Fire Island Inlet to Montauk Point, NY

Final General Reevaluation Report

APPENDIX A4

Numerical Modeling of Old Inlet Breach Opening

U.S. Army Corps of Engineers
New York District

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FIRE ISLAND TO MONTAUK POINT REFORMULATION STUDY – FINAL GRR
Appendix A4

Numerical Modeling of Old Inlet Breach Opening

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Memorandum

To: Lynn Bocamazo

From: Rafael Canizares

Date: September 11, 2015

Subject: Numerical Modeling of Breach Open at Old Inlet

Project: Fire Island to Montauk Point, NY

Contract: W912BU-10-D-0002, Task Order No. 0020

CC: Santiago Alfageme, Rob Hampson, Steve Couch

1.0 INTRODUCTION

Moffatt & Nichol (M&N) is contracted to provide engineering and numerical modeling services to the U.S. Army Corps of Engineers (USACE) in support of the Fire Island to Montauk Point (FIMP) General Re-valuation Report (GRR). Under Contract No. W912BU-10-D-0002, and Task Order No. 20, M&N performed additional numerical modeling simulations to validate the integrity of the previously completed modeling efforts and examine the applicability of the numerical model to the post-Hurricane Sandy breach open conditions at Old Inlet.

A detailed description of the overall FIMP numerical modeling approach is provided in USACE (2007). A brief overview of the modeling approach is provided below.

The numerical modeling strategy for FIMP addresses a comprehensive list of physical processes (wind conditions, barometric pressure, astronomic tide, wave conditions, and morphologic response, and localized wind and wave setup) by merging hydrodynamic, wave, and sediment transport models. The result is a description of storm surge elevations throughout the project for input into the economic analyses, coastal engineering design, environmental studies, and final alternative selection.

*The modeling method (*Figure 1*) consisted of four (4) process models: 1) WAVAD (i.e., WISWAVE) was applied to determine extreme storm wave conditions; 2) ADCIRC simulated the ocean and nearshore, outside the surf zone, storm water levels; 3) SBEACH was used to estimate pre-inundation dune lowering; and 4) the Delft3D model suite was used to compute the bay water levels under storm conditions, taking into account the contribution of storm surge, waves, winds and the contribution of overwash and/or breaching.*

The focus of this task order was the Delft3D model suite, specifically the hydrodynamic and wave models, and the applicability of the numerical model to the post-Hurricane Sandy breach open conditions at Old Inlet. The following tasks were completed under Task Order No. 20 and are documented in this memorandum:

- Re-validation of model to breach closed conditions

- Validation of model to breach open conditions at Old Inlet (Task 1)
- Impact on tides of breach open conditions at Old Inlet (Task 2c)
- Impact on storm tides of breach open conditions at Old Inlet (Task 2a)
- Stage frequency curves representing breach open conditions at Old Inlet (Task 2b)

The sections below will show that the breach open conditions at Old Inlet have a very small effect (up to 1 inch) on daily tidal fluctuations and small storm tides, but could have a large effect (up to 22 inches) on storm tides during severe Hurricanes and Nor'easters.

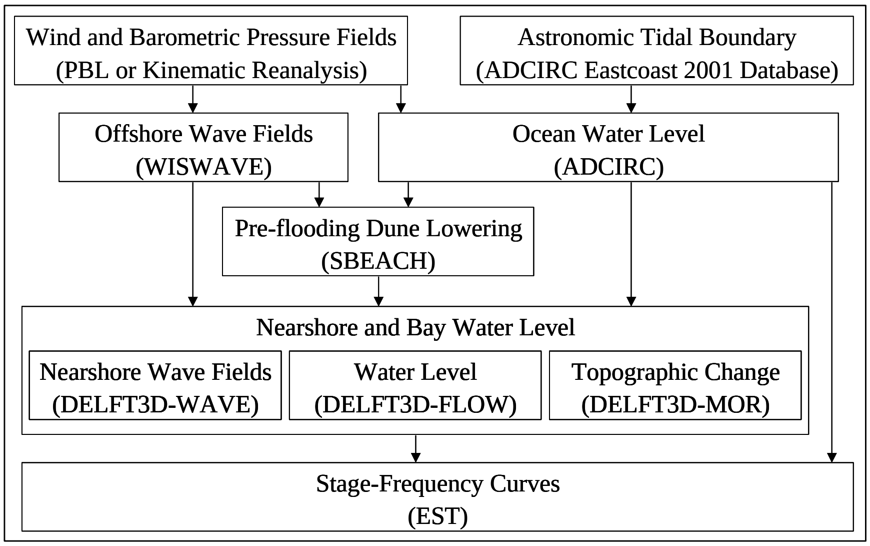

Figure 1: FIMP Modeling Framework

2.0 HYDRODYNAMIC MODELING

2.1 Validation to Breach Closed Conditions

In the years since the previous FIMP modeling work was completed new versions of the Delft3D software have been released and the wave model has been updated (SWAN instead of HISWA). As part of this task M&N updated the FIMP models to latest versions of the Delft3D software, requiring revised wave grids and reformatting wave boundary conditions. M&N repeated the original model validation to verify that the new modeling software produces very similar results to those obtained with the previous version. Simulations of combined hydrodynamics, waves, and winds were performed for model validation.

Model performance was evaluated using the comprehensive data set collected for the FIMP project in 2003 that is representative of breach closed conditions, but including measurements of flow through Fire Island and Moriches inlet. The model performance to reproducing the tidal propagation through the inlets and throughout the bays is evaluated by comparing the observed and modeled tidal constituents as presented in Figure 2. In addition, Figure 3 presents the comparison of simulated and observed flow through Fire Island Inlet and Moriches inlet. Finally, simulated and measured water levels were also compared during the Blizzard of 2003, and are presented in Figure 4. Conclusions of the model performance are:

- The model accurately reproduces the flow through the inlets (Fire Island and Moriches) for the calibrated model parameters and the right bathymetric conditions

- The model accurately reproduces the tidal propagation in the Bays and the exchange between Great South Bay and Moriches Bay

- The model reproduces quite accurately the effect of winds and waves during a storm and the propagation of the storm surge through the existing inlets.

