Great Lakes Flood Mapping

Pilot Studies on Lake Michigan

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Presentation Overview

- I - Event vs. Response for Runup
- II - Sheboygan County Runup Results
- III - Data Sensitivity Analysis
- IV – Lake Ontario Wave & Surge Modeling

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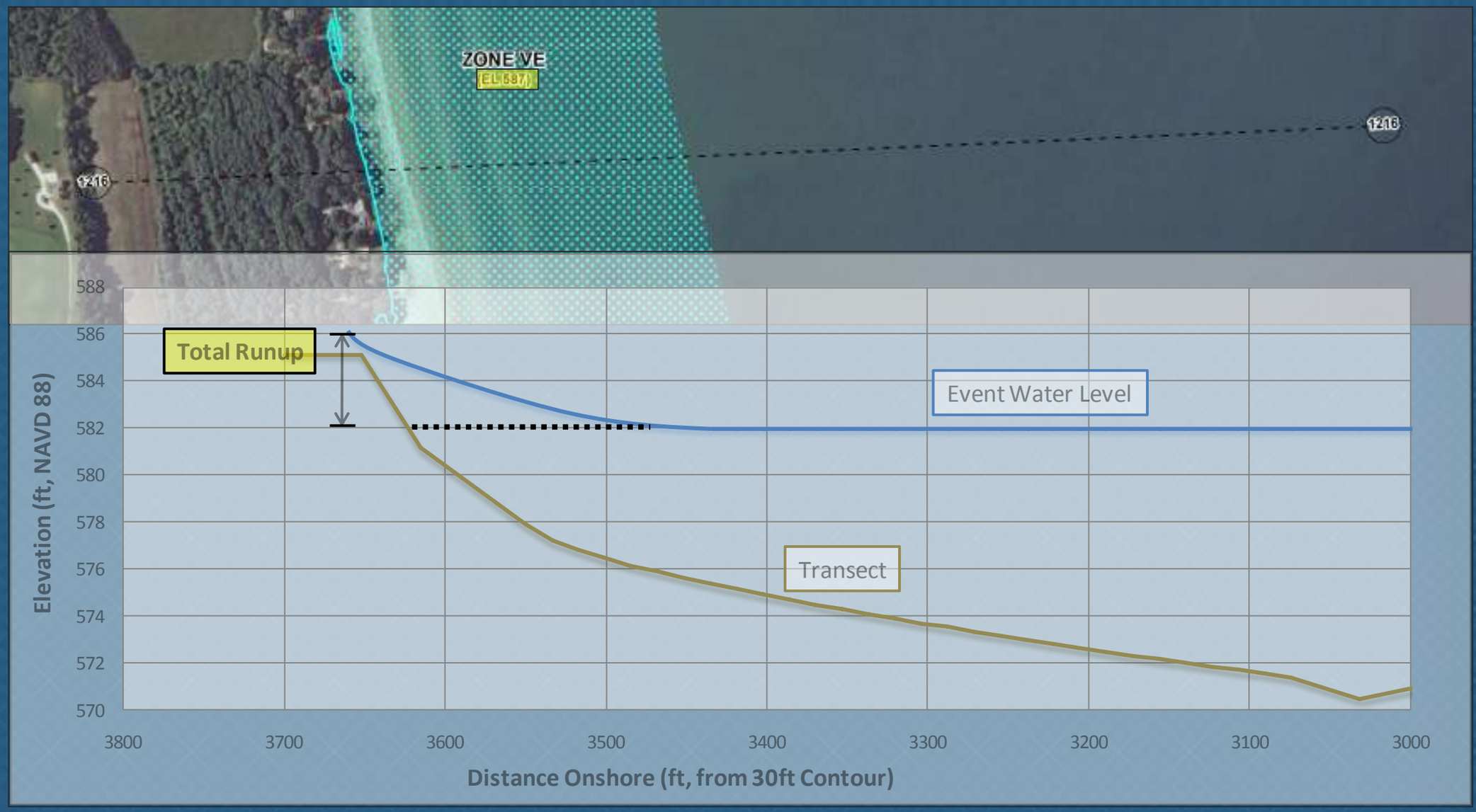
I – Event vs. Response for Runup



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Event Based (G&S, 2003)

- 1% SWEL and 3-yr wave height
  - Extreme value analysis (EVA) on waves
- Single run-up calculation per transect
  - $R_{2\%}$ defines spatial extent of mapping
  - VE/AE transition based on where runup profile is less than 3 ft above terrain

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Response Based (G&S, 2009)

- Hourly wave data screened to select a group of severe events per year
  - Based on wind-wave hindcast
- One event from group selected per year to produce the largest runup value
- $R_{2\%}$ calculated for each event per year
  - Combined runup with storm surge

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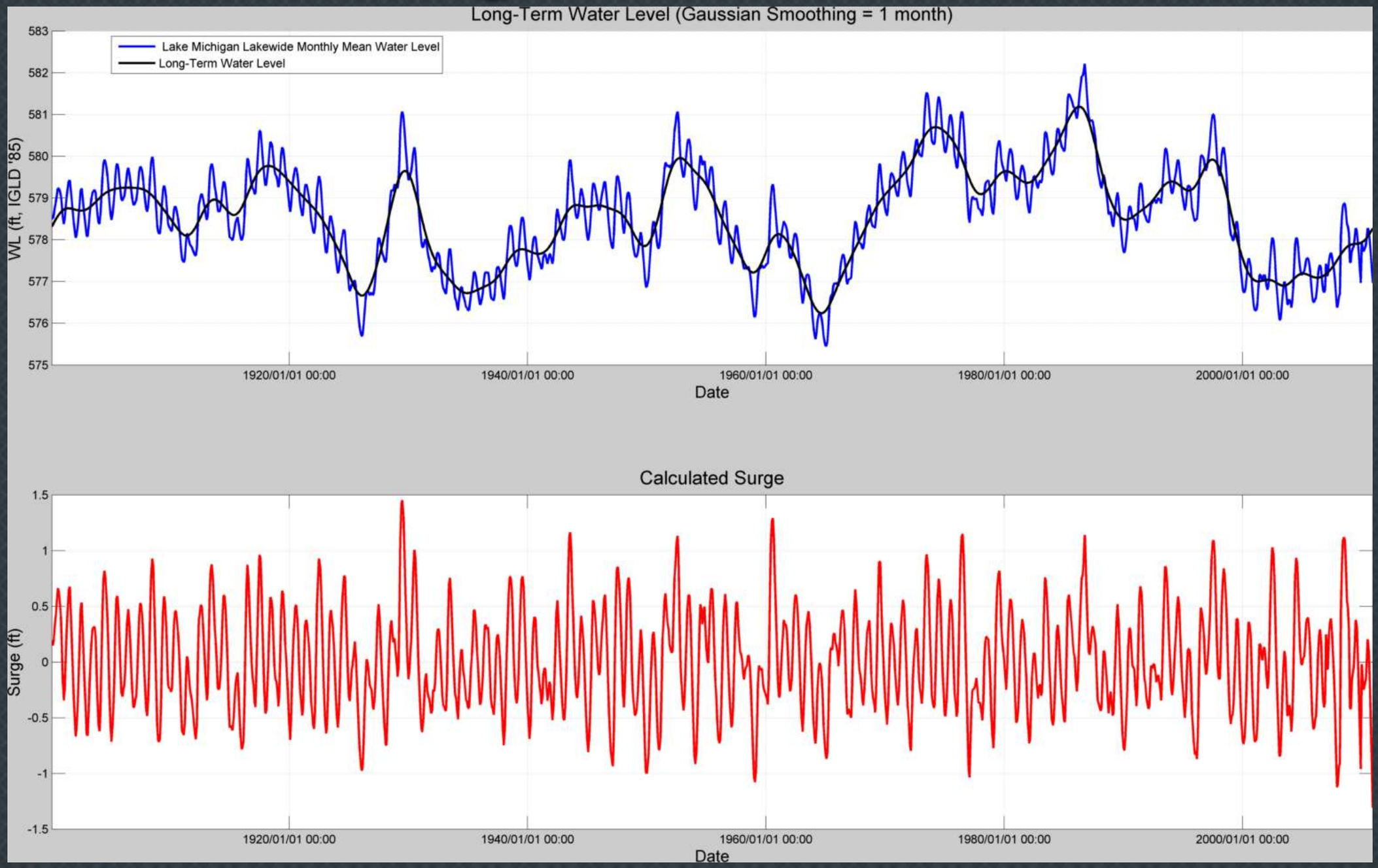
Response (continued)

- EVA completed on combined elevation (surge + $R_{2\%}$) to find 1-percent chance flood level
- This elevation is added to a mean lake level (D.3.4-1) and a K factor (D.3.4-2)
  - K factor incorporates long term variability in lake levels

