Projected Expansion of the Floodplain with Sea Level Rise in Marion, Massachusetts

Buzzards Bay National Estuary Program and
Massachusetts Office of Coastal Zone Management
Technical Report SLR13-5
Draft February 21, 2013

Joseph E. Costa, David Janik, and John Rockwell
Buzzards Bay National Estuary Program
Massachusetts Office of Coastal Zone Management
2870 Cranberry Highway, East Wareham, MA 02538 USA

Acknowledgments
Thanks to Tracy Warncke and Sarah Williams for their editorial review of this report. Thanks also to Richard Zingarelli and Rebecca Haney for their expert and thoughtful technical reviews for which this report benefited greatly.

Corresponding Author: Phone: 508.291.3625 x11, fax: 508.291.3628, joe.costa@state.ma.us.
Data at: http://www.buzzardsbay.org/floodzone-expansion-slr.html.

Suggested citation: Costa, J.E, D. Janik, and J. Rockwell. 2013. Projected Expansion of the Floodplain with Sea Level Rise in Marion, Massachusetts. Buzzards Bay National Estuary Program and Massachusetts Office of Coastal Zone Management. Technical Report SLR13-5. Draft February 21, 2013. 64pp.

Projected Expansion of the Floodplain with Sea Level Rise in Marion, Massachusetts

Summary

The Buzzards Bay National Estuary Program (BBNEP) and the Massachusetts Office of Coastal Zone Management evaluated the potential expansion of the 100-year floodplain[1] in Marion, Massachusetts resulting from 1, 2, and 4-foot increases in sea level. A baseline conditions floodplain was developed by adjusting the most landward extent of the 100-year floodplain as mapped by the Federal Emergency Management Agency (FEMA) in their 2012 digital Flood Insurance Rate Map (FIRM) coverages. This boundary was adjusted by matching the FIRM base flood elevations to a highly detailed elevation data set. This adjusted baseline conditions floodplain map was then expanded by adding 1, 2, and 4-foot increases using the same detailed elevation data. Using a 2012 parcel and assessor's data set for the Town of Marion from MassGIS, the number of buildings, their assessed values, and municipal structures were enumerated within these various floodplain expansion scenarios. This evaluation was not meant as a quantification of the impacts of storms with sea level rise, but rather to define an approximate likely geographical expansion of the floodplain, a jurisdictional area used by many state, federal, and municipal agencies and boards.

There are currently 2,575 built upon parcels in the Marion 2012 MassGIS database. Of these, 796 (30.9%) have the primary structure within the adjusted coastal baseline floodplain of the 100-year storm used in this study. The total primary structure building value of the 796 properties in the adjusted baseline floodplain is $249.5 million, which is 35.2% of the town's $708.6 million total assessed structure value. Ancillary structures (detached garages, sheds, and barns) associated with the 796 properties in the adjusted baseline floodplain total an additional $10.5 million. The placement of the ancillary structures were not characterized for the sea level rise scenarios.

With a 1-ft sea level rise, 111 parcels with primary structure values totaling $28.1 million are added to the adjusted baseline floodplain. With a 2-ft sea level rise, an additional 121 parcels worth $28.1 million are added, and with the 4-ft sea level rise, an additional 184 structures worth $50.5 million are added. Cumulatively, the baseline to 4-ft sea level rise scenario adds 416 additional built parcels with primary structures worth over $104.5 million in assessed value are added to the adjusted baseline floodplain.

At a town-wide level, with a 4-ft sea level rise, the percent area of the town in the expanded adjusted baseline floodplain increased from 35.0% to 45.0%. Similarly the total number of primary structures in the floodplain increased from 30.9% to 47.1% of the total number of primary structures in town , and the property values of primary structures in the floodplain increased from 35.2% to 50.0% of the total town primary structure property value.

There are 13 publicly owned properties with structures totaling $1.4 million currently in the adjusted baseline floodplain. The properties with any appreciable value are the town's Music Hall on Front Street, Bird Island Light House and the Silvershell Beach bathhouse. The Sippican School and the Fire Station will be added under the 4-ft sea level rise scenario. These structures total $1.1 million. Other structures include sewer line pump stations.

The maps resulting from this effort can be used as planning tools to assist the siting and construction of new facilities so that they are less likely to be affected in subsequent decades by sea level rise. These

[1] That is, the area inundated by a storm with a 1% chance of occurring in any particular year.

maps can also be used as a visual aid to educate municipal officials and the public about the potential impacts of sea level rise, and help set priorities for land acquisition and protection, and help define local climate adaptation strategies.

1. Introduction

FEMA Flood Insurance Rate Maps (FIRMs) are the basis for federal, state, and local hazard mitigation planning. They are also used to establish the regulatory jurisdiction for mandated flood insurance, and are used by building inspectors, conservation commissions, and other local regulators to establish standards for the siting, construction, and maintenance of buildings, sea walls, and land alteration. This area is commonly referred to as the "100-year floodplain" by insurers, state building regulations, and local bylaws and ordinances. More precisely, FIRMs generally define the area that has a 1% chance or greater of being flooded in any particular year (commonly called the "100-year storm[2]"). In the coastal zone, these floodplain areas may be designated as being either in the Zone V (Velocity or V-zone); which are areas subjected to waves greater than 3 feet during a storm, or Zone A, which are areas subjected to waves less than 3 feet during a storm. Most typically in coastal areas, these two zones are assigned a base flood elevation (BFE). The BFE corresponds to the top of the wave crest during the projected 100-year storm. The methodology for determining these elevations and their boundaries is described in the *Guidelines and Specifications for Flood Hazard Mapping Partners, Volume 1: Flood Studies and Mapping* (FEMA, 2003).

The predicted landward limit of the floodplain, as depicted in the FEMA FIRMs, corresponds to a specific real-world elevation as defined by the BFE. The FIRMs prepared by FEMA are in fact an approximate depiction of which properties are in or out of the specified flood-zone elevation. While the FEMA FIRMs are generally good for broadly defining which homes are in or out of the jurisdictional floodplain, the maps are limited by the quality of topographic data that is available. Whether a particular structure near a mapped BFE boundary is actually in the floodplain can only be determined definitively by actual field surveys. In fact, FIRMs can be amended based on such field investigations, and often are.

