Washington State Department of Ecology

Environmental Assessment Program

Standard Operating Procedure for Determining Coordinates Via Hand-held GPS Receivers

Version 1.0

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Date - April 20, 2006

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Date – August 30, 2006

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Date – September 6, 2006

EAP013

APPROVED: September 6, 2006

Recertified: May 7, 2010

Signatures on File

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Although Ecology follows the SOP in most instances, there may be instances in which Ecology uses an alternative methodology, procedure, or process.

SOP Revision History

Revision Date	Rev number	Summary of changes	Sections	Reviser(s)
9/6/2006	1.0	Text corrections	all	Bill Kammin
5/7/2010	1.0	Recertified	All	Kammin

Environmental Assessment Program

Standard Operating Procedure for determining coordinates via hand-held GPS receivers

1.0 Purpose and Scope

1.1 This document is the Environmental Assessment Program's (EAP) Standard Operating Procedure (SOP) for consistent accuracy of position coordinate pairs (generally latitude and longitude) when using hand-held global positioning system (GPS) receivers.

1.2 Systematic and random errors are inherent in GPS receiver coordinates due to imperfections in satellite atomic clocks, multi-path interference, receiver noise, and other sources. Additionally, sloping terrain, buildings, and other objects obstruct satellite signals, limiting time periods when accurate coordinates can be collected. However, by combining avoidance of high-error periods with real-time correction, data collected by modestly priced GPS receivers can approach the accuracy of much more expensive receivers and reduce post-processing. Using these methods, estimated position error (EPE) of coordinate pairs often averages <7m without WAAS. With WAAS, EPE may be <3m. On forested slopes, a field crew of two can survey 500+ m during a single data window when collecting coordinates every 20 m.

2.0 Applicability

2.1 WAAS-enabled (or other real-time differential correction equivalent) GPS receiver

3.0 Definitions

3.1 Cold start: satellites broadcast general orbit and status data valid for several months (almanac data) and specific position and timing data valid for a few hours (ephemeris data). If a receiver is moved several hundred miles or turned off several months between uses, signal lock is slow because new almanac data must be downloaded. Warm start is when almanac and ephemeris data are still valid.

3.2 Coordinate system: graticular network draped over a mathematical planetary model.

3.3 Datum: mathematical model specifying the planet shape and coordinate system origin. This defines a frame of reference for measuring horizontal and vertical distances.

3.4 Estimated position error (EPE): estimate of horizontal location error calculated from factors such as dilution of precision and satellite signal strength.

3.5 Global Positioning System (GPS): global space (satellites), ground (control stations), and user (receiver) network using radio signals and atomic clocks to calculate velocity and distance. The U.S. space and ground network is called NAVSTAR.

3.6 Multi-path interference: coordinate error caused by reflection of radio signals, resulting in multiple versions of a signal reaching a receiver at different times.

3.7 Post-processing differential correction: position corrections applied after coordinates are obtained. This requires special software and is somewhat time consuming.

3.8 Real-time differential correction: position corrections transmitted while the receiver is roving. Various private and public networks transmit these corrections. This method is not as reliable as post-processing.

3.9 Wide Angle Augmentation System (WAAS): one form of real-time differential correction, using the International Terrestrial Reference Frame (ITRF 2000) and broadcasting on NAVSTAR channels. This correction technique is usually (but not always) available during optimal GPS windows.

4.0 Personnel Qualifications/Responsibilities

4.1 Understanding of datums, coordinate systems, various coordinate formats, and other terms related to GPS operation. Ability to navigate on unimproved roads with maps and compass. First aid training.

4.2 Typical Job Class: aptitude for field tasks is more important than job class

5.0 Equipment, Reagents, and Supplies

5.1 Equipment: WAAS-enabled GPS receiver, Hip Chain® or 50 m tape, clipboard.

5.2 Reagents: None.

5.3 Supplies: data sheets, pencils, paint markers, flagging, extra batteries

6.0 Summary of Procedure

6.1 PRIOR TO SITE VISIT: Methods 6.2 are software-based satellite constellation filters used to identify data collection windows prior to site visitation. These steps optimize strong signal locks for satellites directly above a given site. Repeat each step for each station.

6.2 Software: Download and install the satellite forecasting freeware: www.trimble.com/planningsoftware_ts.asp

6.2.1 Define stations: Launch the planning software, then select File>Station to open the Station Editor. Type a name for the station, then its latitude and longitude, estimated from a map. Degree seconds are not needed because geographic regions (100+km) experience similar satellite errors and atmospheric distortion. Enter the station's estimated height (elevation) in meters. Click OK to save the station (or continue to next step).

6.2.2 Set Elevation Cutoff Angle: From the Station Editor, enter an elevation cutoff angle (0º=horizon, 90º=overhead). All satellites below this angle, which results in a zone circling the horizon of the angular width specified, will be excluded from constellation forecasts. This option can, for example, filter satellites near the horizon where atmospheric signal path length is longer and likely more distorted.

