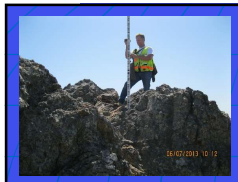

City & County of San Francisco

Contractor's Workshop

BSM: Surveying, Processing & Reporting Requirements

Bruce Storrs, PLS City & County Surveyor
Marilyn Lopes, PLS Chief Surveyor - Bill Blackwell, PLS Chief Surveyor
Neil King,PLS - Jim MacCallum, LSIT - Michael McGee,PLS

Presented June 13, 2018 Revised 06/15/18, 06/20/18

1

Workshop Theme

The intent of this Workshop is to provide all contractors with the same information and understanding of what is needed to be in compliance with the methods and procedures for surveying, processing and reporting BSM survey projects.

We are resolved to improve communications and minimize loss time on both ends.

2

BSM Survey Division

Vertical & Horizontal Reference Systems, Resources & Procedures, and How They Relate to Surveys Performed by Contractors

3

City Website

Survey Reports, Coordinate Lists, Reference Documents, KMZ Files and Documents generated for this Workshop

(Google "HPN Survey")

http://sfpublicworks.org/ccsf-geodetic-network

2013 High Precision Network (HPN) Survey

- HPN Record of Survey *(pdf)*
- HPN Survey Report *(doc)*
- HPN Station Descriptions *(pdf)*
- HPN Station Recovery and Obstruction Diagrams *(pdf)*
- HPN Densification (HPND) Published Coordinates *(doc)*
- HPN Densification (HPND) Station Recovery and Obstruction Diagrams *(pdf)*
- HPN Densification (HPND) Point Descriptions *(xlsx)*
- Horizontal and Vertical Control Network *(kmz file for use in Google Earth, contains basic descr photos accessible by clicking on any point)* UPDATED 08.31.2017

2013 -2014 High Precision Leveling Network

- 2013 Leveling Survey Report *(doc)*
- Leveling Specs & Procedure *(doc)*
- CCSF- VD13 Benchmark Elevations *(doc)*
- CCSF- VD13 Benchmark Descriptions *(xlsx)*

Geodetic Documents and Supporting Files

- CCSF CS13 & VD13 Datums and Reference Frames *(doc)*
- NAD83 (1992) 1991.00 Epoch SPC Zone 3 to NAD83 (2011) 2010.00 Epoch SPC Zone 3 Transformation *(.xlsx)*
- NAD83 (1992) 1991.00 Epoch SPC Zone 3 to NAD83 (2011) 2010.00 Epoch CCSF-CS13 Transformation *(.xlsx)*
- NAD83 (2011) 2010.00 Epoch SPC Zone 3 to NAD83 (2011) 2010.00 Epoch CCSF-CS13 Transformation *(.xlsx)*
- CS13 Projection Files for AutoCAD *(.csd)*

4

"CCSF BSM Projects: Surveying, Processing & Reporting Requirements" Reference Document

CCSF BSM Projects: Surveying, Processing & Reporting Requirements

BSM contractors and their sub-contractors are expected to follow the methods and procedures for surveying, processing and reporting projects addressed herein. Control traverses established by contractors will be closed loops or closed on BSM Control Points. The horizontal and vertical coordinates, descriptions and photos for the control points are typically provided by BSM to control the contractor's field survey measurements and develop coordinates. Unless directed otherwise, the majority of BSM projects will be coordinated on a City specific grid projection called the CCSF Coordinate System of 2013 (CCSF-CS13). The elevations will be based on the CCSF-VD13 Vertical Datum which is NAVD88 as recovered by CCSF in 2013. (Refer to "Geodesy Summary", "Datum-H-V Simplified CCSF", "CCSF 2013 HPN coords", "CCSF-Benchmark List-2013 Vertical Datum" and the "CCSF-HPND Coordinate List and the Public Works web site at http://www.sfpublicworks.org/ccsf-geodetic-network)

In addition to establishing new control points, the traverse must tie existing reference points. All existing points falling in the traverse area of responsibility shall be tied to the control traverse including but not limited to HPN Points, HPND Points, TND Points, Benchmarks and City Monuments.

It is imperative the BSM point numbering scheme be adhered to. New control points are assigned an 8-digit BSM Project Specific number ID for example 17032101, 17032102 etc. and topo points are assigned a 10-digit BSM Project Specific number ID for example 1703210001 (Refer to "Guide-Point Numbering System"). Do not assign new ID's to existing BSM CCSF-CS13 Control Points, CCSF-VD13 Benchmarks and City Monuments.

The field observations should be processed daily. After completion of the control traverse, submit the draft survey report with the minimally constrained and constrained traverse adjustments to BSM for review prior to beginning the topographic survey. BSM will make every effort to review and approve the results within two days.

StarNet is the Least Squares Program used by BSM to adjust traverses and is preferred for processing and adjusting traverse observations in CCSF-CS13 and CCSF-VD13. If there is sufficient redundancy and the adjustment parameters are set up properly, the least squares solution provides the most robust method for detecting blunders, properly distributing random errors and creating a statistical report of the accuracy.

BSM's intention is to have uniform and complete submittals from all contractors to expedite the process on both ends. The field surveys, data processing and preparation of submittals for BSM

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"CCSF BSM Projects: Surveying, Processing & Reporting Requirements"

Documents Emailed to Contractors on 5/24/2018, to be updated

Appendix of Supporting Documents

General

CCSF 2013 HPN coords – 2013 HPN Geodetic and CCSF-CS13 Projection Coordinate Lists
CCSF-Benchmark List-2013 Vertical Datum - Benchmark List of all CCSF-VD13 Benchmarks with the heights in meters and feet current through the indicated date.
CCSF-HPND Coordinate List – HPND Coordinate List (HPN Densification) of latitudes, longitude, ellipsoid heights, CCSF-CS13 coordinates and CCSF-VD13 heights in feet current through the indicated date.
Datum-H-V Simplified CCSF - Explanation of CCSF Datums and Reference Frames in SF
Geodesy Summary – CCSF HPN Network densification description, history and status.

Forms

Form-SurveyRpt-LongForm-Traverse - Example Long Form Traverse Survey Report
Form-SurveyRpt-ShortForm-Traverse - Example Short Form Traverse Report (small projects)

Guides

Guide-FileNamingProtocolsForInstruments
Guide-Instructions for Monument Visit
Guide-PhotoDocumentation-DestroyedSurveyPoints
Guide-PhotoDocumentation-SurveyPoints
Guide-CCSF Point Numbering System - Guide for naming control, topo etc. points
Guide-StarNet v8-CS13 Install Instructions - Setting up the CCSF-CS13 Projection in Starnet
Guide-SurveyProcedure-Establishing SF-CS13 CoordsOnMonuments (subs)
Guide-Traverse Adjustment-Analysis.doc – Training Guide for processing traverse adjustments in Starnet.

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"Datum-H-V Simplified CCSF Version 4.31.docx"

Available on the CCSF Web Site & Supporting Document

CCSF Datums, Coordinates Systems, Reference Frames and Acronyms

CCSF DATUMS & REFERENCE NETWORKS

Geometric & Horizontal Datum:
The City & County of San Francisco (the City) geometric and horizontal datum is the North American Datum of 1983, 2011 Adjustment at the 2010.00 Epoch and referred to as "NAD83 (2011) 2010.00 Epoch". This datum realization is referenced by the published latitudes, longitudes and ellipsoid heights on the 2013 High Precision Network (HPN). A system of plane coordinates was created for the City in 2013 similar to the California State Plane Coordinate System. The System is referred to as the "City & County of San Francisco 2013 Coordinate System" (CCSF-CS13). This System is used for coordinating surveying and mapping projects and GIS. The coordinate system is a low distortion Transverse Mercator Projection designed such that the combined grid factor is generally less than 1/100,000. The projection origin (Projection North = Geodetic North) is located near the center of the City which minimizes the convergence of meridians to less than +/-3 minutes at the east and west edges of the City. This projection is applied to NAD83 (2011) 2010.00 Epoch latitudes and longitudes to obtain grid (plane) coordinates and is properly referred to as the "NAD83 (2011) 2010.00 Epoch City & County of San Francisco 2013 Coordinate System".

Vertical Datum:
The City vertical datum is the "CCSF 2013 NAVD88 Vertical Datum" (CCSF-VD13) based on NAVD88 as recovered by the 2013 City high precision leveling surveys. This datum realization is referenced by benchmarks in the "CCSF 2013 High Precision Leveling Network". See the 2013 High Precision Leveling Report on file with the City & County Surveyor and available on the City's Geodesy web site.

Reference Networks:
The "NAD83 (2011) 2010.00 Epoch" geometric datum and the "City & County of San Francisco 2013 Coordinate System" (CCSF-CS13) are referenced by the CCSF 2013 High Precision Network (CCSF-2013 HPN). A reference to the "HPN" is to the physical monuments constituting the network not to the CCSF-CS13 Coordinate System or CCSF-VD13 Vertical Datum. The "CCSF 2013 NAVD88 Vertical Datum" (CCSF-VD13) is referenced by the benchmarks in the "CCSF 2013 High Precision Leveling Network".

Note: For more information and SF-CS13 Projection Parameters see Record of Survey #8080 and the City web site at http://www.sfpublicworks.org/ccsf-geodetic-network

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Acronyms: City Reference Systems

- HPN = "High Precision Network" of 20 control points established in 2013 and expanded to 28 points in the 2018 HPN Re-Survey to reference the City coordinate systems.

