Rejuvenating pre-GPS era geophysical surveys with *The National Map*

Tom Shoberg

CEGIS/USGS
1400 Independence Road
Rolla, MO 65401-2602
(573) 308-3582
tshoberg@usgs.gov

Michael P. Finn

CEGIS/USGS
Box 25046
Denver Federal Center
Mail Stop 510
Denver, CO 80225-0046
(303) 202-4544
mfinn@usgs.gov

http://cegis.usgs.gov

Paul R. Stoddard

Department of Geology and
Environmental Geosciences
Northern Illinois University
DeKalb, IL 60115
(815) 753-7929
pstoddard@niu.edu

1. Overview

Old geophysical surveys [pre-Global Position Systems (GPS)] stand as a valuable, largely untapped source of scientific data. If these data were in a format that had accuracy, availability, and ease-of-use, they could have a much wider usage. In this paper a pre-GPS survey is integrated into a modern geographic database, *The National Map*. For this investigation, a unique set of data including pre-GPS positional coordinates and elevations interpolated from United States Geological Survey (USGS) topographic 7.5' quadrangles (Cook Station, Cherryville, and Indian Springs), GPS coordinates, and coordinates determined from *The National Map* (*TNM*), and **Li**ght **D**etection **a**nd **R**anging (LiDAR), are compared (see section 3). The comparison of these different data sources indicates that more than 85 percent of the stations could be positioned on the national database within a horizontal distance of 15 meters of the GPS reoccupation location and within 2 meters of the LiDAR elevation data. While on-line database coordinate accuracy is likely to improve with time (especially elevation), these results imply that Web databases have already matured to a point that it is possible to integrate survey coordinate data with a reasonable assurance of positional accuracy.

2. Survey Location

The data cover the Crooked Creek impact structure located in Crawford and Dent Counties in Missouri about 15 kilometers (km) southwest of the city of Steelville. The area of investigation is bounded by 37.89ºN on the north, -91.33ºW on the east, 37.77ºN on the south and -91.47ºW on the west, covering 165 km^2 (fig. 1).

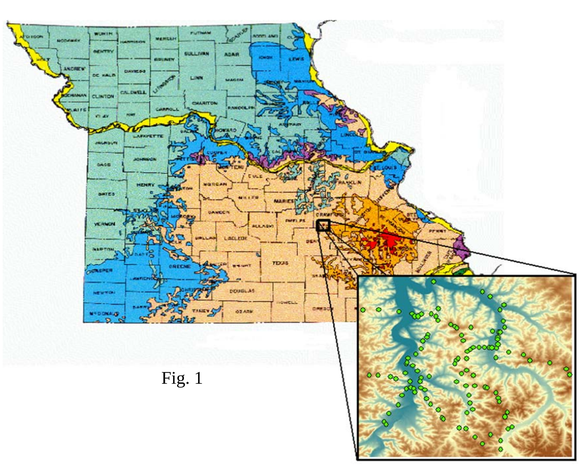

Fig. 1

Fig. 2: Analog Photograph of Station A-27. Photographs like these along with entries in field notebooks made for easy station reoccupation.

3. Data

The following datasets were compiled/used in this study:

- Field notebooks
- Analog photographs (fig. 2)
- Digitized x,y,z coordinates from USGS 7.5' quadrangle maps
- GPS x,y,z coordinates (with uncertainties)
- TNM x,y,z coordinates (with uncertainties, fig. 3)
- LiDAR x,y,z coordinates (fig. 4)
- Digital orthophoto quarter quadrangles (DOQQ, fig. 5)

4. Method

First Occupation:

1) Planned survey station points plotted on 7.5" USGS topographic quadrangle maps
2) Points adjusted (as necessary) during survey occupation
3) Station descriptions in field notebooks and analog photographs recorded
4) x, y, z coordinate triplets digitized from USGS topographic maps.

Reoccupation

5) x, y, z coordinate triplets and uncertainties obtained by GPS

LiDAR

6) LiDAR 'bare-earth' elevation data acquired (fig. 4).

In Lab

6) x, y, z coordinate triplets and uncertainties obtained through positioning stations on the interactive web-browser for *The National Map* (fig. 3).
7) Confidence limits derived from GPS, LiDAR, digitized topographic map coordinates and *The National Map* coordinates (table 1).
8) Differences in position and elevation computed for each set of coordinates (table 2).

Table 1: Average 95% Confidence Limits

	Elevations (m)	Horizontal Distance (m)
GPS	2.69 (8.81 ft)	0.91 (3.00 ft)
LiDAR	0.35 (1.15 ft)	4.96 (16.26 ft)
National Map	3.71 (12.17 ft)	18.10 (59.27 ft)
Topographic Sheets	6.17 (20.23 ft)	20.48 (67.20 ft)

Table 2: Average Differences Between Horizontal and Vertical Coordinates

	GPS-LiDAR	*The National Map* – GPS	*The National Map* – Digitized Topo Sheets	LiDAR – *The National Map*	GPS - Digitized Topo Sheets
Elevation	1.05 m (3.45 ft)	1.51 m (4.96 ft)	1.68 m (5.52 ft)	1.22 m (4.00 ft)	1.42 m (4.65 ft)
Horizontal Distance	___	14.26 m (46.78 ft)	20.71 m (67.93 ft)	___	21.19 m (69.53 ft)

Fig. 3: Location of coordinate picks: GPS (red circle), *The National Map* (blue triangle) and digitized coordinates (green rectangle). Large circle is 95% confidence limit associated with *The National Map* coordinates.