Lake Michigan Lake Levels



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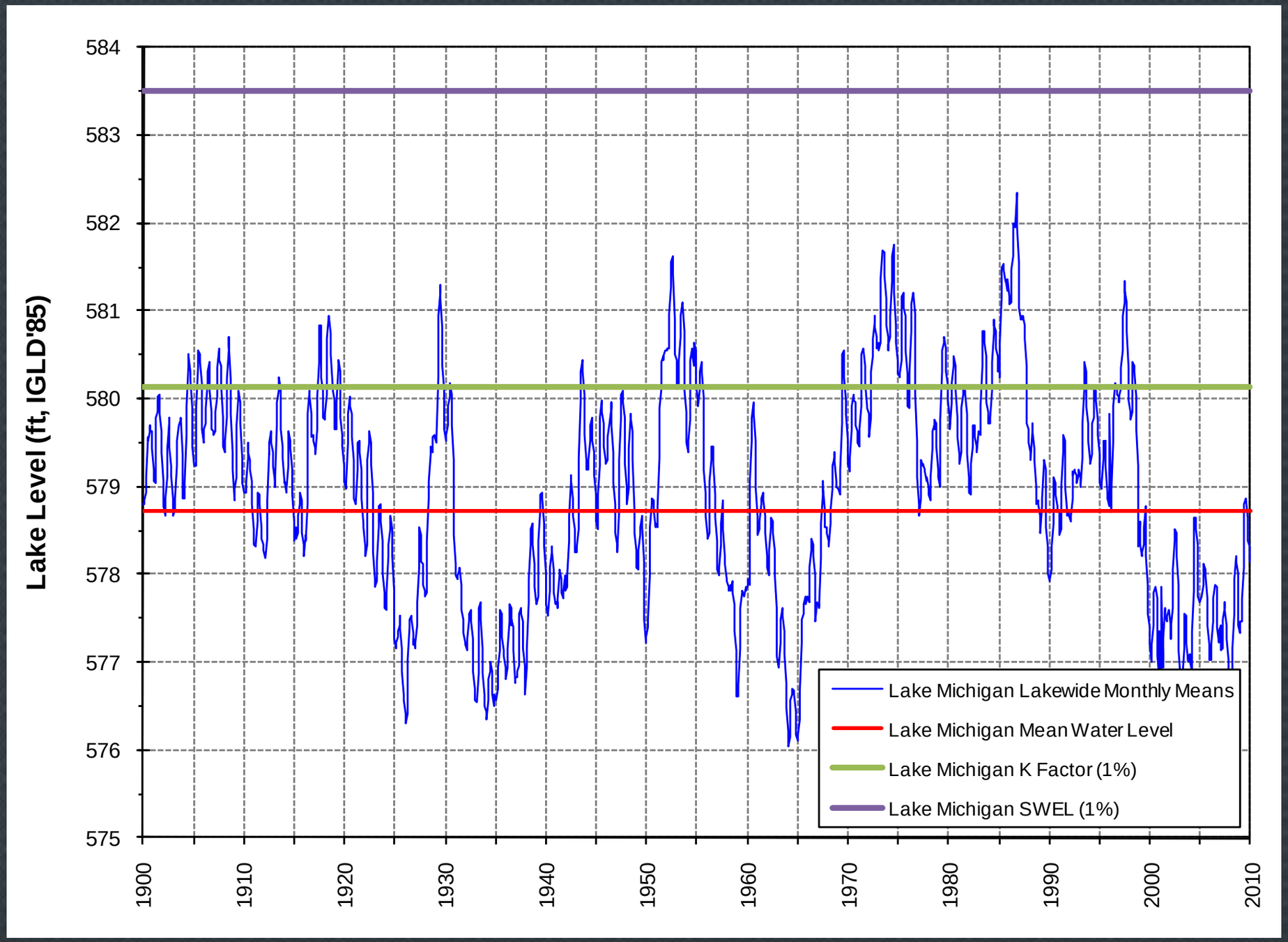
Lake Michigan Lake Levels



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Modified Response

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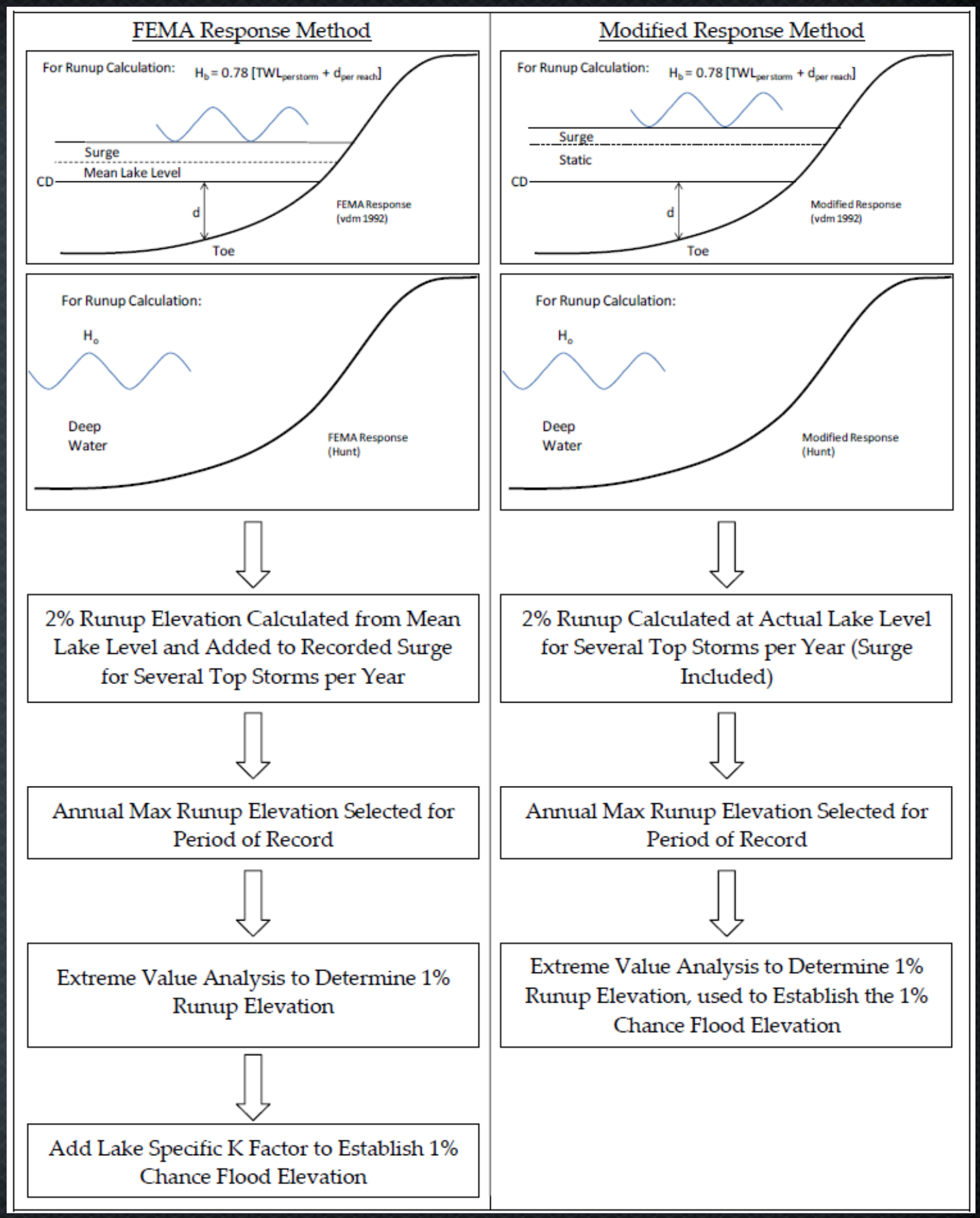
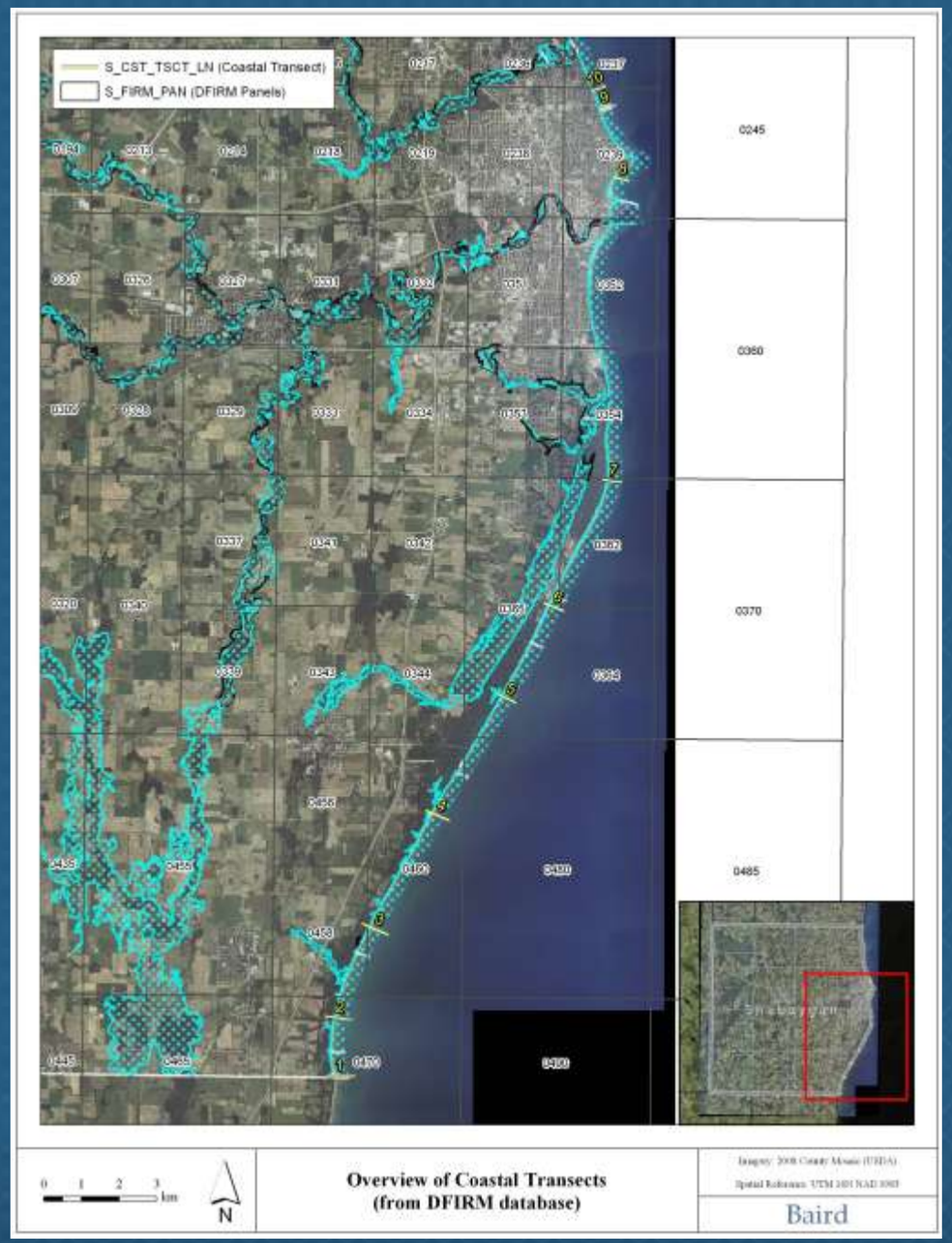


