

# Great Lakes Flood Mapping

## Pilot Studies on Lake Michigan

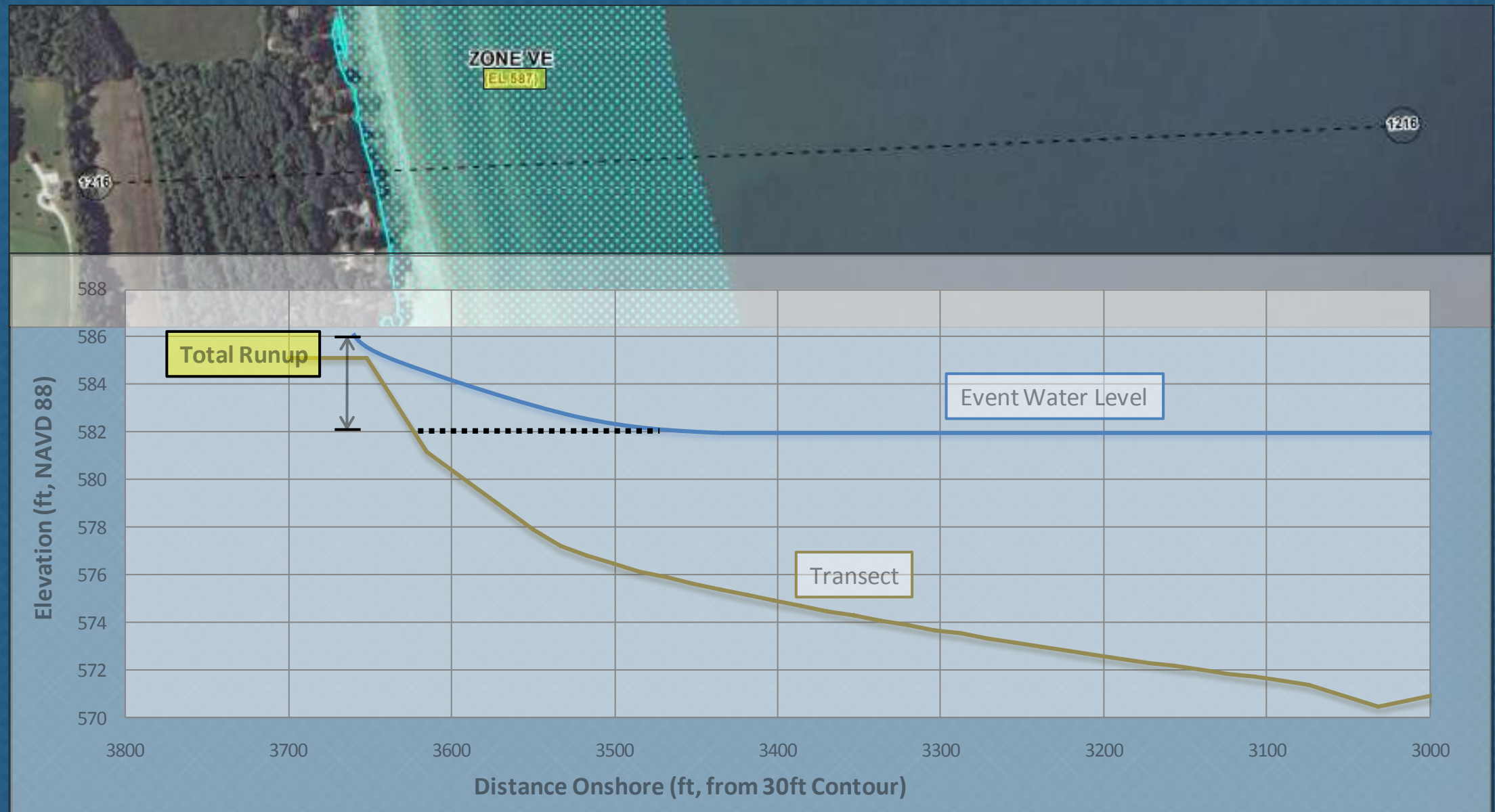
Josh Friedman  
2011 NYSFSMA Conference  
April 28<sup>th</sup>, 2011

