A1: Title and approval sheet

Quality Assurance Project Plan
for
Geographic Information System Analysis of
Buzzards Bay Flood Zone Expansion with Sea Level Rise

Workplan task 13, EPA Cooperative Agreement CE-96144201-0

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Acknowledgments
The principle authors of this plan are Joseph Costa, and John Rockwell of the Buzzards Bay National Estuary Program and David Janik of Massachusetts Office of Coastal Zone Management.

A2. Table of Contents

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Section A: PROJECT MANAGEMENT ELEMENTS

This section describes the design and implementation of the project. Implementation of these elements ensure that appropriate methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are employed and are properly documented.

A3. Distribution list

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Additionally, copies will be on file with the Massachusetts Office of Coastal Zone Management 251 Causeway St., 8th Floor, Boston, MA 02114

A4. Project and task organization

Activities for this project will involve only GIS analysis. The three project leads will develop the necessary GIS coverages and will prepare the final project report and maps for each municipality.

Project Manager: Joseph Costa, Buzzards Bay NEP Executive Director, is the overall project manager and lead principal investigator for the project and is responsible for analysis and integration of data sets, communication, project management, and project reporting. He will develop GIS spatial coverages representing changes in the flood zone.

GIS Analyst: John Rockwell, Buzzards Bay NEP Wetland Specialist, will develop GIS spatial coverages representing changes in the flood zone.

Quality Control Officer: David Janik, MCZM Southeast Regional Coordinator, is the quality control officer for this project, and will ensure that the protocols described here are adopted. He will also develop GIS spatial coverages representing changes in the flood zone, and will ensure that GIS work of the Project Manager and GIS Analyst are consistent with his own.

A5. Problem definition and background

FEMA Flood Insurance Rate Maps (FIRMs) are the basis of federal, state, and local hazard mitigation planning, are used to establish the regulatory requirements 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. In the coastal zone, FIRMs generally define the 1% storm flood zone (commonly called the "100-year storm") 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, these two zones are defined as Zone VE or Zone AE, which indicates that the zones have been assigned a base flood elevation (BFE) which was defined by a model or some other analytical procedure. The BFE corresponds to the top of the wave crest during the projected 1% probability storm. The methodology for determining these elevations and their boundaries are described in the *Guidelines and Specifications for Flood Hazard Mapping Partners, Volume 1: Flood Studies and Mapping* (FEMA, 2003). The flood zones described above are defined by FEMA as follows.

> **A:** Areas with a 1% annual chance of flooding but where no depth or base flood elevations has been calculated.
> **AE:** Areas with a 1% annual chance of flooding and where the base floodplain where base flood elevations are provided based on FEMA analyses and models
> **VE:** Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. Base flood elevations derived from detailed analyses and flood models within these zones.

FEMA Flood Insurance Rate Maps (FIRMs) are graphical representation of the 100-year flood plain used for the federal flood insurance program. In communities that participate in the National Flood Insurance Program (NFIP), mandatory flood insurance purchase requirements apply to federally secured mortgages in all of High Risk Flood Areas.

The predicted landward limit of the floodplain, as depicted in the FEMA FIRMs, corresponds to a specific real-world elevation as defined by the base flood elevation. 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 flood zone, the maps are limited by the quality of topographic data that is available. Whether a particular structure near a mapped base flood elevation boundary is actually in the flood zone 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 2011, FEMA updated the FIRMs in Bristol and Plymouth counties based on recent LiDAR surveys, contracted by FEMA or United States Geological Survey (USGS), and limited new coastal engineering analyses. The basis of the changes in the maps are summarized in Flood Insurance Studies for each municipality available of the FEMA website[1]. Due to funding limitations, FEMA was unable to do new engineering analyses for all portions of each community. These new maps have 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 will consider only the landward most extent of the FIRM base flood (1% storm floodplain), and the published base flood elevation, to define the baseline flood zone used for this analysis. We will then expand this baseline flood zone by adding 1, 2, and 4-ft to the base flood elevation (whether A or V zone). The extrapolations will be based on a digital data

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

set of estimated bare earth elevations established by a 2007 aerial survey using LiDAR[2] technology that was obtained from FEMA and which was used in part to prepare the 2009 updated Bristol and Plymouth County FIRMs (CDM Smith, 2008).

