Control Survey Standards and Specifications

Mentoring Mondays

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I. Definitions

A. Standard

A standard is a level of achievement, a goal. In scientific or engineering terms, a standard is expressed as a tangible absolute or relative number, eg, “Concrete with minimum 4000 psi compressive strength and maximum 2-inch slump.”

B. Specifications

Specification are a set of procedures used to achieve a standard or determine if a standard has been met. Specifications generally have two parts:

1. Procedural requirements. These are designed to ensure a standard is met consistently, not by happenstance.
2. Evaluation methodology. These are a systematic way to determine if the standard has been met.

Specifications provide uniformity – everyone plays by the same rules regardless project size. Ensures consistency and repeatability.

C. Hand-in-Hand

Standards and specifications work together. While there might be a single standard, there can be multiple interpretations on how to attain or verify it. A standard should always be accompanied with the specification(s) that must be used.

Example:

Standard: ≥4000 psi concrete with ≤2 inch slump according to...
Specifications: American Society for Testing and Materials (ASTM)
C150-24 Standard Specification for Portland Cement
C1611-21 Standard Test Method for Slump Flow of Self-Consolidating Concrete
C470-23 Standard Specification for Molds for Forming Concrete Test Cylinders Vertically
C873-23 Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds

D. Surveying Standards: Positional Certainty

Surveying standards ultimately are expressions of positional certainty, either absolute (in a spatial framework) or relative (with respect to another position).

Standards are only important where a project has specific accuracy[1] needs. Establishing a horizontal control network for a highway corridor requires a higher degree of accuracy than does a drainage plan for a lot.

For hundreds of years, surveying consisted of angle, distance, and elevation measurements. Over time the equipment became more sophisticated and accurate, but measurement types were basically the same. Standards were developed and then updated as the instrumentation evolved and higher accuracies were achieved.

The development of air- and space-borne platforms and digital data collection were paradigm shifts in surveying. These did not fit within existing standards frameworks so new ones needed development as did their supporting specifications.

The practice of surveying involves many applications from topographic mapping to cadastral surveys, to control network establishment. Each specialization can have its own unique standards and specifications, some publicly developed, others privately; some mandatory, others voluntary. They can be defined at national, or state levels. Our profession, with closely allied ones, have reached such a diversity of measurement technologies that what once was a “simple” standards and specifications approach has become a bit more complex, intertwined, and confusing.

To keep the scope narrow and sufficiently manageable this presentation is limited to nationally defined control survey standards and specifications (S&S).

II. Evolution

A. Pre-1970s

The first formal national S&S was *Special Publication No. 26 General Instructions for the Field Work of the U.S. Coast and Geodetic Survey*, in 1921. These, and the responsible agency went through a number of iterations introducing different accuracy levels and refining standards to accommodate improved instrumentation. The biggest technology change occurred in 1957 when electronic distance measurement was included for the first time. Replacing time consuming taped distance measurement with electronic instrumentation had a large impact on control network design, measurement, and field time.

1 We know that accuracy mean nearness to the true value of what is measured and since we never know the error amount present, we don’t know the accuracy. What we do know is accuracy is a function of random errors and using higher quality equipment with greater resolution and repeating measurements minimizes the errors and makes our measurement results more accurate. So think of accuracy not as an absolute but as a degree of nearness to the true value.

B. Federal Geodetic Control Committee

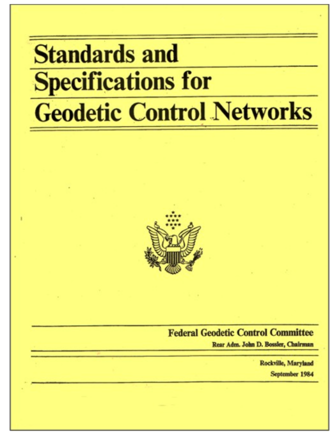

Figure 1: 1984 Control Standards

The Federal Geodetic Control Committee (FGCC) was created in 1974. It consisted of representatives of Federal agencies who used or contributed to the national control network. The FGCC created the *Standards and Specifications for Geodetic Control Networks*[2], bringing together existing S&S into a uniform format. The last version was issued in 1984. Although developed at the Federal level, the FGCC-S&S was designed to also provide support to state and local levels where much of the control network densification took place.

1. Content; Organization

The FGCC-S&S covers eight different control survey categories:

Triangulation
Traverse
Inertial
Geodetic Leveling
Photogrammetry
Satellite Doppler Positioning
Absolute Gravimetry
Relative Gravimetry

Each category is divided into five specification areas:

Network geometry
Instrumentation
Calibration Procedures
Field procedures
Office Procedures

These explain, sometimes in excruciating detail, what must be done in the entire control survey process from inception to analysis.

2. Standards

The standards for each category are given in *Section 2. Standards* and are defined in relative terms. Each standard has Orders and Classes which are different accuracy levels[3]. Although there are eight different control networks covered by the FGCC-S&S, most surveyors were only involved in horizontal

2 This and other publications mentioned in this paper are in the *Standards* topic in the *Mentoring Mondays* section at jerrymahun.com.