# Presentation Overview

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



# I – Event vs. Response for Runup





# 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



# 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

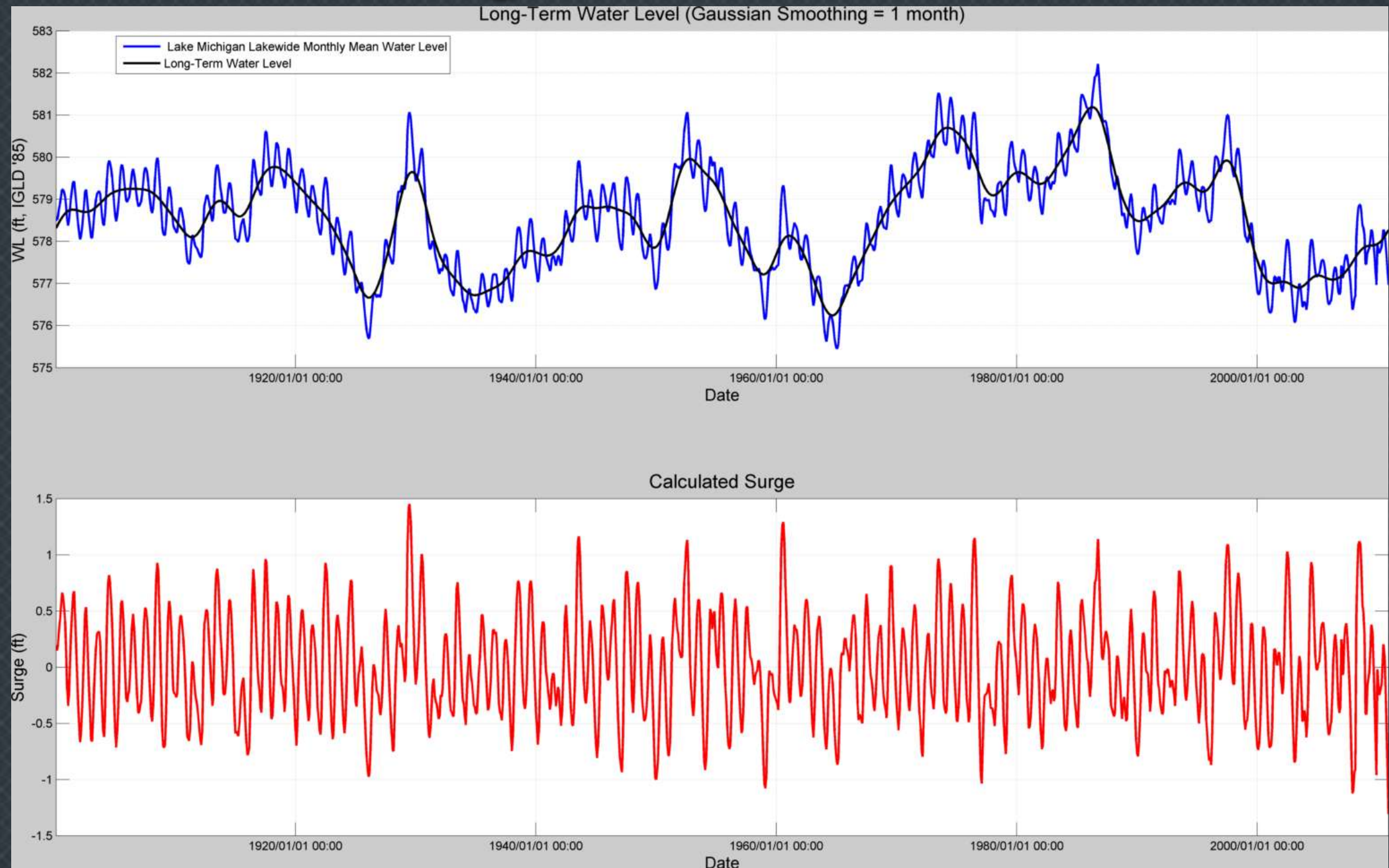


# Response (continued)

- 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

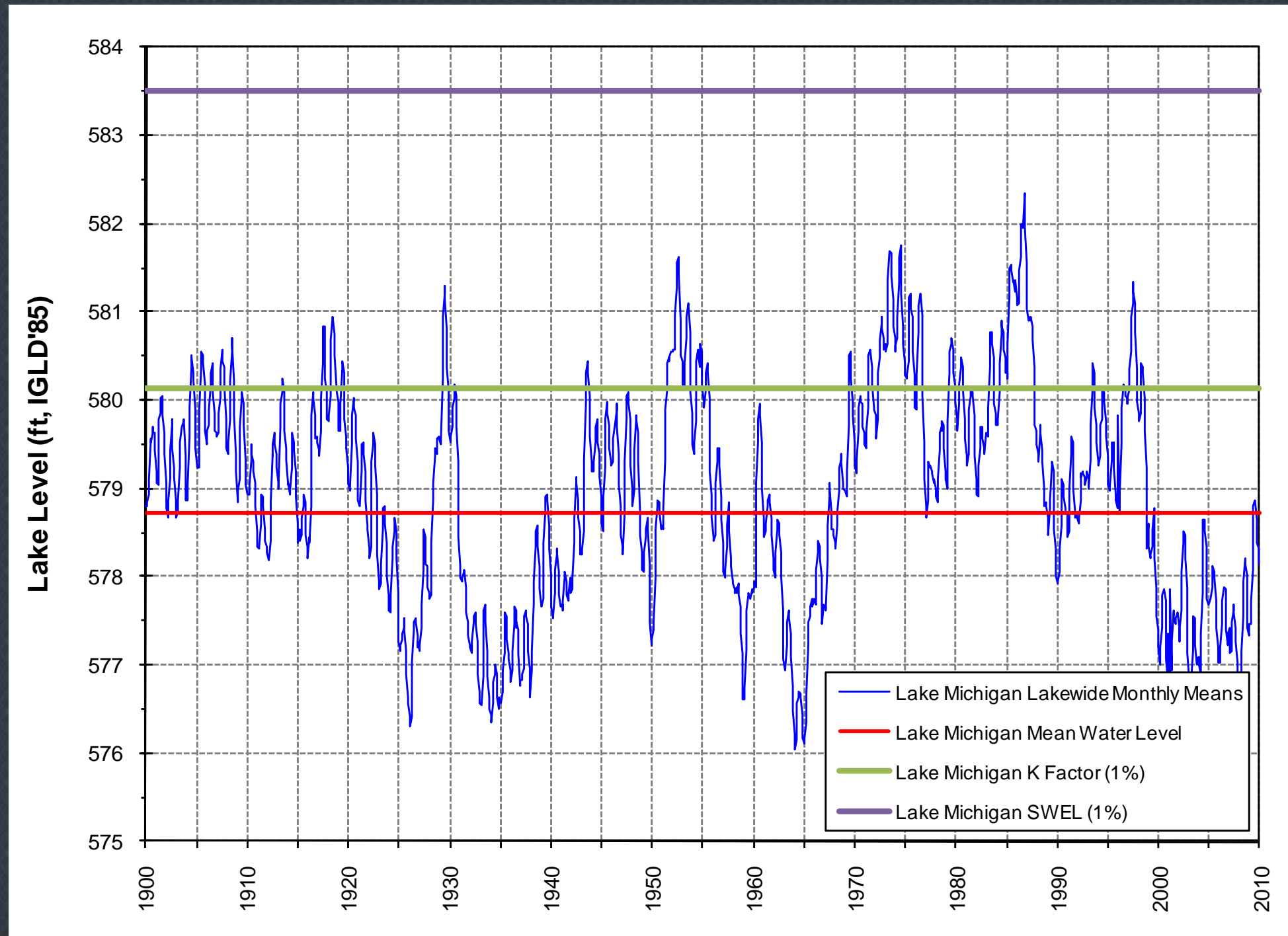


# Lake Michigan Lake Levels



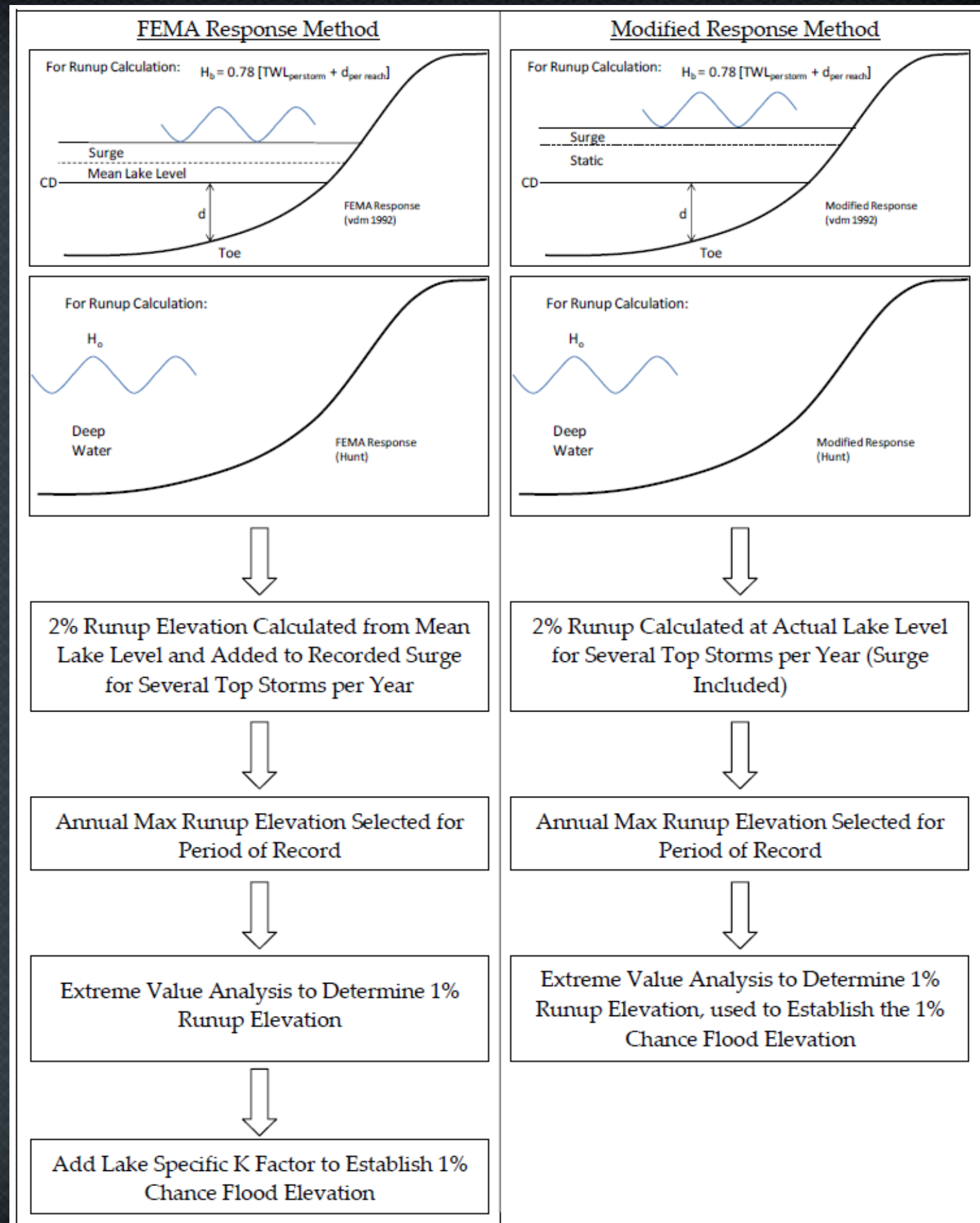
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# Lake Michigan Lake Levels



