

Using Height Modernization Program Stations' GPS-Derived Heights
as Constraints in Leveling Adjustments

[Proposal by a Team Appointed by the Chief of the Observation & Analysis Division, NGS]

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1. Goal: To generate leveling-based, adjusted heights constrained to Height Modernization Program stations' GPS-derived orthometric heights, specifically in areas where doing extensive leveling observations for constraint purposes is not feasible.
2. Special Situations - where this alternative constraint method may be used:
 - a. Leveling was performed to more than three (3) stations having leveling-derived, NAVD 88 (or a RECENT local tidal datum on islands) adjusted heights - but no valid check connection could be achieved, even within third-order allowable misclosure limits (such as in high movement areas).
 - b. Leveling to the nearest stations having leveling-based, NAVD 88 (or RECENT local tidal datum on islands) adjusted heights would result in doing:
 - i. More than ten kilometers (10 KM) of double-run leveling observations.
 - ii. More than three (3) days of double-run leveling observations in unusual terrain or circumstances.
3. Field Data Requirements:
 - a. Valid check connections (in order of preference) to at least:
 - i. One (1) station having a leveling-based, NAVD 88 (or local tidal datum) adjusted height and one (1) station having a Height Modernization/"GPS OBS"-labeled, NAVD 88 (or local tidal datum) published height.
 - ii. Two (2) stations having Height Modernization/"GPS OBS"-labeled, NAVD 88 (or local tidal datum) published heights.
 - iii. One (1) station having a Height Modernization/"GPS OBS"-labeled, NAVD 88 (or local tidal datum) published height - but only with written justification included as *15* COMMENT records within the submitted leveling observations data set.
 - b. With the exceptions regarding check connections as noted above, **at least** third-order, double-run, leveling observations done in accordance with the document entitled "FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems" (ver. 4.1 05/27/1994, currently available on-line at web site: http://www.ngs.noaa.gov/FGCS/tech_pub/Fgcsvert.v41.specs.pdf). Notably, the 3-kilometer limit between stations will not be exceeded.

4. Data Submission to NGS Headquarters:

- a. At a minimum, leveling observations in “Blue Book” format (HGZ file), descriptions in D-FILE (dsc file) format, and an “ERROR”-free output message file from WDDPROC program WCHKDESC **must** be submitted to NGS. The D-FILE must contain a description entry for each station observed in the leveling project.
- b. Quality assurance checks **will** be performed on the “Blue Book” files’ contents and the adjustment results. No quality assurance checks upon the leveling observations’ **field books and/or field abstracts** will be performed at NGS Headquarters; i.e., checking any field data, including the field books and/or field abstracts, is the responsibility of the submitting agency.
- c. **At this time**, if the submitting agency has processed their leveling observations and descriptions through NGS’s (currently UNIX-based) software, then higher priority will be given to loading the data into the NGS Integrated Data Base (NGSIDB). Description data would have to be verified with programs neighbor, discrep, and chkddesc, and the observations data processed through the leveling reduction and adjustment software. **In the future**, as software is developed for PC- and Java-based platforms, this additional processing will be required prior to the leveling project’s submission to NGS Headquarters.

5. Effects of this Proposal:

- a. **Pre-approval/Planning:** The 51 GPS register numbers originally reserved for program PCvGPS for the 50 States and the District of Columbia (DC) may be used for leveling data submission and processing. See Appendix A for a list. The Project Development Branch within the Spatial Reference System Division will be responsible for GPS-prefixed leveling line part tracking.
- b. **Reduction Processing/Software:**
 - i. The reduction Processor will:
 - (1) Verify the “check connection(s)”.
 - (2) Be responsible for notifying the reduction Loader of any special project category codes which must be loaded for the leveling project’s reduced observations.
 - ii. **Program “ld_vobs6”:**
 - (1) The user-specified “-p” command line option should allow entry of a Project Tracking code, currently includes choices of {C,D,P,Q}.
 - (2) New height rows will be loaded with user-specified DATUM code, ELEV_SOURCE=F, and GPS-prefixed HGZ data base identifier (see above).
- c. **Adjustment Processing:**
 - i. **NOTE:** The “check connection” stations (hereafter called “constraints”) will have the following data already existing in the NSIDB. For an example of such a station, see Appendix B. The “2” CODE is determined using instructions outlined within the publication named “NOAA Technical Memorandum NOS NGS-58” (at web site: http://www.ngs.noaa.gov/PUBS_LIB/NGS-58.pdf).

