Village of Bald Head Island, N.C.

Terminal Groin Project Inlet Management Plan Oak Island Monitoring

(Nov 2018 - Nov 2019)

Prepared for:
Village of Bald Head Island

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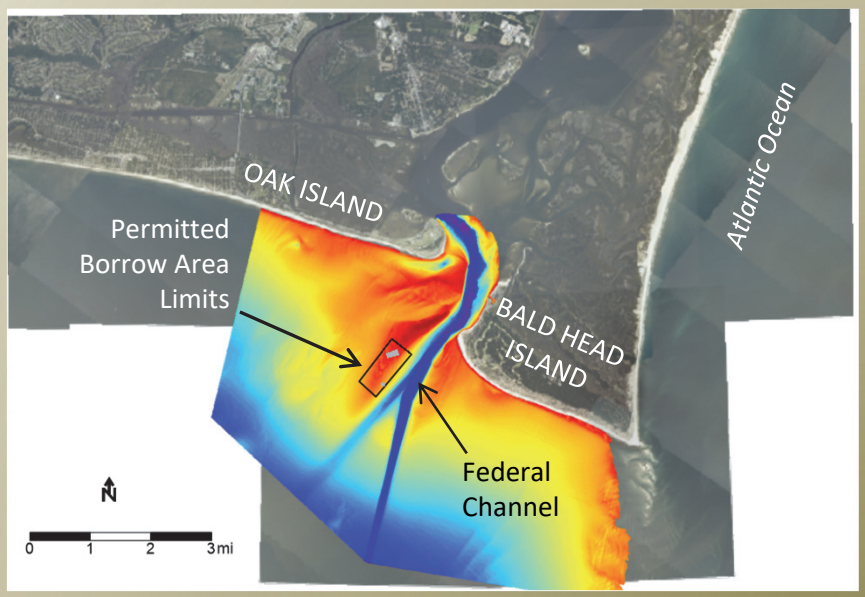

December 2019

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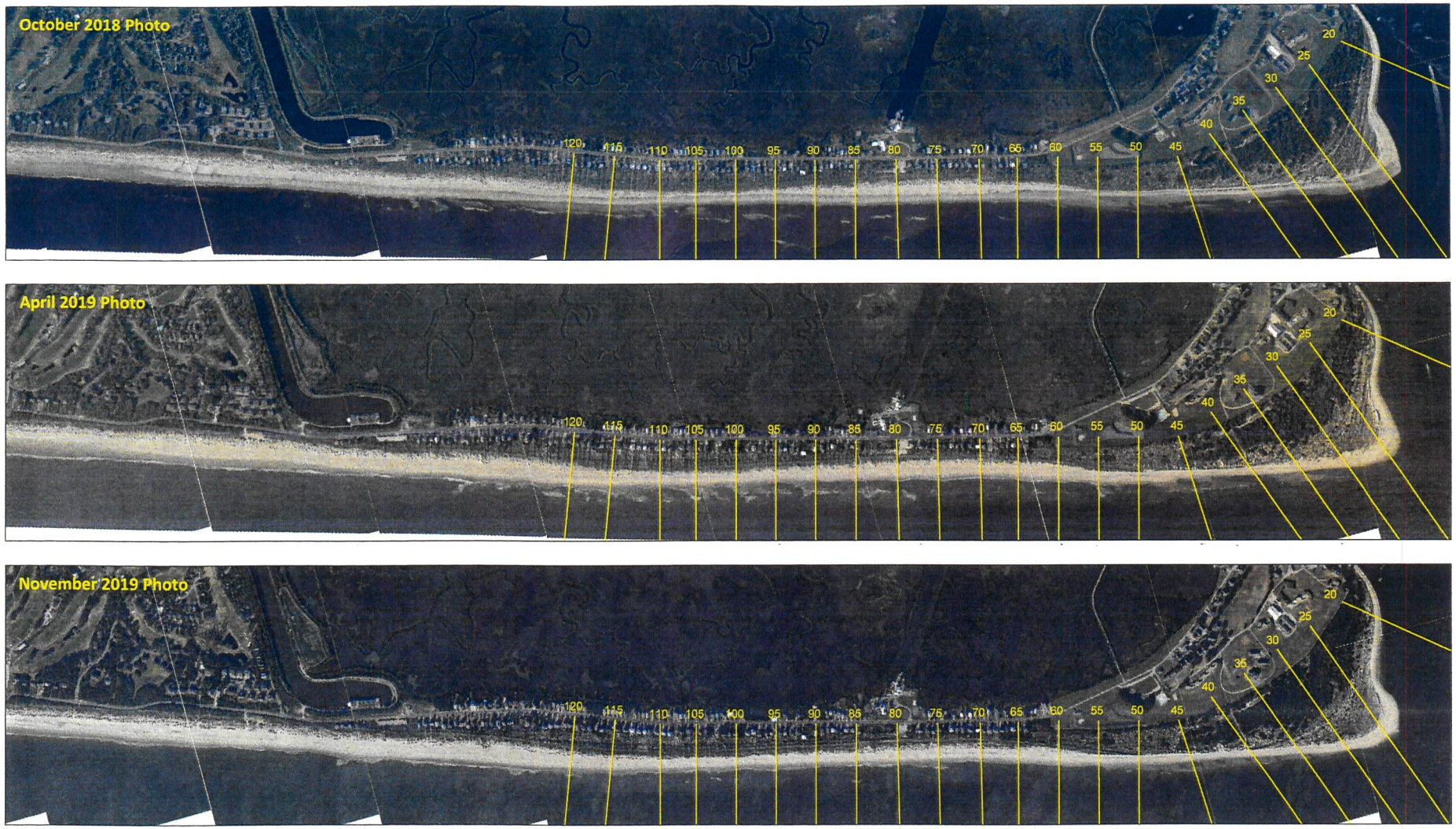
Village of Bald Head Island, N.C.
Terminal Groin Project
Inlet Management Plan
Oak Island Monitoring – Year 1
November 2018 – November 2019

PURPOSE

On October 21, 2014 the Village of Bald Head Island (VBHI) was granted DCM Permit No. 91-14 authorizing the construction of a terminal groin located at the westernmost end of South Beach. The companion federal Permit was No. SAW-2012-00040. Referenced within both Permits was an *Inlet Management Plan* which addressed certain requirements of SB110 (as subsequently amended by SB151) codifying both monitoring and mitigation precepts required for terminal groin construction in the State of N.C.

Specific to this monitoring report of findings was the permit requirement that *if* the VBHI elected to redredge a borrow site previously developed within Jay Bird Shoals – and *if* the volume dredged exceeded 250,000 cy – *then* the VBHI would be required to monitor a section of shoreline on the eastern end of Oak Island between survey baseline Sta. 120 and Sta. 20 (see **Figure 1**). The latter Figure presents three periods of shoreline photography acquired by the VBHI for this Year 1 Monitoring Report.

The purpose of such Oak Island monitoring was intended to ensure no adverse impact via dredge project related erosion therealong and to address the need for mitigation – if said erosion (documented to be caused by the Village dredge project) *exceeded* certain historical limits. The duration of the effective beach monitoring program was to be up to 9 years. *If* pre-determined erosion triggers were documented to have been exceeded, then a three party Technical Advisory Committee (TAC) was to determine the cause and subsequently whether or not mitigation was, or was not required – due to the VBHI project. The full details of the original Permit No 91-14 *Inlet Management Plan* are included as **Appendix A** to this report.



SCALE

0 600 1200 FT

Note: Monitoring Lines 120-20 Shown.

Figure 1: Oak Island Area of Interest.

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Coastal Engineering

Subsequent to acceptance of Permits for terminal groin construction by the VBHI– and the associated Conditions for monitoring and mitigation – the coastal engineering consultant to the Town of Caswell Beach forwarded a letter to the Wilmington District, USACOE indicating that the dredging of Jay Bird Shoals borrow site by the VBHI should *not* negatively impact the Oak Island shoreline. That conclusion was based upon two detailed numerical modeling studies prepared for the VBHI which predicted no project impacts associated with excavation of the Jay Bird Shoals borrow site if dredged to its maximum permitted limits. Moreover, the consultant likewise opined that an area of erosion which appeared *after* the last 2000 federal channel deepening project by the USACOE did *not* appear to be related to the 2009/10 dredging of Jay Bird Shoals borrow site by the Village. Such a finding had likewise been rendered by the Consultant to BHI – prior to issuance of the terminal groin permits. None-the-less, the consultant to Caswell Beach recommended that shoreline monitoring along the subject area of Oak Island should "continue for some reasonable period of time that would clearly demonstrate no shoreline impacts associated with any proposed redredging" of Jay Bird Shoals which exceeds 250,000 cy. Subsequent informal discussions between the coastal engineering consultants to the Town and the Village have indicated that a reasonable period of time may be 1-2 years.

In January through March 2019, the VBHI initiated a 1.1 Mcy beach restoration project which utilized the original Jay Bird Shoals borrow site at the request of the USF&WS. As a result, the 250,000 cy "trigger" made a part of the Terminal Groin Permit terms was exceeded and thus shoreline monitoring of the east end of Oak Island was required. To that end the first monitoring survey was performed in November 2018 in order to document beach conditions immediately prior to the VBHI dredging project. A second survey was performed in May 2019 at the end of the VBHI beach fill project. A third survey was performed in November 2019 for purpose of the formulation of this initial 1-year Report of Findings.

BACKGROUND CONSIDERATIONS

Over the past 12-24 months, there are several significant events which have influenced conditions along the Oak Island shoreline which is subject to monitoring by survey for this report. The first event was the disposal of some 1.15M cy of beach quality sand derived from the

maintenance of the federal navigation project channel. That work was performed in May-June 2018 pursuant to the terms of the Wilmington Harbor Sand Management Plan. More specifically, sand was placed as a "designed" beach fill along segments of shorefront which overlap the monitoring area (see **Figure 2**). As shown therein, sand fill was placed within a portion of the Town of Caswell Beach limits presently subject to monitoring however, the majority of the sand was placed farther westward. Net transport in this area is from west to east. No sand was placed however within the boundaries of the Fort Caswell parcel due to an enforced prohibition of public access along that section of shorefront closest to the Cape Fear River (Sta 60 to Sta 05). The latter lands are owned by the N.C. Baptist Assembly at Fort Caswell. The Corps requires that easements for disposal are provided to the federal government and that the public has open access to lands that receive sand from the navigation project.

Project plans for the 2018 Oak Island beach disposal project portray a hydraulically placed fill berm (with end tapers) extending seaward some 125 ft. (on average) at an elevation of +6ft NAVD88 – within the area of interest. The beach foreshore slope extending another 200 ft. seaward, mol. As such fill berms "equilibrate" to a profile self-similar to that which existed prior to the sand placement, the effective MHWL recedes relatively rapidly over the next 6-18 months, depending upon levels of seasonal wave energy experienced over time. Such naturally occurring "recession" is endemic to the nature of the fill design as well as the sediment quality placed – which varies from channel segment to channel segment dredged during each maintenance contract. To that end, it is likewise of significance that two additional disposal events preceded the 2018 Oak Island fill project: a) 1.594 Mcy between Nov. 09 and March 2010, and b.) 1.18 Mcy in 2001.

Hurricane Florence which occurred in September 2018 had a major adverse influence on the Brunswick County shorelines of both Oak Island and Bald Head Island. To that end post-storm FEMA Claims for beach and dune erosion were submitted by communities on each island. Similarly, but to a much smaller degree Hurricane Dorian in September 2019 brushed the coast of North Carolina thereby resulting in varying (but lesser) degrees of shoreline erosion and recession.

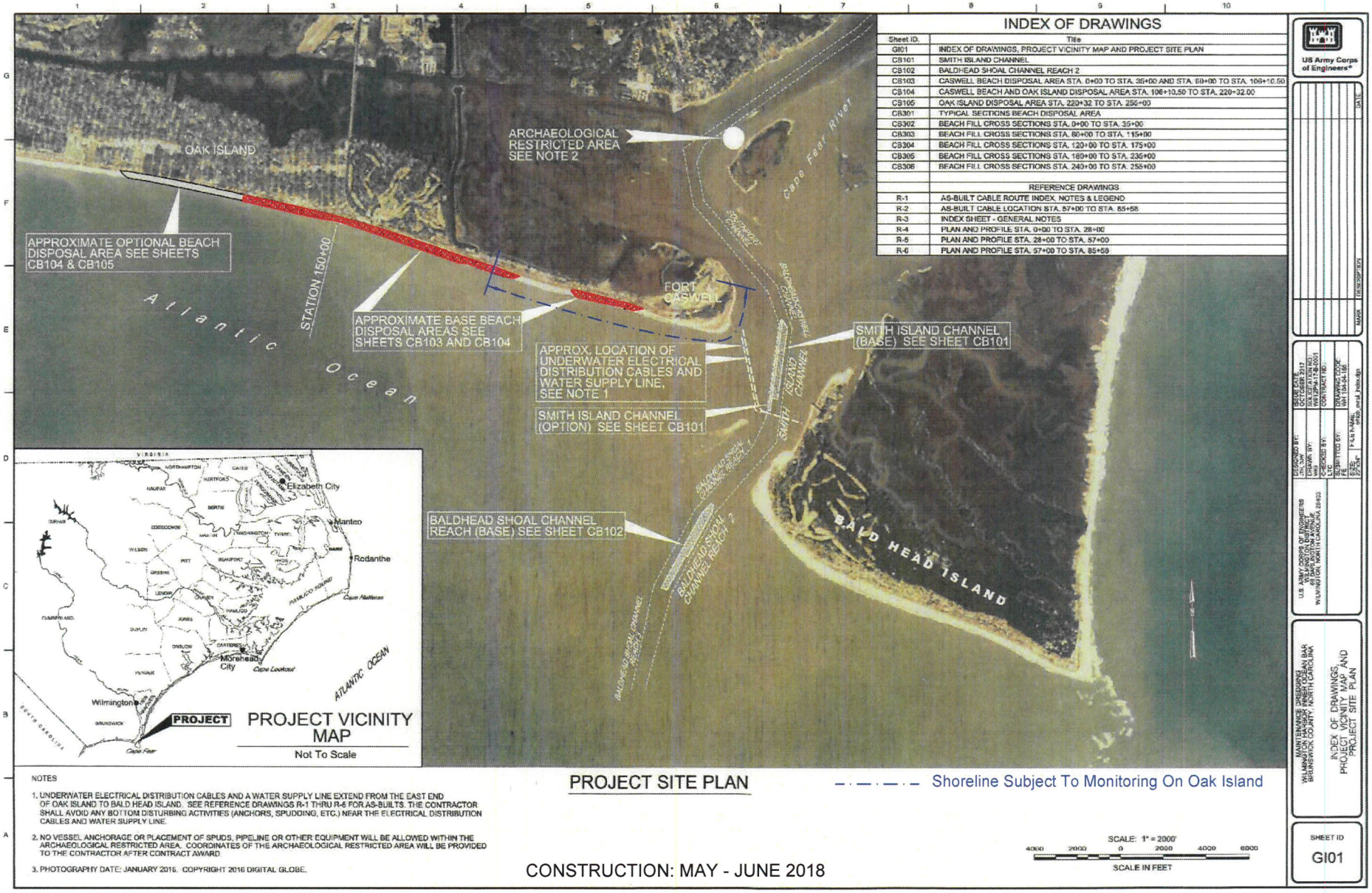


Figure 2: Location of 1.15Mcy Federal Beach Disposal Project - 2018.

A third ongoing phenomenon causing a localized shoreline instability at the east end of Oak Island is the federal navigation project itself. More specifically, there is a present day erosional "hot spot" located in the vicinity of monitoring Sta's 30 and 40 which prior to the 2000 W.H. channel deepening project, had been shown by the Corps to be accretional (see **Table 1**). Beginning in 2000, ten years of shoreline monitoring by the Wilmington District USACOE has well documented that that specific section of shorefront has been *consistently recessional* since the construction of the last channel deepening project. As an example, **Figure 3** depicts such an erosional condition at that location for Wilmington District monitoring surveys beginning in 2000 and extending through January 09 - September 10. More importantly, the District's summary of shoreline change trends for all 10 years of Oak Island monitoring shown by **Figure 3** clearly shows the following trends and the maximum annual recession documented by survey.

TABLE 1 **TRENDS**

	Pre-Project	**Post-Project (10 Yr)**	**Max Annual Change (ft/yr.)**
Profile 35	+29.9 ft/yr	-8.8 ft/yr	-90
Profile 40	+17.2 ft/yr	-4.5 ft/yr	-100

Note: All MHWL "trends" computed by the District are referenced to the date of completion of the last Wilmington Harbor Deepening project (i.e. August 2000).

PERMIT TERM COMPLIANCE

The terms for shoreline monitoring of the east end of Oak Island – as triggered by the VBHI reuse of the Jay Bird Shoal borrow site in early 2019 are codified in the *Village of Bald Head Island, NC, Terminal Groin Project, Inlet Management Plan* dated October 2014 (see **Appendix A**). As noted previously, the monitoring (requirement for Oak Island) to be performed by the VBHI addressed solely the reuse of the Jay Bird Shoal Borrow Site. That is to say, it was unrelated to the construction of the terminal groin itself – but rather the future "source of sand" required to maintain the sand fillet updrift of the structure – which in 2019 turned out to be Jay Bird Shoals. Interestingly, the VBHI had proposed to utilize sand excavated from Frying

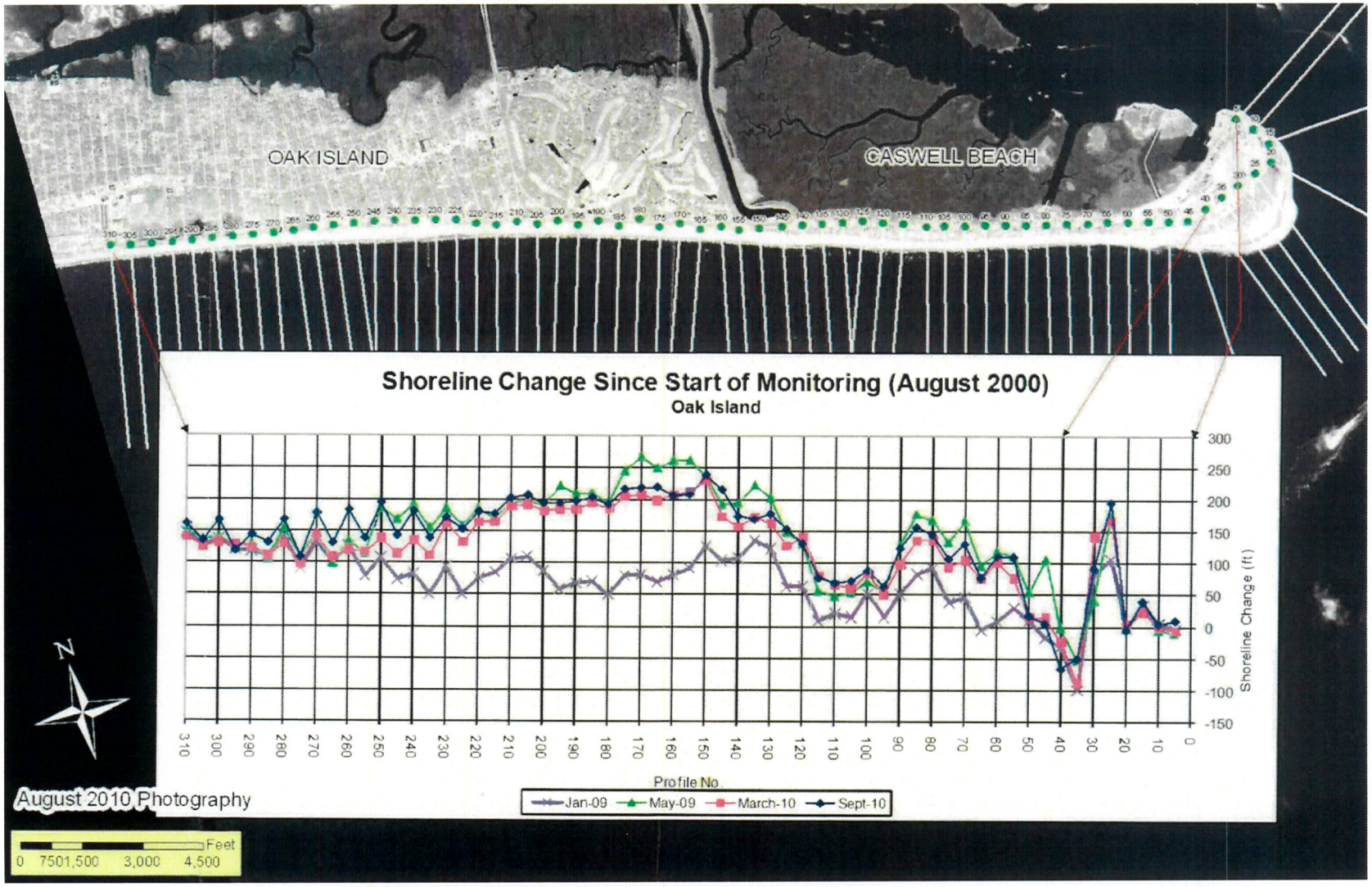


Figure 3: Source– Federal Monitoring Program for Oak Island.

Note: Erosional Hot Spot at STA 35 and STA 40

Pan Shoals for purposes of beach maintenance in 2019, but was required by the USF&WS to return to the original Jay Bird Shoal borrow site.

For the record, the majority of the monitoring Conditions and Triggers enumerated in the original *Inlet Management Plan* made a part of DCM Permit No. 91-14 *cannot be complied with*. For example, a trigger for Technical Advisory Committee (TAC) evaluation of monitoring findings for any one year involved whether or not "annual computed shoreline recession or volume change rates exceeded *baseline* rates by 25% or more." In this regard, the computation of meaningful "baseline rates" is *not* possible. A summary of related facts affecting this conclusion are as follows:

1. Database – The Wilmington District performed monitoring on the east end of Oak Island for the period September 2000 – September 2010. The last District Report of Findings (Report No. 8) is dated June 2011. The VBHI JBS related project monitoring was initialized in November 2018 – over 8 years after beach monitoring was terminated on Oak Island.

2. Beach Disposal Activities – Between 2000 and the present, three (3) beach disposal activities occurred along the east end of Oak Island totaling almost 4.6 Mcy. As a result, all subsequent shoreline change trends – be they volumetric or shoreline changes – have been artificially manipulated over time due to beach fill projects. Each such fill project by design increases beach profile volume and extends the MHWL seaward. The affected shoreline segments are then subject to sand volume redistribution and rapid MHWL recession due to fill berm "equilibration". Any "baseline" values computed by Corps monitoring – to be addressed by subsequent VBHI monitoring findings are therefore highly biased by episodic beach fill projects.

3. COE Published Trend Values. The *Inlet Management Plan* specifically references the use of shoreline "trend analysis" computed by the Wilmington District in the evaluation of the VBHI's post dredge monitoring. Unfortunately, the nature of the *trend* analyses

last published by the District in 2011 (Report No. 8) are to a large degree meaningless for the use intended. To that end, available shoreline change data are limited to shoreline change values computed more or less biannually for a 10 year period (2000- 2010). The published Sta. by Sta. "trends" computed by the COE are included as **Appendix B**. Analysis of the data (by the District) involved only plotting the cumulative change in MHW shoreline and plotting a linear trend line through the data. The slope of the trend line was then ascribed to be the long-term rate of MHW shoreline change. Inspection of the data suggest that the reliance on a linear trend model to compute an annual rate of MHWL change does *not* accurately describe the measured data at each monitoring station and was likely selected for the sake of simplicity and not predictive performance, accuracy or future use as a "trigger"..

For example, the MHW shoreline measurements along Profile 20 (see **Appendix B**) are highly variable with consecutive surveys suggesting annualized MHW shoreline change rates ranging from a seaward MHW *advance* of about +100 ft/yr (2005-2006) to a MHW *recession* of over -120 ft/yr (2003-04). The linear regression model suggests that the long-term annual rate of shoreline change is about -2.5 ft/yr (recession), a rate that neither describes the final position of the MHW shoreline after 10 years, or the aforementioned significant variability in shoreline change throughout the monitoring period. Based on the poorness of fit of the linear model to the measured data, a different statistical method should have been employed to describe long-term shoreline trends. There was no attempt to quantify the statistical accuracy of the linear trend line, which by inspection is likely extremely low. Attempts to do so would highlight the fact that the linear trend has a tendency towards under-prediction of recession for many consecutive survey periods (most of 2000-2006, 60% of the record), further indicating poor statistical relevancy and an overall failure of the trend to extract a meaningful signal. Hence the trends are useless with respect to comparisons required by the *Inlet Management Plan*.

Finally, as stated above the MHW shoreline data include the effects of beach renourishment. The effects of beach fill are impossible to reliably remove from MHW shoreline data, which inherently makes the presented data unreliable for the purpose of describing 'natural' shoreline evolution. At a minimum, one would need to exclude the

data for a given period of time during which the fill was equilibrating prior to drawing conclusion on non-anthropogenic littoral trends. Pragmatically this cannot be done.

OAK ISLAND MONITORING SELECTED PROTOCOL AND FINDINGS

A limited number of Oak Island surveys acquired after the completion of the Wilmington District 10-Year Monitoring project were located for the period Dec 14 through June 16. These data were provided by GEODYNAMICS and are assumed to have been performed for the Wilmington District by that firm. **Table 2** presents the positions of the MHWL for these surveys, in addition to the three (3) surveys performed by the VBHI for this Year-1 Report. The Table likewise presents the change (in ft.) between the surveys. To that end it should be noted that a 1.15 Mcy beach fill constructed in May-June, 2018 affected various stations being monitored. Areas directly affected by either the 2018 fill berm, or end of fill tapers are annotated within the Table with either an 'F' or a 'T'.

In addition, comparative plots of the survey profiles for these dates are included as **Appendix C**. The latter allow for visual interpretation between survey dates beginning in December 2014 and ending with conditions in November 2019. For purposes of this report, attention should be given to the post-Jay Bird Shoals excavation period of May – November 2019. From these comparative profiles, engineering judgement can be relied upon to evaluate the source of changes in profile location or elevation.

Given that there are no meaningful long term trends discernable from the 2000-2010 MHW (and volumetric) data, this report will seek to address and compare the more modern data noted above – using surveys with comparable end dates in order to minimize seasonal effects in MHW location or beach profile volume. **Table 3** presents both MHWL position and MHWL position change (ft/yr) between sequential dates. From the latter tabulation sheet, three (3) timeframes have been presented for analysis by this report. They include the 4-year time period Dec. 14 – Nov. 18; the one-year time period Dec. 14 to Dec. 15 and the most recent survey period Nov. 18 – Nov. 19, the period of monitoring specifically addressed by this report which includes the redredging of the Jay Bird shoal borrow site by the VBHI.

Table 2: Oak Island shoreline positions

MHWL Position (+2.51 ft-NGVD)

	Station	Dec-14	Jul-15	Dec-15	Jun-16 (1)	Nov-18 (1)	May-19	Nov-19
	20+00	525.3	513.4	521.6	502.3	485.2	489.8	468.2
	25+00	1515.6	1548.1	1574.7	1582.0	1586.7	1670.5	1642.1
	30+00	1620.2	1581.3	1612.9	1601.2	1506.6	1461.4	1496.9
	35+00	1418.5	1428.1	1371.6	1371.6	1209.3	1236.3	1204.8
	40+00	1068.4	1024.7	1006.9	980.9	930.5	889.2	896.9
	45+00	612.9	606.4	577.9	554.8	492.7	559.9	516.9
	50+01	526.3	532.2	511.5	514.2	492.3	550.7	536.3
	55+01	499.6	515.6	507.0	538.0	539.2	531.5	531.3
T	60+01	504.4	487.4	469.3	488.6	528.4	508.9	523.2
F	65+01	482.0	436.3	457.0	437.2	508.6	480.4	493.2
F	70+00	449.2	408.6	413.3	407.6	493.5	431.9	451.5
T	75+01	429.9	410.0	416.5	404.6	504.0	446.7	465.3
	80+01	427.1	393.8	411.3	394.9	507.4	446.5	471.0
T	85+02	457.0	429.4	428.8	430.8	508.7	462.2	482.8
F	90+02	479.7	484.5	464.5	457.2	514.1	487.4	495.3
F	95+02	489.2	480.4	466.1	489.4	498.4	502.7	510.4
F	100+02	516.7	528.5	495.1	540.3	507.0	535.3	527.8
F	105+02	533.9	528.9	513.5	539.3	535.4	544.2	544.8
F	109+50	535.5	543.7	519.3	536.2	537.6	551.7	566.4
F	115+03	574.9	592.4	576.9	578.5	600.6	607.9	621.9
F	120+03	596.0	608.6	595.7	604.8	628.5	623.5	640.5

MHWL Position Change Between Dates (+2.51 ft-NGVD)

	Station	Dec-14 Jul-15	Jul-15 Dec-15	Dec-15 Jun-16	Jun-16 Nov-18	Nov-18 May-19	May-19 Nov-19	Nov-18 Nov-19
	20+00	-11.8	8.1	-19.2	-17.1	4.5	-21.6	**-17.1**
	25+00	32.5	26.6	7.2	4.7	83.8	-28.4	**55.5**
	30+00	-38.9	31.6	-11.7	-94.6	-45.2	35.4	**-9.8**
	35+00	9.6	-56.5	0.0	-162.3	27.0	-31.5	**-4.5**
	40+00	-43.6	-17.9	-26.0	-50.4	-41.3	7.8	**-33.6**
	45+00	-6.5	-28.5	-23.1	-62.1	67.2	-43.0	**24.2**
	50+01	5.9	-20.7	2.7	-21.9	58.4	-14.4	**44.0**
	55+01	16.0	-8.6	31.0	1.2	-7.7	-0.2	**-7.9**
T	60+01	-17.0	-18.1	19.3	39.8	-19.5	14.3	**-5.2**
F	65+01	-45.7	20.7	-19.8	71.4	-28.3	12.9	**-15.4**
F	70+00	-40.6	4.7	-5.7	85.9	-61.6	19.6	**-42.0**
T	75+01	-19.8	6.5	-12.0	99.4	-57.3	18.6	**-38.7**
	80+01	-33.2	17.4	-16.4	112.5	-60.9	24.5	**-36.4**
T	85+02	-27.6	-0.7	2.0	77.9	-46.6	20.6	**-25.9**
F	90+02	4.8	-20.0	-7.3	56.9	-26.7	7.9	**-18.8**
F	95+02	-8.8	-14.3	23.3	9.0	4.3	7.7	**12.0**
F	100+02	11.8	-33.4	45.2	-33.3	28.3	-7.5	**20.8**
F	105+02	-5.0	-15.4	25.8	-3.9	8.9	0.6	**9.4**
F	109+50	8.2	-24.4	16.9	1.4	14.1	14.7	**28.8**
F	115+03	17.6	-15.5	1.6	22.1	7.3	13.9	**21.2**
F	120+03	12.5	-12.8	9.1	23.6	-5.0	17.1	**12.1**

(1) Oak Island Beach Disposal Project (May-June 2018) @ 1.15 MCY

F - Fill Berm

T - Fill Taper

Table 3: Oak Island MHWL change rates.

