

CONSTRAINED ADJUSTMENT GUIDELINES

Last Update: June 2016

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INTRODUCTION

The following instructions provide a guide to submitting GPS projects to the National Geodetic Survey (NGS). Study the guidelines before beginning your project. If you have corrections, suggestions or questions about them, notify Julie Prusky at julie.prusky@noaa.gov.

References to "GPS" will be revised to "GNSS" as other satellite constellations become viable and NGS develops procedures to handle the additional data types.

The files in samples.zip, which is part of [ADJUST_all.zip](#), may be used to practice or test the adjustment sequence. Format validation ("checking") programs such as Chkobs and Obschk, as well as other utilities, are also in ADJUST_all.

Update to these guidelines include:

AFILE: As of June 2016 new toggle in the Adjustment Mode Record (see Section 5 for details)

First-time users: Create a C:\ADJUST folder; unzip [ADJUST_all.zip](#) in it, including samples.zip if you want to start developing familiarity with the process using the sample files.

All users: create a root project folder, under which the GPS session folders are placed. File names listed below are suggested, not required. With experience, you may develop or prefer different file names.

If excessive errors are found during the review of a project, the files will be returned to the submitting agency for corrections.

Add c:\ADJUST to the path (Control Panel->System->Advanced->Environment Variables->New User Variable->Variable = "Path", value = "C:\ADJUST"). Usually the "Path" variable already exists, in which case it can simply be appended with the path where "adjust.exe" is located (e.g., ";C\ADJUST\"). Doing this will allow ADJUST (and all other programs in that path) to be run from any folder on the computer.

ACRONYMS, TERMINOLOGY

The following acronyms and terminology will be used in this document:

Afile - Adjustment constraints and processing options

Annex - Part of "Bluebook" below, such as Annex N

Bfile - Data from observation logs; equipment codes; station designations, positions, heights and related codes

[Bluebook](#) - Federal Geodetic Control Subcommittee document "Input Formats and Specifications of the National Geodetic Survey Data Base

Chapter - Part of "Bluebook" above, such as Chapter 4

CORS - Continuously Operating Reference Station

Dfile - Station descriptions and recovery notes

Gfile - Processed GPS vectors and statistics

Hub - a mark that is preferentially selected for inclusion in baselines

IDB - National Geodetic Survey Integrated Data Base

NAD 83 - North American Datum of 1983

NAD 83(2011) - North American Datum of 1983, 2011 realization, epoch 2010.00

NAVD 88 - North American Vertical Datum of 1988

NGVD 29 - National Geodetic Vertical Datum of 1929

Serfil - Station-specific 4-character identifier and 4-digit serial number list

OPUS-Projects Processing (OP)

NGS accepts Bluebook projects created using the NGS On-line User Service (OPUS) projects software. This program is **RESTRICTED** to trained project managers. If you have completed [OPUS Projects](#) training, you are registered and may create a new project. Otherwise, see the [Training Schedule](#). The "[OPUS Projects User Instructions and Technical Guide](#)" and other documents can be found at <ftp://geodesy.noaa.gov/pub/opus-projects/>. Of particular interest will be The "[OPUS Projects Processing Guidance](#)" and the "[OPUS Projects GNSS Background for Surveying](#)".

When using this software to submit data for inclusion into the NGSIDB the following rules must be strictly followed:

REQUIRED:

Provide the project ID and the project manager email address in the Project Report.

Regardless of your project's specifications or intended accuracy,

All stations:

- must have at least two hours of usable data per occupation
- must have a minimum of two occupations
- should use fixed height poles (highly recommended)

All sessions:

- must include a distant CORS with 24 hours of data for tropo correction (about 1000 KM away). It is preferable to use the same distant CORS for all sessions
- use a CORS with 24 hours of data as a central Hub in each session preferably, use the same Hub for all sessions, but this might not always be possible. If not, include CORS selected as Hubs in all sessions.
(this will automatically change the "Session Network Baseline Design" tab to USER)
- each session's Hub must connect to all other Hubs and rover stations
- distant CORS must connect to the session's Hub
- use the "NORMAL" constraint weight option

NOTE for FAA projects reduced with Opus-Projects for airports inside the contiguous U.S. (longer occupations are recommended for all other areas)

- o Two 4-hour simultaneous observation sessions on the PACS, HARN, and bench marks involved in the survey with a 30-60 minutes break between sessions is required.
- o Two 2-hour observations on the SACS with a 30-60 minutes break between sessions is required. Observations must be simultaneous with the PACS.
- o The operator must reset (take down/set up) between the sessions and document same.
- o Start times on subsequent days must be at least 2.5 hours different than the previous start times to incorporate a different satellite geometry.

SECTION 1, MATERIALS NEEDED TO SUBMIT FOR THE PROJECT

1-1. Use the list below to confirm you are sending in all required items. Set up a directory/folder structure that makes sense to you, but it is recommended to submit all files in the project root directory except where "separate folder" is noted. Submit only final files, not interim ones such as test adjustments or checking program output with errors (correct the errors--submit the output showing clean runs).

*Project Report

Include the following on the cover page:

Submitting organization name and 6 character id from [Annex C](#)

Contact name and email

Contracting organization name and 6 character id

State and end dates of GNSS observations

Datum realization and epoch

Number of occupied stations

Number of CORS

Min/Max Lat/Long of project boundaries

*Approved NGS Survey Proposal Tracking Number

*Project Instructions or Contract Specifications

*Pertinent Correspondence

*Project Sketch

*+Descriptions/Recoveries (.dsc file)

Final Bfile (Project and Station Occupation Data)

Final Gfile (Base Line Vectors w/ proper Reference System Codes see Annex N)

^Gfile with HTDP

Adjustments (3 expected)

*Final Free Adjustment

*Final Constrained Horizontal Adjustment

+Final Constrained Vertical Adjustment

Free Vertical Adjustment

*Chkobs Output (checking program for the Bfile)

Obschk Short Output (checking program for the B/Gfiles)

Obschk Long Output (checking program for the B/Gfiles)

Obsdes Output

Neighbor Output

Discrep Output

WinDesc Check

^OPUS Output

^HTDP Output

^Vector Processing Program Output

%Station Photographs (Digital)

*Observation (Field) Logs (scanned)

%Rubbings

*Raw Data Files in both RINEX and proprietary receiver formats.

