Notes on the vertical datum establishment and use at USGS Gauges 8C, 8T, 7 and 9 within WCA 1

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Terminology

- **Vertical Datum.** Reference surface to which measurements are related. Nationally defined vertical datums are conceived and published by the Department of Commerce's *National Geodetic Survey* (NGS).
- **NGVD 1929.** National Geodetic Vertical Datum of 1929. Vertical datum derived from cross country (US and Canada) precision leveling, constrained to observed Mean-Sea-Level (MSL) planes at **26 tide stations** on the **Atlantic, Gulf and Pacific** coasts of the Unites States and Canada. Includes 67,000 miles of leveling.
- **NAVD 1988.** North American Vertical Datum of 1988. Replaces NGVD29. All data adjusted to only **one** tide station's zero MSL. Benefits of NAVD88 include:
  - 450,000 miles of new and re-leveled lines.
  - Refined field procedures.
  - Survey equipment quality improved.
  - Monument types of a greater stability employed.
- ***CERP29…*** An adjustment of the CERP NAVD88 survey network, not published by NGS, and not related to historic water observations.

Datum Transformations

1. VertCon. Computer software and model used to transform point elevations from NGVD29 to NAVD88, or NAVD88 to NGVD29.
2. Model was built using known elevations in both systems on bench marks published in the National Geodetic Survey's database.
3. Survey databases controlled by USACE, SFWMD or USGS were not included in the transformation model.
4. VertCon is typically used as a "last option" regarding vertical datum transformations, with "re-survey", and "re-calculation" being superior methods. Originally designed to transform low-order data, such as topography.

Differential Leveling

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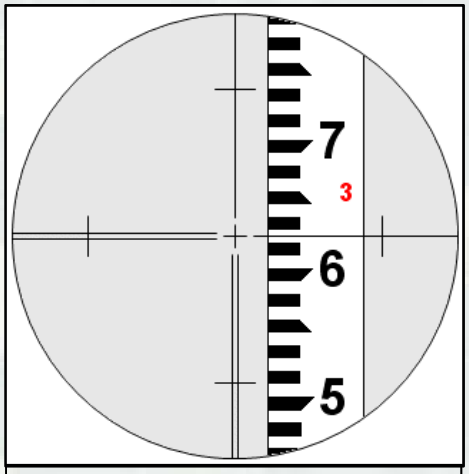
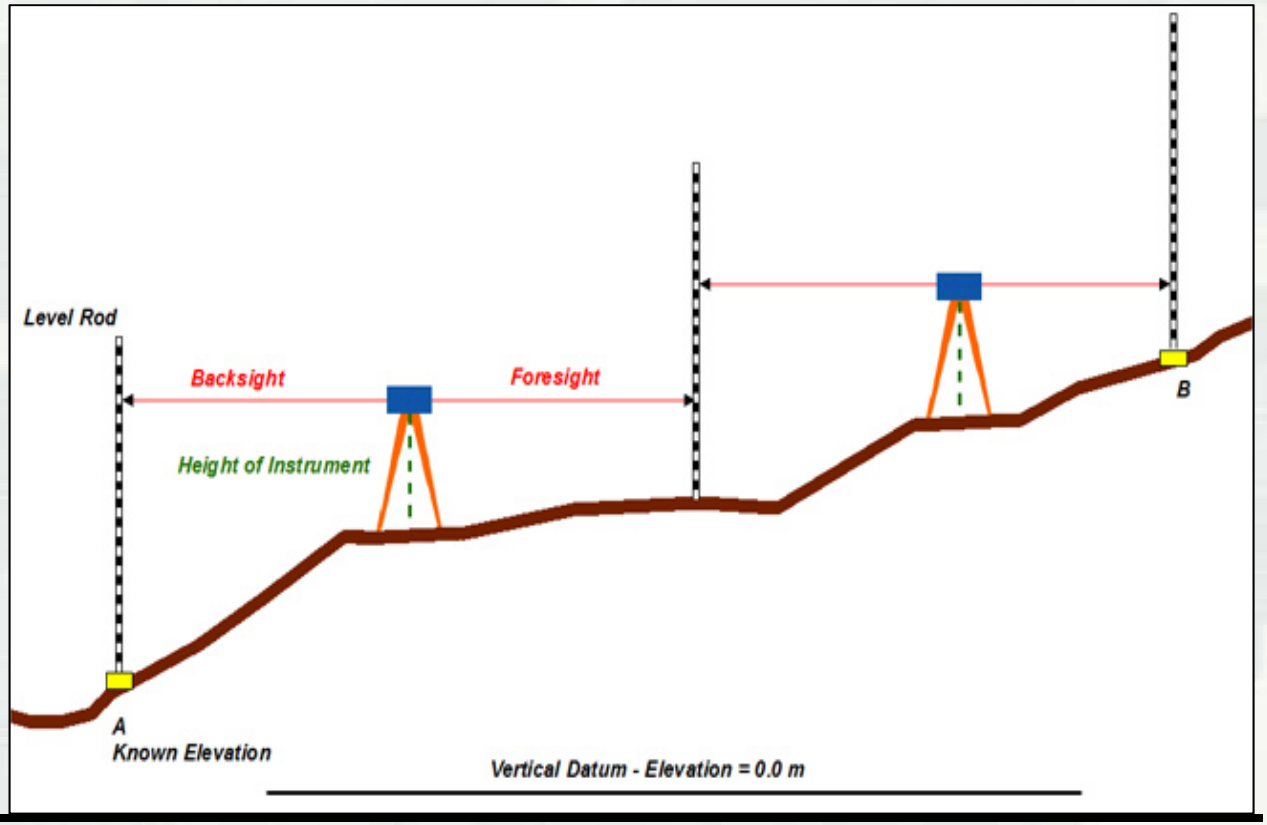
- Method and procedures by which the difference in elevation between two or more points is determined. Leveling is usually done by sighting through a telescope (containing pointing cross-hairs), set-up perpendicular to the direction of gravity, to a graduated staff held vertically.