In 2009 and 2012, FEMA updated the FIRMs in Bristol and Plymouth counties based on recent LiDAR[3] surveys, contracted by FEMA or United States Geological Survey (USGS), and limited new coastal engineering analyses[4]. The basis of the changes in the maps are summarized in Flood Insurance Studies for each county available on the FEMA website[5]. Due to funding limitations, FEMA was unable to do new engineering analyses for all portions of each community. These new maps have

---

[2] Many scientists and regulators encourage the use of the term "1% storm" and "1% storm floodplain", over "100-year storm" and "100-year floodplain" because of public misconceptions that a 100-year storm only occurs once in one hundred years. However, because the term "100-year floodplain" is so pervasive in regulations, in news reports, and the public vernacular, we used it here instead of the less commonly used term "1% floodplain."

[3] Light Detection And Ranging (also abbreviated LiDAR and LADAR) is an optical remote sensing technology that can measure the distance to a target by illuminating it with pulse of light from a laser.

[4] As part of FEMA's Map Modernization project, the 2012 Flood Insurance Rate Maps for Marion have a new datum, NAVD88, or North American Vertical Datum of the 1988-2001 Tidal Epoch. In Marion, the “old” elevation value for 0.0 feet using the National Geodetic Vertical Datum of 1929, or NGVD29 is equal to minus 0.840 feet NAVD88 (calculated for the harbor area near Town Wharf at http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl). In addition, the new maps show increased flood elevations in many areas that reflect improved flood hazard models, landscape changes, and better land elevation measurements.

[5] Go to: https://msc.fema.gov

increased precision and reliability, although like any data set, they are subject to errors in interpretation and processing of the elevation data as described below.

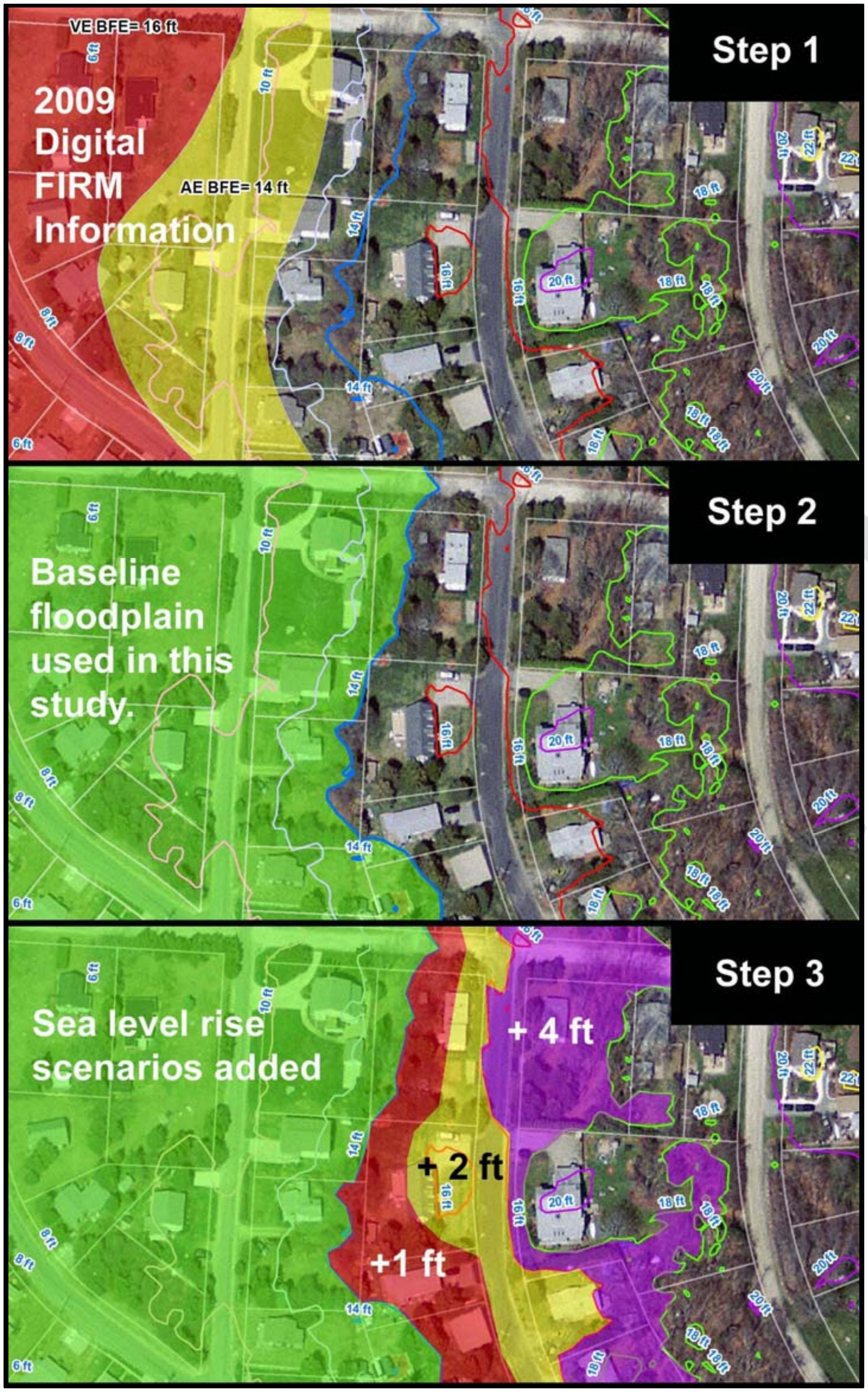
For this study, we considered only the landward-most extent of the FIRM 100-year storm floodplain, and the published BFE, to define the adjusted baseline floodplain. We then expanded this adjusted baseline floodplain by adding 1, 2, and 4-ft. to the BFE (whether A or V zone). The extrapolations were based on a digital data set of estimated bare earth elevations established by a 2007 aerial survey using LiDAR technology that was obtained from FEMA (from (CDM-Smith 2008 study) and which was used in part to prepare the 2009 and 2012 updated Bristol and Plymouth County FIRMs.