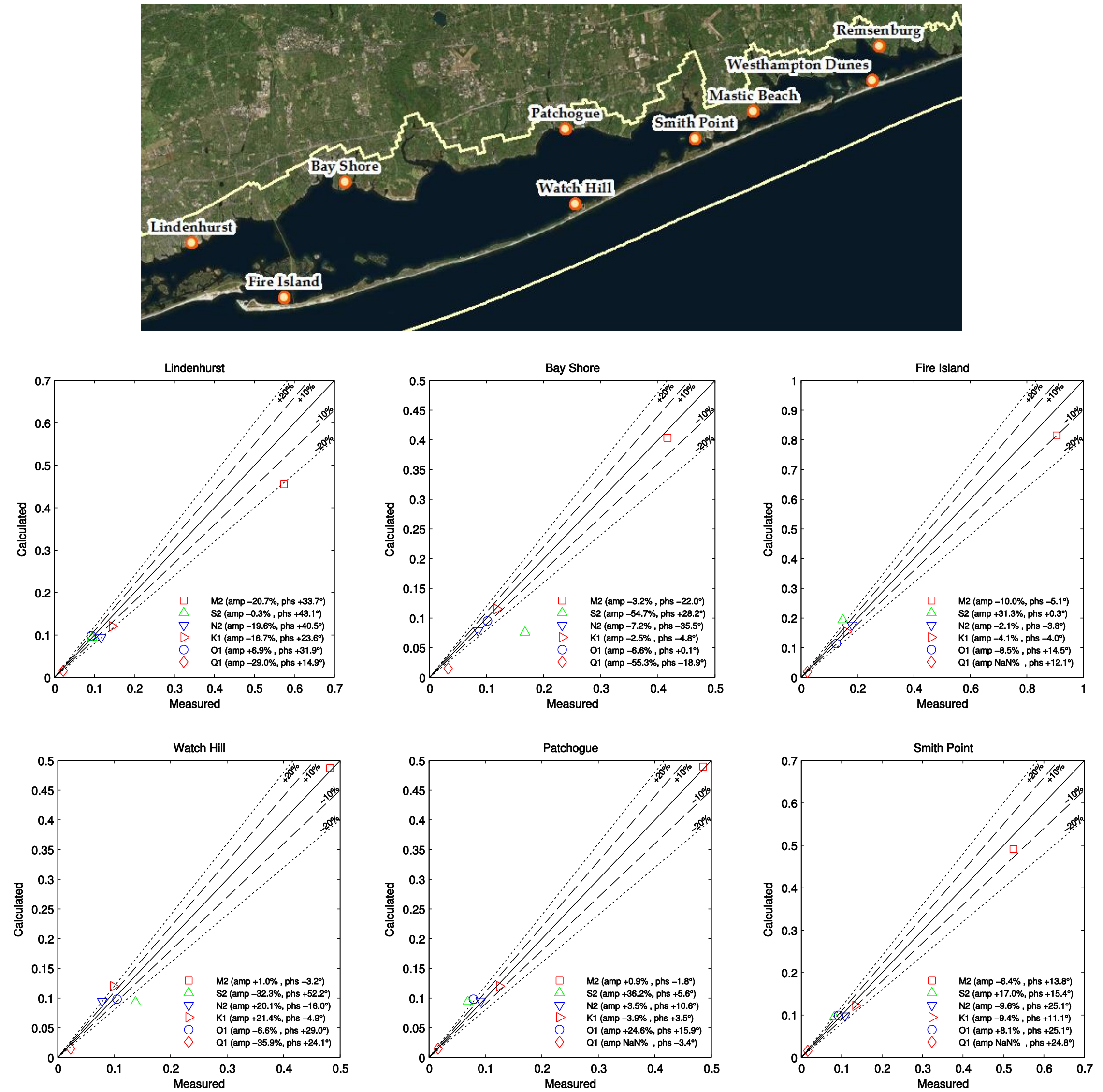

Figure 2: Breach Closed Tidal Constituent Analysis

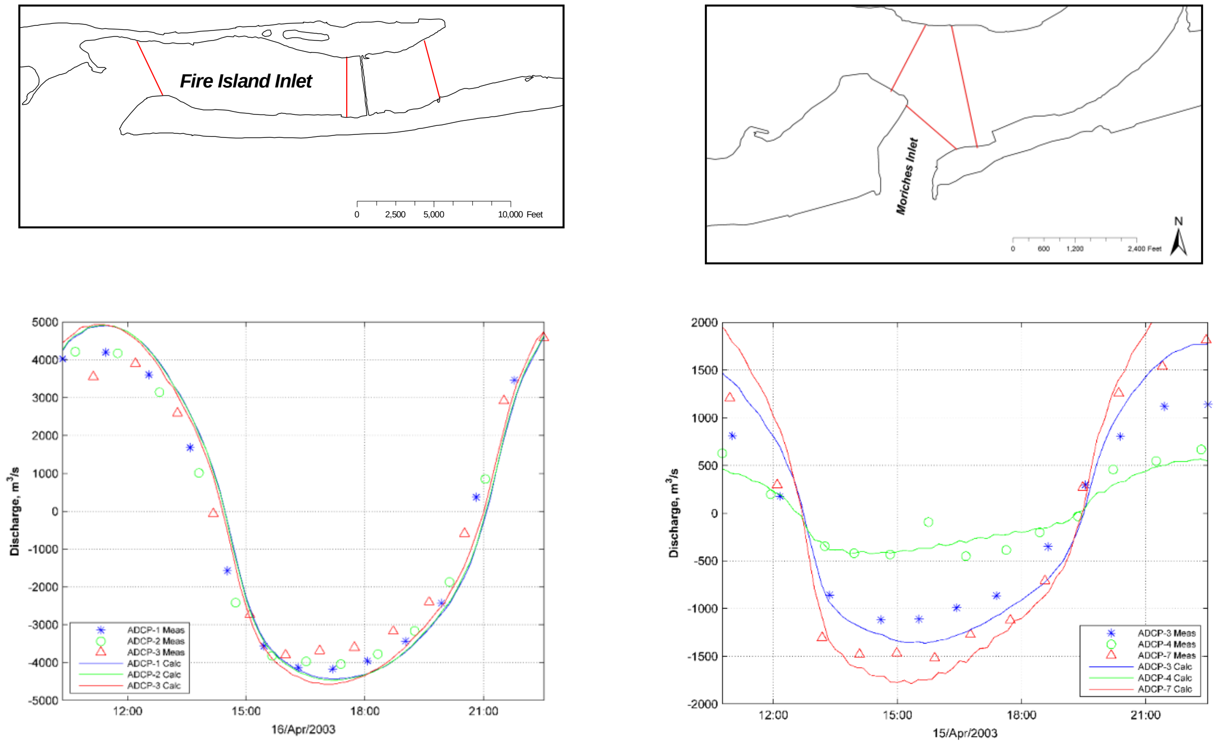

Figure 3: Observed and Modeled Flow through Fire Island and Moriches Inlets

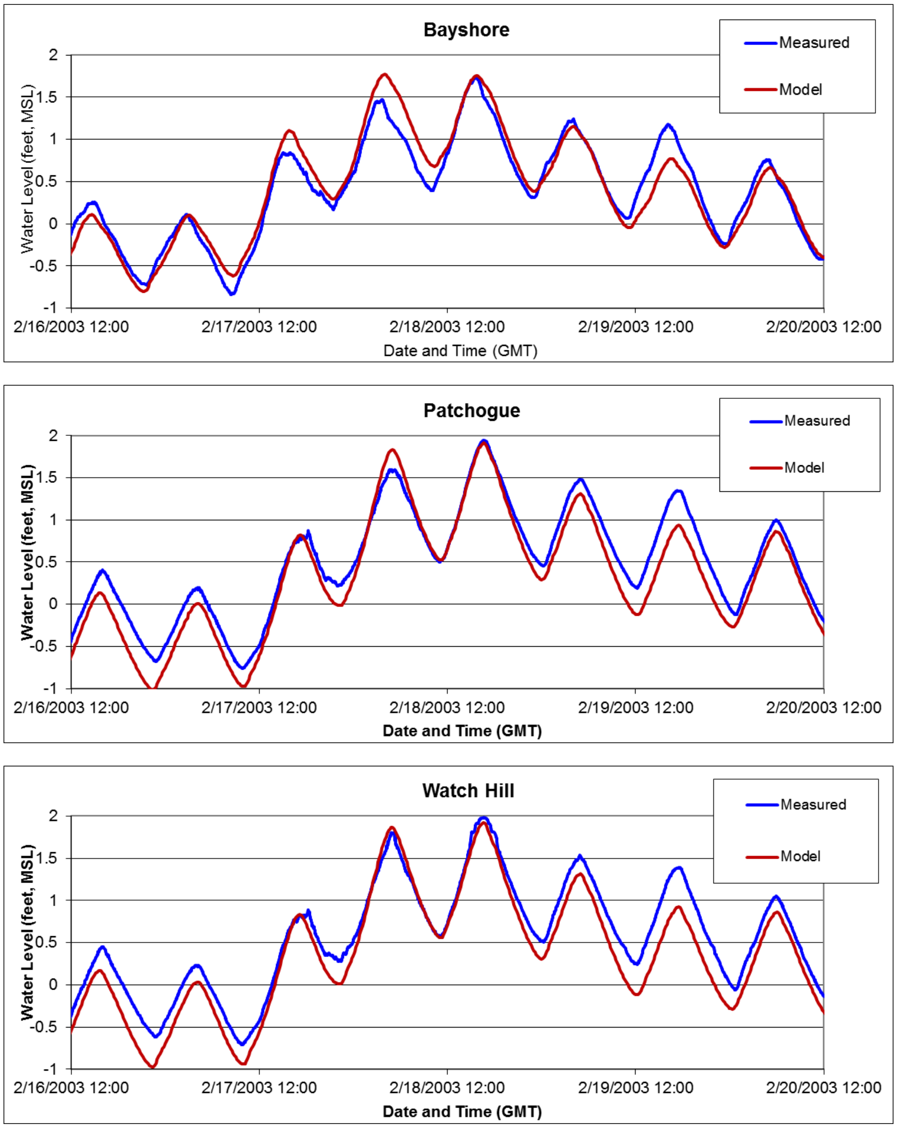

Figure 4: Blizzard of 2003 Observed and Modeled Water Levels

2.2 Validation to Breach Open Conditions

In order to evaluate the performance of the numerical model (Delft3D) in simulating breach open conditions, 2-year model simulation, Nov 1st 2012 to Nov 1st 2014, was performed with a new model bathymetry capturing the breach open conditions at Old Inlet. Regular observations by SUNY Stony Brook, aerial photos and bathymetric surveys, captured the dynamic nature of the breach at Old Inlet. After the formation of the breach during Hurricane Sandy (October 29th, 2013) the breach grew rapidly for the several months before breach growth slowed. A fixed model bathymetry was used to simulate the breach open conditions at Old Inlet rather than trying to model the evolution of the breach morphology. The surveyed conditions at Old Inlet from June of 2014 are used in the revised model bathymetry (Figure 5). The breach open conditions from June of 2014 are representative of the majority of the conditions during the 2-year simulation, however the modeled breach size could lead to an overestimation of the effects of the breach during the first months when the breach was rapidly growing. The June 2014 model bathymetry was also chosen to be consistent and allow comparison with the ongoing modeling efforts by the USGS (van Ormond et al. 2015).