STA	10 Year Period COE Max Annual Loss (ft/yr)	4 Year Period Dec. 14 to Nov. 18 (ft/yr)	1 Year Period Dec. 14 to Dec. 15 (ft/yr)	1 Year Period Nov. 18 to Nov. 19 (ft/yr)
20	-120	-10.2	-3.7	-17.1
25	-70	18.1	59.2	55.5
30	-150	-29.0	-7.3	-9.8
35	-90	-53.4	-46.9	-4.5
40	-100	-35.2	-61.5	-33.6
45	-160	-30.7	-35.0	24.2
50	-120	-8.7	-14.8	44.0
55	-95	10.1	7.5	-7.9
T 60	-90	6.1	-35.1	-5.2
F 65	-90	6.8	-25.1	-15.4
F 70	-60	11.3	-35.9	-42.0
T 75	-100	18.9	-13.3	-38.7
80	-80	20.5	-15.8	-36.4
T 85	-90	13.2	-28.3	-25.9
F 90	-60	8.8	-15.3	-18.8
F 95	-40	2.4	-23.1	12.0
F 100	-50	-2.5	-21.7	20.8
F 105	-40	0.4	-20.4	9.4
F 110	-60	0.5	-16.2	28.8
F 115	-40	6.6	2.1	21.2
F 120	-100	8.3	-0.3	12.1

Notes:

1 F - Beach Fill Berm; T - Fill Taper; Oak Island Disposal Project (May-June 2018) @ 1.15 Mcy

2 Fort Caswell Parcel - STA 20 to STA 60

3 The post-channel deepening "hot spot" (since 2000) is located at STA 35+00 and STA 40+00

In the analysis of the **Table 3** change rates, it is important to consider the beach disposal project which occurred throughout a portion of the study area in May– June, 2018. Such fills are typically subject to rapid MHWL changes due to equilibration of the fill berm. Similarly, one should consider the historical "hot spot" in existence since 2000 at/or about Sta. 35 and Sta. 40. The only long term CORPS monitoring data included with **Table 3** is the first column which presents the highest annual loss rate (ft/yr) documented by the Wilmington District Monitoring program on a Sta. by Sta. basis. It is noted that the federal maximum MHWL changes *exceed all computations* for the four year period and the two (2) one year periods of comparison discussed herein.

Pursuant to the terms of the *Inlet Management Plan*, volumetric change computations throughout the selected monitoring area have been made for the portion of each beach profile above the -2 ft. NGVD contour and above the observed depth of closure. The latter is derived from each ensemble of comparative profiles at a monitoring station since its location varies along the island's shorefront. **Table 4** presents shoreline change volumes for the three time periods being analyzed above the -2' NGVD contour. **Table 5** presents change volumes above the depth of closure.

The original *Inlet Management Plan* made a part of the terminal groin permit required the comparison of volumetric (cy/yr) changes above both the -2 ft NGVD contour and the depth of closure along each beach profile**.** **Table 6** and **Table 7** provide those computations for the three (3) selected timeframes of analysis discussed above. Moreover, **Table 6** summarizes measured rates of change (*averaged*) for Sta. 20 – Sta. 60 which represents the Fort Caswell parcel (only) at the easternmost extent of Oak Island. Along that section of shorefront the most recent time frame (Nov. 18 – Nov. 19) recorded both volumetric accretion and an average progradation of the MHWL seaward. Conversely, the other 1-year and the 4-year period of analyses were erosional in their totality. Similarly, **Table 7** presents measured rates of changes *averaged* for the entire section of shoreline subject to monitoring (i.e. Sta. 20 – Sta. 120). Again, the current monitoring year (Nov. 18 – Nov. 19) demonstrated accretional conditions above the depth of closure and -2 ft. NGVD contour. Although the average MHWL location was slightly recessional at -1.3 ft/yr, it was still the lowest rate computed in comparison to the other two

Table 4: Oak Island shoreline volume changes (above -2' NGVD)

	Stations		Dec-14 to Nov-18		Dec-14 to Dec-15		Nov-18 to Nov-19	
	Start	End	CY	CY/Year	CY	CY/Year	CY	CY/Year
	20+00	25+00	13,300	3,390	3,000	3,000	2,000	2,000
	25+00	30+00	-2,000	-510	1,300	1,300	1,000	1,000
	30+00	35+00	-29,100	-7,420	-1,500	-1,500	-500	-500
	35+00	40+00	-32,700	-8,340	-4,400	-4,400	-2,700	-2,700
	40+00	45+00	-22,600	-5,760	-4,200	-4,200	-4,400	-4,400
	45+00	50+01	-8,200	-2,090	-700	-700	3,300	3,300
	50+01	55+01	-6,200	-1,580	-500	-500	3,100	3,100
	55+01	60+01	1,600	410	-400	-400	2,800	2,800
T	60+01	65+01	5,200	1,330	-300	-300	2,500	2,500
F	65+01	70+00	8,300	2,120	-500	-500	-1,600	-1,600
F	70+00	75+01	12,700	3,240	-500	-500	-3,900	-3,900
T	75+01	80+01	15,700	4,000	200	200	-4,500	-4,500
	80+01	85+02	13,800	3,520	-600	-600	-3,800	-3,800
T	85+02	90+02	9,700	2,470	-800	-800	-1,900	-1,900
F	90+02	95+02	5,100	1,300	-1,100	-1,100	2,100	2,100
F	95+02	100+02	1,100	280	-1,300	-1,300	5,200	5,200
F	100+02	105+02	2,300	590	-100	-100	4,400	4,400
F	105+02	109+50	3,500	890	400	400	4,800	4,800
F	109+50	115+03	6,400	1,630	1,000	1,000	7,900	7,900
F	115+03	120+03	7,900	2,020	1,000	1,000	5,700	5,700
		Total	**5,800**	**1,490**	**-10,000**	**-10,000**	**21,500**	**21,500**

(1) Oak Island Beach Disposal Project (May-June 2018) @ 1.15 MCY

F - Fill Berm

T - Fill Taper

Table 5: Oak Island shoreline volume changes (above approx. depth of closure)

	Stations		Dec-14 to Nov-18		Dec-14 to Dec-15		Nov-18 to Nov-19	
	Start	End	CY	CY/Year	CY	CY/Year	CY	CY/Year
	20+00	25+00	58,200	14,840	23,500	23,500	-11,400	-11,400
	25+00	30+00	14,000	3,570	6,500	6,500	-6,100	-6,100
	30+00	35+00	-39,300	-10,020	-2,800	-2,800	-8,900	-8,900
	35+00	40+00	-54,400	-13,880	-14,900	-14,900	-10,200	-10,200
	40+00	45+00	-62,100	-15,840	-22,000	-22,000	-13,600	-13,600
	45+00	50+01	-40,600	-10,360	-11,400	-11,400	3,000	3,000
	50+01	55+01	-18,300	-4,670	-5,400	-5,400	5,300	5,300
	55+01	60+01	-5,100	-1,300	-3,100	-3,100	4,900	4,900
T	60+01	65+01	400	100	-1,100	-1,100	6,400	6,400
F	65+01	70+00	5,900	1,500	1,500	1,500	500	500
F	70+00	75+01	12,300	3,140	2,000	2,000	-1,700	-1,700
T	75+01	80+01	16,400	4,180	-700	-700	-900	-900
	80+01	85+02	11,800	3,010	-3,800	-3,800	800	800
T	85+02	90+02	9,100	2,320	-200	-200	1,300	1,300
F	90+02	95+02	4,700	1,200	-1,600	-1,600	4,300	4,300
F	95+02	100+02	-800	-200	-2,100	-2,100	7,000	7,000
F	100+02	105+02	0	0	1,700	1,700	5,400	5,400
F	105+02	109+50	3,400	870	2,600	2,600	6,400	6,400
F	109+50	115+03	10,300	2,630	6,500	6,500	7,800	7,800
F	115+03	120+03	10,900	2,780	5,300	5,300	4,800	4,800
		Total	**-63,200**	**-16,130**	**-19,500**	**-19,500**	**5,100**	**5,100**

(1) Oak Island Beach Disposal Project (May-June 2018) @ 1.15 MCY

F - Fill Berm

T - Fill Taper

TABLE 6
MEASURED RATE OF CHANGE – STA 20 to STA 60

A. VOLUME CHANGE ABOVE -2 FT NGVD

Four Year Dec 14 – Nov 18	One Year Dec 14 – Dec 15	One Year Nov 18 – Nov 19
-21,900 cy/yr	-7,400 cy/yr	+4,600 cy/yr

B. VOLUME CHANGE ABOVE DEPTH OF CLOSURE

-29,600 cy/yr	-37,660 cy/yr	+37,000 cy/yr

C. MHWL CHANGE (AVERAGE FT/YR)

-14.8 ft/yr	-17.8 ft/yr	+5.1 ft/yr

TABLE 7
MEASURED RATE OF CHANGE – STA 20 to STA 120

A. VOLUME CHANGE ABOVE -2 FT NGVD

Four Year Dec 14 – Nov 18	One Year Dec 14 – Dec 15	One Year Nov 18 – Nov 19
+1,490 cy/yr	-10,000 cy/yr	+21,500 cy/yr

B. VOLUME CHANGE ABOVE DEPTH OF CLOSURE

-16,130 cy/yr	-19,500 cy/yr	+5,100 cy/yr

C. MHWL CHANGE (AVERAGE FT/YR)

-1.8 ft/yr	-17.2 ft/yr	-1.3 ft/yr

periods of analysis. As noted above, actual comparative beach profiles from which these data are derived are included as **Appendix C**.

SUMMARY AND FINDINGS

Pursuant to the terms of Permit No. 91-14 originally issued for purposes of construction of a terminal groin at Bald Head Island, N.C., monitoring of Oak Island by the permittee (Village of Bald Head Island) was to occur if the Village redredged in excess of 250,000 cy from a borrow site located on Jay Bird Shoals. In early 2019, the Village excavated some 1.2 Mcy from the JBS borrow site thereby triggering the requirement to monitor the easternmost end of Oak Island between baseline stations 20 and 120. This report presents the findings of Year-1 monitoring over the period November 2018 – November 2019.

The original precepts for both monitoring and mitigation (if determined to be relevant) were codified in an *Inlet Management Plan* made a part of Permit No. 91-14. Two events which had bearing on the results of the first year of monitoring were the occurrence of H. Florence in September 2018 and the completion of a 1.15 Mcy beach disposal project along the Oak Island shoreline between the months of May – June 2018. Similarly, H. Dorian in September 2019 affected the coastline of North Carolina resulting in varying (but lesser) degrees of shoreline erosion and recession in comparison to H. Florence.

The majority of the Monitoring Conditions and Triggers enumerated in the original *Inlet Management Plan* (see **Appendix A**), cannot be complied with because they related to baseline rates which were to be dictated by certain shoreline trends computed by the Wilmington District over 10-years of monitoring. Unfortunately, the linear trends last published by the District in 2011 (Report No. 8) were found to be meaningless for the use intended. That is to say, inspection of the data suggested that the reliance on a linear trend model to compute an annual rate of MHWL change did not accurately describe the data at each monitoring station. As an example, examination of the trend analyses (see **Appendix B**) indicates that the linear recession model approach for a long-term annual rate of shoreline change does not realistically describe the final position of the MHW shoreline after 10-years, or the significant variability in shoreline

change documented throughout the monitoring period. Further complicating this data-base was the fact that the federal monitoring program ended in 2010 – approximately 9 years ago.

Alternately, this report relies on other more modern survey data available for the period December 14 – June 16, as well as the surveys acquired for this report (Nov. 18 – Nov. 19). To that end, shoreline recession and volumetric "trends" for three (3) time periods have been selected: The four-year period Dec. 14 – Nov. 18, the one-year period Dec. 14 to Dec. 15 and the most recent survey period acquired for this report, i.e. Nov. 18 – Nov. 19. In addition, analyses have been performed for both the entire monitoring shorefront (Sta. 20 – Sta. 120) as well as the Fort Caswell parcel (Sta. 20 – Sta. 60). Those results, as presented by **Table 6** and **Table 7**, depict a one-year monitoring period, inclusive of the redredging of the Jay Bird Shoal borrow site. In no event were the MHWL changes or volumetric changes in excess of the two (2) historical periods considered. Volumetric analyses were carried out both above the -2 ft contour, as well as above the depth of closure – pursuant to the requirements of the *Inlet Management Plan.* By virtue of these Year-1 findings it is therefore concluded that the T.A.C. does not need to convene pursuant to the terms and conditions associated with DCM Permit No. 91-14.

APPENDIX A

Permit No. 91-14

(w/ *Inlet Management Plan*)

Permit Class
NEW

Permit Number
91-14

STATE OF NORTH CAROLINA
Department of Environment and Natural Resources
and
Coastal Resources Commission

Permit

for

X Major Development in an Area of Environmental Concern pursuant to NCGS 113A-118

X Excavation and/or filling pursuant to NCGS 113-229

Issued to **Village of Bald Head Island, PO Box 3009, Bald Head Island, NC 28461**

Authorizing development in Brunswick County at Atlantic Ocean and Bald Head Island, as requested in the permittee's application dated 7/31/14 (MP-1) and 1/2/14 (MP-2 and MP-4) and AEC Hazard Notice dated 3/19/14, including the attached workplan drawings (21), all as referenced in Condition No. 1 of this permit.

This permit, issued on **October 21, 2014**, is subject to compliance with the application (where consistent with the permit), all applicable regulations, special conditions and notes set forth below. Any violation of these terms may be subject to fines, imprisonment or civil action; or may cause the permit to be null and void.

1) Unless specifically altered herein, all development shall be carried out in accordance with the attached workplan drawings (21), 1-4, 7-17, 20, 21 of 21 dated 9/30/13, 5-6 of 21 dated revised 10/16/14 and 18-19 of 21 dated 10/18/13.

2) Unless specifically altered herein, this permit authorizes construction of the terminal groin structure and its associated development activities, all as expressly and specifically set forth in the attached permit application and workplan drawings. Any additional land development and/or construction activities may require a modification of this permit. Contact a Division of Coastal Management (DCM) representative at (910) 796-7215 for this determination.

(See attached sheets for Additional Conditions)

This permit action may be appealed by the permittee or other qualified persons within twenty (20) days of the issuing date.

This permit must be accessible on-site to Department personnel when the project is inspected for compliance.

Any maintenance work or project modification not covered hereunder requires further Division approval.

All work must cease when the permit expires on

December 31, 2017

In issuing this permit, the State of North Carolina agrees that your project is consistent with the North Carolina Coastal Management Program.

Signed by the authority of the Secretary of DENR and the Chairman of the Coastal Resources Commission.

Dough V Huggett
for
Braxton C. Davis, Director
Division of Coastal Management

This permit and its conditions are hereby accepted.

Cal Rul
Signature of Permittee

ADDITIONAL CONDITIONS

3) To the extent any condition of this permit alters the proposed project, including mitigation and monitoring requirements, in such a manner so as to increase the estimated cost of the project over that for which a financial assurance package was prepared by the permittee and certified by the Department of Environment and Natural Resources (DENR), a modified financial assurance package shall be prepared and approved by DENR prior to project initiation.

4) In order to protect threatened and endangered species and to minimize adverse impacts to offshore, nearshore, intertidal and beach resources, should development seaward of the first line of stable natural vegetation occur from April 1 to November 15 of any year, the permittee shall implement the mitigative measures outlined in the Final Environmental Impact Statement (FEIS) and Biological Opinion (BO) that was prepared for this project.

NOTE: The permittee is advised that there may be additional timing restrictions placed on the authorized project by the U.S. Army Corps of Engineers (USACE) as part of the Federal permitting process. Nothing in this State Permit should be construed as overriding or superseding any such Federal permit requirement.

Staging

5) Land-based equipment necessary for implementation of the permitted activities shall be brought to the site through existing accesses. Should the work result in any damage to existing accesses, the accesses shall be restored to pre-project conditions immediately upon project completion in that specific area.

NOTE: The permittee is advised that any new access sites may require a modification of this permit.

6) All materials, including stones and construction mats, shall be staged above Mean High Water, and landward of the dunes when possible.

Terminal Groin Construction

7) Construction of the terminal groin shall take place entirely within the areas indicated on the attached workplan drawings, unless additional authorizations for an expanded footprint or alternate alignment are first obtained from the DCM.

8) Material used for the construction of the terminal groin shall be free from loose dirt or any other pollutant in other than non-harmful quantities, and be of a size sufficient to prevent its movement from the approved alignment by wave and current action.

9) The terminal groin shall not exceed a length of 1,900 feet.

10) In accordance with commitments made in the attached permit application and workplan drawings by the permittee, the terminal groin shall be constructed in a manner to allow the bypassing of sand through and over the structure.

11) Any post-construction tuning associated with the terminal groin shall be coordinated with the DCM, in consultation with the appropriate permit and resource agencies. Such tuning activities may require a modification of this CAMA Permit.

ADDITIONAL CONDITIONS

12) In accordance with commitments made by the permittee in the project narrative, a Notice to Proceed (NTP) for the Phase II extension of the terminal groin shall be submitted to and approved by the DCM and appropriate resource agencies and stakeholders. The Phase II Extension shall be subject to all the conditions of this permit.

Sand Fillet

13) The permittee has indicated that sand placed on the beach as part of the USACE maintenance dredging of the Wilmington Harbor navigation channel is the preferred source of beach quality sand material for the initial pre-filling of the terminal groin, which shall take place concurrent with the construction of the terminal groin. However, should the timing of the USACE project or the quantity of material available not meet the needs of the terminal groin construction schedule, additional authorization shall be obtained from the DCM prior to excavating sand from any other source, including the Jay Bird Shoals borrow site source.

14) In accordance with commitments made in the inlet management plan dated 10/6/14 by the permittee, prior to utilizing Jay Bird Shoals as a borrow area, to the maximum extent practicable, the permittee shall first consider utilizing sand from a non-Jay Bird Shoals location, such as the Bald Head reaches of the federal navigation channel, and if necessary, paying the additional costs to dredge the Bald Head reaches to the fully authorized depth and width and/or placing material in a different location.

NOTE: If the permittee requests authorization to use Jay Bird Shoals as a borrow source, as outlined in Conditions No. 12 and 13 of this permit, any such use which is authorized under this permit will be limited to a one (1) time use of the borrow site source. Any future use of the borrow area shall require additional permit modification.

15) The seaward sand fillet limit shall be constructed in accordance with the attached work plan drawings.

16) In order to prevent leakage, dredge pipes shall be routinely inspected. If leakage is found and repairs cannot be made immediately, pumping of material shall stop until such leaks are fixed.

Construction Trestle

17) All portions of the proposed construction trestle shall be removed in its entirety after project completion.

18) No portion of the construction trestle shall be left in place between the construction of Phase I and Phase II of the terminal groin.

19) The construction trestle shall be placed in the alignment as depicted on the attached workplan drawings.

Inlet Management Plan - Mitigation and Monitoring

20) Unless specifically altered herein, the permittee shall implement, at its expense, all mitigation and monitoring commitments made in, or submitted with, the permit application, the Inlet Management Plan dated 10/6/14, or the FEIS.

ADDITIONAL CONDITIONS

21) In accordance with commitments made in the inlet management plan dated 10/6/14 by the permittee, within 30 days of completion of the terminal groin and concurrent beach fill project, the applicant shall survey the Mean High Water Line, including the updated transects on the Village of Bald Head Island, as shown on Figure 2 of the Inlet Management Plan, from Station 00+00 to 75+00. The survey activities shall continue at 6-month intervals until such time as the DCM agrees in writing that additional survey activities are no longer necessary.

22) In the event the permittee receives a modification to dredge more than 250,000 cubic yards of material from the Jay Bird Shoals Borrow Site source ("Project"), the following provisions shall become effective:

a. A three (3) member Technical Advisory Committee (TAC) shall be formed no less than ninety (90) days following any permit application (by permit modification or otherwise) for approval of the Project. Additionally, the TAC shall be formed prior to the initiation of the removal of material from Jay Bird Shoals. The TAC shall consist of three (3) North Carolina licensed Professional Engineers meeting the qualifications set forth in the inlet management plan dated 10/6/14. One shall be chosen collectively by the Oak Island parties of Town of Caswell Beach, Town of Oak Island and Fort Caswell, one shall be chosen by the permittee, and one shall be selected jointly by the engineers chosen and shall be subject to approval by the DCM. The permittee shall be responsible for all reasonable costs associated with the formation and operation of the TAC.

b. The permittee shall;

i. Monitor and analyze the shoreline of Oak Island from Station 120 to Station 20, which defines the "Oak Island Monitoring Area", to determine an annual profile by profile shoreline change rate;

ii. Monitor and analyze an annual profile by profile volume change rate out to (a) -2 ft NGVD and (b) -20 NGVD;

iii. Monitor and analyze an annual updated trend rate for both shoreline and volume change rate for each profile;

iv. Monitoring shall continue for a minimum of 9 years subsequent to the utilization of Jay Bird Shoals Borrow source. If, after this 9-year period, the profile by profile volume and change rates have not exceeded 25% or more, and the TAC determines additional monitoring and/or mitigation is not necessary, the permittee may discontinue such monitoring provided that the permittee shall obtain written approval from the DCM before discontinuing the monitoring; and

v. Provide annual reports to the TAC and the DCM detailing the findings of each monitoring effort outlined in items i through iv of this condition.

23) Should the TAC determine that the utilization of the Jay Bird Shoals borrow site caused or contributed to additional erosion or a reduction in accretion along the Oak Island Monitoring Area, in accordance with the inlet management plan dated 10/6/14 the permittee shall mitigate by direct sand placement the damage proportionate to the impact determined by the TAC to have resulted. This direct sand placement shall not utilize sand previously scheduled to be placed on Oak Island as part of the Wilmington Harbor Sand Management Plan.

ADDITIONAL CONDITIONS

24) The DCM may order the modification or removal of the terminal groin structure upon finding that any negative impacts associated with the terminal groin structure outweigh the protective value of the structure. Upon such order, and in compliance with the time frames in the order, the permittee agrees to modify or to remove the terminal groin as in accordance with the order, potentially including up to removal in its entirety including all portions of the structure below grade.

25) In accordance with commitments made by the permittee in the project narrative, any existing individual sand tube groin determined by the permittee, in consultation with the DCM, to be non-essential or counterproductive to terminal groin performance, shall be removed or modified. Modification of the sand tube groin field may require additional authorization.

26) If erosion at "West Beach" reaches its historical worst case condition, or is projected to reach such a condition within six (6) months, and the erosion is determined to be caused by the construction of the terminal groin, the permittee shall implement mitigation measures as proposed in the Inlet Management Plan.

NOTE: Additional authorization from the DCM, as well as other resource agencies, may be required for any proposed mitigation.

27) Should the permittee utilize as a sand source material from Jay Bird Shoals or Bald Head Creek, the applicant shall implement additional consultation with the DCM, in coordination with appropriate resource agencies, to determine necessary monitoring requirements for the borrow area.

28) All monitoring and reporting requirements shall continue until written authorization to terminate the monitoring and reporting is obtained from the DCM.

Sedimentation and Erosion Control

NOTE: An Erosion and Sedimentation Control Plan may be required for this project. This plan must be filed at least thirty (30) days prior to the beginning of any land disturbing activity. Submit this plan to the Department of Environment and Natural Resources, Division of Energy, Mineral and Land Resources, 127 Cardinal Drive Extension, Wilmington, NC 28405.

Cultural Resource Protection

29) There exists the possibility that authorized activities may unearth a beached shipwreck or other archaeological resources. Should such a finding occur, the permittee shall immediately stop work and initiate consultation with the DCM and the NC Department of Cultural Resources (DCR). The Permittee shall also immediately contact the DCR Underwater Archaeology Branch at (910) 458-9042, to determine any appropriate response procedures.

30) In order to protect cultural and historic resources, and in keeping with commitments made by the permittee, the permittee shall, as shown on the attached workplan drawings labeled 3 of 21, maintain a 150-foot buffer surrounding the located shipwreck.

ADDITIONAL CONDITIONS

31) The permittee shall comply with the established cultural resources exclusion zone in the Jay Bird Shoals borrow area.

General

32) No sand shall be placed on any sand bags that have been determined by the DCM to be subject to removal under 15A NCAC 07H .0308(a)(2). In order to ensure compliance with this condition, the DCM shall be contacted at (910) 796-7215 prior to project initiation to allow the DCM to meet on site with the permittee and/or contractor.

NOTE: The permittee is advised that the DCM regulates the removal of existing sandbags and the placement of new sandbags in accordance with 15A NCAC 07H .0308(a)(2)(F), or in accordance with any variances granted by the N.C. Coastal Resources Commission.

33) Dune disturbance shall be allowed only to the extent necessary for development and provided that the dune's protective value is not weakened or reduced. All disturbed areas shall be immediately stabilized with vegetation.

34) Prior to the initiation of any beach nourishment activity above the mean high water contour (MHW) within the limits of the project area, easements or similar legal instruments shall be obtained from all affected property owners.

35) Dredging within Frying Pan Shoals is not authorized by this permit.

36) The permittee and contractor shall schedule a pre-construction conference with the DCM prior to the initiation of each phase authorized by this permit.

37) This permit is not assignable, transferable, or otherwise alienable without the prior written approval of the DCM.

NOTE: The permittee's contractor is advised to contact the U.S. Coast Guard at (910) 815-4895, ext. 108 to discuss operations and appropriate lighting, markers, etc. for all structures located below Mean High Water.

NOTE: This permit does not eliminate the need to obtain any additional state, federal or local permits, approvals or authorizations that may be required, including but not limited to an Individual Permit from the USACE.

NOTE: Future development of the permittee's property may require a modification of this permit. Contact a representative of the DCM at (910) 796-7215 prior to the commencement of any such activity for this determination by the DCM.

NOTE: The N.C. Division of Water Resources (DWR) has authorized the proposed project under DWR Project No. 12-0288.

NOTE: The USACE has assigned the proposed project COE Action Id. No. SAW 2014-00661.

6 October 2014

VILLAGE OF BALD HEAD ISLAND, NC
TERMINAL GROIN PROJECT

INLET MANAGEMENT PLAN

I. SETTING

In order to comply with the requirements of SB110 (as subsequently amended by SB151), an applicant for a permit to construct a terminal groin must formulate a plan for the "management of the inlet and the estuarine and ocean shorelines immediately adjacent to and under the influence of the inlet. The inlet management plan monitoring and mitigation requirements must be reasonable and not impose requirements whose costs outweigh the benefits. The inlet management plan is not required to address sea level rise. The inlet management plan shall do all of the following relative to the terminal groin and its accompanying beach fill project:

a. Describe the post-construction activities that the applicant will undertake to monitor the impacts on coastal resources.

b. Define the baseline for assessing any adverse impacts and the thresholds for when the adverse impacts must be mitigated.

c. Provide for mitigation measures to be implemented if adverse impacts reach the thresholds defined in the plan.

d. Provide for modification or removal of the terminal groin, if the adverse impacts cannot be mitigated." G.S. § 113A-115.1(e)(5).

On Bald Head Island, the section of shorefront subject to continuing monitoring and impact analysis as a downdrift shoreline potentially subject to structure induced damage and resulting mitigation is West Beach. On the Oak Island side of the inlet and exclusively in the event that the Village uses Jay Bird Shoals as a future borrow area for a Village project to dredge a quantity of dredged material greater than 250,000 cubic yards, the section of shorefront subject to similar project related monitoring is the Fort Caswell and Caswell Beach estuarine and oceanfront shoreline from Station 120 to Station 20. The Fort Caswell shoreline is under the influence of the inlet – but outside the limits of sand disposal routinely performed by the Wilmington District, USACOE at Oak Island.

Inlet management plan formulation will be significantly different for an inlet improved for commercial navigation versus one which is in a relatively unimproved condition or which provides only for recreational navigation. Also influencing various potential management precepts is the size of the inlet, its history and any associated sand disposal operation(s) which presently benefits one, or both, of the abutting coastal barrier shorelines. That is to say, beneficial inlet management must involve multiple considerations. Such is the case with the entrance to the Cape Fear River where a proactive Sand Management Plan has been in effect for over a decade. The subject Wilmington Harbor Sand Management Plan ("WHSMP") is implemented by the Wilmington District, United States Army Corps of Engineers ("USACOE" or "Corps") during routine maintenance of the innermost three (3) segments of the Ocean Entrance Channel (Smith Island Reach and Bald Head Reaches 1 and 2) which comprise a portion of the Wilmington Harbor Navigation Project.

Until 1999, the Wilmington Harbor navigation project had historically not included the disposal of littoral sand on the adjacent beaches, or in the active littoral zone. This had been primarily due to the maintenance practices that were established with the inception of the project in the late 1800's. As a result, standard practice for maintaining the ocean entrance channel segments of the project was offshore disposal in water depths of 30 feet or more.

With the last harbor deepening project and coincident reorientation of the ocean entrance channel, the Wilmington District established a new standard for the disposal of littoral sediment. From an engineering perspective, a purpose of the Wilmington Harbor maintenance program was to avoid or mitigate potential erosion of the adjacent beaches by conserving the limited natural resource, sand, through deposition directly on the adjacent coastal barrier beaches.

Pursuant to the adopted Plan, the initial ratio of distribution of littoral sand excavated during routine maintenance operations between Bald Head Island and East Oak Island – Caswell Beach was proposed by the District in the ratio of two-thirds to one-third, respectively. The WHSMP was initiated as part of the first maintenance project following initial improvements of the deepening project. Beach quality sand originating from project widening, deepening and channel reconfiguration was likewise distributed between the two islands with sand being placed on Oak Island, as far westward as Holden Beach. It did not however include the Fort Caswell oceanfront shoreline. In addition, the N.C. Beach and Inlet Management Plan ("BIMP") established for Region 1 – Brunswick County, specifically earmarks the use of Jay Bird Shoals

and Middle Ground at the Cape Fear River Entrance as borrow areas for Region 1 shore stabilization projects – and in particular for Bald Head Island given its proximity to the two depositional features. The latter are predominately comprised of beach quality material.

The Cape Fear River Entrance is a historically federally improved tidal inlet which includes a deep draft commercial navigation project channel authorized by Congress intended to serve the Port of Wilmington Harbor, N.C. Both the inlet's interior flood shoals, the exterior ebb shoals, as well as portions of the navigation channel which are subject to shoaling with beach quality sand, all serve as potential sand sources necessary to meet the performance requirements of SB110 (as amended) regarding terminal groin mitigation – as well as supplemental beach fill necessary to prefill a terminal groin. Depending upon the timing of groin construction, the regularly scheduled disposal of large quantities of high quality sand (typically 1 Mcy per event, or more) associated with the WHSMP offers the opportunity for the applicant for a terminal groin permit to strategically schedule groin implementation in such a manner so as to utilize beach disposal sand to meet, or at least supplement the initial beach fill requirements of the enabling terminal groin legislation. This would not however, obviate potential alternate sand source requirements associated with long-term updrift fillet maintenance, downdrift mitigation at West Beach, etc.

