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Short Contributions— GIS Approach to Water-Level Change Project

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RYAN EDGLEY, California State Polytechnic University, Pomona, CA
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DECLINING WATER LEVEL IN LAKE MICHIGAN-HURON AND THE EFFECT ON ISLANDS IN THE MASSASAUGA PROVINCIAL PARK, ONTARIO
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ABSTRACT

The Great Lakes have been experiencing decreasing water levels over recent years due to many factors that create a negative difference between water input and output. Lake Michigan-Huron has been specifically hard-hit, with water levels below average for over ten years. This has caused concern in local populations about the negative effects of this change. In this study, islands in The Massasauga Provincial Park, Ontario, were studied through ArcGIS using orthoimagery and satellite imagery to determine the past changes in island size and the effect of past water levels. Then, maps were made based on water level projections, as well as arbitrary, but illustrative water level decreases. A Digital Elevation Model (DEM) and Triangulated Irregular Network (TIN) were created to visualize this change and on which to perform area analysis. The results were mixed, with past data on island size not always corresponding to water levels. The 3D models of future levels are useful in assessing possible impacts on local communities.

INTRODUCTION

Lake and ocean water levels are sensitive to daily changes in rates of evaporation and precipitation, as well as long-term global and regional environmental change. This phenomenon can be seen in average monthly water level logs of the Great Lakes, which are carefully recorded by a network of US and Canadian gauging stations on each lake. Lake Michigan-Huron experiences these fluctuations due to differences in input and output in the hydrologic system, but in the last decade water levels have been declining due to many factors. The International Upper Great Lakes Study found that the difference in water level between Lake Michigan-Huron and Lake Erie has declined by about 23 cm between 1963 and 2006 (IUGLS, 2009). This is due to three key factors: a change in conveyance, or water-carrying capacity, of the St. Clair River, which links Lake Huron to Lake Erie (7.1-14.0 cm of the decline), glacial isostatic adjustment (4.1-5.1 cm), and changes in climatic patterns (8.9-17.0 cm). This third factor has become even more important in recent years, accounting for an estimated 58-76 percent of the decline between 1996-2005 (IUGLS, 2009). These fluctuations have caused worry in local and regional communities about the effects on ecology, economics, and the general health and stability of populations that rely on these lakes for their various needs.

Study Area

The Massasauga Provincial Park is located in Ontario at the eastern edge of the Georgian Bay of Lake Huron. Stretching from Parry Sound to the Moon River, it consists of mainland and over 200 islands, which comprise approximately 2,000 hectares (ha) of landmass. The topography of the archipelago is relatively flat, ranging from a few meters below lake level in depression basins to about 50 m above lake level, and is dominated by Canadian Shield bedrock with thin, discontinuous coatings of glacial till and alluvium (Sly & Munawar, 1988). These islands are home to many native plants and animals, like the Massasauga rattlesnake, prairie warblers, five-lined skinks, white oak and white cedar (MacPherson, 2005). The islands also support the local economy by attracting tourists interested in hiking, fishing, swimming, and boating. Declining water levels have already changed the shape and size of islands and affected the local populations of people and wildlife, and there is concern about the damage that may occur if water levels continue to decline.

Geology

The Massasauga Provincial Park is made primarily of Canadian Shield bedrock consisting of two distinct bedrock types: the Parry Sound Greenstone Belt (meta-volcanic, meta-sedimentary, and igneous rocks) and the Ontario Gneiss Belt (igneous rock types), both of Precambrian origin (Sly & Munawar, 1988). Glaciers and lakes have played the most important roles in the sculpting of this area. The Wisconsin Glacier of approximately 30,000 years ago scoured the rocky landscape and deposited thin, discontinuous areas of glacial till. As the glacier retreated north it created Glacial Lake Algonquin, which slowly came to an end when the glacier retreated past the Mattawa Valley. Glacial Lake Algonquin's hydrological actions of about 11,000 years ago were a major creator of the current landscape through the erosion and deposition of alluvium. Once the glacier retreated past the Mattawa Valley, large amounts of water were lost from Lake Algonquin. The loss of water coupled with isostatic rebound in the south produced what is known as the Nipissing Great Lakes. The continued retreat of the glacier and uplift caused the St. Clair River to become a spillway draining the Nipissing Great Lakes, which eventually allowed Lake Huron and the Georgian Bay to recede to their present level and boundaries (Hirvonen & Woods, 1978). At this time, approximately three to four thousand years ago, The Massasauga islands permanently emerged as dry land. Lake levels for the past 2.5 ka show a stabilized mean of 177 m asl (Eschman & Karrow, 1985).