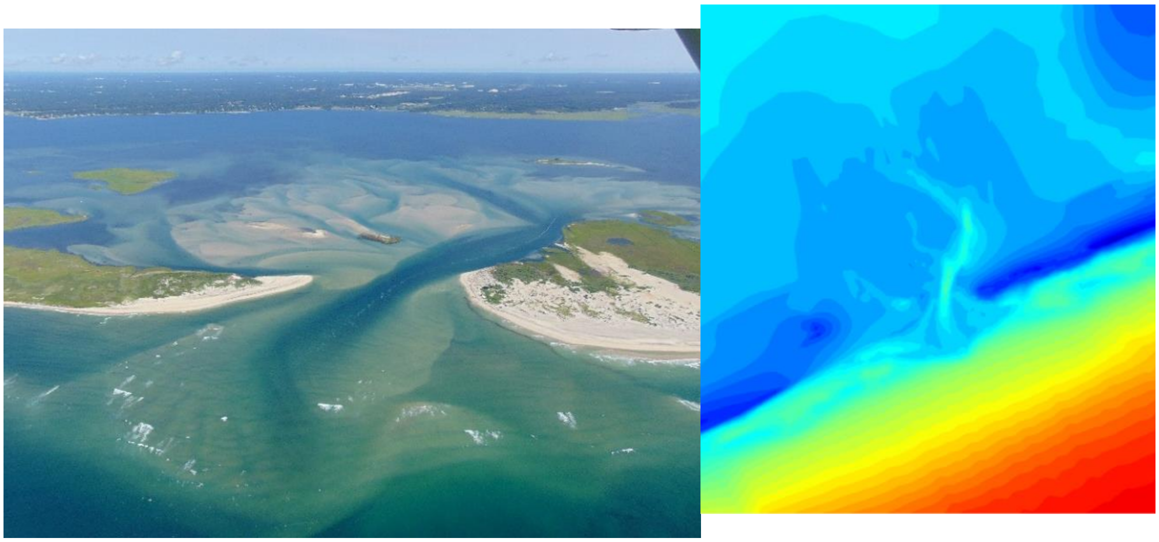

Figure 5: Aerial of Old Inlet Breach on June 24, 2014 (http://po.msrc.sunysb.edu/GSB/) and Model Bathymetry

Hydrodynamic model boundary conditions for the 2-year validation simulation were specified as water levels consisting of astronomical and residual (surge) components. Astronomical water levels were obtained from the Oregon State University TPXO global model, East Coast of the USA model of 1/30° resolution. Residual water levels were extracted from measured water levels at NOAA Station 8518750 The Battery, NY. Waves were not included in the 2-year simulation.

Observed water levels are available at several stations in Great South Bay from SUNY Stony Brook, United States Coast Guard, and USGS. SUNY Stony Brook data at Bellport and Tanner Park, USCG data at Fire Island Inlet, and USGS data Lindenhurst (USGS 01309225) was available for model validation. Reported water levels, referenced to a vertical datum, are available from the NOAA station at Lindenhurst. The available data from SUNY Stony Brook and USCG is pressure readings which M&N converted to water depth fluctuations based on the atmospheric pressure at Long Island MacArthur Airport (METAR KISP). The SUNY and USCG data was demeaned and assumed to be relative to local Mean Sea Level (MSL).

A harmonic analysis of the observed and modeled tidal constituents was performed at these four stations as shown in Figure 6. A relatively long period of uninterrupted data collection is required for the harmonic analysis. The most suitable time period for the harmonic analysis was a two month period January 1st 2014 to March 1st 2014.

The comparison of modeled and observed water level during the nor'easter of November 2012, 1 month after Hurricane Sandy, is shown in Figure 7. Despite the uncertainty in the model bathymetry, boundary conditions, and not considering the effect of waves, the model accurately reproduces the tidal propagation and storm surge propagation in Great South Bay. The differences between the modeled and observed water levels during November 2012 are consistent with those shown by van Ormandt et al. (2015). The model generally over predict the maximum water elevation which could be a consequence of performing the simulations with a larger cross section at the breach than the one that existed during that data period.

