GIS **Matters**

By Rj Zimmer, LS

Rj Zimmer is registered in Oregon and Montana, and has more than 27 years of surveying experience as well as more than 17 years of GIS experience in the private and public sectors. He is a GIS Consultant and manages the GIS Center for the City of Helena and Lewis & Clark County in Montana.

Certifying the Spatial Accuracy of GIS Data

One important role that surveyors have in Geographic Information Systems is to certify the spatial accuracy of GIS data. GIS metadata standards require a statement about spatial accuracy. Usually those statements are rough, unsubstantiated estimates. Generally, such rough estimates are sufficient to give the user or potential user of the data an adequate idea about the utility of the data for one purpose or another. However, such statements are often mere guesses and do not provide any level of assurance of the spatial accuracy. Nevertheless, there are instances when a higher level of assurance of the spatial accuracy of a dataset is important. In order to ensure that the accuracy is sufficient for the intended use, examples of GIS datasets that might be certified would include:

- those used for regulatory purposes (such as flood plain maps);
- those that serve as a base layer upom which other GIS layers are built (such as aerial photography);
- those used to align other GIS layers;
- those used as a basis to determine the spatial accuracy of other datasets; or
- those used for engineering design.

To certify accuracy is to provide a higher level of assurance than to merely state accuracy. To certify is to attest authoritatively: to attest as being true or as represented or as meeting a standard; to inform with certainty: to assure. Anyone may make a statement regarding the accuracy of a GIS dataset, but only a surveyor has the training, experience, and thus the credentials to provide the weight of an authoritative assurance to a statement of spatial accuracy. Surveyors are experts at measuring, detecting measurement blunders, isolating errors, designing error detection procedures, and error analysis. Surveyors know how to gather sufficient measurement data to estimate the spatial error of a dataset, and how to estimate the magnitude and types of error inherent in the measurement equipment and the atmospheric effects on measurements and equipment. The surveyor also understands how to employ redundant measurements, as well as how to analyze the measurement data to determine the accuracy of the measurements, and thus estimate the accuracy of a dataset.

> **[As [people] come to appreciate the importance of reliable spatial accuracy statements, surveyors will increasingly be called upon to certify the accuracy of GIS data.]**

There are two types of spatial accuracy certification: *qualitative* and *quantitative.* Qualitative certification is a statement that the spatial accuracy meets a particular standard, such as *National Map Accuracy Standards*, or *Accuracy Standards for Large-Scale Maps* by the American Society for Photogrammetry and Remote Sensing (ASPRS). A quantitative certification is simply a statement of the numerical value of the accuracy (or error) of a dataset, without reference to a standard. Either type of certification may be called for or both may be used together, depending on the needs of the data developer, the client, the intended use, or standards for an industry. However, it is good practice to always include a quantitative statement when stating whether or not a map or dataset conforms to a qualitative standard. Qualitative accuracy reports require that one determine the magnitude of error, that is, to quantify the accuracy and compare that error against a standard to determine whether or not it meets that standard, or which class within a standard the accuracy does fall.

Where to Find Standards

Map and digital data spatial accuracy standards exist and anyone who has a mapping project may elect to apply an existing standard a dataset. When existing standards are insufficient or inapplicable, one may devise a threshold for accuracy based on the requirements for a particular use of a dataset. The more common standards are the *U.S. National Map Accuracy Standards, the ASPRS Standards for Large Scale Maps*, the Federal Geographic Data Committee standard for geospatial positioning, and the U.S. Army Corps of Engineers standards manuals.