  Known as "Primary Control" - Accuracy of 5 x 5 mm at 95% - ID Range 101-199

- HPND = "High Precision Network Densification" of 285+ control points set for control on City projects since 2014.

  Known as "Secondary Control" – Accuracy of 10 x 15 mm at 95% - ID Range 200-1999

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Acronyms: City Reference Systems

- TND = "Tertiary Network Densification" points set for control on City projects beginning in late 2017.

  Known as "Tertiary Control" - Accuracy of 2 x 3 cm at 95% - ID Range 6000-8999

  Used to establish control on-site in real-time utilizing the Smartnet RTN as referenced to a special SF "Mount Point"

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Acronyms: City Horizontal & Vertical Coordinate Systems

- CCSF-CS13 = "City & County of San Francisco Coordinate System of 2013": The City's official horizontal grid coordinate system is a low distortion projection centered in the City unlike the CA State Plane Coordinate System a project centered on the State.
- CCSF-VD13 = "City & County of San Francisco Vertical Datum of 2013": The City's official orthometric height system based on the recovery of NAVD88 in the City

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2013 City Coordinate System

City & County of San Francisco Coordinate System of 2013 "CCSF-CS13"

- Custom coordinate system designed for and centered on the City & County of SF
- A "Low Distortion Projection" that converts NAD83(2011) Epoch 2010.00 geodetic coordinates to grid coordinates (plane coordinates).

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CCSF-CS13: Low Distortion Projection

Designed to Minimize the Difference in Grid verses Ground Distances, The Distances are not Ground.

- SFSF-CS13 provides a grid scale distortion of less than 1:100,000 (10 ppm) in most parts of CCSF
- On average, a ground distance of 1000.00 feet is equal to:

  1000.00 feet in the CCSF-CS13

  Verses

  999.93 feet in State Plane Coordinates Zone 3

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CCSF-CS13: City Coordinate System

- CCSF-CS13 is a local coordinate system created coincidental with the City's 2013 HPN Survey and based on NAD83(2011) Epoch 2010.00.
- Prior to the creation of CCSF-CS13, most surveys were based on a scaled to ground version of NAD83(1992) Epoch 1991.35 CA State Plane Coordinates.
- CCSF-CS13, like CA State Plane Coordinates, is a grid projection but there is no relationship. SPC's is just another coordinate system.

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CCSF-CS13 - A Low Distortion Projection,

- The projection surface height where the Combined Scale Factor is 1.0 (no distortion) is positioned vertically above the GRS Ellipsoid so as to minimize the distortion across the City.
- The elevation of the projection surface where the scale = 1, is 253 feet on CCSF-VD13 = NAVD88 Shown as the purple contour on next slide.

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CCSF-CS13: "Combined Scale" Contours

Yellow= -10 ppm, Purple= 0 ppm (Scale=1), Green= +10 ppm

ORIGIN
111
201
110
112
120
103
113
119
109
101
104
114
203
102
108
202
115
116
105
117
106
107
Geary Blvd
Lincoln Way
San Francisco
Central Ave
Ave of the Stars
Sunset Blvd
Great Highway
Ocean Ave
Alemany Blvd
Junipero Serra Blvd
Bay Shore Blvd
Mission St
Van Ness Ave
Gough St
Fillmore St
Divisadero St
Lincoln Park
Golden Gate Park
Presidio
Presidio Terrace
Sea Cliff
Richmond District
Sunset District
Ingleside
Excelsior
Bernal Heights
Mission District
Potrero Hill
Bayview
Hunters Point
Visitacion Valley
Mission Bay
Dogpatch
Bernal Heights
Glen Park
Diamond Heights
Twin Peaks
Sutro Heights
Lake Merced
Stonestown
Parkmerced
Ingleside Terrace
Balboa Park
Excelsior District
Outer Mission
Bayshore
Visitacion Valley
Portola
Ocean View
Merced Heights
Sunset District
Richmond District
Presidio Heights
Pacific Heights
Cow Hollow
Marina District
Russian Hill
Nob Hill
Tenderloin
Mission District
Potrero Hill

New CCSF-CS13 Coordinate System

- *Projection specifications for input in user's software:*

  Projection: Transverse Mercator
  Ellipsoid: GRS-80
  Scale: 1.000007 (sets the surface above the ellipsoid)
  Latitude of Origin: 37°45'00" (37.75°)
  Central Meridian: -122°27'00" (-122.45°)
  False Northing: 24000 meters (78740 feet)
  False Easting: 48000 meters (157480 feet)

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VERTICAL DATUMS in SF

Old "City Datum"

National Geodetic Vertical Datum of 1929 (NGVD29)

North American Vertical Datum of 1988 (NAVD88)

18

Vertical Datum Relationships

Old City Datum, NGVD29, NAVD88 = CCSF-VD13

```
---- 0.00 -- Old "City Datum" (Zero) ------------
        |
        |
        |
        |
        |
        |
      8.6' +/- (varies with location}
        |
        |
        |
        |
        |
  ----0.00 ---  NGVD29 ~ Mean Sea Level ~ NAVD2022
        |
      2.7' +/-(varies with location)
        |
----- 0.00 ---  NAVD88 = CCSF-VD13 ~ MLLW not by design
```

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VERTICAL DATUMS in SF

- Old "City Datum"
  - The SF legacy datum primarily is use until 2013
- National Geodetic Vertical Datum of 1929 (NGVD29)
  - Zero is approximately mean sea level
- The North American Vertical Datum of 1988 (NAVD88)
  - The current national datum superseded the NGVD29 in 1991.
  - Zero is approximately at mean lower low water (not by design)
  - Zero is about -11.35 feet on the Old City Datum
  - CCSF-VD13 is based on NAVD88 as recovered in the City in 2013
- New National Datums coming in 2022?

20

2013 & 2014-2015 High Precision Leveling Network

142 Miles of Leveling - Average Closures <0.01'

21

RECOVERING THE NAVD88 DATUM

- The NAVD88 Datum is realized by NGS Benchmarks
- All NGS BM's are shown below; the brown are Vertcon
- NAVD88 network (green & yellow) were leveled 1977-1989, adjusted 1991 and published

22

NAVD88 DATUM RECOVERY:

- The 2013 Precise Leveling Network including 35 NGS, of which 26 were "Adjusted" NAVD88 Benchmarks

23

CCSF-VD13 = NAVD88 in the City

- "CCSF-VD13" is a realization of the NAVD88 Datum, in the City, as a result of the 2013 leveling surveys
  - Based on the best fit of the published heights on 25
  - "Adjusted" NGS NAVD88 Benchmarks and a subset of 12 Stability A/B. The datum was recovered with a standard deviation of 0.008 feet.
- This realization improved the relative accuracy of the NGS benchmarks having been in the ground for 30 years since the original leveling and supersedes the published heights on the NGS Data Sheets
- Report, Specifications & Benchmark List are on the City Web Site

24

CCSF-VD13 verses the Old City datum

- CCSF-VD13 supersedes the old "City Datum"

WHY?

Not Maintained,

Subsidence,

Benchmarks in same intersection can differ 0.2',

Many are lost - most will be in a few years

25

Old City Datum Benchmark Sheet

MISSION ST: 11TH ST intersection [24421000]

subdivision & mapping

benchmark

bench id	location	date of survey	surveyor	book	page	box	comments
503	11TH ST: MISSION ST intersection	MARCH 1991	SCOTT	492	16	4	NONE

strCORNER	strBENCH	strELEVATION	destroyed
NE	crow cut outer rim SWI	29.476	
NW	+ cut E rim MRY MH in walk	30.475	
SE	crow cut outer rim SWI	29.627	
SW	+ cut S rim MRY MH in walk	30.294	
SE 30'S	+ cut top conc fdn. 1' up	31.051	

Many are lost - most will be in a few years

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Old City Datum Benchmarks

BM's in the same intersection do not agree!

BM DESCRIPTION		NAVD88	CITY	DIFF
SE	3 cuts low stop cock fire hydrant	18.036	6.777	11.259
SE	crow cut outer rim SWI	15.767	4.494	11.273
SW	crow cut outer rim SWI	15.883	4.582	11.301
SW	+ cut ASW @ bldg	16.930	5.608	11.322
	AVERAGE DIFF			11.289

< Diff's vary up to 0.06'

< Xn-Xn Diff's vary 0.14'

INTERSECTION: 16TH ST & CONNECTICUT ST (Book 482, Page 37, Record No. 588)

BM DESCRIPTION		NAVD88	CITY	DIFF
SE	3 cuts low stop cock fire hydrant	17.278	6.103	11.175
SW	crow cut outer rim SWI	15.010	3.747	11.263
SW	+ cut ASW @ bldg	15.968	4.700	11.268
CC 30' N	+ cut conc cess	15.553	4.362	11.191
	AVERAGE DIFF			11.224

< Diff's vary up to 0.10'

INTERSECTION: 16TH ST & MISSOURI ST (Book 482, Page 36, Record No. 582)

BM DESCRIPTION		NAVD88	CITY	DIFF
SW	crow cut outer rim SWI	14.526	3.224	11.302
SW 35'W	+ cut E end low conc step	17.174	5.829	11.345
SE	3 cuts low stop cock fire hydrant	17.142	5.850	11.292

The differences between CCSF-VD13 and the Old City Datum varies 10.9 to 11.8 feet City wide

27

Converting CCSF-VD13 Heights to Old City Datum

- In 2013, the City & County Surveyor approved a conversion to be applied to CCSF-VD13 heights that estimates elevations in the Old City Datum as follows:

CCSF-VD13 - 11.35 feet = Old City Datum

~~City Datum + 11.35 feet = CCSF-VD13~~

Converting from the Old City Datum to CCSF-VD13 is UNDEFINED

- **Do Not Use the Old City Datum Unless it is Job Specified**

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Methods to Recovering the Old City Datum

Recover Generically: Apply the approved conversion
CCSF-VD13 - 11.35 feet ~ Old City Datum
Accuracy probably a ½ foot across the City.