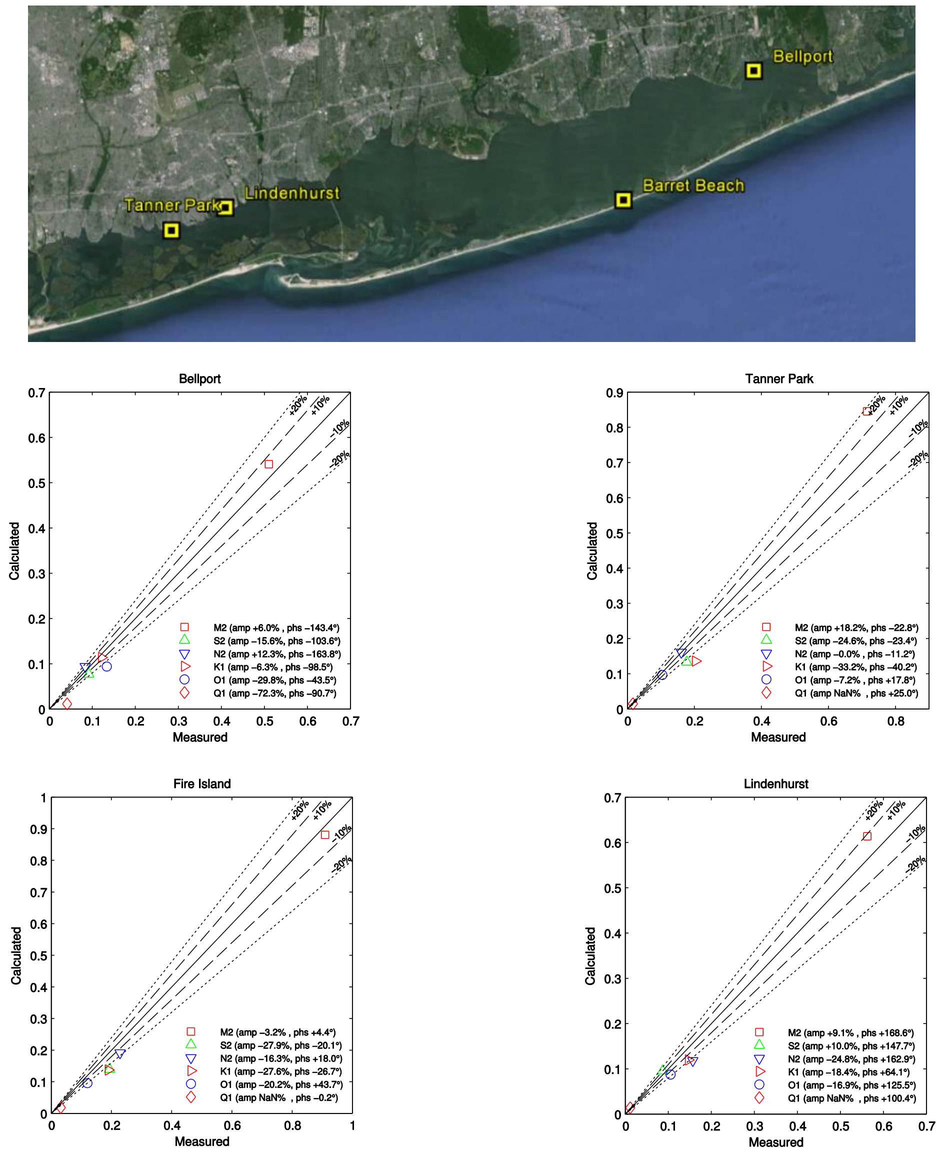

Figure 6: Breach Open Tidal Constituent Analysis

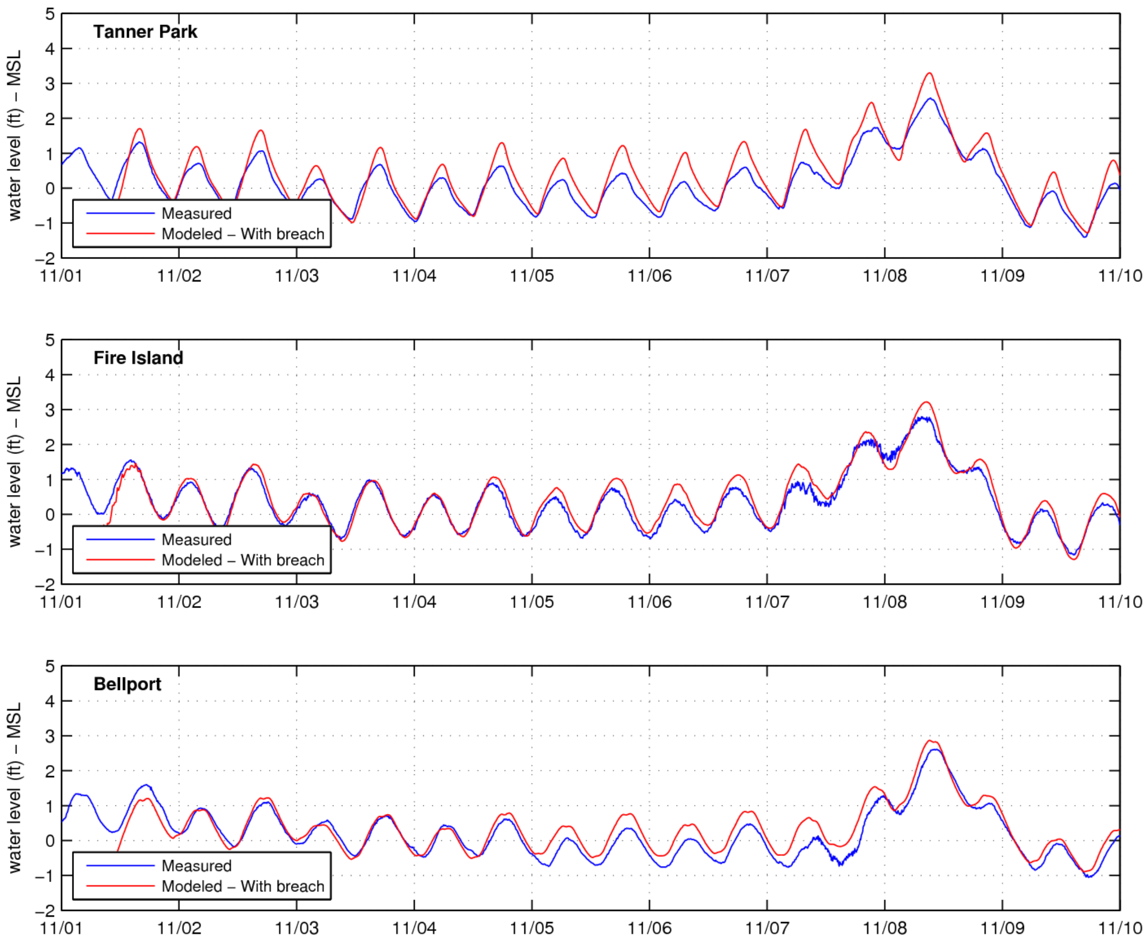

Figure 7: Nov 2012 Observed and Modeled Water Levels with Breach Open

2.3 Impact on Tides of Breach Open

2.3.1 Impact on Astronomical Tide

In order to assess the impact of the breach open conditions at Old Inlet on tides and small storm tides the 2-year validation simulation, Nov 1st 2012 to Nov 1st 2014, was repeated with breach closed conditions. A comparison of the calculated M2 tidal constituent and Mean High Water (MHW) was performed to characterize the effect of the breach on tides in Great South Bay. A summary of the results is provided in Table 1. The absolute changes in inches and relative changes in percent of the M2 tidal constituent and MHW are shown in Table 2. The changes to the tide at Fire Island, Tanner Park, and Bellport are all relatively small (less than 4%) or 0.4 inches. However, the change at Lindenhurst is much greater, and shows an increase of up to 1 inch in the amplitude of the M2 tidal constituent and MHW. These results are consistent with van Ormondt et al. (2015) which showed a relatively large increase (15%) in the amplitude of the M2 tidal constituent at Lindenhurst and only minor increase (2%) in the M2 tidal constituent at Bellport.

Table 1: Observed and Modeled Tidal Datums

Tidal Datum	Observed	Modeled	
		Breach Open	Breach Closed
Fire Island			
MHW (ft)	0.921	0.892	0.885
MSL (ft)	0.000	0.000	0.000
MLW (ft)	-0.946	-0.893	-0.886
Tanner Park			
MHW (ft)	0.799	0.801	0.774
MSL (ft)	0.000	0.000	0.000
MLW (ft)	-0.765	-0.802	-0.775
Bellport			
MHW (ft)	0.545	0.493	0.499
MSL (ft)	0.000	0.000	0.000
MLW (ft)	-0.526	-0.493	-0.498
Lindenhurst			
MHW (ft)	0.624	0.566	0.476
MSL (ft)	0.000	0.000	0.000
MLW (ft)	-0.597	-0.567	-0.476

Table 2: Impact to Tides of Breach Open at Old Inlet

Station	Absolute Change (inches)		Percent Change	
	M2	MHW	M2	MHW
Fire Island	0.09	0.09	0.9%	0.8%
Tanner Park	0.33	0.33	3.5%	3.5%
Bellport	-0.08	-0.07	-1.3%	-1.2%

Station	Absolute Change (inches)		Percent Change	
	M2	MHW	M2	MHW
Lindenhurst	1.07	1.09	19.0%	19.0%

2.3.2 Impact on Small Storm Tides

The impact of the breach open conditions at Old Inlet on storm tides (i.e. tides plus storm surge) during relatively small storm events was also evaluated from the 2-year model simulation. Figure 8 shows an example of the modeled storm tides during a two small storm events during December of 2012. It is apparent from Figure 8 that peak storm tides at Lindenhurst and Bellport were a 1 to 3 inches higher with the breach open during these small storm events. The effects of the breach during the 2-year simulation were quantified by performing a linear regression analysis of the twice-daily high water levels (including storm surge). The results of the analysis, Figure 8, indicate that there was an increase in the peak water levels at Lindenhurst and a slight decrease in the peak water levels at Bellport.

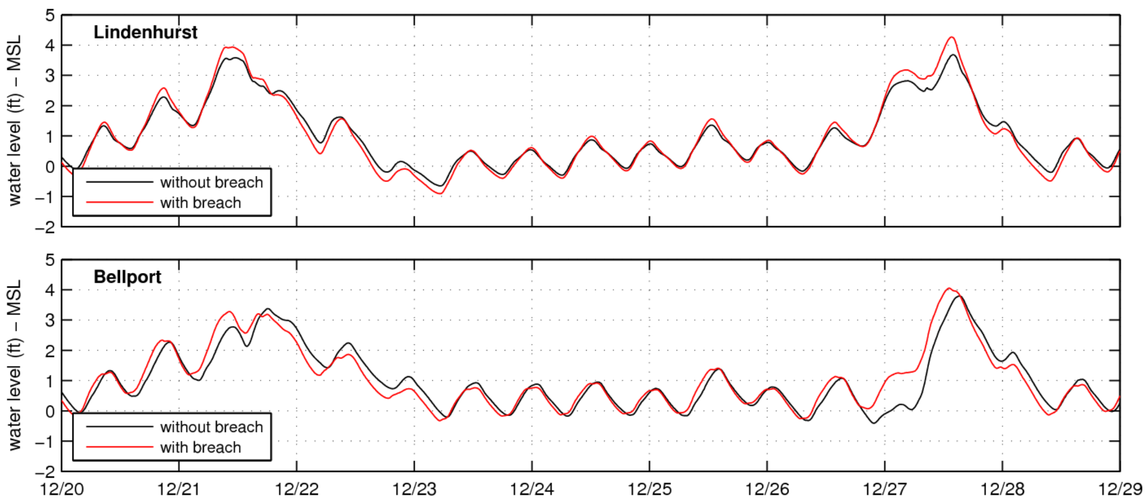

Figure 8: Dec 2012 Modeled Water Levels With and Without Breach

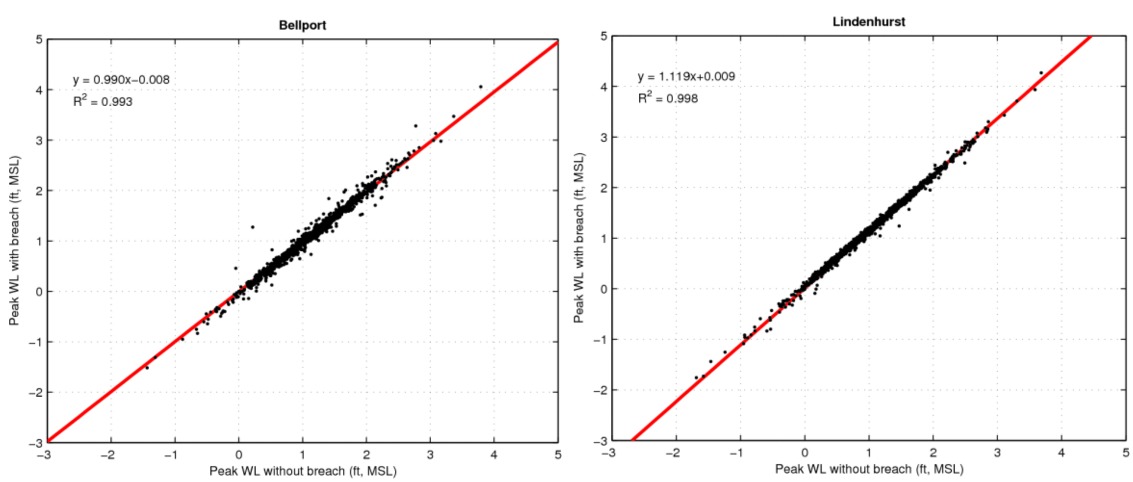

Figure 9: Linear Regression of Twice Daily High Water Levels

2.4 Impact on Storm Tides of Breach Open

The impact of the breach open conditions at Old Inlet on storm tides during large storm events was evaluated by simulating six storm events. These storms were originally selected in collaboration with NAN as the best set of storms that will provide enough information to adjust the stage-frequency curves for Breach Open Conditions (BOC). Model simulations were performed for both the breach open conditions at Old Inlet and breach closed conditions. The six storms are:

