

Visualization of Shoreline and Water Level Changes in Great Lakes Coastal Communities

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July 12, 2011

Final Report on Visualization of Shoreline and Water Level Changes for the National Oceanic and Atmospheric Administration, Sectoral Applications Research Program titled "Preparing Coastal Communities for Climate Change: Translating Model Results to Prepare, Ports, Harbors and Stormwater Management Facilities in an Era of Climate Variability and Scientific Uncertainty"

Few residents of Great Lakes coastal communities fully appreciate the potential consequences of the range of water levels that may result from a changing climate. In part, this is because regional climate and lake level projections are provided via abstract data and charts that do not indicate specific consequences for coastal residents and local officials. Other information is widely dispersed and inaccessible to non-specialists. Coastal communities need interpretive tools that synthesize dispersed data and translate the predictions of regional climate change models and lake level forecasts into user-friendly, local information that anyone can understand.

Geographic information systems (GIS) and 3D visualization are tools that can effectively communicate the impacts of Great Lakes water level changes to coastal constituents. Schwartz et al. (2004) utilized GIS and an integrated topographic/bathymetric elevation dataset to model the impacts of changes in the water level of Lake Huron on the community of Goderich, Ontario. Their work incorporated water level scenarios from regional climate models and projected the impacts on harbor dredging, cargo vessel capacity, marina dredging, shoreline recreation, and municipal water supply and concluded that LiDAR derived digital elevation models would significantly improve the physical elements of climate change impacts; coastal process models could be linked to a GIS to more accurately model shoreline change and introduce a temporal component to the research; and animation and 3D display could make the model more useful to researchers, local decision-makers, and stakeholders.

This project utilized more recent GIS software, updated climate modeling, and new topographic/bathymetric data to visualize the potential impacts of increased variability of Great Lakes water levels on sections of Duluth/Superior and Toledo harbors. A comparison of the capabilities of visualization software packages was also completed.

Topo/Bathy Data Discovery, Acquisition, and Integration

Integrated topography/bathymetry digital terrain models have been developed for sections of the Ports of Toledo and Duluth/Superior. Multiple sources of spatial data were used to develop the topo/bathy models, including terrestrial and bathymetric LiDAR, multibeam sidescan sonar, and nautical charts (Figure 1). A report was prepared documenting the methods used to create the models, as well as issues faced during their creation. Metadata for the topo/bathy datasets will be distributed through the geospatial catalog of the Wisconsin Coastal Atlas (<http://wicoastalatlus.net>).