Recover Locally: Include the nearest Old City Datum Benchmarks in the survey.
Accuracy probably a 0.1 feet locally.

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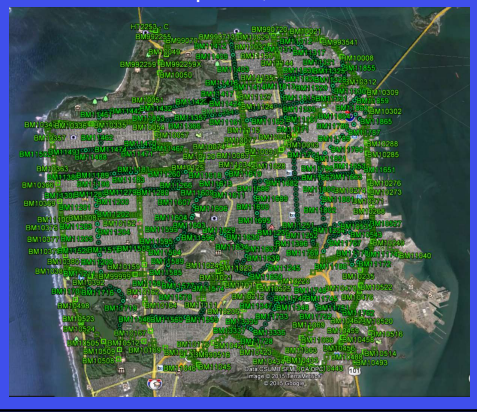
2013 & 2014-2015 High Precision Leveling Network

142 Miles of Leveling - Average Closures <0.01'

30

2013-2015 Established1454 CCSF-VD13 Benchmarks in San Francisco

KMZ File for Viewing in Google Earth (below),
Benchmark Descriptions, Photos on Website



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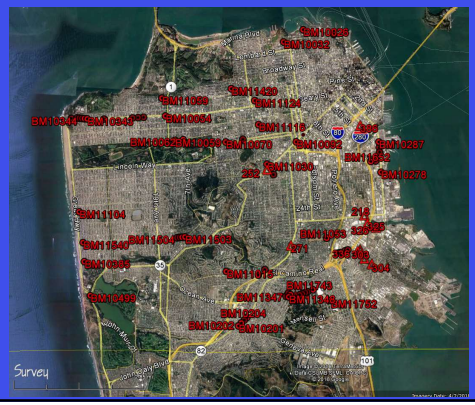
Destroyed Benchmarks & HPND Mon's

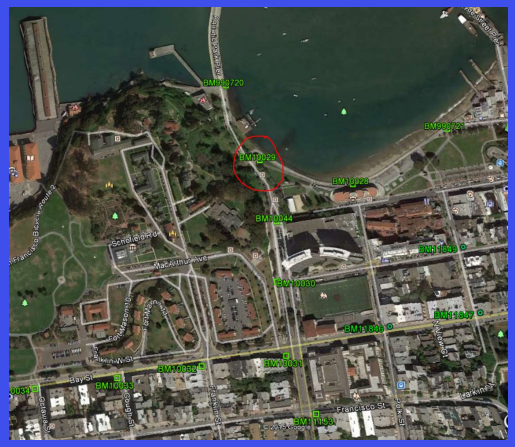
Please Email Geodesy if aware of any monument type found to be destroyed.
geodesy@sfdpw.org



32

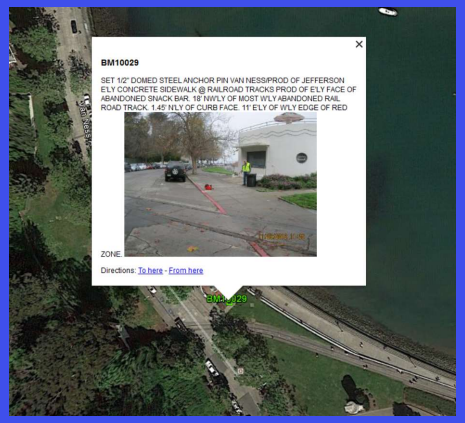
Load the various KMZ's in Google Earth

Zoom in to an area of interest



33

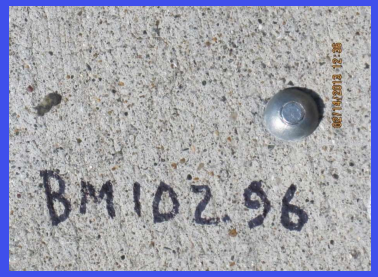
View Benchmark Description & Photos



34

631 Benchmarks Established in 2013

2013 Benchmark Monument



35

823 Benchmarks Established in 2014-15

2014-15 Benchmark Monument
&
HPND and TND (stamped with ID)

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2013 Leveling Report (below), Survey Specifications and Benchmark Elevation List Available on the Web Site

Survey Report
on the
City & County of San Francisco 2013 Second Order Leveling Network Survey and the "CCSF 2013 NAVD88 Vertical Datum"
February 28, 2014
prepared by
McGee Surveying Consulting and F3 & Associates, Inc.

PROJECT OVERVIEW: The City & County of San Francisco (CCSF) performed a Second Order Leveling Survey between January and October 2013. The purpose was to recover the North American Vertical Datum of 1988 (NAVD88) and establish a vertical control reference network within the City and County henceforth known as the "CCSF 2013 NAVD88 Vertical Datum" (see Figure 1). Heights resulting from this survey supersede previously published NAVD88 Heights and the old CCSF Datum. This network will support the utilization of GNSS technology for establishing orthometric heights within the County.

DATUM, REFERENCE SYSTEM and HISTORY: Orthometric heights (elevations) published by this survey are based on the North American Vertical Datum of 1988 (NAVD 88) established by the National Geodetic Survey (NGS) as referenced by monuments in the National Spatial Reference System (NSRS). The analysis and recovery assessment of the NAVD88 Datum in the City and County is provided hereafter.

Circa 1977 and 1988 the NGS performed "First Order Class I" leveling surveys along the northeast side of San Francisco and from Highway 101 south along Highway 1. These surveys were part of a national leveling effort to produce the NAVD88 Datum. The results were published in 1991 as the original national adjustment of NAVD88 superseding the National Geodetic Vertical Datum of 1929 (NGVD29). Zero on NAVD88 is approximately 0.83 meters (2.72 feet) lower than zero on NGVD29 and varies approximately 0.80 to 0.86 meters in CCSF.

Figure 1: Level Network and High Precision Network Points

VERTICAL NETWORK: The vertical control network consists of 22 loops totaling 113 kilometers (72 miles) and range from 2-177 meters (6-581 feet) above sea level. The loops were assigned letter designations of "A" through "V" shown in Figures 1 and 2. Five primary loops labeled "A" through "E" form the backbone network totaling 77 kilometers with 17 secondary loops totaling 38 kilometers. Approximately 670 new permanent benchmarks were established. The "CCSF 2013 High Precision Network" (CCSF-HPN) (points 101-120) were included in the network (see the "Survey Report of the City and County of San Francisco 2013 High Precision Network" on file in the City and County Surveyor's Office).

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Benchmark Descriptions
Available on the CCSF Website

BM#	STATUS	TYPE	LOCATION	DESCRIPTION	DATE SET/ RECOVERED	AB#	COMMENTS	LEVEL FILE # DATE
BM10013	SET	1/2" DOWED STEEL ANCHOR PIN	SOUTHEAST CORNER OF SANSOME @ CHESTNUT/EMBARCADERO	IN CONCRETE SIDEWALK BETWEEN 2 HANDICAP RAMPS - ONE FACING SANSOME, ONE FACING EMBARCADERO. 5.1' RADIAL FROM FACE OF CURB @ ± 1/2 DELTA. 2.2' SOUTH OF CENTER TRAFFIC SIGNAL PULLBOX. 8.0' NORTH OF TRAFFIC SIGNAL CABINET. 18' NORTH OF TRAFFIC SIGNAL LIGHT @ EMBARCADERO.	11/24/2012	0058		D003AL01 1/3/2013
BM10014	SET	1/2" DOWED STEEL ANCHOR PIN	SOUTHWEST CORNER OF MONGOMERY @ CHESTNUT 1621 MONTGOMERY ST	1621 MONTGOMERY ST. IN SIDEWALK SOUTH OF HANDICAP RAMP FACING CHESTNUT. 6.4' RADIAL DIST FROM FACE OF CURB @ CATCH BASIN. 3.3' SOUTHWESTERLY FROM CENTER OF CABLE TV BOX. 2.5' NORTHWEST FROM CENTER TRAFFIC LIGHT BOX. 9' NORTHWESTERLY FROM STREET LAMP.	11/24/2012	0060		D003AL01 1/3/2013
BM10015	SET	1/2" DOWED STEEL ANCHOR PIN	SOUTHWEST CORNER OF MONTGOMERY @ FRANCISCO	55 FRANCISCO ST. 6.3' SOUTHWEST - RADIALLY FROM FACE OF CURB @ CATCH BASIN. WEST OF HANDICAP RAMP - FACING MONGOMERY ST. 4.4' SOUTHWEST OF FIRE ALARM BOX. 4.2' SOUTHEAST OF STREET SIGN.	11/24/2012	0056		D003AL01 1/3/2013
BM10016	SET/RECOVER	1/2" DOWED STEEL ANCHOR PIN	SOUTHWEST CORNER OF KEARNY @ BAY	SET 1/2" DOWED STEEL ANCHOR PIN SOUTHWEST CORNER OF KEARNY @ BAY. SOUTH SIDE OF NORTH POINT WATER TREATMENT PLANT. 6.2' RADIALLY FROM FACE OF CURB. SW OF TWO HANDICAP RAMPS - ONE FACING KEARNY, ONE FACING BAY. 1.2' NORTH OF ELECTRIC BOX. 5.0' NORTHWEST OF TRAFFIC LIGHT SIGNAL @ KEARNY ST. 11.0' SOUTHEAST OF TOP OF WALL @ BAY ST.	11/24/2012	0057		
BM10017	SET	1/2" DOWED STEEL ANCHOR PIN	SOUTHWEST CORNER OF BAY @ MIDWAY	125 BAY ST. 5.4' RADIALLY FROM FACE OF CURB @ CATCH BASIN. WEST OF HANDICAP RAMP FACING MIDWAY. 5' SOUTHEAST OF HIGH PRESSURE FIRE HYDRANT. 1.8' SOUTH OF POSE PULLBOX. 10' NORTHWEST OF STREET LIGHT @ MIDWAY.	11/24/2012	0039		D003AL01 1/3/2013