- January 1979 Historical
- March 1984 Historical
- January 1996 Historical
- September 1938 cdf 1.0
- September 1985 cdf 1.0
- November 1950 cdf 1.0

The six storms represent mixture of nor'easter's and hurricanes as well as small and large storm events. Modeled barrier island conditions were similar to the one used in the Future With-Project simulations, where no flow was allowed over the barrier. The relative impact of the breach at Old Inlet is captured in Figure 10 and Figure 11 below. These figures show a map of the difference in the modeled peak water level in the beach open conditions versus the breach closed conditions. The modeled effect of the breach open may be as high as 10 inches during smaller storm events and up to 22 inches during the larger storm events.

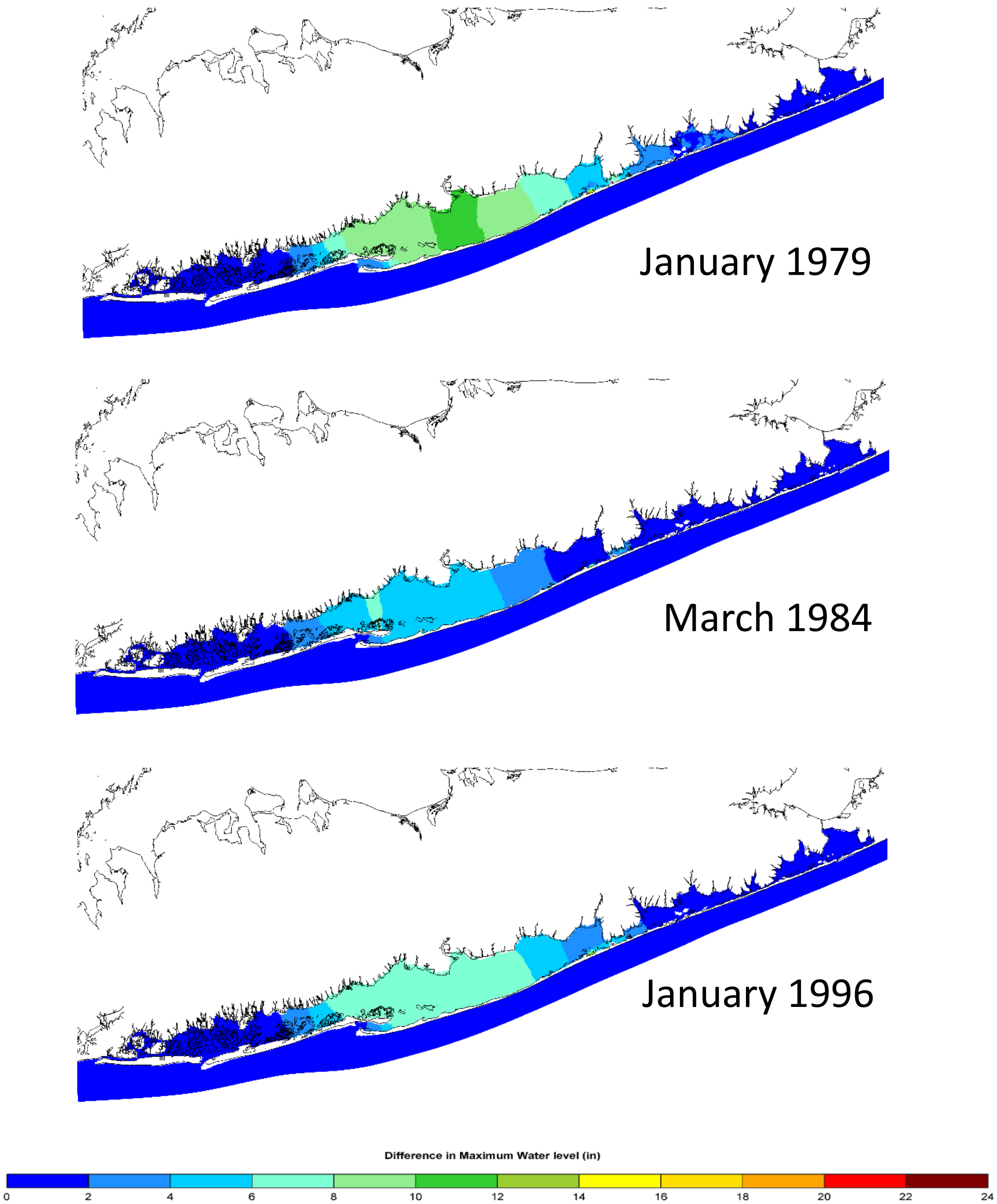

Figure 10: Comparison of Modeled Peak Water Levels With and Without Breach

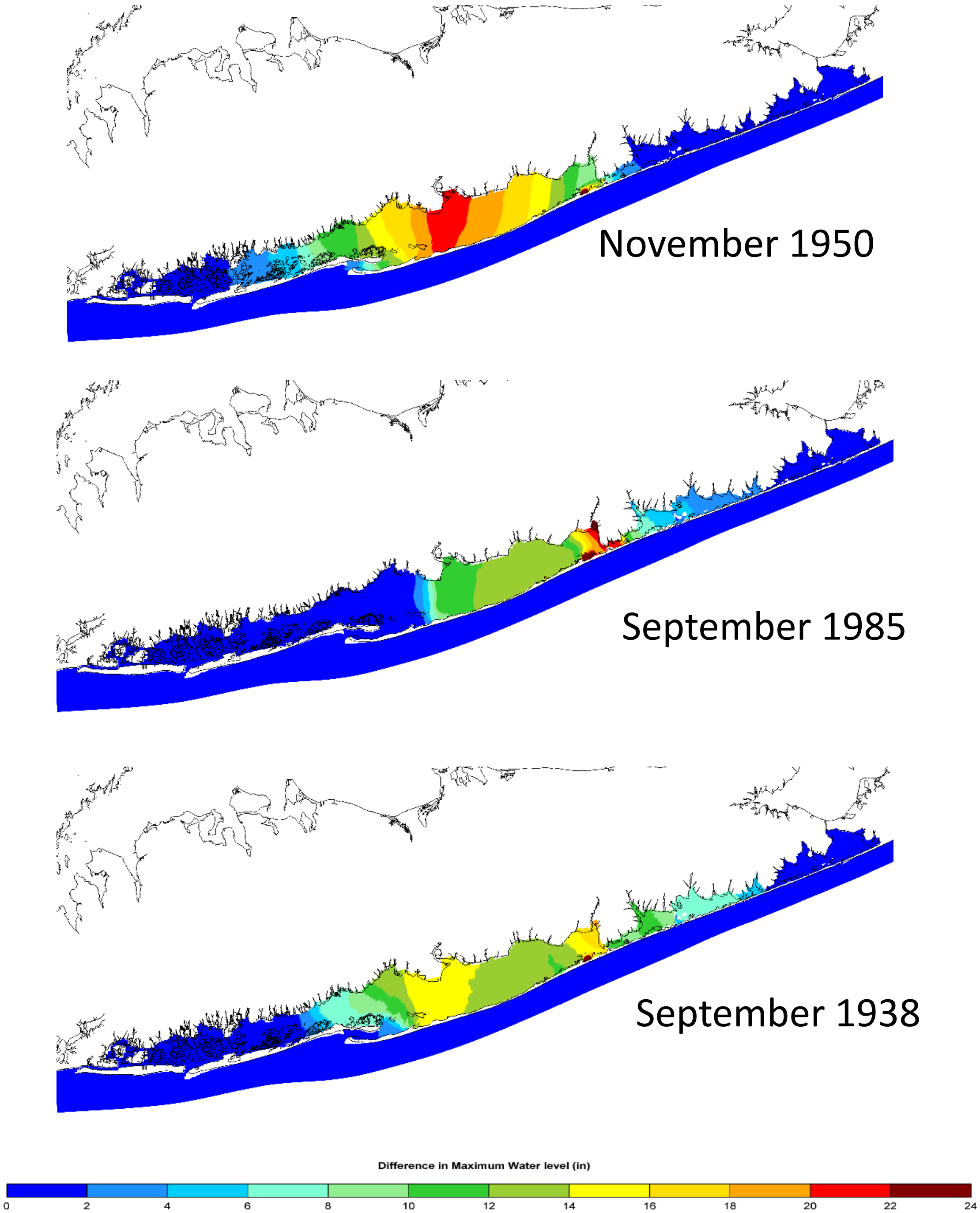

Figure 11: Comparison of Modeled Peak Water Levels With and Without Breach

3.0 REVISED STAGE FREQUENCY CURVES

3.1 Revised Stage-Frequency Curves

The objective of this task is to revise the existing baseline stage-frequency curves to reflect the June 2014 breach open condition at Old Inlet. A reduced number of representative storms were simulated (see previous task) for the June 2014 breach open condition at Old Inlet. These storms were originally selected in collaboration with NAN as the best set of storms that will provide enough information to adjust the stage-frequency curves for Breach Open Conditions (BOC).