Reading would be:
3.625



Terminology

- **BM = Bench Mark.** Permanent, typically metallic, readily identifiable object, from which horizontal and/or vertical measurements originate.
- **RM = Reference Monument.** Can be viewed as a back-up, or support, to the site's primary BM.
- **RP = Reference Point.** Similar to a RM in use, but selected from existing objects firmly attached to the gauge structure.
- **MP Shelf.** Platform on which measuring devices are installed and; therefore, the gauge "datum" - the point from which the water level reading is taken.
- **FGDC.** Federal Geographic Data Committee. The interagency committee that promotes the coordinated development, use, sharing, and dissemination of geospatial data.

Types of Bench Marks

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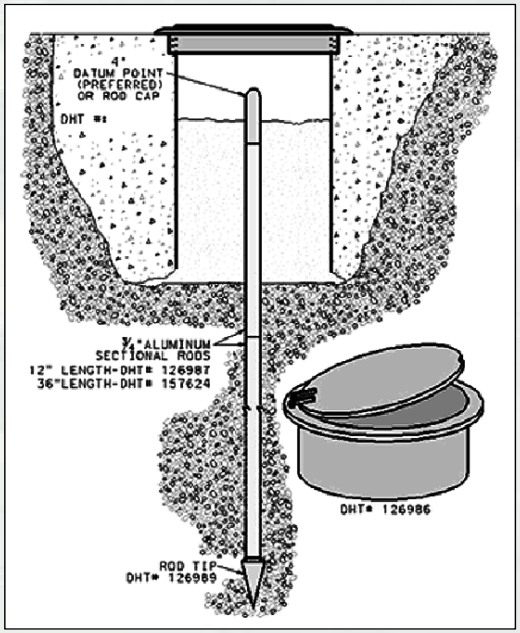
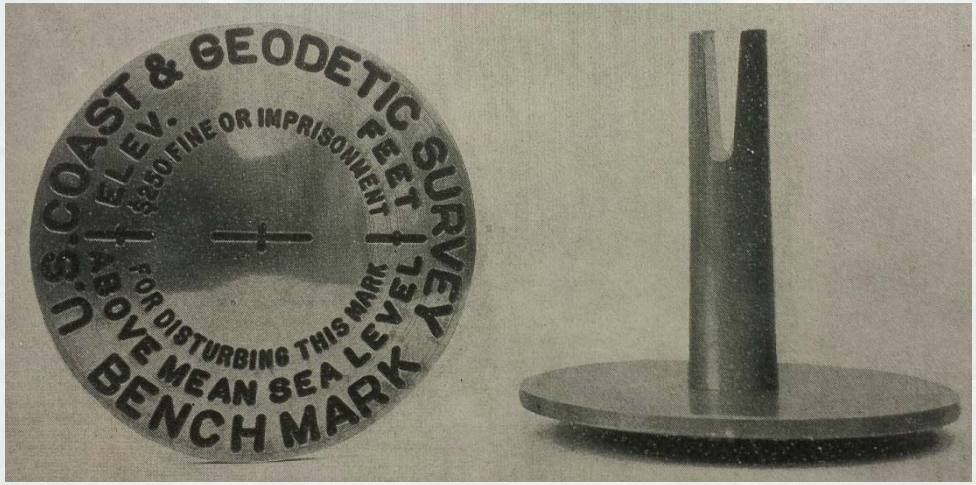
Bronze or Brass disks set in poured-in-place concrete, or existing structure with a deep foundation.



