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Designing for the Impact of Future Climate Conditions

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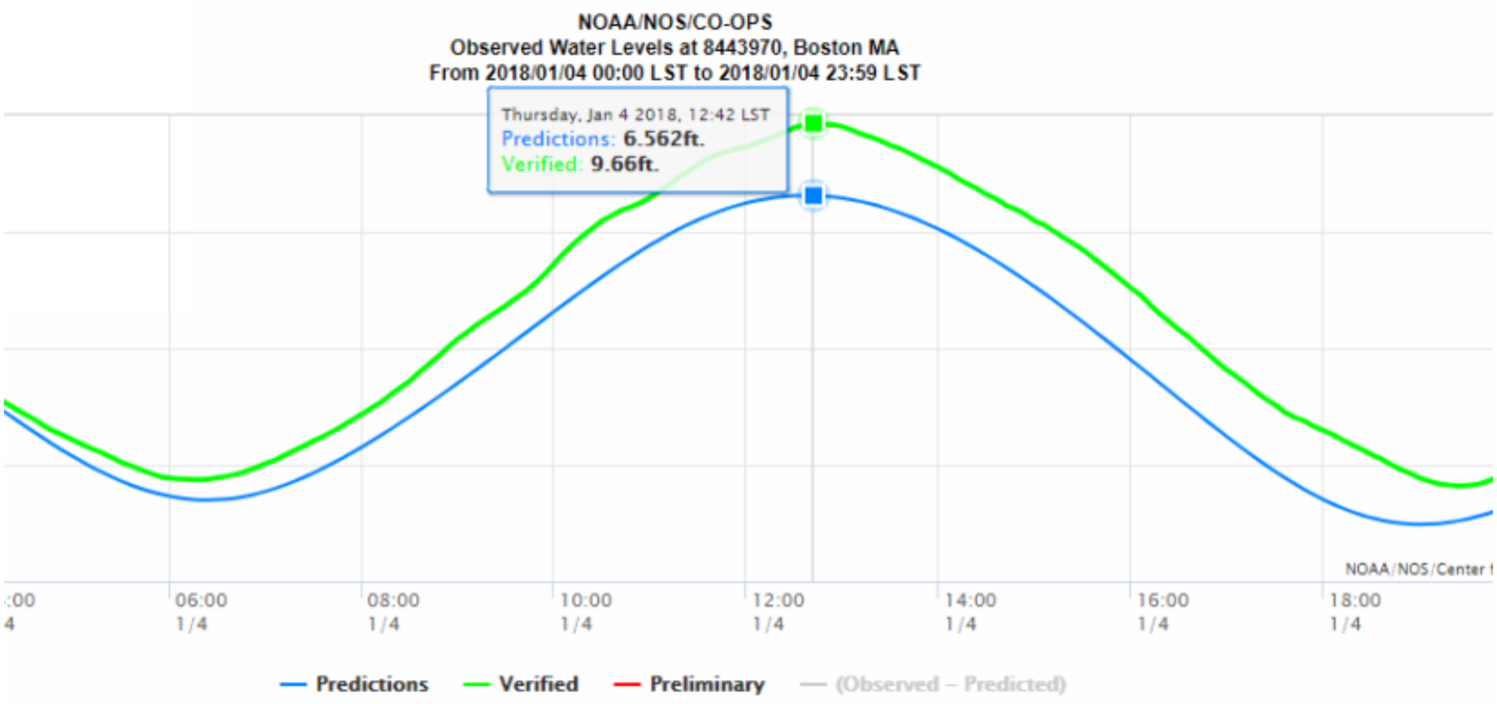
May 7, 2018

Today's Presentation

- Recent storm events
- Climate change design "regulations" & drivers for analysis
- Design Parameters
- Case Study
  - Coastal
  - Riverine
- Analyzing impacts on abutters

