FINAL REPORT

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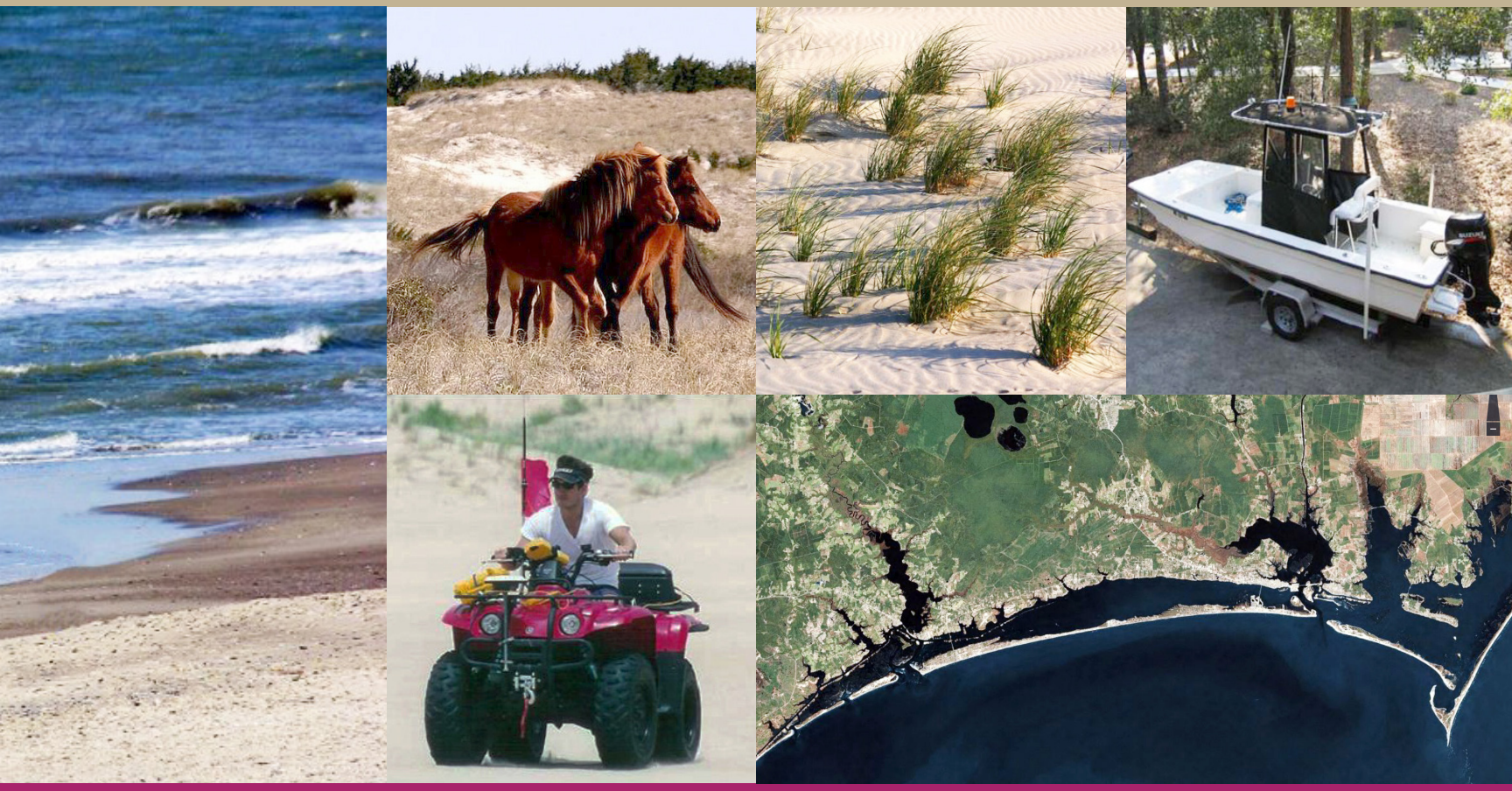

Bogue Banks Beach
and Nearshore Mapping Program

December 2014

moffatt & nichol

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Executive Summary

Comprehensive surveying of the Bogue Banks shoreline began in 1999 to develop the Bogue Banks Beach Restoration Project. In Spring 2004, the Bogue Banks Beach and Nearshore Mapping Program was initiated to assess beach conditions and form strategies for future beach nourishment projects. Bear Island was added to the program in October 2004 and Shackleford Banks was added in May 2005. Currently, surveys are performed annually during 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 2014 by Geodynamics. For this evaluation, the spring/summer 2014 survey was compared with the spring/summer 2013 survey to assess the changes in the beach 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).

Key statistics were computed for defined regions along the Bogue Banks shoreline, Bear Island, and Shackleford Banks between the 2013 and 2014 survey profiles including;

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Banks Oceanfront (1-112)	128,393	8.7	1.6	207,286	6.7	864,617	9.3	1,190,683	10.2	1,306,571	7.2	921,954
Bogue Banks County Project (9-76)	88,094	-10.3	-1.7	-151,559	2.0	173,450	1.9	168,803	3.9	344,611	1.2	109,950
Bear Island (1-18)	16,500	-22.0	-2.4	-39,033	0.0	-676	5.2	85,216	3.9	65,060	2.8	46,051
Shackleford Banks (1-24)	46,001	-60.1	-4.0	-186,222	-8.8	-403,748	-14.6	-671,231	-21.3	-980,665	-23.5	-1,082,016

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

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	13.1	-0.6	-4,354	2.5	18,535	1.6	11,826	-6.9	-51,174	-9.4	-69,639
Emerald Isle-West (9-25)	22,344	-10.2	-1.8	-39,609	5.0	112,404	6.8	152,049	4.3	95,596	0.4	8,998
Emerald Isle-Central (26-36)	15,802	-23.9	-4.0	-62,907	1.5	23,144	-0.1	-1,999	1.0	15,834	-2.4	-37,964
Emerald Isle-East (37-48)	13,220	5.3	-1.3	-17,722	2.6	34,974	2.0	26,034	4.5	59,774	2.5	33,022
Indian Beach-Salter Path (49-58)	12,850	-1.9	-2.0	-25,716	4.8	62,219	4.6	58,729	9.6	123,056	9.2	118,733
Pine Knoll Shores-West (59-65)	9,063	-19.1	-1.7	-15,840	-0.8	-7,008	-0.9	-7,812	5.4	48,694	5.0	45,413
Pine Knoll Shores-East (66-76)	14,815	-11.8	0.7	10,236	-3.5	-52,282	-3.9	-58,200	0.1	1,656	-3.9	-58,253
Atlantic Beach (77-102)	26,176	41.1	8.7	228,589	14.0	365,764	21.9	573,232	22.2	579,829	18.0	471,512
Fort Macon State Park (103-112)	6,691	126.8	20.1	134,611	45.9	306,869	65.3	436,823	64.8	433,305	61.3	410,131
Beaufort Inlet (112B-116)	2,000	40.2	8.7	17,348	11.2	22,349	0.6	1,199	10.9	21,707	16.0	31,967
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

The Bogue Banks oceanfront shoreline has experienced overall accretion at MHW over the past year. However, this is heavily influenced by the impact of the Morehead City Harbor Maintenance Dredging project which occurred in Fort Macon and Atlantic Beach just before the 2014 survey was performed. A look at the County Project numbers indicates a trend of shoreline recession at MHW most of in the reaches that were not nourished (Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores). The volumetric analysis indicates an overall gain of sand along the oceanfront above MHW, -5 ft NAVD88, -12 ft NAVD88, -20 ft NAVD88, and -30 ft NAVD88. Once again, this is heavily influenced by the 1,107,585 cy of material placed in Fort Macon and Atlantic Beach just before the survey was performed. The County Project numbers indicate a loss of material above MHW but a gain of material above all other elevations

in a majority of the reaches not affected by nourishment (Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores). This is an indication of material being pulled from the recreational/visible beach to an elevation below MHW but still within the system. Of importance is the storm protection estimated by the volume of sand above -12 ft NAVD88 along the oceanfront. Approximately 1.19 million cy of material was gained above -12 ft NAVD88, most of this coming from the Morehead City Harbor Maintenance Dredging project. A look at the County Project, which was unaffected by the nourishment, indicates that those reaches also experienced a slight gain in material above -12 ft NAVD88 of approximately 168,800 cy.

The Post-Irene Renourishment Project (February/March 2013) performance was also analyzed by comparing the 2014 survey data with post-fill surveys taken at the time of the project. It is apparent that some material has been lost from the upper elevations of the profile (berm & beachface). **However, M&N is confident that this material has been captured above -12 ft NAVD88 and is still within the system, providing protection to the beach.**

In addition, FEMA beach maintenance calculations were performed to estimate the amount of material remaining on the beach in excess of the baseline nourishment condition established by the Phase I, Phase II, and Phase III components of the Bogue Banks Beach Restoration Project (County Project). It was determined that the Phase I, Phase II, and Phase III project reaches contain more sand than was originally in place after the earlier baseline projects with 129%, 129%, and 235% remaining in each reach, respectively. These numbers were very similar to this calculated in 2013. The most change was seen in Pine Knoll Shores East which has lost some material and dropped from 104% to 96%.

Bear Island appears to have experienced a moderate amount of shoreline recession over the past year. As with Bogue Banks, volumetric calculations indicate a loss in material above MHW but a gain in material at lower elevations which is indicative of material being pulled from the recreational/visible beach to lower elevations but still remaining within the system. Most importantly, there was a gain of approximately 85,200 cy of material above -12 ft NAVD88.

Shackleford Banks appears to have experienced a significant amount of shoreline recession and volume loss. The majority of the shoreline recession and volume loss was located at Transects 21-24, adjacent to Beaufort Inlet, including major losses to the both the dunes and beachface. The remaining transects along Shackleford Banks (1-20) appear to have been impacted similar to Bogue Banks and Bear Island with losses of material above MHW and capture of that material at lower elevations, remaining in the system and providing protection to the beach. Approximately 601,000 cy of the total 671,200 cy lost above -12 ft NAVD88 was located in Transects 21-24 near Beaufort Inlet.

It is expected that next year's annual monitoring report will be performed under the new Bogue Banks Master Beach Nourishment Plan. The transition will bring with it slightly new management reaches and nourishment triggers. However, the types of analysis performed will remain consistent with previous monitoring reports. In fact, a preliminary assessment of current conditions compared to the new triggers was completed as part of this report. The new overall weighted trigger for the island is 233 cy/ft above -12 ft NAVD88, with varying triggers in each management reach. Using historical erosion rates (background and storm), it would appear that the next nourishment action may be need within 3-6 years if there is significant storm activity. Otherwise, the next nourishment action is not expected for 8-12 years.

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1.0 Objective

The Bogue Banks Beach and Nearshore Mapping Program (BBBNMP) is sponsored by Carteret County and formally began in June 2004 as a continuation of a monitoring program initiated in 1999 for assessing beach conditions and forming strategies for the Bogue Banks Beach Restoration Project or County Project (Phases I, II, and III). Bear Island was first surveyed and added to the BBBNMP in October 2004 while Shackleford Banks was added in May 2005. Since May 2005, surveys along Bogue Banks, Bear Island, and Shackleford Banks have been performed annually during the spring/summer timeframe. In addition, Bogue Banks is also surveyed 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 was completed during spring and summer of 2014 by Geodynamics LLC (Geodynamics). This report documents the data sources, methods, and results of a survey evaluation performed to compare the spring/summer 2014 survey with a previous survey performed in spring/summer 2013 as well as a post-fill survey taken in February/March 2013 as part of the Post-Irene Renourishment Project to determine how the project is performing a little over one year later.

2.0 Summary of Previous Work

Previous beach monitoring studies performed by Coastal Science & Engineering (CSE) between 2004 and 2007 were reviewed to gain an understanding of previous survey methods, associated coastal analysis, and observed trends (Note: UNC-IMS completed the 2003 work). Each year, comparisons along Bogue Banks were made to an initial survey performed in 1999, providing 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 1** and **Table 2** show the long-term and short-term volume changes over the various reaches of shoreline included in the BBBNMP.

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

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

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

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

3.0 Survey Methods and Data Sources

Most recently, Geodynamics conducted a survey of Shackleford Banks, Bear Island, and Bogue Banks in February through June 2014. The profile lines and origins used in previous studies were also used for the most recent survey for ease of comparison. **Figure 1** and **Figure 2** show the location of the profile lines and origins applied by Geodynamics for the surveying. Two transects were added near Beaufort Inlet (112B) and Bogue Inlet (117B) in 2008 to better track sand movement near the inlets. The established profile lines and origins will be used in all future survey periods. As shown, lines were stationed from west to east along Bogue Banks and east to west along Bear Island and Shackleford Banks. The survey data was provided in ASCII (xyz), Excel (xyz), Shapefile (GIS), and ISRP (BMAP) formats allowing for compatibility with multiple programs. The survey was referenced in NAD 1983 State Plane North Carolina (feet) with a vertical datum of NAVD 1988.

Several steps were taken by Geodynamics to ensure the most accurate survey data. The spring/summer 2014 survey represents a continuation of previous surveys conducted for the Carteret County Shore Protection Office using high-density singlebeam sonar and topographic survey of Bogue Banks. This survey meets the requirements specified in the NOS (National Ocean Service) Hydrographic Surveys Specifications and Deliverables (April, 2007), the OCS (Office of Coast Survey) Field Procedures Manual for Hydrographic Surveying (June 2008) and the criteria for Navigation and Dredging Support Hydrographic Surveys as outlined in the U.S. Army Corps of Engineers Hydrographic Surveying Manual, EM 1110-2-1003 (EM 1110-2-1003 January 2002). The following sections will discuss the singlebeam (bathymetric) and topographic data acquisition including its associated equipment, quality control procedures, and data processing.

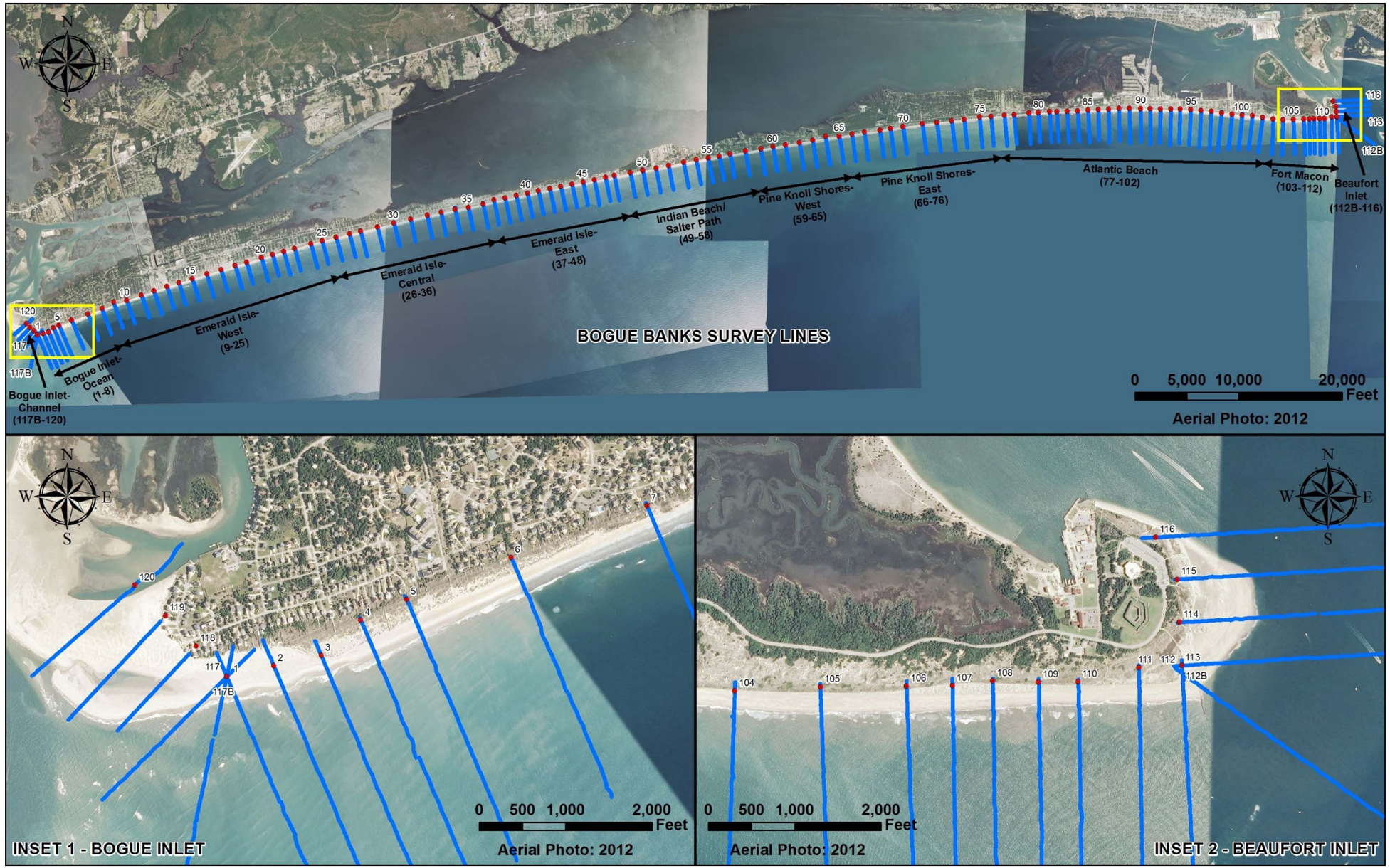


Figure 1. BBBNMP Profile Line Locations – Bogue Banks

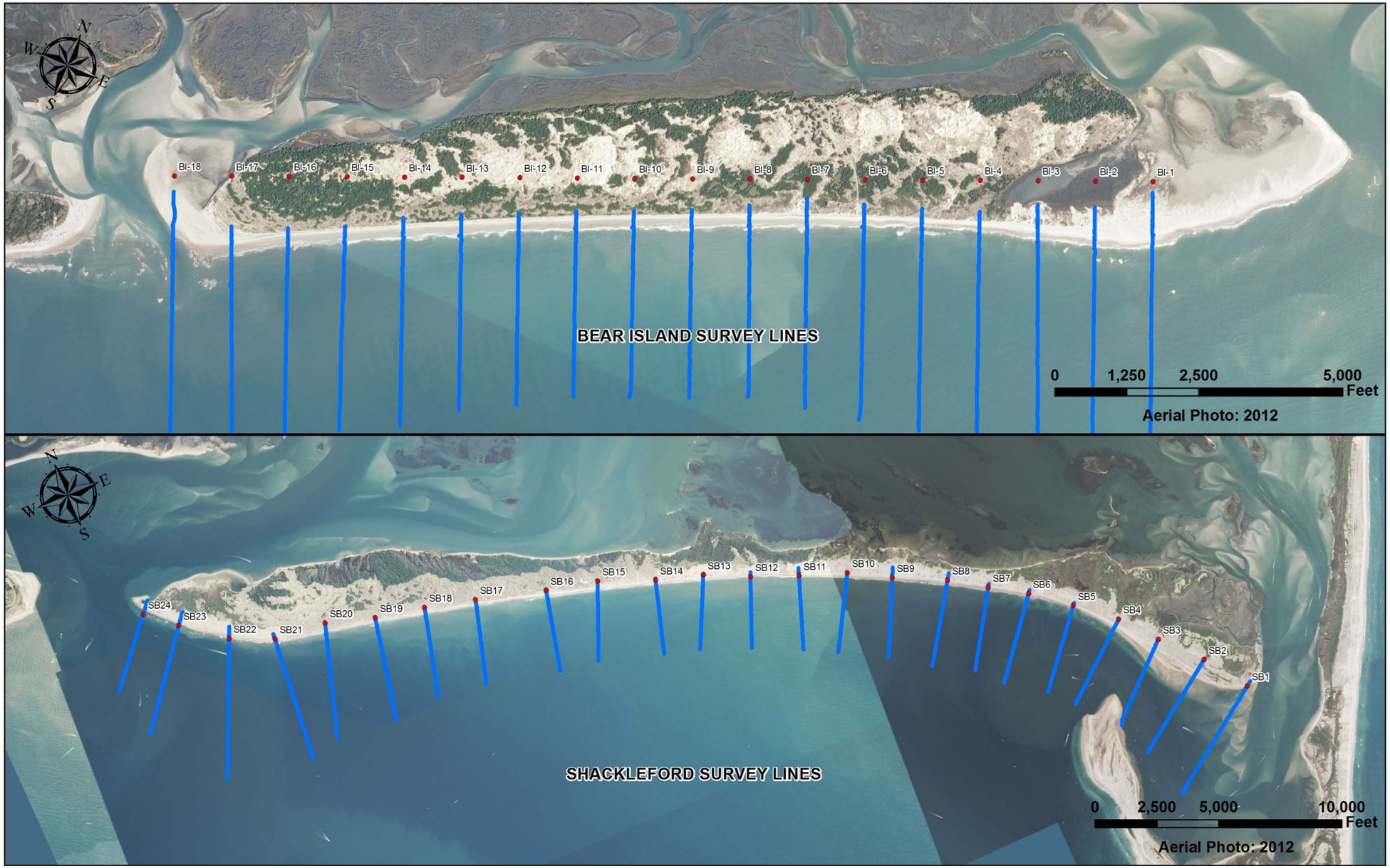


Figure 2. BBBNMP Profile Line Locations – Bear Island and Shackleford Banks

3.1 Singlebeam (Bathymetric) Data Acquisition and Processing

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

3.1.1 Singlebeam Survey Equipment, Hardware, and Software

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

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

Table 3. Singlebeam Hardware Systems Inventory

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

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

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

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

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

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

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

Table 4. Singlebeam Software Systems Inventory

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

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

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

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

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

3.1.2 Singlebeam Quality Control

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

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

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

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

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

3.1.3 Corrections to Echo Soundings

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

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

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

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

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

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

3.2 Topographic Data Acquisition and Processing

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

3.2.1 Topographic Survey Equipment, Hardware, and Software

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

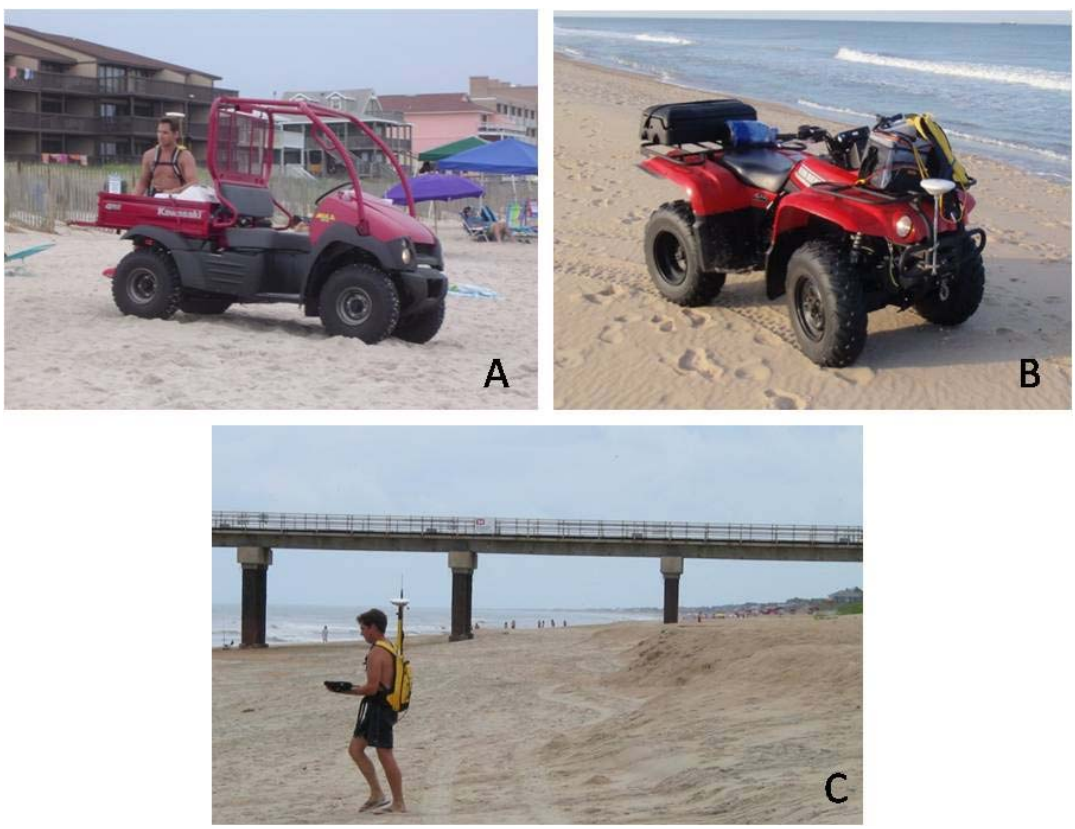


Figure 4. The (A) Kawasaki Mule, (B) Yamaha ATV, and (C)Trimble 5700 RTK-GPS Rover Backpack

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

Table 5. Topographic Hardware Systems Inventory

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

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

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

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

Table 6. Topographic Software Systems Inventory

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

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

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

3.2.2 Topographic Quality Control

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

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

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

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

3.3 Vertical and Horizontal Control

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

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

3.4 Merging Topographic and Bathymetric Data

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

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

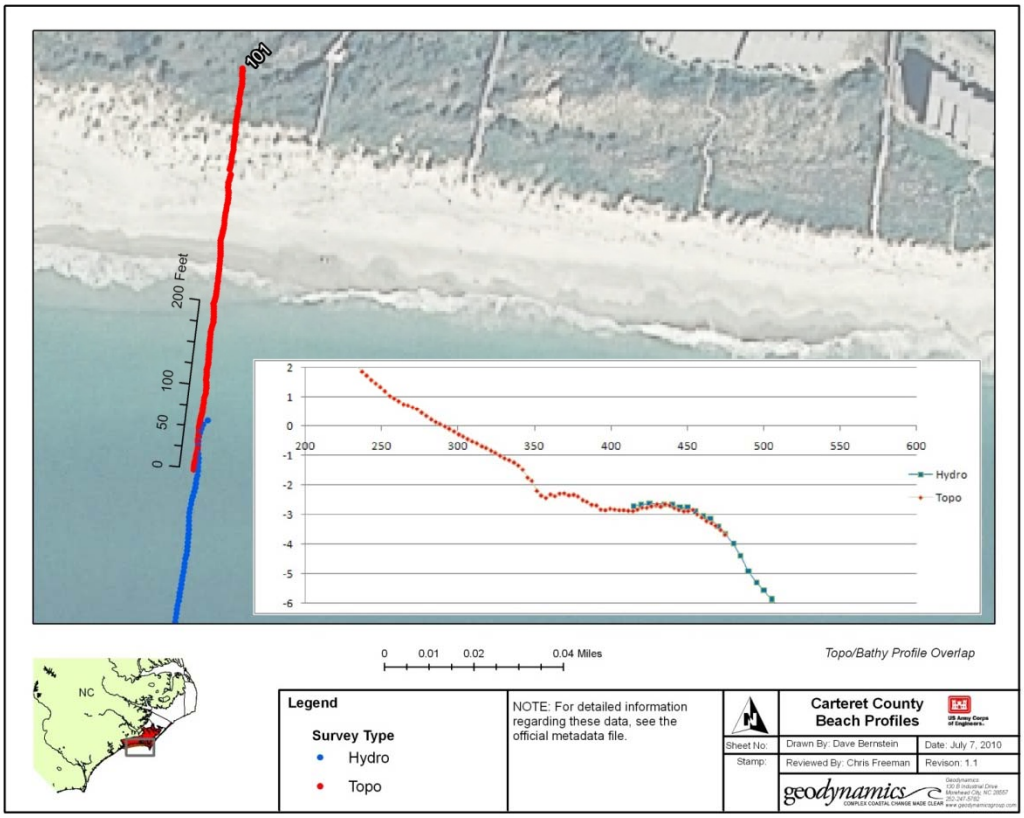


Figure 5. Example of Topographic and Bathymetric Data Overlap in Surfzone

3.5 Survey Data Acquisition Timeline

The most recent survey data was collected by Geodynamics during February through June of 2014. The Shackleford Banks survey was completed on February 25, 2014. Bear Island surveys were performed on April 22-25, 2014. For this report, April 25, 2014 was used as the survey date for all profile lines on Bear Island. The Bogue Banks survey, due to weather, was performed over a longer range of dates from May 13, 2014 to June 26, 2014. The date used for the Bogue Banks profiles for this report is June 23, 2014, when a majority of the June surveying was completed.

The previous set of annual survey data, used for comparison in this report, was also collected by Geodynamics during April through July of 2013. The Shackleford Banks survey was done on April 25, 2013 through April 26, 2013. For this report, April 26, 2013 was used as the survey date for all profile lines on Shackleford Banks. Bear Island surveys were performed on July 17 through July 18, 2013. For this report, July 18, 2013 was used as the survey date for all profile lines on Bear Island. The Bogue Banks survey, due to weather, was performed over a longer range of dates from March 20, 2013 to July 18, 2013. The date used for the Bogue Banks profiles for this report is June 21, 2013 when a majority of the data was collected.

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 2013 and spring/summer 2014 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, 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 2013 and spring/summer 2014 profiles. The resulting value represents the shoreline change (ft) over the time period between surveys. The shoreline change rate (ft/yr) was then calculated by dividing by the amount of time between survey dates in order to better compare changes between different time periods.

Then, representative volume changes were calculated at each transect between spring/summer 2013 and spring/summer 2014. Volume changes were calculated for five different extents in order to better understand the processes occurring onshore and offshore of the Bogue Banks beach area. Calculations included volume change above MHW (+1.1 ft NAVD88-equivalent to +2.1 ft NGVD29), above -5 ft NAVD88 (wading depth/recreational beach-equivalent to -4 ft NGVD29), above -12 ft NAVD88 (outer bar-equivalent to -11 ft NGVD29), above -20 ft NAVD88, and above -30 ft NAVD88. Upon inspection of recent survey data, it appears the depth of closure is somewhere between -20 ft NAVD88 and -30 ft NAVD88 (likely closer to -20 ft NAVD88). For those profiles which did not extend to -30 ft NAVD88, volume calculations were performed above -30 ft out to the extent of the shortest survey. As with the shoreline change, the results represent volume change (cy/ft) over the period of time between surveys. The volume change rate (cy/ft/yr) was then calculated by dividing by the amount of time between survey dates in order to better compare changes between different time periods. In addition, the volume changes were converted to cumulative changes over the entire shoreline. This was done by applying the average end area method to the unit volume changes (cy/ft) and unit volume change rates (cy/ft/yr) computed at each transect and summing the total volume changes over the entire shoreline. The resulting value indicated the total loss or gain of material between survey periods based on the applicable profile extents. It should be noted that the uncertainty in the hydrographic portion of the survey is approximately ±0.11 ft. If this uncertainty is applied along the portion of the profile between the seaward side of the outer bar (approximately 1300 ft offshore) and a depth of -30 ft NAVD88 (approximately 2850 ft offshore) along all 128,393 ft of oceanfront shoreline, this lends itself to an uncertainty of approximately ±811,000 cy.

Volume changes calculated for portions of the profiles above MHW are representative of changes in the amount of material in the dune system and on the subaerial beach. These areas are highly influenced by the impact of storm activity. Volume comparisons for portions of the profiles above -5 ft NAVD88, which is an approximate wading depth, are representative of changes in the portion of the beach used for recreation. Volume comparisons above -12 ft NAVD88 help to track sand movement to and from the outer sand bar and are ultimately used in decision making for future beach nourishment projects. Volume comparisons above -20 ft NAVD88 allow for the tracking of sand movement offshore while reducing the amount of

uncertainty associated with the survey data by eliminating changes beyond this depth related to the vertical margin of uncertainty in the hydrographic survey data. Finally, volume comparisons above -30 ft NAVD88 allow the complete tracking of sand movement offshore. However, hydrographic survey measurement accuracy may impact these calculations. This is a comprehensive way to assess the impact of storm activity on the subaerial beach and dune system as well as track the movement of sand offshore and quantify total gains and losses in the entire system. **Figure 6** presents a graphic showing the various calculation lenses.

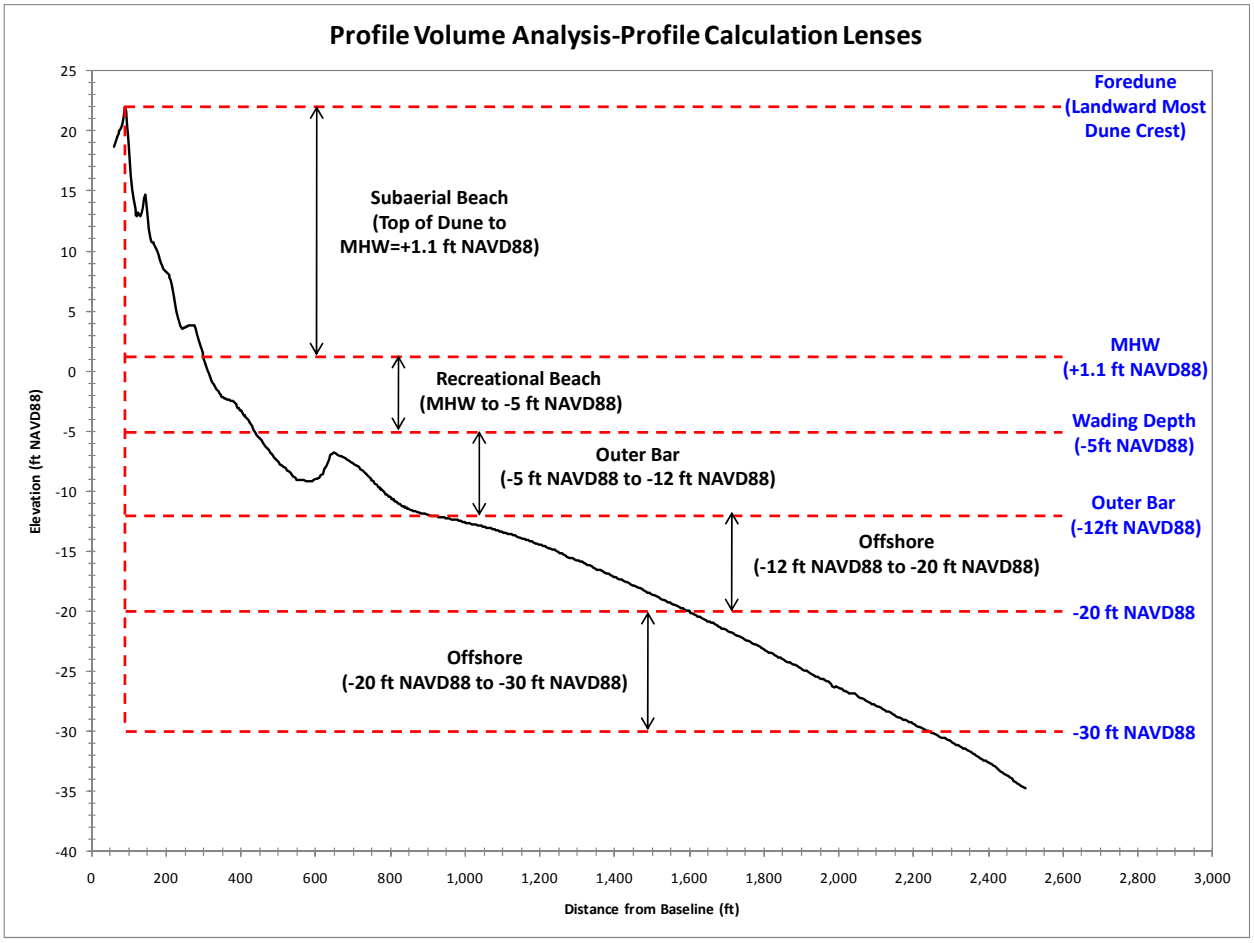


Figure 6. Profile Volume Calculation Lenses

In addition to the annual 2013/2014 comparison, the volumes calculated for the spring/summer 2014 survey were also compared to the post-fill surveys completed in February/March 2013 after the Post-Irene Renourishment Project. The comparison was done above MHW (+1.1 ft NAVD88), -5 ft NAVD88 and -12 ft NAVD88 which was roughly the seaward extent/depth of the nourishment template and the post-fill survey. These calculations give an idea as to how much of the nourishment material remains on the recreational/visible beach and how much is still located above -12 ft NAVD88 and is thus providing protection of the beach. However, crosshore transport of the beyond -12 ft is difficult to quantify due to the extents of the post-fill survey. In addition, the longshore transport of material to adjacent transects is difficult to calculate but an attempt was made to capture some of this based on visual inspection of the profile plots.

Furthermore, FEMA beach maintenance calculations were performed based on a baseline nourishment condition consisting of the post-nourishment surveys from Phase I, Phase II, and Phase III of the County Project (2002, 2003, and 2005, respectively). Profile volumes above -12 ft NAVD88 (equal to previously utilized elevation of -11 ft NGVD29) from spring/summer 2014 were compared to profile volumes above -12 ft NAVD88 from the post-fill surveys. The amount of remaining fill was computed by subtracting the amount of fill placed in the restoration project from the volume change calculated between the post-nourishment surveys and 2014.

Finally, in preparation for management under the upcoming Master Beach Nourishment Plan, a preliminary assessment of current conditions compared to the new nourishment triggers was completed as part of this report. Using historical erosion rates, an estimate of time remaining until the next nourishment action was developed.

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 2013 and spring/summer 2014 profile data. The MHW shoreline position contour was extracted from the spring/summer 2013 and spring/summer 2014 DEMs and plotted on aerials. These figures are presented in **Appendix A**.

5.0 Discussion of Annual Surveying Evaluation

This section will discuss long-term background erosion rates, recent events (i.e. nourishment projects, storms, etc.), overall shoreline trends, regional shoreline trends, post-Irene project performance, and FEMA beach maintenance analysis. Plots of the shoreline and volume changes from spring/summer 2013 and spring/summer 2014 surveys at each transect, for Bogue Banks, Bear Island, and Shackleford Banks, are presented in **Appendix B**. Profile comparison plots for individual transects, which include the spring/summer 2013 and spring/summer 2014 surveys are presented in **Appendix C**. Where applicable, the Irene post-fill profiles (February/March 2013) are also plotted for comparison. The computed shoreline changes and volume changes at each individual transect for the time periods being covered are tabulated in **Appendix D**. FEMA beach maintenance calculations for comparison to the original County Project are presented in **Appendix E**.

5.1 Determination of Background Erosion Rate for Bogue Banks

Due to the numerous nourishment projects which have taken place along Bogue Banks since the monitoring program was initiated in 1999, it is important to determine a background erosion rate without nourishment from which to compare the performance of the various projects and to develop long-term trends in volume losses/gains. Therefore, the historical volume changes above -12 ft NAVD88 and beach nourishment volumes were documented. The Bogue Banks area has undergone extensive beach nourishment throughout the duration of the monitoring effort as part of the County Project, the USACE Section 933 Project, USACE Dredge Disposal Projects, and post-storm FEMA work. **Table 7** and **Table 8** summarize the nourishment projects in the study area since the monitoring program was initiated.

Table 7. Nourishment Volumes by Project

Project	Reach	Year	In-Place Volume (cy)
County Phase 1	Pine Knoll Shores - East & West	2002	1,276,586
County Phase 1	Indian Beach/Salter Path	2002	456,994
USACE Disposal	Fort Macon	2002	209,348
County Phase 2	Emerald Isle - East & Central (berm)	2003	1,743,788
County Phase 2	Emerald Isle - East & Central (dune)	2003	123,938
USACE Section 933	Indian Beach/Salter Path & Pine Knoll Shores - West	2004	699,282
FEMA Post Isabel	Emerald Isle - East & Central	2004	156,000
Brandt Island Pump Out	Atlantic Beach	2005	2,390,000
USACE Disposal	Fort Macon	2005	530,729
County Phase 3	Emerald Isle - West	2005	690,868
USACE Section 933	Pine Knoll Shores - East & West	2007	507,939
FEMA Post Ophelia	Emerald Isle, Pine Knoll Shores, & Indian Beach/Salter Path	2007	1,229,836
USACE Disposal	Fort Macon	2007	184,828
AIWW Tangent B Disposal	Pine Knoll Shores East	2008	148,393
USACE Disposal	Atlantic Beach	2011	799,504
USACE Disposal	Fort Macon	2011	547,196
FEMA Post Irene	Pine Knoll Shores & Emerald Isle	2013	965,011
USACE Disposal	Atlantic Beach	2014	522,518
USACE Disposal	Fort Macon	2014	585,067
		Total	**13,767,825**

Table 8. Nourishment Volumes by Reach

Reach	Nourishment Volume (cy)
Bogue Inlet - Ocean	59,272
Emerald Isle - West	1,133,823
Emerald Isle - Central & East	2,819,736
Indian Beach/Salter Path	1,358,842
Pine Knoll Shores	2,626,962
Atlantic Beach	3,712,022
Fort Macon	2,057,168
Total	**13,767,825**

To calculate the background erosion rate, nourishment volumes were subtracted from total volume changes above -12 ft NAVD88 between a baseline survey taken in 1999 and the spring/summer 2014 survey. The volume changes were established by adding the yearly volume changes calculated by M&N since 2008 to the volume changes from 1999-2007 calculated in the 2007 monitoring report (CSE 2007). **Table 9** shows the computed volume change (including nourishments) above -12 ft NAVD88 from 1999-2014 for the defined reaches.

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

Reach	Volume Change (cy) (1999-2007)	Volume Change (cy) (2007-2008)	Volume Change (cy) (2008-2009)	Volume Change (cy) (2009-2010)	Volume Change (cy) (2010-2011)	Volume Change (cy) (2011-2012)	Volume Change (cy) (2012-2013)	Volume Change (cy) (2013-2014)	Volume Change (cy) (1999-2014)
Bogue Inlet-Ocean	147,797	-218,444	169,134	-82,982	-28,440	-199,903	91,493	11,826	-109,520
Emerald Isle West	1,185,131	-107,631	75,690	-107,529	30,257	-264,467	408,863	152,049	1,372,363
Emerald Isle Central & East	1,727,705	117,522	-96,085	-281,475	57,244	-293,600	684,367	24,036	1,939,714
Indian Beach/ Salter Path	1,155,522	-116,245	-118,761	-118,078	55,234	-163,958	-44,355	58,729	708,088
Pine Knoll Shores	1,753,427	-57,453	-53,514	-162,946	-81,597	-313,077	385,385	-66,012	1,404,213
Atlantic Beach	1,194,947	27,172	-106,720	-11,803	750,462	-530,856	59,686	573,232	1,956,119
Fort Macon State Park	221,169	-137,402	-151,048	-46,357	595,792	-167,964	-79,760	436,823	671,254
Total	**7,385,698**	**-492,481**	**-281,305**	**-811,170**	**1,378,951**	**-1,933,825**	**1,505,678**	**1,190,683**	**7,942,230**

Table 10 shows the average annual background erosion rates for each reach of the Bogue Banks oceanfront. The average background erosion rate for the entire Bogue Banks shoreline is approximately -3.0 cy/ft/yr. This result is slightly lower than last year and more in line with calculations from previous years likely due to natural recovery during a quiescent year as well as the helpful effects of the Post-Irene Renourishment Project and recent Morehead City Harbor Maintenance Dredging project.

Table 10. Average Annual Background Erosion Rates (1999-2014)

Reach	Length (ft)	Volume Change Above -12 ft NAVD88 (cy) (1999-2014)	Nourishment Volume (cy)	Background Erosion (cy)	Average Annual Background Erosion Rates (cy/ft/yr)
Bogue Inlet-Ocean	7,432	-109,520	59,272	-168,792	-1.51
Emerald Isle West	22,344	1,372,363	1,133,823	238,540	0.71
Emerald Isle Central & East	29,022	1,939,714	2,819,736	-880,022	-2.02
Indian Beach/Salter Path	12,850	708,088	1,358,842	-650,754	-3.38
Pine Knoll Shores	23,878	1,404,213	2,626,962	-1,222,749	-3.41
Atlantic Beach	26,176	1,956,119	3,712,022	-1,755,903	-4.47
Fort Macon State Park	6,691	671,254	2,057,168	-1,385,914	-13.81
Total	**128,393**	**7,942,230**	**13,767,825**	**-5,825,595**	**-3.02**

5.2 Key Events During the Reporting Period

Beach changes are greatly influenced by natural and engineering 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.

5.2.1 Storm Events

Wave data from the NDBC Onslow Bay Outer-Station 41036 buoy was downloaded for the period of time between the 2013 and 2014 surveys and plotted in order to analyze storm activity which may have impacted the study area. **Figure 7** shows the location of the buoy and **Figure 8** presents a plot of the wave heights during the reporting period. The 2013 Atlantic hurricane season (June 2013 – November 2013) was relatively mild with 14 (Sub)Tropical Storms, only 2 of which became hurricanes. Offshore significant wave height exceeded 10 ft only twice at buoy 41036 in Onslow Bay. On the contrary, the winter storm season (December 2013 – May 2014) was very active. Wave data indicates five instances where offshore wave heights reached 12-14 feet and two events where offshore wave heights exceeded 16 ft. The duration of these events

was, on average, 2 days. The impact of these long duration winter storms can often be seen on the beach, as the berm material is slowly transported to lower elevations over the course of each event.

Figure 7. Onslow Bay Outer-Station 41036 Buoy Location

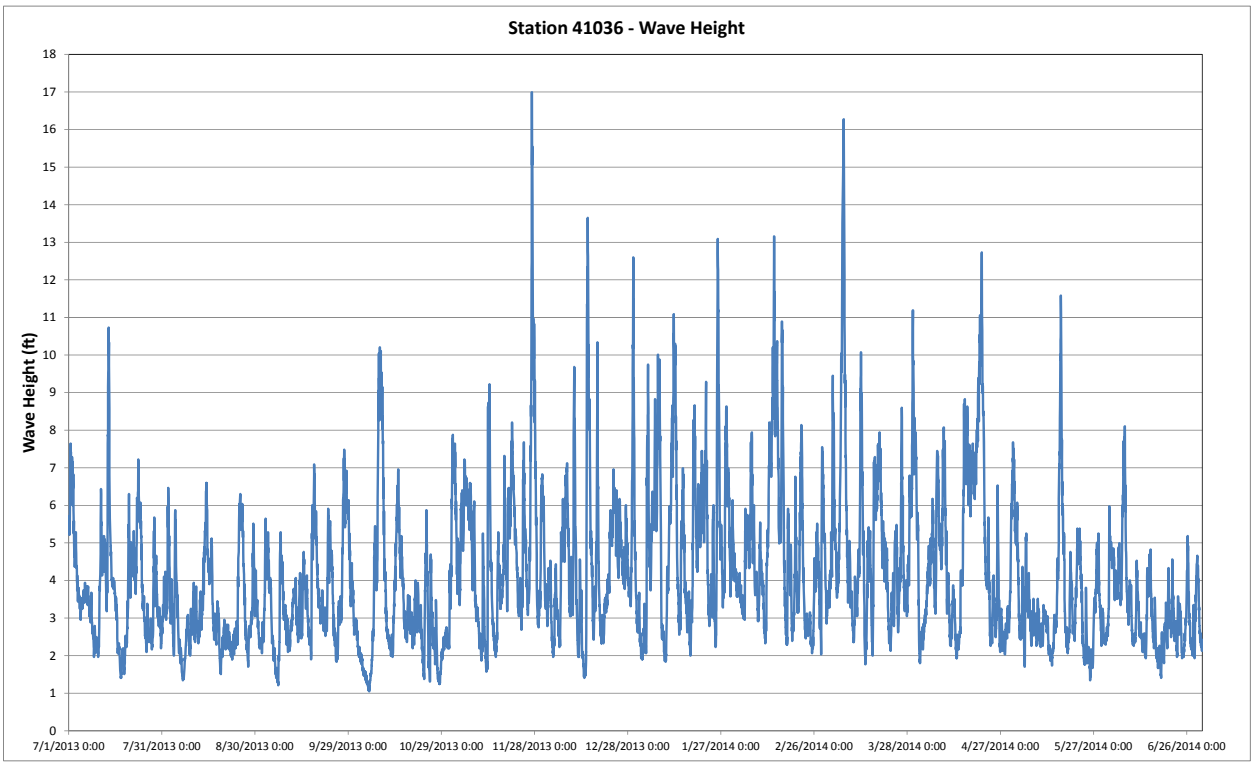


Figure 8. Onslow Bay Outer-Station 41036 Wave Height

5.2.2 Nourishment Events

As a reminder, during the 2011-2012 monitoring cycle, Hurricane Irene impacted Carteret County, in particular Bogue Banks. Based on pre- and post-storm monitoring efforts, Moffatt & Nichol determined that Bogue Banks lost approximately 1.4 million cubic yards (cy) of material as a result of the storm. The Post-Irene Renourishmnet Project, funded by FEMA, the County's Beach Commission/Shore Protection Office, and local communities, took place in February and March of 2013. The entire project took just under seven weeks and 965,011 cy of material was placed along three reaches of Bogue Banks. Pine Knoll Shores (Reach 1) received a total of 315,221 cy of material over 12,905 ft of beach for an average of 24.4 cy/ft. Emerald Isle East (Reach 2) received approximately 451,600 cy of material over 12,504 ft of beach for an average of 36.1 cy/ft. Emerald Isle West (Reach 3) received approximately 198,190 cy of material over 9,485 ft of beach for an average of 20.9 cy/ft.

Most recently, the Morehead City Harbor Maintenance Project placed 1,107,585 cy on the beach in Fort Macon (585,067 cy) and Atlantic Beach (522,518 cy), equating to 130 cy/ft and 105 cy/ft, respectively. **Figure 9** shows the 2014 nourishment placement.

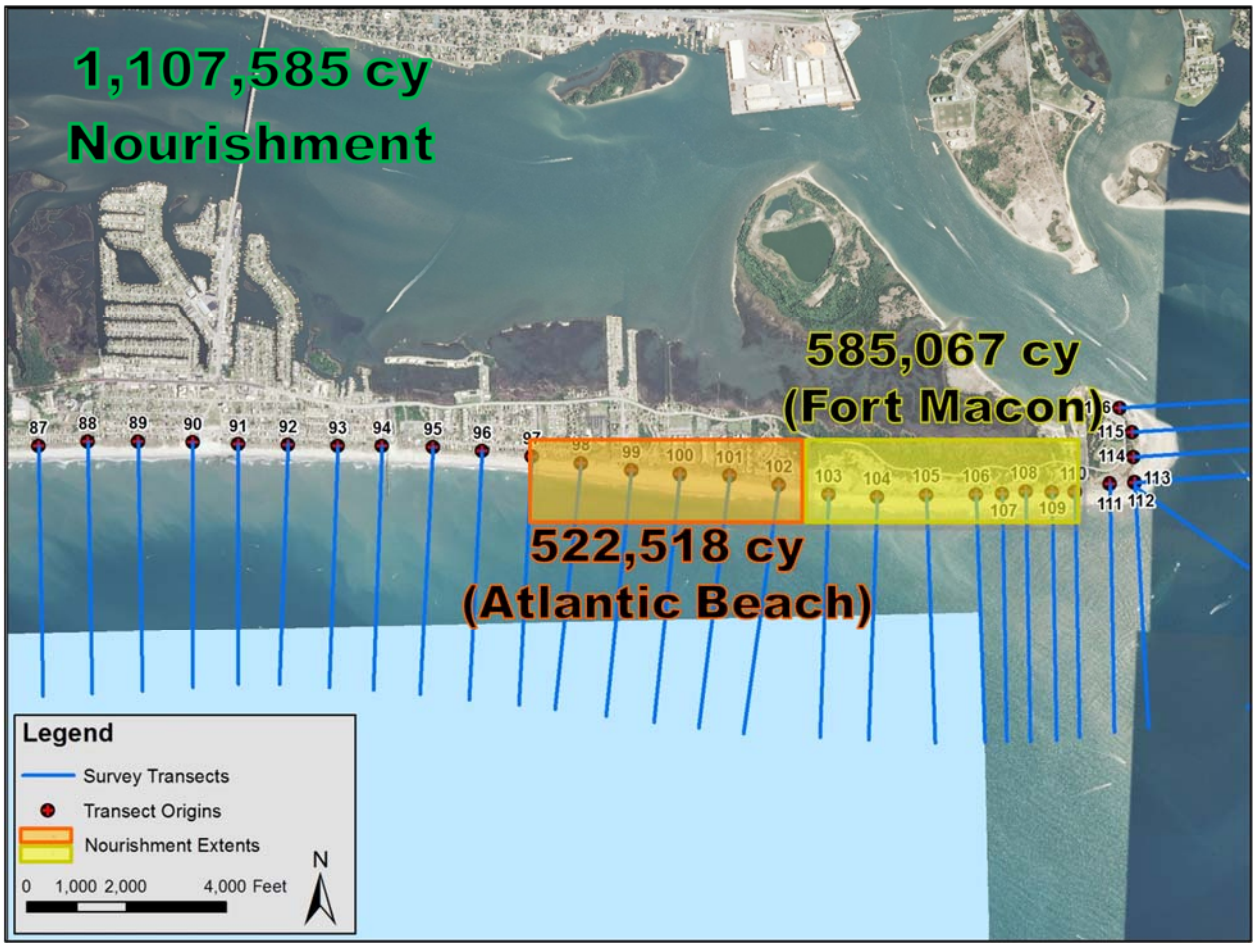


Figure 9. 2014 Morehead City Harbor Maintenance Project

5.3 Regional Shoreline and Volume Trends

Key statistics were calculated to quantify average shoreline and volume changes for each individual shoreline reach as well as the entire oceanfront shoreline. The computed statistics include average shoreline change, average volume change, and cumulative volume change (e.g. total volume of material lost or gained along a section of shoreline). A summary of the resulting statistics for the reporting period comparison are presented in **Table 11** through **Table 13** for Bogue Banks, Bear Island, and Shackleford Banks. Evaluation of the computed statistics will take into account volume changes computed for portions of the profile above MHW (+1.1 ft NAVD88), above -5 ft NAVD 88, above -12 ft NAVD88, above -20 ft NAVD88, and above -30 ft NAVD88 in order to better understand onshore and offshore processes. Since each reach consists of a different length of shoreline, a weighted average for unit shoreline change (ft) and unit volume change (cy/ft) at each transect was calculated for the Bogue Banks Oceanfront and County Project based on the length of each reach.

Table 11. Bogue Banks Regional Shoreline and Volume Change Statistics (Spring/Summer 2013 – Spring/Summer 2014 Comparison)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	13.1	-0.6	-4,354	2.5	18,535	1.6	11,826	-6.9	-51,174	-9.4	-69,639
Emerald Isle-West (9-25)	22,344	-10.2	-1.8	-39,609	5.0	112,404	6.8	152,049	4.3	95,596	0.4	8,998
Emerald Isle-Central (26-36)	15,802	-23.9	-4.0	-62,907	1.5	23,144	-0.1	-1,999	1.0	15,834	-2.4	-37,964
Emerald Isle-East (37-48)	13,220	5.3	-1.3	-17,722	2.6	34,974	2.0	26,034	4.5	59,774	2.5	33,022
Indian Beach-Salter Path (49-58)	12,850	-1.9	-2.0	-25,716	4.8	62,219	4.6	58,729	9.6	123,056	9.2	118,733
Pine Knoll Shores-West (59-65)	9,063	-19.1	-1.7	-15,840	-0.8	-7,008	-0.9	-7,812	5.4	48,694	5.0	45,413
Pine Knoll Shores-East (66-76)	14,815	-11.8	0.7	10,236	-3.5	-52,282	-3.9	-58,200	0.1	1,656	-3.9	-58,253
Atlantic Beach (77-102)	26,176	41.1	8.7	228,589	14.0	365,764	21.9	573,232	22.2	579,829	18.0	471,512
Fort Macon State Park (103-112)	6,691	126.8	20.1	134,611	45.9	306,869	65.3	436,823	64.8	433,305	61.3	410,131
Beaufort Inlet (112B-116)	2,000	40.2	8.7	17,348	11.2	22,349	0.6	1,199	10.9	21,707	16.0	31,967
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reach Length	Weighted Avg	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total
County Project (9-76)	88,094	-10.3	-1.7	-151,559	2.0	173,450	1.9	168,803	3.9	344,611	1.2	109,950
Oceanfront (1-112)	128,393	8.7	1.6	207,286	6.7	864,617	9.3	1,190,683	10.2	1,306,571	7.2	921,954

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

Table 12. Bear Island Shoreline and Volume Change Statistics (Spring/Summer 2013 – Spring/Summer 2014 Comparison)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bear Island (1-18)	16,500	-22.0	-2.4	-39,033	0.0	-676	5.2	85,216	3.9	65,060	2.8	46,051

Table 13. Shackleford Banks Shoreline and Volume Change Statistics (Spring/Summer 2013 – Spring/Summer 2014 Comparison)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Shackleford Banks (1-24)	46,001	-60.1	-4.0	-186,222	-8.8	-403,748	-14.6	-671,231	-21.3	-980,665	-23.5	-1,082,016

Table 11 indicates that the Bogue Banks oceanfront shoreline has experienced overall accretion at MHW over the past year, averaging +8.7 ft. However, this is heavily influenced by the impact of the Morehead City Harbor Maintenance Dredging project which occurred in Fort Macon and

Atlantic Beach. The County Project numbers indicate a trend of shoreline recession at MHW in most of the reaches that were not nourished (Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores), averaging -10.3 ft. The volumetric analysis indicates an overall gain of sand along the oceanfront above MHW, -5 ft NAVD88, -12 ft NAVD88, -20 ft NAVD88, and -30 ft NAVD88. Once again, this is heavily influenced by the 1,107,585 cy of material placed in Fort Macon and Atlantic Beach. The County Project numbers indicate a loss of material above MHW but a gain of material above all other elevations in most the reaches not affected by nourishment (Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores). This is an indication of material being pulled from the recreational/visible beach to an elevation below MHW but still within the system. Profile plots in **Appendix C** show that material lost from above MHW has been captured landward of the offshore bar, above -12 ft NAVD, and thus is still within the system and providing protection to the beach. Approximately 1.19 million cy of material was gained above -12 ft NAVD88 along the entire oceanfront, most of this coming from the Morehead City Harbor Maintenance Dredging project. A look at the County Project, which was unaffected by the nourishment, indicates that those reaches also experienced a slight gain in material above -12 ft NAVD88 of approximately 168,800 cy.

Bear Island appears to have experienced a moderate amount of shoreline recession over the past year, as shown in **Table 12**. As with Bogue Banks, volumetric calculations indicate a loss in material above MHW but a gain in material at lower elevations which is indicative of material being pulled from the recreational/visible beach to lower elevations but still remaining within the system. After examining the profile plots in **Appendix C**, it is apparent that material lost from above MHW was captured landward of the offshore bar, above -12 ft NAVD, and thus is still within the system and providing protection. Most importantly, there was a gain of approximately 85,200 cy of material above -12 ft NAVD88.

Shackleford Banks appears to have experienced a significant amount of shoreline recession and volume loss, as shown in **Table 13**. The volume change plots in **Appendix B** and profile plots in **Appendix C** indicate that the majority of the shoreline recession and volume loss was located at Transects 21-24, adjacent to Beaufort Inlet, including major losses to both the dunes and beachface. The remaining transects along Shackleford Banks (1-20) appear to have been impacted similar to Bogue Banks and Bear Island with losses of material above MHW and capture of some of that material at lower elevations (see **Appendix C** profile plots). Overall, Shackleford Banks lost approximately 671,200 cy of storm protection material above -12 ft NAVD88, with 601,000 cy of it being lost from Transects 21-24.

Figure 10 and **Figure 11** display the trends seen in **Table 11** through **Table 13** with bar plots of the average unit volume changes and cumulative volume changes at each reach for Bogue Banks, Bear Island, and Shackleford Banks. Apparent from these figures is the significant volume gains seen throughout Atlantic Beach and Fort Macon due to the nourishment project. The remaining County Project reaches, for the most part, show volume losses above MHW but volume gains above lower elevations. Pine Knoll Shores East is the only reach that indicates some losses above lower elevations, however they are not significantly large or consistent across all elevations.

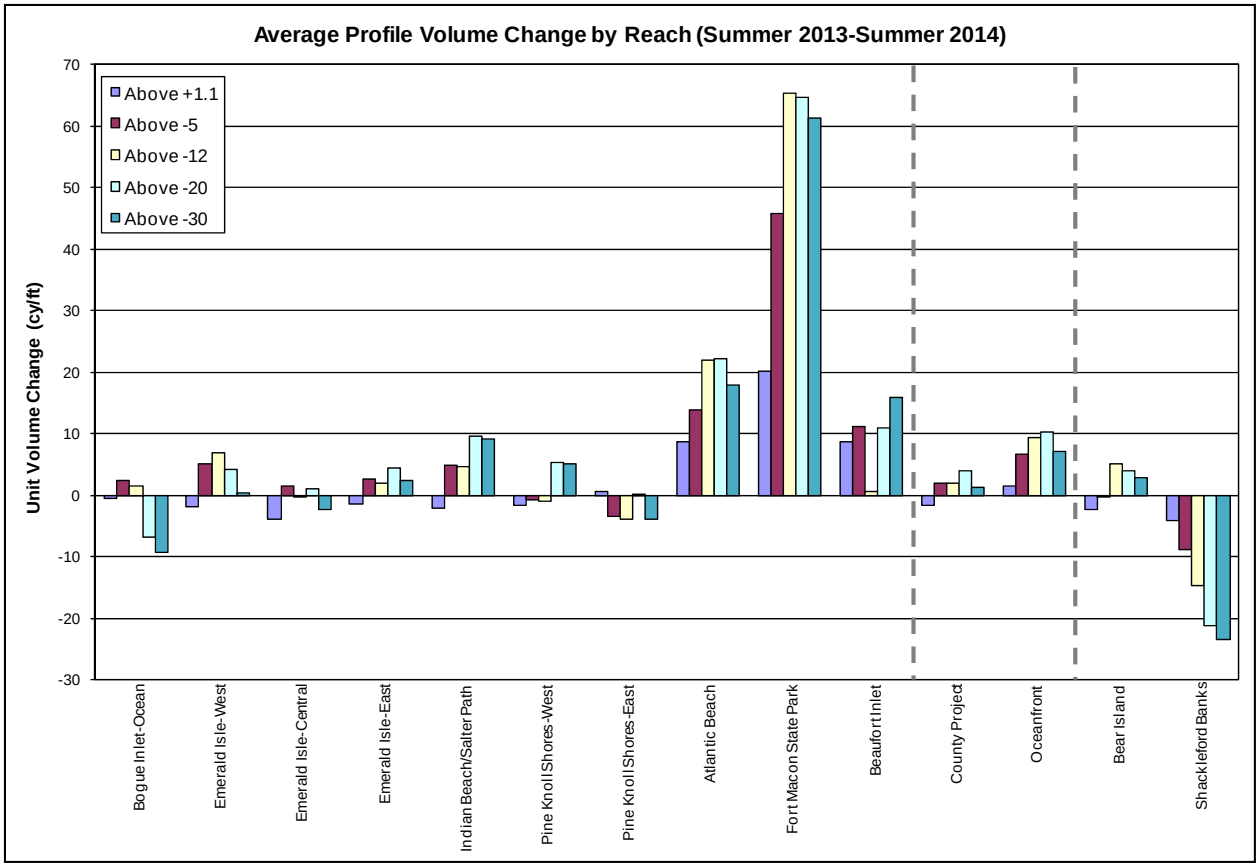


Figure 10. Average Unit Volume Change by Reach

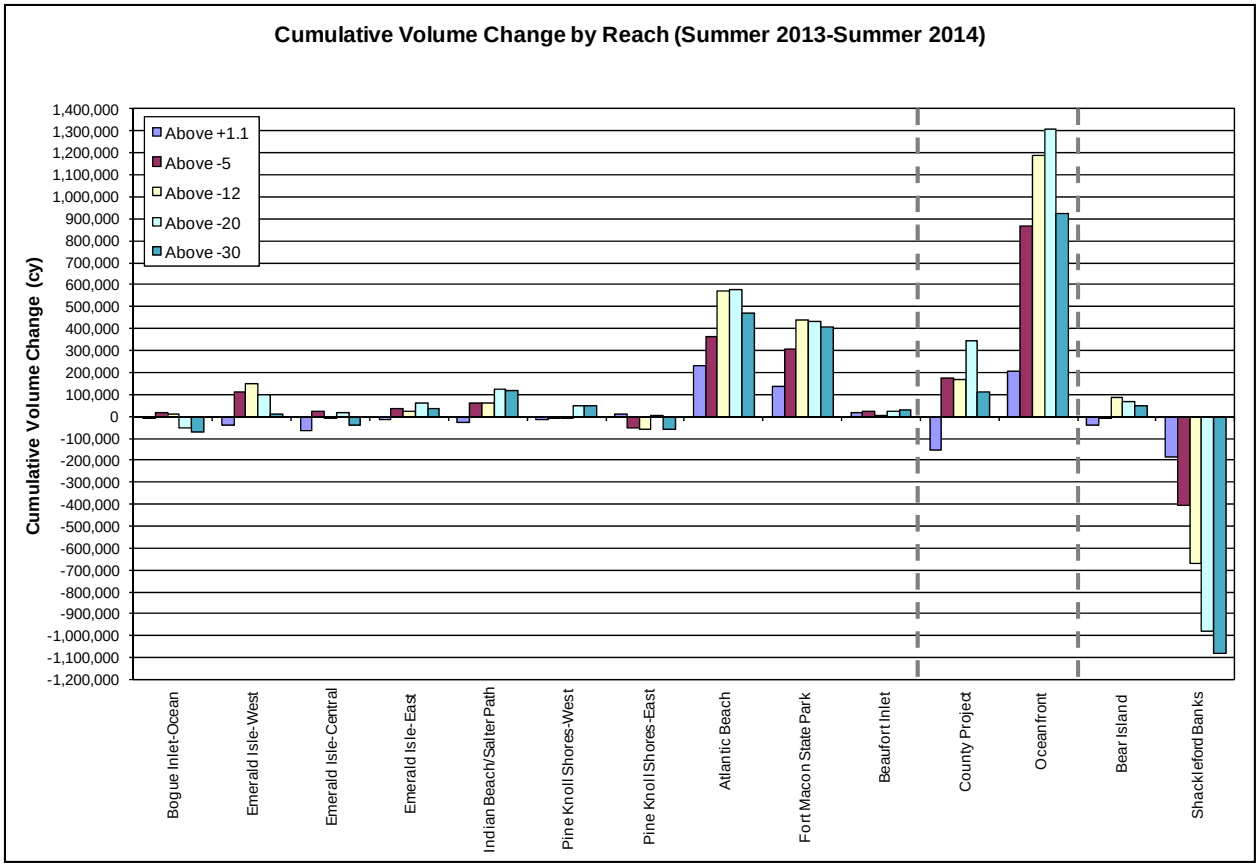


Figure 11. Cumulative Volume Change by Reach

A target minimum volume for each profile from the foredune (landward most crest of the primary dune) to the outer bar (above -12 ft NAVD88) was established at 225 cy/ft during the formulation of the County Project. **Figure 12** displays the average profile volume to the outer bar per transect within each reach of shoreline for 2008 - 2014. Values displayed in the graph are tabulated in **Table 14**. As shown in **Figure 12**, there are currently no reaches along Bogue Banks that are close to the minimum target of 225 cy/ft. Many of the reaches gained material above -12 ft NAVD88 over the past year. Pine Knolls Shores East saw the largest loss of material over the past year, though it was not a significant amount.

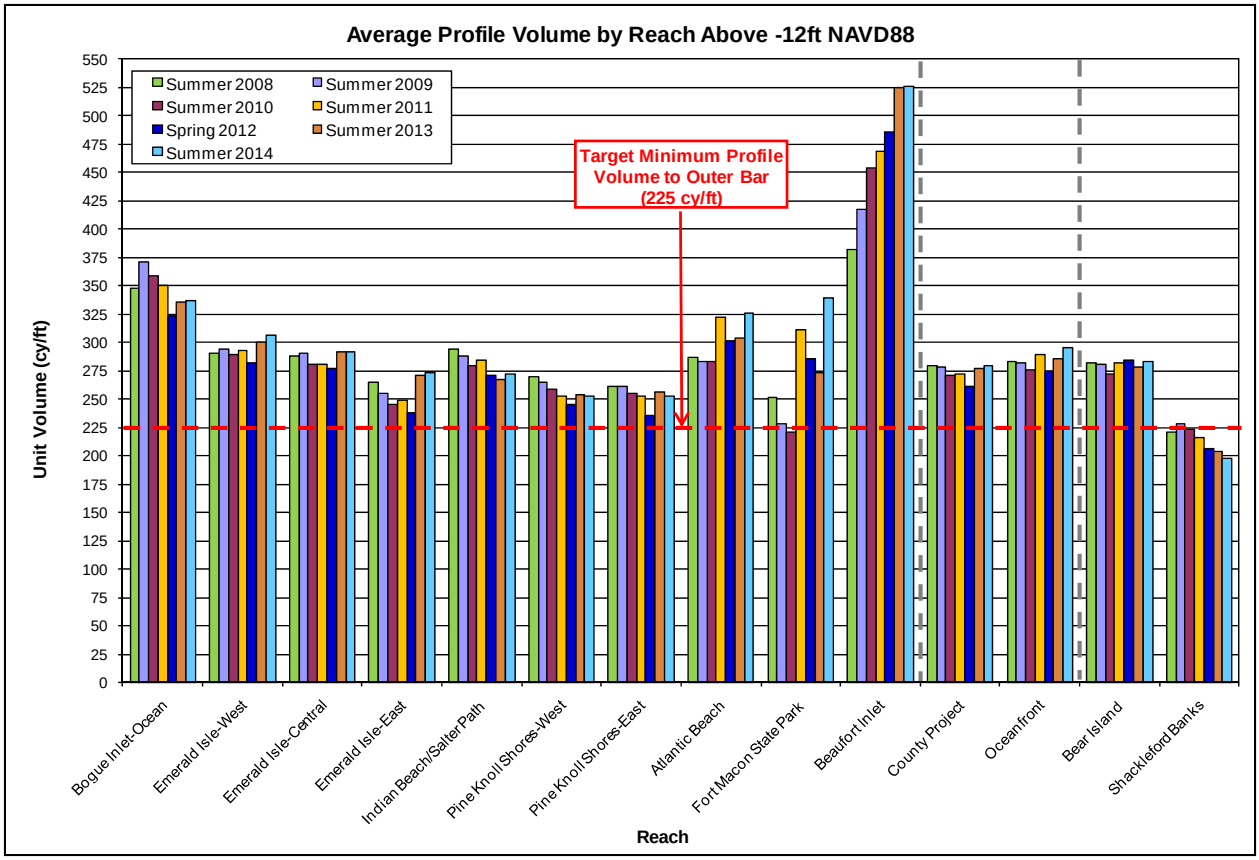


Figure 12. Average Profile Volume From Foredune to Outer Bar by Reach

Table 14. Average Profile Volume From Foredune to Outer Bar by Reach

Reach	July 2008	June 2009	June 2010	June 2011	April 2012	July 2013	June 2014
Bogue Inlet-Channel (117-120)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bogue Inlet-Ocean (1-8)	348	371	359	350	323	336	337
Emerald Isle-West (9-25)	290	294	289	293	282	300	307
Emerald Isle-Central (26-36)	288	291	280	281	277	292	292
Emerald Isle-East (37-48)	265	255	245	249	238	271	273
Indian Beach/Salter Path (49-58)	294	289	280	284	271	268	272
Pine Knoll Shores-West (59-65)	270	265	258	253	245	254	253
Pine Knoll Shores-East (66-76)	261	262	255	253	236	256	252
Atlantic Beach (77-102)	287	284	283	322	302	304	326
Fort Macon State Park (103-112)	251	229	222	311	286	274	339
Beaufort Inlet (113-116)	382	418	455	469	485	525	526
County Project	280	278	271	272	261	277	279
Oceanfront	284	282	276	289	274	286	295
Bear Island (1-18)	282	281	272	282	284	279	284
Shackleford Banks (1-24)	221	229	223	216	207	204	198

5.4 Local Shoreline and Volume Trends

Local shoreline trends are discussed below for the defined regions of Bogue Banks (**Figure 1**) as well as Bear Island and Shackleford Banks. A summary of the information in **Table 11** through **Table 13** and plots in **Appendix B** has been created for each region of study.

5.4.1 Emerald Isle

The Emerald Isle region covers Transects 9 through 48. Since monitoring began in 1999, Emerald Isle has received a total of 3.95 million cy of nourishment material as a result of the County Project and FEMA post-storm work (Isabel, Ophelia, and Irene). Most recently, Emerald Isle West received 198,190 cy of material and Emerald Isle East received 451,600 cy of material during the 2013 post-Irene Renourishment Project. A summary of average shoreline and volume changes between 2013 and 2014 for the Emerald Isle region are presented in **Table 15**.

Table 15. Average Shoreline and Volume Change for Emerald Isle (2013-2014)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Emerald Isle-West (9-25)	22,344	-10.2	-1.8	-39,609	5.0	112,404	6.8	152,049	4.3	95,596	0.4	8,998
Emerald Isle-Central (26-36)	15,802	-23.9	-4.0	-62,907	1.5	23,144	-0.1	-1,999	1.0	15,834	-2.4	-37,964
Emerald Isle-East (37-48)	13,220	5.3	-1.3	-17,722	2.6	34,974	2.0	26,034	4.5	59,774	2.5	33,022

Shoreline change at MHW showed a mixed response throughout the reaches of Emerald Isle with shoreline recession in Emerald Isle West and Central and shoreline accretion in Emerald Isle East. The shoreline change plot in **Appendix B** and profile plots in **Appendix C** show pockets of shoreline recession and accretion throughout Emerald Isle that span several transects at a time. Volumetrically, **Table 15** indicates that the reaches of Emerald Isle experienced a loss in material above MHW but a gain in material above lower elevations. Most importantly, the Emerald Isle region gained 176,000 cy of material above -12 ft NAVD88. The largest gains occurred in Emerald Isle West in Transects 10-16 with alternating pockets of volume gain and loss throughout the remainder of the reach. Emerald Isle Central and Emerald Isle East saw alternating volume gains and losses through each reach. Lastly, it is important to note that the profiles in **Appenidx C** show that the material lost above MHW has been captured landward of the offshore bar, above -12 ft NAVD88 and is therefore still within the system and providing protection. **Figure 13** displays the unit volume change at each transect above the five elevations that were analyzed. Upon inspection of profile plots in **Appendix C**, it appears that the offshore bar at Transects 28 and 29 was much closer to shore in 2013 than the surrounding transects and has suffered deflation over the past year, possibly allowing increased wave energy into the area and contributing towards the significant erosion seen at Transect 29.

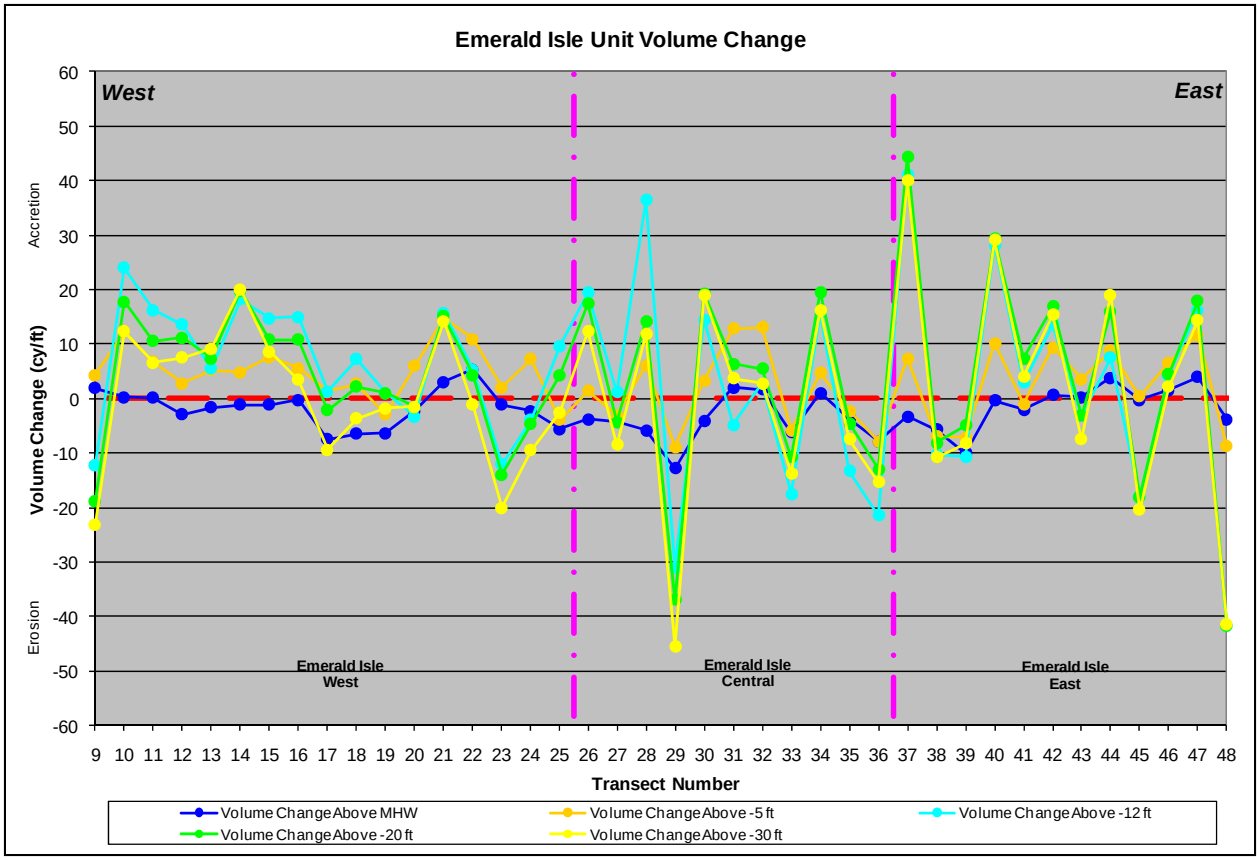


Figure 13. Emerald Isle Unit Volume Change (2013 - 2014)

5.4.2 Indian Beach/Salter Path

The Indian Beach region covers Transects 49 through 58. Since monitoring efforts began in 1999, this region has received 1.36 million cy of nourishment material from the County Project, USACE Section 933, and FEMA post-storm work (Ophelia). A summary of average shoreline and volume changes between 2013 and 2014 for the Indian Beach/Salter Path region are presented in **Table 16**.

Table 16. Average Shoreline and Volume Change for Indian Beach/Salter Path (2013-2014)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Indian Beach-Salter Path (49-58)	12,850	-1.9	-2.0	-25,716	4.8	62,219	4.6	58,729	9.6	123,056	9.2	118,733

Shoreline change at MHW in the Indian Beach/Salter Path area showed a slight recession of approximately -1.9 ft between the last two surveys. However, the shoreline change plot in **Appendix B** and profile plots in **Appendix C** show that there was a mix of shoreline recession and accretion throughout the reach. Volumetrically, **Table 16** indicates that the Indian Beach/Salter Path area lost material above MHW but gained material above lower elevations. As with Emerald Isle, the profile plots in **Appendix C** show that the material lost above MHW has been captured landward of the offshore bar, above -12 ft NAVD88 and is therefore still within the system and providing protection. **Figure 14** displays the unit volume change at each

transect for the Indian Beach/Salter path region. The above mentioned pattern of losses above MHW and gains at lower elevations is fairly consistent throughout the reach.

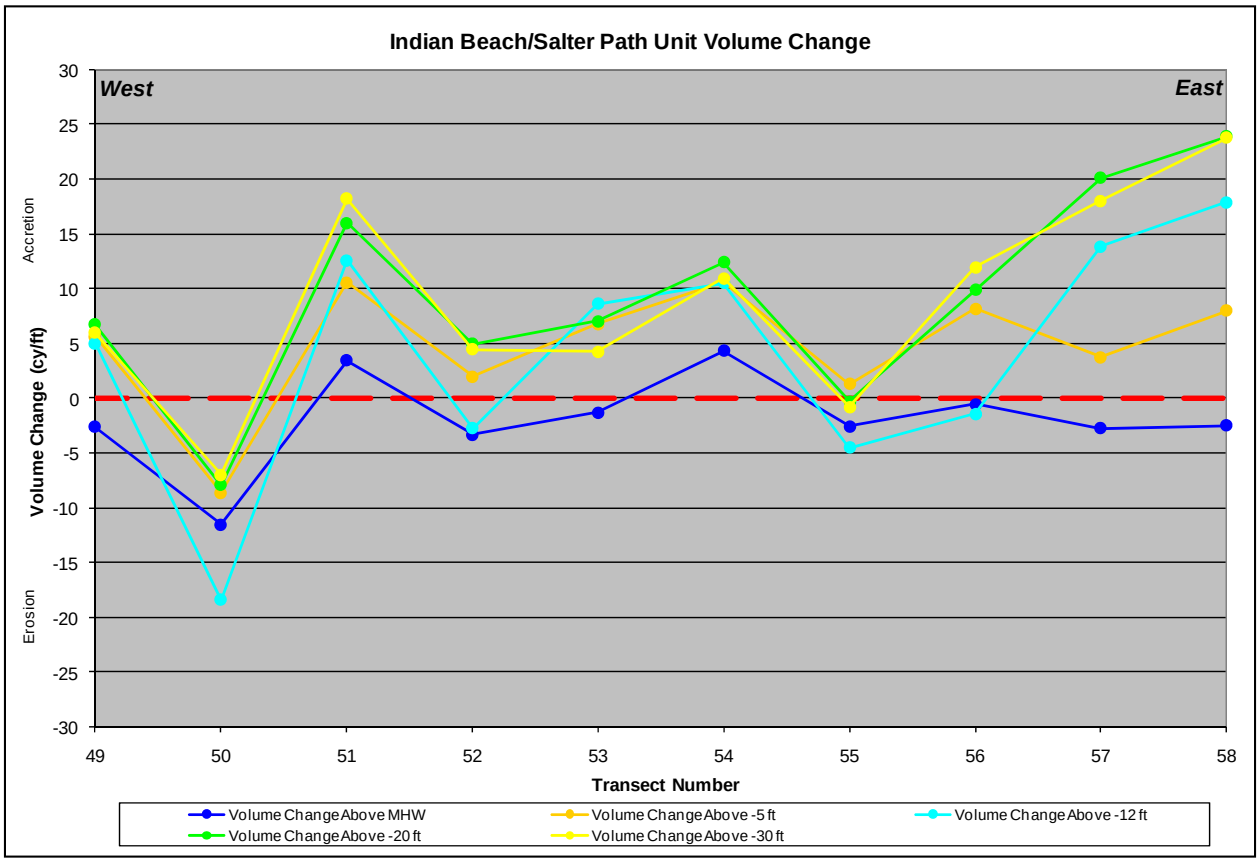


Figure 14. Indian Beach/Salter Path Unit Volume Change (2013 - 2014)

5.4.3 Pine Knoll Shores

The Pine Knoll Shores region covers Transects 59 through 76. Since monitoring efforts began in 1999, the Pine Knoll Shores region has received 2.63 million cy of nourishment material as a result of the County Project, USACE Section 933, and FEMA post-storm work (Ophelia and Irene). Most recently, Pine Knoll Shores received 315,221 cy of material as part of the 2013 post-Irene Renourishment Project. A summary of average shoreline and volume changes between 2013 and 2014 for the Pine Knoll Shores region are presented in **Table 17**.

Table 17. Average Shoreline and Volume Change for Pine Knoll Shores (2013-2014)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Pine Knoll Shores-West (59-65)	9,063	-19.1	-1.7	-15,840	-0.8	-7,008	-0.9	-7,812	5.4	48,694	5.0	45,413
Pine Knoll Shores-East (66-76)	14,815	-11.8	0.7	10,236	-3.5	-52,282	-3.9	-58,200	0.1	1,656	-3.9	-58,253

Shoreline change at MHW showed overall recession in both reaches of Pine Knoll Shores. The shoreline change plot in **Appendix B** and the profile plots in **Appendix C** indicate that this behavior was fairly consistent throughout each reach. Volumetrically, **Table 17** indicates that Pine Knoll Shores West experienced a loss of material above MHW, with smaller losses above

-5 ft NAVD88 and -12 ft NAVD88 and gains in material above -20 ft NAVD88 and -30 ft NAVD88. On the contrary, Pine Knoll Shores East experienced an overall gain in material above MHW but losses above the lower elevations. Pine Knoll Shores East experienced the most noteworthy loss above -12 ft NAVD88, of approximately 58,000 cy. However, this is not considered to be a significant amount of loss or indication of poor condition of the beach. **Figure 15** displays the unit volume change at each transect for the Pine Knoll Shores region. It can be seen that Pine Knoll Shores West had alternating pockets of volume loss and volume gain throughout the reach while Pine Knoll Shores East showed sustained losses over consecutive transects. Upon inspection of the profile plots in **Appendix C**, it appears that the offshore bar at Transects 60-62 and Transects 65-67 has flattened out significantly over the past year which could be the cause of increased wave energy in these areas, creating the substantial losses seen at Transects 61 and 66.

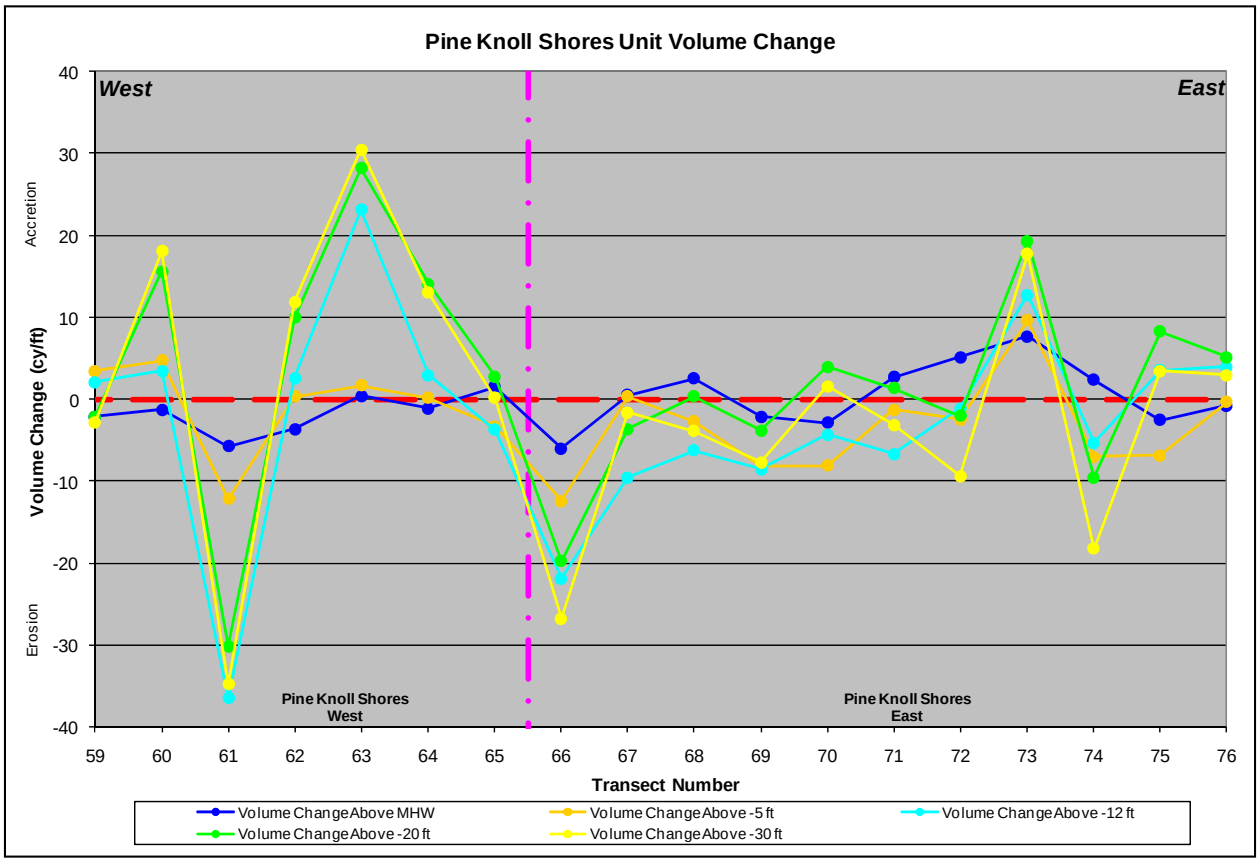


Figure 15. Pine Knoll Shores Unit Volume Change (2013 - 2014)

5.4.4 Atlantic Beach

The Atlantic Beach region covers Transects 77 through 102. Since monitoring began in 1999, the region has received 3.71 million cy of nourishment material from the Brandt Island Pump Out and USACE dredge disposal. Most recently, approximately 522,518 cy of material was placed on Atlantic Beach in spring 2014 as part of the Morehead City Harbor Maintenance Dredging Project. A summary of average shoreline and volume changes between 2013 and 2014 for the Atlantic Beach region are presented in **Table 18**.

Table 18. Average Shoreline and Volume Change for Atlantic Beach (2013-2014)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Atlantic Beach (77-102)	26,176	41.1	8.7	228,589	14.0	365,764	21.9	573,232	22.2	579,829	18.0	471,512

Atlantic Beach experienced an overall seaward shoreline advancement at MHW of approximately 41.1 ft over the past year, most of which occurred in Transects 98-102 where the nourishment was placed. The shoreline change plot in **Appendix B** and profile plots in **Appendix C** show that in areas where the nourishment was placed, the shoreline change was on the order of 150-200 ft. However, the remainder of the reach which wasn't nourished also generally saw a seaward advancement of the shoreline at MHW with the exception of a few transects. Volumetrically, the reach experienced large gains in material above each elevation between 2013 and 2014 due to the nourishment project. **Table 18** shows that Atlantic Beach gained approximately 573,200 cy above -12 ft NAVD 88, indicating some additional gains in material before the nourishment was placed. **Figure 16** displays the unit volume change for each transect in the Atlantic Beach region. The large gains due to the nourishment project are evident at the eastern end of the reach. However, the remainder of the reach appears to show a slight gain in volume above MHW and above -12 ft NAVD88 as well.

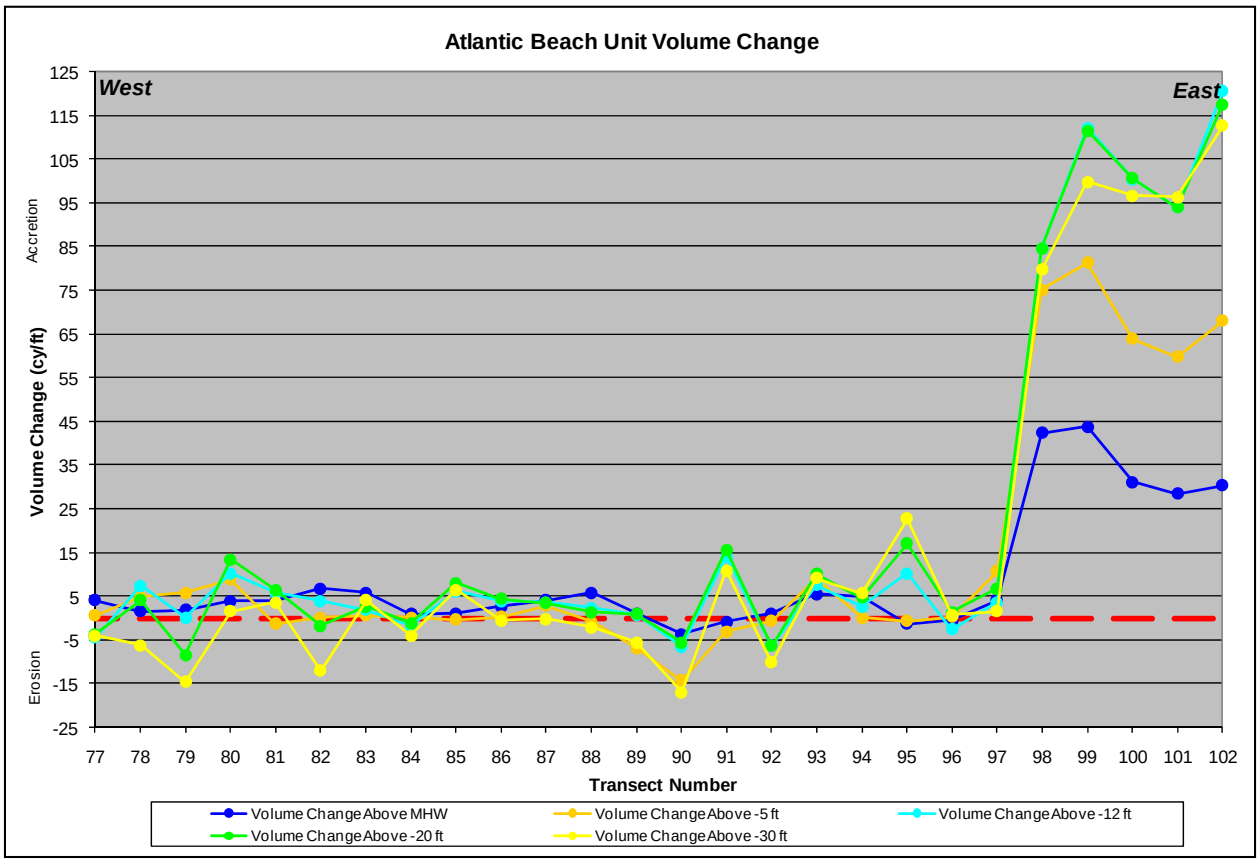


Figure 16. Atlantic Beach Unit Volume Change (2013 - 2014)

5.4.5 Fort Macon State Park

The Fort Macon State Park region covers Transects 103 through 112. Since monitoring began in 1999, this region has received 2.06 million cy of nourishment material from USACE Inner Harbor Dredging Disposal. Most recently, 585,067 cy of material was placed on Fort Macon in Spring 2014 as part of the Morehead City Harbor Maintenance Dredging Project. A summary of average shoreline and volume changes between 2013 and 2014 for the Fort Macon State Park region are presented in **Table 19**.

Table 19. Average Shoreline and Volume Change for Fort Macon State Park (2013-2014)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Fort Macon State Park (103-112)	6,691	126.8	20.1	134,611	45.9	306,869	65.3	436,823	64.8	433,305	61.3	410,131

Fort Macon experienced an overall seaward shoreline advancement at MHW of approximately 126.8 ft over the past year, most of which occurred in Transects 103-107 where the nourishment was placed. The shoreline change plot in **Appendix B** and profile plots in **Appendix C** show that in areas where the nourishment was placed, the shoreline change was on the order of 150-175 ft. However, the remainder of the reach which wasn't nourished also saw a seaward advancement of the shoreline at MHW due to the longshore transport of material towards Beaufort Inlet even before the nourishment project occured. Volumetrically, the reach experienced large gains in material above each elevation between 2013 and 2014 due to the nourishment project. **Table 19** shows that Fort Macon gained approximately 436,800 cy above -12 ft NAVD 88, indicating some additional losses in material may have occurred before the nourishment was placed. **Figure 17** displays the unit volume change for each transect in the Fort Macon region. The large gains due to the nourishment project are evident at the western end of the reach. However, the remainder of the reach appears to show a slight gain in volume above MHW and above -12 ft NAVD88 as well.

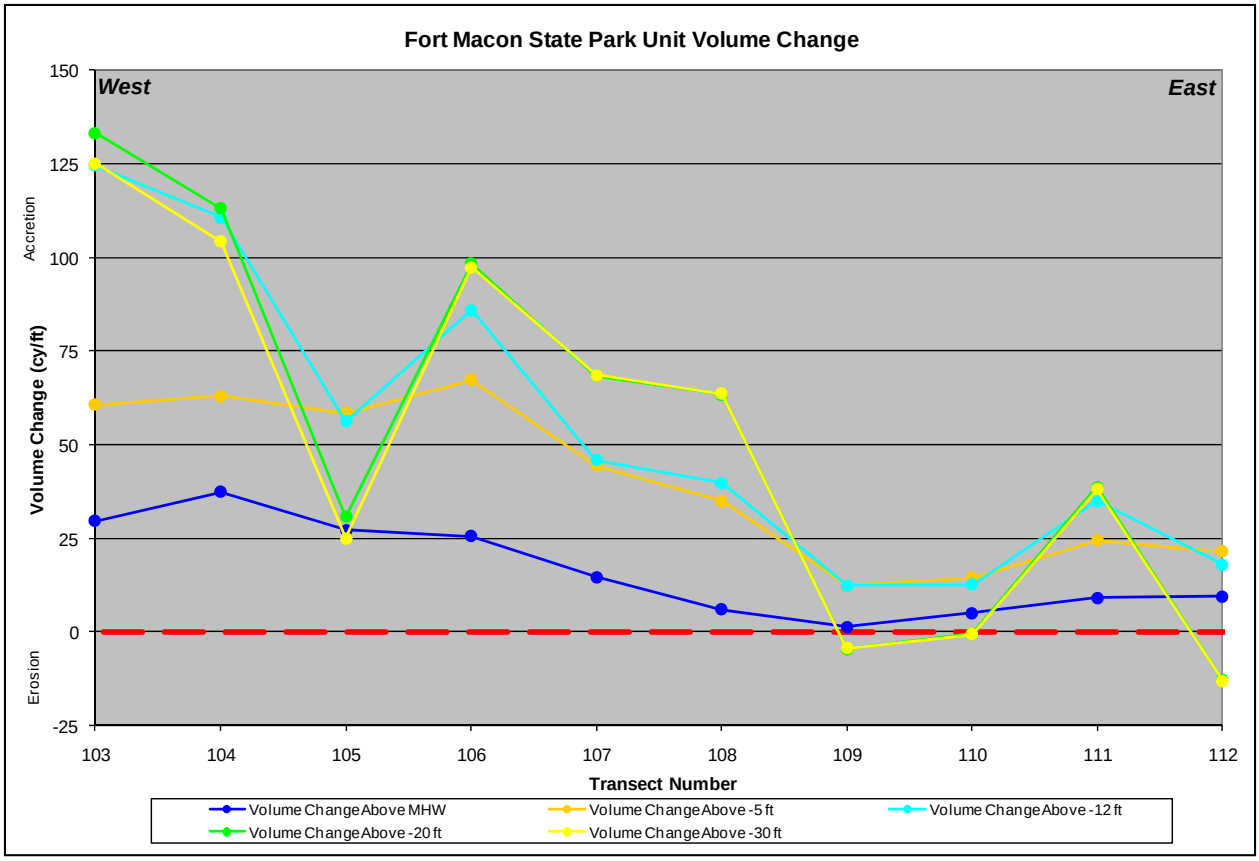


Figure 17. Fort Macon State Park Unit Volume Change (2013 - 2014)

5.4.6 Bogue Inlet

The Bogue Inlet region is comprised of an area along the western terminus of Bogue Banks which covers Transects 1 through 8 and an area along the eastern side of Bogue Inlet covering Transects 117 through 120. A summary of average shoreline and volume changes between 2013 and 2014 for the Bogue Inlet region are presented in **Table 20**.

Table 20. Average Shoreline and Volume Change for Bogue Inlet (2013-2014)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	13.1	-0.6	-4,354	2.5	18,535	1.6	11,826	-6.9	-51,174	-9.4	-69,639
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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

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 the spit has continued to grow westward over the past year. Although also dynamic, calculations are able to be performed for the Bogue Inlet-Ocean region, which experienced small volumetric losses above MHW with larger changes occurring around the offshore bar where approximately 11,800 cy of material was gained. **Figure 18** displays the unit volume change at each transect for the

Bogue Inlet-Ocean region. It can be seen that the majority of the changes occurred at lower elevations, mostly around -12 ft NAVD88, with Transect 1, nearest Bogue Inlet, showing the largest losses.

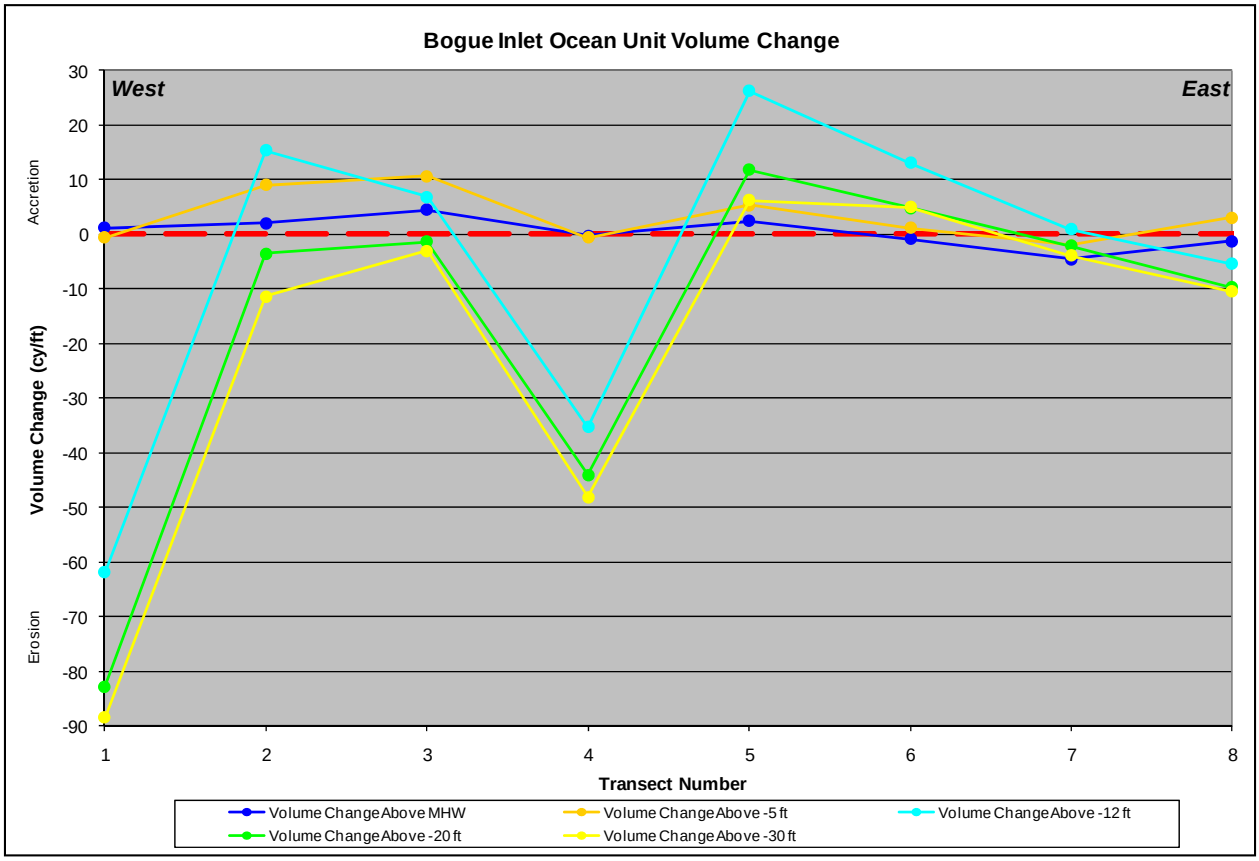


Figure 18. Bogue Inlet Ocean Unit Volume Change (2013 - 2014)

5.4.7 Beaufort Inlet

The Beaufort Inlet region is comprised of an area along the western side of Beaufort Inlet which covers Transects 112B through 116. A summary of average shoreline and volume changes between 2013 and 2014 for the Beaufort Inlet region are presented in **Table 21**.

Table 21. Average Shoreline and Volume Change for Beaufort Inlet (2013-2014)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Beaufort Inlet (112B-116)	2,000	40.2	8.7	17,348	11.2	22,349	0.6	1,199	10.9	21,707	16.0	31,967

Shoreline changes at MHW showed a large seaward advancement of approximately 40.2 ft and volume changes at Beaufort Inlet showed volume gain over the past year above all elevations. It is likely that material from Fort Macon has been transported alongshore, around the terminal groin, to supply these gains. Profiles for this region can be seen in **Appendix C**. They show large gains in volume to the berm and beachface out to the wading depth in transects 112B and

113, nearest the terminal groin. The remaining transects show little change from the previous year. **Figure 19** displays the unit volume change at each transect in the Beaufort Inlet region.

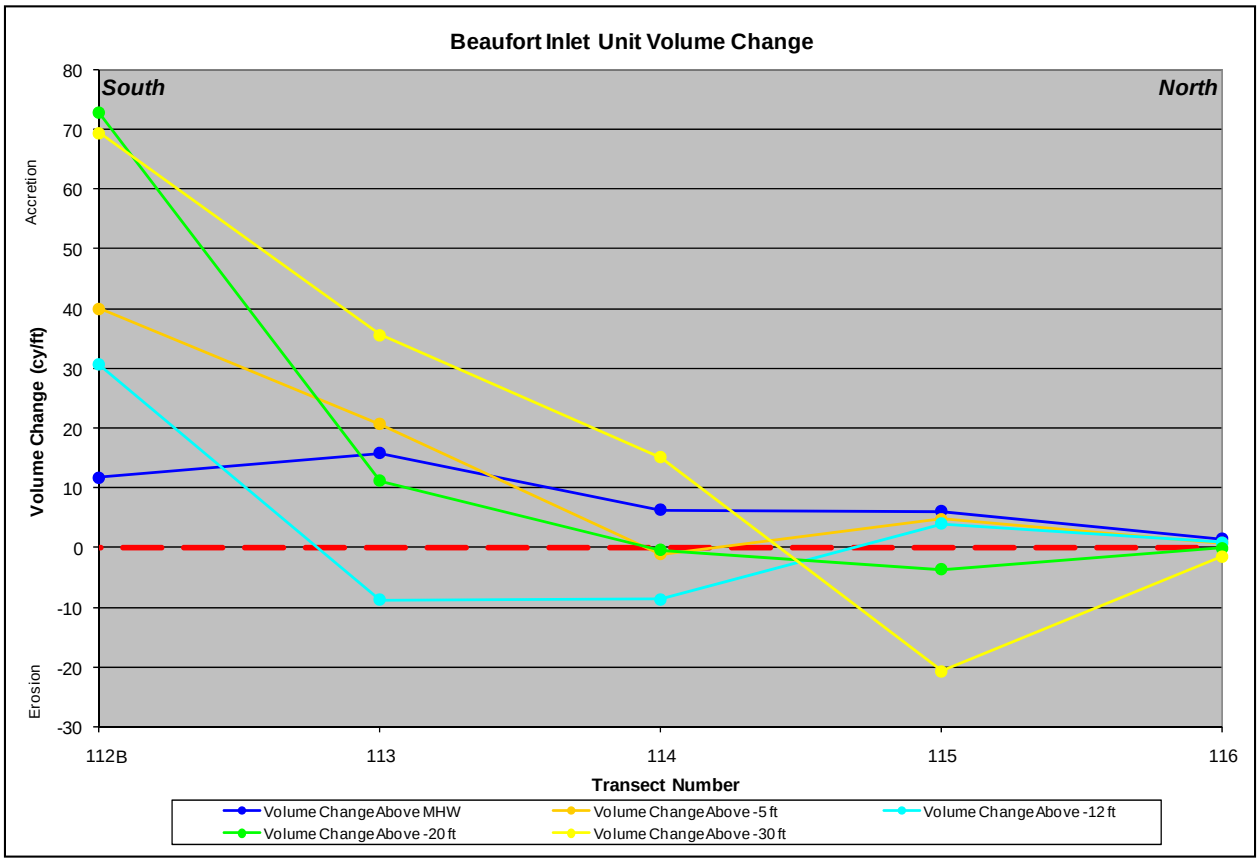


Figure 19. Beaufort Inlet Unit Volume Change (2013 - 2014)

5.4.8 Bear Island

Bear Island contains 18 transects spaced 1000 ft apart. A summary of average shoreline and volume changes between spring/summer 2013 and spring/summer 2014 for the Bear Island region are presented in **Table 22**.

Table 22. Average Shoreline and Volume Change for Bear Island (2013-2014)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bear Island (1-18)	16,500	-22.0	-2.4	-39,033	0.0	-676	5.2	85,216	3.9	65,060	2.8	46,051

Bear Island appears to have experienced a moderate amount of shoreline recession over the past year, as shown in **Table 22**. As with much of Bogue Banks, volumetric calculations indicate a loss in material above MHW but a gain in material at lower elevations which is indicative of material being pulled from the recreational/visible beach to lower elevations but still remaining within the system. After examining the volume change plots in **Appendix B** and profile plots in **Appendix C**, it is apparent that material lost from above MHW was captured landward of the offshore bar, above -12 ft NAVD and thus is still within the system and providing protection.

Most importantly, there was a gain of approximately 85,200 cy of material above -12 ft NAVD88. **Figure 20** displays the unit volume change at each transect on Bear Island. Most of the changes occur around the inlets with the remainder of the island appearing fairly stable. Profiles from Transect 18 were not included in the analysis due to the absence of dry land at this transect.

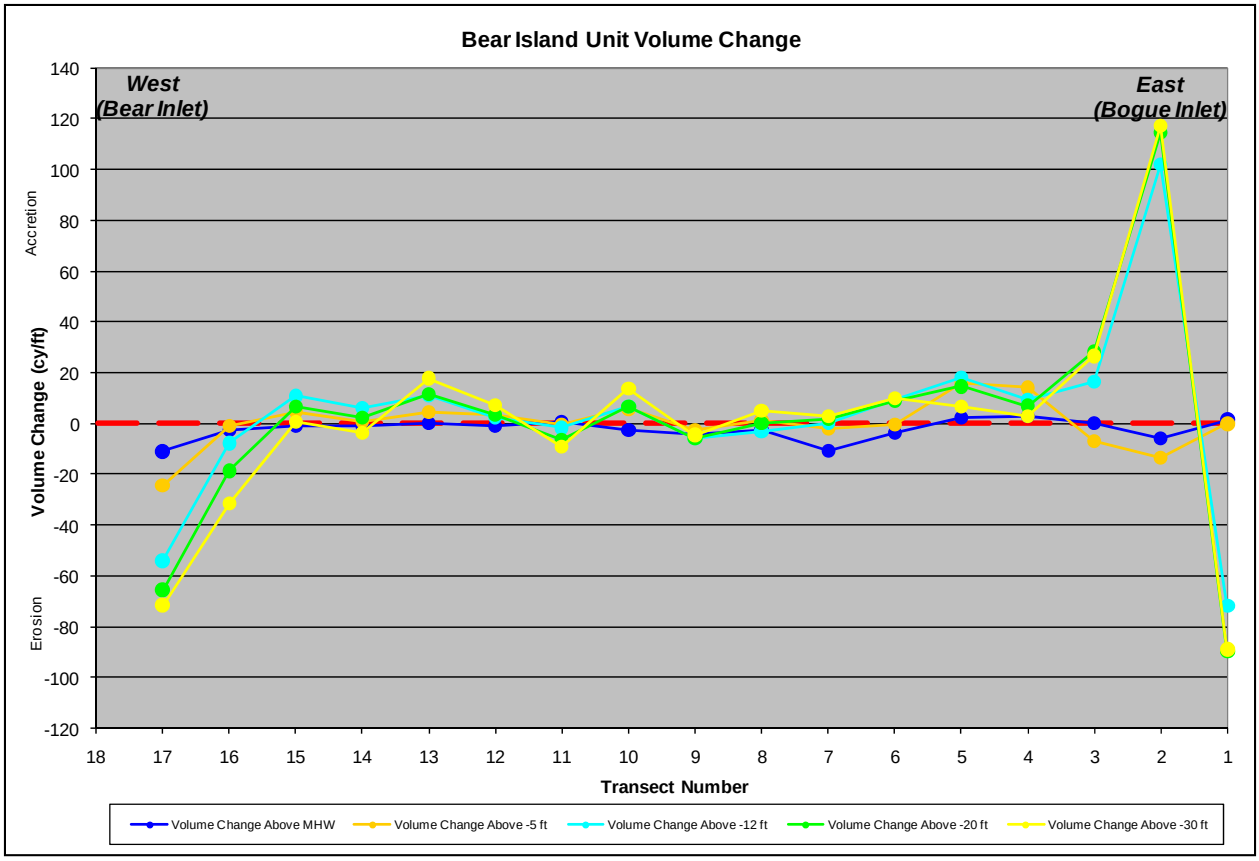


Figure 20. Bear Island Unit Volume Change (2013 - 2014)

5.4.9 Shackleford Banks

Shackleford Banks is comprised of 24 transects and is a natural shoreline, receiving no nourishment. As a result, varying accretion and erosion occurs along the island. A summary of average shoreline and volume changes between spring/summer 2013 and spring/summer 2014 for the Shackleford Banks region are presented in **Table 23**.

Table 23. Average Shoreline and Volume Change for Shackleford Banks (2013-2014)

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Shackleford Banks (1-24)	46,001	-60.1	-4.0	-186,222	-8.8	-403,748	-14.6	-671,231	-21.3	-980,665	-23.5	-1,082,016

Shackleford Banks appears to have experienced a significant amount of shoreline recession and volume loss, as shown in **Table 23**. The volume change plots in **Appendix B** and profile plots in **Appendix C** indicate that the majority of the shoreline recession and volume loss was located at Transects 21-24, adjacent to Beaufort Inlet, including major losses to the both the dunes and

beachface. The remaining transects along Shackleford Banks (1-20) appear to have been impacted similar to Bogue Banks and Bear Island with losses of material above MHW but capture of that material below MHW, landward of the offshore bar, remaining in the portion of the system which provides protection to the beach. If the westernmost transects (21-24) are considered separately from the rest of the island, the average shoreline recession near Beaufort Inlet was approximately -318 ft while it was only -17 ft along the remainder of the island. Likewise, if volume change for the westernmost transects is considered separately, approximately 601,000 cy of material was lost near Beaufort Inlet above -12 ft NAVD88 while only 70,000 cy was lost from the remainder of the island above -12 ft NAVD88. **Figure 21** 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 21 through 24, adjacent to Beaufort Inlet.

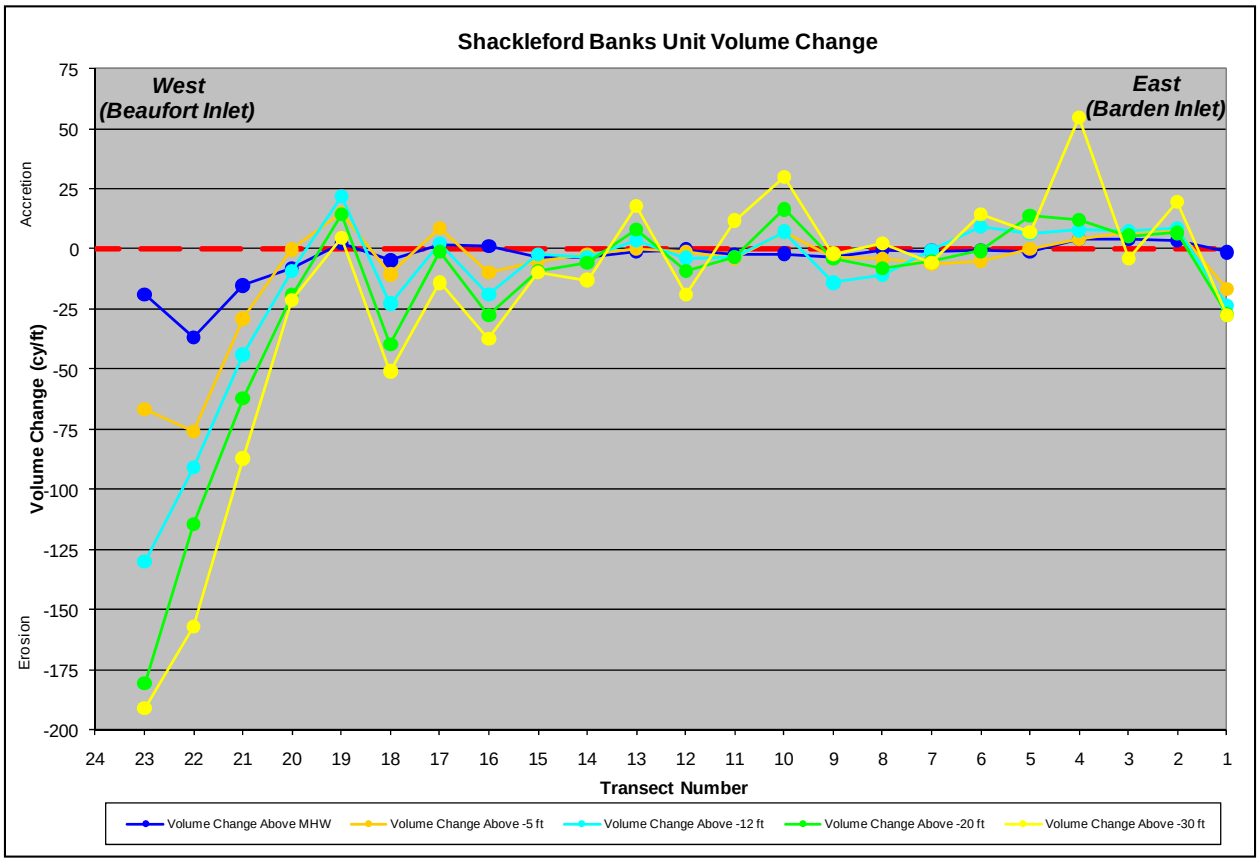


Figure 21. Shackleford Banks Unit Volume Change (2013 – 2014)

5.5 Post-Irene Project Analysis

This section provides an overall analysis of the performance of the 2013 Post-Irene Renourishment Project at each of the three reaches along Bogue Banks where nourishment material was placed. Volume change between the spring/summer 2014 survey and the post-fill (AD) survey above elevations +1.1 ft NAVD88 (MHW), -5 ft NAVD88, and -12 ft NAVD88 was calculated to determine the amount of nourishment material remaining at various elevations. It is important to note some of the nourishment material has been transported alongshore outside

the nourishment reach and cross-shore beyond a depth of -12 ft NAVD88 and may not be captured in these calculations.

The nourishment extents within Emerald Isle West (Reach 3) include Transects 10 through 16. **Table 24** presents the amount of material placed above each elevation based on the before dredge (BD) and after dredge/post-fill (AD) surveys, the change in volume between the AD survey and the spring/summer 2014 survey, and the percent difference which indicates what percentage of material has been lost or gained at each elevation since the nourishment project. In Emerald Isle West, approximately 36% of the material placed above MHW has been lost. However, the positive numbers above -5 ft NAVD88 and -12 ft NAVD88 indicate that this volume and additional sand has been captured above these elevations and is still providing protection to the system.

Table 24. Emerald Isle – West Project Performance

Elevation (ft NAVD88)	Cumulative Volume Change BD - AD (cy)	Difference in Cumulative Volume Change AD - 2014 (cy)	Percent Difference AD - 2014
1.1	111,365	-40,292	-36.2%
-5	152,899	6,099	4.0%
-12	198,190	97,627	49.3%

The nourishment extents within Emerald Isle East (Reach 2) include Transects 35 through 45. **Table 25** presents the amount of material placed above each elevation based on the before dredge (BD) and after dredge/post-fill (AD) surveys, the change in volume between the AD survey and the spring/summer 2014 survey, and the percent difference which indicates what percentage of material has been lost or gained at each elevation since the nourishment project. In Emerald Isle East, approximately 42.1% of the material placed above MHW has been lost while approximately 16.7 % of the material placed above -5 ft NAVD88 has been lost. However, the gain above -12 ft NAVD88 (33.4 %) indicates that this volume and additional sand has been captured above these elevations and is still providing protection to the system.

Table 25. Emerald Isle - East Project Performance

Elevation (ft NAVD88)	Cumulative Volume Change BD - AD (cy)	Difference in Cumulative Volume Change AD - 2014 (cy)	Percent Difference AD - 2014
1.1	169,748	-71,539	-42.1%
-5	330,050	-55,257	-16.7%
-12	451,600	150,923	33.4%

The nourishment extents within Pine Knoll Shores (Reach 1) include Transects 62 through 71. **Table 25** presents the amount of material placed above each elevation based on the before dredge (BD) and after dredge/psot-fill (AD) surveys, the change in volume between the AD survey and the spring/summer 2014 survey, and the percent difference which indicates what percentage of material has been lost or gained at each elevation since the nourishment project. In Pine Knoll Shores, approximately 43.9% of the material placed above MHW and approximately 42.6% of the material placed above -5 ft NAVD88 has been lost. However, the gain (26.7%) in material above -12 ft NAVD88 indicates that this volume and additional sand has been captured above this elevation and is still providing protection to the system.

Table 26. Pine Knoll Shores Project Performance

Elevation (ft NAVD88)	Cumulative Volume Change BD - AD (cy)	Difference in Cumulative Volume Change AD - 2014 (cy)	Percent Difference AD - 2014
1.1	152,123	-66,788	-43.9%
-5	258,562	-110,275	-42.6%
-12	315,221	84,236	26.7%

It is apparent that the material placed in Pine Knoll Shores has seen the most significant losses in that more material has been lost from the recreational/visible beach (above MHW) out to wading depth (-5 ft NAVD88) and captured slightly further offshore (between -5 ft NAVD88 and -12 ft NAVD88) than the material in Emerald Isle which experienced slightly less loss above MHW and has been mostly captured above -5 ft NAVD88. This behavior will likely lead to the recommendation additional advanced fill will be required at Pine Knoll Shores during future nourishment projects. **However, M&N is confident that all of the material placed from the Post-Irene Renourishment Project has been captured above -12 ft NAVD88 and remains within the system, providing protection to the beach.** In fact, there is more material above -12 ft NAVD88 now that there was immediately after the nourishment project. It should also be noted that the percent losses above MHW and -5 ft NAVD88 stated in last year's report ranged from 21 to 37%. Therefore, the rate of equilibration/volume losses at these higher elevations appears to be slowing.

5.6 FEMA Beach Maintenance Analysis

Analysis was performed to calculate the amount of fill remaining from Phase I, Phase II, and Phase III of the County Project. Using the volume change above -12 ft NAVD88 between the Phase I, Phase II, and Phase III post-nourishment surveys and the spring/summer 2014 survey along with the amount of fill placed during Phase I, Phase II, and Phase III, the percentage of remaining fill was determined. If any reach falls below 50% of fill remaining, this area needs to be considered for nourishment. FEMA beach maintenance calculations for applicable reaches are presented in **Appendix E. Table 27** presents the results of the 2013 and 2014 FEMA beach maintenance analysis for comparison. Due to the Post-Irene Renourishment Project, the overall percent fill remaining increased significantly in 2013 and there has not been much change since the previous year. The most notable change is the loss of material in Pine Knoll Shores East, lowering the percent fill remaining from 103.8% to 95.8%. However, none of the reaches is close to the 50% threshold.

