FGDC-STD-007.3-1998

National Spatial Data Infrastructure

Geospatial Positioning Accuracy Standards
Part 3: National Standard for Spatial Data Accuracy

Subcommittee for Base Cartographic Data
Federal Geographic Data Committee

Federal Geographic Data Committee
Department of Agriculture • Department of Commerce • Department of Defense • Department of Energy
Department of Housing and Urban Development • Department of the Interior • Department of State
Department of Transportation • Environmental Protection Agency
Federal Emergency Management Agency • Library of Congress
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Federal Geographic Data Committee

Established by Office of Management and Budget Circular A-16, the Federal Geographic Data Committee (FGDC) promotes the coordinated development, use, sharing, and dissemination of geographic data.

The FGDC is composed of representatives from the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, the Interior, State, and Transportation; the Environmental Protection Agency; the Federal Emergency Management Agency; the Library of Congress; the National Aeronautics and Space Administration; the National Archives and Records Administration; and the Tennessee Valley Authority. Additional Federal agencies participate on FGDC subcommittees and working groups. The Department of the Interior chairs the committee.

FGDC subcommittees work on issues related to data categories coordinated under the circular. Subcommittees establish and implement standards for data content, quality, and transfer; encourage the exchange of information and the transfer of data; and organize the collection of geographic data to reduce duplication of effort. Working groups are established for issues that transcend data categories.

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3.1 Introduction

3.1.1 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.

3.1.2 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.

3.1.3 Applicability

Use the NSSDA to evaluate and report the positional accuracy of maps and geospatial data produced, revised, or disseminated by or for the Federal Government. According to Executive Order 12906, Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure (Clinton, 1994, Sec. 4. Data Standards Activities, item d), "Federal agencies collecting or producing geospatial data, either directly or indirectly (e.g. through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the FGDC process."

Accuracy of new or revised spatial data will be reported according to the NSSDA. Accuracy of existing or legacy spatial data and maps may be reported, as specified, according to the NSSDA or the accuracy standard by which they were evaluated.

3.1.4 Related Standards

Data producers may elect to use conformance levels or accuracy thresholds in standards such as the National Map Accuracy Standards of 1947 (U.S. Bureau of the Budget, 1947) or Accuracy Standards for Large-Scale Maps [American Society for Photogrammetry and Remote Sensing (ASPRS) Specifications and Standards Committee, 1990] if they decide that these values are truly applicable for digital geospatial data.

Positional accuracy of geodetically surveyed points is reported according to Part 2, Standards for Geodetic Control Networks (Federal Geographic Data Committee, 1998), Geospatial Positioning Accuracy Standards. Ground coordinates of points collected according to Standards and Specifications for Geodetic Control Networks (Federal Geodetic Control Committee, 1984) are used in the National Spatial Reference System (NSRS). NSRS is a consistent national coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the Nation, and how these values change with time. Consequently, it ties spatial data to georeferenced positions. NSRS points may be selected as an independent source of higher accuracy to test positional accuracy of maps and geospatial data according to the NSSDA.

Part 4, Standards for A/E/C and Facility Management (Facilities Working Group, 1997), uses the NSSDA for accuracy testing and verification. The NSSDA may be used for fully georeferenced maps for A/E/C and Facility Management applications such as preliminary site planning and reconnaissance mapping.

3.1.5 Standards Development Procedures

The National Standard for Spatial Data Accuracy was developed by the FGDC *ad hoc* working group on spatial data accuracy, with the intent to update the United States National Map Accuracy Standards (NMAS) (U.S. Bureau of the Budget, 1947). The ASPRS Accuracy Standards for Large-Scale Maps (ASPRS Specifications and Standards Committee, 1990) formed the basis for update of the NMAS. The NSSDA, in its former version as the draft National Cartographic Standards for Spatial Accuracy (NCSSA), extended the ASPRS Accuracy Standards to map scales smaller than 1:20,000. The NCSSA were released for public review through the Federal Geographic Data Committee and were substantially rewritten as a result.

