ICCE 2018
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The State of the Art and Science of Coastal Engineering

Sediment Transport And Shoreline Response To Nearshore Placement Of Dredged Sediment In Southern Lake Michigan, USA

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COASTAL & HYDRAULICS LABORATORY

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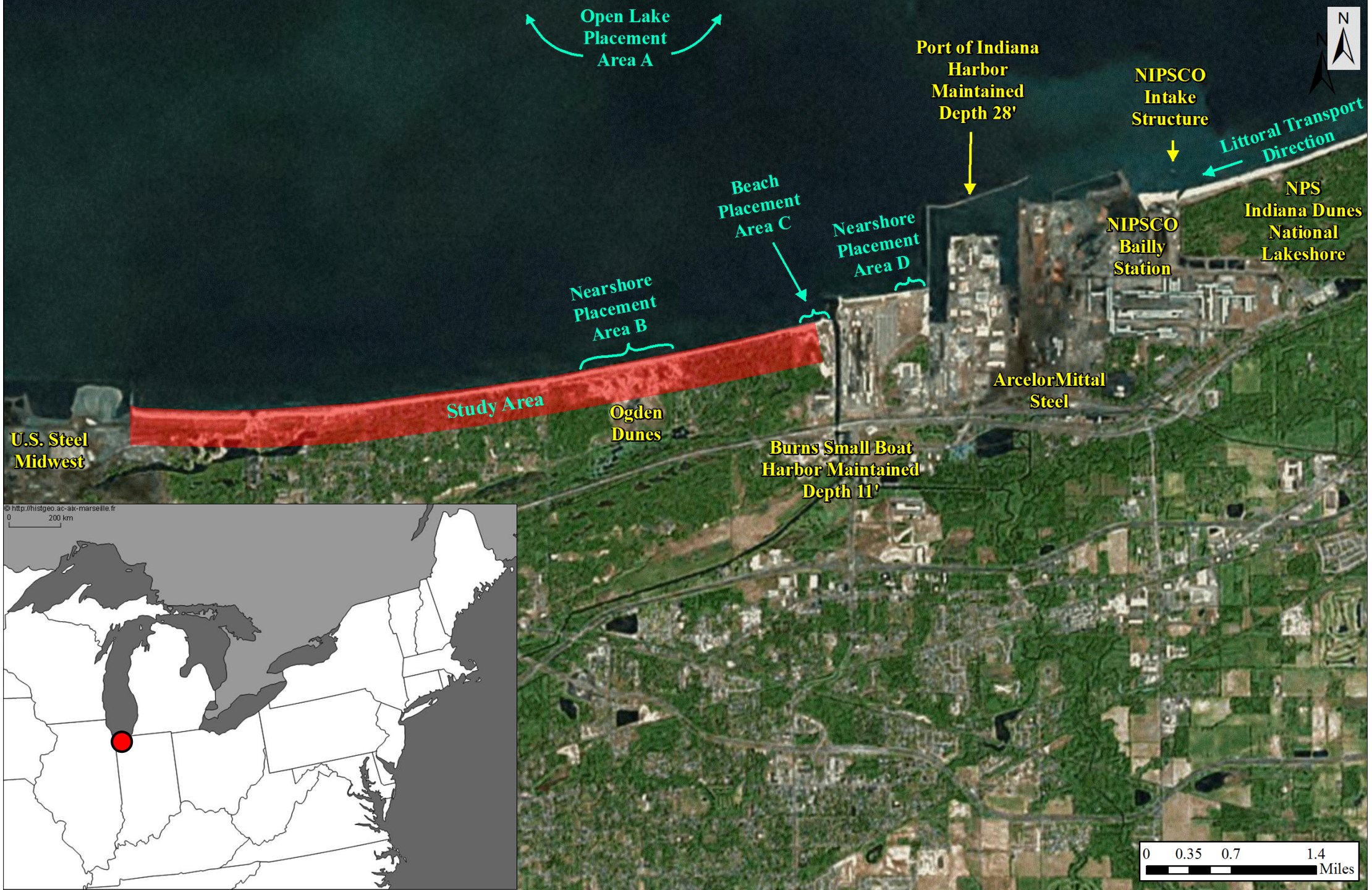
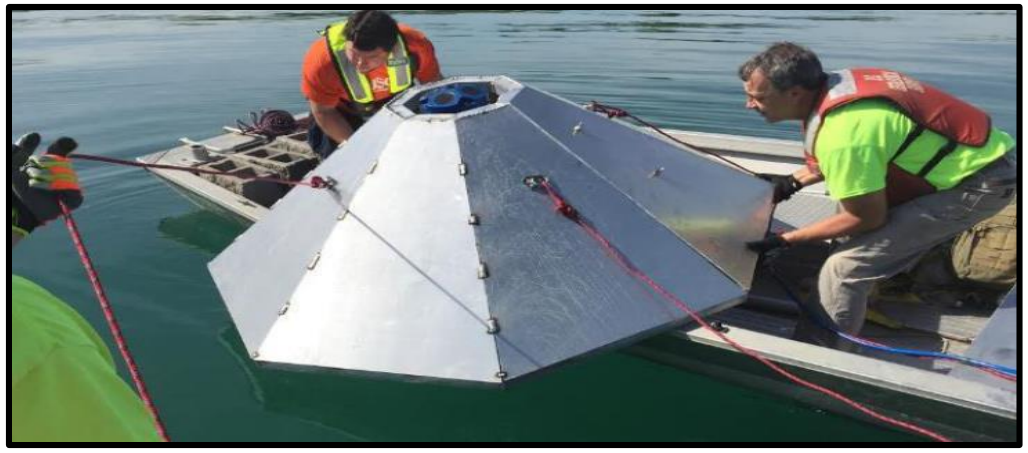

Open Lake Placement Area A
Port of Indiana Harbor Maintained Depth 28'
NIPSCO Intake Structure
Littoral Transport Direction
N
Beach Placement Area C
Nearshore Placement Area D
NIPSCO Bailly Station
NPS Indiana Dunes National Lakeshore
Nearshore Placement Area B
Study Area
ArcelorMittal Steel
Ogden Dunes
U.S. Steel Midwest
Burns Small Boat Harbor Maintained Depth 11'
© http://histgeo.ac-aix-marseille.fr
0 200 km
0 0.35 0.7 1.4
Miles