Deep-driven rod mark, sometimes with cap, most often without. Datum point is the tip of the rod, with the name stamped on the aluminum collar/cover.

Disk Detail



- The elevation used to be directly stamped on the disk. This turned out to be a bad idea because repeat field work and data adjustments resulted in numerous modifications. Now, just the name and year are stamped.
- Usually Brass or Bonze, and as a result, non-magnetic.
- Bench Marks can be challenging to find because they do not always respond to metal locators used by surveyors, which are more tuned to find iron property markers. Additionally, the exact horizontal position of the mark was never an important part of the elevation program.

Overview

1st objective is to provide some history of the gauges' heights and how the datum/elevation has or has not been adjusted since the 1978-1980 time period.

- **1979-1980**: Leveling was performed originating near **Site 8C**, and extending to the areas which are now occupied by **Sites 8T, 7** and **9**.
- These surveys originated on monument ***"ROOS"***, having an NGVD29 elevation of USACE origin. More information on this survey mark in a few slides…

Overview

- From an examination of the paper originals, and the USACE bench mark database, it appears that the reported elevations have remained “static”, with no adjustment to the marks associated with the WCA gauges.
- Requests for original field books/notes from “Records Holding” were unsuccessful in returning information about these surveys.

2nd objective will be to provide historic elevation background on the gauges 8C, 8T, 7 and 9.

Site 8C

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- 1991: USGS established vertical datum from Nov 1982 datasheet for ***"PB 44",*** SFWMD monument Palm Beach 44 attached to a concrete mass in the levee
- July 2004: problem observed with data at 8C, suspect issue with monument ***"PB 44"***; levels run to nearby monuments T536 and ROOS.
- Sept 2004: Hurricane Francis destroys **Site 8C**.
- Nov 2004: station rebuilt and set using existing RMs.
- March 2005: adjusted to ***ROOS*** using Aug 1989 elevation to tie into historical record.

Site 8C

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Survey Mark : ROOS

- **1970**: Originally established by *NGS,* only published as a horizontal station; Latitude and Longitude established by classical triangulation.
- **1980**: The USACE establishes, and uses, an NGVD29 elevation at this mark. Exactly how the NGVD29 was transferred to ROOS, or from which existing Bench Marks which were used in that survey is not known.

  This NGVD29 elevation is not a product of NGS operations.
- **2002**. NGS publishes high order NAVD88 height as part of the CERP Geodetic Vertical Control Network.
- **2004:** Site 8C rebuilt and **MP Shelf** elevation established, first using existing RMs (***PB 44*** based), later by **1980-vintage**, USACE determined NGVD29 elevation on ***ROOS***.

Site 8C

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Working from Nov 2014 report back to March 2004.

2014 Leveling per USGS Report		
MARK	**ELEVATION**	**BM Differential**
RM 1	18.674	
		-1.006
RM 3	19.680	
		0.038
RP 1	19.642	
		-0.325
ROOS	19.967	
19.967 elevation on ROOS from 1980 leveling project.		

2003 Leveling per USGS Report		
MARK	**ELEVATION**	**BM Differential**
RM 1	18.780	
		-1.006
RM 3	19.786	
		0.034
RP 1	19.752	

BM Δ	
-0.106	
-0.106	
-0.110	
-0.107	**MEAN**

-0.107 value is a snap shot in time, only applying to the March 2004 Site Report (USGS), and it's relation to pre-1991 conditions.

Site 8C

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Period	Adjustment to 1980
1980 – 4/1991:	0
4/1991 – 10/31/1995:	-0.10
11/1/1995 – 9/14/1997:	-0.11
9/15/1997 – 7/14/1999:	-0.12
07/15/1999 – 5/31/2001:	-0.13
6/1/2001 – 3/31/2003:	-0.14
4/1/2003 – 7/30/2003:	-0.15
7/31/2003 – 9/5/2004:	-0.13
9/6/2004 – present	0

SOURCE: USGS, April 2016.

