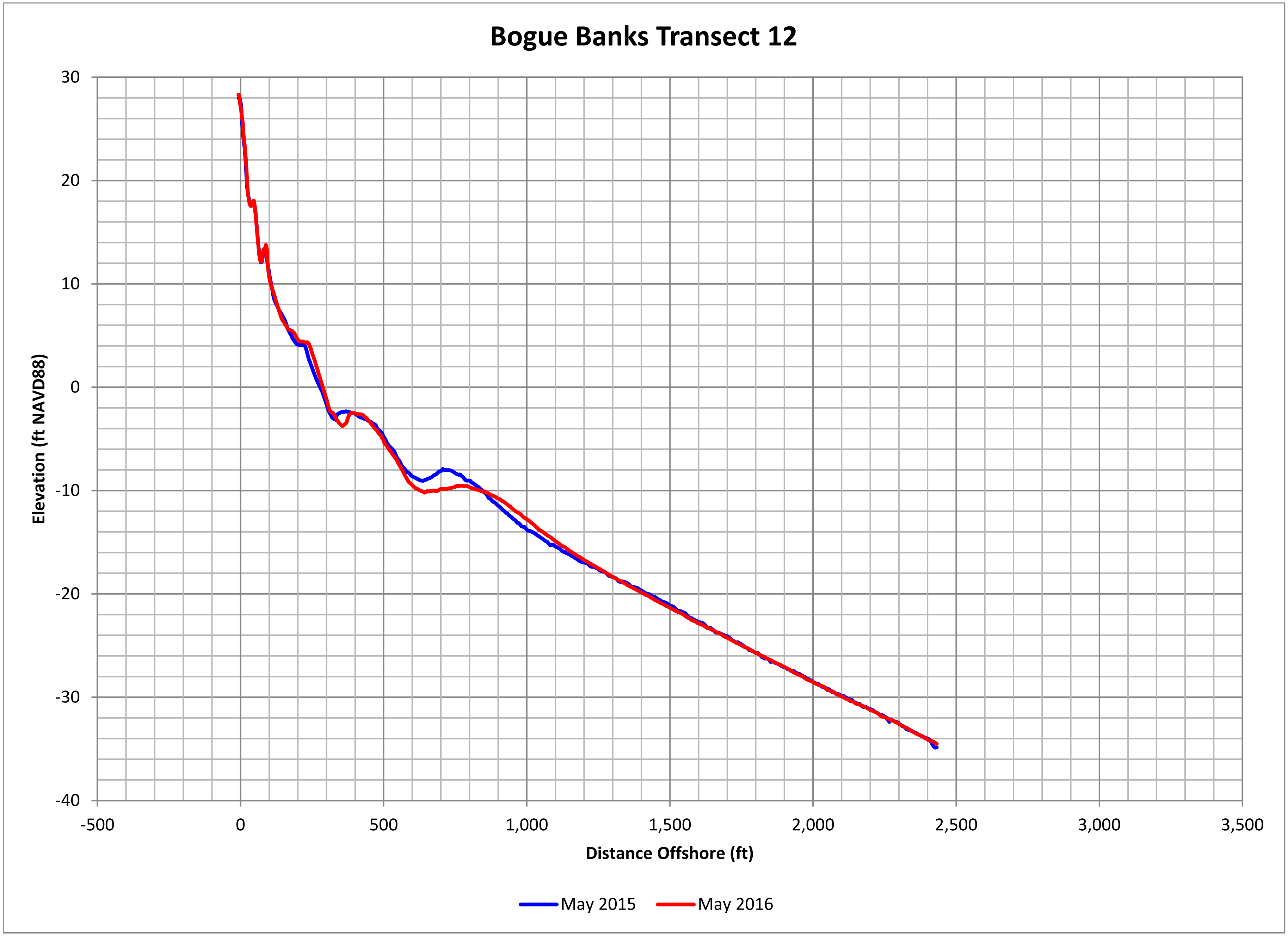


Figure C-14. Bogue Banks Profile Comparison Plot

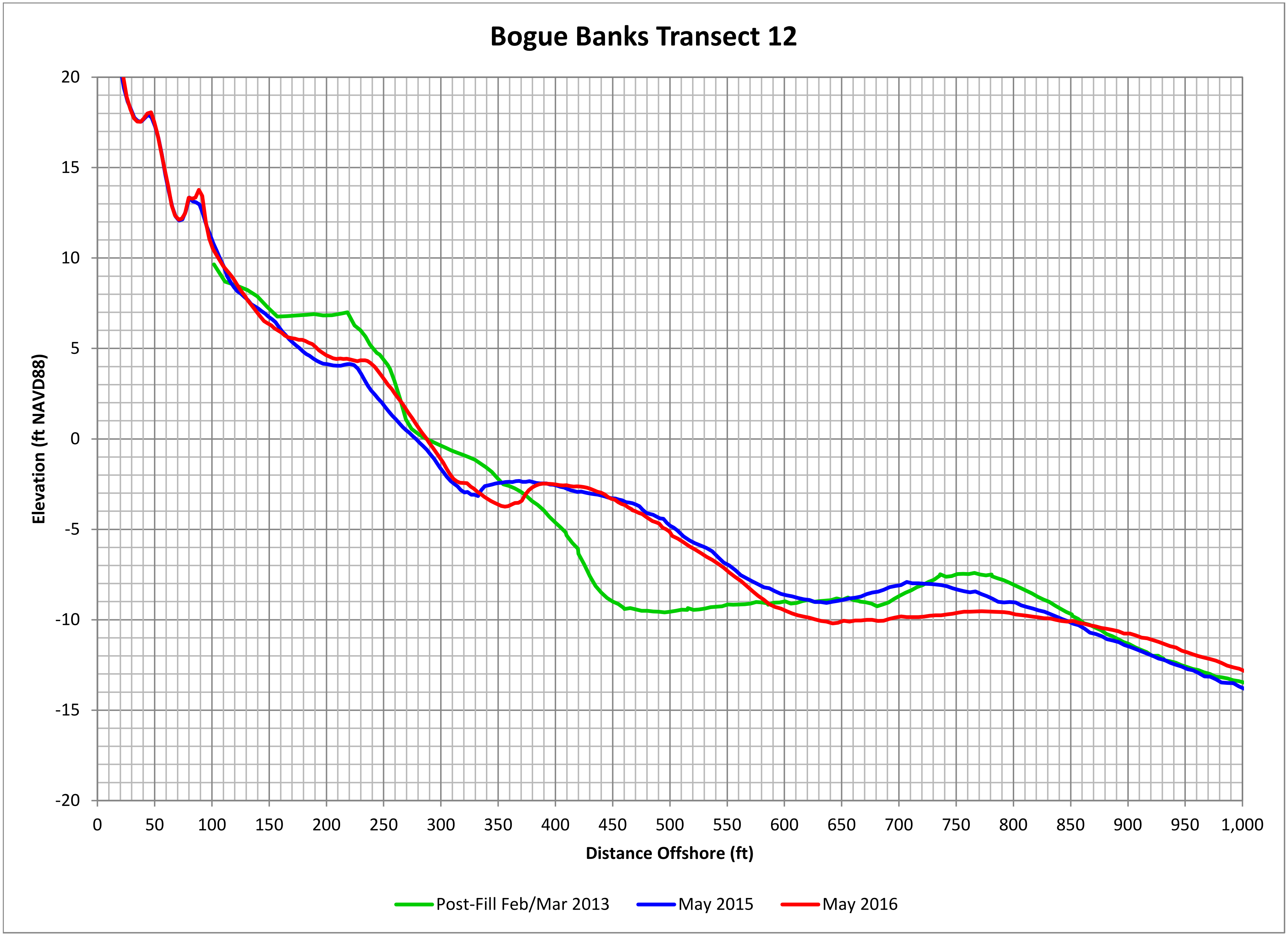


Figure C-15. Bogue Banks Profile Comparison Plot

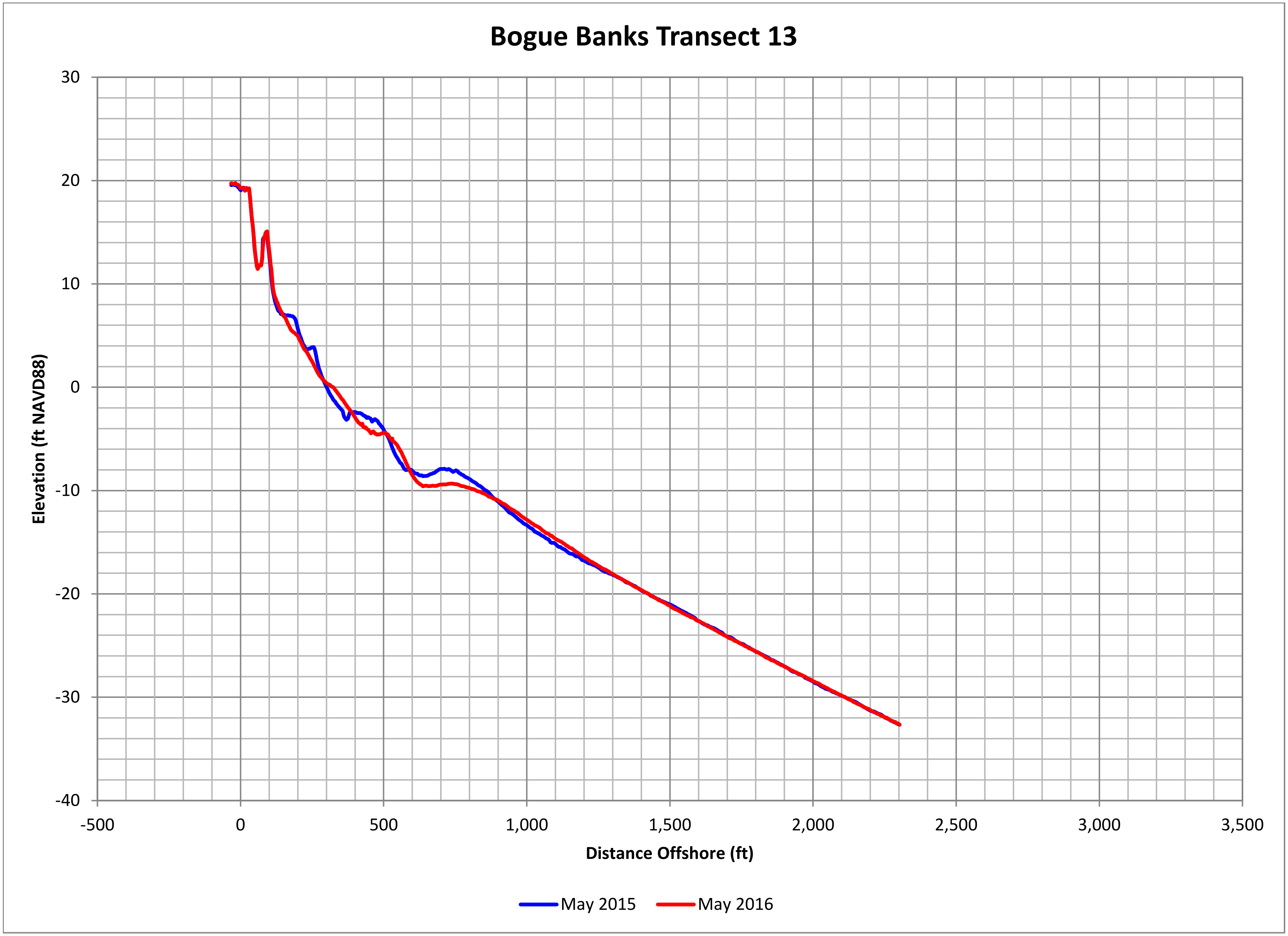


Figure C-16. Bogue Banks Profile Comparison Plot

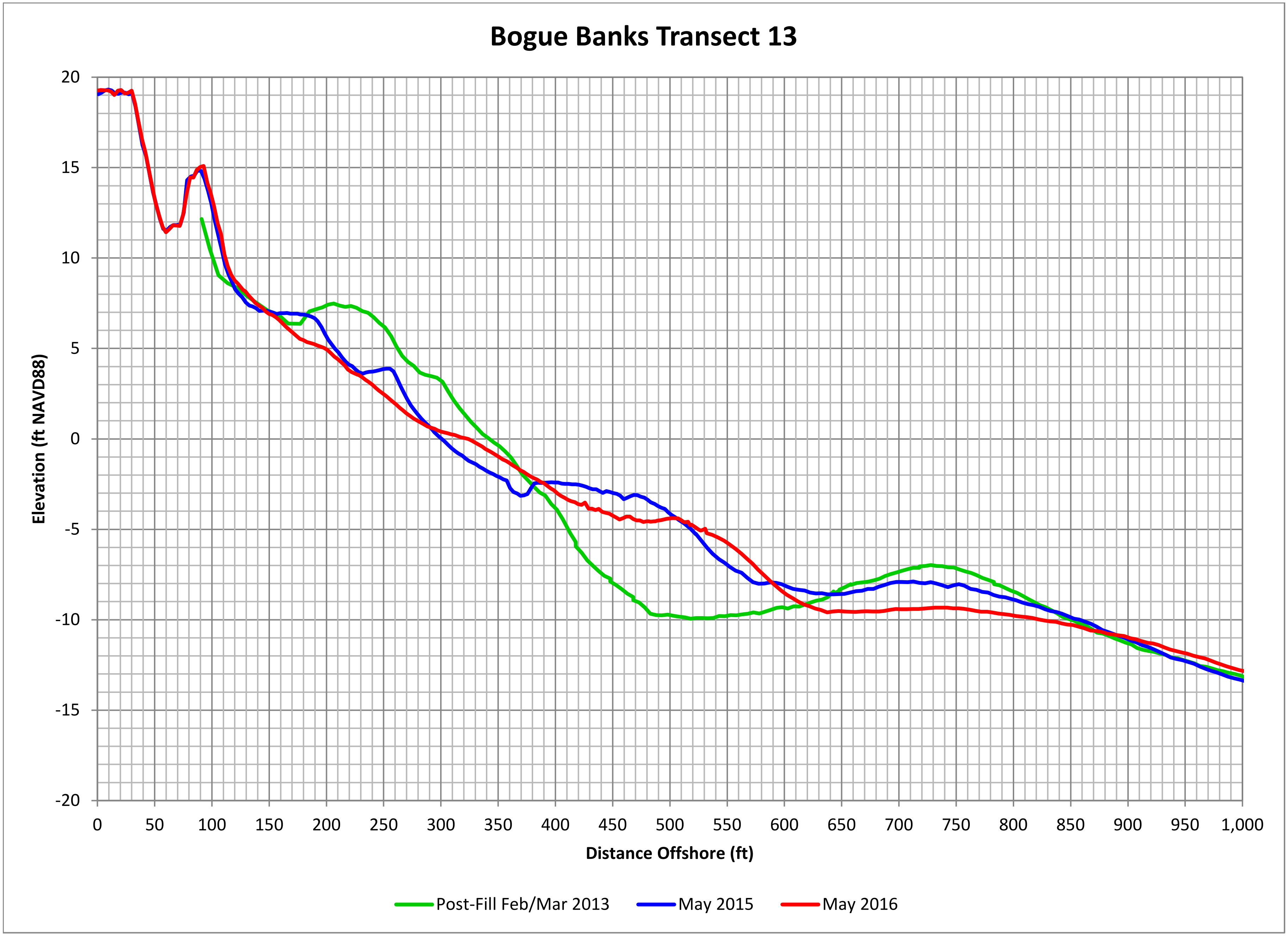


Figure C-17. Bogue Banks Profile Comparison Plot

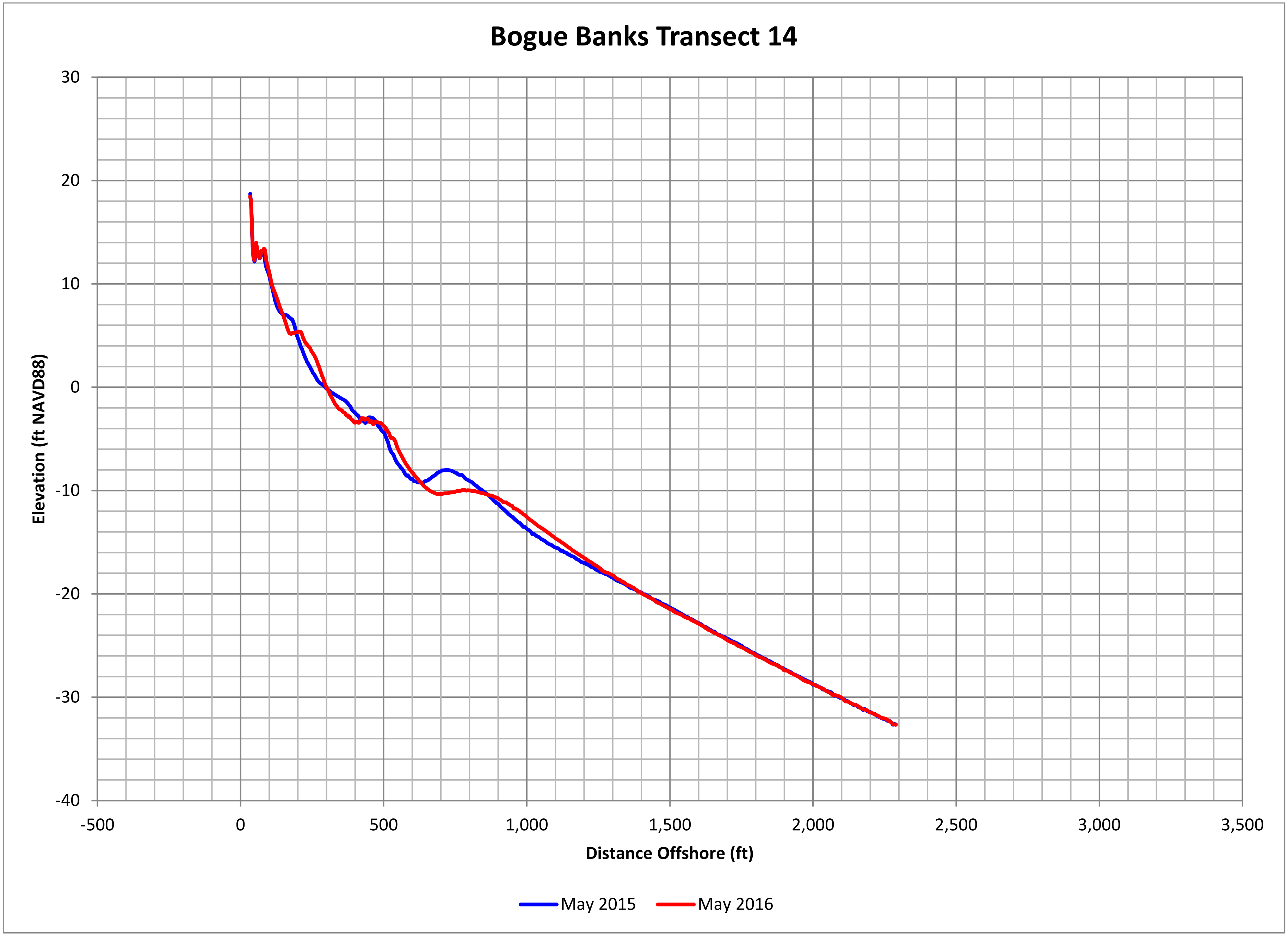


Figure C-18. Bogue Banks Profile Comparison Plot

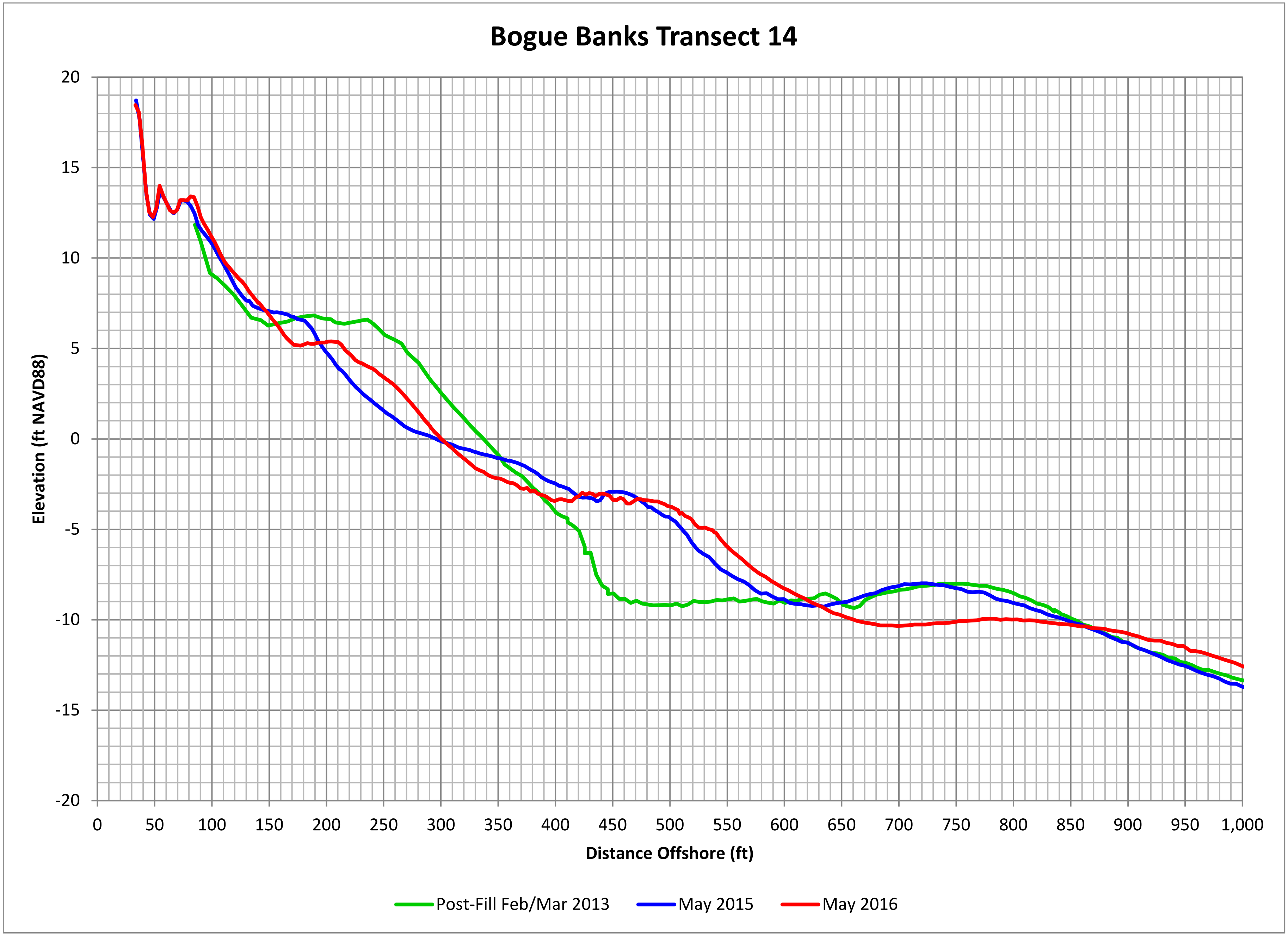


Figure C-19. Bogue Banks Profile Comparison Plot

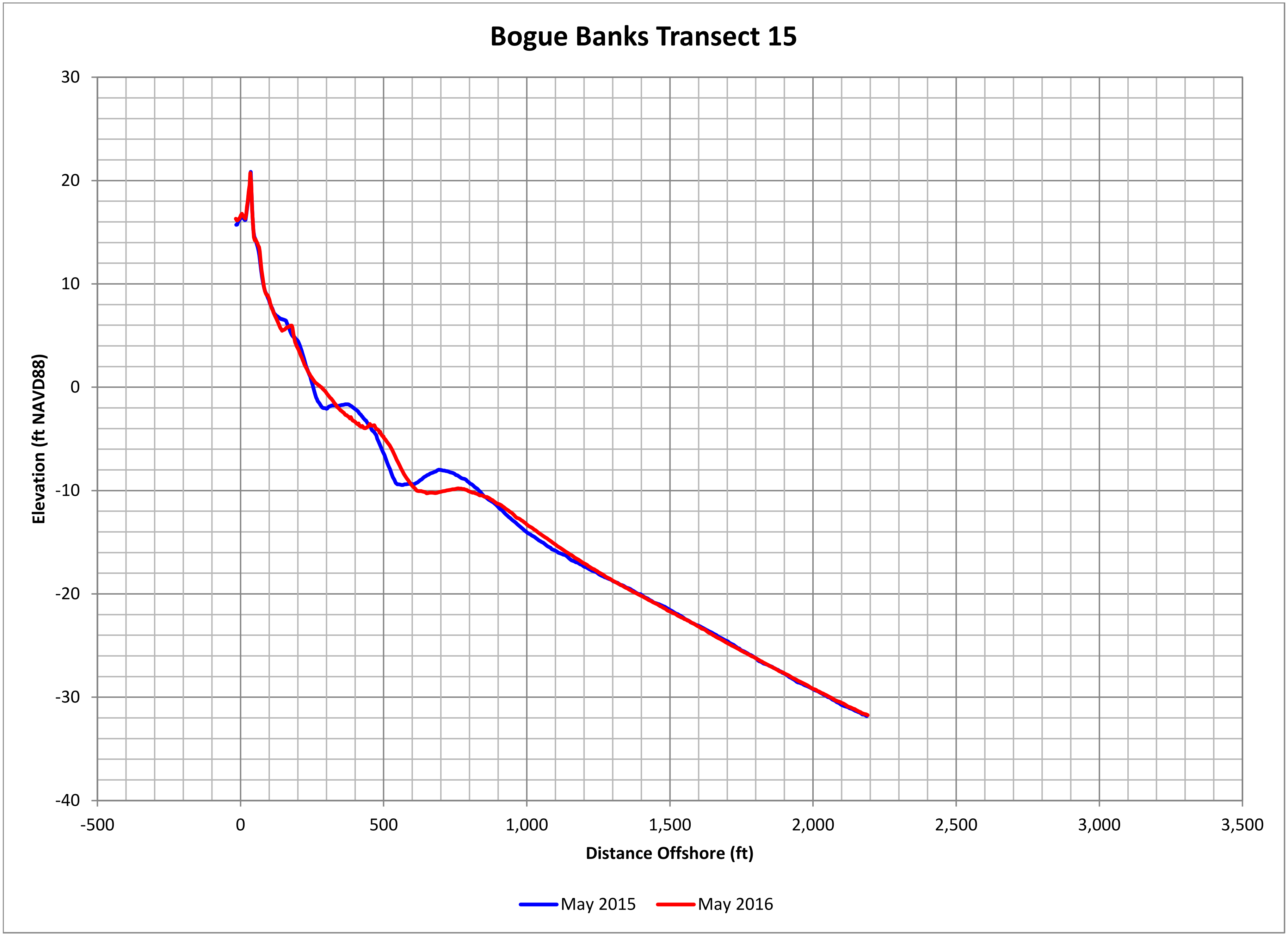


Figure C-20. Bogue Banks Profile Comparison Plot

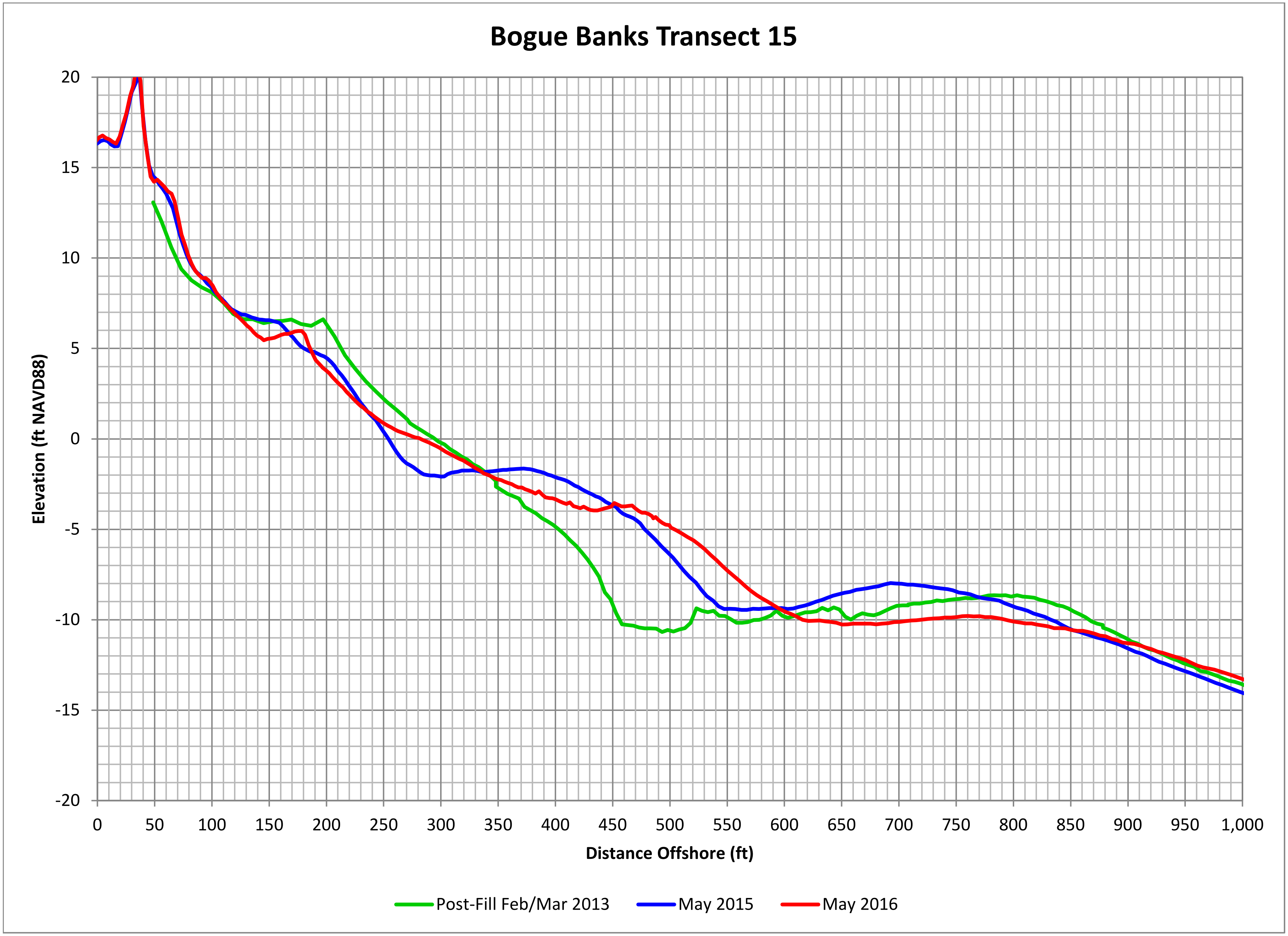


Figure C-21. Bogue Banks Profile Comparison Plot

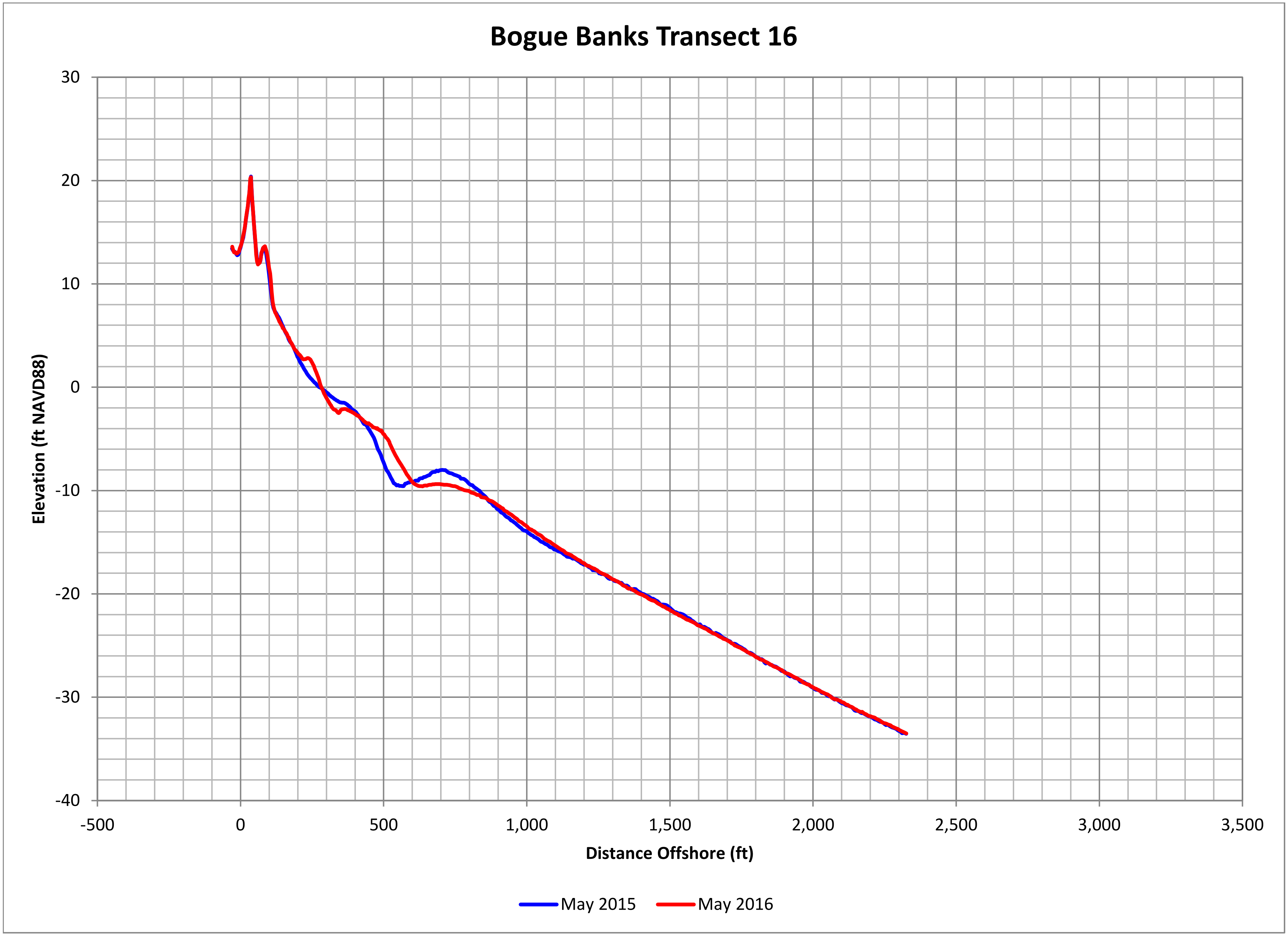


Figure C-22. Bogue Banks Profile Comparison Plot

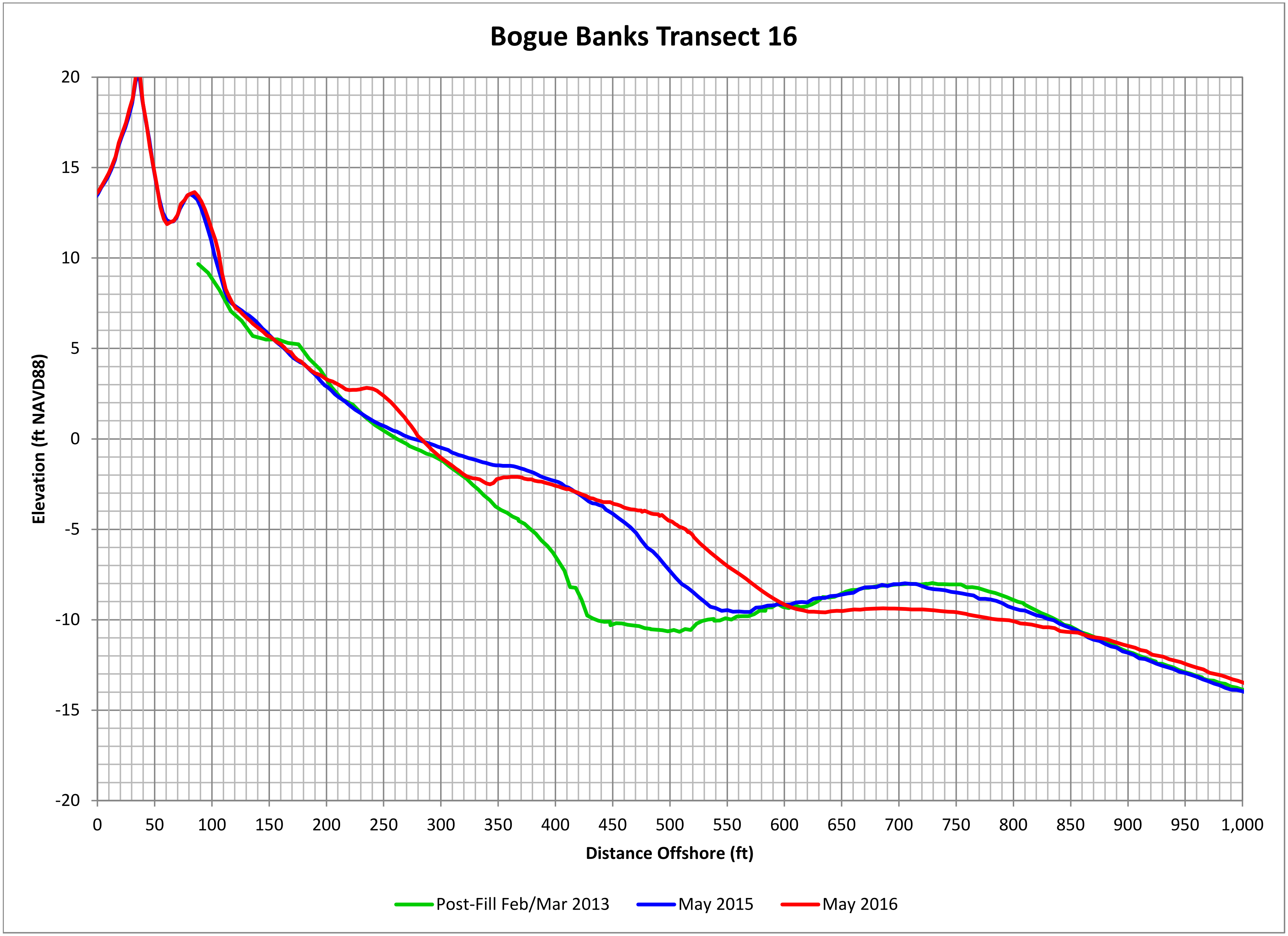


Figure C-23. Bogue Banks Profile Comparison Plot

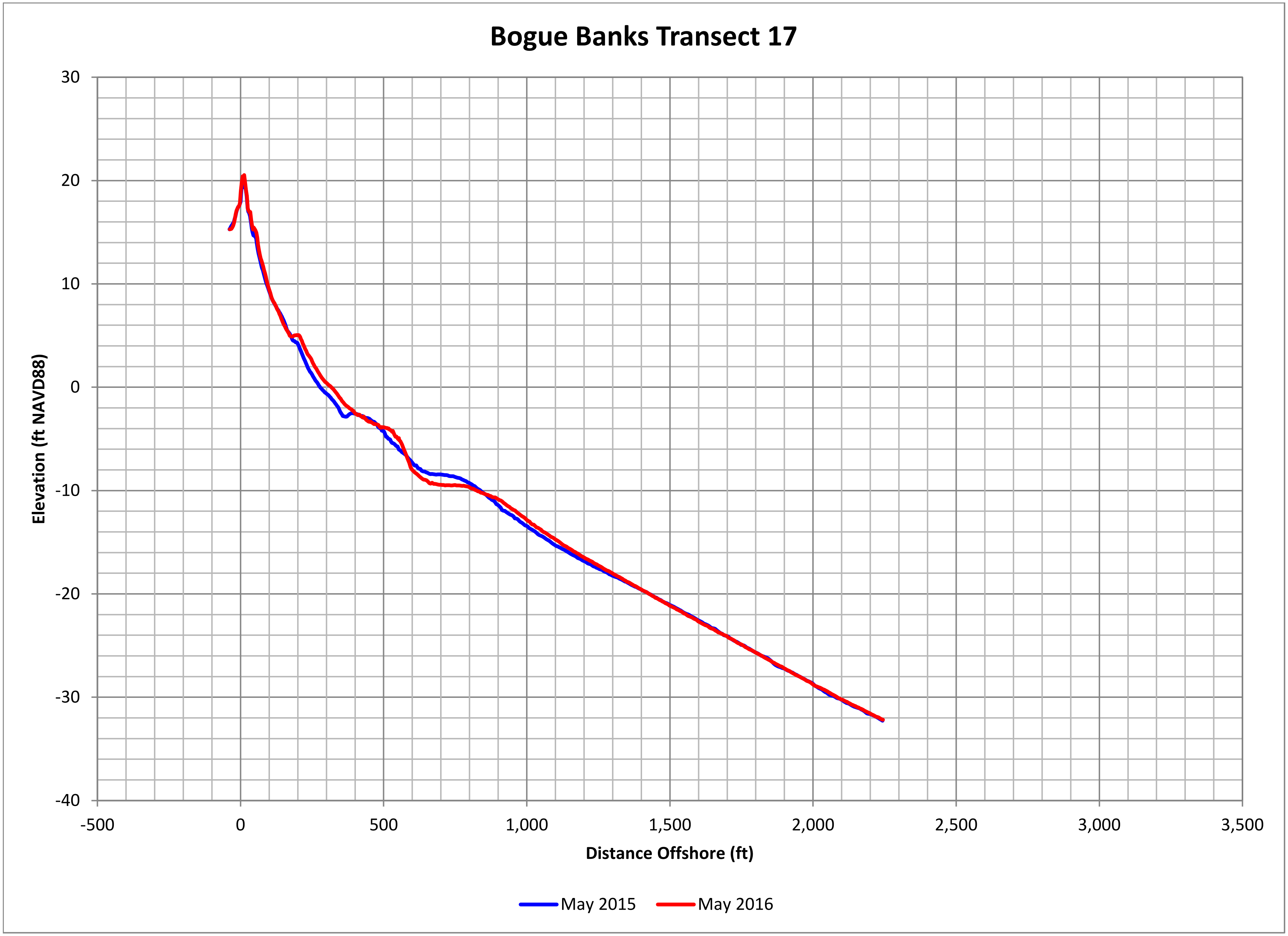


Figure C-24. Bogue Banks Profile Comparison Plot

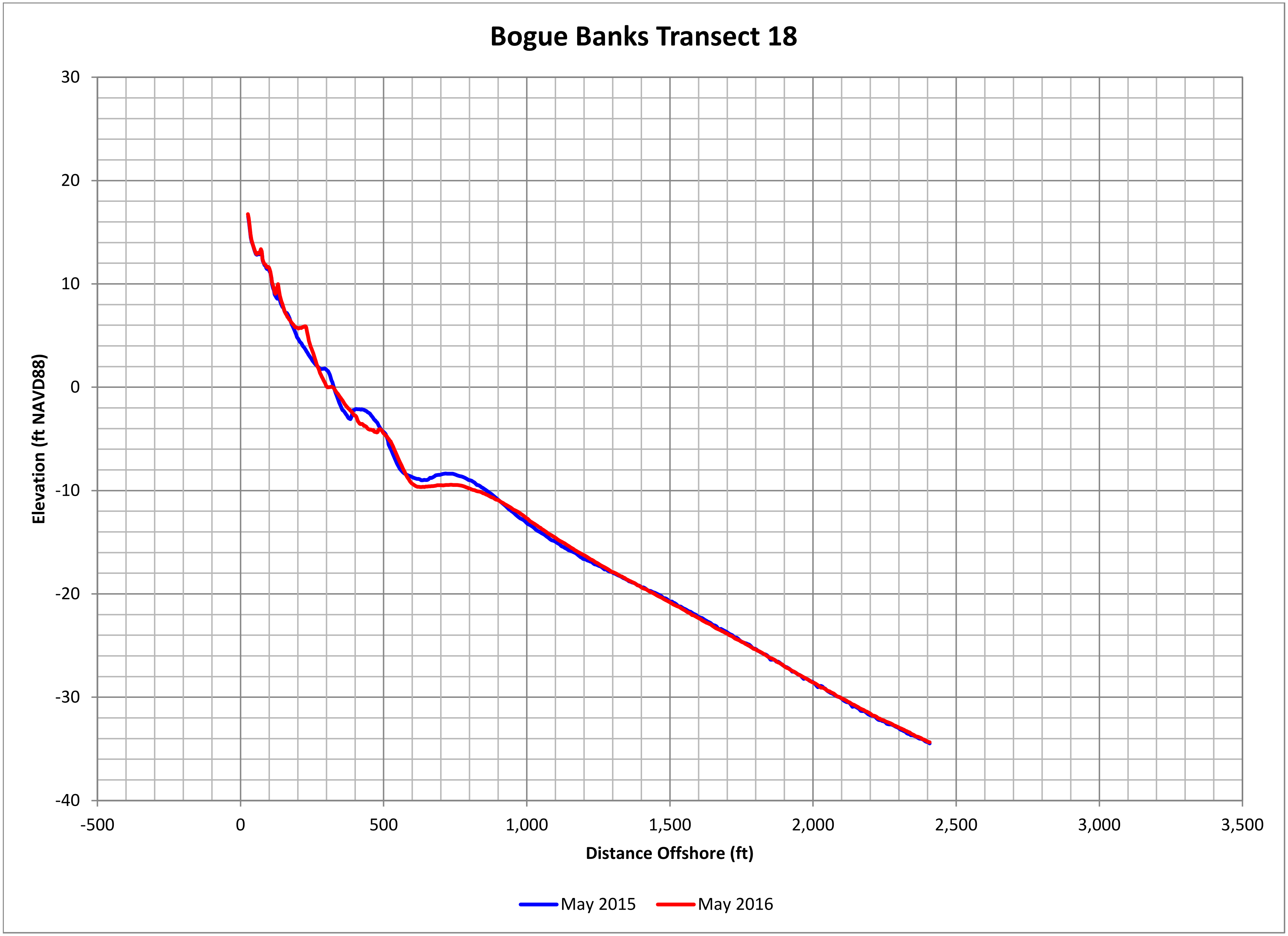
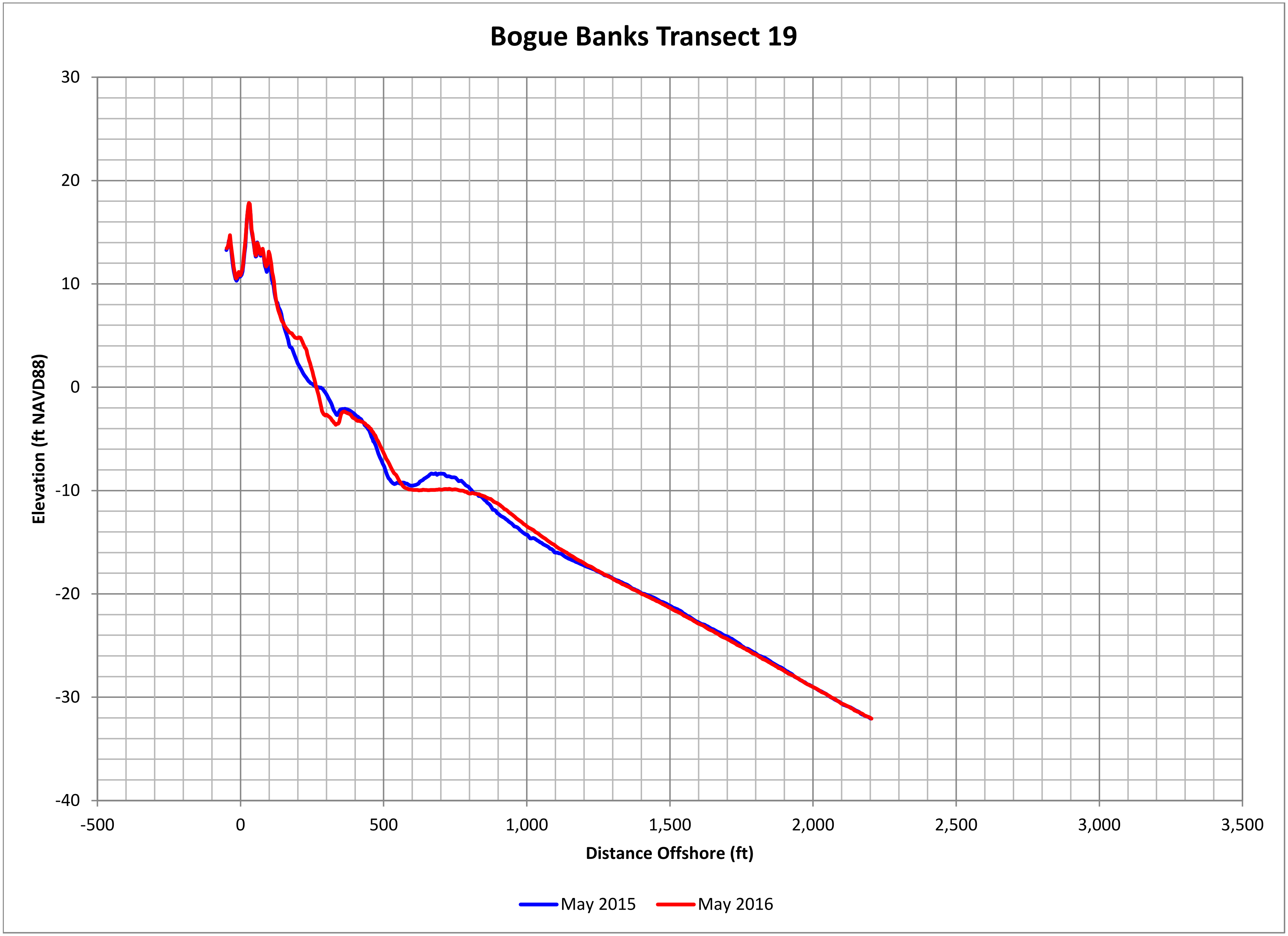


Figure C-25. Bogue Banks Profile Comparison Plot



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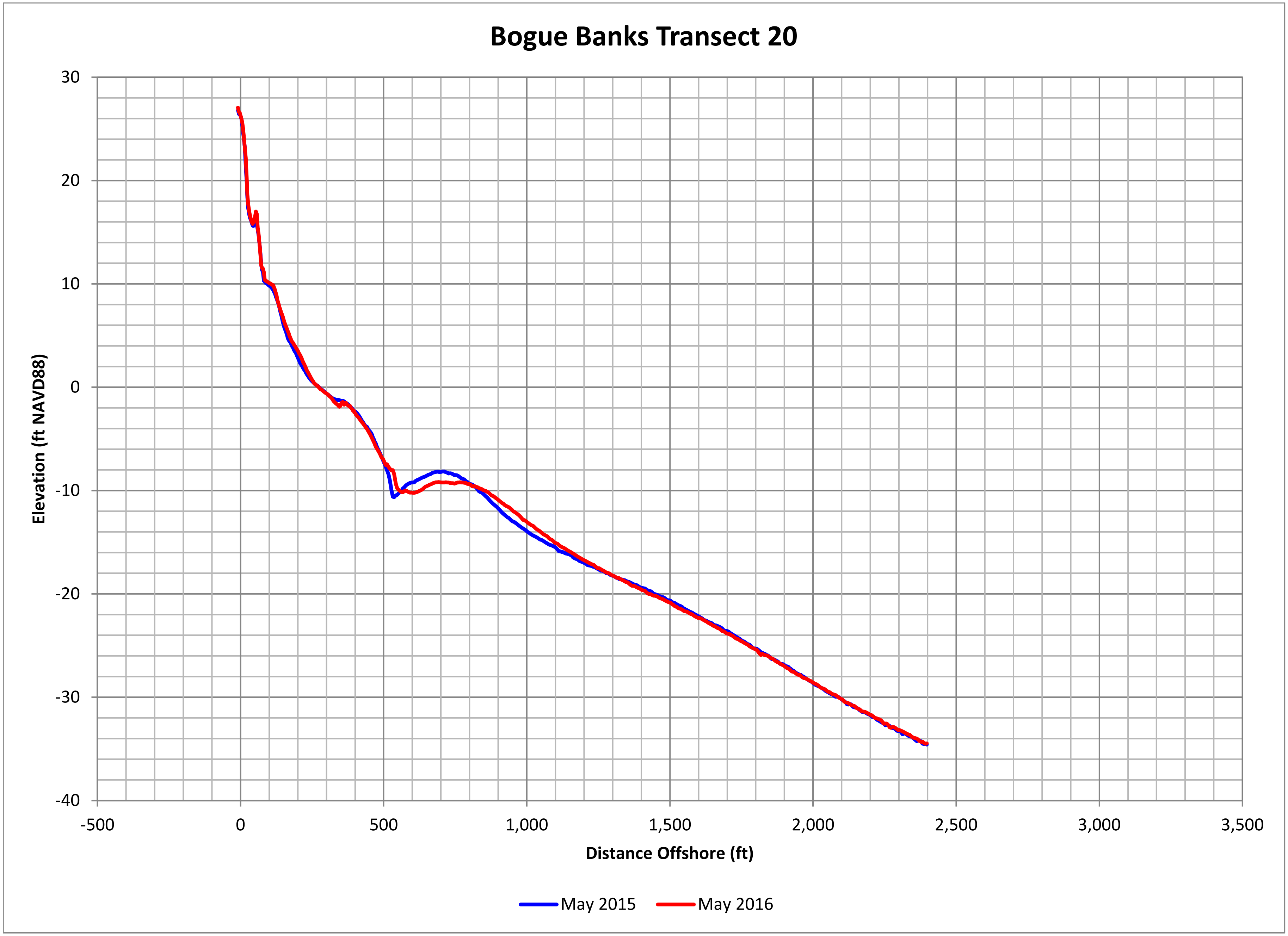


Figure C-27. Bogue Banks Profile Comparison Plot

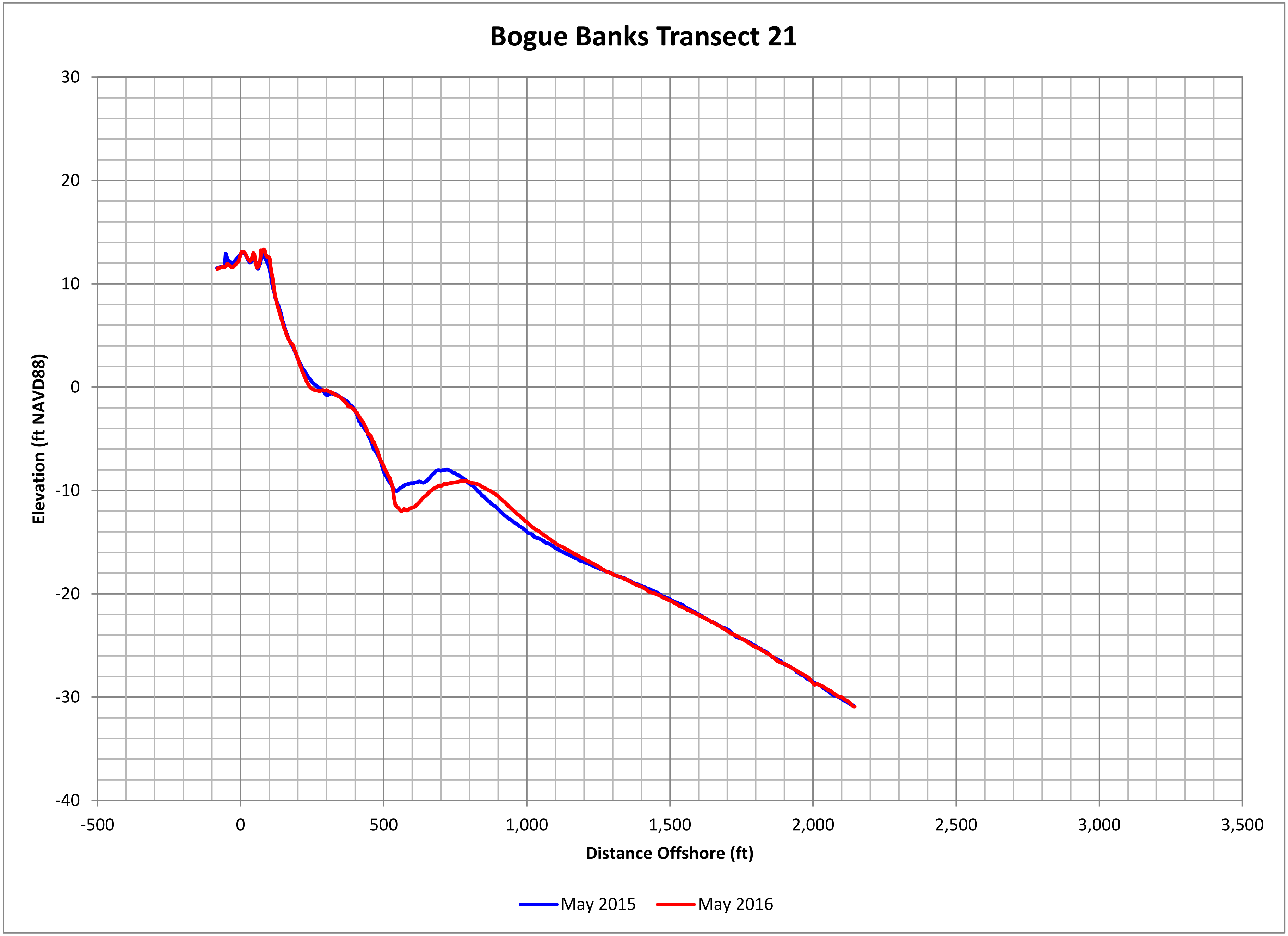
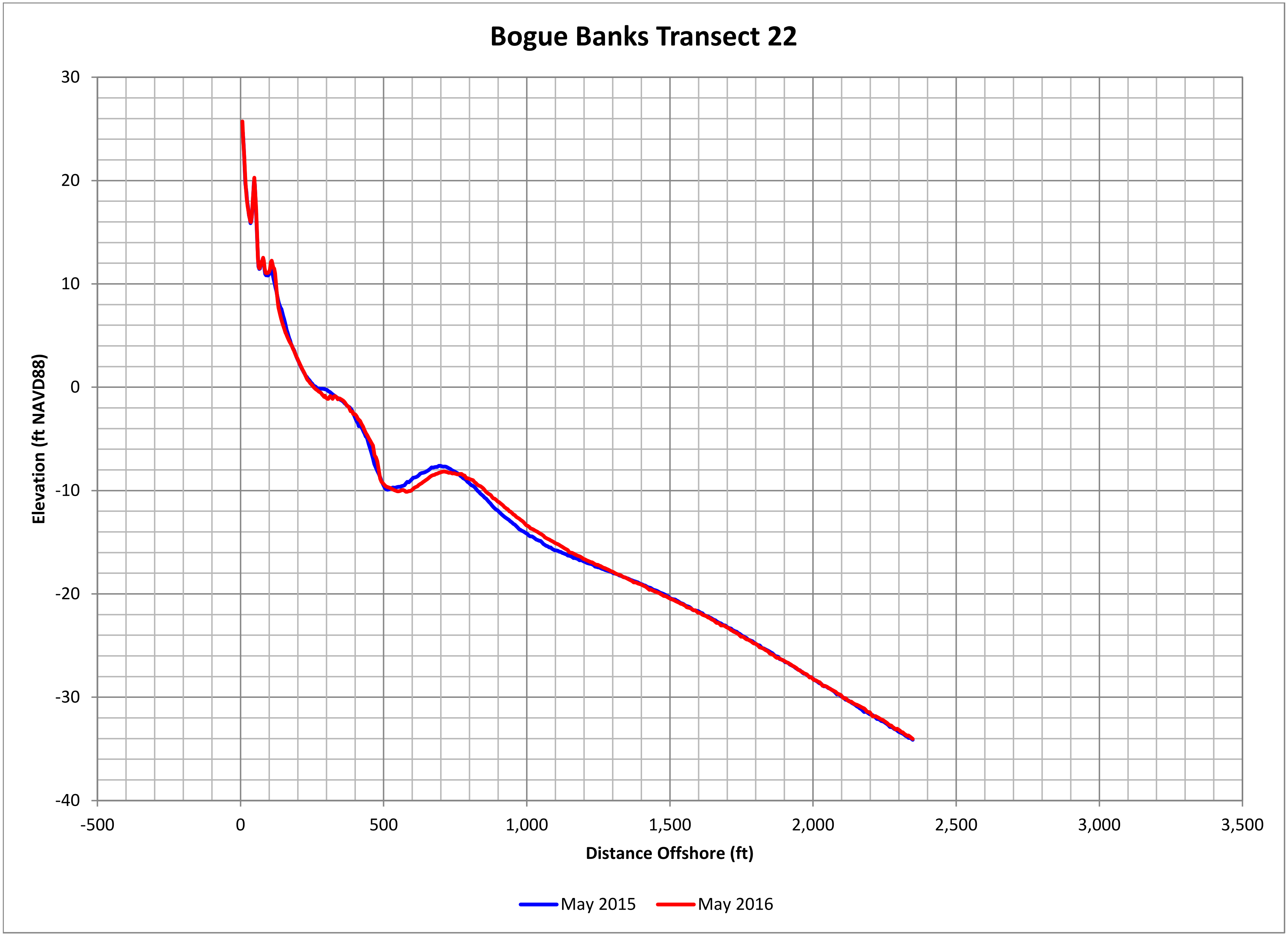


Figure C-28. Bogue Banks Profile Comparison Plot



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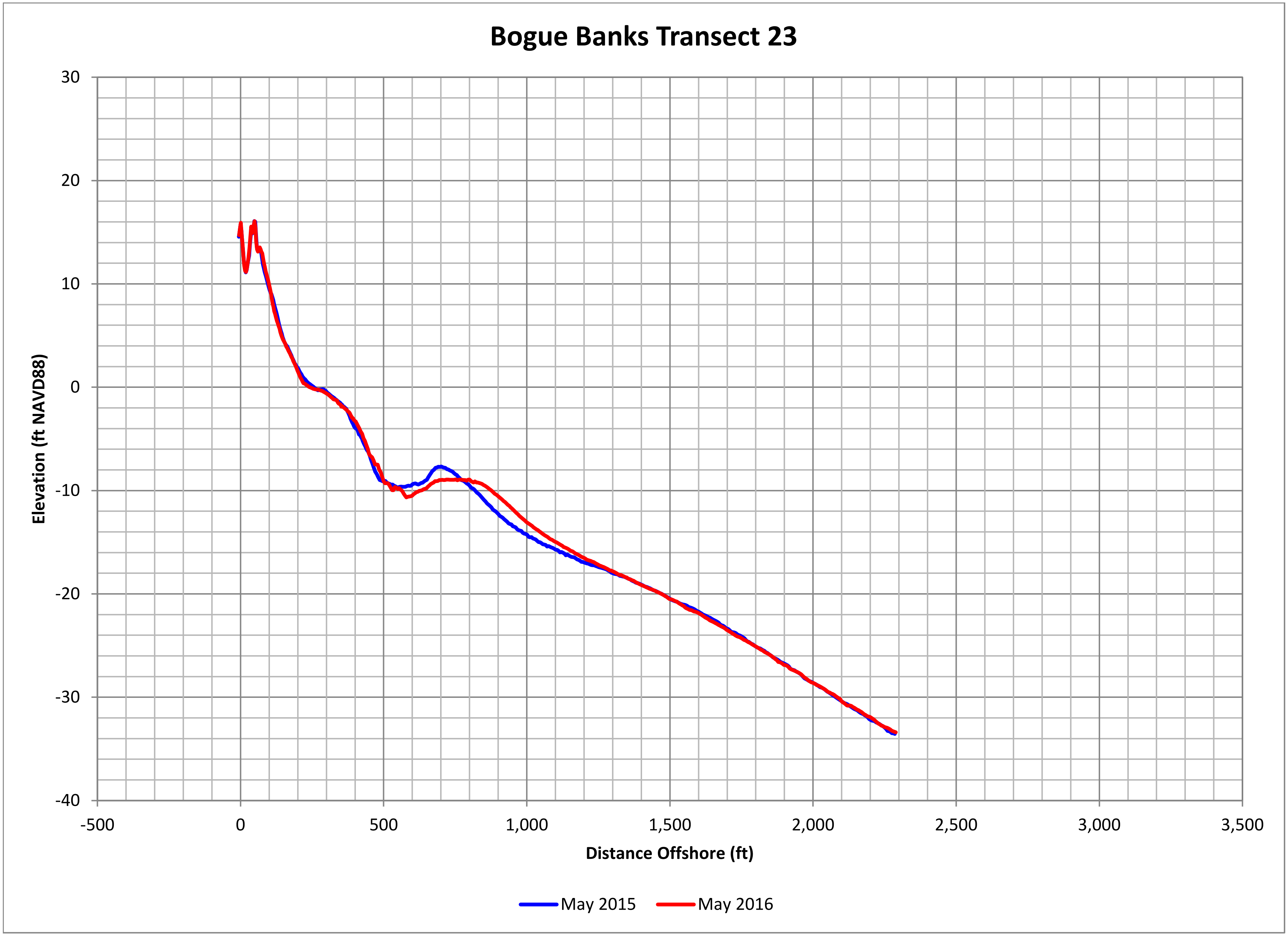


Figure C-30. Bogue Banks Profile Comparison Plot

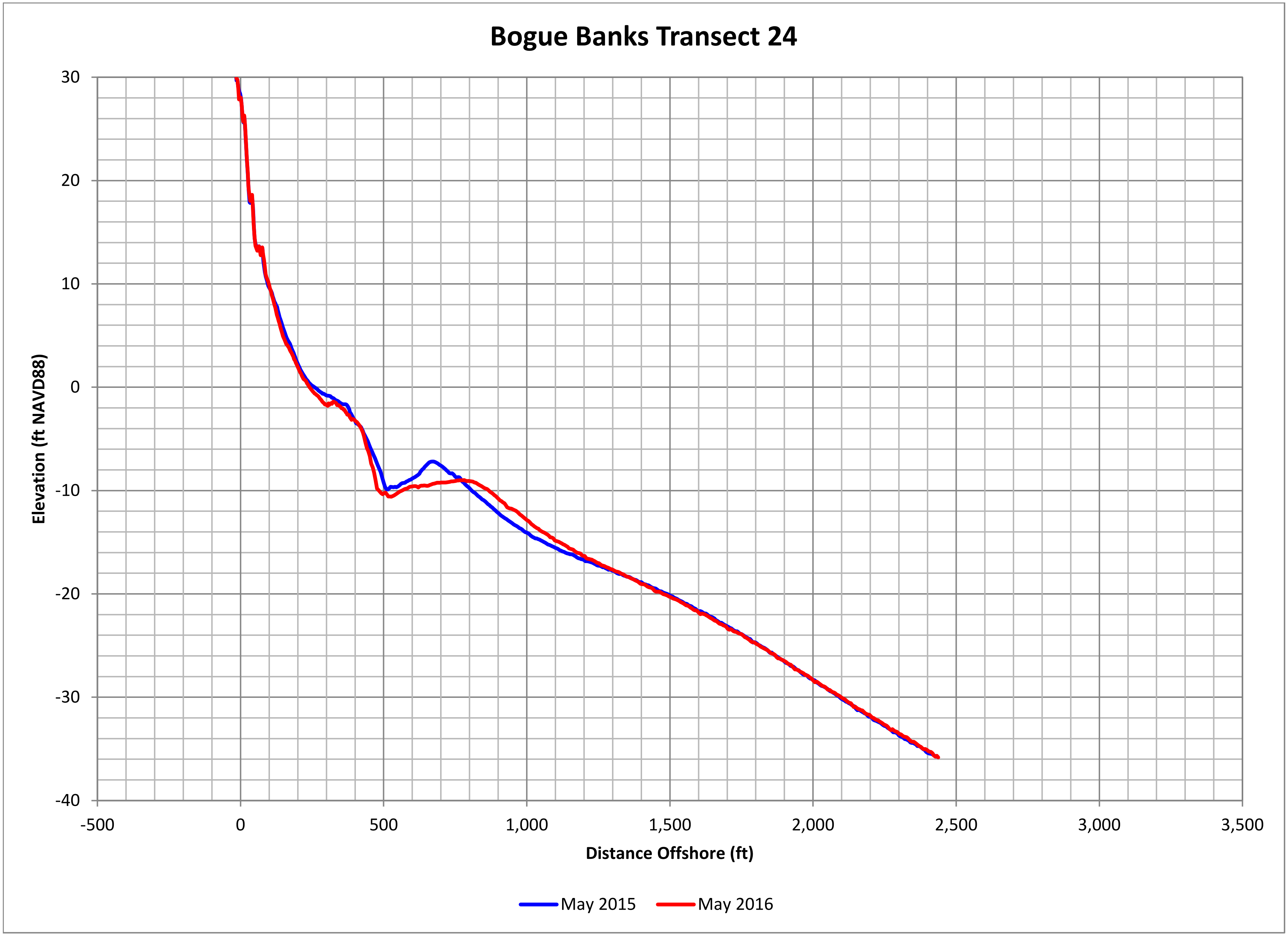


Figure C-31. Bogue Banks Profile Comparison Plot

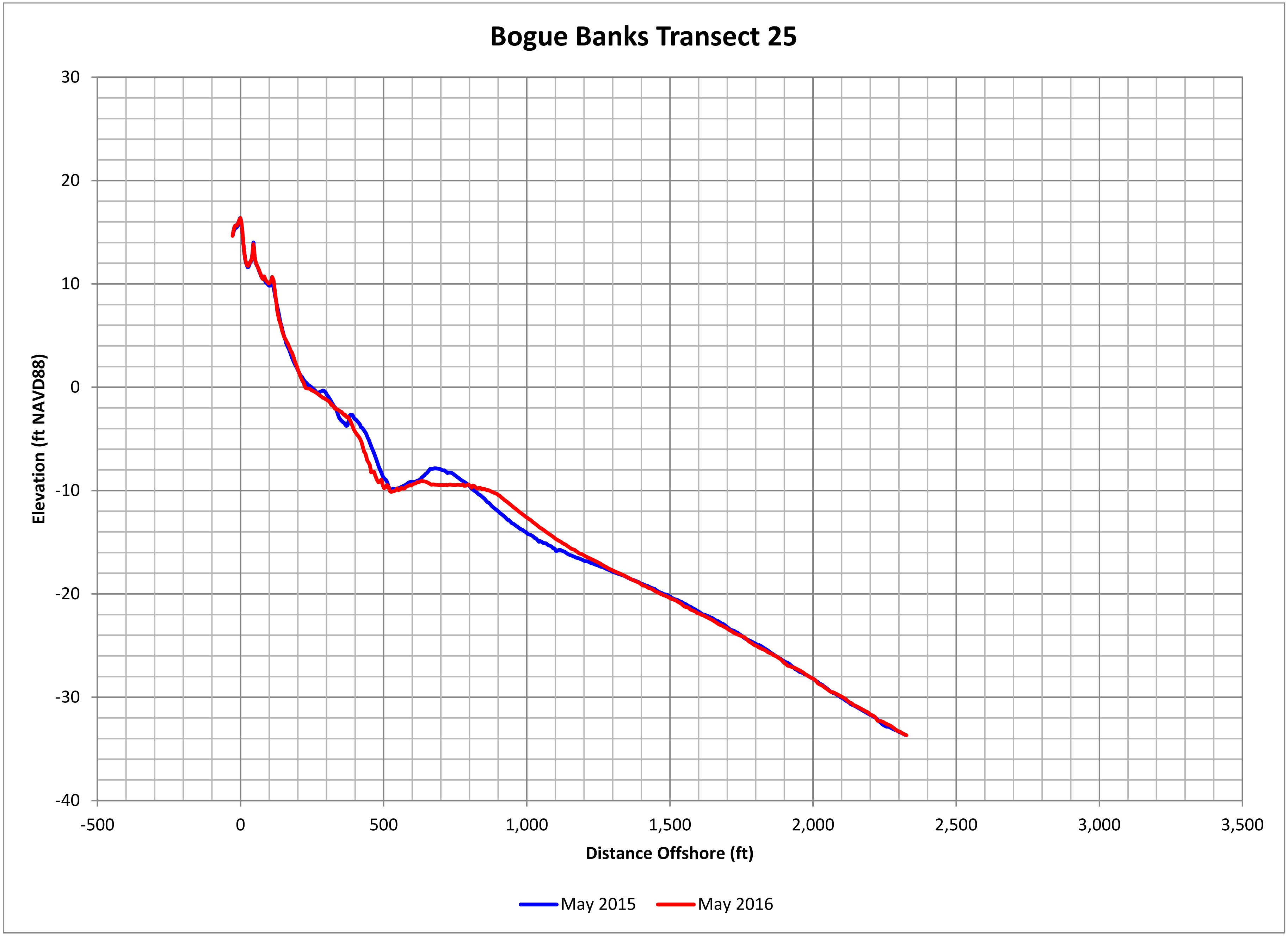


Figure C-32. Bogue Banks Profile Comparison Plot

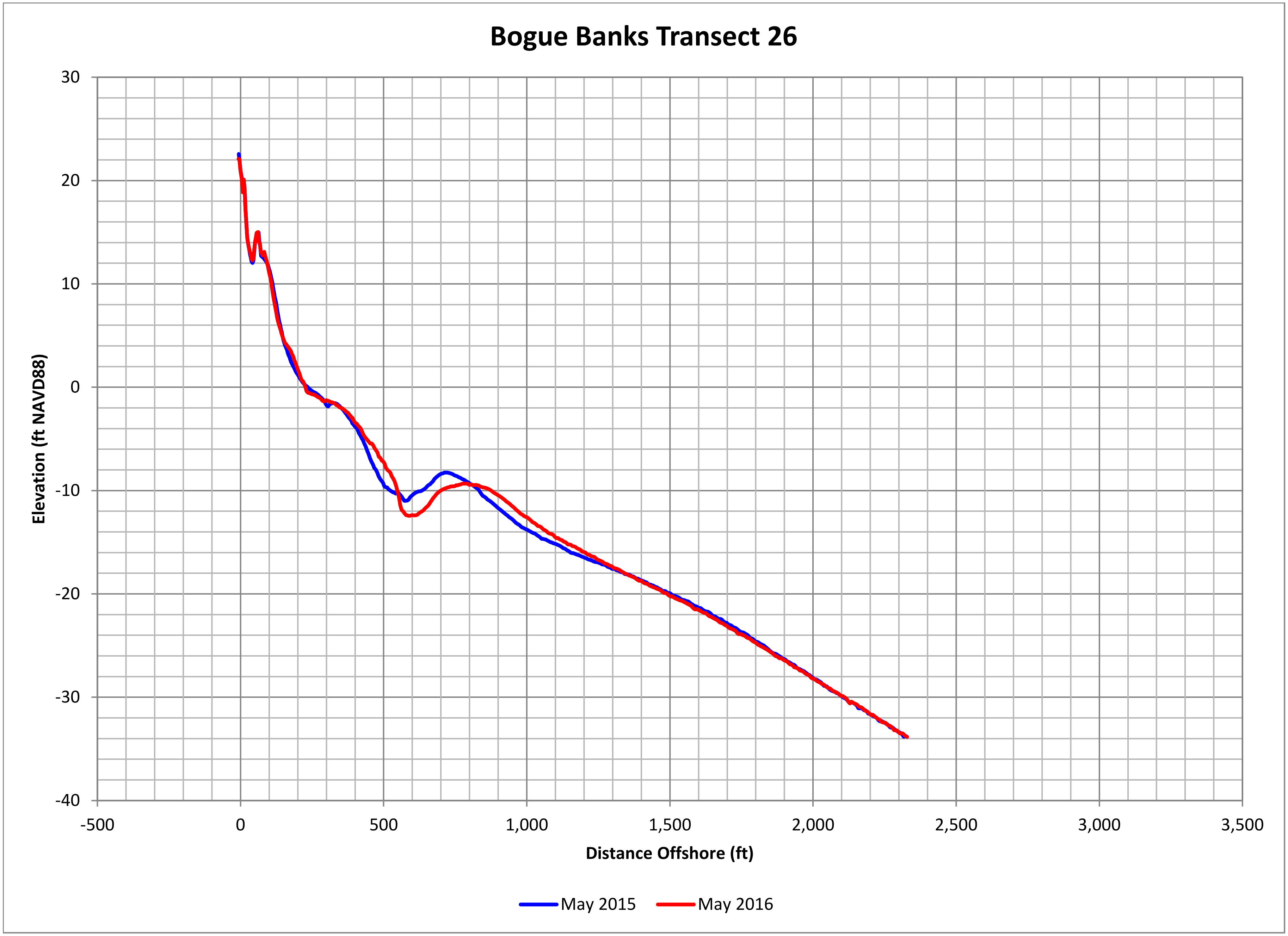


Figure C-33. Bogue Banks Profile Comparison Plot

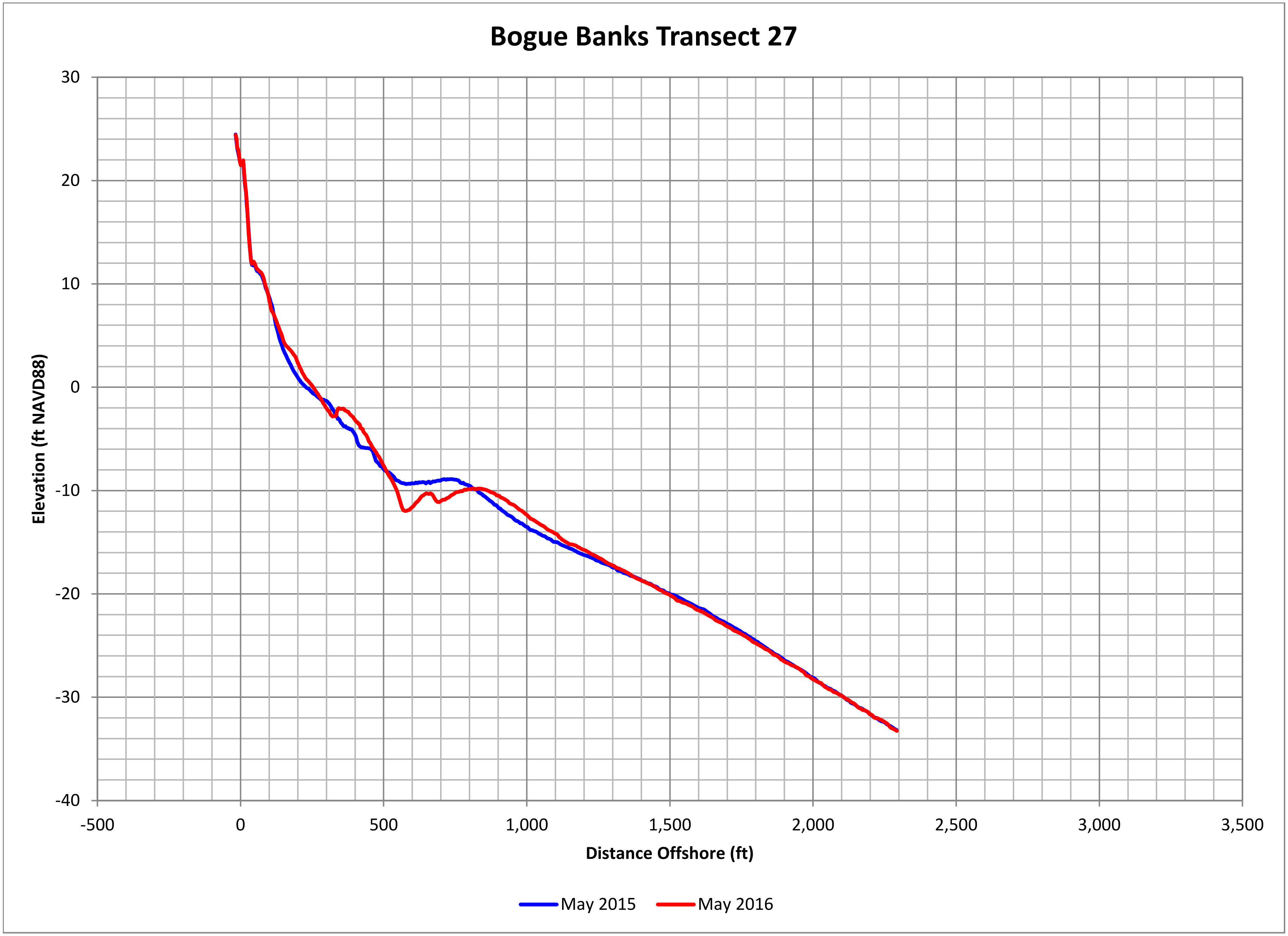


Figure C-34. Bogue Banks Profile Comparison Plot

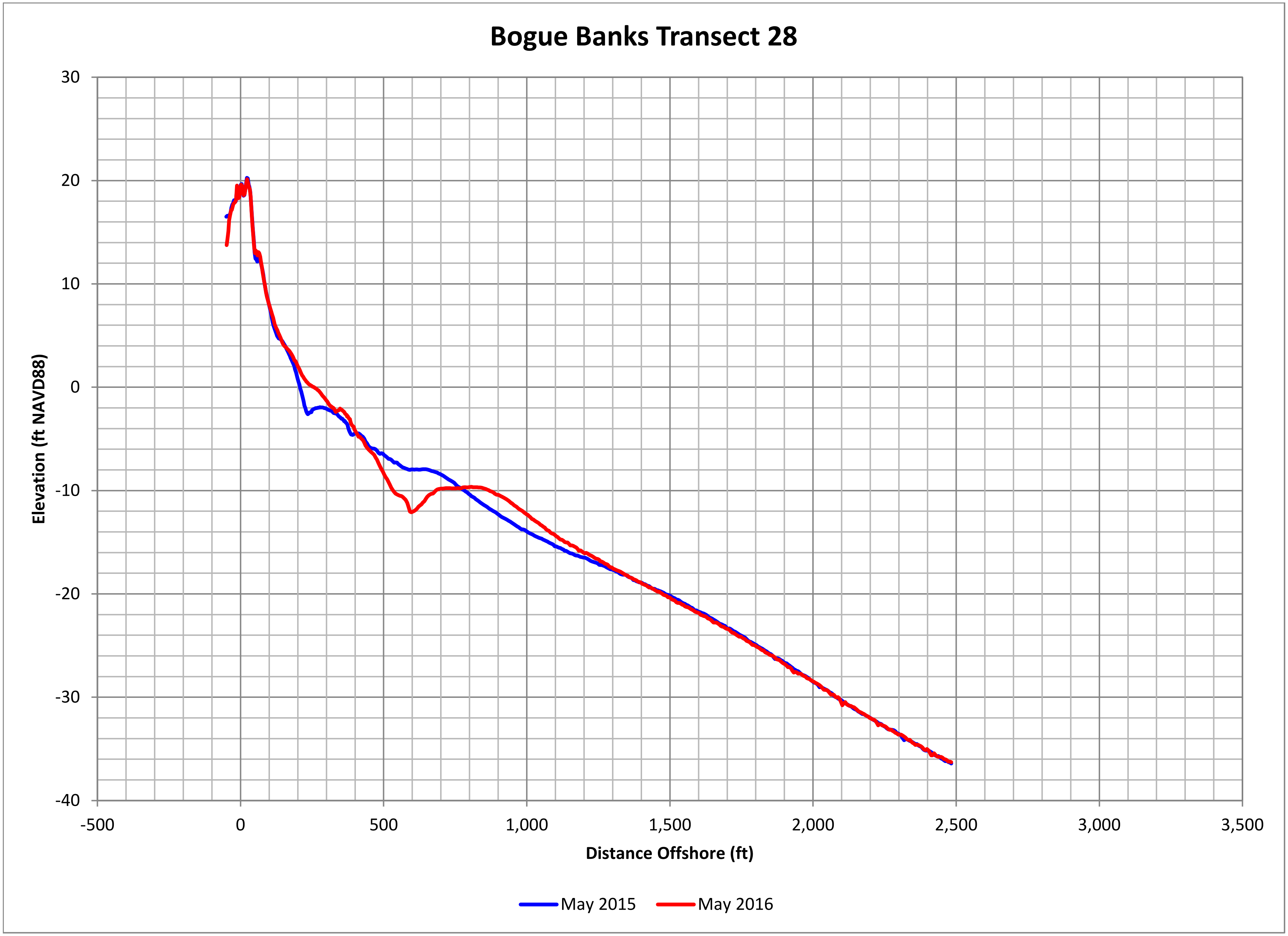


Figure C-35. Bogue Banks Profile Comparison Plot

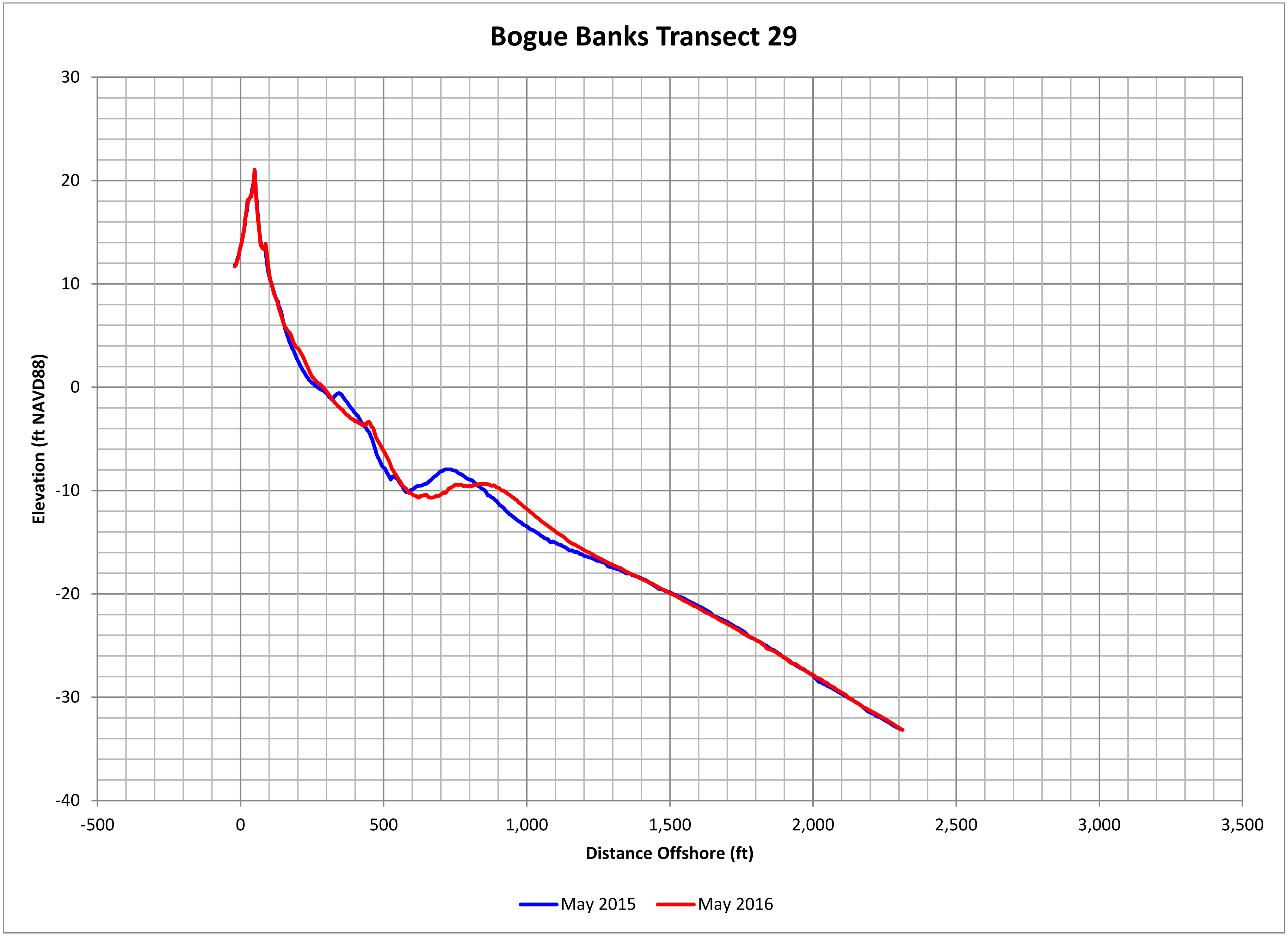


Figure C-36. Bogue Banks Profile Comparison Plot

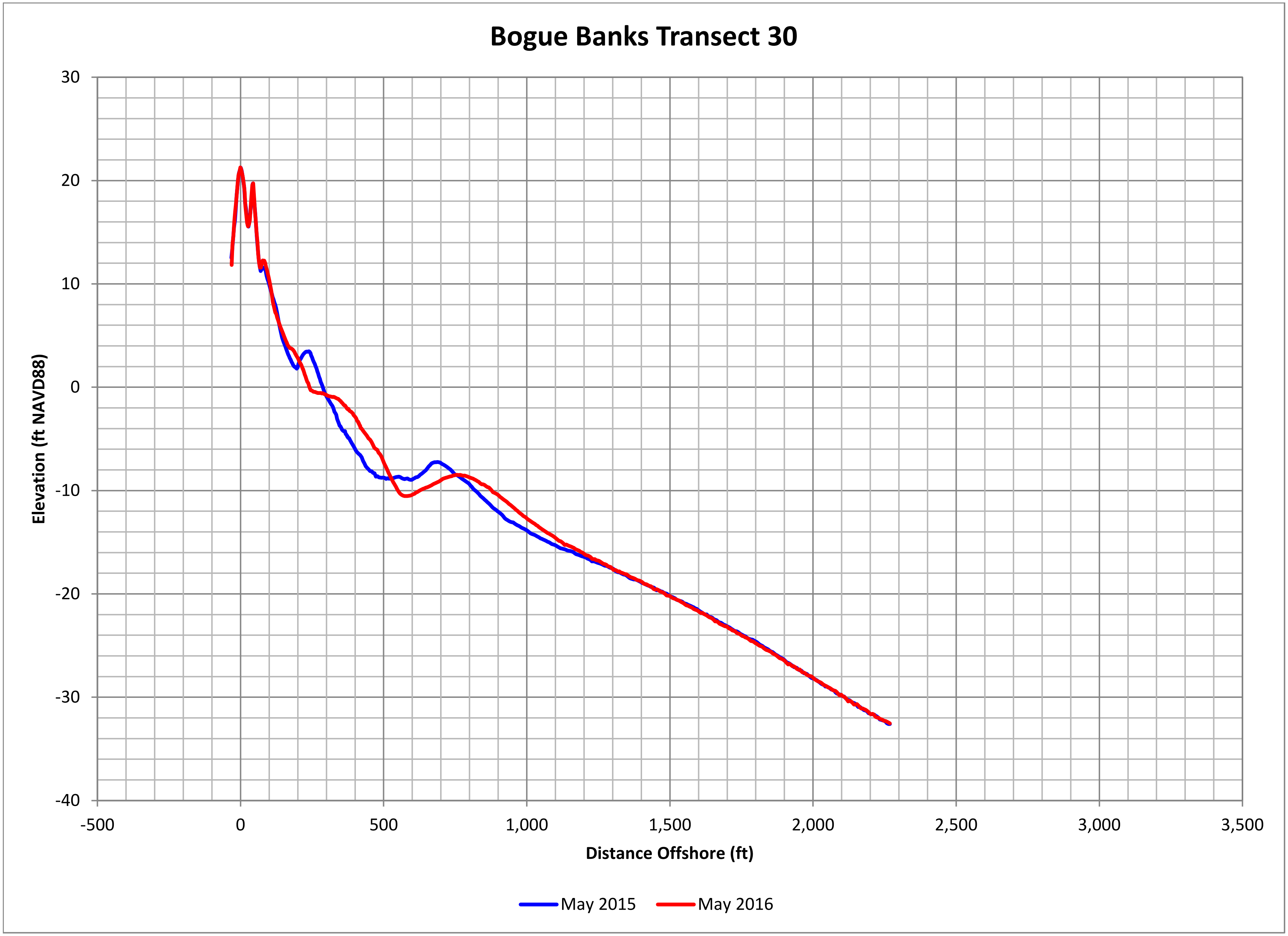


Figure C-37. Bogue Banks Profile Comparison Plot

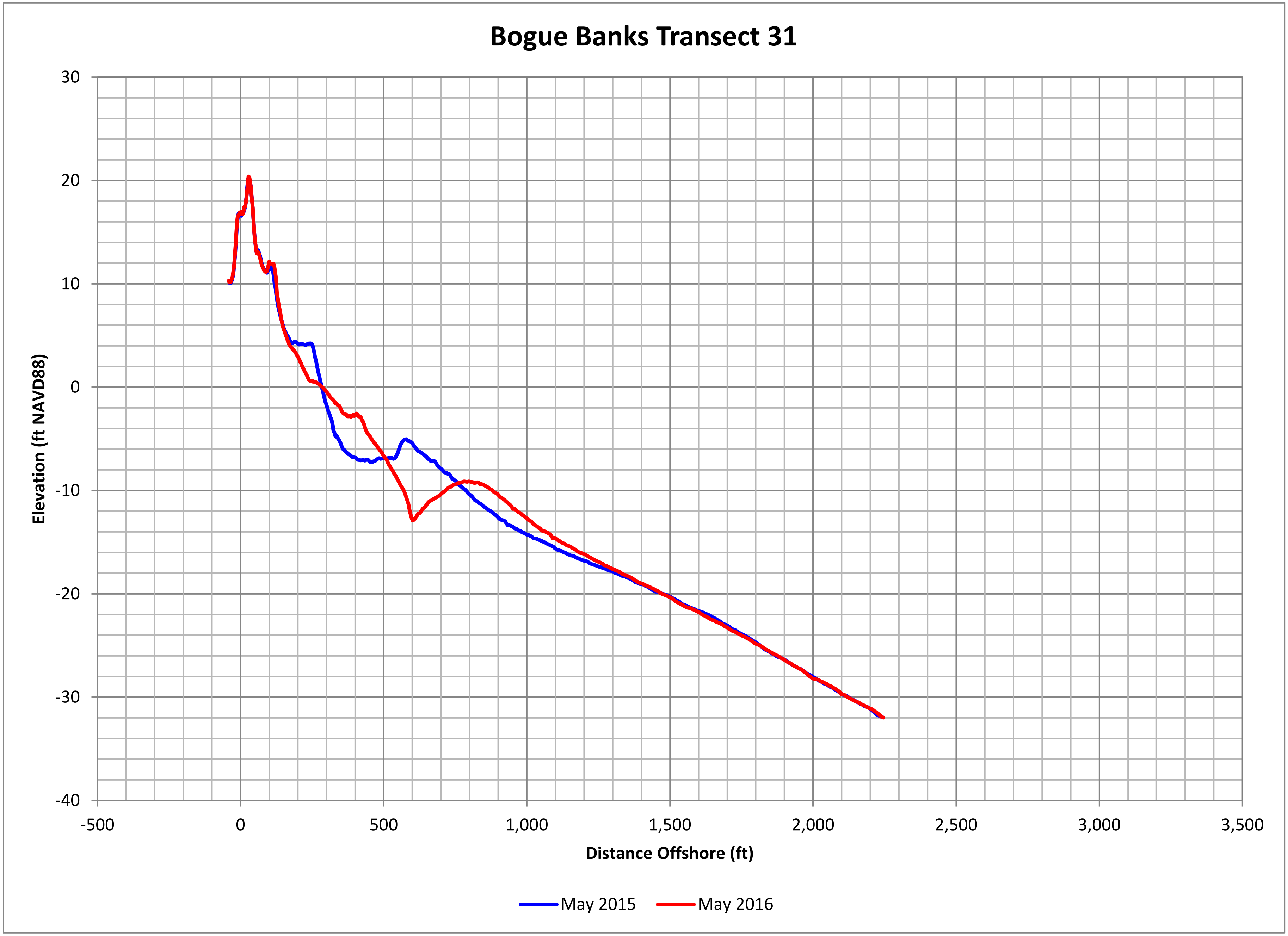
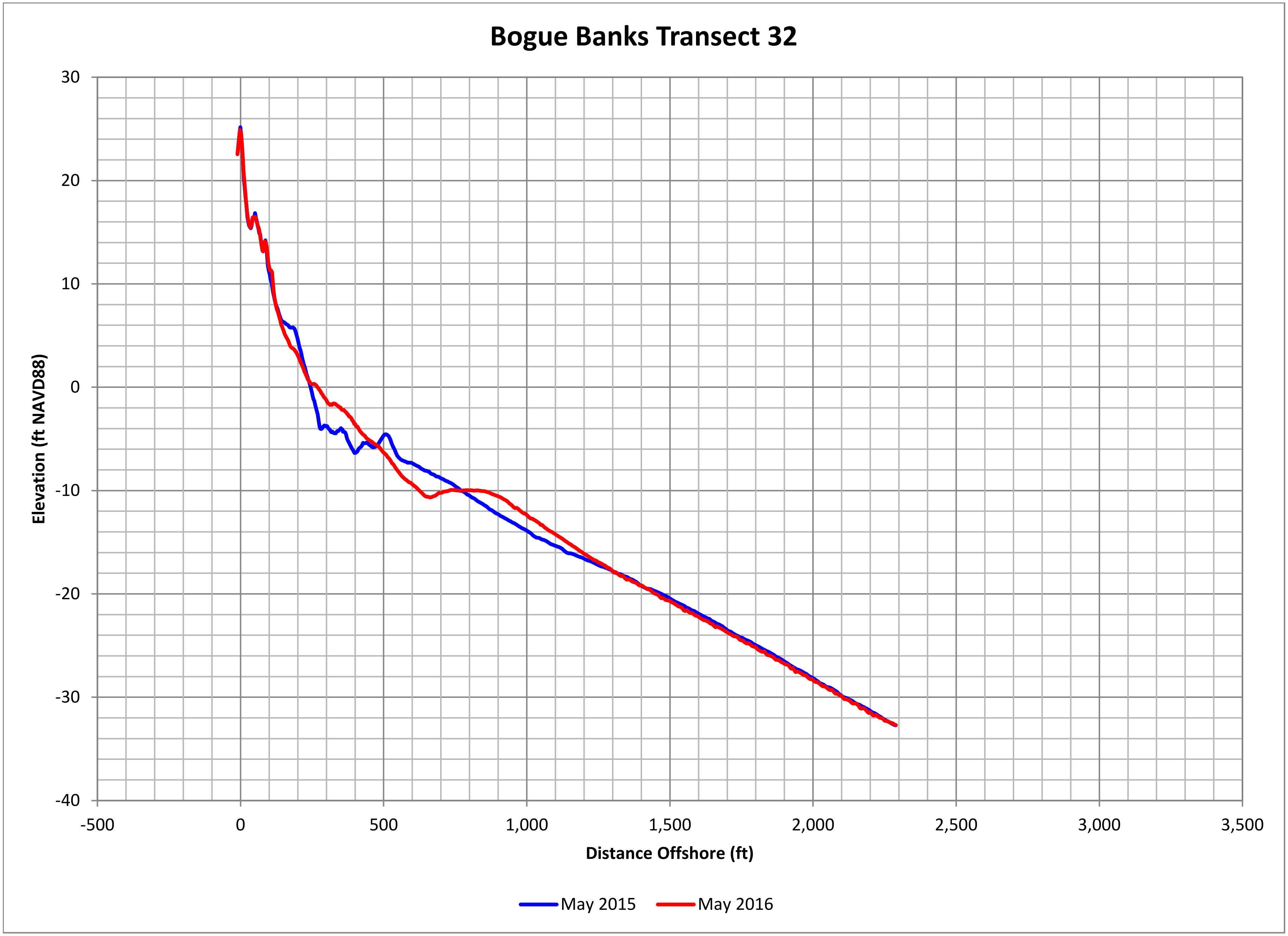