Key:

*Required

%Either Photos or Rubbings are required. (Both are preferred but not necessary)

*+Required in most cases. An exception would be if there is leveling to all GPS stations and descriptions are submitted separately with the leveling portion.

This must be explained in the report.

+Required in most cases. An exception might be if all stations are leveled or the vertical adjustment is delayed awaiting completion of the leveling control observation and adjustment. This must be explained in the report.

^If applicable due to region or project Statement of Work (SOW).

All items listed above are to be submitted electronically including the field logs.

1-2. Keep a project log to document field and office problems, analyze the project and prepare the final report. Note unusual situations or procedures. In the station list, categorize stations as new or recovered, fixed, readjusted, bench marks, etc.

1-3. The project report must include any problems mentioned in the field report, especially those which affect the adjustment or analysis. Review the output of the format checking programs, adhering to the discussion in Section 2 of allowed error messages. Verify final positions and heights submitted in the Bfile to ensure correct adjusted values are present and the final files are free of format errors.

1-4. If the project is in an area known for significant [horizontal crustal motion](#), determine the epoch required for the final positions. Use the Horizontal Time-Dependent Positioning program [HTDP](#) to update the observations to the correct epoch. Submit the original and updated Gfiles to NGS ensuring the original has all modifications such as rejected vectors.

SECTION 2, PRELIMINARY PROCESSING

**Two checking programs—Chkobs and Obschk, and Make86 (run from the DOS prompt)
Geoid (run from NGS Toolkit website)**

2-1. Files can be managed in one of two ways.

A. Move them to the directory where the Adjust executable is located and work with them there, or B. leave them in the project directory and specify the path to them from the ADJUST location (note that if the location of Adjust is specified in the "Path" Environment Variable as described in the Introduction, that Adjust and all other executables in that location can be run from any folder without specifying the path). Someone familiar with DOS who likes to type will prefer B; otherwise A is recommended. Either way, first copy Bfile and Gfile as Bfile.org and Gfile.org (or similar) in the project folder.

For A, do the following: Move Bfile, Gfile to c:\ADJUST. Run Chkobs and Obschk there. Make changes to Bfile and Gfile as needed. Move them back to the project directory once all errors have been corrected. Run Make86 (see section 2-5) in the project directory (by putting ADJUST in the "Path" Environment Variable).

For B, keep Bfile and Gfile in the project folder after copying them; run the checking programs from this location \Adjust, and specify the full path to the files (only necessary if ADJUST is not in the "Path" Environment Variable).

Please sort the *80* records alphabetically. Follow each *80* record with its associated *86* record, one pair for each SSN (Make86 does this automatically).

2-2. Solution Coordinate System Code— Adjust transforms the vectors from the satellite reference frame to NAD 83. Ensure the session header records (B-records), have the appropriate 2-digit code in columns 52-53. Refer to [Annex N](#) in the bluebook formats document and the precise ephemeris (i.e. .sp3 file) used for processing. Note the reference frame listed in cc 47-51 of the first record in the sp3 file; select from the list of codes in Annex N, p. N-6 that matches it. Example: "IGb08" in the sp3 file matches "**28 -- IGb08 (epoch 2005.0)**" to put in the Gfile. The PAGES software and SINEX2G, automatically inserts the correct code. Vendor software may require hand entry. Note: Though very unusual, there are instances where the vectors are already in the NAD 83 coordinate reference system in which case the proper code for (cc) 52-53 of the Gfile's B-record is 02 despite what the table says.

2-3. Examine the Bfile for obvious errors and correct them. Verify that the 6-character organization abbreviation in cc 19-24 of the first [Data Set ID]

record exists, and that it matches the corresponding entry in the contrib.dat file for the submitting organization. Request new organization abbreviations (contributor codes) from Deb.Brown@noaa.gov.

2-4. Perform the following series of three checking programs.

Run [Chkobs](#). **Input:** Bfile, **Output:** chkobs.out.

Resolve messages which are not related to *86* record codes (edit Bfile making needed corrections); rerun Chkobs until a clean run (no error messages) is obtained.

Run [Obschk](#). **Input:** Bfile, Gfile; **Output:** obschks.out (**s** for short output file name), obschk1.out (1 for long). As with Chkobs, correct the B and/or Gfiles as needed; rerun Obschk until a clean run is obtained. Warnings should be checked and reported in the project report. All other messages must be resolved. OBSCHK should be run each and every time any changes have been made to either the Bfile or the Gfile.

Obschk mimics the program used for loading the project data into the IDB. Unresolved messages other than warnings in Obschk will cause the data loading process to fail.

Any one type of error appearing consistently through a file may generate voluminous repetitive messages which will all disappear after the corrections are made.

CR8BB will insert one value from the look-up table of antenna offsets, given the other value. If ARP heights are entered (e.g., 2000 with implied decimal point), CR8BB will compute and insert the L1PC height (2068), and conversely. The ARP height is required. Though the L1PC height has been removed from the FGCS Bluebook no error will be produced if it is present.

2-5. Run [Make86](#) if *86* records are not in the Bfile (preferable situation for running Chkobs and Obschk). **Input:** Bfile, **Output:** Bfile.86. The result is a new Bfile with pairs of *80* and *86* such as the following

```
001460*80*0701JAY                36253855817N094470567140W      OKBA
001470*86*0701                N88                A  A
```

SECTION 3, DETERMINE CONTROL

3-1. Determine which horizontal and vertical datums will control the adjustment and note them in the project report. Currently only NAD 83(2011) and NAVD 88 are allowed to be used in the contiguous US; Outside the contiguous US, check the data sheets in the area to determine valid datums. See also http://www.ngs.noaa.gov/INFO/incorp_data.shtml.

3-2. Retrieve datasheets for the existing marks in the project. Ensure that all published positions, ellipsoid heights and orthometric heights constrained in the project match the values currently published on data sheets.

3-3. Research orthometric heights. If adequate NAVD 88 vertical control exists, use only that control in the vertical adjustment. Acceptable heights include bench marks and stations with heights determined with height modernization specifications as noted on the data sheet. Usually, 3-4 are considered sufficient for a non-height modernization or non-airport project. If insufficient NAVD 88 control exists, determine whether there are NGVD 29 control points that can be transformed to NAVD 88 using [Vertcon](#). (The *86* record for the transformed stations should have a "D" in the orthometric height code field.) Document such stations in the project report. Verify height codes for all stations per *86* record formats given in [Chapter 4](#) of the Bluebook.

