Chapter 4
Accuracy Standards for Engineering, Construction, and Facility Management Control and Topographic Surveys

4-1. Purpose

This chapter sets forth accuracy standards and other related criteria that are recommended for use in large-scale site plan topographic surveys for engineering and construction purposes. These standards relate to surveys 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. In many cases, these engineering surveys are performed to provide the base horizontal and vertical control used for area mapping, GIS development, preliminary planning studies, detailed site plan drawings for construction plans, construction measurement and payment, preparing as-built drawings, installation master planning mapping, future maintenance and repair activities, and other AM/FM products. Most engineering surveying standards currently used are based on local practice, or may be contained in State minimum technical standards. The standards given in this chapter conform to the criteria prescribed in EM 1110-1-2909 (*Geospatial Data and Systems*) and the FGDC *Geospatial Positioning Accuracy Standard.* See Appendix A for a list of these FGDC standards.

4-2. General Surveying and Mapping Specifications

Construction plans, maps, facility plans, and CADD/GIS databases are created by a variety of terrestrial, satellite, acoustic, or aerial mapping techniques that acquire planimetric, topographic, hydrographic, or feature attribute data. Specifications for obtaining these data should be "performance-based" and not overly prescriptive or process oriented. They should be derived from the functional project requirements and use recognized industry accuracy standards where available.

a. Industry standards. Maximum use should be made of industry standards and consensus standards established by private voluntary standards bodies--in lieu of Government-developed standards. Therefore, industry-developed accuracy standards should be given preference over Government standards. A number of professional associations have published surveying and mapping accuracy standards, such as the American Society for Photogrammetry and Remote Sensing (ASPRS), the American Society of Civil Engineers (ASCE), the American Congress on Surveying and Mapping (ACSM), and the American Land Title Association (ALTA). When industry standards are non-existent, inappropriate, or do not meet a project's functional requirement, FGDC, DOD, DA, or USACE standards may be specified as criteria sources. Minimum technical standards established by state boards of registration, especially on projects requiring licensed surveyors, should be followed when legally applicable. Local surveying and mapping standards should not be developed where consensus industry standards or DOD/DA standards exist.

b. Performance specifications. Performance-oriented (i.e. outcome based) specifications are recommended in procuring surveying and mapping services. Performance specifications set forth the end results to be achieved (final map format, data content, and/or accuracy standard) and not the means, or technical procedures, used to achieve those results. Performance-oriented specifications typically provide the most flexibility and use of state-of-the-art instrumentation and techniques. Performance specifications should succinctly define only the basic mapping requirements that will be used to verify conformance with the specified criteria, e.g., mapping limits, feature location and attribute requirements, scale, contour interval, map format, sheet layout, and final data transmittal, archiving or storage requirements, required accuracy criteria standards for topographic and planimetric features that are to be depicted, and quality assurance procedures. Performance-oriented specifications should be free from unnecessary equipment, personnel, instrumentation, procedural, or material limitations; except as needed to establish comparative cost estimates for negotiated services.

c. Prescriptive (procedural) specifications. Use of prescriptive specifications should be kept to a minimum, and called for only on highly specialized or critical projects where only one prescribed technical method is appropriate or practical to perform the work. Prescriptive specifications typically require specific field instrumentation, equipment, personnel, office technical production procedures, or rigid project phasing with on-going design or construction. Prescriptive specifications may, depending on the expertise of the writer, reduce flexibility, efficiency, and risk, and can adversely impact project costs if antiquated methods or instrumentation are required. Prescriptive specifications also tend to shift most liability to the Government. Occasionally, prescriptive specifications may be applicable to Corps projects involving specialized work not routinely performed by private surveying and mapping firms, e.g., mapping tactical operation sites, mapping hazardous, toxic, and radioactive waste (HTRW) clean-up sites, military/tactical surveying, or structural deformation monitoring of locks, dams, and other flood control structures.

d. Quality control and quality assurance. Quality control (QC) of contracted surveying and mapping work should generally be performed by the contractor. Therefore, USACE quality assurance (QA) and testing functions should be focused on whether the contractor meets the required performance specification (e.g., accuracy standard), and not the intermediate surveying, mapping, and compilation steps performed by the contractor. The contractor's internal QC will normally include independent tests that may be periodically reviewed by the Government. Government-performed (or monitored) field testing of map accuracies is an optional QA requirement, and should be performed when technically and economically justified, as determined by the ultimate project function.

e. Metrication. Surveying and mapping performed for design and construction should be recorded and plotted in the units prescribed for the project by the requesting Command or project sponsor. During transition to the metric system, inch-pound (IP) units or soft conversions may be required for some geospatial data.

f. Spatial coordinate reference systems. Where practical, feasible, or applicable, civil and military projects should be adequately referenced to nationwide or worldwide coordinate systems directly derived from, or indirectly connected to, GPS satellite observations. In addition, navigation and flood control projects in tidal areas should be vertically referenced to the latest datum epoch established by the Department of Commerce--see Appendix B (*Requirements and Procedures for Referencing Coastal Navigation Projects to Mean Lower Low Water (MLLW) Datum*) for detailed requirements and procedures.

4-3. Accuracy Standards for Engineering and Construction Surveying

a. Accuracy standards. Engineering and construction surveys are normally specified and classified based on the horizontal (linear) point closure ratio or a vertical elevation difference closure standard. This type of performance criteria is most commonly specified in Federal agency, state, and local surveying standards, and should be followed and specified by USACE commands. 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). These accuracy standards are summarized in the following tables.

