WA4-11 Water and Community Adaptation Methods and Applications

MEMO NUMBER: 77500292-CBI-PL-CBI-000002	TITLE: Mattapoisett Bay SLOSH Modeling Results
DISCIPLINE: SLOSH Modeling	ORIGINATOR: Quin Robertson

PURPOSE:

Details on SLOSH modeling efforts

MEMORANDUM:

The goal of the study is to run the SLOSH model to determine storm surge extent for the southeastern Massachusetts coast from the Cape Cod Canal entrance to the Massachusetts/Rhode Island border along Buzzards Bay and use Mattapoisett as a detailed case study. This model was based on data inputs that were derived from previous studies and previous hurricane conditions. Primary inputs include a matrix of hurricane parameters extracted from NOAA's historical hurricane database and the SeaPlan study concluded in 2014 (Longley and Lipsky, 2014).

1. SLOSH verification

   The SLOSH model does not have a calibration option. However, the SLOSH model can be verified using an historical storm. This study utilized the 1991 Hurricane Bob. SLOSH model results for Hurricane Bob were compared with the closest tide gauge at Woods Hole, MA, Station ID: 8447930 and a digitized inundation line provided by EPA. The SLOSH model compared well with the measured water levels at Woods Hole during Hurricane Bob (Figure 1).

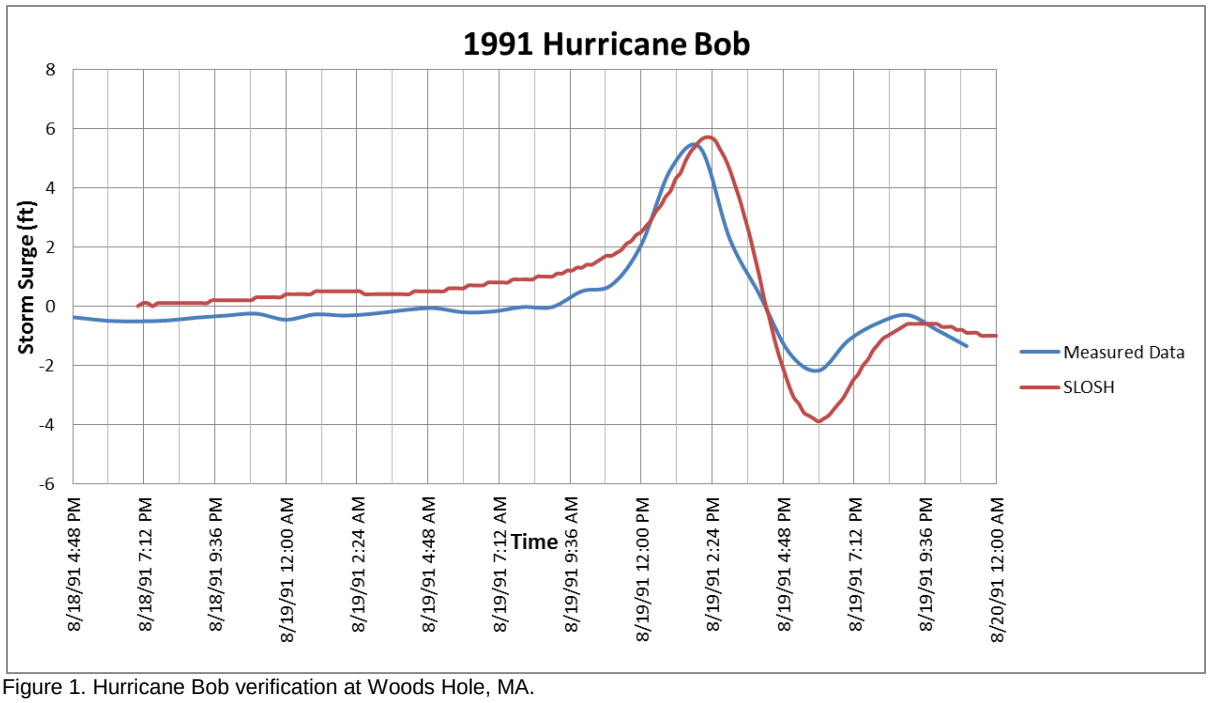


Figure 1. Hurricane Bob verification at Woods Hole, MA.

EPA provided a PDF image of a line indicating the flooding extent during Hurricane Bob. This image was georeferenced with the assumption that the grid lines were in UTM Zone 19, with intervals of 1,000 meters and an origin of 50 meters in the X and 200 meters in the Y (Figure A01). These numbers were

determined by comparing the image to a map with a similar base map and alternating the projection and origin. The digitized inundation line is in red, and the flooding calculated by SLOSH due to Hurricane Bob is in colors of blue to red. The values represent water levels above ground.

The SLOSH model compares well to the digitized inundation line to the north, but not to the south. The success to the north is due to the inundation line following the local topography. The inundation line to the south appears to follow Mattapoisett Neck Road which crosses several low areas that appear to be hydraulically connected to the bay. Errors in the creation of the inundation line could contribute to the offset, and it is not known how the inundation line was created.

2. Model Production Runs

Past storms were reviewed to ensure that modeling runs include hurricane parameters that have occurred in the past (Table 1). Storms for the Mattapoisett area were loaded and analyzed using the historical SLOSH database. Change in pressure (ΔP), maximum radius of tropical storm force winds (Rmax), maximum 1 minute velocities (Vmax), hurricane track speed (Speed), and direction were tabulated. Additional modeling inputs were based on the 2014 SeaPlan study.

Table 1. Historical Storms for the Mattapoisett Area

Name	ΔP (mb)	Rmax (mile)	1-min Vmax (knot)	Speed (mph)	Direction
1635	74	35	117	40	NNE - NE
1815	53	30	106	47	N - NNE
1938 First	73	57	104	48	NNW - N
1938 Second	77	30	135	62	NNW - N
1944 First	46	32	91	33	NNE - NE
1944 Second	54	38	98	39	NNE - NE
1954 Carol	58	25	115	45	N - NNE
1985 Gloria	36	24	105	36	NNE - NE
1991 Bob	56	48	88	31	NNE - NE
1999 Floyd	39	39	81	33	NNE - NE
Maximum	77	57	135	62	
Minimum	36	24	81	31	

Inputs for the SLOSH modeling are listed in Table 2. The landfall location is the same as the Hurricane Bob landfall location, which is approximately 50 kilometers southwest of the Mattapoisett Dam. Pressure, radius of maximum wind, forward speed, and track directions were based on the historical hurricanes. Four sea level rise scenarios (existing, 1 feet, 2 feet and 4 feet) were run based on the 2014 SeaPlan study. The sea levels were set prior to the model run. Thus higher sea levels translated to further inland inundation prior to the model run depending on the land elevation. The total SLOSH runs were 432.

Table 2. SLOSH Model Inputs

Parameters	Values	Number of Variations
Landfall Location	1 (Hurricane Bob)	1
Pressure (mb)	40, 60, 80	3
Radius of Maximum Wind (mi)	25, 40, 55	3
Forward Speed (mph)	30,45,60	3
Track Direction (degree)	NNW, N, NNE, NE	4
Sea Level Rise (ft)	0, 1, 2, 4	4
Total Number of Runs		432

The SLOSH modeling runs were grouped based on sea level rise and relative hurricane categories. Hurricane categories 2, 3 and 4 represent pressures 40, 60 and 80, respectively. The maximum of maximum (MOM) of each category and sea level was calculated based on the highest water elevation for each cell in the SLOSH basin. The 3 hurricane categories and 3 sea levels yielded 12 MOMs.

3. Results

SLOSH modeling outputs are attached to this memorandum as Appendix A. Figures A02 through A13 show the maximum of maximum (MOM) predicted flooding height for their respective hurricane category and sea level. The MOM flood elevations were differenced from the 2014 post Hurricane Sandy LiDAR data collected by USGS for the State of Massachusetts. Time series for two locations are attached as Appendix B. The two locations of the Town of Mattapoisett and Mattapoisett Dam correspond to SLOSH cells 71-122 and 70-121, respectively.

4. Discussion

Verification of the SLOSH model yielded mixed results. The SLOSH model compared well with the measured water levels at Woods Hole during Hurricane Bob (Figure 1), but the extent of flooding based on the inundation line provided by EPA did not match well to the south. Source information regarding the inundation line is not well known, and the inundation line to the south crosses several low marsh areas indicating the flooding extent is not accurate. Until additional information is obtained on the source of the inundation line, it is assumed that the SLOSH model for Hurricane Bob is accurate.

All modeling runs in this study cause flooding over the Mattapoisett Dam. This is largely due to the hurricane path going directly north. Another factor is the relatively low elevation of the road near the dam, and the lowest category simulated was a Category 2 hurricane. It is possible that a Category 1 or smaller tropical storm would fail to top the Mattapoisett Dam. To confirm the predictions that the SLOSH model produced in this study, modeling runs were compared to similar inputs that were modeled in the SeaPlan study. Figure 2 was scanned from Figure A-20 of the SeaPlan study. Figure 3 is the output of this study with a similar color classification. The flooding areas are almost identical. The primary difference is areas where the SLOSH model in this study did not predict flooding due to its large cell size. The relatively large SLOSH cell size is a well-known limitation of the SLOSH model. Other differences are due to the different approaches of the two studies along with an updated DEM that this study utilized.

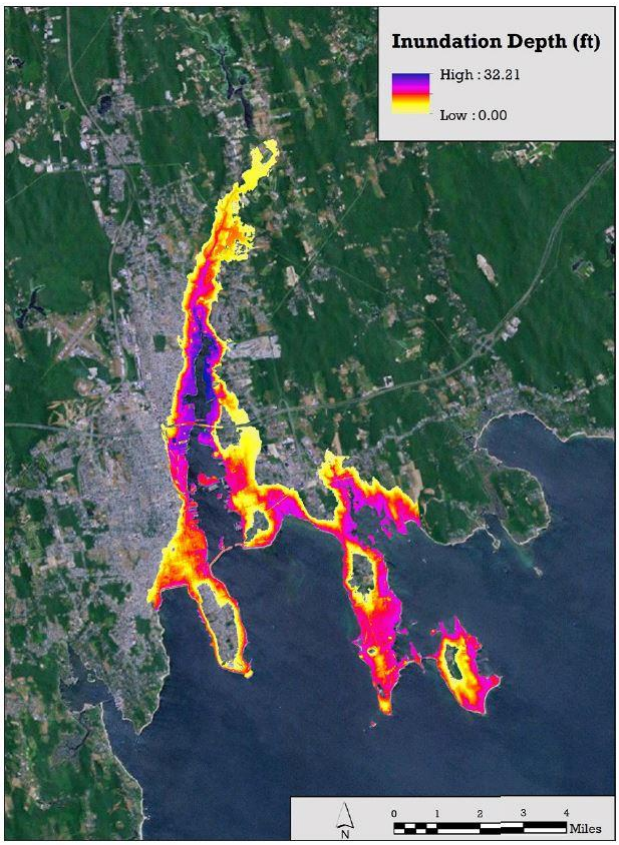


Figure 2. Figure scanned from the SeaPlan study, Figure A-20.