The selected 1, 2, and 4-ft elevation increases in this study were chosen as convenient management elevation markers. The relative sea level rise rate documented for Woods Hole, MA has been 10.3 inches per century since 1932[6]. The international consensus range for sea level rise, applied to this region, is 1 to 4.5 feet by year 2100[7]. However, some other studies with alternative scenarios with more expanded Greenland and Antarctic glacier melting, or changes in the North Atlantic gyre predict higher local sea level rise rates. We thus leave open ended how quickly the 1, 2, and 4-ft elevation increases may occur.

2. Methods

In this study, ArcGIS® software by Esri (ArcMap Desktop versions 9.3 and 10.1) was used to manipulate the various existing digital data sets, with some additional analysis completed in spreadsheets using pivot table functions. No field collection of data or ground truthing was required for this analysis. We used a 2007 LiDAR study contracted by FEMA, and described in detail in CDM-Smith's *Mapping Activities for Plymouth and Bristol Counties, Massachusetts. Task Order 18 Activity 1--Topographic Data Development / Acquisition Summary Report.* These LiDAR data were provided to the Buzzards Bay NEP as both 2-ft contour lines, and as digital elevation models in the form of Triangular Irregular Network (TIN) raster files. To a limited degree, for certain floodplain expansion areas we also used 2011 Northeast National Map LiDAR project data[8]. In general, the precision of the LiDAR data is 1 cm, but the accuracy is approximately 6 inches over the entire southeast study area, and the relative accuracy over a small geographic area along the same flight path is considerably better[9].

[6] Data available at http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8447930. This is the average rate for the period 1932 to 2006.
[7] IPCC, 2007.
[8] LiDAR for the Northeast (ARRA LiDAR Task Order, USGS Contract: G10PC00026, Task Order Number: G10PD02143, Task Order Number: G10PD01027), project meets U.S. Geological Survey National Geospatial Program Base LiDAR Specification, Version 12, see USGS (2009).Note that dates of LiDAR coverages collected under this contract range from 2009 to 2012.
[9] USGS, 2008



Comments

The adjusted baseline floodplain developed for this study was based on the base flood elevations and other information contained in the 2012 FIRM digital data set. At this site, the base flood elevation of the AE Zone or the 100-year storm was designated as 14 ft.

To ensure consistency of comparisons among the data sets, an adjusted baseline floodplain was created for this study by precisely matching its boundary to the LiDAR contour elevations. In this case, the adjusted boundary was matched to the 14-ft LiDAR based contour line (blue line).

The process was continued for the 1, 2, and 4-ft sea level rise scenarios. If any portion of a house was in the new boundary, it was included in that sea level rise scenario. A house that crossed multiple boundaries was assigned to the lowest elevation.

Fig. 1. Summary of approach for defining expanding floodplains for each of the sea level rise scenarios. Step 1: The landward most base flood elevations for a 100-year storm from 2012 digital FIRM data were compared to LiDAR contours (or digital elevation models). Step 2: An adjusted baseline floodplain area was defined (shaded green) for the purposes of this study. Step 3: The adjusted baseline floodplain was expanded for the 1-ft (shaded red), 2-ft (shaded yellow), and 4-ft (shaded magenta) sea level rise scenarios.

For the parcel and structure values, we used 2012 MassGIS Level 3 parcel data and assessors records[10]. To assign the placement of building locations within the parcels, we used a draft MassGIS database of building footprints based on a 2011 aerial survey[11]. Because a single parcel may have more than 1 structure, points were automatically generated for the largest structure on each parcel using the Geospatial Modeling Environment Software[12]. Generally, the largest structure is the primary structure, but during the review of the placement of the label points within the structure with respect to the floodplain, point placement was adjusted as necessary to correspond to the apparent primary structure[13].

