USER'S GUIDE
FOR
GPS OBSERVATIONS

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

TABLE OF CONTENTS

USER'S GUIDE FOR GPS OBSERVATIONS

1.0 Introduction

This User's Guide for Global Positioning System (GPS) Observations for the tidal 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), and consist of slight modifications of NOAA Technical Memorandum NOS NGS-58, Version 4.3, as described below, 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. Modifications made to NOAA Technical Memorandum NOS NGS-58 guidelines and requirements involve the length of the GPS observations required, in this document. This Guide must be used in conjunction with NGS-58 for collecting the GPS data at water level stations.

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 or CO-OPS' contractors for the National Water Level Observation Network (NWLON), for hydrographic and photogrammetric surveys either by NOS Office of Coast Survey (OCS) and NGS field parties will be submitted to NGS for data processing – "blue-booking" is a term used to describe this processing according to the Input Formats and Specifications of the National Geodetic Survey Database, Appendix L – Guidelines for Submitting GPS Relative Positioning Data.

All GPS data must be collected as per NGS specifications and as described later in this document and processed first using NGS Online Positioning User Service (OPUS). All GPS data and documentation shall be submitted to CO-OPS, which will then be forwarded to NGS, as per the contracts, project instructions, statement of work, or as appropriate.

1.1. Reference Documents

The following reference documents are referred in various sections of this document.

(1) "CO-OPS GPS Observations Implementation Plan, January 2003".

(2) "NOAA Technical Memorandum "NOS NGS-58, Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards 2 cm and 5 cm), Version 4.3".

(3) "User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, October 1987".

(4) "Standards and Specifications for Geodetic Control Networks", Federal Geodetic Control

Committee, September 1984.

(5) “Attachment R, Requirements for Digital Photographs of Survey Control, NGS, July 2005”

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. More important than antenna type, i.e. choke ring or ground plane, is that the same antennas or identical antennas models should be used during the entire observing sessions. If not, a correction for the difference in antenna phase patterns (modeled phase patterns) must be applied. This is extremely critical for obtaining precise vertical results. The antenna cable length between the antenna and receiver should be kept to a minimum when possible; 10 meters is the typical antenna cable length. If a longer antenna cable is required, the cable must be fabricated from low loss coaxial cable (RG233 for up to 30 meters and RG214 over 30 meters).

A fixed height 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. 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 air transportation. The center pole is adjustable on this tripod; therefore, if not fully extended to the 2 meter position, 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.

The manufacturer, model, and complete serial numbers of all receivers and antennas must be included for each occupation on each station/bench mark observation log sheet as shown in Figure 3.

3.0 Geodetic connections and datums relationship

Water level datums are local vertical datums which may change 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 vertical datum of the National Spatial Reference System (NSRS) for the conterminous United States and Alaska and is officially supported by NGS. The relationship of tidal datums to NAVD 88 has many hydrographic, coastal mapping and engineering applications including monitoring sea level change and the deployment of GPS electronic chart display and information systems, etc.

Existing geodetic marks in the vicinity of a subordinate tidal station shall be searched for and recovered. A search routine is available at http://www.ngs.noaa.gov. An orthometric level connection and ellipsoidal GPS tie is required at a subordinate tide station which has at least one geodetic bench mark located nearby as stated below for Sections "NAVD 88 Level Tie" and "NAD 83 GPS Tie" requirements. NAVD 88 heights for published bench marks are given in Helmert orthometric height units by NGS. The GPS ellipsoid network height accuracies are classified as conforming to 2 cm or 5 cm standards accuracies (Refer to NOAA Technical Memorandum NOS NGS-58). At the present time, GPS ellipsoid heights conforming to the 2 cm accuracy standards are required for all GPS survey projects.

A connection to the geodetic datums at a water level station enhances the value of the tidal data, allowing comparison with other data sets. The geodetic network essentially serves as a global reference datum to which all tidal datums can be referenced.

The connection to geodetic datums involves the following three ties:

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

3.1. Level Connections

3.1.1. NAVD88 Level Tie

At all water level stations, a valid level tie to at least two Geodetic Bench Marks (GBM) is required on each set of levels, where appropriate marks are available within 1.6 KM (1 mi) leveling distance of the station location. A GBM is defined as a bench mark that exists, is useable, is available in the NGS database, has a Permanent ID (PID), and has a NAVD 88 elevation published on the datasheet. At many NWLON stations, the Primary Bench Mark (PBM) is a GBM. At the majority of NWLON stations, there are two or more tidal bench marks that are also GBM, thus increasing the chance that the geodetic level tie will be valid.

Make a Second-Order, Class I tie for all NWLON stations in the conterminous United States and Caribbean Islands. A Third-Order tie is used for all NWLON stations in Alaska, Hawaii, and Pacific Island areas.

At stations supporting hydro or other special projects, the tie shall be consistent with the accuracy of the levels required for the project.

Information on performing a valid level tie is provided in the Federal Geodetic Control Committee (FGCC) Standards and Specifications for Geodetic Control Networks, listed at the following website:
http://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-geodetic-control-networks.htm#3.5

Also, *Section 3.4 of "User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, October 1987"* provides information regarding how to perform a valid level tie.

The Second-Order, Class I tie is a requirement for digital levels to be accepted into the NGS database. Short level runs to the sensor, PBM, and two marks are excluded from this requirement since they are usually meant to verify sensor stability only. Since a level connection to GBMs with dynamic heights defines the International Great Lakes Datum of 1985 (IGLD 85) datum offset at each station in the Great Lakes, a valid connection to at least two GBMs is required at each site.