Constrained leveled heights may be of several types, per the *86* record Table of orthometric height codes. The most common such codes are A, B and L.

If the field crew leveled from a known bench mark, the leveled height (generally code L) can be used for control, subject to consistency with other bench mark heights in the project. Discuss any such leveling in the project report.

In rare situations, it may be desirable to add leveled differences of elevation to the IDB for documentation purposes. This is achieved by including *45* and *47* records in the Bfile. In order to load any such leveling observations in the IDB, *80* series records must exist in the Bfile for both ends of the line. If neither the standpoint nor forepoint is positioned, do not include the *45* and *47* records. If one end of the line is unpositioned, add a *82* record for the point, coding it as if it were a peripheral point for the positioned end of the line. However, Adjust does not recognize these records in the Bfile. In order for these leveling differences to participate in the adjustment, code a CH record for them in the Afile (See "[ADJUST_supplemental.txt](#)").

Orthometric heights determined by GPS observations and a geoid model should have one of three codes: "K" (restricted to height-modernization projects, published to cm), "G" (for regular GPS projects, generally published to dm, and FAA projects published to cm), or "J" (when the GPS height is only published to a meter--as in Alaska for some projects). Airport stations designated as PACS and SACS are published to cm in order to maintain the required differential relationship between the stations. Therefore, "G" would be the correct code unless other circumstances exist (e.g. the station is a bench mark).

Leveling to be included in the IDB should be discussed with NGS. Contact Vasanthi Kammula: Vasanthi.Kammula@noaa.gov.

3-4. Station names in the Bfile *80* records must match those in the Dfile (see naming conventions per [Annex D](#), e.g. remove dates and agency abbreviations). If a change from a published name is needed, include the changed designation in both files and note it in the project report. Recommended: Sort the *80* records alphabetically. Follow each *80* record with its associated *86* record, one pair for each SSN (Make86 does this automatically).

3-5. Order and type (OT) and order class codes are no longer required.

3-6. PACS and SACS-Supplemental Guidance for GPS Observation and Adjustment of Airport Geodetic Control

When the PACS is found in good condition and its unmoved position verified, but one or more new SACS are to be established, **a minimum of two GPS observation sessions of all SACS are required along with simultaneous observations of the PACS.** Follow the guidance provided in the Adjustment Section 4 through Section 7.

When determining the position of one or more new SACS in a survey involving a published PACS and one published SACS, analysts should include the position and ellipsoid height of the published SACS as a constraint in the Horizontal Constrained adjustment when it fits well with the published PACS. Likewise, include well-fitting orthometric heights as constraints during the Constrained Vertical Adjustment.

For SACS horizontal adjustments, the 2 cm horizontal and 4 cm ellipsoid height "rule of thumb" values mentioned in Section 5-2 of this document may not allow the required SACS accuracy standards to be maintained. Additional guidance follows.

Horizontal Adjustments: Run the horizontal free adjustment, constraining the published position and ellipsoid height of the PACS. Compute the inverse between the output position and ellipsoid height of the SACS and its published values. For adjusted vs. published differences exceeding either 1 cm in horizontal position or 1.5 cm in ellipsoid height, readjust the SACS. Otherwise, include the published SACS as a constraint during the constrained horizontal adjustment.

Vertical Adjustments: Run the vertical free adjustment constraining the published

position and height of the PACS. Compare the adjusted heights of SACS with published values. For adjusted vs. published GPS-derived height differences exceeding 2 cm, readjust the height. Otherwise, hold the published height fixed.

SECTION 4, MINIMALLY CONSTRAINED (FREE) HORIZONTAL ADJUSTMENT

4-1. Create the horizontal free Afile (Afilehf). This can be done in two ways. Either use an existing Afile and edit it for the new project, or use WinDesc->File->Export->GPS Project Files. Exercise caution when editing Afiles as data written to Afile option records are column sensitive. Afile option records are defined in file "ADJUST_supplemental.txt."

In the Afile, constrain only one station position and ellipsoid height (EH) per component, using published values from a datasheet. (Multiple components occur in rare cases when disjointed networks are combined in one adjustment.)

Generally, a CORS will be constrained; but in principle, any well positioned mark can be constrained in the free adjustment. The latitude, longitude and EH can all refer to the same mark (usual procedure), or the EH can be from a different mark. All three data elements for a station can be in one CC record, or the lat/long and EH can appear in separate CC. An EH is indicated by "E" in column 77.

The VV record (defined below) is on a separate line at the end of the Afile. Since it affects the distribution of residuals, the VV record should be used for all free adjustments. In some cases, such as when large blunders occur, VVHU may prevent ADJUST converging to a solution. The VV record can be removed to resolve such issues, or to expedite the initial adjustment of large projects, but it should otherwise be used as part of the free adjustment analysis. Once the adjustment is clean, the final run is used to determine the sigma scale factors used in the Afile VS record (defined in Section 5) for all subsequent adjustments. To include comments in the Afile or to change a record to a comment place two asterisks, "**", in cc 1-2.

```
70-76 Height, units of millimeters      (integer)
77-77 Height Code      E ---- ellipsoidal height
```

The 0.71, 0.58, and 2.82 values are standard deviations of the latitude, longitude, and ellipsoid height. These are described in Section 5.

Sample Afile:

```
CC      1001  0.71  0.58  2.82                37312217766N092421254079W 360616E
**1001 CNWM CORS ARP lat, long & EH constrained
DD3
II109999999
NLY (Optional in the free adjustment - see Section 5-1)
MM3YY
PP22
VVHU
```

Or, as mentioned above, break up the position and EH on two lines:

```
CC      1001  0.71  0.58                37312217766N092421254079W
CC      1001                2.82                360616E
```

The VVHU record is a special application of the VV (Variance Factor Indicator and Constraint) record, which is defined in "ADJUST_supplemental.txt." The observation type code "HU" is used to solve for variance factors for the horizontal and vertical components of the GPS observations. This is done by computing the sum of squares of the residuals for the horizontal and vertical observations separately, computing the redundancy numbers of the horizontal and vertical components of the observations, and estimating the standard deviation for each. The resulting adjustment will produce a variance of unit weight equal to 1.00.