Table 4-1
Minimum Closure Accuracy Standards for Engineering and Construction Surveys

USACE Classification	Closure Standard	
Engr & Const Control	Distance (Ratio)	Angle (Secs)
First-Order	1:100,000	$2\cdot\sqrt{N}$ [1]
Second Order, Class I	1:50,000	$3\cdot\sqrt{N}$
Second Order, Class II	1:20,000	$5\cdot\sqrt{N}$
Third Order, Class I	1:10,000	$10\cdot\sqrt{N}$
Third Order, Class II	1: 5,000	$20\cdot\sqrt{N}$
Engineering Construction (Fourth-Order)	1: 2,500	$60\cdot\sqrt{N}$

[1] N = Number of angle stations

Table 4-2
Minimum Elevation Closure Accuracy Standards for Engineering and Construction Surveys

USACE Classification	Elevation Closure Standard (ft)[1]	(mm)
First-Order, Class I	$0.013\cdot\sqrt{M}$	$3\cdot\sqrt{K}$
First-Order, Class II	$0.017\cdot\sqrt{M}$	$4\cdot\sqrt{K}$
Second Order, Class I	$0.025\cdot\sqrt{M}$	$6\cdot\sqrt{K}$
Second Order, Class II	$0.035\cdot\sqrt{M}$	$8\cdot\sqrt{K}$
Third Order	$0.050\cdot\sqrt{M}$	$12\cdot\sqrt{K}$
Construction Layout	$0.100\cdot\sqrt{M}$	$24\cdot\sqrt{K}$

[1] $\sqrt{M}$ or $\sqrt{K}$ = square root of distance in Miles or Kilometers

b. Survey closure standards. Survey closure standards listed in Tables 4-1 and 4-2 should be used as a basis for classifying, standardizing, and evaluating survey work. The point and angular closures (i.e. traverse misclosures) relate to the relative accuracy derived from a particular survey. This relative accuracy (or, more correctly, precision) is estimated based on internal closure checks of a traverse survey run through the local project, map, land tract, or construction site. Relative survey accuracy estimates are always expressed as ratios of the traverse/loop closure to the total length of the survey (e.g., 1:10,000).

(1) Horizontal closure standard. The horizontal point closure ratio is determined by dividing the linear distance misclosure of the survey into the overall circuit length of a traverse, loop, or network line/circuit. When independent directions or angles are observed, as on a conventional traverse or closed loop survey, these angular misclosures should be distributed (balanced) before assessing positional misclosure. In cases where differential GPS vectors are measured in three-dimensional geocentric coordinates, then the horizontal component of position misclosure is assessed relative to Table 4-1.

(2) Vertical control standards. The vertical accuracy of a survey is determined by the elevation misclosure within a level section or level loop. For conventional differential or trigonometric leveling, section or loop misclosures (in millimeters or feet) should not exceed the limits shown in Table 4-2, where the line or circuit length is measured in the applicable units. Fourth-Order accuracies are intended for construction layout grading work.

c. Construction survey accuracy standards. Construction survey procedural and accuracy specifications should follow recognized industry and local practices. General procedural guidance is contained in a number of standard commercial texts--e.g., Kavanagh 1997. Accuracy standards for construction surveys will vary with the type of construction, and may range from a minimum of 1:2,500 up to 1:20,000. A 1:2,500 "4th-Order Construction" classification is intended to cover temporary control used for alignment, grading, and measurement of various types of construction, and some local site plan topographic mapping or photo mapping control work. 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, and highway pavement. 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 required. Grade elevations are usually observed to the nearest 0.01 ft for most construction work, although 0.1 ft accuracy is sufficient for riprap placement, earthwork grading, and small diameter pipe placement. Construction control points are usually marked by semi permanent or temporary monuments (e.g., plastic hubs, P-K nails, iron pipes, wooden grade stakes). Construction control is usually set from existing boundary, horizontal, and vertical control points.

d. Geospatial positioning accuracy standards. Many control surveys are now being efficiently and accurately performed using radial (spur) techniques--e.g., single line vectors from electronic total stations or kinematic differential GPS to monumented control points, topographic feature points, property corners, etc. Since these surveys may not always result in loop closures (i.e. closed traverse) alternative specifications for these techniques must be allowed. This is usually done by specifying a radial positional accuracy requirement. The required positional accuracy may be estimated based on the accuracy of the fixed reference point, instrument, and techniques used. Ratio closure standards in Tables 4-1 and 4-2 may slowly decline as more use is made of nation-wide augmented differential GPS positioning and electronic total station survey methods.

(1) GPS satellite positioning technology allows development of map features to varying levels of accuracy, depending on the type of equipment and procedures employed. Government and commercial augmented GPS systems allows direct, real-time positioning of static AM/FM type features and dynamic platforms (survey vessels, aircraft, etc.). Site plan drawings, photogrammetric control, and related GIS features can be directly constructed from GPS or differential GPS observations, at accuracies ranging from 1 cm to 20 meters (95%).

(2) Accuracy classifications of maps and related GIS data developed by GPS methods can be estimated based on the GPS positioning technique employed. Permanent GPS reference stations (Continuously Operating Reference Stations or CORS) can provide centimeter-level point positioning accuracies over wide ranges; thus providing direct map/feature point positioning without need for preliminary control surveys.

e. Higher-order surveys. Requirements for relative line accuracies exceeding 1:50,000 are rare for most facility engineering, construction, or mapping applications. Surveys requiring accuracies of First-Order (1:100,000) or better (e.g., A- or B-Order) should be performed using FGDC geodetic standards and specifications. These surveys must be adjusted and/or evaluated by the National Geodetic Survey (NGS) if official certification relative to the national network is required.

f. Instrumentation and field observing criteria. In accordance with the policy to use performance-based standards, rigid prescriptive requirements for survey equipment, instruments, or operating procedures are discouraged. Survey alignment, orientation, and observing criteria should rarely be rigidly specified; however, general guidance regarding limits on numbers of traverse stations, minimum traverse course lengths, auxiliary azimuth connections, etc., may be provided for information. For some highly specialized work, such as dam monitoring surveys, technical specifications may prescribe that a general type of instrument system be employed, along with any unique operating, calibration, or recordation requirements. Appendix A contains a number of technical references that may be used.

g. Connections to existing control. Surveys should normally be connected to existing local control or project control monuments/benchmarks. These existing points may be those of any Federal (including Corps project control), State, local, or private agency. Ties to local Corps or installation project control and boundary monuments are absolutely essential and critical to design, construction, and real estate. In order to minimize scale or orientation errors, at least two existing monuments should be connected. It is recommended that Corps surveys be connected with one or more stations on the National Spatial Reference System (NSRS), when practicable and feasible. Connections with local project control that have previously been connected to the NSRS are normally adequate in most cases. Connections with the NSRS shall be subordinate to the requirements for connections with local/project control. Details on these NSRS connections are given in Chapter 6.

h. Survey computations, adjustments, and quality control/assurance. Survey computations, adjustments, and quality control should be performed by the organization responsible for the actual field survey. Contract compliance assessment of a survey should be based on the prescribed point closure standards of internal loops, not on closures with external networks of unknown accuracy. In cases where internal loops are not observed, then assessment must be based on external closures. Specifications should not require closure accuracy standards in excess of those required for the project, regardless of the accuracy capabilities of the survey equipment. Least-squares adjustment methods should be optional for Second-Order or lower-order survey work. Details on network adjustments are covered in EM 1110-1-1003 (*NAVSTAR GPS Surveying*). Professional contractors should not be restricted to rigid computational methods, software, or recording forms. Use of commercial software adjustment packages is strongly recommended.

i. Data recording and archiving. Field survey data may be recorded and submitted either manually or electronically. Manual recordation should follow standard industry practice, using field book formats outlined in various technical manuals.