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CCSF-VD13 2013-2015 Benchmark List (Blue Doc)
Available on the CCSF Web Site
Supporting Document

CITY & COUNTY OF SAN FRANCISCO

CCSF Vertical Datum of 2013 (CCSF-VD13) Benchmark List
NAVD88 Datum as Recovered by CCSF in 2013
Publish Date: Septemebre15, 2015, Revised February 9, 2017, June 6, 2018

City & County of San Francisco
2013 NAVD88 Vertical Datum (CCSF-VD13) Benchmark List

The City & County of San Francisco (CCSF) completed 72 miles of precise leveling surveys in 2013 and established 631 benchmarks. The survey recovered the North American Vertical Datum of 1988 (NAVD88) based on 35 National Geodetic Survey (NGS) Benchmarks. The published NAVD88 Heights on NGS benchmarks were found to vary +/- 2 centimeters from a best fit solution used to establish a vertical reference frame known as the "CCSF 2013 NAVD88 Vertical Datum" (referred to as CCSF-VD13). For details see the February 28, 2014 Survey Report titled "CCSF 2013 Second Order Leveling Network Survey and the CCSF 2013 NAVD88 Vertical Datum" on file with the County Surveyor and posted on the City web site. In 2014, a densification effort established 823 benchmarks adding 70 miles to the network. The 2014 densification surveys were constrained to the 2013 network. As of September 2015, 1454 CCSF-VD13 Benchmarks had been established notwithstanding monuments lost due to construction. Please report destroyed monuments to geodesy@sfdpw.org. The point number range reserved for benchmarks is 10001-15999.

The accuracy of the network is indicated by the loop closures. The pre-adjustment closures of the 2013 loops were generally 0.01 feet (3 millimeters). The pre-adjustment closures of the 2014 densification loops on the 2013 network were generally less than 0.01 feet (3 millimeters). The relative accuracy of undisturbed benchmarks is expected to be 1-2 millimeters. The survey was performed in metric units carried to the nearest millimeter. The heights are provided below in meters and US survey feet. The units of feet are provided to three decimal places to preserve the metric accuracy of 1 millimeter (0.003 feet). These heights supersede preliminary adjustments of the 2014 densification benchmarks which may vary 0.01 feet.

CCSF-VD13 supersedes the old City Datum. The difference between CCSF-VD13 and the Old City Datum varies across the City. The conversion approved by the City & County Surveyor to estimate the Old City Datum follows: CCSF-VD13 (feet) - 11.35 feet = Old City Datum in feet. The actual differences on Old City Datum benchmarks may vary between 11.2' and 11.5' or greater due to subsidence and lack of maintenance. Adding

Listed below are the CCSF-VD13 orthometric heights of NGS Benchmarks utilized in the recovery of NAVD88 by the City in 2013. NGS Benchmarks were assigned "99" + "last 4 digits of its NGS PID" (see Survey Report referred to above for details).

CCSF ID (aka)	NGS PID	Feet	Meters
990515	HT0515	300.285	91.527
990516	HT0516	304.209	92.723
990517	HT0517	295.531	90.078
990604	HT0604	15.390	4.691
990687	HT0687	12.402	3.780
990692	HT0692	15.528	4.733
990697	HT0697	16.480	5.023
990698	HT0698	13.937	4.248
990700	HT0700	13.894	4.235
990701 (111)	HT0701	13.123	4.000
990702	HT0702	13.071	3.984

Listed below are the CCSF-VD13 Heights of the City's High Precision Network (HPN) established in 2013 and described in RS #8080.

HPN	Feet	Meters
101	494.746	150.799
102	560.993	170.991
103	152.076	46.353
104	24.770	7.550
105	185.331	56.489
106	361.882	110.302
107	12.129	3.697
108	14.711	4.484
109	11.355	3.461
110	10.758	3.279
111	13.123	4.000
112	178.294	54.344

City & County of San Francisco
2013 NAVD88 Vertical Datum (CCSF-VD13) Benchmark List

Benchmark	Feet	Meters	Benchmark	Feet	Meters
318	13.574	4.137	10029	18.993	5.789
319	17.332	5.283	10030	69.275	21.115
321	8.758	2.669	10031	86.785	26.452
322	11.814	3.601	10032 #	76.578	23.341
323	20.347	6.202	10033	66.525	20.277
325	12.458	3.797	10034	56.188	17.126
336	23.739	7.236	10035	41.640	12.692
340	20.351	6.203	10036	28.504	8.688
10001	9.715	2.961	10037	23.629	7.202
10002	9.180	2.798	10038	17.193	5.240

Horizontal, 3D Regional and City Control Network

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HORIZONTAL DATUMS & REALIZATIONS

- North American Datum of 1927 "NAD27"
- North American Datum of 1983 "NAD83(1986)"

Newer Realization of NAD83

- NAD83(1992) Epoch 1991.35
- NAD83(2011) Epoch 2010.00

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NAD27 - HORIZONTAL DATUM

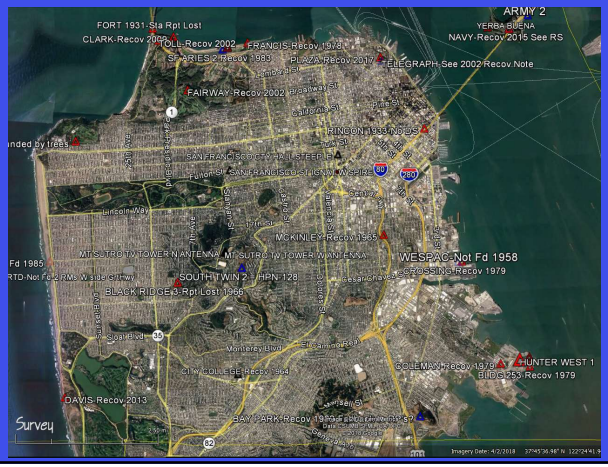
North American Datum of 1927

- National Datum superseded by NAD83
- Constrained to a single point in Kansas (Meade's Ranch)
- Based on old measured triangulation
- Some BSM projects are based on NAD27 State Plane Coordinates (SPC)
- Referenced by the legacy NGS Triangulation Stations in the City with a relative accuracy of about ½ foot

42

Legacy NGS Triangulation Stations in SF

Source for Recovering NAD27 & NAD83(1986) Datums



43

NAD83 - HORIZONTAL DATUM

North American Datum of 1983 Adj'd 1986

- NAD83 was based on the old NAD27 triangulation measurements and some EDM measurements
- Constrained to the global Very Long Baseline Interferometry Network (VLBI) at Epoch 1984.0. "NAD83(1986) Epoch 1984.0".
- The difference between an NAD83 coordinate and a NAD27 coordinate on the same monument is about 300 feet from NAD27.
- NAD83(1986) is referenced by the legacy NGS Tri-Stations with a relative accuracy of about ½ foot.

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North American Datum of 1983 "NAD83(1992) Epoch 1991.35"

- The accuracy and precision of NAD83 was upgraded with a new realization in 1992 after satellite based measurement systems (GPS) became available
- The 1992 adjustment is a high precision realization of NAD83, independently constrained to the VLBI Network and physically referenced by the High Precision Geodetic Network (HPGN) in California.
- This realization has a relative accuracy of several centimeters and is referred to as "NAD83(1992) Epoch 1991.35"

45

Recovering "NAD83(1992) Epoch 1991.35"

- The legacy triangulation stations (based on legacy conventional measurements) were later re-adjusted and constrained to the 1992 HPGN Adjustment; however, they have no ellipsoid heights because they are not based on GPS and the relative accuracy is still about ½ foot
- The recovery of NAD83(1992) Epoch 1991.35 should be based on the HPGN or stations with ellipsoid heights, not the legacy triangulation stations even though their positions are listed in the NGS Data Sheets as "NAD83(1992) Epoch 1991.35"

46

Compare a GPS measured position with the position derived from a re-adjustment of legacy triangulation measurements at Epoch 1991.35

NGS PID

HT0613 = "Hunter West 1" Triangulation Sta.

