NCEES
advancing licensure for engineers and surveyors

FS | Fundamentals of Surveying

Reference Handbook
Version 2.0

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PREFACE

About the *Handbook*

The Fundamentals of Surveying (FS) exam is computer-based, and the *FS Reference Handbook* is the only resource material you may use during the exam. Reviewing it before exam day will help you become familiar with the charts, formulas, tables, and other reference information provided. You won't be allowed to bring your personal copy of the *Handbook* into the exam room. Instead, the computer-based exam will include a PDF version of the *Handbook* for your use. No printed copies of the *Handbook* will be allowed in the exam room.

The PDF version of the *FS Reference Handbook* that you use on exam day will be very similar to this one. Pages not needed to solve exam questions—such as the cover and this introductory material—will not be included in the exam-day PDF. In addition, NCEES will periodically revise and update the *Handbook*, and each FS exam will be administered using the updated version.

The *FS Reference Handbook* does not contain all the information required to answer every question on the exam. Basic theories, conversions, formulas, and definitions examinees are expected to know have not been included. Special material required for the solution of a particular exam question will be included in the question itself.

Errata

To report errata in this book, send your correction through your MyNCEES account on NCEES.org. Examinees are not penalized for any errors in the *Handbook* that affect an exam question.

Updates on Exam Content and Procedures

NCEES.org is our home on the Web. Visit us there for updates on everything exam-related, including specifications, exam-day policies, scoring, and practice tests.

Contents

APPENDICES

1 ABBREVIATIONS AND ACRONYMS

ALTA	American Land Title Association
ALTA/NSPS	ALTA/NSPS Land Title Surveys. Formerly, ALTA/ACSM
BIM	Building Information Modeling
BLM	Bureau of Land Management
CADD	computer-aided design and drafting
DEM	digital elevation model
DOD	Department of Defense
DOI	Department of the Interior
DOT	Department of Transportation
DTM	digital terrain model
EDM	electronic distance measurement
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FGCS	Federal Geodetic Control Subcommittee
GIS	geographic information system
GLO	General Land Office
GNSS	Global Navigation Satellite Systems
GPS	global positioning system
LIDAR	light detection and ranging
NAD	North American Datum
NAVD	North American Vertical Datum
NGVD	National Geodetic Vertical Datum
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NSPS	National Society of Professional Surveyors, successor organization to the American Congress on Surveying and Mapping (ACSM)
NSSDA	National Standards for Spatial Data Accuracy
OPUS	Online Positioning User Service

OSHA	Occupational Safety and Health Administration
PLSS	Public Land Survey System
PPP	precise point positioning
RTK	real-time kinematic
RTK GPS	real-time kinematic global positioning system
SPCS	State Plane Coordinate System
TIN	triangulated irregular network
UAS	unmanned aircraft system
USGS	United States Geological Survey

2 CONVERSIONS AND OTHER USEFUL RELATIONSHIPS

Units of Linear Measure

1 chain = 100 links

= 66 ft (U.S. survey foot)

= 4 poles, perches, rods

1 mile = 80 chains

= 5,280 ft (U.S. survey foot)

Units of Area

1 acre = 10 square chains

= 43,560 ft2 (U.S. survey foot)

Metric Conversions

U.S. Survey Foot

1 m = 39.37 in. (exact)

1 U.S. survey foot = 0.3048006096 m

1 link = 0.2011684023 m

1 m = 3.2808333333 U.S. survey foot

1 acre = 0.40468726099 hectare

International Foot (SI)

1 in = 25.4 mm (exact)

1 SI foot = 0.3048 m (exact)

1 m = 3.2808398950 SI foot

1 mile = 1.60935 km

$1 \text{ rad} = \frac{180^\circ}{\pi}$

1 kg = 2.2046 lb

1 L = 0.2624 gal

1 ft^3 = 7.481 gal

1 gal of water weighs 8.34 lb

1 ft^3 of water weighs 62.4 lb

1 atm = 29.92 in. Hg = 14.696 psi

Gravity acceleration (g) = 9.807 m/s^2 = 32.174 ft/sec^2

Speed of light in a vacuum (c) = 299,792,458 m/s = 186,282 miles/sec

°C = (°F – 32)/1.8

1 min of latitude (ϕ) ≅ 1 nautical mile

1 nautical mile = 6,076 ft

Mean radius of the earth ≅ 20,906,000 ft ≅ 6,372,000 m

Metric Prefixes		
Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	**micro**	**μ**
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d

Metric Prefixes		
Multiple	Prefix	Symbol
10^{1}	deka	da
10^{2}	**hecto**	**h**
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	**peta**	**P**
10^{18}	exa	E

Land Description Diagram

The diagram that follows is from the U.S. Department of the Interior, Bureau of Land Management.

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

LAND DESCRIPTION DIAGRAM

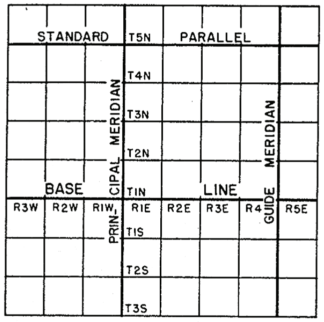


Diagram showing division of tract into Townships

36	31	32	33	34	35	36	31
1	6	5	4	3	2	1	6
12	7	8	9	10	11	12	7
13	18	17	16	15	14	13	18
24	19	20	21	22	23	24	19
25	30	29	28	27	26	25	30
36	31	32	33	34	35	36	31
1	6	5	4	3	2	1	6

Sectional map of Township showing adjoining Sections

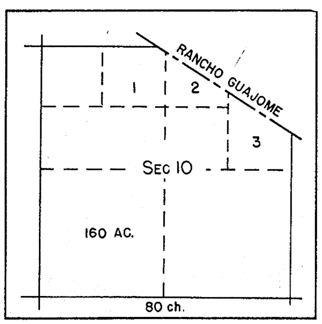
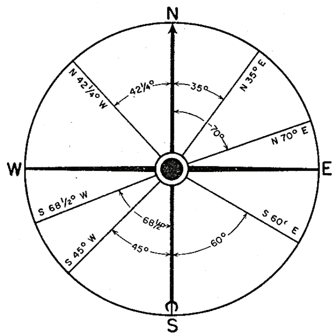
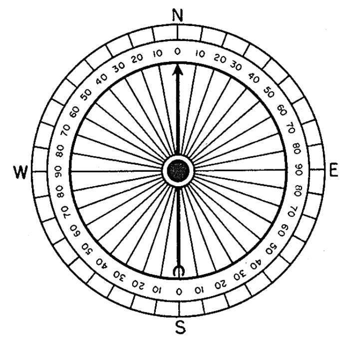


Diagram illustrating division of Fractional Section into Government Lots



60 seconds equal one minute
60 minutes equal one degree



90 degrees in a right angle
360 degrees in a circle

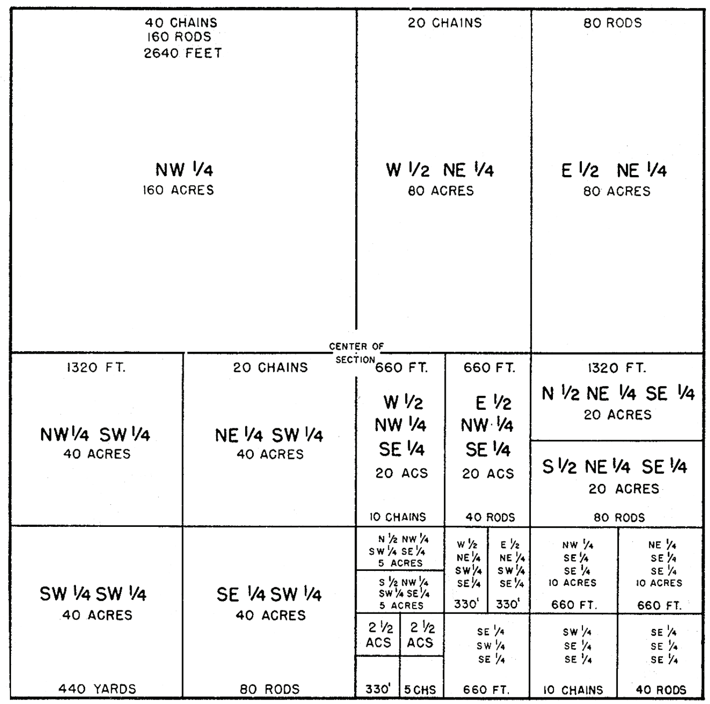


Table of Land Measurements

LINEAR MEASURE

1 inch =	**.0833 ft.**
7.92 inches =	**1 link**
12 inches =	**1 foot**
1 vara =	**33 inches**
2 3/4 feet =	**1 vara**
3 feet =	**1 yard**
25 links =	**16 ½ feet**
25 links =	**1 rod**
100 links =	**1 chain**
16½ feet =	**1 rod**
5½ yards =	**1 rod**
4 rods =	**100 links**
66 feet =	**1 chain**
80 chains =	**1 mile**
320 rods =	**1 mile**
8000 links =	**1 mile**
5280 feet =	**1 mile**
1760 yards =	**1 mile**

SQUARE MEASURE

144 sq. in. =	**1 sq. foot**
9 sq. feet =	**1 sq. yard**
30¼ sq. yds. =	**1 sq. rod**
16 sq. rods =	**1 sq. chain**
1 sq. rod =	**272¼ sq. ft.**
1 sq. ch. =	**4356 sq. ft.**
10 sq. chs. =	**1 acre**
160 sq. rods =	**1 acre**
4840 sq. yds. =	**1 acre**
43560 sq. ft. =	**1 acre**
640 acres =	**1 sq. mile**
1 sq. mile =	**1 section**
36 sq. miles =	**1 Twp.**
6 miles sq. =	**1 Twp.**
1 sq. mi. = 2.59 sq. kilm	

An Acre is:

43,560 sq. feet.	**660 feet x 66 feet.**
165 feet x 264 feet.	**160 square rods.**
198 feet x 220 feet.	**208' 8" square.**

or any rectangular tract, the product of the length and width of which totals 43,560 sq. ft.

3 MATHEMATICAL AND SURVEYING-RELATED FORMULAS

Quadratic equation

$$ax^2 + bx + c = 0$$

$$x = \text{Roots} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

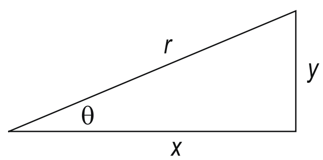
Trigonometry

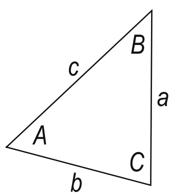
Trigonometric functions are defined using a right triangle.

$\sin\theta = y/r$, $\cos\theta = x/r$

$\tan\theta = y/x$, $\cot\theta = x/y$

$\csc\theta = r/y$, $\sec\theta = r/x$





Law of Sines $\dfrac{a}{\sin A} = \dfrac{b}{\sin B} = \dfrac{c}{\sin C}$

Law of Cosines

$$a^2 = b^2 + c^2 - 2bc\cos A$$

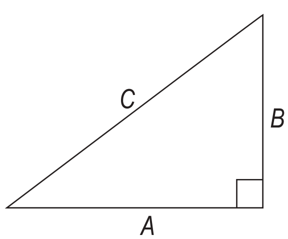
$$b^2 = a^2 + c^2 - 2ac\cos B$$

$$c^2 = a^2 + b^2 - 2ab\cos C$$

Brink, R.W., *A First Year of College Mathematics*, D. Appleton-Century Co., Inc., Englewood Cliffs, NJ, 1937.

Right Triangles

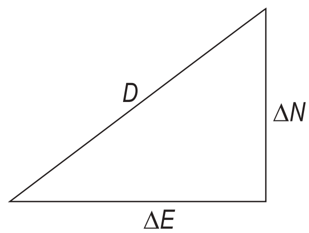
Pythagorean Theorem



$$A^2 + B^2 = C^2$$

$$C = \sqrt{A^2 + B^2}$$

Inverse Distance



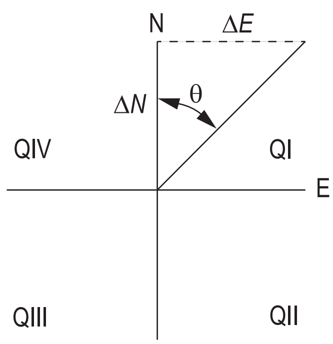
D = distance

ΔN = change in northing (latitude)

ΔE = change in easting (departure)

$$D = \sqrt{\Delta N^2 + \Delta E^2}$$

Inverse Direction



QI–QIV are quadrant numbers

$$\theta = \arctan \frac{\Delta E}{\Delta N} + C$$

where

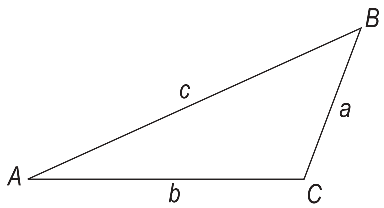
C = 0° in QI

C = 180° in QII

C = 180° in QIII

C = 360°in QIV

Oblique Triangles



Law of sines

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Law of cosines

$$a^2 = b^2 + c^2 - 2bc\cos A$$

or

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

Area of a Triangle

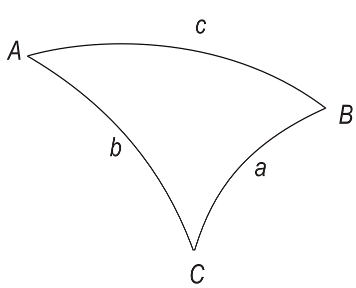
$$\text{Area} = \frac{ab\sin C}{2}$$

$$\text{Area} = \frac{a^2 \sin B \sin C}{2\sin A}$$

$$\text{Area} = \sqrt{s(s-a)(s-b)(s-c)}$$

where $s = (a + b + c)/2$

Spherical Triangles



Law of sines

$$\frac{\sin a}{\sin A} = \frac{\sin b}{\sin B} = \frac{\sin c}{\sin C}$$

Law of cosines

$\cos a = \cos b \cos c + \sin b \sin c \cos A$

$\text{Area of sphere} = 4\pi R^2$

$\text{Volume of sphere} = \frac{4}{3}\pi R^3$

$\text{Spherical excess in sec} = \frac{bc \sin A}{9.7 \times 10^{-6} R^2}$

where R = mean radius of the earth

Horizontal Circular Curves

D = degree of curve, arc definition

D_c = degree of curve, chord definition

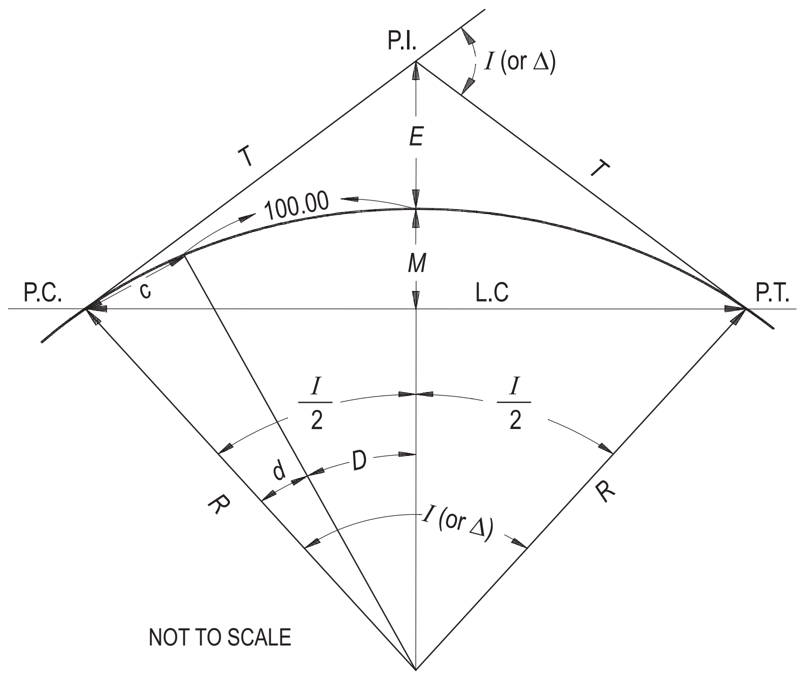
L = length of curve from P.C. to P.T.

c = length of sub-chord

ℓ = length of arc for sub-chord

d = central angle for sub-chord

I or Δ = angle of interior or delta



$D = \frac{5{,}729.58}{R}$

Radius by chord definition, $R = \frac{50}{\sin \frac{I}{2} D}$

$T = R \tan\left(\frac{I}{2}\right)$

$L = RI\frac{\pi}{180} = \frac{I}{D}(100)$

$LC = 2R \sin\left(\frac{I}{2}\right)$

$c = 2R \sin\left(\frac{d}{2}\right)$

$d = \ell D/100$

$M = R\left[1 - \cos\left(\frac{I}{2}\right)\right]$

$E = R\left[\frac{1}{\cos\left(\frac{I}{2}\right)} - 1\right]$

$\text{Area of sector} = \frac{RL}{2} = \frac{\pi R^2 I}{360}$

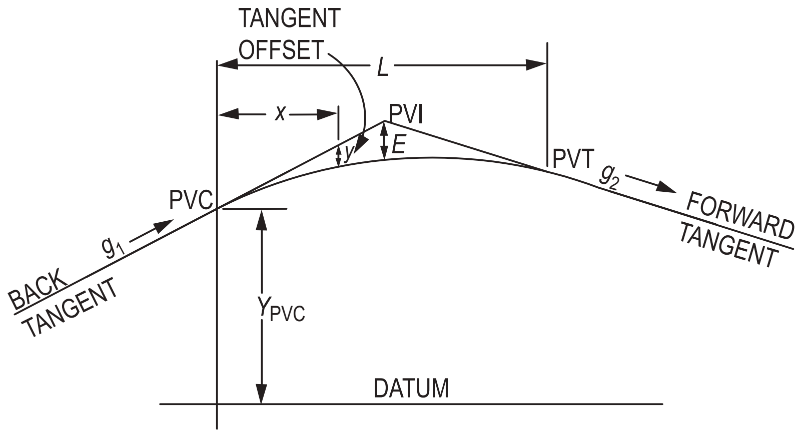
$\text{Area of segment} = \frac{\pi R^2 I}{360} - \frac{R^2 \sin I}{2}$

Area between curve and tangents = $R(T - L/2)$

$R = \frac{AC}{2 \sin(a + b)}$

Equation of a circle, $X^2 + Y^2 = R^2$

Vertical Curve Formulas



VERTICAL CURVE FORMULAS
NOT TO SCALE

L = length of curve (horizontal)

PVC = point of vertical curvature

PVI = point of vertical intersection

PVT = point of vertical tangency

g_1 = grade of back tangent

g_2 = grade of forward tangent

x = horizontal distance from PVC (or point of tangency) to point on curve

a = parabola constant

y = tangent offset

E = tangent offset at PVI

r = rate of change of grade

Tangent elevation $= Y_{\text{PVC}} + g_1 x$

and $= Y_{\text{PVI}} + g_2 (x - L/2)$

Curve elevation $= Y_{\text{PVC}} + g_1 x + ax^2$

$= Y_{\text{PVC}} + g_1 x + [(g_2 - g_1)/(2L)]\, x^2$

$y = ax^2;\quad a = \dfrac{g_2 - g_1}{2L}$ = parabola constant

$E = a\left(\dfrac{L}{2}\right)^2;\quad r = \dfrac{g_2 - g_1}{L}$ = rate of change of grade

Horizontal distance to min/max elevation on curve, $x_m = -\dfrac{g_1}{2a} = \dfrac{g_1 L}{g_1 - g_2}$

Photogrammetry

Vertical images:

$$\text{Scale} = \frac{\text{distance } ab}{\text{distance } AB} = \frac{f}{H-h}$$

$$\text{Relief displacement} = \frac{rh}{H}$$

H = C-factor × contour interval

Parallax equations:

$$p = x - x'$$

$$X = \frac{xB}{p}$$

$$Y = \frac{yB}{p}$$

$$h = H - \frac{fB}{p}$$

$$h_2 = h_1 + \frac{(p_2 - p_1)}{p_2}(H - h_1)$$

where:

f = focal length

h = height above datum

H = flying height above datum

r = radial distance from principal point

p = parallax measured on stereo pair

B = air base of stereo pair

x, y = coordinates measured on left photo of stereo pair

x' = coordinate measured on right photo of stereo pair

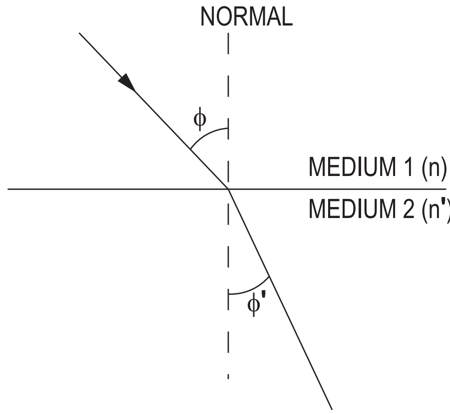
X, Y = ground coordinates

C-factor = empirical value based on precision of photogrammetric instrumentation

Physics

Lens equation:

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f}$$



where:

o = object distance

$\imath$ = image distance

f = focal length

Snell's laws:

$n \sin \phi = n' \sin \phi'$

where:

n = refractive index

ϕ = angle of incidence

$$s = \frac{1}{2}at^2$$

where:

s = distance traveled starting from zero velocity

a = constant acceleration

t = time of travel

Curvature and Refraction

Curvature (c) and atmospheric refraction (r) corrections for vertical angles:

$c \approx 4.905$ sec/1,000 ft $c \approx 16.192$ sec/1 km

$(c \,\&\, r) \approx 4.244$ sec/1,000 ft $(c \,\&\, r) \approx 13.925$ sec/1 km

and for level rod readings:

$c \approx 0.0240\, D^2$ ft $c \approx 0.0785\, K^2\, m$

$(c \,\&\, r) \approx 0.0206\, D^2$ ft $(c \,\&\, r) \approx 0.0675\, K^2\, m$

where:

D = thousands of ft

K = kilometers

$c \approx 0.667\, M^2$

$(c \,\&\, r) \approx 0.574\, M^2$

where:

M = distance in miles

Allowable angular error for an individual angle:

$$\tan \measuredangle = \frac{1}{10{,}000}$$

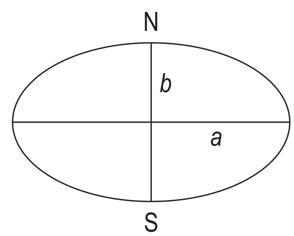
Geodesy

Ellipsoid

a = semimajor axis

b = semiminor axis

ϕ = latitude



Flattening, $f = \dfrac{a-b}{a}$ (usually published as $1/f$)

Eccentricity, $e^2 = \dfrac{a^2-b^2}{a^2}$

Radius in meridian, $M = \dfrac{a\left(1-e^2\right)}{\left(1-e^2 \sin^2 \phi\right)^{3/2}}$

Radius in prime vertical, $N = \dfrac{a}{\left(1-e^2 \sin^2 \phi\right)^{1/2}}$

Angular convergence of meridians

$$\theta_{rad} = \frac{d \tan\phi\left(1-e^2 \sin^2 \phi\right)^{1/2}}{a}$$

Linear convergence of meridians

$$= \frac{\ell d \tan\left(1-e^2 \sin^2 \phi\right)^{1/2}}{a}$$

where:

ϕ = latitude

d = distance along parallel at latitude ϕ

ℓ = length along meridians separated by d

Ellipsoid definitions:

GRS80: a = 6,378,137.0 m

$1/f$ = 298.25722101

Clark 1866: a = 6,378,206.4 m

$1/f$ = 294.97869821

Orthometric correction:

Correction = –0.005288 sin2ϕ h Δϕ arc1'

where:

ϕ = latitude at starting point

h = datum elevation in meters or feet at starting point

Δϕ = change in latitude in minutes between the two points (+ in the direction of increasing latitude or towards the pole)

$h \approx H + N$

where:

h = ellipsoidal height

N = geoid undulation

H = orthometric height

State Plane Coordinates

Reduce horizontal ground distance (DH) to geodetic (ellipsoidal) distance (DE)

$$DE = DH \times EF$$

where:

$$EF = \text{elevation factor} = \frac{R}{R + H + N}$$

and:

R = ellipsoidal radius

H = orthometric height

N = geoid height

Reduce geodetic (ellipsoidal) distance (DE) to grid distance (DG)

$$DG = DE \times SF$$

where:

SF = projection scale factor

For precisions less than 1/200,000, may use approximate ellipsoid radius R ≈ 20,906,000 ft and neglect geoid height.

Arc distance (AR) to chord distance (CH) correction

$$AR - CH = \frac{CH^3}{24R^2}$$

where R is radius of the arc distance

Electronic Distance Measurement

$$V = c/n$$

$$\lambda = V/f$$

$$D = \left(\frac{m\lambda + d}{2}\right)$$

where:

V = velocity of light through the atmosphere (m/s)

c = velocity of light in a vacuum

n = index of refraction

λ = wave length (m)

f = modulated frequency in hertz (cycles/sec)

D = distance measured

m = integer number of full wavelengths

d = fractional part of the wavelength

Atmospheric Correction

A 10°C temperature change or a pressure difference of 1 in. of mercury produces a distance correction of approximately 10 parts per million (ppm).

Area Formulas

Area by coordinates where i is point order in a closed polygon.

$$\text{Area} = \frac{1}{2}\left[\sum_{i=1}^{n} X_i Y_{i+1} - \sum_{i=1}^{n} X_i Y_{i-1}\right]$$

Trapezoidal Rule

$$\text{Area} = w\left(\frac{h_1 + h_n}{2} + h_2 + h_3 + h_4 + \ldots + h_{n-1}\right)$$

Simpson's 1/3 Rule

$$\text{Area} = w\left[h_1 + 2\left(\sum h_{\text{odds}}\right) + 4\left(\sum h_{\text{evens}}\right) + h_n\right]/3$$

where w = length of a common interval between offsets

Earthwork Formulas

Average end area formula

Volume = $L(A_1 + A_2)/2$

Prismoidal formula

Volume = $L(A_1 + 4A_m + A_2)/6$

where:

A_m = area of mid-section

L = distance between A_1 and A_2

Pyramid or cone

Volume = h(area of base)/3

Probability and Statistics

Standard Deviation

$$\sigma = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{\Sigma v^2}{n-1}}$$

where:

σ = standard deviation (sometimes referred to as standard error)

Σv^2 = sum of the squares of the residuals (deviation from the mean)

n = number of observations

$\bar{x}$ = mean of the observations (individual measurements x_i)

Error Propagation

$$\sigma_{\text{sum}} = \sqrt{\sigma_1^2 + \sigma_2^2 + \ldots + \sigma_n^2}$$

$$\sigma_{\text{series}} = \sigma\sqrt{n}$$

$$\sigma_{\text{mean}} = \frac{\sigma}{\sqrt{n}}$$

$$\sigma_{\text{product}} = \sqrt{A^2\sigma_b^2 + B^2\sigma_a^2}$$

$$\Sigma = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} \\ \sigma_{xy} & \sigma_y^2 \end{bmatrix}$$

$\tan 2\theta = \dfrac{2\sigma_{xy}}{\sigma_x^2 - \sigma_y^2}$ where θ = the counterclockwise angle from the x axis

Relative Weights

Relative weights are inversely proportional to variances, or:

$$W_a \propto \frac{1}{\sigma_a^2}$$

Weighted mean:

$$\overline{M}_w = \frac{\sum WM}{\sum W}$$

where:

$\overline{M}_w$ = weighted mean

ΣWM = sum of individual weights times their measurements

ΣW = sum of the weights

Confidence Intervals

Confidence Interval for the Mean μ of a Normal Distribution

(A) Standard deviation σ is known

$$\overline{X} - Z_{\alpha/2}\frac{\sigma}{\sqrt{n}} \le \mu \le \overline{X} + Z_{\alpha/2}\frac{\sigma}{\sqrt{n}}$$

(B) Standard deviation σ is known

$$\overline{X} - t_{\alpha/2}\frac{s}{\sqrt{n}} \le \mu \le \overline{X} + t_{\alpha/2}\frac{s}{\sqrt{n}}$$

where $t_{\alpha/2}$ corresponds to n–1 degrees of freedom.

Confidence Interval for the Variance σ² of a Normal Distribution

$$\frac{(n-1)s^2}{x^2_{\alpha/2,\, n-1}} \le \sigma^2 \le \frac{(n-1)s^2}{x^2_{1-\alpha/2,\, n-1}}$$

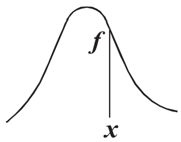
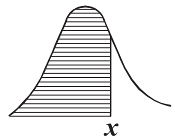
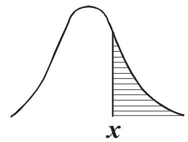
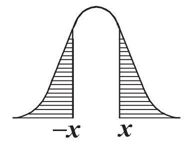
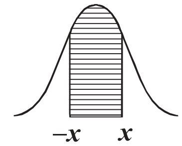
Confidence Interval for the Ratio of Two Normal Distribution Variances

$$\frac{S_1^2}{S_2^2 F_{\alpha/2,\, n_1-1, n_2-1}} \le \frac{\sigma_1^2}{\sigma_2^2} \le \frac{S_1^2}{S_2^2 F_{\alpha/2,\, n_2-1, n_1-1}}$$

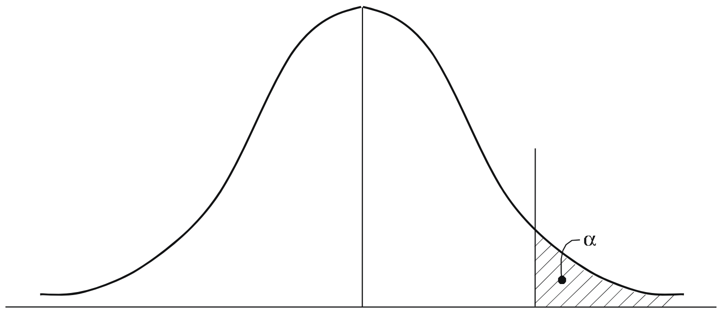
Values of $Z_{\alpha/2}$

Confidence Interval	$Z_{\alpha/2}$
80%	1.2816
90%	1.6449
95%	1.9600
96%	2.0537
98%	2.3263
99%	2.5758

Unit Normal Distribution Table

					
x	*f*(*x*)	*F*(*x*)	*R*(*x*)	2*R*(*x*)	*W*(*x*)
0.0	0.3989	0.5000	0.5000	1.0000	0.0000
0.1	0.3970	0.5398	0.4602	0.9203	0.0797
0.2	0.3910	0.5793	0.4207	0.8415	0.1585
0.3	0.3814	0.6179	0.3821	0.7642	0.2358
0.4	0.3683	0.6554	0.3446	0.6892	0.3108
0.5	0.3521	0.6915	0.3085	0.6171	0.3829
0.6	0.3332	0.7257	0.2743	0.5485	0.4515
0.7	0.3123	0.7580	0.2420	0.4839	0.5161
0.8	0.2897	0.7881	0.2119	0.4237	0.5763
0.9	0.2661	0.8159	0.1841	0.3681	0.6319
1.0	0.2420	0.8413	0.1587	0.3173	0.6827
1.1	0.2179	0.8643	0.1357	0.2713	0.7287
1.2	0.1942	0.8849	0.1151	0.2301	0.7699
1.3	0.1714	0.9032	0.0968	0.1936	0.8064
1.4	0.1497	0.9192	0.0808	0.1615	0.8385
1.5	0.1295	0.9332	0.0668	0.1336	0.8664
1.6	0.1109	0.9452	0.0548	0.1096	0.8904
1.7	0.0940	0.9554	0.0446	0.0891	0.9109
1.8	0.0790	0.9641	0.0359	0.0719	0.9281
1.9	0.0656	0.9713	0.0287	0.0574	0.9426
2.0	0.0540	0.9772	0.0228	0.0455	0.9545
2.1	0.0440	0.9821	0.0179	0.0357	0.9643
2.2	0.0355	0.9861	0.0139	0.0278	0.9722
2.3	0.0283	0.9893	0.0107	0.0214	0.9786
2.4	0.0224	0.9918	0.0082	0.0164	0.9836
2.5	0.0175	0.9938	0.0062	0.0124	0.9876
2.6	0.0136	0.9953	0.0047	0.0093	0.9907
2.7	0.0104	0.9965	0.0035	0.0069	0.9931
2.8	0.0079	0.9974	0.0026	0.0051	0.9949
2.9	0.0060	0.9981	0.0019	0.0037	0.9963
3.0	0.0044	0.9987	0.0013	0.0027	0.9973
Fractiles					
1.2816	0.1755	0.9000	0.1000	0.2000	0.8000
1.6449	0.1031	0.9500	0.0500	0.1000	0.9000
1.9600	0.0584	0.9750	0.0250	0.0500	0.9500
2.0537	0.0484	0.9800	0.0200	0.0400	0.9600
2.3263	0.0267	0.9900	0.0100	0.0200	0.9800
2.5758	0.0145	0.9950	0.0050	0.0100	0.9900

t-Distribution Table

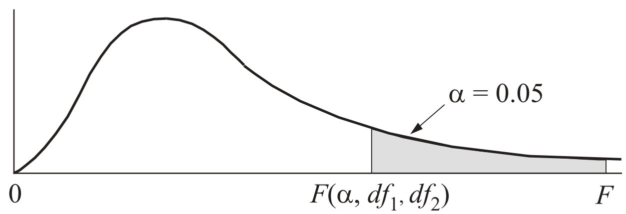


VALUES OF $t_{\alpha,n}$

n	α = 0.10	α = 0.05	α = 0.025	α = 0.01	α = 0.005	n
1	3.078	6.314	12.706	31.821	63.657	1
2	1.886	2.920	4.303	6.965	9.925	2
3	1.638	2.353	3.182	4.541	5.841	3
4	1.533	2.132	2.776	3.747	4.604	4
5	1.476	2.015	2.571	3.365	4.032	5
6	1.440	1.943	2.447	3.143	3.707	6
7	1.415	1.895	2.365	2.998	3.499	7
8	1.397	1.860	2.306	2.896	3.355	8
9	1.383	1.833	2.262	2.821	3.250	9
10	1.372	1.812	2.228	2.764	3.169	10
11	1.363	1.796	2.201	2.718	3.106	11
12	1.356	1.782	2.179	2.681	3.055	12
13	1.350	1.771	2.160	2.650	3.012	13
14	1.345	1.761	2.145	2.624	2.977	14
15	1.341	1.753	2.131	2.602	2.947	15
16	1.337	1.746	2.120	2.583	2.921	16
17	1.333	1.740	2.110	2.567	2.898	17
18	1.330	1.734	2.101	2.552	2.878	18
19	1.328	1.729	2.093	2.539	2.861	19
20	1.325	1.725	2.086	2.528	2.845	20
21	1.323	1.721	2.080	2.518	2.831	21
22	1.321	1.717	2.074	2.508	2.819	22
23	1.319	1.714	2.069	2.500	2.807	23
24	1.318	1.711	2.064	2.492	2.797	24
25	1.316	1.708	2.060	2.485	2.787	25
26	1.315	1.706	2.056	2.479	2.779	26
27	1.314	1.703	2.052	2.473	2.771	27
28	1.313	1.701	2.048	2.467	2.763	28
29	1.311	1.699	2.045	2.462	2.756	29
∞	1.282	1.645	1.960	2.326	2.576	∞

CRITICAL VALUES OF THE F DISTRIBUTION – TABLE

For a particular combination of numerator and denominator degrees of freedom, entry represents the critical values of F corresponding to a specified upper tail area (α).