A note shall be made in the remarks of the leveling section of the Site Report that a valid tie was achieved or not achieved. If a valid tie is not achieved, an explanation shall be provided and/or recommendations made for making a valid tie in the future.

If the NWLON water level station does not have two or more GBMs within 1.6 km (1 mi) leveling distance of the station location, then the level tie requirement is waived.

3.1.2. Leveling at Continuously Operating Reference Stations (CORS)

For any NGS CORS reference bench mark that is located within 1.6 km (1 mi) leveling distance of a water level station Data Collection Platform (DCP), a leveling connection shall be made to the tidal bench marks in the water level station network every two years.

Information about NGS CORS can be obtained at http://www.ngs.noaa.gov/CORS/.

As of 2007, there are a limited number of water level stations in this category, but NGS and CO-OPS are attempting to secure funding to establish additional co-located sites to support long-term sea level trends monitoring.

3.2. GPS Connections

3.2.1. References

Static GPS observations shall be performed at water level stations in accordance *with "NOAA Technical Memorandum "NOS NGS-58, Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards 2 cm and 5 cm), Version 4.3"*. 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. GPS Observations - Goals and Planning

Precise positioning of NWLON stations in a global geocentric reference framework is needed to support NOS marine safe navigation and height modernization projects, in addition to monitoring vertical crustal motions for absolute sea level and global climate change studies.

CO-OPS shall initiate a program of making periodic GPS observations at water level stations, as resources permit. CO-OPS activities shall be coordinated with NGS activities for best use of available resources.

GPS technology and procedures shall be implemented in the operational plan:

(1) To support the development of a seamless, geocentric reference system for the acquisition, management, and archiving of NOS water level data. This will provide a national and global digital database, which will comply with the minimum geo-spatial metadata standards of the National Spatial Data Infrastructure (NSDI) and connect the NOS water level datums to the NGS NSRS;

(2) To establish transformation functions between NOS chart datum Mean Lower Low Water (MLLW) or Low Water Datum (LWD) in the Great Lakes, and the geocentric reference system to support NOS 3-dimensional hydrographic surveys, the implementation of Electronic Chart Display and Information Systems (ECDIS), and the NOS Vertical Datum transformation (VDatum tool) and tidal datum models. Integration of GPS procedures will support the development of tidally-controlled Digital Elevation Maps and Models for use in programs such as marsh restoration.

(3) To support water level datum transfers by using GPS derived orthometric heights.

(4) To monitor crustal motions (horizontal and vertical) to support global climate change investigations.

The GPS surveys should be scheduled during routine annual maintenance trips to NWLON or PORTS® stations and during the installation of secondary and tertiary water level stations to support the survey projects, U.S. Army Corps of Engineers (USACE) projects, COASTAL project stations, tsunami stations, and special purpose surveys. CO-OPS shall continue to coordinate the GPS occupation of water level network bench marks with NGS, USACE, and the National Geospatial-Intelligence Agency (NGA), as appropriate.

GPS-derived orthometric heights can be accurately determined and used for water level datum transfers according to the following criteria: (a) use the established guidelines for 3-D precise relative positioning to measure ellipsoid heights; (b) properly connect to several NAVD 88 bench marks; and (c) use the latest high-resolution modeled geoid heights for the area of interest. In many remote locations, the use of GPS-derived orthometric heights for datum transfer will be more efficient (timely) and more cost-effective than the use of conventional differential surveying techniques and may, under certain circumstances, preclude the installation of additional water level stations to establish a datum.

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.

As of March 2007, 20 NWLON stations have been identified where annual GPS observations are required because of the sea level rise in those areas. These 20 NWLON stations – 8 in Alaska and 12 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.

3.2.3. Static Surveys

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

1. National Water Level Observation Network (NWLON), PORTS®, and tsunami stations.
2. Long term operating secondary water level stations.
3. New tertiary survey, COASTAL stations, and special project stations.
4. Historical subordinate water level stations with an accepted MLLW value on the current official tidal datum epoch

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.

3.2.4. 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 or stability; (b) historic GPS use; (c) satellite visibility; and (d) safety and convenience.

(a) Permanence or 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. GPS observations on the PBM are preferred if the PBM is either stability code A or B, and is suitable for satellite observations. Stability code C and D bench marks shall not be used for GPS observations, unless NGS has previously made GPS observations on those marks.

(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.

Priority shall be given to a GBM for GPS observations because the GBM already has a NSRS height (NAVD 88). 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 survey or special projects.

(c) Satellite Visibility

The most desirable bench mark for GPS observations 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 3-D rod mark shall be established. This new mark shall be connected to the station bench mark network through conventional geodetic leveling, and then 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 APP field of the electronic leveling HA file or on a copy of the published bench mark sheet, stating the suitability of GPS observations for each mark. The GPS visibility obstruction diagram as shown in Figure 5 under Section 6 GPS Project Documentation shall also be completed for each mark observed.

(d) Safety and Convenience

The location of the GPS bench mark 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 as collecting the GPS data. The safety of the GPS equipment (vandalism proof) should be considered in the mark selection process.

The bench mark selected for GPS observations 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 from the station DCP should also be convenient.

3.2.5. Planning, Position, and Photograph of the GPS Bench Mark

Regarding 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 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 (GPS) mark, it may be necessary to use one of these marks. In selecting a GPS mark, priority should be given to the NWLON PBM or an NGS, NSRS, mark with a First or Second-Order NAVD 88 height on a NGS datasheet.