Table 27. Comparison of Percent Fill Remaining from Base Nourishment

2013

Reach	Percent Fill Remaining	
Indian Beach/Salter Path	**174.1**	
Pine Knoll Shores West	*136.0*	**116.1**
Pine Knoll Shores East	*103.8*	
PHASE I	**131.4**	
Emerald Isle Central	*165.3*	**126.3**
Emerald Isle East	*83.6*	
PHASE 2	**126.3**	
Emerald Isle West	**218.9**	
Bogue Inlet	**168.0**	
PHASE 3	**215.5**	

2014

Reach	Percent Fill Remaining	
Indian Beach/Salter Path	**176.7**	
Pine Knoll Shores West	*137.6*	**111.8**
Pine Knoll Shores East	*95.8*	
PHASE I	**128.9**	
Emerald Isle Central	*165.0*	**128.7**
Emerald Isle East	*89.1*	
PHASE 2	**128.7**	
Emerald Isle West	**240.9**	
Bogue Inlet	**160.7**	
PHASE 3	**235.5**	

5.7 Statistical Analysis of Recent Volume Change Trends

Using the seven most recent high quality survey datasets (2008-2014), statistical analyses were performed to determine if any long-term trends in the Bogue Banks oceanfront behavior are beginning to appear. The average volume change per year was calculated using the volume changes from the current monitoring report along with the five previous reports (M&N 2009 2010, 2011, 2012, and 2013). The recent nourishments (Post-Irene - February/March 2013 and MCH Maintenance Dredging in 2011, 2014) were subtracted out at each transect based on an average cubic yard per foot placed along each reach of beach in order to determine the background erosion rate. Therefore, these numbers are subject to some uncertainty since the same amount of nourishment was likely not placed at each transect. **Figure 22** shows the mean volume change with nourishment and **Figure 23** shows the mean volume change with the nourishment subtracted out from 2008-2014. The hotspots and Emerald Isle and Pine Knoll Shore are very visible as well as the increased erosion rates in Atlantic Beach and Fort Macon.

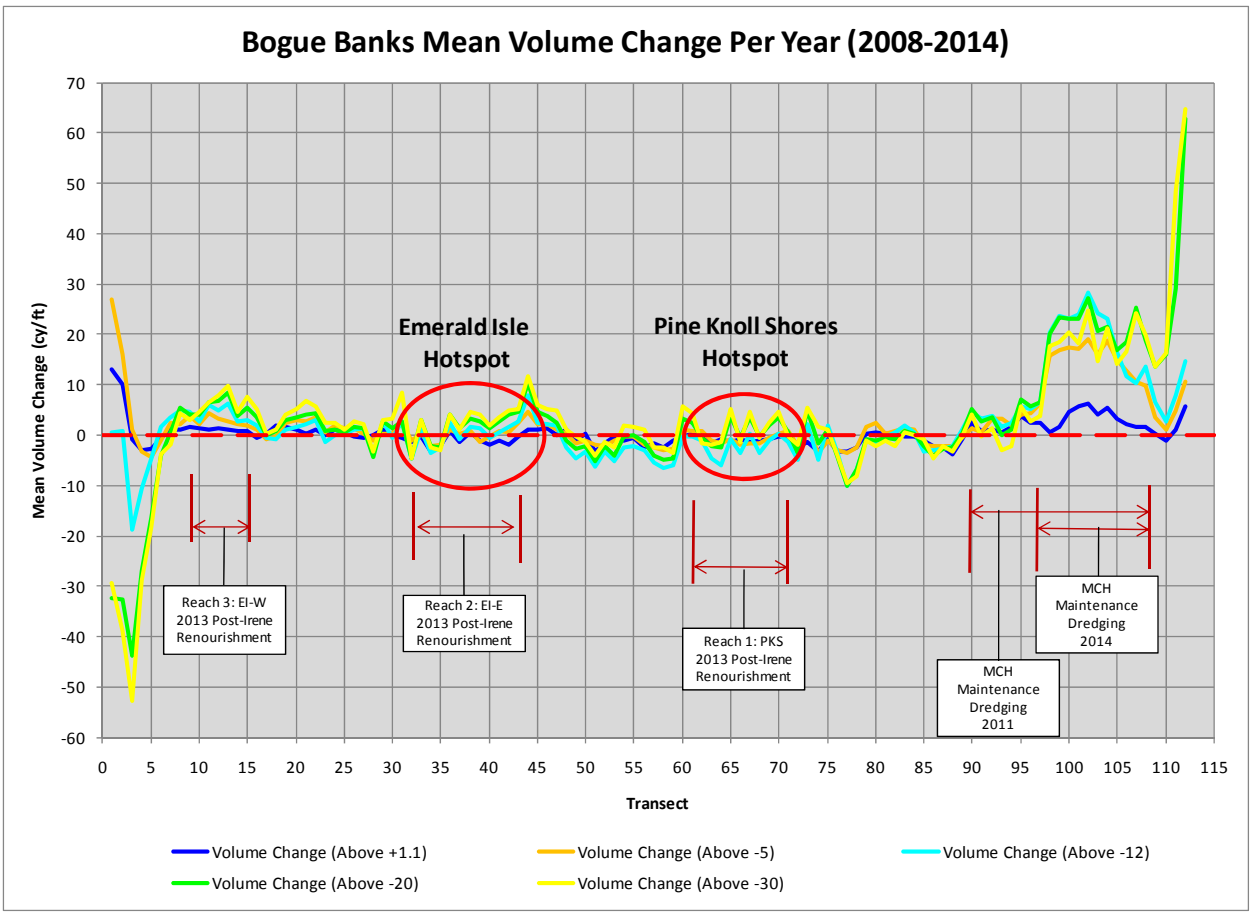


Figure 22. Bogue Banks Mean Volume Change (With Nourishment)

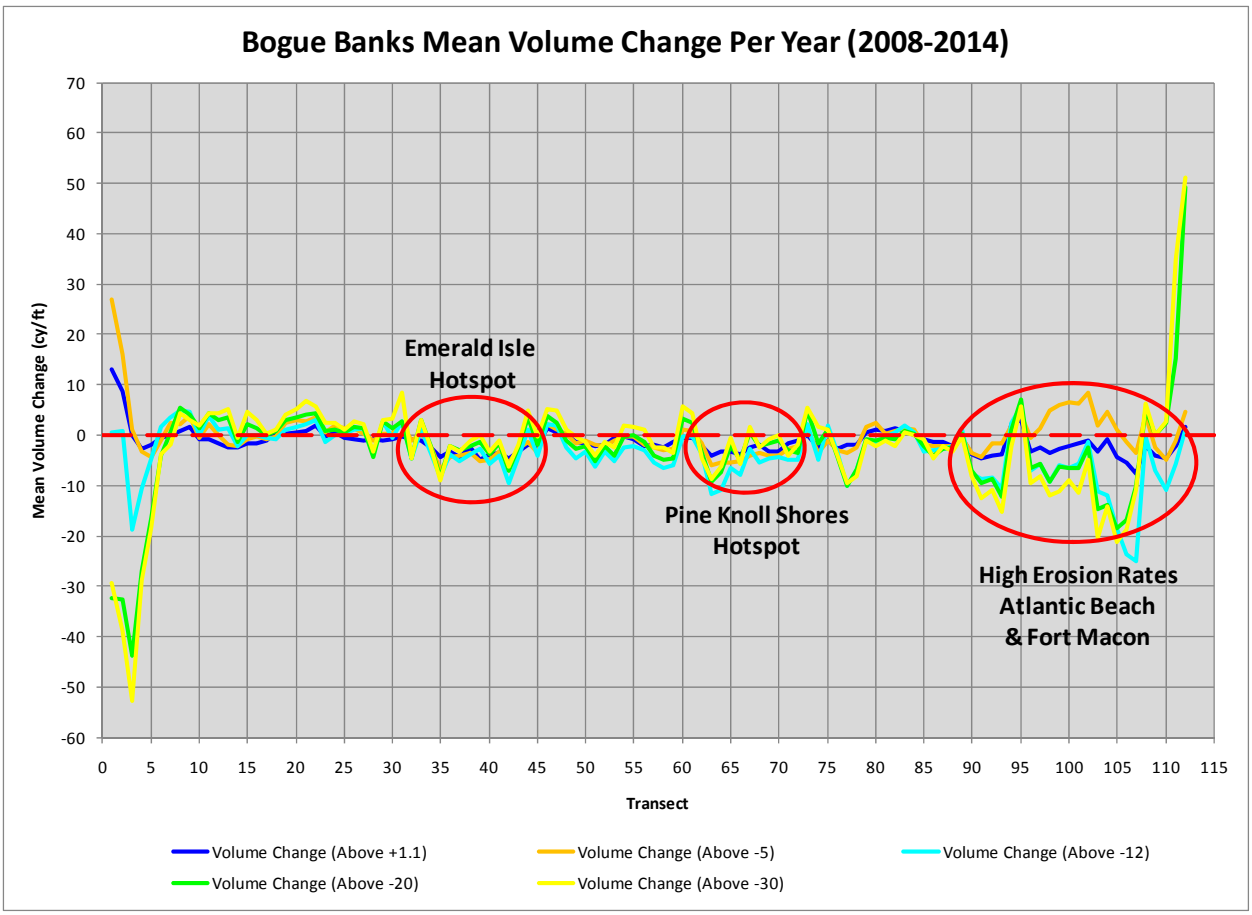


Figure 23. Bogue Banks Mean Volume Change (Without Nourishment)

The standard deviation of the mean volume change per year were also calculated. **Figure 24** through **Figure 28** shows the mean volume change per year with standard deviation bars at plus or minus one standard deviation for each of the elevations above which volume change was calculated.

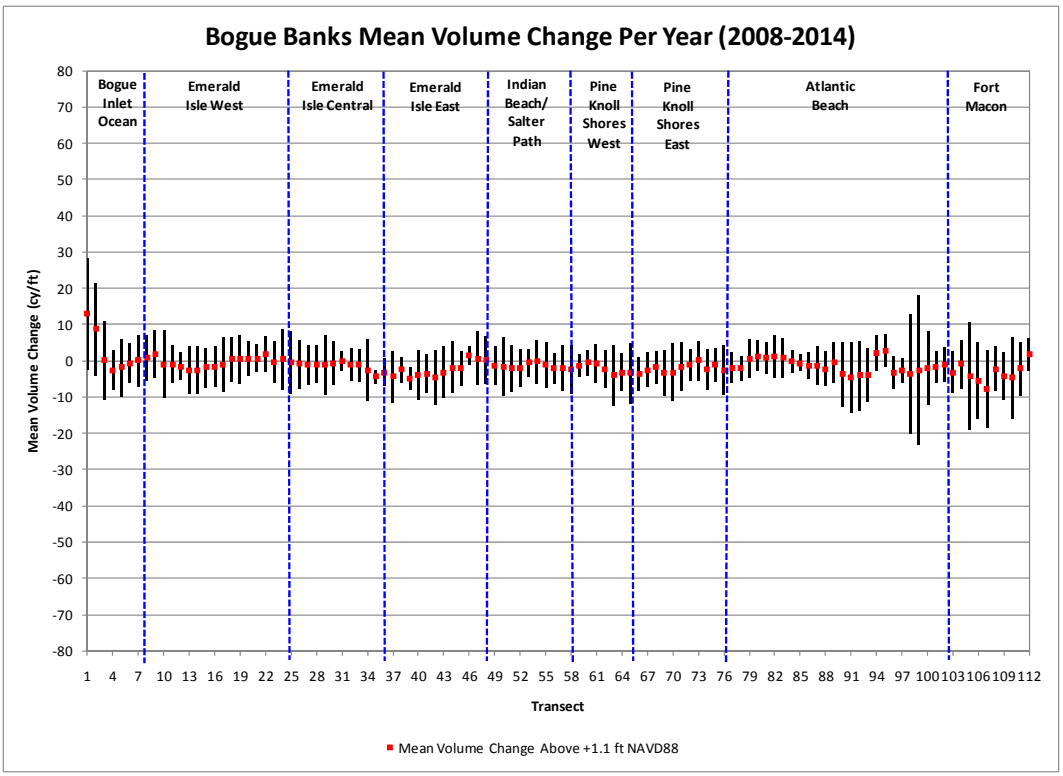


Figure 24. Statistical Analysis of Volume Change Above +1.1 ft NAVD88

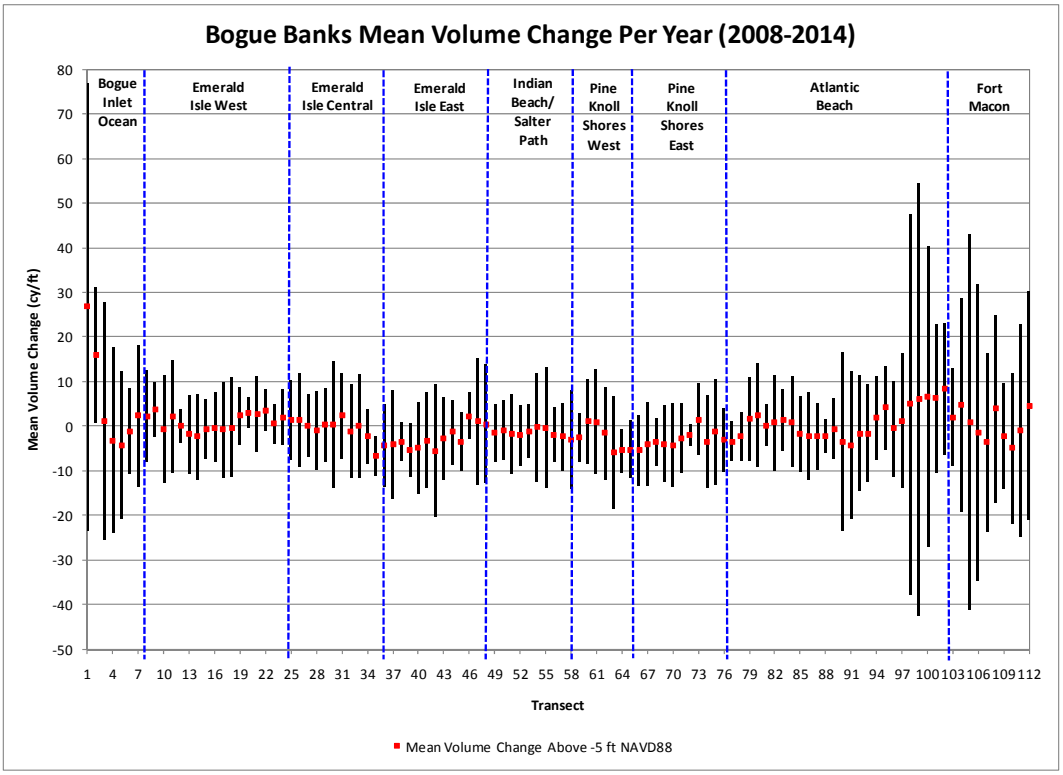


Figure 25. Statistical Analysis of Volume Change Above -5.0 ft NAVD88

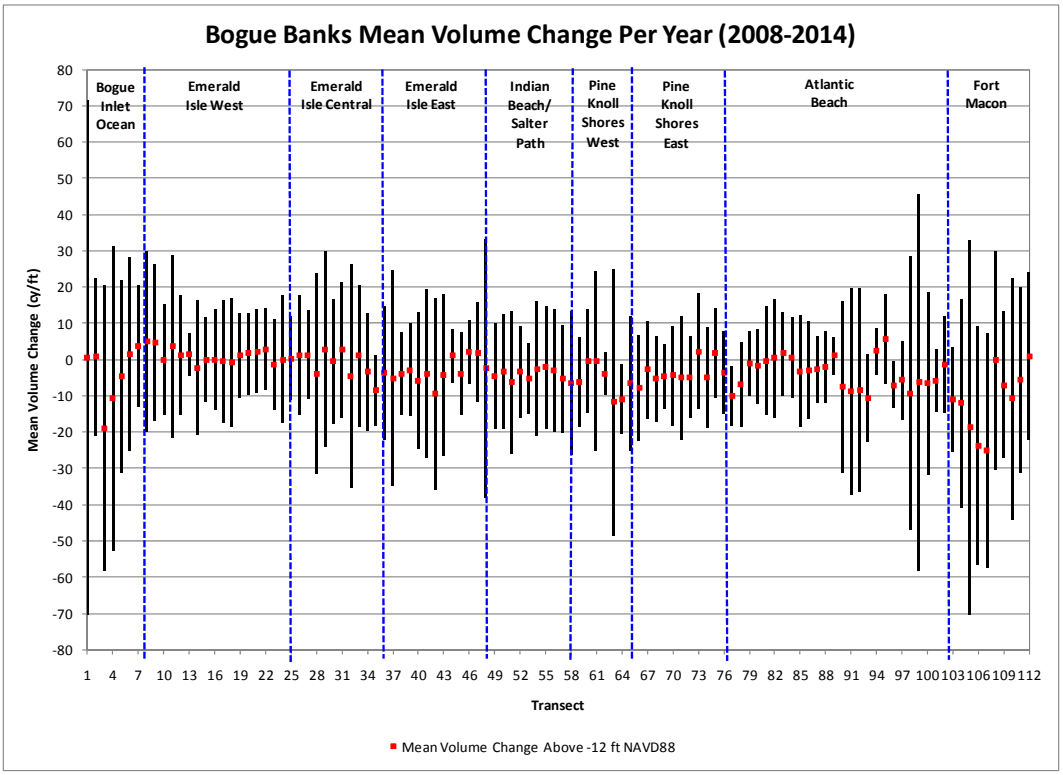


Figure 26. Statistical Analysis of Volume Change Above -12.0 ft NAVD88

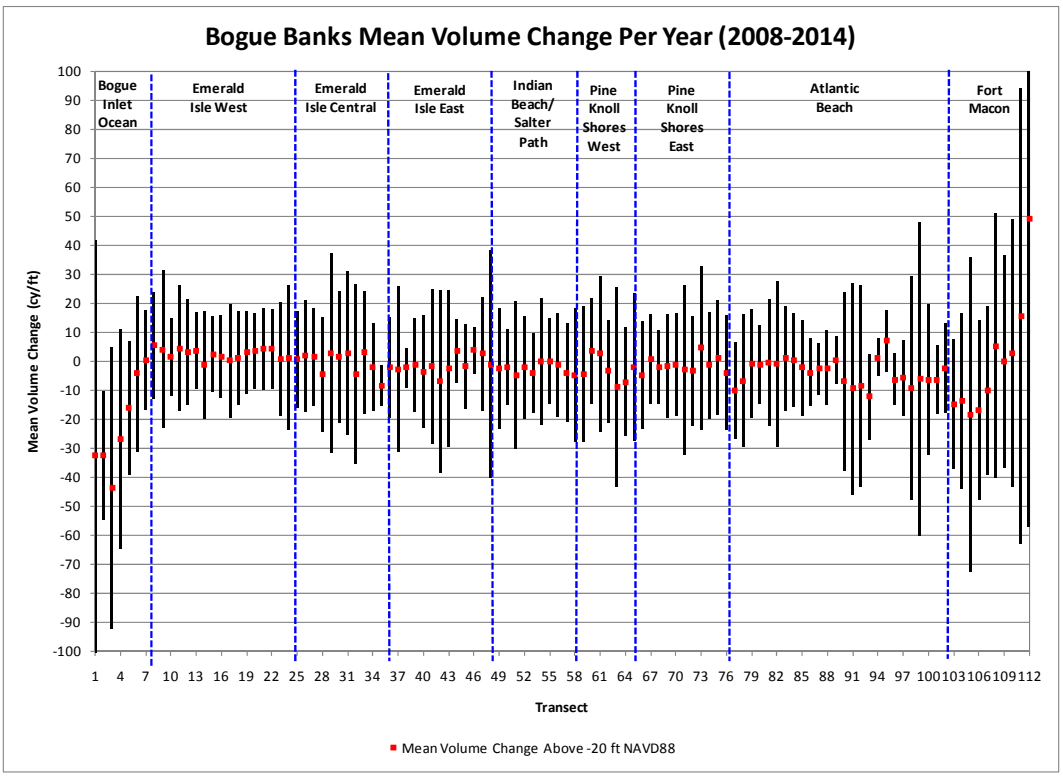


Figure 27. Statistical Analysis of Volume Change Above -20.0 ft NAVD88

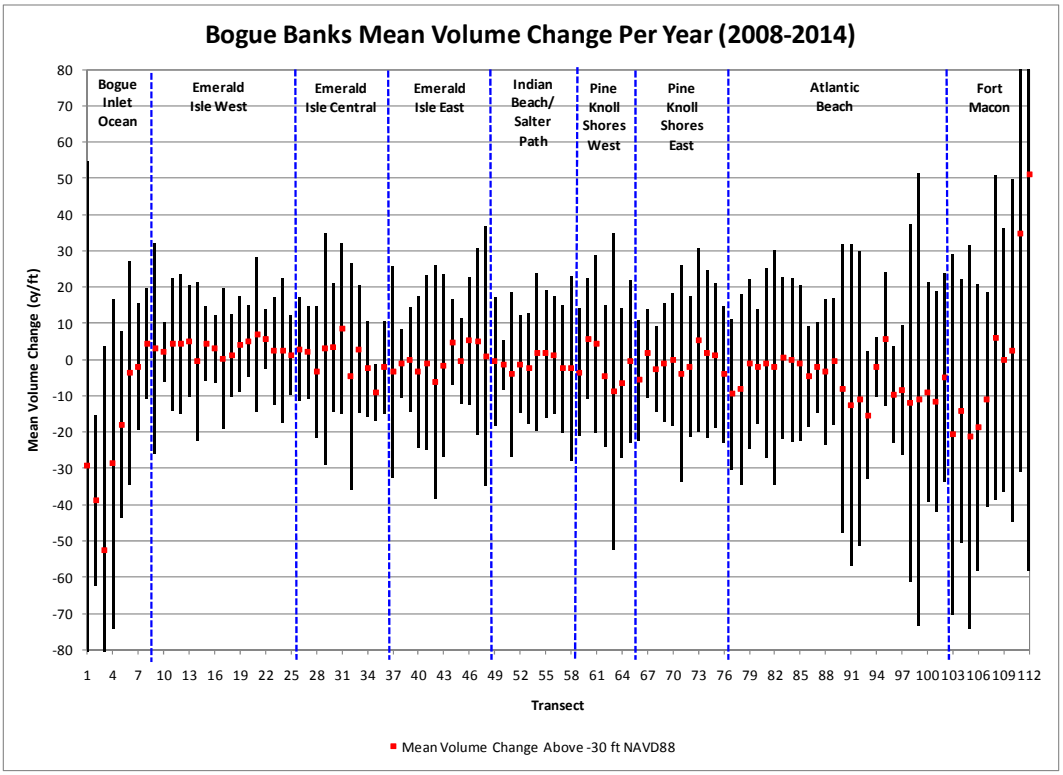


Figure 28. Statistical Analysis of Volume Change Above -30.0 ft NAVD88

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

6.0 Transition to Bogue Banks Master Beach Nourishment Plan

Carteret County is currently in the process of developing a programmatic 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, taking out the time-consuming process of permitting each individual project and allowing for placement of sand when it is needed. The engineering portion of the EIS, which provides detailed analysis of the estimation of nourishment needs and sediment source quantities, has been completed by Moffatt & Nichol and is currently being reviewed and incorporated into the remainder of the EIS which is being drafted by Dial Cordy & Associates. It is expected that by the next annual survey (spring/summer 2015), Carteret County will be operating under the new

Master Plan. Incorporation of the Master Plan into ongoing annual monitoring efforts will require some changes to the current analysis which will be explained in the following section.

6.1 New Management Reaches and Nourishment Triggers

Currently, one of the triggers for nourishment action is if the average profile volume from the foredune (landward most crest of the primary dune) to the outer bar (above -12 ft NAVD88) in any of the established reaches (see Figure 1) falls below 225 cy/ft. This method provides for an equal amount of sand for everyone but not necessarily and equal amount of protection. 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. The engineering analysis included detailed SBEACH modeling which was used to determine the amount of material that is needed to provide a 25-yr event level of protection in each reach. This is different for each reach depending on existing dune height, berm width, offshore slope, etc. In addition, some changes were made to the reaches including slightly increasing the size of the Bogue Inlet-Ocean reach and consequently slightly decreasing the size of the Emerald Isle West reach and combining Pine Knoll Shores West and East into one reach based on beach profile morphology as well as detailed Crystal Ball analytical analysis of historical erosion rates. **Table 28** presents the current and future management reaches and nourishment triggers. Each reach will have a slightly different volume trigger, with an island wide weighted average of 233 cy/ft. **Figure 29** presents the new triggers with respect to the historical profile volume above -12 ft NAVD88.

Table 28. Current and Future Management Reaches and Nourishment Triggers

CURRENT REACHES:				NEW MANAGEMENT REACHES:			
Reach (Profiles)	**Length (ft)**	**2014 Volume Above -12 ft (cy/ft)**	**-12 ft Trigger (cy)**	**Reach (Profiles)**	**Length (ft)**	**2014 Volume Above -12 ft (cy/ft)**	**-12 ft Trigger (cy)**
Bogue Inlet-Ocean (1-8)	7,432	337	225	Bogue Inlet (1-11)	11,488	322	235
Emerald Isle-West (9-25)	22,344	307	225	Emerald Isle West (12-25)	18,288	310	266
Emerald Isle-Central (26-36)	15,802	292	225	Emerald Isle Central (26-36)	15,802	292	211
Emerald Isle-East (37-48)	13,220	273	225	Emerald Isle East (37-48)	13,220	273	221
Indian Beach-Salter Path (49-58)	12,850	272	225	Indian Beach/Salter Path (49-58)	12,850	272	224
Pine Knoll Shores-West (59-65)	9,063	253	225	Pine Knoll Shores (59-76)	23,878	253	211
Pine Knoll Shores-East (66-76)	14,815	252	225				
Atlantic Beach (77-102)	26,176	326	225	Atlantic Beach (77-102)	26,176	326	254

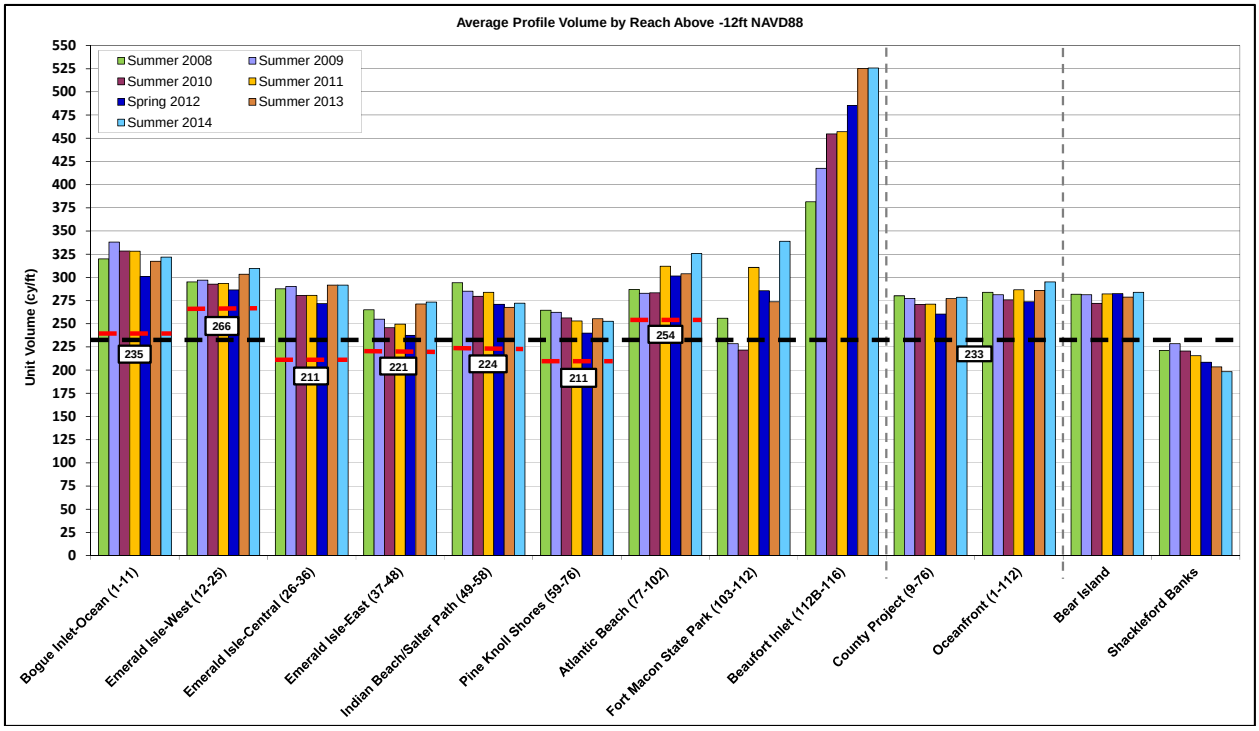


Figure 29. Future Management Reaches and Nourishment Triggers

6.2 Estimation of Years Remaining Until Next Nourishment

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 2014 survey data and historical erosion rates. **Table 29** presents the estimates of the remaining time until the new nourishment triggers are realized within each reach based on various confidence intervals. It appears that the first nourishments will be required in an 8-12 year range under average conditions (see 50% and 55% confidence intervals). However, if a storm were to impact the area, these estimates could go down to 3-6 years (see 75% and 85% confidence intervals).

Table 29. Years Remaining Until Nourishment

Reach (Profiles)	Management Reach Length (ft)	-12 ft 2014 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	322	235	87	22	14	10	8	6	5	4
Emerald Isle West (12-25)	18,288	310	266	44	128	128	128	69	27	16	8
Emerald Isle Central (26-36)	15,802	292	211	81	51	41	25	18	14	11	7
Emerald Isle East (37-48)	13,220	273	221	52	11	9	7	6	5	4	3
Indian Beach/Salter Path (49-58)	12,850	272	224	48	10	8	6	5	5	4	3
Pine Knoll Shores (59-76)	23,878	253	211	42	12	9	7	6	5	4	3
Atlantic Beach (77-102)	26,176	326	254	72	11	10	9	8	7	6	5
TOTAL	**121,702**										
AVERAGE		**293**	**233**	**61**	**35**	**31**	**27**	**17**	**10**	**7**	**5**
		weighted	weighted								

7.0 Summary

Comprehensive surveying of the Bogue Banks shoreline began in 1999 as a way to formulate the Bogue Banks Beach Restoration Project. In spring 2004, the Bogue Banks Beach and Nearshore Mapping Program was initiated to assess beach conditions and form strategies for future beach nourishment projects. Bear Island was added to the project in October 2004 and Shackleford Banks was added in May 2005. Surveys are performed annually during 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 2014 by Geodynamics. For this evaluation, the spring/summer 2014 survey was compared with the spring/summer 2013 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 were computed for defined regions along the Bogue Banks shoreline, Bear Island, and Shackleford Banks between the 2013 and 2014 survey profiles including;

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Banks Oceanfront (1-112)	128,393	8.7	1.6	207,286	6.7	864,617	9.3	1,190,683	10.2	1,306,571	7.2	921,954
Bogue Banks County Project (9-76)	88,094	-10.3	-1.7	-151,559	2.0	173,450	1.9	168,803	3.9	344,611	1.2	109,950
Bear Island (1-18)	16,500	-22.0	-2.4	-39,033	0.0	-676	5.2	85,216	3.9	65,060	2.8	46,051
Shackleford Banks (1-24)	46,001	-60.1	-4.0	-186,222	-8.8	-403,748	-14.6	-671,231	-21.3	-980,665	-23.5	-1,082,016

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

	Reach Length	avg shoreline change @ MHW	avg volume change above +1.1 ft NAVD	cumulative volume change above +1.1 ft NAVD	avg volume change above -5 ft NAVD	cumulative volume change above -5 ft NAVD	avg volume change above -12 ft NAVD	cumulative volume change above -12 ft NAVD	avg volume change above -20 ft NAVD	cumulative volume change above -20 ft NAVD	avg volume change above -30 ft NAVD	cumulative volume change above -30 ft NAVD
Reach (Profiles)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (1-8)	7,432	13.1	-0.6	-4,354	2.5	18,535	1.6	11,826	-6.9	-51,174	-9.4	-69,639
Emerald Isle-West (9-25)	22,344	-10.2	-1.8	-39,609	5.0	112,404	6.8	152,049	4.3	95,596	0.4	8,998
Emerald Isle-Central (26-36)	15,802	-23.9	-4.0	-62,907	1.5	23,144	-0.1	-1,999	1.0	15,834	-2.4	-37,964
Emerald Isle-East (37-48)	13,220	5.3	-1.3	-17,722	2.6	34,974	2.0	26,034	4.5	59,774	2.5	33,022
Indian Beach-Salter Path (49-58)	12,850	-1.9	-2.0	-25,716	4.8	62,219	4.6	58,729	9.6	123,056	9.2	118,733
Pine Knoll Shores-West (59-65)	9,063	-19.1	-1.7	-15,840	-0.8	-7,008	-0.9	-7,812	5.4	48,694	5.0	45,413
Pine Knoll Shores-East (66-76)	14,815	-11.8	0.7	10,236	-3.5	-52,282	-3.9	-58,200	0.1	1,656	-3.9	-58,253
Atlantic Beach (77-102)	26,176	41.1	8.7	228,589	14.0	365,764	21.9	573,232	22.2	579,829	18.0	471,512
Fort Macon State Park (103-112)	6,691	126.8	20.1	134,611	45.9	306,869	65.3	436,823	64.8	433,305	61.3	410,131
Beaufort Inlet (112B-116)	2,000	40.2	8.7	17,348	11.2	22,349	0.6	1,199	10.9	21,707	16.0	31,967
Bogue Inlet-Channel (117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

The Bogue Banks oceanfront shoreline has experienced overall accretion at MHW over the past year, averaging +8.7 ft. However, this is heavily influenced by the impact of the Morehead City Harbor Maintenance Dredging project which occurred in Fort Macon and Atlantic Beach. The County Project numbers indicate a trend of shoreline recession at MHW in most of the reaches that were not nourished (Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores), averaging -10.3 ft. The volumetric analysis indicates an overall gain of sand along the oceanfront above MHW, -5 ft NAVD88, -12 ft NAVD88, -20 ft NAVD88, and -30 ft NAVD88. Once again, this is heavily influenced by the 1,107,585 cy of material placed in Fort Macon and Atlantic Beach. The County Project numbers indicate a loss of material above MHW but a gain of material above all other elevations in most of the reaches not affected by nourishment (Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores). This is an indication of

material being pulled from the recreational/visible beach to an elevation below MHW but still within the system. Profile plots show that material lost from above MHW has been captured landward of the offshore bar, above -12 ft NAVD, and thus is still within the system and providing protection to the beach. Approximately 1.19 million cy of material was gained above -12 ft NAVD88 along the entire oceanfront, most of this coming from the Morehead City Harbor Maintenance Dredging Project. A look at the County Project, which was unaffected by the nourishment, indicates that those reaches also experienced a slight gain in material above -12 ft NAVD88 of approximately 168,800 cy.

The Post-Irene Renourishment Project performance to date was also analyzed by comparing the 2014 data with some post-fill surveys taken at the time of the project. It is apparent that some material has been lost from the upper elevations of the profile. Emerald Isle West, Emerald Isle East, and Pine Knoll Shores have lost 36%, 42%, and 44%, respectively, of the nourishment material above MHW. **However, M&N is confident that all of the material placed from the Post-Irene Renourishment Project has been captured above -12 ft NAVD88 and remains within the system, providing protection to the beach.** In fact, there is more material above -12 ft NAVD88 now that there was immediately after the nourishment project. It should also be noted that the percent losses above MHW and -5 ft NAVD88 stated in last year's report ranged from 21 to 37%. Therefore, the rate of equilibration/volume losses at these higher elevations appears to be slowing. It is apparent that the material placed in Pine Knoll Shores has seen the most significant losses in that more material has been lost from the recreational/visible beach (above MHW) out to wading depth (- 5 ft NAVD88) and captured slightly further offshore (between -5 ft NAVD88 and -12 ft NAVD88) than the material in Emerald Isle which experienced slightly less loss above MHW and has been mostly captured above -5 ft NAVD88. This behavior will likely lead to the recommendation additional advanced fill will be required at Pine Knoll Shores during future nourishment projects.

In addition, FEMA beach maintenance calculations were performed to estimate the amount of material remaining on the beach in excess of the baseline nourishment condition established by the Phase I, Phase II, and Phase III components of the Bogue Banks Beach Restoration Project (County Project). It was determined that the Phase I, Phase II, and Phase III project reaches contain more sand than was originally in place after the earlier baseline projects with 129%, 129%, and 235% remaining in each reach, respectively. The most loss was seen in Pine Knoll Shores East which dropped from 104% to 96%.

Bear Island appears to have experienced a moderate amount of shoreline recession over the past year. As with Bogue Banks, volumetric calculations indicate a loss in material above MHW but a gain in material at lower elevations which is indicative of material being pulled from the recreational/visible beach to lower elevations but still remaining within the system. Most importantly, there was a gain of approximately 85,200 cy of material above -12 ft NAVD88.

Shackleford Banks appears to have experienced a significant amount of shoreline recession and volume loss. The majority of the shoreline recession and volume loss was located at Transects 21-24, adjacent to Beaufort Inlet, including major losses to the both the dunes and beachface. The remaining transects along Shackleford Banks (1-20) appear to have been impacted similar to Bogue Banks and Bear Island with losses of material above MHW and capture of that material at

lower elevations, remaining in the system and providing protection to the beach. Approximately 601,000 cy of the total 671,200 cy lost above -12 ft NAVD88 was located in Transects 21-24 near Beaufort Inlet.

It is expected that next year's annual monitoring report will be performed under the new Bogue Banks Master Beach Nourishment Plan. The transition will bring with it slightly new management reaches and nourishment triggers. However, the types of analysis performed will remain consistent with previous monitoring reports. In fact, a preliminary assessment of current conditions compared to the new triggers was completed as part of this report. The new overall weighted trigger for the island is 233 cy/ft above -12 ft NAVD88, with varying triggers in each management reach. Using historical erosion rates (background and storm), it would appear that the next nourishment action may be need within 3-6 years if there is significant storm activity. Otherwise, the next nourishment action is not expected for 8-12 years.

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 MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-2. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-3. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

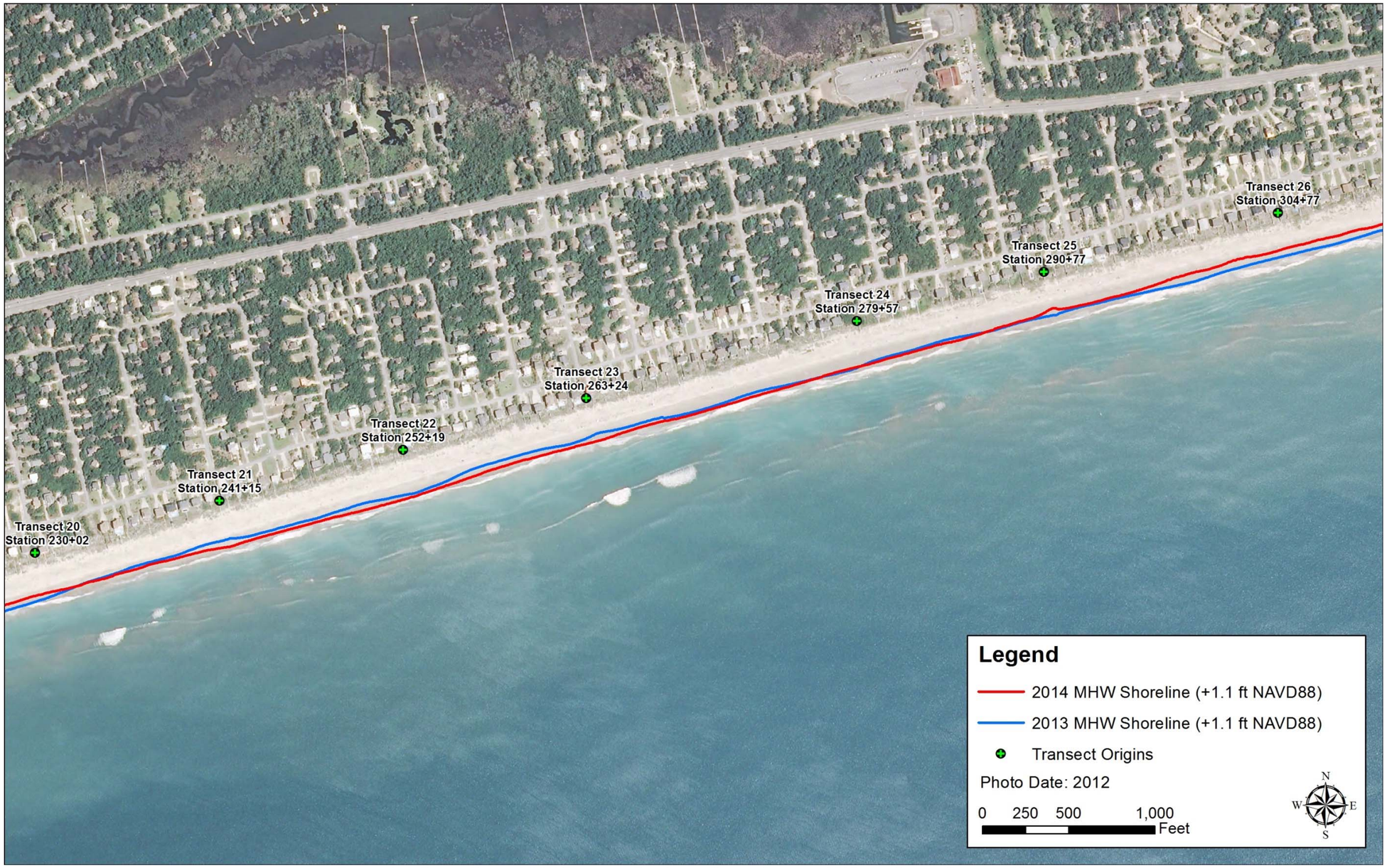


Figure A-4. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-5. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

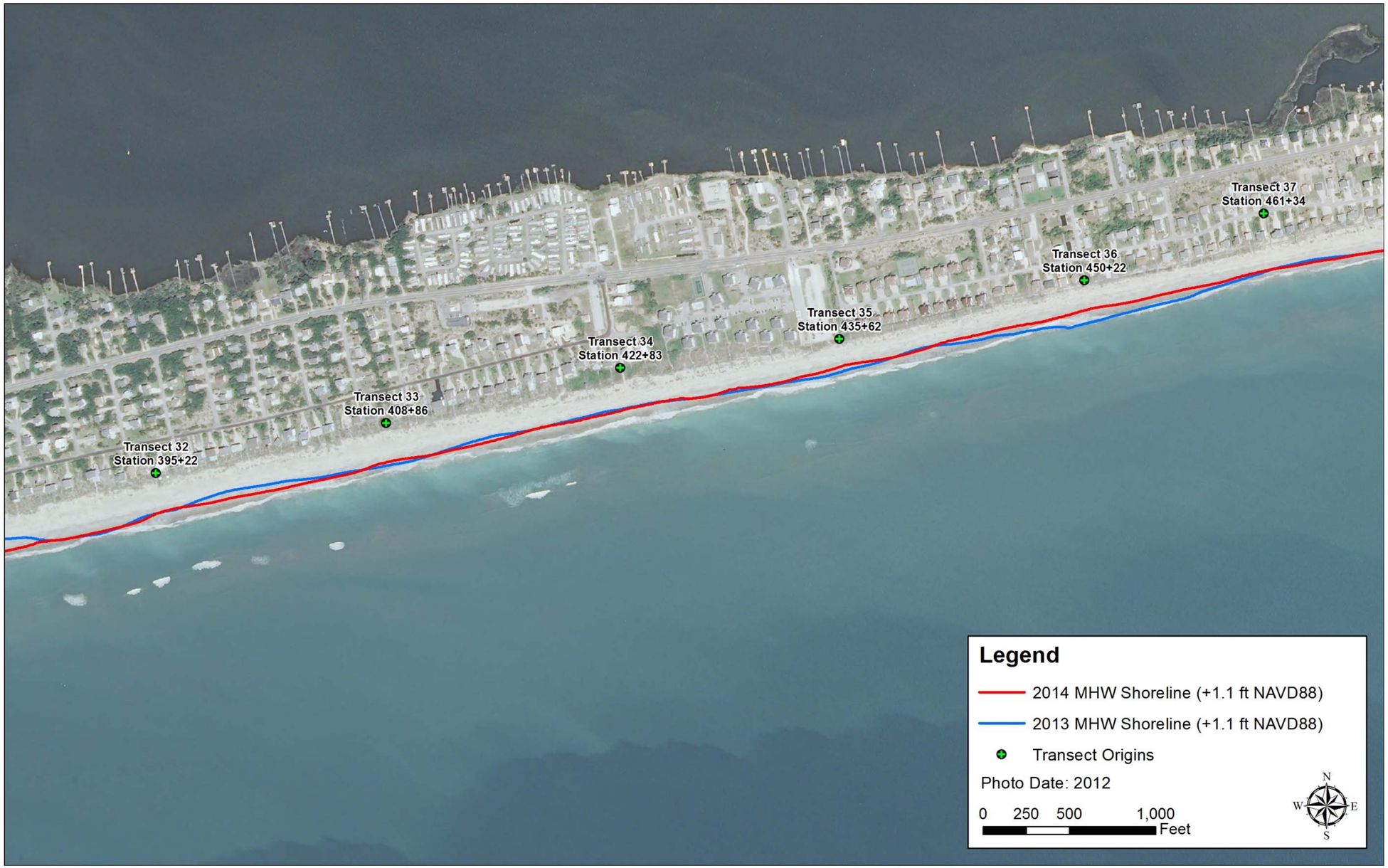


Figure A-6. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-7. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-8. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

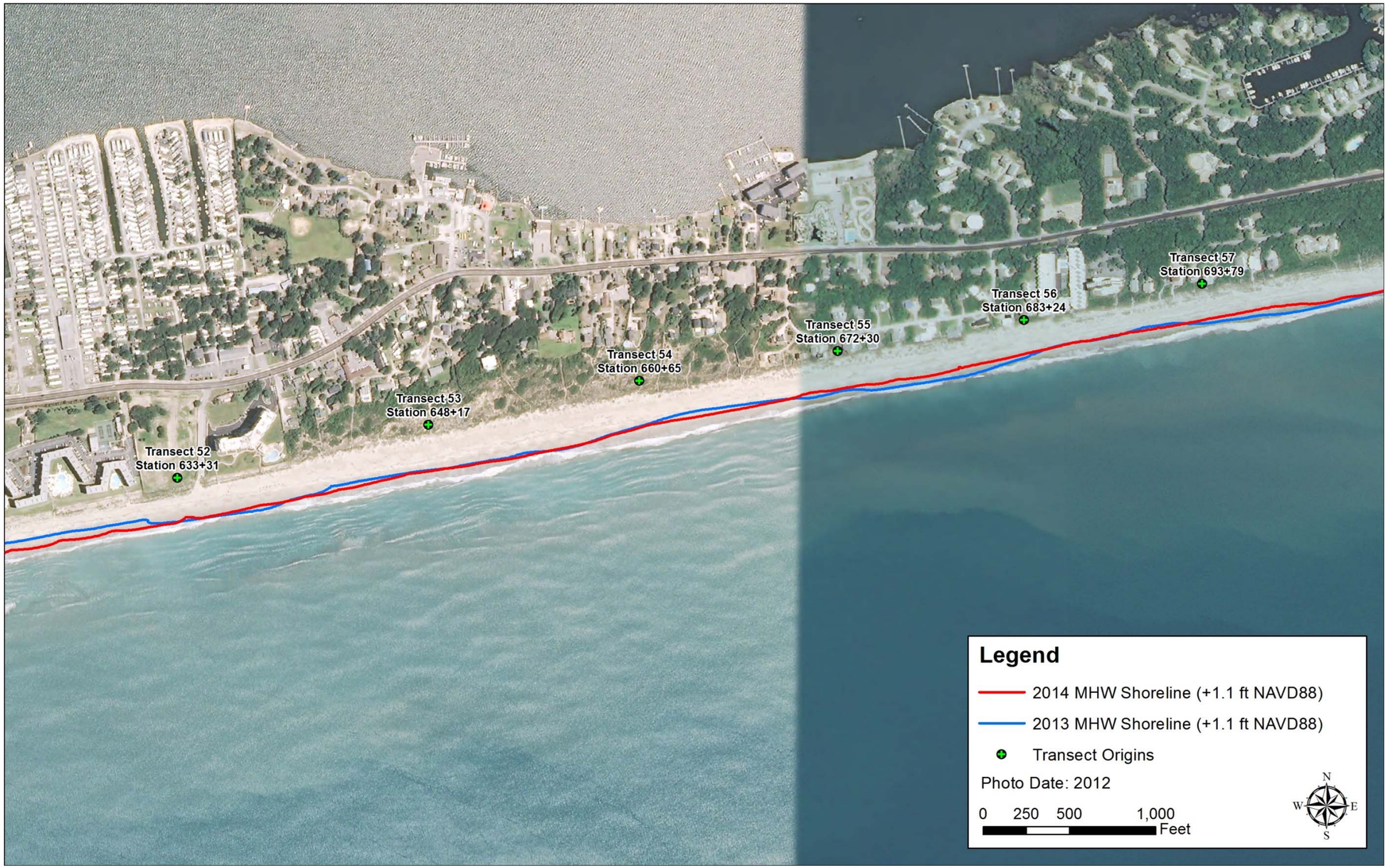


Figure A-9. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

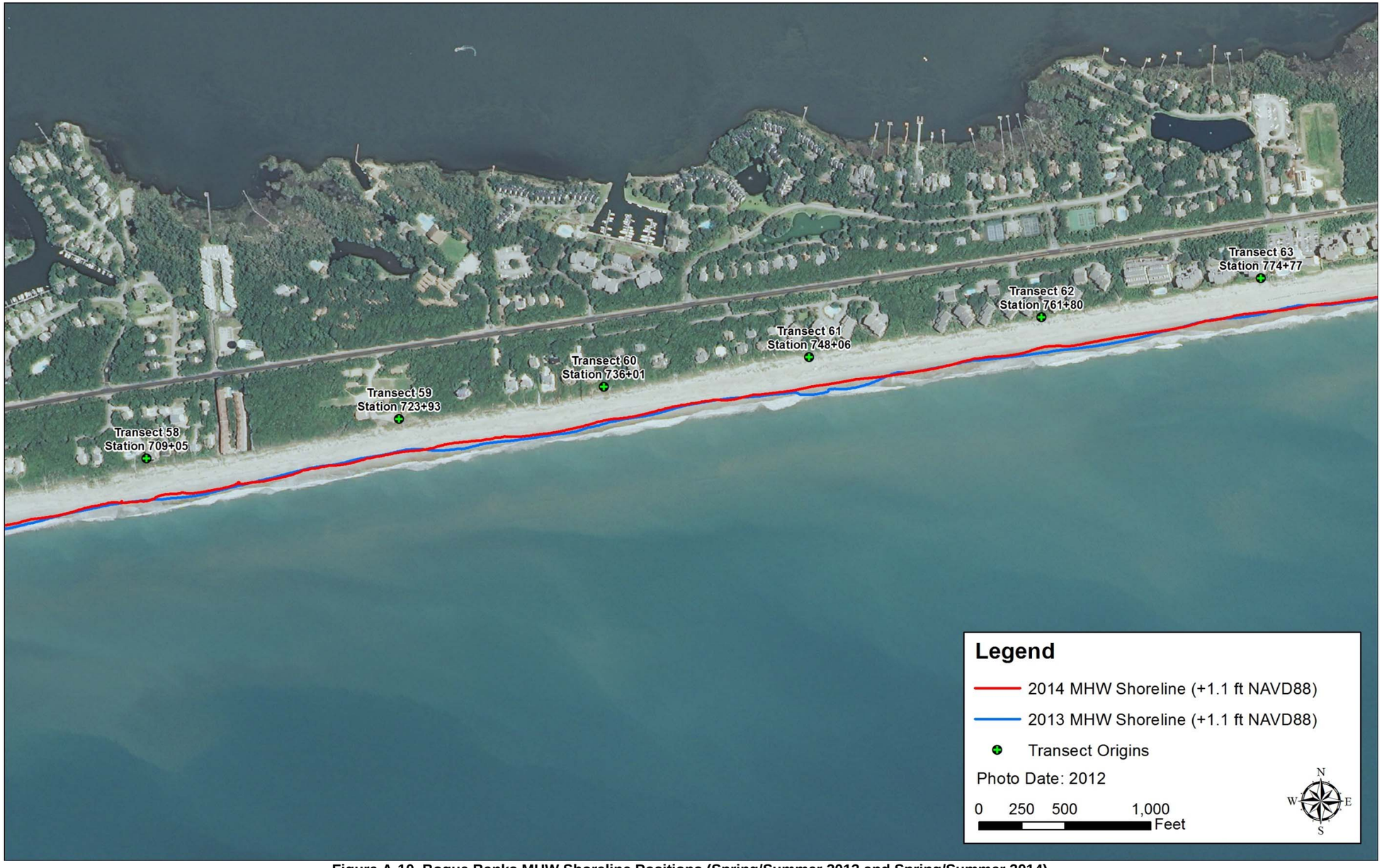


Figure A-10. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-11. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

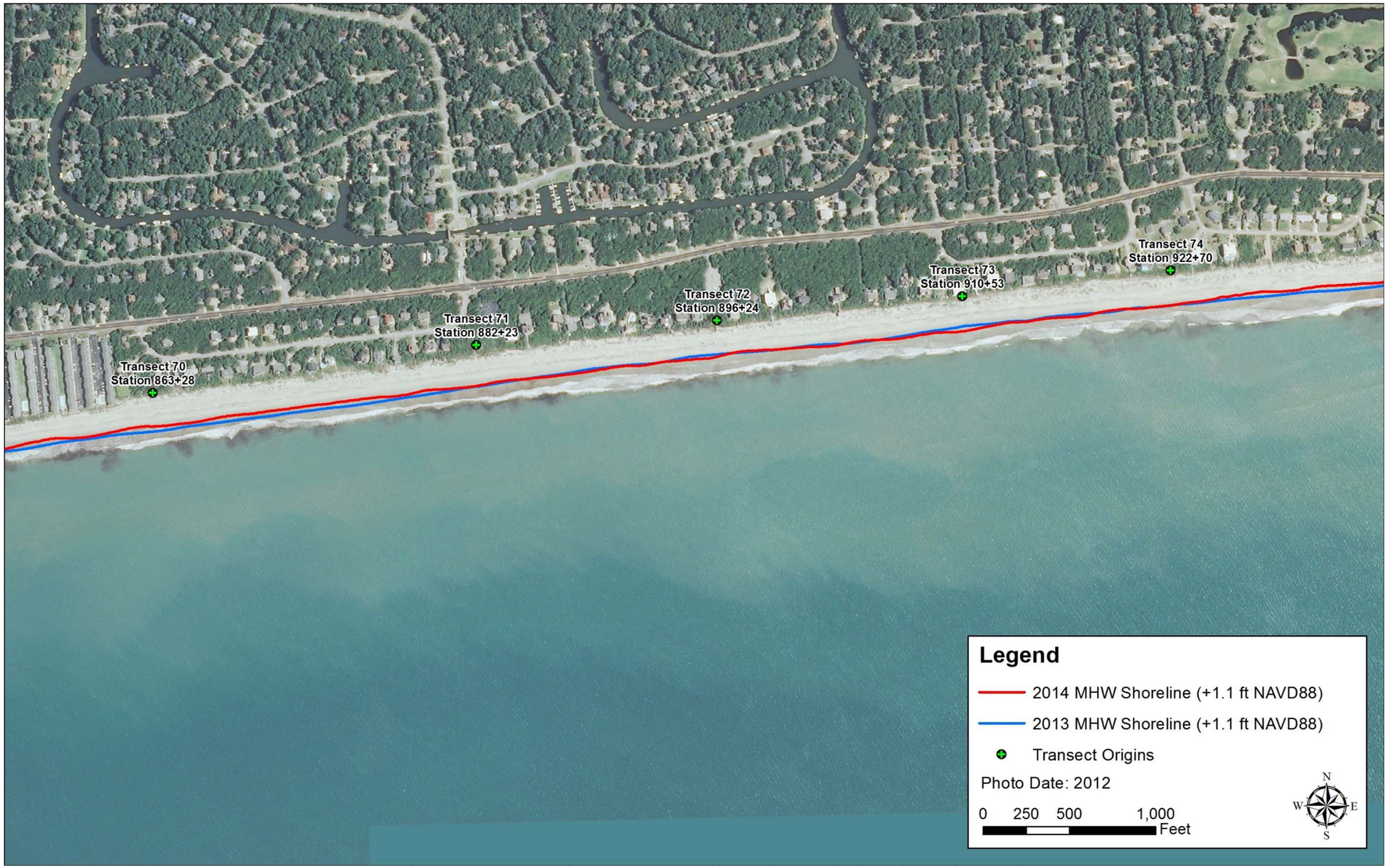


Figure A-12. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

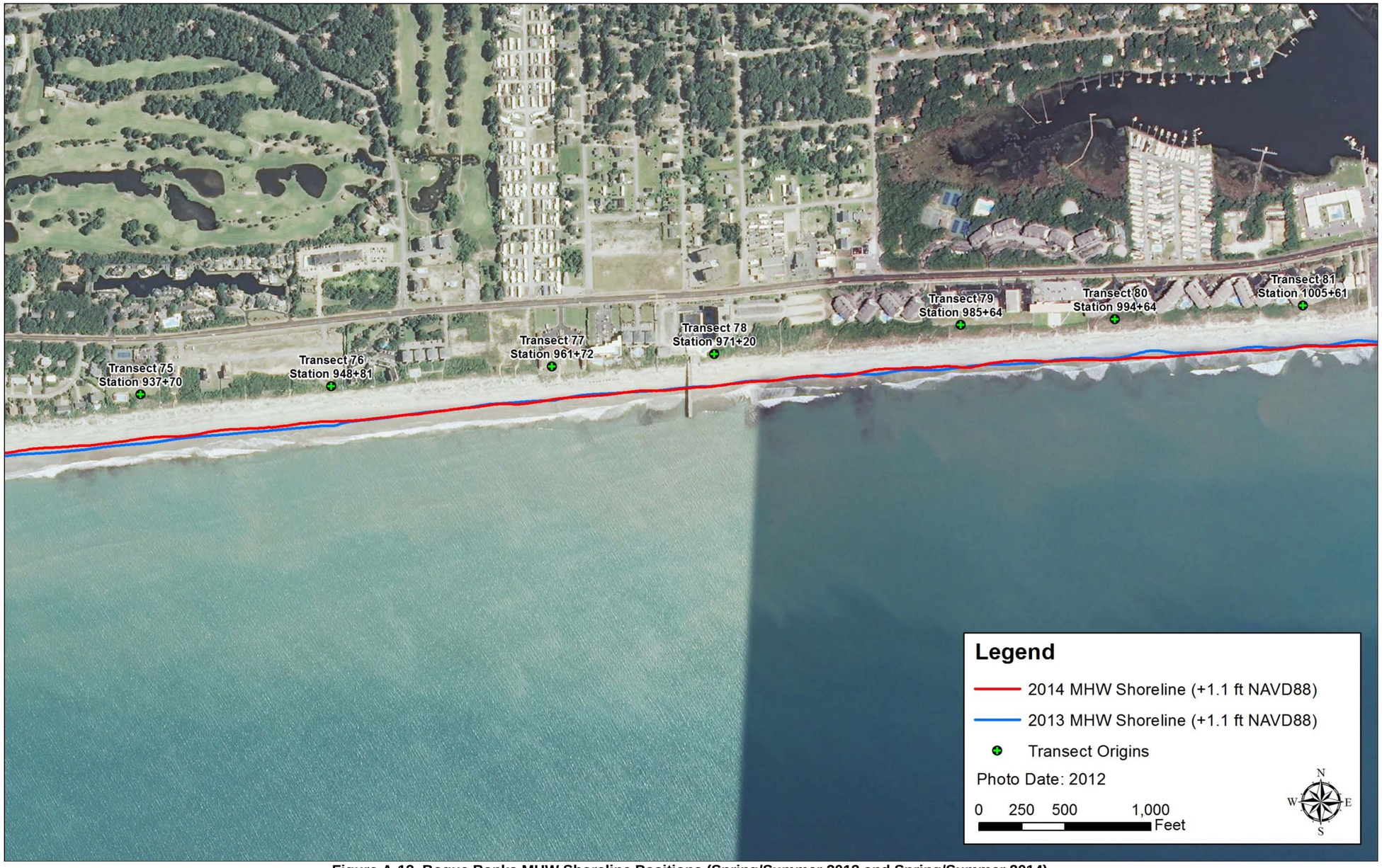


Figure A-13. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-14. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-15. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-16. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

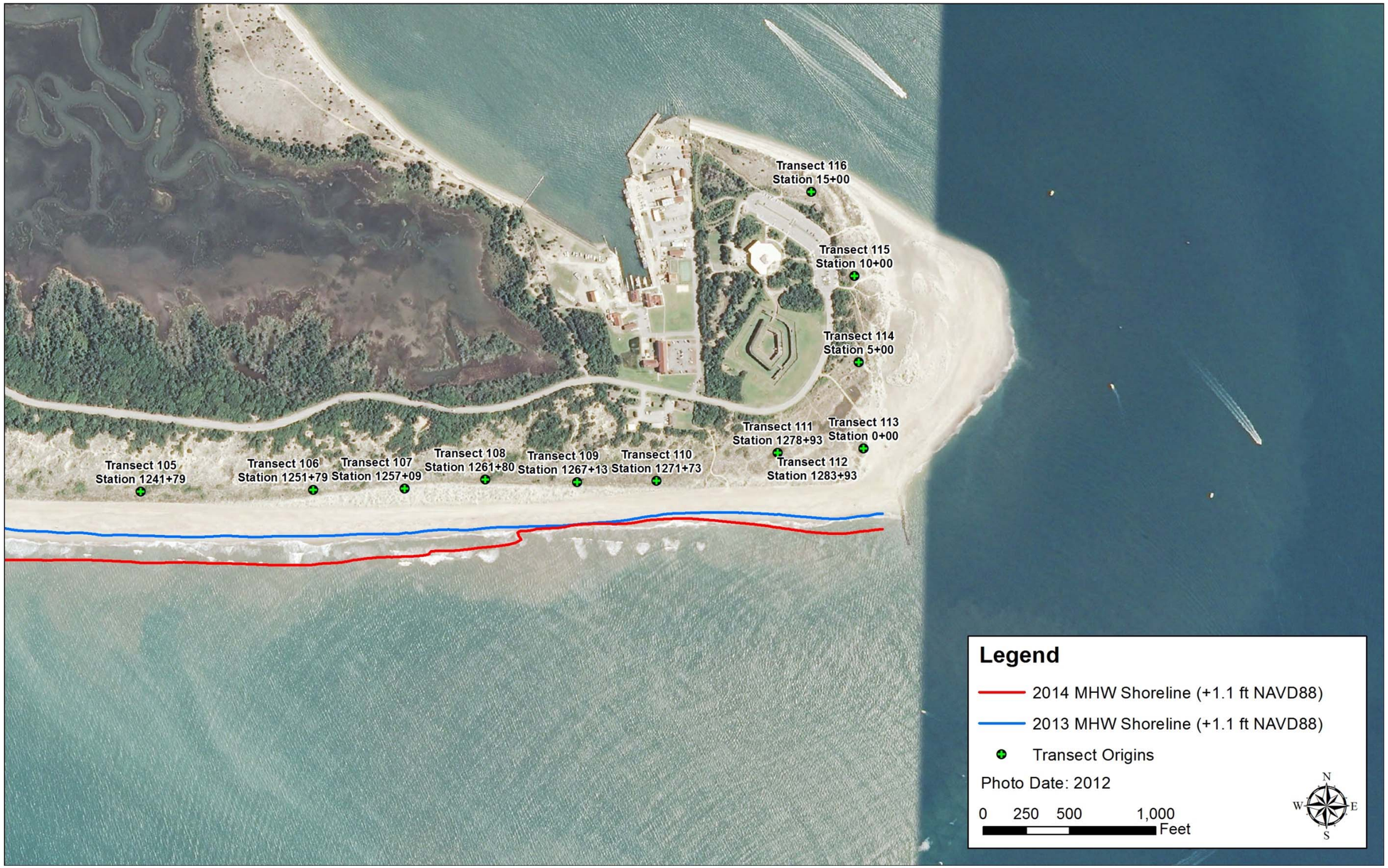


Figure A-17. Bogue Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-18. Bear Island MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-19. Bear Island MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-20. Bear Island MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

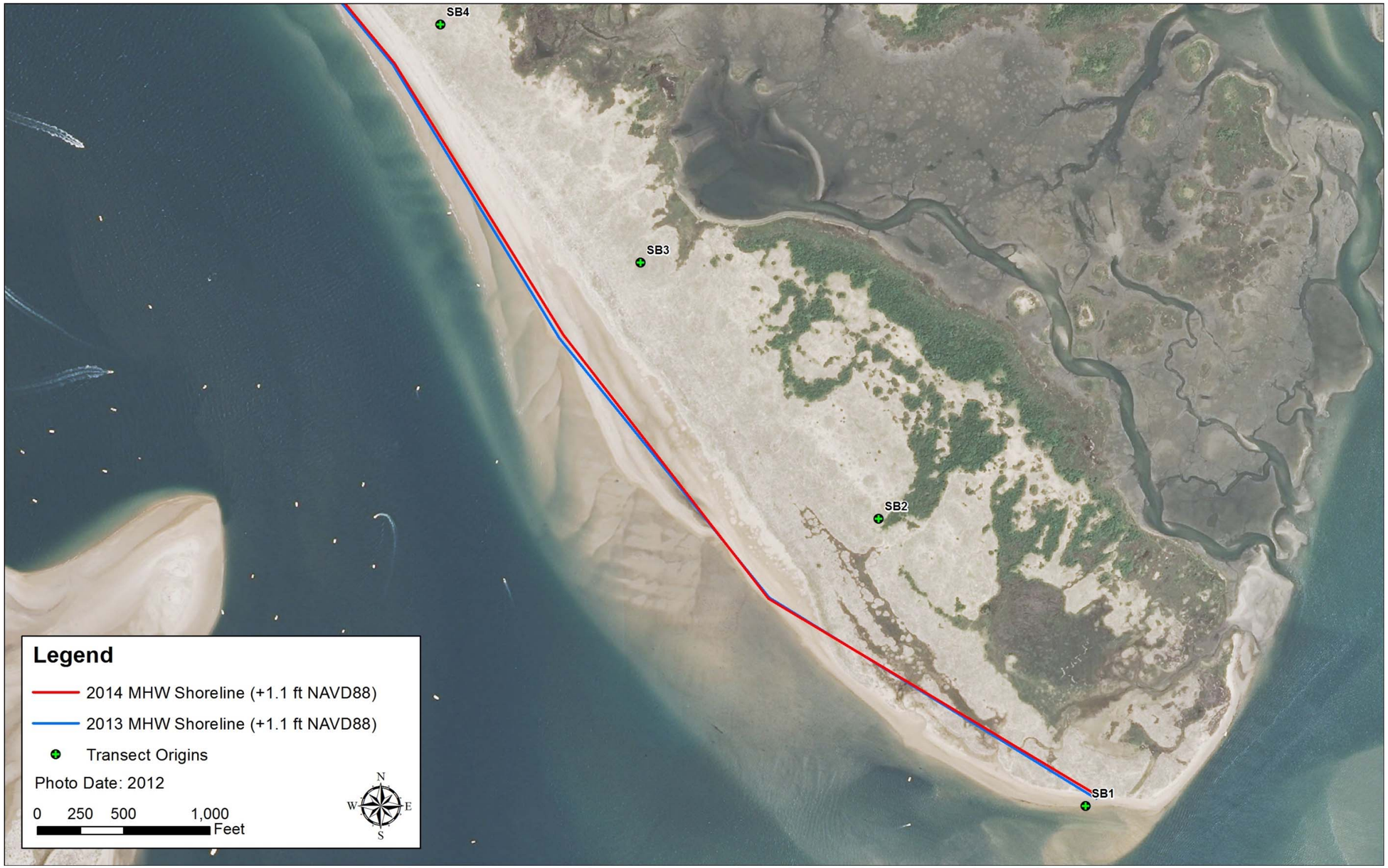


Figure A-21. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-22. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-23. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

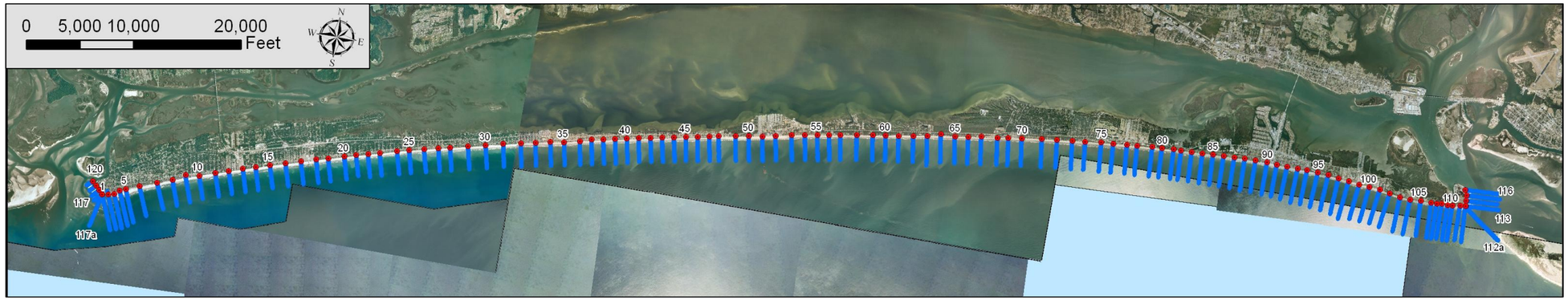
Figure A-24. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-25. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

Figure A-26. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2013 and Spring/Summer 2014)

APPENDIX B

Shoreline & Volume Change Plots



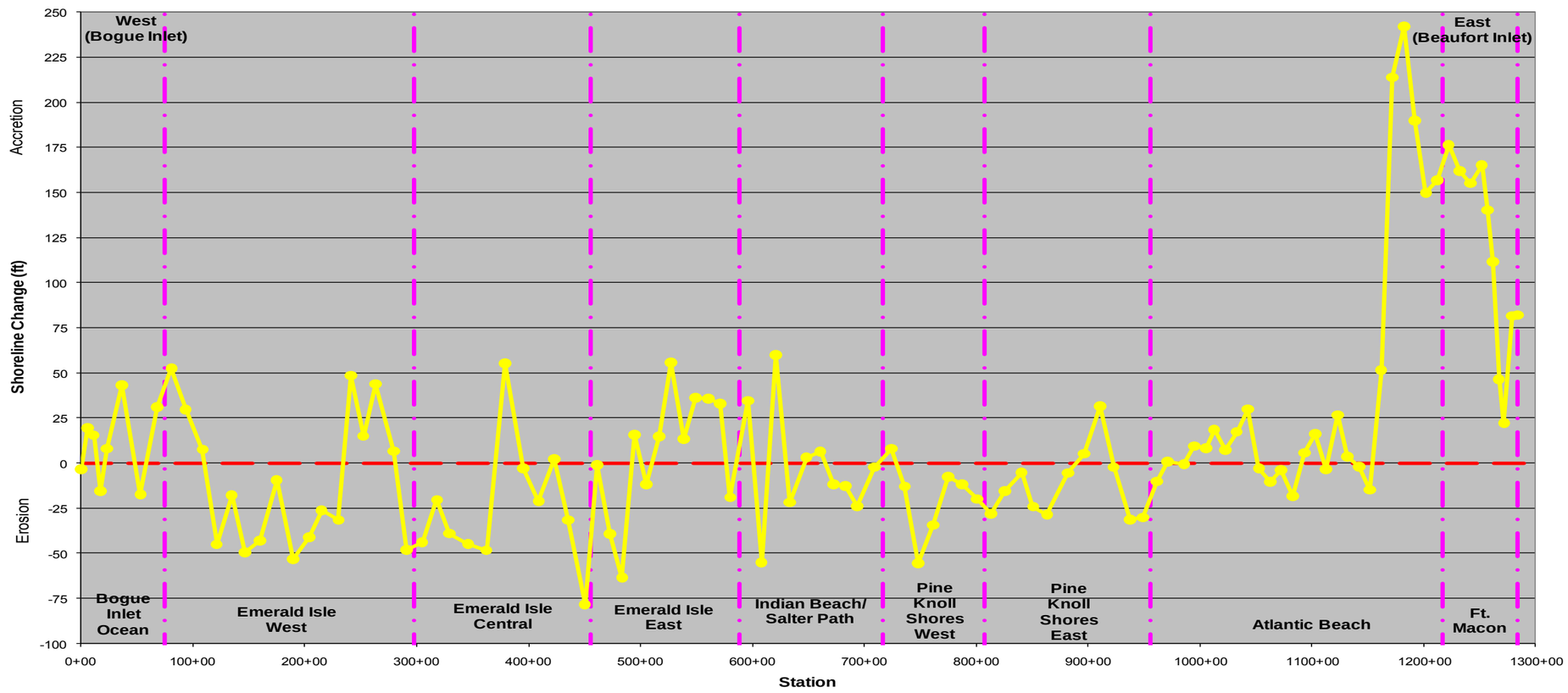
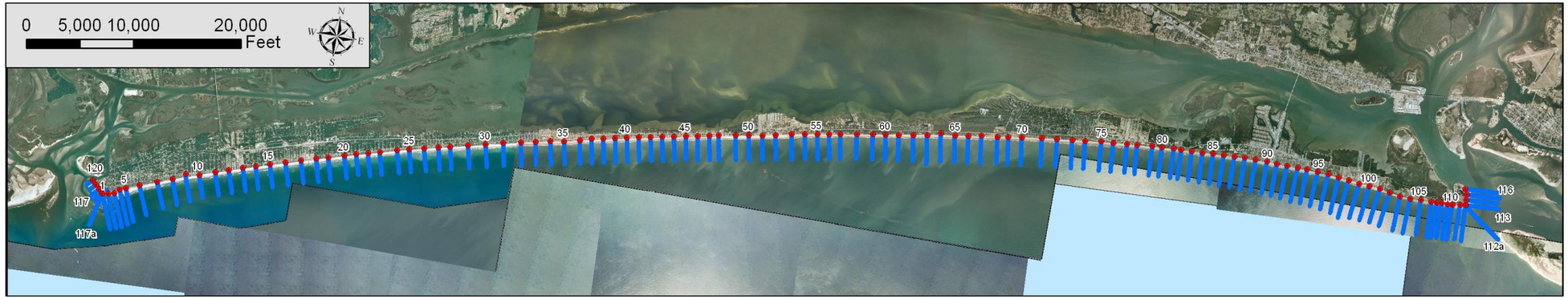


Figure B-1. Shoreline Change for Bogue Banks (Spring/Summer 2013 – Spring/Summer 2014)



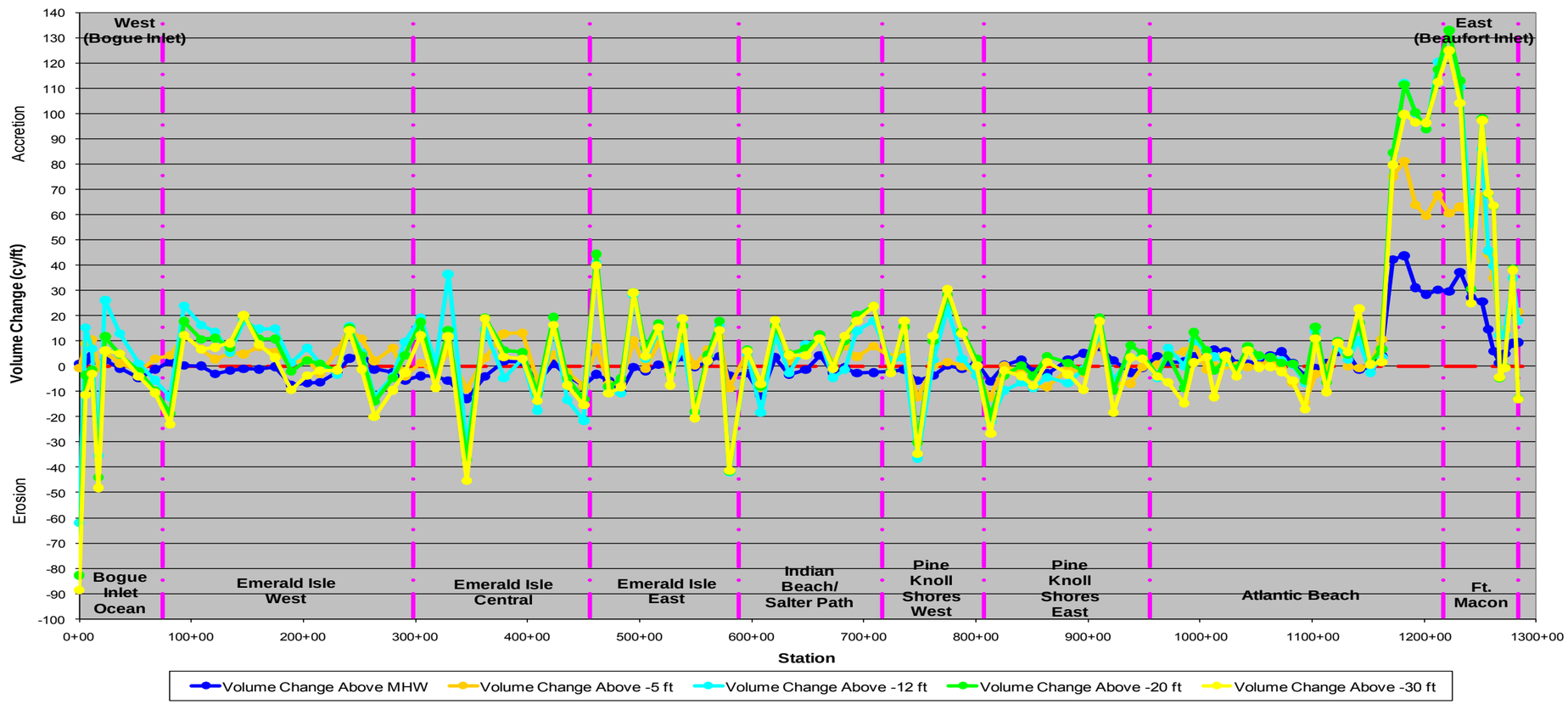
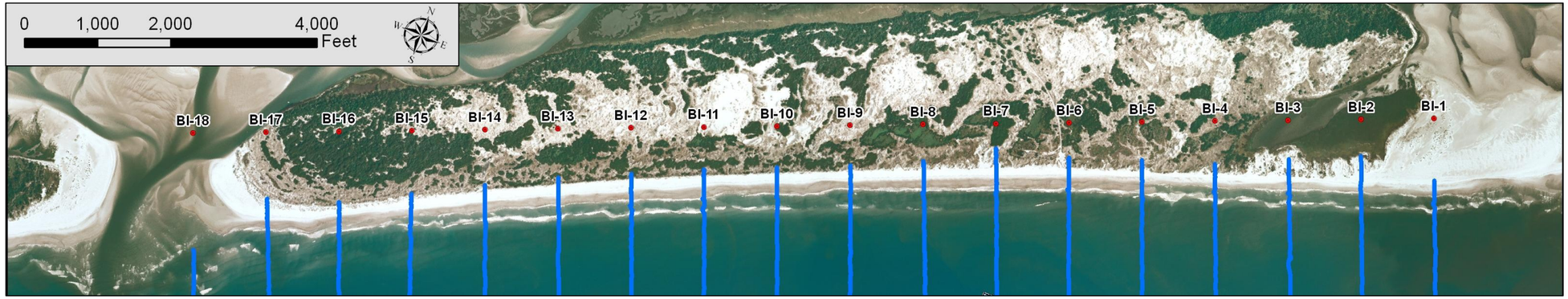


Figure B-2. Volume Change for Bogue Banks (Spring/Summer 2013 - Spring/Summer 2014)



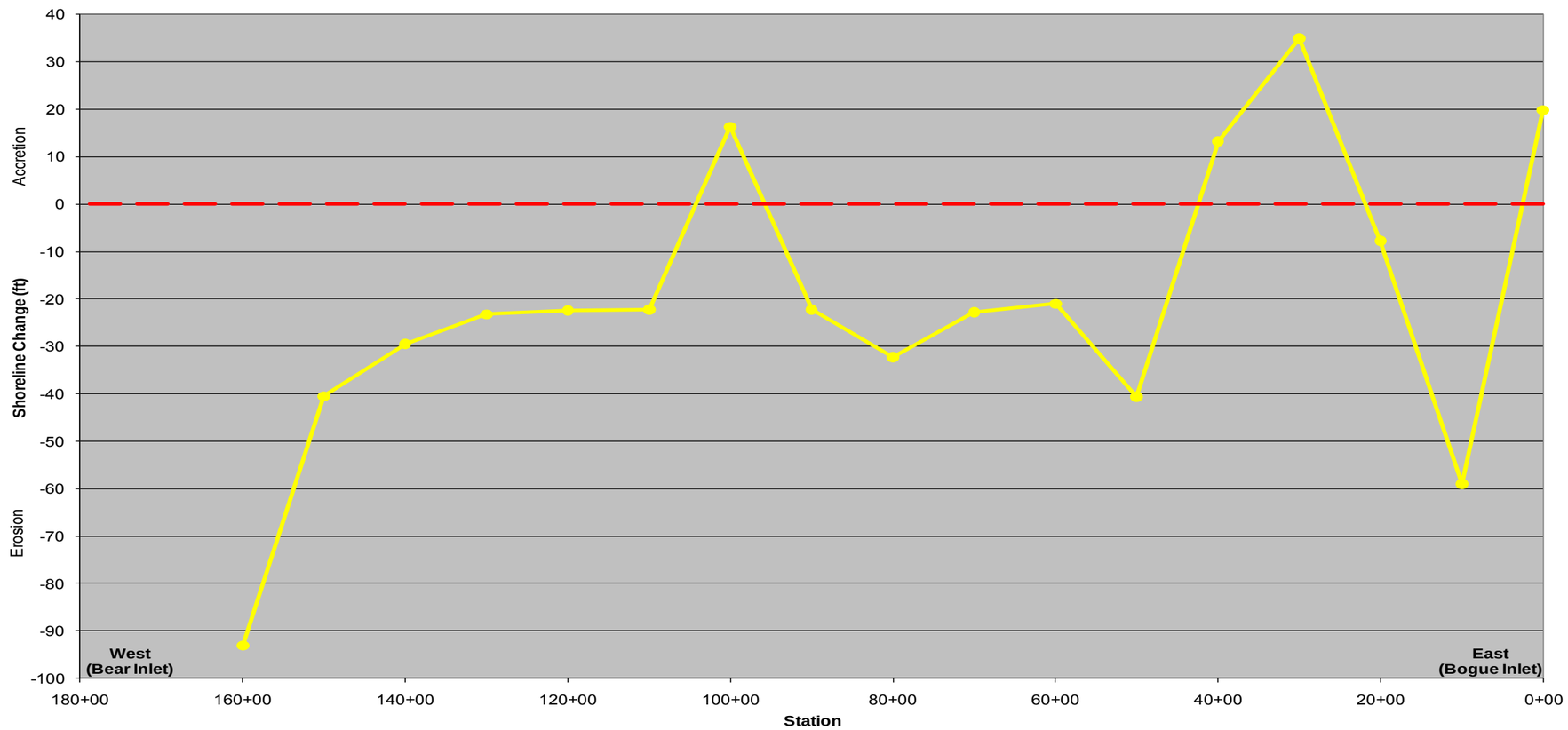
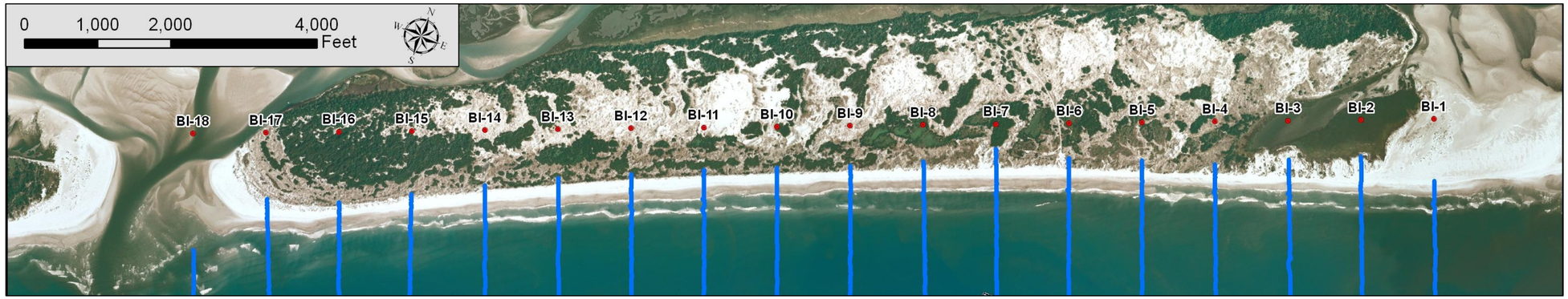


Figure B-3. Shoreline Change for Bear Island (Spring/Summer 2013 - Spring/Summer 2014)



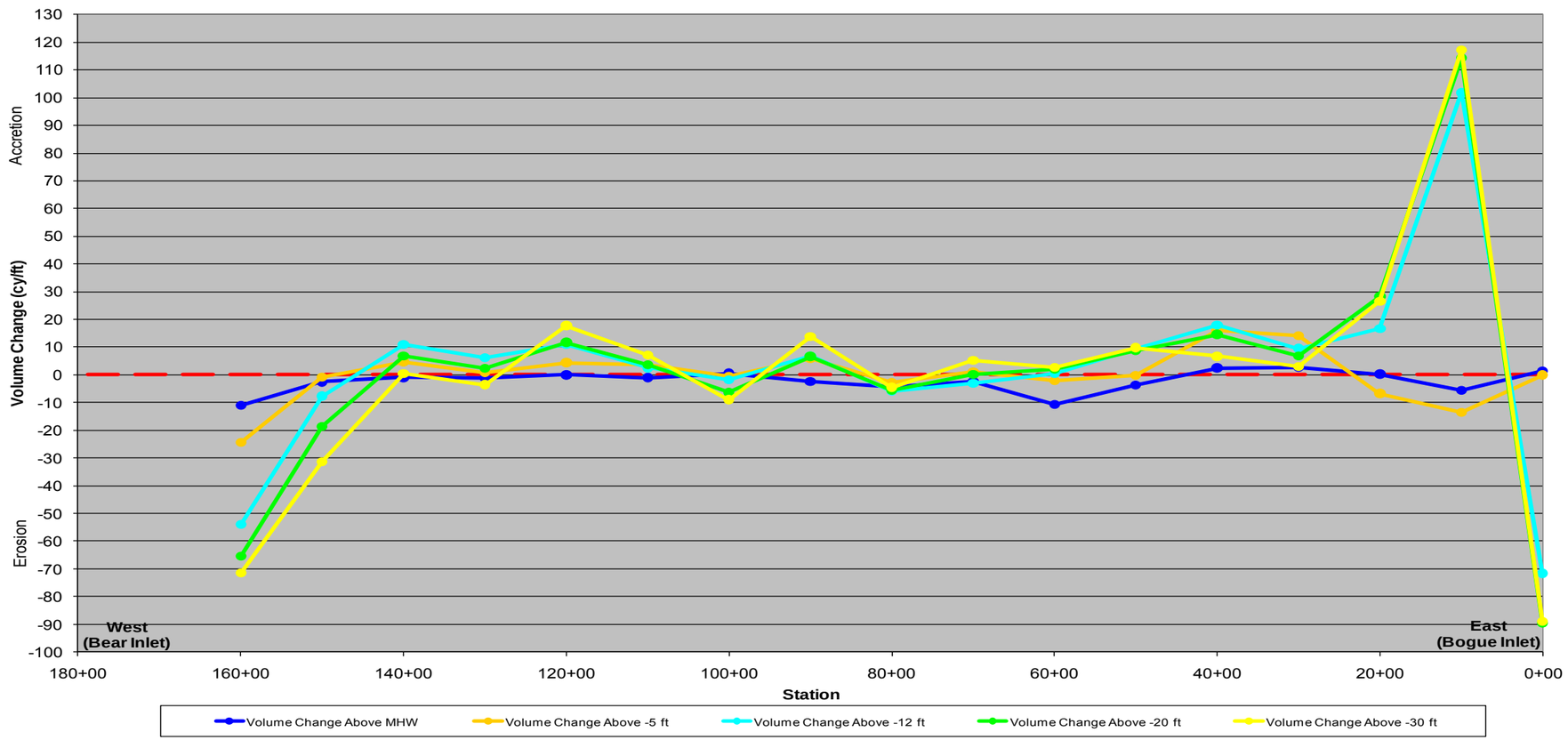


Figure B-4. Volume Change for Bear Island (Spring/Summer 2013 - Spring/Summer 2014)

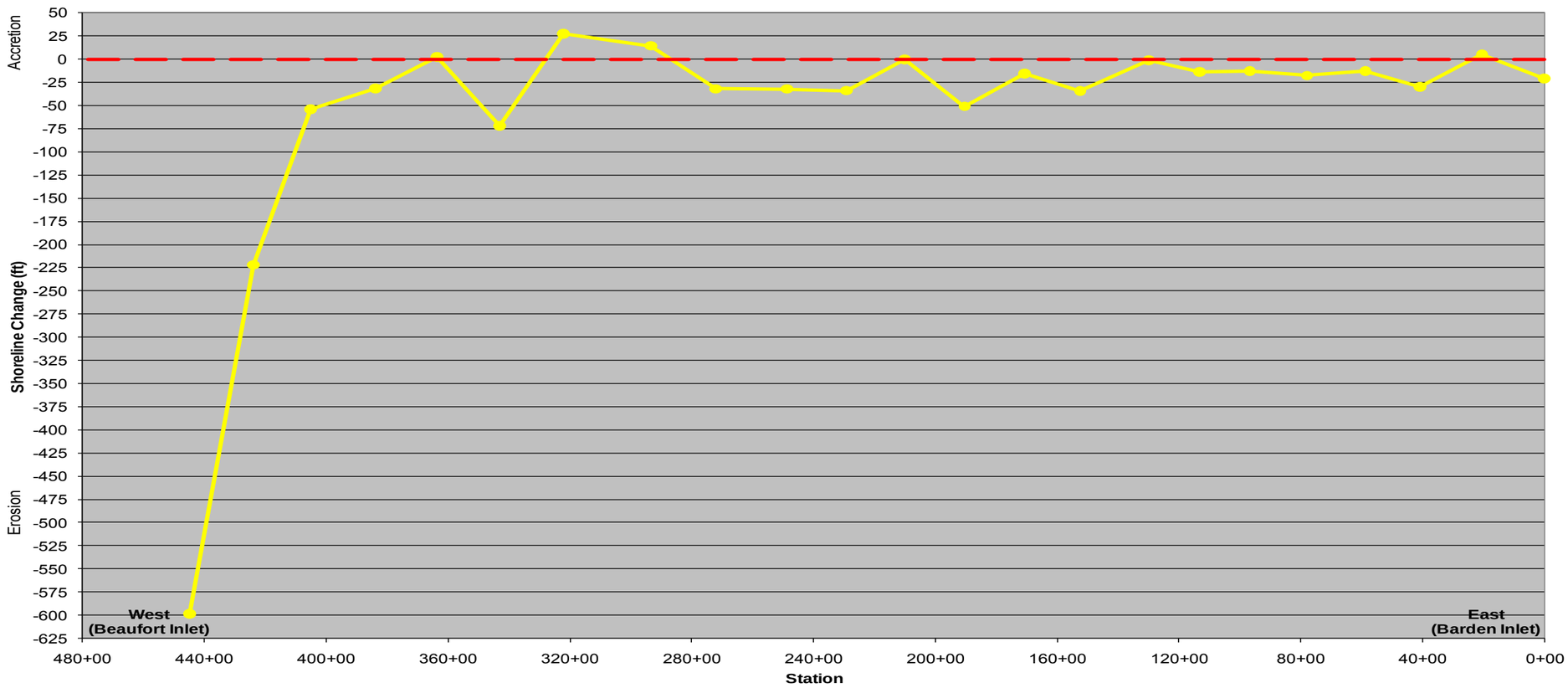


Figure B-5. Shoreline Change for Shackleford Banks (Spring/Summer 2013 - Spring/Summer 2014)

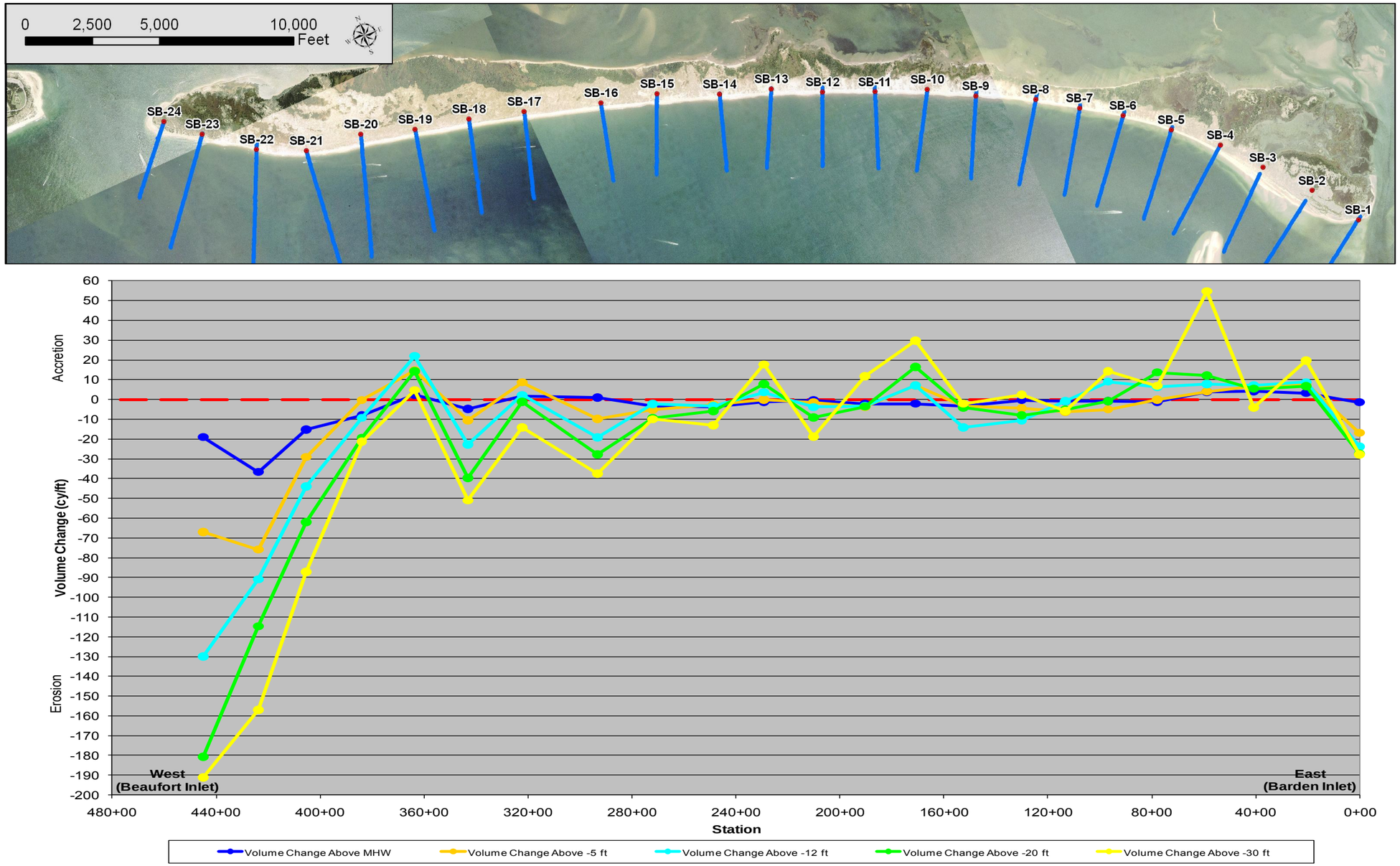


Figure B-6. Volume Change for Shackleford Banks (Spring/Summer 2013 - Spring/Summer 2014)