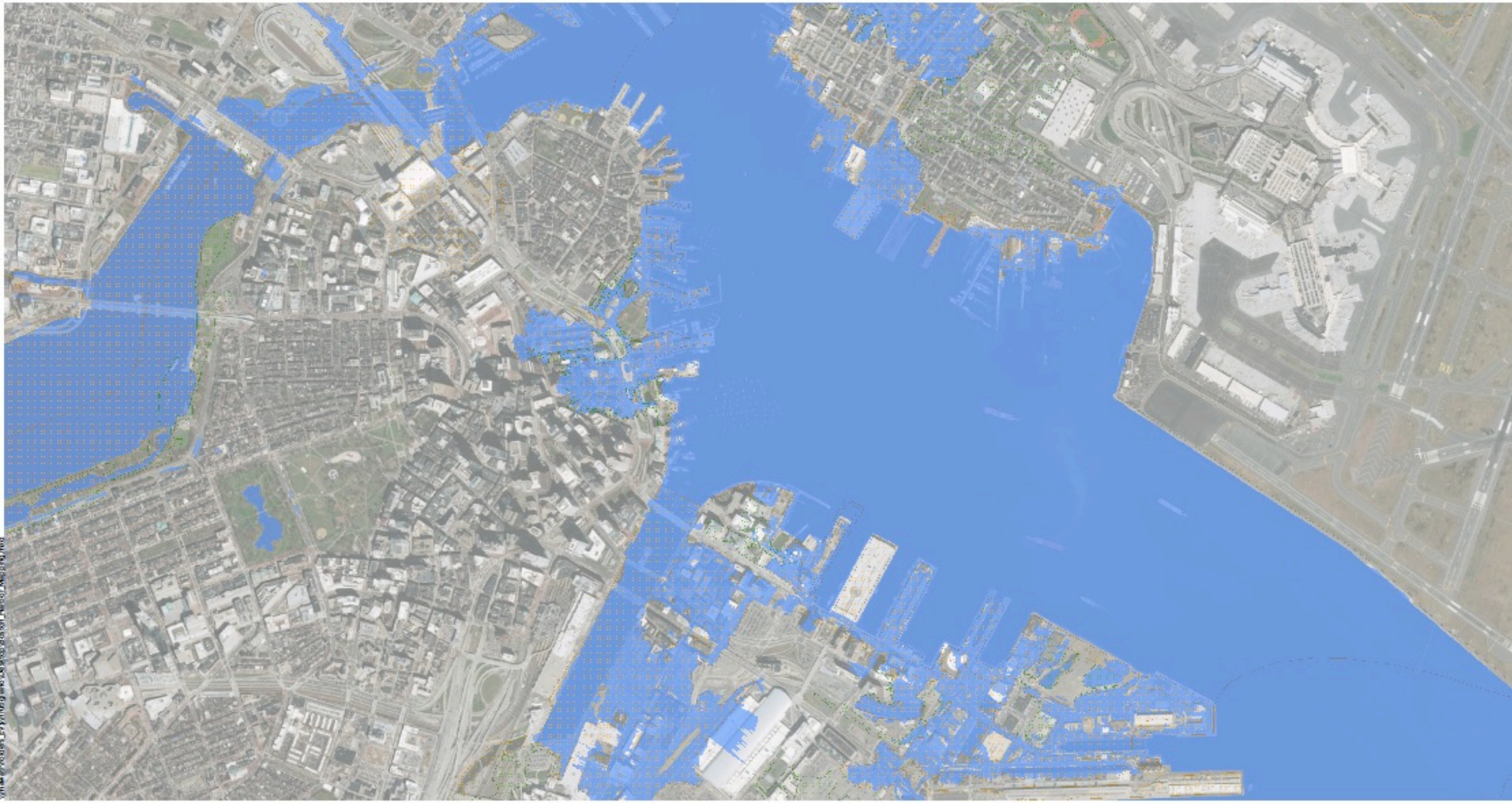
Winter Storm Grayson



- January 4, 2018 – National Oceanic and Atmospheric Administration (NOAA) Boston Tidal Station recorded its highest reading ever of elevation 9.66-feet (NAVD 88).
- Previous high was elevation 9.61-feet (NAVD 88) – Blizzard of 1978

Winter Storm Grayson

vhb January 15, 2018 | **FIGURE 1**



0 650 1300 2600 Feet

Coastal Flooding Inundation | Boston, MA

Legend

- AE: 1% Annual Chance of Flooding, with BFE
- VE: High Risk Coastal Area
- X: 0.2% Annual Chance of Flooding
- Approx. Winter Storm Grayson Inundation Area

Note:

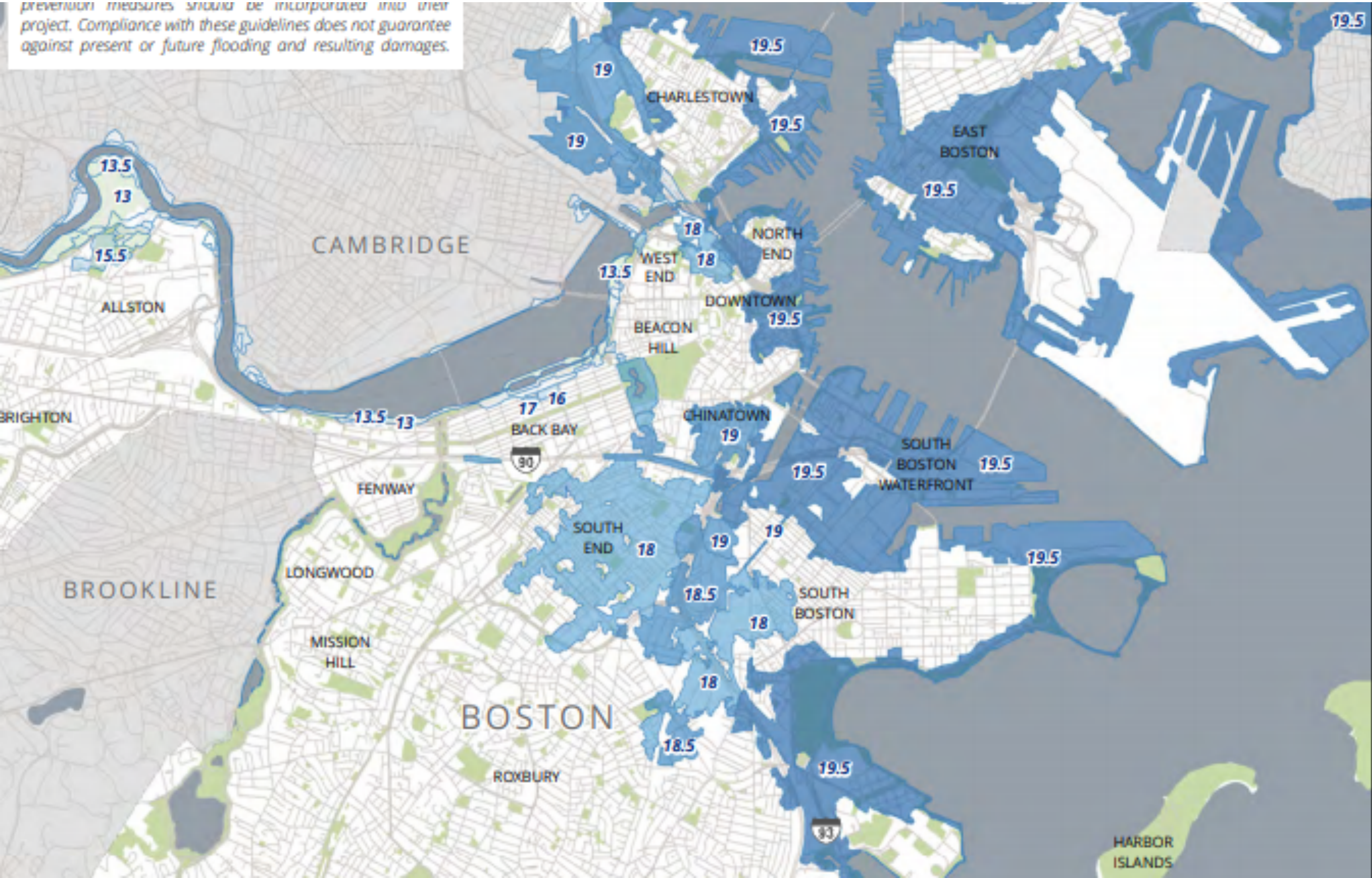
1. Flood inundation area mapped using peak water surface elevations reported at NOAA's Boston Tidal Gage and the USGS Charles River gage on January 4, 2018.