The geospatial data community has diversified to include many data producers with different product specifications and many data users with different application requirements. The NSSDA was developed to provide a common reporting mechanism so that users can directly compare datasets for their applications. It was realized that map-dependent measures of accuracy, such as publication scale and contour interval, were not fully applicable when digital geospatial data can be readily manipulated and output to any scale or data format. Principal changes included requirements to report numeric accuracy values; a composite statistic for horizontal accuracy, instead of component (x,y) accuracy, and alignment with emerging Federal Geographic Control Subcommittee (FGCS) accuracy standards (FGDC, 1998). The NCSSA was renamed the National Standard for Spatial Data Accuracy to emphasize its applicability to digital geospatial data as well as graphic maps.

3.1.6 Maintenance

The U.S. Department of the Interior, U.S. Geological Survey (USGS), National Mapping Division, maintains the National Standard for Spatial Data Accuracy (NSSDA) for the Federal Geographic Data Committee. Address questions concerning the NSSDA to: Chief, National Mapping Division, USGS, 516 National Center, Reston, VA 20192.

3.2 Testing Methodology And Reporting Requirements

3.2.1 Spatial Accuracy

The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points[1].

Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product.

3.2.2 Accuracy Test Guidelines

According to the Spatial Data Transfer Standard (SDTS) (ANSI-NCITS, 1998), accuracy testing by an independent source of higher accuracy is the preferred test for positional accuracy. Consequently, the NSSDA presents guidelines for accuracy testing by an independent source of higher accuracy. The independent source of higher accuracy shall the highest accuracy feasible and practicable to evaluate the accuracy of the dataset.[2]

The data producer shall determine the geographic extent of testing. Horizontal accuracy shall be tested by comparing the planimetric coordinates of well-defined points[3] in the dataset with coordinates of the same points from an independent source of higher accuracy. Vertical accuracy shall be tested by comparing the elevations in the dataset with elevations of the same points as determined from an independent source of higher accuracy.

Errors in recording or processing data, such as reversing signs or inconsistencies between the dataset and independent source of higher accuracy in coordinate reference system definition, must be corrected before computing the accuracy value.

A minimum of 20 check points shall be tested, distributed to reflect the geographic area of interest and the distribution of error in the dataset.[4] When 20 points are tested, the 95% confidence level allows one point to fail the threshold given in product specifications.

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[1] see Appendix 3-A

[2] see Appendix 3-C, section 2

[3] see Appendix 3-C, section 1

[4] see Appendix 3-C, section 3

If fewer than twenty points can be identified for testing, use an alternative means to evaluate the accuracy of the dataset. SDTS (ANSI-NCITS, 1998) identifies these alternative methods for determining positional accuracy:

- Deductive Estimate
- Internal Evidence
- Comparison to Source

3.2.3 Accuracy Reporting

Spatial data may be compiled to comply with one accuracy value for the vertical component and another for the horizontal component. If a dataset does not contain elevation data, label for horizontal accuracy only. Conversely, when a dataset, e.g. a gridded digital elevation dataset or elevation contour dataset, does not contain well-defined points, label for vertical accuracy only.

A dataset may contain themes or geographic areas that have different accuracies. Below are guidelines for reporting accuracy of a composite dataset:

- If data of varying accuracies can be identified separately in a dataset, compute and report separate accuracy values.
- If data of varying accuracies are composited and cannot be separately identified AND the dataset is tested, report the accuracy value for the composited data.
- If a composited dataset is not tested, report the accuracy value for the least accurate dataset component.

Positional accuracy values shall be reported in ground distances. Metric units shall be used when the dataset coordinates are in meters. Feet shall be used when the dataset coordinates are in feet. The number of significant places for the accuracy value shall be equal to the number of significant places for the dataset point coordinates.

Accuracy reporting in ground distances allows users to directly compare datasets of differing scales or resolutions. A simple statement of conformance (or omission, when a map or dataset is non-conforming) is not adequate in itself. Measures based on map characteristics, such as publication scale or contour interval, are not longer adequate when data can be readily manipulated and output to any scale or to different data formats.