APPENDIX C

Survey Profile Comparison Plots

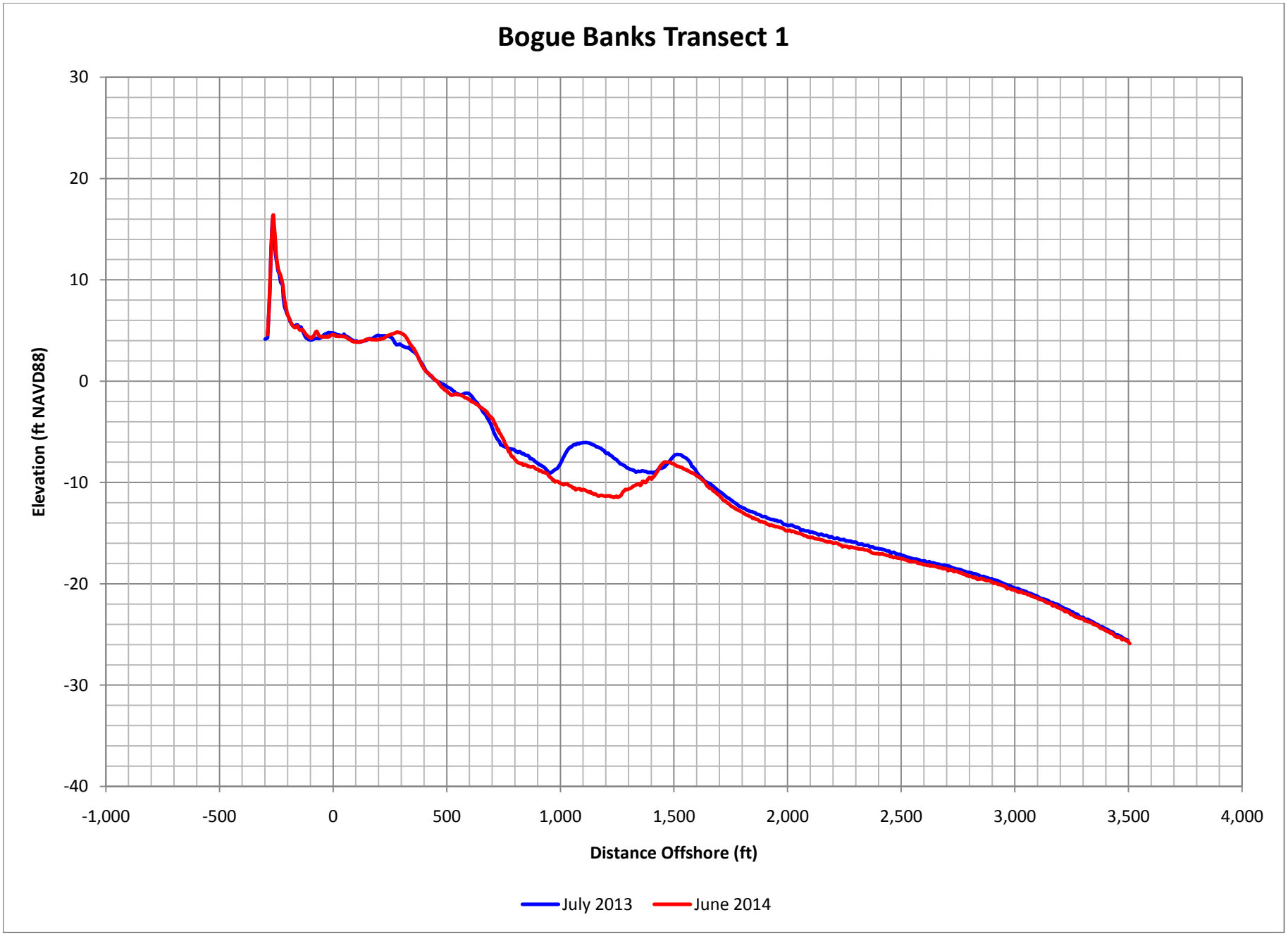


Figure C-1. Bogue Banks Profile Comparison Plot

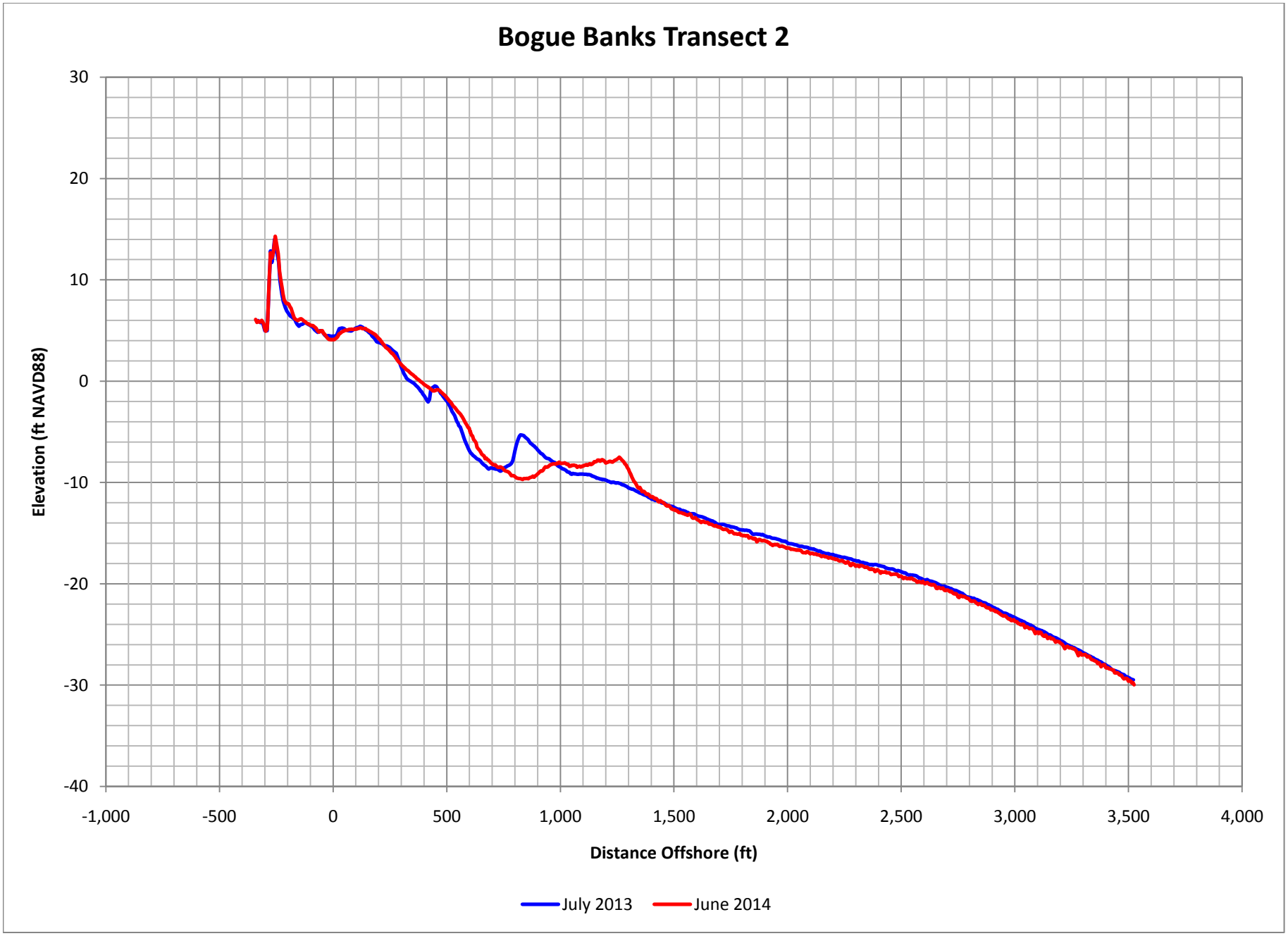


Figure C-2. Bogue Banks Profile Comparison Plot

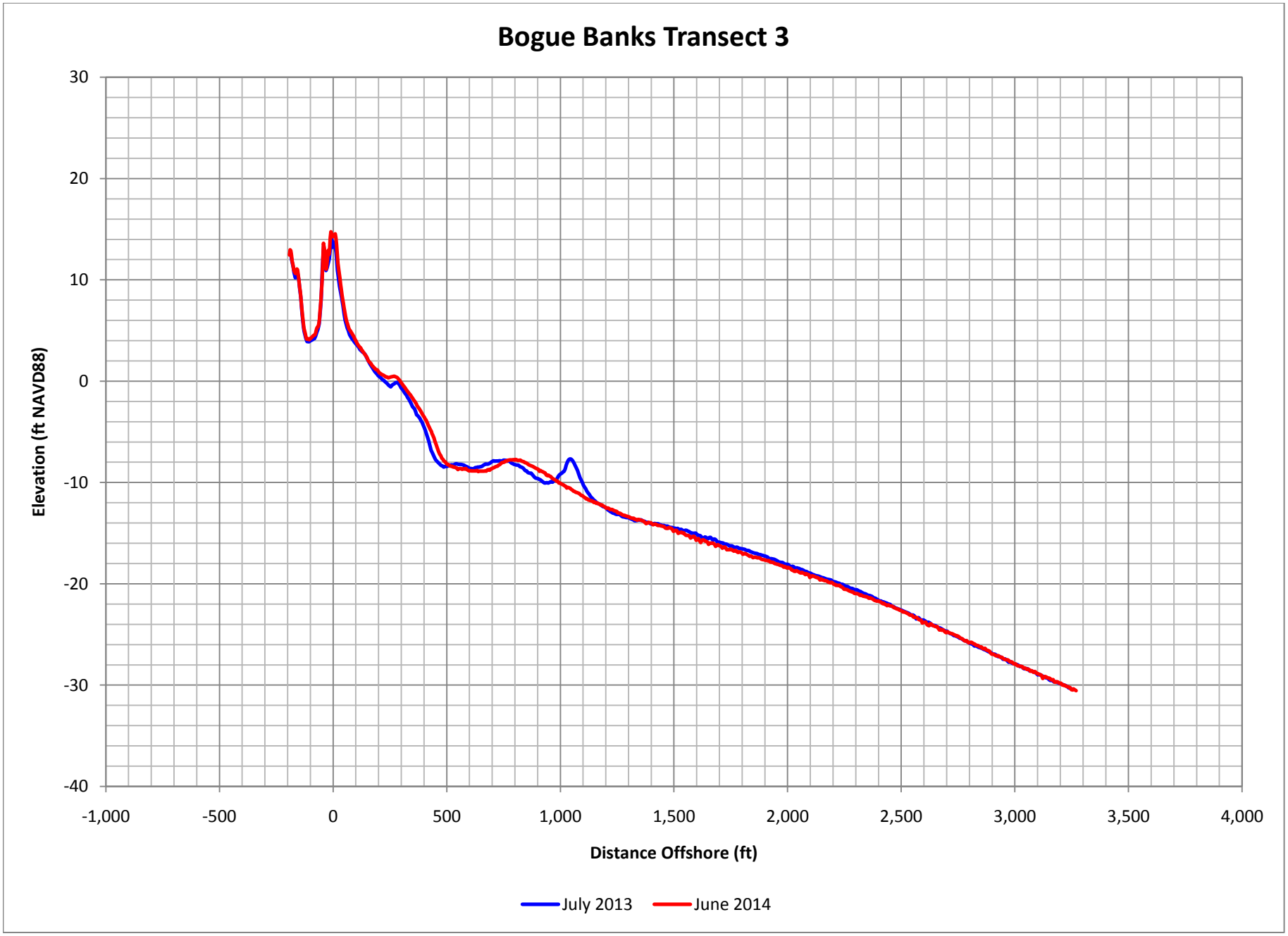


Figure C-3. Bogue Banks Profile Comparison Plot

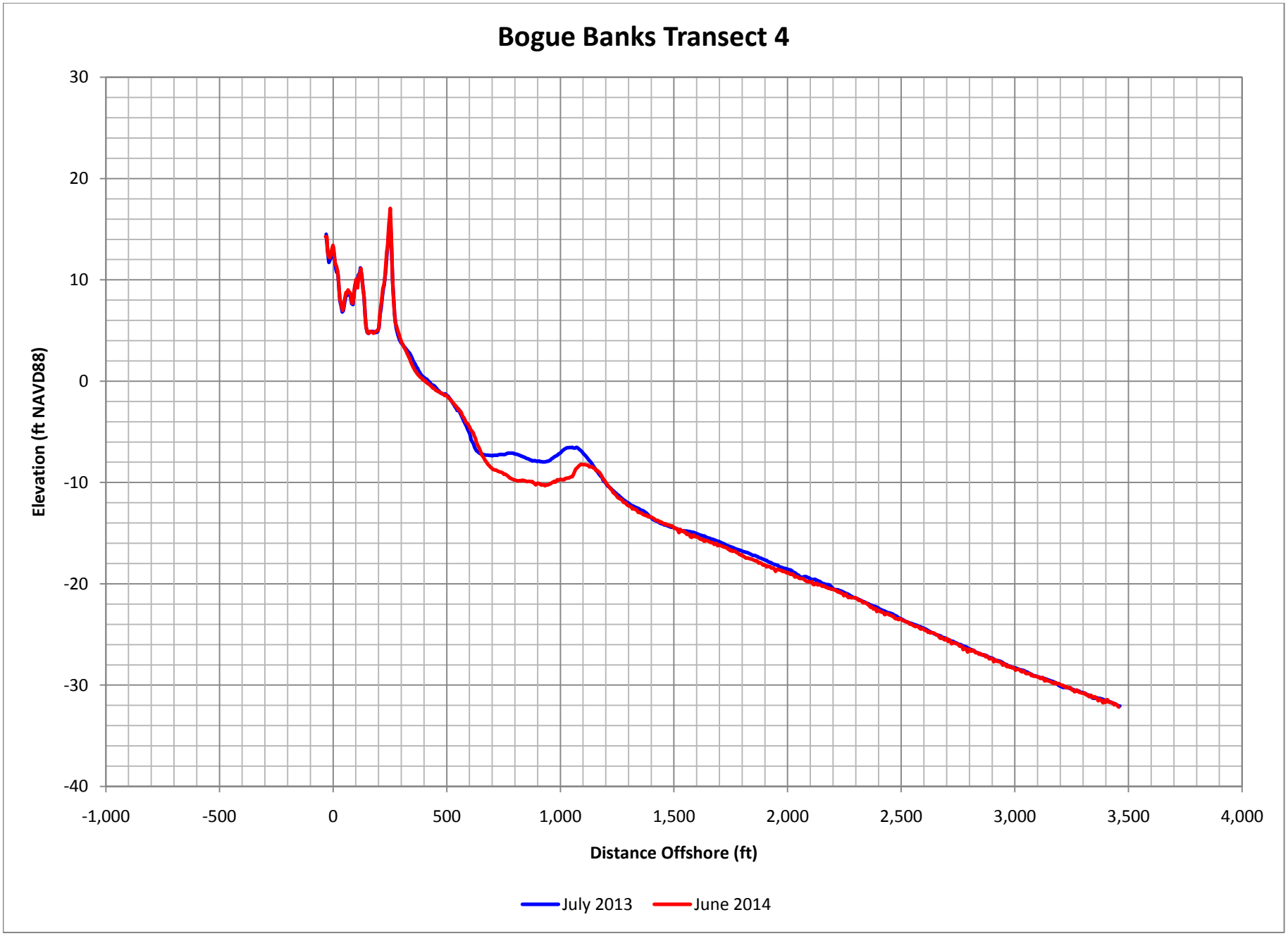


Figure C-4. Bogue Banks Profile Comparison Plot

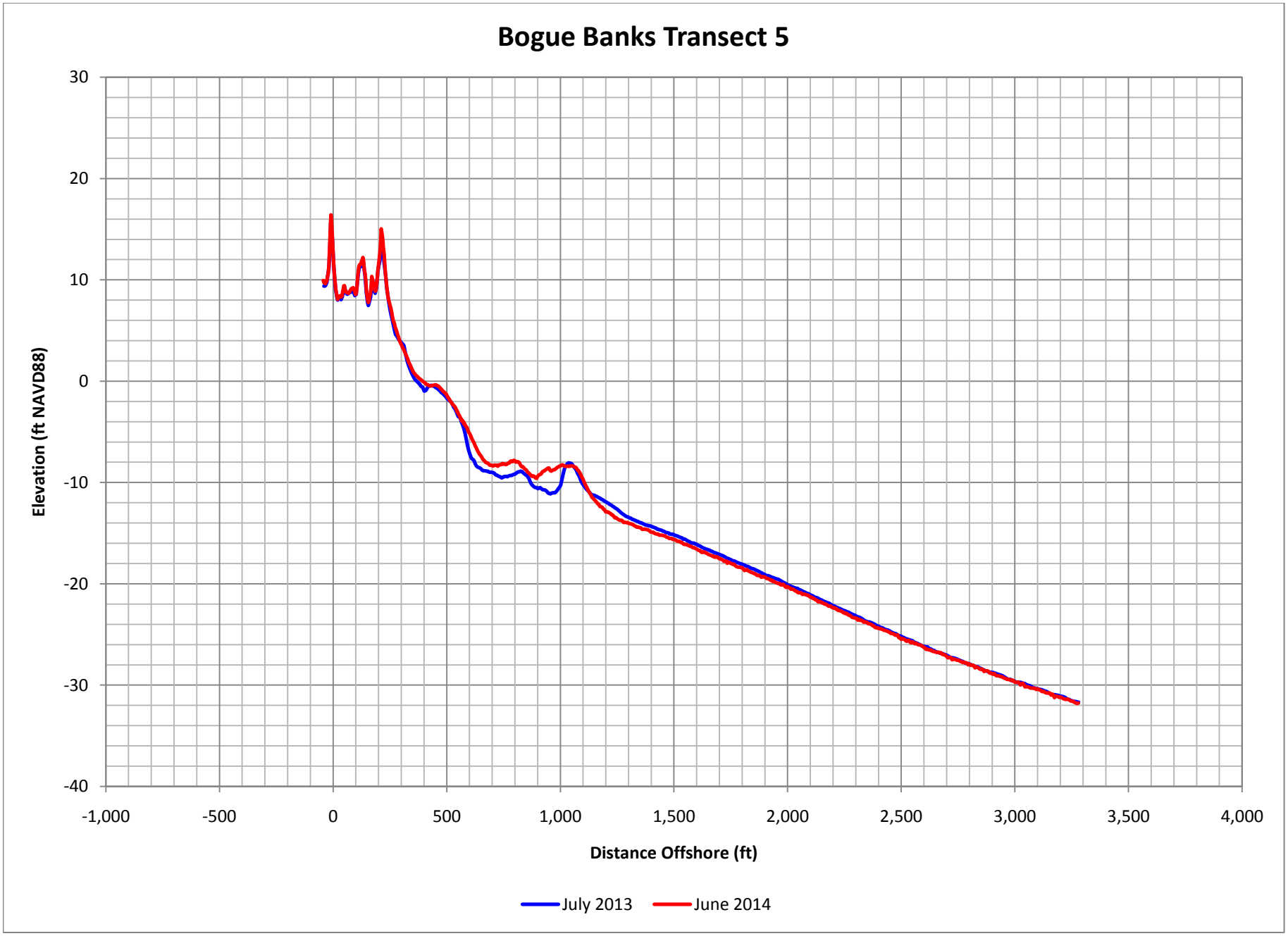


Figure C-5. Bogue Banks Profile Comparison Plot

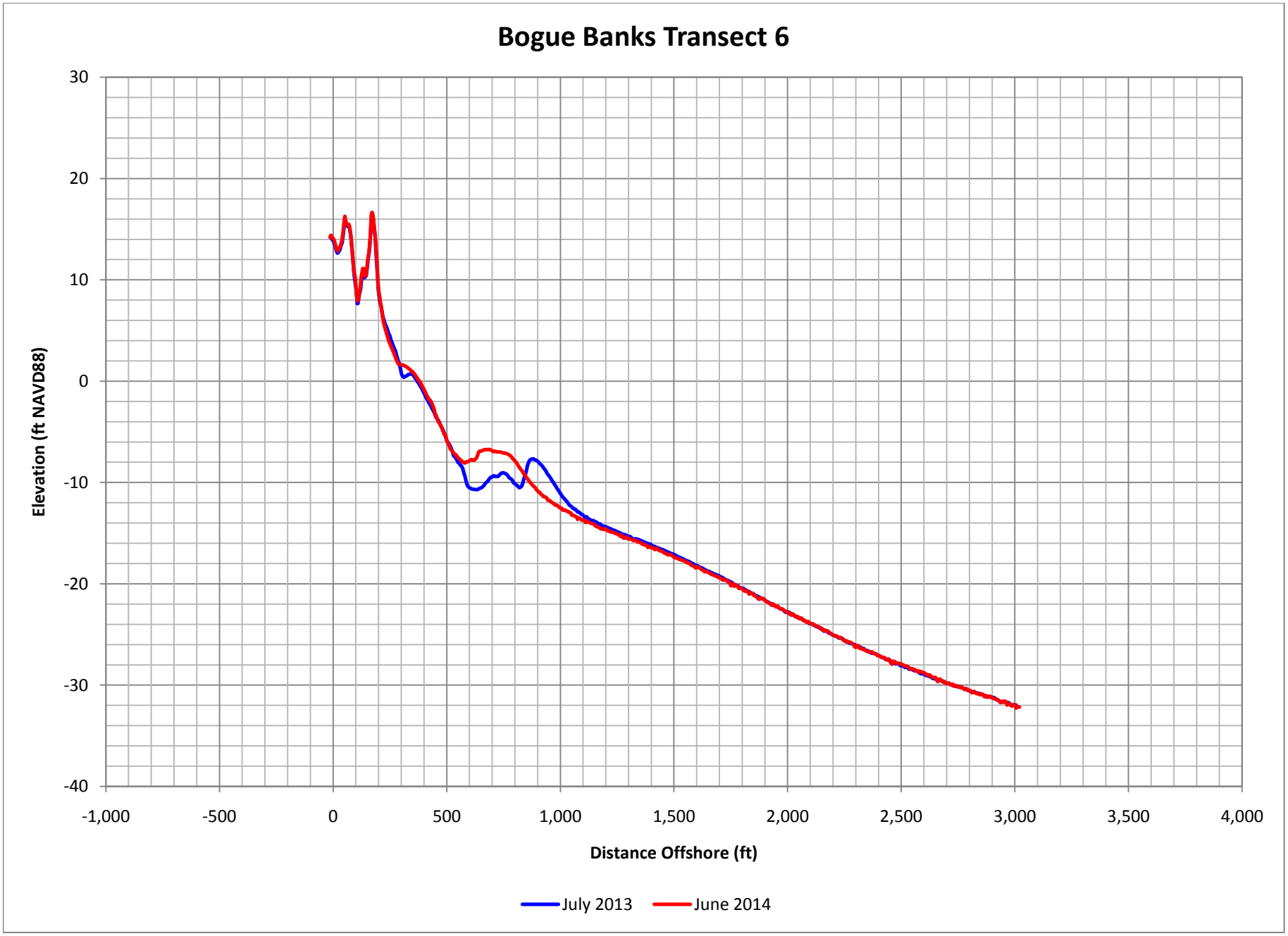


Figure C-6. Bogue Banks Profile Comparison Plot

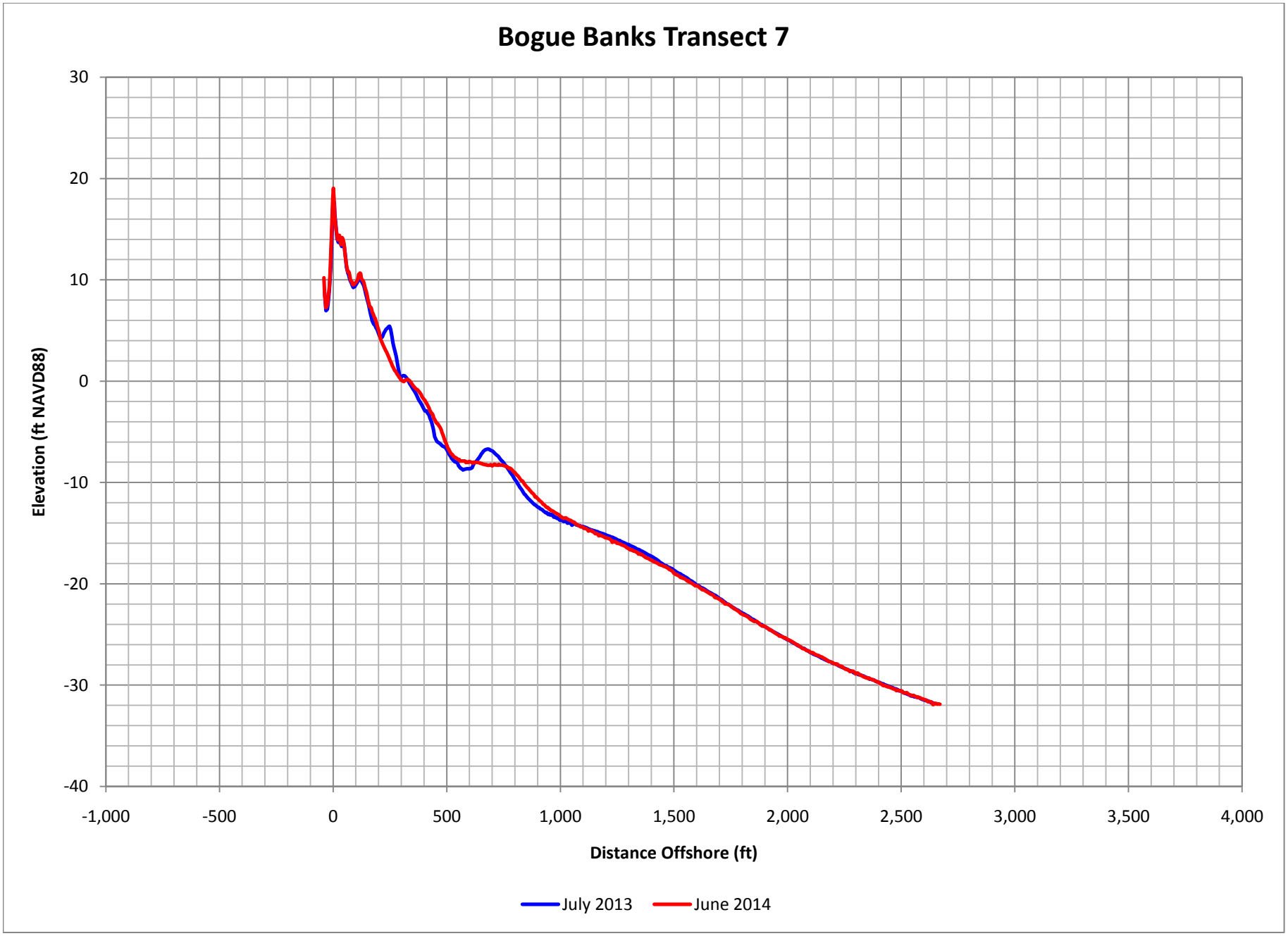


Figure C-7. Bogue Banks Profile Comparison Plot

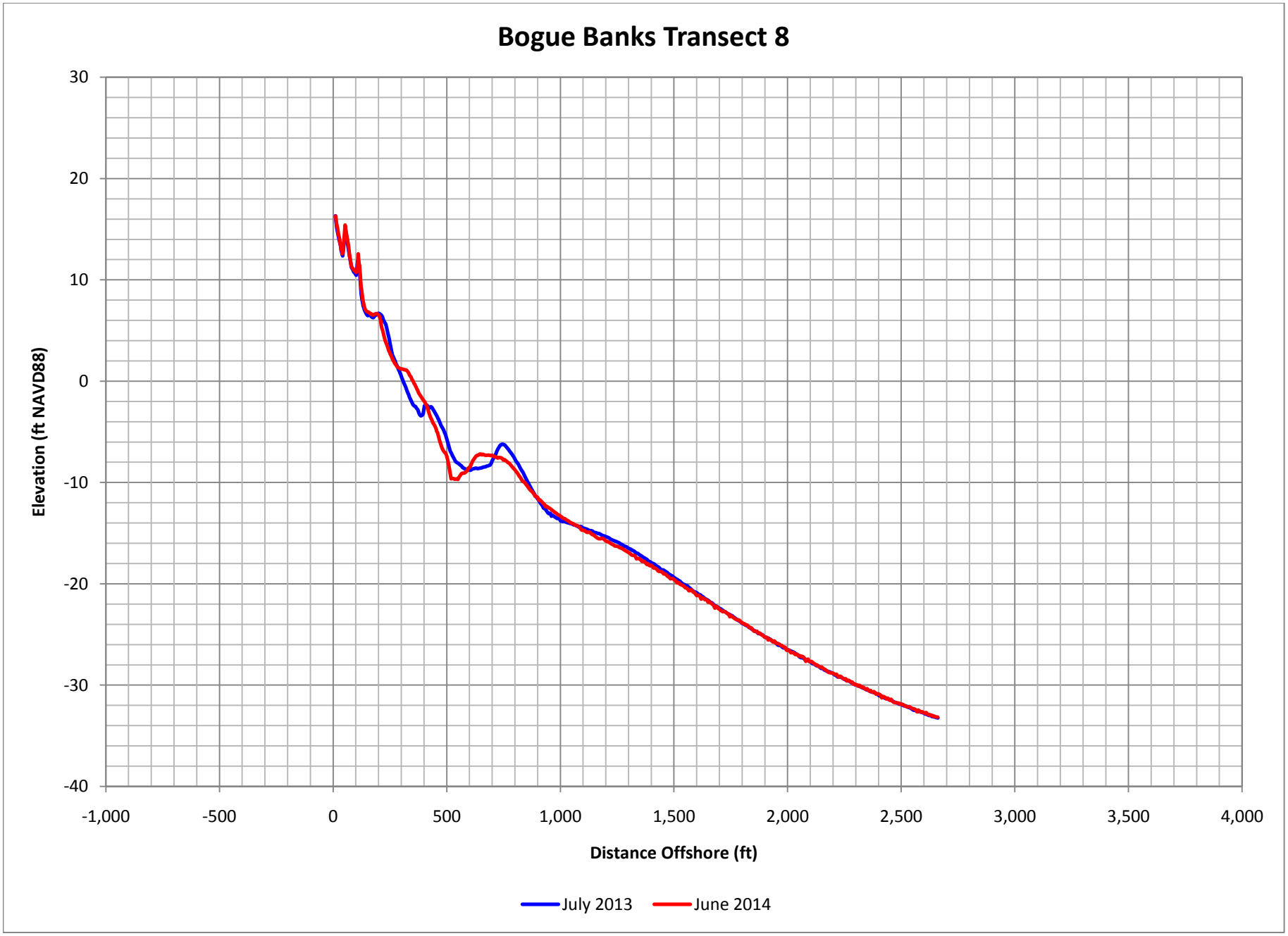


Figure C-8. Bogue Banks Profile Comparison Plot

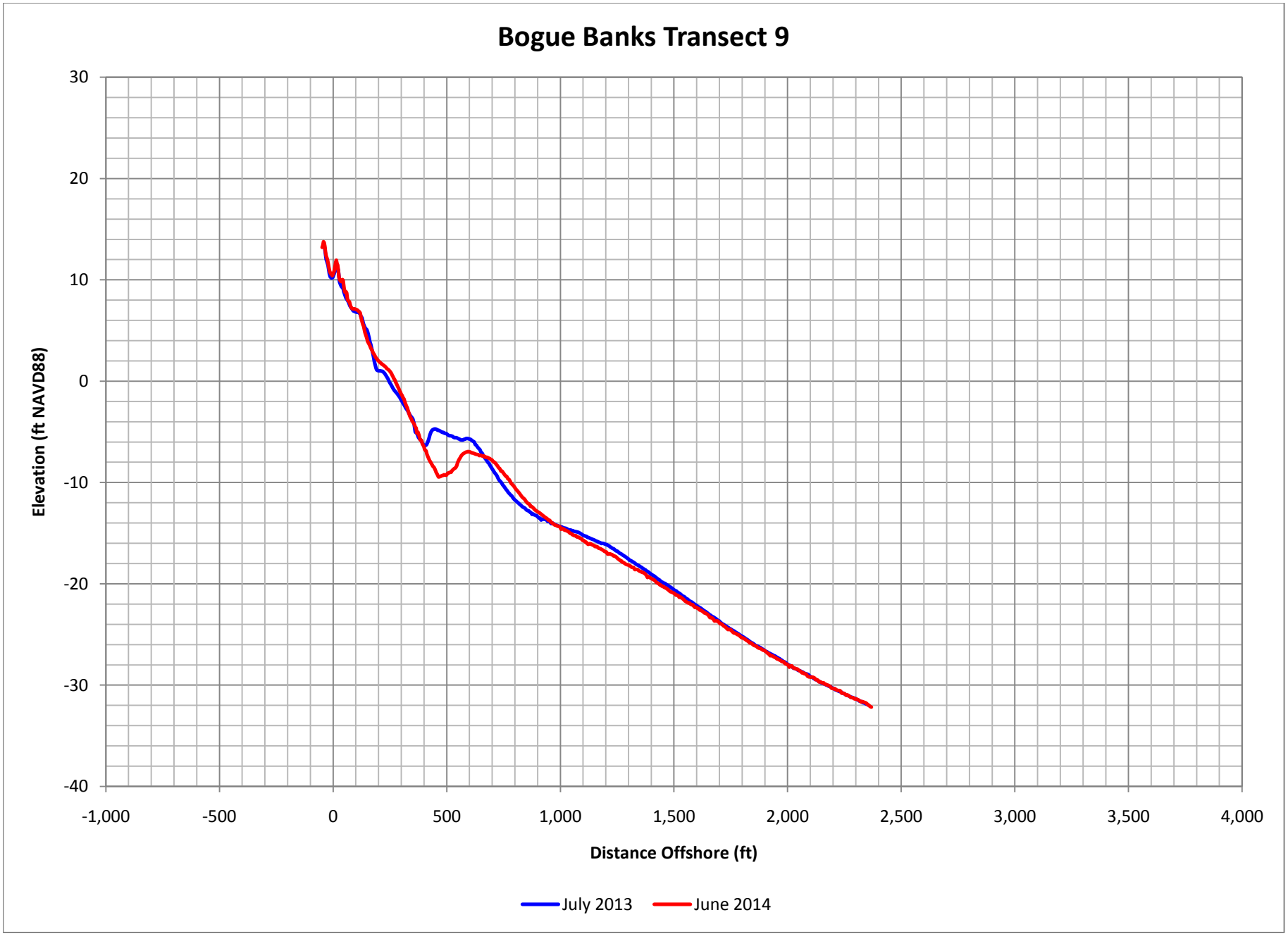


Figure C-9. Bogue Banks Profile Comparison Plot

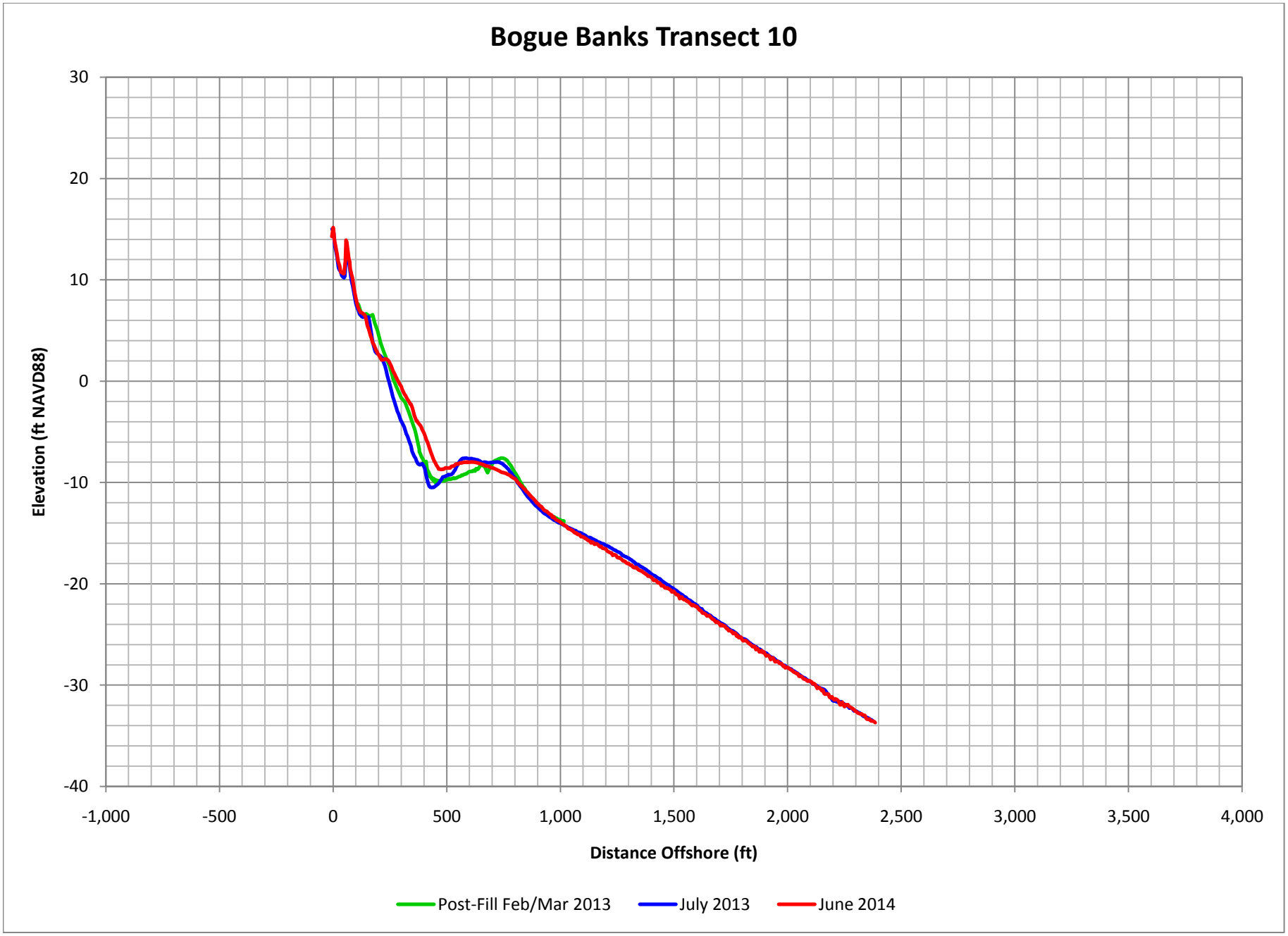


Figure C-10. Bogue Banks Profile Comparison Plot

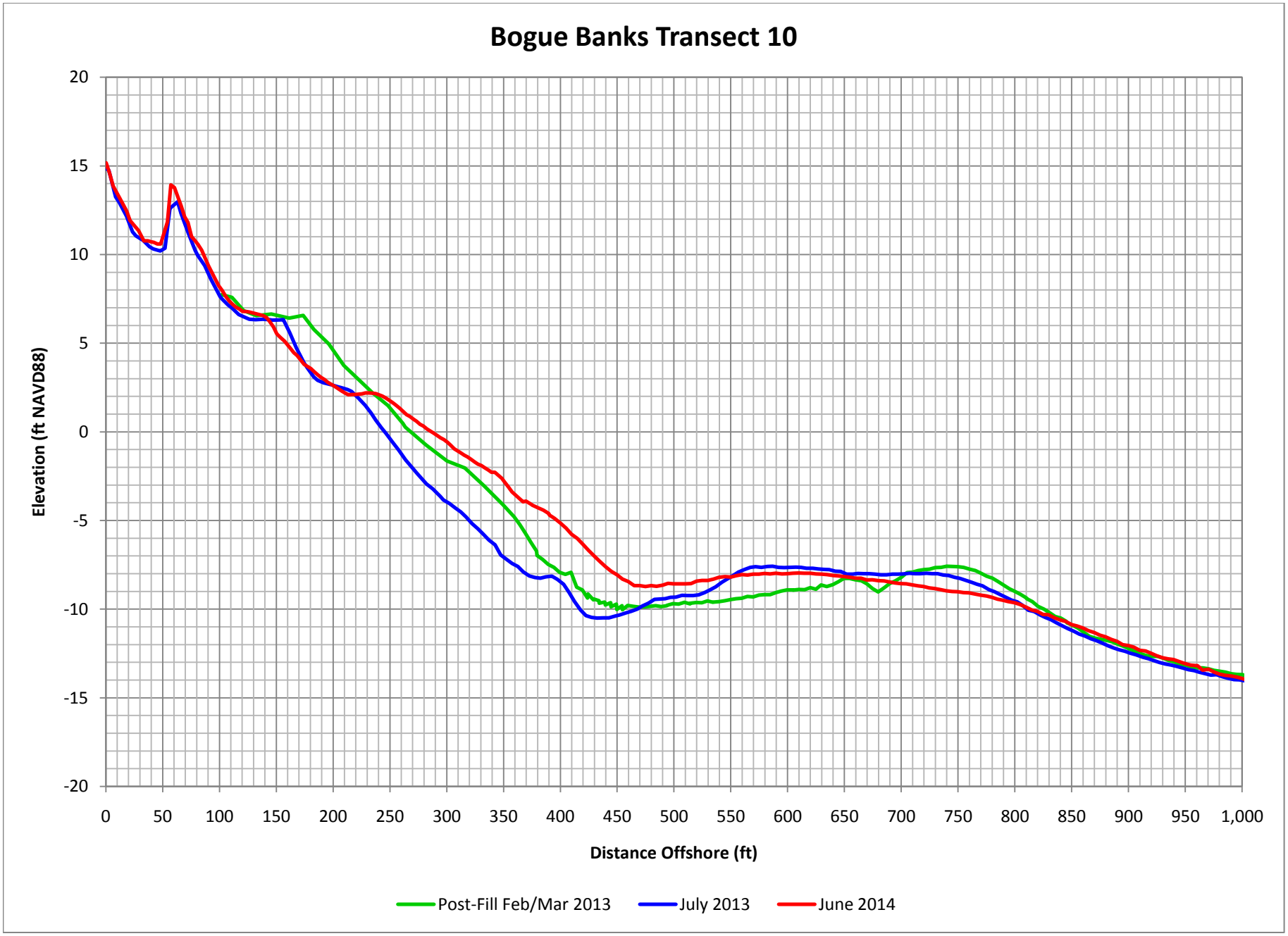


Figure C-11. Bogue Banks Profile Comparison Plot

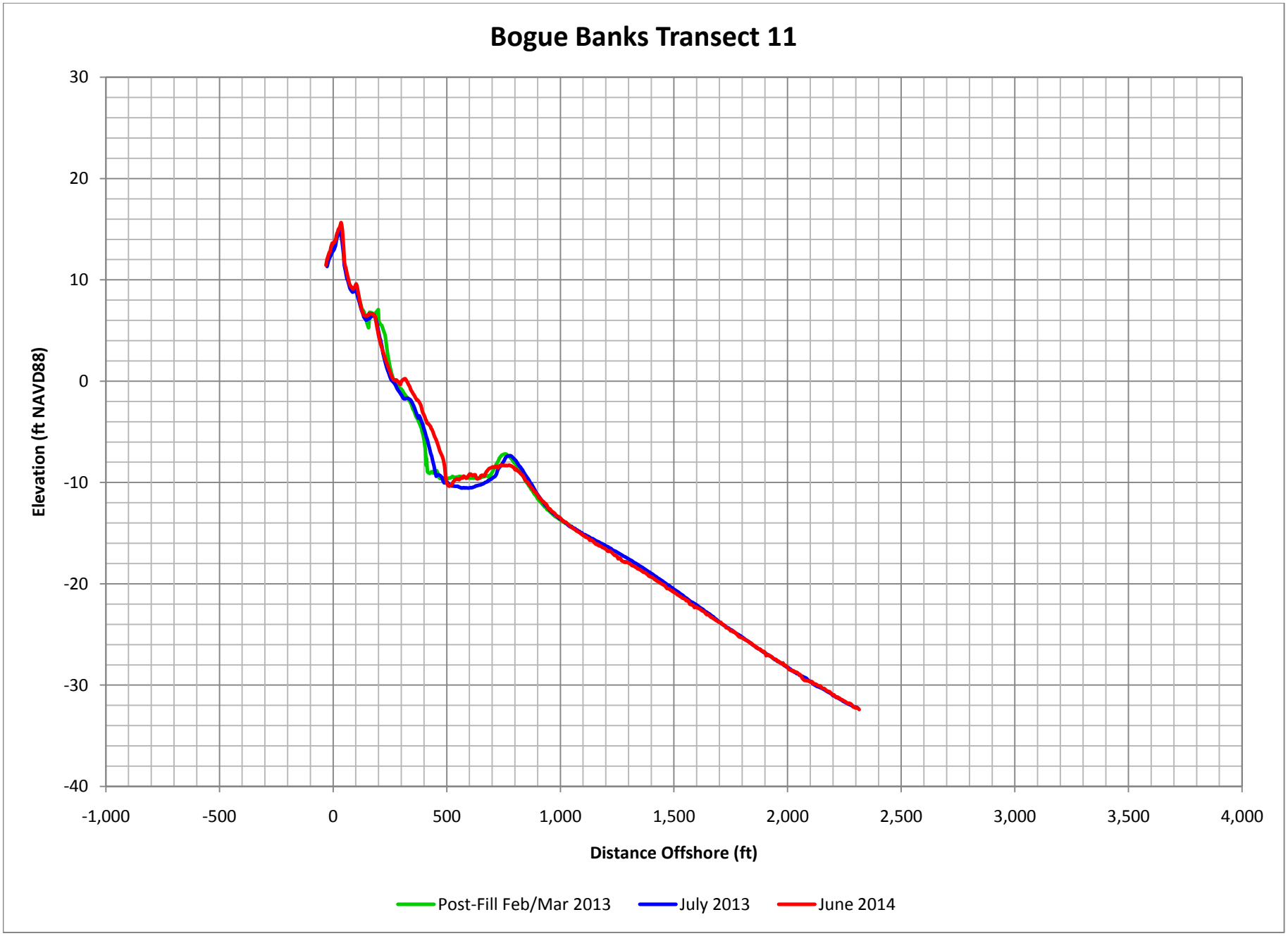


Figure C-12. Bogue Banks Profile Comparison Plot

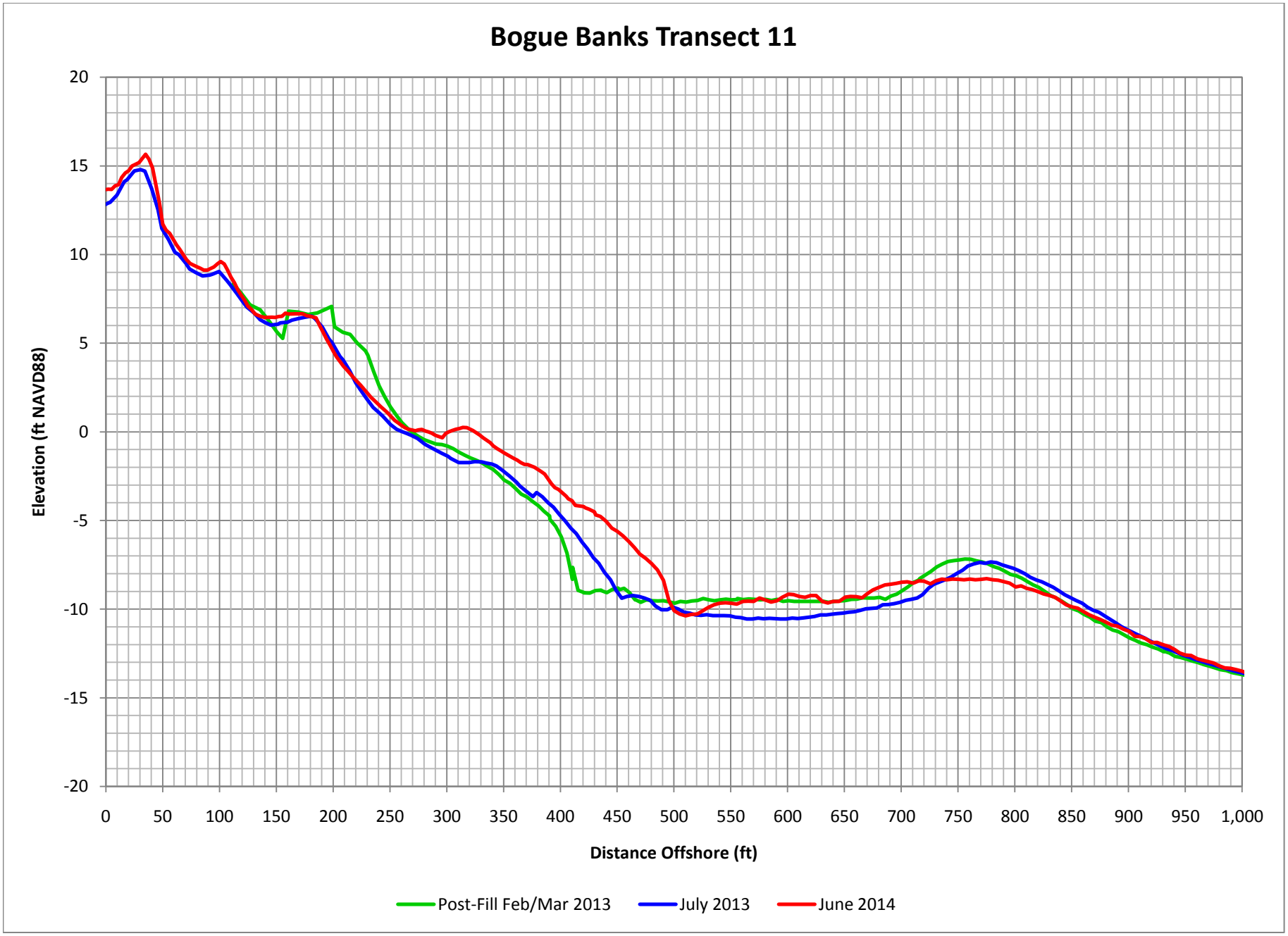


Figure C-13. Bogue Banks Profile Comparison Plot

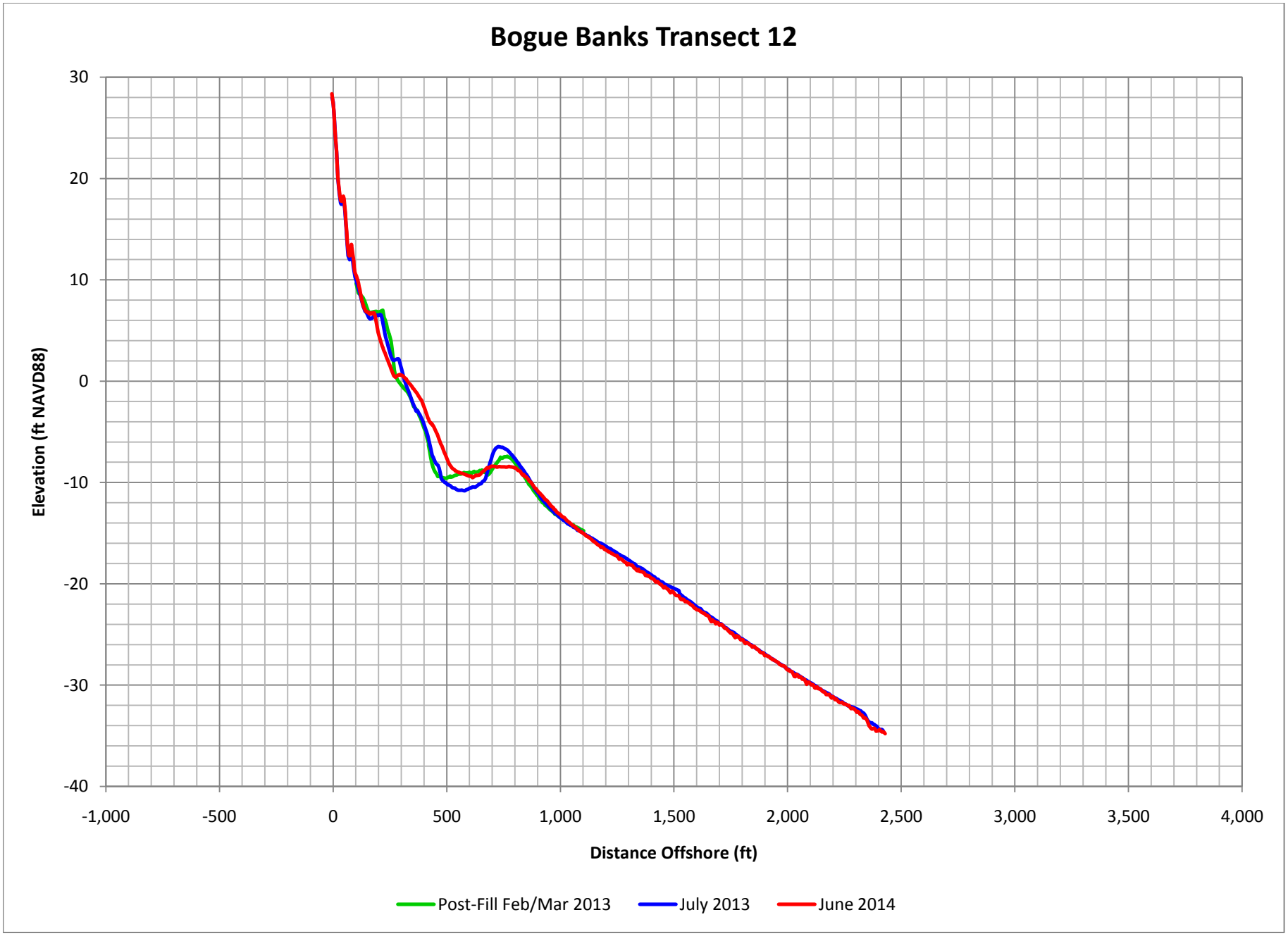


Figure C-14. Bogue Banks Profile Comparison Plot

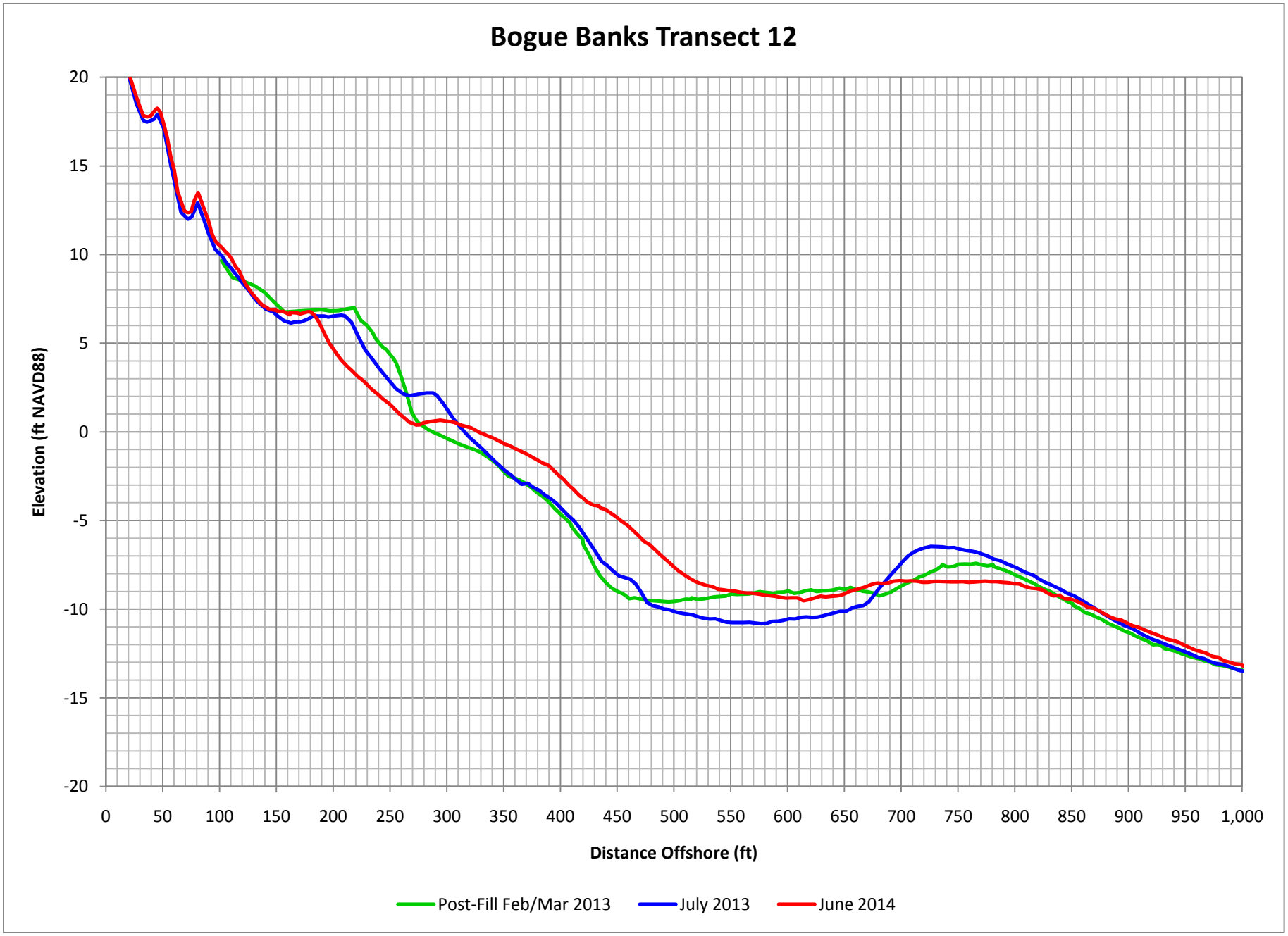


Figure C-15. Bogue Banks Profile Comparison Plot

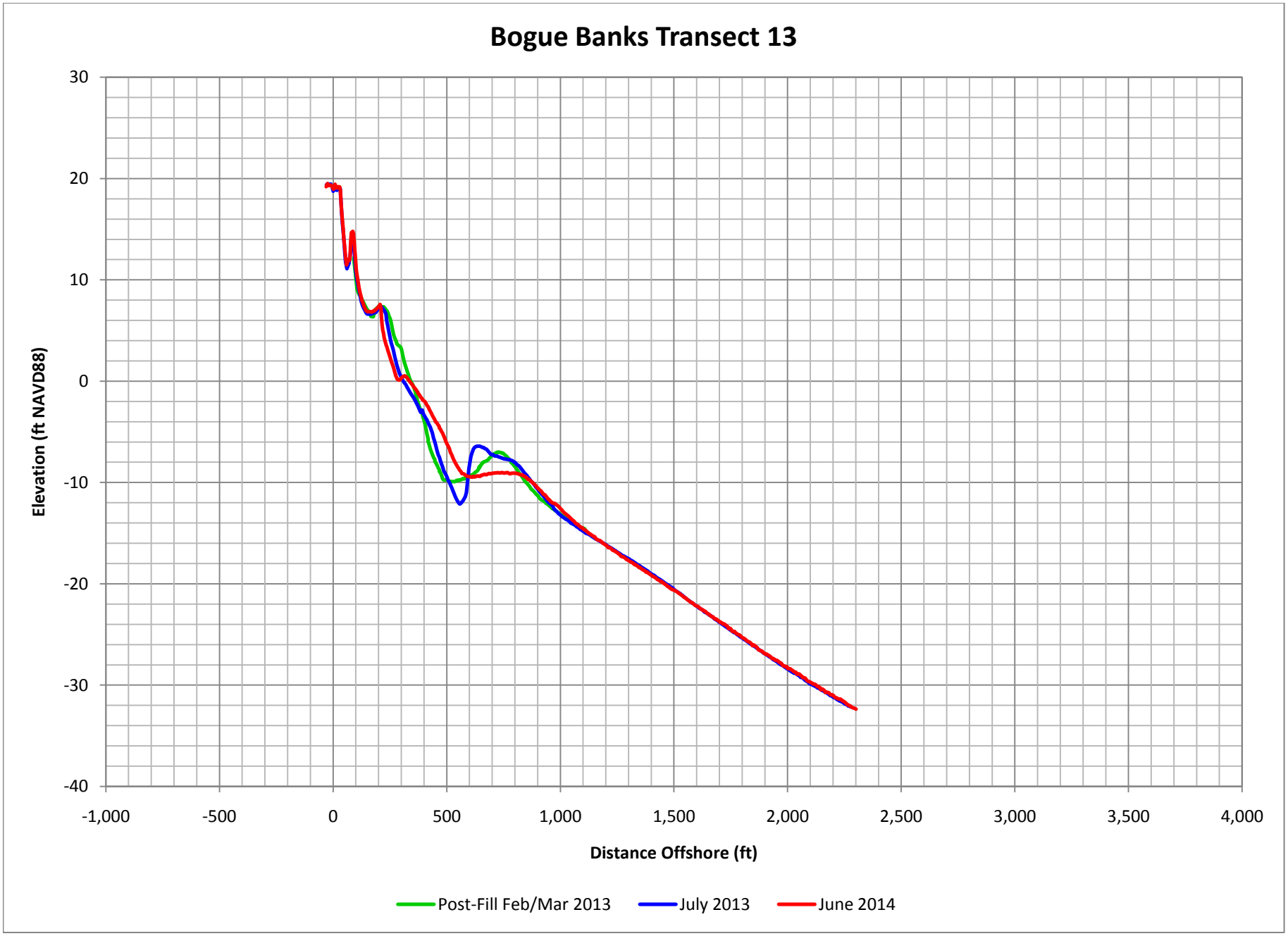


Figure C-16. Bogue Banks Profile Comparison Plot

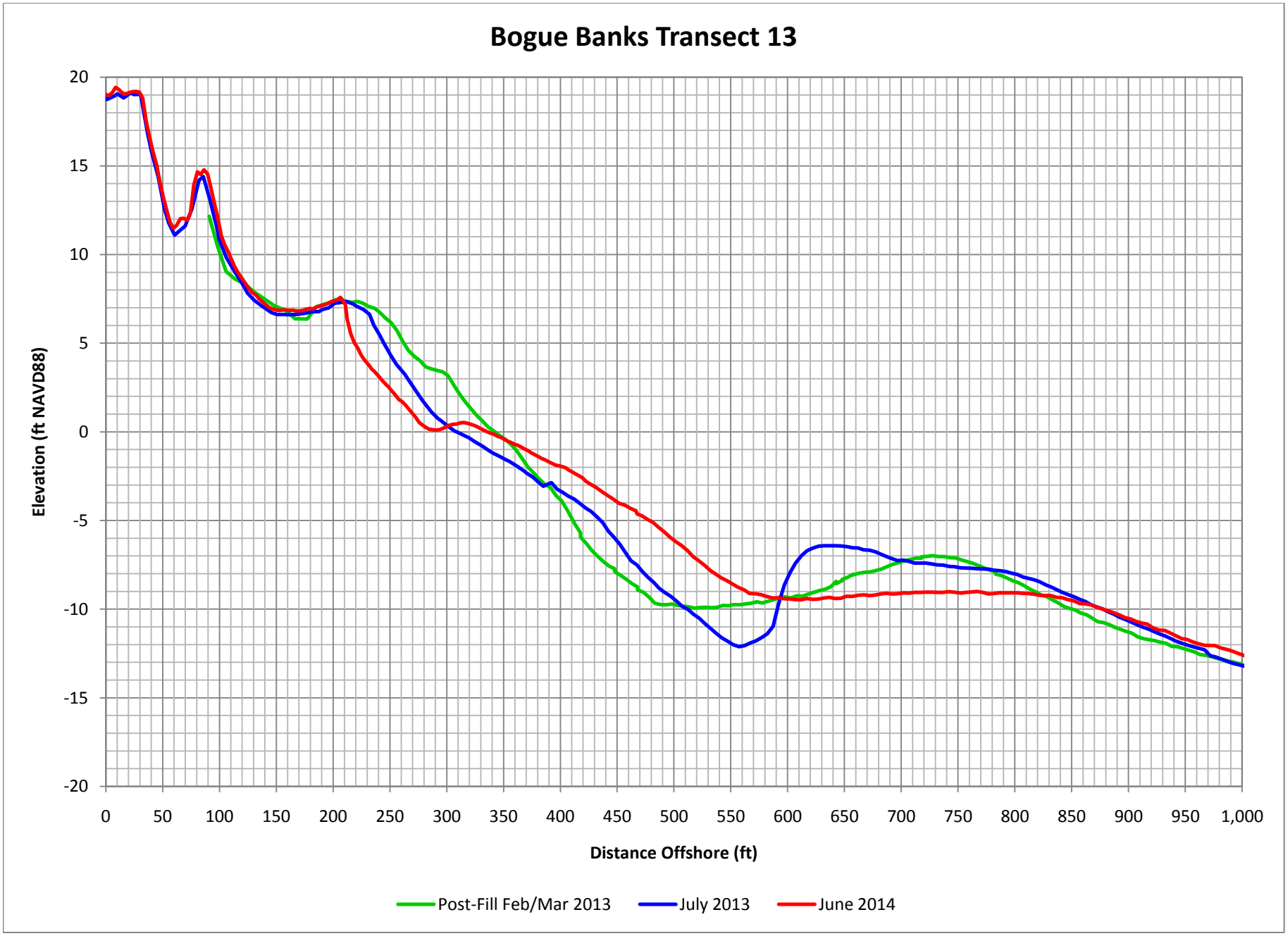


Figure C-17. Bogue Banks Profile Comparison Plot

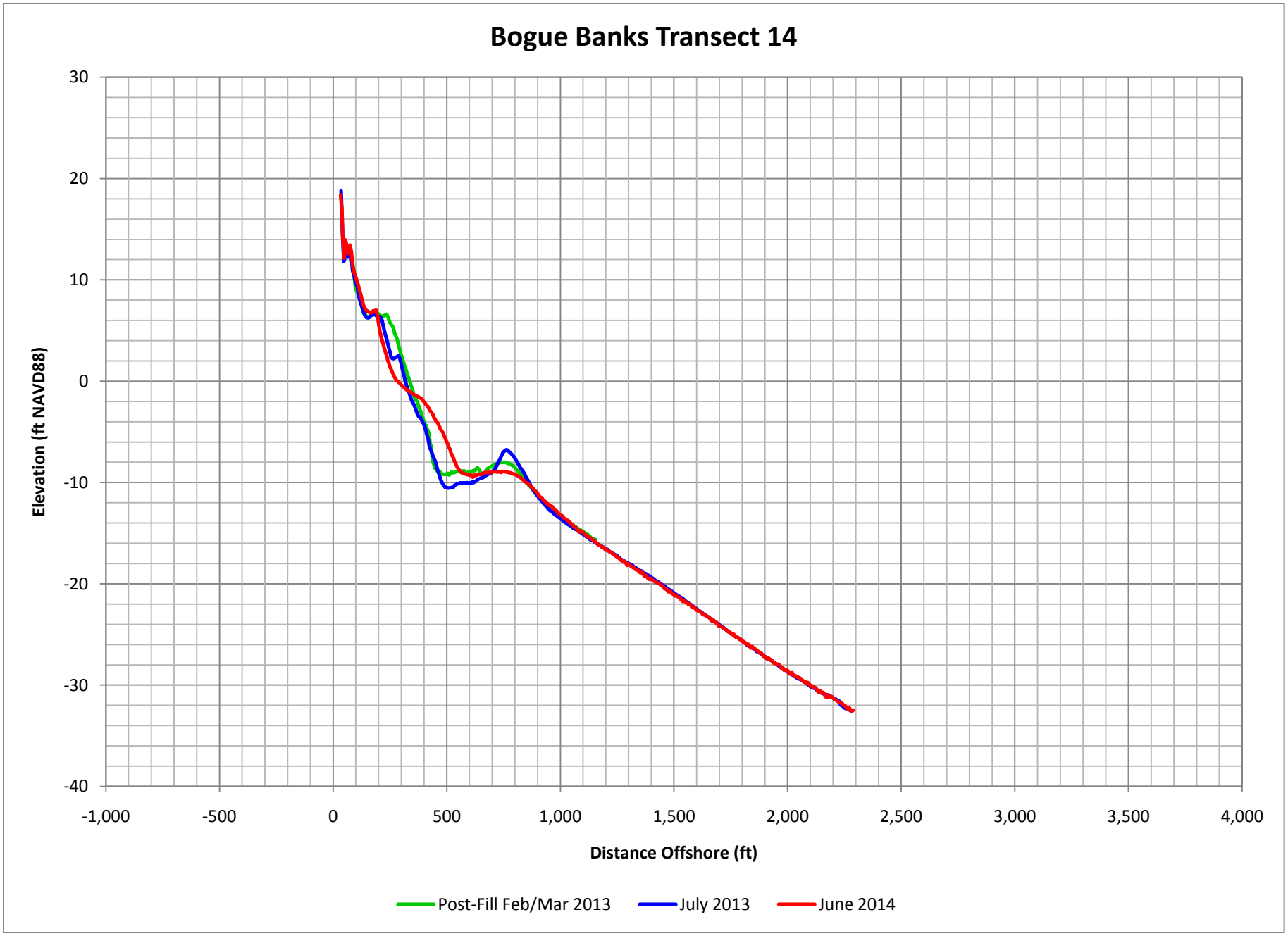


Figure C-18. Bogue Banks Profile Comparison Plot

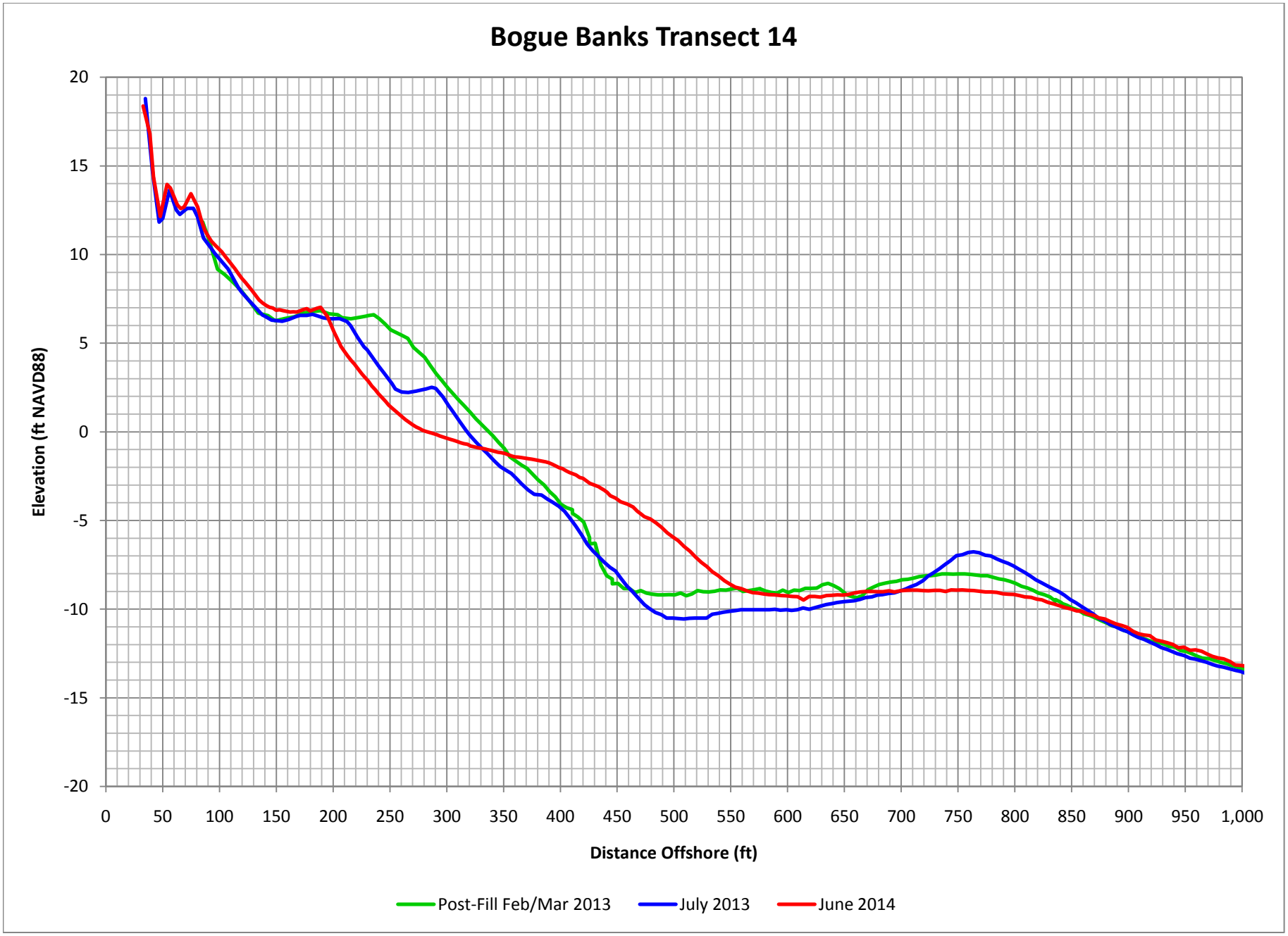


Figure C-19. Bogue Banks Profile Comparison Plot

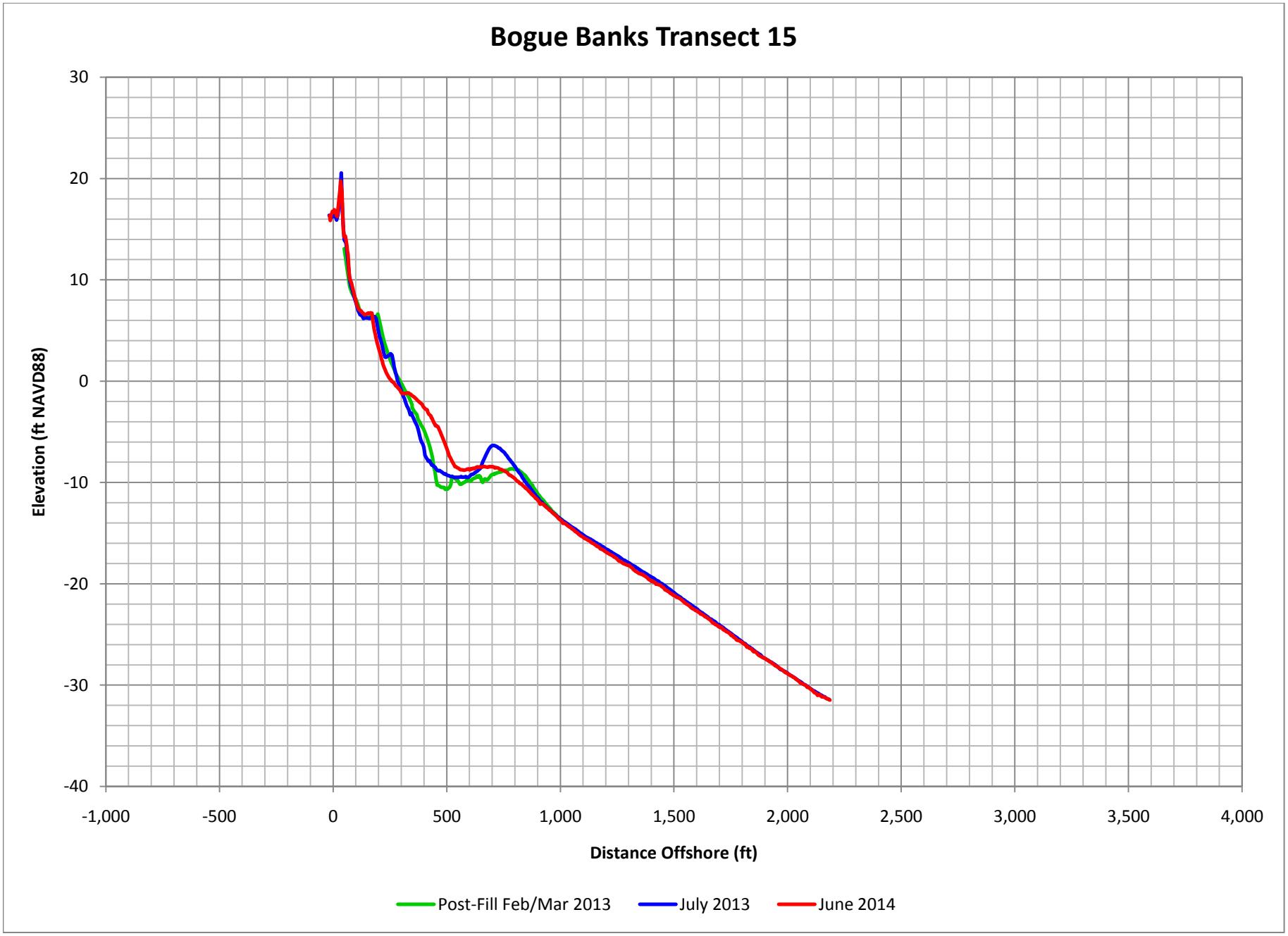


Figure C-20. Bogue Banks Profile Comparison Plot

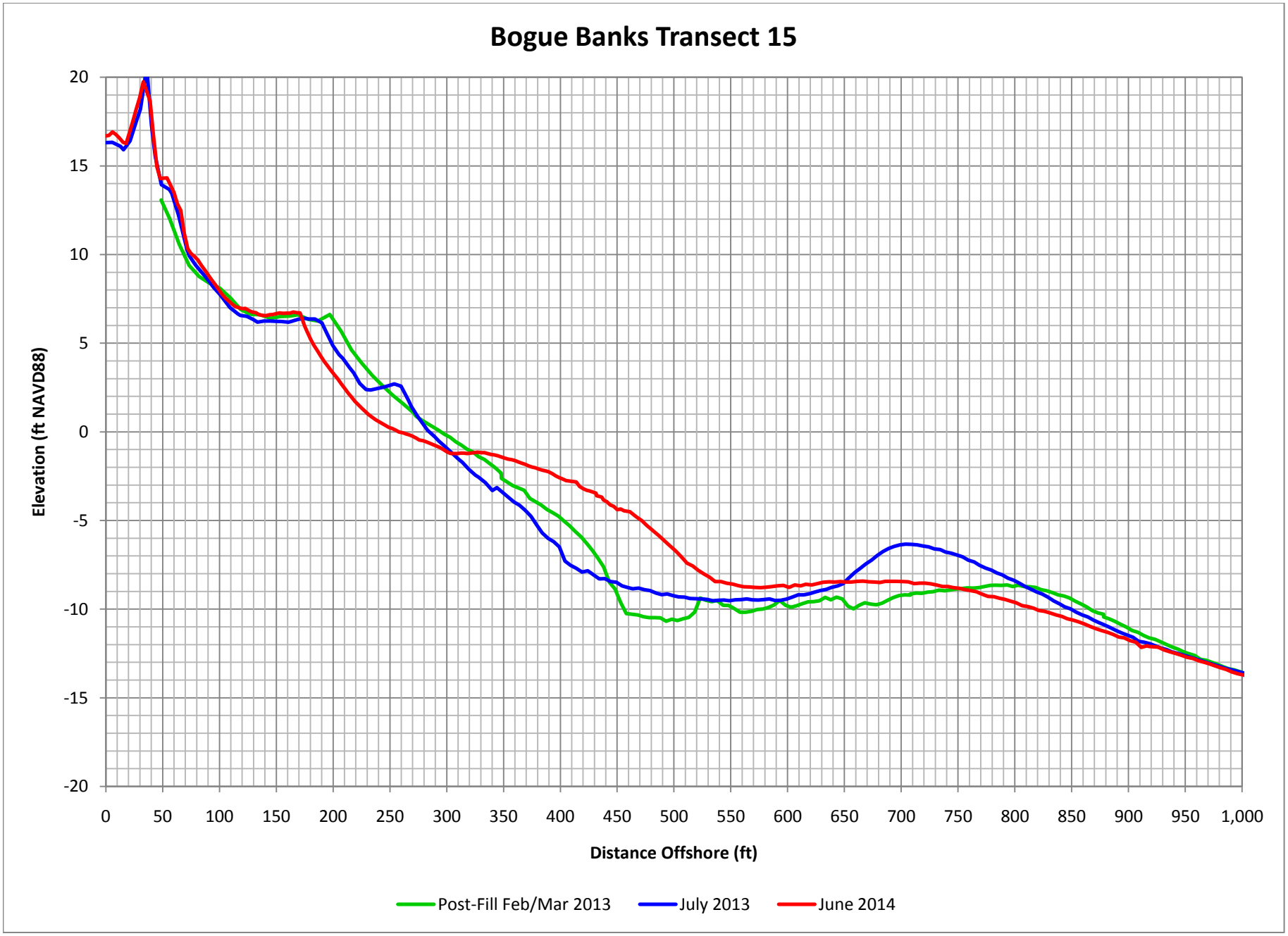


Figure C-21. Bogue Banks Profile Comparison Plot

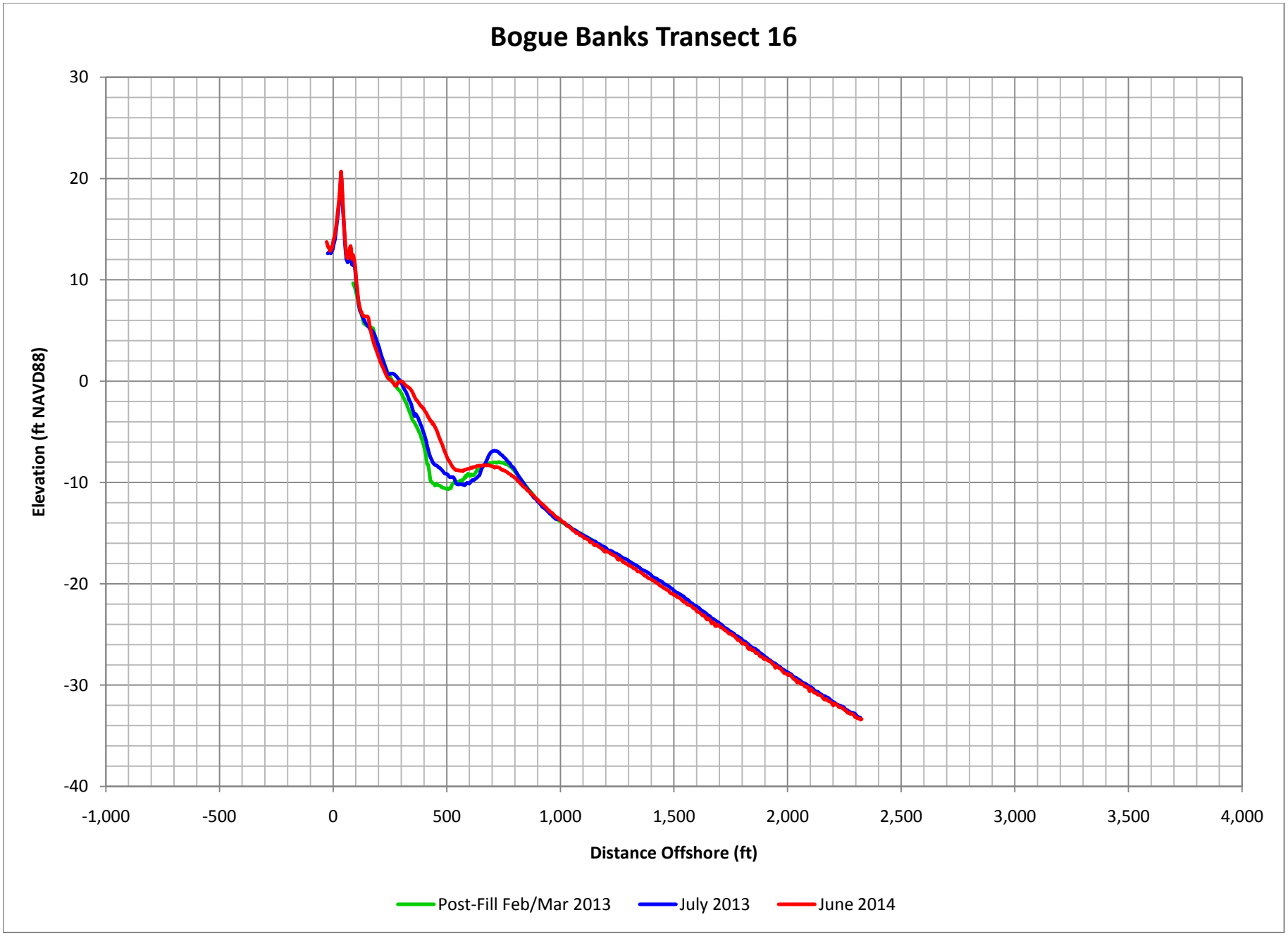


Figure C-22. Bogue Banks Profile Comparison Plot

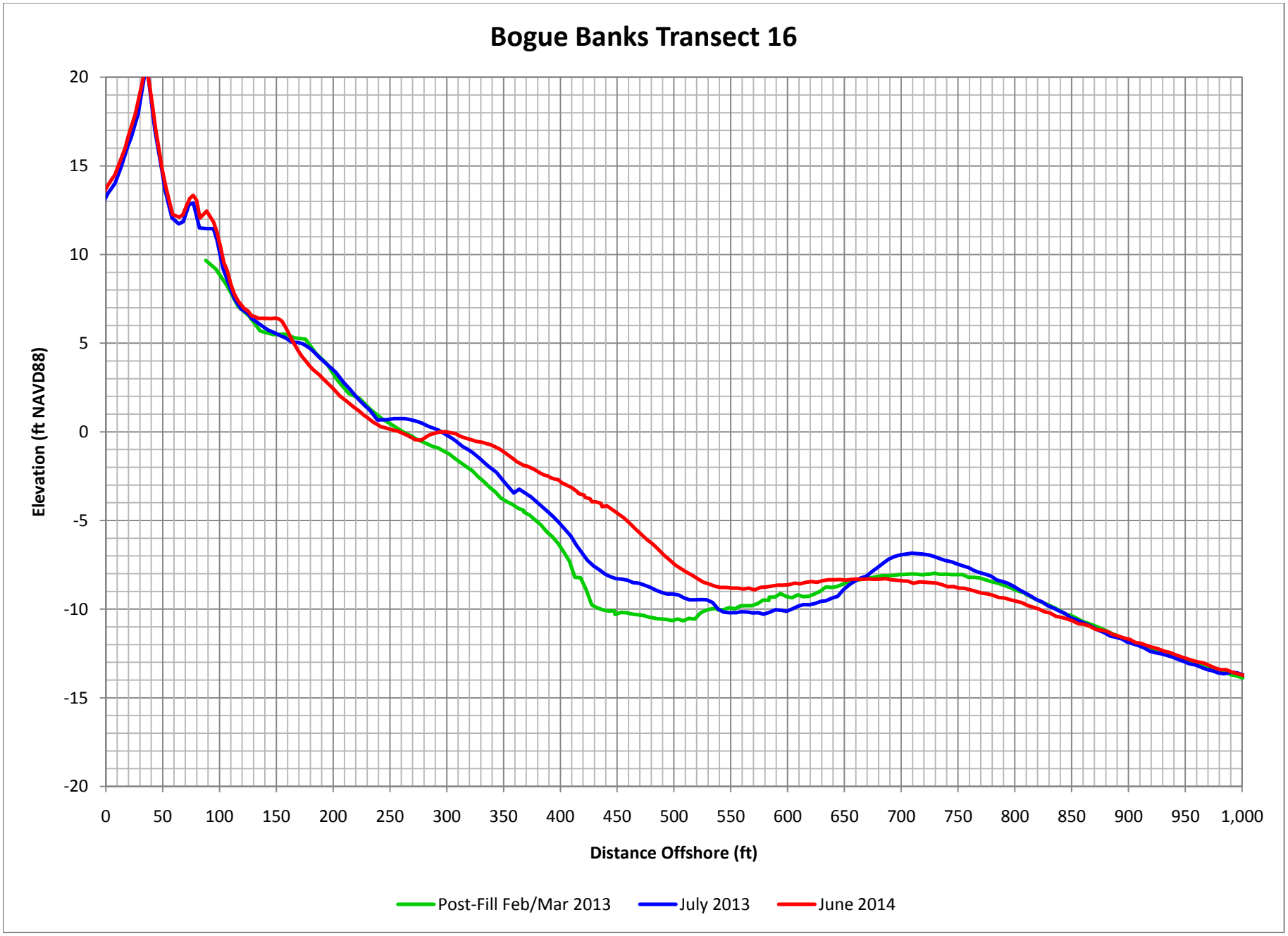


Figure C-23. Bogue Banks Profile Comparison Plot

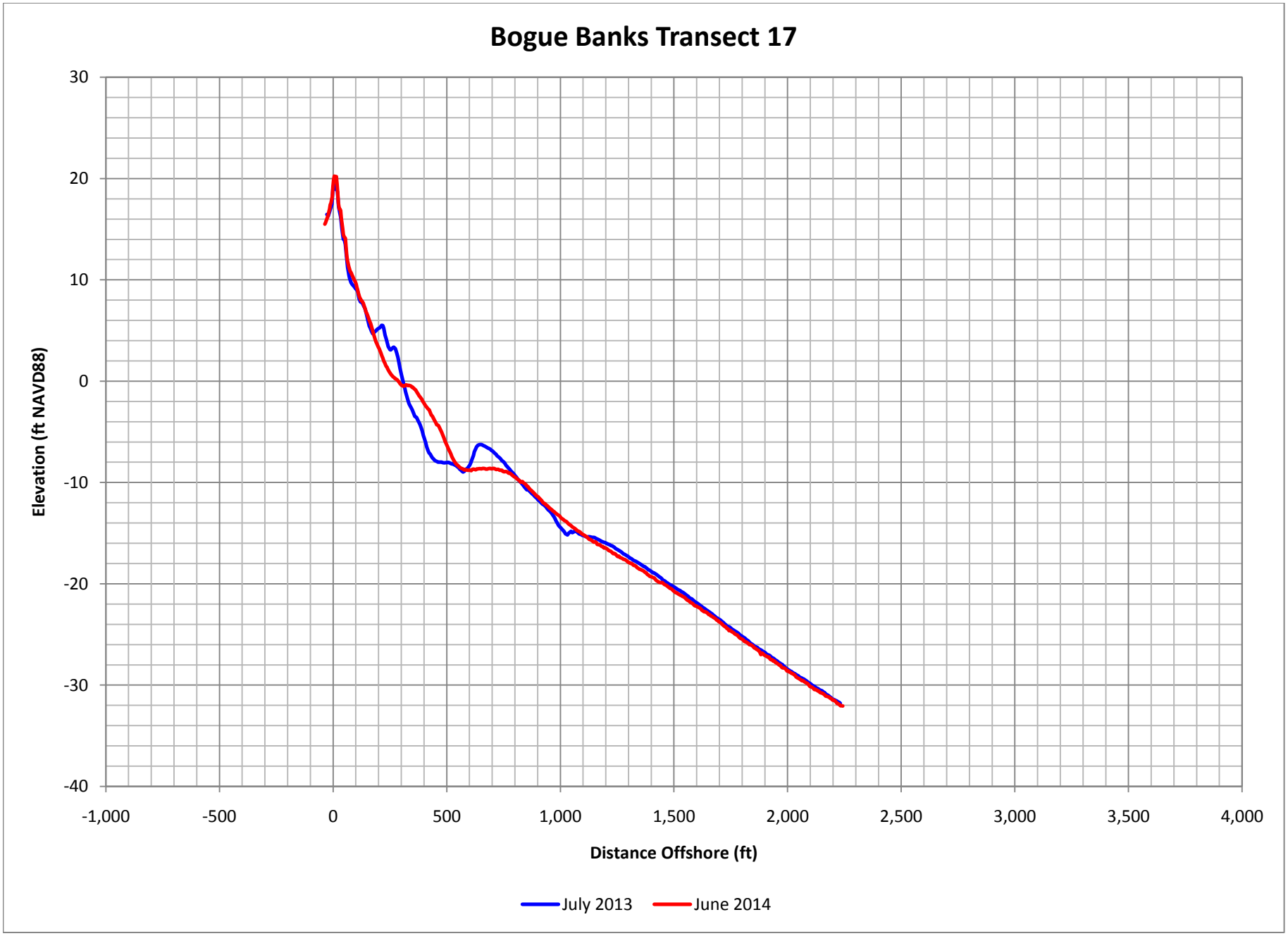


Figure C-24. Bogue Banks Profile Comparison Plot

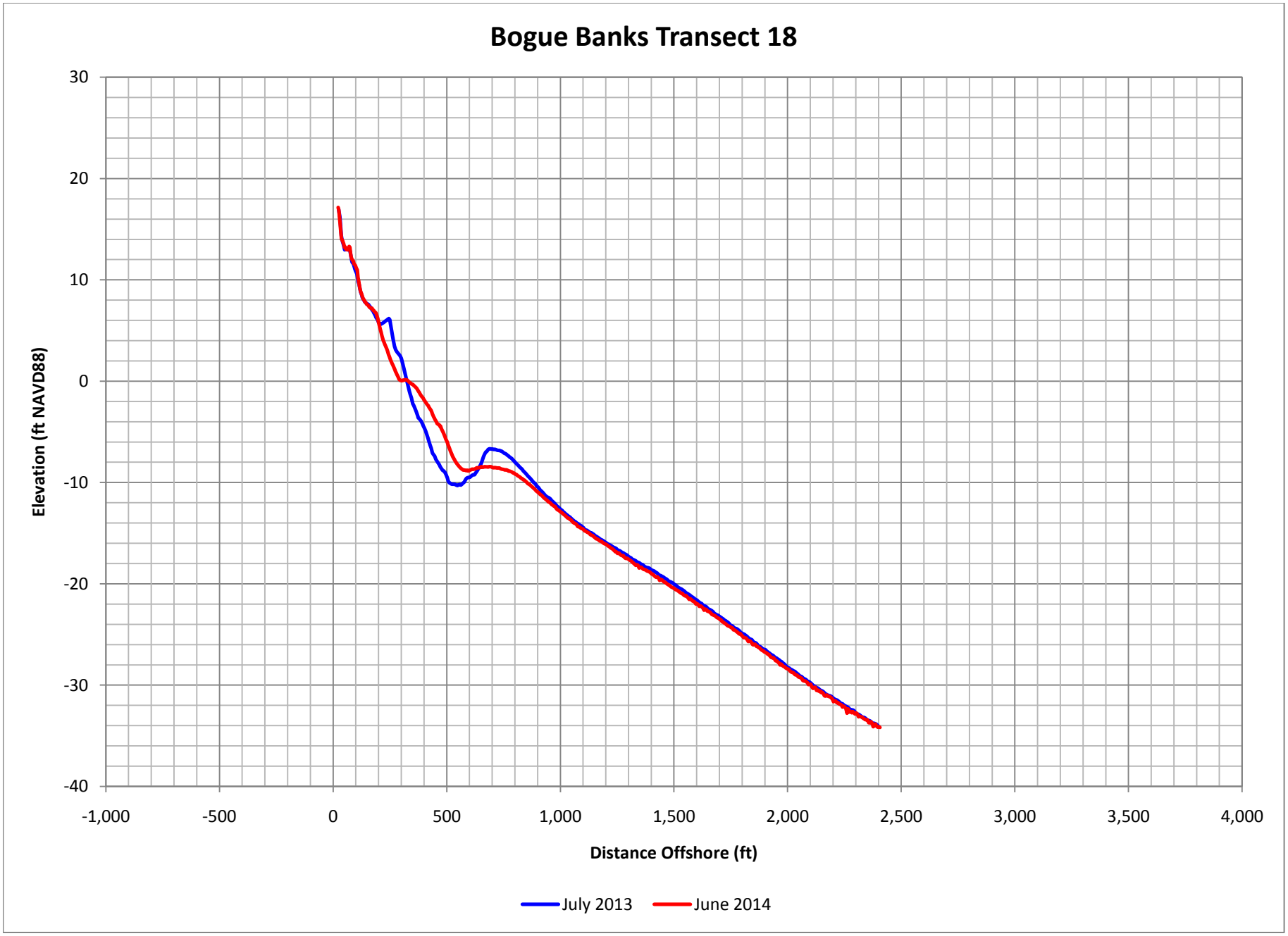


Figure C-25. Bogue Banks Profile Comparison Plot

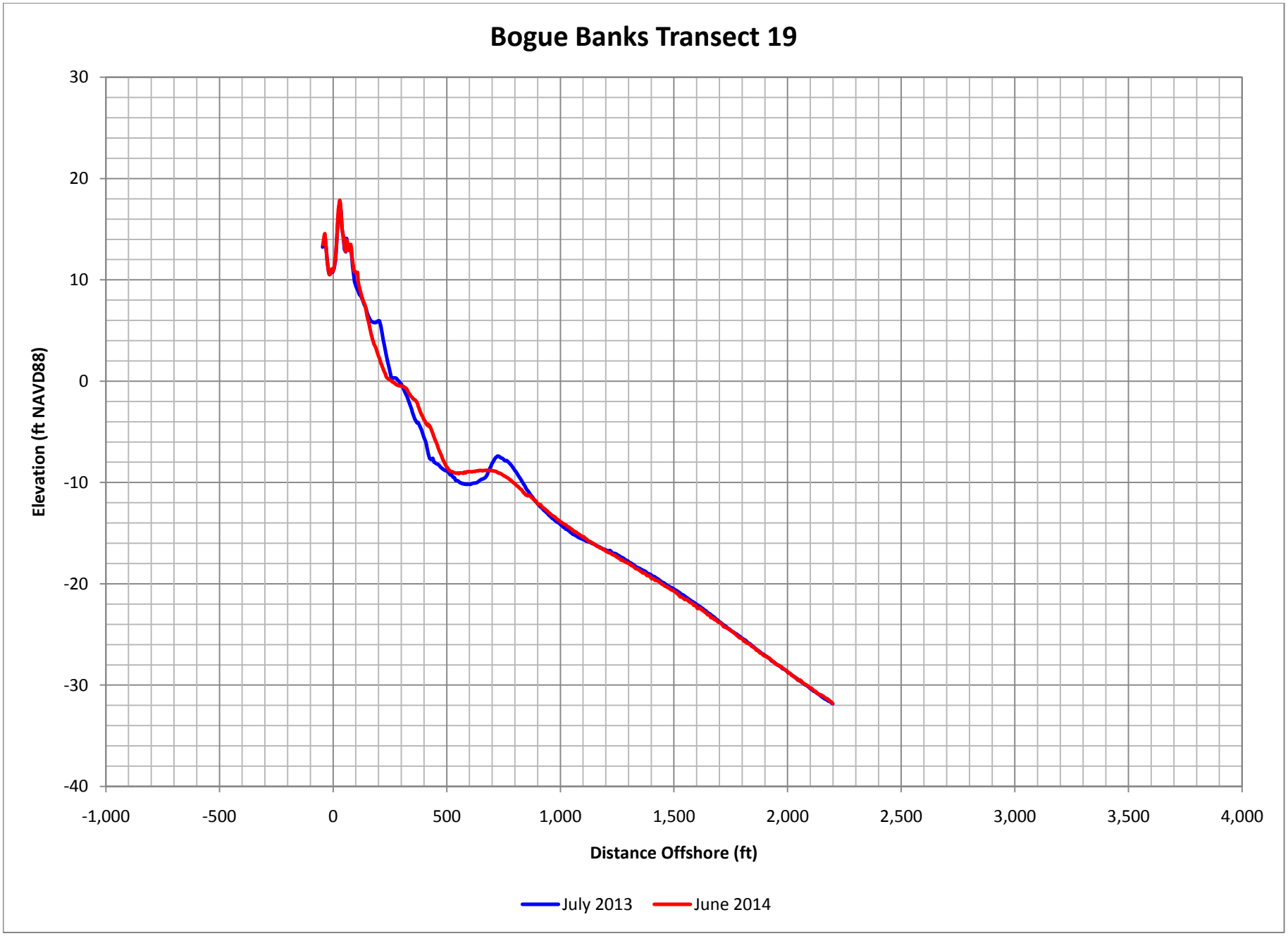


Figure C-26. Bogue Banks Profile Comparison Plot

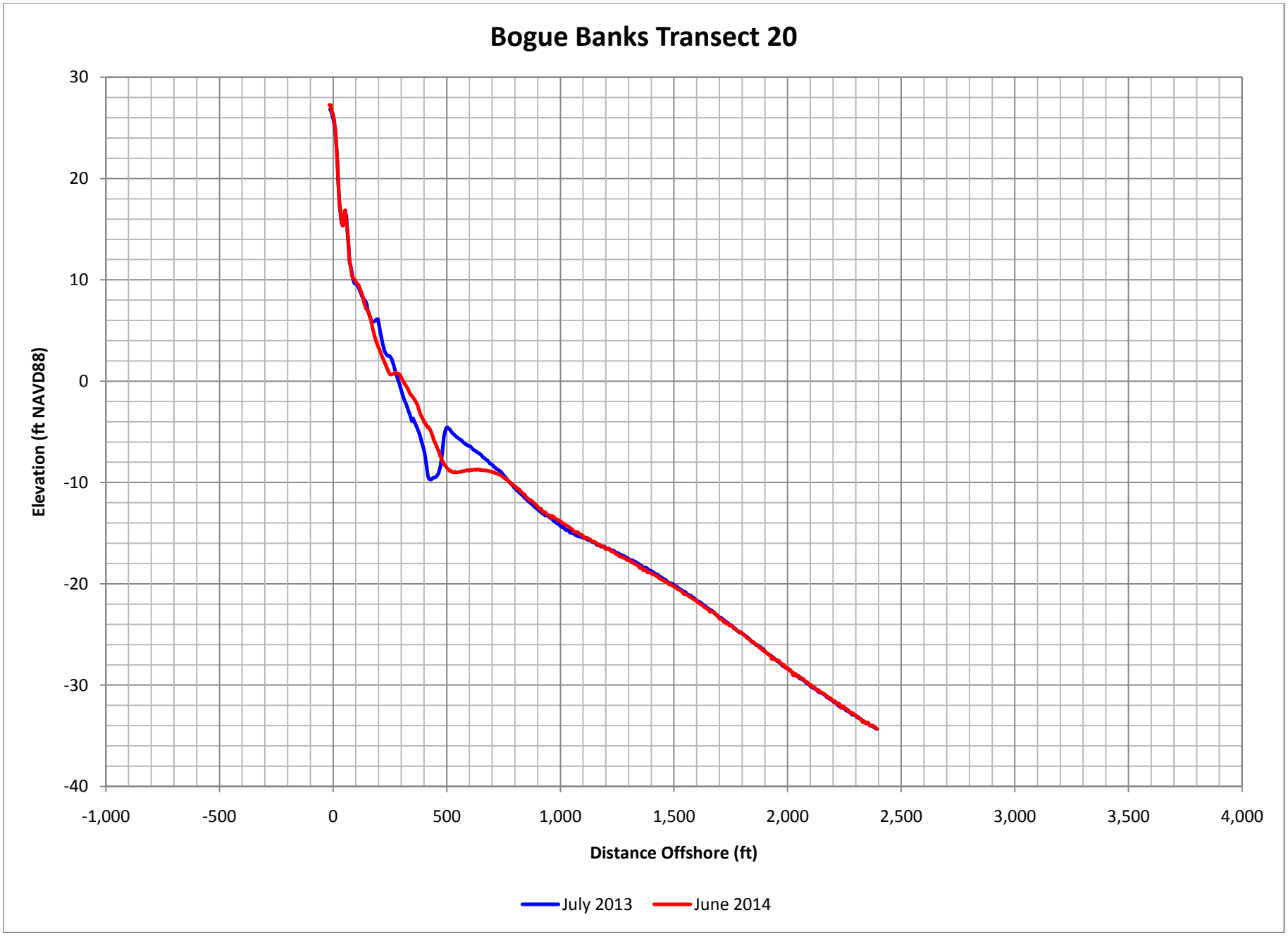


Figure C-27. Bogue Banks Profile Comparison Plot

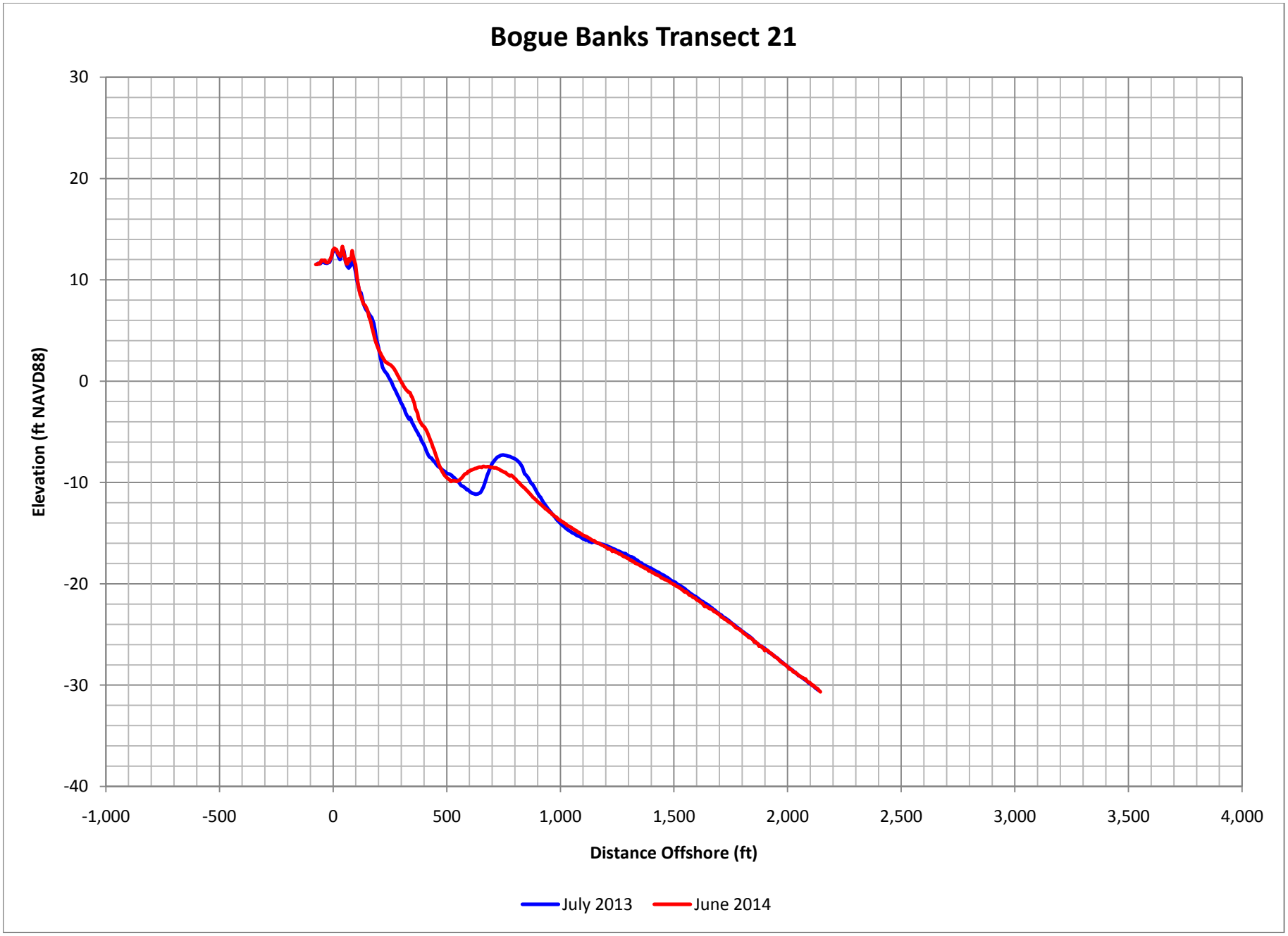


Figure C-28. Bogue Banks Profile Comparison Plot

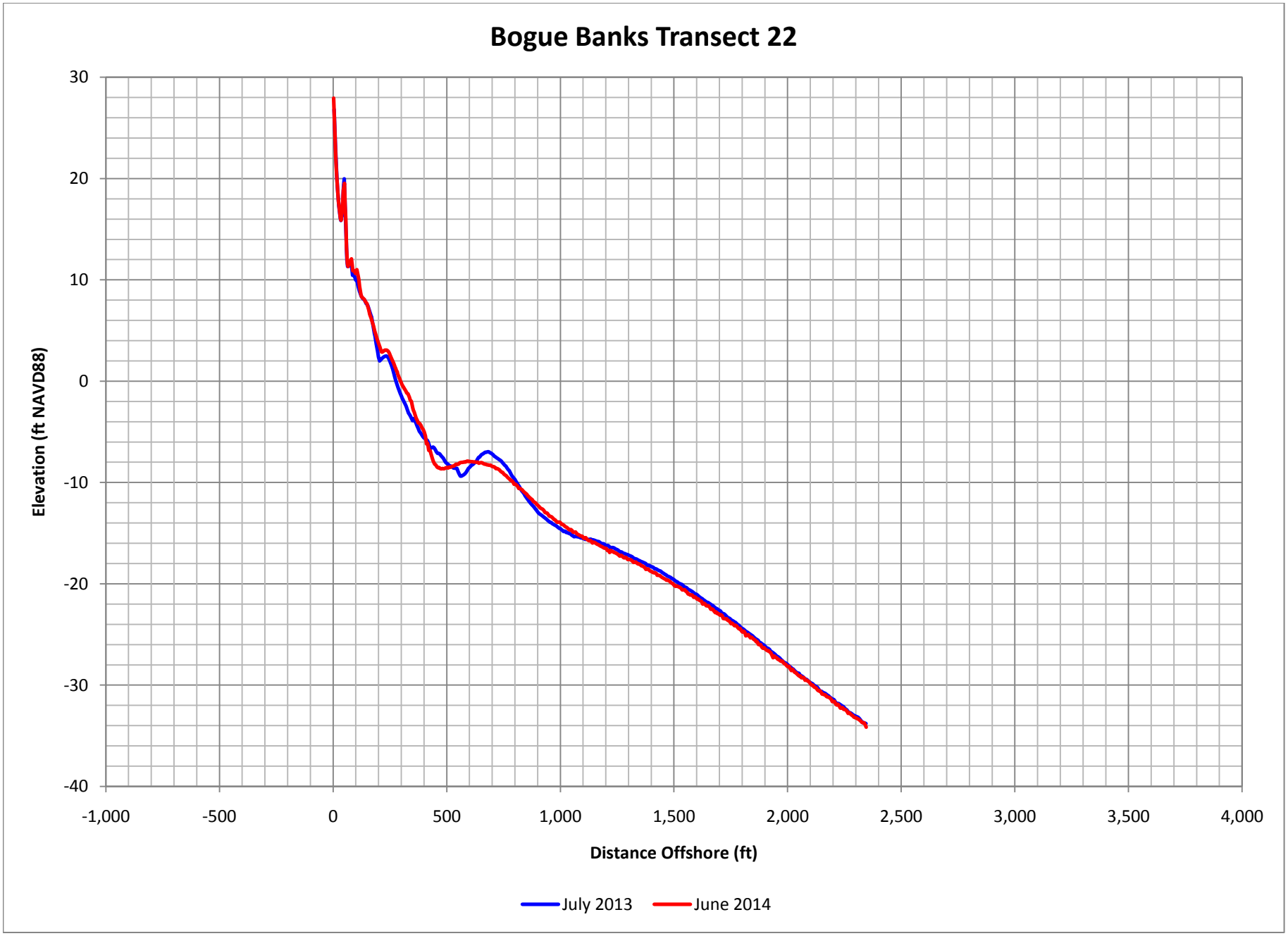


Figure C-29. Bogue Banks Profile Comparison Plot

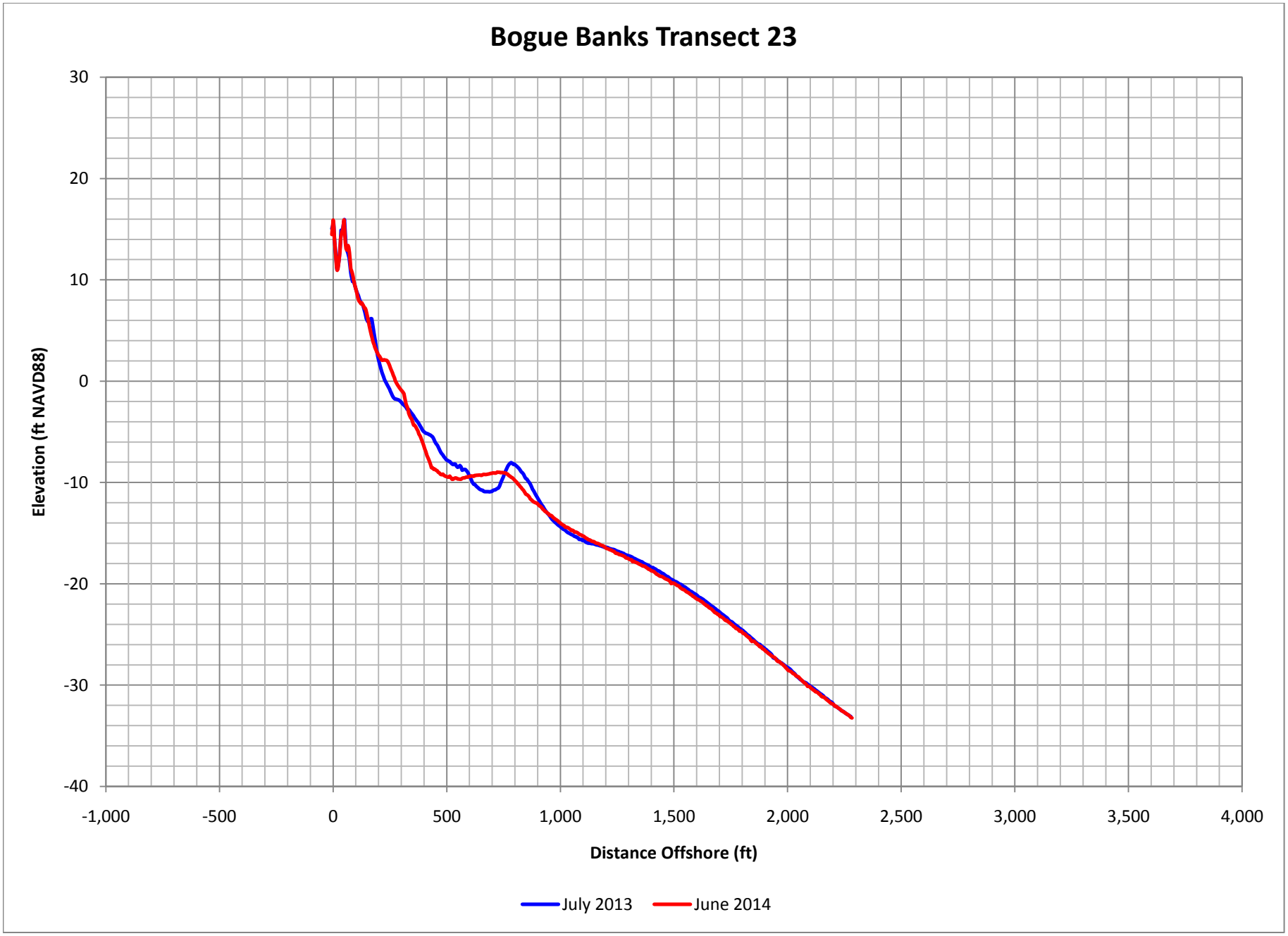


Figure C-30. Bogue Banks Profile Comparison Plot

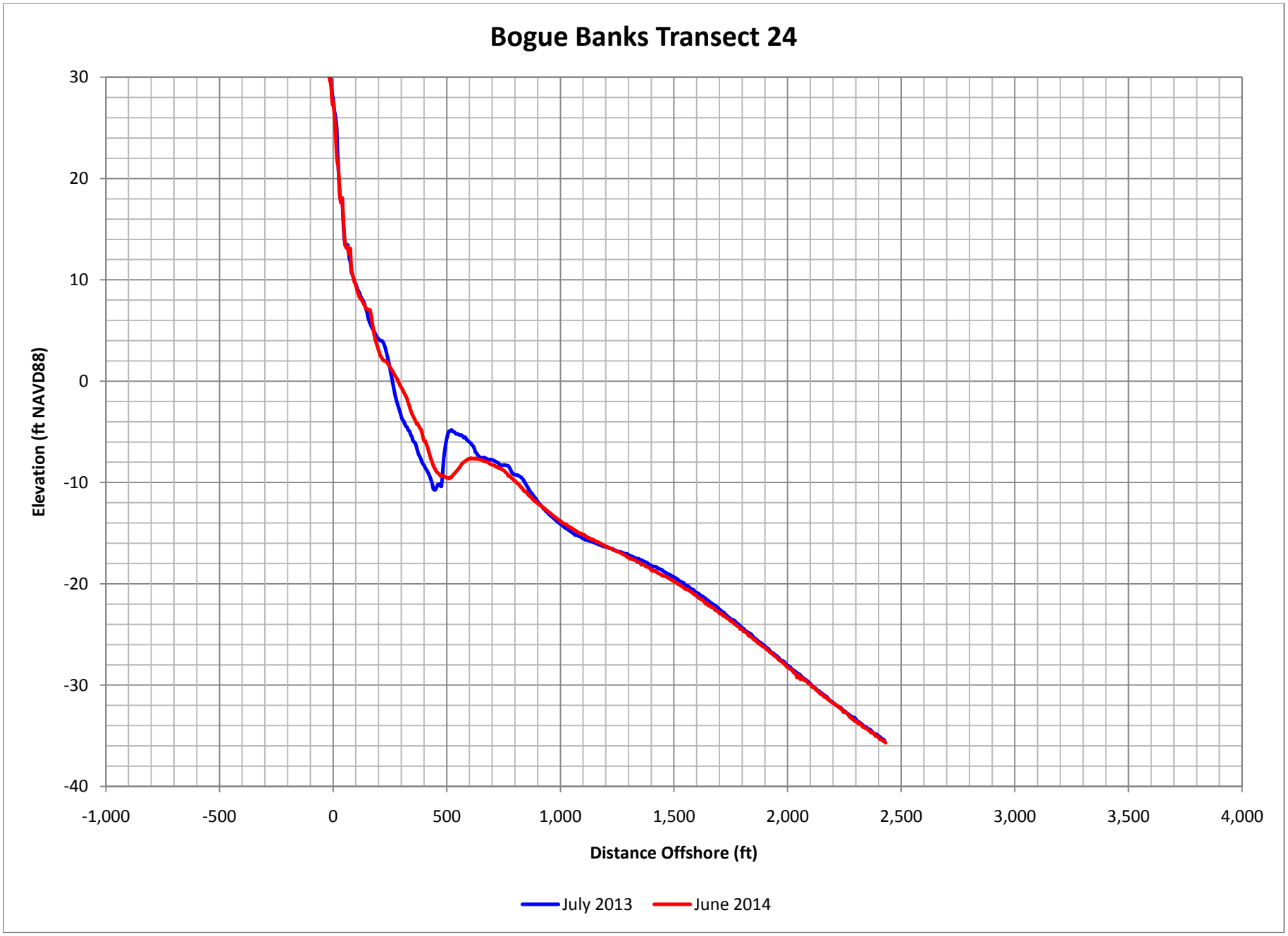


Figure C-31. Bogue Banks Profile Comparison Plot

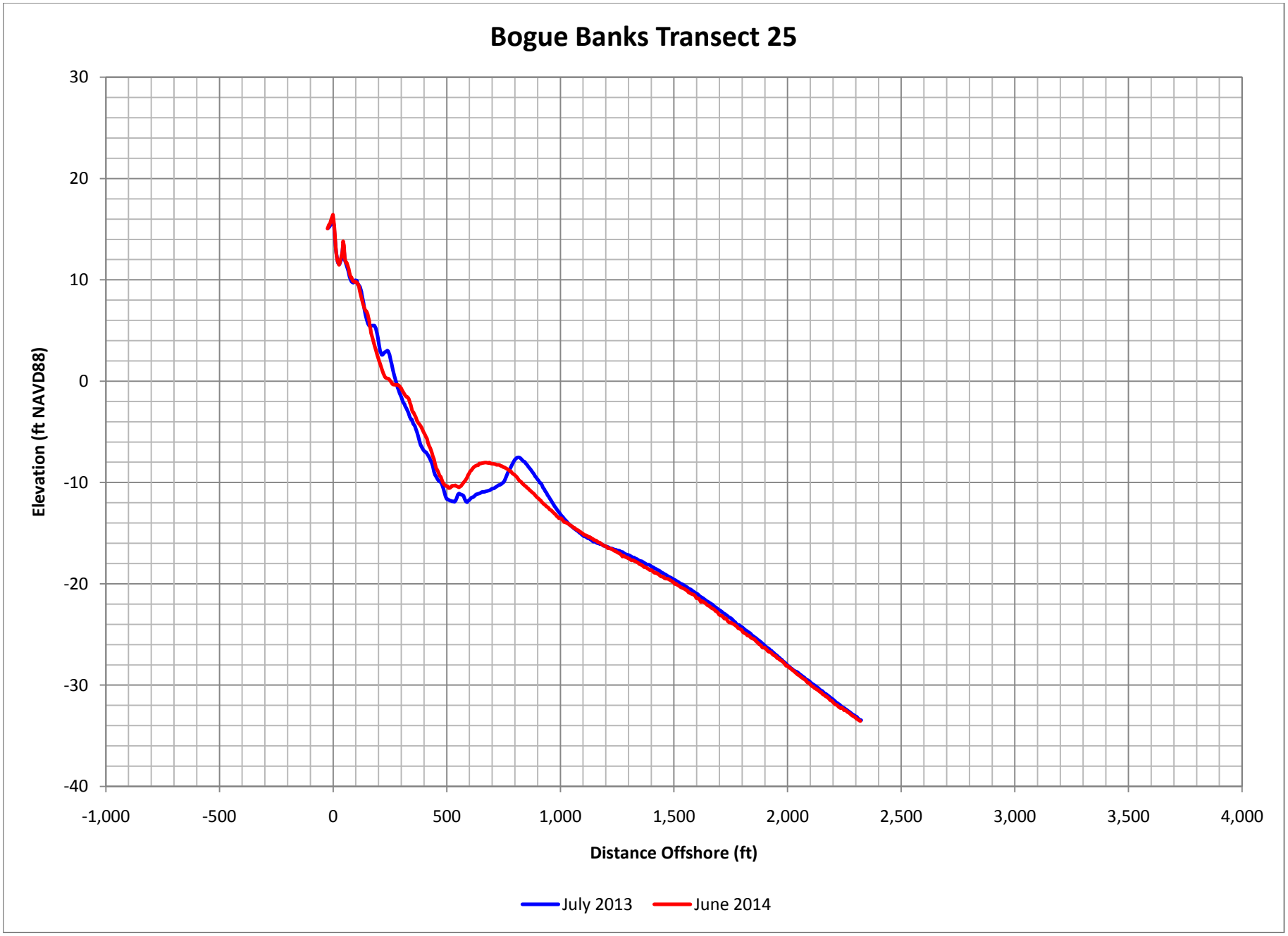
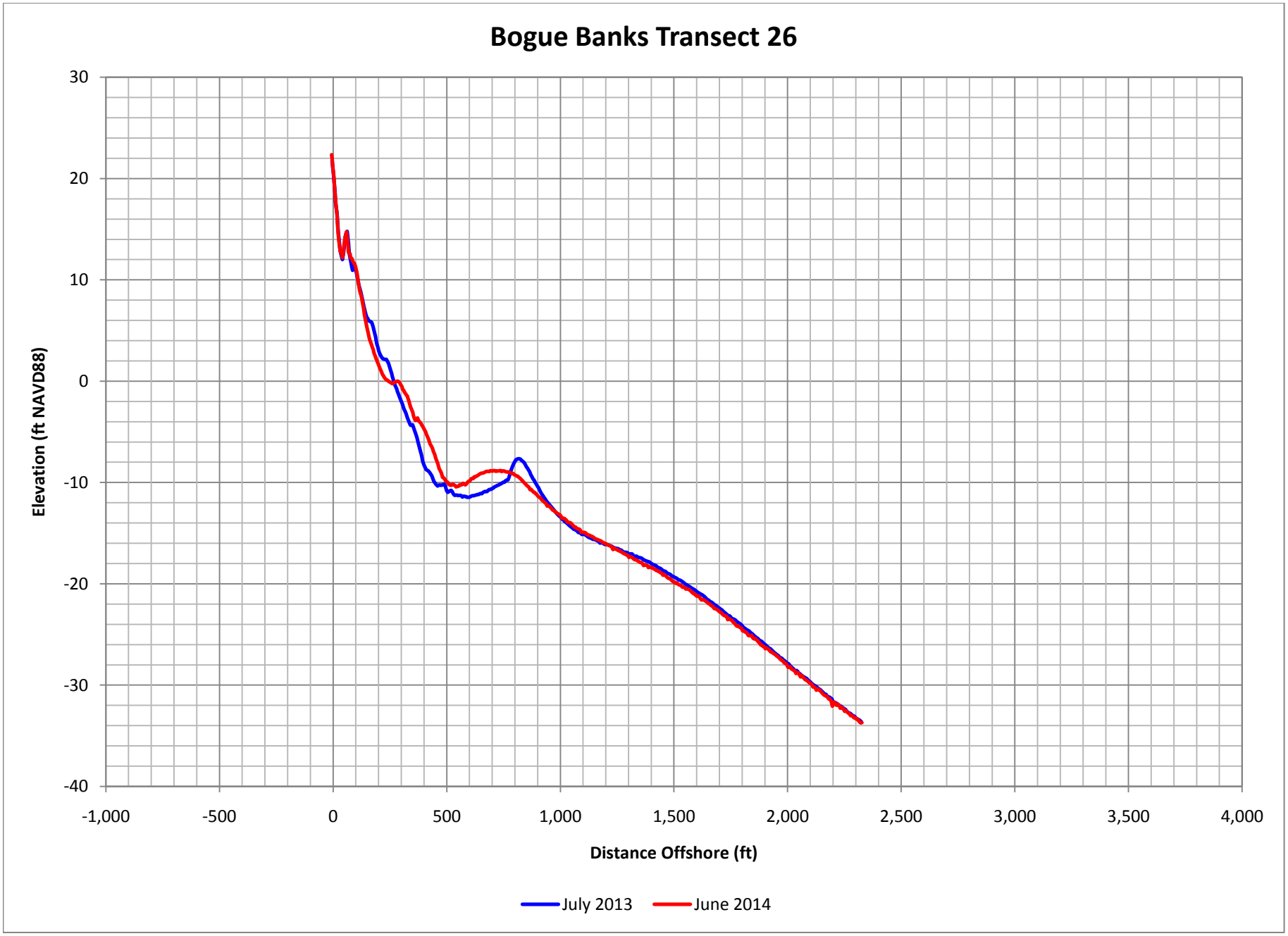


Figure C-32. Bogue Banks Profile Comparison Plot



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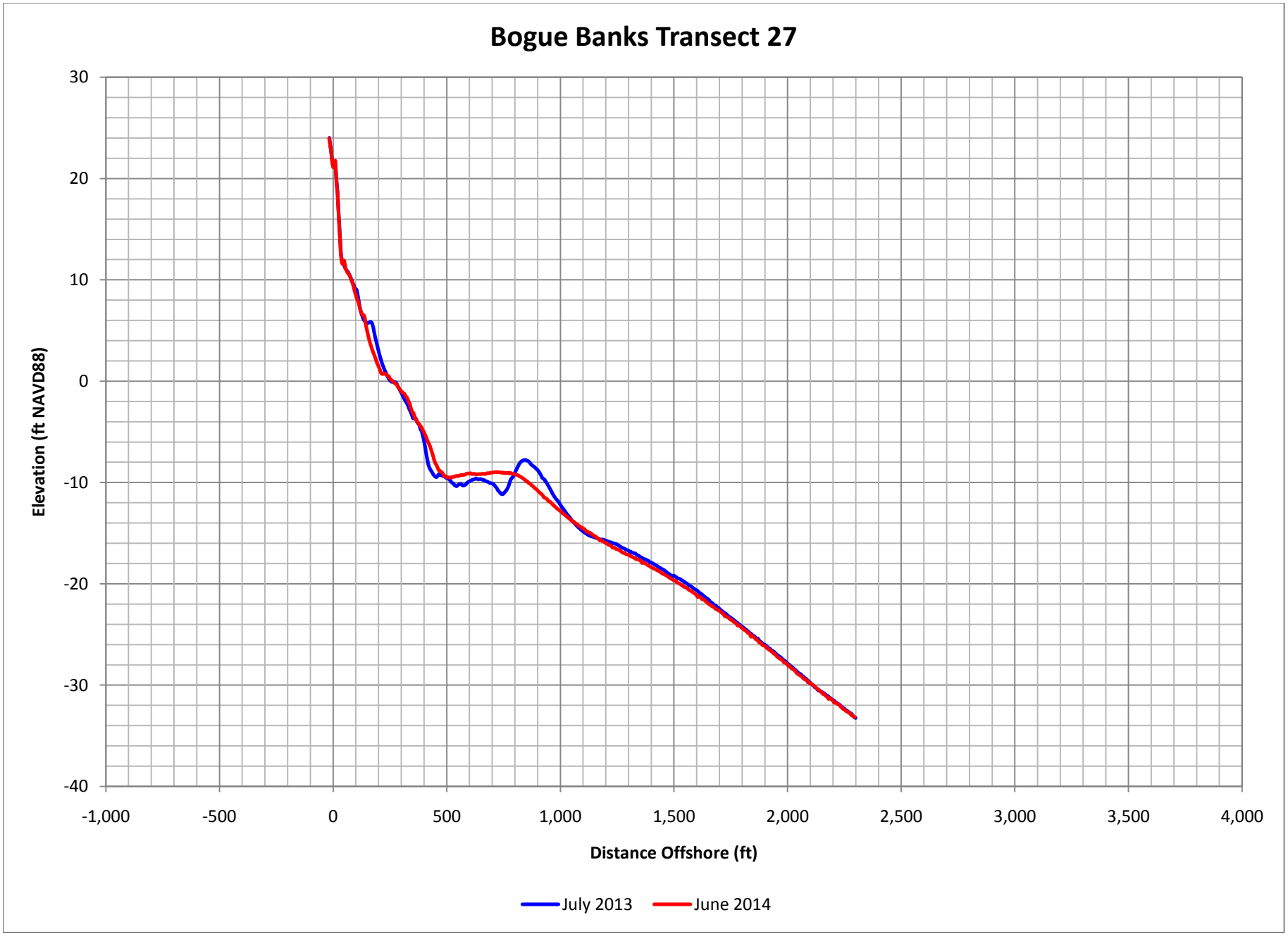

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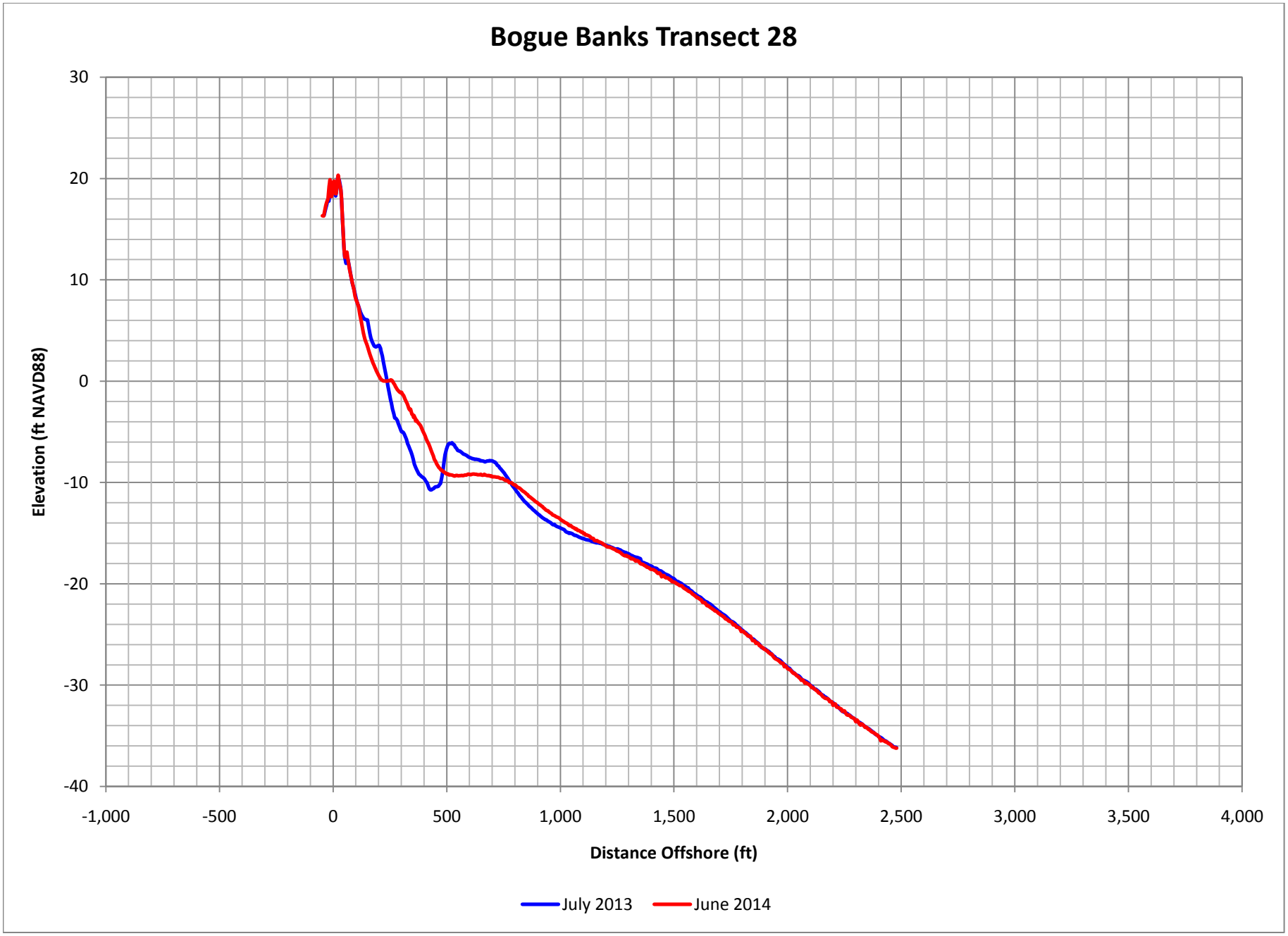