Denominator df_2	Numerator df_1																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5	241.9	243.9	245.9	248.0	249.1	250.1	251.1	252.2	253.3	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	**6.61**	**5.79**	**5.41**	**5.19**	**5.05**	**4.95**	**4.88**	**4.82**	**4.77**	**4.74**	**4.68**	**4.62**	**4.56**	**4.53**	**4.50**	**4.46**	**4.43**	**4.40**	**4.36**
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	**4.96**	**4.10**	**3.71**	**3.48**	**3.33**	**3.22**	**3.14**	**3.07**	**3.02**	**2.98**	**2.91**	**2.85**	**2.77**	**2.74**	**2.70**	**2.66**	**2.62**	**2.58**	**2.54**
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	**4.54**	**3.68**	**3.29**	**3.06**	**2.90**	**2.79**	**2.71**	**2.64**	**2.59**	**2.54**	**2.48**	**2.40**	**2.33**	**2.29**	**2.25**	**2.20**	**2.16**	**2.11**	**2.07**
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	**4.35**	**3.49**	**3.10**	**2.87**	**2.71**	**2.60**	**2.51**	**2.45**	**2.39**	**2.35**	**2.28**	**2.20**	**2.12**	**2.08**	**2.04**	**1.99**	**1.95**	**1.90**	**1.84**
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	**4.24**	**3.39**	**2.99**	**2.76**	**2.60**	**2.49**	**2.40**	**2.34**	**2.28**	**2.24**	**2.16**	**2.09**	**2.01**	**1.96**	**1.92**	**1.87**	**1.82**	**1.77**	**1.71**
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.15	2.07	1.99	1.95	1.90	1.85	1.80	1.75	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20	2.13	2.06	1.97	1.93	1.88	1.84	1.79	1.73	1.67
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.77	1.71	1.65
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18	2.10	2.03	1.94	1.90	1.85	1.81	1.75	1.70	1.64
30	**4.17**	**3.32**	**2.92**	**2.69**	**2.53**	**2.42**	**2.33**	**2.27**	**2.21**	**2.16**	**2.09**	**2.01**	**1.93**	**1.89**	**1.84**	**1.79**	**1.74**	**1.68**	**1.62**
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

4 ECONOMICS

Factor Name	Converts	Symbol	Formula
Single Payment Compound Amount	to F given P	$(F/P, i\%, n)$	$(1+i)^n$
Single Payment Present Worth	to P given F	$(P/F, i\%, n)$	$(1+i)^{-n}$
Uniform Series Sinking Fund	to A given F	$(A/F, i\%, n)$	$\frac{i}{(1+i)^n-1}$
Capital Recovery	to A given P	$(A/P, i\%, n)$	$\frac{i(1+i)^n}{(1+i)^n-1}$
Uniform Series Compound Amount	to F given A	$(F/A, i\%, n)$	$\frac{(1+i)^n-1}{i}$
Uniform Series Present Worth	to P given A	$(P/A, i\%, n)$	$\frac{(1+i)^n-1}{i(1+i)^n}$
Uniform Gradient Present Worth	to P given G	$(P/G, i\%, n)$	$\frac{(1+i)^n-1}{i^2(1+i)^n}-\frac{n}{i(1+i)^n}$
Uniform Gradient † Future Worth	to F given G	$(F/G, i\%, n)$	$\frac{(1+i)^n-1}{i^2}-\frac{n}{i}$
Uniform Gradient Uniform Series	to A given G	$(A/G, i\%, n)$	$\frac{1}{i}-\frac{n}{(1+i)^n-1}$

Nomenclature and Definitions

A ....Uniform amount per interest period
B ....Benefit
BV.........Book value
C..........Cost
d...........Inflation adjusted interest rate per interest period
D_j ....Depreciation in year j
EV.........Expected value
F ....Future worth, value, or amount
f ....General inflation rate per interest period
G...........Uniform gradient amount per interest period
i ....Interest rate per interest period
i_e ....Annual effective interest rate
MARR..Minimum acceptable/attractive rate of return
m...........Number of compounding periods per year
n............Number of compounding periods; or the expected life of an asset
P ....Present worth, value, or amount
r............Nominal annual interest rate
S_n ....Expected salvage value in year n

Subscripts

j ....at time j

n..........at time n

†..........$F/G = (F/A - n)/i = (F/A) \times (A/G)$

Nonannual Compounding

$$i_e = \left(1 + \frac{r}{m}\right)^m - 1$$

Depreciation

Straight Line

$$D_j = \frac{C - S_n}{n} \backslash$$

Modified Accelerated Cost Recovery System (MACRS)

D_j = (factor from table below) C

MACRS FACTORS				
Year	Recovery Period (Years)			
	3	5	7	10
	Recovery Rate (Percent)			
1	33.33	20.00	14.29	10.00
2	44.45	32.00	24.49	18.00
3	14.81	19.20	17.49	14.40
4	7.41	11.52	12.49	11.52
5		11.52	8.93	9.22
6		5.76	8.92	7.37
7			8.93	6.55
8			4.46	6.55
9				6.56
10				6.55
11				3.28

Book Value

BV = initial cost – ΣD_j

Capitalized Costs

Capitalized costs are present worth values using an assumed perpetual period of time.

Capitalized Costs = $P = \frac{A}{i}$

Benefit-Cost Analysis

In a benefit-cost analysis, the benefits B of a project should exceed the estimated costs C.

$B - C \geq 0$, or $B/C \geq 1$

5 ETHICS

Surveyor's Canons

Canon 1. A Professional Surveyor should refrain from conduct that is detrimental to the public.

Canon 2. A Professional Surveyor should abide by the rules and regulations pertaining to the practice of surveying within the licensing jurisdiction.

Canon 3. A Professional Surveyor should accept assignments only in one's area of professional competence and expertise.

Canon 4. A Professional Surveyor should develop and communicate a professional analysis and opinion without bias or personal interest.

Canon 5. A Professional Surveyor should maintain the confidential nature of the surveyor-client relationship.

Canon 6. A Professional Surveyor should use care to avoid advertising or solicitation that is misleading or otherwise contrary to the public interest.

Canon 7. A Professional Surveyor should maintain professional integrity when dealing with members of other professions.

Source: Excerpt from the National Society of Professional Surveyors (NSPS) Surveyor's Creed and Canons, https://www.nsps.us.com/page/CreedandCanons, as posted on April 18, 2019.

Model Rules

The three major sections of the NCEES *Model Rules* address (1) Licensee's Obligation to the Public, (2) Licensee's Obligation to Employers and Clients, and (3) Licensee's Obligation to Other Licensees. The principles amplified in these sections are important guides to appropriate behavior of professional surveyors.

Application of the code in many situations is not controversial. However, there may be situations in which applying the code may raise more difficult issues. In particular, there may be circumstances in which terminology in the code is not clearly defined, or in which two sections of the code may be in conflict. For example, what constitutes "valuable consideration" or "adequate" knowledge may be interpreted differently by qualified professionals. These types of questions are called *conceptual issues*, in which definitions of terms may be in dispute. In other situations, *factual issues* may also affect ethical dilemmas. Many decisions regarding surveying may be based upon interpretation of disputed or incomplete information. In addition, *tradeoffs* revolving around competing issues of risk vs. benefit, or safety vs. economics may require judgments that are not fully addressed simply by application of the code.

No code can give immediate and mechanical answers to all ethical and professional problems that a surveyor may face. Creative problem solving is often called for in ethics, just as it is in other areas of surveying.

From Model Rules, Section 240.15, Rules of Professional Conduct

To safeguard the health, safety, and welfare of the public and to maintain integrity and high standards of skill and practice in the engineering and surveying professions, the rules of professional conduct provided in this section shall be binding upon every licensee and on all firms authorized to offer or perform engineering or surveying services in this jurisdiction.

A. Licensee's Obligation to the Public

1. Licensees shall be cognizant that their first and foremost responsibility is to safeguard the health, safety, and welfare of the public when performing services for clients and employers.
2. Licensees shall sign and seal only those plans, surveys, and other documents that conform to accepted engineering and surveying standards and that safeguard the health, safety, and welfare of the public.
3. Licensees shall notify their employer or client and such other authority as may be appropriate when their professional judgment is overruled under circumstances in which the health, safety, or welfare of the public is endangered.
4. Licensees shall, to the best of their knowledge, include all relevant and pertinent information in an objective and truthful manner within all professional documents, statements, and testimony.
5. Licensees shall express a professional opinion publicly only when it is founded upon an adequate knowledge of the facts and a competent evaluation of the subject matter.
6. Licensees shall issue no statements, criticisms, or arguments on engineering and surveying matters that are inspired or paid for by interested parties, unless they explicitly identify the interested parties on whose behalf they are speaking and reveal any interest they have in the matters.
7. Licensees shall not partner, practice, or offer to practice with any person or firm that they know is engaged in fraudulent or dishonest business or professional practices.
8. Licensees who have knowledge or reason to believe that any person or firm has violated any rules or laws applying to the practice of engineering or surveying shall report it to the board, may report it to appropriate legal authorities, and shall cooperate with the board and those authorities as may be requested.
9. Licensees shall not knowingly provide false or incomplete information regarding an applicant in obtaining licensure.

10. Licensees shall comply with the licensing laws and rules governing their professional practice in each of the jurisdictions in which they practice.

B. Licensee's Obligation to Employer and Clients

1. Licensees shall undertake assignments only when qualified by education or experience in the specific technical fields of engineering or surveying involved.
2. Licensees shall not affix their signatures or seals to any plans or documents dealing with subject matter in which they lack competence, nor to any such plan or document not prepared under their responsible charge.
3. Licensees may accept assignments and assume responsibility for coordination of an entire project, provided that each technical segment is signed and sealed by the licensee responsible for preparation of that technical segment.
4. Licensees shall not reveal facts, data, or information obtained in a professional capacity without the prior consent of the client, employer, or public body on which they serve except as authorized or required by law or rules.
5. Licensees shall not solicit or accept gratuities, directly or indirectly, from contractors, their agents, or other parties in connection with work for employers or clients.
6. Licensees shall disclose to their employers or clients all known or potential conflicts of interest or other circumstances that could influence or appear to influence their judgment or the quality of their professional service or engagement.
7. Licensees shall not accept compensation, financial or otherwise, from more than one party for services pertaining to the same project, unless the circumstances are fully disclosed and agreed to in writing by all interested parties.
8. Licensees shall not solicit or accept a professional contract from a governmental body on which a principal or officer of their organization serves as a member. Conversely, licensees serving as members, advisors, or employees of a government body or department, who are the principals or employees of a private concern, shall not participate in decisions with respect to professional services offered or provided by said concern to the governmental body that they serve. (Section 150, Disciplinary Action, NCEES *Model Law*)
9. Licensees shall not use confidential information received in the course of their assignments as a means of making personal profit without the consent of the party from whom the information was obtained.

C. Licensee's Obligation to Other Licensees

1. Licensees shall not falsify or permit misrepresentation of their, or their associates', academic or professional qualifications. They shall not misrepresent or exaggerate their degree of responsibility in prior assignments nor the complexity of said assignments. Presentations incidental to the solicitation of employment or business shall not misrepresent pertinent facts concerning employers, employees, associates, joint ventures, or past accomplishments.
2. Licensees shall not offer, give, solicit, or receive, either directly or indirectly, any commission, or gift, or other valuable consideration in order to secure work, and shall not make any political contribution with the intent to influence the award of a contract by public authority.
3. Licensees shall not injure or attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other licensees, nor indiscriminately criticize other licensees' work.
4. Licensees shall make a reasonable effort to inform another licensee whose work is believed to contain a material discrepancy, error, or omission that may impact the health, safety, or welfare of the public, unless such reporting is legally prohibited.

6 SAFETY

Definition of Safety

Safety is the condition of protecting people from threats or failures that could harm their physical, emotional, occupational, psychological, or financial well-being. Safety is also the control of known threats to attain an acceptable level of risk.

The United States relies on public codes and standards, engineering designs, and corporate policies to ensure that a structure or place does what it should do to maintain a steady state of safety—that is, long-term stability and reliability. Some *Safety/Regulatory Agencies* that develop codes and standards commonly used in the United States are shown in the table.

Abbreviation	Name	Jurisdiction
ANSI	American National Standards Institute	Nonprofit standards organization
CGA	Compressed Gas Association	Nonprofit trade association
CSA	Canadian Standards Association	Nonprofit standards organization
FAA	Federal Aviation Administration	Federal regulatory agency
IEC	International Electrotechnical Commission	Nonprofit standards organization
ITSNA	Intertek Testing Services NA (formerly Edison Testing Labs)	Nationally recognized testing laboratory
MSHA	Mine Safety and Health Administration	Federal regulatory agency
NFPA	National Fire Protection Association	Nonprofit trade association
NIOSH	National Institute for Occupational Safety and Health	Federal regulatory agency
OSHA	Occupational Safety and Health Administration	Federal regulatory agency
RCRA	Resource Conservation and Recovery Act	Federal law
UL	Underwriters Laboratories	Nationally recognized testing laboratory
USCG	United States Coast Guard	Federal regulatory agency
USDOT	United States Department of Transportation	Federal regulatory agency
USEPA	United States Environmental Protection Agency	Federal regulatory agency

Safety and Prevention

A traditional preventive approach to both accidents and occupational illness involves recognizing, evaluating, and controlling hazards and work conditions that may cause physical or other injuries.

Hazard is the capacity to cause harm. It is an inherent quality of a material or a condition. For example, a rotating saw blade or an uncontrolled high-pressure jet of water has the capability (hazard) to slice through flesh. A toxic chemical or a pathogen has the capability (hazard) to cause illness.

Risk is the chance or probability that a person will experience harm and is not the same as a hazard. Risk always involves both probability and severity elements. The hazard associated with a rotating saw blade or the water jet continues to exist, but the probability of causing harm, and thus the risk, can be reduced by installing a guard or by controlling the jet's path. Risk is expressed by the equation:

$$\text{Risk} = \text{Hazard} \times \text{Probability}$$

When people discuss the hazards of disease-causing agents, the term *exposure* is typically used more than *probability*. If a certain type of chemical has a toxicity hazard, the risk of illness rises with the degree to which that chemical contacts your body or enters your lungs. In that case, the equation becomes:

$$\text{Risk} = \text{Hazard} \times \text{Exposure}$$

Organizations evaluate hazards using multiple techniques and data sources.

Job Safety Analysis

Job safety analysis (JSA) is known by many names, including activity hazard analysis (AHA), or job hazard analysis (JHA). Hazard analysis helps integrate accepted safety and health principles and practices into a specific task. In a JSA, each basic step of the job is reviewed, potential hazards identified, and recommendations documented as to the safest way to do the job. JSA techniques work well when used on a task that the analysts understand well. JSA analysts look for specific types of potential accidents and ask basic questions about each step, such as these:

Can the employee strike against or otherwise make injurious contact with the object?

Can the employee be caught in, on, or between objects?

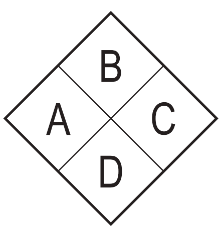
Can the employee strain muscles by pushing, pulling, or lifting?

Is exposure to toxic gases, vapors, dust, heat, electrical currents, or radiation possible?

Hazard Assessments

Hazard Assessment

The fire/hazard diamond below summarizes common hazard data available on the Safety Data Sheet (SDS) and is frequently shown on chemical labels.



Position A – Health Hazard (*Blue*)

0 = normal material

1 = slightly hazardous

2 = hazardous

3 = extreme danger

4 = deadly

Position B – Flammability (*Red*)

0 = will not burn

1 = will ignite if preheated

2 = will ignite if moderately heated

3 = will ignite at most ambient temperature

4 = burns readily at ambient conditions

Position C – Reactivity (*Yellow*)

0 = stable and not reactive with water

1 = unstable if heated

2 = violent chemical change

3 = shock short may detonate

4 = may detonate

Position D – (*White*)

ALKALI = alkali

OXY = oxidizer

ACID = acid

Cor = corrosive

~~W~~ = use no water

☢ = radiation hazard

GHS

The *Globally Harmonized System of Classification and Labeling of Chemicals*, or GHS, is a system for standardizing and harmonizing the classification and labeling of chemicals. GHS is a comprehensive approach to:

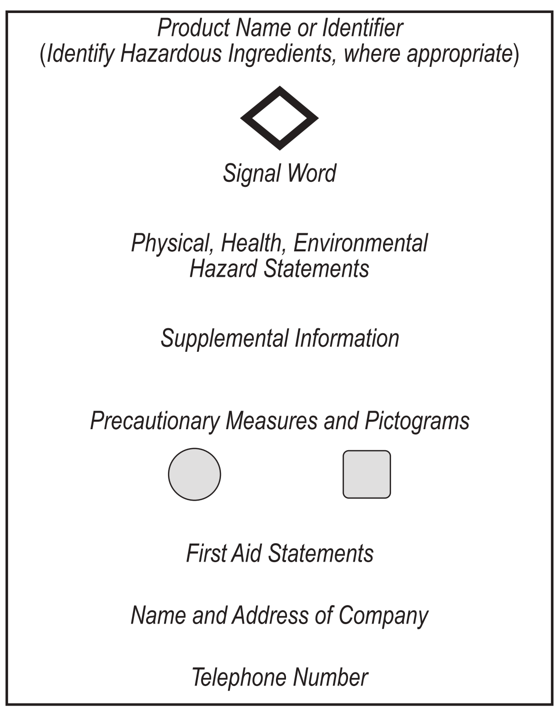
- Defining health, physical, and environmental hazards of chemicals
- Creating classification processes that use available data on chemicals for comparison with the defined hazard criteria
- Communicating hazard information, as well as protective measures, on labels and Safety Data Sheets (SDSs), formerly called Material Safety Data Sheets (MSDSs).

GHS label elements include:

- Precautionary statements and pictograms: Measures to minimize or prevent adverse effects
- Product identifier (ingredient disclosure): Name or number used for a hazardous product on a label or in the SDS
- Supplier identification: The name, address, and telephone number of the supplier
- Supplemental information: nonharmonized information

Other label elements include symbols, signal words, and hazard statements.

GHS LABEL ELEMENTS

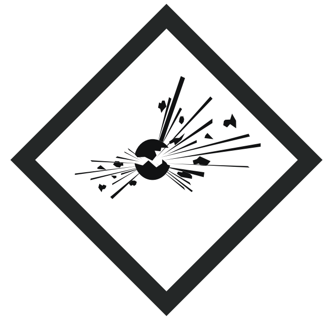


Occupational Safety and Health Administration, *A Guide to The Globally Harmonized System of Classification and Labelling of Chemicals (GHS),* United States Department of Labor, https://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf

GHS PICTOGRAMS AND HAZARD CLASSES

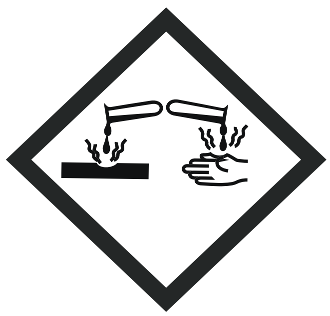
- OXIDIZERS

- FLAMMABLES
- SELF-REACTIVES
- PYROPHORICS
- SELF-HEATING
- EMITS FLAMMABLE GAS
- ORGANIC PEROXIDES

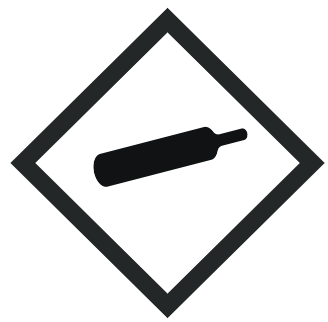


- EXPLOSIVES
- SELF-REACTIVES
- ORGANIC PEROXIDES

- ACUTE TOXICITY (SEVERE)

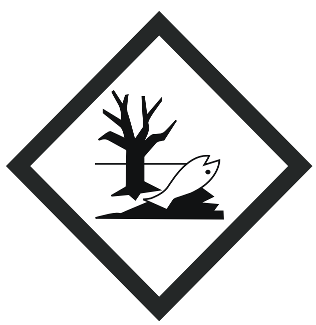


- CORROSIVES



- GASES UNDER PRESSURE

- CARCINOGEN
- RESPIRATORY SENSITIZER
- REPRODUCTIVE TOXICITY
- TARGET ORGAN TOXICITY
- MUTAGENICITY
- ASPIRATION TOXICITY



- ENVIRONMENTAL TOXICITY

- IRRITANT
- DERMAL SENSITIZER
- ACUTE TOXICITY (HARMFUL)
- NARCOTIC EFFECTS
- RESPIRATORY TRACT IRRITATION

Occupational Safety and Health Administration, *A Guide to The Globally Harmonized System of Classification and Labelling of Chemicals (GHS),* United States Department of Labor, https://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf

TRANSPORT PICTOGRAMS

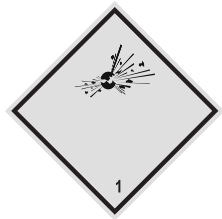
FLAMMABLE LIQUID
FLAMMABLE GAS
FLAMMABLE AEROSOL

FLAMMABLE SOLID
SELF-REACTIVE SUBSTANCES

PYROPHORICS (SPONTANEOUSLY COMBUSTIBLE)
SELF-HEATING SUBSTANCES

SUBSTANCES, WHICH IN CONTACT WITH WATER, EMIT FLAMMABLE GASES (DANGEROUS WHEN WET)

OXIDIZING GASES
OXIDIZING LIQUIDS
OXIDIZING SOLIDS

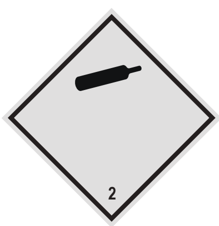


EXPLOSIVE DIVISIONS 1.1, 1.2, 1.3

EXPLOSIVE DIVISION 1.4

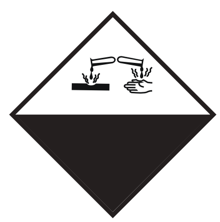
EXPLOSIVE DIVISION 1.5

EXPLOSIVE DIVISION 1.6



COMPRESSED GASES

ACUTE TOXICITY (POISON): ORAL, DERMAL, INHALATION



CORROSIVE

MARINE POLLUTANT

ORGANIC PEROXIDES

Occupational Safety and Health Administration, *A Guide to The Globally Harmonized System of Classification and Labelling of Chemicals (GHS),* United States Department of Labor, https://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf

ACUTE ORAL TOXICITY

	CATEGORY 1	CATEGORY 2	CATEGORY 3	CATEGORY 4	CATEGORY 5
LD_{50}	≤ 5 mg/kg	$> 5 < 50$ mg/kg	$\geq 50 < 300$ mg/kg	$\geq 300 < 2{,}000$ mg/kg	$\geq 2{,}000 < 5{,}000$ mg/kg
PICTOGRAM					NO SYMBOL
SIGNAL WORD	DANGER	DANGER	DANGER	WARNING	WARNING
HAZARD STATEMENT	FATAL IF SWALLOWED	FATAL IF SWALLOWED	TOXIC IF SWALLOWED	HARMFUL IF SWALLOWED	MAY BE HARMFUL IF SWALLOWED

Safety Data Sheet (SDS)

The SDS provides comprehensive information for use in workplace chemical management. Employers and workers use the SDS as a source of information about hazards and to obtain advice on safety precautions. The SDS is product related and, usually, is not able to provide information that is specific for any given workplace where the product may be used. However, the SDS information enables the employer to develop an active program of worker protection measures, including training, which is specific to the individual workplace, and to consider any measures that may be necessary to protect the environment. Information in an SDS also provides a source of information for those involved with the transport of dangerous goods, emergency responders, poison centers, those involved with the professional use of pesticides, and consumers.

The SDS has 16 sections in a set order, and minimum information is prescribed.

The Hazard Communication Standard (HCS) requires chemical manufacturers, distributors, or importers to provide SDSs to communicate the hazards of hazardous chemical products. As of June 1, 2015, the HCS requires new SDSs to be in a uniform format, and include the section numbers, the headings, and associated information under the headings below:

Section 1, Identification: Includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use

Section 2, Hazard(s) identification: Includes all hazards regarding the chemical; required label elements

Section 3, Composition/information on ingredients: Includes information on chemical ingredients; trade secret claims

Section 4, First-aid measures: Includes important symptoms/effects, acute, and delayed; required treatment

Section 5, Fire-fighting measures: Lists suitable extinguishing techniques, equipment; chemical hazards from fire

Section 6, Accidental release measures: Lists emergency procedures; protective equipment; proper methods of containment and cleanup

Section 7, Handling and storage: Lists precautions for safe handling and storage, including incompatibilities

Section 8, Exposure controls/personal protection: Lists OSHA's Permissible Exposure Limits (PELs); Threshold Limit Values (TLVs); appropriate engineering controls; personal protective equipment (PPE)

Section 9, Physical and chemical properties: Lists the chemical's characteristics

Section 10, Stability and reactivity: Lists chemical stability and possibility of hazardous reactions

Section 11, Toxicological information: Includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity

Section 12, Ecological information*

Section 13, Disposal considerations*

Section 14, Transport information*

Section 15, Regulatory information*

Section 16, Other information: Includes the date of preparation or last revision

*Note: Since other Agencies regulate this information, OSHA will not be enforcing Sections 12 through 15 (29 CFR 1910.1200(g)(2)).

Occupational Safety and Health Administration, *A Guide to The Globally Harmonized System of Classification and Labelling of Chemicals (GHS),* United States Department of Labor, https://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf

Signal Words

The signal word found on every product's label is based on test results from various oral, dermal, and inhalation toxicity tests, as well as skin and eye corrosion assays in some cases. Signal words are placed on labels to convey a level of care that should be taken (especially personal protection) when handling and using a product, from purchase to disposal of the empty container, as demonstrated by the Pesticide Toxicity Table.

Pesticide Toxicity Categories

Signal Word on Label	Toxicity Category	Acute-Oral LD_{50} for Rats	Amount Needed to Kill an Average Size Adult	Notes
Danger–Poison	Highly Toxic	50 or less	Taste to a teaspoon	Skull and crossbones; Keep Out of Reach of Children
Warning	Moderately Toxic	50 to 500	One to six teaspoons	Keep Out of Reach of Children
Caution	Slightly Toxic	500 to 5,000	One ounce to a pint	Keep Out of Reach of Children
Caution	Relatively Nontoxic	>5,000	More than a pint	Keep Out of Reach of Children

From *Regulating Pesticides*, U.S. Environmental Protection Agency.

NSPS MODEL STANDARDS

Section A

INTRODUCTION

Approved 3/12/2002

The primary responsibility for developing and adopting standards rests with the individual state associations, professional registration boards, state surveying agencies and federal agencies. These model standards of practice are to be used as guidelines for those that have the authority to develop and adopt standards. These recommended standards intended to foster uniformity in the professional practice of surveying.

Standards are not intended to be used in place of professional judgement. It must be understood that there will be circumstances and conditions that make it impossible to comply with some provisions of a standard. If the professional surveyor deviates from the standard or guideline, this deviation should be noted, described and justified.

Section B

NSPS MODEL STANDARDS FOR PROPERTY SURVEYS

Approved 3/12/02

1. INTRODUCTION

Standards for property surveys have been adopted by almost all of the state associations and professional registration boards. This model standard is not intended to take the place of those standards, but to serve as a guide to review and evaluate existing or proposed standards.

Standards are not intended to be used in place of professional judgment. It must be understood that there will be circumstances and conditions that make it impossible to comply with some provisions of a standard. If the professional surveyor (Surveyor) deviates from the standard or guideline, this deviation should be noted, described and justified by the Surveyor.

2. RESEARCH, IDENTIFICATION, MEASUREMENTS AND COMPUTATIONS

The Surveyor in conducting a property survey shall:

a. Execute a survey based on the legal description of the parcel or tract taken from the last deed of record as provided by the client.
b. Search pertinent documents that may include, but are not limited to maps, deeds, title reports, title opinions, and United States Public Land Survey records.
c. Diligently search for and identify monuments and other physical evidence that could affect the location of the boundaries.
d. Conduct field measurements to correlate all found evidence.
e. Make all measurements to a precision compatible with the size and geometric shape of the parcel, and consistent with the accuracy desired for the class of property being surveyed.
f. Compare and analyze all of the data gathered and reach a professional opinion as to the most probable location of the corners of the property.

3. IDENTIFICATION AND RESOLUTION OF CONFLICTS

If a Surveyor has a material disagreement with the measurements or monumented corner positions of another surveyor, the Surveyor shall contact the other surveyor and they shall attempt to resolve the disagreement.

The Surveyor shall advise the client of discrepancies that raise concerns as to the integrity of the surveyed boundary line and provide a written report to the client detailing the basis for those concerns.

4. IDENTIFICATION AND DESCRIPTION OF MONUMENTS

All monuments must be thoroughly described and specifically identified as set or found, whenever shown on maps or referred to in documents prepared by the Surveyor. Descriptions of monuments must be sufficient in detail to readily facilitate future recovery by other surveyors and to enable positive identification.

5. SURVEY DRAWING AND CERTIFICATION

The Surveyor shall prepare an appropriately scaled drawing of the survey. The survey drawing should include at a minimum, the following items:

a. The record description of the property or the reference to the source of the record description. The survey description shall be given if the survey is an original survey.
b. North arrow
c. Scale
d. Bearings, azimuth or angles, and the distances for all courses
e. Basis of bearings or azimuth
f. Monuments identified per Section 4 above
g. Observed evidence of possession or use by others in the parcel or across any perimeter lines of the property
h. Sufficient data to indicate the theory of location applied in formulating the opinions as to the probable location of the boundaries and corners of the property
i. Name, registration number, address and phone number of the Surveyor
j. Name of the client
k. Date of survey
l. Certification

6. CLASSIFICATION AND ACCURACY STANDARDS

The various classifications of property surveys and the positional accuracy of these classes are described in Section C of these model standards.

7. LEGAL DESCRIPTIONS OF PROPERTY

If a Surveyor is called upon to prepare a legal description of a property the following items shall be included:

a. A clear statement of the relationship between the described property and the survey control or the basis of the unique location.
b. The basis of bearings when bearings are used.
c. Metes and bounds descriptions shall include bearings or angles and distances in order to allow for the computation of a mathematical closure.
d. Citations to the recording information or other identifying documentation for any maps, plats and other documents referenced.
e. Detailed description of any natural or artificial monument referenced.
f. The Surveyor's name, address, telephone number, registration number and professional seal.

8. CORNER RECORDS

When a corner record is required to be presented for recordation pursuant to state statutes or regulations, the Surveyor shall reconstruct or rehabilitate the monument and accessories to the corner, such that it shall be, as much as reasonably possible, permanent and locatable with ease by Surveyors in the future.