Report accuracy at the 95% confidence level for data *tested* for both horizontal and vertical accuracy as:

Tested ____ (meters, feet) horizontal accuracy at 95% confidence level
____ (meters, feet) vertical accuracy at 95% confidence level

Use the “compiled to meet” statement below when the above guidelines for testing by an independent source of higher accuracy cannot be followed and an alternative means is used to evaluate accuracy. Report accuracy at the 95% confidence level for data *produced according to procedures that have been demonstrated to produce data with particular horizontal and vertical accuracy values* as:

Compiled to meet ____ (meters, feet) horizontal accuracy at 95% confidence level
____ (meters, feet) vertical accuracy at 95% confidence level

Report accuracy for data *tested* for horizontal accuracy and *produced according to procedures that have been demonstrated to comply with a particular vertical accuracy value* as:

Tested ____ (meters, feet) horizontal accuracy at 95% confidence level
Compiled to meet ____ (meters, feet) vertical accuracy at 95% confidence level

Show similar labels when data are *tested* for vertical accuracy and *produced according to procedures that have been demonstrated to produce data with a particular horizontal accuracy value*.

For digital geospatial data, report the accuracy value in digital geospatial metadata (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_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)

Regardless of whether the data was tested by a independent source of higher accuracy or evaluated for accuracy by alternative means, provide a complete description on how the values were determined in metadata, as appropriate to dataset spatial characteristics (Federal Geographic Data Committee, 1998, Section 2):

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Report)
and/or
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Report)

3.3 NSSDA and Other Map Accuracy Standards

Accuracy of new or revised spatial data will be reported according to the NSSDA. Accuracy of existing or legacy spatial data and maps may be reported, as specified, according to the NSSDA or the accuracy standard by which they were evaluated. Appendix 3-D describes root mean square error (RMSE) as applied to individual x-, y- components, former NMAS, and ASPRS Accuracy Standards for Large-Scale Maps. These standards, their relationships to NSSDA, and accuracy labeling are described to ensure that users have some means to assess positional accuracy of spatial data or maps for their applications.

If accuracy reporting cannot be provided using NSSDA or other recognized standards, provide information to enable users to evaluate how the data fit their applications requirements. This information may include descriptions of the source material from which the data were compiled, accuracy of ground surveys associated with compilation, digitizing procedures, equipment, and quality control procedures used in production.

No matter what method is used to evaluate positional accuracy, explain the accuracy of coordinate measurements and describe the tests in digital geospatial metadata (Federal Geographic Data Committee, 1998, Section 2) , as appropriate to dataset spatial characteristics:

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Report)
and/or

(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Report)

Provide information about the source data and processes used to produce the dataset in data elements of digital geospatial metadata (Federal Geographic Data Committee, 1998, Section 2) under (Data_Quality_Information/Lineage).

References

American National Standards Institute, Information Technology - Spatial Data Transfer Standard (SDTS) (ANSI-NCITS 320:1998): New York, New York.

American Society for Photogrammetry and Remote Sensing (ASPRS) Specifications and Standards Committee, 1990, ASPRS Accuracy Standards for Large-Scale Maps: Photogrammetric Engineering and Remote Sensing, v. 56, no. 7, p. 1068-1070.

Clinton, William J., 1994, Executive Order 12906, Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure: Washington, DC, Federal Register, Volume 59, Number 71, pp. 17671-17674.

Facilities Working Group, 1997, Part 4, Draft Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management, Geospatial Positioning Accuracy Standards: Washington, DC, U.S. Army Corps of Engineers, 21 p.

Federal Geodetic Control Committee, 1984, Standards and Specifications for Geodetic Control Networks: Silver Spring, Md., National Geodetic Survey, National Oceanic and Atmospheric Administration, 29 p.

Federal Geographic Data Committee, 1998, Content Standards for Digital Geospatial Metadata (version 2.0), FGDC-STD-001-1998: Washington, D.C., Federal Geographic Data Committee, 66 p.

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Greenwalt, C.R. and M.E. Schultz, 1968, Principles and Error Theory and Cartographic Applications, ACIC Technical Report No. 96: St. Louis, Mo., Aeronautical Chart and Information Center, U.S. Air Force, 89 p.

National Mapping Division, 1987, Procedure Manual for Map Accuracy Testing (*draft*): U.S. Geological Survey, Reston, Va.