USGS Standards

The United States National Map Accuracy Standards "defines accuracy standards for published maps, including horizontal and vertical accuracy, accuracy testing method, accuracy labeling on published maps, labeling when a map is an enlargement of another map, and basic information for map construction as to latitude and longitude boundaries." (http://geography.usgs.gov/standards/)

ASPRS Standards

ASPRS has draft standards that are useful for aerial photography and photogrammetry. They are referenced often, and provide excellent guidelines for photography and photogrammetry projects. (www.asprs.org/)

FGDC Standards

The Federal Geographic Data Committee developed four standards for positioning that are of interest to the surveyor. The standards are for reporting methodology, geodetic control networks, spatial data accuracy, and architecture/engineering/construction (A/E/C) and facilities management. The aim of the FGDC standards is to provide consistency in determining and reporting spatial accuracy and, for certain categories of data such as A/E/C, to provide accuracy thresholds for data. The Geospatial Postitioning Accuracy Standards may be found on the FGDC website, and they are very important standards for the geospatial community:

- Part 1, Reporting Methodology, FGDC-STD-007.1-1998
- Part 2, Geodetic Control Networks, FGDC-STD-007.2-1998
- Part 3, National Standard for Spatial Data Accuracy, FGDC-STD-007.3-1998 (The U.S. Geological Survey has submitted a proposal to revise this standard.)
- Part 4: Architecture, Engineering Construction and Facilities Management, FGDC-STD-007.4-2002

Federal agencies and the GIS community are encouraged to follow FGDC standards for geospatial positioning accuracy. As an example, the "objective" and "scope" of the National Standard for Spatial Data Suucracy (Part 3) is shown below:

Objective
The National Standard for Spatial Data Accuracy (NSSDA) implements a statistical and testing methodology for estimating the positional accuracy of points on maps and in digital geospatial data, with respect to georeferenced ground positions of higher accuracy.

Scope
The NSSDA applies to fully georeferenced maps and digital geospatial data, in either raster, point, or vector format, derived from sources such as aerial photographs, satellite imagery, and ground surveys. It provides a common language for reporting accuracy to facilitate the identification of spatial data for geographic applications.

This standard is classified as a ***Data Usability Standard*** *by the Federal Geographic Data Committee Standards Reference Model . A Data Usability Standard describes how to express "the applicability or essence of a dataset or data element" and includes "data quality, assessment, accuracy, and reporting or documentation standards" (FGDC, 1996, p. 8) This standard does not define threshold accuracy values. Agencies are encouraged to establish thresholds for their product specifications and applications and for contracting purposes. Ultimately, users identify acceptable accuracies for their applications. Data and map producers must determine what accuracy exists or is achievable for their data and report it according to NSSDA.*

It is important to note that, in most instances, the FGDC Geospatial Accuracy standard does not describe what accuracy a dataset *ought* to have, rather, the standard describes procedures for determining the accuracy and a language for communicating the accuracy.

Corps of Engineers

The U.S. Army Corps of Engineers is responsible for developing and maintaining the A/E/C geospatial positional accuracy data standards for the Facilities Working Group of the Federal Geographic Data Committee. Address questions concerning the standards to: Headquarters, U.S. Army Corps of Engineers, ATTN: CECW-EP, 20 Massachusetts Avenue NW, Washington, D.C. 20314-1000. www.usace.army.mil/usace-docs/eng-manuals/em1110-1-1000/toc.htm

Determining Accuracy

Basically, the procedures to determine the spatial accuracy of a dataset are to identify distinct point features in the test dataset; obtain the coordinates of those points from the dataset; perform field measurements or measurements in a comparison dataset of the same features (independent source); compare the two sets of measurements; and report the results.

There are two methods for determining the spatial accuracy of a dataset, perform new field measurements or perform comparative measurements against another (independent) dataset that is know to have a higher spatial accuracy than the test dataset. To determine the spatial accuracy of a dataset, one must select distinct points on the dataset that can be located on the ground or located in a reference dataset. Some examples of test features for spatial accuracy testing are shown in the chart below.