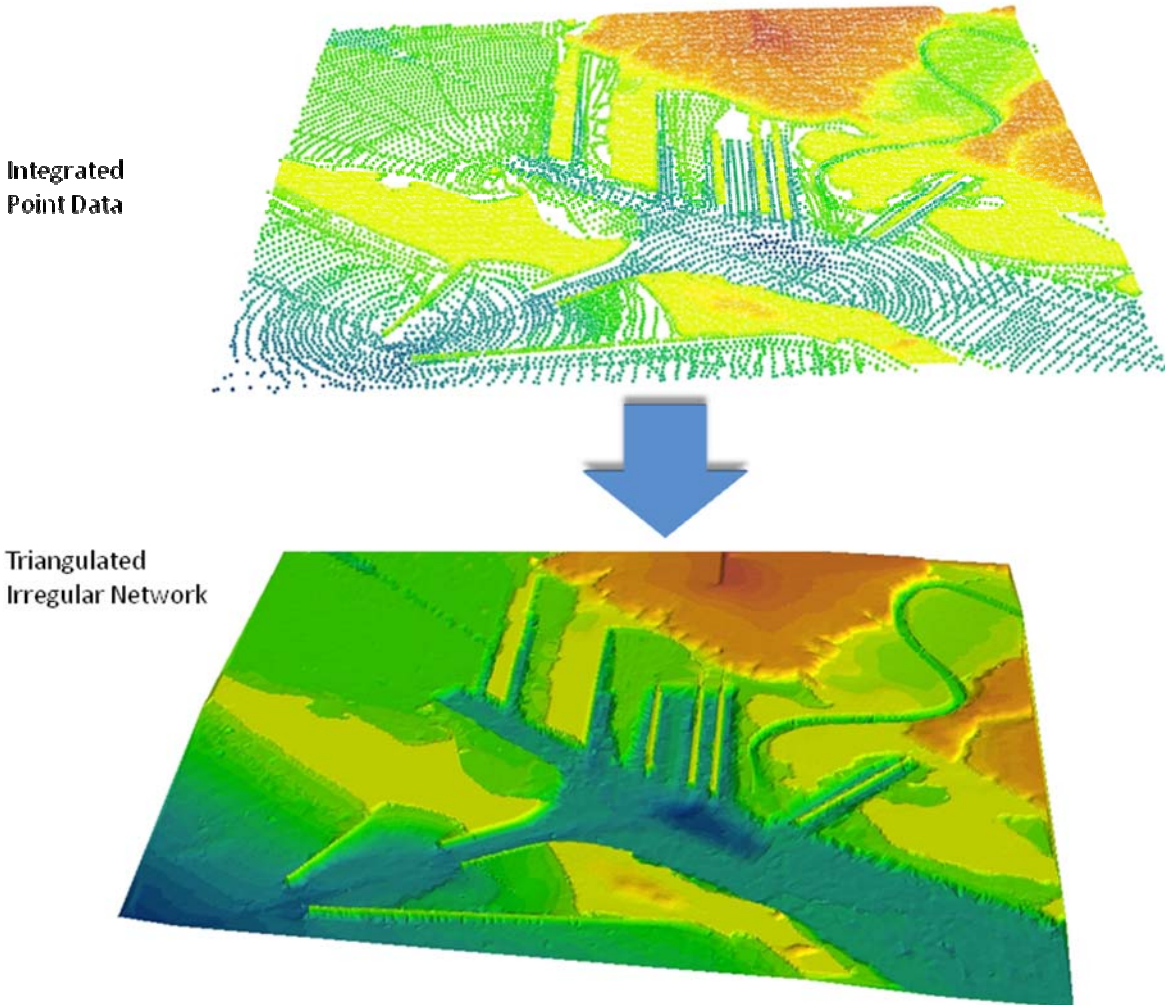


Figure 1. Steps in creation of an integrated topography/bathymetry model for the Superior Harbor entrance and Allouez Bay, Wisconsin

Visualization Software Comparison

A comparison of visualization software has been completed that includes a matrix of 14 variables for 27 software packages in six categories (Figure 2). The categories of software packages include computer-aided drafting, geographic information systems, landscape modeling, photo manipulation, planning support, and virtual globes. The variables including animation, real-time, image draping, and texture capabilities; ease of use; specialty areas; cost; training; and input/output file formats.

A Comparison of Visualization Software							
3D Software	Version	Category	Real Time	Image draping	Textures	Animation	Ease of Use
CAD- Based							
SketchUp	7	CAD-Based	maybe	yes	yes	Pro version only	Easy
Terravista Base	6.1	CAD-Based	yes	yes / tiled	yes	Pro version only	Hard
Microstation	V8i	CAD-Based	maybe	no	yes	Keyframes, time-based	Medium/Hard
Autodesk 3ds Max	12	CAD-Based	maybe	no	yes	Object animation, Keyframes, path-controlled	Hard
GIS-Based							
ArcGIS 3d Analyst ArcScene	9.3.1	GIS-Based	yes	yes	no	Time based, fly throughs, object oriented	Easy
ArcGIS 3d Analyst ArcGlobe	9.3.1	GIS-Based	yes	yes	yes	Time based, fly throughs, walk throughs	Easy
IMAGINE VirtualGIS	10.1	GIS-Based	yes	yes / tiled	yes	Object animations, some flight, time based	Medium/Hard
GeoViz Toolkit	0.8.5	GIS-Based	no	no	no	None	Medium

Figure 2. Part of the spreadsheet that compares the capabilities of a range of visualization software.

Water Level Visualizations

Visualizations of shorelines associated with historic water levels and water level scenarios anticipated relative to climate change have been prepared for both the Duluth/Superior and Toledo harbors. A range of reference, historic, and potential water levels for Lakes Superior and Erie and the water level gages at Duluth and Toledo were developed to guide the visualizations. These include chart datum, lake monthly averages (means and records), record high and low gage readings, possible storm induced rise applied to record high lake monthly averages, and climate scenarios based on combining the variability of extreme gage readings with projections by Angel and Kunkel (2010) and Lofgren and Hunter (2010). Visualizations of potential shorelines based on the topo/bathy models were produced for record historic water levels and the most extreme climate scenarios utilizing ArcScene within the ArcGIS software suite. Figures 3 through 6 provide example visualizations for the Superior, Wisconsin harbor entry. A report was prepared documenting the methods used for the visualizations. The visualizations will help the case study communities understand the potential impacts of changing water levels, flood patterns, and storm events and serve as a model for understanding water level variability in other Great Lakes coastal communities.