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Appendix 3-A.
Accuracy Statistics
(normative)

EXPLANATORY COMMENTS

1. Horizontal Accuracy

Let:

$RMSE_x = sqrt[\sum(x_{data, i} - x_{check, i})^2/n]$
$RMSE_y = sqrt[\sum(y_{data, i} - y_{check, i})^2/n]$

where:
$x_{data, i}$, $y_{data, i}$ are the coordinates of the i th check point in the dataset
$x_{check, i}$, $y_{check, i}$ are the coordinates of the i th check point in the independent source of higher accuracy
n is the number of check points tested
i is an integer ranging from 1 to n

Horizontal error at point i is defined as $sqrt[(x_{data, i} - x_{check, i})^2 +(y_{data, i} - y_{check, i})^2]$. Horizontal RMSE is:

$RMSE_r = sqrt[\sum((x_{data, i} - x_{check, i})^2 +(y_{data, i} - y_{check, i})^2)/n]$
$= sqrt[RMSE_x^2 + RMSE_y^2]$

Case 1: Computing Accuracy According to the NSSDA when $RMSE_x = RMSE_y$

If $RMSE_x = RMSE_y$,
$RMSE_r = sqrt(2*RMSE_x^2) = sqrt(2*RMSE_y^2)$
$= 1.4142*RMSE_x = 1.4142*RMSE_y$

It is assumed that systematic errors have been eliminated as best as possible. If error is normally distributed and independent in each the x- and y-component and error, the factor 2.4477 is used to compute horizontal accuracy at the 95% confidence level (Greenwalt and Schultz, 1968). When the preceding conditions apply, $Accuracy_r$, the accuracy value according to NSSDA, shall be computed by the formula:

$Accuracy_r = 2.4477 * RMSE_x = 2.4477 * RMSE_y$
$= 2.4477 * RMSE_r /1.4142$
$Accuracy_r = 1.7308 * RMSE_r$

Case 2: Approximating circular standard error when $RMSE_x \neq RMSE_y$

If $RMSE_{min}/RMSE_{max}$ is between 0.6 and 1.0 (where $RMSE_{min}$ is the smaller value between $RMSE_x$ and $RMSE_y$ and $RMSE_{max}$ is the larger value), circular standard error (at 39.35% confidence) may be approximated as $0.5*(RMSE_x + RMSE_y)$ (Greenwalt and Schultz, 1968). If error is normally distributed and independent in each the x- and y-component and error, the accuracy value according to NSSDA may be approximated according to the following formula:

$$Accuracy_r \sim 2.4477 * 0.5 * (RMSE_x + RMSE_y)$$

2. Vertical Accuracy

Let:

$RMSE_z = sqrt[\sum(z_{data\ i} - z_{check\ i})^2/n]$

where

$z_{data\ i}$ is the vertical coordinate of the i th check point in the dataset.
$z_{check\ i}$ is the vertical coordinate of the i th check point in the independent source of higher accuracy
n = the number of points being checked
i is an integer from 1 to n

It is assumed that systematic errors have been eliminated as best as possible. If vertical error is normally distributed, the factor 1.9600 is applied to compute linear error at the 95% confidence level (Greenwalt and Schultz, 1968). Therefore, vertical accuracy, $Accuracy_z$, reported according to the NSSDA shall be computed by the following formula:

$$Accuracy_z = 1.9600 * RMSE_z.$$

Appendix 3-B
Horizontal Accuracy Computations
(informative)

Horizontal Accuracy Computations

The data for horizontal accuracy computations come from the draft National Mapping Program (NMP) Technical Instructions, Procedure Manual for Map Accuracy Testing (National Mapping Division, 1987). Positions on the Crider, Kentucky 1:24,000-scale USGS topographic quadrangle were tested against a triangulated solution of positions independent of the control solution used to produce the map. The photography used to collect the independent source was different from that used for the map compilation, and a different control configuration was utilized.

- Coordinates are on the State Plane Coordinate System (south zone), based on NAD 27. Units are in feet.
- x (computed) and y (computed) are coordinate values from the triangulated solution.
- x (map) and y (map) are coordinate values for map positions.