4-2. Run Adjust in 3D with minimum constraints. Respond to the prompts:

Input: Bfile.86, Afilehf, Gfile, **Output:** adjhf.out, Bfilehf

View output file adjhf.out with a text editor. Check for a successful run indicated by "HAVE A NICE DAY" message at the end of file. If the Adjust run failed, review the output file for error messages and verify that program input filenames were correctly entered. Other causes of failure, such as a singularity, may require more analysis. Note the variance of unit weight and degrees of freedom for the report. The variance of unit weight should equal 1.00 since the VVHU option is used.

Programs [CompVecs](#) and PrePlt2 may be useful for analysis purposes. CompVecs finds differences among redundant vectors in a G-file. It needs a horizontal bluebook with *80* position data. Preplt2 reads ADJUST output files and writes residual components, baseline length, SSNs and designations to an output file in tabular format. In adjustments containing numerous vectors, sorting columns of DN, DE, or DU residuals will help locate large residuals.

Inspect individual computed-observed (C-O) residuals in adjhf.out. Investigate large residuals to rule out blunders in the processing. The RESIDUAL STATISTICS section of the output file contains summaries displaying the observation numbers of the 20 greatest component residuals. Sample summaries follow.

```
OBSERVATION NUMBERS OF 20 GREATEST GPS DU COMPONENT RESIDUALS (V)
54   48   66   72   69   15   36   12   27   75   24
OBSERVATION NUMBERS OF 20 GREATEST GPS DL COMPONENT RESIDUALS (V)
69   48   51   42   63   24   12   54   33   36   30
```

"LARGE MISCLOSURE" messages: Generally ignore these, as opposed to the computed- observed (C-O) residuals. They are only the shift between positions in the input Bfile and adjusted positions. Unless the position in the Afile is wrong, they do not indicate a problem. To see this is so, re-run the adjustment, using the output from the first adjustment as input to the second; those messages will not appear. The "LARGE MISCLOSURES" are in units of .0001 m, tenths of mm—thus a small distance like 2 cm can look large (200.0). Ellipsoid heights that start off as blanks or zeroes in the input Bfile will shift to their adjusted values in the output Bfile, with correspondingly "large misclosures" reported.

Attempt to reduce large residuals (exceeding 2 cm horizontal and 4 cm vertical) by reviewing vector processing for blunders such as incorrect antenna height, improper antenna pattern, etc. and reprocess any affected sessions. Other reprocessing options to consider include raising the elevation mask or deleting noisy satellite data. Before adding a reprocessed vector solution to the Gfile, delete the original vector solution.

With reprocessing completed to correct the blunders and tweak the processing options, reject observations which continue to have a high residual (rule of thumb, over 2 cm horizontal and 4 cm vertical). Reject a vector by entering "R" in column 58 of the G-file C record for the affected vector--see example below. Do not, however, allow rejections to result in a new station being no-check (only one observation to it). Remaining large residuals may indicate the need for reobservations.

Example portion of a Gfile, showing one rejected vector, the third C record, with R in column 58:

```
AXE2012030720120307
B2012 3 716582012 3 722 0 3 page5 v0708.16IGS      126 1 2 27NCGS  2012 411IFDDPF
C01000005 -174930970   12  -3224990   26   47107500   19 R067210100R067210005
C01000003 -104942635   11  -44430269   26  -27797463   19 R067210100R067210003
C01000001  137309864   11  -11638474   24  -55689308   18RR067210100R067210001
```

```

D 1 2 -5723833 1 3 5025210 1 4 5613055 1 5 -2179673 1 6 2882670
D 1 7 1165649 1 8 -2571102 1 9 3029782 2 3 -8854411 2 4 -3123343
D 2 5 4961192 2 6 -4373273 2 7 -2910199 2 8 3982316 2 9 -3397965
D 3 4 2662336 3 5 -4427962 3 6 4806815 3 7 3053212 3 8 -3505623
D 3 9 3938813 4 5 -6271706 4 6 6563317 4 7 2220115 4 8 -2615862
D 4 9 2912531 5 6 -8778901 5 7 -3346597 5 8 3920148 5 9 -3267809
D 6 7 2552310 6 8 -3546802 6 9 4188493 7 8 -6345931 7 9 5391172
D 8 9 -8733045

```

Run all adjustments in mode 3 (normalized residuals). Do this by coding the MM record in the Afile as "MM3". This mode computes residuals scaled relative to the standard deviation of the residual (normalized residuals).

Once you are satisfied that there are no blunders or preventable outliers:

SECTION 5, CONSTRAINED HORIZONTAL ADJUSTMENT

5-1. Horizontal Constrained Afile (Afilehc)

Fix all currently published positions and ellipsoid heights from a data sheet retrieval. (In crustal motion areas, it may be necessary to update these positions with HTDP). As with the free adjustment, lat/long and EH can be combined on one CC record for each station or separated--lat/long on CC records in one group, EH in another.

Weight the Constraints

Add the network (point) standard deviations (sigmas) found on the datasheets.

The sigmas for a given station are entered in centimeters in columns 15-32 of the constraint record as shown below. For example the values from the datasheet for PID=[AE8289](#), are

```

StdN   StdE   Stdh
0.15   0.12   0.27

```

```

0           1           2           3           4           5           6           7           8
1234567890123456789012345678901234567890123456789012345678901234567890
CC           0005   0.14   0.11   0.25           46462910992N092053738770W 156085E

```

The network sigmas can also be generated in Afile format using the NGS program WinDesc. Once station PIDs have been added to the WinDesc description (*.des) file, the sigmas can be populated under the WebTools > Get > Positions for all PIDs.

Network Standard Deviations for CORS

Most CORS have formal accuracy values determined in the Multi-Year CORS Solution (MYCS) and their accuracies are provided on NGS datasheets in the same format as passive marks. However, there are many CORS that do not have formal accuracies. For these CORS, sigmas for use in weighting constraints can be obtained from the short-term time series, available through a link on the individual CORS web pages. These are given as \pm root mean square error (RMSE) values in parentheses on the plots. A screen capture of the time series should be provided in the project report or in a directory aptly named.