Source Info
1. NOAA
2. ESRI World Imagery

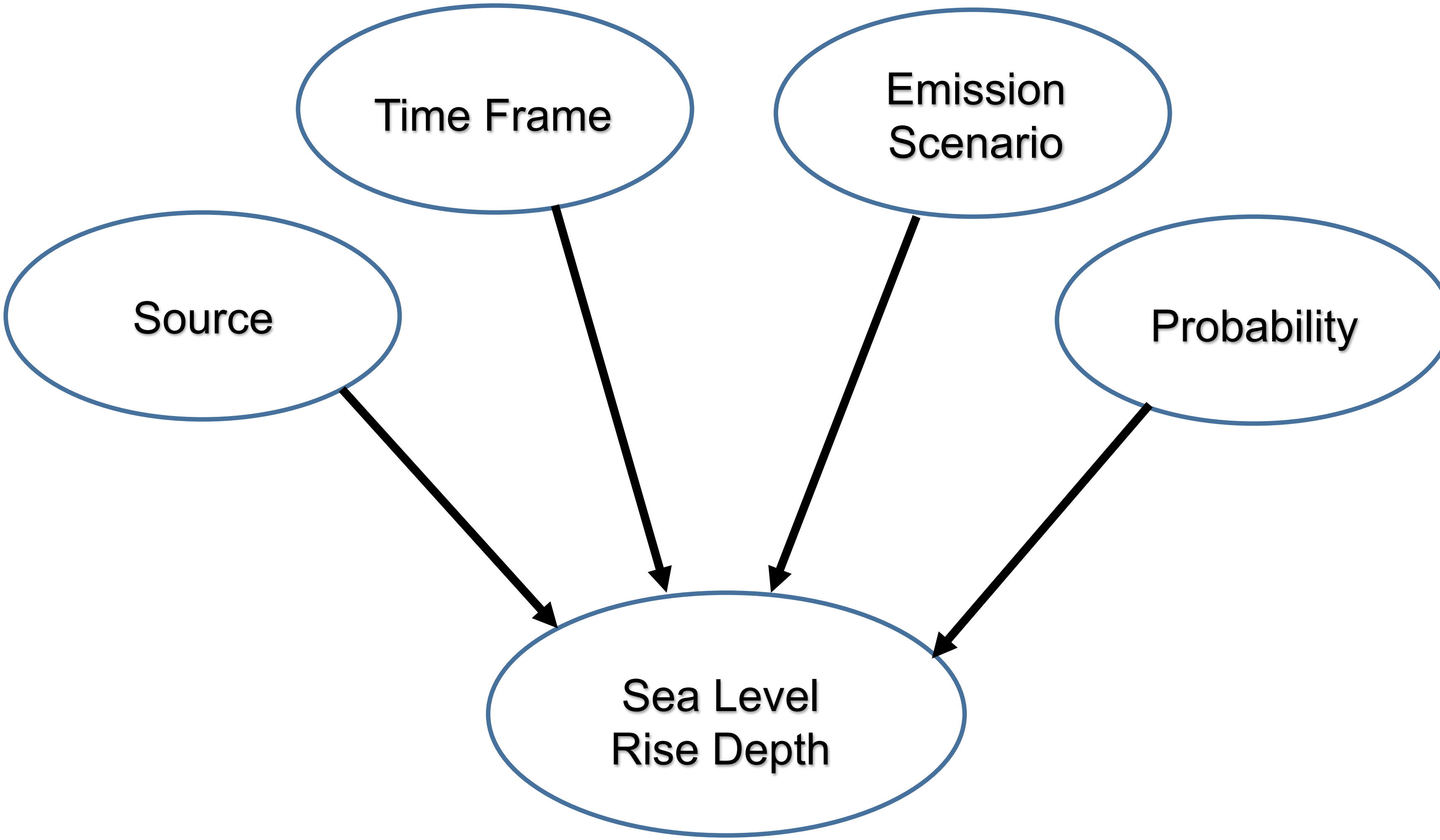
Climate Change Analysis Triggers (Massachusetts)

- Massachusetts Environmental Policy Act Office (MEPA)
- Federal Consistency Review with the Office of Coastal Zone Management
- Chapter 91 – Waterways License
- Local Municipalities/Commissions/Boards (For example BPDA)
- Insurers
- Owners
- Massachusetts Executive Order 569
- Little to no performance standards

Boston Planning and Development Authority



Design Parameters – Sea Level Rise



Design Parameter - Source

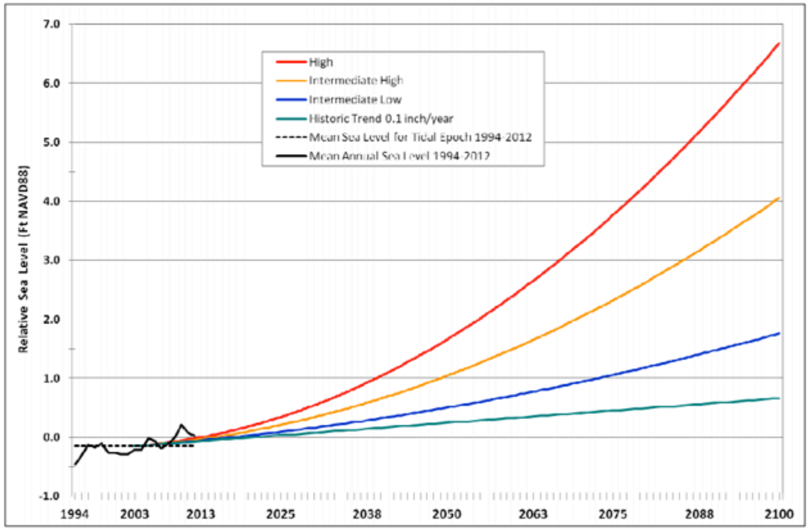
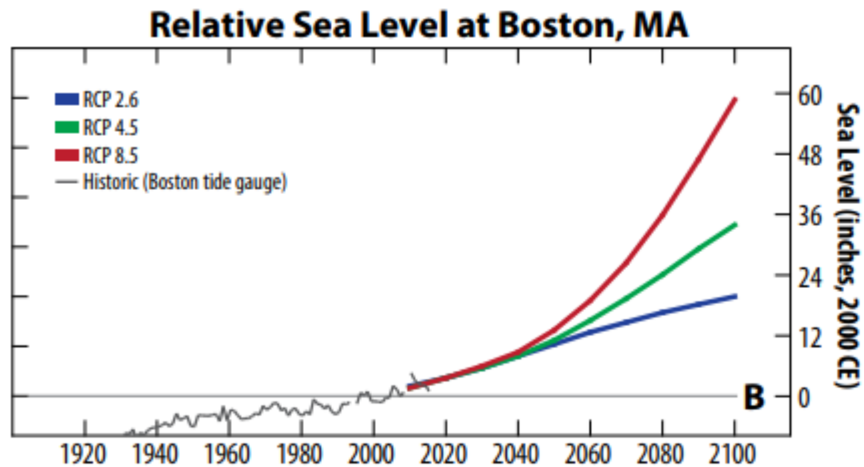
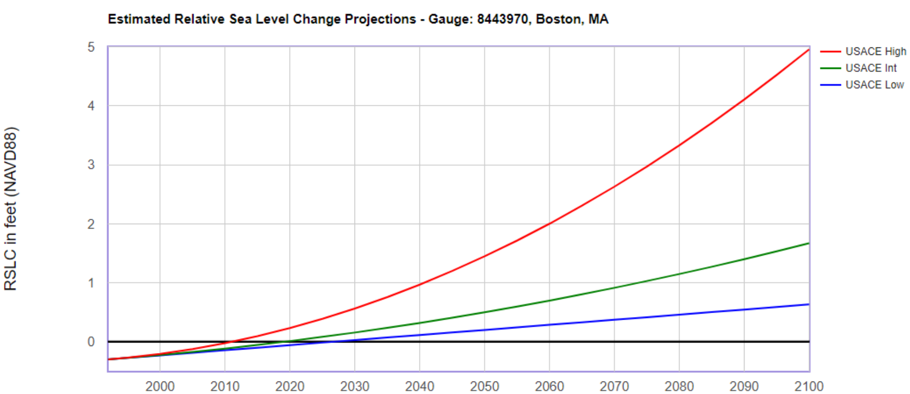