9. ELECTRONIC DATA DISTRIBUTION

The client may request the Surveyor to provide the survey data in an electronic format. These formats include such files as CADD drawing files, digital terrain model (DTM) files, or digital elevation model (DEM) files. When the Surveyor provides these files, they are only for the benefit of the client on this specific survey. In every case the surveyor shall also provide a signed and sealed hard copy drawing or representation of the survey. This drawing shall be the official plat or map and shall be deemed to be correct and superior to the electronic data. The electronic data file shall also contain a statement that the file is not a certified document and that the official document was issued and sealed by (*name and registration number of the Surveyor*) on (*date*).

The Surveyor may also need to address additional liability issues in appropriate contract language.

Section C

NSPS CLASSIFICATION AND ACCURACY STANDARDS FOR PROPERTY SURVEYS

Approved 3/12/2002

1. PURPOSE

The purpose of this standard is to prescribe accuracy standards to be used by a professional surveyor (Surveyor) for the execution of property surveys.

2. RELATIVE POSITIONAL ACCURACY

Relative Positional Accuracy of a survey is a value expressed in feet or meters that represents the uncertainty of the location of any point in a survey relative to any other point in the same survey at the 95 percent confidence level. Therefore, it is also the accuracy of the distance between all points on the same survey.

Relative Positional Accuracy may be tested by comparing the relative location of points in a survey as measured by an independent survey of higher accuracy. The test should include both distances and direction. Relative Positional Accuracy may also be tested by the results from a minimally constrained, correctly weighted least square adjustment of the survey.

3. PROCEDURE

The Surveyor shall select the proper equipment and methods necessary to achieve the Acceptable Relative Positional Accuracy required of this standard. The survey work shall be executed in a professional manner by the Surveyor or by personnel under the direct personal supervision of the Surveyor. The Surveyor shall conduct check measurements to assure that the intended accuracy of the survey is achieved.

4. CLASSIFICATION OF SURVEY BY LAND USE

The degree of precision and accuracy necessary for a particular property survey shall be based upon the intended use of the land. If the client does not include information regarding the intended use, the classification of the survey shall be based upon the current use of the land.

The classifications of surveys are as follows:

a. <u>Urban Surveys</u> - Urban surveys are performed on land lying within or adjoining a city or town, and include commercial and industrial properties condominiums, townhouses, apartments and other multi-unit developments, regardless of geographic location. All ALTA/ACSM Land Title Surveys are included in this classification.

b. Suburban Surveys - Suburban surveys are performed on land lying outside of urban areas and developed for single family residential use.

c. Rural Surveys - Rural surveys are performed on undeveloped land lying outside of urban and suburban areas such as farms.

5. RELATIVE POSITIONAL ACCURACY

Classification of Survey	Acceptable Relative Positional Accuracy
Urban	0.07 feet (21 mm) plus 50 ppm
Suburban	0.13 feet (40 mm) plus 100 ppm
Rural	0.26 feet (79 mm) plus 200 ppm

Accuracy is given at the 95 percent confidence level.

Section D

NSPS MODEL STANDARDS

FOR CONSTRUCTION LAYOUT SURVEYS

Approved 3/12/02

1. INTRODUCTION

A professional surveyor (Surveyor) shall approach the task of construction staking in precisely the same manner as any survey in which a high degree of competence is required. The public welfare shall be paramount in the Surveyor's decision to take on such a task.

Surveyors shall only concern themselves with the direct interpretation of an approved set of plans. It is not the responsibility of the Surveyor or the surveyor's staff to correct or revise erroneous architectural or engineering plans. If the approved design plans are found to lack sufficient information for proper layout, the Surveyor shall immediately notify his client, the owner, the engineer and/or architect responsible for the project.

Proper field procedures shall be employed to ensure correct placement of construction stakes or other control. Appropriate precautionary measures shall be taken to protect the Surveyors employees, agents, and others from undue physical risks associated with construction projects.

2. PROCEDURAL STANDARDS

A. **Preliminary Research and Planning**

The Surveyor shall:

1. Obtain from the client, or other proper sources, the approved contract documents (plans and specifications) setting forth the project for which the layout survey is to be performed.
2. Determine the appropriate number of horizontal and vertical monuments to be established and the relationship of those monuments to construction lines, grades and offsets.

B. Analysis of Research and Preliminary Conclusions

The surveyor shall:

1. Examine and analyze the data.
2. Test the consistency of the data and bring any inconsistencies to the attention of the client.
3. Plan the necessary methods and procedures for conducting the construction survey.

C. Field Investigation and Layout

The Surveyor shall, in coordination with the client:

1. Search for and substantiate monuments, lines or objects indicated by the construction documents as the intended references for the horizontal and vertical project datum.
2. When necessary, establish, adjust and monument the control points and lines needed to perform the layout survey.
3. Establish the final layout control monuments in proper relationship to construction lines and grades.
4. Obtain sufficient check measurements to verify the work.
5. Record all information on/in an appropriate form.
6. Immediately bring to the attention of the client or his designated representative any inconsistencies disclosed by the survey or by examination of the plans.
7. Refuse to set layout monuments for any inconsistent portion of the project until authorized to do so in writing by the client.

3. TECHNICAL MINIMUMS

A. Measurements

Measurements shall be obtained with an accuracy compatible with Section 4 of these construction standards or as required in a written agreement with the client or within the construction documents.

B. Monumentation.

1. Construction layout monuments shall be of a type and character consistent with intended use.
2. Monuments shall be set in a manner providing a degree of permanency consistent with the terrain, physical features and intended use.
3. Sufficient monuments and offset information shall be provided to enable the user to check the accuracy of any point or line established therefrom.
4. Monuments shall be witnessed in a manner that will allow them to be easily found by the user for a reasonable period of time. Any witness stakes or laths that show offsets and/or cut-and-fill data should be labeled with sufficient information to identify the position of the point being referenced.

C. Field Notes

All pertinent information, measurements and observations made in the field during the course of the survey shall be recorded on an appropriate form (e.g., cut sheet) and in a manner that is clear and legible.

D. Presentation of Data

When requested, the client shall be furnished with the results of the survey on an appropriate form, such as plats, maps, grade sheets, etc. It is important to note that to be effective and useful, any document depicting completed fieldwork must be prepared in a timely manner and reviewed by the client prior to construction taking place. The form selected should show the following:

1. The client's name, date of the fieldwork, file number and the Surveyor's name, address, signature and registration number.
2. A location description of the project referenced to the title description and political subdivision or to the geographic location, and when appropriate, the specific description of the constructed facility surveyed.
3. The identification of the construction documents used in the survey, a statement as to whether they were marked on their face as "approved," and the date of their latest revision.
4. Sufficient information to reference the layout to the construction documents.
5. Identification of the horizontal and vertical datum on which the survey was based and the specific descriptions of the monuments that were used.
6. North arrow and scale.
7. Horizontal dimensions and directions with sufficient notations to indicate their source, such as per plans or calculated from data shown on plans.

8. All pertinent monuments with a notation indicating which were found and which were set, and identified as to their character. Found monuments should be accompanied by a reference as to their origin when it is known. Where there is no available documented reference, this should be so stated.
9. Sufficient information for all layout control lines and points to allow retracement of the work with minimal difficulty.
10. Any discrepancies or inconsistencies between the construction documents and the layout as surveyed and shown on markups, with a statement of the Surveyor's authority for deviating from the construction documents.
11. A qualifying statement of excluded information.
12. An index and cross reference when the presentation consists of more than a single document.
13. When requested, a certificate stating the final date of the field survey and that the survey was conducted either by or under the direction the Surveyor. The certificate should bear the signature, registration number and seal of the Surveyor and the date of certification.

4. RELATIVE POSITIONAL ACCURACY

The following relative positional accuracies are provided as a guide for the placement of stakes or other materials utilized to mark the location of proposed fixed works:

	Horizontal Positional Accuracy		**Vertical Positional Accuracy**	
	Meters	**Feet**	**Meters**	**Feet**
Rough Grading Stakes	± 300 mm	± 1.0 ft	± 60 mm	± 0.20 ft
Subgrade Red Head Stakes	± 150mm	± 0.50 ft	± 15 mm	± 0.05 ft
Finish Grade Blue Top Stakes	± 150 mm	± 0.50 ft	± 15 mm	± 0.05 ft
Building Offset Stakes	± 10 mm	± 0.03 ft	± 10 mm	± 0.03 ft
Sewer Offset Stakes	± 30 mm	± 0.10 ft	± 10 mm	± 0.03 ft
Waterline Offset Stakes	± 30 mm	± 0.10 ft	± 30 mm	± 0.10 ft
Hydrant Offset Stakes	± 30 mm	± 0.10 ft	± 15 mm	± 0.05 ft
Street Lights	± 60 mm	± 0.20 ft	± 30 mm	± 0.10 ft
Curb Offsets	± 15 mm	± 0.05 ft	± 10 mm	± 0.03 ft

Positional Accuracy is given at the 95 percent confidence level

5. ELECTRONIC DATA DISTRIBUTION

The client may request the Surveyor to provide the survey data in an electronic format. These formats include such files as CADD drawing files, digital terrain model (DTM) files, or digital elevation model (DEM) files. When the Surveyor provides these files, they are only for the benefit of the client on this specific survey. In every case the surveyor shall also provide a signed and sealed hard copy drawing or representation of the survey. This drawing shall be the official plat or map and shall be deemed to be correct and superior to the electronic data. The electronic data file shall also contain a statement that the file is not a certified document and that the official document was issued and sealed by (*name and registration number of the Surveyor*) on (*date*).

The Surveyor may also need to address additional liability issues in appropriate contract language.

Section E
NSPS MODEL STANDARDS
FOR
TOPOGRAPHIC SURVEYS

Approved 3/12/02

1. INTRODUCTION

This standard is written to provide the professional surveyor (Surveyor) and the client with a guideline for producing an adequate topographic survey.

2. APPLICATION OF THE STANDARD

This standard applies to topographic surveys that are intended to show the contour of the earth's surface and/or the position of fixed objects thereon. The Surveyor in making topographic surveys uses accepted terrestrial or GPS surveying methods. This standard does not apply to topographic surveys using photogrammetric methods. Topographic surveys that additionally depict the location of property lines must also be in compliance with the current standard for property surveys.

3. DEFINITIONS

A. Bench Mark is a relatively permanent material object, natural or artificial, bearing a marked point whose elevation above or below and adopted datum is known.
B. A Contour is an imaginary line on the ground, all points of which are of the same elevation above or below a specified datum.
C. The Parcel is the area designated by the client and is usually, but not necessarily, given by a legal description of the property.
D. Utilities are services provided by governmental and private entities that provide the following: electric power, telephone, water, sanitary and storm sewer, gas, etc.

4. RESEARCH AND INVESTIGATION

The Surveyor shall acquire the elevation and datum of all bench marks to be used in the survey. The elevation used shall be based on a nationally accepted datum whenever practical or unless otherwise instructed by the client. The client shall specifically describe the parcel to be surveyed.

5. THE SURVEY

The topographic survey shall be performed on the ground to obtain the information required in this standard and any additional information requested by the client. The Surveyor shall select the equipment and procedures necessary to obtain the horizontal and vertical positional accuracy required by these standards.

6. THE PUBLISHED RESULT

A topographic map or plat shall be prepared that shall be of a scale, size and accurately to clearly show the results of the survey.

7. DATA

The surveyor shall locate and show on the topographic survey map or plat the following information:

A. Existing contours lines indicating the shape and elevation of the land over the entire parcel in accordance with the following table, unless specifically excluded in the contract with the client:

Map or Plat Scale	Contour Interval
1" = 20'	1 foot
1" = 30'	1 foot
1" = 40'	1 foot
1" = 50'	1 foot
1" = 100'	1 or 2 feet
1" = 200'	2 or 4 feet
1" = 400'	4, 5 or 10 feet

B. The location of permanent structures including retaining walls, bridges, and culverts.
C. The location of street or road paving, entrance drive openings and sidewalks.
D. Elevations on the top of curbs, gutters and sidewalks.
E. The official street or road names and address numbers assigned to the parcel.
F. North arrow and scale of drawing.
G. Legend depicting the symbols and abbreviations used on the drawing.
H. Spot elevations covering the entire survey limits showing high points, low points, grade changes, and at sufficient intervals to represent the general character of the terrain.
I. Provide main floor elevations of buildings.
J. Location and elevation of lakes, rivers, streams or drainage courses on or near the surveyed parcel.
K. Description, location and elevation of bench marks used in the survey.
L. All Optional items required in Section 9.

8. POSITIONAL ACCURACY

The following relative positional accuracies are provided as a guide for topographic surveys.

	Vertical Positional Accuracy Feet	**Horizontal Positional Accuracy Feet**
Contour line 1' interval	± 0.65 ft	± 1 ft
Contour line 2' interval	± 1.30 ft	± 2 ft
Contour line 4' interval	± 2.60 ft.	± 4 ft
Contour line 5' interval	± 3.20 ft	± 4. ft
Contour line 10' interval	± 6.50 ft	± 8 ft
Floor elevations	± 0.05 ft	± 1 ft
Spot paving elevations	± 0.05 ft	± 1 ft
Spot ground elevations	± 0.20 ft	± 2 ft
Sewer invert elevations	± 0.05ft	± 1 ft
Well defined planimetric features	± 0.10 ft	± 1 ft

Positional Accuracy is given at the 95 percent confidence level.

9. OPTIONAL ITEMS

The following items may be included in the requirements to be shown on a topographic survey if specifically and mutually agreed upon by the client and surveyor:

A. Boundary survey of the parcel. (Must comply with boundary survey standards)
B. Plot the location of easements and rights-of-way as shown on the recorded subdivision plat and all easements evidenced by a recorded document provided by the client. The reference book and page, or document number of each shall be shown.
C. Vicinity map with subject property highlighted.
D. Observable evidence of site use as a solid waste dump, sump or sanitary landfill.
E. Observable evidence of recent earth moving work, borrow or fill.
F. Location and the top elevation of soil borings or monitoring wells if ascertainable. (Performed by others)
G. Cross-section of offsite drainage courses for engineering studies.
H. Location and elevation of at least one bench mark within the limits of the survey.
I. Existing contours shall not be drawn but the drawing shall show existing elevations in both directions over the parcel at 25-foot intervals in rough ground and 50-foot intervals on level ground and spot elevations at any abrupt changes.

J. Elevations at the inside of walk, top of curb, and gutter at approximately one-inch (1”) intervals at the final map scale.
K. Dimensions of curb, sidewalk, and gutter lines or ditch lines and centerline of all streets, alleys or roads adjoining the parcel. Indicate type of paving surface and condition.
L. Location, width and elevation at both ends of all existing sidewalks. Include a description of the kind and general condition of the sidewalk.
M. Location, diameter, and species of all trees over a _____ inch diameter.
N. Perimeter outline only of thickly wooded areas unless otherwise directed.
O. Electric utilities – the location of power poles, guy wires, anchors, vaults, etc., on the parcel or in the streets, roads, alleys, or railroad right of way adjoining the parcel.
P. Storm, sanitary or combined sewers – the location of all observable manholes and other structures such as culverts, headwalls, catch basins and clean-outs on the parcel or in streets, roads alleys or railroad right of way adjoining the parcel. Include elevations of the top and bottom of manholes and catch basins. Show type, size, direction of flow and invert elevation of all pipes or culverts.
Q. Water – the location of any water valves, standpipes, regulators, fire hydrants, etc. that are visible on the parcel.
R. Gas – the location of all valves, meters, and gas line markers that are visible on the parcel. Show elevation on top of any valves.
S. Telephone – the location of all poles, manholes, boxes, etc that are visible on the parcel.
T. Street lighting – the location of all lamp poles, boxes etc
U. Heating – the location of all steam manholes and vaults that are visible on the parcel.
V. Location and dimensions of any existing buildings, tanks, fences, miscellaneous structures, driveways, or other obstructions on the parcel.
W. Location and description of any building or major structure on adjoining land that is not more than ____ feet outside the parcel being surveyed
X. Location and elevation of the 100 year floodplain, if applicable for the surveyed parcel.
M. Location and elevation of swamps, or wetland limits if determined by other experts.
Y. Location of visible rock formations.
Z. Information about the utilities providing service to the parcel. This shall include as a minimum the name of the corporation, address, phone number, fax number and type of service.

10. ELECTRONIC DATA DISTRIBUTION

The client may request the Surveyor to provide the survey data in an electronic format. These formats include such files as CADD drawing files, digital terrain model (DTM) files, or digital elevation model (DEM) files. When the Surveyor provides these files, they are only for the benefit of the client on this specific survey. In every case the surveyor shall also provide a signed and sealed hard copy drawing or representation of the survey. This drawing shall be the official plat or map and shall be deemed to be correct and superior to the electronic data. The electronic data file shall also contain a statement that the file is not a certified document and that the official document was issued and sealed by (*name and registration number of the Surveyor*) on (*date*).

The Surveyor may also need to address additional liability issues in appropriate contract language.

Section F

NSPS MODEL STANDARDS
FOR
LAND INFORMATION/GEOGRAPHIC INFORMATION SYSTEM SURVEYS

Approved 3/12/02

1. PURPOSE:

The purpose of these standards is to provide the professional surveyor (Surveyor) with a guideline for surveys that provide the location of infrastructure information used in a land information system (LIS) or a geographic information system (GIS). The primary objective of this standard is to insure that surveyed information in an LIS/GIS is reliable and can be used to make definitive decisions. These standards are not to be used in place of professional judgment.

2. THE SURVEY:

The Surveyor shall select the proper equipment and methods necessary to achieve at least the Minimum Horizontal and Vertical Accuracy required in Sections 6 and 7 of these standards. The survey work will be executed in a professional manner by the Surveyor or by personnel under the direct personal supervision of the Surveyor.

3. COORDINATE SYSTEM AND DATUM:

Coordinate values should be in the National coordinate systems. Horizontal coordinate values should be in the North American Datum of 1983 (NAD 83). Vertical coordinate values should be in the North American Vertical Datum of 1988 (NAVD 88) or the National Geodetic Vertical Datum of 1929 (NGVD 29). If coordinates are not referenced to the National coordinate system, identify the local coordinate system used and its relationship to the National coordinate system. Coordinates shall be given in either metric or English units. Unless otherwise defined by state statutes, the preferred English unit is the U.S. Survey foot.

4. THE SURVEY REPORT:

The results of the survey shall be transmitted to the client in either the form of a drawing or in a digital format. The following information shall be included in the drawing and/or in the Metadata:

1. The accuracy classification to which the data was gathered.
2. The methods used to obtain the data (such as EDM, GPS, etc.)
3. Date of the survey work.
4. Datum used for the survey.

5. ACCURACY STANDARD:

The minimum positional accuracy of the survey data is a Geospatial Positional Accuracy that is relative to the mapping scale, and therefore it is the accuracy of the base map on which the GIS/LIS is based.

The reporting methodology shall be in accordance with the Federal Geographic Data Committee, Geospatial Positioning Accuracy Standards, Part 1 Reporting Methodology.

The Geospatial Position Accuracy shall be reported by positional accuracy as defined in two components: horizontal and vertical.

Horizontal Positional Accuracy is the radius of the circle of uncertainty, such that the true or theoretical location of the point falls within that circle 95-percent of the time. Horizontal Accuracy may be tested by comparing the planimetric coordinates of surveyed ground points with the coordinates of the same points from an independent source of higher order.

Vertical Positional Accuracy is a linear uncertainty value, such that the true or theoretical location of the point falls within +/- of that linear uncertainty value 95-per cent of the time. Vertical Accuracy may be tested by comparing the elevation of surveyed ground points with the elevations of the same point determined from a source of higher accuracy.

6. MINIMUM HORIZONTAL ACCURACY
The horizontal accuracy is based upon the American Society of Photogrammetry and Remote Sensing (ASPRS) Standard for Class 2 and reported in agreement with the National Standard for Spatial Data Accuracy. The NSSDA Horizontal Positional Accuracy Statistic at the 95% confidence level is determined by multiplying the Root Mean Square Error (RMSE) of the data set by 1.7308.

Acceptable

Base Mapping Scale of LIS/GIS	Positional Accuracy Statistic of Survey Data
1”= 20 ft.	0.7 feet
1”= 50 ft.	1.7 feet
1”= 100 ft.	3.5 feet
1”= 200 ft.	6.9 feet
1”= 400 ft.	13.8 feet
1”= 500 ft	17.3 feet
1”= 1000 ft.	34.6 feet
1”= 2000 ft.	69.2 feet

7. MINIMUM VERTICAL ACCURACY

The vertical accuracy is based upon the ASPRS Standard for Class 1 and reported in agreement with the National Standard for Spatial Data Accuracy. The NSSDA Vertical Positional Accuracy Statistic at the 95% confidence level is determined by multiplying the Root Mean Square Error (RMSE) of the data set by 1.9600.

Acceptable

Base Mapping Contour Interval	Positional Accuracy Statistic of Survey Data
1 foot	0.7 feet
2 feet	1.3 feet
5 feet	3.2 feet
10 feet	6.5 feet
15 feet	9.7 feet

Section G

POSITIONAL ACCURACY DEFINITIONS AND PROCEDURES

Approved 3/12/02

1. INTRODUCTION

Modern surveying standards use the concept of positional accuracy instead of error of closure. Although the concepts of positional accuracy are well known and completely discussed in surveying textbooks, it is important that the concepts and procedures be discussed as part of national standards.

The surveying methods used by the professional surveyor (Surveyor) vary with the purpose of survey to be made and the equipment available. Also, surveying technology is constantly changing, therefore a national standard for a particular type or class of survey cannot specify methods or equipment lest it become obsolete even before it is adopted. A modern standard must be limited to a general description of the survey along with reporting and accuracy requirements. A national survey standard should tell (1) what the survey is to accomplish and what items are to be investigated, (2) how the results are to be reported, and (3) how accurate the results are to be.

It is the responsibility of the Surveyor to select the appropriate procedures and equipment to obtain the accuracy required by the standard. In other words, the surveyor is expected to design a survey measurement specification that will obtain the required accuracy. A standard should not specify surveying procedures but only results.

The NSPS Model Standards use two types of accuracy standards. Relative Positional Accuracy is used in property surveys, construction surveys and topographic surveys. Geospatial Positional Accuracy is used in mapping, geographic information systems (GIS), and geodetic control surveys.

2. RELATIVE POSITIONAL ACCURACY

A. Definitions

Relative Positional Accuracy is a value expressed in feet that represents the uncertainty of the location of any point in a survey relative to any other point in the same survey at the 95 percent confidence level. Therefore it is also the accuracy of the distance between all points on the same survey.

Relative Positional Accuracy may be tested by comparing the relative location of points in a survey as measured by an independent survey of higher accuracy. The comparison should include the measurement of both distances and directions. Relative Positional Accuracy may also be tested by the results from a minimally constrained, correctly weighted least squares adjustment of the survey data. Note that sufficient redundancy in the survey measurements is required, if accuracy is to be tested this way, so as to make the application of the least squares adjustment a valid process.

B. Design of a measurement specification

The NSPS Standards prescribe the level of accuracy that should be obtained in the survey and not survey procedures. Accuracy is the deviation of survey measurement of quantities such as distances, angles or elevations from the correct values. The Surveyor has two responsibilities with regard to the accuracy of a survey. First, the Surveyor must use his or her judgment and experience to determine what procedures and equipment are necessary to obtain the required accuracy. Second, the Surveyor must test the accuracy of the completed survey measurements.

The Surveyor is the expert in land measurements and this expertise is used to develop a measurement specification for the survey. This specification describes the equipment and procedures to be used in the field survey. The equipment to be used will, to a large extent, determine the methods that are to be followed. The surveyor should be guided by experience, computations and the recommendations of the equipment suppliers in the development of this specification. Error analysis computations can be used to determine what accuracy can be expected with the procedures and equipment prescribed in the specification. The Surveyor is not expected to make these computations for every survey. The scope, extent, requirements and objectives of many surveys are of a repetitive nature and therefore the same specification can be used on similar surveys. The error analysis computations are completely discussed and examples are given in many surveying texts and printed articles.

The measurement specifications should be designed so that the accuracy of the measurements meet or exceed the positional accuracy required in the NSPS Standards. It is very likely that each Surveyor will have a specification for various sizes and types of surveys**.** In any event the Surveyor should know what accuracy he or she can expect with the procedures and equipment selected.

Survey measurement specifications must cover some of following items:

1. Periodic testing of EDM equipment over an approved base line.
2. Accurately taking into account atmospheric condition.
3. Periodic testing of optical plumbing.
4. Using the correct prism constant for the equipment.
5. Calibration and testing of steel tapes.
6. Examination and testing of the adjustment and performance characteristics of survey equipment and accessories to verify that the errors resulting from using them according to the Surveyor’s procedures are within the error that the specifications allow.

7. Periodic adjustment of equipment by the surveyor or workshops specializing in such work, when examination and testing indicates a need for such adjustment or when good practice indicates that sufficient time has elapsed since the last adjustment.

C. Testing the completed survey

The Surveyor must check the survey work to assure that the intended accuracy is being achieved. Most standards in the past used relative error of closure as a measure of the quality of the survey. That was because many surveys were based upon traverse procedures. Many standards were issued by federal and other agencies for the same reason.

The Surveyor in private practice today performs many surveys that contain measurements that do not result in a closed traverse. This is a result of new equipment and changes in the computing capability available today. Relative error of closure is primarily a measure of the consistency of measurements, but it also can be a valuable tool in testing for accuracy.

Relative Positional Accuracy does not pertain to the location of a particular point or corner in the world but to the accuracy of the measurements used in the survey. Therefore a good test of the relative positional accuracy is to take check measurements of some of the distances in the survey.

The Surveyor should check his or her survey fieldwork by making redundant measurements whenever possible. This is not a new concept. It has always been one of the best ways to make sure that the fieldwork has met the quality that was expected. This does not mean that every survey must have a series of detailed checks. The Surveyor must realize that when a statement is made or inferred that the survey meets a specific standard, the Surveyor has the responsibility to be certain that it actually does meet that standard.

There are many opportunities to check the quality of the survey. For example, in laying out a rectangle (stake out of a building), one of the final checks the Surveyor will probably use before concluding that the work is correct is to measure and compare the diagonals of that rectangle. The Surveyor can easily compute the length of the diagonals and this can be compared with what was measured. In fact just comparing each of the diagonal measurements against each other is important. The allowable variation between the computed diagonal and the measured diagonal or the allowable variation between the two diagonals is a measure of the accuracy of the survey work. The variation should be less than the positional accuracy specified in the standard. The surveyor will also know from developing the measurement specification and from experience what variation can be expected, and anything that is greater than that value would cause the original measurements to be suspect.

There are many instances when distances are obtained by indirect measurements. For example a radial survey used to lay out the lot corners in a subdivision. The actual distance between the exterior corners and the corners of lots are not directly measured in the field. The Surveyor can check the quality of work by directly measuring some of the lines that were indirectly determined. When radial survey procedures are used the

Surveyor recognizes that the distances to be shown on the plat are indirectly determined. As many as possible of those indirect distances should be directly measured to check that the procedures have produced the required accuracy.

The positional accuracy standard is a yardstick by which the Surveyor can judge the quality of the work. The result of the Surveyor's comparison between the computed measurement and the actual measurement must be within the guidelines given in the standards. This comparison not only checks the quality of the distance measurements but also the quality of the angles.

An example of this type of a check is as follows:

The Surveyor uses a total station having an angle quality of 10 seconds (DIN) and a distance quality of 5 mm plus 5 ppm. One corner of the property is measured to be 100.00 feet from the instrument and the other is 200.00 feet. The angle between the corners is measured to be 20 degrees 0 minutes and 0 seconds. The distance between the corners is computed to be 111.41 feet. As a check the distance is directly measured and is 111.37 feet. The variation is 0.04 feet or approximately 0.08 feet at the 95 % confidence level. The required accuracy according to the Standards is 0.08 feet for Urban or 0.14 feet for Suburban Survey. The survey appears to be acceptable for both classes of survey.

The required procedure is to test the quality of the survey by making selected measurements and comparing those measurements with the intended or computed distances. It also stands to reason that the check measurements must have a quality at least equal to or better than the work that it is intended to be check.

Another application of positional accuracy can be seen in the following example:

The Surveyor is to measure a closed traverse having a total length of 1400 feet. The equipment used will be a total station having an angle accuracy of 5 seconds (DIN) and distance quality of 5 mm plus 3 ppm. The survey is to meet Urban Standards and therefore the required positional accuracy is computed to be 0.14 feet. The actual traverse closure is computed to be 0.05 feet and this is similar to a closure of 0.10 feet at the 95 percent confidence level of the NSPS Standard. The survey appears to be in compliance with the standards. If the actual closure had been 0.10 feet or 0.20 at 95% it would not have appeared to meet the standard. In this latter situation one of the diagonals should be computed and measured. The diagonal is computed to be 500 feet and the computed positional accuracy from the standard for an Urban survey will be 0.10 feet. Therefore the measured and computed diagonals should not vary by not more than 0.05 feet or ½ of the required value. If the Surveyor is using a computer program that adjusts the traverse by least squares it probably will analyze the traverse. The error ellipses from these programs should be compared for compliance with the positional accuracy standard.

D. Confidence levels

Most standards in use today are specified at the 95 percent confidence level. This means that if we have a measured distance of 1000 feet with stated reliability of plus or minus 0.10 feet at 95 percent confidence level we can be confident that a measurement of that line will be between 999.90 feet and 1000.10 feet 95 out of 100 times.

As an example, a Surveyor establishes two corners by a radial survey. The distance between the corners is computed and shown on the plat. As a check the Surveyor measures directly between the corners not once, but 100 times. The measurements are made on different days and under different conditions. If all corrections for systematic error are made, the average of those measurement probably approaches the correct length of that line and the standard deviation of those measurements is a good measurement of the accuracy of that distance. If the value of the standard deviation is 0.05 feet, then we would say that the line length is equal to the average distance, plus or minus 0.05 feet at the 68 percent confidence level. In other words, of the 100 measurements there could have been 32 measurements that differed by more than 0.05 feet from the average. At the 95 percent confidence level we can expect that there will be 5 measurements that are 2 times 0.05 feet or 0.10 feet more or less than the average distance. As a practical matter a Surveyor does not measure a line 100 times. The Surveyor makes one high quality check measurement. The Surveyor makes the assumption that this check measurement is the correct value. The difference between the correct distance and the calculated distance is assumed to be an approximation of the standard deviation. The 95 percent confidence interval value will be 2 times the approximate standard deviation. This double value is the value that is compared in the NSPS Standard**.** It must be pointed out again that the check measurements should be a very reliable measurement based on a specification that will provide accuracy above those being checked.

For many years experienced Surveyors have recognized a value that they considered an acceptable variation for their measurements in the field. This value is similar to the standard deviation, or a value at the 68 percent confidence level. Therefore this value is ½ of the value at the 95 percent confidence level that is used in the NSPS Standards. In other words, if the Surveyor's normally acceptable variation is 0.05 feet, that really is 0.10 feet at the 95 percent confidence level.

3. GEOSPATIAL POSITIONAL ACCURACY FOR SPATIAL DATA

A. Definitions

The Geospatial Position Accuracy shall be reported by positional accuracy as defined in two components: horizontal and vertical.

Horizontal Positional Accuracy is the radius of the circle of uncertainty, such that the true or the theoretical location of the point falls within that circle 95-percent of the time. Horizontal Accuracy may be tested by comparing the planimetric coordinates of surveyed ground points with the coordinates of the same points from an independent source of higher accuracy.

Vertical Positional Accuracy is a linear uncertainty value, such that the true or theoretical location of the point falls within the sum of the positive and negative ranges of that linear uncertainty value 95-per cent of the time. Vertical Accuracy may be tested by comparing the elevation of surveyed ground points with the elevations of the same point determined from a source of higher accuracy.

The development of geographic information systems (GIS) and global positing systems (GPS) has created the need for the development of the National Standard for Spatial Data Accuracy. These national standards speak to the quality of data developed in and for GIS applications. The standards apply to both geographic data developed from map products (photogrammetry) and from survey data to be used in a GIS.

B. Design of a measurement specification

The design of survey measurement specification is the responsibility of the Surveyor. The equipment and methods in this area of professional surveying is new and ever changing. The Surveyor should be guided by the latest published methodologies and the recommendations of the equipment manufactures. The Surveyor should develop methods to test procedures before they are used in an actual survey situation.

C. Testing the completed survey

The geospatial data set is tested by comparing the coordinates of several points within the data set to the coordinates of the same points from a control data set of greater accuracy. The points used in the test must be well defined and easy to measure both in the field and on the digital data product.

The control data set must be of a higher quality than the data being tested. It is best that the quality of the control data set be at least twice as accurate as the expected accuracy of the data set being tested. The control data set should uniformly cover the area of the data being tested and there should be a sufficient number of points to determine valid results.

The positional accuracy statistic is computed for the data being reviewed. This statistic is a value for all the data not for individual data. It is actually the Root Mean Square Error (RMSE) for the data. The value of the statistic is compared with the positional accuracy value in the standards.