3 I was going to call them sub-standards, but that didn't seem right.

(triangulation and traverse[4]) and vertical control surveys so this discussion is limited to those two.

a. Horizontal

Horizontal standards are distance-based ratios, 1/a

Table 1: Horizontal Standards

	First Order	Second Order		Third Order	
		Class I	Class II	Class I	Class II
Accuracy	1/100,000	1/50,000	1/20,000	1/10,000	1/5,000
Use	Primary national network, Metro area networks, Scientific studies.	Additional control to strengthen and densify primary network.	Further densification, Supplemental control.	Provide greater accessibility for lower accuracy local survey needs.	

These are the *minimum* accuracies between points of the same network. Being ratios, they are dimensionless.

$$a = {}^{d}\!/\!_{S}$$

d: distance between points

S: std dev of distance between points from a correctly weighted, minimally constrained, least squares adjustment

Example: The minimum distance between two adjacent Second Order Class I triangulation stations is 10 km. What is the maximum allowable error along that distance?

$$Max\ Err\ =\ \frac{1}{50,000} \times 10\ km \times \frac{1000\ m}{1\ km} \times \frac{100\ cm}{1\ m} = 20\ cm$$

4 These are briefly described in Appendix A.

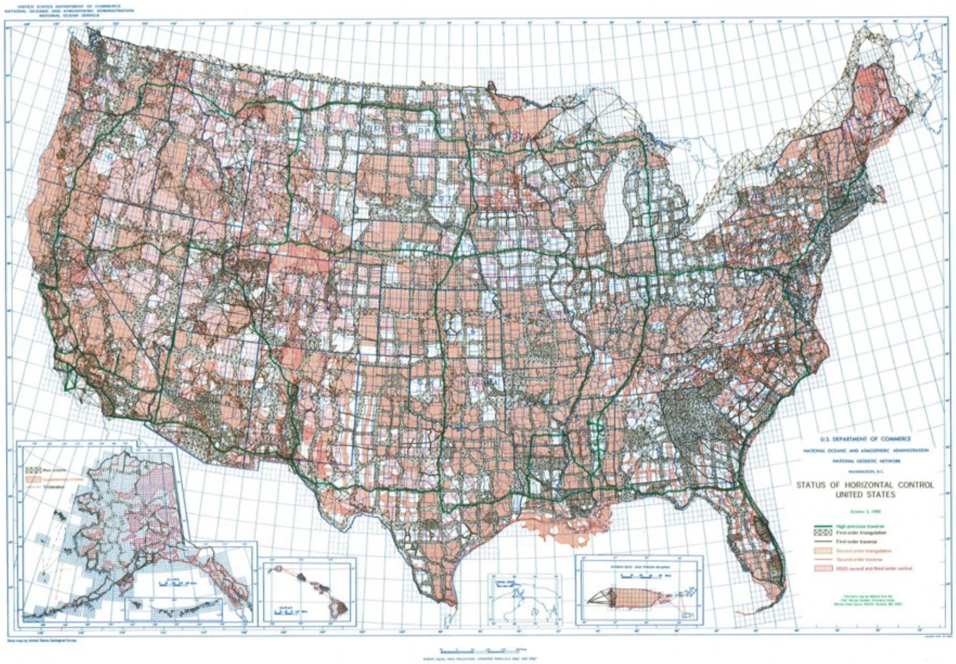

Figure 2: Horizontal Control Framework

b. Vertical

The vertical standard is an elevation difference standard deviation between any two points in the same network. It is determined by multiplying an elevation difference accuracy value by the square root of the distance between the points

Table 2: Vertical Standards

	First Order		Second Order		Third Order
	Class I	Class II	Class I	Class II	
b	0.5	0.7	1.0	1.3	2.0
Use	Basic framework of the National Network and of Metro area control; Extensive engr projects		Secondary Nat'l & Metro control	Control Densification	Local control

$$b = {}^{S}\!/_{\sqrt{K}} \quad \Rightarrow \quad S = b \times \sqrt{K}$$

b: elevation difference accuracy; ${}^{mm}\!/_{\sqrt{km}}$

K: approximate distance between points; km

S: std dev of elev diff between points from a correctly weighted, minimally constrained, least squares adjustment; mm

Example: A Second Order Class I level run between two points is 2.0 km. What is the maximum allowable elevation difference between the points?

$$S = 1.0 \, {}^{mm}\!/\!_{\sqrt{km}} \times \sqrt{2\ km} = \pm 1.41\ mm$$

That's about the thickness of this line: ▬▬▬▬▬▬ ... in 2 km.