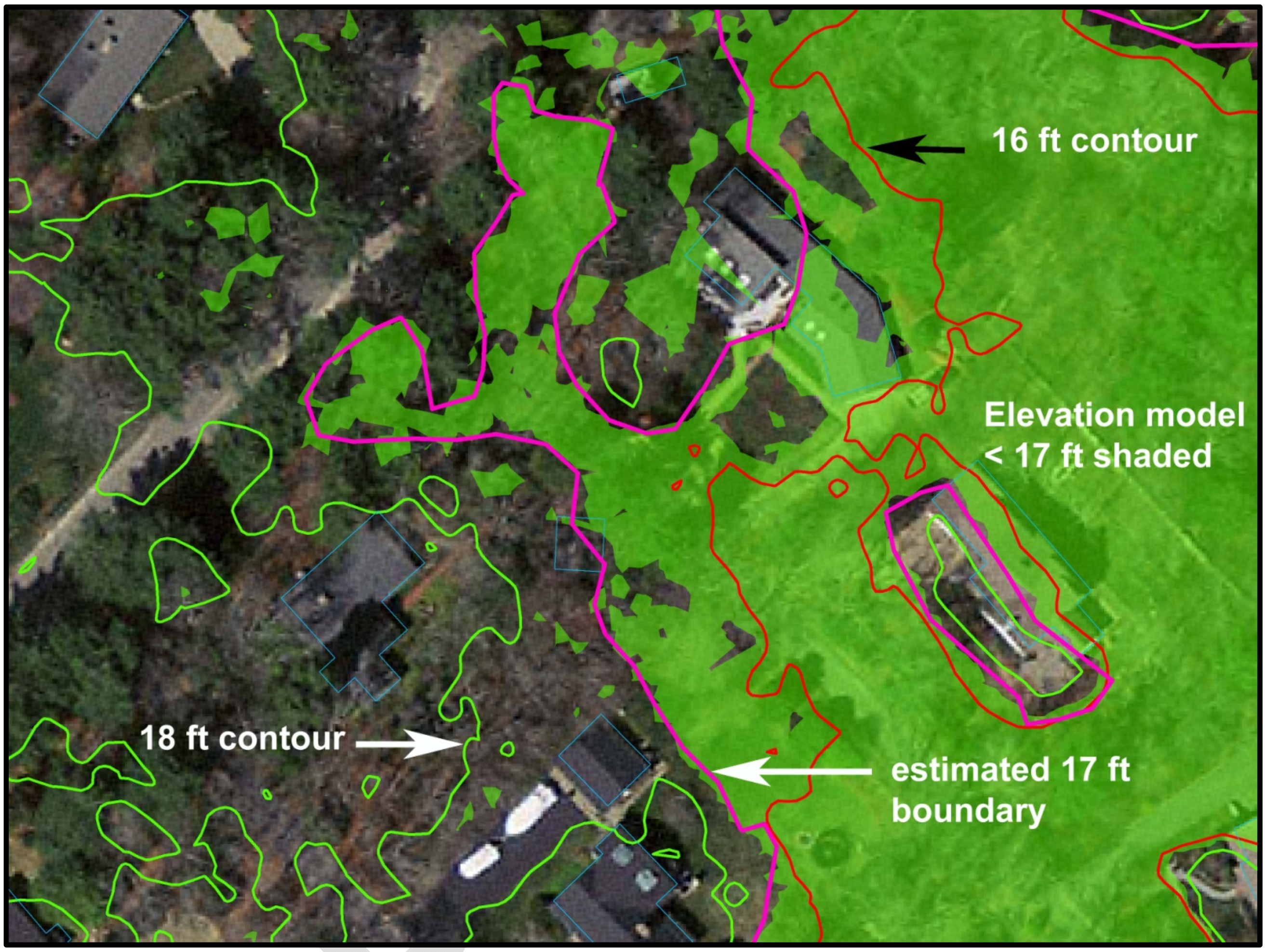


Fig. 2. Mapping Base Flood Elevations (BFEs) with odd numbered values. In areas where the base flood elevation was set to an odd number value and elevation contours wide spaced, the TIN raster digital elevation model files were coded to match the same base flood elevation boundaries. In this image, a floodplain scenario (shaded green, right) was used to estimate a 17-ft contour (shaded magenta).

---

[10] Available at: http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/l3parcels.html. Last download 1/8/2013.
[11] Courtesy Paul Nutting, MassGIS.
[12] Geospatial Modeling Environment (Version 0.7.2.1) (c) Hawthorne L. Beyer 2009-2012. Available at: www.spatialecology.com, email: hawthorne@spatialecology.com.
[13] For example, a point was moved in one instance from a large barn to the residence, which was easily discerned by features such as cows, driveways, vehicles, and apparent architecture.

The base flood elevations from the FIRMs released by FEMA for Marion in 2012 were overlain on the detailed LiDAR contour data (Fig. 1) and digital elevation models (Fig. 2). Typically, the LiDAR 2-ft elevation contour lines were adequate to estimate expansion or adjustments of the boundaries of each sea level rise scenario. However, where land slopes were slight, and the base flood elevation was set to an odd-number value, the digital elevation model TIN raster images were often used to visually estimate the respective new floodplain boundaries, (see Fig. 2). In this way, an adjusted baseline floodplain was defined and used as the initial conditions for the purposes of this study allowing for more meaningful and precise comparisons among the sea level rise scenarios.

This adjusted baseline floodplain was then expanded to account for 1, 2, and 4-foot sea level rises. This was done by using the LiDAR elevations, and the BFEs identified on the FIRMs to which was added each sea level rise scenario (see Fig. 1). Thus, if the BFE on the FIRM was specified as 14 feet for a site, the boundary of the baseline floodplain would be expanded to the 18-ft LiDAR contour in the 4-ft sea level rise scenario.