4-4. Accuracy Standards for Maps and Related Geospatial Products

Map accuracies are defined by the positional accuracy of a particular graphical or spatial feature depicted. A map accuracy standard classifies a map as statistically meeting a certain level of accuracy. For most engineering projects, the desired accuracy is stated in the specifications, usually based on the final development scale of the map--both the horizontal "target" scale and vertical relief (specified contour interval or digital elevation model). Often, however, in developing engineering plans, spatial databases may be developed from a variety of existing source data products, each with differing accuracies--e.g., mixing 1 inch = 60 ft topo plans with 1 inch = 400 ft reconnaissance topo mapping. Defining an "accuracy standard" for such a mixed database is difficult and requires retention (attribution) of the source of each data feature in the base. In such cases the developer must estimate the accuracy of the mapped features.

a. ASPRS Standard. For site mapping of new engineering or planning projects, there are a number of industry and Federal mapping standards that may be referenced in contract specifications. The recommended standard for facility engineering is the ASPRS "Accuracy Standards for Large Scale Maps" (ASPRS 1989). This standard, like most other mapping standards, 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, plane table. The ASPRS standard has application to different types of mapping, ranging from wide-area, small-scale, GIS mapping to large-scale construction site plans. It is applicable to all types of horizontal and vertical geospatial mapping derived from conventional topographic surveying or photogrammetric surveys. This standard may be specified for detailed construction site plans that are developed using conventional ground topographic surveying techniques (electronic total stations, plane tables, kinematic GPS). The ASPRS standard is especially applicable to site plan development work involving mapping scales larger than 1:20,000 (1 inch = 1,667 ft); it therefore applies to the more typical engineering map scales in the 1:240 (1 inch = 20 ft) to 1:4,800 (1 inch = 400 ft) range. Its primary advantage over other standards is that it contains more definitive statistical map testing criteria, which, from a contract administration standpoint, is desirable. Using the guidance in Tables 4-3 and 4-4 below, specifications for site plans need only indicate the ASPRS map class, target scale, and contour interval.

b. Horizontal (planimetric) accuracy criteria. The ASPRS planimetric standard compares the root mean square error (RMSE) of the average of the squared discrepancies, or differences in coordinate values between the map and an independent topographic ground survey of higher accuracy (i.e. a check survey). The "limiting RMSE" is defined in terms of meters (feet) at the ground scale rather than in millimeters (inches) at the target map scale. This results in a linear relationship between RMSE and target map scale--as map scale decreases, the RMSE increases linearly. The RMSE is the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation, and final extraction of ground dimensions from the target map. The limiting RMSE shown in Table 4-3 is the maximum permissible RMSE established by the ASPRS standard. These ASPRS limits of accuracy apply to well-defined map test points only--and only at the specified map scale.

c. Vertical (topographic) accuracy criteria. Vertical accuracy has traditionally been, and currently still is, defined relative to the required contour interval for a map. In cases where digital elevation models (DEM) or digital terrain models (DTM) are being generated, an equivalent contour interval can be specified, based on the required digital point/spot elevation accuracy. The contours themselves may be later generated from a DEM using computer software routines. The ASPRS vertical standard also uses the RMSE statistic, but only for well-defined features between contours containing interpretative elevations, or spot elevation points. The limiting RMSE for Class 1 contours is one-third of the contour interval. Testing for vertical map compliance is also performed by independent, equal, or higher accuracy ground survey methods, such as differential leveling. Table 4-4 summarizes the limiting vertical RMSE for well-defined points, as checked by independent surveys at the full (ground) scale of the map.

Table 4-3a. ASPRS Planimetric Feature Coordinate Accuracy Requirement (Ground X or Y in Meters) for Well-Defined Points

Target Map Scale	ASPRS Limiting RMSE in X or Y (Meters)		
Ratio m/m	Class 1	Class 2	Class 3
1:50	0.0125	0.025	0.038
1:100	0.025	0.05	0.075
1:200	0.050	0.10	0.15
1:500	0.125	0.25	0.375
1:1,000	0.25	0.50	0.75
1:2,000	0.50	1.00	1.5
1:2,500	0.63	1.25	1.9
1:4,000	1.0	2.0	3.0
1:5,000	1.25	2.5	3.75
1:8,000	2.0	4.0	6.0
1:10,000	2.5	5.0	7.5
1:16,000	4.0	8.0	12.0
1:20,000	5.0	10.0	15.0
1:25,000	6.25	12.5	18.75
1:50,000	12.5	25.0	37.5
1:100,000	25.0	50.0	75.0
1:250,000	62.5	125.0	187.5

Table 4-3b. ASPRS Planimetric Feature Coordinate Accuracy Requirement (Ground X or Y in Feet) for Well-Defined Points

Target Map Scale		ASPRS Limiting RMSE in X or Y (Feet)		
1"= x ft	Ratio ft/ft	Class 1	Class 2	Class 3
5	1:60	0.05	0.10	0.15
10	1:120	0.10	0.20	0.30
20	1:240	0.2	0.4	0.6
30	1:360	0.3	0.6	0.9
40	1:480	0.4	0.8	1.2
50	1:600	0.5	1.0	1.5
60	1:720	0.6	1.2	1.8
100	1:1,200	1.0	2.0	3.0
200	1:2,400	2.0	4.0	6.0
400	1:4,800	4.0	8.0	12.0
500	1:6,000	5.0	10.0	15.0
800	1:9,600	8.0	16.0	24.0
1,000	1:12,000	10.0	20.0	30.0
1,667	1:20,000	16.7	33.3	50.0

Table 4-4a. ASPRS Topographic Elevation Accuracy Requirement for Well-Defined Points (Meters)

