Center for Coastal Studies Provincetown

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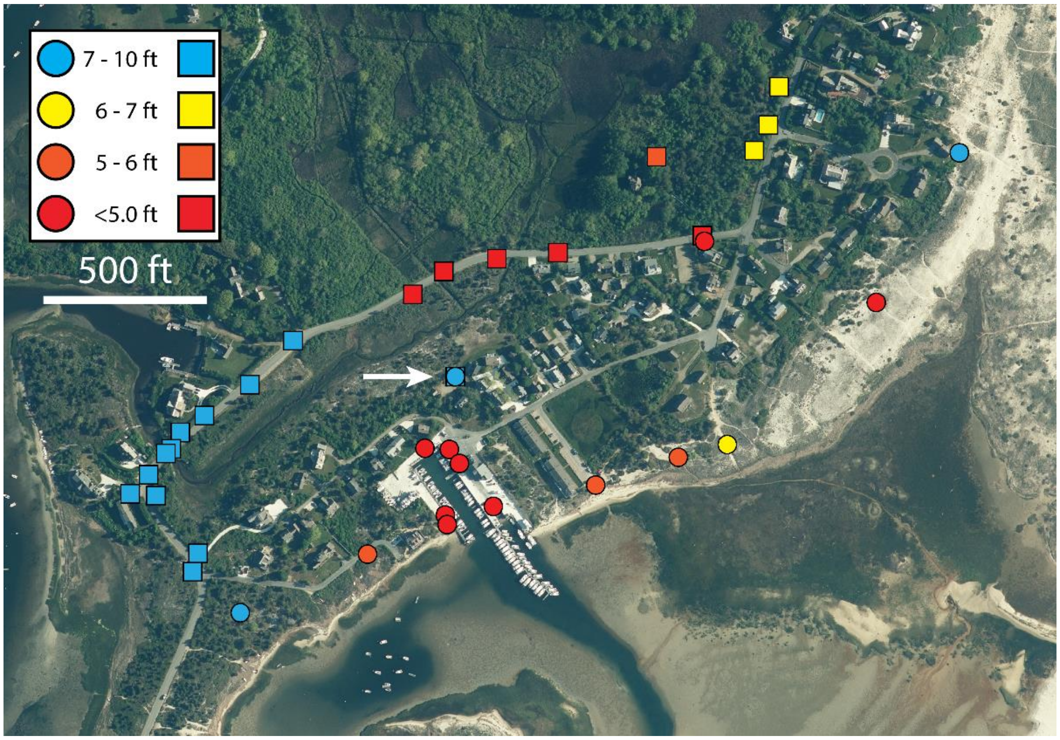
MAPPING STORM TIDE PATHWAYS IN THE LITTLE BEACH AREA OF CHATHAM, MASSACHUSETTS



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August 2018

Introduction

The northeast storms of January and March 2018 caused extensive flooding from the Atlantic Ocean in the Little Beach area of Chatham. After multiple storms the flood waters did not recede leaving low-lying areas with standing water. The Center for Coastal Studies (CCS) was asked to map the location of storm tide pathways for the Town using a technique developed by CCS for the Coastal Resiliency Grant program administrated by the State's Office of Coastal Zone Management. Unlike traditional "bathtub" or inundation modeling, the storm tide pathways method combines: 1) contemporary and historical elevation data associated with community storm and astronomical tidal profiles; 2) contemporary topographic information from the most recent Lidar data; and 3) field verification and mapping of threshold elevations that, when exceeded by storm tide levels, activate pathways that convey destructive flood waters inland. A key benefit of this method is elimination of the need for assumptions related to: winds; waves; storm frequency, intensity, or probability; rate(s) of sea level rise, etc., which contribute to the uncertainties associated with coastal inundation models. Further, maps of storm tide pathways provide communities with the information necessary to respond to approaching storms and to plan for future events.

Overview of Methodology

The term *storm tide* as defined by the National Atmospheric and Oceanic Administration (NOAA) refers to, '*…the total observed seawater level during a storm, which is the combination of storm surge and astronomical [predicted] tide.'* A storm tide pathway represents a mapped location (latitude, longitude, and elevation) where water will begin to flow inland during a flood event. Both location and elevation of each pathway are then incorporated into a database that is linked to maps stored in a GIS database.