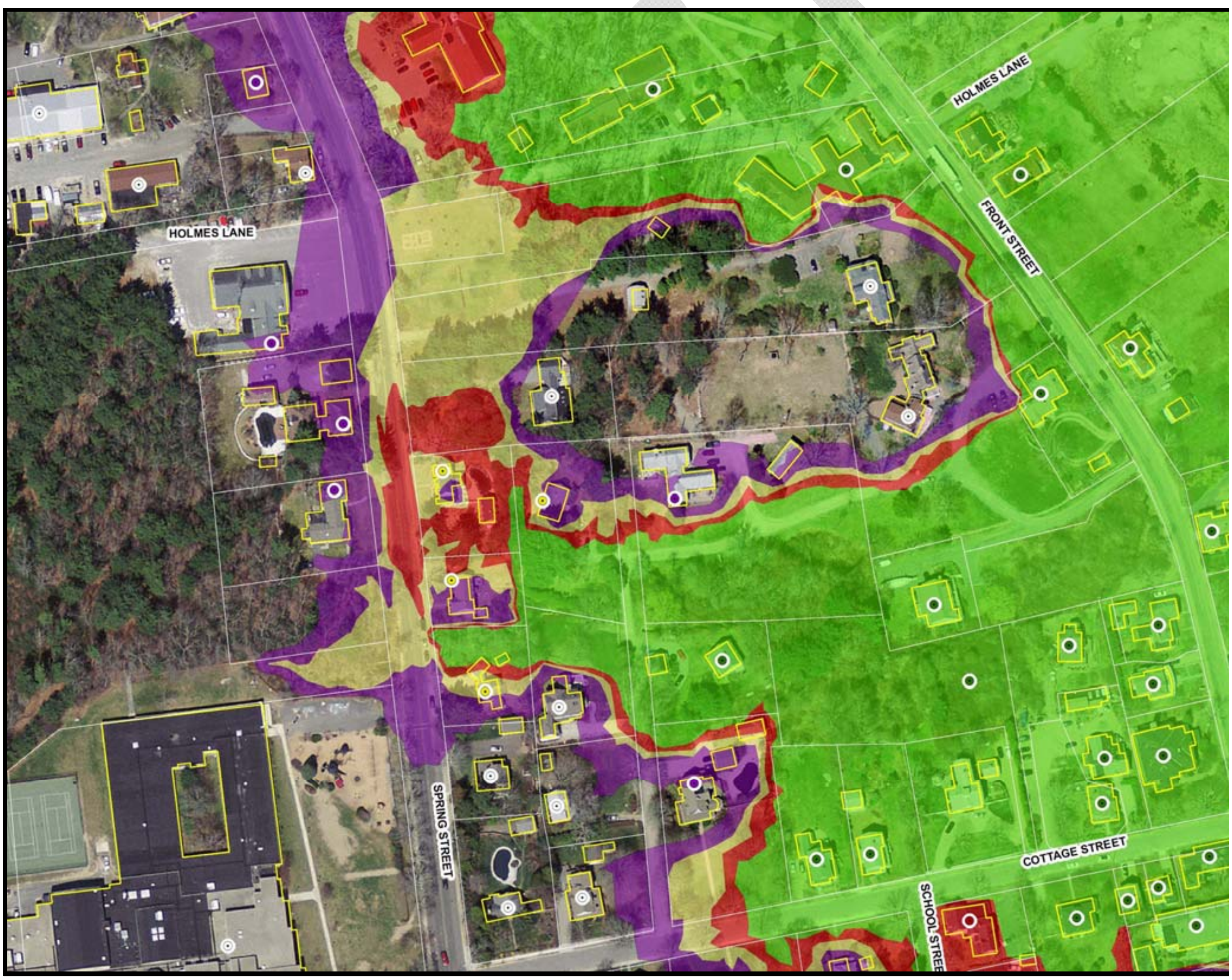


Fig. 3. Structure Assignment in Floodplain Expansion Areas with Different Sea Level Rise Scenarios. Multiple structures (outlined in yellow), if present on a parcel, were converted to label points representing the position of the largest structure. If no structure was present on the GIS coverage, a label point was created for the parcel. The position of these points were used to initially place the primary structure in a flood zone scenario. If several scenarios crossed the footprint of a house, the point location was adjusted to place the building in the lowest elevation zone.

This is a simplified approach, and a more accurate approach would involve predictions of erosion and landform change, and detailed engineering analyses to determine how much the flood elevations would rise along the coast given the submergence of land in the new floodplain areas, but such an effort was beyond the scope of this study.

After the floodplain scenario boundaries were created, the precise placement of the primary structure was assigned to a floodplain scenario (or out of the floodplain). In the first step, to approximate the locations of primary structures, a centroid label point was created for each parcel to represent the location of each primary structure. The position of these points, representing the vulnerability of the structures to sea level rise, was carefully examined on aerial photograph base maps for all parcels crossed by a sea level rise scenario. The positions of these points were moved to precisely coincide with the house footprint. If a house was crossed by several floodplain scenarios, the point was placed in the lowest elevation scenario as illustrated in Fig. 3. Secondary or ancillary detached structures were ignored, and the property building value was assigned to the main structure, typically the primary residential structure. On some parcels, there are multiple detached or attached dwelling units (for example, condominium units), but no parcels of this particular type were bisected by a floodplain in Marion. The cumulative value of these units was included in the total structure value for the town.

Once the position of structures was set relative to the sea level rise scenarios, the position of these points were converted to x y coordinates for each parcel, matched to the assessor's database file[14], which was imported into ArcGIS®. This extra step captured those parcels where many tax records (and multiple structures and owners) exist on one parcel, as is the case with parcels containing condominiums. The new point data set (containing assessor's data and sea level rise scenario location) was then evaluated[15] to quantify the number and value of primary structures in each floodplain scenario.

Various quality control and data validation approaches were implemented to ensure the accuracy of the data following the protocols described above. These validation techniques included check sum approaches to ensure property counts and values and other data are not inadvertently double counted or omitted. Additional information on the methods, the QAPP, and the digital data sets related to this study area available at the Buzzards Bay NEP website: http://www.buzzardsbay.org/floodzone-expansion-slr.html.

3. Results

Fig. 4 shows the difference between the FIRM 100-year floodplain (i.e. a storm with a 1% chance of occurring in a particular year) and the adjusted baseline floodplain used in this study. There were 101 parcels with primary structures within the FIRM 100-year floodplain, but not within the adjusted baseline floodplain used in this study, and 90 built parcels with primary structures within the adjusted baseline floodplain used in this study, but not within the FIRM 100-year floodplain.

Within the baseline floodplain, there were 50 properties with structures that did not have a "building" value assigned in the database. Most of these properties appeared to be companion lots with barns, sheds, etc. These properties were assigned the value in the "Other" building value in the database to ensure each identified primary structure had an assessed value assigned.

[14] The data sets were logically joined using the "LOC_ID" variable in the two data sets.
[15] The shapefile's dbf files was imported into Excel and analyzed in a pivot table.