ASPRS Limiting RMSE in Meters

Target Contour Interval	Topographic Feature Points			Spot or Digital Terrain Model Elevation Points		
Meters	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
0.10	0.03	0.07	0.10	0.02	0.03	0.05
0.20	0.07	0.13	0.2	0.03	0.07	0.10
0.25	0.08	0.17	0.25	0.04	0.08	0.12
0.5	0.17	0.33	0.50	0.08	0.16	0.25
1	0.33	0.66	1.0	0.17	0.33	0.5
2	0.67	1.33	2.0	0.33	0.67	1.0
4	1.33	2.67	4.0	0.67	1.33	2.0
5	1.67	3.33	5.0	0.83	1.67	2.5
10	3.33	6.67	10.0	1.67	3.33	5.0

Table 4-4b. ASPRS Topographic Elevation Accuracy Requirement for Well-Defined Points (Feet)

ASPRS Limiting RMSE in Feet

Target Contour Interval	Topographic Feature Points			Spot or Digital Terrain Model Elevation Points		
ft	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
0.5	0.17	0.33	0.50	0.08	0.16	0.2
1	0.33	0.66	1.0	0.17	0.33	0.5
2	0.67	1.33	2.0	0.33	0.67	1.0
4	1.33	2.67	4.0	0.67	1.33	2.0
5	1.67	3.33	5.0	0.83	1.67	2.5

d. Map accuracy quality assurance testing and certification. Independent map testing is a quality assurance function that is performed independent of normal quality control during the mapping process. Specifications and/or contract provisions should indicate the requirement (or option) to perform independent map testing. Independent map testing is rarely performed for engineering and construction surveys. If performed, map testing should be completed within a fixed time period after delivery, and if performed by contract, after proper notification to the contractor. In accordance with the ASPRS standard, the horizontal and vertical accuracy of a map is checked by comparing measured coordinates or elevations from the map (at its intended target scale) with spatial values determined by a check survey of higher accuracy. The check survey should be at least twice (preferably three times) as accurate as the map feature tolerance given in the ASPRS tables, and a minimum of 20 points tested. Maps and related geospatial databases found to comply with a particular ASPRS standard should have a statement indicating that standard. The compliance statement should refer to the data of lowest accuracy depicted on the map, or, in some instances, to specific data layers or levels. The statement should clearly indicate the target map scale at which the map or feature layer was developed. When independent testing is not performed, the compliance statement should clearly indicate that the procedural mapping specifications were designed and performed to meet a certain ASPRS map classification, but that a rigid compliance test was not performed. Published maps and geospatial databases whose errors exceed those given in a standard should indicate in their legends or metadata files that the map is not controlled and that dimensions are not to scale. This accuracy statement requirement is especially applicable to GIS databases that may be compiled from a variety of sources containing known or unknown accuracy reliability.

e. National Standard for Spatial Data Accuracy (NSSDA). The traditional small-scale "United States National Map Accuracy Standard" (Bureau of the Budget 1947) has been revised by the FGDC as the NSSDA ("Geospatial Positioning Accuracy Standards, PART 3: National Standard for Spatial Data Accuracy"). This latest version of the NSSDA indicates it is directly based on the ASPRS standard; however, the ASPRS coordinate-based standard is converted to a 95% radial error statistic and the vertical standard is likewise converted from a one-sigma (68%) to 95% standard. The NSSDA defines positional accuracy of spatial data, in both digital and graphic form, as derived from sources such as aerial photographs, satellite imagery, or other maps. Its purpose is to facilitate the identification and application of spatial data by implementing a well-defined statistic (i.e. the 95% confidence level) and testing methodology. As in the ASPRS standard, accuracy is assessed by comparing the positions of well-defined data points with positions determined by higher accuracy methods, such as ground surveys. Unlike the above ASPRS tables, the draft NSSDA standard does not define pass-fail criteria--data and map producers must determine what accuracy exists for their data. Users of that data determine what constitutes acceptable accuracies for their applications. Unlike the ASPRS standard that uses the RMSE statistic in the X, Y, and Z planes, the NSSDA defines horizontal spatial accuracy by circular error of a data set's horizontal (X & Y) coordinates at the 95% confidence level. Vertical spatial data is defined by linear error of a data set's vertical (Z) coordinates at the 95% confidence level. ASPRS lineal horizontal accuracies in X and Y can be converted to NSSDA radial accuracy by multiplying the limiting RMSE values by 2.447, that is:

$$\textit{Radial Accuracy}_{NSSDA} = 2.447 \cdot RMSE_{ASPRS\text{--}\,X\ or\ Y} \qquad \text{(Eq 4-1)}$$

ASPRS 1-sigma (68%) vertical accuracies can be converted to NSSDA 95% lineal accuracy by multiplying the limiting RMSE values by 1.96, or:

$$\textit{Vertical Accuracy}_{NSSDA} = 1.96 \cdot RMSE_{ASPRS\,\text{--}\,Z} \qquad \text{(Eq 4-2)}$$

In time, it is expected that the NSSDA will be the recognized standard for specifying the accuracy of all mapping and spatial data products, and the ASPRS standard will be modified to 95% confidence level specifications.

f. Other mapping standards. When work is performed for DOD tactical elements or other Federal agencies or overseas, mapping standards other than ASPRS may be required.

4-5. Photogrammetric Mapping Standards and Specifications

Most smaller scale (e.g., less than 1 inch = 100 ft or 1:1,200) engineering topographic mapping and GIS data base development is accomplished by aerial mapping techniques. The ASPRS standards should be used in specifying photogrammetric mapping accuracy requirements. Procedures for developing photogrammetric mapping specifications are contained in EM 1110-1-1000 (*Photogrammetric Mapping*). This manual contains guidance on specifying flight altitudes, determining target scales, and photogrammetric mapping cost estimating techniques. A full contract guide specification is also contained in an appendix to EM 1110-1-1000.

