

Using Geographic Information Systems (GIS) to Map Bathymetric Changes in the Saint Croix River 1968-2008

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Introduction

- The Indianhead Flowage, located along the Saint Croix River (MNWI) between Taylors Falls and Sunrise River, was created by the building of the St. Croix Falls hydroelectric dam in 1908.
- Many dams create predictable sediment backup patterns, whereby the area above the dam begins to "backfill" (become more shallow) and the area below the dam becomes more sediment starved.
- Hornbach and Hove (2006) have recently observed an increase in sediment fineness in endangered mussel habitat below the Saint Croix Dam at Interstate State Park.
- Understanding how dams effect riverbed bathymetry may be key in understanding why an increase in fine sediment transport has recently occurred below the dam.
- The purpose of this project is to use GIS to study changes in riverbed bathymetry behind the Saint Croix Dam between 1968, 1975 and 2008.

How can we use GIS?

- Geographic Information Systems (GIS) is a powerful computer data processing and analysis tool that inputs raw spatial data and perform queries and analysis on data to visually display information.
- Although GIS is only as accurate as the data it works from, it allows for spatial processing and analysis at a faster, more precise, detailed level than similar human effort would procure.
- We used ESRI's ArcView9.2 (includes ArcMap, ArcView, and ArcCatalog plus basic spatial datasets) to visualize riverbeds, create bathymetric change maps, and display water velocity information.

Data Input & Processing

1968 Topographic Map

- Scanned version of map downloaded from the WI DNR in 3 parts.
- Each section of map was georeferenced in ArcMap. Control points were derived from ArcGIS shapefiles of USGS quadrangle grids and from clearly indicated river markers (e.g. dam locations, tributary intersections, etc.)
- River contours for each section were digitized into ArcGIS using the ArcEditor tool.
- The contour data was merged together to create a single shapefile of riverbed contours.
- Once a single shapefile of riverbed contours was complete, we used the Spatial Analyst tool "Topo to Raster" to interpolate the contours (vector data) to individualized cells of 3 meters X 3 meters (raster data) showing riverbed bathymetry.

1975 Topographic Map

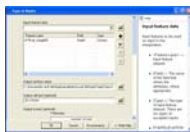
- Scanned version of a previously georeferenced 7.5 minute map downloaded from the USGS.
- River contours were digitized into ArcGIS using the ArcEditor tool.
- Once a single shapefile of riverbed contours was complete, we used the Spatial Analyst tool "Topo to Raster" to interpolate the contours (vector data) to individualized 3 x 3 meter cells (raster data) showing riverbed bathymetry.

2006 & 2008 Depth Points

- Depth points were collected with a Lowrance X25c sonar unit with integrated Trimble GPS with WAAS. These 30,000+ points were collected by crusing the flowage in July/August 2006 and 2008. The vast majority of our data points came from 2008; only a small portion of the mid and lower sections of river contained 2006 data. River heights taken at the USGS gauging station just downstream for July 2006 and August 2008 indicated the river height varied little between these 2 different years for these months; ~3 ft in July/August 2006, and ~2.5 ft in July/August 2008. However, we have accounted for some error between river gauge heights for these years and in the topographic maps by indicating a change of less than 0.5 meters as "no change".

Data Analysis

- Once we had created raster datasets showing the riverbed bathymetry for the years 1968, 1975, and 2008, we used the Spatial Analyst tool "Map Algebra" to create three change maps.
- Positive output values from map algebra indicate where the river is becoming shallower. Negative output values indicate where the river is becoming shallower.
- We estimated the water holding capacity of the river during each of these 3 time periods by using the Spatial Analyst tool "Surface Volume" to calculate the water holding capacity.