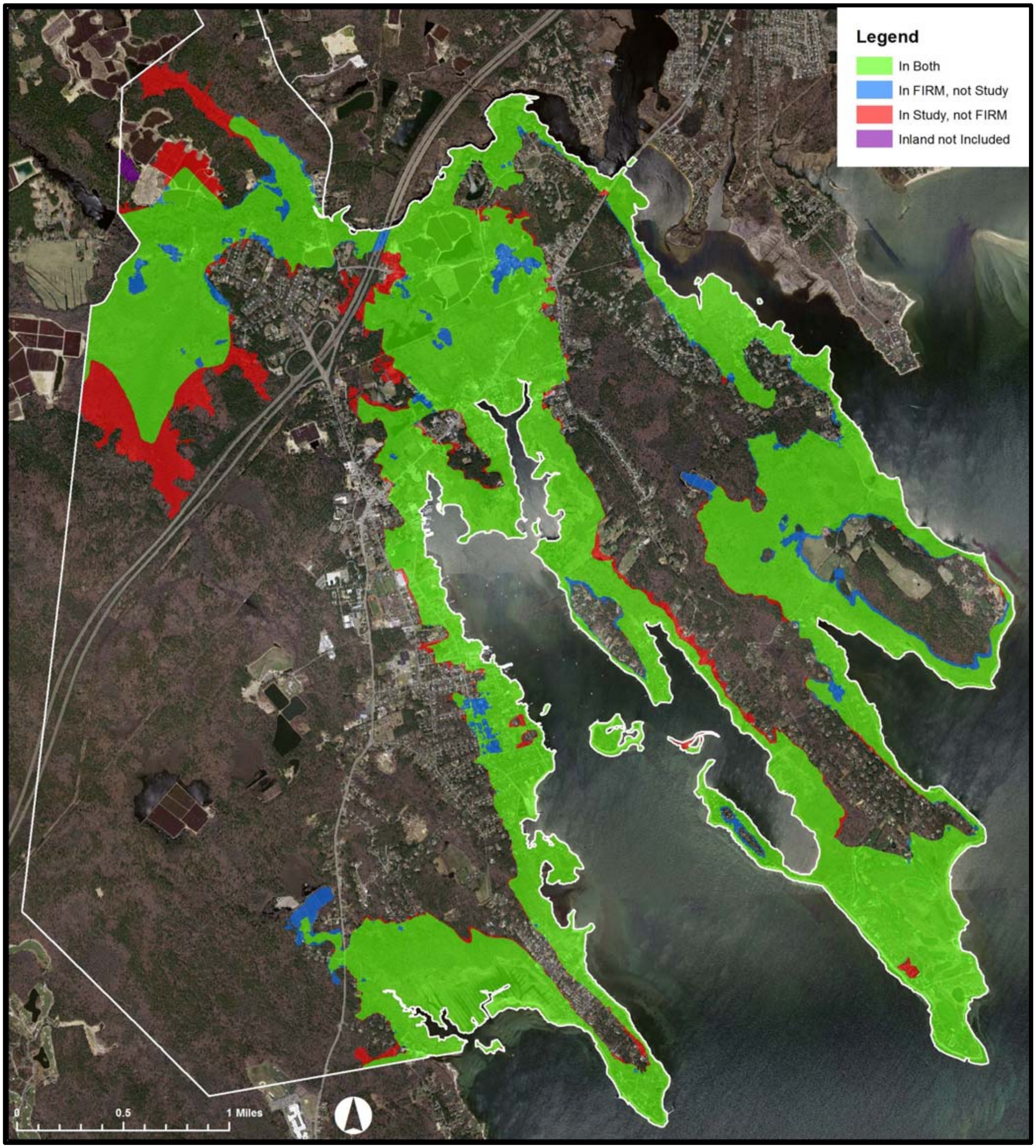


Fig. 4. Comparison of FIRM 100-yr Floodplain to Adjusted Baseline Floodplain in Marion. Figure shows the adjusted baseline floodplain conditions adopted in this study, and how it differed from the 2012 FIRMs 100-year (1% annual risk) coastal floodplain. Inland floodplain areas (shaded magenta, only one small area in northwest Marion) were excluded from the analysis.

Fig. 5 shows a town-wide overview of the adjusted baseline floodplain and the various sea level rise scenarios. Appendix A has detailed maps of this analysis. As shown in Table 1, there are 796 parcels with building structures in the adjusted baseline floodplain used in this study, out of a town-wide total of 2,575 built parcels, or 35.0% of the total. The total building value of the primary structure of these 796 properties in the floodplain is $249.5 million, which is 35.2% of the $708.6 million in primary structure assessed value in the Town. The location of ancillary structures (detached garages, sheds, and barns) were not evaluated in this study, but for the 796 properties in the baseline floodplain, these ancillary structures had an assessed value that totaled $10.5 million (4.2% additional value). Thus, the value of all structures (primary and ancillary) in the baseline floodplain is closer to $260 million.

With a 1-ft sea level rise, 111 parcels with primary structure values totaling $28.1 million are added to the adjusted baseline floodplain. With a 2-ft sea level rise, an additional 121 parcels worth $25.9 million are added, and with the 4-ft sea level rise, an additional 184 structures worth $50.5 million are added. Cumulatively, the baseline to 4-ft sea level rise scenario adds 416 additional built parcels with primary structures worth over $104.5 million in assessed value added to the adjusted baseline floodplain.

At a town-wide level, with a 4-ft sea level rise, the percent area of the town in the expanded adjusted baseline floodplain increased from 35.0% to 45.0% (Fig. 6, top). Similarly, the total number of primary structures in the floodplain increased from 30.9% to 47.1% of the total number of primary structures in town (Fig. 6, middle), and the property values of primary structures in the floodplain increased from 35.2% to 50.0% of the total town primary structure property value (Fig. 6, bottom).

Table 1. Expansion of floodplain with different sea level rise (SLR) scenarios. Totals are for the parcels with the primary structure building values greater than zero using a MassGIS Level 3 2012 assessor's records and parcel database[16].

Floodplain	parcels with structures	cumulative parcels w/ structures	value of primary structures*	cumulative value of primary structures
Adjusted baseline	796	796	$249,458,400	$249,458,400
1-ft SLR	111	907	$28,113,200	$277,571,600
2-ft SLR	121	1,028	$25,907,300	$303,478,900
4-ft SLR	184	1,212	$50,505,400	$353,984,300
Outside of coastal floodplain	1,363	2,575	$354,607,900	$708,592,200
Net change baseline to +4ft		416		$104,525,900
Percent change baseline to +4ft		52.3%		41.9%

* = total assessed primary structure value

[16] MassGIS 2012 Level 3 parcel data set downloaded at: http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/ftpl3parcels.html (accessed 10 January 2013). Town-wide, 79 of 2575 built parcels (mostly companion parcels to an adjacent lot) had no "building" value assigned to them in the assessor records (i.e. no primary structure). In these cases, the value of the "other" structure (typically a shed, garage, or other uninhabitable feature) in the assessor's data was assigned to the structure so that every built parcel had a structure value assigned to it. Only 50 such parcels were located in any one of the floodplain scenarios.