Figure C-38. Bogue Banks Profile Comparison Plot



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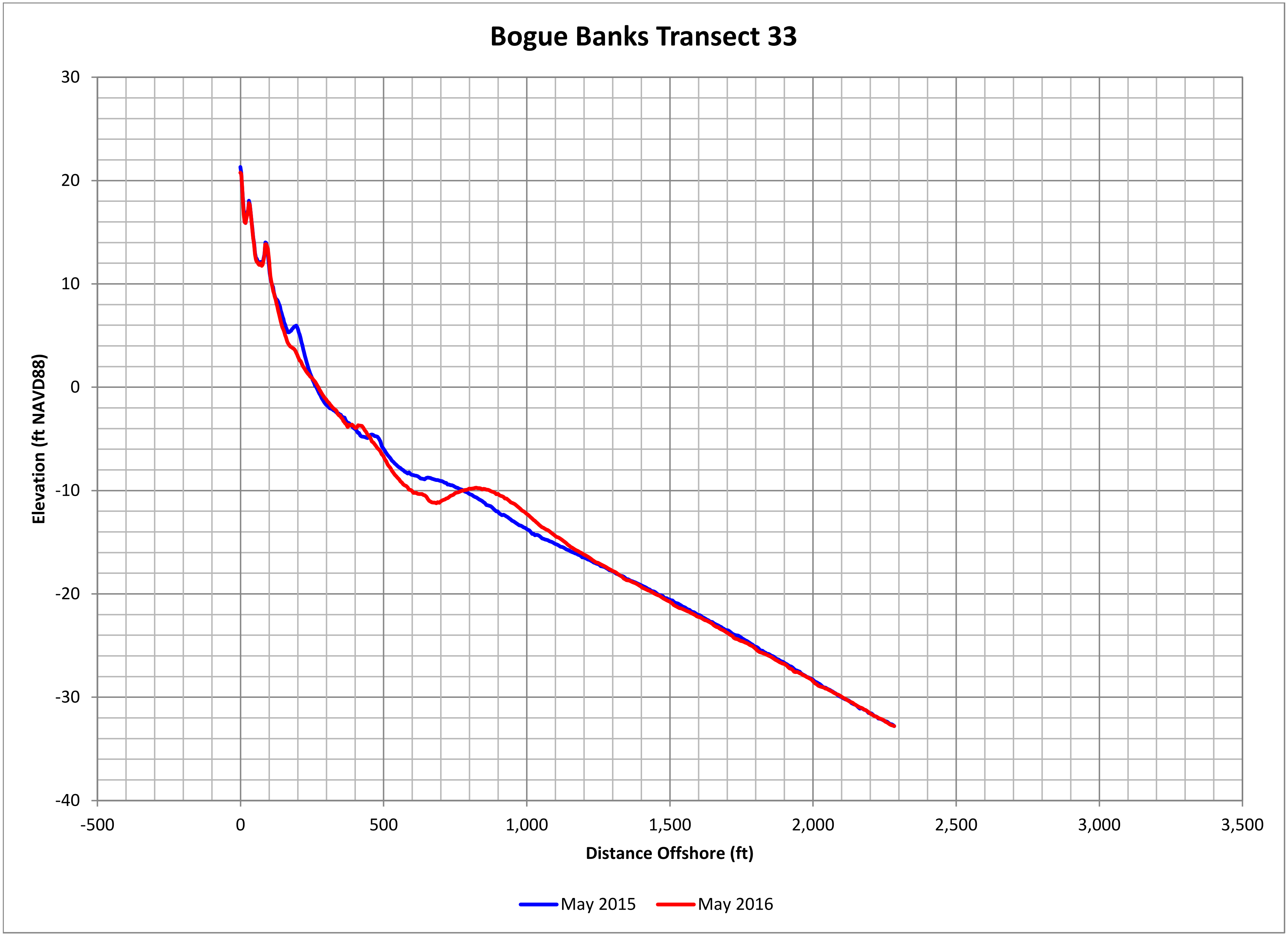

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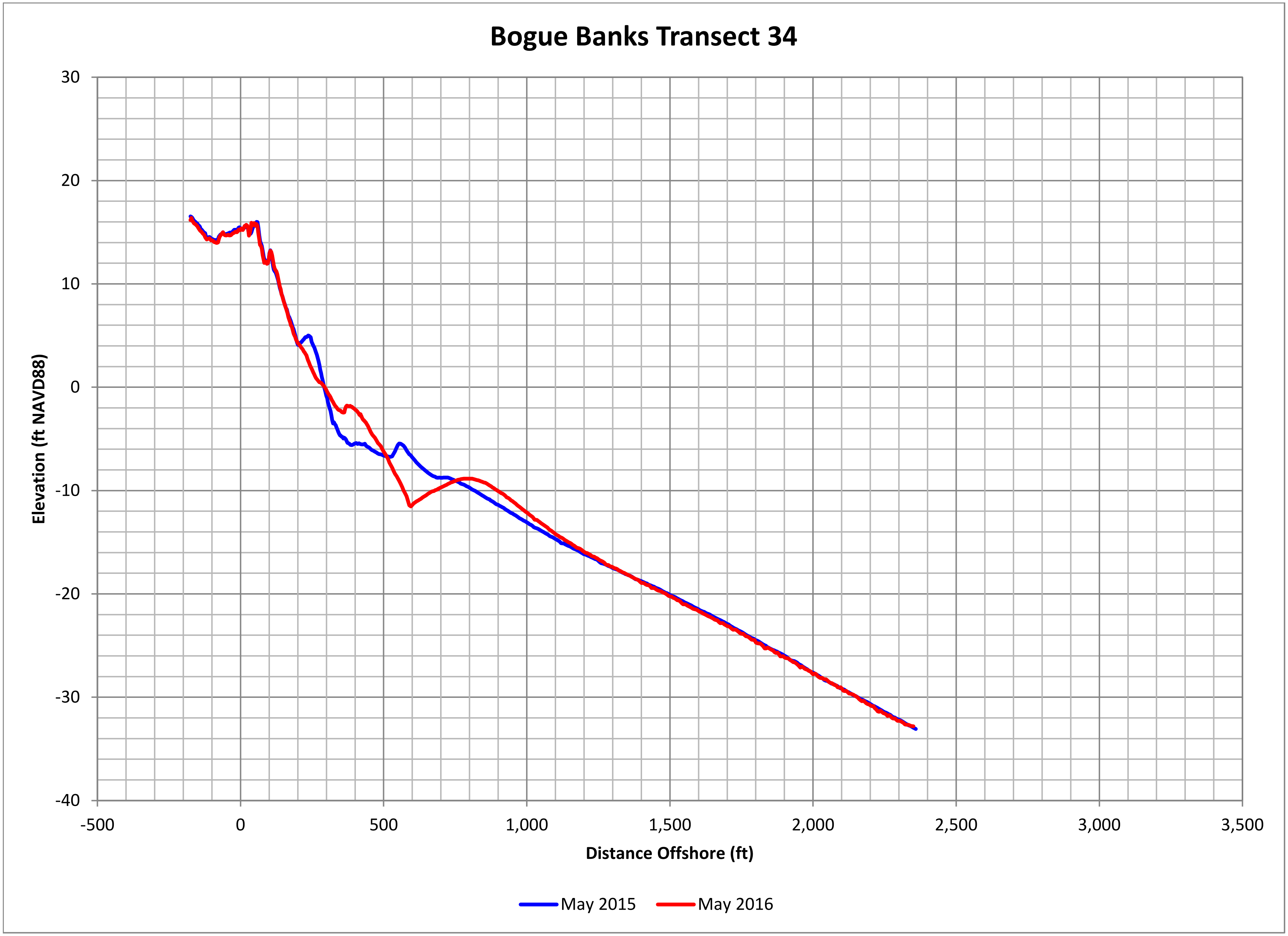

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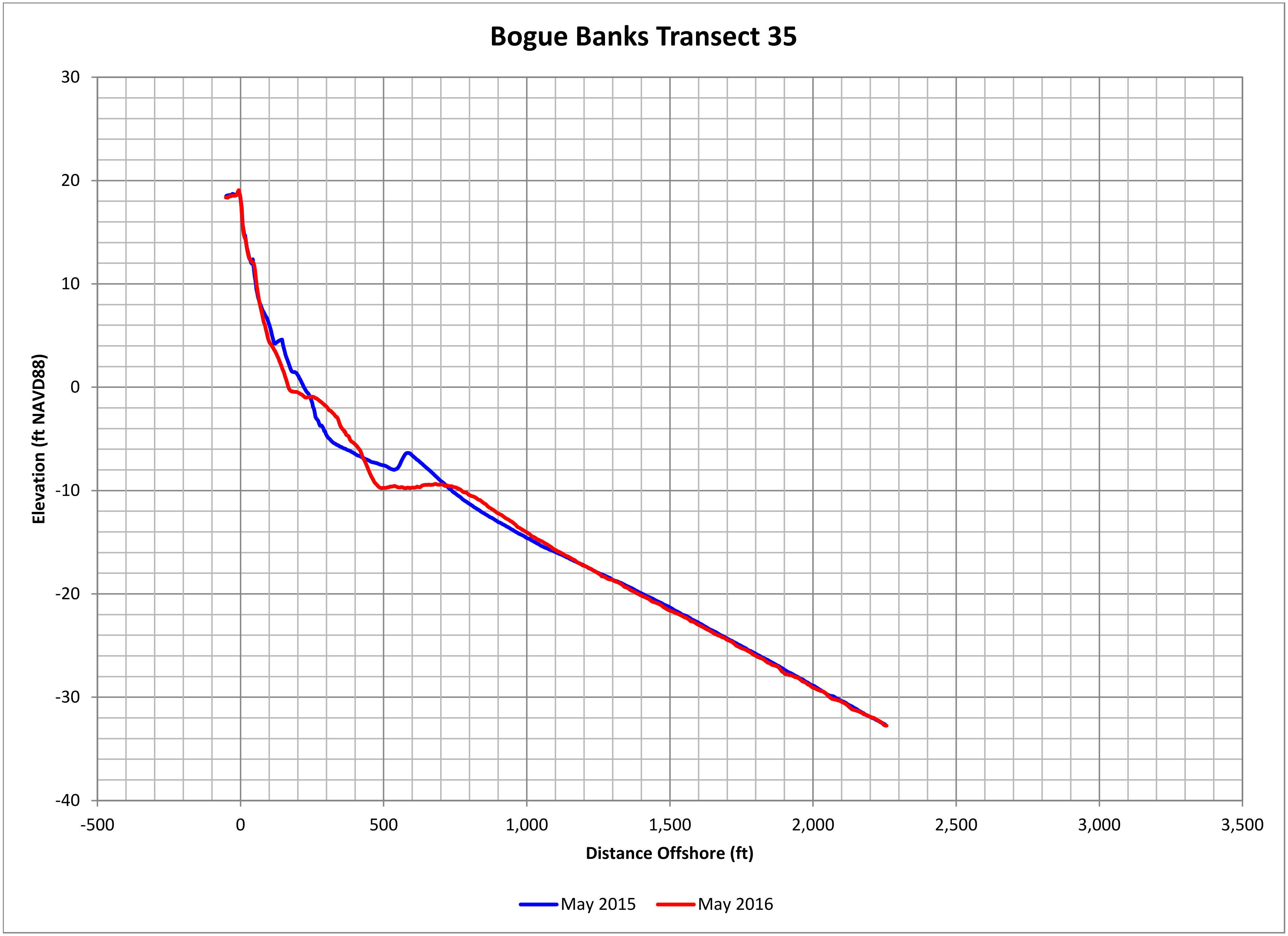
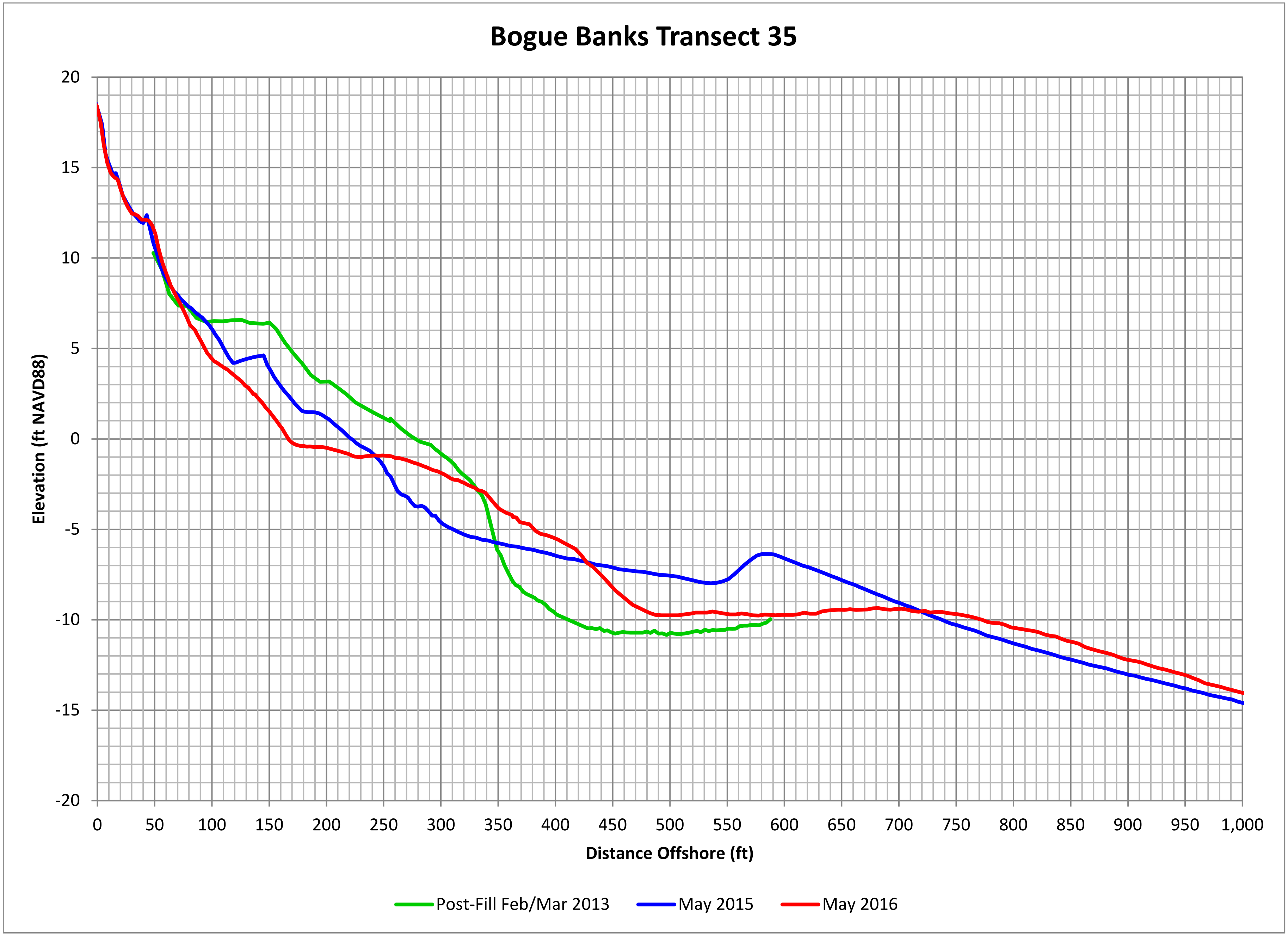


Figure C-42. Bogue Banks Profile Comparison Plot



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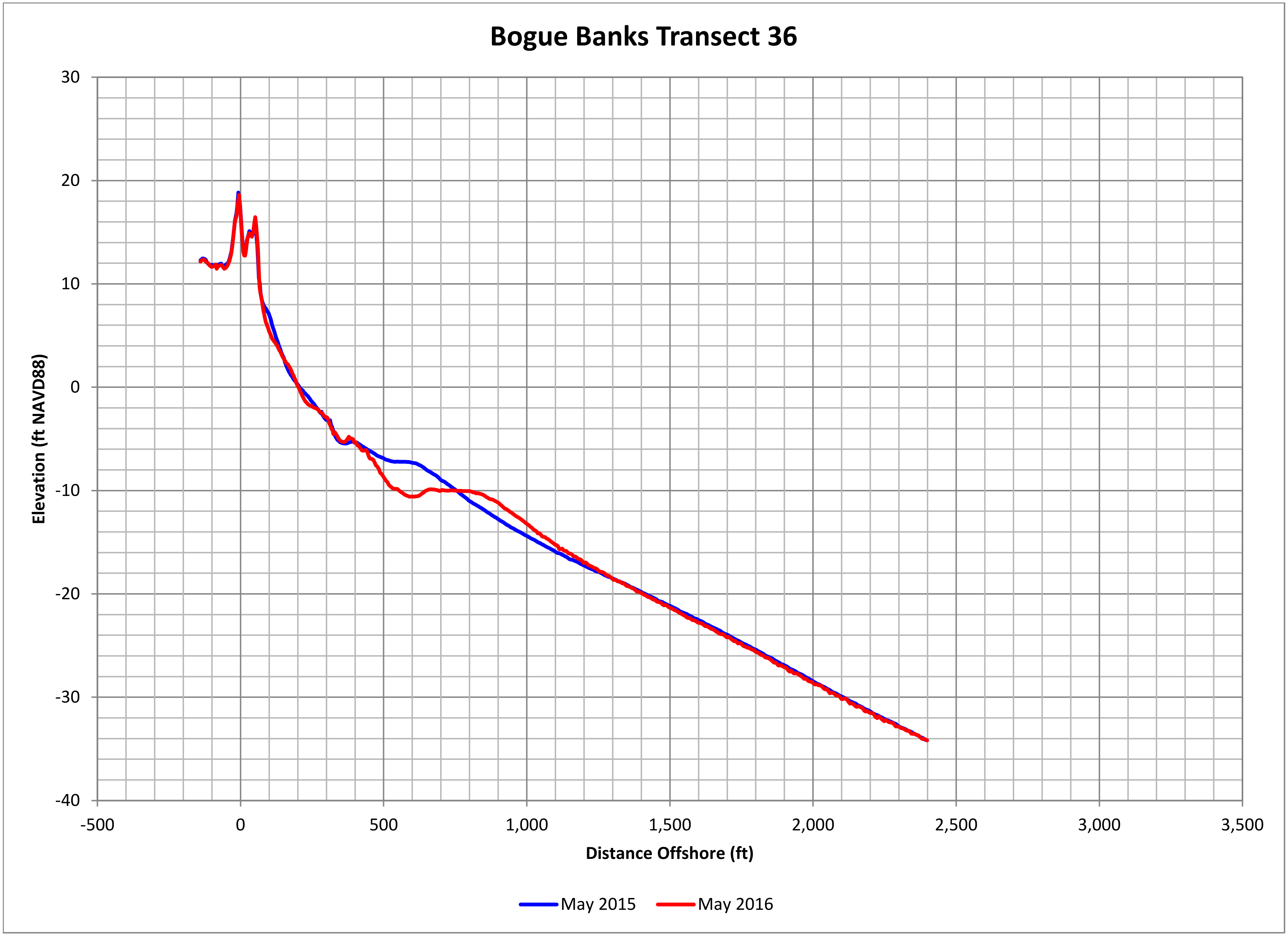

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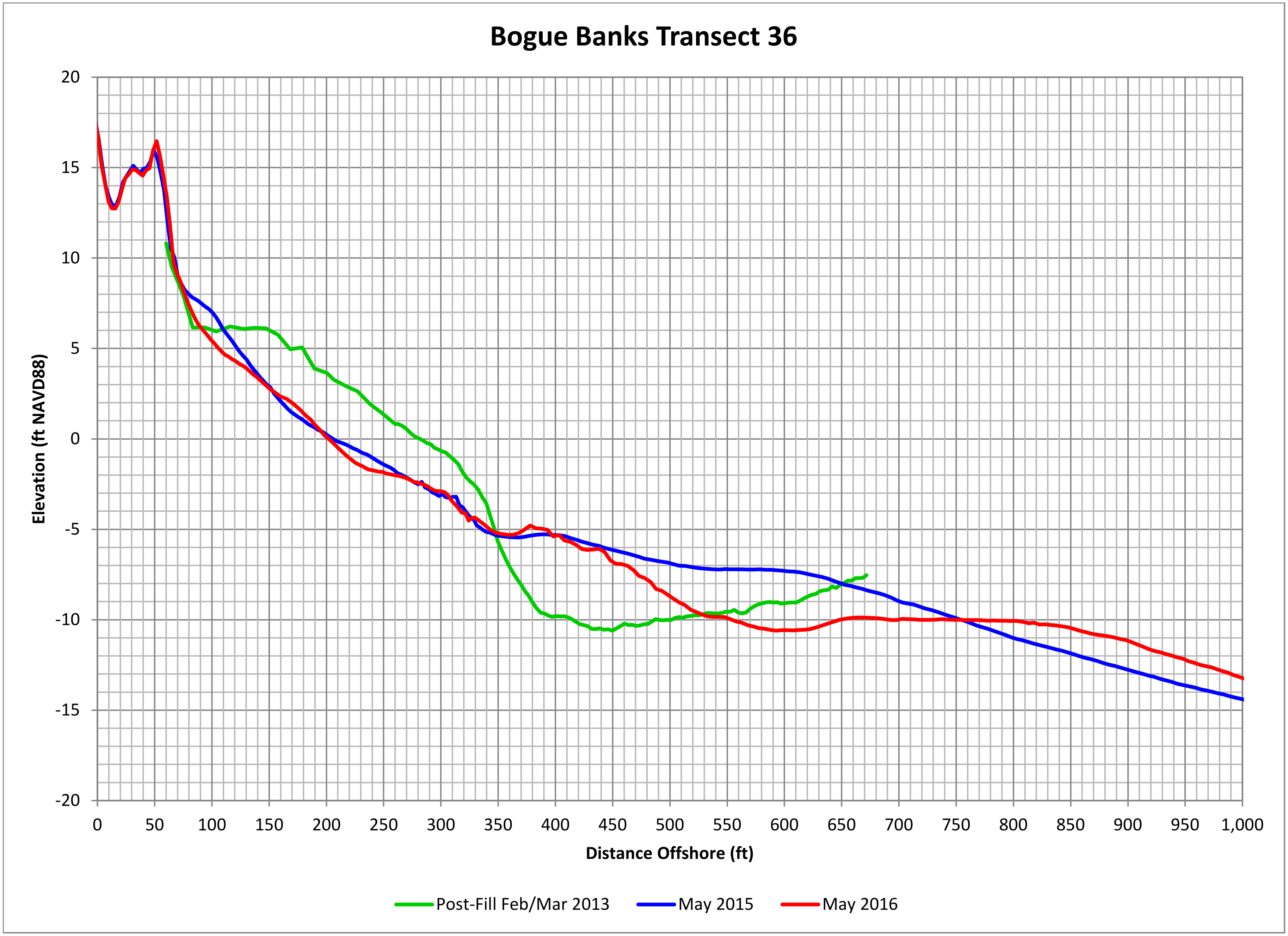

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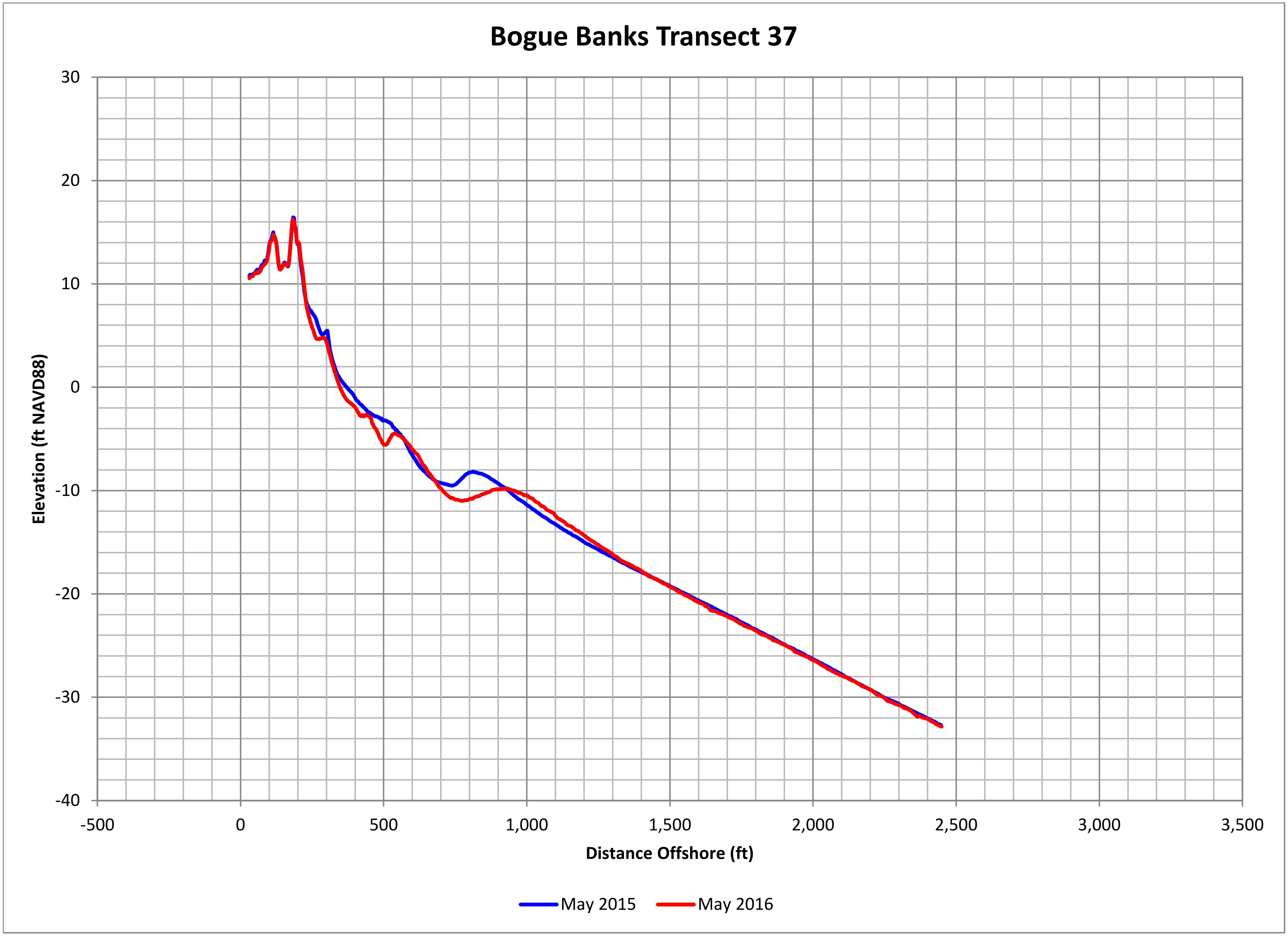
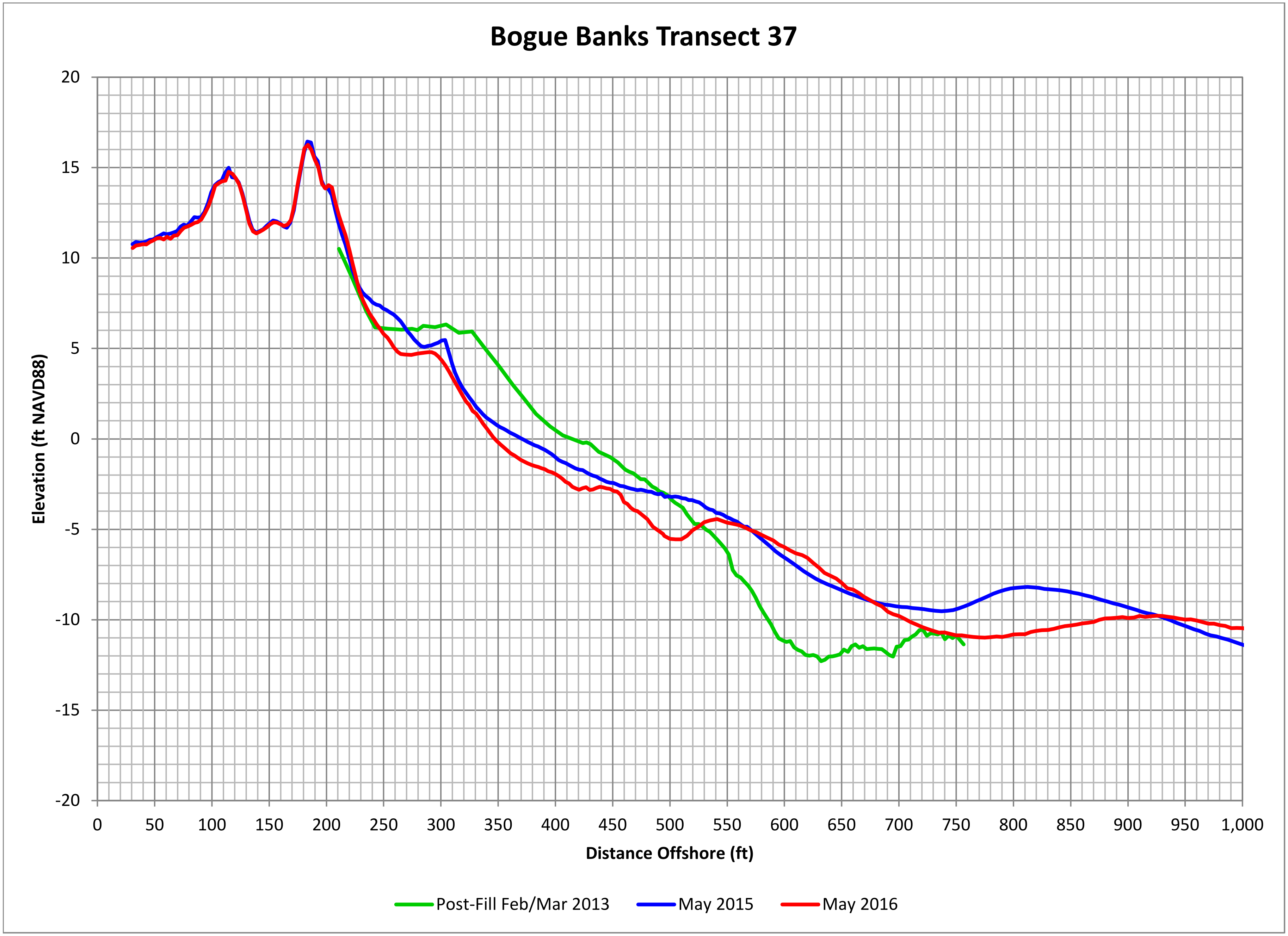


Figure C-46. Bogue Banks Profile Comparison Plot



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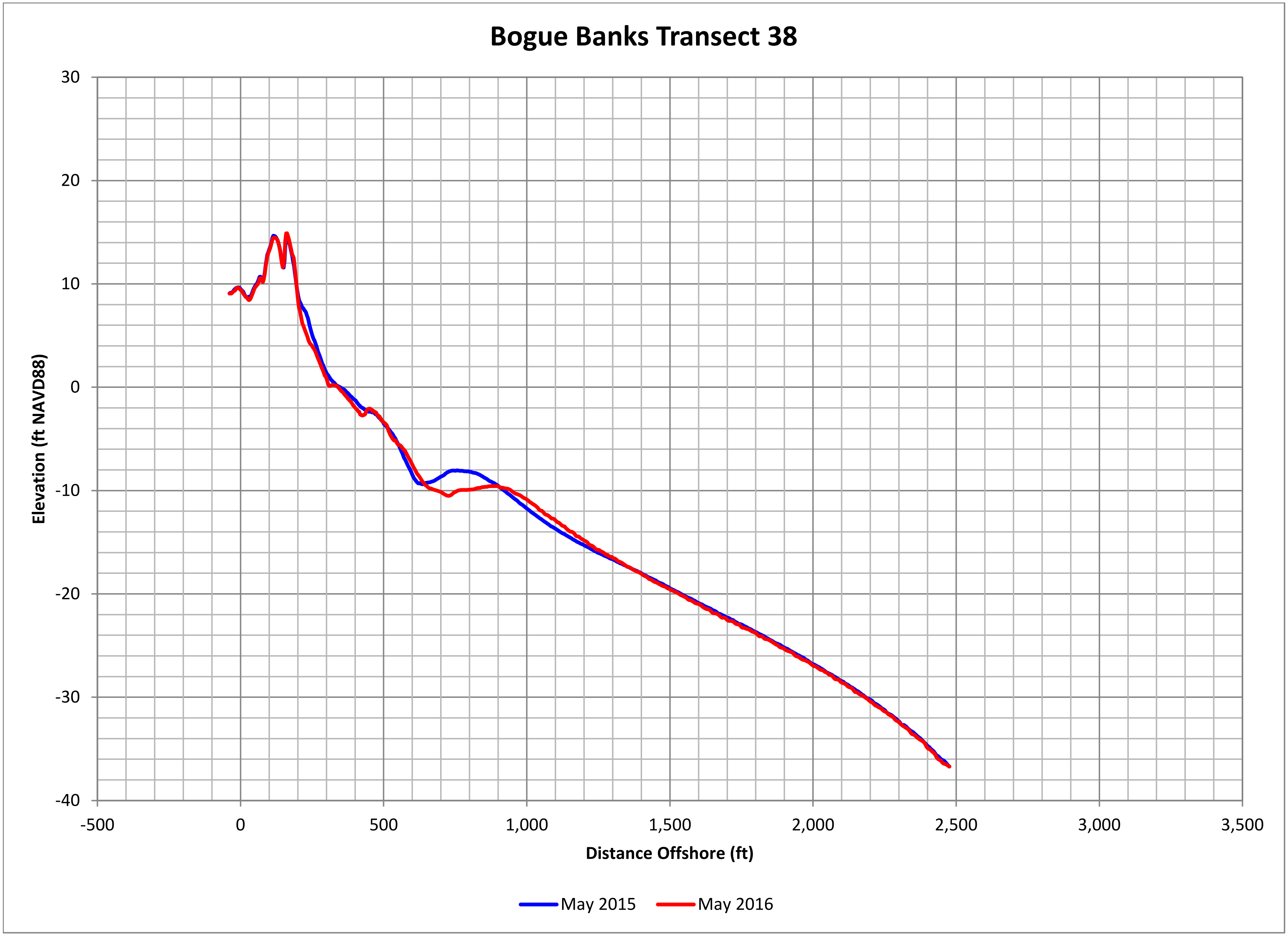


Figure C-48. Bogue Banks Profile Comparison Plot

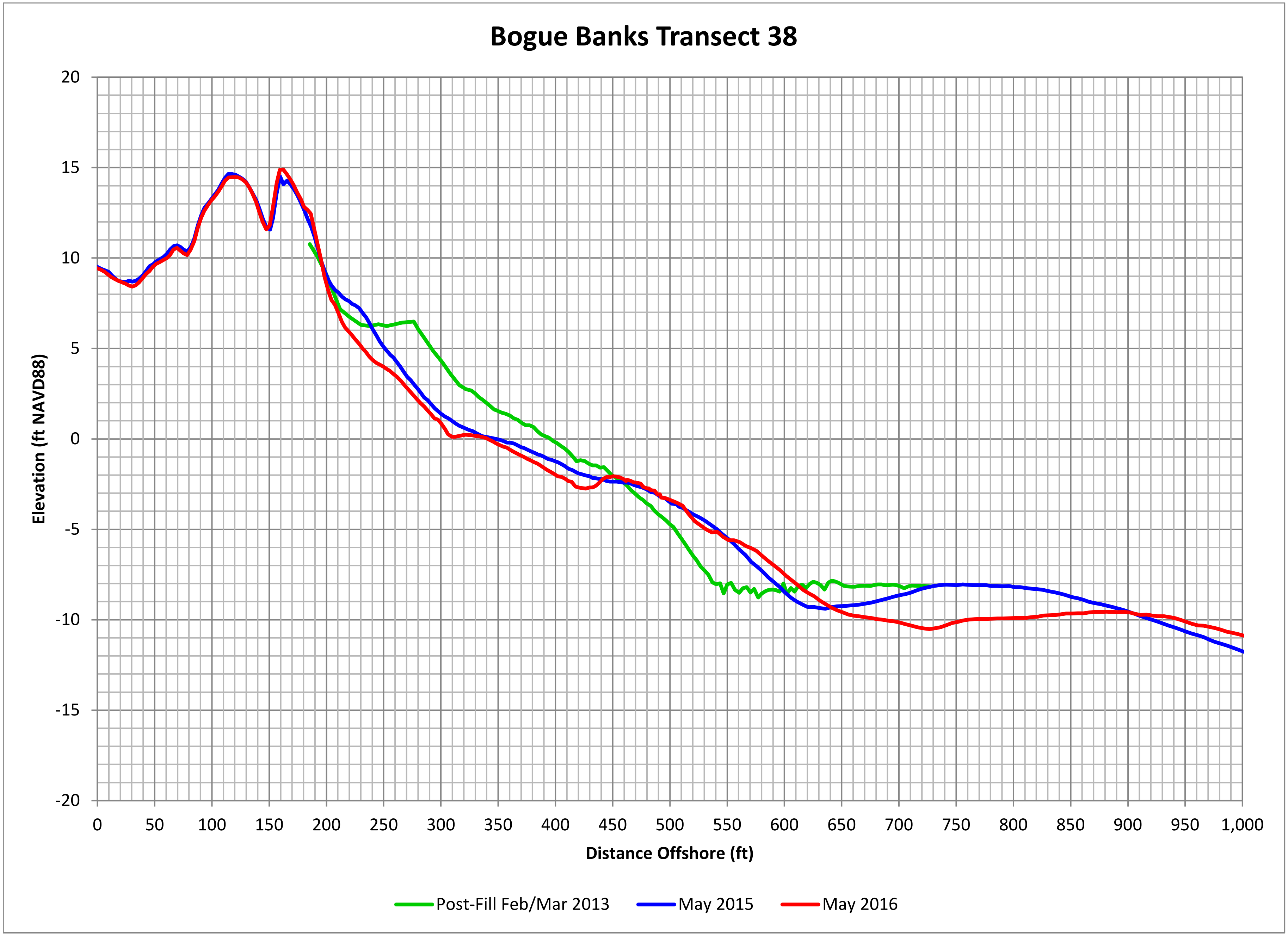


Figure C-49. Bogue Banks Profile Comparison Plot

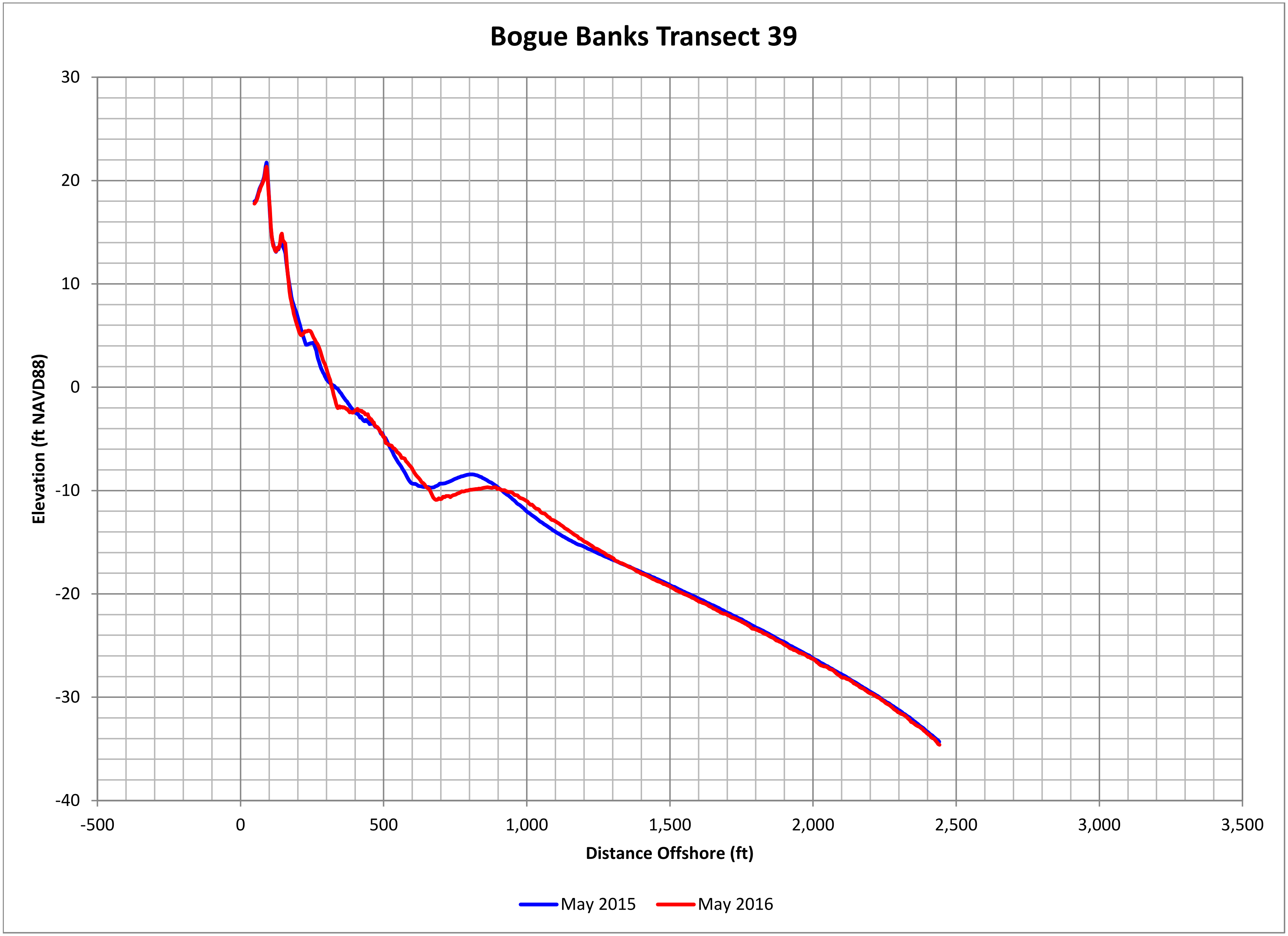


Figure C-50. Bogue Banks Profile Comparison Plot

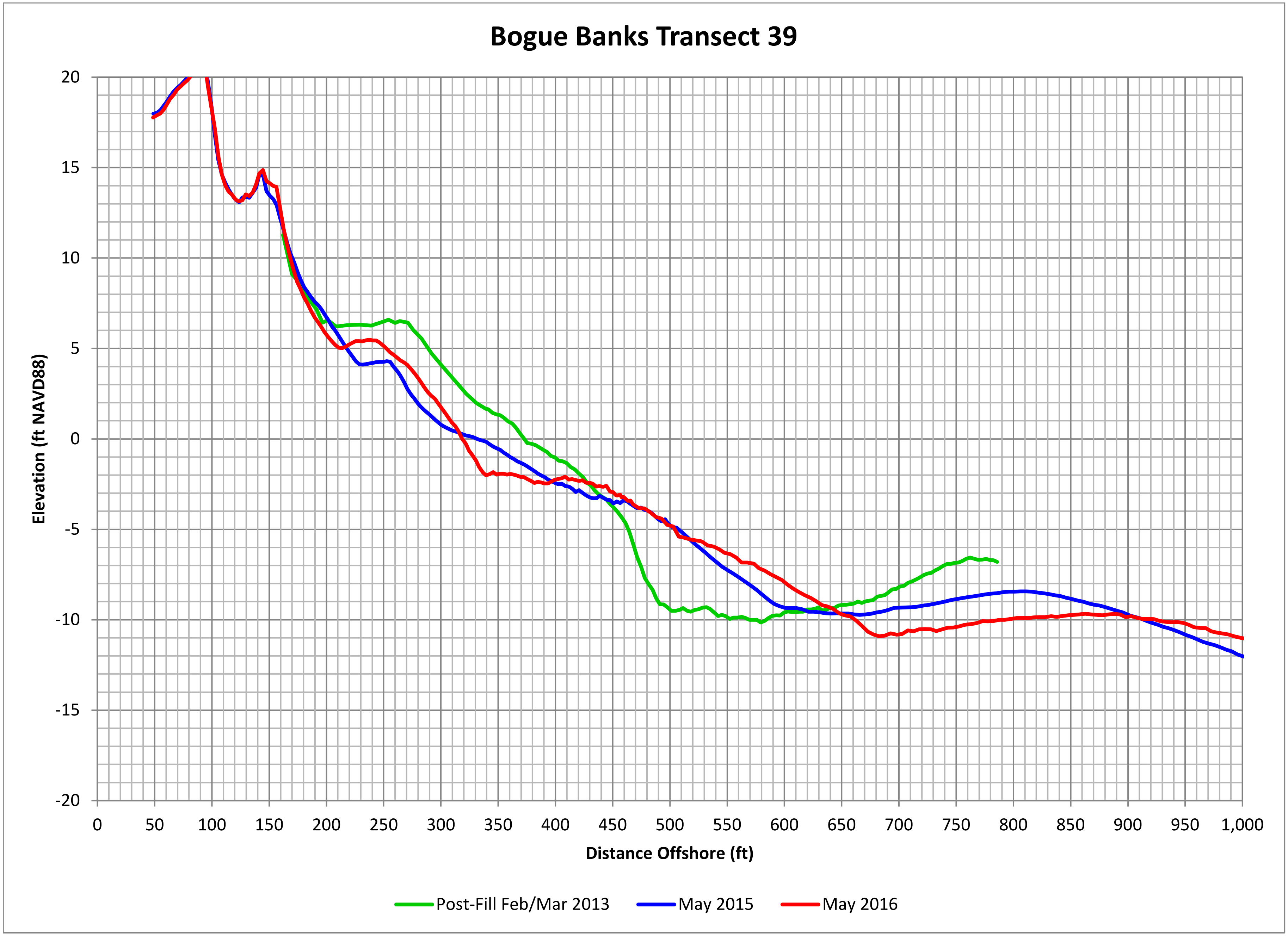
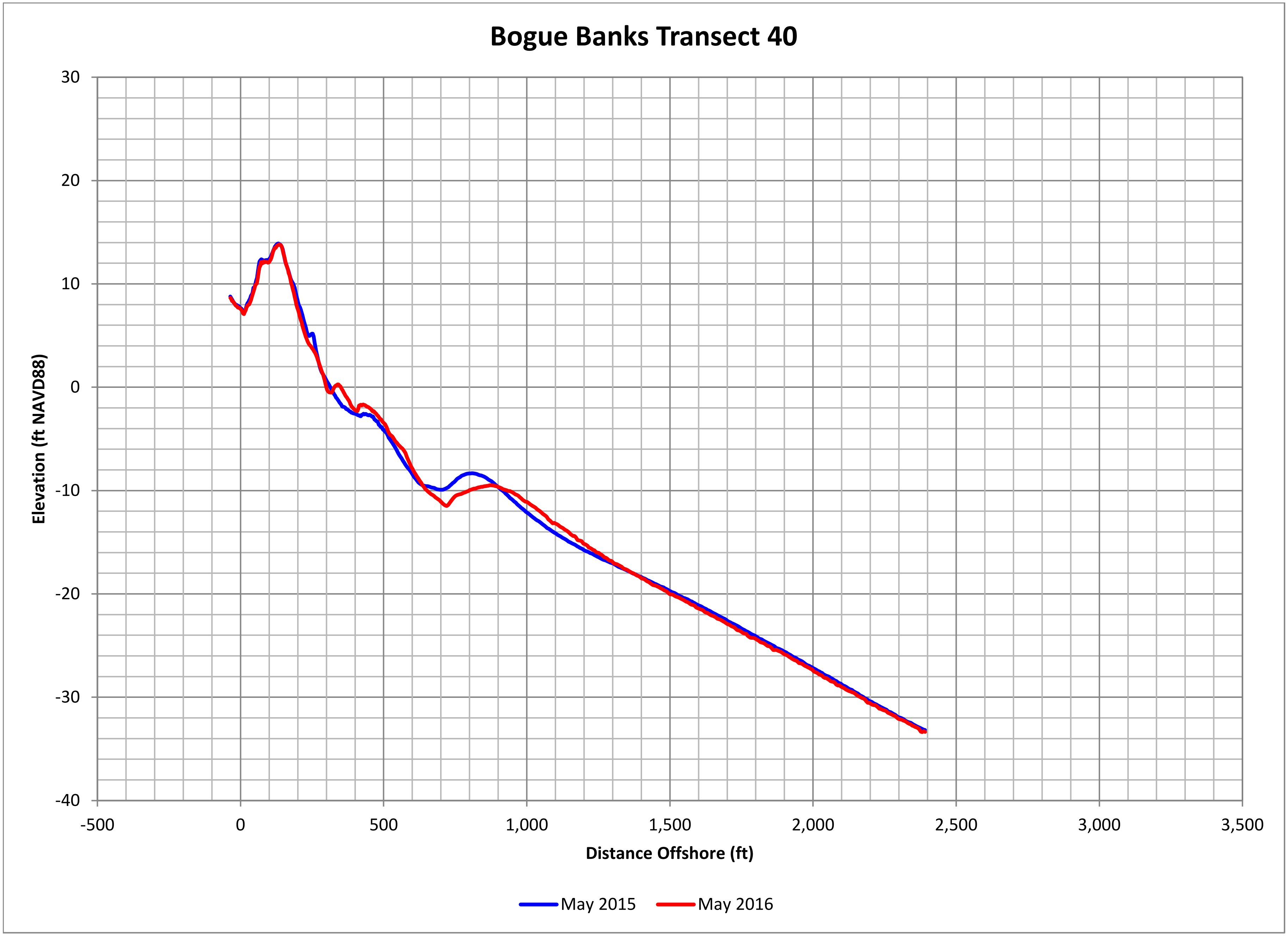


Figure C-51. Bogue Banks Profile Comparison Plot



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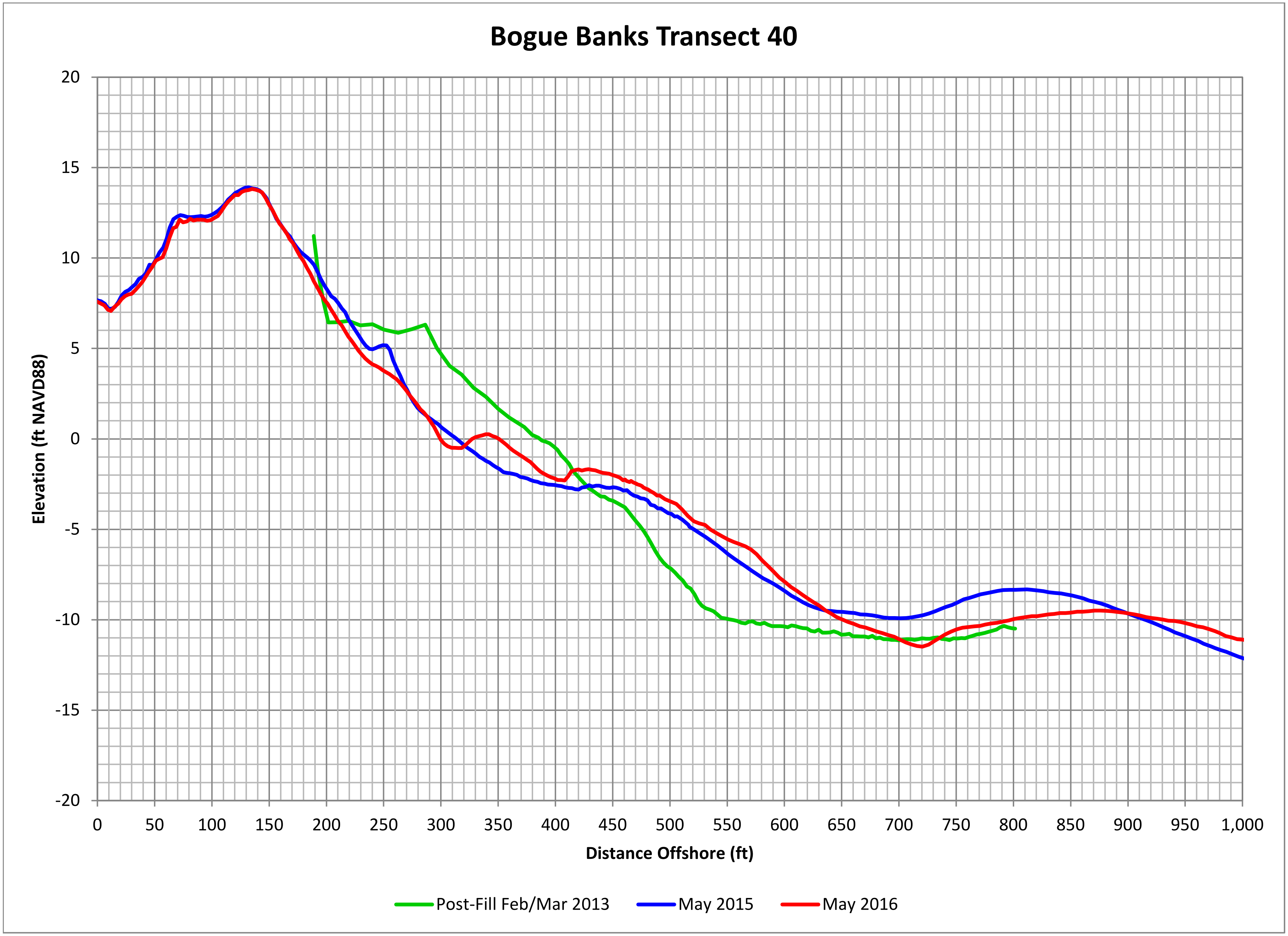

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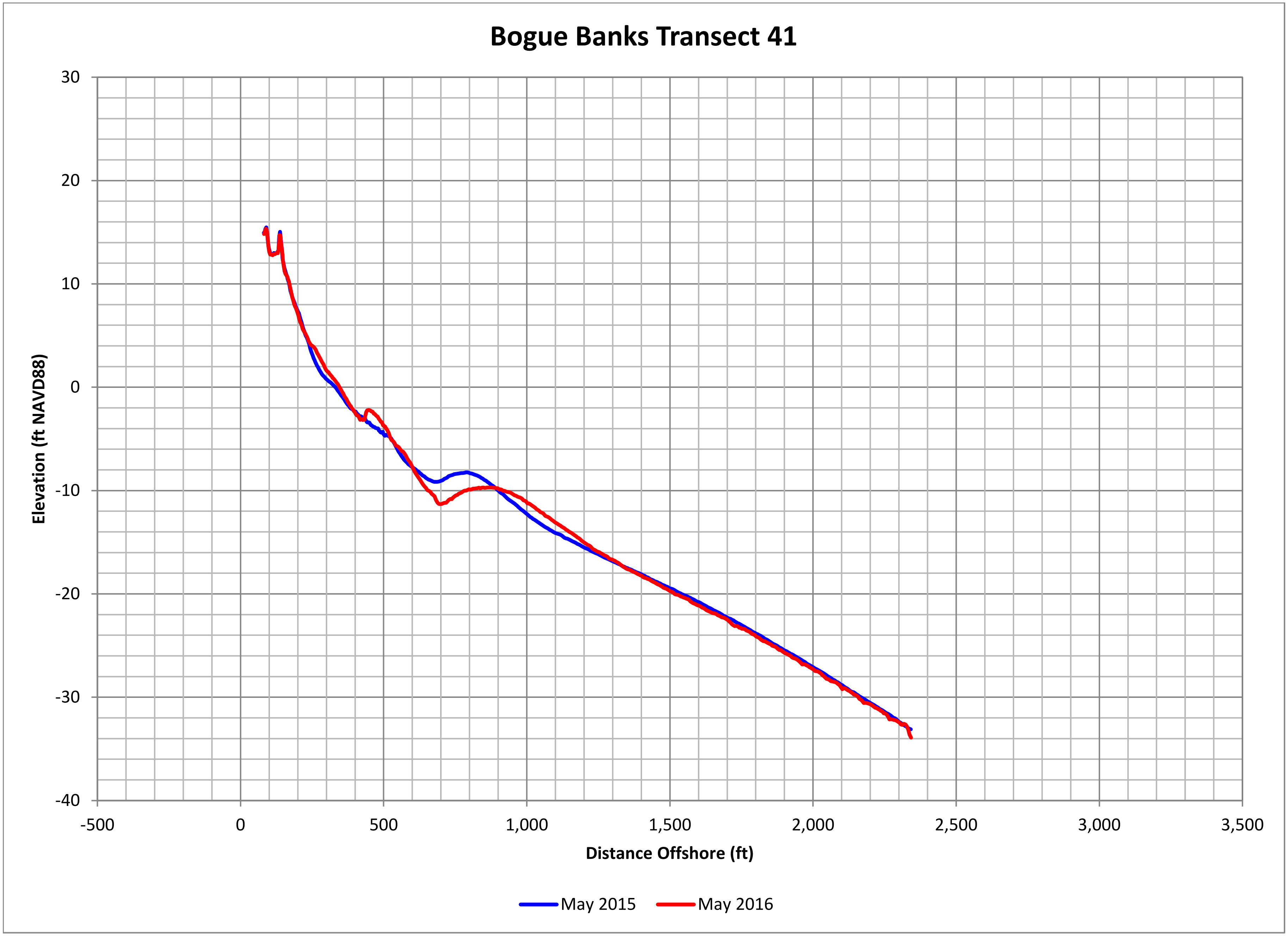
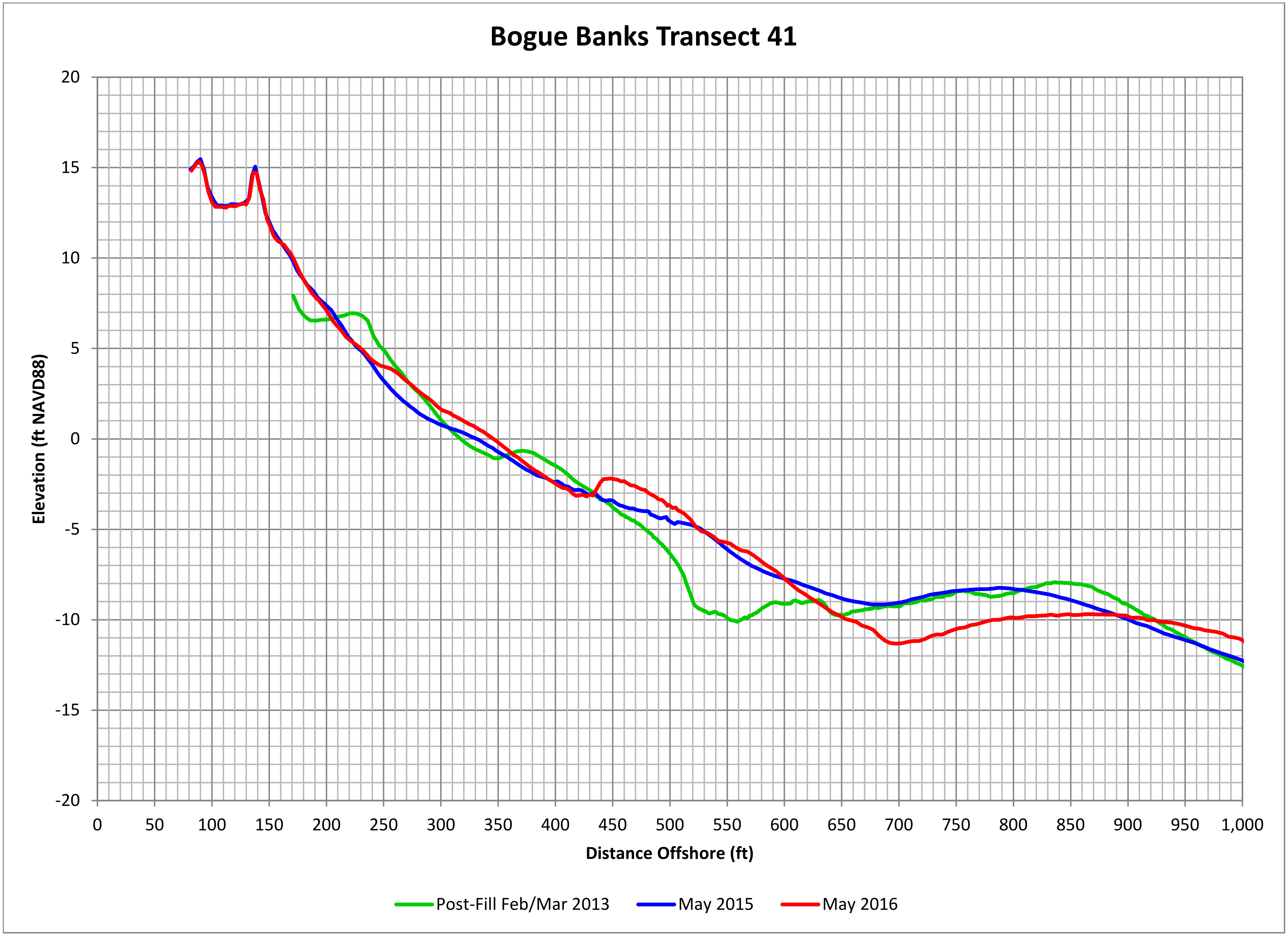


Figure C-54. Bogue Banks Profile Comparison Plot



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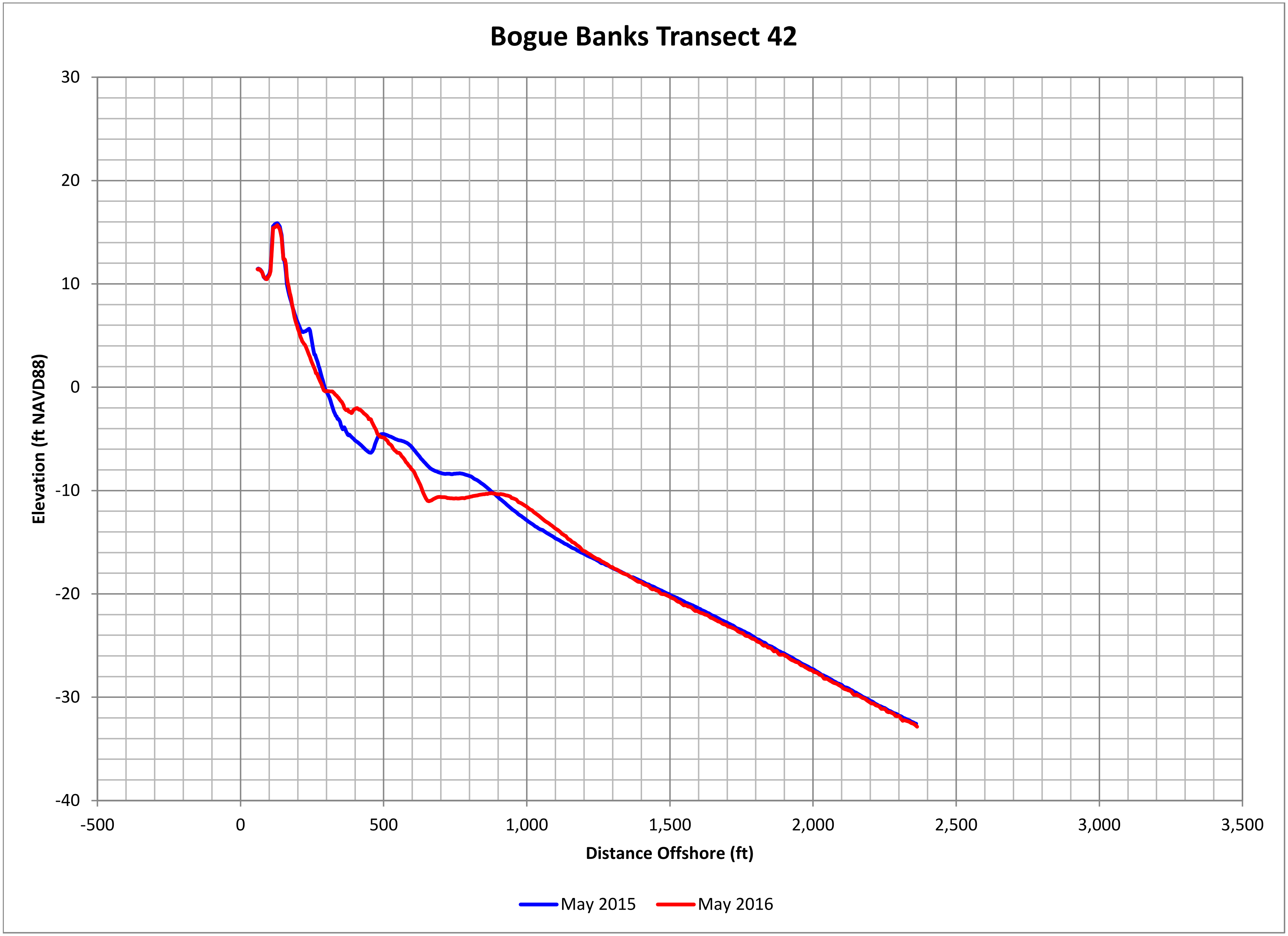


