USER'S GUIDE
FOR GPS OBSERVATIONS
AT TIDE AND WATER LEVEL STATION
BENCH MARKS

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Engineering Division
Center for Operational Oceanographic Products and Services
National Ocean Service
National Oceanic and Atmospheric Administration

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USER'S GUIDE FOR GPS OBSERVATIONS AT TIDE AND WATER LEVEL STATION BENCH MARKS

1.0 Introduction

This User's Guide for Global Positioning System (GPS) Observations at tide and water level station bench marks is prepared to support the Center for Operational Oceanographic Products and Services (CO-OPS) GPS Implementation Plan. The field observation procedures are developed in collaboration with the National Ocean Service (NOS), National Geodetic Survey (NGS), to obtain relative accuracy in connecting water level stations to the International Terrestrial Reference Frame (ITRF) and the North American Datum of 1983 (NAD 83) coordinate systems.

The GPS is a valuable tool for tidal surveyors. It provides an easy and accurate way to position marks, track their stability over time on a global reference frame, and increase access to tidal datums by integrating them with nationwide leveling and GPS survey networks for modern mapping and navigation uses.

This guide describes just one GPS method, static GPS surveying, which is accurate, automated, and available at all tide and water level station locations. The field requirements are simple and the data processing and publishing via NOAA's Online-Online Positioning User Service (OPUS) are quick and easy.

It is assumed that the field personnel are familiar with the basic operating principles of the GPS equipment, the cable connections and the antenna/tripod setup procedures. A detailed discussion of GPS processing software and processing procedures is outside the scope of this Guide. GPS data collected by CO-OPS, CO-OPS' contractors, Office of Coast Survey (OCS) and National Geodetic Survey (NGS) and their contractors, shall be submitted to the NGS Online Positioning User Service Data Base (OPUS DB). OPUS DB allows qualified users to submit results for publication in the OPUS database.

All GPS data must be collected as per NGS specifications and as described later in this document, and processed using OPUS (database publication).

1.1 Requirement

When required in the project instructions, or as stated in the contract documents for each tide or water level station visited, carefully perform at least one static GPS observation a minimum of four hours on one tidal or water level bench mark, and publish the data as an OPUS datasheet.

If your observations happen to be in low lying areas such as valleys, then you may need more than 4 hours because the observations are based upon the number of satellites observed. Hence, as a general requirement, obtain a minimum of 4 hours of GPS observations.

2.0. Equipment and Setup

High accuracy static differential GPS surveys require a geodetic quality, dual frequency, full-wavelength GPS receiver with a minimum of 10 channels for tracking GPS satellites. A choke ring antenna is preferred; however, any geodetic quality ground plane antenna may be used. The antenna type must have been calibrated by NGS so that the data can be accepted by OPUS.

A precise GPS antenna tripod is required for this type of a survey. This is a fixed height, 2 meter pole with three adjustable legs, a bulls-eye bubble to plumb the antenna, and a magnetic compass to align the antenna to North, if needed (Trimble antennas are not required to be aligned to the north). These fixed height tripods reduce the chance of introducing a Height of Instrument (HI) "blunder" during the post-processing of the data. There are situations where it may be necessary to use the adjustable precise GPS antenna tripod, such as when a bench mark is elevated above ground level or when using baggage-limiting air transportation. The center pole is adjustable on this tripod; therefore, if not fully extended to the 2 meter position, faulty data will be collected. The antenna height is measured with a steel tape (several times) and entered into the receiver and onto the GPS Observation Log Sheet. In fact, even in the 2 meter position, it is recommended that the adjustable tripod be measured to verify the length. There is a screw-on point at the bottom of the center pole - of both the fixed and adjustable tripods - that must be inspected each time the tripod is setup to ensure that the point is tight and not bent. The tripod must be stable during observations; therefore, the tripod legs must be secured, preferably with sand bags.

Antenna set-up is critical to the success of the project. Plumbing bubbles on the antenna pole of the fixed-height tripod must be shaded when plumbness is determined. Plumbing bubbles must be shaded for at least 3 minutes before checking and/or re-plumbing. Rotate the pole 180 degrees while leveling the tripod to ensure it is plumb.

Before your field campaign begins, test your GPS equipment by submitting to OPUS a sample dataset to confirm that your data format and GPS antenna type are OPUS-capable.

2.1. Data Collection and setup

Set the epoch update or recording interval (REC INT) for 15-seconds, which should agree with the recording interval of the reference stations (CORS) used to post-process the data. The elevation mask (ELEV MASK) is typically set for 10 degrees for static surveys; low angle satellites can degrade the final solution. Set the minimum number of satellites to zero.

It is suggested that as much GPS data as possible be collected if time and schedule permit, so that blunders or invalid data, if any, can be removed during processing, still leaving the required minimum number of hours of valid data for one GPS session.

3.0 Geodetic and GPS Connections

Water level datums at different locations are local vertical datums which may vary considerably within a geographical area. A geodetic datum is a reference surface relative to which heights are determined. The North American Vertical Datum of 1988 (NAVD 88) is the accepted geodetic vertical datum of the National Spatial Reference System (NSRS) for the conterminous United States and Alaska and is officially supported by NGS. The relationships of tidal datums to geodetic datums such as NAVD 88 and to ellipsoid heights (above GRS 80 ellipsoid) support many hydrographic, coastal mapping, and engineering applications including monitoring of sea level changes, the deployment of GPS Electronic Chart Display and Information Systems (ECDIS), and the NOS Vertical Datum (VDatum) transformation tool.

Existing Geodetic Bench Marks (GBM) in the vicinity (up to 1.6 km (1 mile) leveling distance) of a water level station (primary and subordinate) shall be searched for and recovered. If a mark is either not recovered or not used in the survey/project, a separate non-recovery note (report) shall be made using the NGS on-line Mark Recovery Entry Form at http://www.ngs.noaa.gov/ngs-cgi-bin/recvy_entry_www.prl

An orthometric level connection and ellipsoidal GPS tie is required at each water level station (primary and subordinate) which has at least one GBM located nearby (within 1.6 km (1 mi) leveling distance of a water level station). The required "NAVD 88 Level Tie" is described in the Standing Project Instructions which are available on CO-OPS' web page at http://tidesandcurrents.noaa.gov/pub. The required GPS tie is described under the section "NAD 83 GPS Tie" in this document.

3.1. GPS Bench Mark

3.1.1. Criteria for Bench Mark Selection for GPS Observations

The GPS Water Level Station Bench Mark (GPSBM) shall be selected based on the following criteria: (a) Permanence and Stability; (b) Historic GPS use; (c) Satellite Visibility; and (d) Safety and Convenience.

(a) Permanence and Stability of Bench Marks

NGS has defined the following monumentation quality codes, also called the stability codes, for various bench mark settings.

Stability code A – monuments of the most reliable nature which may be expected to hold their elevations very well; e.g. Class A rod marks, or marks installed on large boulders/rock outcrop.
Stability code B – monuments which probably hold their elevations well; e.g. Class B rod marks, or marks installed on large concrete footings/foundations.

Stability code C – monuments which may hold their elevations but which are commonly subject to surface ground movements; e.g. pavement or concrete monuments.

Stability code D – movements of questionable or unknown reliability.

The station bench mark selected for GPS observations shall be of stability code A or B and in rare case of stability C only when NGS has previously made GPS observations on that mark. GPS observations on the PBM are preferred (if the PBM has either stability code A or B) and if it is suitable for satellite observations. Leveling history, if available, can also show if a mark is stable or not.