Latitude	Longitude	Source
37 43 41.93549	122 21 43.69289	HPGN
37 43 41.93343	122 21 43.68924	Tri-Station

Diff ~ S 0.2' x E 0.3'

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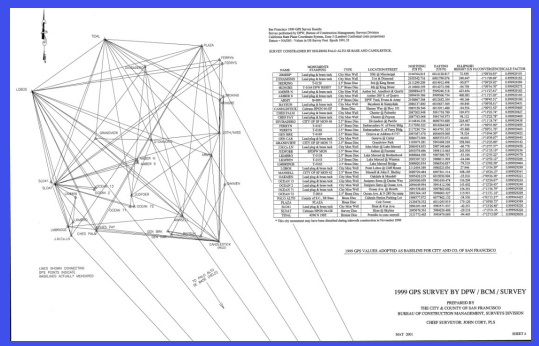
CCSF 1992-1999 Control Networks

GPS Control Networks were established in SF between 1992 and 1999 as shown on a seven page map; coordinates agree 0.05 feet with the "NAD83(1992) Epoch 1991.35" positions on the HPGN Data Sheets. Not Used



1991-1999 GPS Surveys (Page 4/7) *Available on the CCSF Web Site*

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NAD83(2011) Epoch 2010.00, Epochs & Velocities in SF

- Numerous re-adjustments of NAD83 have resulted in newer realizations
- The latest is "NAD83(2011) Epoch 2010.00" which is the reference frame for all coordinates in SF since 2013.
- The difference in the coordinates of a point measured and published on the 1991.35 Epoch and the current 2010.00 Epoch is about 2.08 feet.

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NAD83(2011) Epoch 2010.00, Epochs & Velocities in SF

- "Epochs" are necessary because SF is moving NNW'ly with a velocity of N 33-54-31 W 0.111 feet per year;

Therefore, the actual position (physical location) is changing relative to the fixed North American Plate, but we retain the NAD83(2011) Epoch 2010.00 positions in the City.

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Expect SF to remain on the NAD83(2011) 2010.00 Realization

- Why? 2018 Re-Survey Findings! (see next slide)
  No Differential Movement within the City,
  no rotation or scale change,
  City moving as a block (see next slide)
- What about the upcoming 2022 Datums?
  Everything shifts 6 feet horizontal & 0.8 feet vertical

51

2D Conformal Transformation of the 2013 HPN Coordinates to the 2018 HPN Coordinates

Relative Position Analysis of 2013 & 2018 HPN Surveys

Triad Transformation Solution: Fit 2013 to 2018 HPN Positions

(2D Conformal - with 105 set free)

2013 verses 2018 Differences in Positions (Meters)

2013	To> 2018	North	East	N.Azim & 2D Dist
13101	101	+0.000	+0.002	92° 0.002
13102	102	-0.002	+0.001	150° 0.003
13103	103	-0.002	-0.001	221° 0.002
13104	104	+0.001	-0.005	287° 0.005
13105	105	+0.006	-0.014	294° 0.015
13106	106	+0.005	-0.002	343° 0.006
13107	107	+0.003	-0.001	333° 0.003
13108	108	+0.001	+0.003	65° 0.003
13109	109	-0.002	+0.003	121° 0.004
13110	110	+0.000	+0.002	80° 0.002
13111	111	-0.002	-0.001	215° 0.002
13112	112	-0.002	-0.004	242° 0.005
13113	113	-0.002	-0.001	206° 0.002
13114	114	+0.000	-0.001	289° 0.001
13115	115	+0.003	-0.001	350° 0.003
13116	116	+0.003	-0.001	341° 0.003
13117	117	+0.001	+0.001	44° 0.001
13118	118	+0.001	+0.005	80° 0.005
13119	119	-0.004	+0.002	153° 0.005
13120	120	-0.002	-0.001	197° 0.002

Mean 2D Difference = 3.1 mm, SD = 1.6 mm, Range 1-6 mm (not including 105)

Scale Factor = 0.99999985 Standard Deviation = 0.00000012

Rotation = +0° 00' 00.1" Standard Deviation = 0° 00' 00.0"

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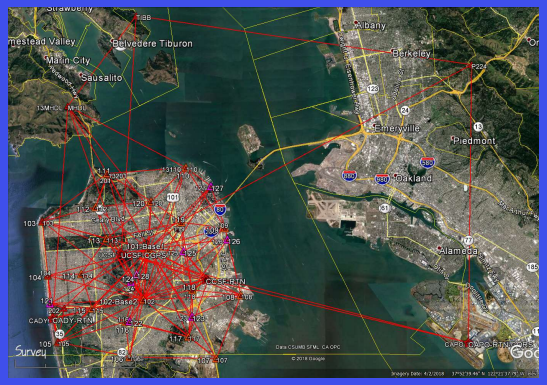
HPN–CGPS-RTN-CORS 2018 Network



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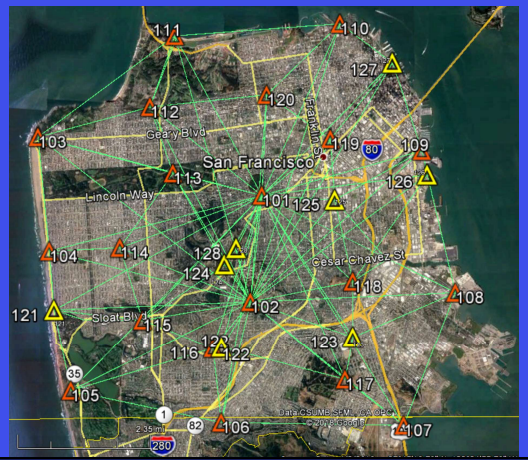
CCSF 2018 High Precision Network (HPN) of 28 Points (8 New Points)



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HPN Monuments in Rock Outcrops

HPN-101 top of Corona Hts Park
(North Central Radial Base)

HPN-102 off Marietta Drive
(South Central Radial Base)

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HPN Monuments Set in Stable Structures

HPN 103 at Lands End

HPN 116 at San Francisco City College

HPN Monuments

Set HPN 108 Monument

Existing NGS Monument
Used for HPN 104

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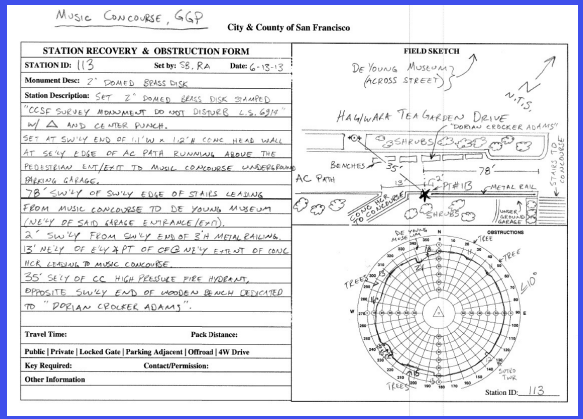
HPN Station Recovery-Obstruction Diagrams, Photos and KMZ Files

Available on the CCSF Web Site



Music Concourse, GGP

City & County of San Francisco

STATION RECOVERY & OBSTRUCTION FORM

STATION ID: 113 **Set by:** SB, RA **Date:** 6-13-13

Monument Desc: 2" DOMED BRASS DISK

Station Description: SET 2" DOMED BRASS DISK STAMPED "CCSF SURVEY MONUMENT DO NOT DISTURB L.S. 6914" W/ △ AND CENTER PUNCH.
SET AT SW'LY END OF 11'W x 1.2'H CONC HEAD WALL AT SE'LY EDGE OF AC PATH RUNNING ABOVE THE PEDESTRIAN EXIT/ENT TO MUSIC CONCOURSE UNDERGROUND PARKING GARAGE.
78' SW'LY OF SW'LY EDGE OF STAIRS LEADING FROM MUSIC CONCOURSE TO DE YOUNG MUSEUM (NE'LY OF SAID GRASS ENTRANCE/EXIT).
2' SW'LY FROM SW'LY END OF 2'H METAL RAILING.
13' NE'LY OF EXT/ENT OF CFG NE'LY EXT/ENT OF CONC. PCR LEADING TO MUSIC CONCOURSE.
35' SE'LY OF CC HIGH PRESSURE FIRE HYDRANT, OPPOSITE SW'LY END OF WOODEN BENCH DEDICATED TO "DORIAN CROCKER ADAMS".

Travel Time: **Pack Distance:**

Public | Private | Locked Gate | Parking Adjacent | Offroad | 4W Drive

Key Required: **Contact/Permission:**

Other Information

FIELD SKETCH

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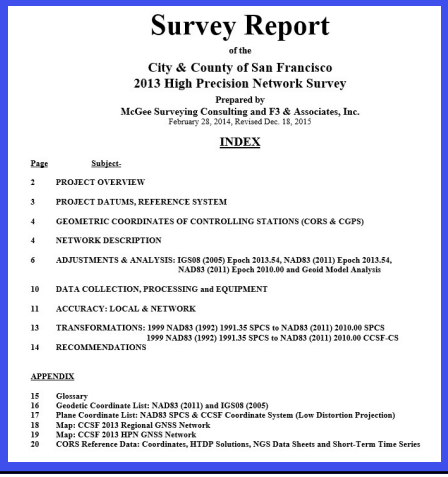
2013 GNSS Survey Report and Coordinate Lists

Available on the CCSF Web Site



Survey Report

of the

City & County of San Francisco
2013 High Precision Network Survey

Prepared by
McGee Surveying Consulting and F3 & Associates, Inc.
February 28, 2014, Revised Dec. 18, 2015

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2013 HPN Coordinate List

Available on the CCSF Web Site - Supporting Document

CCSF Plane Coordinates: NAD83(2011) 2010.00 Epoch and NAVD88 Heights per CCSF 2013 2nd Order Leveling Survey