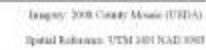


# Modified Response





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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* $(\gamma_r, \gamma_p, \gamma_b, \gamma_\beta)$	-	1,1,1,1	-	-

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



# 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 <sub>2%</sub> (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 ( $\gamma_r, \gamma_p, \gamma_b, \gamma_\beta$ )	-	1, 1, 1, 1	-	1, 1, 1, 1



# 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



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

	m <sub>beach</sub> (cot)	Hunt (1959)	de Waal & van der Meer (1992)
Reach 1215	24.2	<b>586</b> (2.1)	<b>587</b> (2.7)
Reach 1216	22.6	<b>586</b> (2.2)	<b>587</b> (3.1)
Reach 1217	16.3	<b>587</b> (3.1)	<b>588</b> (4.1)
Reach 1218	21.4	<b>586</b> (2.3)	<b>587</b> (3.0)
Reach 1219	24.4	<b>586</b> (2.0)	<b>587</b> (2.7)
Reach 1220	23.3	<b>586</b> (2.1)	<b>587</b> (2.9)
Reach 1221	21.4	<b>586</b> (2.3)	<b>587</b> (3.0)
Reach 1222	23.6	<b>586</b> (2.1)	<b>587</b> (2.9)
Reach 1223	21.4	<b>586</b> (2.3)	<b>587</b> (3.0)
Reach 1224	21.2	<b>586</b> (2.3)	<b>587</b> (3.0)
Reaches 1225-1231	20.0	<b>587</b> (2.5)	<b>587</b> (3.3)
Reaches 1232-1234	21.6	<b>586</b> (2.3)	<b>587</b> (3.0)
Reach 1235	19.8	<b>587</b> (2.5)	<b>587</b> (3.4)
Reach 1239	21.4	<b>586</b> (2.3)	<b>587</b> (3.0)
Reach 1247	23.0	<b>586</b> (2.2)	<b>587</b> (3.3)
Reach 1248	20.5	<b>586</b> (2.4)	<b>588</b> (3.6)
Reach 1249	23.3	<b>586</b> (2.1)	<b>587</b> (3.2)
Reach 1250	20.0	<b>587</b> (2.5)	<b>587</b> (3.3)
<i>Median 1% Flood Level (NAVD '88)</i>		<b>586</b>	<b>587</b>



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

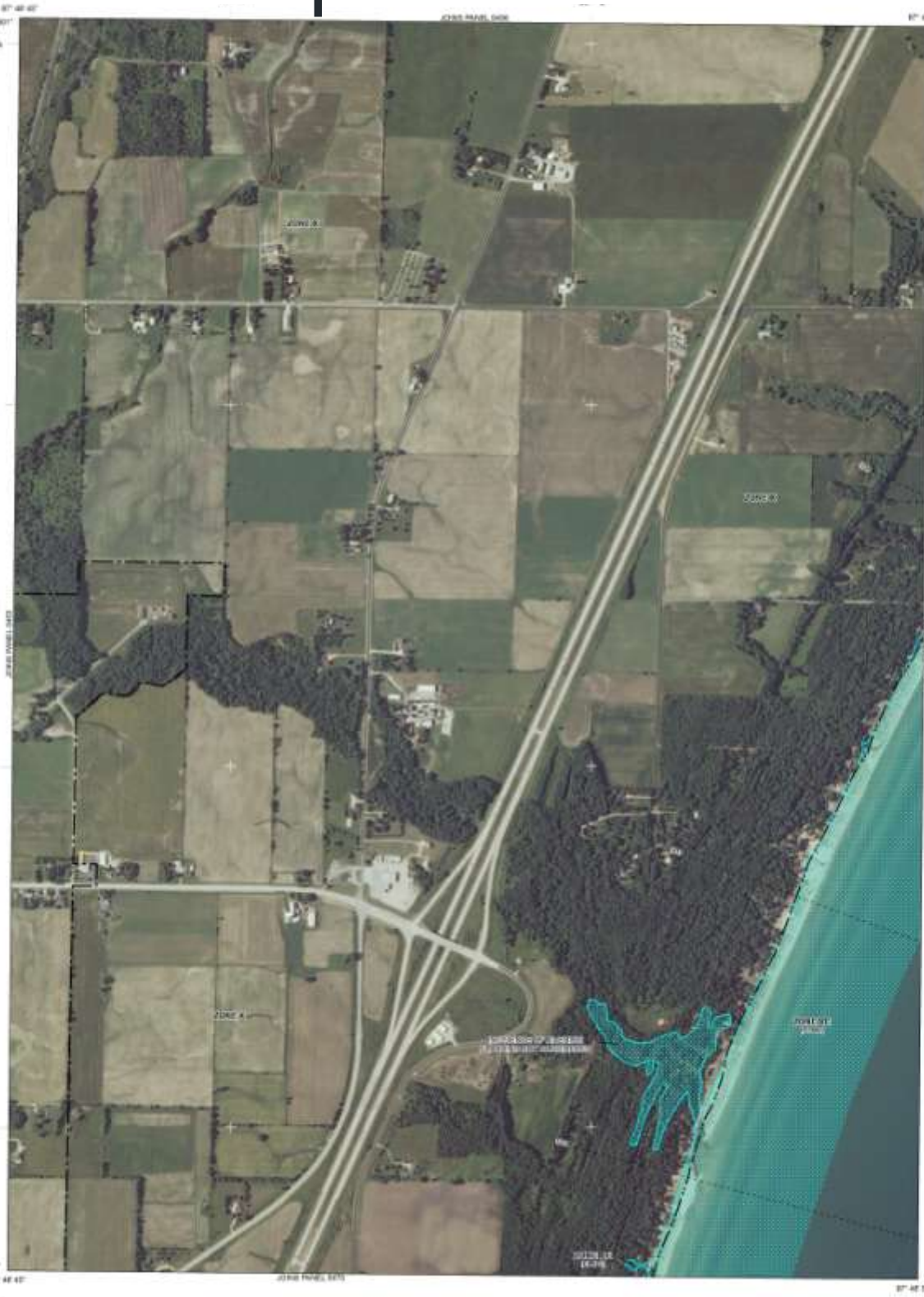
	Proposed Response Method		Modified Response Method	
	Hunt (1959)	de Waal & van der Meer (1992)	Hunt (1959)	de Waal & van der Meer (1992)
Reach 1215	585	586	586	587
Reach 1216	585	586	586	588
Reach 1217	586	587	587	589
Reach 1218	585	586	586	588
Reach 1219	585	586	586	587
Reach 1220	585	586	586	587
Reach 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
<i>Median 1% Flood Level (NAVD '88)</i>	585	586	586	588



# Event Based



# Response Based



**LEGEND**

**SPECIAL FLOOD HAZARD AREAS (SFHA) SUBJECT TO FLOODING BY THE 1% ANNUAL CHANCE FLOOD**  
The 1% annual chance flood is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zone A, AE, AH, AO, X, and VE. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood.

**ZONE A**  
No Base Flood Elevation determined. Base Flood Elevation determined.

**ZONE AE**  
Flood depths of 1 to 3 feet (depths of 1 to 3 feet). Base Flood Elevation determined.

**ZONE AH**  
Flood depths of 1 to 3 feet (depths of 1 to 3 feet). Base Flood Elevation determined.

**ZONE AO**  
Special Flood Hazard areas formerly designated as Zone X, but which have been determined to be in a flood zone by the 1% annual chance flood. Areas of Special Flood Hazard include Zone A, AE, AH, AO, X, and VE. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood.