Site 8C

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MP Shelf Elevations at new station on various *datums*:

24.155	Current MP shelf elevation related to 1980 datum.
24.048	Elevation on the current MP Shelf (2015 Report).
22.447	Current MP shelf elevation in NAVD88. (Calculated).

Result: Post Nov. 2004 elevations are -0.107 (“lower”) than pre July 2004, vs. -0.121 (by USGS), diff. of 0.014.

Site 8C (Relation to NAVD88)

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ROOS		
Time Frame	***Elevation***	***Elev. Δ***
CALCULATED - BASED ON ***2003/2004 CONDITIONS*** (NGVD29)	20.074	
		0.107
1980 USACE (NGVD29)- NOT USED UNTIL POST FRANCIS (2004)	19.967	
		0.100
2002 - POST CERP NETWORK (NGVD29.TXT)	19.867	
		1.501
2002 - NAVD88 (NGS PUBLISHED RESULT OF CERP NETWORK)	18.366	

By this analysis, the total conversion value from the Historic Gauge Datum (pre-Hurricane Francis) to NAVD88 would be 1.708ft. Quite a contrast to the VertCon transformation(s) shown below:

VertCon 1994 model (Official NGS) = 1.473ft

VertCon 2005 (post CERP model) = 1.489ft

Site 8T

- **Pre 2003**: Original site Reference Marks determined by differential level run (1980) beginning on **ROOS** and establishing marks **"BM" (USCE 128T), "RM #1" (USCE 128T RM), and "RM #2"** (Radio Tower Bolt).
- **2003**: FL-DEP performs high-order survey campaign throughout WCA to establish GPS derived elevations. Results converted to NGVD29 via VERTCON (1994).
- **2004**: USGS *STATION DESCRIPTION* report modifies MP SHELF height to reflect use of new GPS bench mark **"WCA 1 1 8T"** aka. **RM #3**.

Site 8T

FROM NGS DATA SHEET FOR : *"WCA 1 1 8T"*

DESIGNATION - WCA 1 1 8T

NAVD 88 ORTHO HEIGHT - **4.85** (meters) 15.9 (feet) GPS OBS

Network accuracy estimates per FGDC Geospatial Positioning Accuracy Standards:

	FGDC (95% conf, **cm**)		Standard deviation (cm)			CorrNE
	Horiz	Ellip	SD_N	SD_E	SD_h	(unitless)
NETWORK	1.03	**1.00**	0.39	0.45	0.51	-0.09129792

1. NAVD88 height published to nearest cm.
2. Ellipsoid Height (elevation directly measured by GPS) network accuracy 1cm.
3. Same statistic also applies to "new" bench marks at Sites 7 and 9.
4. *Note on using VertCon 1994:* "Model can be considered accurate at the 2 cm level, on the marks that built the model (per VertCon documentation).

Site 8T

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The only “bench mark” through time, having a string of recorded elevations is the MP SHELF.

Observation Period	MP SHELF Ht.	MP SHELF Ht. Height Δ	MP SHELF Ht. Total Δ
Pre-2003	21.705		
		-0.038	
2004	21.667		-0.063
		-0.025	
2014	21.642		
		-1.465	
2014 (NAVD88)	20.177		
	TOTAL	-1.528	

Result: It appears that current readings are -**0.063’** lower than historic elevations, vs. -**0.038’** per USGS presentation.

The total resulting conversion from NAVD88 to the Pre-2003 NGVD29 would be a total of +1.528 feet.

Site 7

- Like Site 8T, original reference marks have their original elevation from USACE leveling in 1980.
- Site is now controlled by a GPS derived NAVD88 height, *"WCA 1 SITE 7"* converted to NGVD29 by VertCon, including the same positional uncertainties as Site 8T.
- VertCon is 1.460 feet at Site 7.
- Only common marks at this site are the two USACE benchmarks "FCE 1017" and "FCE 1018".

R. M.	1980 Leveling	2002 USGS Report	2014 USGS Report	Elev. Δ
FCE 1017	18.384	18.384	18.266	-0.118
FCE 1018	18.139	18.139	18.025	-0.114
	Vs. -0.102 from USGS report.		MEAN	-0.116

Result: It appears that current readings are -0.116' ("lower") than historic, vs -0.102 per USGS presentation.