If time permits, conduct a site reconnaissance survey prior to starting the GPS sessions, to select the proper mark(s) to occupy with GPS. A site survey consists of preparing an obstruction diagram for each useable mark using an inclinometer and placing a GPS unit (hand-held or better) over the bench mark to determine how many satellites can be tracked at that location. Determine the location of a suitable weather proof location, if any, for the GPS receiver. Measure the distance from the mark to this location to determine the antenna cable length required. Ideal marks should have approximately 360 degree unobstructed visibility above the 10 degree elevation mask. However, satellite geometry changes with time, so for 4-hour tracking sessions some obstructions, particularly those to the north of the mark, may not degrade the precision or accuracy of the final solution.

GPS (horizontal) positions (latitude and longitude) of each bench mark installed or recovered shall be listed on the HA files for laser levels, if used, or on the bench mark descriptions sheet for optical leveling, as applicable, at each subordinate water level station occupied for all projects.

Digital photographs shall be taken of all station bench mark disks in accordance with Reference 5 - *Attachment R, Requirements for Digital Photographs of Survey Control, NGS, July 2005*". A minimum of three photos shall be taken: close-up of the disk face; waist or chest level view of disk and setting; and horizontal view of location and direction of view. All digital station photo files should be named such that the name of the file will indicate the station number and the type of photo taken. For example, the bench mark A face photo for San Francisco water level station shall be named as 94142901 BM A face photo .jpg.

A digital photo of the stamping of the bench mark occupied must be made as shown in Figure 7. If a digital photo is not available, then a rubbing of the bench mark must be done as shown in Figure 6. A digital photo of the stamping is preferred over rubbing of the mark.

3.2.6. 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 (IGS or CORS) used to post-process the data. For GPS sessions greater than 30 minutes, collect data at 15-second epoch intervals, starting at an even minute. 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 four. For static surveying, setting the minimum number of satellites (MIN SV) is not as critical as for kinematic surveying. However, if the number of satellites tracked drops below four, it could be an indication of other problems, such as an antenna or antenna cable connection problem, RF interference, or an obstruction from traffic (vehicle or vessel). The GPS signal from the satellite is not very strong when entering the receiver, so anything that produces further attenuation of the signal can cause the receiver to stop tracking satellites.

Always collect a little bit of extra data if time and schedule permit, so that blunders or invalid data, if any, can be removed during processing still leaving required minimum number of hours of valid data for one GPS session.

It is recommended that after each session is complete, two independent downloads be done from the GPS receiver to the laptop computer, so that if one downloaded file gets corrupted, the other file may have good data. Since two downloads of the GPS observation file is a requirement, do not make copy of the downloaded file twice to the laptop instead, as both the files will have the same problem, if there exists a problem. Send both copies of digital GPS data so that one copy of the data can be forwarded to NGS and other copy will be kept for record in CO-OPS' Requirements and Development Division's Operational Engineering Team (RDD/OET).

Data should be compressed and copied to a CD-ROM, diskette, and/or zip disk, as appropriate, at the end of each GPS day for transporting data from the field to the office, or hotel as the case may be, for processing. If data are logged to a PCMCIA card (flash card) in the receiver, consult the receiver User Reference Guide about re-formatting the card prior to beginning observations.

Data should be collected during periods when the Vertical Dilution of Precision (VDOP) is less than 6 for at least 90% of each 30-minute or longer GPS observations, if VDOP maps or data are available for the site.

3.2.7. North American Datum 1983 (NAD83) GPS Tie

At each NWLON station, GPS observations shall be performed as listed in the Annual Project Instructions, Annual Station Specific Requirements, and contract documents. The frequency of repeated observations on the GPSSBM shall be determined based upon the rate of sea level rise and general stability of bench marks in the local leveling network.

The NGS OPUS is now used extensively for quick and convenient processing of the GPS raw data for a variety of applications. The position solution provided by OPUS is considered preliminary data and is not retained by NGS. Further information on using OPUS is provided later in this document.

The expected ellipsoid height accuracy for a 4 hour OPUS solution is 1.8 cm, (at the 67% confidence level), and that is desirable, practical, and achievable with the requirements as specified in reference #2, NOAA Technical Memorandum "NOS NGS-58, Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards 2 cm and 5 cm), Version 4.3.

The length of GPS observation sessions depends upon the length of time the field crew has available for GPS observations, security of the equipment, number of satellites available at a site, number of GPS receivers available for GPS observations, etc.

For all water level stations, collect a minimum of 4 hours of GPS data on the GPSBM. Extra care shall be taken to ensure that the antenna height is precisely recorded, and that the antenna setup is stable. A continuous long session (at least 4 hours long but less than 24 hours) repeated annually is preferred to two or more shorter sessions (of less than 4 hours each) repeated on the same visit, providing better data for OPUS and more independent observations.

After the data collection session is complete, two independent downloads are required from the GPS receiver to the laptop computer. If one downloaded file gets corrupted, the other file may have good data. Do not make a copy of the downloaded file, as both the files will have the same problem, if there is a problem. Follow the NGS guidelines for naming these files. Submit both copies of the digital GPS data along with the necessary documentation as specified below.

3.2.8. GPS Data Processing Using OPUS

Field parties shall use OPUS for processing the raw GPS observations. OPUS provides an easily accessible, rapid method for submitting GPS data and receiving an almost instantaneous solution response from NGS via email.

The NGS OPUS web page can be obtained at http://www.ngs.noaa.gov/OPUS/.
The following information is found on the OPUS web page but is also presented here for convenience of the reader.

