Technological Advances IN Bathymetric Mapping Methodologies

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Abstract

Bathymetric mapping employs a diverse set of cartographic skills proceeding from the survey of lake depths, to the interpolation of depth contours, and the design and printing of maps that meet DNR standards. Over the past 20 years, advances in GPS, GIS and PostScript mapping technologies have reshaped bathymetric mapping methodologies. While the impact of these new technologies is evident in all three stages of bathymetric mapping, knowledge of glacial and fluvial landforms remains a critical asset for accurate mapping.

Lake Survey

A detailed and thorough lake survey is crucial for the construction of an accurate bathymetric map. With the advent of GPS technologies, free format xy-z point surveys have replaced transect surveys and 'Game Boy' data entry techniques yields a high number of depth points.

Geo-Processing

The second stage of bathymetric mapping involves using the lake survey to locate depth contours and calculate lake statistics. Geographic Information System (GIS) technologies provide fast and accurate coordinate based measurements of lake area and volume, and can accurately locate depth contours for glacial lakes. However, fluvial lake structures are still most accurately mapped manually, using survey data and knowledge of fluvial features to locate contours.

Map Production

The final stage of bathymetric mapping may be considered 'presentation.' The design and production of a bathymetric map should facilitate easy interpretation of lake depths and structures. PostScript map production via *Adobe Illustrator* facilitates the construction of smooth contour lines, with shading applied to clarify the sequencing of depths. To further aid interpretation of locational features, depth contour features may be placed over scanned aerial photographs or DOQ images to create a bathymetric PhotoMap. PostScript graphics support high-resolution image setter printing of lake maps and booklets, and PDF files for web display.

Advances in Lake Survey Techniques

Time Frame	Depth Measurement	Geo-Referencing	Positional Accuracy	Survey Strategy	Innovation
Pre 1960	Weighted Depth String	50' Grid Surveyed on Ice	2-5 Meters	XY-Z Point Data Collected at Grid Intersections	Produced First Generation of Lake Maps
1960-1992	Lowrance Graphing Depth Sounder	Locating Transects on Aerial Photographs	3-30 Meters Problems With Big Lakes	Transect Data Plotted on Aerial Photos	Graphing Sounder Records All Depths Along Transects
1992-1996	Lowrance Graphing Depth Sounder	Locating Transects with Trimble Pathfinder GPS	2-10 Meters	Transect Data Located by GPS in a GIS	GPS Improves Accuracy in Locating Transects
1997-1999	Furuno Depth Sounder with NMEA Output	Depths Located as Points with Trimble Pathfinder ProXR GPS	1 Meter	XY-Z Point Data organized along Transects with Free-Form Deviations in Areas of Interest	Free-Form Survey not Restricted to Transects and Automated Data Collection Interfacing Depth Sounder and GPS
1999-2000	HumminBird Wide3D Depth Sounder with Six Beam Display	Depths Entered as Points with Trimble Pathfinder ProXR GPS with Data Logger	1 Meter	XY-Z Point Data organized along Transects with Free-Form Deviations in Areas of Interest	High-Speed, Hand-Entered Data Collection of 600 to 1,000 Data Points per Hour

Geo-Processing Techniques

Survey Strategy	Mapping Survey Data	Mapping Depth Contours	Calculation of Bathymetric Statistics
Grid Surveys	• Locate Grid on Map or Aerial Photographs • Plot Intersection Depths • Draw Shoreline Based on Grid or Aerial Photo	• Manual Interpolation of Contour Depth Points Along Grid Lines • Hand Draw Contour Lines Connecting Contour Depth Points	Map-Based Measurement Skills
Transect Surveys	Human Technology • Locate Transects on Map or Aerial Photographs • Locate Contour Depth Points Along Transects	• Hand Draw Contour Lines Connecting Contour Depth Points • Draw Shoreline	Map-Based Measurement Skills
	GPS and GIS Technology • Use GPS Positions to Plot Shoreline and Transects • Digitize Depth Points Along Transects	• Computer Interpolation of Contour Lines • Check for Interpolation Error	Coordinate-Based GIS Measurement
XY-Z Point Surveys	• Use GPS Positions to Plot Shoreline and XY-Z Points • Plot Shoreline and Depth Points over a DOQ	*Fluvial Lakes* • Symbolize Depth Points • Hand Draw Contour Lines *Glacial Lakes* • Generate DEM • Interpolation of Contour Lines • Check for Interpolation Error	Coordinate-Based GIS Measurement

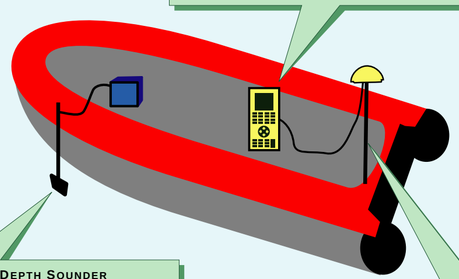
Map Production Techniques

Mapping Technology	Low-End Map Production	High-End Map Production
Traditional Map Production	Traditional Pen & Ink Line Artwork Hand Draw Contour Lines and Other Map Features	Photo-Chemical Map Production Screening Depth Shading Producing Color separations
GIS Map Production	Vector Graphics Coordinate-Based Linework Geo-Referenced Map Features organized in Map Layers	Surface rendering 3D TIN Surfaces Relief Shading Dynamic 3D Images
PostScript Graphics	PostScript Mapping Complete Artistic Control Via *Adobe Illustrator* High Resolution Map Production with Image Setter Printing Composition of Multi-Map Booklets	Photo-Mapping Maps Superimposed over Digital Aerial Photographs Hybrid of *Adobe Illustrator* and *Adobe PhotoShop* Skills Construction of Locational Maps