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 1930[3]. The IPCC (2007) consensus range for sea level rise, applied to this region, is 1 to 4.5 feet by year 2100. However, some other studies with alternative scenarios with more expanded Greenland and Antarctic glacier melting, or changes in the North Atlantic gyre may result in higher local sea level rise rates. We thus leave open ended how quickly the 1, 2, and 4-ft elevation increases may occur.

In 2009 and 2011, FEMA updated the FIRMS based on recent LiDAR surveys (contracted by FEMA or USGS). These new maps have 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.

The Buzzards Bay National Estuary Program and Massachusetts Coastal Zone Management have proposed to use the new LiDAR data to extrapolate possible increases in the 100-year flood plain using the newly prepared FEMA Flood Insurance Rate Maps (FIRMs). More specifically, the FEMA base flood elevations will be extrapolated by 1, 2 and 4-ft increases in base flood elevation, to illustrate the potential expansion of the flood zone with a 1, 2 and 4-ft increase in sea level elevation. The generated new GIS data sets will be overlain onto municipal parcel data that contains information about structures and assessed values. Buildings will be converted to point coverages and structures will be assigned in or out of flood zones. Intersection of the parcel data with the new project flood zone GIS data sets will be compared and quantified.

The findings of this study will be summarized in a map and a report for each municipality along the shore of Buzzards Bay. These documents are expected to be used by both the state and municipalities for general planning purposes related to climate adaptation and to illustrate the potential increase in properties in the 100-year flood zone with three different scenarios of rising sea level. The maps and report will be used for educational purposes and they will not be used for regulatory decision-making. This project will not consider the possibility of increased intensity of storms that could result from climate change, and this issue and other confounding factors will be discussed in the final reports prepared for each community.

A6.1. Task Descriptions

This is a geospatial project that will use existing data from a source external to the Buzzards Bay National Estuary Program. These data sets will be manipulated to create new

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[2] 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.

[3] Data available at http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8447930. This is the average rate for the period 1932 to 2006.

maps to be used for planning purposes. The data sets chosen for this study are the definitive data sets used by state and federal agencies.