II. PHYSICAL MONITORING PLAN

A. Existing Monitoring Programs

The Village of Bald Head Island, NC ("Village") has performed comprehensive beach monitoring of South Beach, the Point and West Beach since 1999. Prior to that date, less formal surveys of the "dry" beach (only) were also accomplished at varying dates in time. In 2008, East Beach was added to the current Village monitoring plan. In 1999, the Wilmington District USACOE likewise initiated physical monitoring of Oak Island and Bald Head Island shorelines – prior to the construction of the last authorized channel deepening project. Elements of the present day federal survey program under the WHSMP have also included portions of the ebb shoal delta as well as annual condition surveys within the federal navigation project. Borrow sites have likewise been monitored by the Village for a minimum period of 3 years after any non-federally sponsored dredging project required for shore protection. Borrow site monitoring typically includes both physical and biological surveys.

A detailed Island-wide Monitoring Report is issued annually by the coastal engineering firm Olsen Associates, Inc., on behalf of the Village, which generally addresses:

1. Recent volume and shoreline position changes measured over the prior twelve (12) months.
2. Comparisons of existing and long-term conditions relative to pre-fill conditions documented since November 2000 by annual surveys.
3. Discussions of the performance of each last major sand placement project, (federal as well as non-federal).
4. Recent navigation channel changes including those at/or abutting the Point – an area of chronic shoaling and highly dynamic shoreline change.
5. Commentary regarding borrow site recovery (physical and biological) for three years following each Village sponsored dredging contract.

Long-term average annual shoreline change rates (1938-2000) for Oak Island/Caswell Beach portray, for the most part, a highly erosional condition, averaging slightly less than -5ft./yr. of recession. Conversely, during the same period of time the extreme easternmost end of the island near the inlet was determined to be increasingly accretional.

Both the ongoing (2000 - present) beach monitoring plans for Oak Island and Bald Head Island being implemented by the Village and the Wilmington District, quantitatively well-describe shoreline changes along both shorefronts. On Oak Island, all of the shorefront subject to episodic beach disposal from the channel is highly improved – relative to its pre-project condition. One exception (where disposal sand placement does *not* occur because of lack of public access) is at Fort Caswell where a section of oceanfront shoreline has experienced a documented persistent erosional hot spot since 1996. At that location, published average annual shoreline erosion "trend rates" between August 2000 and September 2010 have ranged between -4.5 ft/yr. and -8.8 ft/yr. Localized computed annual shoreline change rates at survey profiles 35 and 40, however, have been as high as -90 ft/yr and -200 ft/yr, respectively.

On Bald Head Island, shoreline conditions are much more spatially variable relative to the 1999 baseline survey condition. As expected however, the highest rates of documented shoreline change at any one time occur along the western end of South Beach nearest the inlet. Additionally, Bald Head Island has experienced more frequent sand placement from not only the navigation project pursuant to the WHSMP, but also from two (2) borrow sites – located at the

entrance to Bald Head Creek to the north, and Jay Bird Shoals to the south. Ongoing erosion experienced on West Beach has likewise necessitated sand placements in 2006, 2009, 2012 and 2013.

B. Plan Purpose

The monitoring plan discussed herein is intended to meet the requirements of State and Federal law addressing a.) beach restoration activities on Bald Head Island including borrow site creation, as well as b.) permits for a terminal groin structure proposed for construction at the western end of South Beach – along with any attendant borrow site excavation (as necessary) and resultant sand fill(s). The plan is likewise intended to be reasonable and cost-effective as provided by the enabling legislation (G.S. 113A-115.1(e)(5)).

Specific elements of new work associated with the monitoring of the terminal groin will be directed toward the identification of – and quantification of – any detrimental project related downdrift changes to West Beach which could potentially warrant mitigation. Interpretation of post-construction surveys will be influenced by historical data detailing ongoing erosional trends at these two locations. For example, documented beach erosion at West Beach over the last decade (in the absence of the terminal structure) has necessitated several protective sand fills at that location, with the most recent event occurring in early 2013. The latter occurred as part of a federal maintenance dredging operation with sand disposal totaling 1.8 Mcy placed at Bald Head Island. Hence, an important component of the expanded monitoring program will be to not only evaluate structure performance, but also to discern any differences in downdrift erosion that could be associated with the construction of a terminal groin – and that warrant near term attention by the Village or which can be addressed by a reliably scheduled pending federal disposal operation.

Additionally, the Village as Applicant for a terminal groin is charged with preparing a plan for the management of the inlet and the estuarine and ocean shorelines *immediately adjacent to and under the influence of the inlet*. The Division of Coastal Management ("DCM") has taken the position that, despite the presence of the approximately two (2) mile distance between islands, the spatial extent of the intervening ebb tidal shoal formations represented by Middle Ground and Jay Bird shoals, the intervening impacts of Western Channel and an episodically dredged navigation channel, some monitoring is required at the easternmost end of Oak Island. The shoreline immediately adjacent to and under the influence of the inlet includes portions of

the oceanfront and estuarine shorefront of Fort Caswell and Caswell Beach. Both the historical database and ongoing comprehensive beach monitoring program being implemented by the Wilmington District at Oak Island more than adequately meet the requirement for monitoring. Redundant surveying by the Applicant would therefore be both unreasonable and not cost-effective.

C. Beach Surveys

i. Bald Head Island

For purposes of documenting both future beach disposal and terminal groin project performance and shoreline change, The Village will continue to perform comprehensive annual beach monitoring as carried out over the past thirteen (13) years at Bald Head Island. The survey baseline for this work is depicted by **Figure 1**. Profiles are surveyed twice annually (seasonally) on approximately 400-ft. intervals. Profiles generally extend some 2400-ft. or more offshore and include the depth of closure for natural beach conditions – except where intersected by the federal navigation channel, or a major shoal feature. All surveys are performed by a certified hydrographic surveyor registered in the State of North Carolina.

Several additional profile lines will be added to the existing survey program in the vicinity of the terminal structure (see **Figure 2**). In addition, the project surveyor will be required to annually perform an approximate MHWL survey between Station 0+00 and 75+00 (see **Figure 3**). Each survey will be compared to prior surveys and utilized for trend analysis. Digitally controlled aerial photography taken at approximate 6-month intervals will likewise be used to supplement analysis of the post-terminal groin shoreline condition.

The first post-construction MHWL survey will be performed within 30 days of the completion of the proposed terminal groin and updrift beach fill, thereby documenting the as-built shoreline condition. The entire island-wide monitoring surveys will be performed on a six-month basis at the same approximate time as previous seasonal survey program addressed by the existing (pre-terminal groin) comprehensive island-wide beach monitoring program.

ii. Oak Island

For approximately the past 12 years, the Wilmington District, USACOE has performed comprehensive physical monitoring which included both the Oak Island and Bald Head Island shorelines. The purpose of this program has been to examine the response of adjacent beaches, entrance channel shoaling patterns and the ebb tidal delta to the Wilmington Harbor channel

deepening and realignment project. As a result, a comprehensive survey data base has been developed which portrays shoreline changes at both locations for over a decade. Other sources of shoreline location and change are also available. For purposes of assessing post-construction oceanfront shoreline conditions on the eastern end of Oak Island, the Village's coastal engineering consultant will utilize publicly available survey data acquired by the Wilmington District, USACOE (see **Figure 4**). Similarly, the consultant shall access and utilize relevant federal aerial photography of the Oak Island area of interest, including historical photography.

Exclusively in the event the Village uses Jay Bird Shoals as a future borrow site area for a Village project to dredge a quantity of dredged material greater than 250,000 cubic yards ("cy"), the following conditions shall apply:

Priority. Prior to utilizing Jay Bird Shoals as a borrow area, to the maximum extent practicable, VILLAGE shall first consider utilizing sand from a non-Jay Bird Shoals location, such as the Bald Head reaches of the federal navigation channel, if necessary, paying the additional costs to (i) dredge the Bald Head reaches to fully-authorized depth and width and/or (ii) placing the dredged material in a different location.

Monitoring Location. Village shall monitor and analyze the shoreline of Oak Island utilizing all Corps profiles from Station 120 on oceanfront shoreline to Station 20 on the estuarine shoreline (the "Oak Island Monitoring Area"). Village may utilize survey data acquired by the Corps. Survey data shall be collected at least once annually by either the Corps or Village. Village shall also obtain and utilize relevant federal aerial photography of the Oak Island Monitoring Area.

Monitoring Duration. Village's obligation to monitor the Oak Island Monitoring Area and analyze the data for purposes of assessing potential impacts associated with the use of Jay Bird Shoals as a borrow area, shall commence once Village utilizes Jay Bird Shoals as a borrow area. Village's responsibility for monitoring the Oak Island Monitoring Area and analysis of the post-borrow area data shall terminate if nine (9) years of monitoring subsequent to utilization of Jay Bird Shoals as a borrow area fails to indicate that any triggers are met and the Technical Advisory Committee (below discussed) determines that mitigation is not required.

D. Borrow Site Monitoring Surveys

The existing permitted borrow area located on Jay Bird Shoals was surveyed both immediately prior to and after construction of the 09/10 Village sponsored 1.8 Mcy beach

restoration project (see **Figure 5**). Subsequent surveys are being performed at 12-, 24- and 36-months and biennially thereafter. The area surveyed includes a minimum of 500-ft. of coverage outside the permit limits of the borrow site. The survey is performed by single beam sonar on a density line spacing of 100-ft. Due to shallow water portions of Jay Bird Shoal northward of the borrow area, up to 72-acres of shallow seabed may need to be surveyed by non-sonar methods. In this area the surveyor may use single beam sonar on a shallow draft boat, or wading profiles at low tide using RTKGPS. A100-ft. grid spacing will continue to be maintained at this location, irrespective of methodology required. Subsequent to a Post-Irene emergency dredging project at South and West Beach constructed in 2011/12, a Bald Head Creek borrow site is subject to annual surveys beginning in January 2013 (see **Figure 5**). The project fill volume was 120,000 cy.

Permitted borrow sites utilized for locally funded sand placement operations at Bald Head Island shall be monitored in accordance with the Permit Condition associated with each project. Subsequent to sand placements required by the construction of the terminal groin based upon the borrowing of sand from within the remaining (1.5 Mcy+) unexcavated (permitted) portion of the Jay Bird Shoal borrow site; the northward expansion of the borrow site at the entrance to Bald Head Creek; the Smith Island Range of the federal navigation channel, or any other permitted site, annual monitoring of that site shall be performed -- pursuant to the terms of the associated Permit(s), unless being monitored by another agency. Monitoring results shall be addressed in each subsequent Village annual monitoring report.

E. Hydrographic Survey Standards

In general, the following will apply to *all* surveys:

- Surveys will be performed to meet or exceed the Minimum Performance Standards for the USACOE Hydrographic Surveys. Specifications manual EM 1110-2-1003, January 2002 (or its successor).
- All data will be corrected for tide and heave.
- The survey vessel will be positioned using RTKGPS. Soundings will be in feet and 10th's.
- Vertical Datum will be local NGVD29.
- Horizontal Datum will be NC NAD83.

F. Aerial Photography

The Village of Bald Head Island will continue to perform controlled (color) rectified digital aerial photography of the island shoreline(s) twice a year – usually coincident with the timing of each seasonal beach survey. The present minimum areas of coverage are the West Beach, South Beach and East Beach shorelines. Oblique low altitude photography is likewise performed periodically as required to document the occurrences of any storm, or man-made event of interest. Any repair of the sand tube groinfield is likewise documented by ground level digital photography.

G. Reporting

A comprehensive report-of-findings at Bald Head Island will continue to be issued annually which presents, analyses and discusses all data acquired over the prior twelve (12) month period. Of particular interest will be beach and borrow site changes which occur over time and any potential effects downdrift of the proposed terminal structure. Each report will likewise discuss, consider and compare the relevant portions of the historical database as it relates to the most current survey(s).

All patterns of erosion, accretion or shoaling will be documented, quantified and graphically depicted. For any project borrow site, map differencing will be performed annually (and cumulatively over time) for purposes of visually demonstrating spatially occurring changes in elevations due to shoaling. For the Point and West Beach downdrift shorelines, comparative MHWL and aerial mapping will be presented subsequent to terminal groin construction along with volumetric analyses currently being computed every 6 months.

The Village consultant will maintain and expand the present day comprehensive monitoring report format and deliverables to include specific Sections which specifically address borrow site construction and all subsequent changes over time, as well as terminal groin and sand fillet performance and downdrift (post-structure) shoreline history, on Bald Head Island

H. Deliverables

Each Annual Monitoring Report will be delivered to the Village of Bald Head Island, off-island Stakeholders and all relevant State or Federal regulatory agencies within 90-days of completion and acceptance by the Village consultant (i.e., after QA/QC) of the last survey performed for the reporting period of interest. Additionally, digital data acquired or addressed by each Annual Report can be transferred to an Agency or Stakeholder, upon request.

III. MITIGATION THRESHOLDS

A. Baselines for Evaluation

Both the West Beach downdrift shoreline and the cross-inlet Oak Island oceanfront shoreline immediately adjacent to and under the influence of the inlet have over 12 years' worth of post-deepening (1999-present) survey data sufficient to document present day shorefront conditions. Most data take the form of cross-shore profiling at intervals sufficient to document volumetric change and contour location along the shorefront of interest. Supplementary aerial photography is likewise available to assist with the interpretation of survey data on Bald Head Island.

The post-1999 survey data are considered most relevant due to associated changes in navigation project dimensions, corresponding episodic dredging operations within the entrance channel storm events and, most importantly, the equilibration of multiple beach disposal projects intended to improve shoreline conditions on both barrier islands. Interpretation of the latter phenomena will be extremely important since the temporal variation in shoreline change (volume and location) – after a beach fill – is typically significant. Segments of both Oak Island and Bald Head Island have received, and will continue to receive, large scale beach disposal projects (often exceeding 1 Mcy per event) in accordance with the Wilmington Harbor Sand Management Plan (WHSMP).

B. Impact Determination – West Beach (Bald Head Island) (Sta 0+00 to Sta 24+00)

Both West Beach and the depositional spit feature known as the Point lie downdrift of the terminal structure proposed for construction at the westernmost limit of South Beach. As a result, both are subject to change as the downdrift shorefront seeks a post-structure equilibrium condition. Currently, it is expected (and supported by in-depth modeling) that a portion of the West Beach shorefront will potentially require beach disposal on a 3-year basis – *with or without* terminal structure implementation. The principal borrow source for interim small scale sand placement at that location (if necessary) will be the expanded Bald Head Creek borrow site. The assignment of "impact" on West Beach due to a terminal structure will therefore need to weigh the following site specific factors potentially affecting shoreline conditions downdrift of the groin:

- Interval between sand placement projects?
- Have average annual shoreline recession rates (volumes and MHWL location) increased by over 50%? Has beach fill equilibration been accounted for? Is the duneline being impacted?
- Can a documented cause and effect relationship be assigned to downdrift shoreline reconfiguration, or is any newly developed "hot spot" isolated and therefore not the result of a quantifiable trend?
- Do numerical modeling results support or refute the observed shoreline erosion trends?
- Can extraordinary meteorological conditions be defined as a cause of accelerated erosion?
- Have navigation channel maintenance operations changed in frequency or scope

C. Baseline for Action – West Beach, Bald Head Island

The baseline for action along West Beach (Station 0+00 – Station 24+00 by definition) shall be determined by analysis of historical surveys along this reach acquired on almost a 6-month basis since 2000. Over this 14 year period, either the Village or the Corps have placed sand when the limit of erosion reached "critical" condition portions – in most cases where the limit of erosion was located at/or within the primary dune. All such landward limits of erosion locations are well documented by survey. Hence, the "baseline" for remedial actions by the Village along West Beach is the point at which the limit of upland erosion reaches its historical worst case condition – as documented by survey since 2000 – or is projected to reach such a condition in the next 6 months. In no event shall the terminal groin be deemed responsible for any impacts or shoreline change from storms or other natural phenomena; including, without limitation, the influences of the adjacent shipping channel, channel maintenance dredging, federal beach disposal design, or any delay or absence of sand placement from channel maintenance dredging.

D. Impact Determination and Baseline for Action – Oak Island (Fort Caswell and Caswell Beach)

In depth numerical modeling analyses of Oak Island predict *no quantifiable impact* to littoral transport patterns or rates and associated shoreline change at that location due to either

terminal groin construction or the continued use of the Jay Bird Shoal borrow area (to the limits of excavation permitted in 2008). The latter sand source was only partially dredged by the Village in 09/10, however all modeling analyses (including the most recent DELFT 3D model) have assumed the borrow area has been excavated in its entirety. Similarly, the model predicts no changes in inlet hydrodynamics of significance to any stakeholder, be they federal or non-federal. Historical shoreline documentation included in the first USACOE physical monitoring report required for the deepening of the Wilmington Harbor Navigation Project depicted a strong trend of accretion for both the oceanfront and inlet facing shorelines located on the easternmost mile of Oak Island – for the period 1933 - 1983. Most of that segment is located within the privately held Fort Caswell parcel. Between 1983 and 1996, the same COE report documents a general trend of recession along the Fort oceanfront (E-W) shorefront and continuing modest accretion along the majority of the inlet facing (N-S) shoreline. Subsequently, the Corps likewise has documented (by survey) Post-Harbor Deepening annualized shoreline change rates of -90 and -200 ft/yr at survey profiles 35 and 40, respectively – for the survey period 2000 – 2010. Those profiles extend seaward of the Fort Caswell oceanfront shoreline.

The most recent, *published* USACOE survey monitoring data for Oak Island (through 2010) indicates a near term general trend of beach stability (after two disposal projects) on Oak Island with very modest average annual sediment losses. The littoral transport processes supporting such a condition are corroborated by the DELFT3D model. One *exception* to the measured trend is at Corps baseline monitoring Stations 35 and 40 where the above discussed localized "hot spot" clearly continues to be in existence. Both back-beach and dune erosion at this location have been of recent concern to local interests associated with the Fort Caswell property. The latter shoreline is outside the limits of sand placement from navigation channel maintenance. It is likewise adjacent to a large scale marginal flood channel. Both the lack of direct beach disposal and the effects of the marginal flood channel can be considered to be two of several contributors to the present day erosional hot spot. **Table 1** provides a summary of historical data for Sta 60 to Sta 30 – a non-nourished segment of shorefront in proximity to the inlet.

The comprehensive DELFT3D modeling performed on behalf of the Applicant demonstrates *no level of potential impact on any segment of Oak Island shoreline*. .

Exclusively in the event the Village uses Jay Bird Shoals as a future borrow site area for a Village project to dredge a quantity of dredged material greater than 250,000 cy, the following conditions shall apply:

Baseline. Survey data collected by the Corps from 2000 to present will be used to establish baseline conditions as well as determine past storm and beach fill effects for use in the assessment data when triggers are potentially exceeded. Survey data prior to 2000 also may be used.

Triggers. Survey data from the Oak Island Monitoring Area shall be analyzed annually by Village. Village shall determine (i) an annual profile-by-profile shoreline change rate, (ii) an annual profile-by-profile volume change rate out to (a) -2 ft NGVD and (b) -20 ft NGVD, (iii) and an updated trend rate for both shoreline and volume change rate for each profile. If annual computed shoreline recession or volume change rates exceed the baseline rates by 25%, or more, the Technical Advisory Committee ("TAC") shall be requested to evaluate and determine the source of the additional erosion or reduction in accretion.

Data. The Village shall deliver annually to DCM, upon formation of the TAC, a report of its findings and results. Unless otherwise provided to the Oak Island Parties by the Corps, Village shall provide the Oak Island Parties the survey data, the monitoring results, and the analytical results for the Oak Island Monitoring Area within sixty (60) days of their availability.

TAC. The TAC shall be formally established within ninety (90) days following any permit application (by permit modification or otherwise) for approval of a specific project by Village to dredge a quantity of dredged material greater than 250,000 cy from Jay Bird Shoals. The TAC shall be comprised of three (3) North Carolina-licensed professional engineers with substantial experience and employment experience in coastal engineering, consisting of one representing Village, one representing the Oak Island Stakeholders (the towns of Caswell Beach, Oak Island and Fort Caswell) and one coastal engineer selected by the other two (2) engineers (three (3) total coastal engineers on TAC).

In evaluating whether the utilization of Jay Bird Shoals as a borrow area caused or contributed to the additional erosion or reduction in accretion, the TAC shall evaluate, without limitation, the following factors: comparisons of historic and present shoreline and volume conditions; beach disposal events or delay thereof; and storms or other natural events.

IV. MITIGATION

A. West Beach

The highest priority for any required mitigation on West Beach would be alongshore sand placement sufficient to protect endangered residential structures and the total loss of protective dune formations. It is probable however that the timing of an expeditious (and sizeable) sand placement project may be adversely affected by other factors such as design document formulation, dredge availability, and public project bid requirements. As a result, the following interim actions may likewise need to be considered: (1) sand bag revetment construction along the section of shorefront where threatened structures exist, (2) temporary borrowing of sand mechanically from the updrift impoundment fillet of the terminal groin – with placement along the chronically eroded shorefront, or (3) both actions.

Coincident with any level of remedial action should be consideration of structure modification. In most instances, such an action would consist of rock removal from the structure crest sufficient to increase its transmissivity to sand transport. That is to say, its permeability (or "leakiness") would be increased. Such an action would *not* be expected to result in immediate benefits. Hence, it should be considered to be a secondary response in the hierarchy of remedial actions, as noted above, and as discussed in Section V.

B. Oak Island – Fort Caswell and Caswell Beach

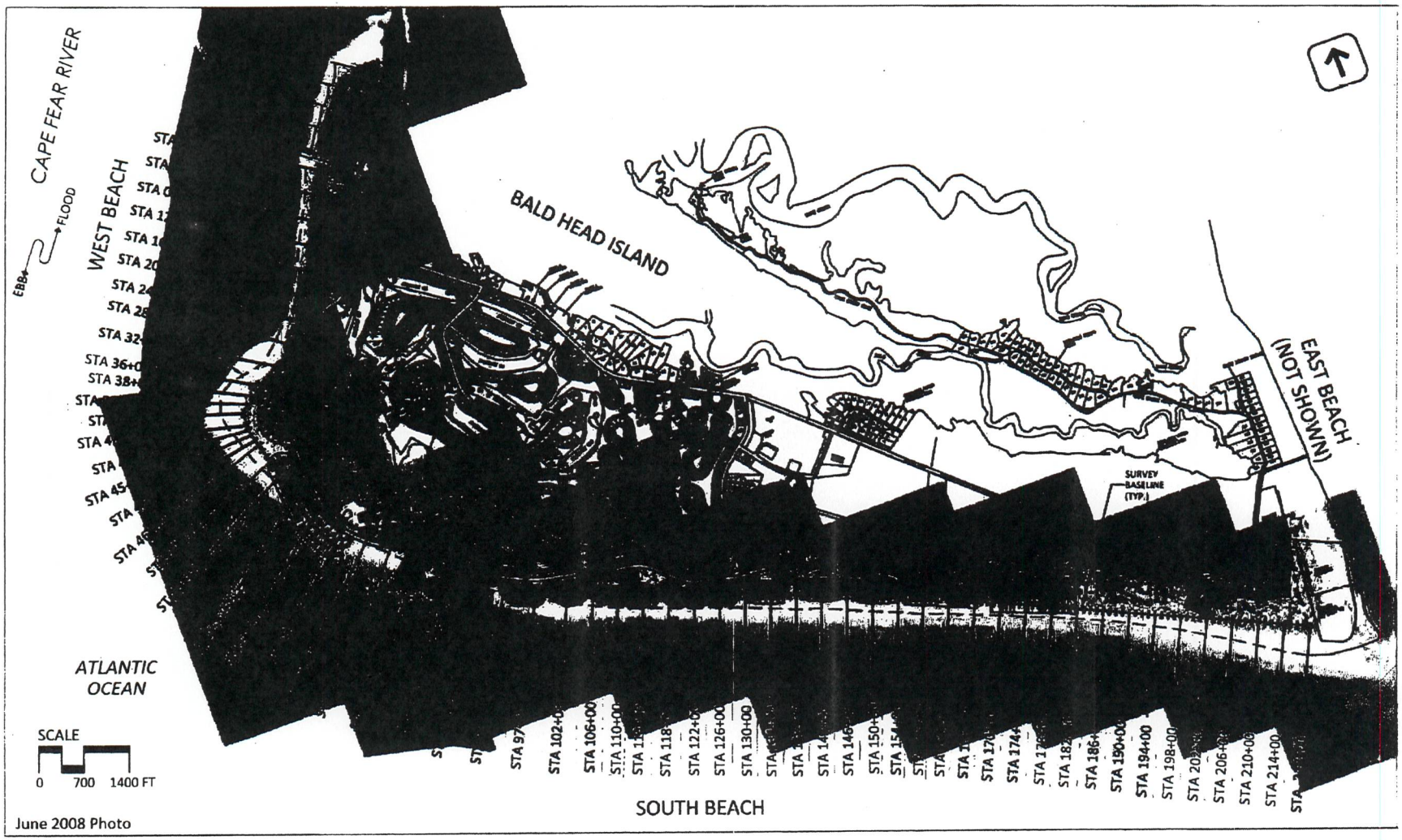
If a majority of the TAC determines that the utilization of Jay Bird Shoals as a borrow area has caused or contributed in any material way to the additional erosion or reduction in accretion, the Village shall mitigate the damage caused or contributed by use of Jay Bird Shoals as a borrow area to the proportionate extent such impact by direct placement of sand. The source of sand may include, but is not limited to, sand dredged from the federal navigation channel provided that the sand would not otherwise be placed on Oak Island pursuant to the Sand Management Plan ("SMP") or the Revised SMP.

V. TERMINAL STRUCTURE ALTERATION

As discussed previously, the proposed terminal groin is to be constructed as a "leaky" structure with some level of reduced sediment transport continuing to occur either through and/or over the structure crest. As a rubble mound structure, sand permeability can be physically increased through the removal of stones. Any reduction in effective structural elevation will increase sediment transport across the groin. Increased transport would be conducive to spit or

dry beach growth on the downdrift side of the structure which, in effect, would be expected to increase sediment transport to West Beach. Such "tuning" of a permeable structure is often desirable even if mitigation is not required. Normally, tuning would not occur without the benefit of significant post-construction monitoring, since the transmissivity of such a structure varies over time – dependent upon the condition (*i.e.* size and elevation) of the updrift sand fillet, seasonal wave climatology, storm effects and other site specific factors. In an extreme circumstance, and absent more reasonable, cost-effective alternatives, effective "removal" or major dismantling of the structure may be required.

To that end it should not be automatically assumed that if the Phase I terminal groin fails to meet its design goals that it should be completely removed from the shorefront. It is entirely likely, that the subject rock structure could be lowered to the point that it is almost entirely transparent to littoral transport – such that is posed no threat to the downdrift West Beach shoreline. At the same time however, a very low level structure would serve to benefit the updrift – South Beach profile – albeit at a significantly lower level than originally proposed. That is to say, even without the creation of a protective updrift fillet, a low level rock structure could serve to beneficially act as a "template" to the overall updrift beach profile – thereby continuing to provide some level of benefit to both the island and the navigation project.



June 2008 Photo

Physical Monitoring Program

Figure 1: Island-wide beach monitoring baseline.

olsen associates, inc.