**ZONE X**  
Areas to be protected from the 1% annual chance flood by a levee or flood protection system, including levees, flood walls, or other flood protection systems. Coastal flood areas with publicly owned levees or flood walls. Base Flood Elevation determined.

**ZONE VE**  
Special Flood Hazard areas with velocity hazard (wave action). Base Flood Elevation determined.

**FLOODWAY AREAS IN ZONE AE**  
The Floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachments so that the 1% annual chance flood can be carried without substantial increases in flood heights.

**OTHER FLOOD AREAS**  
**ZONE D**  
Areas of 0.2% annual chance flood. Areas of 1% annual chance flood with average depths of less than 1 foot or with average wave heights of 2 feet or less. Areas are primarily for waterways. The 1% annual chance flood.

**OTHER AREAS**  
**ZONE G**  
Areas determined to be outside the 1% annual chance floodplain. Areas in which flood hazards are considered, but not mapped.

**COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS**  
**OTHERWISE PROTECTED AREAS (OPA)**  
CBRS areas and other areas currently under study or subject to special flood hazard studies. 1% Annual Chance Floodplain Boundary. Floodway boundaries. Zone D boundary. CBRS and OPA boundary. Boundary of Special Flood Hazard Area. Areas of Special Flood Hazard include Zone A, AE, AH, AO, X, and VE. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zone A, AE, AH, AO, X, and VE. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood.

**Map Scale: 1" = 500'**

**MAP REPRODUCTION**  
This map is reproduced for use in the community. The community is responsible for the accuracy of the map. The community is responsible for the accuracy of the map. The community is responsible for the accuracy of the map.

**NATIONAL FLOOD INSURANCE PROGRAM**

**PANEL 4450F**

**FIRM**

**FLOOD INSURANCE RATE MAP**

**SHEBOYGAN COUNTY**

**PANEL 445 OF 445**

**(SEE MAP INDEX FOR FIRM PANEL LAYOUT)**

**CONTOUR**

**COMMUNITY**

**DATE**

**REVISION**

**MAP NUMBER**

**55117C0450F**

**EFFECTIVE DATE**

**APRIL 2, 2009**

**Federal Emergency Management Agency**

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# Event versus Response

- Event

$$= \text{SWEL}_{1\%} + R_{2\%}$$

$$= 583.5 + R_{2\%}$$

---

- Response

$$= \text{Mean Lake Level} + K + \text{Surge} + R_{2\%}$$

$$= 578.7 + 1.4 + \text{Surge} + R_{2\%}$$


$$580.1$$

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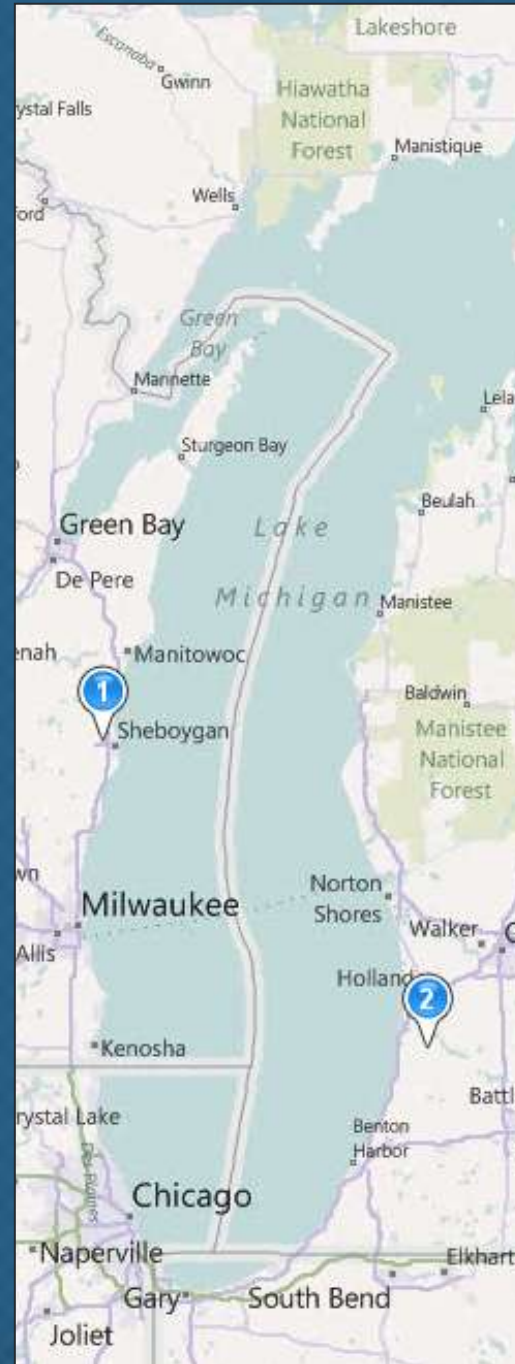


# Summary

- 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**



# III – Data Sensitivity Analysis



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# Transect Resolution (Sheboygan)

- High Resolution
- $R_{2\%} = 589$  ft
- Low Resolution
- $R_{2\%} = 587$  ft

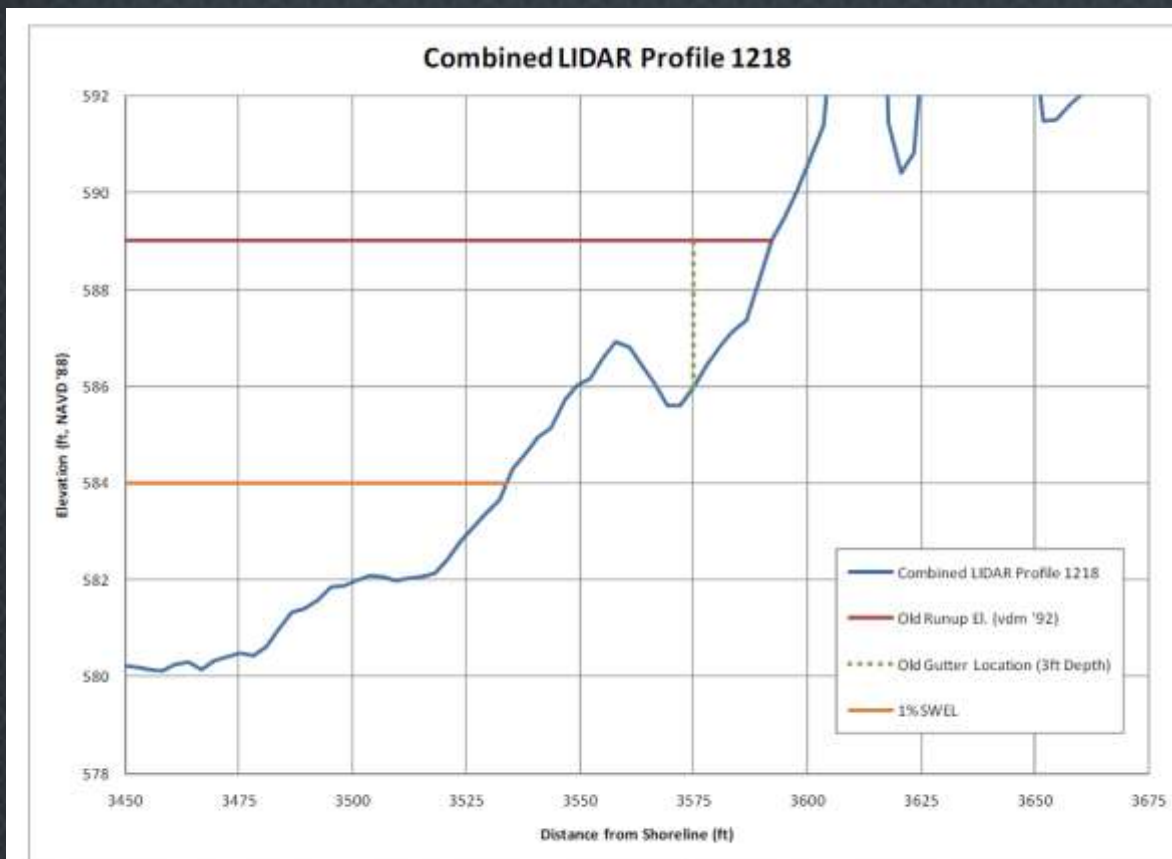


Figure 3.1 Combined High Resolution LIDAR Transect for 1218 in Sheboygan County with Runup