Lake Survey Technology

Trimble Asset Surveyor Data Logger

The Trimble Asset Surveyor Data Logger supports two modes of XY-Z data collection. First, the Data Logger may be interfaced with a sounder via a RS232 data port. The Data Logger reads NMEA depth data from the sounder every 10-20 seconds, and merges depths with lat-long coordinates. The 'Game Boy' method of hand-entered depths yields a much faster rate of data collection. First, a data dictionary is created that include point features for every one foot of lake depth (i.e. 1,2,...87). As the boat navigates the lake, the Data Entry Technician reads depths off the screen, and toggles through the data dictionary to the appropriate depth, and then records a GPS position named for its depth.



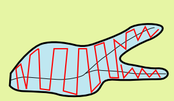
HumminBird Wide3D Depth Sounder with Six Beam Display

The HumminBird Sounder provides an accurate reading of water depth directly below the boat, and with a 6 beam scan, generates a 3D plot of lake structure on either side of the boat. Bathymetric Data Entry Technicians read depths off the screen, and enter depths via the datalogger. The sounder is placed at the front of the boat, such that in the time it takes to enter the depth, the boat will move the GPS antenna over the point where the depth was recorded. The 3D plot is a rolling display of lake structure on either side of the boat - and is used to locate areas of complex structure.

Trimble Pathfinder ProXR GPS

The ProXR is a 12 channel GPS receiver with a radio beacon processing real-time Differential GPS corrections. With adequate satellite positions (PDOP <4), the ProXR attains sub-meter accuracy on the fly. The accuracy of the ProXR, combined with a sounder interface or 'Game Boy' data entry, facilitates a 'free format' survey, rather than the more restrictive transect navigation. Simply put, the boat can be navigated throughout the lake in any fashion. The goal is to collect a great number of XY-Z data points spatially distributed throughout the lake.

Comparison of Mapping Strategies for Glacial and Fluvial Lakes

Glacial Lakes		Fluvial Lakes
	Knowledge of Lake Structures	
 Survey Transects Navigated to Criss-Cross Glacial Depressions	Lake Survey	 Survey Transects Navigated Perpendicular to Submerged River Channel
Glacial Lakes are well suited for a GIS Rendering of Lake Structure Generate DEM Based on XY-Z Data Points Set Interpolation Parameters Interpolation of Contour Lines Check for Interpolation Error	Locating Depth Contours	Significant Method Produced Errors Occur with GIS Interpolation that often Generates Glacial-Like Depression Contours. Despite All the available Technology, Manual Interpolation, Based on a Plot of Color Coded Depth Points and an Extensive Knowledge of Fluvial Structures, Still Yields the Best Results.

Bathymetric Mapping Workflow

1 Lake Survey

- Survey Technologies
  - Depth Sounder / Plotters
  - Depth Sounder / Plotters with GPS
  - Depth Sounder Interfaced with GPS
- Survey Techniques
  - Transect Survey with Air Photographs
  - Random Survey based on Lake Structure
  - Field Checking Draft Contours
  - Collecting Lake Bottom Samples

2 Geo-Processing Survey Data

- Exporting GPS Data to GIS (ArcView)
- Mapping Depth Data
- Plotting Depth Contours
  - Software Based Interpolation
  - Controlling for Interpolation Error
  - Attuning Contours to Landforms

- Lake Measurement with GIS
  - Lake Area
  - Lake Volume
  - Impact of Dam or Lake Level Drawdowns
  - Length of Shoreline
  - Developed Shoreline - Eroded Shoreline

3 Map Construction in *Illustrator*

- Draw Shorelines and Depth Contours
- Symbolize Developed and Eroded Shoreline
- Locate & Symbolize Boat Landing and Parks
- Locate & Symbolize Lake Vegetation Info
- Locate & Symbolize Lake Bottom Sediments
- Locate & Symbolize Fish Cribs and hazards
- Draw and Label Roads and Civil Divisions
- Scan, Edit and Add Photo / Images
- Construct Lake Area and Lake Volume Graphs
- Print Draft • Review • Edit Artwork

4 Map Review and Editing

- Review by Wisconsin DNR
  - Depth Contours and Map Content
  - Adherence to DNR Lake Mapping Standards
- Review by Other Funding Agencies
  - NSP • USACOE • Lake Management Groups
- Make Changes and Corrections to Maps
- Repeat Review Cycle
  - DNR → NSP → Other Agencies
- Make Final Changes and Corrections to Maps

5 Map Printing

- Design of Printing Format and Layout
  - Divide Map into Booklet Pages
- Convert Map Files to Printer's Format
- Test Print Files on High Resolution Printer
- Fine-Tune Graphics and Edit as Needed
- FINAL DNR Approval of Map
- Print Map Booklets