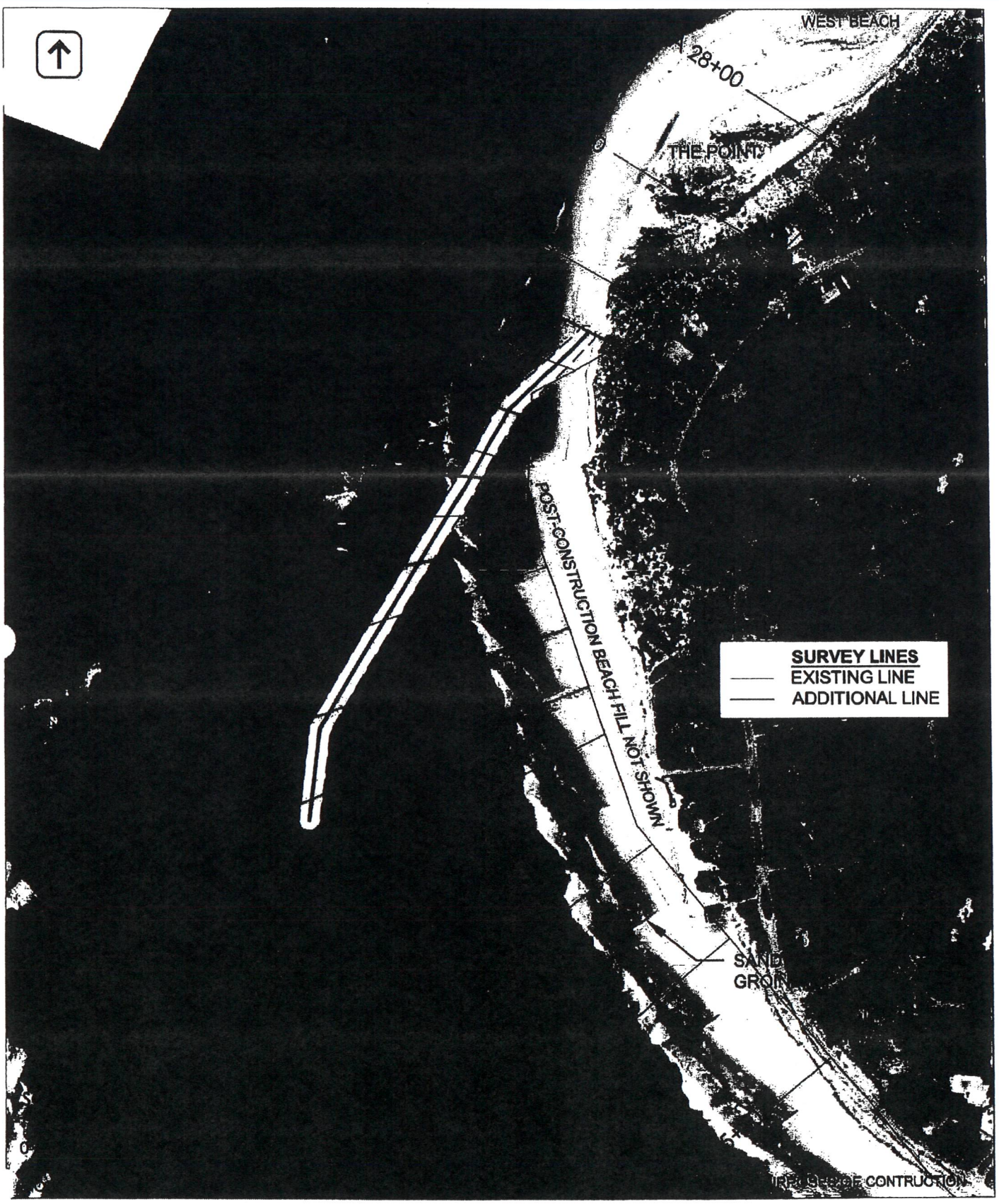


Figure 2: Survey Profile Lines in the Vicinity of the Terminal Structures

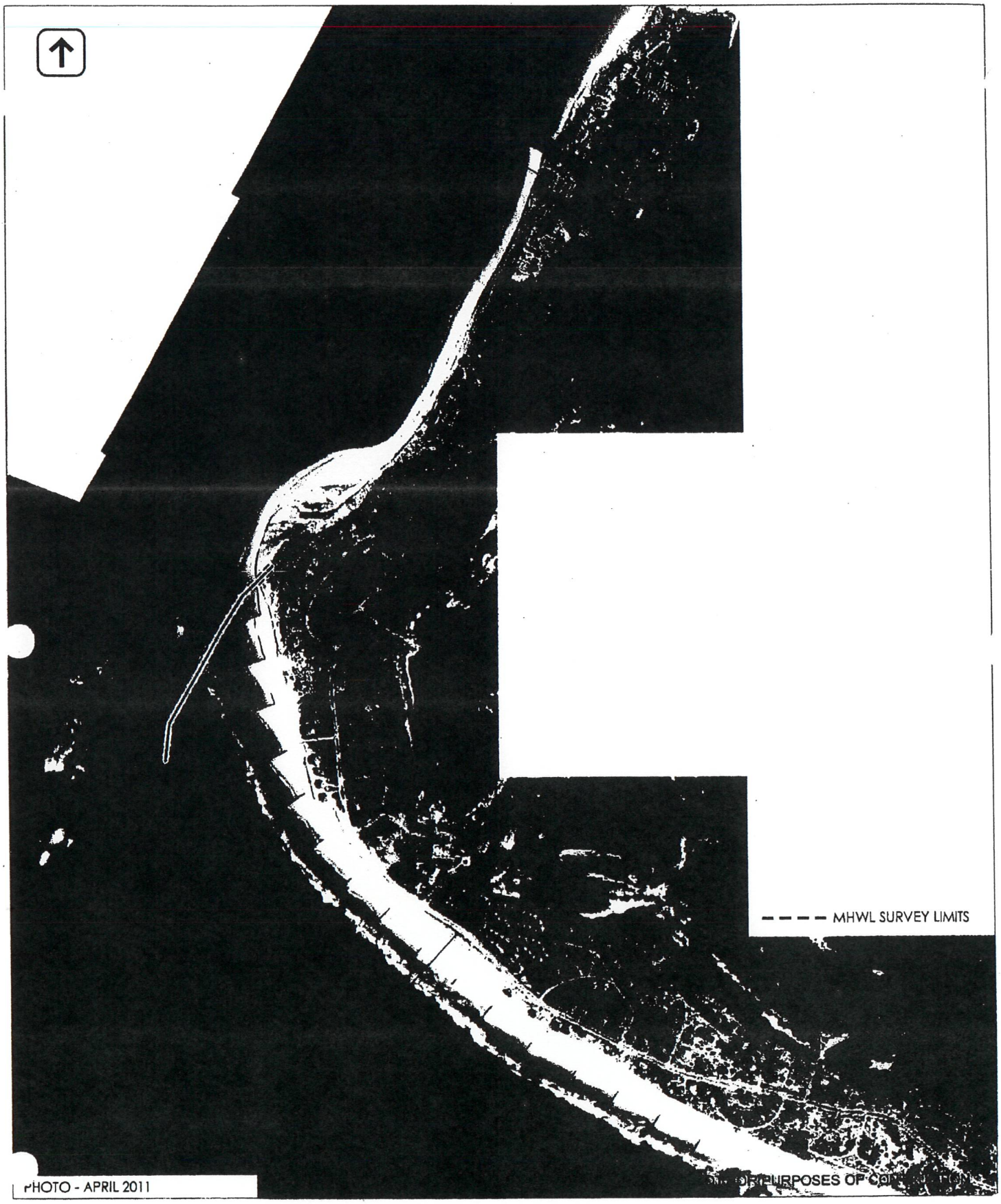


Figure 3: Location of Annual MHWL Surveys

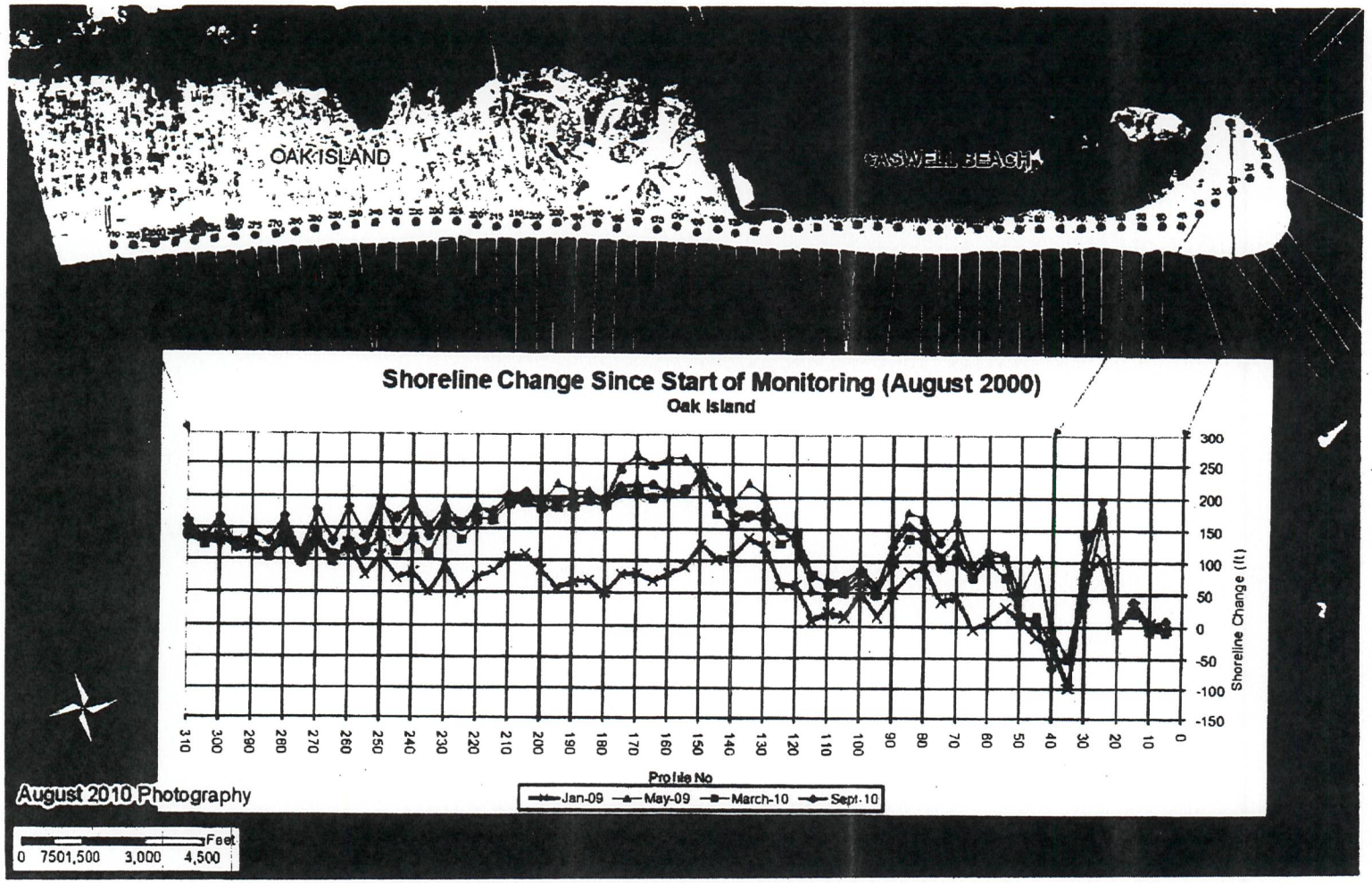


Figure 4: Example – Federal Monitoring Program for Oak Island.

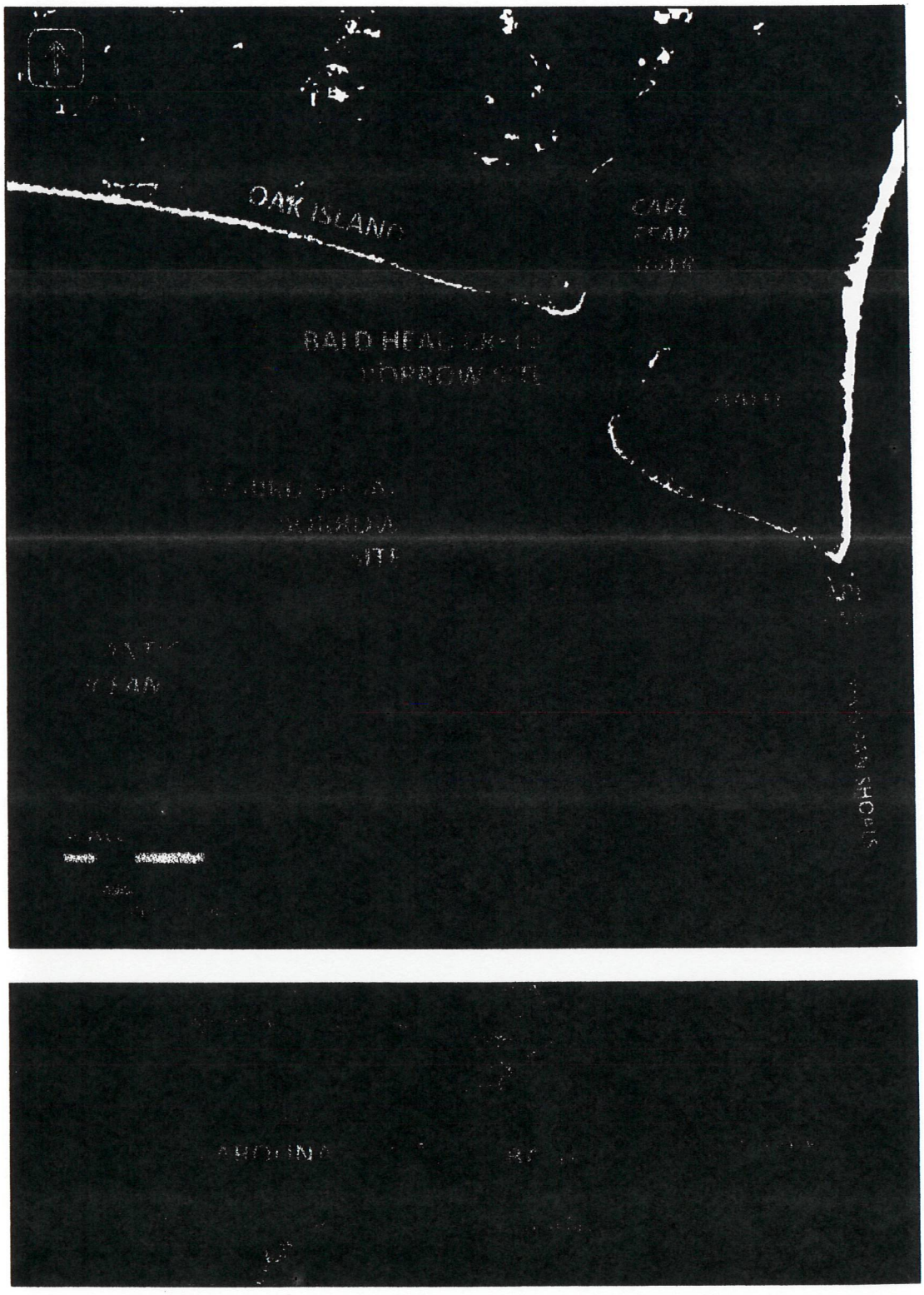


Figure 5: Borrow Sites Subject to Permit Required Monitoring

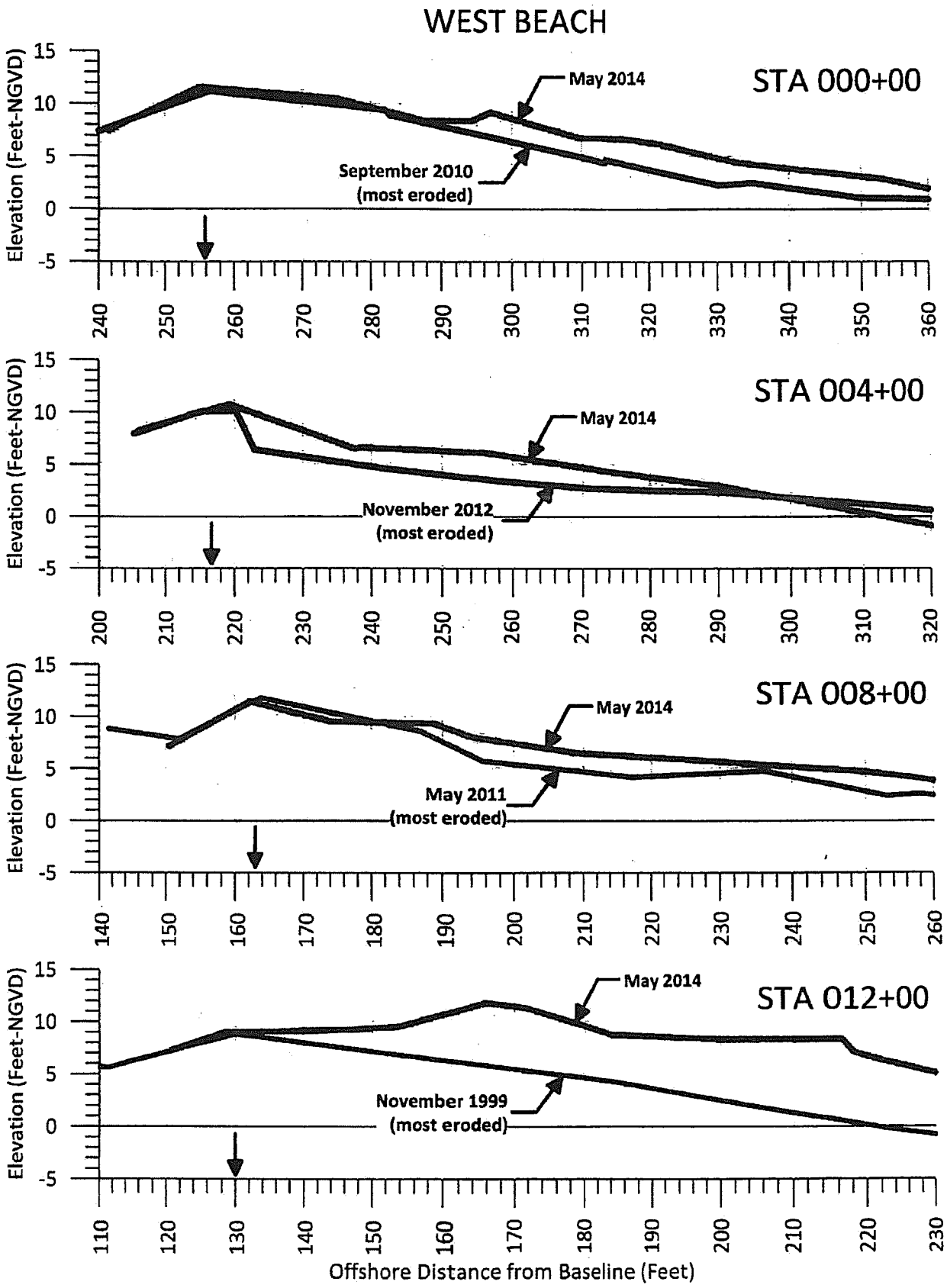


Figure 6: Location of maximum erosion at West Beach (2000-present).

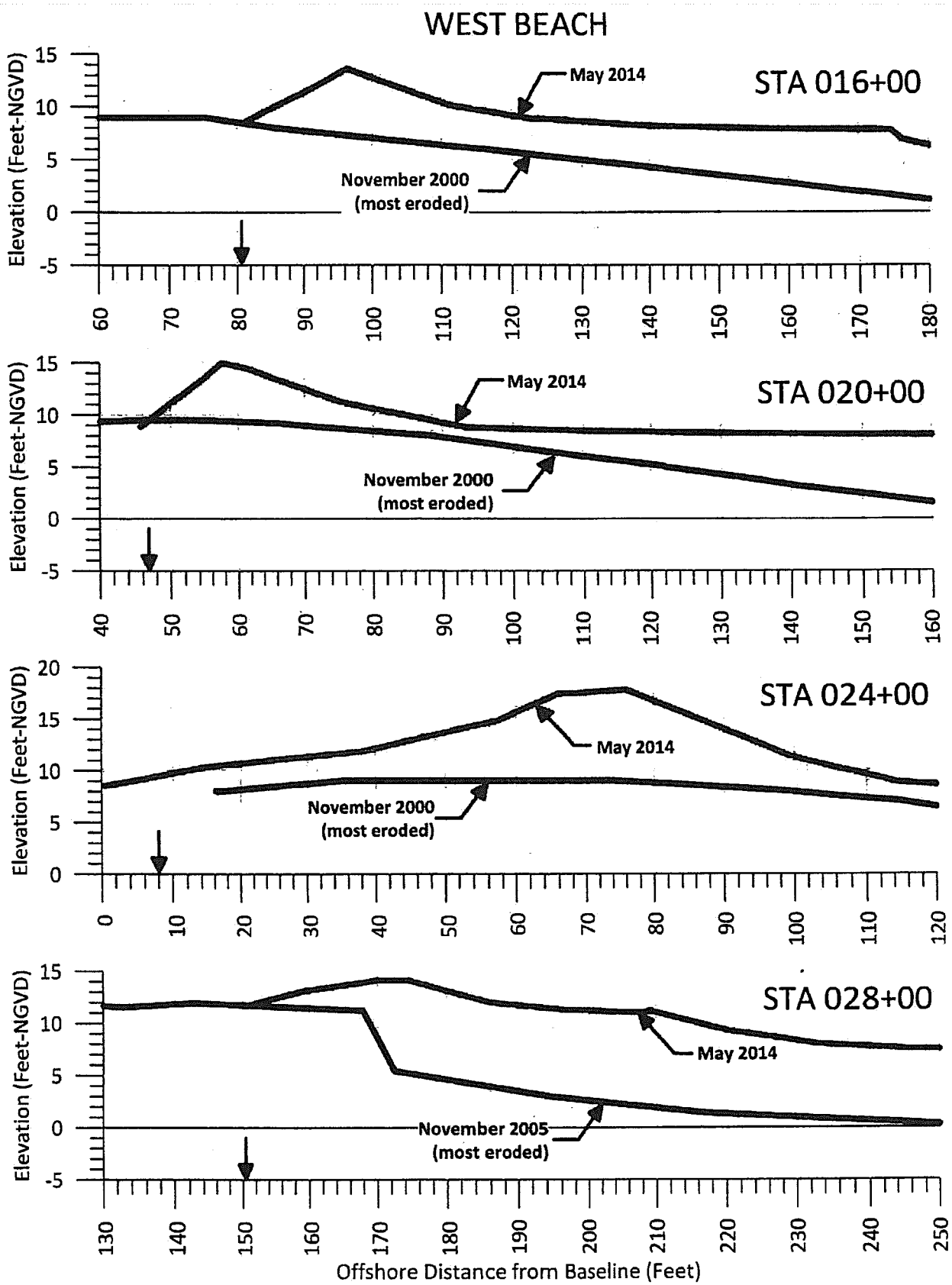


Figure 7: Location of maximum erosion at West Beach (2000-present).

TABLE 1

CASWELL BEACH MONITORING DATA[1] (STA 30 – 60)

Survey Station	Trend Long Term Rate.[(1)]	Shoreline Maximum Annual Recession Rate [(2)]	Date of Occurrence
STA 60	+10.4 ft/yr.	-90 ft/yr.	2002
STA 55	+9.3 ft/yr.	-94 ft/yr.	2003
STA 50	+4.8 ft/yr.	-120 ft/yr.	2005
STA 45	+5.6 ft/yr.	-80 ft/yr.	2009
STA 40	-4.5 ft/yr.	-200 ft/yr.	2006
STA 35	-8.8 ft/yr.	-90 ft/yr.	2006
STA 30	+12.4 ft/yr.	-150 ft/yr.	2004

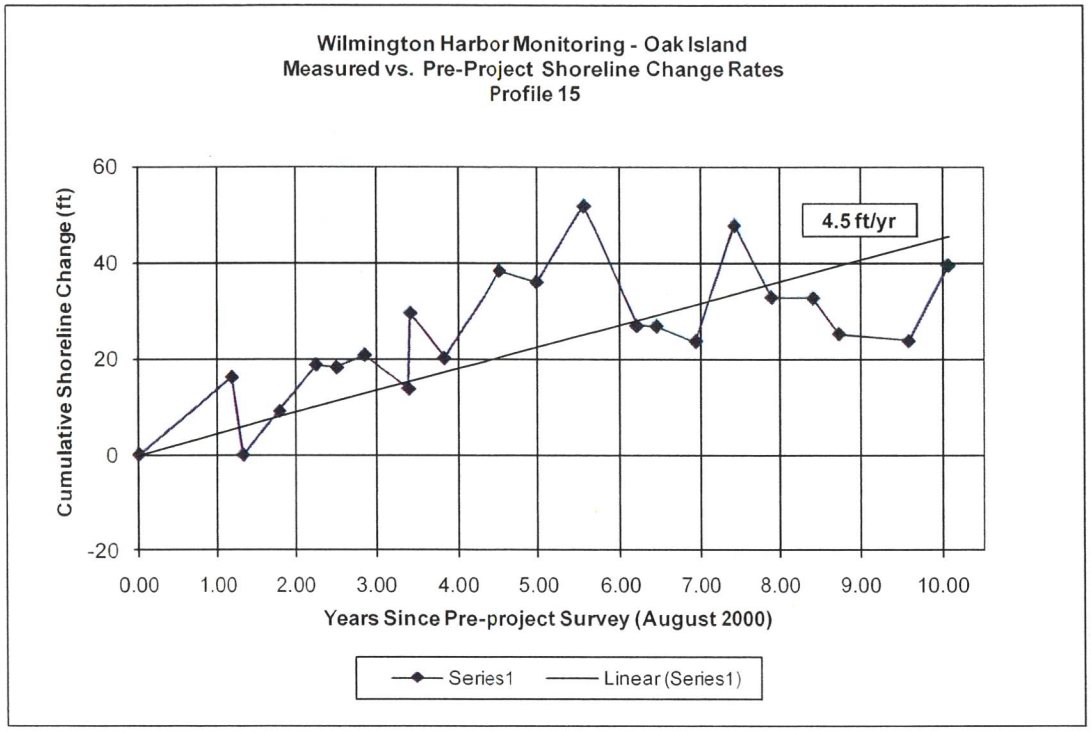
_____ . _____ . _____ . _____ . _____ . _____

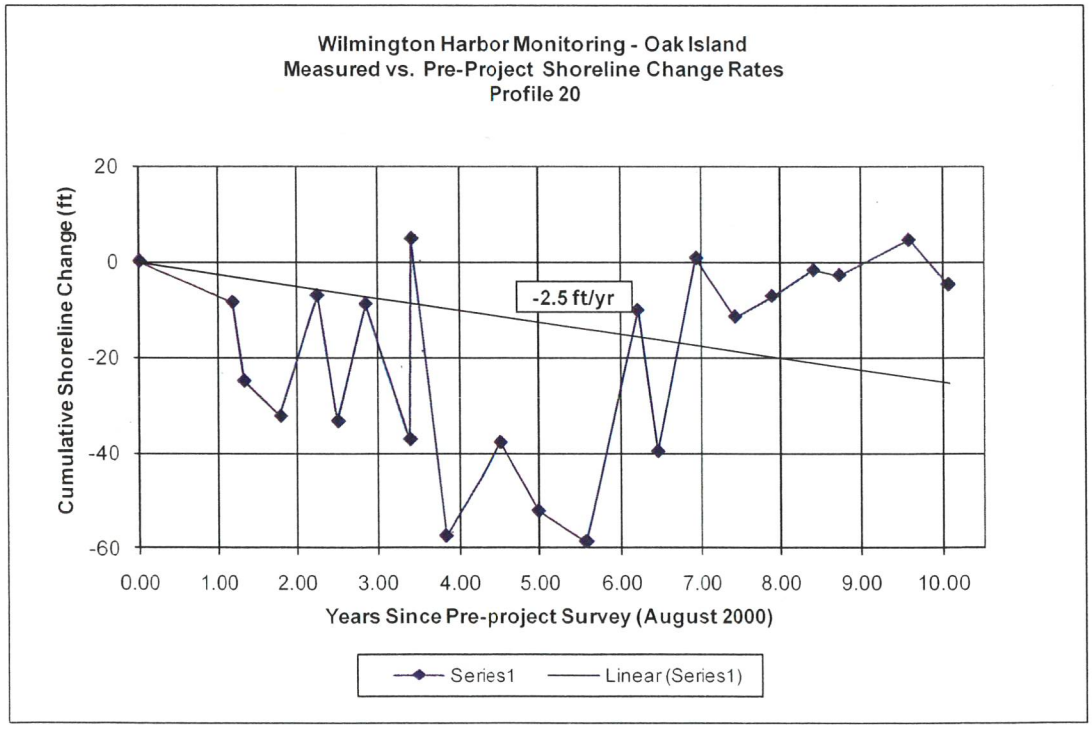
(1) Source – Wilmington District USACOE (2000-2010 – last published monitoring data – Report No. 8)

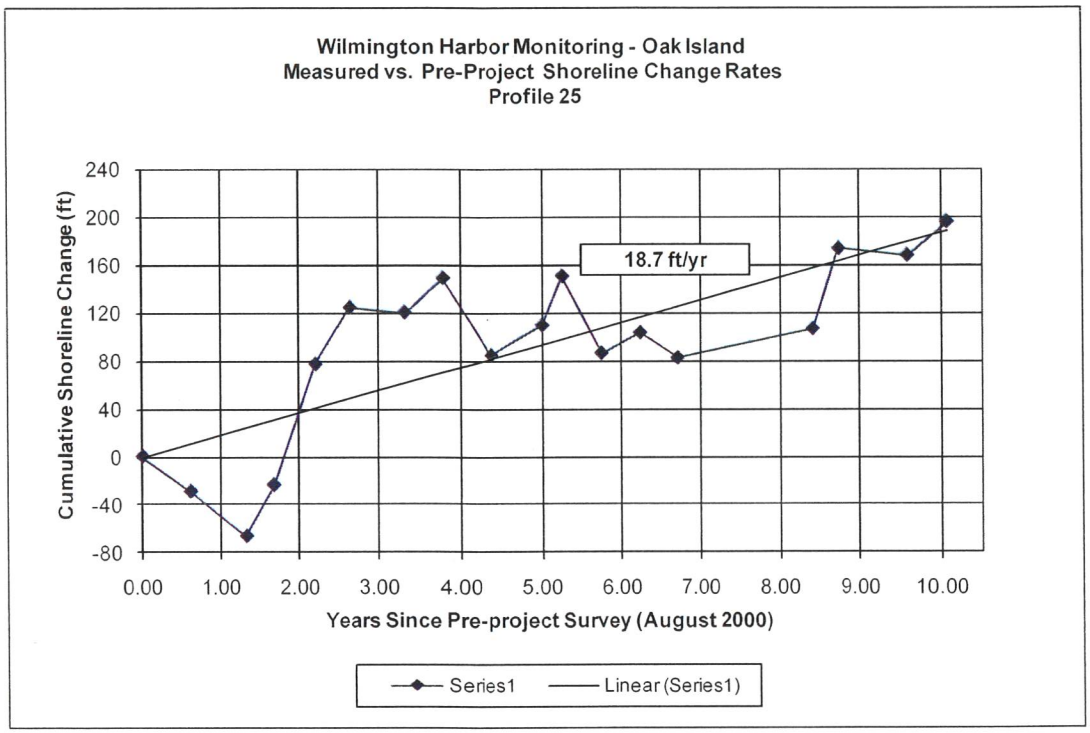
(2) Computed from COE survey data (6 mo. or 12 mo. Survey intervals)

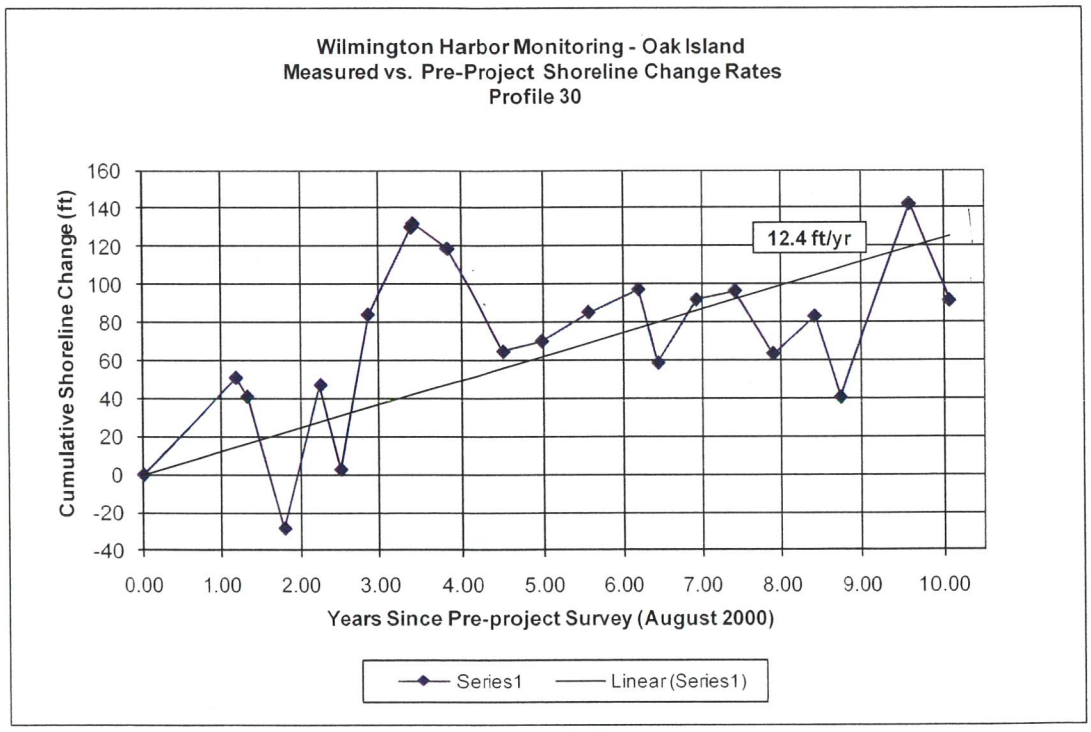
APPENDIX B

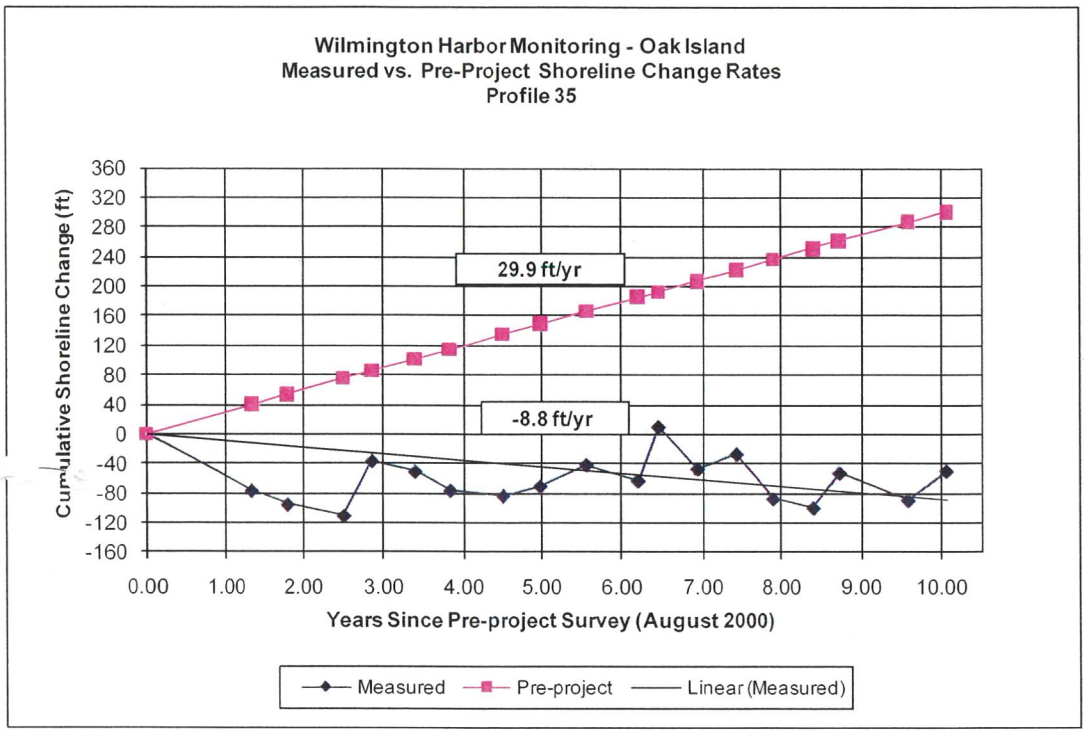
COE SHORELINE "TRENDS"

