Great Lakes Flood Mapping Pilot Studies on Lake Michigan

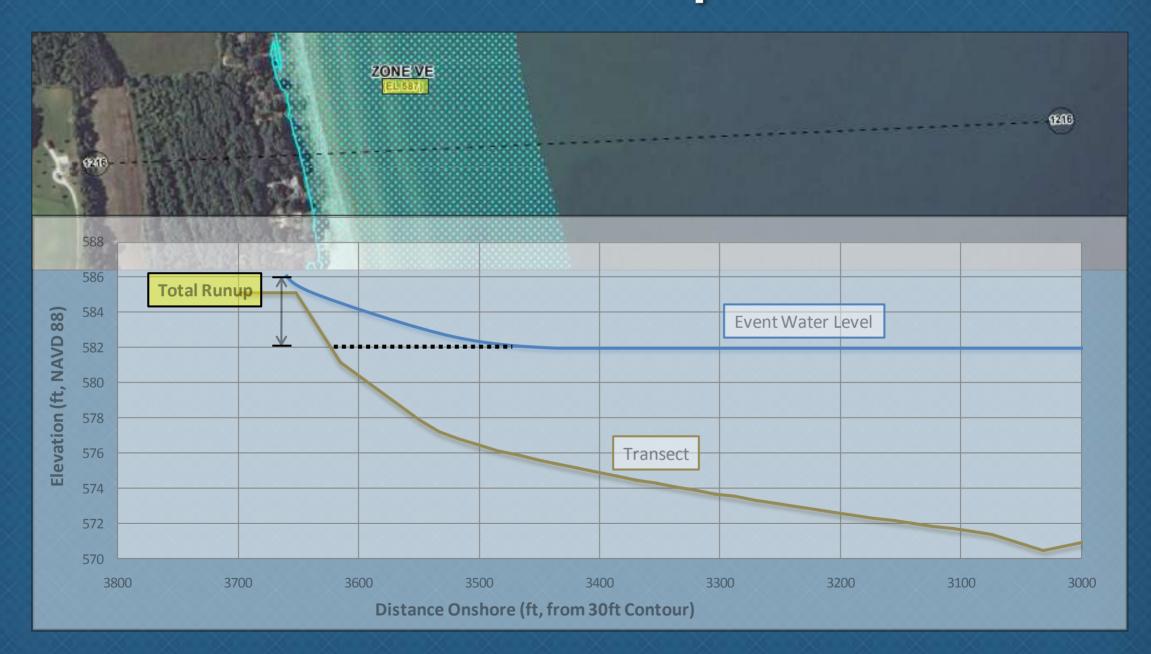
Josh Friedman 2011 NYSFSMA Conference April 28th, 2011

Baird OCEANS, LAKES & RIVERS. INNOVATION, EXCELLENCE & SERVICE.

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
- <u>Single</u> 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)

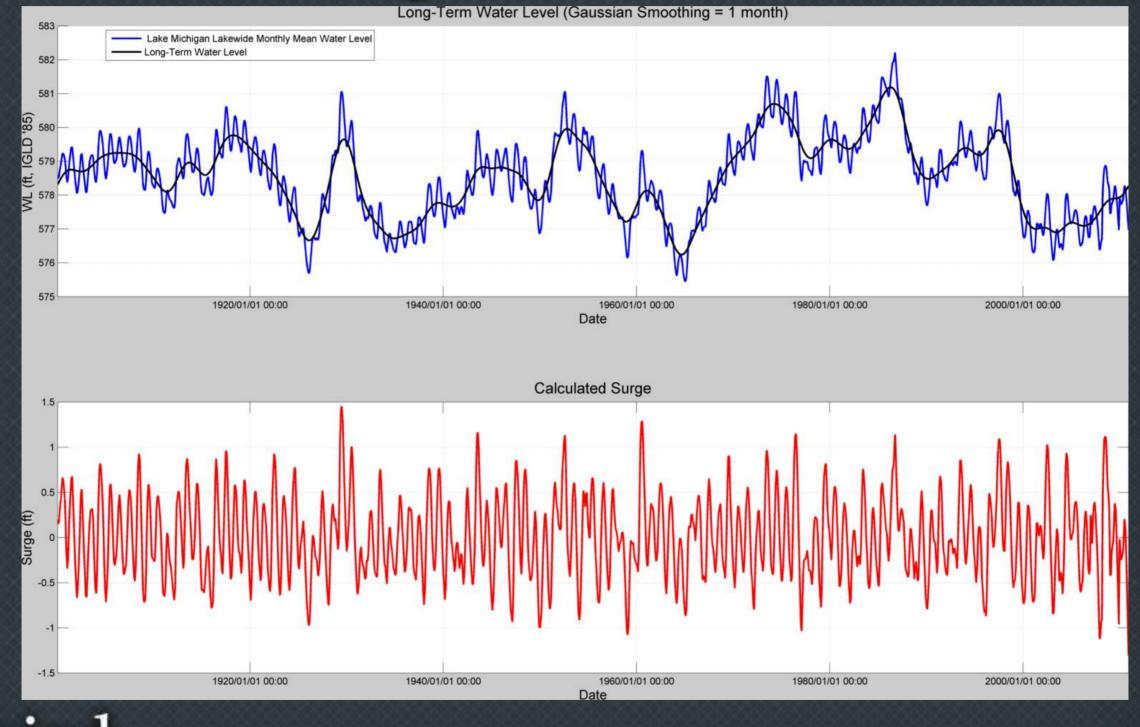
- Hourly wave data screened to select a group of severe events per year
 - Based on wind-wave hindcast
- One event from group selected per year to produce the largest runup value
- R_{2%} calculated for each event per year
 Combined runup with storm surge