(b) Historic GPS Use

In many states, CO-OPS has provided NGS with lists of selected marks suitable for GPS observations at water level stations, and NGS has completed observations on these marks. Some tidal marks designated as Federal Base Network (FBN) or Cooperative Base Network (CBN) marks may be of stability code C. Generally once a mark is selected for GPS observations, future GPS observations shall be done on the same mark. If leveling reveals instability of the mark over time, select another mark. Also, if a designated GPSBM becomes unsuitable for observations, select another stable mark with good visibility.

Priority shall be given to a GBM for GPS observations because the GBM already has a NAVD 88 height. The GBM considered here is one of the 10 tidal or water level bench marks at a NWLON water level station, or one of the 5 bench marks for subordinate station for survey or special projects.

(c) Satellite Visibility

The most desirable GPSBM should have 360 degrees clearance around the mark at 10 degrees and greater above the horizon. Newly established marks shall be set in locations that have these clearances, if at all possible. If a station does not have any marks suitable for GPS observations, and it has been selected as needing GPS observations, a new stable mark shall be established. This new mark shall be connected to the station bench mark network through conventional geodetic leveling, and GPS observations shall be made.

All existing station bench marks at operating stations shall be assessed for feasibility of GPS observations, as time and resources permit. A note shall be made, either in the description file, or on a copy of the published bench mark sheet, stating the suitability of GPS observations for each mark.

(d) Safety and Convenience

The location of the GPSBM should be safe, secure, and convenient. Bench mark locations which allow unattended GPS data collection are desirable as the field crew can multi-task at the same time while collecting the GPS data. The safety of the GPS equipment (from vandalism or theft) should be considered in the bench mark selection process.

The GPSBM should be located on public property rather than on private property, as permissions from private owners may be required in the future to access the bench mark and for collecting the GPS data. The distance to the GPS mark from the station Data Collection Platform (DCP) should also be convenient (within 1 mile).

Consider adding a new tidal bench mark when practical, in cases where no existing marks meet the above requirements and the new mark would provide a substantial improvement. Information about mark descriptors, images, recovery, reset, etc., are available at http://www.ngs.noaa.gov/marks/

3.1.2. Planning for GPS Bench Mark Selection

To determine the suitability of a mark for GPS observations, a review should be made first of the historical bench mark information in the station files and level records, if access to that information via database is available, or if the information is available. Stable marks from the level records are identified and copies of the descriptions and sketches are made. Descriptions and sketches are examined and marks are eliminated that have obvious obstructions, such as vertical marks, marks set several meters from medium to large structures, etc. Do not eliminate marks that are near poles, fences (at least three meters away from large metal objects) or about 20 meters from small structures at this time during the preliminary planning. If no other mark is available or found suitable, and time does not permit the installation of a new GPSBM, it may be necessary to use one of these marks. In selecting a GPSBM, priority should be given to the NWLON PBM or an NGS, NSRS, mark with a First or Second-Order NAVD 88 height on an NGS datasheet.

3.1.3. Recording of Position Accuracies of the GPS Bench Mark

GPS (horizontal) positions (latitude and longitude) of each bench mark installed or recovered shall be noted in the description file for electronic leveling, or on the bench mark descriptions sheet for optical leveling, as applicable. The position of each bench mark recovered using a hand held GPS receiver shall be listed in the following format: degrees, minutes, seconds and tenth of a second (e.g. 45 degrees 34’ 45.6”). As advanced handheld GPS technology becomes

available, it will be possible to obtain positions to the hundredth of a second. The more precise position shall be used in the description file, depending on the model of handheld GPS unit used. The position of the bench mark as obtained from a static GPS session and submitted through OPUS shall be recorded (where applicable) as degrees, minutes, seconds and one hundred thousandths of a second (e.g. 55 degrees, 42' 25.78912"), and the elevation above the ellipsoid shall be listed as +/- XX.XXX m (e.g. -22.907 m).

Once the GPS data is submitted to OPUS and the data is accepted, then a position is determined by OPUS. If the bench mark has a Permanent Identification (PID) number assigned by NGS, you may be able to retrieve the position online from the NGS datasheet. Published OPUS datasheets use a PID that is formatted differently from that used on the NGS datasheet (i.e. AAAAxx, where A is four alpha characters followed by two numbers), and can be retrieved online from the OPUS web page.

3.1.4. Photographs of the GPS Bench Mark

NGS requires a minimum of two photos of the GPS bench mark taken as follows: (1) close-up of the disk face (see Figure 1 A); (2) horizontal view of the location of the bench mark and direction of view (see Figure 1 C).

CO-OPS requires two additional photos as follows: (3) chest level or eye level view of the disk and setting (see Figure 1 B); and (4) a horizontal view of the bench mark and direction perpendicular to the direction of the photo taken in (2) above (see Figure 1 D). Thus, two photos in the vertical direction (Figures 1A and 1B) and two photos in the horizontal direction (Figures 1 C and 1D) as described above are required. If these four photos have been taken previously and are available to be included in the documentation, another set of photos is not necessary.

There are no file naming rules for OPUS but there are some suggestions for naming of the files as follows, compatible with the file naming for tidal/water level marks.

All digital station bench mark photo files should be named such that the name of the file will indicate the station number, dash, PID number (if available), dash, stamping or designation, dash, photo type, dash, date, dot.jpg. For a new mark, the PID is not applicable as it is unavailable. A close-up photo vertically taken of the bench mark is photo type 1, eye level photo vertically taken of the bench mark is photo type 2, and the horizontal view taken of the bench mark is photo type 3. For photo type 3 include the cardinal direction (N, NE, S, SE, etc) that the camera is pointing. If there is more than one type of photo taken then re-name them as 1A, 1B, 2A, 2B, 3A, 3B, etc. If a PID is available, then use the designation instead of the stamping for the naming of the file. Use a maximum of 30 alpha numeric characters to the left of the dot. If you are exceeding 30 alpha numeric characters in the name, then truncate the stamping or designation so that the maximum characters in the name are 30 (including spaces and hyphens).

For example, the bench mark 7130 E close-up photo for Seattle water level station should be named as 9447130-7130 E 1990-1-20090101.jpg.

Sample file names for photo files

New bench mark without a PID and disk face photo	9414290-4290A2008-1-20090101.jpg
Existing bench mark with a PID and eye level view photo	9410660-DY2512-BM N-2-20090101.jpg
Existing bench mark without a PID and north direction photo	9447130-7130E1990-3N-20090101.jpg

In addition, put a caption on each photograph, as shown in Figures 11- 13, indicating the stamping or designation of the mark, PID, photo type with cardinal direction, and the date of photograph taken. The Windesc program for electronic leveling has a function to assist with the photo caption. The program produces a caption that is slightly different from the file name format. Additional information about caption is available at the following resource: http://tidesandcurrents.noaa.gov/publications/AttachmentR_Requirements_for_Digital_Photographs_of_Survey_Control_Std_V13C_updated_January_2008.pdf

NGS Coastal Mapping Surveys require a slightly different file naming convention as described in Attachment R of the NGS Specs which is located at http://www.ngs.noaa.gov/ContractingOpportunities/SOW_Main_Text_V13B_new.pdf . All photos collected for NGS Coastal Mapping Surveys for both contract and in-house projects shall be named according to NGS convention.

Figure 1 A: Close Up View of Face of Mark

Figure 1 B: Eye Level Settings View of Mark

Figure 1 C: Horizontal View 1 of Mark

Figure 1 D: Horizontal view 2 of Mark

3.2. GPS Observations

3.2.1. References

These guidelines are written for establishing GPS derived ellipsoid height accuracy standards of 2 cm for all NWLON, PORTS®, hydrographic/Photogrammetry survey projects, COASTAL projects, and special project applications.