Table 1 assumes that $RMSE_x = RMSE_y$. Therefore, the accuracy value according to the NSSDA, at 95% confidence, is computed by the formula given in Case 1 in Appendix 3-A (normative). The accuracy value according to the NSSDA is 35 feet. Of twenty-five points tested, only point # 10360 has a positional error that exceeds 35 feet.

Table 2 uses the formula given in Case 2 in Appendix 3-A (normative) to estimate accuracy when $RMSE_x \neq RMSE_y$. The accuracy value according to the NSSDA, at 95% confidence, is 35 feet.

Table 1.
Accuracy Calculations for Crider, Kentucky USGS 1:24,000-scale Topographic Quadrangle
$RMSE_x = RMSE_y$ assumed

Number	Description	x (computed)	x (map)	diff in x	squared diff in x (1)	y (computed)	y (map)	diff in y	squared diff in y (2)	(1) +(2)	square root of [(1) +(2)]
10351	T-RD-W	1373883	1373894	11	121	298298	298297	-1	1	122	11.05
10352	T-RD-E	1370503	1370486	-17	289	303727	303747	20	400	689	26.25
10353	RD AT RR	1361523	1361537	14	196	302705	302705	0	0	196	14.00
10354	T-RD-SW	1357653	1357667	14	196	298726	298746	20	400	596	24.41
10355	T-RD-SE	1348121	1348128	7	49	299725	299755	30	900	949	30.81
10356	RD AT RR	1345601	1345625	24	576	309911	309910	-1	1	577	24.02
10357	T-RD-E	1350505	1350507	2	4	318478	318477	-1	1	5	2.24
10358	X-RD	1351781	1351792	11	121	307697	307698	1	1	122	11.05
10359	T-RD-E	1352361	1352379	18	324	311109	311099	-10	100	424	20.59
10360	X-RD	1360657	1360645	-12	144	316720	316761	41	1681	1825	42.72
10361	Y-RD-SW	1368215	1368202	-13	169	309842	309869	27	729	898	29.97
10362	T-RD-W	1370299	1370282	-17	289	316832	316849	17	289	578	24.04
10363	T-RD-S	1373855	1373839	-16	256	319893	319886	-7	49	305	17.46
10364	Y-RD-W	1379981	1379962	-19	361	311641	311633	-8	64	425	20.62
10365	T-RD-E	1378625	1378628	3	9	334995	335010	15	225	234	15.30
10366	T-RD-SE	1374735	1374742	7	49	333909	333922	13	169	218	14.76
10367	T-RD-NW	1370581	1370576	-5	25	324098	324095	-3	9	34	5.83
10368	Y-RD-SE	1359379	1359387	8	64	328690	328691	1	1	65	8.06
10369	T-RD-S	1346459	1346479	20	400	330816	330812	-4	16	416	20.40
10370	T-RD-E	1347101	1347109	8	64	335869	335850	-19	361	425	20.62
10371	T-RD-SE	1350733	1350748	15	225	332715	332725	10	100	325	18.03
10372	T-RD-N	1354395	1354411	16	256	335337	335345	8	64	320	17.89
10373	T-RD-S	1358563	1358570	7	49	335398	335406	8	64	113	10.63
10374	X-RD	1365561	1365574	13	169	333873	333877	4	16	185	13.60
10375	X-RD	1373645	1373643	-2	4	339613	339609	-4	16	20	4.47
									sum	10066	
									average	402.64	
									RMSEr	20.07	
									Accuracy per NSSDA (2.4477 * RMSEr)	35	

Table 2.
Accuracy Computations for Crider, Kentucky USGS 1:24,000-scale Topographic Quadrangle
$RMSE_x \neq RMSE_y$