METHODS

All analyses were conducted in ArcMap and ArcScene of ESRI ArcGIS 10.2. Analysis of the Massasauga region relied heavily on orthophotographs and satellite imagery. The images were input into ArcMap, where they were georeferenced. Then, island shapefiles were created and each island was carefully digitized by hand. The data were analyzed by joining the attribute tables from every year based on the Island ID category. The total area of the sample islands was calculated for each year and compared to the mean annual water levels for the respective year of the island shapefile.

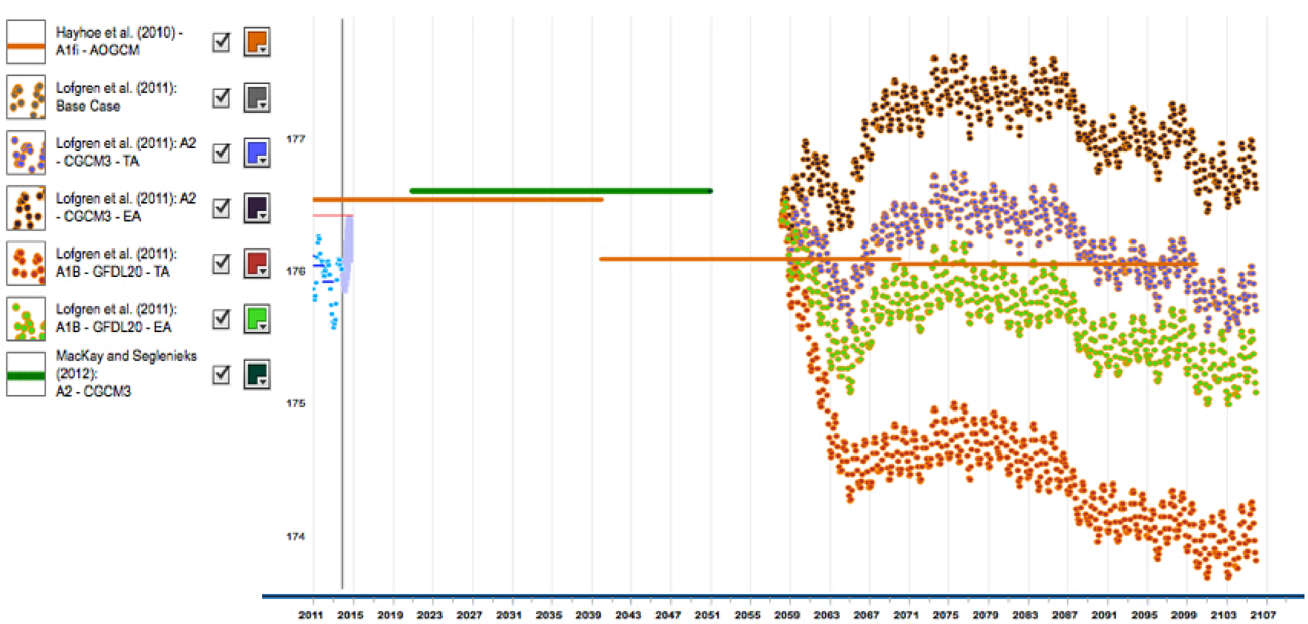

Figure 1. Future projections based on several studies that incorporate different climate models and methods. (Source: NOAA, http://www.glerl.noaa.gov/data/now/wlevels/levels.html)

A Digital Elevation Model (DEM) was created to represent the topography in the area from a combination of GPS elevation data and topographical contours. This DEM was used to create models of the shoreline at several different water levels using the raster reclassify tool. These water level predictions represent moderate, and probable predictions for the future (Fig. 1), as well as arbitrary, more drastic changes to illustrate the sensitivity of the area to water level changes of even a few meters. To illustrate further how sensitive the area is to water level change, the percent of the map area that is land or water was computed using raster classification.