Figure C-56. Bogue Banks Profile Comparison Plot

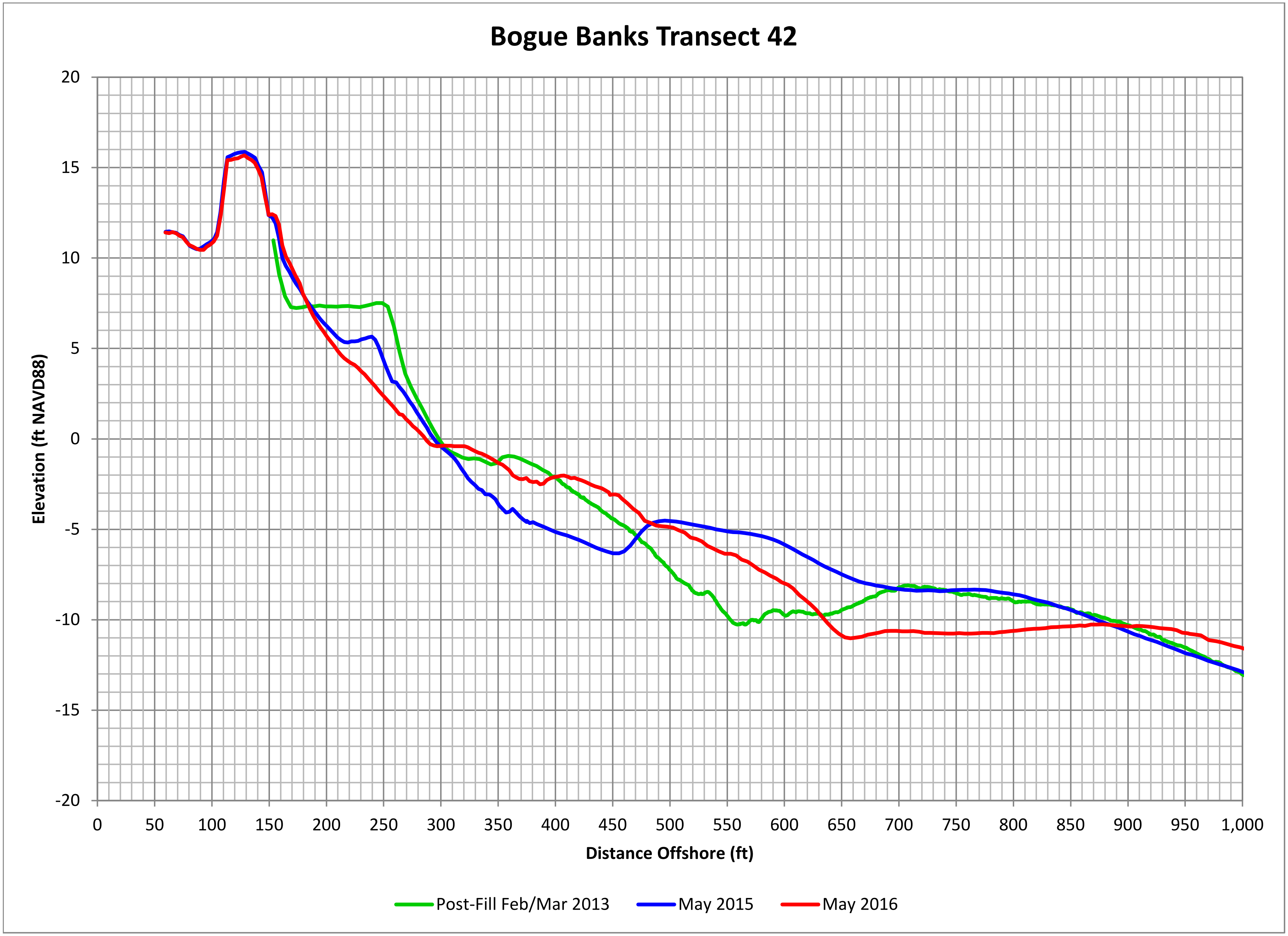


Figure C-57. Bogue Banks Profile Comparison Plot

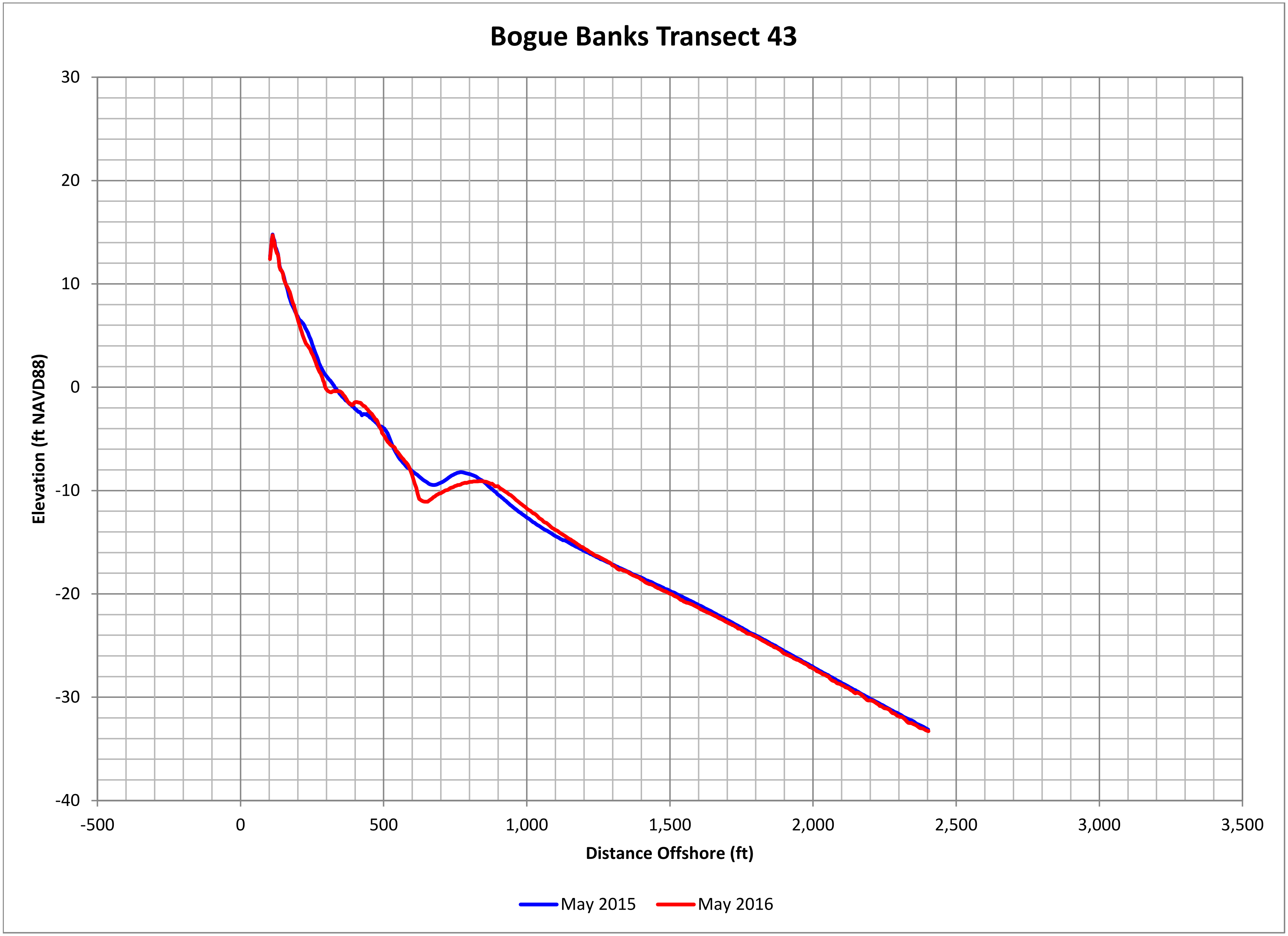


Figure C-58. Bogue Banks Profile Comparison Plot

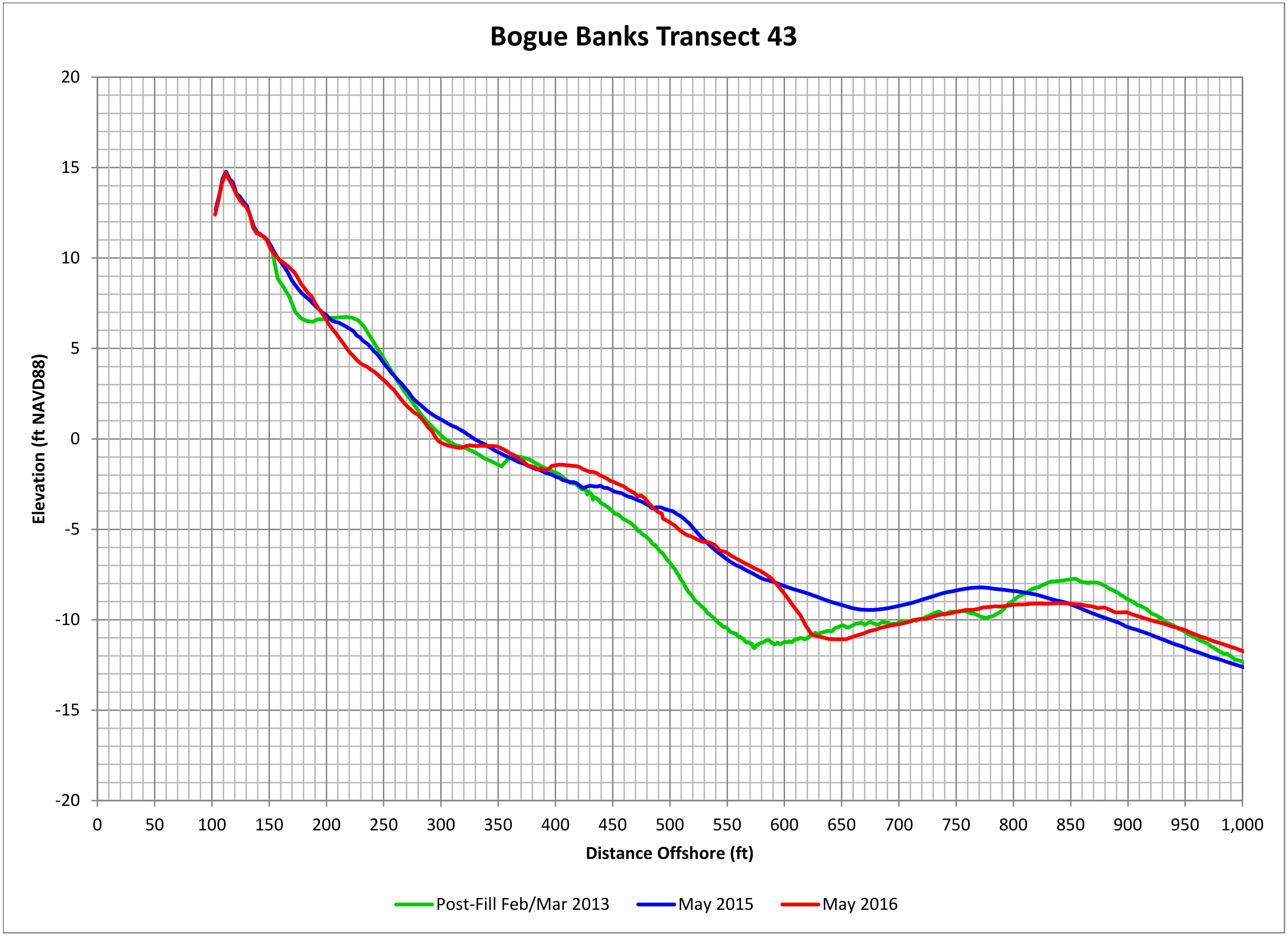


Figure C-59. Bogue Banks Profile Comparison Plot

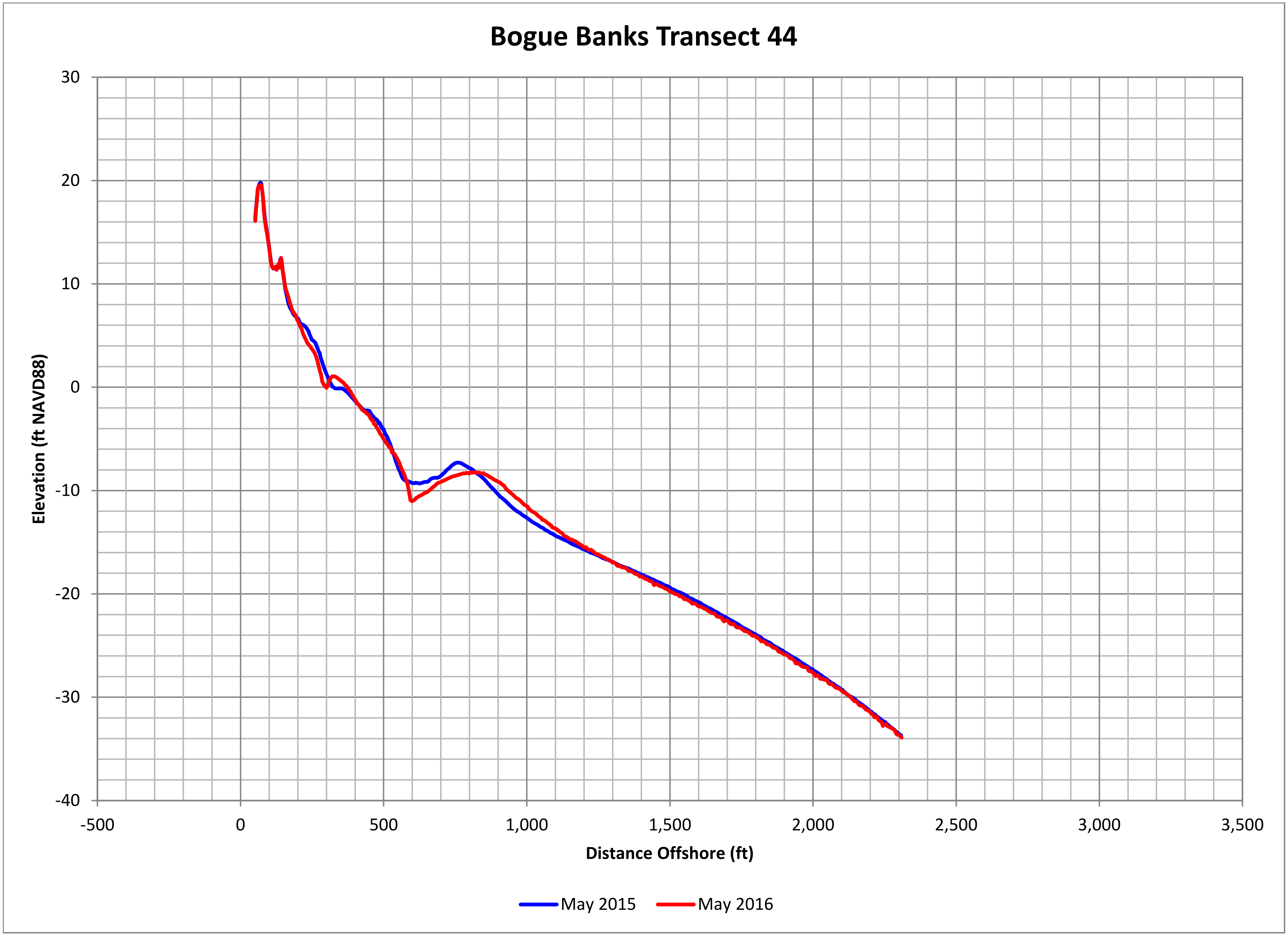


Figure C-60. Bogue Banks Profile Comparison Plot

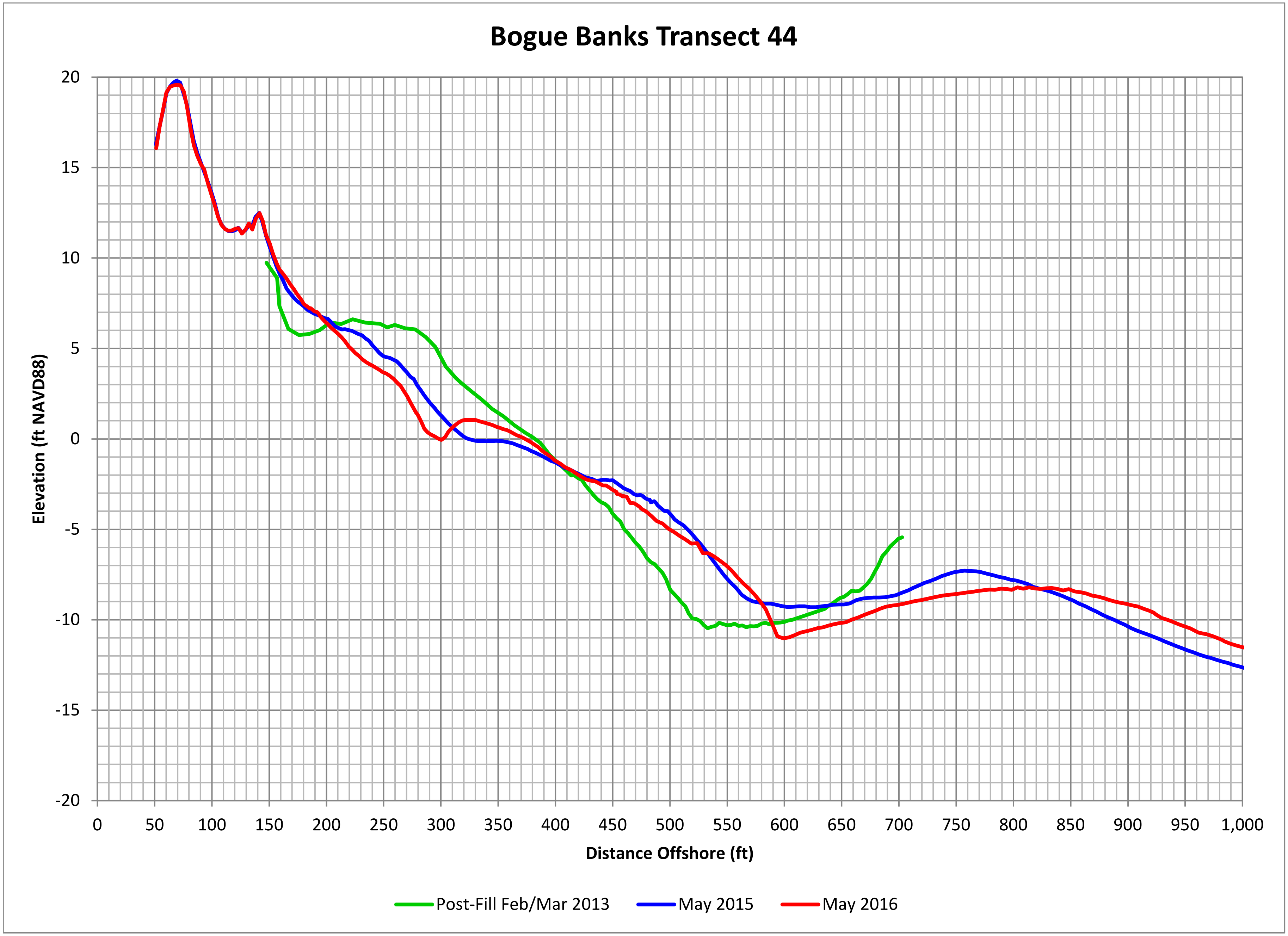


Figure C-61. Bogue Banks Profile Comparison Plot

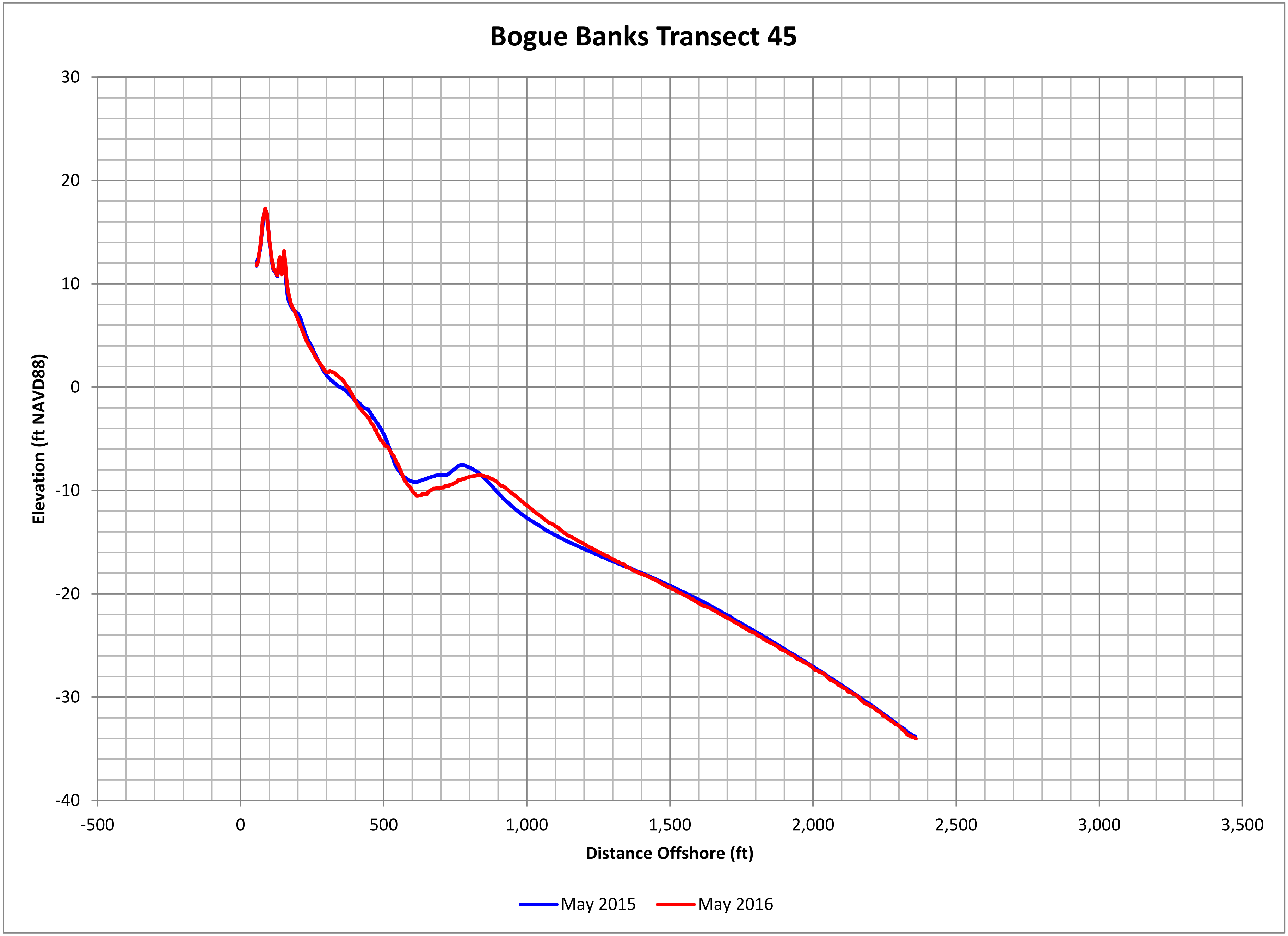


Figure C-62. Bogue Banks Profile Comparison Plot

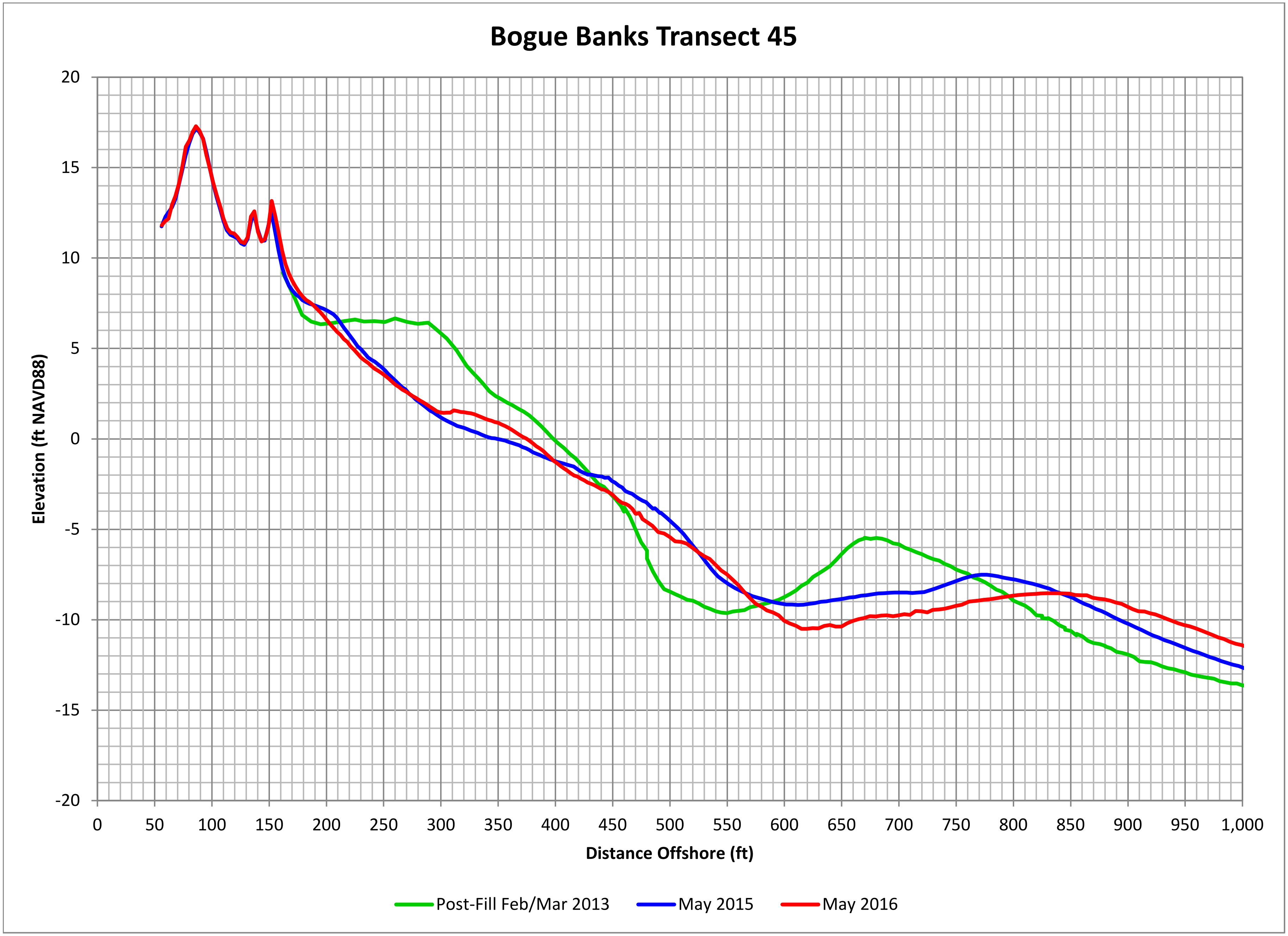


Figure C-63. Bogue Banks Profile Comparison Plot

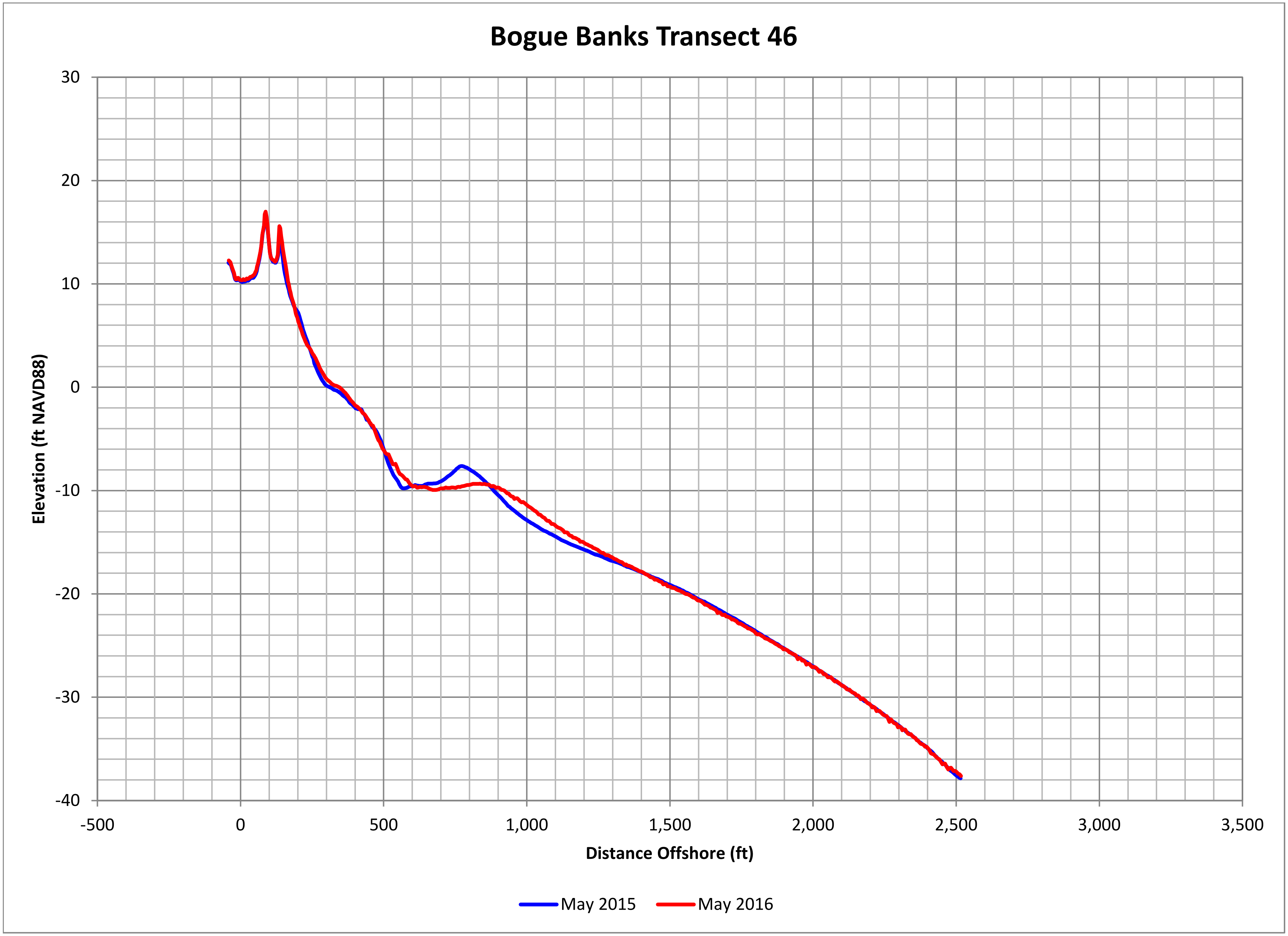


Figure C-64. Bogue Banks Profile Comparison Plot

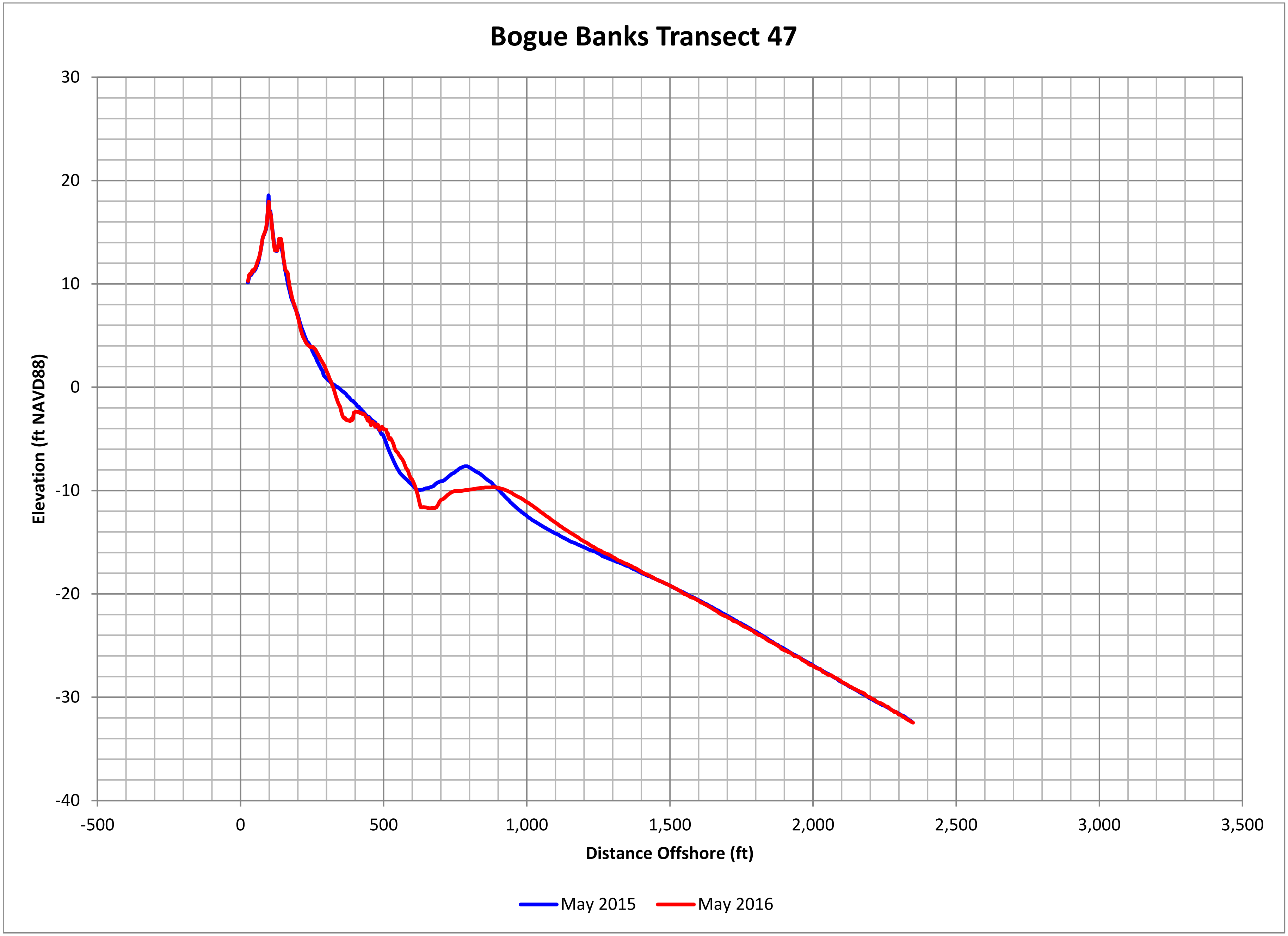


Figure C-65. Bogue Banks Profile Comparison Plot

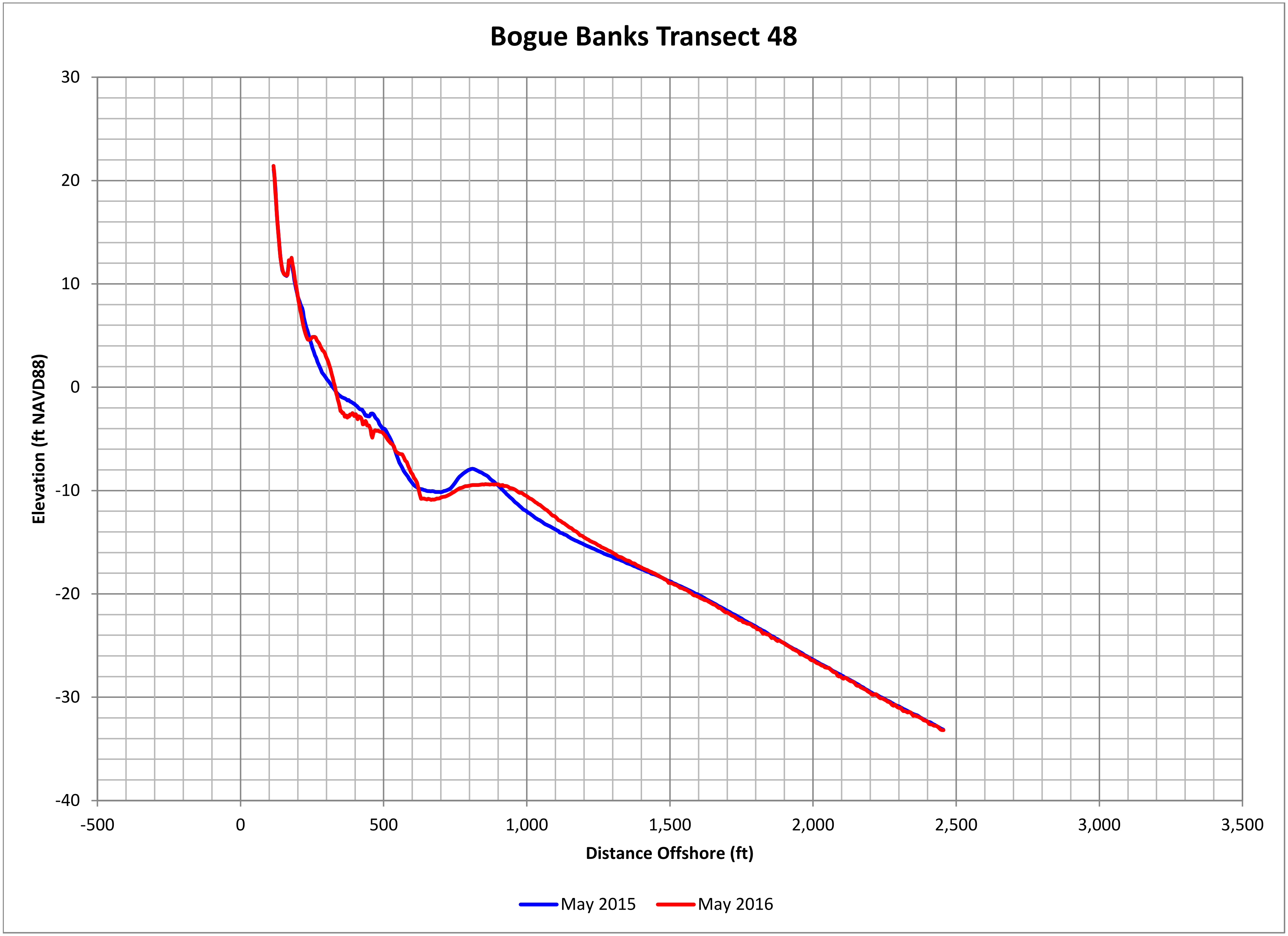


Figure C-66. Bogue Banks Profile Comparison Plot

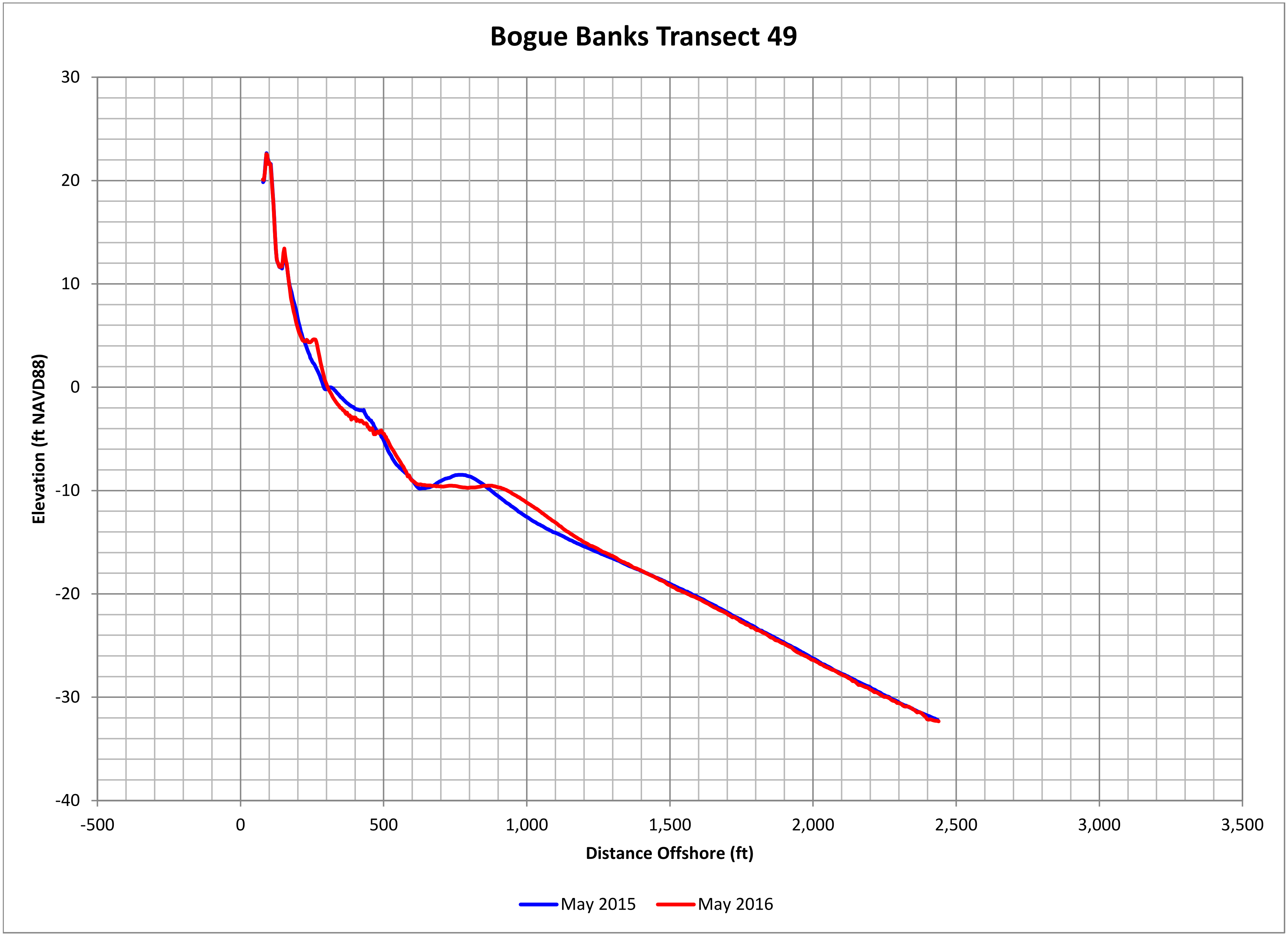


Figure C-67. Bogue Banks Profile Comparison Plot

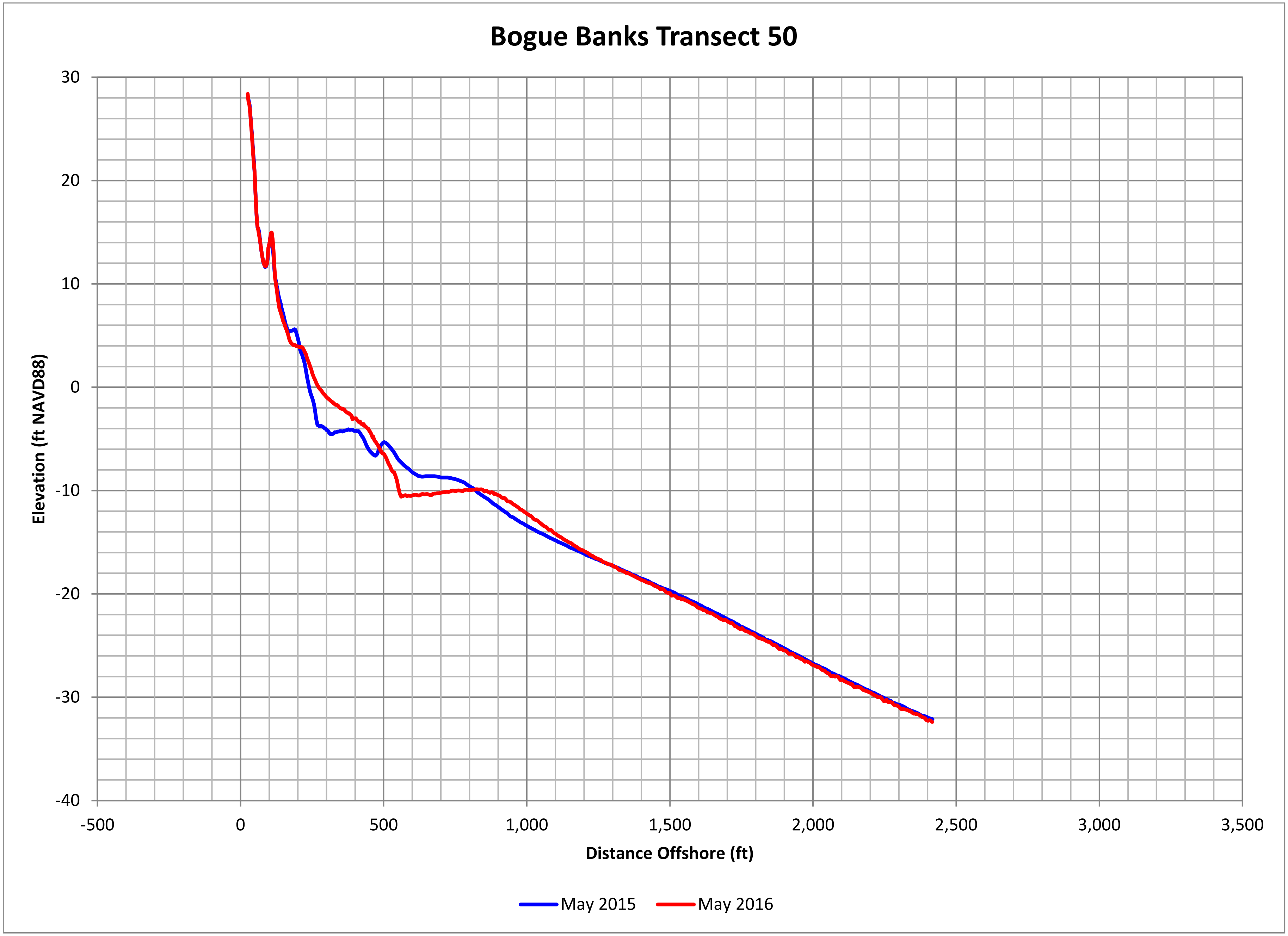


Figure C-68. Bogue Banks Profile Comparison Plot

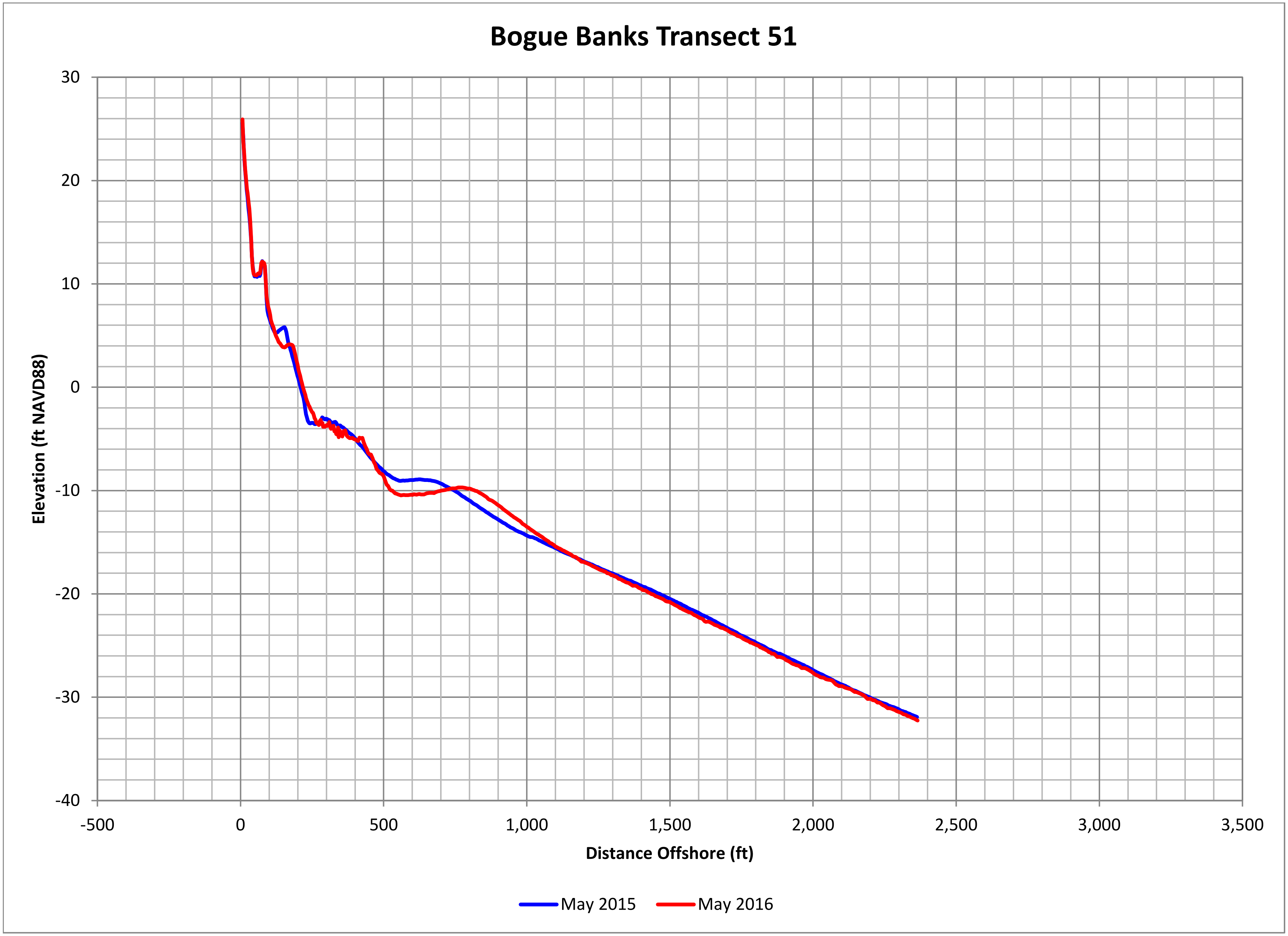


Figure C-69. Bogue Banks Profile Comparison Plot

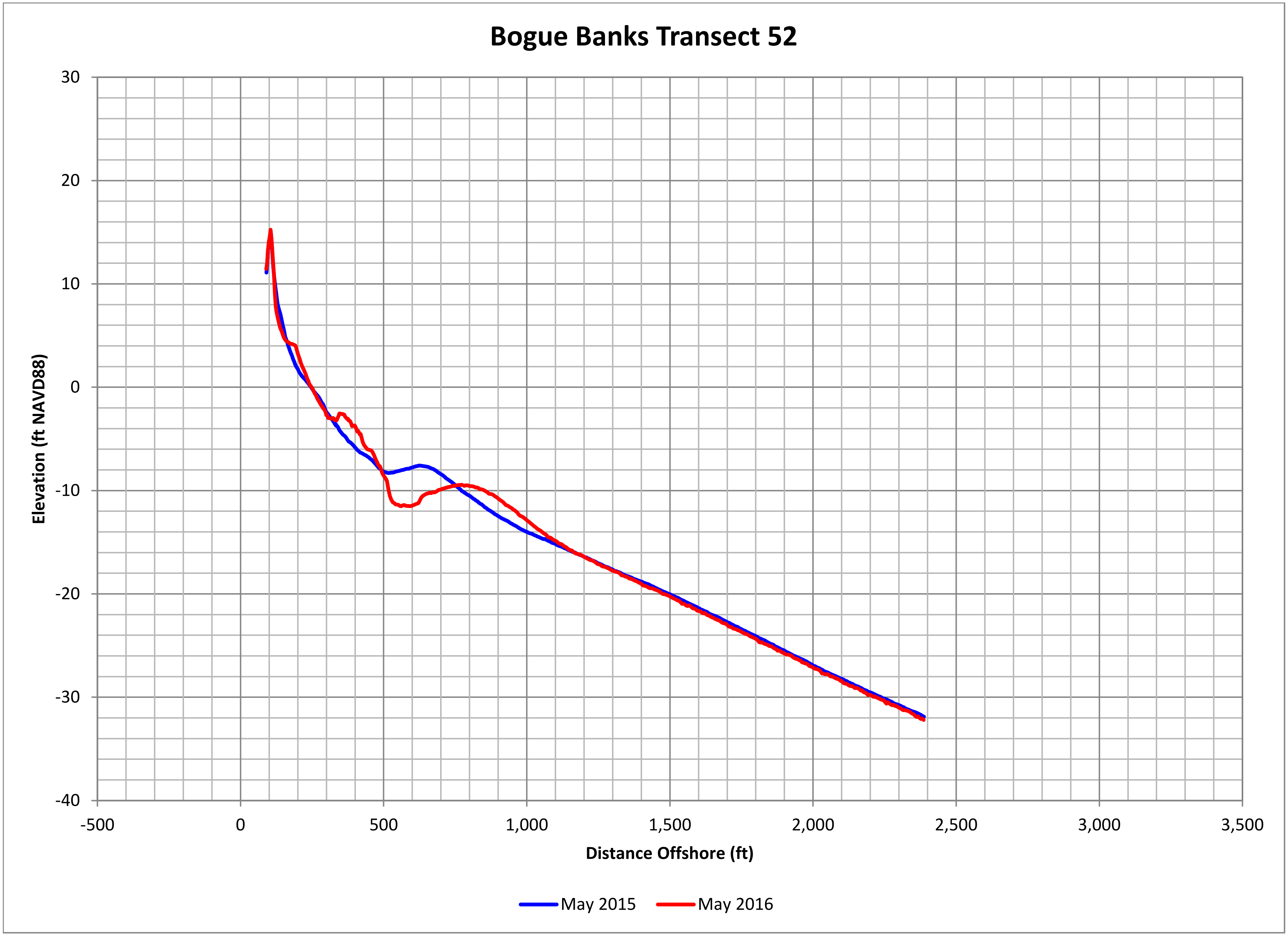


Figure C-70. Bogue Banks Profile Comparison Plot

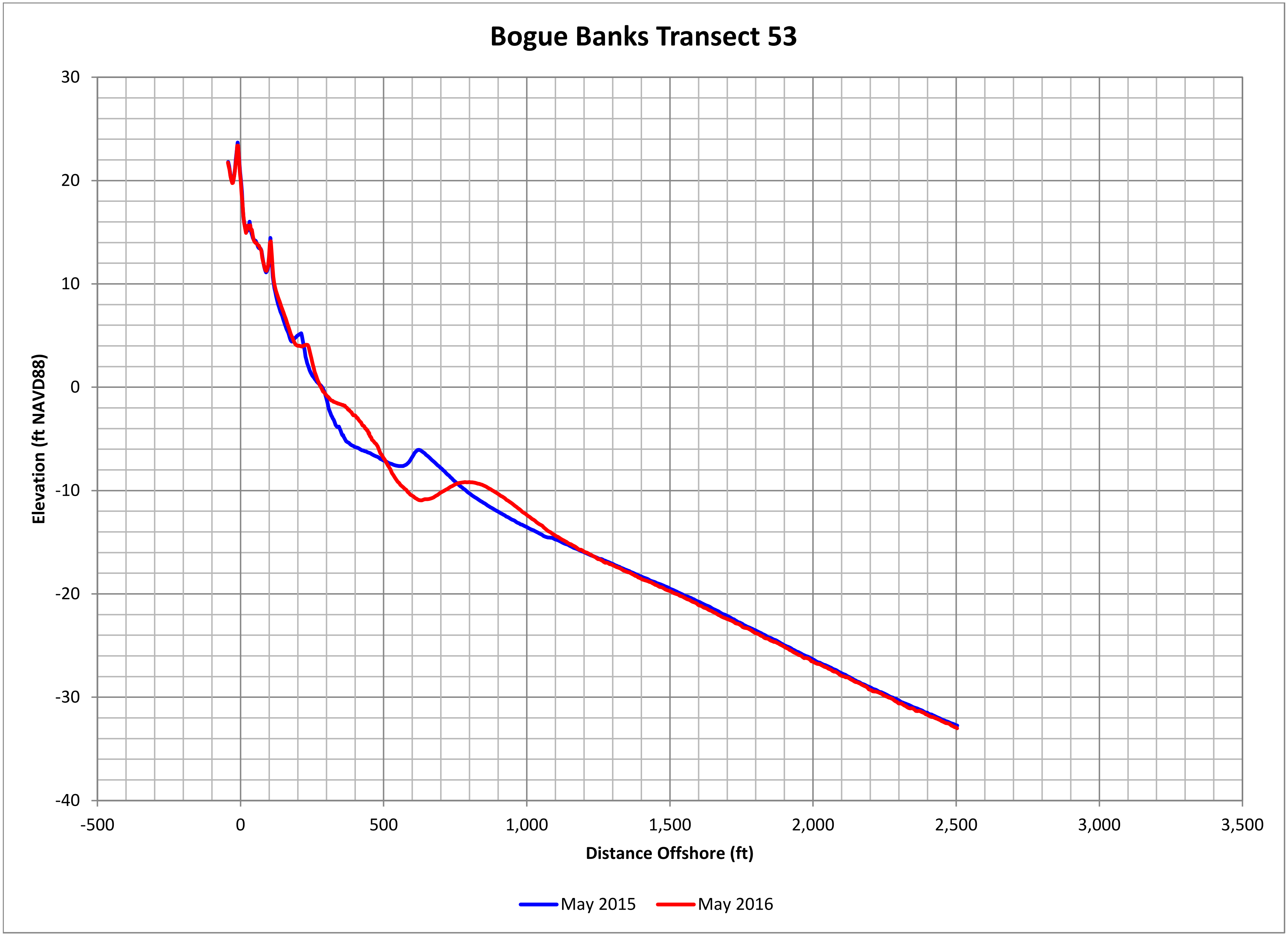


Figure C-71. Bogue Banks Profile Comparison Plot

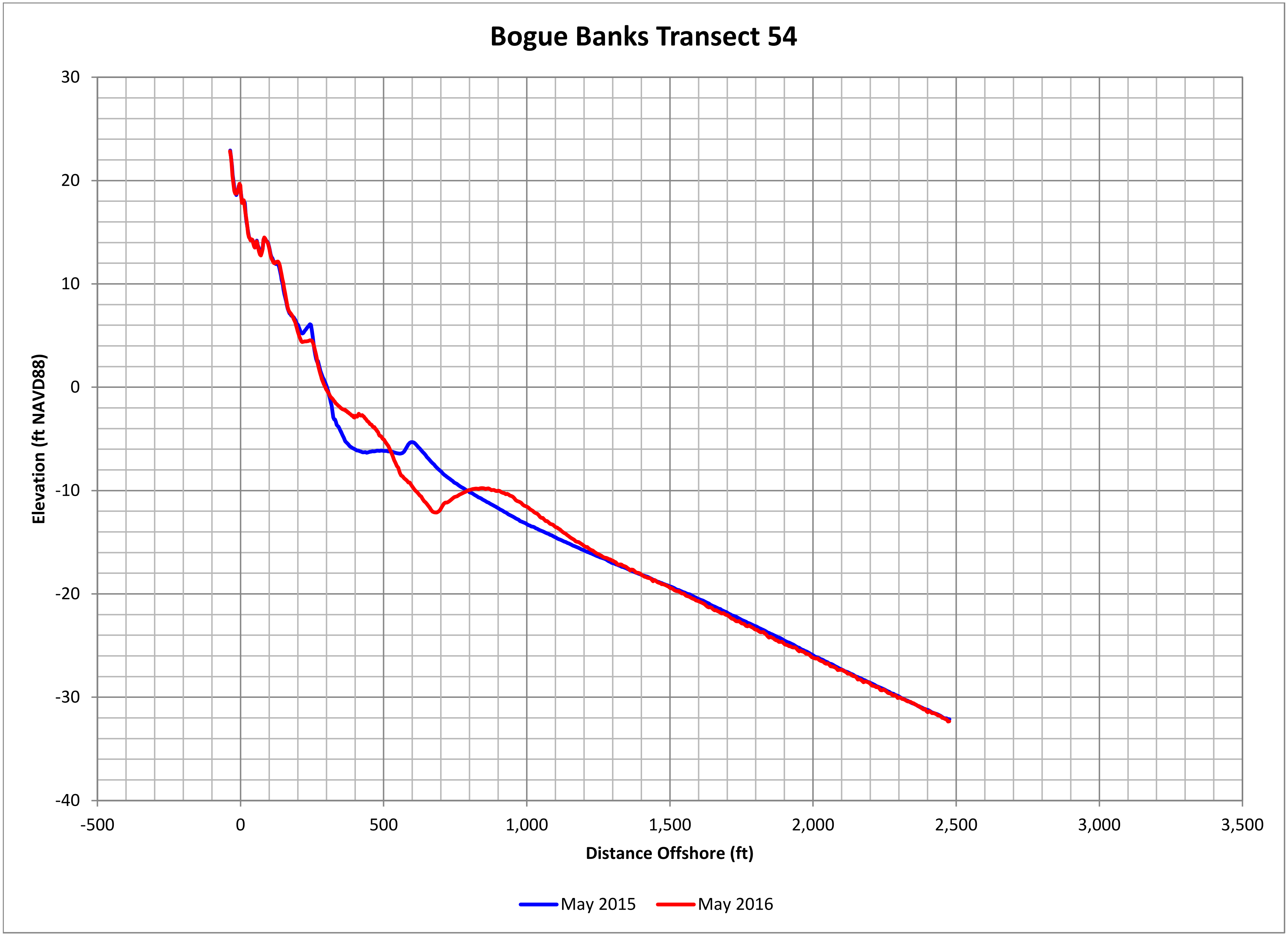


Figure C-72. Bogue Banks Profile Comparison Plot

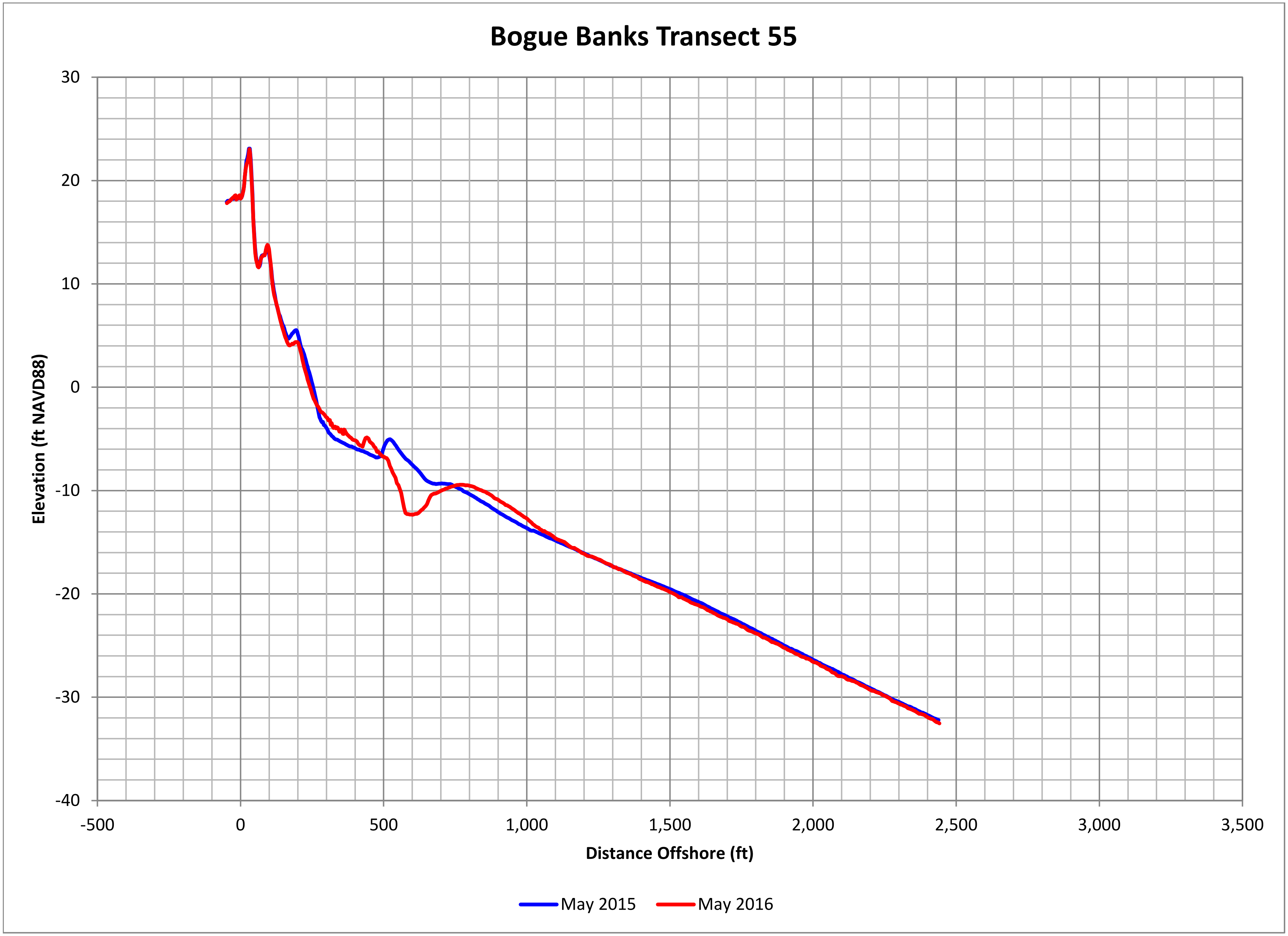


Figure C-73. Bogue Banks Profile Comparison Plot

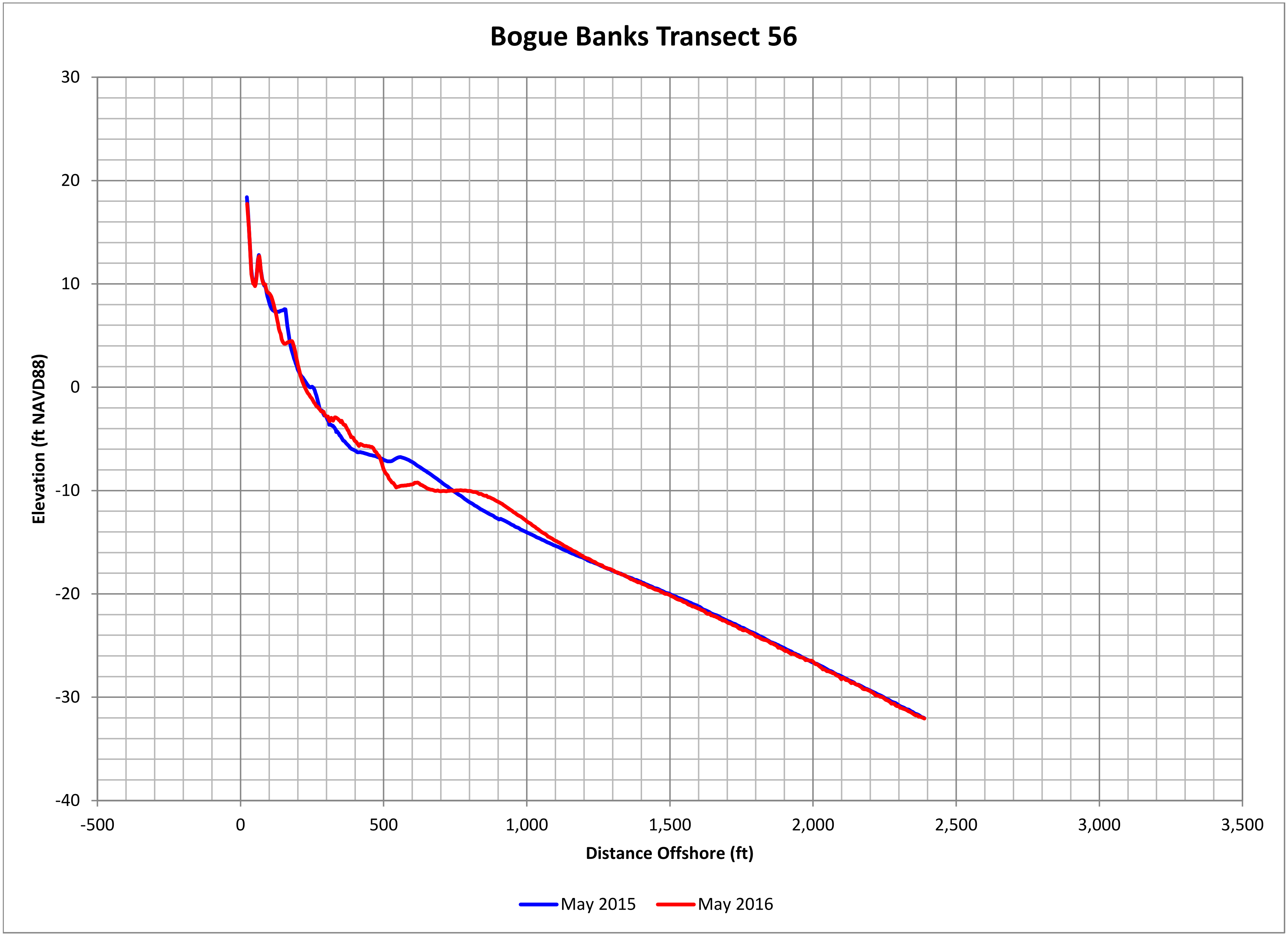


Figure C-74. Bogue Banks Profile Comparison Plot

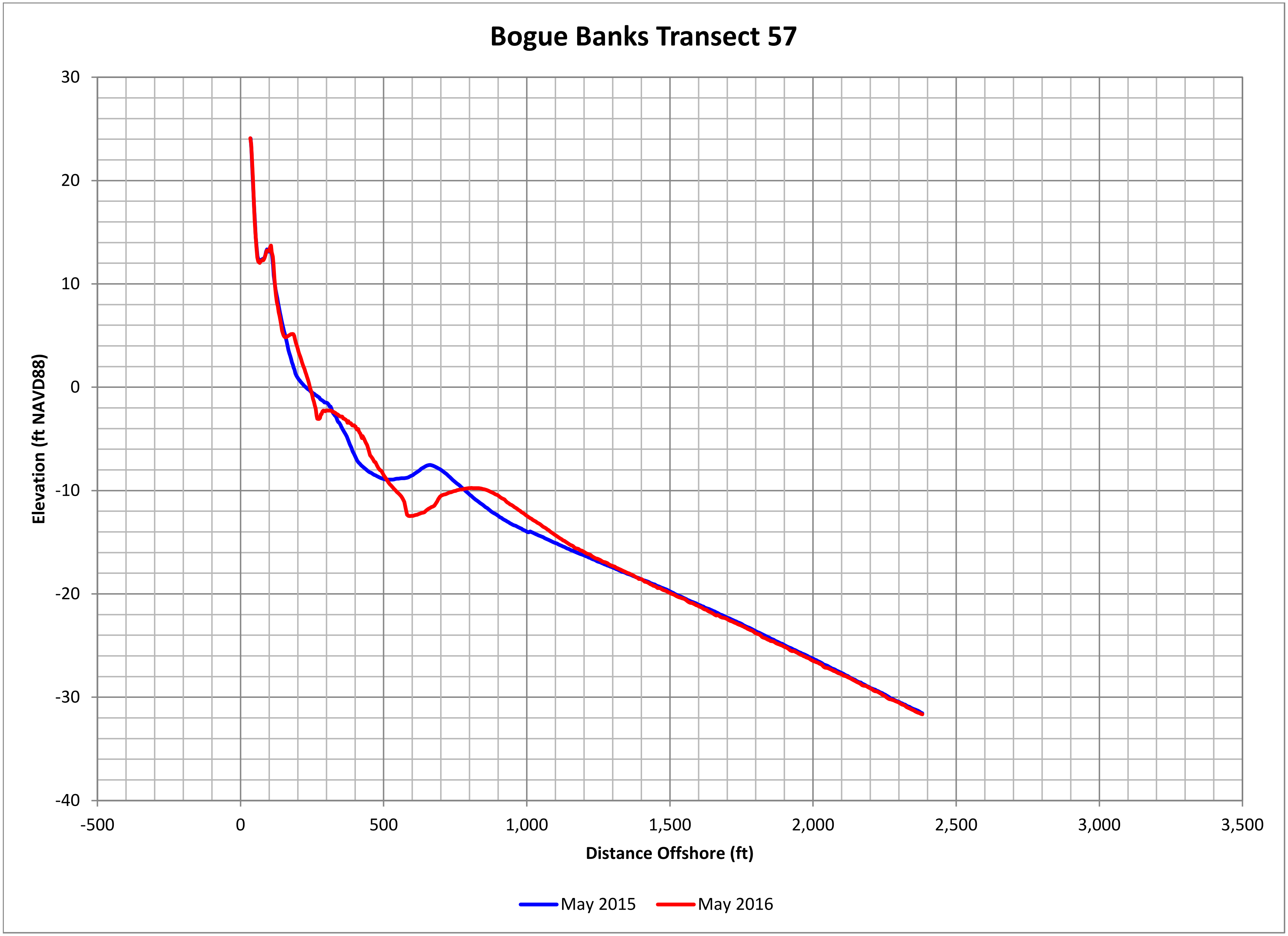


Figure C-75. Bogue Banks Profile Comparison Plot

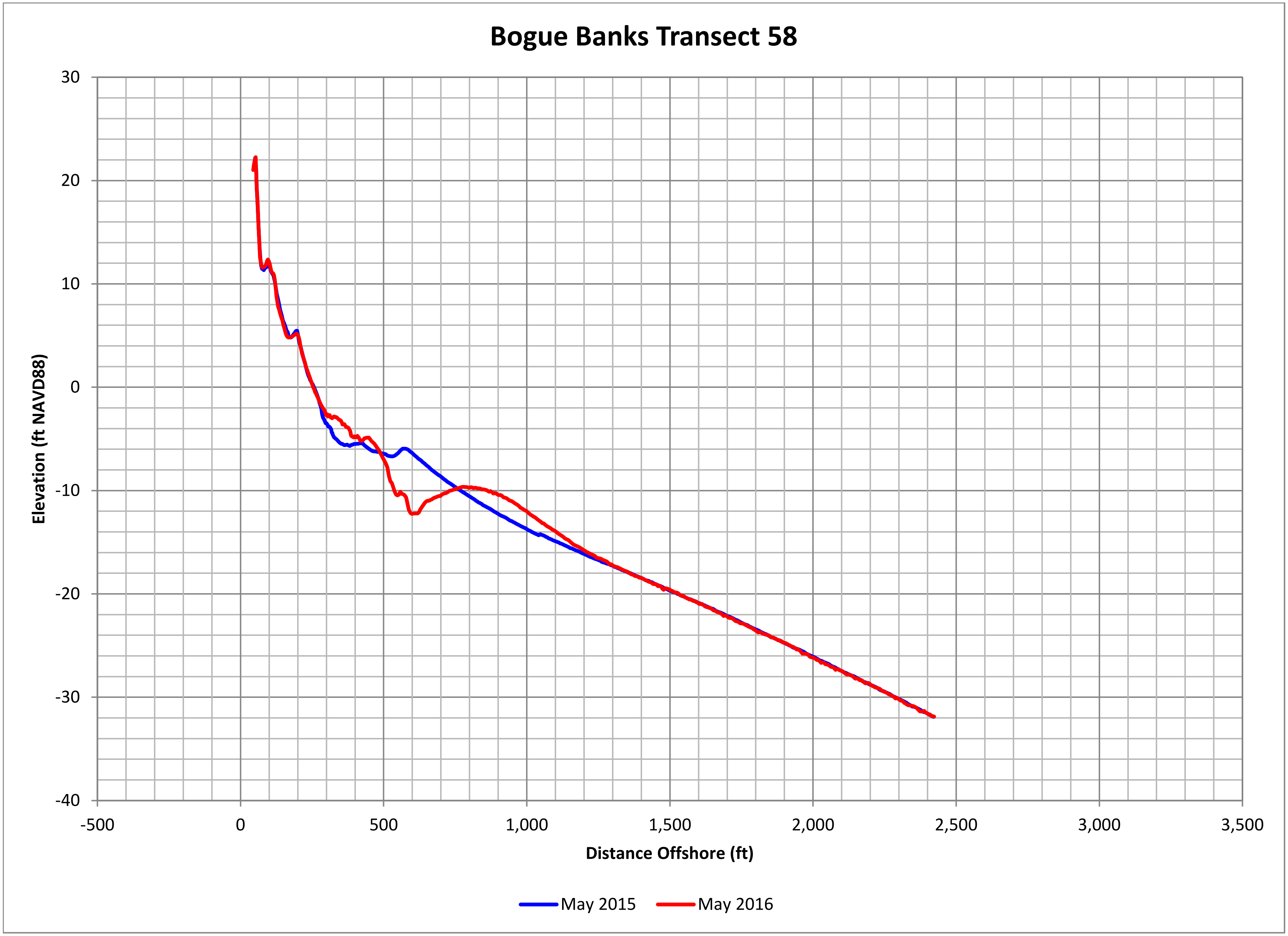


Figure C-76. Bogue Banks Profile Comparison Plot

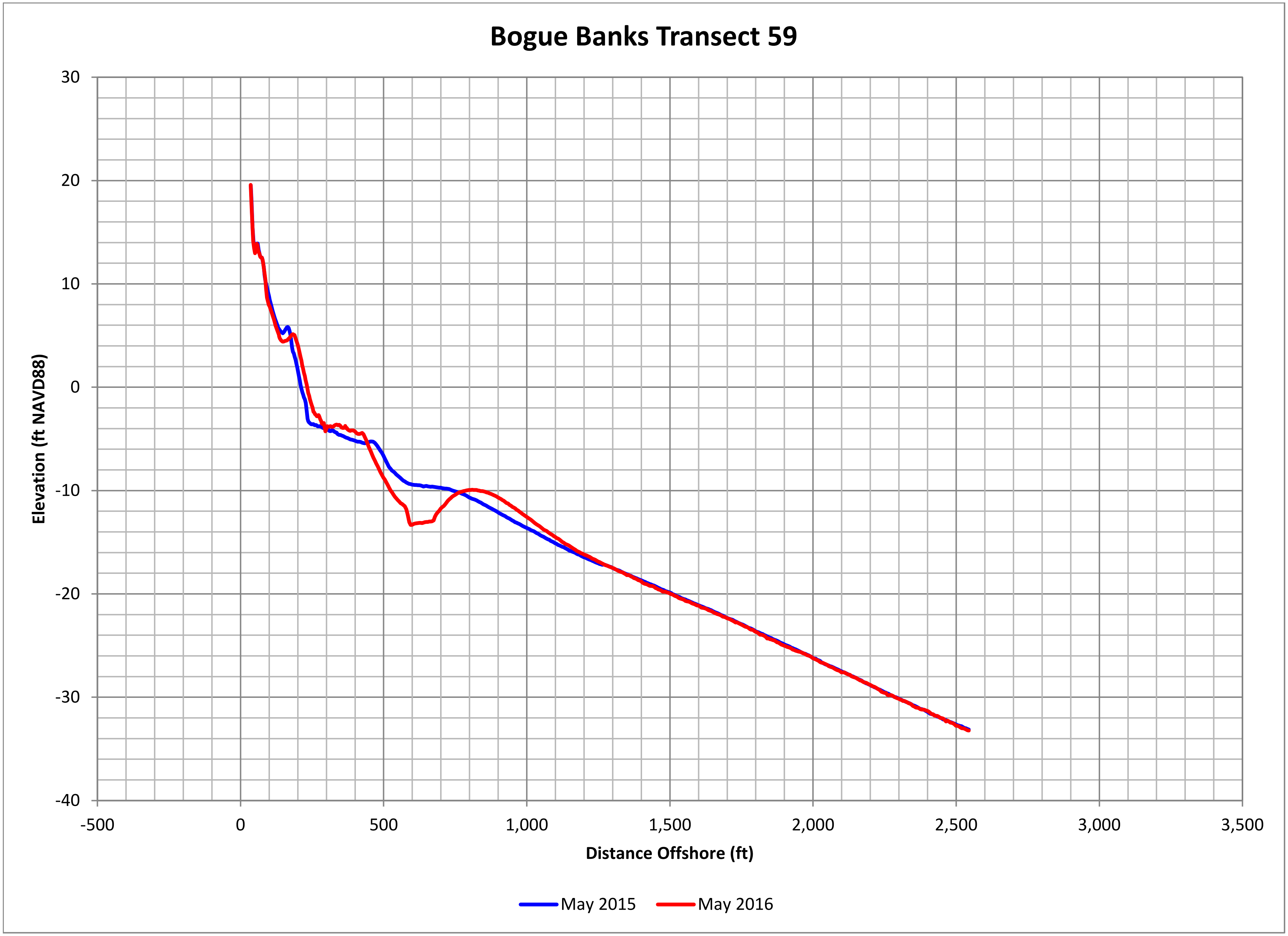


Figure C-77. Bogue Banks Profile Comparison Plot

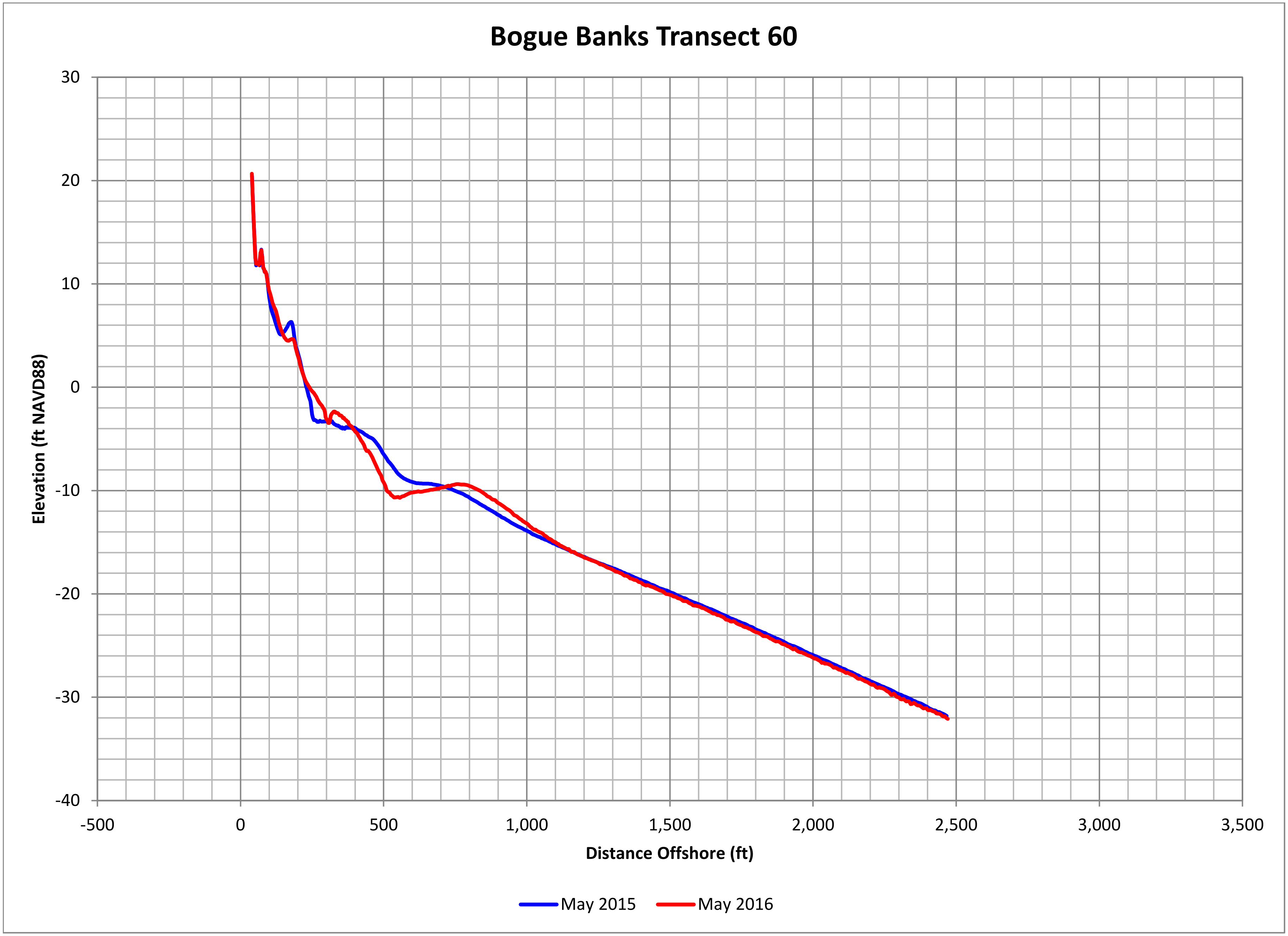


Figure C-78. Bogue Banks Profile Comparison Plot

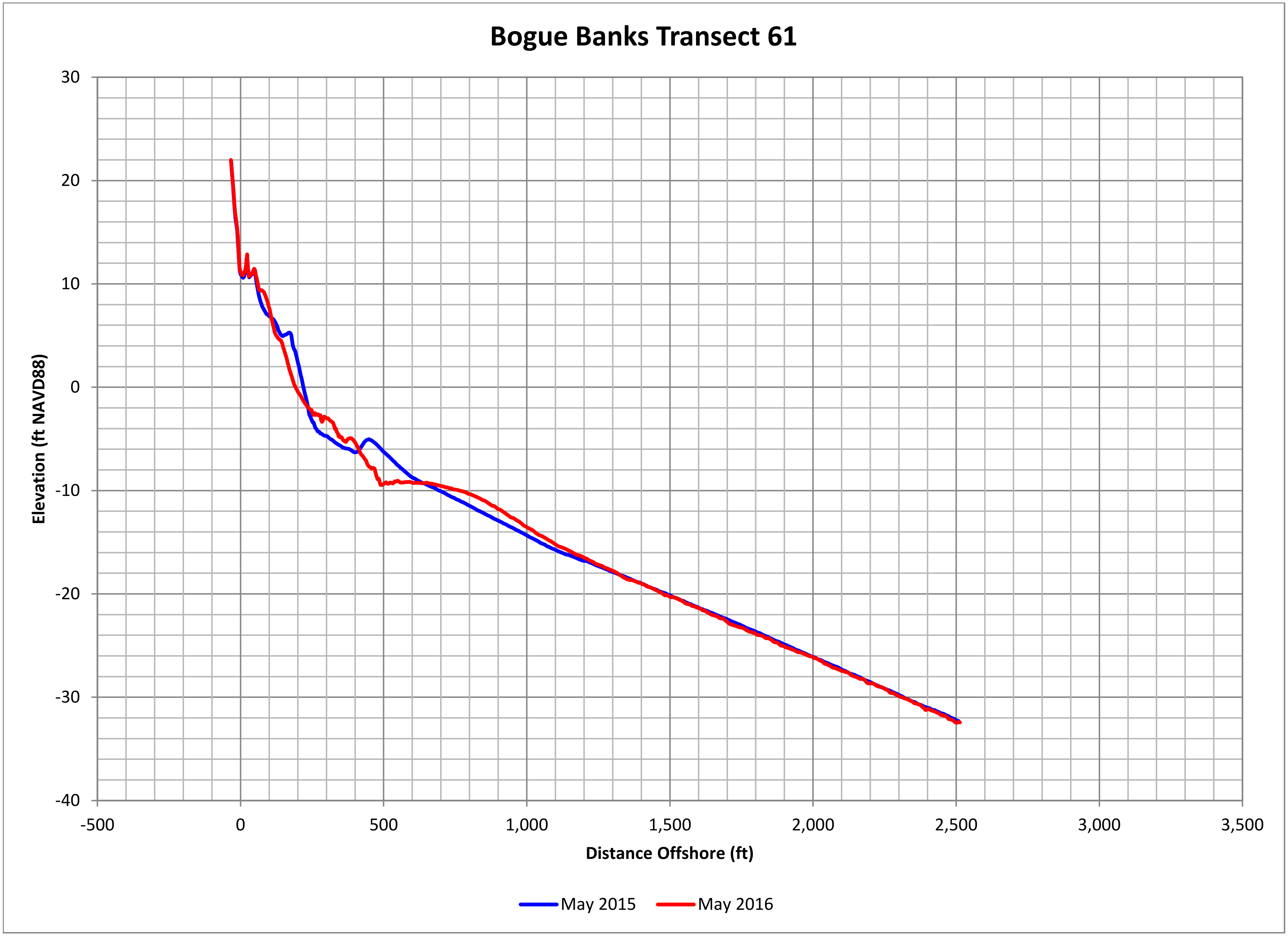


Figure C-79. Bogue Banks Profile Comparison Plot

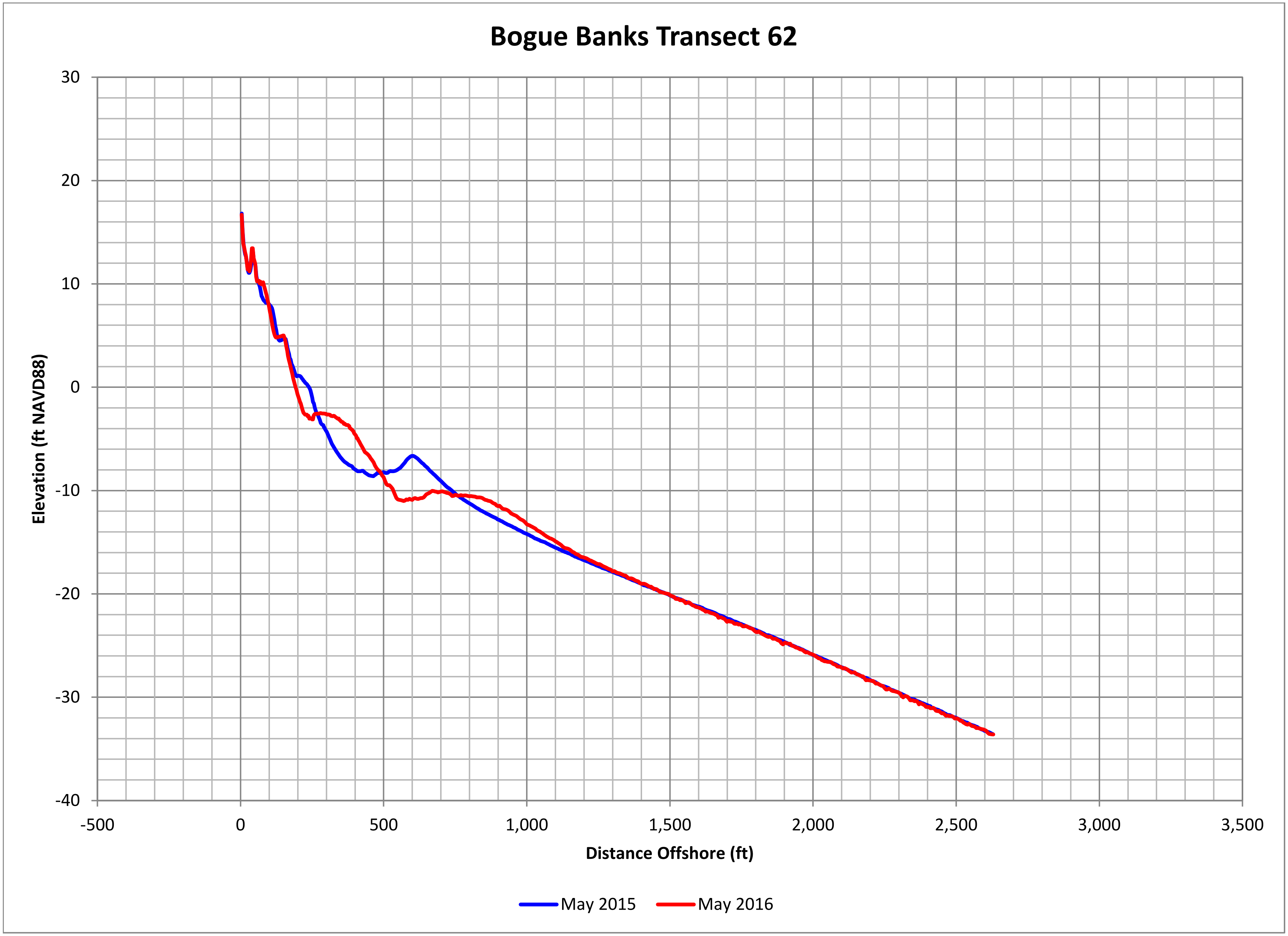


Figure C-80. Bogue Banks Profile Comparison Plot

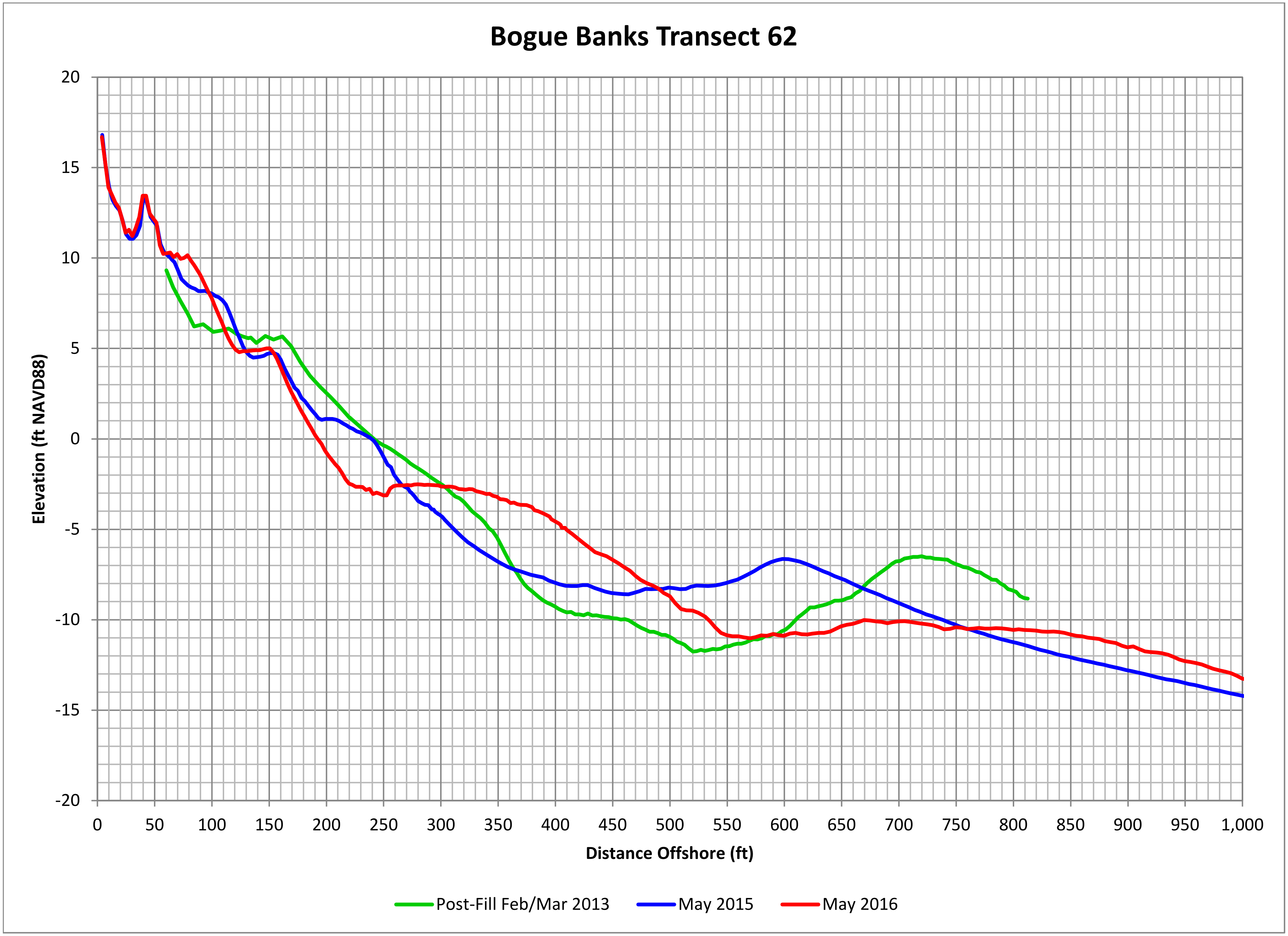