- September 1938 cdf 1.0
- September 1985 cdf 1.0
- November 1950 cdf 1.0
- January 1979 Historical
- March 1984 Historical
- January 1996 Historical

Originally in 2006 the BOC stage-frequency curves were developed by combining the water level differences between the No-Breach/No Morphology condition and the Baseline Condition, thereby ensuring that the BOC stage-frequency relationships realistically reflected all water level contributions. The Empirical Simulation Technique (EST) was employed for each BOC case by adjusting the Baseline Conditions combined-storm probability distribution function at each output station using the BOC water levels for the six storms simulated.

After reviewing the process used in 2006 to create the BOC stage-frequency curves it was decided that the most rational approach to create stage-frequency curves for the June 2014 breach open conditions at Old Inlet would be a simple adjustment to the BOC-1 (3 month) curves. A comparison of the modeling results for two breach open conditions, (a) June 2014 breach open at Old Inlet and (b) BOC-1 3 month, showed that the impact on bay water levels for both conditions is similar in magnitude and spatial extent. The BOC-1 (3 month) condition included a 2,500 foot-wide and 7 foot-deep (MSL) breach at Old Inlet. The cross-sectional area of the BOC-1 (3 month) breach is larger than the June 2014 breach, however the deep channel and more mature inlet channels captured in the June 2014 breach are believed to increase hydraulic conveyance.

Consideration was given to whether the adjustment should be a constant shift in the curve or a linear adjustment with a larger increase at low-frequencies. However, initial attempts to fit a line to the differences in the two breach open conditions led to unrealistic results. More robust and rational results were produced with a simple shift up or down for the entire stage-frequency curve based on the small relative differences between the model results. The adjustment varies by station and is generally between +0.1 feet and +0.23 feet. It is noted that the BOC-1 (3 month) stage-frequency curve already captures non-uniform increases in bay water levels across the frequency domain. Therefore, the June 2014 breach open condition at Old Inlet also incorporates these same non-uniform increased in bay water levels.

3.1.1 Comparison of BOC-1 (3 month) and June 2014 Breach at Old Inlet

A visual comparison of the increase in bay water levels (above the No Breach/No Morphology) for the six storms for the two breach open conditions was performed. A set of maps was prepared (Attachment C) that shows that increase in bay water levels was similar in magnitude at all the FIMP stations in Great South Bay and Moriches Bay. An example map for the September 1938 storm is shown below. In general the largest differences between the BOC-1 (3 month) and June 2014 breach open condition occurred at the stations closest to Old Inlet. Although the agreement for the September 1938 storm was excellent at nearly all the stations.

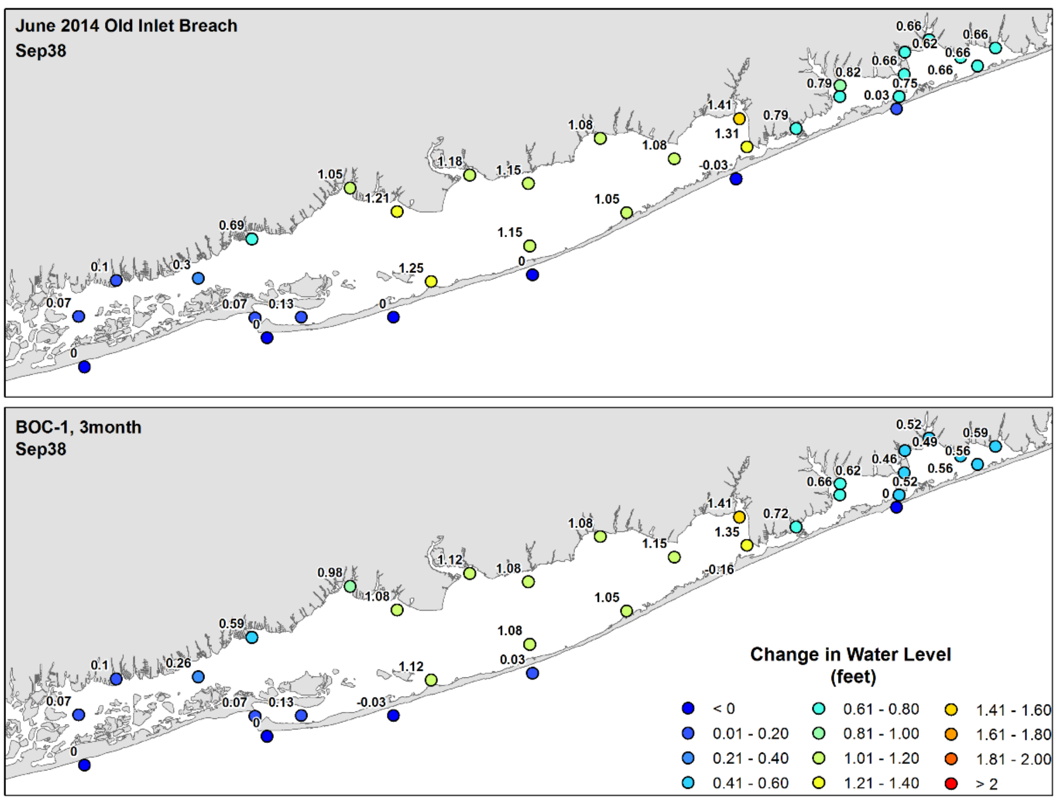

Figure 12: Example Increase in Water Levels caused by Breach Open Condition.

A second analysis was performed comparing the relative increase in bay water levels caused by the breach open conditions versus return period. The purpose of this analysis was to determine whether there was a distinct trend such as greater differences at greater return periods. The results showed that there was generally a lot of scatter at the lower return periods and at higher return periods the June 2014 breach open condition at Old Inlet resulted in slightly higher water levels.

Figure 13 shows an example of the analysis conducted at Station 10. The y-axis on the top-panel shows the difference in water levels between the breach open condition and no breach/no morphology condition. The black dots represent the 6 storms for the June 2014 breach open condition at Old Inlet and the red dots represent the 6 storms for the BOC-1

(3 month) condition. Essentially the top-panel is comparing the impact on bay water levels for both the June 2014 breach open condition at Old Inlet and BOC-1 (3 month) condition.