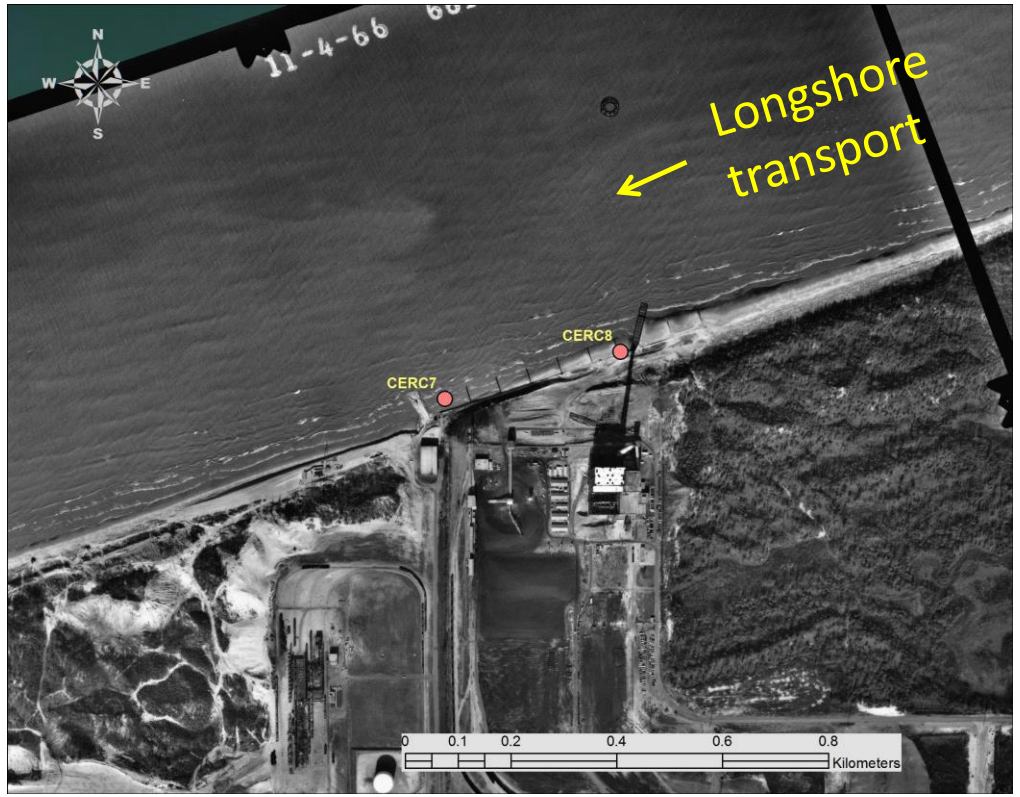
Shoreline Investigation

- Historical Analysis
  - Aerial Imagery Analysis
  - Nourishment Records
  - Wave Hindcasts
- Project Monitoring
- Numerical Modeling
  - Sediment Mobility Tool
  - Coastal Modeling System



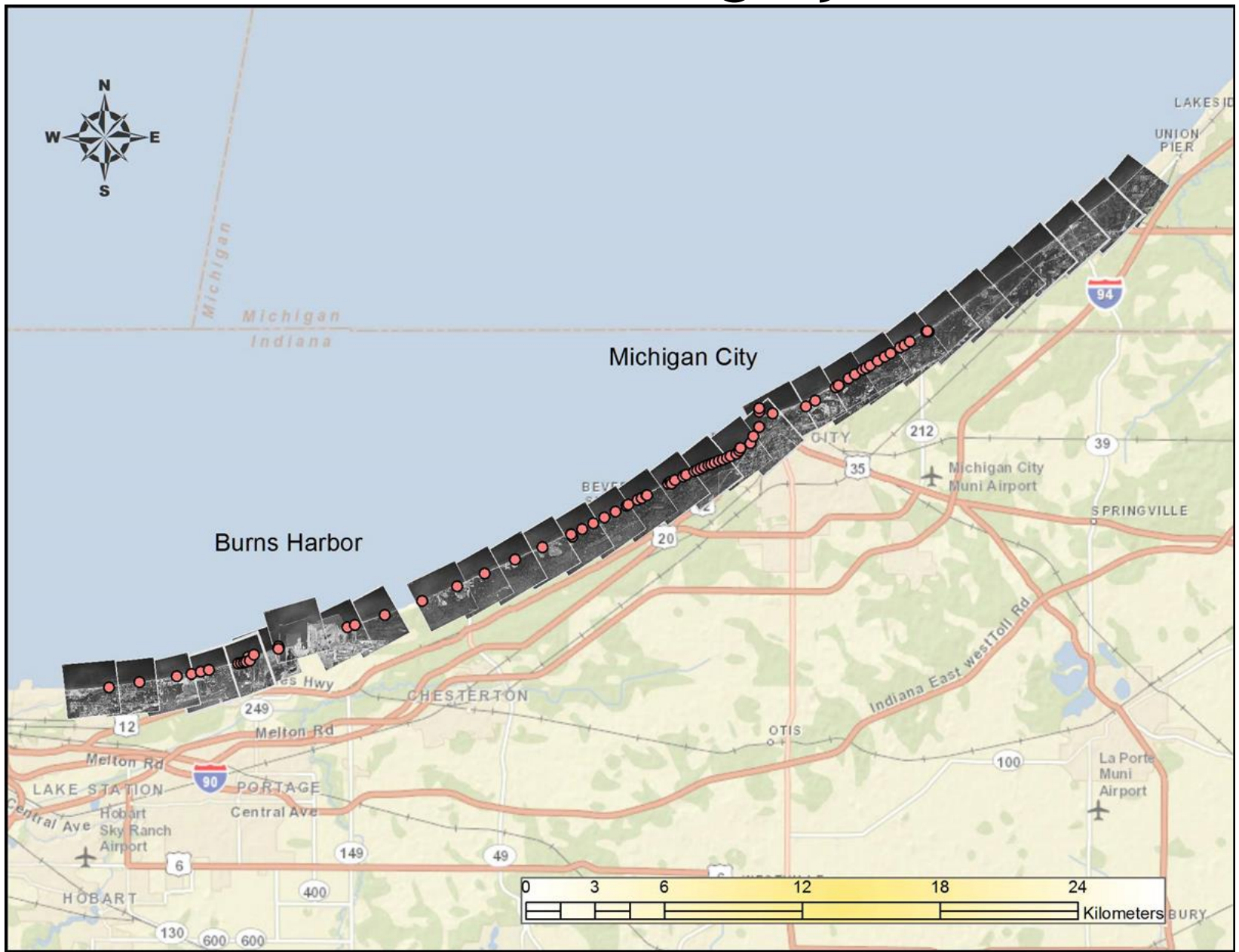
Historical Analysis

- Aerial Imagery
  - 1969, 1973, 1998, 2005, 2010, 2012, 2014
- USGS Digital Shoreline Analysis System (DSAS)
  - Cross-shore transects every 50 m
- Water Level – Calumet Harbor, IL
- Shore slope from USDA's Geospatial Data Gateway - LiDAR Bare Earth DEM



