

Standard Operating Procedure #6: Using the Global Positioning System

Version 1.1

In GLKN Amphibian Monitoring Protocol

Prepared by:

David VanderMeulen and Mark Hart
National Park Service
Great Lakes Inventory and Monitoring Network
2800 Lakeshore Drive East
Ashland, Wisconsin 54806

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Revision History Log

The following table lists all edits and amendments to this document since the original publication date. Information entered in the log must be complete and concise. Users of this standard operating procedure will promptly notify the program manager and/or the Great Lakes Network (GLKN) data manager about recommended and required changes. The program manager must review and incorporate all changes, complete the revision history log, and change the date and version number on the title page and in the header of the document file. For complete instructions, please refer to Revising the Protocol, SOP #10.

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
1.0	9/22/2017	U. Gafvert	6.1 - added relevance to use in amphibian monitoring program; 6.2.3 GPS to GIS section – Added updates to recent changes in differential correction		1.1
Add rows as needed for each change or set of changes tied to an updated version number					

Acknowledgements

Major portions of this SOP have been adopted from the GLKN GPS Field Data Collection Guide. The guide was originally published as Appendix K to the Great Lakes Inventory and Monitoring Data Management Plan (Hart and Gafvert 2005). Appendix A of this SOP was also adopted from that document, and contains a summary discussion of the general types of GPS units available, as well as definitions of terms commonly associated with use of GPS units.

Definitions

Accuracy —The degree of conformance between the estimated or measured position, time, and/or velocity of a GPS receiver and its true time, position, and/or velocity as compared with a constant standard.

Almanac —Data transmitted by a GPS satellite, which include orbit information on all the satellites, clock correction, and atmospheric delay parameters. The almanac is used to facilitate rapid satellite vehicle (SV) acquisition. The orbit information is a subset of the ephemeris data with reduced precision.

Attribute —Tabular information about a specific feature.

Base Station —GPS files collected continuously from community base stations, local base stations, or Continually Operating Reference Stations (CORS). Gathering base files will require an internet connection and software that dials into a server that houses the base station data collected at the same time of the rover. Data stored on these servers will not be available in real-time - hence this step is conducted after field collection. Trimble users would use the Differential Correction utility supplied in Pathfinder Office.

Differential Correction —The merging of rover file data with base map data to correct position errors due to atmospheric interference. Autonomous data (rover) are collected in the field while base data are stored at the stationary base station. The two datasets are loaded into a post-processing software package where corrections are applied. This process will reduce errors in the field collected data (the rover) by correlating and correcting for known errors recorded in the base file that has the same time tag. As distance between the rover and base file increase, there is degradation in post-processed accuracy. In general, a degradation of one part per million (1ppm) occurs as the distance between the base station and rover increases. For example, one millimeter of degradation occurs for every kilometer between base and rover.

Datum (geodetic datum) —A mathematical model that is designed to fit a point on the earth's surface to an ellipsoid. Commonly used datums are WGS84, a global datum, and NAD 1983, modeled to represent the North American continent.

Feature —A feature is the spatial location of a physical object, or some event or phenomenon. Features are often referred to as graphic data in a GIS. Examples include a tree (point), road (line), or land parcel (polygon).

FGDC —The Federal Geographic Data Committee is a 19 member interagency committee composed of representatives from the Executive Office of the President, Cabinet-level and independent agencies who develop policies, standards, and procedures for organizations to cooperatively produce and share geographic data. (www.fgdc.gov/index.html)

Global Positioning Systems (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, between 11,000 – 12,000 miles above the surface of the Earth

Lines —geographic term related to the scale that describe how a feature is drawn. Lines are linear measures of a feature (such as a line representing a trail)

Mapping Grade —GPS receivers capable of attaining accuracy of five meters or better using differential correction.

Metadata —Data about the data. Usually comes in the form of a text or html document with information on the dataset's quality, current projection, attributes, distribution and citation. In the National Park Service, this generally implies a file compliant to the FGDC Content Standard for Digital Geospatial Metadata.