Figure 5. Relative sea level rise scenarios estimates (in feet NAVD88) for Boston, MA. Global scenarios from were adjusted to account for local vertical land movement with 2003 as the beginning year of analysis.

Source: Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning (2013 CZM)



Source: Boston Research Advisory Group (BRAG) Advisory Report (2016)



Source: United States Army Corps of Engineers – Sea Level Chance Curve Calculator

NE CSC
Northeast Climate Science Center

Design Parameters – Emission Scenarios

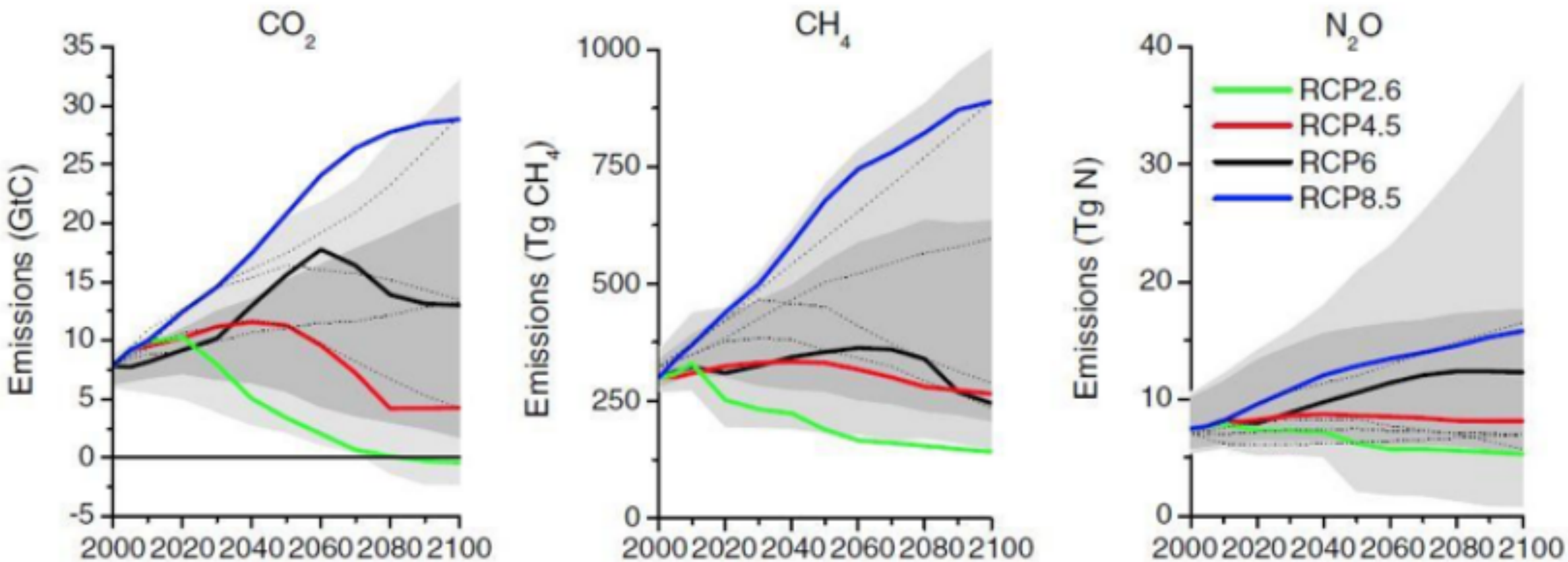


***Figure i-2:** Greenhouse gas emission trajectories used for RCP development (Source: van Vuuren et al., 2011).*

Source: Boston Research Advisory Group (BRAG) Advisory Report (2016)