3.2.2. Static Surveys

Static GPS surveys shall be conducted on a minimum of one tidal bench mark at each water level station, according to the priority levels below. Generally, one bench mark at each station is designated as the GPSBM and observations shall be made to that mark (as per the required GPS observation frequency) unless otherwise specified in the Station Specific Requirements, Project Instructions, or contract documents.

1. National Water Level Observation Network (NWLON), PORTS®, and tsunami stations.
2. Long term operating secondary water level stations.
3. New and historic tertiary stations supporting hydrographic and photogrammetric surveys, COASTAL stations, and special project stations.

Static GPS surveys shall be conducted at water level stations periodically over time to establish a history of relationship between the tidal or water level datums, and the ellipsoid.

As of October 2008, 26 NWLON stations have been identified where annual GPS observations are required because of the sea level rise in those areas. These 26 NWLON stations – 8 in Alaska and 18 in the Gulf of Mexico – will be identified in the annual Project Instructions. The rest of the NWLON stations require GPS observations every five years. These guidelines will be updated as GPS technology improves and the policy or regulations change in the future.

As specified in the Annual Project Instructions, Annual Station Specific Requirements, or in the contract documents, installer shall be required to perform GPS observations at each water level station at specified intervals over time, depending on the rate of sea level rise in that water area of the coast.

3.2.3. Connections to Ellipsoidal Datums – GPS Ties

The connections to ellipsoidal datums involve the following two ties:

(1) NAD 83 GPS Tie
(2) NAVD88 GPS Tie

3.2.4. North American Datum 1983 (NAD 83) GPS Tie

At each water level station, GPS observations shall be performed as listed in the Annual Project Instructions, Annual Station Specific Requirements, and contract documents.

The NGS OPUS-DB is now used for processing and storing of the GPS data for a variety of applications.

The expected ellipsoid height accuracy for a single four-hour OPUS solution is 1.8 cm, (at the 67% confidence level), and that is desirable, practical, and achievable. Confidence increases with repeated observations.

3.2.5. GPS Data Processing Using OPUS

After GPS data is collected, the collector shall submit the GPS data to NGS OPUS-DB for processing the GPS observations and determining the position of the GPSBM. OPUS provides an easily accessible, rapid method for submitting GPS data and receiving an almost instantaneous solution response from NGS via email.

OPUS allows users to submit their GPS data files to NGS, where the data will be processed to determine a NAD-83 position using NGS computers and software. Each data file that is submitted will be processed with respect to three CORS sites. The CORS sites selected may not be the nearest to the observed site, but CORS sites are selected automatically based upon distance to the observed site, number of observations, site stability, etc. The position for the observed data will be reported back to you via email in both - ITRF and NAD 83 coordinates as well as Universal Transverse Mercator (UTM), U. S. National Grid (USNG) and State Plane Coordinates (SPC) northing and easting.

To publish OPUS datasheets, you must meet the minimal field and data requirements for OPUS publishing. These evolving requirements are described at http://www.ngs.noaa.gov/OPUS/view.jsp and are hereby superseded where any requirement below exceeds that of OPUS.

- Always use a calibrated 2-meter fixed-height tripod, unless prevented by logistics circumstances (e.g., air cargo limits, unusual setup).
- Alternate tripod or antenna mount must allow precise antenna positioning and height measurement.
- Verify tripod stability and antenna height at the beginning and end of every session. Tripod leveling bubbles should be shaded when not in use.
- A digital camera is required to capture mark close-up and horizon photos.
- In addition to the 2 photos required by OPUS, provide for CO-OPS two additional photos as described in Section 3.1.4 Photographs of the GPS Bench Mark.
- Submit to OPUS all mark information listed as both required and optional on OPUS forms. See figures 7 & 8 below for current form elements.

Step 1 of 4:
In order to publish the OPUS results, users will need to complete a one-time registration. Click the "View" tab at the top of the page and follow the instructions. Once registered, you can now use OPUS as follows:

(A) OPUS requires only a minimal amount of information from the user. The NGS OPUS web page can be obtained at http://www.ngs.noaa.gov/OPUS/. Then enter the following information:

(1) The email address where you want the results sent
(2) The GPS data file that you want to process (which you may select using the browse feature; raw or RINEX accepted)
(3) The antenna type used to collect this data file (selected from a list of calibrated GPS antennas)
(4) The height of the Antenna Reference Point (ARP) above the monument or mark that you are positioning.
(5a) Customize your solution, report, and publishing options. Click on the Option button.

Figure 2: OPUS Step 1 of 4 – OPUS Upload Screen

(B) Once this information is complete, you then click the 5a Options button to customize the solution, report, and publishing options. Then you will see a screen like this.

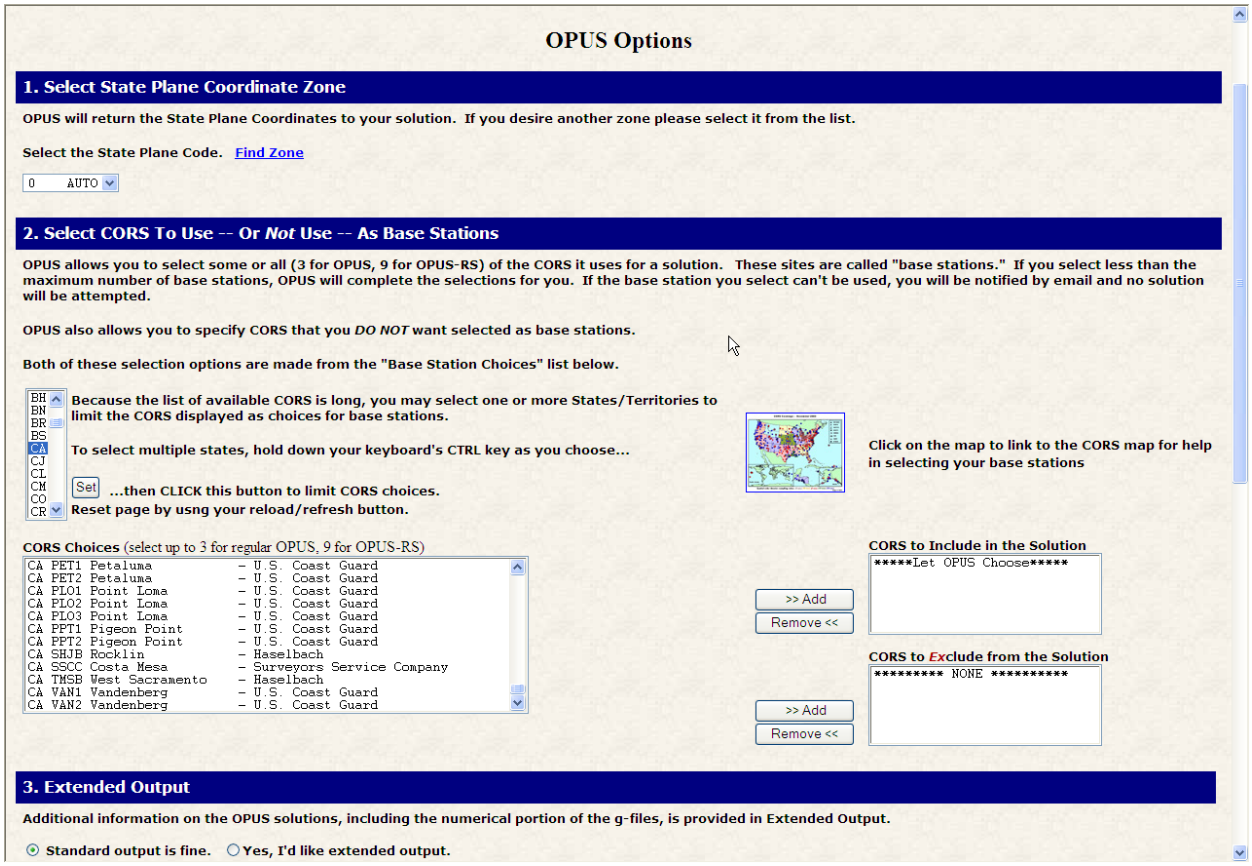


Figure 3: OPUS Step 1 of 4 – OPUS Options Screen Shot 1

The Options page asks you eight questions as described below:

Leave options 1 through 6 as defaults and only select option 8 "Submit to Database."

