Bathymetry, GPS and GIS: Techniques for Mapping Nebraska Reservoir Volumes

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Abstract

Using GIS in combination with GPS and bathymetry has enhanced the collection, analysis, and interpretation of data on the volume of water in Nebraska reservoirs. Historically, sediment accumulation due to erosion of soils in the watershed has decreased the storage capacity of the reservoirs. It is important for managers to have an accurate determination of each reservoir's capture capacity. Utilization of GIS with GPS and bathymetry is an efficient approach to volume determination.

This paper describes tools and methods to grid and incorporate spatially distributed field data. The incorporation of GRID, TIN, ArcMap, and ArcScene as analysis tools is described.

INTRODUCTION

Understanding the hydrologic and topographic characteristics of Nebraska's reservoirs, and how those characteristics have changed over time, is essential for the effective management of these valuable resources. Reservoirs experience physical changes as a result of sediment deposition, shoreline erosion, and wind processes over time. The lake headwaters can be influenced by sedimentation resulting from deposition of stream sediments as water enters the reservoir. By comparing the current bathymetric surveys to final-graded as-built survey data collected during reservoir construction, it is possible to assess quantities and rates of reservoir sedimentation. This data collection project was in cooperation with the Nebraska Department of Environmental Quality (NDEQ).

GPS AND BATHYMETRY – DATA COLLECTION

Bathymetric data are collected as a series of cross-section lines (Figure 1) across the reservoir perpendicular to the longitudinal axis of the reservoir streamline. The lines are 30 to 45 feet apart. The bathymetry data are collected using a U.S. Geological Survey (USGS) boat with a survey grade echo sounder using a 200-kHz transducer (Innerspace Technology, 2001), and a Differentially corrected Global Positioning System (DGPS) with the antenna mounted over the echo sounder transducer. The echo sounder collects discrete depth points approximately 1 foot apart depending on water depth, boat speed and other operational parameters. The error range of the bathymetric data is plus or minus .5 foot.

Data collection for above water features starts with a base station set at a known National Geodetic Survey (NGS) benchmark. The base station sets the vertical and horizontal control for the data collection. For quality control, DGPS is collected at two more NGS benchmarks. At the reservoir site, point features, including impoundment structure elevation, water's edge, and additional land features, are collected. If the reservoir elevation is below full pool level, more control points are taken at the water's edge, and incrementally up the slope to full pool elevation.

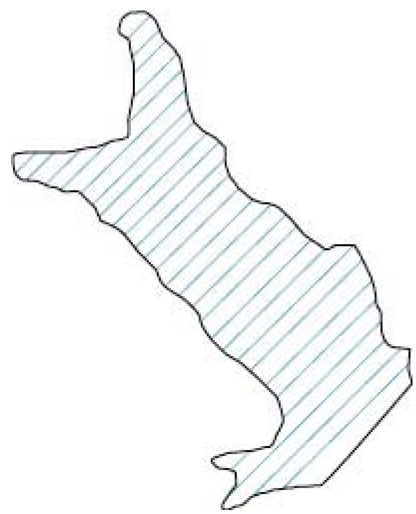

Figure 1. Schematic of cross-section lines in a reservoir.

GIS PROCESSING

The data from the cross-section lines, DGPS survey, water's edge points and control points are received as a text file of northing and easting coordinates and depth. All data are projected and converted to a common projection (Universal Transverse Mercator (UTM) zone 14) and horizontal North American Datum 1983 (NAD83) and North American Vertical Datum 1988 (NAVD 88) for use in geographic information system processing (Snyder, 1982). The text file is used to generate the point coverage. The point coverage is plotted with a digital orthophotograph quadrangle (DOQQ) of the reservoir and surrounding area in ArcMap (figure 2), to assure the data reasonably cover the reservoir and to inspect for data errors.