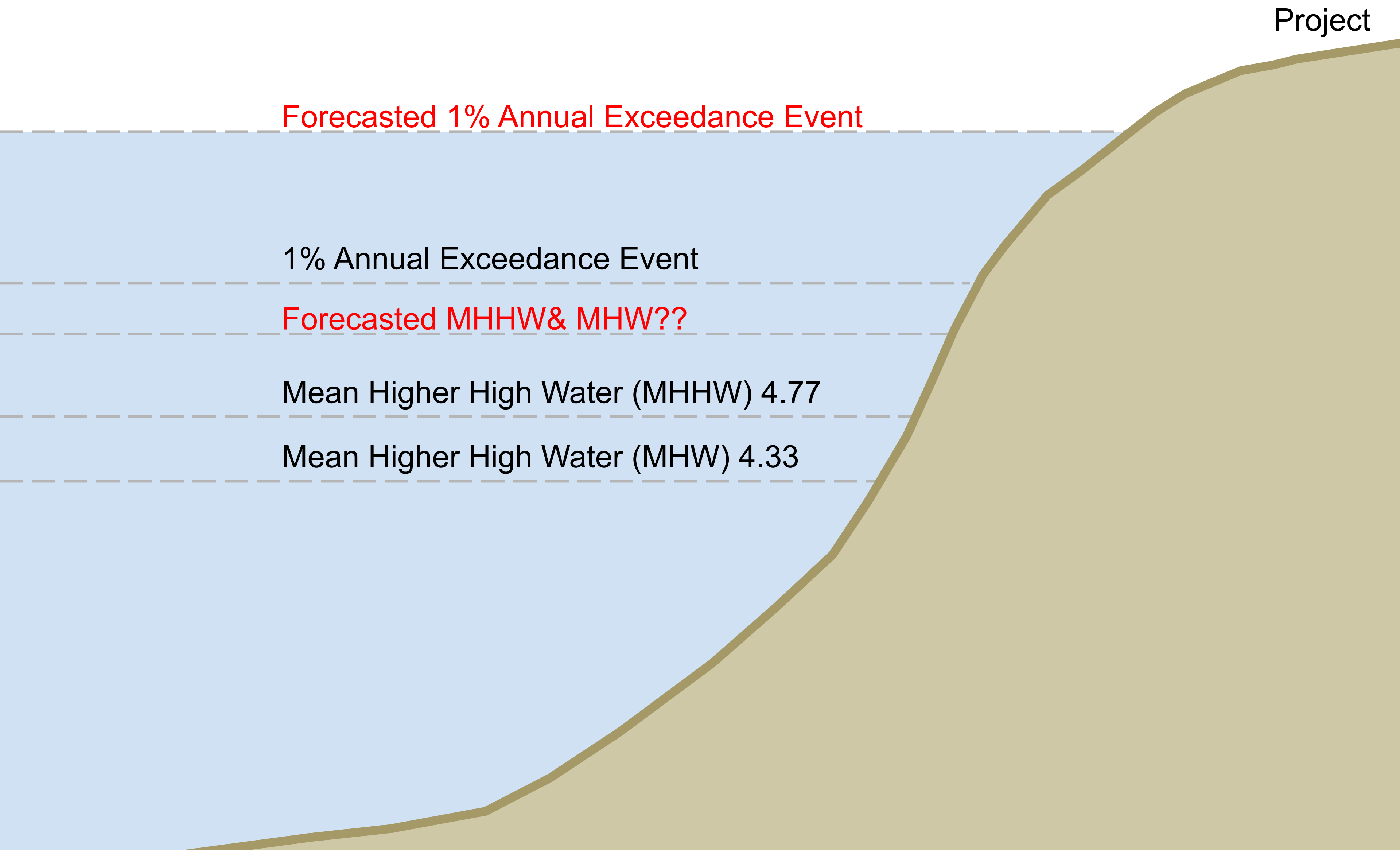
Design Parameters – Time Frame and Percent Probable

			Likely range					Maximum
	0.99	0.95	0.833	0.5	0.167	0.05	0.01	0.001
RCP8.5								
2030	-0.1	0.1	0.3	0.5	0.7	0.9	1.0	1.2
2050	0.1	0.4	0.7	1.1	1.5	1.8	2.1	2.4
2070	0.6	1.0	1.5	2.2	3.1	3.7	4.3	4.8
2100	1.6	2.4	3.2	4.9	7.4	8.6	9.5	10.5
2200	18.9	19.9	21.4	26.1	32.8	34.1	35.3	36.9
RCP4.5								
2030	-0.1	0.1	0.3	0.5	0.7	0.9	1.0	1.2
2050	0.1	0.4	0.7	1.0	1.4	1.7	2.0	2.3
2070	0.4	0.9	1.3	1.9	2.6	3.1	3.6	4.1
2100	0.9	1.7	2.4	3.6	5.1	6.1	7.0	8.0
2200	5.5	6.2	7.2	10.9	16.5	18.0	19.3	20.9
RCP2.6								
2030	-0.1	0.1	0.3	0.5	0.7	0.9	1.0	1.2
2050	0.1	0.4	0.6	1.0	1.4	1.7	2.0	2.3
2070	0.3	0.7	1.1	1.7	2.3	2.7	3.1	3.6
2100	0.4	1.2	1.8	2.8	3.8	4.6	5.3	6.2
2200	3.6	4.4	5.2	6.4	7.7	8.8	9.9	11.8

