Standards for Collecting Mapping Grade Global Positioning System Positions

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Standards for Collecting Mapping Grade Global Positioning System Positions and GPS Metadata

Introduction
The State Land Information Board developed this document in order to support the legislative initiatives to establish the Arkansas Spatial Data Infrastructure (Act 1250 of 2001). It is intended that these Standards will benefit the Global Positioning System (GPS) and Geographic Information Systems (GIS) user communities in numerous ways. These standards specifically address the collection of GPS features and proper metadata collection. GPS data / metadata that meet the following standards will be viewed as a reliable addition to the ever-growing Arkansas spatial data repository.

Background
The State Land Information Board (SLIB) was created by Act 914 of the 1997 General Assembly and is responsible for:

- Identifying problems and solutions in implementing a spatial data repository
- Developing and coordinating a schedule for state spatial data projects
- Recommending methods of financing for state spatial data projects
- Providing educational programs that are focused on spatial data technologies
- Coordinating collaborative projects; and
- Establishing spatial data standards (Section 4. (f) (1) of Act 1250 of 2001).

Act 1250 of 2001 (An Act to Amend the Arkansas Code to Create the Geographic Information Office and Establish the Arkansas Spatial Data Infrastructure; (and for other purposes) establishes these SLIB principles:

- Validity, consistency, comprehensiveness, availability, and currentness of data are essential components of all automated land information systems.
- Coordination with federal, state, regional, county, and municipal agencies, state universities and colleges, private firms, and others who require the same spatial data will reduce duplication of efforts and expense.
- Creation of new data in an accurate and usable format in accordance with the states shared technology architecture will ensure availability across state agencies.

Purpose
The SLIB has developed the following set of Global Positioning System (GPS) data collection standards. The standards presented within this document seek to accomplish the following objectives:

(1) Eliminate or reduce known and potential systematic errors;
(2) Establish a common means of collecting GPS data in Arkansas;
(3) Provide standards for supplying metadata about GPS receivers used to collect spatial data (features); and
(4) Supply GPS users with common GPS terms and abbreviations.

Meeting each of the tasks above will provide Arkansas with GPS features that have known accuracies, and reliable metadata for future spatial data users.

The standards presented in this document are intended to provide consistency among GPS collected data. This document only addresses the use of Code Phase or Mapping Grade GPS. Mapping Grade receivers use binary code (coarse acquisition (C/A), pseudo random noise code) for civilian access. Standards for the use of GPS for carrier phase (L1 and L2) or surveying grade receivers (i.e., +-1cm) are not covered in this document. **Surveying standards are more stringent and beyond the scope of this document.** This document is a work in progress and will continue to be developed, updated, and edited. These standards are based on current technology and will require periodic review by the State Land Information Board as GPS technology evolves.

Mapping Grade GPS Receiver Standards:

GPS receivers should be:

- Capable of producing and storing data in a format compatible with standard base station data used to perform differential corrections (rinex, ssf, etc.)
- Capable of storing attribute data about features collected
- Capable of storing time and coordinates of features collected
- Capable of exporting features collected to a format that can be used by a GIS

Suggested GPS Receiver Settings:

Name	***Standard***
Almanac	acquired within 10 days
Altitude reference	Height above Ellipsoid (HAE) or Mean Sea Level (MSL); if MSL is used, indicate Geoid Model
Antenna heights	1.0 – 2 meters
Datum	WGS-84
Elevation mask	15 degrees
Feature types	point, line, area (polygon)
Logging intervals	Point 1 second Line / Area Walking 5 seconds Driving 1 second
Note: To achieve the highest degree of accuracy the GPS receiver -logging rate should be synchronized with the base station supplying differential information logging rate. Otherwise, interpolation of points will occur, reducing the accuracy of the GPS receiver.	
Minimum number of positions for a point feature	4
Mode	2D / 3D
PDOP Mask	6.0 or less
Position mode	manual 3D
Satellite vehicles	3 (for 2D collection) / 4 (for 3D collection)
SNR Mask	6.0 or greater
Unit of Measure	meters or feet

An almanac provides information for satellite acquisition in the field and for mission planning in the office. Typically, almanacs are considered current for up to thirty days. In the field almanacs are acquired every 12 minutes when using a GPS receiver. For mission planning you should acquire a fresh almanac. Almanacs can be acquired from a GPS receiver, GPS software, base station file, or the Internet.

Antenna heights will vary depending on the specific application. Typically, the antenna height should be set at 1.0 - 2 meters. The antenna height is directly related to vertical and horizontal accuracies. It is imperative to properly set the antenna height when collecting vertical GPS data.

Position Dilution of Precision (PDOP) can be monitored by setting the receiver to collect data with a PDOP of 6.0 or less. This will insure that the satellite vehicles are adequately distributed. Collecting fixed positions during periods when the PDOP is higher than 6.0 could result in less accurate data.