4-6. Cadastral or Real Property Survey Accuracy Standards

a. General. Many State codes, rules, statutes, or general professional practices prescribe minimum technical standards for real property surveys. Corps in-house surveyors or contractors should follow applicable State technical standards for real property surveys involving the determination of the perimeters of a parcel or tract of land by establishing or reestablishing corners, monuments, and boundary lines, for the purpose of describing, locating fixed improvements, or platting or dividing parcels. Although some State standards relate primarily to accuracies of land and boundary surveys, other types of survey work may also be covered in some areas. Refer to ER 405-1-12, (*Real Estate Handbook*), and the "*Manual of Instructions for the Survey of the Public Lands of the United States*" (US Bureau of Land Management 1973) for additional technical guidance on performing cadastral surveys, or surveys of private lands abutting or adjoining Government lands.

b. ALTA/ACSM standards. Real property survey accuracy standards recommended by ALTA/ACSM are contained in "*Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys*" (ALTA 1999), a portion of which is excerpted below. (Note that these ALTA standards are periodically updated--the latest version should be obtained from the reference noted in Appendix A-3). This standard was developed to provide a consistent national standard for land title surveys and may be used as a guide in specifying accuracy closure requirements for USACE real property surveys. However, it should be noted that the ALTA/ACSM standard itself not only prescribes closure accuracies for land use classifications but also addresses specific needs particular to land title insurance matters. The standards contain requirements for detailed information and certification pertaining to land title insurance, including information discoverable from the survey and inspection that may not be evidenced by the public records. The standard also contains a table as to optional survey responsibilities and specifications that the title insurer may require. USACE cadastral surveys not involving title insurance should follow State minimum standards, not ALTA/ACSM standards. On land acquisition surveys which may require title insurance, the decision to perform an ALTA/ACSM standard survey, including all optional survey responsibilities and specifications, should come from the project sponsor. Meeting ALTA/ACSM Urban Class accuracy standards is considered impractical for small tracts or parcels less than 1 acre in size.

Accuracy Standards for ALTA-ACSM Land Title Surveys

Introduction

These Accuracy Standards address Positional Uncertainty and Minimum Angle, Distance and Closure Requirements for ALTA-ACSM Land Title Surveys. In order to meet these standards, the Surveyor must assure that the Positional Uncertainties resulting from the survey measurements made on the survey do not exceed the allowable Positional Tolerance. If the size or configuration of the property to be surveyed or the relief, vegetation, or improvements on the property will result in survey measurements for which the Positional Uncertainty will exceed the allowable Positional Tolerance, the surveyor must alternatively apply the within table of "Minimum Angle, Distance and Closure Requirements for Survey Measurements Which Control Land Boundaries for ALTA-ACSM Land Title Surveys" to the measurements made on the survey or employ, in his or her judgment, proper field procedures, instrumentation and adequate survey personnel in order to achieve comparable results.

The lines and corners on any property survey have uncertainty in location which is the result of (1) availability and condition of reference monuments, (2) occupation or possession lines as they may differ from record lines, (3) clarity or ambiguity of the record descriptions or plats of the surveyed tracts and its adjoiners and (4) Positional Uncertainty.

The first three sources of uncertainty must be weighed as evidence in the determination of where, in the professional surveyor's opinion, the boundary lines and corners should be placed. Positional Uncertainty is related to how accurately the surveyor is able to monument or report those positions.

Of these four sources of uncertainty, only Positional Uncertainty is controllable, although due to the inherent error in any measurement, it cannot be eliminated. The first three can be estimated based on evidence; Positional Uncertainty can be estimated using statistical means.

The surveyor should, to the extent necessary to achieve the standards contained herein, compensate or correct for systematic errors, including those associated with instrument calibration. The surveyor shall use appropriate error propagation and other measurement design theory to select the proper instruments, field procedures, geometric layouts and computational procedures to control and adjust random errors in order to achieve the allowable Positional Tolerance or required traverse closure.

If radial survey methods are used to locate or establish points on the survey, the surveyor shall apply appropriate procedures in order to assure that the allowable Positional Tolerance of such points is not exceeded.

Definitions:

"Positional Uncertainty" is the uncertainty in location, due to random errors in measurement, of any physical point on a property survey, based on the 95% confidence level.

"Positional Tolerance" is the maximum acceptable amount of Positional Uncertainty for any physical point on a property survey relative to any other physical point on the survey, including lead-in courses.

Computation of Positional Uncertainty

The Positional Uncertainty of any physical point on a survey, whether the location of that point was established using GPS or conventional surveying methods, may be computed using a minimally constrained, correctly weighted least squares adjustment of the points on the survey.

Positional Tolerances for Classes of Survey

0.07 feet (or 20mm) + 50ppm

Application of Minimum Angle, Distance, and Closure Requirements

The combined precision of a survey can be statistically assured by dictating a combination of survey closure and specified procedures for an ALTA/ACSM Land Title Survey. ACSM, NSPS and ALTA have adopted the following specific procedures in order to assure the combined precision of an ALTA/ACSM Land Title Survey. The statistical base for these specifications is on file at ACSM and available for inspection.

American Congress On Surveying and Mapping
Minimum Angle, Distance and Closure Requirements for Survey Measurements

Which Control Land Boundaries for ALTA/ACSM Land Title Surveys
(Note 1)

Dir. Reading of Instrument (Note 2)	*Instrument Reading Estimated (Note 3)*	*Number of Observations Per Station (Note 4)*	*Spread From Mean of D&R Not To Exceed (Note 5)*	*Angle Closure Where N=No. of Stations Not To Exceed*	*Linear Closure (Note 6)*	*Distance Measurement (Note 7)*	*Minimum Length of Measurements (Notes 8, 9, 10)*
20" <1'> 10"	*5" <0.1'> N.A.*	*2 D&R*	*5"<0.1'> 5"*	*10" $\sqrt{N}$*	*1:15,000*	*EDM or Double tape with Steel Tape*	*(8) 81m, (9) 153m, (10) 20m*

Note (1) All requirements of each class must be satisfied in order to qualify for that particular class of survey. The use of a more precise instrument does not change the other requirements, such as number of angles turned, etc.

Note (2) Instrument must have a direct reading of at least the amount specified (not an estimated reading), i.e.: 20" = Micrometer reading theodolite, <1'> = Scale reading theodolite, 10" = Electronic reading theodolite.

Note (3) Instrument must have the capability of allowing an estimated reading below the direct reading to the specified reading.

Note (4) D & R means the Direct and Reverse positions of the instrument telescope, i.e., Urban Surveys require that two angles in the direct and two angles in the reverse position to be measured and meaned.

Note (5) Any angle measured that exceeds the specified amount from the mean must be rejected and the set of angles re-measured.

Note (6) Ratio of closure after angles are balanced and closure calculated.

Note (7) All distance measurements must be made with a properly calibrated EDM or Steel tape, applying atmospheric, temperature, sag, tension, slope, scale factor and sea level corrections as necessary.

Note (8) EDM having an error of 5 mm, independent of distance measured (Manufacturer's specifications).

Note (9) EDM having an error of 10 mm, independent of distance measured (Manufacturer's specifications).