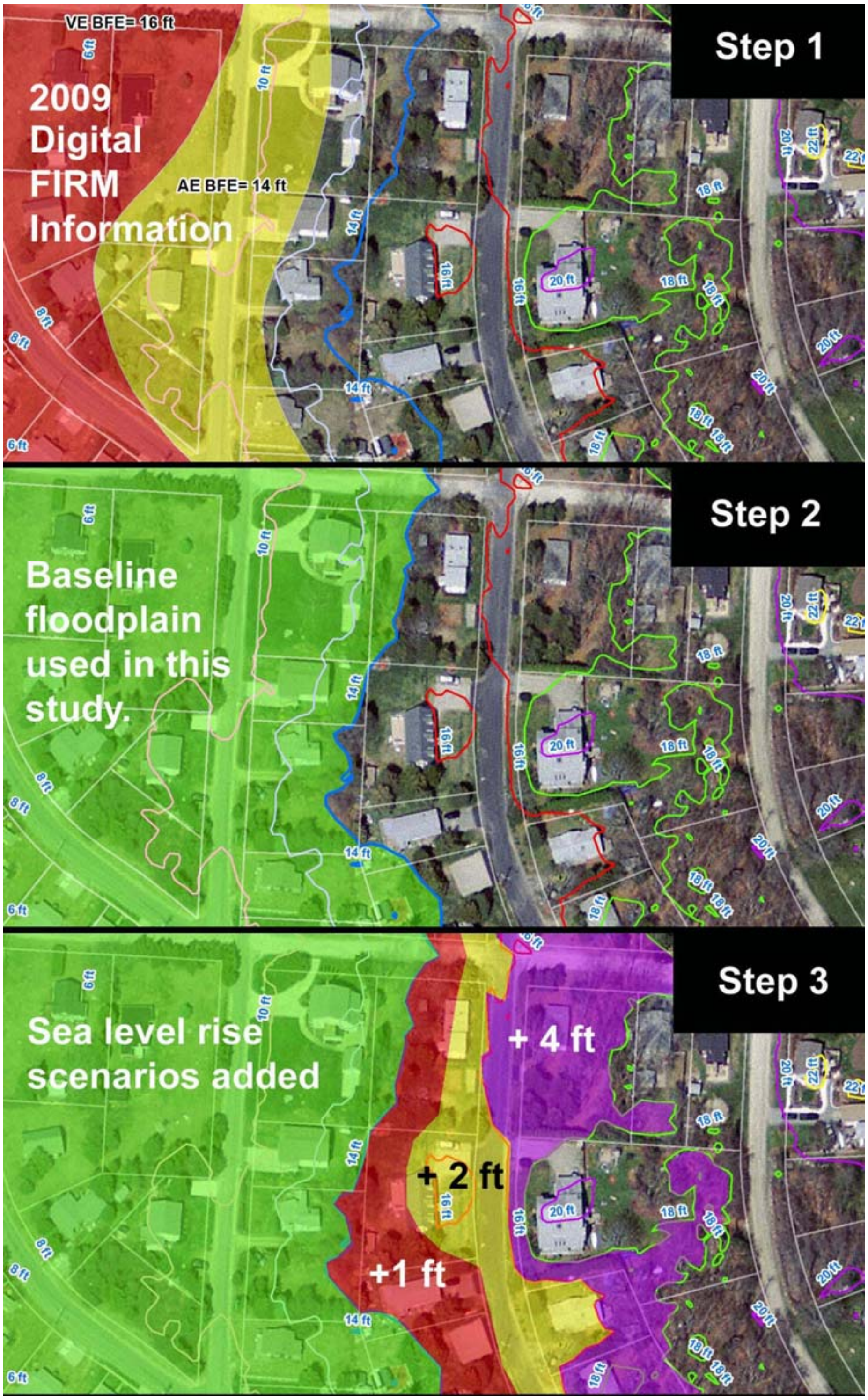
A6.1.1: Creation of baseline floodplain and sea level rise scenario floodplains

ArcMap GIS software (ArcView license) will be 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 will be required for this analysis. We will use a 2007 LiDAR study contracted by FEMA, and described in detail in CDM Smith (2008). These LiDAR data were provided to the Buzzards Bay NEP as both 2-ft contour lines, and as digital elevation models (DEMs) in the form of Triangular Irregular Network (TIN) raster files. To a limited degree, for certain flood zone expansion areas we will also use 2011 Northeast National Map LiDAR project data (unpublished[4]). 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 (USGS, 2004).

The base flood elevations from the Flood Insurance Rate Maps (FIRMs) released by FEMA for Fairhaven in 2009 will be overlain on the detailed LiDAR contour data (Fig. 1, step 1) and digital elevation models (Fig. 2). Because the flood zone delineations on the FIRMs do not exactly follow LiDAR contours for a number of reasons, this step will be necessary to establish a detailed baseline floodplain that could be consistently expanded by the projected sea level rise scenarios. Typically, the LiDAR 2-ft elevation contour lines will be adequate to estimate expansion or adjustments of the boundaries each of the sea level rise scenario. However, where land slopes are slight, and the base flood elevation will be set to an odd-number value, then TIN raster images will be often used to visually estimate the respective new flood zone boundaries, as in Fig. 2. In this way a baseline floodplain zone will be defined which will be used as the initial conditions for the purposes of this study and allow for more meaningful and precise comparisons among the sea level rise scenarios.

This baseline floodplain will be then expanded to account for 1, 2, and 4-foot sea level rises by adjusting the boundaries to the LiDAR elevations that corresponded to the base flood elevations identified on the FIRMS (as in Figs. 1 and 2). Thus, if the base flood elevation on the FEMA FIRM will be 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. 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 0-4-ft zone, but such an effort is beyond the scope of this study

[4] 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).



Comments

The baseline floodplain developed for this study was based on the base flood elevations and other information contained in the 2009 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, a baseline floodplain was created for this study by precisely matching its boundary to the LiDAR contour elevations. In this case, the boundary was matched to the 14-ft LiDAR based contour line (blue line).