Figure C-81. Bogue Banks Profile Comparison Plot

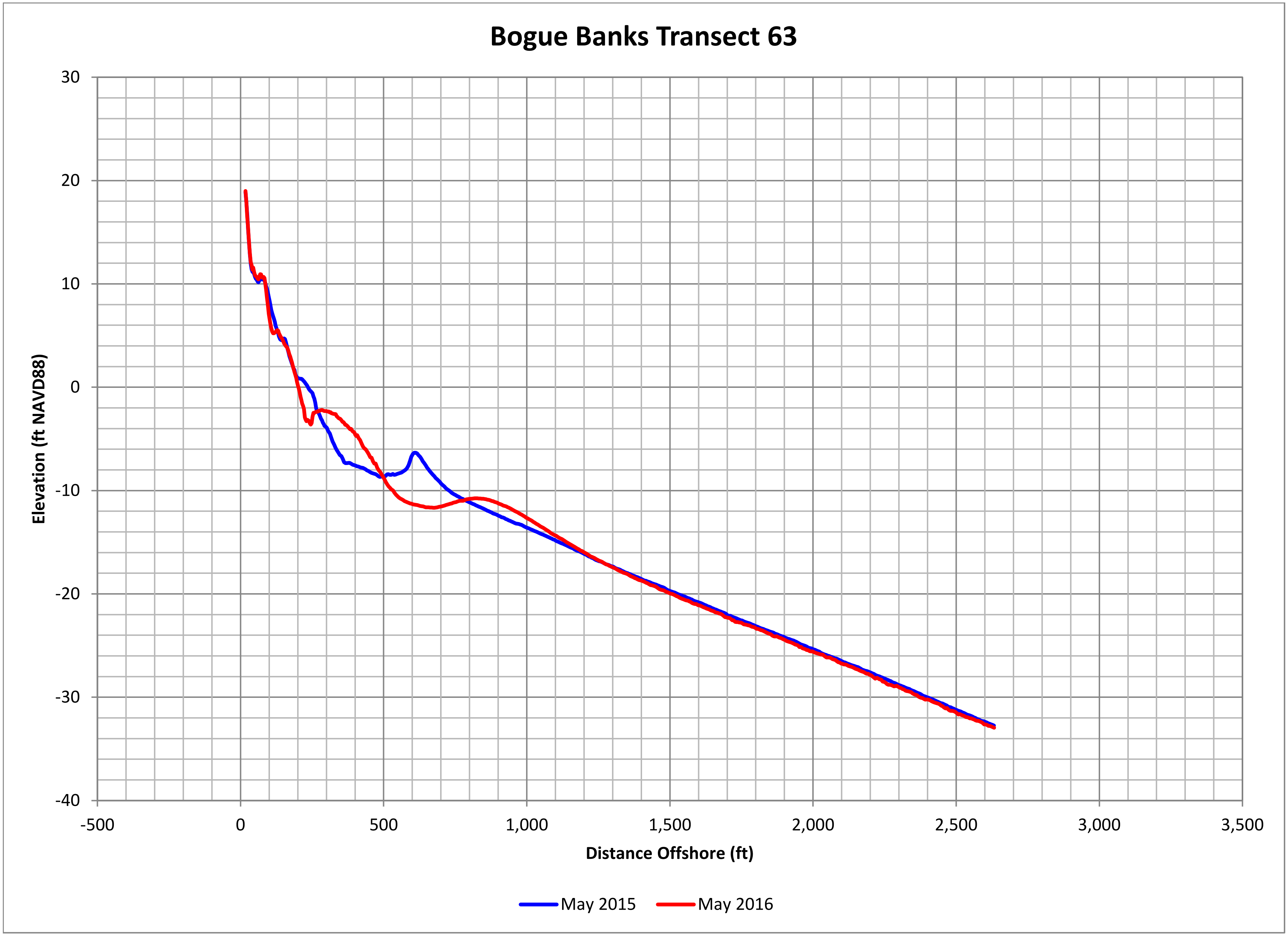


Figure C-82. Bogue Banks Profile Comparison Plot

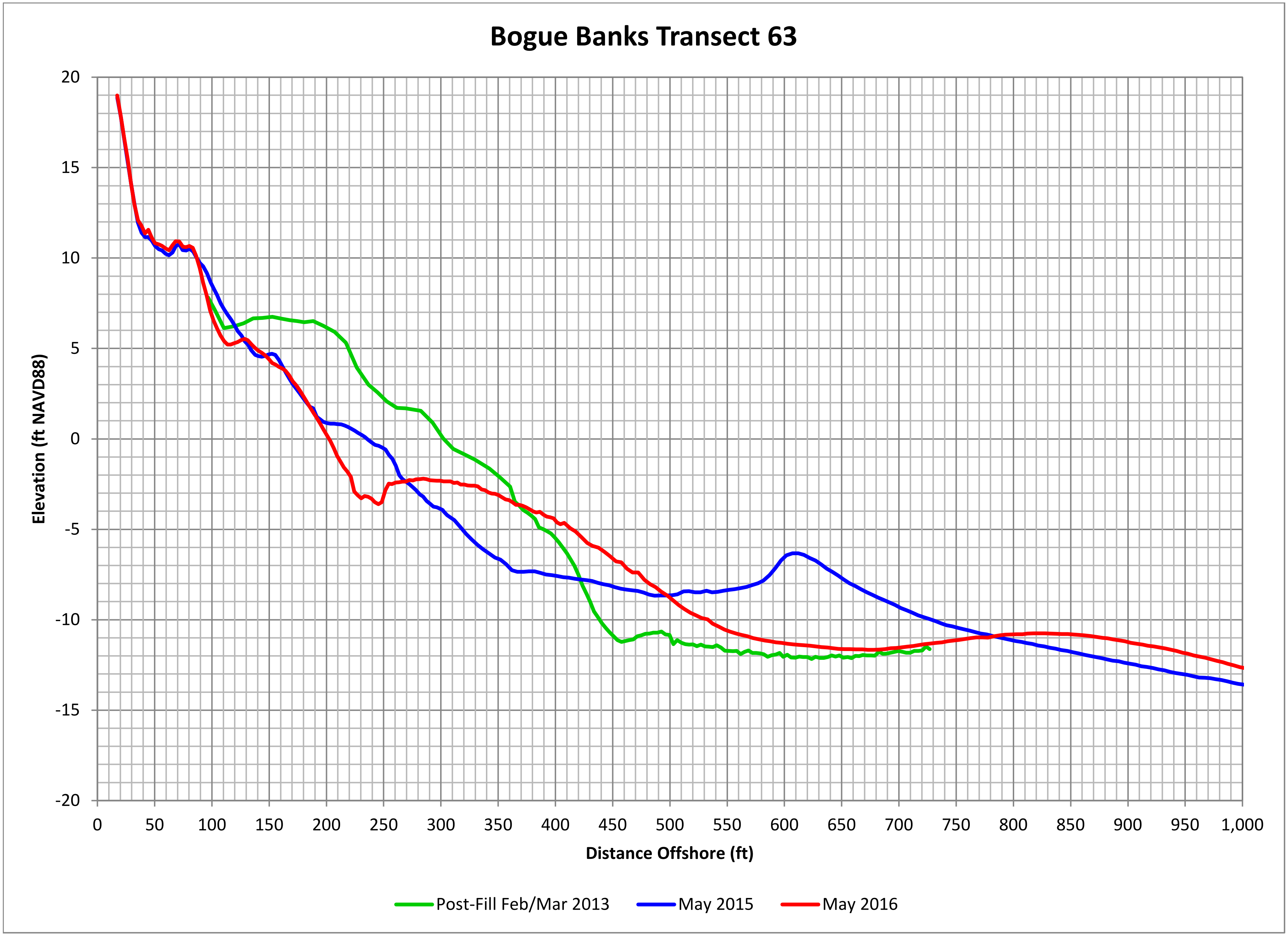


Figure C-83. Bogue Banks Profile Comparison Plot

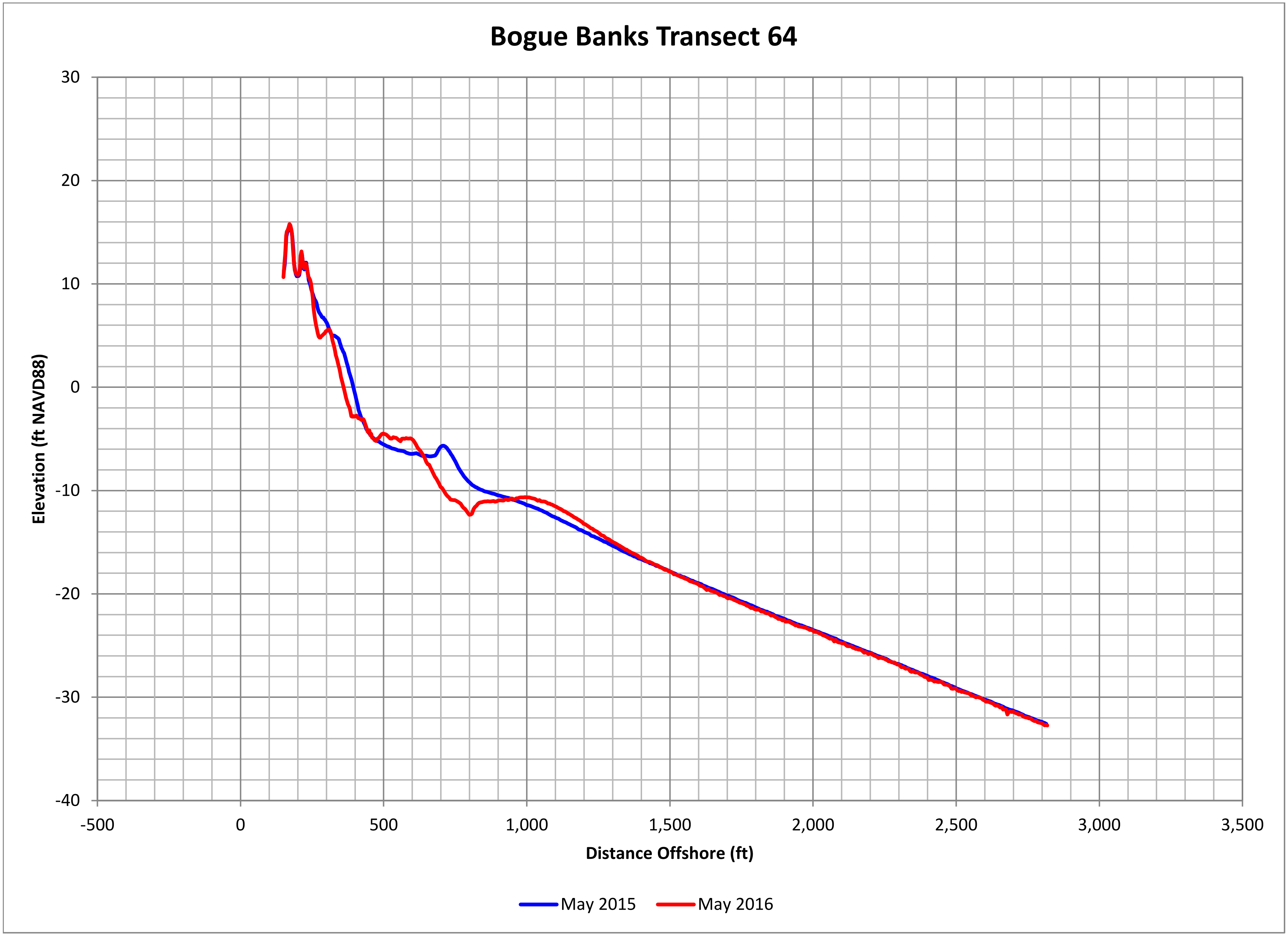


Figure C-84. Bogue Banks Profile Comparison Plot

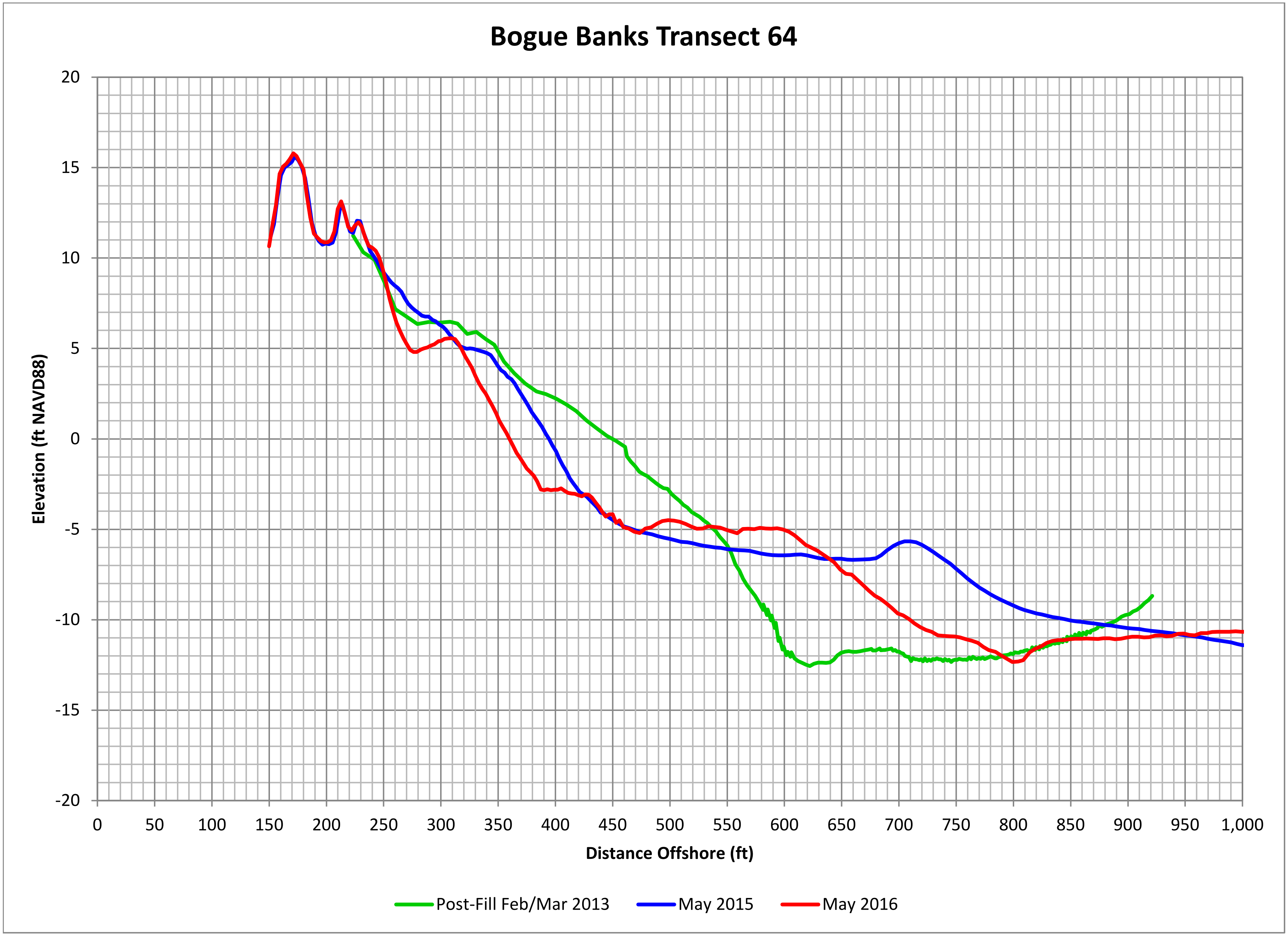


Figure C-85. Bogue Banks Profile Comparison Plot

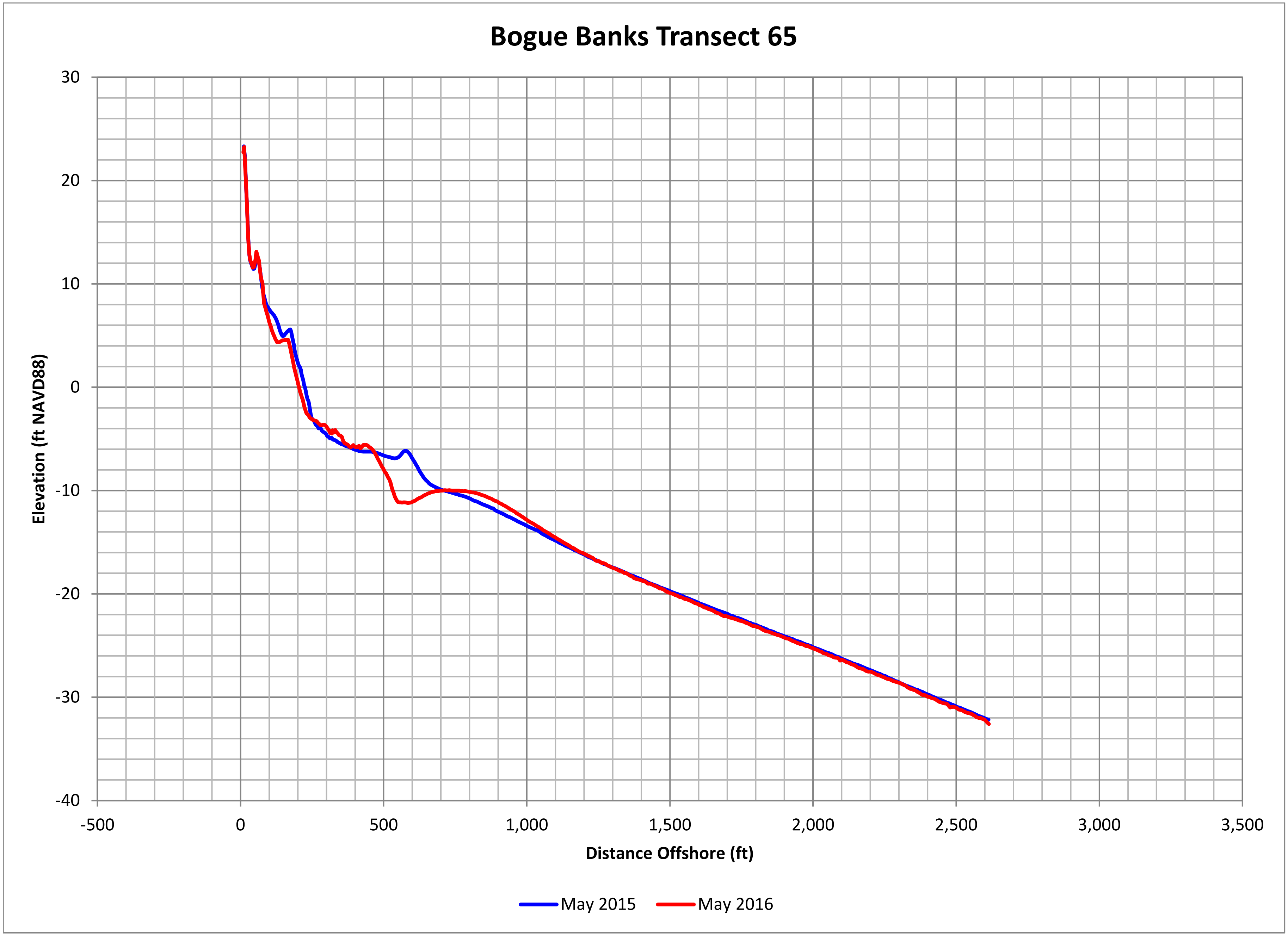


Figure C-86. Bogue Banks Profile Comparison Plot

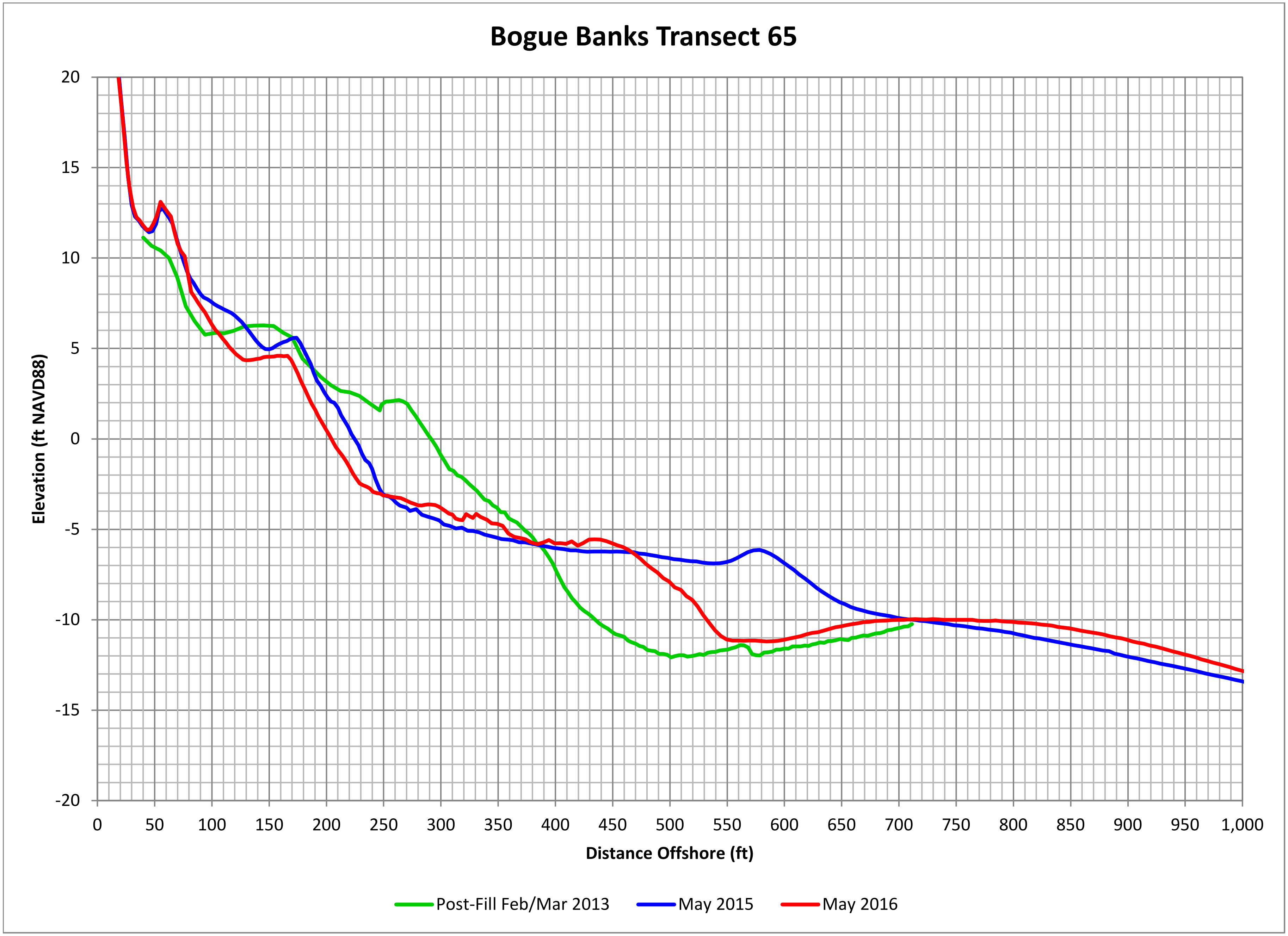


Figure C-87. Bogue Banks Profile Comparison Plot

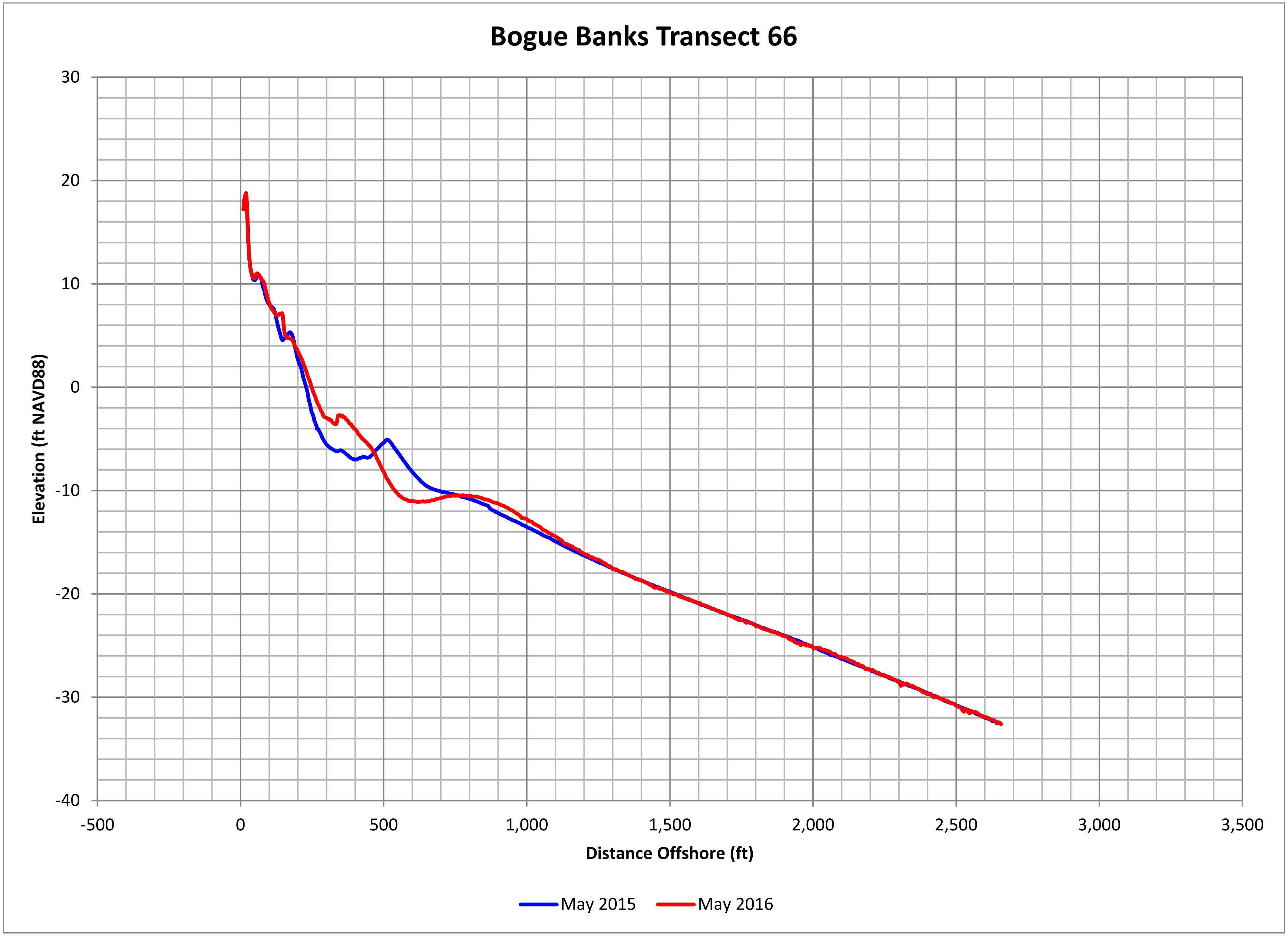


Figure C-88. Bogue Banks Profile Comparison Plot

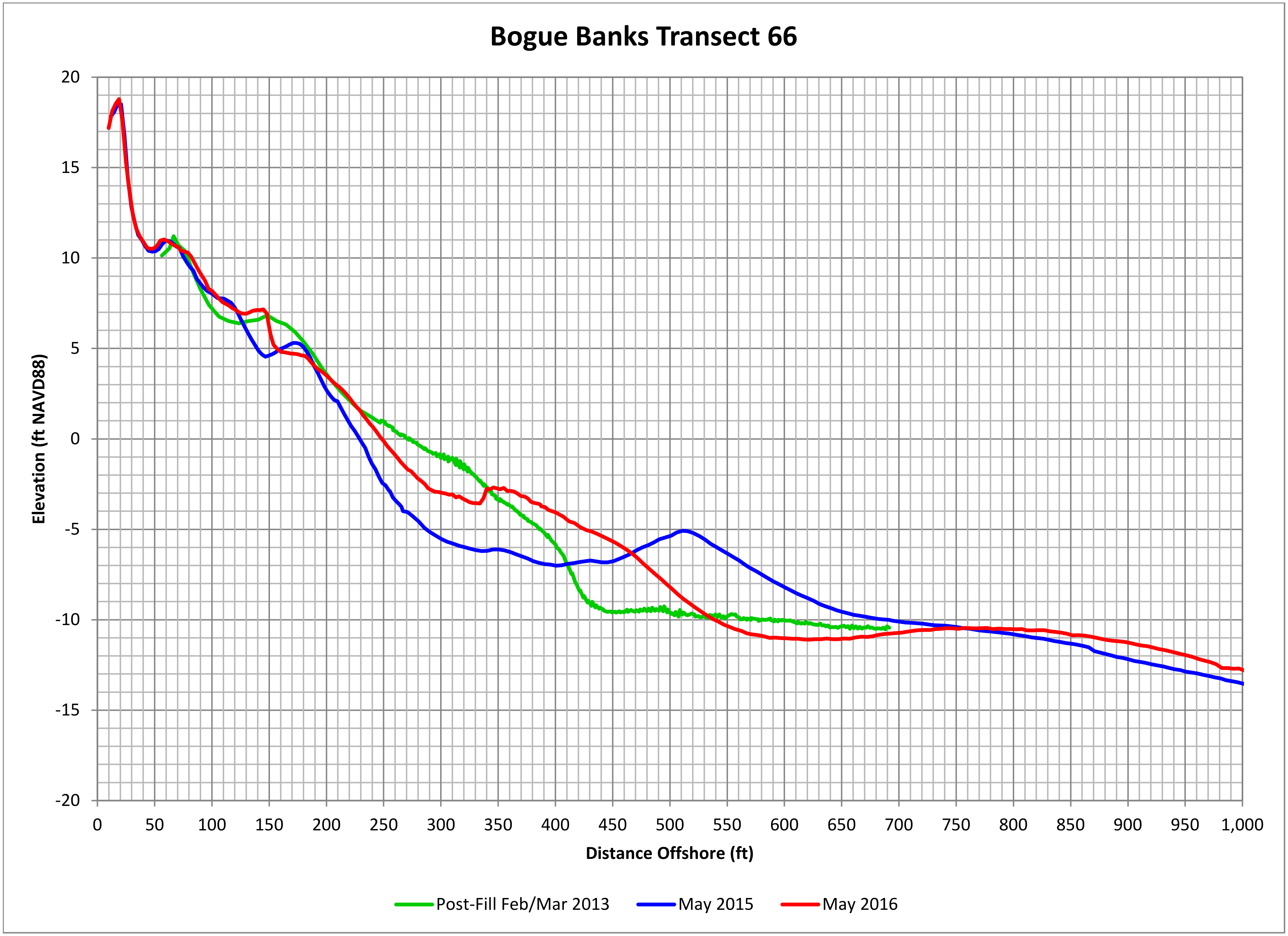


Figure C-89. Bogue Banks Profile Comparison Plot

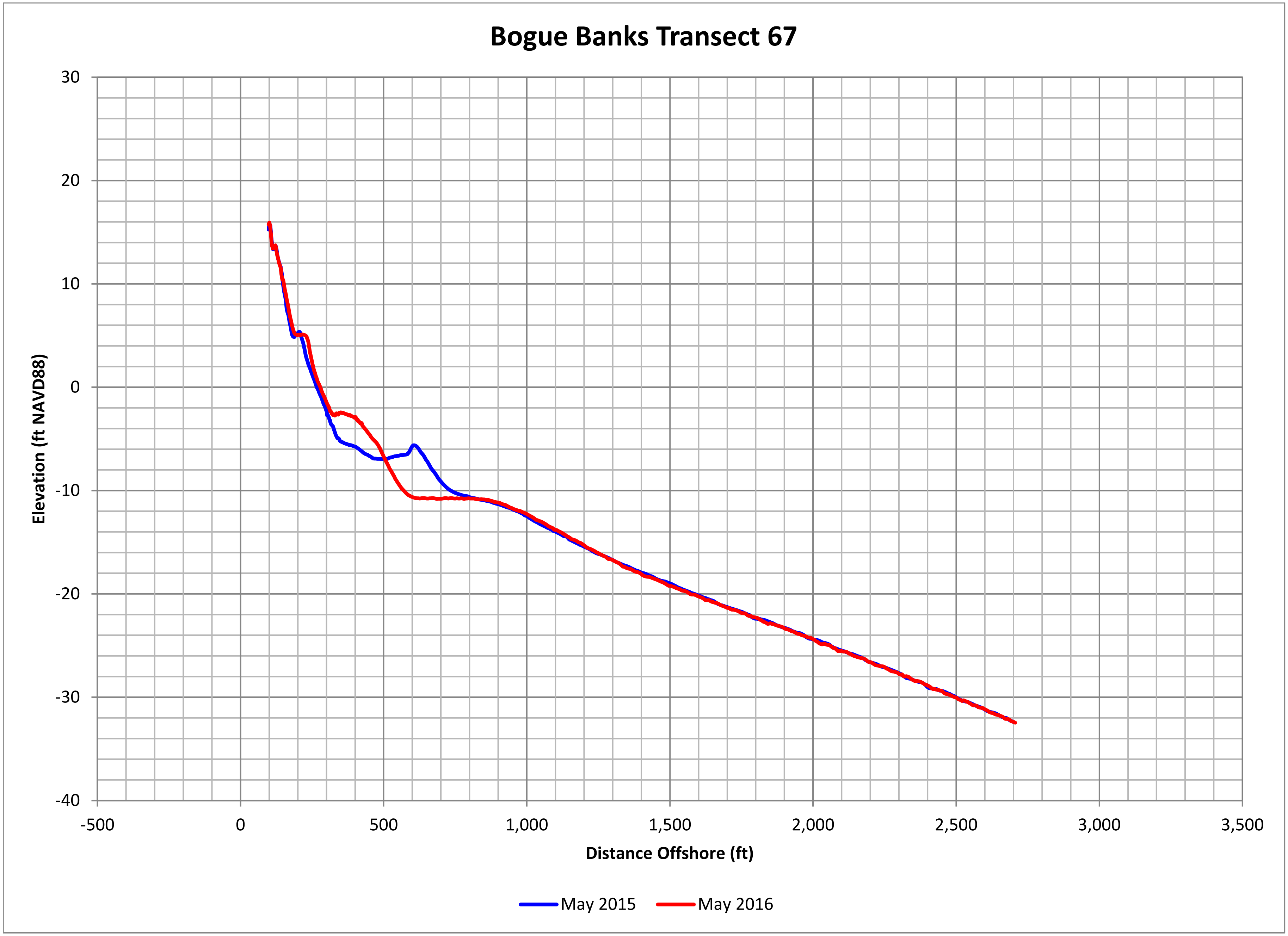


Figure C-90. Bogue Banks Profile Comparison Plot

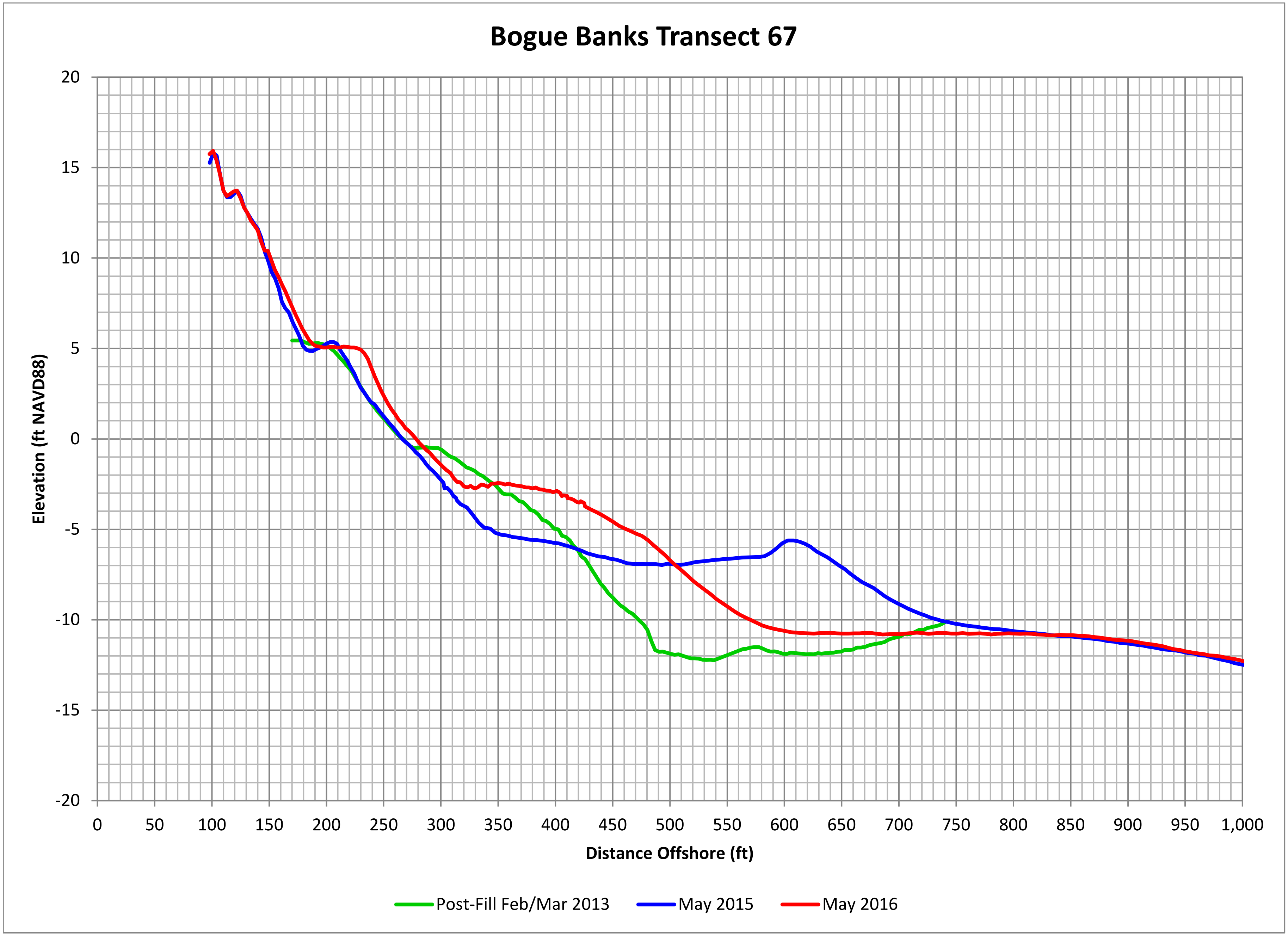


Figure C-91. Bogue Banks Profile Comparison Plot

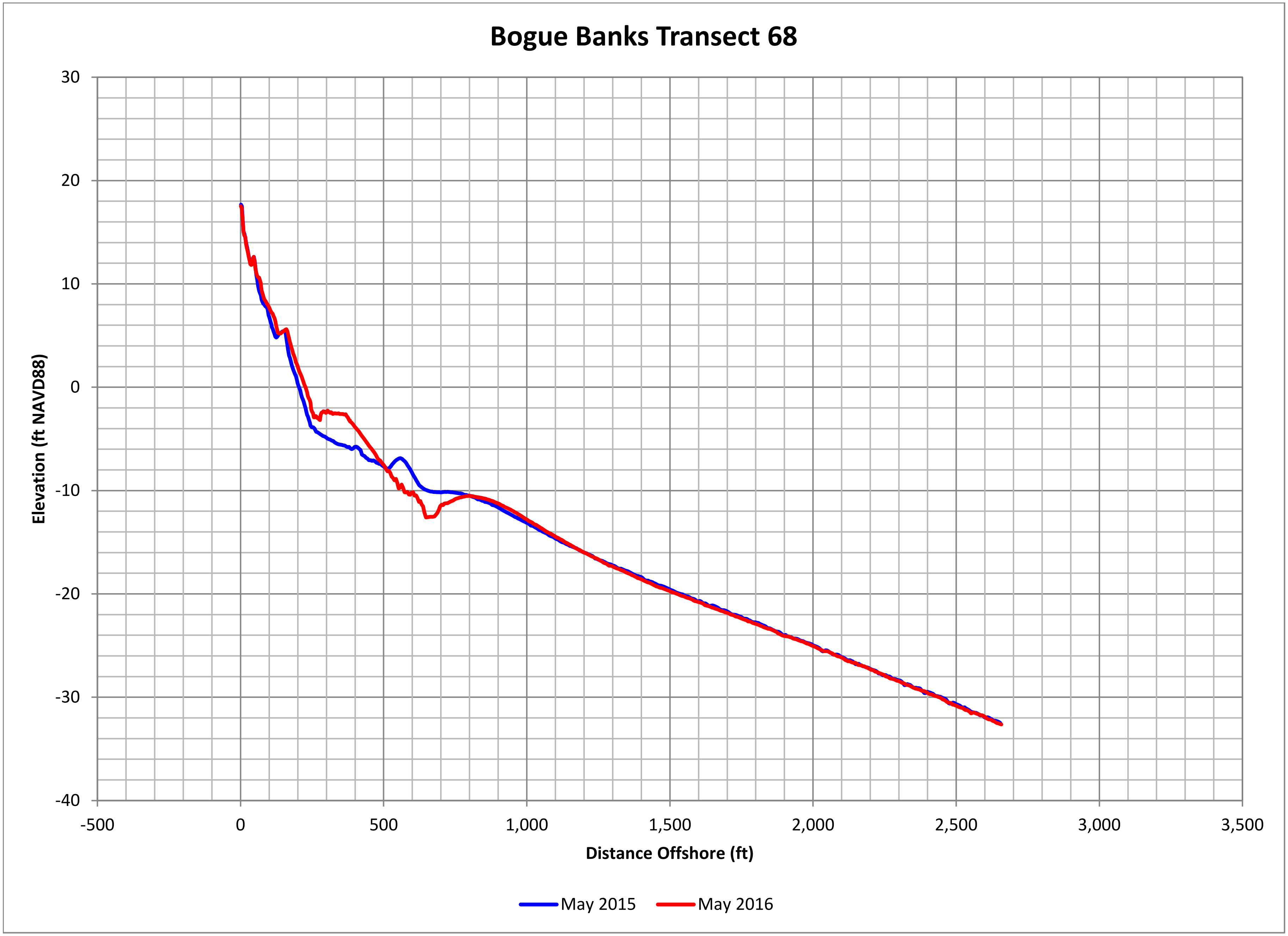


Figure C-92. Bogue Banks Profile Comparison Plot

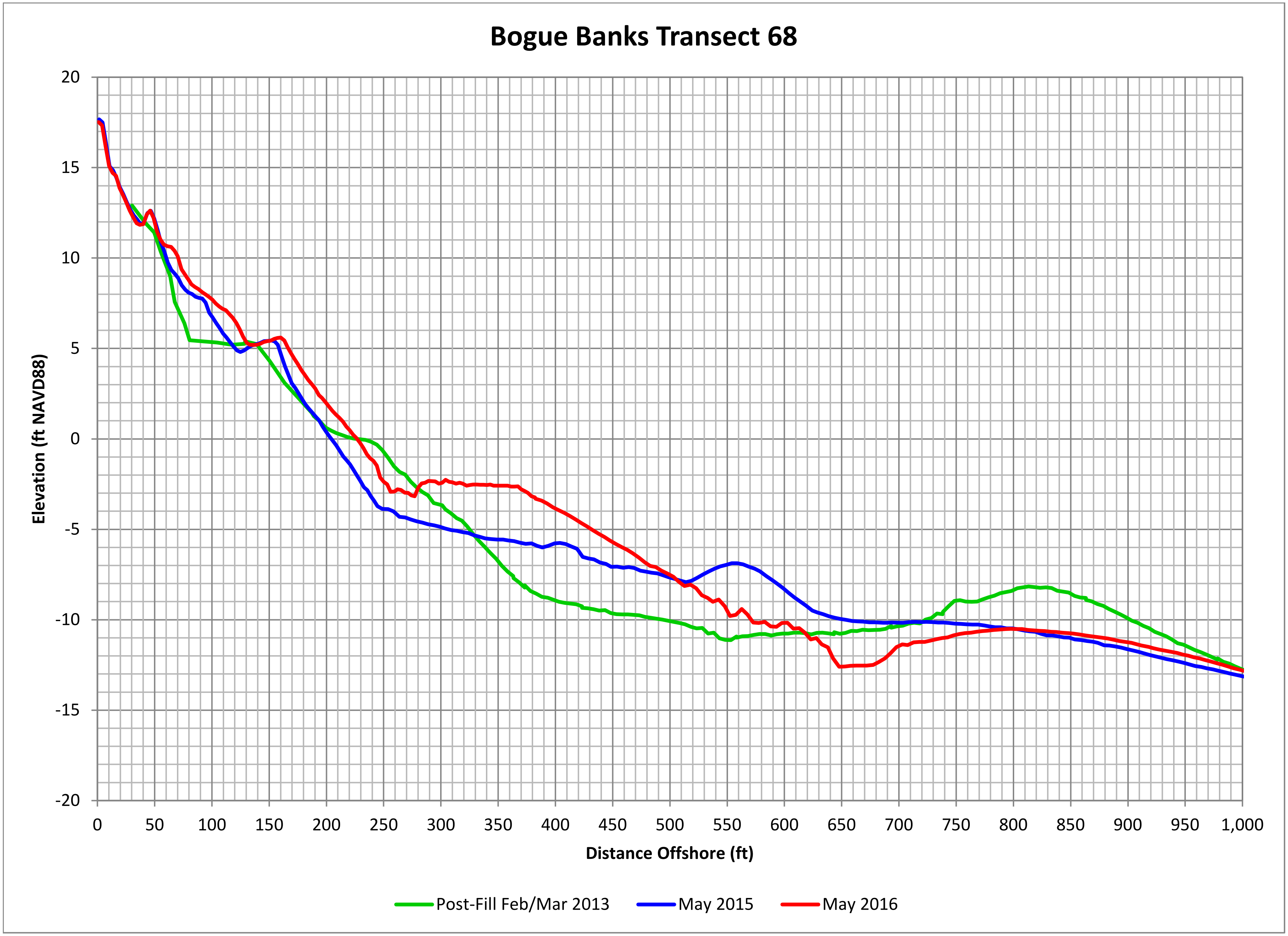


Figure C-93. Bogue Banks Profile Comparison Plot

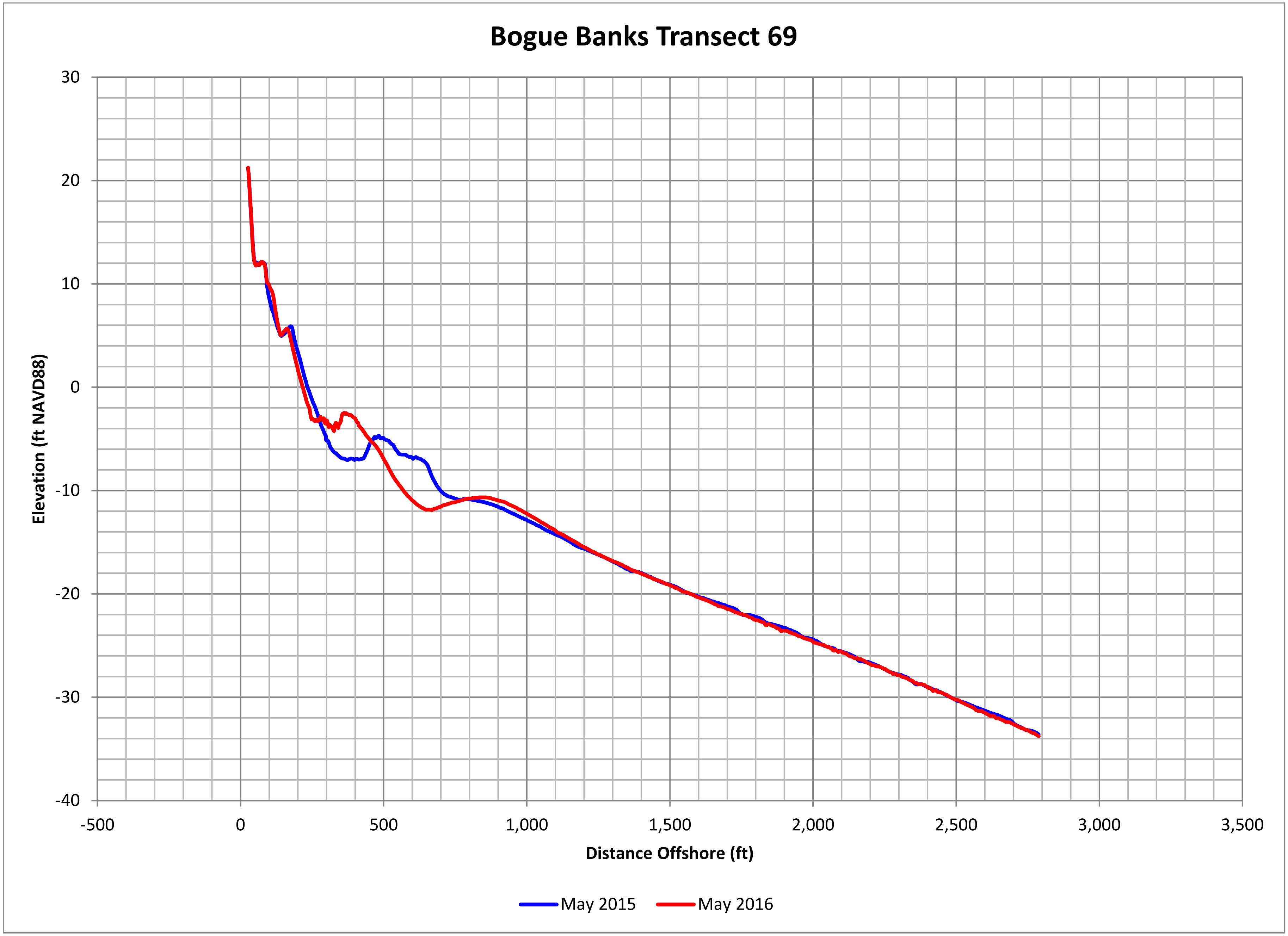


Figure C-94. Bogue Banks Profile Comparison Plot

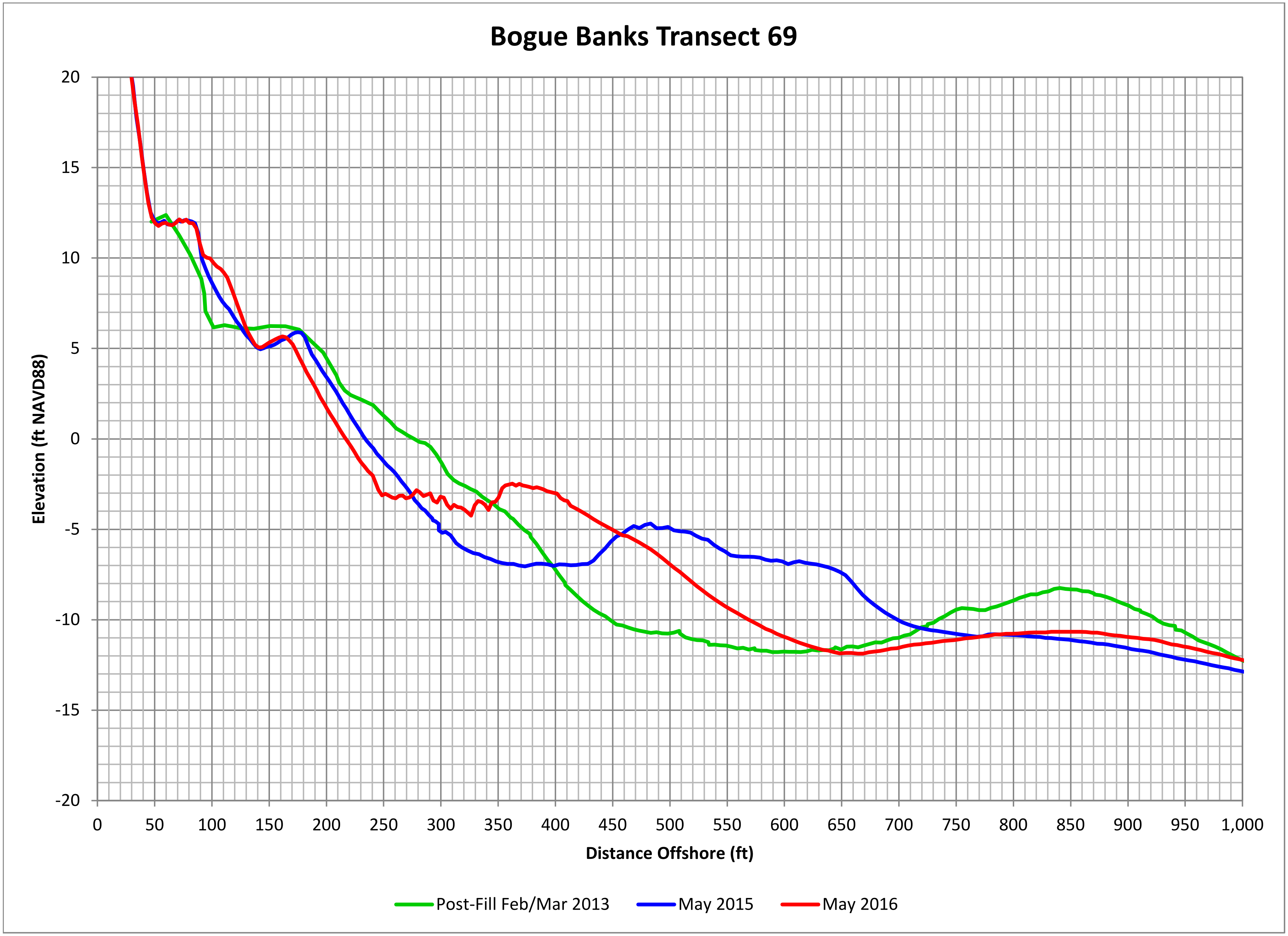


Figure C-95. Bogue Banks Profile Comparison Plot

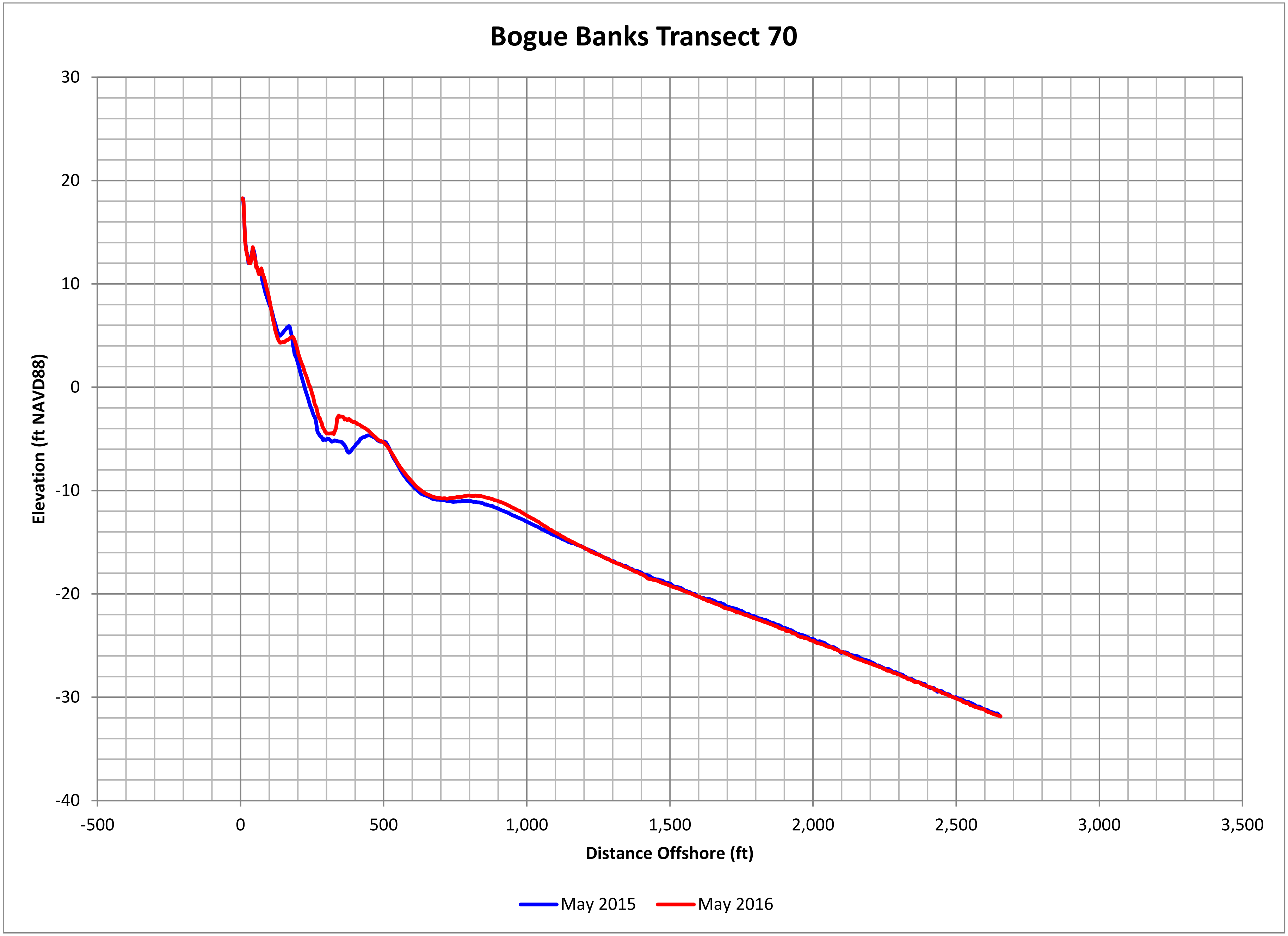


Figure C-96. Bogue Banks Profile Comparison Plot

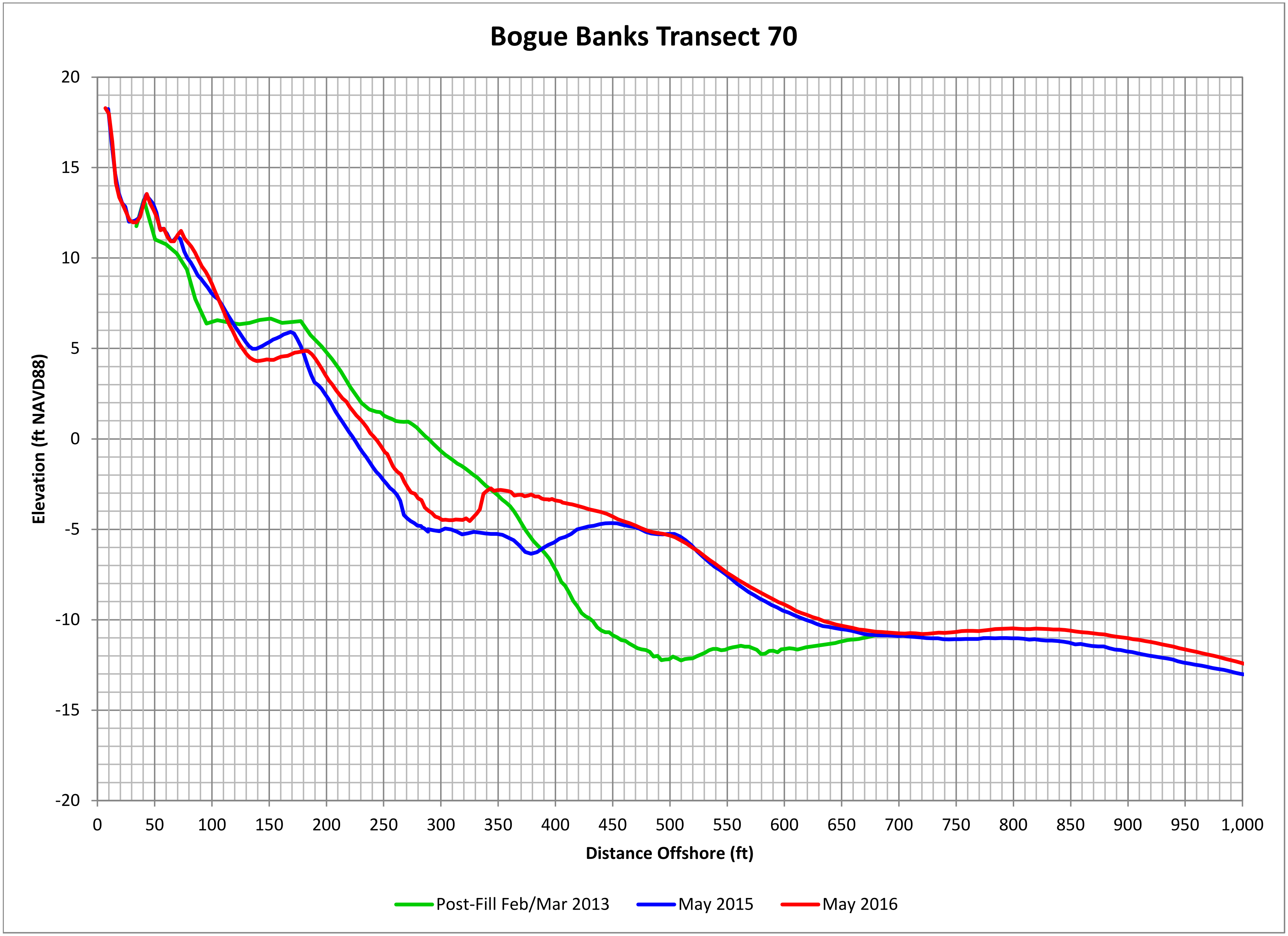


Figure C-97. Bogue Banks Profile Comparison Plot

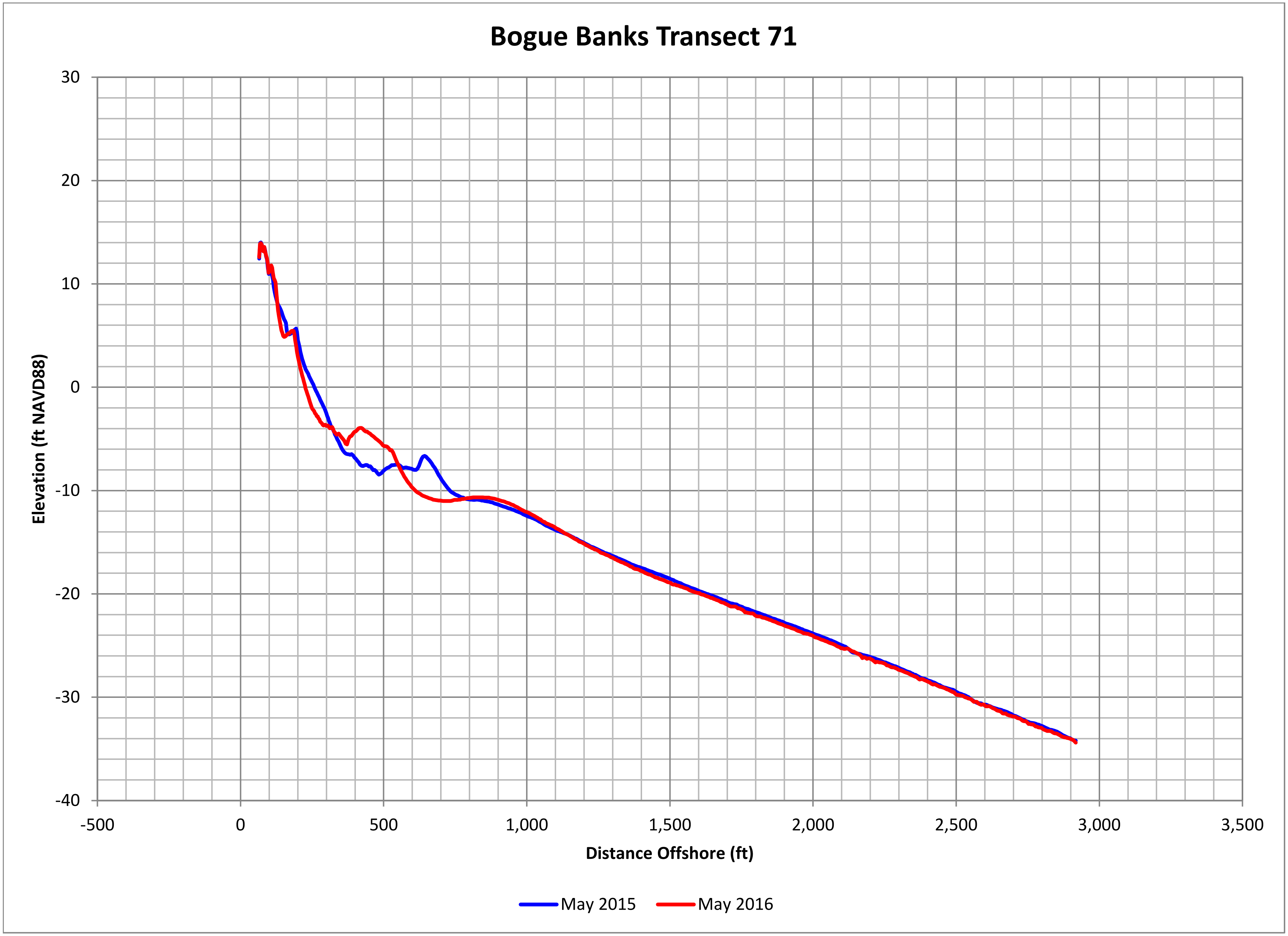


Figure C-98. Bogue Banks Profile Comparison Plot

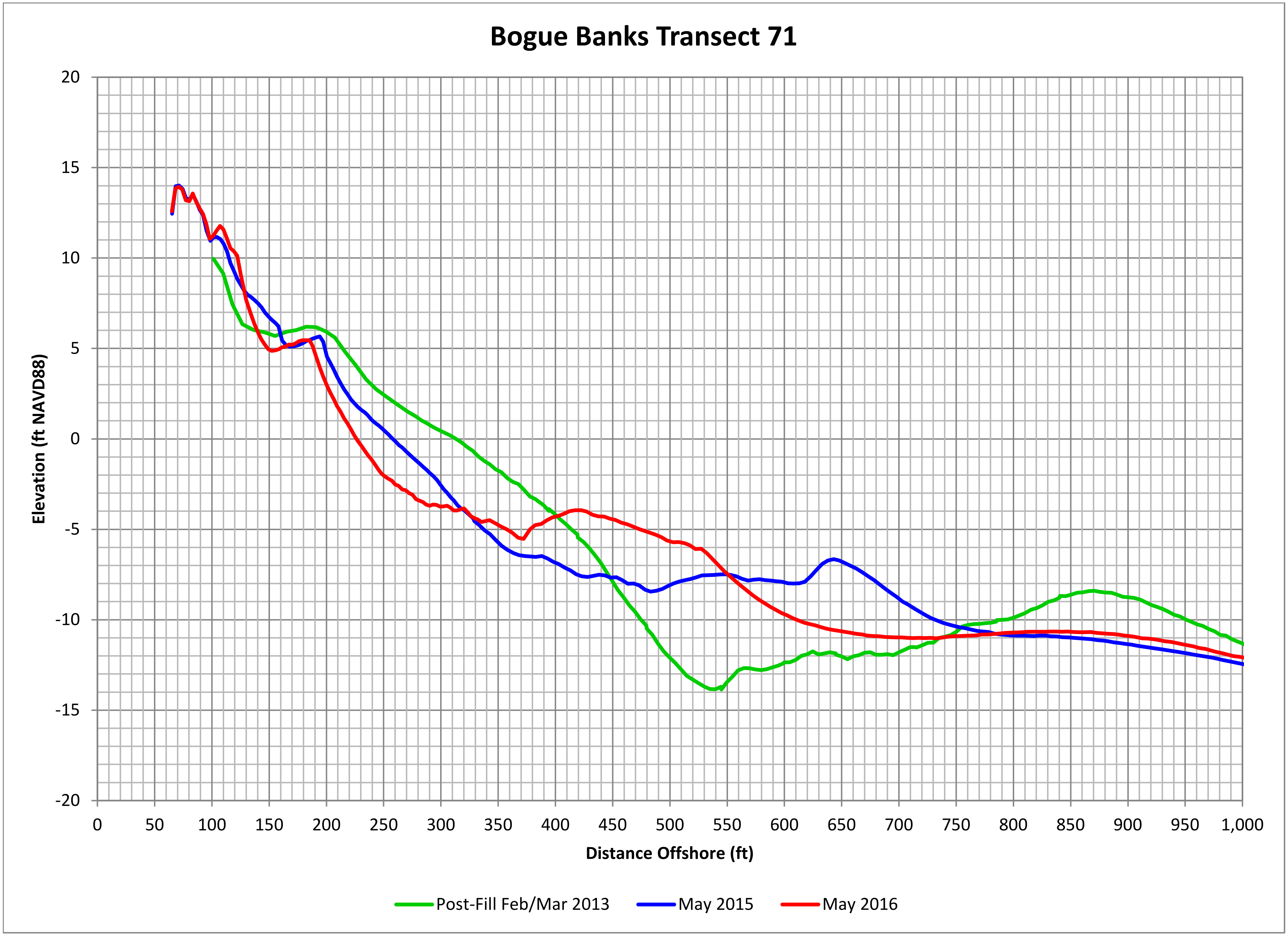


Figure C-99. Bogue Banks Profile Comparison Plot

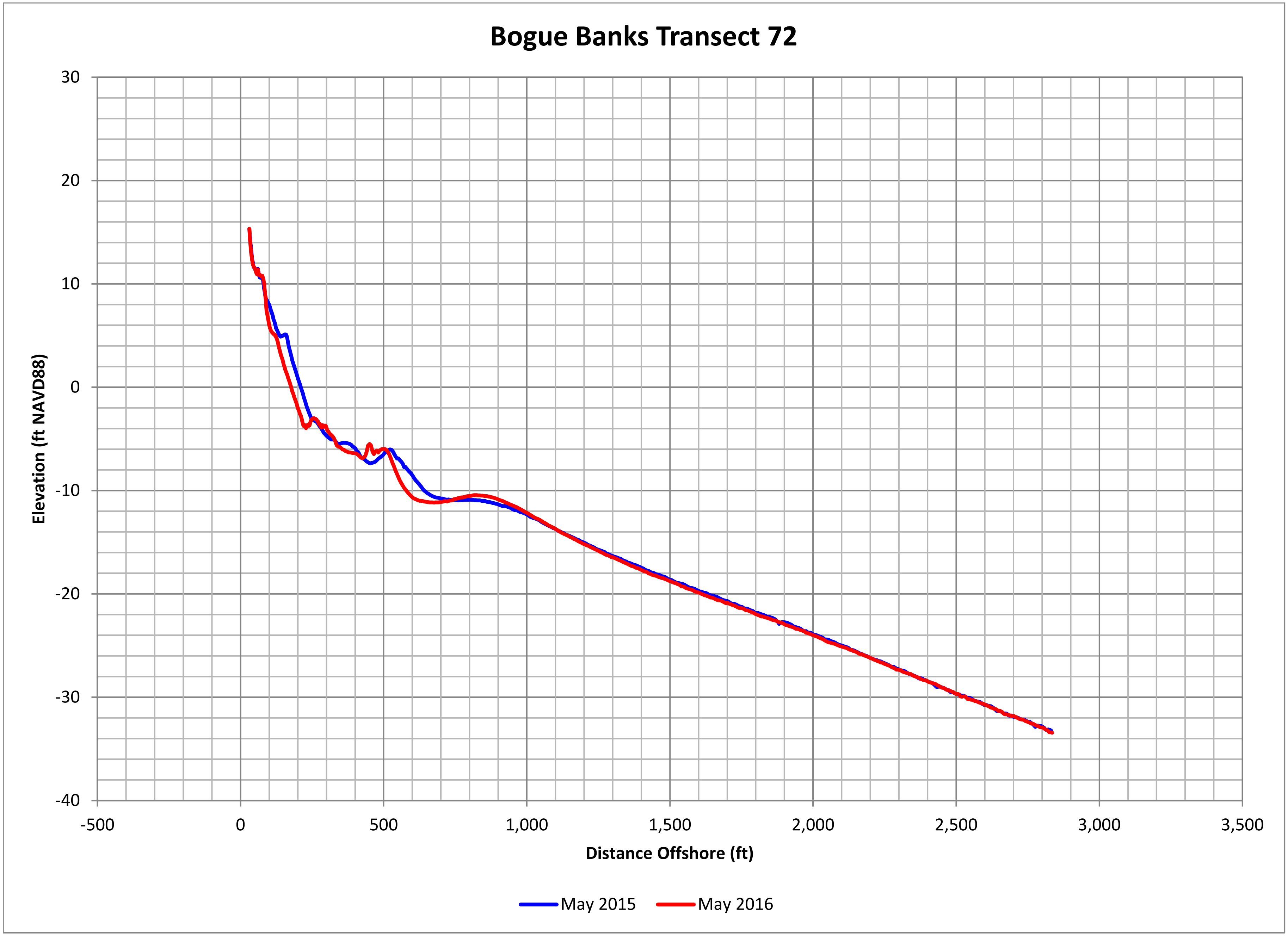


Figure C-100. Bogue Banks Profile Comparison Plot

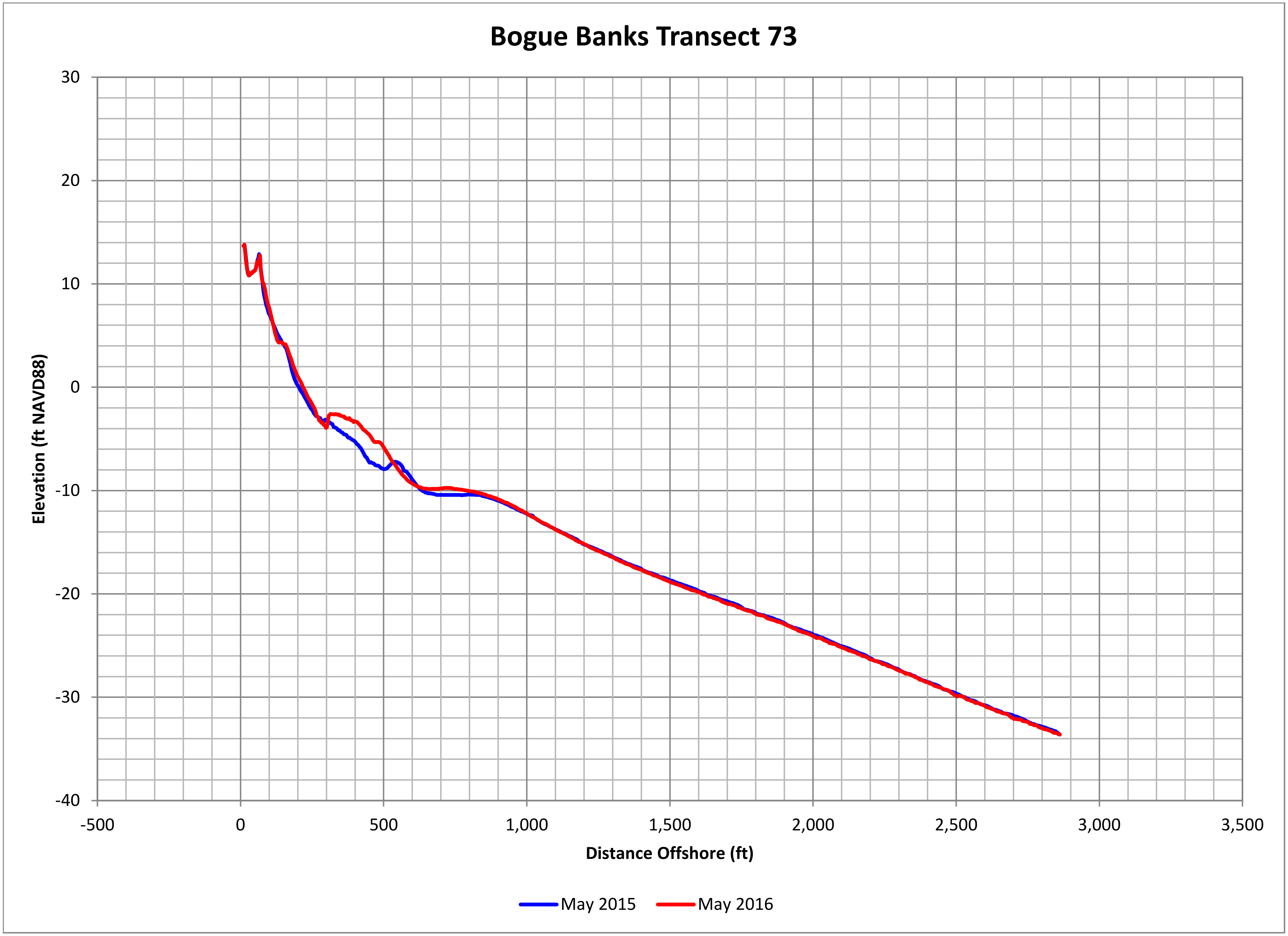


Figure C-101. Bogue Banks Profile Comparison Plot

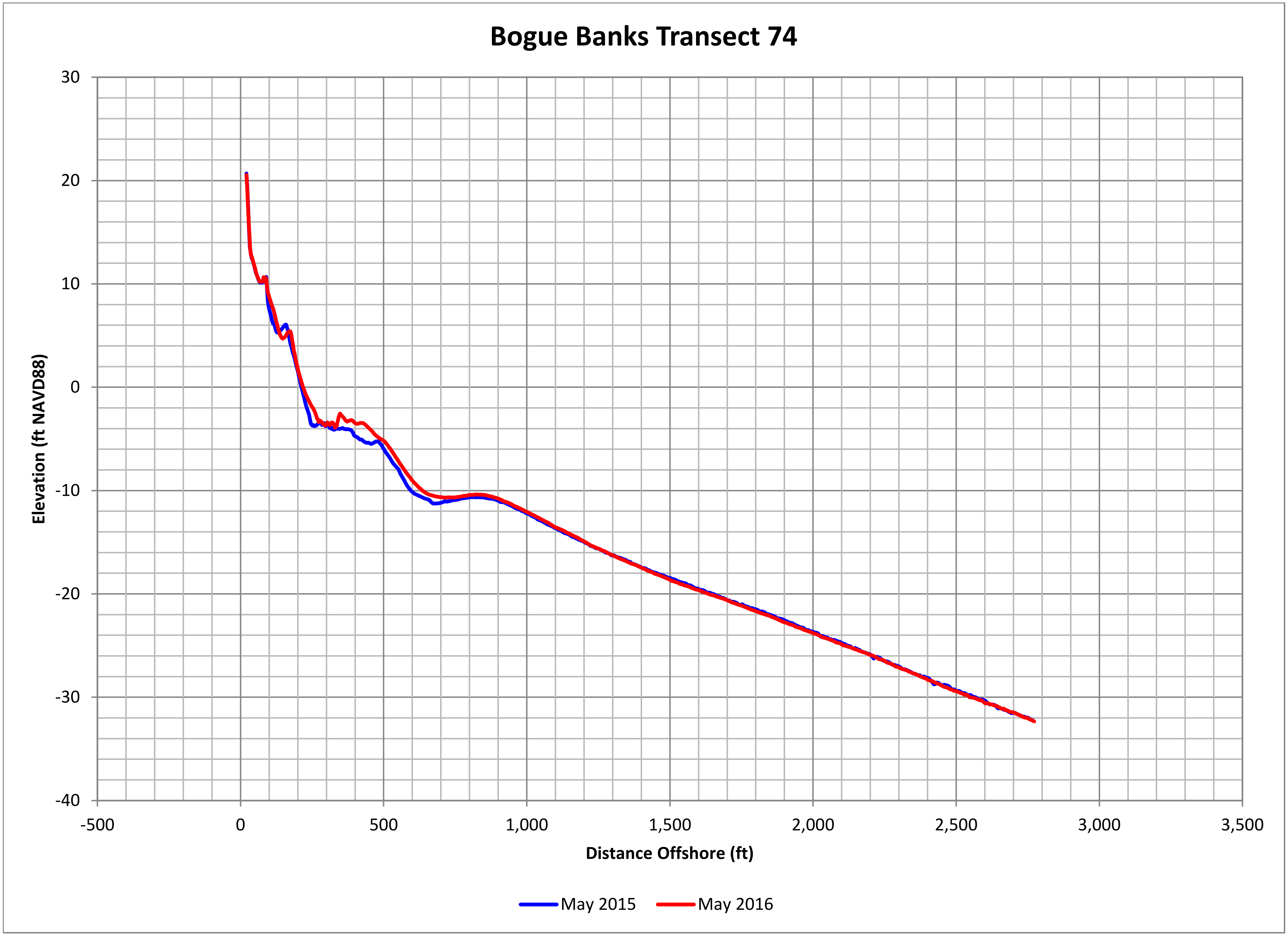


Figure C-102. Bogue Banks Profile Comparison Plot

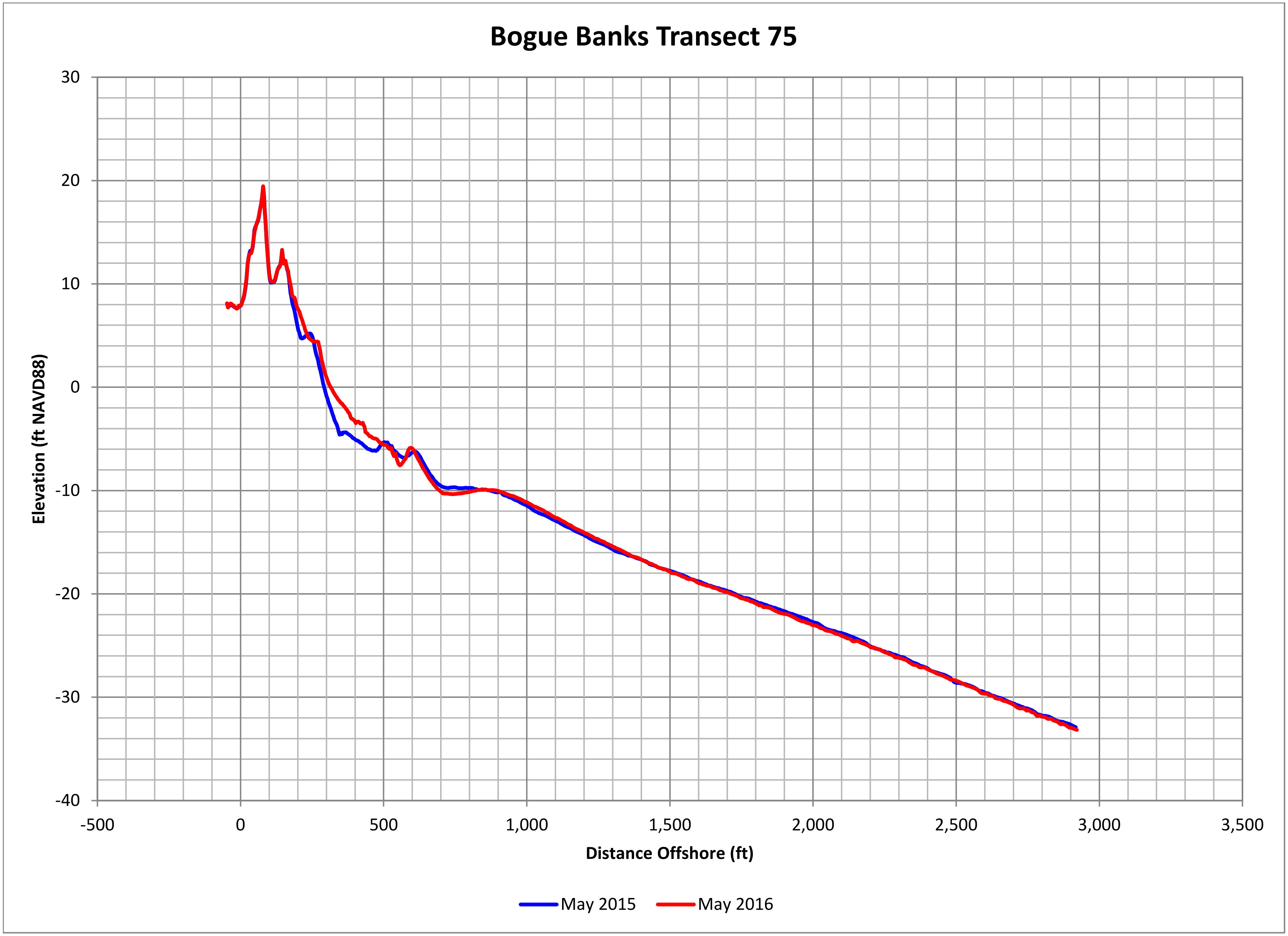


Figure C-103. Bogue Banks Profile Comparison Plot

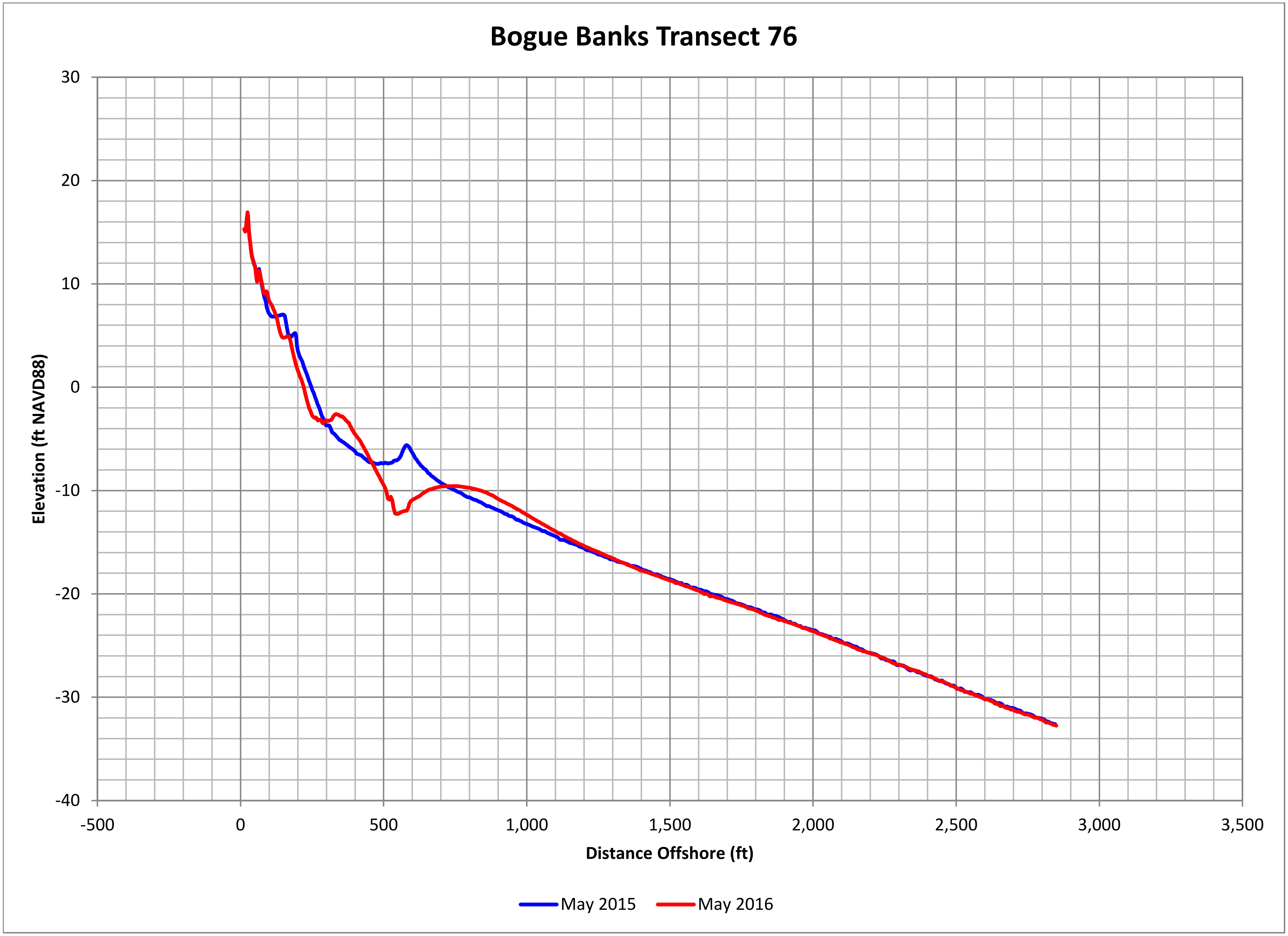


Figure C-104. Bogue Banks Profile Comparison Plot

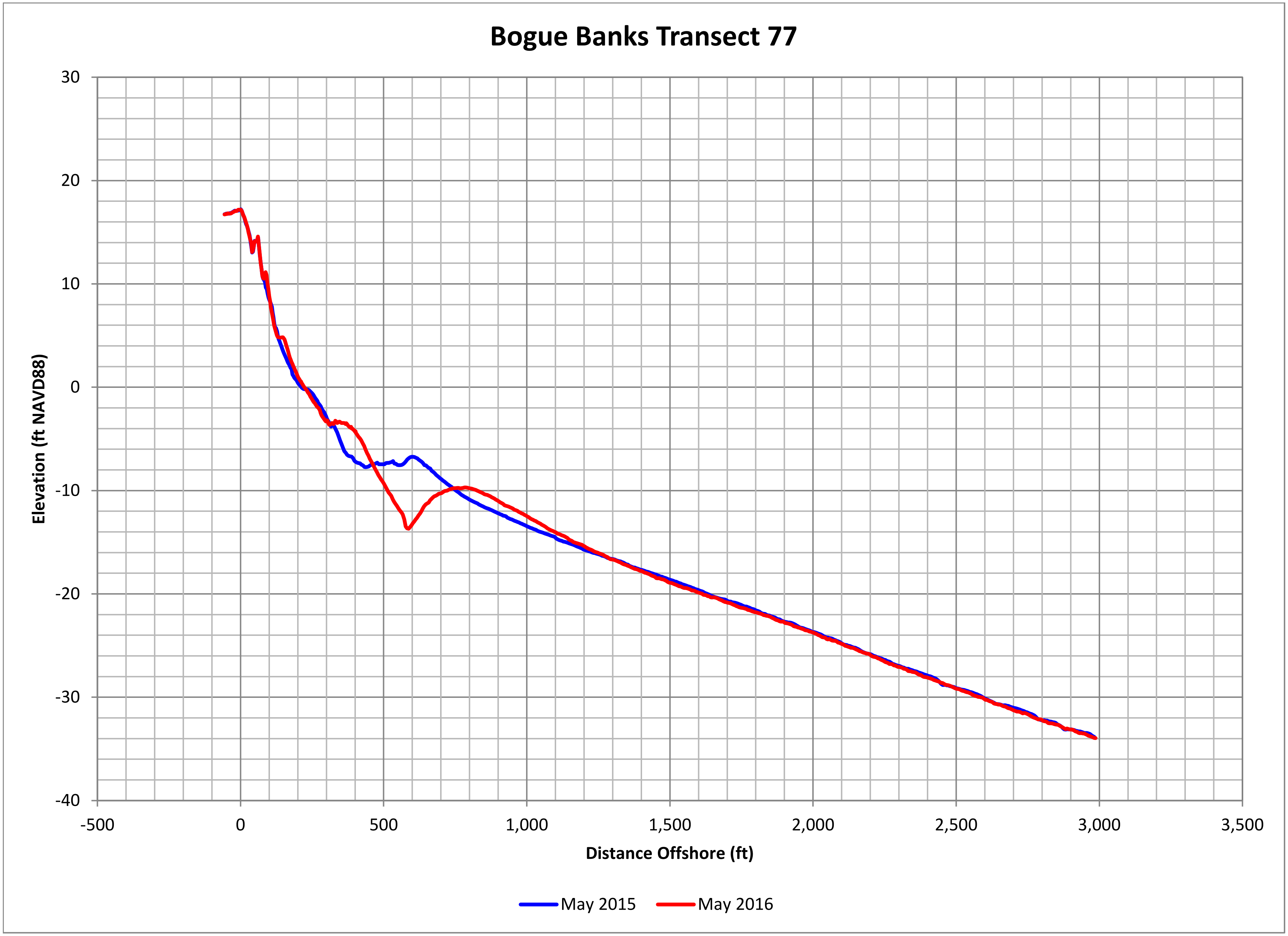


Figure C-105. Bogue Banks Profile Comparison Plot

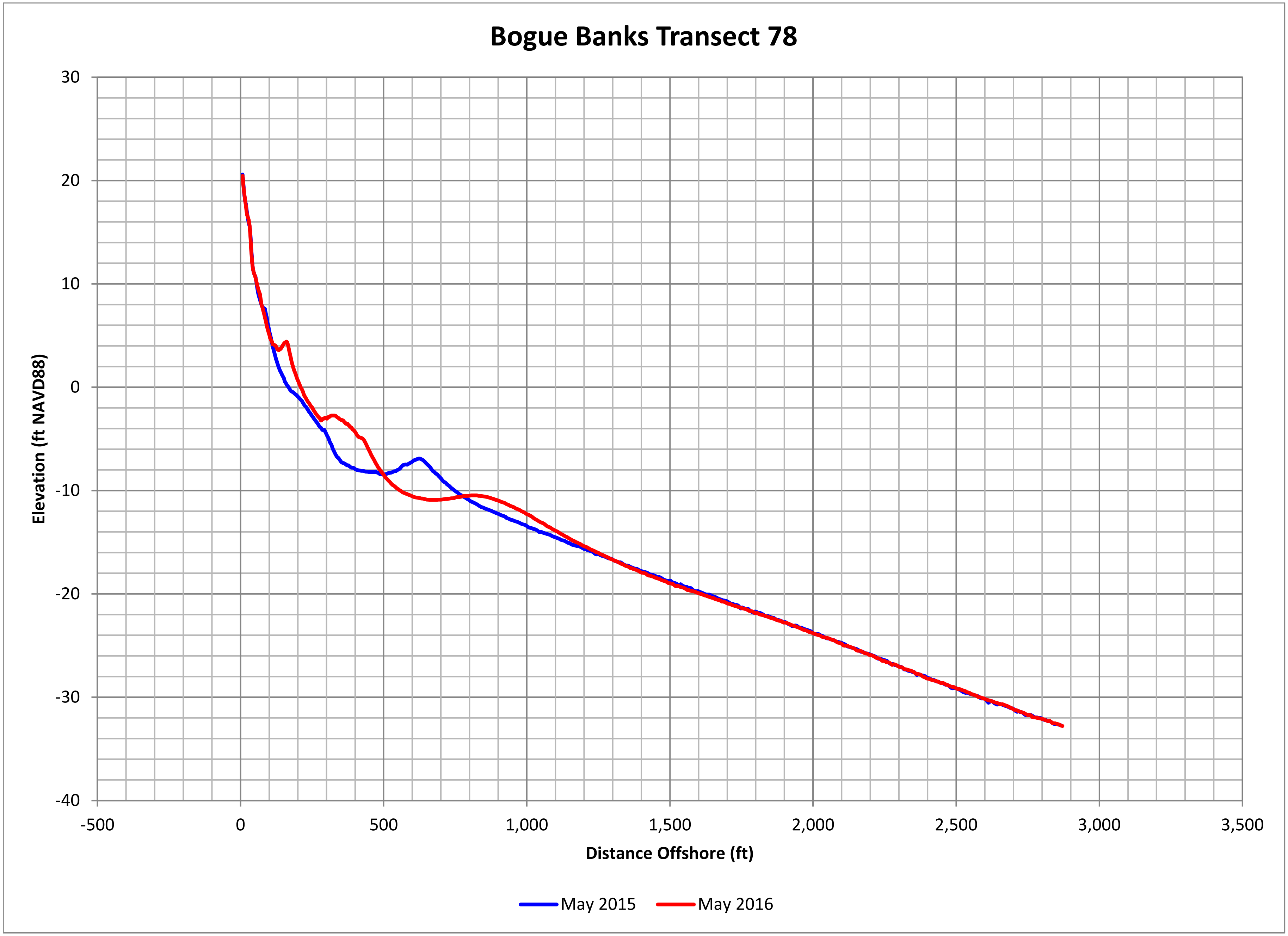


