DEPARTMENT OF THE ARMY
U. S. Army Corps of Engineers
Washington, D.C. 20314-1000

ETL 1110-1-183

CECW-EP

Technical Letter
No. 1110-1-183

1 April 1998

Engineering and Design

USING DIFFERENTIAL GPS POSITIONING FOR ELEVATION DETERMINATION

1. Purpose

This engineer technical letter provides technical guidance for using Differential Global Positioning System (DGPS) to determine elevations of survey benchmarks for wide-area mapping and GIS database development applications. Recommended procedural specifications for field DGPS observation sessions are included.

2. Applicability

This letter is applicable to major subordinate commands, districts, laboratories, and field operating activities having responsibility for civil works, military construction, or environmental restoration projects. These DGPS guidelines and specifications are intended for densifying vertical control over large project areas, such as an entire military installation or watershed basin mapping project. The DGPS methods outlined in this letter are generally ***not*** intended, nor would be cost-effective, for small projects or any type of construction lay out work where vertical grades or benchmarks require an accuracy better than 30 millimeters (mm). In such cases, conventional differential leveling methods should be used.

3. References

a. FGCC, (1991), Standards and Specifications for Geodetic Control Networks, Silver Spring, Maryland. (FGCC is currently known as FGCS)

b. Milbert, D.G. and Smith D.A. (1996). Converting GPS Height into NAVD88 Elevation with the Geoid96 Geoid Height Model. National Geodetic Survey, Silver Spring, Maryland.

c. U.S. Army Corps of Engineers (1994), Deformation Monitoring and Control Surveying. Engineer Manual 1110-1-1004, U.S. Army Corps of Engineers, Washington, D.C.

d. U.S. Army Corps of Engineers (1996), NAVSTAR Global Positioning System Surveying. Engineer Manual No. 1110-1-1003, U.S. Army Corps of Engineers, Washington, D.C.

e. Zilkoski, D.B., D'Onofrio, Joseph D., and Frankes, Stephen J. (1997) Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm), Version 4.1.1. Silver Spring, Maryland. NGS Unpublished Report.

f. Zilkoski, D.B., Richards, J.H., and Young, G.M. (1992). Special Report: Results of the General Adjustment of the North American Vertical Datum of 1988, Silver Spring, Maryland.

4. Distribution

This information is approved for public release. Distribution is unlimited.

5. Discussion

a. Global Positioning System (GPS) surveying produces a set of X-Y-Z coordinates which can be transformed into geodetic latitude, longitude, and ellipsoidal height by using an reference ellipsoid to model the earth. In the U.S., most GPS ellipsoid heights are measured with respect to North American Datum of 1983 (NAD83) control values, which are based on the Geodetic Reference System of 1980 (GRS80) ellipsoid. Published

orthometric elevations on national vertical control benchmarks in the North American Vertical Datum of 1988 (NAVD88) height system are established with respect to the geoid, a model of the earth based on gravity measurements. A determination of a NAVD88 elevation using GPS measurements at a given point requires a transformation between ellipsoid and geoid based height systems. The conversion between the NAD83 GPS ellipsoid and NAVD88 orthometric height is made using the geoidal undulation (also referred to as geoid height) value that represents the geoid-ellipsoid separation distance.

b. DGPS may provide an efficient and cost-effective means of densifying elevation data over large, extended project areas when compared to conventional differential leveling. Height measurement accuracy that meets most USACE mapping requirements can be successfully achieved from several different GPS surveying techniques. However, DGPS vertical elevation techniques may not be sufficiently accurate for construction control or may not be cost-effective for small project areas.

c. GPS relative vertical positioning and calculated geoid height differences for the determination of NAVD88 orthometric heights may be used when an accuracy no better than 30 mm is required. This GPS height accuracy satisfies feature elevation tolerances specified for most USACE engineering mapping activities. However, it may not be sufficiently accurate for hydraulic engineering studies or construction activities. Guidance for GPS survey accuracies and procedures can be found in EM 1110-1-1003.

d. Recent advances in geoid modeling have also led to more accurate conversions between NAD 83 GPS and NAVD 88 orthometric height systems. Accuracies of 30 mm or better have been obtained when converting ellipsoid heights from GPS surveys, based on NAD 83 control, to NAVD 88 orthometric heights using the latest geoid model (GEOID96). The initial GPS survey data must be valid for the elevation transfer method to be effective. Guidance for GPS survey accuracies and procedures can be found in EM 1110-1-1003, NAVSTAR Global Positioning System Surveying.

e. Appendix A presents the basic methodology for using GPS to determine NAVD88 elevations. GPS positioning techniques, coordinate systems, and vertical datum concepts are introduced and discussed along with operational requirements and computational schemes used to obtain NAVD88 elevations from GPS coordinates. These operational requirements are based on field test results conducted by U.S. Army Topographic Engineering Center (CETEC) and the National Geodetic Survey (NGS) using several different GPS surveying methods and comparing these results to conventional differential leveling networks.

6. Proponency and Technical Assistance

The HQUSACE proponent for this technical letter is CECW-EP. Technical assistance in performing GPS surveys may be obtained by contacting the U.S. Army Topographic Engineering Center, ATTN: CETEC-TD-G, 7701 Telegraph Road, Alexandria, VA 22315-3864, (703) 428-6767.

FOR THE DIRECTOR OF CIVIL WORKS

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Appendix A
Determination of Elevations
with GPS Surveying Techniques