6.2.3 Set Obstacle Mask: From the Station Editor, click Obstacles to display a diagram that looks like a bulls eye labeled with two systems of angular measure—elevation angle (0-90º) and azimuth (0-360º). After assessing topographic obstructions, either from a map or a visit to the site, position the cursor at the location of the obstacle, then drag while clicking the left mouse button to create polygons. The polygon regions will be excluded from the forecast. For example, polygons approximating the azimuth and elevation angle of mountains obstructing sky sectors can be drawn. The viewshed under forest canopy can also be narrowed in this way.

6.2.4 Set Forecast Interval: From the Station Editor, set start date, start time, duration (hours) and interval (minutes) of the forecast. Click OK to close the Station Editor.

6.2.5 Select Satellite Systems (Networks): There are check boxes on the software main menu to identify satellite networks included in forecasts. Check GPS and WAAS.

6.2.6 Forecast: Constellations are predicted for the station selected in the Station Editor. If correct, move the cursor across the colored icons just below the program main menu bar. These icons display forecasts in different formats. For example, the elevation icon tracks time vs. angular elevation of each satellite (Fig. 1). Two other useful formats are satellite number (vertical bars) and satellite visibility (horizontal bars) (Fig. 2). Using these forecast diagrams, select a time window when at least four satellites are available.

6.2.7 Four strong satellite locks are needed to minimize X,Y, and Z error. Though logically three satellite locks seem adequate to determine coordinates, the fourth satellite averages out receiver error. In Western Washington, there are generally two favorable GPS data collection windows--one morning, one afternoon--averaging roughly two hours each in forested uplands, but widening as topography flattens and canopy interference declines. Timing and number of satellites visible during these windows vary somewhat daily so forecasts are day specific.

6.3 DURING SITE VISIT: Methods 6.4 enable real-time correction to coordinates and monitor accuracy during collection of coordinates. The receiver is most accurate when in motion. Sweeping the receiver through the air slowly may improve reception. Arrive at the location such that the GPS receiver is in position during the window, allowing time to lock onto satellite signals. Depending on degree of obstruction, and cold start vs. warm start, establishing four signal locks may take 15+ minutes.

6.3.1 Differential corrections use many different reference frames so mixing post-processing and real-time methods can introduce new errors. WAAS does not use NAD83 as a reference datum so the best defense against datum shifts is to post-process all data. However, if the objective is feature identification or for illustrative purposes such that coordinate error of a few meters is acceptable there is probably no need to post-process.

6.4 Datum: Confirm that the primary datum of the GPS receiver is set to North American Datum 1983 (NAD83). Usually this is accomplished by scrolling through menus but see the receiver's manual. ArcMap automatically applies 'virtual reprojection' to align new layers in existing data frames but this sometimes introduces datum shifts. Record the datum on the data sheet.

6.4.1 Coordinate System: Confirm that coordinates are being collected as latitude/longitude. Data can be converted to State Plane, Washington South later. Record the coordinate system on the data sheet.

6.4.2 Coordinate format: Select decimal degrees. If data is collected as degrees/minutes/seconds it will need to be converted to decimal degrees later.

6.4.3 Mode: Operate the receiver in 3D (X,Y,Z) rather than 2D (X,Y) mode. Though receiver-derived elevation (Z) error is often high even with WAAS, horizontal coordinates without an elevation estimate can be off by >2km.

6.4.4 EPE: Confirm that display and error units are meters. For each set of coordinates, a corresponding position error should be displayed. Record the error in the EPE column on the data sheet.

6.4.5 WAAS: Real-time differential correction is only possible with a WAAS-enabled receiver (or receiver keyed to other corrections). When the receiver displays WAAS, the signal is being corrected in real time by ground control stations for some of the error discussed above. If a receiver displays WAAS when coordinates are collected, write WAAS in the EPE column on the data sheet. Newer receivers simultaneously display number of satellite locks.

7.0 Records Management

7.1 A single form is used. A copy is attached (Appendix 1). Revise field headers for non-stream features.

8.0 Quality Control and Quality Assurance Section

8.1 Data Collection: Each staff member should 1) understand the data sheet and various codes, 2) record EPE or WAAS for each coordinate pair, 3) be able to set the receiver's datum, coordinate system, etc in case of battery failure or other problem.

8.1.1 If further estimates of X or Y error are needed, bench marks can be created at field locations for features thought to be visible in photos or of established coordinates. For example, distance from a landmark and another object can be measured with the hip chain along a bearing. Distance between the object's coordinate pairs can then be measured in ArcMap.

8.2 Data Entry: 1) After transfer of data to a db file or spreadsheet, each entry of each record is proofed twice (separate staff).

9.0 Safety

9.1 As needed be aware of slash and forest undergrowth, steep slopes, large animals and bees, fire, potholes, washboards, road dust, log trucks, and hunters.

10.0 References

10.1 Ferguson, M. 1997. GPS Land Navigation. Glassford Publishing. Boise, ID.

Appendix 1: GPS data form

DNRT5_GPS_2006

Region __________ Stand __________________ Date______________ Datum __________

Coord Sys __________

Crew ___________________ Recorder__________________ Mode __________

Stream	Segment	Station	Lat	Long	EPE	# of Sat