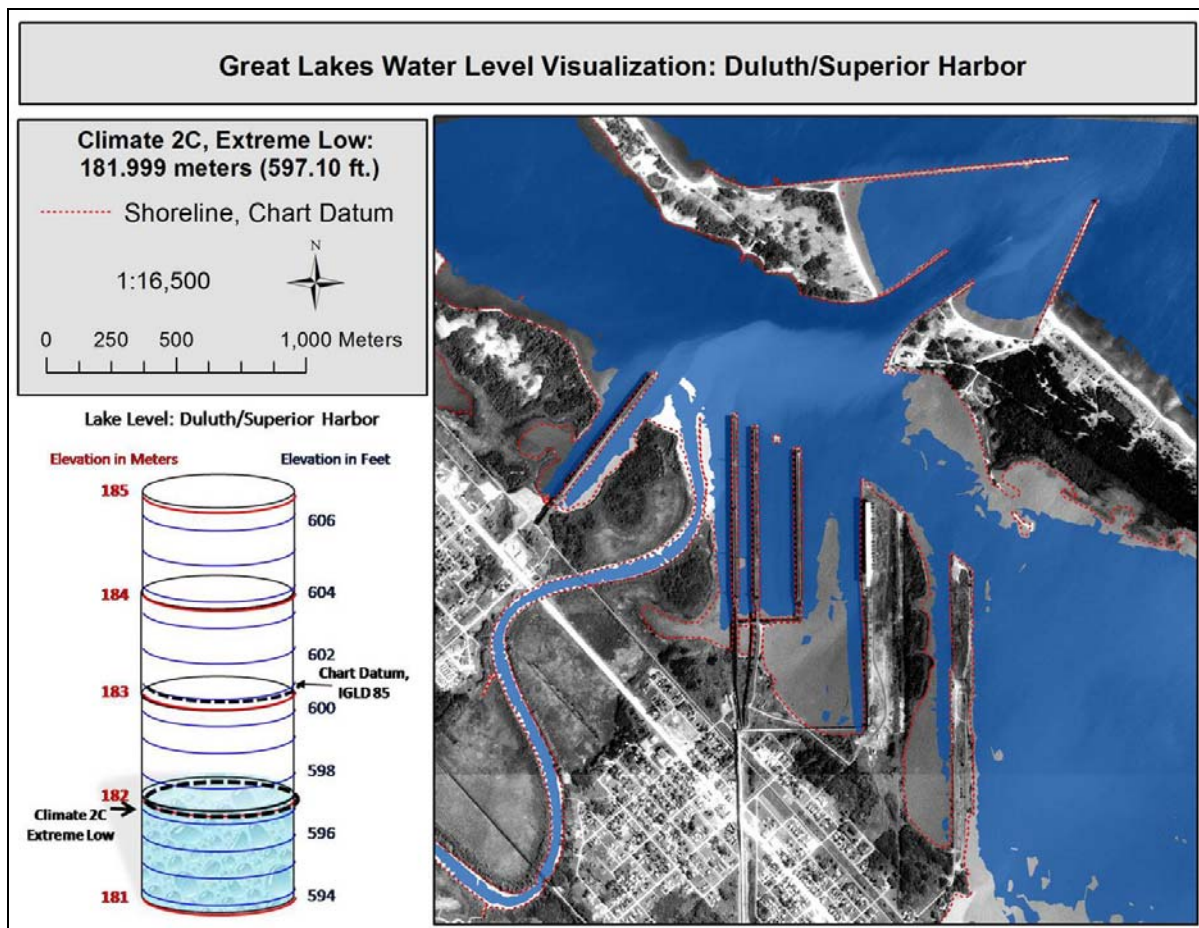


Figure 3. Visualizing a potential decrease in the water level of the Superior, Wisconsin harbor entrance due to climate change. The water level in this image is based on subtracting the lowest value for the GCM/GLERL simulations of lake level changes on Lake Superior for the A2 high level emission scenario for 2080-94 by Angel and Kunkel (2010) from the extreme low reading for the Duluth water level gage from 1996-2010.