II – Sheboygan County Runup Results



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Inputs

- Lake Level
  - Hourly NOAA water level (1970 - 2010)
  - 1% level from USACE 1988
- Waves
  - 1D Baird hindcast (1956 - 1998)
- Transects
  - Coarse 1km-spaced (LMPDS)

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Table 1.3 Comparison of 2% Runup for Event Based Method (Reach 1219)

		Hunt (1959)	de Waal & van der Meer (1992)	ACES	CHAMP
	$R_{2\%}$ (ft above CD) =	**8.22**	**8.89**	**9.48**	**8.04**
	$R_{2\%}$ (Rounded) =	**8**	**9**	**9**	**8**
Wave Heights (ft)	3 -year H_b (depth limited)	-	5.4	-	-
	3-year H_o	13.9	-	13.9	13.9
Period (s)	T_{avg}	-	7.9	-	-
	T_P	9.8	-	9.8	9.8
WL (ft) above CD	$SWEL_{1\%}$	6.2	6.2	6.2	6.2
Slope	m_{beach} (cot)	24.4	24.4	24.4	24.4
	$m_{nearshore}$ (cot)	-	111.1	-	-
Special Inputs	Runup Reduction Factors* (γ_r , γ_P, γ_b, γ_β)	-	1,1,1,1	-	-

*Runup Reduction Factors all set to 1 (default), since profile features smooth sound beach (no structures).

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Response Based (Reach 1219)

Combined waves (from hindcast) & WLs (NOAA) to create stormlisting

Year	Duration	Hs (m)	Tp (s)	Dir	Surge (m)
1998	15	2.92	8.61	22	0.22
1998	13	3.27	8.24	22	0.17
1998	23	3.65	9.44	22	0.16
1998	37	3.92	8.88	22	0.53
1998	23	2.96	7.07	112	0.25
1998	14	3.01	8.87	22	0.2
1998	49	4.24	9.74	22	0.35
1997	21	2.95	7.67	45	0.28
1997	7	2.55	7.16	22	0.33
1997	14	2.64	7.78	45	0.25
1997	3	2.5	7.82	135	0.21
1997	8	2.4	7.53	90	0.15
1996	2	2.47	7.23	158	0.1
1996	1	2.35	6.8	112	0.11
1996	5	2.68	7.67	135	0.15

Waves transformed to the nearshore, calculate $R_{2\%}$

$R_{2\%}$ (m)
0.914
0.875
1.002
0.943
0.751
0.942
1.034
0.814
0.760
0.826
0.830
0.799
0.768
0.722
0.814

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Response (continued)

Year	$R_{2\%}$ (m)
1998	0.914
1998	0.875
1998	1.002
1998	0.943
1998	0.751
1998	0.942
1998	1.034
1997	0.814
1997	0.760
1997	0.826
1997	0.830
1997	0.799
1996	0.768
1996	0.722
1996	0.814
1996	0.893
1996	0.850
1996	0.810
1996	0.859

Extreme value analysis of top annual runup

Adjustment Factor $K^*_{1\%}$ =	1.41	ft
Mean Lake Level =	578.72	ft, IGLD '85

1% event + K + mean lake level = **BFE**

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Table 1.5 Calculated 2% Runup for Response Based Method (Reach 1219)

		Proposed Response Method		Modified Response Approach	
	Runup Method	Hunt (1959)	de Waal & van der Meer (1992)	Hunt (1959)	de Waal & van der Meer (1992)
	$R_{2\%}$ (ft above CD) =	**7.1**	**8.6**	**8.7**	**9.6**
	$R_{2\%}$ (Rounded) =	**7**	**9**	**9**	**10**
Wave Heights (ft)	H_b	-	per storm	-	per storm
	H_o	per storm	-	per storm	-
Period (s)	T_{avg}	-	per storm	-	per storm
	T_P	per storm	-	per storm	-
WL (ft)	Lake Adjustment Factor ($K_{1\%}$)	1.41	1.41	-	-
	Mean Lake Level	578.72	578.72	-	-
Slope	m_{beach} (cot)	24.4	24.4	24.4	24.4
Special Inputs	Actual Peak Water Level above CD			per storm	per storm
	Actual Surge	per storm	per storm		
	Runup Reduction Factors (γ_r , γ_P, γ_b, γ_β)	-	1, 1, 1, 1	-	1, 1, 1, 1

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Modified Response Approach

- Runup added to actual peak lake level for each storm event
- EVA completed on annual maxima (runup + actual wl) to estimate 1% flood level
- A more robust response approach
  - Not using factors, but actual water level

Summary for Reach1219

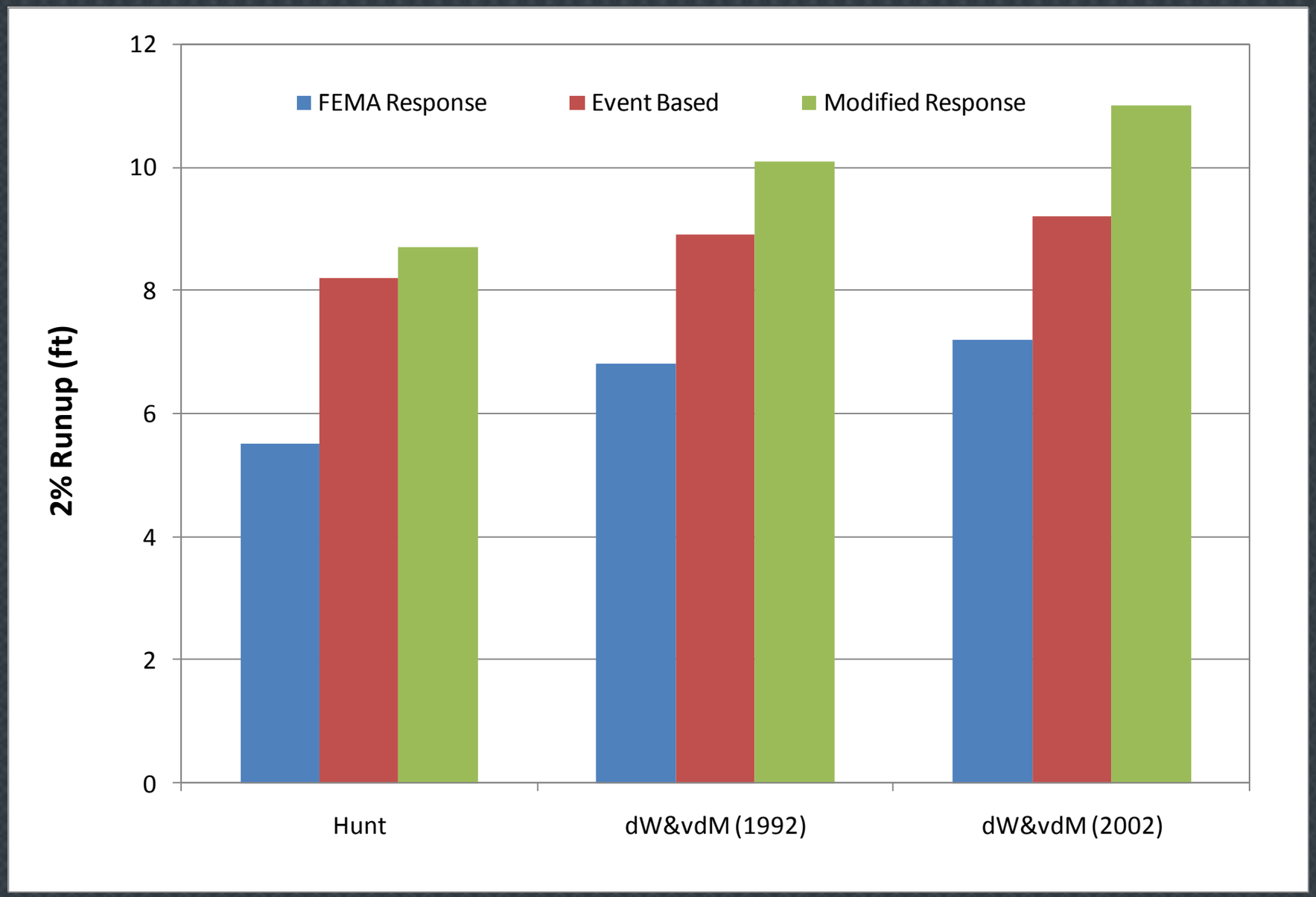

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Table 2.11 Summary of Existing Methodology Results for Sheboygan County (1% Flood Level in Bold, Actual Runup in Parenthesis)