<u>Table Name</u>	<u>Attribute Name</u>	<u>Attribute Entry</u>
GPS_HT_PRECISION	CODE	2
ELEVATION	ELEV_SOURCE	H
ELEVATION	ELEV_TECH	G

- ii. The Adjuster must:
 - (1) Retrieve NGS Data Sheets for each verified constraint used in his/her adjustment and submit copies thereof to the Loader of the leveling adjustment.
 - (2) As usual, submit a partially completed "REQUEST FOR IDB LOAD OF ADJUSTED HEIGHTS" form with:
 - (a) A **post-1987** DATUM.
 - (b) An ELEV_SOURCE=**H** for these unusually constrained adjustments.
 - (c) Any special "project category" codes, currently includes choices of {C,D,P,Q}.

- d. **Adjustment Software:**
 - i. **Program ret_vconstraints:**
 - (1) Change the traditional protocol for retrieving the "best" leveling-based adjusted height from the ELEVATION table to include the "best" Height Mod-related, orthometric height instead.
 - (a) If the vertical DATUM code is in {88,AS,GU,NM,PR},¹ then use the ELEV_SOURCE code precedence of:
 - (i) {A,P,M,N,U,R} where ELEV_TECH=N. (ELEV_SOURCE code "G"² can be added if it is accepted.)
 - (ii) Then, if none are retrieved, try {H} where ELEV_TECH=N.
 - (iii) Then, if none are retrieved again, try {H} where ELEV_TECH=G and GPS_HT_PRECISION table's CODE=2 for that height's ADJ_ID.
 - (b) Split the test for DATUM codes {29, LT}.
 - (i) The ELEV_SOURCE code list remains the same for DATUM code {29}, unless ELEV_SOURCE code "G" is added.
 - (ii) For DATUM code {LT}, use the existing list first; i.e., the current documentation file has {A,B,P,M,N,U,C,R}. (ELEV_SOURCE code "G" can be added if it is accepted.) Then, repeat sequential steps (a)(ii-iii) above.
 - (c) If two or more "H" rows are retrieved, choose the one with the most recent adjustment date (i.e., latest ADJ_ID-related ADJ_DATE in the ADJUSTMENTS table).
 - (2) The "CONSTRAIN PID" commands inserted into the CONSTRAINTS file with ELEV_SOURCE=H will be preceded by a remark symbol (#). The order and class may remain blank where their entries are NULL.
 - ii. **Program set_vorder:** No order/class will be entered for these specially constrained heights.
 - iii. **Program "ld_vhts5"** (and beta test version "ld_vhts6):
 - (1) Within the command line, "H" should be added to the list of allowed ELEV_SOURCE attribute codes.
 - (2) As usual, the vertical datum code will be user-specified; however, command line parameters vertical_datum=29 and ELEV_SOURCE attribute=H within the same command line should cause the program to ABORT.
 - (3) The "-a" (ADJ_ID user-specified) command line option should allow entry of a **GPSO**-prefixed adjustment identifier.
 - (4) The user-specified "-p" command line option should allow entry of a Project

¹ Additional **recent** local tidal DATUM codes have been proposed for other islands.

² "G" is a new ELEV_SOURCE code proposed by Kathy Koepsell in association with the USGS third - order leveling data entry task being coordinated by Gary Perasso.