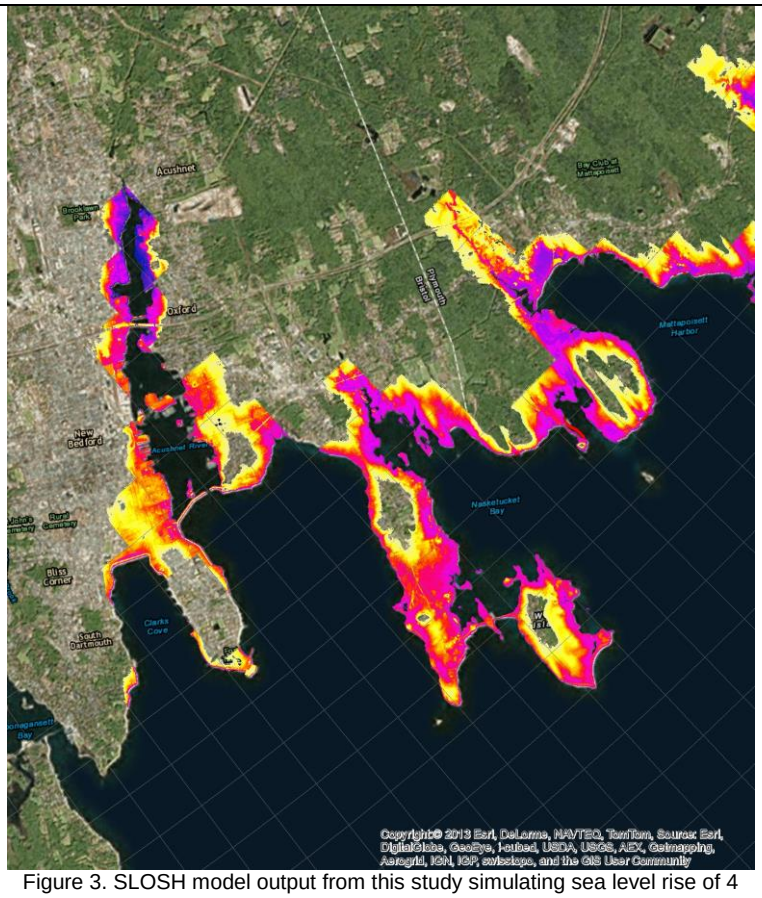
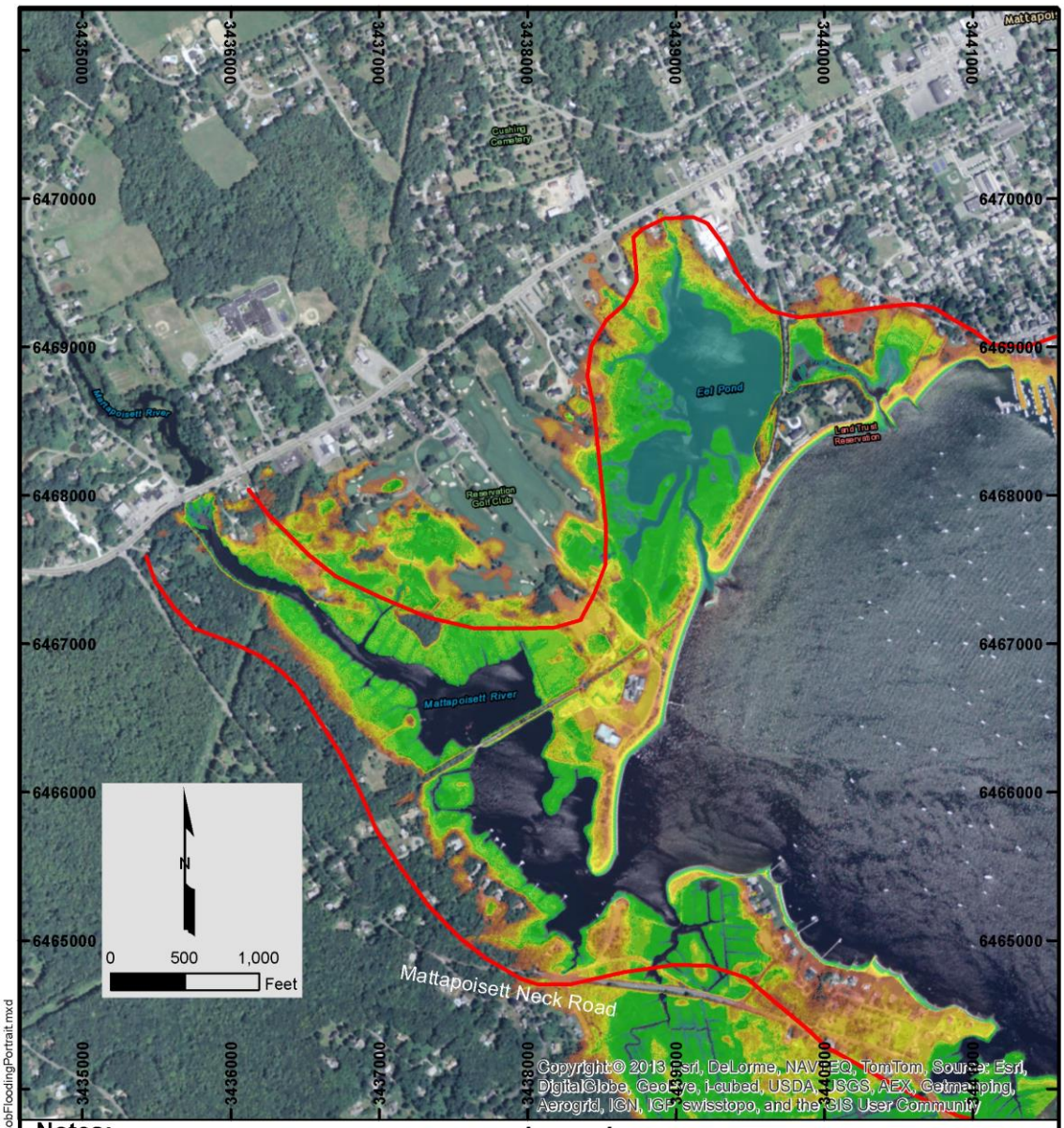


Figure 3. SLOSH model output from this study simulating sea level rise of 4 feet and a Category 4 hurricane.

5. References

Longley, K. and Lipsky, A., 2014. Climate Change Vulnerability Assessment and Adaptation Planning Study for Water Quality Infrastructure in New Bedford, Fairhaven and Acushnet. SeaPlan, Boston (MA): Doc #220.14.01, 215 p.

Appendix A



Notes:

1. Coordinates are in meters based on the UTM Coordinate System, Zone 19, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by ESRI Base Maps, collected in 2011.

Legend:

- Bob Inundation

Water Above Ground (m)

- 2.51 - 2.75
- 2.26 - 2.5
- 2.01 - 2.25
- 1.76 - 2
- 1.51 - 1.75
- 1.26 - 1.5
- 1.01 - 1.25
- 0.76 - 1
- 0.51 - 0.75
- 0.26 - 0.5
- 0 - 0.25

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Date:09/29/2015	By: QR	Comm. No.: 77500292	**Figure No. A01**

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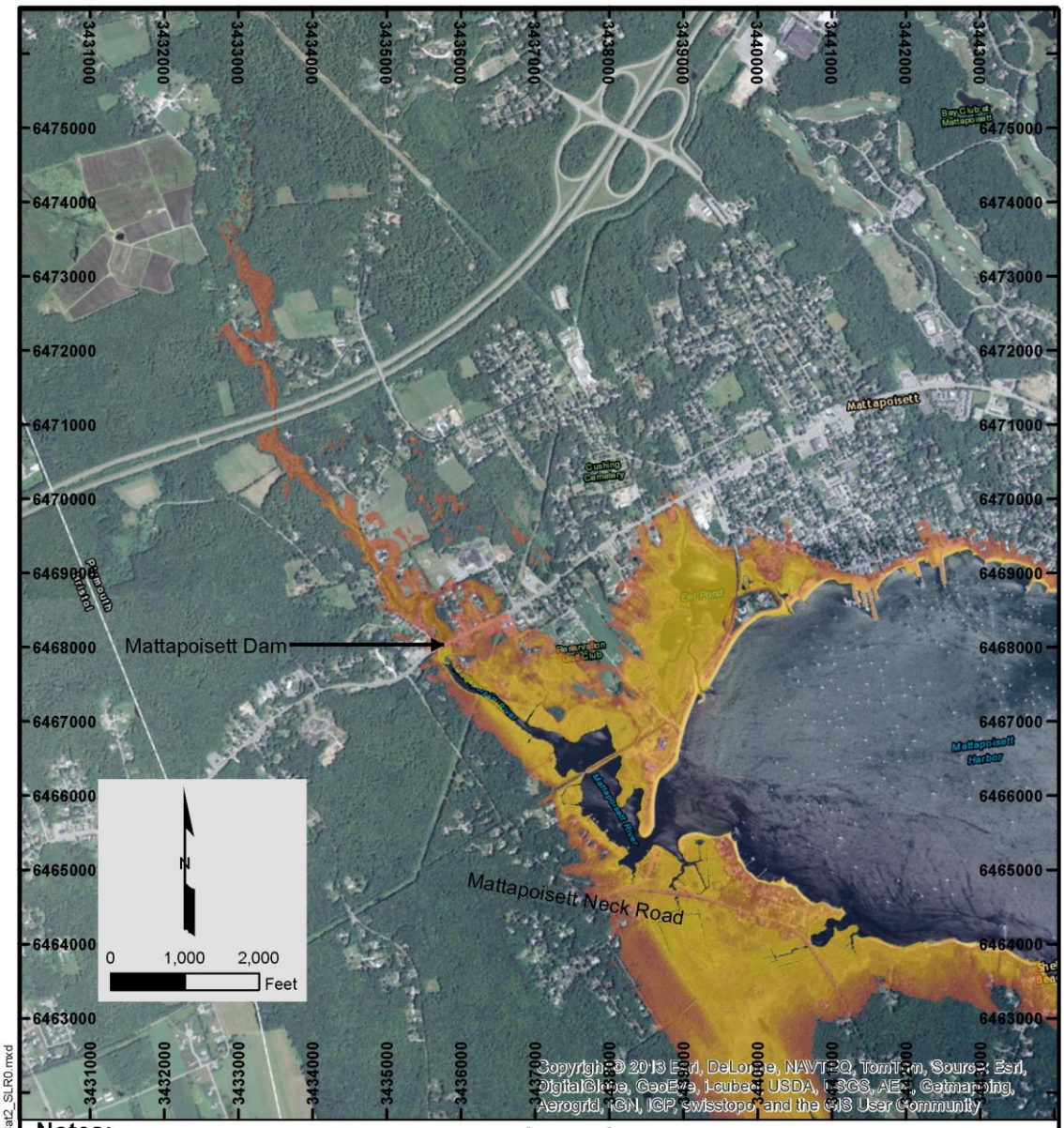

Notes:

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2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR0_Cat2