Site 7

- Oct 1, 2003: USGS adjusted gage by -0.102 from VertCon on FDEP elevation.
- From Oct 1, 2003 to Aug 2014, subsequent levels indicates -0.014 change.

Period	Adjustment to 1980
1980 – 9/30/2003:	0
10/01/2003:	+0.102
Aug 2014:	+0.116

SOURCE: USGS, April 2016.

Site 7 (Relation to NAVD88)

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Elevations on Bench Marks at Site 7			
	NGVD29	NAVD88	DATUM Δ
FCE 1017	18.384	16.799	1.585
FCE 1018	18.139	16.558	1.581

- NGVD29 taken from the 2002 USGS Station Report, NAVD88 derived from the 2014 USGS Report.
- VertCon (ver. 1994) at this site is 1.460 ft.
- VertCon (ver. 2005) at this site is also 1.460 ft.

Site 9

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- NGVD29 - USACE leveling (1980) to site, establishes “USCE 142, FCE 1014 and FCE 1016 (spur line from the Site 7 run).
- NAVD88 - NGS published, GPS derived, mark *“WCA 1 SITE 9”* (PID: DF7194), part of same GPS project as Sites 8T and 7, (etc.).
- 2004 - VertCon derived NGVD29 use begins.
- Only common thread, or bench mark, is the MP Shelf:

MP SHELF	Elevation per Report	Elevation Δ
1980 Leveling	20.731	
		-0.015
2004 USGS Report	20.716	
		-0.010
2015 USGS Report	20.706	
	Total:	-0.025

Result: It appears that the current readings are -0.025’ (“lower”) than historic, vs. -0.015 per USGS presentation.

Site 9

- Oct 1, 2003: USGS adjusted gage by -0.015 from VertCon on FDEP elevation.
- From Oct 1, 2003 to Aug 2014, subsequent levels indicates -0.010 change.

Period	Adjustment to 1980
1980 – 9/30/2003:	0
10/01/2003:	+0.015
Aug 2014:	+0.010

SOURCE: USGS, April 2016.

Site 9 (Relation to NAVD88)

Elevations at MP SHELF			
FEATURE	**Pre 2004 (NGVD29)**	**2015 USGS Report (NAVD88)**	**Datum Δ**
MP SHELF	20.731	19.223	1.508

- NGVD29 taken from the 2003 USGS Station leveling, NAVD88 derived from the 2015 USGS Report.
- VertCon (ver. 1994) at this site is 1.483 ft.
- VertCon (ver. 2005) at this site is also 1.486 ft.

Comparison and Summary

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Site Name	USGS Report	USACE Report
8C	-0.121	-0.107
8T	-0.038	-0.063
7	-0.102	-0.116
9	-0.015	-0.025
All units in feet.		

- At all four Sites, the calculations performed by the USACE result in a computed difference no greater than 0.025 ft. when compared to the USGS reported offsets. Repeat measurements and MP Shelf adjustments by the USGS are not addressed by this table.
- In each of the four sites discussed in this document, the historic gauge height was previously published at a higher elevation than is currently reported.
- The application of the computed conversion value, would be to subtract the offset value from the current reading to relate them to historic data.

USACE REGULATION

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1. 1994: **Technical Letter 1110-1-152 Conversion to the North American Vertical Datum of 1988**.
2. 2003: CERP Geodetic Vertical Control Network published into the National Spatial Reference System (NSRS) maintained by the U.S. Department of Commerce.
3. 2005: REMER control surveys to tie structures and gauges to NSRS.
4. 2006: IPET. Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System Volume II Geodetic Vertical and Water Level Datums.
5. 2007: USACE/NOAA train and certify District Datum Coordinators, establishing clear and strict guidance for project vertical datums, and launching the Comprehensive Evaluation of Project Datums.
6. 2009: **ER 1110-2-8160 Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums**.
7. 2010: **EM 1110-2-6056 Standards and Procedures for Referencing Project Elevation Grades to Nationwide Vertical Datums**.
8. 2009-2010: ARRA control surveys to tie structures and gauges to NSRS.
9. PRESENT: USACE continues to work closely with NOAA to ensure close adherence to the NSRS and NWLON (National Water Level Observation Network) frameworks maintained by the U.S. Department of Commerce and a smooth transition to future national frameworks.