The highest resolution, and most recent elevation data available for the Little Beach area was used in our preliminary analysis. Lidar (a remote sensing method of collecting detailed elevation data), collected by the United States Geological Survey (USGS) on April 4th 2014 to conduct Post-Hurricane Sandy studies, was downloaded from the Massachusetts Coastal Zone Management (MCZM) online mapping tool, *MORIS* (maps.massgis.state.ma.us/map_ol/moris.php). These data were brought into a state-of-the-art data visualization software package (Fledermaus™) and used as the basis for initial mapping of storm tide pathways. After further desktop analysis, the horizontal and vertical position of each potential pathway was verified in the field using survey-grade, GPS equipment. While in the field, the topographic setting was further evaluated to ensure that potential pathways, not visible on the Lidar were not overlooked. This process is an iterative sensitivity analysis to identify pathways associated with the maximum water elevation recorded during previous storms and high water events, such as spring tides, king tides, and other periodic or episodic 'nuisance flooding'.

After the pathways have been field verified, the extent of inundation potential of each pathway is mapped in ½-foot increments starting from the elevation that water first begins to flow over the pathway and up to the maximum study elevation (11.0 ft NAVD88). These elevations typically begin at the highest predicted tide of the year and proceed to a maximum elevation represented by the storm of record plus three feet. The analysis is extended to elevations 3 feet beyond the storm of record to identify pathways that have never flooded but will be susceptible to future flooding with projected increases in sea level rise. These types of insights can be invaluable to town managers and planners, residents and other stakeholders.

Tidal Datums

The effects of storm tides on coastal communities are dependent on many factors including: shoreline orientation (e.g., east facing v. south facing); tide range (e.g., the elevation of mean high water (MHW) in Boston Harbor is 4.31 ft NAVD88 while that of Stage Harbor is 1.52 ft NAVD88); topography of adjacent upland; nearshore bathymetry (e.g., the deeper the water relative to shore, the greater the potential wave energy); topographic relief (i.e., a measure of the flatness or steepness of the land with flatter areas more sensitive to small changes in water elevation); nature of coastal landforms (e.g., rock shorelines of the north shore v. the dynamic sandy shorelines of Cape Cod); and vertical relationship between historical community development and adjacent water levels.

With such variation in natural and human-altered characteristics, the initial step in the identification of storm tide pathways for a community is development of a datum-referenced tidal profile that characterizes average tidal heights, nuisance flooding, and historical storm tides.

In addition to the more common tidal datums of mean high water springs (MHWS), mean higher high water (MHHW), mean high water (MHW), and mean sea level (MSL), to be useful this tidal profile must include datum-referenced storm tides of the past, including the elevation of the maximum storm tide experienced (i.e., the storm of record) for the area, and future sea level rise.

In March of 2017, the Center for Coastal Studies installed a HOBO™ U20 water level logger in Outermost Harbor anticipating a potential new inlet formation through South Beach. On April 1, 2017, a new inlet formed across from Outermost Harbor approximately 2 miles to the south of the Fish Pier in Chatham Harbor. The water level logger is referenced vertically to NAVD88 (a geodetic datum) and water elevations are logged every six minutes. After collecting these data in NAVD88 they can be converted to local tidal datums by developing monthly averages for these values (Appendix A). Following standard NOAA-COOP procedures these values were used to translate one month of datum-referenced tidal observations into 1983 – 2001 National Tidal Datum Epoch (NTDE) values for comparison with datums published for NOAA Stations #8447435 (Aunt Lydia's Cove) and #8447505 (Stage Harbor) (NOAA, 2003). For more information see Appendix A.

Table 1 represents the tidal profile constructed to complete the storm tide pathway analysis for the Little Beach area. Rounding to the nearest foot from the table, the maximum storm tide elevation considered in this analysis was 11.0 ft (13.7 ft MLLW). This elevation represents the maximum elevation recorded by CCS at Outermost Harbor during the January 4, 2018 nor'easter of 7.76 ft NAVD88 (10.42 ft MLLW) plus 3 feet, rounded up to the nearest ½ foot increment (10.76 ft → 11.00 ft). Prior to this event, the storm of record reported by NOAA for Aunt Lydia's Cove (Sta # 8447435) was 6.95 ft NAVD88 (9.76 ft MLLW). To evaluate potential nuisance flooding associated with more frequent non-storm tidal events, the lowest elevation considered in the STP analysis was 2.80 ft NAVD88 (5.46 ft MLLW), which was rounded down to the next ½ foot increment from the elevation of mean higher high water (MHHW) calculated for Outermost Harbor (2.80 ft → 2.5 ft), rounding up would have missed water between 2.8 to 2.99 ft.