The following example illustrates the testing of this kind of data. A Surveyor is employed to provide the location of sewers (manhole lids) to a city for the inclusion in a Geographic Information System (GIS). The data to be provided is the state coordinates of the manholes. The coordinates are to be obtained by a combination of methods including GPS, total stations and laser ranging. This data is to meet the standards for a base mapping scale of 1” = 100’. In order to check compliance with the standards a higher accuracy GPS survey is conducted. The coordinates of some of the manhole covers determined in the GIS project are determined by this check survey. The GPS procedures used in the check survey should be designed to produce accuracy at least in the 0.10 feet range at 68 percent confidence level. The difference between the x and the y coordinates for the GIS data and the check data are determined. The difference in the x and y coordinates is squared and added together. The average of these values is computed. The square root of the average is the RMSE and is used to calculate the statistic for the data set. The RMSE value is multiplied by 1.7308 to obtain the accuracy statistic value at the 95% confidence level used in the standards. Note that there should be enough test points to have a statistically correct result.

As an example: One inch equal 400 feet base maps for a county level GIS were checked for compliance with the standards. The coordinates of points on the maps were compared with high quality GPS coordinates of the same points. Thirty three (33) points were used in the test and the RMSE was calculated to be 6.53 feet therefore the geospatial horizontal accuracy statistic was 11.30 feet (1.7308*6.53). The allowable geospatial horizontal accuracy statistic for this project was 13.48 feet. The project was accepted as meeting the accuracy standard for 1"= 400' mapping.

4. GEOSPATIAL POSITIONAL ACCURACY FOR GEODETIC NETWORKS

A. Definitions

The national standard is published by the FGDC as the Draft Geospatial Positioning Accuracy Standards, Part 2: Standards for Geodetic Networks - December 1996. These standards define the accuracy that is to be evaluated. They are as follows:

The **local accuracy** of a control point is a value expressed in centimeters that represents the uncertainty in the coordinates of the control point relative to the coordinates of other directly connected, adjacent control points at the 95- percent confidence level.

The **network accuracy** of a control point is a value expressed in centimeters that represents the uncertainty in the coordinates of the control point with respect to the geodetic datum at the 95- percent confidence level.

B. Design of a measurement specification

For a detailed description of this standard please refer to the FGDC standard.

C. Testing the completed survey

Accuracies of geodetic control surveys are tested by the results of a minimally constrained, least squares adjustment of the survey measurements. Both the local accuracy and the network accuracy should be reported for horizontal control, ellipsoidal height and orthometric height. For details see the FGDC standard.

Section H
STANDARDS REFERENCES
Approved 3/12/02

I. TEXTS

Analysis and Adjustment of Survey Measurements, by Mikhail and Gracie, 1981.

Errors in Practical Measurements in Science, Engineering and Technology, by Bro. Barry 1978.

Adjustment Computations, by Paul R. Wolf, 1980.
Urban Surveying and Mapping, by Blachut, Chrzanowski, Saastamoinen, 1979.

Evidence and Procedures for Boundary Location, by Brown and Eldridge, 1967.

Surveying Measurements and their Analysis, by R.B. Buckner, 1983.

II. ARTICLES

"Positional Tolerance in Land Surveying", by David Tyler, Journal of Survey Engineering October, 1987.

Principles of Error Theory and Cartographic Applications: Technical Report No 96. United States Air Force aeronautical chart and information center St Louis MO. By C.R. Greenwalt and M.E. Shultz.

III. STANDARDS

Standards and Guidelines for Cadastral Surveys using Global Positioning System Methods, US Forest Service and Bureau of Land Management. April 28, 2000.

Standards and Specifications for Cadastral Control Surveys, Bureau of Land Management, March 1989.

Implementing the National Standard for Spatial Data Accuracy, Minnesota Governor's Council on Geographic Information, GIS Standards Committee, October 1998

American Society for Photogrammetry and Remote Sensing (ASPRS) Specification and Standards Committee. 1990. "ASPRS Accuracy Standards for Large Scale Maps." *Photogrammetric Engineering & Remote Sensing.* Washington, DC. V56, no7,pp 1068-1070.

Federal Geographic Data Committee. 1998. *Geospatial Positioning Accuracy Standards; Part 3:* National Standards for Spatial Data Accuracy FGDC-STD-007.3. FGDC. Washington D.C.

Federal Geographic Data Committee. 1998. *Content Standards for Digital Geospatial Metadata (version 2.0)* FGDC-STD-001. FGDC. Washington, DC.

Best Practice Guidelines – Use of the Global Positioning System (GPS) for Surveying Applications from Australia and New Zealand

MINIMUM STANDARD DETAIL REQUIREMENTS FOR ALTA/NSPS LAND TITLE SURVEYS

(Effective February 23, 2016)

MINIMUM STANDARD DETAIL REQUIREMENTS FOR
ALTA/NSPS LAND TITLE SURVEYS
(Effective February 23, 2016)

***NOTE**: Attention is directed to the fact that the National Society of Professional Surveyors, Inc. (NSPS) is the legal successor organization to the American Congress on Surveying and Mapping (ACSM) and that these 2016 Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys are the next version of the former Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys.*

1. Purpose–Members of the American Land Title Association® (ALTA®) have specific needs, unique to title insurance matters, when asked to insure title to land without exception as to the many matters which might be discoverable from survey and inspection, and which are not evidenced by the public records.

For a survey of real property, and the plat, map or record of such survey, to be acceptable to a title insurance company for the purpose of insuring title to said real property free and clear of survey matters (except those matters disclosed by the survey and indicated on the plat or map), certain specific and pertinent information must be presented for the distinct and clear understanding between the insured, the client (if different from the insured), the title insurance company (insurer), the lender, and the surveyor professionally responsible for the survey.

In order to meet such needs, clients, insurers, insureds, and lenders are entitled to rely on surveyors to conduct surveys and prepare associated plats or maps that are of a professional quality and appropriately uniform, complete, and accurate. To that end, and in the interests of the general public, the surveying profession, title insurers, and abstracters, the ALTA and the NSPS jointly promulgate the within details and criteria setting forth a minimum standard of performance for ALTA/NSPS Land Title Surveys. A complete 2016 ALTA/NSPS Land Title Survey includes:

- (i) the on-site fieldwork required pursuant to Section 5,
- (ii) the preparation of a plat or map pursuant to Section 6 showing the results of the fieldwork and its relationship to documents provided to or obtained by the surveyor pursuant to Section 4,
- (iii) any information from Table A items requested by the client, and
- (iv) the certification outlined in Section 7.

2. Request for Survey–The client shall request the survey, or arrange for the survey to be requested, and shall provide a written authorization to proceed from the person or entity responsible for paying for the survey. Unless specifically authorized in writing by the insurer, the insurer shall not be responsible for any costs associated with the preparation of the survey. The request shall specify that an **"ALTA/NSPS LAND TITLE SURVEY"** is required and which of the optional items listed in Table A, if any, are to be incorporated. Certain properties or interests in real properties may present issues outside those normally encountered on an ALTA/NSPS Land Title Survey (e.g., marinas, campgrounds, trailer parks; easements, leases, other non-fee simple interests). The scope of work related to surveys of such properties or interests in real properties should be discussed with the client, lender, and insurer; and agreed upon in writing prior to commencing work on the survey. The client may need to secure permission for the surveyor to enter upon the property to be surveyed, adjoining properties, or offsite easements.

3. Surveying Standards and Standards of Care

- **A. Effective Date–**The 2016 Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys are effective February 23, 2016. As of that date, all previous versions of the Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys are superseded by these standards.
- **B. Other Requirements and Standards of Practice–**Many states and some local jurisdictions have adopted statutes, administrative rules, and/or ordinances that set out standards regulating the practice of surveying within their jurisdictions. In addition to the standards set forth herein, surveyors shall also conduct their surveys in accordance with applicable jurisdictional survey requirements and standards of practice. Where conflicts between the standards set forth herein and any such jurisdictional requirements and standards of practice occur, the more stringent shall apply.
- **C. The Normal Standard of Care–**Surveyors should recognize that there may be unwritten local, state, and/or regional standards of care defined by the practice of the "prudent surveyor" in those locales.
- **D. Boundary Resolution–**The boundary lines and corners of any property being surveyed as part of an ALTA/NSPS Land Title Survey shall be established and/or retraced in accordance with appropriate boundary law principles governed by the set of facts and evidence found in the course of performing the research and fieldwork.

E. **Measurement Standards–**The following measurement standards address Relative Positional Precision for the monuments or witnesses marking the corners of the surveyed property.

i. "Relative Positional Precision" means the length of the semi-major axis, expressed in feet or meters, of the error ellipse representing the uncertainty due to random errors in measurements in the location of the monument, or witness, marking any corner of the surveyed property relative to the monument, or witness, marking any other corner of the surveyed property at the 95 percent confidence level. Relative Positional Precision is estimated by the results of a correctly weighted least squares adjustment of the survey.

ii. Any boundary lines and corners established or retraced may have uncertainties in location resulting from (1) the availability, condition, history and integrity of reference or controlling monuments, (2) ambiguities in the record descriptions or plats of the surveyed property or its adjoiners, (3) occupation or possession lines as they may differ from the written title lines, or (4) Relative Positional Precision. Of these four sources of uncertainty, only Relative Positional Precision is controllable, although, due to the inherent errors in any measurement, it cannot be eliminated. The magnitude of the first three uncertainties can be projected based on evidence; Relative Positional Precision is estimated using statistical means (see Section 3.E.i. above and Section 3.E.v. below).

iii. The first three of these sources of uncertainty must be weighed as part of the evidence in the determination of where, in the surveyor's opinion, the boundary lines and corners of the surveyed property should be located (see Section 3.D. above). Relative Positional Precision is a measure of how precisely the surveyor is able to monument and report those positions; it is not a substitute for the application of proper boundary law principles. A boundary corner or line may have a small Relative Positional Precision because the survey measurements were precise, yet still be in the wrong position (i.e., inaccurate) if it was established or retraced using faulty or improper application of boundary law principles.

iv. For any measurement technology or procedure used on an ALTA/NSPS Land Title Survey, the surveyor shall (1) use appropriately trained personnel, (2) compensate for systematic errors, including those associated with instrument calibration, and (3) use appropriate error propagation and measurement design theory (selecting the proper instruments, geometric layouts, and field and computational procedures) to control random errors such that the maximum allowable Relative Positional Precision outlined in Section 3.E.v. below is not exceeded.

v. The maximum allowable Relative Positional Precision for an ALTA/NSPS Land Title Survey is 2 cm (0.07 feet) plus 50 parts per million (based on the direct distance between the two corners being tested). It is recognized that in certain circumstances, the size or configuration of the surveyed property, or the relief, vegetation, or improvements on the surveyed property, will result in survey measurements for which the maximum allowable Relative Positional Precision may be exceeded. If the maximum allowable Relative Positional Precision is exceeded, the surveyor shall note the reason as explained in Section 6.B.x. below.

4. <u>Records Research</u>–It is recognized that for the performance of an ALTA/NSPS Land Title Survey, the surveyor will be provided with appropriate and, when possible, legible data which can be relied upon in the preparation of the survey. The request for an ALTA/NSPS Land Title Survey shall set forth the current record description of the property to be surveyed or, in the case of an original survey prepared for purposes of locating and describing real property that has not been previously separately described in documents conveying an interest in the real property, the current record description of the parent parcel that contains the property to be surveyed.

In order to complete an ALTA/NSPS Land Title Survey, the surveyor must be provided with complete copies of the most recent title commitment or, if a title commitment is not available, other title evidence satisfactory to the title insurer. In addition, the surveyor must be provided with the following:

(i) The following records established under state statutes for the purpose of imparting constructive notice of matters relating to real property (public records):
   (a) The current record descriptions of any adjoiners to the property to be surveyed, except where such adjoiners are lots in platted, recorded subdivisions;
   (b) Any recorded easements benefitting the property;
   (c) Any recorded easements, servitudes, or covenants burdening the property;

(ii) Any unrecorded documents affecting the property being surveyed and containing information to which the survey shall make reference, if desired by the client.

Except, however, if the documents outlined above in (i) and (ii) of this section are not provided to the surveyor or if non-public or quasi-public documents are required to complete the survey, the surveyor shall be required to conduct only that research which is required pursuant to the statutory or administrative requirements of the jurisdiction where the property being surveyed is located and that research (if any) which is negotiated and outlined in the terms of the contract between the surveyor and the client.

5. **<u>Fieldwork</u>–**The survey shall be performed on the ground (except as otherwise negotiated pursuant to Table A, Item 15 below, if selected by the client). The fieldwork shall include the following, located to what is, in the surveyor's professional opinion, the appropriate degree of precision based on (a) the planned use of the property, if reported in writing to the surveyor by the client, lender, or insurer, or (b) the existing use, if the planned use is not so reported:

A. Monuments

- **i.** The location, size, character, and type of any monuments found during the fieldwork.
- **ii.** The location, size, character, and type of any monuments set during the fieldwork, if item 1 of Table A was selected or if otherwise required by applicable jurisdictional requirements and/or standards of practice.
- **iii.** The location, description, and character of any lines that control the boundaries of the surveyed property.

B. Rights of Way and Access

- **i.** The distance from the appropriate corner or corners of the surveyed property to the nearest right of way line, if the surveyed property does not abut a right of way.
- **ii.** The name of any street, highway, or other public or private way abutting the surveyed property, together with the width of the travelled way and the location of each edge of the travelled way including on divided streets and highways. If the documents provided to or obtained by the surveyor pursuant to Section 4 indicate no access from the surveyed property to the abutting street or highway, the width and location of the travelled way need not be located.
- **iii.** Visible evidence of physical access (e.g., curb cuts, driveways) to any abutting streets, highways, or other public or private ways.
- **iv.** The location and character of vehicular, pedestrian, or other forms of access by other than the apparent occupants of the surveyed property to or across the surveyed property observed in the process of conducting the fieldwork (e.g., driveways, alleys, private roads, railroads, railroad sidings and spurs, sidewalks, footpaths).
- **v.** Without expressing a legal opinion as to ownership or nature, the location and extent of any potentially encroaching driveways, alleys, and other ways of access from adjoining properties onto the surveyed property observed in the process of conducting the fieldwork.
- **vi.** Where documentation of the location of any street, road, or highway right of way abutting, on, or crossing the surveyed property was not disclosed in documents provided to or obtained by the surveyor, or was not otherwise available from the controlling jurisdiction (see Section 6.C.iv. below), the evidence and location of parcel corners on the same side of the street as the surveyed property recovered in the process of conducting the fieldwork which may indicate the location of such right of way lines (e.g., lines of occupation, survey monuments).
- **vii.** Evidence of access to and from waters adjoining the surveyed property observed in the process of conducting the fieldwork (e.g., paths, boat slips, launches, piers, docks).

C. Lines of Possession and Improvements along the Boundaries

- **i.** The character and location of evidence of possession or occupation along the perimeter of the surveyed property, both by the occupants of the surveyed property and by adjoiners, observed in the process of conducting the fieldwork.
- **ii.** Unless physical access is restricted, the character and location of all walls, buildings, fences, and other improvements within five feet of each side of the boundary lines, observed in the process of conducting the fieldwork. Trees, bushes, shrubs, and other natural vegetation need not be located other than as specified in the contract, unless they are deemed by the surveyor to be evidence of possession pursuant to Section 5.C.i.
- **iii.** Without expressing a legal opinion as to the ownership or nature of the potential encroachment, the evidence, location and extent of potentially encroaching structural appurtenances and projections observed in the process of conducting the fieldwork (e.g., fire escapes, bay windows, windows and doors that open out, flue pipes, stoops, eaves, cornices, areaways, steps, trim) by or onto adjoining property, or onto rights of way, easements, or setback lines disclosed in documents provided to or obtained by the surveyor.

D. Buildings

The location of buildings on the surveyed property observed in the process of conducting the fieldwork.

E. Easements and Servitudes

- **i.** Evidence of any easements or servitudes burdening the surveyed property as disclosed in the documents provided to or obtained by the surveyor pursuant to Section 4 and observed in the process of conducting the fieldwork.
- **ii.** Evidence of easements, servitudes, or other uses by other than the apparent occupants of the surveyed property not disclosed in the documents provided to or obtained by the surveyor pursuant to Section 4, but observed in the process of conducting the fieldwork if they appear to affect the surveyed property (e.g., roads; drives, sidewalks, paths and other ways of access; utility service lines; water courses; ditches; drains; telephone, fiber optic lines, or electric lines; or water, sewer, oil or gas pipelines on or across the surveyed property and on adjoining properties).

iii. Surface indications of underground easements or servitudes on or across the surveyed property observed in the process of conducting the fieldwork (e.g., utility cuts, vent pipes, filler pipes).

iv. Evidence on or above the surface of the surveyed property observed in the process of conducting the fieldwork, which evidence may indicate utilities located on, over or beneath the surveyed property. Examples of such evidence include pipeline markers, manholes, valves, meters, transformers, pedestals, clean-outs, utility poles, overhead lines and guy wires.

F. Cemeteries

As accurately as the evidence permits, the perimeter of cemeteries and burial grounds, and the location of isolated gravesites not within a cemetery or burial ground, (i) disclosed in the documents provided to or obtained by the surveyor, or (ii) observed in the process of conducting the fieldwork.

G. Water Features

i. The location of springs, ponds, lakes, streams, rivers, canals, ditches, marshes, and swamps on, running through, or outside, but within five feet of the perimeter boundary of, the surveyed property, observed during the process of conducting the fieldwork.

ii. The location of any water feature forming a boundary of the surveyed property. The attribute(s) of the water feature located (e.g., top of bank, edge of water, high water mark) should be congruent with the boundary as described in the record description or, in the case of an original survey, in the new description (see Section 6.B.vi. below).

6. **Plat or Map**–A plat or map of an ALTA/NSPS Land Title Survey shall show the following information. Where dimensioning is appropriate, dimensions shall be annotated to what is, in the surveyor's professional opinion, the appropriate degree of precision based on (a) the planned use of the property, if reported in writing to the surveyor by the client, lender, or insurer, or (b) existing use, if the planned use is not so reported.

A. The evidence and locations gathered, and the monuments and lines located during the fieldwork pursuant to Section 5 above, with accompanying notes if deemed necessary by the surveyor or as otherwise required as specified below.

B. Boundary, Descriptions, Dimensions, and Closures

i. (a) The current record description of the surveyed property, or
(b) In the case of an original survey, the current record description of the parent tract that contains the surveyed property.

ii. Any new description of the surveyed property that was prepared in conjunction with the survey, including a statement explaining why the new description was prepared. Except in the case of an original survey, preparation of a new description should be avoided unless deemed necessary or appropriate by the surveyor and insurer. Preparation of a new description should also generally be avoided when the record description is a lot or block in a platted, recorded subdivision. Except in the case of an original survey, if a new description is prepared, a note shall be provided stating (a) that the new description describes the same real estate as the record description or, if it does not, (b) how the new description differs from the record description.

iii. The point of beginning, the remote point of beginning or point of commencement (if applicable) and all distances and directions identified in the record description of the surveyed property (and in the new description, if one was prepared). Where a measured or calculated dimension differs from the record by an amount deemed significant by the surveyor, such dimension shall be shown in addition to, and differentiated from, the corresponding record dimension. All dimensions shown on the survey and contained in any new description shall be ground dimensions unless otherwise noted.

iv. The directional, distance and curve data necessary to compute a mathematical closure of the surveyed boundary. A note if the record description does not mathematically close. The basis of bearings and, where it differs from the record basis, the difference.

v. The remainder of any recorded lot or existing parcel, when the surveyed property is composed of only a portion of such lot or parcel, shall be graphically depicted. Such remainder need not be included as part of the actual survey, except to the extent necessary to locate the lines and corners of the surveyed property, and it need not be fully dimensioned or drawn at the same scale as the surveyed property.

vi. When the surveyed property includes a title line defined by a water boundary, a note on the face of the plat or map noting the date the boundary was measured, which attribute(s) of the water feature was/were located, and the caveat that the boundary is subject to change due to natural causes and that it may or may not represent the actual location of the limit of title. When the surveyor is aware of natural or artificial realignments or changes in such boundaries, the extent of those changes and facts shall be shown or explained.

vii. The relationship of the boundaries of the surveyed property with its adjoiners (e.g., contiguity, gaps, overlaps), where ascertainable from documents provided to or obtained by the surveyor pursuant to Section 4 and/or from field evidence gathered during the process of conducting the fieldwork. If the surveyed property is composed of multiple parcels, the extent of any gaps or overlaps between those parcels shall be identified. Where gaps or overlaps are identified, the surveyor shall, prior to or upon delivery of the final plat or map, disclose this to the insurer and client.

viii. When, in the opinion of the surveyor, the results of the survey differ significantly from the record, or if a fundamental decision related to the boundary resolution is not clearly reflected on the plat or map, the surveyor shall explain this information with notes on the face of the plat or map.

ix. The location of all buildings on the surveyed property, located pursuant to Section 5.D., dimensioned perpendicular to those perimeter boundary lines that the surveyor deems appropriate (i.e., where potentially impacted by a setback line) and/or as requested by the client, lender or insurer.

x. A note on the face of the plat or map explaining the site conditions that resulted in a Relative Positional Precision that exceeds the maximum allowed pursuant to Section 3.E.v.

xi. A note on the face of the plat or map identifying areas, if any, on the boundaries of the surveyed property, to which physical access within five feet was restricted (see Section 5.C.ii.).

xii. A note on the face of the plat or map identifying the source of the title commitment or other title evidence provided pursuant to Section 4, and the effective date and the name of the insurer of same.

C. Easements, Servitudes, Rights of Way, Access, and Documents

i. The location, width, and recording information of all plottable rights of way, easements, and servitudes burdening and benefitting the property surveyed, as evidenced by documents provided to or obtained by the surveyor pursuant to Section 4.

ii. A summary of all rights of way, easements and servitudes burdening the property surveyed and identified in the title evidence provided to or obtained by the surveyor pursuant to Section 4. Such summary shall include the record information of each such right of way, easement or servitude, a statement indicating whether or not it is shown on the plat or map, and a related note if:

(a) the location cannot be determined from the record document;
(b) there was no observed evidence at the time of the fieldwork;
(c) it is a blanket easement;
(d) it is not on, or does not touch, the surveyed property;
(e) it limits access to an otherwise abutting right of way;
(f) the documents are illegible; or
(g) the surveyor has information indicating that it may have been released or otherwise terminated.

In cases where the surveyed property is composed of multiple parcels, indicate which of such parcels the various rights of way, easements, and servitudes cross or touch.

iii. A note if no physical access to a public way was observed in the process of conducting the fieldwork.

iv. The locations and widths of rights of way abutting or crossing the surveyed property, and the source of such information, (a) where available from the controlling jurisdiction, or (b) where disclosed in documents provided to or obtained by the surveyor pursuant to Section 4.

v. The identifying titles of all recorded plats, filed maps, right of way maps, or similar documents which the survey represents, wholly or in part, with their recording or filing data.

vi. For non-platted adjoining land, recording data identifying adjoining tracts according to current public records. For platted adjoining land, the recording data of the subdivision plat.

vii. Platted setback or building restriction lines which appear on recorded subdivision plats or which were disclosed in documents provided or obtained by the surveyor.

D. Presentation

i. The plat or map shall be drawn on a sheet of not less than 8 ½ by 11 inches in size at a legible, standard engineering scale, with that scale clearly indicated in words or numbers and with a graphic scale.

ii. The plat or map shall include:

(a) The boundary of the surveyed property drawn in a manner that distinguishes it from other lines on the plat or map.
(b) If no buildings were observed on the surveyed property in the process of conducting the fieldwork, a note stating "No buildings observed."
(c) A north arrow (with north to the top of the drawing when practicable).
(d) A legend of symbols and abbreviations.
(e) A vicinity map showing the property in reference to nearby highway(s) or major street intersection(s).
(f) Supplementary or detail diagrams when necessary.

(g) Notes explaining any modifications to Table A items and the nature of any additional Table A items (e.g., 21(a), 21(b), 21(c)) that were negotiated between the surveyor and client.
(h) The surveyor's project number (if any), and the name, registration or license number, signature, seal, street address, telephone number, company website, and email address (if any) of the surveyor who performed the survey.
(i) The date(s) of any revisions made by the surveyor who performed the survey.
(j) Sheet numbers where the plat or map is composed of more than one sheet.
(k) The caption "ALTA/NSPS Land Title Survey."

iii. When recordation or filing of a plat or map is required by law, such plat or map shall be produced in recordable form.

7. **Certification**–The plat or map of an ALTA/NSPS Land Title Survey shall bear only the following certification, unaltered, except as may be required pursuant to Section 3.B. above:

To (name of insured, if known), (name of lender, if known), (name of insurer, if known), (names of others as negotiated with the client):

This is to certify that this map or plat and the survey on which it is based were made in accordance with the 2016 Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys, jointly established and adopted by ALTA and NSPS, and includes Items ___________ of Table A thereof. The fieldwork was completed on ___________ [date].

Date of Plat or Map: ___________ (Surveyor's signature, printed name and seal with Registration/License Number)

8. **Deliverables**–The surveyor shall furnish copies of the plat or map of survey to the insurer and client and as otherwise negotiated with the client. Hard copies shall be on durable and dimensionally stable material of a quality standard acceptable to the insurer. A digital image of the plat or map may be provided in addition to, or in lieu of, hard copies pursuant to the terms of the contract. When required by law or requested by the client, the plat or map shall be produced in recordable form and recorded or filed in the appropriate office or with the appropriate agency.

TABLE A

OPTIONAL SURVEY RESPONSIBILITIES AND SPECIFICATIONS

NOTE: The twenty (20) items of Table A may be negotiated between the surveyor and client. Any additional items negotiated between the surveyor and client shall be identified as 21(a), 21(b), etc. and explained pursuant to Section 6.D.ii.(g). Notwithstanding Table A Items 5 and 11, if an engineering design survey is desired as part of an ALTA/NSPS Land Title Survey, such services should be negotiated under Table A, Item 21.

If checked, the following optional items are to be included in the ALTA/NSPS LAND TITLE SURVEY, except as otherwise qualified (see note above):

1. _____ Monuments placed (or a reference monument or witness to the corner) at all major corners of the boundary of the property, unless already marked or referenced by existing monuments or witnesses in close proximity to the corner.

2. _____ Address(es) of the surveyed property if disclosed in documents provided to or obtained by the surveyor, or observed while conducting the fieldwork.

3. _____ Flood zone classification (with proper annotation based on federal Flood Insurance Rate Maps or the state or local equivalent) depicted by scaled map location and graphic plotting only.

4. _____ Gross land area (and other areas if specified by the client).

5. _____ Vertical relief with the source of information (e.g., ground survey, aerial map), contour interval, datum, and originating benchmark identified.

6. _____ (a) If set forth in a zoning report or letter provided to the surveyor by the client, list the current zoning classification, setback requirements, the height and floor space area restrictions, and parking requirements. Identify the date and source of the report or letter.

   _____ (b) If the zoning setback requirements are set forth in a zoning report or letter provided to the surveyor by the client, and if those requirements do not require an interpretation by the surveyor, graphically depict the building setback requirements. Identify the date and source of the report or letter.

7. _____ (a) Exterior dimensions of all buildings at ground level.

   (b) Square footage of:

   _____ (1) exterior footprint of all buildings at ground level.

   _____ (2) other areas as specified by the client.

   _____ (c) Measured height of all buildings above grade at a location specified by the client. If no location is specified, the point of measurement shall be identified.

8. _____ Substantial features observed in the process of conducting the fieldwork (in addition to the improvements and features required pursuant to Section 5 above) (e.g., parking lots, billboards, signs, swimming pools, landscaped areas, substantial areas of refuse).

9. _____ Number and type (e.g., disabled, motorcycle, regular and other marked specialized types) of clearly identifiable parking spaces on surface parking areas, lots and in parking structures. Striping of clearly identifiable parking spaces on surface parking areas and lots.

10. _____ (a) As designated by the client, a determination of the relationship and location of certain division or party walls with respect to adjoining properties (client to obtain necessary permissions).

_____ (b) As designated by the client, a determination of whether certain walls are plumb (client to obtain necessary permissions).

11. _____ Location of utilities existing on or serving the surveyed property as determined by:

- observed evidence collected pursuant to Section 5.E.iv.
- evidence from plans requested by the surveyor and obtained from utility companies, or provided by client (with reference as to the sources of information), and
- markings requested by the surveyor pursuant to an 811 utility locate or similar request

Representative examples of such utilities include, but are not limited to:

- Manholes, catch basins, valve vaults and other surface indications of subterranean uses;
- Wires and cables (including their function, if readily identifiable) crossing the surveyed property, and all poles on or within ten feet of the surveyed property. Without expressing a legal opinion as to the ownership or nature of the potential encroachment, the dimensions of all encroaching utility pole crossmembers or overhangs; and
- Utility company installations on the surveyed property.

Note to the client, insurer, and lender - With regard to Table A, item 11, source information from plans and markings will be combined with observed evidence of utilities pursuant to Section 5.E.iv. to develop a view of the underground utilities. However, lacking excavation, the exact location of underground features cannot be accurately, completely, and reliably depicted. In addition, in some jurisdictions, 811 or other similar utility locate requests from surveyors may be ignored or result in an incomplete response, in which case the surveyor shall note on the plat or map how this affected the surveyor’s assessment of the location of the utilities. Where additional or more detailed information is required, the client is advised that excavation and/or a private utility locate request may be necessary.

12. _____ As specified by the client, Governmental Agency survey-related requirements (e.g., HUD surveys, surveys for leases on Bureau of Land Management managed lands).

13. _____ Names of adjoining owners according to current tax records. If more than one owner, identify the first owner’s name listed in the tax records followed by "et al."

14. _____ As specified by the client, distance to the nearest intersecting street.

15. _____ Rectified orthophotography, photogrammetric mapping, remote sensing, airborne/mobile laser scanning and other similar products, tools or technologies as the basis for the showing the location of certain features (excluding boundaries) where ground measurements are not otherwise necessary to locate those features to an appropriate and acceptable accuracy relative to a nearby boundary. The surveyor shall (a) discuss the ramifications of such methodologies (e.g., the potential precision and completeness of the data gathered thereby) with the insurer, lender, and client prior to the performance of the survey, and (b) place a note on the face of the survey explaining the source, date, precision, and other relevant qualifications of any such data.

16. _____ Evidence of recent earth moving work, building construction, or building additions observed in the process of conducting the fieldwork.

17. _____ Proposed changes in street right of way lines, if such information is made available to the surveyor by the controlling jurisdiction. Evidence of recent street or sidewalk construction or repairs observed in the process of conducting the fieldwork.

18. _____ If there has been a field delineation of wetlands conducted by a qualified specialist hired by the client, the surveyor shall locate any delineation markers observed in the process of conducting the fieldwork and show them on the face of the plat or map. If no markers were observed, the surveyor shall so state.

19. _____ Include any plottable offsite (i.e., appurtenant) easements or servitudes disclosed in documents provided to or obtained by the surveyor as a part of the survey pursuant to Sections 5 and 6 (and applicable selected Table A items) (client to obtain necessary permissions).

20. _____ Professional Liability Insurance policy obtained by the surveyor in the minimum amount of $____________ to be in effect throughout the contract term. Certificate of Insurance to be furnished upon request, but this item shall not be addressed on the face of the plat or map.

21. _____ ____

Adopted by the Board of Governors, American Land Title Association, on October 8, 2015.
American Land Title Association, 1800 M St., N.W., Suite 300S, Washington, D.C. 20036-5828.
www.alta.org

Adopted by the Board of Directors, National Society of Professional Surveyors, on October 9, 2015.
National Society of Professional Surveyors, Inc., 5119 Pegasus Court, Suite Q, Frederick, MD 21704.
http://www.nsps.us.com/

UNITED STATES NATIONAL MAP ACCURACY STANDARDS

With a view to the utmost economy and expedition in producing maps which fulfill not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual agencies, standards of accuracy for published maps are defined as follows:

1. Horizontal accuracy. For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.

2. Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

3. The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of the testing.

4. Published maps meeting these accuracy requirements shall note this fact on their legends, as follows: “This map complies with National Map accuracy Standards.”

5. Published maps whose errors exceed those aforestated shall omit from their legends all mention of standard accuracy.

6. When a published map is a considerable enlargement of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, “This map is an enlargement of a 1:20,000-scale map drawing,” or “This map is an enlargement of a 1:24,000-scale published map.”

7. To facilitate ready interchange and use of basic information for map construction among all Federal mapmaking agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7.5 minutes, or 3-3/4 minutes in size.

Issued June 10, 1941
Revised April 26, 1943
Revised June 17, 1947

U.S. BUREAU OF THE BUDGET

FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems*

3.5 Geodetic Leveling

Geodetic leveling is a measurement system comprised of elevation differences observed between nearby rods. Geodetic leveling is used to extend vertical control.

Network Geometry

Order Class	First I	First II	Second I	Second II	Third
Bench mark spacing not more than (km)	3	3	3	3	3
Average bench mark spacing not more than (km)	1.6	1.6	1.6	3.0	3.0
Line length between network control points not more than (km)	300[a]	100[a]	50[a]	50[a]	25[b]
Minimum bench mark ties	6	6	4	4	4

[a] Electronic Digital/Bar-Code Leveling Systems, 25 km

[b] Electronic Digital/Bar-Code Leveling Systems, 10 km

As specified in above table, new surveys are required to tie to existing network bench marks at the beginning and end of the leveling line. These network bench marks must have an order (and class) equivalent to or better than the intended order (and class) of the new survey.