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

G:\Enterprise\Massachusetts\77500292_SLOSH_Modeling\mxd\Cat2_SLR0.mxd

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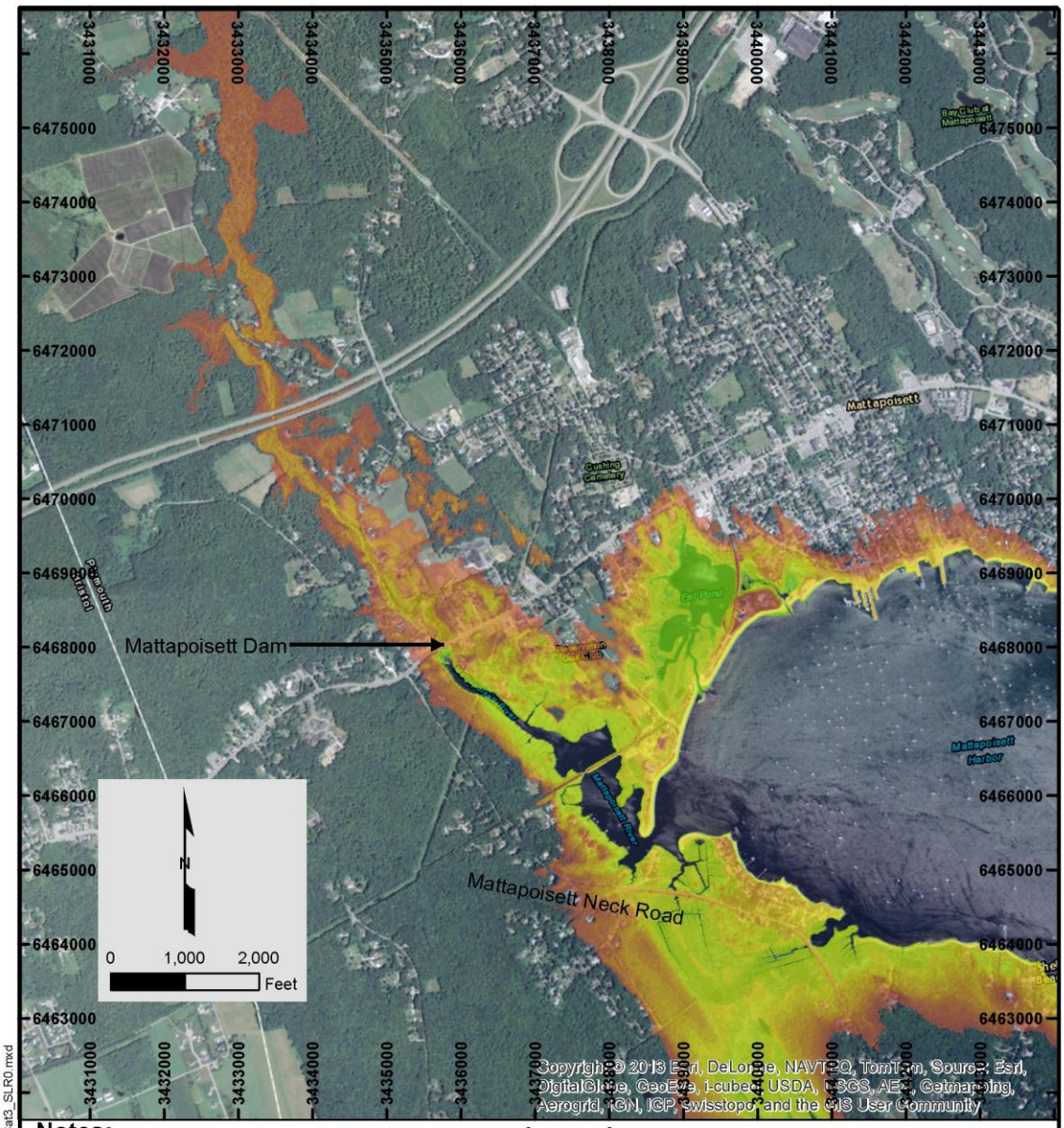
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A02**



Notes:

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2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR0_Cat3

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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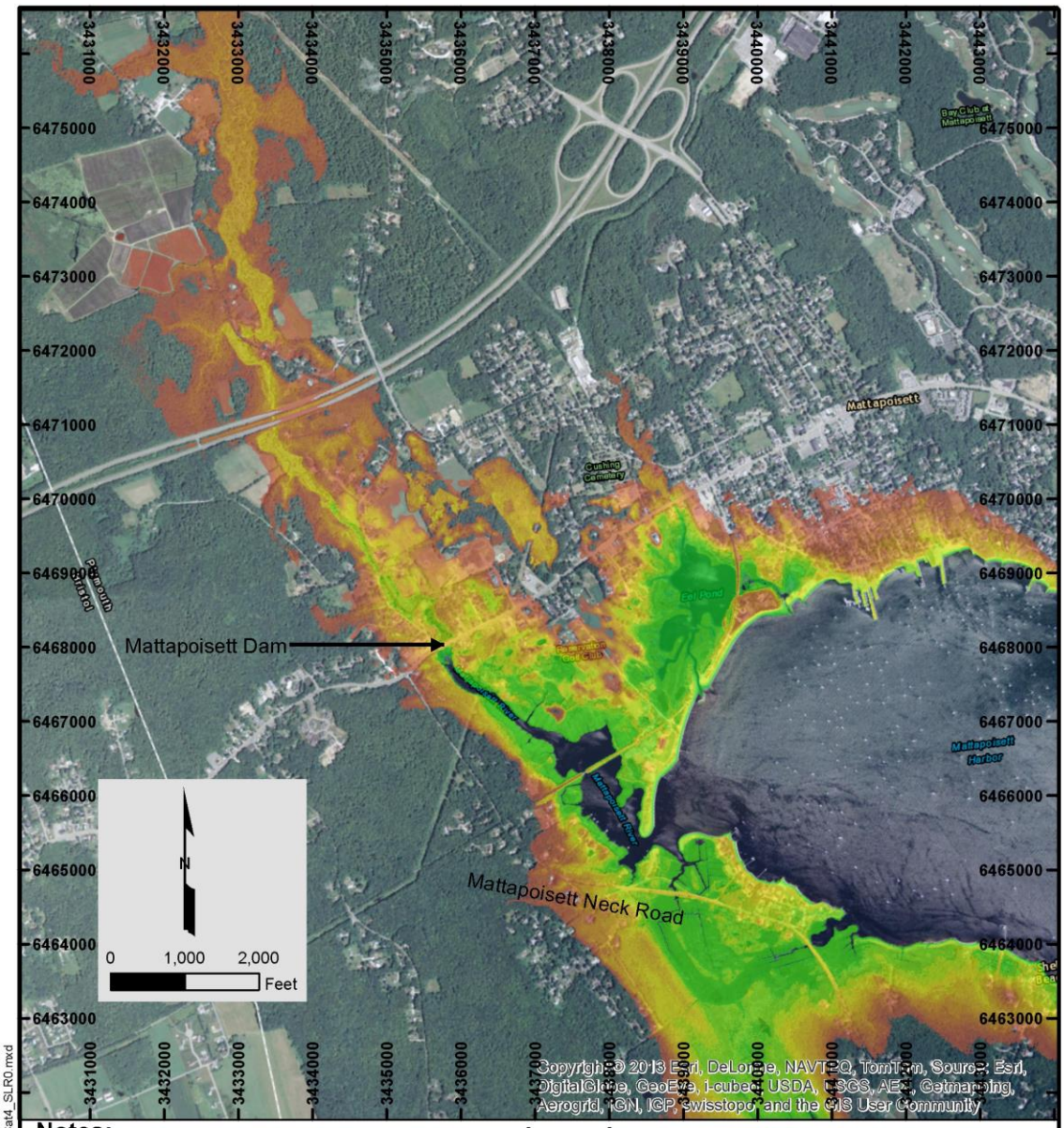
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A03**



Notes:

1. Coordinates are in meters based on the UTM Coordinate System, Zone 19, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR0_Cat4

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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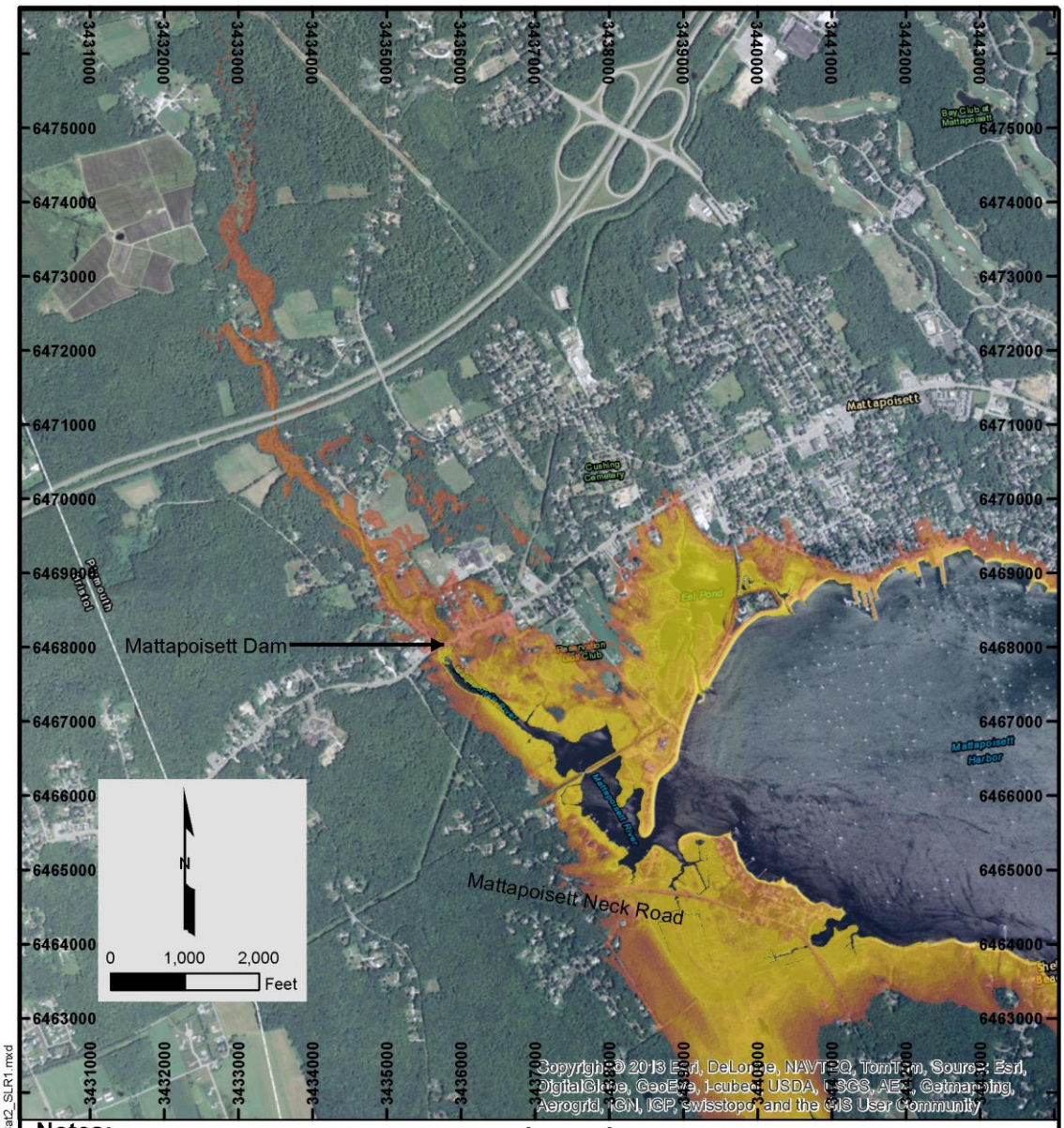
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A04**



Notes:

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2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR1_Cat2

