Great Lakes Coastal Flood Hazard Studies Are More than Meets the Eye

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                   Jeff Gangai (STARR II)
Summary

▸ Great Lakes Coastal Program Overview
▸ Study Status
▸ Lake Level Trends and Meteorological Drivers
▸ Study Methodology Customized for the Great Lakes
▸ Coastal study data use examples
Great Lakes Flood Study

- Latest models, data, and technology
  - Employs continuous time series surface grids and storm sampling built from 50-year record (1960 - 2009) based on NOAA water level stations and compiled datasets for wind, atmospheric pressure and ice cover
  - Comprehensive bathy-LiDAR collections or field-surveyed hydrography
  - VE velocity mapping designation as appropriate

- Starting with 2013 goals, delivers updated flood maps for 64 counties in FEMA Region V states

- Flood maps will include new study for inland rivers and lakes in 12 counties

- Early Outreach conducted to survey possible applications for enabling local advancement of resiliency measures.
Program Goals and Status
Current Study Status

- Lake-Wide Storm Surge and Waves Study
- County Based Overland Analyses
- Workmap Production
- Comment Period
- FIRM Production
- Preliminary FIRM
- Community Coordination Meeting
- Comment and Appeal Periods
- Letter of Final Determination
- Effective FIRM

You are here
Preliminary FIRM Release for Upper Lakes
Planned 24-month schedule
Lake Erie 2D Modeling

▶ Simulated approximately 150 historic storm events selected for high water and waves
▶ 20 storms for water levels and 20 for high wave events, for each station
▶ Considered long- and short-term lake lever variation
▶ Considered effects of shore fast ice
▶ Results are used in Overland Analyses to determine 1%-annual-chance hazards
Ice Impacts

**Great Lakes Annual Maximum Ice Coverage 1973-2019**

- Long-term average (55.7%)
- Percent Coverage

**Annual Maximum Ice Cover - Lake Erie**

- Percent Ice Cover

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Data Availability

- Water levels and waves for historic storms all along shorelines
  - Time-series data
  - Maximum output from each historic storm
    - Water levels
    - Wave heights and periods
    - Winds
    - Velocities

- Historic storms on a variety of lake levels
  - Scenarios and maximum cases of high water level and waves

- Storm erosion and wave runup with each historic event
C SHORE Processes

- 1D cross-shore transect model
- Models near-shore processes simultaneously
  - Sediment transport / erosion
  - Wave setup
  - Wave transformation and breaking
  - Wave runup & overtopping
- Accurate nearshore bathymetry is important
2D to 1D Model Handoff

- 2D model has too large a scale for accurate results in surf zone and onshore
- 1D models were used to analyze erosion, runup and overtopping, and overland wave propagation
- 1D models used 2D time series model results as input
Erosion

USACE CSHORE model:

- Applies real physics
- Near-shore wave processes
- Cross-shore sediment transport

Ashtabula County, Transect 26
Event-based Modeling

- Event-based (1% annual chance) modeling
  - Five scenarios/events modeled using WHAFIS
  - JPM (Joint-Probability Method) for water level/wave analysis
    - Combined probability of water levels and waves at the shoreline
  - Inputs come from CSHORE:
    - Wave conditions at shoreline (unsteady state hydrographs)
Response-Based Wave Runup

- Wave runup is the uprush of water from wave action on a beach or shore barrier such as a steep dune, bluff or coastal structure.
- It was calculated for every time step of the CSHORE simulation for each of the 155 storms at each transect.
- A statistical analysis was performed on the maximum runup results at each transect to obtain the 1-percent-annual-chance runup elevation.
Response-Based Wave Runup

Runup Method Decision Flow Chart

Shoreline Type

Gradually Sloping Beach (1V:10H or more gradual)

- Stockdon

Bluff

Bluff Face Slope

- Between 1V:10H and 1V:1H
  - van Gent

- 1V:1H or Steeper
  - SPM – Vertical Wall Runup
    - Revetment (Structure Slope between 1V:10H and 1V:1H)
      - van Gent
    - SPM – Vertical Wall Runup

Shore Protection Structure

- Vertical Wall (Structure Slope of 1V:1H or Steeper)
- SPM – Vertical Wall Runup
Response-Based Wave Runup

Cuyahoga Transect 22

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RiskMAP
Increasing Resilience Together

18
Vertical Wall Runup

- For very steep slopes and vertical structures the Shore Protection Manual (SPM) was applied to calculate the runup elevation.