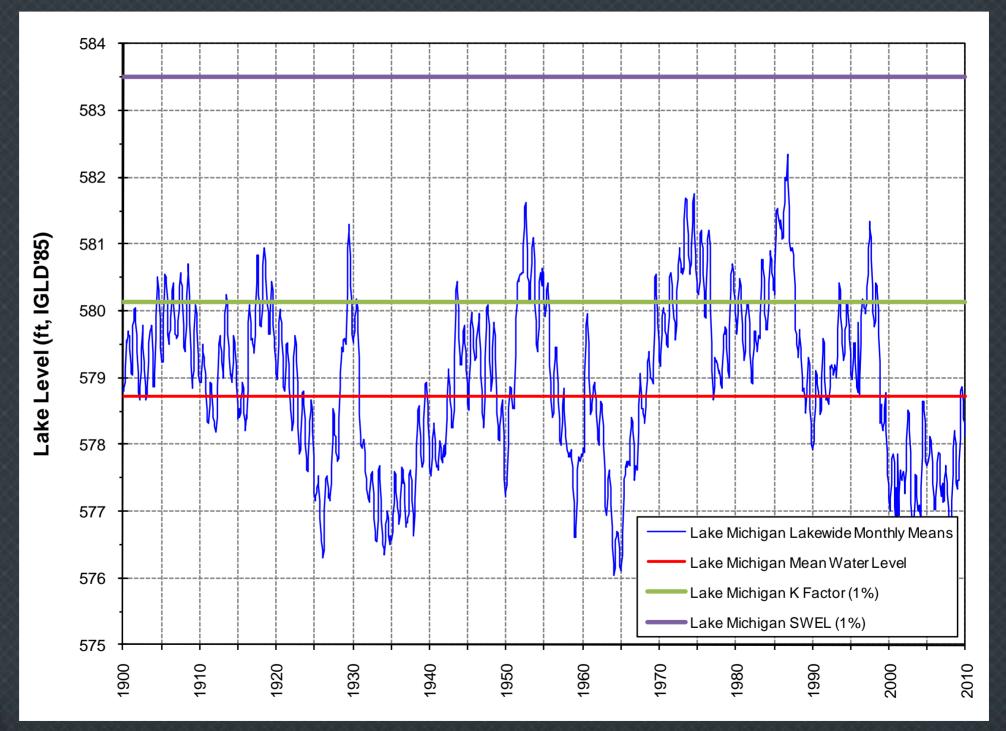
Response (continued)