Figure C-35. Bogue Banks Profile Comparison Plot

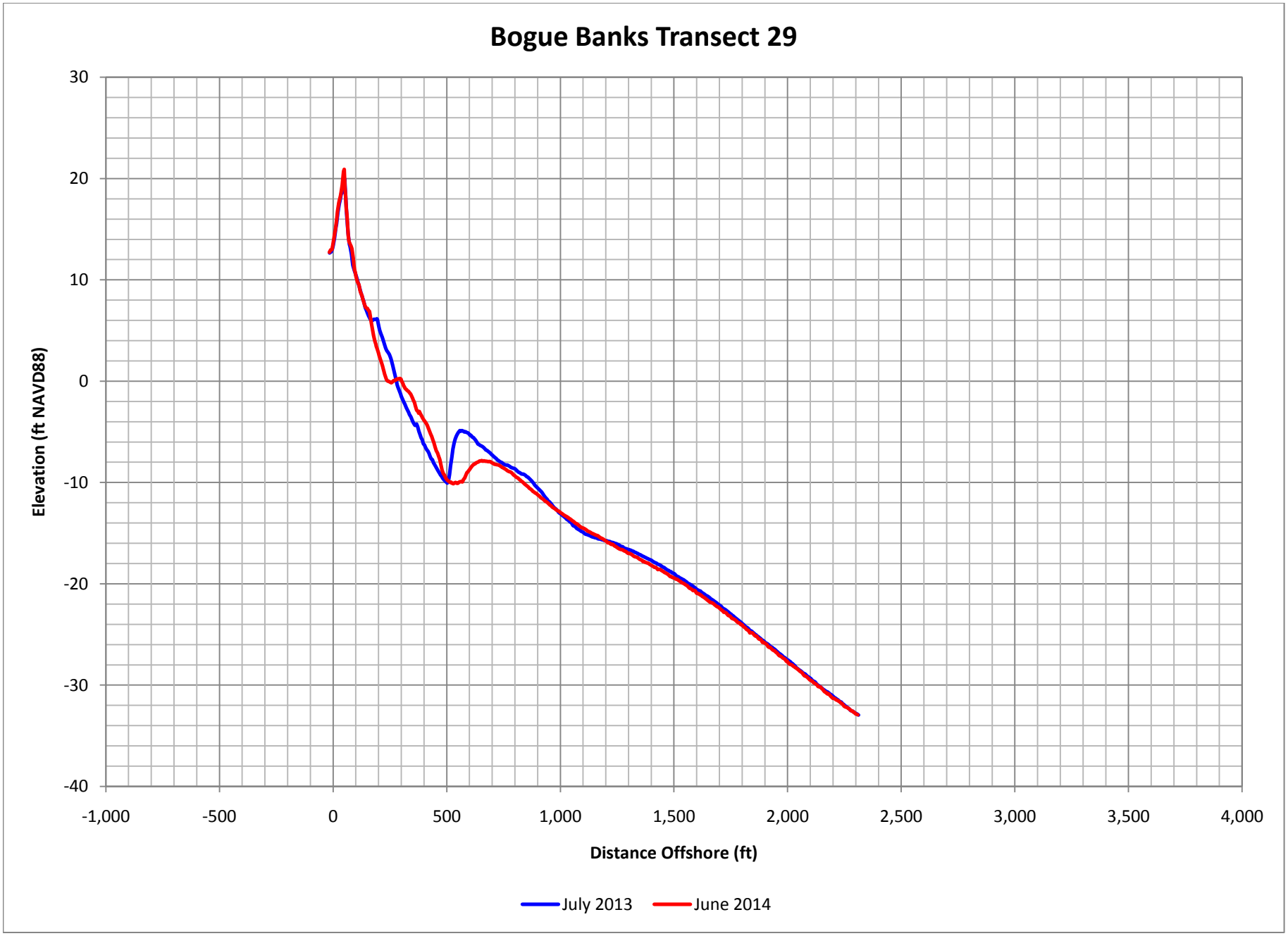


Figure C-36. Bogue Banks Profile Comparison Plot

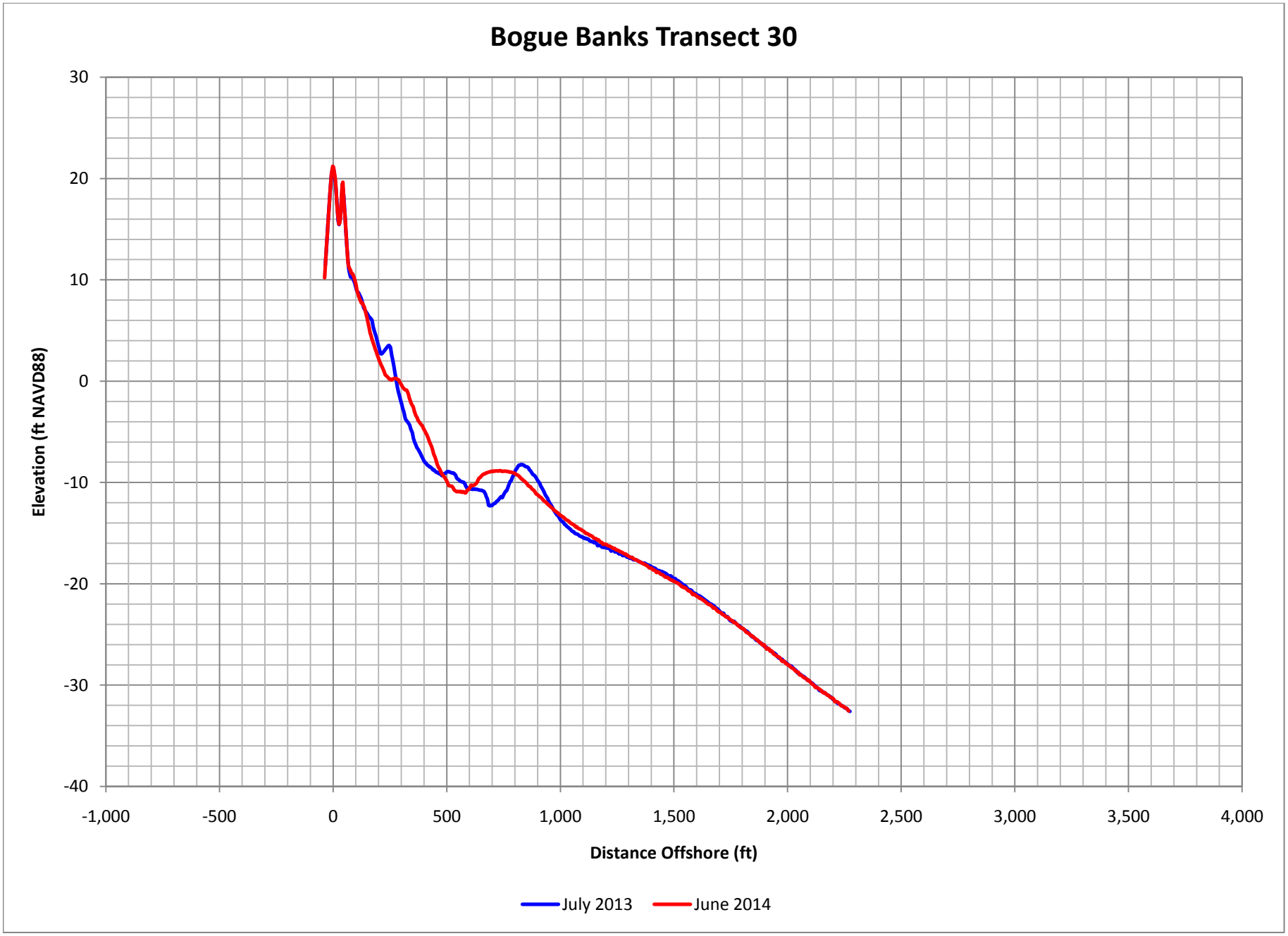


Figure C-37. Bogue Banks Profile Comparison Plot

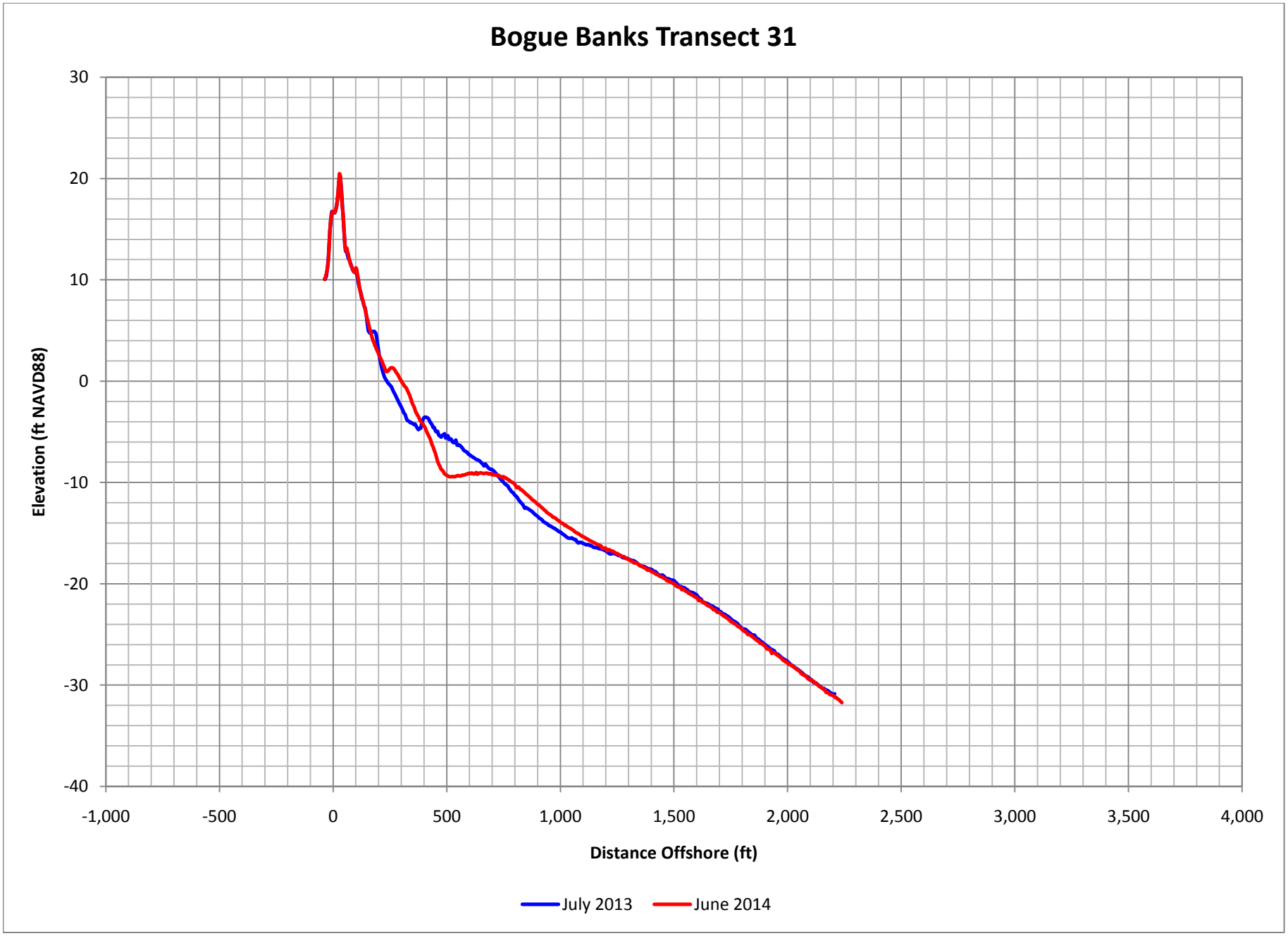


Figure C-38. Bogue Banks Profile Comparison Plot

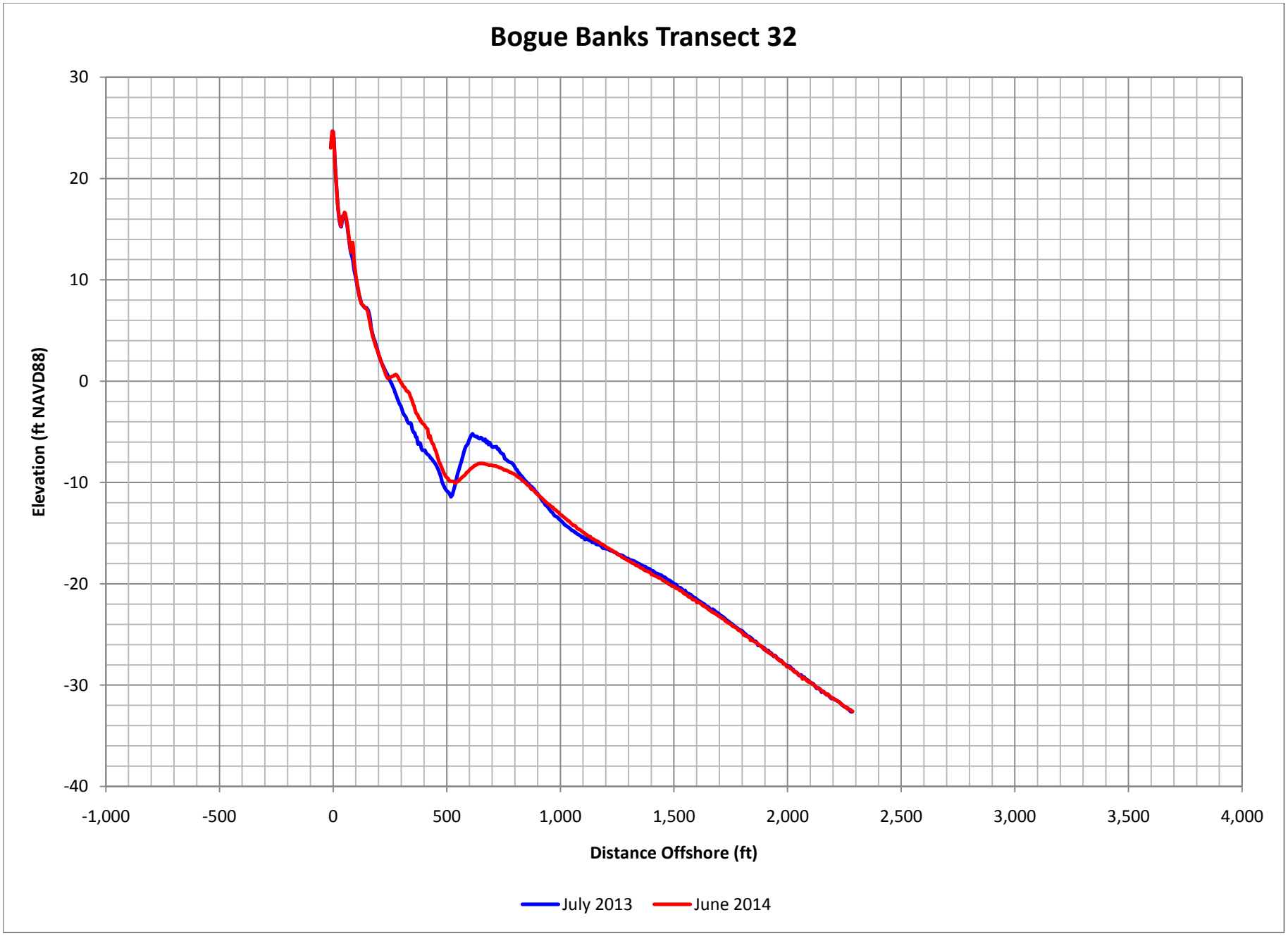


Figure C-39. Bogue Banks Profile Comparison Plot

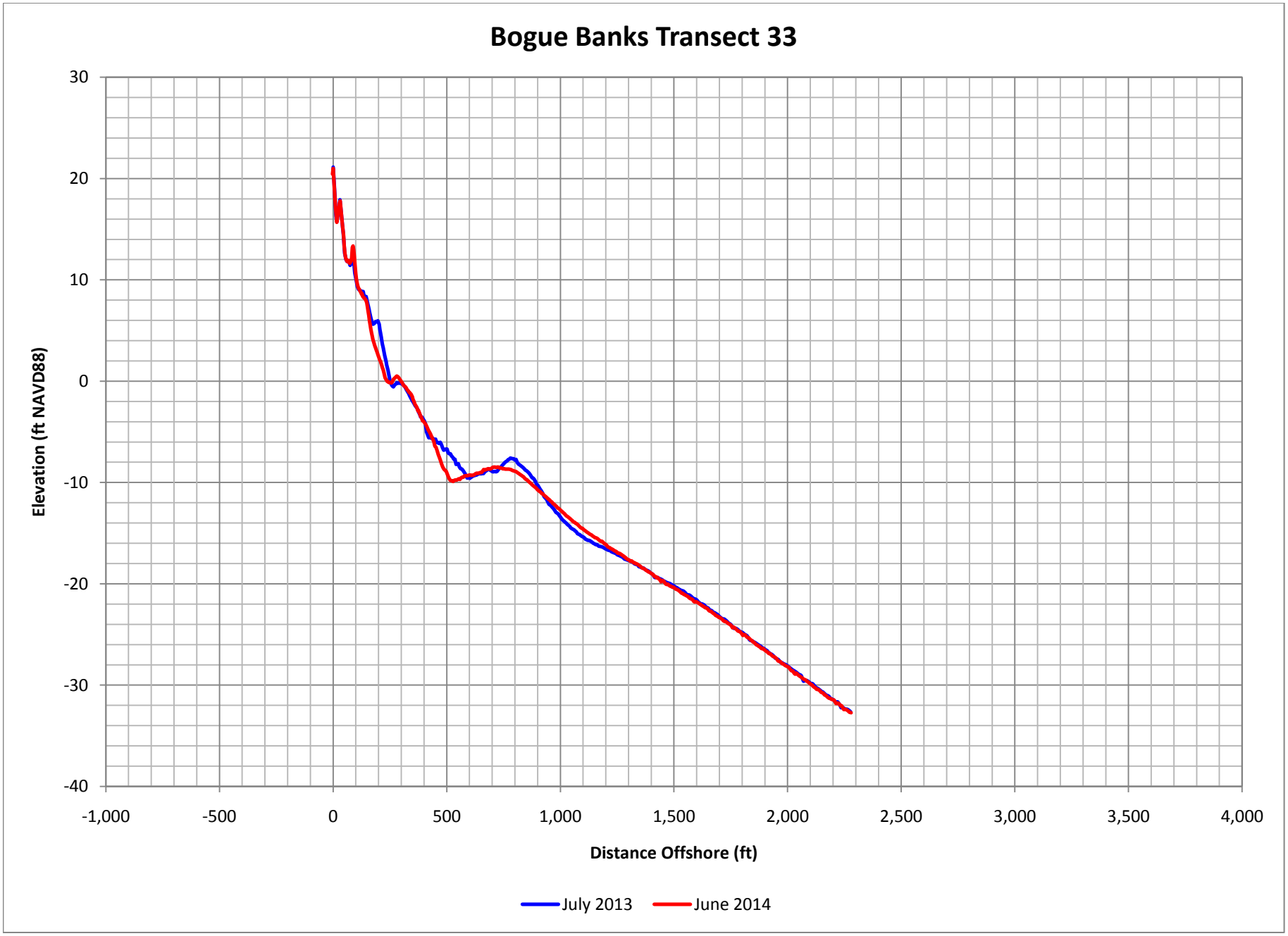


Figure C-40. Bogue Banks Profile Comparison Plot

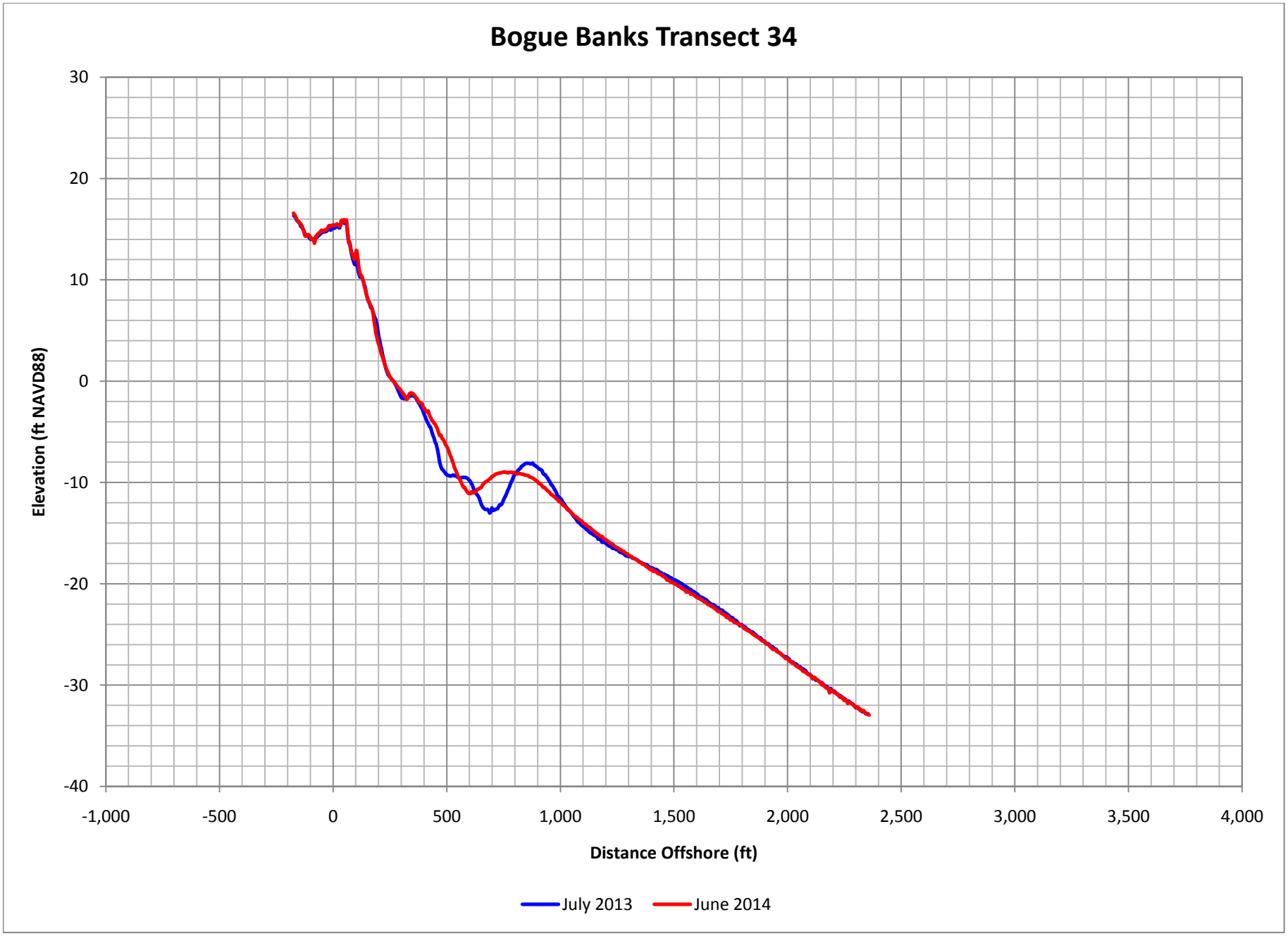


Figure C-41. Bogue Banks Profile Comparison Plot

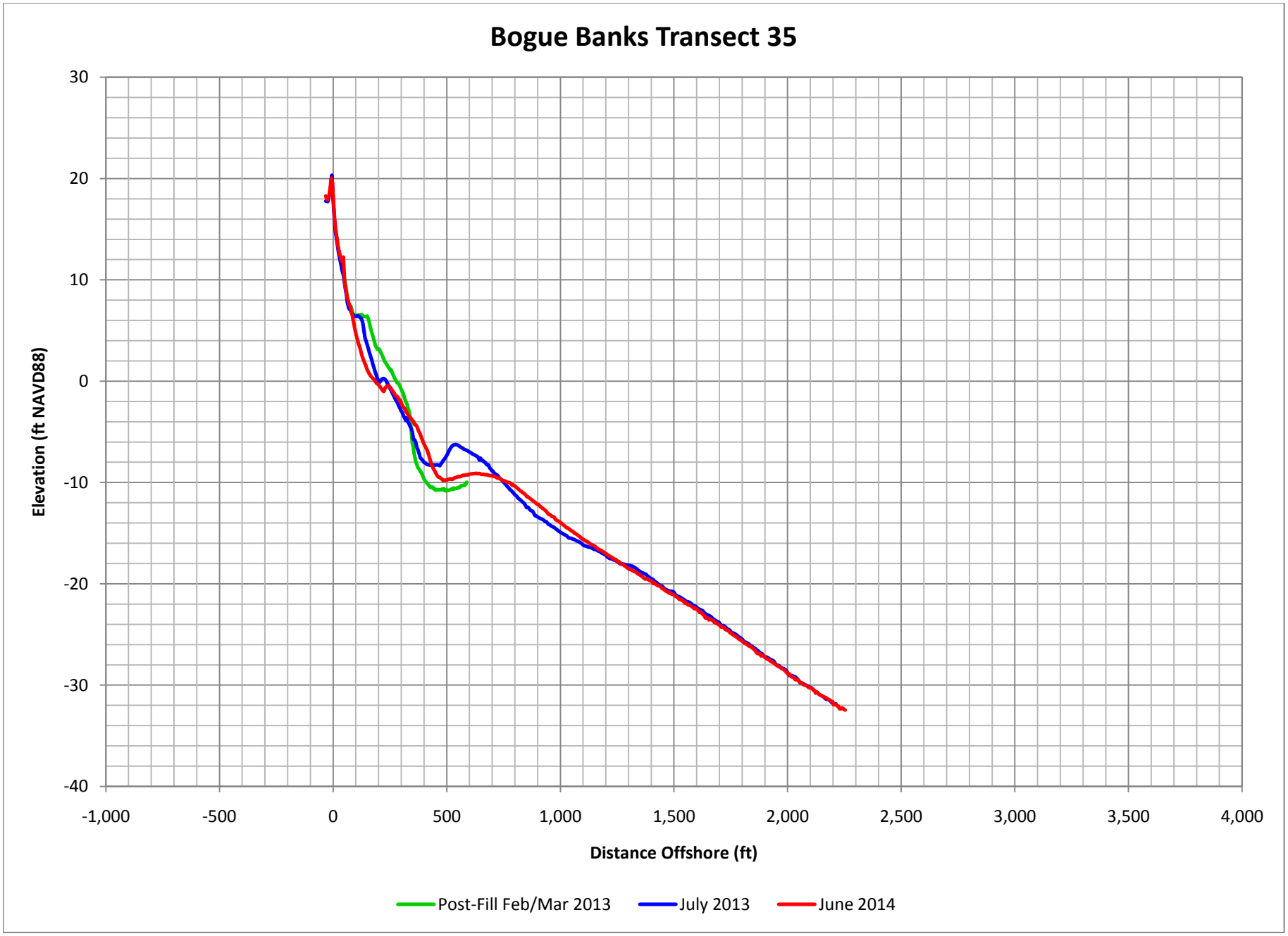


Figure C-42. Bogue Banks Profile Comparison Plot

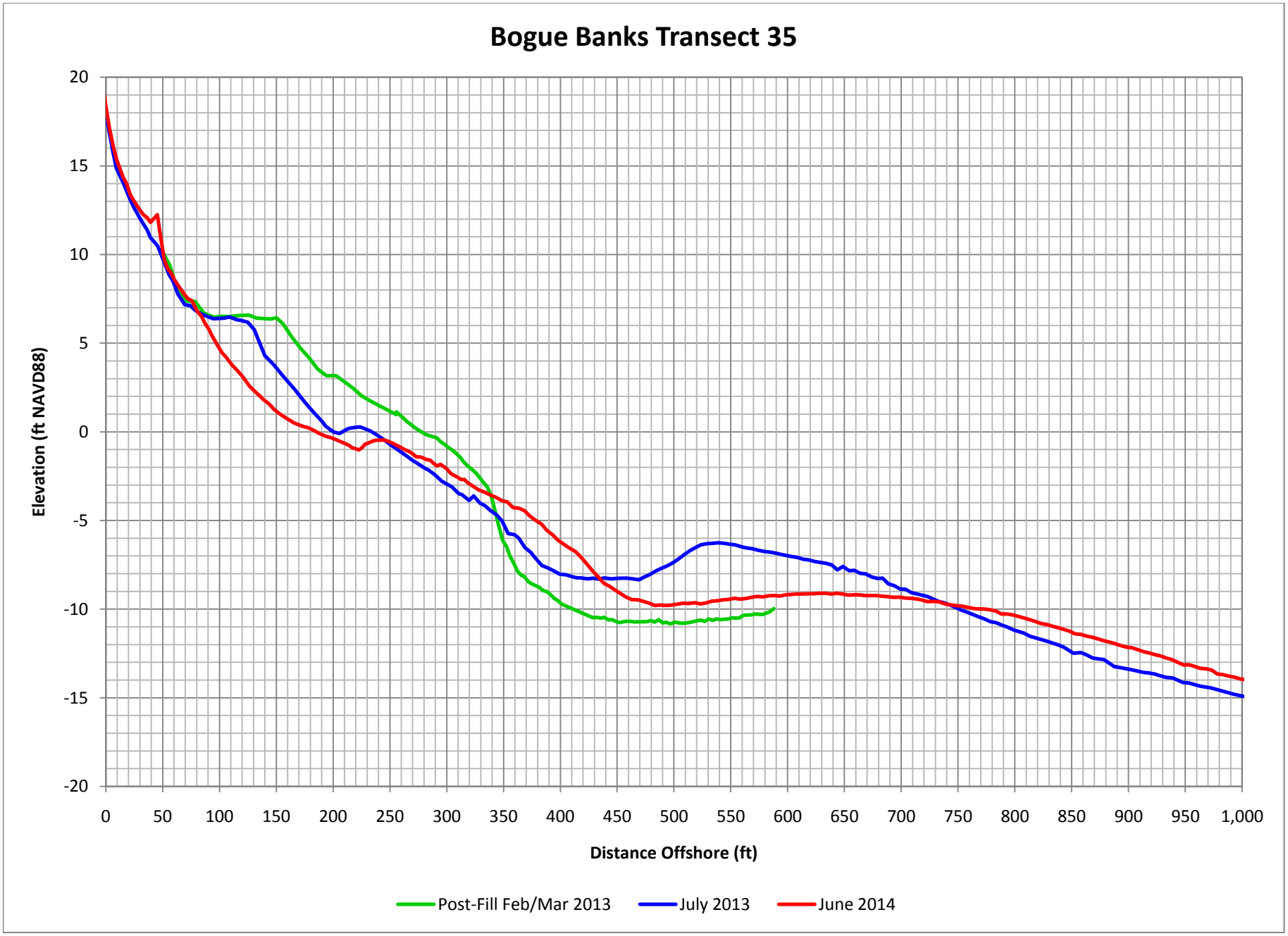


Figure C-43. Bogue Banks Profile Comparison Plot

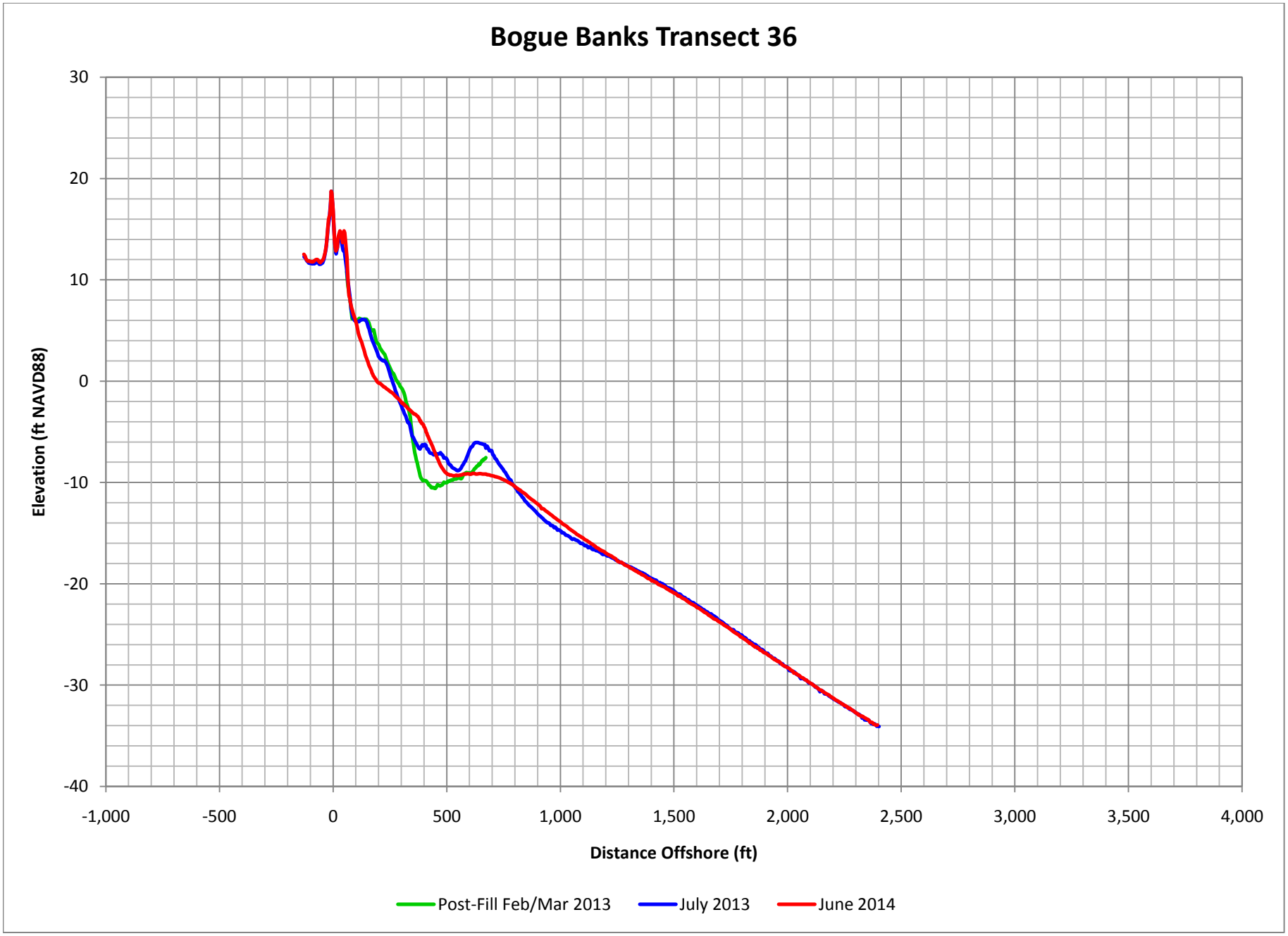


Figure C-44. Bogue Banks Profile Comparison Plot

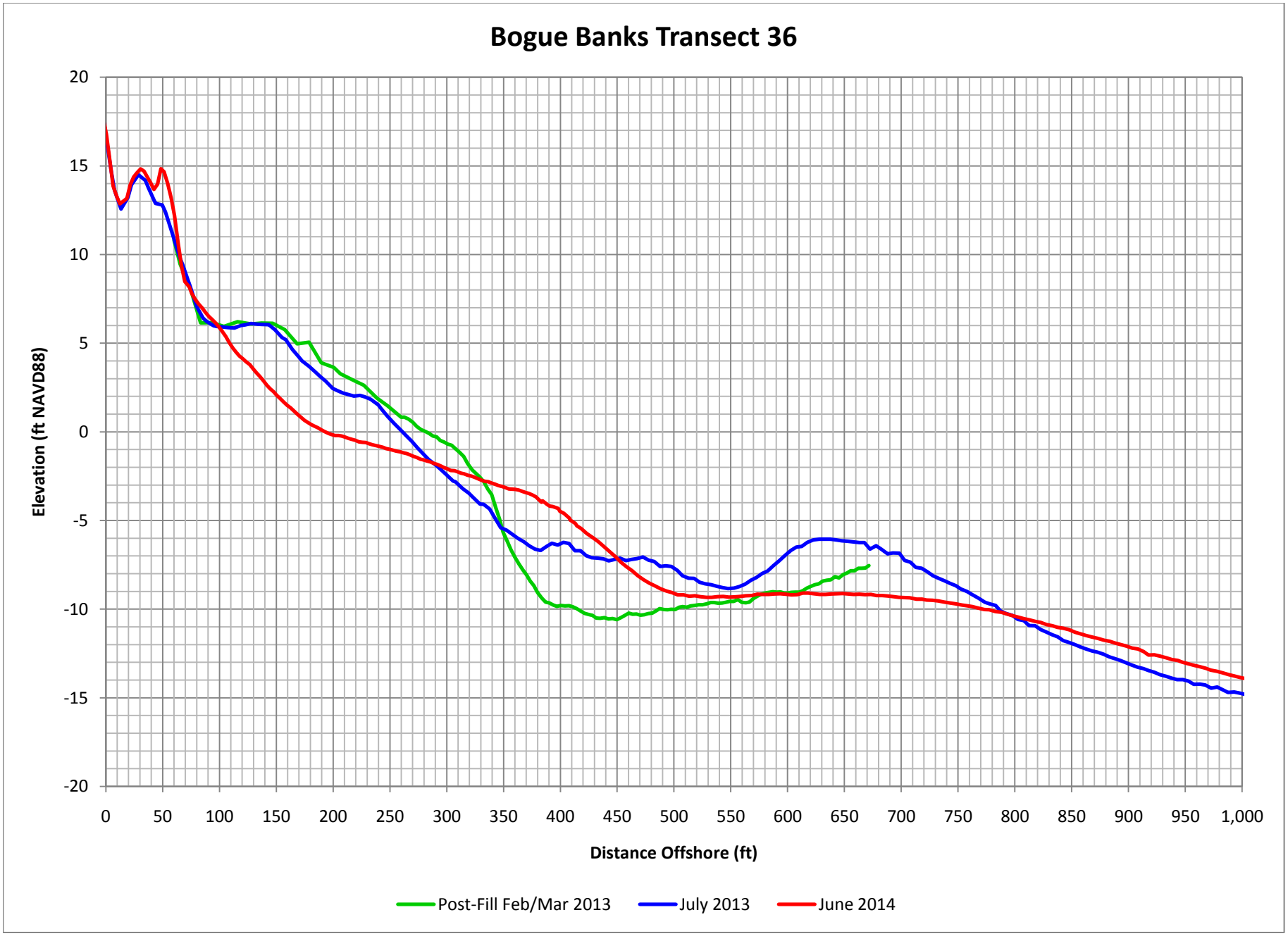


Figure C-45. Bogue Banks Profile Comparison Plot

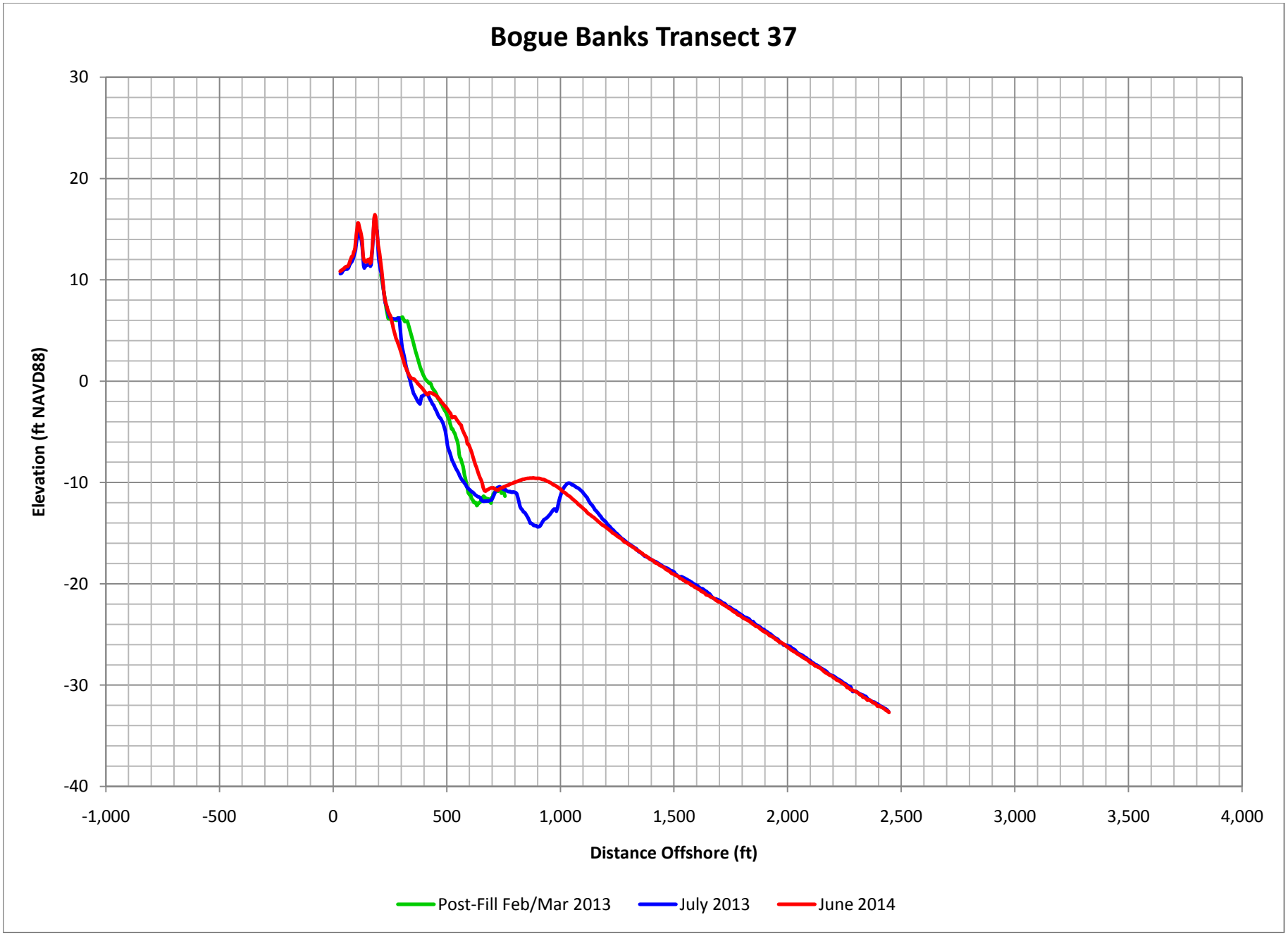


Figure C-46. Bogue Banks Profile Comparison Plot

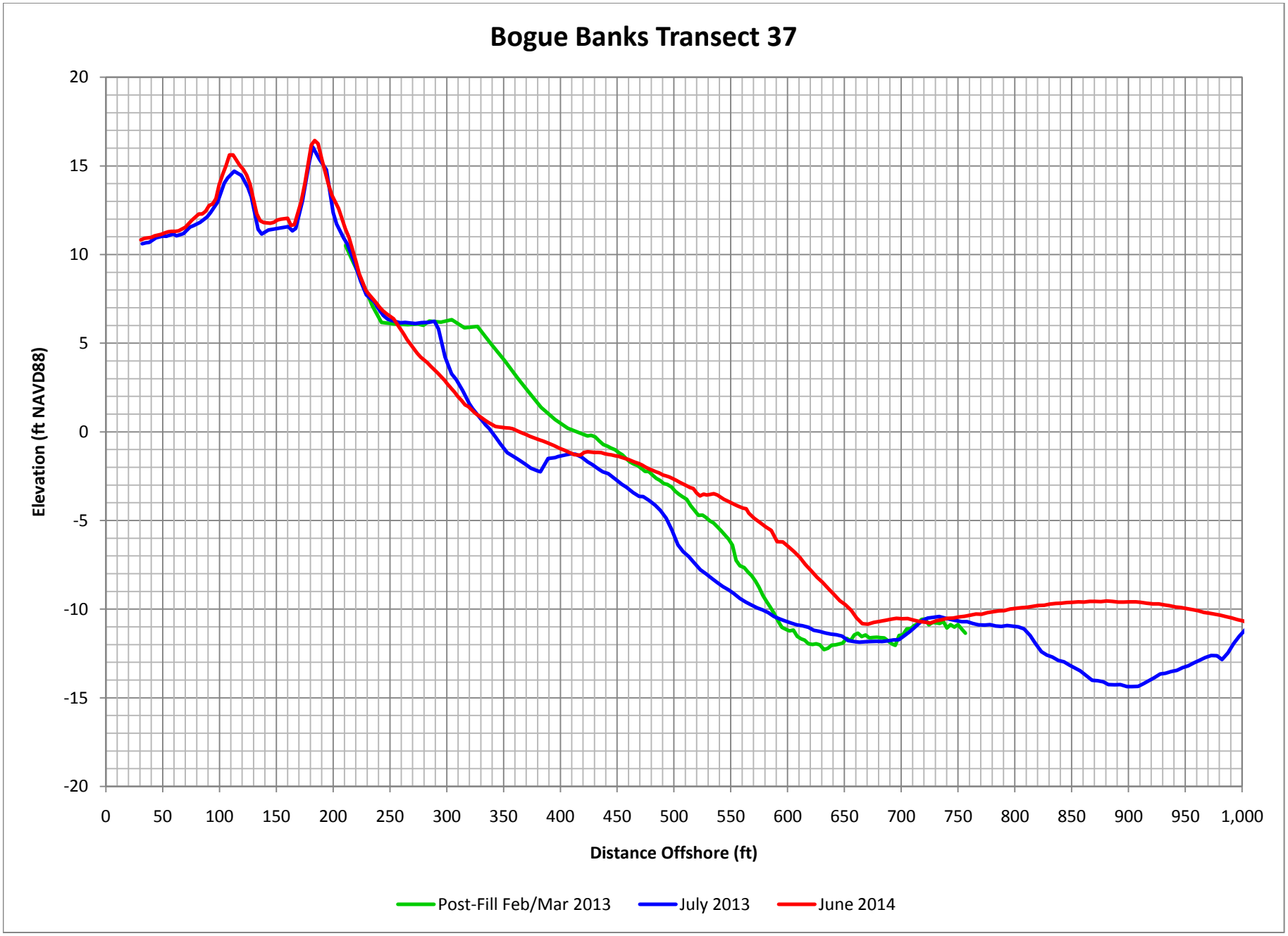


Figure C-47. Bogue Banks Profile Comparison Plot

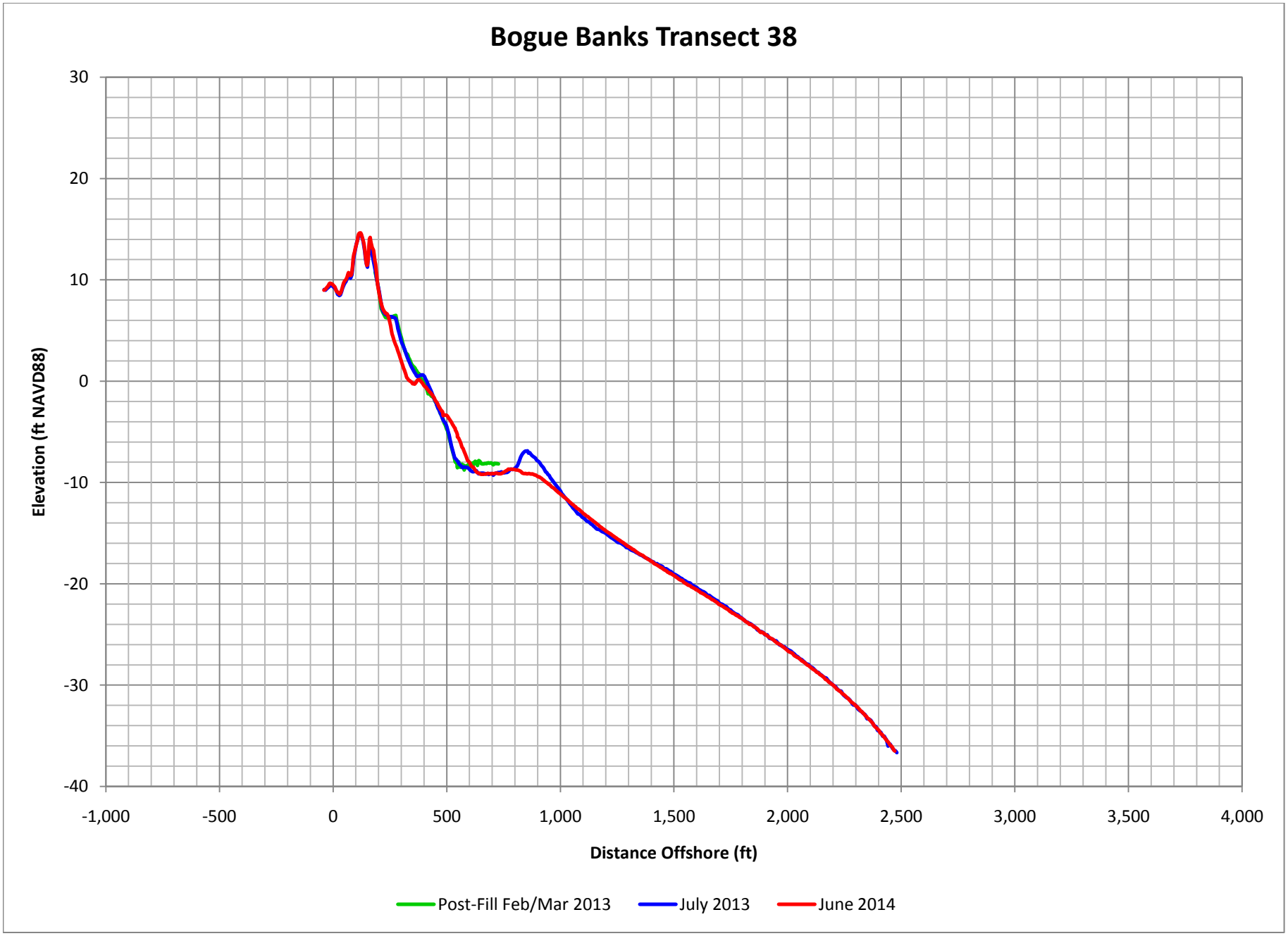


Figure C-48. Bogue Banks Profile Comparison Plot

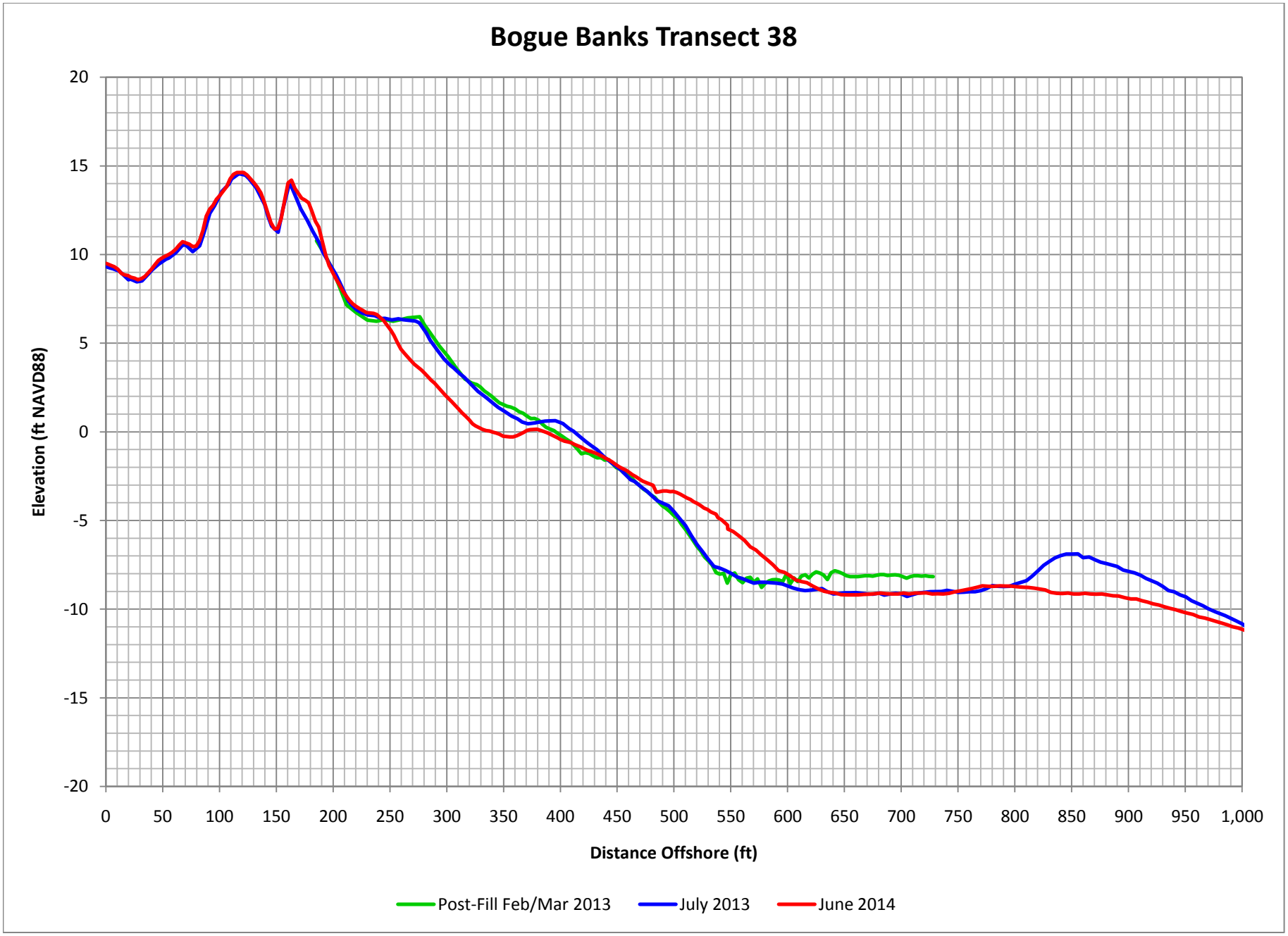


Figure C-49. Bogue Banks Profile Comparison Plot

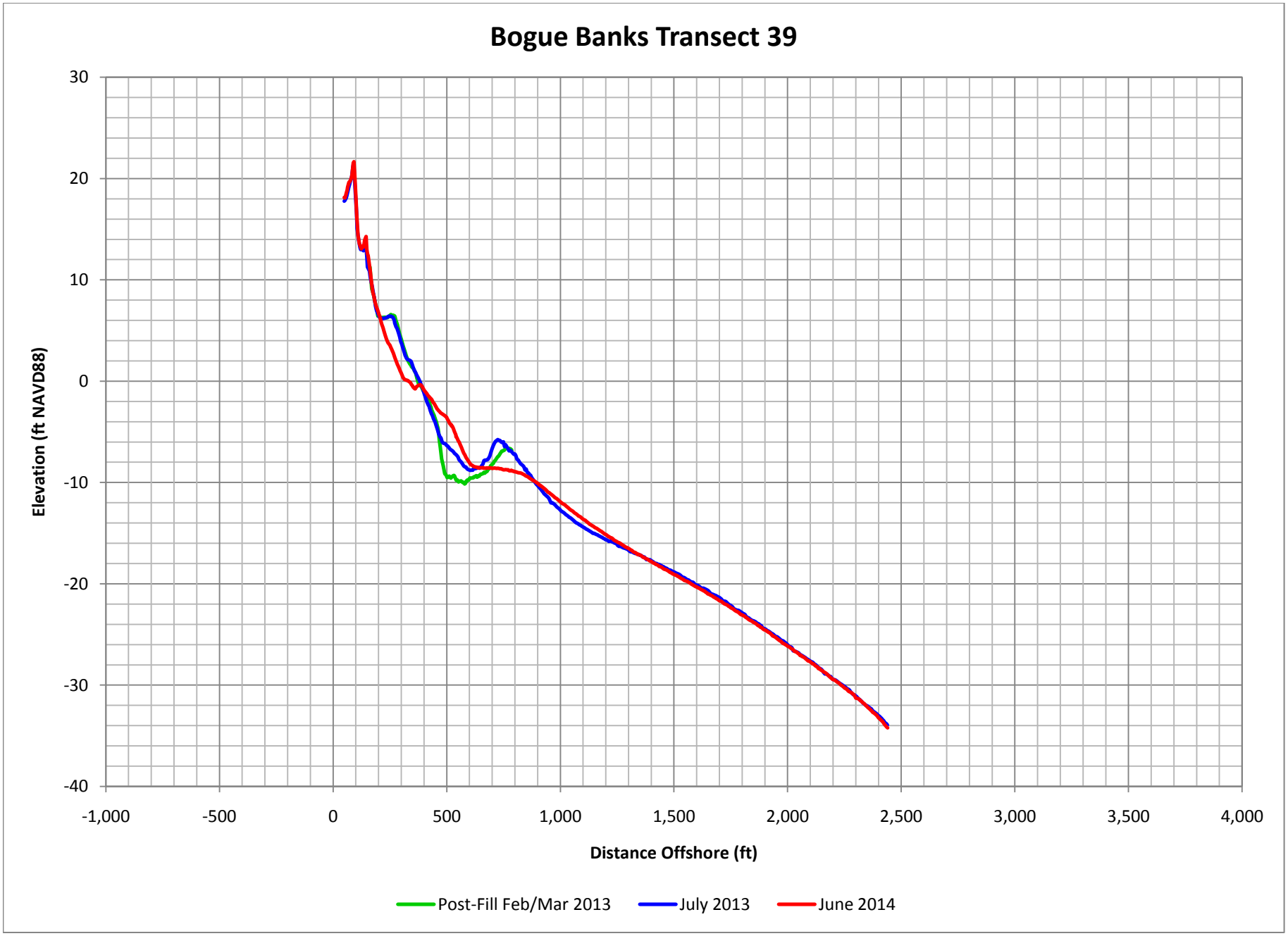


Figure C-50. Bogue Banks Profile Comparison Plot

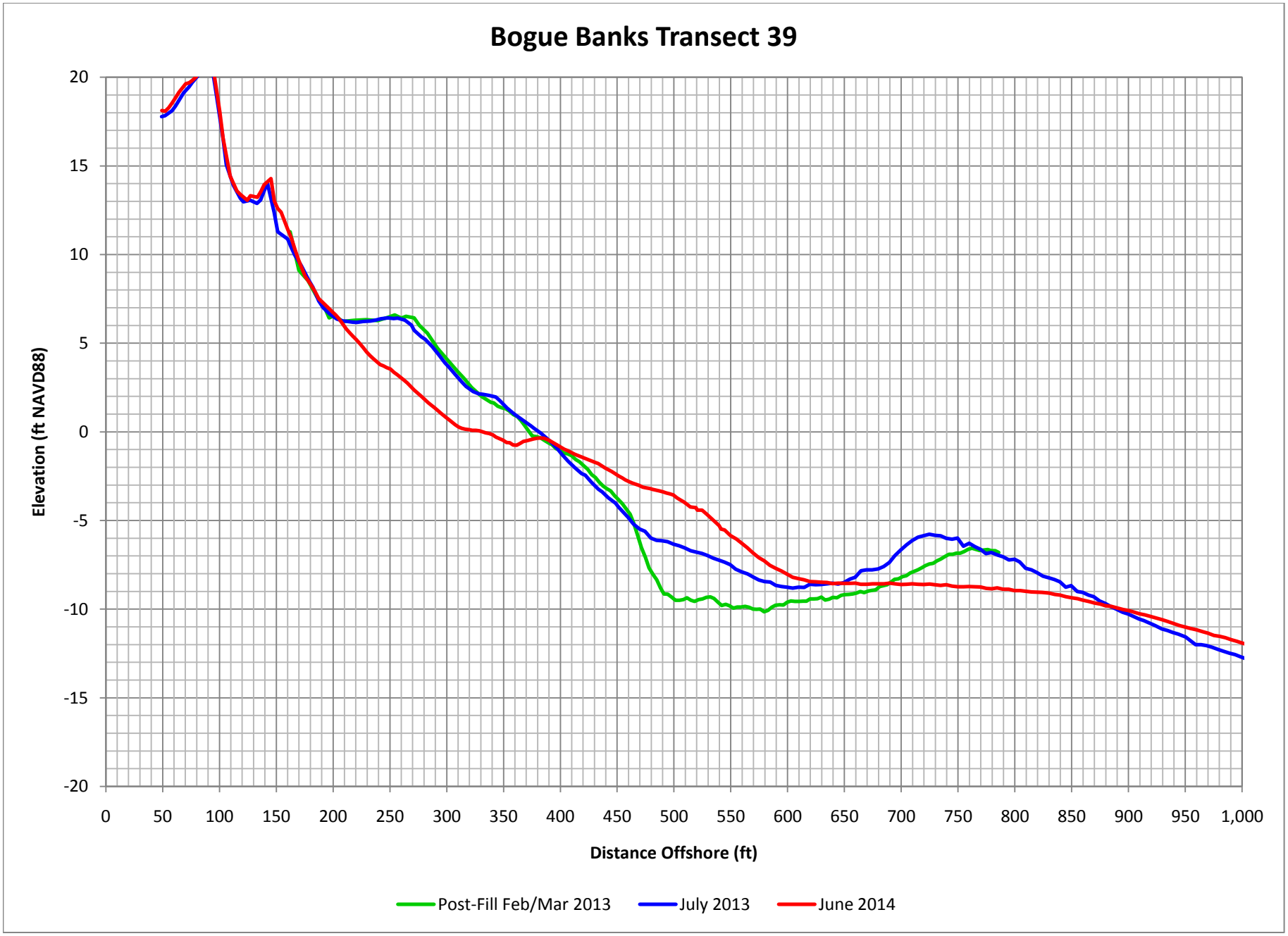


Figure C-51. Bogue Banks Profile Comparison Plot

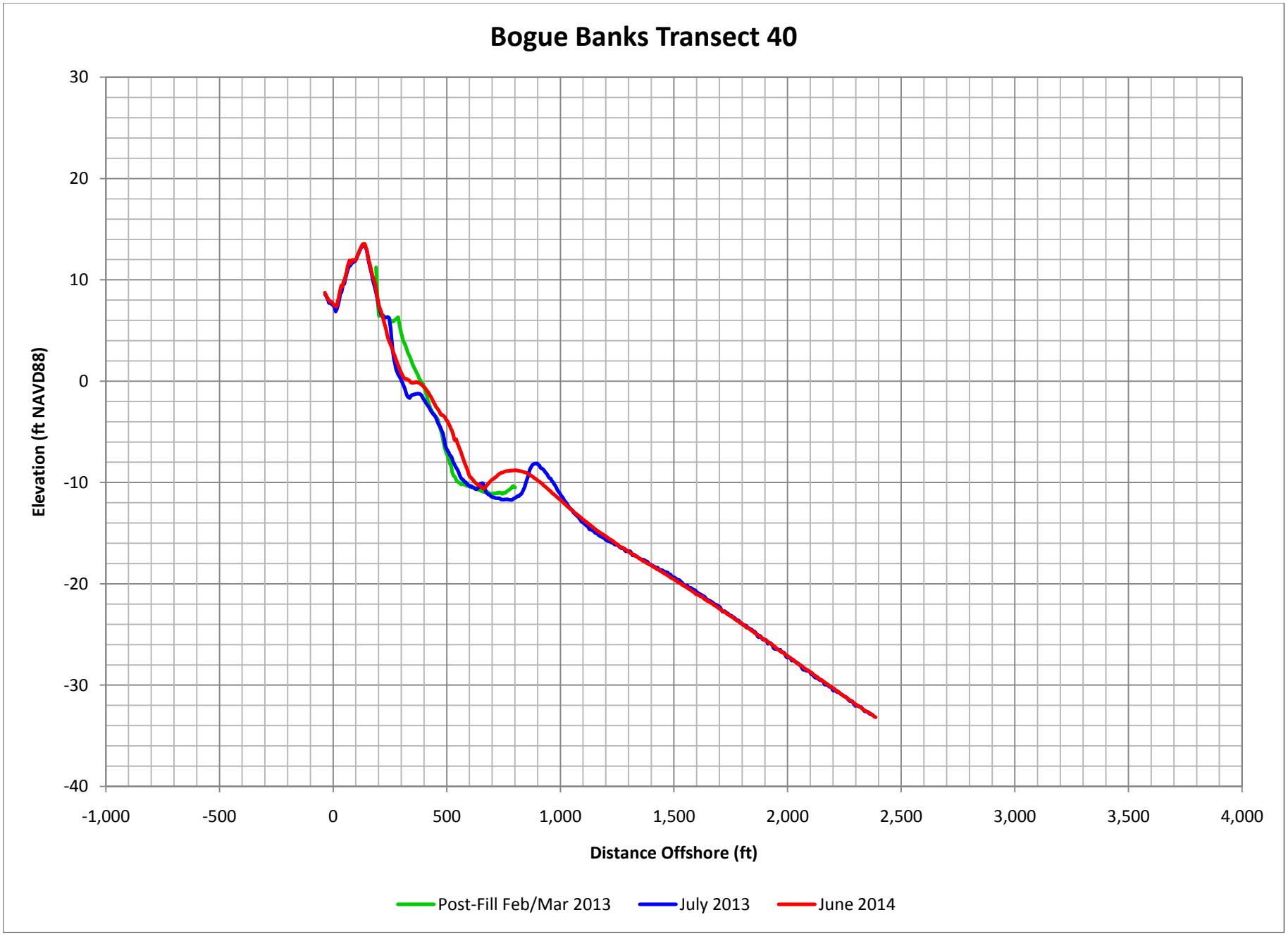


Figure C-52. Bogue Banks Profile Comparison Plot

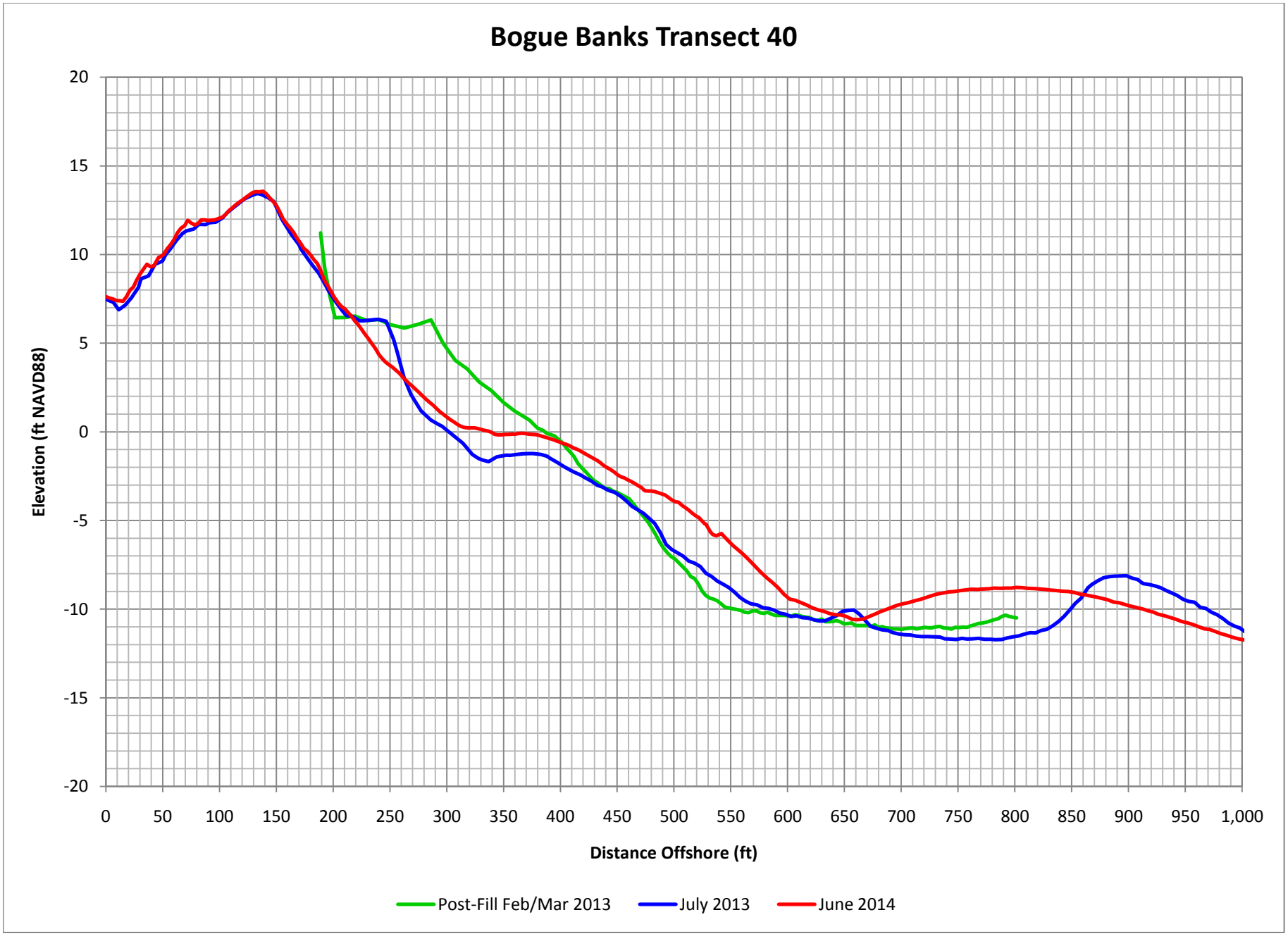
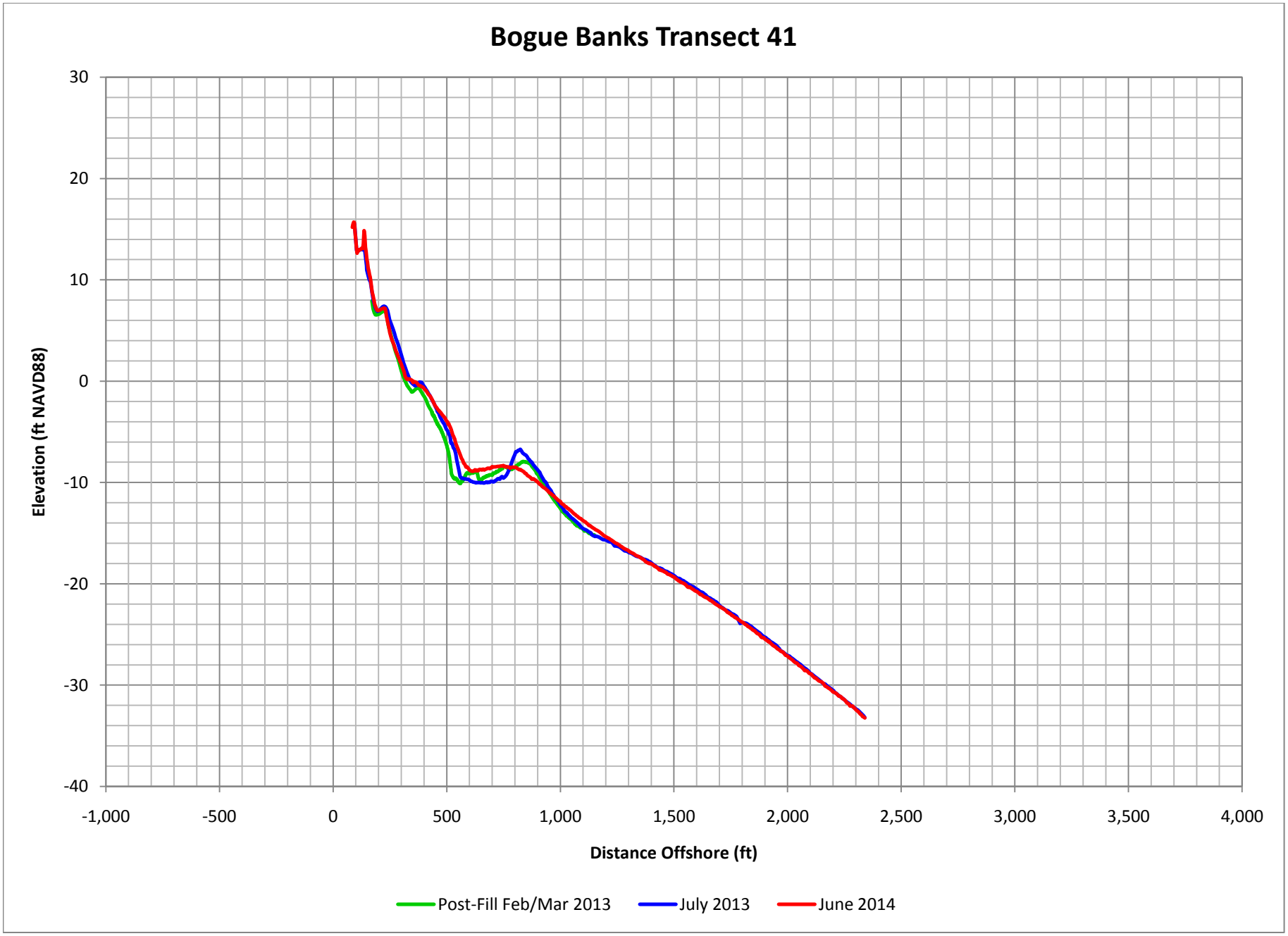


Figure C-53. Bogue Banks Profile Comparison Plot



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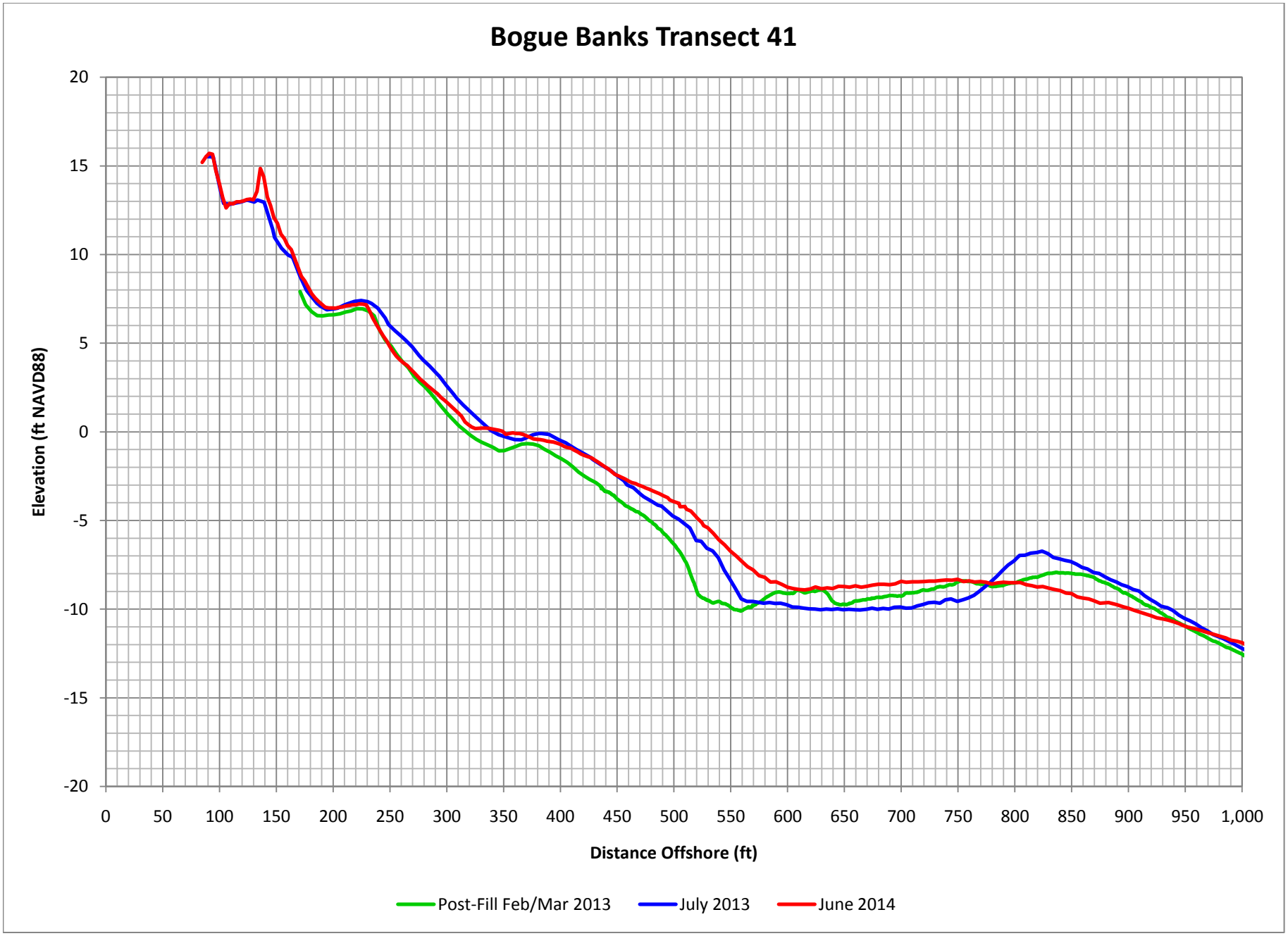