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.

Points —geographic term related to the scale that describe how a feature is drawn. Points are single dimensional features (such as a point representing a spring).

Polygons —geographic term related to the scale that describe how a feature is drawn. Polygons have area associated with the feature (such as a circle representing a parking lot).

Projection —A method of representing the earth's three-dimensional surface as a flat two-dimensional surface. This normally involves a mathematical model that transforms the locations of features on the earth's surface to locations on a two-dimensional surface.

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

Triangulation —The process of determining the distance between points on the earth's surface by dividing up a large area into a series of connected triangles, measuring a base line between two points, and then locating a third point by computing both the size of the angles made by lines from this point to each end of the base line and the lengths of these lines.

Waypoint —a named three-dimensional position on the Earth's surface, that is, having both a latitude and longitude. Waypoints are assigned to a fixed location in the field so it can be navigated to consistently and accurately through time.

6.0 Introduction

This standard operating procedure (SOP) provides guidance on some of the more common operations associated with Global Positioning System (GPS) units. Although most GPS units are capable of multiple functions, only those operations relevant to the protocol established to monitor amphibians are discussed.

GPS units currently (2017) used by the GLKN monitoring staff are the Trimble Geo7X and various models manufactured by Garmin. The Trimble Geo7T is an example of a mapping grade GPS unit, while a Garmin unit is an example of a recreational grade unit. Mapping grade units record data with location accuracy ranging from sub-meter to less than five meters. Recreational grade units generally are not as accurate, with spatial accuracy less than 15 meters. Mapping grade units have greater ability to capture metadata (i.e., attributes) than recreational grade GPS units. A detailed discussion of these types of GPS units can be found in Appendix A.

As of 2016, software pertinent to the use of these GPS units includes:

- TerraSync 5.xx (Trimble Geo7X) – single table forms software
- GPS Pathfinder Office 5.xx (Trimble Geo7X) – desktop GPS processing software
- ESRI ArcGIS 10.x (Trimble Geo7X or Garmin units) – desktop GIS software
- Minnesota Department of Natural Resources DNRGPS (recreational grade units)

Due to the rapid development of commercial software and hardware capabilities, it is likely that other GPS units or software will be used in the future. Therefore, this SOP is meant to act as a working document that is updated periodically as new hardware and software become available. Although nomenclature may differ depending on what hardware and software are used, this document should provide sufficient guidance on the general process of data collection using GPS tools until the SOP is revised. It is strongly recommended that amphibian monitoring staff obtain unit-specific GPS training prior to deploying in the field. The training should include hands-on use, and should be designed to test all appropriate functions and operations prior to going out into the field.

Additionally, this SOP is not intended to be exhaustive or simply a regurgitation of operating manuals, but a document that might be carried into the field or periodically reviewed by field technicians and project leaders. Although some of the information in this SOP is specific to the amphibian monitoring effort by the Great Lakes Network (GLKN), much of the text contained herein is applicable to other data collection efforts by GLKN staff. The objective of this document is to summarize GPS use guidelines applicable to the amphibian monitoring efforts at GLKN parks.

6.1 Role of GPS in Amphibian Monitoring

GPS units are primarily used in the following ways to support amphibian monitoring:

- 1) When a site is selected for acoustical monitoring, it should be marked in the field as described in other sections of this protocol. GPS units are used to record the location of each sampling site prior to, or concurrent with, the initial site establishment and deployment at that location. It is recommended that a mapping-grade GPS unit be used to obtain a higher precision location during site establishment. These coordinates should then be used as the master or default location for the site. New GPS coordinates will need to be established in the event that a site is moved, either due to more suitable habitat within same wetland, or to an entirely new location.
- 2) For amphibian monitoring, navigating to and locating the monitoring sites is accomplished through a combination of:
 - a. Using GPS units to navigate to the previously established GPS point locations
 - b. Using hardcopy topographic maps, aerial photographs, and written notes describing how to get to sites
 - c. Field experience of staff conducting the monitoring
- 3) Supplemental egg mass and adult amphibian searches can be conducted within the vicinity of the song meter location as time allows and staff expertise at identification is available. A GPS unit can be used to record general location of egg masses or adults, or proximity to song meter can just be recorded on the paper datasheet.