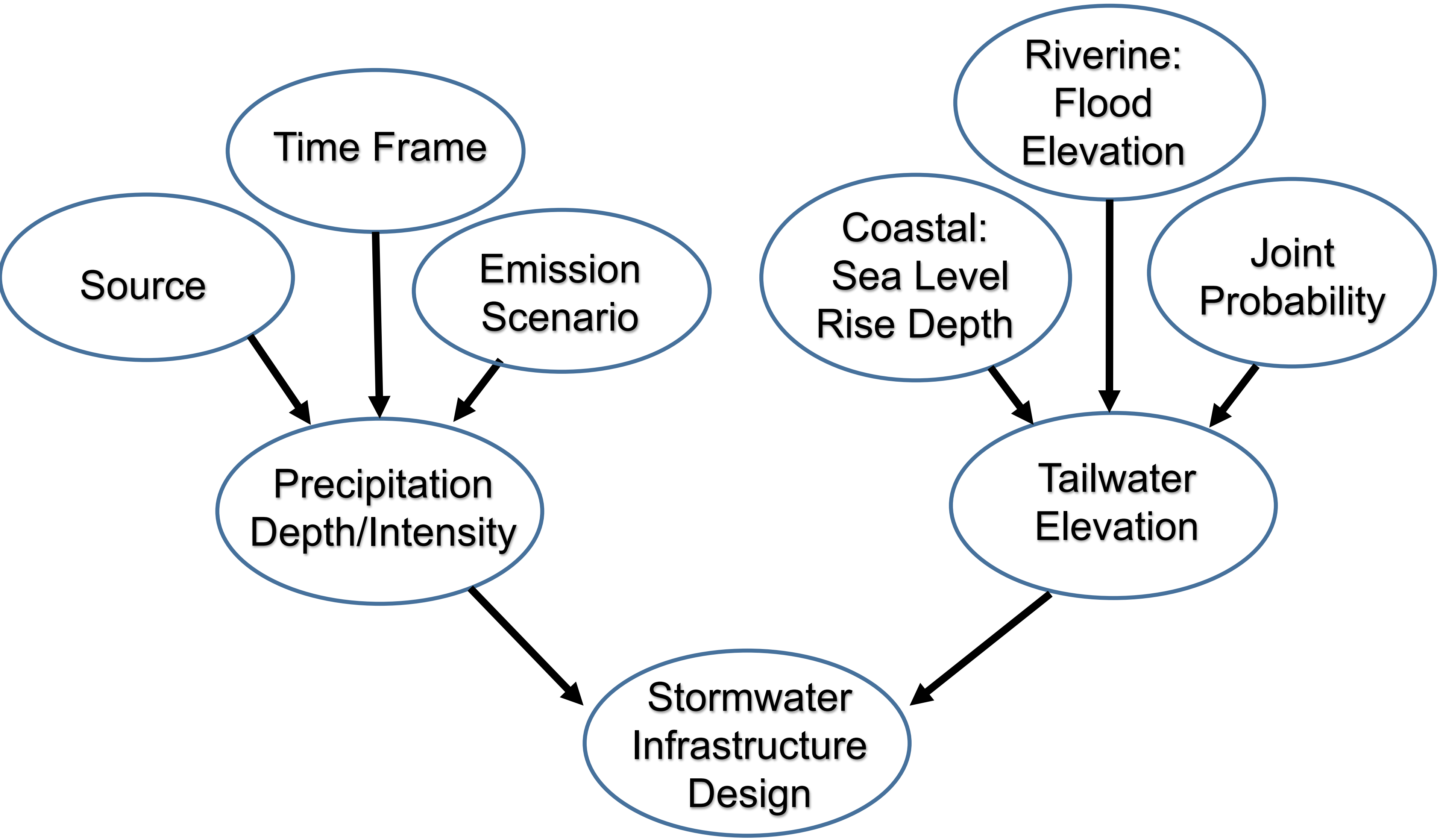
Source: Boston Research Advisory Group (BRAG) Advisory Report (2016)

Total of 120 Sea Level Rise Projections

Coastal Considerations



Design Parameters - Stormwater



Precipitation – Source, Time Frame, and Emissions Scenario

Table 3-1: *Estimates of 10-yr, 24-hour design storms (inches) reported by BWSC and C-CCVA.*

Boston Water and Sewer Commission	Baseline (1948-2012)	Precipitation Depths (in) 2035	2060	2100
B2 (medium)	5.24	5.55	5.76	6.08
A1Fi (precautionary)	5.24	5.60	6.03	6.65
Cambridge CCVA	**Baseline (1971-2000)**	**2030s (2015-2044)**	**2070s (2055-2084)**	
Average values	4.9	5.6	6.4	

Table 3-2: *Additional extreme precipitation metrics (inches) reported by C-CCVA.*

Cambridge CCVA	Baseline (1971-2000)	2030s (2015-2044) Lower	2030s (2015-2044) Higher	2070s (2055-2084) Lower	2070s (2055-2084) Higher
No. days per year > 2 in. rain in 24 hrs	2	3	3	3	3
Max. 5-day precipitation per year (in.)	6	6.5	6.6	7	7.2
24-hr design storms					
10yr	4.9	5.6		6.4	
25 yr	6.2	7.3		8.2	
100 yr	8.9	10.2		11.7	

32% Increase

Design Parameter – Tailwater

- Riverine
  - Joint Probability
  - Increase in Tailwater Flood Flow and Depth
- Coastal
  - Joint Probability – BRAG Report – Low Coincidence
  - Increase in tailwater
  - Localized flooding during joint event

Case Study – Lynn Gearworks

Circle Ave
19th St
Hilton Ave
Harding St
Lynnway
RiverWorksStation
Lynn
Saugus
Site
Hanson St
Saugus River
N. Shore Rd
Lynn
Revere

Coastal Flooding – Case Study

May 03, 2016 | **FIGURE 1**

Projected Mean Higher High Water (MHHW) at the Boston Tide Gage (Feet above NAVD88)

Time Period	USACE Low NOAA Low	USACE Int NOAA Int Low	NOAA Int High	USACE High	NOAA High
Baseline: 1992	4.77'	4.77'	4.77'	4.77'	4.77'
End-of-Century: 2080	5.53'	6.22'	7.74'	8.40'	9.49'

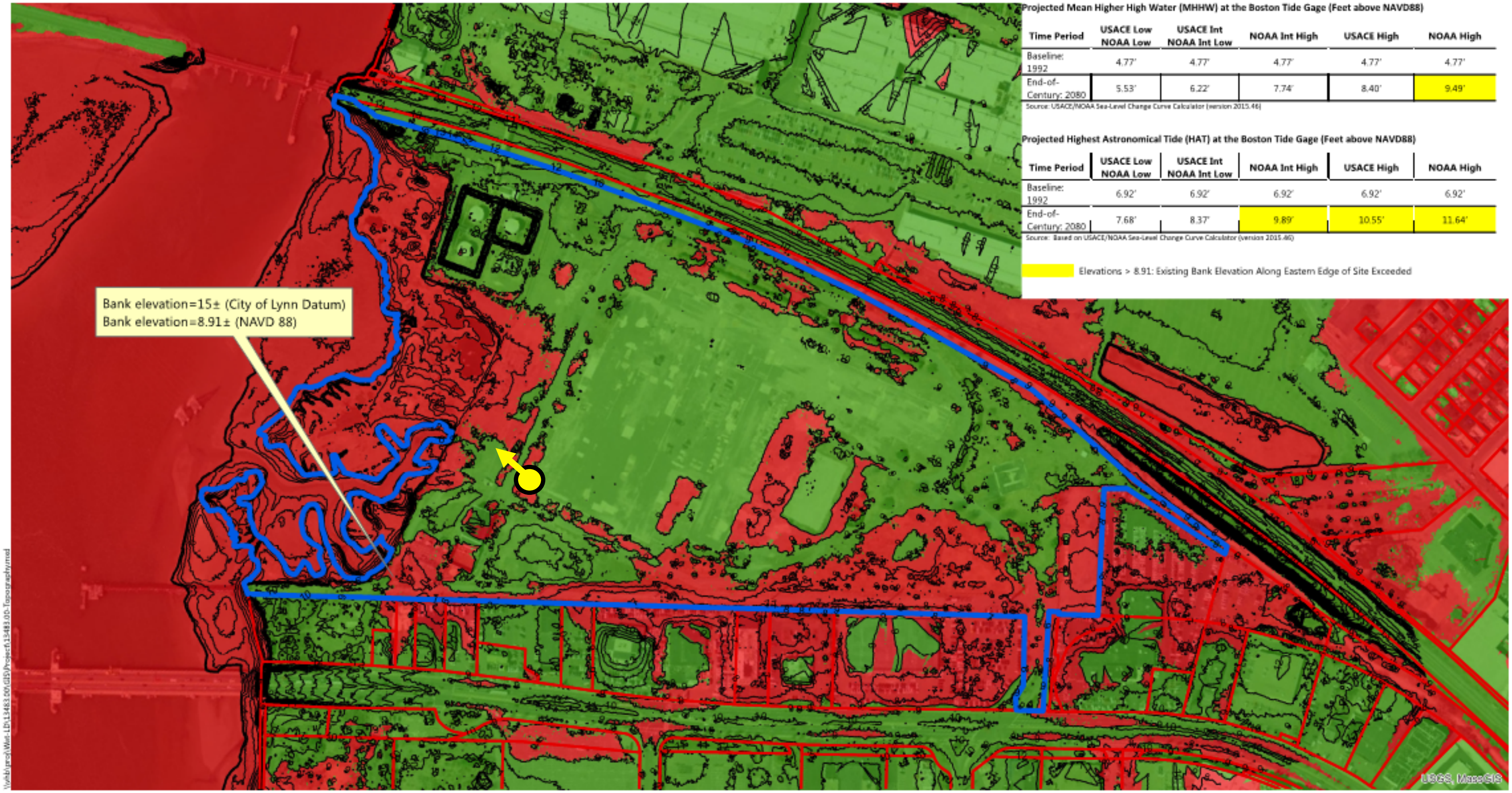
Source: USACE/NOAA Sea-Level Change Curve Calculator (version 2015.46)