(1) Select State Plane Coordinate zone: The default is 0 Auto, leave that as default and do not change this option.

(2) Select CORS To Use – Or Not Use – As Base Stations:

On the left side of the above screen, select the state your GPS bench mark is located and hit the "Set" button to limit the CORS choices. Please note the two boxes on the right side in the above figure – "CORS to include in this solution" and "CORS to exclude in this solution". The "CORS to include in this solution" box has a default of "Let OPUS Choose". For the 1st iteration let the OPUS choose the three closest CORS stations so leave the default option as it is. The 2nd box shows "CORS to Exclude from the solution shows" default option of "NONE". For the 1st

iteration, leave this option. For the 2nd iteration, if the OPUS solution fails to meet the minimum criteria as defined below, then one or more of the CORS stations can be excluded in this step.

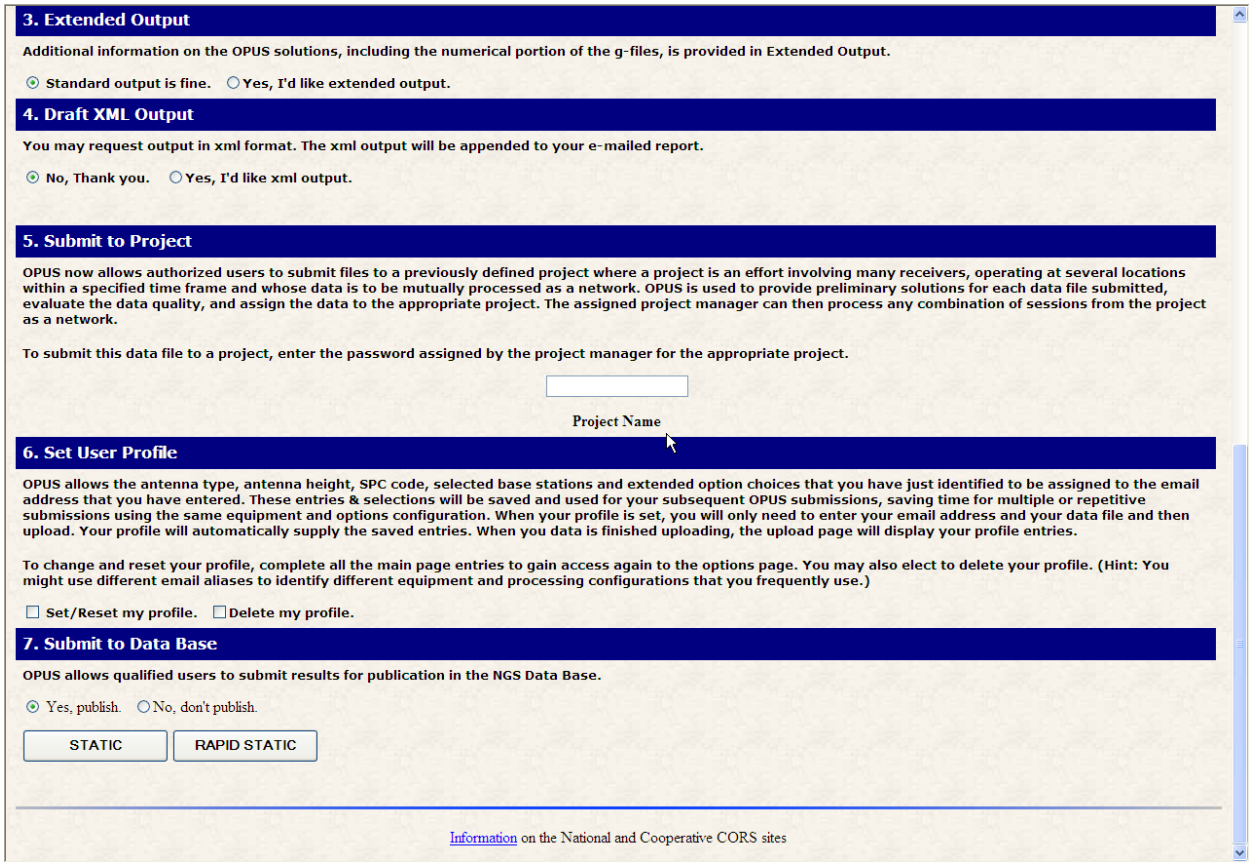


Figure 4: OPUS Step 1 of 4 - Options Screen Shot 2

(3) Select Your Geoid Model: The default is "default = let OPUS Choose," Leave that as the default.

(4) Extended Output: The default is standard output, leave that as the default.

(5) Draft XML output: The default is "No, Thank You." Select the default choice.

(6) Submit to Project: This option is not applicable to CO-OPS' water level work. So skip this option.

(7) Set user Profile: Since CO-OPS water level stations are located in various locations, skip this option.

(8) **Submit to Database**: **Make sure you select the option "Yes, Publish". Then select the Static button only**. Once you hit the Static Button that will bring the Step 2 of 4 "Identify Your Mark" screen as shown below.

Step 2 of 4:

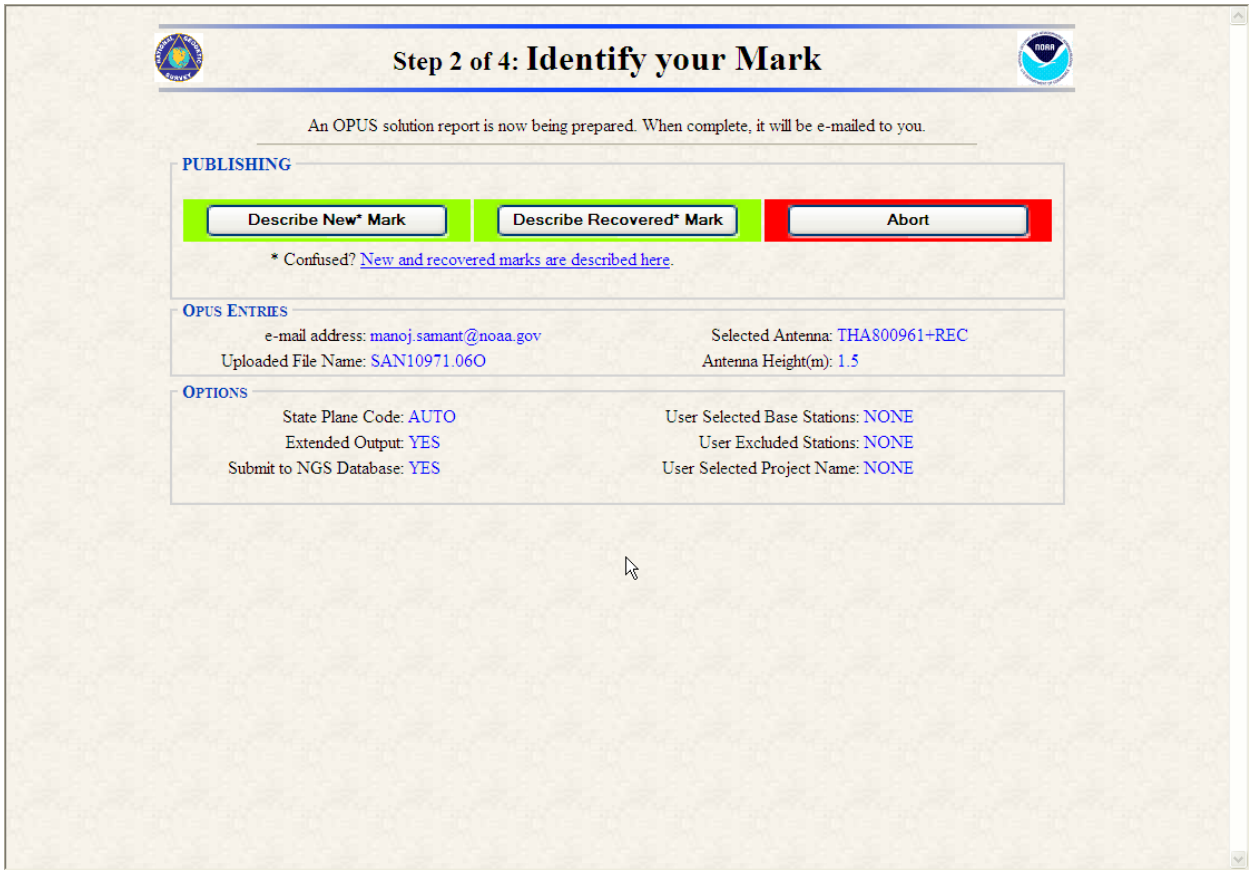
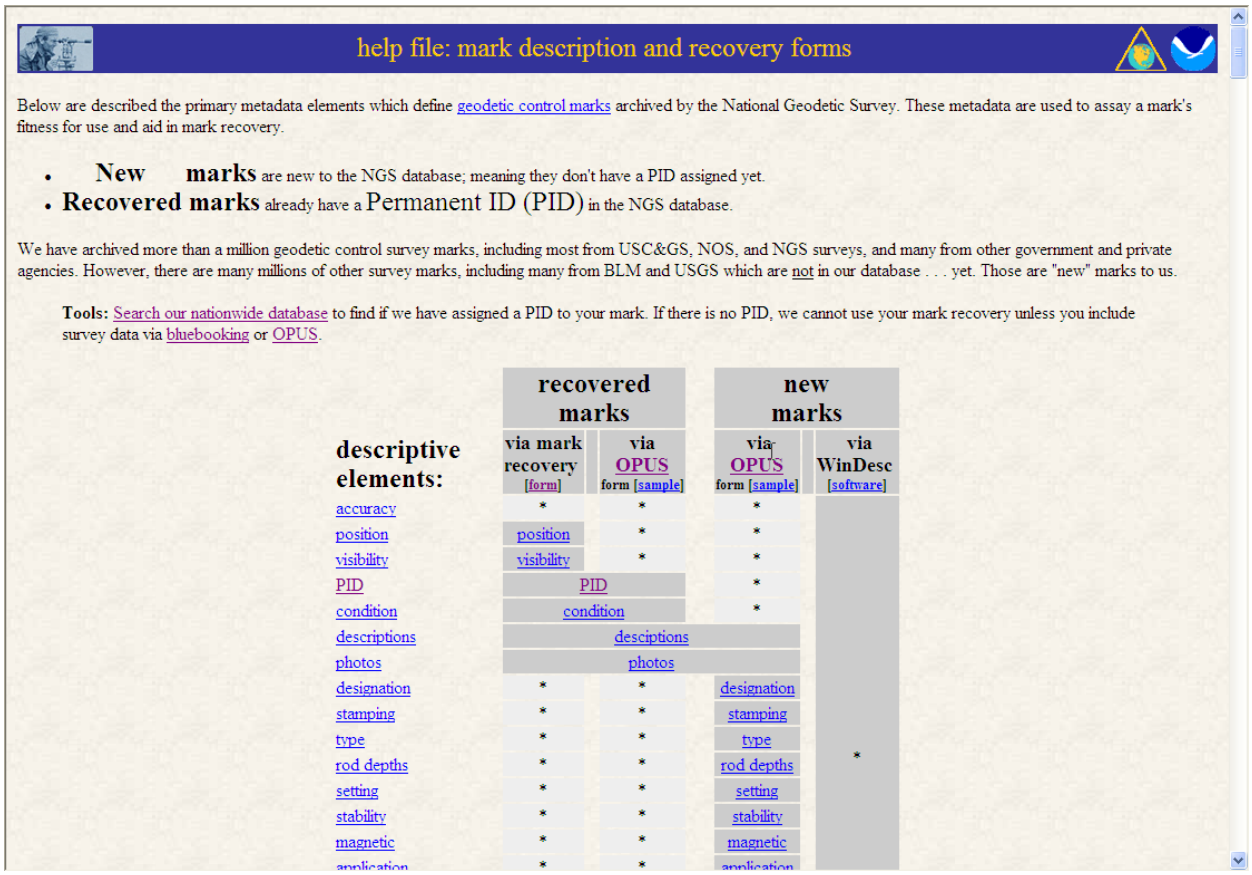


Figure 5: OPUS Step 2 of 4 – Identify Your Mark

You have two choices here – either "Describe New mark" or "Describe Recovered Mark", as shown above. If the mark has a PID assigned by NGS, then only you can select the "Describe Recovered Mark" otherwise you must select "Describe New Mark".

Appropriate context help is also available here – if you hit "Confused? New and recovered marks are described here" link, it will bring a help file (see the next screen) for mark description and recovery forms.



help file: mark description and recovery forms

Below are described the primary metadata elements which define geodetic control marks archived by the National Geodetic Survey. These metadata are used to assay a mark's fitness for use and aid in mark recovery.

- **New marks** are new to the NGS database; meaning they don't have a PID assigned yet.
- **Recovered marks** already have a Permanent ID (PID) in the NGS database.

We have archived more than a million geodetic control survey marks, including most from USC&GS, NOS, and NGS surveys, and many from other government and private agencies. However, there are many millions of other survey marks, including many from BLM and USGS which are not in our database . . . yet. Those are "new" marks to us.

Tools: Search our nationwide database to find if we have assigned a PID to your mark. If there is no PID, we cannot use your mark recovery unless you include survey data via bluebooking or OPUS.

descriptive elements:	recovered marks		new marks	
	via mark recovery [form]	via OPUS form [sample]	via OPUS form [sample]	via WinDesc [software]
accuracy	*	*	*	
position	position	*	*	
visibility	visibility	*	*	
PID	PID		*	
condition	condition		*	
descriptions	descriptions			
photos	photos			
designation	*	*	designation	
stamping	*	*	stamping	
type	*	*	type	
rod depths	*	*	rod depths	*
setting	*	*	setting	
stability	*	*	stability	
magnetic	*	*	magnetic	
application	*	*	application	

Figure 6: OPUS Help File

Use your web browser's back button to go back from the help file.

Step 3A of 4:

If the GPSBM was a recovered mark, the next screen shows you "Step 3 of 4: Describe Recovered Mark". Here (a) you must fill in the PID number (since it was a recovered mark), (b) attach two photos of the GPSBM– one for close up photo of disk face and second for horizon photo,
(c) indicate the condition of the mark by selecting the appropriate radio button – good or poor,
(d) provide a description of the mark in CO-OPS format as per "User's Guide for Writing Bench Mark Descriptions" which is available at CO-OPS web page at http://tidesandcurrents.noaa.gov/publications/bmguide5.pdf ,
(e) Then hit the "continue" button.