	m_{beach} (cot)	Hunt (1959)	de Waal & van der Meer (1992)
Reach 1215	24.2	**586** (2.1)	**587** (2.7)
Reach 1216	22.6	**586** (2.2)	**587** (3.1)
Reach 1217	16.3	**587** (3.1)	**588** (4.1)
Reach 1218	21.4	**586** (2.3)	**587** (3.0)
Reach 1219	24.4	**586** (2.0)	**587** (2.7)
Reach 1220	23.3	**586** (2.1)	**587** (2.9)
Reach 1221	21.4	**586** (2.3)	**587** (3.0)
Reach 1222	23.6	**586** (2.1)	**587** (2.9)
Reach 1223	21.4	**586** (2.3)	**587** (3.0)
Reach 1224	21.2	**586** (2.3)	**587** (3.0)
Reaches 1225-1231	20.0	**587** (2.5)	**587** (3.3)
Reaches 1232-1234	21.6	**586** (2.3)	**587** (3.0)
Reach 1235	19.8	**587** (2.5)	**587** (3.4)
Reach 1239	21.4	**586** (2.3)	**587** (3.0)
Reach 1247	23.0	**586** (2.2)	**587** (3.3)
Reach 1248	20.5	**586** (2.4)	**588** (3.6)
Reach 1249	23.3	**586** (2.1)	**587** (3.2)
Reach 1250	20.0	**587** (2.5)	**587** (3.3)

Median 1% Flood Level (NAVD '88)	586	587

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Table 2.13 Summary of Proposed Methodology for Sheboygan County (1% Flood Level in Bold)

	Proposed Response Method		Modified Response Method	
	Hunt (1959)	de Waal & van der Meer (1992)	Hunt (1959)	de Waal & van der Meer (1992)
Reach 1215	**585**	**586**	**586**	**587**
Reach 1216	**585**	**586**	**586**	**588**
Reach 1217	**586**	**587**	**587**	**589**
Reach 1218	**585**	**586**	**586**	**588**
Reach 1219	**585**	**586**	**586**	**587**
Reach 1220	**585**	**586**	**586**	**587**
Reach 1221	**585**	**586**	**586**	**588**
Reach 1222	**585**	**586**	**586**	**587**
Reach 1223	**585**	**586**	**586**	**588**
Reach 1224	**585**	**586**	**586**	**588**
Reaches 1225-1231	**585**	**587**	**586**	**588**
Reaches 1232-1234	**585**	**586**	**586**	**588**
Reach 1235	**585**	**587**	**586**	**588**
Reach 1239	**585**	**586**	**586**	**588**
Reach 1247	**585**	**586**	**586**	**588**
Reach 1248	**585**	**587**	**586**	**588**
Reach 1249	**585**	**586**	**586**	**588**
Reach 1250	**585**	**587**	**586**	**588**
Median 1% Flood Level (NAVD '88)	585	586	586	588

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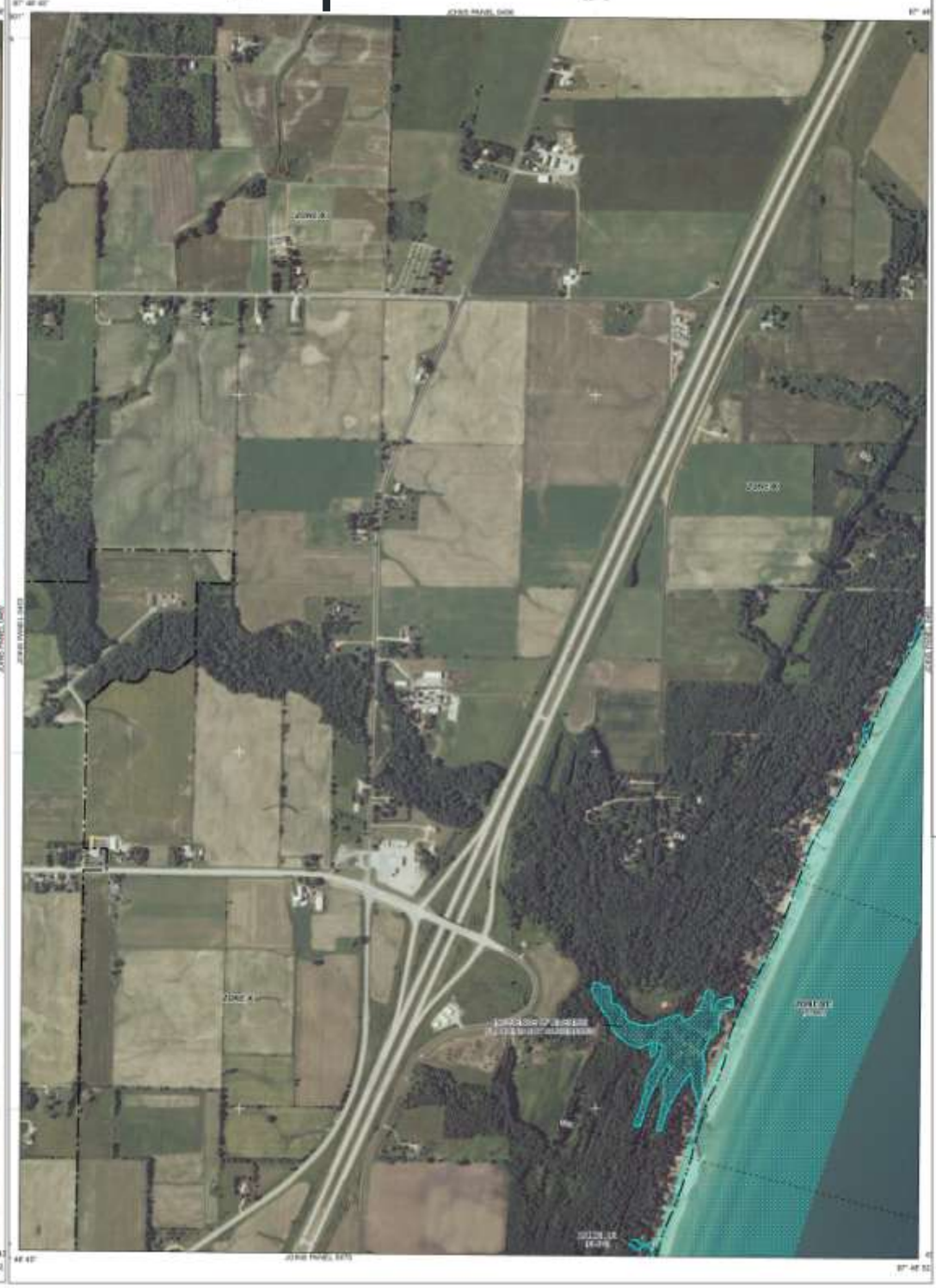
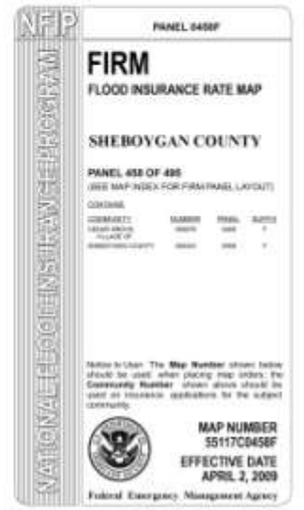
Event Based

Response Based





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Event versus Response

- Event
  = $SWEL_{1\%} + R_{2\%}$
  = $583.5 + R_{2\%}$

- Response
  = Mean Lake Level + K + Surge + $R_{2\%}$
  = $\underbrace{578.7 + 1.4}_{580.1}$ + Surge + $R_{2\%}$

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Summary

- Event produces results ~1 ft higher than the proposed Response Method
- Modified produces results ~1-2 ft higher than the proposed Response Method
- The Proposed Response Method may not be technically defensible
  - K factor, mean lake level
- **Proposed < Event < Modified**

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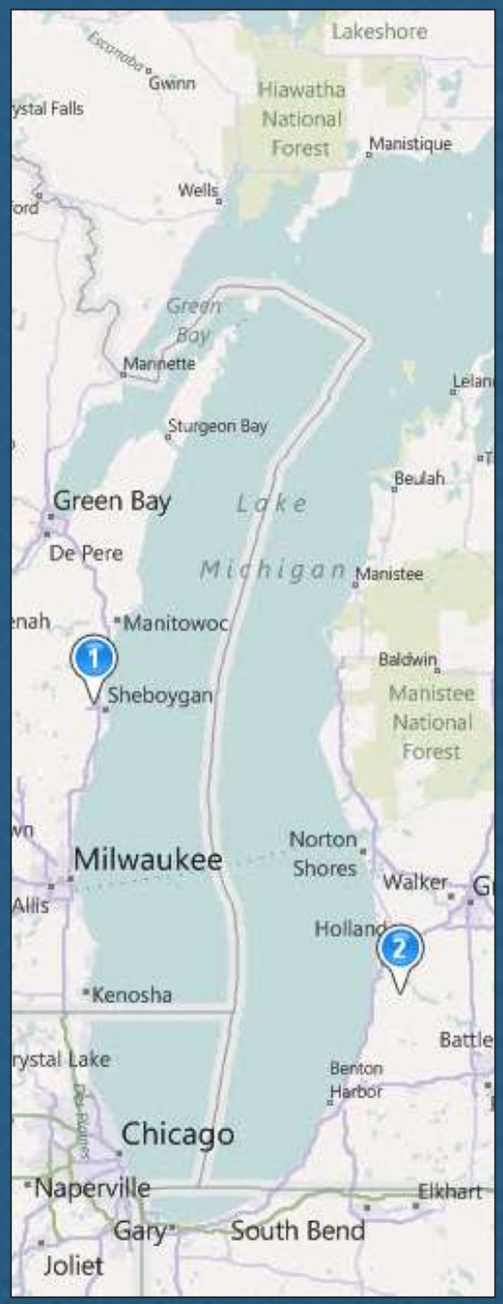
III – Data Sensitivity Analysis