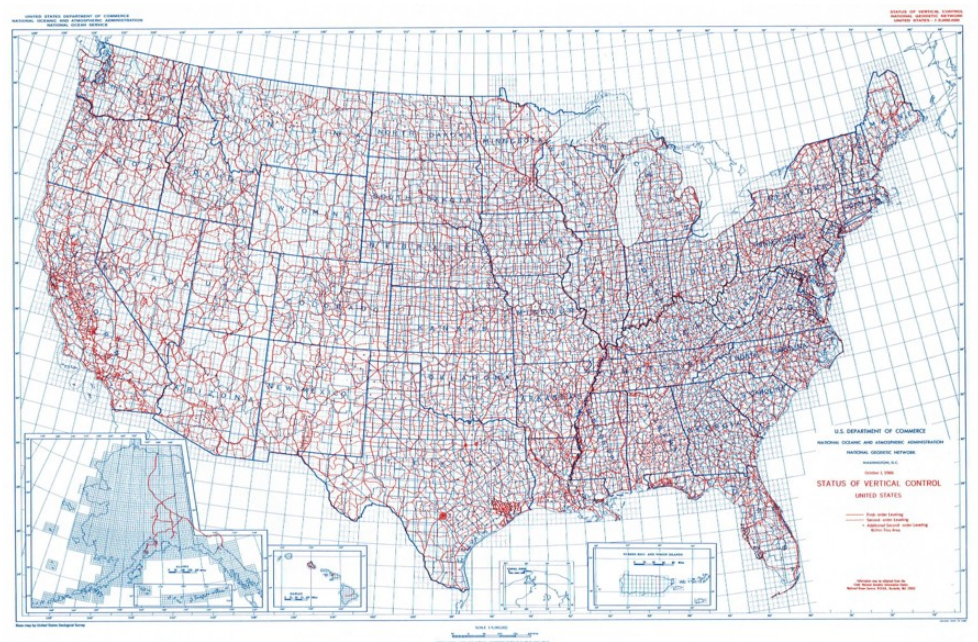

Figure 3: Vertical Control Framework

3. Specifications

For idea of how detailed the specifications could be, we'll briefly examine Triangulation.

3.2 Triangulation

Triangulation is a measurement system comprised of joined or overlapping triangles of angular observations supported by occasional distance and astronomic observations. Triangulation is used to extend horizontal control.

Network Geometry

Order *Class*	*First*	*Second I*	*Second II*	*Third I*	*Third II*
Station spacing not less than (km)	15	10	5	0.5	0.5
Average minimum distance angle† of figures not less than	40°	35°	30°	30°	25°
Minimum distance angle† of all figures not less than	30°	25°	25°	20°	20°
Base line spacing not more than (triangles)	5	10	12	15	15
Astronomic azimuth spacing not more than (triangles)	8	10	10	12	15

† Distance angle is angle opposite the side through which distance is propagated.

Instrumentation

Only properly maintained theodolites are adequate for observing directions and azimuths for triangulation. Only precisely marked targets, mounted stably on tripods or supported towers, should be employed. The target should have a clearly defined center, resolvable at the minimum control spacing. Optical plummets or collimators are required to ensure that the theodolites and targets are centered over the marks. Microwave-type electronic distance measurement (EDM) equipment is not sufficiently accurate for measuring higher-order base lines.

Order *Class*	*First*	*Second I*	*Second II*	*Third I*	*Third II*
Theodolite, least count	0.2″	0.2″	1.0″	1.0″	1.0″

Figure 4: Network and Instrumentation

A triangulation network consists of a series of adjacent and overlapping triangles, Figure 5. The angle at each vertex is measured along with periodic baselines.

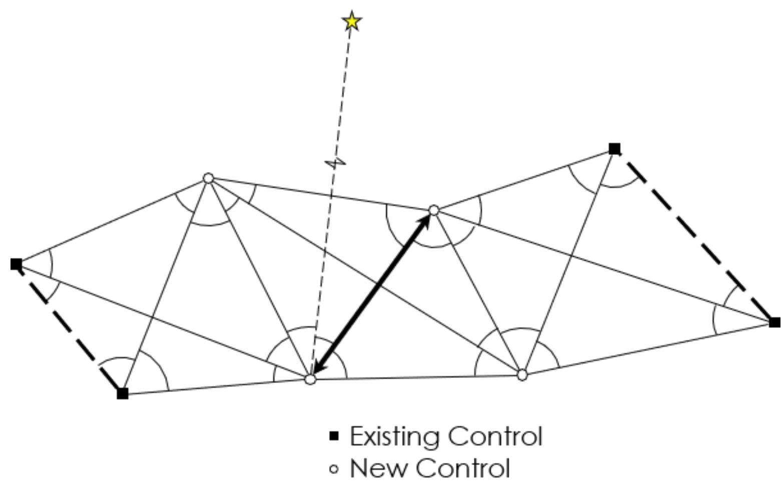

Figure 5: Triangulation Network

Figure 6: Geodetic Theodolites

Angle measurement procedures and criteria.