- Tracking code, currently includes choices of {C,D,P,Q}.
- (5) New heights will be loaded with rows containing the following information: ELEV_SOURCE=H, ELEV_TECH=N, ELEV_QUALITY=4, S_ORDER=NULL, and CLASS=NULL.
 - (6) Concerning pre-existing, leveling-based height rows:
 - (a) Those having ELEV_SOURCE=F and ELEV_TECH=N for the user-specified DATUM code will be removed before insertion of the new row.
 - (b) Those having ELEV_SOURCE in {A,B,C,M,N,P,R,U} AND ELEV_TECH=N for the user-specified DATUM code will be superseded (i.e., the existing row's ELEV_SOURCE code will be updated to "X") before insertion of the new height's row. "G" should be added once it has been accepted.
 - (c) In the future, pre-existing ELEVATION table rows with ELEV_SOURCE=H and ELEV_TECH=N will be left as they are.
- e. **Supplementary Software:**
- i. **Program "project_categories":** Inserts, deletes, and retrieves from the NGSIDB table PROJECT_CATEGORIES wherein the leveling adjustment's **GPSO**-prefixed identifier (or a more specific, reduced leveling line part's **GPS**-prefixed HGZ identifier) is stored in the ADJ_ID attribute with its corresponding project CATEGORY code(s) for "special performance measure projects". The leveling reduction and/or adjustment Loader(s) may have to use this program when he/she forgets to use the "-p" option in a loading program's command line or when multiple codes must be inserted. As noted before, current leveling-related choices are {C,D,P,Q}.
- f. **Data Base Changes** - to be done by the Administrator (DBA):
- i. Insert rows in NGSIDB table EL_SRCE_TECH_CONSTR with ELEV_SOURCE=H and ELEV_TECH=N constraint definitions for (current) DATUM codes {88, AS, LT, NM, PR}. Such constraint definitions may also have to be added for proposed DATUM code "GU".
6. NGS Data Sheet Format/Software Changes - to be submitted through the "Geodetic Products & Services Committee":
- a. Add the new ELEV_SOURCE=H and ELEV_TECH=N combination to the "best" height retrieval protocol. For the same station, this combination's height will be considered better than an existing ELEV_SOURCE=H and ELEV_TECH=G ("GPS OBS"-type) height, as long as its ADJ_DATE is chronologically greater than the "GPS OBS":ADJ_DATE.
 - b. Use the key words of "GPS CON" when these heights are published in "SURVEY CONTROL" areas.
 - c. No order/class data ("VERT ORDER" or codes) will be printed for the "GPS CON" heights.
 - d. Print the following statement associated with key words "GPS CON" under the primary "CURRENT SURVEY CONTROL" area: "The orthometric height was determined by <ADJUSTMENTS table's AGENCY: definition> in <ADJUSTMENTS table's ADJ_DATE for ADJ_ID: Month Year>. However, it was constrained using orthometric height(s) determined by GPS observations and a high-resolution geoid model using precise GPS observation and processing techniques."

APPENDIX A

GPS-Related, Register Numbers in the NGS Records Data Base “ngsrecords”

Note: These 51 numbers were previously assigned for accessioning minimal leveling data collected in support of GPS projects done within the 50 States and the District of Columbia.

```

1> use ngsrecords
2> go
1> select s.state,
2> p.project_no,p.prefix,p.regnum,p.class,p.area,title=substring(p.title,1,30)
3> from projects p,states s
4> where p.prefix='GPS' and
5> p.regnum between 1070 and 1120 and
6> s.area=p.area
7> order by s.state
8> go