First-order surveys are required to perform valid check connections to a minimum of six bench marks, three at each end. All other surveys require a minimum of four valid check connections, two at each end.

A valid "check connection" means that the observed elevation difference agrees with the published adjusted elevation difference within the tolerance limit of the new survey. Checking the elevation difference between two bench marks located on the same structure, or so close together that both may have been affected by the same localized disturbance, is not considered a proper check.

In addition, the survey is required to connect to any network control points within 3 km of its path. However, if the survey is run parallel to existing control, then the following table specifies the maximum spacing of extra connections between the survey and the existing control.

When using Electronic Digital/Bar-Code Leveling Systems for area projects, there must be at least 4 contiguous loops and the loop size must not exceed 25 km. *(Note: This specification may be amended at a future date after sufficient data have been evaluated and it is proven that there are no significant uncorrected systematic errors remaining in Electronic Digital/Bar-Code Leveling Systems.)*

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* NGS' analyses of the data will be the final determination if the data meet the desired FGCS order and class standards.

Surveys Run Parallel to Existing Control Network

Distance, survey to control network	Maximum spacing of extra connections (km)
less than 0.5 km	5
0.5 km to 2.0 km	10
2.0 km to 3.0 km	20

Instrumentation

Order Class	First I	First II	Second I	Second II	Third
Leveling instrument					
Minimum repeatability of line of sight	0.25"[c]	0.25"[c]	0.50"[c]	0.50"[d]	1.00"
Leveling rod construction	IDS[g]	IDS[g]	IDS[e] or ISS	ISS	Wood or Metal
Instrument and rod resolution (combined)					
Least count(mm)	0.1[c]	0.1[c]	0.5-1.0[c,f]	1.0[d]	1.0[d]

IDS -- Invar, double-scale
ISS -- Invar, single-scale

[c] For Electronic Digital/Bar-Code Leveling Systems, 0.40" and 0.01 mm.

[d] For Electronic Digital/Bar-Code Leveling Systems, 0.80" and 0.1 mm.

[e] If optical micrometer is used.

[f] 1.0 mm if 3-wire method; 0.5 mm if optical micrometer.

[g] For Electronic Digital/Bar-Code Leveling Systems, Invar, single-scale.

Leveling rods must be one piece. A turning point consisting of a steel turning pin with a driving cap should be utilized. If a steel pin cannot be driven, then a turning plate ("turtle") weighing at least 7 kg should be substituted. In situations allowing neither turning pins nor turning plates (sandy or marshy soils), a long wooden stake with a double-headed nail should be driven to a firm depth.

According to at least one manufacturer's specifications, the electronic digital leveling instrument should not be exposed to direct sunlight. The manufacturer recommends using an umbrella in bright sunlight.

Order Class	First I	First II	Second I	Second II	Third
Leveling instrument					
Maximum collimation error, single line of sight (mm/m)	0.05	0.05	0.05	0.05	0.10
Maximum collimation error, reversible compensator-type instruments, mean of two lines of sight (mm/m)	0.02	0.02	0.02	0.02	0.04
Time interval between collimation error determinations not longer than (days)					
Reversible compensator	7	7	7	7	7
Other types	1	1	1	1	7[h]
Maximum angular difference between two lines of sight, reversible compensator	40"	40"	40"	40"	60"
Leveling rod					
Minimum scale calibration standard	N[i]	N[i]	N[i]	M	M
Time interval between scale calibrations (yr)	3	3	--	--	--
Leveling rod bubble verticality maintained to within	10'	10'	10'	10'	10'

N -- U.S. National standard
M -- Manufacturer's standard

[h] For Electronic Digital/Bar-Code Systems, collimation error determinations are required at the beginning of each day (0.05 mm/m = 10 arc seconds). Collimation data must be recorded with the leveling data and the daily updated value must be used during the daily data capture.

[i] For Electronic Digital/Bar-Code Rods, until the U.S. National Standard Testing Procedure is implemented, manufacturer's scale calibration standard is acceptable, provided the data used during the calibration are furnished in digital format.

Compensator-type instruments should be checked for proper operation at least every 2 weeks of use. Rod calibration should be repeated whenever the rod is dropped or damaged in any way. Rod levels should be checked for proper alignment once a week. The manufacturer's calibration standard should, as a minimum, describe scale behavior with respect to temperature.

Order Class	First I	First II	Second I	Second II	Third
Minimal observation method	microm-eter[j]	microm-eter[j]	microm-eter[j] or 3 wire	3-wire[j]	center wire[j]
Section running[k]	DR, DS, or MDS	DR, DS, or MDS	DR	DR	DR
Difference of forward and backward sight lengths never to exceed: per setup (m)	2	5	5	10	10
per section (m)	4	10	10	10	10
Maximum sight length (m)[l]	50	60	60	70	90
Minimum ground clearance of line of sight (m)	0.5	0.5	0.5	0.5	0.5
Even number of setups when not using leveling rods with detailed calibration	yes	yes	yes	yes	---
Determine temperature gradient for the vertical range of the line of sight at each setup	yes	yes	yes	---	---
Maximum section misclosure (mm)	$3\sqrt{D}$	$4\sqrt{D}$	$6\sqrt{D}$	$8\sqrt{D}$	$12\sqrt{D}$
Maximum loop misclosure (mm)	$4\sqrt{E}$	$5\sqrt{E}$	$6\sqrt{E}$	$8\sqrt{E}$	$12\sqrt{E}$
3-wire method					
Reading check (difference between top and bottom intervals) for one setup not to exceed (tenths of rod units)	---	---	2	2	3
Read rod 1 first in alternate setup method	---	---	yes	yes	yes
Micrometer single-difference method					
Reading check (difference between low and high scale) for one setup not to exceed (micrometer units)	---	---	3	4	5
Read rod 1 first in alternate setup method	---	---	yes	yes	yes

(continued)

Order Class	First I	First II	Second I	Second II	Third
Electronic Digital/Bar-Code method					
$\Delta h_1 - \Delta h_2$ for one setup not to exceed (mm) for MDS procedure	0.30	0.30	0.60	0.70	1.30
Use multiple reading option to obtain each observation - minimum number of readings[m]	3	3	3	3	3
Double-scale rods, DS procedure					
Low-high scale elevation difference for one setup not to exceed (mm) With reversible compensator	0.40	1.00	1.00	2.00	2.00
Other instrument types: Half-centimeter rods	0.25	0.30	0.60	0.70	1.30
Full-centimeter rods	0.30	0.30	0.60	0.70	1.30

DS -- Double Simultaneous procedure; see summary of observing sequences
MDS - Modified, Double Simultaneous procedure; see summary of observing sequences
DR -- Double-Run
SP -- SPur, must be less than 25 km, must be double-run
D --- shortest one-way length of section in km
E --- length of loop in km

[j] Electronic Digital/Bar-Code method permitted.

[k] For establishing a height of a new bench mark, double-run procedures must be used. Single-run methods can be used to relevel existing work provided the new work meets the allowable section misclosure.

[l] Maximum sight length permitted unless the manufacturer recommends a maximum sight length which is less.

[m] If the standard deviation of the mean exceeds 0.1 mm, continue making readings until it is less than 0.1 mm or repeat observation.

Double-run leveling may always be used, but single-run leveling procedures can only be used where it can be evaluated using published height values, i.e., the difference in published height values can be substituted for the backward running. DS and MDS procedures are recommended for all single-run leveling, but single-difference procedures are permitted.

Rods must be leap-frogged between setups (alternate setup method). The date, beginning and ending times, cloud coverage, air temperature (to the nearest degree), temperature scale, and average wind speed should be recorded for each section, plus any changes in the date, instrumentation, observer, or time zone.

When using the DS and MDS procedures, the instrument need not be off leveled/ releveled between observing the high and low scales when using an instrument with a reversible compensator. The low-high scale difference tolerance for a reversible compensator is used only for the control of blunders.

Summary of Observing Sequences
(Required for first-order; optional for other orders)

DS Procedures
With double-scale rods, the following observing sequence should be used:

backsight, low-scale
backsight, stadia
foresight, low-scale
foresight, stadia
off-level/relevel or reverse compensator
foresight, high-scale
backsight, high-scale

MDS Procedures
With bar-coded scale rods, the following observing sequence should be used:

backsight
backsight distance, standard error
foresight
foresight, distance, standard error
off-level/relevel
foresight, standard error
backsight, standard error

Office Procedures

Order Class	First I	First II	Second I	Second II	Third
Section misclosures					
(backward and forward) Algebraic sum of all corrected section misclosures of a leveling line not to exceed (mm)	$3\sqrt{L}$	$4\sqrt{L}$	$6\sqrt{L}$	$8\sqrt{L}$	$12\sqrt{L}$
Section misclosure not to exceed (mm)	$3\sqrt{D}$	$4\sqrt{D}$	$6\sqrt{D}$	$8\sqrt{D}$	$12\sqrt{D}$
Loop misclosures					
Algebraic sum of all corrected misclosures not to exceed (mm)	$4\sqrt{E}$	$5\sqrt{E}$	$6\sqrt{E}$	$8\sqrt{E}$	$12\sqrt{E}$
Loop misclosure not to exceed (mm)	$4\sqrt{E}$	$5\sqrt{E}$	$6\sqrt{E}$	$8\sqrt{E}$	$12\sqrt{E}$

L -- shortest one-way length of leveling line in km
D -- shortest one-way length of section in km
E -- length of loop in km

The normalized residuals from a minimally constrained least squares adjustment will be checked for blunders. The observation weights will be checked by inspecting the post adjustment estimate of the variance of unit weight. Elevation difference standard errors computed by error propagation in a correctly weighted least squares adjustment will indicate the provisional accuracy classification. A survey variance factor ratio will be computed to check for systematic error. The least squares adjustment will use models that account for:

- gravity effect or orthometric correction
- rod scale errors
- rod (Invar) temperature
- refraction--need latitude and longitude accurate to at least 6" or (preferably) vertical temperature difference observations between 0.5 and 2.5 m above the ground
- earth tides and magnetic field
- collimation error[n]
- crustal motion

[n] For Electronic Digital/Bar-Code Leveling Systems, collimation data must be recorded with leveling data and updated value must be used during data capture.

FEMA

National Flood Insurance Program

ELEVATION CERTIFICATE

AND

INSTRUCTIONS

OMB Control Number: 1660-0008
Expiration: 11/30/2018

Paperwork Reduction Act Notice

Public reporting burden for this data collection is estimated to average 3.75 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining a valid OMB control number is displayed on this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing the burden to: Information Collections Management, Department of Homeland Security, Federal Emergency Management Agency, 1800 South Bell Street, Arlington, VA 20598-3005, Paperwork Reduction Project (1660-0008). **NOTE: Do not send your completed form to this address.**

Privacy Act Statement

Authority: Title 44 CFR § 61.7 and 61.8.

Principal Purpose(s): This information is being collected for the primary purpose of estimating the risk premium rates necessary to provide flood insurance for new or substantially improved structures in designated Special Flood Hazard Areas.

Routine Use(s): The information on this form may be disclosed as generally permitted under 5 U.S.C. § 552a(b) of the Privacy Act of 1974, as amended. This includes using this information as necessary and authorized by the routine uses published in DHS/FEMA-003 - National Flood Insurance Program Files System or Records Notice 73 Fed. Reg. 77747 (December 19, 2008); DHS/FEMA/NFIP/LOMA-1 - National Flood Insurance Program (NFIP) Letter of Map Amendment (LOMA) System of Records Notice 71 Fed. Reg. 7990 (February 15, 2006); and upon written request, written consent, by agreement, or as required by law.

Disclosure: The disclosure of information on this form is voluntary; however, failure to provide the information requested may result in the inability to obtain flood insurance through the National Flood Insurance Program or the applicant may be subject to higher premium rates for flood insurance. Information will only be released as permitted by law.

Purpose of the Elevation Certificate

The Elevation Certificate is an important administrative tool of the National Flood Insurance Program (NFIP). It is to be used to provide elevation information necessary to ensure compliance with community floodplain management ordinances, to determine the proper insurance premium rate, and to support a request for a Letter of Map Amendment (LOMA) or Letter of Map Revision based on fill (LOMR-F).

The Elevation Certificate is required in order to properly rate Post-FIRM buildings, which are buildings constructed after publication of the Flood Insurance Rate Map (FIRM), located in flood insurance Zones A1 -A30, AE, AH, A (with BFE), VE, V1 -V30, V (with BFE), AR, AR/A, AR/AE, AR/A1 -A30, AR/AH, and AR/AO. The Elevation Certificate is not required for Pre-FIRM buildings unless the building is being rated under the optional Post-FIRM flood insurance rules.

As part of the agreement for making flood insurance available in a community, the NFIP requires the community to adopt floodplain management regulations that specify minimum requirements for reducing flood losses. One such requirement is for the community to obtain the elevation of the lowest floor (including basement) of all new and substantially improved buildings, and maintain a record of such information. The Elevation Certificate provides a way for a community to document compliance with the community's floodplain management ordinance.

Use of this certificate does not provide a waiver of the flood insurance purchase requirement. Only a LOMA or LOMR-F from the Federal Emergency Management Agency (FEMA) can amend the FIRM and remove the Federal mandate for a lending institution to require the purchase of flood insurance. However, the lending institution has the option of requiring flood insurance even if a LOMA/LOMR-F has been issued by FEMA. The Elevation Certificate may be used to support a LOMA or LOMR-F request. Lowest floor and lowest adjacent grade elevations certified by a surveyor or engineer will be required if the certificate is used to support a LOMA or LOMR-F request. A LOMA or LOMR-F request must be submitted with either a completed FEMA MT-EZ or MT-1 package, whichever is appropriate.

This certificate is used only to certify building elevations. A separate certificate is required for floodproofing. Under the NFIP, non-residential buildings can be floodproofed up to or above the Base Flood Elevation (BFE). A floodproofed building is a building that has been designed and constructed to be watertight (substantially impermeable to floodwaters) below the BFE. Floodproofing of residential buildings is not permitted under the NFIP unless FEMA has granted the community an exception for residential floodproofed basements. The community must adopt standards for design and construction of floodproofed basements before FEMA will grant a basement exception. For both floodproofed non-residential buildings and residential floodproofed basements in communities that have been granted an exception by FEMA, a floodproofing certificate is required.

Additional guidance can be found in FEMA Publication 467-1, Floodplain Management Bulletin: Elevation Certificate, available on FEMA's website at https://www.fema.gov/media-library/assets/documents/3539?id=1727.

DEPARTMENT OF HOMELAND SECURITY

Federal Emergency Management Agency

ELEVATION CERTIFICATE

IMPORTANT: FOLLOW THE INSTRUCTIONS ON PAGES 9-16

OMB Control Number: 1660-0008
Expiration: 11/30/2018

Copy all pages of this Elevation Certificate and all attachments for (1) community official, (2) insurance agent/company, and (3) building owner.

SECTION A - PROPERTY INFORMATION

FORM INSURANCE COMPANY USE

Policy Number:

Company NAIC Number:

A1. Building Owner's Name

A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No.

City	State	Zip Code

A3. Property Description (Lot and Block Numbers, Tax Parcel Number, Legal Description, etc.)

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.)

A5. Latitude/Longitude: Lat. ________ Long. ________ Horizontal Datum: ◯ NAD 1927 ◯ NAD 1983

A6. Attach at least 2 photographs of the building if the Certificate is being used to obtain flood insurance.

A7. Building Diagram Number ____________

A8. For a building with a crawlspace or enclosure(s):

a) Square footage of crawlspace or enclosure(s) ________ sq ft

b) Number of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade ________

c) Total net area of flood openings in A8.b ________ sq in

d) Engineered flood openings? ◯ Yes ◯ No

A9. For a building with an attached garage:

a) Square footage of attached garage ________ sq ft

b) Number of permanent flood openings in the attached garage within 1.0 foot above adjacent grade ________

c) Total net area of flood openings in A9.b ________ sq in

d) Engineered flood openings? ◯ Yes ◯ No

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

B1. NFIP Community Name & Community Number	B2. County Name	B3. State

B4. Map/Panel Number	B5. Suffix	B6. FIRM Index Date	B7. FIRM Panel Effective/ Revised Date	B8. Flood Zone(s)	B9. Base Flood Elevation(s) (Zone AO, use base flood depth

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9:

◯ FIS Profile ◯ FIRM ◯ Community Determined ◯ Other/Source: ____________

B11. Indicate elevation datum used for BFE in Item B9: ◯ NGVD 1929 ◯ NAVD 1988 ◯ Other/Source: ____________

B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)? ◯ Yes ◯ No

Designation Date: ◯ CBRS ◯ OPA

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ◯ Construction Drawings* ◯ Building Under Construction* ◯ Finished Construction

C2. Elevations - Zones A1 - A30, AE, AH, A (with BFE), VE, V1 - V30, V (with BFE), AR, AR/A, AR/AE, AR/A1 - A30, AR/AH, AR/AO. Complete Items C2.a -h below according to the building diagram specified in Item A7. In Puerto Rico only, enter meters.

* A new Elevation Certificate will be required when construction of the building is complete.

Benchmark Utilized: ____________ Vertical Datum: ____________

Indicate elevation datum used for the elevations in items a) through h) below. ◯ NGVD 1929 ◯ NAVD 1988

◯ Other/Source: ____________

Datum used for building elevations must be the same as that used for the BFE. Check the measurement used.

a) Top of bottom floor (including basement, crawlspace, or enclosure floor) ____ - ____ ◯ feet ◯ meters

b) Top of the next higher floor ____ - ____ ◯ feet ◯ meters

c) Bottom of the lowest horizontal structural member (V Zones only) ____ - ____ ◯ feet ◯ meters

d) Attached garage (top of slab) ____ - ____ ◯ feet ◯ meters

e) Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments) ____ - ____ ◯ feet ◯ meters

f) Lowest adjacent (finished) grade next to building (LAG) ____ - ____ ◯ feet ◯ meters

g) Highest adjacent (finished) grade next to building (HAG) ____ - ____ ◯ feet ◯ meters

h) Lowest adjacent grade at lowest elevation of deck or stairs, including structural support ____ - ____ ◯ feet ◯ meters

ELEVATION CERTIFICATE

OMB Control Number: 1660-0008
Expiration: 11/30/2018

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. *I certify that the information on this Certificate represents my best efforts to interpret the data available. I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.*

☐ Check here if attachments.

Were latitude and longitude in Section A provided by a licensed land surveyor? ◯ Yes ◯ No

Certifier's Name			License Number
Title	Company Name		
Address	City	State	Zip Code
Signature	Date	Telephone	

PLACE SEAL HERE

Copy both sides of this Elevation Certificate for (1) community official, (2) insurance agent/company, and (3) building owner.

Comments (including type of equipment and location , per C2(e), if applicable)"

Signature Date

SECTION E - BUILDING ELEVATION INFORMATION (SURVEY NOT REQUIRED) FOR ZONE AO AND ZONE A (WITHOUT BFE)

For Zones AO and A (without BFE), complete Items E1 -E5. If the Certificate is intended to support a LOMA or LOMR-F request, complete Sections A, B,and C. For Items E1 -E4, use natural grade, if available. Check the measurement used. In Puerto Rico only, enter meters.

E1. Provide elevation information for the following and check the appropriate boxes to show whether the elevation is above or below the highest adjacent grade (HAG) and the lowest adjacent grade (LAG).

a) Top of bottom floor (including basement, crawlspace, or enclosure) is ______ - ______ ◯ feet ◯ meters ☐ above or ☐ below the HAG.

b) Top of bottom floor (including basement, crawlspace, or enclosure) is ______ - ______ ◯ feet ◯ meters ☐ above or ☐ below the LAG.

E2. For Building Diagrams 6 -9 with permanent flood openings provided in Section A Items 8 and/or 9 (see pages 8 -9 of Instructions), the next higher floor (elevation C2.b in the diagrams) of the building is ______ - ______ ◯ feet ◯ meters ☐ above or ☐ below the HAG.

E3. Attached garage (top of slab) is ______ - ______ ◯ feet ◯ meters ☐ above or ☐ below the HAG.

E4. Top of platform of machinery and /or equipment servicing the building is ______ - ______ ◯ feet ◯ meters ☐ above or ☐ below the HAG.

E5. Zone AO only: If no flood depth number is available, is the top of the bottom floor elevated in accordance with the community's floodplain management ordinance? ◯ Yes ◯ No ◯ Unknown. The local official must certify this information in Section G.

SECTION F - PROPERTY OWNER (OR OWNER'S REPRESENTATIVE) CERTIFICATION

The property owner or owner's authorized representative who completes Sections A, B, and E for Zone A (without a FEMA-issued or community-issued BFE) or Zone AO must sign here. The statements in Sections A, B, and E are correct to the best of my knowledge.

Property Owner or Owner's Authorized Representative's Name:

Address	City	State	ZIP Code
Signature	Date	Telephone	

Comments

☐ Check here if attachments.

SECTION G - COMMUNITY INFORMATION (OPTIONAL)

The local official who is authorized by law or ordinance to administer the community's floodplain management ordinance can complete Sections A, B, C (or E), and G of this Elevation Certificate. Complete the applicable item(s) and sign below. Check the measurement used in Items G8 - G10. In Puerto Rico only, enter meters.

G1. ☐ The information in Section C was taken from other documentation that has been signed and sealed by a licensed surveyor, engineer, or architect who is authorized by law to certify elevation information. (Indicate the source and date of the elevation data in the Comments area below.)

G2. ☐ A community official completed Section E for a building located in Zone A (without a FEMA-issued or community-issued BFE) or Zone AO.

G3. ☐ The following information (Items G4 -G10) is provided for community floodplain management purposes.

G4. Permit Number	G5. Date Permit Issued	G6. Date Certificate of Compliance/Occupancy Issued

G7. This permit has been issued for: ◯ New Construction ◯ Substantial Improvement

G8. Elevation of as-built lowest floor (including basement) of the building: ______ - ______ ◯ feet ◯ meters Datum ____________

G9. BFE or (in Zone AO) depth of flooding at the building site: ______ - ______ ◯ feet ◯ meters Datum ____________

G10. Community's design flood elevation: ______ - ______ ◯ feet ◯ meters Datum ____________

Local Official's Name	Title
Community Name	Telephone
Signature	Date

Comments

☐ Check here if attachments.

BUILDING PHOTOGRAPHS

See instructions for Item A6

OMB Control Number: 1660-0008
Expiration: 11/30/2018

IMPORTANT: In these spaces, copy the corresponding information from Section A.			FOR INSURANCE COMPANY USE
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No.			Policy Number:
City	State	Zip Code	Company NAIC Number:

If using the Elevation Certificate to obtain NFIP flood insurance, affix at least 2 building photographs below according to the instructions for Item A6. Identify all photographs with date taken; "Front view" and Rear view"; and, if required, "Right Side View" and "Left Side View." When applicable, photographs must show the foundation with representative examples of the flood openings or vents, as indicated in Section A8. If submitting more photographs than will fit on this page, use the Continuation Page.

BUILDING PHOTOGRAPHS

Continuation Page

OMB Control Number: 1660-0008
Expiration: 11/30/2018

IMPORTANT: In these spaces, copy the corresponding information from Section A.			FORM INSURANCE COMPANY USE
Building Street Address (including Apt., Unit,Suite, and/or Bldg. No.) or P.O.Route and Box No.			Policy Number:
City	State	Zip Code	Company NAIC Number:

If submitting more photographs than will fit on the preceding page, affix the additional photographs below. Identify all photographs with: date taken; "Front View" and "Rear View"' and, if required, "Right Side View" and "Left Side View." When applicable, photographs must show the foundation with representative examples of the flood openings or vents, as indicated in Section A8.

The Elevation Certificate is to be completed by a land surveyor, engineer, or architect who is authorized by law to certify elevation information when elevation information is required for Zones A1 -A30, AE, AH, A (with BFE), VE, V1 -V30, V (with BFE), AR, AR/A, AR/AE, AR/A1 -A30, AR/AH, or AR/AO. Community officials who are authorized by law or ordinance to provide floodplain management information may also complete this form. For Zones AO and A (without BFE), a community official, a property owner, or an owner's representative may provide information on this certificate, unless the elevations are intended for use in supporting a request for a LOMA or LOMR-F. Certified elevations must be included if the purpose of completing the Elevation Certificate is to obtain a LOMA or LOMR-F.

The property owner, the owner's representative, or local official who is authorized by law to administer the community floodplain ordinance can complete Section A and Section B. The partially completed form can then be given to the land surveyor, engineer, or architect to complete Section C. The land surveyor, engineer, or architect should verify the information provided by the property owner or owner's representative to ensure that this certificate is complete.

In Puerto Rico only, elevations for building information and flood hazard information may be entered in meters.

SECTION A - PROPERTY INFORMATION

Items A1 -A4. This section identifies the building, its location, and its owner. Enter the name(s) of the building owner(s), the building's complete street address, and the lot and block numbers. If the building's address is different from the owner's address, enter the address of the building being certified. If the address is a rural route or a Post Office box number, enter the lot and block numbers, the tax parcel number, the legal description, or an abbreviated location description based on distance and direction from a fixed point of reference. For the purposes of this certificate, "building" means both a building and a manufactured (mobile) home.

A map may be attached to this certificate to show the location of the building on the property. A tax map, FIRM, or detailed community map is appropriate. If no map is available, provide a sketch of the property location, and the location of the building on the property. Include appropriate landmarks such as nearby roads, intersections, and bodies of water. For building use, indicate whether the building is residential, non-residential, an addition to an existing residential or non-residential building, an accessory building (e.g., garage), or other type of structure. Use the Comments area of the appropriate section if needed, or attach additional comments.

Item A5. Provide latitude and longitude coordinates for the center of the front of the building. Use either decimal degrees (e.g., 39.5043°, -110.7585°) or degrees, minutes, seconds (e.g., 39° 30' 15.5", -110° 45' 30.7") format. If decimal degrees are used, provide coordinates to at least 5 decimal places or better. When using degrees, minutes, seconds, provide seconds to at least 1 decimal place or better. The latitude and longitude coordinates must be accurate within 66 feet. When the latitude and longitude are provided by a surveyor, check the "Yes" box in Section D and indicate the method used to determine the latitude and longitude in the Comments area of Section D. If the Elevation Certificate is being certified by other than a licensed surveyor, engineer, or architect, this information is not required. Provide the type of datum used to obtain the latitude and longitude. FEMA prefers the use of NAD 1983.

Item A6. If the Elevation Certificate is being used to obtain flood insurance through the NFIP, the certifier must provide at least 2 photographs showing the front and rear of the building taken within 90 days from the date of certification. The photographs must be taken with views confirming the building description and diagram number provided in Section A. To the extent possible, these photographs should show the entire building including foundation. If the building has split-level or multi-level areas, provide at least 2 additional photographs showing side views of the building. In addition, when applicable, provide a photograph of the foundation showing a representative example of the flood openings or vents. All photographs must be in color and measure at least 3" × 3". Digital photographs are acceptable.

Item A7. Select the diagram on pages 7 -9 that best represents the building. Then enter the diagram number and use the diagram to identify and determine the appropriate elevations requested in Items C2.a -h. If you are unsure of the correct diagram, select the diagram that most closely resembles the building being certified.

Item A8.a Provide the square footage of the crawlspace or enclosure(s) below the lowest elevated floor of an elevated building with or without permanent flood openings. Take the measurement from the outside of the crawlspace or enclosure(s). Examples of elevated buildings constructed with crawlspace and enclosure(s) are shown in Diagrams 6 -9 on pages 8 -9. Diagram 2, 4, or 9 should be used for a building constructed with a crawlspace floor that is below the exterior grade on all sides.

Items A8.b -d Enter in Item A8.b the number of permanent flood openings in the crawlspace or enclosure(s) that are no higher than 1.0 foot above the higher of the exterior or interior grade or floor immediately below the opening. (A permanent flood opening is a flood vent or other opening that allows the free passage of water automatically in both directions without human intervention.) If the interior grade elevation is used, note this in the Comments area of Section D. Estimate the total net area of all such permanent flood openings in square inches, excluding any bars, louvers, or other covers of the permanent flood openings, and enter the total in Item A8.c. If the net area cannot be reasonably estimated, provide the size of the flood openings without consideration of any covers and indicate in the Comments area the type of cover that exists in the flood openings. Indicate in Item A8.d whether the flood openings are engineered. If applicable, attach a copy of the Individual Engineered Flood Openings Certification or an Evaluation Report issued by the International Code Council Evaluation Service (ICC ES), if you have it. If the crawlspace or enclosure(s) have no permanent flood openings, or if the openings are not within 1.0 foot above adjacent grade, enter "0" (zero) in Items A8.b -c.

Item A9.a Provide the square footage of the attached garage with or without permanent flood openings. Take the measurement from the outside of the garage.

Items A9.b -d Enter in Item A9.b the number of permanent flood openings in the attached garage that are no higher than 1.0 foot above the higher of the exterior or interior grade or floor immediately below the opening. (A permanent flood opening is a flood vent or other opening that allows the free passage of water automatically in both directions without human intervention.) If the interior grade elevation is used, note this in the Comments area of Section D. This includes any openings that are in the garage door that are no higher than 1.0 foot above the adjacent grade. Estimate the total net area of all such permanent flood openings in square inches and enter the total in Item A9.c. If the net area cannot be reasonably estimated, provide the size of the flood openings without consideration of any covers and indicate in the Comments area the type of cover that exists in the flood openings. Indicate in Item A9.d whether the flood openings are engineered. If applicable, attach a copy of the Individual Engineered Flood Openings Certification or an Evaluation Report issued by the International Code Council Evaluation Service (ICC ES), if you have it. If the garage has no permanent flood openings, or if the openings are not within 1.0 foot above adjacent grade, enter "0" (zero) in Items A9.b -c.

Instructions for Completing the Elevation Certificate (Continued)

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

Complete the Elevation Certificate on the basis of the FIRM in effect at the time of the certification.

The information for Section B is obtained by reviewing the FIRM panel that includes the building's location. Information about the current FIRM is available from the Federal Emergency Management Agency (FEMA) by calling 1-800-358-9616. If a Letter of Map Amendment (LOMA) or Letter of Map Revision (LOMR-F) has been issued by FEMA, please provide the letter date and case number in the Comments area of Section D or Section G, as appropriate.

For a building in an area that has been annexed by one community but is shown on another community's FIRM, enter the community name and 6-digit number of the annexing community in Item B1, the name of the county or new county, if necessary, in Item B2, and the FIRM index date for the annexing community in Item B6. Enter information from the actual FIRM panel that shows the building location, even if it is the FIRM for the previous jurisdiction, in Items B4, B5, B7, B8, and B9.

If the map in effect at the time of the building's construction was other than the current FIRM, and you have the past map information pertaining to the building, provide the information in the Comments area of Section D.

Item B1. NFIP Community Name & Community Number. Enter the complete name of the community in which the building is located and the associated 6-digit community number. For a newly incorporated community, use the name and 6-digit number of the new community. Under the NFIP, a "community" is any State or area or political subdivision thereof, or any Indian tribe or authorized native organization, that has authority to adopt and enforce floodplain management regulations for the areas within its jurisdiction. To determine the current community number, see the NFIP *Community Status Book*, available on FEMA's web site at https://www.fema.gov/national-flood-insurance-program/national-flood-insurance-program-community-status-book, or call 1-800-358-9616.

Item B2. County Name. Enter the name of the county or counties in which the community is located. For an unincorporated area of a county, enter "unincorporated area." For an independent city, enter "independent city."

Item B3. State. Enter the 2-letter state abbreviation (for example, VA, TX, CA).

Items B4 -B5. Map/Panel Number and Suffix. Enter the 10-character "Map Number" or "Community Panel Number" shown on the FIRM where the building or manufactured (mobile) home is located. For maps in a county-wide format, the sixth character of the "Map Number" is the letter "C" followed by a 4-digit map number. For maps not in a county-wide format, enter the "Community Panel Number" shown on the FIRM.

Item B6. FIRM Index Date. Enter the effective date or the map revised date shown on the FIRM Index.

Item B7. FIRM Panel Effective/Revised Date. Enter the map effective date or the map revised date shown on the FIRM panel. This will be the latest of all dates shown on the map. The current FIRM panel effective date can be determined by calling 1-800-358-9616.

Item B8. Flood Zone(s). Enter the flood zone, or flood zones, in which the building is located. All flood zones containing the letter "A" or "V" are considered Special Flood Hazard Areas. The flood zones are A, AE, A1 -A30, V, VE, V1 -V30, AH, AO, AR, AR/A, AR/AE, AR/A1 -A30, AR/AH, and AR/AO. Each flood zone is defined in the legend of the FIRM panel on which it appears.

Item B9. Base Flood Elevation(s). Using the appropriate Flood Insurance Study (FIS) Profile, Floodway Data Table, or FIRM panel, locate the property and enter the BFE (or base flood depth) of the building site. If the building is located in more than 1 flood zone in Item B8, list all appropriate BFEs in Item B9. BFEs are shown on a FIRM or FIS Profile for Zones A1 -A30, AE, AH, V1 -V30, VE, AR, AR/A, AR/AE, AR/A1 -A30, AR/AH, and AR/AO; flood depth numbers are shown for Zone AO. Use the AR BFE if the building is located in any of Zones AR/A, AR/AE, AR/A1-A30, AR/AH, or AR/AO. In A or V zones where BFEs are not provided on the FIRM, BFEs may be available from another source. For example, the community may have established BFEs or obtained BFE data from other sources for the building site. For subdivisions and other developments of more than 50 lots or 5 acres, establishment of BFEs is required by the community's floodplain management ordinance. If a BFE is obtained from another source, enter the BFE in Item B9. In an A Zone where BFEs are not available, complete Section E and enter N/A for Section B, Item B9. Enter the BFE to the nearest tenth of a foot (nearest tenth of a meter, in Puerto Rico).