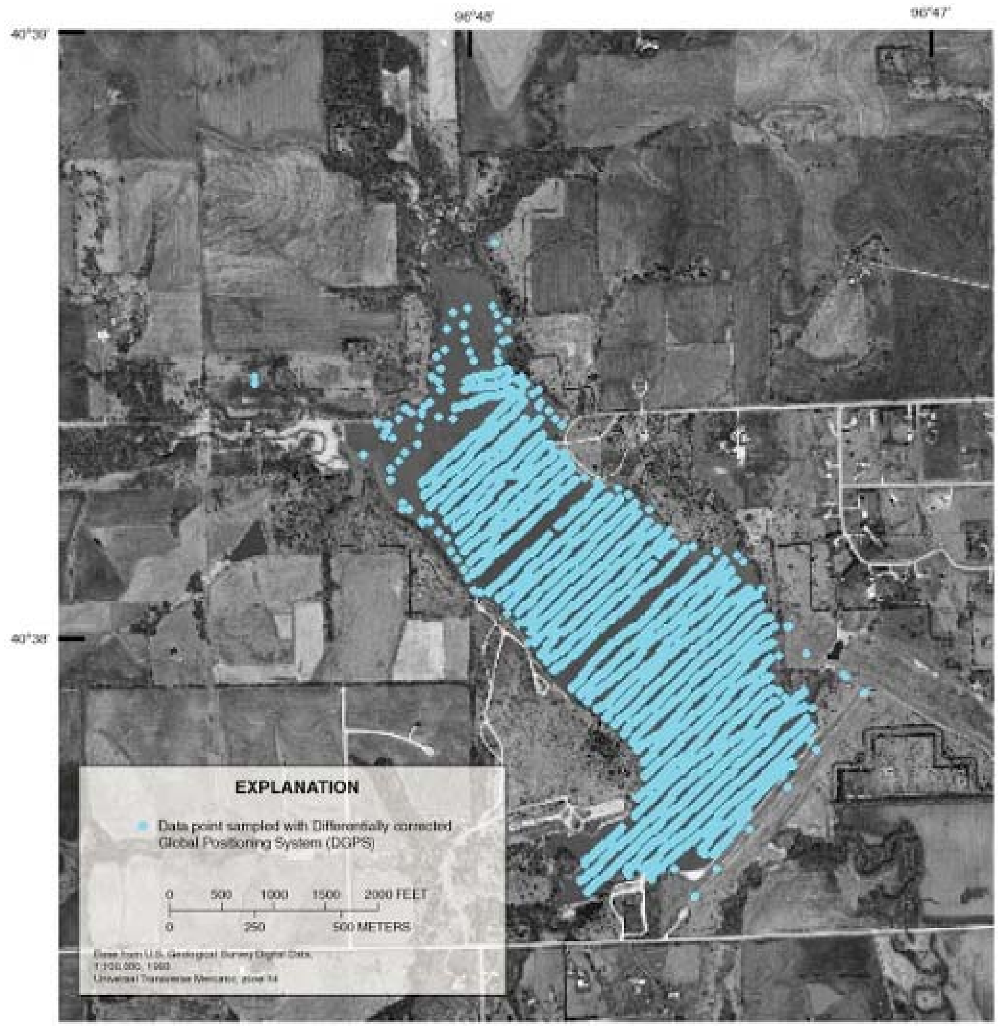

Figure 2. Density of sampled points plotted on a DOQQ.

A Triangulated Irregular Network (TIN) surface is generated from the bathymetric data. The TIN surface is contoured using a 2-foot contour interval. The contour lines are plotted over the DOQQ and Digital Raster Graph (DRG) to assess any errors or anomalies in the TIN or input data. After several iterations, the final contour lines derived from the TIN surface are smoothed in ArcEdit, using the spline and grain tolerance settings. A final map with a 2-foot contour interval is produced (figure 3).