Remember, the PID number and the two photos as listed above in (a) and (b) respectively are required; and the mark condition and the mark description as listed in (c) and (d) are optional for an existing mark, but you are encouraged to submit both optional items. If there are any changes

needed to the stored description, then please submit the revised description. After completion of the information for this screen, hit the "Continue" button.

Figure 7: OPUS Step 3A of 4 – Describe Recovered Mark

Step 3B of 4:

If the mark was a new bench mark and you selected "Describe New Mark" in OPUS Step 2 of 4, then you will see the following screen.

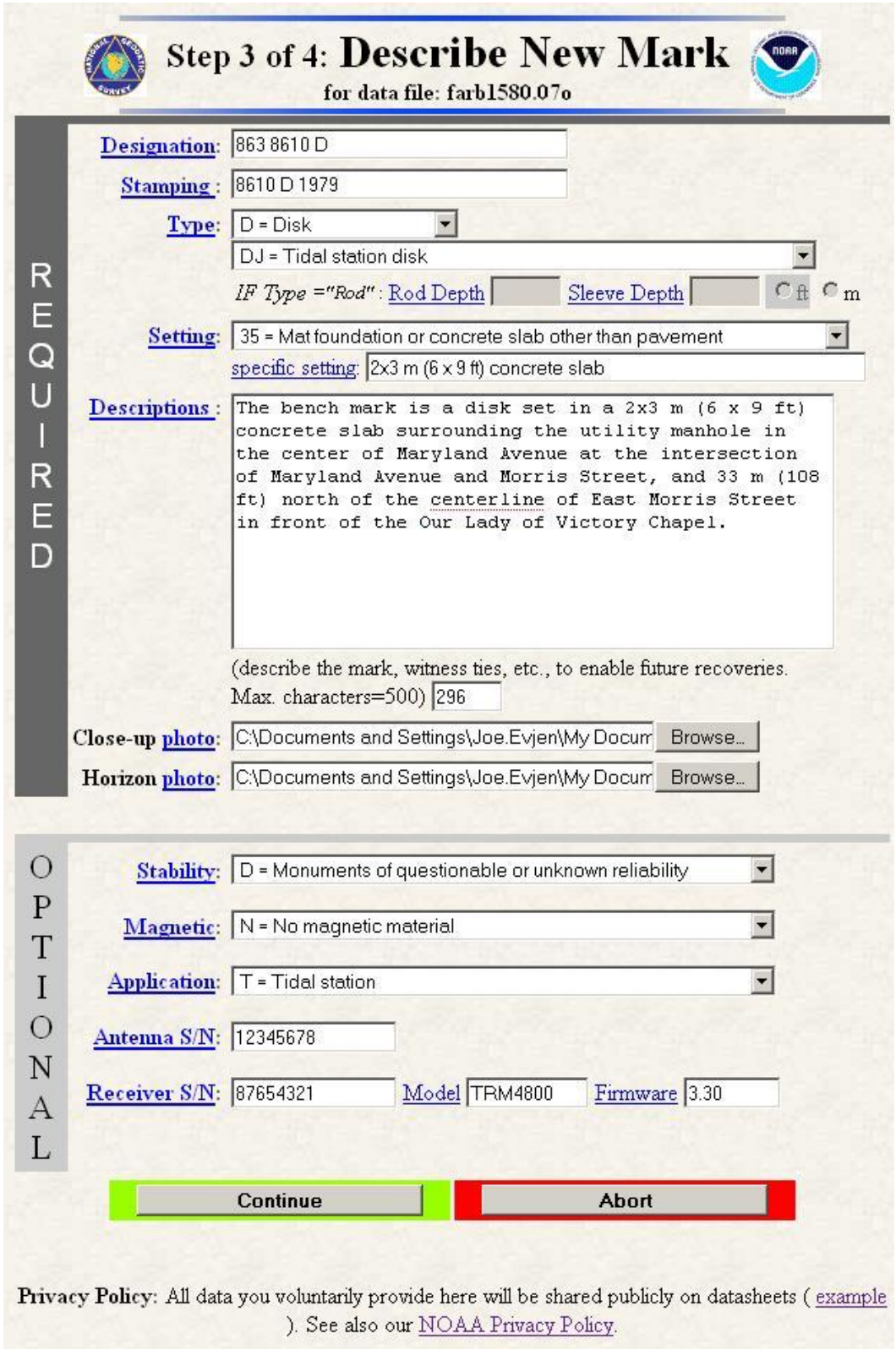


Figure 8: OPUS Step 3B of 4 – Describe New Mark

The “Describe New Mark” part as shown above has seven required elements and five optional elements.

The seven required elements are as follows: designation, stamping, type, setting, descriptions, close-up digital photo, and horizon digital photo. Designation and stamping should be entered as per NOS convention. The selection for type and setting can be done through the choices listed in the drop down boxes as shown. Attach close-up and horizon digital photos of the new mark by indicating the location of the photos on your PC or server, as appropriate.

The five optional elements are as follows: stability, magnetic, application, antenna serial number, and receiver serial number, model and firmware. The selection for stability, magnetic, and application can be done through the choices listed in the drop down boxes as shown.

Everyone is strongly encouraged to provide the information about the optional elements.

After completion of the information for this screen, hit the “Continue” button. Then you will get the following message.