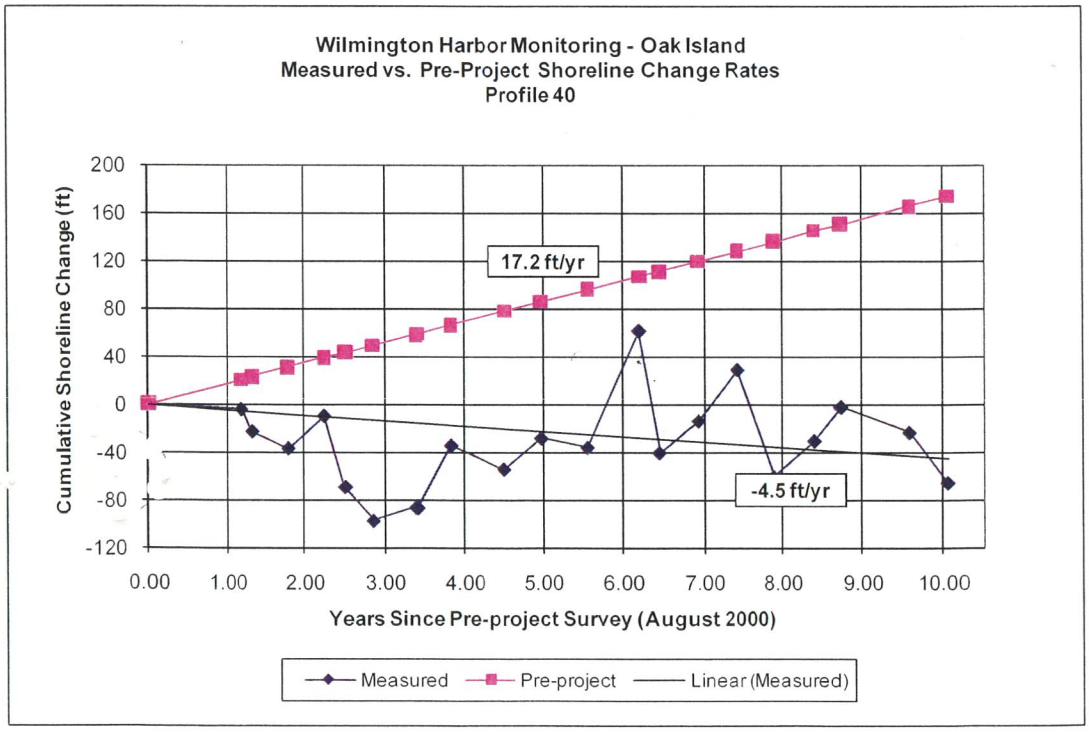

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 15
4.5 ft/yr
Cumulative Shoreline Change (ft)
60
40
20
0
-20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
Series1
Linear (Series1)

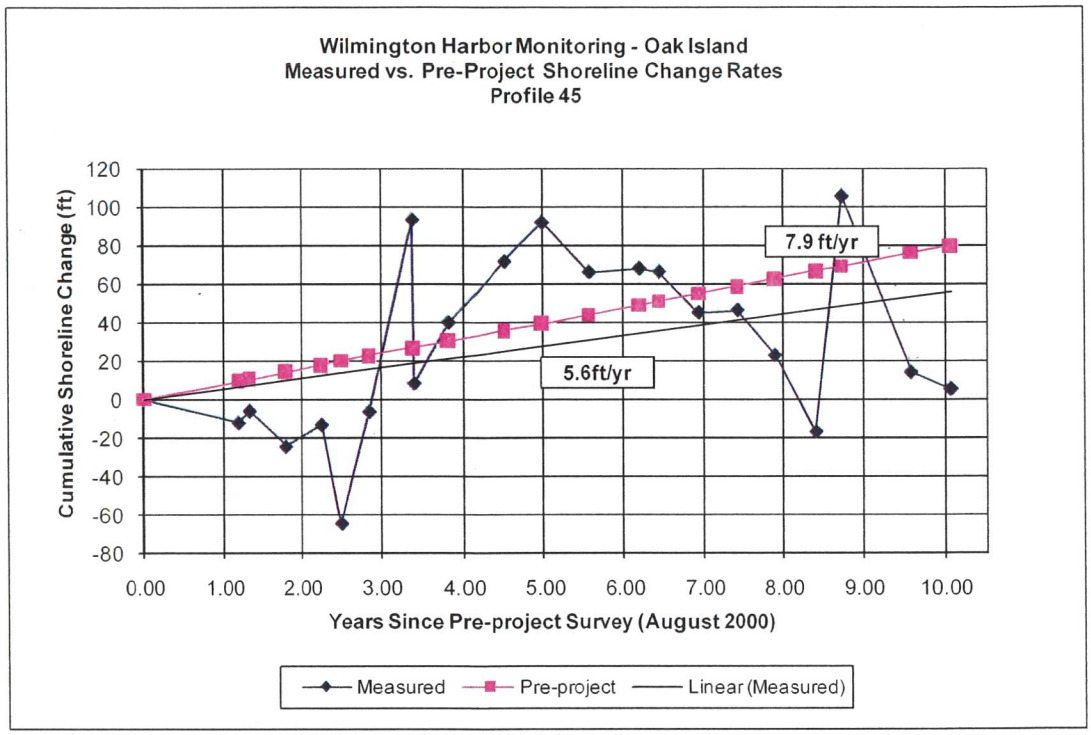

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 20
-2.5 ft/yr
Cumulative Shoreline Change (ft)
20
0
-20
-40
-60
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
Series1
Linear (Series1)

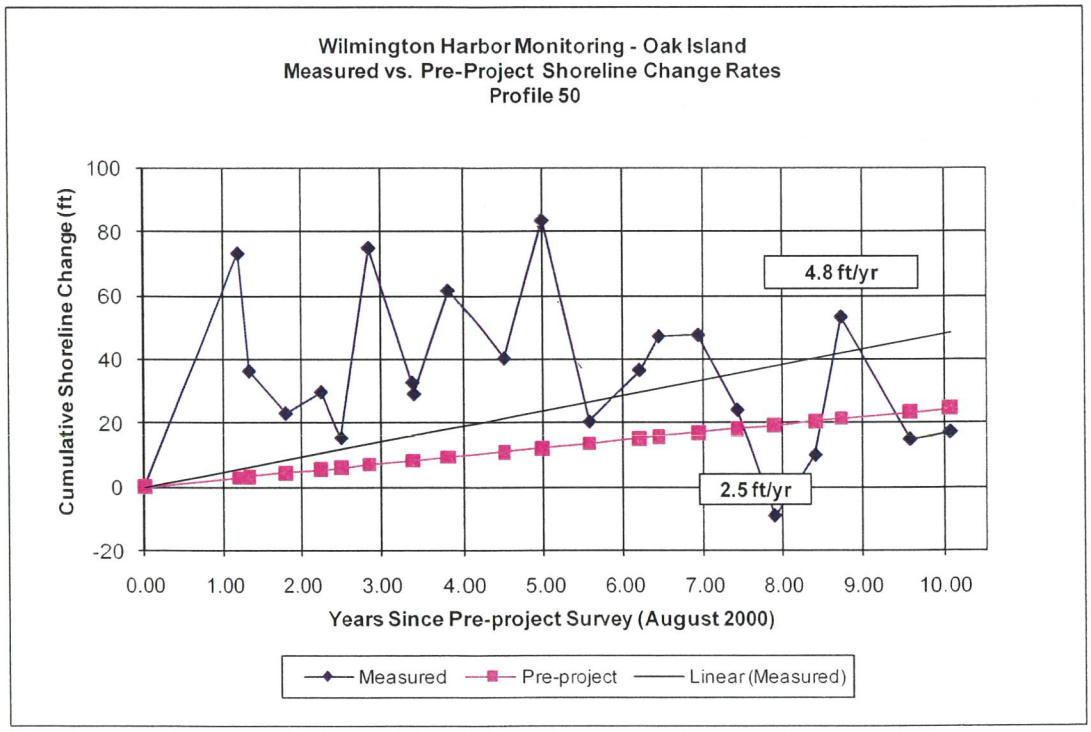

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 25
Cumulative Shoreline Change (ft)
240
200
160
120
80
40
0
-40
-80
18.7 ft/yr
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
Series1
Linear (Series1)

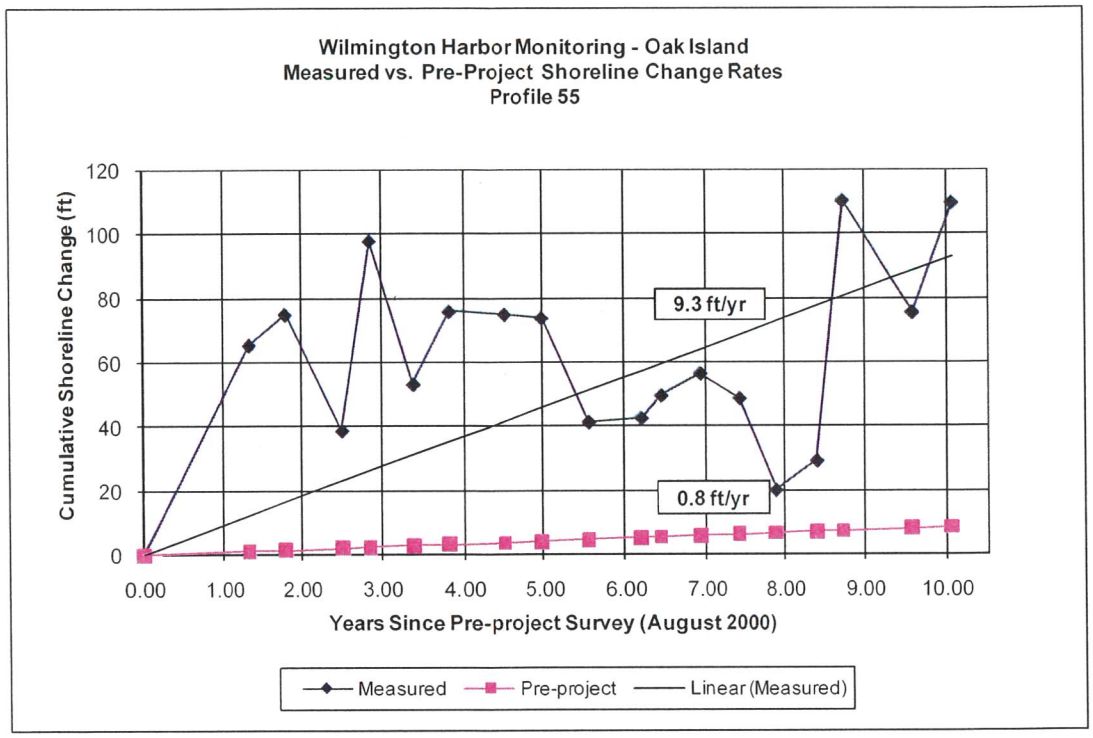

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 30
Cumulative Shoreline Change (ft)
160
140
120
100
80
60
40
20
0
-20
-40
12.4 ft/yr
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
Series1
Linear (Series1)

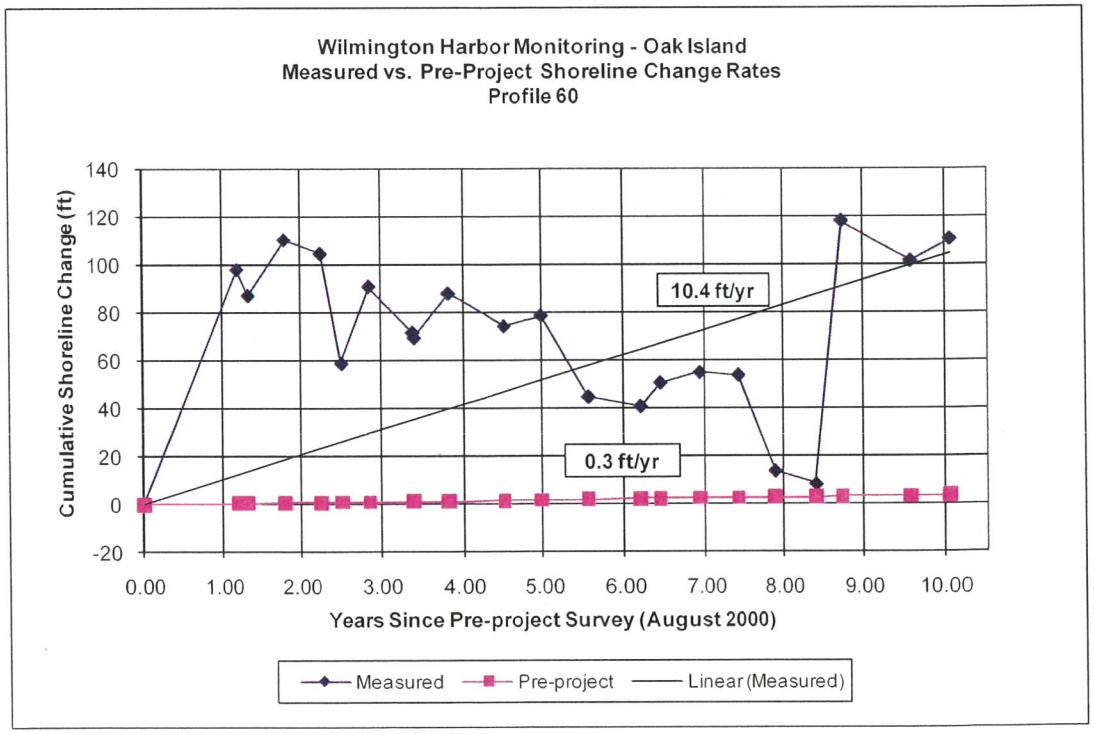

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 35
Cumulative Shoreline Change (ft)
360
320
280
240
200
160
120
80
40
0
-40
-80
-120
-160
29.9 ft/yr
-8.8 ft/yr
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

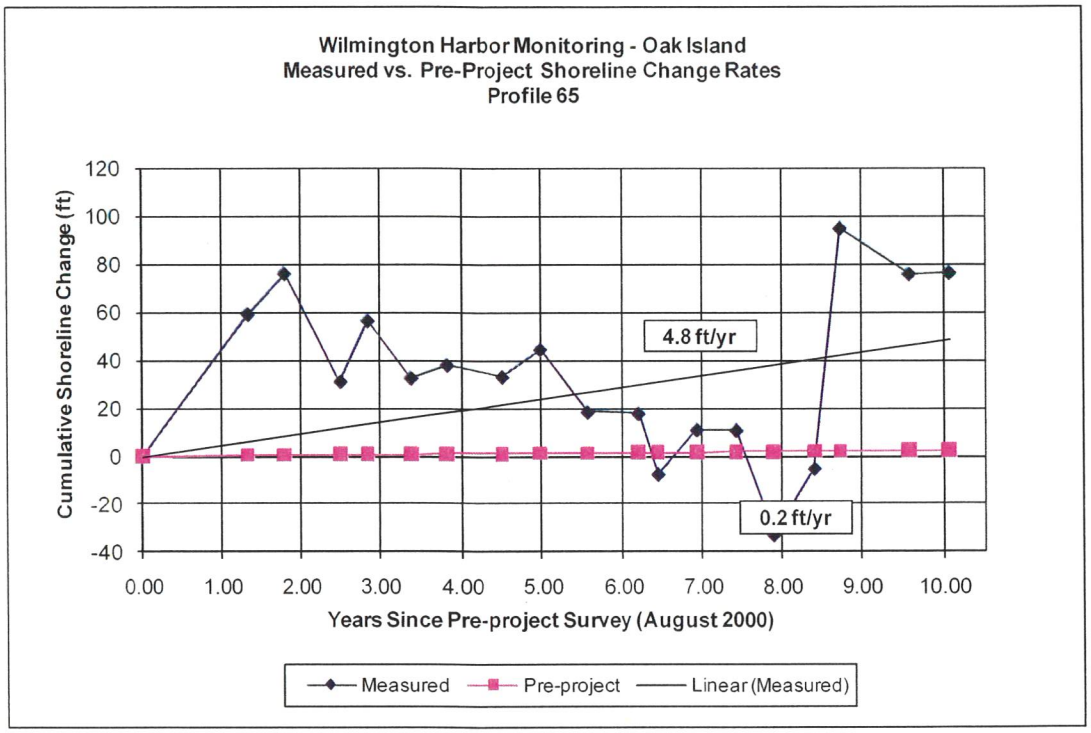

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 40
Cumulative Shoreline Change (ft)
200
160
120
80
40
0
-40
-80
-120
17.2 ft/yr
-4.5 ft/yr
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

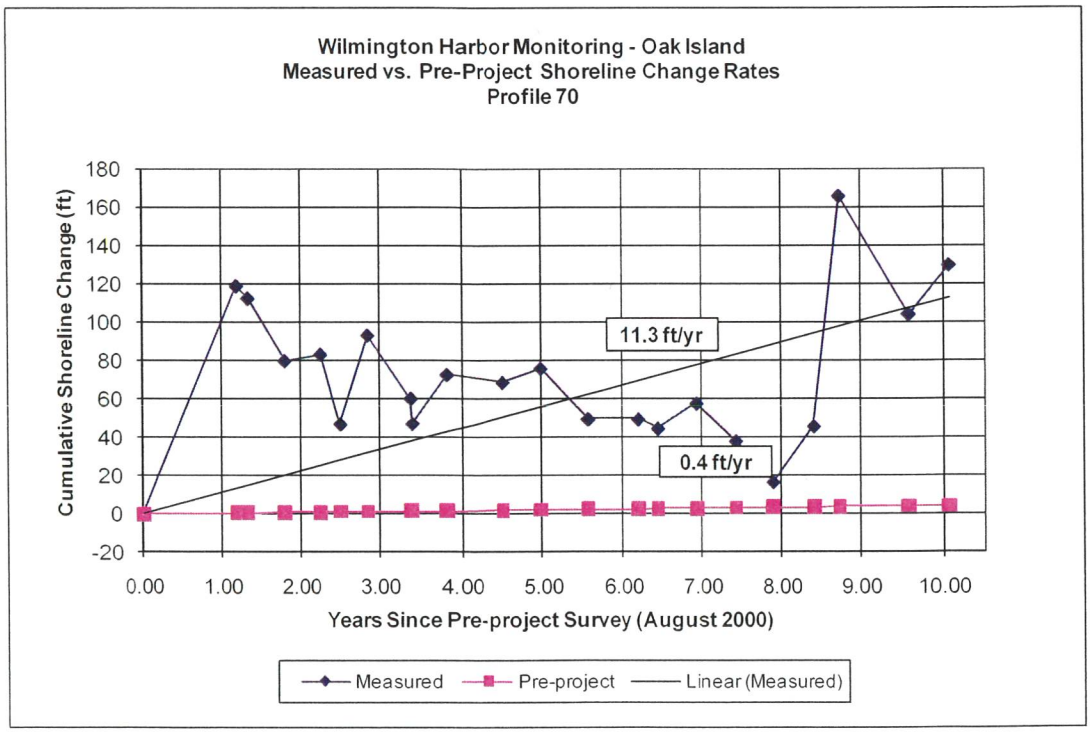

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 45
Cumulative Shoreline Change (ft)
120
100
80
60
40
20
0
-20
-40
-60
-80
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
7.9 ft/yr
5.6ft/yr
Measured
Pre-project
Linear (Measured)

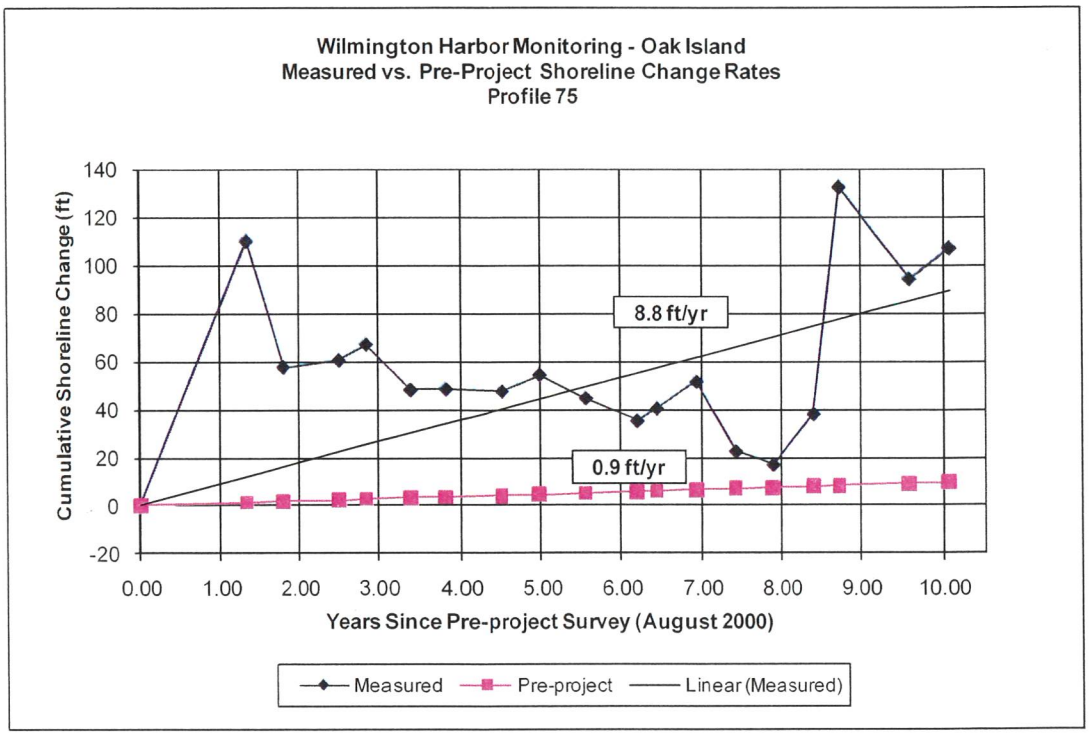

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 50
Cumulative Shoreline Change (ft)
100
80
60
40
20
0
-20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
4.8 ft/yr
2.5 ft/yr
Measured
Pre-project
Linear (Measured)

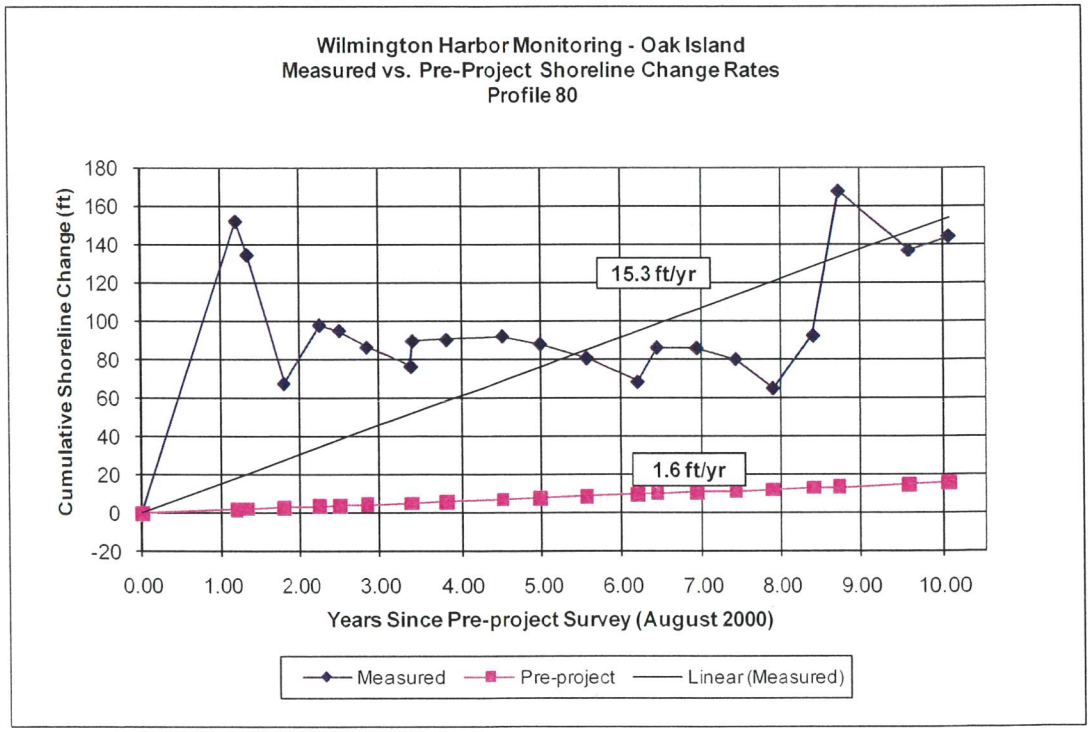

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 55
Cumulative Shoreline Change (ft)
120
100
80
60
40
20
0
9.3 ft/yr
0.8 ft/yr
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

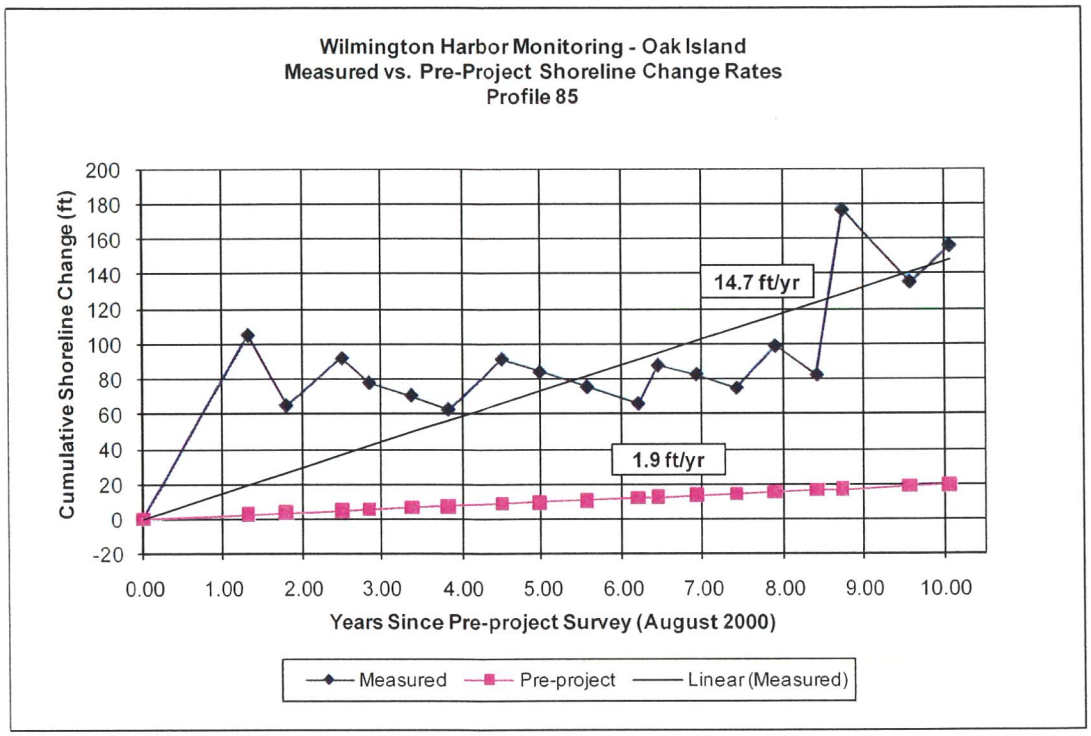

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 60
Cumulative Shoreline Change (ft)
140
120
100
80
60
40
20
0
-20
10.4 ft/yr
0.3 ft/yr
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

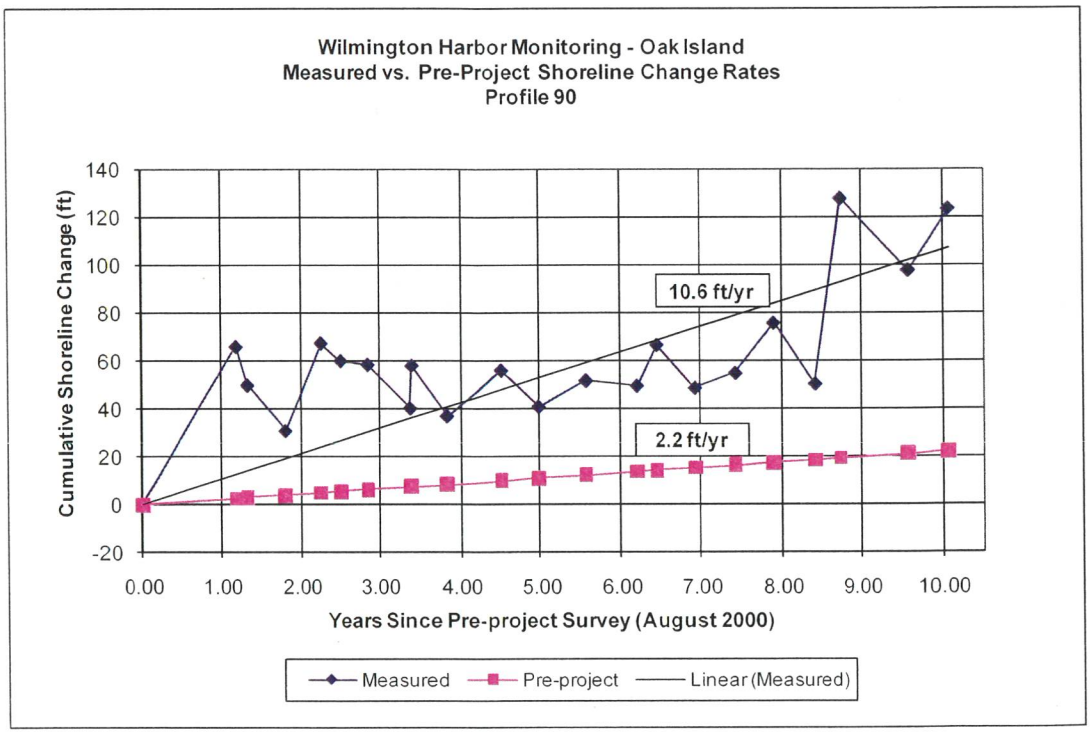

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 65
Cumulative Shoreline Change (ft)
120
100
80
60
40
20
0
-20
-40
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
4.8 ft/yr
0.2 ft/yr
Measured
Pre-project
Linear (Measured)