Horizontal, vertical, astronomic

Conditions
Repetitions
Spread

Distance measurements and criteria

(microwave not included)

Electro-Optical Distances					
Minimum number of days..	2*	2*	1	1	1
Minimum number of measurements/day	2§	2§	2§	1	1
Minimum number of concentric observations/ measurement	2	2	1	1	1
Minimum number of offset observations/ measurement	2	2	2	1	1
Maximum difference from mean of observations (mm)	40	40	50	60	60
Minimum number of readings/observation (or equivalent)	10	10	10	10	10
Maximum difference from mean of readings (mm) ..	‡	‡	‡	‡	‡
Infrared Distances					
Minimum number of days..	—	2*	1	1	1
Minimum number of measurements	—	2§	2§	1	1
Minimum number of concentric observations/ measurement	—	1	1	1	1
Minimum number of offset observations/ measurement	—	2	1	1	1
Maximum difference from mean of observations (mm)	—	5	5	10	10
Minimum number of readings/observation (or equivalent)	—	10	10	10	10
Maximum difference from mean of readings (mm) ..	—	‡	‡	‡	‡

† 8 if 0.2", 12 if 1.0" resolution.
* two or more instruments.
§ one measurement at each end of the line.
‡ as specified by manufacturer.
** carried out at both ends of the line.

Figure 8: Field: Distances

A minimally constrained network adjustment, Figure 10, uses just two control points to fix rotation and scaling. Its purpose is to check how well the measurements fit together.

Field Procedures

Theodolite observations for first-order and second-order, class I surveys may only be made at night. Reciprocal vertical angles should be observed at times of best atmospheric conditions (between noon and late afternoon) for all orders of accuracy. Electronic distance measurements need a record at both ends of the line of wet and dry bulb temperatures to ±1°C, and barometric pressure to ±5 mm of mercury. The theodolite and targets should be centered to within 1 mm over the survey mark or eccentric point.

Order *Class*	*First*	*Second* *I*	*Second* *II*	*Third* *I*	*Third* *II*
Directions					
Number of positions	16	16	8 or 12†	4	2
Standard deviation of mean not to exceed	0.4"	0.5"	0.8"	1.2"	2.0"
Rejection limit from the mean	4"	4"	5"	5"	5"
Reciprocal Vertical Angles (along distance sight path)					
Number of independent observations direct/reverse	3	3	2	2	2
Maximum spread	10"	10"	10"	10"	20"
Maximum time interval between reciprocal angles (hr)	1	1	1	1	1
Astronomic Azimuths					
Observations per night........	16	16	16	8	4
Number of nights	2	2	1	1	1
Standard deviation of mean not to exceed	0.45"	0.45"	0.6"	1.0"	1.7"
Rejection limit from the mean	5"	5"	5"	6"	6"

Figure 7: Field: Angles

Office Procedures

Order *Class*	*First*	*Second* *I*	*Second* *II*	*Third* *I*	*Third* *II*
Triangle Closure					
Average not to exceed	1.0"	1.2"	2.0"	3.0"	5.0"
Maximum not to exceed	3"	3"	5"	5"	10"
Side Checks					
Mean absolute correction by side equation not to exceed	0.3"	0.4"	0.6"	0.8"	2.0"

A minimally constrained least squares adjustment will be checked for blunders by examining the normalized residuals. The observation weights will be checked by inspecting the postadjustment estimate of the variance of unit weight. Distance standard errors computed by error propagation in this 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 which account for the following:

semimajor axis of the ellipsoid ....(a = 6378137 m)
reciprocal flattening of the ellipsoid ....(1/f = 298.257222)
mark elevation above mean sea level........................(known to ±1 m)
geoid heights ....(known to ±6 m)
deflections of the vertical ....(known to ±3")
geodesic correction
skew normal correction
height of instrument
height of target
sea level correction
arc correction
geoid height correction
second velocity correction
crustal motion

Figure 9: Analysis

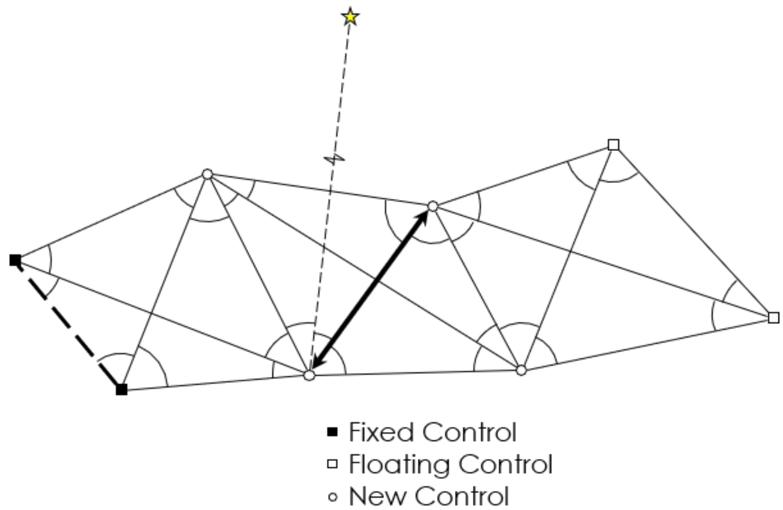

Figure 10: Minimally Constrained Network

4. Augmenting Specifications

There was a little-known companion publication to the FGCC-S&S, *Specifications To Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*. It provided more descriptive information on achieving the standards including network design, error control, and some limited alternative equipment use.