The process was continued for the +1-ft, +2-ft, 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 1% storm from 2009 digital FIRM data will be compared to LiDAR contours (or digital elevation models). Step 2: A new baseline flood zone area was defined (shaded green) for the purposes of this study. Step 3: The baseline floodplain was expanded for the +1-ft (shaded red), +2-ft (shaded yellow), and +4-ft (shaded magenta) sea level rise scenarios.

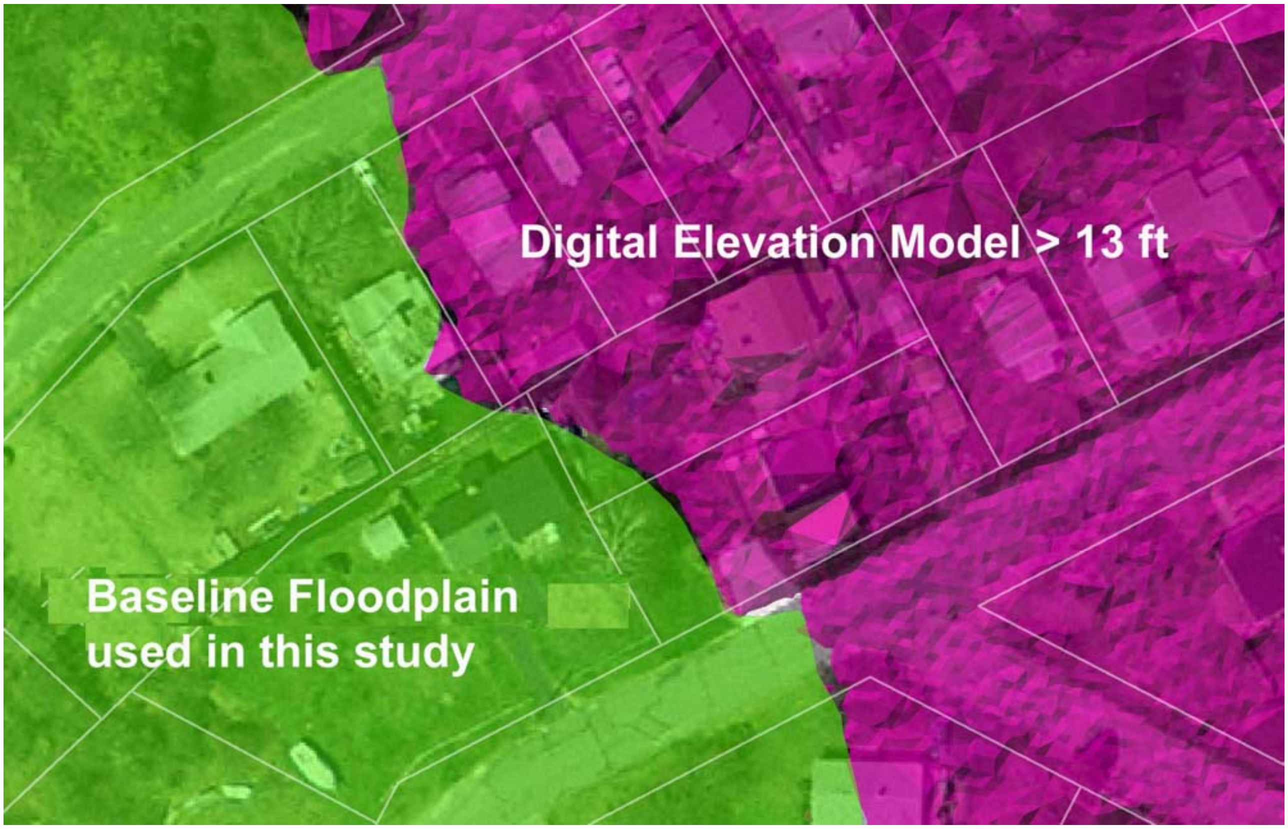


Fig. 2. In areas where the base flood elevation will be set to an odd number value and elevation contours wide spaced, the TIN raster digital elevation model files will be coded to match the same base flood elevation boundaries. In this image, the baseline floodplain used in this study (shaded green, left) will be matched to the 13-ft lidar elevation in the elevation model (shaded magenta, right).