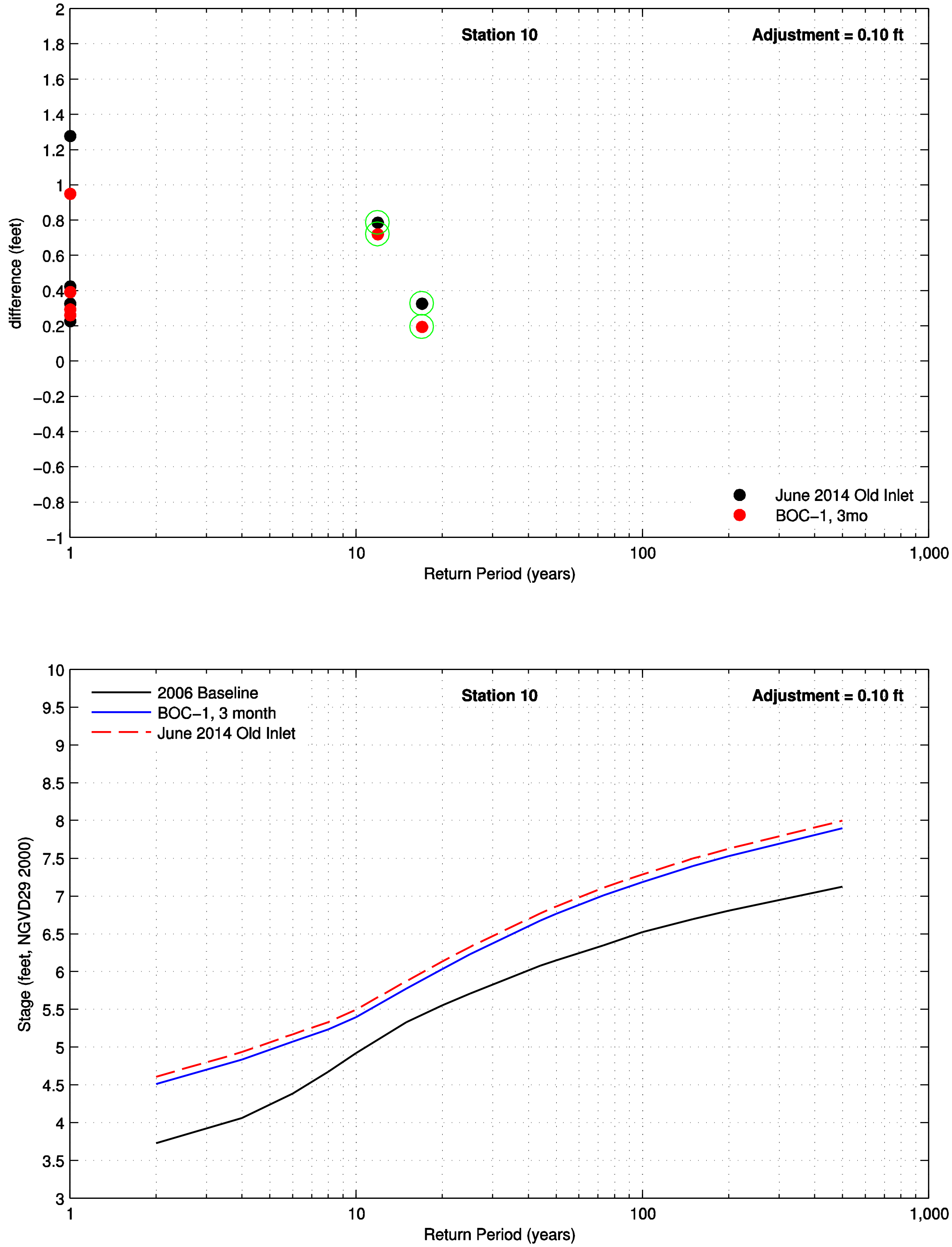

Figure 13: Difference between BOC and No Breach at Station 10

At Station 10, there are only two storm events with a return period greater than 2-years that will have a significant impact on stage-frequency curve (highlighted with green circles). For these two storm events the June 2014 Old Inlet breach open condition produced an increase, on average, in the peak water level 0.10 feet greater than the BOC-1 (3 month) condition. At this station an adjustment of 0.10 feet was selected and used to shift the BOC-1 (3 month) stage frequency curve up 0.10 feet to reflect the June 2014 breach open condition at Old Inlet. The bottom-panel of Figure 13 shows the 2006 Baseline, BOC-1 (3 month), and June 2014 Old Inlet stage-frequency curve at Station 10. The June 2014 Old Inlet stage-frequency curve has been shifted up by 0.0 feet.

This process was repeated for all the stations in Great South Bay and Moriches Bay. A map showing the adjustment value at all the stations is presented in Figure 14.

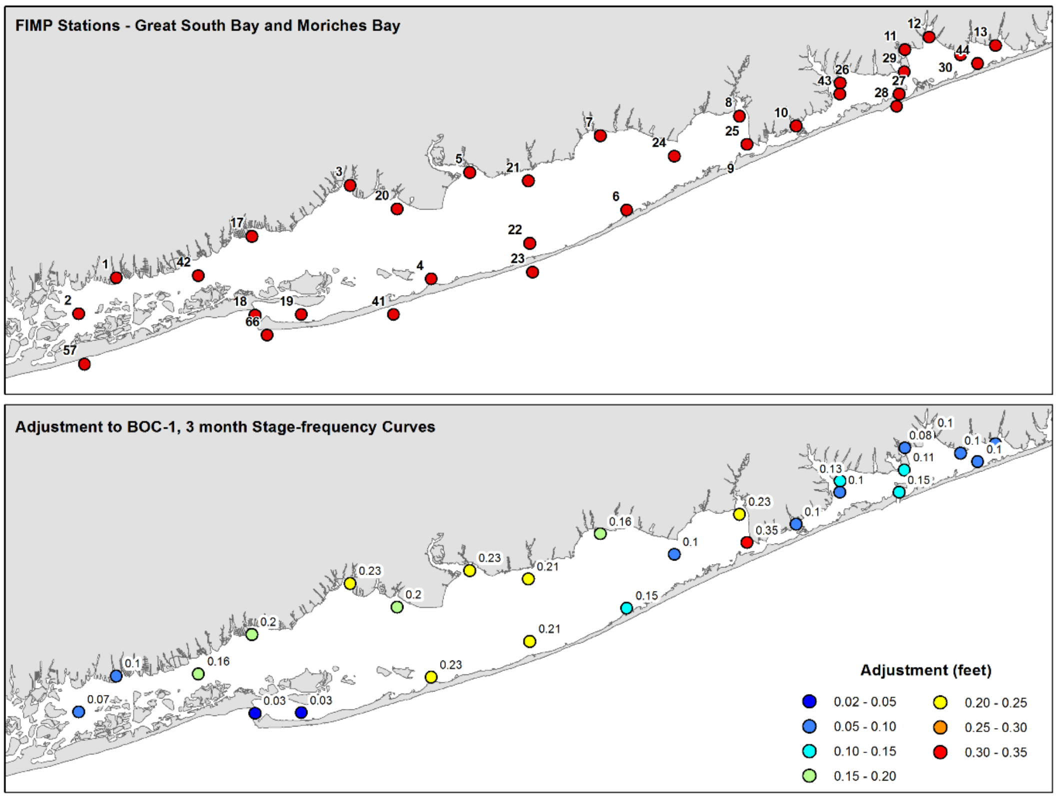

Figure 14: Stage-Frequency Adjustment Values by Station

3.1.2 2014 BLC, WP, FVC, and BCC Stage-Frequency Curves

Baseline (BLC), With Project (WP), Future Vulnerable conditions (MVC), and Breach Closed Conditions (BCC) represent different possible conditions of the barrier island topography. The barrier island topography affects the likelihood of overwash and new breach formation during large storm events. Previously, modeling simulations were conducted to capture the impact of the barrier island topography on bay water levels and create stage-frequency curves for each scenario.

This section describes the approach used to develop a set of new stage frequency curves based on the June 2014 breach open condition at Old Inlet. In general the approach used to define the complete set of stage frequency curves assumes that water level contributions associated with the barrier island topography (i.e. overwash, breach formation) may be superimposed on the June 2014 breach open condition at Old Inlet. In reality it is possible that the high water levels associated with the breach at Old Inlet will decrease the head difference slightly between ocean and bay water levels during storm events. A reduction in the head difference between the bay and ocean could decrease the flux of water during overwash and reduce current speeds across the barrier during breach formation. However, these differences are expected to be minor and the approach applied is consistent with the original approach used to define Breach Open Conditions (BOC).

Baseline Conditions (BLC)

The 2014 BLC stage frequency curve is defined by the June 2014 breach open condition at Old Inlet. The development of this stage frequency curve is described above in Section 3.1.1.

The original BLC stage frequency curve and BOC stage frequency curves were based on the barrier island condition captured by September 2000 LIDAR topography. No update to the barrier island topography was performed for the Delft3D simulations of the June 2014 breach open condition at Old Inlet. The purpose of these simulations was to capture the impacts of the new breach at Old Inlet. Therefore, the 2014 BLC stage frequency curves still reflect the September 2000 condition.

With Project Conditions (WP)

The WP condition represents a slightly more robust berm and dune condition than the BLC condition. The WP berm width and dune height is defined by the WP design geometry. The 2014 WP stage frequency curve was developed by adding the difference between the 2006 WP and 2006 BLC to the new 2014 BLC:

$$WP_{2014} = BLC_{2014} + (WP_{2006} - BLC_{2006})$$

Since very limited breaching and/or overwash is expected for the WP conditions, this approach seems appropriate.

Future Vulnerable Conditions (FVC)

The FVC or MVC (Most Vulnerable) represent a barrier island topography that is more vulnerable than the baseline and is reasonable expected to occur at some point during the 50-year project life.

$$FVC_{2014} = BLC_{2014} + (FVC_{2006} - BLC_{2006})$$

It is noted that the 2006 FVC might not be as vulnerable as some of the conditions observed post-Sandy, particularly in the areas outside the FIMI project area, and therefore the 2006 FVC might still overestimate the barrier island protection under post-sandy conditions.