```

state	project_no	prefix	regnum	class	area	title
AK	96519	GPS	1071	GPS	945	GPS Support Leveling in AK
AL	96518	GPS	1070	GPS	873	GPS support leveling in AL
AR	96521	GPS	1073	GPS	881	GPS Support Leveling in AR
AZ	96520	GPS	1072	GPS	938	GPS Support Leveling in AZ
CA	96522	GPS	1074	GPS	941	GPS Support Leveling in CA
CO	96523	GPS	1075	GPS	934	GPS Support Leveling in CO
CT	96524	GPS	1076	GPS	846	GPS Support Leveling in CT
DC	96526	GPS	1078	GPS	859	GPS Support Leveling in DC
DE	96525	GPS	1077	GPS	855	GPS Support Leveling in DE
FL	96527	GPS	1079	GPS	872	GPS Support Leveling in FL
GA	96528	GPS	1080	GPS	867	GPS Support Leveling in GA
HI	96529	GPS	1081	GPS	161	GPS Support Leveling in HI
IA	96533	GPS	1085	GPS	912	GPS Support Leveling in IA
ID	96530	GPS	1082	GPS	932	GPS Support Leveling in ID
IL	96531	GPS	1083	GPS	896	GPS Support Leveling in IL
IN	96532	GPS	1084	GPS	895	GPS Support Leveling in IN
KS	96534	GPS	1086	GPS	925	GPS Support Leveling in KS
KY	96535	GPS	1087	GPS	883	GPS Support Leveling in KY
LA	96536	GPS	1088	GPS	876	GPS Support Leveling in LA
MA	96539	GPS	1091	GPS	844	GPS Support Leveling in MA
MD	96538	GPS	1090	GPS	857	GPS Support Leveling in MD
ME	96537	GPS	1089	GPS	841	GPS Support Leveling in ME
MI	96540	GPS	1092	GPS	901	GPS Support Leveling in MI
MN	96541	GPS	1093	GPS	911	GPS Support Leveling in MN
MO	96543	GPS	1095	GPS	884	GPS Support Leveling MO
MS	96542	GPS	1094	GPS	874	GPS Support Leveling in MS
MT	96544	GPS	1096	GPS	931	GPS Support Leveling in MT
NC	96551	GPS	1103	GPS	865	GPS Support Leveling in NC
ND	96552	GPS	1104	GPS	922	GPS Support Leveling in ND
NE	96545	GPS	1097	GPS	924	GPS Support Leveling in NE
NH	96547	GPS	1099	GPS	842	GPS Support Leveling in NH
NJ	96548	GPS	1100	GPS	853	GPS Support Leveling in NJ
NM	96549	GPS	1101	GPS	937	GPS Support Leveling in NM
NV	96546	GPS	1098	GPS	936	GPS Support Leveling in NV
NY	96550	GPS	1102	GPS	851	GPS Support Leveling in NY
OH	96553	GPS	1105	GPS	892	GPS Support Leveling in OH
OK	96554	GPS	1106	GPS	927	GPS Support Leveling in OK
OR	96555	GPS	1107	GPS	943	GPS Support Leveling in OR
PA	96556	GPS	1108	GPS	854	GPS Support Leveling in PA
RI	96557	GPS	1109	GPS	845	GPS Support Leveling in RI
SC	96558	GPS	1110	GPS	866	GPS Support Leeling in SC
SD	96559	GPS	1111	NULL	923	GPS Support Leveling in SD
TN	96560	GPS	1112	GPS	882	GPS Support Leveling in TN
TX	96561	GPS	1113	GPS	877	GPS Support Leveling in TX
UT	96562	GPS	1114	GPS	935	GPS Support Leveling in UT
VA	96564	GPS	1116	GPS	863	GPS Support Leveling in VA
VT	96563	GPS	1115	GPS	843	GPS Support Leveling in VT
WA	96565	GPS	1117	GPS	944	GPS Support Leveling in WA
WI	96567	GPS	1119	GPS	902	GPS Support Levelig in WI
WV	96566	GPS	1118	GPS	864	GPS Support Leveling in WV
WY	96568	GPS	1120	GPS	933	GPS Support Leveling in WY

(51 rows affected)

APPENDIX B

Sample for a Height Mod Station
with a "GPS OBS"-derived, orthometric height

PID	DESIGNATION	CODE	GHP_ADJ_ID	DATUM	HEIGHT	ORDR	CLAS	SRCE	TECH	E_ADJ_ID	ADJ_DATE
DK2003	MACON	2	GPS1962	29	41.00	NULL	NULL	H	T	17289	19860719
DK2003	MACON	2	GPS1962	88	41.793	NULL	NULL	H	G	GPS1962	20040317

National Geodetic Survey, Retrieval Date = MARCH 18, 2005

DK2003 *****

DK2003 HT_MOD - This is a Height Modernization Survey Station.