Projected Highest Astronomical Tide (HAT) at the Boston Tide Gage (Feet above NAVD88)

Time Period	USACE Low NOAA Low	USACE Int NOAA Int Low	NOAA Int High	USACE High	NOAA High
Baseline: 1992	6.92'	6.92'	6.92'	6.92'	6.92'
End-of-Century: 2080	7.68'	8.37'	9.89'	10.55'	11.64'

Source: Based on USACE/NOAA Sea-Level Change Curve Calculator (version 2015.46)

Elevations > 8.91: Existing Bank Elevation Along Eastern Edge of Site Exceeded



0 150 300 600 Feet

Legend
- Site Parcel (From MassGIS)
- Parcels (From MassGIS)
- LiDAR Contours (NAVD 88 ft)

LiDAR Elevation Data (NAVD 88 ft)
- Elevation ≤ 8.91
- Elevation > 8.91

Lynn Gearworks | Lynn, MA

Existing Topography
LiDAR data source: MassGIS 2013-2014 Sandy

Coastal Flooding – Case Study

Coastal Flood – Case Study

TABLE 11.4 PROJECTED BASE FLOOD ELEVATIONS[a]

	Current (2016)	Near-Term (2030)	Mid-Century (2050)	Late-Century (2080)	End-of-Century (2100)
USACE High[b]	10′	11′	12′	14′	15′
NOAA High[b]	10′	11′	12′	15′	17′
NOAA Int High[b]	10′	11′	11′	13′	14′
COB Low[c]	10′	11′	11′	--	14′
COB Medium[c]	10′	11′	12′	--	15′
COB High[c]	10′	11′	12′	--	18′
BH-FRM High[d]	10′	12′	--	14′ (2070)	--

[a] Feet above NAVD88

Sources: [b] USACE/NOAA Sea-Level Change Curve Calculator (version 2015.46); [c] City of Boston, 2016; [d] Bosma, 2016.

TABLE 11.5 PROJECTED DAYS OF TIDAL FLOODING[A] AT THE PROJECT SITE (APPROX. EL 8.5′ – 10.0′) WITHOUT MITIGATION

Year	Projected SLR (feet)	Days of Tidal Flooding (El 8.5′)	Days of Tidal Flooding (El 10.0′)
2030	0.74	0	0
2050	1.46	0-1	0
2080	2.97	15-37	0-1
2100	4.26	238-294	15-37

Source: Adapted from Kruel, 2016.

[a] NOAA Intermediate High Scenario

Lynn Gearworks

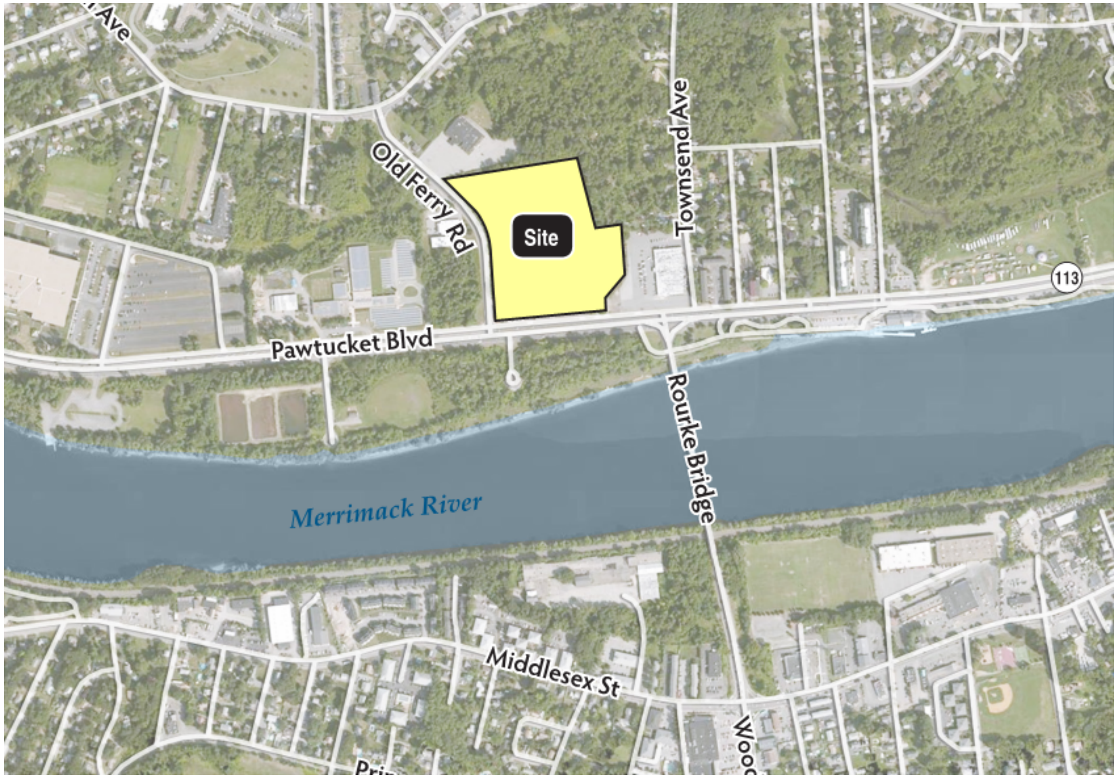
Table 11.6 Projected Days of Tidal Flooding[a] at the Project Site (EL 10.0'-11.0') with Mitigation