Breach Closed Conditions (BCC)

The Breach Closed Conditions (BCC) barrier island topography is defined as the minimum breach closure section under consideration for the FIMP study. This breach closure section is defined by a 9.5 ft NGVD29 dune height and a barrier island width that matches the pre-breach condition. Here, the pre-breach barrier island width is taken as that on the BLC.

$$BCC_{2014} = BLC_{2014} + (BCC_{2006} - BLC_{2006})$$

An example of the 2006 and 2014 stage frequency curves at Station 10 is shown in Figure 15.

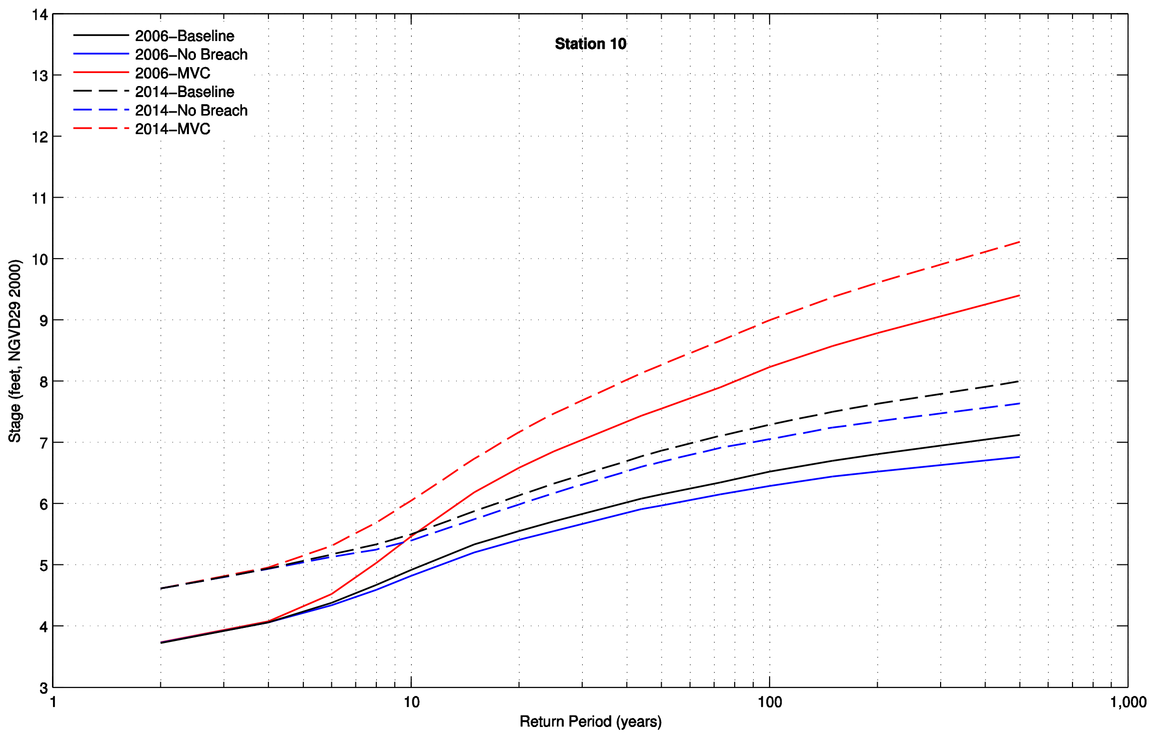

Figure 15: 2006 and 2014 Baseline, WP, and MVC Stage-Frequency Curves

3.1.3 Breach Open Condition (BOC) Stage-Frequency Curves

2006 Approach

A detailed overview of the approach applied to develop the Breach Open Condition curves is included as an attachment to this memo (Attachment A). A total of 12 modeling scenarios were performed in 2006 to support the development of the BOC stage frequency curves. The 12 simulations capture four BOC scenarios and three different breach sizes (3 month, 6 month, and 12 month). Tables showing the BOC scenarios modeled and breach sizes modeled are presented in Table 3 and Table 4. All of the breaches assumed a breach depth of 7 feet (MSL). The three selected breach sizes correspond to the estimated values at 3, 6 and 12 months from breach formation as presented in Table 16 of the Breach Contingency Plan Report of 1995 (USACE-NAN, 1995).

Table 3 – Breach Open Conditions for Numerical Simulation (Original)

Breach Open Scenario	Western GSB	Central GSB	Eastern GSB	Eastern Moriches Bay	Western Shinnecock Bay	Shinnecock Bay
BOC-1						
BOC-2						
BOC-3						
BOC-4						

Table 4 – Breach Width from Breach Formation (Original)

Months from Breach Formation	Breach width at GSB (ft)	Breach width at MB (ft)	Breach width at SB (ft)
3	2,500	1,200	1,300
6	3,700	1,700	1,900
12	4,700	2,100	2,300

2013 Modifications (FIMI)

As in the Breach Contingency Plan Report (USACE-NAN, 1995), it is assumed that the along-shore cross sectional area of the breach will grow according to the exponential breach growth equation:

$$A(t) = A_0\left(1 - e^{-kt}\right)$$

The maximum breach cross sectional area is given by A_0 and the breach growth coefficient is given by k. These parameters vary depending on the bay and were previously obtained as part of the breach inlet stability analysis (USACE-NAN, 1995). Recent cross sectional area measurements following the breach at Old Inlet provide new information regarding breach growth dynamics at Great South Bay. The measurements from C. Flagg (No. 9) include data thru May 30, 2013 and show a fairly stable cross section since the end of February 2013 of approximately 4,300 ft^2. In the previous BCP analysis for Great South Bay, a maximum breach cross section of 36,200 ft^2 was assumed.

In order to reflect the recent observations at Old Inlet an additional cost estimate was developed at all Great South Bay breach locations for a smaller breach with a maximum breach cross sectional area, A_0, of 6,500 ft^2. A uniform distribution of A_0 between 6,500 ft^2 and 36,200 ft^2 will be applied in the updated economic analysis. The cost estimates at Great South Bay are based on a constant growth coefficient of 0.2 $month^{-1}$. The lowest breach size (6,500 ft^2) combined with a k of 0.2 $month^{-1}$ yields and area of 4,850 ft^2 at 7 months, which is consistent with the 2013 observations at Old Inlet.

A_0 and k are summarized for Great South Bay, Moriches Bay, and Shinnecock Bay in Table 5.

Table 5: Breach Growth Coefficients

Location	A_0 (ft^2)	k $(month)^{-1}$
Great South Bay – Small Breach Size	6,500	0.2
Great South Bay – Large Breach Size	36,200	0.2
Moriches Bay	16,000	0.3
Shinnecock bay	17,750	0.3

2015 Approach for BOC with Breach Open at Old Inlet

This section describes the approach used to redefine the stage frequency curves for the set of BOC with the June 2014 breach open conditions at Old Inlet. The important differences between the original (2006) approach and the approach used in 2015 to update the BOC curves is described here.

In the new 2015 BLC the breach at Old Inlet (Eastern GSB) is assumed to remain open. Therefore, the BOC-1 scenario in GSB and Moriches Bay, is now the baseline condition (BLC). Since BOC-2 must now be combined with the breach at Old Inlet it becomes equivalent to BOC-4.

BOC-3, breach in Central GSB, must be combined with the new breach at Old Inlet. No model simulations have ever been performed to estimate bay water levels with simultaneous breach open conditions at Central and Eastern GSB. In the past it was assumed that GSB could not support and maintain two stable inlets at Central and Eastern GSB simultaneously, and that one of them would tend to naturally close. In the absence of any suitable modeling scenarios to define the bay water levels for BOC-3, the water levels will be taken as the maximum of the original BOC-3 and new BLC.

The top half of Table 6 shows the revised 2014 BOC scenario matrix. The bottom half of the table shows additional BOC used in the life-cycle simulations following the same approach used in 2006. It is noted that the bay system of Great South Bay-Moriches Bay is considered independent of Shinnecock Bay. The right half of the table shows the stage frequency curves to be used for the additional BOC-5, BOC-6, BOC-7/BOC-8 scenarios which better approximate the expected values under those breach open conditions.

Table 6 – 2015 Breach Open Conditions and Stage frequency curves to be applied at each Bay Station

Breach Open Scenario	WGSB	CGSB	EGSB	EMB	1-2-3-4-17-20-42	5-6-7-21-22	8-24-25	10-11-12-13-26-27-29-30-43-44
BOC-1 / BLC					BLC	BLC	BLC	BLC
BOC-2 / BOC-4					BOC-4	BOC-4	BOC-4	BOC-4
BOC-3					Max (BLC, BOC-3)	Max (BLC, BOC-3)	Max (BLC, BOC-3)	Max (BLC, BOC-3)
BOC-5					BOC-3	BOC-3	Max(BOC-3, BOC-4)	BOC-4
BOC-6					BOC-4	BOC-4	BLC	BLC
BOC-7 / BOC-8					BLC	BLC	BOC-4	BOC-4

4.0 REFERENCES

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