Figure C-106. Bogue Banks Profile Comparison Plot

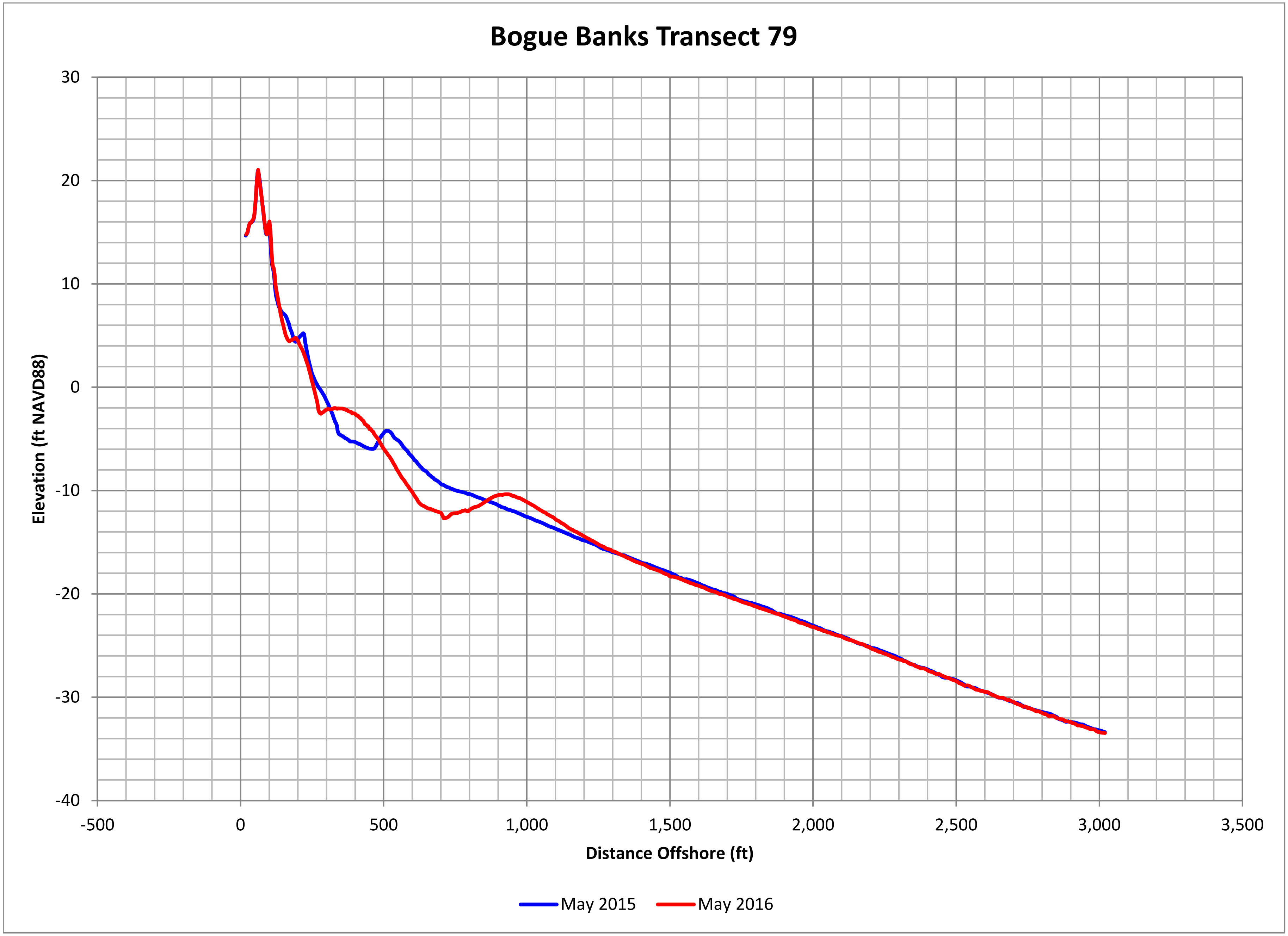


Figure C-107. Bogue Banks Profile Comparison Plot

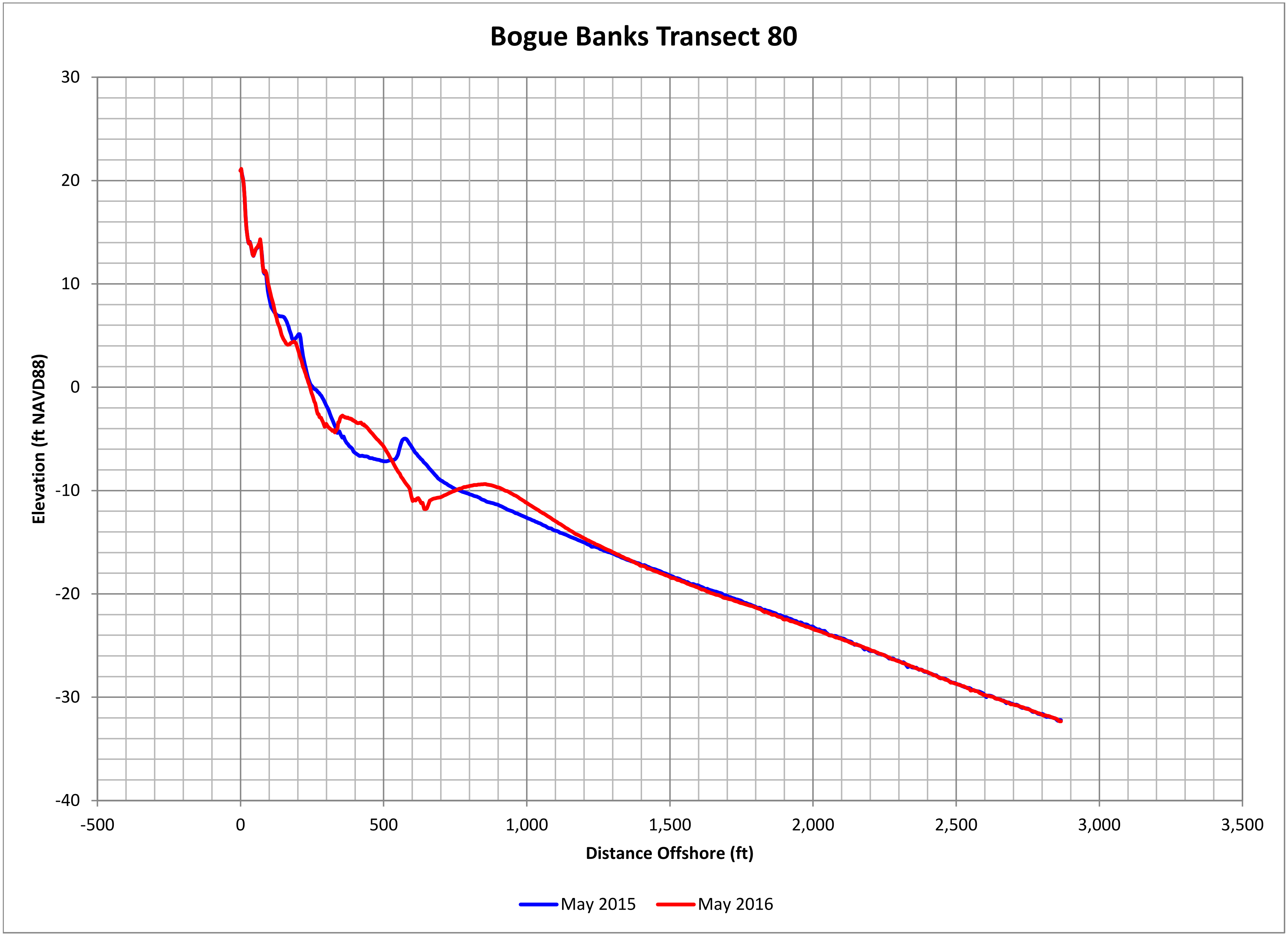


Figure C-108. Bogue Banks Profile Comparison Plot

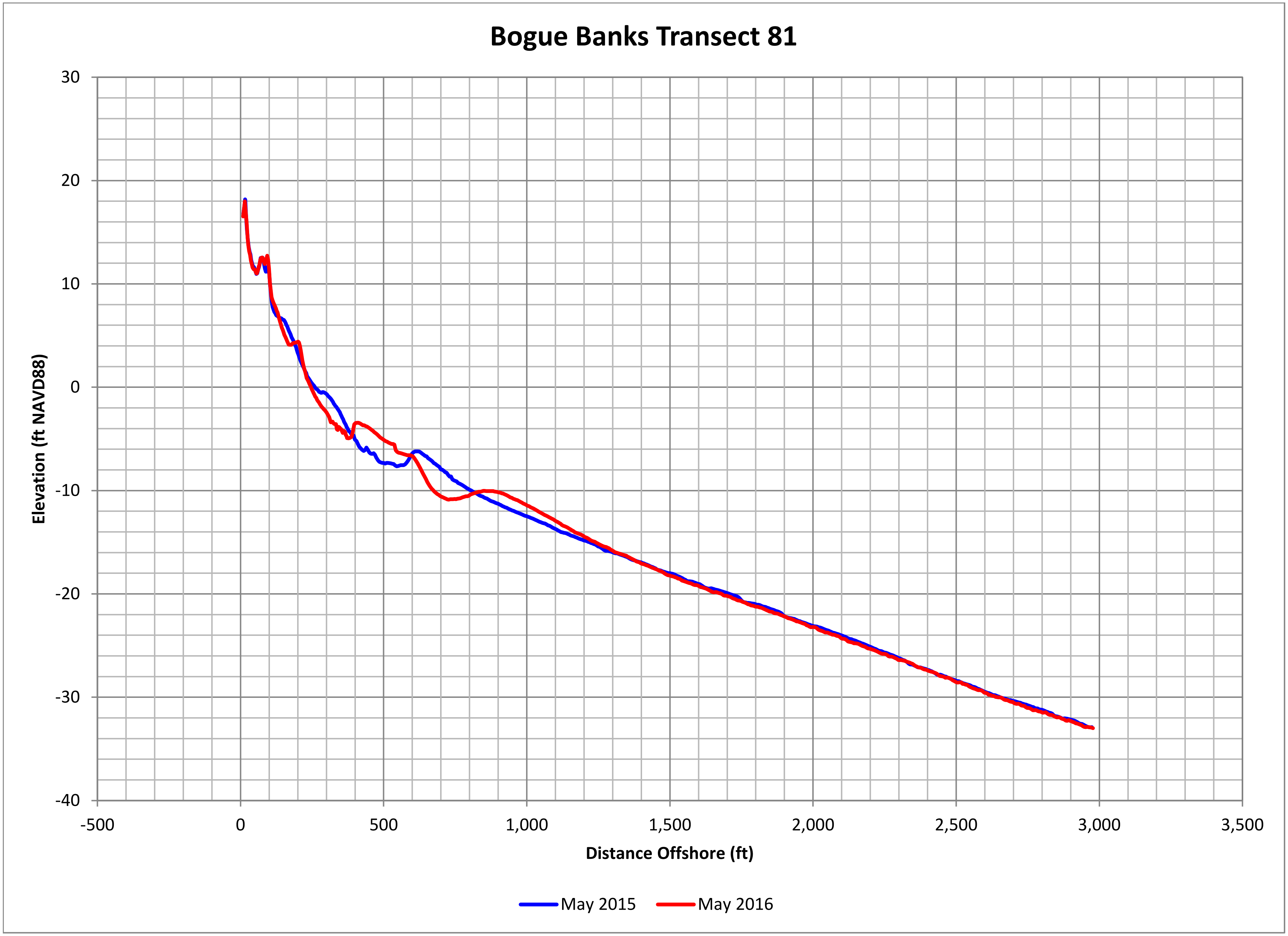


Figure C-109. Bogue Banks Profile Comparison Plot

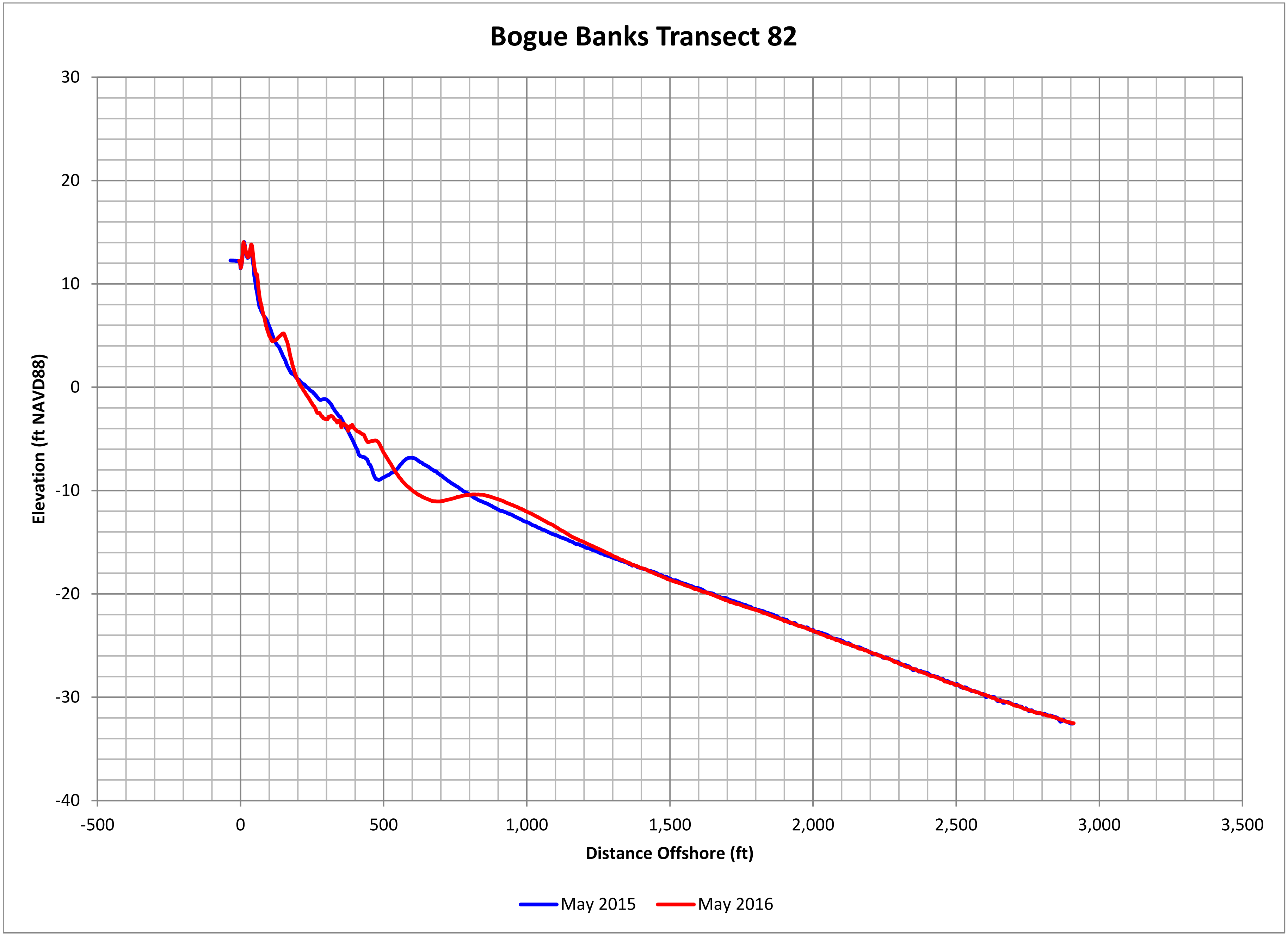


Figure C-110. Bogue Banks Profile Comparison Plot

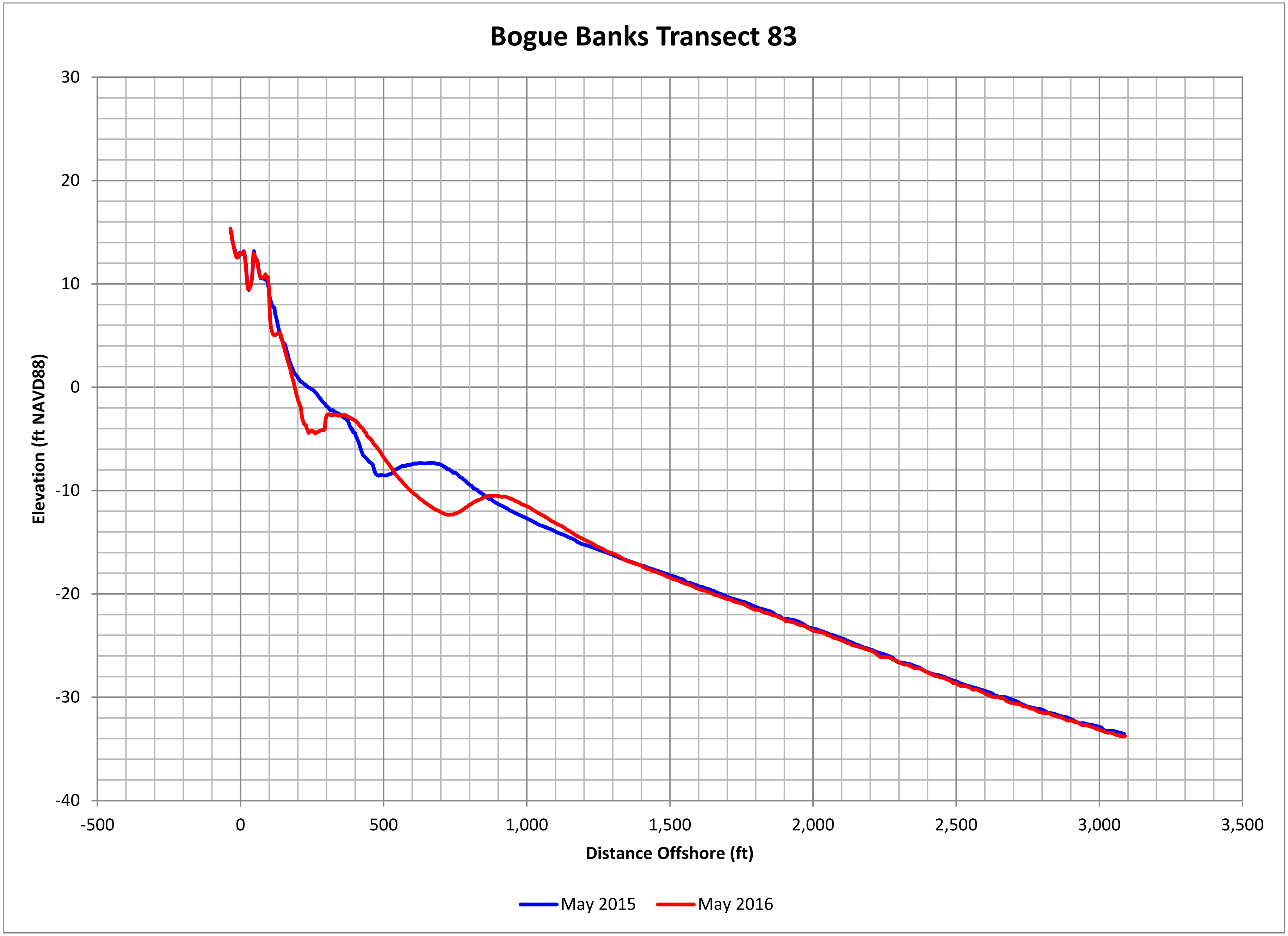


Figure C-111. Bogue Banks Profile Comparison Plot

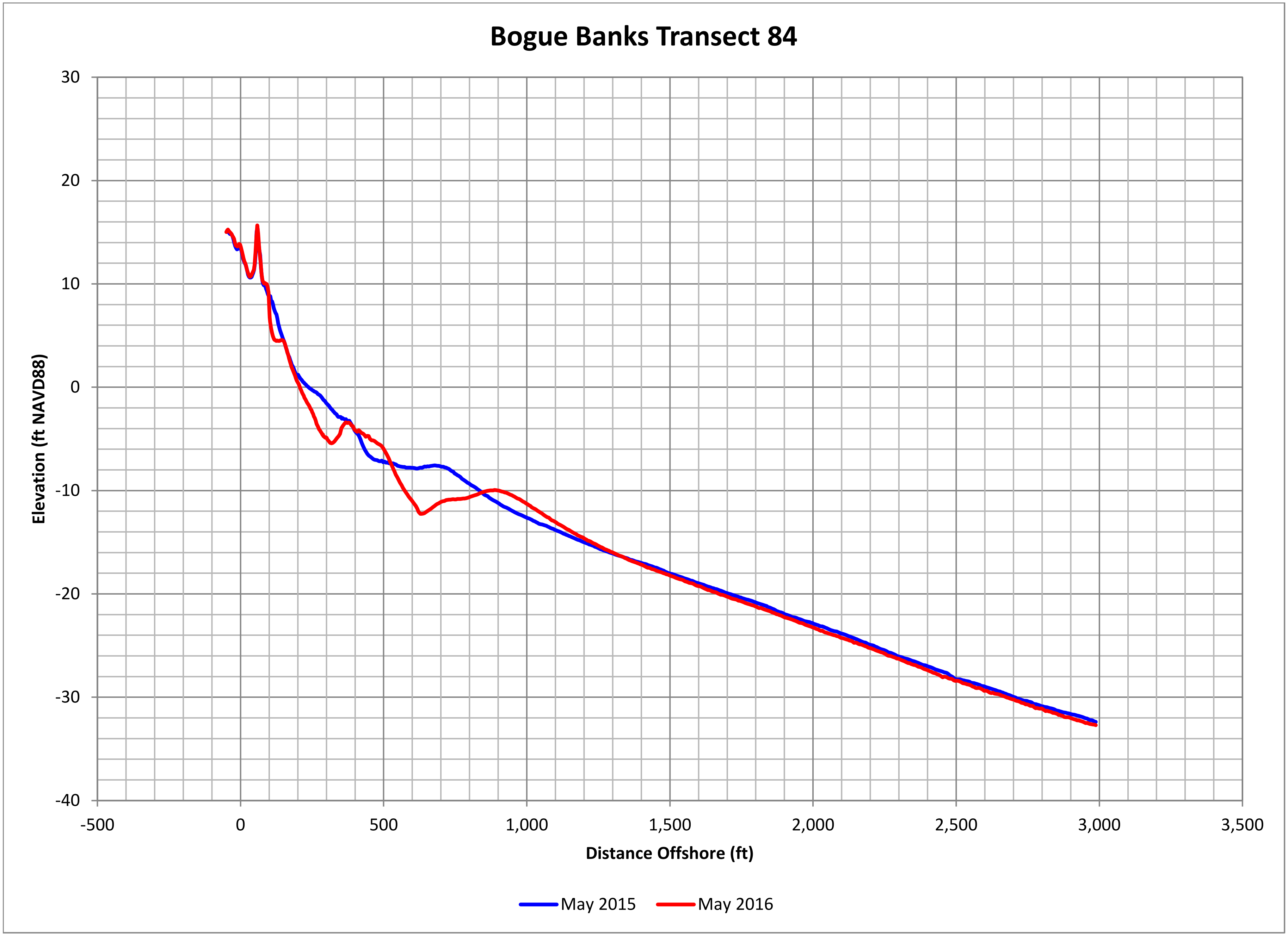


Figure C-112. Bogue Banks Profile Comparison Plot

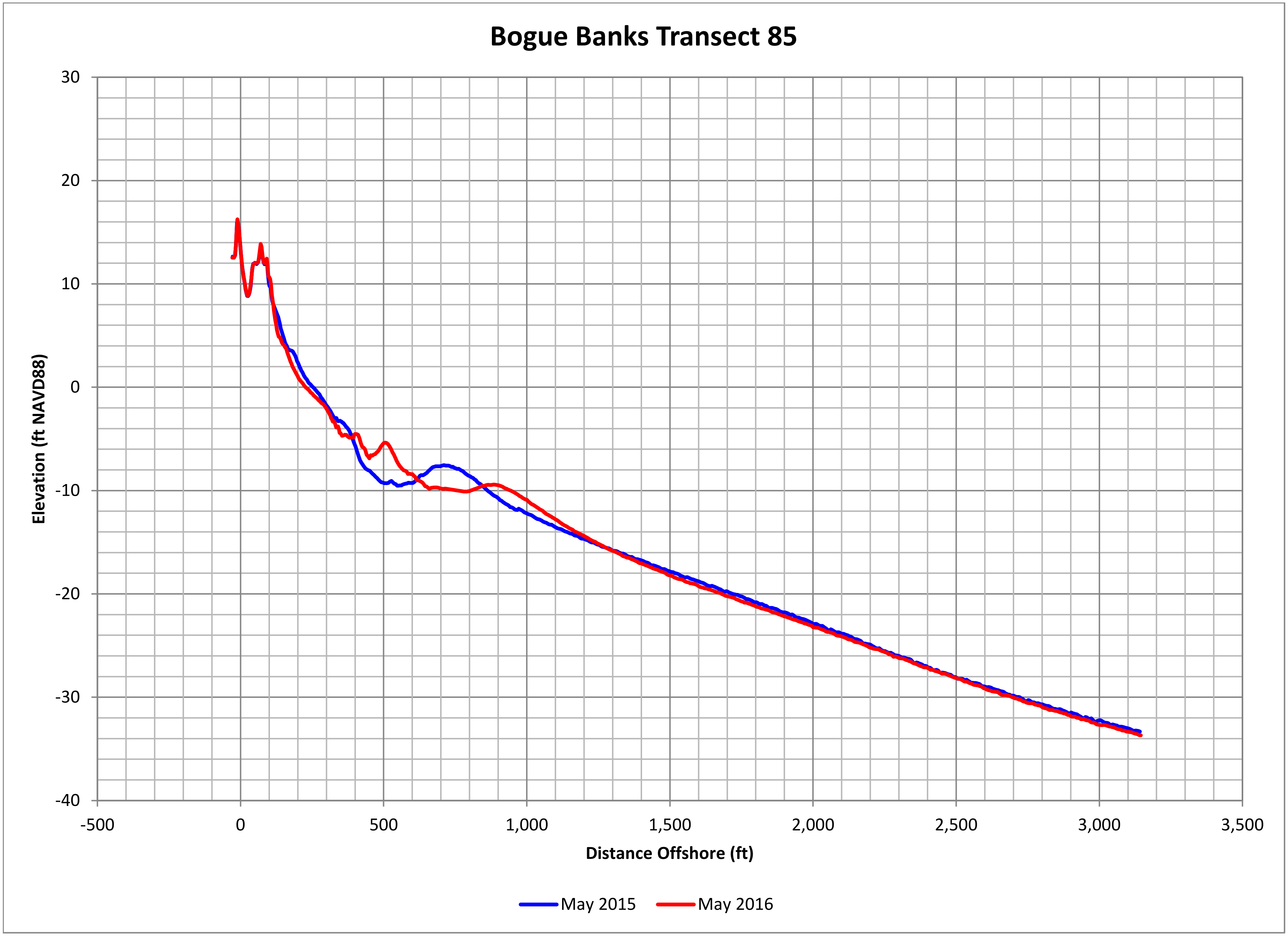


Figure C-113. Bogue Banks Profile Comparison Plot

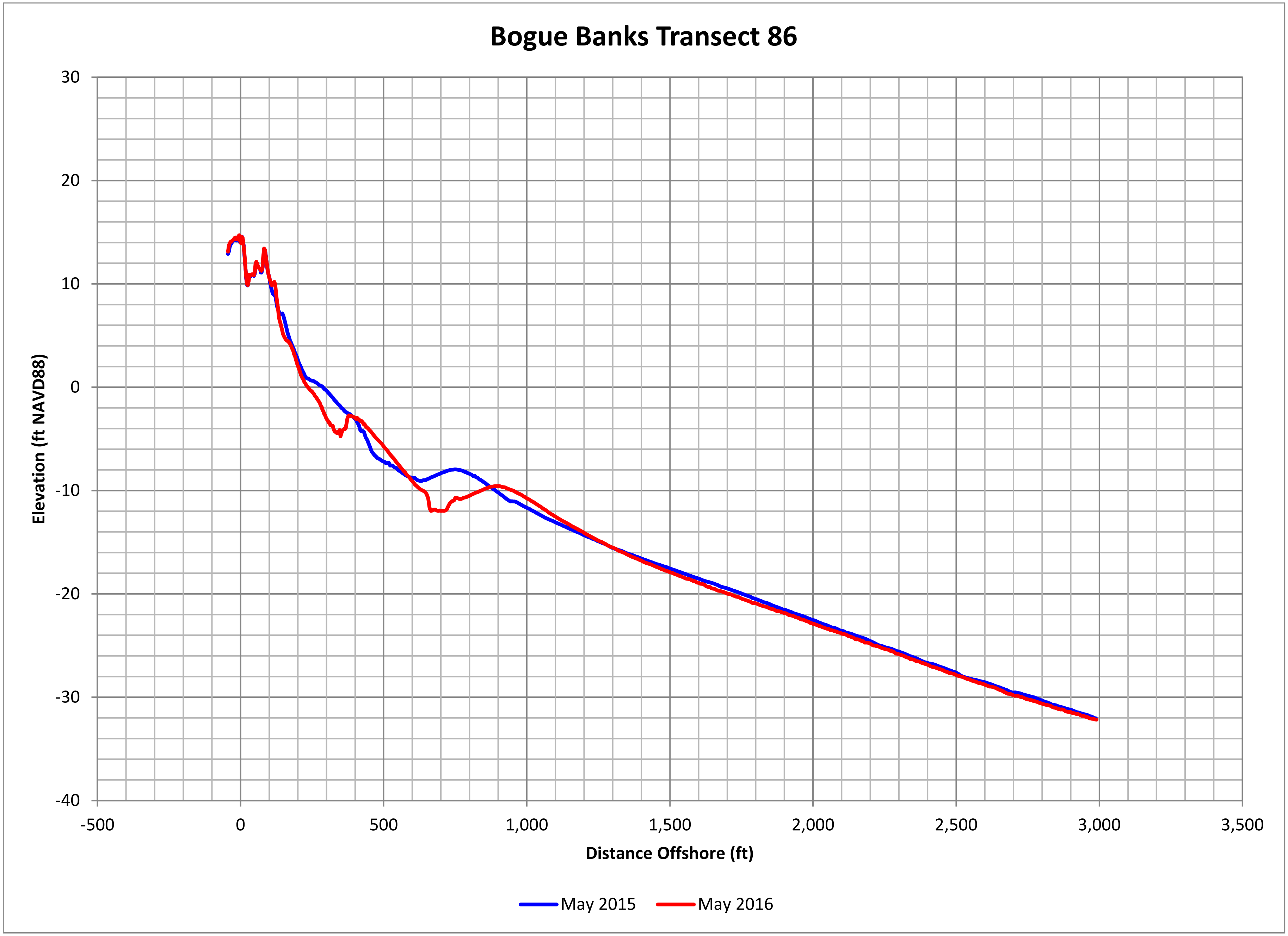


Figure C-114. Bogue Banks Profile Comparison Plot

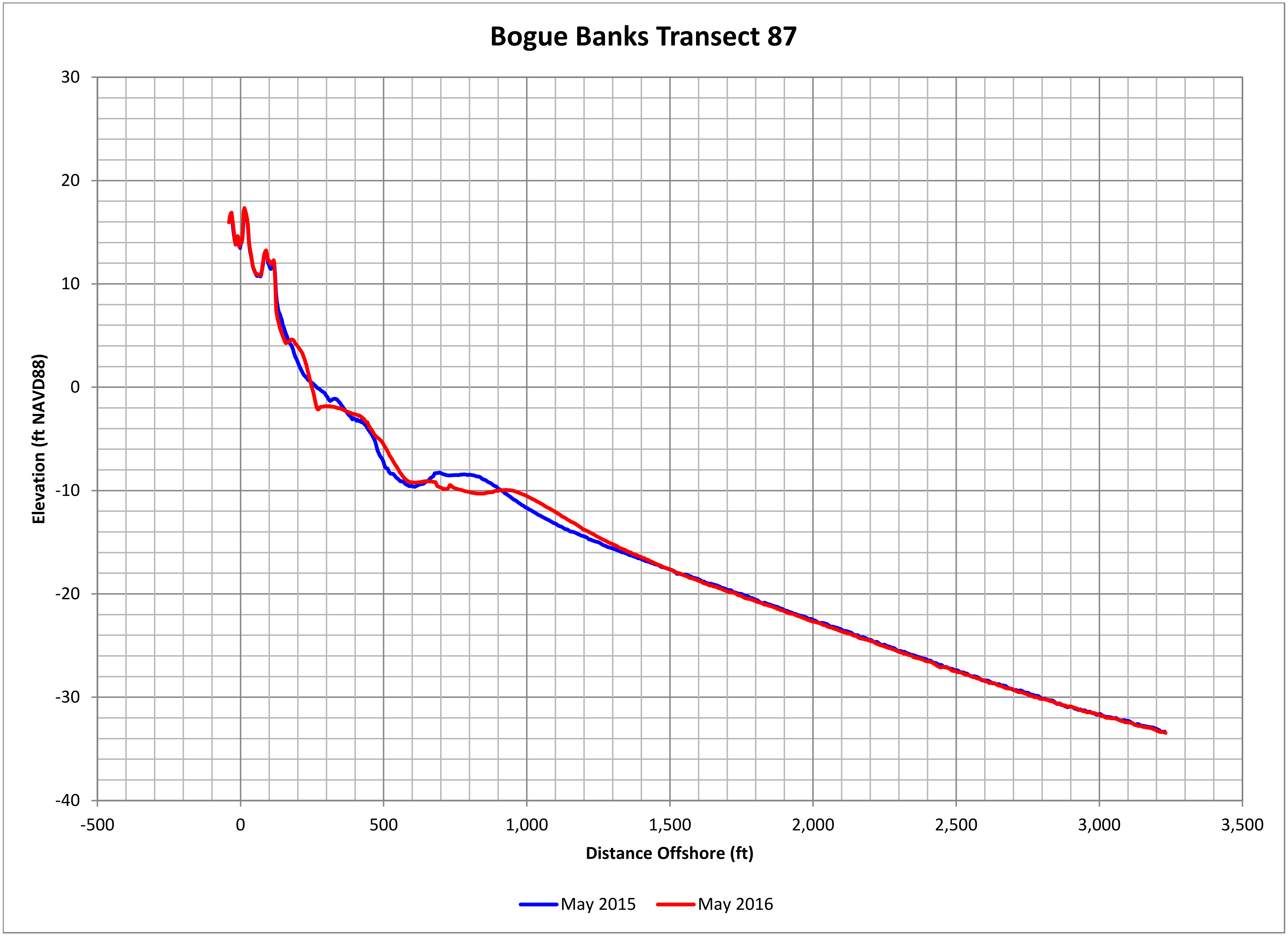


Figure C-115. Bogue Banks Profile Comparison Plot

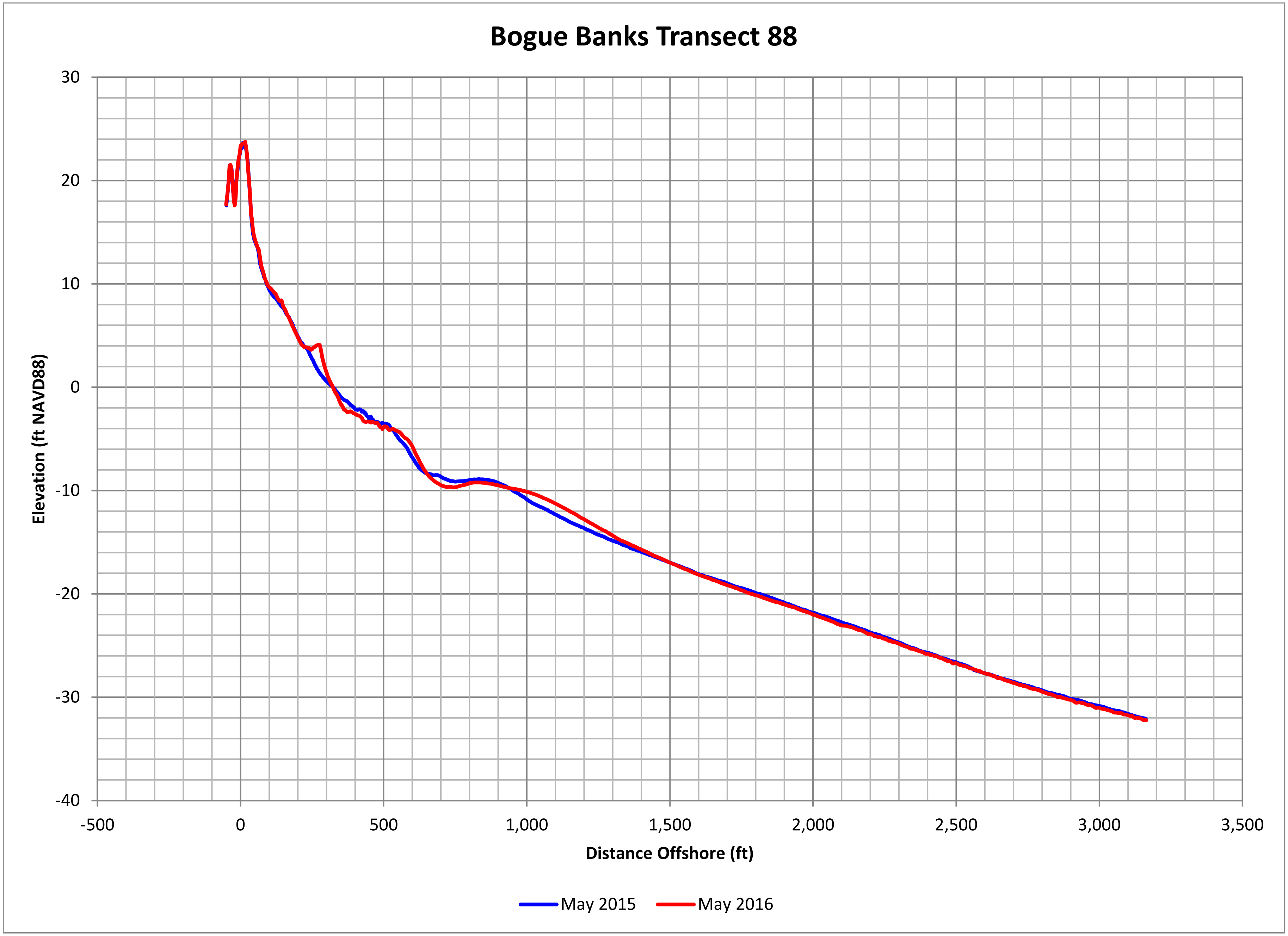


Figure C-116. Bogue Banks Profile Comparison Plot

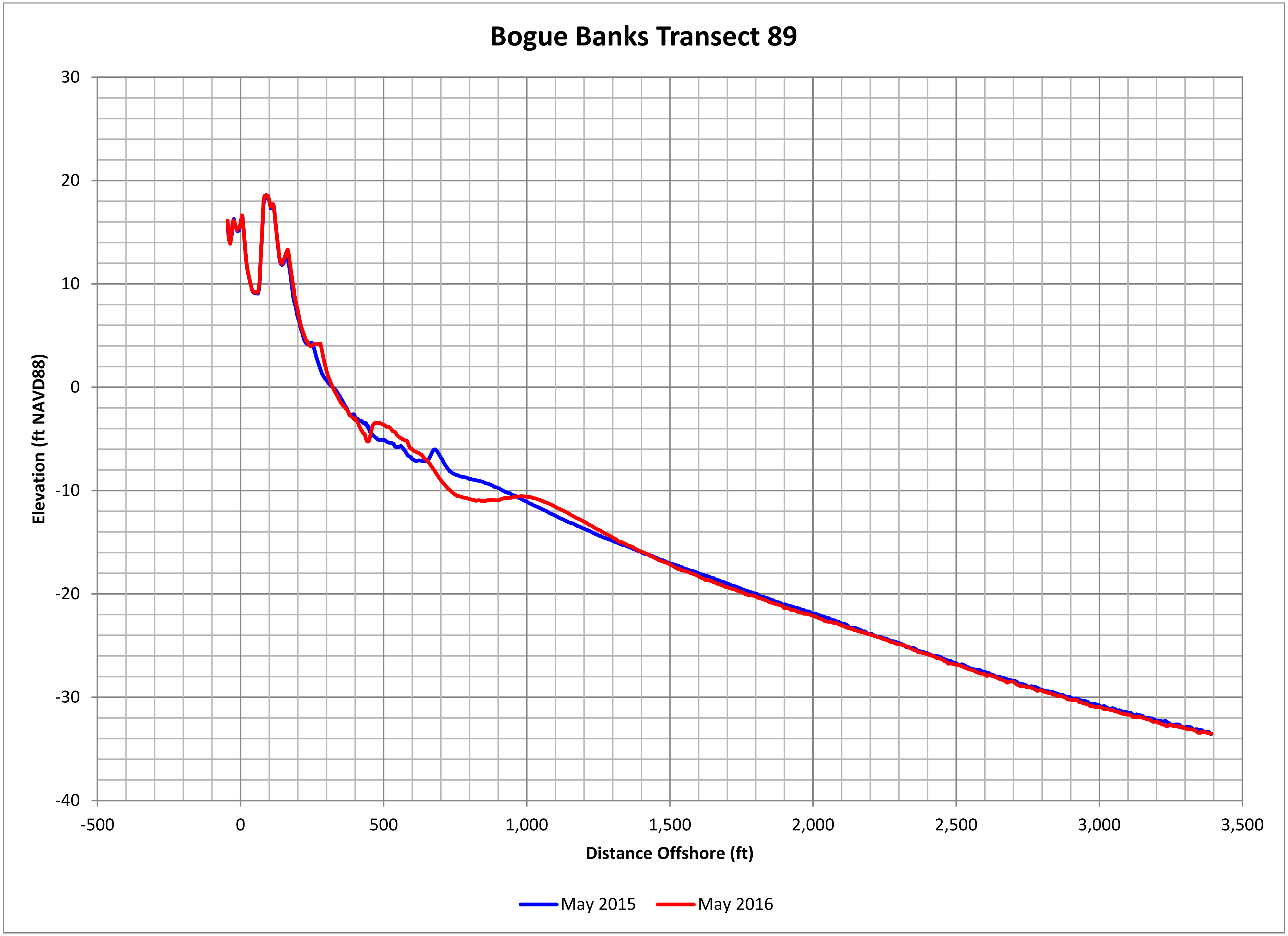


Figure C-117. Bogue Banks Profile Comparison Plot

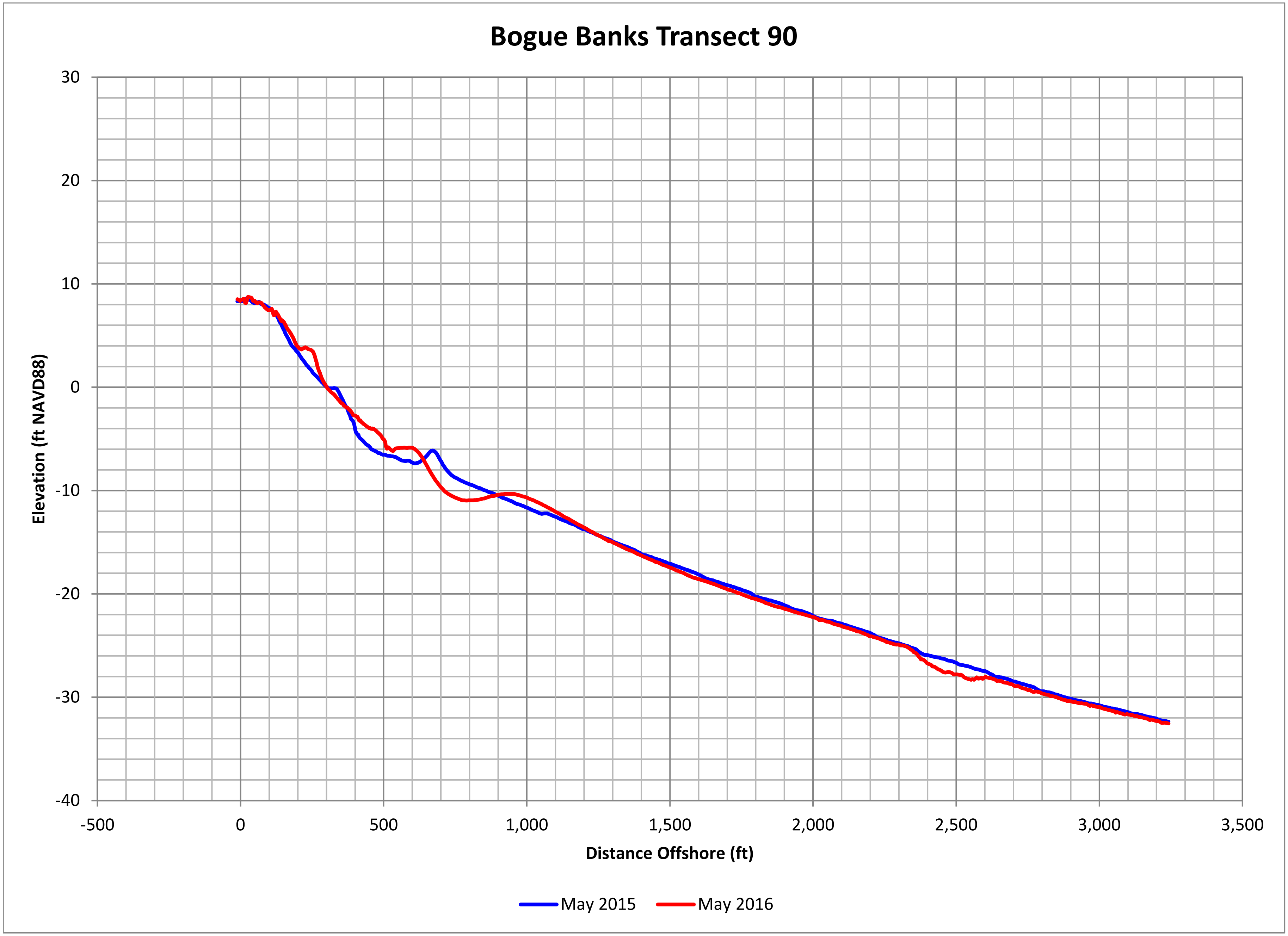


Figure C-118. Bogue Banks Profile Comparison Plot

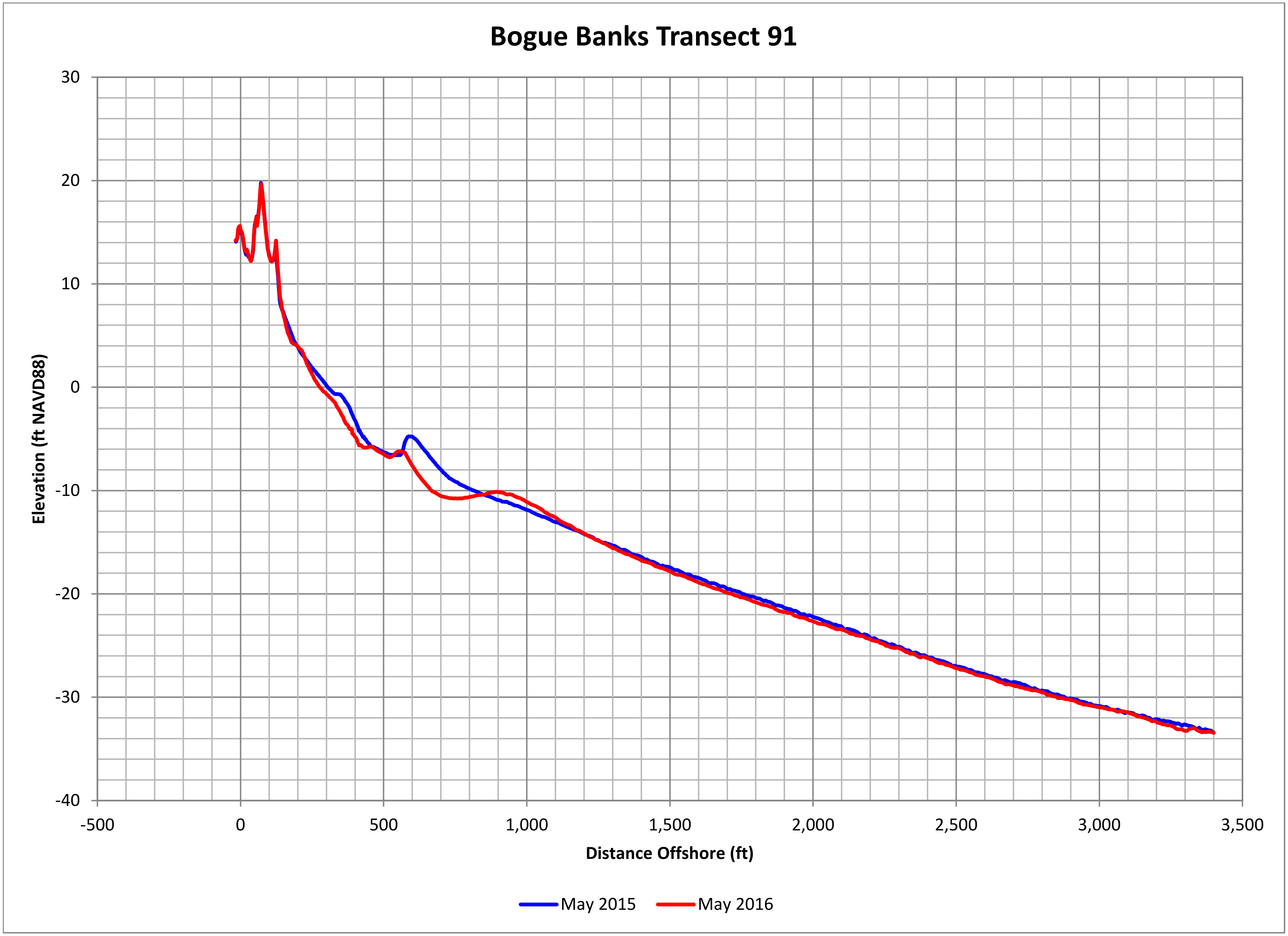


Figure C-119. Bogue Banks Profile Comparison Plot

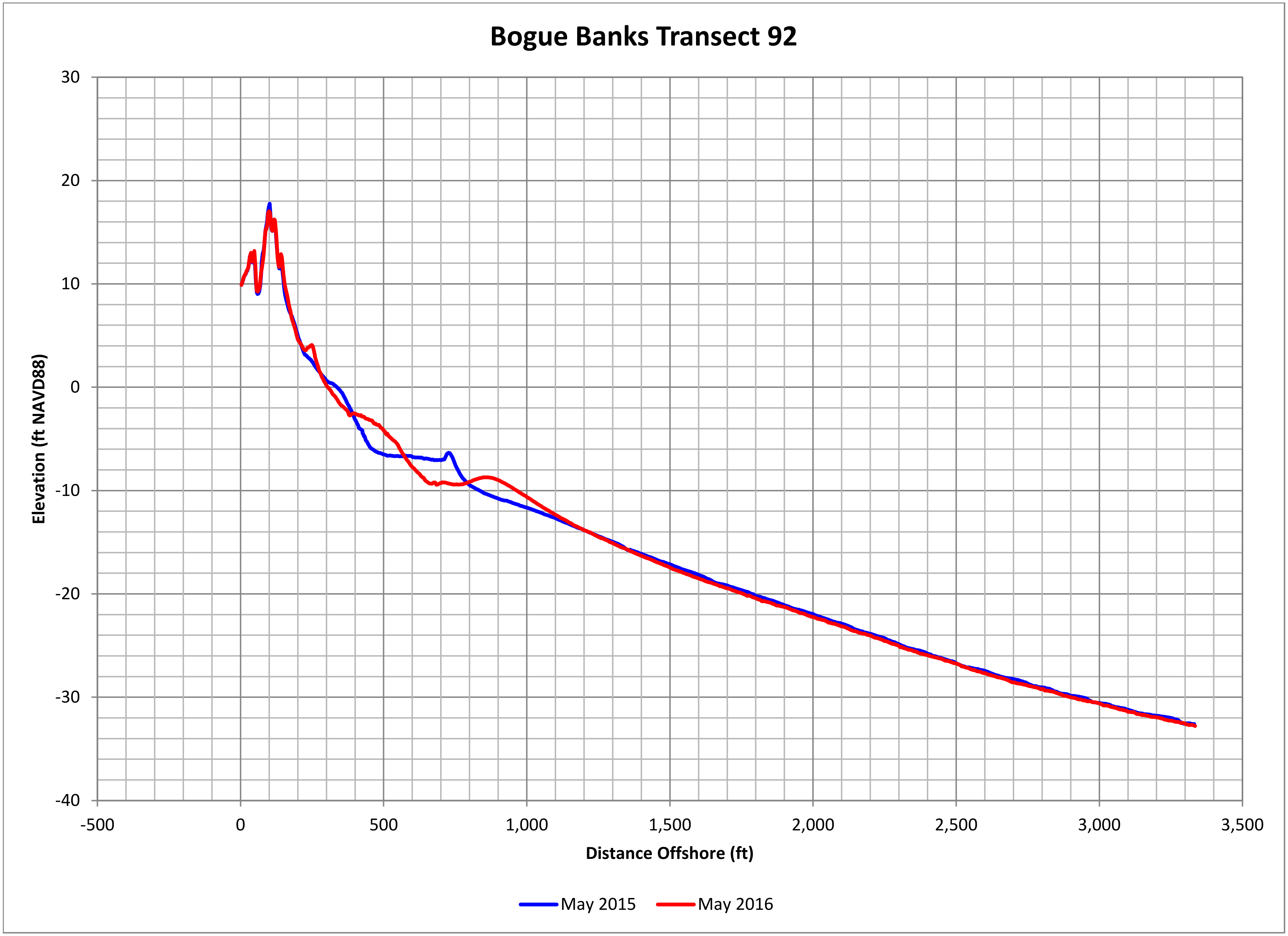


Figure C-120. Bogue Banks Profile Comparison Plot

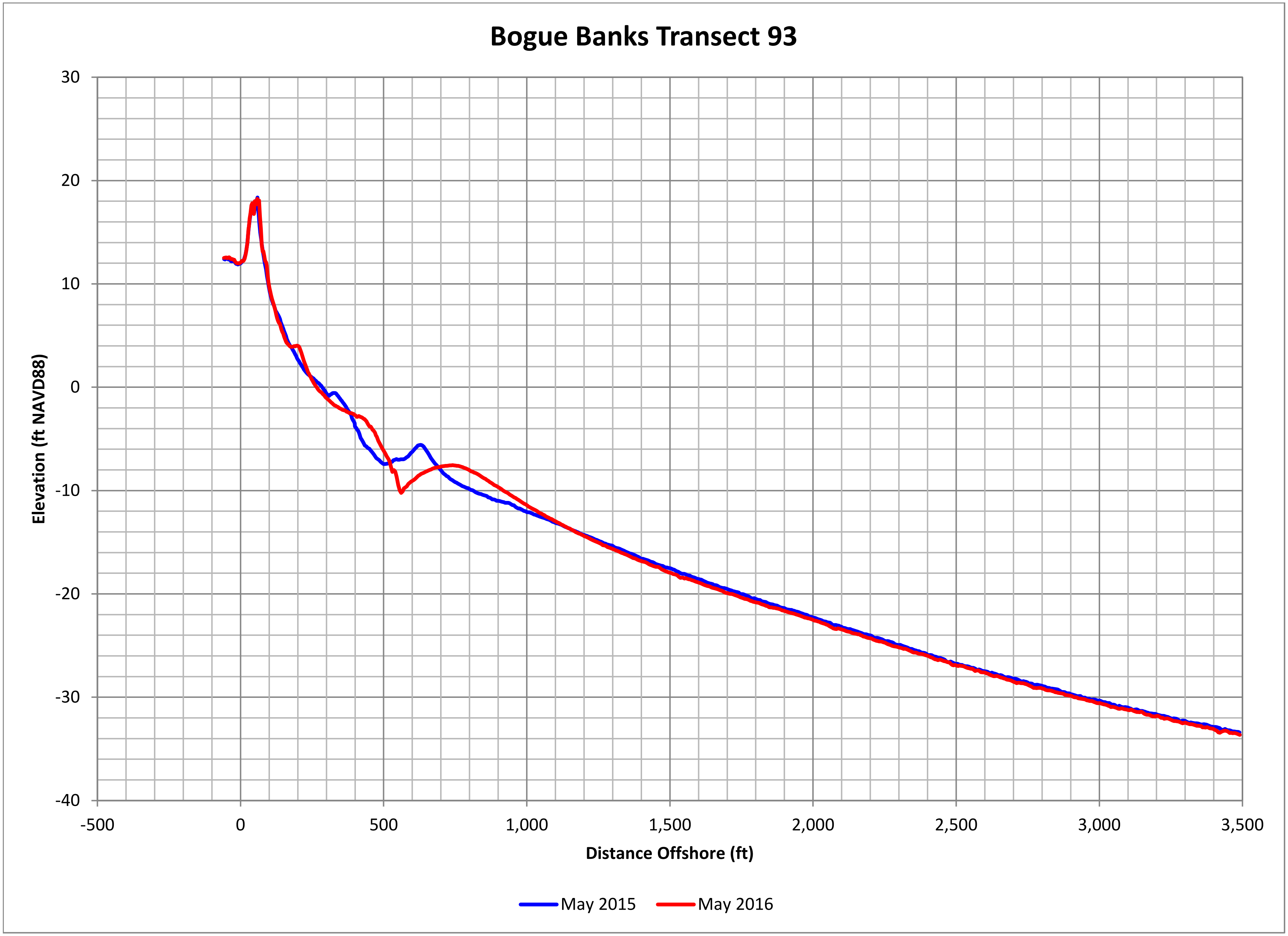


Figure C-121. Bogue Banks Profile Comparison Plot

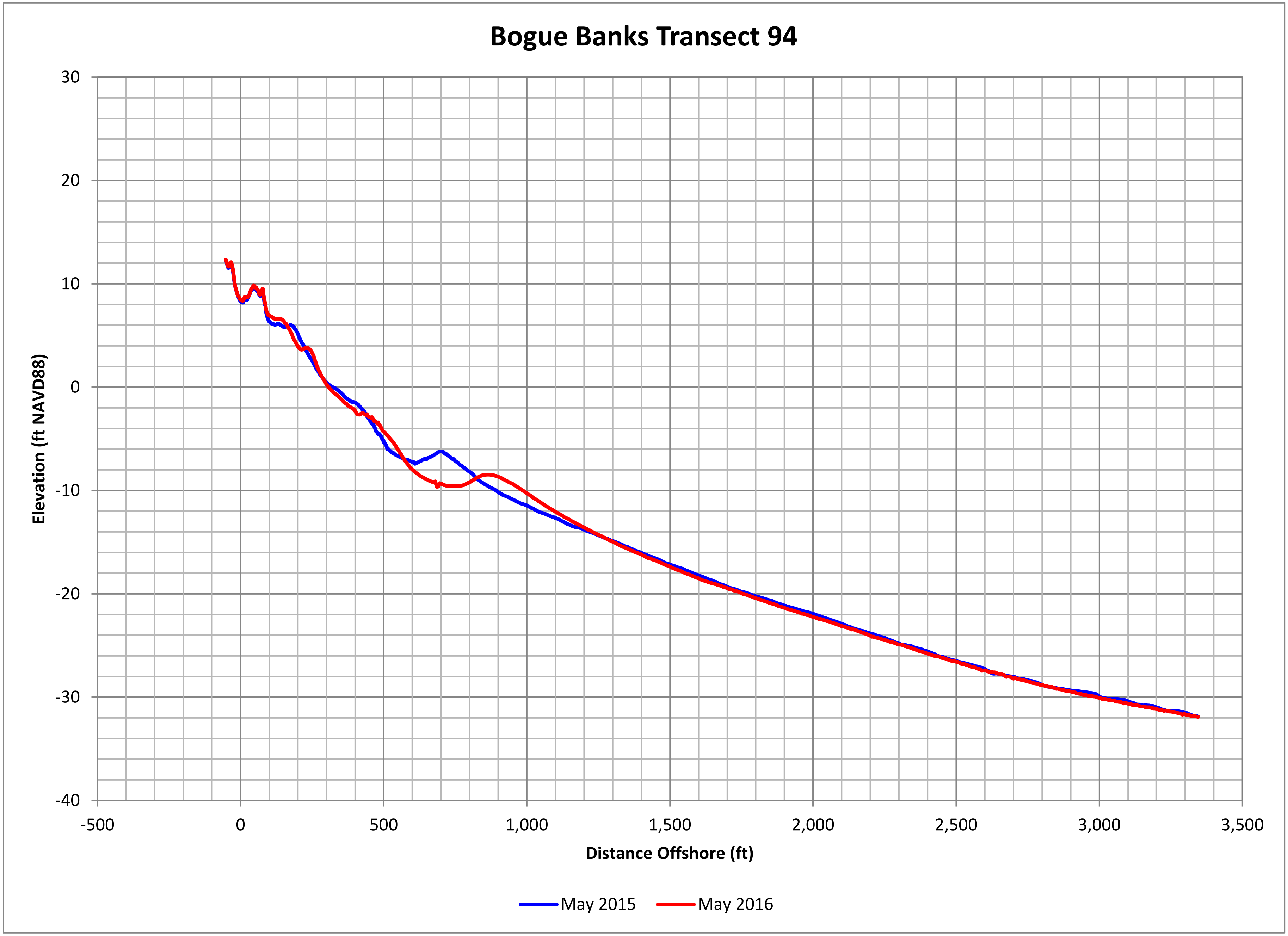


Figure C-122. Bogue Banks Profile Comparison Plot

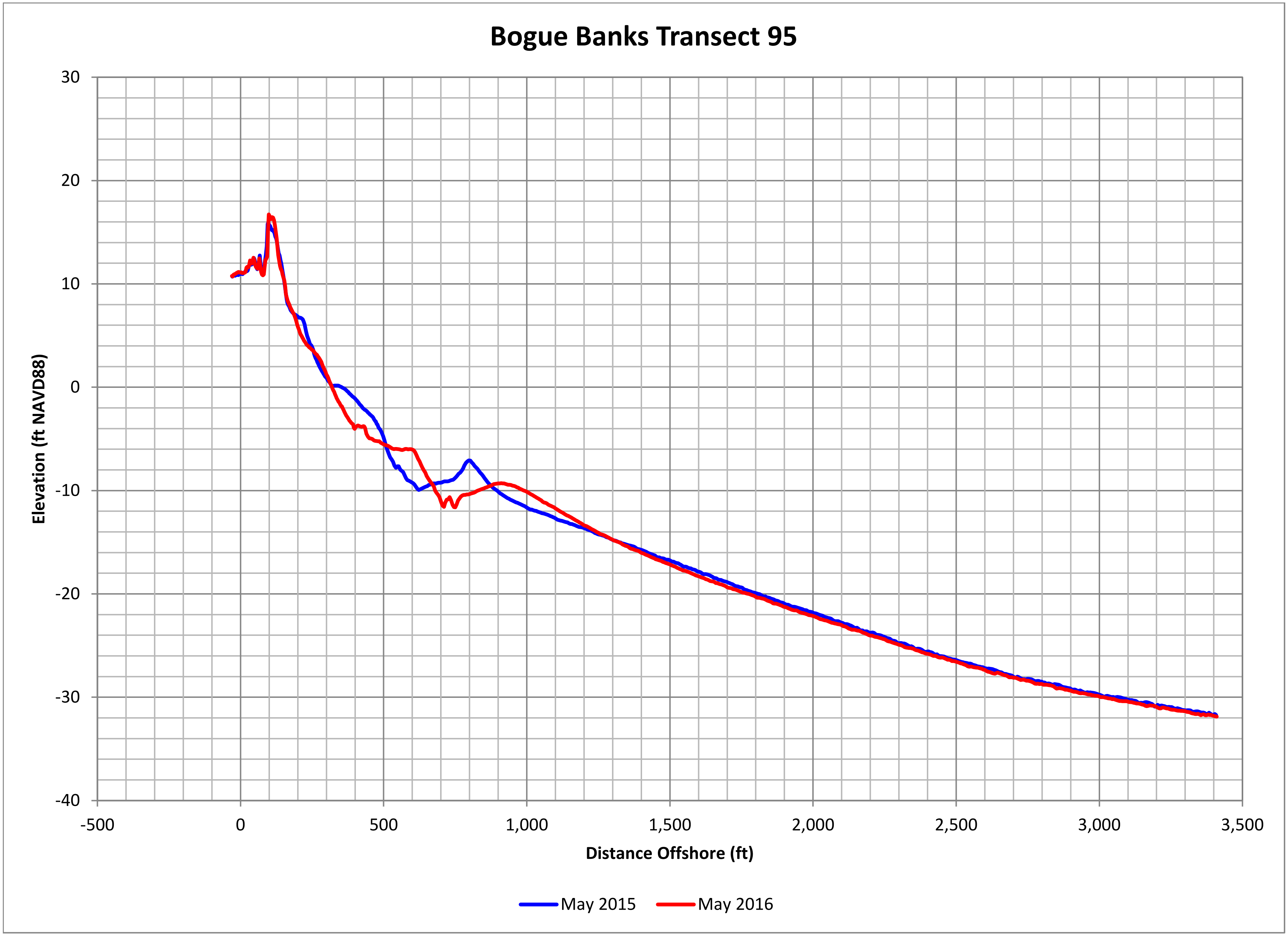


Figure C-123. Bogue Banks Profile Comparison Plot

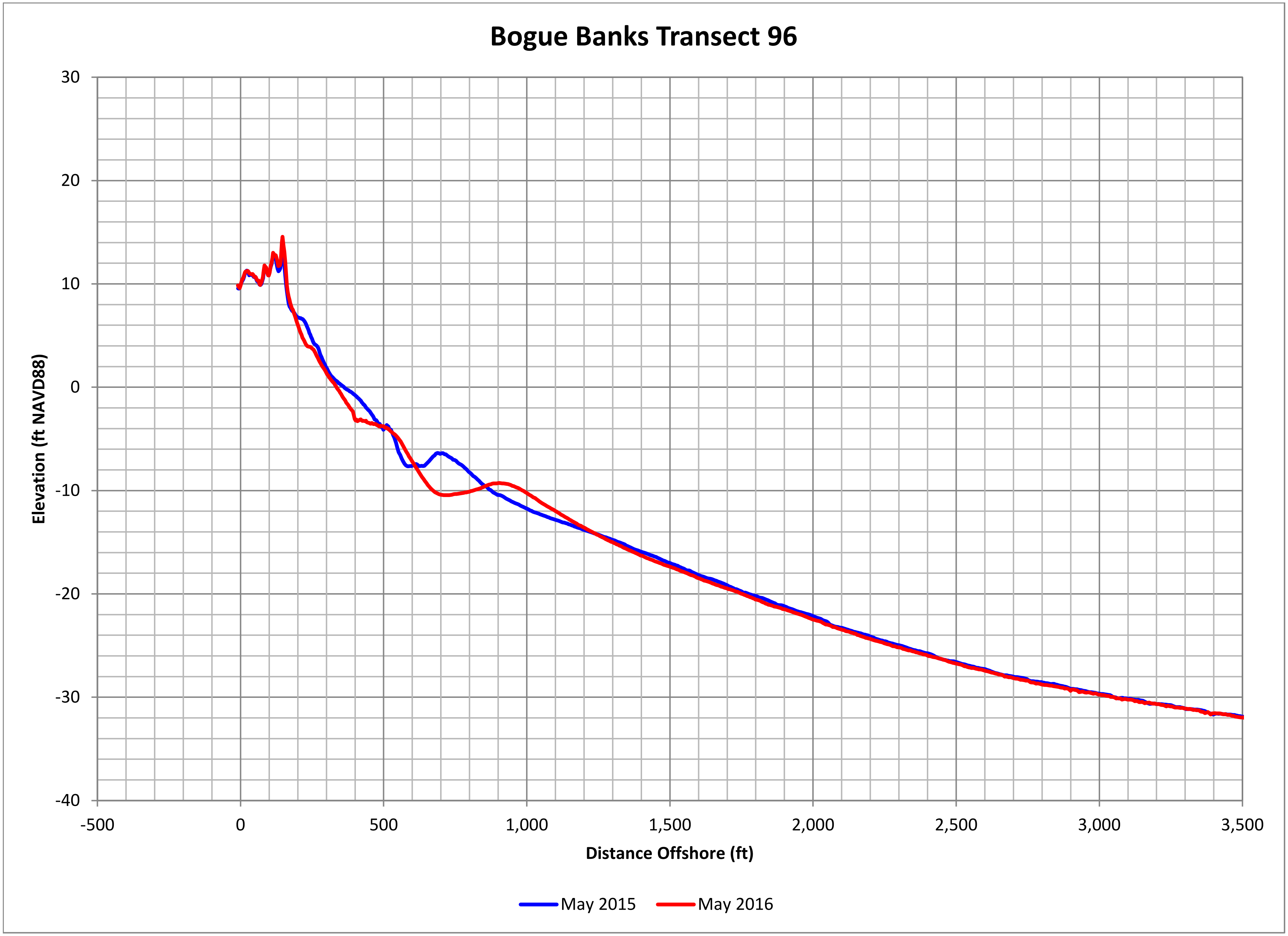


Figure C-124. Bogue Banks Profile Comparison Plot

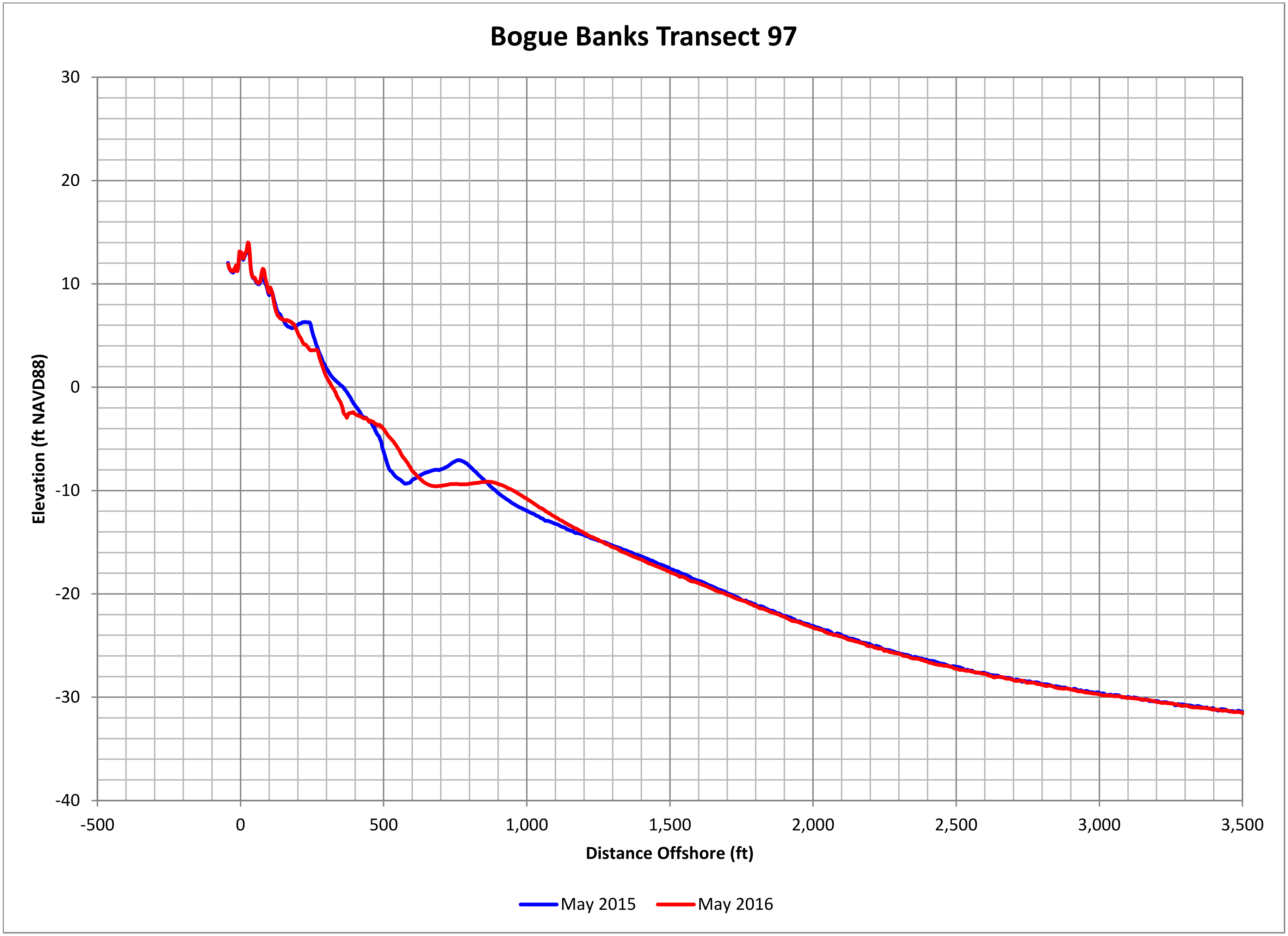


Figure C-125. Bogue Banks Profile Comparison Plot

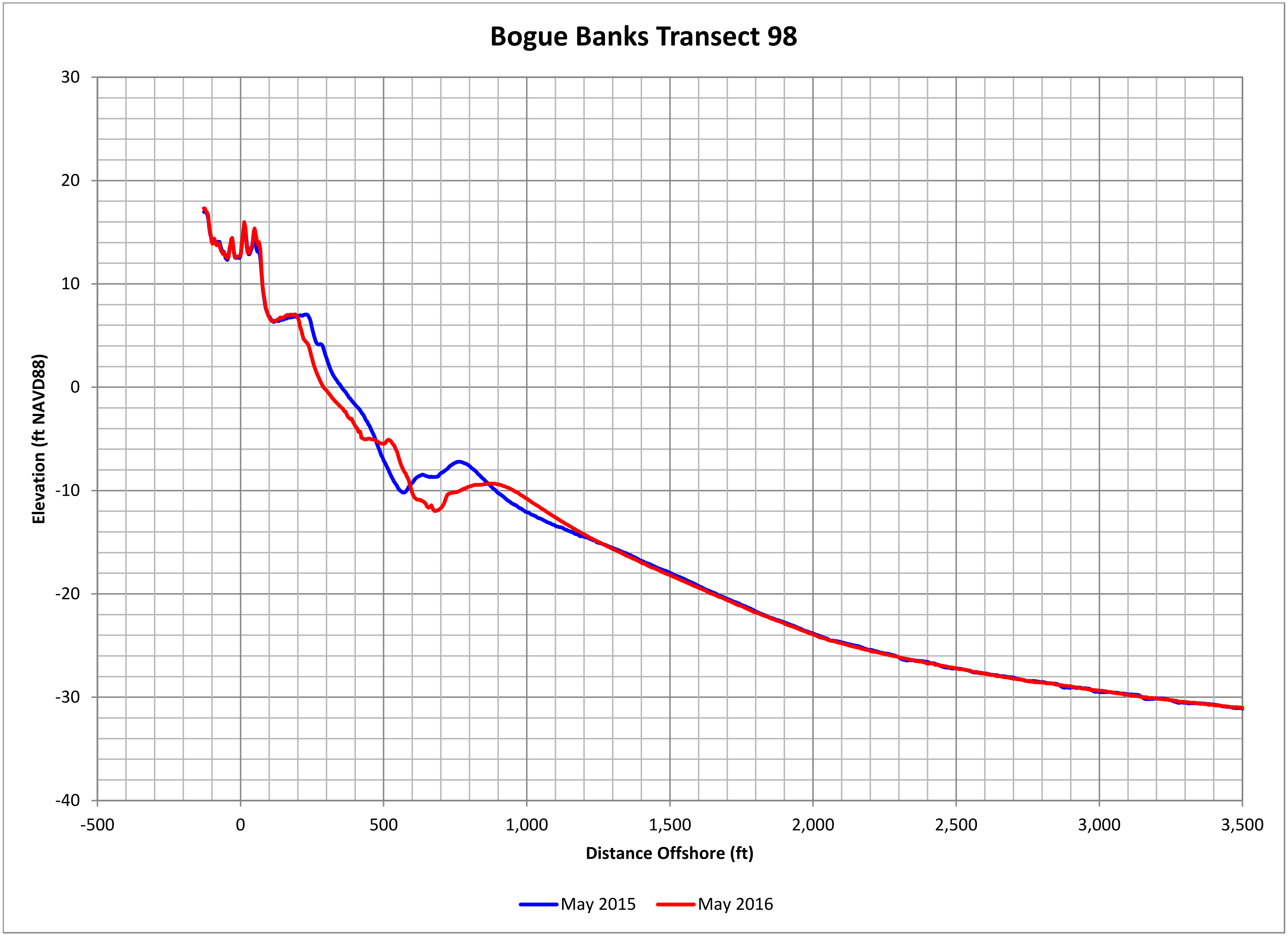


Figure C-126. Bogue Banks Profile Comparison Plot

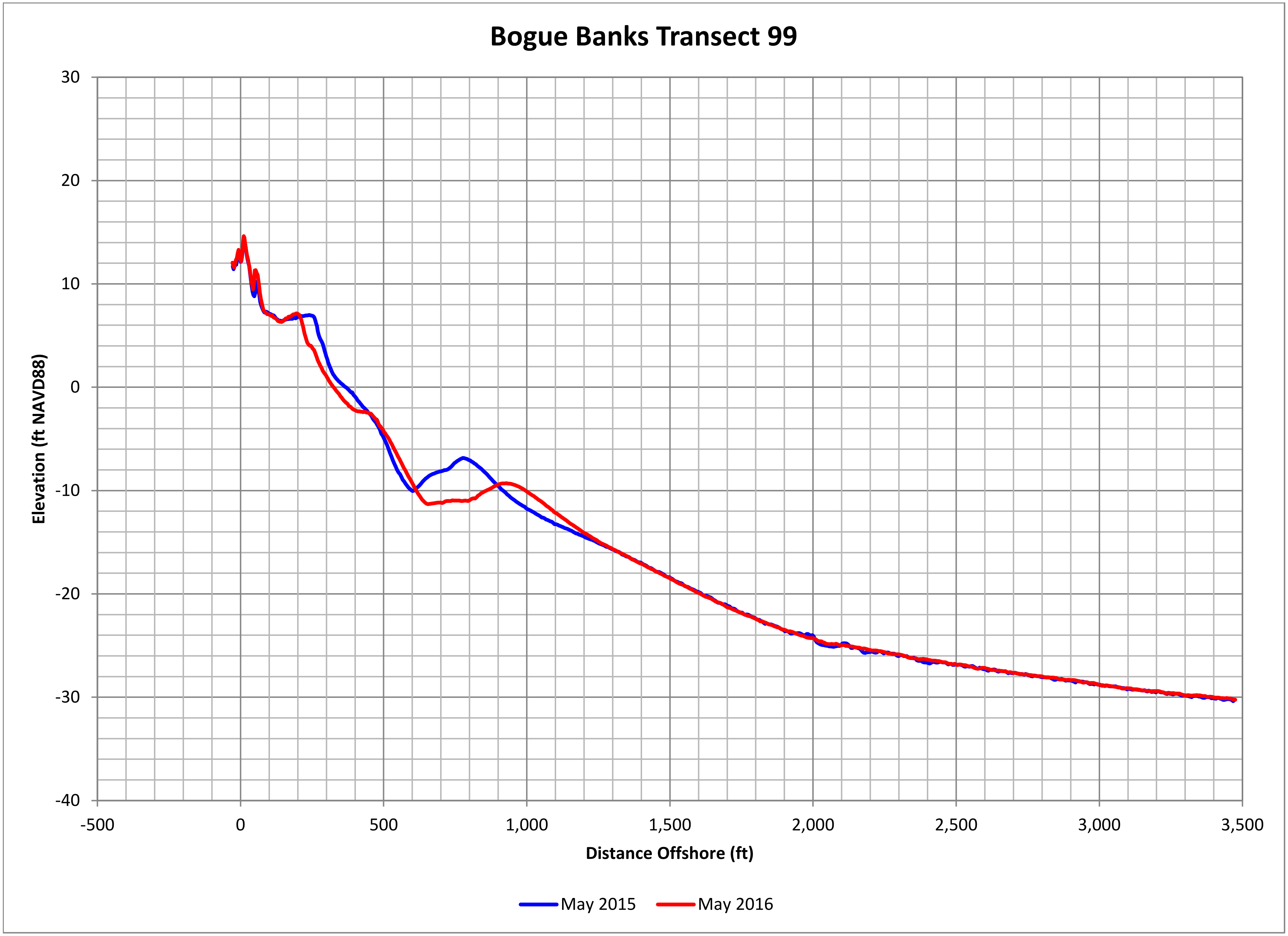


Figure C-127. Bogue Banks Profile Comparison Plot

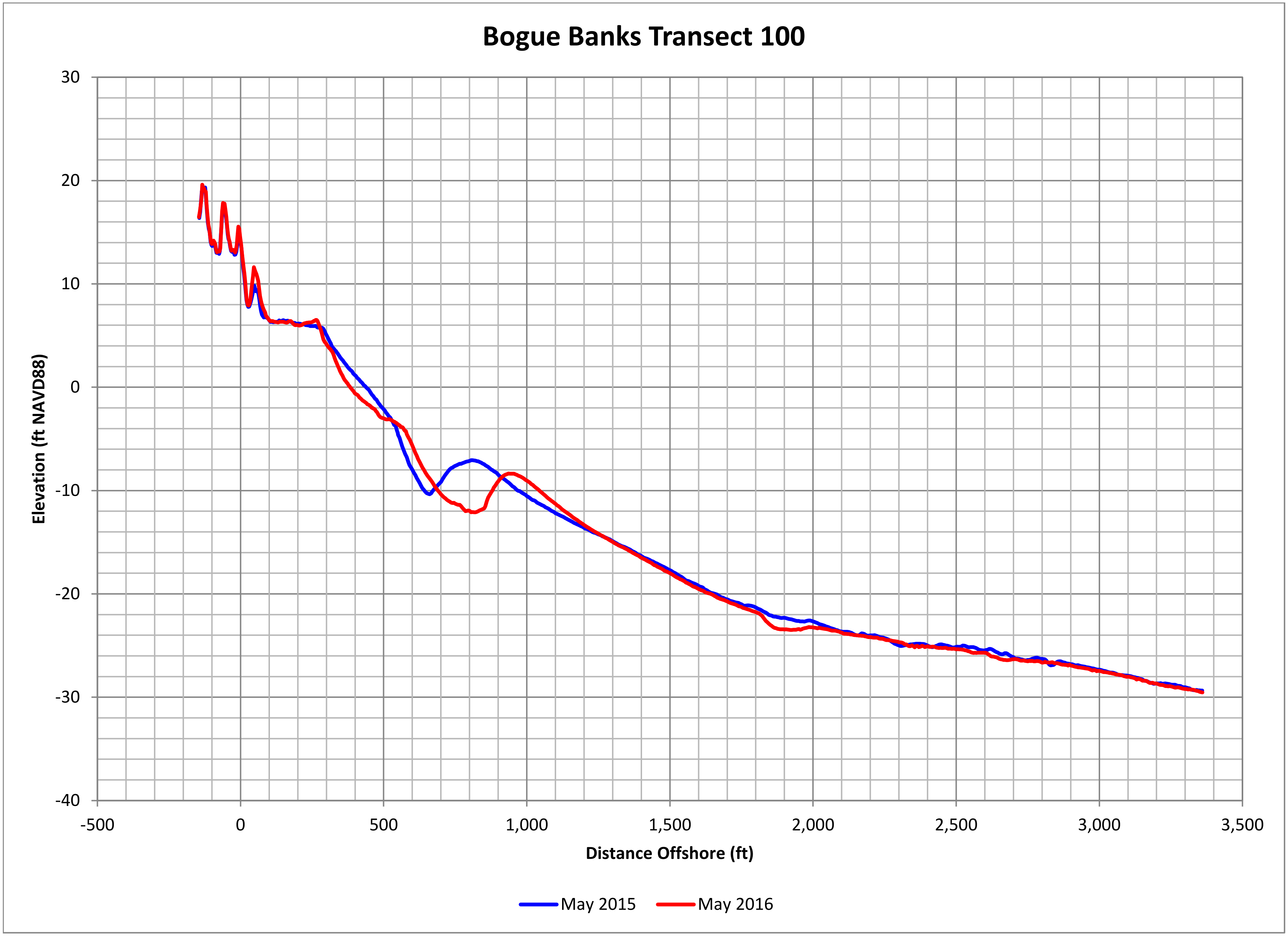


Figure C-128. Bogue Banks Profile Comparison Plot

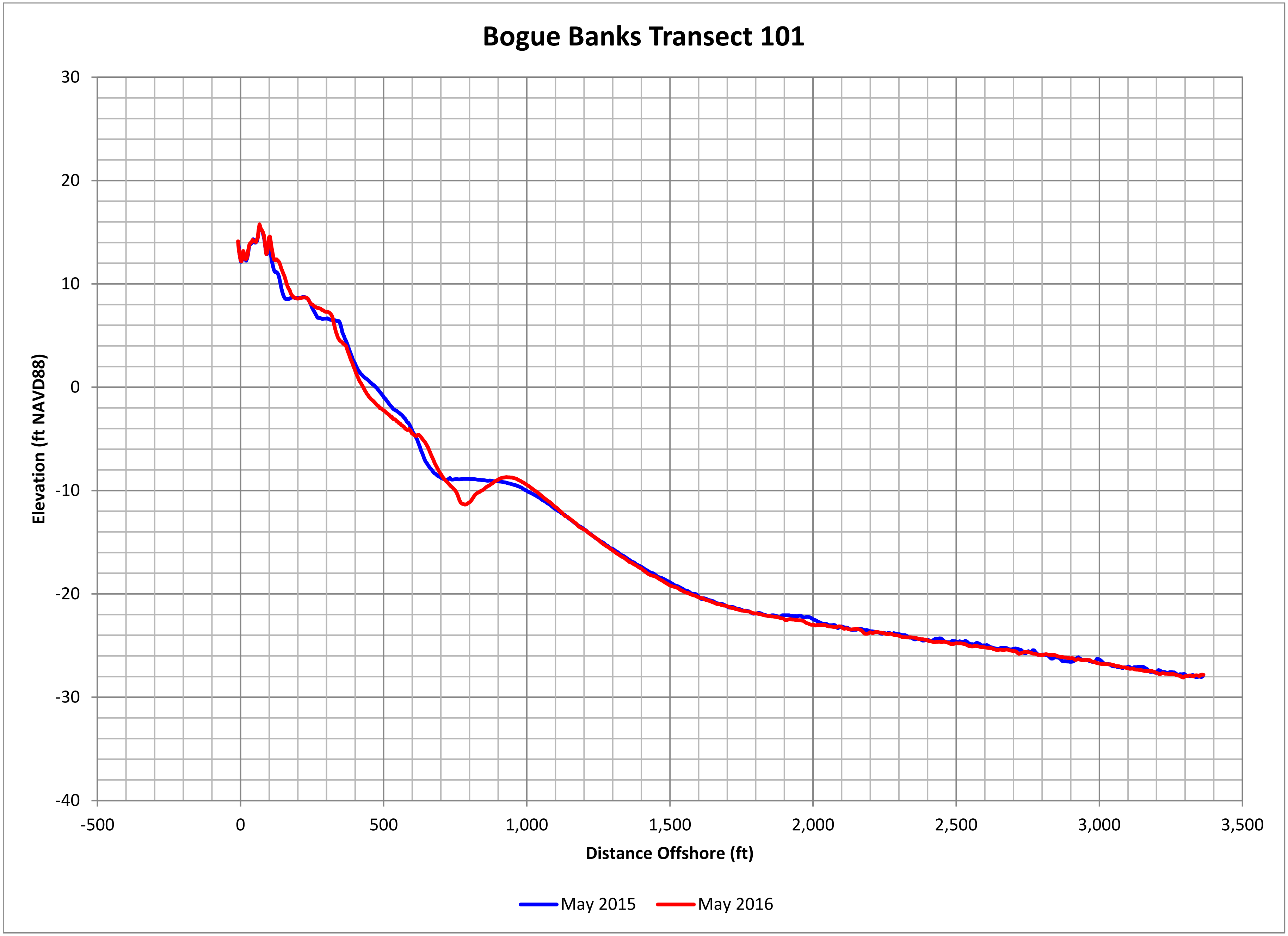


Figure C-129. Bogue Banks Profile Comparison Plot

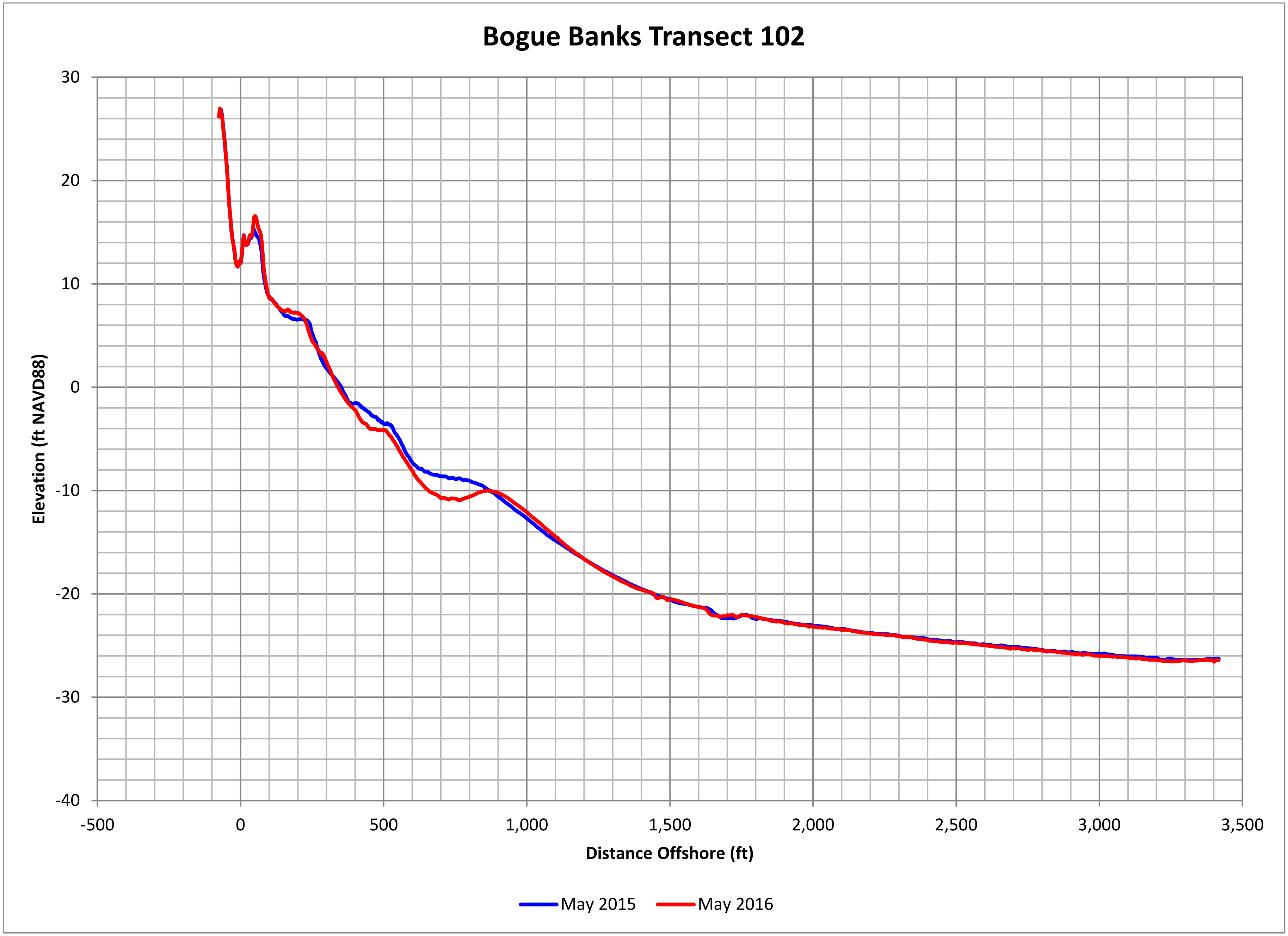


Figure C-130. Bogue Banks Profile Comparison Plot

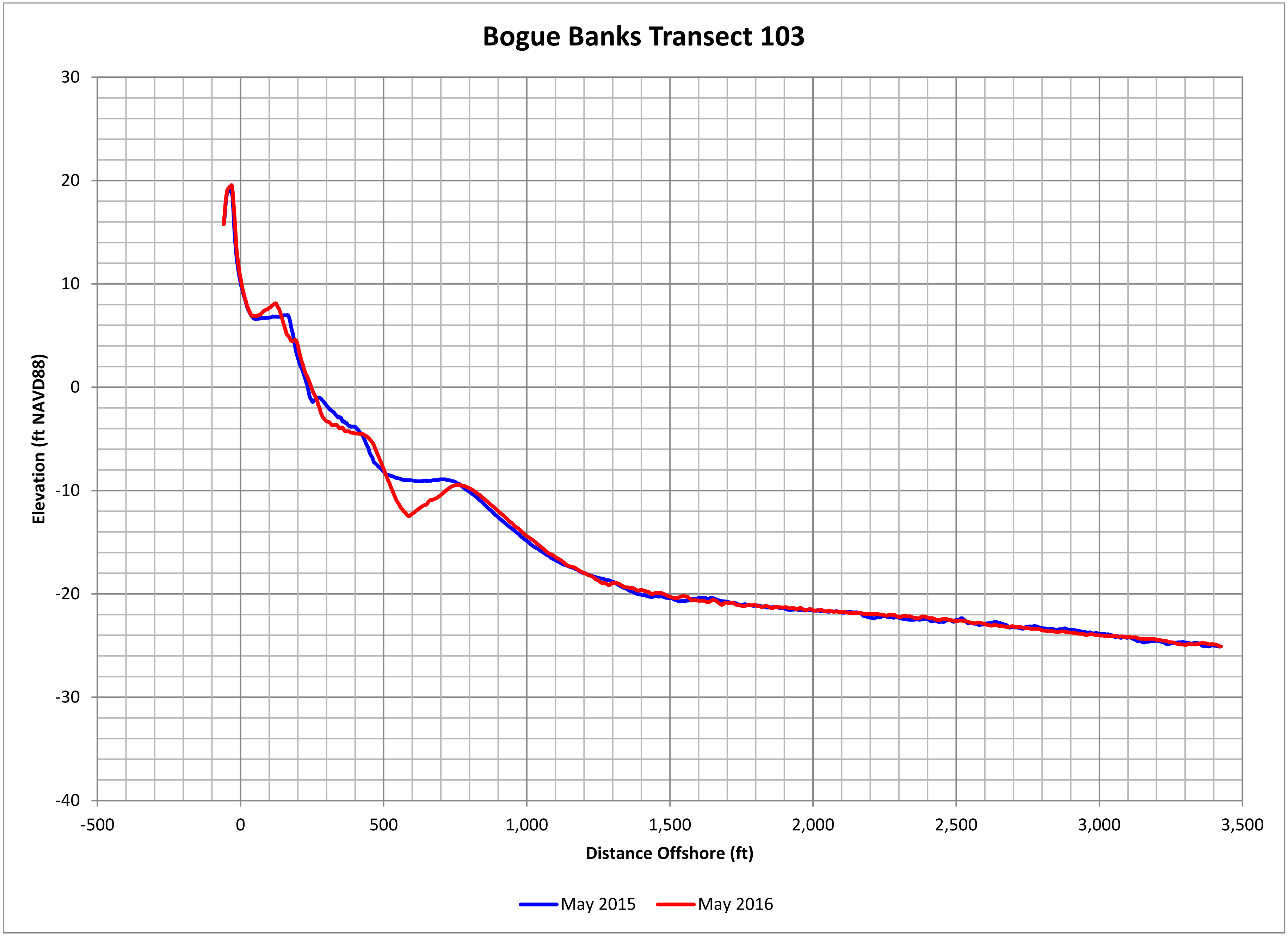