Figure C-55. Bogue Banks Profile Comparison Plot

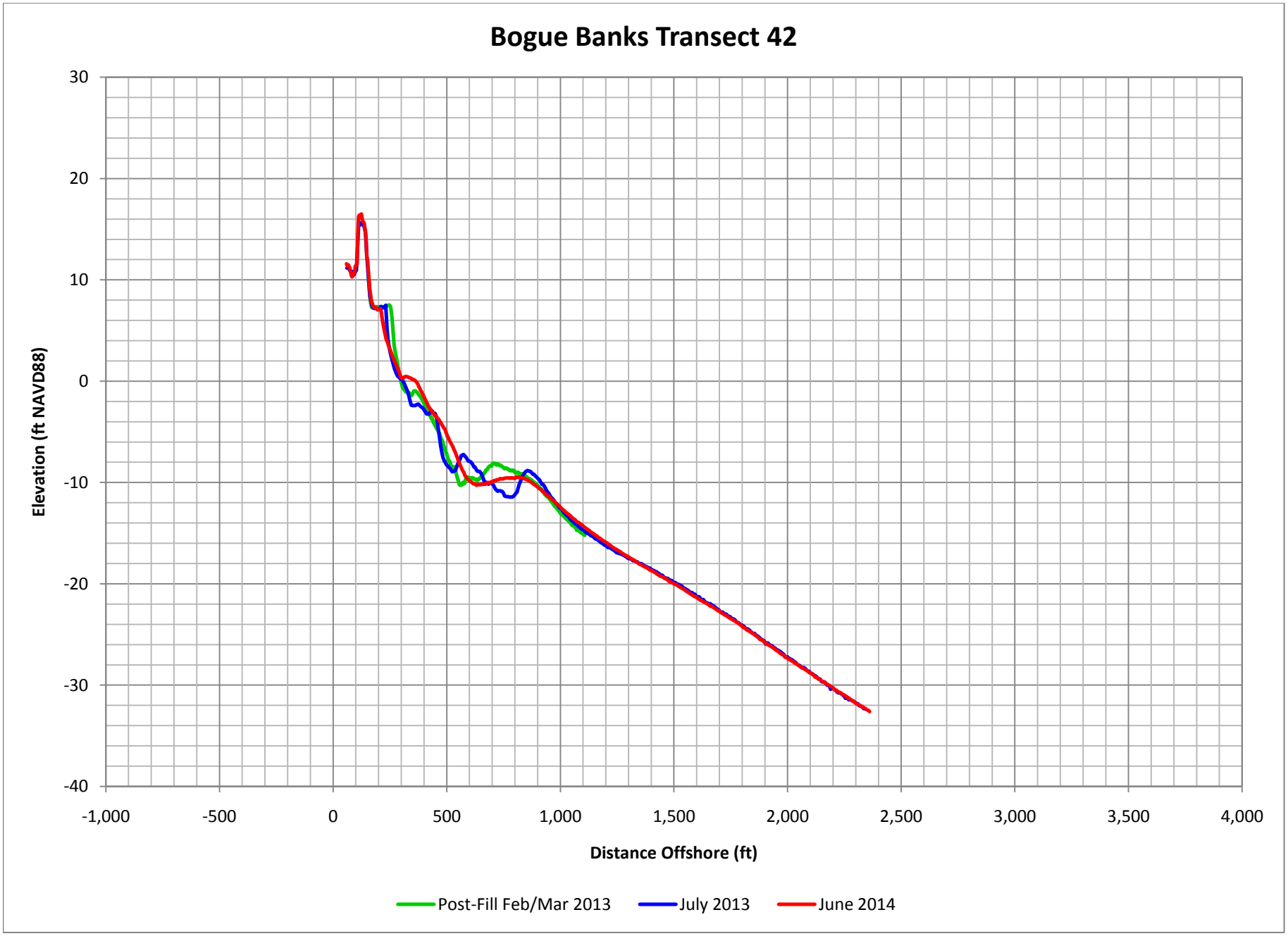


Figure C-56. Bogue Banks Profile Comparison Plot

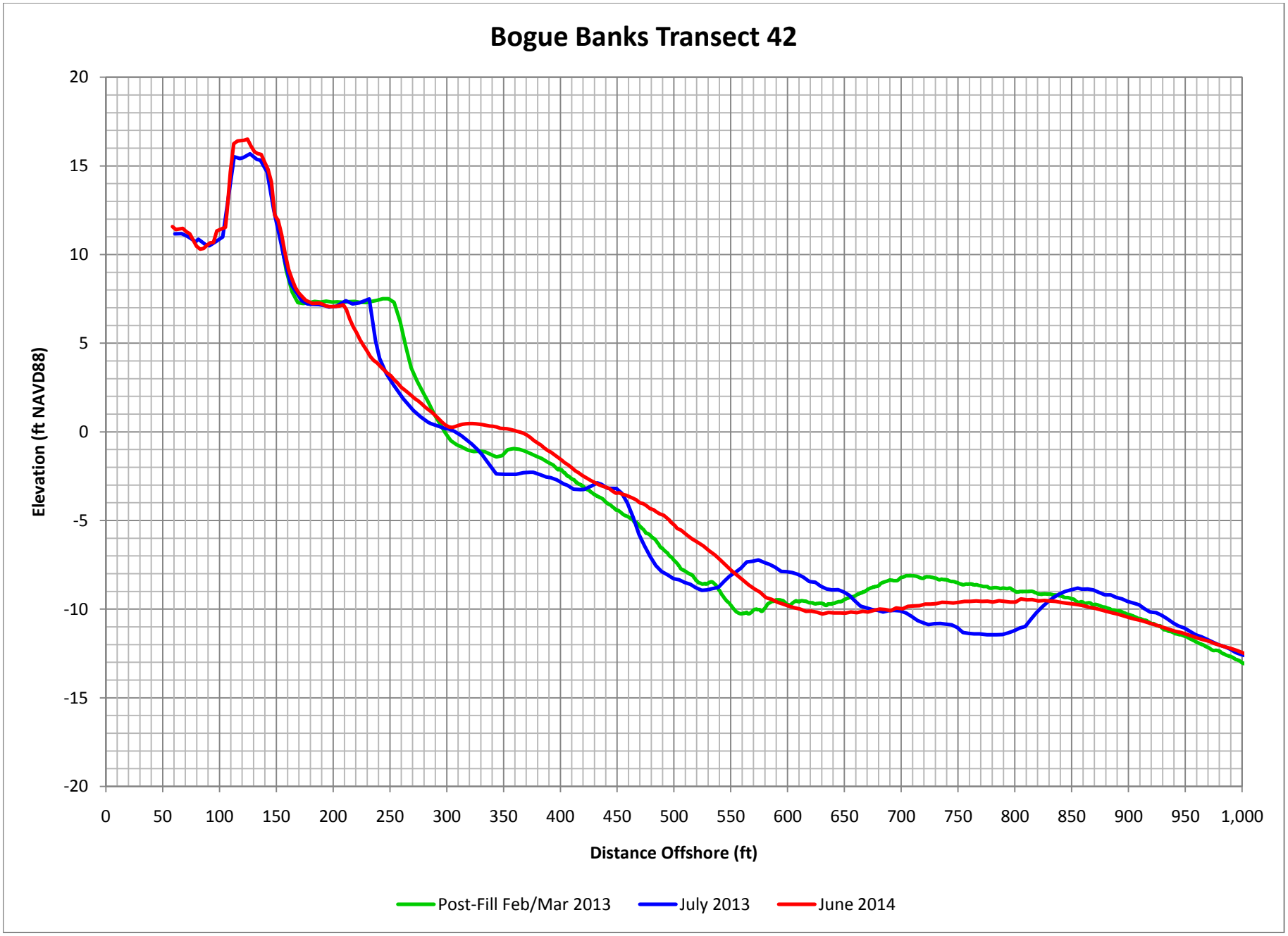


Figure C-57. Bogue Banks Profile Comparison Plot

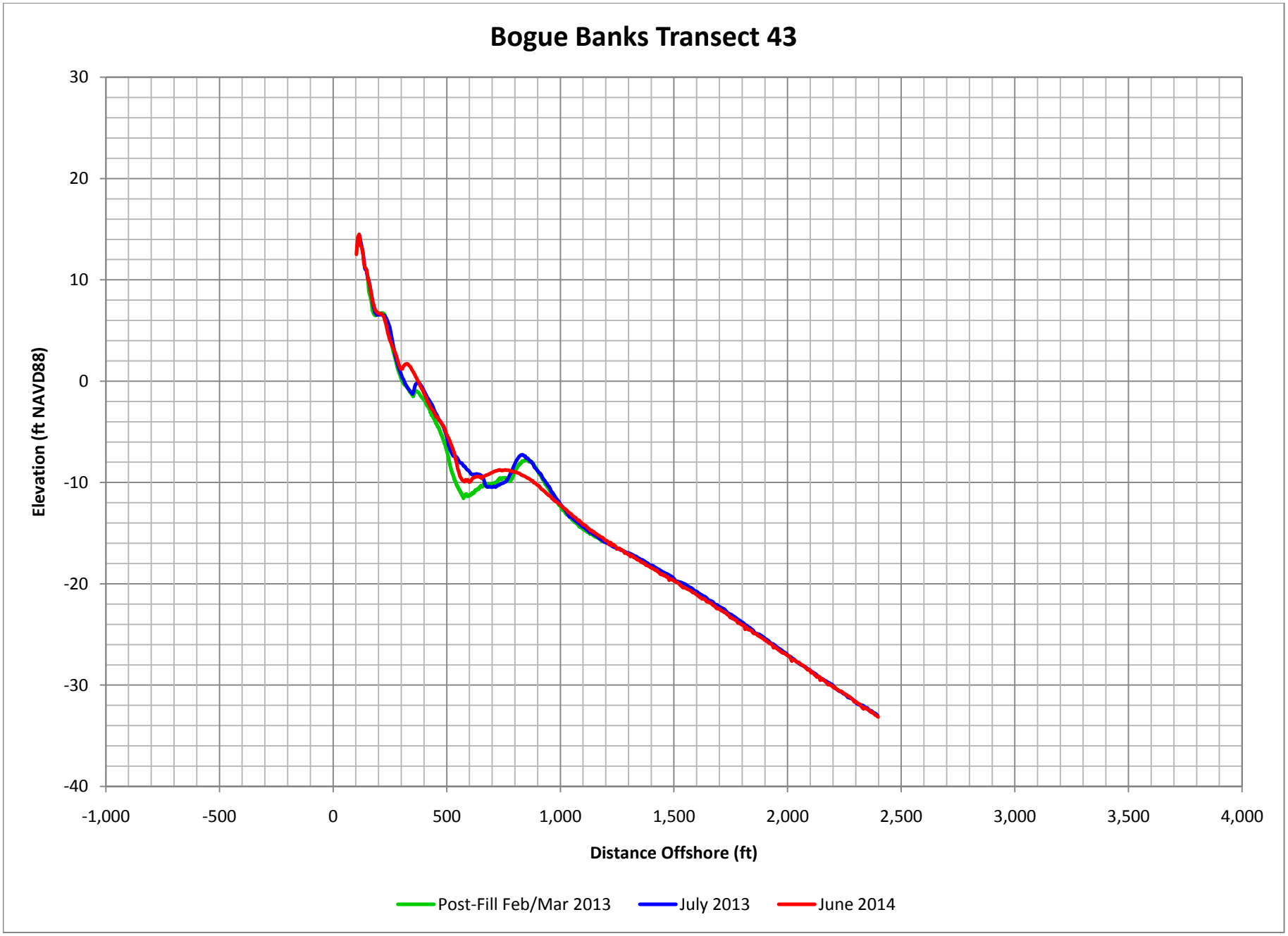


Figure C-58. Bogue Banks Profile Comparison Plot

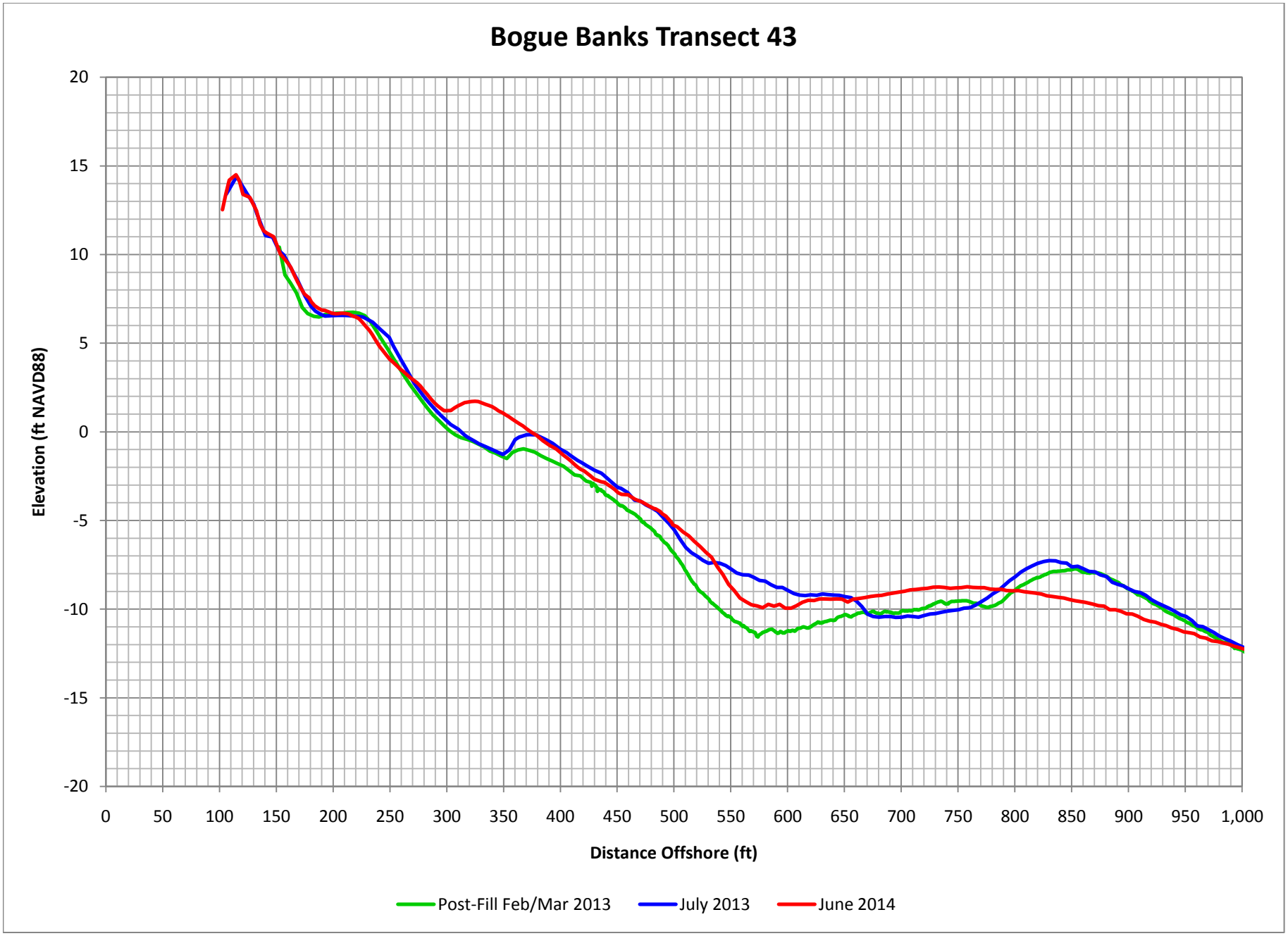


Figure C-59. Bogue Banks Profile Comparison Plot

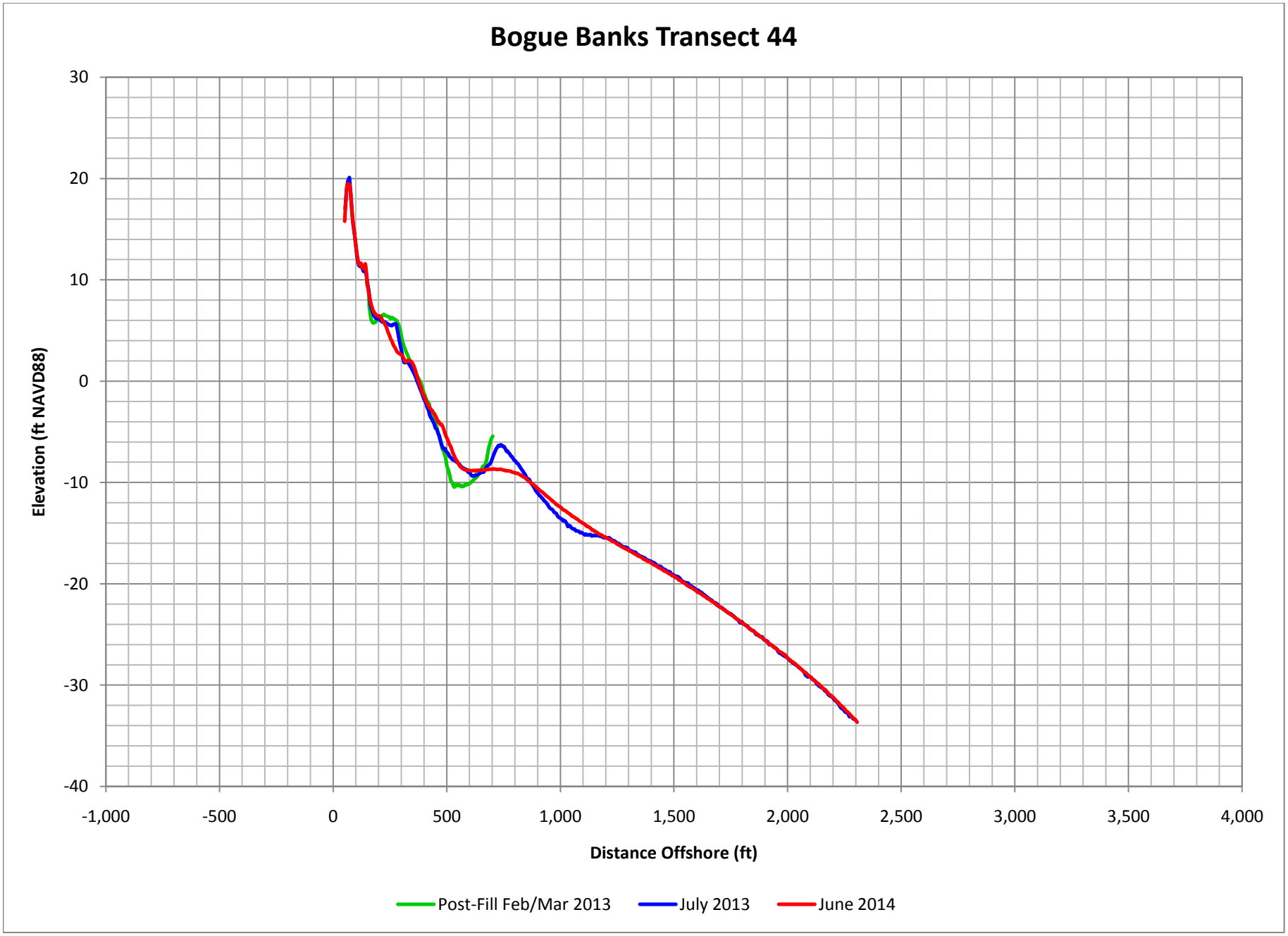


Figure C-60. Bogue Banks Profile Comparison Plot

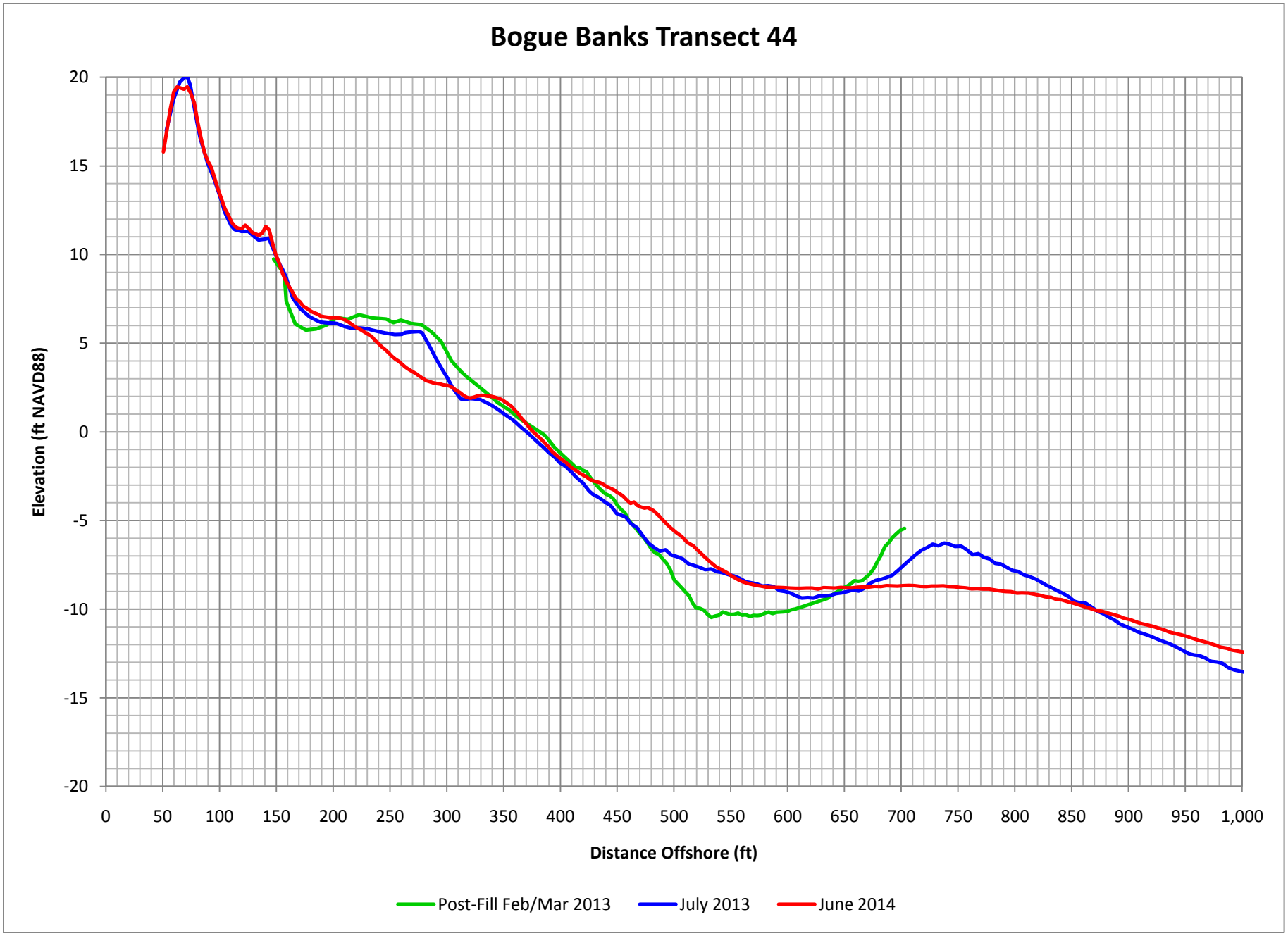


Figure C-61. Bogue Banks Profile Comparison Plot

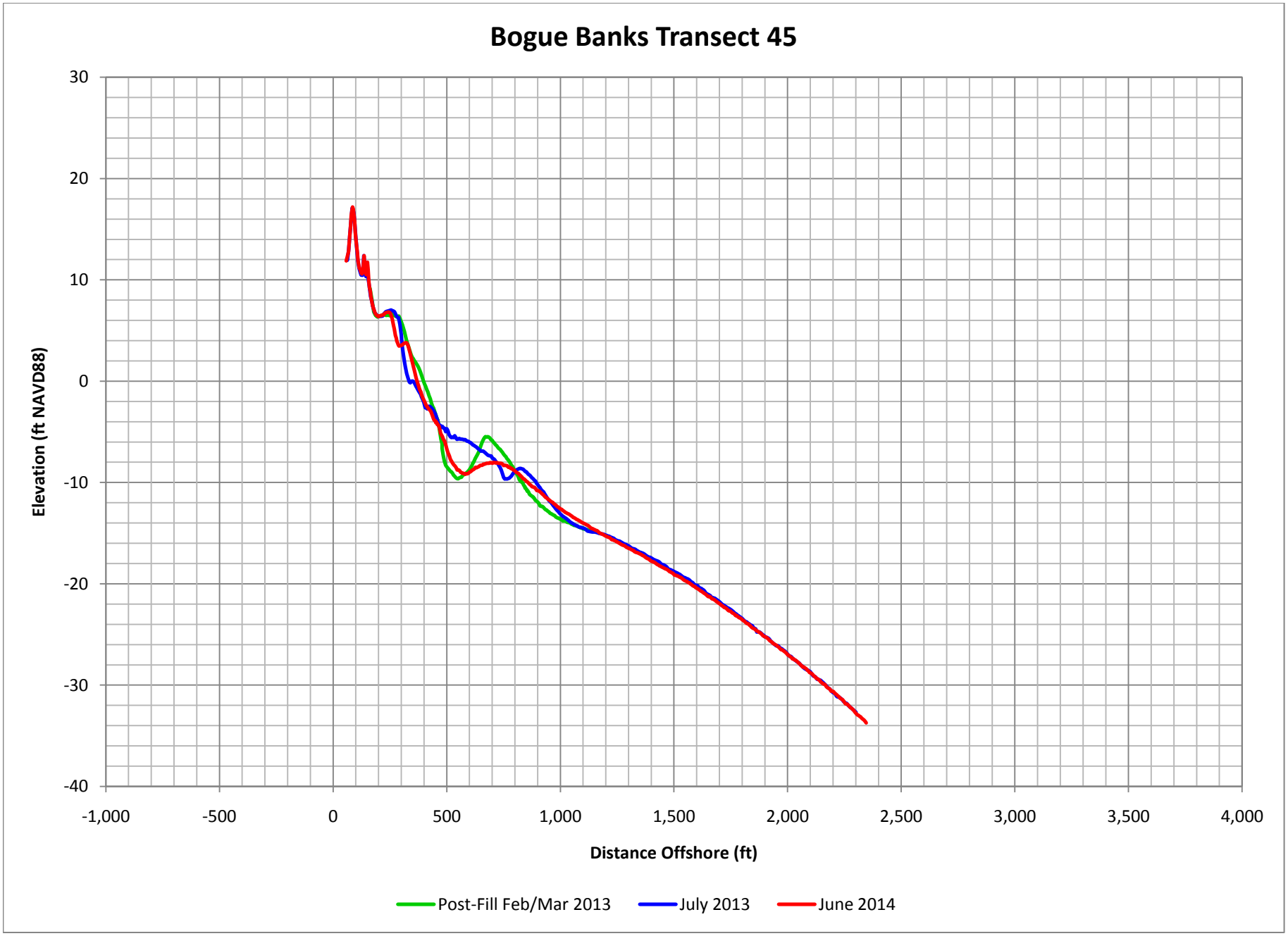


Figure C-62. Bogue Banks Profile Comparison Plot

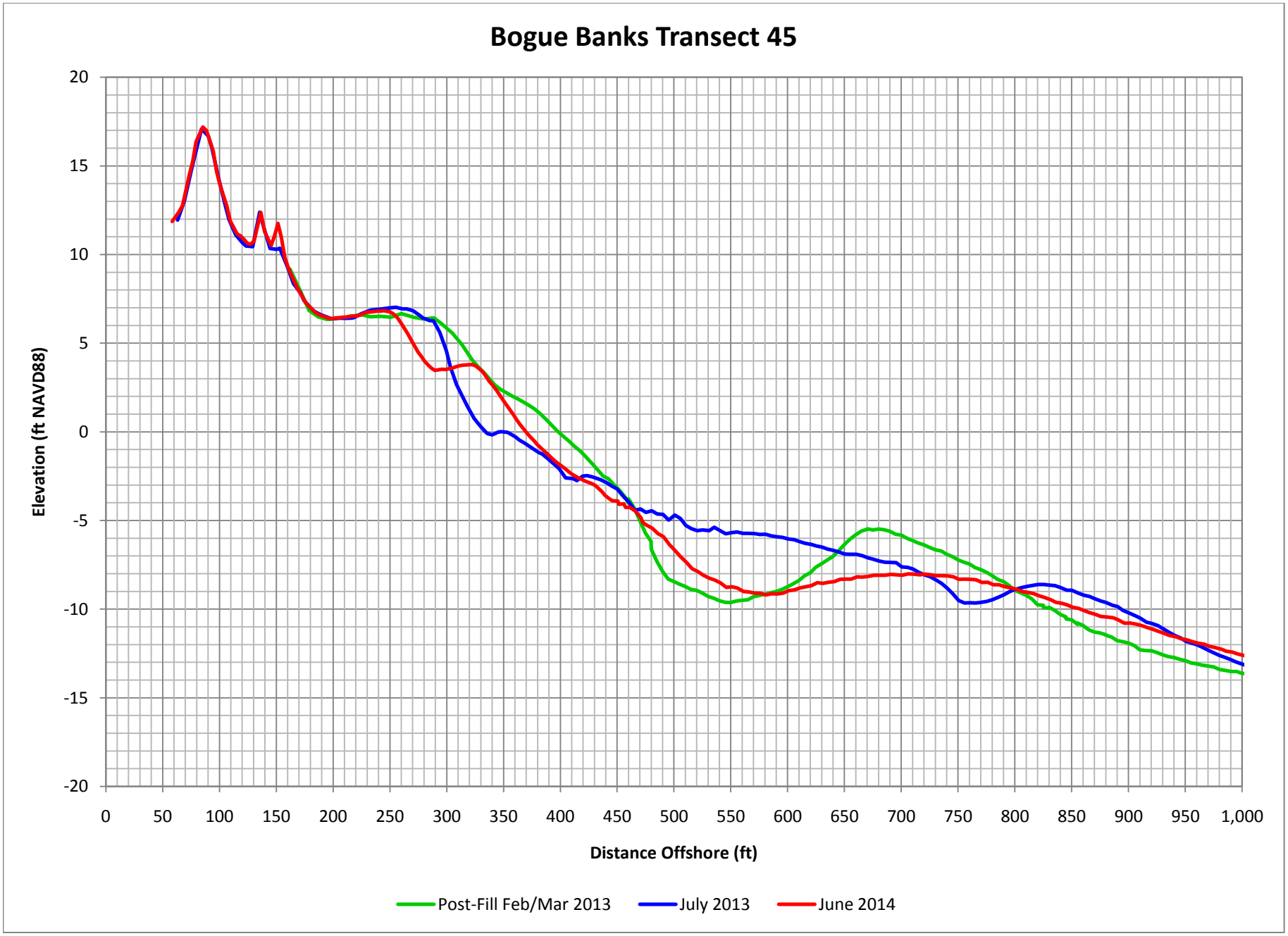


Figure C-63. Bogue Banks Profile Comparison Plot

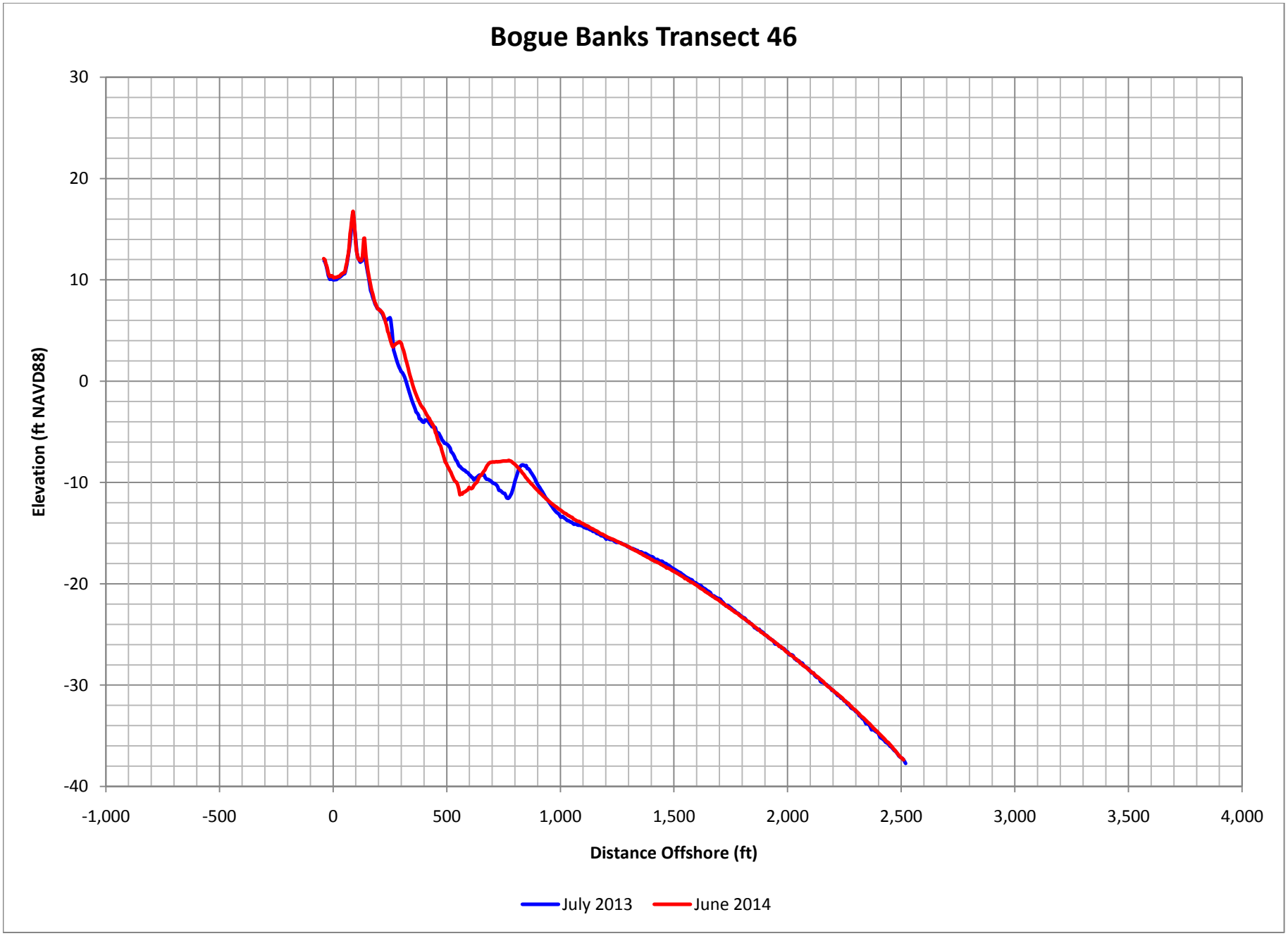


Figure C-64. Bogue Banks Profile Comparison Plot

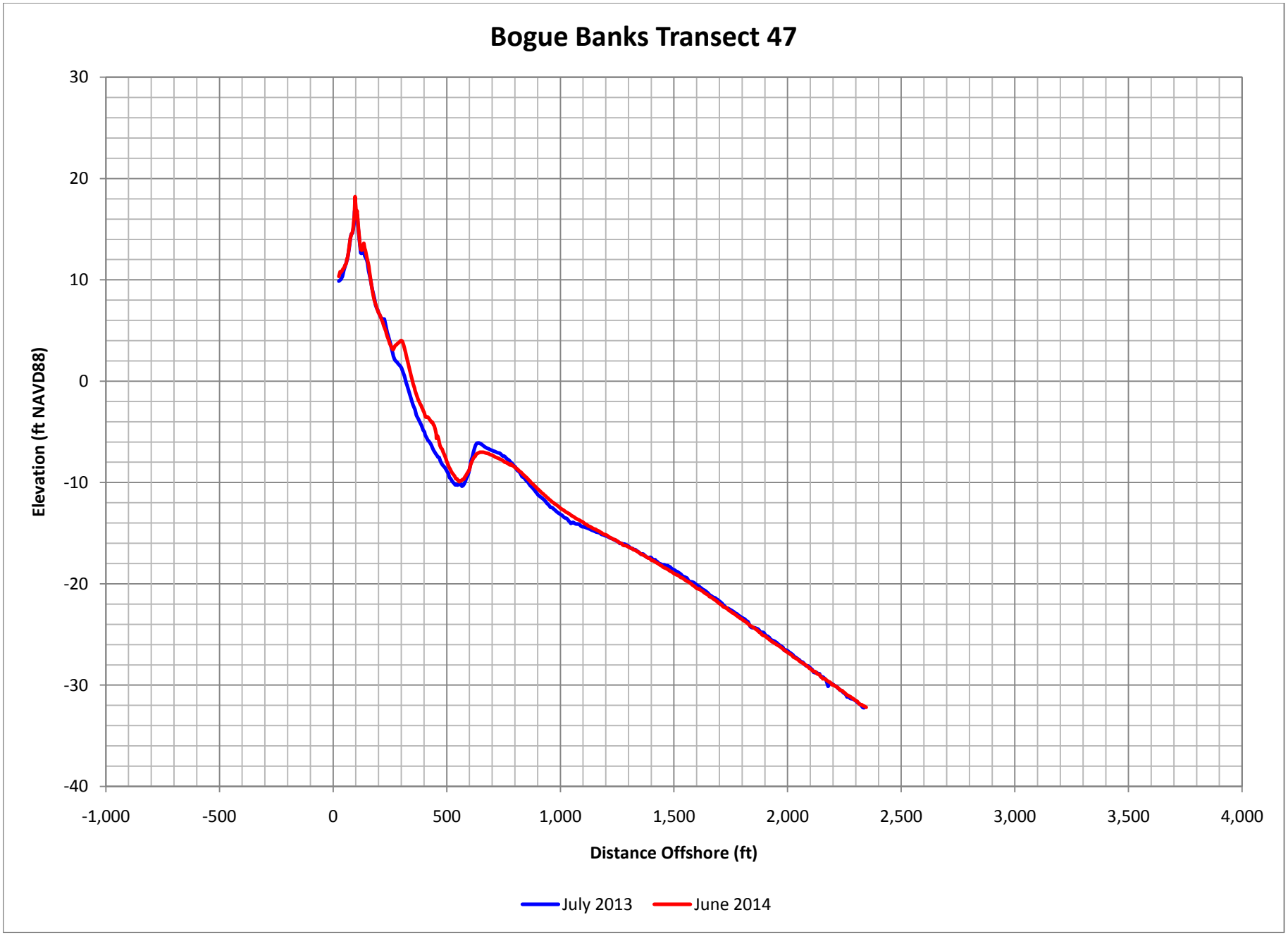


Figure C-65. Bogue Banks Profile Comparison Plot

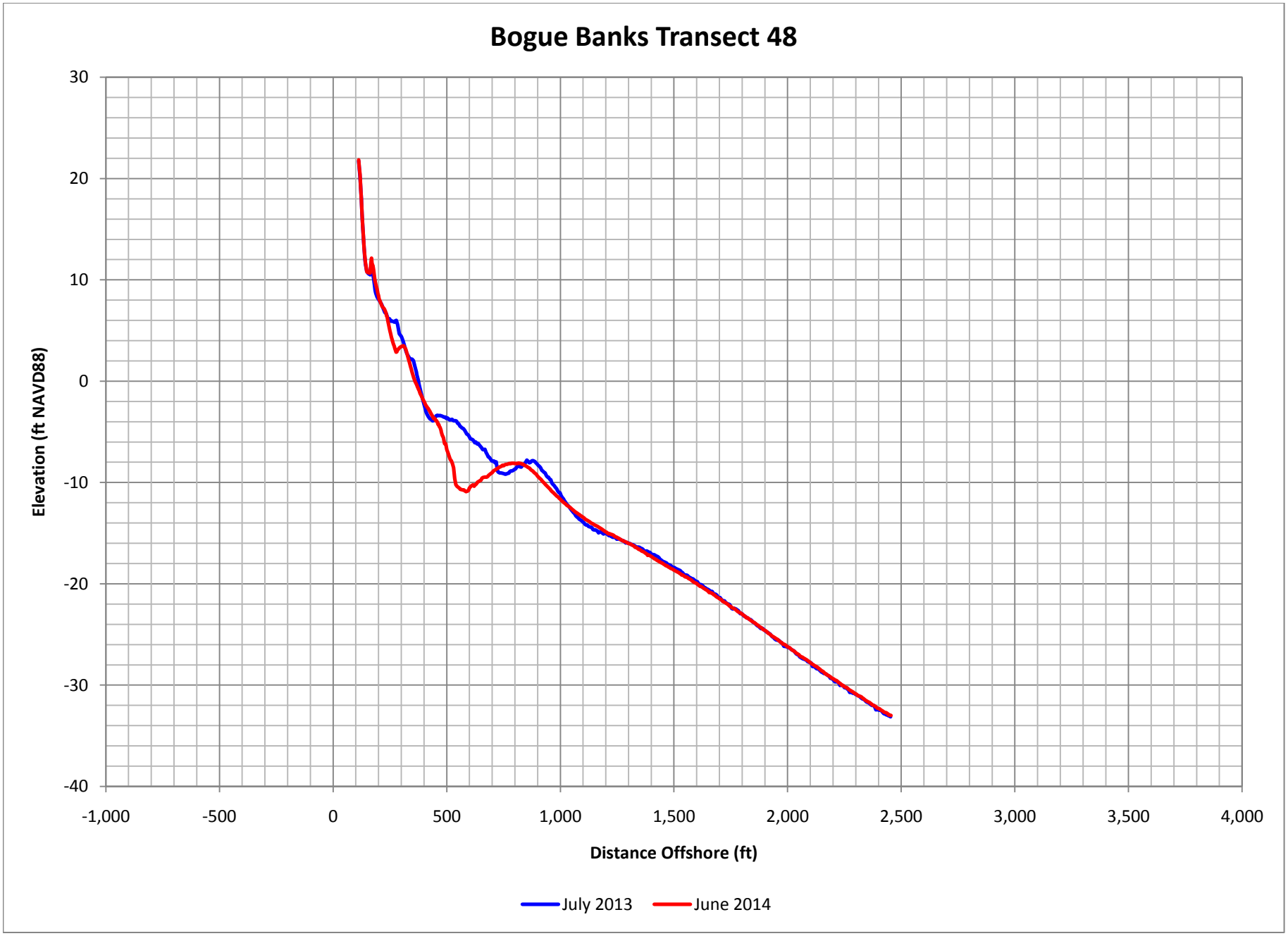


Figure C-66. Bogue Banks Profile Comparison Plot

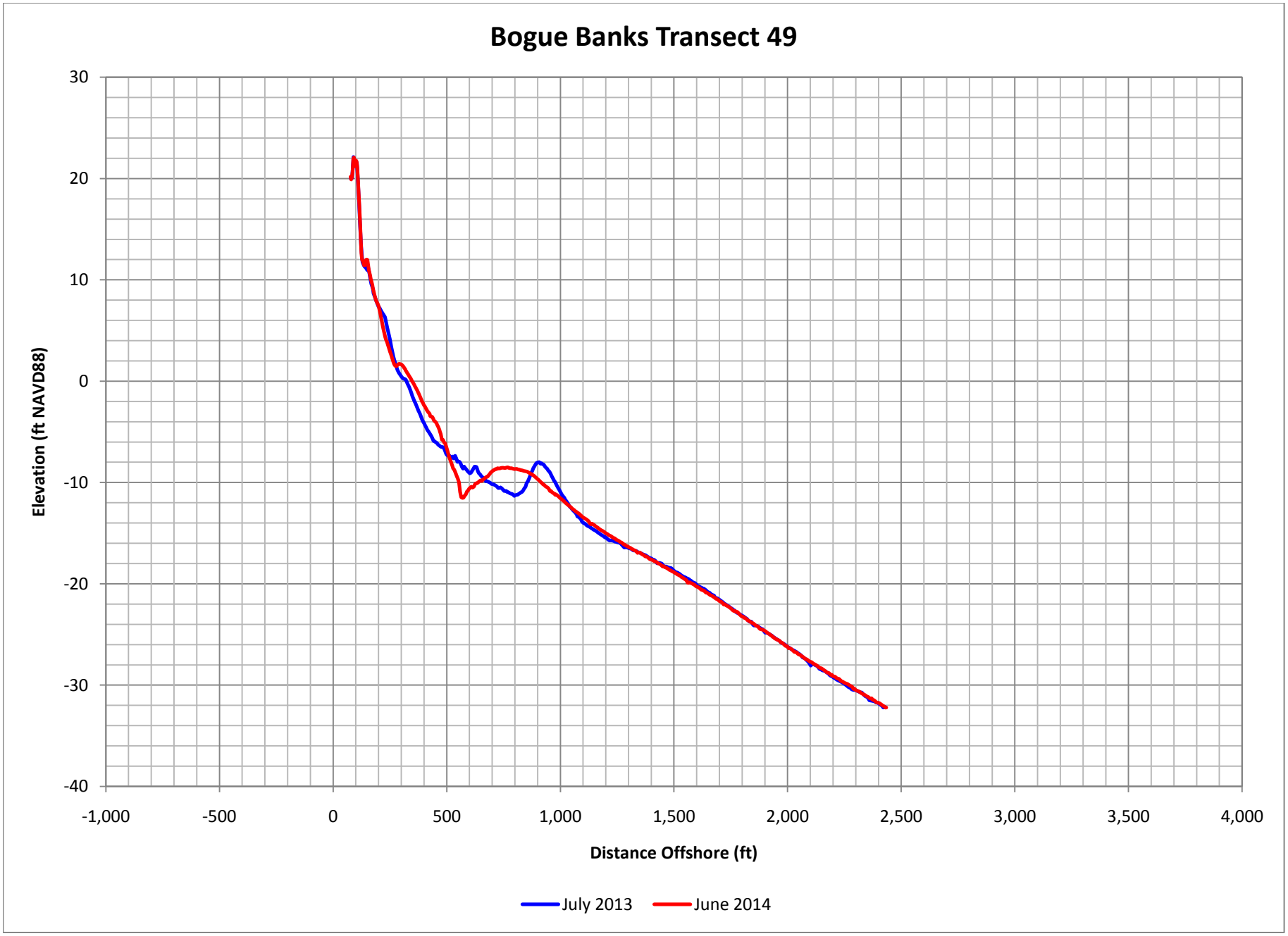


Figure C-67. Bogue Banks Profile Comparison Plot

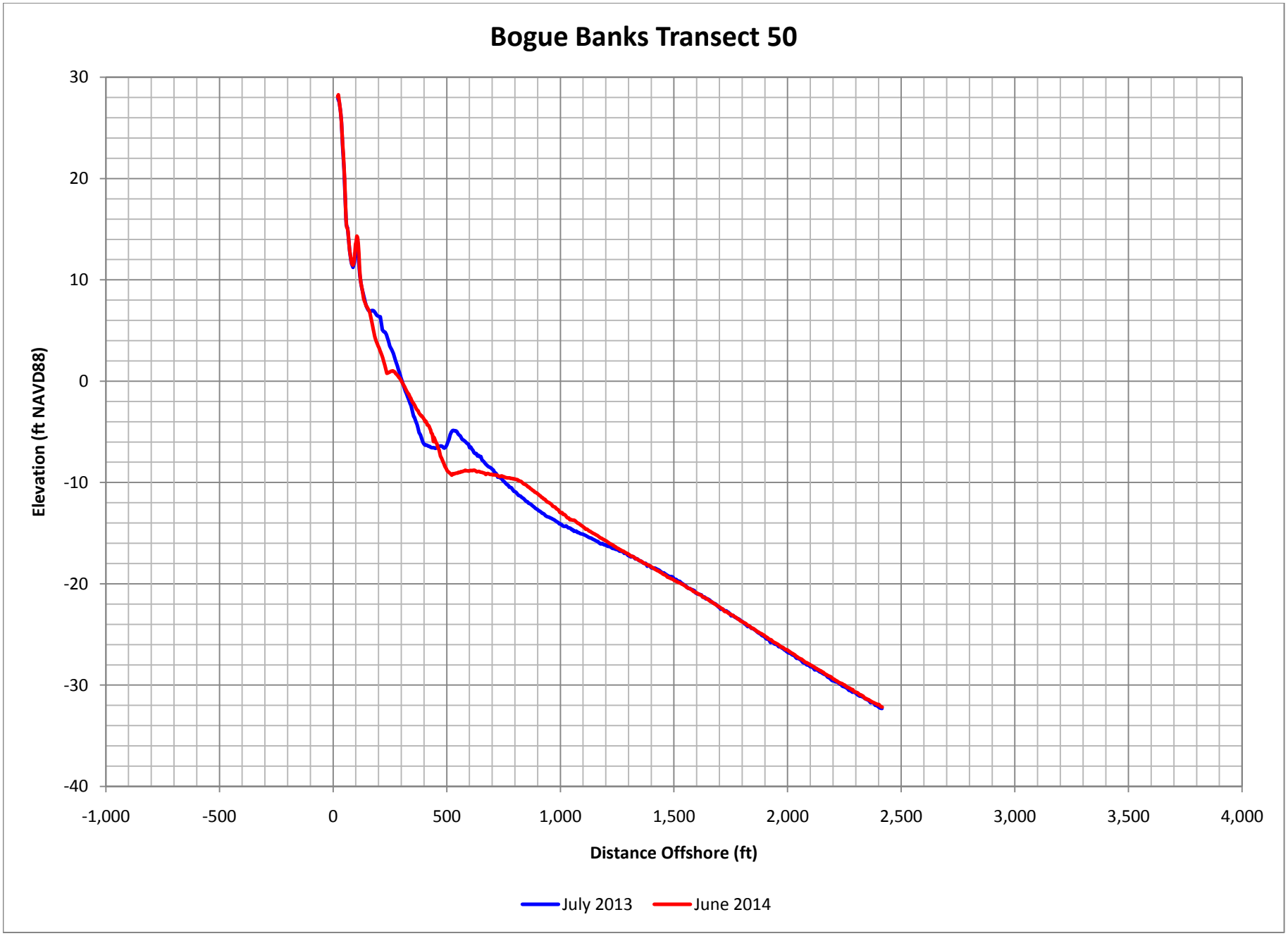


Figure C-68. Bogue Banks Profile Comparison Plot

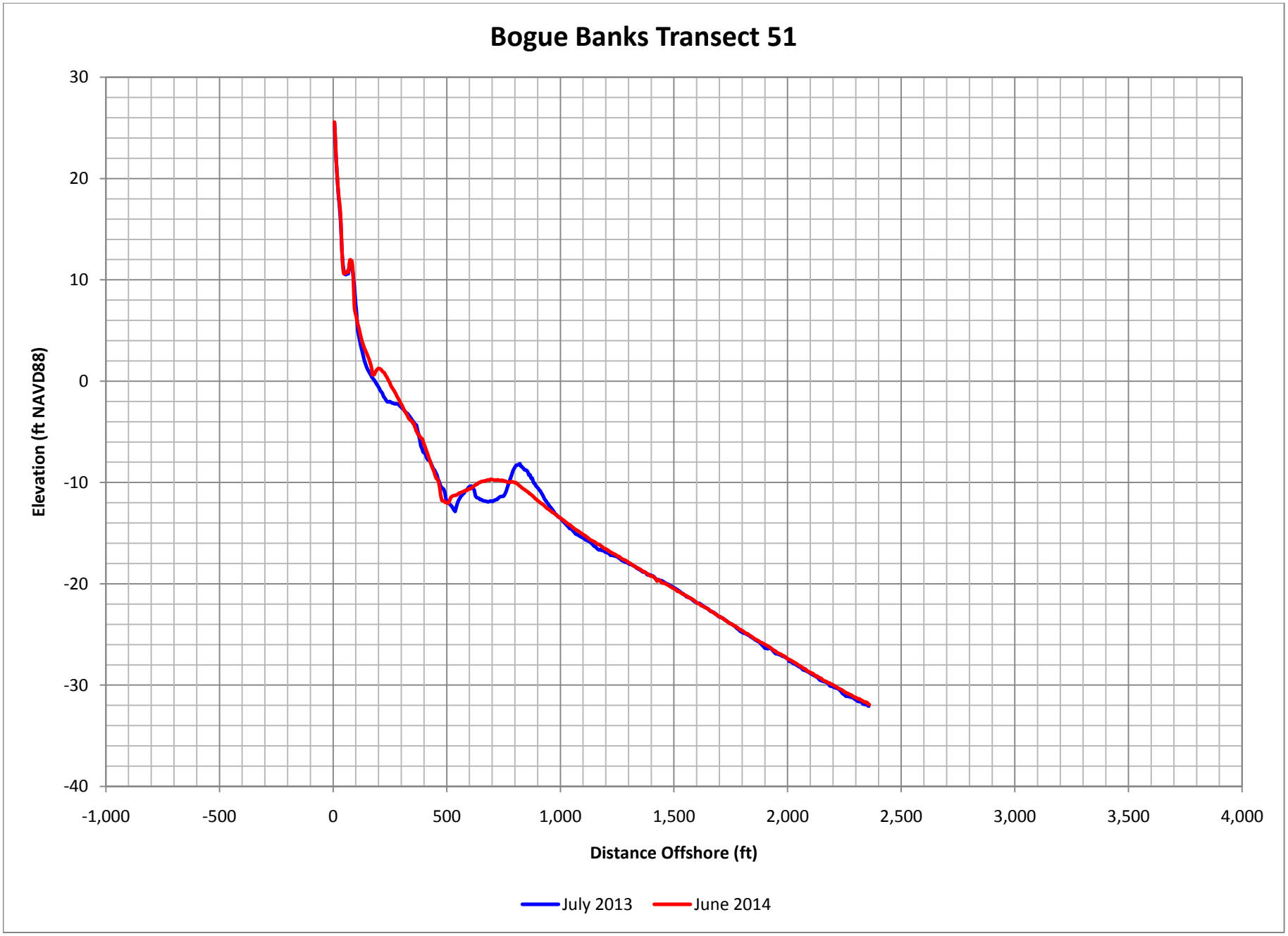


Figure C-69. Bogue Banks Profile Comparison Plot

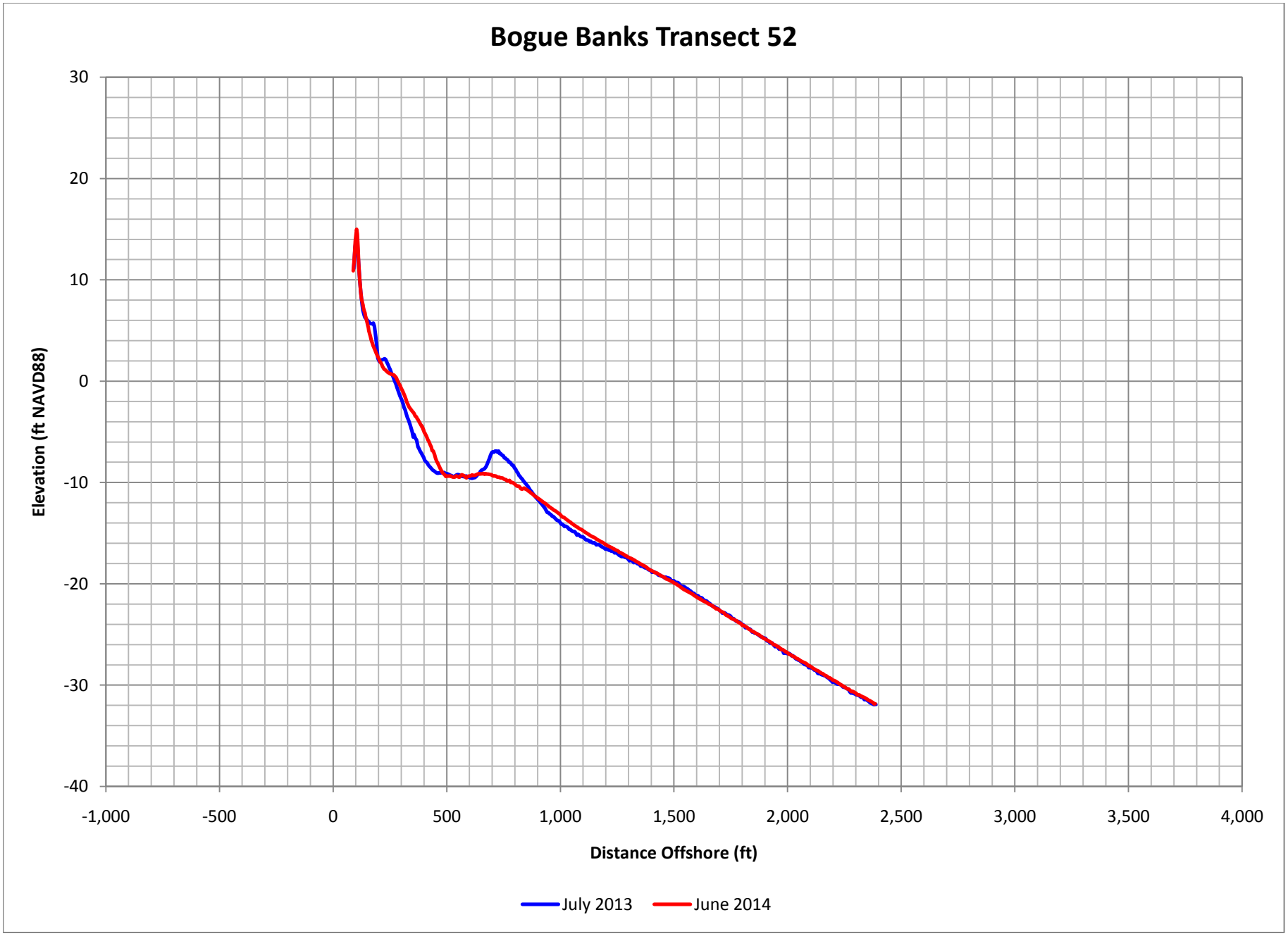


Figure C-70. Bogue Banks Profile Comparison Plot

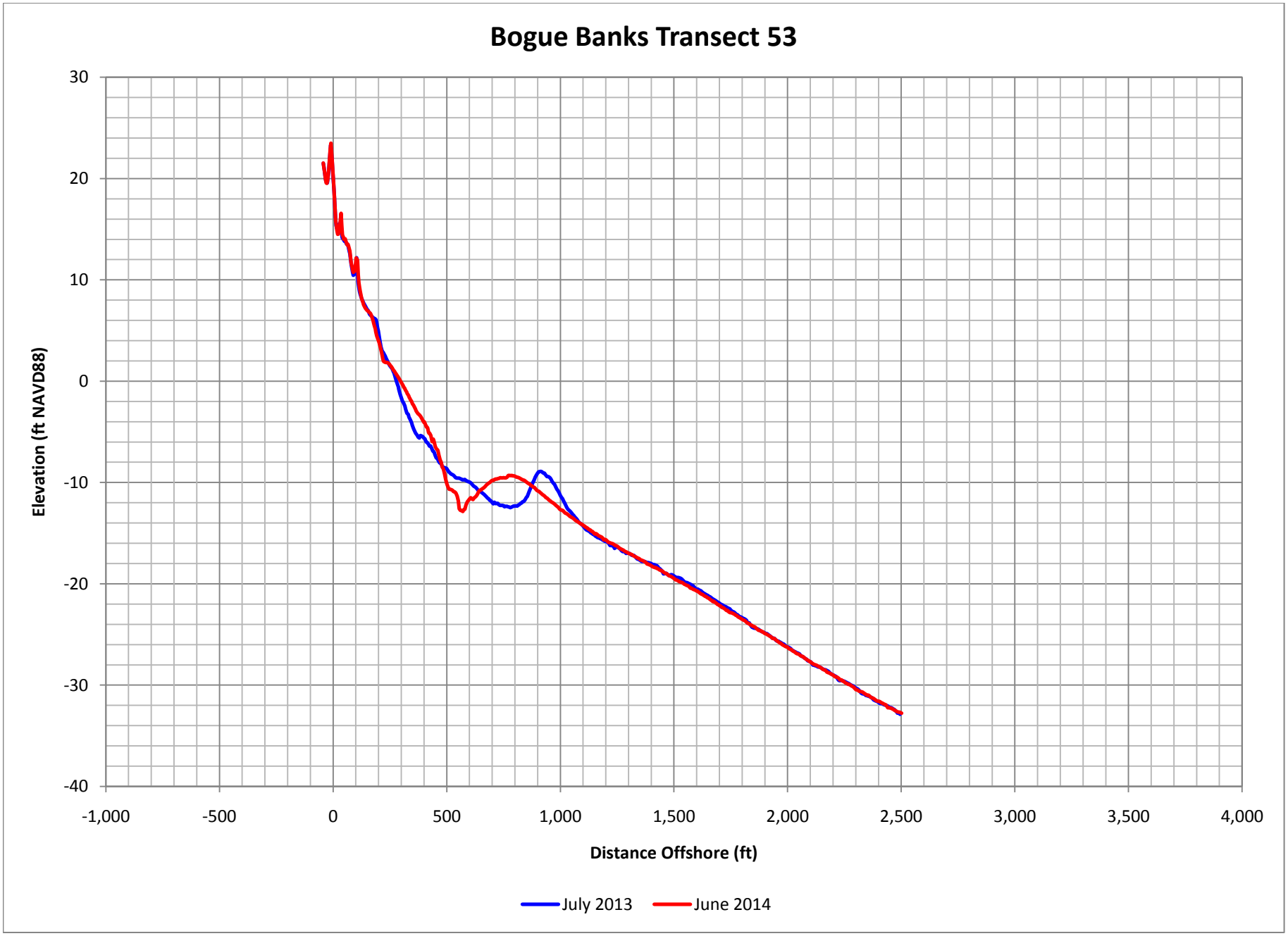


Figure C-71. Bogue Banks Profile Comparison Plot

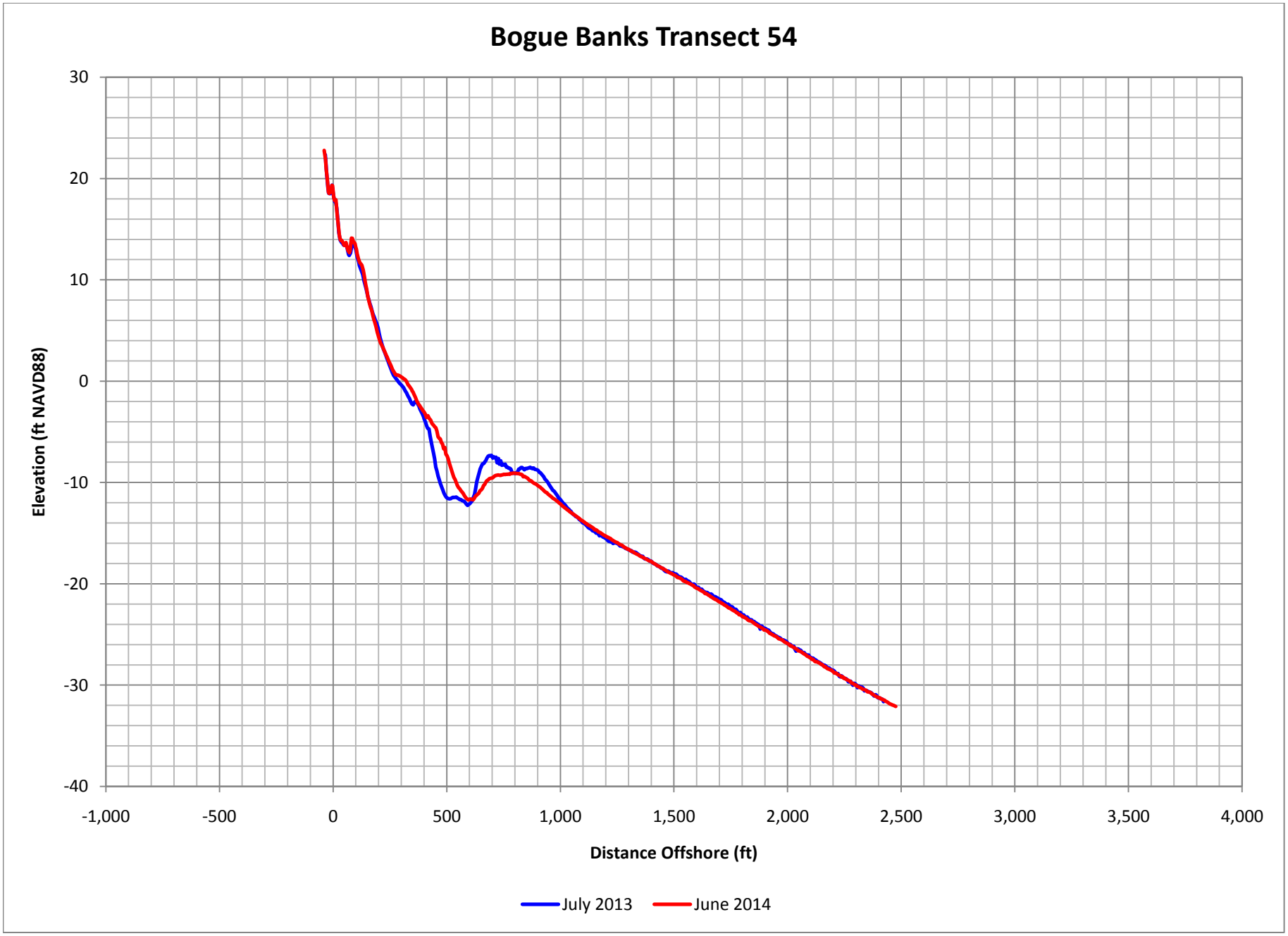


Figure C-72. Bogue Banks Profile Comparison Plot

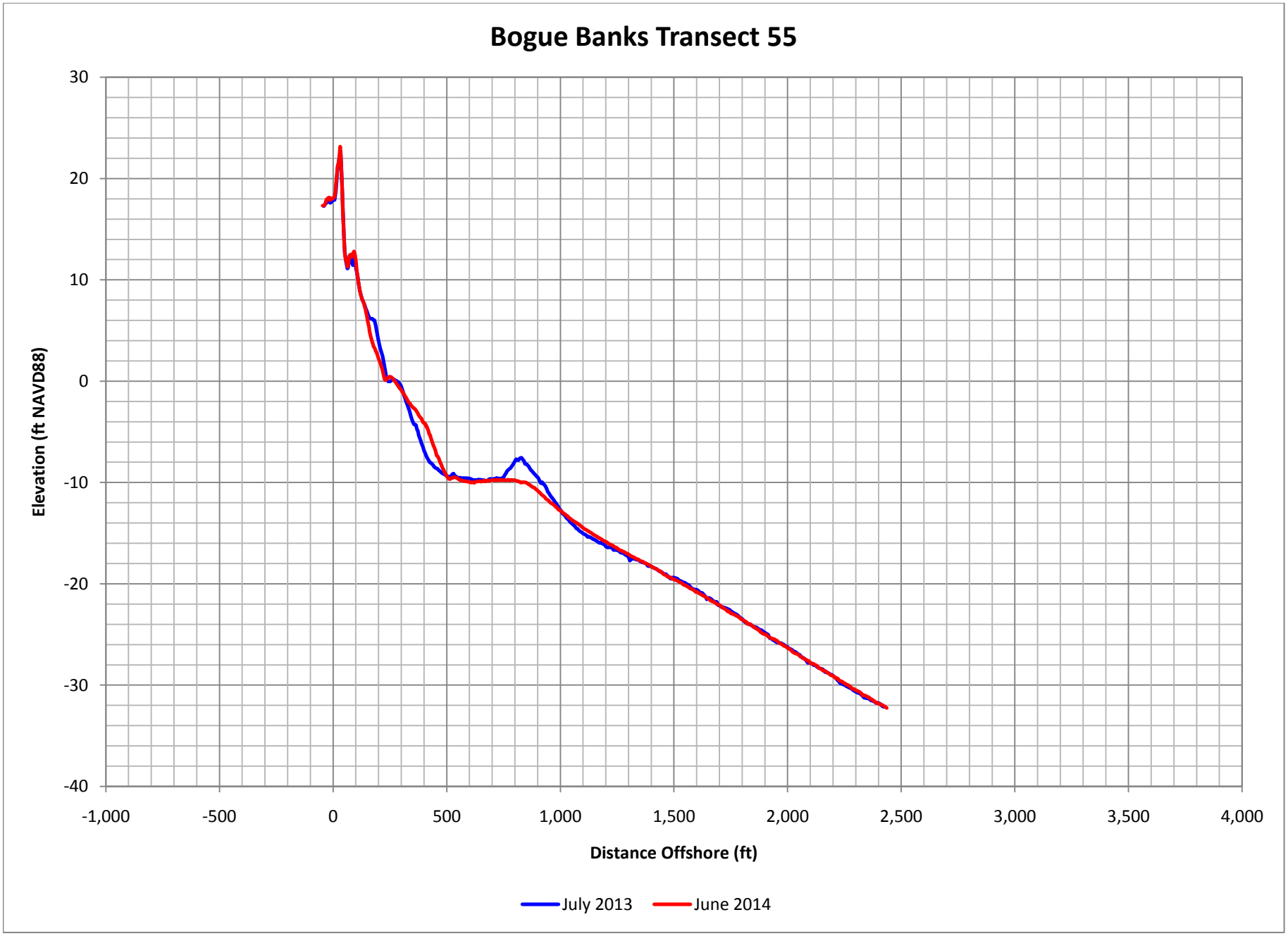


Figure C-73. Bogue Banks Profile Comparison Plot

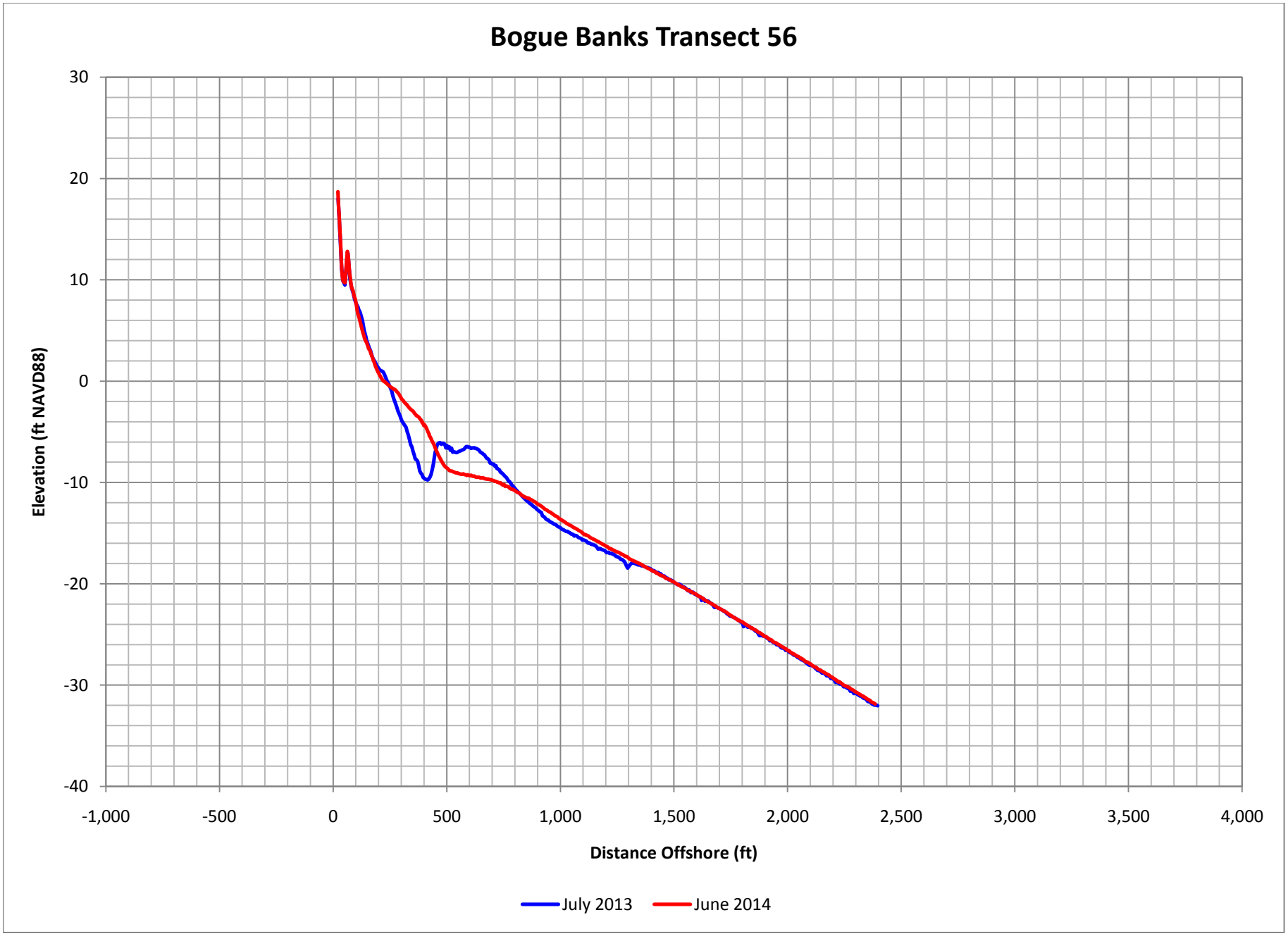


Figure C-74. Bogue Banks Profile Comparison Plot

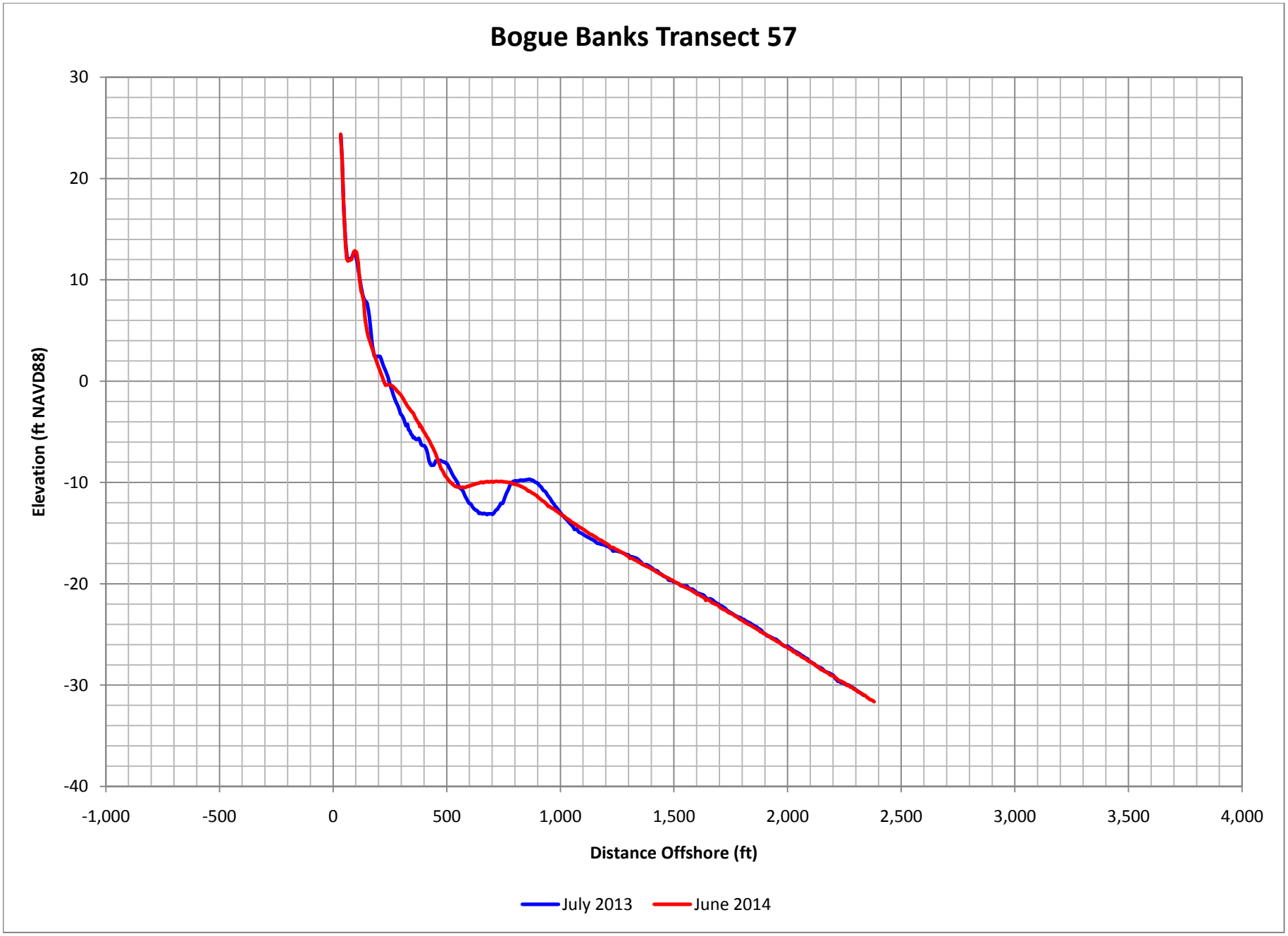


Figure C-75. Bogue Banks Profile Comparison Plot

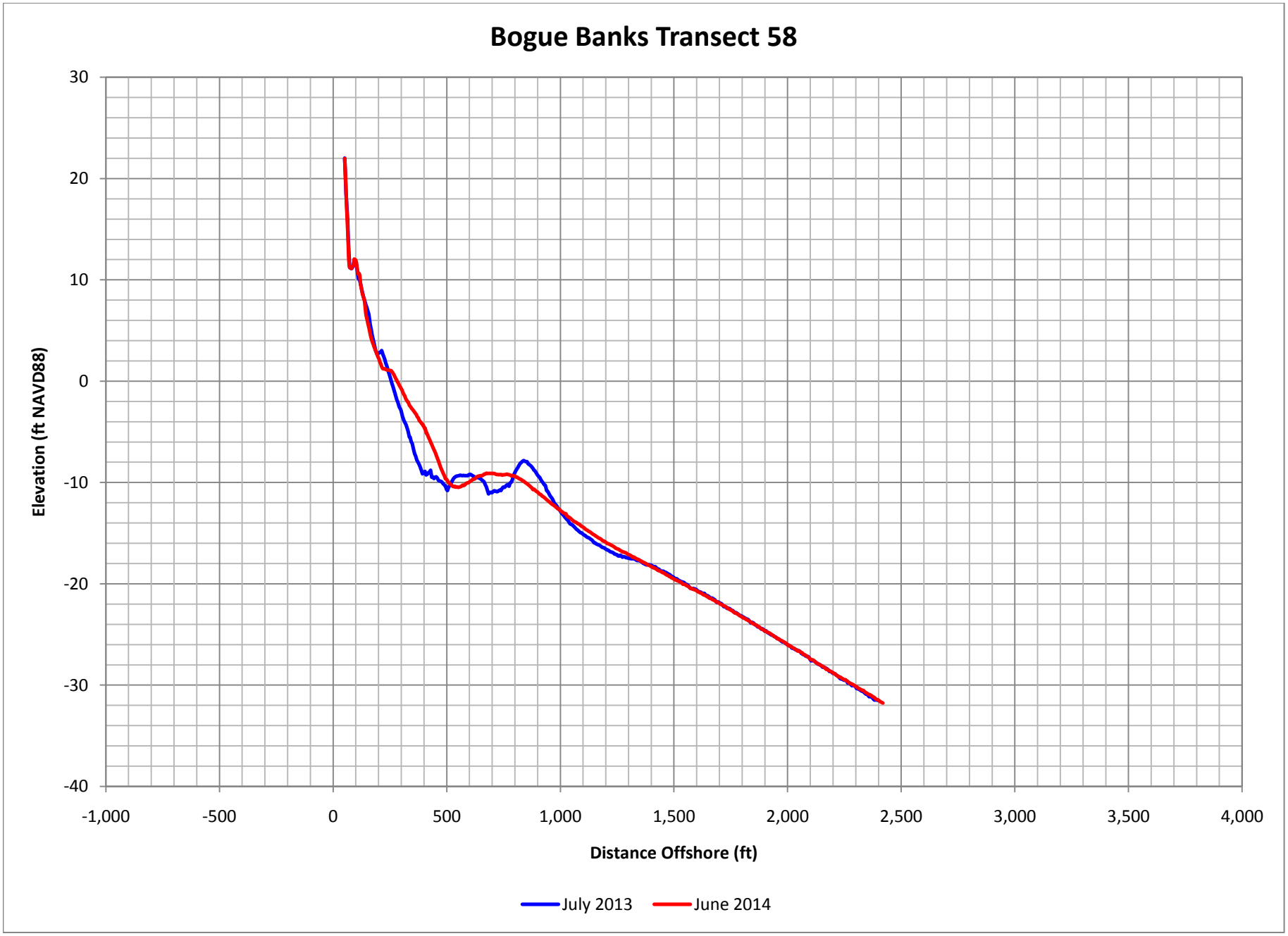


Figure C-76. Bogue Banks Profile Comparison Plot

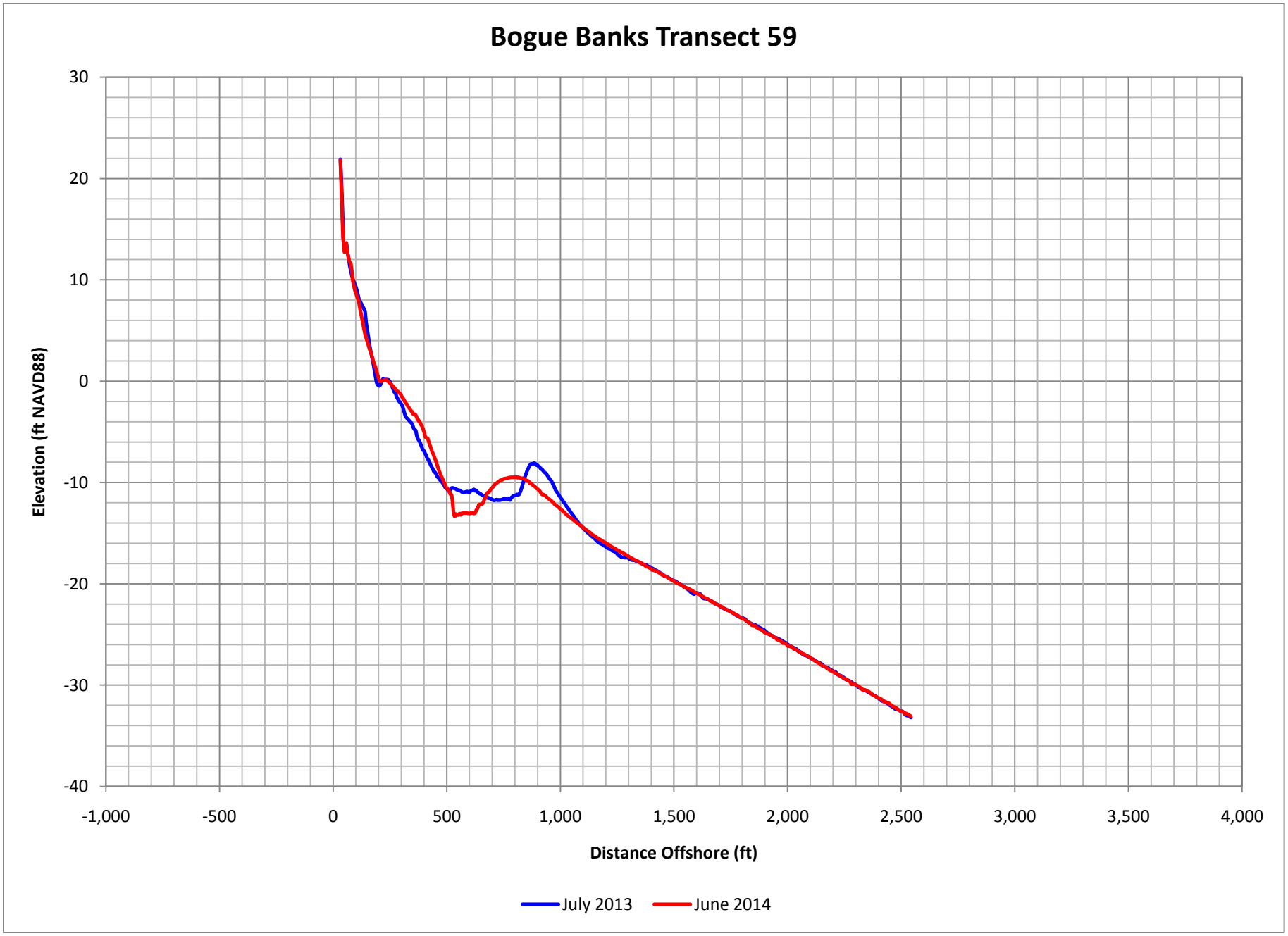


Figure C-77. Bogue Banks Profile Comparison Plot

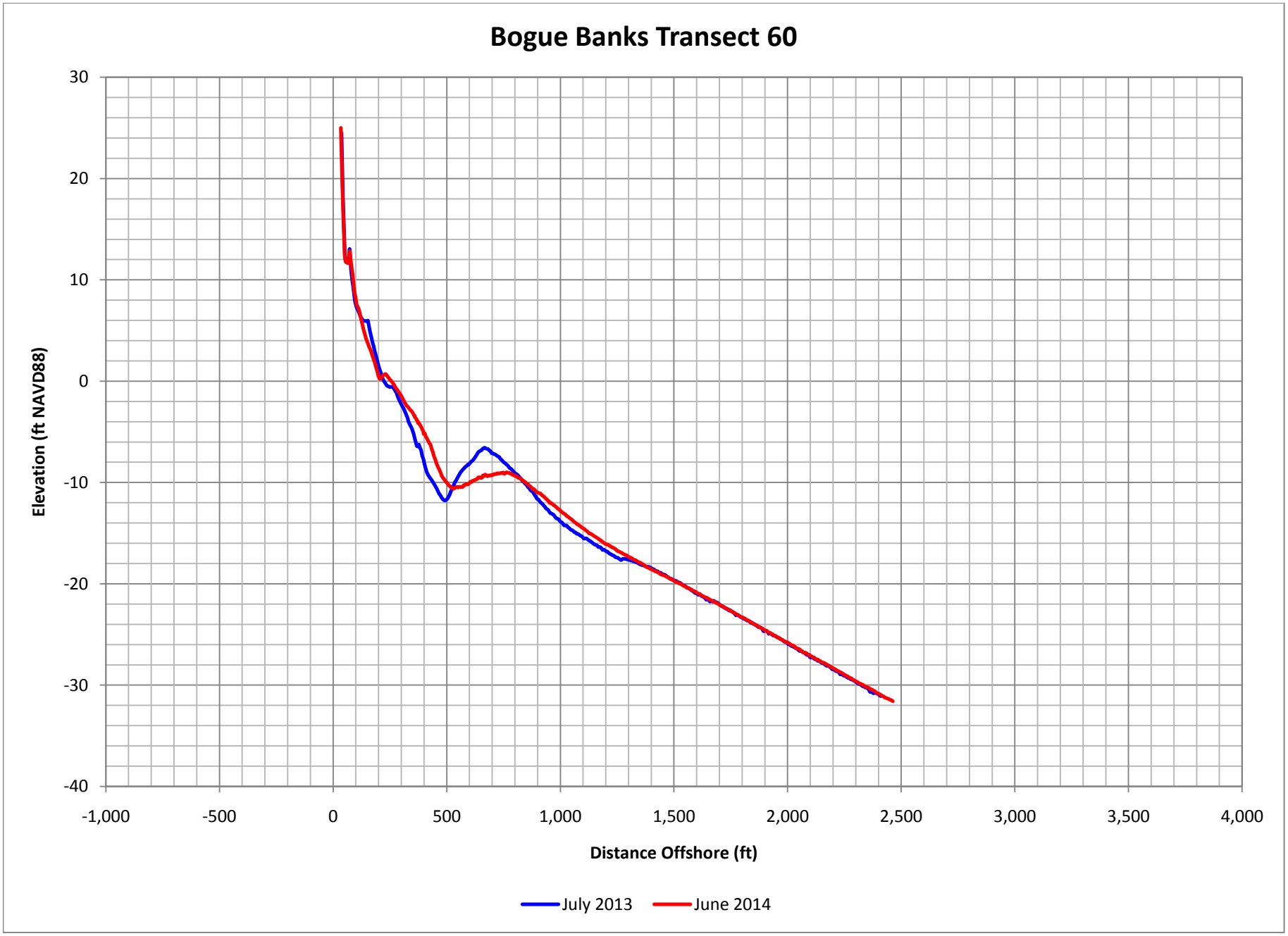


Figure C-78. Bogue Banks Profile Comparison Plot

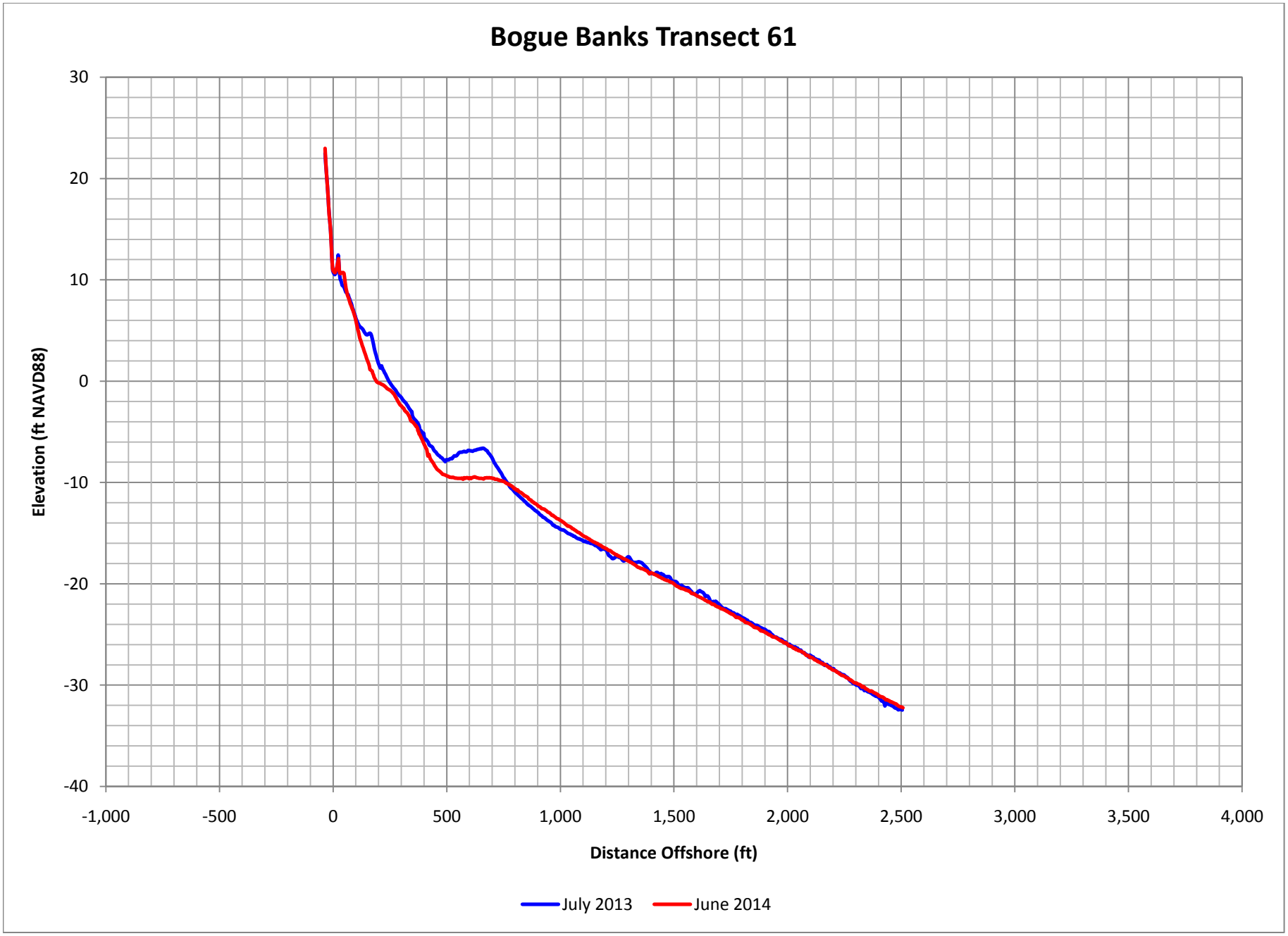


Figure C-79. Bogue Banks Profile Comparison Plot

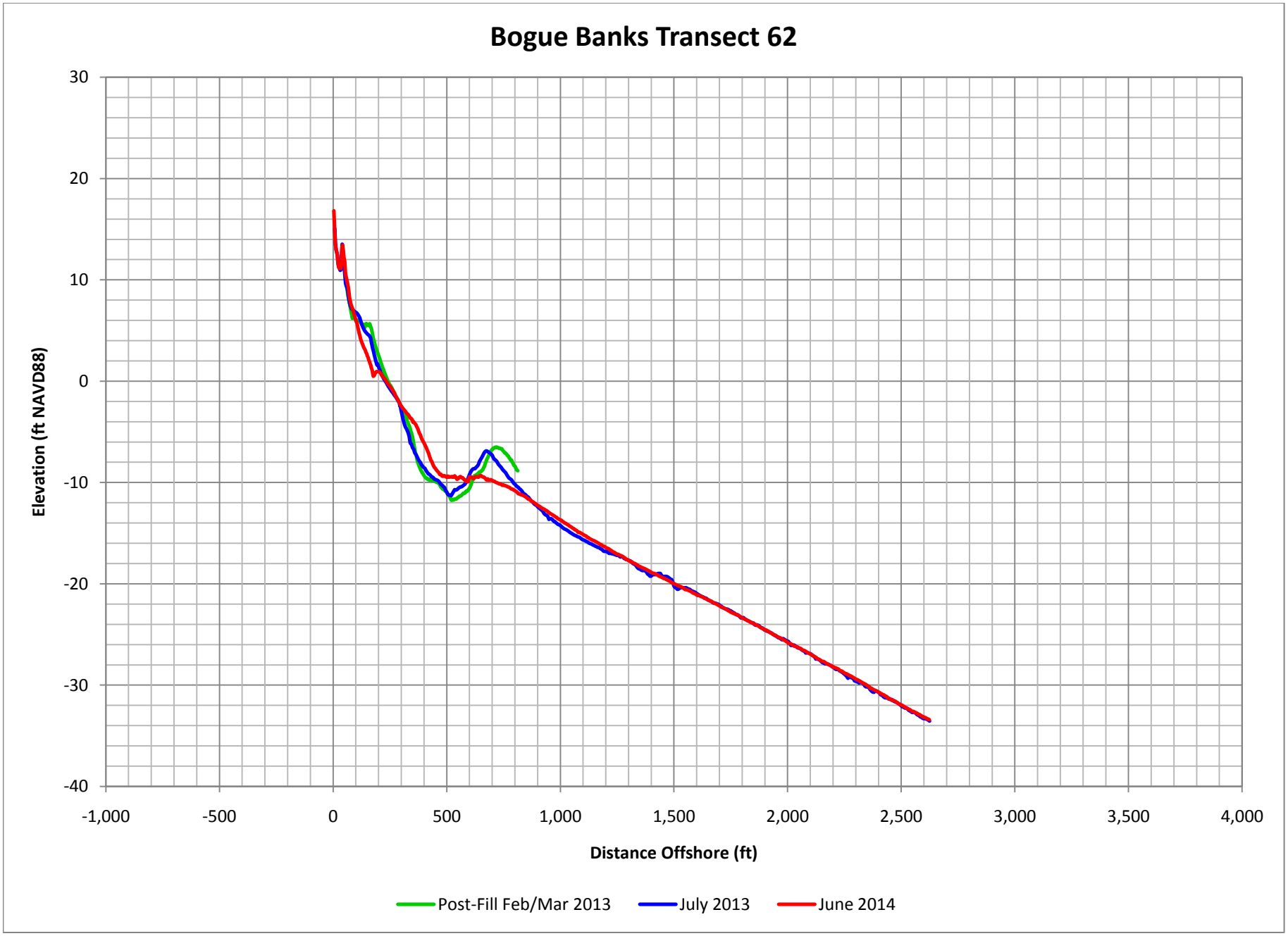


Figure C-80. Bogue Banks Profile Comparison Plot

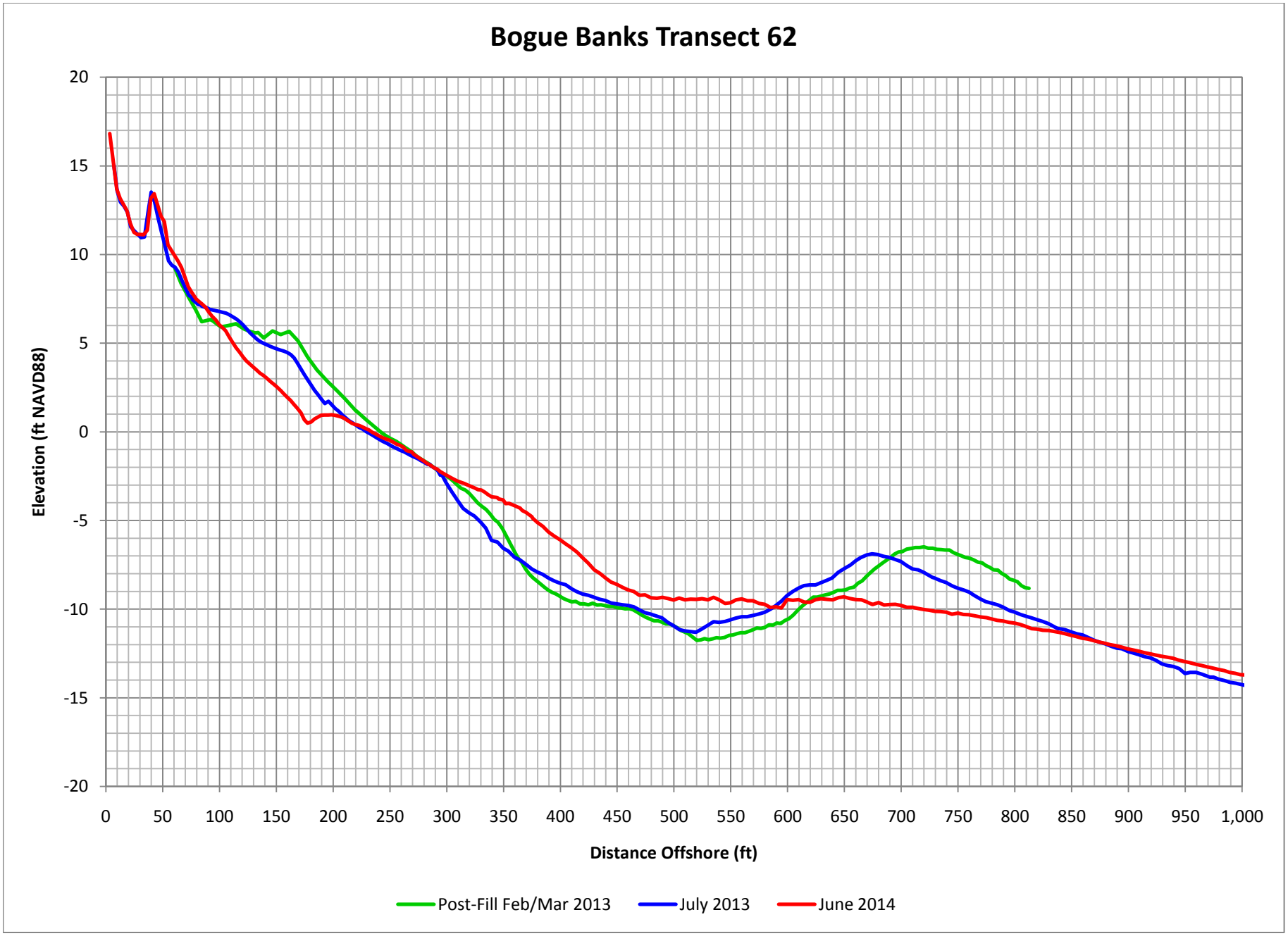


Figure C-81. Bogue Banks Profile Comparison Plot

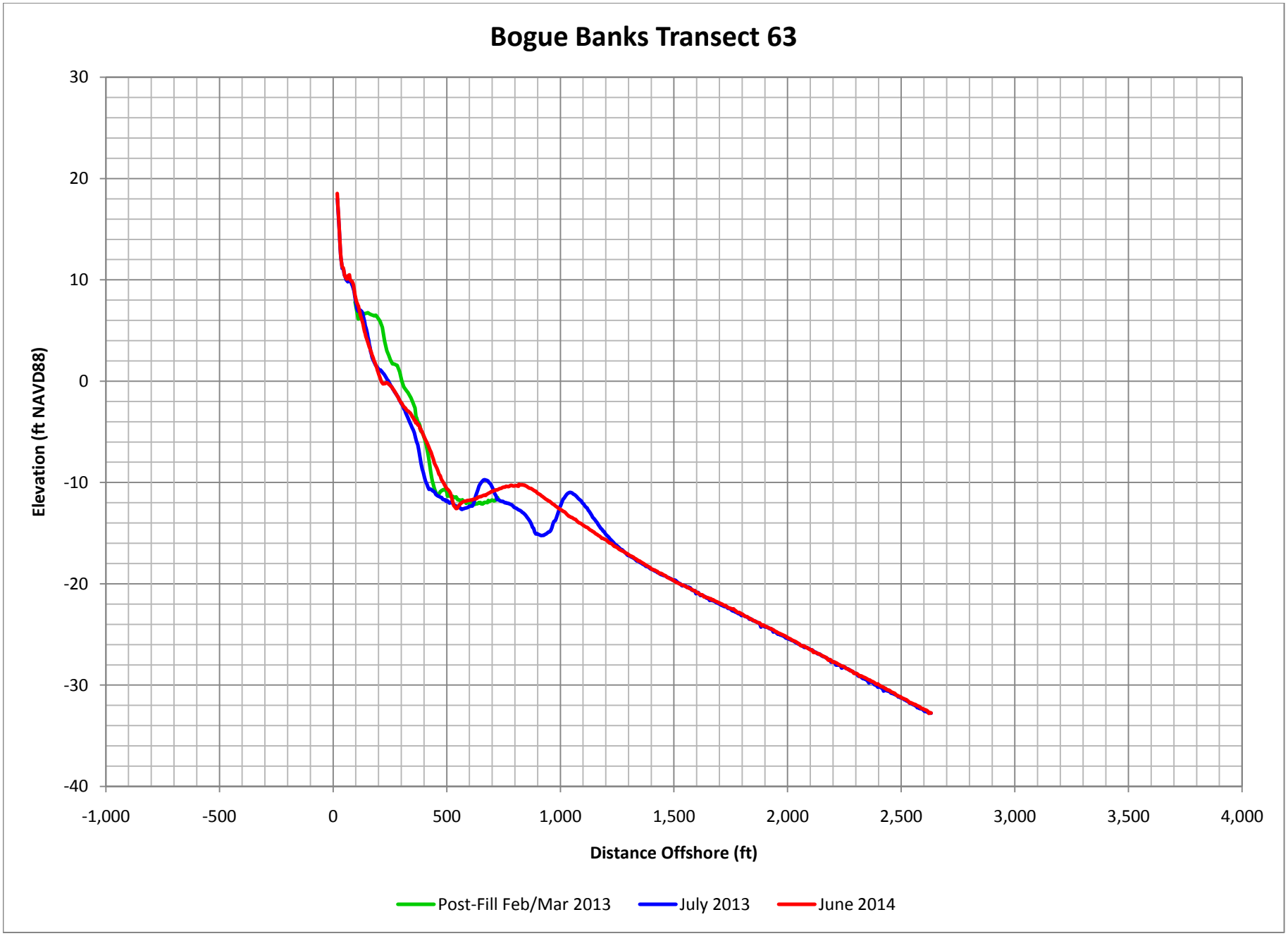


Figure C-82. Bogue Banks Profile Comparison Plot

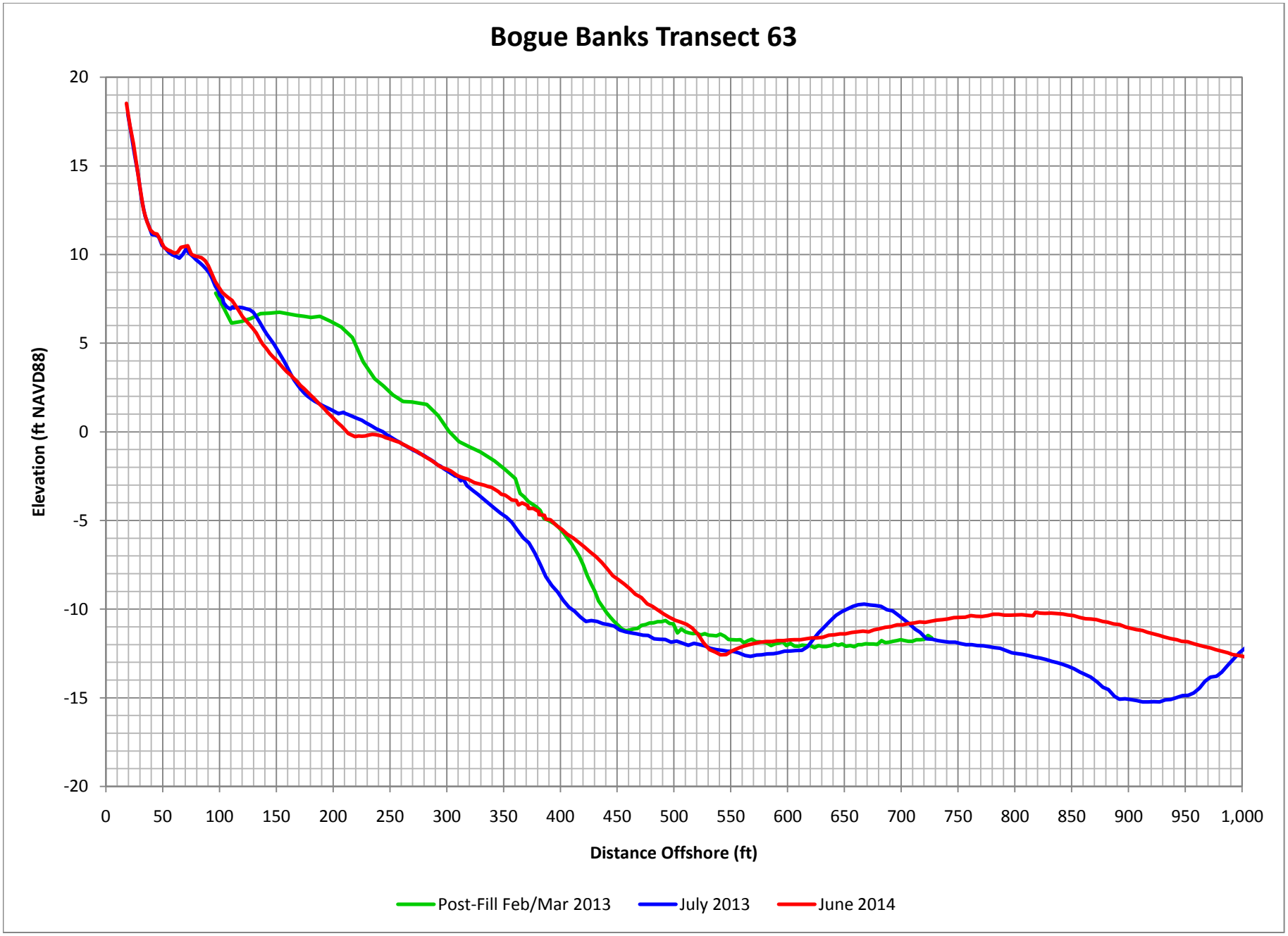


Figure C-83. Bogue Banks Profile Comparison Plot

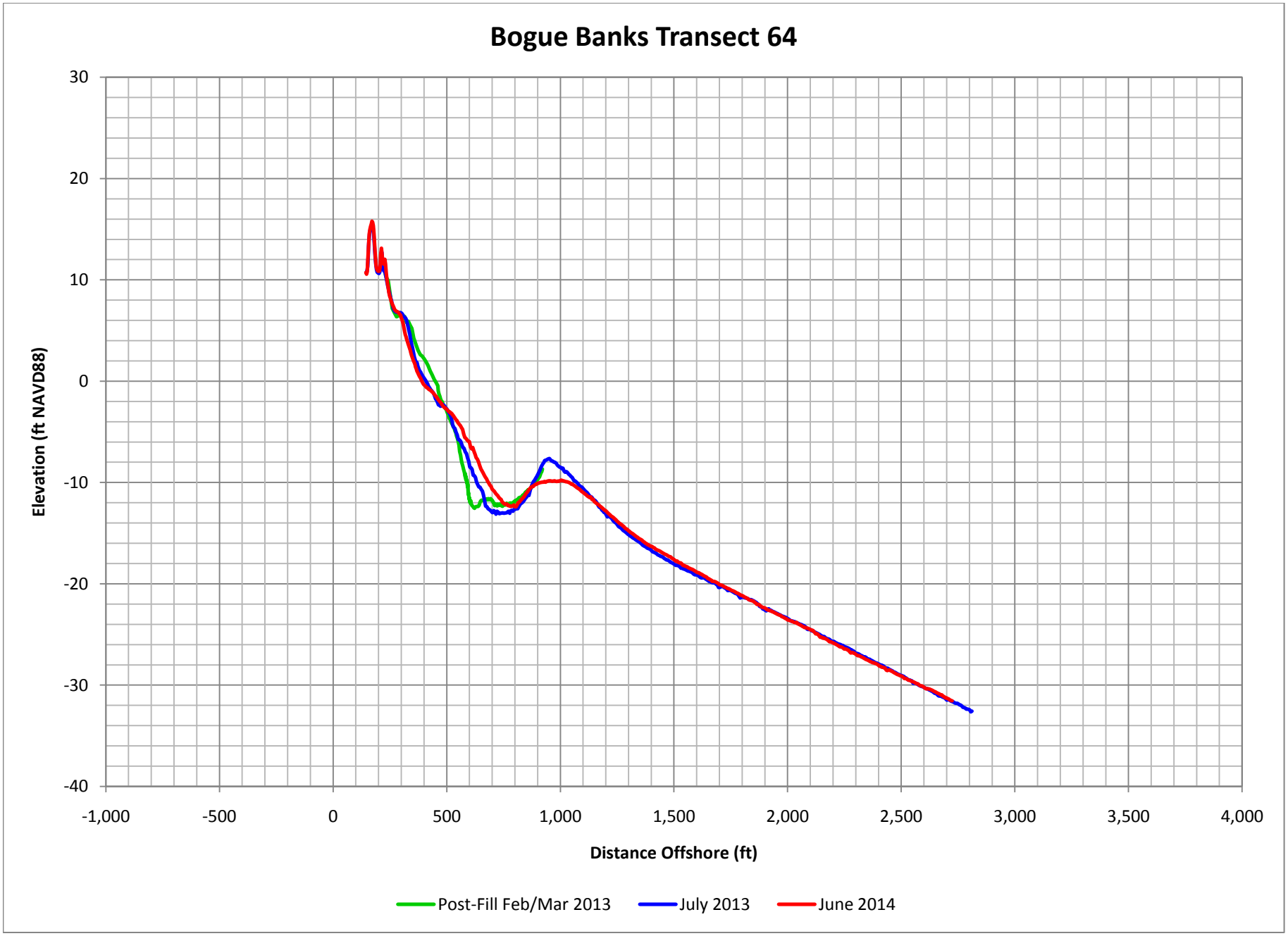


Figure C-84. Bogue Banks Profile Comparison Plot

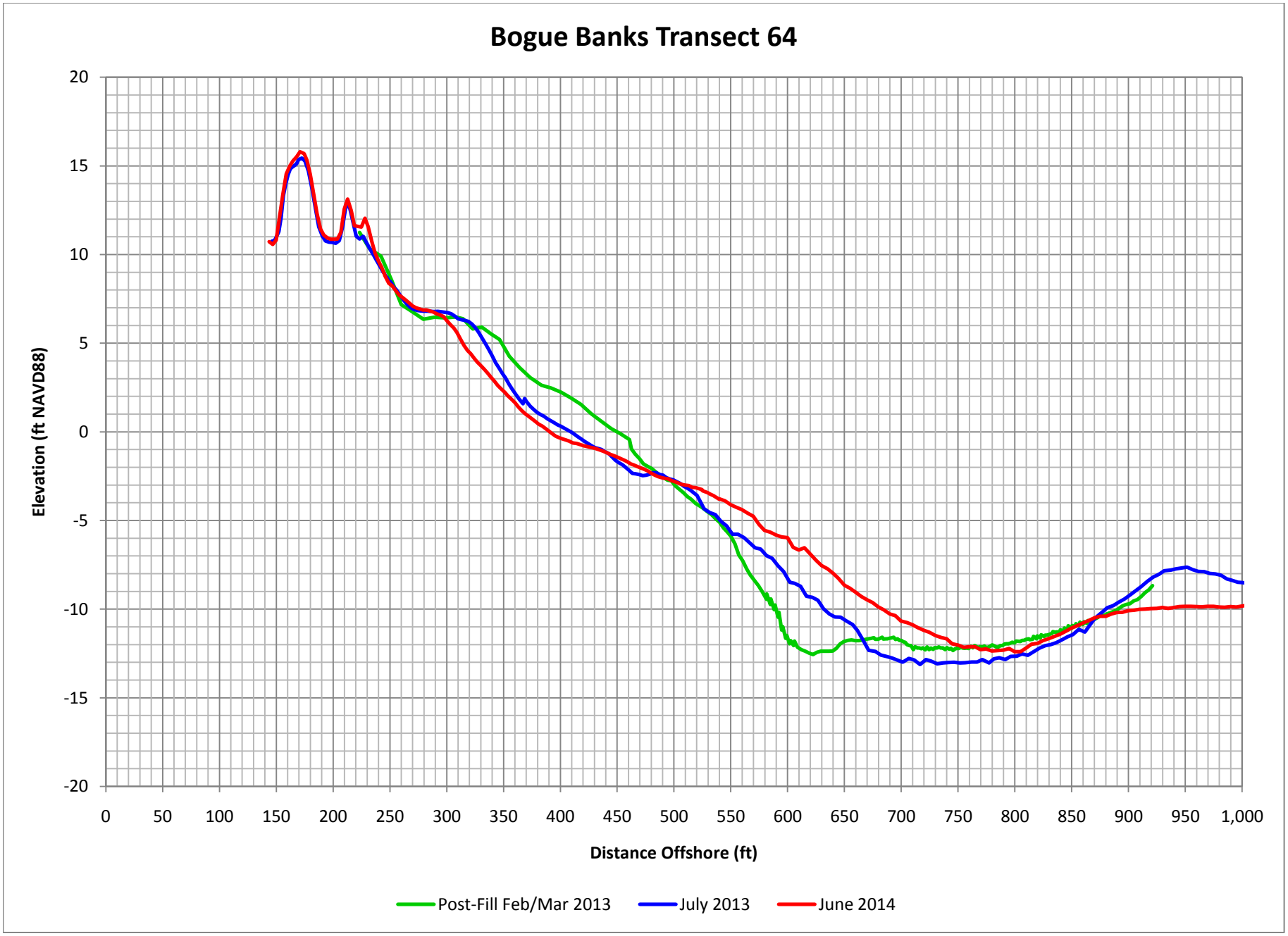


Figure C-85. Bogue Banks Profile Comparison Plot

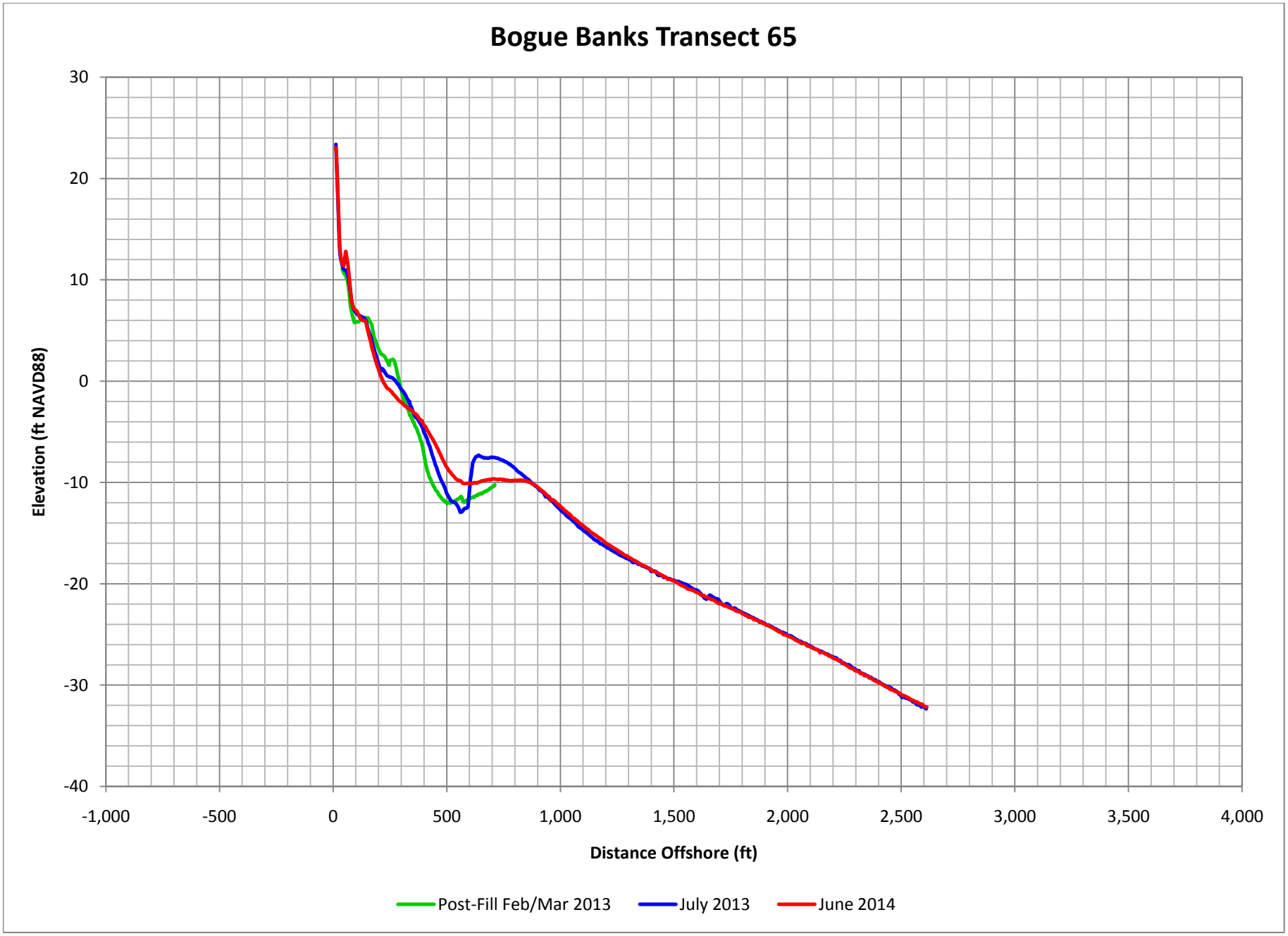


Figure C-86. Bogue Banks Profile Comparison Plot

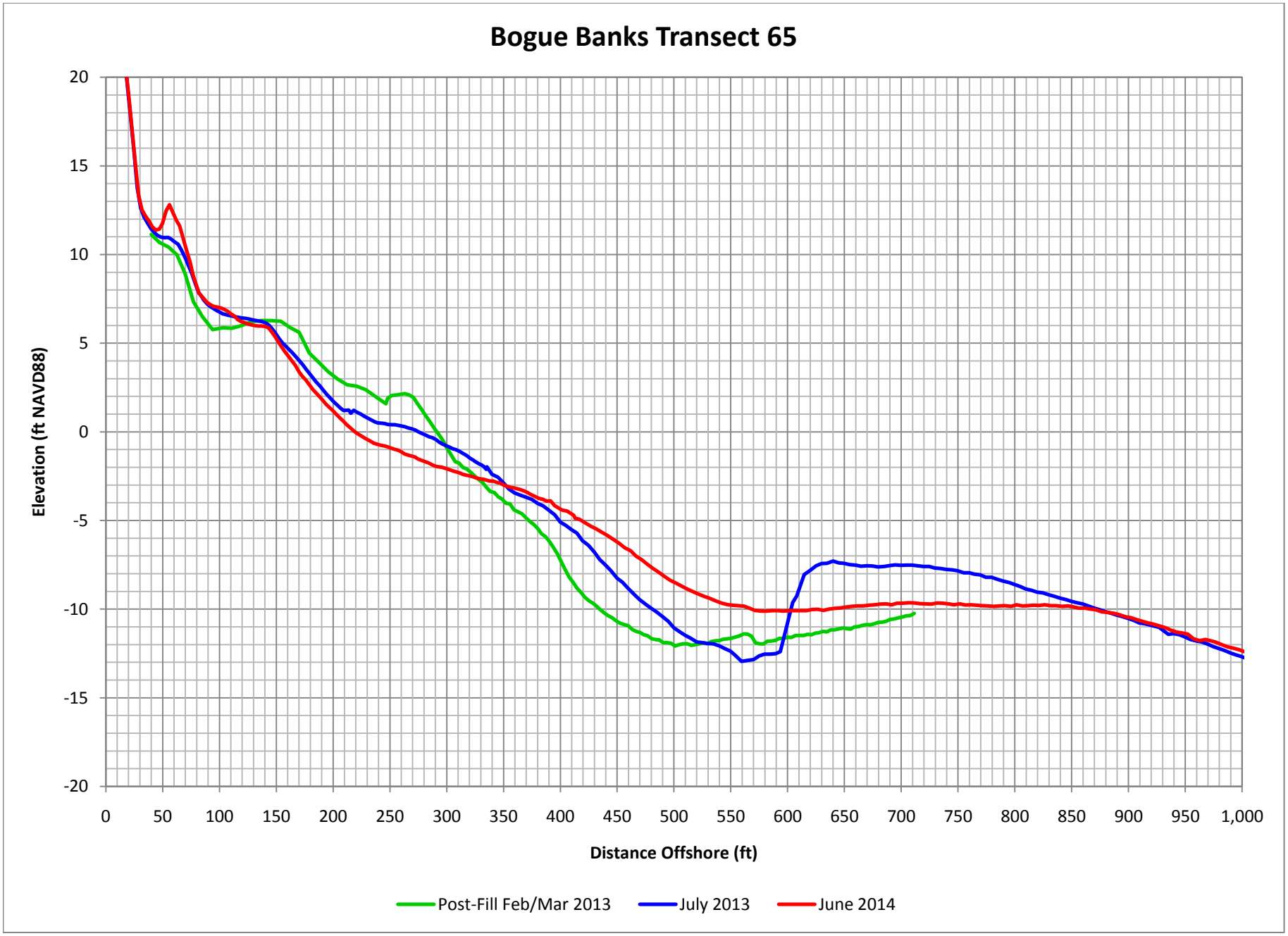


Figure C-87. Bogue Banks Profile Comparison Plot

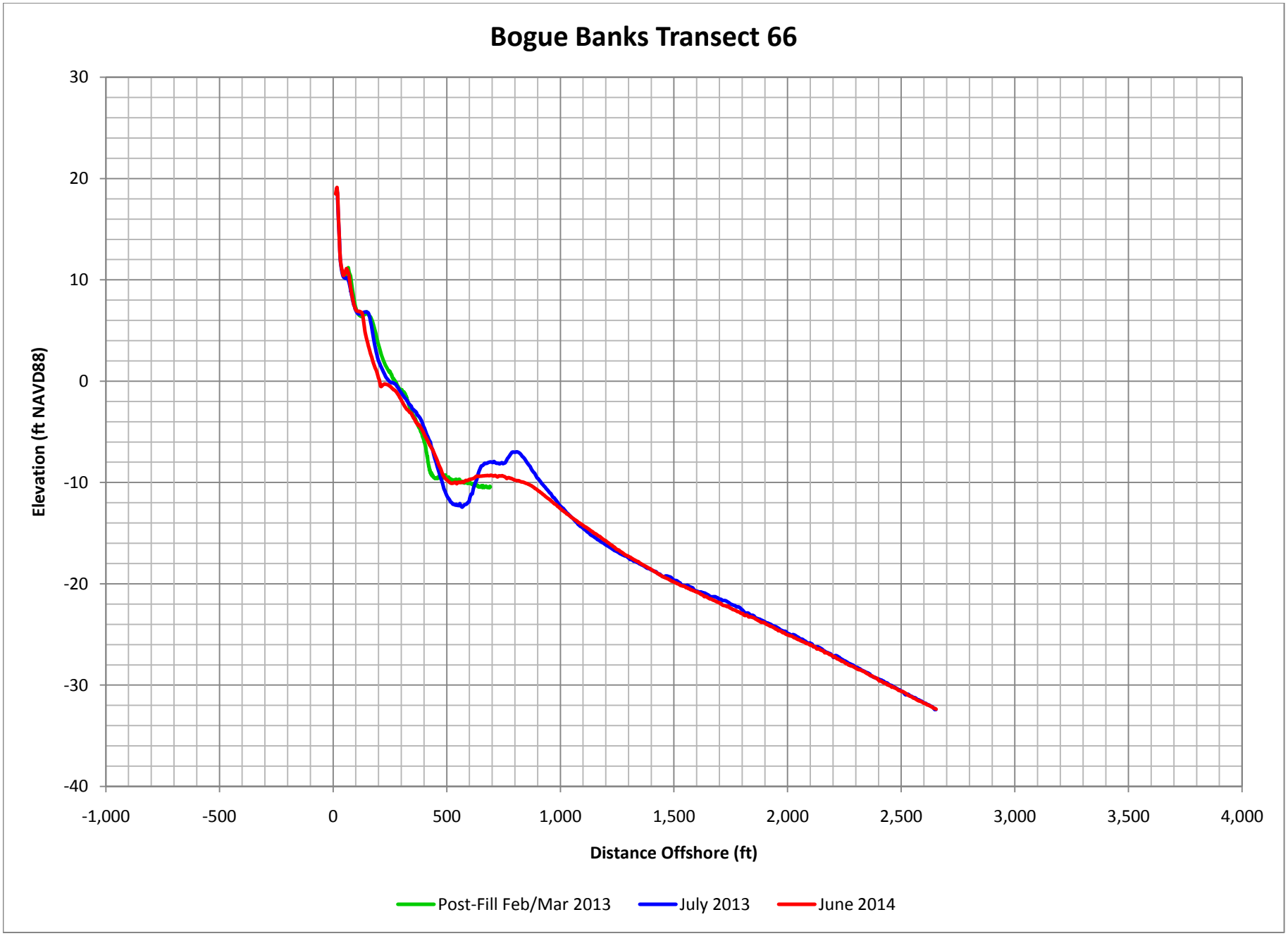


Figure C-88. Bogue Banks Profile Comparison Plot

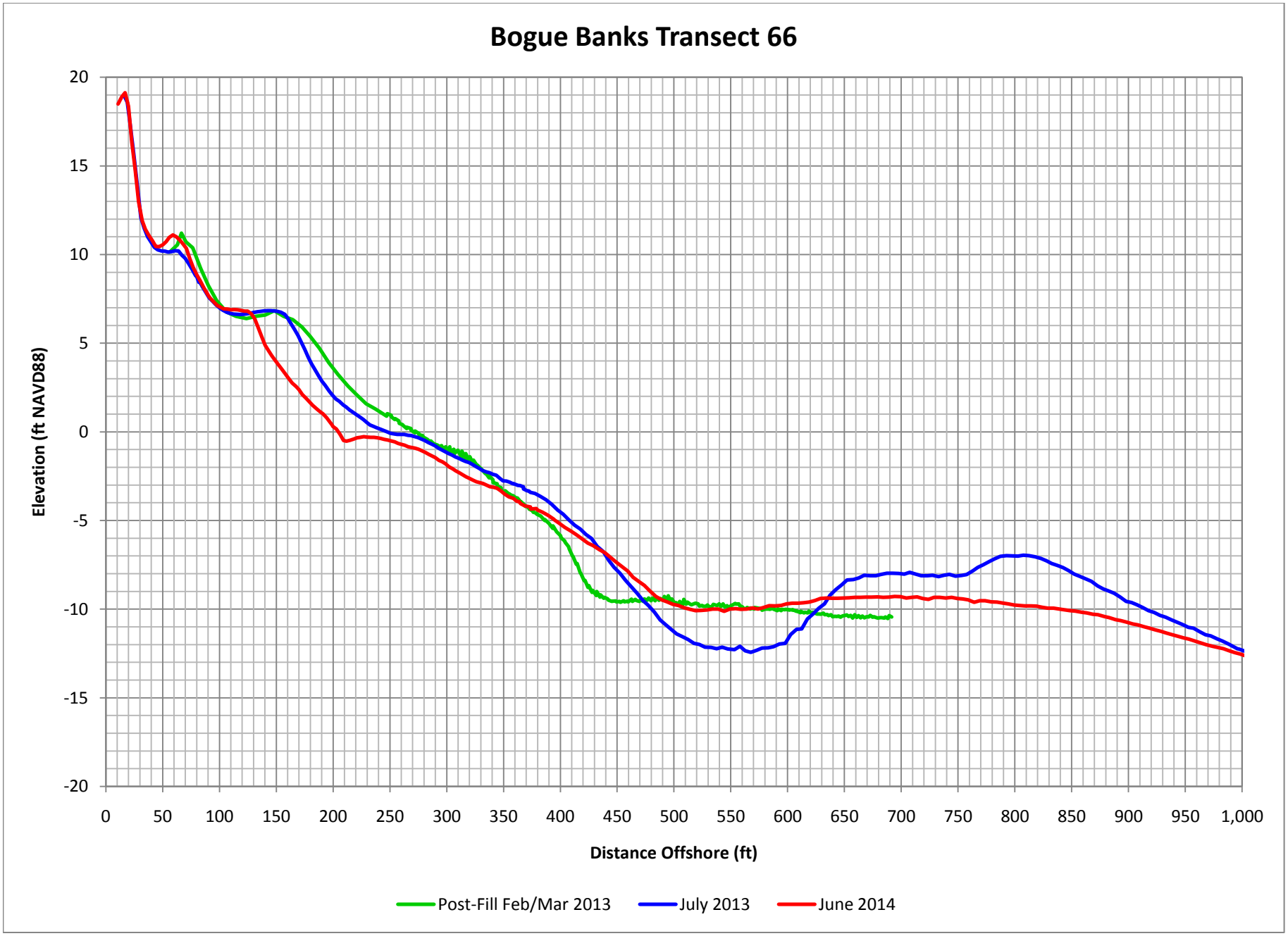


Figure C-89. Bogue Banks Profile Comparison Plot

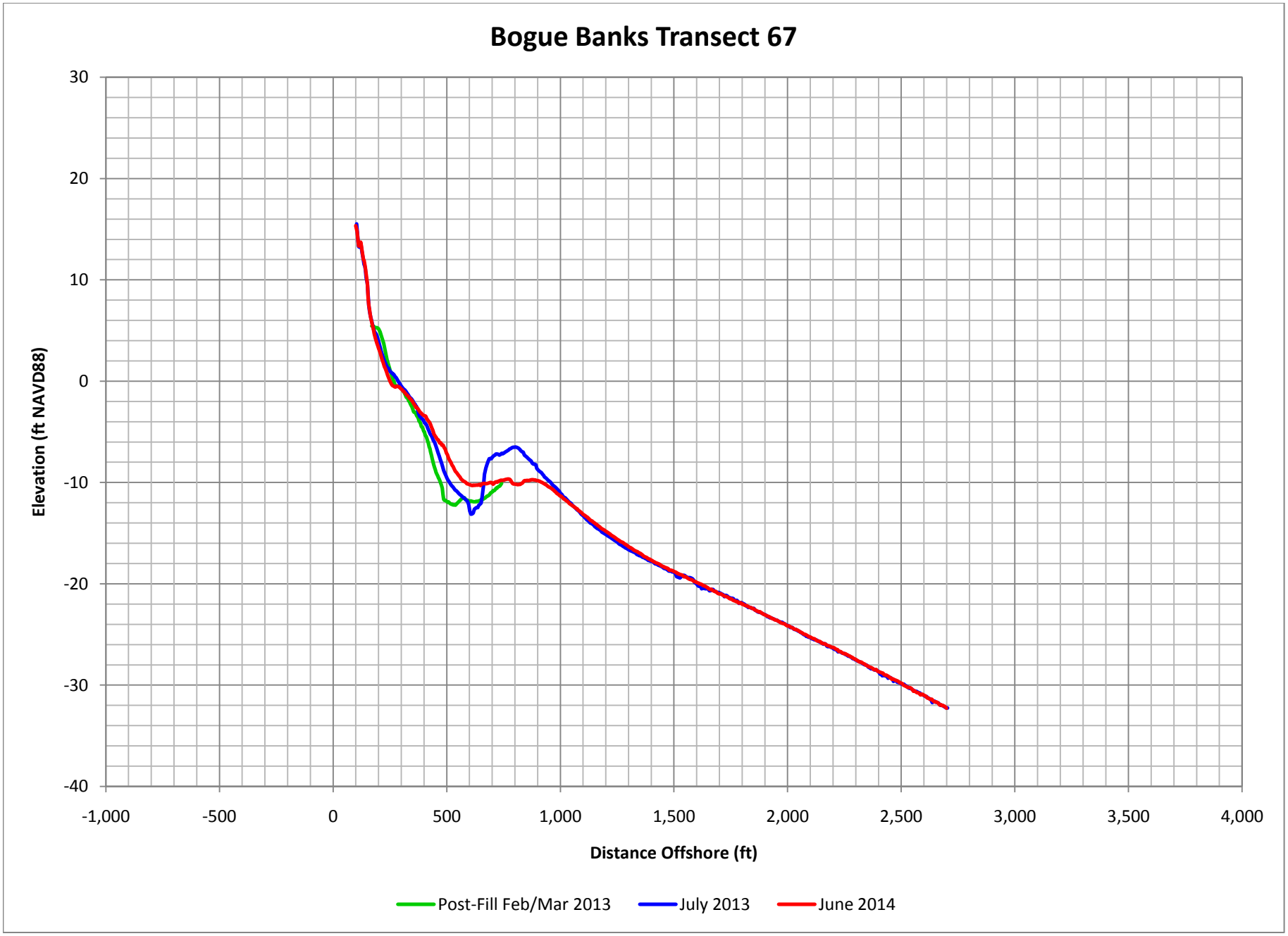


Figure C-90. Bogue Banks Profile Comparison Plot

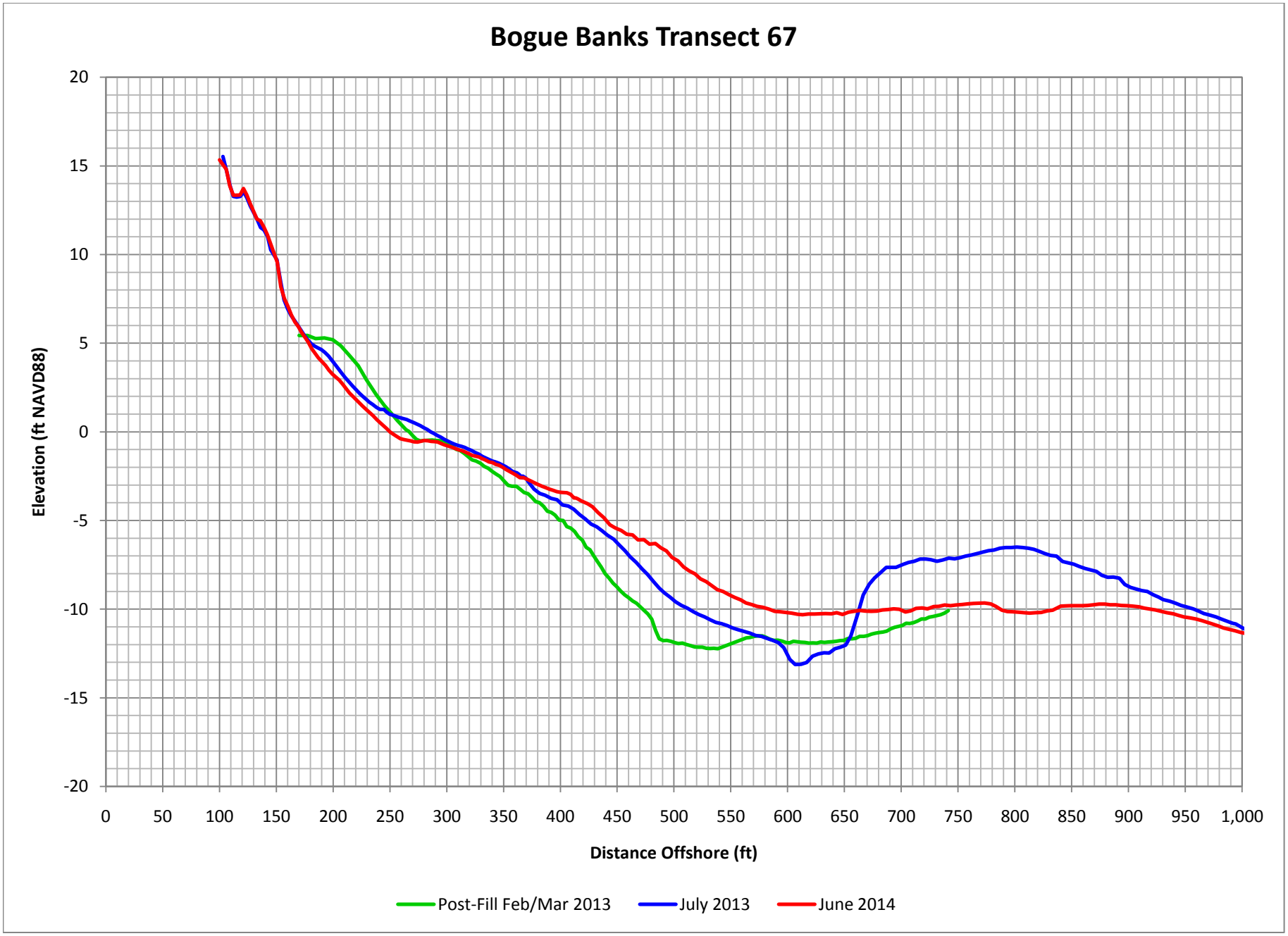


Figure C-91. Bogue Banks Profile Comparison Plot

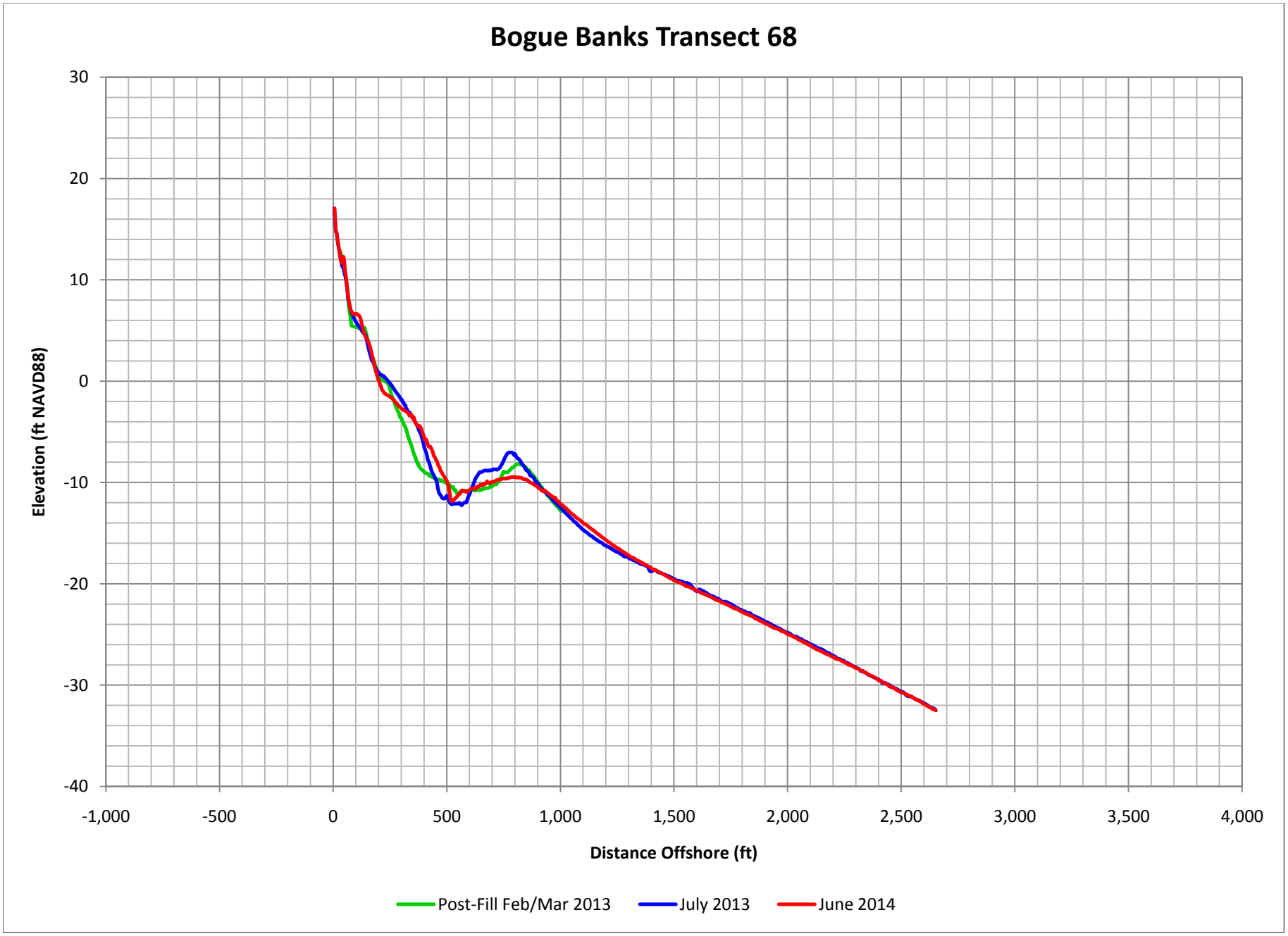


Figure C-92. Bogue Banks Profile Comparison Plot

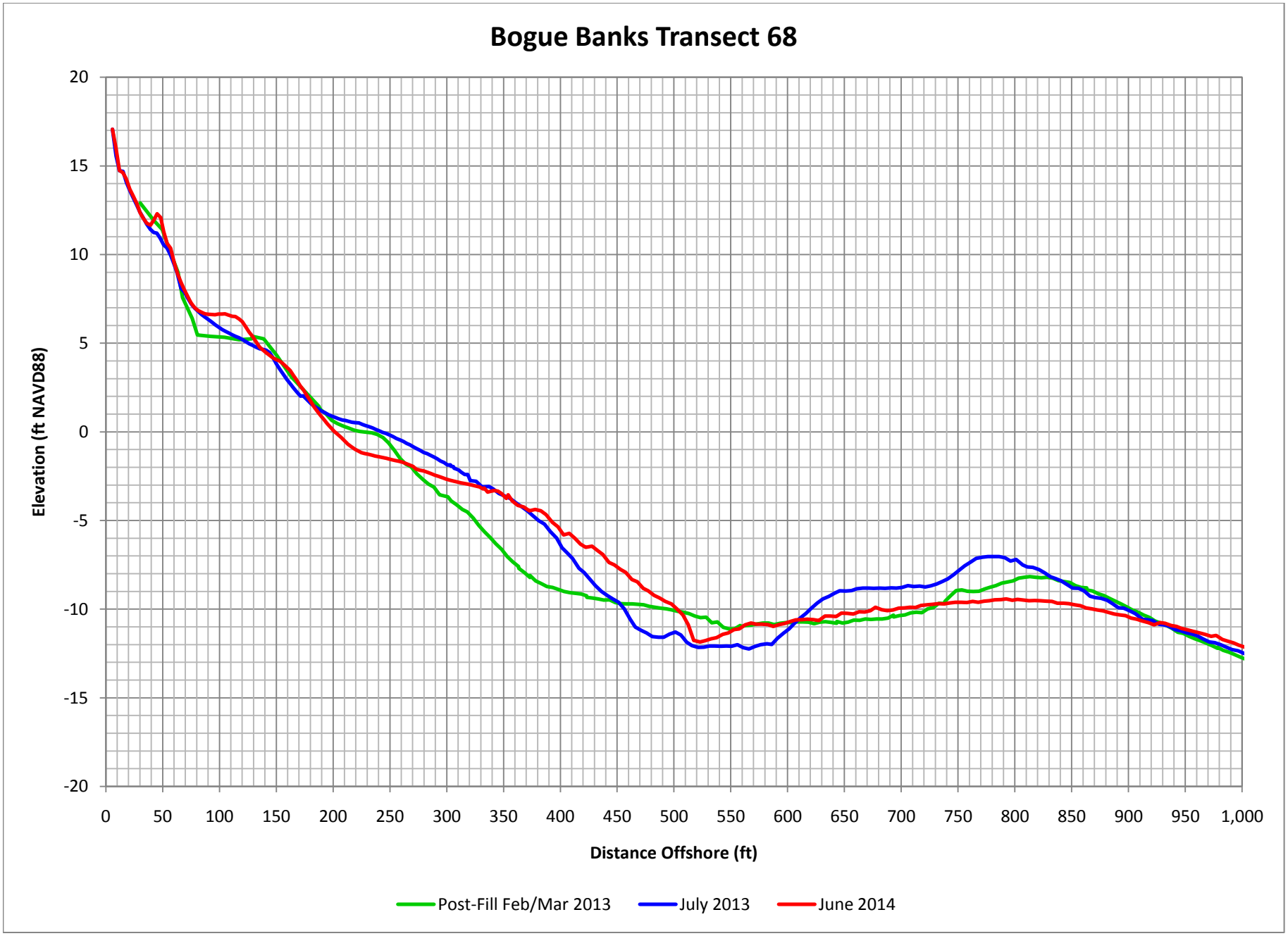


Figure C-93. Bogue Banks Profile Comparison Plot

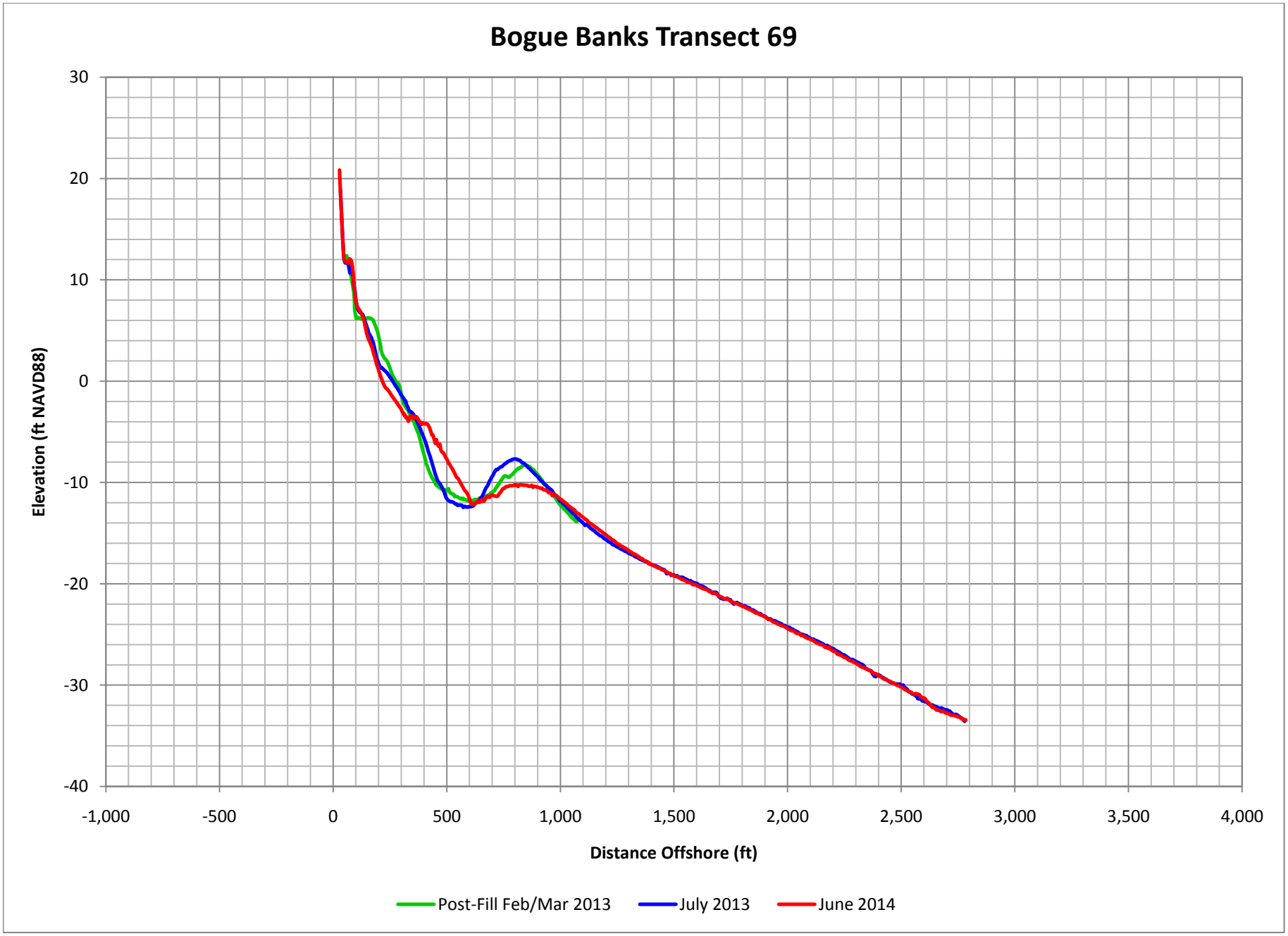


Figure C-94. Bogue Banks Profile Comparison Plot

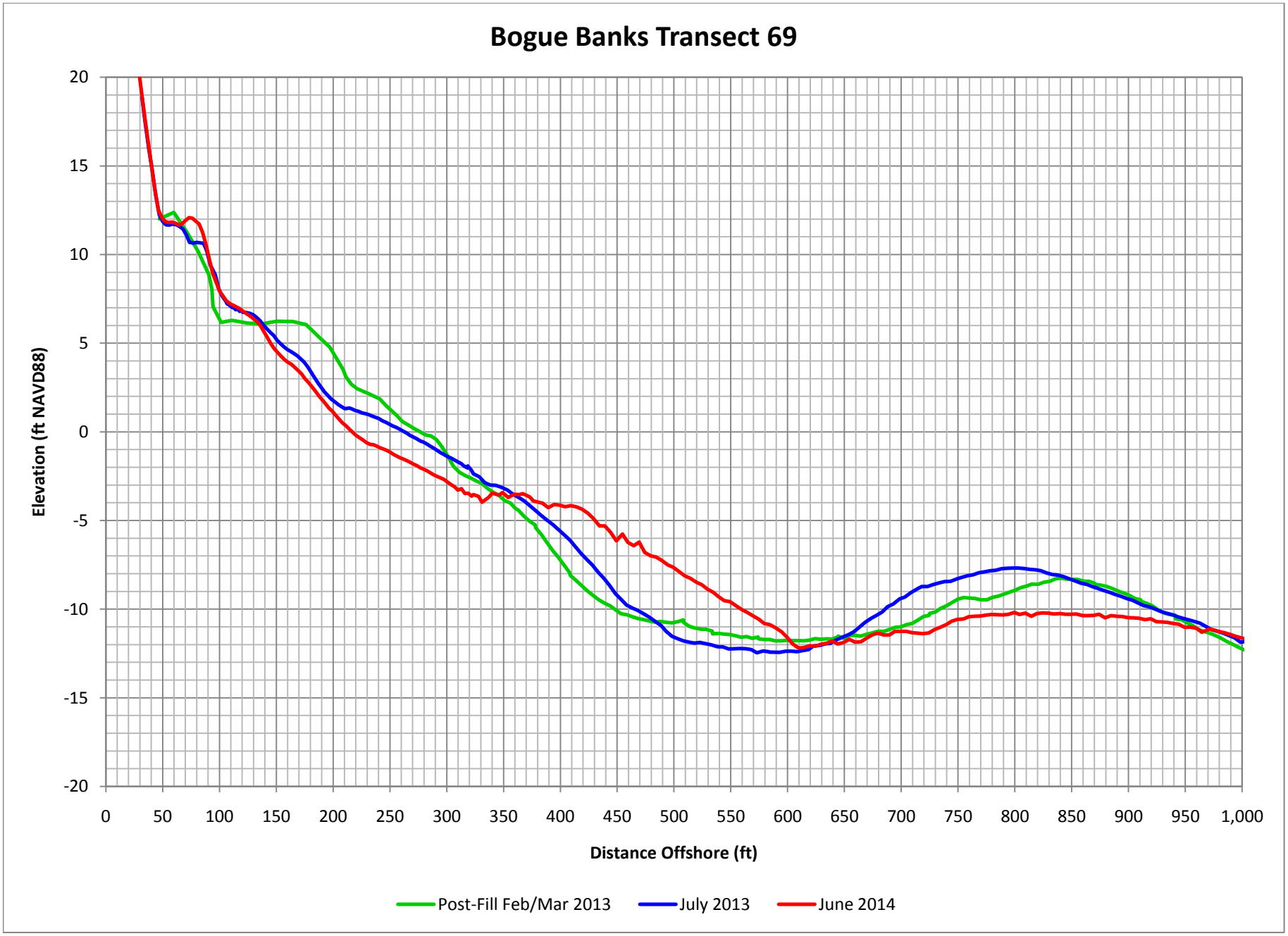


Figure C-95. Bogue Banks Profile Comparison Plot

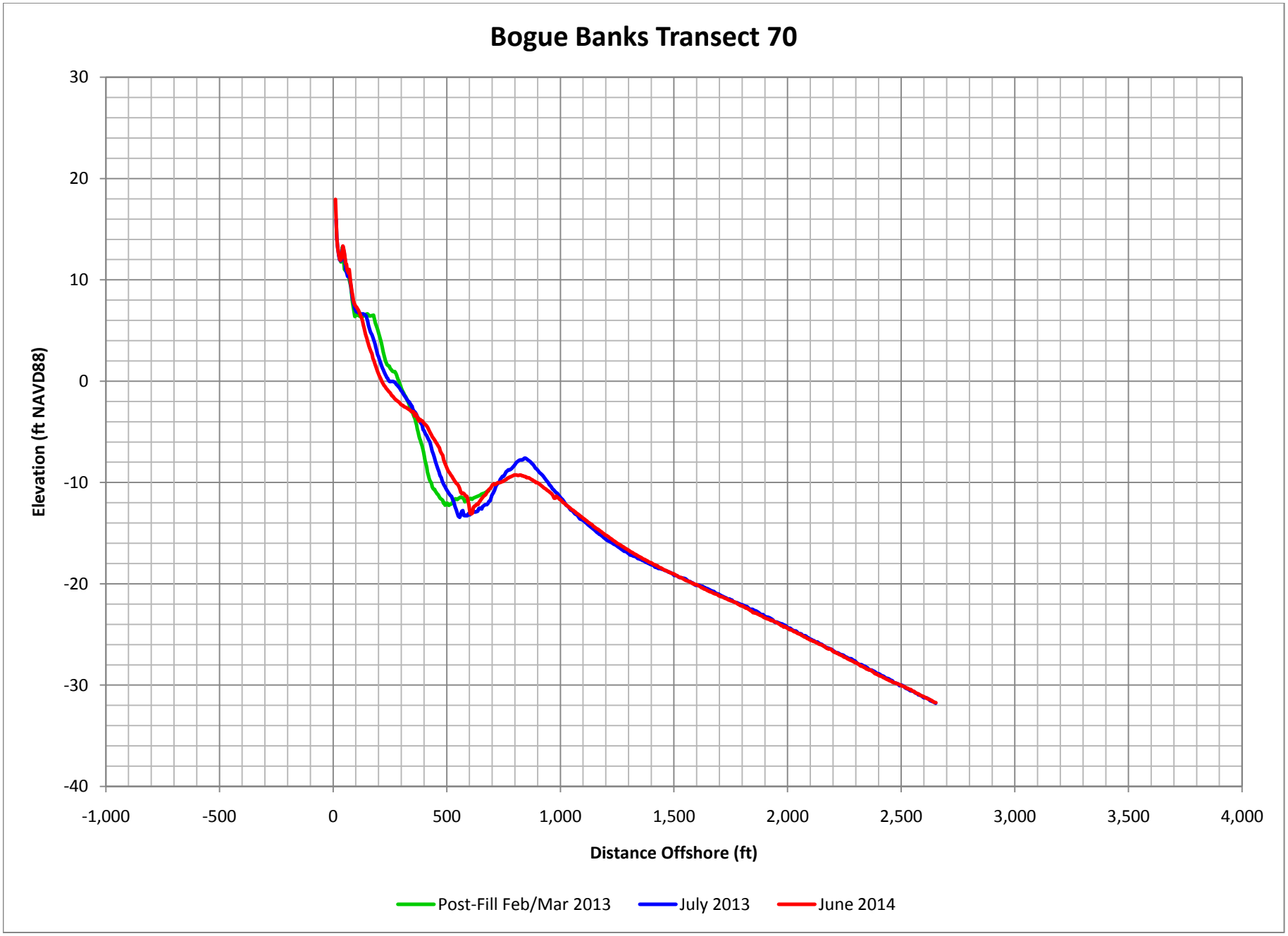
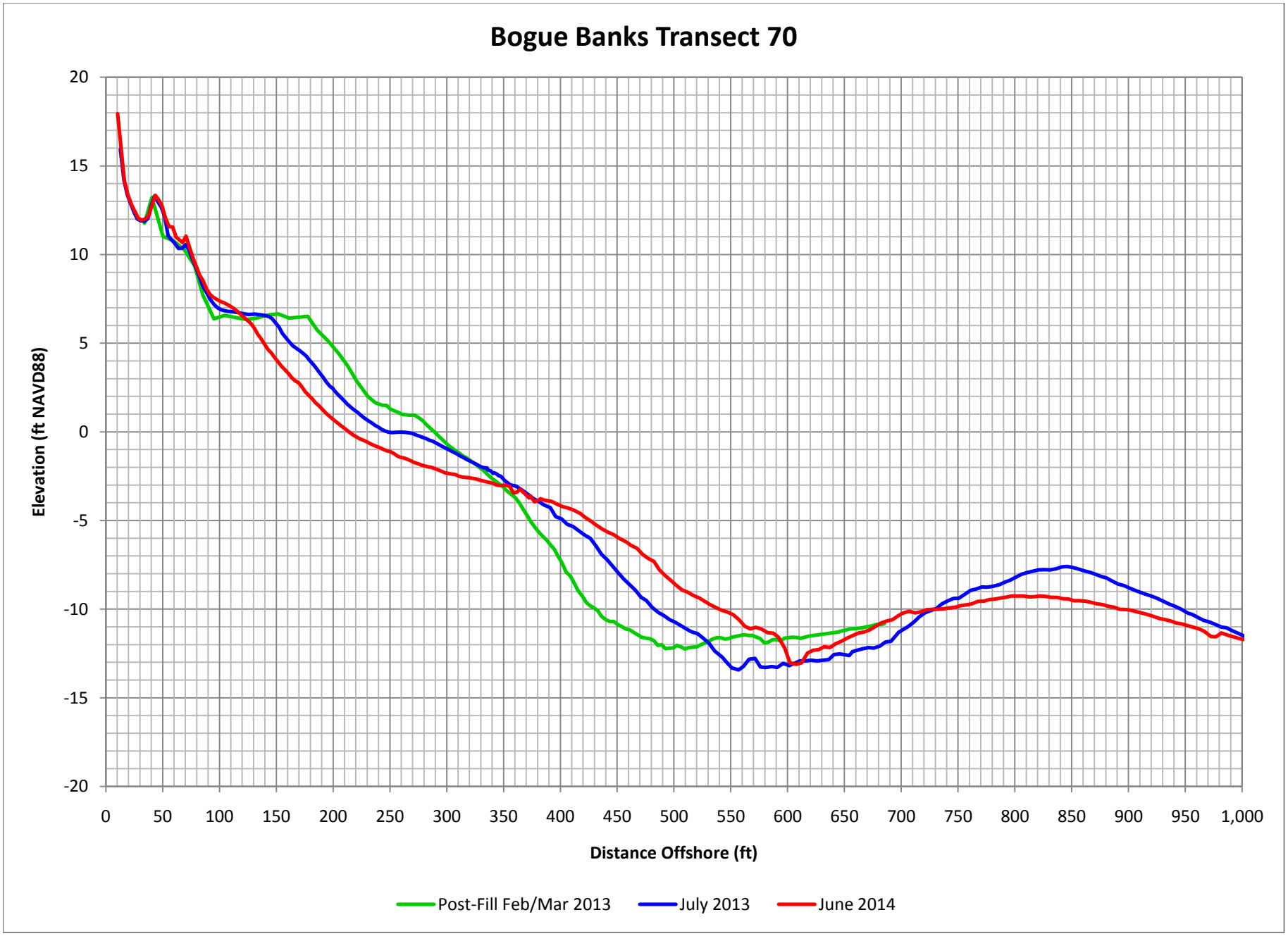


Figure C-96. Bogue Banks Profile Comparison Plot



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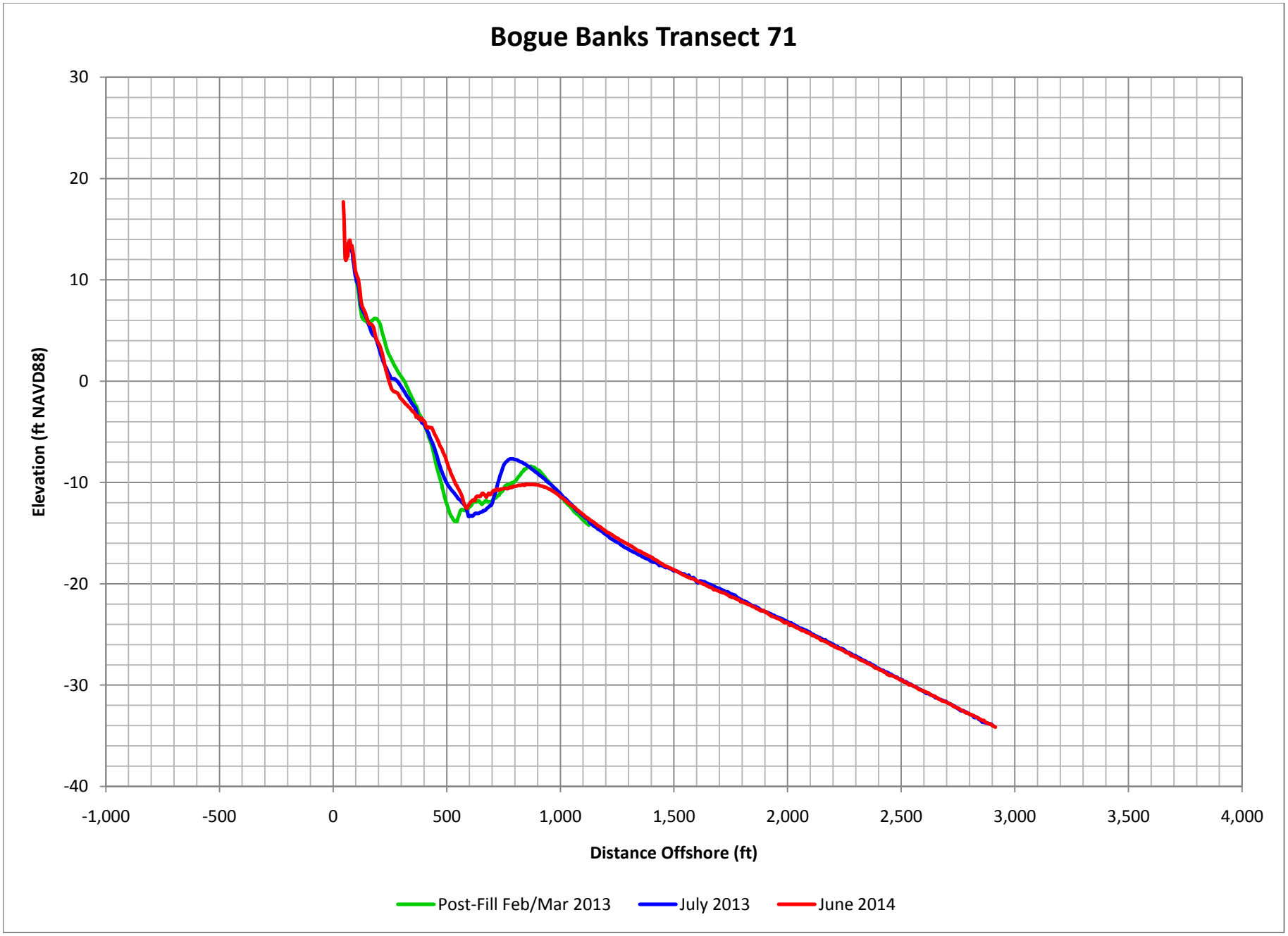

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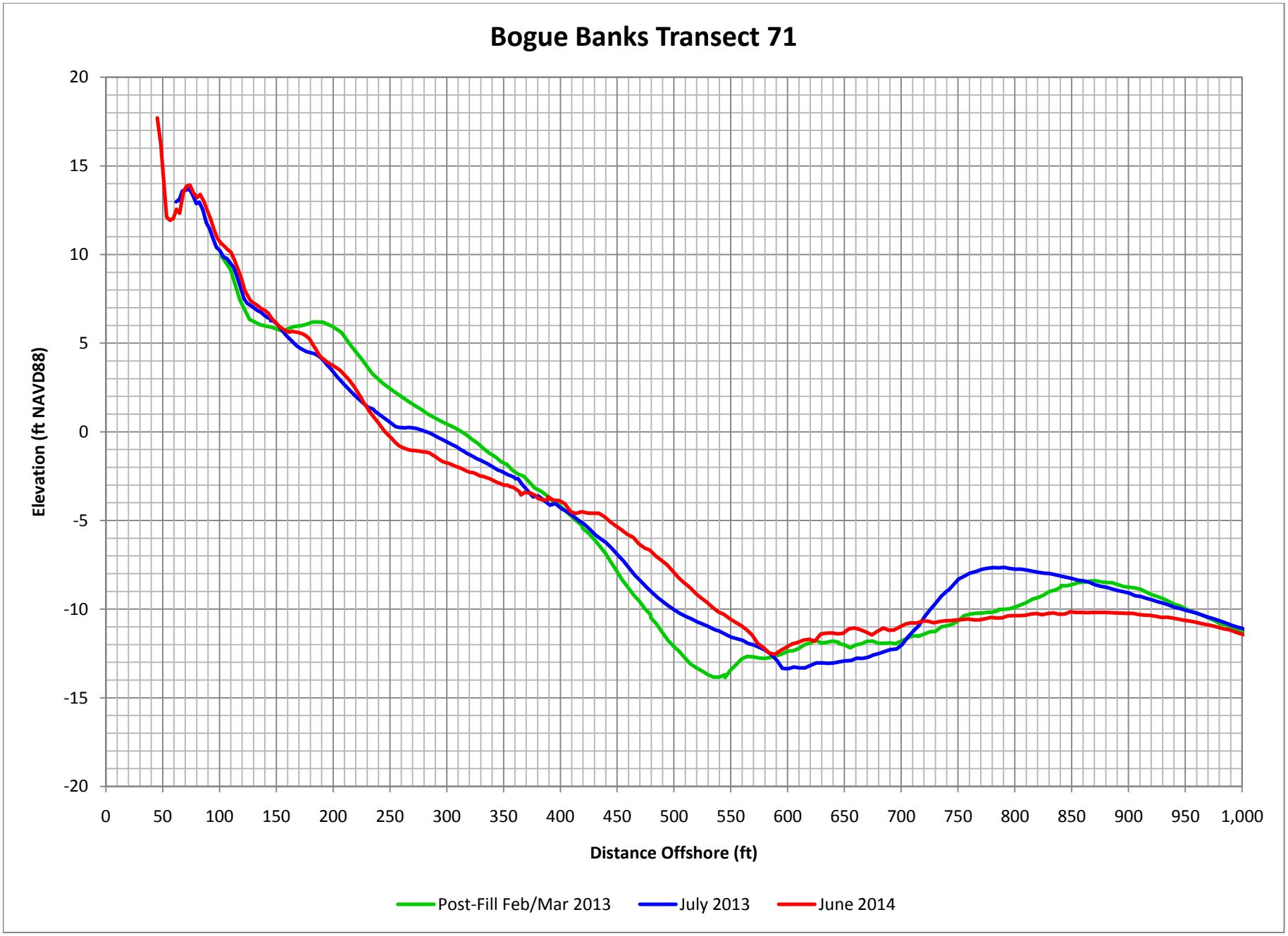

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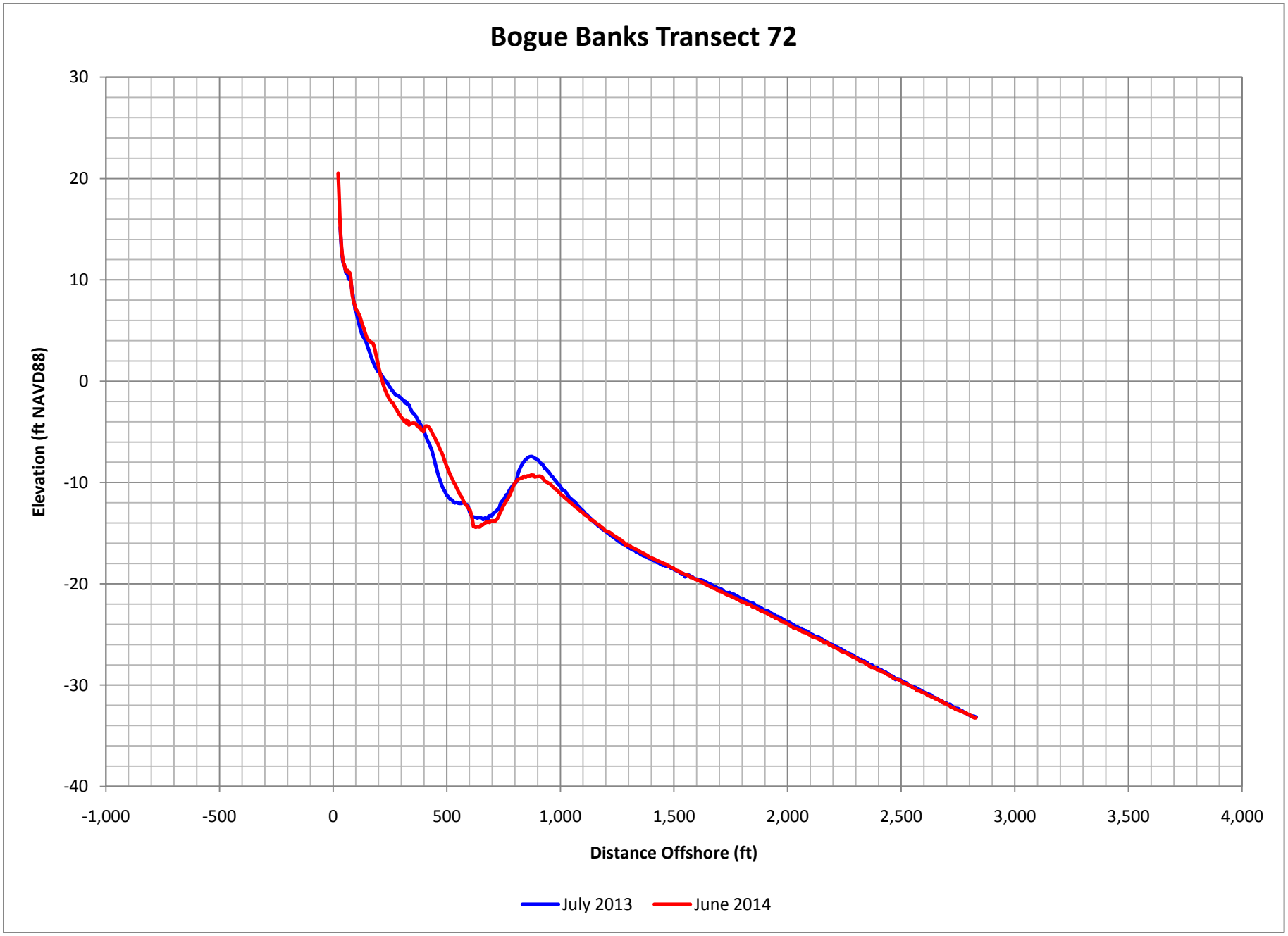