POINT#	CCSF PLANE COORD. NORTH(m)	CCSF PLANE COORD. EAST(m)	NAVD88 HEIGHT(m)	CCSF PLANE COORD. NORTH(ft)	CCSF PLANE COORD. EAST(ft)	NAVD88 HEIGHT(ft)	Convergence Angle	Factors Scale	Factors x Ellipsoid	Factors = Combined
101	25681.275	48940.932	150.799	84255.983	160567.041	494.746	0-00-23.5	1.00000701	0.99998145	0.99998847
102	22665.032	48608.002	170.991	74360.193	159474.752	560.993	0-00-15.2	1.00000700	0.99997829	0.99998530
103	27356.975	42550.378	46.352	89753.676	139600.697	152.073	-0-02-16.4	1.00000723	0.99999787	1.00000523
104	24117.466	42864.322	7.550	79125.385	140630.698	24.770	-0-02-08.4	1.00000732	1.00000397	1.00001129
105	20140.186	43470.358	56.489	66076.592	142618.999	185.331	-0-01-53.1	1.00000725	0.99999630	1.00000355
106	19230.486	47764.351	110.302	63092.021	156706.874	361.882	-0-00-05.9	1.00000700	0.99998783	0.99999483
107	19134.838	52974.838	3.698	62778.214	173801.613	12.133	0-02-04.2	1.00000730	1.00000454	1.00001185
108	22916.205	54461.117	4.484	75184.248	178677.849	14.711	0-02-41.5	1.00000751	1.00000441	1.00001192
109	26939.924	53514.519	3.461	88385.400	175572.218	11.355	0-02-18.0	1.00000737	1.00000457	1.00001194
110	30546.317	51183.622	3.279	100217.376	167924.933	10.758	0-01-19.8	1.00000712	1.00000459	1.00001172
111	30212.789	46460.090	4.000	99123.126	152427.813	13.123	-0-00-36.6	1.00000703	1.00000449	1.00001152
112	28200.678	45752.500	54.344	92521.723	150106.327	178.294	-0-00-56.3	1.00000706	0.99999660	1.00000366
113	26319.011	46403.311	74.816	86348.290	152241.529	245.459	-0-00-40.0	1.00000703	0.99999338	1.00000042
114	24211.614	44882.700	99.656	79434.271	147252.657	326.955	-0-01-18.0	1.00000712	0.99998950	0.99999662
115	22147.178	45523.733	61.448	72661.199	149355.781	201.601	-0-01-01.9	1.00000708	0.99999550	1.00000257
116	21342.501	47533.342	89.985	70021.189	155948.974	295.226	-0-00-11.7	1.00000700	0.99999101	0.99999801
117	20442.606	51304.532	117.172	67068.783	168321.620	384.422	0-01-22.5	1.00000713	0.99998674	0.99999387
118	23236.307	51531.650	78.553	76234.451	169066.754	257.719	0-01-28.3	1.00000715	0.99999279	0.99999994
119	27280.254	50901.352	18.941	89501.966	166998.851	62.142	0-01-12.6	1.00000710	1.00000214	1.00000924
120	28536.156	49084.584	85.887	93622.371	161038.340	281.781	0-00-27.1	1.00000701	0.99999164	0.99999865
201	30172.563	46512.431	3.659	98991.152	152599.533	12.005	-0-00-37.3	1.00000703	1.00000454	1.00001157
202	22161.547	43861.056	23.761	72708.341	143900.815	77.956	-0-01-43.4	1.00000721	1.00000142	1.00000863
203	23862.437	52492.350		78288.679	172218.652		0-01-52.3	1.00000725	1.00000434	1.00001159
CCSF	23866.723	52367.837	16.66*	78302.739	171810.144	54.65	0-01-49.2	1.00000723	1.00000250	1.00000974
MHDL	34247.715	44099.030		112361.043	144681.568		-0-01-37.9	1.00000719	0.99998958	0.99999677
UCSF	25438.989	47283.113	187.77*	83461.083	155128.014	616.03*	-0-00-17.9	1.00000701	0.99997566	0.99998266
						Average	0-00-04.1	1.00000715	0.99999560	1.00000275

Projection Specifications:
Projection: Transverse Mercator, Ellipsoid: GRS-80, Scale: 1.000007, Latitude of Origin: 37°45'00",
Central Meridian: -122°27'00", False Northing: 24000.0 meters, False Easting: 48000.0 meters.

* from Geoidal Modeling

NAD83 GEODETIC COORDINATE LIST

DATUM & REFERENCE FRAME: NAD83(2011) Epoch 2010.00

POINT	N. LATITUDE ° ' "	W. LONGITUDE ° ' "	ELLIPSOID HT meters	ELLIPSOID HT feet
101	37-45-54.52969	122-26-21.55646	118.188	387.754
102	37-44-16.70006	122-26-35.16804	138.344	453.883
103	37-46-48.82346	122-30-42.63982	13.532	44.394

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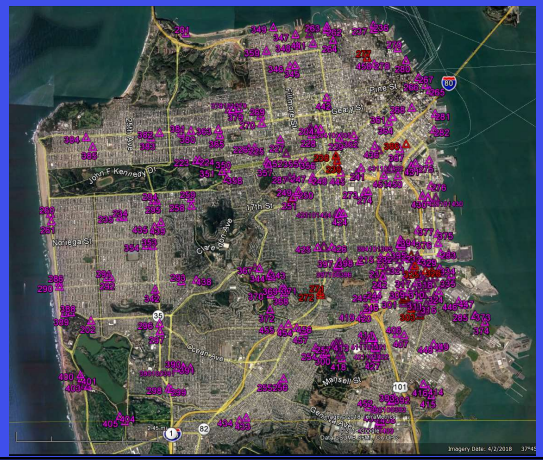
Soon to be updated with the 2018 HPN Re-Survey results

HPND & TND Ongoing Densification of the HPN

285+ HPND Points Set in Support of Projects Since 2014



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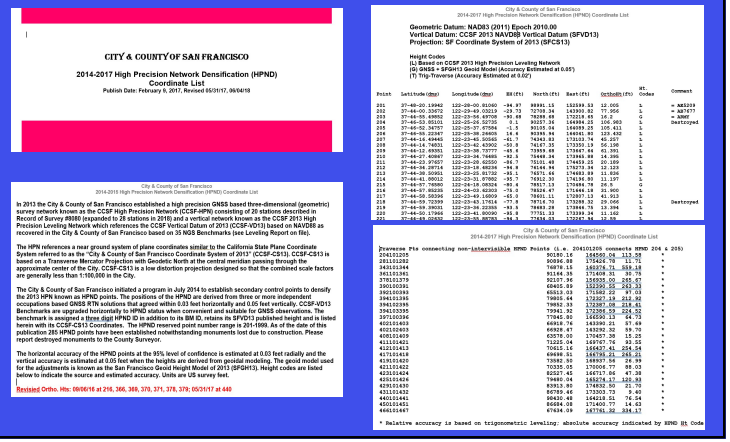
HPND Coordinate List (Red Doc) 2014-2017

Available on the CCSF Web Site - Supporting Document



CITY & COUNTY OF SAN FRANCISCO

2014-2017 High Precision Network Densification (HPND) Coordinate List

Publish Date: February 6, 2017, Revised 05/31/17, 09/04/18

City & County of San Francisco
2014-2015 High Precision Network Densification (HPND) Coordinate List

In 2013 the City & County of San Francisco established a high precision GNSS based three-dimensional (geometric) survey network known as the CCSF High Precision Network (CCSF-HPN) consisting of 20 stations described in Record of Survey #9180 (expanded to 28 stations in 2016) and a vertical network known as the CCSF 2013 High Precision Leveling Network which references the CCSF Vertical Datum of 2013 (CCSF-VD13) based on NAVD88 as recovered in the City & County of San Francisco based on 35 NGS Benchmarks (see Leveling Report on file).

The HPN references a near ground system of plane coordinates similar to the California State Plane Coordinate System referred to as the "City & County of San Francisco Coordinate System of 2013" (CCSF-CS13). CCSF-CS13 is based on a Transverse Mercator Projection with Geodetic North at the central meridian passing through the approximate center of the City. CCSF-CS13 is a low distortion projection designed so that the combined scale factors are generally less than 1:100,000 in the City.

The City & County of San Francisco initiated a program in July 2014 to establish secondary control points to densify the 2013 HPN known as HPND points. The positions of the HPND are derived from three or more independent occupations based GNSS RTN solutions that agreed within 0.03 feet horizontally and 0.05 feet vertically. CCSF-VD13 Benchmarks are upgraded horizontally to HPND status when convenient and suitable for GNSS observations. The benchmark is assigned a three digit HPND ID in addition to its BM ID, retains its SFVD13 published height and is listed herein with its CCSF-CS13 Coordinates. The HPND reserved point number range is 201-1999. As of the date of this publication 285 HPND points have been established notwithstanding monuments lost due to construction. Please report destroyed monuments to the County Surveyor.

The horizontal accuracy of the HPND points at the 95% level of confidence is estimated at 0.03 feet radially and the vertical accuracy is estimated at 0.05 feet when the heights are derived from geoidal modeling. The geoid model used for the adjustments is known as the San Francisco Geoid Height Model of 2013 (SFGH13). Height codes are listed below to indicate the source and estimated accuracy. Units are US survey feet.