The DEM was also used to evaluate consequences of the changing water levels on water depth in the area. Based on necessary depths for boat travel, estimates were made as to the extent of dredging in marinas and important waterways in the area. Polygons drawn over these important areas were multiplied by average depth of dredging necessary to compute a rough amount of debris that would be necessary to remove to keep the area functioning as usual. This was done by assuming that a medium-sided motor boat requires a minimum channel depth of five feet and a width of forty feet (based on recommendations and calculations set out by the US Army Corps of Engineers (US Army Corps, 2002).

This DEM was also used to create a Triangulated Irregular Network (TIN) to illustrate the change in the area of Wreck Island at several different water levels. The TIN utilizes a vertical exaggeration of 5 times to emphasize the topography of the area, which is otherwise very hard to discern due to its smooth, level nature.

RESULTS

The results of the digitizing and area analysis can be seen in Table 1. The total area of the sampled islands was calculated by adding up the areas of the islands present in the shapefiles for every year. The average water levels were obtained from the NOAA website (NOAA, 2014). The trend in water level is primarily decreasing, and island area usually matches this trend, though 2005 does not. This discrepancy will be analyzed in the Discussion.

A map was created using the DEM to show the different scenarios for 3 separate water levels (Fig. 2). In Table 2, the results of the area analysis based on the DEM are listed. Island area increases as water level decreases, though not at a constant rate due to the different shoreline slopes angles at each of these water levels.

Based on analysis of the DEM in conjunction with maps of the area showing major and minor boat routes, dredging would be necessary in many areas if the water level drops past current levels. In fact, many of the listed minor boat routes are already in need of dredging at a modeled water level of 176 m. Based on polygons drawn to represent the area needed for boat travel multiplied by the depth necessary, a rough estimate of 134,000 m^3 would need to be removed from these lesser channels. If water levels drop to 174 m, dredging will be necessary in the Main Channel that runs from Midland to Parry Sound, around The Massasauga. This would require a much larger removal of bottom debris and an increased cost.

A TIN of Wreck Island was created from the DEM and this was used to aid in the visualization of the changing island shape and size from different water level scenarios (Fig. 3).

Table 1. Area Analysis compared to average water level for seven years.

Year	1971	1983	2004	2005	2007	2009	2012
Average Water Level (m IGLD85)	176.805	176.833	176.111	176.09	175.943	176.258	175.916
Change in Water Level (m)	0.028	-0.723	-0.021	-0.147	0.315	-0.343	
Area of Sampled Park Islands (ha)	156.91	154.99	174.84	170.99	174.65	173.17	175.98
Change in Area (ha)	-1.92	1.98	-3.84	3.65	-1.48	2.82	
Percent Change	-1.2	12.8	-2.2	2.1	-0.8	1.6	

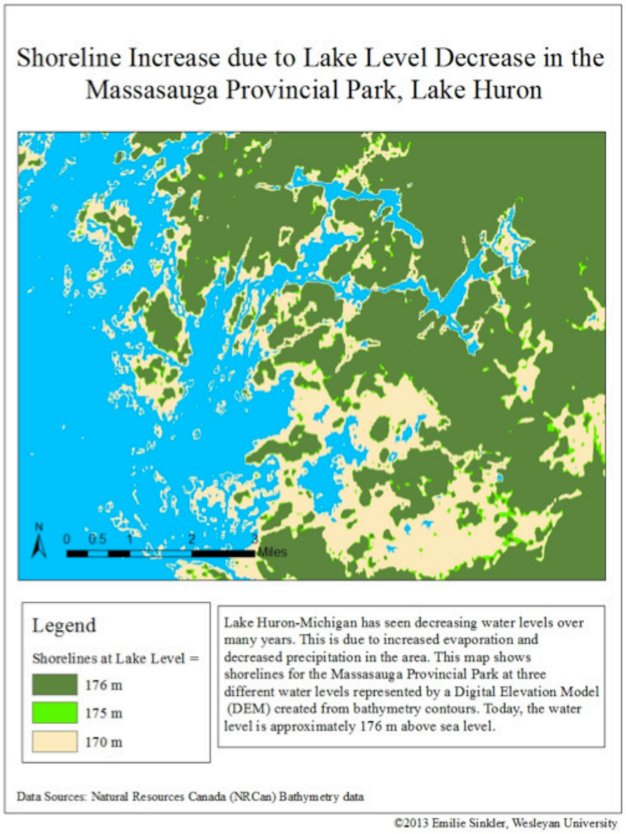

Figure 2. Map showing three shorelines at three different water levels.