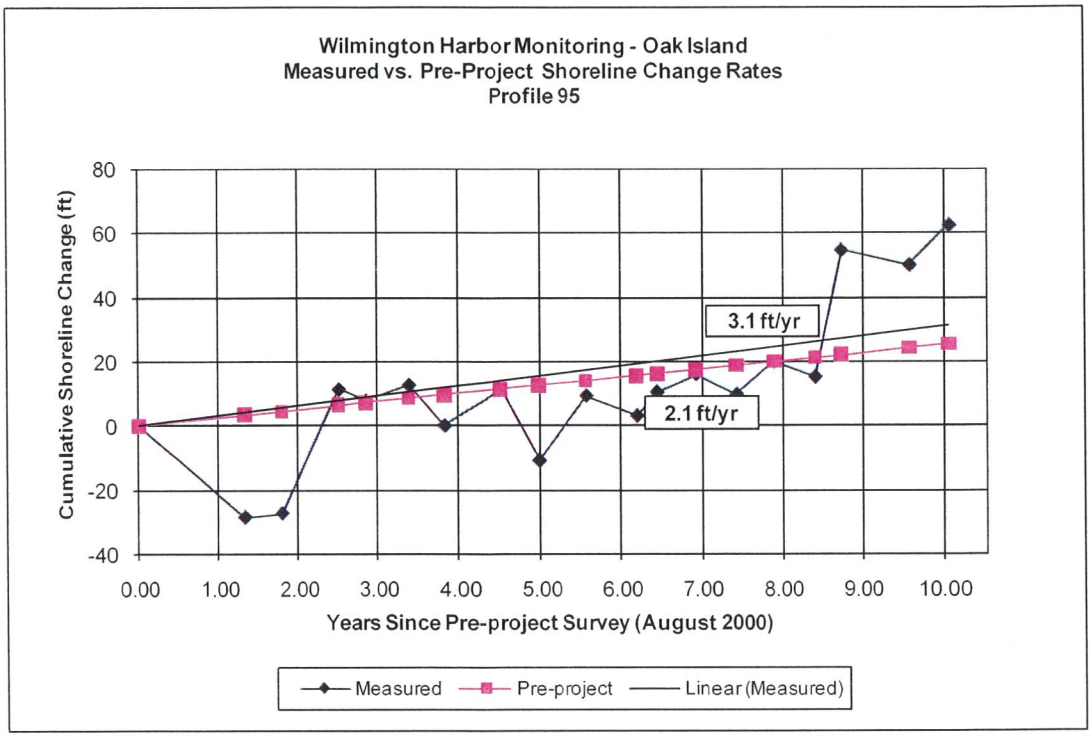

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 70
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
11.3 ft/yr
0.4 ft/yr
Measured
Pre-project
Linear (Measured)

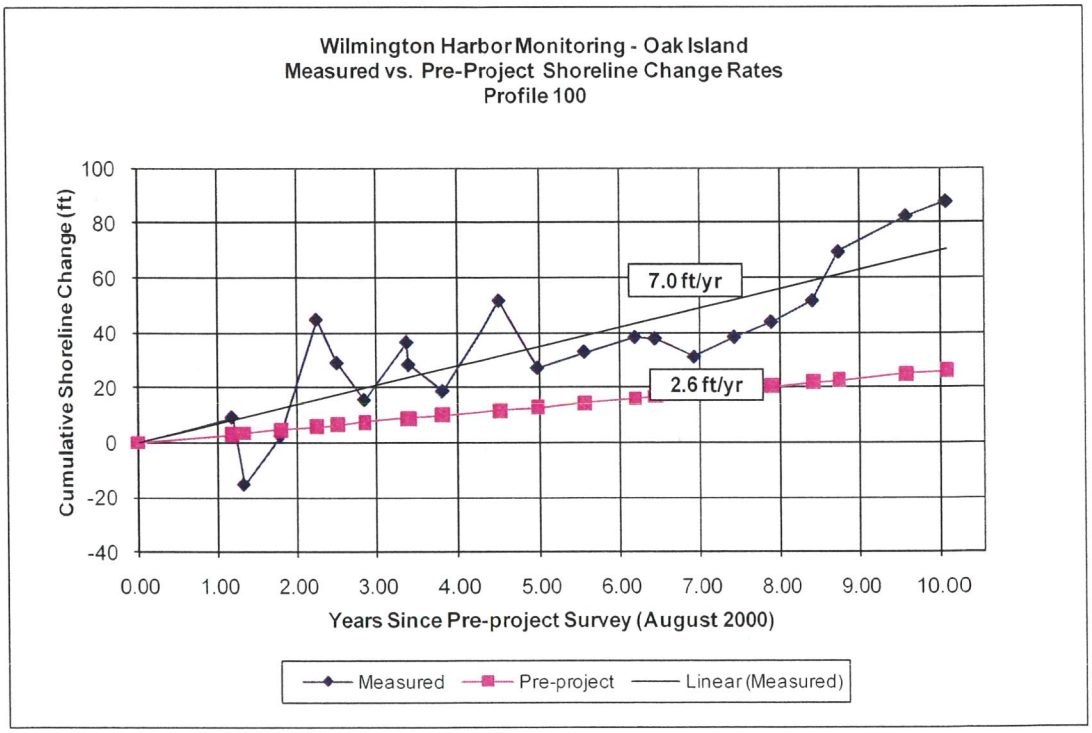

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 75
Cumulative Shoreline Change (ft)
140
120
100
80
60
40
20
0
-20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
8.8 ft/yr
0.9 ft/yr
Measured
Pre-project
Linear (Measured)

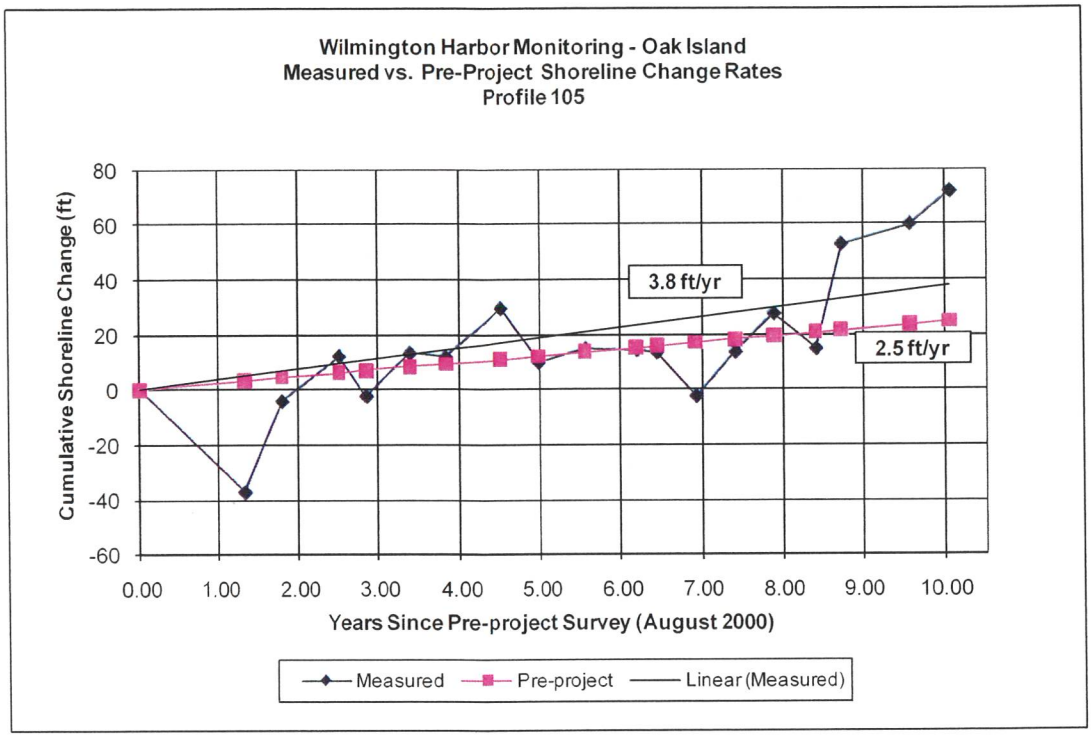

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 80
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
15.3 ft/yr
1.6 ft/yr
Measured
Pre-project
Linear (Measured)

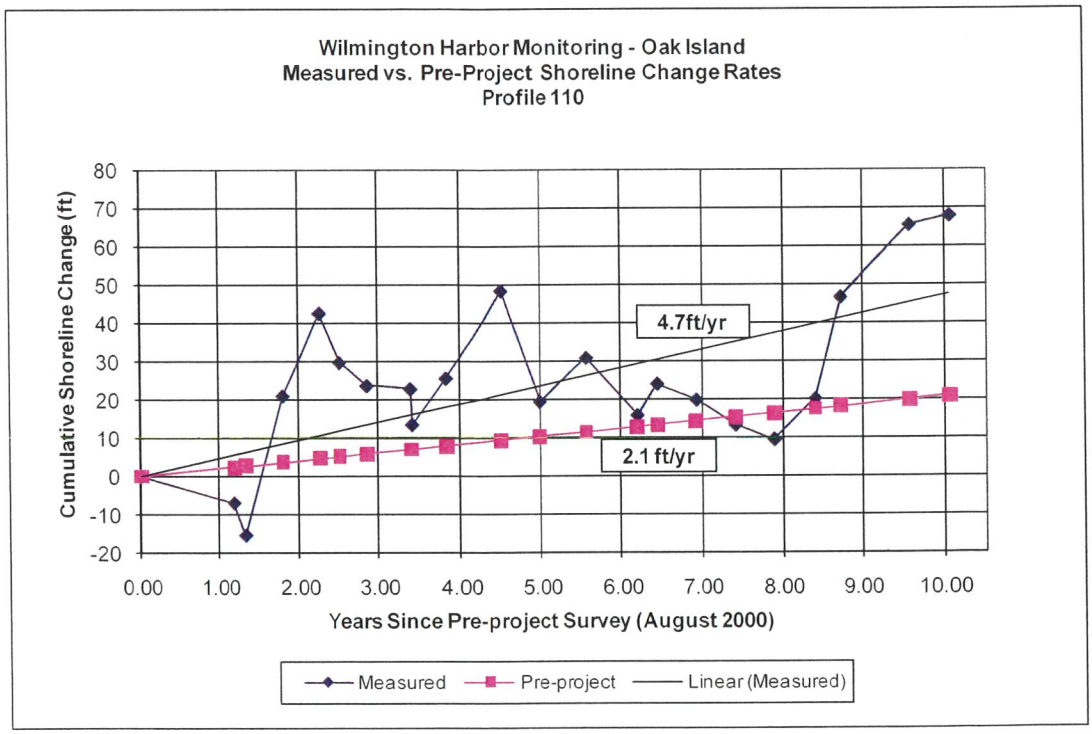

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 85
Cumulative Shoreline Change (ft)
200
180
160
140
120
100
80
60
40
20
0
-20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
14.7 ft/yr
1.9 ft/yr
Measured
Pre-project
Linear (Measured)

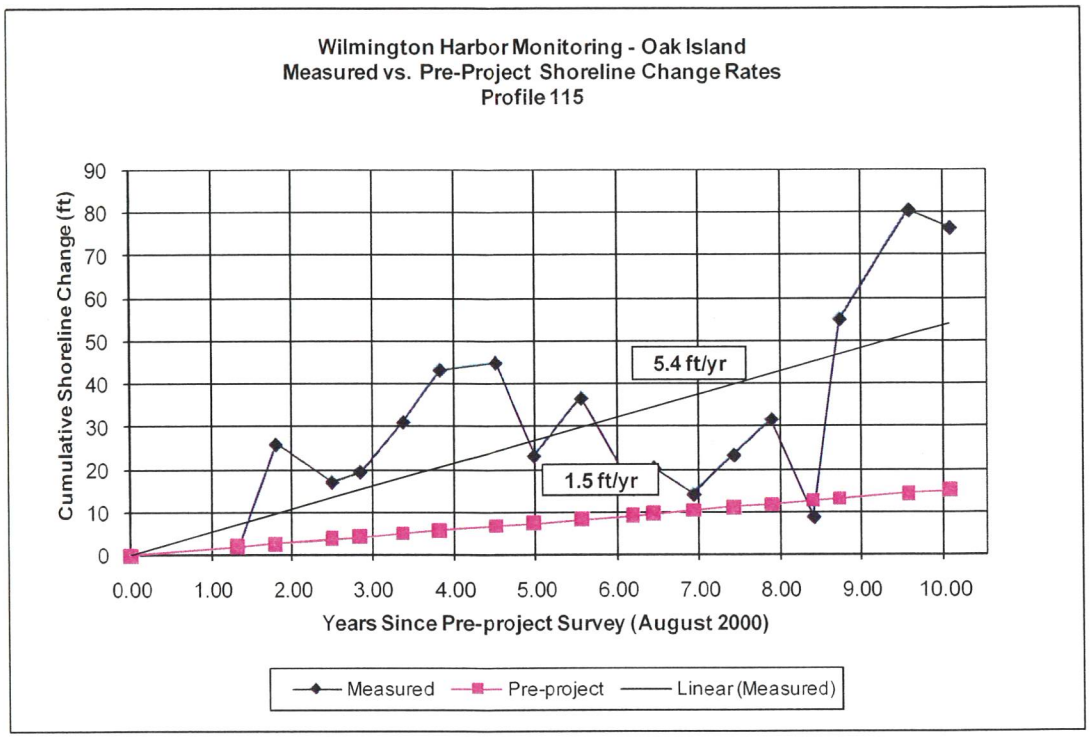

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 90
Cumulative Shoreline Change (ft)
140
120
100
80
60
40
20
0
-20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
10.6 ft/yr
2.2 ft/yr
Measured
Pre-project
Linear (Measured)

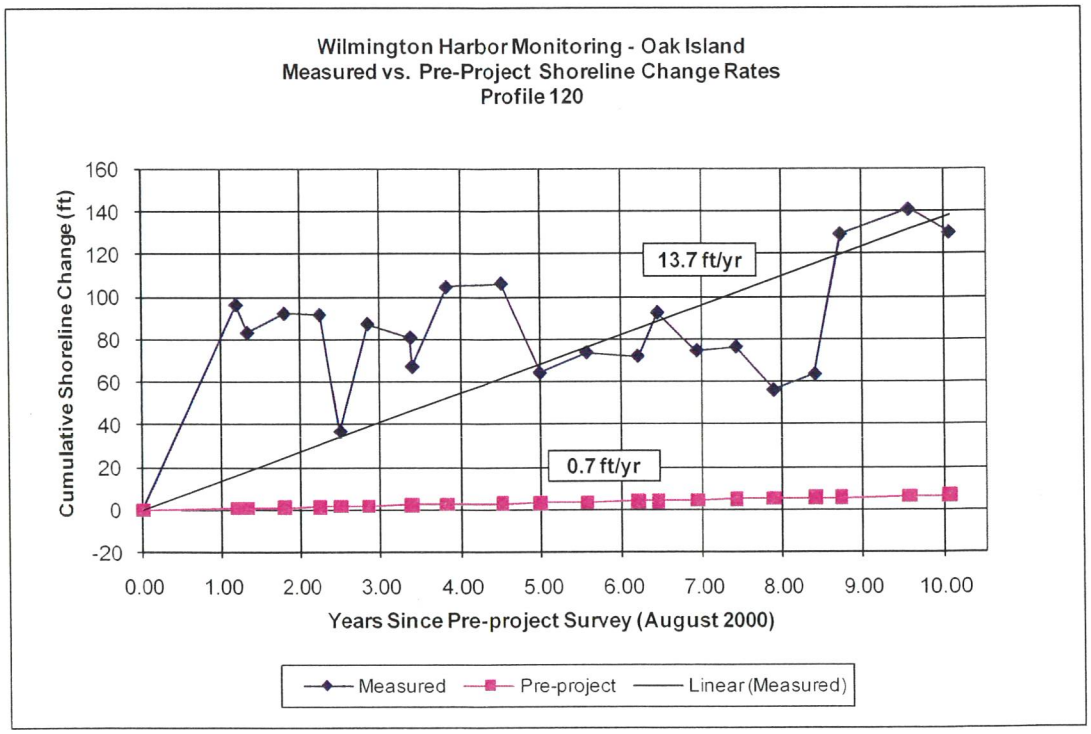

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 95
Cumulative Shoreline Change (ft)
80
60
40
20
0
-20
-40
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
3.1 ft/yr
2.1 ft/yr
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 100
Cumulative Shoreline Change (ft)
100
80
60
40
20
0
-20
-40
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
7.0 ft/yr
2.6 ft/yr
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 105
Cumulative Shoreline Change (ft)
80
60
40
20
0
-20
-40
-60
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
3.8 ft/yr
2.5 ft/yr
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 110
Cumulative Shoreline Change (ft)
80
70
60
50
40
30
20
10
0
-10
-20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
4.7ft/yr
2.1 ft/yr
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 115
Cumulative Shoreline Change (ft)
90
80
70
60
50
40
30
20
10
0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
5.4 ft/yr
1.5 ft/yr
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 120
Cumulative Shoreline Change (ft)
160
140
120
100
80
60
40
20
0
-20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Years Since Pre-project Survey (August 2000)
13.7 ft/yr
0.7 ft/yr
Measured
Pre-project
Linear (Measured)

APPENDIX C

COMPARATIVE BEACH PROFILES

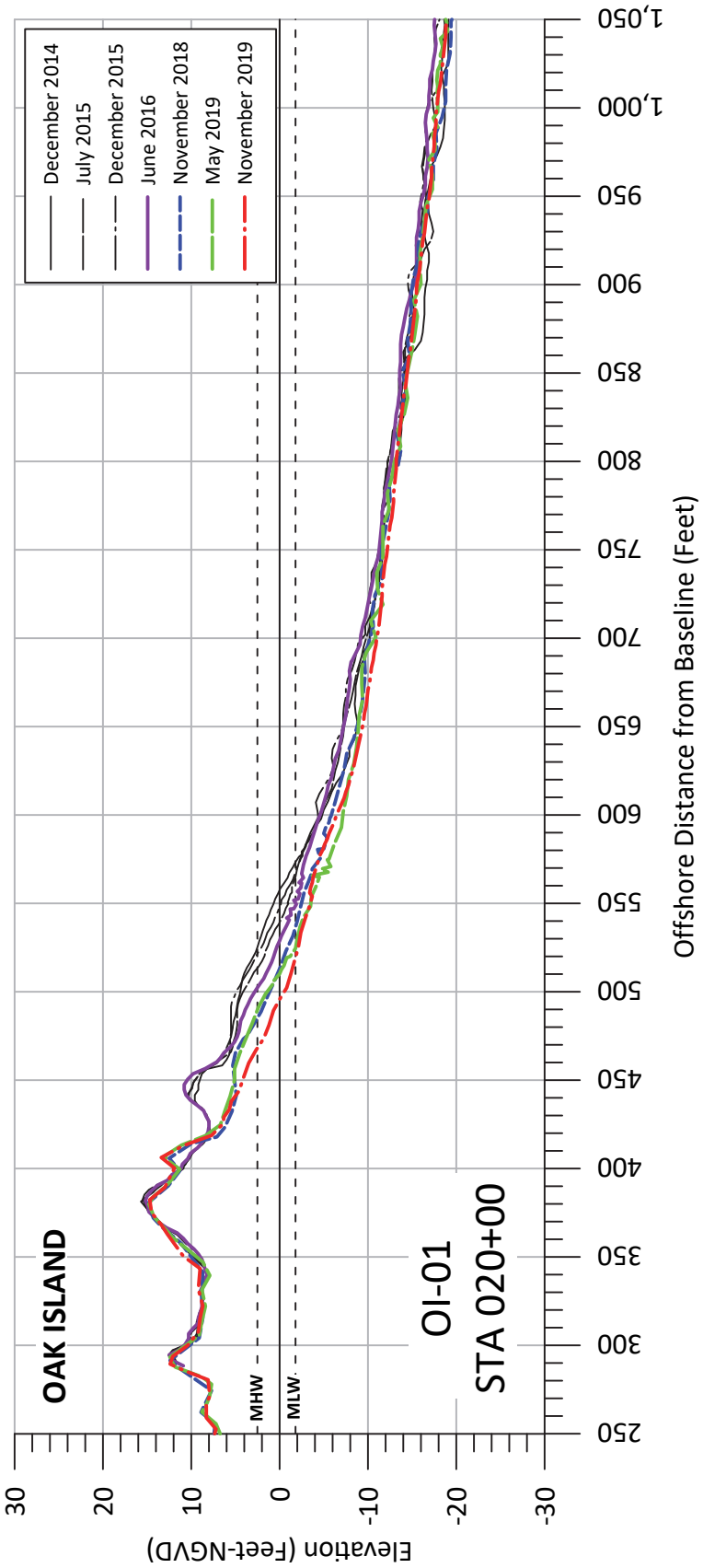


Figure C-01: Measured beach profiles at baseline **Station 020+00**, Oak Island, N.C.

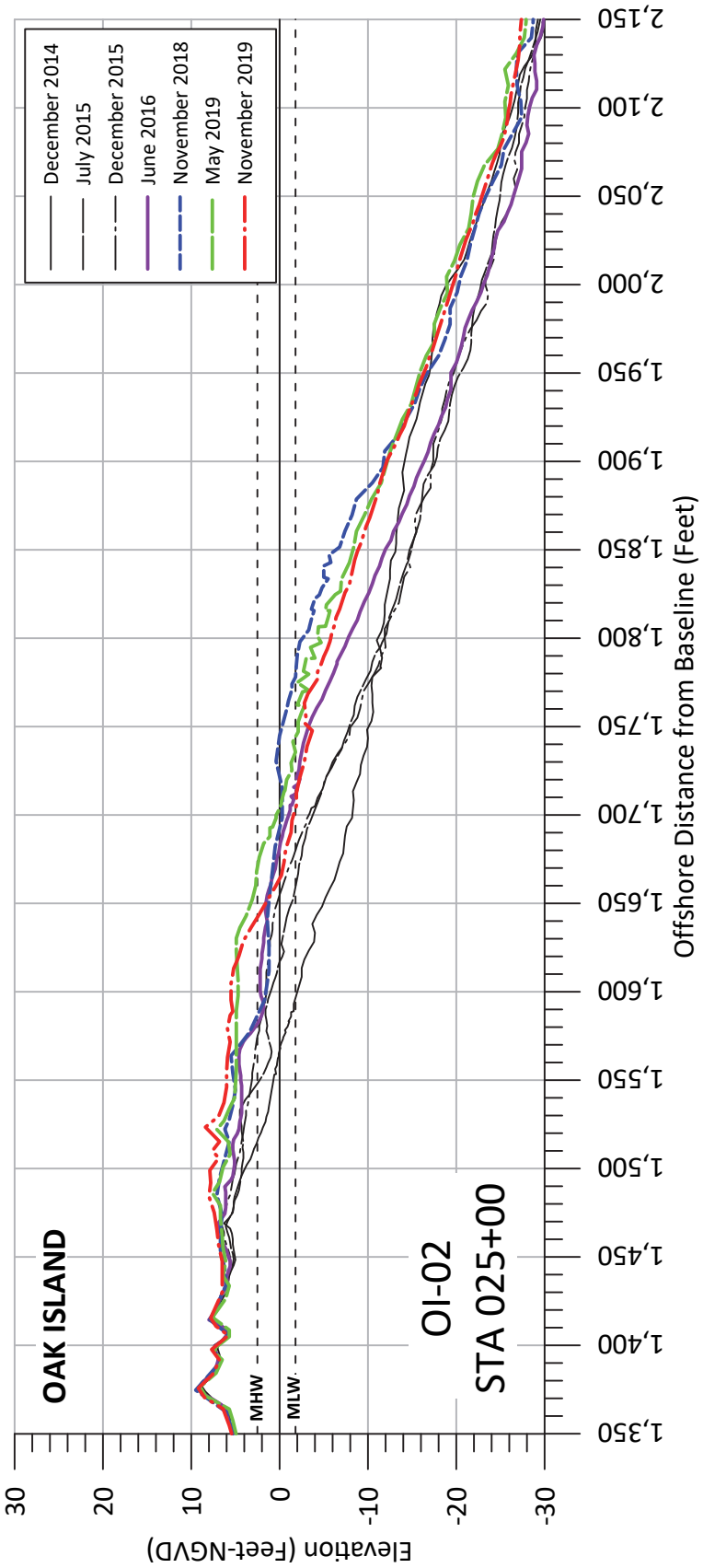


Figure C-02: Measured beach profiles at baseline **Station 025+00**, Oak Island, N.C.

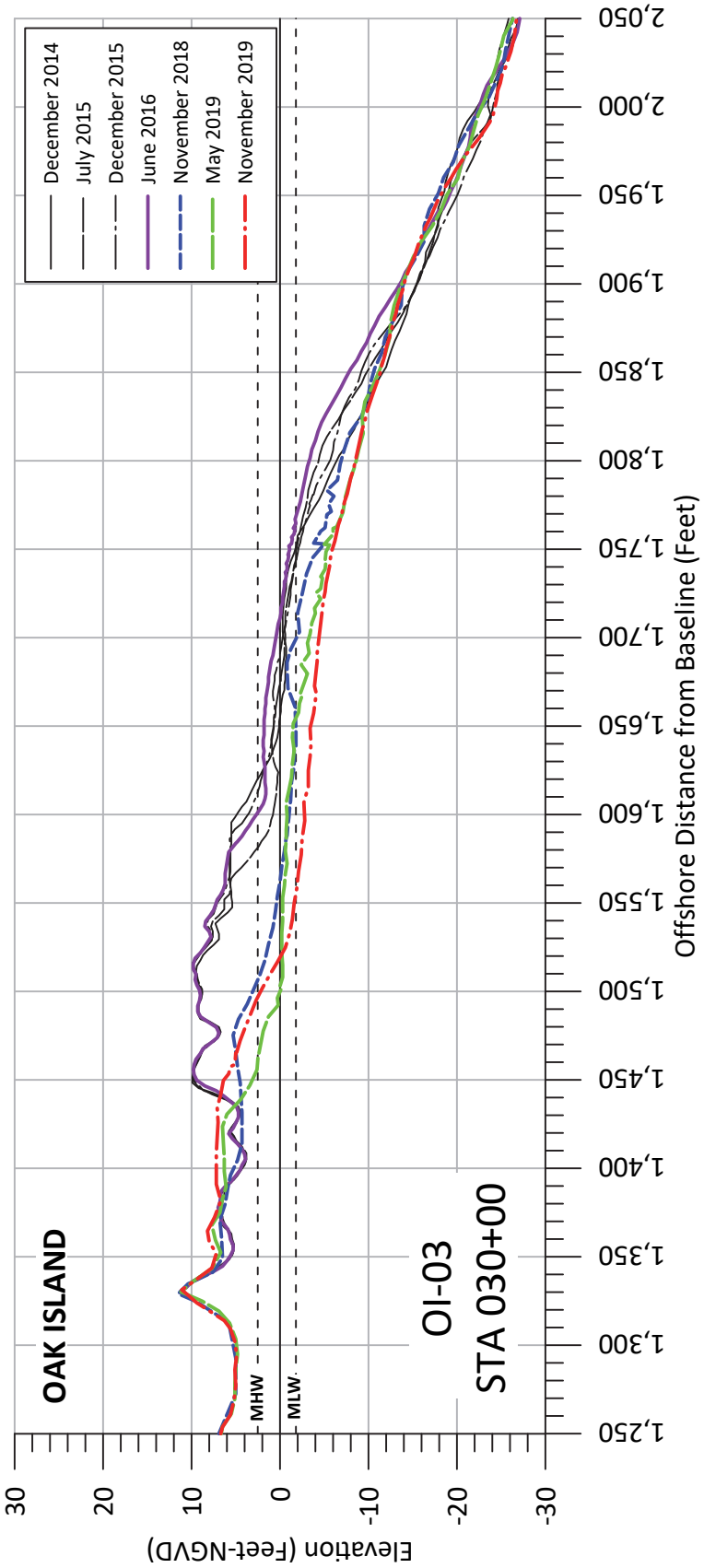


Figure C-03: Measured beach profiles at baseline **Station 030+00**, Oak Island, N.C.

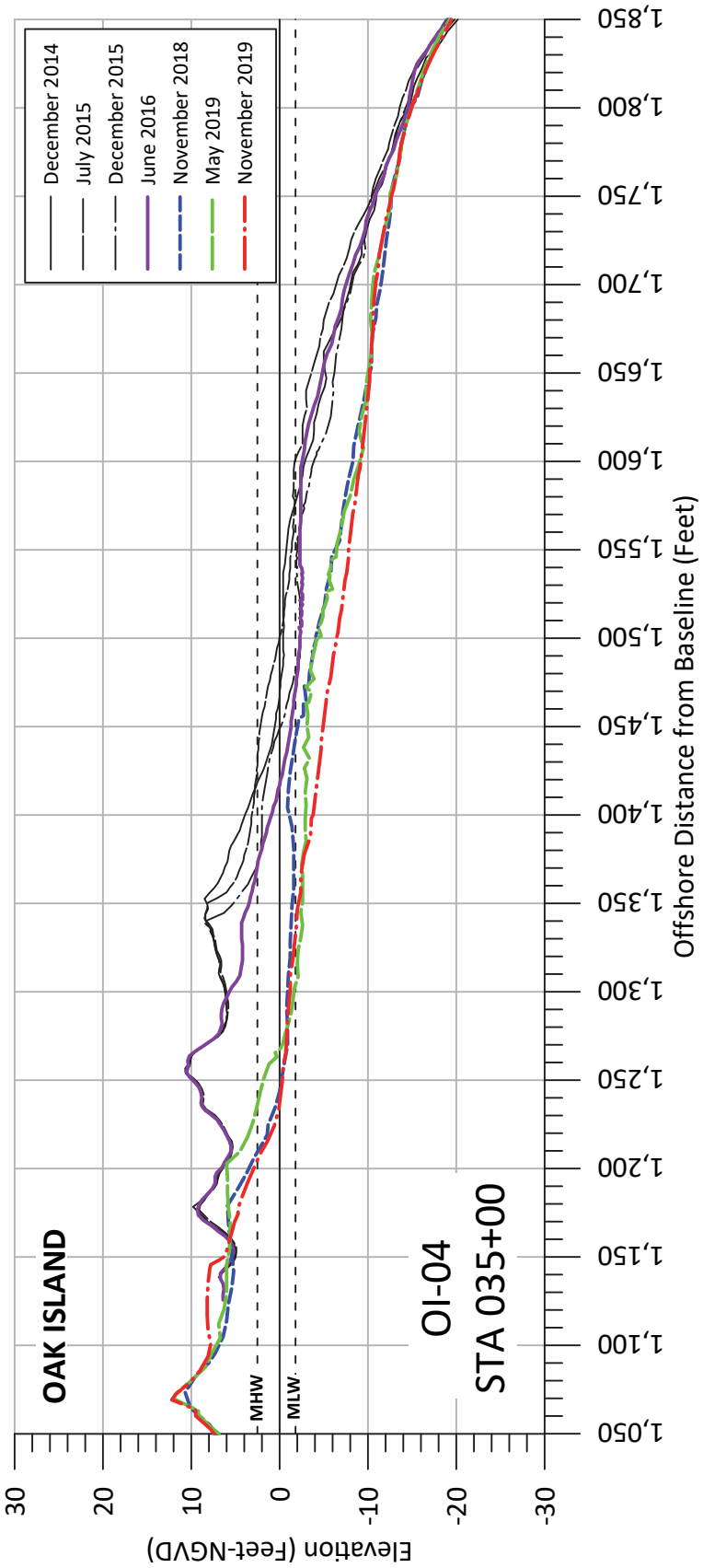


Figure C-04: Measured beach profiles at baseline **Station 035+00**, Oak Island, N.C.