OPUS allows users to submit their GPS data files to NGS, where the data will be processed to determine a position using NGS computers and software. Each data file that is submitted will be processed with respect to three CORS sites. The sites selected may not be the nearest to your site but are selected by distance, number of observations, site stability, etc. The position for your 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.

OPUS is completely automatic and requires only a minimal amount of information from the user, such as:

(a) The email address where you want the results sent
(b) The data file that you want to process (which you may select using the browse feature; raw or RINEX accepted)
(c) The antenna type used to collect this data file (selected from a list of calibrated GPS antennas)
(d) The height of the Antenna Reference Point (ARP) above the monument or mark that you are positioning.

Once this information is complete, you then click the Upload button to send your data to NGS.

Your results will be emailed to you, usually within a few minutes. You may upload multiple data files in a zip archive if you wish. However, be careful, the options that you choose will be applied to all of the data files in that archive (i.e. the same antenna type, ARP height will be used for all of the files in the zip file).

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

(a) Make sure the antenna type and the ARP height are correct.
(b) Review the solution statistics:
    (I) A good quality OPUS run should typically use 90% or more of your observations.
    (II) OPUS should have fixed at least 80% of the ambiguities
    (III) The overall RMS should seldom exceed 3 cm.
    (IV) The maximum peak to peak errors should be less than 2 cm for horizontal and 4 cm for vertical (This depends, of course, on the accuracy you are trying to achieve.)

NGS needs to receive orbit data from IGS in order to obtain a solution. If the data is submitted too quickly (before NGS gets the orbit data from IGS), the submitter may need to re-submit the data at a later time. For best 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 solution in the station inspection documentation package submitted to RDD/OET, as well as to NGS GPS data sets.

3.2.9. OPUS DB Preliminary information

Pending NGS support, OPUS DB will be released by NGS in the near future. This advanced version of OPUS will submit solutions directly to the NGS database for publication as part of NSRS if all required documentation is provided by the submitter. Further guidance will be provided once OPUS DB is released and this document will be updated as appropriate. Any data sets submitted to OPUS will be subsequently re-submitted by RDD/OET to OPUS DB to ensure the data is published by NGS, provided all the proper and required GPS data and documentation (as listed below under data submission section) has been submitted to CO-OPS.

Height modernization guidelines are listed at the following url:
http://www.ngs.noaa.gov/heightmod/guidelines.shtml

The Opus DB datasheet concept is fully listed at the following NGS web site:
http://www.ngs.noaa.gov/PROJECTS/draft/OPUS/OPUS-DB-concept.htm

The following tables identify the required data elements and optional data elements for OPUS DB respectively.

REQUIRED DATA ELEMENTS (15 each):

ELEMENT	RATIONALE
e-mail	For identification & correspondence.
Filename	Necessary to compute position.
Antenna	Necessary to compute position.
antenna height	Necessary to compute position.
name of submitting agency	Identifies the observer.
permanent identifier (PID)	Identifies the station.
Designation	Identifies the station.
descriptive text	Aids in station recovery.
Rod/pipe depth & units	Describes monumentation quality.
sleeve depth & units	Describes monumentation quality.
setting code & specific setting text	Describes monumentation quality.
photograph (of marker)	Aids in station recovery.

OPTIONAL DATA ELEMENTS (11 each):

ELEMENT	RATIONALE
photographs (of equipment, horizon)	Equipment photos describe antenna height and equipment used. Horizon photos aid in station recovery and could explain visibility or multipath problems.
vertical stability code	Useful for stability assessment.
magnetic property code	Aids in station recovery.
antenna s/n	Useful in identifying equipment-specific problems.
receiver	Useful in identifying equipment-specific problems.
receiver s/n	Useful in identifying equipment-specific problems.
receiver firmware	Useful in identifying firmware-specific problems.
stamping	Aids in station identification.
condition code	Useful for stability assessment.
special application codes	Identifies the station type (tidal station, Public Land Survey corner, etc.)
remarks	Allows user to record observation comments.

This information regarding the Required Data Elements and Optional Data Elements is for reference only and not required at the present time. These requirements will be active once OPUS DB is designated operational by NGS. Out of the 15 Required Data Elements, 13 are applicable to all the marks and the remaining two - rod/pipe depth & units and sleeve depth & units – are applicable only to rod marks.

3.2.10. 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 "Height Mod" tie is deferred until such time as NGS enables user-friendly blue-booking of campaign data (OPUS projects).

4.0 GPS Project Documentation and Data Submission

The following information in addition to the results obtained from OPUS shall be submitted to CO-OPS at the end of the project (see the time frames for submission of GPS data later in Section 4.1) so that proper information can be forwarded to NGS for blue-booking purposes.

This documentation is important because most of the information is used to submit the GPS data to NGS. In addition to the log, data must comply with the "Data Submission to NGS Section" of NGS-58 (Reference 2) and the "Input Formats and Specifications of the National Geodetic Survey (NGS) Data Base" (Reference 4) to become part of the NSRS.

GPS data collected by contractors or NOAA Ships for hydrographic survey support, or special projects shall be processed by the parties, and final data product - Receiver Independent Exchange Format (RINEX) data and appropriate forms - shall be submitted to CO-OPS which will be forwarded to NGS, as per the contracts, project instructions, statement of work, or as appropriate.

GPS forms in PDF format can be found at the following NGS Federal Base Network (FBN) web site:

http://www.ngs.noaa.gov/PROJECTS/FBN/index.htm

Refer to Figures 1 through 7 for GPS projects submission checklist and sample package contents.

(a) Project report (Refer to Figure 1):
One project report per GPS project is required.