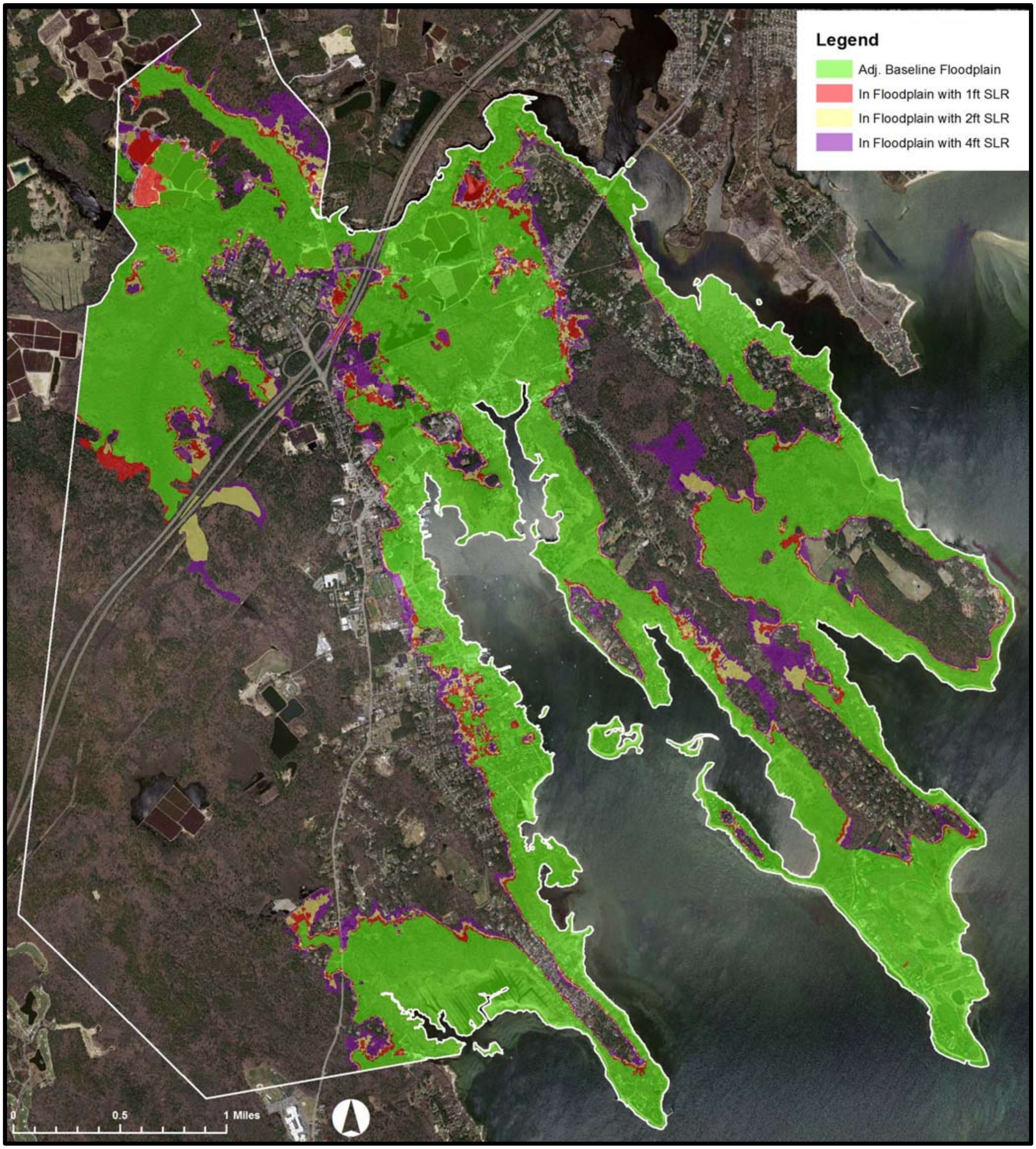


Fig. 5. Overview of the Town of Marion showing changes in expansion of floodplain boundaries with various sea level rise scenarios over the adjusted baseline floodplain. Building footprints are shown in yellow. Note that some changes are too small to see at this scale. See detailed maps in Appendix A.

With respect to public properties, thirteen publicly owned properties have structures in the base-line floodplain, with a total assessed value of $11.4 million for all structures. The Music Hall on Front Street, Bird Island Light House and Silvershell Beach Bath House account for most of this building structure value, although there are also 5 sewer pump stations important to the town's wastewater collection system. No structures were added 1-ft scenario, and only at the 4-ft sea level rise scenario were structures of appreciable value added, in this case the Sippican School and Point Road Fire Station, totaling $1.5 million. Table 2 shows a complete list of public properties and their building values in the adjusted baseline floodplain as defined by this study.

Table 2. Public Properties In The Various Sea Level Rise Scenarios.

Property ID	Primary Structure Value	Other Structure Value	Study Value	Site Address	Owner1	Public Facility
Baseline Floodplain						
M_261713_830996	$62,900	$500	$62,900	185 Wareham St	Town Of Marion	Tax Property, Torn Down
M_263985_828780	$0	$20,100	$20,100	Delano Rd	Town Of Marion	Pump Station
M_265192_824663	$0	$100,000	$100,000	Bird Island	Town Of Marion	Light House
M_261799_830544	$0	$10,500	$10,500	Creek Rd	Town Of Marion	Pump Station
M_261506_831476	$0	$21,600	$21,600	Point Rd	Town Of Marion	Pump Station
M_261067_829407	$0	$62,100	$62,100	Front St	Town Of Marion	Pump Station
M_261060_829367	$0	$6,000	$6,000	Front St	Town Of Marion	Boat Ramp
M_261701_827554	$0	$33,300	$33,300	36 Lewis St	Town Of Marion	Pump Station
M_261840_827526	$0	$125,600	$125,600	1 Front St	Town Of Marion	Silver Shell Beach Bath House
M_261849_827316	$0	$2,700	$2,700	Front St	Town Of Marion	
M_261431_828550	$56,400	$91,000	$56,400	1 Island Wharf Rd	Town Of Marion	Harbor Masters Office
M_261318_828491	$820,700	$48,000	$820,700	164 Front St	Town Of Marion	Music Hall
M_259691_830665	$82,200	$12,700	$82,200	Pumping Station Rd	Town Of Marion	Pumping Station
Total	**$1,022,200**	**$534,100**	**$1,404,100**			
2 ft Sea Level Rise						
M_261870_831468	$0	$16,200	$16,200	Point Rd	Town Of Marion	Pump Station?
M_260670_830360	$0	$30,700	$30,700	30 Washburn Ln	Town Of Marion	Public Toilets
4 ft Sea Level Rise						
M_260813_828570	$905,300	$45,000	$905,300	50 Spring St	Town Of Marion	Sippican School
M_262215_830712	$243,600	$11,300	$243,600	871 Point Rd	Town Of Marion	Fire Station