Figure C-131. Bogue Banks Profile Comparison Plot

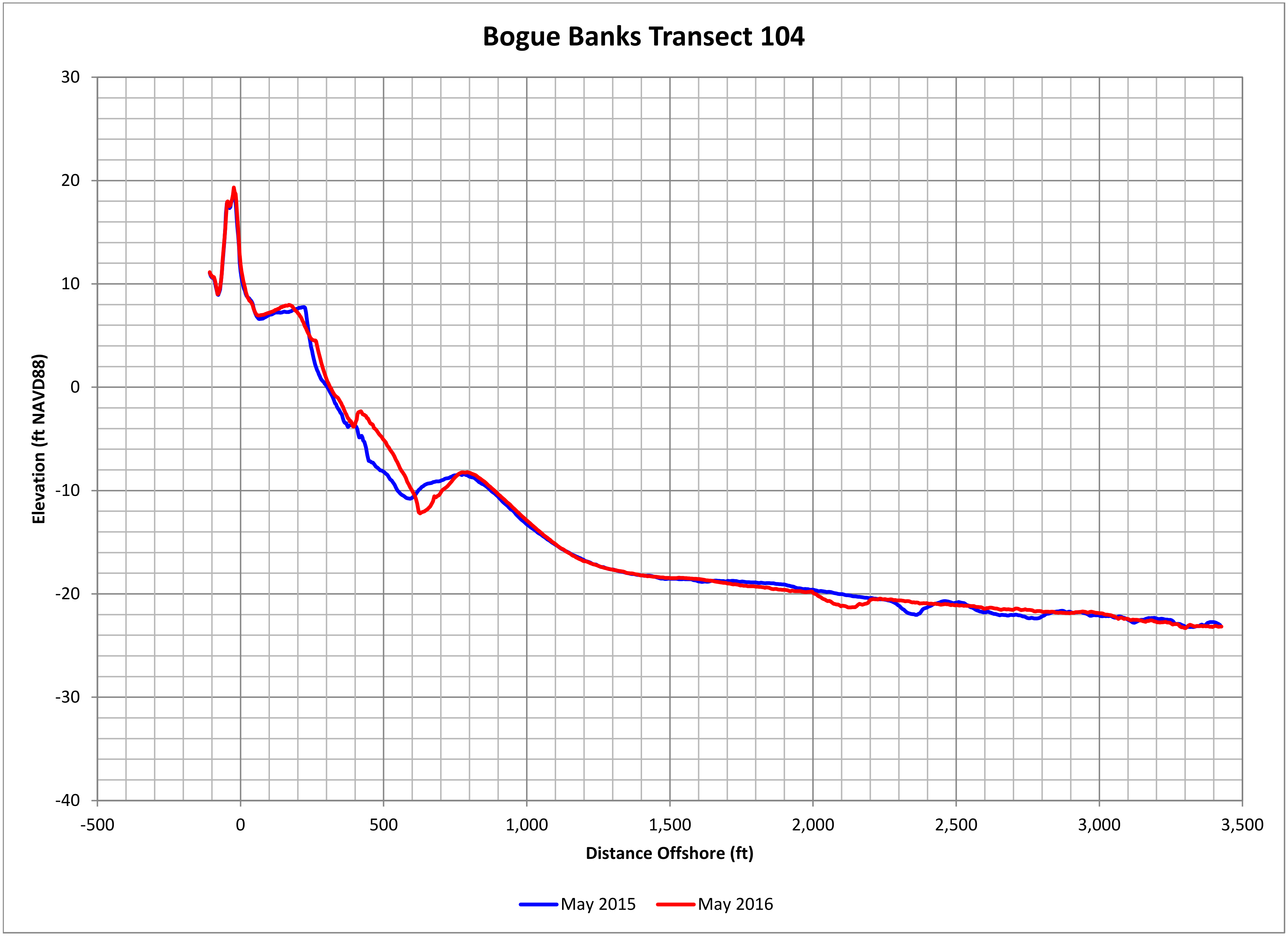


Figure C-132. Bogue Banks Profile Comparison Plot

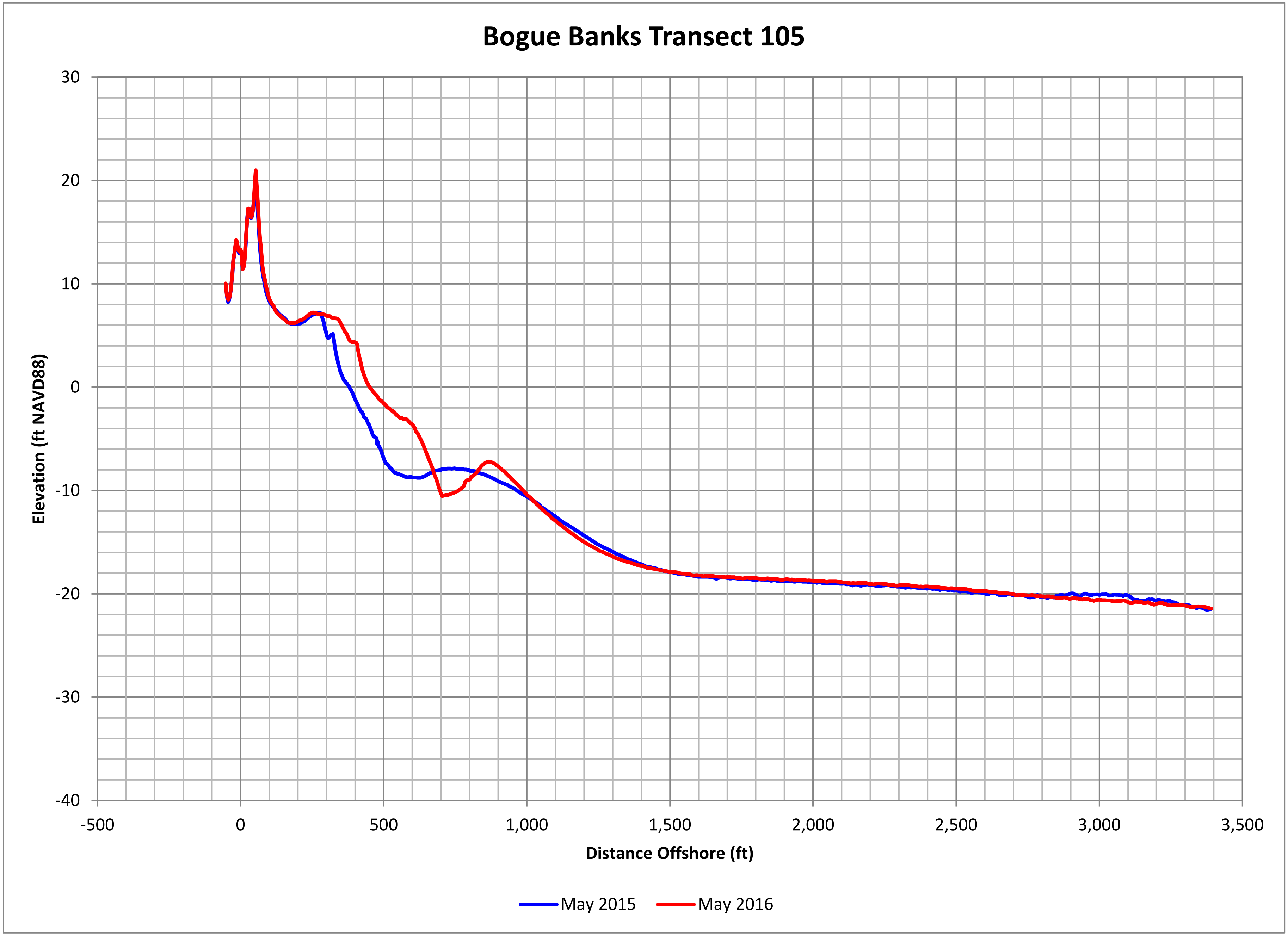


Figure C-133. Bogue Banks Profile Comparison Plot

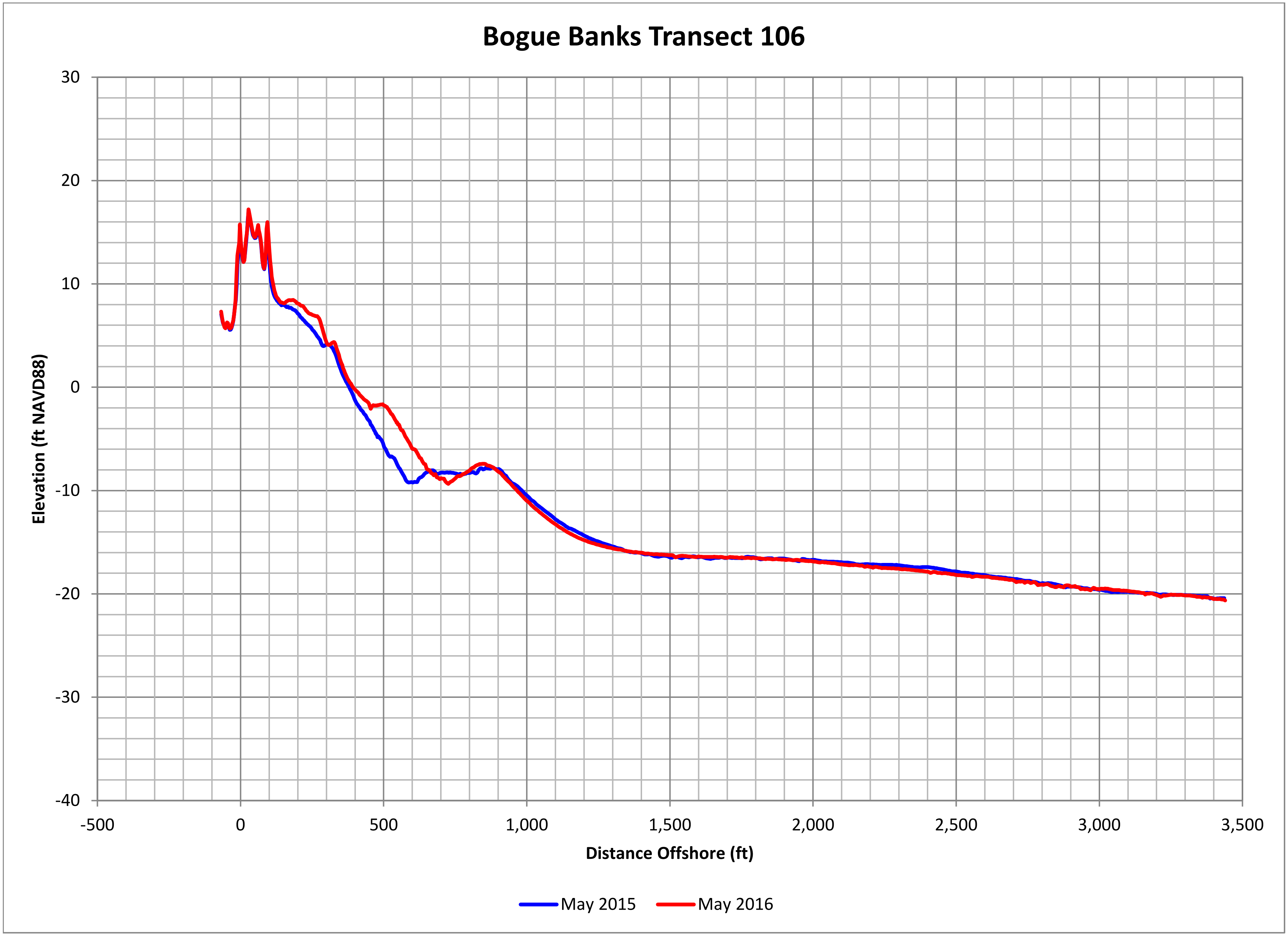


Figure C-134. Bogue Banks Profile Comparison Plot

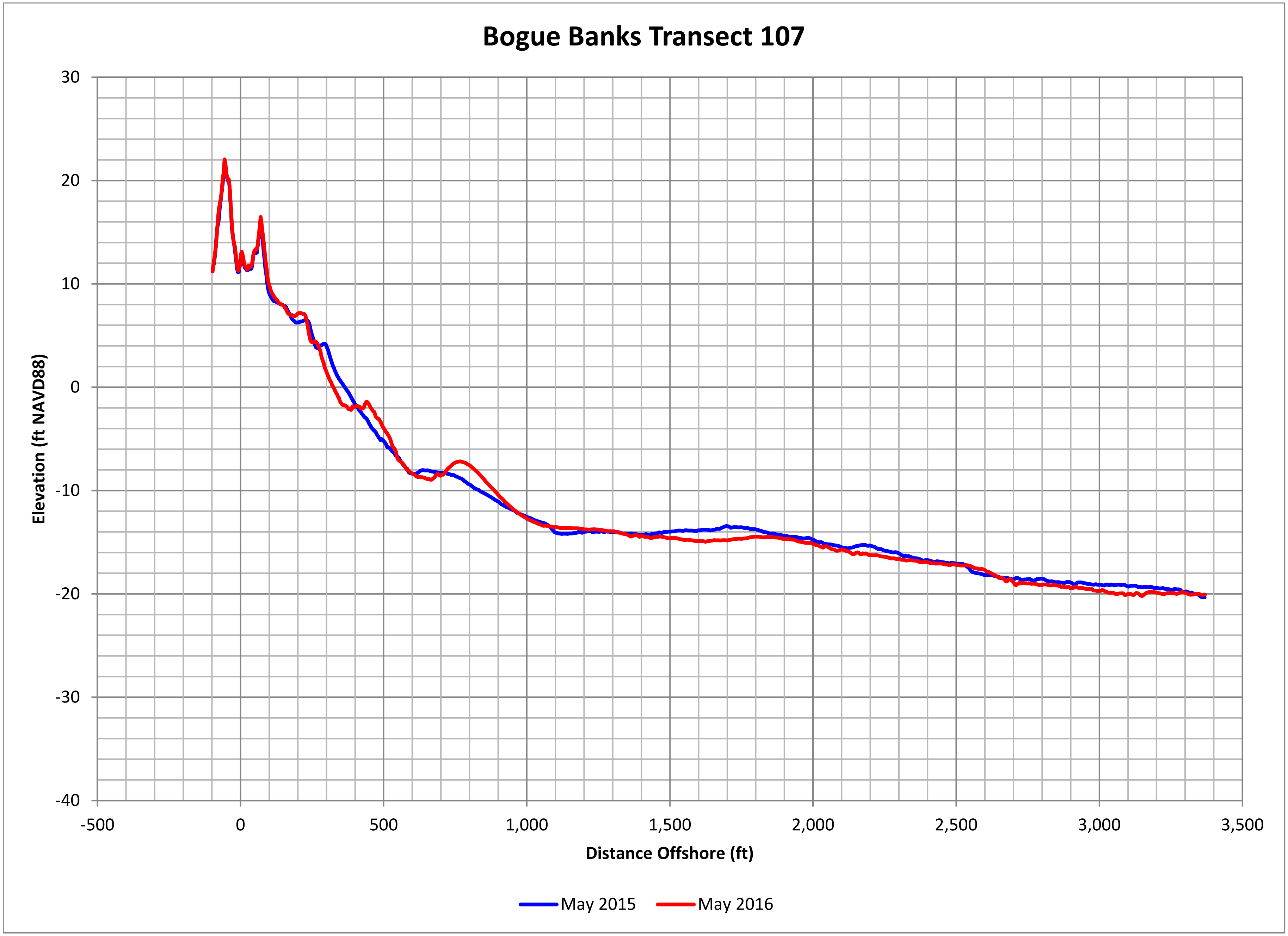


Figure C-135. Bogue Banks Profile Comparison Plot

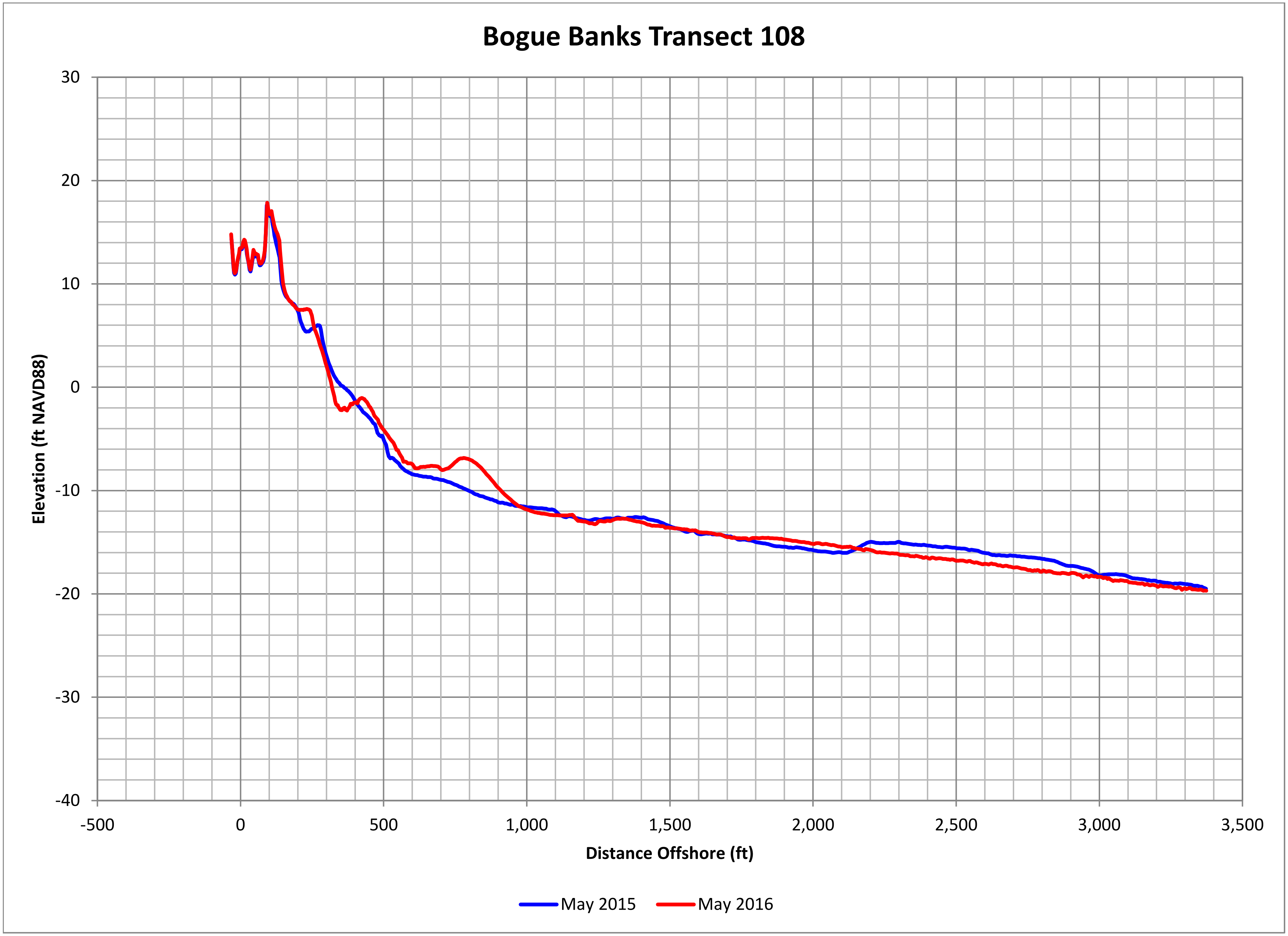


Figure C-136. Bogue Banks Profile Comparison Plot

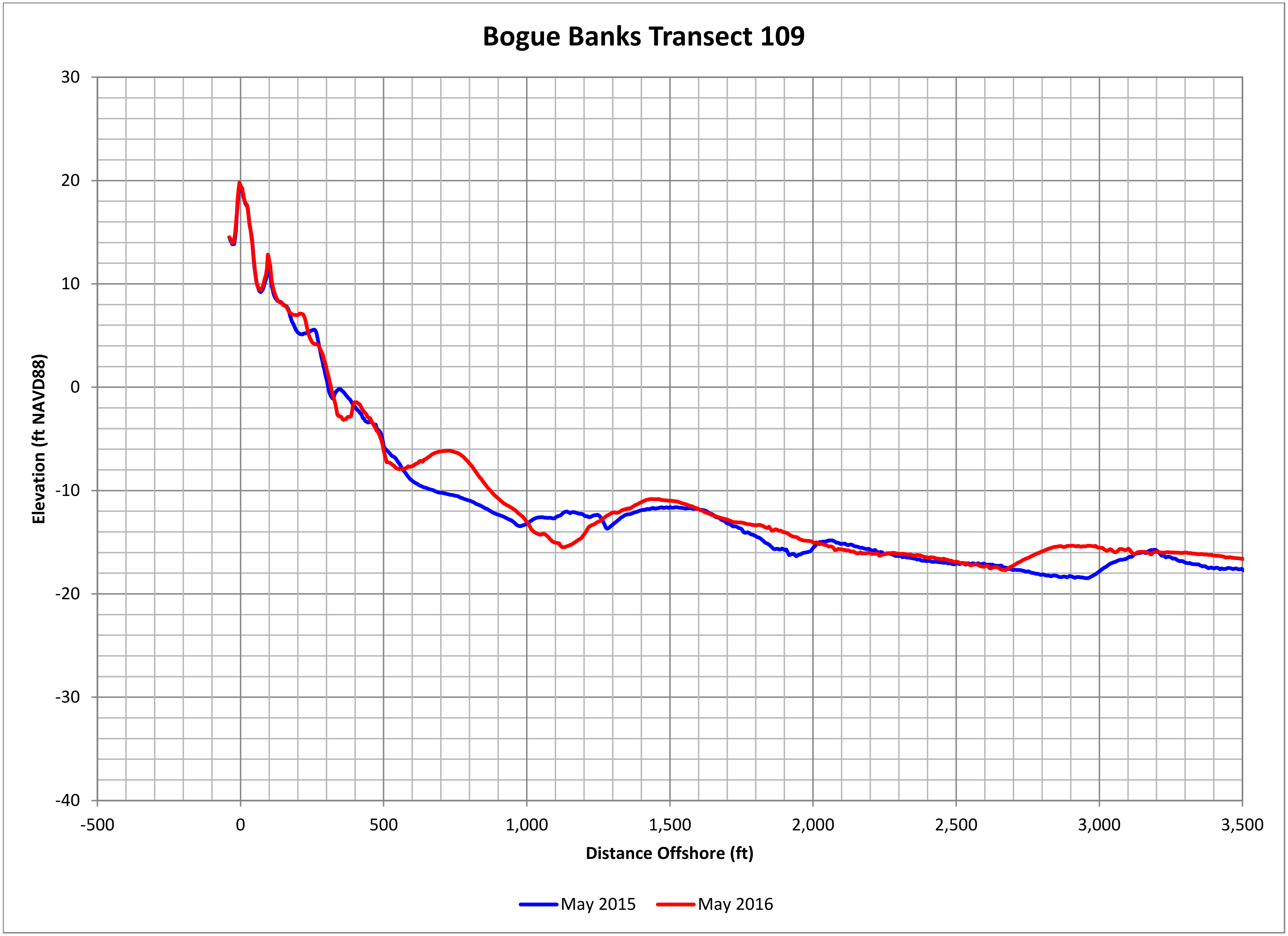


Figure C-137. Bogue Banks Profile Comparison Plot

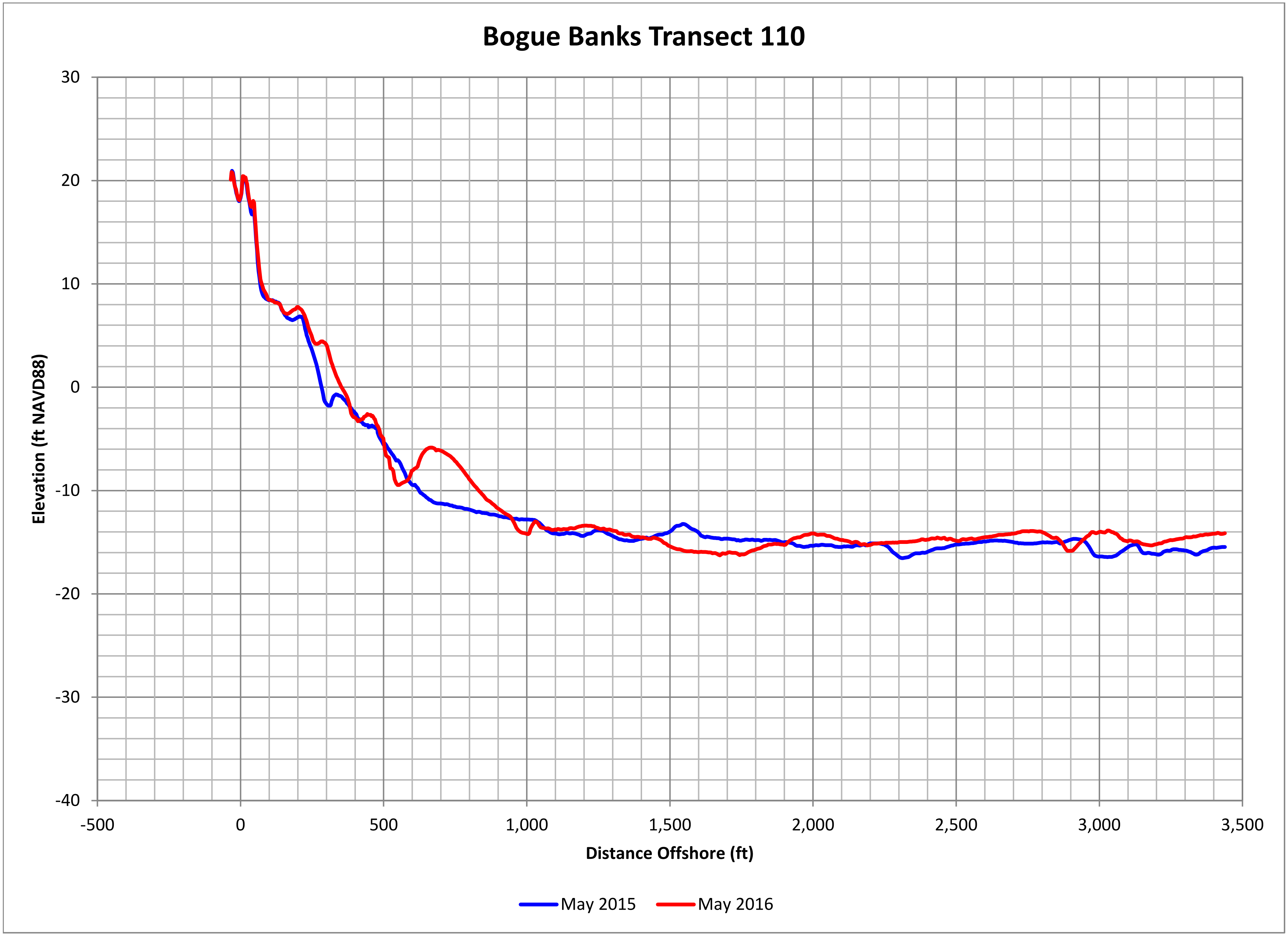


Figure C-138. Bogue Banks Profile Comparison Plot

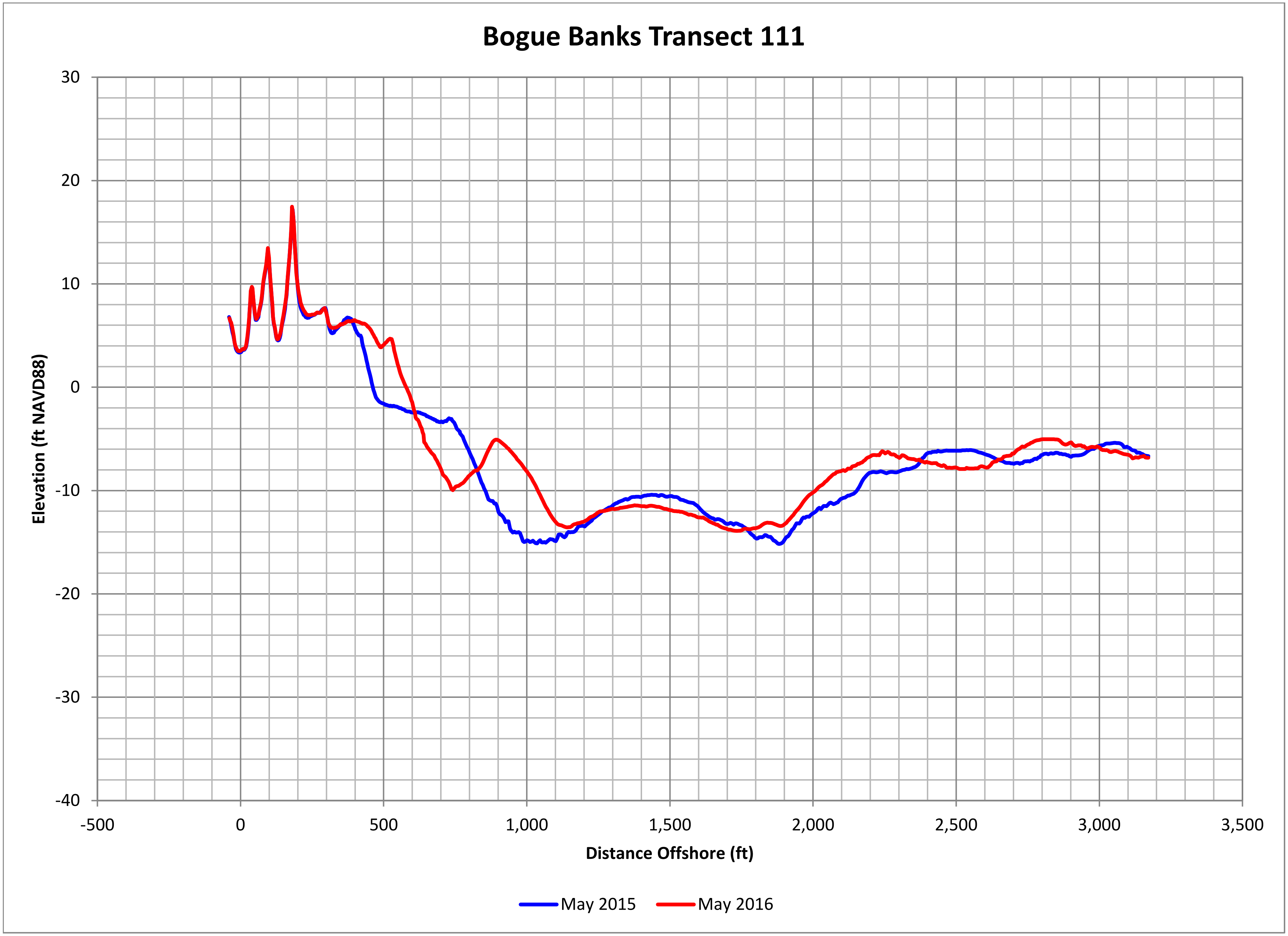


Figure C-139. Bogue Banks Profile Comparison Plot

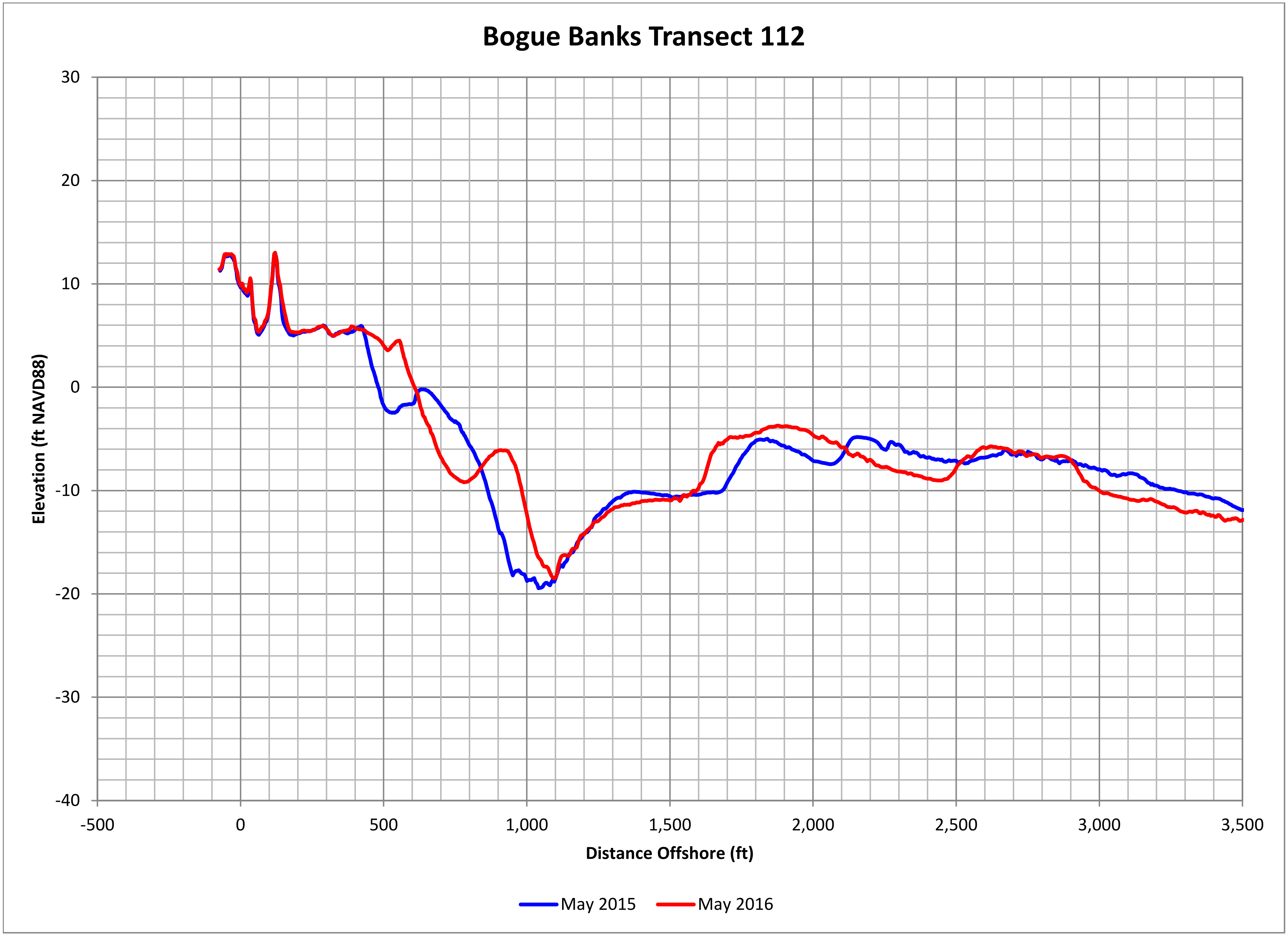


Figure C-140. Bogue Banks Profile Comparison Plot

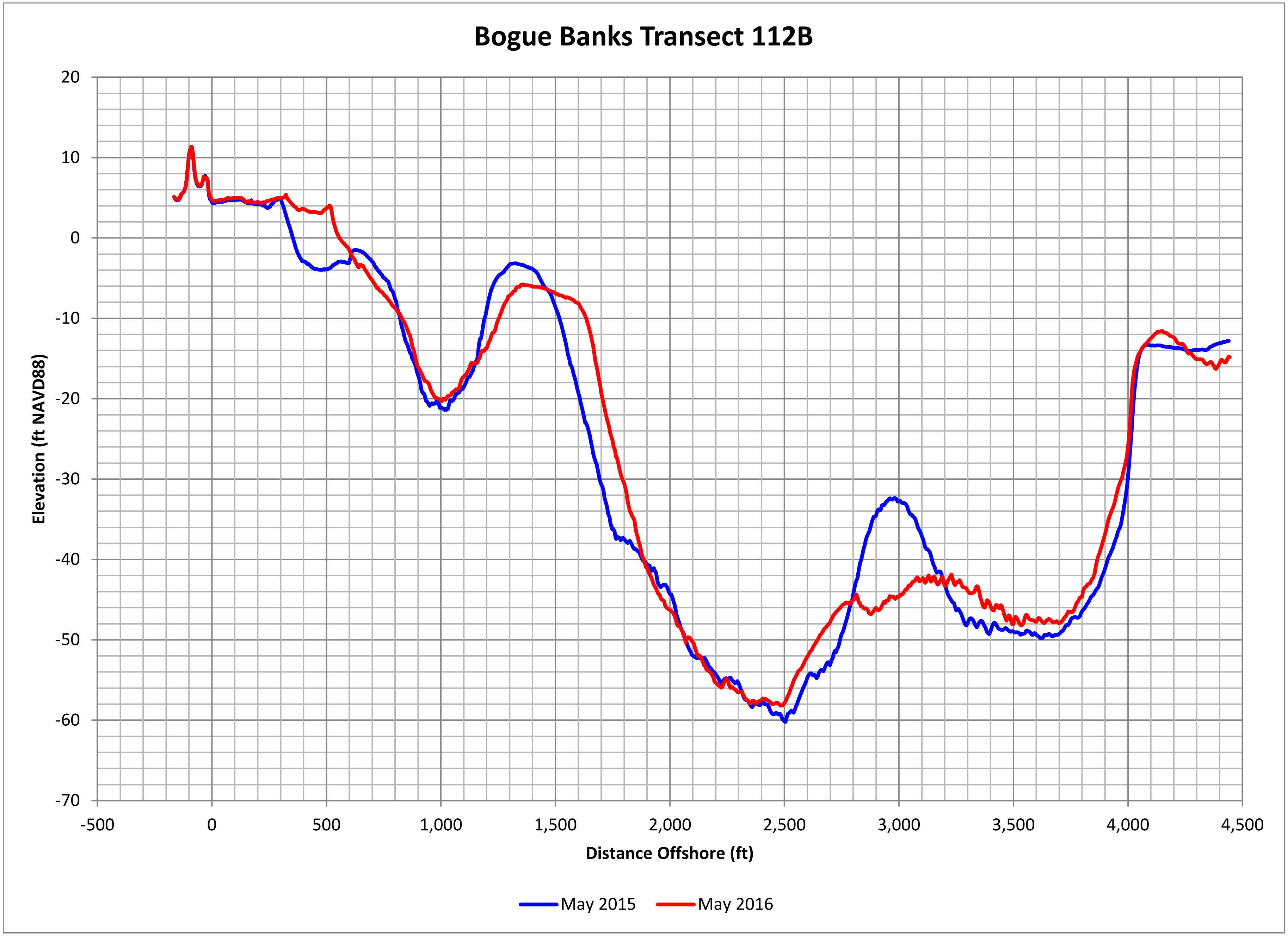


Figure C-141. Bogue Banks Profile Comparison Plot

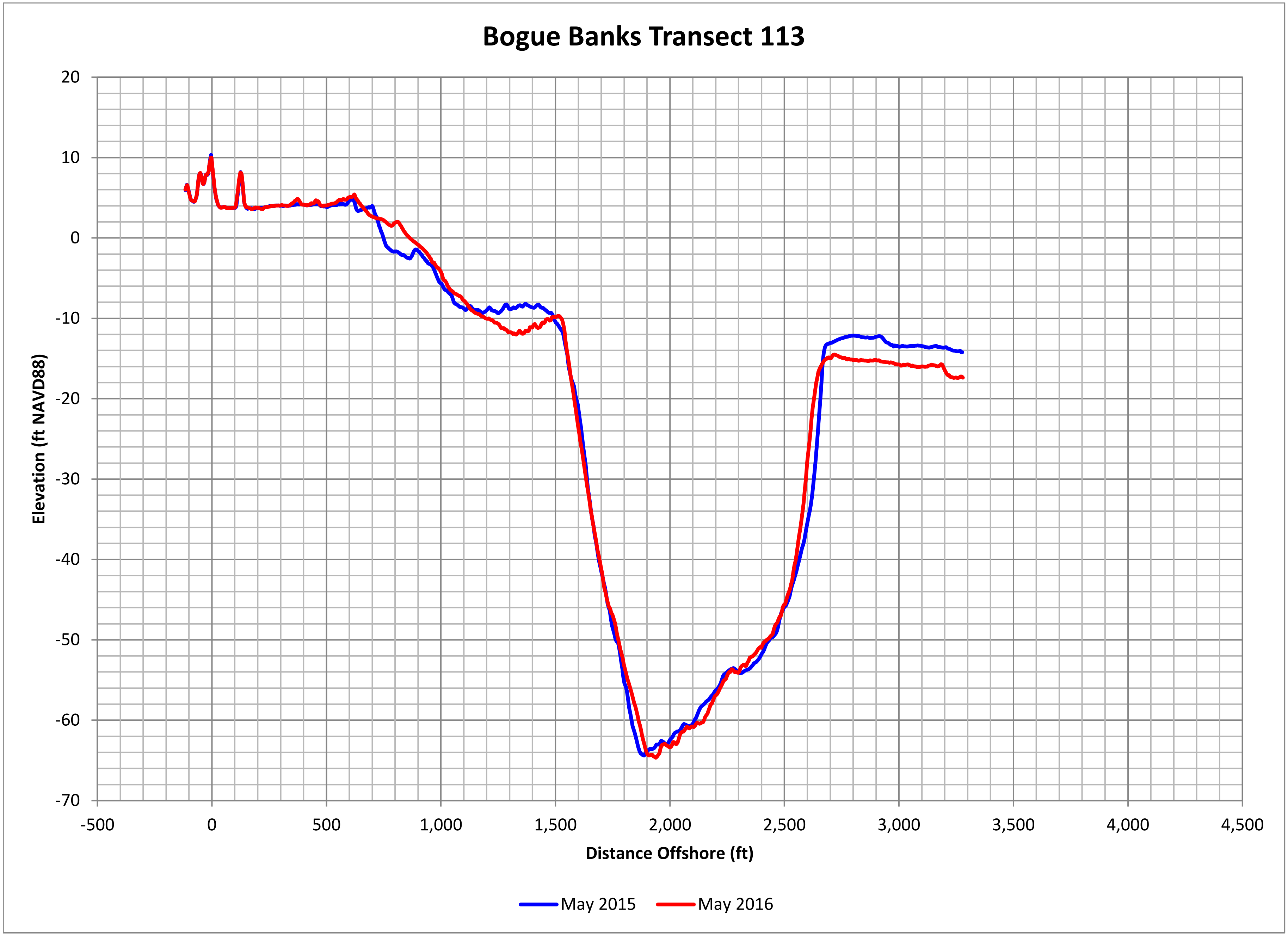


Figure C-142. Bogue Banks Profile Comparison Plot

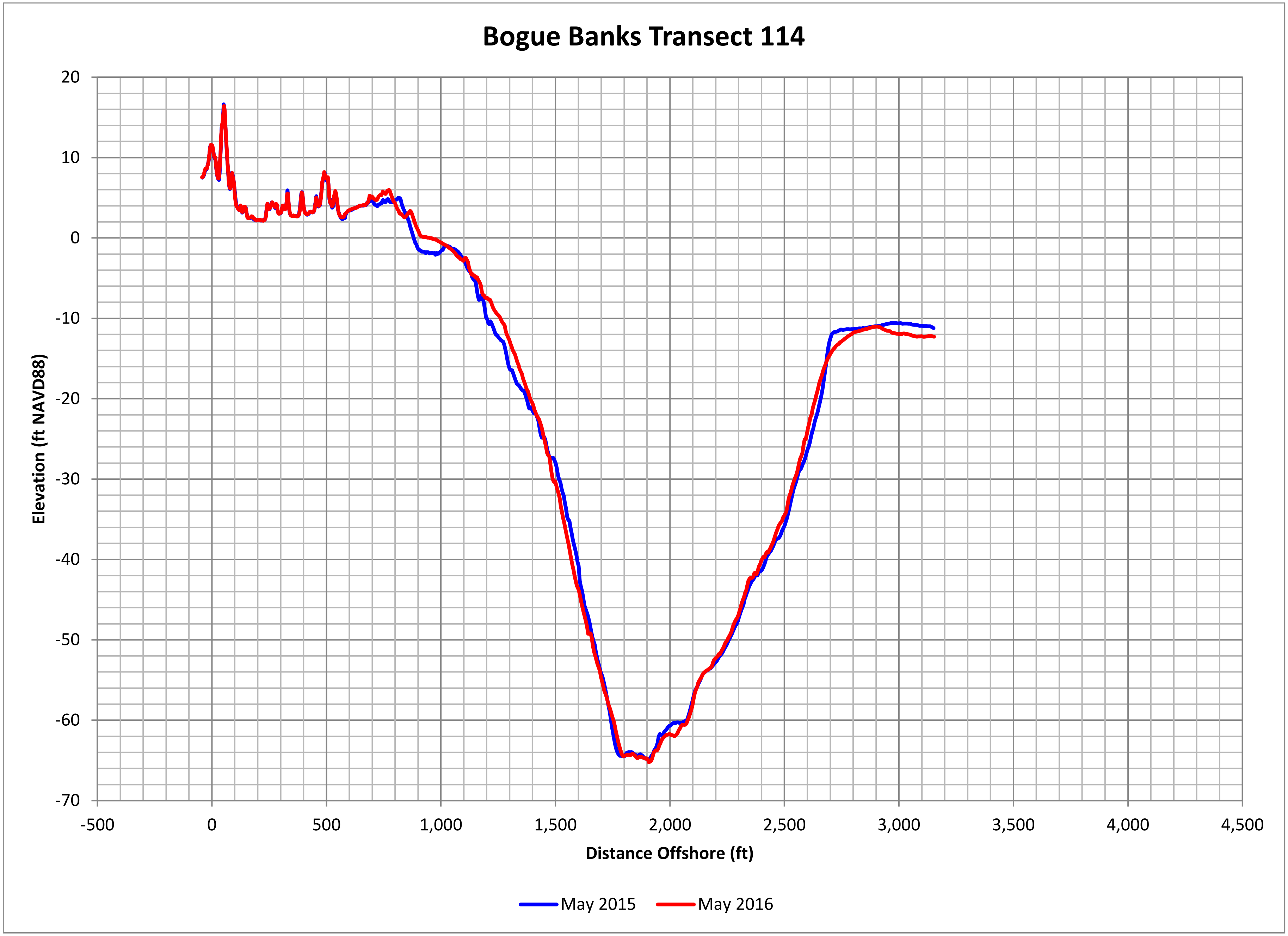


Figure C-143. Bogue Banks Profile Comparison Plot

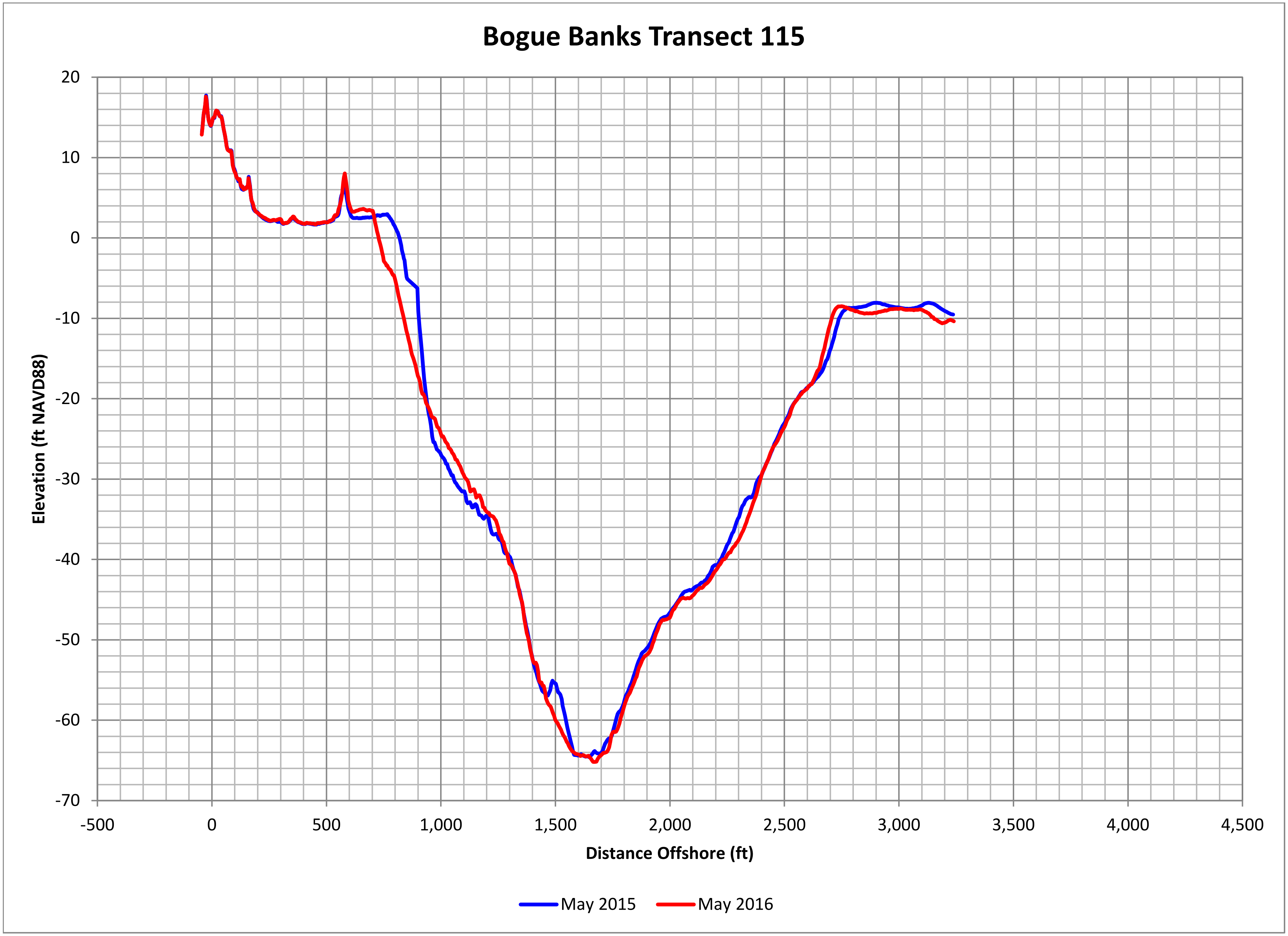


Figure C-144. Bogue Banks Profile Comparison Plot

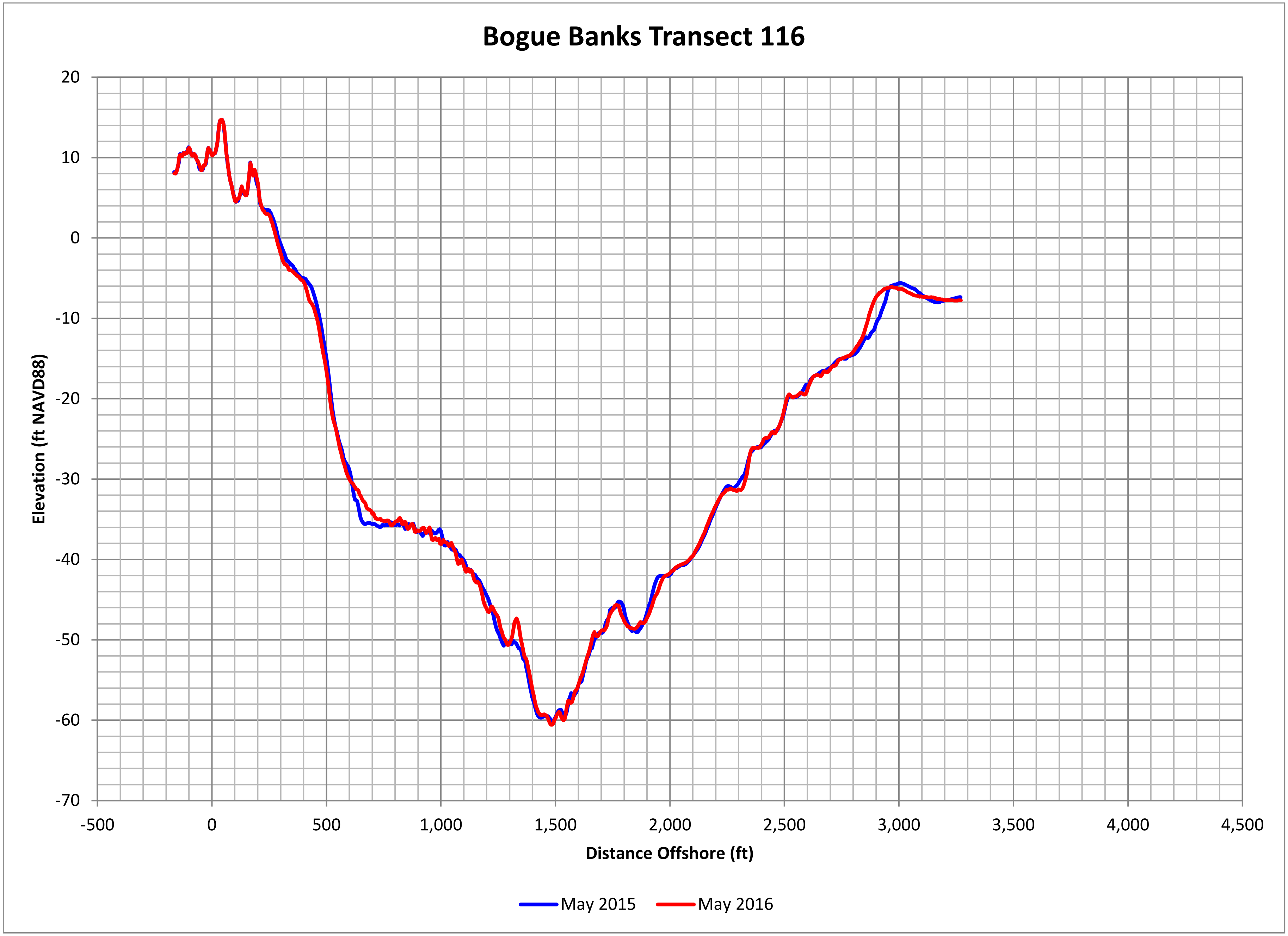


Figure C-145. Bogue Banks Profile Comparison Plot

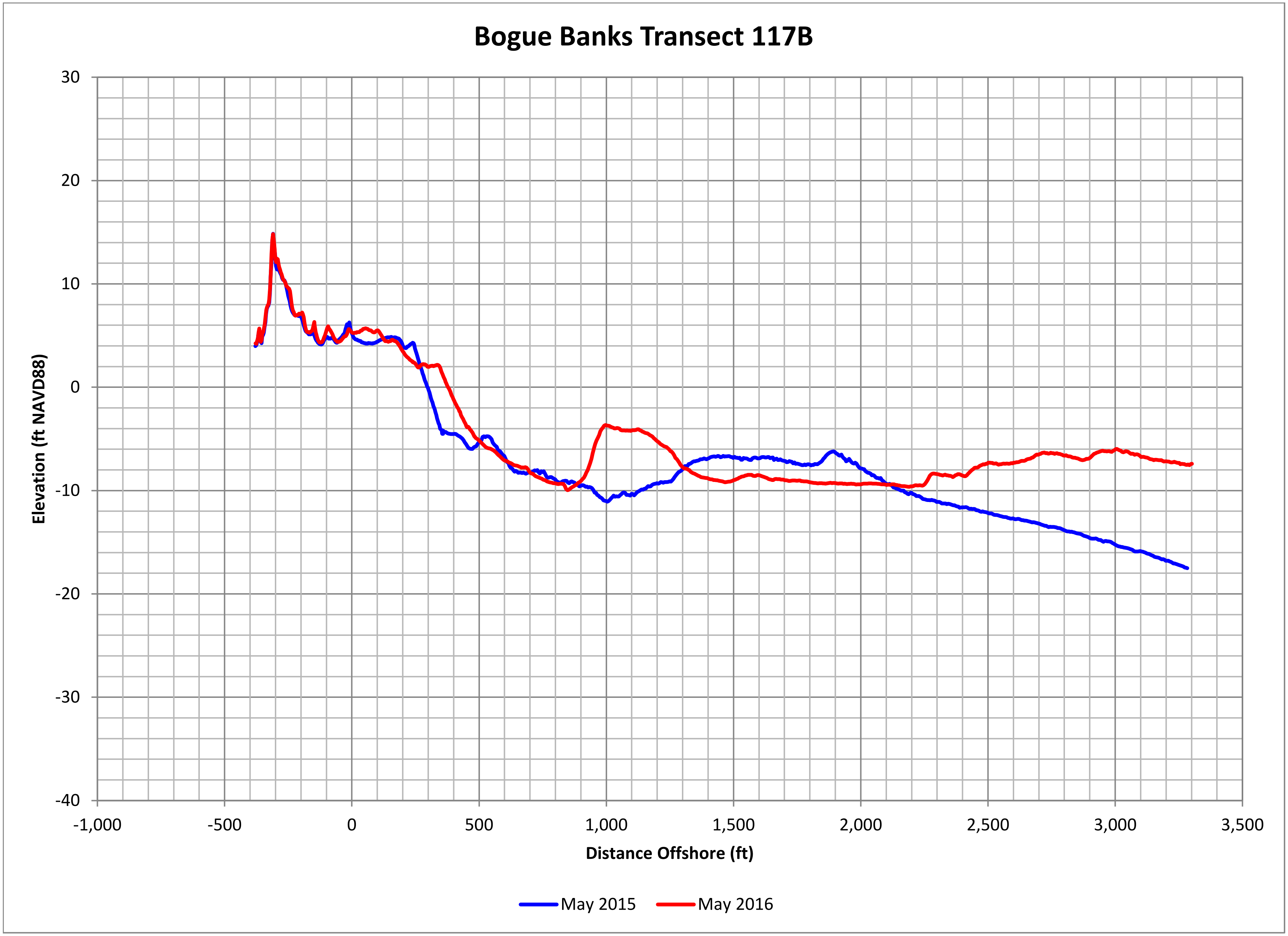


Figure C-146. Bogue Banks Profile Comparison Plot

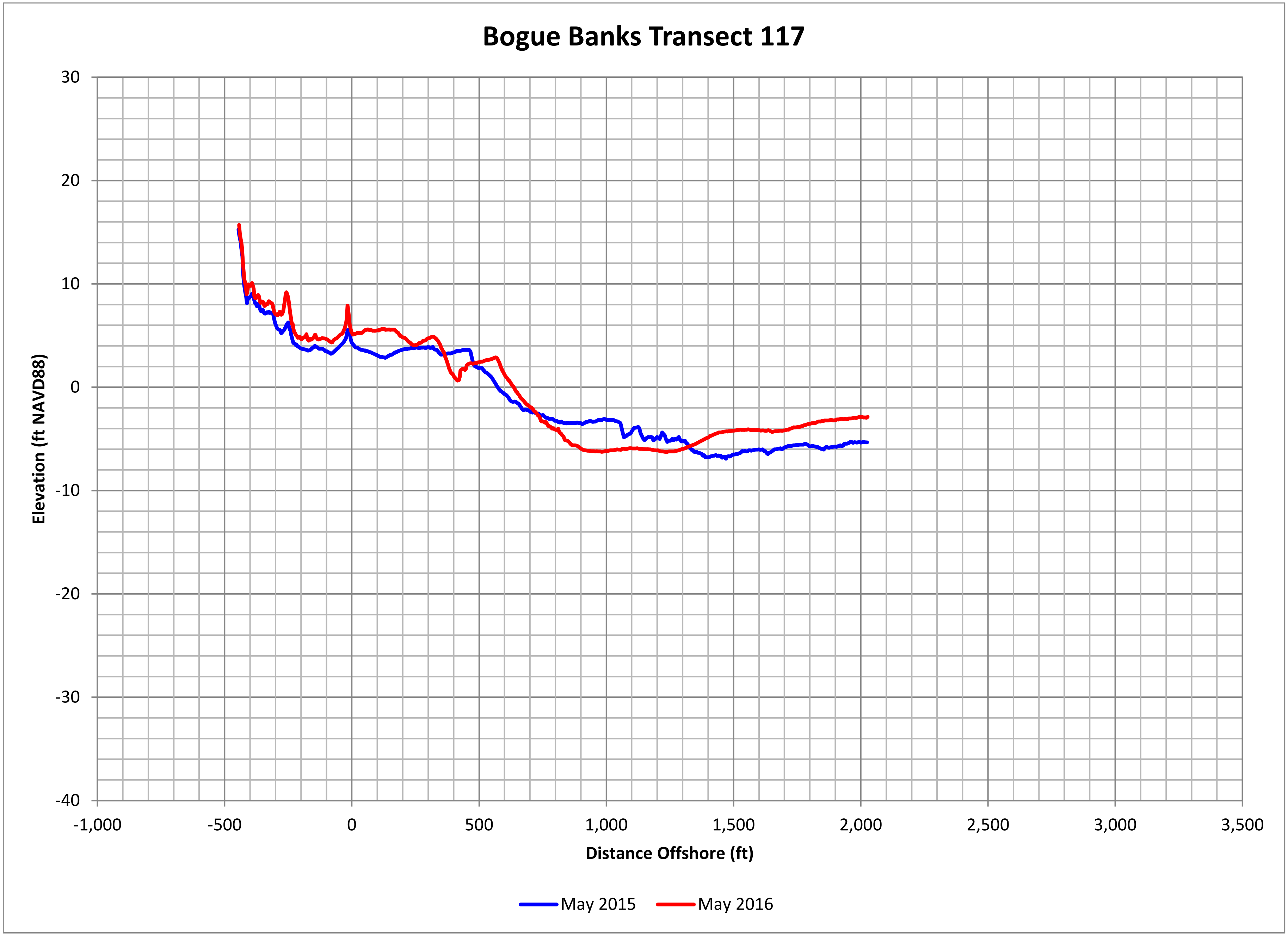


Figure C-147. Bogue Banks Profile Comparison Plot

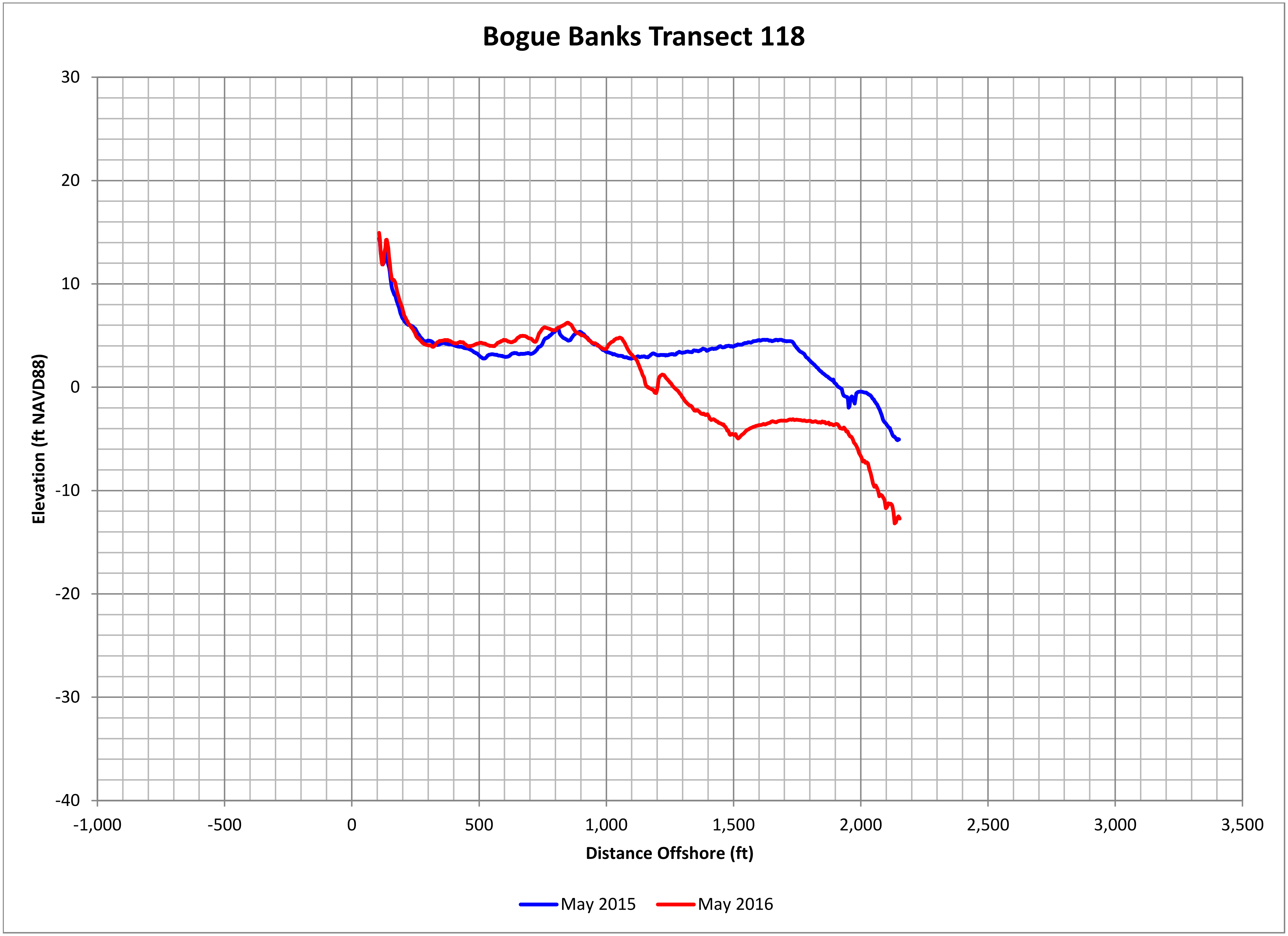


Figure C-148. Bogue Banks Profile Comparison Plot

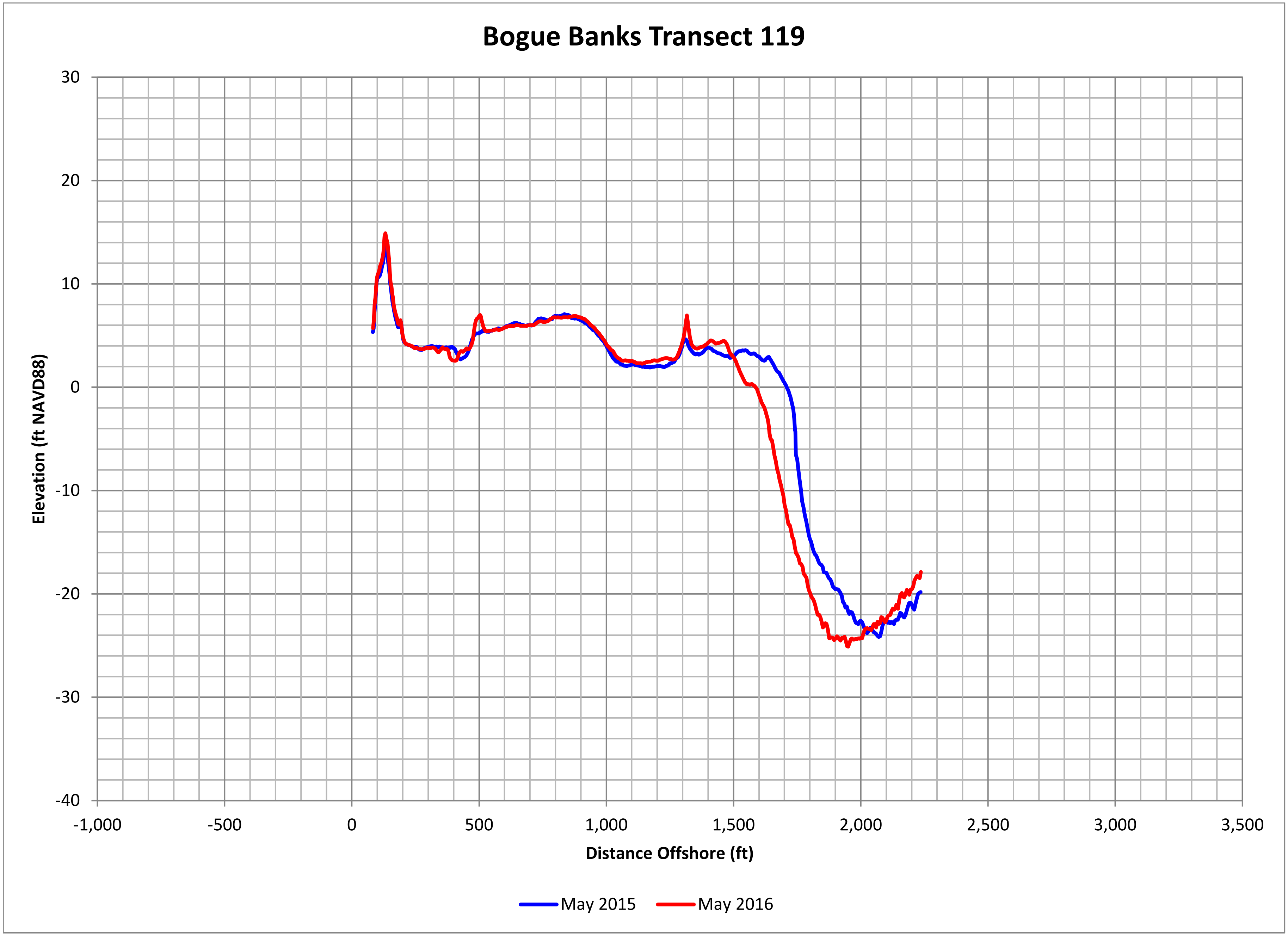


Figure C-149. Bogue Banks Profile Comparison Plot

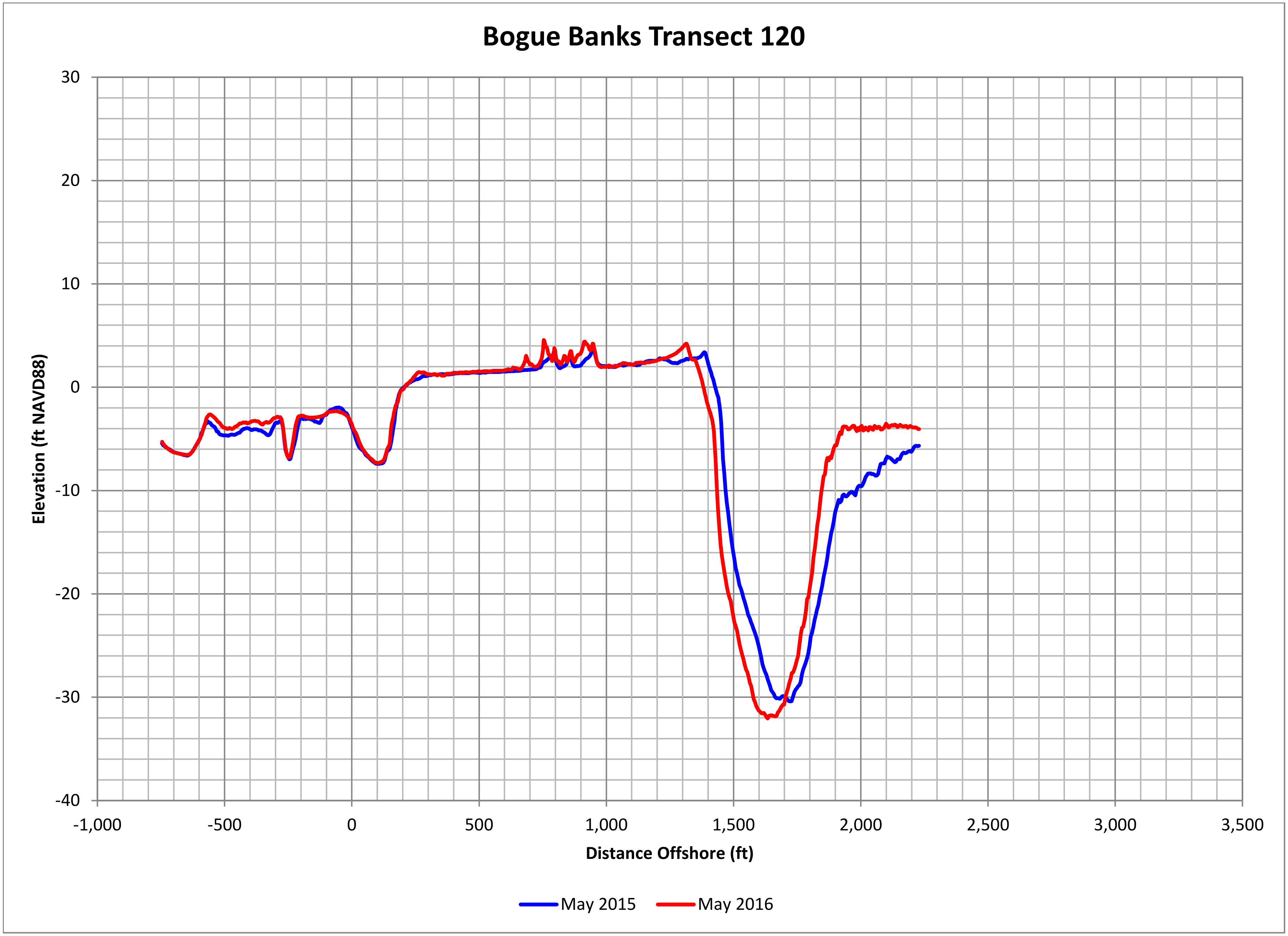


Figure C-150. Bogue Banks Profile Comparison Plot

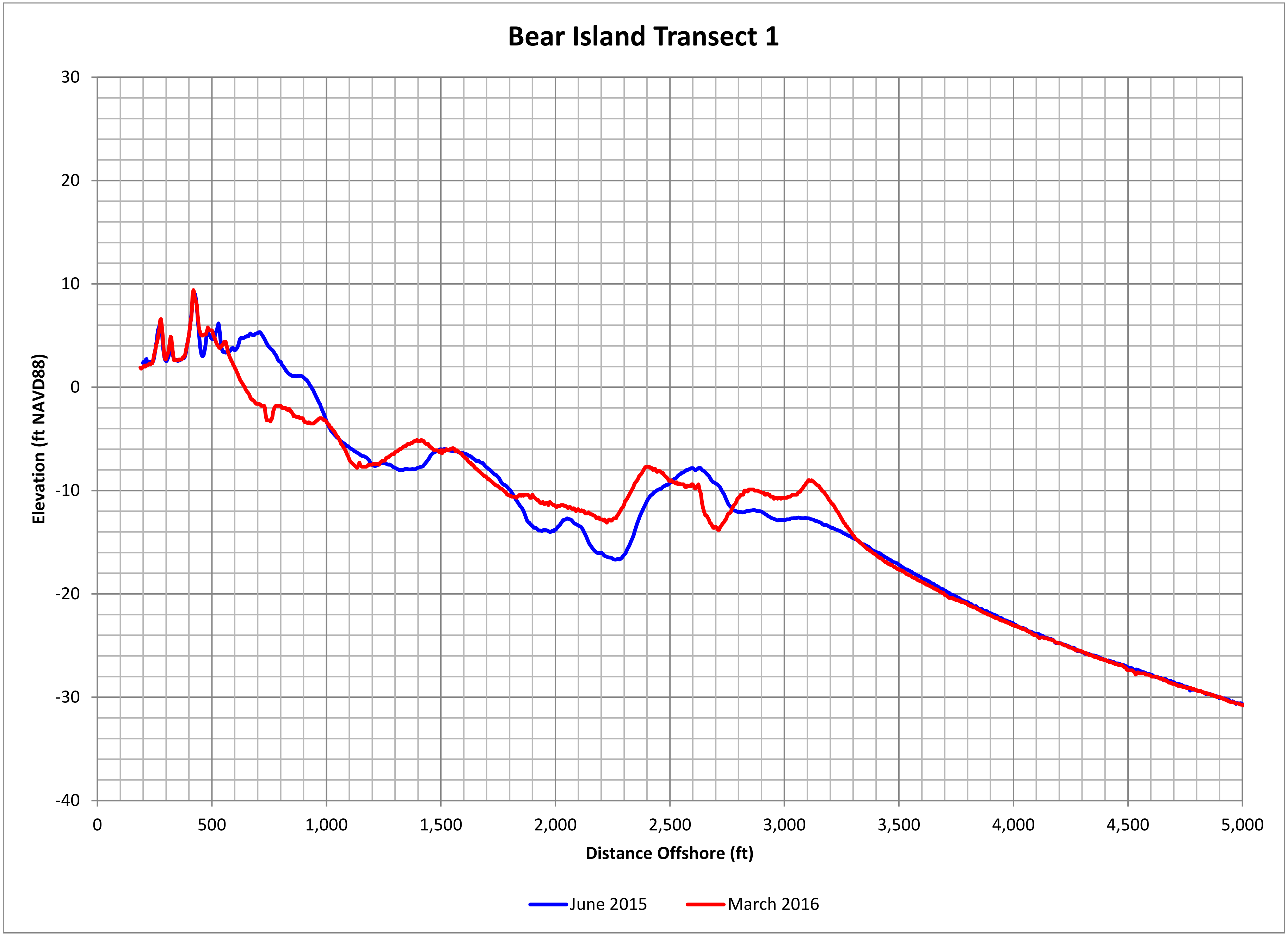


FIgure C-151. Bear Island Profile Comparison Plot

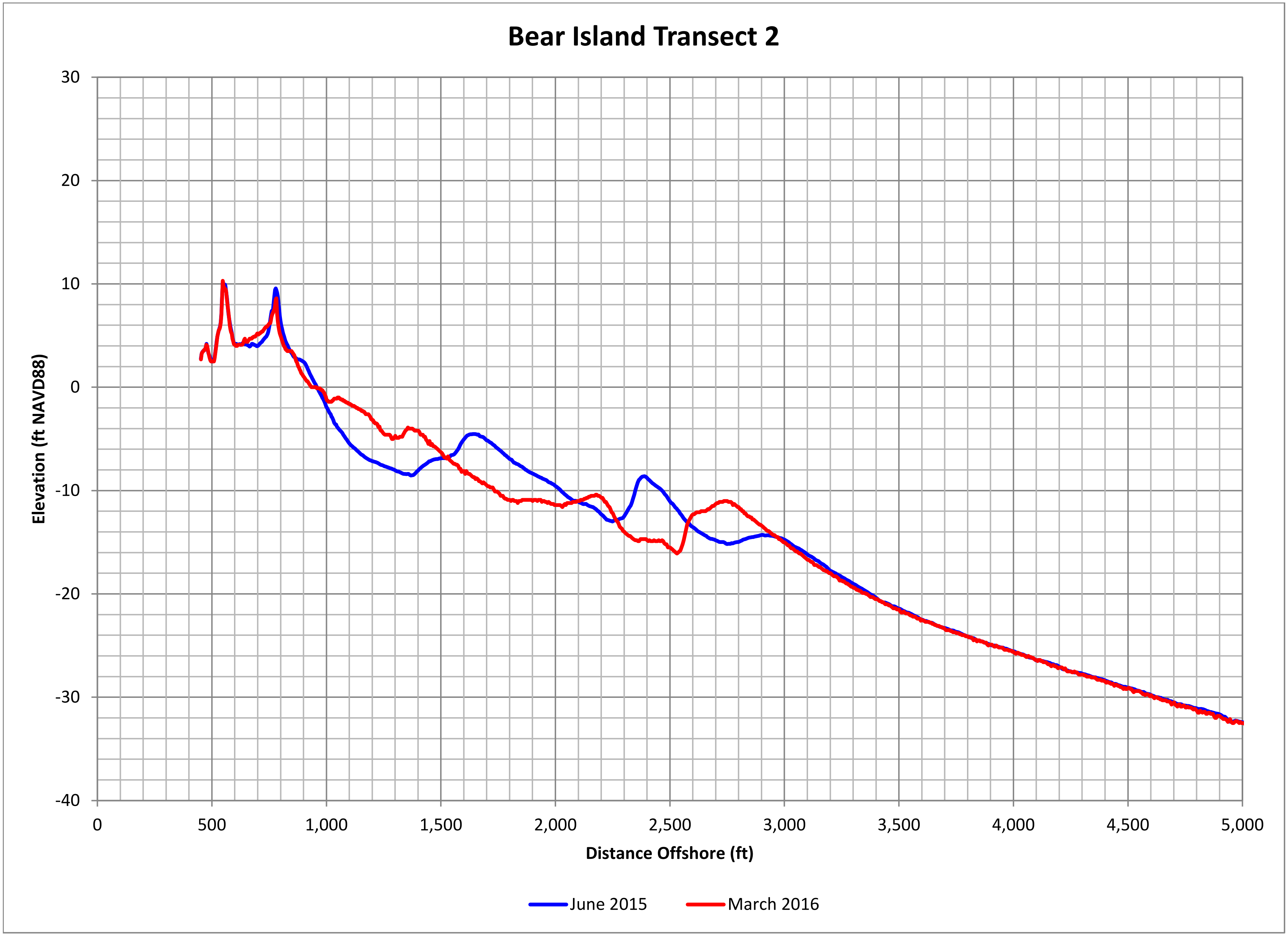


FIgure C-152. Bear Island Profile Comparison Plot

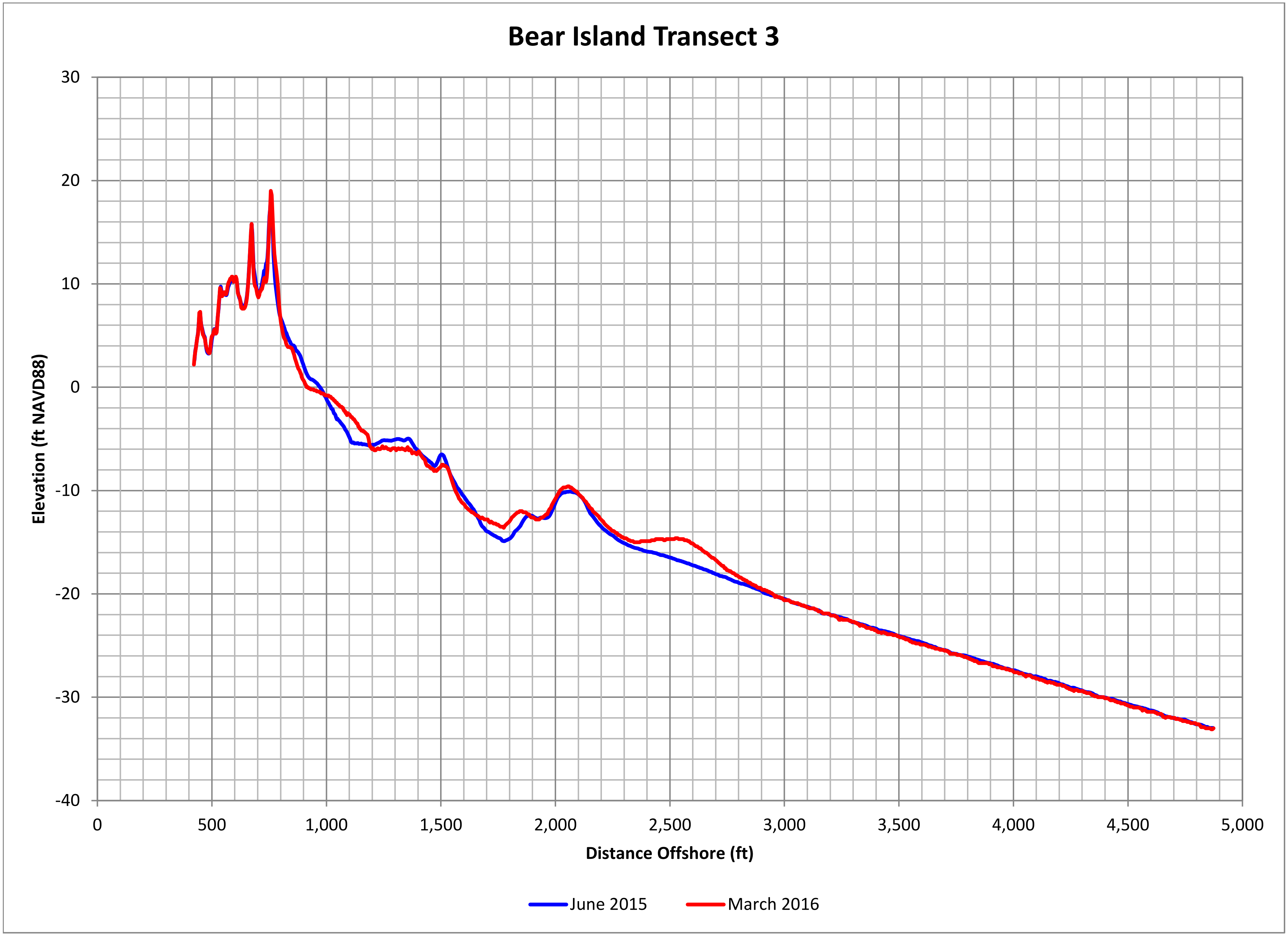


FIgure C-153. Bear Island Profile Comparison Plot

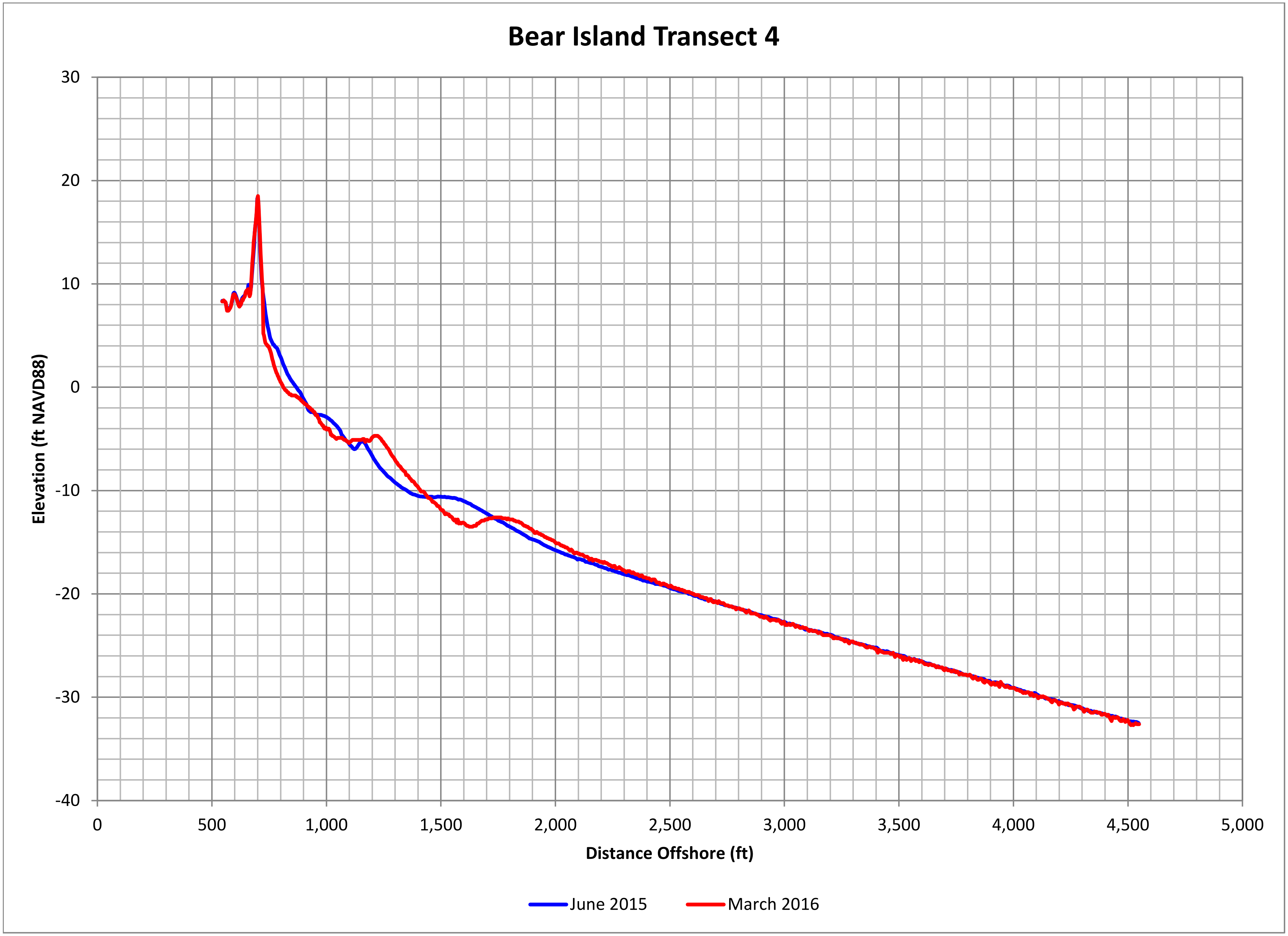
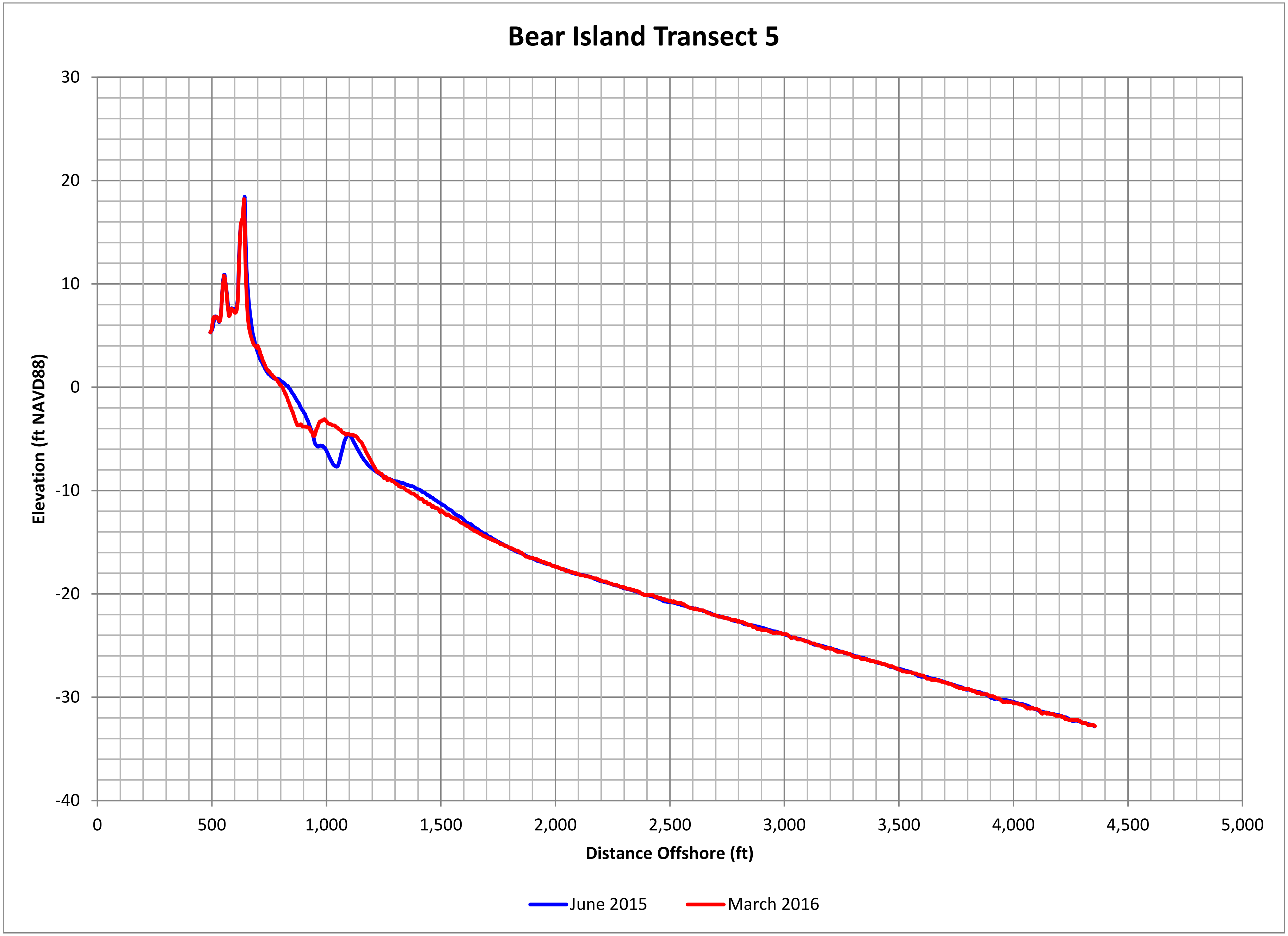


FIgure C-154. Bear Island Profile Comparison Plot



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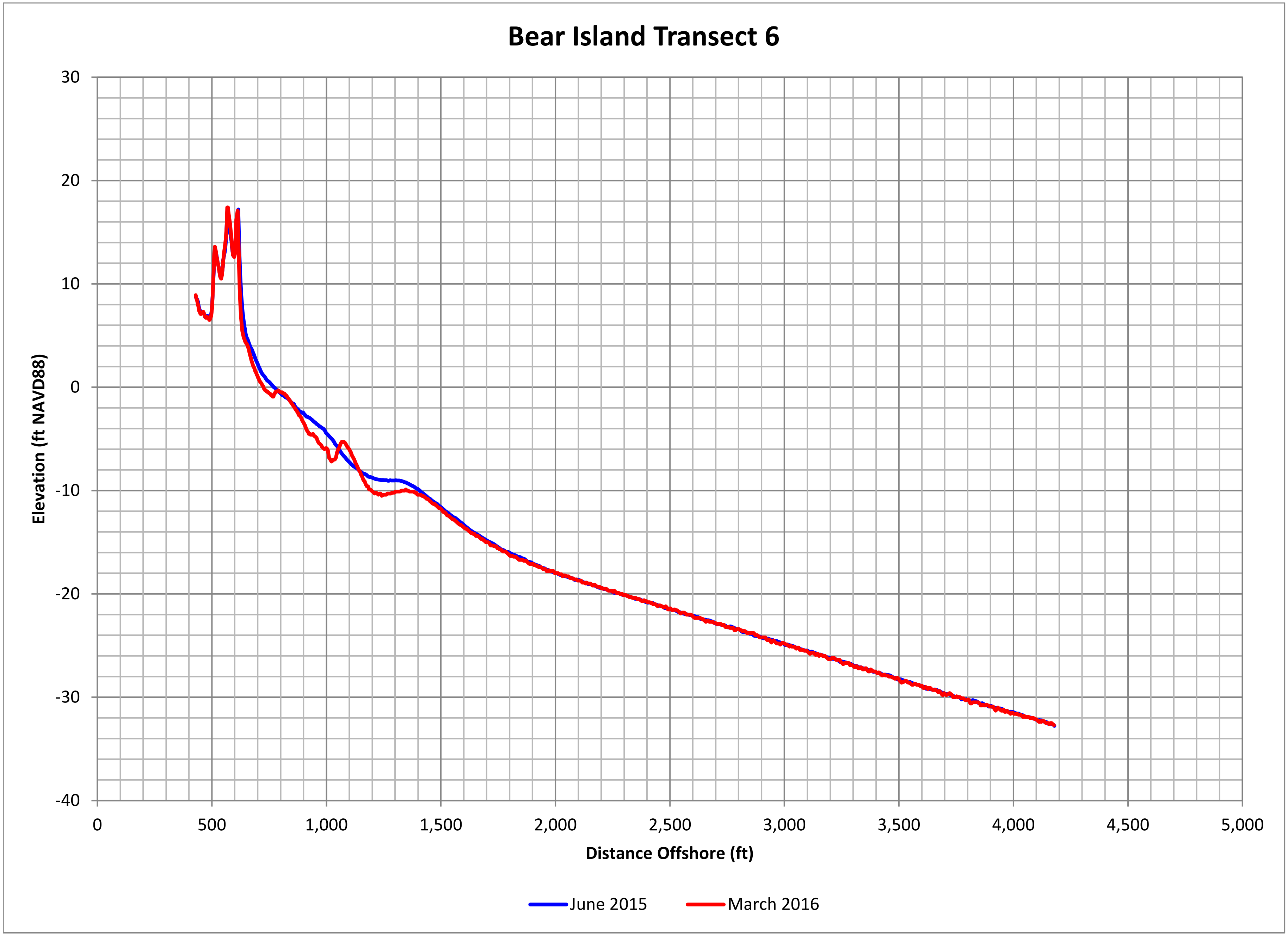