Additional uses of the GPS units may develop over time if the protocol changes or other needs are identified. The next two sections of this SOP outline some of the more common and pertinent functions associated with mapping and recreational-grade GPS units, which are the types of units currently used by GLKN staff for amphibian monitoring.

6.2 Using Mapping-Grade GPS Units

All mapping-grade GPS users should become familiar with GLKN GPS data collection procedures and relevant manufacturer's user guides and operating manuals before GPS operation. For example, prior to using a Trimble Geo7X (mapping-grade) GPS unit, the following documents should be reviewed:

- Appendix A of this SOP
- Trimble Juno ST or Geo7X: Quick Start Guide

- GPS Mapping for GIS with TerraSync and GeoExplorer CE Series or TerraSync Operation Guide v5.2x
- Basic GPS Data Capture Using TerraSync: A Quick Start Guide

Mapping-grade GPS units provide the user with a variety of tools for field data collection. GLKN encourages the use of these units for most projects. These units can be used to acquire spatial data related to points, lines, and polygons along with associated, user defined, tabular attributes. Careful forethought and advanced planning are required to take advantage of these capabilities long before data collection begins.

Mapping-grade GPS units have the capability of storing and displaying background maps or GIS layers, which can be very helpful when navigating in the field. The GLKN data management staff can support preparation of these background layers and, if necessary, assist in loading them onto the GPS hardware.

Each user should be familiar with the capabilities of the GPS hardware and field computers. If possible, amphibian monitoring staff should receive hands-on instruction from someone familiar with the equipment. At a minimum, the equipment user guides and operator's manuals should be reviewed, and the operator should test the functions s/he intends to use.

Each user needs to become familiar with the battery life and memory capabilities of the GPS units. All units have limited battery and memory resources; these features should be thoroughly tested to gain an understanding of the power and memory limitations of the GPS units before being deployed in the field. It is possible to power or recharge these units from a DC power source, such as a vehicle power outlet. Be sure to include spare batteries in the field kit.

6.2.1 Data Dictionaries

TerraSync software on mapping-grade GPS units is capable of creating and using data dictionaries. Data dictionaries define the structure and rules to store attribute information about the feature being mapped and are customized for each project. Field staff currently use paper forms to record pertinent information during site establishment, deployment, mid-season checks, and retrieval of song meters, hence there has not been incentive to develop data dictionaries for this program. Also, monitoring locations are permanent sites, so there is no need to collect high accuracy GPS locations at each visit.

6.2.2 GPS Settings

Positional accuracy of GPS data can be affected by several factors that can be monitored and recorded with mapping-grade GPS units. Table 1 lists these factors, their definitions, and the standard settings for GLKN field work. All spatial data collected shall be analyzed for spatial accuracy and shall meet or exceed the National Map Accuracy Standards (Table 1 in Appendix A, and <http://mapping.usgs.gov/standards/>). Table 2 indicates the coordinate system settings for data collection in GLKN parks.

Table 1. GPS receiver settings, definitions, and standards for use at GLKN parks.