In many cases, the sigmas for CORS are larger than for passive marks, and in such cases the adjustment will be more tightly constrained to the passive marks than the CORS. If it is desired to constrain to the CORS more tightly than the formal sigmas allow, the short-term time series can be used if the RMSE values are less than the formal sigmas. Alternatively, the CORS formal sigmas can be reduced by dividing the sigmas by 2 or 3. However, in no case should the sigmas

used for constraining CORS be modified such that they are less than 0.1 cm horizontally and 0.2 cm vertically. It is important to realize that large sigmas on CORS (as with any other station) indicate greater uncertainty in the coordinates. Because of this, caution should be used if reducing the CORS sigma values, since it will affect the coordinates and accuracies determined in the adjustment. Moreover, constraining too tightly to a station with large errors can adversely impact the adjustment. If CORS sigmas are reduced for a project, it should be documented in the project report, including a comparison to results obtained when the CORS sigmas are not reduced.

AFILE: As of June 2016 a "Y" in cc 6 of the MM. This writes the non-shifted constraints to the output b-file rather than those shifted by the sigmas (required for final submission to NGS).

MM3YYY

Add a VS record on a separate line at the end of the Afile, using the sigma scale factors computed in the final free adjustment. The *93* record of the output Bfile contains these values (they are also given in the ADJUST output file). This scales the uncertainty of the horizontal and vertical components of the GPS vectors before beginning the adjustment.

Compute Local and Network Accuracies: Add a line in the Afile with the codes NLY. This will compute network and local accuracies and write them to the Bfile as *91* and *92* records (see [Chapter 4](#) of the Bluebook).

70-76 Height, units of millimeters (integer)
77-77 Height Code E ---- ellipsoidal height

Example Afile:

0	1	2	3	4	5	6	7	8
1234567890123456789012345678901234567890123456789012345678901234567890								
CC	0001	0.21	0.18	0.27		36244466001N077260841822W		5614E
CC	0003	0.15	0.14	0.45		36263621507N077422648858W		43435E
CC	0005	0.17	0.16	0.54		36313793277N077462610205W		65158E
CC	0200	0.85	0.76	3.40		36243056335N077261530879W		13257E
DD3								
II109999999								
MM3YYY								
PP22								
NLY								
VS	4.000	4.333						

An example of the network (*91*) and local (*92*) records in the output Bfile is given below, along with associated *80* and *86* records. Program Adjust populates columns 1-6 of the *91* and *92* records with the sequence number in column 1-6 of the *80* record (of the "from" station for the *92* record). Similarly, Adjust populates columns 71-76 of the *92* record with the sequence number in column 1-6 of the *80* record of the "to" station. These sequence numbers provide a convenient means of searching the Bfile for network and local accuracy values associated with specific stations. The 4-digits Station Serial Numbers (SSNs) can also be used for searching, but they may not form unique strings within a Bfile, especially for large projects. This use of sequence numbers is included in these guidelines since it is not part of the official Bluebook format.

0	1	2	3	4	5	6	7	8
1234567890123456789012345678901234567890123456789012345678901234567890								
000750*80*0001	JACKSON	AZ	MK			36244465989N077260841820W		NCBA
000760*86*0001	40014A22Y88NGS			-344006		5614A41A		
000770*80*0002	JOYNER					36274043492N077361617205W		NCBA
000780*86*0002	38300A22Y88NGS			-340686		4232A41A		
000790*80*0003	ROANPORT					36263621510N077422648864W		NCBA
000800*86*0003	77390A21Y88NGS			-339546		43436A41A		

000810*80*0004	TOM			36280817246N077364177672W					NCBA
000820*86*0004	44811A22Y88NGS		-340426	10769A41A					
000830*80*0005	VULTARE AZ MK 2			36313793282N077462610199W					NCBA
000840*86*0005	98939A22Y88NGS		-337816	65158A41A					
000850*80*0100	ROANOKE RAPIDS CORS ARP			36282912720N077345660637W					NCBA
000860*86*0100	44652K N88NCGS		-340666	10586A41A					
000870*80*0200	JACKSON CORS ARP			36243056300N077261530868W					NCBA
000880*86*0200	47662K Y88NGS		-344056	13257A41A					
000750*91*0001		0.16	0.18-.10308822	0.28	Y				
000770*91*0002		0.23	0.21-.01402805	0.86	Y				
000790*91*0003		0.14	0.13 .01151952	0.44	Y				
000810*91*0004		0.23	0.21-.00539402	0.86	Y				
000830*91*0005		0.15	0.15-.07689758	0.51	Y				
000850*91*0100		0.21	0.19-.02570723	0.83	Y				
000870*91*0200		0.25	0.26-.20512389	0.96	Y				
000750*92*0001	0100	0.21	0.19-.11268980	0.83	Y	000850			
000750*92*0001	0005	0.19	0.23-.21783842	0.51	Y	000830			
000750*92*0001	0003	0.18	0.20-.06874055	0.44	Y	000790			
000770*92*0002	0100	0.09	0.07 .06230800	0.83	Y	000850			
000770*92*0002	0004	0.10	0.07 .09238057	0.86	Y	000810			
000790*92*0003	0100	0.20	0.20 .00264948	0.83	Y	000850			
000790*92*0003	0005	0.17	0.16-.04880625	0.51	Y	000830			
000810*92*0004	0100	0.10	0.07 .11677967	0.83	Y	000850			
000830*92*0005	0100	0.21	0.21-.07626602	0.83	Y	000850			
000850*92*0100	0200	0.14	0.18-.52775622	0.96	Y	000870			
1234567890123456789012345678901234567890123456789012345678901234567890									
0	1	2	3	4	5	6	7	8	

5-2. Run Adjust. **Input:** Bfilehf, Afilehc, Gfile, **Output:** adjhc.out, Bfilehc

Confirm that the adjustment ran correctly; run PrePlt2 to list and sort residuals. Check position shifts and residuals in adjhc.out; decide whether or not to readjust certain stations. A worse-than-expected network accuracy would tend to favor readjusting a station assuming good quality and quantity of new observations.

Compare the results of the constrained adjustment with the free adjustment. A good rule-of-thumb is that the constrained adjustment variance of unit weight (reference variance) should not exceed 3 times the free adjustment variance of unit weight.