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Transect Resolution (Sheboygan)

- High Resolution
- $R_{2\%}$ = 589 ft

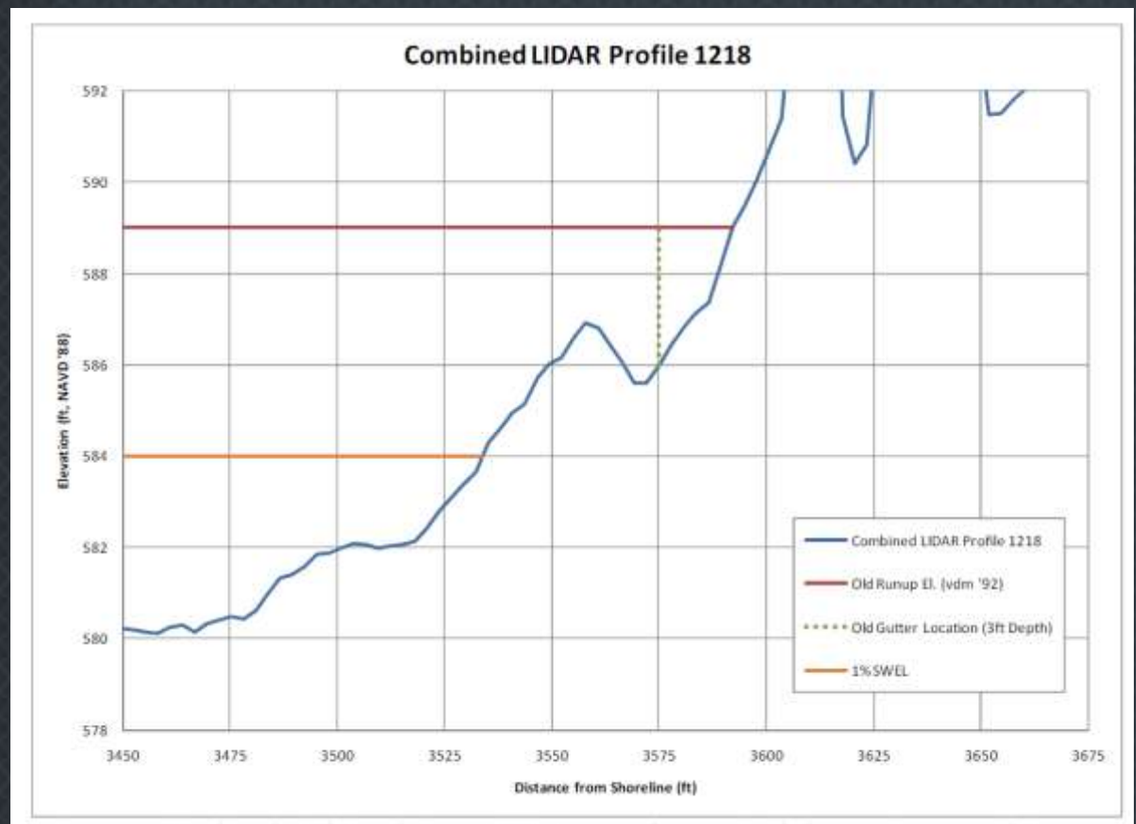

Figure 3.1 Combined High Resolution LIDAR Transect for 1218 in Sheboygan County with Runup

- Low Resolution
- $R_{2\%}$ = 587 ft

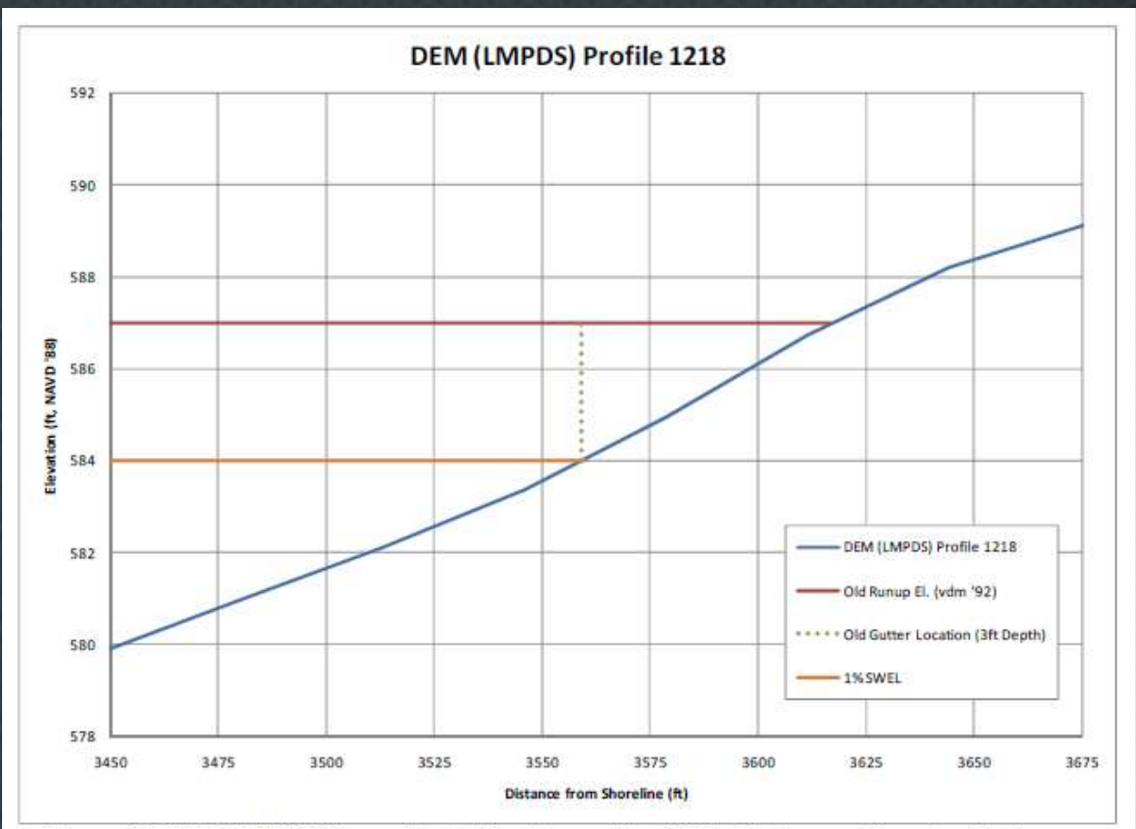

Figure 3.2 DEM/LMPDS Coarse Resolution Transect for 1218 in Sheboygan County with Runup

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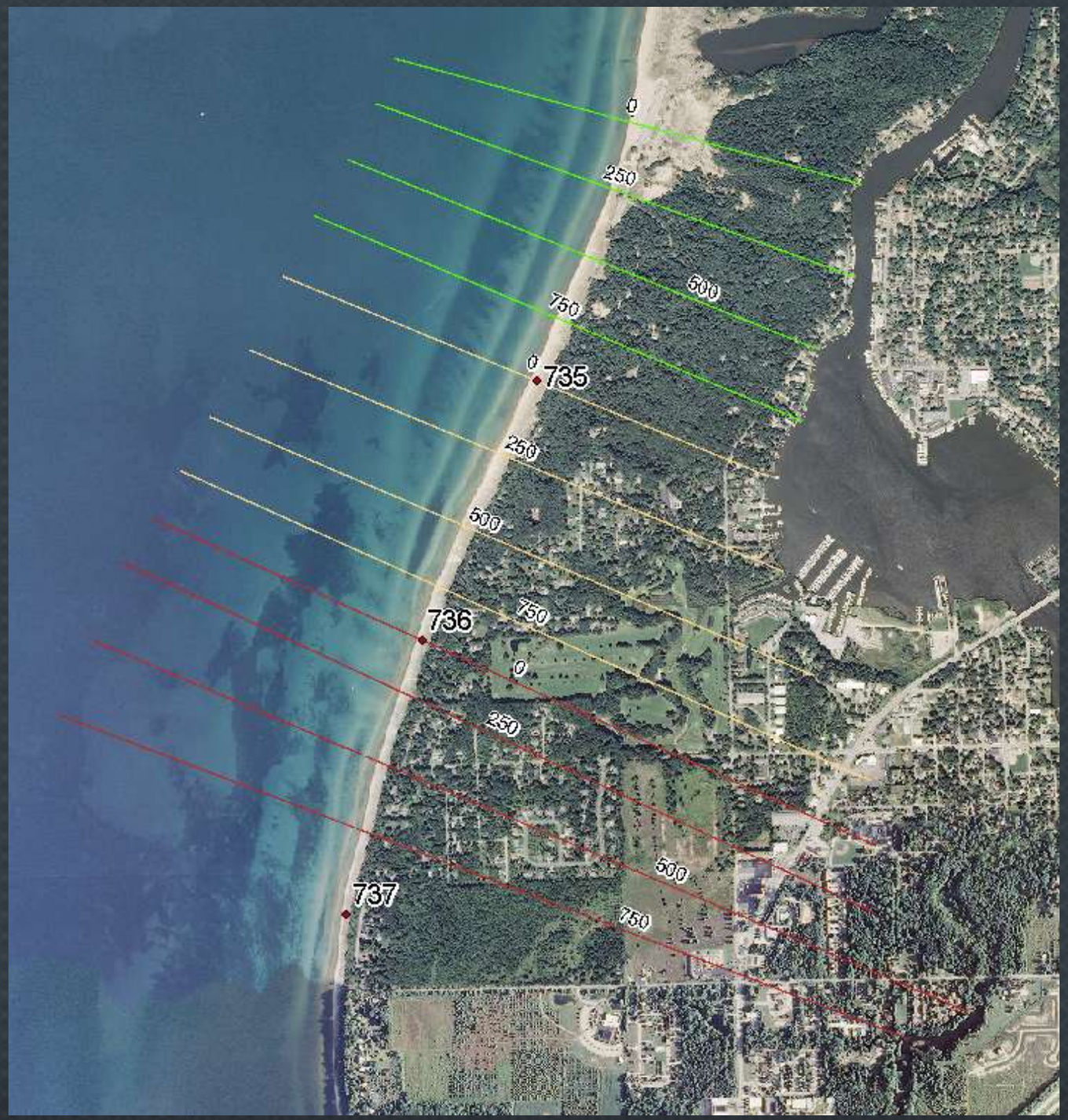
Spacing Resolution (Allegan)