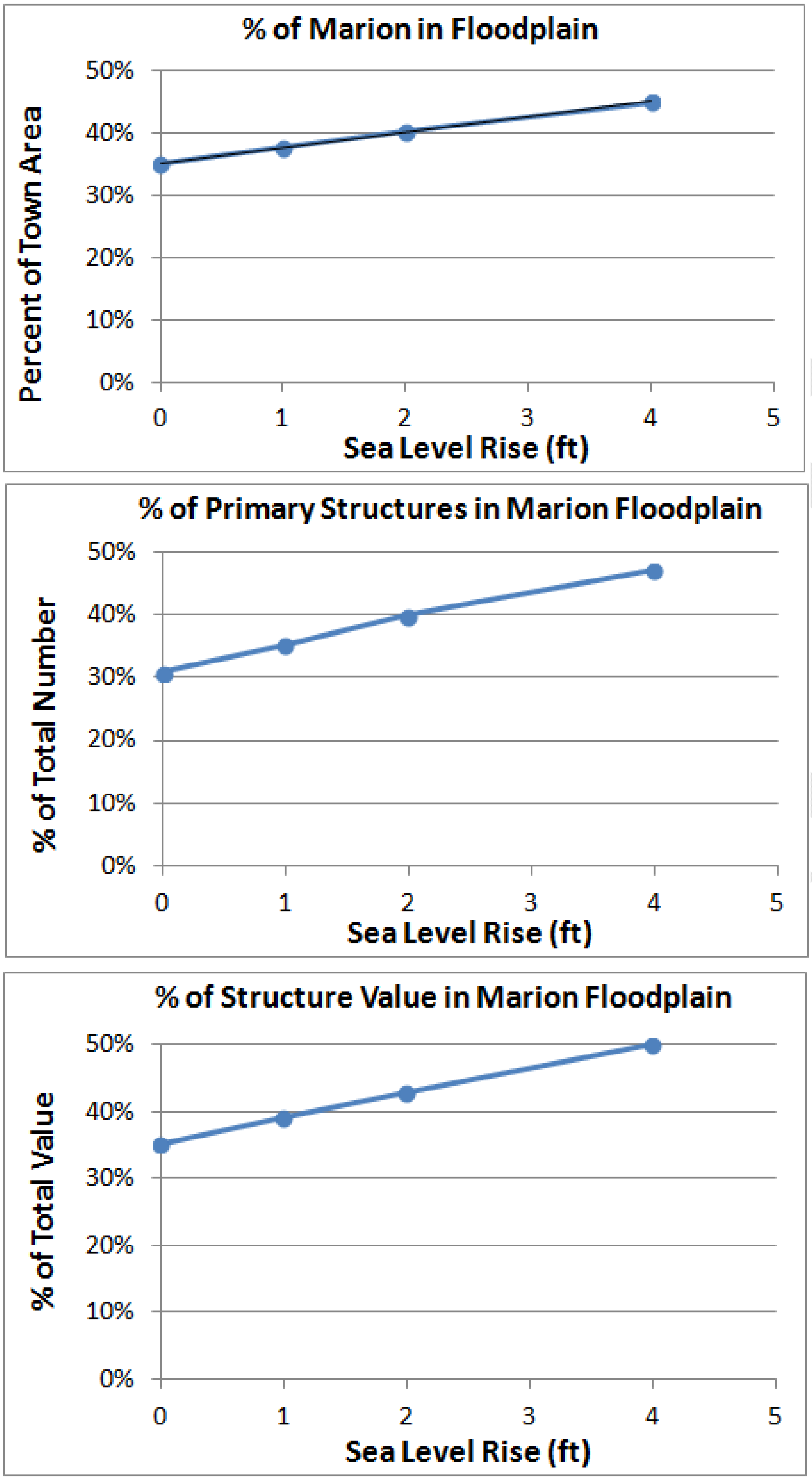


Fig. 6. Percent change in town area within the floodplain (top), percent of total primary structures in the floodplain (middle), and percent of total primary structure value in the floodplain (bottom) for each of the sea level rise scenarios (baseline conditions = 0 ft).

Discussion
There are a number of uncertainties in the analysis presented. If future storms are more severe than in the past, the actual extent of inundation could be greater than described here. Second, this analysis did not consider the elevation of the landscape or elevation of the buildings. Buildings near the elevational margins of a floodplain tend to have minimal flooding compared to properties close to shore and at lower elevations. For these reasons, the maps should be used as general planning tools by public officials and residents about where to construct future structures to minimize their susceptibility to storms with sea level rise, and future liabilities associated with flood insurance. They also can help identify areas that may subsequently enter the jurisdictional regulated area known as the 100-year floodplain that is used by many agencies. In this way, municipal officials and the public could also use these maps to identify sites for open space and habitat protection rather than for construction of public facilities. Other ways this data can be used are described in the Massachusetts Climate Change Adaptation Report (EEA, 2011).

References
CDM-Smith, 2008. Flood Mapping Activities for Plymouth and Bristol Counties, Massachusetts (29 MB). Task Order 18 Activity 1--Topographic Data Development / Acquisition Summary Report. Contract No. EME-2003-CO-0340 Task Order T018. Prepared for: FEMA Region I, February 2008.

EEA (Massachusetts Executive Office of Energy and Environmental Affairs), 2011. Massachusetts Climate Change Adaptation Report September 2011. 128 pp. Available at http://www.mass.gov/eea/air-water-climate-change/climate-change/climate-change-adaptation-report.html.

Flood Insurance Management Agency (FEMA). 2003. Guidelines and Specifications for Flood Hazard Mapping Partners, Volume 1: Flood Studies and Mapping. 110 pp.

IPCC (Intergovernmental Panel on Climate Change), 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Avery, M. Tignor, and H. L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, 996 pp.

Risk Management Solutions, Inc. (RMSI), 2008. The 1938 Great New England Hurricane. Looking to the Past to Understand Today's Risk. 23 pp.

USGS, 2004. Guidelines for Digital Elevation Data, Version 1.0, National Digital Elevation Program (NDEP), May 10, 2004 available at: http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf

Appendix A. Detailed maps showing the expanded floodplain boundaries under the various sea level rise scenarios. The locations of the detailed panel maps can be determined using the key below.