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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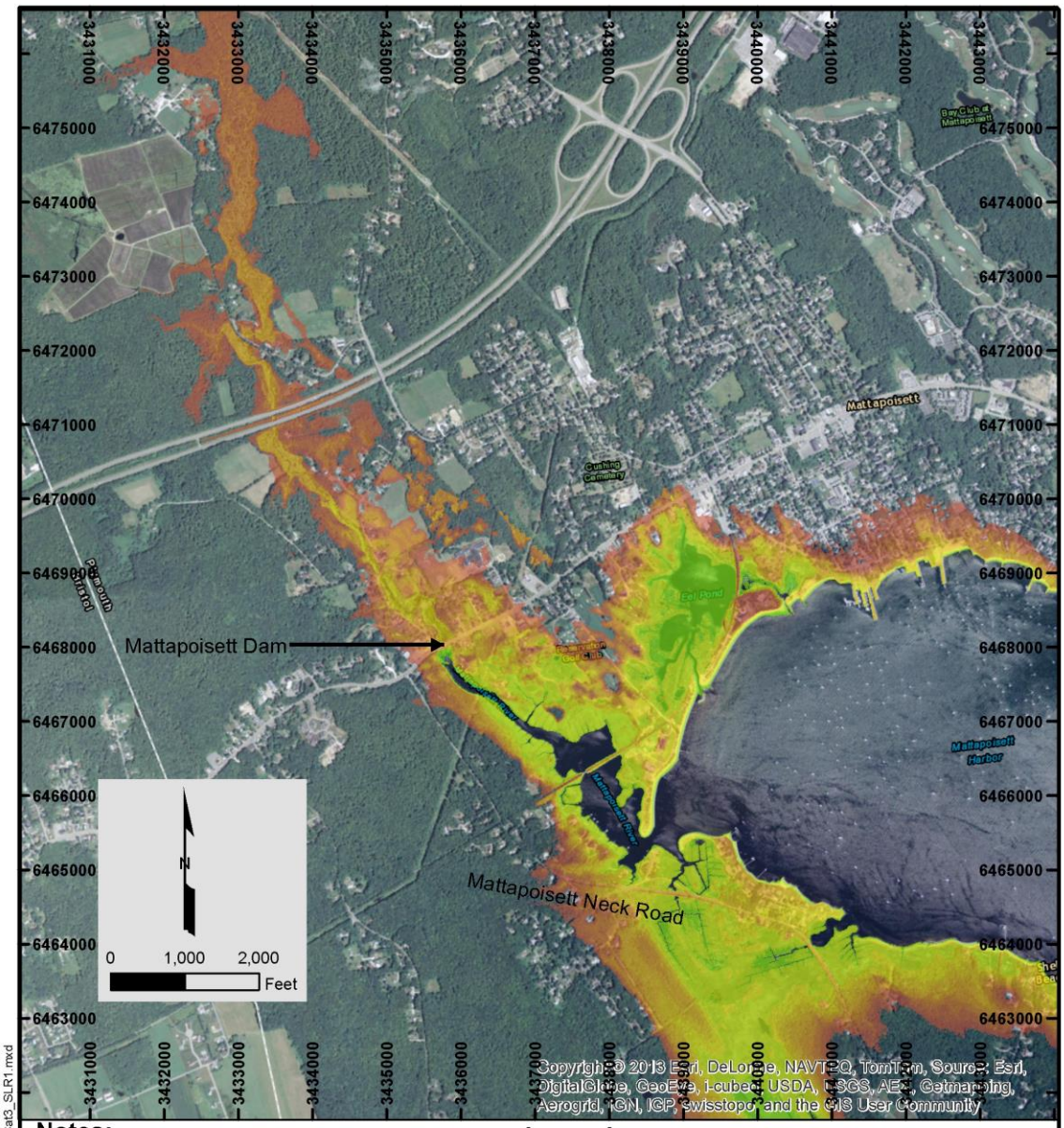
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A05**



Notes:

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2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR1_Cat3

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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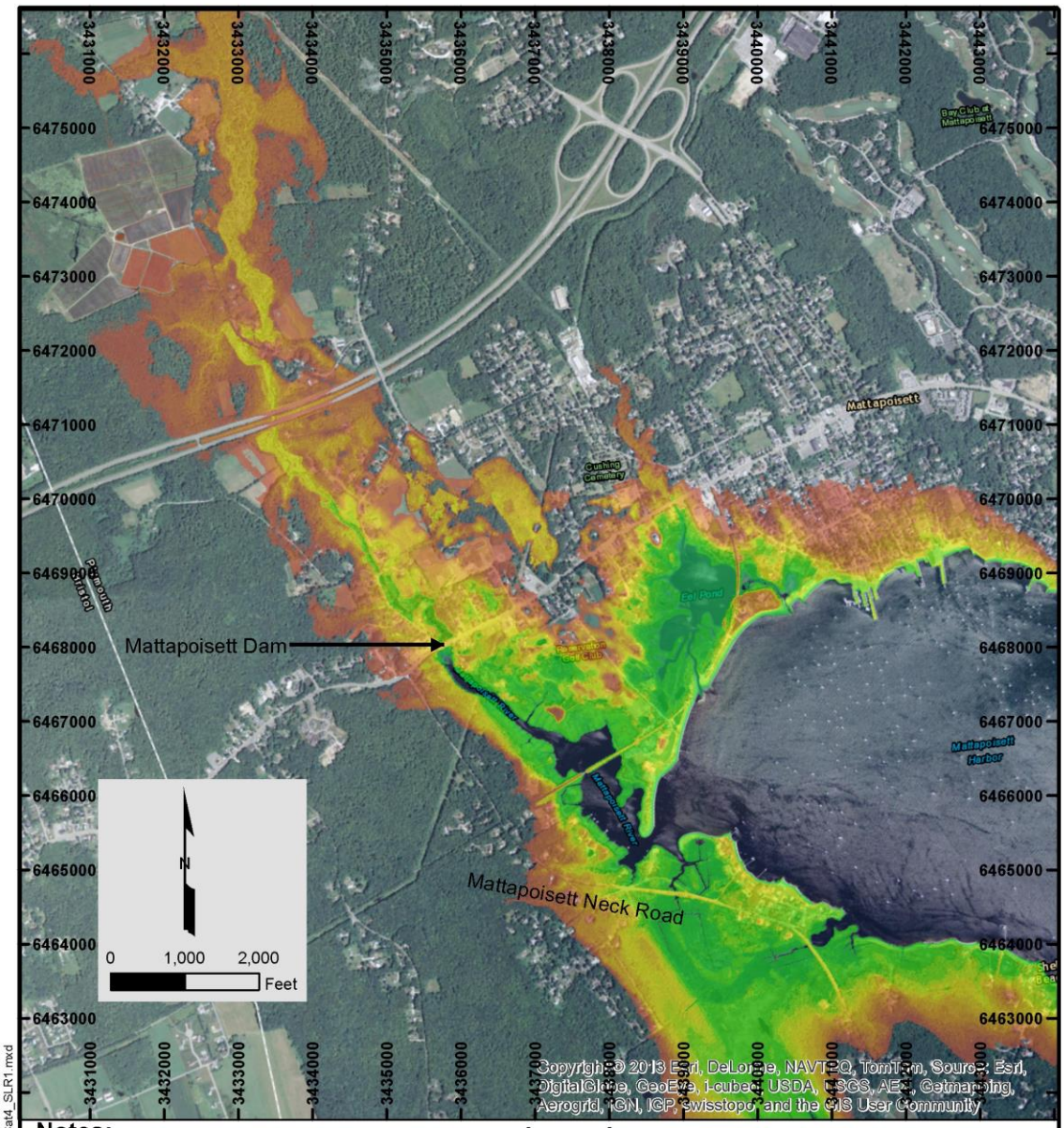
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A06**



Notes:

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2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR1_Cat4

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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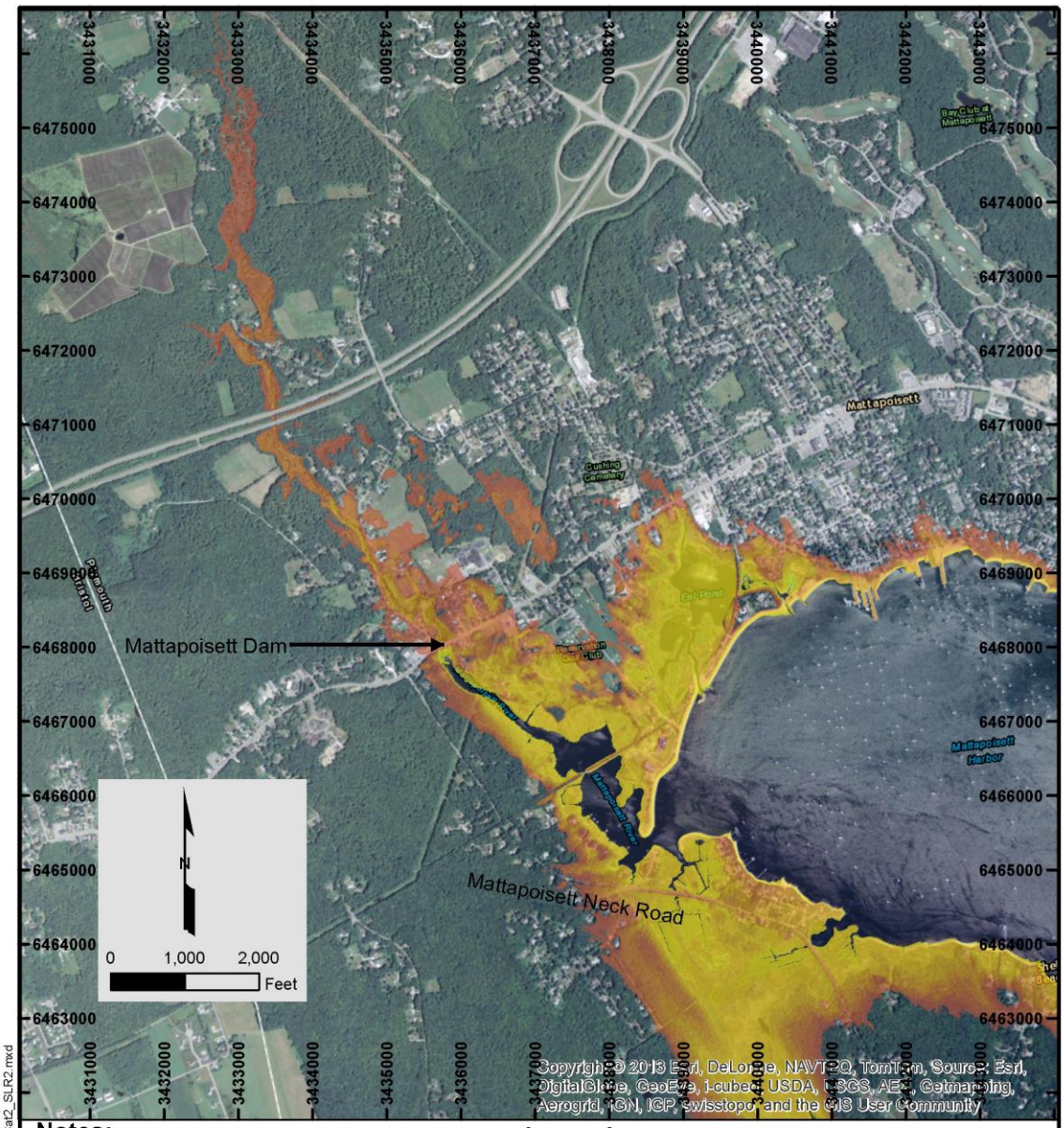
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A07**



Notes:

1. Coordinates are in meters based on the UTM Coordinate System, Zone 19, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR2_Cat2