(b) Station (bench mark) description or recovery notes (Refer to Figure 2)
One per bench mark, for which GPS observations are submitted, is required.

(c) Observation log sheets (Refer to Figure 3 and 4)
One per each GPS observation session is required.

(d) Station/bench mark visibility diagrams (Refer to Figure 5)
One per each bench mark, for which GPS observations are submitted, is required.

(e) Photographs or rubbings of station (bench) marks (Refer to Figure 6 and 7)
One per each bench mark, for which GPS observations are submitted, is required.

(f) Raw GPS data

(g) Rinex GPS data

(h) OPUS results

4.1. Data Submission

All required GPS data and documentation shall be submitted to CO-OPS within 15 business days of the GPS observations or the removal of the gauge whichever is earlier.

All GPS data and documentation shall be submitted in paper format and in digital format such as CD-ROM in duplicate, so that one copy stays with CO-OPS and other copy is forwarded to NGS. For GPS data that are collected according to the contracts, there may be additional requirements for submission, please check with the appropriate Contracting Officer's Representatives.

Submit all GPS project data and documentation to:

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

Figure 1 GPS PROJECT SUBMISSION CHECKLIST

Project Title : _____

Submitting Agency: _____

Observing Agency: _____

Receiver Type: _____

Antenna Type: _____

PACKAGE CONTENTS

( ) Project Report

( ) Station Description or Recovery notes

( ) Observations Log Sheets
Data which must be filled out: Station Designation, Date (UTC), General Location, Day of Year, Project Name, Session ID, Observation Session Times, Agency Full Name, Operator Full Name, Phone Number, GPS Receiver, GPS Antenna, Antenna Height, Data File Name

( ) Antenna height measurements

( ) Station Visibility Diagrams

( ) Photographs or Rubbings of Station Marks

( ) Raw GPS data

( ) Rinex GPS Data - See below

( ) OPUS Results

( ) Other

DATA REFORMATTING

Convert the raw GPS data to RINEX2 format with your manufacturer's software. The software should require you to enter the raw data filename, the output filenames, your name, the observer's name and agency, and the antenna type used.

The NGS-standard data filenames are as follows:

Raw GPS input files: aaaaddds.xxx

Where: aaaa = Alphanumeric 4-character station identifier,
ddd = Julian day of the year,
s = session, yy = year of observations,
and xxx is the receiver-dependent file extension (e.g., .DAT, .EPH, .ION, .MES, etc.)

RINEX2 navigation and observation files shall be named as follows.

RINEX2 Navigation File: aaaaddds.yyn
RINEX2 Observation File: aaaaddds.yyo

For example, RINEX2 filenames for navigation and observation from station BALD 2 on session A of 12/31/06 are BALD365A.06o and BALD365A.06n

Copy the raw GPS data files and the converted RINEX2 data files onto separate 3.5-inch diskettes or CD ROM.

Figure 2: Station (Bench mark) Description/ Recovery Form

--> Click here to clear the sample data <--

NATIONAL GEODETIC SURVEY
STATION DESCRIPTION / RECOVERY FORM

PID: QE2736 Designation & Alias: BALD 2 RESET

Country: (USA / USA) State: OR County: LINCOLN

Latitude: N 44 49 49.17802 " Longitude: W 124 03 56.23447 " Elevation: 17.0 (meter / ft)

Original Description (check one):	
☐ P	Preliminary (mark has not been set yet)
☐ D	A newly set mark
☑ R	A recovered mark
Established by: (NGS / CGS / Other:)	Oregon DOT
Date:	Chief of Party (initials): ???

Recovery Description (check one):	
☐ F	Full description of a station *not* in the database
☑ T	Full description of a station *in* the database
☐ M	*Partial* description of a station in the database
Recovered by: (NGS / Other:)	Oregon DOT
Date:	Chief of Party (initials): CFS

Monument Stability (check one):	
☑ A	Of the most reliable nature; expected to hold well
☐ B	Will probably hold position and elevation well
☐ C	May hold well, but subject to ground movement
☐ D	Of questionable or unknown reliability

Recovery Condition (check one):	
☑ G	Recovered in good condition
☐ N	Not recovered or not found
☐ P	Poor, disturbed, or mutilated
☐ X	Surface mark known destroyed

Setting Information:	
Marker Type: (Rod / Disk / Other)	
Setting Type: (Bedrock / Concrete / Other:)	
☑ / N / ?	Monument contains magnetic material?

Stamping:	BALD 2 1991
Agency Inscription: (NGS / CGS / Other:)	Oregon DOT
Rod Depth: (meter/ft), Sleeve Depth:	(meter/ft)
Monument is: (flush / projecting / recessed)	(cm/inch)

Special Type (check all applicable):	
☐ F	Fault monitoring site
☐ T	Tidal Station
☑ --	Control Station: (FBN / CBN / Benchmark)
☐ --	Airport Control Station: (PACS / SACS)
☑ /N	Mark is suitable for GPS use?

Transportation (check one):	
☑ C	Car
☐ P	Light truck (pickup, carry-all, etc.)
☐ X	Four-Wheel Drive Vehicle
☐ __	Other (SnowCat, Plane, Boat; describe)
☑ /N	Pack Time (hike) to mark? (hh:mm): 00:03

See Back of Form to add Text Description

General Station Location: The station is located in about 10 km south from Lincoln Bay, 13 km north from Depoe Bay, and at the US101 Boiler Bay wayside rest area.

(Describe general location; include airline distances to three towns or mapped features.)