The elevation mask should be set to 15 degrees in most GPS collection projects. There are projects that may require a higher or lower degree of mask, but these instances should be reviewed and documented in the GPS metadata.

The position mode setting on the GPS receiver should be set to manual 2D or 3D. This will provide positions collected with a minimum of three or four satellites. The 3D mode will allow for horizontal and vertical data collection.

Signal to noise ratio (SNR) refers to the strength of the code given off by the satellite vehicle. If the SNR falls below 6.0 the code is considered weak. The SNR should be set to accept positions when the SNR is 6.0 or higher.

GPS Metadata Standards: (for GPS collected Data)

Requirements	***Example***
Type of receiver	Manufacturer / Type Racall- Mark IV Landstar Trimble- GeoExplorer III
Number of receiver channels	12
Horizontal accuracy of receiver (manufacturer's specifications for predicted error, including reporting statistic)	1-5 meters+ 2ppm (root mean square)
Vertical accuracy as stated by manufacturer	3-5 meters+ 2ppm (root mean square)
Approximate distance from the base station used for differential correction	20-30 miles
Base station used for differential correction	Latitude 33^{o} 35' 31.84178" N Longitude 91^{o} 48' 53.43183" W Elevation 64.359 m HAE http://sal.uamont.edu/sal/pages/gps.htm
Coordinate system	Geographic (lat/long)
Datum	WGS 84
Date of collection	01/01/01
GPS methodology utilized	autonomous, differential, or phase-differential
Altitude reference	Height above Ellipsoid (HAE) or Mean Sea Level (MSL); if MSL is used, indicate Geoid Model
Minimum number of positions for a point feature	4
PDOP Mask	Maximum of 6
SNR Mask	Minimum of 6

Units of Measure	Meters or feet

If it is your intent to follow the standards, metadata shall be prepared for all GPS features. GPS features require two forms of metadata. This document only addresses the documentation of metadata specific to the GPS receiver (GPS metadata). Refer to the Federal Geographic Data Committee (FGDC) metadata standards for spatial data (features). GPS metadata should include: accuracy of receiver, base station used for differential correction, coordinate system, dates of collection, datum, differential correction applied, elevation setting, horizontal and vertical accuracy, minimum number of positions collected, PDOP, SNR, type of receiver, and units of measure. The metadata should be supplied with the feature data set. (Refer to GPS Metadata Standards, page 4)

Supplying metadata will assist end-users of the spatial data with the information needed to employ its appropriate use. A number of projects or unavoidable circumstances may warrant receiver settings or collection methods outside of the standard presented above. When this occurs it should be precisely documented in the metadata.

Systematic Errors

Positions acquired using GPS receivers are determined based on a measurement of time and distance. Receivers calculate the time and distance from a minimum of three satellite vehicles to acquire a horizontal position and four satellite vehicle to acquire a 3D (horizontal and vertical) position. There are several known sources of error that should be taken into consideration when collecting GPS positions.

Atmospheric delay occurs when GPS signals are interrupted by the earth's ionosphere and troposphere. As the signal is disrupted, the time it takes to reach the earth is altered, and can contribute approximately 1 meter of error. Since GPS positions are determined by time and distance, this alteration in time has an adverse effect on the accuracy of GPS fixed positions collected. The heat of the day is when atmospheric delay is greatest. Satellite vehicle signals low on the horizon also experience higher delays because the signal travels through more atmosphere.

Dilution of Precision (DOP) is the combination of error factors caused by poor satellite vehicle geometry that can alter position and time solutions. The receiver is using trilateration to determine its fixed position. If the satellite vehicles are not properly spaced the DOP values are higher and the horizontal position is degraded. Setting the receiver to accept positions when the PDOP is 6.0 or less (lower is better) will control this source of error by not allowing data with high DOPs to be saved by the receiver. Errors incurred by PDOP's higher than 6.0 can cause approximately 1 meter of inaccuracy.

Multipath error occurs when a satellite vehicles signal is reflected off an object prior to reaching the receiver, thus causing a time delay. This can cause several meters of error. Buildings, trees, mountains, signs, etc, may cause multipath errors. Generally multipath errors are easily recognized when the GPS data collected is viewed in a geographic information system (GIS).

Obstruction errors occur when the GPS receiver loses a lock from a satellite vehicle from which it is receiving code. Receivers and base stations both require a clear view of the sky. Weather generally does not affect the functionality of a receiver. Extreme conditions could impede a receiver's performance. A clear view of the sky is one that is not blocked by solid objects.

Satellite vehicle clock error and receiver rounding error also contribute to GPS data inaccuracies. Operator error caused by using the wrong datum or coordinate system is the biggest source of error and may result in 100+ km of error.