A6.1.2: Processing of sea level rise scenario floodplains with parcel information

After the floodplain boundaries are created, assessor's data will be joined to the GIS parcel data set. In the first step to approximate the locations of buildings, a centroid label point will be created for each parcel to represent the location of each house. If a GIS building footprint exists, that data set will be used instead. The position of these points, representing the vulnerability of the structures to sea level rise, will be carefully examined on aerial photograph base maps for all parcels crossed by a sea level rise scenario. The positions of these points will be moved to precisely coincide with the house footprint. If a house is crossed by several floodplain scenarios, the point will be placed in the lowest elevation scenario as illustrated in Fig. 3 (note houses near Indian Way). Secondary or ancillary detached structures will be ignored, and the property building value will be assigned to the main structure, typically the primary residential structure.

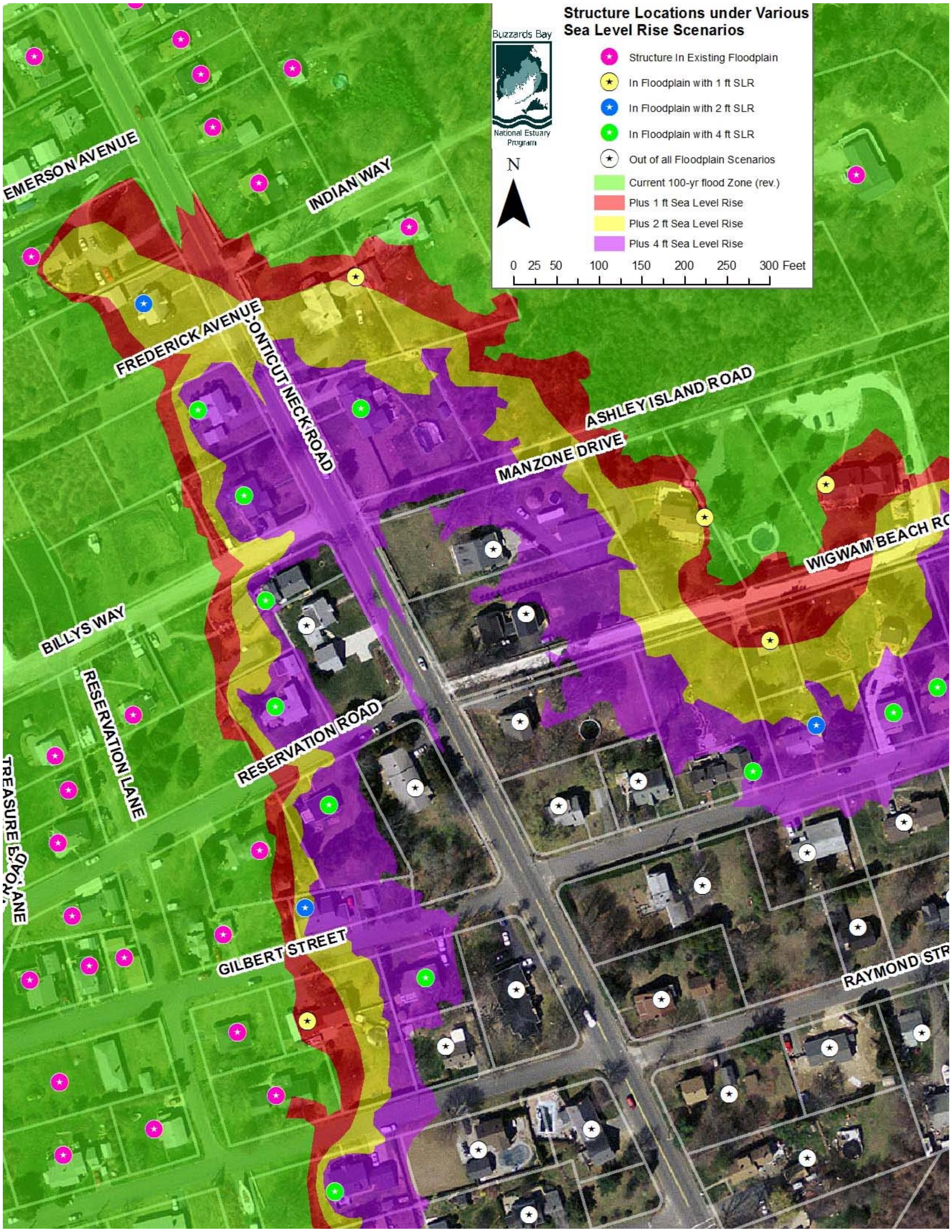