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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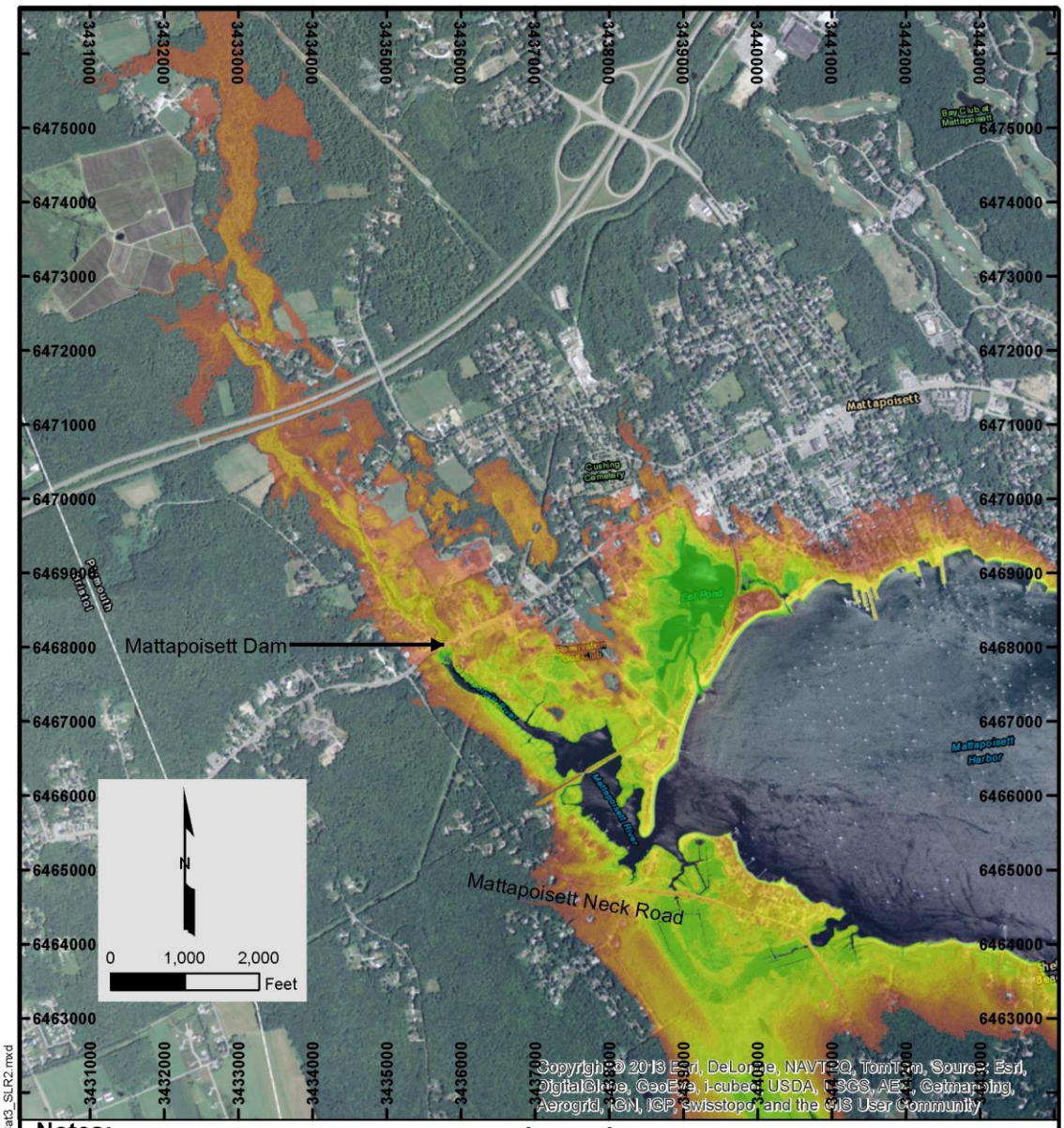
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A08**



Notes:

1. Coordinates are in meters based on the UTM Coordinate System, Zone 19, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR2_Cat3

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
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- 6.1 - 6.5
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- 7.6 - 8
- 8.1 - 8.5

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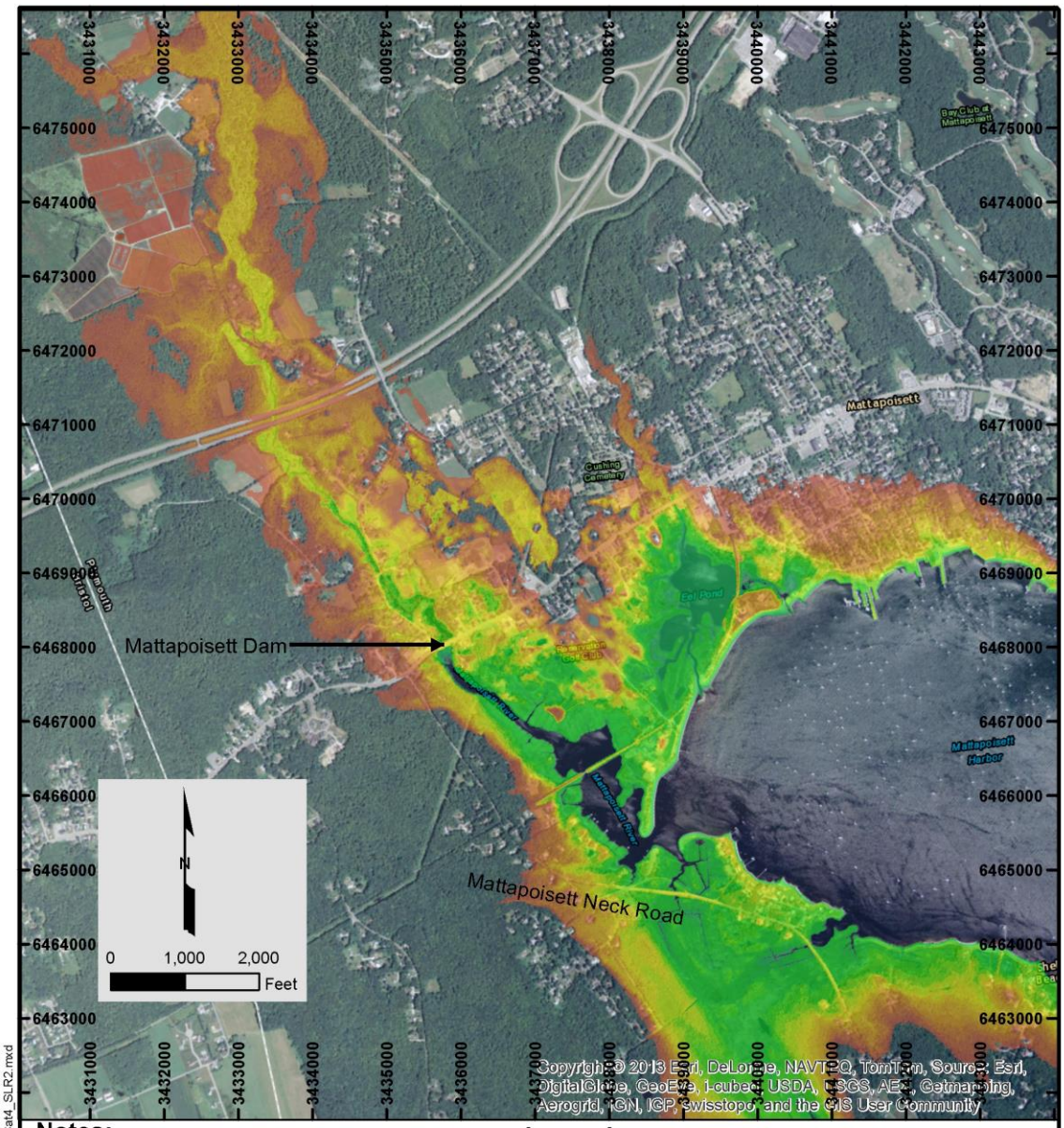
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A09**



Notes:

1. Coordinates are in meters based on the UTM Coordinate System, Zone 19, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR2_Cat4

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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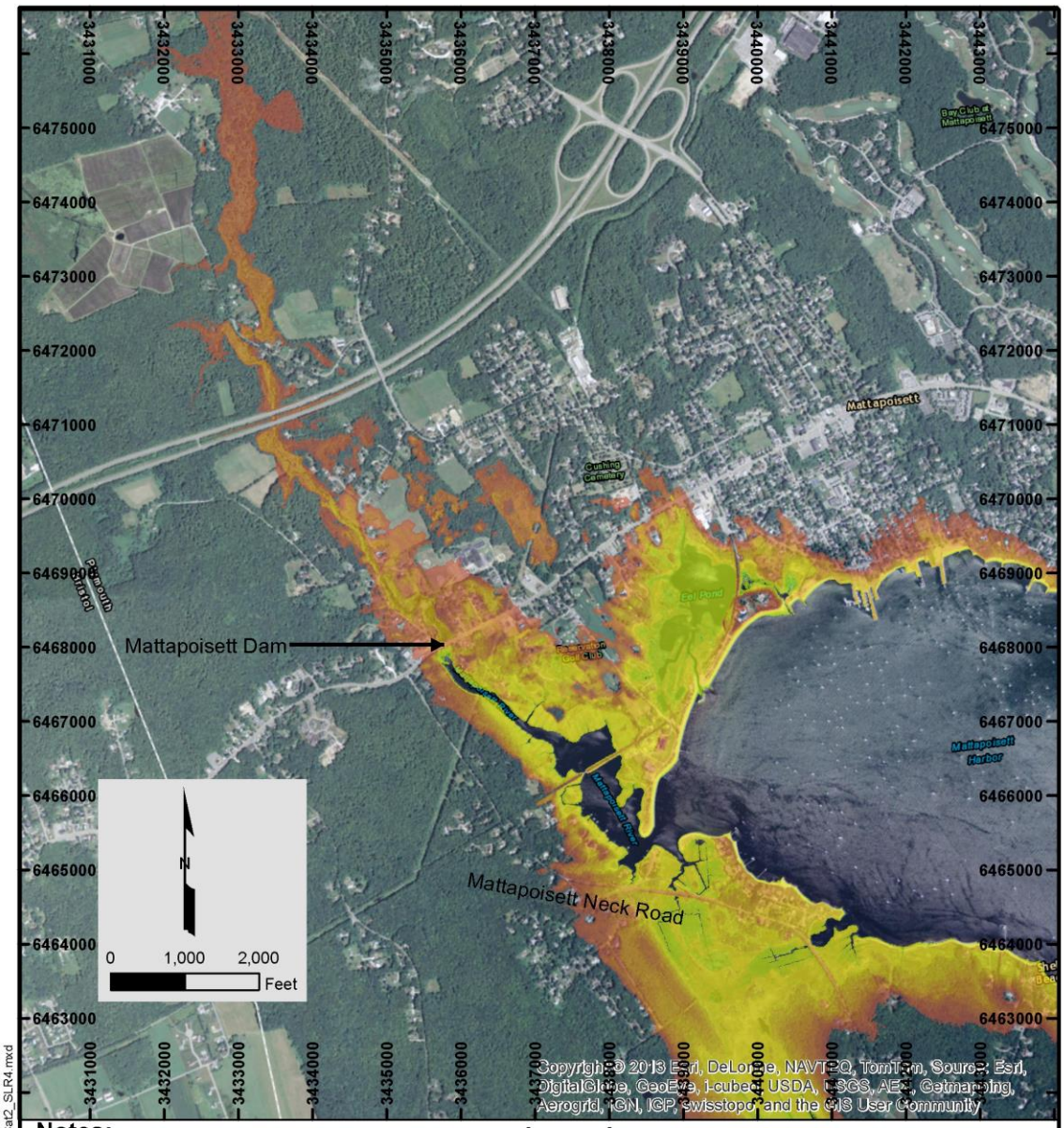
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A10**



Notes:

1. Coordinates are in meters based on the UTM Coordinate System, Zone 19, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR4_Cat2

