ASPRS' TENTATIVE MAP ACCURACY STANDARDS FOR LARGE-SCALE MAPS

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Spatial accuracy standards used for maps compiled in the United States have been the United States National Map Accuracy Standards. These standards were originally adopted in 1947 by the Bureau of the Budget [1947] and used with little modifications since that time. With the introduction of digital processes in the collection, compilation and distribution of maps and map related information, it became evident that a new standards of spatial accuracy was necessary. Beginning in 1979, within the American Society of Photogrammetry, a series of steps were taken to initiate a standards setting process. A Standards Committee was formed and chaired by Maurice E. Lafferty. This was followed by the formation of a Standards Steering Committee chaired by Morris M. Thompson and this lead to a Task Committee for Photogrammetry Standards. By 1982 the standards setting activity had been reorganized under the Standards and Specifications Committee of the Professional Practice Division of the American Society for Photogrammetry and Remote Sensing (ASPRS).

During the period between 1979 and 1987, the standards setting process within the Society evolved. Early work during this period included preparation of standards for image based maps, metric quality photography and for map spatial accuracy standards. It became evident that care should be taken that all parties concerned with the ultimate use of the standards be involved with the preparation of the standard. Procedures were established by the Committee to assure a balance of member representation including both users and producers of large scale maps. This concept of "due process" was reinforced by the United States Supreme Court decision against the American Society of Mechanical Engineers in favor of Hydro Level for lack of due process. This decision resulted in an award of $1,000,000.00 and caused the Committee to reassess its procedures to assure due process. This resulted in the adoption of procedures similar to those of the American National Standards Institute [ANSI, 1982]. Upon approval by the ASPRS Board of Direction, the preparation of the map accuracy standard continued in accord with ANSI like procedures.

As the draft for the map accuracy standard developed, it was published several times for comments. In addition, open public sessions were held to explain the standard and to encourage discussion and questions. Public sessions were held at:

- Niagara Falls, ASP/ACSM semi-annual meeting, October, 1980
- Denver, ASP/ACSM annual meeting, March 1982
- Washington, D.C., ASPRS/ACSM annual meeting, March 1986
- Baltimore, ASPRS/ACSM annual meeting, March 1987

As a result of the publications and open meetings, it was possible to form a broad user's community consensus on the map accuracy standard. A final draft was accepted unanimously by the Standards and Specifications Committee and subsequently by the ASPRS Board of Directors at its March 1988 meeting in St. Louis.

The standard, which is included with this paper, is maintained by the ASPRS as a voluntary technical standard and is offered as an alternative to the U.S. National Map Accuracy Standard for Large Scale Maps. Since it is understood that in time, changes to the current standard may be adopted, it is requested that comments pertaining to the current standard be sent to:

Chairman, Standards and Specifications Committee/PPD
The American Society for Photogrammetry and Remote Sensing
210 Little Falls Street
Falls Church, VA 22046-4398
USA

The new map accuracy standard is believed to be an improvement in that it facilitates the estimates of spatial accuracy after the merger of spatially related digital data files. With digitally based processes, the possibility of merging a series of map data sets, each taken from maps of different scales and quality, makes it desirable to state accuracy in terms of the only spatially common factor, that is at full or ground scale. The new standard states spatial accuracies at ground scale.

In addition, the new standard specifies a test procedure to assess compliance of a map with the spatial accuracy statements. The concept of the test is based on comparison of test points on the map (in plan and in elevation) to those determined independently by a survey of higher accuracy. Test survey requirements are stated in terms of survey standards adopted by the Federal Geodetic Control Committee of the United States [FGCC, 1984].

The ASPRS map accuracy standard is presented in the following paragraphs followed by a series of explanatory comments in the Appendix.

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ASPRS INTERIM ACCURACY STANDARDS FOR LARGE-SCALE MAPS

The American Society for Photogrammetry
and Remote Sensing - 1988

These standards have been developed by the Specifications and Standards Committee of the American Society for Photogrammetry and Remote Sensing (ASPRS). It is anticipated that these ASPRS standards may form the basis for revision of the U.S. National Map Accuracy Standards for both small-scale and large-scale maps. A major feature of these ASPRS standards is that they indicate accuracy at ground scale. Thus, digital spatial data of known ground-scale accuracy can be related to the appropriate map scale for graphic presentation at a recognized standard.

These standards concern the definitions of spatial accuracy as they pertain to large-scale topographic maps prepared for special purposes or engineering applications. Emphasis is on the final spatial accuracies that can be derived from the map in terms most generally understood by the users.