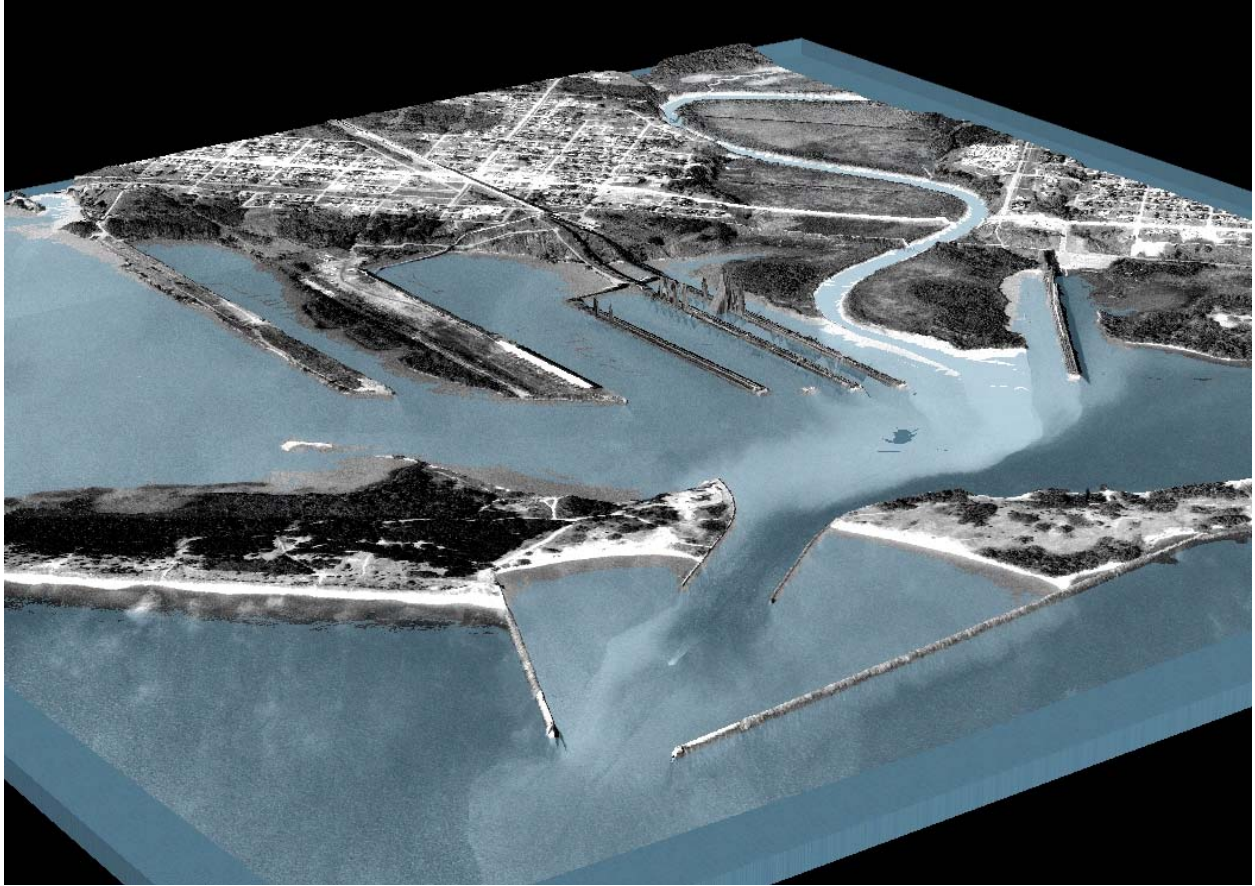


Figure 4. Visualizing the water level scenario from Figure 3 at an oblique angle using ArcScene.