Table 1. Outermost Harbor Storm Tide Profile

Outermost Harbor Tidal Profile (Adjusted to 1983 - 2001 NTDE based on CCS Tide Readings)			
	NAVD88 (FT)	**MLLW (FT)**	**Comments**
Storm of Record plus 3 Feet	10.76	13.42	Upper Limit of Storm Tide Pathway Analysis
Coastal Storm 1/4//2018	7.76	10.42	Storm of Record Based on CCS Observations
Coastal Storm 1/3/2014	6.95	9.61	Based on Highest Observed Storm Records for Aunt Lydia's Cove NOAA
Maximum 2018 Predicted High	6.37	9.03	From 2018 NOAA Tide Predictions
MHHW	2.80	5.46	Adjusted to 1983-2001 NTDE
MHW	2.28	4.94	Adjusted to 1983-2001 NTDE
MSL	---	---	Adjusted to 1983-2001 NTDE
MTL	0.11	2.77	Adjusted to 1983-2001 NTDE
MLW	-2.06	0.60	Adjusted to 1983-2001 NTDE
MLLW	-2.66	0.00	Adjusted to 1983-2001 NTDE

Results

Initial analysis of the Lidar data using visualization software yielded 42 potential storm tide pathways throughout the Little Beach study area. Each location was inspected by the 3-person field team and, where necessary, storm tide pathways (STP) were adjusted when it was determined that the 2014 Lidar did not represent 2018 conditions. Based on this field work, the final STP dataset developed for this project contains 36 storm-tide pathways (Table 2). These

Table 2. Summary of Storm Tide Pathways. See Appendix B for more information.

Source of Water	**Pathways**	**Standard (STP)**	**Spillway (STP-S)**	**Roadway (STP-R)**	**Unverified (STP-U)**
Atlantic Ocean	15	1	9	0	5
Stage Harbor	21	1	12	4	4
TOTAL	**36**	**2**	**21**	**4**	**9**

pathways were further characterized based on whether the source of the inundation was Stage Harbor (Nantucket Sound) or the Atlantic Ocean. One STP was found to be in a position where it could potentially be flooded in either direction (Figure 1).