Residuals which increased markedly from the free to constrained adjustment require specific investigation. The increase results from problems with the constraints. **Do not reject any observations due to constraints.** Verify that the control positions and heights used are correct and are all on a consistent datum realization (e.g. do all positions have the NAD 83(2011) datum tag with a 2010.00 epoch?).

For observations with large residuals check for misidentifications. A wrong SSN in the Afile, for example, can cause residuals so large that they overflow the field and cause ***** to be written in place of actual values. If no problems can be identified and solved, determine whether published positions and/or EH should be readjusted. Consider the requirements of the project. Save the adjusted positions (output Bfile) from the final constrained run.

Because weighted (stochastic) constraints are used for adjustments, the adjusted coordinates of the constrained stations will not equal the constrained values. The magnitude of the coordinate change (shift) will depend mostly on the standard deviations (sigmas) used for the weights, where larger shifts will typically occur for stations with larger sigmas. As a general rule, if the adjusted values of the constrained coordinates of a station shift by more than 2 cm horizontally and/or 4 cm in height, its horizontal coordinates and/or ellipsoid height, respectively, should be unconstrained. Doing so means that

the published values for the unconstrained passive control station will be updated by the adjusted values determined in the submitted survey (CORS coordinates will **not** be updated). This 2 cm horizontal and 4 cm vertical threshold is consistent with that used by NGS for updating published CORS coordinates, although for CORS this is done by NGS independent of individual campaign-style GPS projects. It is important to realize that this threshold is merely a "rule of thumb." For individual projects, unconstraining a station may be necessary if shifts are less than the "rule of thumb" threshold, and in some cases it can remain constrained even if shifts slightly exceed the threshold. The decision to constrain or not constrain also depends on other factors, such as the statistics of the adjustment, residuals, shifts at other stations, and station accuracies. It requires judgment and should not simply be an automatic response to constrained station shifts.

The constrained station shifts are given in the Adjust output file at the beginning of the NORMALIZED RESIDUALS section. They are shown as "V=C-O" ("residual equals computed minus observed") in meters. An example Adjust output is shown below for two constrained stations, where the first station shifted by 0.4 cm horizontally and the second by SQRT ($0.1^2 + 0.2^2$) = 0.22 cm horizontally and 0.1 cm in ellipsoid height.

ONORMALIZED RESIDUALS

			COMPUTED				OBSERVED	V=C-O	
								SEC	METER
1	LA	36 24	44.65989N	36 24	44.66001N	-0.00012	-0.004		
2	LO	77 26	8.41820W	77 26	8.41822W	0.00002	0.000		
3	EH		5.614		5.614		0.000		
4	LA	36 26	36.21510N	36 26	36.21507N	0.00003	0.001		
5	LO	77 42	26.48864W	77 42	26.48858W	-0.00006	-0.002		
6	EH		43.436		43.435		0.001		

Discuss all readjusted stations in the project report in addition to any investigations and conclusions reached as a result of the analysis.

5-3. Run Geoid. After the horizontal adjustments have been completed, run the current [Geoid](#) program as appropriate for your area, to add geoid heights to the final constrained adjustment Bfile output. This can be done conveniently using the appropriate Geoid model from the [NGS Geodetic Tool Kit](#). Another method would be from one's own PC by downloading the "Intg.exe" program along with the appropriate data models for the project area and then running Intg.exe. More information, such as comparing various models, is available on the [Geoid](#) web page. The example below shows -28769 geoid height (implied 3 decimal places) and "6" geoid ht code (for Geoid12B).

Run Geoid. Input: Bfilehc, Output: Bfileght

```
001470*86*0701          N88          -287696      237794A  A
```

SECTION 6, VERTICAL ADJUSTMENTS (FREE AND CONSTRAINED)

6-1. Create the vertical free Afile (Afilevf). Fix one position and one published orthometric height. They can be from the same station or different stations (e.g., good horizontal position in one CC record for a CORS, good OH in separate CC record for a bench mark). Leaving column 77 of the CC record blank indicates the record contains an orthometric height value. Standard deviations of the constrained coordinates and heights should NOT be entered (i.e., columns 15-32 of the CC record should be blank).

Include the VS record from the horizontal constrained Afile.

70-76 Height, units of millimeters (integer)
 77-77 Height Code blank -- orthometric height

6-2. Run Adjust with minimum constraints. **Input:** Bfileght, Afilevf, Gfile,
Output: adjvf.out, Bfilevf

Assuming the adjustment ran to completion, the statistics of this run will be identical to those of the horizontal free adjustment. Check adjvf.out for big shifts between published and free-adjusted heights.

It would be helpful to compute the shifts between the results of the vertical free adjusted and the published heights. Additionally, plot these shifts on a project sketch to determine if several heights near each other are shifting consistently or a height appears to be an outlier and therefore should not be used as control. For inconsistent shifts use resources available such as recovery notes, photographs, and rubbings of the mark. Possible causes could include movement, an unintended mark was observed such as the underground mark instead of the surface mark, or occupying a reference mark rather than the parent station. Look for inconsistent shifts as opposed to areas where the shifts, even high shifts, are consistent. Likewise, look at the geoid heights to ensure they are consistent. If no cause for the shift can be found, the orthometric height may need to be readjusted.

6-3. Create the vertical constrained Afile (Afilevc). Constrain all previously adjusted orthometric heights as indicated above and one NAD 83 adjusted position. The same comments about CC records apply. All GPS-derived Ht Mod heights should be constrained along with bench marks. For ht mod stations the datasheet will read:

HT_MOD - This is a Height Modernization Survey Station.

Include the VS record with its appropriate values.

6-4. Run Adjust with vertical constraints. **Input:** Bfilevf, Afilevc, Gfile,
Output: adjvc.out, Bfilevc

Run PrePlt2 to list and sort the residuals. Investigate observations with large shifts or residuals to see if any heights should be readjusted. Apply the same rule as in the horizontal constrained adjustment: no rejections due to constraints. Free any heights in question and rerun as a test. Note the differences between the published and readjusted heights obtained from the vertical constrained adjustment. Consider the requirements of the project before deciding whether to readjust additional points. Save the output Bfile from the final constrained vertical adjustment.

SECTION 7, COMBINING THE HORIZONTAL AND VERTICAL RESULTS

7-1. When the constrained horizontal and vertical adjustments are complete, run Elevup to combine the positions and ellipsoid heights from the horizontal adjustment with the orthometric and geoid heights from the vertical adjustment into a final Bfile. This will be the file, after final editing, that is loaded into the IDB. The file name should indicate that it is indeed the final one.
Input - Bfilehc, Bfilevc; Output - Bfile.fnl; SSN length 4.