Setting Name	Definition	GLKN Setting Standard
Almanac	File containing estimated position of satellites, time corrections, and atmospheric delay parameters	Acquired automatically by GPS unit or from online sources within 10 days prior to GPS field work
Altitude reference	Ellipsoid model	Height above Ellipsoid (HAE) (preferred) or Mean Sea Level: if MSL is used, indicate Geoid Model
Antenna height	GPS antenna height above the ground	Variable, usually 1.0 meters for handheld and 1.5 m for backpack
Datum	Geodetic model designed to fit a point on the earth's surface to an ellipsoid	NAD 83 (CONUS) WGS 84 [GPS default, as fallback] NAD 83 (2011) [for Trimble GPS Units]
Elevation mask	The minimum angle above the horizon at which a GPS receiver will track a satellite	15 degrees
Feature types	Geometry of spatial data	GIS native formats; point, line and polygon
Logging interval	Time interval between the recording of individual GPS fixes	Points: 1 second Lines and Polygons: 5 seconds, but 1 second in some circumstances
Minimum fixes for point positions	Number of GPS fixes that are used to calculate a single position for a point feature	50 fixes (120 points in the case of Geo7X)
Mode	2-dimensional for horizontal positions and 3-dimensional with an elevation position	3-dimensional (4 satellite minimum)
PDOP mask	Positional Dilution of Precision, a GPS quality estimate based on satellite geometry	6.0 or less
Real-time settings	GPS unit may be capable of performing differential correction of data during collection	Select Integrated WAAS (unless using H-star, e.g., Geo7X unit); setting will be 'auto' or 'on'
Satellite vehicles	Number of satellites used for position fixes	4 minimum
SNR mask	Signal-to-Noise ratio is a measure of the satellite signal relative to background noise	4.0 minimum, 6.0 or greater preferred
Unit of measure	Linear unit of measure	Meter (metric)

Table 2. Coordinate system settings for Great Lakes Network parks. Bold font indicates parks where amphibian monitoring is being conducted by network and park staff.

Park	UTM Zone	Datum
APIS	15	NAD 1983 (Conus)
GRPO	16	NAD 1983 (Conus)
INDU	16	NAD 1983 (Conus)
ISRO	16	NAD 1983 (Conus)
MISS	15	NAD 1983 (Conus)
PIRO	16	NAD 1983 (Conus)
SACN	15	NAD 1983 (Conus)
SLBE	16	NAD 1983 (Conus)
VOYA	15	NAD 1983 (Conus)

6.2.3 GPS to GIS

After GPS collection of site location information in the field is complete, download data from the Trimble unit onto a computer, using Trimble Pathfinder Office data transfer utility (or the GPS Analyst extension. This requires that Windows Mobile Device Center be installed on the computer in order to be able to communicate with the GPS unit. The downloaded file(s) will have a .ssf file name extension. The data should then be differentially corrected, again using a Pathfinder Office utility. (Note: Trimble Pathfinder Office and GPS Analyst are relatively expensive. However, Trimble also offers a free data transfer utility to download data from the GPS units to a Windows-based PC, which can then be sent to network staff to complete the post processing.)

Differential correction involves using existing Continuously Operating Reference Stations (CORS) Networks. CORS stations maintain a constant link to the GPS constellations, and then store and broadcast highly accurate GPS position information. There are currently two sets of CORS stations, the National Geodetic Survey (NGS CORS), and newly operational State Department of Transportation (DOT CORS). State programs exist in all states pertinent to GLKN parks in Indiana, Michigan, Minnesota, and Wisconsin. All state and NGS CORS sites now read both GPS and GLONASS, the new Russian satellite constellation. Check the CORS data sheet for the site to confirm, as well as to check which datum (WGS84 or NAD83) the site is broadcasting.

Typically, choose the base station closest to GPS data collection.

WGS84 and NAD83 datums are roughly 1.3m apart, so knowing the datum of a CORS site is necessary to avoid introducing significant error in the data. Coordinates for all DOT CORS sites are now in the new NAD83(2011) epoch 2010 datum. NGS CORS are now most often in NAD83(2011) as well, but best policy is to check the site's data sheet. Some DOT CORS sites are also available through NGS (not all!).

If you choose to manually download the RINEX files, then when differentially correcting using Pathfinder, select radio button for Use Reference Position from Base Files, NOT Use Reference Position from Base Provider. (Base Provider option accesses Trimble's coordinate database, these are WGS84 coordinates, and not reliably updated). Then navigate to the correction files downloaded directly from CORS site. Follow the necessary steps through Pathfinder, and run the process. The output will be a .cor (correction) file.