Item B10. Indicate the source of the BFE that you entered in Item B9. If the BFE is from a source other than FIS Profile, FIRM, or community, describe the source of the BFE.

Item B11. Indicate the elevation datum to which the elevations on the applicable FIRM are referenced as shown on the map legend. The vertical datum is shown in the Map Legend and/or the Notes to Users on the FIRM.

Item B12. Indicate whether the building is located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA). (OPAs are portions of coastal barriers that are owned by Federal, State, or local governments or by certain non-profit organizations and used primarily for natural resources protection.) Federal flood insurance is prohibited in designated CBRS areas or OPAs for buildings or manufactured (mobile) homes built or substantially improved after the date of the CBRS or OPA designation. For the first CBRS designations, that date is October 1, 1983. Information about CBRS areas and OPAs may be obtained on the FEMA web site at https://www.fema.gov/national-flood-insurance-program/coastal-barrier-resources-system.

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

Complete Section C if the building is located in any of Zones A1 -A30, AE, AH, A (with BFE), VE, V1 -V30, V (with BFE), AR, AR/A, AR/AE, AR/A1 -A30, AR/AH, or AR/AO, or if this certificate is being used to support a request for a LOMA or LOMR-F. If the building is located in Zone AO or Zone A (without BFE), complete Section E instead. To ensure that all required elevations are obtained, it may be necessary to enter the building (for instance, if the building has a basement or sunken living room, split-level construction, or machinery and equipment).

Surveyors may not be able to gain access to some crawlspaces to shoot the elevation of the crawlspace floor. If access to the crawlspace is limited or cannot be gained, follow one of these procedures.

- Use a yardstick or tape measure to measure the height from the floor of the crawlspace to the "next higher floor," and then subtract the crawlspace height from the elevation of the "next higher floor." If there is no access to the crawlspace, use the exterior grade next to the structure to measure the height of the crawlspace to the "next higher floor."

- Contact the local floodplain administrator of the community in which the building is located. The community may have documentation of the elevation of the crawlspace floor as part of the permit issued for the building.

- If the property owner has documentation or knows the height of the crawlspace floor to the next higher floor, try to verify this by looking inside the crawlspace through any openings or vents.

In all 3 cases, provide the elevation in the Comments area of Section D on the back of the form and a brief description of how the elevation was obtained.

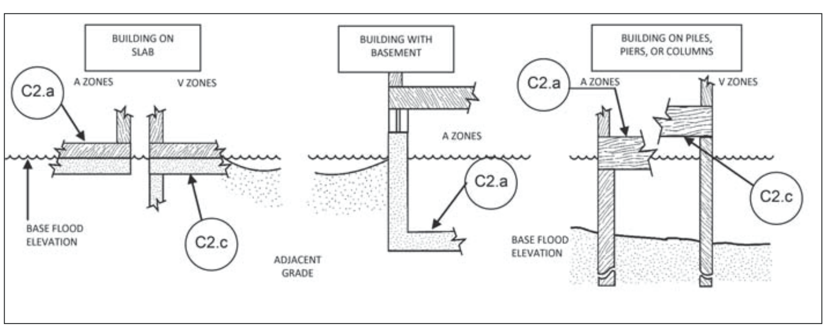
Item C1. Indicate whether the elevations to be entered in this section are based on construction drawings, a building under construction, or finished construction. For either of the first 2 choices, a post-construction Elevation Certificate will be required when construction is complete. If the building is under construction, include only those elevations that can be surveyed in Items C2.a -h. Use the Comments area of Section D to provide elevations obtained from the construction plans or drawings. Select "Finished Construction" only when all machinery and/or equipment such as furnaces, hot water heaters, heat pumps, air conditioners, and elevators and their associated equipment have been installed and the grading around the building is completed.

Item C2. A field survey is required for Items C2.a -h. Most control networks will assign a unique identifier for each benchmark. For example, the National Geodetic Survey uses the Permanent Identifier (PID). For the benchmark utilized, provide the PID or other unique identifier assigned by the maintainer of the benchmark. For GPS survey, indicate the benchmark used for the base station, the Continuously Operating Reference Stations (CORS) sites used for an On-line Positioning User Service (OPUS) solution (also attach the OPUS report), or the name of the Real Time Network used.

Also provide the vertical datum for the benchmark elevation. All elevations for the certificate, including the elevations for Items C2.a -h, must use the same datum on which the BFE is based. Show the conversion from the field survey datum used if it differs from the datum used for the BFE entered in Item B9 and indicate the conversion software used. Show the datum conversion, if applicable, in the Comments area of Section D.

For property experiencing ground subsidence, the most recent reference mark elevations must be used for determining building elevations. However, when subsidence is involved, the BFE should not be adjusted. Enter elevations in Items C2.a -h to the nearest tenth of a foot (nearest tenth of a meter, in Puerto Rico).

Items C2.a -d Enter the building elevations (excluding the attached garage) indicated by the selected building diagram (Item A7) in Items C2.a -c. If there is an attached garage, enter the elevation for top of attached garage slab in Item C2.d. (Because elevation for top of attached garage slab is self-explanatory, attached garages are not illustrated in the diagrams.) If the building is located in a V zone on the FIRM, complete Item C2.c. If the flood zone cannot be determined, enter elevations for all of Items C2.a -h. For buildings in A zones, elevations a, b, d, and e should be measured at the top of the floor. For buildings in V zones, elevation c must be measured at the bottom of the lowest horizontal structural member of the floor (see drawing below). For buildings elevated on a crawlspace, Diagrams 8 and 9, enter the elevation of the top of the crawlspace floor in Item C2.a, whether or not the crawlspace has permanent flood openings (flood vents). *If any item does not apply to the building, enter "N/A" for not applicable.*



Item C2.e Enter the lowest platform elevation of at least 1 of the following machinery and equipment items: elevators and their associated equipment, furnaces, hot water heaters, heat pumps, and air conditioners in an attached garage or enclosure or on an open utility platform that provides utility services for the building. Note that elevations for these specific machinery and equipment items are required in order to rate the building for flood insurance. Local floodplain management officials are required to ensure that all machinery and equipment servicing the building are protected from flooding. Thus, local officials may require that elevation information for all machinery and equipment, including ductwork, be documented on the Elevation Certificate. If the machinery and/or equipment is mounted to a wall, pile, etc., enter the platform elevation of the machinery and/or equipment. Indicate machinery/equipment type and its general location, e.g., on floor inside garage or on platform affixed to exterior wall, in the Comments area of Section D or Section G, as appropriate. *If this item does not apply to the building, enter "N/A" for not applicable.*

Items C2.f -g Enter the elevation of the ground, sidewalk, or patio slab immediately next to the building. For Zone AO, use the natural grade elevation, if available. This measurement must be to the nearest tenth of a foot (nearest tenth of a meter, in Puerto Rico) if this certificate is being used to support a request for a LOMA or LOMR-F.

Item C2.h Enter the lowest grade elevation at the deck support or stairs. For Zone AO, use the natural grade elevation, if available. This measurement must be to the nearest tenth of a foot (nearest tenth of a meter, in Puerto Rico) if this certificate is being used to support a request for a LOMA or LOMR-F.

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

Complete as indicated. This section of the Elevation Certificate may be signed by only a land surveyor, engineer, or architect who is authorized by law to certify elevation information. Place your license number, your seal (as allowed by the State licensing board), your signature, and the date in the box in Section D. You are certifying that the information on this certificate represents your best efforts to interpret the data available and that you understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001. Use the Comments area of Section D, on the back of the certificate, to provide datum, elevation, openings, or other relevant information not specified on the front.

SECTION E - BUILDING ELEVATION INFORMATION (SURVEY NOT REQUIRED) FOR ZONE AO AND ZONE A (WITHOUT BFE)

Complete Section E if the building is located in Zone AO or Zone A (without BFE). Otherwise, complete Section C instead. Explain in the Section F Comments area if the measurement provided under Items E1 -E4 is based on the "natural grade."

Items E1.a and b Enter in Item E1.a the height to the nearest tenth of a foot (tenth of a meter in Puerto Rico) of the top of the bottom floor (as indicated in the applicable diagram) above or below the highest adjacent grade (HAG). Enter in Item E1.b the height to the nearest tenth of a foot (tenth of a meter in Puerto Rico) of the top of the bottom floor (as indicated in the applicable diagram) above or below the lowest adjacent grade (LAG). For buildings in Zone AO, the community's floodplain management ordinance requires the lowest floor of the building be elevated above the highest adjacent grade at least as high as the depth number on the FIRM. Buildings in Zone A (without BFE) may qualify for a lower insurance rate if an engineered BFE is developed at the site.

Item E2. For Building Diagrams 6 -9 with permanent flood openings (see pages 8 -9), enter the height to the nearest tenth of a foot (tenth of a meter in Puerto Rico) of the next higher floor or elevated floor (as indicated in the applicable diagram) above or below the highest adjacent grade (HAG).

Item E3. Enter the height to the nearest tenth of a foot (tenth of a meter in Puerto Rico), in relation to the highest adjacent grade next to the building, for the top of attached garage slab. (Because elevation for top of attached garage slab is self-explanatory, attached garages are not illustrated in the diagrams.) *If this item does not apply to the building, enter "N/A" for not applicable.*

Item E4. Enter the height to the nearest tenth of a foot (tenth of a meter in Puerto Rico), in relation to the highest adjacent grade next to the building, of the platform elevation that supports the machinery and/or equipment servicing the building. Indicate machinery/equipment type in the Comments area of Section F. *If this item does not apply to the building, enter "N/A" for not applicable.*

Item E5. For those communities where this base flood depth is not available, the community will need to determine whether the top of the bottom floor is elevated in accordance with the community's floodplain management ordinance.

SECTION F - PROPERTY OWNER (OR OWNER'S REPRESENTATIVE) CERTIFICATION

Complete as indicated. This section is provided for certification of measurements taken by a property owner or property owner's representative when responding to Sections A, B, and E. The address entered in this section must be the actual mailing address of the property owner or property owner's representative who provided the information on the certificate.

SECTION G - COMMUNITY INFORMATION (OPTIONAL)

Complete as indicated. The community official who is authorized by law or ordinance to administer the community's floodplain management ordinance can complete Sections A, B, C (or E), and G of this Elevation Certificate. Section C may be filled in by the local official as provided in the instructions below for Item G1. If the authorized community official completes Sections C, E, or G, complete the appropriate item(s) and sign this section.

Check **Item G1** if Section C is completed with elevation data from other documentation that has been signed and sealed by a licensed surveyor, engineer, or architect who is authorized by law to certify elevation information. Indicate the source of the elevation data and the date obtained in the Comments area of Section G. If you are both a community official and a licensed land surveyor, engineer, or architect authorized by law to certify elevation information, and you performed the actual survey for a building in Zones A1 -A30, AE, AH, A (with BFE), VE, V1 -V30, V (with BFE), AR, AR/A, AR/A1 -A30, AR/AE, AR/AH, or AR/AO, you must also complete Section D.

Check **Item G2** if information is entered in Section E by the community for a building in Zone A (without a FEMA-issued or community-issued BFE) or Zone AO.

Check **Item G3** if the information in Items G4 -G10 has been completed for community floodplain management purposes to document the as-built lowest floor elevation of the building. Section C of the Elevation Certificate records the elevation of various building components but does not determine the lowest floor of the building or whether the building, as constructed, complies with the community's floodplain management ordinance. This must be done by the community. Items G4 -G10 provide a way to document these determinations.

Item G4. Permit Number. Enter the permit number or other identifier to key the Elevation Certificate to the permit issued for the building.

Instructions for Completing the Elevation Certificate (Continued)

Item G4. Permit Number. Enter the permit number or other identifier to key the Elevation Certificate to the permit issued for the building.

Item G5. Date Permit Issued. Enter the date the permit was issued for the building.

Item G6. Date Certificate of Compliance/Occupancy Issued. Enter the date that the Certificate of Compliance or Occupancy or similar written official documentation of as-built lowest floor elevation was issued by the community as evidence that all work authorized by the floodplain development permit has been completed in accordance with the community's floodplain management laws or ordinances.

Item G7. New Construction or Substantial Improvement. Check the applicable box. "Substantial Improvement" means any reconstruction, rehabilitation, addition, or other improvement of a building, the cost of which equals or exceeds 50 percent of the market value of the building before the start of construction of the improvement. The term includes buildings that have incurred substantial damage, regardless of the actual repair work performed.

Item G8. As-built lowest floor elevation. Enter the elevation of the lowest floor (including basement) when the construction of the building is completed and a final inspection has been made to confirm that the building is built in accordance with the permit, the approved plans, and the community's floodplain management laws or ordinances. Indicate the elevation datum used.

Item G9. BFE. Using the appropriate FIRM panel, FIS Profile, or other data source, locate the property and enter the BFE (or base flood depth) of the building site. Indicate the elevation datum used.

Item G10. Community's design flood elevation. Enter the elevation (including freeboard above the BFE) to which the community requires the lowest floor to be elevated. Indicate the elevation datum used.

Enter your name, title, and telephone number, and the name of the community. Sign and enter the date in the appropriate blanks.

Building Diagrams

The following diagrams illustrate various types of buildings. Compare the features of the building being certified with the features shown in the diagrams and select the diagram most applicable. Enter the diagram number in Item A7, the square footage of crawlspace or enclosure(s) and the area of flood openings in square inches in Items A8.a -c, the square footage of attached garage and the area of flood openings in square inches in Items A9.a -c, and the elevations in Items C2.a -h.

In A zones, the floor elevation is taken at the top finished surface of the floor indicated; in V zones, the floor elevation is taken at the bottom of the lowest horizontal structural member (see drawing in instructions for Section C).

DIAGRAM 1A

All slab-on-grade single- and multiple - floor buildings (other than split-level) and high-rise buildings, either detached or row type (e.g., townhouses); with or without attached garage.

Distinguishing Feature - The bottom floor is at or above ground level (grade) on at least 1 side.*

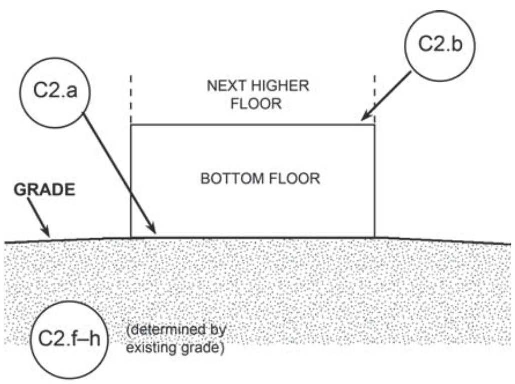


DIAGRAM 1B

All raised-slab-on-grade or slab-on-stem-wall-with-fill single- and multiple-floor buildings (other than split-level), either detached or row type (e.g., townhouses); with or without attached garage.

Distinguishing Feature - The bottom floor is at or above ground level (grade) on at least 1 side.*

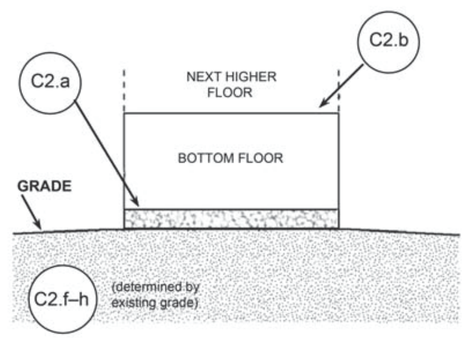


DIAGRAM 2A

All single- and multiple-floor buildings with basement (other than split-level) and high-rise buildings with basement, either detached or row type (e.g., townhouses); with or without attached garage.

Distinguishing Feature - The bottom floor (basement or underground garage) is below ground level (grade) on all sides.*

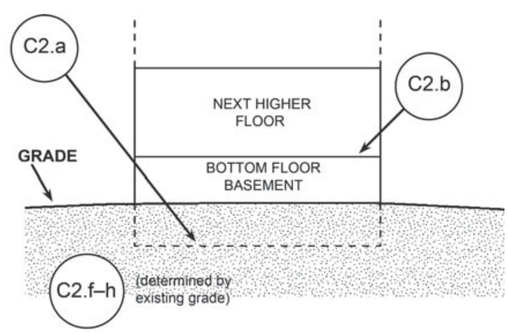
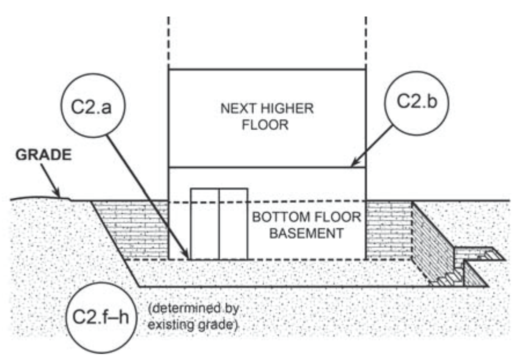


DIAGRAM 2B

All single-and multiple-floor buildings with basement (other than split-level) and high-rise buildings with basement, either detached or row type (e.g., townhouses); with or without attached garage).

Distinguishing feature - The bottom floor (basement or under ground garage) is below ground level (grade) on all sides; most of the height of the walls are below ground level on all sides and the door and area of egress is also below ground level on all sides.*



* A floor that is below ground level (grade) on all sides is considered a basement even if the floor is used for living purposes, or as an office, garage, workshop, etc.

DIAGRAM 3

All split-level buildings that are slab-on-grade, either detached or row type (e.g., townhouses); with or without attached garage.

Distinguishing Feature - the bottom floor (excluding garage) is at or above ground level (grade) on at least 1 side. *

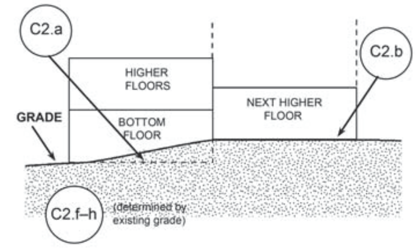


DIAGRAM 4

All split-level buildings (other than slab-on-grade), either detached or row type (e.g., townhouses); with or without attached garage.

Distinguishing Feature - The bottom floor (basement or underground garage) is below ground level (grade) on al sides. *

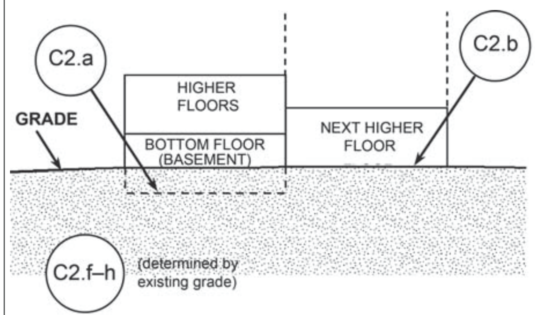


DIAGRAM 5

All buildings elevated on piers, posts, piles, columns, or parallel shear walls. No obstructions below the elevated floor.

Distinguishing Feature - For all zones, the area below the elevated floor is open, with no obstruction to flow of floodwaters (open lattice work and /or insect screening is permissible).

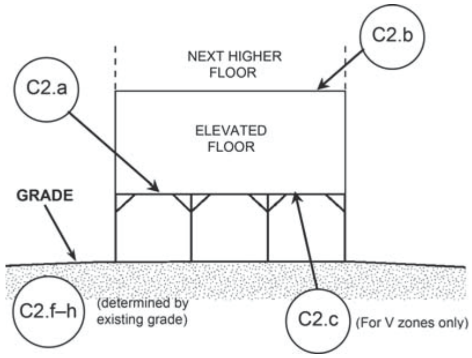
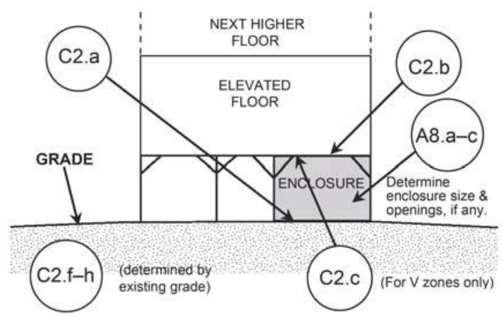


DIAGRAM 6

All buildings elevated on piers, posts, piles, columns, or parallel shear walls with full or partial enclosure below the elevated floor.

Distinguishing Feature - For all zones, the area below the elevated floor is enclosed, either partially or fully. In A Zones, the partially or fully enclosed area below the elevated floor is with or without openings ** present in the walls of the enclosure. Indicate information about enclosure size and openings in Section A - Property Information.



* A floor that is below ground level (grade) on all sides is considered a basement even if the floor is used for living purposes, or as an office, garage, workshop, etc.

** An "opening" is a permanent opening that allows for the free passage of water automatically in both directions without human intervention. Under the NFIP, a minimum of 2 openings is required for enclosures or crawlspaces. The openings shall provide a total net area of not less than 1 square inch for every square foot of area enclosed, excluding any bars, louvers, or other covers of the opening. Alternatively, an Individual Engineered Flood Openings Certification or an Evaluation Report issued by the International Code Council Evaluation Service (ICC ES) must be submitted to document that the design of the openings will allow for the automatic equalization of hydrostatic flood forces on exterior walls. A window, a door, or a garage door is not considered an opening; openings may be installed in doors. Openings shall be on at least 2 sides of the enclosed area. If a building has more than 1 enclosed area, each area must have openings to allow floodwater to directly enter. The bottom of the openings must be no higher than 1.0 foot above the higher of the exterior or interior grade or floor immediately below the opening. For more guidance on openings, see NFIP Technical Bulletin 1.

DIAGRAM 7

All buildings elevated on full-story foundation walls with a partially or fully enclosed area below the elevated floor. This includes walkout levels, where at least 1 side is at or above grade. The principal use of this building is located in the elevated floors of the building.

Distinguishing Feature - For all zones, the area below the elevated floor is enclosed, either partially or fully. In A Zones, the partially or fully enclosed area below the elevated floor is with or without openings ** present in the walls of the enclosure. Indicate information about enclosure size and openings in Section A - Property Information.

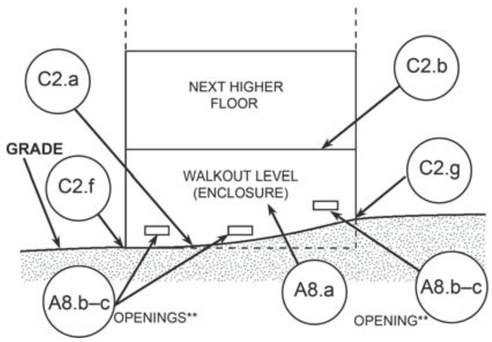


DIAGRAM 8

All buildings elevated on a crawlspace with the floor of the crawlspace at or above grade on at least 1 side, with our without an attached garage.

Distinguishing Feature - For all zones below the first floor is enclosed by solid or partial perimeter walls. In all A zones, the crawlspace is with or without openings** present in the walls of the crawlspace. Indicate information about crawlspace size and openings in Section A - Property Information.

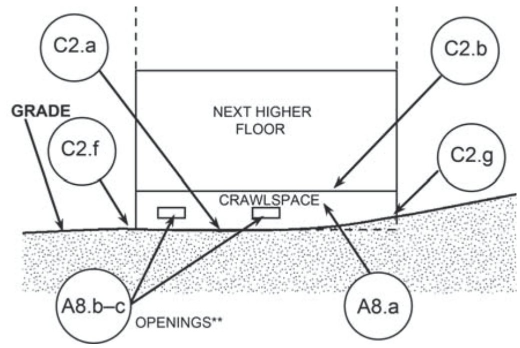
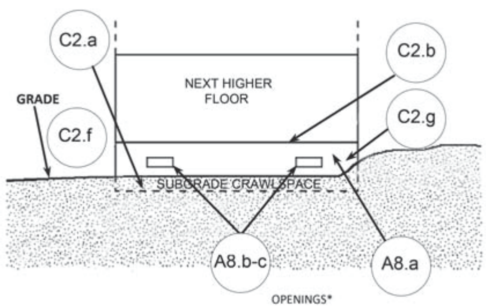


DIAGRAM 9

All buildings (other than split-level) elevated on a sub-grade crawlspace, with or without attached garage.

Distinguishing Feature - The bottom (crawlspace) floor is below ground level (grade) on all sides. * (If the distance from the crawlspace floor to the top of the next higher floor is more than 5 feet, or the crawlspace floor is more than 2 feet below the grade (LAG) on all sides, use Diagram 2.)



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FGDC-STD-007.1-1998

National Spatial Data Infrastructure

Geospatial Positioning Accuracy Standards
Part 1: Reporting Methodology

Federal Geodetic Control Subcommittee
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
National Aeronautics and Space Administration • National Archives and Records Administration
Tennessee Valley Authority

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For more information about the committee, or to be added to the committee's newsletter mailing list, please contact:

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World Wide Web: http://fgdc.er.usgs.gov/fgdc.html

CONTENTS

1.1 Introduction

1.1.1 Objective

This document provides a common methodology for reporting the accuracy of horizontal coordinate values and vertical coordinate values for clearly defined features where the location is represented by a single point coordinate: examples are survey monuments, such as brass disks and rod marks; prominent landmarks, such as church spires, standpipes, radio towers, tall chimneys, and mountain peaks; and targeted photogrammetric control points. It provides a means to directly compare the accuracy of coordinate values obtained by one method (e.g., a cartographically-derived value) with that obtained by another method (e.g., a Global Positioning System (GPS) geodetic network survey) for the same point. It is increasingly important for users to not only know the coordinate values, but also the accuracy of those coordinate values, so users can decide which coordinate values represent the best estimate of the true value for their applications.

1.1.2 Scope

Activities which collect or produce data coordinates include geodetic network and crustal motion surveys; national, regional, state, and county topographic mapping; bathymetric mapping and nautical charting; engineering, construction, and facilities management mapping and drawing; cadastral and boundary surveying; etc. These activities support geospatial data applications in areas such as transportation, community development, agriculture, emergency response, environmental management, and information technology.

This document is being developed in parts to address various activities. Each data activity will apply the same general accuracy standard to develop a reporting classification scheme for its particular data. The following parts have been submitted to date:

Part 2, STANDARDS FOR GEODETIC NETWORKS. Geodetic control surveys are usually performed to establish a basic control network (framework) from which supplemental surveying and mapping work, covered in other parts of this document, are performed. Geodetic network surveys are distinguished by use of redundant, interconnected, permanently monumented control points that comprise the framework for the National Spatial Reference System (NSRS) or are often incorporated into the NSRS. These surveys must be performed to far more rigorous accuracy and quality assurance standards than control surveys for general engineering, construction, or topographic mapping. Geodetic network surveys included in the NSRS must be performed to meet automated data recording, submission, project review, and least squares adjustment requirements established by the National Geodetic Survey (NGS). The lead agency is the Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, NGS; the responsible FGDC unit is the Federal Geodetic Control Subcommittee (FGCS).

Part 3, NATIONAL STANDARD FOR SPATIAL DATA ACCURACY. The National Standard for Spatial Data Accuracy (NSSDA) implements a testing and statistical methodology for positional accuracy of 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. The NSRS is the framework that references positions to the national datums. Positional accuracy of geodetically surveyed points in the National Spatial Reference System is reported according to Part 2, Standards for Geodetic Control Networks, Geospatial Positioning Accuracy Standards. NSRS points may also be selected as an independent source of higher accuracy to test positional accuracy of maps and geospatial data according to the NSSDA. The lead agency is the Department of the Interior, U.S. Geological Survey, National Mapping Division. The responsible FGDC unit is the Subcommittee on Base Cartographic Data.

In addition, two other parts have been identified for inclusion in this document and are under development:

Part 4, ENGINEERING, CONSTRUCTION, AND FACILITIES MANAGEMENT. This part will provide accuracy standards for engineering surveys and maps used to support planning, design, construction, operation, maintenance, and management of facilities, installations, structures, transportation systems, and related projects. It uses the NSSDA for accuracy testing and verification of fully georeferenced maps for A/E/C and Facility Management applications such as preliminary site planning and reconnaissance mapping. It will also provide guidance in developing positional accuracy specifications for geospatial data products, such as architectural and engineering drawings, construction site plans, regional master planning maps, and related Geographical Information Systems (GIS), Computer-Aided Drafting and Design (CADD), and Automated Mapping/Facility Management (AM/FM) products, that may not be referenced to a national datum and where accuracy is based on survey closure ratios or elevation differences. The lead agency is the Department of Defense, U.S. Army Corps of Engineers. The responsible FGDC unit is the Facilities Working Group.

Part 5, NAVIGATION CHARTS AND HYDROGRAPHIC SURVEYS. This part will specify minimum standards for hydrographic surveys so that hydrographic (sounding) data are sufficiently accurate and spatial uncertainty is adequately quantified for safe use by mariners. The accuracy of hydrographic surveying is highly dependent upon knowledge of tidal datum planes and the special accuracy requirements to support safe navigation. This part will provide a standardized methodology for evaluating survey data and reporting resultant data quality through a standard statistical approach. It will be based on the recently revised International Hydrographic Organization (IHO) Standard for Hydrographic Surveys, which is in the final stages of review by the international community. The lead agency is Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of the Coast Survey. The responsible FGDC subcommittee is the Bathymetric and Nautical Chart Subcommittee.

1.1.3 Applicability

Use Geospatial Positioning Accuracy Standards to evaluate and report the positional accuracy of spatial 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."

1.1.4 Related Standards

1.1.4.1 FGDC Standards

The Spatial Data Transfer Standard (SDTS) (ANSI-NCITS, 1998) specifies that a data quality report accompany the data in a standard transfer. Because the quality report will function in the assessment for fitness of use, it must also be obtainable in its entirety and separately from the actual data. The quality report consists of five portions: lineage, **positional accuracy**, attribute accuracy, logical consistency, and completeness. Positional accuracy reported according to Geospatial Positioning Accuracy Standards will be included in the data quality report.

Part 2, Data Quality Information, of Content Standards for Digital Geospatial Metadata (Federal Geographic Data Committee, 1998) adopts the five elements of data quality specified by SDTS. Consequently, positional accuracy reported according to Geospatial Positioning Accuracy Standards will be encoded in Metadata.

1.1.4.2 ISO Technical Committee (TC) 211 Geographic Information/Geomatics Standards

ISO Standard 15046-13, Geographic Information - Quality Principles defines a data quality model and identifies **positional accuracy** as a data quality element and various subelements of positional accuracy. It provides a means of measuring how well the data set maps geospatial phenomena according to its product specification.

ISO Standard 15046-14, Geographic Information - Quality - Evaluation Procedures provides data quality evaluation models for both data producers and data users. The procedures are used to determine data quality results consistent with the data quality model defined by ISO Standard 15046-13. They establish a framework to report data quality results in metadata and when necessary, in a separate data quality report.

1.1.5 Standards Development Procedures

Part 2, Standards for Geodetic Networks and Part 3, National Standard for Spatial Data Accuracy (NSSDA) were originally developed independently. Following the first public review of the NSSDA, in its previous version as National Cartographic Standards for Spatial Accuracy, the NSSDA was aligned with emerging standards from the Federal Geodetic Control Subcommittee (FGCS). The FGCS has broad participation from various Federal agencies. Noting how individual FGDC subcommittees and working groups were developing accuracy standards, the FGCS membership agreed to sponsor an FGDC standards project to compile the various accuracy standards into one document and minimize redundancies. The FGDC Standards Working Group has endorsed this approach. This is the first FGDC standards project to integrate standards for various data themes and applications.

1.1.6 Maintenance Authority

The U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Geodetic Survey, maintains Part 1, Reporting Methodology, Geospatial Positioning Accuracy Standards for the Federal Geographic Data Committee. Address questions concerning Part 1, Reporting Methodology, Geospatial Positioning Accuracy Standards to: Director, National Geodetic Survey, NOAA, N/NGS, 1315 East-West Highway, Silver Spring, Maryland 20910.

1.2 Accuracy Standard

All spatial data activities should develop a classification scheme following the standard given below. The standard for reporting positional accuracy is defined for horizontal and/or vertical coordinates, depending on the characteristics of the data sets.

Horizontal: The reporting standard in the horizontal component is the radius of a circle of uncertainty, such that the true or theoretical location of the point falls within that circle 95-percent of the time.

Vertical: The reporting standard in the vertical component is a linear uncertainty value, such that the true or theoretical location of the point falls within +/- of that linear uncertainty value 95-percent of the time. The reporting accuracy standard should be defined in metric (International System of Units, SI) units. However, accuracy will be reported in English (inch-pound) units where the point coordinates or elevations are reported in English units.

The method used to evaluate accuracy should be described. Examples include: statistical testing, least squares adjustment results, comparison with values of higher accuracy, repeat measurements, estimation, etc. The accuracy standard for point data in each part of the document will identify the type of application and if applicable, the accuracy level recommended for that application.