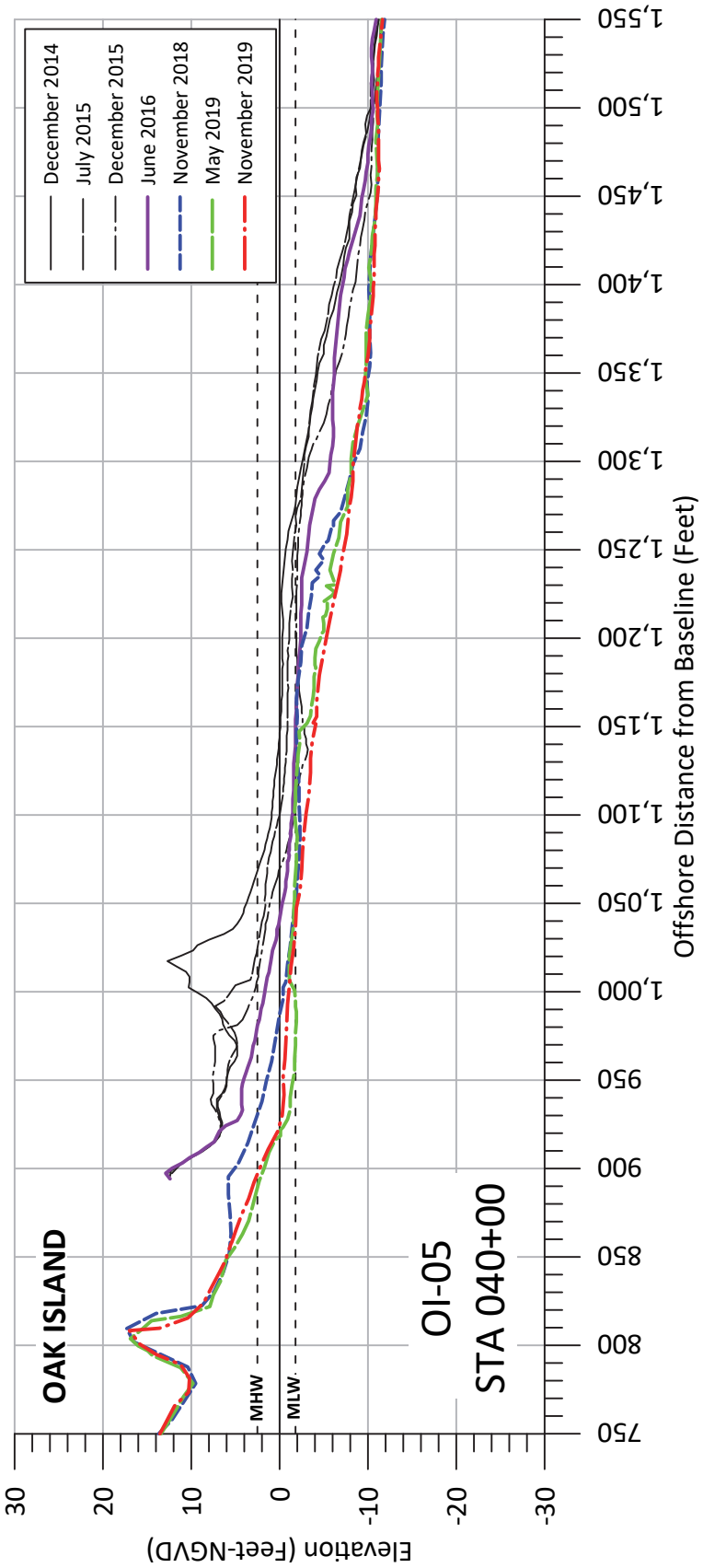


Figure C-05: Measured beach profiles at baseline **Station 040+00**, Oak Island, N.C.

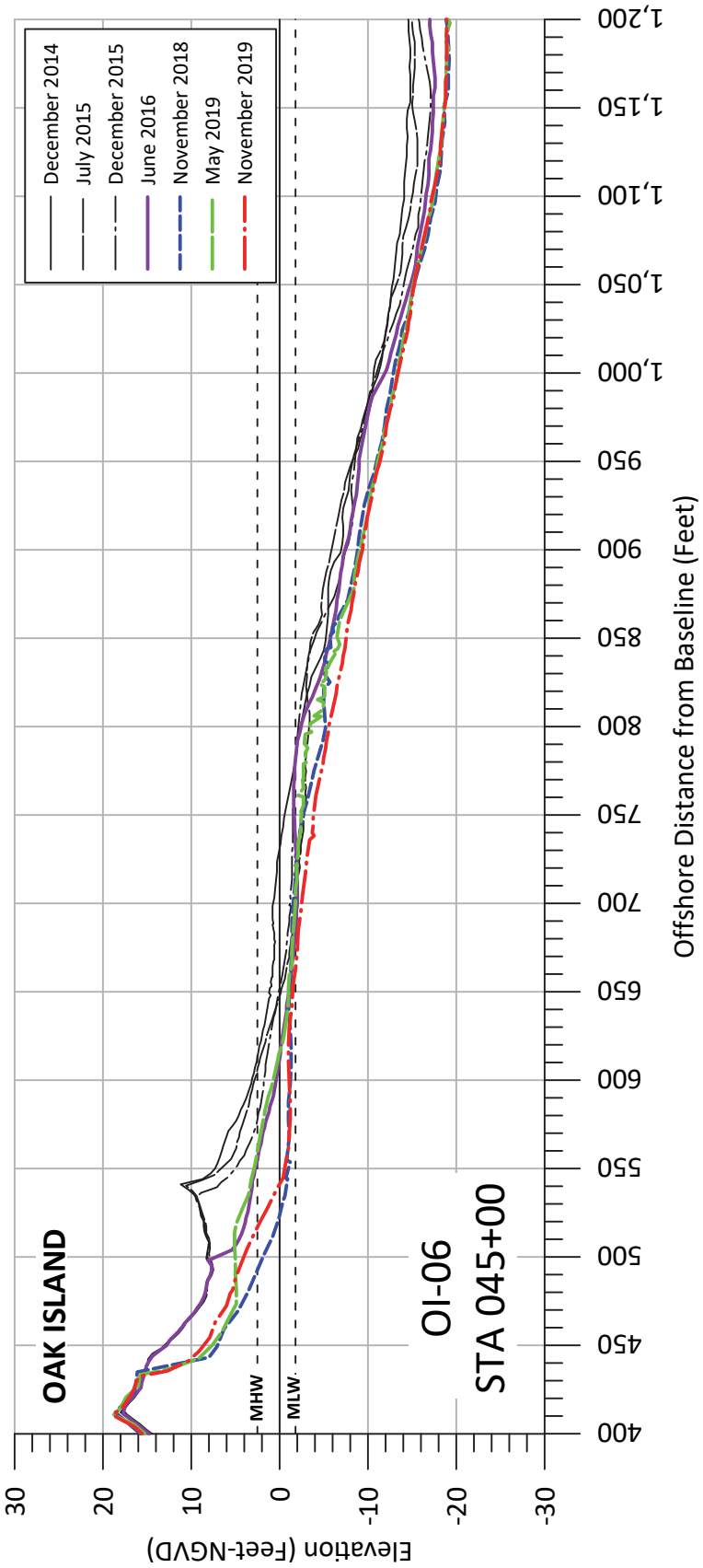


Figure C-06: Measured beach profiles at baseline **Station 045+00**, Oak Island, N.C.

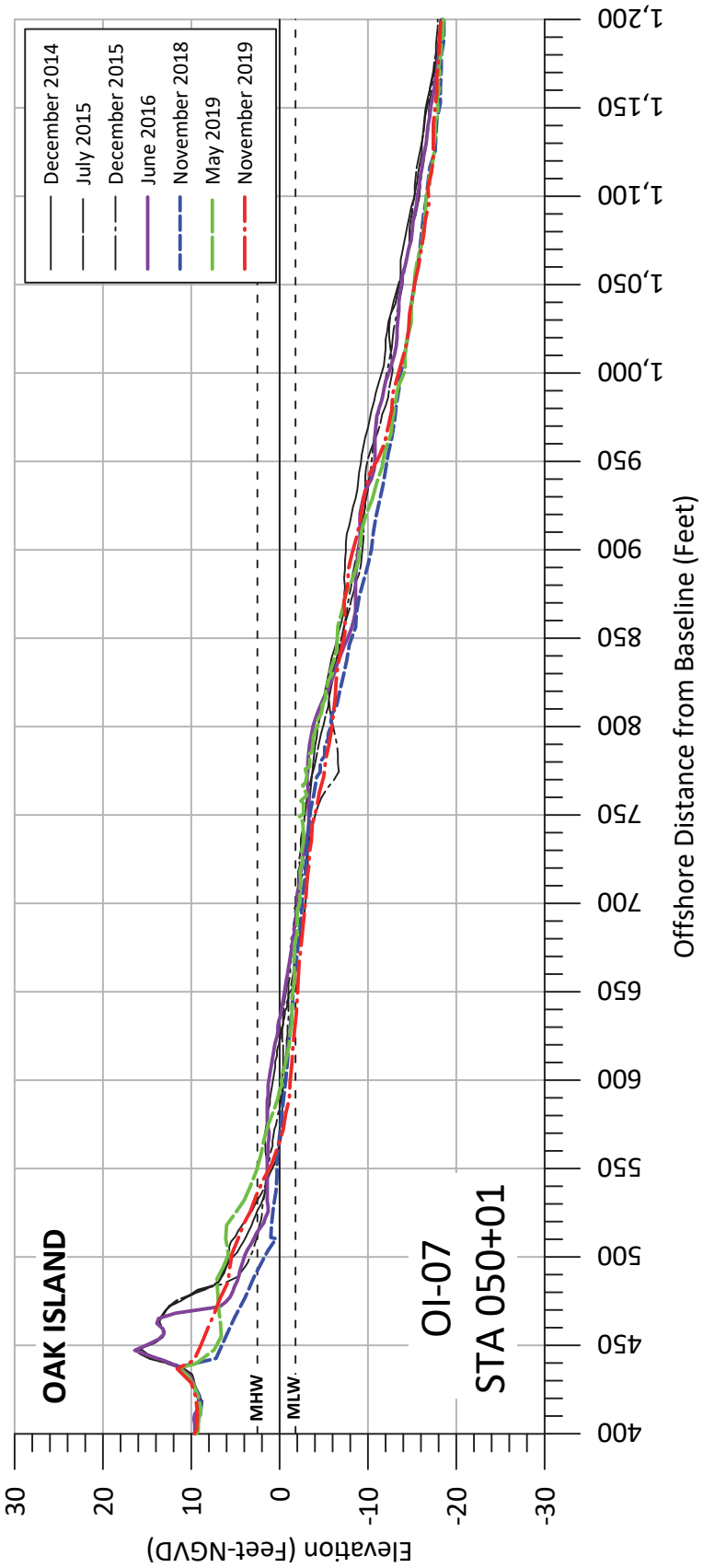


Figure C-07: Measured beach profiles at baseline **Station 050+01**, Oak Island, N.C.

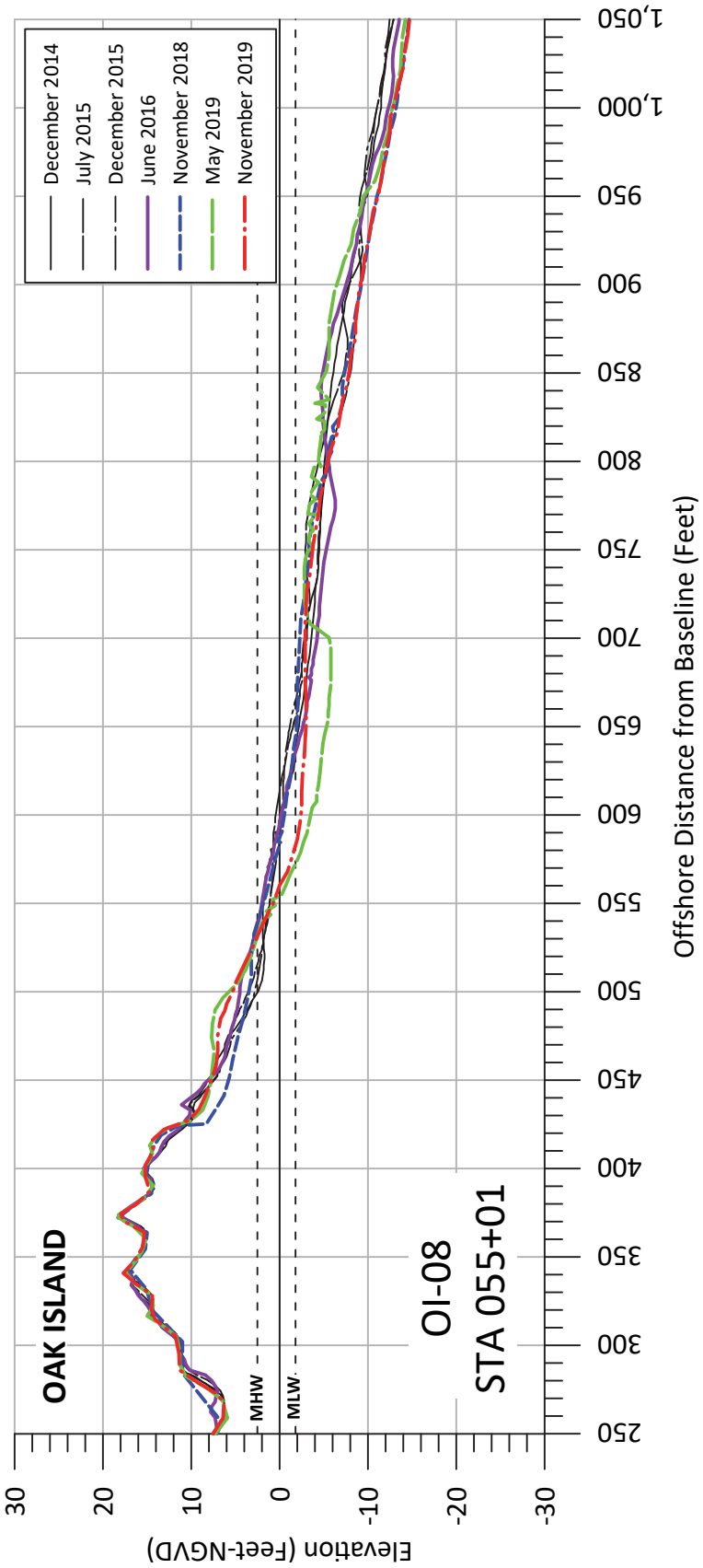


Figure C-08: Measured beach profiles at baseline **Station 055+01**, Oak Island, N.C.

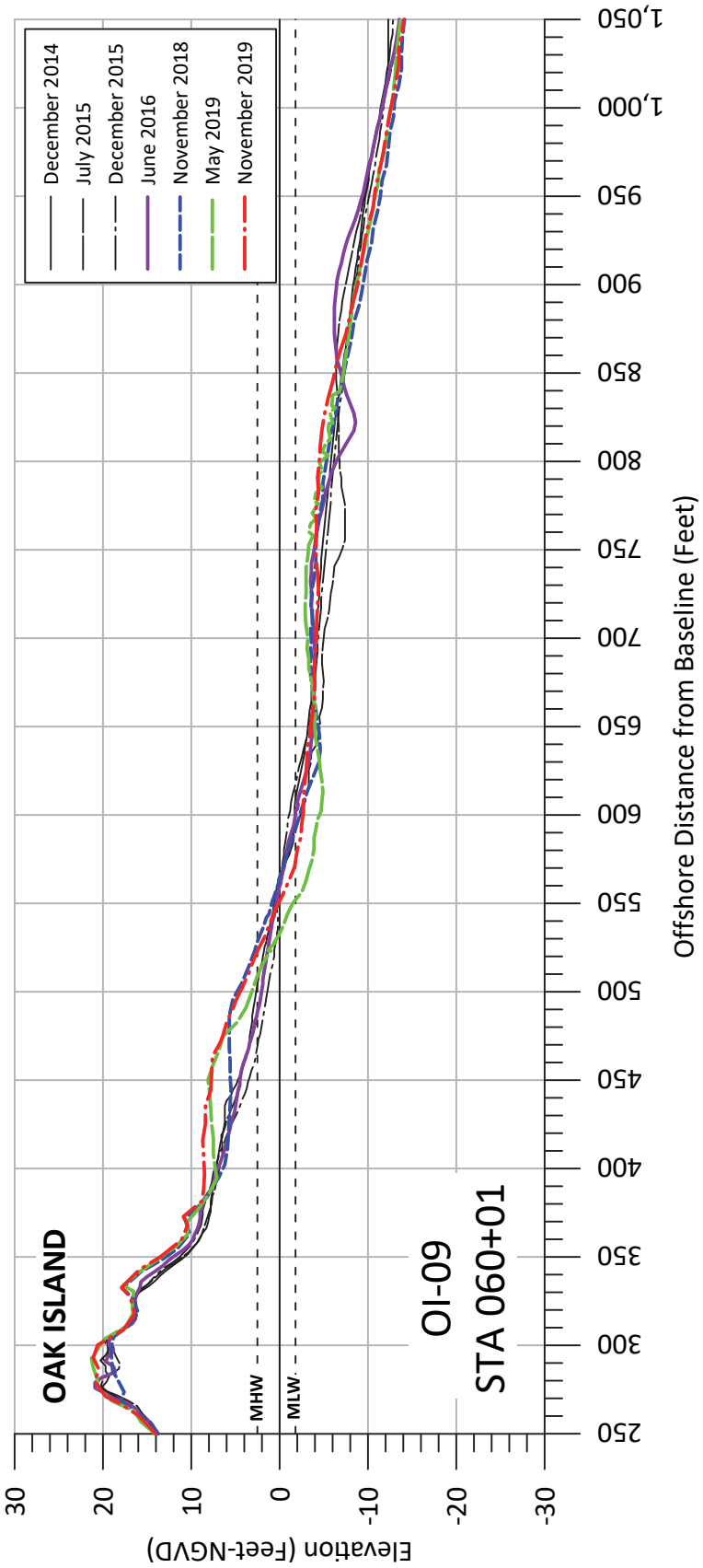


Figure C-09: Measured beach profiles at baseline **Station 060+01**, Oak Island, N.C.

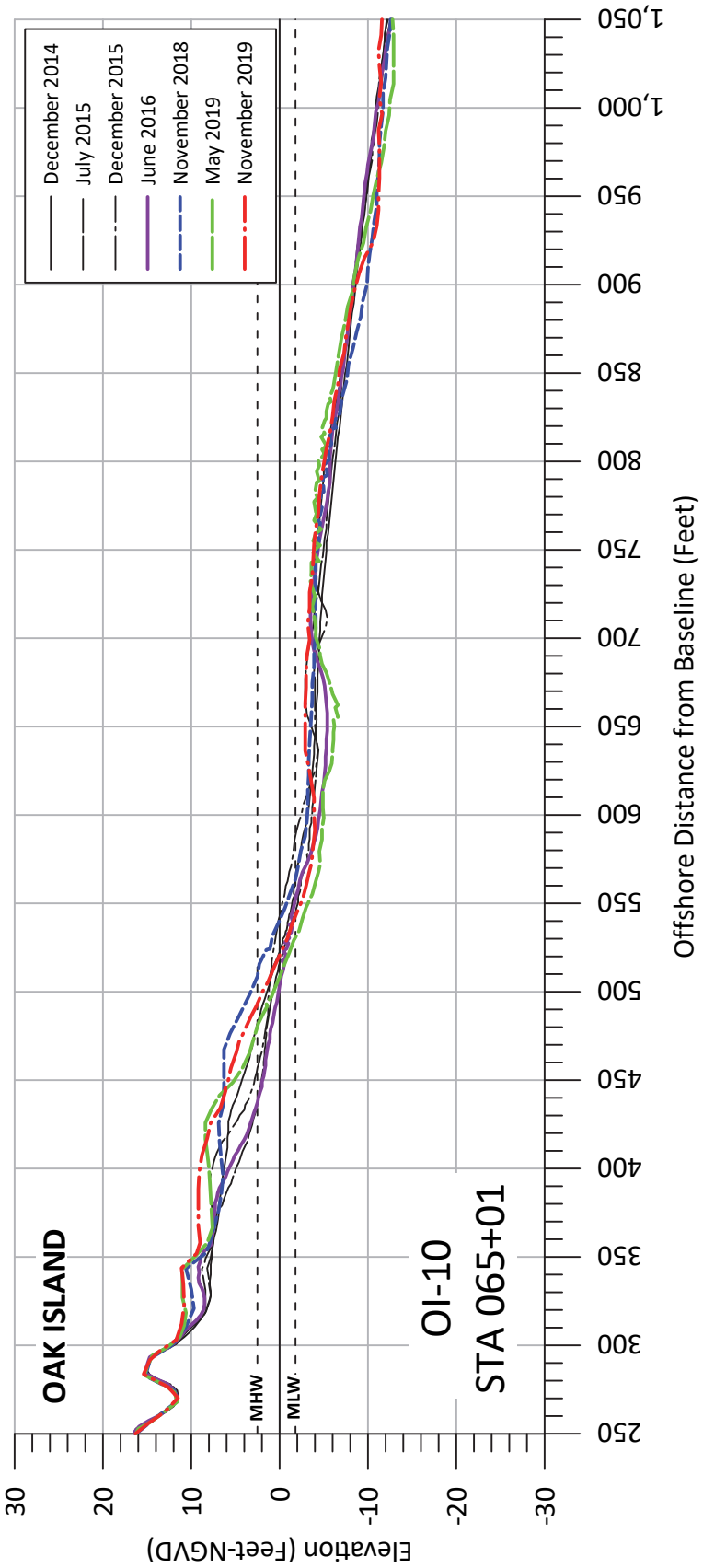


Figure C-10: Measured beach profiles at baseline **Station 065+01**, Oak Island, N.C.

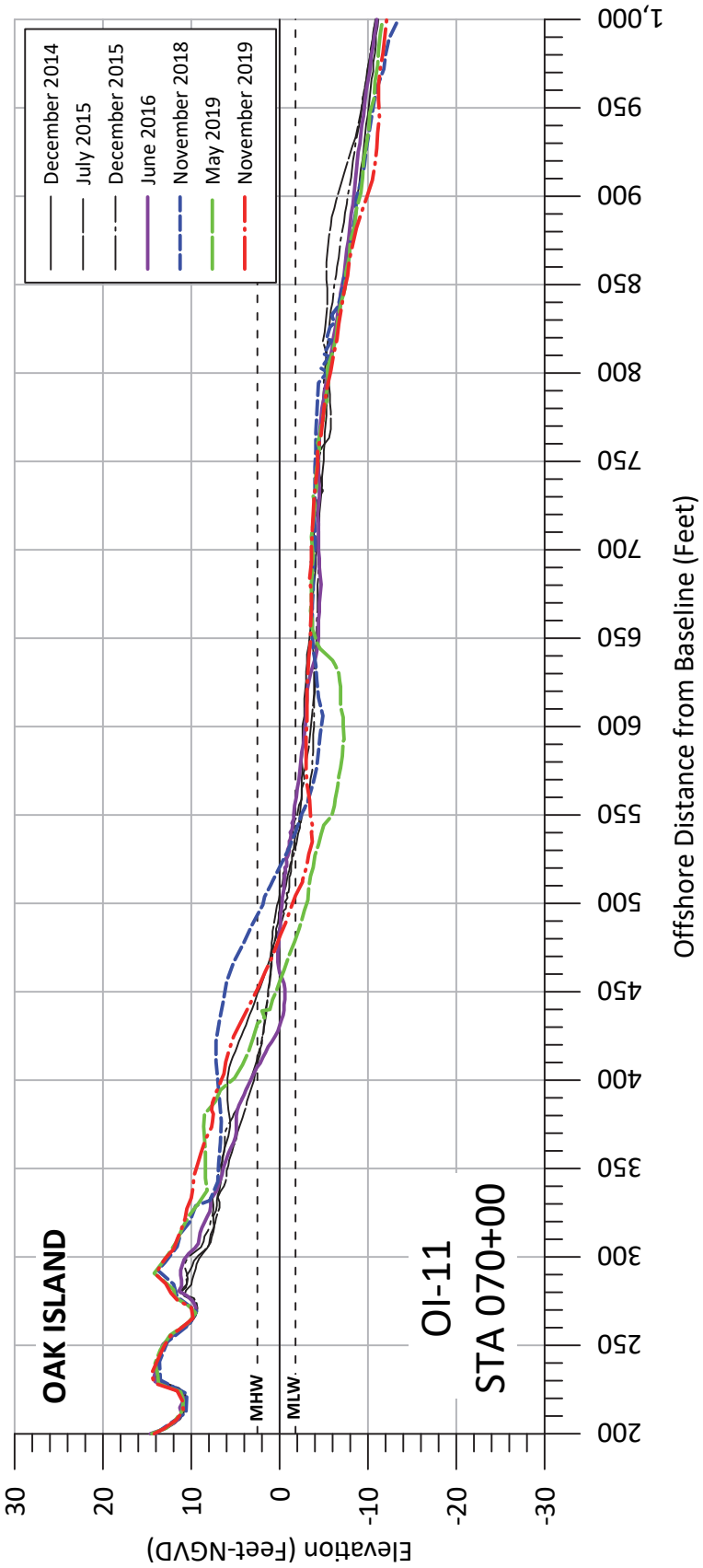


Figure C-11: Measured beach profiles at baseline **Station 070+00**, Oak Island, N.C.

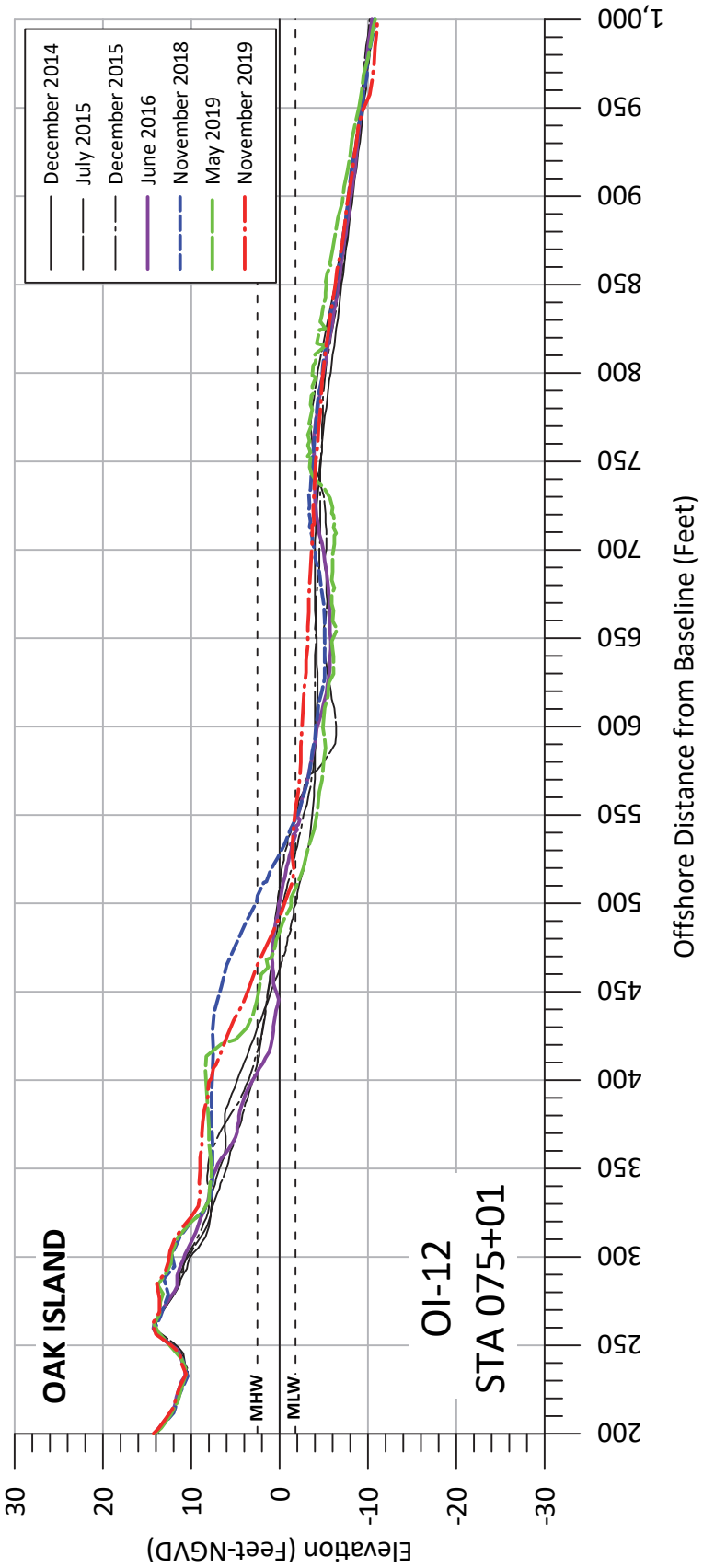


Figure C-12: Measured beach profiles at baseline **Station 075+01**, Oak Island, N.C.