Fig. 3. Parcels (outlined in white) will be converted to label points representing the position of structures. The precise placement of these points is important only for properties near one of the flood zone scenario boundaries. If a house is crossed by several scenarios, the point location will be adjusted to place the building in the lowest elevation zone.

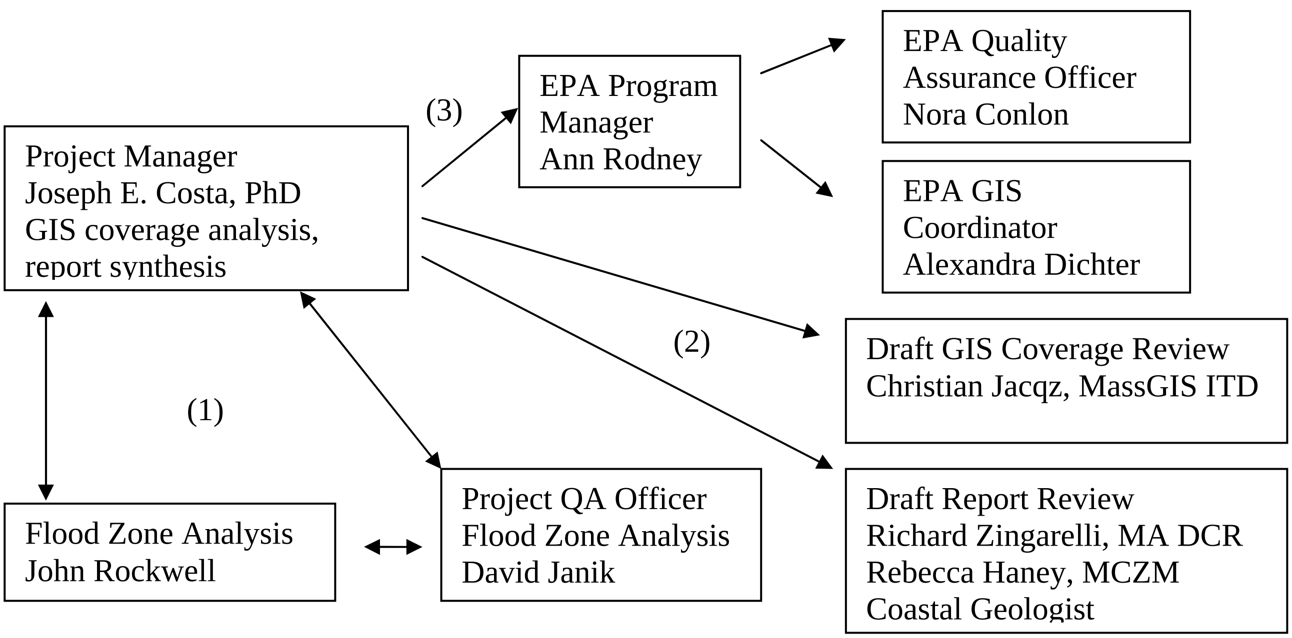
Once the position of structures is set relative to the sea level rise scenarios, and assigned assessed values for total building structures on the parcel linked to these points, this digital point coverage will be intersected with flood zone sea level rise scenario polygons. The resulting data set will be processed in an Excel spreadsheet, and a pivot table will be used to quantify building data using various classifications of structures by flood zone and inside or outside of the hurricane barrier.

A7. Special training certification

Personnel performing the GIS analysis under this QAPP will be familiar with and have previous experience using ArcMap ArcView software, and will receive any necessary training by the Project Manager.