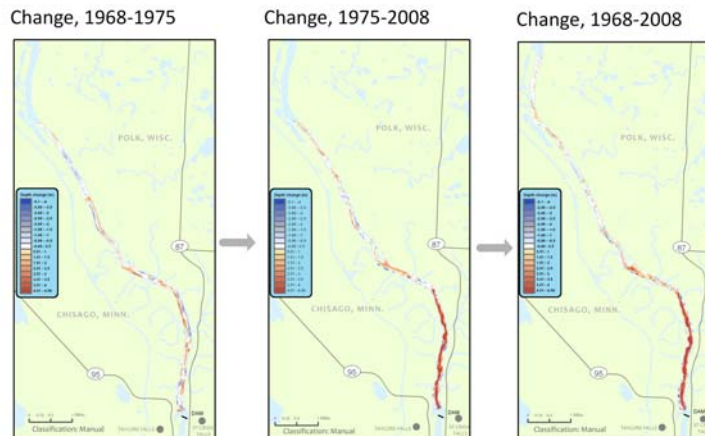
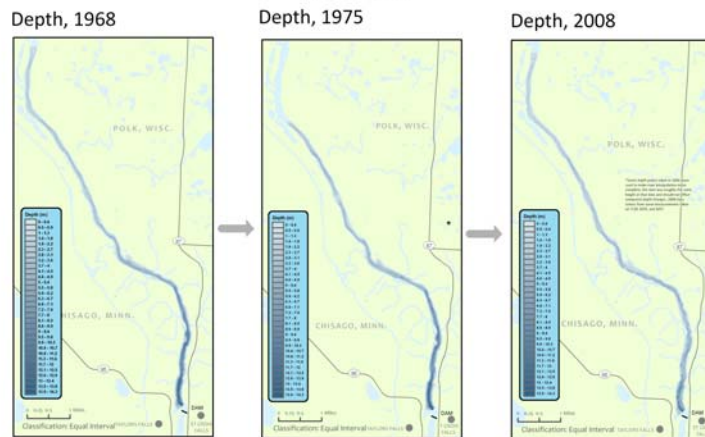
Interpolating sonar depth points to raster data using the "Natural Neighbor" function.



Interpolating river contours to raster data using "Topo to Raster" function.

Bathymetric Changes to the Indianhead Flowage

Between 1968, 1975, and 2008



Riverbed bathymetry in 1968 and 2008 just north of the Saint Croix Dam

Conclusions

- In 1968, the area just upstream of the dam is generally quite deep (about 10 – 15 meters).
- In 1975 the river was slightly deeper upstream of the westerly meander and becomes somewhat shallower downstream.
- By 2008, however, the river is significantly shallower especially between the Saint Croix Dam and the first westerly bend in the river (See 1968 to 2008 depth change detail map).
- In 1968, the holding volume of the river between the Saint Croix Dam and the Wild River boat launch was 10,987 km³.
- In 1975, the holding capacity was 9908 km³.
- By 2008, the holding capacity of the river was only 8,130 km³.
- Thus the holding capacity decreased 9.8% between 1968 and 1975.
- The volume loss was 17.9% between 1975 and 2008.
- There was a total loss of 2,857 km³ of water between 1968 and 2008.
- Overall, there was a 26% percent loss in volume between 1968 and 2008**
- One fourth of the water flowing through this section of the river in 1968 now backs up upstream or goes over the dam.**
 - Lenz (2004) has indicated that the discharge rate has increased below the dam over this period. He suggested that factors such as land use patterns due to increased population growth may be related to the increase.
 - Land use changes could lead to increased sedimentation and a decrease in the volume of the reservoir.

Caveats

- The results of this study are preliminary, and more work should be undertaken to assess changes to water velocity, flow levels, and sediment deposition more frequently throughout the year and over a greater time period for the Saint Croix River.
- It is also important to remember that the accuracy and precision of our data are only as good as the historical maps from which we worked.
- However, our results indicate that there has been significant backfilling of the river behind the Saint Croix Dam.

Acknowledgements

The National Park Service, Frenzel Fund for Macalester, Macalester College