DK2003 DESIGNATION - MACON

DK2003 PID - DK2003

DK2003 STATE/COUNTY- AR/CHICOT

DK2003 USGS QUAD - HALLEY (1981)

DK2003

DK2003 *CURRENT SURVEY CONTROL

DK2003

DK2003* NAD 83(1997)- 33 30 26.24569(N) 091 18 11.66163(W) ADJUSTED

DK2003* NAVD 88 - 41.79 (meters) 137.1 (feet) GPS OBS

DK2003

DK2003 X - -121,080.013 (meters) COMP

DK2003 Y - -5,322,258.981 (meters) COMP

DK2003 Z - 3,501,017.050 (meters) COMP

DK2003 LAPLACE CORR- -2.30 (seconds) DEFLEC99

DK2003 ELLIP HEIGHT- 15.40 (meters) (11/18/03) GPS OBS

DK2003 GEOID HEIGHT- -26.30 (meters) GEOID03

DK2003

DK2003 HORZ ORDER - B

DK2003 ELLP ORDER - FOURTH CLASS I

DK2003

DK2003.The horizontal coordinates were established by GPS observations

DK2003.and adjusted by the National Geodetic Survey in November 2003.

DK2003

DK2003.The orthometric height was determined by GPS observations and a

DK2003.high-resolution geoid model using precise GPS observation and

DK2003.processing techniques.

DK2003

DK2003.Photographs are available for this station.

DK2003

DK2003.The X, Y, and Z were computed from the position and the ellipsoidal ht.

DK2003

DK2003.The Laplace correction was computed from DEFLEC99 derived deflections.

DK2003

DK2003.The ellipsoidal height was determined by GPS observations

DK2003.and is referenced to NAD 83.

DK2003

DK2003.The geoid height was determined by GEOID03.

DK2003

DK2003; North East Units Scale Factor Converg.