Ownership: The station is on the property of Oregon State Department of Parks and Recreation.

(name, address, phone of landowner)

To Reach Narrative: To reach the station from the intersection of US routes 5 and 101 in Depoe Bay, go north on US 101 for 1 km to the south entrance of the Boiler Bay wayside. Bear left on entrance road for 0.4 km to the parking area on the left. Pack northwest inside fence for about 90 meters to end of fence and the station on the right.

(Leg-by-leg distances and directions from major road intersection to mark)

Monument Description and Measurements: The station is set into drill hole in bedrock, 7.6 m south from the north fence corner, 8.8 m east from the west fence corner, and 3.6 m southeast from the northwest end of the outcrop.

(Add at least three measurements to permanent, identifiable, nearby objects; and a description of the monument size, shape, height, etc.)

NOTE: - Include a pencil rubbing, sketch, or photographs of mark.

Described by: John Q. Surveyor Phone: (301) 713-3194 e-mail: jqs@ordot.gov

Figure 3: GPS Station Observation Log

--> Click here to clear the sample data <--

GPS STATION OBSERVATION LOG (01-Nov-2000)

Station Designation: (check applicable: FBN / CBN / PAC / SAC / PM) BALD 2 RESET		Station PID, if any: QE2736	Date (UTC): 31-Dec-98
General Location: Boiler Bay Wayside	Airport ID, if any: ---	Station 4-Character ID: BALD	Day of Year: 365
Project Name: Sample GPS, 1998	Project Number: GPS- 1234	Station Serial # (SSN):	Session ID:(A,B,C etc) A

NAD83 Latitude 44° 49' 49.17802"	NAD83 Longitude 124° 03' 56.23447"	NAD83 Ellipsoidal Height -6.44 meters NAVD88 Orthometric Ht. 17.0 meters GEOID99 Geoid Height -23.52 meters	Agency Full Name: Operator Full Name: Oregon DOT John Q. Surveyor Phone #: ( ) (301) 713-3194 e-mail address: jqs@ordot.gov
Observation Session Times (UTC) Sched. Start 12:00 Stop 17:30 Actual Start 11:55 Stop 17:32	Epoch Interval= 15 Seconds Elevation Mask = 10 Degrees		

GPS Receiver:
Manufacturer & Model: Leica SR530
P/N: p/n 667122
S/N: s/n 0030354
Firmware Version: Version 3.0
✔ CamCorder Battery, ☐ 12V DC, ☐ 110V AC, ☐ Other

GPS Antenna:
Manufacturer & Model: Trimble Choke Ring
P/N: p/n 29659-00
S/N: s/n 02200-63591
Cable Length, meters: 30 meters
Vehicle is Parked 25 meters N (direction) from antenna.

		Circle Yes or No -If no, explain "
Antenna plumb before session?	✔(Y / N)	
Antenna plumb after session?	✔(Y / N)	
Antenna oriented to true North?	✔(Y / N)	
Weather observed at antenna ht	✔(Y / N)	
Antenna ground plane used?	✔(Y / N)	
Antenna radome used?	(Y / N) ✔	If yes, describe. Use Vis. form
Eccentric occupation (>0.5 mm)?	(Y / N) ✔	
Any obstructions above 10°?	(Y / N) ✔	
Radio interference source nearby	(Y / N) ✔	

Tripod or Ant. Mount: Check one:
✔ Fixed-Height Tripod, ☐ Slip-Leg Tripod, ☐ Fixed Mount
Manufacturer & Model:
P/N: SECO
S/N: none.
Last Calibration date: 97-G 1998-11-01

Tribrach: Check one:
✔ None, ☐ Wild GDF 22, ☐ Topcon, ☐ Other (describe)
Last Calibration date:

**** ANTENNA HEIGHT ****
(see back of form for measurement illustration)

	Before Session Begins: measure and record both Meters	AND Feet	After Session Ends: measure and record both Meters	AND Feet
A= Datum point to Top of Tripod (Tripod Height)	2.000		2.000	
B=Additional offset to ARP if any (Tribrach/Spacer)	-0.003		-0.003	
H= Antenna Height = A + B = Datum Point to Antenna Reference Point (ARP)				

Note: Meters = Feet X (0.3048)
Height Entered Into Receiver = 2.000 Meters.
Please note &/or sketch **ANY** unusual conditions. Be **Very Explicit** as to where and how Measured!

Barometer:
Manufacturer & Model:
P/N: pretel altiplus A2
S/N: none. J.Q.S.
Last Calibration or check Date: 11-Sep-01

Psychrometer:
Manufacturer & Model:
S/N: Psychrodyne J.Q.S.

Weather DATA	Time (UTC)	Dry-Bulb Temp Fahrenheit	Dry-Bulb Temp Celsius	WetBulb Temp Fahrenheit	WetBulb Temp Celsius	Rel. % Humidity	Atm. Pressure inches Hg	Atm. Pressure millibar	Weather Codes *
Before	12:00	74.0		68.0		74	29.4		00000
Middle	14:45	77.0		72.5		81	29.6		00001
After	17:30	82.5		78.0		82	29.7		00102
Average of Readings				Calculate					* See back of form for codes

Remarks, Comments on Problems, Sketches, Pencil Rubbing, etc:

1. Winds, calm at start, gradually increased to 20 knots by end of session.

2. Semi-trailer parked 12 meters SSE of antenna from 15:17 to 15:32 UTC, possibly blocking satellites and causing multipath environment.

3. Center pole of tripod projected 3 mm into dimple of disk.
Antenna height was therefore 2 m - 3 mm = 1.997 m

Note: Entries are Required in all Unshaded areas.