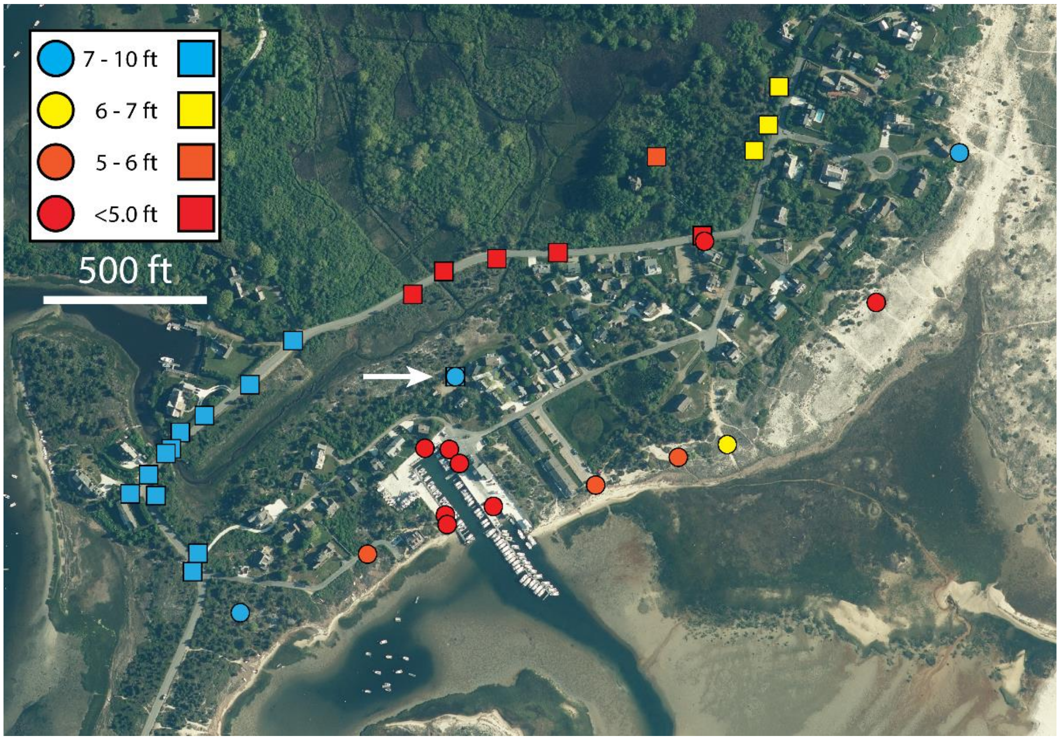

Figure 1. Storm tide pathways for the Little Beach Area. Thirty-six (36) pathways are color-coded to reflect elevation at which storm tide water will begin to flow at those locations. All elevations are relative to NAVD88 feet for their respective sources of water, Atlantic Ocean (circles) and Stage Harbor (square). One STP, a blue circle overlain onto a blue square, (noted by white arrow) could be flooded from both bodies of water. Aerial photograph taken in June 2017 (provided by the Town of Chatham).

There are several types of STPs included in this dataset: standard Storm Tide Pathways (STP) discussed above; ‘spillways’ (STP-S); ‘roadways’ (STP-R); and unverified (STP-U) (Table 2). These sub-types were developed to reflect different on-the-ground morphologies and techniques needed to identify and/or describe potential inundation at these locations.

The ‘standard’ STP can be described as a relatively narrow low-lying area where flowing water is directed inland by the natural topography or human-altered landscape (Figure 2A). As opposed to the discrete point-like nature of the standard STPs, the term ‘spillway’ is used as a way to reflect the low relief of the area. The spillway STPs are situated in very flat areas and are representative of long broad weir-like formations (Figure 2B). Actions planned to mitigate spillway STPs generally must be implemented along a wide area and designed in conjunction with detailed topographic surveys in order to minimize associated flooding during future events. While difficult to visualize, spillway STPs are often of greatest concern because of the associated broad, flat areas of inundation with undefined pathways for controlling flood waters. Spillway STPs were the most prevalent (21 out of 36) in the Little Beach area.

Figure 2. A. Example of a standard type of storm tide pathway (STP). In this instance a human-altered STP. B. An example of a 'spillway' STP near the Outermost Harbor Marina.

A roadway STP (STP-R) designation is used for those inundation pathways that generally impact roadways with little to no flooding in other areas of concern. Four (4) STP-Rs were mapped in this study on Morris Island Road, the only access into or out of the area and a potential concern for emergency vehicles.

Finally, 9 STP-Us were identified in low-lying areas that would likely experience flooding, however, the precise location of the pathway could not be obtained. Unverified STPs (STP-U) are defined to be STPs that were identified during the Lidar analysis but for various reasons could not be located or occupied by the field team. For example, the elevation data used for this study is a ‘bare earth’ Lidar data set. Since these data are processed to remove vegetation, (trees, bushes, beach grass, salt marsh, etc.) and structures (houses, buildings, etc.) occasionally STPs that appear accessible during the analysis are found to be inaccessible in the field. In addition, while not data-related, where STPs were clearly located on private property (Figure 3) they were not occupied if property owners could not be asked for permission.