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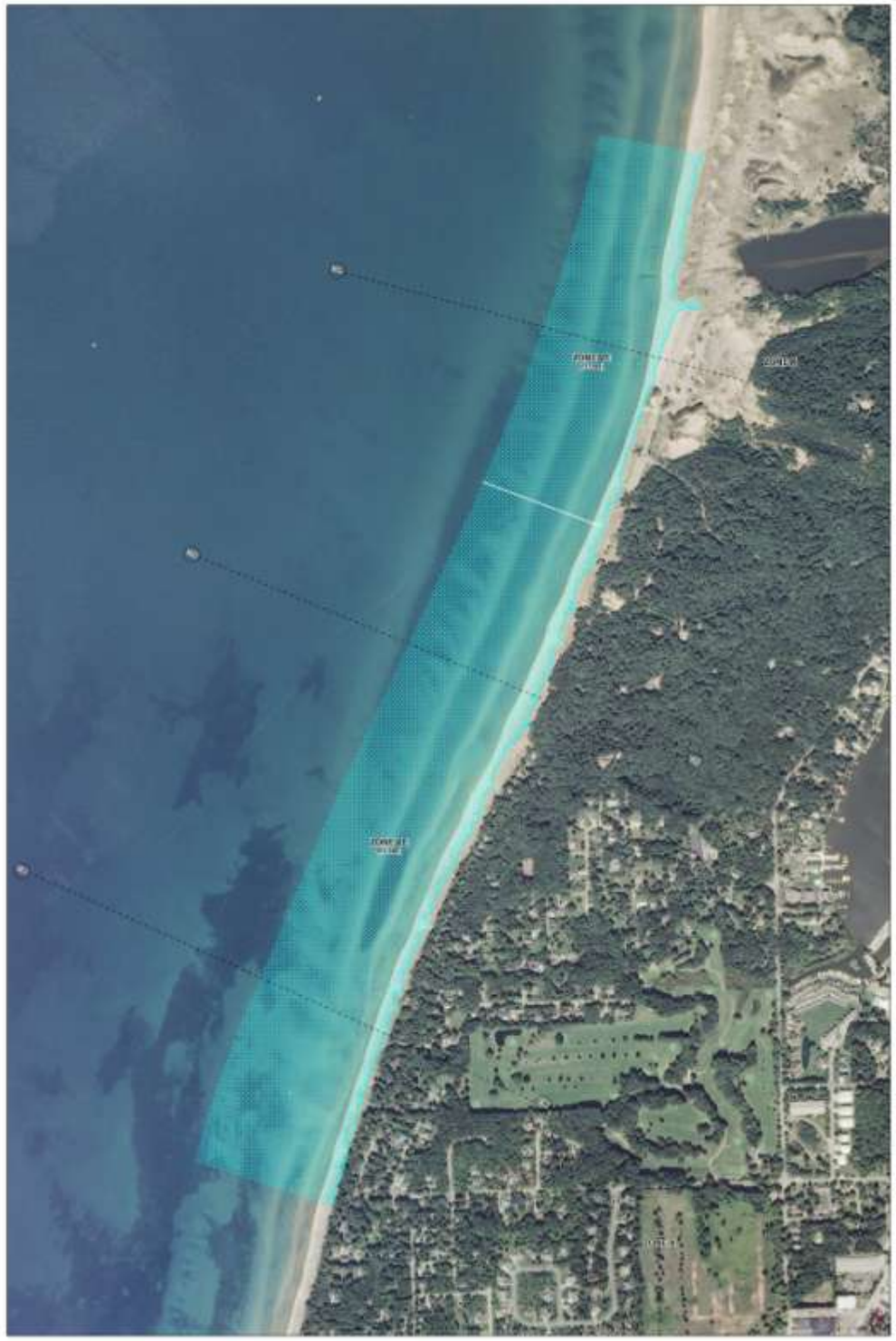
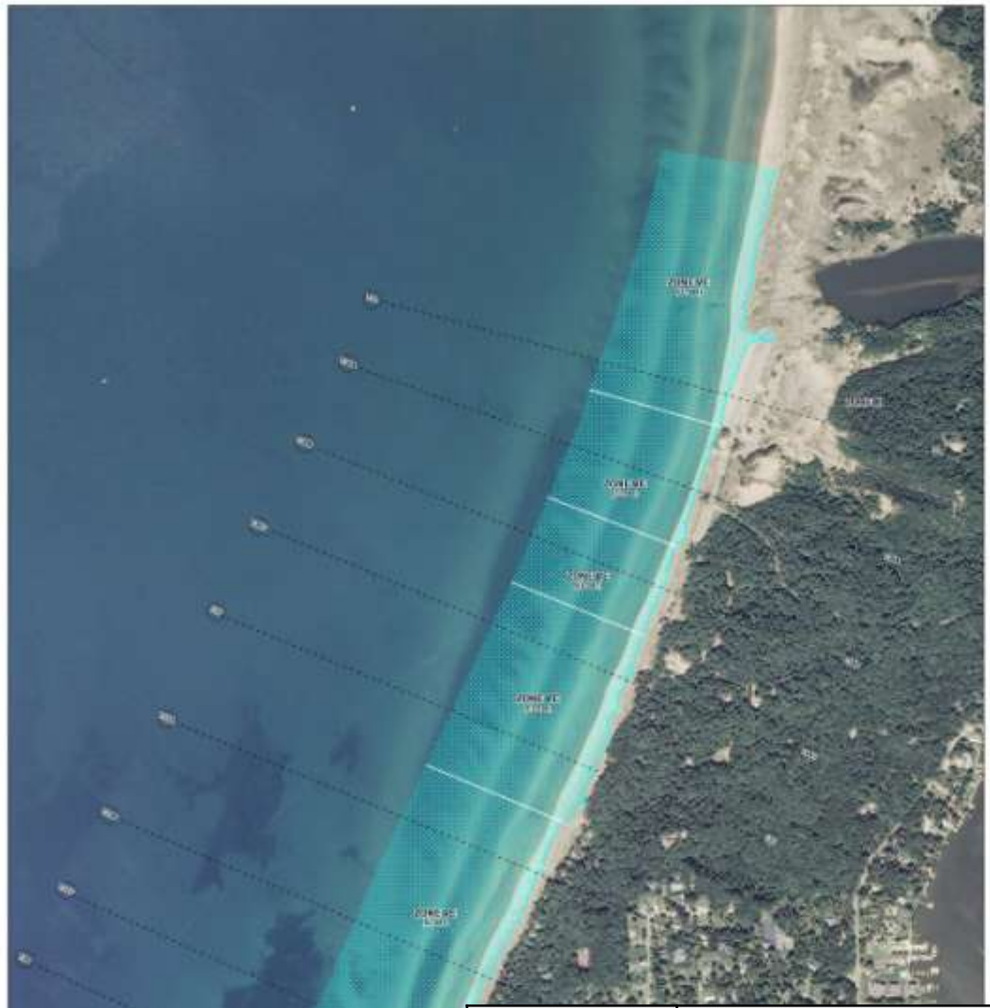
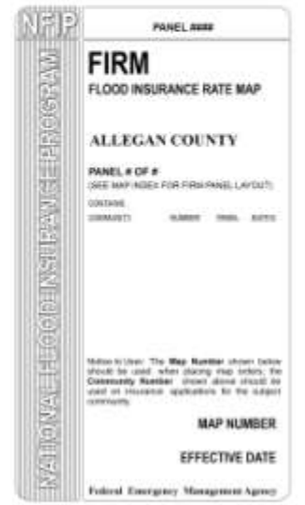
SENSITIVITY ANALYSIS - FEW COASTAL TRANSECTS