1. Horizontal Accuracy:

Horizontal map accuracy is defined as the rms error[1] in terms of the project's planimetric survey coordinates (X,Y) for checked points as determined at full (ground) scale of the map. The rms error is the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation and final extraction of ground dimensions from the map. The limiting rms errors are the maximum permissible rms errors established by this standard. These limiting rms errors for Class 1. maps are tabulated in

Table 1E (feet) and Table 1M (meters) along with typical map scales associated with the limiting errors. These limits of accuracy apply to tests made on well-defined points only[2].

PLANIMETRIC (X OR Y) ACCURACY[3] (limiting rms error, feet)	TYPICAL MAP SCALE
0.05	1:60
0.1	1:120
0.2	1:240
======================================	=====*
0.3	1:360
0.4	1:480
0.5	1:600
1.0	1:1,200
2.0	1:2,400
4.0	1:4,800
5.0	1:6,000
8.0	1:9,600
10.0	1:12,000
16.7	1:20,000

Table 1E. Planimetric Coordinate Accuracy Requirement (ground X or Y in feet) for Well-defined Points - Class 1. Maps
*indicates the practical limit for aerial methods - for scales above this line, ground methods are normally used

PLANIMETRIC (X OR Y) ACCURACY[3] (limiting rms error, meters)	TYPICAL MAP SCALE
0.0125	1:50
0.025	1:100
0.050	1:200
======================================	=====*
0.125	1:500
0.25	1:1,000
0.50	1:2,000
1.00	1:4,000
1.25	1:5,000
2.50	1:10,000
5.00	1:20,000

Table 1M. Planimetric Coordinate Accuracy Requirement (ground X or Y in meters) of Well-defined Points - Class 1. Maps
*indicates the practical limit for aerial methods - for scales above this line, ground methods are used

2. Vertical Accuracy:

Vertical map accuracy is defined as the rms error in elevation in terms of the project's elevation datum for well-defined points only. For Class 1. maps the limiting rms error in elevation is set by the standard at <u>one-third</u> the indicated contour interval for well-defined points only. Spot heights shall be shown on the map within a limiting rms error of <u>one-sixth</u> of the contour interval.

3. Lower-Accuracy Maps:

Map accuracies can also be defined at lower spatial accuracy standards. Maps compiled with limiting rms errors of twice or three times those allowed for a Class 1. map shall be designated Class 2. or Class 3. maps respectively. A map may be compiled that complies with one class of accuracy in elevation and another in plan. Multiple accuracies on the same map are allowed provided a diagram is included which clearly relates segments of the map with the appropriate map accuracy class.

4. Map Accuracy Tests[4]:

Tests for compliance of a map sheet are optional. Testing for horizontal accuracy compliance is done by comparing the planimetric (X and Y) coordinates of well-defined ground points to the coordinates of the same points as determined by a horizontal check survey of higher accuracy. The check survey shall be designed according to the Federal Geodetic Control Committee (FGCC) [FGCC, 1984] standards and specifications to achieve standard deviations equal to or less than one-third of the "limiting rms error" selected for the map. The distance between control points (d) used in the FGCC standard for the design of the survey shall be the horizontal ground distance across the diagonal dimension of the map sheet.

Testing for vertical accuracy compliance shall be accomplished by comparing the elevations of well-defined points as determined from the map to corresponding elevations determined by a survey of higher accuracy. For purposes of checking elevations, the map position of the ground point may be shifted in any direction by an amount equal to twice the limiting rms error in position. The vertical check survey should be designed to produce rms errors in elevation differences at check point locations no larger than 1/20th of the contour interval. The distance (d) between bench marks used in the FGCC standard for the design of the survey vertical check survey shall be the horizontal ground distance across the diagonal of the map sheet. Generally, vertical control networks based on surveys conducted according to the FGCC standards for Third Order provide adequate accuracy for conducting the vertical check survey.

Discrepancies between the X, Y or Z coordinates of the ground point, as determined from the map and by the check survey, that exceed three times the limiting rms error shall be interpreted as blunders and will be corrected before the map is considered to meet this standard.

The same survey datums, both horizontal and vertical, must be used for both the project and the check control surveys. Although a national survey datum is preferred, a local datum is acceptable.

A minimum of 20 check points shall be established throughout the area covered by the map and shall be distributed in a manner agreed upon by the contracting parties[5].