Note (10) Calibrated steel tape.

4-7. Hydrographic Surveying Accuracy Standards

Hydrographic surveys are performed for a variety of engineering, construction, and dredging applications in USACE. Accuracy standards, procedural specifications, and related technical guidance are contained in EM 1110-2-1003 (*Hydrographic Surveying*). This manual should be attached to any A-E contract containing hydrographic surveying work, and must be referenced in construction dredging contracts involving in-place measurement and payment. Standards in this manual apply to Corps river and harbor navigation project surveys, such as dredge measurement and payment surveys, channel condition surveys of inland and coastal Federal navigation projects, beach renourishment surveys, and surveys of other types of marine structures. Accuracy standards are given for different project conditions and depths. Standards for nautical charting surveys or deep-water bathymetric charting surveys should conform to applicable DOD, National Ocean Survey (NOS), or US Naval Oceanographic Office (USNAVOCEANO) accuracy and chart symbolization criteria.

4-8. Structural Deformation Survey Standards

Deformation monitoring surveys of Corps structures require high line vector and/or positional accuracies to monitor the relative movement of monoliths, walls, embankments, etc. Deformation monitoring survey accuracy standards vary with the type of construction, structural stability, failure probability and impact, etc. Since many periodic surveys are intended to measure "long-term" (e.g., monthly or yearly changes) deformations relative to a stable network, lesser survey precisions are required than those needed for short-term structural deflection type measurements. Long-term structural movements measured from points external to the structure may be tabulated or plotted in either X-Y-Z or by single vector movement normal to a potential failure plane. Accuracy standards and procedures for structural deformation surveys are contained in EM 1110-2-1009 (*Structural Deformation Surveying*). Horizontal and vertical deformation monitoring survey procedures are performed relative to a control network established for the structure. Ties to the National Spatial Reference System are not necessary other than for general reference, and then need only USACE Third-Order connection.

4-9. Geodetic Control Survey Standards

Geodetic control surveys are usually performed for the purpose of establishing a basic framework of the National Spatial Reference System (NSRS). These geodetic network densification survey functions are clearly distinct from the traditional engineering and construction surveying and mapping standards covered in this chapter. Geodetic control surveys of permanently monumented control points that are incorporated in the NSRS must be performed to far more rigorous standards and specifications than are control surveys used for general engineering, construction, mapping, or cadastral purposes. When a project requires NSRS densification, or such densification is a desirable by-product and is economically justified, USACE Commands should conform to published FGDC survey standards and specifications. This includes related automated data recording, submittal, project review, and adjustment requirements mandated by FGDC and the National Geodetic Survey. Geodetic survey accuracy and procedural specifications published by the FGDC or NGS include:

- "Standards and Specifications for Geodetic Control Networks" (FGCS 1984)

- "Input Formats and Specifications of the National Geodetic Survey Data Base," NOAA, National Geodetic Survey, (NOAA 1994)

- "Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques (Preliminary)" (FGCS 1988)

- "Guidelines for Submitting GPS Relative Positioning Data to the National Geodetic Survey" (NGS 1988)

- "Geospatial Positioning Accuracy Standards--Part 2: Standards for Geodetic Networks" (FGDC 1998b)

- "Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm)" (NOAA 1997)

Copies of these specifications and standards can be downloaded from the NGS website--see Appendix A. These FGCS/NGS standards and specifications should rarely be specified for Corps control surveys in that they prescribe far more demanding criteria than that needed to establish control for most engineering projects. These FGDC/NGS standards can also easily add 50% or more time and cost to a control survey project.

Part 2 of the FGDC *Geospatial Positioning Accuracy Standards* (Standards for Geodetic Networks)--FGDC 1988b-- prescribes a positional accuracy criteria instead of the traditional linear closure (misclosure) criteria. It is expected that this positional accuracy standard will gradually replace the misclosure standards in Tables 4-1 and 4-2. This new standard is excerpted in Table 4-5 below.

Table 4-5. FGDC Part 2 Accuracy Standards for Geodetic Networks 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 "

NOTE: The classification standard for geodetic networks is based on accuracy. Accuracies are categorized separately according to horizontal, ellipsoid height, and orthometric height. Note: although the largest entry in the table is 10 meters, the accuracy standards can be expanded to larger numbers if needed.

4-10. State and Local Accuracy Standards

Most State and local governments prescribe survey and map accuracy standards. These are usually similar to those standards given in the previous tables in this chapter. State surveyor licensing boards may prescribe "minimum technical standards" for various real property surveys. State transportation departments may have additional standards unique to their design and construction requirements.

a. General state surveying and mapping standards. Below is an excerpt of surveying accuracy standards taken from the Florida Administrative Code (FAC 2003). These standards for general boundary surveys are representative of minimum technical standards used by many states.

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(1) Survey and Map Accuracy

(a) REGULATIONAL OBJECTIVE: The public must be able to rely on the accuracy of measurements and maps produced by a surveyor and mapper. In meeting this objective, surveyors and mappers must achieve the following minimum standards of accuracy, completeness, and quality.

(b) The accuracy of the survey measurements shall be premised upon the type of survey and the expected use of the survey and map. All measurements must be in accordance with the United States standard, using either feet or meters. Records of these measurements shall be maintained for each survey by either the individual surveyor and mapper or the surveying and mapping business entity. Measurement and computation records must be dated and must contain sufficient data to substantiate the survey map and insure that the accuracy portion of these standards has been met.

(c) Vertical Control: Field-measured control for elevation information shown upon survey maps shall be based on a level loop. Closure in feet must be accurate to a standard of plus or minus .05 ft. times the square root of the distance in miles. All surveys and maps with elevation data shall indicate the datum and a description of the benchmark(s) upon which the survey is based. Minor elevation data may be obtained on an assumed datum provided the base elevation of the datum is obviously different than the established datum.

(d) Vertical Feature Accuracy:

1. If contour lines are shown, then sufficient data must be obtained in order to insure that 90% of ground point elevations taken from contours are within 1/2 of the contour interval, and the remainder are not in error more than the contour interval.

2. For surveys performed by photogrammetric methods, vertical positional accuracy of map elevations, contours, or other forms of terrain models must be stated. The stated accuracy is a plus or minus tolerance that encompasses 90% of elevation differences between survey measured values and ground truth. All such survey maps or reports with elevation data shall have a statement to the effect: "Elevations of well-identified features contained in this survey been measured to an estimated vertical positional accuracy of: ____ (ft) (m)." If different accuracy levels exist for different features, then applicable features and accuracies shall be identified with similar statements.