SENSITIVITY ANALYSIS - MANY COASTAL TRANSECTS



Reach	Runup Zone El. (ft)
734	589
734+250m	588
734+500m	587
734+750m	588
735	588
735+250m	587
735+500m	587
735+750m	587
736	588



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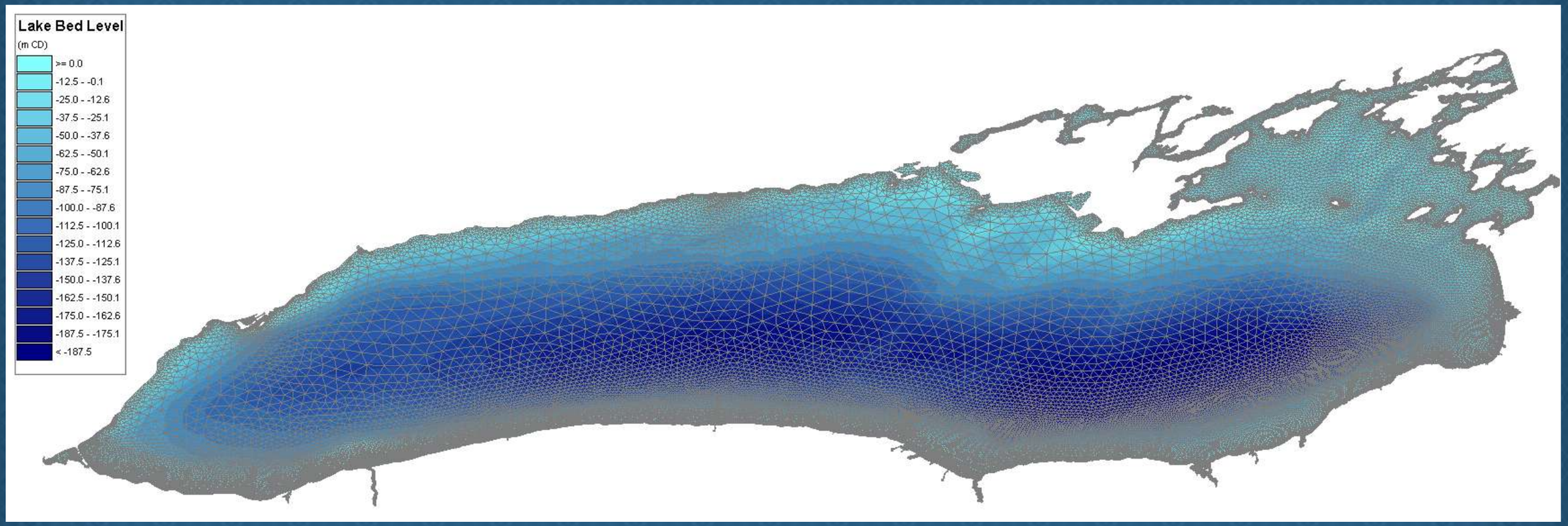
IV – Lake Ontario Wave and Surge Modeling



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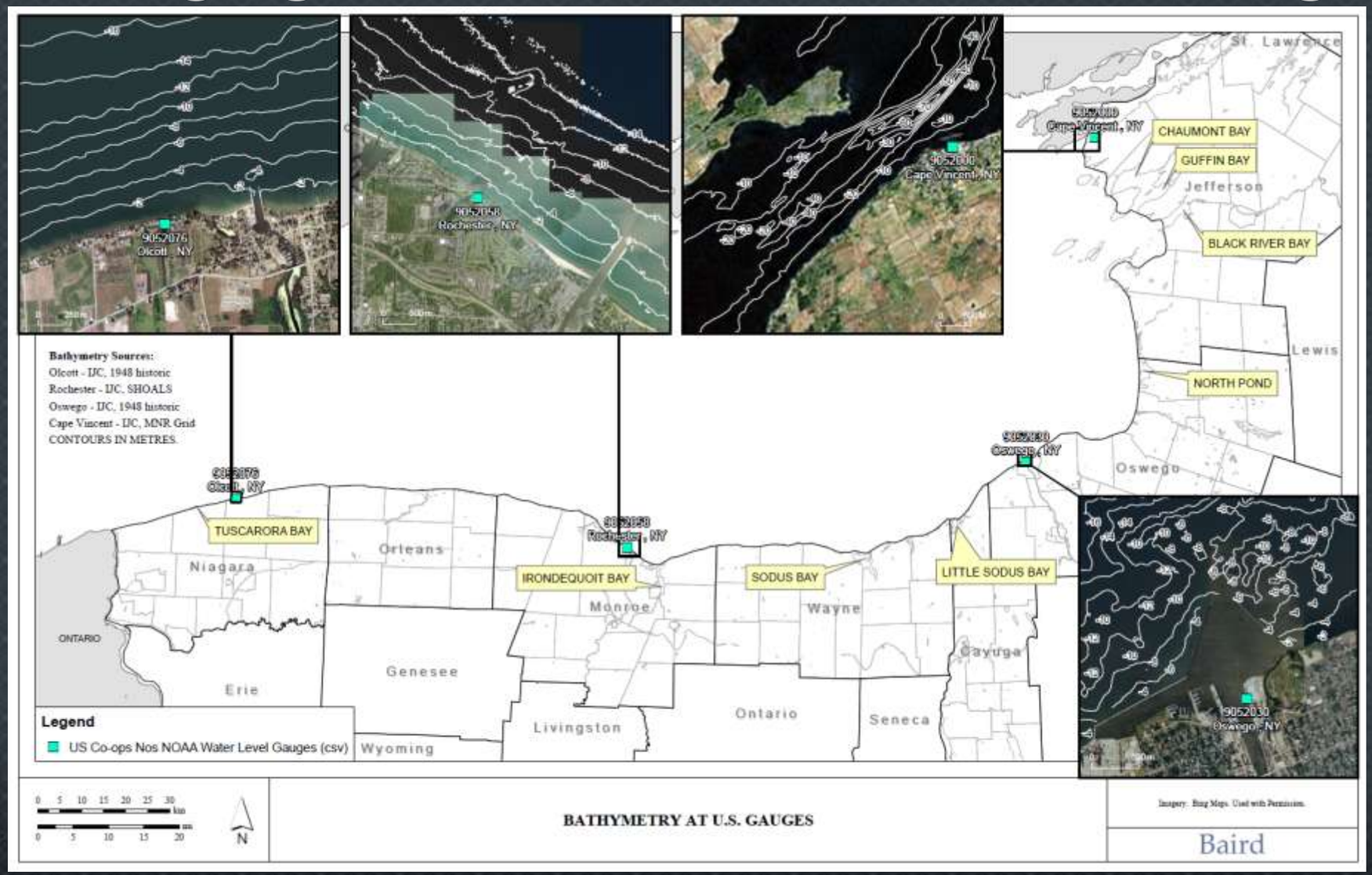
ADCIRC – Storm Surge Model

- Will be calibrated against four US NOAA gages to simulate storm surge



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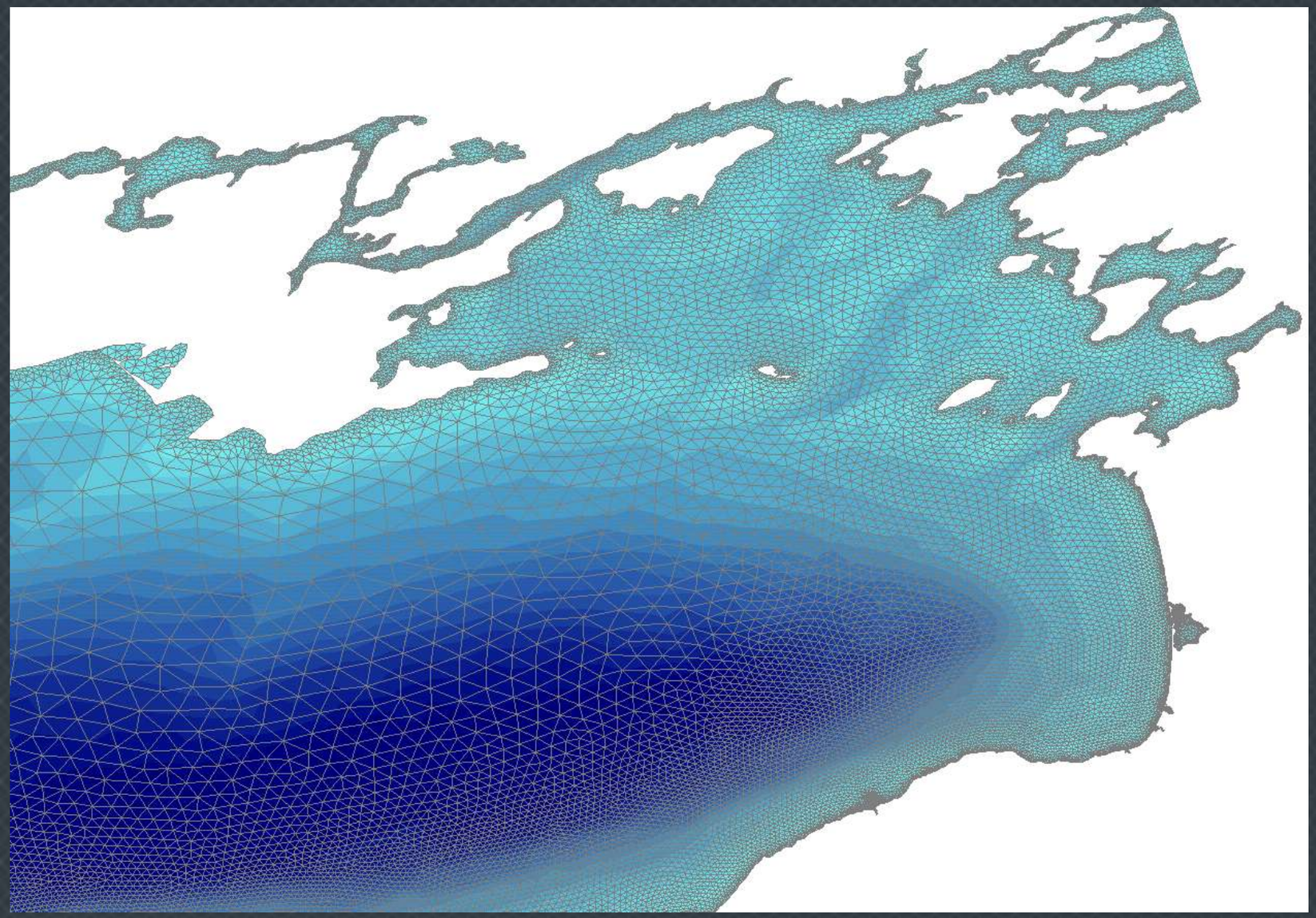
SWAN – Wave Model