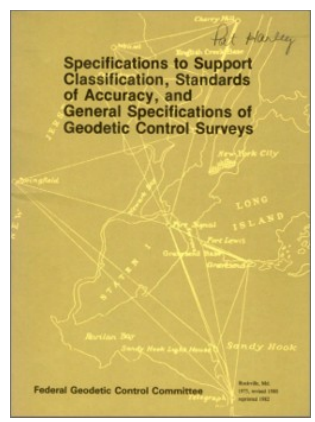

Figure 11: FGCC Companion

C. Transitive Technologies

1. Digital Levels

After 1984, the only significant modification of the existing FGCC-S&S was the addition of Electronic Digital/Bar-Code Leveling Systems in the *Instrumentation* and *Calibration* sections of the Geodetic Leveling category in 1989, then updated in 2004 (Section B.2). This

2. GPS

When GPS appeared in the late 1980s, it immediately achieved horizontal relative accuracies much better than First Order's 1/100,000.

FGCC-S&S had a *Satellite Doppler Positioning* category but that was a different way of using orbital platforms than GPS. Doppler's accuracy was considerably less than GPS' limiting its use to long baselines, no less than 40 km for First Order surveys. Receivers were expensive and data collection took 12 to 48 hours[5]

GPS was a totally different measurement technology from anything already included in the FGCC-S&S.

State DOTs, realizing the advantages GPS had, adopted the technology early. Initial testing revealed the technology was routinely more accurate than the recently completed first realization of NAD 83[6]. To address this, and create a denser network and with more accessible control points, States began building their own High Accuracy Reference Networks (HARN).

After extensive field testing, NGS created version 1.0 of the *Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques* in 1985. It followed a similar format as the existing FGCC-S&S but created three new relative accuracy levels: AA-Order (1/100,000,000), A-Order (1/10,000,000), and B-Order (1/1,000,000) relative accuracy levels. As an indication of the rapidly evolving technology[7], its forward stated:

> "The document is subject to frequent revisions as requirements for classification of geodetic control surveys change, as the definitions for accuracy standards are modified, as we gain experience in performing GPS surveys with an enhanced satellite system, as GPS surveying equipment are improved, as the field procedures are streamlined, and as refinements are made to processing software."

True to form it reached version 5.0 by 1988 and was adopted by the FGCC as an interim standard and specification. But it was understood that existing standards and specifications as a complete package had to be re-thought.

D. Federal Geodetic Control Subcommittee

1. What's in a Name?

Here's where it gets a bit confusing. There was a fundamental shift in how standards and specifications would be developed. At the same time other separately defined, but related Federal standards and specifications would be brought together under a single umbrella committee: the Federal Geographic Data Committee (FGDC). FGCC was incorporated within FGDC as the Federal Geodetic Control *Sub*committee (FGCS). FGCC became FGCS under FGDC, see?

2. Integrated Approach to Spatial Standards

To bring together other related standards, additional entities were aggregated or created under the FGDC: Facilities Working Group, Subcommittee on Marine and Coastal Spatial Data, and Subcommittee

5 And recorded on state-of-the-art (for the time) cassette tapes.

6 Except for literally a handful of GPS observations, the technology was not used in the initial NAD 83 redefinition and readjustment.

7 Only a partial constellation available initially and the author can attest to the fact that the best four-hour observation window in January was in the middle of the night. In Wisconsin. In ten to twenty below temperatures. In the dark.

for Base Cartographic Data.

Each sub-entity was responsible for developing a specific part of a new five-part set of *Geopositioning Standards*.

Part 1: Reporting Methodology, FGDC-STD-007.1-1998
Part 2: Standards for Geodetic Networks, FGDC-STD-007.2-1998
Part 3: National Standard for Spatial Data Accuracy, FGDC-STD-007.3-1998
Part 4: Standards for Architectural, Engineering, Construction, and Facility Management, FGDC-STD-007.4-2002
Part 5: Standards for Nautical Charting Hydrographic Surveys, FGDS-STD-007.5-2005

Part 2 is the responsibility of the FGCS.

Although still in draft form (since 1998!), the standards have been adopted by most applicable Federal agencies.

3. Survey Standards

How survey standards are defined has changed considerably. Unlike the FGCC-S&S, there is less specific detail in the *Geopositioning Standards Part 2* (GS2): where the old publication was 29 pages long, GS2 is only 6.

Federal Geographic Data Committee FGDC-STD-007.2-1998
Draft Geospatial Positioning Accuracy Standards
Part 2: Standards for Geodetic Networks

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Figure 12: Geopositioning Standards Part 2 Content

Instead of Orders and Classes, there is an Accuracy Classification Standard based on error propagation at the 95% confidence Interval.