Selective availability (SA) is an intentional degradation of the code sent from satellite vehicles. The Department of Defense degrades the code. On May 1, 2000 the Department of Defense turned off selective availability. Selective availability may be activated anytime and without notice. Errors caused by selective availability can be difficult to observe. Post-processing aids in removing time and location errors collected by the receiver. Most receivers come with post-processing software. Arkansas has a number of base stations that are available for public use. All fixed positions collected should be post-processed. This will increase and standardize horizontal and vertical accuracies. Raw data from the receiver and base station should be archived. Future software may allow for finer post-processing accuracies.

Recommendations

Training: Individuals who are involved in collecting spatial data utilizing GPS technologies should have adequate training. Prior knowledge of sources of error, the proper uses of GPS, and limitations will help ensure that quality spatial data is obtained with GPS receivers. Training classes are offered by a number of vendors, state agencies and universities.

Testing GPS receivers: GPS receivers should be tested on a regular basis to ensure receivers are in proper working order. A zero baseline test will provide a degree of equipment reliability. Acquiring a fixed position on a known point on the earth's surface (such as a horizontal control station), post-processing the data and comparing it to the known point is one way to determine a receiver's working condition.

Project planning considerations: Mission planning should be conducted to determine which type of capture and processing best suits the project. There are a number of methods for capturing and processing GPS data including: autonomous, real-time correction, and post-processing. Each of these methods will produce different accuracies. It is important for GPS users to be aware of what method they are utilizing and make sure it is properly documented in the GPS metadata.

GPS data collection: GPS data should be collected in one of three geometries (point, line or area). Each geometric shape requires a specific collection method. A point feature should be collected at one-second intervals with a minimum of 4 positions collected.

Line and area features should be collected at five-second intervals if walking and one-second intervals if driving. An area should be collected by closing the feature prior to returning to the first point acquired. This will reduce “bow ties” commonly found in area data.

Post-processing: The closest available base station should be used for post-processing when possible. Post-processing should always be done with data from a base station within a maximum of 300 miles of all positions collected. It is strongly recommended that positions be post-processed utilizing base station data within fifty to one hundred miles of the working area.

Appendix I- Public Base Stations Maintained by State Universities

Center for Advanced Spatial Technologies, University of Arkansas, Fayetteville
Latitude 36° 04' 04.4431"N
Longitude –94 ° 10' 15.8570"W
Elevation 422.11 m HAE (Datum - NAD83)
Logging Rate: 1-second intervals
http://web.cast.uark.edu/local/gps/base.html
Contact: Dr. Fred Limp
Phone: 501.575.6159

GIS Applications Laboratory, University of Arkansas, Little Rock
Latitude 34° 43' 27.77488" N
Longitude 92° 20' 27.06917" W
Elevation 113.2 m / 371 ft (Datum - NAD83)
Logging Rate: 1-second intervals
http://argis.ualr.edu/gpsinfo.htm
Contact: Phyllis Smith
Phone: 501.569.8534

Spatial Analysis Laboratory, University of Arkansas, Monticello
Latitude 33 ° 35’ 31.84178” N
Longitude 91 ° 48’ 53.43183” W
Elevation 64.359 m HAE
Logging Rate: 1-second intervals
http://sal.uamont.edu/sal/pages/gps.htm
Contact: Dr. Bob Weih
Phone: 870.460.1248

A comprehensive list of Continuously Operating Reference Station (CORS) network coordinated by the National Geodetic Survey can be obtained from CORS website http://www.ascsci.com/dgps.html.

Appendix II- Terms, Abbreviations, & Definitions

Accuracy - an indication of how closely a measurement is to the true value.

Almanac - location and time supplied by satellite vehicles orbiting the earth. This information contains estimated position of satellite vehicles, precise time corrections, and potential atmospheric delay parameters.

Attributes - tabular information supplied about features. Tabular information should include latitude and longitude coordinates for the data GPS collected features. It may include other information such as feature type, quality, time, etc.

Autonomous - calculating a fixed position based solely on satellite vehicles information and a receiver. This is the least accurate means of GPS collection and typically produces accuracy errors ranging from 10-100 meters.

Base station (base receiver / base unit) - a GPS receiver that is placed in a precisely known location and serves as a means, by which the positions collected by all other receivers can be corrected. A base station is used to collect data from a number of satellite vehicles at a known position. This information may be used during real-time and differential correction processes.

C/A code- the standard (Coarse/Acquisition) GPS code; also known as the civilian code or S-code. A sequence of 1023 pseudo-random, binary, biphase modulations on the GPS carrier at a chip rate of 1.023 mhz.

Carrier phase - the difference between the carrier signals generated by the internal oscillator of a receiver and the carrier signal coming from the satellite vehicle.

Code - precise time and location information emitted by satellite vehicles.