- 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

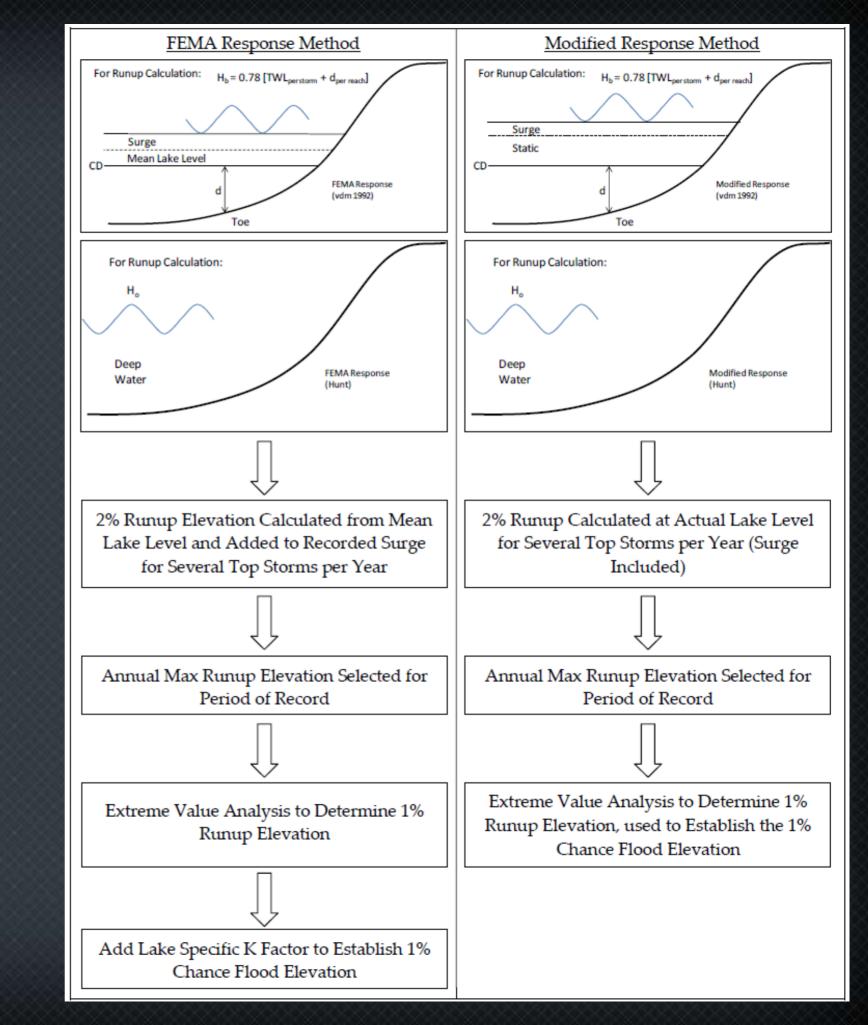
Lake Michigan Lake Levels



Lake Michigan Lake Levels



Modified Response



II – Sheboygan County Runup Results



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)

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
5	$R_{2\%}$ (Rounded) =	8	9	9	8
Wave Heights (ft)	3 -year H₀(depth limited)	-	5.4	121	-
W He (3-year H₀	13.9	≂	13.9	13.9
od (Tavg	129	7.9	-	-
Period (s)	T_{P}	9.8	-	9.8	9.8
WL (ft) above CD	SWEL1%	6.2	6.2	6.2	6.2
ope	mbeach (cot)	24.4	24.4	2 4 .4	24.4
Slo	mnearshore (cot)	-	111.1	-	-
Special Inputs	Runup Reduction Factors* (γr , γP, γb, γβ)	-	1,1,1,1	Э	-

*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

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

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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**

		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
ve ;hts :)	H _b	-	per storm		per storm
Wave Heights (ft)	Ho	per storm	-	per storm	-
eriod (s)	Tavg	-	per storm	5	per storm
Period (s)	$T_{\rm P}$	per storm	-	per storm	-
WL (ft)	Lake Adjustment Factor (K1%)	1.41	1.41	-	
M	Mean Lake Level	578.72	578.72		د جار
Slope	m _{beach} (cot)	24.4	24.4	24.4	24.4
outs	Actual Peak Water Level above CD			per storm	per storm
Inf	Actual Surge	per storm	per storm		
Special Inputs	Runup Reduction Factors (γr, γP, γb, γβ)	-	1, 1, 1, 1	<u>-</u> 2	1, 1, 1, 1