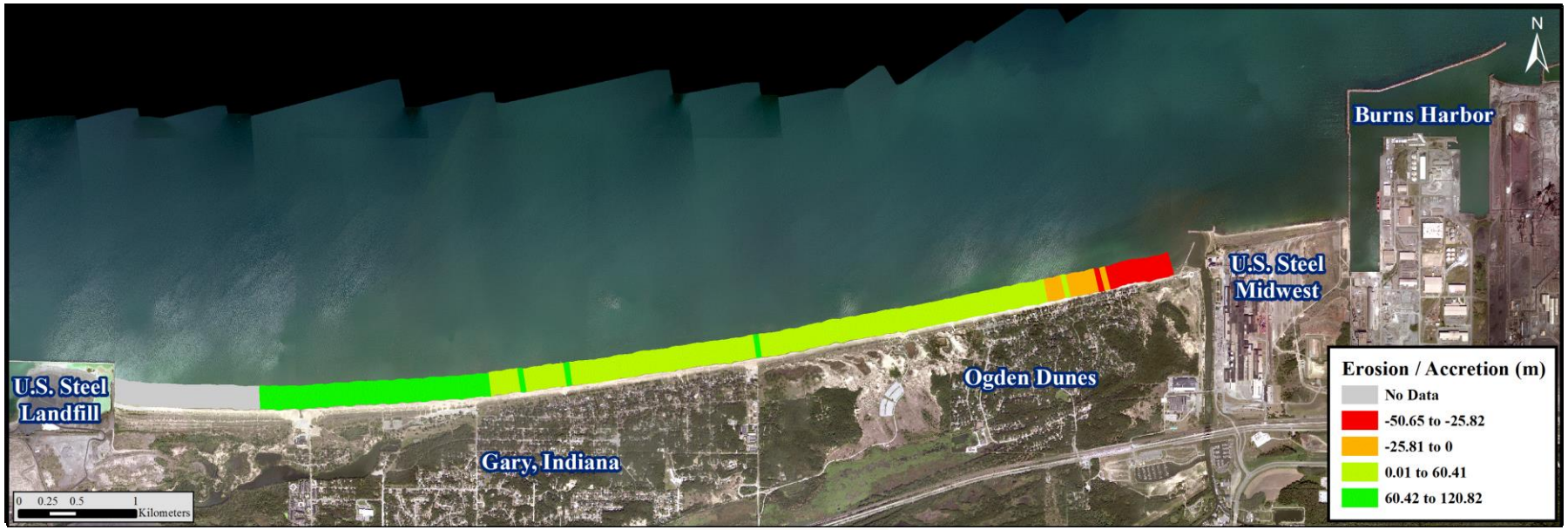
Arnold et al. (2018)

Aerial Imagery



Historical Analysis

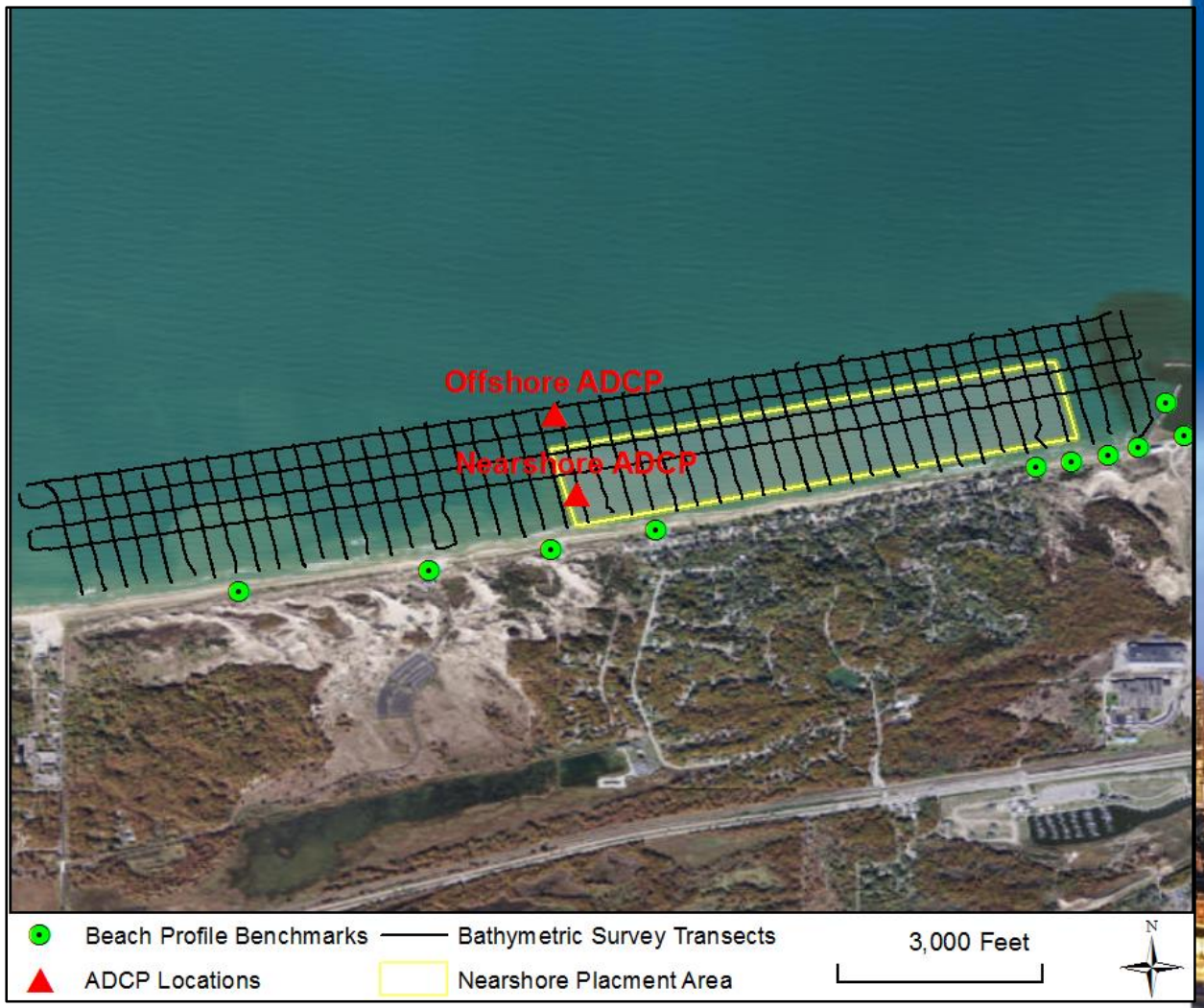
Date Range	Erosion/Accretion Average (m)	Material Placed – Beach & Nearshore (m^3)
1969 to 1973	-2.57	-
1973 to 1998	10.88	717k
1998 to 2005	42.34	204k
2005 to 2010	6.83	422k
2010 to 2012	2.09	-
2012 to 2014	-0.92	104k
1969 to 2014	45.37	1.5M