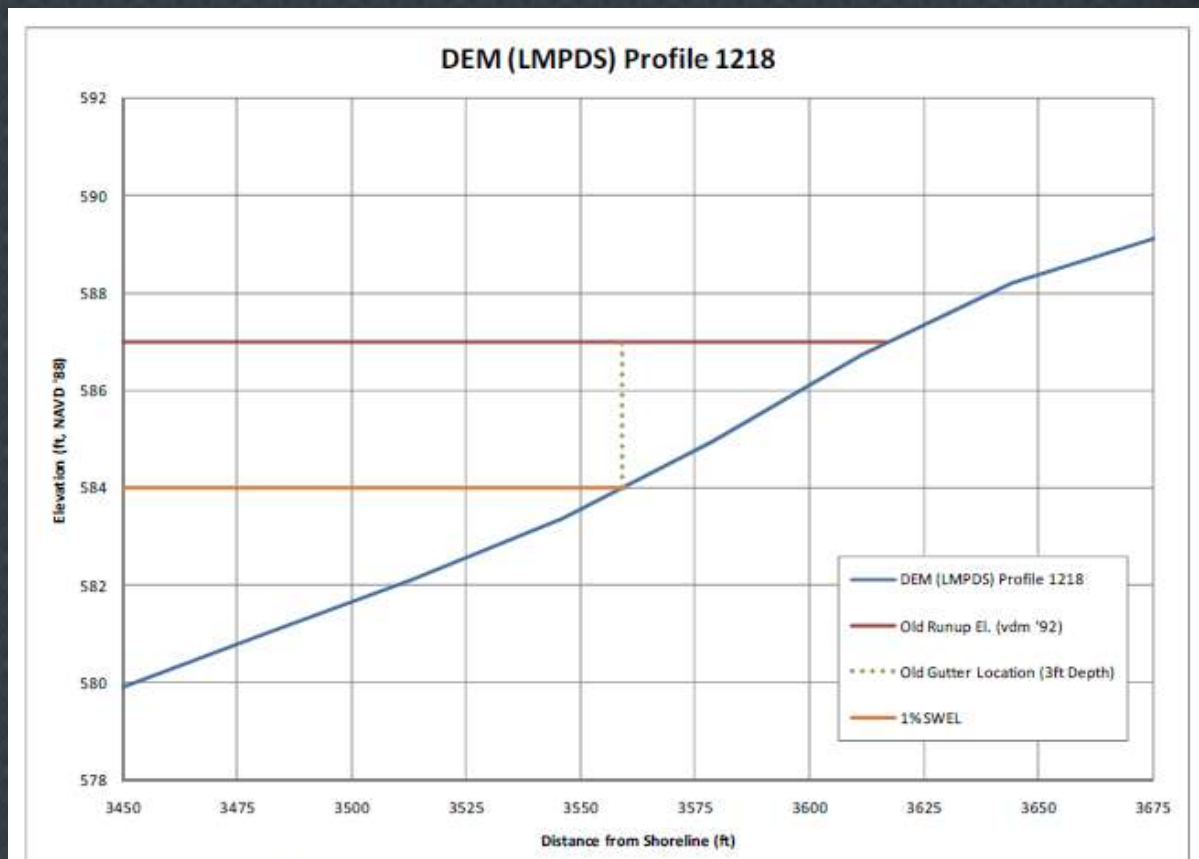
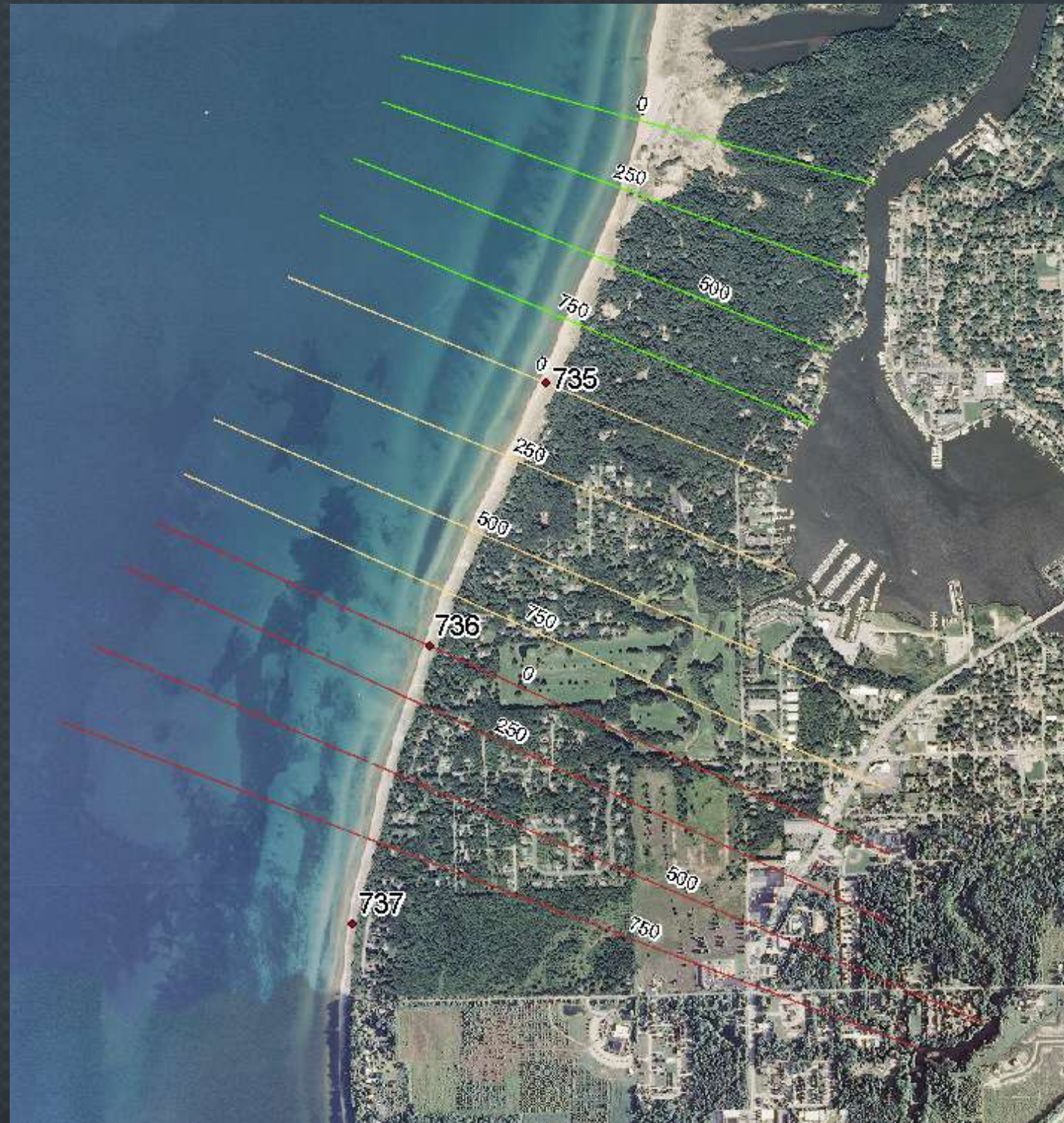