Figure C-100. Bogue Banks Profile Comparison Plot

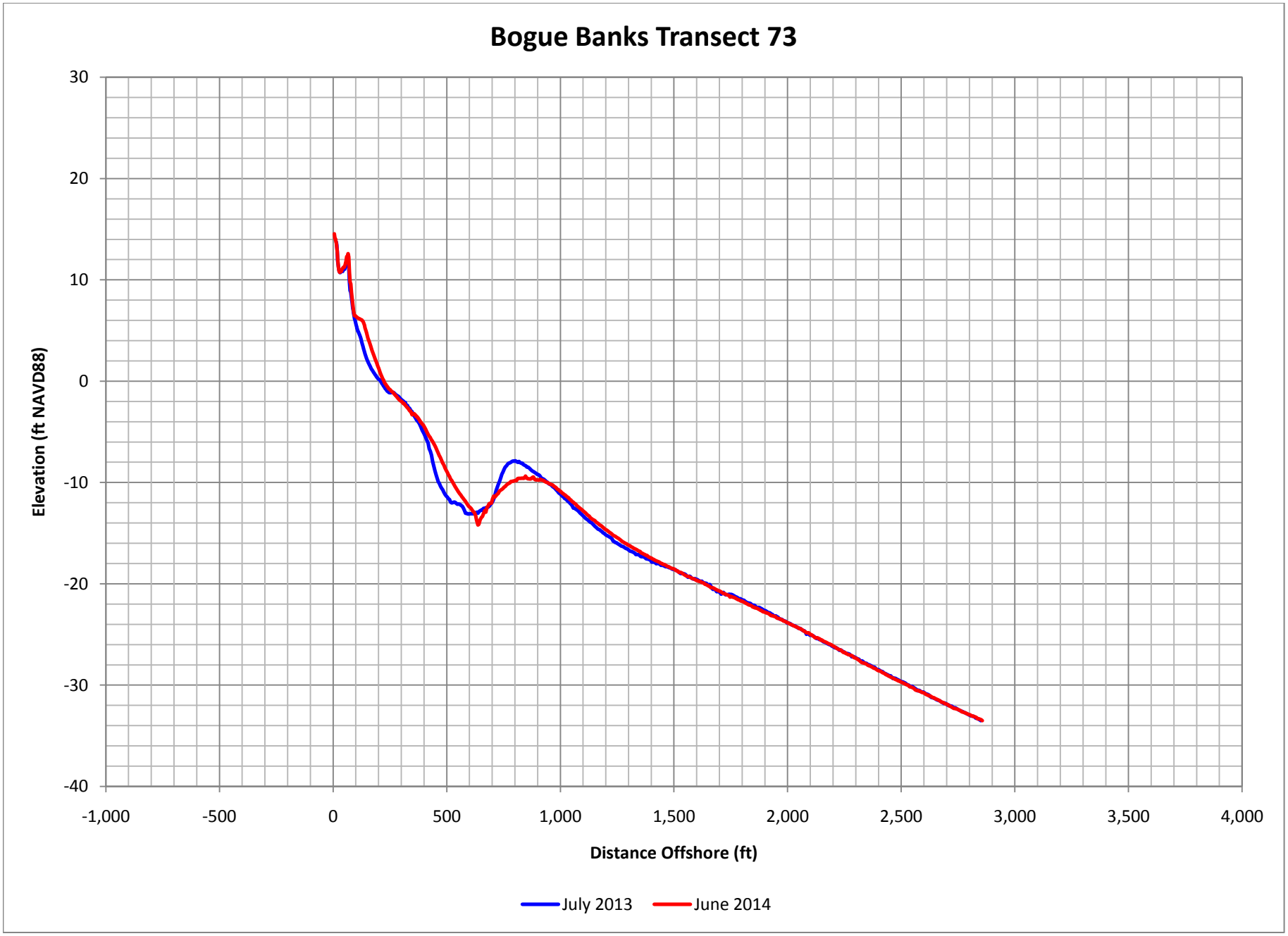


Figure C-101. Bogue Banks Profile Comparison Plot

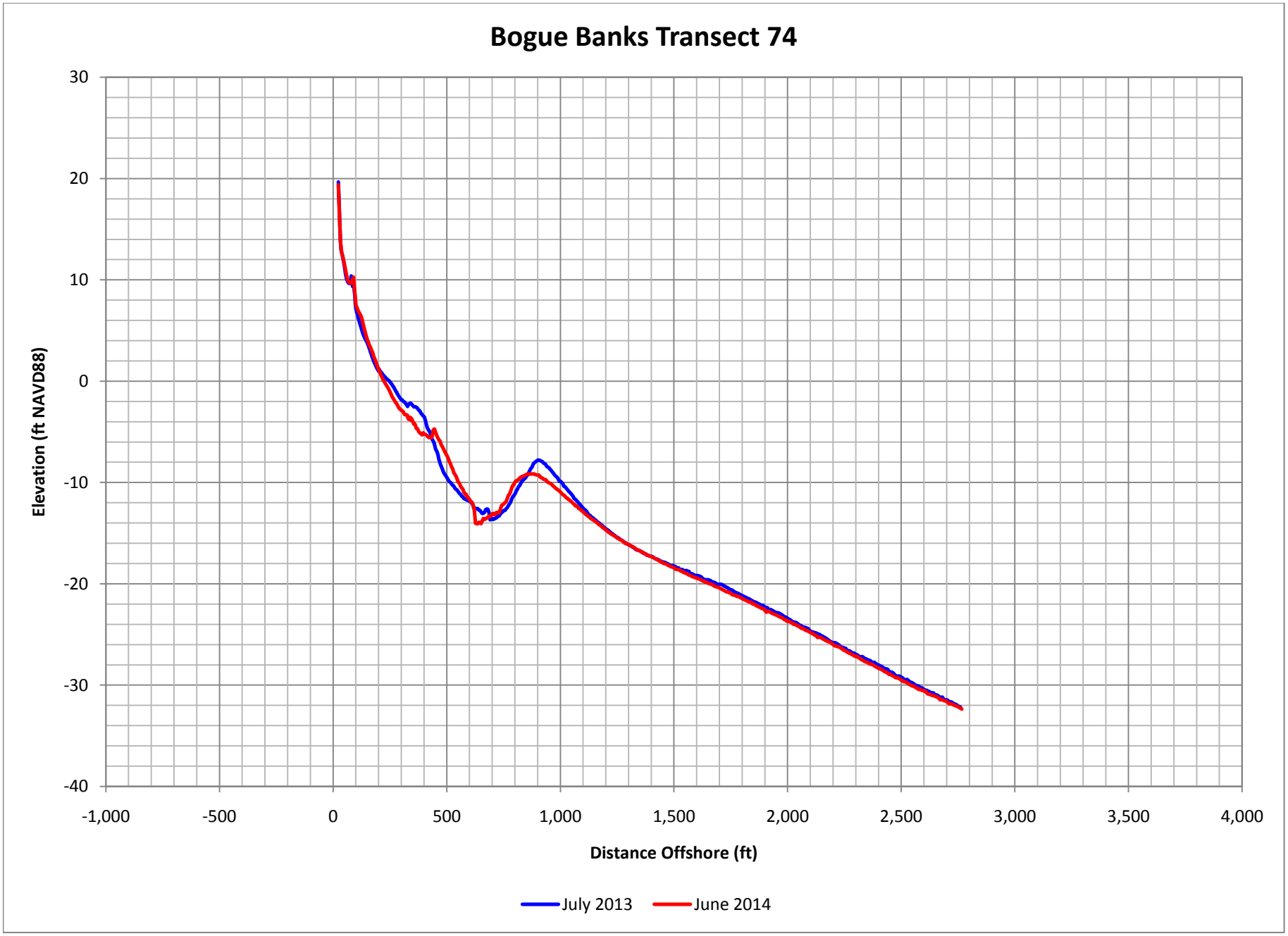


Figure C-102. Bogue Banks Profile Comparison Plot

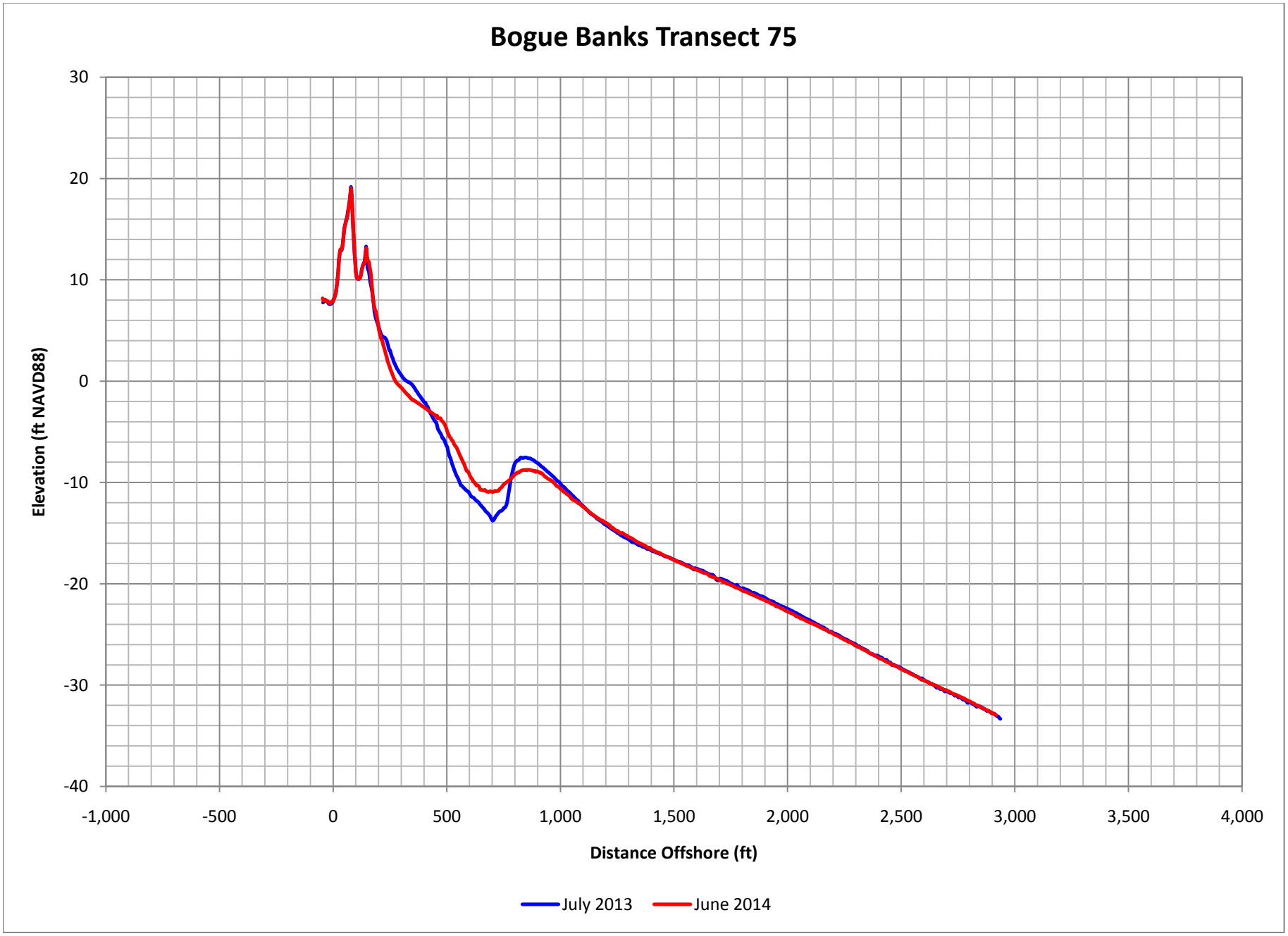


Figure C-103. Bogue Banks Profile Comparison Plot

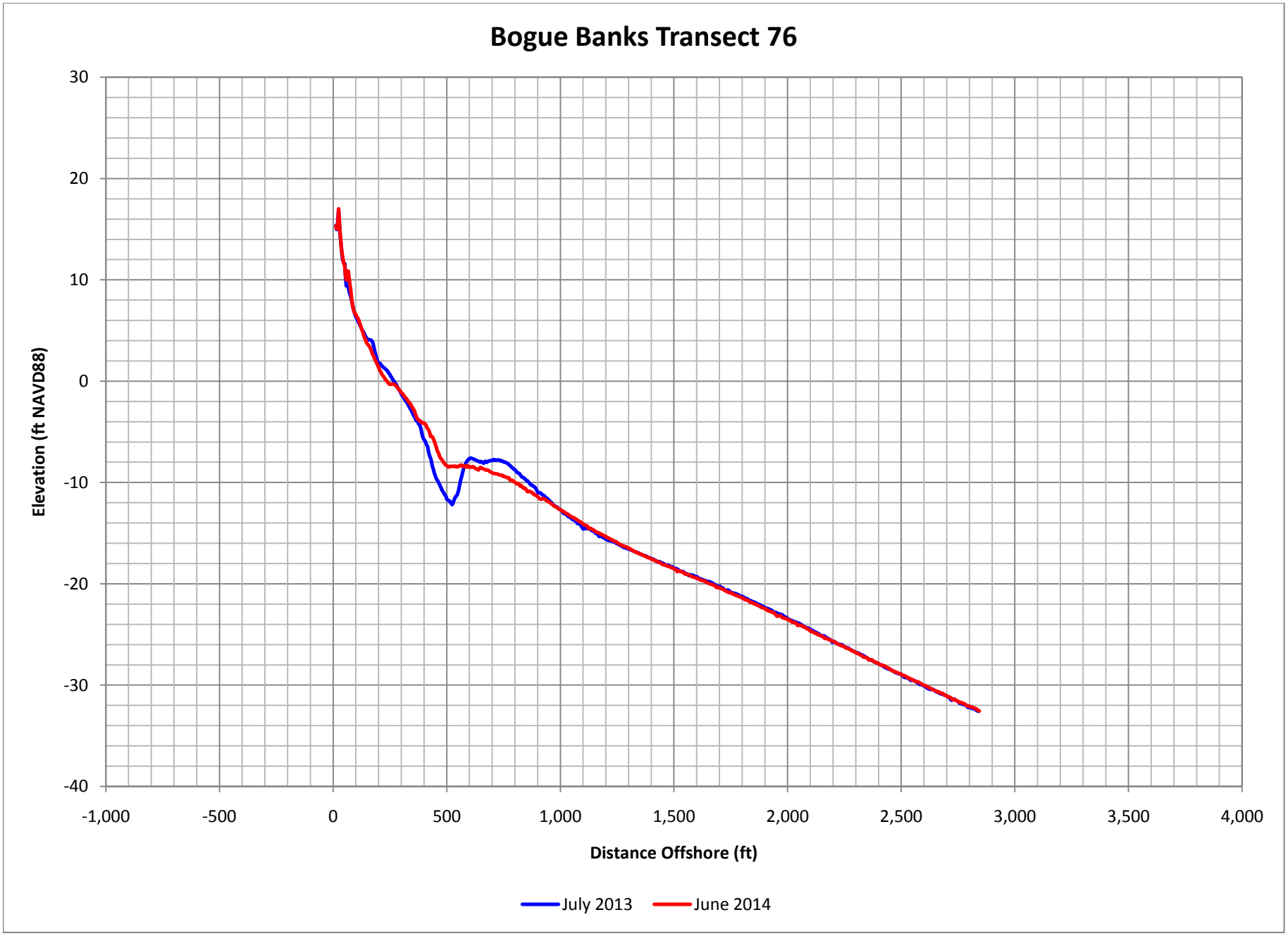


Figure C-104. Bogue Banks Profile Comparison Plot

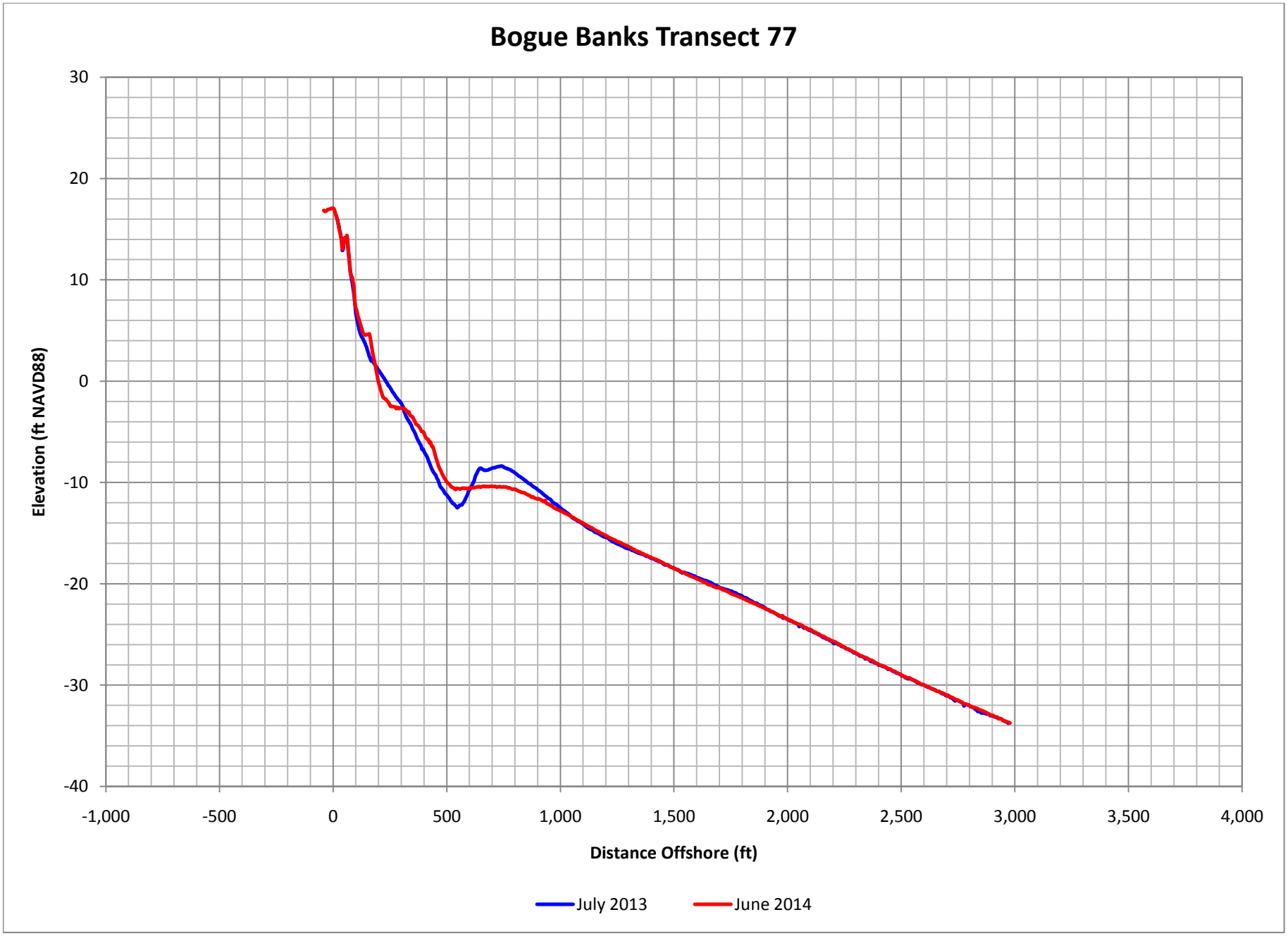


Figure C-105. Bogue Banks Profile Comparison Plot

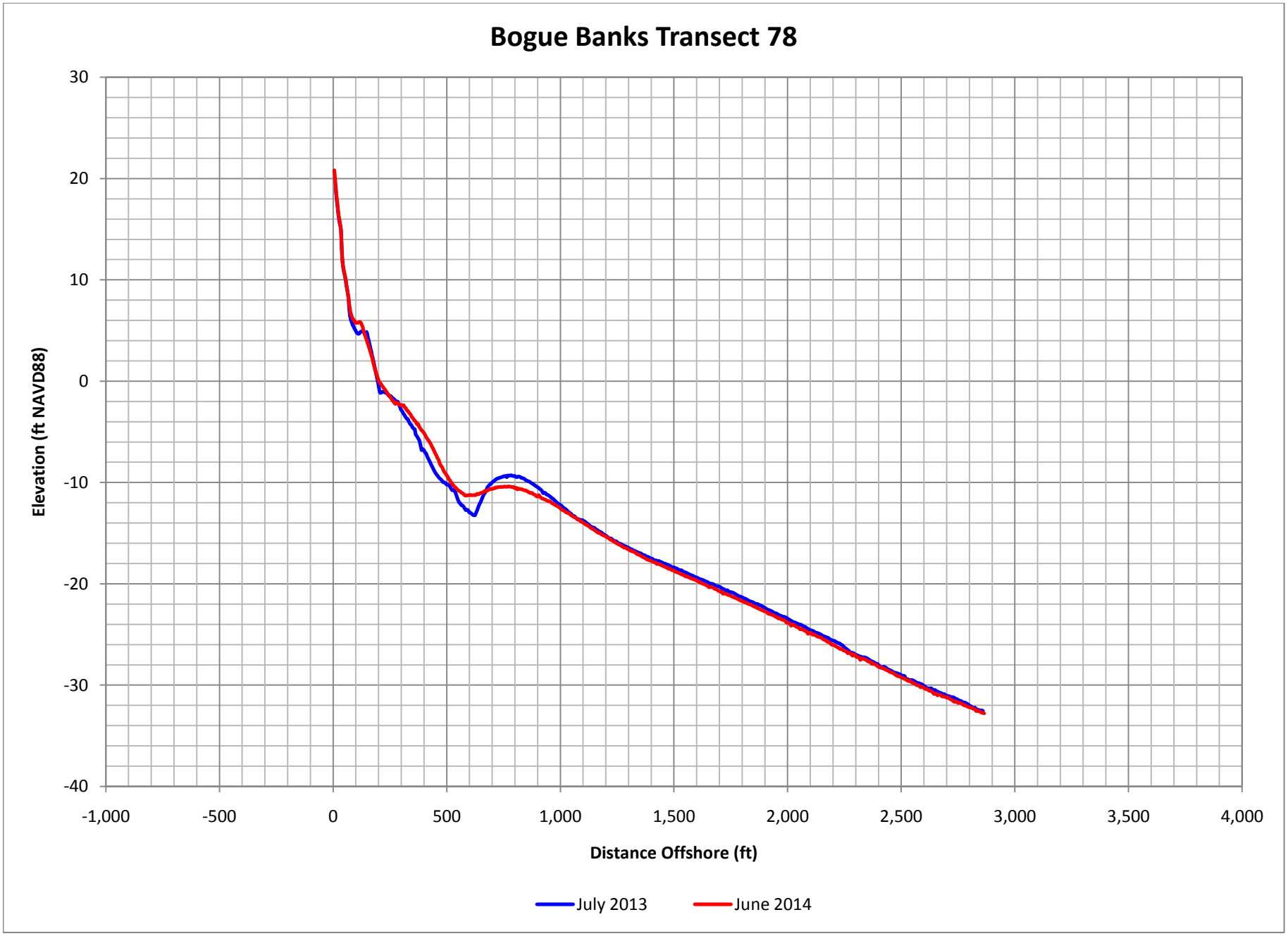


Figure C-106. Bogue Banks Profile Comparison Plot

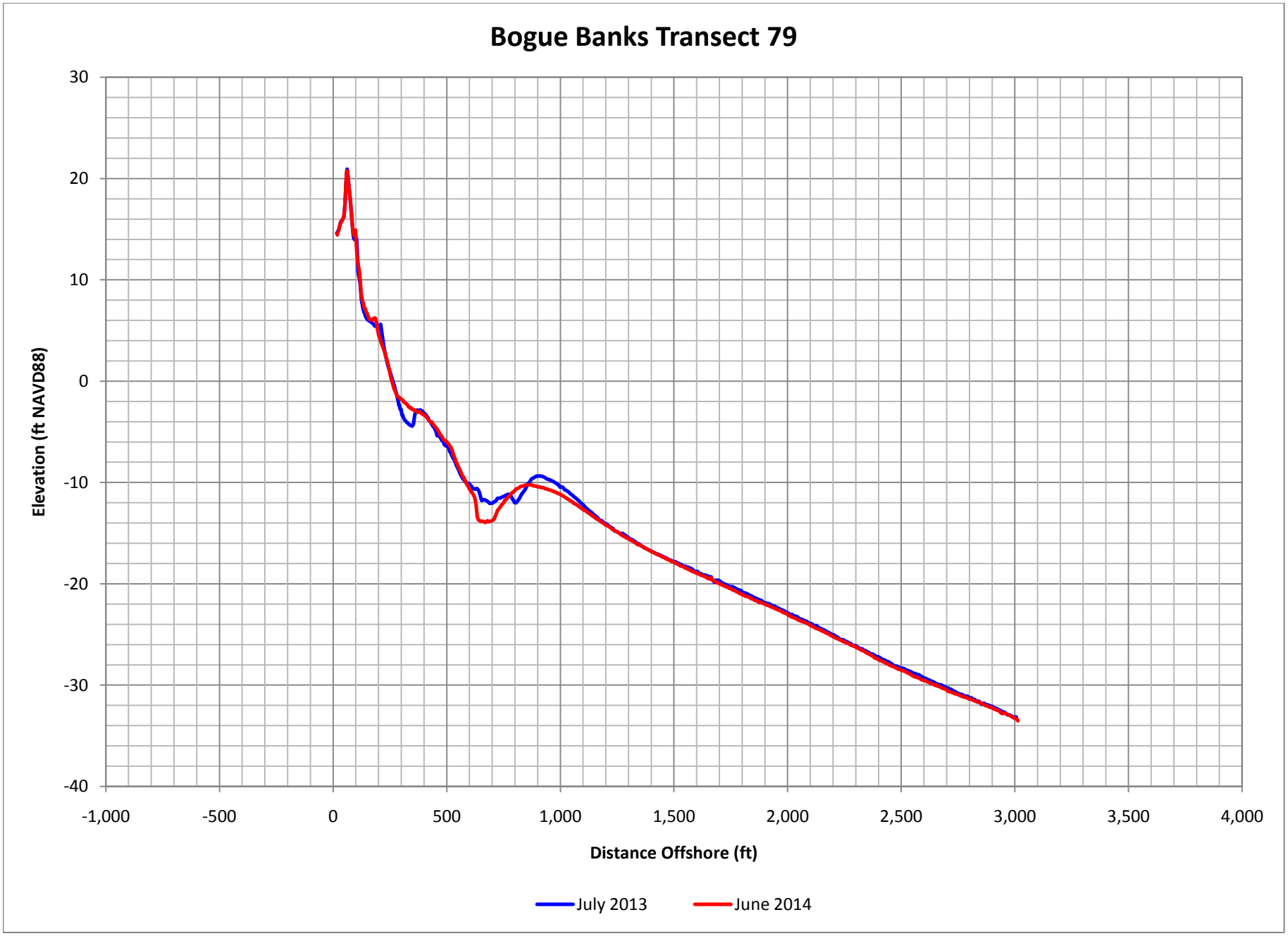


Figure C-107. Bogue Banks Profile Comparison Plot

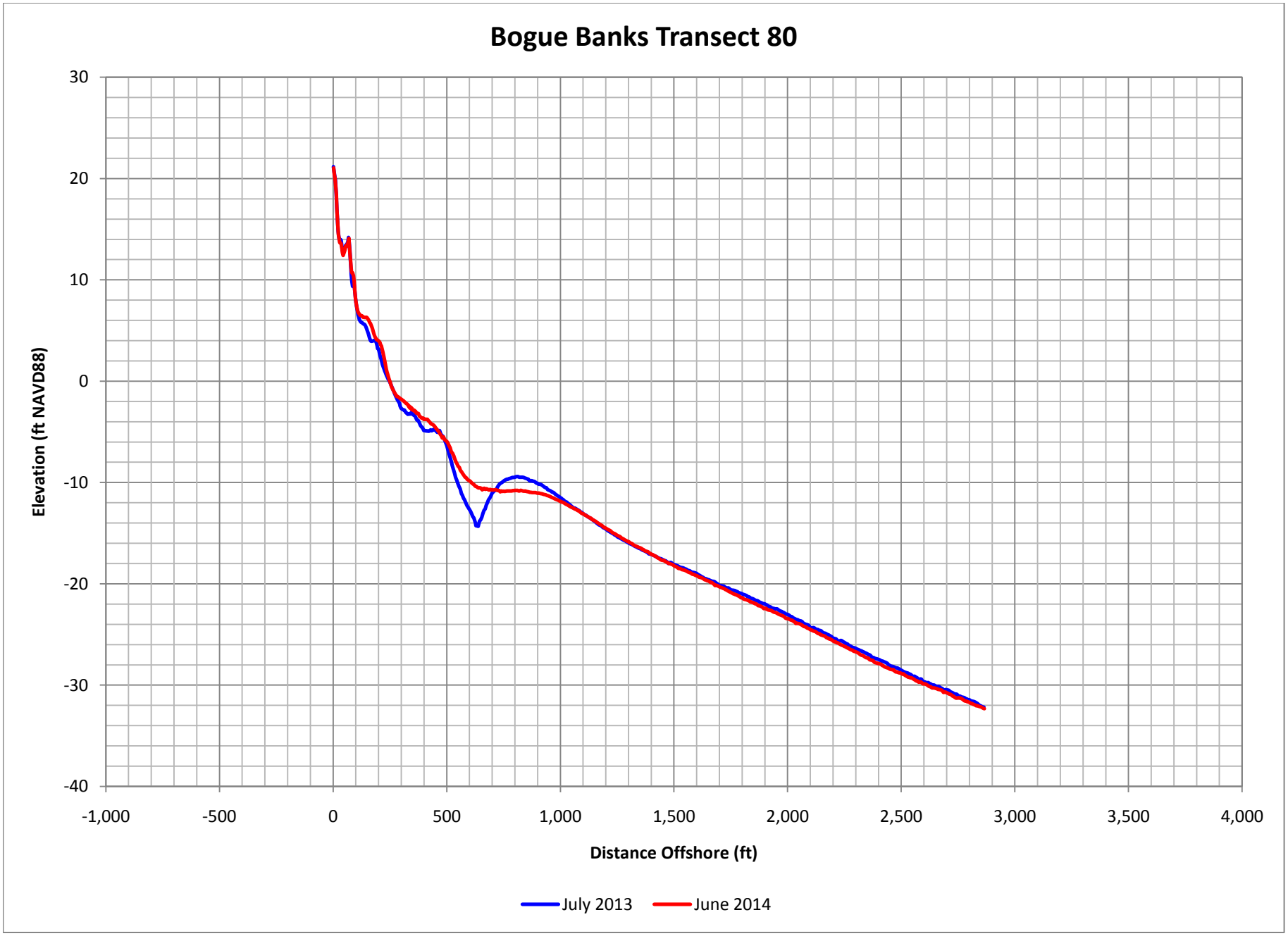


Figure C-108. Bogue Banks Profile Comparison Plot

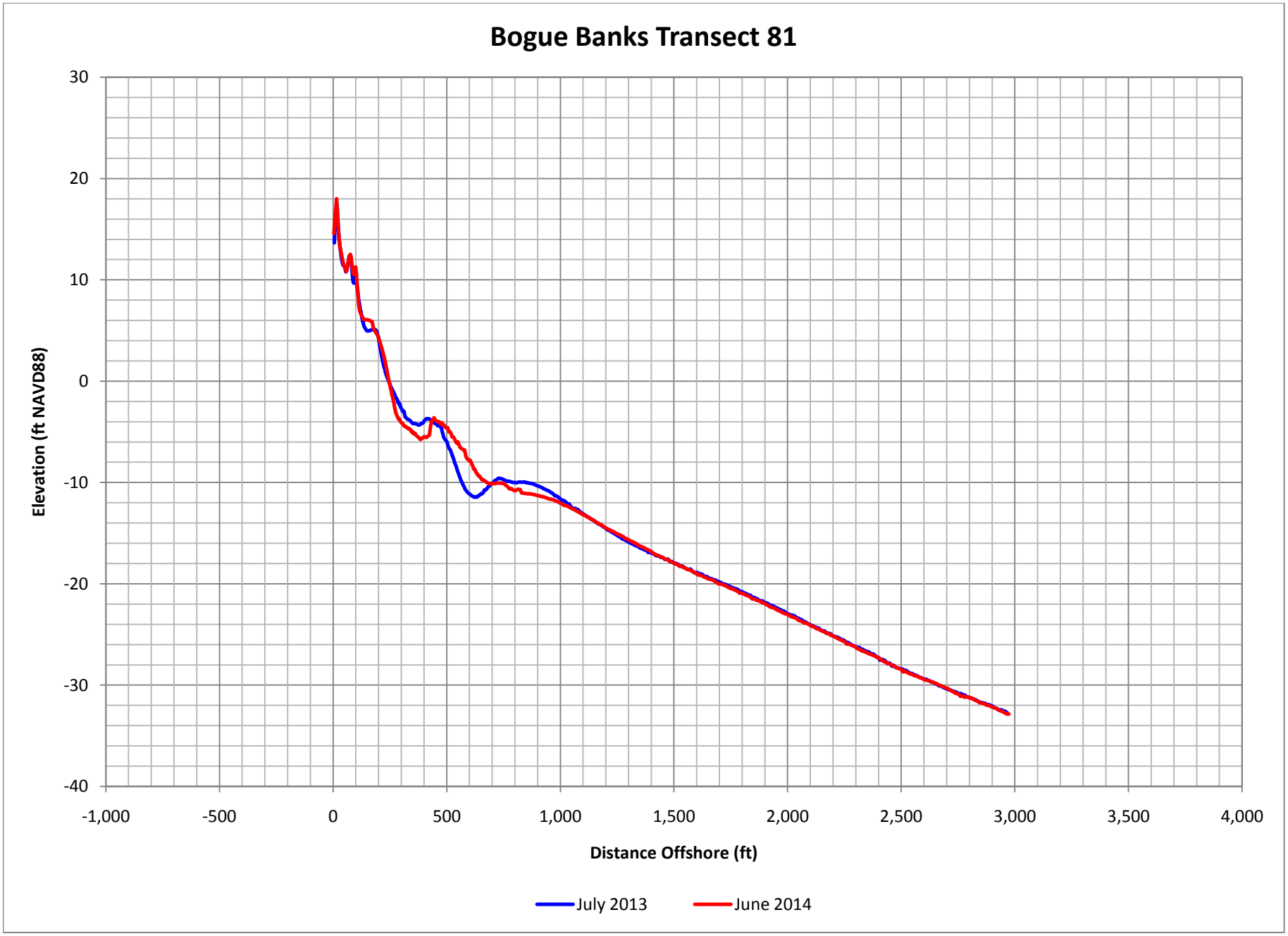


Figure C-109. Bogue Banks Profile Comparison Plot

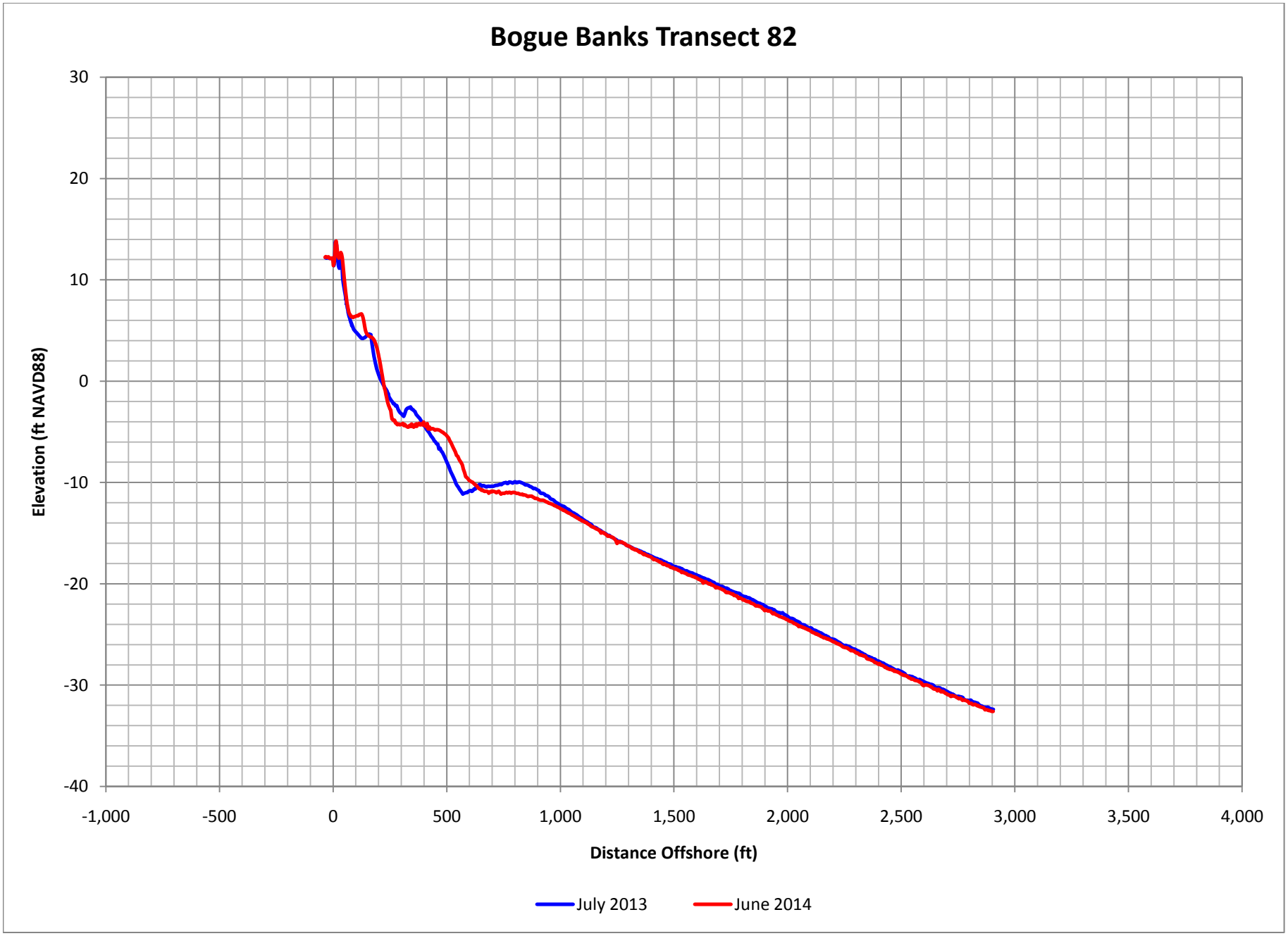


Figure C-110. Bogue Banks Profile Comparison Plot

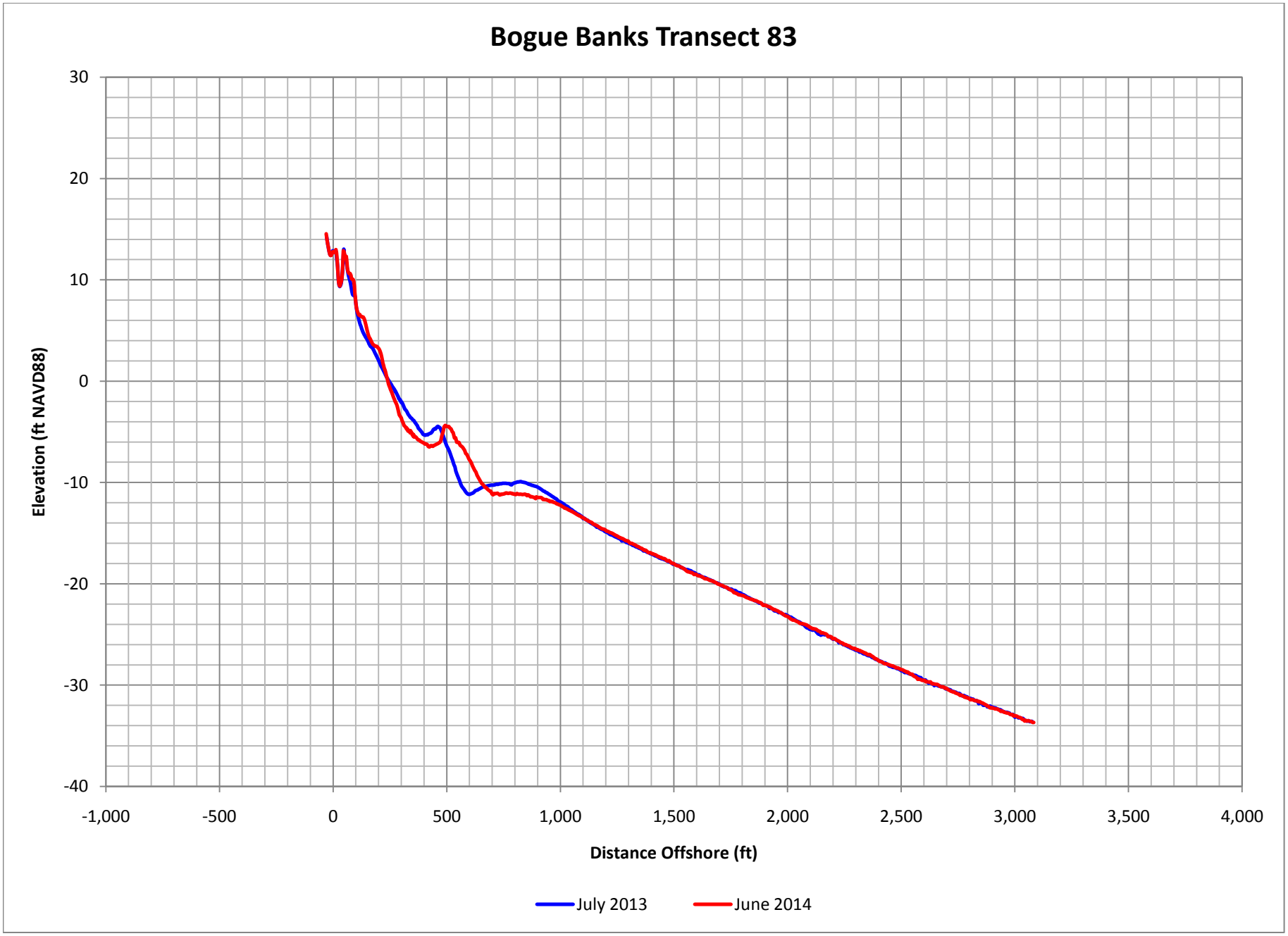


Figure C-111. Bogue Banks Profile Comparison Plot

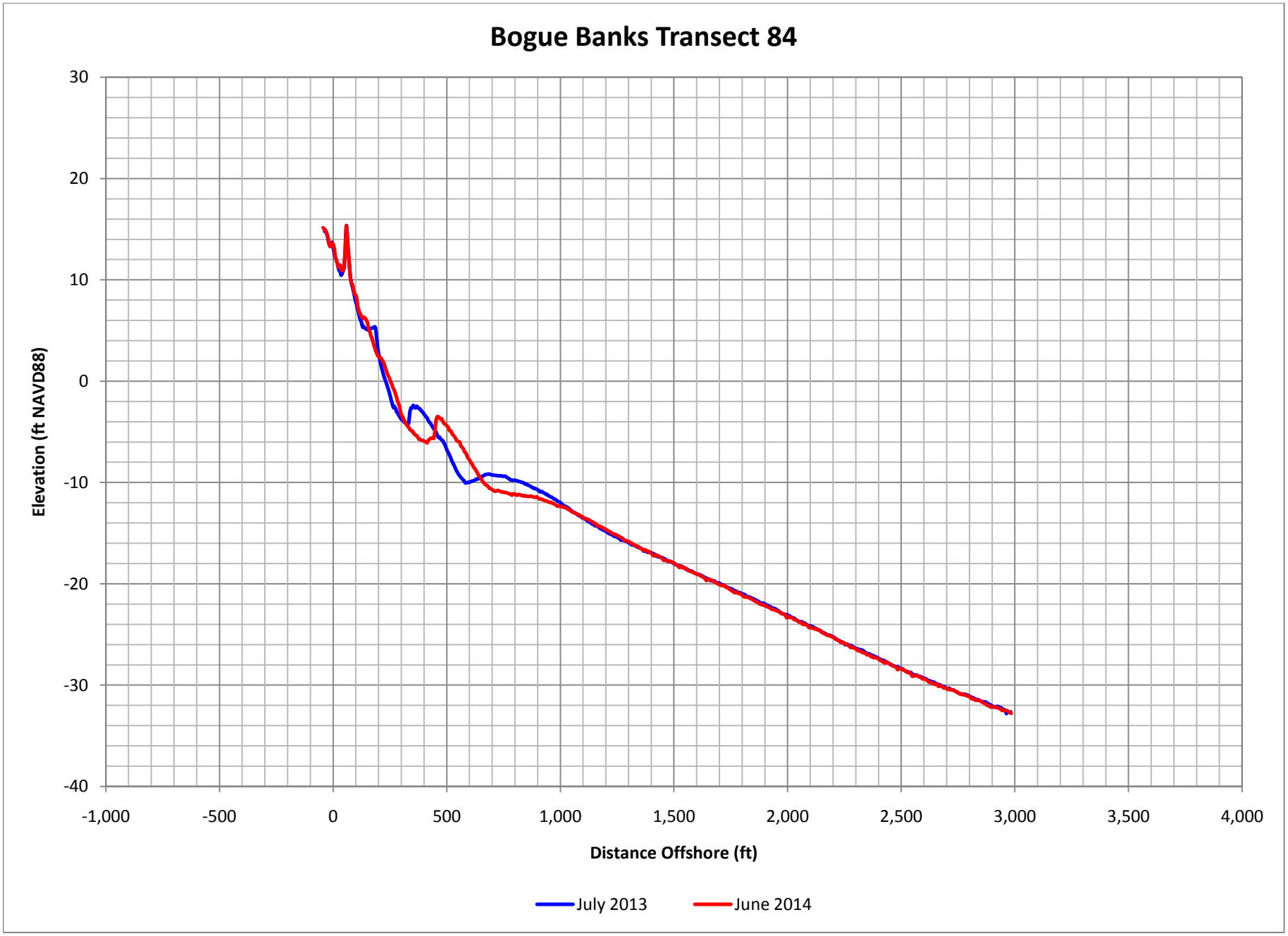


Figure C-112. Bogue Banks Profile Comparison Plot

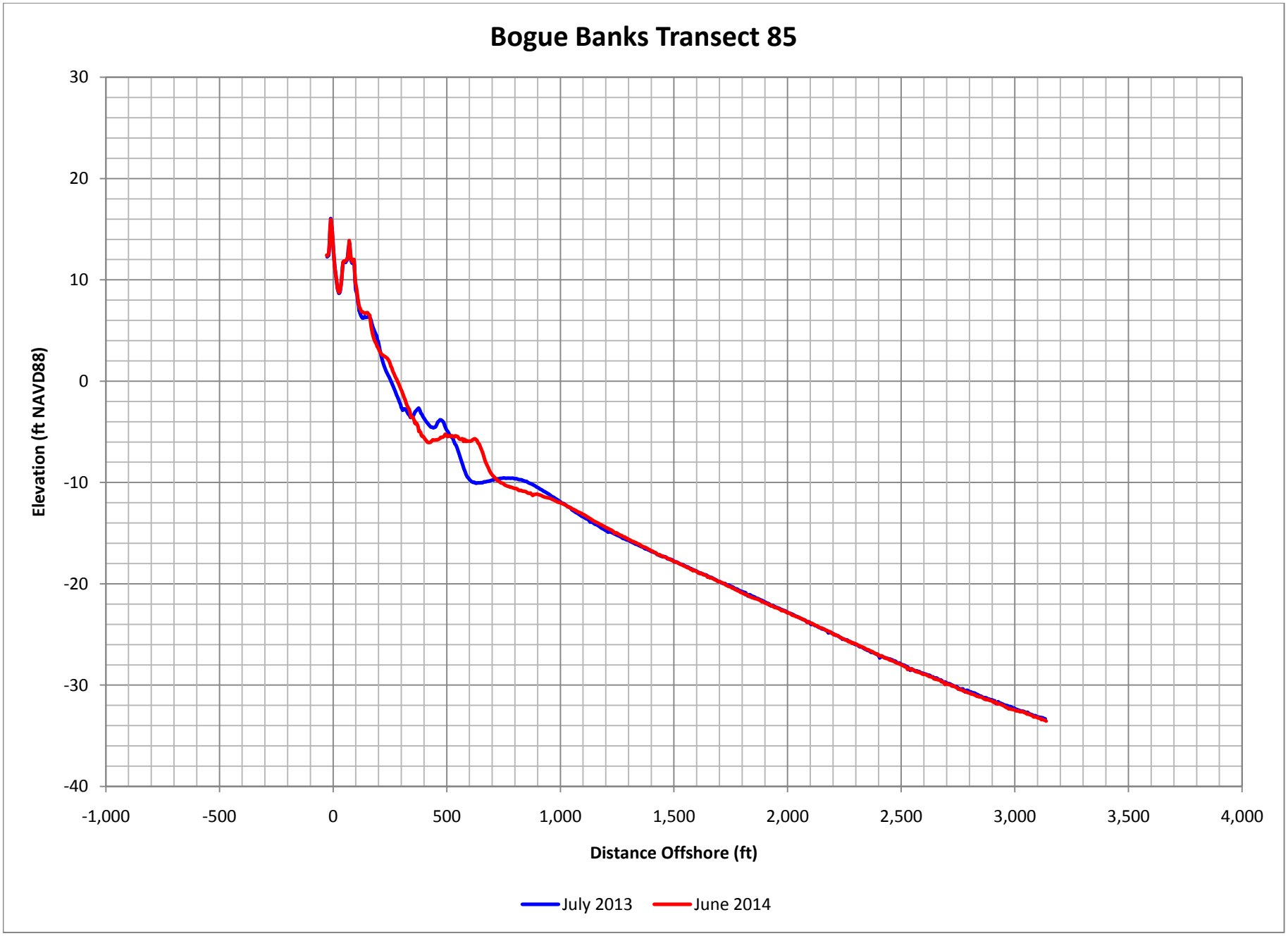


Figure C-113. Bogue Banks Profile Comparison Plot

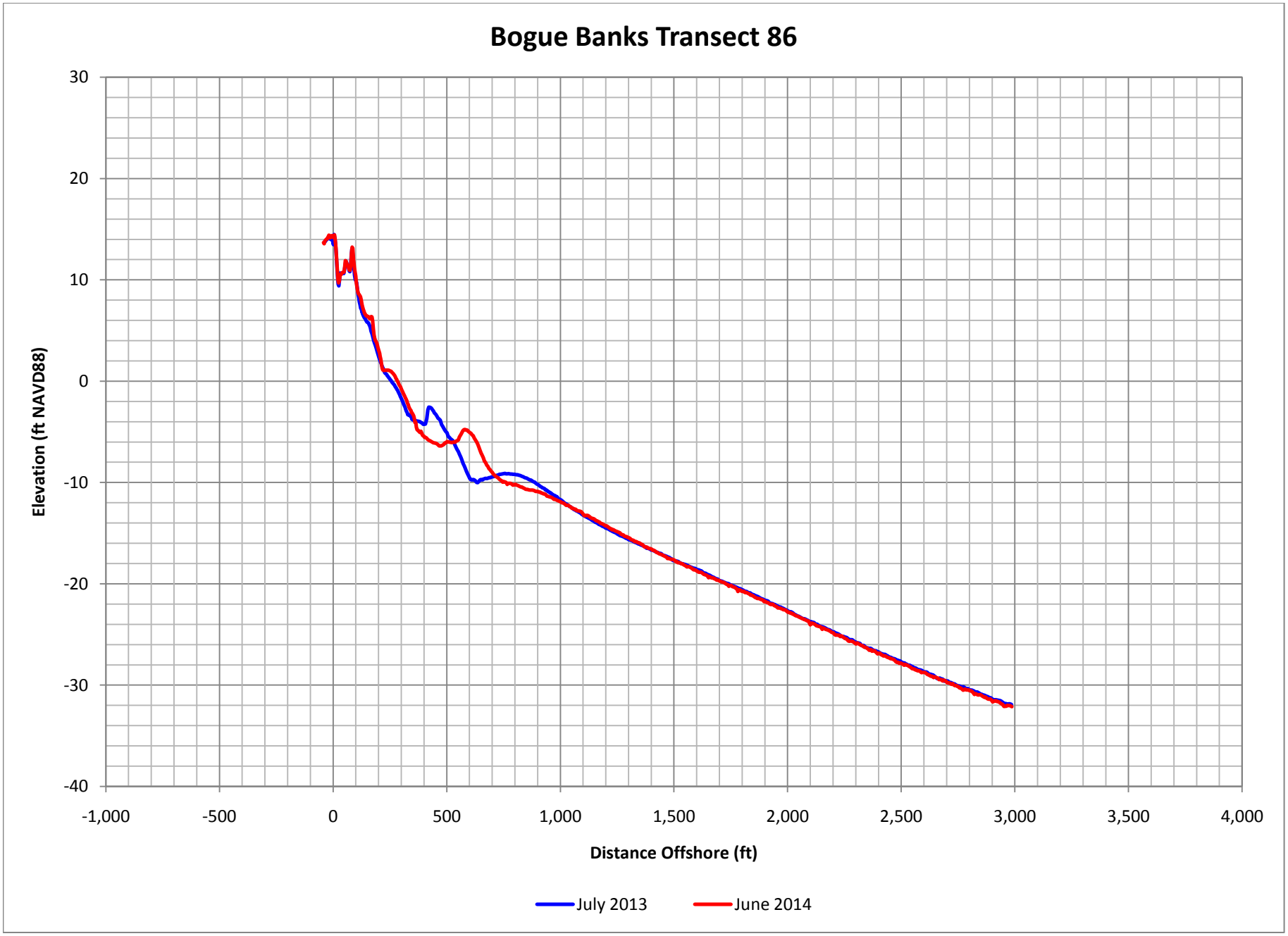


Figure C-114. Bogue Banks Profile Comparison Plot

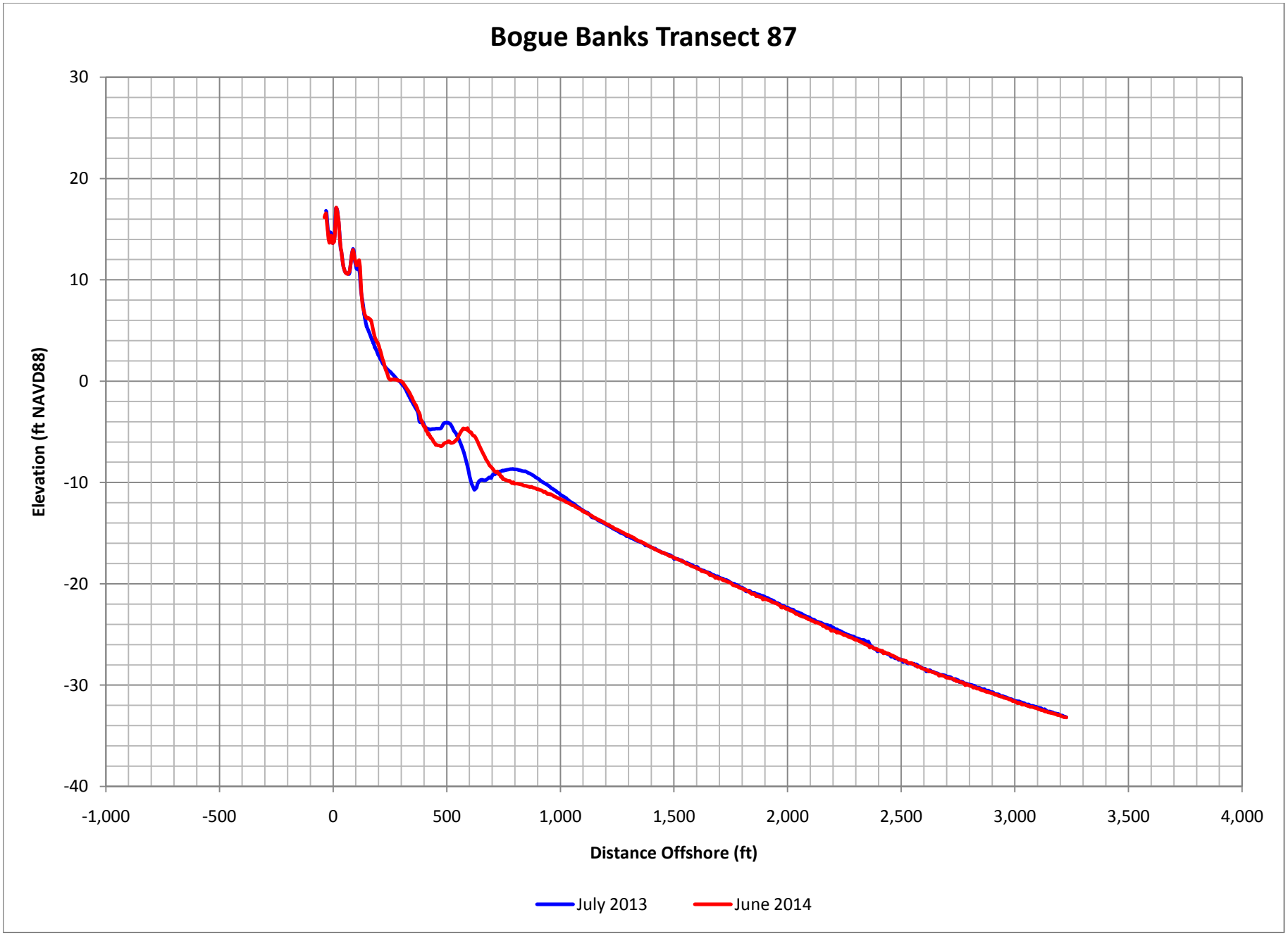


Figure C-115. Bogue Banks Profile Comparison Plot

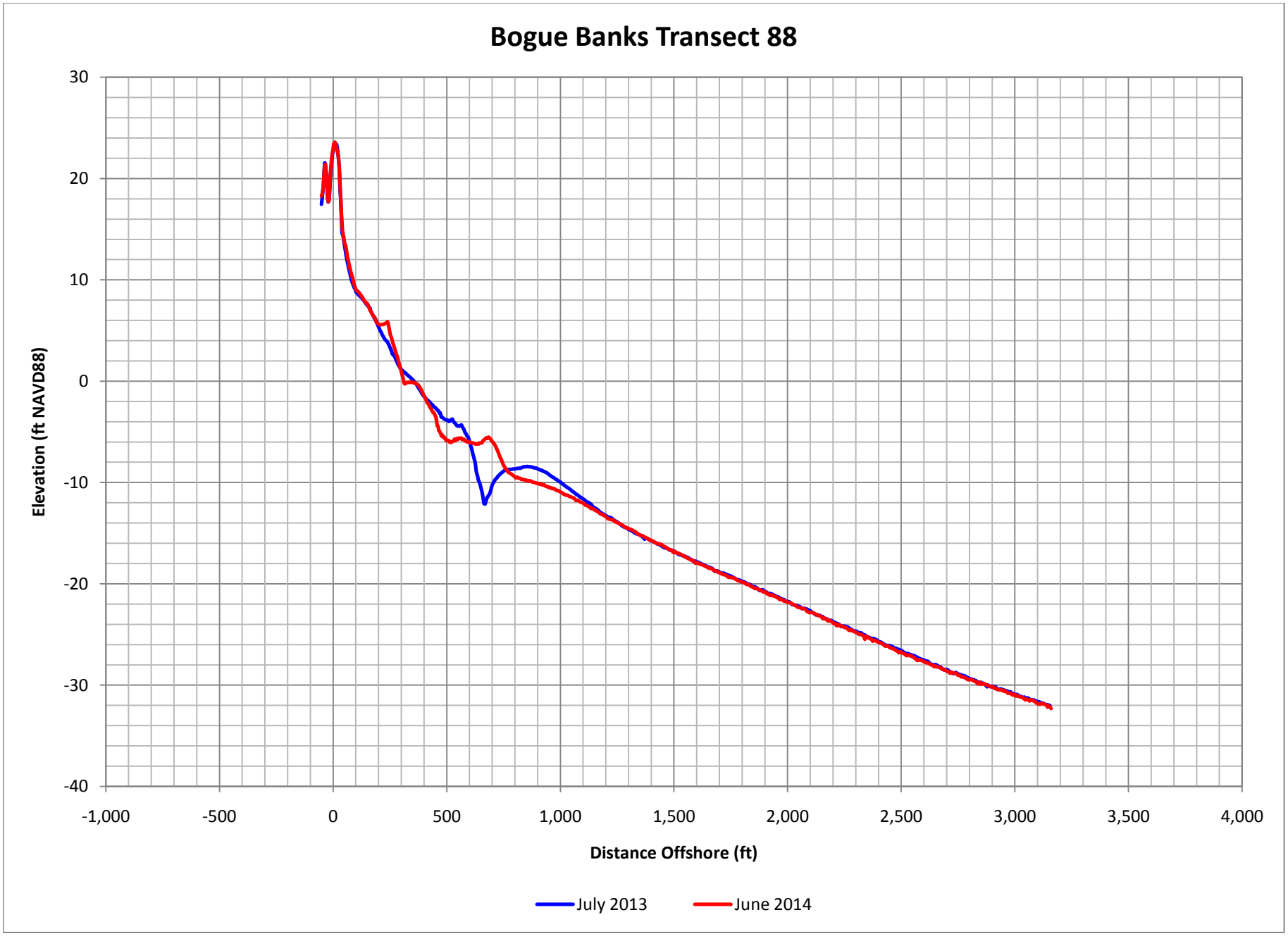


Figure C-116. Bogue Banks Profile Comparison Plot

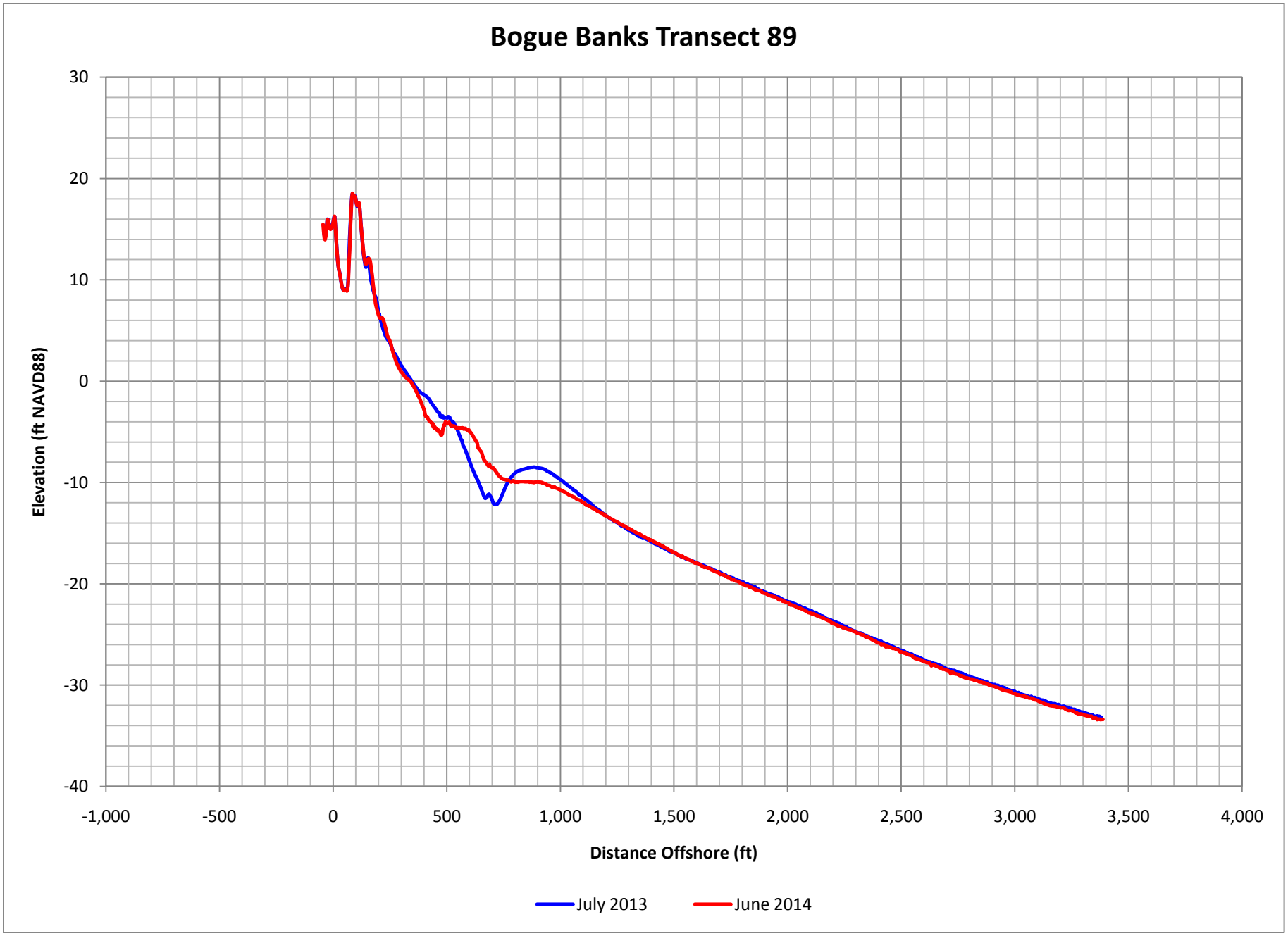


Figure C-117. Bogue Banks Profile Comparison Plot

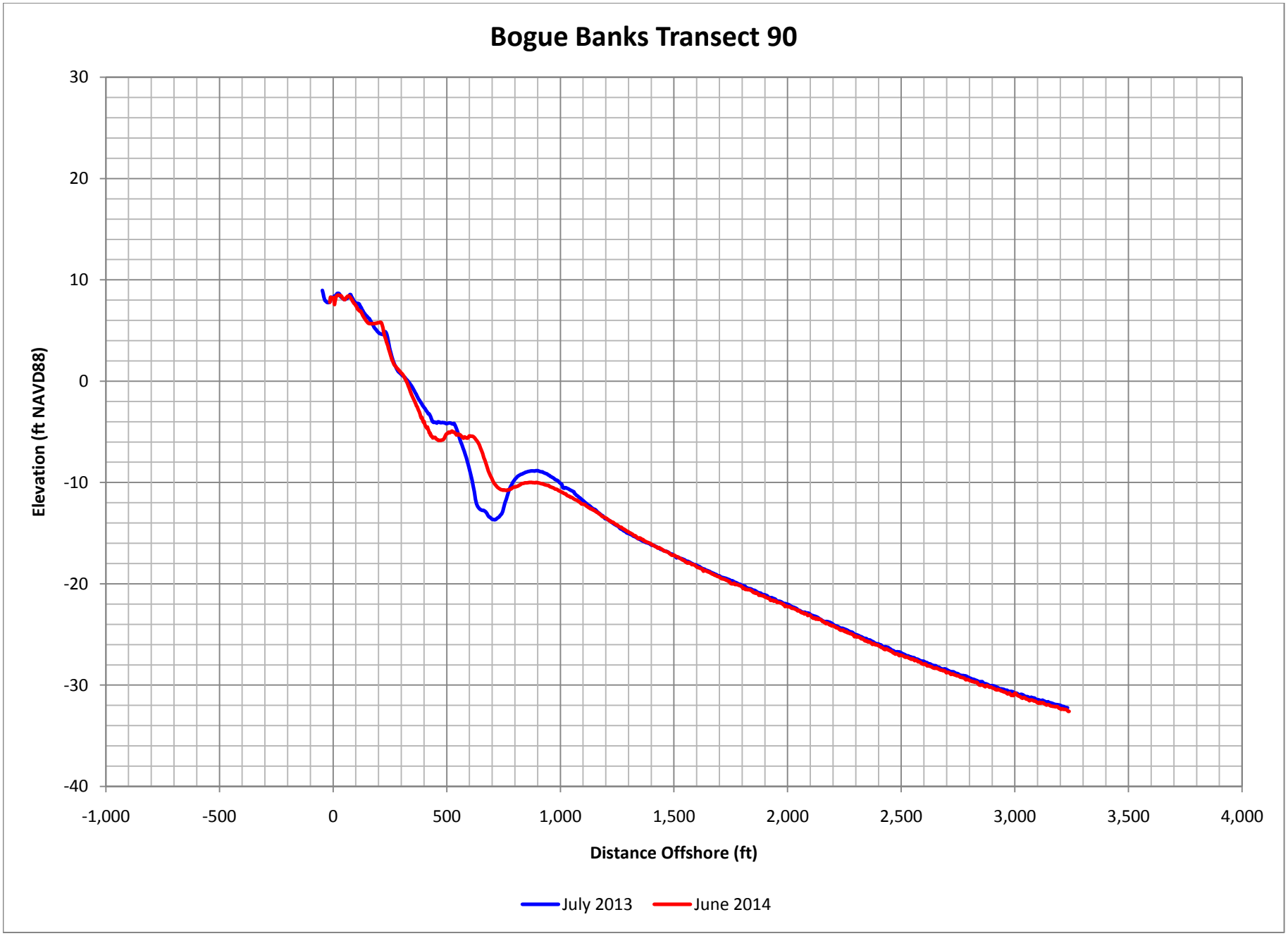


Figure C-118. Bogue Banks Profile Comparison Plot

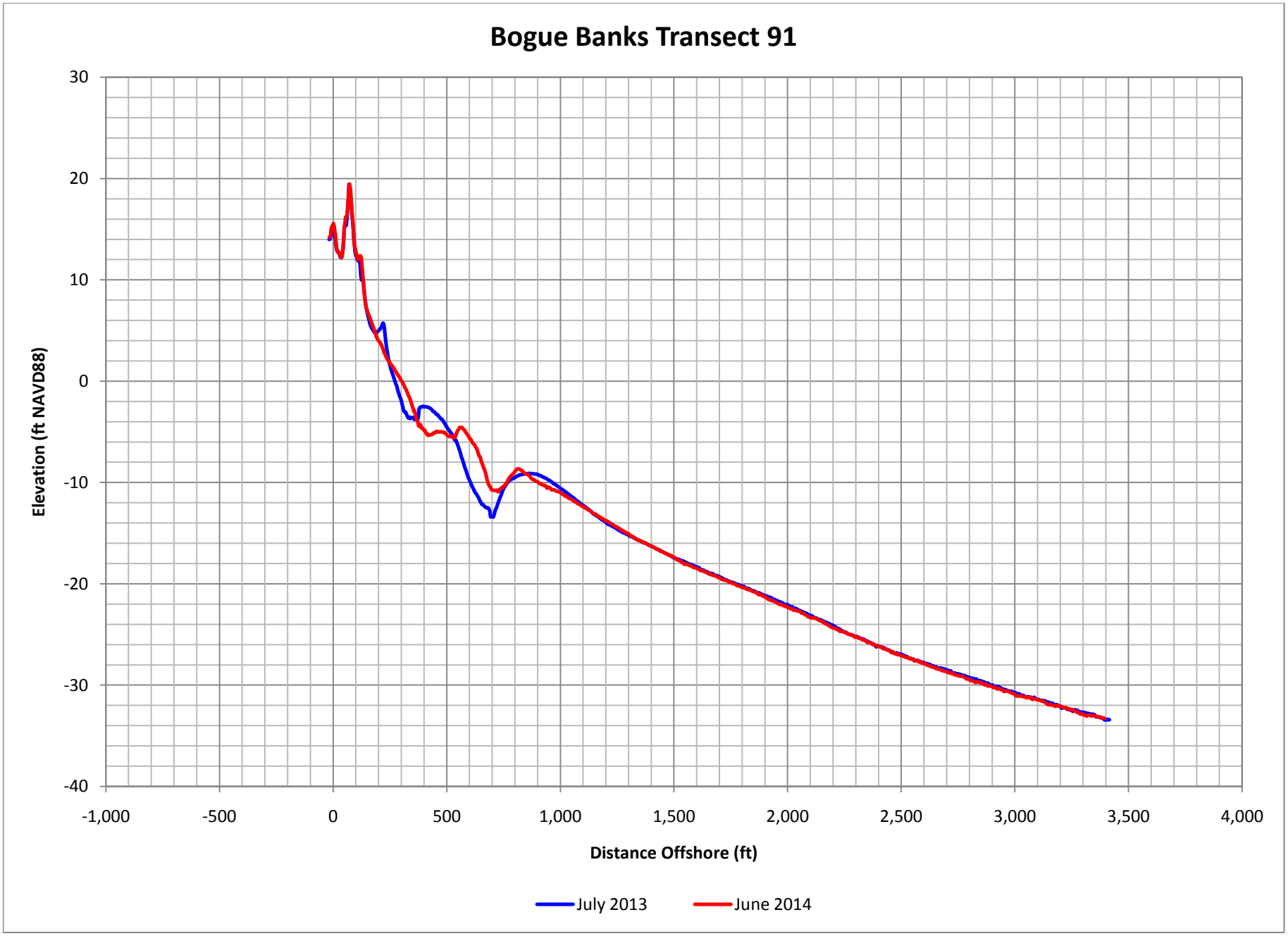


Figure C-119. Bogue Banks Profile Comparison Plot

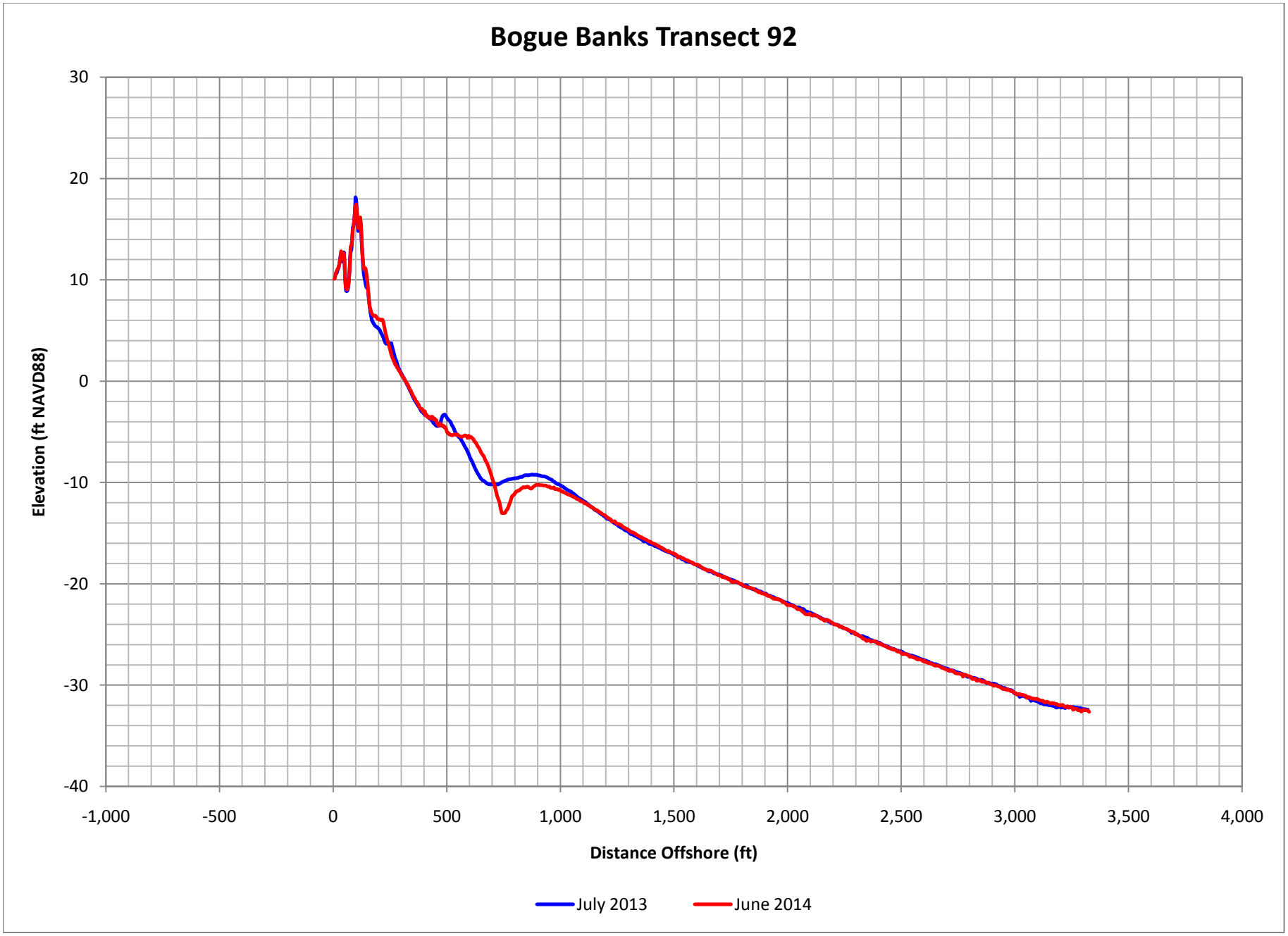


Figure C-120. Bogue Banks Profile Comparison Plot

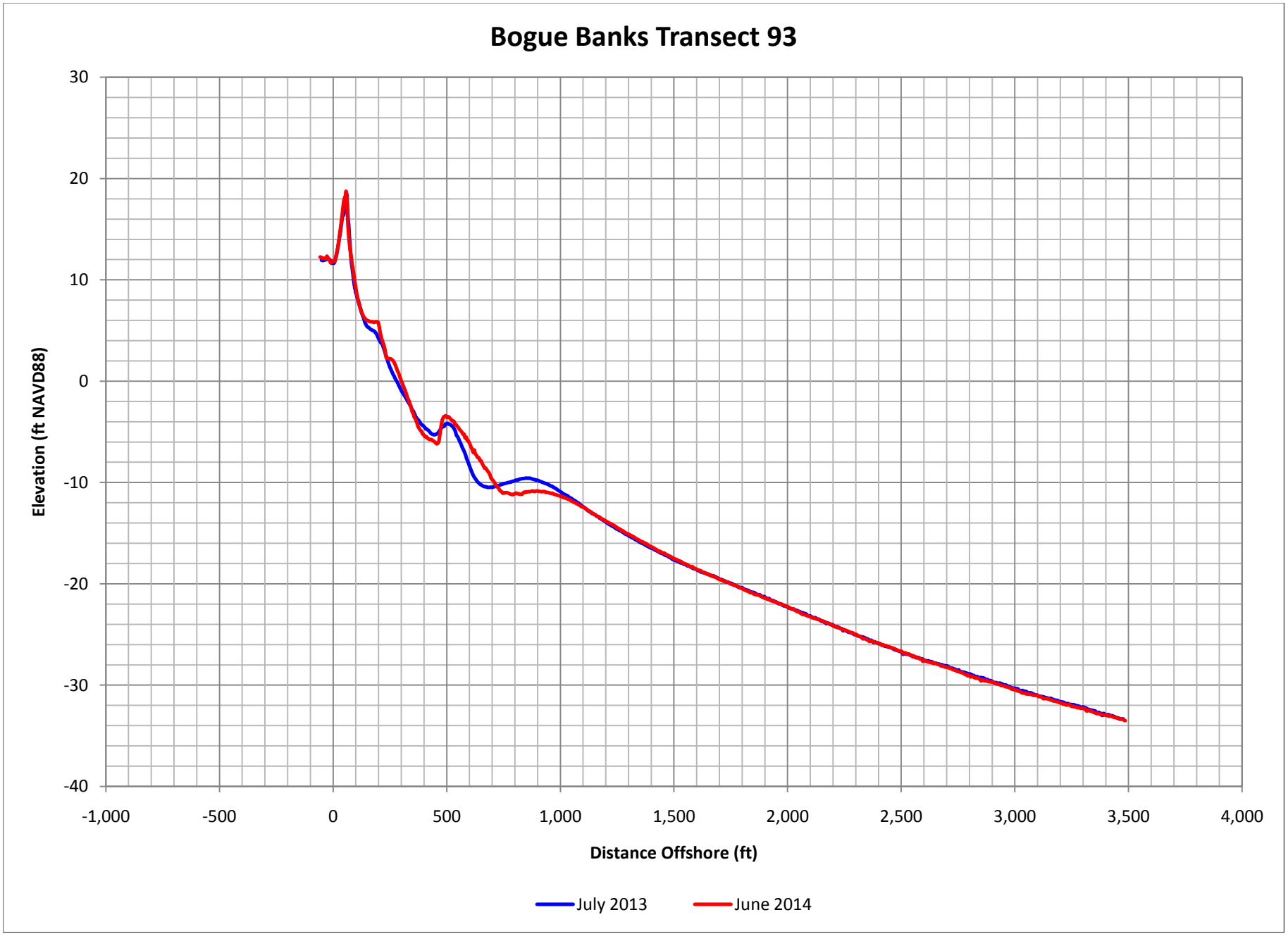


Figure C-121. Bogue Banks Profile Comparison Plot

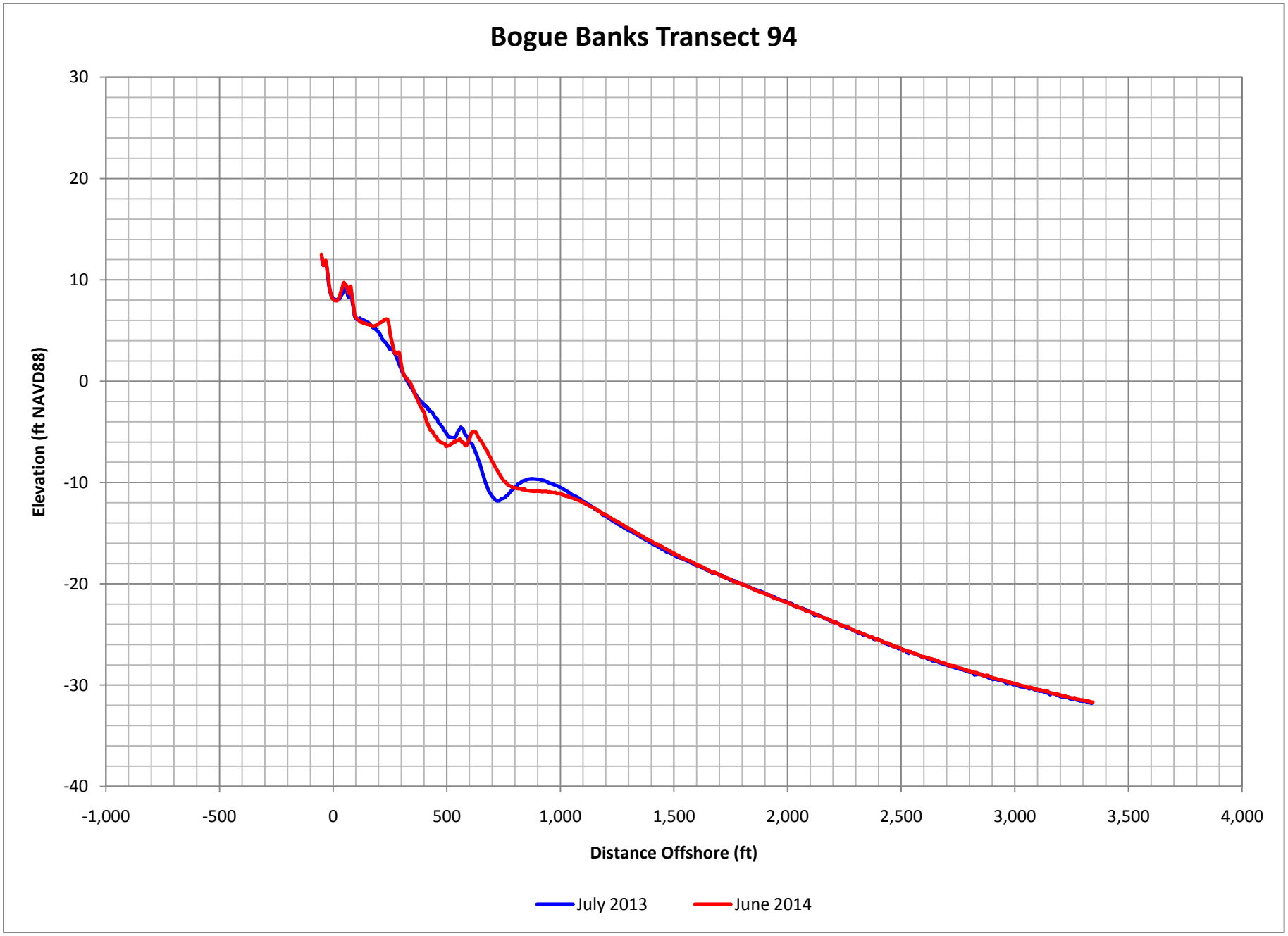


Figure C-122. Bogue Banks Profile Comparison Plot

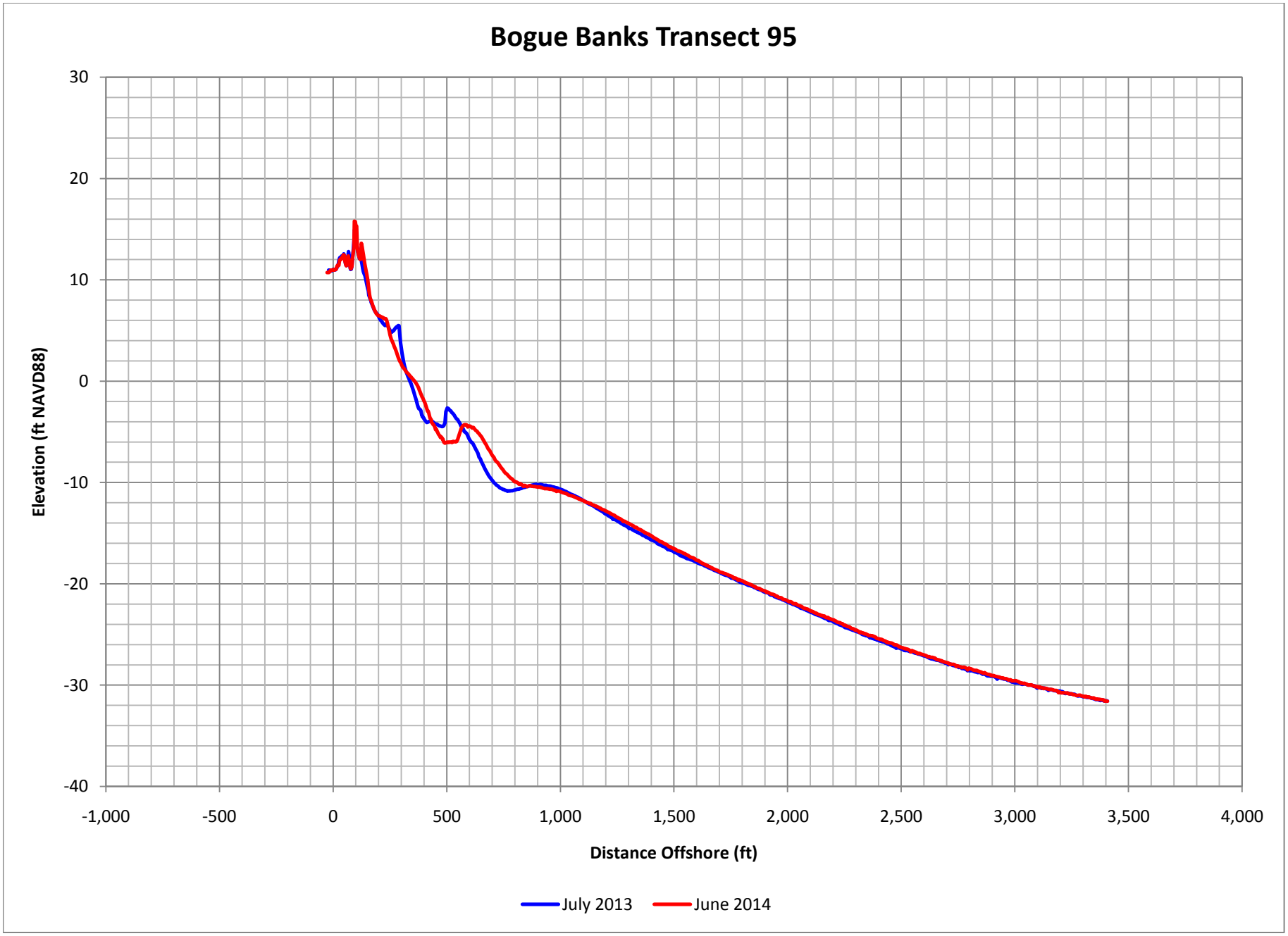


Figure C-123. Bogue Banks Profile Comparison Plot

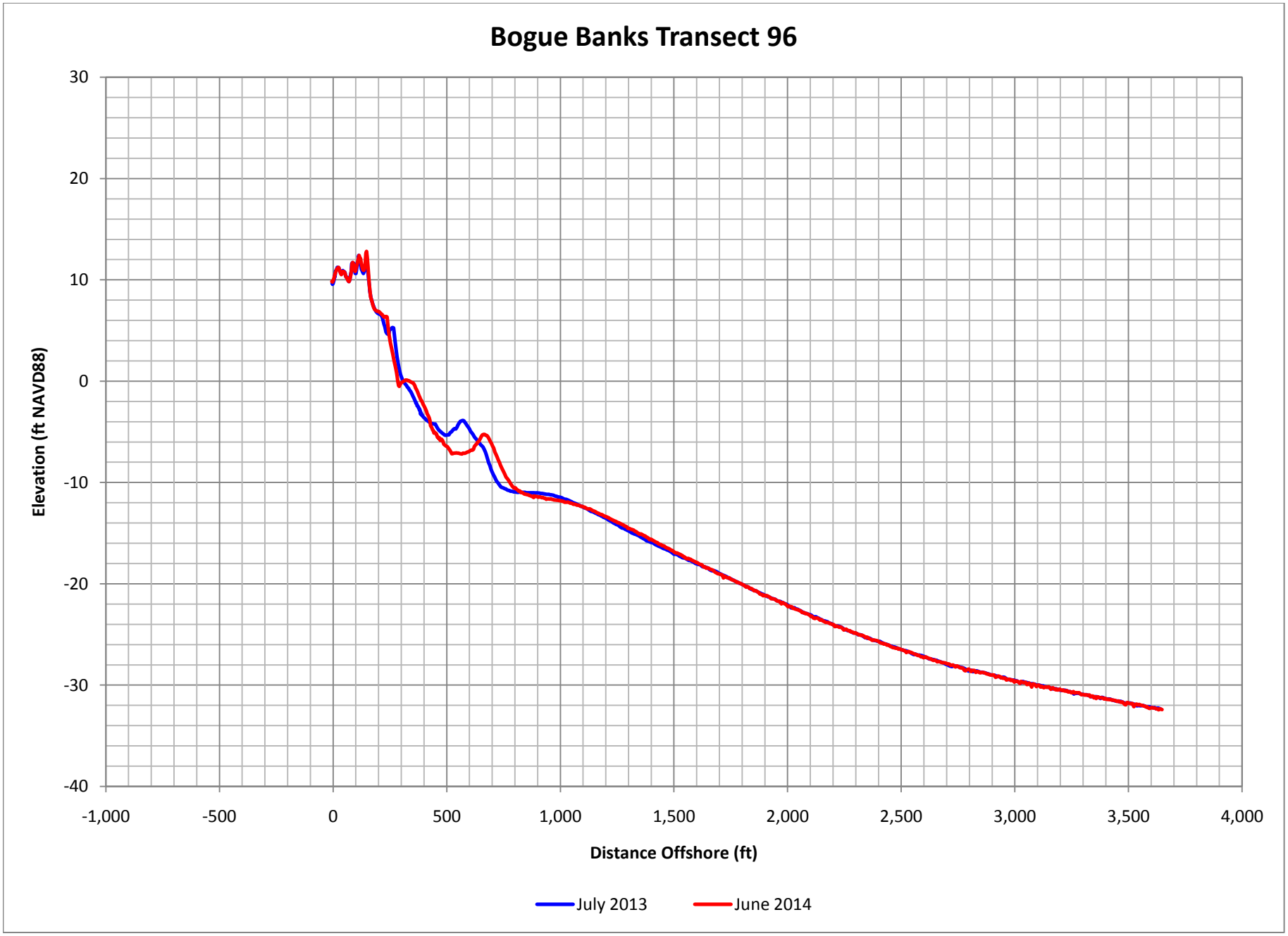


Figure C-124. Bogue Banks Profile Comparison Plot

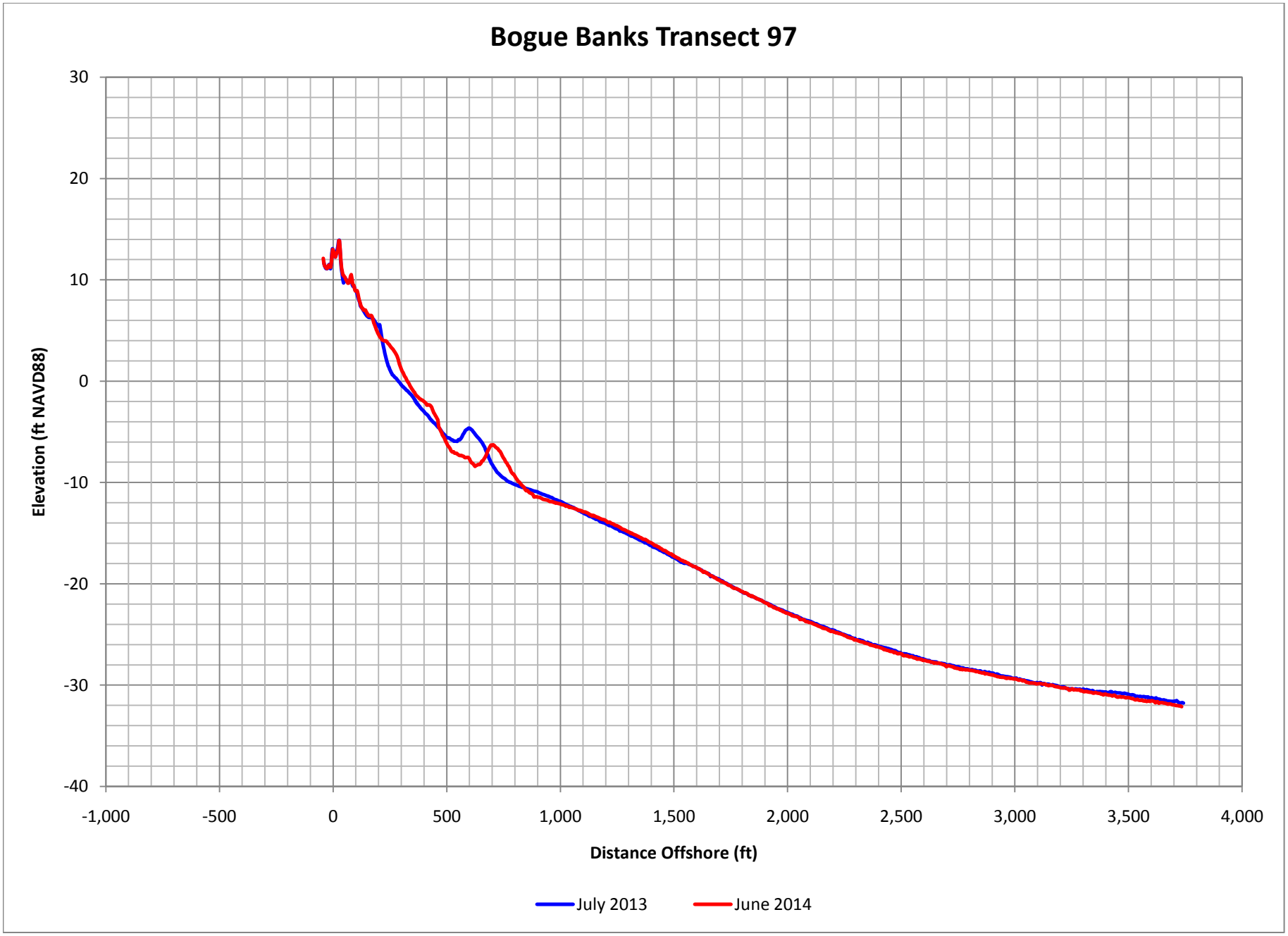


Figure C-125. Bogue Banks Profile Comparison Plot

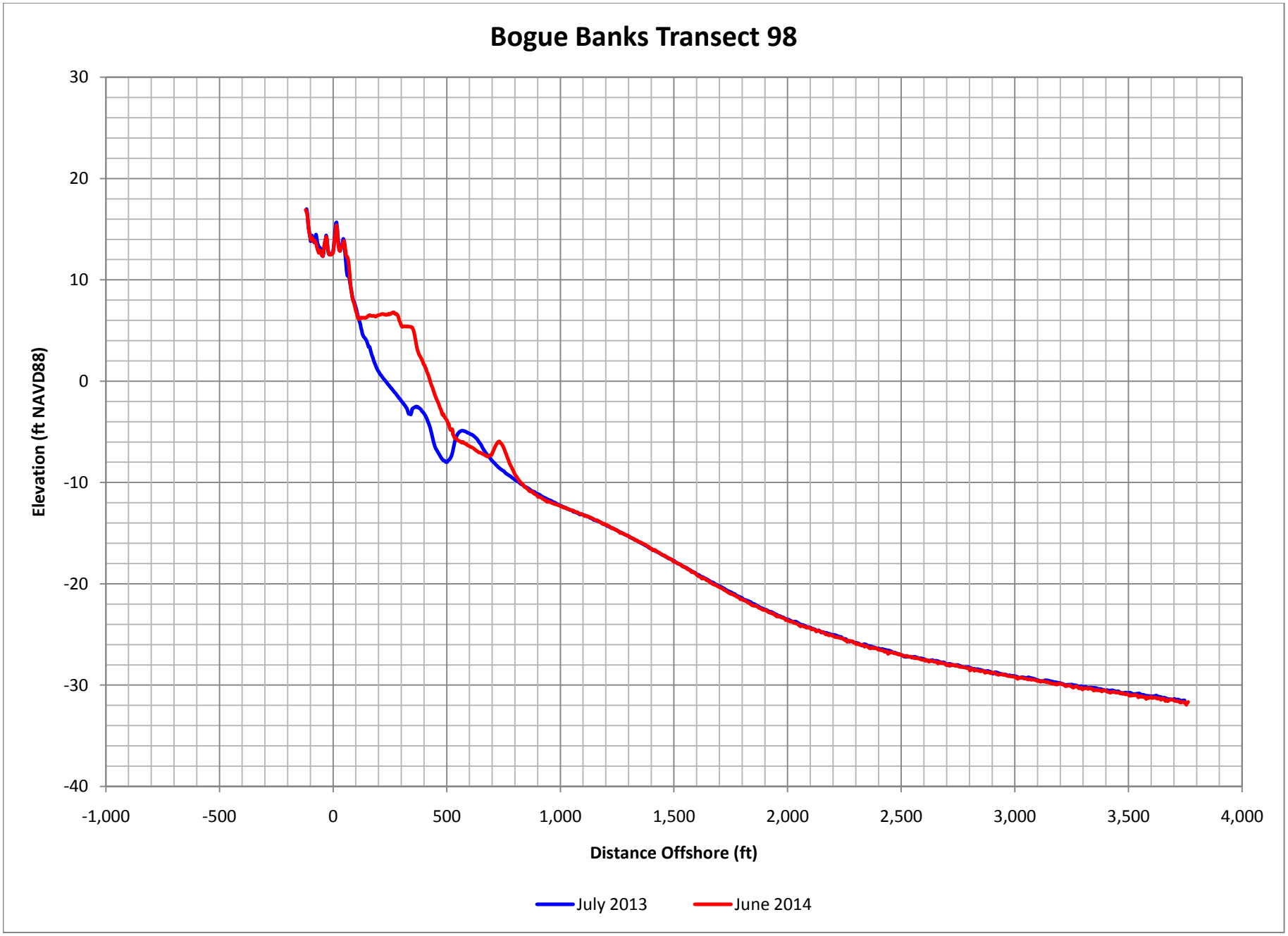


Figure C-126. Bogue Banks Profile Comparison Plot

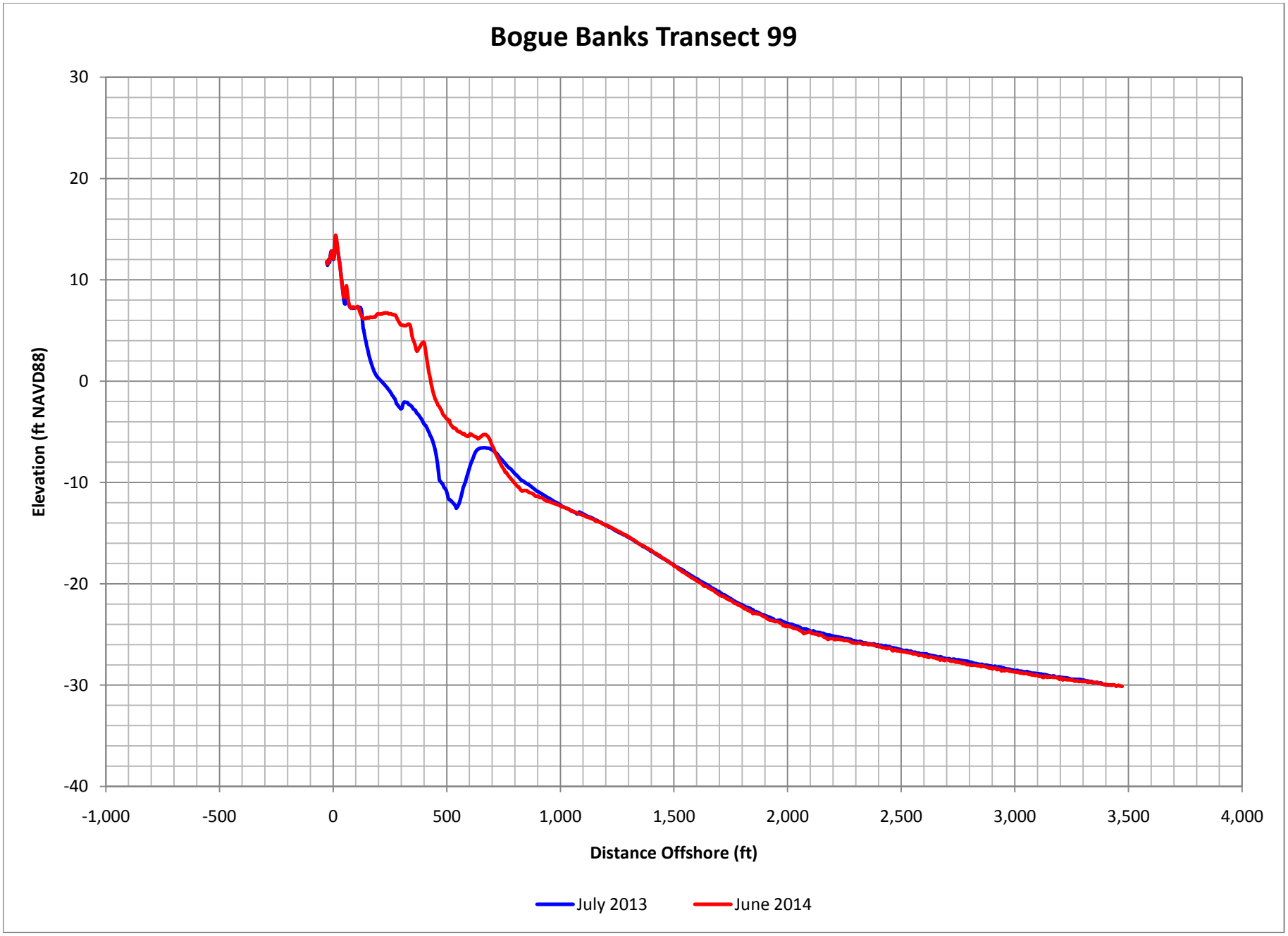


Figure C-127. Bogue Banks Profile Comparison Plot

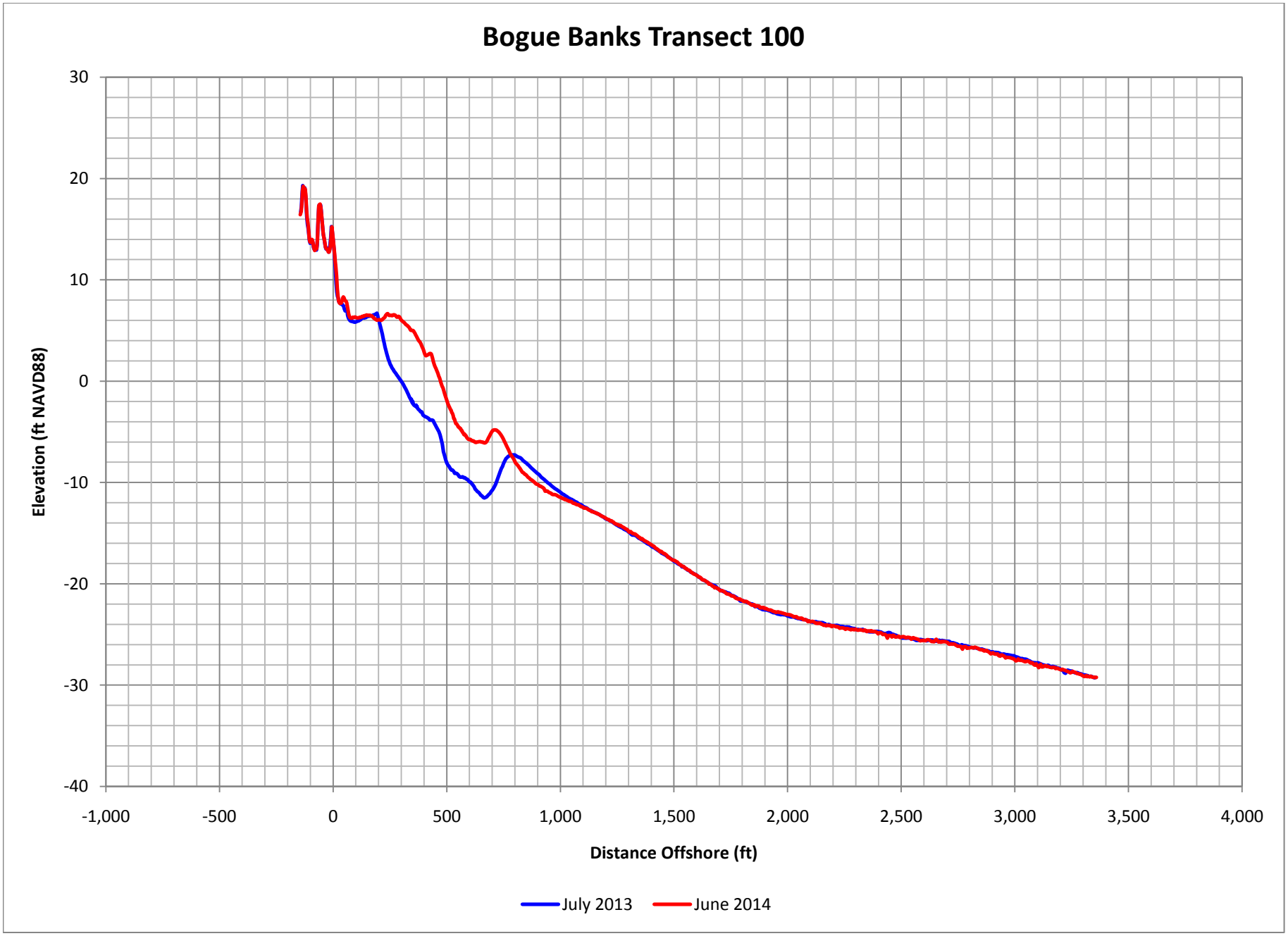


Figure C-128. Bogue Banks Profile Comparison Plot

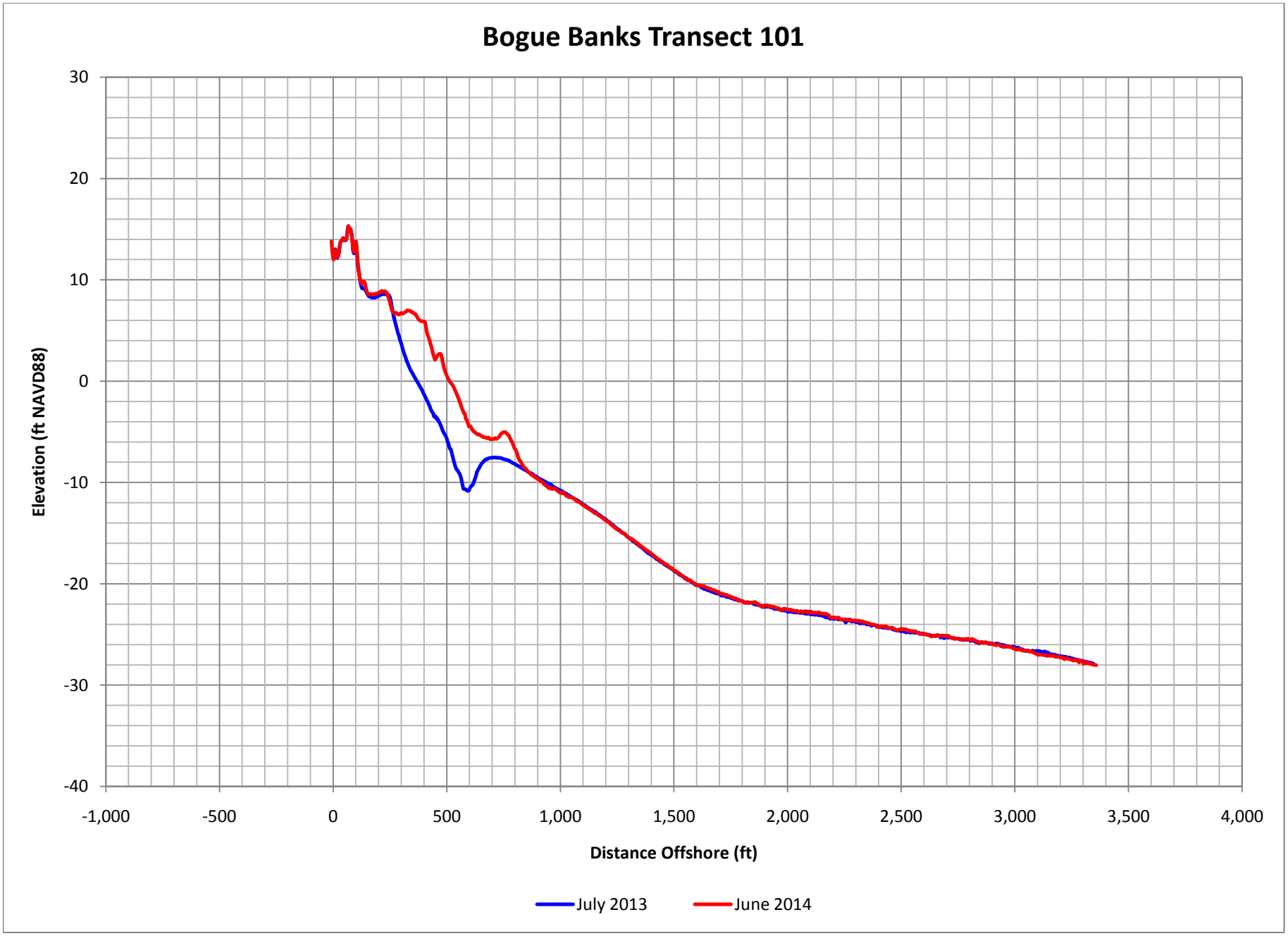


Figure C-129. Bogue Banks Profile Comparison Plot

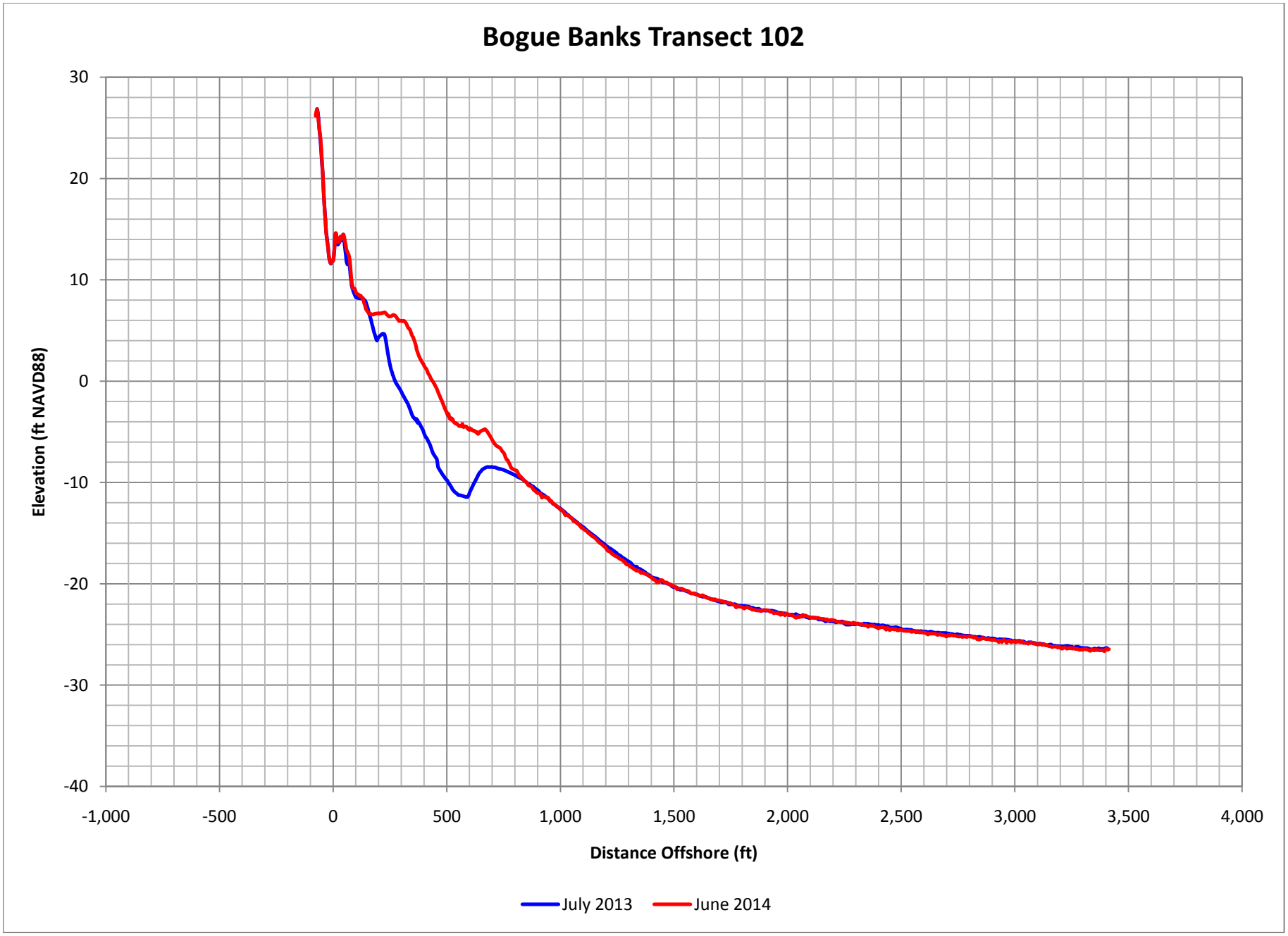


Figure C-130. Bogue Banks Profile Comparison Plot

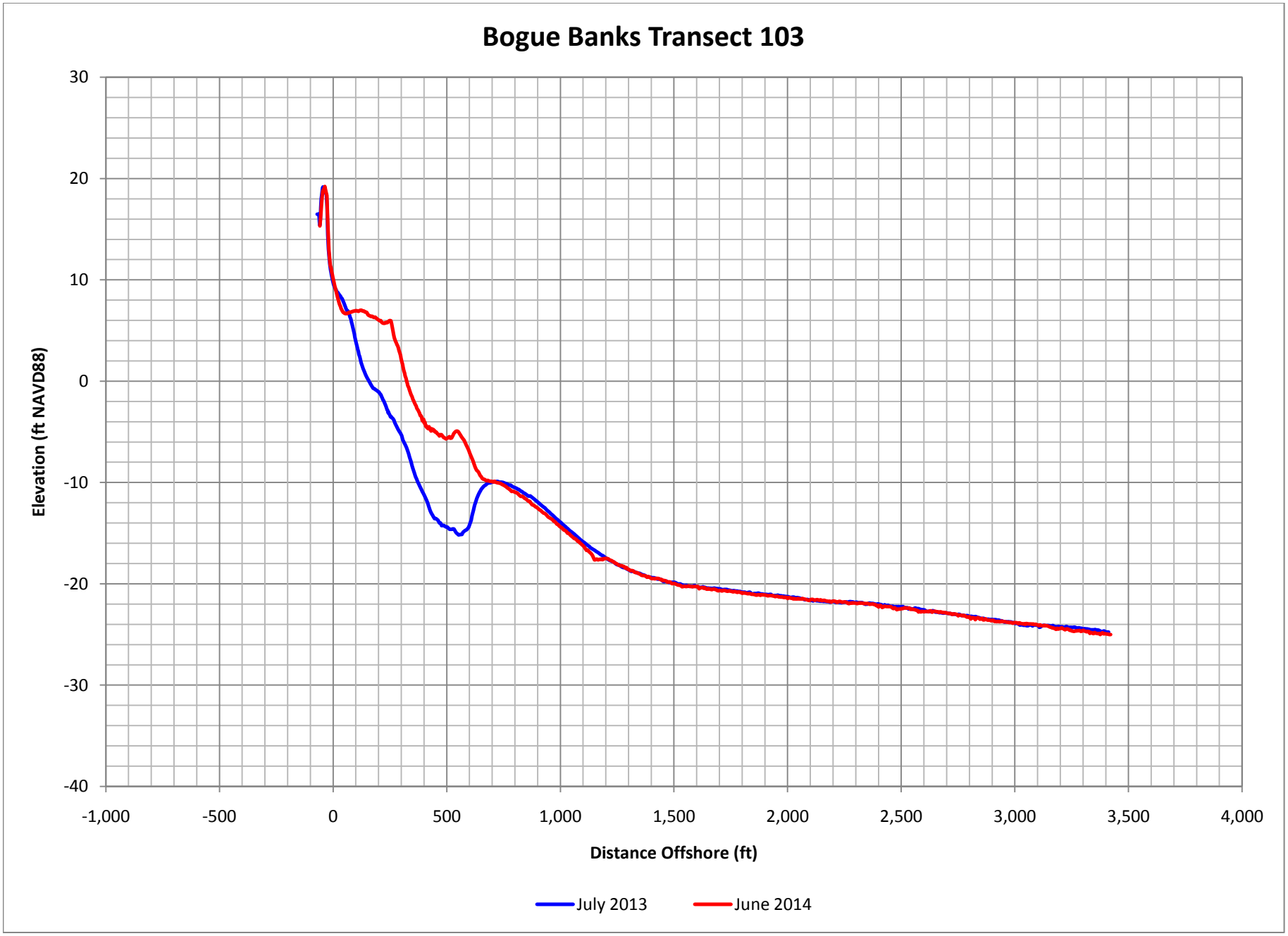


Figure C-131. Bogue Banks Profile Comparison Plot

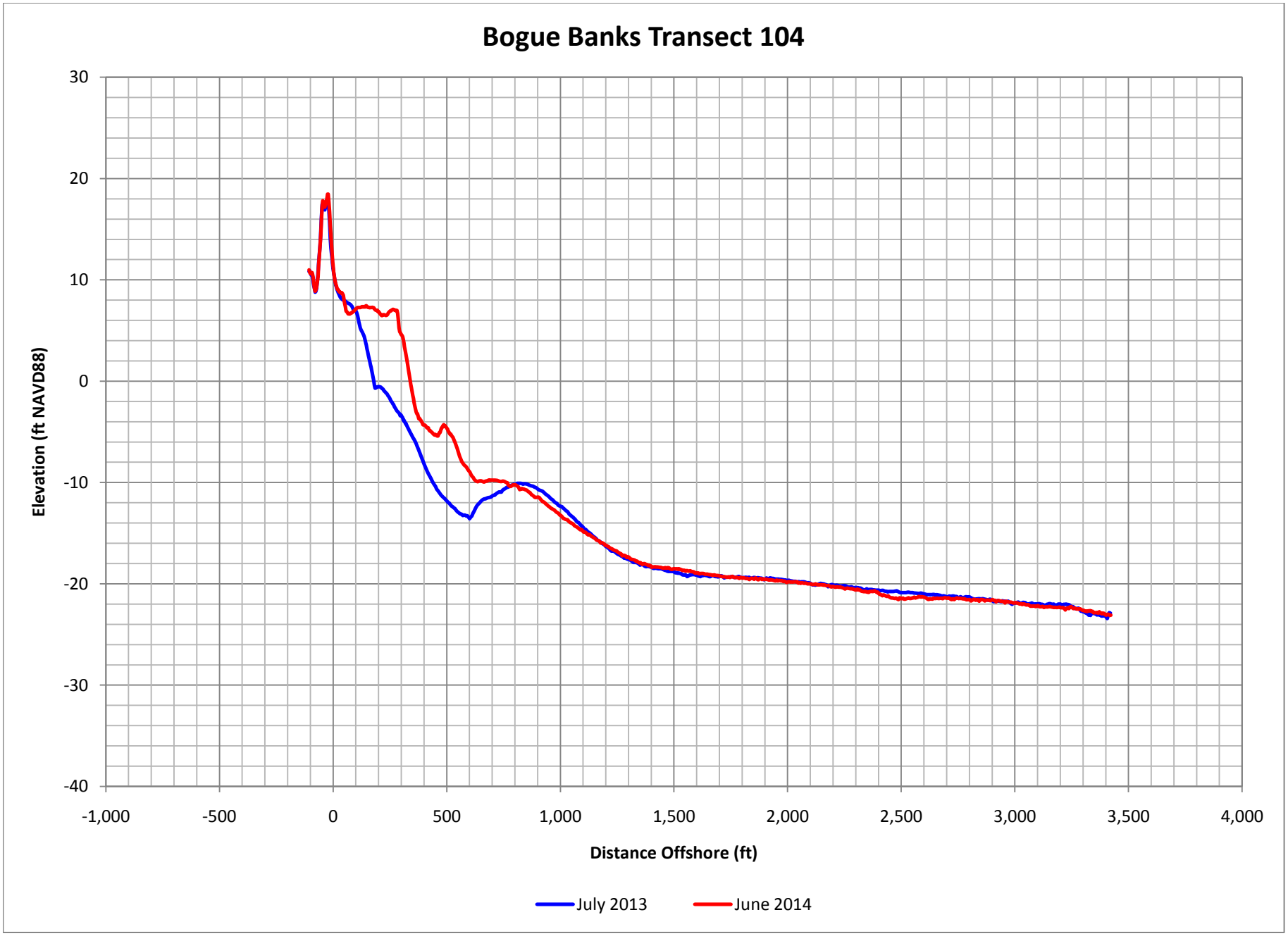


Figure C-132. Bogue Banks Profile Comparison Plot

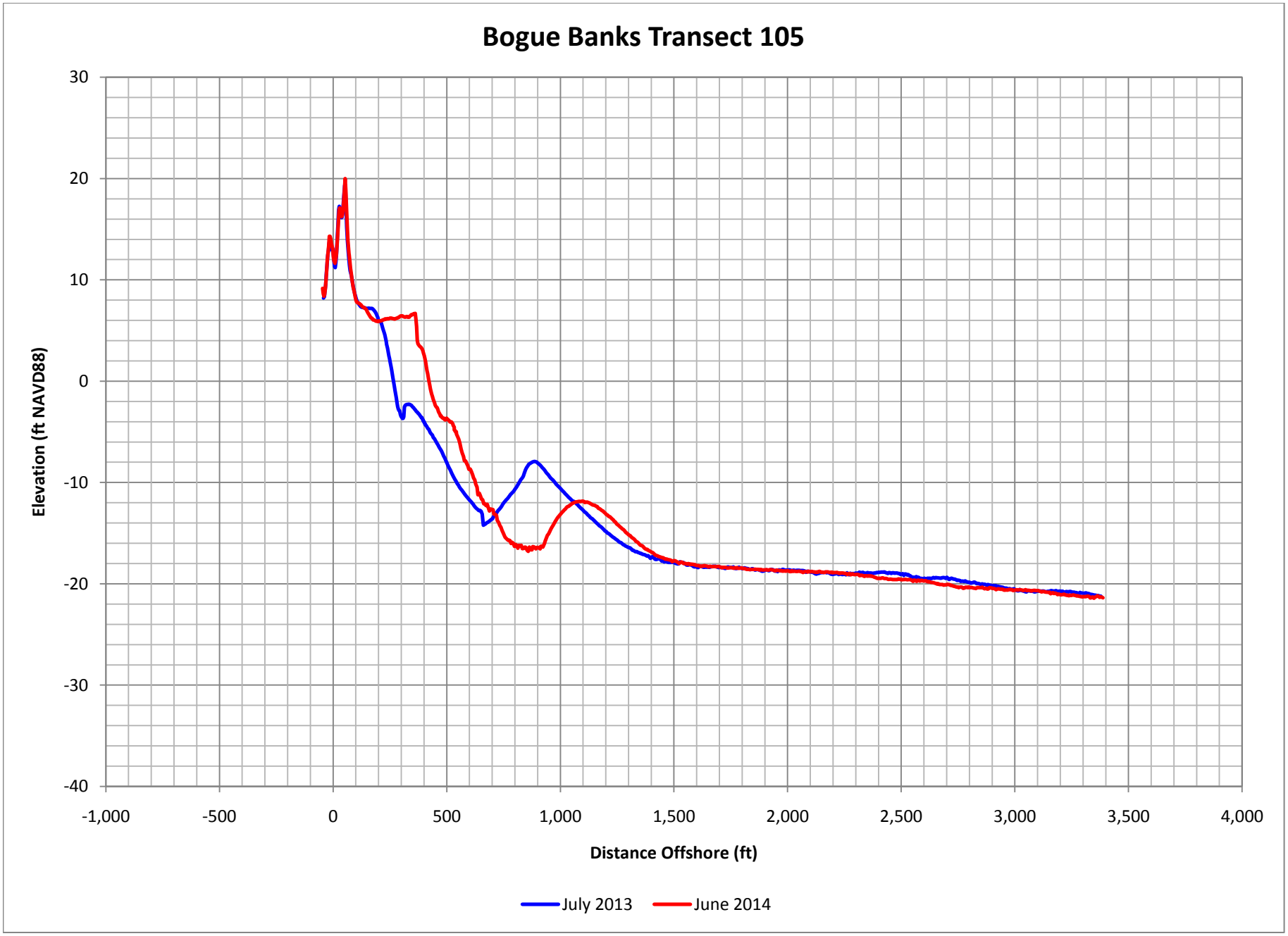


Figure C-133. Bogue Banks Profile Comparison Plot

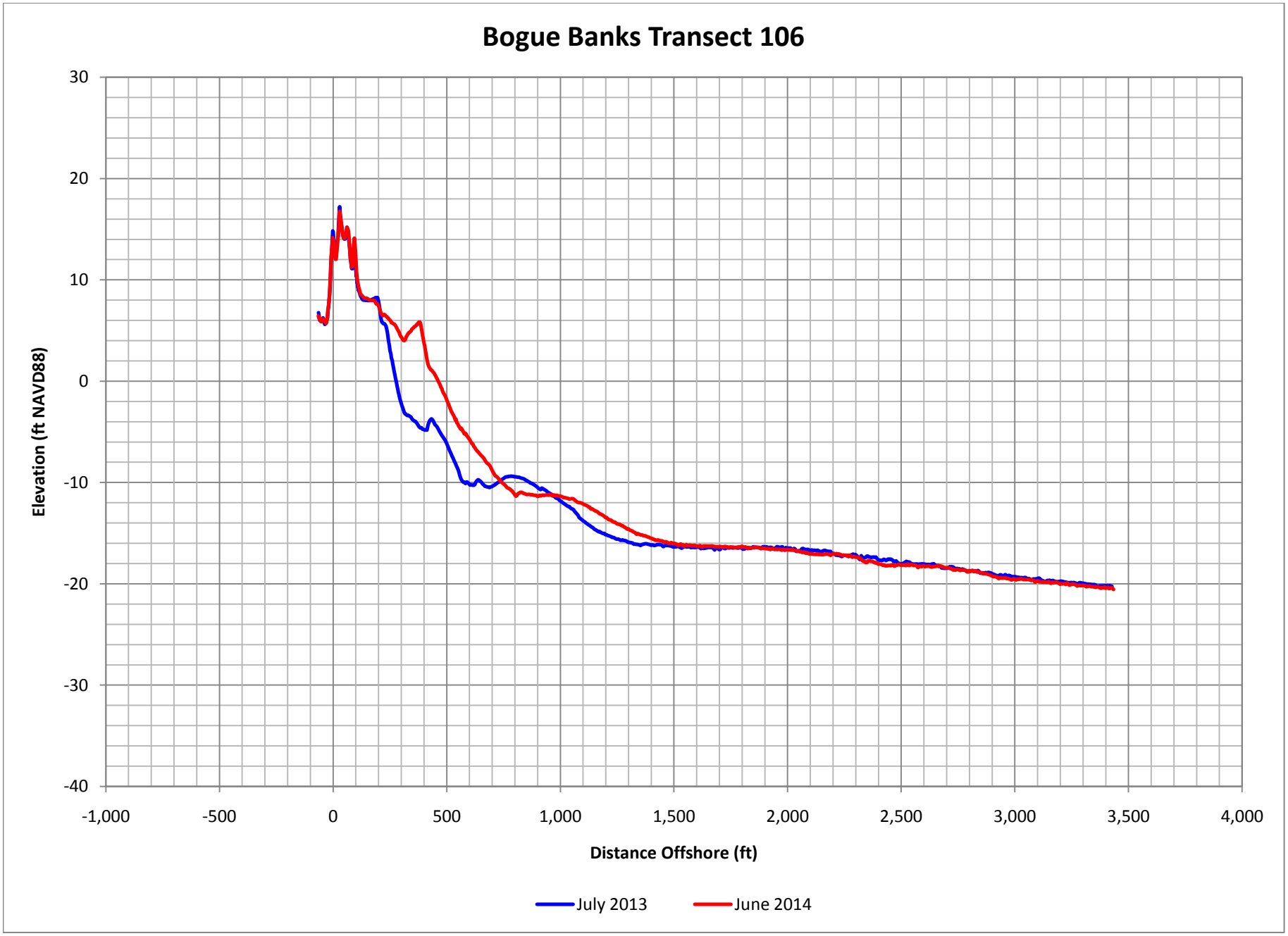


Figure C-134. Bogue Banks Profile Comparison Plot

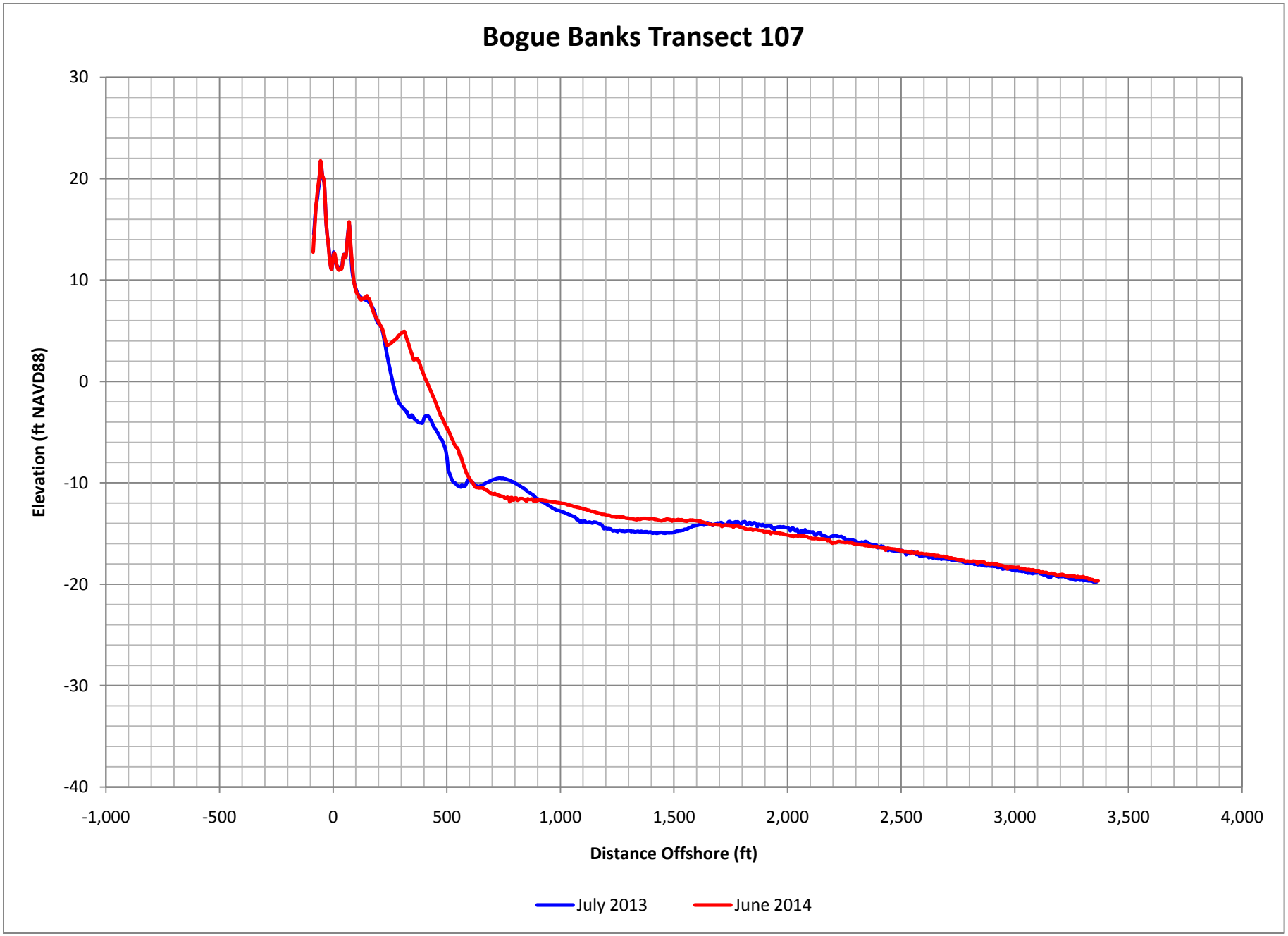


Figure C-135. Bogue Banks Profile Comparison Plot

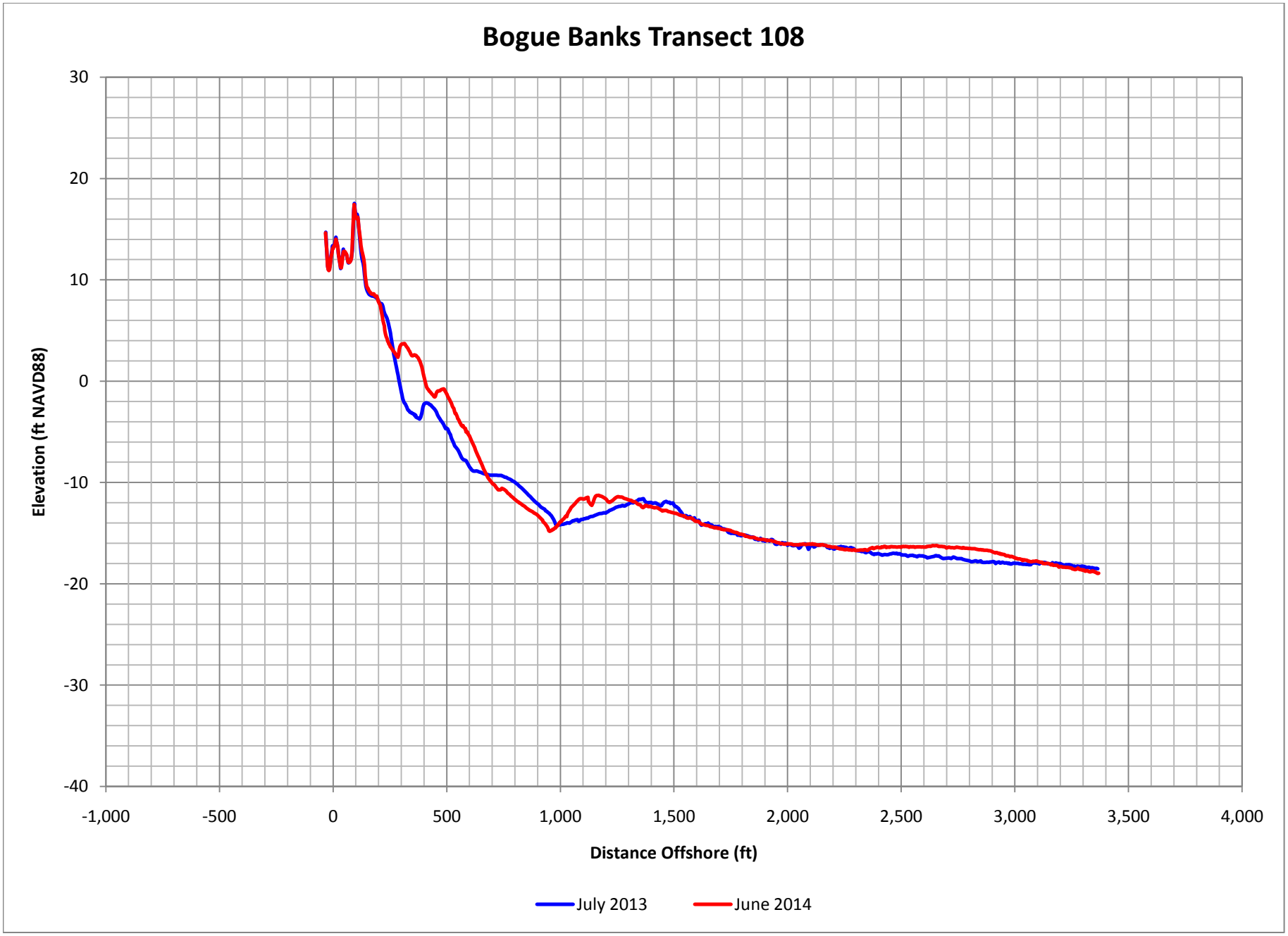


Figure C-136. Bogue Banks Profile Comparison Plot

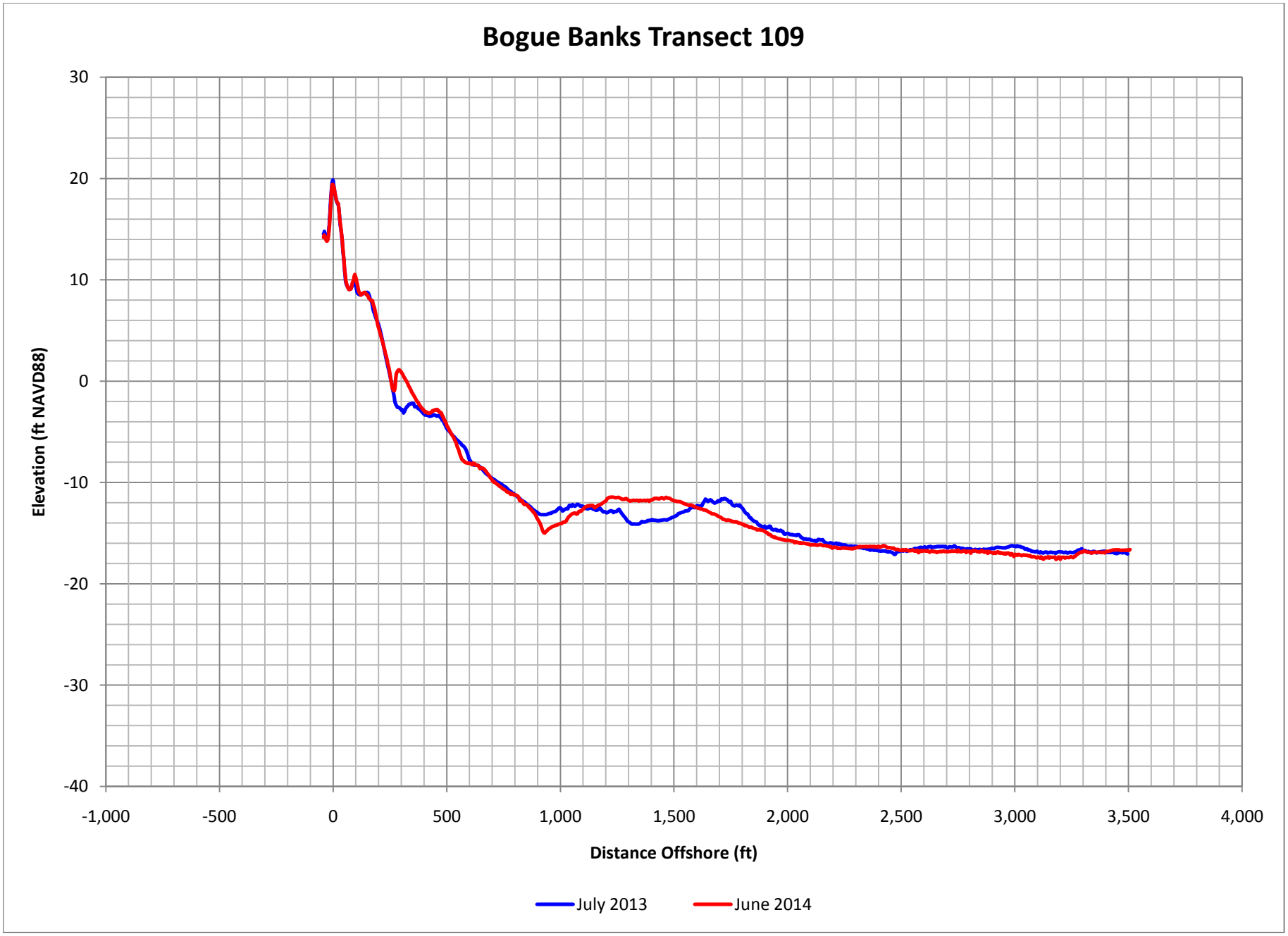


Figure C-137. Bogue Banks Profile Comparison Plot

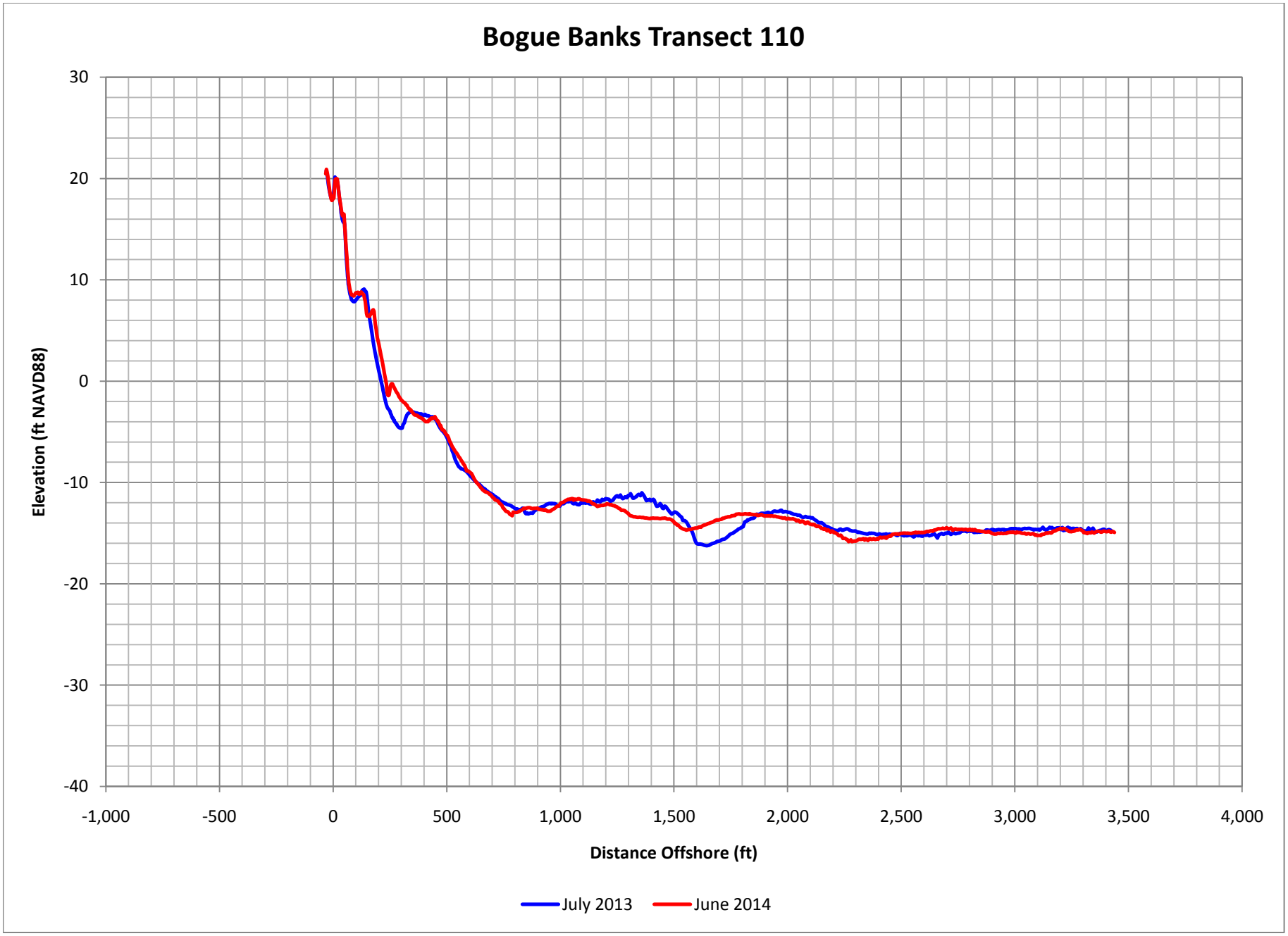


Figure C-138. Bogue Banks Profile Comparison Plot

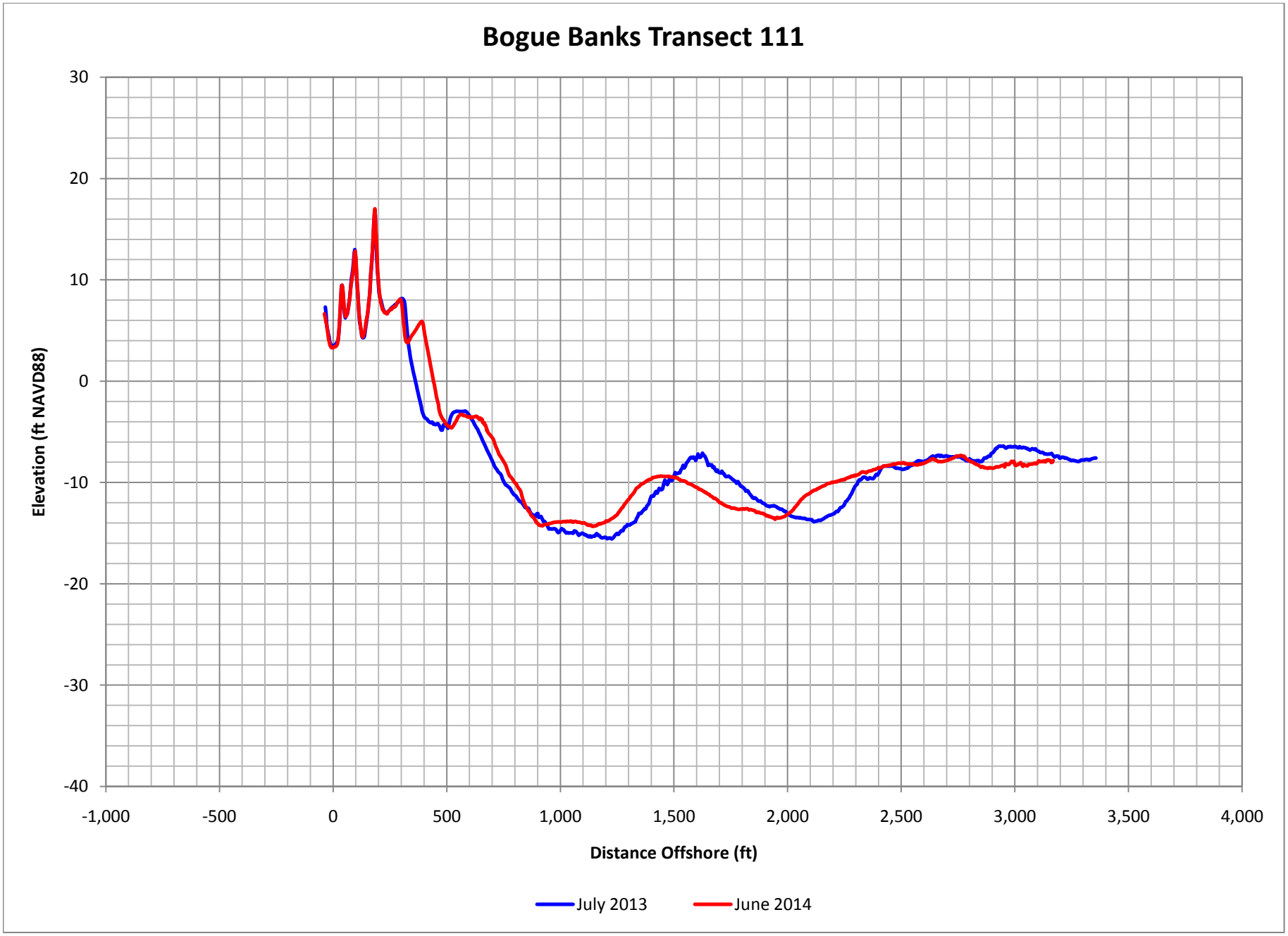


Figure C-139. Bogue Banks Profile Comparison Plot

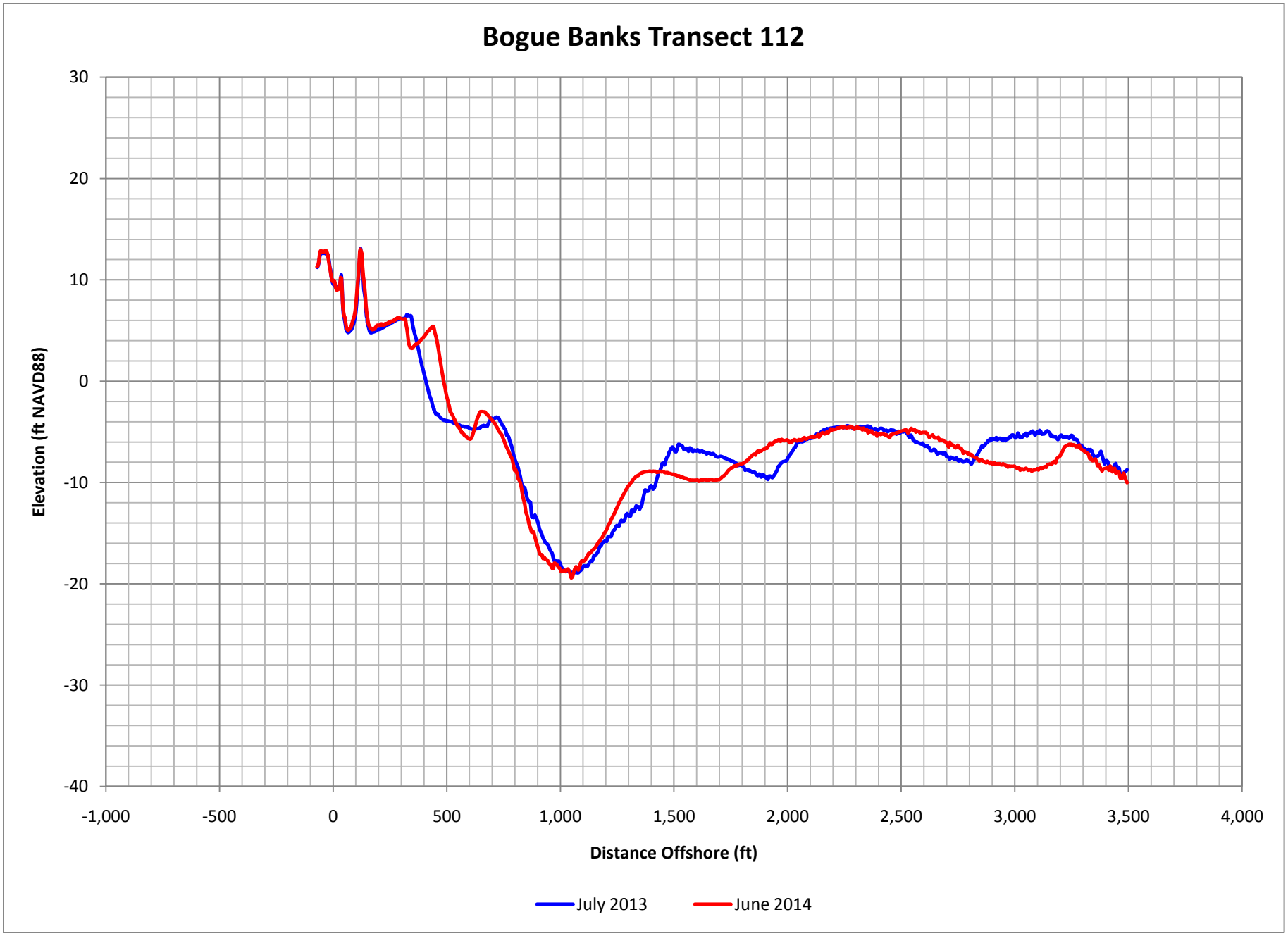


Figure C-140. Bogue Banks Profile Comparison Plot

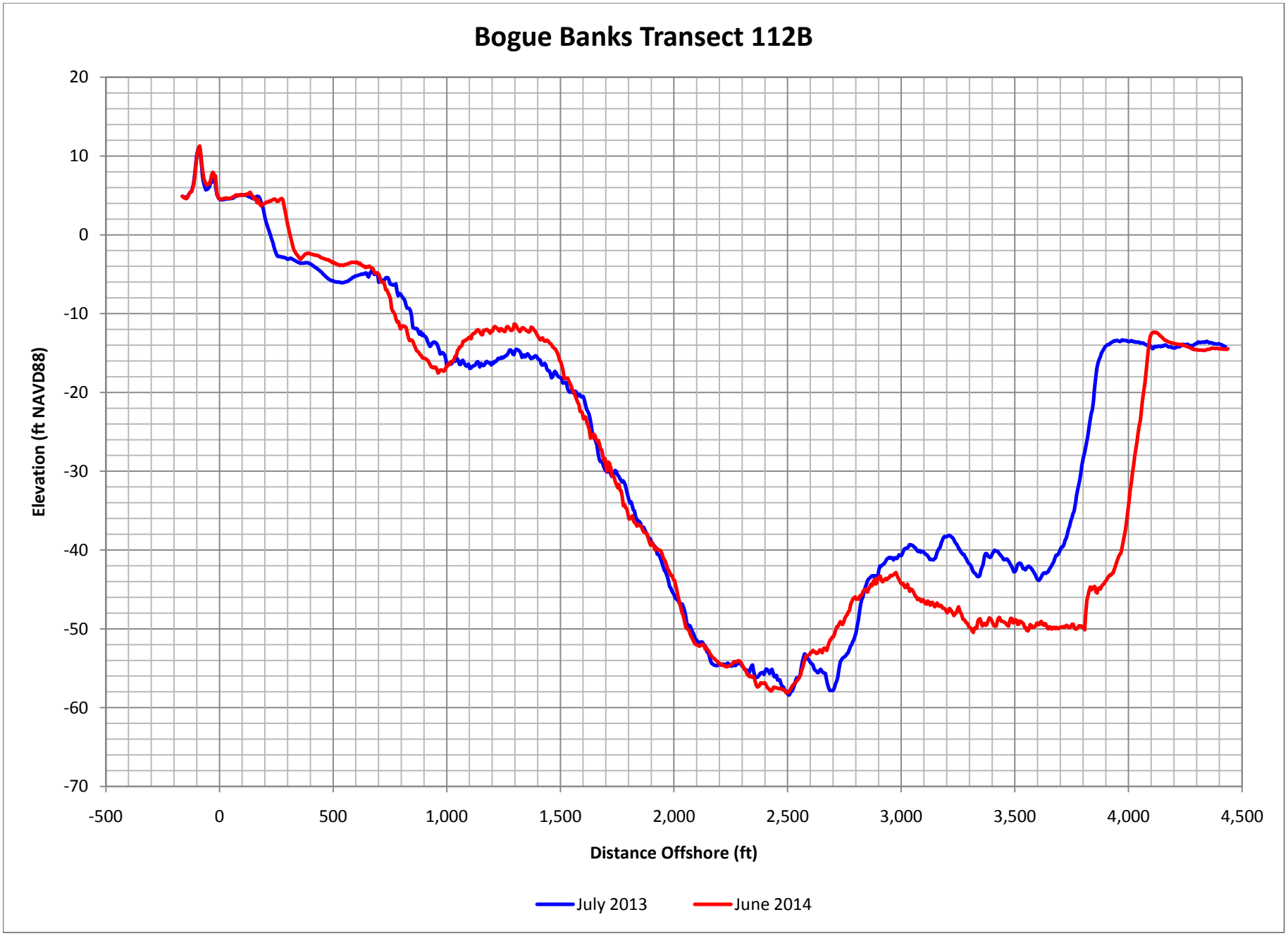


Figure C-141. Bogue Banks Profile Comparison Plot

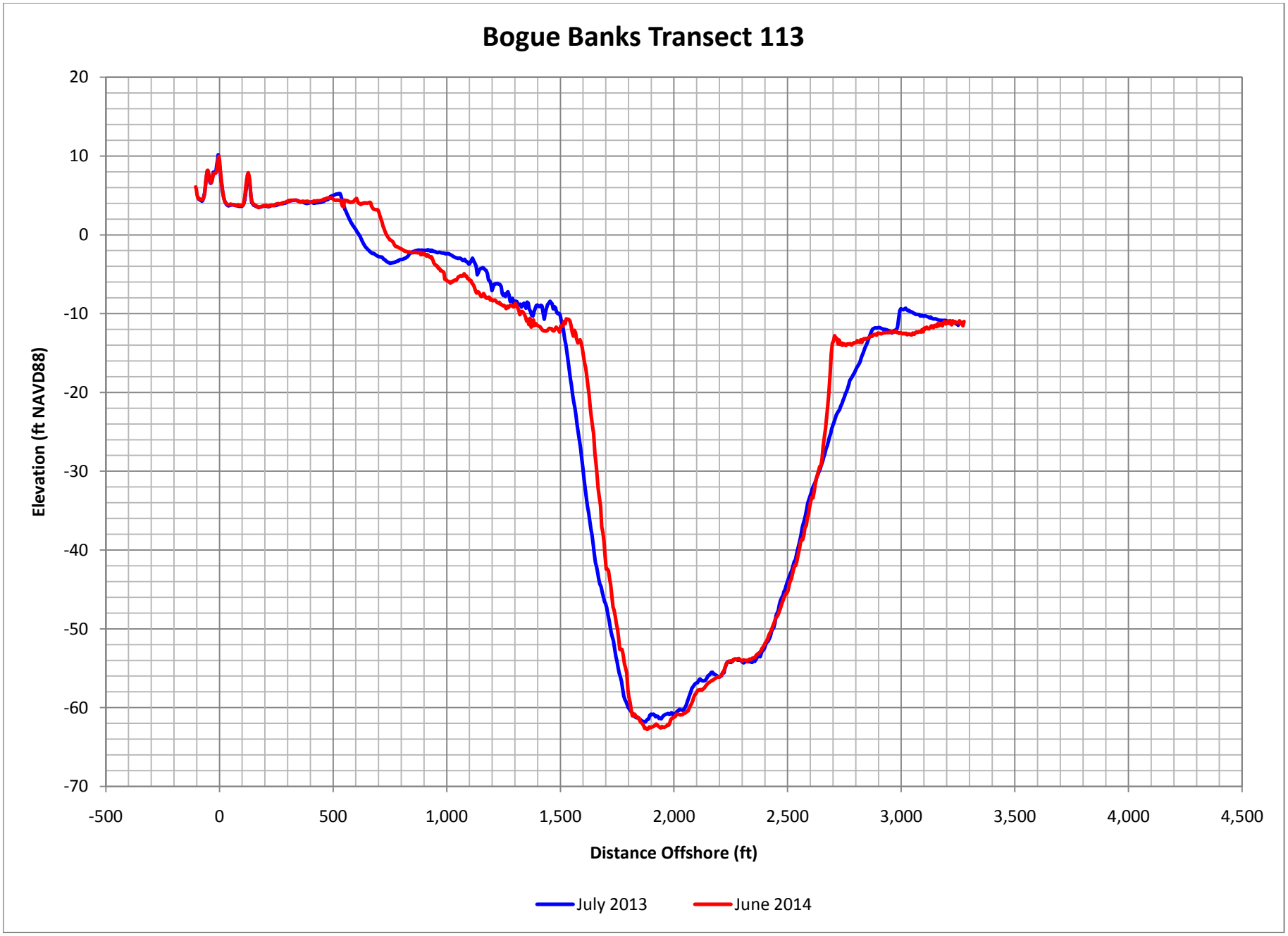


Figure C-142. Bogue Banks Profile Comparison Plot

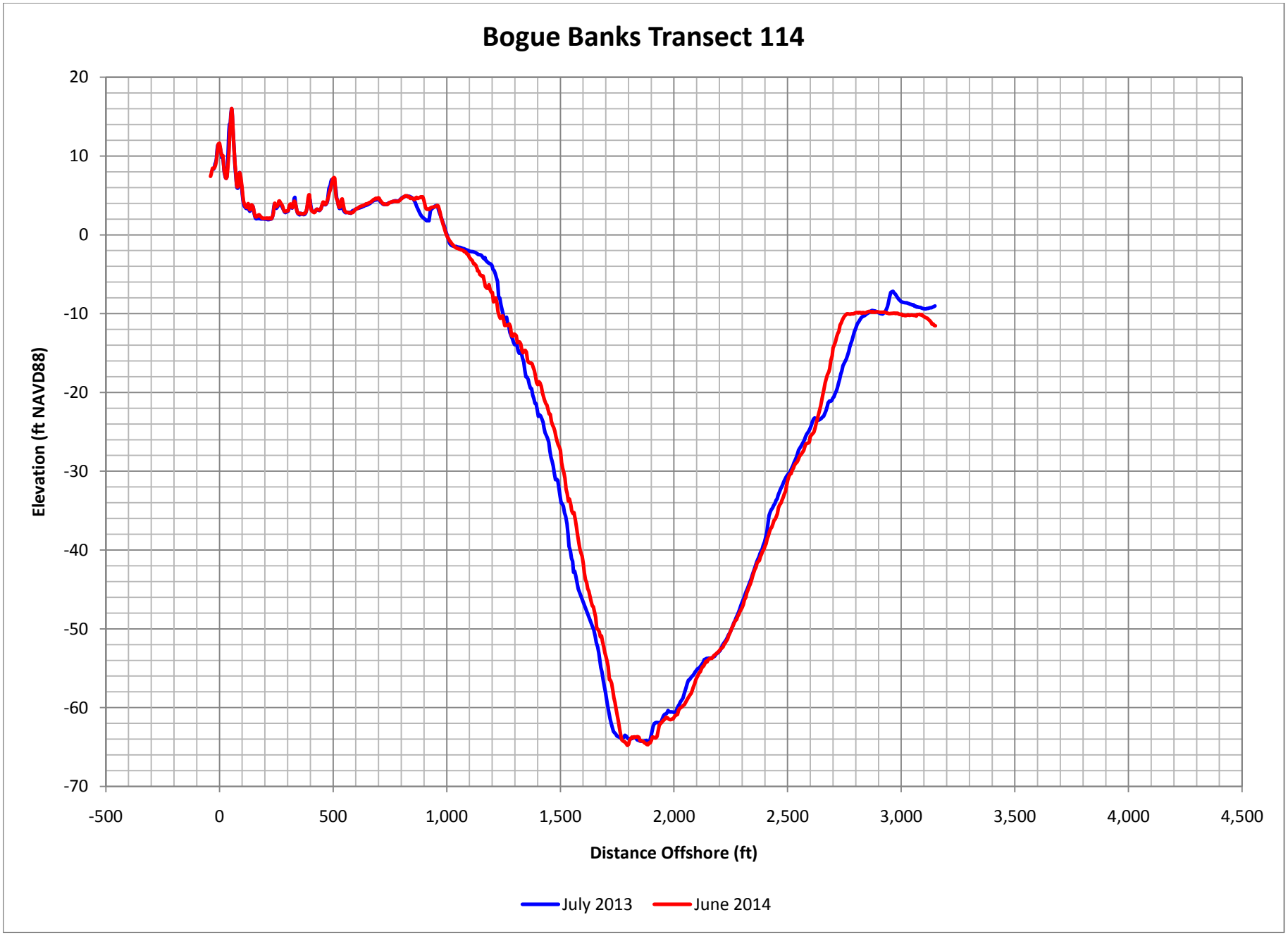


Figure C-143. Bogue Banks Profile Comparison Plot

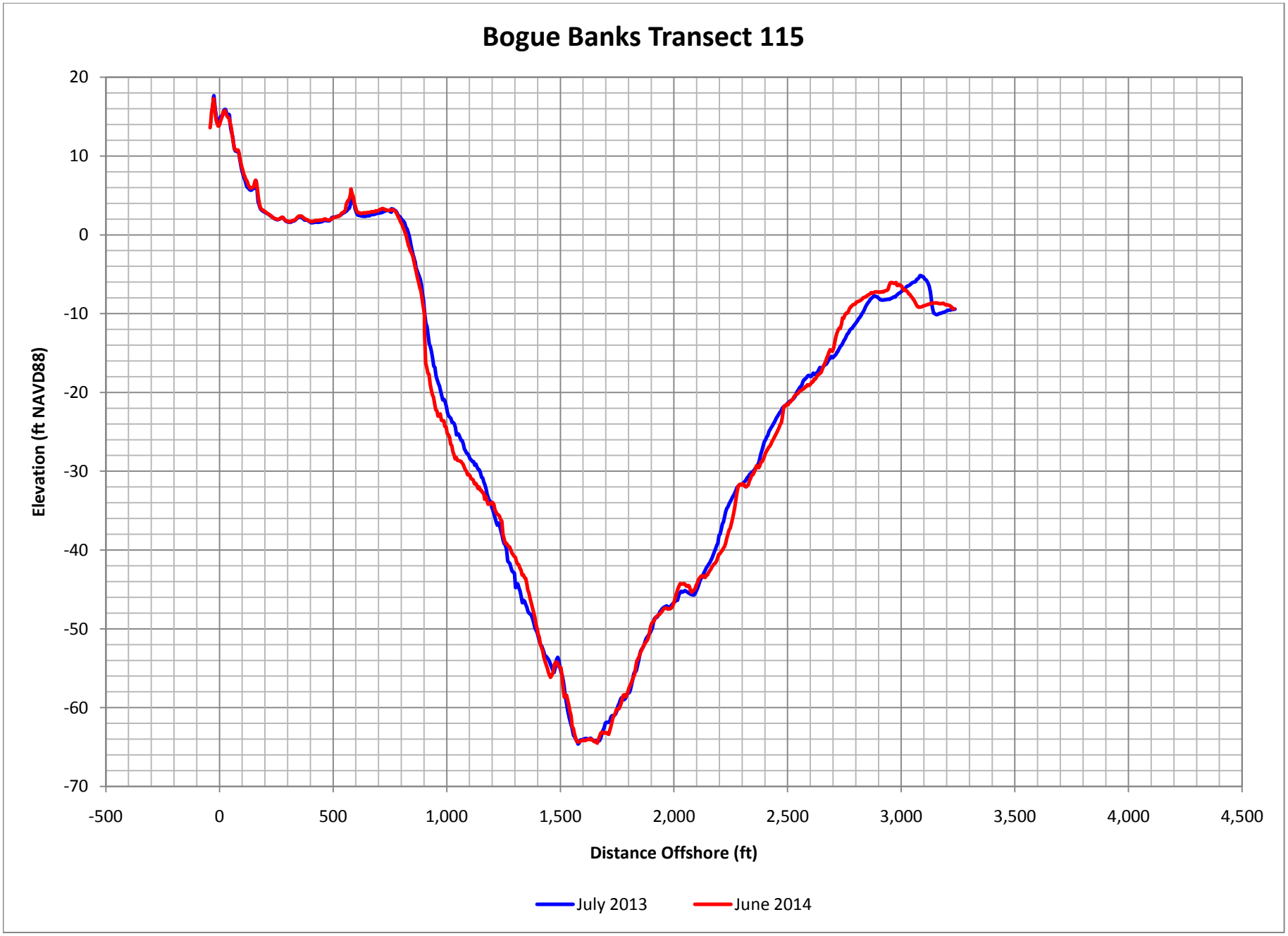


Figure C-144. Bogue Banks Profile Comparison Plot

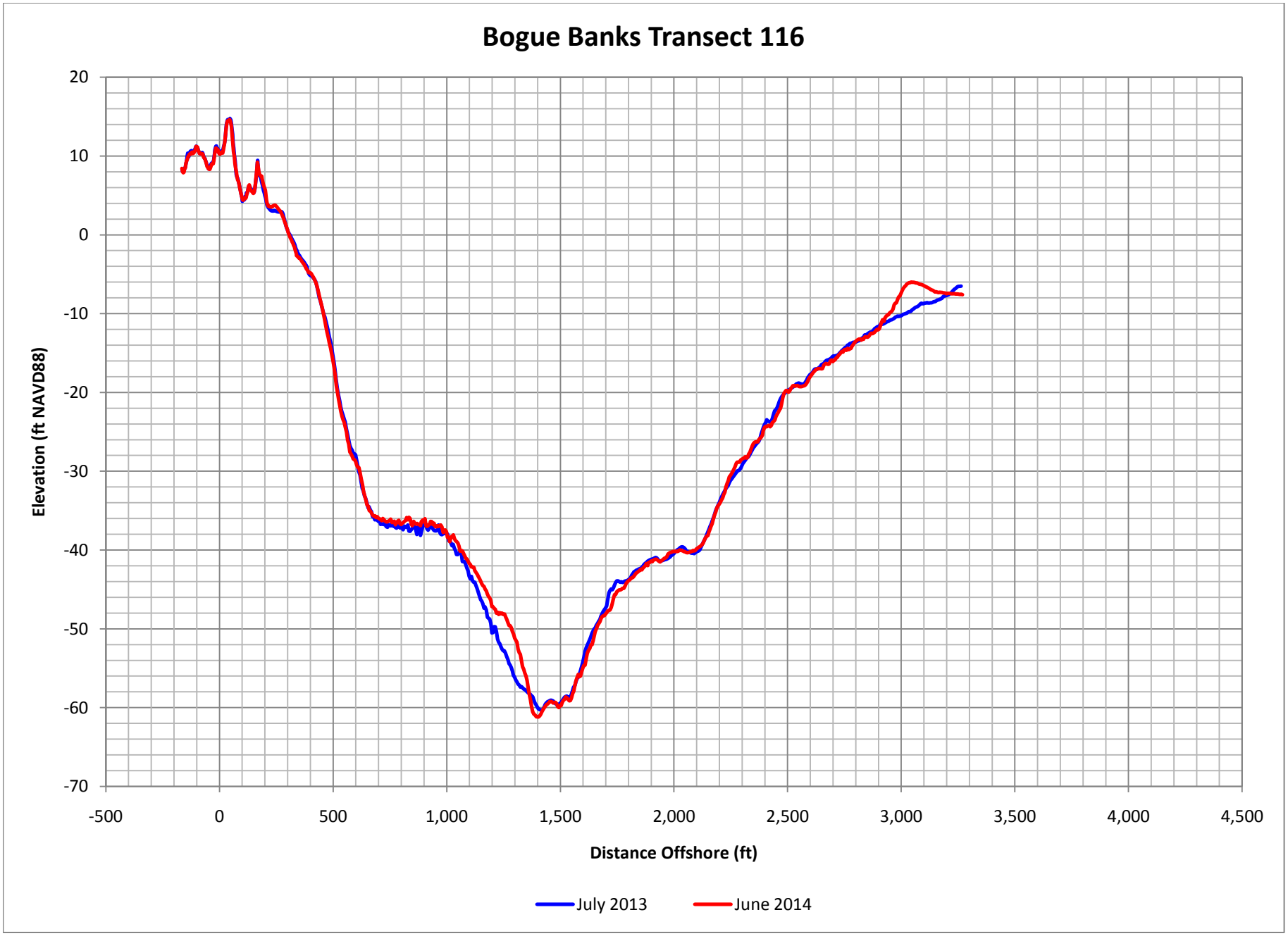


Figure C-145. Bogue Banks Profile Comparison Plot

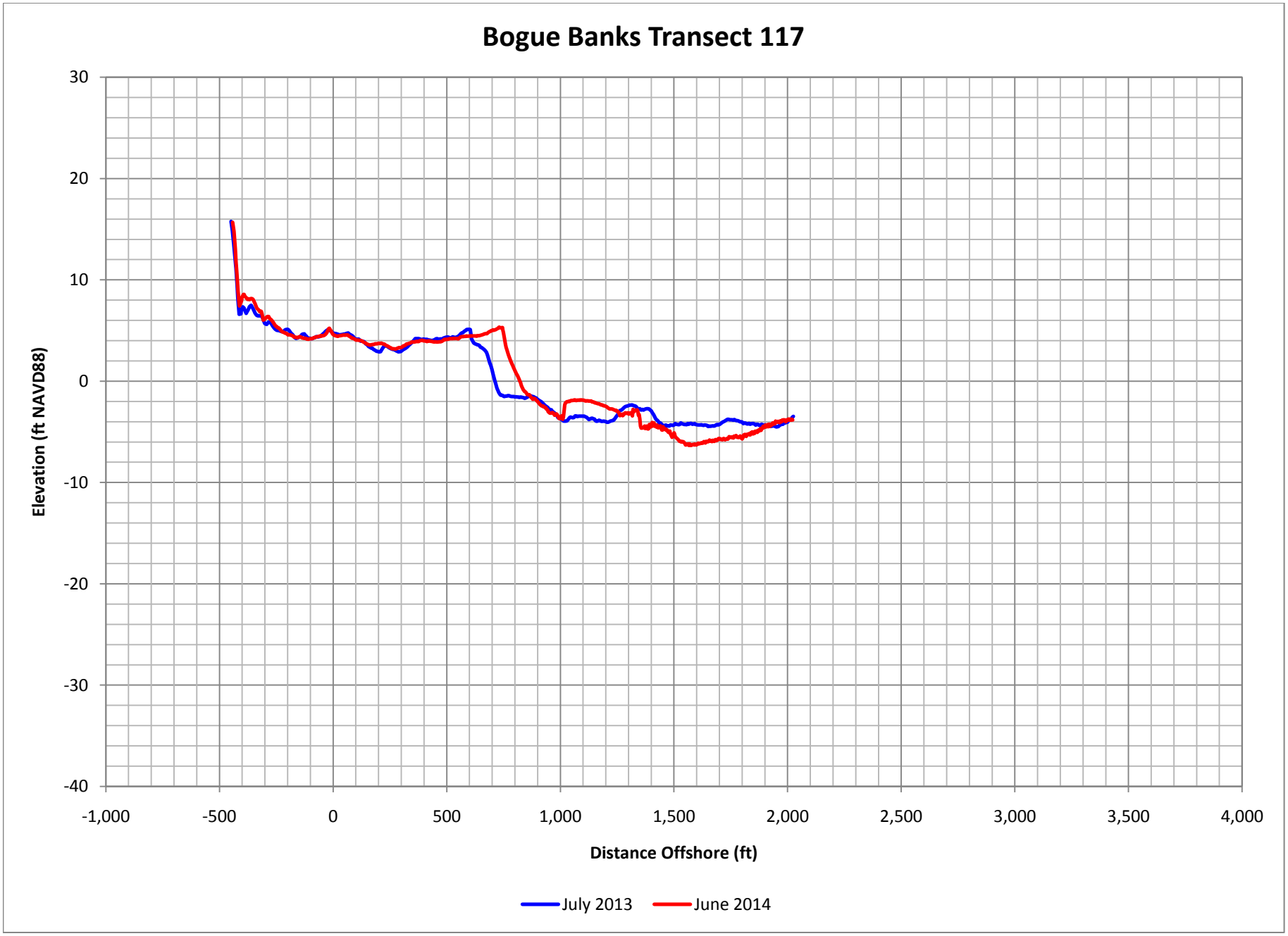


Figure C-146. Bogue Banks Profile Comparison Plot

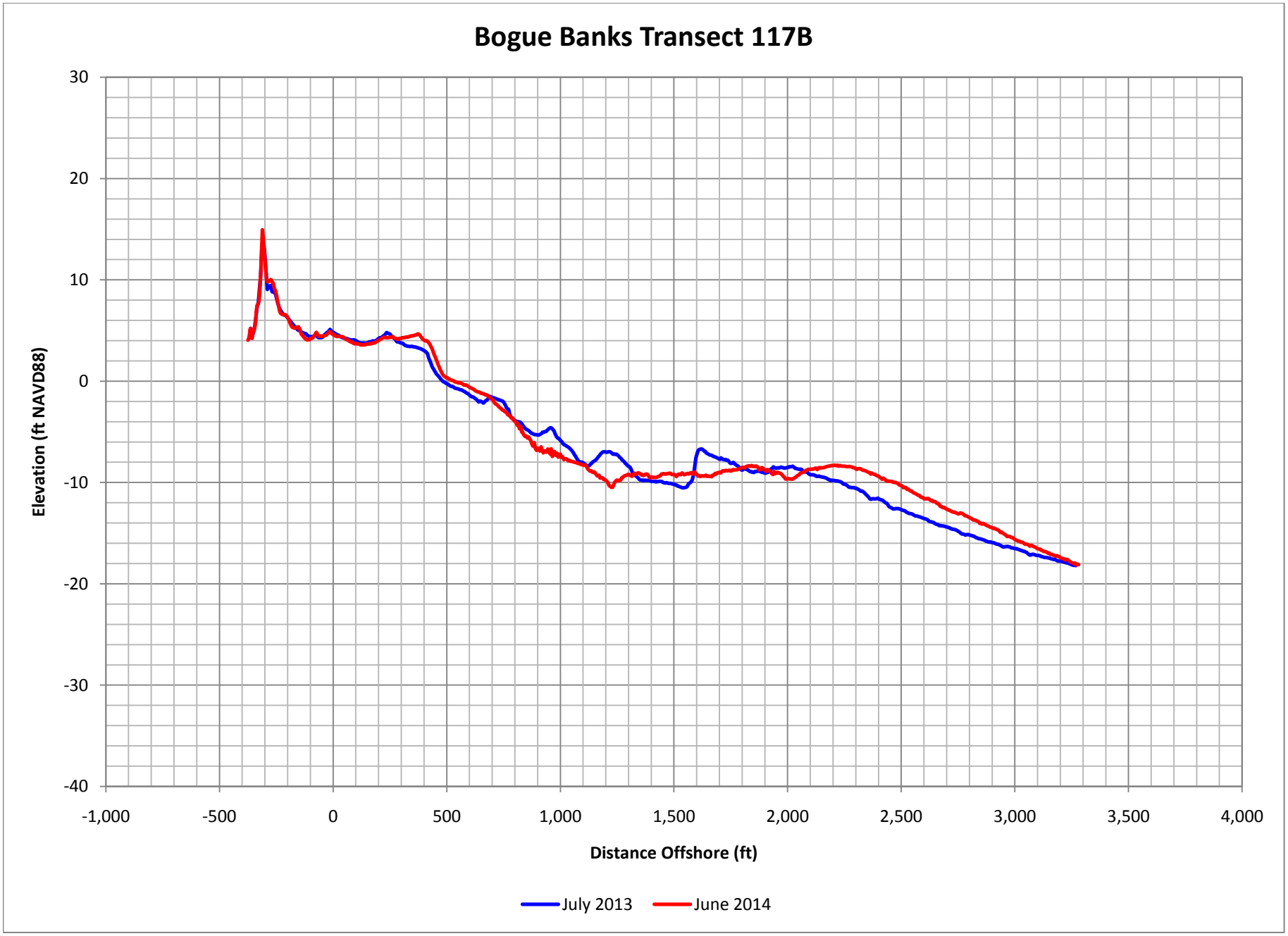


Figure C-147. Bogue Banks Profile Comparison Plot

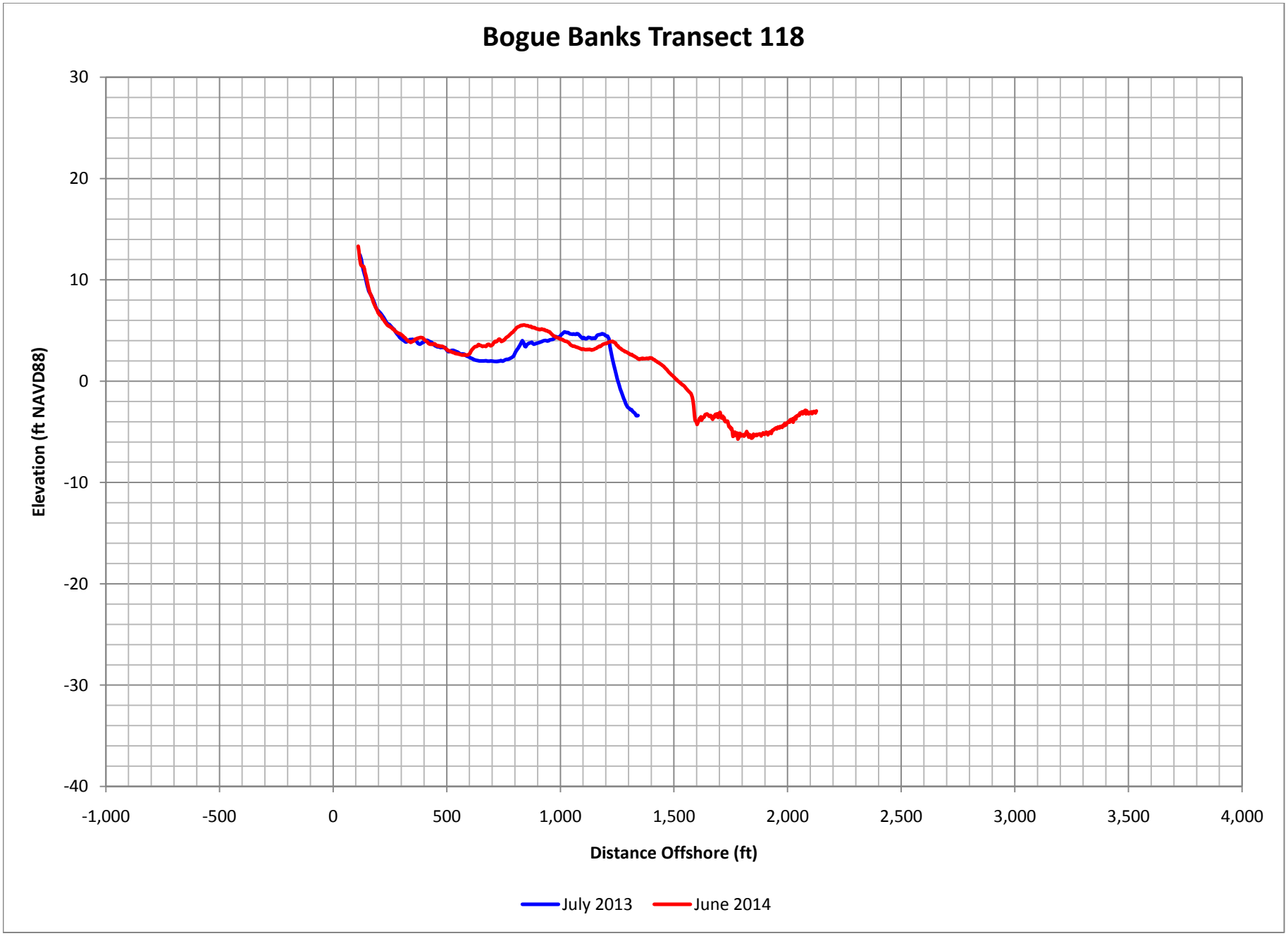


Figure C-148. Bogue Banks Profile Comparison Plot

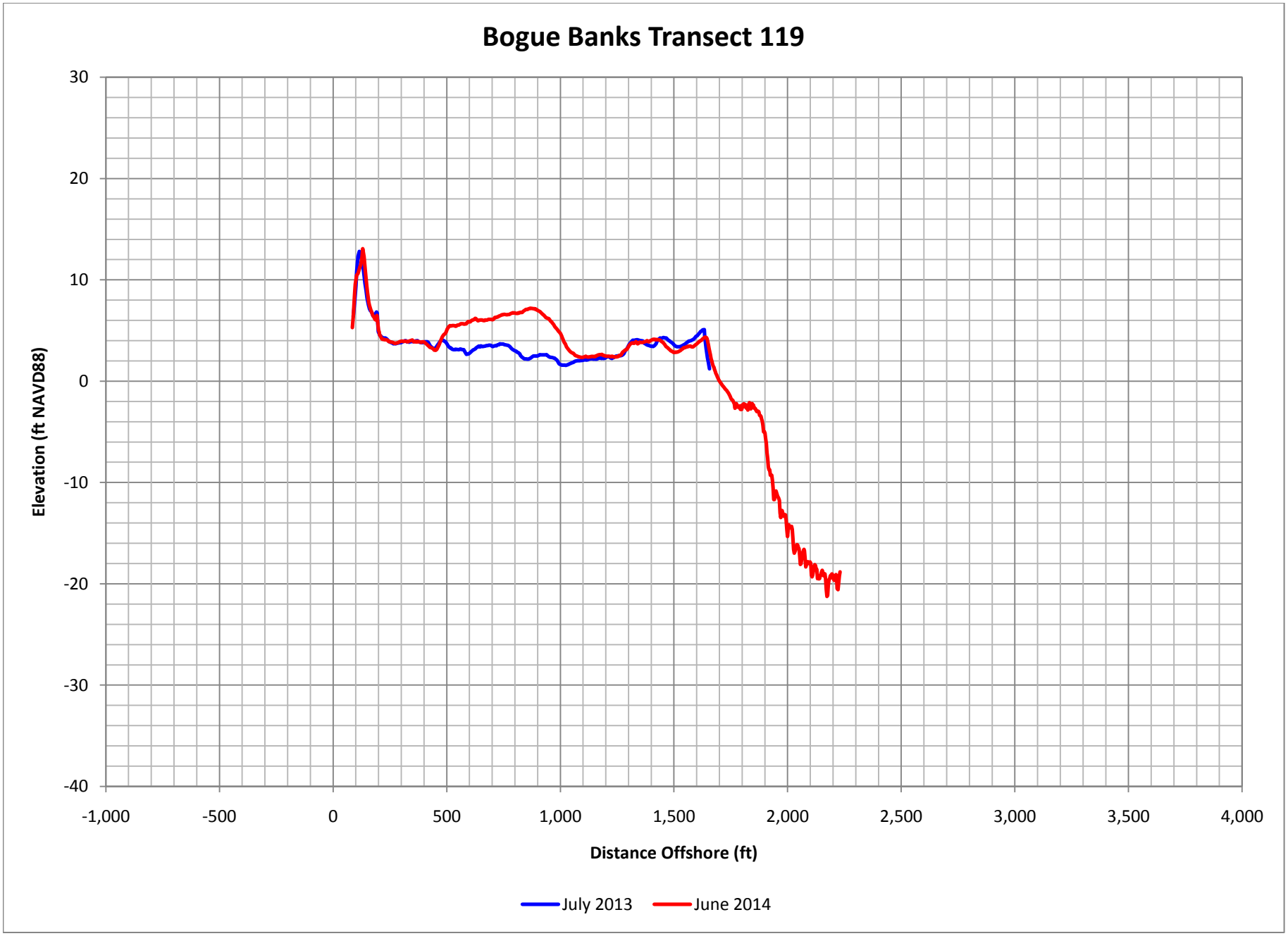


Figure C-149. Bogue Banks Profile Comparison Plot

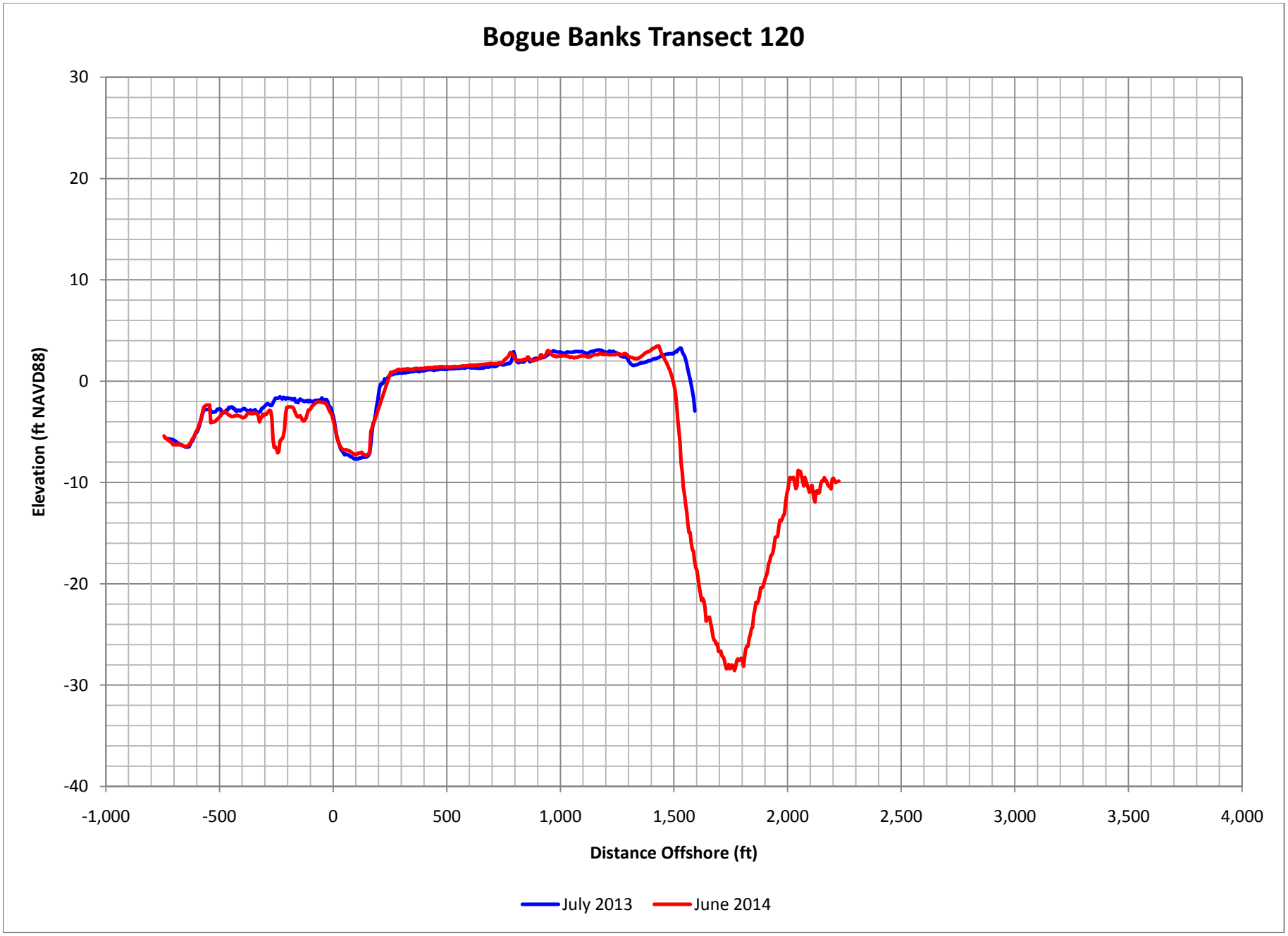


Figure C-150. Bogue Banks Profile Comparison Plot

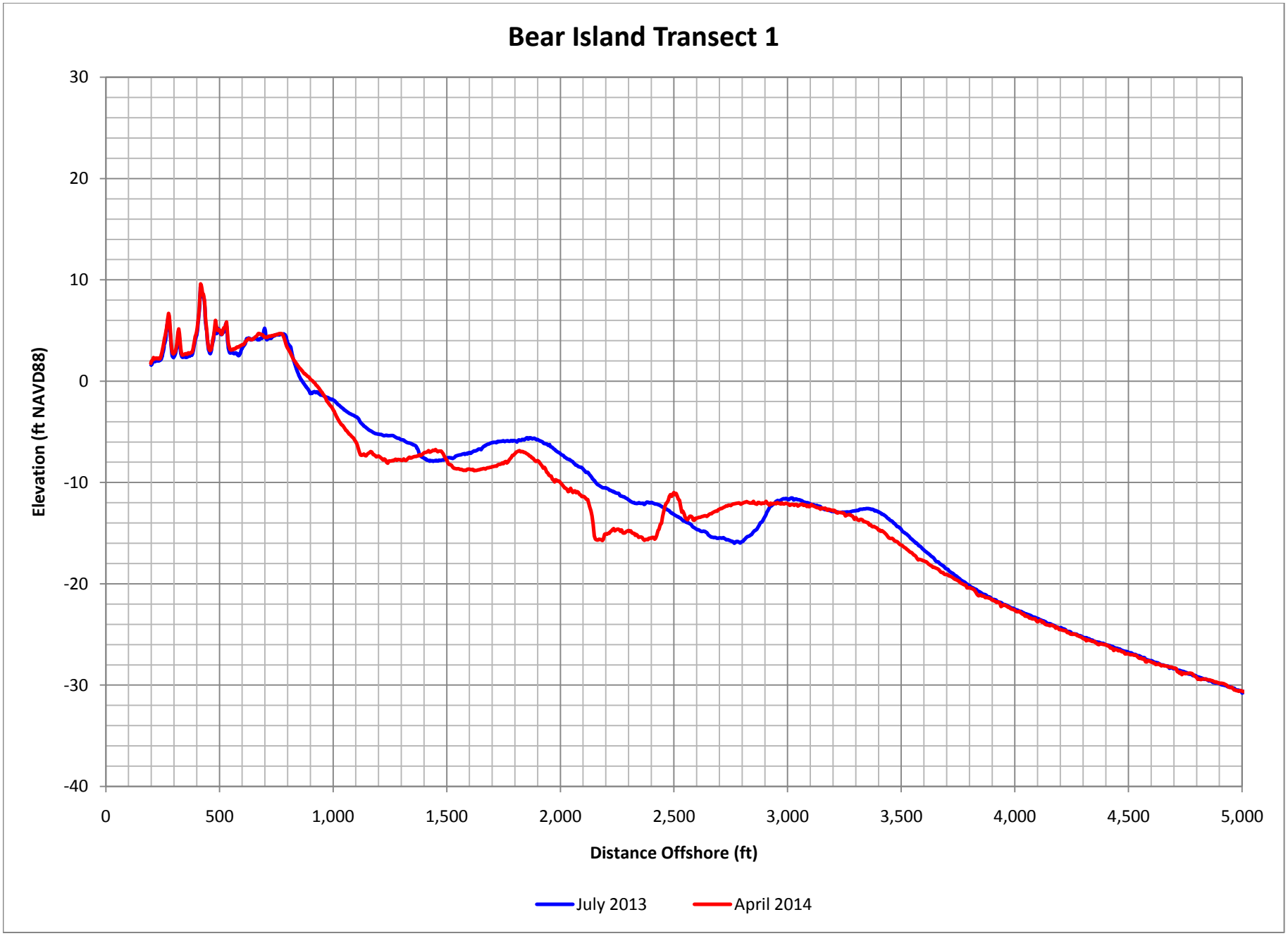


Figure C-151. Bear Island Profile Comparison Plot

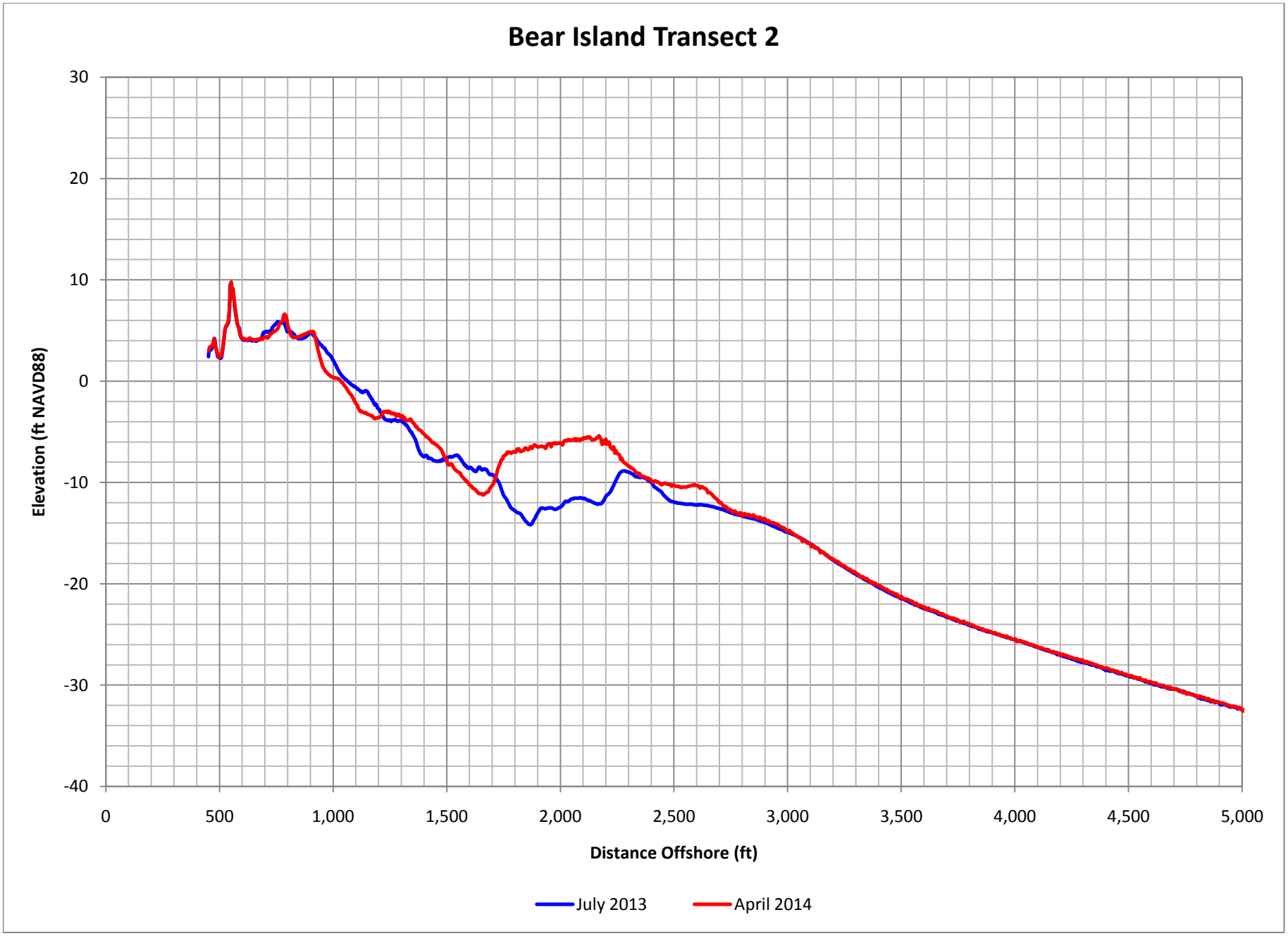


Figure C-152. Bear Island Profile Comparison Plot

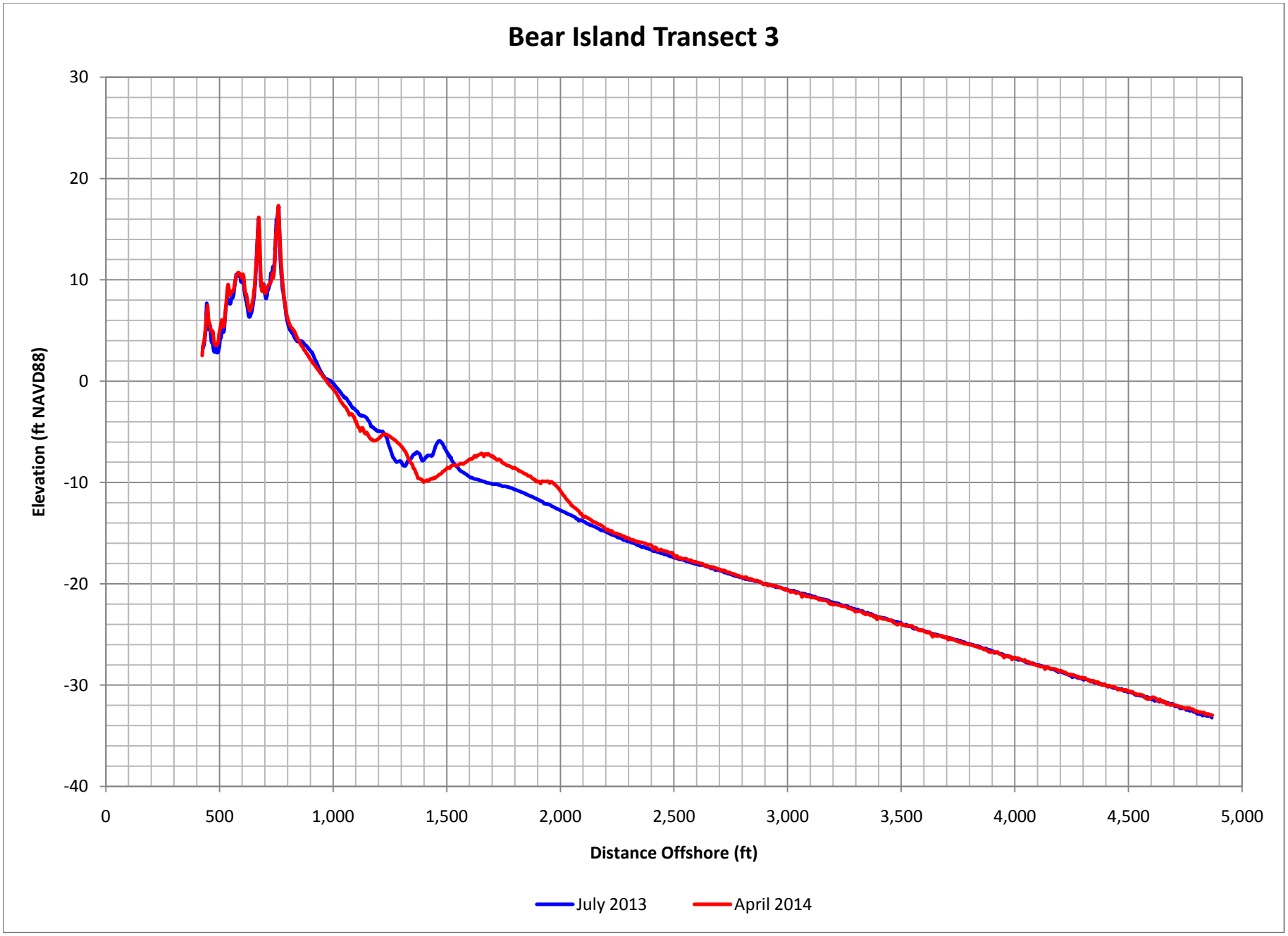


Figure C-153. Bear Island Profile Comparison Plot

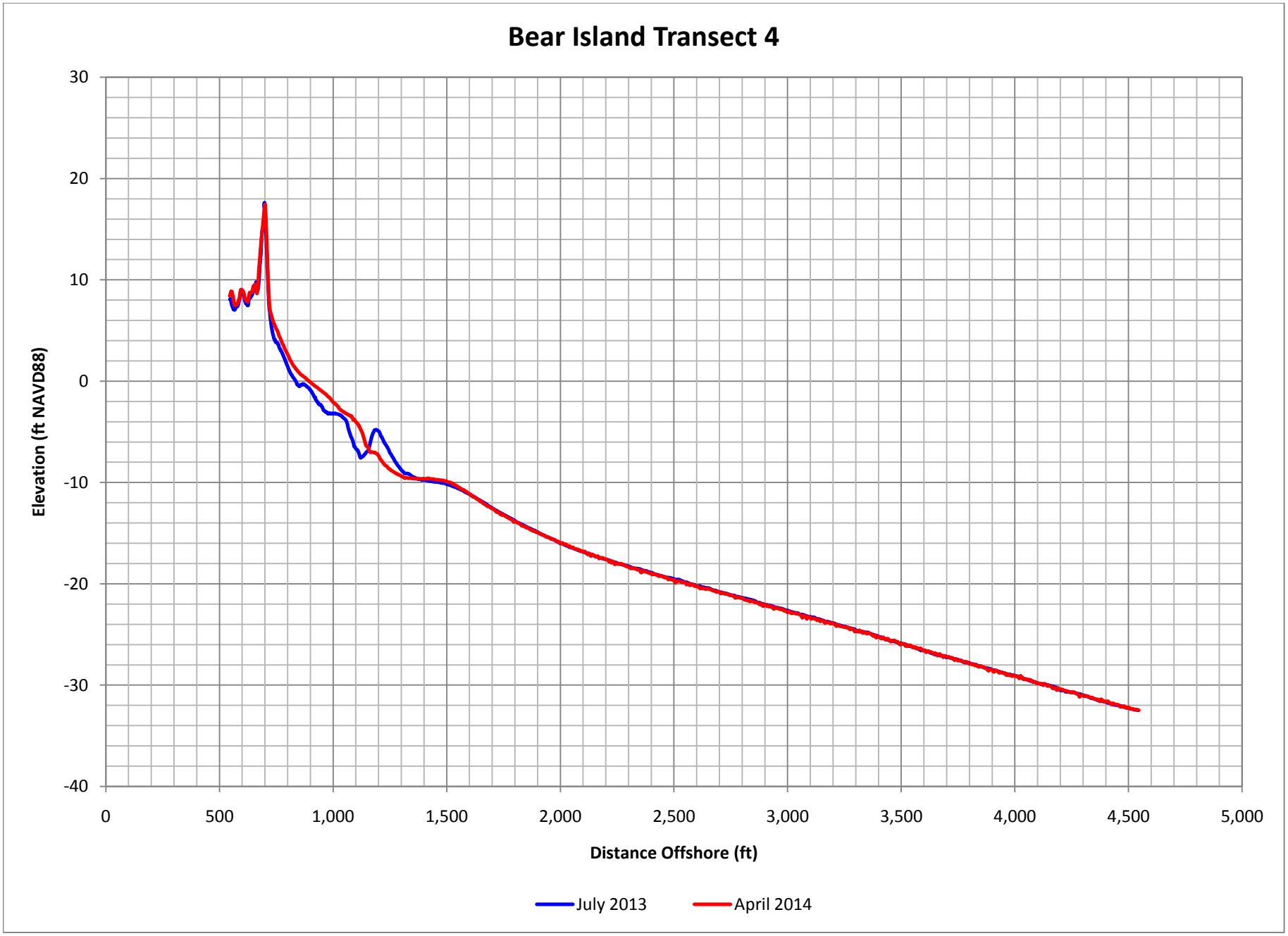


Figure C-154. Bear Island Profile Comparison Plot

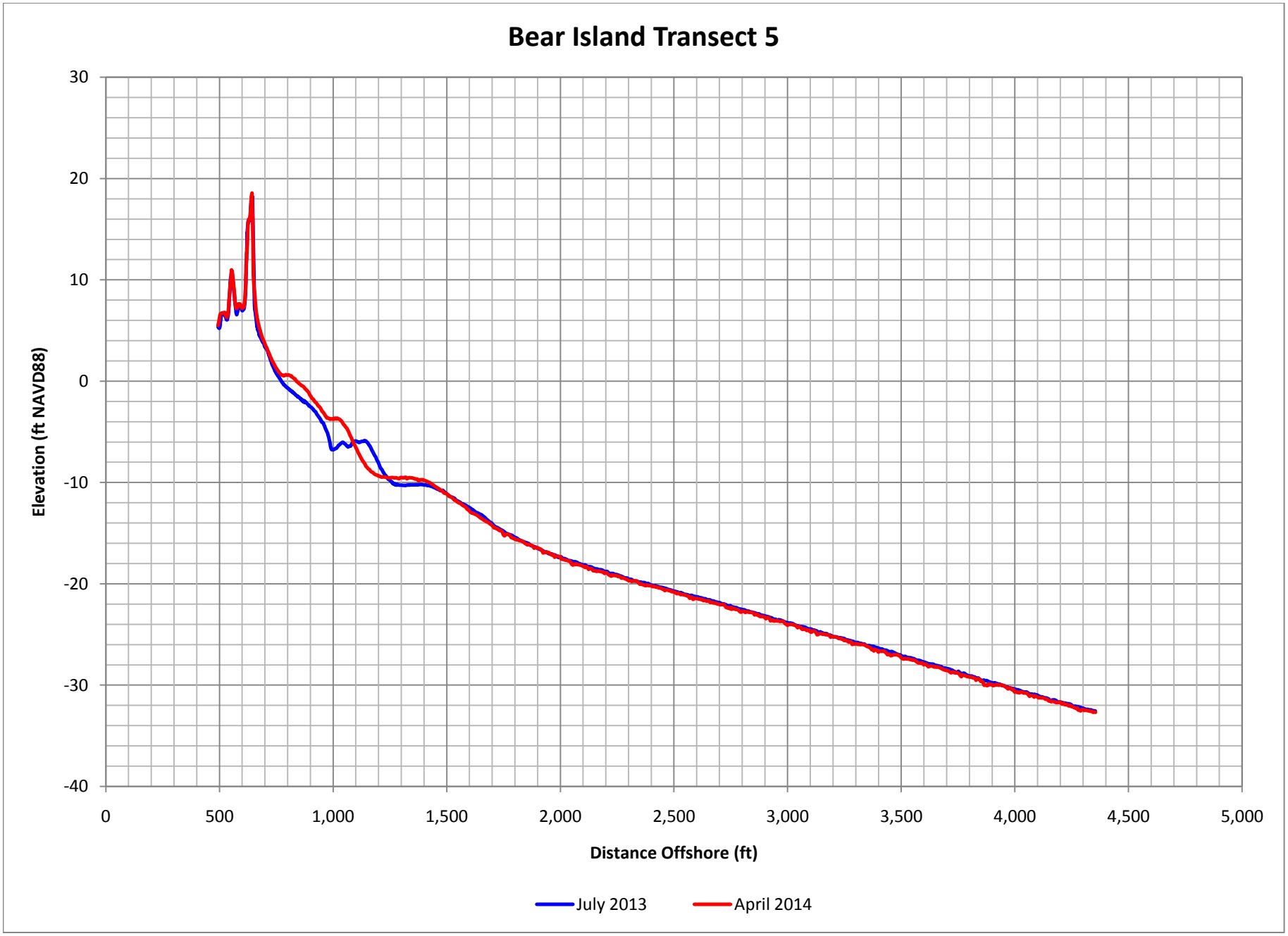


Figure C-155. Bear Island Profile Comparison Plot

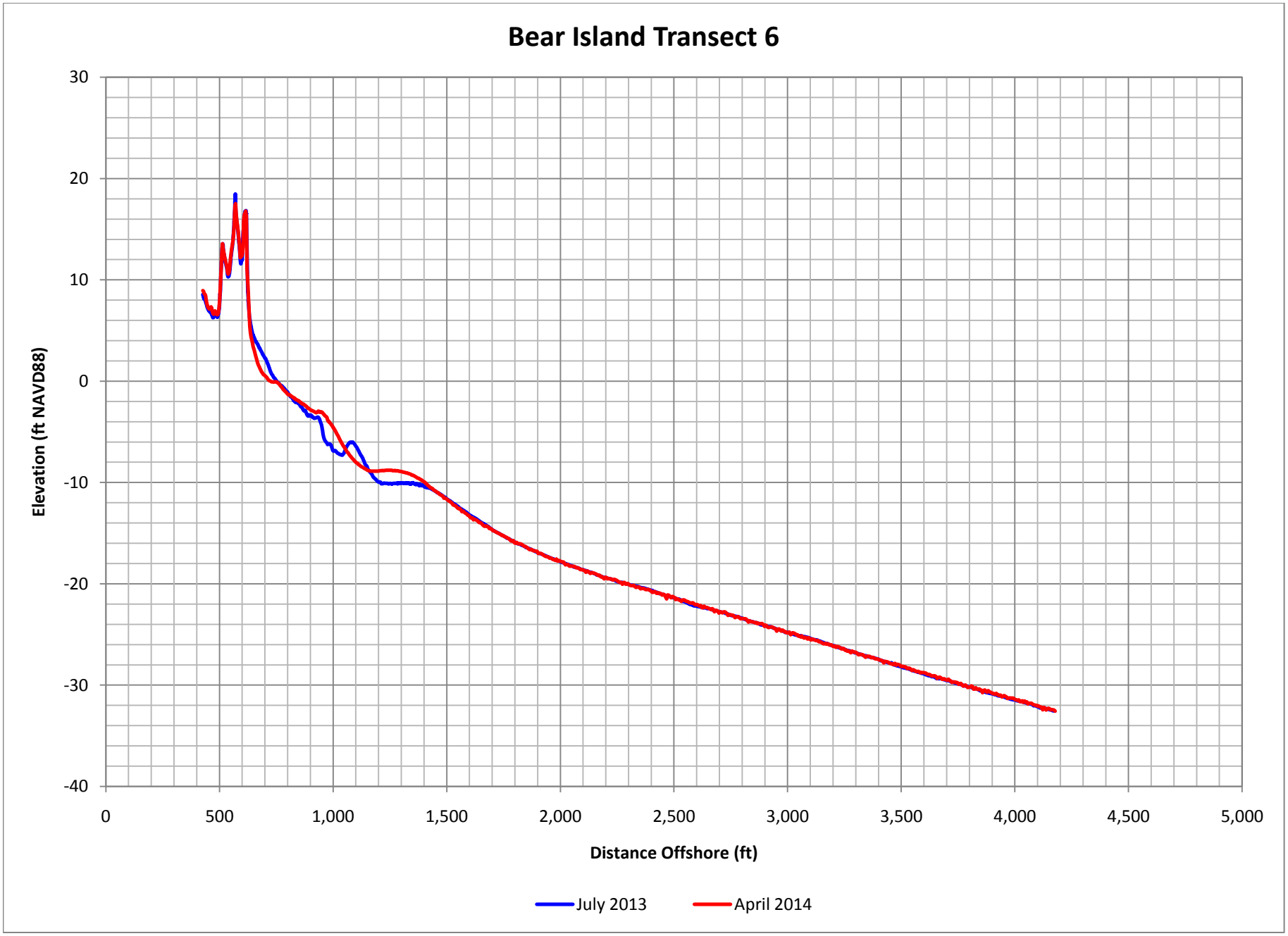


Figure C-156. Bear Island Profile Comparison Plot

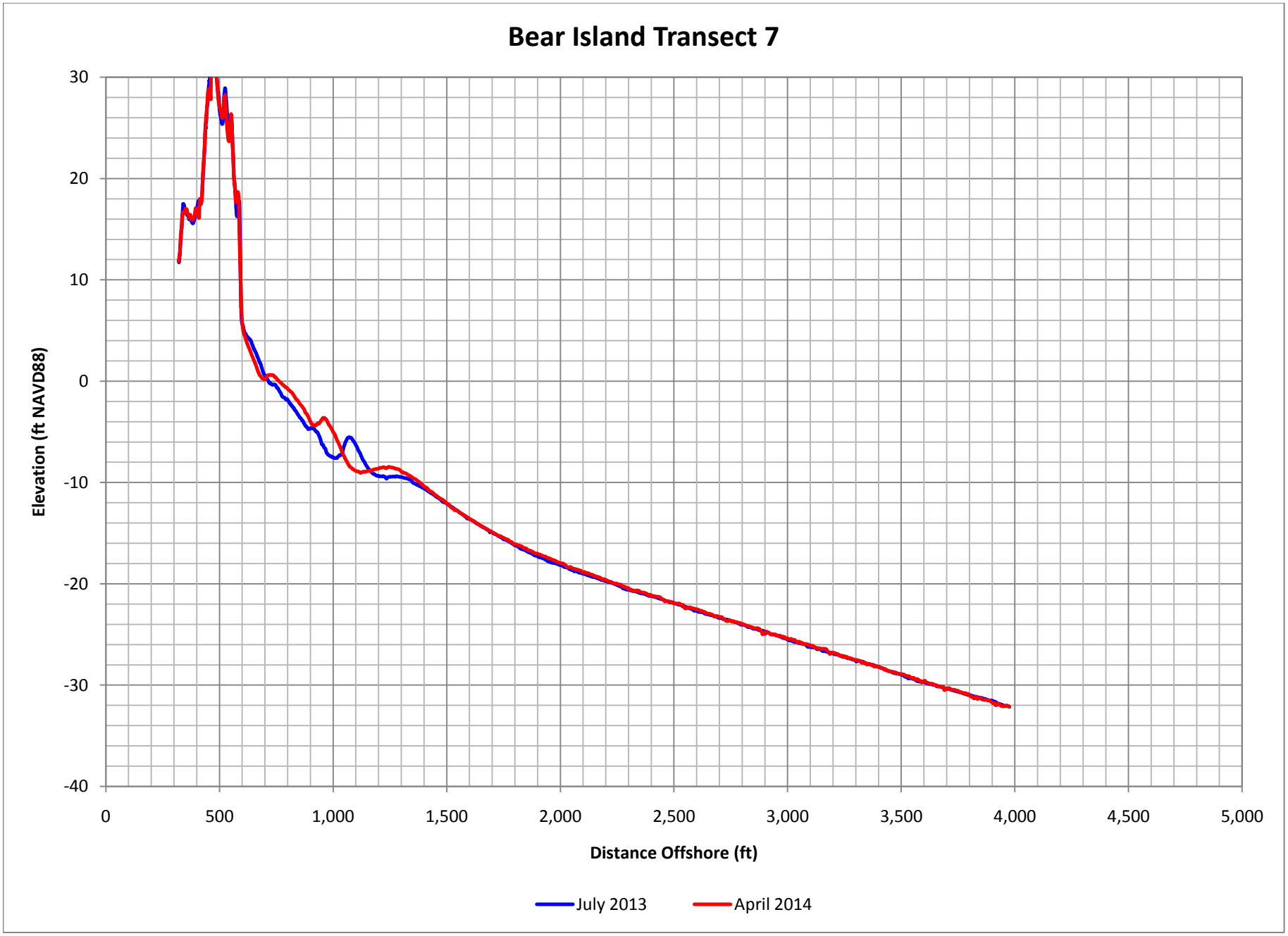


Figure C-157. Bear Island Profile Comparison Plot

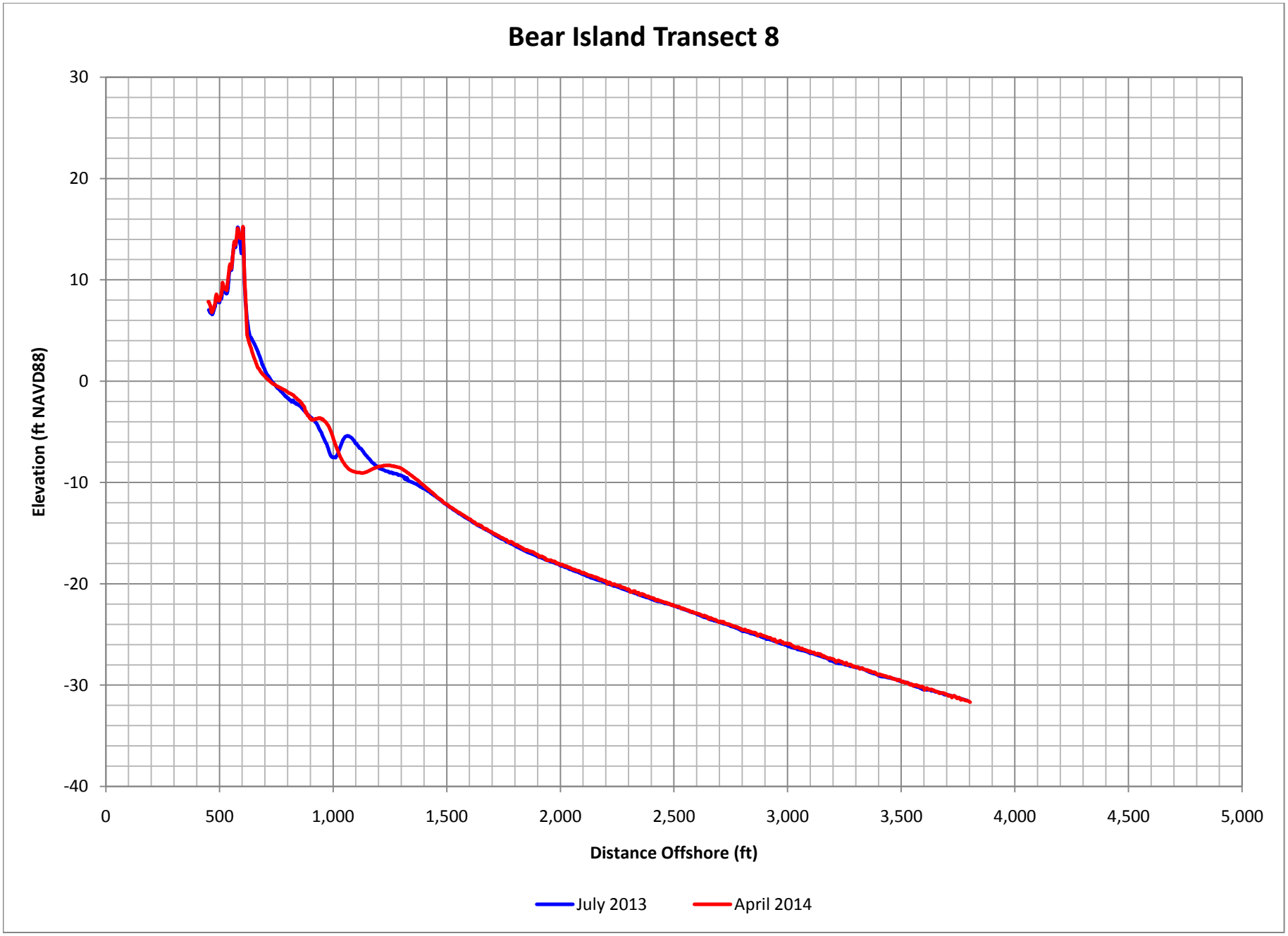


Figure C-158. Bear Island Profile Comparison Plot

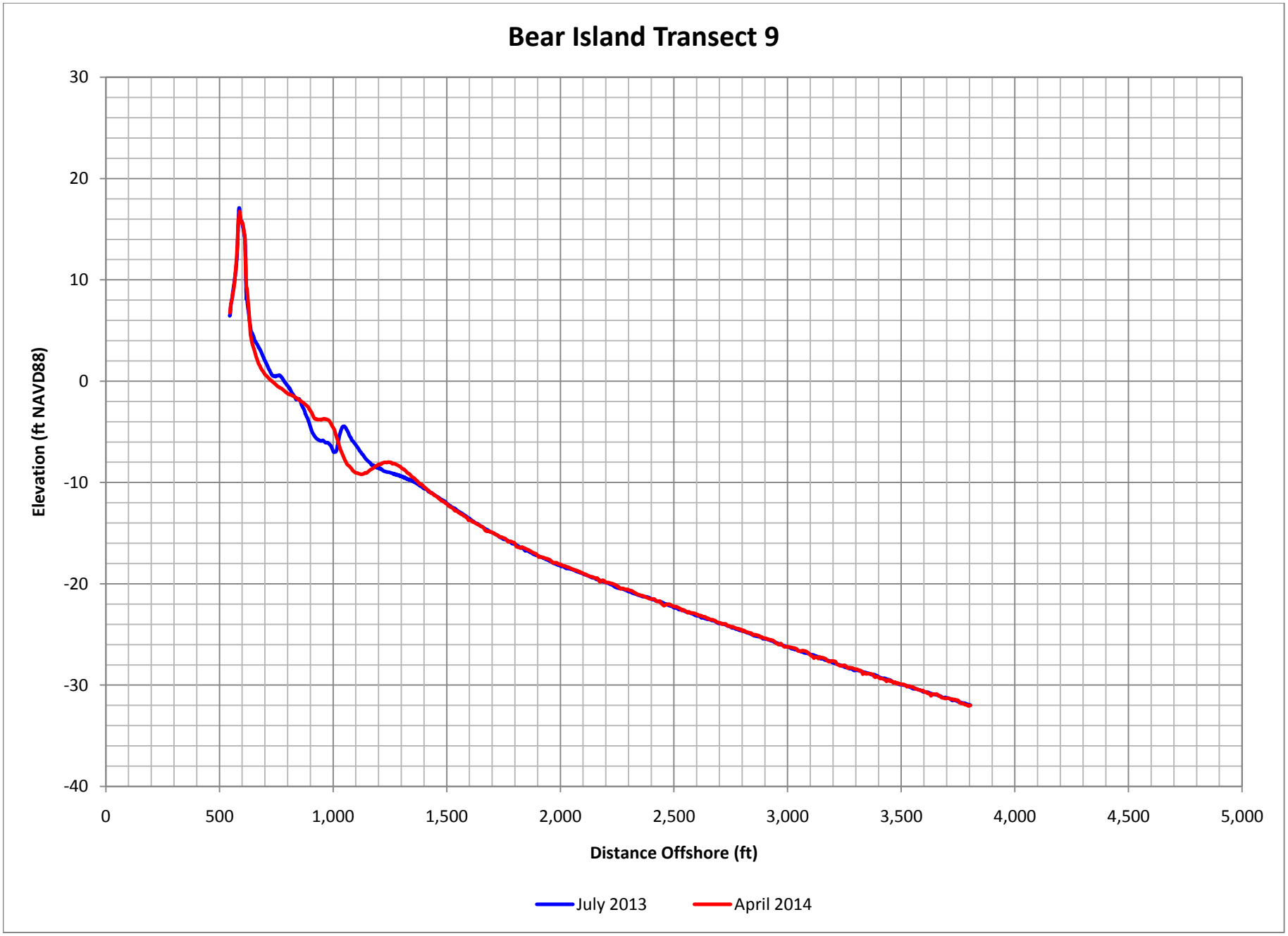


Figure C-159. Bear Island Profile Comparison Plot

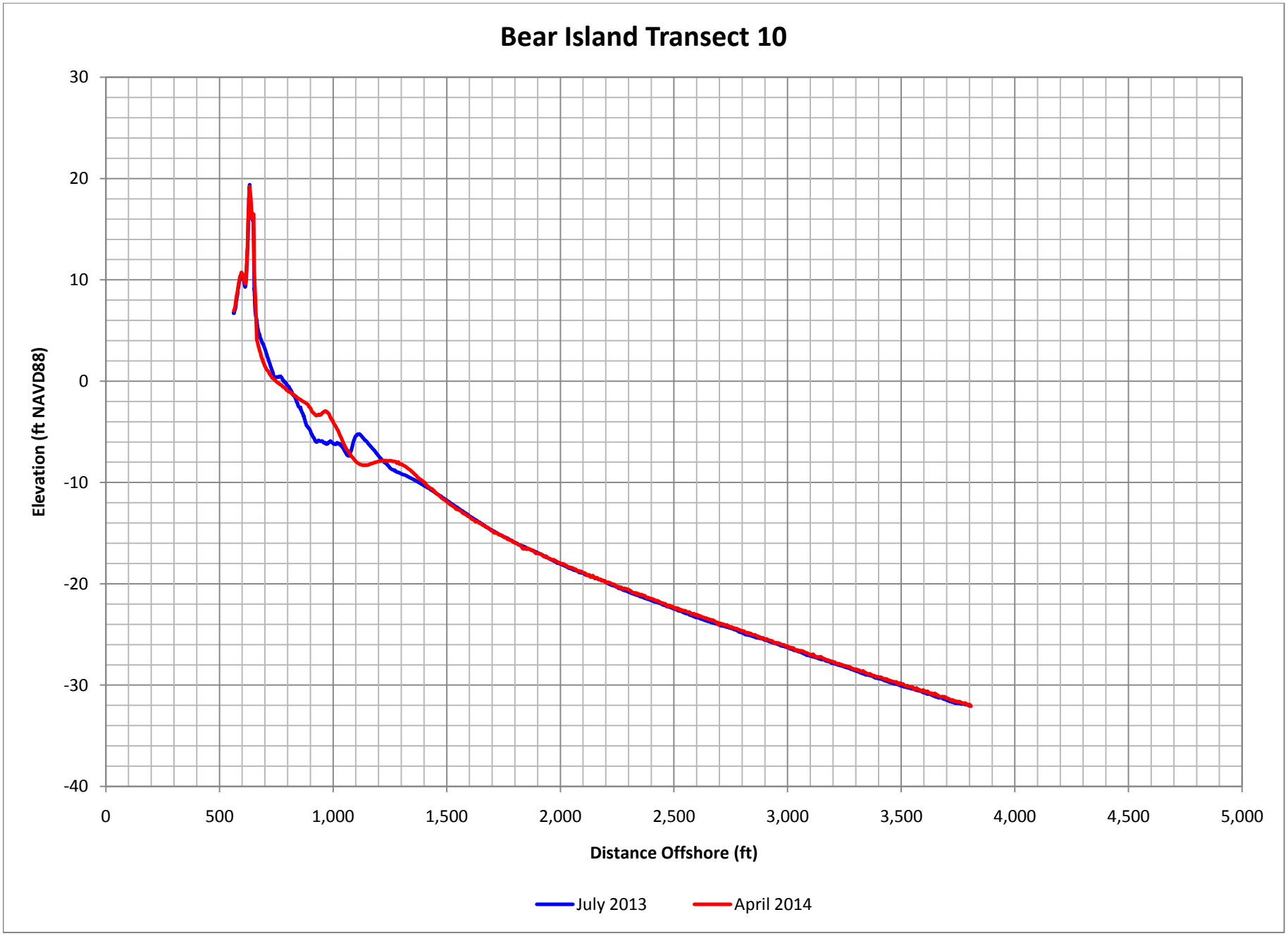


Figure C-160. Bear Island Profile Comparison Plot

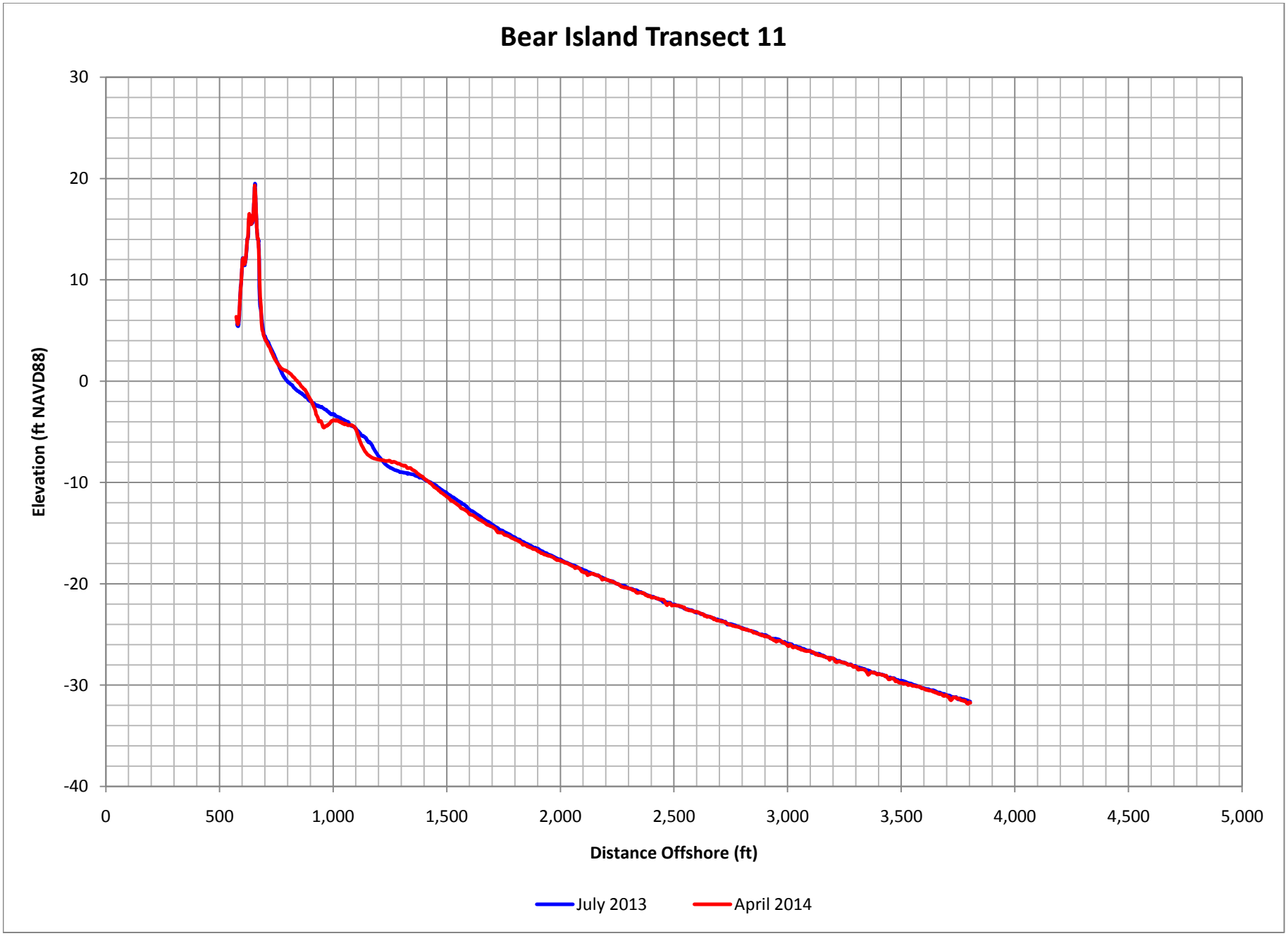


Figure C-161. Bear Island Profile Comparison Plot

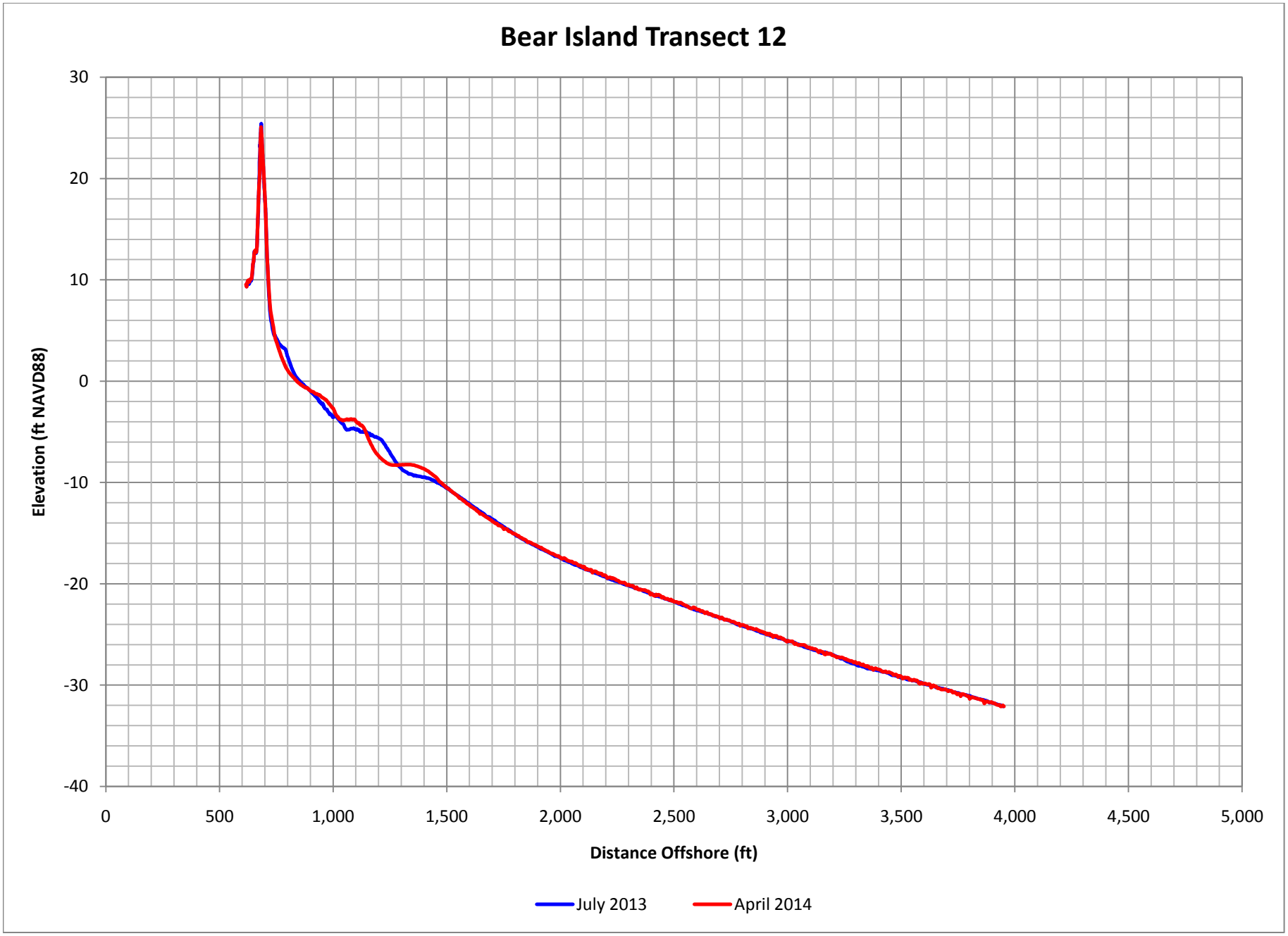


Figure C-162. Bear Island Profile Comparison Plot

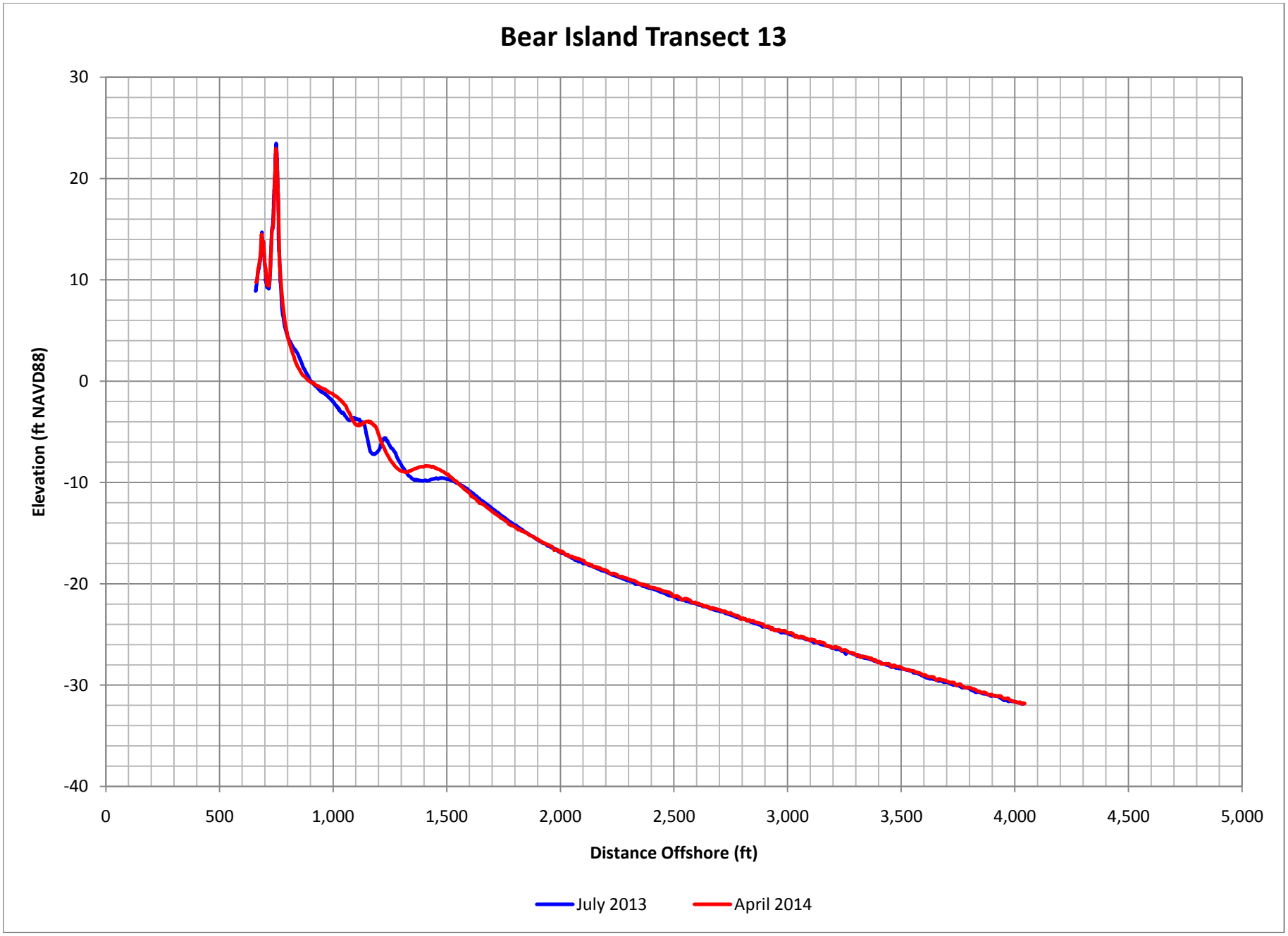


Figure C-163. Bear Island Profile Comparison Plot

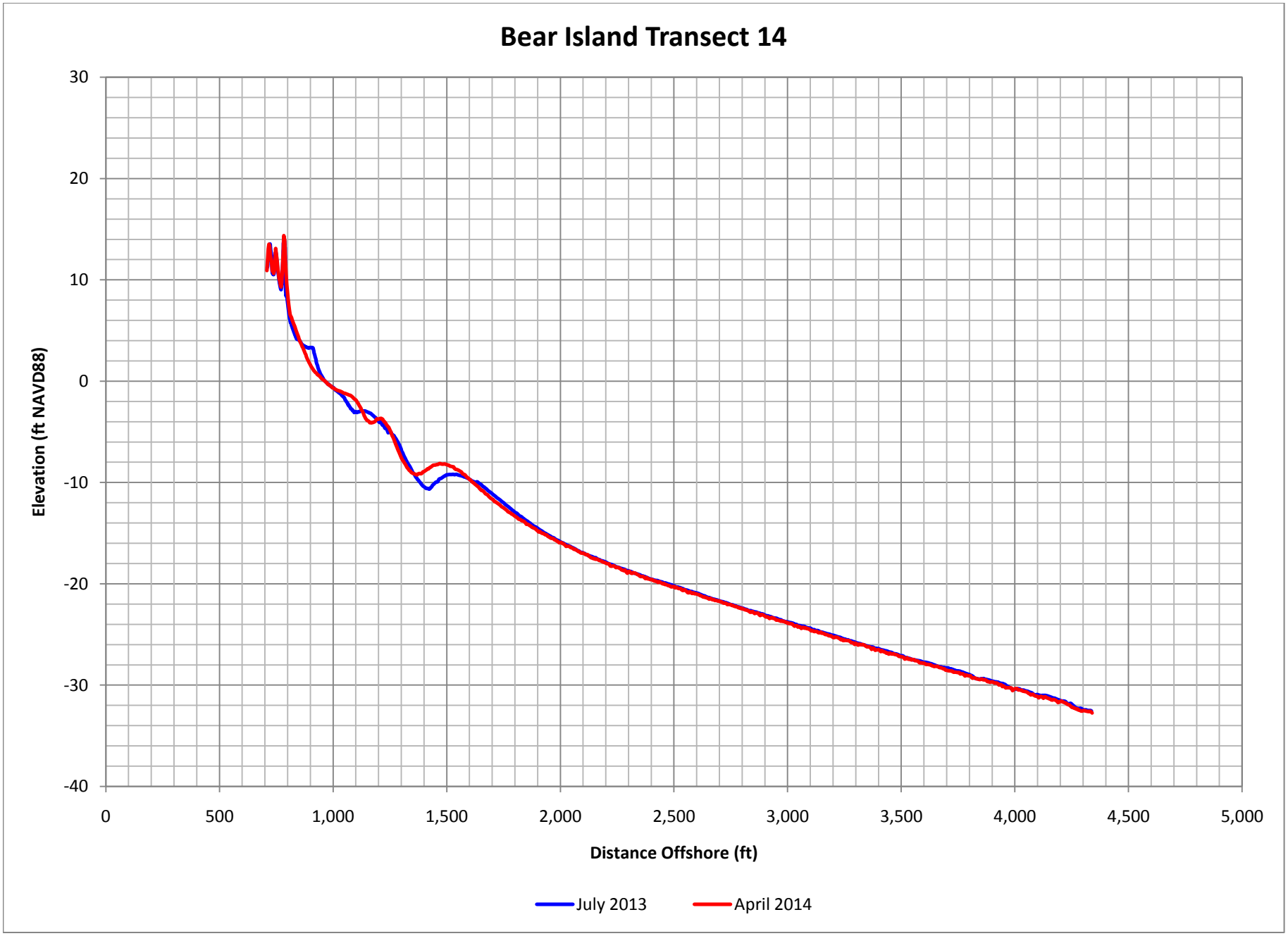


Figure C-164. Bear Island Profile Comparison Plot

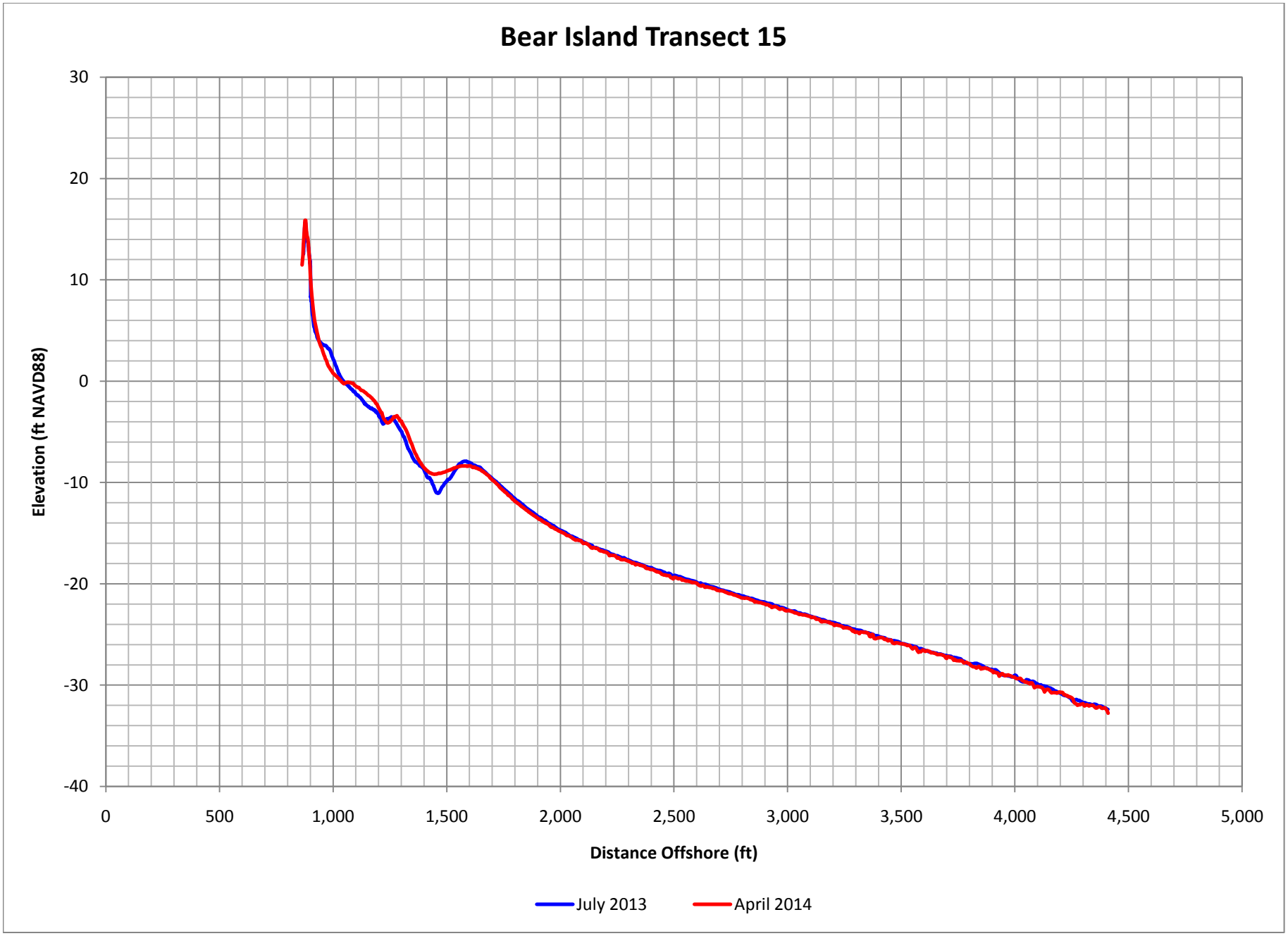


Figure C-165. Bear Island Profile Comparison Plot

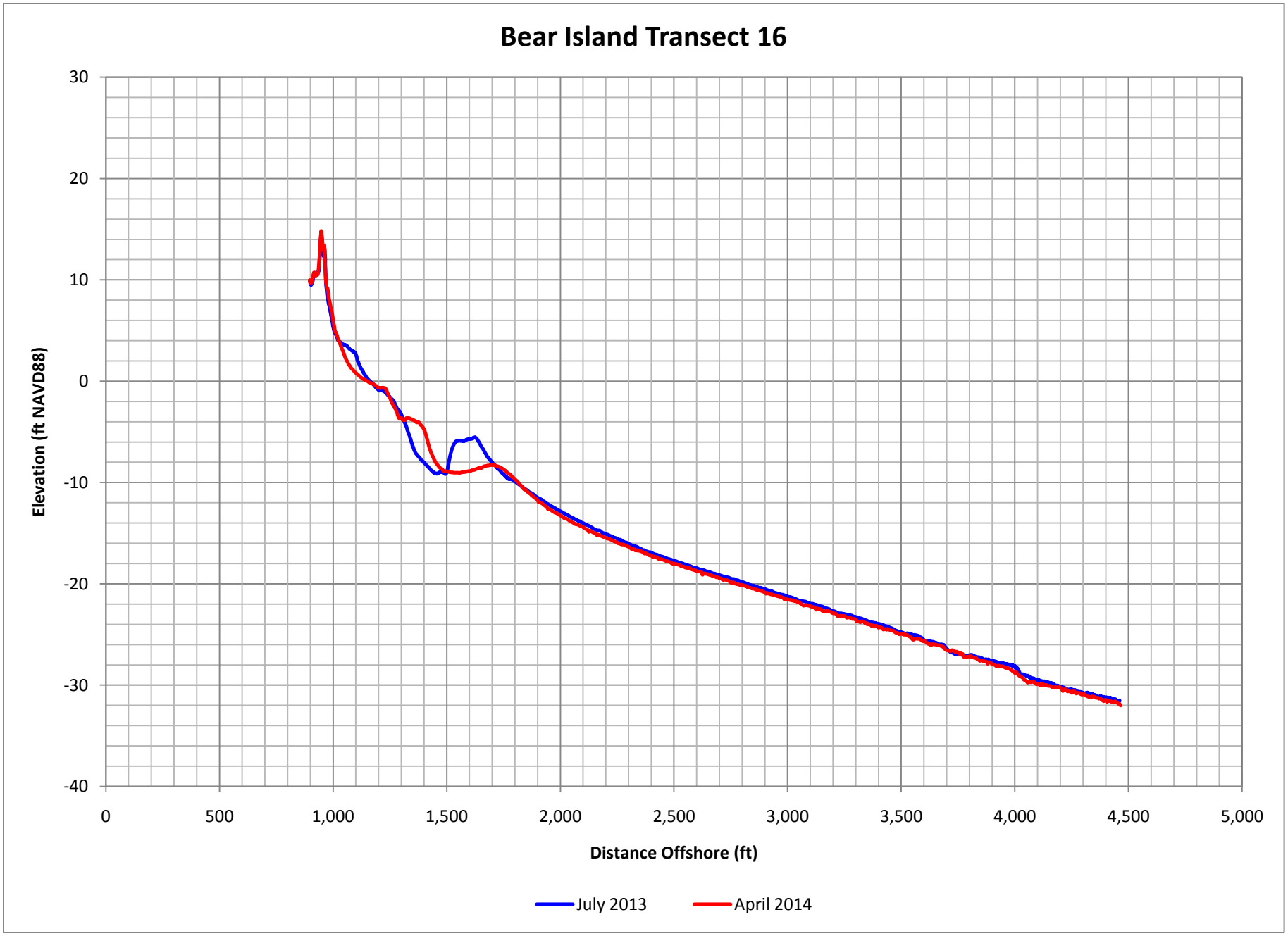


Figure C-166. Bear Island Profile Comparison Plot

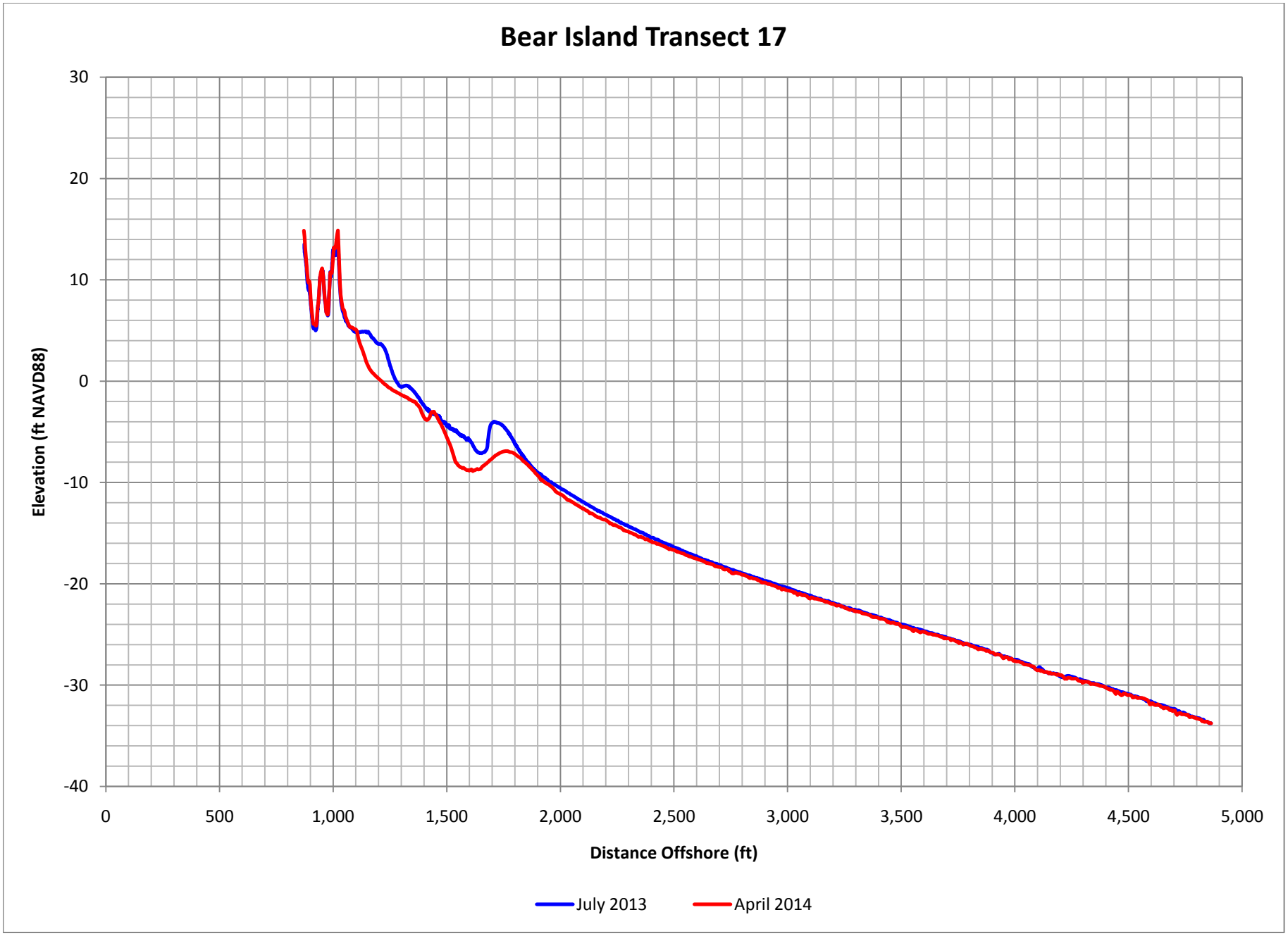


Figure C-167. Bear Island Profile Comparison Plot

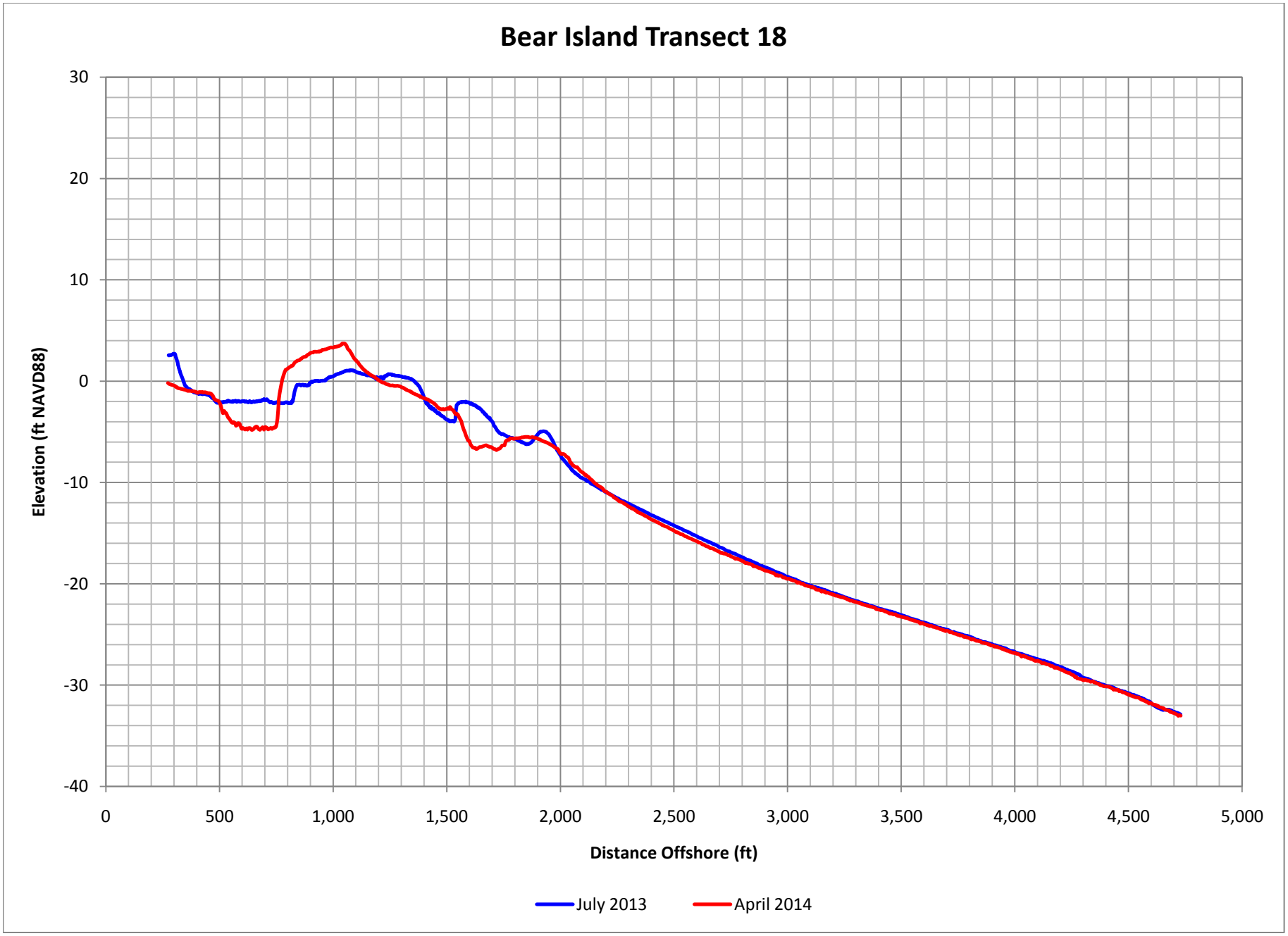


Figure C-168. Bear Island Profile Comparison Plot

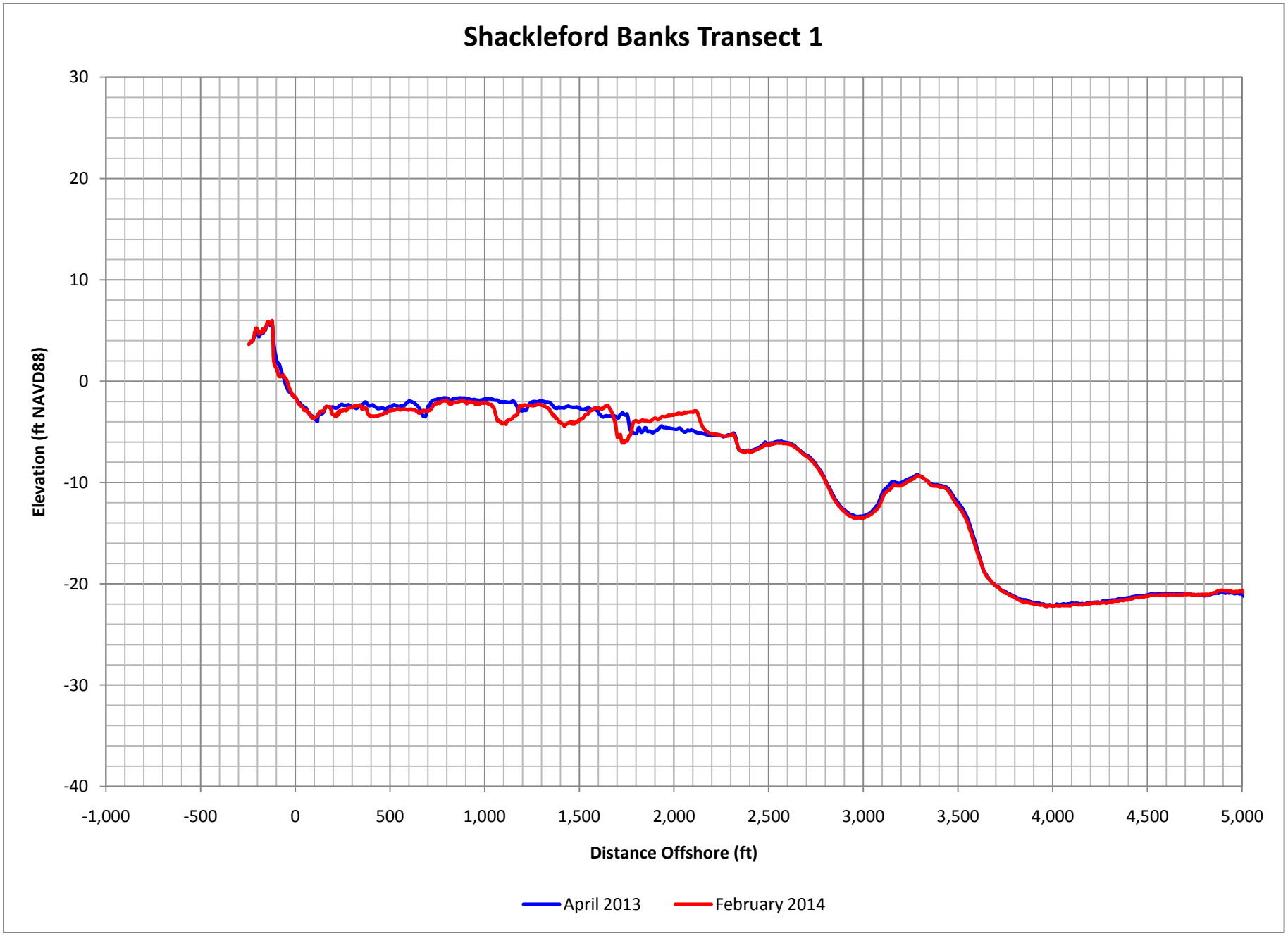


Figure C-169. Shackleford Banks Profile Comparison Plot

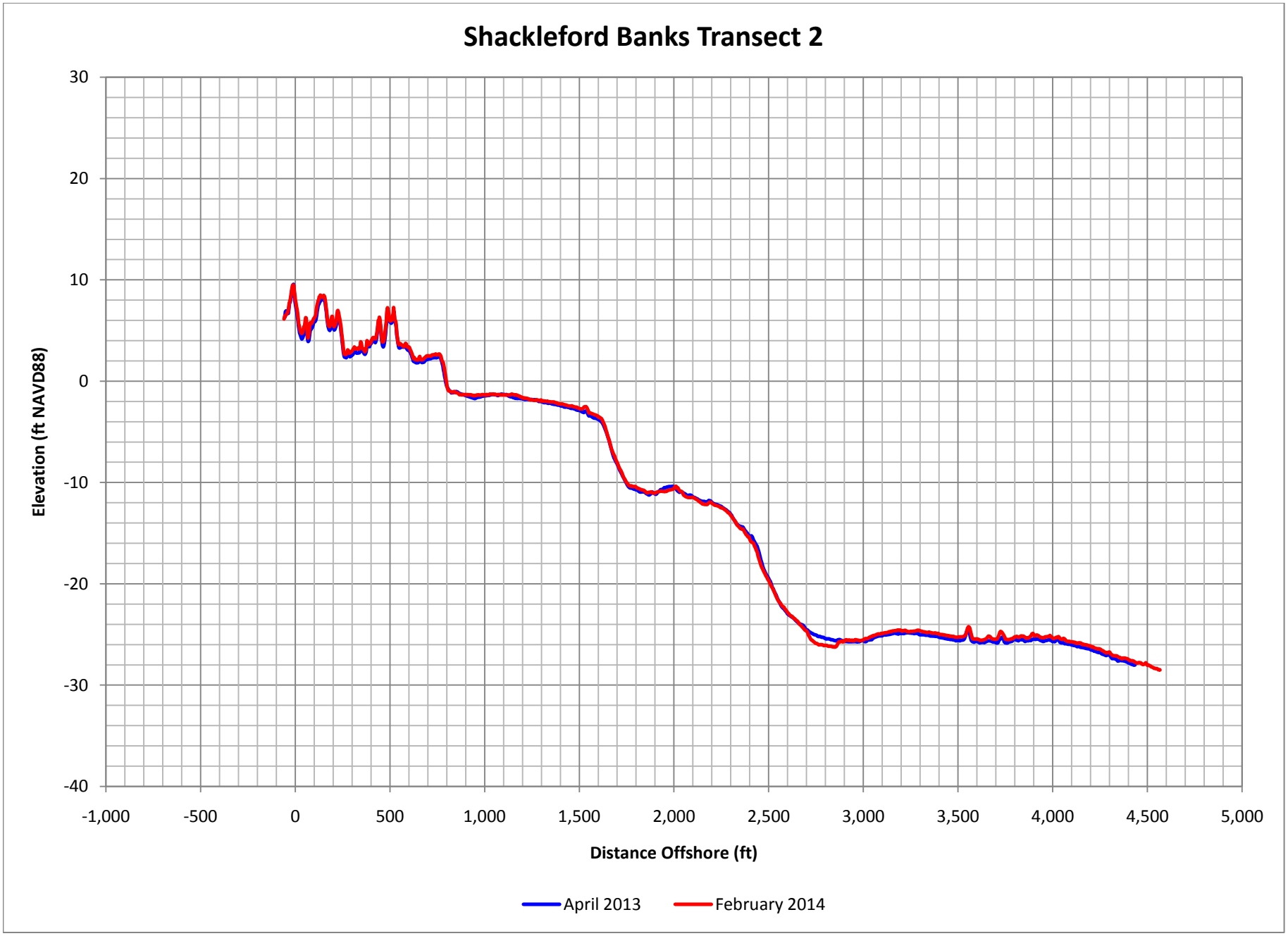


Figure C-170. Shackleford Banks Profile Comparison Plot

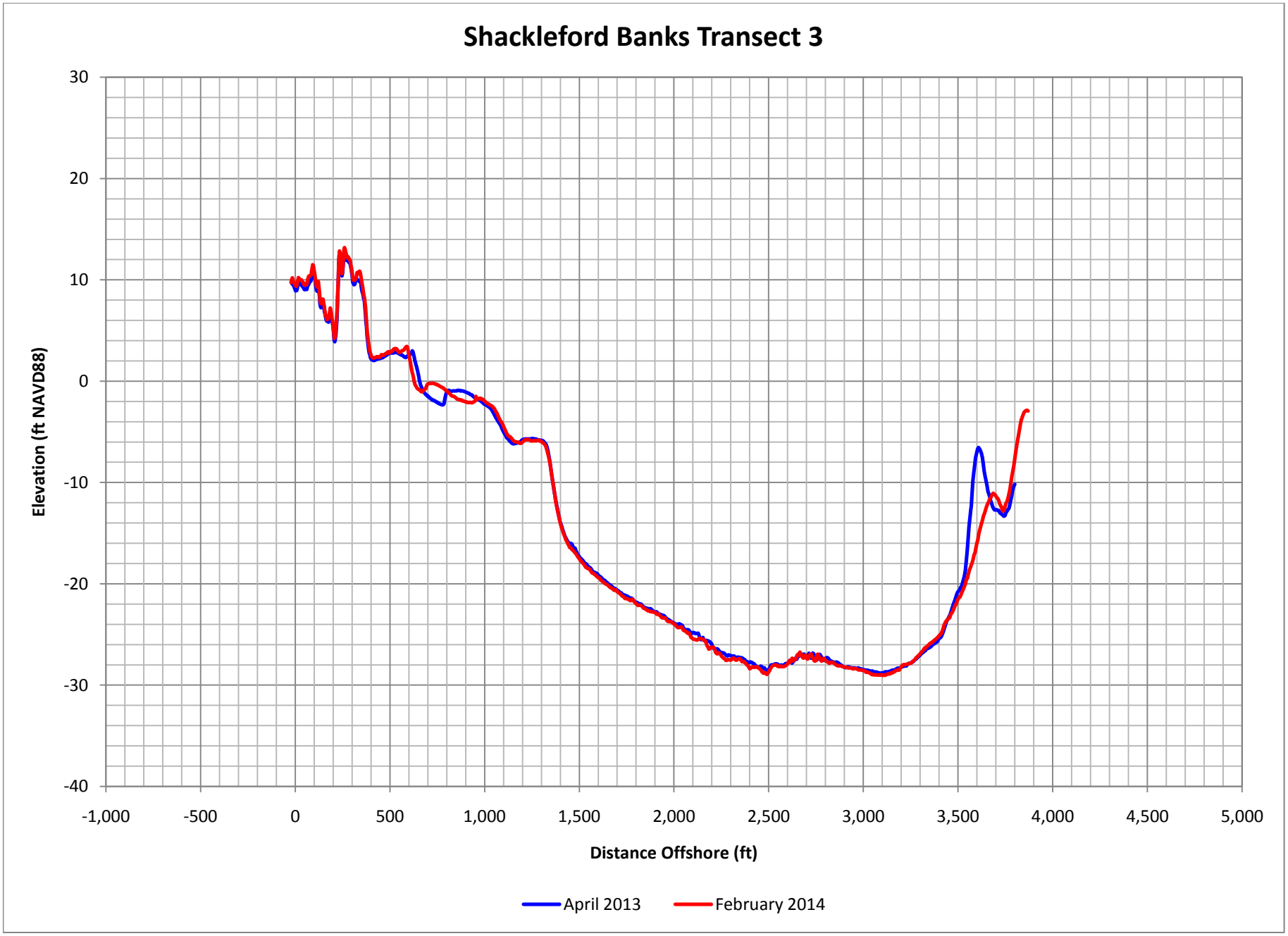


Figure C-171. Shackleford Banks Profile Comparison Plot

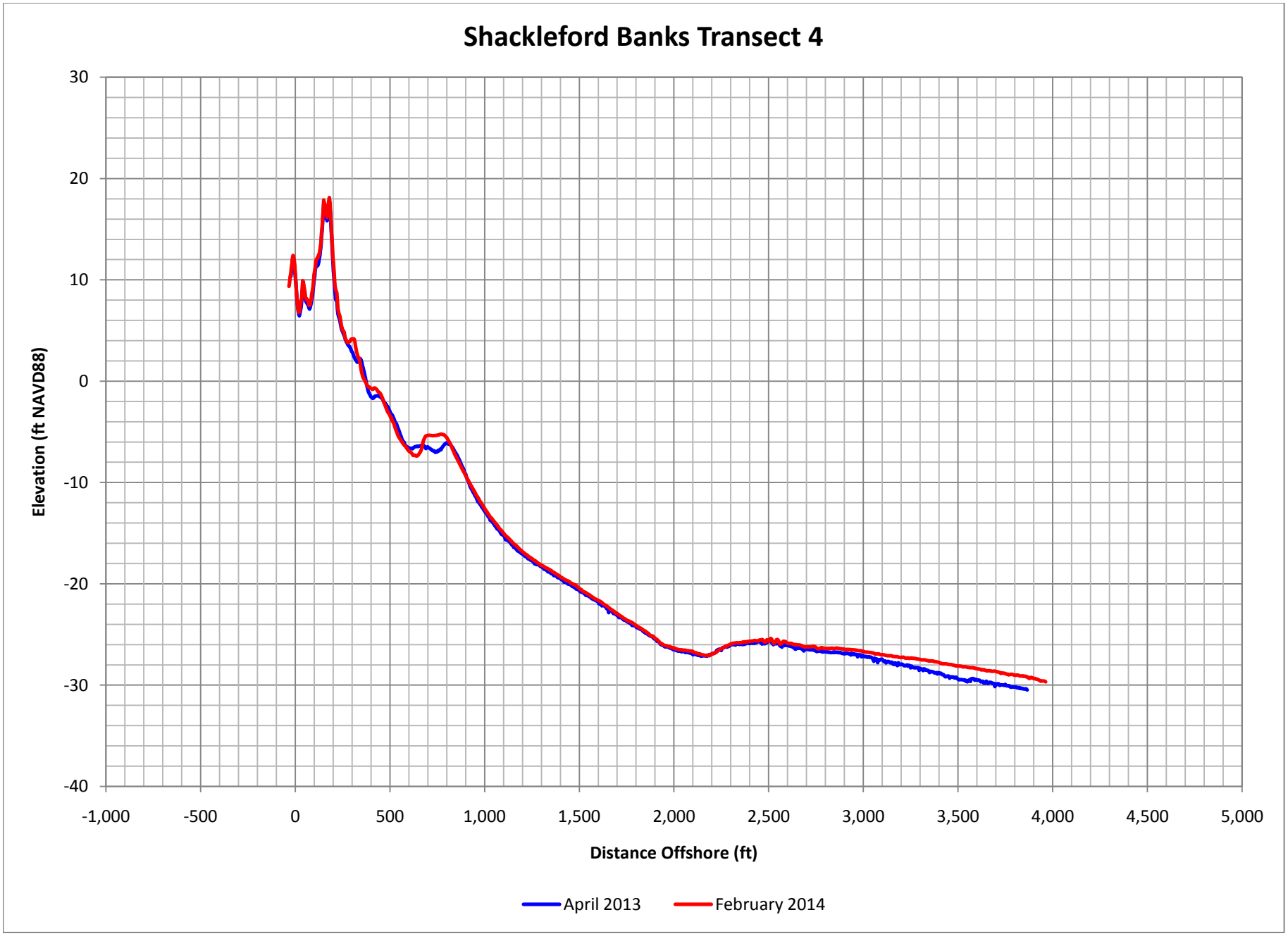


Figure C-172. Shackleford Banks Profile Comparison Plot

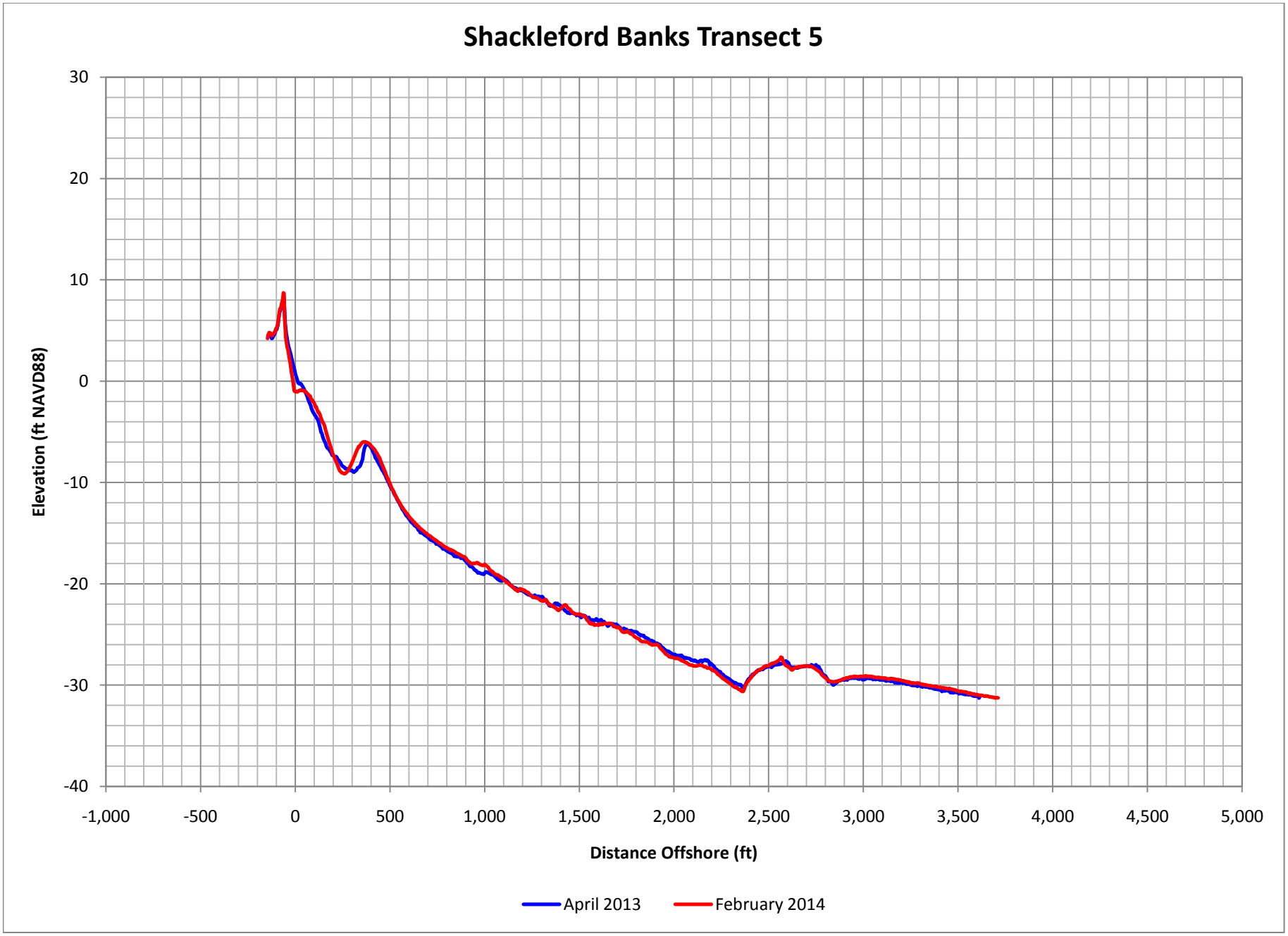


Figure C-173. Shackleford Banks Profile Comparison Plot

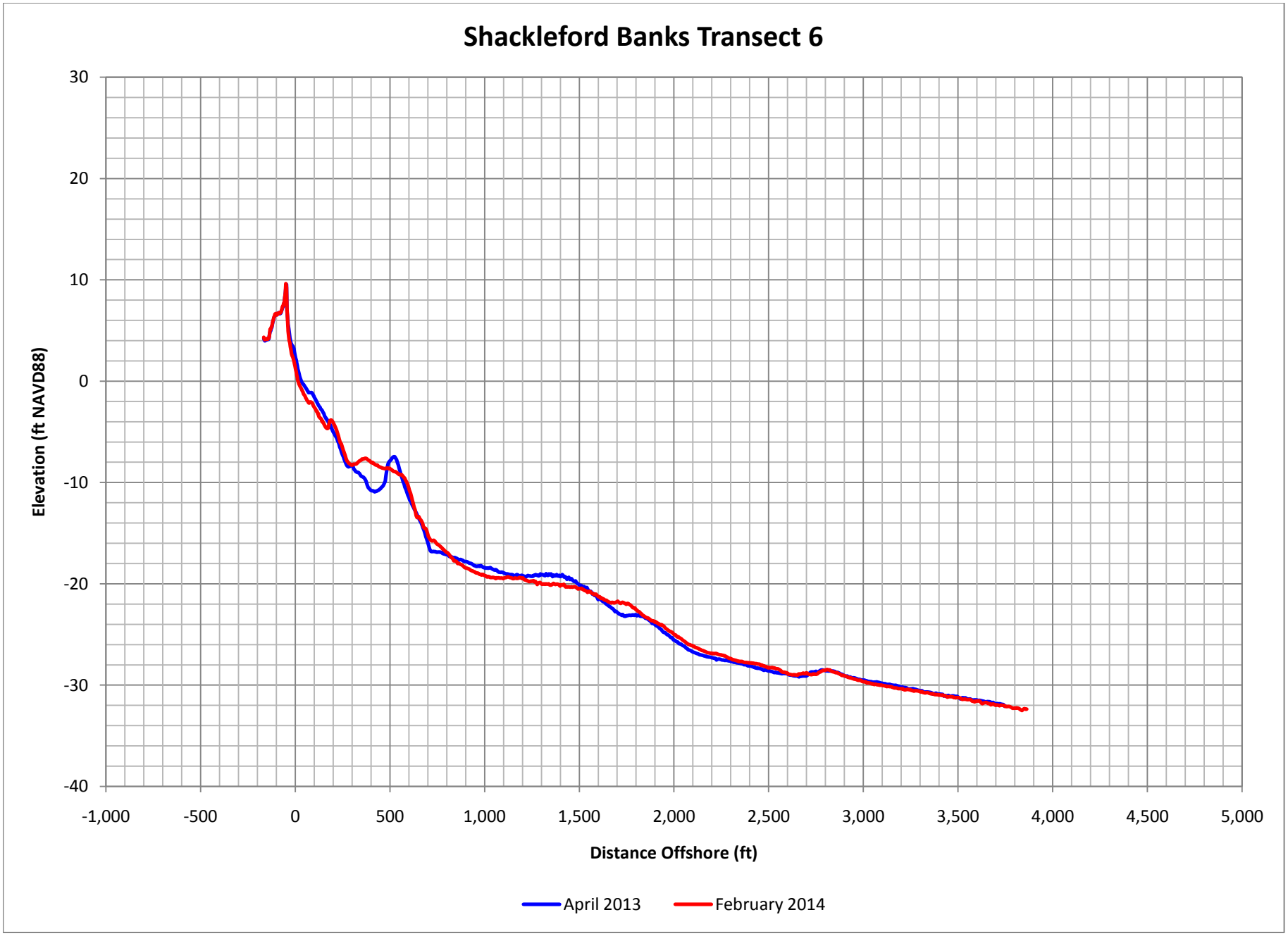


Figure C-174. Shackleford Banks Profile Comparison Plot

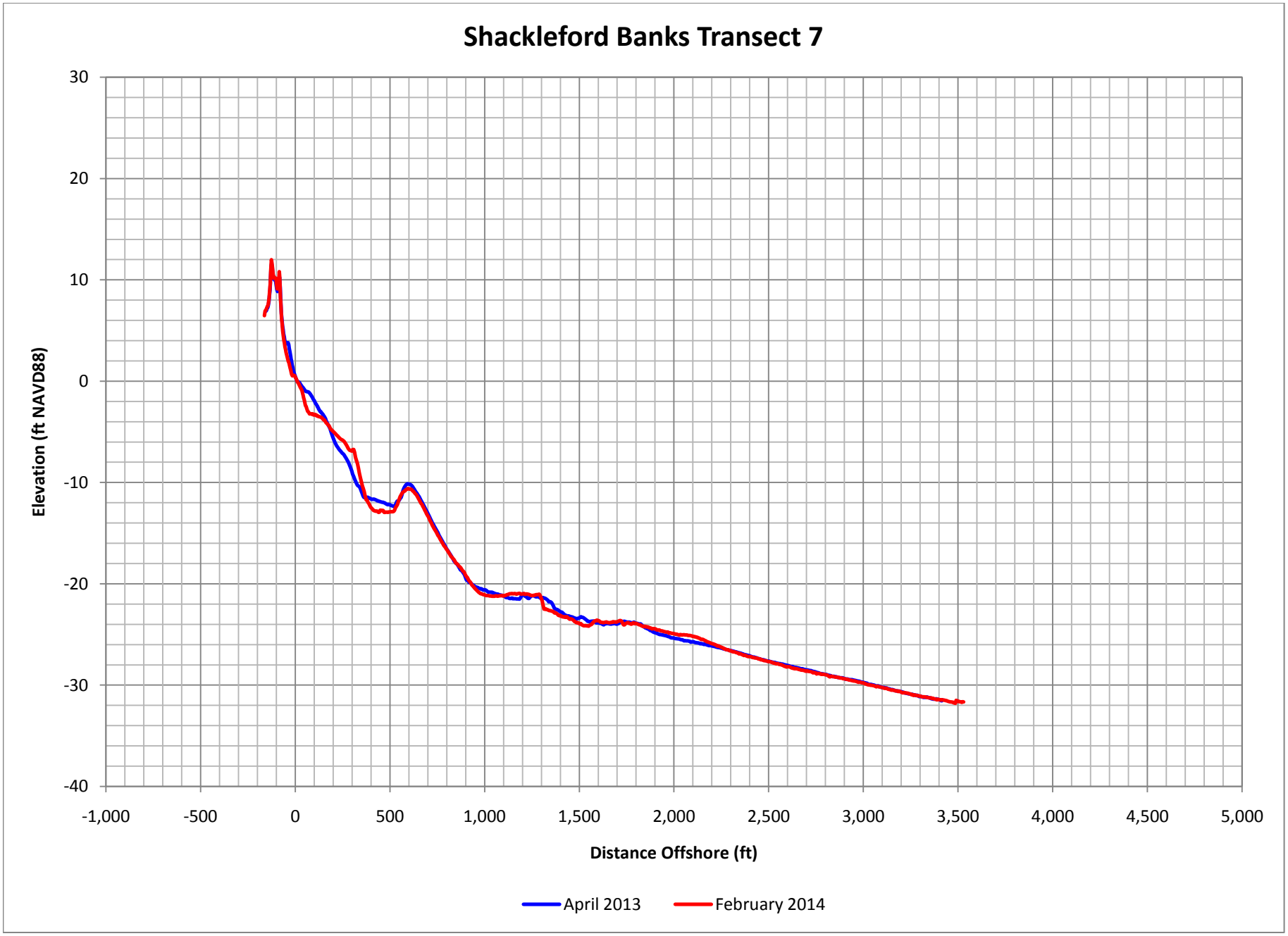


Figure C-175. Shackleford Banks Profile Comparison Plot

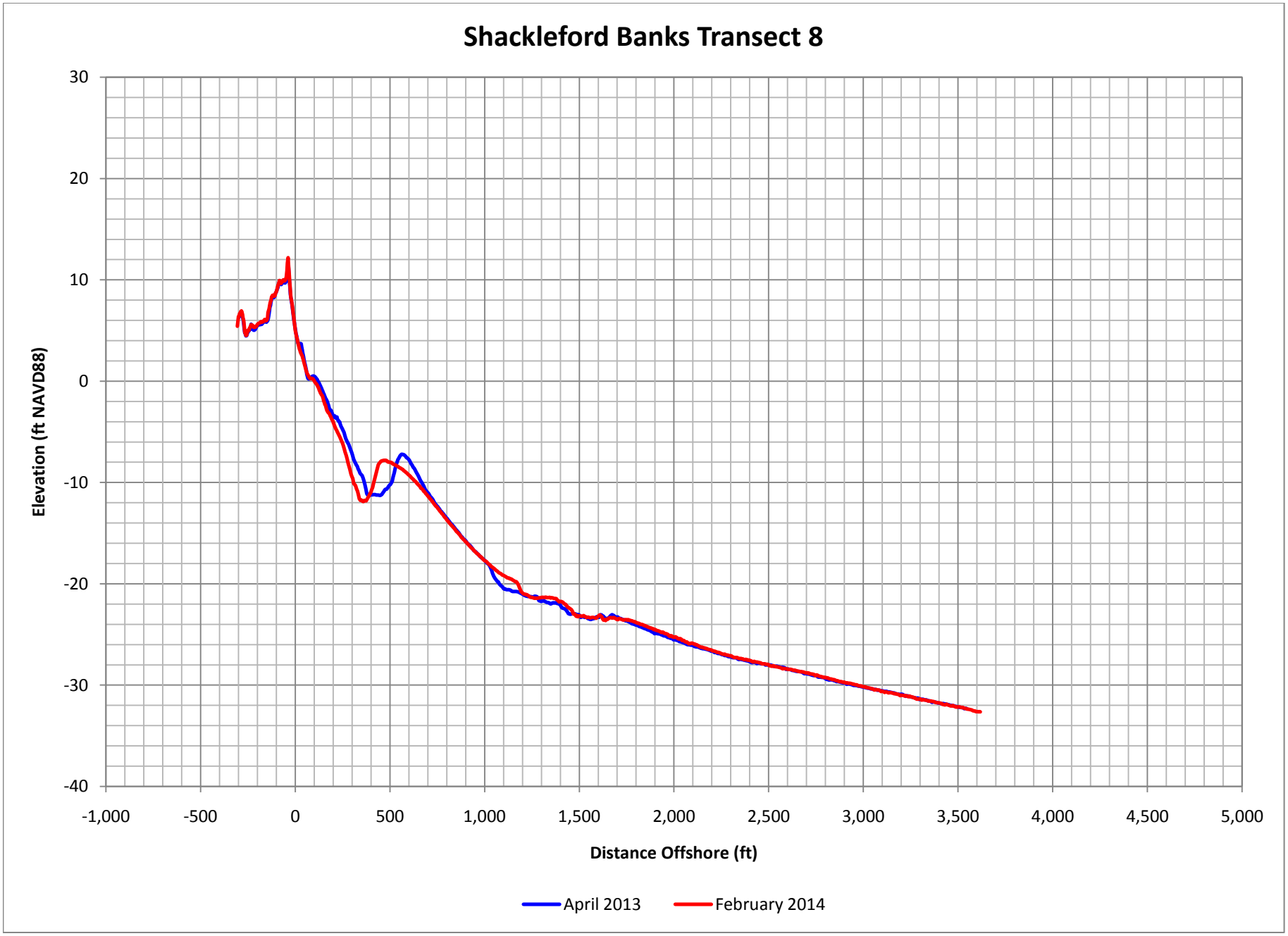


Figure C-176. Shackleford Banks Profile Comparison Plot

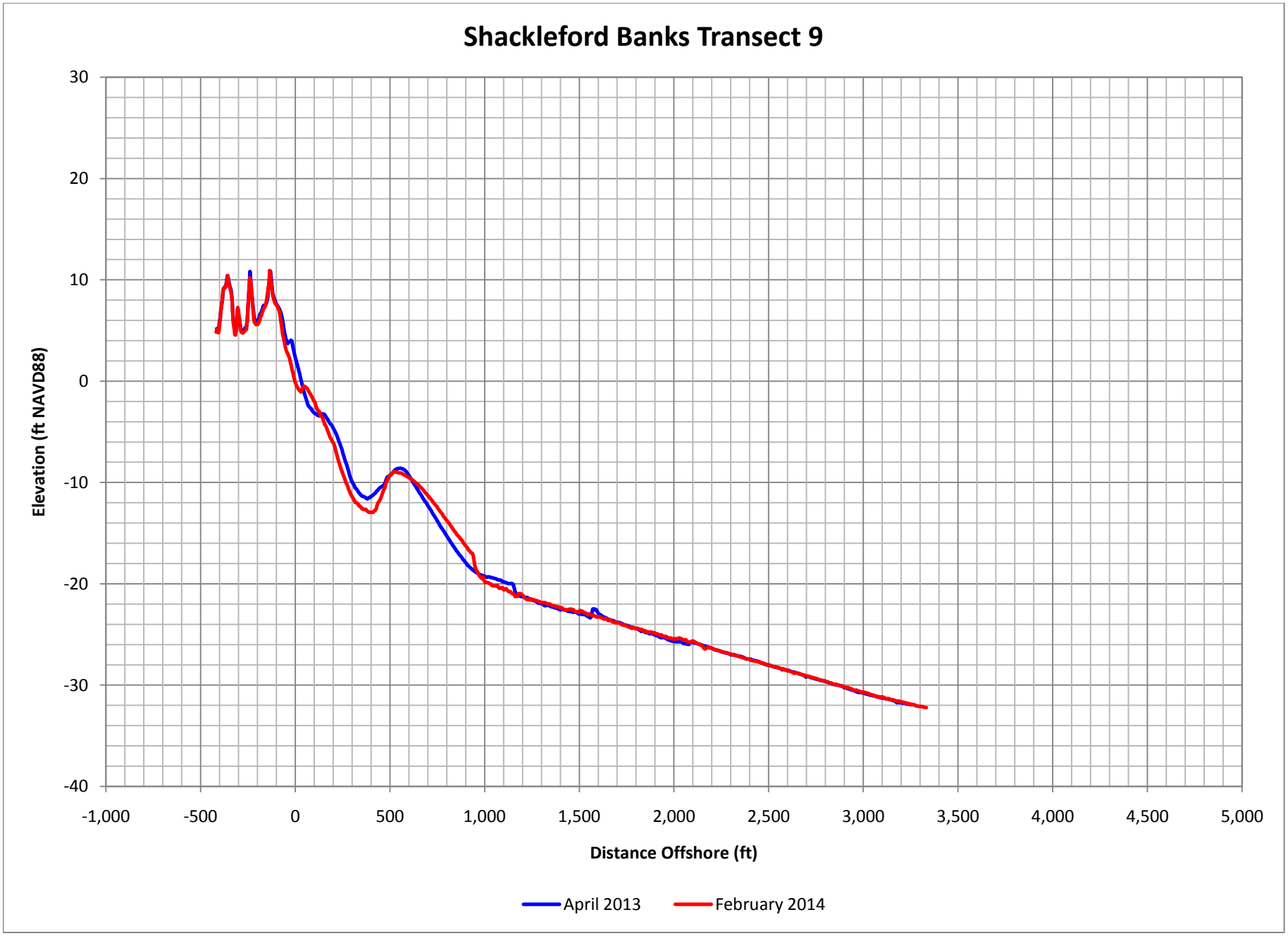


Figure C-177. Shackleford Banks Profile Comparison Plot

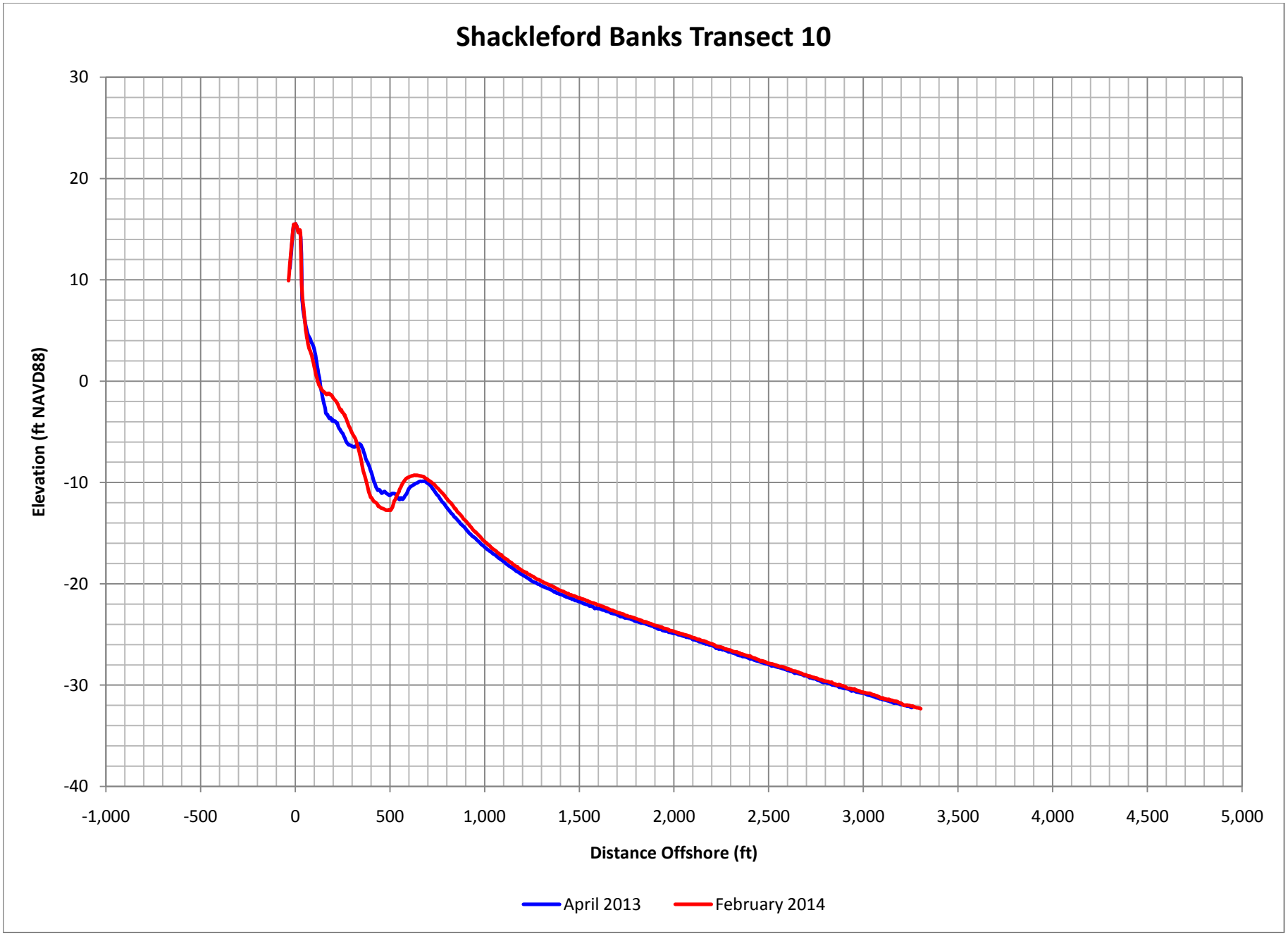


Figure C-178. Shackleford Banks Profile Comparison Plot

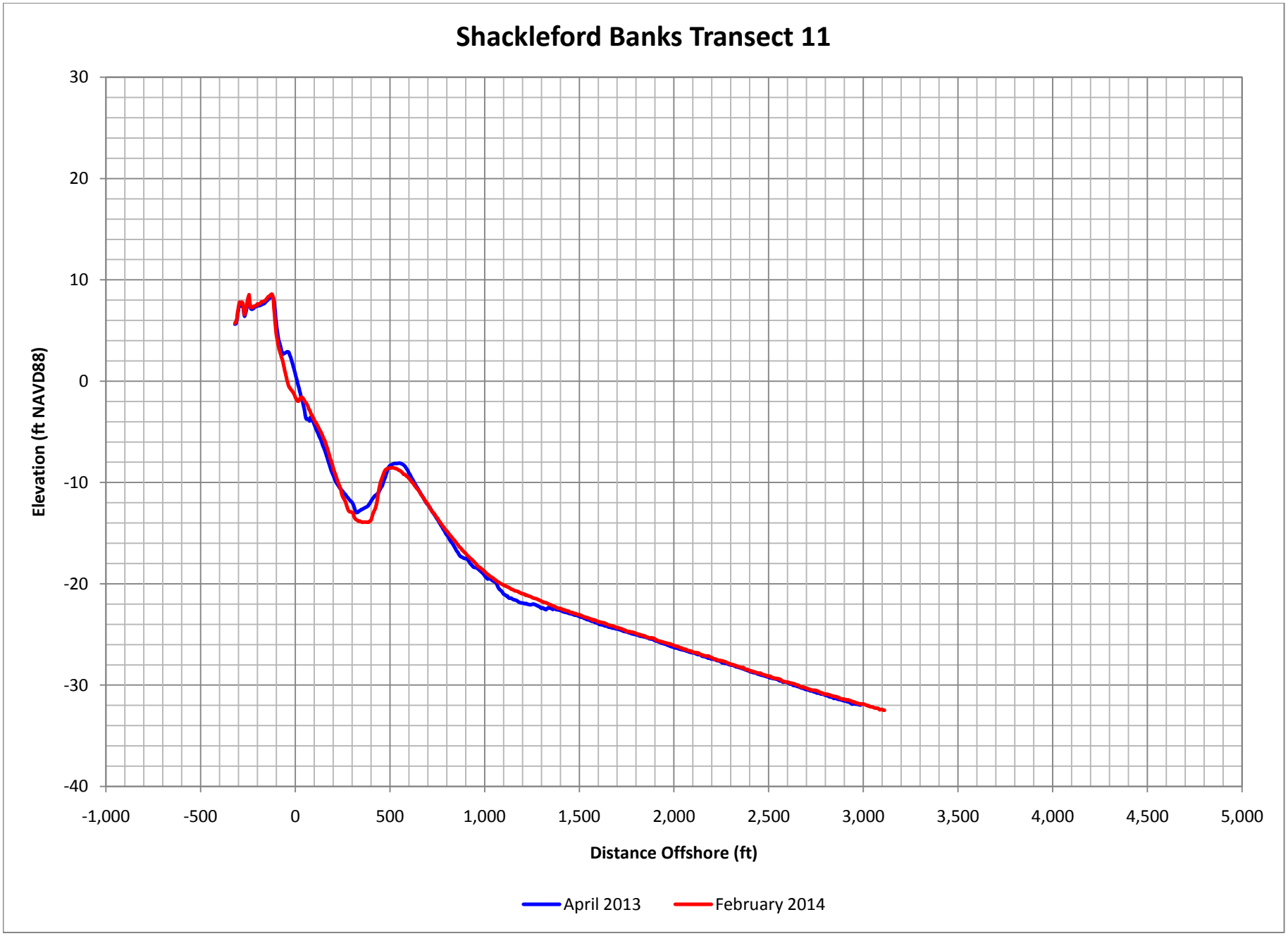


Figure C-179. Shackleford Banks Profile Comparison Plot

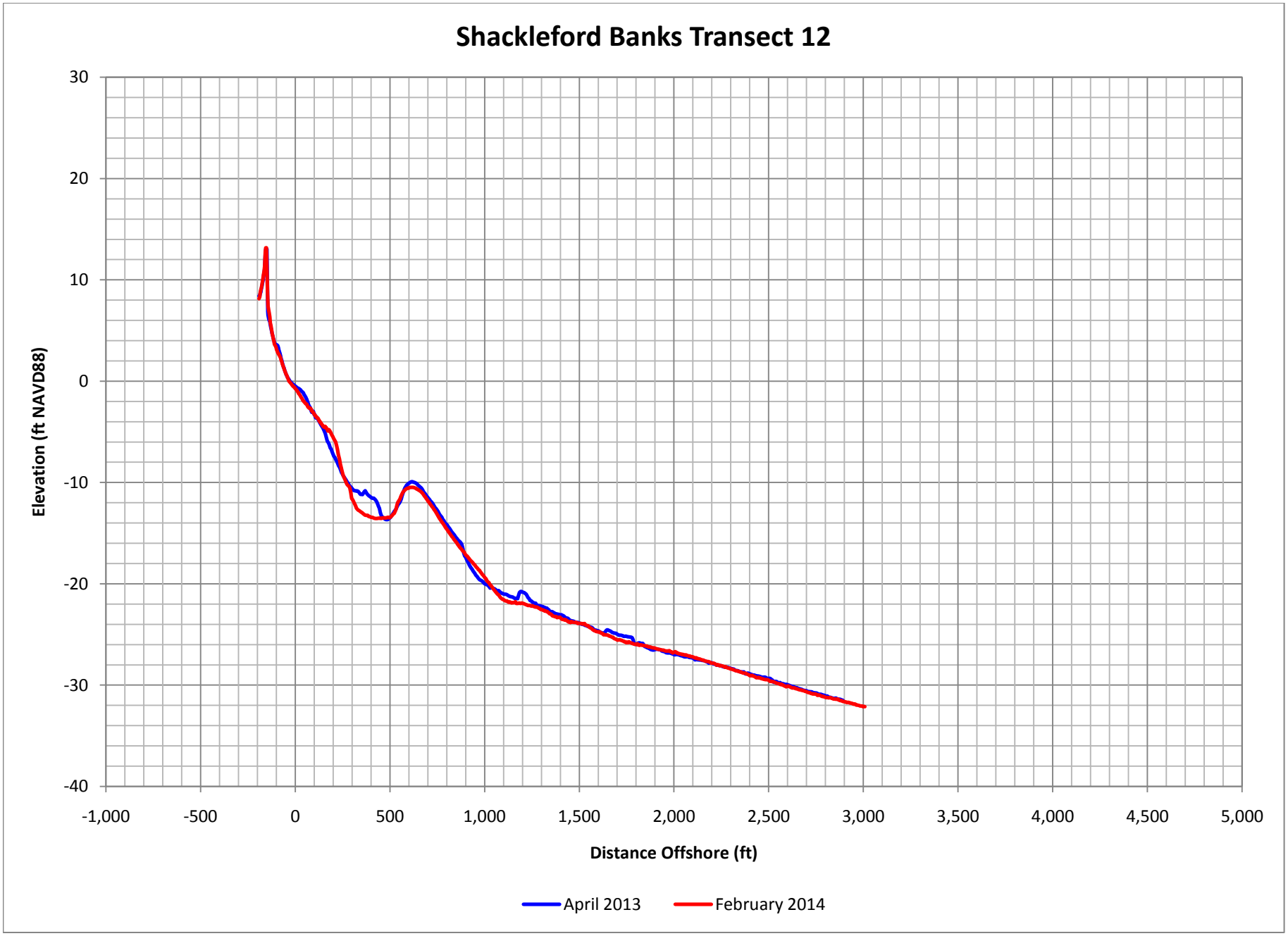


Figure C-180. Shackleford Banks Profile Comparison Plot

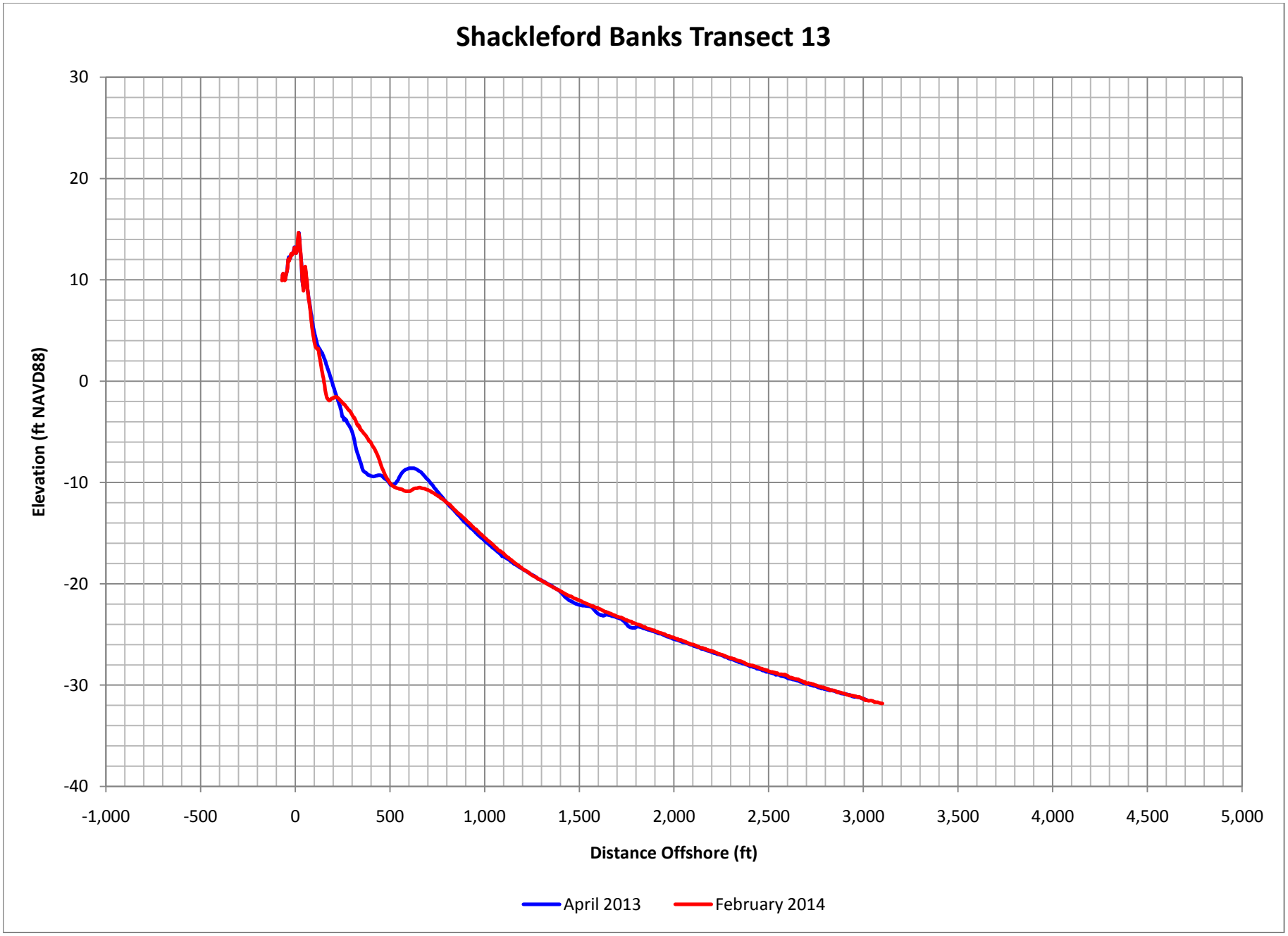


Figure C-181. Shackleford Banks Profile Comparison Plot

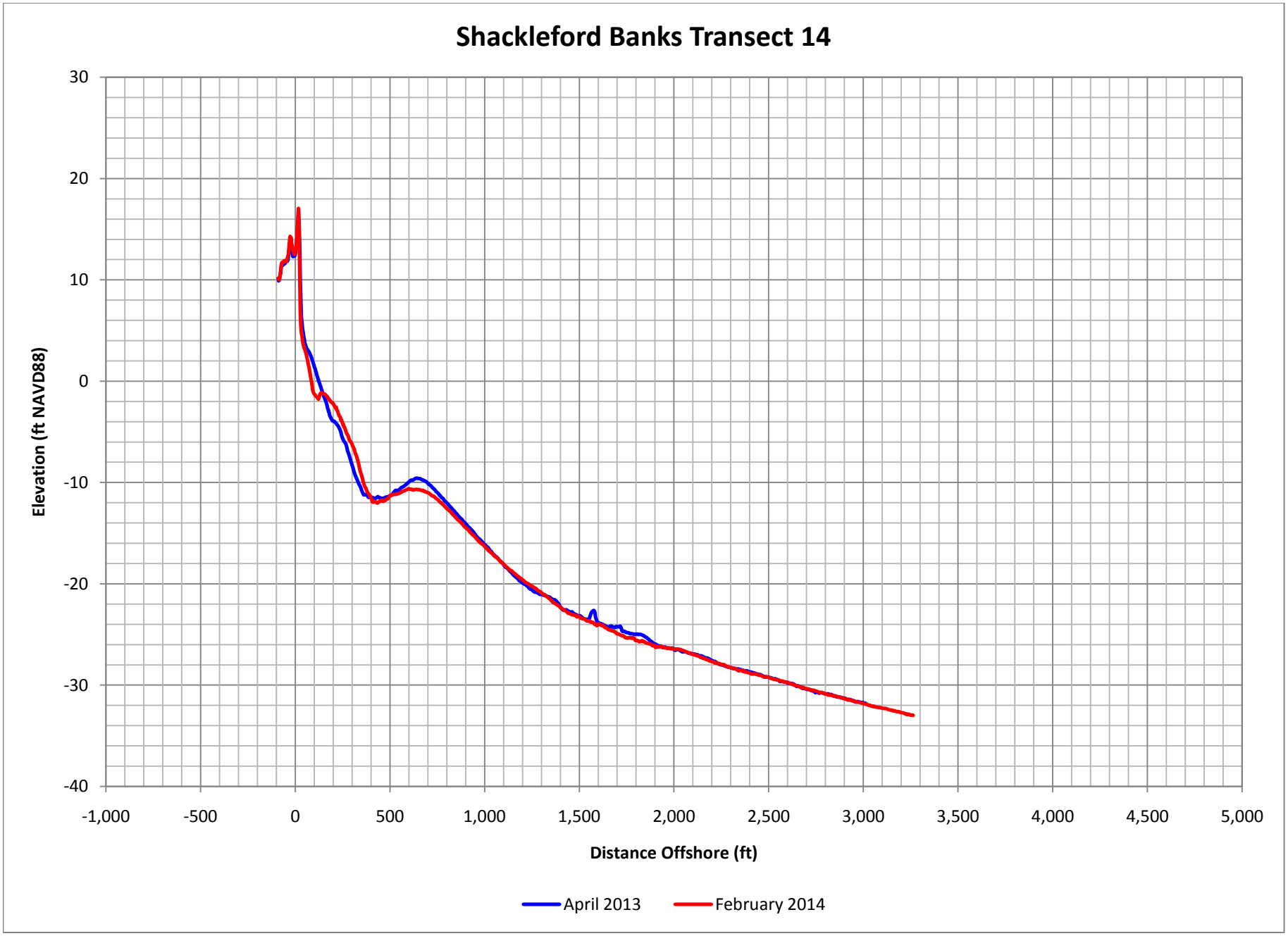


Figure C-182. Shackleford Banks Profile Comparison Plot

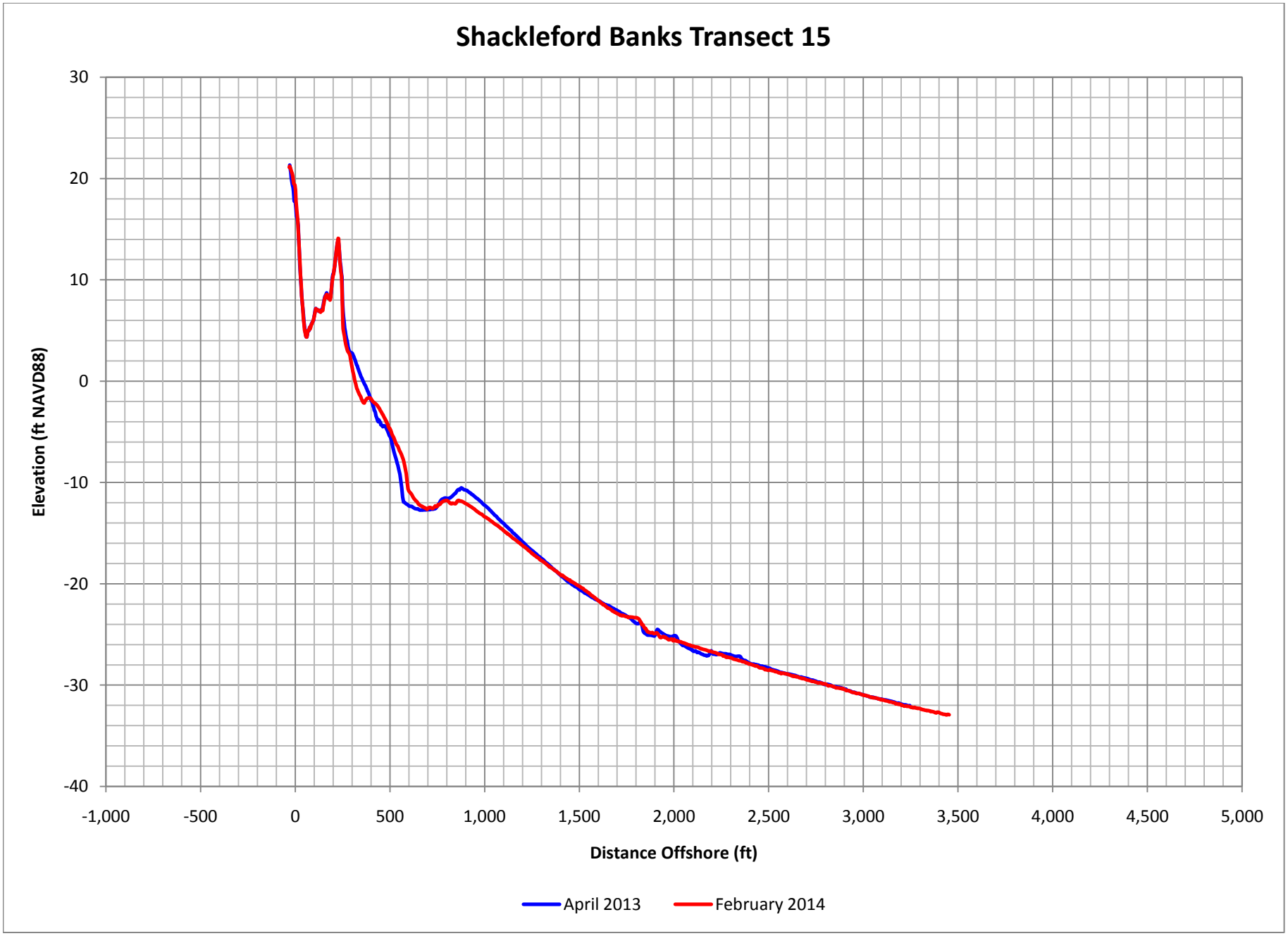


Figure C-183. Shackleford Banks Profile Comparison Plot

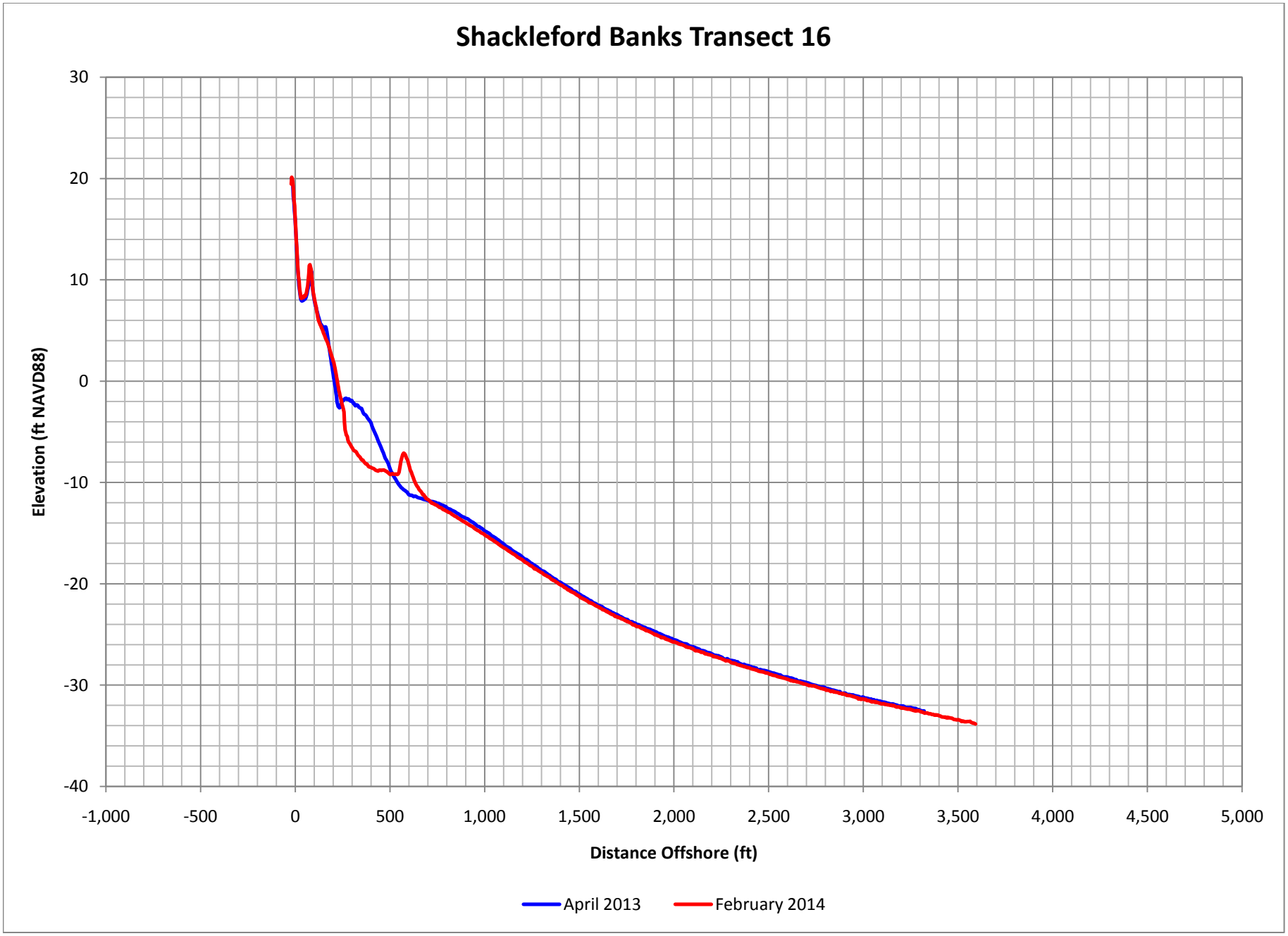


Figure C-184. Shackleford Banks Profile Comparison Plot

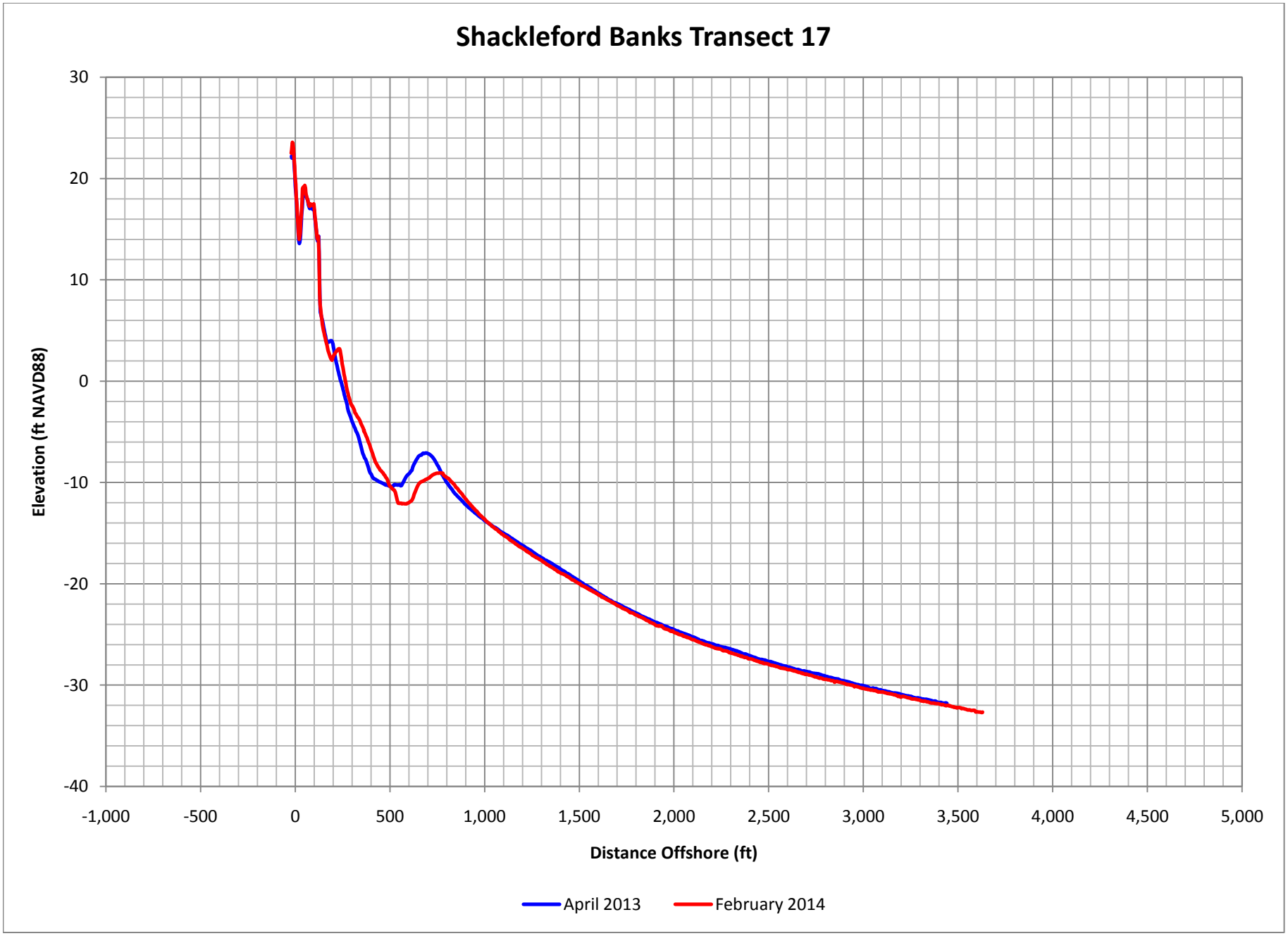


Figure C-185. Shackleford Banks Profile Comparison Plot

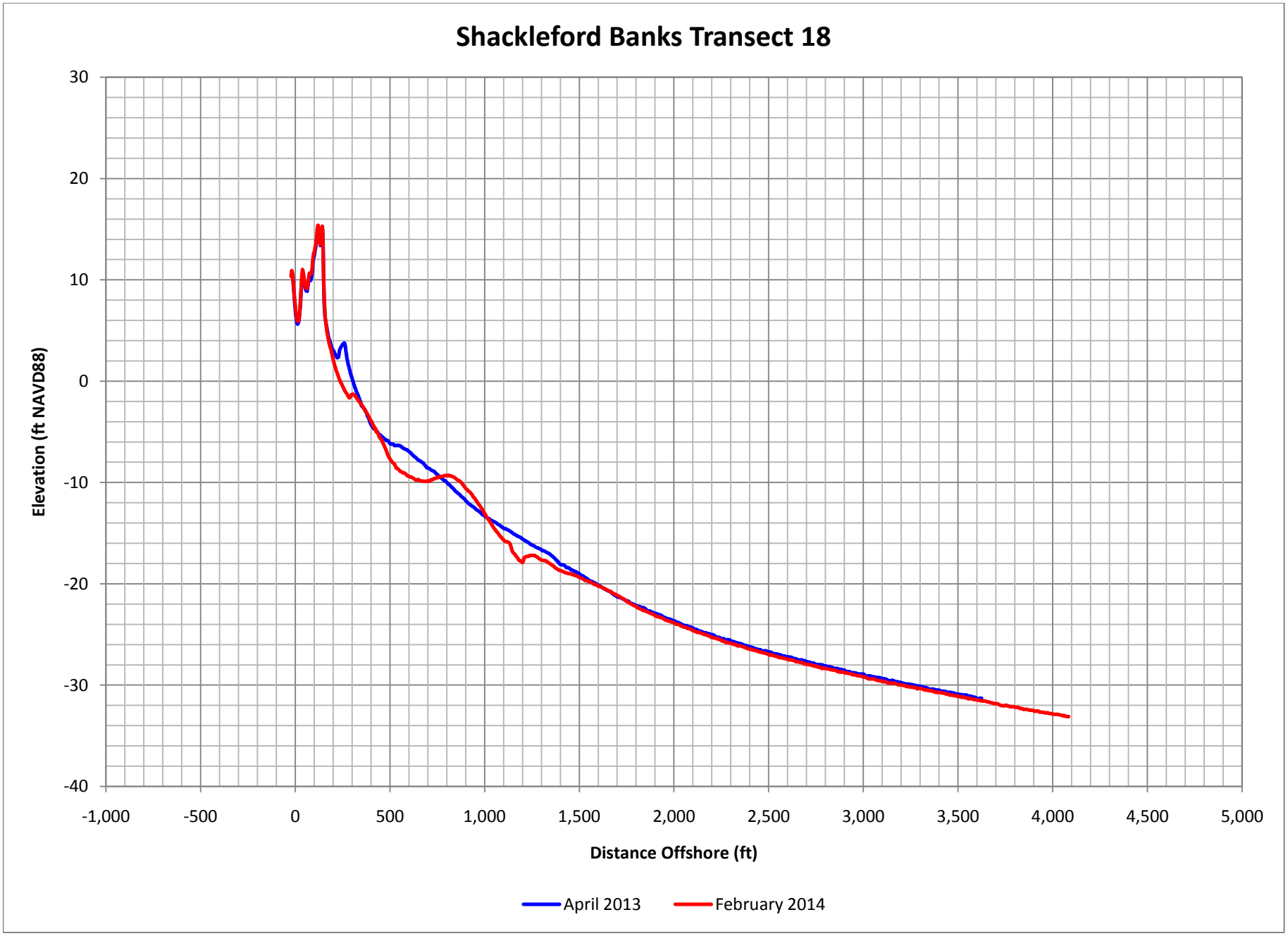


Figure C-186. Shackleford Banks Profile Comparison Plot

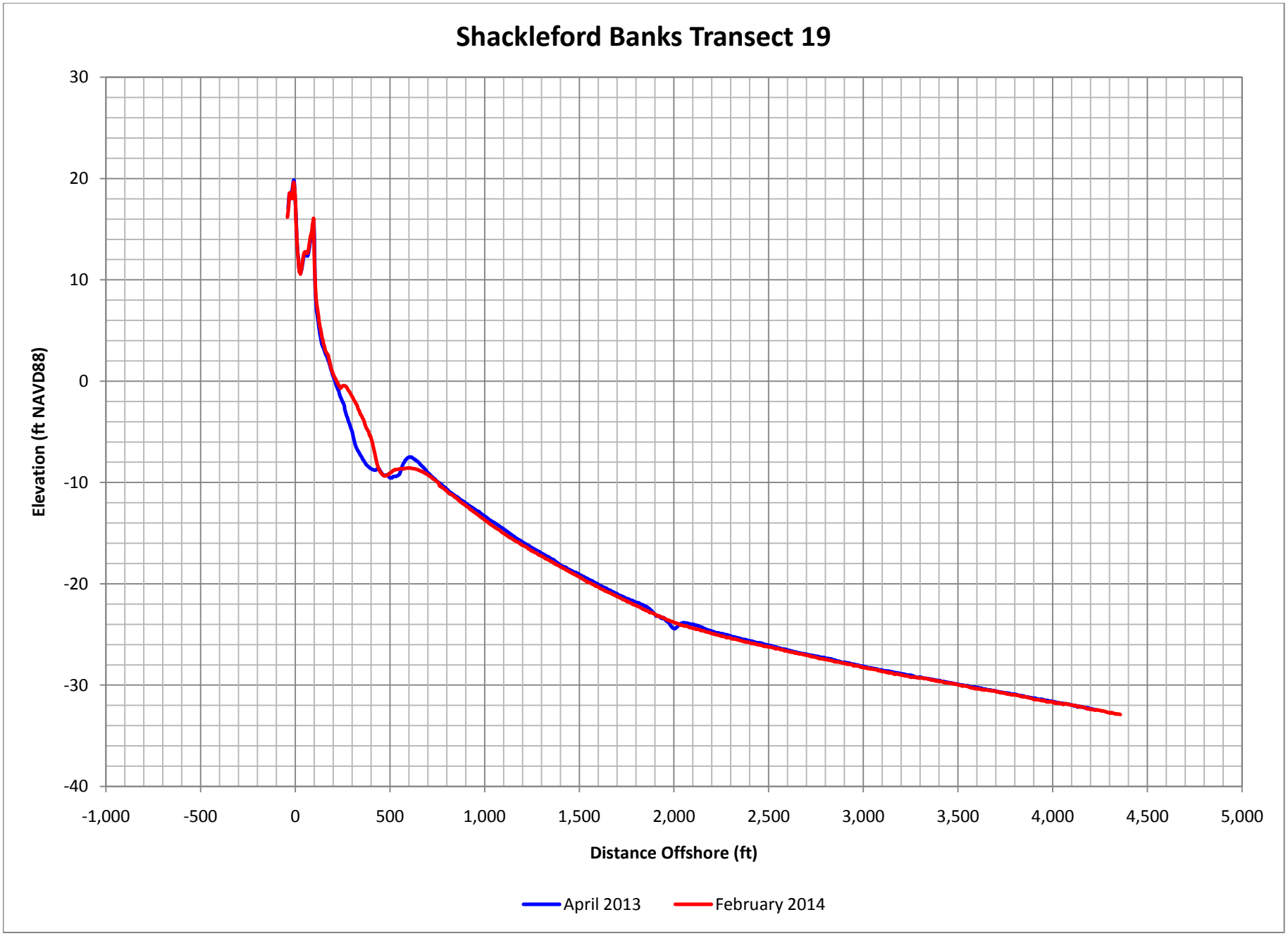


Figure C-187. Shackleford Banks Profile Comparison Plot

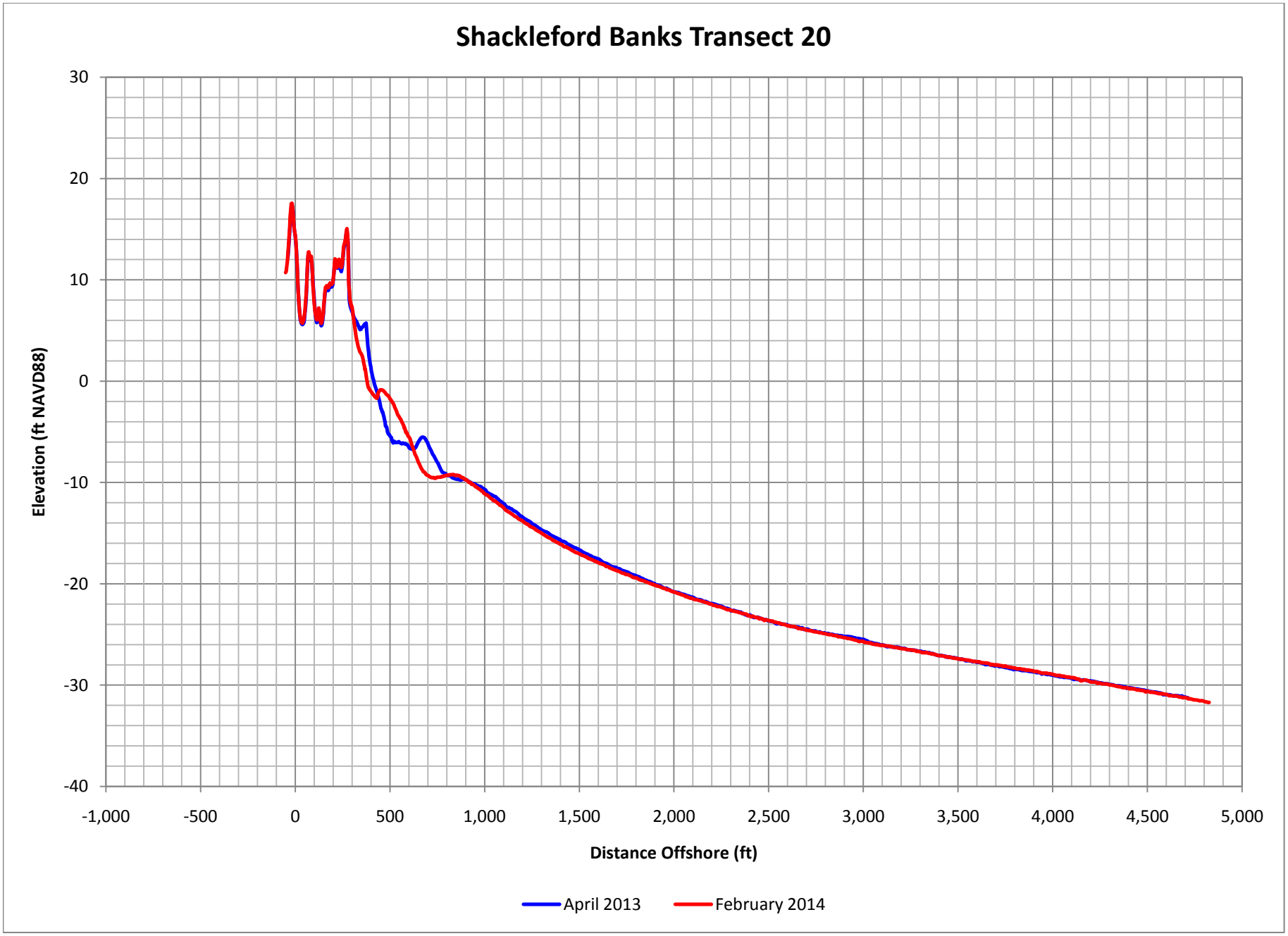


Figure C-188. Shackleford Banks Profile Comparison Plot

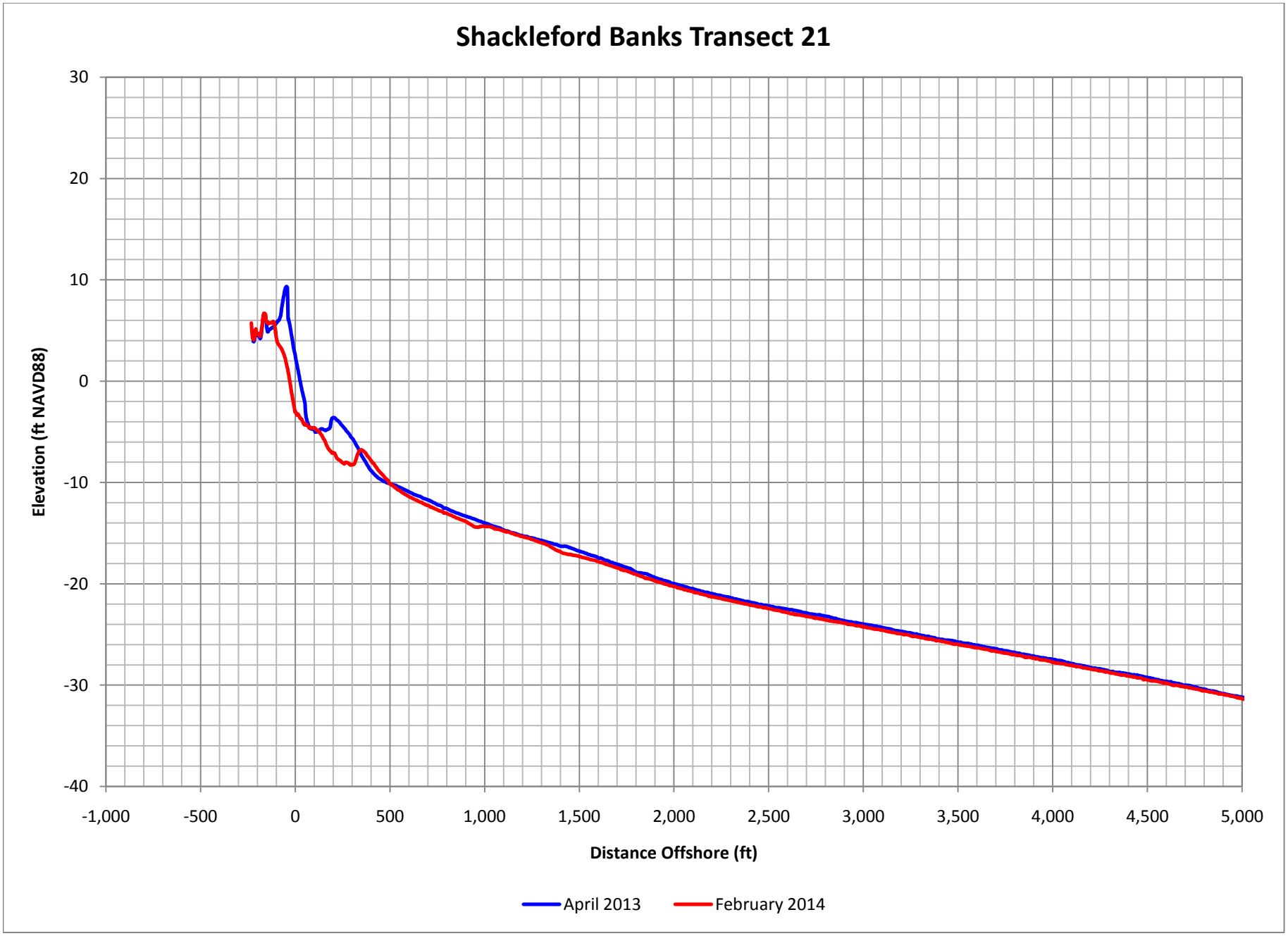


Figure C-189. Shackleford Banks Profile Comparison Plot

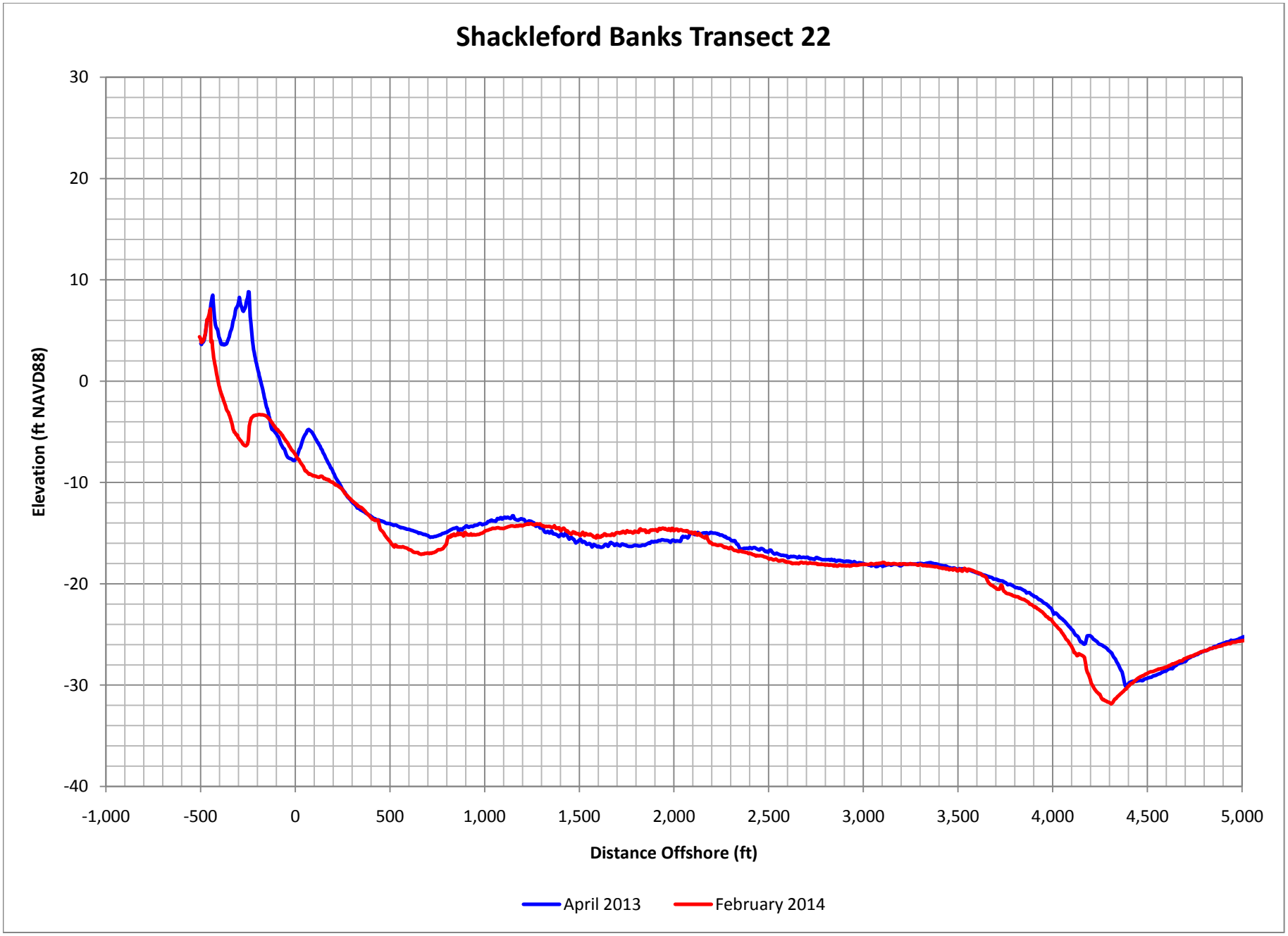


Figure C-190. Shackleford Banks Profile Comparison Plot

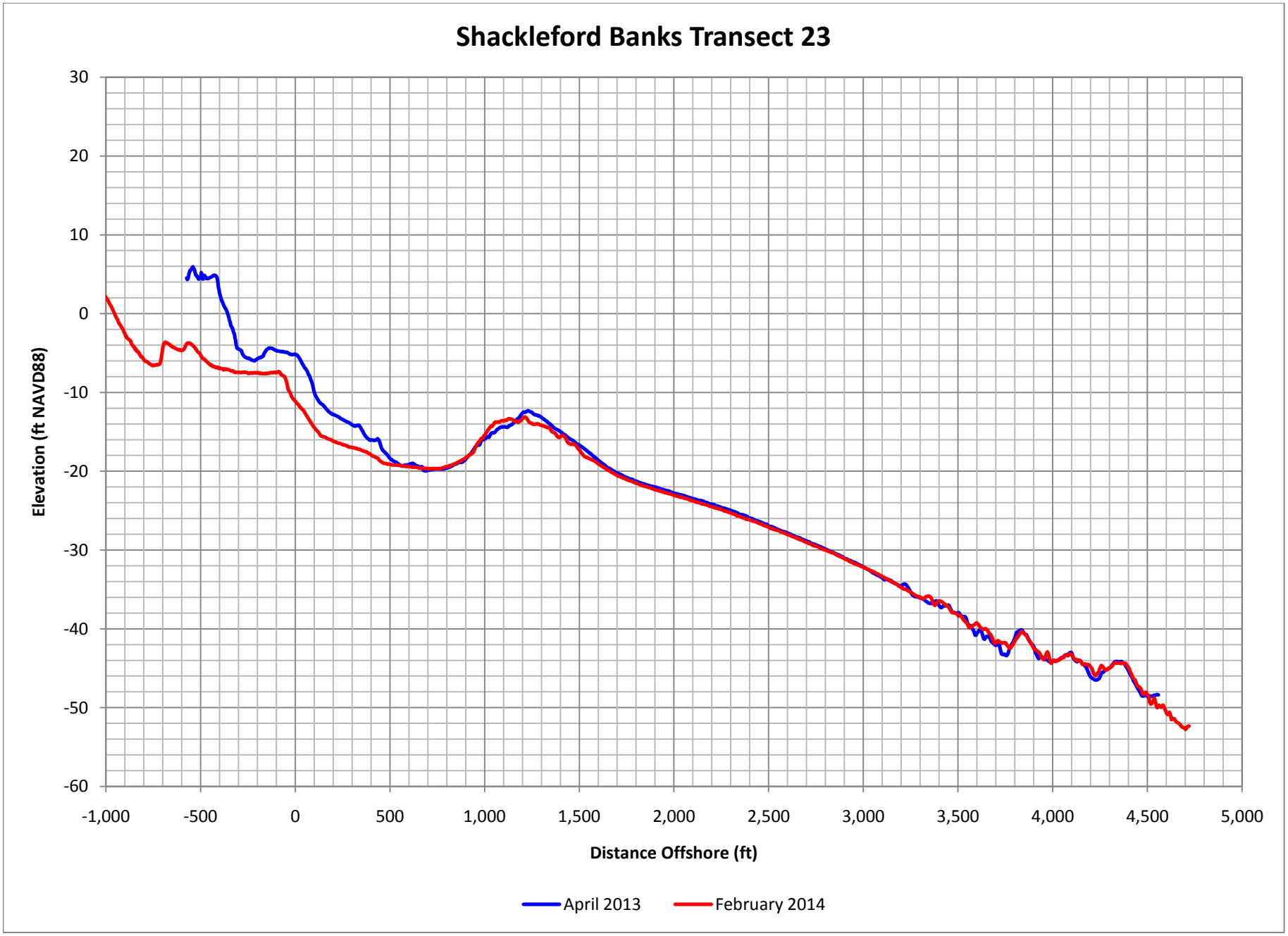


Figure C-191. Shackleford Banks Profile Comparison Plot

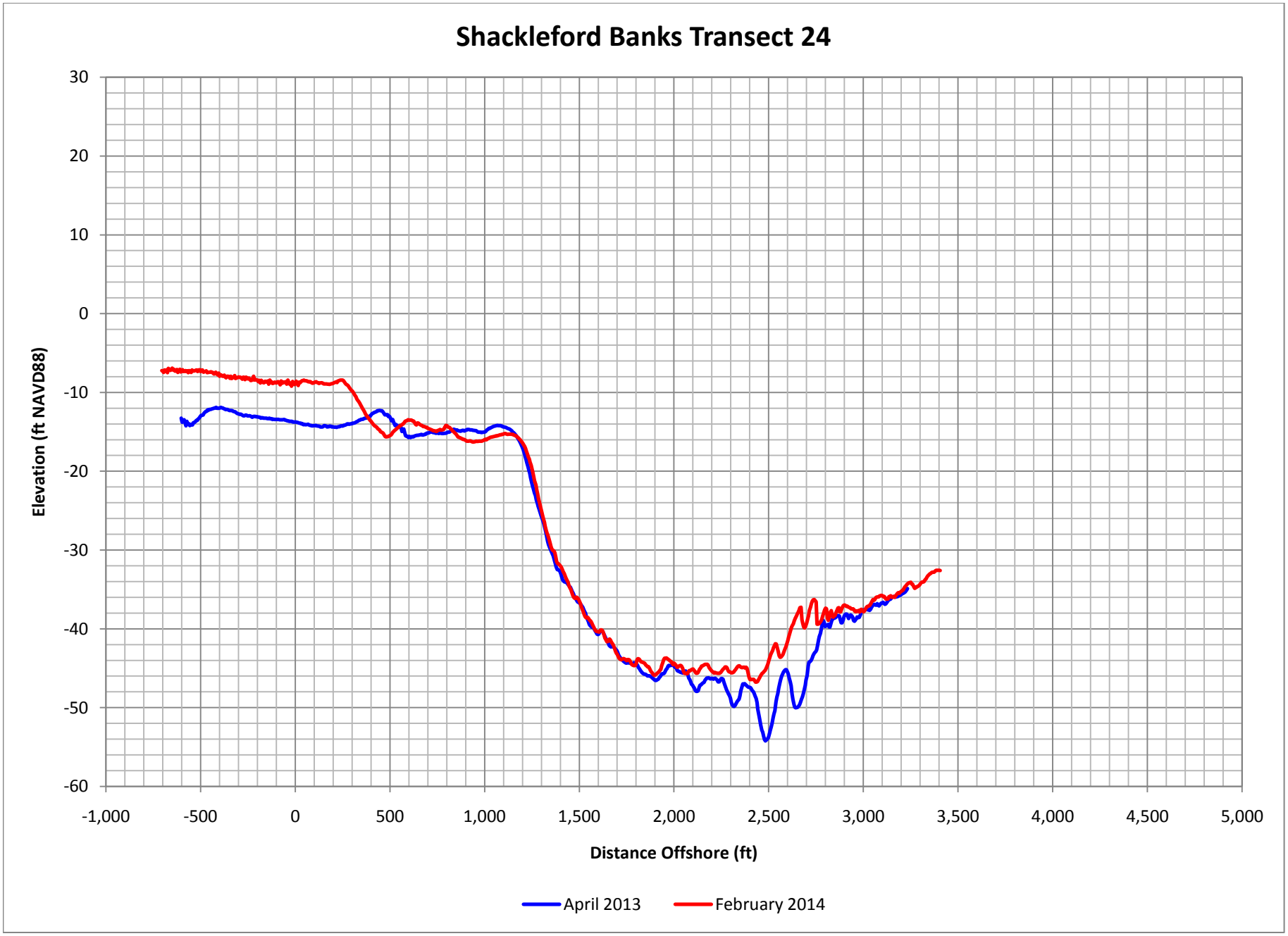


Figure C-192. Shackleford Banks Profile Comparison Plot

APPENDIX D

Results Tables

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (Summer 2013 to Summer 2014)

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 July 17, 2013 to June 23, 2014.

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	
				2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)
Bogue Inlet-Ocean	1	0+00	-3.32	92.55	1.05	283.81	-0.70	629.75	-61.89	1375.31	-82.86	2703.71	-88.58
	2	5+59	19.54	95.19	1.93	268.15	8.98	598.54	15.23	1262.88	-3.55	2509.36	-11.45
	3	11+23	15.52	49.23	4.33	137.05	10.65	341.46	6.86	848.24	-1.38	1870.95	-3.12
	4	17+39	-15.50	14.47	-0.35	70.94	-0.63	231.14	-35.33	652.98	-44.07	1542.06	-48.20
	5	23+22	7.95	50.66	2.37	133.22	5.33	325.62	26.13	741.32	11.74	1611.36	6.15
	6	36+28	43.10	26.39	-0.87	83.58	1.16	233.07	12.97	583.37	4.78	1340.42	4.93
	7	53+10	-17.48	73.03	-4.63	161.29	-2.03	340.27	0.87	709.37	-2.16	1439.87	-3.94
	8	67+74	31.18	72.94	-1.25	159.71	3.02	333.95	-5.54	691.50	-9.78	1389.35	-10.57
Emerald Isle West	9	80+91	52.41	59.66	1.85	139.62	4.26	310.70	-12.19	658.64	-18.79	1336.20	-23.07
	10	93+40	29.56	56.73	0.21	131.12	12.31	294.25	23.95	636.10	17.74	1293.36	12.25
	11	108+58	7.49	47.82	0.08	121.26	6.75	277.73	16.29	612.94	10.54	1259.21	6.63
	12	121+18	-45.11	91.44	-2.95	177.89	2.76	352.80	13.53	701.68	11.16	1358.72	7.48
	13	134+61	-17.78	79.32	-1.64	165.46	5.15	337.72	5.46	689.96	7.31	1347.57	9.15
	14	146+67	-49.68	57.94	-1.10	135.62	4.85	300.01	18.10	637.00	19.79	1276.97	20.12
	15	160+16	-42.99	48.24	-1.19	121.34	7.65	284.76	14.76	616.14	10.78	1251.56	8.68