Data File Name(s): BALD365A.dat (Standard NGS Format = aaaaddds.xxx) where aaaa=4-Character ID, ddd=Day of Year, s=Session ID, xxx=file dependant extension	Updated Station Description: ✔ Attached ☐ Submitted earlier Visibility Obstruction Form: ✔ Attached ☐ Submitted earlier Photographs of Station: ✔ Attached ☐ Submitted earlier Pencil Rubbing of Mark: ✔ Attached	LOG CHECKED BY: JGE

Figure 4: GPS Antenna Height Measurements

ILLUSTRATION FOR ANTENNA HEIGHT MEASUREMENTS:

I. Instructions for Fixed-Height Tripods:

Measure & record the fixed-height tripod length **(A)** and other offsets, if any, between the tripod and the Antenna Reference Point (ARP) **(B)**

$$Antenna.Height = H = A + B$$

II. Instructions for Slip-Leg Tripods:

1. Measure the Slant Height (S)

Measure the slope distance from the mark to at least three notches on the Bottom of Ground Plane (BGP) using two independent rulers (e.g., metric and Imperial). Record measurements in the table below, and compute the average.

Measure S	Notch #_	Notch #_	Notch #_	Average
Before, cm	223.40	223.30	223.30	
Before, inch	87.95	87.94	87.93	
After, cm	223.40	223.40	223.30	
After, inch	87.97	87.96	87.95	
Note: cm= inch x (2.54)		Overall average, cm		

S = _____ cm

2. Record the Antenna Radius (R) and the Antenna Constant (C)

The antenna radius (R) is the horizontal distance from the center of the antenna to the measurement notch. The antenna constant (C) is the vertical distance from the ARP to the BGP. Consult your antenna users manual for exact measurements.

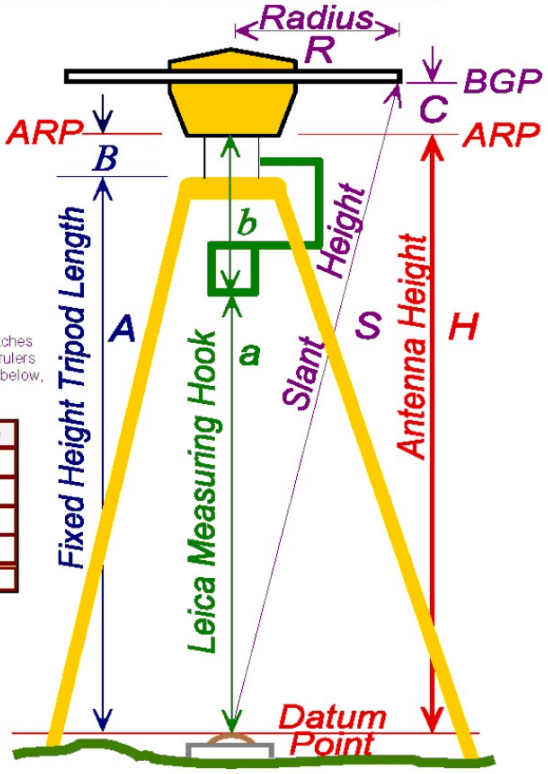
R = 19.05 cm

C = 3.50 cm

3. Compute Antenna Height (H)

Use the following Pythagorean equation:

$$Antenna.Height = H = ((\sqrt{S^2 - R^2}) - C)$$



III. Instructions for using the Leica Brand Measuring Hook:

Follow the Leica operating instructions, being sure to reduce the height to the Antenna Reference Point (ARP), NOT the L1 Phase Center.

$$Antenna.Height = H = a + b$$

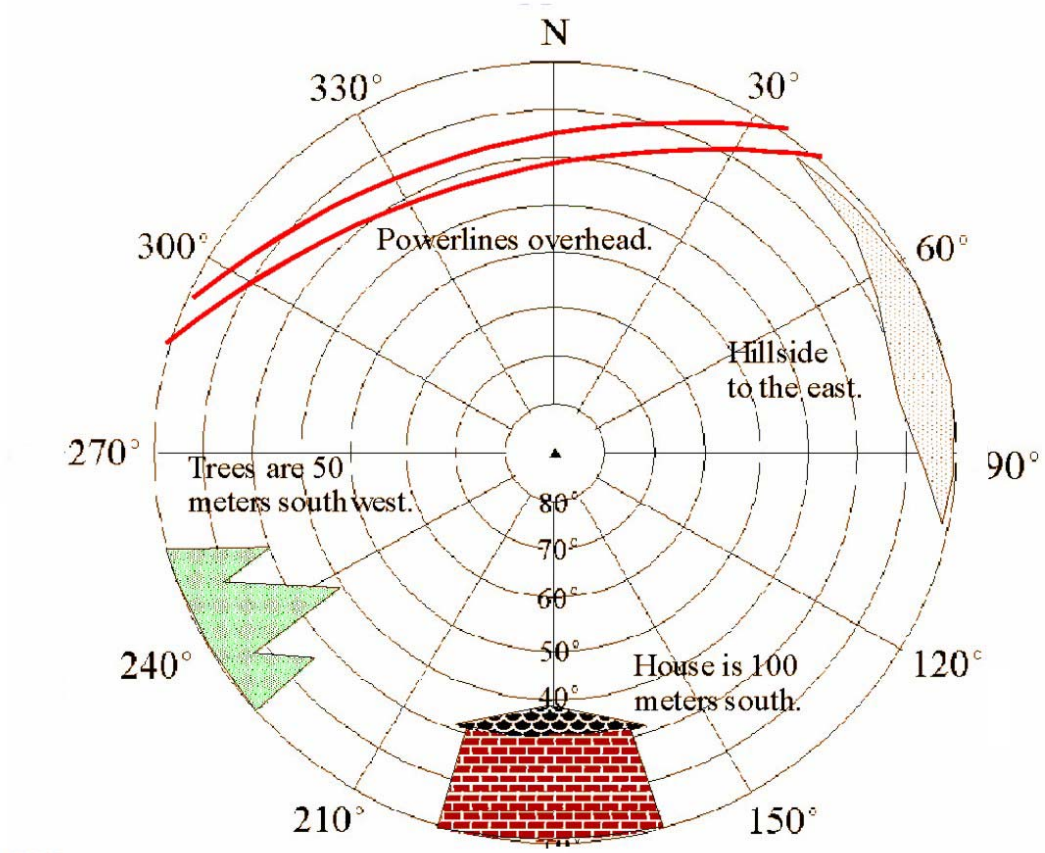
Table of Weather Codes -- for entry into Weather Data Table on front of form:

CODE	PROBLEM	VISIBILITY	TEMPERATURE	CLOUD COVER	WIND
0	NO PROBLEMS encountered	GOOD More than 15 miles	NORMAL 32° F to 80°F	CLEAR Below 20%	CALM Under 5mph (8km/h)
1	PROBLEMS encountered	FAIR 7 to 15 miles	HOT Over 80°F (27 C)	CLOUDY 20% to 70%	MODERATE 5 to 15 mph
2	-- NOT USED --	POOR Less than 7 miles	COLD Below 32° F (0 C)	OVERCAST Over 70%	STRONG over15mph (24km/h)
Examples: Code 00000 =	0 - No problems,	0 - good visibility,	0 - normal temperature,	0 - clear sky,	0 - calm wind
Code 12121 =	1 - Problems,	2 - poor visibility,	1 - hot temperature,	2 - overcast,	1 - moderate wind

Figure 5: Visibility Obstruction Diagram

--> Click here to clear the sample data <--

NATIONAL GEODETIC SURVEY
VISIBILITY OBSTRUCTION DIAGRAM



INST

Identify obstructions by azimuth (magnetic) and elevation angle (above horizon) as seen from station mark.
Indicate distance and direction to nearby structures and reflective surfaces (potential multipath sources).

Designation: BALD 2 RESET PID: QE2736

Location: Boiler Bay Wayside County: LINCOLN

Reconnaissance By: John Q. Surveyor Height above mark: 2 Meters

Agency/Company: Oregon DOT Phone: ((301))713-3194 Date: 1998-12-31

Figure 6: Station Pencil Rubbing Form

Station Pencil Rubbing Form

--> Click here to clear the sample data <--

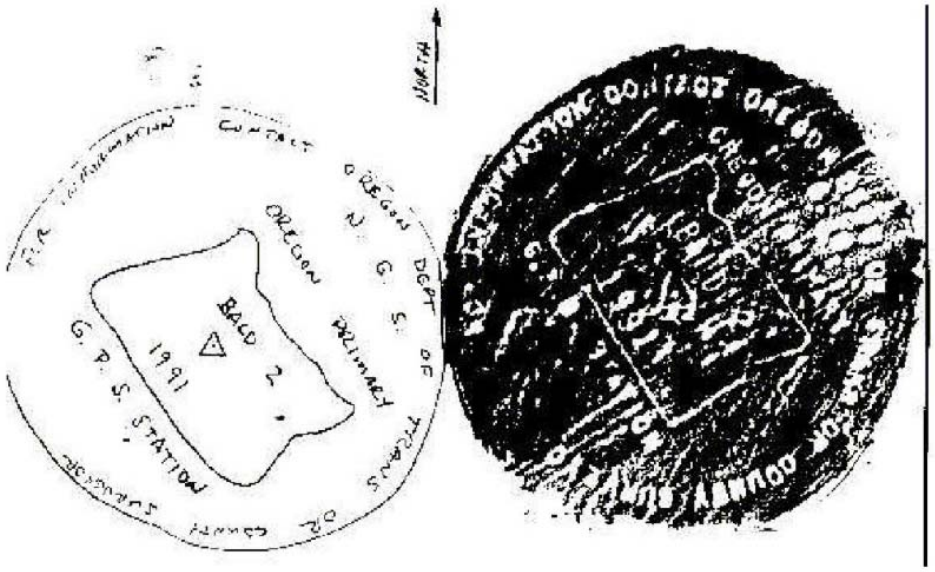
Location / Airport Name and ID: Boiler Bay Wayside Project: Sample GPS, 1998

Station Designation: BALD 2 RESET PID: QE2736 Date: 1998-12-31

Circle all applicable: PACS SACS ~~PM~~ FBN ~~CM~~ OTHER_____ Observer & Organization: John Q. Surveyor, ORDOT

Station Pencil Rubbing

Instructions: Place the blank form (or other blank paper) over the mark and rub over the entire disk with a pencil. For rod marks, rub only the designation and date stamping from the rim of the aluminum logo cap. If it is impossible to make a rubbing of the mark, or if the rubbing appears indistinct, a sketch and/or photograph may be substituted.



Remarks:
This disk is reset into the same drill hole as the original station BALD 1962.

Monument Type: Brass Disk

Inscribed Agency: Oregon DOT

Stamping: BALD 2 1991

Figure 7: Digital Photograph of a Stamping of a Bench Mark