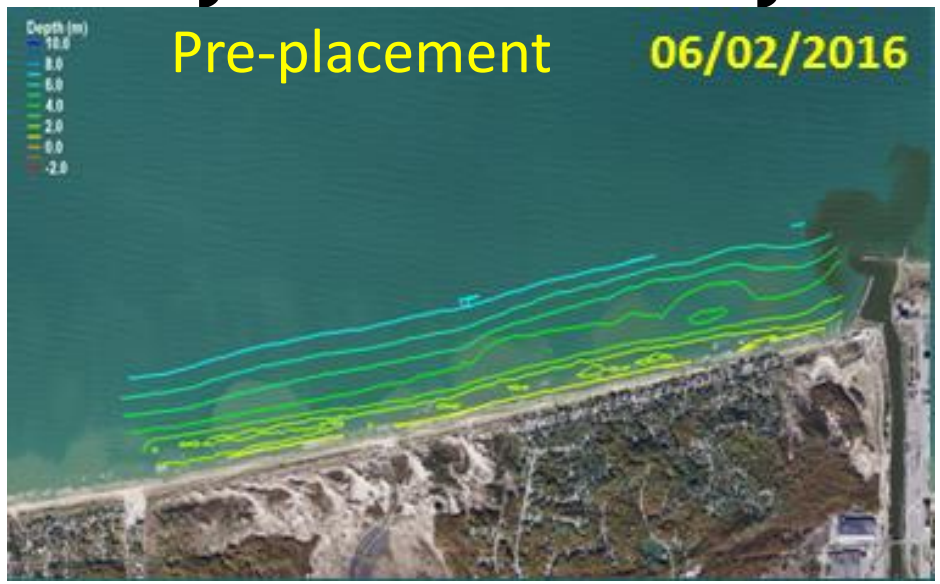
1969-2014

Monitoring

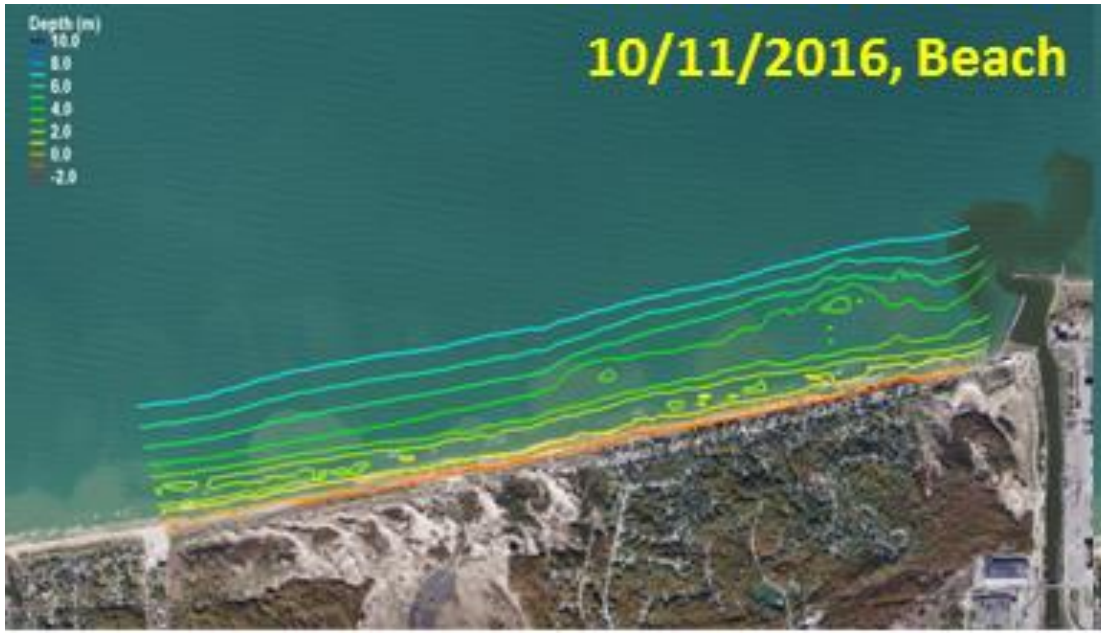
- July 2016
- 107,000 m^3 of Dredged Sediment
- Placed 5.5 m depth
- 2 ADCP's
- 3 Surveys
  - Pre-placement
  - Post Placement
  - ~1 month after Post Placement
    (before lake freezes over)
- USGS – Indiana, Illinois, & Kentucky Water Science Centers

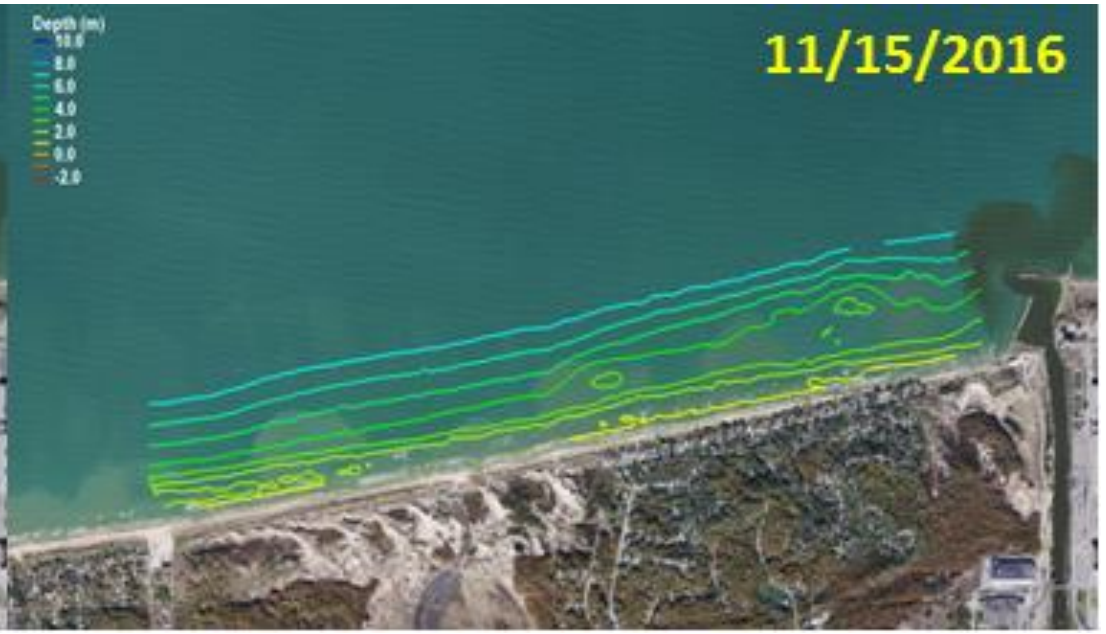


Bathymetric Surveys



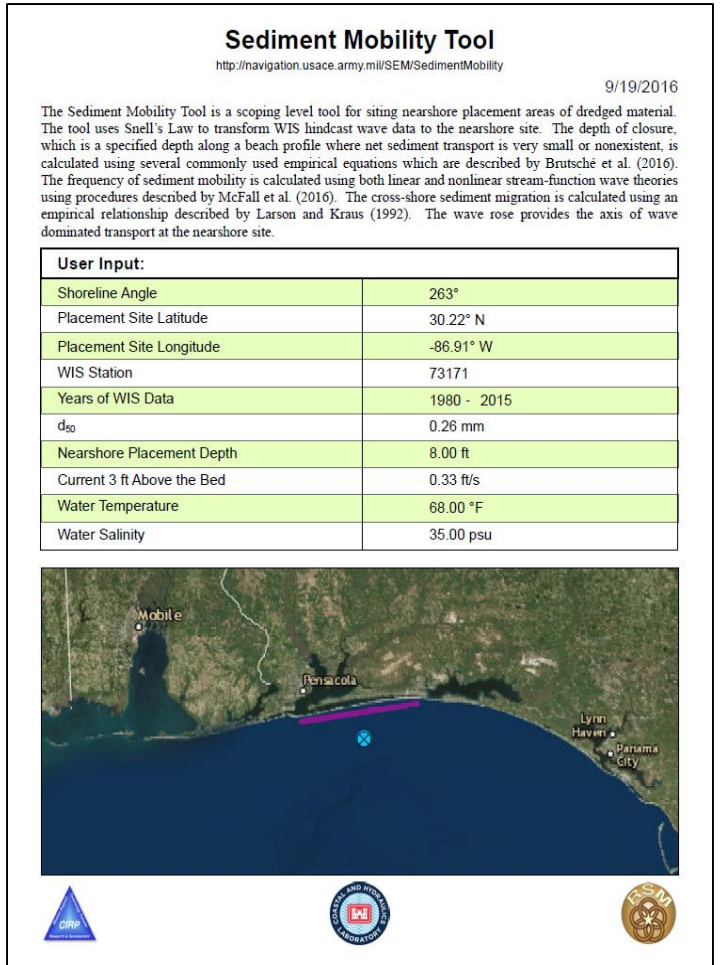
Post-placement:





Modeling

- Sediment Mobility Tool
- Coastal Modeling System (CMS) Wave and Flow



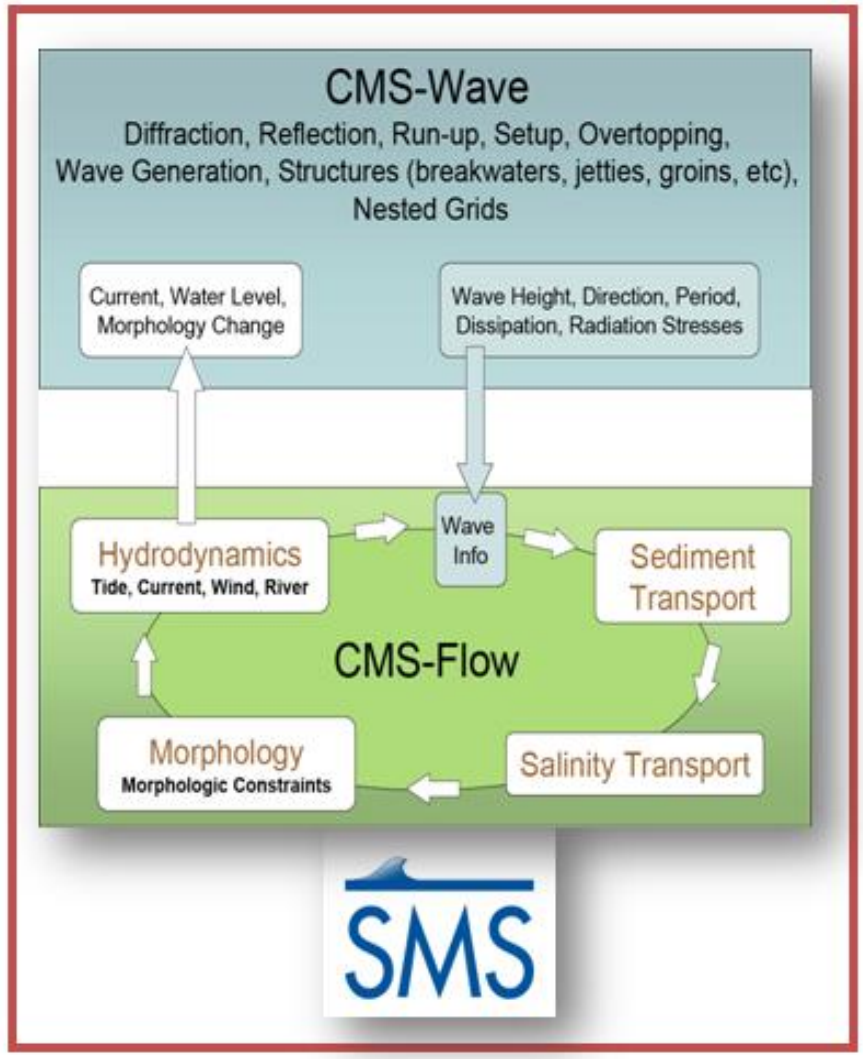
Sediment Mobility Tool

http://navigation.usace.army.mil/SEM/SedimentMobility

9/19/2016

The Sediment Mobility Tool is a scoping level tool for siting nearshore placement areas of dredged material. The tool uses Snell's Law to transform WIS hindcast wave data to the nearshore site. The depth of closure, which is a specified depth along a beach profile where net sediment transport is very small or nonexistent, is calculated using several commonly used empirical equations which are described by Brutsché et al. (2016). The frequency of sediment mobility is calculated using both linear and nonlinear stream-function wave theories using procedures described by McFall et al. (2016). The cross-shore sediment migration is calculated using an empirical relationship described by Larson and Kraus (1992). The wave rose provides the axis of wave dominated transport at the nearshore site.

User Input:	
Shoreline Angle	263°
Placement Site Latitude	30.22° N
Placement Site Longitude	-86.91° W
WIS Station	73171
Years of WIS Data	1980 - 2015
d_{50}	0.26 mm
Nearshore Placement Depth	8.00 ft
Current 3 ft Above the Bed	0.33 ft/s
Water Temperature	68.00 °F
Water Salinity	35.00 psu



Sediment Mobility Tool Background

- Answers:
  - Will the Sediment Placed in the Nearshore Move?
  - Where Is Sediment Likely To Go?
- Ideal for:
  - Preliminary Siting of a Nearshore Placement Projects
  - Small Projects That Don't Warrant a Full Numerical Model
- Maximizes use of readily available data
- Developed into a Web App

http://navigation.usace.army.mil/SEM/SedimentMobility

McFall et al. (2016)

Sediment Mobility Tool Background

- Frequency of Mobility:
  - Linear Wave Theory (Bed Shear Stress)

$$\tau_{cr} = \theta_{cr}\, g\, (\rho_s - \rho)\, d_{50} \qquad \tau_m = \tau_c \left[1 + 1.2 \left(\frac{\tau_w}{\tau_c + \tau_w}\right)^{3.2}\right]$$

$$\tau_{max} = [(\tau_m + \tau_w \cos\phi)^2 + (\tau_w \sin\phi)^2]^{1/2}$$

  - Stream Function Wave Theory (Near-bed Velocity)

$$u_{cr} = \sqrt{8\, g\, \gamma\, d_{50}} \qquad d_{50} \leq 2.0\ mm$$

$$u_{\max\, crest} = \left(\frac{H}{T}\right)\left(\frac{h}{L_o}\right)^{-0.579} \exp\left[0.289 - 0.491\left(\frac{H}{h}\right) - 2.97\left(\frac{h}{L_o}\right)\right]$$

http://navigation.usace.army.mil/SEM/SedimentMobility

McFall et al. (2016)

Sediment Mobility Tool Analysis

- WIS Station 94001
  - All Waves: 1976-2014
- d_{50} = 0.15 mm
- Depth = 5.5 m (18 ft)
- Estimated longshore current: 0.05 m/s

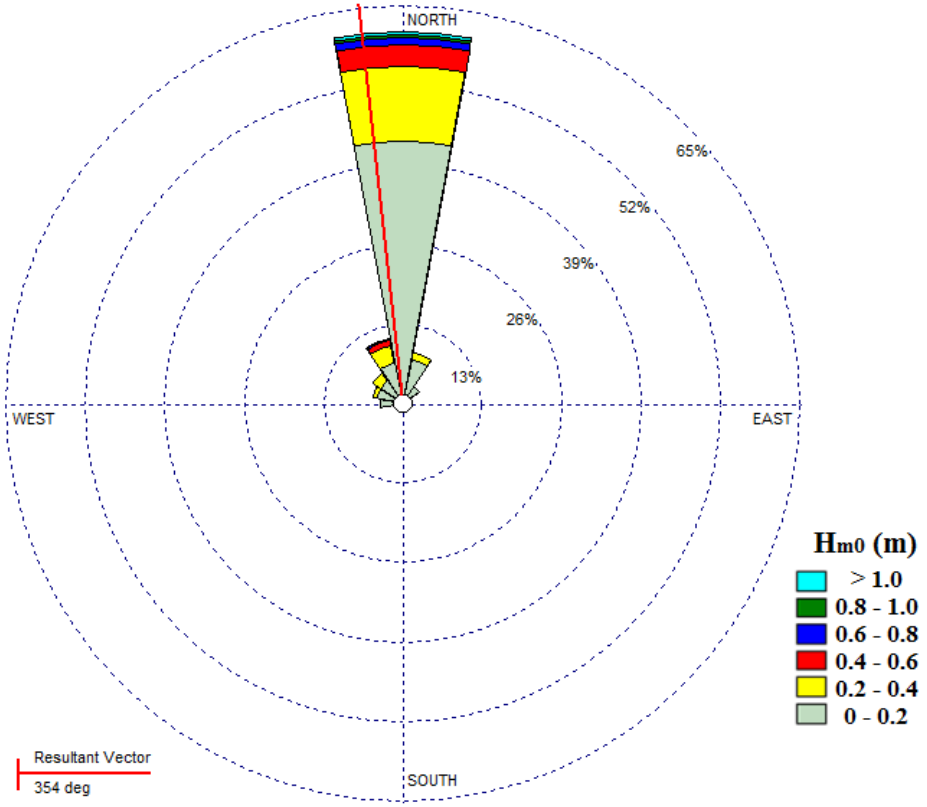
http://navigation.usace.army.mil/SEM/SedimentMobility