Table 2. Change in area shown on map in Figure 2. Total Area = 29,587 ha.

Water Level (m)	Percent Water	Percent Land
177	57.1	42.9
176	55.5	45.5
175	53.6	46.4
174	51.4	48.6
173	48.8	51.2
172	46.1	53.9
171	41	59
170	39	61

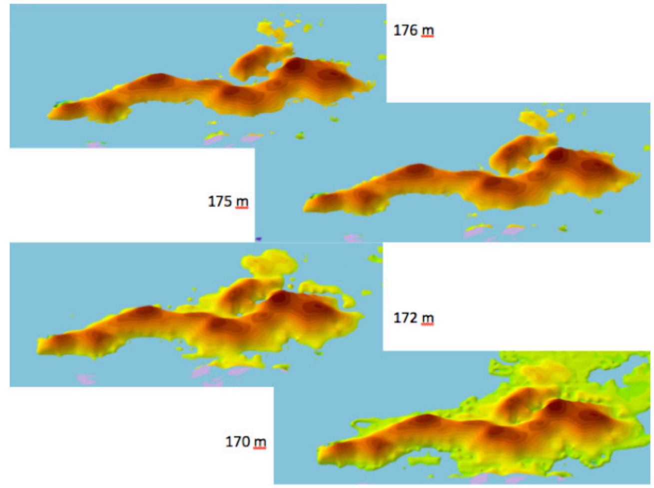

Figure 3. Four representations of the TIN of Wreck Island showing four different water level scenarios, the first four being within projected ranges, and the 170 m being a drastic scenario, mostly for illustrative purposes. The TIN has been exaggerated 5x.

DISCUSSION

The data representing the area of the digitized islands conflicts with the expected results based on the mean water for 2004-2005. When water levels trend downward, the island areas are expected to increase. There are several possible causes of this discrepancy. First, it is possible that the imagery is not very detailed or contains barriers that cause it to be hard to digitize. This lack of visual accuracy, whether from pixelization, clouds or other barrier objects, or hard to identify shallowly-sloping shorelines due to the transparent nature of water, could impact the accuracy of the digitization. This is most likely the case for the years 2004-2005 because the 2005 map was a nautical chart rather than aerial or satellite imagery, allowing for much less precision. Another factor that could be causing this discrepancy is the fluctuation of water levels from day-to-day and season-to-season. It would be much more accurate to look up the exact water level on the day that the photo or satellite image was taken to ensure that we are comparing accurate measurements, although this is not available for some of the photographs. A third factor that could account for some of this discrepancy is the differential rate of isostatic rebound across the region. The most accurate comparison would be between island area and the water level at the closest water gauging station (in this case at Parry Sound) on the specific day that the photo or satellite image was taken.

The DEM and TIN are useful in understanding potential impacts on island shape and the potential connectivity of the land. This could have effects on the plant biodiversity on the islands because plant species have an easier time travelling across land than water. This could also affect the spread of invasive species on these islands. Economic effects can be seen in the need to extend docks to reach the water, as well as in probable dredging to keep important passageways clear. Dredging has occurred locally at marinas. However, the park does not have the resources to determine which channels to prioritize for dredging. Identification of several channels important to medium and small-sized boats entering from inland locations in the park led to the calculation of about 134,000 m^3 of dredging necessary in the region with even a single meter drop in water level.

CONCLUSION

The water levels in Lake Michigan-Huron are highly variable, but show an undeniable extended period of decline. This is potentially harmful for the economics and ecology of the area, as well as the general health and stability of the lake. Many factors are responsible for this decline and a multi-pronged approach must be used to combat it. The shapefiles, DEM, and TINs created from this study will be added to an increasing body of data that can be used to further analyze this problem – all results from this study will be submitted to the Ontario Ministry of Natural Resources.
The results herein are a significant step toward understanding the evolution of the area and possible effects of water level decline.