On export of the .cor file from Pathfinder, if data is corrected using WGS84 coordinates, use the NAD83(2011) datum shifter to get the data into NAD83. If the CORS site is broadcasting NAD83(2011), which includes all State DOT sites, then you want to do a 0, 0, 0 transformation, and select NAD83 CONUS, (in Trimble Pathfinder). In ArcGIS, this is the NAD83_To_WGS84_1 transform. This 'do nothing' transformation is necessary because the differentially corrected data is already in NAD83. Identify the NAD83 flavor (epoch) in the metadata for the file.

The network also has a very high precision mapping grade unit which uses H-Star technology (i.e., Trimble Geo 7x with H-Star). When differentially correcting these GPS files, the user needs to select a group of three CORS base stations is necessary to realize the maximum accuracy from an H-Star receiver.

Several data attributes can be included in the data exports. Data attributes recommended by GLKN are listed in Table 3.

Table 3. Recommended fields to be exported in addition to GPS features.

All Features	Point Features	Line Features	Area Features
PDOP	Height	Length (2D)	Area (2D)
Correction status	Position	Length (3D)	Perimeter (2D)
Receiver type			Perimeter (3D)
Date recorded			
Data file name			
Total positions			
Data dictionary name			

Managing the incoming GPS data can be a challenge, especially if there are multiple units per project. Common practices used by GLKN include:

Download all data to a computer or network drive that is regularly backed up.

- Keep GPS data and GIS data separate through electronic file management.
- Directories and file names should not contain non-alpha-numeric characters and/or spaces (except underscores).

- Keep GPS data in well-organized directories (see Hart and Gafvert [2005], GLKN Data Management Plan, for more details).

At the end of a project, all data and background files should be removed from the GPS unit to free available memory. Data files should not be left on a unit if they have been properly downloaded and verified. In addition, some GPS units require their batteries to be re-charged periodically. Failure to do so can cause the GPS unit batteries to discharge completely, and may cause some files and software to be deleted.

Additional information can be found at <http://www.nps.gov/gis/gps/gps4gis/>, which describes the steps outlined here in greater detail.

6.3 Using Recreational-Grade GPS Units

DNRGPS, developed by Minnesota DNR, is freely available software for exporting GPS data from recreational grade receivers to shapefile or geodatabase for use in GIS. This software can transform data from WGS84 to other datum/projections, such as NAD83, but it is generally a better workflow to keep the data in WGS84, and do the projection and datum transformation in GIS software, such as ArcGIS. When doing the data transformation in Arc, use the WGS_84_To_NAD_83_5 datum transformation option. This will correctly transform the data to NAD83 (2011).

Recreational-grade GPS units can be used to acquire location information (generally points) when spatial accuracy is not paramount to the project. Recreational GPS units do not have data dictionaries for storing attribute information with the point location. However, using a recreational-grade unit to capture a waypoint at each sampling site is a reliable means to verify the correct sampling site has been reached, even if a GPS location is not needed.

As with mapping-grade GPS units, personnel that use recreational-grade GPS units should become familiar with GLKN GPS collection procedures and relevant manufacturers' user guides and operating manuals before GPS operation. For example, prior to using a Garmin 76S (recreational-grade) GPS unit, the following documents should be reviewed:

- Appendix A of this SOP
- GPSMAP 76S Quick Start Guide
- GPSMAP 76S Owner's Manual and Reference Guide
- Garmin MapSource™ User's Manual and Reference Guide

Smartphones and PDAs often have integrated GPS capabilities. These units generally have the same level of performance as an inexpensive recreational grade GPS, typically with 5–10 m accuracy. They use the native WGS84 datum and a latitude/longitude fix. Smartphone GPS systems can give you an instantaneous GPS fix, but the accuracy (still low) can be improved by leaving the phone exposed to the sky for a few minutes before collecting a position. Smartphones often use assisted GPS, which incorporates the triangulation of radio frequency sources (wi-fi and/or cell phone towers) to improve GPS accuracy. Assisted GPS gives little enhancement in field conditions found in parks, and is intended to improve accuracy in urban or indoor locations. Smartphones usually have very little ability to view or record the metadata associated with getting a GPS fix. Many smartphones don't have the native capability to collect waypoint (see below), but that can be added by using an auxiliary app, such as MotionX-GPS for the Apple iPhone, Groundspeak Geocaching for multiple smartphone OS's, or Trimble's Geocache Navigator for other phone platforms.