Coordinate values should be based on National datums. Horizontal coordinate values should preferably be referenced to the North American Datum of 1983 (NAD 83). Vertical coordinate values should preferably be referenced to North American Vertical Datum of 1988 (NAVD 88). However, it is recognized that many legacy maps and geospatial data are referenced to older national datums, such as the North American Datum of 1927 (NAD 27) and the National Geodetic Vertical Datum of 1929 (NGVD 29).

If coordinate values are not referenced to the National datum but their relationship to the national datum is known, identify the datum and its relationship to a National datum. If the relationship between the local datum and the National datum is not specified, identify the datum, but state that its relationship to a National datum is unspecified.

1.3 References

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

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

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.

Geodetic Survey Division, 1996, Accuracy Standards for Positioning, Version 1.0: Ottawa, Canada, Natural Resources Canada, 28 p.

National Geodetic Survey, 1986, Geodetic Glossary: Rockville, Maryland, National Geodetic Survey, 274 p.

Subcommittee for Base Cartographic Data, 1998, Final Draft Content Standards for Digital Gridded Land Elevation Data: Reston, Virginia, U.S. Geological Survey, 37 p.

Draft standards not released to the public:

ISO/Technical Committee 211 Geographic information/Geomatics, Working Group 3 - Geospatial Data Administration, ISO Standard 15046-13 Geographic Information - Quality - Principles

ISO/Technical Committee 211 Geographic information/Geomatics, Working Group 3 - Geospatial Data Administration, ISO Standard 15046-14 Geographic Information - Quality - Evaluation Procedures

Appendix 1-A
Glossary of Terms
(informative)

The following are definitions of various terms used throughout the Geospatial Positioning Accuracy Standards.

accuracy - closeness of an estimated (e.g., measured or computed) value to a standard or accepted [true] value of a particular quantity. (National Geodetic Survey, 1986).

> NOTE Because the true value is not known, but only estimated, the accuracy of the measured quantity is also unknown. Therefore, accuracy of coordinate information can only be estimated (Geodetic Survey Division, 1996).

accuracy testing - process by which the accuracy of a data set may be checked.

check point - one of the points in the sample used to estimate the positional accuracy of the data set against an independent source of higher accuracy.

component accuracy - positional accuracy in each x, y, and z component.

confidence level - the probability that the true (population) value is within a range of given values.

> NOTE in the sense of this standard, the probability that errors are within a range of given values.

dataset - identifiable collection of related data.

datum - any quantity or set of such quantities that may serve as a basis for calculation of other quantities. (National Geodetic Survey, 1986)

elevation - height of a point with respect to a defined vertical datum.

ellipsoidal height - distance between a point on the Earth's surface and the ellipsoidal surface, as measured along the perpendicular to the ellipsoid at the point and taken positive upward from the ellipsoid.

> NOTE also called geodetic height (National Geodetic Survey, 1986)

horizontal accuracy - positional accuracy of a dataset with respect to a horizontal datum. (Adapted from Subcommittee for Base Cartographic Data, 1998)

horizontal error - magnitude of the displacement of a feature's recorded horizontal position in a dataset from its true or more accurate position, as measured radially and not resolved into x, y.

independent source of higher accuracy - data acquired independently of procedures to generate the dataset that is used to test the positional accuracy of a dataset.

> NOTE the independent source of higher accuracy shall be of the highest accuracy feasible and practicable to evaluate the accuracy of the data set.

local accuracy - The *local accuracy* of a control point is a value that represents the uncertainty in the coordinates of the control point relative to the coordinates of other directly connected, adjacent control points at the 95-percent confidence level. The reported local accuracy is an approximate average of the individual local accuracy values between this control point and other observed control points used to establish the coordinates of the control point.

network accuracy - The *network accuracy* of a control point is a value that represents the uncertainty in the coordinates of the control point with respect to the geodetic datum at the 95-percent confidence level. For NSRS network accuracy classification, the datum is considered to be best expressed by the geodetic values at the Continuously Operating Reference Stations (CORS) supported by NGS. By this definition, the local and network accuracy values at CORS sites are considered to be infinitesimal, i.e., to approach zero.

orthometric height - distance measured along the plumb line between the geoid and a point on the Earth's surface, taken positive upward from the geoid. (adapted from National Geodetic Survey, 1986).

positional accuracy - describes the accuracy of the position of features (adapted from ISO Standard 15046-13)

precision - in statistics, a measure of the tendency of a set of random numbers to cluster about a number determined by the set. (National Geodetic Survey, 1986).

> NOTE If appropriate steps are taken to eliminate or correct for biases in positional data, precision measures may also be a useful means of representing accuracy. (Geodetic Survey Division, 1996).

root mean square error (RMSE) - square root of the mean of squared errors for a sample.

spatial data - information that identifies the geographic location and characteristics of natural or constructed features and boundaries of earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies (Federal Geographic Data Committee, 1998).

> NOTE also known as geospatial data.

vertical accuracy - measure of the positional accuracy of a data set with respect to a specified vertical datum. (adapted from Subcommittee for Base Cartographic Data, 1998).

vertical error - displacement of a feature's recorded elevation in a dataset from its true or more accurate elevation.

well-defined point - point that represents a feature for which the horizontal position is known to a high degree of accuracy and position with respect to the geodetic datum.

FGDC-STD-007.2-1998

National Spatial Data Infrastructure

Geospatial Positioning Accuracy Standards
Part 2: Standards for Geodetic Networks

Federal Geodetic Control Subcommittee
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
National Aeronautics and Space Administration • National Archives and Records Administration
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World Wide Web: http://fgdc.er.usgs.gov/fgdc.html

CONTENTS

2.1 Introduction

2.1.1 Objective

This document provides a common methodology for determining and reporting the accuracy of horizontal coordinate values and vertical coordinate values for geodetic control points represented by survey monuments, such as brass disks and rod marks. It provides a means to directly compare the accuracy of coordinate values obtained by one method (e.g., a classical line-of-sight traverse) with the accuracy of coordinate values obtained by another method (e.g., a Global Positioning System (GPS) geodetic network survey) for the same point.

2.1.2 Scope

Geodetic control surveys are usually performed to establish a basic control network (framework) from which supplemental surveying and mapping work, covered in other parts of this document, is performed. Geodetic network surveys are distinguished by use of redundant, interconnected, permanently monumented control points that comprise the framework for the National Spatial Reference System (NSRS) or are often incorporated into the NSRS.

These surveys must be performed to far more rigorous accuracy and quality assurance standards than those for control surveys for general engineering, construction, or topographic mapping purposes. Geodetic network surveys included in NSRS must be performed to meet automated data recording, submittal, project review, and least squares adjustment requirements established by the Federal Geodetic Control Subcommittee (FGCS).

2.1.3 Applicability

Geodetic network surveys are often employed when large geopolitical area (e.g., county-level or larger) mapping control is required, and where seamless connection with adjacent political areas is critical. Accurate network control may also be required for controlling interstate transportation corridors (highways, pipelines, railroads, etc.); long-span bridge construction alignment; geophysical studies; structural deformation monitoring of dams, buildings, and similar facilities.

2.1.4 Related Standards

Part 6: Point Profile, The Spatial Data Transfer Standard (FGDC, 1998) defines the format to be used to transfer geodetic coordinate data, including the accuracy of the coordinate values, between geographic information systems.

Part 3, National Standard for Spatial Data Accuracy (NSSDA), Geospatial Positioning Accuracy Standards (FGDC, 1998)provides the statistical and testing methodology for estimating the accuracy of point coordinate values produced from maps and other digital geospatial data with respect to geo-referenced ground positions of higher accuracy.

The public review draft of Part 4, Standards for A/E/C and Facility Management, Geospatial Positioning Accuracy standards, uses the NSSDA for accuracy testing and verification. The NSSDA may be used for fully geo-referenced maps for A/E/C and Facility Management applicaitons such as preliminary site planning and reconnaissance mapping.

2.1.5 Standards Development Procedures

Draft accuracy standards for geodetic networks were developed by the FGCS Methodology Work Group, Federal Geographic Data Committee. The draft accuracy standards were released for public review through the FGCS and evolved into the final form presented in Table 2.1 of this publication.

2.1.6 Maintenance

The U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Geodetic Survey, maintains accuracy standards for geodetic networks for the Federal Geodetic Control Subcommittee, Federal Geographic Data Committee. Address questions concerning accuracy standards for geodetic networks to: Director, National Geodetic Survey, NOAA, N/NGS, 1315 East-West Highway, Silver Spring, Maryland 20910.

2.2 Testing Methodology And Reporting Requirements

2.2.1 Accuracy Standards

Note that the following accuracy standards supersede and replace the accuracy standards found in FGCC 1984 and FGCC 1988 (see Section 2.3). The classification standard for geodetic networks is based on accuracy. Accuracies are categorized separately according to Table 2.1 for horizontal, ellipsoid height, and orthometric height. Note: although the largest entry in Table 2.1 is 10 meters, the accuracy standards can be expanded to larger numbers if needed.

Table 2.1 -- Accuracy Standards
Horizontal, Ellipsoid Height, and Orthometric Height

Accuracy Classification	95-Percent Confidence
	Less Than or Equal to:
1-Millimeter	0.001 meters
2-Millimeter	0.002 "
5-Millimeter	0.005 "
1-Centimeter	0.010 "
2-Centimeter	0.020 "
5-Centimeter	0.050 "
1-Decimeter	0.100 "
2-Decimeter	0.200 "
5-Decimeter	0.500 "
1-Meter	1.000 "
2-Meter	2.000 "
5-Meter	5.000 "
10-Meter	10.000 "

When control points in a survey are classified, they have been verified as being consistent with all other points in the network, not merely those within that particular survey. It is not observation closures within a survey which are used to classify control points, but the ability of that survey to duplicate already established control values. This comparison takes into account models of crustal motion, refraction, and any other systematic effects known to influence survey measurements.

2.2.2 Accuracy Determination

The classification standard for NSRS is based on Table 2.1.

The procedure leading to classification involves four steps:

1. The survey measurements, field records, sketches, and other documentation are examined to verify compliance with the specifications for the intended accuracy of the survey. This examination may lead to a modification of the intended accuracy.

2. Results of a minimally constrained, least squares adjustment of the survey measurements are examined to ensure correct weighting of the observations and freedom from blunders.

3. Local and network accuracy measures computed by random error propagation determine the provisional accuracy. In contrast to a constrained adjustment where coordinates are obtained by holding fixed the datum values of the existing network control, accuracy measures are computed by weighting datum values in accordance with the network accuracies of the existing network control.

4. The survey accuracy is checked by comparing minimally constrained adjustment results against established control. The result must meet a 95 percent confidence level. This comparison takes into account the network accuracy of the existing control, as well as systematic effects such as crustal motion or datum distortion. If the comparison fails, then both the survey and network measurements must be scrutinized to determine the source of the problem.

Users with specialized applications that require more exacting accuracy estimates at the CORS sites should contact NGS. It is not necessary to directly connect to a CORS to compute the network accuracy of a control point. However, it is necessary that the survey be properly connected to existing NSRS control points with established network accuracy values.

By supporting both local accuracy and network accuracy, the diverse requirements of NSRS users can be met. Local accuracy is best adapted to check relations between nearby control points. For example, a surveyor checking closure between two NSRS points is mostly interested in a local accuracy measure. On the other hand, someone constructing a Geographic or Land Information System (GIS/LIS) will often need some type of positional tolerance associated with a set of coordinates. Network accuracy measures how well coordinates approach an ideal, error-free datum.

Thus, for control points in the NSRS, both local accuracy and network accuracy will be reported for each geodetic component (horizontal control, ellipsoidal height, and orthometric height).

2.2.3 Accuracy Reporting

When providing geodetic point coordinate data, a statement should be provided that the data meets a particular accuracy standard for both the *local accuracy* and the *network accuracy*. For example, these geodetic control data meet the 2-centimeter local accuracy standard for the horizontal coordinate values and the 5-centimeter local accuracy standard for the vertical coordinate values (heights) at the 95-percent confidence level. A similar statement should be provided for these same data reporting the network accuracy.

Note: In the above statement the data may comply with one accuracy value for the horizontal component and a different accuracy value for the vertical component. If a dataset does not contain elevation data, label it for horizontal accuracy only; conversely, when a dataset does not contain horizontal data, label it for vertical accuracy only.

It is preferred that accuracy value(s) be reported in metric units; however, feet shall be used when the dataset coordinates are in feet (i.e., State Plane Coordinates in feet). The number of significant digits for the accuracy value(s) shall be consistent with the number of significant digits for the dataset point coordinates. For most geodetic control network applications, centimeters should be used for reporting local accuracy and network accuracy values.

2.3 References

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

Federal Geodetic Control Committee, 1988, Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques, Version 5.0, reprinted with corrections, August 1, 1989: Silver Spring, Maryland, National Geodetic Survey, National Oceanic and Atmospheric Administration.

Federal Geodetic Control Subcommittee, 1994, Input Formats and Specifications of the NGS Data Base, Vol. I, Horizontal: Silver Spring, Maryland, National Geodetic Survey, National Oceanic and Atmospheric Administration.

Federal Geographic Data Committee, 1998, Part 1, Reporting Methodology, Geospatial Positioning Accuracy Standards, FGDC-STD-007.1-1998: Washington, D.C., Federal Geographic Data Committee, 10 p.

Federal Geographic Data Committee, 1998, Part 3, National Standard for Spatial Data Accuracy, Geospatial Positioning Accuracy Standards, FGDC-STD-007.3-1998: Washington, D.C., Federal Geographic Data Committee, 28 p.

Federal Geographic Data Committee, 1998, Part 6, Point Profile, Spatial Data Transfer Standard, FGDC-STD-002.6: Washington, D.C., Federal Geographic Data Committee.

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
National Aeronautics and Space Administration • National Archives and Records Administration
Tennessee Valley Authority

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.

For more information about the committee, or to be added to the committee's newsletter mailing list, please contact:

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CONTENTS

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.

Federal Geographic Data Committee, 1998, Part 2, Standards for Geodetic Networks, Geospatial Positioning Accuracy Standards, FGDC-STD-007.2-1998: Washington, D.C., Federal Geographic Data Committee, 9 p.

Federal Geographic Data Committee, 1996, FGDC Standards Reference Model: Reston, Va., Federal Geographic Data Committee, 24 p.

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.

U.S. Bureau of the Budget, 1947, United States National Map Accuracy Standards: U.S. Bureau of the Budget, Washington, D.C.

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

National Spatial Data Infrastructure

Geospatial Positioning Accuracy Standards
PART 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management

Facilities Working Group
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
National Aeronautics and Space Administration • National Archives and Records Administration
Tennessee Valley Authority

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.

For more information about the committee, or to be added to the committee's newsletter mailing list, please contact:

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World Wide Web: http://fgdc.er.usgs.gov/fgdc.html

CONTENTS

TABLES

4.1 INTRODUCTION

4.1.1 Objective

PART 4 provides accuracy standards for engineering drawings, maps, and surveys used to support planning, design, construction, operation, maintenance, and management of facilities, installations, structures, transportation systems, and related projects. It is intended to support geospatial mapping data used in various engineering documents, such as architectural, engineering, and construction (A/E/C) drawings, site plans, regional master planning maps, and related Geographical Information System (GIS), Computer-Aided Drafting and Design (CADD), and Automated Mapping/Facility Management (AM/FM) products. These products are typically created from terrestrial, satellite, acoustic, or aerial mapping techniques that output planimetric, topographic, hydrographic, or feature attribute data.

4.1.2 Scope

This standard defines accuracy criteria, accuracy testing methodology, and accuracy reporting criteria for object features depicted on A/E/C spatial data products and related control surveys. It references established voluntary standards that may be used for some smaller-scale A/E/C mapping applications. In addition, Appendix A contains general guidance for specifying accuracy criteria for selected types of A/E/C features or control surveys. Using the standards and guidance contained in this section, end users of A/E/C products (e.g., planners, designers, constructors) can specify surveying and mapping accuracy requirements needed for their projects or specific CADD/GIS layers, levels, or entities. From these specifications, data producers (e.g., surveyors, mappers, photogrammetrists) can determine the instrumentation, procedures, and quality control processes required to obtain and verify the defined accuracies.

4.1.3 Applicability

These standards are applicable to geospatial data products used on various A/E/C or facilities management projects. A/E/C projects are normally confined to small geographical areas typically less than 4,000 ha (10,000 acres) where simple survey techniques are employed to establish project control points, perform topographic or photogrammetric mapping, or provide construction layout and alignment control. Unlike geospatial map products covered under PART 3, A/E/C data products are often only locally referenced within a project site, may not contain absolute georeferenced coordinates, and are typically compiled at scales larger than 1:20,000 (1 in = 1,667 ft). These standards may apply to the following types of engineering applications: transportation systems (roads, railroads, airfields, canals); utility systems (water supply, sanitary sewer, fuel, communication, electrical, mechanical); residential, commercial, recreational, and industrial structures and facilities; flood control and navigation systems (dams, levees, locks); architectural site or landscape plans; engineering master planning studies; environmental mapping, modeling, and assessment studies; hydraulic and hydrological studies; geophysical exploration surveys; and construction measurement and payment surveys. These standards do not generally apply to - architectural, mechanical, or electrical detail data inside of a building or structure that are typically used with a CADD system for engineering and design.

4.1.4 Related Standards

This standard was largely taken from existing U.S. Army Corps of Engineers engineering, surveying, and mapping standards, and from Department of Defense Tri-Service Facility Engineering CADD/GIS standards--see References. The American Society for Photogrammetry and Remote Sensing (ASPRS) "Accuracy Standards for Large-Scale Maps" outlined in PART 3, Appendix B, also is directly applicable to PART 4--see paragraph 4.4.1 for specific relationships between ASPRS and Part 4.

This PART 4 may be used in conjunction with, or independent of, other Parts of the overall Geospatial Positioning Accuracy Standard.

PART 1 Reporting Methodology applies directly to this Part, in particular, accuracy standard reporting. Certain portions of Part 2, Standards for Geodetic Networks, apply to A/E/C projects or features within an A/E/C project that are connected by control surveys to an established regional geodetic control network (i.e., geo-referenced).

PART 2 does not apply to engineering, construction, topographic, or photogrammetric mapping surveys that are referenced to boundary control or physical features (streets, structures, etc.) within, or adjacent, to the project site. If A/E/C projects, or sub features within a project, are connected by control surveys to an established regional geodetic control network (i.e., geo-referenced), then certain portions of PART 2 may be applicable.

PART 3, National Standard for Spatial Data Accuracy, applies to those A/E/C map products that are fully geo-referenced. The spatial accuracy definitions, accuracy testing, and accuracy reporting criteria in PART 3 may be used for georeferenced A/E/C map products.

PART 4 applies to engineering drawings, maps, and surveys used to support planning, design, construction, operation, maintenance, and management of facilities, installations, structures, transportation systems, and related projects. Part 4 also applies to marine construction and dredging of navigation channels, including related hydrographic surveying support.

PART 5 should be consulted for hydrographic surveying standards applicable to preparation of nautical charts.

4.1.5 Standards Development Procedures

This standard was developed and periodically reviewed by the FGDC Facilities Working Group during the period 1996-1998. The initial draft of the standard was taken from U.S. Army Corps of Engineers Engineer Circular 1110-1-87, Standards for Maps, Drawings, Engineering Surveys, Construction Site Plans, and Related Geospatial Data Products.

4.1.6 Maintenance Authority

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.

4.2 SPATIAL ACCURACY

As defined in PART 1, horizontal spatial accuracy is the circular error of a data set's horizontal coordinates at the 95% confidence level. Vertical spatial accuracy is defined by the linear error of a data set's vertical coordinates at the 95% confidence level. A spatial data set may include CADD/GIS object features, such as points, lines, areas, volumes. Accuracy reported at the 95% confidence level means that 95% of positional accuracies will be equal to or smaller than the reported accuracy value. The reported accuracy value is the cumulative result of all uncertainties, including those introduced by local project control coordinates, field topographic surveys, photogrammetric compilation, or final extraction of ground coordinate values in the spatial data. The reference scheme for radial or linear errors must be defined as relative to absolute geospatial reference networks or local (internal construction) schemes. Spatial data may be compiled to comply with one level of accuracy in the vertical component and another in the horizontal component.

4.3 REFERENCE DATUMS AND COORDINATE SYSTEMS

A/E/C projects should be referenced to local boundary control, spatial datums, plane coordinate grids, or vertical reference planes commonly used in the project area. Where practical and feasible, A/E/C projects should be referenced to national coordinate systems: horizontal coordinates should be in a system (e.g., State Plane Coordinate System, Universal Transverse Mercator Grid) based upon the North American Datum of 1927 (NAD 27) or North American Datum of 1983 (NAD 83), and vertical coordinates should be based on the National Geodetic Vertical Datum of 1929 (NGVD 29) or the North American Vertical Datum of 1988 (NAVD 88)--see PART 2. In most instances, however, A/E/C projects are not referenced to geodetic datums but are accurately tied into existing project or boundary control schemes relevant to the work. Reference datums and coordinate systems used shall be clearly identified in reporting A/E/C project data sets--see PART 1.

4.3.1 Local Construction Control

Projects that are not referenced to national coordinate systems based on geodetic datums shall be classified and reported as having a local reference or construction control system--local X-Y grid, chainage-offset, local reference benchmark elevation, etc. Accuracies of spatial data points are determined, reported, and certified relative to this local construction control scheme. If the relationship between the local coordinate system and a National coordinate system is known, describe the relationship between the two systems. If the relationship between the local coordinate system and a National coordinate system is unknown, identify the local coordinate system but state that the relationship in "UNKNOWN"--see PART 1.

4.3.2 NSRS Referenced Control

Accuracies of A/E/C data set coordinates that are referenced to a National coordinate system are determined and reported relative to NSRS accuracies.

4.4 ACCURACY STANDARDS FOR A/E/C MAPS AND DRAWINGS

A/E/C drawings and related spatial data sets may have accuracy standards specified relative to (1) a required performance standard based on detailed project requirements, or (2) an established standard such as National Map Accuracy Standard (NMAS) or ASPRS. Typically, detailed site plan drawings at scales as large as 1:360 (1 in = 30 ft) have acceptable quality levels relative to critical construction specifications (e.g., required accuracy of invert elevations, road/curb grades, building locations, etc.). Preliminary planning or reconnaissance maps at smaller scales typically use general industry standards, such as ASPRS, NMAS, etc. Both types of standards may be specified for portions of CADD levels on the same project. Accuracy is evaluated and reported based on intended field data acquisition methodology or independent tests. For most A/E/C mapping, performance-based (outcome-based) specifications detail the end results to be achieved (i.e., map feature accuracy or accuracy standard) and not the means, or technical procedures, used to achieve those results. Performance specifications define the required accuracy criteria standards for each feature, object, class, layer, level, etc. of topographic and planimetric features depicted, along with related mapping limits, feature location and attribute requirements, scale, contour interval, map format, sheet layout, final data transmittal, archiving or storage requirements, and quality assurance procedures that will be used to verify conformance with the specified accuracy. Table A-3 in Appendix A provides examples of accuracy specifications commonly used for various types of A/E/C projects.

4.4.1 ASPRS Large-Scale Accuracy Standards

For generalized A/E/C site mapping work at scales from 1:2,400 (1 in = 200 ft) to 1:20,000 (1 in = 1,667 ft), the ASPRS "Accuracy Standards for Large-Scale Maps" may be used as a reference accuracy standard. The ASPRS accuracy standard is linearly dependent on the target horizontal scale or target contour interval; thus it is only applicable to mapped features that are compiled using a consistent type of data acquisition process (e.g., photogrammetry) where all spatial objects receive approximately the same accuracy. The ASPRS standard may not be especially applicable to detailed CADD/GIS features at larger scales down to 1:240 (1 in. = 20 ft) where CADD/GIS accuracies are usually project dependent, not scale dependent, and where accuracy standards are best defined based on project needs. As described in PART 3, the ASPRS standard defines map accuracy by comparing the mapped location of selected well-defined points to their "true" location, as determined by a more accurate, independent field survey. Alternately, when no independent check is feasible or practicable, a map's accuracy may be estimated based on the accuracy of the technique used to locate mapped features--e.g., photogrammetry, GPS, total station, planetable. The ASPRS standard may be specified for site plans that are developed using conventional ground topographic surveying techniques (i.e., electronic total stations, planetables, kinematic DGPS).

4.4.2 Multiple Accuracies in A/E/C Drawings or CADD Levels

4.4.2.1 Horizontal and Vertical Accuracies

Spatial data may have different accuracies in the horizontal and vertical components.

4.4.2.2 A/E/C CADD/GIS Feature Layer/Level Accuracies

A/E/C data is often separated into various layers or levels in CADD/GIS systems. For example, planimetric features, utility invert elevations, and topographic elevations are often separated into three different levels or layers. These layers often contain objects or geographic areas that were surveyed/compiled to widely differing accuracies--e.g., utility invert elevations accurate to 0.05 ft versus topographic contours accurate to only 5 ft . If readily available, useful, and practical, these variable accuracies may be retained as an attribute to the layer or feature. In addition, accuracy information about these layers or features should be recorded in the accuracy section of the metadata for this database.

4.5 ACCURACY STANDARDS FOR A/E/C CONTROL SURVEYS

Control surveys are performed to locate, align, and stake out construction for civil and military projects, e.g., buildings, utilities, roadways, runways, flood control and navigation projects, training ranges, etc. They provide the base horizontal and vertical control used for preliminary studies, photogrammetric and topographic mapping, detailed site plan drawings for construction plans, construction stake out, construction measurement and payment, preparing as-built drawings, installation master planning mapping, and future maintenance and repair activities. Two types of survey accuracies may be specified: (1) Positional accuracy or (2) Relative closure ratio accuracy. PART 2 geodetic survey accuracy standards are not applicable to locally referenced A/E/C projects covered under this PART 4 standard.

4.5.1 Positional Accuracy

Base control surveys should be performed to a 95% positional confidence level consistent with the engineering or construction application or specifications. In general, horizontal and vertical control point accuracies should be twice as accurate as positional or elevation tolerances required for features or objects on the site plans or maps. Determination and verification of 95% radial positional accuracies will require use of rigorous least-squares adjustment techniques similar to that required under PART 2.

4.5.2 Relative Closure Ratio Accuracy

The accuracy of A/E/C control surveys may be evaluated, classified, and reported based on closure ratios for the horizontal point or the vertical elevation difference, as obtained in the field when points or benchmarks are redundantly occupied. This relative accuracy standard is applicable to most types of survey equipment and practices (e.g., total station traverses, differential GPS, differential spirit leveling). Many state codes and/or state minimum technical standards require that accuracies of A/E/C surveys be evaluated and reported using survey closure ratios. Tables A-1 and A-2 in Appendix A contain orders of closure commonly specified in A/E/C work. There is no simple correlation between relative closure accuracies and 95% radial positional accuracies; thus, determining a closure order based on a specified feature accuracy requirement is, at best, only an approximate process (see guidance in Appendix A). Where practical and allowable, positional accuracy standards should be used instead of closure accuracy standards.

4.6 ACCURACY TESTING AND VERIFICATION

Project specifications will specify the geographic extent of data to be tested and the amount of testing (if any). Map testing should be performed within a fixed time period after delivery. Normally, a mapping organization will perform quality control tests under quality assurance oversight by the requesting agency. Accuracies of A/E/C features are reported at the 95% confidence level. Field observed X, Y or Z coordinate differences are converted to 95% confidence errors following the procedures outlined in PART 3. Horizontal accuracy is tested by comparing the planimetric coordinates of well-defined ground points with coordinates of the same points from an independent source of higher accuracy, following the methodology outlined under PART 3. Vertical accuracy is tested by comparing the elevations of well-defined points with elevations of the same points as determined from a source of higher accuracy, also following the methodology outlined in PART 3. Both ground surface topography and object elevations may be tested.

4.7 ACCURACY REPORTING AND CERTIFICATION

4.7.1 Tested Products

Maps, surveys, and related geospatial data that are tested and found to comply with a specified standard shall have a certification statement. If applicable, the statement shall clearly indicate the target map scale at which the map or feature layer was developed.

4.7.2 Untested Products

Due to the high cost of field testing, not all deliverable map products will be tested. In such cases, the statement shall clearly indicate that the procedural ground surveying or aerial mapping specifications were designed and performed to meet a certain accuracy standard (project dependent, ASPRS, NMAS, etc.), but that the accuracy is estimated. An estimated accuracy statement is especially applicable to CADD, GIS, or FM databases that may be compiled from a variety of sources containing known or unknown accuracy reliability.

4.7.3 Reporting Units

Report accuracy of A/E/C spatial data in ground units using either metric (SI) units or English (IP) units, consistent with the project units.

4.7.4 Variable Accuracies

Report varying accuracies in the same spatial data set if information exists that relates accuracy to individual portions/objects of the data set, and only if such detailed sub-feature data set reporting is practical and warranted. If data of varying accuracies are composited and cannot be separately identified AND the data set is tested, report the accuracy value for the composited data. If a composited data set is not tested, report the accuracy value for the least accurate data set component.

4.7.5 Reporting Statements

Report tested and non-tested accuracies following general guidance provided in PART 3 (Accuracy Reporting).

4.8 REFERENCES

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. 1,068-1,070.

Federal Geographic Data Committee, Part 1, Reporting Methodology, Geospatial Positioning Accuracy Standards, FGDC-STD-0007.1-1998, Washington, D.C., 1998.

Federal Geographic Data Committee, Part 2., Standards for Geodetic Networks, Geospatial Positioning Accuracy Standards, FGDC-STD-007.2-1998: Washington, D.C., 1998.

Federal Geographic Data Committee, Part 3., National Standard for Spatial Data Accuracy, Geospatial Positioning Accuracy Standards, FGDC-STD-007.3-1998: Washington, D.C., 1998.

U.S. Army Corps of Engineers, Engineer Circular 1110-1-87, Standards for Maps, Drawings, Engineering Surveys, Construction Site Plans, and Related Geospatial Data Products, 1 July 1996.

U.S. Department of Defense, Tri-Service CADD/GIS Technology Center, Tri-Service A/E/C CADD Standards and Spatial Data Standards, (latest version at <http://tsc.wes.army.mil>)

APPENDIX A

RECOMMENDED A/E/C SURVEYING AND MAPPING STANDARDS

(Informative)

A.1 A/E/C CONTROL SURVEY STANDARDS

Engineering and construction surveys are normally specified, classified, and reported based on the horizontal (linear) point closure ratios or the vertical elevation difference closures. This performance criterion is most commonly specified in Federal agency, State, and local surveying standards. These control surveys are performed to establish control, location, alignment, and grade of various types of construction.

Local accuracy standards for survey control will vary with the type of construction. Commonly specified and reported Orders of horizontal closure accuracy standards are shown in Table A-1. Relative accuracy closure ratios for horizontal A/E/C surveys typically range from a minimum of 1:2,500 up to 1:20,000. Lower accuracies (1:2,500-1:5,000) are acceptable for earthwork, dredging, embankment, beach fill, and levee alignment stakeout and grading, and some site plan, curb and gutter, utility building foundation, sidewalk, and small roadway stakeout. Moderate accuracies (1:5,000) are used in most pipeline, sewer, culvert, catch basin, and manhole stakeouts, and for general residential building foundation and footing construction, major highway pavement, bridges, and concrete runway stakeout work. Somewhat higher accuracies (1:10,000-1:20,000) are used for aligning longer bridge spans, tunnels, and large commercial structures. For extensive bridge or tunnel projects, 1:50,000 or even 1:100,000 relative accuracy alignment work may be specified.

Orders of elevation closure ratio standards are shown in Table A-2. Most construction work is performed to Third-Order standards. These standards are applicable to most types of engineering and construction survey equipment and practices (e.g., total station traverses, differential GPS, differential spirit leveling).

Table A-1
Minimum Closure Standards for Engineering and Construction Control Surveys

Classification Order	Closure Standard	
Engr & Const Control	Distance (Ratio)	Angle (Secs)
Second-Order, Class I	1:50,000	3oN [1]
Second-Order, Class II	1:20,000	5oN
Third-Order, Class I	1:10,000	10oN
Third-Order, Class II	1: 5,000	20oN
Construction (Fourth-Order)	1: 2,500	60oN

[1] N = Number of angle stations

Table A-2
Minimum Elevation Closure Standards for Vertical Control Surveys

Classification Order	Elevation Closure Standard (ft)[1]	(mm)
First-Order, Class I	0.013oM	3oK
First-Order, Class II	0.017oM	4oK
Second-Order, Class I	0.025oM	6oK
Second-Order, Class II	0.035oM	8oK
Third-Order	0.050oM	12oK
Construction Layout	0.100oM	24oK

[1] oM or oK = square root of distance in Miles or Kilometers

A.2 TYPICAL ACCURACY STANDARDS FOR SELECTED A/E/C PROJECTS

General guidance for determining project-specific mapping accuracy standards is contained in Table A-3 at the end of this Appendix. This table may be used in developing specifications for map scales, feature location and elevation tolerances, and contour intervals for typical A/E/C projects. Since Table A-3 is based on current industry practices (and primarily those used by the Corps of Engineers), the scales and corresponding 95% positional tolerances shown in this table will differ from the ASPRS positional or elevation accuracy standards. Where available, project-specific accuracy standards should be used rather than generic standards such as ASPRS. Metric (SI) conversions from IP units are only approximate since standardized use of SI units is still under development.