McFall et al. (2016)

Sediment Mobility Tool Analysis

d_{50} (mm)	All Waves (1976-2014)	
	Frequency of Mobilization	**Sediment Migration**
0.1	41 - 54%	68% Onshore
0.15	**37 - 48%**	**91% Onshore**
0.2	34 - 44%	97% Onshore
0.3	30 - 38%	99% Onshore

During Monitoring Period		
0.15	**37 - 48%**	**64% Onshore**



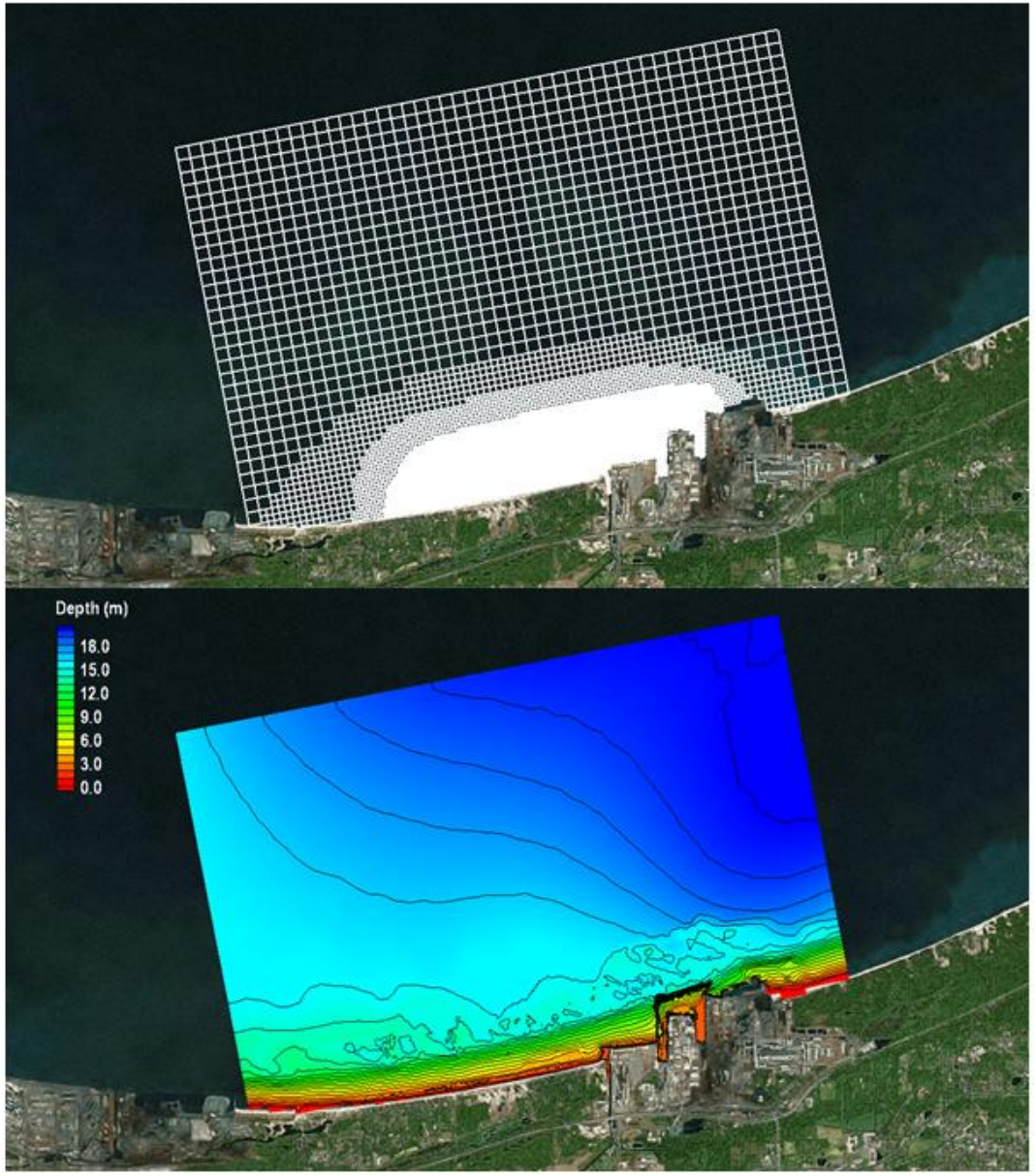
CMS Modeling

Model Forcing:

- Offshore Wind and Waves:
  - NDBC 45007
  - Transformation validated against ADCP
- Water Level Measurements:
  - Calumet Harbor, Illinois

Nearshore Wave Conditions:

- Summer: H_{m0}= 0.14 m
- Fall: H_{m0}= 0.6 m
- Entire time: H_{m0}= 0.4 m, T_p=3.8 s