6.3.1 Planning

If a recreational-grade GPS meets the criteria of the project, the unit chosen must have the capability of downloading collected data to a personal computer. Downloading data is usually accomplished with a parallel or USB cable connection.

Much of the data collected by GPS will eventually reside in a relational database. Each GPS feature collected should contain a unique identifier that relates the feature to an associated record in a database. Since recreational GPS units have only one text field for input, careful consideration should be given to the use of this field and the design of unique identifiers. GLKN data management and GIS staff can assist in creating unique IDs on a project by project basis.

6.3.2 Data Collection

Location data are captured by recreational-grade GPS units as *waypoints*. When taking a waypoint, enter the site ID or site designation in the text field provided. It is also good practice to collect reference points at regular intervals. These reference point positions should be taken at known locations (e.g., trailheads, parking lots, stream confluences) that can later be used in GIS to check the accuracy of waypoint data.

If navigation to preset waypoints is applicable to a project, the waypoints must be loaded onto the GPS unit before departure to the field. This can be done using DNRGPS software. Some recreational grade GPS units have the ability to store and display topographic maps, which can aid in navigation. Printed topographic maps of the waypoint locations can also be used to maximize field time and efficiently navigate between waypoints.

6.3.3 Data Processing

Data should be downloaded from GPS units as soon as feasible after a field session. The DNRGPS freeware product: (<http://www.dnr.state.mn.us/mis/gis/DNRGPS/DNRGPS.html>) can be used to download data from Garmin GPS units. Data should be downloaded both as a text file and a shapefile. Each file name should include the download date (for example N2017102715A.txt indicates unit 'N', year 2017, month October 27, hour 15, first record in hour, text file). Points should be checked for reasonable spatial accuracy and errors. Subsequent downloads should be error-checked in the same manner. When data collection is finished, all files should be compiled into one spatial file, and along with the raw downloads, should be saved to the appropriate location on GLKN servers (refer to SOP #11, Data Entry and Management for more detail).

6.4 Metadata

Regardless of the type of GPS unit used to collect data, all resulting GIS datasets need to have information documenting how the GPS data were collected. NPS requires that FGDC (Federal Geographic Data Committee, www.fgdc.gov/index.html) compliant metadata be written for all geospatial layers created (Executive Order 12906).

Until final FGDC metadata is written, the data collection and management process is incomplete. Tracking GPS projects depends on the complexity of the project, how many participants, length of project etc. Documentation can be a simple 'readme' text file, or a detailed daily log.

GLKN recommends formal metadata be written by the data collectors, as they are the ones most familiar with the project and resulting data. However, Network data management and GIS staff are usually the ones documenting someone else's work. Chapter 7 of the GLKN Data Management Plan (Hart and Gafvert 2005) includes a detailed discussion of metadata procedures. At a minimum, the following details should be documented to facilitate final FGDC metadata:

- Name of project
- Name(s) of data collectors
- EHE/EPE or maximum PDOP (using 4 satellites)
- Coordinate system (projection, datum, and zone)
- Type (or types) of GPS units used
- The range of field collection dates
- Name of base station(s) used for differential correction
- Name and version of software used for downloading
- Any major editing performed on the raw data (e.g., moving of points)
- All versions of data dictionaries used

6.5 Quality Assurance/Quality Control

Long-term monitoring is only useful if users have confidence in the data. Efforts to detect trends and patterns in ecosystem processes require high-quality, well-documented data that minimize error and bias. Data of inconsistent or poor quality can result in loss of sensitivity and lead to incorrect interpretations and conclusions.