A.2.1 Target Scale and Contour Interval Specifications

Table A-3 provides commonly used map scales and contour intervals for a variety of A/E/C applications. The selected target scale for a map or construction plan should be based on the detail necessary to portray the project site. Topographic elevation density or related contour intervals are specified consistent with existing site gradients and the accuracy needed to define site layout, drainage, grading, etc., or perform quantity take offs. Photogrammetric mapping flight altitudes or ground topographic survey accuracy and density requirements are determined from the design map target scale and contour interval. In practice, design or real property features are located or layed out during construction to a far greater relative accuracy than that which can be scaled at the target (plot) scale, such as property corners, utility alignments, first-floor or invert elevations, etc. Coordinates/elevations for such items are usually directly input as feature attributes in a CADD or AM/FM database.

A.2.2 Feature Location Tolerances

Table A-3 indicates recommended positional and elevation tolerances of planimetric features at the 95% confidence level. These tolerances define the primary topographic mapping effort necessary to delineate physical features on the ground. A/E/C feature tolerances are defined relative to adjacent points within the confines of a specific area, map sheet, or structure--not to the overall project, installation boundaries, or an external geodetic control network. These relative accuracy tolerances are determined between two points that must functionally maintain a given accuracy tolerance between themselves, such as adjacent property corners; adjacent utility lines; adjoining buildings, bridge piers, approaches, or abutments; overall building or structure site construction limits; runway ends; catch basins; levee baseline sections; etc. Feature tolerances indicated are determined from the functional requirements of a typical project/structure (e.g., field construction/fabrication, field stakeout or layout, alignment, etc.). Few A/E/C projects require that relative accuracies be rigidly maintained beyond the range of the detailed design drawing for a project/structure (or its equivalent CADD design file limit). In many instances, a construction feature may need to be located to an accuracy well in excess of its plotted/scaled accuracy on a construction site plan; therefore, feature location tolerances should not be used to determine the required scale of a drawing. In these instances, surveyed coordinates, internal CADD grid coordinates, or rigid relative dimensions are used.

A.3 A/E/C TOPOGRAPHIC SURVEYS AND CONSTRUCTION SITE PLANS

Topographic surveys and construction site plan surveys are performed for the master planning, design, and construction of installations, buildings, housing complexes, roadways, airport facilities, flood control structures, navigation locks, etc. Construction plans are developed using electronic/DGPS total stations, plane tables, or low-altitude photogrammetric mapping methods. Some of the more common surveys are described below:

A.3.1 Reconnaissance Topographic Surveys

Reconnaissance surveys are typically performed at scales from 1:4,800 (1 in = 400 ft) to 1:12,000 (1 in = 1,000 ft). They provide a basis for general studies, site suitability decisions, or preliminary site layouts. General location of existing roads and facilities are depicted, and only limited feature and rough elevation detail is shown – 5- to 10-foot contour intervals usually being adequate. Enlarged USGS 1:24,000 maps may be substituted in many cases.

A.3.2 General/Preliminary Site Plans.

General or Preliminary site plans are performed at scales from 1:2,400 (1 in = 200 ft) to 1:4,800 (1 in = 400 ft). They depict general layout for potential construction, proposed transportation systems, training areas, and existing facilities.

A.3.3 Detailed Topographic Surveys for Construction Plans

These surveys are performed at scales from 1:240 (1 in = 20 ft) to 1:2,400 (1 in = 200 ft) and at contour intervals of 0.2 m or 0.5 m (1 or 2 ft). They are performed to prepare a base map for detailed site plans (general site layout plan, utility plan, grading plan, paving plan, airfield plan, demolition plan, etc.). The scope of mapping is confined to an existing/proposed building area. These drawings are used as a base for subsequent as-built drawings of facilities and utility layout maps (i.e., AM/FM databases).

A.3.4 As-Built Surveys and AM/FM Mapping

As-built drawings may require topographic surveys of constructed features, especially when field modifications are made to original designs. These surveys, along with original construction site plans, should be used as a base framework for a facility's AM/FM database. Periodic topographic surveys also may be required during maintenance and repair projects in order to update the AM/FM database.

Table A-3. RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Feature Position Tolerance Vertical SI/IP	Contour Interval SI/IP
DESIGN, CONSTRUCTION, OPERATION & MAINTENANCE OF MILITARY FACILITIES				
Maintenance and Repair (M&R)/Renovation of Existing Installation Structures, Roadways, Utilities, Etc				
General Construction Site Plans & Specs:	1:500	100 mm	50 mm	250 mm
Feature & Topographic Detail Plans	40 ft/in	0.1-0.5 ft	0.1-0.3 ft	1 ft
Surface/subsurface Utility Detail Design Plans	1:500	100 mm	50 mm	N/A
Elec, Mech, Sewer, Storm, etc	40 ft/in	0.2-0.5 ft	0.1-0.2 ft	
Field construction layout		0.1 ft	0.01-0.1 ft	
Building or Structure Design Drawings	1:500	25 mm	50 mm	250 mm
	40 ft/in	0.05-0.2 ft	0.1-0.3 ft	1 ft
Field construction layout		0.01 ft	0.01 ft	
Airfield Pavement Design Detail Drawings	1:500	25 mm	25 mm	250 mm
	40 ft/in	0.05-0.1 ft	0.05-0.1 ft	0.5-1 ft
Field construction layout		0.01 ft	0.01 ft	
Grading and Excavation Plans	1:500	250 mm	100 mm	500 mm
Roads, Drainage, Curb, Gutter etc.	30-100 ft/in	0.5-2 ft	0.2-1 ft	1-2 ft
Field construction layout		1 ft	0.1 ft	
Recreational Site Plans	1:1,000	500 mm	100 mm	500 mm
Golf courses, athletic fields, etc.	100 ft/in	1-2 ft	0.2-2 ft	2-5 ft
Training Sites, Ranges, and Cantonment Area Plans	1:2,500	500 mm	1,000 mm	500 mm
	100-200 ft/in	1-5 ft	1-5 ft	2 ft
General Location Maps for Master Planning	1:5,000	1,000 mm	1,000 mm	1,000 mm
AM/FM and GIS Features	100-400 ft/in	2-10 ft	1-10 ft	2-10 ft
Space Management Plans	1:250	50 mm	N/A	N/A
Interior Design/Layout	10-50 ft/in	0.05-1 ft		
As-Built Maps: Military Installation Surface/Subsurface Utilities (Fuel, Gas, Electricity, Communications, Cable,		100 mm	100 mm	250 mm
		0.2-1 ft	0.2 ft	1 ft

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Vertical SI/IP	Contour Interval SI/IP
Storm Water, Sanitary, Water Supply, Treatment Facilities, Meters, etc.)	1:1000 or 50-100 ft/in (Army) 1:500 or 50 ft/in (USAF)			
Housing Management GIS (Family Housing, Schools, Boundaries, and Other Installation Community Services)	1:5,000 100-400 ft/in	10,000 mm 10-15 ft	N/A	N/A
Environmental Mapping and Assessment Drawings/Plans/GIS	1:5,000 200-400 ft/in	10,000 mm 10-50 ft	N/A	N/A
Emergency Services Maps/GIS Military Police, Crime/Accident Locations, Post Security Zoning, etc.	1:10,000 400-2000 ft/in	25,000 mm 50-100 ft	N/A	N/A
Cultural, Social, Historical Plans/GIS	1:5000 400 ft/in	10,000 mm 20-100 ft	N/A	N/A
Runway Approach and Transition Zones: General Plans/Section	1:2,500 100-200 ft/in	2,500 mm 5-10 ft	2,500 mm 2-5 ft	1,000 mm 5 ft
Approach maps	1:5,000 (H) 1:1,000 (V)			
Approach detail	1:5,000 (H) 1:250 (V)			
DESIGN, CONSTRUCTION, OPERATIONS AND MAINTENANCE OF CIVIL TRANSPORTATION & WATER RESOURCE PROJECTS Site Plans, Maps & Drawings for Design Studies, Reports, Memoranda, and Contract Plans and Specifications, Construction plans & payment				
General Planning and Feasibility Studies, Reconnaissance Reports	1:2,500 100-400 ft/in	1,000 mm 2-10 ft	500 mm 0.5-2 ft	1,000 mm 2-10 ft
Flood Control and Multipurpose Project Planning, Floodplain Mapping, Water Quality Analysis, and Flood Control Studies	1:5,000 400-1000 ft/in	10,000 mm 20-100 ft	100 mm 0.2-2 ft	1,000 mm 2-5 ft

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Feature Position Tolerance Vertical SI/IP	Contour Interval SI/IP
Soil and Geological Classification Maps	1:5,000 400 ft/in	10,000 mm 20-100 ft	N/A	N/A
Land Cover Classification Maps	1:5,000 400-1,000 ft/in	10,000 mm 50-200 ft	N/A	N/A
Archeological or Structure Site Plans & Details (Including Non-topographic, Close Range, Photogrammetric Mapping)	1:10 0.5-10 ft/in	5 mm 0.01-0.5 ft	5 mm 0.01-0.5 ft	100 mm 0.1-1 ft
Cultural and Economic Resource Mapping Historic Preservation Projects	1:10,000 1000 ft/in	10,000 50-100 ft	N/A	N/A
Land Utilization GIS Classifications Regulatory Permit Locations	1:5,000 400-1000 ft/in	10,000 mm 50-100 ft	N/A	N/A
Socio-Economic GIS Classifications	1:10,000 1000 ft/in	20,000 mm 100 ft	N/A	N/A
Grading & Excavation Plans	1:1,000 100 ft/in	1,000 mm 0.5-2 ft	100 mm 0.2-1 ft	1,000 mm 1-5 ft
Flood Control Structure Clearing & Grading Plans (e.g., revetments)	1:5,000 100-400 ft/in	2,500 mm 2-10 ft	250 mm 0.5 ft	500 mm 1-2 ft
Federal Emergency Management Agency Flood Insurance Studies	1:5,000 400 ft/in	1,000 mm 20 ft	250 mm 0.5 ft	1,000 mm 4 ft
Locks, Dams, & Control Structures Detail Design Drawings	1:500 20-50 ft/in	25 mm 0.05-1 ft	10 mm 0.01-0.5 ft	250 mm 0.5-1 ft
Spillways & Concrete Channels Design Plans	1:1,000 50-100 ft/in	100 mm 0.1-2 ft	100 mm 0.2-2 ft	1,000 mm 1-5 ft
Levees and Groins: New Construction or Maintenance Design Drawings	1:1,000 100 ft/in	500 mm 1-2 ft	250 mm 0.5-1 ft	500 mm 1-2 ft

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Vertical SI/IP	Contour Interval SI/IP
Construction In-Place Volume Measurement	1:1,000	500 mm	250 mm	N/A
Granular cut/fill, dredging, etc.	40-100 ft/in	0.5-2 ft	0.5-1 ft	
Beach Renourishment/Hurricane	1:1,000	1,000 mm	250 mm	250 mm
Protection Project Plans	100-200 ft/in	2 ft	0.5 ft	1 ft
Project Condition Survey Reports				
Base Mapping for Plotting Hydrographic	1:2,500	10,000 mm	250 mm	500 mm
Surveys: line maps or aerial plans	200-1,000 ft/in	5-50 ft	0.5-1 ft	1-2 ft
Dredging & Marine Construction Surveys				
New Construction Plans	1:1,000	2,000 mm	250 mm	250 mm
	100 ft/in	6 ft	1 ft	1 ft
Maintenance Dredging Drawings	1:2500	5,000 mm	500 mm	500 mm
	200 ft/in	15 ft	2 ft	2 ft
Hydrographic Project Condition Surveys	1:2500	5,000 mm	500 mm	500 mm
	200 ft/in	16 ft	2 ft	2 ft
Hydrographic Reconnaissce Surveys	-	5,000 m	500 mm	250 mm
		15 ft	2 ft	2 ft
Offshore Geotechnical Investigations	-	5,000 mm	50 mm	N/A
Core Borings /Probings/etc.		5-15 ft	0.1-0.5 ft	
Structural Deformation Monitoring Studies/Surveys				
Reinforced Concrete Structures: Locks, Dams, Gates, Intake Structures, Tunnels, Penstocks, Spillways, Bridges	Large-scale vector movement diagrams or tabulations	10 mm 0.03 ft (long term)	2 mm 0.01 ft	N/A
Earth/Rock Fill Structures: Dams, Floodwalls	N/A	(same as above)	30 mm	15 mm

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Feature Position Tolerance Vertical SI/IP	Contour Interval SI/IP
Levees, etc. -- slope/crest stability & alignment		0.1 ft (long term)	0.05 ft	
Crack/Joint & Deflection Measurements: piers/monoliths--precision micrometer	tabulations	0.2 mm 0.01 inch	N/A	N/A
REAL ESTATE ACTIVITIES: ACQUISITION, DISPOSAL, MANAGEMENT, AUDIT Maps, Plans, & Drawings Associated with Military and Civil Projects				
Tract Maps, Individual, Detailing Installation or Reservation Boundaries, Lots, Parcels, Adjoining Parcels, and Record Plats, Utilities, etc.	1:1,000 1:1,200 (Army) 50-400 ft/in	10 mm 0.05-2 ft	100 mm 0.1-2 ft	1,000 mm 1-5 ft
Condemnation Exhibit Maps	1:1,000 50-400 ft/in	10 mm 0.05-2 ft	100 mm 0.1-2 ft	1,000 mm 1-5 ft
Guide Taking Lines/Boundary Encroachment Maps: Fee and Easement Acquisition	1:500 20-100 ft/in	50 mm 0.1-1 ft	50 mm 0.1-1 ft	250 mm 1 ft
General Location or Planning Maps	1:24,000 2,000 ft/in	10,000 mm 50-100 ft	5,000 mm 5-10 ft	2,000 mm 5-10 ft
GIS or LIS Mapping, General Land Utilization and Management, Forestry Management, Mineral Acquisition	1:5,000 200-1,000 ft/in	10,000 mm 50-100 ft	N/A	N/A
Easement Areas and Easement Delineation Lines	1:1,000 100 ft/in	50 mm 0.1-0.5 ft	50 mm 0.1-0.5 ft	-
HAZARDOUS, TOXIC, RADIOACTIVE WASTE (HTRW) SITE INVESTIGATION, MODELING, AND CLEANUP				
General Detailed Site Plans HTRW Sites, Asbestos, etc.	1:500 5-50 ft/in	100 mm 0.2-1 ft	50 mm 0.1-0.5 ft	100 mm 0.5-1 ft

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

	Target	Feature Position Tolerance		Contour
	Map Scale	Horizontal	Vertical	Interval
Project or Activity	**SI/IP**	**SI/IP**	**SI/IP**	**SI/IP**
Surface Geotoxic Data Mapping and Modeling	1:500 20-100 ft/in	100 mm 1-5 ft	500 mm 1-2 ft	500 mm 1-2 ft
Contaminated Ground Water Plume Mapping/Modeling	1:500 20-100 ft/in	1,000 mm 2-10 ft	500 mm 1-5 ft	500 mm 1-2 ft
General HTRW Site Plans & Reconnaissance Mapping	1:2,500 50-400 ft/in	5,000 mm 2-20 ft	1,000 mm 2-20 ft	1,000 mm 2-5 ft

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NSDI

National Spatial Data Infrastructure

Geospatial Positioning Accuracy Standards
Part 5: Standards for Nautical Charting Hydrographic Surveys

Subcommittee on Marine and Coastal Spatial 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
National Aeronautics and Space Administration • National Archives and Records Administration
Tennessee Valley Authority

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.

For more information about the committee, or to be added to the committee's newsletter mailing list, please contact:

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CONTENTS

5.1 Introduction

5.1.1 Objective

This document provides minimum standards for the horizontal and vertical accuracy of features associated with hydrographic surveys that support nautical charting. Such features include, but are not limited to, water depths, objects on the seafloor, navigational aids, and shoreline.

5.1.2 Scope

For the purposes of this Standard, hydrographic surveys are defined as those surveys conducted to determine the configuration of the bottom of water bodies and to identify and locate all features, natural and man-made, that may affect navigation. Nautical charts are compilations of data from numerous sources, principally hydrographic surveys, designed specifically to meet the requirements of marine navigation. The scope of these standards includes the coastal waters of the U.S. and its territories.

5.1.3 Applicability

These standards are intended to be used by federal agencies and their contractors for conducting hydrographic surveys that will be used for updating nautical charts. They do not apply to hydrographic surveys for river and harbor navigation projects or surveys for project construction which are covered by Part 4 of the FGDC Geospatial Positioning Accuracy Standards. Local authorities may also prescribe these standards for high quality surveys for other purposes.

5.1.4 Related Standards

These standards may be used in conjunction with, or independent of, other Parts of the overall Geospatial Positioning Accuracy Standard. Part 1 (Reporting Methodology) applies directly to this part with the exception that vertical coordinate values should be referenced to the applicable chart datum and not one of the geodetic vertical datums (NAVD 88 or NGVD 29). See section 5.3.

There may be occasions where geodetic control points need to be established to support hydrographic surveys. In such instances, the specifications in Part 2 (Standards for Geodetic Networks) should be referenced. The accuracy testing described in Part 3 (National Standard for Spatial Data Accuracy) is generally inapplicable to this Part 5 since the referenced features are not repeatedly measured. Part 4 (Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management) provide accuracy standards for other categories of hydrographic surveys (Contract Payment, Project Condition and Reconnaissance) that are not explicitly conducted to support nautical charts.

5.1.5 Standards Development Procedures

This standard was developed by the FGDC Bathymetric Subcommittee during 1998 and generally follows the Standards for Hydrographic Surveys adopted by the International Hydrographic Organization in April 1998.

5.1.6 Maintenance

The U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Coast Survey, is responsible for developing and maintaining Standards for Nautical Charting Hydrographic Surveys for the FGDC Subcommittee on Marine and Coastal Spatial Data. Address questions concerning the standards to: Director, Office of Coast Survey, NOAA, N/CS, 1315 East-West Highway, Silver Spring, Maryland 20910.

5.2 Spatial Accuracy

As defined in Part 1, horizontal spatial accuracy is the two-dimensional circular error of a data set?s horizontal coordinates at the 95% confidence level. Vertical spatial accuracy is defined by the one-dimensional linear error of depths at the 95% confidence level.

5.3 Reference Datums

The horizontal reference datum should be the North American Datum of 1983 (NAD 83). If other datums or coordinate systems are used, their relationship to NAD 83 should be documented. Vertical coordinate values should be referenced to the applicable chart datum and not one of the geodetic vertical datums (NAVD 88 or NGVD 29). The Mean Lower Low Water (MLLW) datum is used for Atlantic, Pacific and Gulf coast charts. The nautical chart vertical datum for each of the Great Lakes is referenced to the International Great Lakes Datum (1985). Other water level-based datums are used on lakes and rivers.

5.4 Classification of Surveys

To accommodate in a systematic manner different accuracy requirements for areas to be surveyed, four orders of survey are defined. These are described below, with specific details provided in Table 1.

5.4.1 Special Order

Special Order hydrographic surveys approach engineering standards and their use is intended to be restricted to specific critical areas with minimum underkeel clearance and where bottom characteristics are potentially hazardous to vessels. These areas must be explicitly designated by the agency responsible for survey quality. Examples are harbors, berthing areas, and associated critical channels. All error sources must be minimized. Special Order requires the use of closely spaced lines in conjunction with side scan sonar, multi-transducer arrays or high resolution multibeam echosounders to obtain 100% bottom search. It must be ensured that cubic features greater than 1 meter can be discerned by the sounding equipment. The use of side scan sonar in conjunction with a multibeam echosounder may be necessary in areas where thin and dangerous obstacles may be encountered. Side scan sonar should not be used for depth determination but to define areas requiring more detailed and accurate investigation.

5.4.2 Order 1

Order 1 hydrographic surveys are intended for harbors, harbor approach channels, recommended tracks, inland navigation channels, and coastal areas of high commercial traffic density where underkeel clearance is less critical and the geophysical properties of the seafloor are less hazardous to vessels (e.g. soft silt or sand bottom). Order 1 surveys should be limited to areas with less than 100 m water depth. Although the requirement for seafloor search is less stringent than for Special Order, full bottom search is required in selected areas where the bottom characteristics and the risk of obstructions are potentially hazardous to vessels. For these areas searched, it must be ensured that cubic features greater than 2 m up to 40 m water depth or greater than 10% of the depth in areas deeper than 40 m can be discerned by the sounding equipment. In some areas the detection of 1-meter cubic features may be specified.

5.4.3 Order 2

Order 2 hydrographic surveys are intended for areas with depths less than 200 m not covered by Special Order and Order 1 and where a general description of the bathymetry is sufficient to ensure there are no obstructions on the seafloor that will endanger the type of vessel expected to transit or work the area. It is the criteria for a variety of maritime uses for which higher order hydrographic surveys cannot be justified. Full bottom search may be required in selected areas where the bottom characteristics and the risk of obstructions may be potentially hazardous to vessels.

5.4.4 Order 3

Order 3 hydrographic surveys are intended for all areas not covered by Special Order, and Orders 1 and 2 in water depths in excess of 200 m.

TABLE 1
Summary of Minimum Standards for Hydrographic Surveys

ORDER	Special	1	2	3
Examples of Typical Areas	Harbors, berthing areas, and associated critical channels with minimum underkeel clearances	Harbors, harbor approach channels, recommended tracks and some coastal areas with depths up to 100 m	Areas not described in Special Order and Order 1, or areas up to 200 m water depth	Offshore areas not described in Special Order, and Orders 1 and 2
Horizontal Accuracy (95% Confidence Level)	2 m	5 m + 5% of depth	20 m + 5% of depth	150 m + 5% of depth
Depth Accuracy for (1) **Reduced Depths (95% Confidence Level)** (2)	a = 0.25 m b = 0.0075	a = 0.5 m b = 0.013	a = 1.0 m b = 0.023	Same as Order 2
100% Bottom Search (3)	Compulsory	Required in selected areas	May be required in selected areas	Not applicable
System Detection Capability	Cubic features > 1 m	Cubic features > 2 m in depths up to 40 m; 10% of depth beyond 40 m	Same as Order 1	Not applicable
Maximum Line Spacing (4)	Not applicable, as 100% search compulsory	3 x average depth or 25 m, whichever is greater	3-4 x average depth or 200 m, whichever is greater	4 x average depth

(1) To calculate the error limits for depth accuracy the corresponding values of a and b listed in Table 1 should be introduced into:

$$? \sqrt{[a^2 + (b * d)^2]}$$

where:

a is a constant depth error, i.e. the sum of all constant errors, b*d is the depth dependent error, i.e. the sum of all depth dependent errors where b is a factor of depth dependent error, and d is depth.

(2) The confidence level percentage is the probability that an error will not exceed the specified maximum value.

(3) A method of exploring the seabed which attempts to provide complete coverage of an area for the purpose of detecting all features addressed in this publication.

(4) The line spacing can be expanded if procedures for ensuring an adequate sounding density are used

The rows of Table 1 are explained as follows:

Row 1 "Examples of Typical Areas" gives examples of areas to which an order of survey might typically be applied.

Row 2 "Horizontal Accuracy" lists positioning accuracies to be achieved to meet each order of survey.

Row 3 "Depth Accuracy" specifies parameters to be used to calculate accuracies of reduced depths to be achieved to meet each order of survey.

Row 4 "100% Bottom Search" specifies occasions when full bottom search should be conducted.

Row 5 "System Detection Capability" specifies the detection capabilities of systems used for bottom search.

Row 6 "Maximum Line Spacing" is to be interpreted as either (1) spacing of sounding lines for single beam sounders or (2) distance between the outer limits of swaths for swath sounding systems

5.5 Positioning

The horizontal accuracy, as specified in Table 1, is the accuracy of the position of soundings, dangers, and all other significant submerged features with respect to a geodetic reference frame, specifically NAD 83. The exception to this are Order 2 and Order 3 surveys using single-beam echo sounders where it is the positional accuracy of the sounding system sensor. In such cases, the agency responsible for the survey quality should determine the accuracy of the positions of soundings on the seafloor.

If the accuracy of a position is affected by different parameters, the contributions of all parameters to the total position error should be accounted for. A statistical method, combining different error sources, for determining positioning accuracy should be adopted. The position error, at 95% confidence level, should be recorded together with the survey data. Although this should preferably be done for each individual sounding, the error estimate may also be derived for a number of soundings or even for an area, provided differences between error estimates can be safely expected to be negligible.

It is strongly recommended that whenever positions are determined by terrestrial systems, redundant lines of position should be observed. Standard calibration techniques should be completed prior to and after the acquisition of data. Satellite systems should be capable of tracking at least five satellites simultaneously; integrity monitoring for Special Order and Order 1 surveys is recommended.

Primary shore control points should be located by ground survey methods to a relative accuracy of 1 part in 100,000. When geodetic satellite positioning methods are used to establish such points, the error should not exceed 10 cm at 95% confidence level. Secondary stations for local positioning, which will not be used for extending the control, should be located such that the error does not exceed 1 part in 10,000 for ground survey techniques or 50 cm using geodetic satellite positioning.

The horizontal positions of navigation aids and other important features should be determined to the accuracy stated in Table 2, at 95% confidence level.

Table 2

Summary of Minimum Standards for Positioning of Navigation Aids and Important Features

	Special Order surveys	Order 1 surveys	Order 2 and 3 surveys
Fixed aids to navigation and features significant to navigation	2 m	2 m	5 m
Natural Coastline	10 m	20 m	20 m
Mean position of floating aids to navigation	10 m	10 m	20 m
Topographical features	10 m	20 m	20 m

5.6 Depths

The navigation of commercial vessels requires increasingly accurate and reliable knowledge of the water depth in order to exploit safely the maximum cargo capabilities. It is imperative that depth accuracy standards in critical areas, particularly in areas of marginal underkeel clearance and where the possibility of obstructions exists, be more stringent than those established in the past and that the issue of adequate bottom coverage be addressed.

In determining the depth accuracy of the reduced depths, the sources of individual errors should be quantified and combined to obtain a Total Propagated Error (TPE) at the 95% confidence level. Among others these errors include:

a) measurement system and sound velocity errors
b) tidal measurement and modeling errors, and
c) data processing errors.

A statistical method for determining depth accuracy by combining all known errors should be adopted and checked. Recognizing that both constant and depth dependent errors affect the accuracy of depths, the formula under Table 1 is to be used to compute the allowable depth errors at 95% confidence level by using the values from row 3 for a and b. As an additional check on data quality, an analysis of redundant depths observed at crossline intersections should be made.

For wrecks and obstructions which may have less than 40 m clearance above them and may be dangerous to normal surface navigation, the least depth over them should be determined either by high definition sonar examination or physical examination (diving). Mechanical sweeping may be used when guaranteeing a minimum safe clearance depth.

All anomalous features previously reported in the survey area and those detected during the survey should be examined in greater detail and, if confirmed, their least depth should be determined. The agency responsible for survey quality may define a depth limit beyond which a detailed seafloor investigation, and thus an examination of anomalous features, is not required.

Measured depths should be reduced to chart or survey datum, by the application of tidal or water level height. Tidal reductions should not be applied to depths greater than 200 m, except when tides contribute significantly to the TPE.

5.7 Sounding Density

In planning the density of soundings, both the nature of the seabed in the area and the requirements of the users have to be taken into account to ensure adequate bottom coverage. It should be noted that no method, not even 100% search, guarantees by itself the reliability of a survey nor can it disprove with certainty the existence of hazards to navigation, such as isolated natural hazards or man made objects such as wrecks, between survey lines.

Line spacing for the various orders of hydrographic surveys is proposed in Table 1. The results of a survey should be assessed using procedures developed by the agency responsible for the survey quality. Based on these procedures the adequacy of the sounding density should be determined and the line spacing reduced if warranted.

5.8 Bottom Sampling

The nature of the seabed should be determined by sampling or may be inferred from other sensors (e.g. single beam echo sounders, side scan sonar, sub-bottom profiler, video, etc.) up to the depth required by local anchoring or trawling conditions. Under normal circumstances sampling is not required in depths greater than 200 meters. Samples should be spaced according to the seabed geology, but should normally be 10 times that of the main scheme line spacing. In areas intended for anchorages, density of sampling should be increased. Any inference technique should be substantiated by physical sampling.

5.9 Tidal Observations

Tidal height observations should be made throughout the course of a survey for the purpose of providing tidal reductions for soundings, and providing data for tidal analysis and subsequent prediction. Observations should extend over the longest possible period, and if possible, for not less than 29 days. Tidal heights should be observed so that the total measurement error at the tide gauge, including timing error, does not exceed +/- 5 cm at 95% for Special Order surveys. For other surveys +/- 10 cm should not be exceeded.

5.10 Metadata

To allow a comprehensive assessment of the quality of survey data it is necessary to record or document certain information together with the survey data. Such information is important to allow exploitation of survey data by a variety of users with different requirements, especially as requirements may not be known when survey data is collected. The information describing the data is called metadata. Examples of metadata include overall quality, data set title, source, positional accuracy and copyright. Metadata is data implicitly attached to a collection of data.

Metadata should comprise at least the following information:

- the survey in general (e.g. date, area, equipment used, name of survey platform)
- the horizontal and vertical datum
- calibration procedures and results
- sound velocity for corrections to echo soundings
- tidal datum and reduction procedures
- accuracies achieved and the respective confidence levels.

Metadata should preferably be in digital form in compliance with the FGDC-endorsed Content Standard for Digital Geospatial Metadata (version 2.0), FGDC-STD-001-1998, and an integral part of the survey record. Shoreline metadata should comply with the Metadata Profile for Shoreline Data. If this is not feasible, similar information should be included in the documentation of a survey. It is recommended that agencies responsible for the survey quality systematically develop and document a list of metadata used for their survey data.

It is understood that each sensor (i.e. positioning, depth, heave, pitch, roll, heading, seabed characteristic sensors, water column parameter sensors, tidal reduction sensor, data reduction models etc.) possesses unique error characteristics. Each survey system should be uniquely analyzed to determine appropriate procedure(s) to obtain the required spatial statistics. These analysis procedure(s) should be documented or referenced in the survey record.

5.11 Elimination of Doubtful Data

To improve the safety of navigation it is desirable to eliminate doubtful data, i.e. data which are usually denoted on charts by PA (Position Approximate), PD (Position Doubtful), ED (Existence Doubtful), SD (Sounding Doubtful) or as "reported danger". To confirm or disprove the existence of such data it is necessary to carefully define the area to be searched and subsequently survey that area according to the standards outlined in this publication.

No empirical formula for defining the search area can suit all situations. For this reason, it is recommended that the search radius should be 3 times the estimated position error of the reported hazard at the 95% confidence level as determined by a thorough investigation of the report on the doubtful data by a qualified hydrographic surveyor. If such report is incomplete or does not exist at all, the position error must be estimated by other means as, for example, a more general assessment of positioning and depth measurement errors during the era when the data in question was collected.

The methodology for conducting the search should be based on the area in which the doubtful data is reported and the estimated danger of the hazard to navigation. Once this has been established, the search procedure should be that of conducting a hydrographic survey of the extent defined in the preceding paragraph, to the standards established in this publication. If not detected, the agency responsible for the survey quality shall decide whether to retain the hazard as charted or to expunge it.

5.12 Quality Control

To ensure that the required accuracies are achieved it is necessary to check and monitor performance. Establishing quality control procedures which ensure that data or products meet certain standards and specifications should be a high priority for hydrographic authorities. This section provides guidelines for the implementation of such procedures.

Quality control for positioning ideally involves observing redundant lines of position and/or monitor stations which are then analyzed to obtain a position error estimate. If the positioning system offers no redundancy or other means of monitoring system performance, rigorous and frequent calibration is the only means of ensuring quality.

A standard quality control procedure should be to check the validity of soundings by conducting additional depth measurements. Differences should be statistically tested to ensure compliance of the survey with the standards given in Table 1. Anomalous differences should be further examined with a systematic analysis of contributing error sources. All discrepancies should be resolved, either by analysis or re-survey during progression of the survey task.

Crosslines intersecting the principal sounding lines should always be run to confirm the accuracy of positioning, sounding, and tidal reductions. Crosslines should be spaced so that an efficient and comprehensive control of the principal sounding lines can be effected. As a guide it may be assumed that the interval between crosslines should normally be no more than 15 times that of the selected sounding lines.

The proposed line spacing from Table 1 may be altered depending on the configuration of the seafloor and the likelihood of dangers to navigation. In addition, if side scan sonar is used in conjunction with single beam or multibeam sonar systems, the specified line spacing may be increased.

Multibeam sonar systems have great potential for accurate seafloor coverage if used with proper survey and calibration procedures. An appropriate assessment of the accuracy of measurements with each beam is necessary for use in areas surveyed to Special Order and Order 1 standards. If any of the outer beams have unacceptable errors, the related data may be used for reconnaissance but the depths should be otherwise excluded from the final data set. All swaths should be intersected, at least once, by a crossline to confirm the accuracy of positioning, depth measurements and depth reductions.

References

International Hydrographic Organization, April 1998, IHO Standards for Hydrographic Surveys, Special Publication No. 44, 4th Edition, 23p.