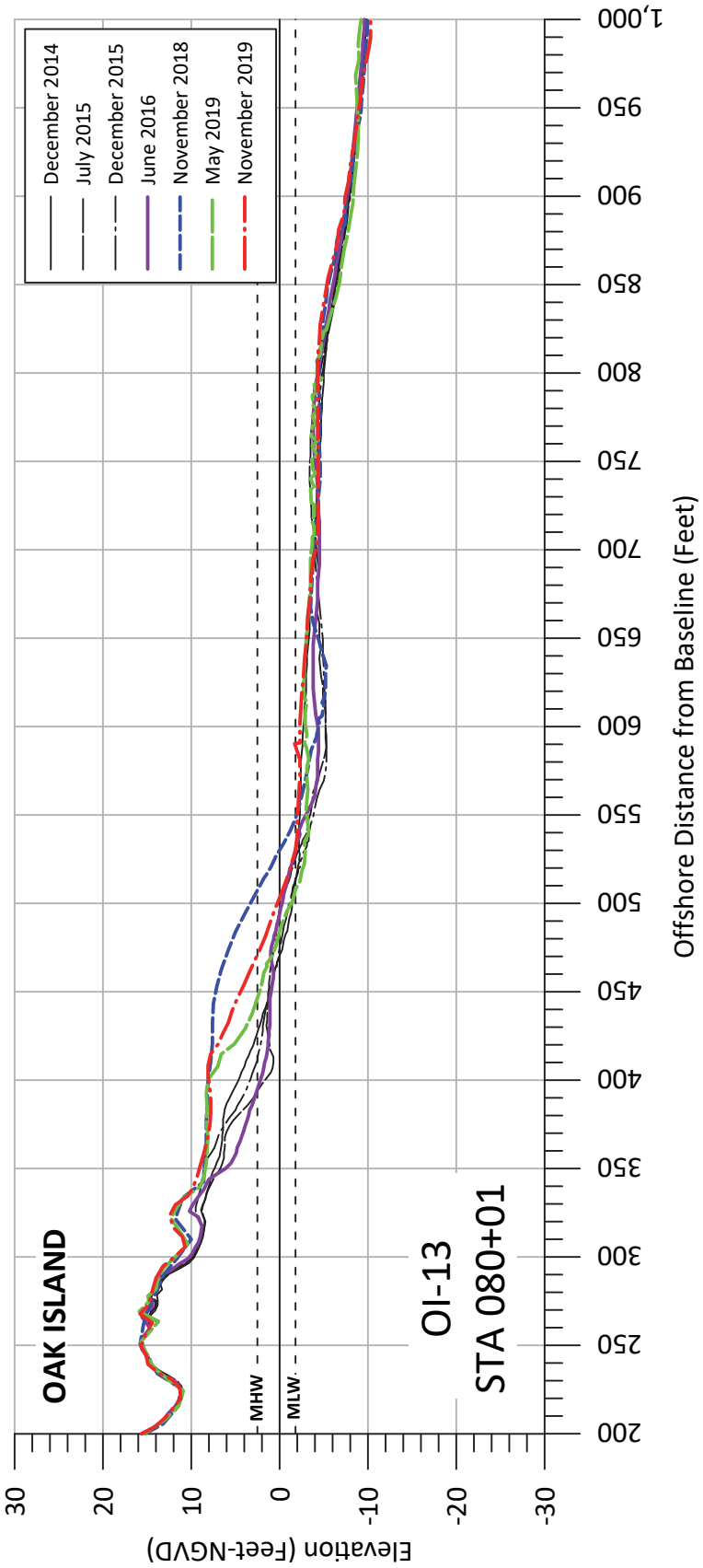


Figure C-13: Measured beach profiles at baseline **Station 080+01**, Oak Island, N.C.

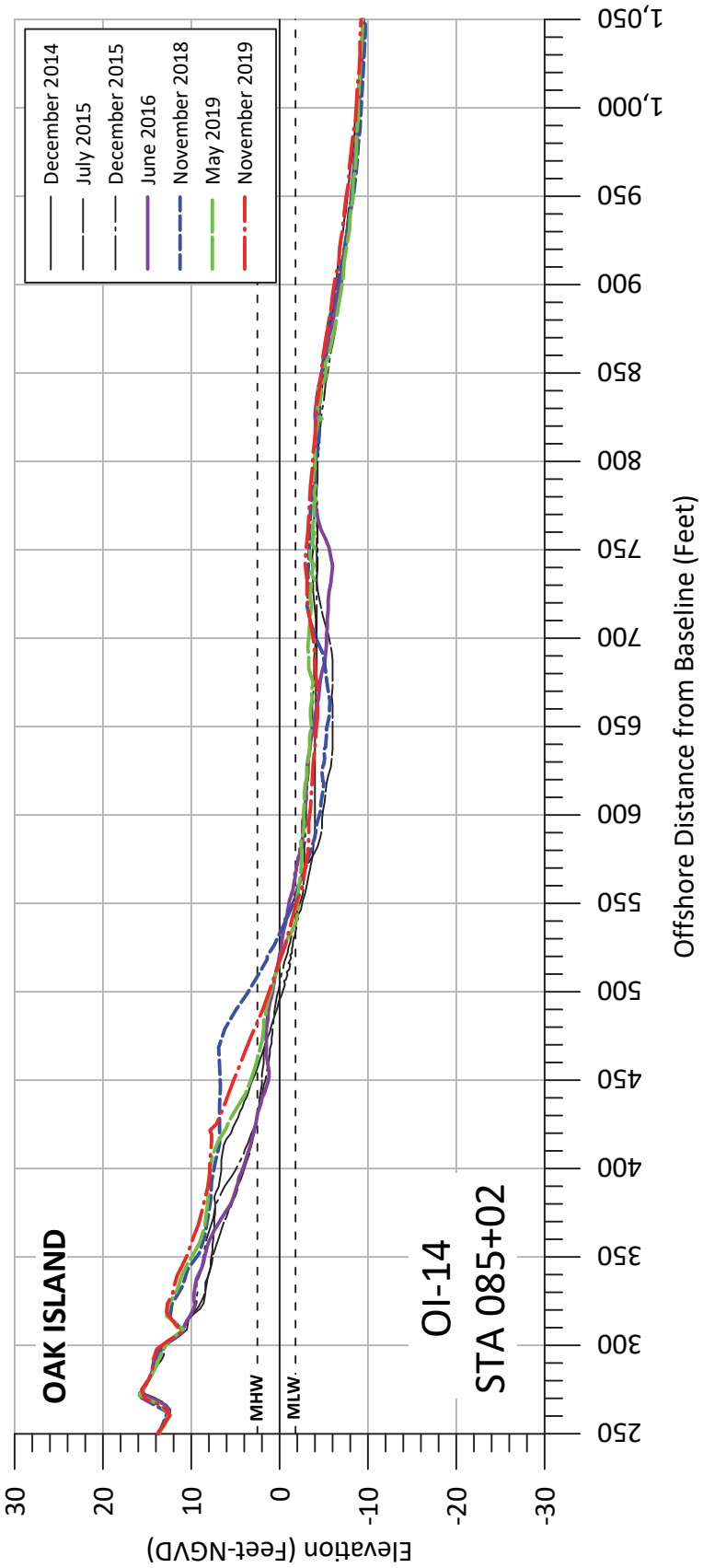


Figure C-14: Measured beach profiles at baseline **Station 085+02**, Oak Island, N.C.

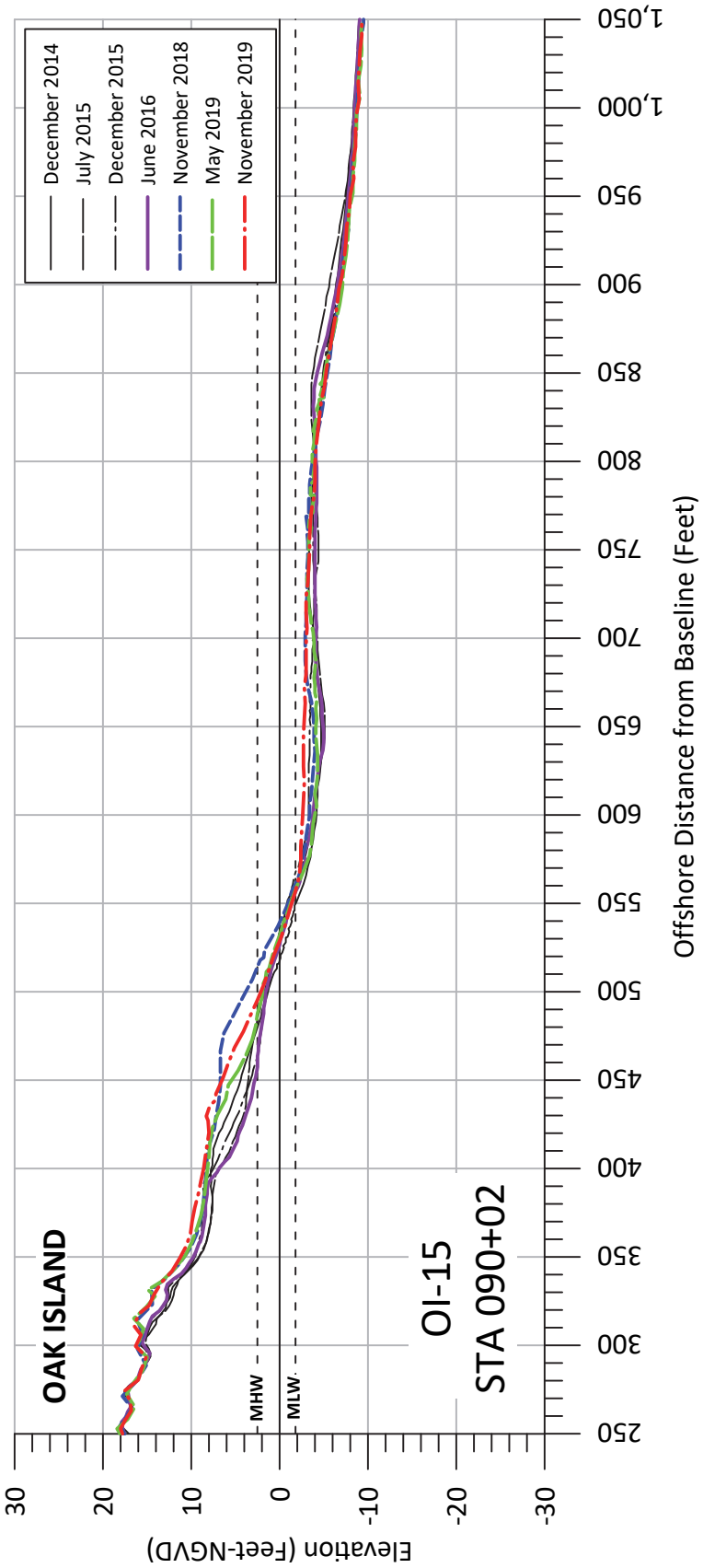


Figure C-15: Measured beach profiles at baseline **Station 090+02**, Oak Island, N.C.

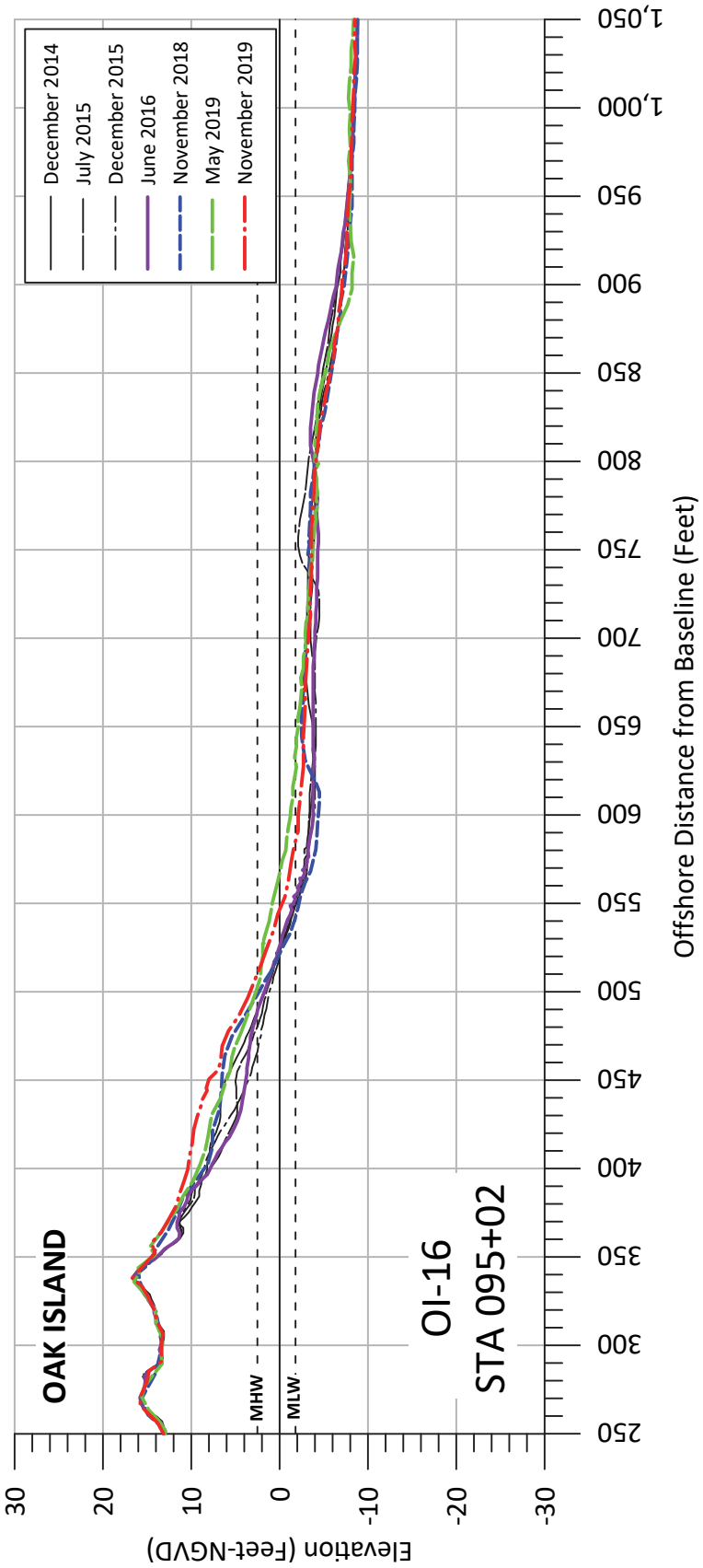


Figure C-16: Measured beach profiles at baseline **Station 095+02**, Oak Island, N.C.

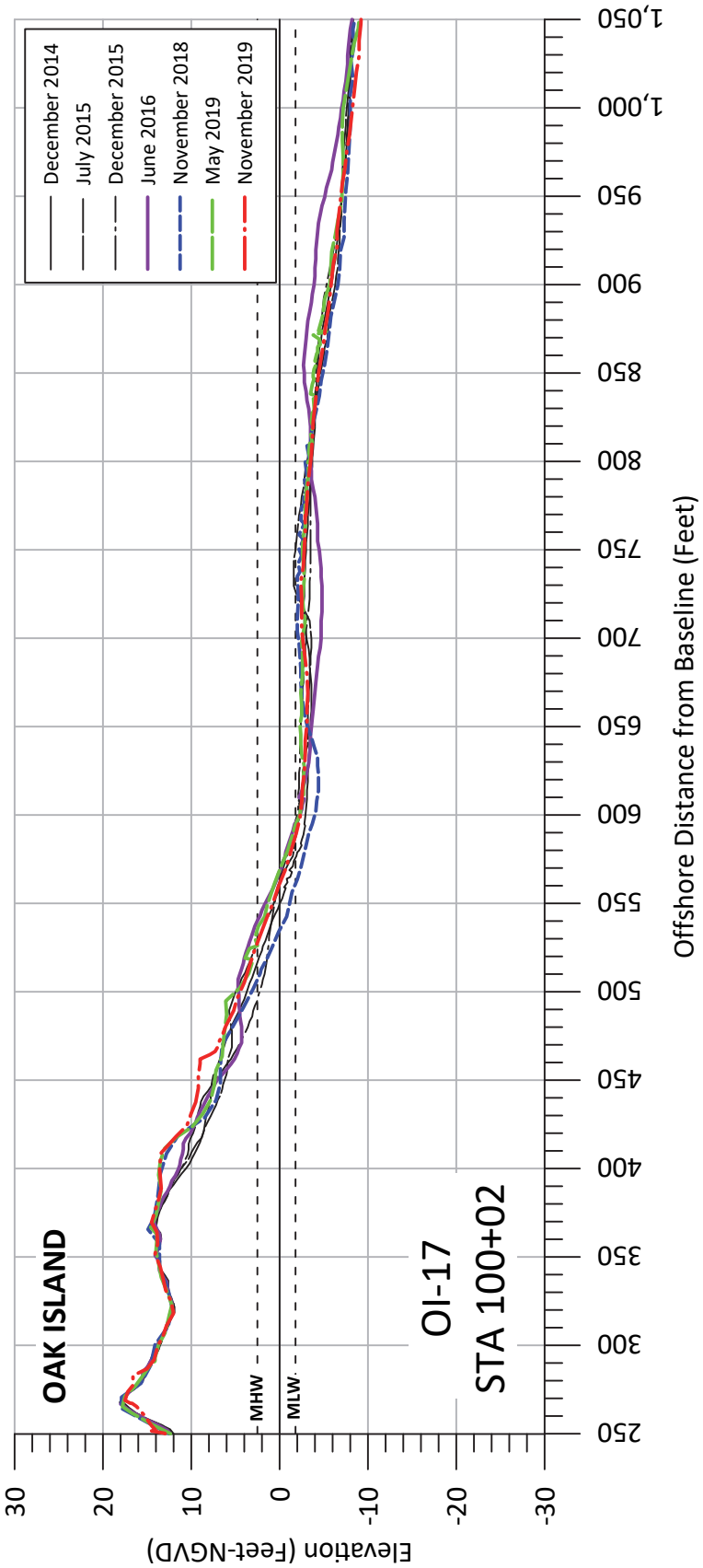


Figure C-17: Measured beach profiles at baseline **Station 100+02**, Oak Island, N.C.

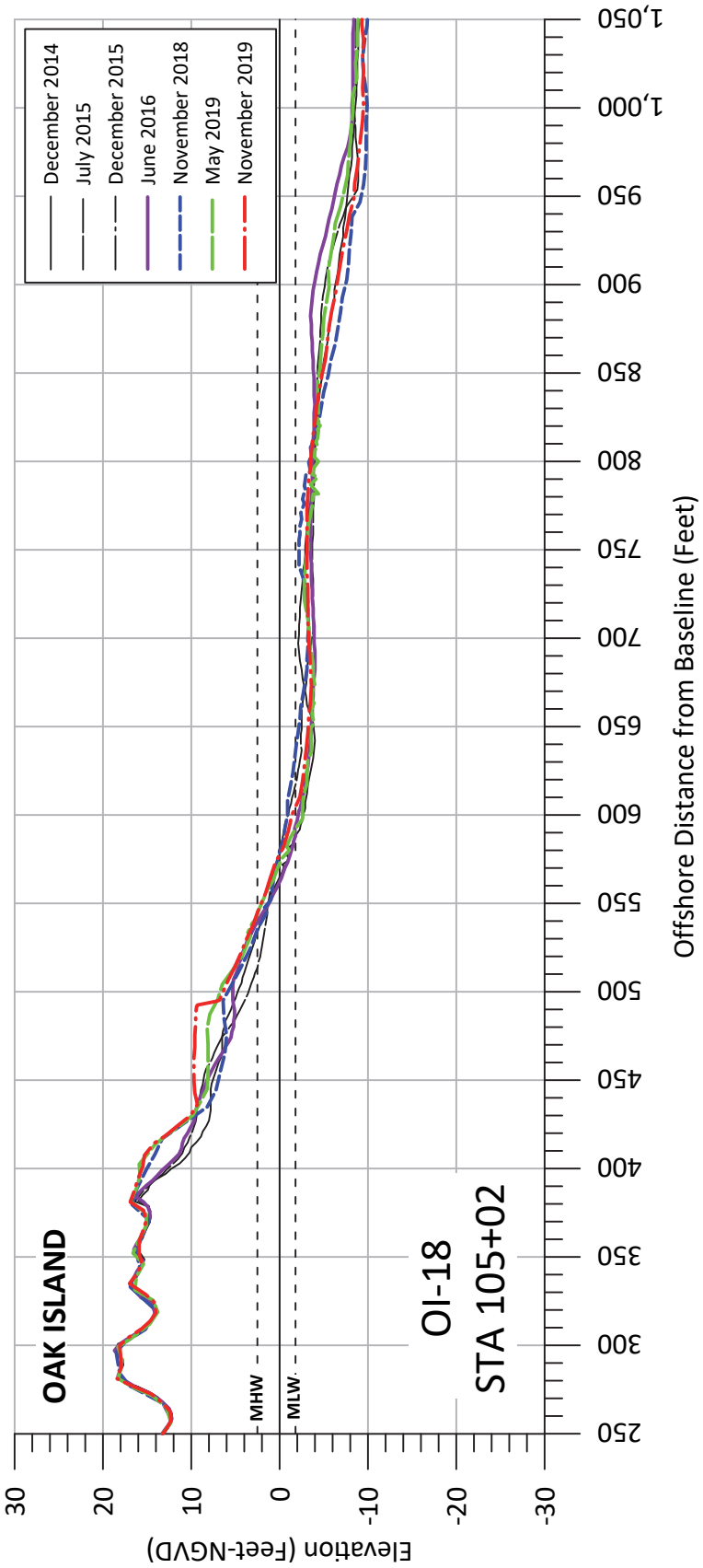


Figure C-18: Measured beach profiles at baseline **Station 105+02**, Oak Island, N.C.

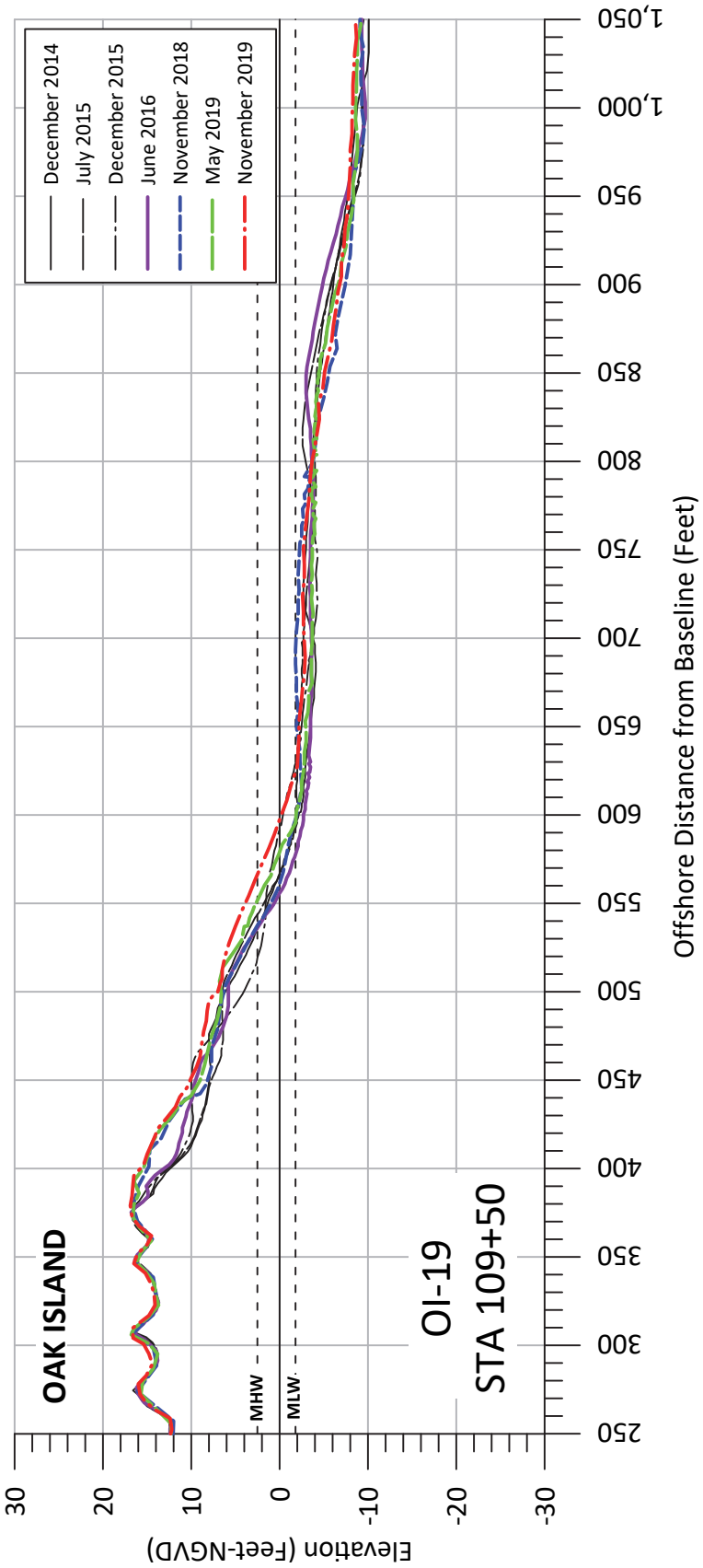


Figure C-19: Measured beach profiles at baseline **Station 109+50**, Oak Island, N.C.

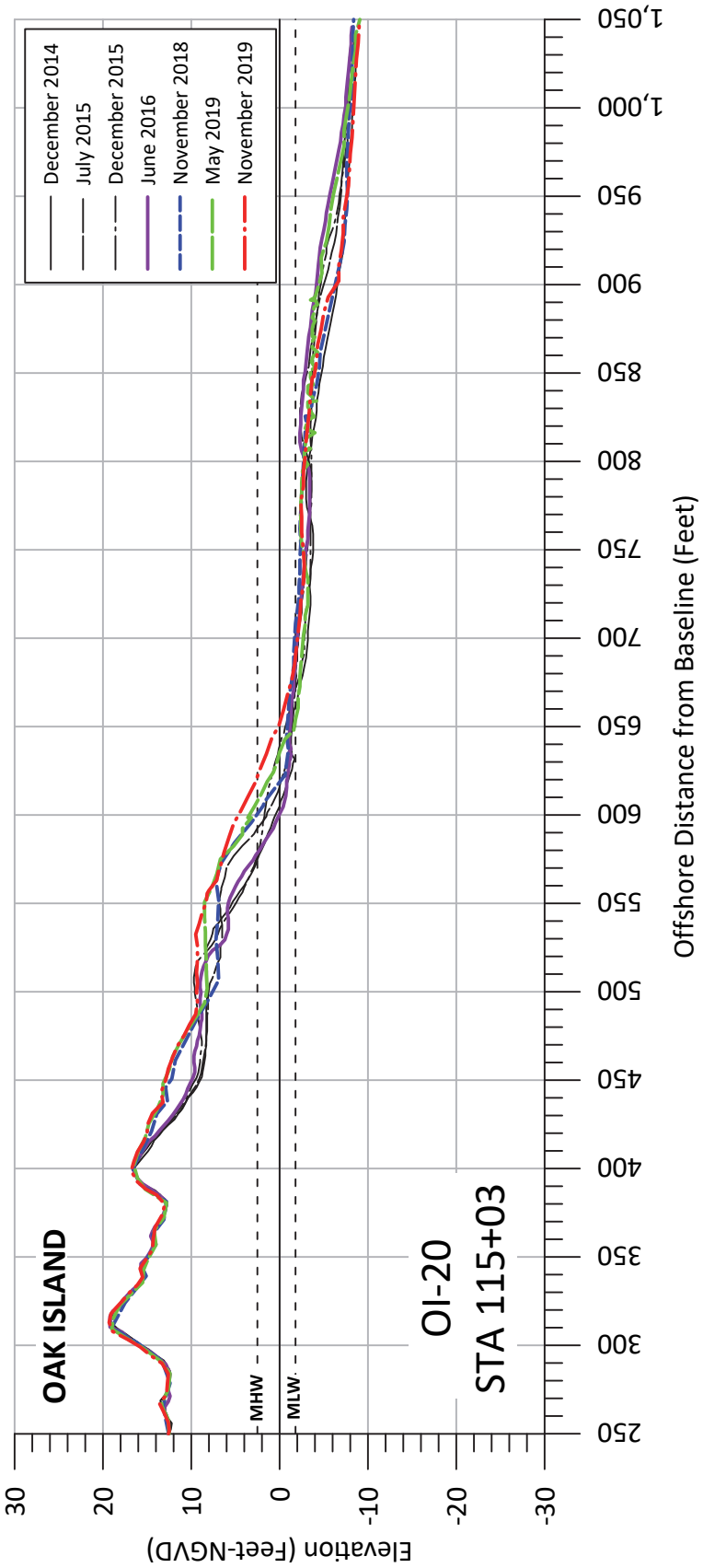


Figure C-20: Measured beach profiles at baseline **Station 115+03**, Oak Island, N.C.

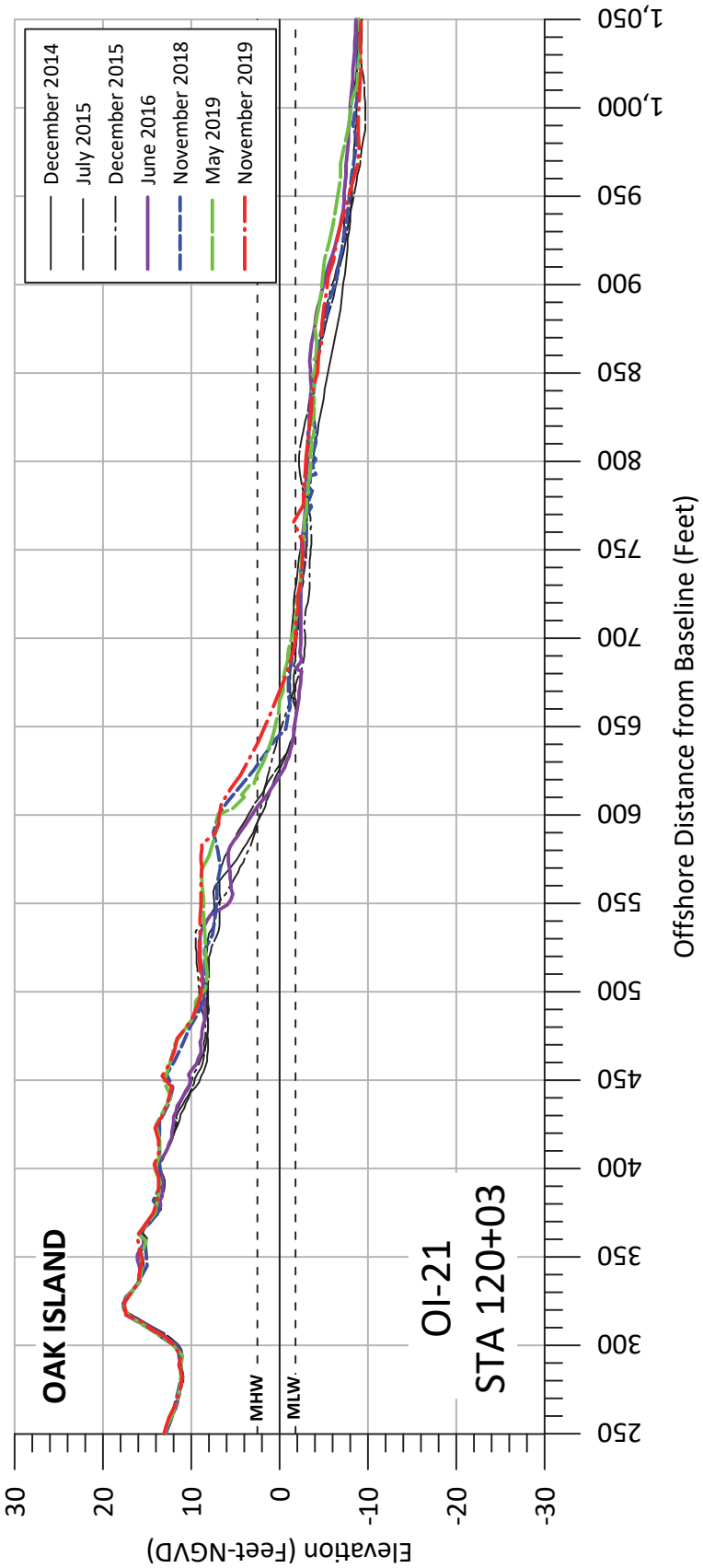


Figure C-21: Measured beach profiles at baseline **Station 120+03**, Oak Island, N.C.