A8. Organizational Chart

The flow of information and analyses, data, and report review will follow the organization chart below for the various phases of the project which including (1) internal project analysis, data development, and review; (2) external reviews of draft data sets and draft reports, and (3) submission of draft final materials to EPA for review and approval.



A9. Data quality objectives and criteria

This effort involves a Geographic Information System (GIS) analysis using existing state, federal, and local GIS data sets. Recently approved FEMA FIRM maps, and the specified base flood elevation (BFE) for each area of the coast, will be extrapolated to prepare reasonably meaningful maps that identify potential flood zone expansion that may result in 1, 2, and 4-ft increases in sea level. The postulated expansion of the existing 100-year flood zone will be based on the same LiDAR data on which the new FEMA FIRMS are largely based. This new LiDAR data is available as digital elevation models (DEMs) in the form of Triangular Irregular Network (TINs), DEM img files and as 2 ft-contour data. The details and quality of this data is summarized in the 2008 report *Flood Mapping Activities for Plymouth and*

Bristol Counties, Massachusetts (CDM Smith, 2008[5]). For Cape Cod, data from the 2012 NE LiDAR project will be used. This data exists as DEM raster IMG files.

The Data Quality Objectives (DQOs) for this study shall include the following criteria:

1) BFE polygon boundaries are generally accurate within 50 ft.
2) Assessors data used shall be 2007 year data or later.
3) Assessors data parcel joining shall exceed 99.5% success.
4) If any portion of a structure occurs within a BFE elevation, that structure will be placed in the BFE polygon

The maps resulting from this effort can be used as planning tools to assist municipalities to site and construct new facilities so that they will less likely to be affected in subsequent decades by sea level rise. The maps and reports will also summarize municipal buildings within existing and projected 100-year flood zones. The maps will also help illustrate to each level of government how much additional area and existing structures (and existing values) and may be included in flood zone later in the century. The prepared flood zone expansion maps will also be used to illustrate the inclusion of new areas and existing structures in potential future expanded flood zones, and to help target public land acquisitions in sensitive areas.

A10. Documentation and records

It is anticipated that a majority of the internal documentation and record transfer within the project will be completed electronically. Hard copy and electronic copy submittals of deliverables to EPA Region 1 will be submitted to MassGIS for peer review as appropriate, then delivered to EPA. Electronic and hard copy documentation version control, updates, storage, tracking, and distribution will be the responsibility of the Project Manager. Examples of electronic documentation include meta data to accompany GIS data files generated. Because existing software will be used for all phases of this project, it is not necessary to develop any new file types or protocols.

SECTION B: DATA ACQUISITION AND FILE MANAGEMENT

This section addresses aspects of project design and implementation to ensure that appropriate methods for the collection of existing data sets are used in this study. This study does not require the generation of new field data.

B1. Collection and processing of existing data.

The GIS data for this study has already been obtained from USGS and FEMA, and is available from the MASSGIS website. Parcel data and municipal assessor's office data sets will also be obtained from each municipality in the watershed.

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[5] Flood Mapping Activities for Plymouth and Bristol Counties, Massachusetts. 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.

Electronic documentation and data will be stored on individual computers with weekly full backups and daily incremental backups. The backup data will be hosted on USB drives with additional monthly archiving on CDs stored offsite. Upon completion data will be posted online in final form, including shapefiles with appropriate meta data.

B2. Acquisition Methods
Most data sets will be obtained by email from most data sources.

B3. Chain of Custody
Chain of Custody is not applicable to this study.

B4. Analytical methods
The parcel coverage will be converted to a label point coverage that represents the position of the principal structures on the parcel. If a building footprint coverage exists for a municipality, this coverage will be used instead to locate principal structure. Generally, the position of small ancillary structures will be ignored.

ArcView GIS has all the necessary functions to manipulate and intersect the data sets. The GIS data can also be used in an ArcView environment for simple applications such as calculating the amount of area in the flood zones. No field collection of data or ground truthing is required for this analysis.