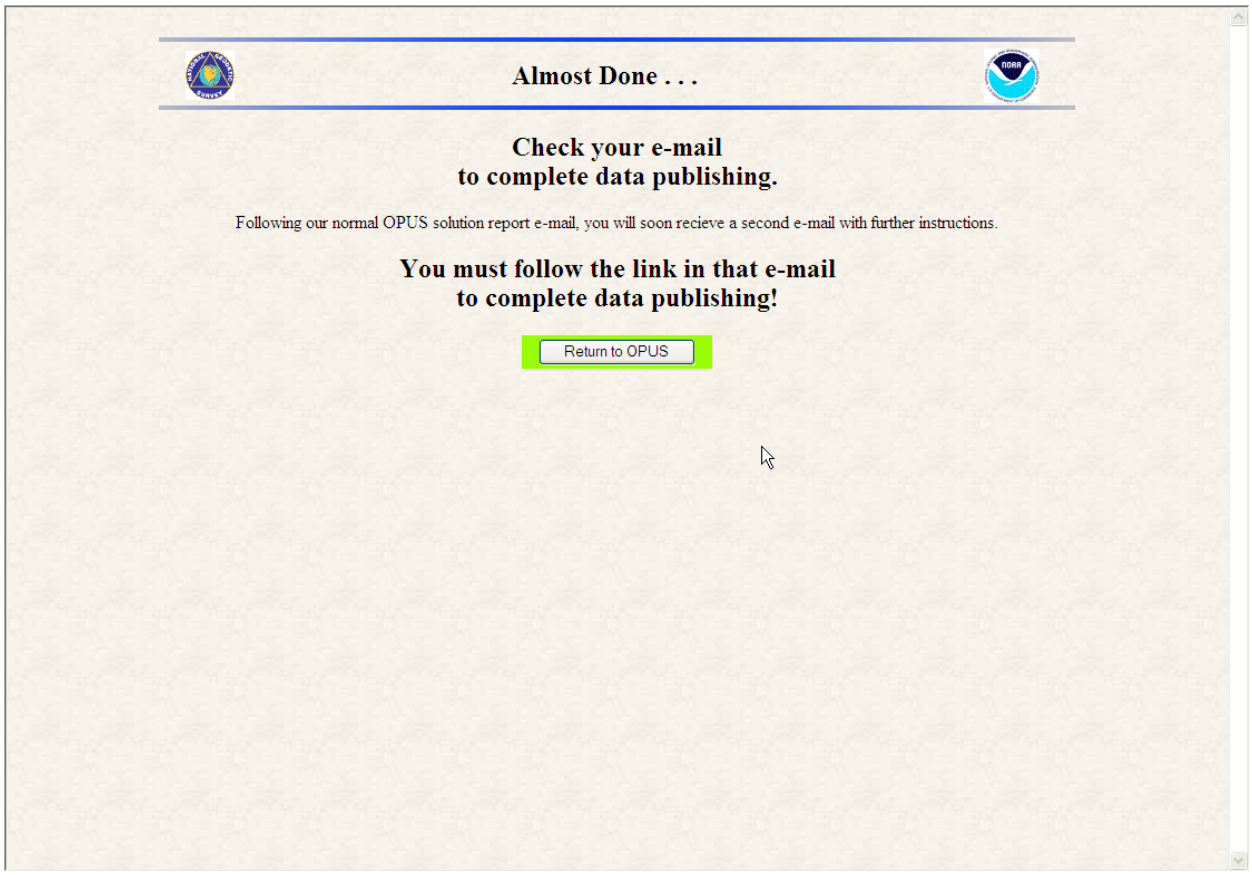


Figure 9: OPUS Step 3 of 4 – Almost Done

You will receive three e-mails, one of the e-mails will provide you the summary and that will look like the following window:

Step 4 of 4:

```
5001
 5001   OPUS Quality Control Report
 5001
 5001   The RINEX dataset and supporting files submitted to OPUS
failed to
 5001   pass an initial set of quality control tests.
 5001
 5001   Please re-submit the data if you can correct the errors
listed in the
 5001   output from the verification process.
 5001
 5001   See hints at http://www.ngs.noaa.gov/OPUS/about.html#FAQ
 5001

RINEX FILE:  san1097o.06o.gz



EPHEMERIS:      OK.
OBS USED:       OK    73.64 %.
OBSERVATIONS:   OK   13212.
FIXED AMB:      OK    78.15 %.
ANTENNA:        THA800961+REC   NONE.
ARP HGT:        OK   1.5 (m).
RMS:            OK   0.026 (m).
LAT RANGE:      FAILED  --> LAT. peak to peak 0.088 (m) too high.  A
value less that or equal to 0.04 (m) is needed.
LON RANGE:      FAILED  --> LON. peak to peak 0.055 (m) too high.  A
value less that or equal to 0.04 (m) is needed.
HGT RANGE:      FAILED  --> HGT. peak to peak 0.153 (m) too high.  A
value less that or equal to 0.08 (m) is needed.
```

Figure 10: OPUS Step 4 of 4 – E-Mail Message and Statistics

This e-mail provides you information about whether your submission passed or failed various checks as follows:

(a) Ephemeris: The satellite configuration when the data was collected, whether OK or not.
(b) OBS Used: The percent of observations used for processing the data.
(c) Observations: The number of GPS observations (data points) used.
(d) Fixed AMB: The percent of ambiguities fixed.
(e) Antenna : Lists the antenna type that you provided as an input in Step 1.
(f) ARP HGT: Lists the antenna height that you provided as an input in Step 1.
(g) RMS: Provides the root mean square of the solution.

(h) LAT RANGE: Provides the information about the peak to peak errors for the latitude derived. The peak to peak errors for the latitude should be less than 0.04 m (4 cm).
(i) LON RANGE: Provides the information about the peak to peak errors for the longitude derived. The peak to peak errors for the longitude should be less than 0.04 m (4 cm).
(j) HGT RANGE: Provides the information about the peak to peak errors for the height derived. The peak to peak errors for the height should be less than 0.08 m (8 cm).

The following are some simple guidelines for analyzing the OPUS solutions.

(a) Make sure the antenna type and the ARP height (stored in the receiver) are correct.
(b) Review the solution statistics:
    (I) A good quality OPUS run should typically use 70% or more of your observations.
    (II) OPUS should have fixed at least 70% of the ambiguities
    (III) The overall RMS should seldom exceed 3 cm.
    (IV) The maximum peak to peak errors should be less than 4 cm for horizontal (for both latitude and longitude) and 8 cm for vertical.

If the OPUS solution e-mailed to you exceeds the allowable tolerances as specified in guidelines (b) above, then you must resubmit data but select an option for dropping one or more of the three CORS stations selected automatically by the NGS OPUS software and resubmit the data. To do so, check the OPUS solution e-mailed to you and select one of the CORS stations which shows the maximum errors that exceed the tolerances and then select the options button in Step 1 of 4, (B) (2) as shown above, and exclude that CORS station name and resubmit the GPS data by clicking the Upload to Static button. If the 2nd solution provided by the OPUS software does not meet the allowable tolerances as listed in (b), then submit the data to NGS independently for further evaluation.

If your data does not meet OPUS guidelines after a 2nd OPUS processing attempt and if you are still at the water level station site, another option is to Select a different CORS site and see if the results improve.

NGS needs to receive orbit data from the International GPS Service (IGS) (soon to be renamed as the International Global Navigation Satellite System) in order to obtain a solution. The submitter may need to re-submit the data at a later time if it is submitted before NGS gets the orbit data from IGS. A quick submission of the data to OPUS (not published) may indicate if the solution will be acceptable for publishing. For best final results, submit the GPS data to OPUS at least 17 hours after the first midnight (in Greenwich Mean Time) following the time when the observations were recorded. Compare the resultant solution to the last previous solution made at the station, if available, to ensure that you do not have a blunder in the antenna setup. This will be revealed by a noticeable discrepancy in the ellipsoid height. Include a copy of the OPUS solution as shown for samples in Figure 11, 12, 13 in the GPS Deliverables.

WHAT TO DO IF OPUS FAILS?

- Data submission to OPUS should be performed by the GPS observer as soon as is practical, while on-site, details are fresh in memory, and the opportunity exists for additional observations.
- Consider repeating the OPUS submission using the OPUS option #2, "CORS to Exclude", to remove a transient base station.
- Consider adding a new third CORS station and resubmitting the data.
- Consider repeating the OPUS submission on the afternoon following the observation day, after the GPS orbit models are updated.
- Consider repeating your GPS observation at a different time of day (night observations may improve results at lower latitudes.)
- Consult with the OPUS help desk on other suggestions to improve the data.

ADDITIONAL SUGGESTIONS:

- More GPS data is better than less. The minimum GPS observation duration requirement, currently 4 hours, should be extended whenever practicable, e.g., overnight in secure areas.
- Horizon photos should be taken during the GPS observation, thereby documenting the GPS equipment in use and highlighting the mark location.
- Additional photos are helpful alternatives to paper field logs (e.g., to document equipment serial #s, antenna height, observer and mark IDs, observation times, weather conditions, etc.)
- Additional suggestions are available at http://www.ngs.noaa.gov/PROJECTS/INSTRUCTIONS/GPSmanual/

3.2.6. NAVD 88 GPS Tie

The NAVD 88 GPS Tie involves simultaneous GPS observations at the GPSBM and one or more GBMs located up to 10 KM (6.26 mi) from the GPSBM. This tie is deferred until such time as NGS enables user-friendly blue-booking of campaign data (OPUS projects), and will be included in the project instructions when required.

4.0 GPS Deliverables

Submit the OPUS results (sample datasheet as shown in Figures 11 or 12 or 13) and 4 photos of the GPSBM in electronic format for each observation for each water level station. For example, GPS submission for the San Francisco tide station shall be provided in a folder as follows:

9414290 San Francisco FY 09 Annual Inspection
/OPUS Published Datasheet
/Photos of GPSBM

4.1. Points of Contact for GPS Deliverables

All required GPS OPUS deliverables as listed in Section 4.0 above, shall be submitted to the proper point of contact as listed in the project instructions, and/or contract documents, if applicable; or to NGS or CO-OPS within 15 business days of the GPS observations, the removal of the water level gauge, or as specified in the Statement of Work or contract, whichever is earlier. All GPS data and documentation shall be submitted to NGS OPUS.