Datum (geodetic datum) - a mathematical model that is designed to fit a point on the earth's surface to an ellipsoid. Commonly used datum's are North American Datum (NAD) 1927, and NAD 1983. GPS coordinates are based on the World Geodetic System 1984 (WGS84 datum).

Differential Correction - the process of improving fixed positions utilizing data from a base station.

Dilution of Precision (DOP) - refers to the geometry of satellite vehicles to the position of a GPS receiver. There are several types of DOP. The most common type of DOP is termed PDOP (position dilution of precision).

Elevation Mask - the minimum angle at which a GPS receiver will track satellite vehicles.

Feature - the physical location of spatial data.
A GPS receiver typically collects points, lines, and areas (polygons).

Fixed position - the spatial location computed by averaging a predetermined number of positions. A fixed position is the single point or points (line and area) derived from a number of positions accepted by the GPS receiver.

Global Positioning System (GPS) - a constellation of a minimum of twenty-four satellite vehicles orbiting the earth approximately every twelve hours at an approximate pacing of sixty degrees.

Ionosphere- the part of the earth's atmosphere in which ionization of atmospheric gases affects the propagation of radio waves, which extends from about 30 miles (50 kilometers) to the exosphere, which is divided into regions of one or more layers whose altitudes and degrees of ionization vary with time of day, season, and solar cycle, and which is contiguous with the upper portion of the mesosphere and the thermosphere

Mapping grade - GPS receivers capable of attaining five meters of accuracy or better using differential correction.

Metadata - data about the content, quality, condition, and other characteristics of data.

Multipath - error which occurs when a GPS signal sent from a satellite vehicle is bounced or redirected by an object, prior to reaching a GPS receiver. Multipath will cause the time it takes a GPS signal sent by a satellite vehicle to reach a GPS receiver to be inflated. This will cause inaccuracies in positions collected.

PDOP mask - the maximum PDOP value that a receiver will accept positions.

Phase differential - utilizes radios to transmit signals between a mobile GPS receiver and a base station in order to differentially correct data as it is being collected.

Position - spatial location acquired from positions averaged to determine a fixed position.

Post processing - utilizing base station data, GPS software, and data acquired by a GPS receiver in the field to gain an accurate fixed position.

Precision - the degree of refinement with which an operation is performed or a measurement stated.

Pseudo-random code - a signal with random-noise like properties. It is a very complicated but repeating pattern of 1's and 0's.

Receiver, rover, GPS unit / handheld - a mobile GPS receiver that consists of an antenna, and computer that will collect and store code sent from satellite vehicles.

Selective Availability (SA) - implemented by the United States Department of Defense, degrades the satellite vehicles signal sent to receivers. SA may be turned off or on at anytime. A GPS user should always assume SA is on and take the necessary steps to correct the GPS data collected.

Signals - *see code*

Signal-to-noise ratio (SNR) - a measure of the strength of a satellite signal. SNR ranges vary based on a number of factors. GPS data should only be collected when the SNR value is six or higher.

Spatial data - information that identifies the geographic location and characteristics of natural or constructed features and / or boundaries on the earth.

Trilateration - position of an unknown point is determined by measuring the lengths of the sides of a triangle between the unknown point and two or more known points (i.e. satellite vehicles).

Troposphere - the lowest densest part of the earth's atmosphere in which most weather changes occur and temperature generally decreases rapidly with altitude and which extends from the surface to the bottom of the stratosphere.

References

North Carolina Statewide Global Positioning System Data Collection and Documentation standards Version 2, 1999- Adopted December 14, 1999
http://cgia.cgia.state.nc.us/gicc/

Trimble Introduction to GPS and GIS users Manual, 1999
www.trimble.com

Federal Geographic Data Committee, Geospatial Positioning Accuracy standards Part 1: Reporting Methodology, 1998 (FGDC-STD-007.1-1998)
http://www.fgdc.gov/standards/status/sub1_1.html

Acknowledgements

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http://Argis.ualr.edu/forum

Learon Dalby, GIS Program Manager
Arkansas Geographic Information Office
learon.dalby@mail.state.ar.us

Mike Daniels, Environmental Management Specialist - Agriculture
University of Arkansas, Cooperative Extensions
mdaniels@uaex.edu

Tracy Ford, GIS Coordinator
Arkansas Game and Fish Commission
tford@agfc.state.ar.us

Dr. Mike Garner, GIS / Remote Sensing Professor
WestArk College
mgarner@westark.edu

Randy Jones, GIS Analysis
First Electric Corporation
rjones@fecc.com

Dr. Paul Medley, Assistant Professor of Spatial Information Systems and GIS
University of Arkansas at Monticello, Spatial Analysis Laboratory
medley@uamont.edu

Suzanne Wiley, Chair
Arkansas State Land Information Board
wiely@uamont.edu