More research needs to be done to assess the specific effects of the water level decline on economics and ecology. More detailed volumetric analysis for dredging, utilizing a trapezoidal channel, can be performed on the TIN, and data about specific costs of dredging can be obtained. Lengths of docks and prices for them can be calculated from the shapefiles and data on local dock prices. Effects of water level on tourism in the area can also be analyzed based on trends in the recent past, though this must be analyzed with respect to economic conditions that also effect tourism.

More accurate bathymetry data would benefit a study like this in the future. LiDAR data at accuracy levels on the order of centimeters, versus current bathymetry with accuracy on the order of meters, would be advantageous. Volumetric analysis performed on this data would be much more accurate, and TINs created using LiDAR would resemble the islands much more closely.

REFERENCES

Bishop, C.T., 1990, Historical variation of water levels in Lakes Erie and Michigan-Huron, Journal of Great Lakes Research, v. 16, p. 406-425.

Eschman, D.F., and Karrow, P.F., 1985, Huron Basin glacial lakes: a review, Quaternary Evolution of the Great Lakes, Geological Survey of Canada Special Paper 30, Association of Canada, p. 79-93.

Gronewold, A.D., Fortin, V., Lofgren, B., Clites, A., Stow, C.A., and Quinn, F., 2013, Coasts, water levels, and climate change: A Great Lakes perspective, Climatic Change.

Gronewold, A.D., et al., 2013, A dynamic graphical interface for visualizing projected, measured, and reconstructed surface water elevations on the earth's largest lakes, Environmental Modelling & Software, v. 49, p. 34-39.

Hayhoe, K, VanDorn, J., Croley, T., Schlegal, N., and Wuebbles, D., 2010, Regional climate change projections for Chicago and the US Great Lakes, Journal of Great Lakes Research, v. 36, p. 7-21.

Hirvonen, R., and Woods, R.A., 1978, Georgian Bay Islands National Park Integrated Resource Survey, Forest Management Institute, Ottawa.

IUGLS, 2009, Impacts on Upper Great Lakes Water Levels: St. Clair River: http://www.ijc.org/files/publications/IUGLS%20St%20Clair%20Report%20Summary.pdf.

Lofgren, B.M., Hunter, T.S., and Wilbarger, J., 2011, Effects of using air temperature as a proxy for potential evapotranspiration in climate change scenarios of Great Lakes basin hydrology, Journal of Great Lakes Research, v. 37, p. 1-9.

MacPherson, A., 2005, Ontario Provincial Parks, Boston Mills Press.

NOAA Great Lakes Environmental Research Laboratory, 2014, Great Lakes Water Levels:

http://www.glerl.noaa.gov/data/now/wlevels/levels.html.

Schwartz, R.C., Deadman, R.J., Scott, D.J., and Mortsch, L.D., 2007, Modeling the impacts of water level changes on a Great Lakes community, Journal of the American Water Resources Association, v. 40, p. 647-662.

Sly, P.G., and Munawar, M., 1988, Great Lakes Manitoulin: Georgian Bay and the North Channel, Hydrobiologia, 163, p. 1-19.

US Army Corps of Engineers, 2002, CEM Part V – Coastal Project Planning and Design, Coastal Engineering Manual, p. 34-47.

van Luit, H., 1987, Blackstone Harbour: Management Plan Background Information Document, Ontario Ministry of Natural Resources, Division of Parks, Parry Sound, Ontario.

APPENDIX: GIS DATA SOURCES

a. Photo Bases from which islands were digitized

2004 data: WPSGN_Imagery, West Parry Sound GIS, Orthophoto, WMS server-based http://www.wpsgn.ca/datawarehouse.htm

2005 data: Nautical Chart 2202, Canadian Hydrographic Service

2007 data: FRI Imagery, Ontario Ministry of Natural Resources Forest Resource, Orthophoto, Forest Resource Inventory imagery, Block ID C1z17

2009 data: ArcGIS online basemap, ESRI ArcGIS Online, satellite image

2012 data: MassasauagaProvincialPark-2012, DigitalGlobe, WVII satellite image

b. DEM and TIN

Natural Resources Canada (NRCan) Bathymetry data, 1999, www.geogratis.gc.ca/