- The runup elevation was evaluated using the 5 WHAFIS Scenarios:
  - Impractical to use SPM method in response based analyses
  - Choose highest runup as 1% hazard (same as WHAFIS technique)

See Figure 7-13, correction for model scale effect.

Figure 7-14. Wave runup on impermeable, vertical wall versus $H_o/gT^2$. 

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RiskMAP
Increasing Resilience Together
Runup Mapping

Cuyahoga County

Legend:
- Coastal Work Map
- Transect Lines (zoom in to make visible)
- Limit of Moderate Wave Action (LMWA) (zoom in to make visible)
- Boundary of Wave Energy (zoom in to make visible)
- 0.2% Annual Chance Flood Hazard
- 1% Annual Chance Flood Hazard
- Contours (zoom in to make visible)
- Boundary Area (zoom in to make visible)
- Boundary Lines

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RiskMAP
Increasing Resilience Together
Shoreline Structures

- **Major Structures**
  - High relative to lake
  - Designed for storm protection
  - Continuous along shoreline

- **Minor Structures**
  - Low relative to lake
  - Not designed for storm protection
  - Small scale
Wave Overtopping

- Overtopping rate considerations for establishing Flood Insurance Rate Zones
- Magnitude of overtopping rates was calculated by applying formulas of the EurOTop Manual
- Overtopping rate determines AO Zone (sheet flow) depth

Wave overtopping on the coast of Lake Ontario during a 1973 Storm, Edgemere Drive, Monroe County, NY.

— Photo Courtesy of Dr. Martin
FIRM Mapping

FLOOD ZONES ALONG A COASTLINE DOMINATED BY WAVE RUN UP AND OVERTOPPING

SFHA

CHHA
VE

Wave Runup Height ≤ 3ft

AO, or AE

Depth 1-3ft
Or Wave Runup Height < 3ft

Moderate Flood Risk

UNSHADED X

Lower Flood Risk

BFE = Base Flood Elevation
CHHA = Coastal High Hazard Area
SFHA = Special Flood Hazard Area
SWEL = Stillwater Flood Elevation

fema.gov
Integrating Riverine and Coastal Data

* Controlled by coastal flooding – see Flood Insurance Rate Map for regulatory base flood elevation

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**Floodway**

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* Controlled by coastal flooding – see Flood Insurance Rate Map for regulatory base flood elevation.
Integrating Riverine and Coastal Data

System morphology

- Tribs outflowing to lakes will have one of following characteristics:
  1. Small streams that discharge from steep-slope ravines
  2. Shallow, slow-moving tributaries that outflow from low-bluff regions
  3. Larger rivers that transition into a dredged or widened condition or inland lake system
- Exceptions found on Lake Superior and north Lake Michigan where streams outflow through non-cohesive and mostly sandy substrate.

Issues for Flood Map Production

- Nature and currency of current NFIP model for contributing trib: Are lake TSWL elevations higher or lower than stream BFE at lowest modeled point for free-flow conveyance? For large unsheltered rivers, is joint probability analysis appropriate?
- FEMA and STARR II production teams drafted additional guidance in March 2019
The Great Lakes cover lands inside U.S. involving more than 80 counties across eight states.

Methods and terminology references for the FEMA FIS were required for unique coastal language and customized methods:

- Tidal gage tables are replaced by tables showing employed NOAA water level stations
- Building on draft documents compiled during analysis phase, comprehensive review was made for Wave Hazard Analysis summary descriptions
- Numerous graphics are updated

An “edits roadmap” was compiled for future production efforts inside FEMA
Online Resources

Great Lakes Coastal Flood Study: http://www.greatlakescoast.org/
Many new Fact Sheets

Great Lakes Coastal Resilience Planning: http://www.greatlakesresilience.org/

High resolution oblique aerial images http://greatlakes.erdc.dren.mil/
Great Lakes Coastal Flood Study Review

- Great Lakes coastal flood risk has changed and will continue to change
- Study will advance our scientific understanding of the interrelated Great Lakes System
- Comprehensive analysis of coastal Great Lakes flood hazards uses latest models, technology, and data
- Study provides FEMA, States, and coastal communities with valuable coastal data and planning tools to adapt and thrive in a changing environment
Questions

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