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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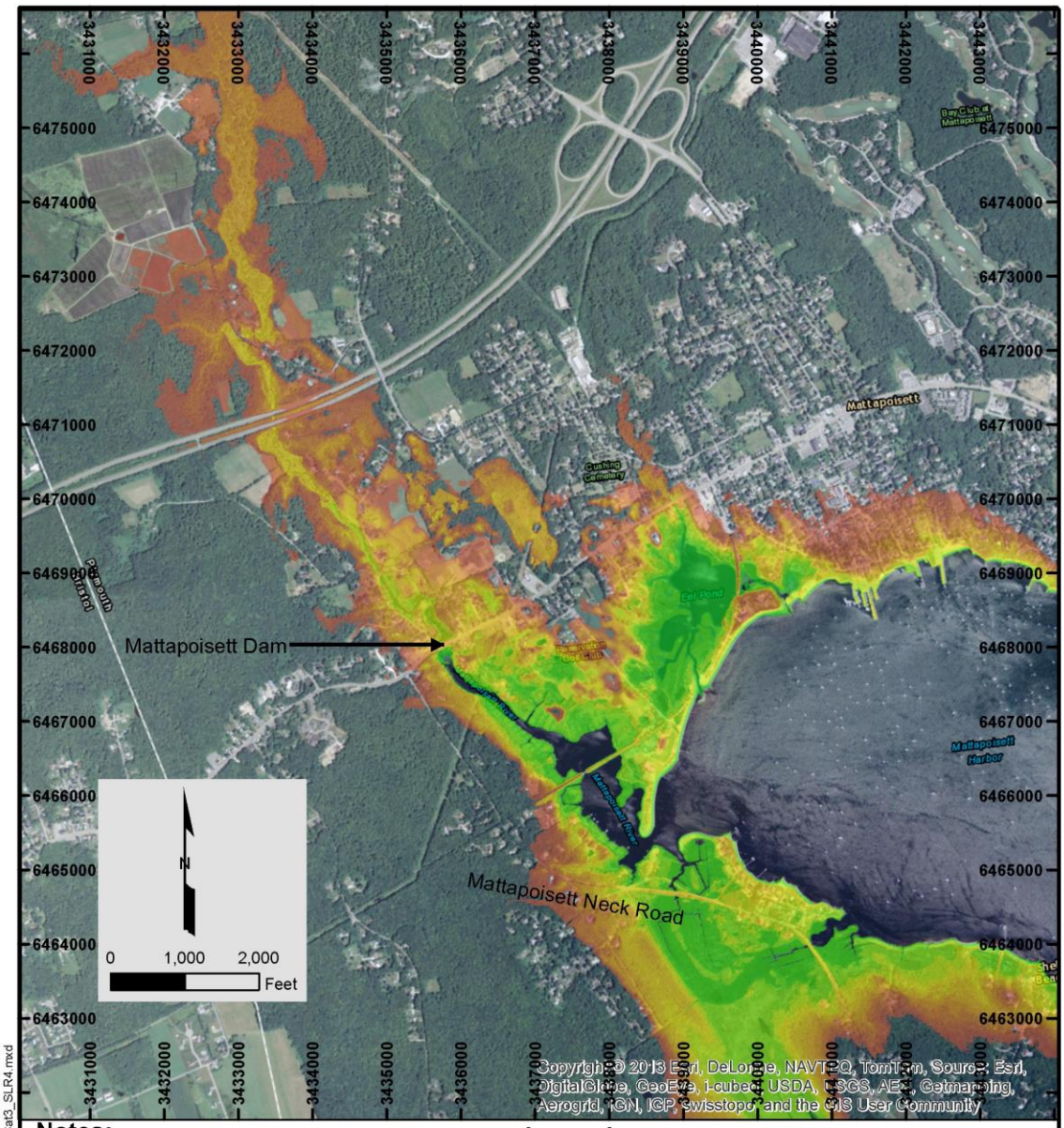
Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A11**



Notes:

1. Coordinates are in meters based on the UTM Coordinate System, Zone 19, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR4_Cat3

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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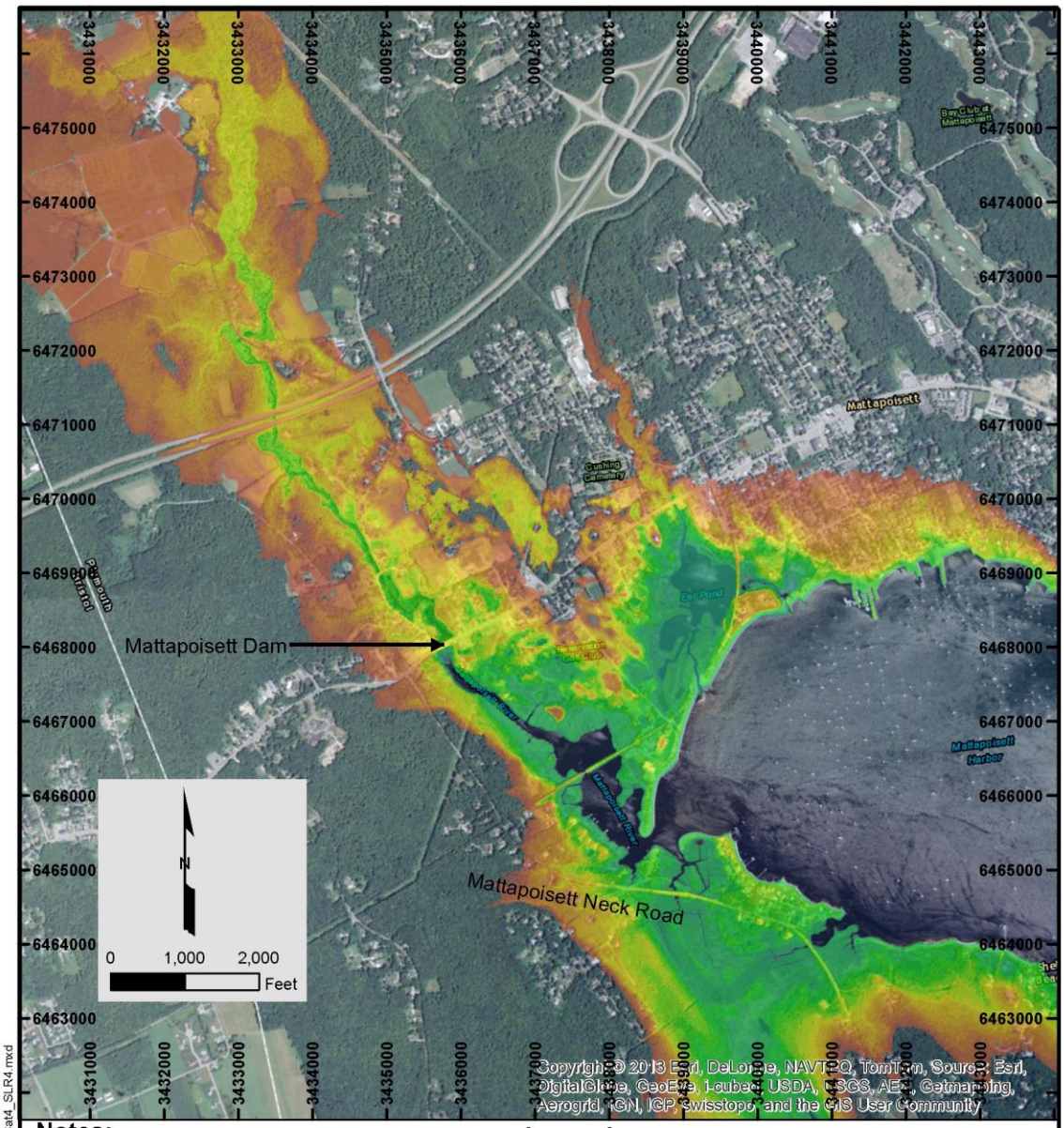
CB&I
Environmental & Infrastructure, Inc.
2481 N. W. Boca Raton Blvd.
Boca Raton, FL 33431
Ph. (561) 391-8102
Fax (561) 391 9116

TITLE:

SLOSH SLR 4, Category 3
WA4-11 Water and Community Adaptation
Mattapoisett, MA

Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A12**



Notes:

1. Coordinates are in meters based on the UTM Coordinate System, Zone 19, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by ESRI Base Maps, collected in 2011.
3. Elevations are water level above ground in meters.

Legend:

SLR4_Cat4

- 0 - 0.5
- 0.6 - 1
- 1.1 - 1.5
- 1.6 - 2
- 2.1 - 2.5
- 2.6 - 3
- 3.1 - 3.5
- 3.6 - 4
- 4.1 - 4.5
- 4.6 - 5
- 5.1 - 5.5
- 5.6 - 6
- 6.1 - 6.5
- 6.6 - 7
- 7.1 - 7.5
- 7.6 - 8
- 8.1 - 8.5

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Environmental & Infrastructure, Inc.
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Boca Raton, FL 33431
Ph. (561) 391-8102
Fax (561) 391 9116

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Mattapoisett, MA

Date:12/15/2015	By: QR	Comm. No.: 77500292	**Figure No. A13**

Appendix B

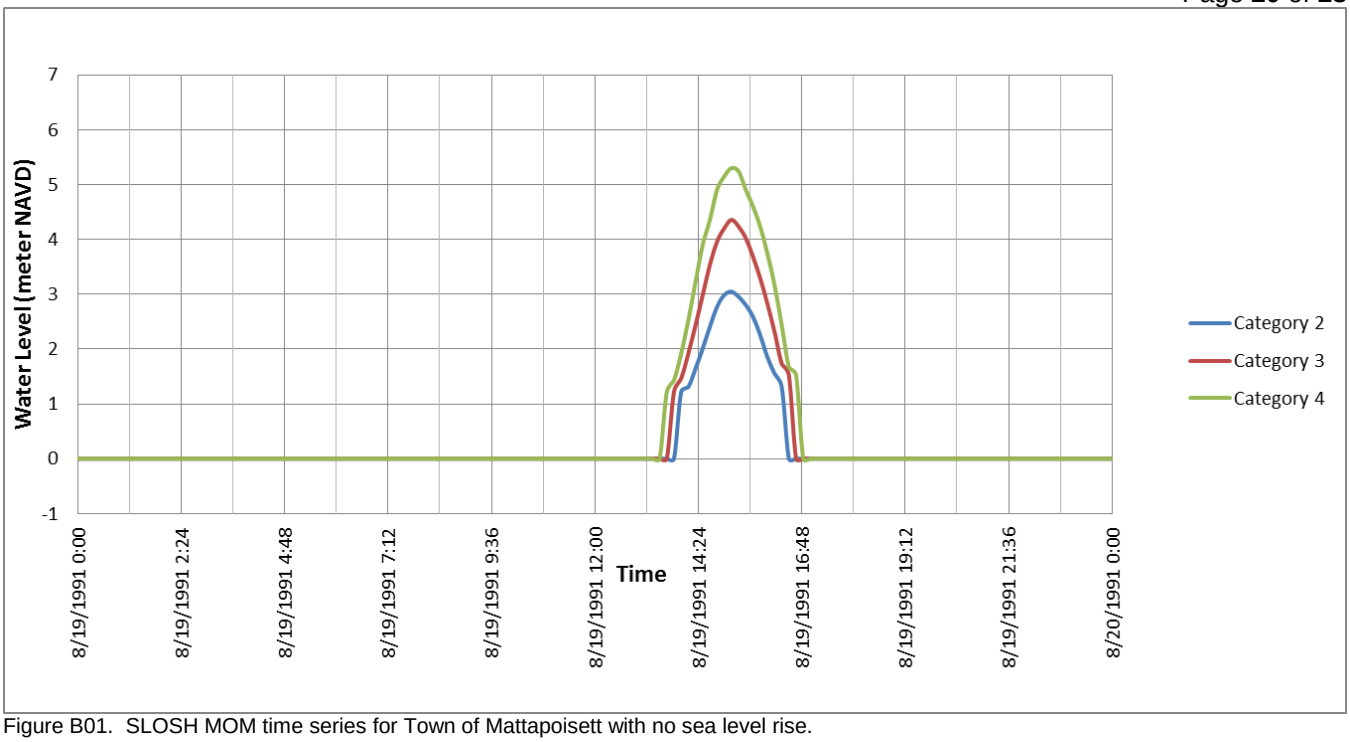

Figure B01. SLOSH MOM time series for Town of Mattapoisett with no sea level rise.