FIgure C-156. Bear Island Profile Comparison Plot

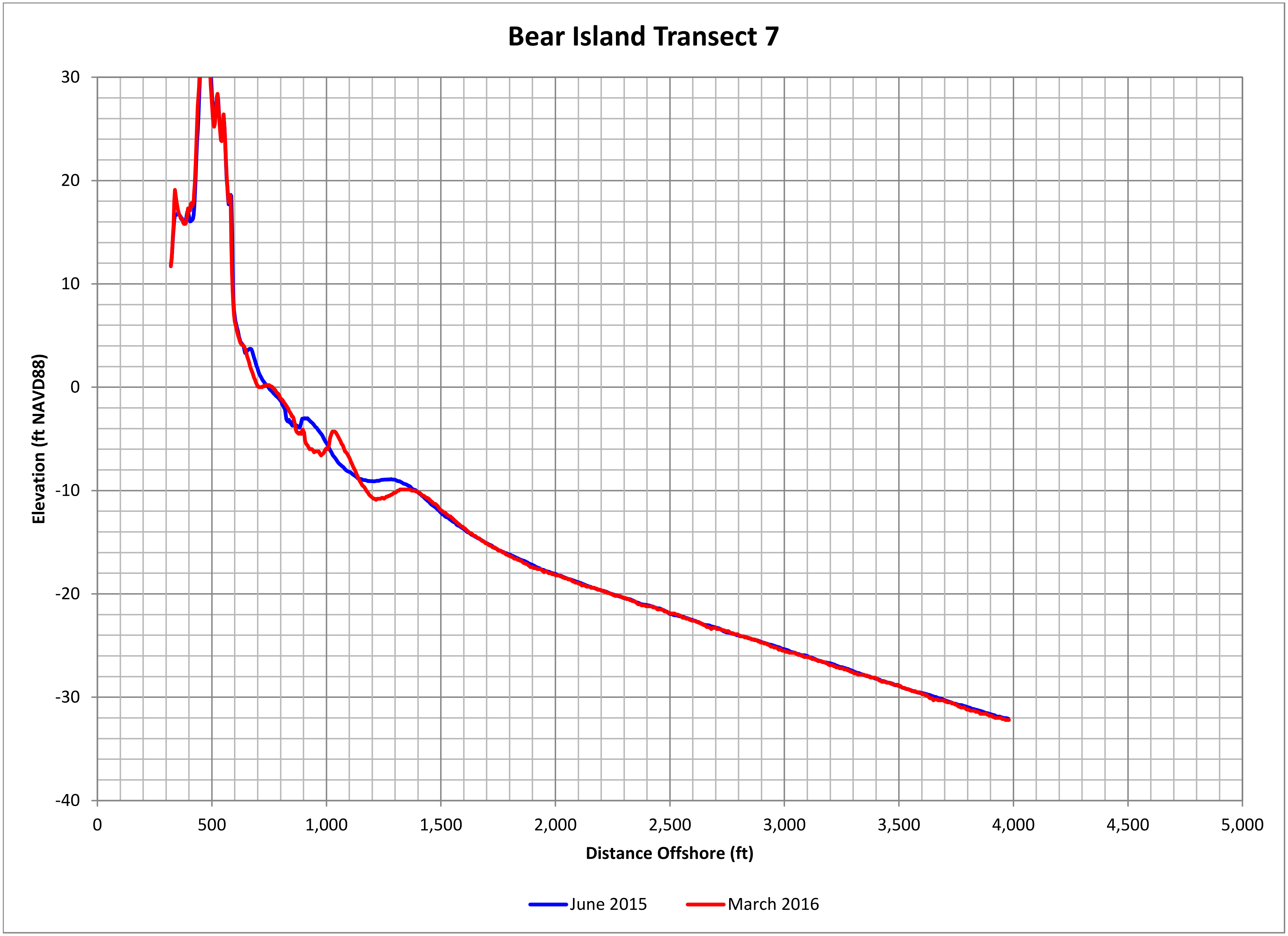


FIgure C-157. Bear Island Profile Comparison Plot

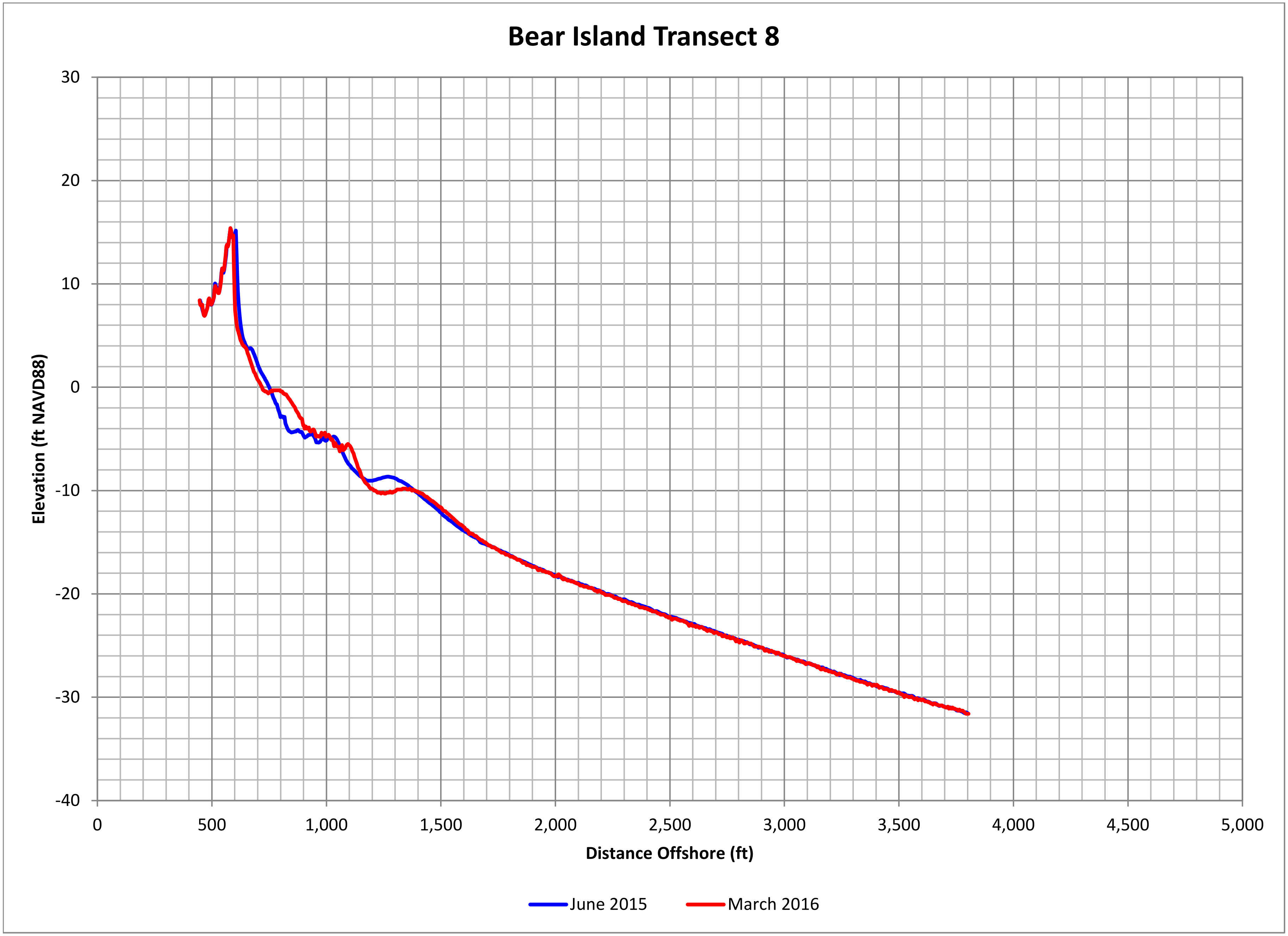


FIgure C-158. Bear Island Profile Comparison Plot

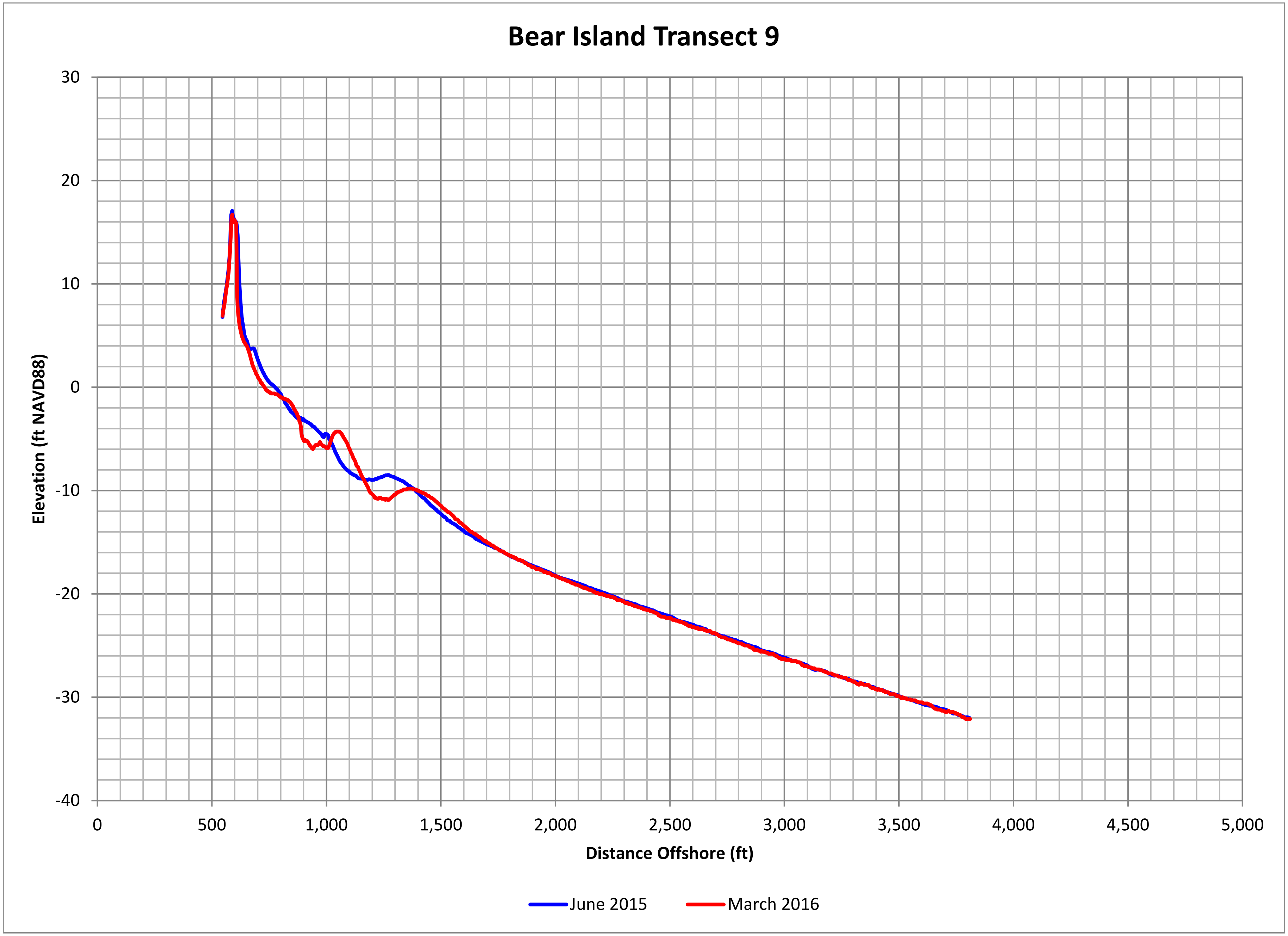


FIgure C-159. Bear Island Profile Comparison Plot

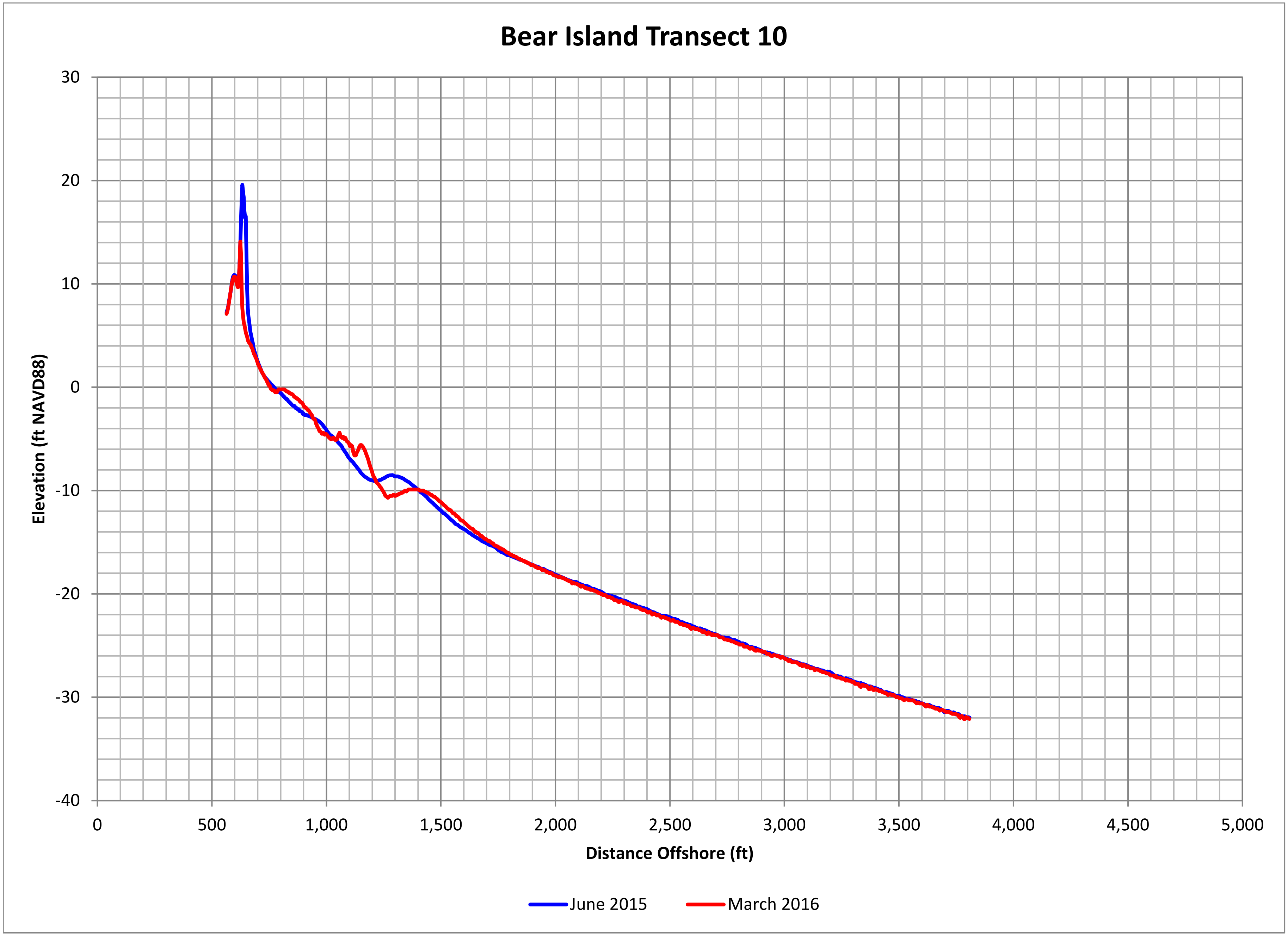


FIgure C-160. Bear Island Profile Comparison Plot

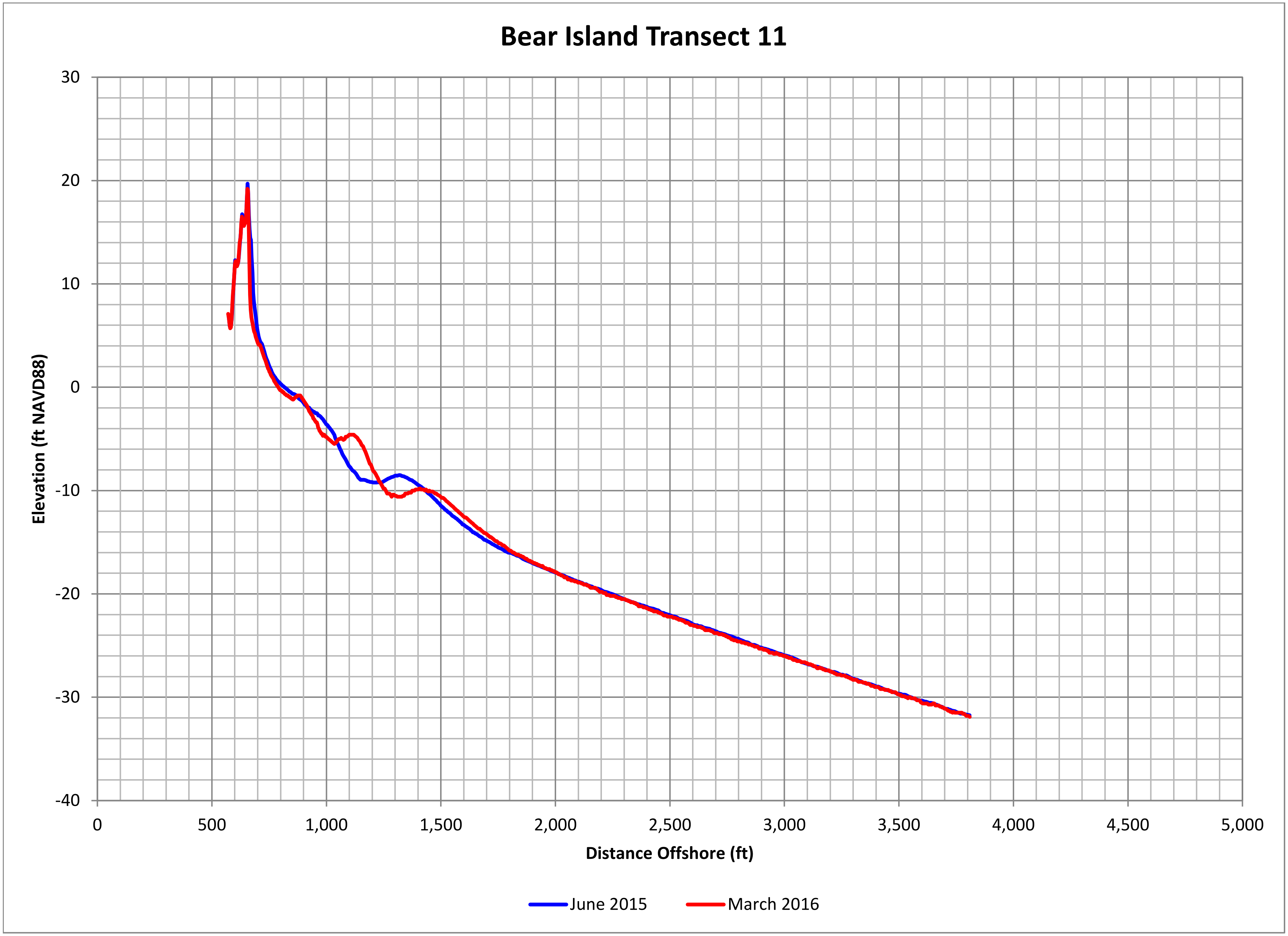


FIgure C-161. Bear Island Profile Comparison Plot

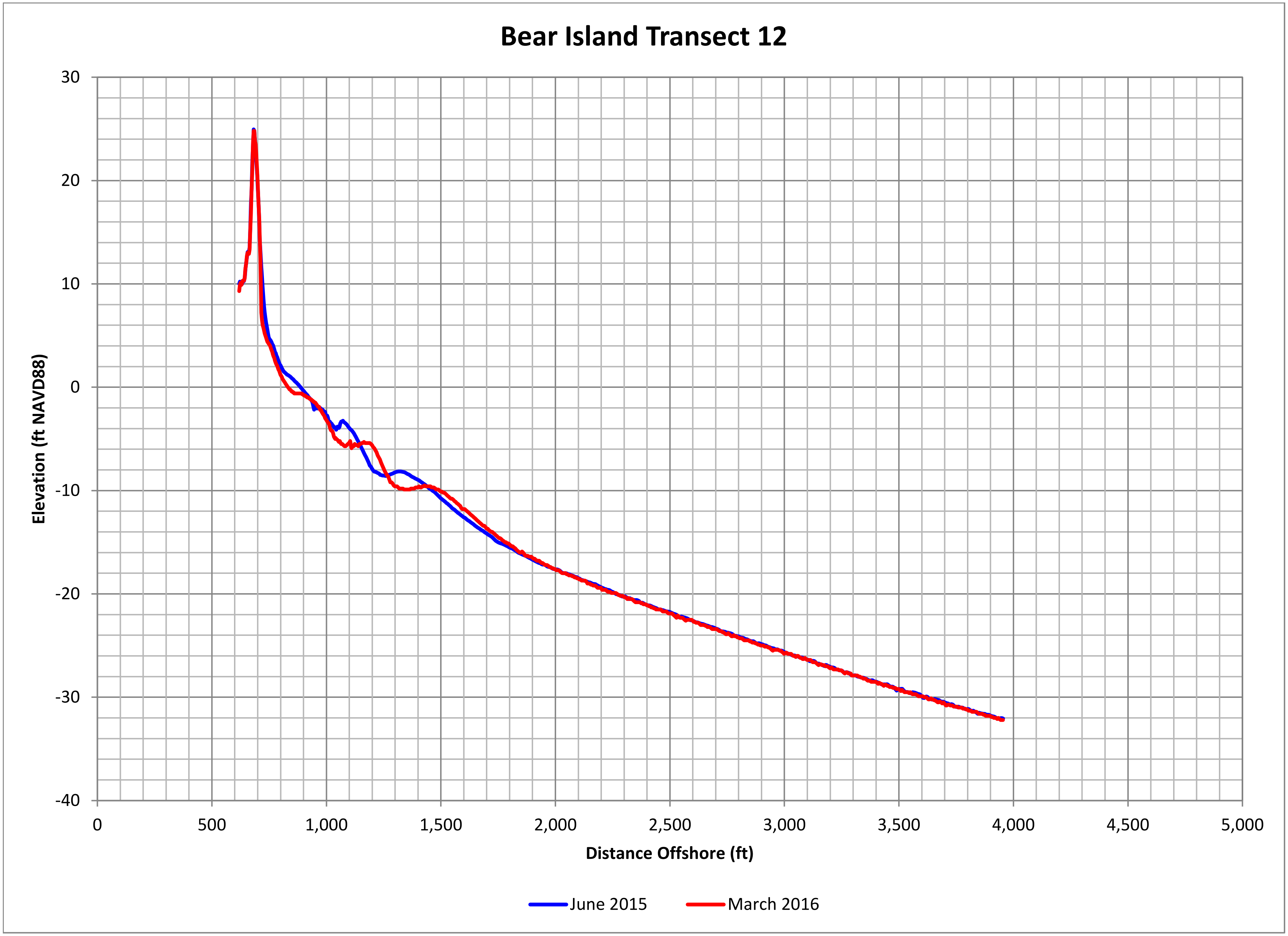


FIgure C-162. Bear Island Profile Comparison Plot

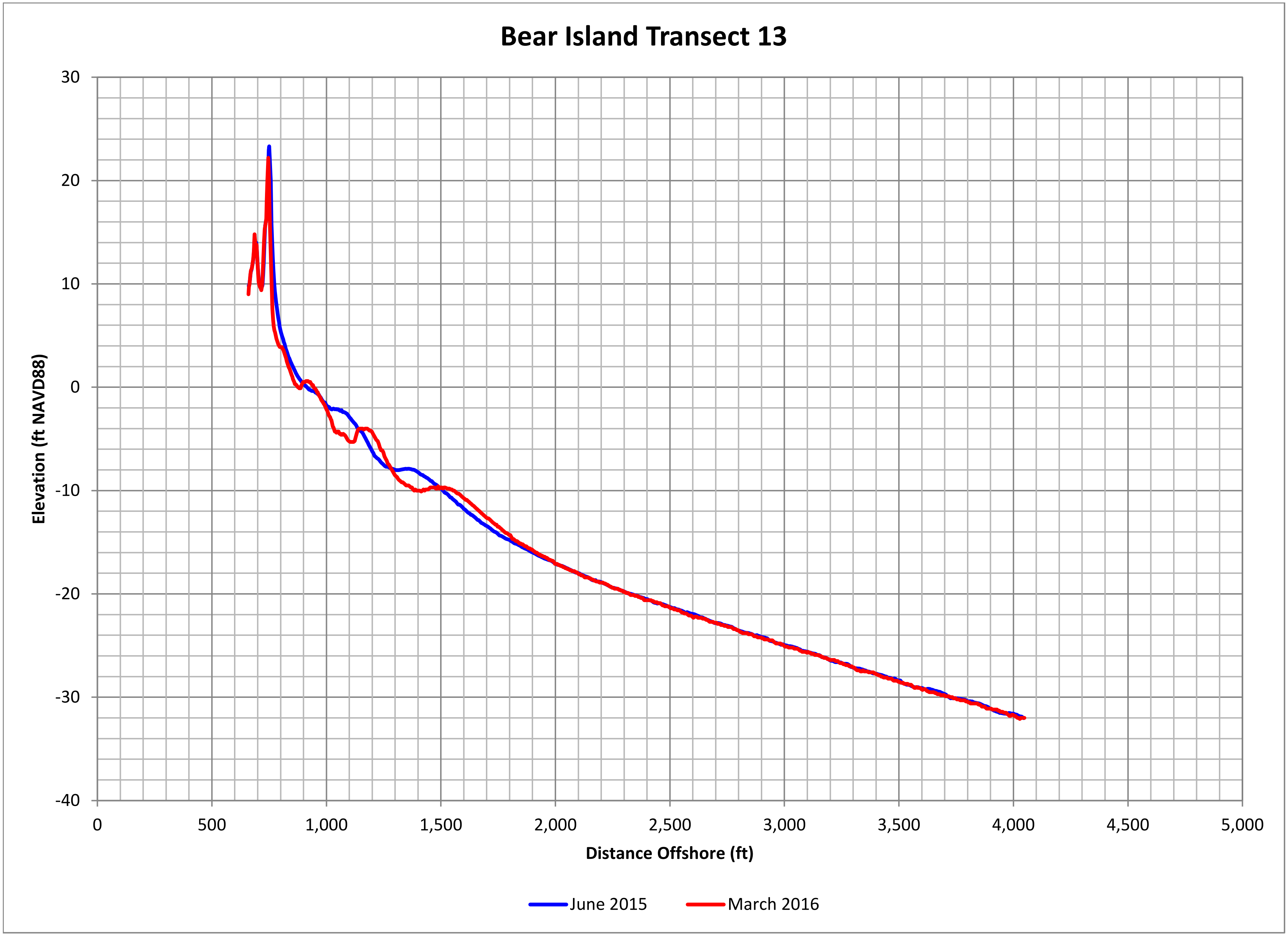


FIgure C-163. Bear Island Profile Comparison Plot

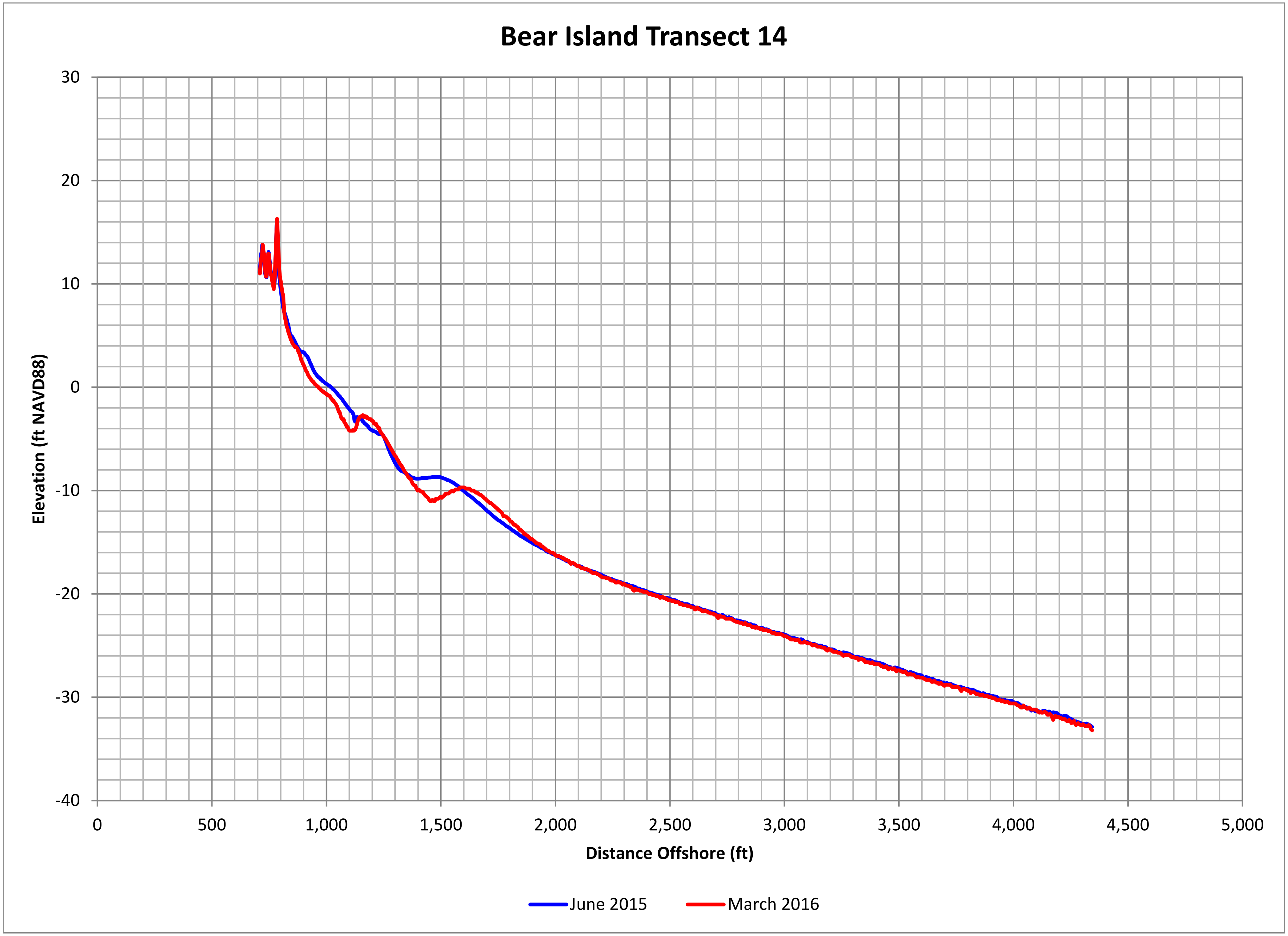


FIgure C-164. Bear Island Profile Comparison Plot

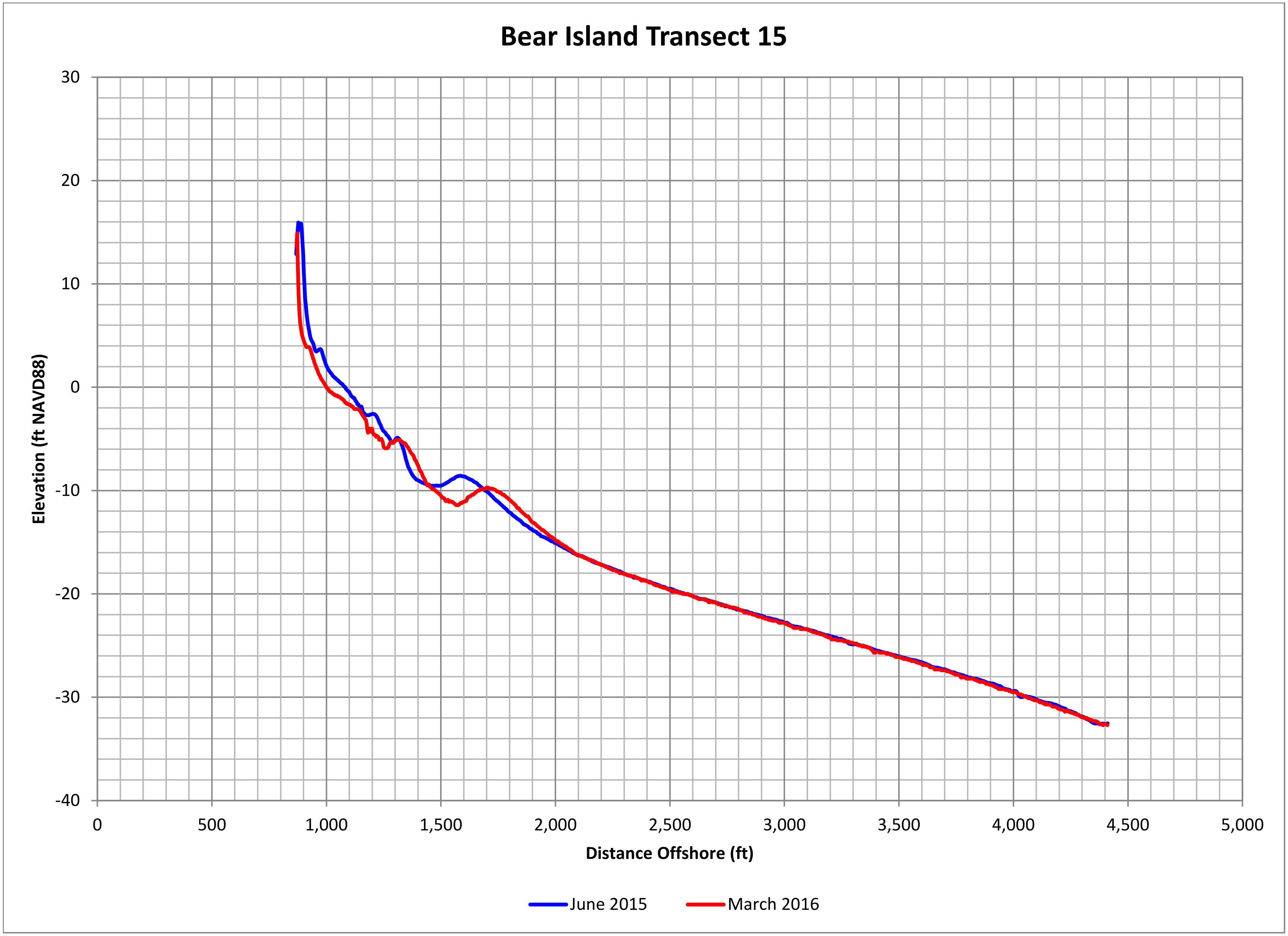


FIgure C-165. Bear Island Profile Comparison Plot

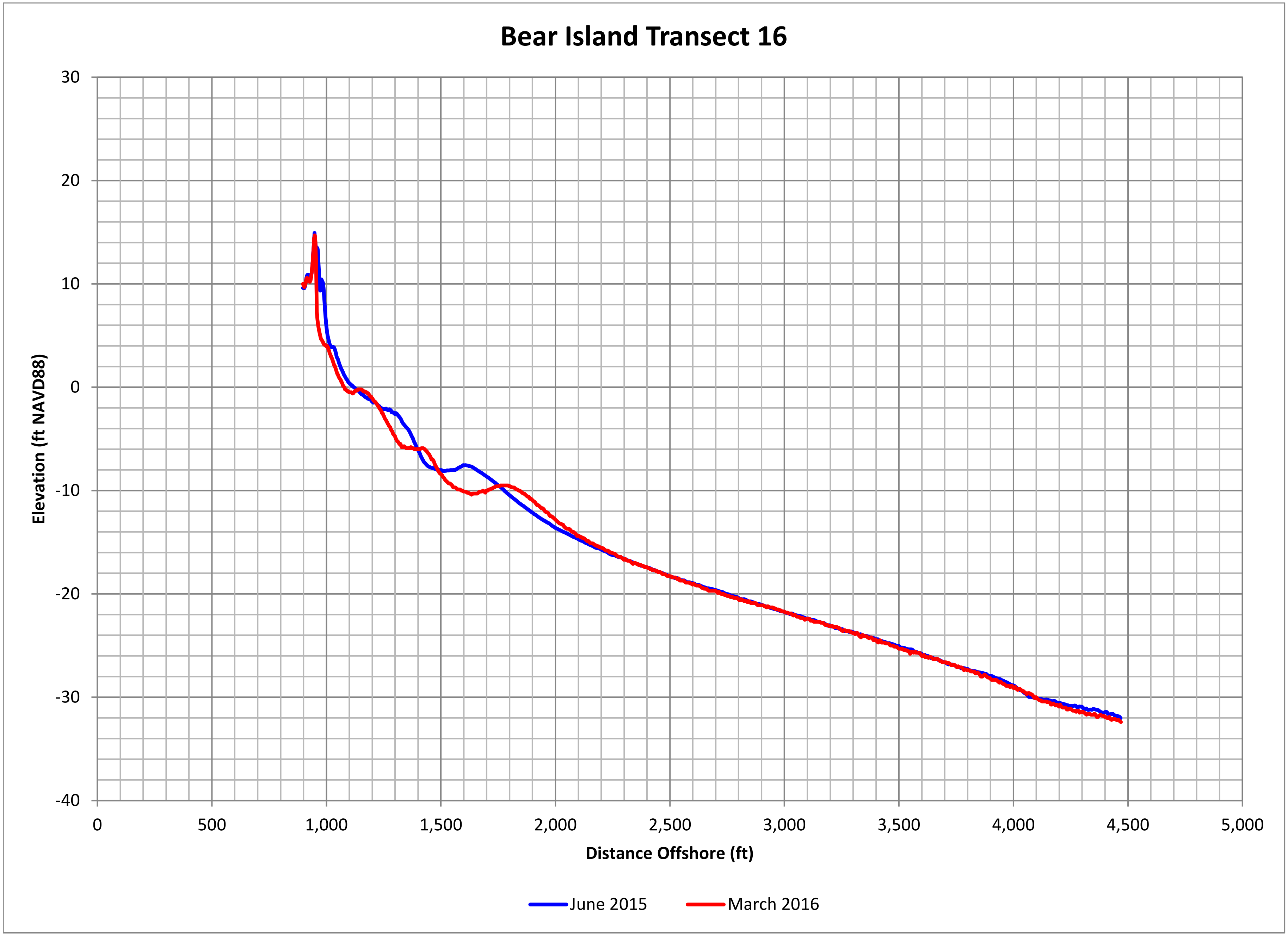


FIgure C-166. Bear Island Profile Comparison Plot

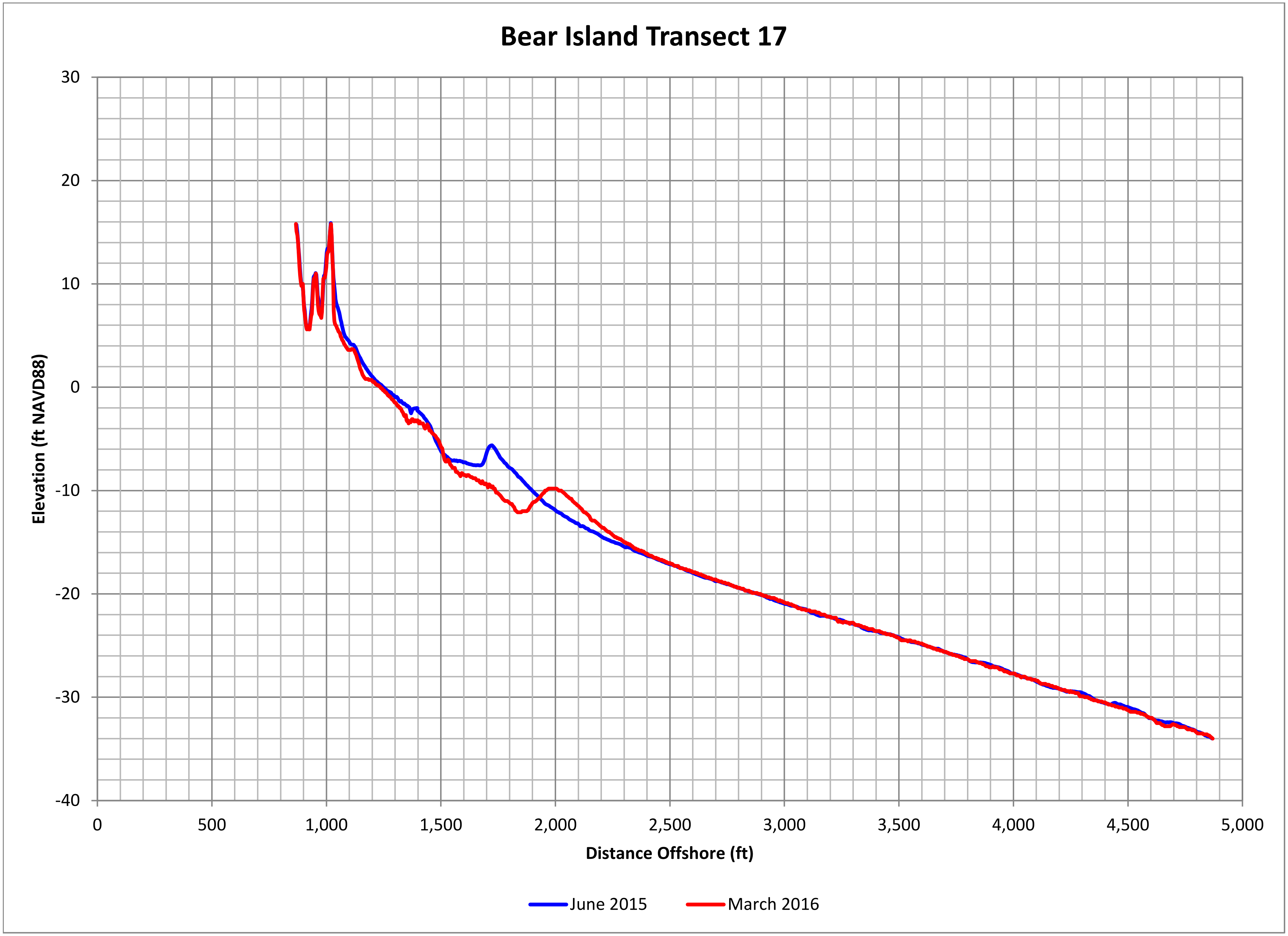


FIgure C-167. Bear Island Profile Comparison Plot

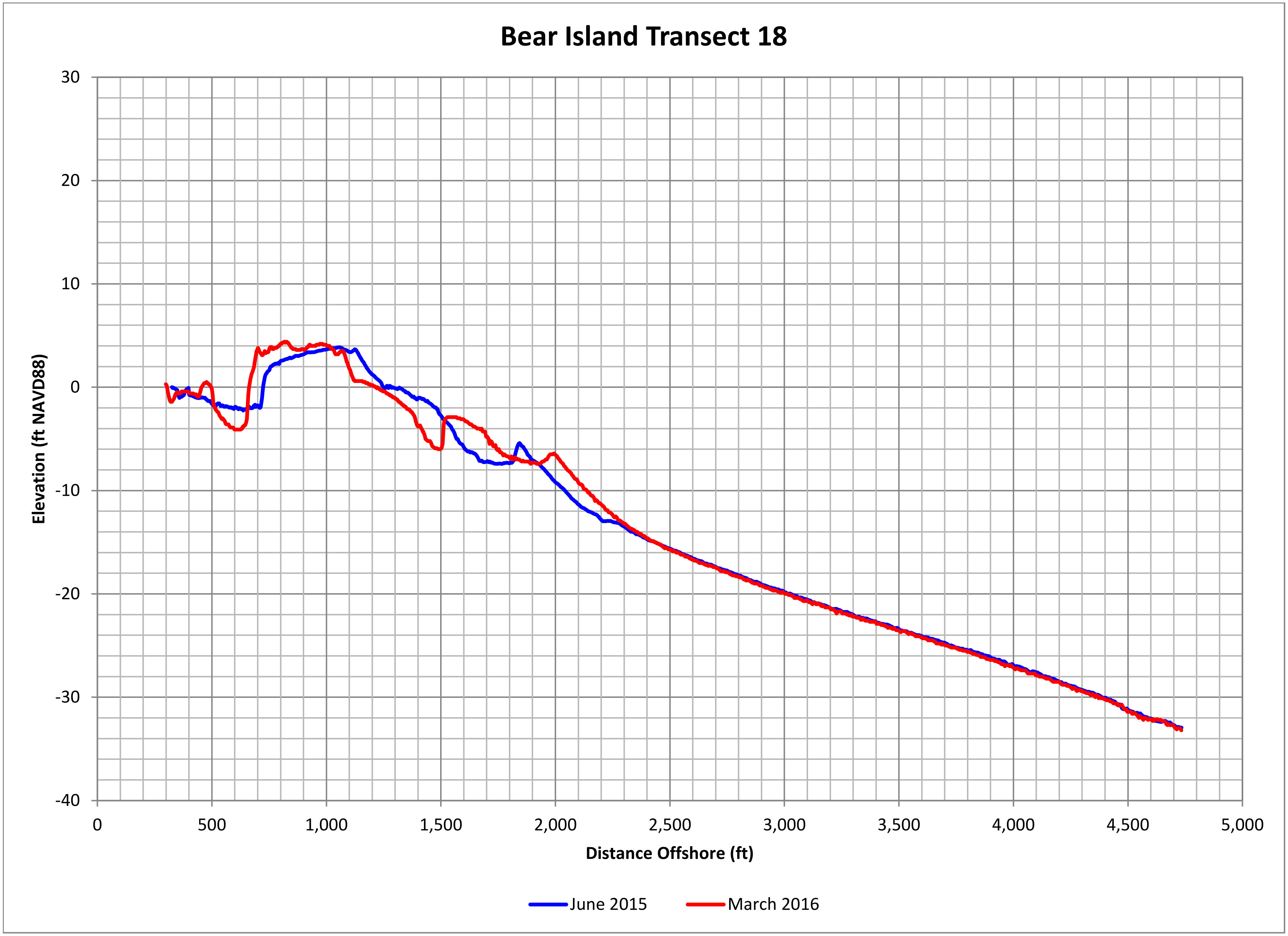


FIgure C-168. Bear Island Profile Comparison Plot

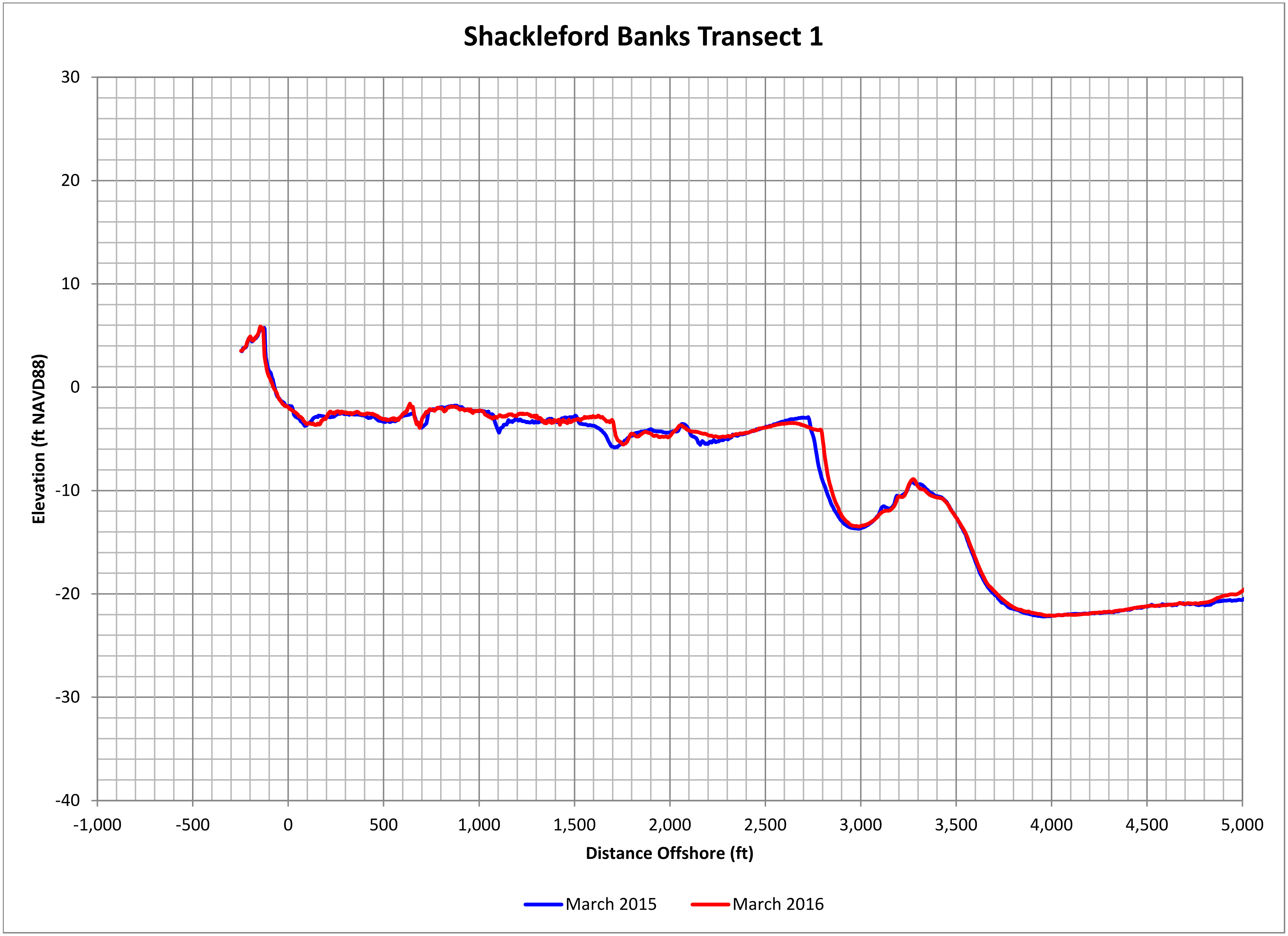


Figure C-169. Shackleford Banks Profile Comparison Plot

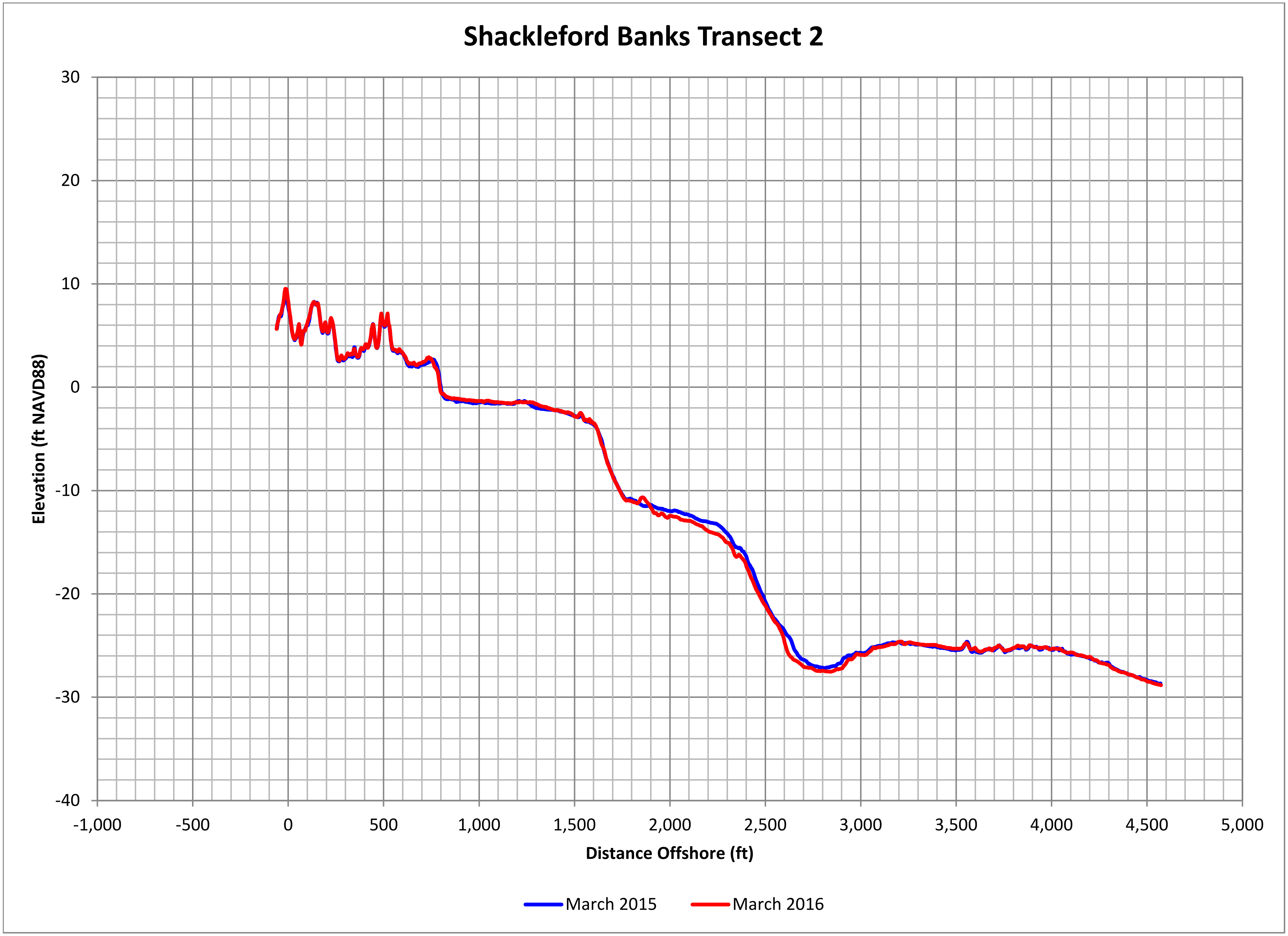


Figure C-170. Shackleford Banks Profile Comparison Plot

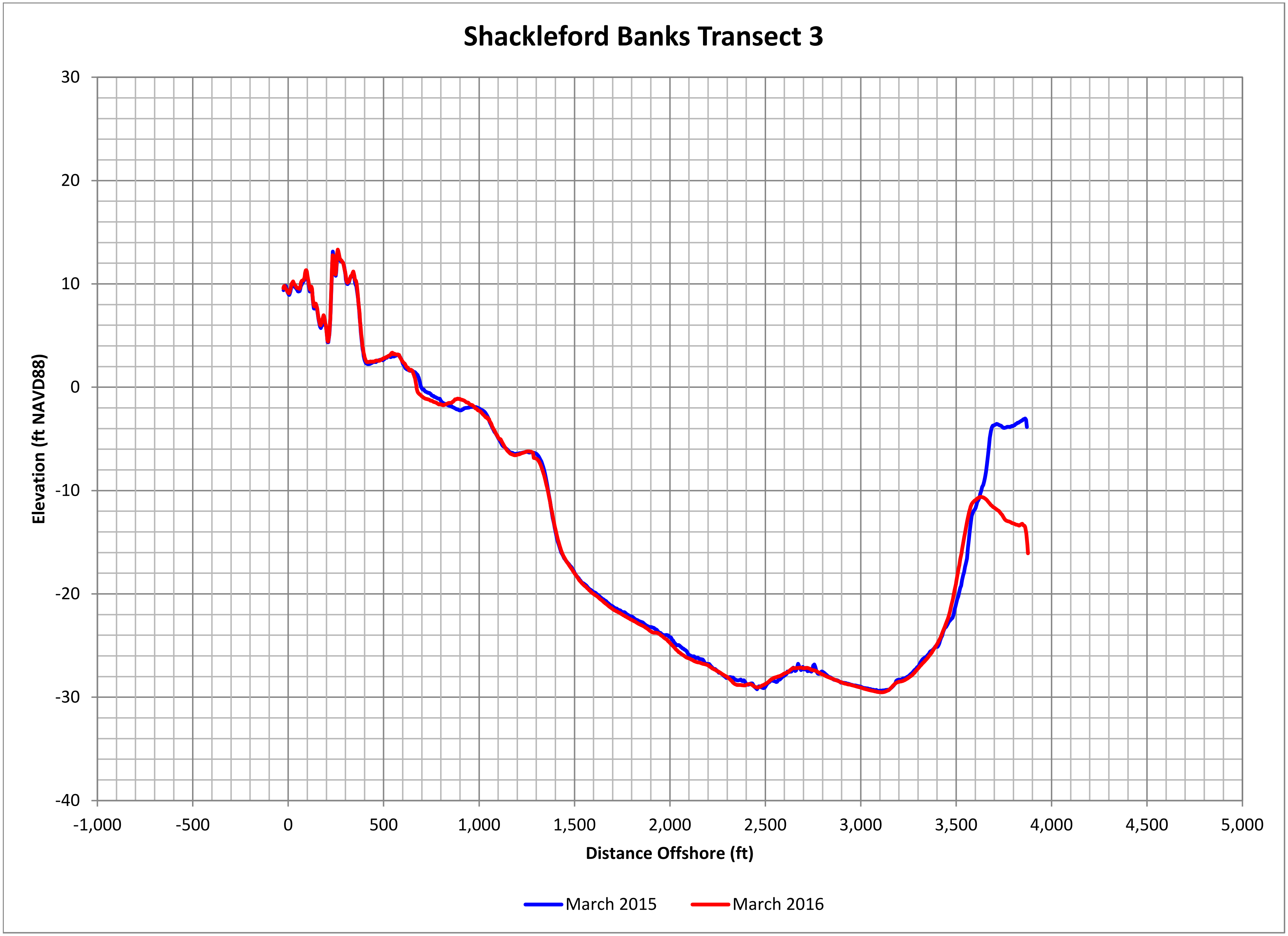


Figure C-171. Shackleford Banks Profile Comparison Plot

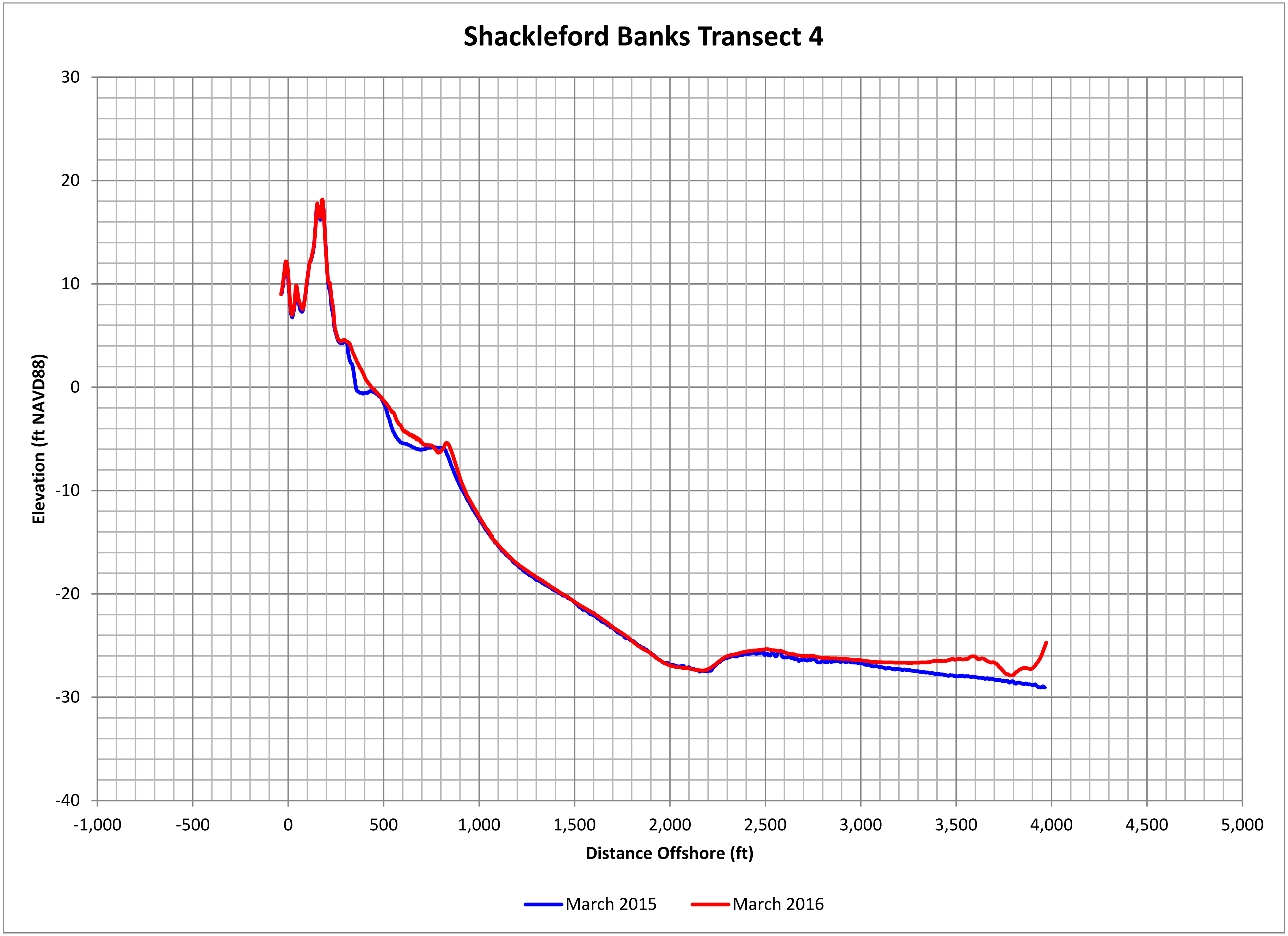


Figure C-172. Shackleford Banks Profile Comparison Plot

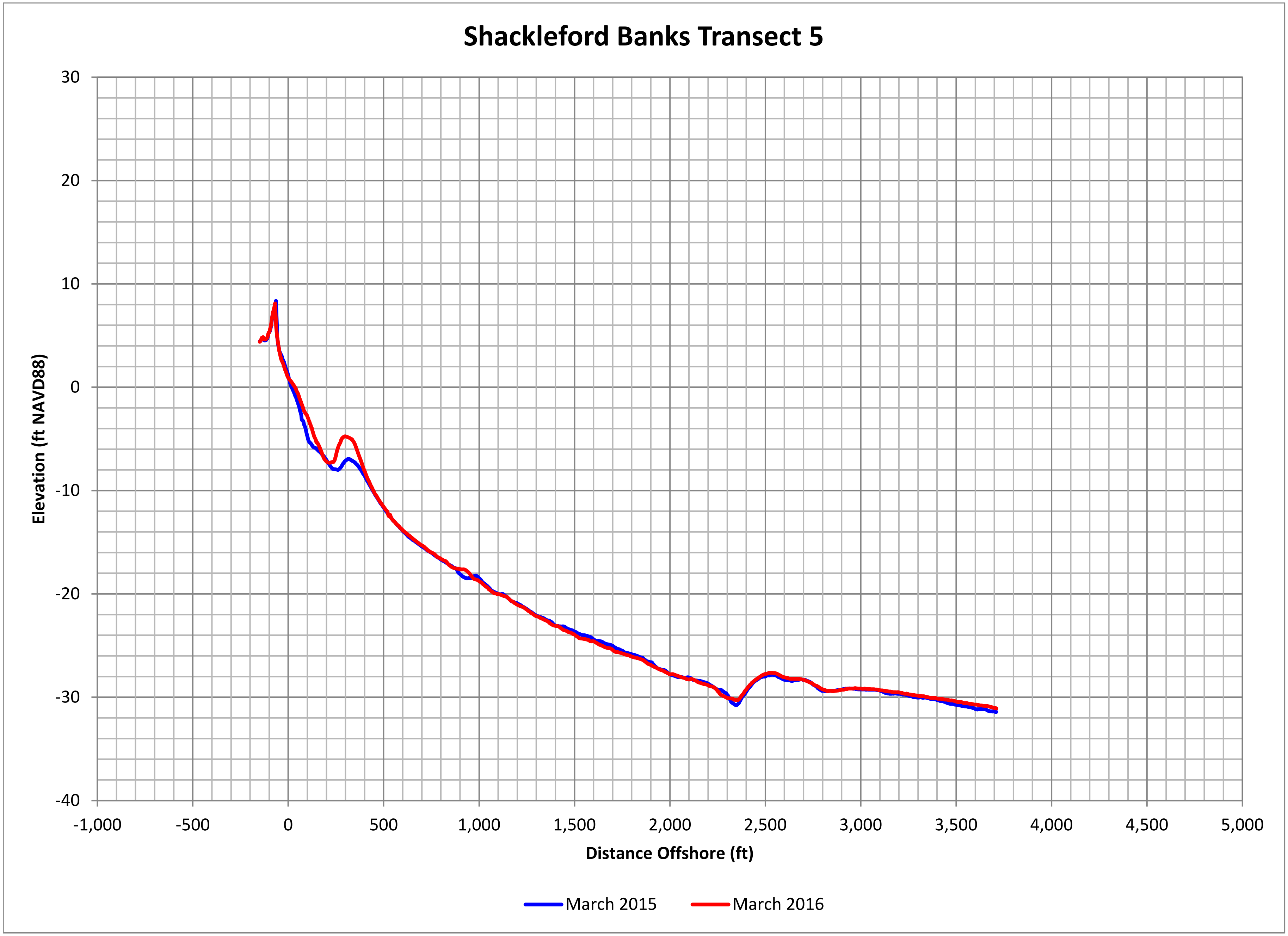


Figure C-173. Shackleford Banks Profile Comparison Plot

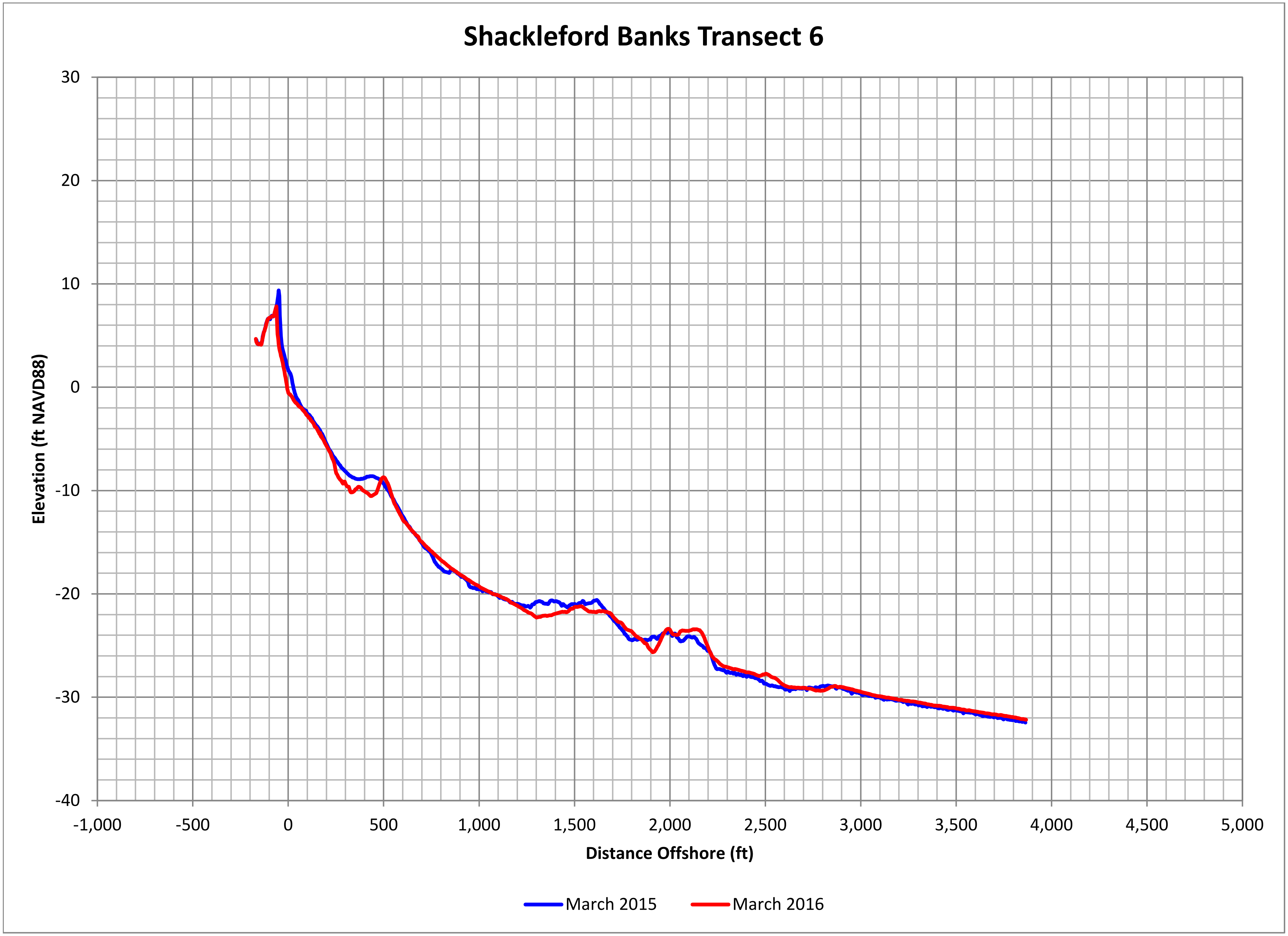


Figure C-174. Shackleford Banks Profile Comparison Plot

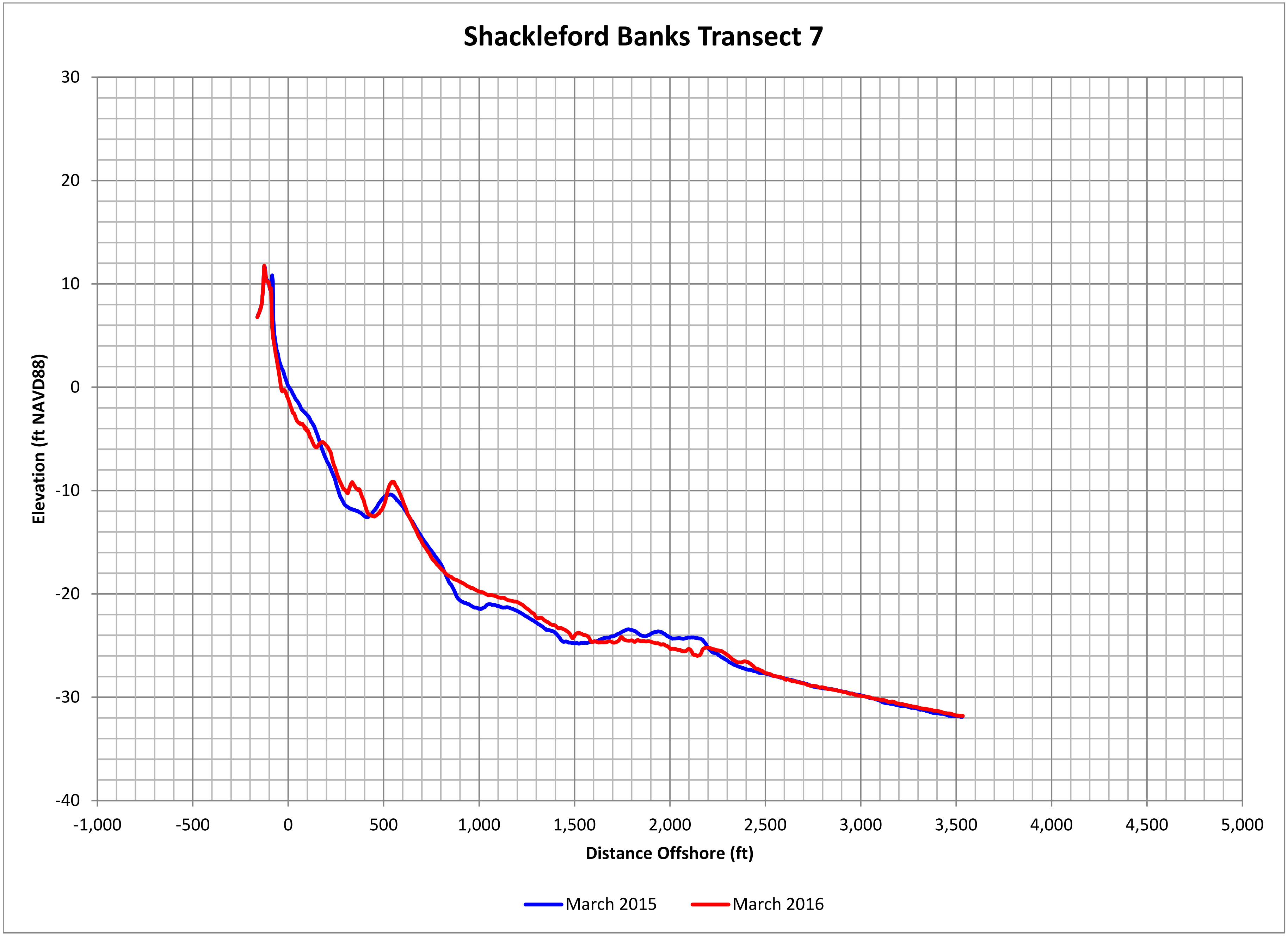


Figure C-175. Shackleford Banks Profile Comparison Plot

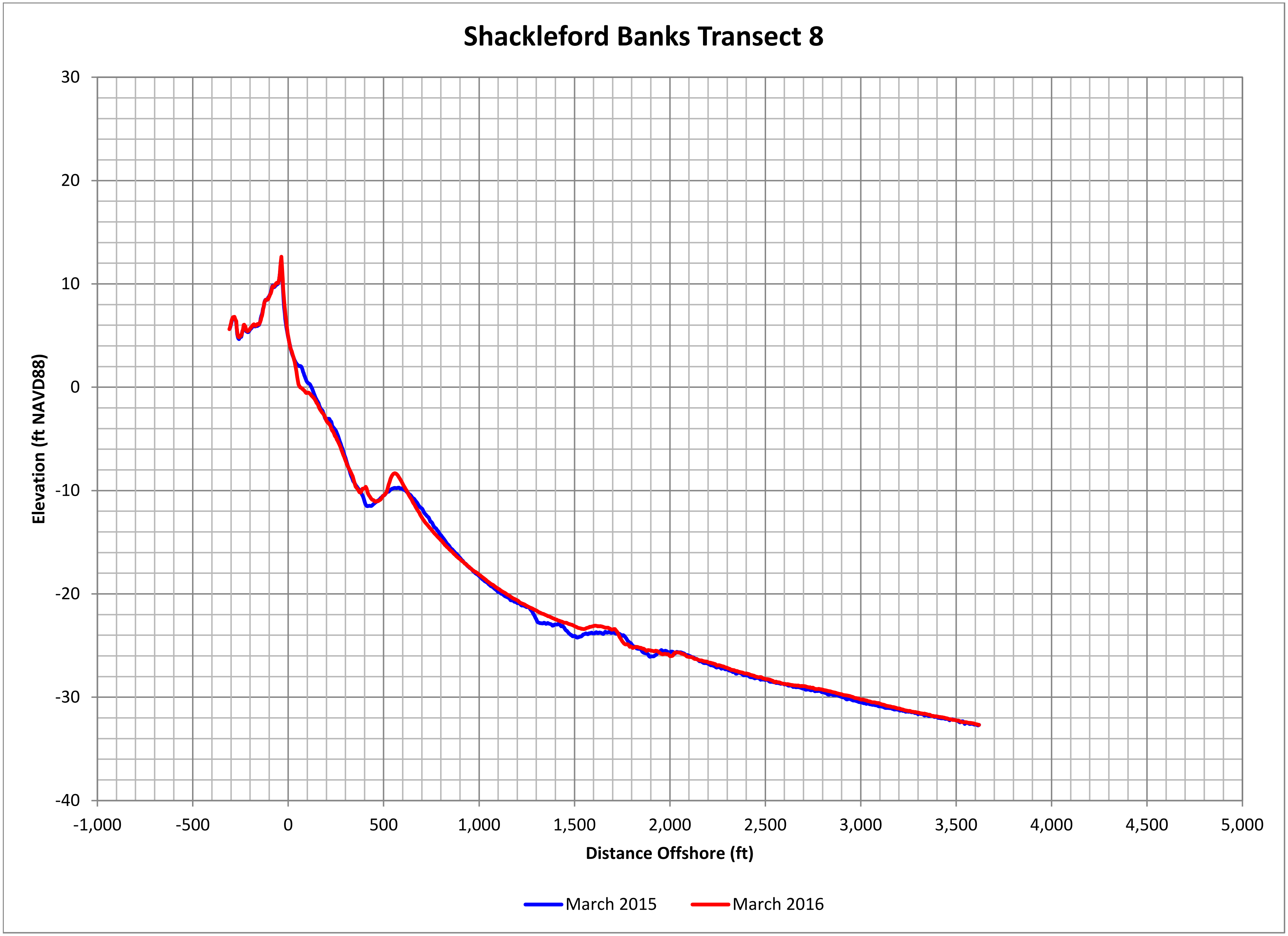


Figure C-176. Shackleford Banks Profile Comparison Plot

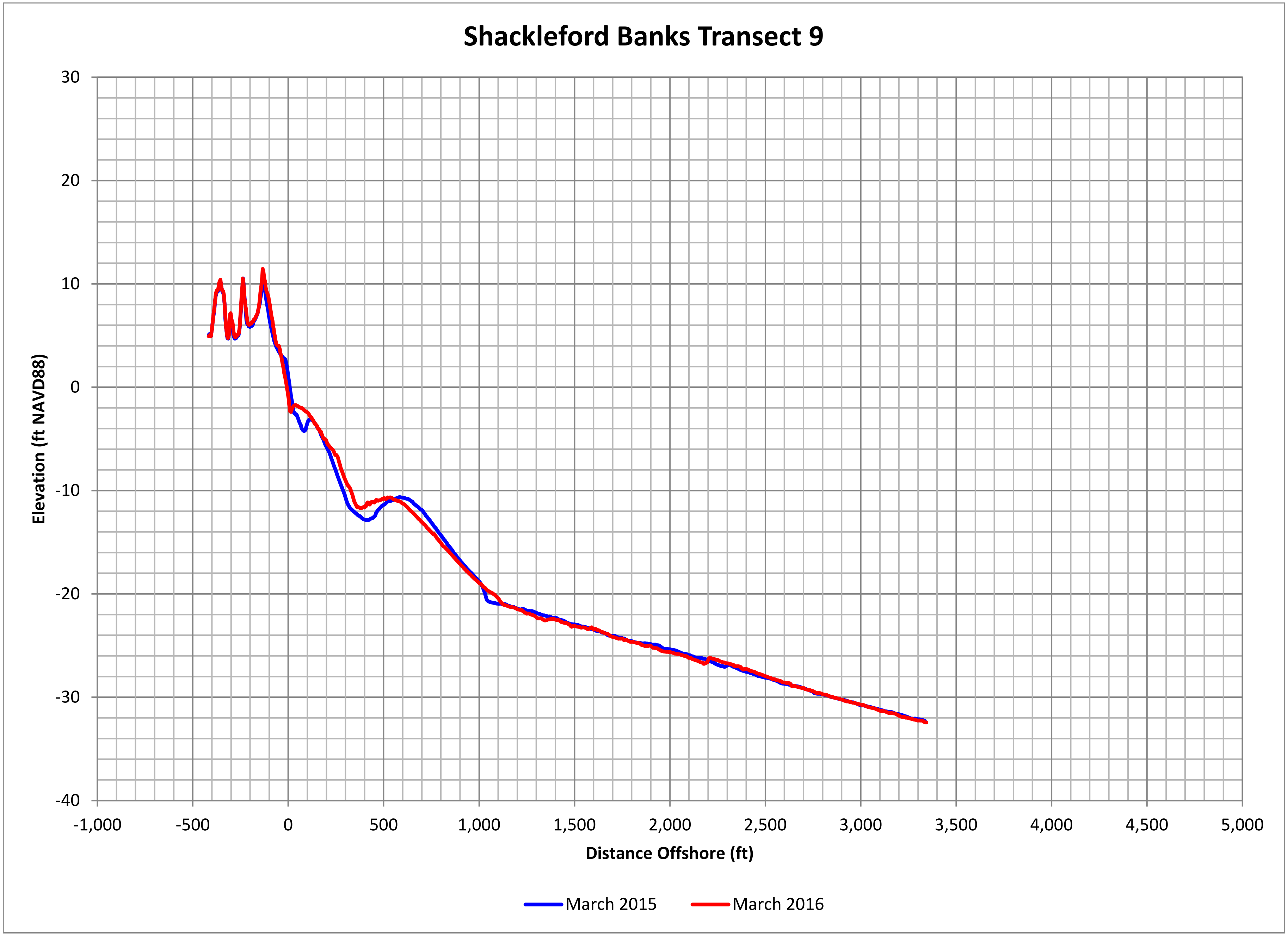


Figure C-177. Shackleford Banks Profile Comparison Plot

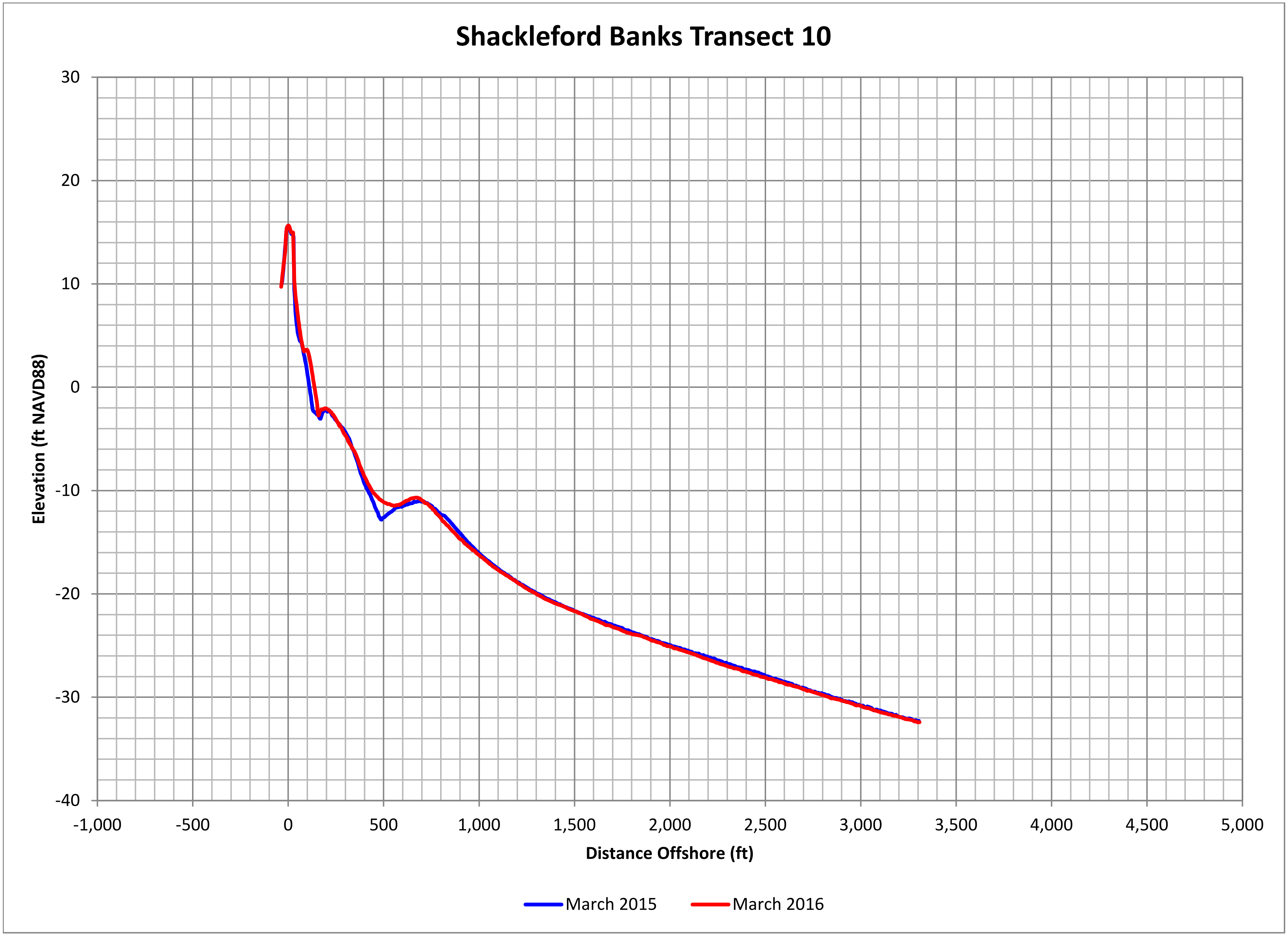


Figure C-178. Shackleford Banks Profile Comparison Plot

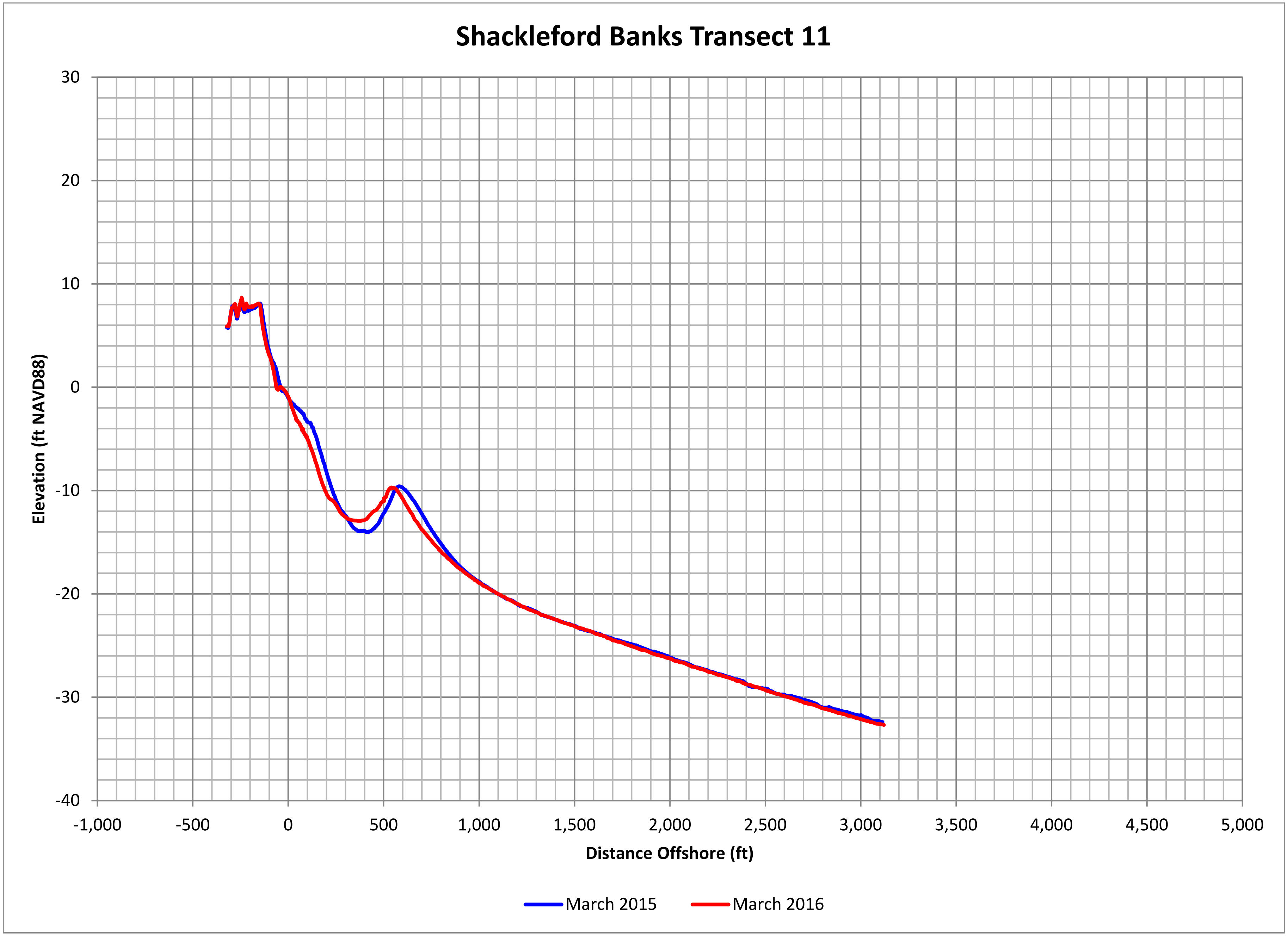


Figure C-179. Shackleford Banks Profile Comparison Plot

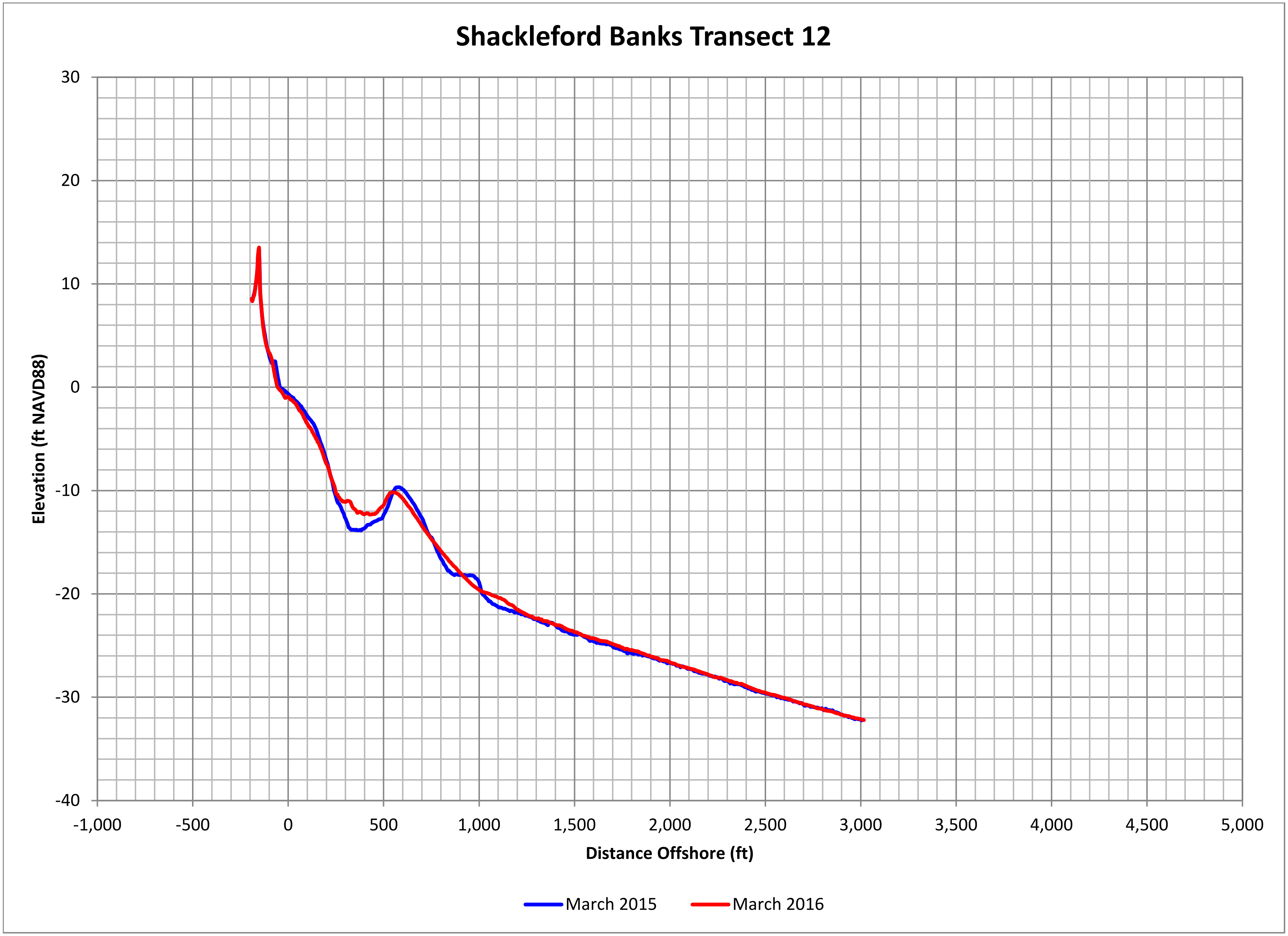


Figure C-180. Shackleford Banks Profile Comparison Plot

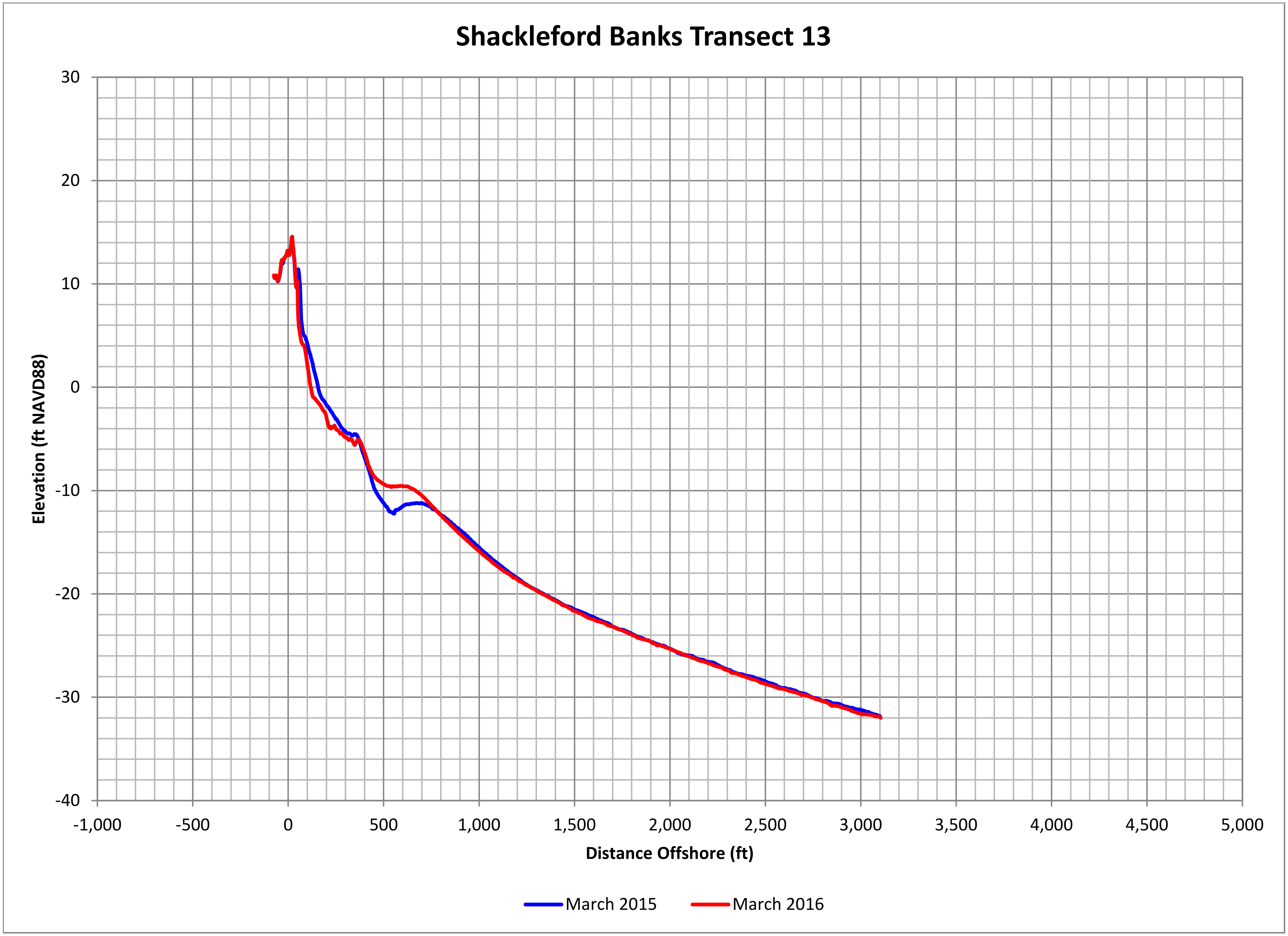


Figure C-181. Shackleford Banks Profile Comparison Plot

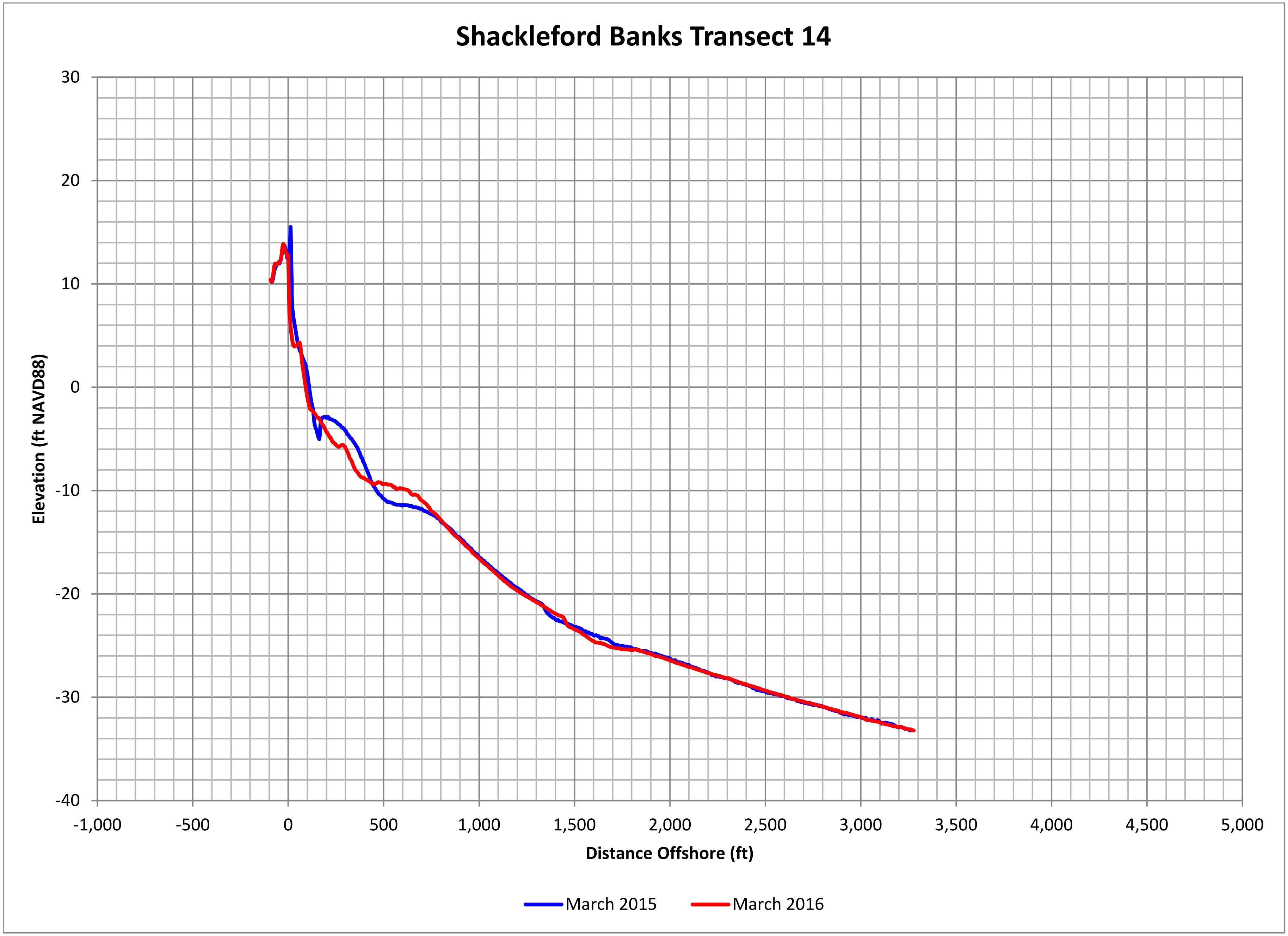


Figure C-182. Shackleford Banks Profile Comparison Plot

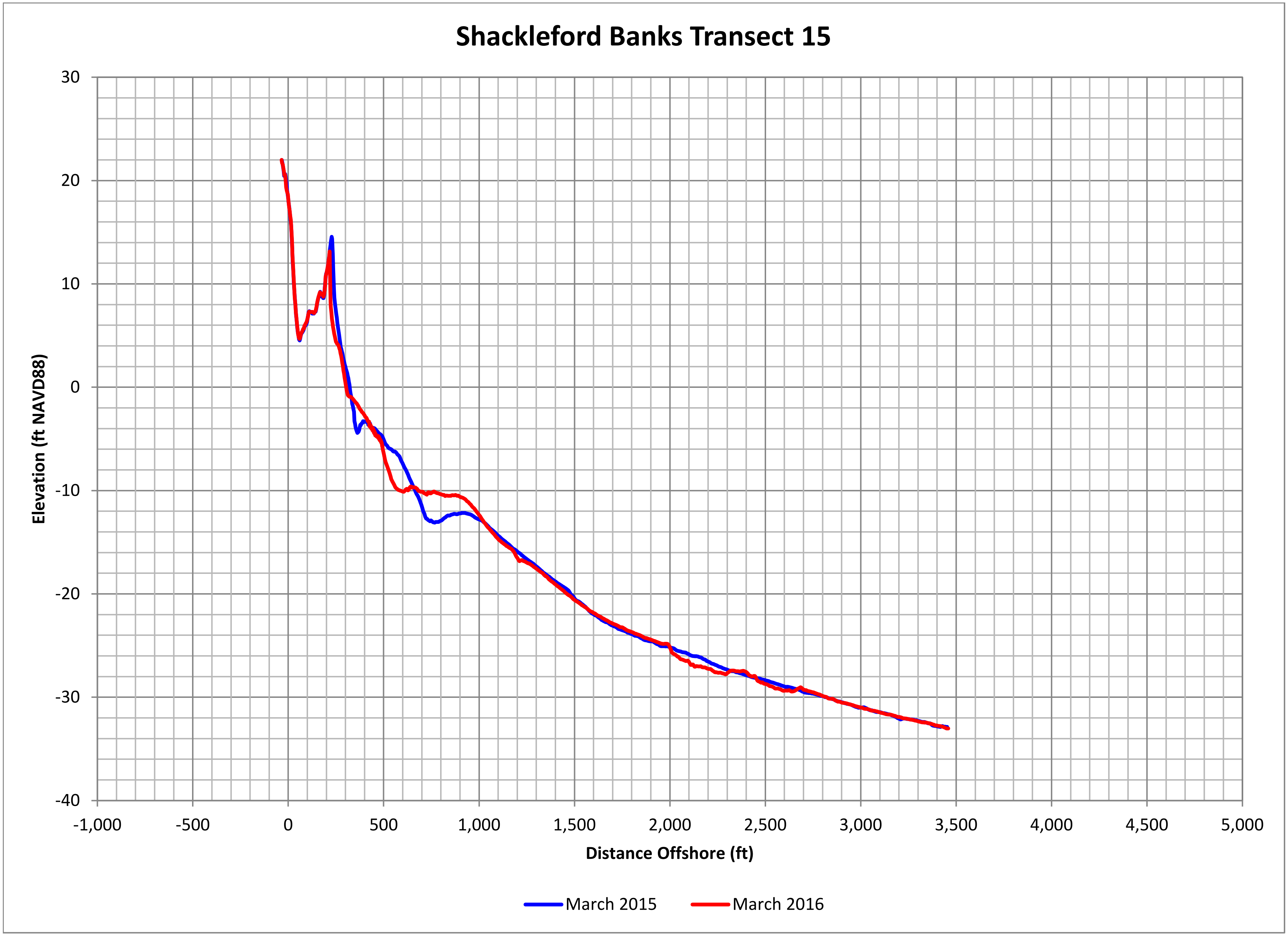


Figure C-183. Shackleford Banks Profile Comparison Plot

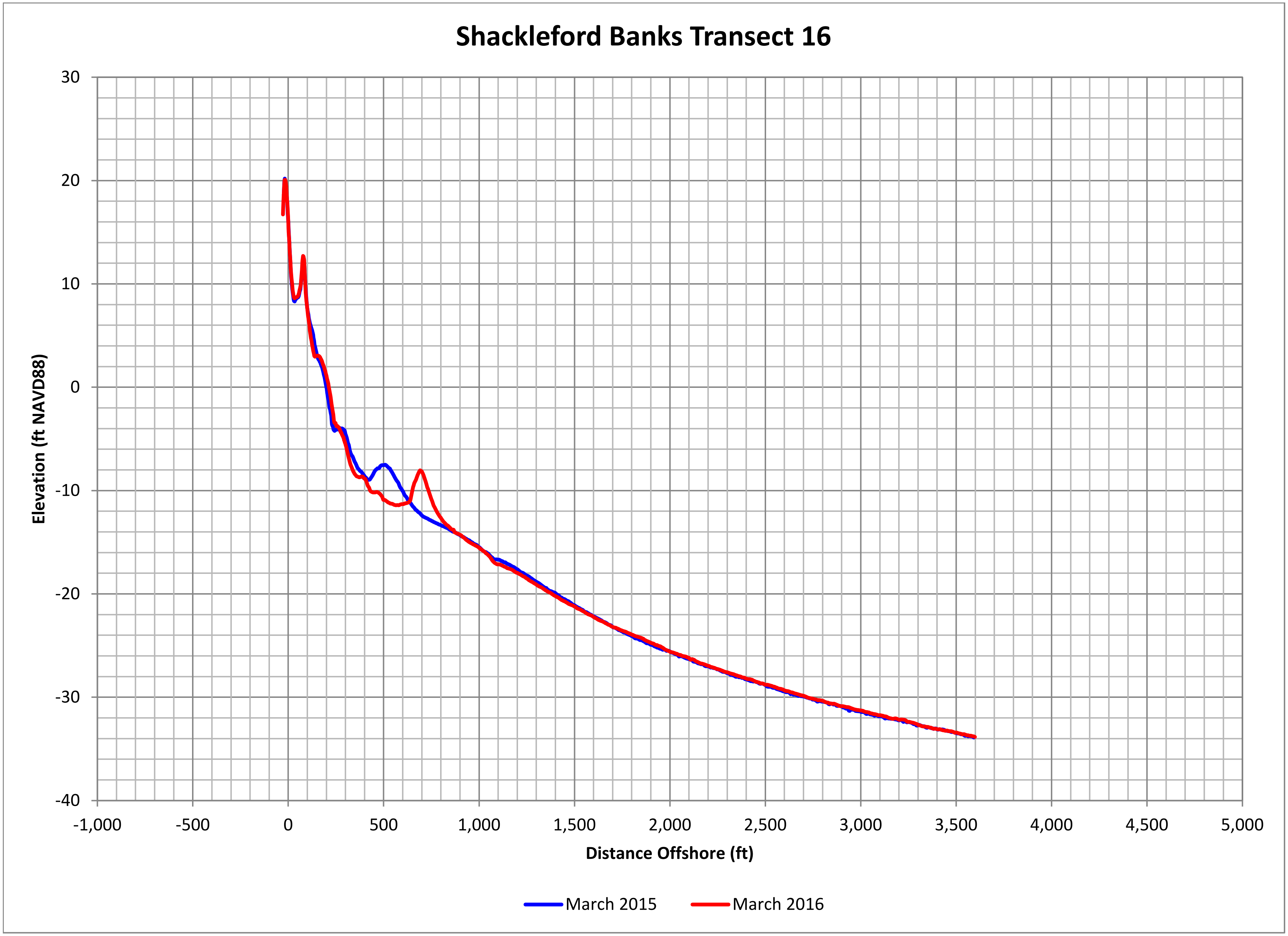


Figure C-184. Shackleford Banks Profile Comparison Plot

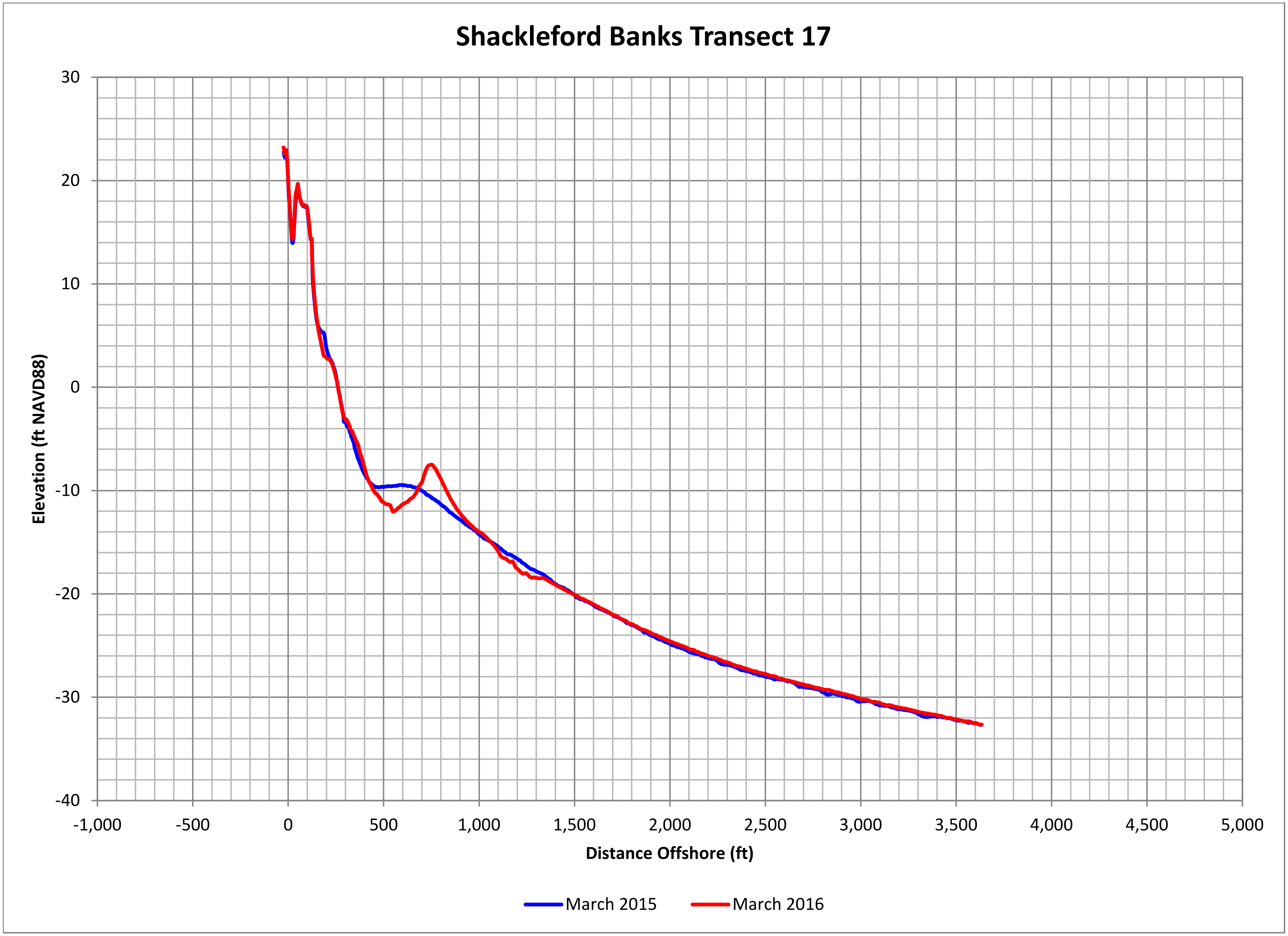


Figure C-185. Shackleford Banks Profile Comparison Plot

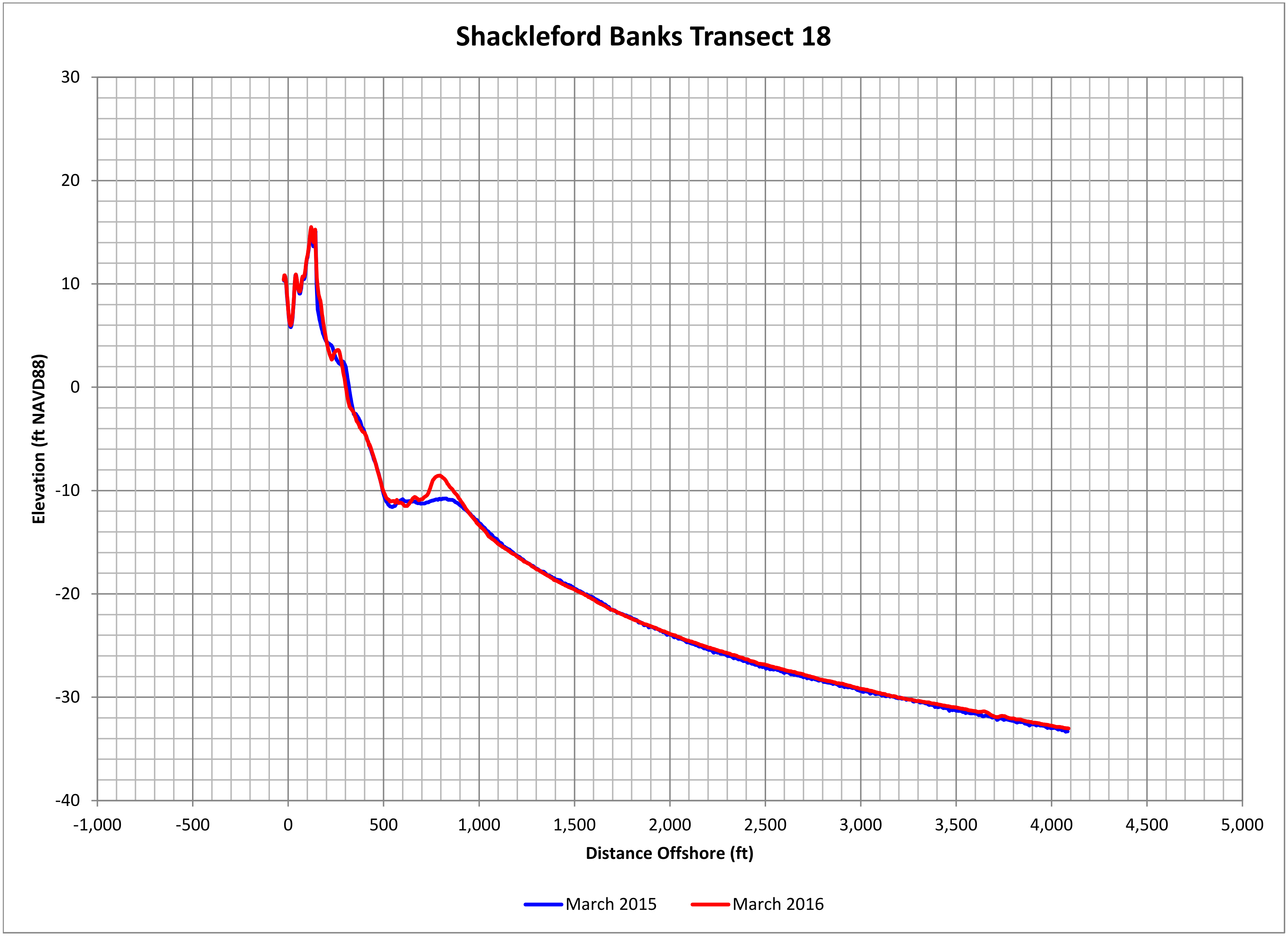


Figure C-186. Shackleford Banks Profile Comparison Plot

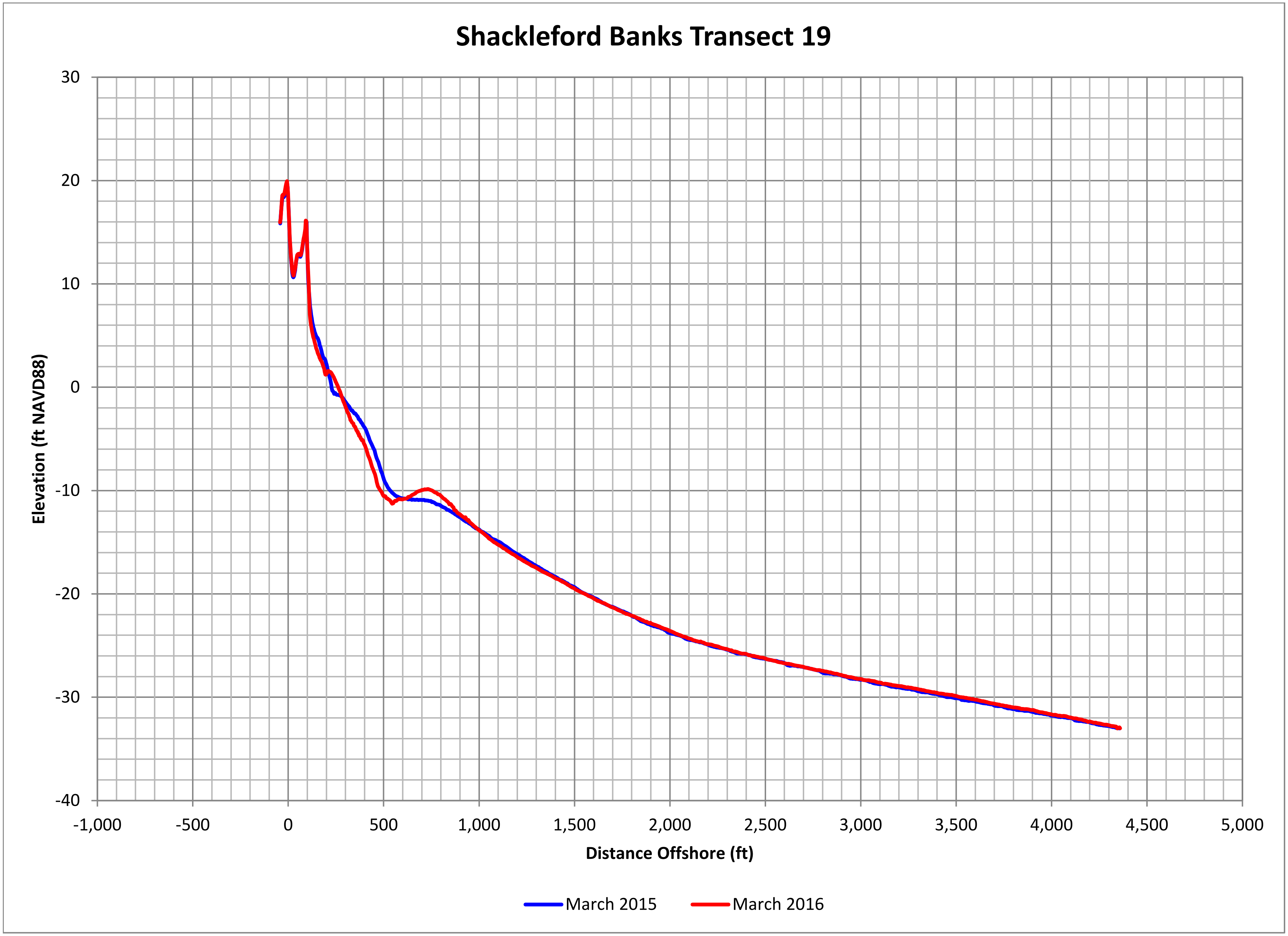


Figure C-187. Shackleford Banks Profile Comparison Plot

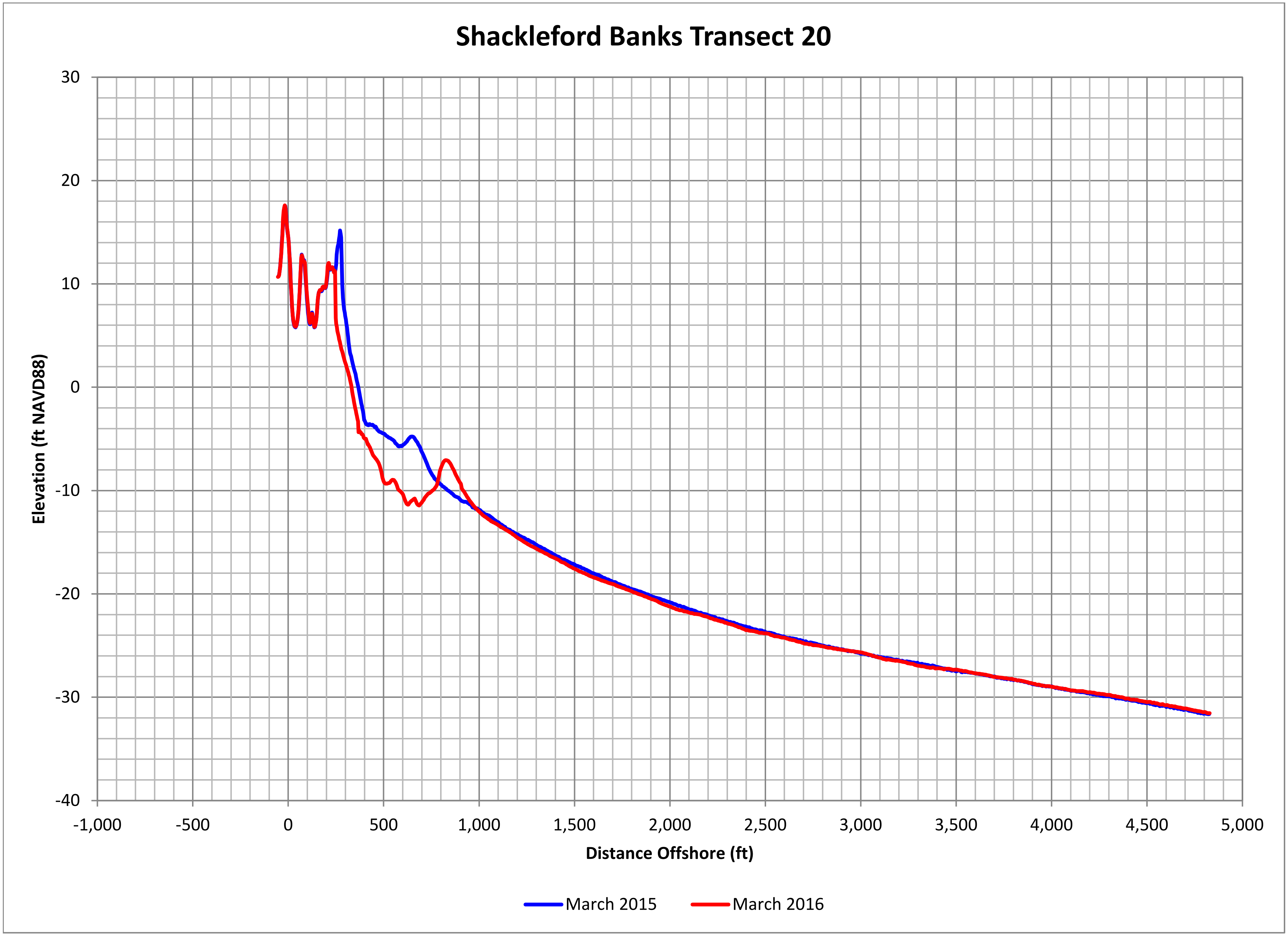


Figure C-188. Shackleford Banks Profile Comparison Plot

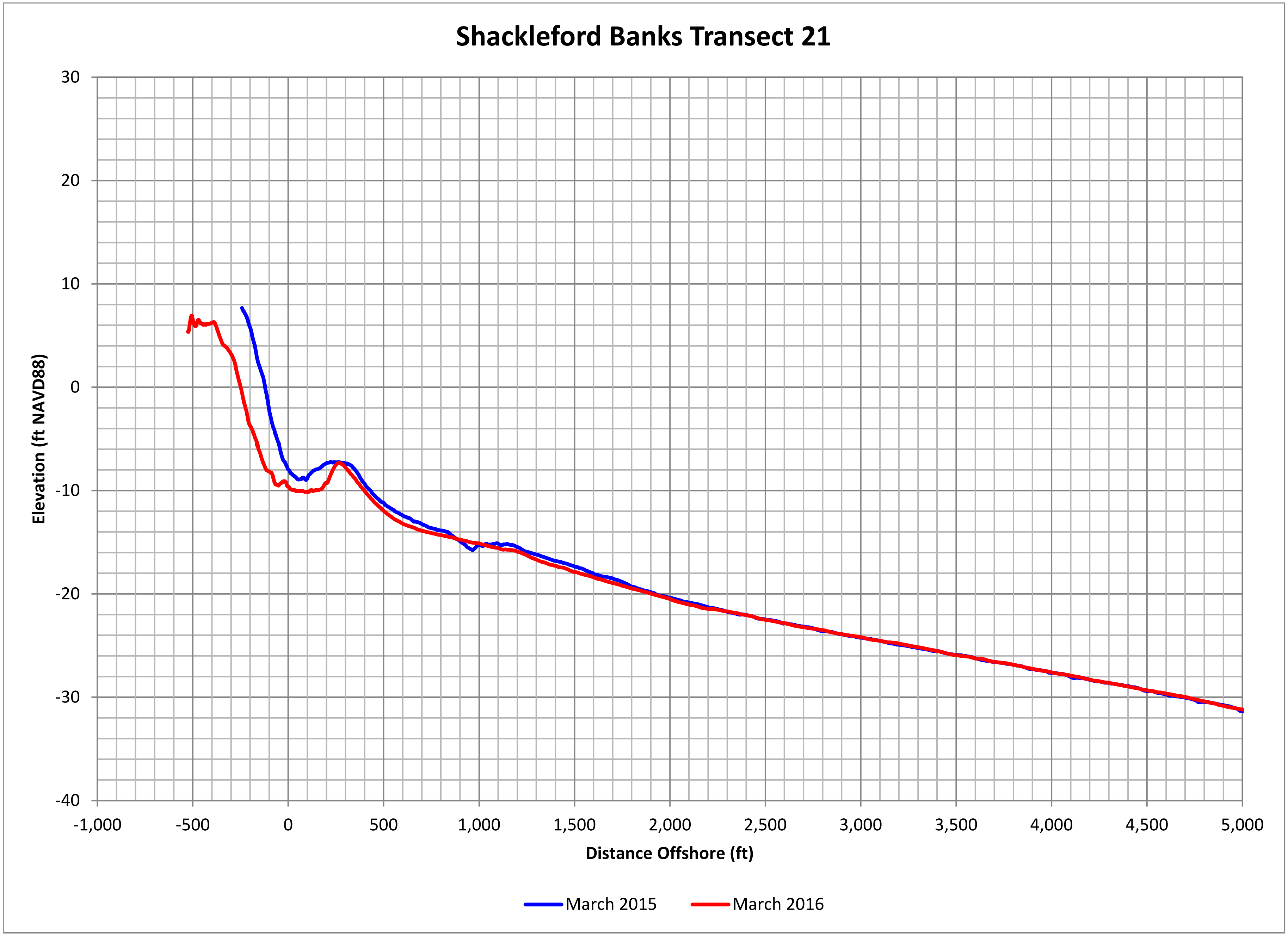


Figure C-189. Shackleford Banks Profile Comparison Plot

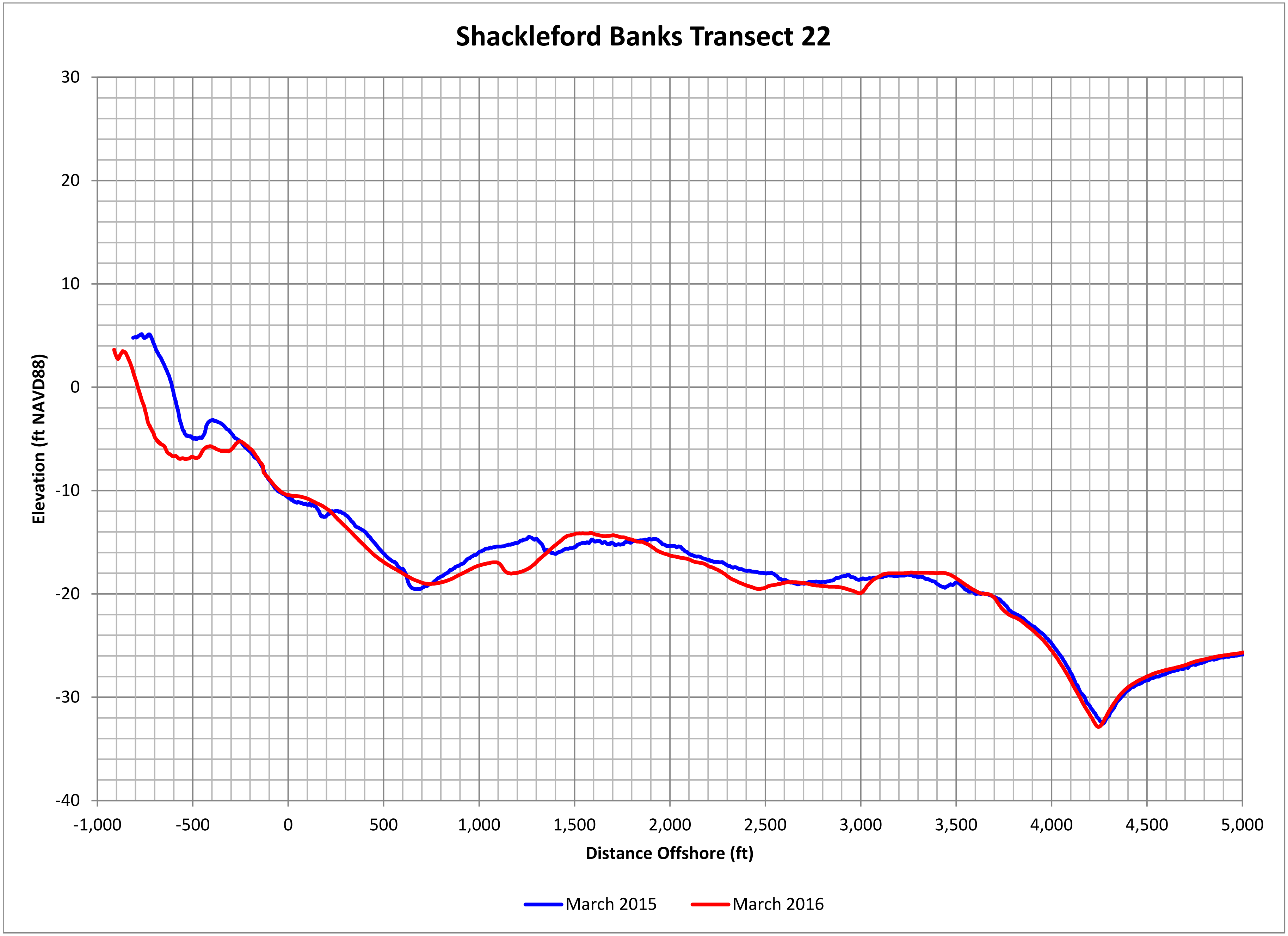


Figure C-190. Shackleford Banks Profile Comparison Plot

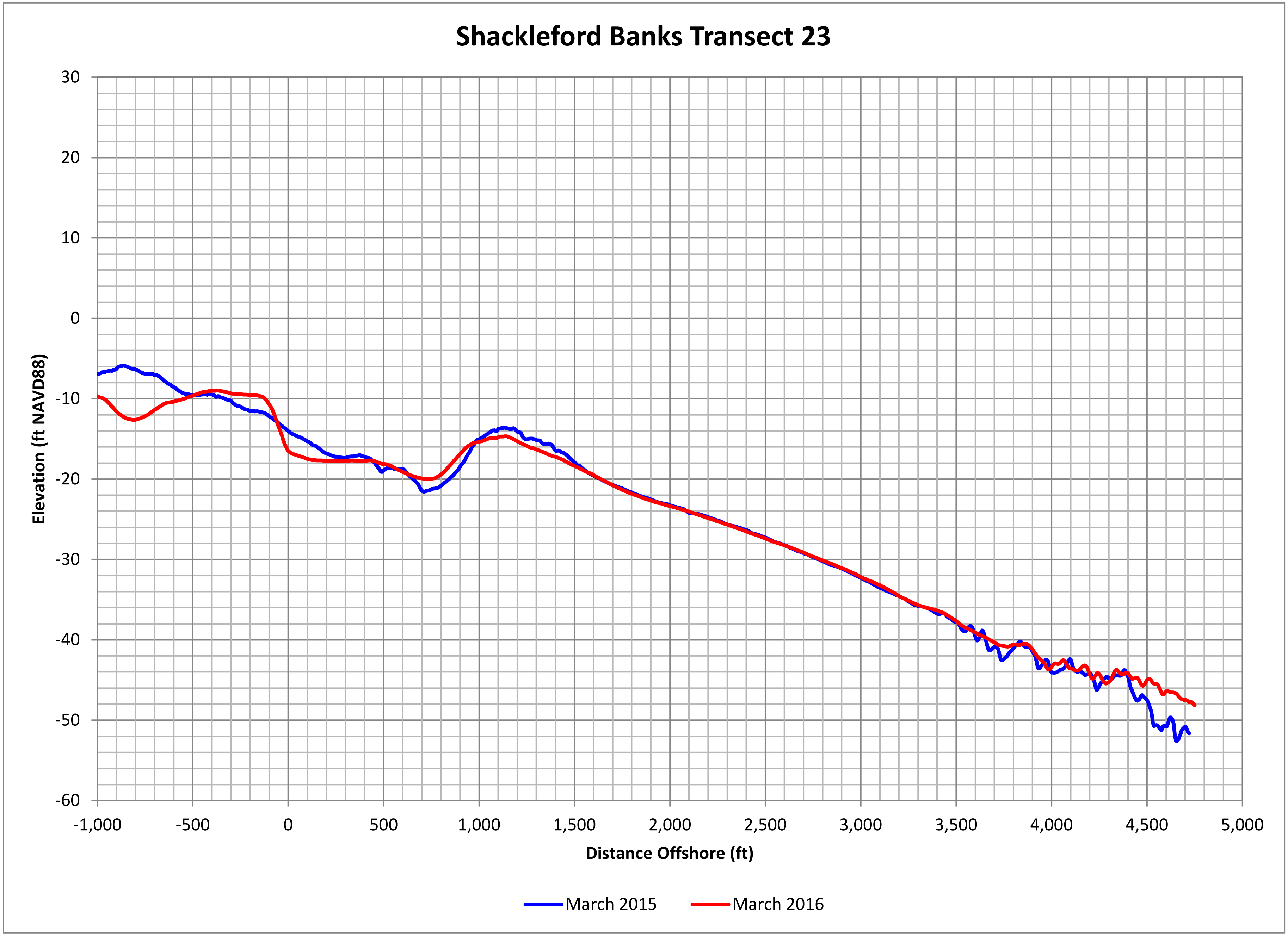


Figure C-191. Shackleford Banks Profile Comparison Plot

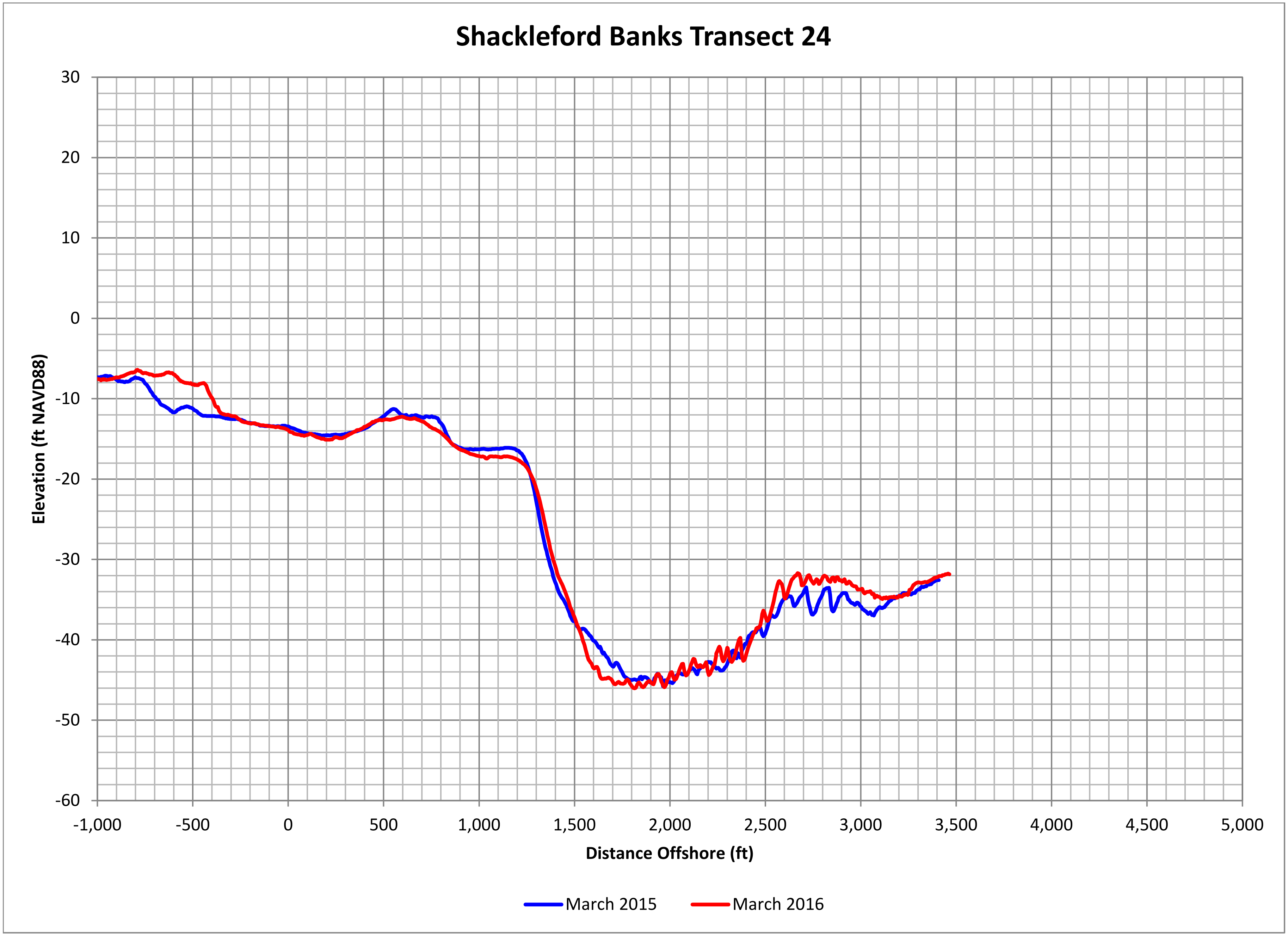


Figure C-192. Shackleford Banks Profile Comparison Plot

APPENDIX D

Results Tables

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2015 to 2016)

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from May 20, 2015 to May 16, 2016.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)
Bogue Inlet-Ocean/ Emerald Isle West	1	0+00	53.47	86.12	8.91	228.86	23.77	576.24	44.04	1274.16	25.34	2596.51	18.96
	2	5+59	45.37	98.13	6.08	243.90	-0.09	509.99	-31.81	1149.04	-43.13	2389.60	-51.45
	3	11+23	43.97	56.14	6.39	139.14	6.47	319.27	-14.24	810.35	-41.73	1823.83	-46.70
	4	17+39	64.64	23.81	12.10	92.05	18.93	267.65	27.73	700.25	37.20	1595.61	40.85
	5	23+22	84.58	64.56	15.21	154.35	22.45	342.67	17.38	753.47	16.75	1624.14	15.36
	6	36+28	-11.92	27.88	-0.81	85.90	-7.00	237.31	-10.88	577.86	-9.38	1327.53	-16.54
	7	53+10	-3.83	71.08	-0.87	160.64	0.84	347.97	3.44	713.87	6.61	1439.39	5.62
	8	67+74	-2.59	68.82	-0.05	158.14	0.50	336.01	0.24	693.41	6.33	1384.10	5.71
	9	80+91	8.70	55.14	1.00	139.49	4.02	306.69	-0.44	656.55	5.98	1329.22	4.71
	10	93+40	25.13	55.44	2.55	128.14	-0.16	291.81	-0.65	633.04	5.31	1286.51	3.88
	11	108+58	37.77	51.01	8.35	122.77	4.94	284.53	3.05	620.60	8.42	1262.73	6.20
Emerald Isle West	12	121+18	14.96	95.07	3.94	177.13	3.51	350.27	-6.15	698.96	0.37	1351.24	-1.37
	13	134+61	-6.21	76.41	-2.76	160.43	-3.22	335.91	-10.38	683.22	-4.50	1332.71	-4.96
	14	146+67	24.73	60.77	4.47	138.73	2.48	305.16	-2.24	644.51	8.04	1277.33	6.31
	15	160+16	2.56	48.38	-0.15	121.37	1.15	280.25	-3.18	610.38	3.65	1234.79	3.31
	16	174+79	31.20	51.39	2.63	125.71	2.50	287.70	3.57	616.51	7.61	1243.77	5.86
	17	189+23	27.15	72.58	2.21	160.80	7.30	340.19	2.42	687.76	7.80	1335.17	6.03
	18	203+53	-30.50	67.80	4.21	148.16	0.75	315.73	-5.96	660.96	-1.36	1307.59	-2.50
	19	214+90	30.75	59.71	8.77	128.18	5.12	282.71	2.05	614.27	9.54	1247.47	7.02
	20	230+02	6.80	87.77	3.41	171.25	2.40	339.49	-0.33	688.48	6.11	1347.61	3.64
	21	241+15	-11.79	62.22	2.68	143.34	3.10	300.88	-4.40	647.77	3.31	1307.90	4.12
	22	252+19	-0.64	71.98	1.34	150.45	1.03	315.06	1.14	661.37	9.11	1325.98	8.61
	23	263+24	-8.26	42.50	0.68	111.15	1.02	263.94	2.19	603.51	13.81	1251.61	12.94
	24	279+57	-7.33	105.99	-4.65	187.48	-8.85	353.25	-17.92	715.34	-8.72	1393.68	-10.87
	25	290+77	-3.13	58.51	0.12	131.25	-2.92	290.39	-9.66	645.31	1.97	1311.35	-0.84

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2015 to 2016) Cont.

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from May 20, 2015 to May 16, 2016.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)
Emerald Isle Central	26	304+77	6.11	71.05	1.34	146.87	2.39	304.71	2.02	664.82	10.79	1337.66	7.47
	27	318+11	25.97	74.94	3.88	153.48	9.41	312.09	0.43	679.25	9.52	1355.49	5.88
	28	329+10	19.76	71.57	3.16	148.21	12.85	306.18	-2.95	668.74	11.14	1336.42	9.01
	29	345+80	18.80	49.27	3.81	119.38	2.82	276.52	2.86	627.37	15.14	1285.38	14.56
	30	362+22	-47.26	70.87	0.34	149.63	6.82	318.84	12.41	675.79	22.76	1345.15	22.16
	31	378+80	-42.21	56.75	-5.04	130.57	6.77	284.78	-5.31	631.33	9.52	1290.30	8.30
	32	395+22	-2.76	77.73	-2.44	154.43	11.93	321.05	5.19	678.02	18.09	1338.66	12.62
	33	408+86	-5.14	70.83	-6.44	146.35	-4.89	308.45	-12.48	663.72	-3.01	1322.44	-7.03
	34	422+83	-23.47	61.21	-6.56	135.49	5.00	295.91	-3.62	645.63	1.02	1306.84	-2.83
	35	435+62	-46.71	42.73	-6.65	106.90	-1.66	255.70	-14.08	591.16	-9.82	1235.15	-14.80
	36	450+22	7.38	50.18	-3.34	110.03	-4.83	261.92	-21.09	605.58	-11.13	1257.27	-16.69
Emerald Isle East	37	461+34	-7.33	32.88	-3.50	83.56	-12.15	226.20	-20.48	556.40	-14.38	1191.17	-17.72
	38	472+44	-11.52	49.08	-3.51	117.98	-5.93	274.74	-13.29	619.01	-8.22	1268.96	-11.60
	39	483+48	12.97	58.84	2.49	126.56	1.28	283.49	-2.22	635.48	3.92	1306.00	-0.88
	40	494+44	-1.61	33.90	-4.29	98.10	0.78	244.61	-5.02	577.10	1.04	1208.29	-6.53
	41	505+39	27.83	54.88	2.88	128.85	7.79	286.97	-1.80	636.07	4.97	1289.25	-0.32
	42	516+57	-13.18	31.06	-4.06	88.60	8.15	228.23	-12.73	553.64	-5.82	1183.38	-11.55
	43	527+37	-15.88	38.21	-2.69	104.95	-2.47	256.00	-8.42	589.11	-4.75	1232.38	-9.73
	44	538+39	-21.41	59.40	-3.55	138.17	-3.91	305.38	-5.58	654.71	-2.04	1310.86	-7.70
	45	549+45	37.44	52.11	0.44	127.28	-0.04	286.58	-5.10	635.95	1.61	1294.14	-2.66
	46	560+42	16.11	52.84	0.93	124.01	2.71	277.76	1.16	628.95	10.67	1289.82	8.20
	47	571+43	15.76	51.22	1.19	116.55	-3.86	266.10	-12.38	616.59	-3.25	1274.93	-4.93
	48	580+13	26.94	51.92	4.20	112.16	-2.08	265.58	-2.78	619.20	7.12	1283.09	4.67

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2015 to 2016) Cont.

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from May 20, 2015 to May 16, 2016.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)
Indian Beach/Salter Path	49	595+84	13.84	58.89	3.09	122.41	-1.49	281.68	2.05	635.18	9.87	1308.36	6.25
	50	608+06	22.50	73.40	0.19	147.48	17.87	303.49	4.97	658.64	11.77	1340.44	6.40
	51	620+90	8.67	56.12	0.02	113.35	0.15	262.81	-3.18	603.41	1.41	1269.95	-6.08
	52	633+31	15.95	19.09	1.27	65.94	5.76	190.82	-5.32	512.08	0.44	1157.08	-6.14
	53	648+17	12.73	87.16	3.42	170.79	14.71	338.80	6.01	704.76	11.20	1408.85	5.76
	54	660+65	-4.64	116.10	-1.57	208.73	10.42	385.25	-2.58	769.20	7.76	1493.09	1.98
	55	672+30	-12.22	55.87	-4.03	113.58	-1.57	261.96	-14.22	611.54	-11.30	1298.36	-18.30
	56	683+24	-2.32	45.08	-2.61	104.94	-1.69	257.42	-6.72	603.08	1.44	1286.60	-2.66
	57	693+79	35.73	56.69	5.22	118.35	7.64	258.23	-0.53	608.68	10.26	1295.53	6.19
	58	709+05	2.70	46.45	-2.01	103.41	2.86	246.60	-14.15	596.06	-3.33	1284.69	-5.34
Pine Knoll Shores West	59	723+93	20.63	44.14	0.57	99.42	8.49	233.76	-7.04	577.00	-3.56	1268.16	-5.21
	60	736+01	0.01	43.64	0.11	104.16	5.87	247.47	-2.38	587.28	0.63	1278.04	-6.81
	61	748+06	-33.09	62.45	-3.25	127.43	-0.29	287.91	-4.43	645.64	4.85	1360.78	1.28
	62	761+80	-23.12	46.56	-0.01	105.90	1.05	250.50	-3.44	600.50	7.22	1308.44	4.99
	63	774+77	-1.98	42.66	-1.23	100.50	0.48	235.46	-10.22	589.83	-4.27	1303.91	-12.42
	64	787+61	-33.34	45.64	-6.31	96.66	-10.15	240.09	-23.71	598.10	-17.25	1320.83	-21.09
	65	800+91	-20.60	45.91	-7.09	98.19	-8.14	244.71	-22.22	598.65	-19.08	1321.95	-24.93
Pine Knoll Shores East	66	813+33	16.86	49.54	2.28	114.27	15.04	256.74	4.33	609.11	9.97	1336.01	9.76
	67	825+53	10.73	38.84	3.38	93.70	14.43	221.48	-4.15	564.03	-3.66	1284.86	-5.17
	68	840+55	19.69	51.51	5.01	118.13	20.71	264.83	12.14	622.63	12.18	1357.62	9.91
	69	850+84	-16.54	49.60	0.38	108.42	6.61	251.34	-9.48	615.14	-4.81	1358.37	-7.60
	70	863+28	16.91	51.75	0.14	117.37	11.88	279.64	20.52	646.42	22.55	1397.53	17.84
	71	882+23	-23.04	35.68	-2.96	81.96	-6.61	226.49	-4.40	583.91	-7.13	1328.20	-14.40
	72	896+24	-33.99	30.81	-7.02	73.52	-11.79	216.40	-16.76	585.61	-19.06	1346.34	-21.88
	73	910+53	13.74	43.61	1.19	108.64	9.81	274.76	20.56	649.31	18.82	1415.75	15.49
	74	922+70	2.70	47.27	1.42	109.55	10.06	271.96	19.80	648.75	19.52	1420.97	16.40
	75	937+70	15.07	58.86	4.35	124.48	15.83	288.02	14.97	667.31	17.36	1446.93	12.13
	76	948+81	-26.49	43.54	-3.31	101.55	-2.21	244.42	-17.91	613.49	-12.39	1390.34	-14.26

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2015 to 2016) Cont.

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from May 20, 2015 to May 16, 2016.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)
Atlantic Beach	77	961+72	15.35	57.65	2.76	122.34	5.61	265.88	-11.22	636.91	-8.27	1417.15	-12.57
	78	971+20	47.10	44.08	5.00	106.16	17.41	253.39	14.96	625.34	22.00	1402.81	20.59
	79	985+64	-8.09	49.14	-4.21	112.15	1.91	251.25	-21.38	626.34	-18.08	1407.32	-21.91
	80	994+64	-4.23	66.51	-4.02	135.64	-2.30	306.48	-4.35	697.28	1.82	1493.84	-0.96
	81	1005+61	-3.09	55.94	0.21	122.30	-3.15	298.58	-0.75	688.09	4.33	1485.29	-0.53
	82	1012+68	3.51	40.56	5.56	102.94	1.70	259.69	-2.70	639.17	5.85	1425.48	4.52
	83	1022+69	-16.36	29.92	-2.37	78.84	-13.23	219.93	-33.87	594.10	-28.56	1372.38	-34.24
	84	1032+70	-12.40	25.05	-3.16	69.91	-16.11	213.73	-34.43	587.79	-30.52	1370.30	-43.04
	85	1042+73	-23.41	56.62	-2.74	124.43	-6.83	305.47	4.02	703.31	4.31	1516.33	-4.11
	86	1052+75	-12.46	66.53	-1.82	140.22	-11.21	315.62	-22.07	722.01	-24.32	1548.52	-35.07
	87	1062+69	14.95	59.75	1.08	133.95	-1.64	310.08	-2.36	714.50	5.10	1540.63	0.02
	88	1072+62	20.52	83.56	5.25	172.40	2.76	373.59	5.96	797.59	12.18	1653.87	7.01
	89	1082+69	17.15	66.56	5.06	135.00	7.31	305.27	-3.24	701.55	-0.88	1525.44	-7.78
	90	1093+69	17.64	44.33	4.02	123.56	6.28	304.06	2.64	709.09	-3.09	1542.50	-22.41
	91	1102+82	-20.96	43.71	-2.04	102.40	-10.20	257.47	-26.75	637.75	-30.80	1450.26	-42.88
	92	1112+81	-2.96	43.09	3.73	108.02	6.76	277.86	11.20	659.53	8.67	1477.37	1.25
	93	1122+81	0.87	38.63	2.37	106.03	3.47	280.20	9.97	660.88	5.07	1487.25	-5.08
	94	1131+73	1.66	63.42	1.11	160.42	-0.01	366.14	-4.55	789.71	-5.63	1664.60	-12.88
	95	1141+97	8.16	73.27	-1.85	147.90	-14.48	329.41	-9.34	738.42	-12.35	1591.00	-23.55
	96	1151+92	-10.45	71.68	-3.77	157.20	-11.69	342.31	-21.23	748.67	-24.66	1597.44	-34.01
	97	1161+91	-18.41	70.22	-3.45	159.35	-6.92	351.08	-2.81	753.74	-2.63	1590.33	-7.72
	98	1171+91	-54.98	64.23	-7.81	140.26	-20.08	312.37	-26.52	704.78	-24.31	1525.75	-26.37
	99	1182+17	-28.35	60.55	-6.74	149.72	-11.14	323.30	-26.64	714.91	-21.53	1546.47	-18.85
	100	1191+90	-45.85	140.49	0.93	275.97	-4.27	505.63	-14.49	951.49	-15.01	1902.66	-30.81
	101	1201+93	-19.90	104.04	3.88	207.13	-3.29	405.64	-3.85	784.43	-5.45	1709.82	-11.50
	102	1211+94	-0.96	130.48	5.04	237.22	-1.37	430.71	-15.96	803.01	-13.27	1785.59	-17.90

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2015 to 2016) Cont.

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from May 20, 2015 to May 16, 2016.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)
Fort Macon	103	1222+11	8.91	60.69	-0.30	134.33	-5.25	290.01	-19.62	625.88	-16.95	1716.60	-17.06
	104	1231+86	20.75	88.94	4.01	184.83	12.02	369.76	21.31	755.33	18.09	1953.09	19.44
	105	1241+79	78.07	99.89	18.40	212.47	43.68	416.83	61.13	841.40	62.21	2069.44	57.55
	106	1251+79	10.94	91.60	9.71	193.72	23.57	396.06	34.16	915.24	24.50	2175.41	24.15
	107	1257+09	-32.35	113.29	0.90	219.00	1.57	424.79	10.85	1040.37	-20.85	2308.04	-20.31
	108	1261+80	-17.12	60.44	1.28	132.00	-0.73	310.16	23.79	947.52	-8.90	2162.11	-9.64
	109	1267+13	9.35	88.89	5.08	176.28	2.47	382.27	43.67	1143.82	85.39	2443.90	86.14
	110	1271+73	60.20	88.06	12.44	177.98	20.50	362.56	53.50	1132.12	84.27	2402.70	84.78
	111	1278+93	108.64	72.90	17.96	168.70	22.00	355.93	39.96	1448.36	80.45	2556.27	81.18
	112	1283+93	122.50	74.35	16.96	189.94	16.17	384.69	23.45	1681.13	22.02	2968.28	22.03
Beaufort Inlet	112B	0+00	197.46	83.49	23.34	241.68	43.21	540.32	34.78	998.37	74.53	1678.71	113.66
	113	5+00	97.27	100.74	5.69	322.33	22.32	639.72	2.31	1117.00	1.75	1731.01	-2.23
	114	10+00	28.09	95.09	2.95	319.85	11.12	623.61	20.35	1005.08	29.74	1521.63	28.24
	115	15+00	-85.81	107.03	1.64	282.36	-16.93	503.31	-35.22	774.68	-44.74	1160.94	-31.15
	116	20+00	-9.96	46.50	-1.26	107.98	-4.88	211.88	-9.84	347.86	-12.67	538.53	-15.40
Bogue Inlet	117B	0+00	-	-	-	-	-	-	-	-	-	-	-
	117	5+00	-	-	-	-	-	-	-	-	-	-	-
	118	10+00	-	-	-	-	-	-	-	-	-	-	-
	119	15+00	-	-	-	-	-	-	-	-	-	-	-
	120	20+00	-	-	-	-	-	-	-	-	-	-	-

Table D-2. Summary of Shoreline Change and Volume Change Along Bear Island (2015 to 2016)

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from June 4, 2015 to March 16, 2016.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)
Bear Island	1	0+00	-273.70	0.00	-3.14	21.07	-28.73	309.70	10.32	1086.03	56.96	2374.78	52.20
	2	10+00	-33.56	49.99	-2.30	177.86	21.32	478.97	-8.66	1192.52	-14.38	2447.45	-17.84
	3	20+00	-27.39	25.69	-2.27	91.64	4.13	288.26	-2.88	815.82	36.24	1880.83	31.00
	4	30+00	-46.96	15.41	-8.26	63.60	-16.37	234.01	-6.49	648.09	1.31	1628.37	-2.76
	5	40+00	9.85	15.32	-0.17	70.18	0.63	235.94	5.79	604.22	4.48	1535.19	4.78
	6	50+00	-28.33	11.71	-2.89	62.68	-9.99	214.65	-20.52	574.09	-22.06	1465.42	-22.19