Figure 3.2 DEM/LMPDS Coarse Resolution Transect for 1218 in Sheboygan County with Runup



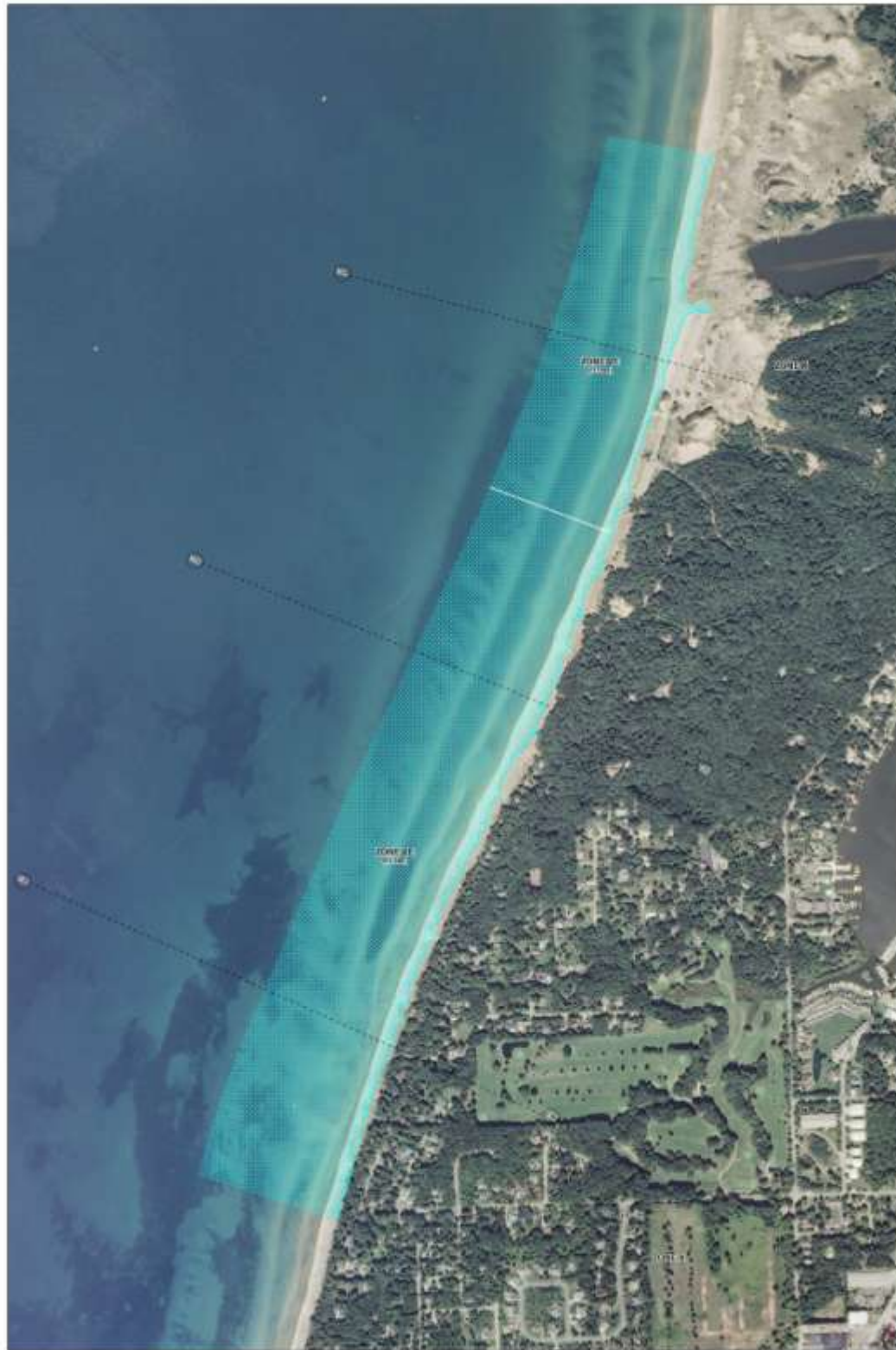
# Spacing Resolution (Alleghen)



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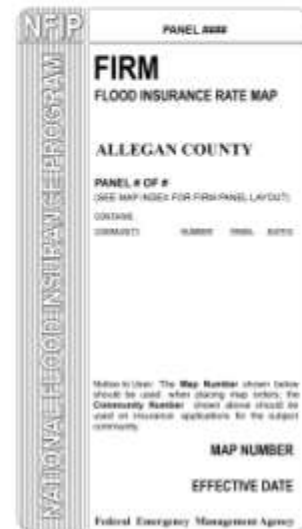
# SENSITIVITY ANALYSIS - FEW COASTAL TRANSECTS



# SENSITIVITY ANALYSIS - MANY COASTAL TRANSECTS

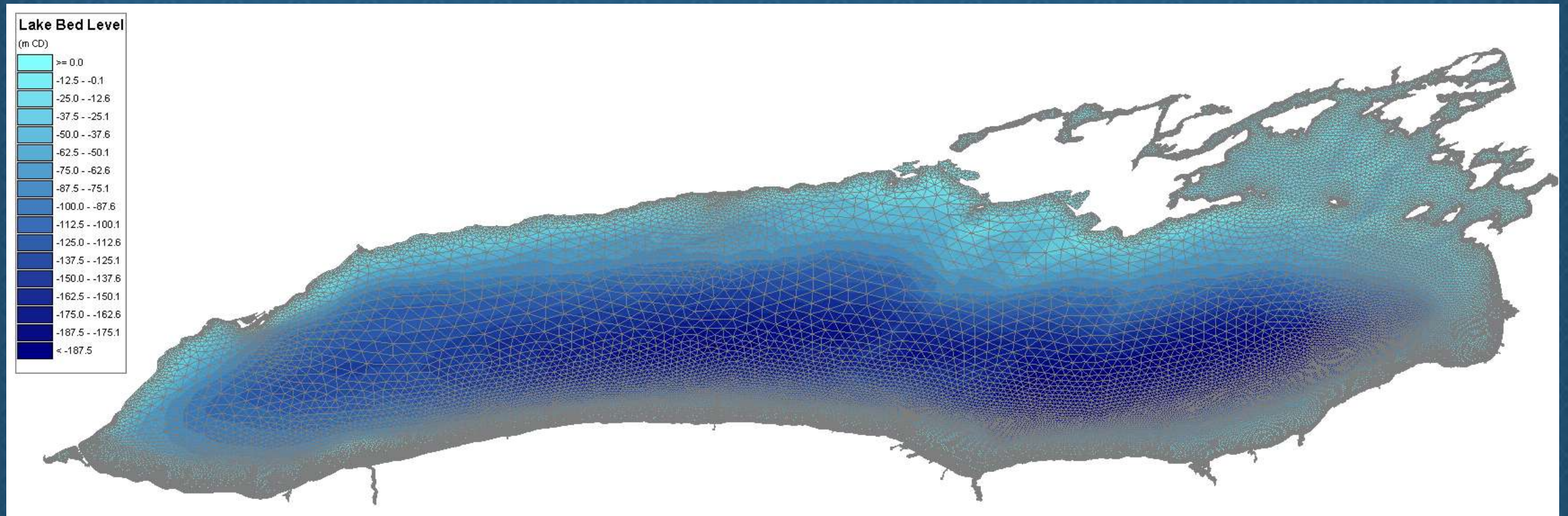


Reach	Runup Zone El. (ft)
734	589
734+250m	588
734+500m	587
734+750m	588
735	588
735+250m	587
735+500m	587
735+750m	587
736	588