For all CO-OPS in-house work, and OCS contract hydrographic surveys, submit GPS Deliverables to:

Chief, Engineering Division
CO-OPS, N/OPS1, SSMC 4
1305 East-West Highway, Station 6531
Silver Spring, MD 20910-3233
Tel: 301-713-2897 x 145

For all CO-OPS contracts, submit GPS Deliverables to:
Marty Welch,
Contracting Officers Representative
CO-OPS, SSMC 4
1305 East-West Highway, Station 6544
Silver Spring, MD 20910-3233
Tel: 301-713-2981 x 129

For NGS contract shoreline mapping surveys, submit GPS Deliverables to:
Mr. George Leigh
Contracting Officers Representative
NOAA/NOS/National Geodetic Survey
SSMC 3, Station # 8609
1315 East-West Highway
Silver Spring, MD 20910-3281
Tel # 301-713- 3167

SURVEY DATASHEET (prototype version 1.1)

PID: UV9037
Designation: ASTRO
Stability: Monuments of questionable or unknown reliability
Setting: Object surrounded by mass of concrete
Mark Condition: G
Description: The station is an unstamped disk set flush in a 0.3 m (1.0 ft) diameter concrete block atop a hill due west of the Russian Orthodox Church, 66 m (216 ft) northwest of a 2 m high wooden cross memorial for the "First Orthodox Church in Alaska", 29.5 m (96.8 ft) southeast of the southeast corner of a green single story abandoned home, 9.49 m (31.1 ft) east-northeast of bench mark 9462450 Astro RM 2, 6.09 m (20.0 ft) WSW of Astro RM 1, and 1 m (3 ft) north of the centerline of an ATV trail.
Observed: 2006-06-25T12:00:00Z See Also 1957
Source: OPUS - page5 0612.06

Close Up View

REF_FRAME: NAD_83(CORS96)	EPOCH: 2003.0000	SOURCE: NAVD88 (Computed using GEOID06)	UNITS: m	SET PROFILE	DETAILS

LAT: 52° 56' 17.46520"	± 0.026 m	
LON: -168° 51' 50.26526"	± 0.023 m	
ELL HT: 23.808	± 0.016 m	
X: -3779654.430	± 0.024 m	
Y: -744007.824	± 0.019 m	
Z: 5066419.563	± 0.027 m	
ORTHO HT: 14.242	± 0.121 m	

	UTM 2	SPC 5010(AK10)
NORTHING:	5867529.775m	239444.272m
EASTING:	643545.845m	1478918.338m
CONVERGENCE:	1.70481640°	5.68686800°
POINT SCALE:	0.99985291	0.99984961
COMBINED FACTOR:	0.99984918	0.99984588

CONTRIBUTED BY

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John Oswald and Associates, LLC

Horizontal View

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedure used.

Figure 11: Sample # 1 of OPUS Results

SURVEY DATASHEET (prototype version 1.1)

PID: BBBB44
Designation: 9454240 T
Stability: Most reliable; expected to hold position well
Setting: In rock outcrop or ledge
Description: The station is a disk set in bedrock at the top of a bluff at the southeast corner of the intersection of Clifton Drive and Hazelet Ave, 25 m (82 ft) (slope distance) southwest of light pole no 238, 20.3 m (66.6 ft) southeast (slope distance) of the center of a manhole cover, 17.7 m (58.1 ft) southeast (slope distance) of light pole no 237, and 4 m (13 ft) west of the center of the clearing at the top of bluff where the two trails up the bluff converge.
Observed: 2006-06-08T00:00:00Z
Source: OPUS - page5 0612.06

Close Up View

REF_FRAME: NAD_83(CORS96)	EPOCH: 2003.0000	SOURCE: [Geoid06 NAVD88]	UNITS: m	SET PROFILE	DETAILS

LAT: 61° 7' 37.84208"	± 0.009 m	
LON: -146° 21' 34.48747"	± 0.014 m	
ELL HT: 30.954	± 0.010 m	
X: -2570640.470	± 0.011 m	
Y: -1710544.690	± 0.013 m	
Z: 5562226.434	± 0.010 m	
ORTHO HT: 15.310	± 0.027 m	

	UTM 6	**SPC** 5003(AK 3)
NORTHING:	6777122.026m	793722.893m
EASTING:	534498.705m	480623.882m
CONVERGENCE:	0.56081734°	-0.31488277°
POINT SCALE:	0.99961458	0.99990460
COMBINED FACTOR:	0.99960974	0.99989975

CONTRIBUTED BY

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John Oswald and Associates, LLC

Horizontal View

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedure used.

Figure 12: Sample # 2 of OPUS Results

SURVEY DATASHEET (prototype version 1.1)

PID: BBBD29
Designation: 8762075 A
Stability: Monument will probably hold position well
Setting: Stainless steel rod without sleeve (10FT+ or 3.048M+)
Description: The station is set 23.55 meters (77.26 ft) south of the centerline of A.J. Estay road, 20.50 m (67.26 ft) east of the gravel road leading to the marina, 17.13 m (56.20 ft) north of the south face of the marina bulkhead, 1.70 m (5.58 ft) east of a power pole, and 0.83 m (2.72 ft) south of a witness post. The datum point is set 0.33 m below the ground, being the top of a stainless steel rod driven 29.81 m (97.80 ft) to refusal and encased in a 5-inch NOS logo cap.
Observed: 2007-10-13T03:55:00Z
Source: OPUS - page5 0612.06

Close Up View

REF_FRAME: NAD_83(CORS96)	EPOCH: 2002.0000	SOURCE: NAVD88 (Computed using GEOID03)	UNITS: m	SET PROFILE	DETAILS

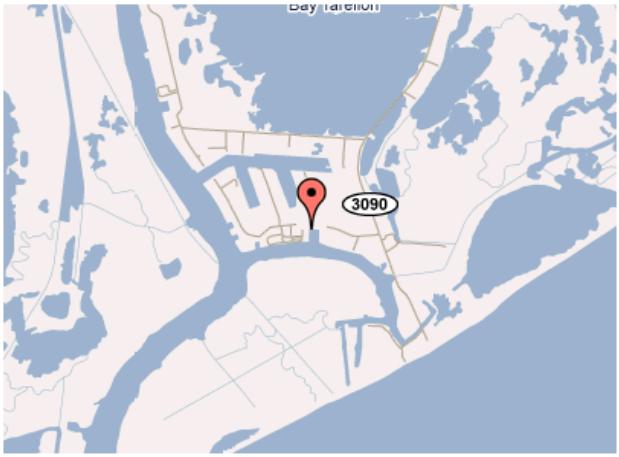
LAT:	29° 6' 56.84603"	± 0.003 m
LON:	-90° 12' 0.43218"	± 0.005 m
ELL HT:	-22.970	± 0.016 m
X:	-19477.598	± 0.005 m
Y:	-5576550.808	± 0.012 m
Z:	3085108.464	± 0.011 m
ORTHO HT:	0.908	± 0.073 m

	UTM 15	**SPC** 1702(LAS)
NORTHING:	3224055.209m	68804.989m
EASTING:	772461.138m	1110298.846m
CONVERGENCE:	1.36319588°	0.56662102°
POINT SCALE:	1.00051616	1.00004410
COMBINED FACTOR:	1.00051977	1.00004770

CONTRIBUTED BY

erik@joasurveys.com
John Oswald and Associates, LLC

Horizontal View



This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedure used.

Figure # 13: Sample # 3 of OPUS Results