DK2003;SPC AR S - 493,456.404 464,736.288 MT 0.99996050 +0 23 23.9

DK2003;UTM 15 - 3,708,815.977 657,600.105 MT 0.99990622 +0 56 12.8

DK2003

DK2003! - Elev Factor x Scale Factor = Combined Factor

DK2003!SPC AR S - 0.99999758 x 0.99996050 = 0.99995808

DK2003!UTM 15 - 0.99999758 x 0.99990622 = 0.99990380

DK2003

DK2003: Primary Azimuth Mark Grid Az

DK2003:SPC AR S - MACON AZ MK 129 14 20.8

DK2003:UTM 15 - MACON AZ MK 128 41 31.9

DK2003

DK2003 |-----|

DK2003 | PID Reference Object Distance Geod. Az

DK2003 | | | | dddmmss.s

DK2003 | DK2002 MACON RM A 29.616 METERS 00148

DK2003 | CY6922 MACON AZ MK 1293744.7

DK2003 | CY6923 MACON RM 1 44.053 METERS 17944

DK2003 | CY6924 MACON RM 2 34.650 METERS 28200

DK2003 | DK2006 HALLEY MUN TANK APPROX. 9.2 KM 3034736.4

DK2003 |-----|

DK2003

DK2003 SUPERSEDED SURVEY CONTROL
DK2003
DK2003 NAD 83(1997)- 33 30 26.24639(N) 091 18 11.66077(W) AD() 1
DK2003 NAD 83(1997)- 33 30 26.24984(N) 091 18 11.65850(W) AD() 1
DK2003 NAD 83(1986)- 33 30 26.25480(N) 091 18 11.65611(W) AD() 1
DK2003 NAD 27 - 33 30 25.84882(N) 091 18 11.23735(W) AD() 1
DK2003 NGVD 29 (07/19/86) 41.0 (m) 135. (f) VERT ANG
DK2003
DK2003.Superseded values are not recommended for survey control.
DK2003.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
DK2003.See file dsdata.txt to determine how the superseded data were derived.
DK2003
DK2003_U.S. NATIONAL GRID SPATIAL ADDRESS: 15SXT5760008816(NAD 83)
DK2003_MARKER: DS = TRIANGULATION STATION DISK
DK2003_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
DK2003_SP_SET: TOP OF SQUARE CONCRETE MONUMENT
DK2003_STAMPING: MACON 1965
DK2003_MARK LOGO: CGS
DK2003_MAGNETIC: N = NO MAGNETIC MATERIAL
DK2003_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
DK2003+STABILITY: SURFACE MOTION
DK2003_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
DK2003+SATELLITE: SATELLITE OBSERVATIONS - July 29, 2003
DK2003
DK2003 HISTORY - Date Condition Report By
DK2003 HISTORY - 1965 MONUMENTED CGS
DK2003 HISTORY - 20020723 GOOD PYBURN
DK2003 HISTORY - 20020914 GOOD PYBURN
DK2003 HISTORY - 20030729 GOOD EMCINC
DK2003
DK2003 STATION DESCRIPTION
DK2003
DK2003'DESCRIBED BY COAST AND GEODETIC SURVEY 1965 (BIW)
DK2003'STATION IS LOCATED ABOUT 10 MILES SOUTHEAST OF MCGEHEE, 8 MILES
DK2003'EAST OF DERMOTT AND 5 MILES SOUTHWEST OF EUNICE LANDING, WHICH
DK2003'IS ON THE WEST BANK OF THE MISSISSIPPI RIVER. IT IS IN THE
DK2003'SOUTH 1/2 OF SECTION 3, T 14 S, R 2 W.
DK2003'
DK2003'ALL MARKS ARE STANDARD DISKS, SET IN THE TOP OF ROUND, CONCRETE
DK2003'MONUMENTS.
DK2003'
DK2003'STATION IS REACHED FROM THE JUNCTION OF U.S. HIGHWAY 65 AND
DK2003'STATE HIGHWAY 35 WHICH IS ABOUT 4 MILES EAST OF DERMOTT. GO
DK2003'EAST ON HIGHWAY 35 FOR 2.6 MILES TO A RAILROAD TRACK, CONTINUE
DK2003'EAST ON HIGHWAY 35 FOR 0.3 MILE TO A CROSSROADS AND COXS STORE
DK2003'IN THE NORTHWEST ANGLE. TURN RIGHT, SOUTHERLY, STILL ON STATE
DK2003'HIGHWAY 35 FOR 2 MILES TO WHERE HIGHWAY 35 TURNS EAST, CONTINUE
DK2003'EAST ON HIGHWAY 35, NOW A GRAVELED ROAD, FOR 1.2 MILES TO A
DK2003'CONCRETE BRIDGE. CONTINUE EASTERLY FOR 0.75 MILE TO A FARM
DK2003'ROAD, LEFT. TURN LEFT, NORTH, ON FARM ROAD FOR 0.2 MILE TO
DK2003'STATION AS DESCRIBED.
DK2003'
DK2003'TO REACH AZIMUTH FROM STATION, GO 0.2 MILE SOUTH TO THE
DK2003'GRAVELED ROAD, AND TURN LEFT, EAST, FOR 0.25 MILE TO AZIMUTH MARK
DK2003'ON RIGHT AS DESCRIBED.
DK2003'
DK2003'STATION MARK IS STAMPED MACON 1965 AND IS SET ABOUT 12 INCHES
DK2003'BELOW THE SURFACE OF THE GROUND. IT IS 95.6 FEET
DK2003'NORTH-NORTHWEST OF A POWERLINE POLE WITH TRANSFORMER, 23 FEET
DK2003'WEST OF A TRACK ROAD AT WEST EDGE OF A CULTIVATED FIELD AND 80
DK2003'FEET NORTH OF CENTER OF A DRIVEWAY LEADING TO A BRICK HOUSE.
DK2003'
DK2003'REFERENCE MARK NUMBER 1 IS STAMPED MACON NO 1 1965 AND IS
DK2003'FLUSH WITH THE SURFACE OF THE GROUND. IT IS 64.2 FEET
DK2003'SOUTH-SOUTHWEST OF THE POWERLINE POLE WITH TRANSFORMER, 13 FEET