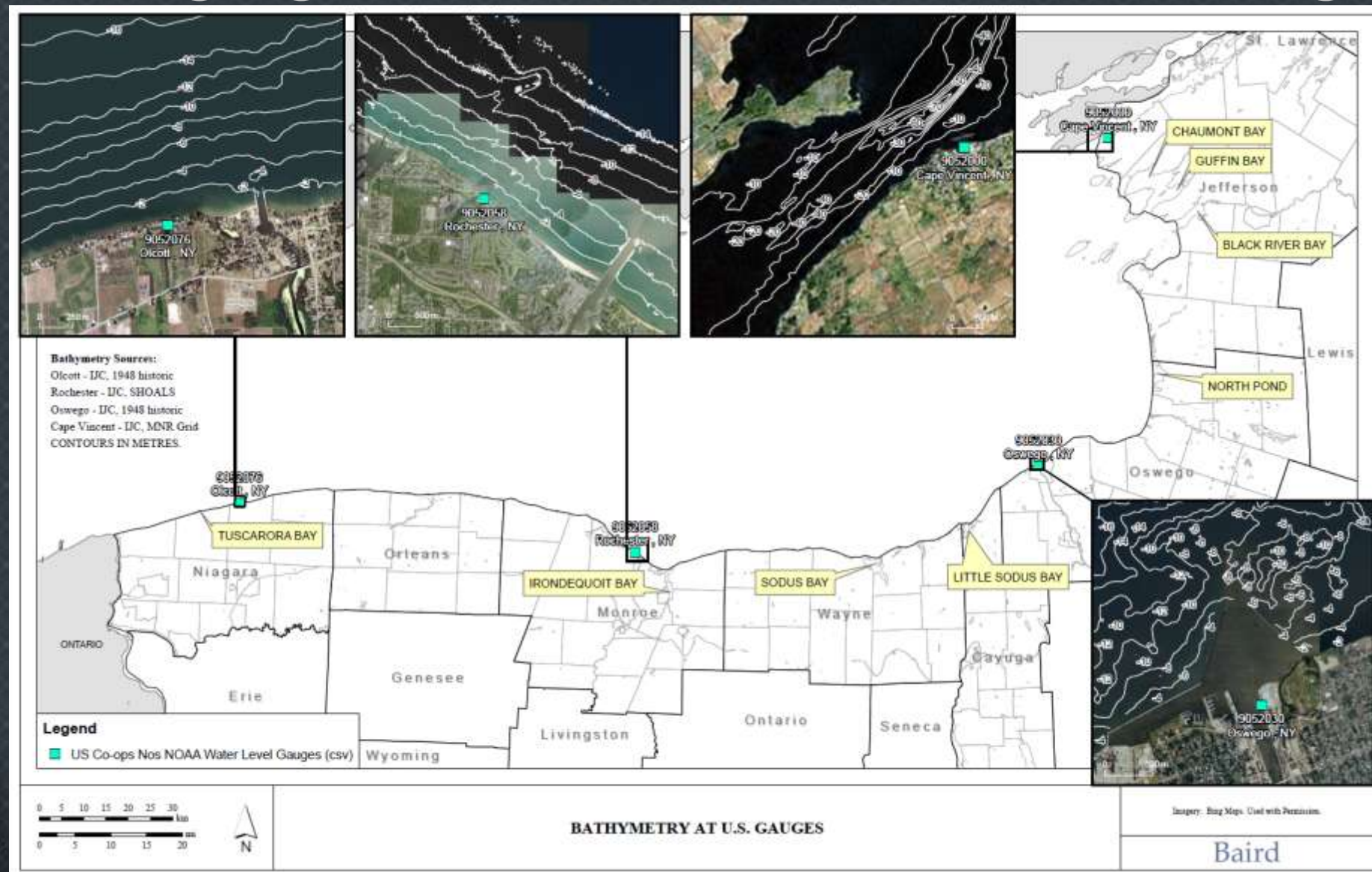
# IV – Lake Ontario Wave and Surge Modeling