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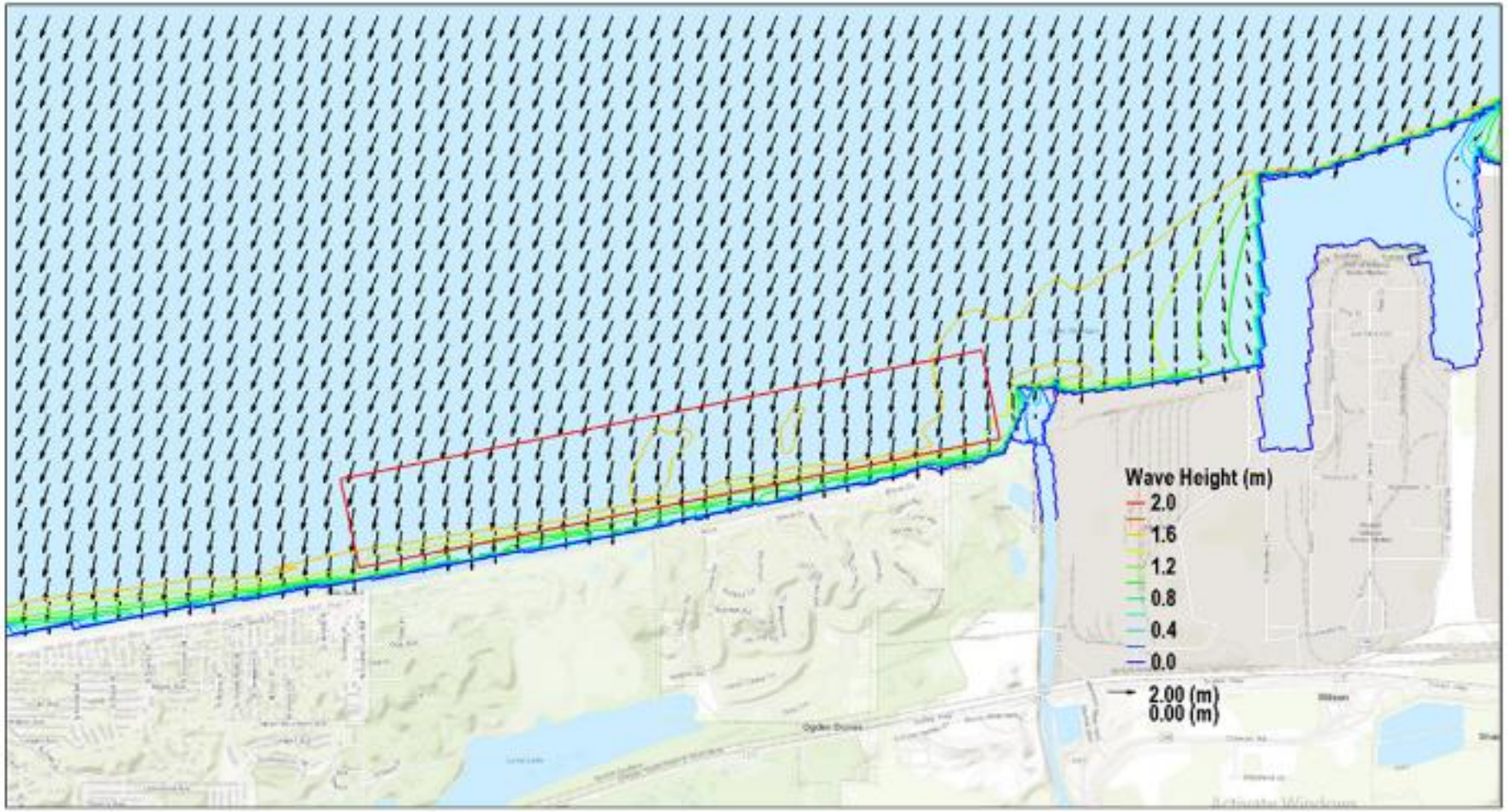
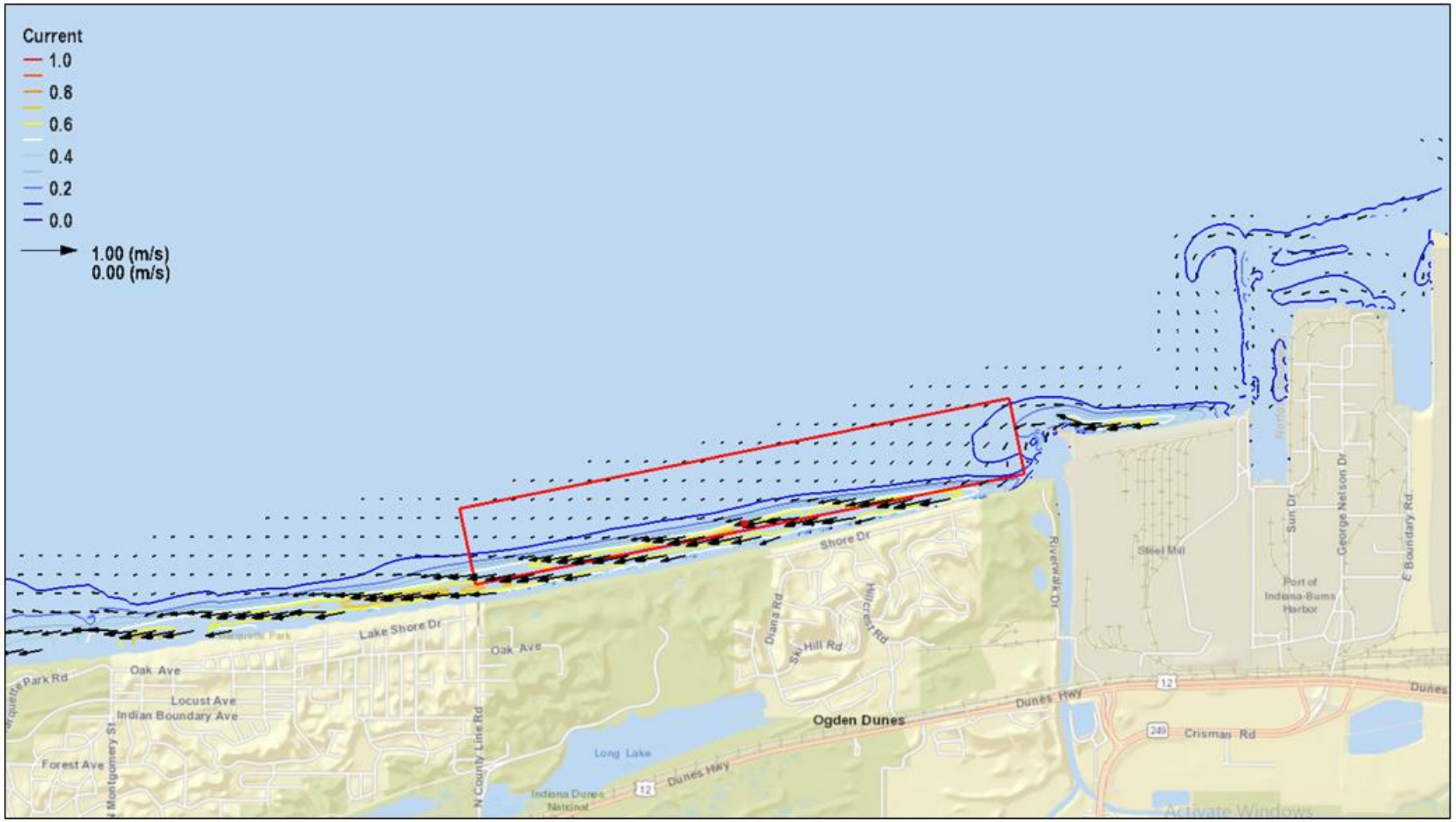
CMS Modeling