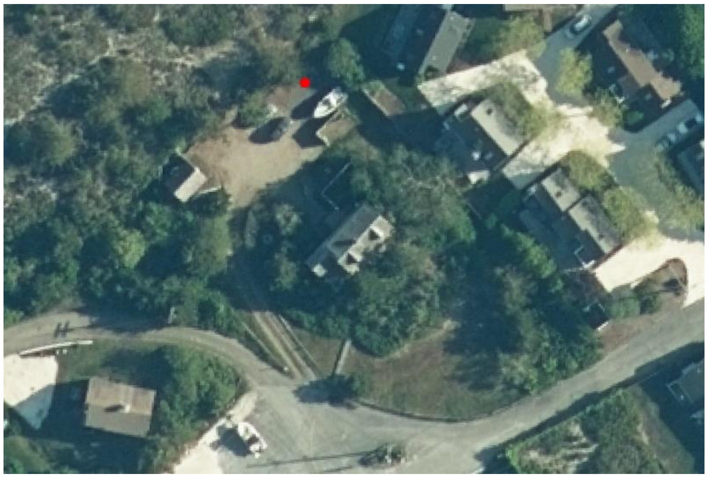

Figure 3. Example of an STP-U. This was an unverified STP as it is located on private property. The red dot is the approximate location of the unverified pathway determined during the Lidar analysis.

Based on the results of the field survey, a total of 15 storm tide pathways were identified with the potential to convey storm tide waters to Little Beach from the Atlantic Ocean. Thirteen of the pathways occurred at elevations ranging between 4.3 – 6.0 ft NAVD88 and should be of primary interest to the town. Significantly, spillway STPs make up 9 out of the 15 pathways identified. While this is perhaps intuitive given the flat topography of the area, 8 out of 9 of these pathways are below 6.0 ft NAVD88 and, as noted above, may present more of a challenge to address due to the length of affected areas.

The lowest elevation storm tide pathways are those conveying storm tide water from Stage Harbor. These elevations range from 3.68 to 9.79 ft NAVD88; however, the tidal restriction near

326 Morris Island Road minimizes the likelihood that water from Stage Harbor would be able to flood these pathways. Of the 21 pathways that flood from Stage Harbor, 13 are tidally restricted. Further, all of the STPs that are below 8.50 ft NAVD88 pass through the same tidal restriction. A total of 15 out of 21 pathways that flood from Stage Harbor cross Morris Island Road at varying depths. Based on the results of the field survey, this tidal restriction will be vital to continue to aid in the control of flooding from Stage Harbor into the future.

Conclusions

The land in and around Outermost Harbor Marina is a flat, low-lying area made more vulnerable to inundation with formation of the new inlet on April 1st, 2017. Many storm-tide pathways are located in this area. As evidenced by the January and March 2018 storms, they are among the lowest pathways that can convey storm tide water to much of the Little Beach area.

Although 36 pathways were identified in this study, it appears that focusing on the general area proximate to Outermost Harbor Marina would reduce the more frequent flooding of the Little Beach area associated with the more frequent, less powerful coastal storm tide events (<6 ft NAVD88). As shown in Figure 4, the area of focus for these mitigation efforts is located generally to the southwest of the Marina continuing to the dune field to the northeast. It should be noted that the line provided in Figure 4 signifies the area of interest alongshore and does not represent the location of a proposed structure.

Figure 4. The orange line represents an area that could be addressed to reduce or eliminate storm tide flooding for a significant area of Little Beach lying below elevation 5 ft NAVD88 that experiences inundation from the Atlantic Ocean. All elevations are in feet and refer to NAVD88.

Due to the relatively flat topography throughout the Little Beach area, solutions for many individual pathways may be unfeasible. For this reason, the results of this study would suggest that a micro-regional approach that focuses on potential solutions to multiple pathways of similar elevation over broad areas may be the most productive approach to consider. As with any design solution, a qualified engineer should be consulted to design and evaluate various alternatives.

A similar approach should be implemented for a detailed evaluation of the tidal restriction crossing the storm tide pathway from Stage Harbor that passes under Morris Island Road. This low-lying area, if flooded from Stage Harbor, could also inundate areas that are typically only flooded from the Atlantic Ocean. Given the complex nature of the hydrologic and hydraulic connections in this area, solutions to storm tide related flooding must necessarily consider inundation possibilities from both Stage Harbor and the Atlantic Ocean.

Recommendations

Recognizing that addressing storm tide pathways with elevations exceeding 8.0 ft NAVD88 present significant design challenges, we recommend that in the short term, the following actions be explored to minimize associated flooding:

1. Address the low-lying storm tide pathways in areas proximate to Outermost Harbor Marina
2. Address the storm tide pathway low-lying areas at the end of Starfish Lane.
3. Evaluate and manage the existing tidal restriction under Morris Island to maximize its potential to control storm tide related flooding.
4. Conduct a detailed tide study of Stage Harbor and Outermost Harbor tides to understand the relationship between tidal flow in, and between, Nantucket Sound and the Atlantic Ocean and the potential effects on storm tide pathways of the Little Beach area.