(e) Horizontal Control: All surveys and maps expressing or displaying features in coordinate position shall indicate the coordinate datum and a description of the control points upon which the survey is based. Minor coordinate data may be obtained on an assumed datum provided the numerical basis of the datum is obviously different than an established datum. The accuracy of field-measured control measurements shall be statistically verified by measurement and calculation of a closed geometric figure. All control measurements shall be made with a transit and steel tape, or devices with equivalent or higher degrees of accuracy. The relative distance accuracy must be better than the following:

- *Commercial/High Risk Linear: 1 foot in 10,000 feet;*
- *Suburban: Linear: 1 foot in 7,500 feet;*
- *Rural: Linear: 1 foot in 5,000 feet;*

*(f) Horizontal Feature Accuracy (for surveys by photogrammetric methods only): A survey and map's horizontal positional accuracy must be stated. The stated accuracy is a plus or minus tolerance that encompasses 90% of coordinate differences between survey measured values and ground truth. All survey maps or reports shall have a statement of the effect: "Well-identified features in this survey and map have been measured to an estimated horizontal positional accuracy of *[____] (ft) (m)." If different accuracy levels exist for different features, then applicable features and accuracies shall be identified with similar statements.*

(g) Map Plotting Accuracy: The horizontal position of physical features surveyed by field methods must be plotted to within 1/20 of an inch at the map scale.

*(h) Intended Display Scale: At the maximum intended display scale, a survey and map's positional accuracy value occupies 1/20" on the display. All maps or reports of surveys produced by photogrammetric methods and delivered with digital coordinate files must contain a statement to the effect of: "This map is intended to be displayed at a scale of 1/ *[______] or smaller."*

(2) Other Provisions that Apply to All Surveys and Maps.

(a) REGULATIONAL OBJECTIVE: In order to avoid misuse of a survey and map, the surveyor and mapper must adequately communicate the survey results to the public through a map, report, or report with an attached map. Any survey map or report must identify the responsible surveyor and mapper and contain standard content. In meeting this objective, surveyors and mappers must meet the following minimum standards of accuracy, completeness, and quality:

(b) Each survey map and report shall state the type of survey it depicts consistent with the types of surveys defined in Rule 61G17-6.002(8)(a)-(k), F.A.C. The purpose of a survey, as set out in Rule 61G17-6.002(8)(a)-(l), F.A.C., dictates the type of survey to be performed and depicted, and a licensee may not avoid the minimum standards required by rule of a particular survey type merely by changing the name of the survey type to conform with what standards or lack of them the licensee chooses to follow.

(c) All survey maps and reports must bear the name, certificate of authorization number, and street and mailing address of the business entity issuing the map and report, along with the name and license number of the surveyor and mapper in responsible charge. The name, license number, and street and mailing address of a surveyor and mapper practicing independent of any business entity must be shown on each survey map and report.

(d) All survey maps must reflect a survey date, which is the date of the field survey or the date of image acquisition for photogrammetric surveys. If the graphics of a map are revised, but the survey date stays the same, the map must list dates for all revisions.

(l) Responsibility Clearly Stated. The responsibility for all mapped features must be clearly depicted on any map or report signed by a Florida licensed surveyor and mapper. In the case that features surveyed by the signing surveyor and mapper have been integrated with features surveyed by others, then the full extent of responsibility shall be clearly depicted on the map or report, and the signing surveyor and mapper shall include in the map or report an assessment of the quality and accuracy of all mapped features delivered.

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b. DOT control survey standards. The following Third-Order survey standards shown in Figures 4-1and 4-2 below are from the CALTRANS *Surveys Manual*. The first standard is for establishing permanent Third-Order horizontal control using a total station. The second is a Third-Order standard for differential leveling--covering different types of levels. Figure 4-3 depicts a CALTRANS accuracy standard for setting primary control around a project site. The classifications and closure standards are identical with those in Tables 4-1 and 4-2. The "G" classification is roughly comparable to USACE "4th Order" classification

Specifications	Traverse/Network Resection Double Tie
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Begin and end of each setup
Use plummet to check position of target and instrument over points	Begin and end of each setup
Measure temperature and pressure and enter ppm correction into total station	First set-up of day
Measure distance to backsight and foresight at each setup	Required
Observe traverse multiple ties to improve least squares adjustment	As Feasible
Close all traverses	Required
Horizontal angle observations, minimum	3D, 3R
Vertical angle observations, minimum	3D, 3R
Angular rejection limit, residual not to exceed	5"
Maximum value for the standard error of the mean	1.2"
Minimum distance measurement to meet horizontal accuracy standard	50 m
Minimum number of distance measurements	3
Distance rejection limit: residual not to exceed	2mm + 2 ppm
Maximum distance measurement to meet vertical accuracy standard	100 m

Figure 4-1. CALTRANS Third-Order horizontal control standards (Total Station)

Operation/Specification	Compensator-Level Three-Wire Observation	Compensator-Level Single-Wire Observation	Electronic/Digital Bar Code Level
Difference in length between fore and back sights, not to exceed per setup	10 m	10 m	10 m
Cumulative difference in length between fore and backsights, not to exceed per loop or section	10 m	10 m	10 m
Maximum sight lengths	90 m	90 m	90 m *(See Note 1)*
Minimum ground clearance of sight line	0.5 m	0.5 m	0.5 m
Maximum section misclosure	$12\ mm \times \sqrt{D}$ *(See Note 2)*	$12\ mm \times \sqrt{D}$ *(See Note 2)*	$8\ mm \times \sqrt{D}$ *(See Note 2)*
Maximum loop misclosure	$12\ mm \times \sqrt{E}$ *(See Note 3)*	$12\ mm \times \sqrt{E}$ *(See Note 3)*	$8\ mm \times \sqrt{E}$ *(See Note 3)*
Difference between top and bottom interval not to exceed	0.30 of rod unit	N/A	N/A
Collimation (Two-Peg) Test	Daily *(See Note 4)* (not to exceed 2 mm)	Daily	Daily
Minimum number of readings (Use repeat measure option for each observation)	N/A	N/A	3 *(See Note 5)*