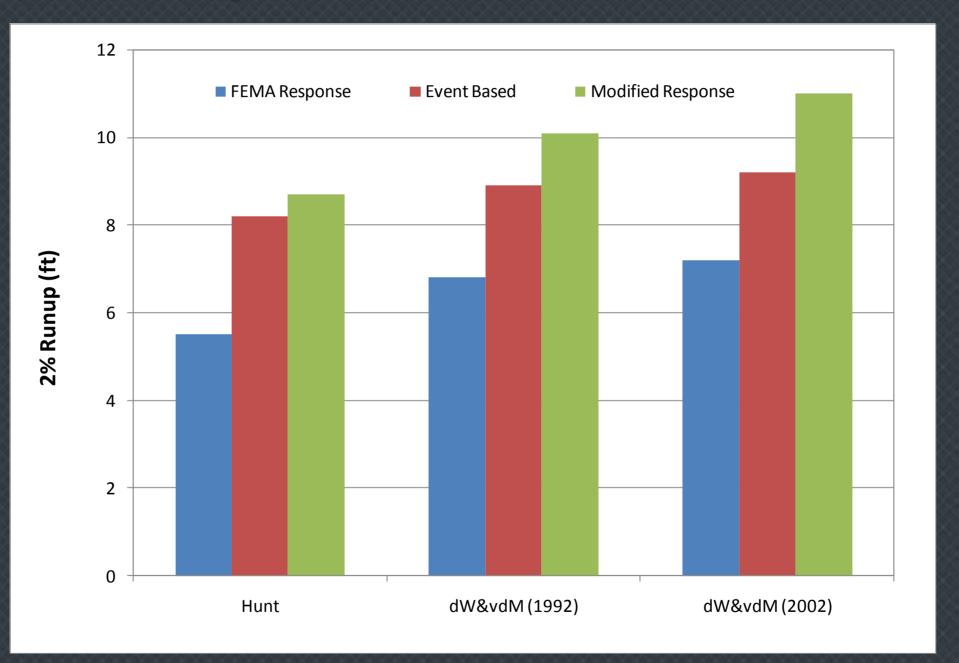
Table 1.5 Calculated 2% Runup for Response Based Method (Reach 1219)

Modified Response Approach

- Runup added to <u>actual peak lake level</u> 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 <u>actual</u> water level



Summary for Reach1219



	Mbeach (cot)	Hunt	: (1959)	van d	Vaal & er Meei 992)
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)

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

Median 1% Flood Level (NAVD '88)

586

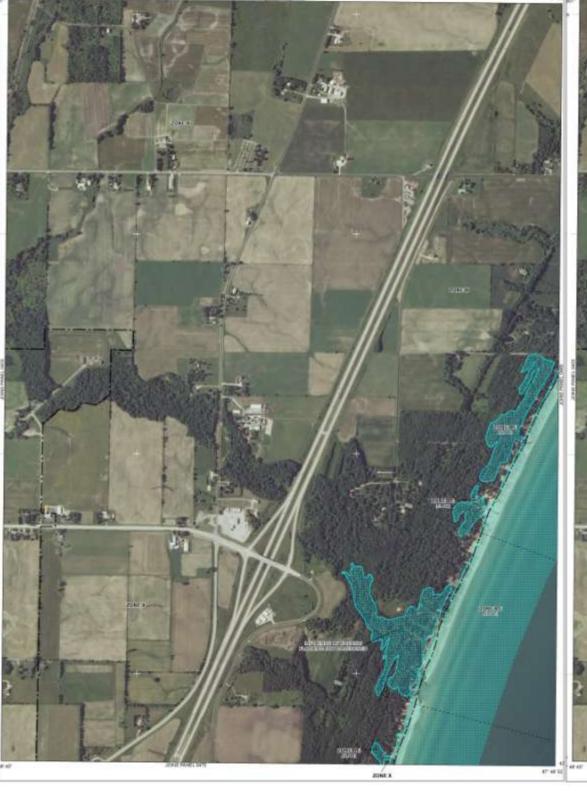
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Table 2.13 Summary of Proposed Methodology for Sheboygan County (1% Flood Level in Bold)

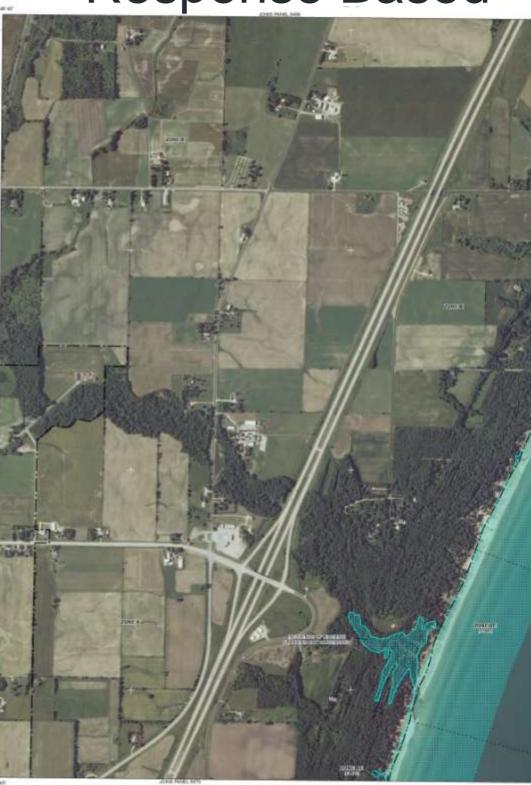
	Proposed Response Modified Resp Method Method		and the second	
	Hunt (1959)	de Waal & van der Meer (1992)	Hunt (1959)	de Waal & van der Meer (1992)
Reach 1215	585	<mark>586</mark>	586	587
Reach 1216	585	586	5 <mark>8</mark> 6	588
Reach 1217	586	587	587	589
Reach 1218	585	586	586	588
Reach 1219	585	586	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