Great Lakes Water Level Visualization: Duluth/Superior Harbor

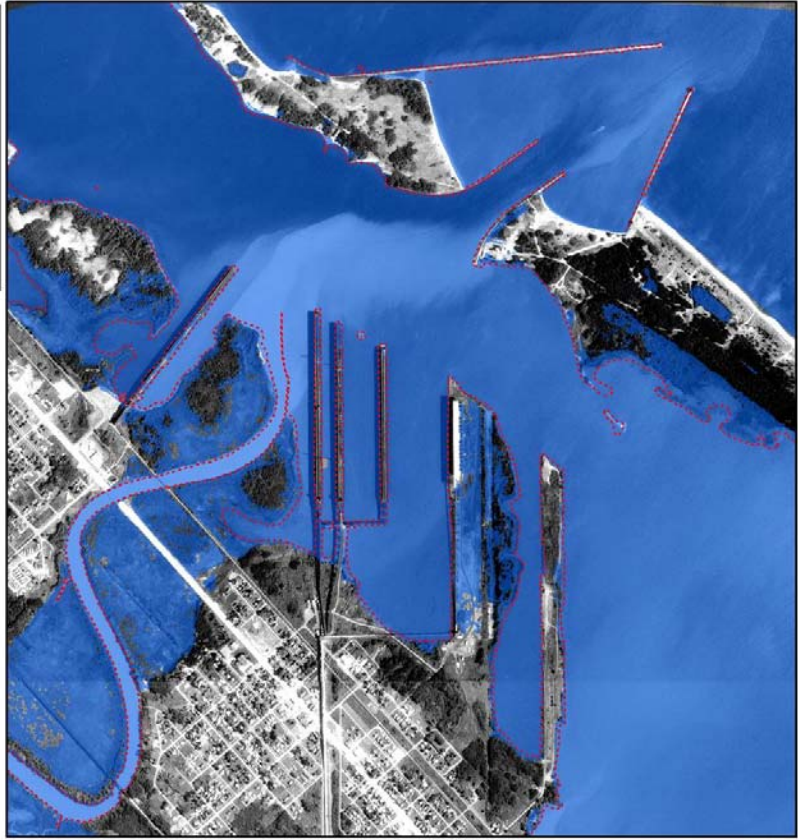
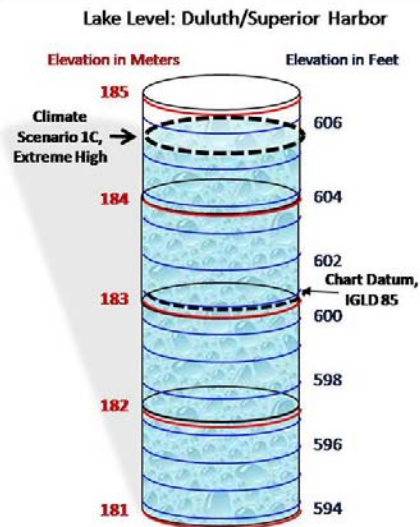
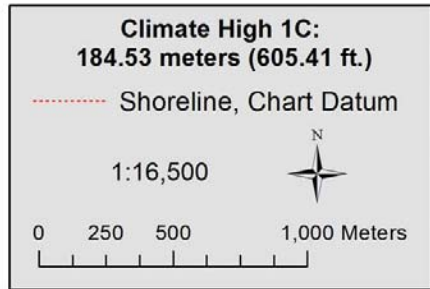


Figure 5. Visualizing a potential increase in the water level of the Superior, Wisconsin harbor entrance due to climate change. The water level in this image is based on adding the highest value for the GCM/GLERL simulations of lake level changes on Lake Superior for the A2 high level emission scenario for 2080-94 by Angel and Kunkel (2010) to the extreme high reading for the Duluth water level gage from 1996-2010.