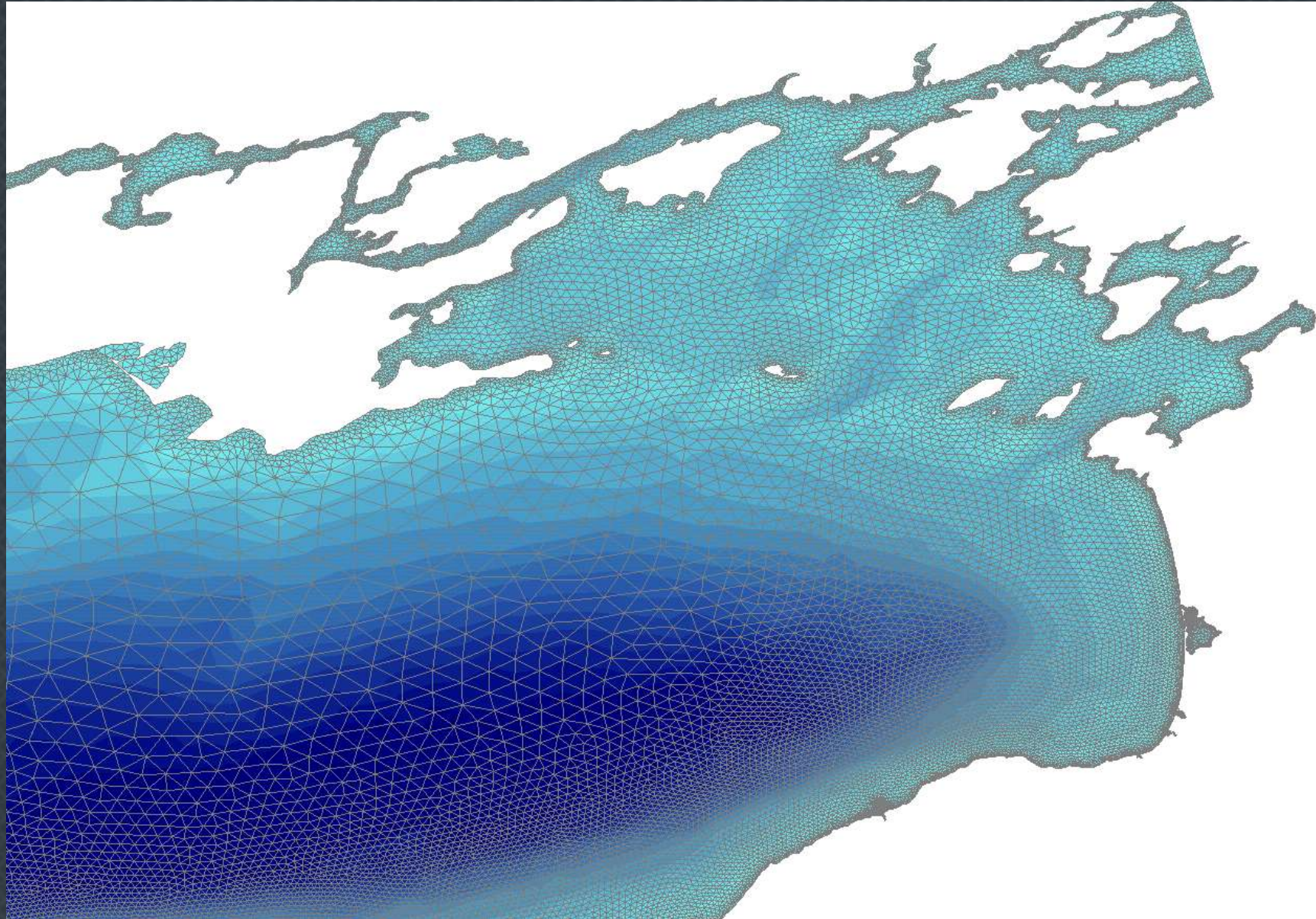
# ADCIRC – Storm Surge Model

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





# SWAN – Wave Model

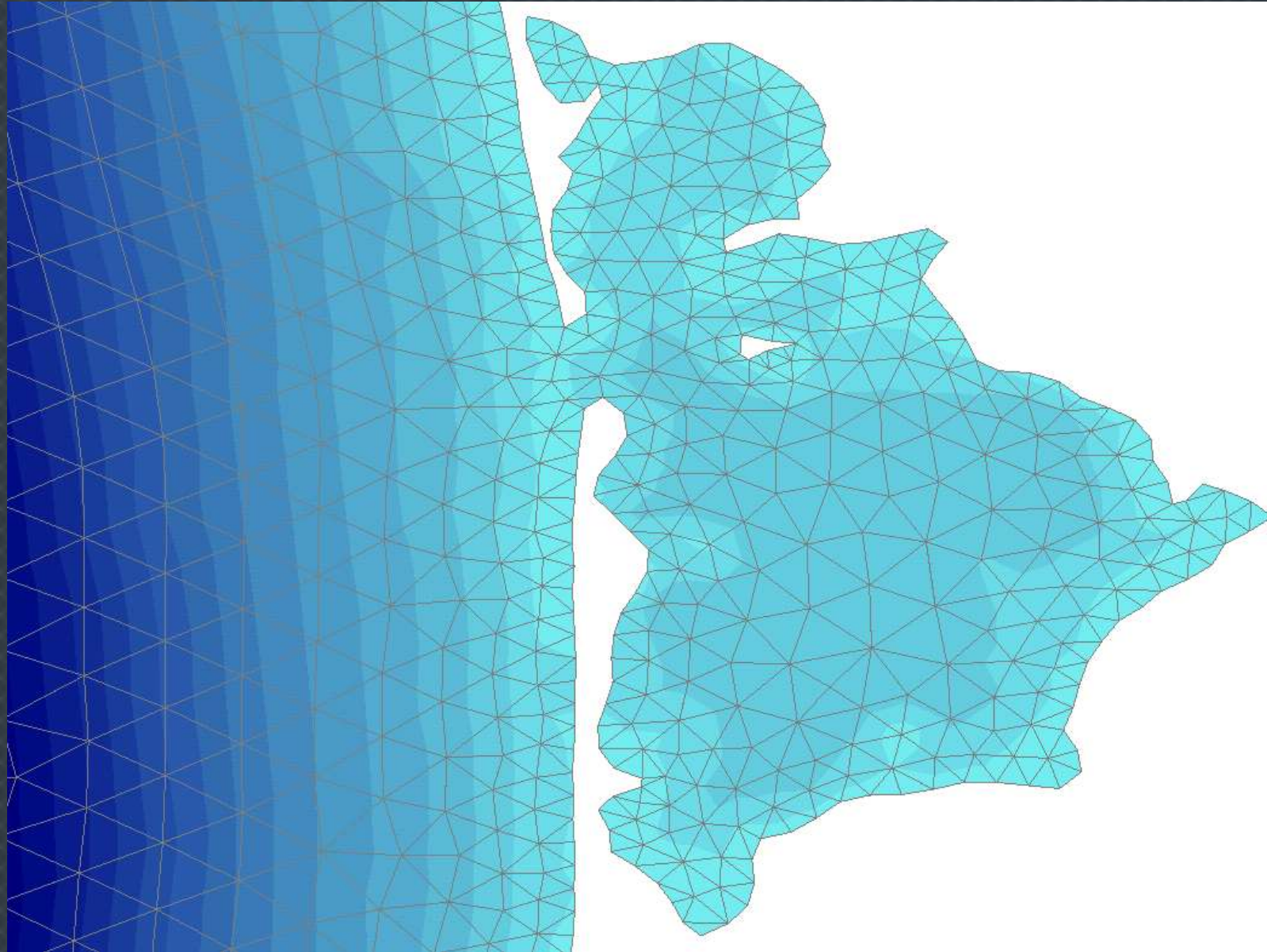


Eastern Lake Ontario

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# SWAN – Wave Model II

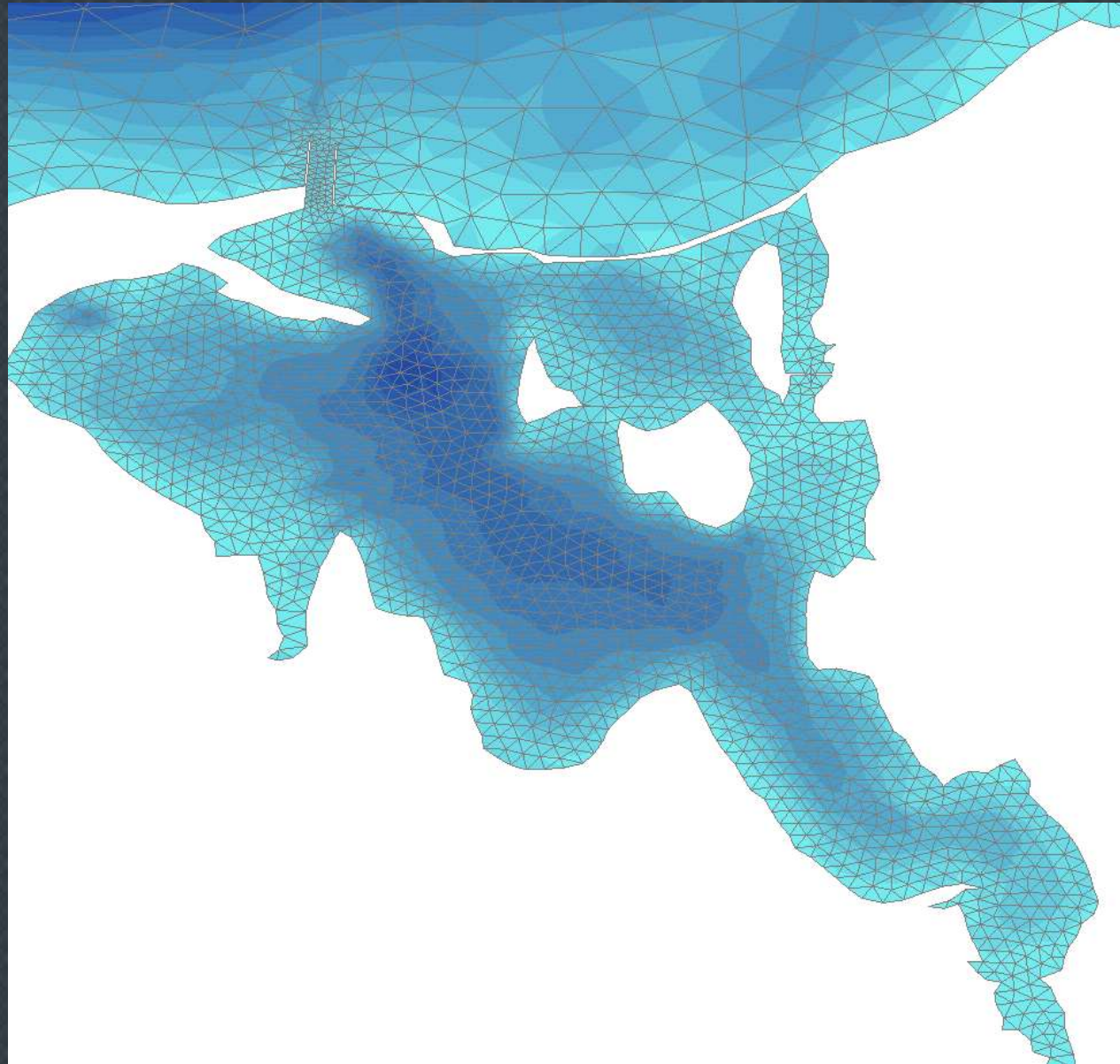


North Pond

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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!