Figure 4-2. CALTRANS Third-Order differential leveling standards

CALTRANS ORDER (Note 1)	STANDARDS			MONUMENT SPACING AND SURVEY METHODS (Note 2)			APPLICATION – TYPICAL SURVEYS	
	CLASSICAL		POSITIONAL	MONUMENT SPACING (MINIMUM)	TYPICAL SURVEY METHOD			
	HORIZONTAL (Note 4)	VERTICAL (Note 5)			HORIZONTAL	VERTICAL	HORIZONTAL	VERTICAL
B (Note 3)	1:1,000,000	Not Applicable	Per NGS Specifications	10 k	GPS: Static	Not Applicable	High Precision Geodetic Network (HPGN)	Not Applicable
First (Note 3)	1:100,000 (Note 10)	$e = 5\sqrt{E}$	Per NGS Specifications	3 k	GPS: Static Fast Static	Bar Code	Basic (Corridor) Control – HPGN-D Project Control – Horizontal (perferred, when feasible)	Rarely used. Crustal Motion Surveys, etc.
Second	1:20,000	$e = 8\sqrt{E}$	(Note 8)	500 m	GPS: Static Fast Static TSSS: Net Traverse	Bar Code 3-Wire TSSS: Trig	Project Control – Horizontal (see First Order also)	Basic (Corridor) Control HPGN and HPGN-D Project Control
Third	1:10,000	$e = 12\sqrt{E}$	(Note 8)	As Required	GPS: Static Fast Static Kinematic RTK (Note 13) TSSS: Net Traverse Resection Double Tie (Note 9)	Bar Code Single Wire TSSS: Trig GPS: Static (Note 7) RTK (Note 11)	Supplemental Control > Engineering > Construction • Interchange • Major Structure Photo. Control – Horizontal Right of Way Surveys Construction Surveys (Note 6) Topographic Surveys (Note 6) Major Structure Points (Staked)	Project Control – Vertical Supplemental Control Photo. Control – Vertical Construction Surveys (Note 6) Topographic Surveys (Note 6) Major Structure Points (Staked)
G (General)	As required, see appropriate survey procedure section in this manual for accuracy standards/tolerances.			Not Applicable	GPS: Fast Static Kinematic RTK TSSS: Radial	GPS: Fast Static Kinematic, RTK (Note 12) TSSS: Trig Single Wire Direct Elevation Rod	Topographic Surveys (Data Points) Supplement Design Data Surveys Construction Surveys (Staked Points) Environmental Surveys GIS Data Surveys Right of Way Flagging	

Notes

1. The standards, specifications, and procedures included in this Manual are based on Federal Geodetic Control Subcommittee (FGCS) standards and specifications. Except where otherwise noted, the FGCS requirements have been modified to meet Caltrans needs.
2. Refer to other Manual sections for detailed procedural specifications for specific survey methods and types of surveys.
3. "B" Order and First Order surveys are performed to FGCS standards and specifications or other requirements approved by National Geodetic Survey.
4. Distance accuracy standard.
5. Closure between established control; e = maximum misclosure in mm, E = distance in km.
6. Survey setup points used for radial stake out.
7. For example a static GPS may be used to establish NAV88 at the project site from a distant NAVD National Spatial Reference System Control.
8. As required by the local survey needs.
9. Instead of including a point as a network point, certain survey points may be positioned by observations from two or more control points (i.e., double tied). If survey points are not included in a network, double ties must be performed to ensure that blunders are eliminated and the positions established are within stated accuracy standard. Double tie procedures should be only used when appropriate; possible examples are photo control points, land net and monumentation points, and major structure stake points.
10. The distance accuracy standard for Basic (Corridor) Control – HPGN-D surveys is 1:500,000.
11. Not to include vertical project control or vertical for major structure points.
12. Not to include pavement elevations.
13. Not to include major structures.

Figure 4-3. CALTRANS accuracy classifications and standards

4-11. CADD/GIS Technology Center Standards

The CADD/GIS Technology Center [for Facilities, Infrastructure, and Environment] is located at the USACE Waterways Experiment Station in Vicksburg, MS. The Center's primary mission is to serve as a multi-service vehicle to set computer-aided design and drafting (CADD) and geographic information system (GIS) standards; coordinate CADD/GIS facilities systems within the Department of Defense (DOD); promote CADD/GIS system integration; support centralized CADD/GIS hardware and software acquisition; and provide assistance for the installation, training, operation, and maintenance of CADD and GIS systems. The intent of the CADD/GIS Technology Center standards development initiatives has been to develop usable CADD, GIS, and facility management (FM) standards that will satisfy the project life-cycle concept for digital data. This concept requires a set of CADD, GIS, and FM standards for initial data collection, analysis, design, construction, and subsequent master planning, facility management, and maintenance. This allows for direct integration from CADD engineering design or as-builts to such GIS analysis tasks as master planning and FM. The Center has issued a number of geospatial standards and related CADD/GIS guidance. Some of these standards include:

- Spatial Data Standard for Facilities, Infrastructure, and Environment (SDSFIE)
- Facility Management Standard for Facilities, Infrastructure, and Environment (FMSFIE)
- A/E/C CADD Standard

These A/E/C CADD standards define symbology, level/layer assignments, drafting templates, sheet layouts, and other criteria required in a CADD environment. The SDSFIE Standards define the attributes and attribute values for geospatial data features. These standards should be specified for in-house or A-E services requiring delivery of CADD, GIS, and other spatial and geospatial data covered by this chapter.

4-12. Mandatory Standards

The accuracy standards in the following tables in this chapter are considered mandatory.

- Table 4-1: Minimum Closure Accuracy Standards for Engineering and Construction Surveys

- Table 4-2: Minimum Elevation Closure Accuracy Standards for Engineering and Construction Surveys

- Table 4-3a: ASPRS Planimetric Feature Coordinate Accuracy Requirement (Ground X or Y in Meters) for Well-Defined Points

- Table 4-3b: ASPRS Planimetric Feature Coordinate Accuracy Requirement (Ground X or Y in Feet) for Well-Defined Points

- Table 4-4a: ASPRS Topographic Elevation Accuracy Requirement for Well-Defined Points (Meters)

- Table 4-4b: ASPRS Topographic Elevation Accuracy Requirement for Well-Defined Points (Feet)

HQUSACE has directed that geospatial data collected for architectural, engineering, and construction projects shall be compliant with the A/E/C CADD Standard and/or the SDSFIE Standard. This includes data that is collected, developed, or contracted for, and/or otherwise executed by the Corps of Engineers. Topographic survey data falls within this directive.