"Section 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 "

Table 2.1 takes the place of the separate horizontal and vertical standards of FGCC-S&S. The new standard uses, possibly even influenced, the current 95% confidence interval (CI) analysis.

Accuracies are based on a correctly weighted, minimally constrained, least squares adjustment.

What is a "correctly weighted" adjustment? Weights are based on estimated random errors in the measurements - the smaller the expected error, the greater the weight. Expected errors depend on the survey operation, equipment used, and personnel experience. For GPS it includes the manufacturer's stated horizontal and vertical errors, receiver height and centering errors. For analog leveling, sight distance and reading resolution.

These are used as initial *a priori* error estimates for the adjustment. They may need refinement based on the adjustment results in order to attain a statistically strong solution.

Sec 2.2.2 *Accuracy Determination* explains a four-step process to determine the accuracy classification for control points that will be submitted for *National Spatial Reference System* (NSRS) inclusion. These must have Local and Network accuracies, Figure 13 and Figure 14, all at the 95% CI:

> Local – point position uncertainty relative to other directly connected adjacent points.
> Network – point position uncertainty relative to the geodetic datum.

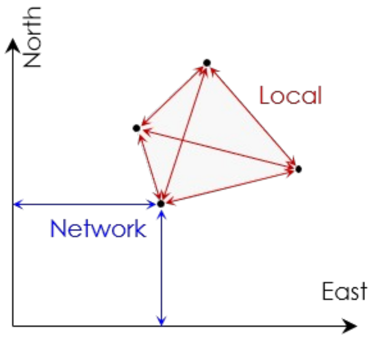


Figure 13: Network and Local Accuracy

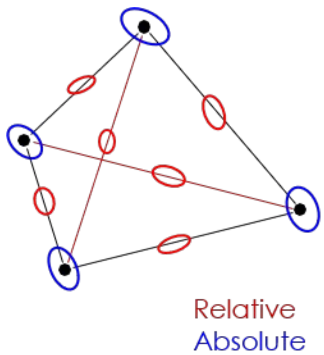


Figure 14: Error Ellipses

Surveyors have greater discretion in equipment selection and field operations than under the FGCC-SS.

4. On The Level

Despite the development of FGCS-GS2, the digital leveling standards that were created by the FGCC were still around. Because digital equipment technology had matured, GNSS still had not reached orthometric accuracy equal to traditional control leveling, and NGS initiated the Height Modernization program, FGCS updated the standards, the last version being issued in 2004.

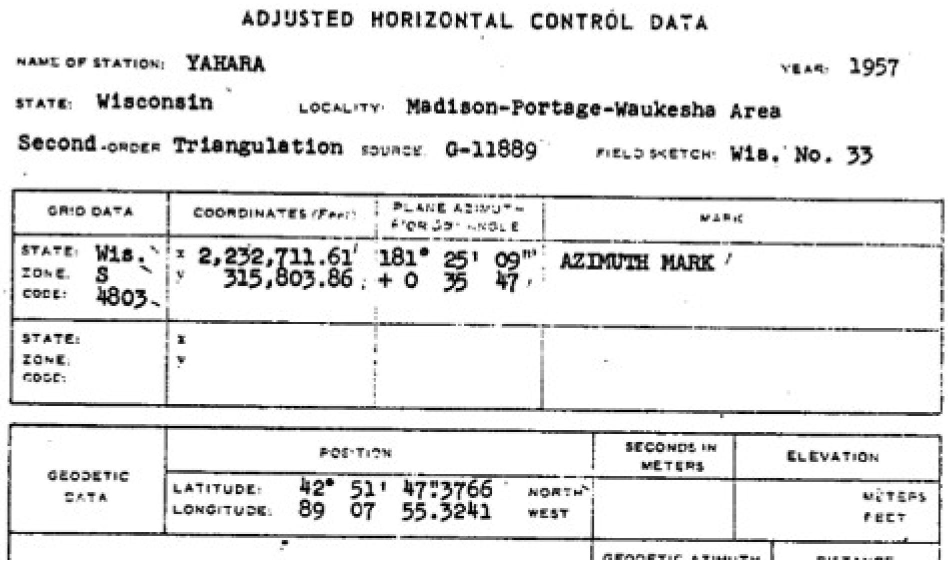
E. So Are the FGCC-S&S Dead and Buried?

Well, no. They still exist as a legacy and we can see this in the NSRS datasheets for passive points.