DATASET	TEST FEATURES
Aerial Photography	road intersections, fence corners, manholes
Parcel lines	property corners, right-of-way
Contours	vertical and horizontal location of sidewalk corners, rock outcrops, existing bench marks

The number of sample points to measure should consist of sufficient number of points to provide a statistically reliable level of confidence in the determination. The Federal Geographic Data Committee (FGDC) recommendation *(Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data Accuracy)* is to measure a minimum of twenty (20) test points. If twenty test points are used, then one

ASPRS Accuracy Standards

These data were checked for accuracy and found to conform to the ASPRS standard for Class (1., 2., 3.) Accuracy.

ASPRS Accuracy Standards for Large-Scale Maps Class 1 horizontal (x or y) limiting RMSE for various map scales at ground scale for *metric* units.

MAP SCALE	CLASS 1 PLANIMETRIC ACCURACY LIMITING RMSE (METERS)
1:50	0.0125
1:100	0.025
1:200	0.050
1:500	0.125
1:1,000	0.25
1:2,000	0.50
1:4,000	1.00
1:5,000	1.25
1:10,000	2.50
1:20,000	5.00

measurement can fail the test at the 95% percent confidence level for a given threshold. Other numbers of test points (more or less), may be used depending on the number of features in the dataset, scale of the data, availability of the test points, field access issues, etc.

The geographic distribution of the test points should correspond with the distribution of the features within the dataset, unless other factors indicate otherwise. Other factors may be such things as physical and legal accessibility of the selected points for field measurements, which features or areas in the dataset are more important, the location and distribution of features in the dataset.

Reporting

Reporting conventions vary according to the standard that is being used. Examples are listed below. Spatial accuracy reporting consists of a statement of the numerical accuracy of the dataset at the 95% confidence level, and/or the standard met (or failed). In addition to a statement of the standard and/or numerical value, one should also include a description of how the test measurements were made, and the methods used to determine the spatial accuracy. Numerical accuracy should be reported in ground units. Depending on requirements, there may be statements of horizontal accuracy and/or vertical accuracy. Also note that spatial accuracy certification may be part of the data compilation, and not necessarily a post-compilation accuracy test. Statements regarding compilation are usually similar to statements for testing but for the substitution of the word *compiled* for the word *tested.*

A simple numerical statement of spatial accuracy may look something like the FGDC statement:

Tested __ (meters, feet) horizontal accuracy at 95% confidence level (Part 1, Reporting Methodology, FGDC-STD-007.1-1998)

Quantitative statements such as National Map Accuracy Standards or ASPRS are listed with the charts.

Metadata Statements

Although there are a variety of forms for metadata, the most commonly accepted form is the FGDC format. The FGDC for guidelines on how to report the spatial accuracy of a digital dataset in a (FGDC compliant) metadata report (section 2) are shown below:

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Assessment/Horizontal_Positional_Accuracy_Value)

and/or:
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Assessment/Vertical_Positional_Accuracy_Value)

Enter the text "National Standard for Spatial Data Accuracy" for these metadata elements (Federal Geographic Data Committee, 1998, Section 2), as appropriate to dataset spatial characteristics:

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Assessment/Horizontal_Positional_Accuracy_Explanation)

and/or:
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Assessment/Vertical_Positional_Accuracy_Explanation)

As the GIS community and the public come to appreciate the importance of reliable spatial accuracy statements, surveyors will increasingly be called upon to certify the accuracy of GIS data.

National Map Accuracy Standards

This map complies with National Map Accuracy Standards of 1947 for horizontal [or vertical or horizontal and vertical] accuracy.

NATIONAL MAP ACCURACY STANDARDS FOR LARGE SCALE MAPPING

SCALE 1 INCH = X	FEET	HORIZONTAL ACCURACY (FT)	VERTICAL ACCURACY (FT)
1:1200	100	3.33	[Contour Interval]*0.5
1:2400	200	6.67	[Contour Interval]*0.5
1:4800	400	13.33	[Contour Interval]*0.5
1:12000	1000	33.33	[Contour Interval]*0.5
1:24000	2000	40.0	[Contour Interval]*0.5