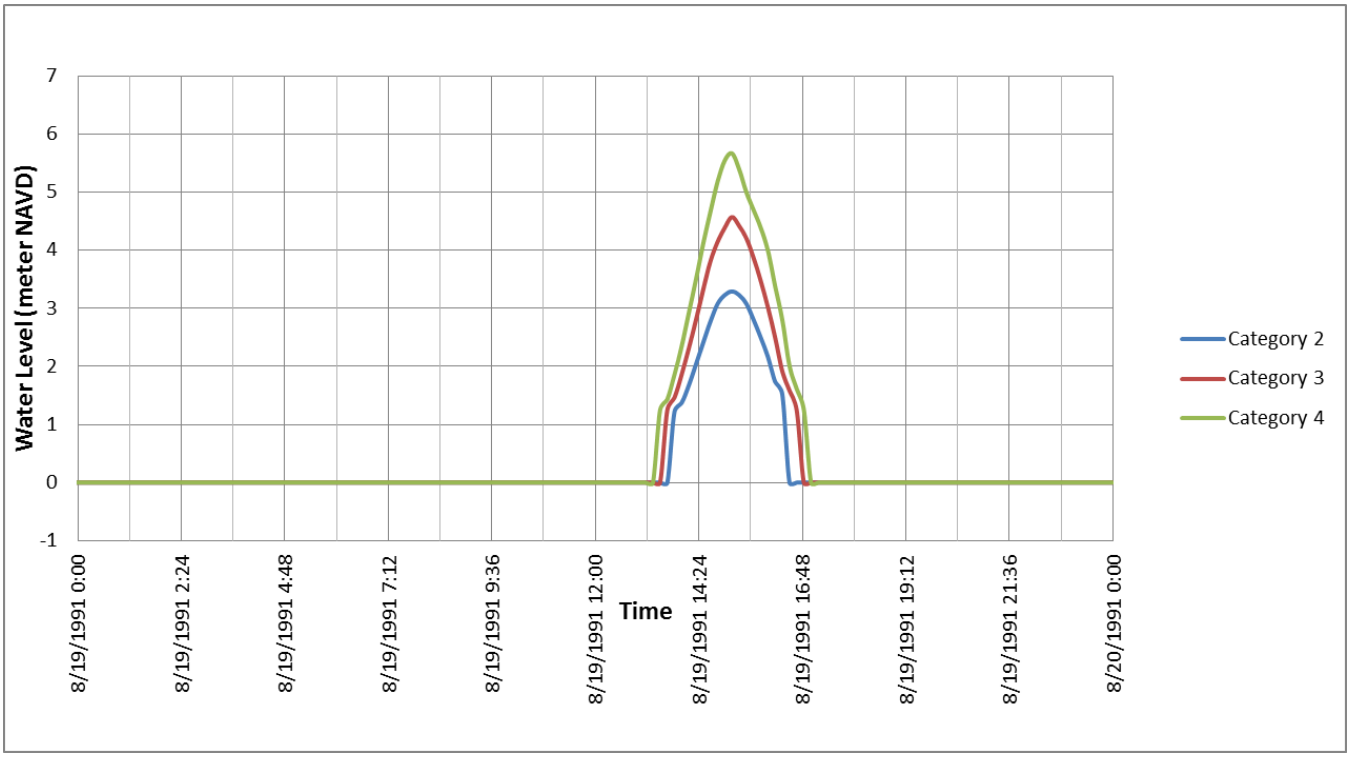

Figure B02. SLOSH MOM time series for Town of Mattapoisett with a sea level rise of 1 foot.

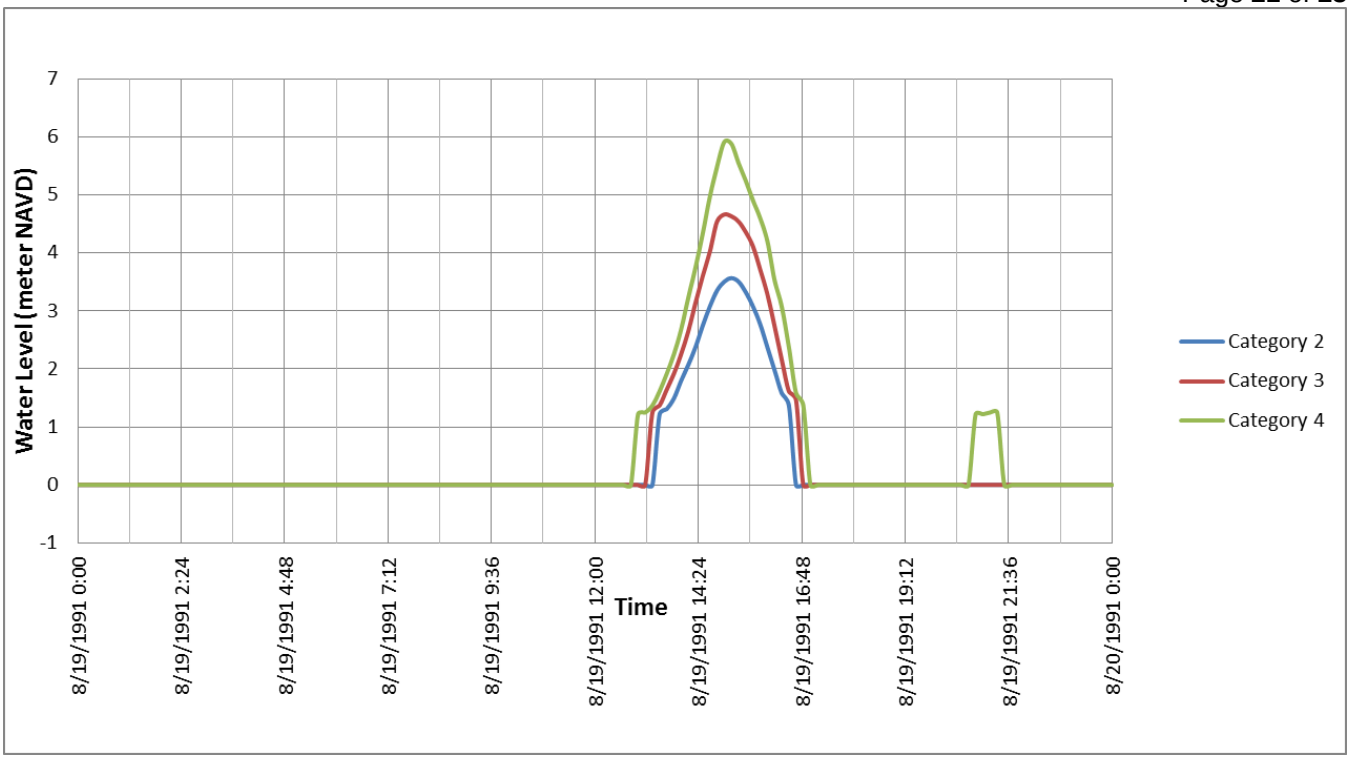

Figure B03. SLOSH MOM time series for Town of Mattapoisett with a sea level rise of 2 feet.

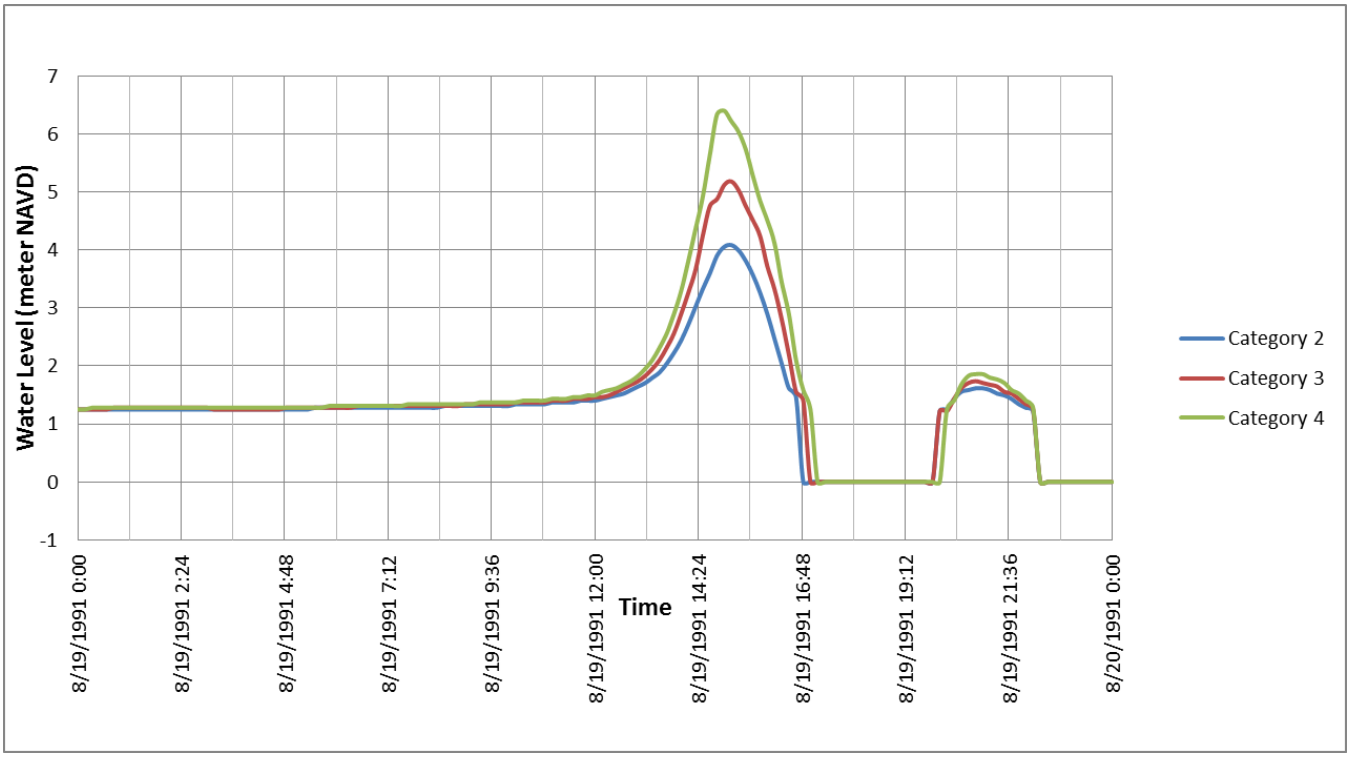

Figure B04. SLOSH MOM time series for Town of Mattapoisett with a sea level rise of 4 feet.

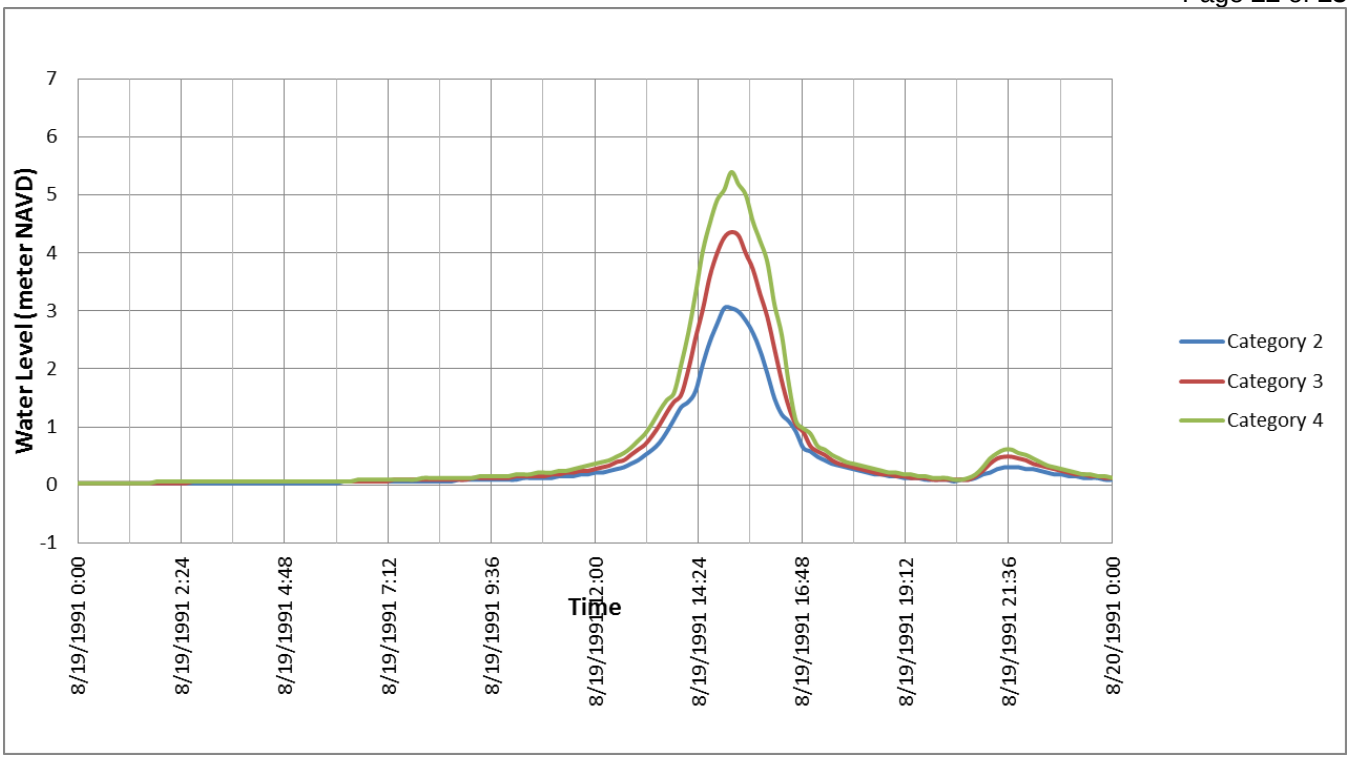

Figure B05. SLOSH MOM time series for the Mattapoisett Dam with no sea level rise.