APPENDIX A: Calculating Local Tidal Datums

An NTDE represents a specific 19-year period adopted by the National Ocean Service (NOS) as the official period over which tide observations are taken and reduced to obtain mean elevations of tidal datums (e.g., mean lower low water, etc.) at various tidal stations along the East, West, and Gulf Coasts (Gill & Schultz,. 2001). A nineteen-year period is used to compute tidal datums because it is the closest full year to the 18.6-year nodal cycle, the period required for the regression of the moon's nodes to complete a circuit of 360 degrees of longitude (Gill & Schultz, 2001; NOAA, 2003). The NTDE is used as the fixed period of time for the determination of tidal datums because it includes all significant tidal periods, is long enough to average out the local meteorological and seasonal temperature effects on sea level, and by specifying the NTDE, a uniform approach is applied to the tidal datums for all stations.

The present NTDE is for the period 1983-2001 and as with all epochs, tidal data is reviewed annually for possible revision. Regardless of any annual changes, NTDE values for each tidal station are actively reviewed for revision approximately every 25 years (NOAA, 2003). Since for comparative and reporting purposes tidal datums are specified with regard to the current 19-year NTDE, tidal datums computed from month long tidal readings for Outermost Harbor were translated to the 1983-2001 NTDE using the *Modified-Range Ratio Method* as described in NOAA, 2003. As a primary tide station used historically as the control station for Cape Cod tide information, NOAA tide station #8443970 located in Boston Harbor was used to adjust the month long Outermost Harbor tide readings to the 1983-2001 NTDE.

All heights are referenced to the North American Vertical Reference Datum of 1988 (NAVD88) to facilitate comparisons with tidal datum profiles calculated by NOAA for Stage Harbor and Aunt Lydia's Cove as shown in Table A-1 . The uncertainty associated with tidal datums computed from a short series of records (i.e., 1-month versus the 19-year tidal epoch) is estimated to be 0.13 ft (3.96 cm) (Bodnar, 1981).[1]

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[1] Notwithstanding the generalized accuracy reported for east coast epoch values calculated from one month of tide readings, the dynamic nature of the most recent southerly inlet indicates that the tidal profile for Outermost Harbor may not have stabilized. For this reason, this study recommends conducting a detailed study of the tides in this area, based on longer series of tide readings.

		Station: 8447505 **Stage Harbor** **NTDE: 1983-2001** **Accepted: Apr 17, 2003**	**Station: 8447435** **Aunt Lydia's Cove** **NTDE: 1983-2001** **Accepted: Feb. 9, 2007**	**CCS Readings** **Outermost Harbor** **NTDE: 1983-2001** **Jan 1 -31, 2018**
Datum	**Description**	**NAVD88 (FT)**	**NAVD88 (FT)**	**NAVD88 (FT)**
MHHW	Mean Higher-High Water	1.89	2.69	2.80
MHW	Mean High Water	1.52	2.32	2.28
MTL	Mean Tide Level	-0.45	-0.16	0.11
MSL	Mean Sea Level	-0.35	-0.05	---
DTL	Mean Diurnal Tide Level	-0.40	-0.06	0.07
MLW	Mean Low Water	-2.43	-2.63	-2.06
MLLW	Mean Lower-Low Water	-2.69	-2.81	-2.66
GT	Great Diurnal Range	-5.80	5.51	5.46
MN	Mean Range of Tide	3.95	4.95	4.34
HWI	Greenwich High Water Interval (hours)	4.5	4.87	4.48
LWI	Greenwich Low Water Interval (hours)	10.25	11.59	11.58

Table B-1. Tidal datum profiles for Aunt Lydia’s Cove, Stage Harbor, and Outermost Harbor (NAVD88 feet)

Appendix B-1. Storm Tide Pathways affected by water from the Atlantic Ocean. See GIS data sets for more information.