Revised Ortho. Hts: 09/06/16 at 216, 366, 369, 370, 371, 378, 379; 05/31/17 at 440

City & County of San Francisco
2014-2017 High Precision Network Densification (HPND) Coordinate List

Geometric Datum: NAD83 (2011) Epoch 2010.00
Vertical Datum: CCSF 2013 NAVD88 Vertical Datum (SFVD13)
Projection: SF Coordinate System of 2013 (SFCS13)

Height Codes
(L) Based on CCSF 2013 High Precision Leveling Network
(G) GNSS + SFGH13 Geoid Model (Accuracy Estimated at 0.05')
(T) Trig.Traverse (Accuracy Estimated at 0.02')

Point	Latitude (dms)	Longitude (dms)	BH (ft)	North (ft)	East (ft)	Orthoht (ft)	Ht. Code	Comment
201	37-46-20.19942	122-28-00.81060	-34.97	88991.13	152399.32	12.005	L	= AA5239
202	37-46-00.35872	122-23-49.03219	-29.73	72709.34	143920.82	77.956	L	= AZ7677
203	37-46-55.89602	122-23-54.69708	-55.69	76288.48	172216.85	16.2	G	= AM987
205	37-46-52.50101	122-23-24.52735	-0.1	89257.36	144884.23	206.983	L	Destroyed
207	37-46-52.34757	122-23-37.67584	-1.5	90105.04	164893.25	105.413	L	
208	37-46-53.22347	122-23-38.28605	16.6	90395.94	164811.90	123.432	L	
209	37-46-14.94651	122-23-40.50020	-51.3	74242.83	173133.74	46.297	L	
210	37-46-12.78831	122-23-38.72577	-45.7	74143.57	173519.14	52.197	L	
212	37-46-27.40987	122-23-24.74485	-92.5	79448.24	173945.88	14.386	L	
211	37-46-23.37527	122-23-28.02550	-86.7	75151.48	174433.22	20.159	L	
213	37-46-34.29714	122-23-18.68236	-94.8	76144.44	175273.34	12.123	L	
214	37-46-41.90512	122-23-31.97856	-85.5	76812.20	174194.95	11.197	L	
215	37-46-41.90512	122-23-31.97856	-85.5	76812.20	174194.95	11.197	L	
215	37-46-37.76580	122-23-18.08324	-85.4	78517.13	175894.78	26.8	G	
216	37-46-57.86285	122-24-03.62203	-72.3	78224.47	171446.16	31.900	L	
217	37-46-55.58395	122-23-49.16809	-65.0	78031.11	172907.13	41.913	L	
218	37-46-54.39031	122-23-49.22188	-63.8	77951.33	173399.34	11.162	L	Destroyed
219	37-46-54.39031	122-23-49.22188	-63.8	78949.28	173844.76	12.996	L	
220	37-46-50.17946	122-23-41.80090	-65.8	77751.33	173399.34	11.162	L	
221	37-46-45.06830	122-23-46.88738	-63.9	77414.41	172214.85	12.59	L	

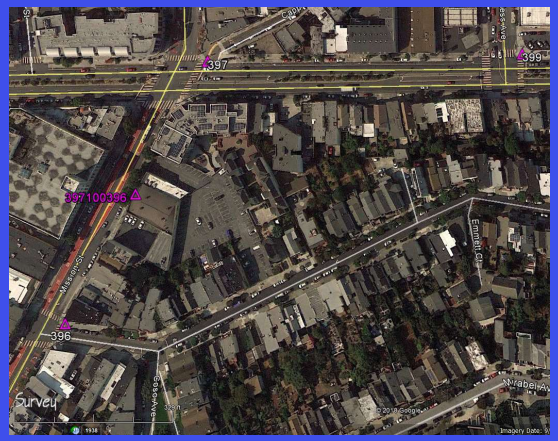
City & County of San Francisco
2014-2017 High Precision Network Densification (HPND) Coordinate List

Traverse Pts connecting non-interviable HPND Points (i.e. 204101205 connects HPND 204 & 205)

204101205	90180.16	164580.04	113.58	*	
281101202	90896.88	175424.78	11.71	*	
343101344	76878.15	165274.71	559.18	*	
361101361	91144.35	171408.21	35.75	*	
378101379	92107.36	165335.00	245.67	*	
379101378	92107.36	165335.00	245.67	*	
380101393	65812.03	171582.25	97.03	*	
394101395	79805.64	172327.18	212.92	*	
394101395	79892.33	172387.08	218.61	*	
394103395	79941.92	172388.59	224.52	*	
397103396	77945.80	164590.13	64.73	*	
402101403	68918.74	163390.21	57.49	*	
402103403	68928.47	163292.32	59.70	*	
408101409	63578.00	174457.38	15.25	*	
411101412	70415.14	164437.41	254.54	*	
412101413	70415.14	164437.41	254.54	*	
417101418	69698.51	168795.31	245.21	*	
419101420	73092.50	168937.56	24.99	*	
421101422	70335.05	172006.77	88.03	*	
421101424	82107.45	164717.84	47.38	*	
425101426	79480.04	165274.17	120.93	*	
428101430	83913.80	174832.50	21.70	*	
431101432	86789.46	173303.73	9.40	*	
432101433	86789.46	173303.73	9.40	*	
450101451	66884.09	171400.77	14.63	*	
466101467	67634.09	167761.92	334.17	*	

* Relative accuracy is based on trigonometric leveling; absolute accuracy indicated by HPND Ht Code

Conventional Checks & Tie Points



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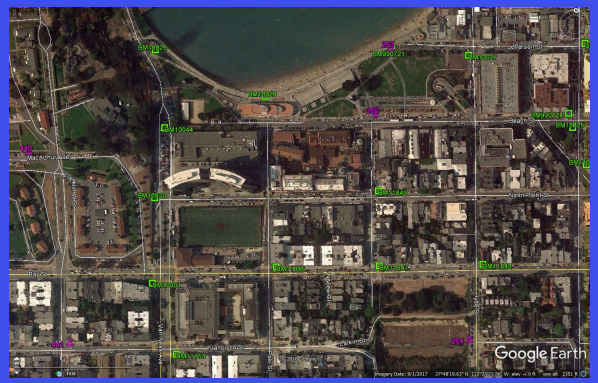
Researching CCSF Control

Load the Benchmark, HPN & HPND kmz's into Google Earth

Zoom in to the area of interest



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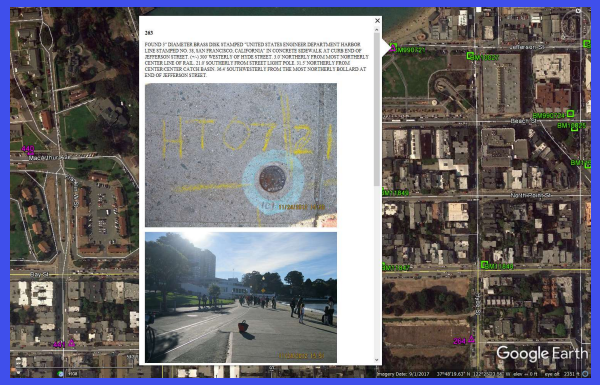
Click & View Control Point Description & Photos



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2D Transformations

NAD83 1991.35 Epoch SPC to CCSF-CS13

NAD83 2010.00 Epoch SPC to CCSF-CS13

NAD83 1991.35 Epoch SPC to 2010.00 Epoch SPC

Available on the CCSF Web Site (soon to be updated)

D10 =E3*B10-E4*C10+E6

	A	B	C	D	E
1	TRIAD TRANSFORMATION SPREADSHEET				
2				Constants	
3	SYSTEM(1): 1999 NAD83(1991) 1991.35 SPC			A1	0.9998615081
4				A2	-0.0208347280
5	SYSTEM(2): 2013 NAD83(2011) 2010.00 CCSF-CS			A3	-5795833.91914
6				A4	-2147359.74825
7					
8		Enter Coordinate		Transformed Coordinate	
9	POINT#	NORTH (1)	EAST (1)	NORTH (2)	EAST (2)
10	107	2085128.546	6013911.480	62778.234	173801.597
11					
12					
13					

66

Transformation: NAD83 1991.35 Epoch SPC to CCSF-CS13

```
INPUT COORDINATES (Feet)
     1999 NAD83(1991) 1991.35 SPC          NAD83( 2011) 2010.00 SFCS13
PT#          North(1)       East(1)          PT#   North(2)     East(2)
CANDLESTICK 2085128.546  6013911.480         107  62778.214  173801.613
TIDAL       2121772.462  5993470.060         201  98991.152  152599.533
SLOAT       2095678.561  5984226.406         202  72708.341  143900.815
ARMY        2100667.364  6012652.104         203  78288.679  172218.652

                 TRANSFORMATION SOLUTION RESIDUALS (Feet)
    1999            2013      North      East     N.Azim & Dist
    CANDLESTICK      107     -0.020    +0.016     140° 0.026
    TIDAL            201     -0.032    -0.009     195° 0.033
    SLOAT            202     +0.034    -0.012     340° 0.036
    ARMY             203     +0.018    +0.004      13° 0.018

Root Mean Square of the North and East Residuals   =  0.02
Scale Factor =  1.00007856      Standard Deviation =  0.00000079
Rotation      = -1° 11' 37.4"    Standard Deviation =  0° 00' 00.2"
TRANSFORMATION EQUATIONS   N2=A1*N1-A2*E1+A4   E2=A2*N1+A1*E1+A3
A1= 0.9998615081 A2= -0.0208347280 A3= -5795833.91914 A4= -2147359.74825
```