SECTION 8, POST-ADJUSTMENT PREPARATION FOR SUBMISSION

8-1. Write report--See FGCS Bluebook [INTRODUCTION](#).

8-2. Double check all output.

8-3. Rerun checking programs on final files--there should be no errors.

8-4. Process Descriptions

Descriptions--At some point, whether at the beginning, middle or end of processing, use [WinDesc](#) to create the Dfile for recovery notes and new mark descriptions. Verify and change, if necessary, the SSNs in the Dfile to match the B- and Gfiles. Make sure the full station names in the Dfile and *80* records of the Bfile are correct and match (e.g. do not use 4-character IDs for station names in the Bfile). Run Obsdes and WinDesc Check (see below) and resolve error messages and inconsistencies.

A description or recovery note does not need to be submitted for CORS currently published by NGS. If one is submitted, uncheck the load option. Messages about missing descriptions for these CORS are allowed in the Obsdes output. CORS which are expected to be published by NGS in the future should have a minimal description for the purpose of assigning a permanent identifier (PID) in the IDB.

[WinDesc](#) uses a proprietary file type *.des which must be converted to Dfile *.dsc. After creation of the Dfile, Neighbor and Discrep must be run from WinDesc Tools, then WinDesc Check must be run. Neighbor and Discrep access the IDB to check for stations not assigned a PID but which might be already in the IDB (Neighbor) and any code mismatches between the IDB and the recovery notes (Discrep). WinDesc Check performs a format and information check on the Dfile. WinDesc Check 'ERROR' messages are not allowed and **MUST** be corrected--the loading programs will not accept a Dfile which resulted in even one error message. The only exception is an error due to the lack of an assigned GPS number. Leave this field blank and ignore the error message. 'WARNING' messages should be checked, and corrected if appropriate.

The Dfile must be corrected to conform to current acceptable codes as noted in the checking program output. After all changes have been made, analysis completed, and a clean run has been obtained (with the one exception noted above) export the *.des file to *.dsc inside WinDesc (File->Export->Dfile) for submission to NGS.

After a checking program has identified errors and these have been corrected, run the checking program again to confirm that the needed corrections occurred with no new errors. Run the checking programs on the final files to assure that all applicable codes have been added.

8-6. Prepare the final Bfile for submission. Most of these items will have been completed before the final adjustment, but should be double-checked at this time. Use the checklist in [Appendix B](#).

A. Identify horizontal and vertical no-check stations in the project. In the *80* record, change cc 6 to 'N' for horizontal no-checks. For an orthometric height, change cc 5 to N in the *86* record. A new station is no-check when all of

its observations get a zero residual in the constrained adjustment. The 'N' in the observational summary is a means of identifying stations which have only one vector but this may not correctly identify a no-check station. For example, in a GPS project, a station determined by only one vector might be correlated with other vectors resulting in a non-zero residual. The observational summary will show an 'N' but unless the residuals on all components of the vector are zero, the station is checked. Document any no-check cases in the report. (See information in Section 4-2).

B. Verify that station names conform to the bluebook naming conventions, e.g., no dates or agency abbreviations, and a published station's designation matches that on the datasheet. [Annex D](#) discusses designations.

C. Check all height codes as discussed in [Section 3-3](#). It is important to ensure all orthometric height codes are correct, as they affect future publication on the datasheet. For example, **if a bench mark was not held fixed**, it should not carry a leveled code (A, B or L) in the final Bfile. Similarly a leveled height held fixed should not have a GPS code (G or K) but rather a leveled code.

D. Verify state abbreviations in cc 77-78 of the *80* records.

E. The first record in the Bfile must contain the NGS provided agency code of the observing organization (left-justified). This organization must be listed in [Annex C](#). If the organization is not listed, request an addition to the contributor table as noted in [Section 2](#))

8-7. Organize files for submission to NGS.

APPENDIX A, Processing Programs

ADJUST - required. Performs a least-squares adjustment in 3 dimensions using the Bfile and Gfile.

Input - Bfile (observations, positions and heights), Afile (ADJUST instruction parameters), Gfile (GPS vectors), Output - adjustment output (messages, results and statistics) and Bfile (positions updated with adjusted values), if requested.

CHKOBS - required. Bfile validity check.

Input - Bfile
Output - listing of format error messages

CLUSTER - optional. Compares *80* records between files, e.g. Bfile and an IDB retrieval file or another Bfile.

Input - 2 Bfiles or files of *80* format records
Output - list showing the positional and height differences between the same stations in the 2 files and a file of common stations

CR8BB - optional - Bfile creation program.

DIFLATLON - optional. Computes differences between stations with the same SSN in two different Bfiles, e.g. free versus constrained adjustment. Lists the differences in latitude, longitude, ellipsoid height, and orthometric height as well as the shift in meters.

Input - two Bfiles or files of *80* records
Output - listing of differences between corresponding stations

DISCREP - required as part of description submission. Run from WinDesc->WebTools. Identifies differences between codes in the Dfile and those in the IDB for all stations with PIDs. It is important to understand values from the user file will override the database value, such as for stamping, agency code, setting, etc.

Make sure the file information is correct, especially when it disagrees with the existing database information.

Output - listing of comparisons between codes in IDB and those in file

ELEVUP - required. Combines results of the constrained horizontal adjustment with the vertical adjustment to produce a final Bfile containing the final adjusted positions and heights to be loaded into the IDB.

Input - two Bfiles, one with adjusted positions and ellipsoid heights and one with orthometric and geoid heights

Output - one updated Bfile containing all adjusted values

GEOID - required. Updates *86* records with geoid heights from the latest geoid model, whichever is appropriate for the region.

Input - Bfile

Output - updated Bfile

HTDP - optional (see comments in [Section 1-4](#)).

Predicts and updates coordinates and/or observations to a user-specified date to facilitate adjusting survey data to particular epochs in crustal motion areas.

Input -Interactive or Bfile, Gfile

Output - updated coordinates or Bfile, Gfile

MAKE86 - optional. Creates *86* records in Bfile. Will not remove existing *86* records; uses orthometric heights from the *80* records if present.