							Activation Level					
Final_ID	**Station**	**Easting**	**Northing**	**Elevation**	**Type**	**Status**	**Nav88 m**	**Nav88 ft**	**MLLW m**	**MLLW ft**	**Range_MLLW**	**Range_Navd**
1	21	420210.1	4612942	2.732	STP-S	Verified	2.73	8.96	3.49	11.46	11.51 ft - 12.00 ft	9.01ft - 9.50ft
2	24	420332.2	4612998	1.703	STP-S	Verified	1.70	5.59	2.46	8.09	8.01 ft - 8.50 ft	5.51ft - 6.00ft
3	30	420408.6	4613027	1.344	STP-S	Verified	1.34	4.41	2.10	6.91	7.01 ft -7.50 ft	4.51ft - 5.00ft
4	29	420406.9	4613036	1.493	STP-S	Verified	1.49	4.90	2.25	7.40	7.01 ft -7.50 ft	4.51ft - 5.00ft
5	28	420387.2	4613099	1.453	STP-S	Verified	1.45	4.77	2.21	7.27	7.01 ft -7.50 ft	4.51ft - 5.00ft
6	25	420410.7	4613099	1.421	STP-S	Verified	1.42	4.66	2.18	7.16	6.51 ft - 7.00 ft	4.01ft - 4.50ft
7	26	420420.3	4613085	1.354	STP-S	Verified	1.35	4.44	2.11	6.94	6.51 ft - 7.00 ft	4.01ft - 4.50ft
8	27	420452.9	4613044	1.332	STP-S	Verified	1.33	4.37	2.09	6.87	7.01 ft -7.50 ft	4.51ft - 5.00ft
9	42	420416.7	4613169	0	STP-U	Unverified	1.39	4.56	2.15	7.06	7.01 ft -7.50 ft	4.51ft - 5.00ft
10	31	420551	4613064	1.581	STP	Verified	1.58	5.19	2.34	7.69	7.01 ft -7.50 ft	4.51ft - 5.00ft
11	32	420630.3	4613091	0	STP-U	Unverified	1.62	5.31	2.38	7.81	7.51 ft - 8.00 ft	5.01ft - 5.50ft
12	34	420677.4	4613104	0	STP-U	Unverified	1.83	6.00	2.59	8.50	8.51 ft - 9.00 ft	6.01ft - 6.50ft
13	40	420819.9	4613240	0	STP-U	Unverified	1.48	4.86	2.24	7.36	10.51 ft - 11.00 ft	8.01ft - 8.50ft
14	41	420899.9	4613383	0	STP-U	Unverified	3.04	9.97	3.80	12.47	12.51ft - 13.00 ft	10.01ft - 10.50ft
15	5	420655.3	4613298	1.311	STP-S	Verified	1.31	4.30	2.07	6.80	6.51 ft - 7.00 ft	4.01ft - 4.50ft

Appendix B-2. Storm Tide Pathways affected by water from Stage Harbor. See GIS data sets for more information.