FGCC-S&S straddled the transition from NAD 27 to NAD 83. Approximately 270,000 horizontal control points were readjusted in 1986 to the new datum. Based on readjustment statistics, some control points dropped one Order or Class

1. NAD 27 Datasheet

A control point's datasheet was literally a sheet of paper maintained in file cabinets. Points were organized by sequential identification number in a quarter of a one-degree latitude by one-degree longitude block. Figure 15 is part of point *Yahara*'s datasheet,



ADJUSTED HORIZONTAL CONTROL DATA

NAME OF STATION: YAHARA YEAR: 1957

STATE: Wisconsin LOCALITY: Madison-Portage-Waukesha Area

Second-ORDER Triangulation SOURCE: G-11889 FIELD SKETCH: Wis. No. 33

GRID DATA	COORDINATES (Feet)	PLANE AZIMUTH FOR 2ND ANGLE	MARK
STATE: Wis. ZONE: S CODE: 4803	x 2,232,711.61 y 315,803.86	181° 25' 09" + 0 35 47	AZIMUTH MARK
STATE: ZONE: CODE:	x y		

GEODETIC DATA	POSITION	SECONDS IN METERS	ELEVATION
	LATITUDE: 42° 51' 47".3766 NORTH		METERS
	LONGITUDE: 89 07 55.3241 WEST		FEET

Figure 15: Yahara NAD27 Datasheet Excerpt

Besides its geodetic and State Plane coordinates, *Yahara*'s datasheet includes when the point was set (1957), other control points observed from *Yahara* (not shown here), and condition information (also not shown). *Yahara* was part of a Second-Order triangulation network. Although not identified on the datasheet, *Yahara* was also part of a vertical control network, however its pre-NAVD 88 record is not available.

2. NAD 83 Datasheet

Control point datasheet format and content was changed as part of the new NAD 83 creation. It contained more information and was designed as a digital document for more efficient editing and retrieval.

NGS did not use classical terrestrial-based measurements in the last two NAD 83 realizations (2007 and 12011), only GNSS measurements. While datasheets of older control points will still indicate Order and Class, their latest horizontal position will be on a pre-NAD 83 (NSRS 2007) realization. Newer points will have their accuracies expressed in Local and Network terms in accordance with FGDC-STD-007.2-1998.

Yahara's earlier conventional terrestrial-based measurements were used for the NAD 83 adjustment/readjustment up through 1991. Due to its location under heavy tree cover and near farm buildings, *Yahara* was never GPS-observed. It is a passive mark because velocities were not determined for it.

```
NH1309 ***********************************************************************
NH1309  DESIGNATION -  YAHARA
NH1309  PID         -  NH1309
NH1309  STATE/COUNTY-  WI/DANE
NH1309  COUNTRY     -  US
NH1309  USGS QUAD   -  COOKSVILLE (2018)
NH1309
NH1309                         *CURRENT SURVEY CONTROL
NH1309  ______________________________________________________________________
NH1309* NAD 83(1991) POSITION- 42 51 47.40667(N) 089 07 55.72846(W)   ADJUSTED
NH1309* NAVD 88 ORTHO HEIGHT -   277.66  (+/-2cm)      911.0   (feet) VERTCON3
NH1309  ______________________________________________________________________
NH1309  GEOID HEIGHT    -        -34.155 (meters)                     GEOID18
NH1309  LAPLACE CORR    -          -0.02  (seconds)                   DEFLEC18
NH1309  HORZ ORDER      -  THIRD
NH1309  VERT ORDER      -  THIRD ? (See Below)
NH1309
NH1309.The horizontal coordinates were established by classical geodetic methods
NH1309.and adjusted by the National Geodetic Survey in November 1991.
NH1309
NH1309.The NAVD 88 height was computed by applying the VERTCON shift value to
NH1309.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)

NH1309                          SUPERSEDED SURVEY CONTROL
NH1309
NH1309  NAD 83(1986)-  42 51 47.39576(N)    089 07 55.72916(W) AD(       ) 3
NH1309  NAD 27      -  42 51 47.37660(N)    089 07 55.32410(W) AD(       ) 3
NH1309  NGVD 29            277.68   (m)          911.0    (f) LEVELING    3
```

Figure 16: Yahara Contemporary Datasheet Excerpt

Yahara's horizontal position was downgraded to Third Order from Second. Its vertical order is shown as Third followed by a question mark. The *Superseded Survey Control* section shows previous positions for the point. The number at the end of each position line indicates its Order.

3. NAD 83 Datasheet: Active Point

GNSS-observed control points were the only ones included in the 2007 and 2011 NAD 83 realizations. Beginning in 2007, Class and Order were no longer used to classify points. Instead, Local and Network Accuracies are included on these datasheets.

Johnson is a control point originally set in 1931 and part of a First Order triangulation network. It was included in the NAD 27, NAD 83 (86), (91) and (97) adjustments. WIDOT used it in the state HARN network adding GNSS observations to its conventional measurements. Its GNSS-only observations were included in the NSRS 2007 and 2011 NAD 83 readjustments.