Number	Description	x (computed)	x (map)	diff in x	squared diff in x	y (computed)	y (map)	diff in y	squared diff in y
10351	T-RD-W	1373883	1373894	11	121	298298	298297	-1	1
10352	T-RD-E	1370503	1370486	-17	289	303727	303747	20	400
10353	RD AT RR	1361523	1361537	14	196	302705	302705	0	0
10354	T-RD-SW	1357653	1357667	14	196	298726	298746	20	400
10355	T-RD-SE	1348121	1348128	7	49	299725	299755	30	900
10356	RD AT RR	1345601	1345625	24	576	309911	309910	-1	1
10357	T-RD-E	1350505	1350507	2	4	318478	318477	-1	1
10358	X-RD	1351781	1351792	11	121	307697	307698	1	1
10359	T-RD-E	1352361	1352379	18	324	311109	311099	-10	100
10360	X-RD	1360657	1360645	-12	144	316720	316761	41	1681
10361	Y-RD-SW	1368215	1368202	-13	169	309842	309869	27	729
10362	T-RD-W	1370299	1370282	-17	289	316832	316849	17	289
10363	T-RD-S	1373855	1373839	-16	256	319893	319886	-7	49
10364	Y-RD-W	1379981	1379962	-19	361	311641	311633	-8	64
10365	T-RD-E	1378625	1378628	3	9	334995	335010	15	225
10366	T-RD-SE	1374735	1374742	7	49	333909	333922	13	169
10367	T-RD-NW	1370581	1370576	-5	25	324098	324095	-3	9
10368	Y-RD-SE	1359379	1359387	8	64	328690	328691	1	1
10369	T-RD-S	1346459	1346479	20	400	330816	330812	-4	16
10370	T-RD-E	1347101	1347109	8	64	335869	335850	-19	361
10371	T-RD-SE	1350733	1350748	15	225	332715	332725	10	100
10372	T-RD-N	1354395	1354411	16	256	335337	335345	8	64
10373	T-RD-S	1358563	1358570	7	49	335398	335406	8	64
10374	X-RD	1365561	1365574	13	169	333873	333877	4	16
10375	X-RD	1373645	1373643	-2	4	339613	339609	-4	16
				sum	4409				5657
				average	176.36				226.28
				RMSE	13.28				15.04
				$RMSE_{min}/RMSE_{max}$					0.88

Since $RMSE_{min}/RMSE_{max}$ is between 0.6 and 1.0, the formula $Accuracy_r \sim 2.4477 * 0.5 * (RMSE_x + RMSE_y)$ may be used to estimate accuracy according to the NSSDA. $Accuracy_r$ ~35 feet.

Appendix 3-C.
Testing guidelines
(informative)

1. Well-Defined Points

A well-defined point represents a feature for which the horizontal position is known to a high degree of accuracy and position with respect to the geodetic datum. For the purpose of accuracy testing, well-defined points must be easily visible or recoverable on the ground, on the independent source of higher accuracy, and on the product itself. Graphic contour data and digital hypsographic data may not contain well-defined points.

The selected points will differ depending on the type of dataset and output scale of the dataset. For graphic maps and vector data, suitable well-defined points represent right-angle intersections of roads, railroads, or other linear mapped features, such as canals, ditches, trails, fence lines, and pipelines. For orthoimagery, suitable well-defined points may represent features such as small isolated shrubs or bushes, in addition to right-angle intersections of linear features. For map products at scales of 1:5,000 or larger, such as engineering plats or property maps, suitable well-defined points may represent additional features such as utility access covers and intersections of sidewalks, curbs, or gutters.

2. Data acquisition for the independent source of higher accuracy

The independent source of higher accuracy shall be acquired separately from data used in the aerotriangulation solution or other production procedures. The independent source of higher accuracy shall be of the highest accuracy feasible and practicable to evaluate the accuracy of the dataset.

Although guidelines given here are for geodetic ground surveys, the geodetic survey is only one of many possible ways to acquire data for the independent source of higher accuracy. Geodetic control surveys are designed and executed using field specifications for geodetic control surveys (Federal Geodetic Control Committee, 1984). Accuracy of geodetic control surveys is evaluated using Part 2, Standards for Geodetic Networks (Federal Geographic Data Committee, 1998). To evaluate if the accuracy of geodetic survey is sufficiently greater than the positional accuracy value given in the product specification, compare the FGCS **network accuracy** reported for the geodetic survey with the accuracy value given by the product specification for the dataset.

Other possible sources for higher accuracy information are Global Positioning System (GPS) ground surveys, photogrammetric methods, and data bases of high accuracy point coordinates.