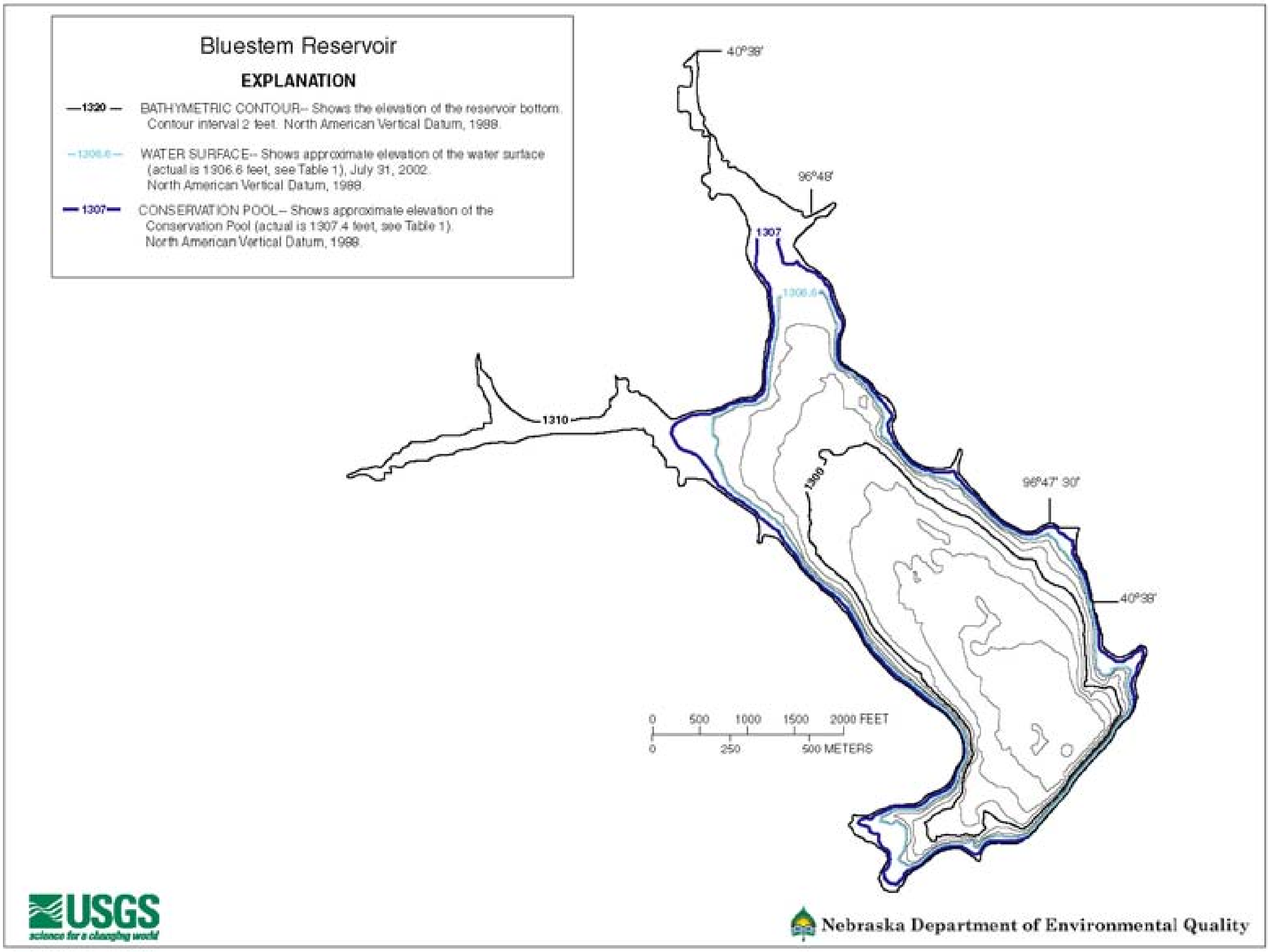

Figure 3. Example of the final contour map.

VOLUME DETERMINATION

An elevation, area and volume table is calculated from the final TIN surface. The volume table is generated at a 1-foot interval using the *VOLUMES* command at the ARC prompt. The final table contains the elevation, area and volume in acre-feet (figure 4).