Event Based

Response Based



Baird



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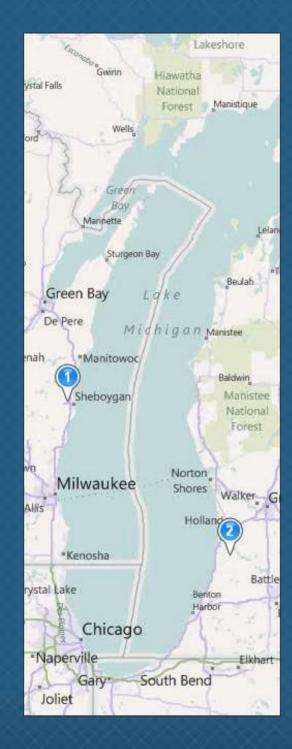
Event versus Response

- Event = SWEL_{1%} + R_{2%} = 583.5 + R_{2%}
- Response
- = Mean Lake Level + K + Surge + $R_{2\%}$ = 578.7 + 1.4 + Surge + $R_{2\%}$ 580.1 Baird

Summary

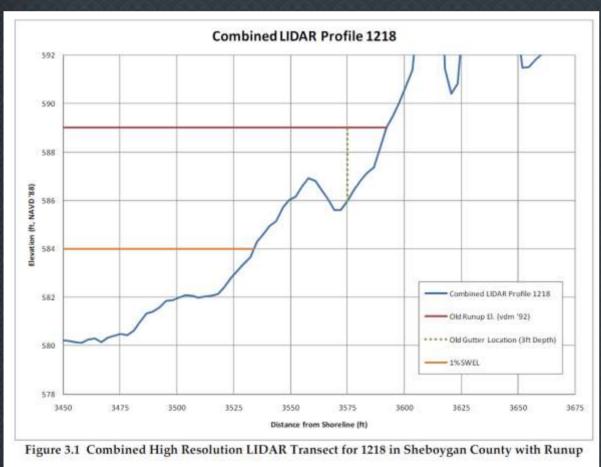
- Event produces results ~1 ft higher than the proposed Response Method
- Modified produces results ~1-2 ft higher than the proposed Response Method
- The Proposed Response Method may not be technically defensible
 - K factor, mean lake level
- Proposed < Event < Modified

III – Data Sensitivity Analysis

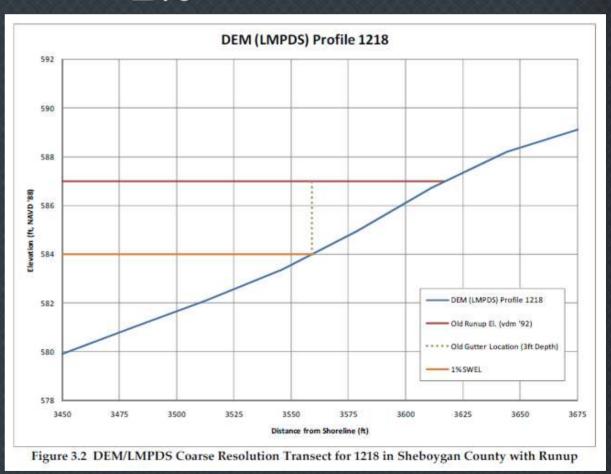


Transect Resolution (Sheboygan)