Maps produced according to this spatial accuracy standard shall include the following statement in the title block:

THIS MAP WAS COMPILED TO MEET THE ASPRS
STANDARD FOR CLASS 1. MAP ACCURACY

If the map was checked and found to conform to this spatial accuracy standard, the following statement shall also appear in the title block:

THIS MAP WAS CHECKED AND FOUND TO CONFORM TO THE ASPRS
STANDARD FOR CLASS 1. MAP ACCURACY

[1]see Appendix A., Section A1.
[2]see Appendix A., Section A2.
[3]see Appendix A., Section A3.
[4]see Appendix A., Section A4.
[5]see Appendix A., Section A5.

APPENDIX A. EXPLANATORY COMMENTS

A1. Root Mean Square Error

The "root mean square" (rms) error is defined to be the square root of the average of the squared discrepancies. In this case, the discrepancies are the differences in coordinate or elevation values as derived from the map and as determined by an independent survey of higher accuracy (check survey). For example, the rms error in the X coordinate direction can be computed as:

$$rms_x = \sqrt{(D^2/n)}$$

where:

$$D^2 = d_1^2 + d_2^2 + \text{---------} + d_n^2$$

d = discrepancy in the X coordinate direction

$$= X_{map} - X_{check}$$

П = total number of points checked on the map in the X coordinate direction

A2. Well-defined Points

The term "well-defined points" pertains to features that can be sharply identified as discrete points. Points which are not well-defined (that is poorly-defined) are excluded from the map accuracy test. In the case of poorly-defined image points, these may be of features that do not have a well-defined centers such as roads that intersect at shallow angles [U.S. National Map Accuracy Standards, 1941]. In the case of poorly defined ground points, these may be such features as soil boundaries or timber boundaries. As indicated in the ASPRS Standard, the selection of well-defined points is made through agreement by the contracting parties.

A3. Relationship to U.S. National Map Accuracy Standards

Planimetric accuracy in terms of the "limiting rms error" can be related to the United States National Map Accuracy Standards (NMAS) provided the following assumptions are made:

- the discrepancies are normally distributed about a zero mean
- the standard deviations in the X and Y coordinate directions are equal
- sufficient check points are used to accurately estimate the variances

To compute the " circular map accuracy standard" (CMAS) which corresponds to the 90% circular map error defined in the NMAS [ACIC, 1962, p. 26, p. 41]:

$$CMAS = 2.146\ \sigma_x \quad \text{or;} \quad CMAS = 2.146\ \sigma_y$$

Given these relationships and assumptions, the limiting rms errors correspond approximately to the CMAS of 1/47th of an inch for all errors and related scales indicated in Table 1E. For the metric case indicated in Table 1M, the CMAS is 0.54mm for all rms erros and corresponding scales. It is emphasized that for the ASPRS Standard, spatial accuracies are stated and evaluated at full or ground scale. The measures in terms of equivalent CMAS are only approximate and are offered only to provide a comparison to the National Map Accuracy Standard of CMAS of 1/30th inch at map scale.

A4. Check Survey

Both the vertical and horizontal (planimetric) check surveys are designed based on the National standards of accuracy and field specifications for control surveys established by the Federal Geodetic Control Committee (FGCC). These standards and specifications [FGCC, 1984] are intended to establish procedures which produce accuracies in terms of relative errors. For horizontal surveys, the proportional accuracies for the various orders and classes of survey are stated in Table 2.1 of the FGCC document and for elevation accuracy in Table 2.2. These tables along with their explanations are reproduced here. From FGCC [1984]:

"2.1 HORIZONTAL CONTROL NETWORK STANDARDS

When a horizontal control point is classified with a particular order and class, NGS certifies that the geodetic latitude and longitude of that control point bear a relation of specific accuracy to the coordinates of all other points in the horizontal control network. This relationship is expressed as a distance accuracy, 1:a. A distance accuracy is the ratio of relative positional error of a pair of control points to the horizontal separation of those points.

Table 2.1 - Distance accuracy standards

Classification	Minimum distance accuracy
First-order	1:100,000
Second-order, class I	1: 50,000
Second-order, class II	1: 20,000
Third-order, class I	1: 10,000
Third-order, class II	1: 5,000

"A distance accuracy, 1:a, is computed from a minimally constrained, correctly weighted, least squares adjustment by:

$$a=d/s$$

where

a = distance accuracy denominator
s = propagated standard deviation of distance between survey points obtained from the least squares adjustment
d = distance between survey points

"VERTICAL CONTROL NETWORK STANDARDS

When a vertical control point is classified with a particular order and class, NGS certifies that the orthometric elevation at that point bears a relation of specific accuracy to the elevations of all other points in the vertical control network. That relation is expressed as an elevation difference accuracy, b. An elevation difference accuracy is the relative elevation error

When a vertical control point is classified with a particular order and class, NGS certifies that the orthometric elevation at that point bears a relation of specific accuracy to the elevations of all other points in the vertical control network. That relation is expressed as an elevation difference accuracy, b. An elevation difference accuracy is the relative elevation error between a pair of control points that is scaled by the square root of their horizontal separation traced along existing level routes.