All data files, input and output files, spreadsheet, database, and word processing files will be stored in an appropriate format for the software used. Current and widely used software packages will be used for electronic spreadsheets (Excel) and word processing (MS Word). Intersected data sets will primarily be analyzed in Excel spreadsheets using built in pivot table functionality. If necessary, files for these software packages can be converted back and forth between formats without a loss of data.

B5. Quality control
Various check sum approaches will be used to ensure properties values and other data are not inadvertently double counted or omitted. For example, number of properties inside and outside the flood zone and their total value must equal (within 0.5%, see DQOs) the total numbers of structures and total valuation for each community. Assignment of structures inside or outside the flood zone will be visually inspected on maps by project staff and outside reviewers (e.g. municipalities).

B6.-B9. Standard QA plan data acquisition elements
These standard QA plan elements are not applicable because no new data will be acquired in this study. The project involves only a synthesis and analysis of existing data using the protocols described.

B10. Data Management
The Buzzards Bay NEP is the governmental authority for storage, access, and disposal of all records. Relevant records and data pertaining to the project will be sent to EPA in the final report. In addition, all hard copy project files will be stored in the EPA OCCWQ office for at

least five years after the project's termination, then moved to the OCC warehouse indefinitely. All electronic files will be maintained on the EPA OCC electronic server indefinitely. Digital data will be posted on the BBNEP website www.buzzardsbay.org. All GIS data files will be fully documented in corresponding Meta data files.

SECTION C: ASSESSMENT AND OVERSIGHT

This section addresses the activities for assessing the effectiveness of the implementation of the project and associated QA and QC activities, particularly the development of the base conditions for the 1 percent flood zone, and its expansion with the three sea level rise scenarios. This section also applies to the integration assessors' data into the analysis, and the review of draft materials by outside reviewers, including town officials.

C1. Data review, validation, and verification requirements

After the base conditions flood zone is defined by adjusting the FEMA 100-year flood zones boundary to the LiDAR data sets to match the FIRM , the respect maps will be reviewed by the Project Manager and GIS QAQC officer. These final coverages will also be sent to MassGIS for review. As part of the data review and validation, inadequacies of the FEMA data set, or inconsistencies will be discussed with the Project Manager. Any problem areas shall be documented and revised if necessary. Only after the BFE boundaries for each scenario are finalized, will the structure points be created and adjusted relative to flood zone boundaries as specified in the DQOs.

After the structure locations are set for each flood zone scenario, the final maps (similar to figure 4), will be reviewed by the Project Manager and GIS QAQC officer

SECTION D: DATA VALIDATION AND USABILITY

This section describes QA activities that occur after the data collection or generation phase of the project is completed, specifically related to the draft and final reports and maps to be prepared for municipalities. Implementation of these elements ensures that the data conform to the specified DQO criteria, thus achieving the project objectives.

D1. Validation and verification methods

Because this project involves an extrapolation of a management boundary that may or may not coincide with real-world elevations, and because the LiDAR data set is being used as a relative measure of sea level rise from the elevation of an existing boundary, no real world validation or verification of the boundaries are possible or necessary. We will however, compare each of the elevation classes to one another to ensure that boundaries expand beyond the previous elevation.

D2. Reconciliation with user requirements

Results will be reviewed internally and externally, as described to assess usability in the context of their specific intended use (identified in project specific QAPP appendices). Project leaders will meet with representatives of MassGIS as required (at least once) to reconcile any differences between data quality and data requirements. Specifically, once the final maps are determined to meet the DQOs of the project, the maps and draft report of findings will be sent to the municipal assessor's office, planning department, or other suitable department designated by the town administrator or manager.

Comments received from municipalities will be included in the final reports and maps. In general, the maps produced will be deemed usable if acceptance criteria are met and the Project Manager determines that municipal comments were suitably addressed. However, if performance criteria do not meet the project's requirements for DQO's as outlined in this QAPP, the shapefiles may be revised, and the structure point file data will be re-intersected with the appropriate coverages. A QAQC report on all of the above items will be included as an Appendix to the Final Report to each municipality.

If Data Quality Objectives are not met, corrective actions will include discussion with MassGIS regarding rejecting or revising data sets, and updates of related reports and maps.