							Activation Level					
Final_ID	**Station**	**Easting**	**Northing**	**Elevation**	**Type**	**Status**	**Nav88 m**	**Nav88 ft**	**MLLW m**	**MLLW ft**	**Range_MLLW**	**Range_Navd**
1	20	420164.7	4612981	2.708	STP-R	Verified	2.71	8.88	3.47	11.38	11.51 ft - 12.00 ft	9.01ft - 9.50ft
2	19	420169.6	4612999	2.926	STP-S	Verified	2.93	9.60	3.69	12.10	12.01 ft - 12.50 ft	9.51ft - 10.00ft
3	18	420104.8	4613056	2.98	STP-S	Verified	2.98	9.78	3.74	12.28	12.01 ft - 12.50 ft	9.51ft - 10.00ft
4	17	420129.2	4613054	2.594	STP-R	Verified	2.59	8.50	3.35	11.00	11.51 ft - 12.00 ft	9.01ft - 9.50ft
5	16	420122.5	4613074	2.895	STP-S	Verified	2.90	9.50	3.66	12.00	11.51 ft - 12.00 ft	9.01ft - 9.50ft
6	15	420139	4613095	2.942	STP-S	Verified	2.94	9.65	3.70	12.15	11.51 ft - 12.00 ft	9.01ft - 9.50ft
7	14	420144.1	4613099	2.95	STP-S	Verified	2.95	9.68	3.71	12.18	12.01 ft - 12.50 ft	9.51ft - 10.00ft
8	13	420152.7	4613115	2.955	STP-S	Verified	2.95	9.69	3.71	12.19	12.01 ft - 12.50 ft	9.51ft - 10.00ft
9	12	420176	4613131	2.891	STP-S	Verified	2.89	9.48	3.65	11.98	12.01 ft - 12.50 ft	9.51ft - 10.00ft
10	11	420219.4	4613161	2.983	STP-S	Verified	2.98	9.79	3.74	12.29	12.01 ft - 12.50 ft	9.51ft - 10.00ft
11	10	420260.7	4613203	2.936	STP-S	Verified	2.94	9.60	3.70	12.10	11.51 ft - 12.00 ft	9.01ft - 9.50ft
12	9	420375.6	4613247	1.122	STP-R	Verified	1.12	3.68	1.88	6.18	6.01 ft - 6.50 ft	3.51ft - 4.0ft
13	8	420405.5	4613269	1.352	STP-R	Verified	1.35	4.44	2.11	6.94	6.51 ft - 7.00 ft	4.01ft - 4.50ft
14	7	420456.5	4613281	1.391	STP-S	Verified	1.39	4.56	2.15	7.06	7.01 ft - 7.50 ft	4.51ft - 5.00ft
15	42	420416.7	4613169	0	STP	Unverified	1.39	4.56	2.15	7.06	7.01 ft - 7.50 ft	4.51ft - 5.00ft
16	6	420514.9	4613287	1.389	STP-S	Verified	1.39	4.56	2.15	7.06	7.01 ft - 7.50 ft	4.51ft - 5.00ft
17	5	420653.5	4613304	1.286	STP-S	Verified	1.29	4.22	2.05	6.72	6.51 ft - 7.00 ft	4.01ft - 4.50ft
18	4	420609.6	4613379	0	STP-U	Unverified	1.55	5.09	2.31	7.59	7.51 ft - 8.00 ft	5.01ft - 5.50ft
19	3	420703.3	4613385	0	STP-U	Unverified	2.03	6.66	2.79	9.16	9.01 ft - 9.50 ft	6.51ft - 7.00ft
20	2	420716.5	4613410	0	STP-U	Unverified	2.10	6.89	2.86	9.39	9.01 ft - 9.50 ft	6.51ft - 7.00ft
21	1	420726.9	4613446	0	STP-U	Unverified	2.11	6.92	2.87	9.42	9.01 ft - 9.50 ft	6.51ft - 7.00ft

APPENDIX C: GIS Data

Several shapefiles were created to document the spatial extent water would cover under different inundation scenarios. Data are binned at six-inch intervals, vertically, beginning with 5.0 ft MLLW (2.5 ft Navd88). The layer “Little_Beach_Range” contains each separate shapefile polygon for each ½ foot elevation interval. Each polygon was extracted at the upper value of the six-inch interval and is so labeled. The shapefile titled “Little_Beach_Range.shp” contains all the individual polygons in the previously described layer in one shapefile. The combination of these files into one polygon allows for easy display of different ranges simultaneously or sequentially. A complimentary data set was created titled “Stage_Harbor”. Data sets titled “Little_Beach” document the extent of water from the Atlantic Ocean direction and data sets titled “Stage_Harbor” identify water flowing from the Stage Harbor, Nantucekt Sound direction.
The Layer “Little_Beach_Data”, include a point shapefile of the final location of the pathways. The “Little_Beach_Inundation_Pathways.shp” includes the location and all associated data in both NAVD88 and MLLW vertical datums, as well as the range into which they correspond. The layer titled “Little_Beach_Individual” contains polygons that describe the spatial extent inundation would occur if water rose to that elevation and are labeled to correspond with specific inundation pathway shapefiles. A complimentary data set was created titled “Stage_Harbor”.
Several shapefiles were created containing data from the desktop analysis and the field portion of the data. In the “Desktop and Field” layer, “Desktop_Inundation_Pathways.shp” describe all 42 locations identified through the initial desktop examination. The “Inundation_Pathway_all.shp” file, includes every pathway identified in the desktop analysis and the status of each (rejected or included) and associated data collected from field surveying. The data set “Inundation_Pathway.shp” includes the final 36 inundation pathways identified throughout the study.

5

MLLW FT

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographic
Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS

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6.5

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