Figure 17 is part of *Johnson*'s contemporary datasheet. Near the bottom of this excerpt are the Network Accuracy for both horizontal position and ellipsoidal height. Its 3.90 cm horizontal accuracy places it in the 5-centimeter classification of GS2 Table 2.1.

```
NH1608 ***********************************************************************
NH1608  DESIGNATION -  JOHNSON
NH1608  PID         -  NH1608
NH1608  STATE/COUNTY-  WI/GREEN
NH1608  COUNTRY     -  US
NH1608  USGS QUAD   -  BLANCHARDVILLE (2018)
NH1608
NH1608                         *CURRENT SURVEY CONTROL
NH1608  ______________________________________________________________________
NH1608* NAD 83(2011) POSITION- 42 50 34.33689(N) 089 46 56.35673(W)   ADJUSTED
NH1608* NAD 83(2011) ELLIP HT-   317.474 (meters)        (06/27/12)   ADJUSTED
NH1608* NAD 83(2011) EPOCH   -  2010.00
NH1608* NAVD 88 ORTHO HEIGHT -   351.1   (meters)     1152.    (feet) VERTCON3
NH1608  ______________________________________________________________________
NH1608  GEOID HEIGHT    -        -33.788 (meters)                     GEOID18
NH1608  NAD 83(2011) X  -     17,795.734 (meters)                     COMP
NH1608  NAD 83(2011) Y  - -4,684,039.461 (meters)                     COMP
NH1608  NAD 83(2011) Z  -  4,314,935.105 (meters)                     COMP
NH1608  LAPLACE CORR    -          0.56  (seconds)                    DEFLEC18
NH1608
NH1608  Network accuracy estimates per FGDC Geospatial Positioning Accuracy
NH1608  Standards:
NH1608         FGDC (95% conf, cm)     Standard deviation (cm)     CorrNE
NH1608            Horiz  Ellip           SD_N   SD_E   SD_h      (unitless)
NH1608  -------------------------------------------------------------------
NH1608  NETWORK    3.90   3.98           1.05   1.88   2.03     -0.25097645
NH1608  -------------------------------------------------------------------
NH1608  Click here for local accuracies and other accuracy information.
```

Figure 17: Johnson NAD 83 (2011) Data and Network Accuracy

Clicking the here link below the Network Accuracies opens the Local Accuracies window, Figure 18. These points were directly connected to *Johnson* by measurements.

```
NH1608  Horiz and Ellip are the horizontal and ellipsoid height accuracies
NH1608  at the 95% confidence level per Federal Geographic Data Committee
NH1608  Geospatial Positioning Accuracy Standards.  SD_N, SD_E and SD_h are
NH1608  the standard deviations (one sigma) of the coordinates (NETWORK) or
NH1608  of the difference in the coordinates (LOCAL) in latitude, longitude
NH1608  and ellipsoid height.  CorrNE is the (unitless) correlation
NH1608  coefficient between the latitude and longitude components of either
NH1608  the coordinate (NETWORK) or coordinate difference (LOCAL).  Dist is
NH1608  the three-dimensional straight-line slope distance, in km, between
NH1608  station NH1608 and the corresponding local station.  Local stations
NH1608  are stations processed simultaneously in a session regardless of
NH1608  distance.
NH1608
NH1608  Accuracy and standard deviation values are given in cm.
NH1608
NH1608  Type/PID  Horiz  Ellip  Dist(km)  SD_N   SD_E   SD_h        CorrNE
NH1608  -------------------------------------------------------------------
NH1608  NETWORK   3.90   3.98             1.05   1.88   2.03   -0.25097645
NH1608  -------------------------------------------------------------------
NH1608  LOCAL (007 points):
NH1608  NH0943    2.02   2.23     4.12    0.56   0.97   1.14   -0.22477372
NH1608  NH0939    1.87   3.14     5.24    0.95   0.13   1.60   +0.04331544
NH1608  NH0941    2.02   2.12     6.84    0.55   0.97   1.08   -0.23580162
NH1608  NH0936    1.48   2.61     8.21    0.75   0.16   1.33   -0.08955868
NH1608  NH0937    2.06   3.55    10.47    1.05   0.17   1.81   +0.02575059
NH1608  NH0934    2.74   2.90    11.94    0.74   1.32   1.48   -0.23214961
NH1608  NH0932    2.84   2.96    16.41    0.82   1.35   1.51   -0.26168730
NH1608
NH1608  MEDIAN    2.02   2.90     8.21
NH1608  -------------------------------------------------------------------
```

Figure 18: Johnson Local Accuracies

III. Summary

Although the FGCC *Standards and Specifications for Geodetic Control Networks* have been superseded by the FGCS *Standards for Geodetic Networks*, you will still encounter some of the older terminology on NSRS datasheets for passive points. But be careful: those points are *not* on the current datum realization. Control points on different realizations should not be mixed on the same project. The only possible use of per-2011 adjusted data is if you are working with other spatial data on earlier realizations.

You are more likely to encounter the older FGCC standards and specifications at the state or local level. Many Dept of Transportation adopted the older standards and may still use them for control networks, particularly in Height Modernization projects. Local units of government (County, Parish, Municipality) might also have adopted them for control networks or PLS remonumentation surveys.

Although the FGCC standards and specifications have been replaced at the national level, that doesn't mean they aren't useful in other applications.

Above all, although it's easy to do, don't confuse FGCC with FGCS. The former morphed into the latter, but each is associated with different standards and specifications.