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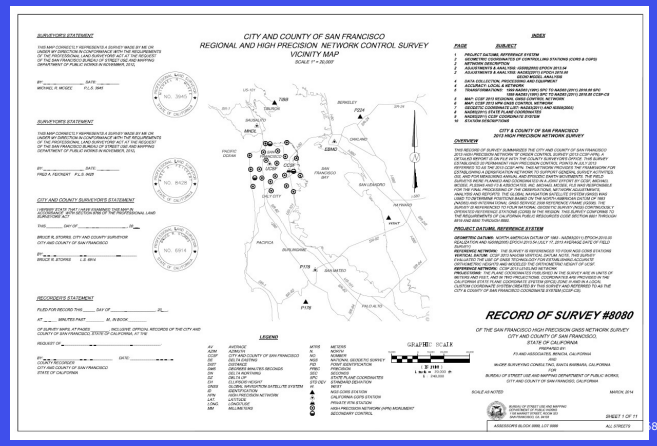
RECORD of SURVEY #8080

Available on the CCSF Web Site



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Monument falling in the traverse area of responsibility shall be tied according to BSM Procedures: i.e. City Monuments, Benchmarks, HPN, HPND & TND Control Points

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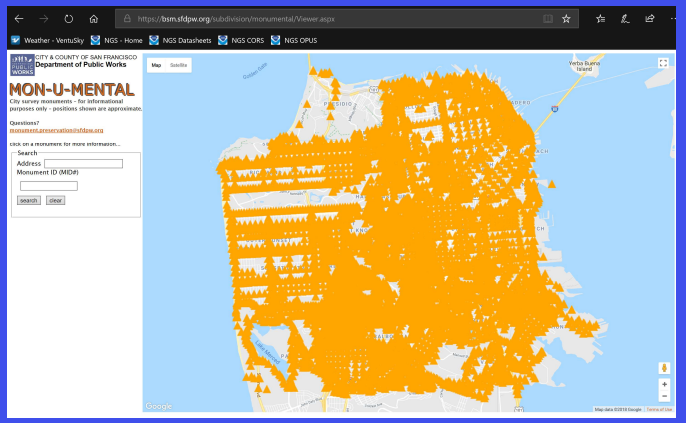
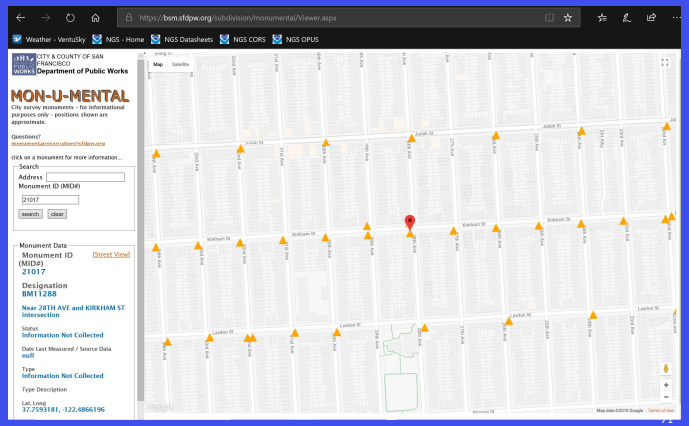
Mon-u-mental Link (public)

https://bsm.sfdpw.org/subdivision/monumental/viewer.htm



70

Zoom In and Click on Mon.



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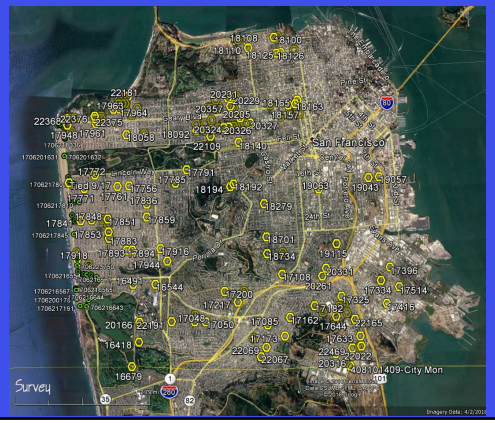
Establishing CCSF-CS13 on City Monuments

160+ Mons Surveyed with GNSS to Tertiary Standards for future conversion of City Monumentation Maps to CCSF-CS13 in support of a City GIS



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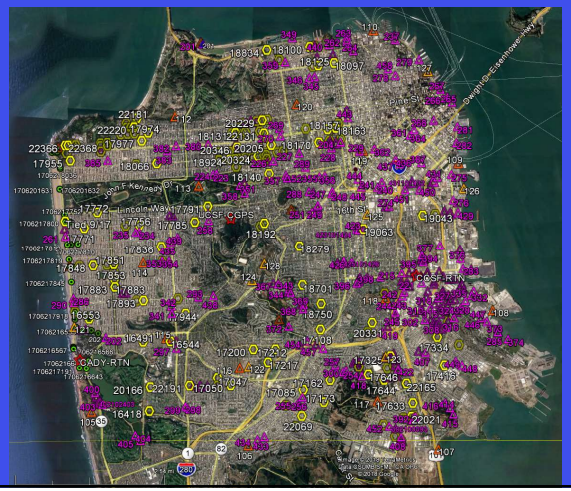
ALL Vertical & HORIZONTAL MONUMENT SURVEYED SINCE 2013

5/1/2014

73

ALL Surveyed 3D Monuments Positioned in CCSF-CS13 Since 2013



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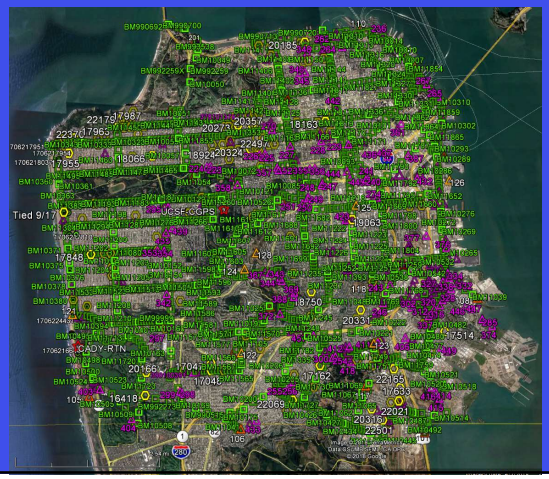
ALL Surveyed 3D Monuments Positioned in CCSF-CS13 Plus CCSF-VD13 Benchmarks



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Example Map Note for Surveys Based on CCSF-CS13 & CCSF-VD13

See Support Document
"Datum-H-V Simplified CCSF Version 4.31.docx"

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Example Map Note for Surveys Based on CCSF-CS13
Horizontal Datum & Reference System

Basis of Survey

Horizontal Datum & Reference System

- The horizontal datum is the North American Datum of 1983: NAD83 (2011) 2010.00 Epoch referenced by the CCSF-2013 High Precision Network (HPN) points 101 and 102 shown hereon. Grid coordinates are based on the "City & County of San Francisco 2013 Coordinate System" (CCSF-CS13). See Record of Survey #8080 in Book EE of Survey Maps, 147-157 SFCR and the CCSF DPW Web Site.

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Example Map Note for Surveys Based on CCSF-VD13
Vertical Datum & Reference System

Basis of Survey

Vertical Datum & Reference System

- The vertical datum is "CCSF 2013 NAVD88 Vertical Datum" (CCSF-VD13) as referenced by CCSF-VD13 Benchmarks 10001, 10002 and 10003 shown hereon and described on the CCSF PW BSM Web Site.

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Workshop Theme

The intent of this Workshop is to provide all contractors with the same information and understanding of what is needed to be in compliance with the methods and procedures for surveying, processing and reporting BSM survey projects.

What's Working - What's Not Working

Working Together For a Consistent & Complete Work Product

We are resolved to improve communications, minimize loss time and create a team effort.

Win-Win

Increase Your Profit Margin and Expediate Delivery

79

Traverse Adjustments using Least Squares

To Least Squares or Not To Least Squares?

If a traverse is not required and only a Short Form Survey Report is necessary then there is no adjustment

80

Step One: Minimally Constrained Adjustment

- Fix one horizontal point and a bearing (called the constraints), or fix two horizontal points (for a backsight). Fix one point for elevation and run a 3D adjustment (always) for redundancy and integrity. The vertical constraint does not have to be the same as the horizontal. Set other known points free in their n, e & elevation.
- The least squares adjustment will best fit all observations mathematically so as to minimize the residuals (note, multiple redundant observations or points with redundant occupations will result in residuals. The traverse is treated like a solid object anchored to the fixed coordinate(s) and the differences between the calculated positions and the known coordinates at other 'set free' points are listed.
- If the residuals and closures on the other known points are acceptable then compute the Constrained Adjustment to develop final coordinates. If the residuals are not acceptable, then go into blunder detection mode and try to identify the problem observations or control points.

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Step Two: Free-Weighted Constrained Adjustment

- Free-Weighted Constrained Adjustment is very useful for blunder detection. All known horizontal & vertical control points (constraints) are assigned an arbitrary weight of 1 foot i.e. n=1, e=1, elv=1.
- The computed solution attempts to best fit the traverse to all the known points as opposed to holding or fixing any points. This results in differences at all points.
- Because least squares attempts to minimize the sum of the square of the residuals, larger difference will likely appear at or near the problem. These larger than expected differences may indicate a problem with a control point's position or a traverse observation. The problem may be using the wrong coordinate, or the wrong point number. Additional analysis is necessary to identify the problem.

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Step Three: Constrained Adjustment

- After any bad observations are identified and removed, re-run the 'Minimally Constrained Adjustment' as previously described to demonstrate and document the acceptable closures on other know control points.
- Once an acceptable 'Minimally Constrained Adjustment' is determined, process the 'Constrained Adjustment' fixing all acceptable known control points to develop the final coordinates for publishing.

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