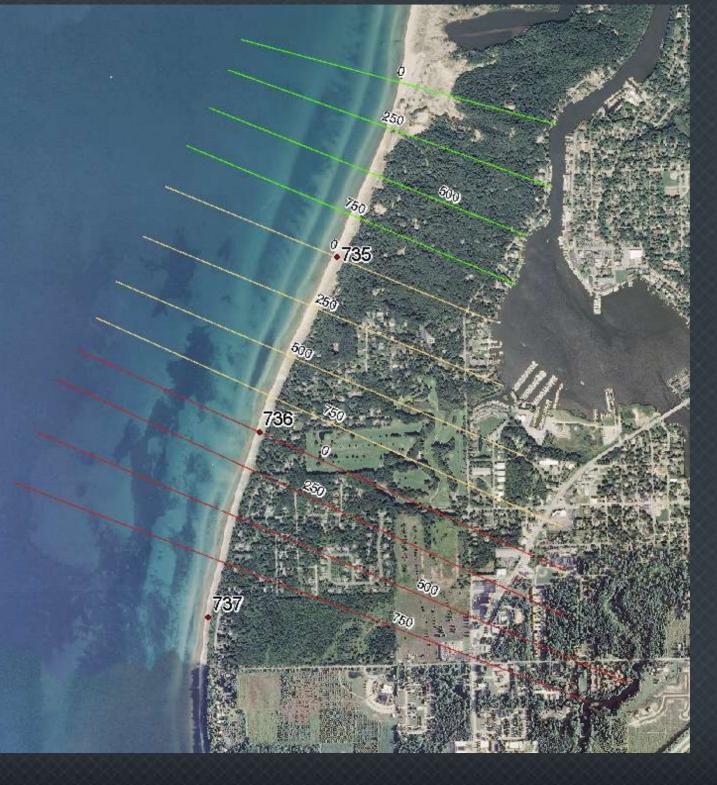
- High Resolution
- $R_{2\%} = 589 \text{ ft}$



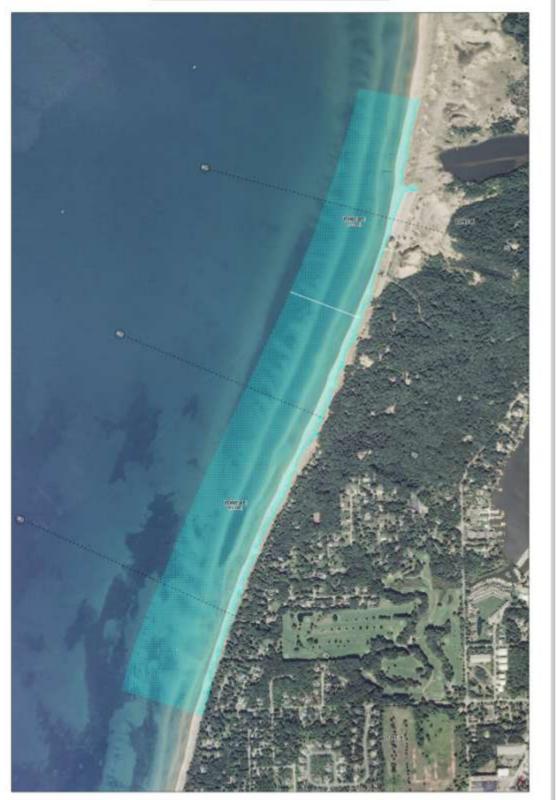
• Low Resolution • $R_{2\%} = 587 \text{ ft}$



Spacing Resolution (Allegan)