Eastern Lake Ontario

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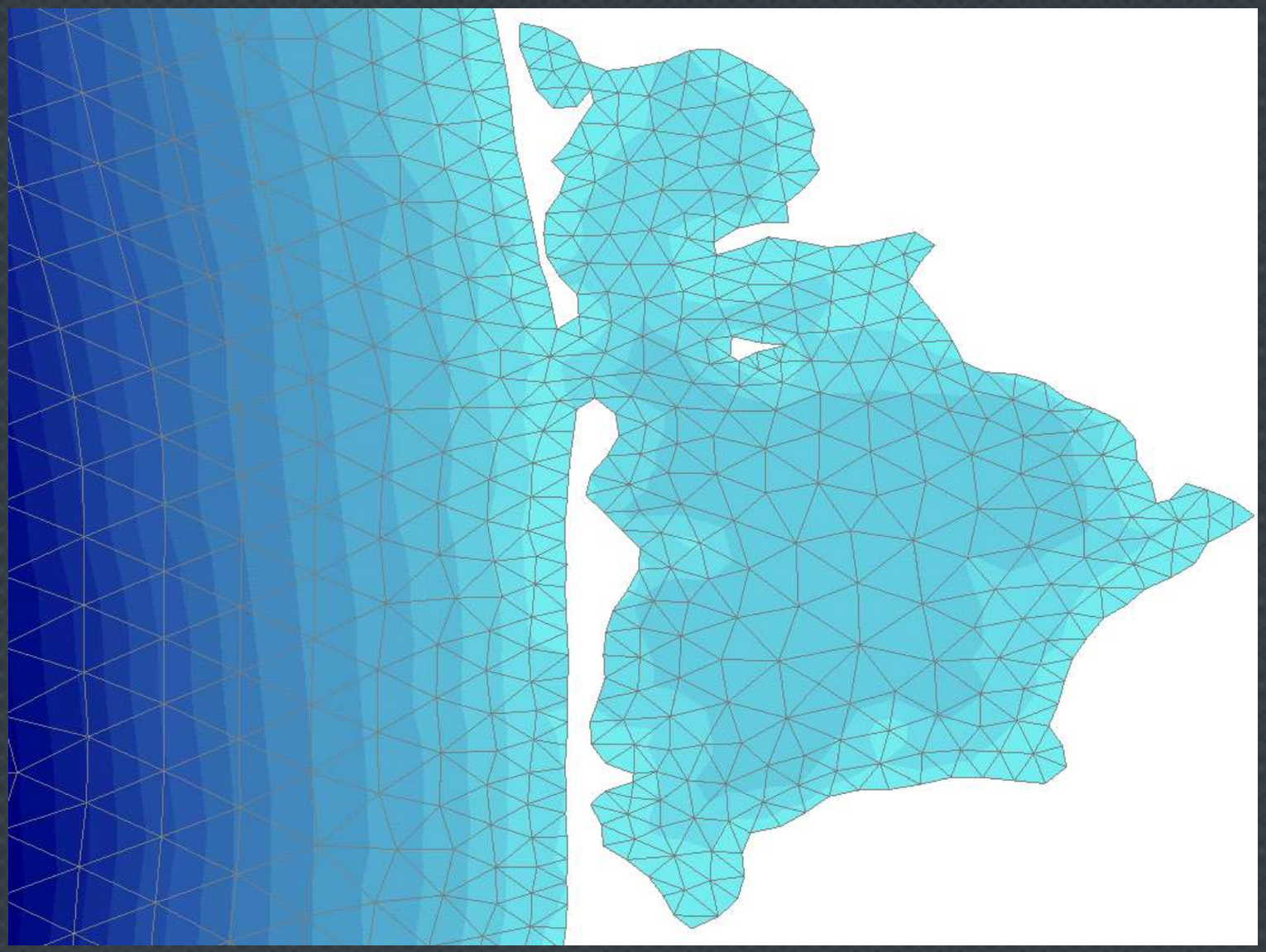
SWAN – Wave Model II



North Pond

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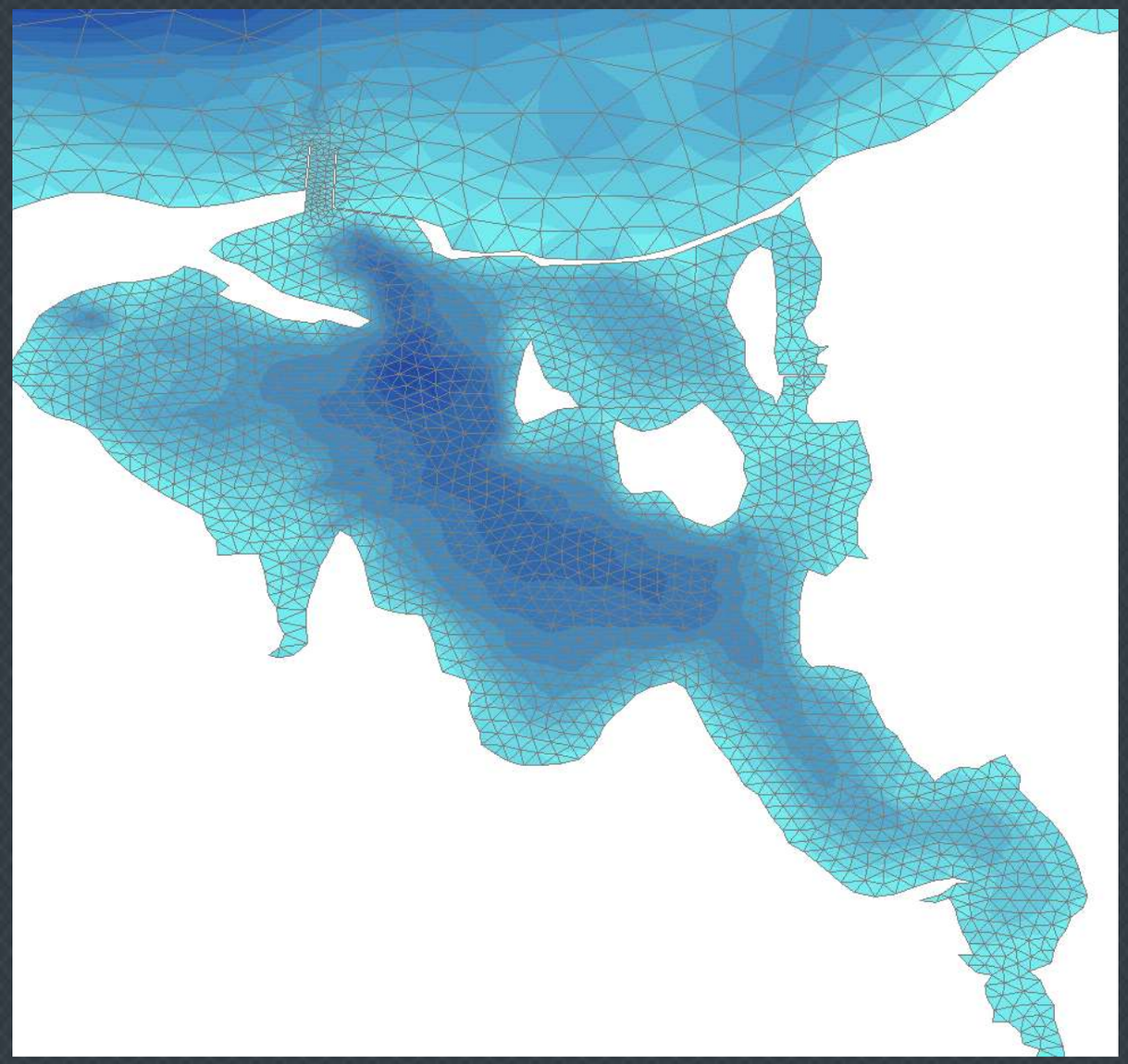
SWAN – Wave Model III



Sodus Bay

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Production Simulations

- Approximately 20 to 30 storms will be run for each coastal county
- Time series storm surge and wave parameters will be saved at all grid points
- Surge and wave height can then be used to estimate flooding for each coastal county

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Thank You!