3. Check Point Location

Due to the diversity of user requirements for digital geospatial data and maps, it is not realistic to include statements in this standard that specify the spatial distribution of check points. Data and/or map producers must determine check point locations. This section provides guidelines for distributing the check point locations.

Check points may be distributed more densely in the vicinity of important features and more sparsely in areas that are of little or no interest. When data exist for only a portion of the dataset, confine test points to that area. When the distribution of error is likely to be nonrandom, it may be desirable to locate check points to correspond to the error distribution.

For a dataset covering a rectangular area that is believed to have uniform positional accuracy, check points may be distributed so that points are spaced at intervals of at least 10 percent of the diagonal distance across the dataset *and* at least 20 percent of the points are located in each quadrant of the dataset.

Appendix 3-D.
Other Accuracy Standards
(informative)

1. Root-Mean-Square Error (RMSE) Component Accuracy

1.1 Relationship between NSSDA (horizontal) and RMSE (x or y)

From Appendix 3-A, Section 1, assuming $RMSE_x = RMSE_y$ and error is normally distributed and independent in each the x- and y-component, $RMSE_x$ and $RMSE_y$ can be estimated from $RMSE_r$ using:

$$RMSE_x = RMSE_y = RMSE_r /1.4142$$

Using the same assumptions, $RMSE_x$ and $RMSE_y$ can also be computed from $Accuracy_r$, the accuracy value according to NSSDA:

$$RMSE_x = RMSE_y = Accuracy_r/2.4477$$

1.2 Relationship between NSSDA (vertical) and RMSE (vertical)

From Appendix 3-A, Section 2, if vertical error is normally distributed, $RMSE_z$ can be determined from $Accuracy_z$, vertical accuracy reported according to the NSSDA:

$$RMSE_z = Accuracy_z/1.9600$$

1.3 RMSE Accuracy Reporting

Label data or maps as described in Section 3.2.3, "Accuracy Reporting," but substitute "RMSE" for "accuracy at 95% confidence level." For horizontal accuracy, provide separate statements for each RMSE component.

For digital geospatial metadata, follow the guidelines for preparing metadata in Section 3.2.3, "Accuracy Reporting," but substitute “Root-Mean-Square Error” for “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)

2. Former National Map Accuracy Standards (NMAS)

2.1 Relationship between NSSDA and NMAS (horizontal)

NMAS (U.S. Bureau of the Budget, 1947) specifies that 90% of the well-defined points that are tested must fall within a specified tolerance:

- For map scales larger than 1:20,000, the NMAS horizontal tolerance is 1/30 inch, measured at publication scale.
- For map scales of 1:20,000 or smaller, the NMAS horizontal tolerance is 1/50 inch, measured at publication scale.

If error is normally distributed in each the x- and y-component and error for the x-component is equal to and independent of error for the y-component, the factor 2.146 is applied to compute circular error at the 90% confidence level (Greenwalt and Schultz, 1968). The circular map accuracy standard (CMAS) based on NMAS is:

$$\begin{aligned} CMAS &= 2.1460 * RMSE_x = 2.1460 * RMSE_y \\ &= 2.1460 * RMSE_r / 1.4142 \\ &= 1.5175 * RMSE_r \end{aligned}$$

The CMAS can be converted to accuracy reported according to NSSDA, $Accuracy_r$, using equations from Appendix 3-A, Section 1:

$$Accuracy_r = 2.4477/2.1460 * CMAS = 1.1406 * CMAS.$$

Therefore, NMAS horizontal accuracy reported according to the NSSDA is:

1.1406* [S * (1/30")/12"] feet, or 0.0032 * S, for map scales larger than 1:20,000
1.1406* [S * (1/50")/12"] feet, or 0.0019 * S, for map scales of 1:20,000 or smaller

where S is the map scale denominator.