	16	174+79	-9.54	48.53	-0.24	121.81	5.58	283.47	14.96	615.25	10.82	1250.17	3.44
	17	189+23	-53.15	67.08	-7.48	151.32	1.22	323.63	1.28	669.11	-2.14	1323.92	-9.41
	18	203+53	-41.25	66.19	-6.53	149.80	2.69	321.65	7.29	669.72	2.22	1324.24	-3.64
	19	214+90	-26.26	52.41	-6.37	123.30	-2.90	276.89	0.98	610.35	1.01	1254.73	-1.77
	20	230+02	-31.58	94.76	-2.27	178.44	5.92	342.26	-3.31	692.68	-1.55	1364.66	-1.58
	21	241+15	48.51	62.69	3.08	139.45	14.74	297.34	15.77	645.06	15.07	1313.51	14.20
	22	252+19	14.93	80.54	5.30	156.23	10.86	317.44	5.31	662.98	4.33	1333.89	-1.20
	23	263+24	43.79	45.18	-1.17	107.48	2.08	246.39	-12.07	582.54	-14.01	1236.91	-20.00
	24	279+57	6.56	113.29	-2.27	194.05	7.19	362.80	-3.97	723.79	-4.64	1409.69	-9.48
	25	290+77	-48.04	59.49	-5.55	131.76	-3.90	289.70	9.69	642.10	4.37	1315.02	-2.57

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (Summer 2013 to Summer 2014) 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 July 17, 2013 to June 23, 2014.

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	
				2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)
Emerald Isle Central	26	304+77	-44.10	69.89	-3.83	144.01	1.35	301.59	19.39	660.58	17.42	1339.26	12.36
	27	318+11	-20.36	73.10	-4.19	149.09	-3.02	313.78	1.16	680.19	-4.36	1363.89	-8.56
	28	329+10	-39.10	68.94	-5.79	141.78	6.04	297.35	36.45	654.39	14.24	1331.11	11.81
	29	345+80	-44.91	48.75	-12.88	115.56	-8.92	268.97	-30.94	619.12	-36.89	1285.59	-45.42
	30	362+22	-48.43	70.61	-4.08	145.63	3.33	299.26	14.48	656.87	19.26	1334.27	18.87
	31	378+80	55.19	54.27	2.09	125.58	12.81	272.85	-4.78	611.61	6.38	1277.51	3.74
	32	395+22	-2.93	78.90	1.65	156.44	13.13	322.17	2.81	675.13	5.51	1345.30	2.85
	33	408+86	-20.97	69.81	-6.22	146.80	-5.81	313.01	-17.56	668.19	-10.84	1334.31	-13.67
	34	422+83	2.16	59.93	1.00	132.61	4.71	293.22	15.60	648.00	19.49	1317.26	16.31
	35	435+62	-31.65	43.58	-3.72	108.21	-2.32	256.97	-13.39	596.43	-4.61	1249.31	-7.55
	36	450+22	-78.31	49.63	-7.85	117.60	-7.84	273.48	-21.51	614.65	-12.97	1276.57	-15.38
Emerald Isle East	37	461+34	-1.21	30.38	-3.24	92.25	7.41	233.03	41.01	564.63	44.41	1205.74	40.04
	38	472+44	-39.23	51.06	-5.70	124.07	-7.02	286.37	-10.26	632.55	-8.11	1290.00	-10.79
	39	483+48	-63.55	54.33	-10.00	129.86	-7.10	296.22	-10.72	645.98	-4.92	1323.67	-8.22
	40	494+44	15.79	35.89	-0.35	102.87	10.16	251.44	28.19	583.90	29.36	1224.65	29.08
	41	505+39	-11.69	57.00	-1.97	134.06	-1.05	300.08	2.89	646.25	7.34	1305.10	4.06
	42	516+57	14.62	35.32	0.58	98.95	9.45	238.30	13.61	562.07	16.85	1199.99	15.38
	43	527+37	55.89	40.11	0.29	109.00	3.53	256.21	-3.12	587.60	-3.14	1234.29	-7.52
	44	538+39	13.26	67.60	3.79	147.65	8.74	310.93	7.43	663.05	15.99	1329.09	19.03
	45	549+45	36.03	61.16	-0.25	133.97	0.43	290.26	-18.17	638.83	-18.06	1303.71	-20.50
	46	560+42	35.71	57.66	1.54	124.73	6.59	271.13	4.29	620.45	4.41	1289.43	2.15
	47	571+43	32.91	55.15	3.88	120.29	11.66	275.72	16.31	622.63	17.90	1286.77	14.40
	48	580+13	-19.09	55.43	-3.80	121.42	-8.79	270.00	-41.79	621.26	-41.62	1292.06	-41.39

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (Summer 2013 to Summer 2014) 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 July 17, 2013 to June 23, 2014.

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	
				2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)
Indian Beach/Salter Path	49	595+84	34.58	56.41	-2.65	124.93	5.63	275.62	5.02	629.12	6.70	1306.90	5.99
	50	608+06	-54.98	72.88	-11.52	146.40	-8.61	303.93	-18.42	659.67	-7.95	1350.64	-6.96
	51	620+90	59.85	51.05	3.41	115.92	10.55	250.00	12.60	594.97	15.99	1270.29	18.18
	52	633+31	-21.85	19.01	-3.33	69.33	1.96	196.48	-2.76	521.62	4.92	1175.87	4.44
	53	648+17	3.19	81.06	-1.29	161.23	6.79	311.85	8.61	680.11	7.04	1390.27	4.27
	54	660+65	6.32	108.91	4.31	201.36	10.57	373.49	10.51	759.21	12.41	1489.61	10.96
	55	672+30	-11.94	52.02	-2.58	119.10	1.31	266.42	-4.55	620.02	-0.27	1313.32	-0.82
	56	683+24	-12.82	39.25	-0.54	104.17	8.15	250.76	-1.41	596.36	9.88	1287.02	11.97
	57	693+79	-23.94	51.55	-2.75	113.24	3.74	252.33	13.86	600.74	20.07	1292.18	18.02
	58	709+05	-2.33	43.18	-2.49	106.28	8.00	249.12	17.90	596.97	23.87	1290.62	23.77
Pine Knoll Shores West	59	723+93	7.93	41.03	-2.14	102.98	3.46	233.91	2.12	580.95	-2.13	1279.33	-2.77
	60	736+01	-12.92	40.06	-1.28	102.17	4.66	247.03	3.45	596.71	15.63	1299.94	18.01
	61	748+06	-55.46	56.76	-5.80	127.66	-12.22	282.08	-36.51	639.32	-30.19	1361.95	-34.79
	62	761+80	-34.33	39.44	-3.68	103.88	0.29	246.32	2.59	593.74	9.96	1309.04	11.88
	63	774+77	-7.54	42.35	0.39	104.76	1.63	233.56	23.07	591.41	28.20	1313.91	30.43
	64	787+61	-11.68	48.40	-1.09	115.63	0.18	259.32	2.92	622.33	14.06	1349.01	12.98
	65	800+91	-19.93	49.17	1.48	114.82	-3.32	271.44	-3.72	629.98	2.78	1360.64	0.15
Pine Knoll Shores East	66	813+33	-28.09	41.19	-5.99	103.92	-12.40	254.92	-21.88	611.88	-19.81	1343.98	-26.77
	67	825+53	-15.68	31.10	0.46	85.24	0.27	225.95	-9.53	579.71	-3.70	1310.47	-1.62
	68	840+55	-5.13	43.18	2.47	104.31	-2.70	251.91	-6.30	616.41	0.34	1354.68	-3.88
	69	850+84	-24.15	43.76	-2.11	102.75	-8.13	246.05	-8.59	613.29	-3.85	1360.97	-7.73
	70	863+28	-28.42	45.30	-2.89	109.96	-8.16	262.08	-4.35	634.24	3.96	1388.93	1.54
	71	882+23	-5.49	46.50	2.69	107.86	-1.27	247.47	-6.66	619.53	1.32	1378.49	-3.17
	72	896+24	5.19	42.37	5.14	98.51	-2.51	241.86	-1.15	612.55	-2.04	1378.17	-9.37
	73	910+53	31.42	45.80	7.69	112.66	9.58	261.68	12.69	644.22	19.33	1416.66	17.73
	74	922+70	-2.24	40.91	2.31	99.09	-7.05	247.83	-5.32	623.73	-9.55	1396.92	-18.28
	75	937+70	-31.31	46.82	-2.52	112.63	-6.83	274.36	3.48	656.90	8.27	1441.76	3.46
	76	948+81	-30.19	36.69	-0.79	103.41	-0.40	262.15	3.97	632.21	5.08	1413.33	2.91

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (Summer 2013 to Summer 2014) 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 July 17, 2013 to June 23, 2014.

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	
				2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)
Atlantic Beach	77	961+72	-10.20	64.74	4.07	128.62	0.55	273.22	-4.56	655.90	-3.67	1451.35	-4.05
	78	971+20	0.77	45.76	1.57	107.94	4.88	247.57	7.35	621.42	4.14	1399.69	-6.29
	79	985+64	-0.68	51.27	1.80	112.58	5.75	253.32	0.16	629.95	-8.50	1414.10	-14.68
	80	994+64	9.44	65.10	3.93	137.95	8.80	296.99	10.16	689.02	13.40	1481.05	1.45
	81	1005+61	8.38	56.52	3.85	116.79	-1.30	283.75	5.87	675.20	6.38	1477.34	3.64
	82	1012+68	18.57	41.22	6.72	97.12	0.09	251.71	3.85	628.72	-1.76	1413.44	-12.16
	83	1022+69	7.27	35.65	5.86	87.83	0.51	238.05	1.80	615.72	2.61	1401.52	4.12
	84	1032+70	17.27	31.89	0.86	85.35	0.13	235.81	-1.79	610.42	-1.15	1392.80	-4.00
	85	1042+73	29.84	63.75	1.07	138.20	-0.32	322.18	6.05	723.67	7.95	1545.26	6.40
	86	1052+75	-3.04	68.41	2.62	145.22	0.25	333.46	3.92	740.23	4.31	1569.30	-0.50
	87	1062+69	-10.35	60.32	4.10	134.83	2.79	320.40	3.58	724.36	3.51	1553.84	-0.20
	88	1072+62	-3.90	82.05	5.81	170.58	-0.82	373.41	2.33	796.21	1.38	1654.73	-2.17
	89	1082+69	-18.35	61.12	1.13	130.42	-6.78	308.57	0.71	707.99	0.94	1537.95	-5.61
	90	1093+69	5.73	48.31	-3.71	125.67	-14.27	313.03	-6.48	724.61	-5.52	1567.82	-16.94
	91	1102+82	16.14	45.76	-0.89	106.71	-3.01	281.60	13.98	672.28	15.57	1494.53	10.88
	92	1112+81	-3.44	42.13	1.08	104.72	-0.75	266.44	-6.42	656.19	-6.33	1478.07	-10.17
	93	1122+81	26.65	44.12	5.54	109.92	9.01	275.64	7.55	668.80	10.05	1504.32	9.18
	94	1131+73	3.71	67.27	5.06	158.80	0.03	358.25	2.67	790.96	4.63	1677.44	5.65
	95	1141+97	-2.13	74.88	-1.27	158.55	-0.70	352.36	10.16	776.97	17.08	1647.91	22.79
	96	1151+92	-14.89	71.66	-0.48	151.96	0.32	332.23	-2.52	749.70	1.44	1612.40	0.74
	97	1161+91	51.54	66.38	4.08	155.65	10.64	341.10	3.56	752.62	6.79	1603.82	1.59
	98	1171+91	213.96	84.51	42.29	185.56	75.13	377.60	84.61	772.00	84.58	1605.95	79.73
	99	1182+17	241.95	80.42	43.82	182.88	81.22	377.23	112.11	767.43	111.56	1606.49	99.78
	100	1191+90	190.00	148.14	31.14	292.10	63.85	541.21	100.42	988.51	100.65	1953.80	96.62
	101	1201+93	149.91	110.06	28.44	225.17	59.69	438.37	93.89	821.59	94.01	1765.28	96.35
	102	1211+94	156.88	140.17	30.39	266.12	67.92	491.93	120.50	864.26	117.48	1855.80	112.54

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (Summer 2013 to Summer 2014) 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 July 17, 2013 to June 23, 2014.

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	
				2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)
Fort Macon	103	1222+11	176.37	76.21	29.52	165.89	60.61	346.52	124.54	687.99	133.07	1789.46	125.05
	104	1231+86	161.85	96.67	37.38	189.36	63.08	369.79	110.54	756.41	113.02	1959.41	104.15
	105	1241+79	155.12	90.20	27.19	187.00	58.46	334.68	56.23	735.89	30.72	1949.06	25.03
	106	1251+79	165.19	94.65	25.54	201.72	67.22	381.12	85.88	923.05	98.20	2176.43	97.38
	107	1257+09	140.33	113.99	14.65	227.87	44.42	400.24	45.80	1081.15	68.36	2342.94	68.61
	108	1261+80	111.77	57.76	5.90	147.62	34.94	301.99	39.81	954.42	63.43	2158.12	63.56
	109	1267+13	46.57	74.41	1.34	162.03	12.33	334.09	12.38	1058.02	-4.65	2350.07	-4.45
	110	1271+73	22.09	66.15	4.95	137.18	14.51	289.45	12.51	1091.77	-0.44	2344.12	-0.68
	111	1278+93	81.52	47.67	9.08	118.36	24.44	268.62	34.97	1277.74	38.58	2383.06	38.12
	112	1283+93	82.08	56.28	9.44	152.18	21.52	323.67	17.96	1629.27	-12.87	2865.88	-12.99
Beaufort Inlet	112B	0+00	90.09	56.94	11.68	171.40	39.92	389.80	30.60	820.27	72.68	1458.88	69.33
	113	5+00	130.84	94.88	15.80	296.78	20.70	629.39	-8.70	1118.50	11.18	1745.97	35.52
	114	10+00	-2.75	99.07	6.24	327.00	-1.16	627.30	-8.62	1013.77	-0.39	1539.19	15.11
	115	15+00	-12.73	106.79	6.07	302.56	4.84	540.52	3.97	818.88	-3.71	1199.28	-20.61
	116	20+00	0.62	47.59	1.48	116.21	0.73	222.24	0.89	359.20	-0.02	553.25	-1.49
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 (Summer 2013 to Spring 2014)

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 July 18, 2013 to April 25, 2014.

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	
				2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)
Bear Island	1	0+00	19.81	5.82	1.50	51.39	-0.07	280.09	-71.66	1035.15	-89.66	2338.49	-88.92
	2	10+00	-59.00	54.34	-5.71	187.60	-13.59	591.47	101.86	1338.12	114.43	2599.96	117.28
	3	20+00	-7.71	25.00	0.26	87.15	-6.77	310.74	16.64	795.46	28.25	1866.48	26.59
	4	30+00	34.99	19.28	2.74	85.41	14.06	247.09	9.49	644.05	6.89	1626.88	2.94
	5	40+00	13.20	14.66	2.48	77.66	16.14	233.70	18.00	601.17	14.61	1530.85	6.67