SENSITIVITY ANALYSIS - FEW COASTAL TRANSECTS



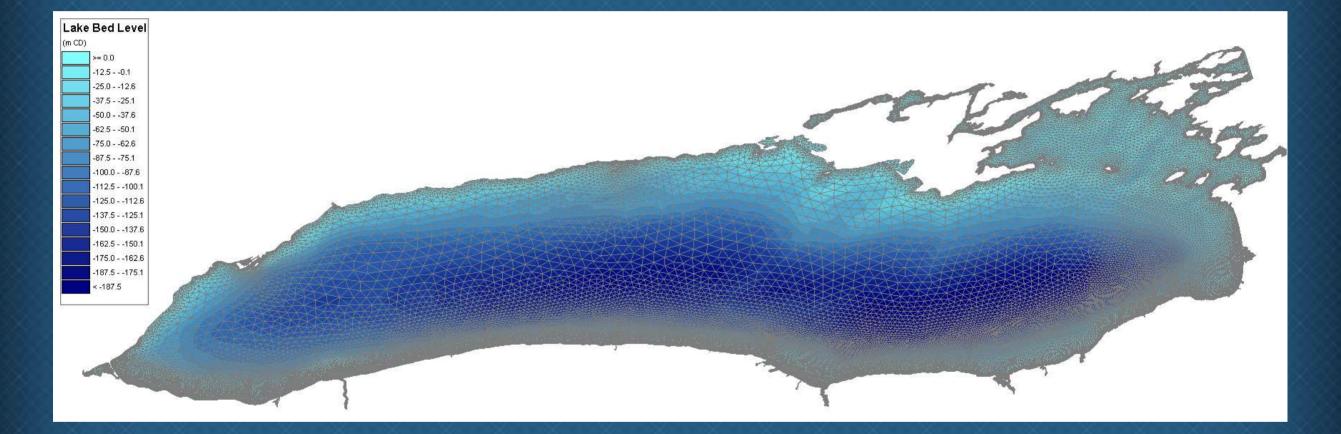
Baird

SENSITIVITY ANALYSIS	- MANY COASTAL TRANS	ECTS	-
	Reach	Runup Zone El. (ft)	
	734	589	
	734+250m 734+500m	588 587	
	734+300m 734+750m	588	
	735	588	
	735+250m	587	
The second se	735+500m	587	
	735+750m	587	
	736	588	

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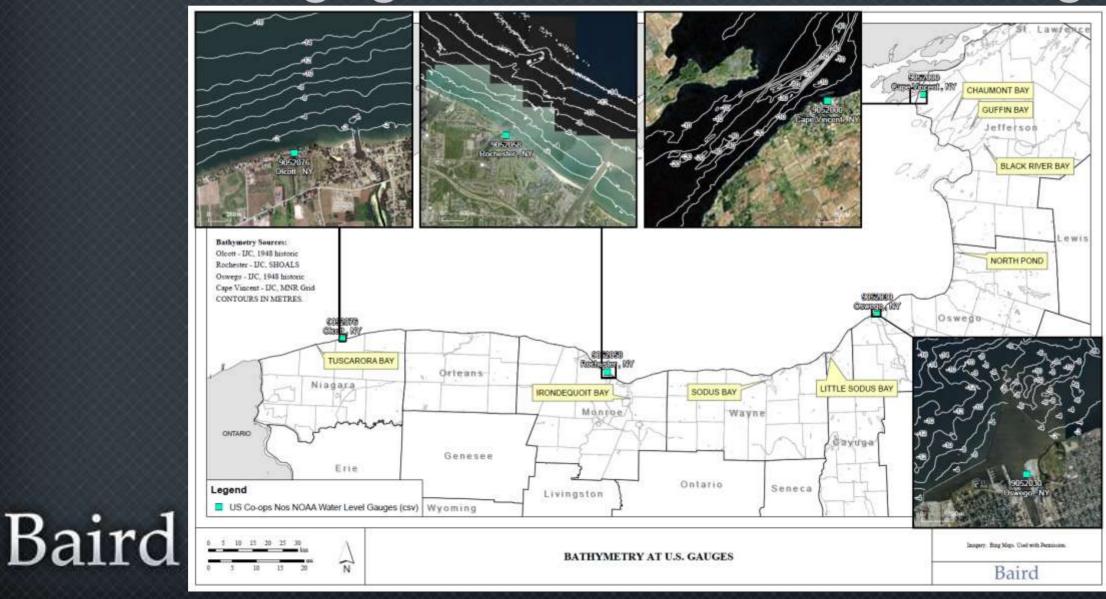
LEGEND