Elevation (feet)	Area (acres)	Volume (acre-ft)	Elevation (feet)	Area (acres)	Volume (acre-ft)
1,291.0	0.0	0.0	1,300.0	147.5	587.9
1,292.0	1.6	0.4	1,301.0	163.3	743.3
1,293.0	12.7	6.1	1,302.0	180.0	914.4
1,294.0	31.5	28.7	1,303.0	196.9	1,103.4
1,295.0	54.1	71.5	1,304.0	212.7	1,308.2
1,296.0	73.8	135.4	1,305.0	225.9	1,527.5
1,297.0	96.1	221.0	1,306.0	236.4	1,758.8
1,298.0	114.4	325.7	1,306.1	237.4	1,782.5
1,299.0	131.1	448.5	1,307.0	248.0	2,000.5

Figure 4. Example of reservoir elevation, area and volume table.

ARCSCENE

ArcScene is a tool used to visualize the initial point data as well as the final TIN and contour data. In the following figure, the final TIN is converted to a grid format and combined with a Digital Elevation Model (DEM) for use in ArcScene (Figure 5). ArcScene allows managers to view the original conditions, resurveyed reservoir bottom and sediment distribution data in three dimensions.

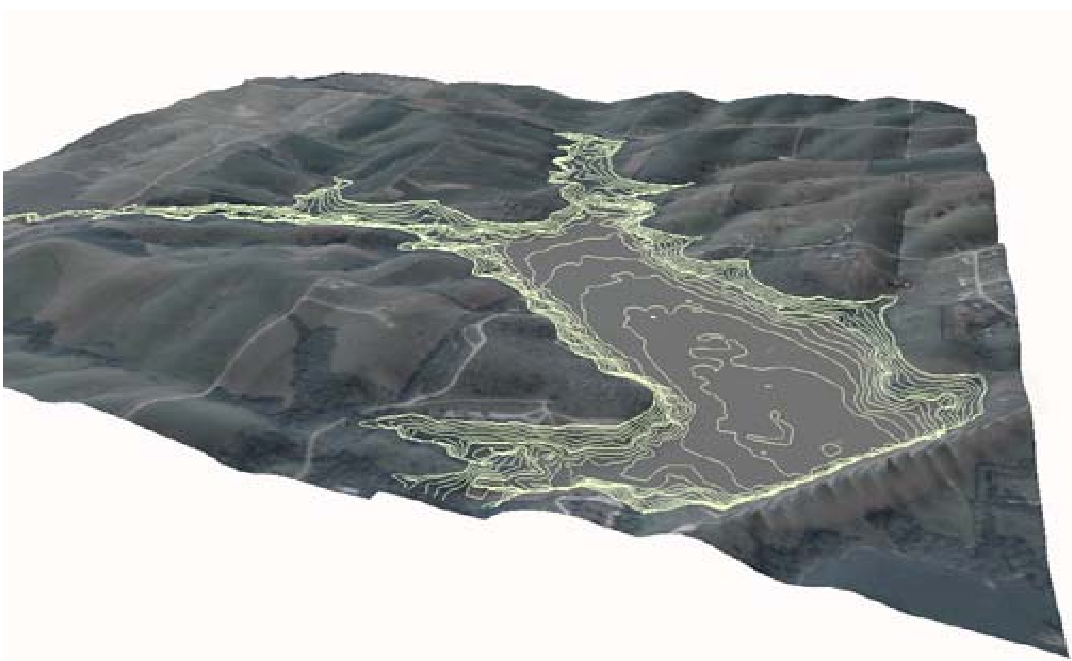

Figure 5. Example of a three-dimensional surface draped with a DOQQ and contour lines. Scale varies in this perspective.

CONCLUSIONS

Water resource managers are concerned with the loss of storage caused by sediment accumulation in Nebraska reservoirs and need a reliable, cost-effective method to determine the degree of storage loss in the reservoirs. Integration of GPS and echo sounder data with GIS software is an efficient and cost-effective way to determine the current storage capacity and to map the bathymetry of a reservoir.

ACKNOWLEDGEMENTS
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REFERENCES

Innerspace Technology, 2001, Model 456 Survey Echo Sounder Owners Manual, Waldwick, N.J. Accessed 3-1-03 at http://www.innerspacetechnology.com/depth_sounding.htm

Snyder, John P., 1982, Map Projections Used by the U.S. Geological Survey. 2d ed. United States Government Printing Office, Washington, D.C., 313 pages.

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