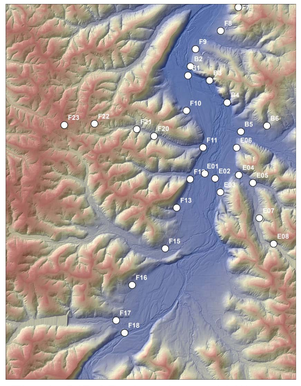

Fig. 4: LiDAR elevation and hillshade data. Survey stations are shown as labeled circles. Local roads and streams are clearly visible with the LiDAR data.

Fig. 5: Digital Elevation Model (DEM) with DOQQ overlay of survey area. Station locations are shown by triangles. Red triangles show stations where GPS coordinates differ significantly (95% confidence limit) from *The National Map* coordinates.

5. Results

Of the 109 stations recorded using the GPS, five were found to disagree with both LiDAR and *The National Map* elevations at the 95% confidence level (the five stations are shown in red in fig. 5). The agreement in of horizontal coordinate values between GPS and *The National Map* appear to be quite good as does elevation value comparisons between GPS sites, LiDAR data, and *The National Map*. Fig. 6 shows the agreement between the coordinates of stations placed on *The National Map* with their respective GPS coordinates. This comparison shows that 86% of the stations located on *The National Map* are within a 15 meter (50 foot) radius of their corresponding GPS positioning. In essence, it is clear that with well-documented field notes, it is possible to accurately recreate the station horizontal coordinates on *The National Map*, particularly when the station locations are at clearly discernable locations such as road intersections. The elevation data are slightly more problematic, largely because of the higher standard of accuracy required for a good fit. 40.4% of all stations show a less than 1 meter difference between elevations derived from *The National Map* and those recorded by GPS receivers, further 73.4% of all stations show a difference within 2 meters of each other (fig. 7). Also, 82% of the elevations read from *The National Map* were within 2 meters of the LiDAR data. The GPS coordinates displayed a much better agreement, with more than 62% of the stations reporting a less than 1 meter difference in elevation from the LiDAR data.

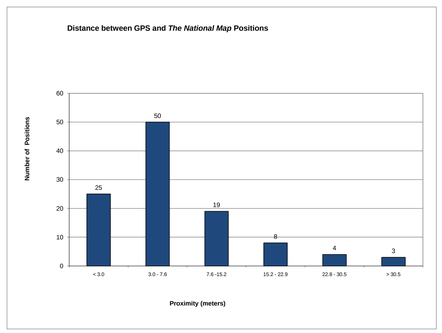

Fig. 6: Horizontal distances between GPS and National Map coordinates. 94 (of 109) stations from *The National Map* were within 15.2 m of corresponding GPS locations

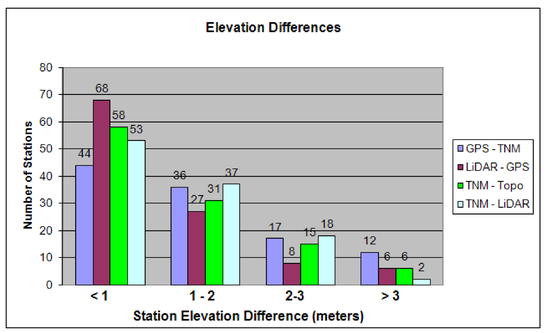

Fig. 7: Elevation difference between GPS, *The National Map*, LiDAR and digitized topographic sheets. There is good agreement at 2 m or less for all methods of coordinate extraction.

6. Conclusion

The advent of large geographic databases available for use over the World Wide Web has the potential to greatly facilitate the preparation, dissemination, and archiving of geophysical surveys. In particular the ability to locate landmarks associated with surveys such as road intersections, creek crossings, and parking lots, using precisely registered DOQQs has the potential to greatly affect methods of survey preparation, archiving, and reacquisition. Also, the integration of DOQQs with elevation data sets such as LiDAR or NED give the potential for any user to precisely locate in three dimensional space, any or all stations from a survey. Although elevation control is better constrained than the horizontal control (a few meters precision for elevation, a few tens of meters for horizontal control), usually for geophysical surveys the data are more sensitive to vertical inaccuracy than horizontal. Nevertheless, as vertical precision on noted landmarks continue to improve, it may soon be possible to place pre-GPS survey data inside such a database and not only rejuvenate its utility, but actually improve its quality. As the cost of acquiring new survey data continues to increase, the need for storing old survey data in a manner that provides accurate, available, and easy access will increase. It is clear that Web-based geographic systems such as *The National Map* have matured to a level that such an archiving system is possible.

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