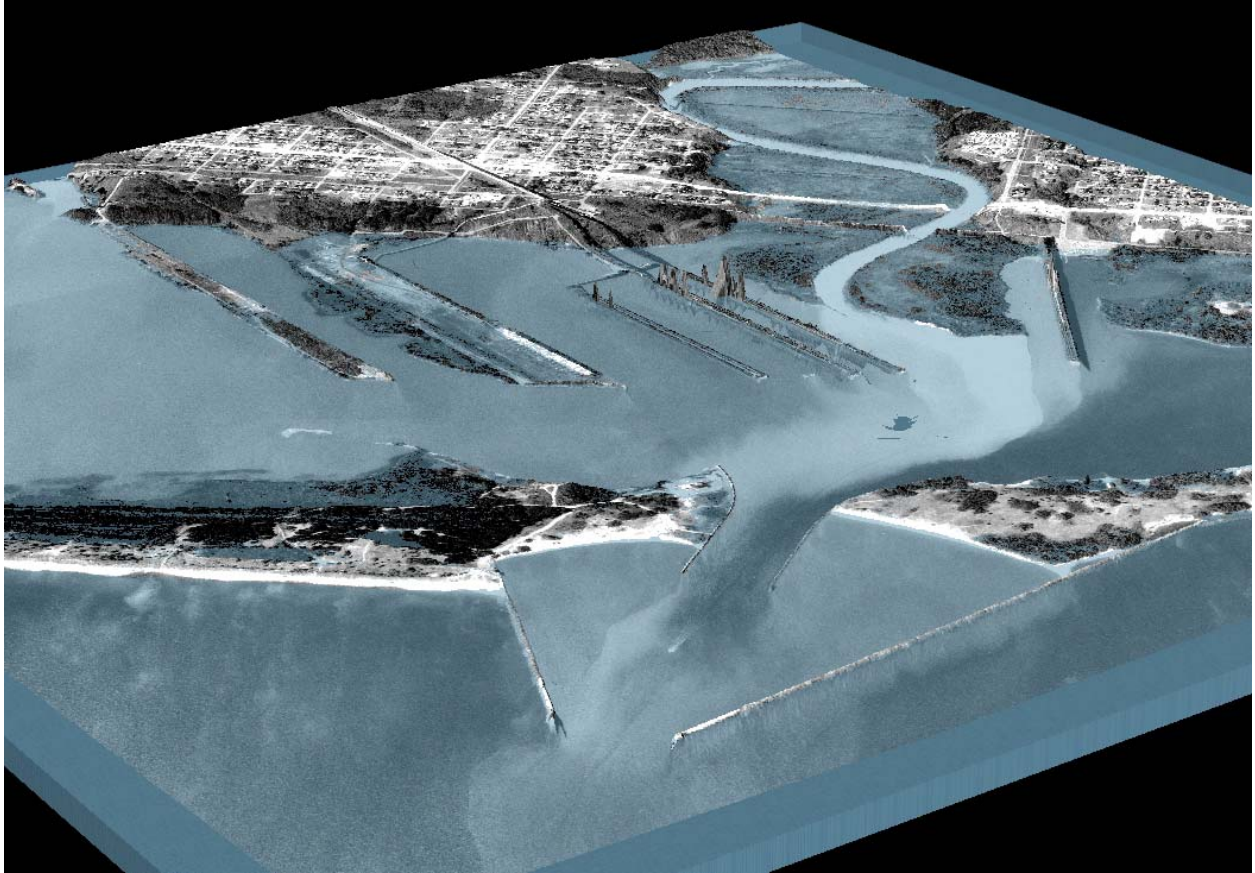


Figure 6. Visualizing the water level scenario from Figure 5 at an oblique angle using ArcScene.

Products

Greene R. and D. Hart. 2011. Topographic/Bathymetric Models for the Harbors of Toledo and Duluth/Superior: Data Acquisition, Integration, and Visualization. University of Wisconsin Sea Grant Institute. July 2011.

(A report documenting the creation of topo/bathy GIS data sets and visualizations of water level changes for sections of the Duluth/Superior and Toledo harbors.)

McClintock, T., Greene, R. and D. Hart. 2011. A Comparison of Visualization Software. University of Wisconsin Sea Grant Institute. July 2011.

(A comparison of visualization software that includes a matrix of 14 variables for 27 software packages in six categories. Available in Microsoft .xls and Adobe Acrobat .pdf formats)

Greene R. and D. Hart. 2011. Topographic/Bathymetric Model for part of the Port of Toledo, Ohio. [digital geospatial data]. University of Wisconsin Sea Grant Institute. July 2011.

(A digital elevation model available through the Wisconsin Coastal Atlas geospatial catalog – <http://wicoastalatlans.net/>).

Greene R. and D. Hart. 2011. Topographic/Bathymetric Model for part of the Ports of Superior, Wisconsin and Duluth, Minnesota. [digital geospatial data]. University of Wisconsin Sea Grant Institute. July 2011.

(A digital elevation model available through the Wisconsin Coastal Atlas geospatial catalog – <http://wicoastalatlans.net/>).

Hart, D. 2009. Visualizing the Impact of Changing Water Levels on the Great Lakes. Presentation at the State of Lake Michigan 2009 conference in Milwaukee, Wisconsin. September 30, 2009.

(A conference presentation reaching 40 attendees)

References

Angel, James R. and Kenneth E. Kunkel. 2010. The response of Great Lakes water levels to future climate scenarios with an emphasis on Lake Michigan-Huron. Journal of Great Lakes Research. Vol. 36, pp. 51–58.

Lofgren, Brent M. and Timothy S. Hunter. 2010. Final Report: NOAA Great Lakes Environmental Research Laboratory's Climate and Hydrologic Modeling Activities Associated with the Project "NOAA Sectoral Applications Research Program (SARP): Coastal Resource Management/Water Resources Management". Ann Arbor: NOAA Great Lakes Environmental Research Laboratory.

Schwartz , Ryan C., Peter J. Deadman, Daniel J. Scott, and Linda D. Mortsch. 2004. "Modeling the Impacts of Water Level Changes on a Great Lakes Community" AWRA Journal of the American Water Resources Association. June 2004 pp. 647-662.