Input - Bfile

Output - updated Bfile

NEIGHBOR - required as part of description submission. Run from WinDesc->WebTools. Compares description/recovery notes within a specified radius to aid in identifying marks already in the IDB.

Output - listing of IDB matches with each description/recovery note

OBSCHK - required; checks formats in a Bfile and Gfile as well as the relationship between the two files.

Input - Bfile, Gfile

Output - listing of validity check errors in a short and long formats

OBSDES - required as part of description submission. Checks the Bfile against the .dsc description file (or older "unified" format)

Input - .dsc Dfile or older .ha unified format description file, Bfile

Output - listing of inconsistencies

SPCS83 (not required for submission to NGS). Computes state plane coordinates from geodetic positions (or vice versa) on the NAD 83 datum. (Also SPCS83EH, showing ellipsoid heights).

Input -Interactive, or file of coordinates

Output - file of computed state plane coordinates or NAD 83 positions.

UTMS (not required for submission to NGS). Computes UTM coordinates from geodetic positions and vice versa for NAD 27 and NAD 83.

Input - Interactive or file of UTM coordinates or geodetic positions

Output - file of updated positions or coordinates

VERTCON - optional. Transforms NGVD 29 heights to NAVD 88

WINDESC CHECK - required as part of description submission. Description file validity check, part of WinDesc

Output - listing of format error messages

APPENDIX B, Final Bfile Checklist

1. The first record contains the observing organization's agency code provided by NGS.
2. Antenna heights and types match field logs.
3. Names of new stations follow current conventions and names of existing stations match data sheets.
4. State codes in *80* records and height codes in *86* records are correct.
5. *80* records exist for the marks at both ends of leveled height differences.
6. In the rare case of horizontal and/or vertical no-checks, they have been identified with 'N' in cc 6 of the *80* for the position and ellipsoid height, and cc 5 in the *86* record for the orthometric height.
7. *80* records are sorted alphabetically (recommended, optional).
8. *86* records are interleaved with *80* records, one pair for each SSN.
9. Checking programs have been run on the final B-, D- and Gfiles and show no errors except those noted above.
10. Positions and heights match final submitted adjustments.

APPENDIX C, Project Report Checklist

Title Pages

Project Title
 Location
 Agency for which the work was conducted (and NGS provided agency code)
 Agency conducting the survey (and NGS provided agency code)
 Agency conducting the adjustment (and NGS provided agency code)

Statistics Page

Datum (Horizontal and Vertical)
 Geoid Model used
 Latitude/Longitude Project Boundaries (nearest minute)
 Observation start and stop dates
 Number of new, existing stations (other than CORS)
 Number of CORS

Original Project Plan and NGS approval

Sketch

Number and type of antennas and receivers, serial numbers

Purpose of project

Problems encountered in the field and resolution

Procedural changes (not expected); if so, process of approval by NGS

List all non NGS software used

Checking program results

Results of free, horizontally constrained, and vertically constrained adjustments

Horizontal and vertical fixed control and source of each

Accuracies which fall below expectations, and discussion

Any readjusted stations and discussion

Overall results

Notes on description file - CORS not included, changes to the IDB revealed by Discrep, unusual designations, etc.

Submit only final files.

APPENDIX D, UPDATES

June, 2016

Section 1-1. Changed the title of the "Approved NGS Survey Proposal Form" to "Approved NGS Survey Proposal Tracking Number."

Guidance for airport surveys using OPUS-Projects.

Listed specific metadata to be included in the project report.

Section 3-6. Guidance for PACS/SACS adjustments was added for newly established SACS when there is an existing PACS and SACS.

Section 5-1. New requirement: Use MM3YYY in the A-file when running the constrained horizontal adjustment. The Y in cc6 allows the program to write non-shifted constraints to the output bfile.

Section 5-3. The Geoid Model example was updated to Geoid12B.

Section 8. Identifying vertical no-check stations. Vertical orthometric height no-checks must be indicated in the *86* record cc 5 rather than the *80* record.

July, 2015

Change the computation of horizontal and vertical project error scale factors, use of variable weights on constrained stations, determination of network and local accuracies in program ADJUST.

Add new files to samples.zip. Update adjust_supplemental.txt. Include NOAA Technical Memorandum NOS NGS-47. Remove reference to superseded sections of the FGCS Bluebook.

Add specifications and links for OPUS-Projects. OPUS-Projects can now be used to create B- & G-files for input into ADJUST.

November, 2012

Add new procedures to scale the project, weight the constraints, and compute local and network accuracies. Add examples in body. Add new sample files to sample.zip.

December, 2010

Remove confusion of when to run Geoid. Clean up some confusing language. Add information about description processing.

February, 2010

Delete section 2-7 about running Geoid [before any adjustments]; leave this step only in section 5-3 [after good positions have been obtained through the horizontal adjustments].

October 2009

Add information about rejecting a vector; include example Gfile--p. 8 of document, section 4-2.

January 2009

Rewrite to address only GPS projects.

Delete references to scaling project.

Delete programs only available for in-house users.

Delete reference to programmers for each software program. Delete APPENDIX B-Processing Outline (duplicate of step-by-step) Delete most references to in-house processing for loading.

Include ATTACHMENT 1-step-by-step (revised)

November 2004

Changes in procedures resulting from update to Adjust to identify ellipsoid height constraints.

Changes to text to clarify procedures and other instructions.

New contact for guidelines.

Refer to Bluebook for orbit codes.

Refer to Bluebook for detailed project report instructions.

February 2003

Remove references to OBSDESED; program is obsolete.

Added information to Appendix A identifying which programs are appropriate for in-house use, and which programs were required for project submission.

Update Appendix A, Adjustment Processing Programs.

July 2002

Recommended filenames removed since they are inconsistent with other documentation and therefore confusing.

Appendix describing description processing removed. These procedures are no longer used since new description formats have been in place. Refer to instructions which come with WDDPROC software.

Add Solution Coordinate Reference System Codes 21 and 22 to Section One.

September 2000

Section 7, step added to process Adjust using a-posteriori standard deviation of unit weight for A- and B-order projects to assure the accuracies are computed correctly.

Input Bfile name changed from final.bfl to cons1.bfl.

Add Solution Coordinate Reference System Codes 18-20 to Section One.