Wave Height and Direction during the 11 November 2016 storm

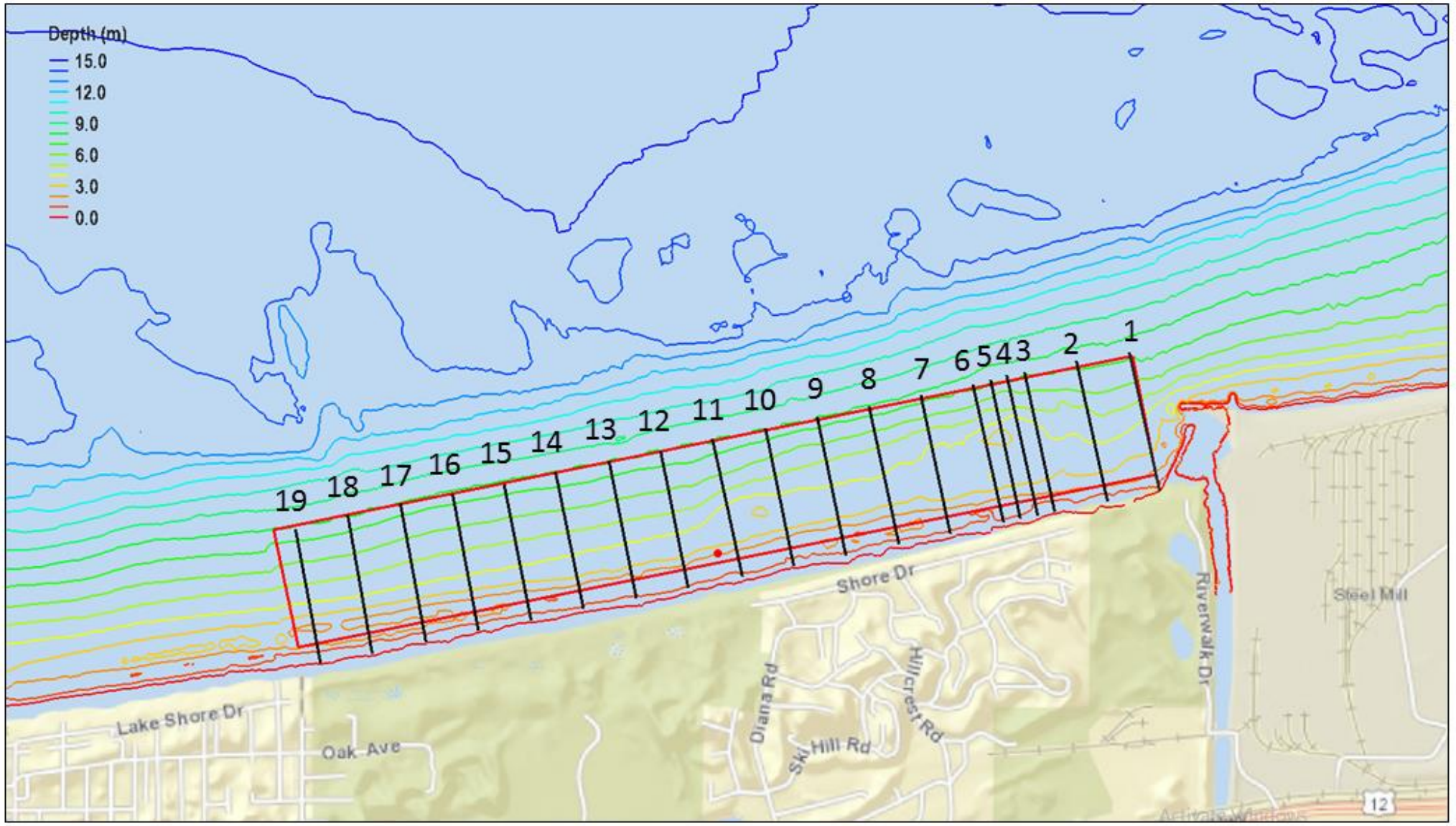


CMS Modeling

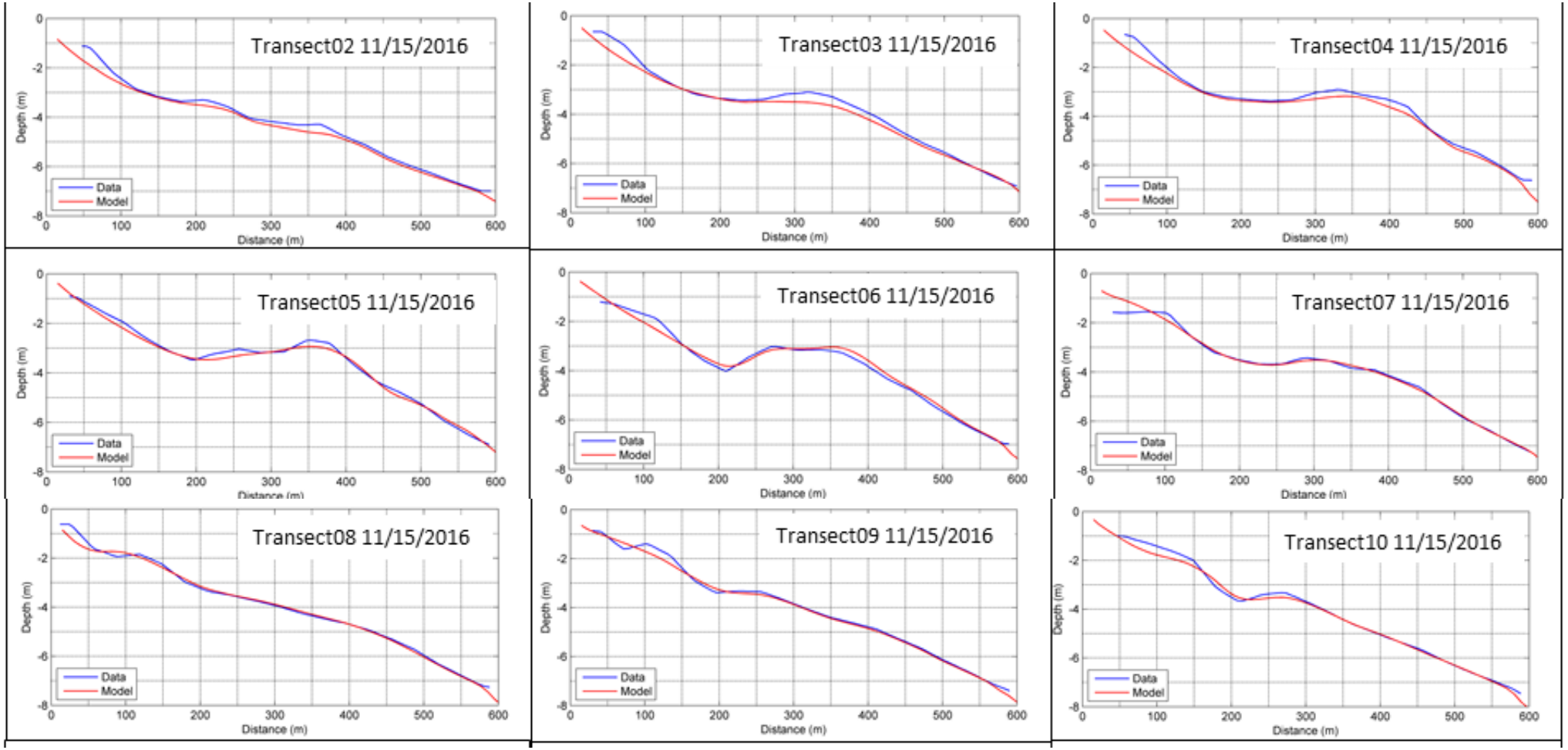
Currents during the 11 November 2016 storm



CMS Modeling



CMS Modeling



Summary

- Historical imagery, dredging records, and wave hindcasts can be used improve the understanding of the system
- Project monitoring was integral for the evaluation of physical forces driving sediment transport and model validation
- Sediment Mobility Tool showed accretionary wave climate with longshore transport
- CMS capable of simulating waves, current, sediment transport, and morphology changes in a coastal lake environment
- All the techniques could be used in other locations to monitor nearshore placement areas

THANK YOU!

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