Table 2.2-Elevation accuracy standards

Classification	Minimum elevation difference accuracy
First-order, class I	0.5
First-order, class II	0.7
Second-order, class I	1.0
Second-order, class II	1.3
Third-order	2.0

"An elevation difference accuracy, b, is computed from a minimally constrained, correctly weighted, least squares adjustment by

$$b=S/\sqrt{d}$$

where

d = approximate horizontal distance in kilometers between control point positions traced along existing level routes.
S = propagated standard deviation of elevation difference in millimeters between survey control points obtained from a least squares adjustment. Note that the units of b are (mm)/ (km)."

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For an example of designing a check survey (selecting an order and class), assume that a survey is to be designed to check a map which is intended to possess a planimetric (horizontal) "limiting rms error" (see Table 1E. of the map standard) of <u>one</u> foot and a contour interval of <u>two</u> feet. In contrast to survey accuracies, which are stated in terms of relative horizontal distances to adjacent points, map features are intended to possess accuracies relative to all other points appearing on the map. Therefore, for purposes of the check survey, the distance between survey points (d) is taken as the diagonal distance on the ground across the area covered by the map. According to the FGCC survey standards this is the distance across which the "minimum distance accuracy" and "maximum elevation difference accuracy" is required (see Table 2.1 and 2.2 of the [FGCC,1984] document).

For the planimetric check survey, assume that the diagonal distance on the ground covered by the map is 6000 feet. The propagated standard deviation (s) required for the check survey is one-third of the limiting rms error of one foot or 0.33 foot in this example. Returning to the equation from the FGCC [1984] document relating distance between survey points (d), standard deviation (s) and distance accuracy denominator (a);

$$a=d/s=(6000 \text{ feet})/(0.33 \text{ feet})=18{,}182$$

For the vertical check survey, the distance (d) is also taken as a diagonal ground distance across the map to account for the fact that elevation accuracy pertains to all mapped features. The propagated standard deviation in elevation (S) is required by this standard to be equal or less than 1/20th of the contour interval of two feet;

$$S = (1/20)\ CI = 0.10 \text{ feet}$$

Returning to Table 2.2 of the FGCC document, relating distance between bench marks (d in km), the standard deviation in elevation (S in mm), and the elevation difference accuracy (b);

where;

$S = 0.10$ feet $= 30.5$ mm
$d = 6000$ feet $= 1.181$ km

then;

$$b = S/\ d = 28.1 \text{ mm}/\sqrt{\text{km}}$$

It is clear that a third-order survey for elevation differences is more than adequate for purposes of conducting the check survey for this map example. Other methods for conducting the check survey for elevation are acceptable provided they have demonstrated accuracy capability equal to that required by this map standard. Such departures however must be agreed upon by the contracting parties prior to conducting the survey.

A5. Check Point Location

Due to the diversity of requirements anticipated for any large scale special purpose or engineering map, it is not realistic to include statements that specify the spatial distribution of check points designed to assess the spatial accuracy of the map. For instance, it may be preferred to distribute the check points more densely in the vicinity of important structures or drainage features and more sparsely in areas that are of little or no interest. Of course suitable notation, such as a change in map class for the region of lesser interest, should be included accordingly on the map sheet.

For a map sheet, however, of conventional rectangular dimensions, intended to portray a uniform spatial accuracy over the entire map sheet, it may be reasonable to specify the distribution. For instance, given the minimum of twenty check points, it could be specified that at least 20% of the points be located in each quadrant of the map sheet and that these points be spaced at intervals equal to at least 10% of the map sheet diagonal.

REFERENCES

ANSI (1982),"Procedures for the Development and Coordination of American National Standards," American National Standards Institute, 1430 Broadway, New York NY 10018, Sept. 1, 1982

Bureau of the Budget (1947), "United States National Map Accuracy Standard," U.S. Bureau of the Budget, June 17, 1947

Federal Geodetic Control Committee (1984), "Standards and Specifications for Geodetic Control Networkds," Federal Geodetic Control Committee, Sept. 1984