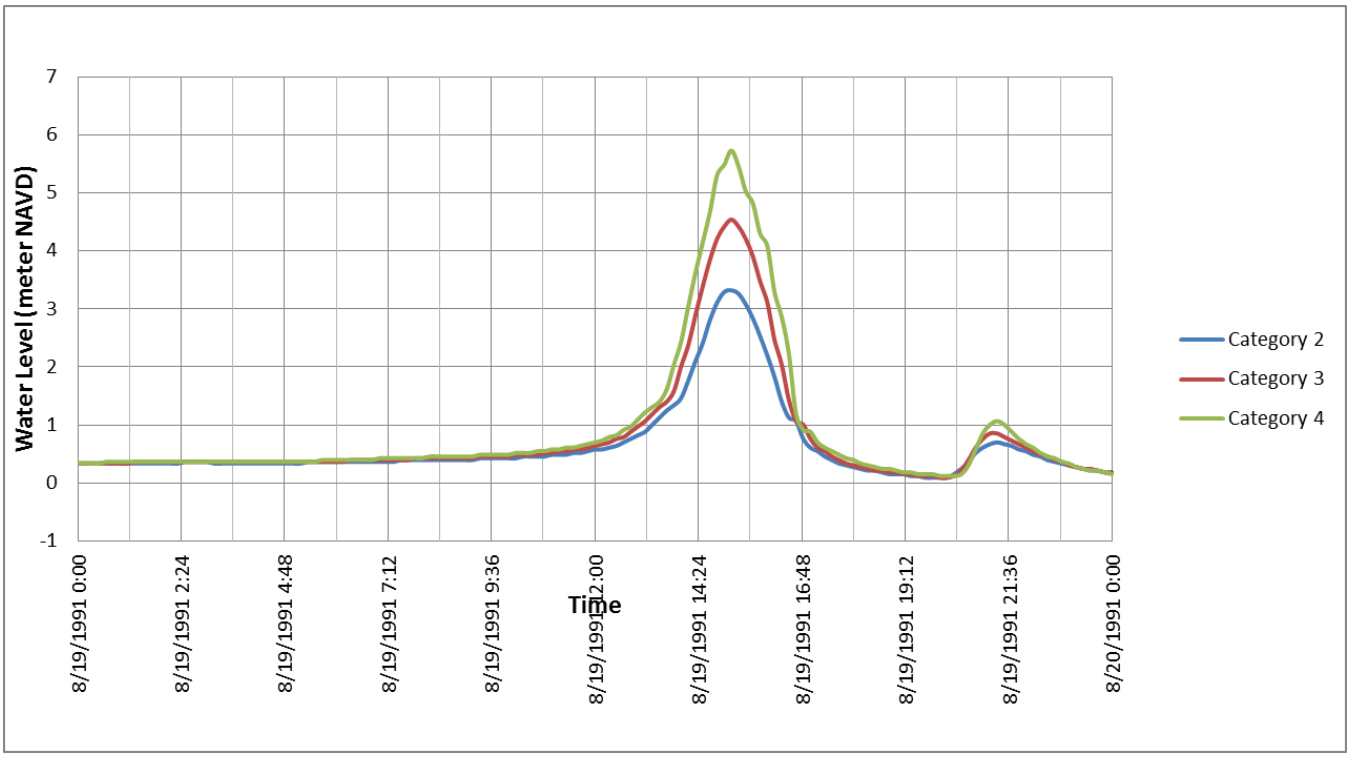

Figure B06. SLOSH MOM time series for the Mattapoisett Dam with a sea level rise of 1 foot.

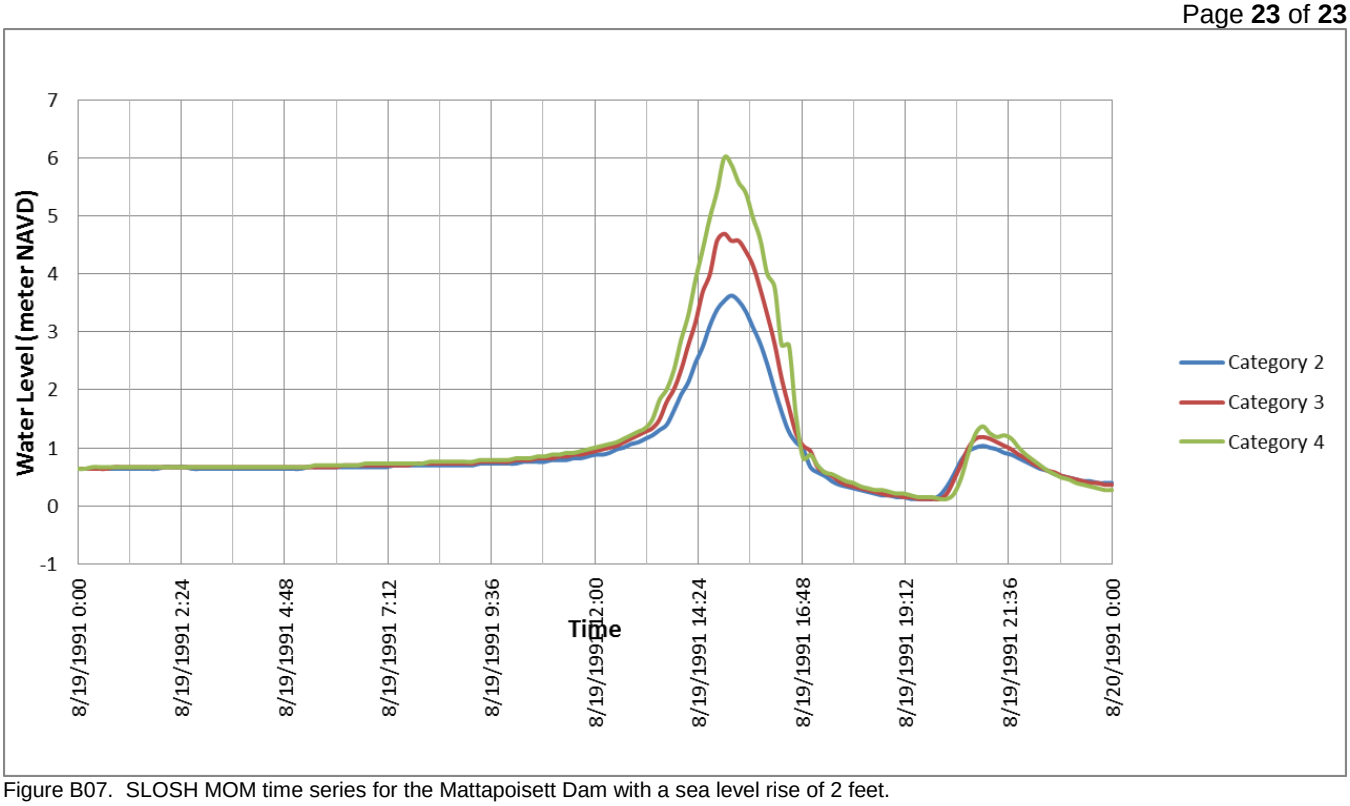

Figure B07. SLOSH MOM time series for the Mattapoisett Dam with a sea level rise of 2 feet.

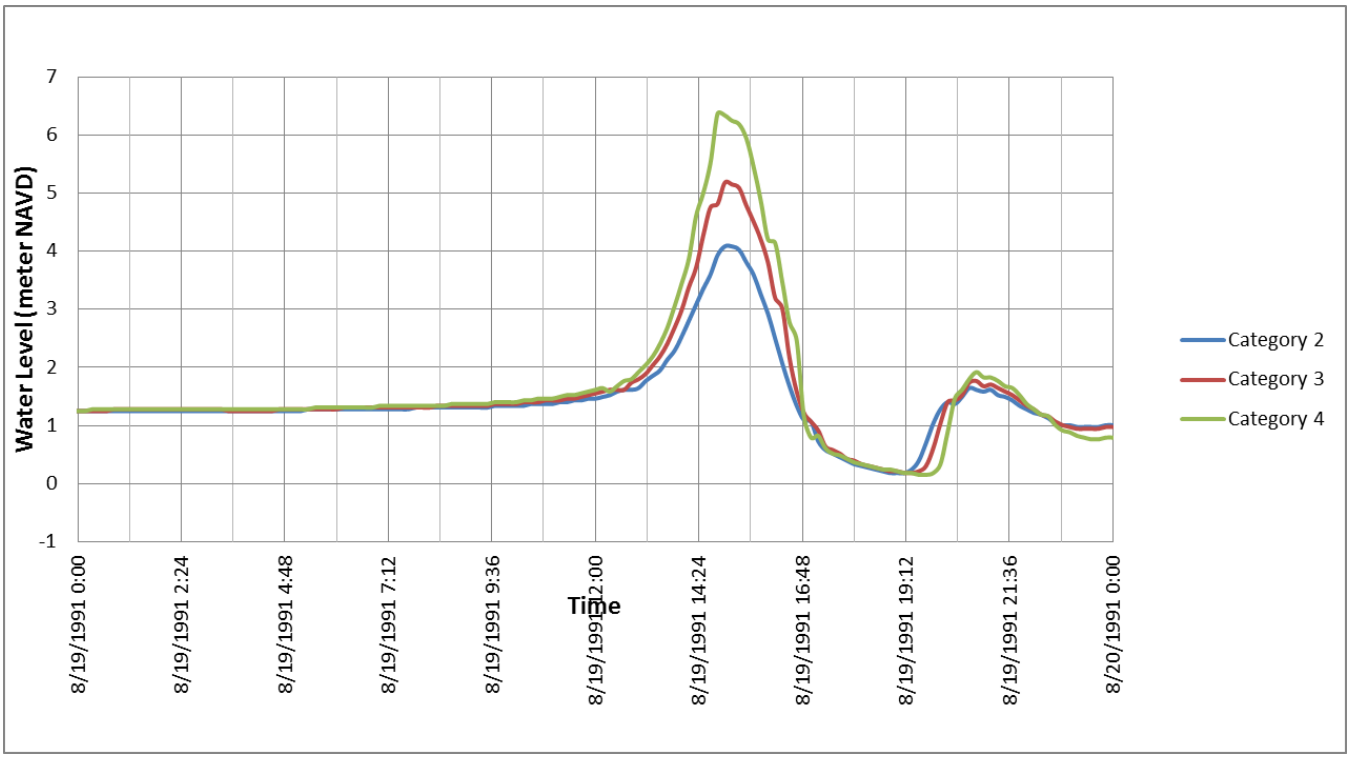

Figure B08. SLOSH MOM time series for the Mattapoisett Dam with a sea level rise of 4 feet.