	7	60+00	-30.86	128.46	10.08	208.52	9.44	395.70	6.54	794.73	9.52	1713.00	11.44
	8	70+00	-31.76	22.75	-3.93	84.43	8.41	253.00	8.15	618.99	11.98	1470.42	11.56
	9	80+00	-32.20	20.44	-7.70	74.84	-12.94	235.84	-15.36	597.20	-13.22	1432.57	-17.89
	10	90+00	-0.11	11.92	-6.82	71.18	-2.69	236.88	3.06	591.60	9.68	1409.34	6.25
	11	100+00	-11.32	15.87	-5.77	70.24	-10.57	232.64	-1.68	587.02	4.66	1407.29	0.33
	12	110+00	-34.52	30.55	-4.65	88.79	-12.59	256.81	-11.44	613.31	-6.79	1440.68	-9.84
	13	120+00	-23.97	17.12	-6.38	73.70	-12.67	237.89	-12.16	592.90	-4.84	1431.16	-6.48
	14	130+00	-36.91	21.78	-3.68	86.05	-11.27	252.09	-16.79	618.50	-13.37	1490.87	-21.46
	15	140+00	-56.66	11.24	-14.09	63.31	-25.62	222.90	-28.37	595.67	-22.17	1503.51	-24.79
	16	150+00	-27.46	12.64	-11.68	70.01	-19.98	236.27	-28.81	629.68	-23.86	1558.42	-27.57
	17	160+00	-36.69	18.29	-7.00	87.22	-14.16	258.40	-38.23	676.32	-27.21	1633.71	-27.34
	18	170+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-3. Summary of Shoreline Change and Volume Change Along Shackleford Banks (2015 to 2016)

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from March 10, 2015 to March 8, 2016.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)	2016 Measured Volume (cy/ft)	2015-2016 Volume Change (cy/ft)
Shackleford Banks	1	0+00	-14.25	3.93	-0.98	199.99	13.23	990.31	23.36	2092.99	31.57	4007.20	65.47
	2	20+51	-4.17	24.34	0.90	192.04	4.10	511.84	3.07	1048.93	-11.49	2112.13	-13.31
	3	40+80	-19.63	58.98	0.70	201.96	-1.03	472.37	-2.92	826.49	-3.72	1522.08	-12.72
	4	58+81	53.25	54.95	5.31	138.86	15.77	328.68	23.58	628.80	26.51	1499.73	79.60
	5	77+99	-4.78	4.99	0.17	38.06	6.41	156.06	20.04	405.24	22.71	1087.18	20.49
	6	96+76	-31.13	3.93	-1.60	33.41	-3.07	137.21	-11.06	386.12	-3.41	1168.88	1.39
	7	113+28	-26.91	16.73	-3.61	50.43	-14.23	164.32	0.01	426.33	2.76	1194.83	10.93
	8	130+01	-39.08	12.48	-1.14	55.18	-6.09	171.33	-2.18	442.13	-5.12	1165.23	10.63
	9	152+46	-18.14	21.03	1.17	66.16	3.27	184.42	12.31	475.55	7.53	1229.37	5.59
	10	170+79	25.70	32.42	4.00	78.81	7.86	193.71	14.96	492.02	11.15	1238.76	2.42
	11	190+43	-16.37	44.90	-0.70	115.00	-6.97	244.42	-17.25	572.19	-18.57	1351.68	-22.32
	12	210+07	-14.04	11.09	-1.90	54.05	-7.28	160.11	-7.70	446.50	0.77	1151.60	11.38
	13	229+21	-33.92	17.72	-6.97	53.40	-16.52	183.27	1.49	480.31	-3.14	1202.96	-9.28
	14	248+63	-19.02	6.90	-4.53	34.19	-11.63	149.71	-7.71	434.53	-10.06	1099.21	-13.99
	15	272+15	-17.76	10.07	-4.00	45.02	0.43	152.12	5.64	443.00	9.89	1103.27	7.33
	16	293+38	12.12	55.19	0.89	112.58	3.26	233.37	-5.71	547.73	-5.57	1284.67	-2.51
	17	322+18	-2.18	59.54	-6.88	113.41	-7.77	236.16	-6.16	557.87	-13.27	1323.71	-6.16
	18	343+08	-17.10	32.66	1.48	81.72	-1.47	198.31	10.03	515.84	6.60	1300.92	13.71
	19	363+54	19.27	62.40	-4.18	132.73	-7.71	271.46	-10.73	624.37	-13.98	1495.67	-9.06
	20	383+92	-35.49	2.66	-11.64	20.72	-23.64	113.93	-62.82	436.99	-72.83	1408.84	-80.81
	21	405+26	-130.99	0.00	-14.40	5.08	-41.53	93.12	-78.59	507.80	-96.89	1801.05	-97.04
	22	423+85	-181.38	0.05	-19.78	13.22	-66.85	185.13	-81.12	829.88	-139.30	2793.12	-174.80
	23	444+92	0.00	0.00	0.00	0.00	-26.91	230.64	-141.97	970.52	-173.78	2534.18	-170.23
	24	460+01	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E

Statistics Tables

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2016)

Average Annual Volume Change (2008-2016)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Bogue Inlet-Ocean	1	0+00	8.90	16.28	13.26	56.36	-6.17	72.02	-36.95	74.98	-36.51	83.14
	2	5+59	6.91	11.60	8.96	19.44	-10.52	28.55	-38.59	23.17	-45.13	23.90
	3	11+23	0.93	9.37	1.09	22.75	-16.92	33.42	-37.56	44.40	-45.42	51.08
	4	17+39	-0.77	6.96	0.27	19.16	-3.45	38.36	-14.24	40.27	-14.83	46.74
	5	23+22	0.36	9.12	-0.64	16.83	-1.39	23.72	-10.64	22.73	-11.96	25.05
	6	36+28	-0.26	4.75	-0.54	9.25	1.69	23.61	-3.80	22.91	-4.37	26.60
	7	53+10	-0.15	6.01	1.67	13.50	3.72	14.24	0.88	14.76	-1.58	15.17
	8	67+74	0.07	5.60	1.51	8.85	3.92	21.25	4.25	15.84	2.71	14.00
Emerald Isle West	9	80+91	0.77	6.14	2.84	5.86	2.93	18.49	2.76	23.45	1.43	25.03
	10	93+40	-0.86	8.05	-0.86	10.22	-0.36	12.93	0.71	11.98	0.66	8.33
	11	108+58	-0.28	5.74	1.81	10.84	3.64	21.24	4.30	18.34	3.64	15.63
	12	121+18	-0.73	3.85	-0.02	3.85	0.49	14.20	1.99	15.41	2.27	16.68
	13	134+61	-2.28	5.60	-2.01	7.56	0.84	7.23	1.89	11.53	2.02	14.29
	14	146+67	-1.54	6.06	-1.32	8.35	-1.07	16.04	-0.16	16.10	-0.32	18.83
	15	160+16	-1.28	4.65	-0.58	5.65	-0.56	9.91	0.97	11.83	1.29	12.29
	16	174+79	-0.86	4.98	0.22	6.70	0.45	11.77	1.26	12.53	1.51	9.68
	17	189+23	-0.15	6.61	0.61	9.47	1.64	15.26	2.41	17.06	1.54	16.53
	18	203+53	0.55	5.50	-0.47	9.51	-1.28	15.05	-0.42	14.00	-1.17	11.04
	19	214+90	1.21	6.38	2.37	5.68	1.63	9.85	2.75	12.70	2.24	13.05
	20	230+02	-0.40	5.81	2.54	3.19	2.30	9.72	3.74	11.04	3.72	9.06
	21	241+15	0.46	3.56	2.55	7.24	2.16	10.31	3.42	11.98	4.48	18.88
	22	252+19	0.94	4.74	2.77	4.26	2.87	9.57	4.26	11.95	4.73	7.87
	23	263+24	-0.55	5.03	0.86	3.87	1.24	11.99	3.21	17.22	3.61	13.17
	24	279+57	-0.54	7.32	0.65	6.51	-1.15	16.65	-0.24	21.40	-0.16	17.70
	25	290+77	-0.55	7.25	1.03	7.70	0.35	11.04	0.87	14.08	0.39	9.51

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2016) Cont.

Average Annual Volume Change (2008-2016)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Emerald Isle Central	26	304+77	-0.50	5.69	1.45	8.90	1.29	13.85	1.83	16.98	1.82	12.90
	27	318+11	-0.67	4.91	0.67	7.11	0.76	10.28	0.85	15.25	0.49	12.40
	28	329+10	-0.36	4.49	0.03	9.24	-1.77	23.97	-1.49	17.73	-1.84	15.97
	29	345+80	-0.81	7.22	0.75	6.97	3.00	22.91	3.14	29.58	2.20	28.09
	30	362+22	-0.51	5.01	0.75	12.35	2.09	15.30	3.46	20.84	3.83	17.48
	31	378+80	0.21	4.13	2.42	8.42	3.57	17.05	4.51	23.95	8.01	20.03
	32	395+22	-0.83	3.98	-1.13	11.28	-3.62	26.32	-3.03	27.87	-4.25	27.67
	33	408+86	-0.75	5.41	0.10	10.10	0.22	17.51	1.65	18.19	0.70	15.50
	34	422+83	-1.76	8.30	-1.23	5.75	-2.21	14.10	-1.90	12.79	-3.16	11.34
	35	435+62	-3.35	4.11	-5.18	4.71	-6.53	11.50	-7.03	7.67	-8.53	7.82
	36	450+22	-2.30	4.13	-4.19	7.82	-4.24	17.58	-2.69	15.27	-4.02	12.06
Emerald Isle East	37	461+34	-2.93	6.91	-4.15	11.12	-4.72	26.75	-3.26	24.81	-4.34	25.34
	38	472+44	-2.08	3.41	-3.35	3.97	-4.39	10.34	-3.35	6.16	-3.40	9.05
	39	483+48	-3.16	4.23	-4.37	5.55	-3.72	11.17	-2.37	14.63	-2.25	13.49
	40	494+44	-3.19	6.13	-4.29	8.94	-5.20	15.99	-3.64	16.43	-4.56	17.82
	41	505+39	-2.95	5.06	-3.02	10.65	-4.63	19.88	-2.57	23.05	-2.69	20.88
	42	516+57	-4.05	6.52	-5.43	14.43	-8.32	22.83	-6.28	26.56	-6.67	27.21
	43	527+37	-2.63	6.04	-2.59	7.87	-3.22	19.37	-1.61	23.02	-1.60	21.72
	44	538+39	-2.18	5.92	-1.81	6.15	0.52	6.84	2.13	9.71	2.04	11.35
	45	549+45	-2.76	4.96	-3.45	5.78	-3.43	9.79	-1.73	12.39	-1.48	10.28
	46	560+42	0.46	3.28	1.64	4.79	2.39	7.55	3.83	7.55	3.98	15.65
	47	571+43	0.01	6.52	0.40	12.11	0.27	12.62	1.16	16.70	2.21	22.31
	48	580+13	-0.29	6.38	-0.87	11.52	-2.34	30.19	-1.16	33.34	-0.39	30.86

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2016) Cont.

			Average Annual Volume Change (2008-2016)									
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Indian Beach/Salter Path	49	595+84	-0.76	4.67	-1.48	5.44	-2.68	12.70	-1.24	18.16	-0.09	15.28
	50	608+06	-1.13	6.73	-0.63	10.86	-2.45	13.78	-1.70	12.93	-2.34	8.58
	51	620+90	-0.97	5.89	-1.67	7.62	-3.12	18.36	-2.74	21.97	-3.10	19.47
	52	633+31	-1.39	4.47	-1.99	6.92	-3.16	10.75	-2.86	15.19	-3.27	12.12
	53	648+17	0.36	3.57	0.37	7.86	-0.51	12.57	0.09	13.95	0.50	14.07
	54	660+65	0.72	6.09	0.73	11.00	-0.41	16.80	1.11	18.63	1.87	18.42
	55	672+30	-0.22	6.30	-0.95	11.51	-2.16	15.69	-1.03	13.30	-0.58	16.47
	56	683+24	-0.90	5.19	-1.31	5.39	-1.50	15.65	-0.14	15.09	0.78	13.76
	57	693+79	-0.78	5.82	-1.13	7.34	-3.25	13.24	-2.02	15.13	-1.43	15.22
	58	709+05	-1.45	6.21	-2.69	9.66	-5.14	18.26	-3.80	19.75	-2.51	21.57
Pine Knoll Shores West	59	723+93	-0.58	2.97	-2.39	7.22	-4.59	11.39	-3.93	19.88	-4.02	14.93
	60	736+01	0.67	4.21	1.76	8.22	0.74	12.60	2.48	15.40	2.91	14.99
	61	748+06	0.22	5.72	0.66	9.89	0.49	21.37	2.66	22.79	3.14	20.78
	62	761+80	-0.78	5.45	-0.89	8.81	-2.36	6.44	-1.72	15.38	-3.44	16.81
	63	774+77	-2.95	7.28	-4.98	10.86	-8.48	32.18	-7.03	29.43	-7.81	37.19
	64	787+61	-2.73	5.21	-6.47	4.59	-10.53	11.03	-8.45	16.32	-8.29	18.19
	65	800+91	-2.90	7.64	-6.06	5.64	-8.28	16.73	-5.45	22.54	-5.22	21.03
Pine Knoll Shores East	66	813+33	-1.71	5.42	-2.63	9.79	-5.62	13.01	-4.03	16.98	-5.22	15.84
	67	825+53	-0.91	5.10	-1.89	10.29	-2.67	11.37	-1.50	13.70	-1.91	12.92
	68	840+55	-0.29	4.72	-0.93	9.90	-2.37	11.73	-0.90	11.89	-1.52	11.10
	69	850+84	-1.74	6.11	-2.25	8.21	-2.84	10.51	-0.99	15.35	-1.02	14.12
	70	863+28	-1.63	7.60	-2.21	9.75	-1.10	14.64	0.68	17.71	1.03	17.16
	71	882+23	-1.22	5.99	-3.27	6.77	-3.69	14.67	-3.21	24.64	-4.80	25.60
	72	896+24	-1.62	4.29	-3.78	4.09	-5.58	10.74	-4.48	17.23	-3.60	18.20
	73	910+53	0.13	4.68	1.15	8.60	4.10	15.16	5.20	24.70	5.26	22.04
	74	922+70	-0.95	5.39	-1.26	9.98	-0.68	14.74	1.99	17.26	4.32	20.15
	75	937+70	0.76	5.19	0.58	11.70	3.09	11.50	2.11	18.02	1.50	17.67
	76	948+81	-1.20	7.44	-2.50	6.08	-4.87	10.99	-5.52	16.94	-5.92	16.46

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2016) Cont.

Reach	Transect Number	Station	Average Annual Volume Change (2008-2016)									
			Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Atlantic Beach	77	961+72	-1.19	3.87	-1.77	4.95	-6.40	12.87	-7.27	15.74	-8.06	18.39
	78	971+20	-1.62	4.25	-1.99	10.80	-4.36	12.56	-4.58	22.41	-5.79	24.78
	79	985+64	0.15	4.89	1.18	8.05	-1.15	13.26	-1.03	18.02	-1.74	22.01
	80	994+64	1.08	4.34	1.53	10.02	-0.17	10.44	0.19	11.94	0.03	14.45
	81	1005+61	0.60	3.80	0.82	5.19	1.61	13.90	1.21	18.84	0.25	22.33
	82	1012+68	0.86	5.93	1.34	9.12	1.32	14.42	0.67	24.37	-0.10	27.60
	83	1022+69	-0.17	4.87	-0.05	7.99	-0.92	17.20	-2.03	18.82	-3.18	22.60
	84	1032+70	-0.90	3.07	-1.20	10.44	-2.36	16.44	-2.57	18.01	-2.82	26.04
	85	1042+73	-1.43	2.36	-3.08	7.50	-4.47	14.68	-4.22	16.37	-4.32	20.04
	86	1052+75	-1.33	3.10	-2.32	9.52	-4.39	13.63	-5.33	12.94	-6.05	17.86
	87	1062+69	-1.16	4.50	-1.72	6.31	-3.29	8.06	-3.18	9.21	-3.22	11.33
	88	1072+62	-1.46	4.88	-1.48	3.70	-1.60	9.11	-1.64	12.46	-2.62	17.44
	89	1082+69	0.33	5.16	0.13	6.46	0.36	4.66	-0.52	7.26	-1.83	14.99
	90	1093+69	-3.30	8.17	-2.83	17.34	-6.78	20.38	-7.19	26.09	-9.26	34.02
	91	1102+82	-3.70	8.37	-3.77	14.54	-9.63	25.38	-11.35	31.75	-14.91	39.23
	92	1112+81	-2.88	8.51	-0.81	11.39	-4.94	24.77	-6.07	30.01	-8.21	34.59
	93	1122+81	-3.59	6.85	-1.71	9.64	-7.43	12.42	-10.20	13.89	-13.61	15.33
	94	1131+73	1.10	4.83	1.63	7.93	2.74	7.15	0.76	6.18	-3.20	7.95
	95	1141+97	1.99	4.23	1.81	10.26	1.36	13.08	0.52	15.55	-2.86	22.35
	96	1151+92	-2.41	4.56	0.27	11.96	-4.00	16.07	-4.99	15.13	-9.07	18.12
	97	1161+91	-1.44	4.52	1.40	13.65	-3.02	11.32	-4.16	11.61	-7.88	15.27
	98	1171+91	-5.23	14.39	-1.96	38.20	-15.11	33.90	-15.43	34.75	-19.01	44.25
	99	1182+17	-4.44	17.89	0.43	42.44	-11.30	44.98	-11.19	46.62	-15.79	53.83
	100	1191+90	-2.49	8.92	2.90	29.29	-9.28	21.85	-9.45	22.70	-13.24	26.82
	101	1201+93	-2.04	5.21	2.49	16.05	-8.38	10.99	-9.51	13.33	-15.72	28.36
	102	1211+94	-1.94	6.90	2.69	17.79	-8.64	19.31	-9.56	20.58	-12.86	30.01

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2016) Cont.

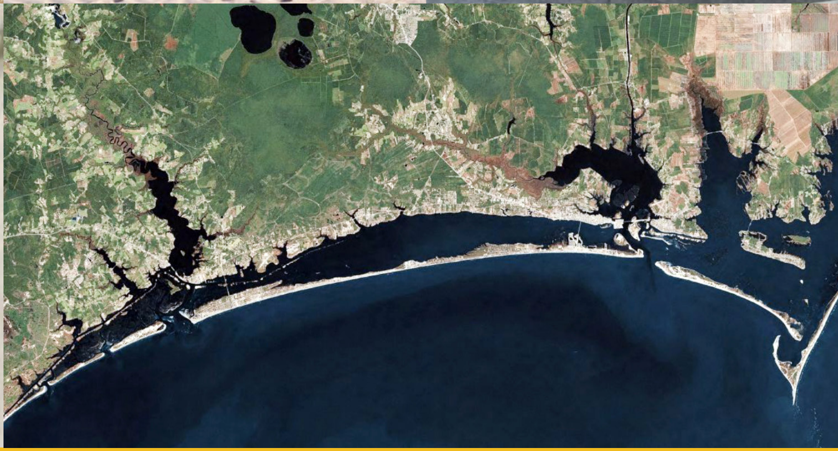
Average Annual Volume Change (2008-2016)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Fort Macon	103	1222+11	-4.32	6.67	-2.43	13.56	-15.38	15.20	-18.80	21.83	-24.99	44.31
	104	1231+86	-1.58	7.23	2.97	21.85	-9.06	27.36	-10.49	28.07	-12.11	33.85
	105	1241+79	-4.13	12.75	0.88	36.99	-11.10	46.17	-8.08	50.79	-9.86	51.41
	106	1251+79	-6.63	9.38	-5.06	30.05	-23.30	27.85	-21.10	27.45	-22.41	34.12
	107	1257+09	-5.86	9.75	-3.76	17.22	-15.74	32.31	-12.69	24.99	-13.37	25.37
	108	1261+80	-1.30	5.50	0.96	18.91	0.92	27.55	2.90	38.81	3.57	38.23
	109	1267+13	-1.31	7.75	0.05	11.18	0.73	24.64	10.45	43.27	10.52	43.26
	110	1271+73	-0.74	11.89	1.43	18.49	1.06	36.78	5.79	53.94	5.91	54.65
	111	1278+93	1.53	9.74	5.56	23.49	6.69	31.54	32.67	73.80	47.38	60.22
	112	1283+93	3.53	6.60	8.23	22.70	8.35	24.11	38.03	92.79	39.48	95.39

Table E-2. Summary of Average Annual Volume Change Statistics Along Bear Island (2008 to 2016)

Average Annual Volume Change (2008-2015)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Bear Island	1	0+00	-2.82	11.97	-9.35	33.84	-3.00	86.67	22.33	142.37	22.61	146.86
	2	10+00	0.15	4.59	2.55	20.69	8.94	66.18	30.28	84.05	31.69	89.19
	3	20+00	0.62	6.21	2.37	15.08	6.16	28.79	19.82	36.85	20.83	39.11
	4	30+00	-1.00	5.26	-1.12	12.82	-0.66	11.92	0.92	12.16	-0.28	12.71
	5	40+00	-2.22	4.67	-2.47	11.08	-1.86	12.37	-4.57	13.81	-5.14	18.67
	6	50+00	-2.19	5.51	-2.48	9.94	-2.98	17.60	-5.68	18.93	-6.45	22.57
	7	60+00	-3.63	12.82	-3.75	11.80	-5.11	10.48	-7.23	20.28	-7.81	28.60
	8	70+00	-0.25	4.06	-0.36	4.99	-0.10	7.65	-2.25	11.45	-3.70	18.98
	9	80+00	-1.65	4.34	-2.70	6.98	-3.66	10.77	-6.35	7.87	-7.89	13.59
	10	90+00	-1.94	3.65	-1.41	10.96	-1.66	15.25	-4.62	13.95	-6.81	18.08
	11	100+00	-1.51	4.45	-2.28	9.08	-3.36	10.90	-6.37	7.84	-8.90	8.42
	12	110+00	-0.57	4.59	-1.01	8.04	-1.95	6.63	-5.52	7.98	-9.26	13.14
	13	120+00	-2.63	5.28	-3.24	9.86	-4.08	11.35	-7.78	8.55	-11.93	15.72
	14	130+00	-1.89	5.18	-2.67	10.99	-3.55	17.78	-7.29	17.97	-12.31	22.42
	15	140+00	-3.52	5.90	-5.10	10.33	-6.69	12.68	-10.31	10.01	-15.63	13.21
	16	150+00	-3.05	9.08	-4.95	19.96	-7.26	28.82	-9.30	35.81	-13.81	43.72
	17	160+00	-0.94	7.44	-2.50	18.91	-6.32	38.85	-10.66	35.00	-15.73	33.87
	18	170+00	-	-	-	-	-	-	-	-	-	-

Table E-3. Summary of Average Annual Volume Change Statistics Along Shackleford Banks (2008 to 2016)

Average Annual Volume Change (2008-2016)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Shackleford Banks	1	0+00	-0.77	0.90	8.09	20.76	15.31	25.32	16.29	26.78	26.63	32.40
	2	20+51	1.07	1.50	3.46	4.82	-1.19	9.26	-7.89	12.82	-9.62	24.13
	3	40+80	3.36	3.70	6.14	7.39	7.91	9.00	8.01	10.23	-0.54	17.34
	4	58+81	2.27	2.88	5.38	4.86	9.80	6.37	10.29	7.88	22.69	30.29
	5	77+99	-0.75	2.46	-1.32	5.42	-1.62	11.77	-5.33	19.82	-15.49	22.44
	6	96+76	-0.97	2.60	-2.17	6.00	-3.67	15.94	-6.46	18.70	-5.25	20.74
	7	113+28	-1.13	3.14	-2.31	7.62	-2.62	14.49	-6.00	15.52	-8.50	18.21
	8	130+01	-0.04	2.59	-0.71	5.34	-1.33	6.29	-5.22	3.82	-8.90	19.39
	9	152+46	0.08	4.13	-0.84	5.42	-2.67	14.81	-4.52	19.93	-7.59	25.84
	10	170+79	-0.12	3.44	-1.07	7.11	-0.34	12.01	-3.32	13.09	-4.15	17.78
	11	190+43	-1.54	2.91	-2.89	9.59	-5.33	16.91	-7.92	21.12	-10.27	28.27
	12	210+07	-3.74	10.36	-4.67	13.26	-6.41	19.96	-8.20	17.99	-10.71	26.48
	13	229+21	-2.18	6.54	-3.86	10.76	-2.64	13.36	-4.45	17.82	-6.65	23.53
	14	248+63	-2.16	7.19	-4.99	8.63	-5.81	15.26	-8.87	18.58	-11.61	22.91
	15	272+15	-0.38	5.15	-0.71	7.14	1.03	4.69	0.14	8.84	0.12	9.45
	16	293+38	-0.54	4.58	-1.65	9.76	-1.86	16.19	-5.21	14.52	-4.06	19.82
	17	322+18	-1.06	4.80	-1.55	7.34	-1.29	10.84	-5.52	14.39	-8.20	21.64
	18	343+08	-1.00	5.68	-0.89	10.47	-0.56	21.52	-5.19	18.12	-5.38	21.75
	19	363+54	-3.68	9.70	-3.91	14.92	-3.36	27.10	-6.86	21.01	-12.39	24.12
	20	383+92	-7.19	8.44	-12.52	10.81	-17.62	30.04	-23.18	26.21	-29.98	25.63
	21	405+26	-10.30	10.28	-22.87	22.34	-35.19	31.15	-49.09	37.91	-48.56	46.35
	22	423+85	-15.30	15.42	-38.13	36.77	-50.17	54.88	-80.73	97.21	-94.08	167.51
	23	444+92	-18.82	14.38	-70.92	81.21	-121.35	119.08	-137.07	134.46	-139.95	142.30
	24	460+01	-23.50	26.13	-55.19	43.83	-100.00	74.10	-108.55	92.16	-91.31	104.36



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