2.2 Relationship between NSSDA and NMAS (vertical)

NMAS (U.S. Bureau of the Budget, 1947) specifies the maximum allowable *vertical* tolerance to be one half the contour interval, at all contour intervals. If vertical error is normally distributed, the factor 1.6449 is applied to compute vertical accuracy at the 90% confidence level (Greenwalt and Schultz, 1968). Therefore, the Vertical Map Accuracy Standard (VMAS) based on NMAS is estimated by the following formula:

$$VMAS = 1.6449 * RMSEz$$

The VMAS can be converted to Accuracy_z, accuracy reported according to the NSSDA using equations from Appendix 3-A, Section 2:

$$\text{Accuracy}_z = 1.9600/1.6449 * \text{VMAS} = 1.1916 * \text{VMAS}.$$

Therefore, vertical accuracy reported according to the NSSDA is (1.1916)/2 * CI = 0.5958 * CI, where CI is the contour interval.

2.3 NMAS Reporting

Map labels provide a statement of conformance with NMAS, rather than reporting the accuracy value. Label maps, as appropriate to dataset spatial characteristics:

This map complies with National Map Accuracy Standards of 1947 for horizontal accuracy
OR
This map complies with National Map Accuracy Standards of 1947 for vertical accuracy
OR
This map complies with National Map Accuracy Standards of 1947 for horizontal and vertical accuracy

For digital geospatial data evaluated by the NMAS, follow the guidelines for preparing metadata in Section 3.2.3, "Accuracy Reporting," but substitute “U.S. National Map Accuracy Standards of 1947" for “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)

3. American Society for Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Large-Scale Maps

3.1 Explanation of ASPRS Accuracy Standards for Large-Scale Maps

ASPRS Accuracy Standards for Large-Scale Maps (ASPRS Specifications and Standards Committee, 1990) provide accuracy tolerances for maps at 1:20,000-scale or larger “prepared for special purposes or engineering applications.” RMSE is the statistic used by the ASPRS standards. Accuracy is reported as Class 1, Class 2, or Class 3. Class 1 accuracy for horizontal and vertical components is discussed below. Class 2 accuracy applies to maps compiled within limiting RMSE’s twice those allowed for Class 1 maps. Similarly, Class 3 accuracy applies to maps compiled within limiting RMSE's three times those allowed for Class 1 maps.

3.2 Relationship between NSSDA and ASPRS Accuracy Standards for Large-Scale Maps (horizontal)

ASPRS Accuracy Standards for Large-Scale Maps (ASPRS Specifications and Standards Committee, 1990) evaluates positional accuracy for the x-component and the y-component individually. Positional accuracy is reported at ground scale. Table 3 shows Class 1 planimetric limiting RMSE *in feet* associated with typical map scales, while Table 4 shows Class 1 planimetric limiting RMSE *in meters* associated with typical map scales.

Table 3
ASPRS Accuracy Standards for Large-Scale Maps
Class 1 horizontal (x or y) limiting RMSE for various map scales
at ground scale for *feet* units

Class 1 Planimetric Accuracy, limiting RMSE (feet)	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 4
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

Class 1 Planimetric Accuracy Limiting RMSE (meters)	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

See Section 1.1 of this appendix on the relationship between horizontal accuracy reported according to the NSSDA and RMSE.

3.3 Relationship between NSSDA and ASPRS Accuracy Standards for Large-Scale Maps (vertical)

Vertical map accuracy is defined by the ASPRS Accuracy Standards (ASPRS Specifications and Standards Committee, 1990) as the RMSE in terms of the project's elevation datum for well-defined points only. See Section 1.3 of this appendix on the relationship between vertical accuracy reported according to the NSSDA and RMSE.
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For Class 1 maps according to the ASPRS Accuracy Standards, the limiting RMSE is set at one-third the contour interval. Spot elevations shall be shown on the map with a limiting RMSE of one-sixth the contour interval or less.

3.4 ASPRS Accuracy Standards for Large-Scale Maps Reporting

Maps evaluated according to ASPRS Accuracy Standards for Large-Scale Maps are labeled by a conformance statement, rather than a numeric accuracy value.

Label maps produced according to this standard:

THIS MAP WAS COMPILED TO MEET THE ASPRS
STANDARD FOR CLASS (1., 2., 3.) MAP ACCURACY

Label maps checked and found to confirm to this standard:

THIS MAP WAS CHECKED AND FOUND TO CONFORM
TO THE ASPRS
STANDARD FOR CLASS (1., 2., 3.) MAP ACCURACY