	6	50+00	-40.58	9.37	-3.64	62.96	-0.27	221.69	9.49	585.20	8.81	1480.58	9.80
	7	60+00	-21.01	110.67	-10.65	193.77	-2.15	384.13	0.36	784.02	1.95	1698.70	2.73
	8	70+00	-22.84	20.47	-2.49	78.68	1.07	240.20	-3.10	606.17	0.13	1457.20	5.23
	9	80+00	-32.23	21.93	-4.25	80.55	-2.79	242.39	-5.78	605.27	-5.71	1443.95	-4.51
	10	90+00	-22.22	16.98	-2.47	70.16	5.88	230.96	6.82	585.01	6.61	1406.85	13.86
	11	100+00	16.32	19.28	0.57	77.46	-0.53	244.62	-1.72	599.06	-6.35	1422.97	-8.96
	12	110+00	-22.29	29.13	-1.04	92.20	3.66	263.14	2.57	622.22	3.56	1455.19	7.10
	13	120+00	-22.40	21.50	0.01	82.48	4.42	248.70	11.04	605.96	11.70	1452.58	17.79
	14	130+00	-23.24	18.40	-1.09	86.06	0.90	259.86	6.21	629.99	2.35	1516.79	-3.56
	15	140+00	-29.50	21.31	-0.94	86.95	4.73	257.31	10.86	631.00	6.74	1549.14	0.53
	16	150+00	-40.54	23.24	-2.57	91.74	-0.91	265.76	-7.72	662.56	-18.55	1602.80	-31.47
	17	160+00	-93.09	29.74	-10.99	104.85	-24.48	301.97	-53.98	728.53	-65.54	1701.37	-71.53
	18	170+00	-	-	-	-	-	-	-	-	-	-	-

Table D-3. Summary of Shoreline Change and Volume Change Along Shackleford Banks (Spring 2013 to Winter 2014)

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 fromApril 26, 2013 to February 25, 2014.

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	
				2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)	2014 Measured Volume (cy/ft)	2013-2014 Volume Change (cy/ft)
Shackleford Banks	1	0+00	-20.91	5.31	-1.37	186.85	-16.86	939.19	-23.80	2035.72	-27.32	3912.83	-27.77
	2	20+51	5.24	24.59	3.28	191.08	8.27	523.18	8.78	1087.80	6.67	2176.18	19.72
	3	40+80	-29.98	57.22	4.14	200.72	6.76	476.60	7.20	834.42	5.43	1557.39	-4.16
	4	58+81	-12.59	49.57	3.93	117.34	4.02	296.42	7.75	600.57	12.23	1426.68	54.76
	5	77+99	-17.56	4.34	-1.25	35.04	-0.18	151.21	6.49	406.10	13.74	1110.43	6.91
	6	96+76	-12.68	5.35	-0.72	35.42	-4.98	159.24	9.08	408.81	-0.86	1199.53	14.38
	7	113+28	-13.87	21.07	-0.95	64.91	-6.25	184.47	-0.81	450.73	-5.24	1217.73	-5.93
	8	130+01	-1.10	13.90	-0.33	55.84	-4.30	173.15	-10.67	457.41	-7.92	1198.26	2.41
	9	152+46	-34.20	19.92	-3.45	69.42	-3.27	187.71	-14.11	485.87	-4.03	1248.82	-2.08
	10	170+79	-15.37	29.04	-2.10	75.99	7.14	190.08	7.15	496.29	16.42	1262.06	29.71
	11	190+43	-50.83	50.03	-2.28	124.18	-3.86	274.97	-3.43	610.08	-3.57	1396.27	11.70
	12	210+07	-0.45	12.30	-0.33	58.62	-1.39	169.39	-3.82	460.07	-9.12	1148.54	-18.85
	13	229+21	-33.89	27.53	-1.27	76.04	-0.08	201.79	3.63	506.06	7.89	1231.59	17.76
	14	248+63	-32.11	7.63	-3.65	41.68	-2.46	135.38	-3.34	422.85	-5.79	1085.99	-12.97
	15	272+15	-31.97	13.20	-3.31	51.41	-5.17	141.91	-2.24	424.12	-9.41	1085.42	-9.96
	16	293+38	14.48	58.75	1.00	117.57	-9.80	246.48	-19.09	567.19	-27.73	1297.59	-37.58
	17	322+18	27.85	61.94	1.75	120.08	8.67	247.24	2.29	583.36	-1.18	1343.33	-14.02
	18	343+08	-71.71	21.79	-4.89	67.55	-10.61	203.12	-22.75	517.36	-39.76	1302.93	-50.99
	19	363+54	2.64	62.04	2.33	131.55	14.66	283.74	22.00	641.23	14.36	1510.76	4.73
	20	383+92	-31.53	15.32	-8.03	61.74	-0.27	188.27	-9.22	527.71	-19.35	1509.56	-21.31
	21	405+26	-53.82	15.57	-15.22	53.68	-29.07	194.37	-43.98	625.65	-62.09	1885.60	-87.10
	22	423+85	-221.88	2.03	-36.67	25.81	-75.84	162.31	-90.91	851.40	-114.68	2691.95	-156.92
	23	444+92	-598.82	0.00	-19.01	0.56	-66.92	95.12	-129.99	455.44	-180.64	1484.67	-191.07
	24	460+01	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E

FEMA Beach Maintenance Calculations

Bogue Banks Restoration Project - Phase I - Indian Beach/Salter Path

Reach	Transect	Station	Distance from Last (ft)	June 2014 Unit Volume Dune to -12 ft (cy/ft)	June 2014 Volume To Next Line (cy)	June 2002 Unit Volume Dune to -12 ft (cy/ft)	June 2002 Volume To Next Line (cy)	Reach Volume June 2014 (cy)	Reach Volume June 2002 (cy)	Fill Volume June 2002 (cy)	Reach Volume Change 6/02-6/14 (cy)	FEMA Maintenance Baseline Cell Volume (50% of fill remaining) (cy)	Percent Original Fill Volume Remaining (%)
Indian Beach/ Salter Path	48	580+13	780	270.00	428,577	211.77	340,767	3,548,535	3,197,794	456,994	350,741	2,969,297	176.7
	49	595+84	1,571	275.62	354,104	222.19	303,971						
	50	608+06	1,222	303.93	355,349	275.43	331,585						
	51	620+90	1,283	250.00	277,042	241.38	299,844						
	52	633+31	1,241	196.48	377,692	241.85	356,945						
	53	648+17	1,486	311.85	426,282	238.56	326,817						
	54	660+65	1,244	373.49	372,748	286.87	315,339						
	55	672+30	1,165	266.42	308,758	254.67	296,512						
	56	683+24	1,194	250.76	265,378	242.00	258,103						
	57	693+79	1,055	252.33	382,603	247.48	367,911						
	58	709+05	1,526	249.12	-	234.71	-						

Bogue Banks Restoration Project - Phase I - Pine Knoll Shores

Reach	Transect	Station	Distance from Last (ft)	June 2014 Unit Volume Dune to -12 ft (cy/ft)	June 2014 Volume To Next Line (cy)	June 2002 Unit Volume Dune to -12 ft (cy/ft)	June 2002 Volume To Next Line (cy)	Reach Volume June 2014 (cy)	Reach Volume June 2002 (cy)	Fill Volume June 2002 (cy)	Reach Volume Change 6/02-6/14 (cy)	FEMA Maintenance Baseline Cell Volume (50% of fill remaining) (cy)	Percent Original Fill Volume Remaining (%)
Pine Knoll Shores West	58	709+05	1,526	249.12	359,374	234.71	350,714	2,311,524	2,127,791	489,073	183,733	1,883,255	137.6
	59	723+93	1,488	233.91	290,488	236.68	276,518						
	60	736+01	1,208	247.03	319,053	221.32	291,683						
	61	748+06	1,206	282.08	363,009	262.60	334,542						
	62	761+80	1,374	246.32	310,482	224.36	272,749						
	63	774+77	1,294	233.56	316,428	197.20	284,111						
	64	787+61	1,284	259.32	352,689	245.34	317,474						
	65	800+91	1,329	271.44	-	232.28	-						
Pine Knoll Shores East	65	800+91	1,329	271.44	326,869	232.28	292,419	3,735,430	3,768,320	787,513	-32,890	3,374,564	95.8
	66	813+33	1,242	254.92	289,723	238.68	304,022						
	67	825+53	1,205	225.95	361,506	265.92	364,368						
	68	840+55	1,513	251.91	256,204	215.73	232,032						
	69	850+84	1,029	246.05	316,059	235.43	300,385						
	70	863+28	1,244	262.08	483,055	247.62	472,497						
	71	882+23	1,896	247.47	342,531	250.90	361,319						
	72	896+24	1,400	241.86	359,775	265.27	373,462						
	73	910+53	1,429	261.68	310,034	257.42	341,064						
	74	922+70	1,217	247.83	391,642	303.08	421,238						
	75	937+70	1,500	274.36	298,032	258.57	305,514						
	76	948+81	1,111	262.15	-	291.46	-						
Phase I	**48-76**		**37,736**		**9,595,489**		**9,093,905**	**9,595,489**	**9,093,905**	**1,733,580**	**501,584**	**8,227,115**	**128.9**

Table E-1. FEMA Maintenance Calculations (Summer 2014)

Bogue Banks Restoration Project - Phase 2 - Eastern Emerald Isle

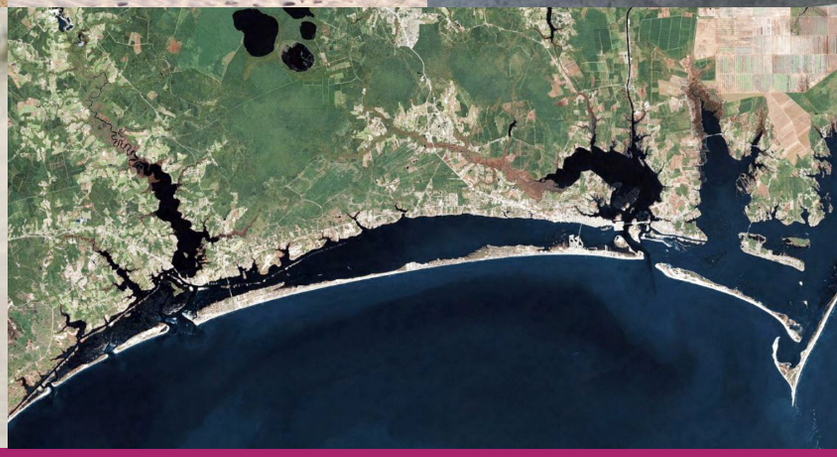
Reach	Transect	Station	Distance from Last (ft)	June 2014 Unit Volume Dune to -12 ft (cy/ft)	June 2014 Volume To Next Line (cy)	March 2003 Unit Volume Dune to -12 ft (cy/ft)	March 2003 Volume To Next Line (cy)	Reach Volume June 2014 (cy)	Reach Volume March 2003 (cy)	Fill Volume March 2003 (cy)	Reach Volume Change 3/03-6/14 (cy)	FEMA Maintenance Baseline Cell Volume (50% of fill remaining) (cy)	Percent Original Fill Volume Remaining (%)
Emerald Isle Central	26	304+77	1,400	301.59	410,761	234.75	331,359	4,244,186	3,616,982	965,386	627,204	3,134,289	165.0
	27	318+11	1,335	313.78	335,819	261.78	272,417						
	28	329+10	1,099	297.35	472,879	234.02	429,196						
	29	345+80	1,670	268.97	466,521	280.11	417,536						
	30	362+22	1,642	299.26	474,284	228.46	393,012						
	31	378+80	1,658	272.85	488,514	245.62	402,306						
	32	395+22	1,642	322.17	433,191	244.4	340,866						
	33	408+86	1,364	313.01	423,144	255.33	352,256						
	34	422+83	1,396	293.22	351,843	249.19	308,099						
	35	435+62	1,279	256.97	387,229	232.44	369,935						
	36	450+22	1,460	273.48	-	274.32	-						
Emerald Isle East	36	450+22	1,460	273.48	281,618	274.32	306,557	3,528,279	3,624,869	882,376	-96,590	3,183,681	89.1
	37	461+34	1,112	233.03	288,263	277.19	320,890						
	38	472+44	1,110	286.37	321,297	300.99	321,541						
	39	483+48	1,103	296.22	300,120	282.04	333,214						
	40	494+44	1,096	251.44	301,958	326.07	326,710						
	41	505+39	1,095	300.08	300,954	270.66	321,097						
	42	516+57	1,118	238.30	267,035	303.6	299,416						
	43	527+37	1,080	256.21	312,490	251.12	287,803						
	44	538+39	1,102	310.93	332,755	271.34	305,903						
	45	549+45	1,107	290.26	307,923	281.48	302,431						
	46	560+42	1,097	271.13	301,040	270.05	288,017						
	47	571+43	1,101	275.72	212,827	253.19	211,290						
	48	580+13	780	270.00	-	288.44	-						
Phase 2	**26-48**		**28,846**		**7,772,464**		**7,241,851**	**7,772,464**	**7,241,851**	**1,847,762**	**530,613**	**6,317,970**	**128.7**

Table E-2. FEMA Maintenance Calculations (Summer 2014)

Bogue Banks Restoration Project - Phase 3 - Western Emerald Isle

Reach	Transect	Station	Distance from Last (ft)	June 2014 Unit Volume Dune to -12 ft (cy/ft)	June 2014 Volume To Next Line (cy)	April 2005 Unit Volume Dune to -12 ft (cy/ft)	April 2005 Volume To Next Line (cy)	Reach Volume June 2014 (cy)	Reach Volume April 2005 (cy)	Fill Volume April 2005 (cy)	Reach Volume Change 4/05-6/14 (cy)	FEMA Maintenance Baseline Cell Volume (50% of fill remaining) (cy)	Percent Original Fill Volume Remaining (%)
Bogue Inlet	7	53+10	1,682	340.27	493,525	311.58	465,293	493,525	465,293	46,540	28,232	442,023	160.7
	8	67+74	1,464	333.95	-	324.06	-						
Emerald Isle West	8	67+74	1,464	333.95	424,497	324.06	405,441	6,869,966	5,962,298	644,328	907,668	5,640,134	240.9
	9	80+91	1,317	310.70	377,790	291.74	351,725						
	10	93+40	1,249	294.25	434,415	271.61	402,140						
	11	108+58	1,519	277.73	397,228	257.87	308,148						
	12	121+18	1,260	352.80	463,682	231.29	337,302						
	13	134+61	1,343	337.72	384,554	271.06	313,715						
	14	146+67	1,206	300.01	394,430	249.24	335,672						
	15	160+16	1,349	284.76	415,663	248.49	378,148						
	16	174+79	1,463	283.47	438,326	268.53	405,138						
	17	189+23	1,444	323.63	461,696	292.72	425,096						
	18	203+53	1,431	321.65	339,970	301.57	317,096						
	19	214+90	1,136	276.89	468,384	256.55	384,395						
	20	230+02	1,513	342.26	355,619	251.64	301,886						
	21	241+15	1,112	297.34	339,670	291.37	306,488						
	22	252+19	1,105	317.44	311,235	263.51	292,137						
	23	263+24	1,104	246.39	497,403	265.58	425,310						
	24	279+57	1,633	362.80	365,403	255.25	272,461						
	25	290+77	1,120	289.70	-	231.20	-						
Phase 3	**7-25**		**25,450**		**7,363,492**		**6,427,591**	**7,363,492**	**6,427,591**	**690,868**	**935,901**	**6,082,157**	**235.5**

Table E-3. FEMA Maintenance Calculations (Summer 2014)



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