Year	Projected SLR (feet)	Number of Days of Tidal Flooding (El 10.0')	Number of Days of Tidal Flooding (El 11.0')
2030	0.74	0	0
2050	1.46	0	0
2080	2.97	0-1	0
2100	4.26	15-37	5-15

Source: Adapted from Kruel, 2016.
[a] NOAA Intermediate High Scenario

Riverine Flooding – Case Study

- Proposed Supermarket Project
- Abutting the Merrimack River in Lowell, MA
- MEPA ENF Certificate *“provide an analysis and discussion of vulnerabilities of the site to the potential effects associated with climate change.”*



Riverine Flooding – Case Study

Riverine Flooding – Case Study

- The Boston Research Area Group (BRAG) report provides projections for Riverine Flooding for 100-year event.

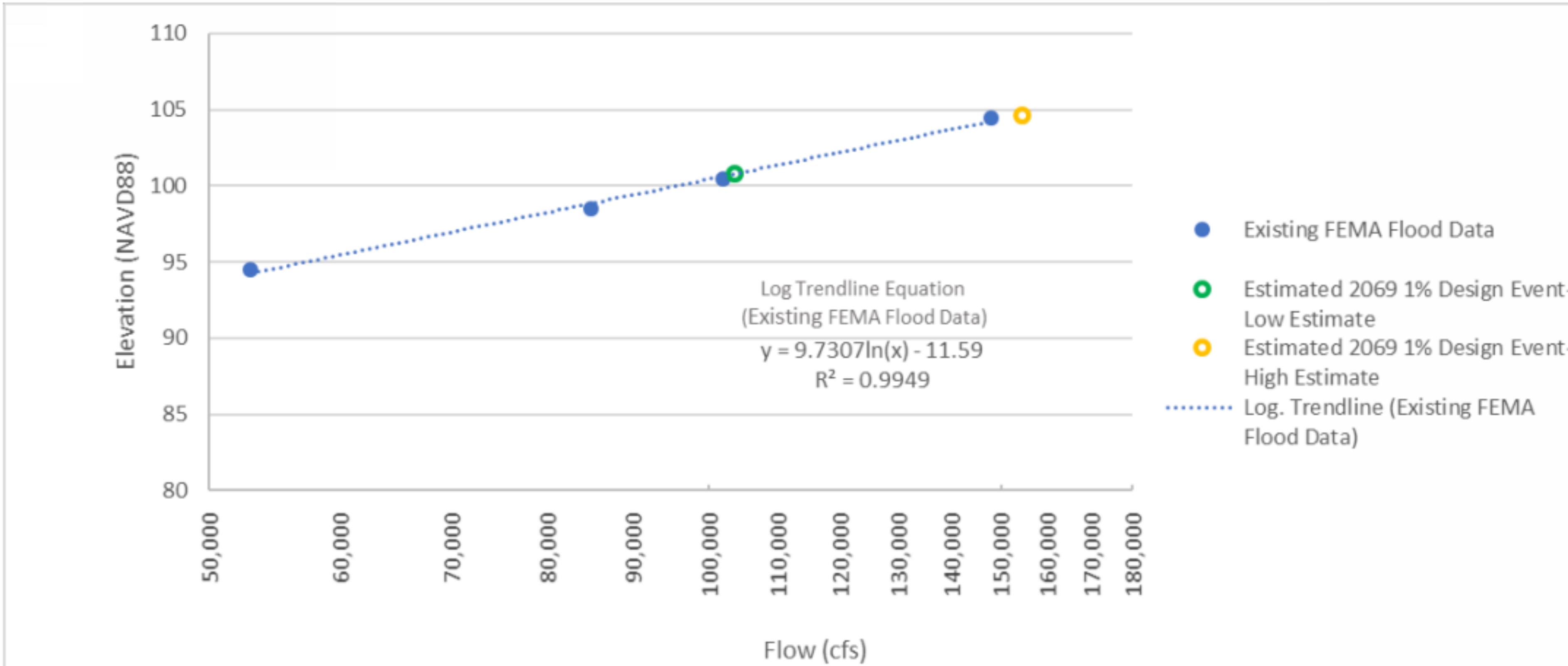
- Project lifespan = 50 years (Year 2069) Low = 2%+ High = 51%+

Flood Type	**2055**	**2085**
Small floods (e.g., 2-year recurrence interval)	0 to 20%	20% to 50%
Design floods (e.g., 100-year)	-10% to 35%	15% to 70%
Flood frequency (floods/year)	increases	increases

- Hydraulic model (HEC-RAS) to determine flood elevations for rivers.

Merrimack River at Nashua, New Hampshire (State Route 111)	Flow (cfs) 93,000	Elevation (ft)
10-Percent	85,000	94.5
2-Percent	102,000	98.5
1-Percent	148,000	100.5
0.2-Percent		104.5

Riverine Flooding – Case Study



- Plotted existing FEMA data: Flow vs. Elevation
- Created a logarithmic best fit trendline.
- Trendline used to a provide approximate planning level method to determine 100-year flood elevation.

Impacts on Abutters

- Projects are being asked to determine impacts on abutters
- Boston Harbor Flood Risk Model
  - Currently being expanded to entire Massachusetts Coastline
  - Only existing conditions
- Access Wave Impacts
  - Create Coastal Transect Model using FEMA guidelines to model Storm Surge and Waves
  - Re-create FEMA FIRM Maps

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