IV – Lake Ontario Wave and Surge Modeling

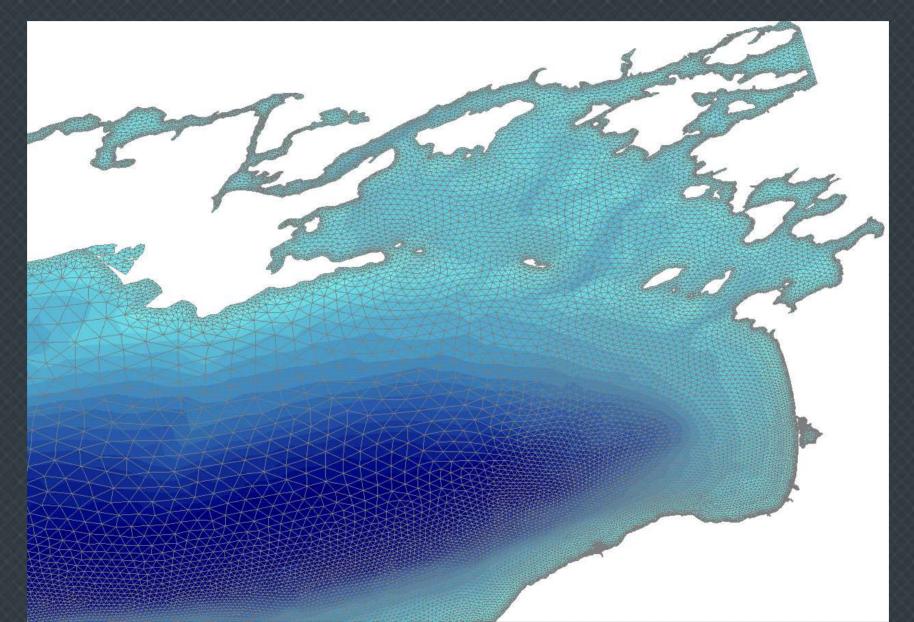


ADCIRC – Storm Surge Model

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



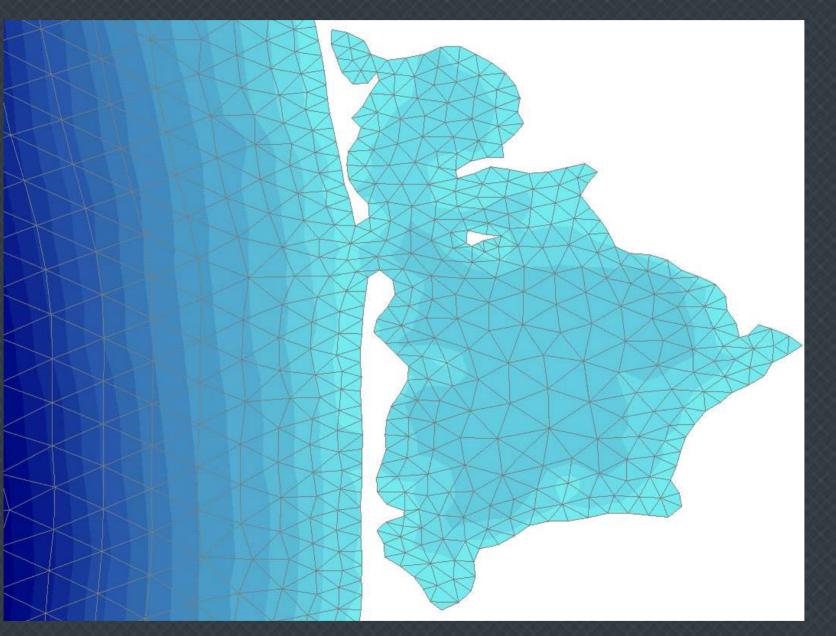
SWAN – Wave Model



Eastern Lake Ontario



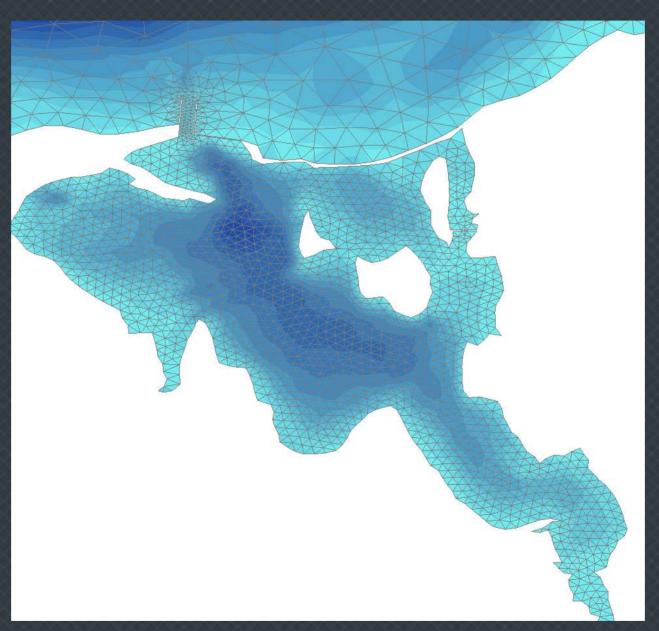
SWAN – Wave Model II



North Pond



SWAN – Wave Model III



Sodus Bay

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 <u>all grid</u> points
- Surge and wave height can then be used to estimate flooding for each coastal county