NPS Director's Order #11B: Ensuring Quality of Information Disseminated by the National Park Service (www.nps.gov/policy/DOrders/11B-final.htm) specifies that information produced by the NPS must be of the highest quality and based on reliable data sources that are accurate, timely, and representative of the most current information available. Therefore, GLKN will establish and document procedures for quality assurance (QA) and quality control (QC) to identify and reduce the frequency and significance of errors at all stages in the data life cycle. Under these procedures, the progression from raw data to verified data to validated data implies increasing confidence in the quality of those data. Quality assurance and quality control procedures will document internal and external review processes and include guidance for addressing problems with data quality.

Examples of general QA/QC practices include:

- Standardized field data collection forms
- Use of field computers and automated data loggers
- Proper calibration and maintenance of equipment
- Training of field crew and data technicians
- Database features such as built-in pick lists and range limits to reduce data entry errors
- Automated error-checking routines

Many of the standard operating procedures associated with the amphibian monitoring protocol include a discussion of QA/QC as it relates to the protocol. Examples of QA/QC practices pertaining to use of GPS include:

- Ensure that GPS-related software is periodically updated as it becomes available and has been tested.
- Record location positions on field data forms as well as with the GPS unit.
- For each monitoring station, compare location positions for different sampling events, including the position recorded during establishment of the monitoring station. This will allow for an assessment of position accuracy over time.
- If data dictionaries are used with mapping-grade GPS units, ensure that the coordinates for the monitoring station match the other attributes recorded on the GPS unit for that monitoring station.
- Check to see if the accuracy of the GPS unit meets or exceeds the National Map Accuracy Standards shown in Table 1 of Appendix A.
- Ensure that the appropriate coordinate system is used when collecting and exporting data.

- Use mapping software (e.g., Pathfinder Office or ArcGIS 10.x) to view waypoints (or features) overlaid on a geo-referenced air photo or topographical map to check for accuracy.
- If applicable, check the accuracy of the attribute(s) recorded on a GPS unit by using mapping software (see bullet above) and look-up tables or in spreadsheets generated after post-processing is complete.

A final report on data quality, including data collected by GPS, will be incorporated into the documentation for this project. Such documentation will include a listing of the specific methods used to assess data quality and an assessment of overall data quality prepared by the program manager. This is a necessary part of the data quality elements of the metadata file.

6.6 Literature Cited

Hart, M., and U. Gafvert (editors). 2006. Data management plan: Great Lakes Inventory and Monitoring Network. Great Lakes Inventory and Monitoring Network. Technical Report GLKN/2006/20. National Park Service, Ashland, Wisconsin.

Appendix A. Role of GPS in Data Management and Types of GPS Units.

The text in this appendix is taken directly from the GLKN GPS Field Collection Guide, which can be found in its entirety in Appendix K of the Great Lakes Inventory and Monitoring Data Management Plan (Hart and Gafvert 2005).

Introduction

Over the past decade new tools have been developed to help researchers collect and manipulate data while in the field. Global Positioning System (GPS) is one such tool. GPS is currently a constellation of 31 US Department of Defense satellites (as of 2012) orbiting 11,000 miles above the Earth, making a complete orbit approximately every 12 hours, and transmitting signals to Earth at precisely the same time. The position and time information transmitted by these satellites is used by a GPS receiver to triangulate a location coordinate on the earth using three or more satellites.

Role of GPS in GLKN Data Management

Data collected using GPS-enabled equipment represents all or part of the acquisition stage of an information resources lifecycle that includes several other stages (see Section 5.4 in GLKN Data Management Plan). The process and methodology used for acquisition, planning, data collecting, and post-processing incorporate several aspects of data management, including quality assurance, data storage and organization, and data stewardship. To promote data quality and simplify data management, GLKN expects to use electronic data logging equipment for some data acquisition. However, parallel or complementary use of hand written data sheets and field notes will remain important for data collection activities.

Types of GPS Units

At the most basic level GPS equipment can just consist of a GPS antenna and the associated signal processing circuitry. The antenna can be a standalone device, be incorporated into a handheld unit, or be integrated into a larger electronic device, such as a personal data assistant (PDA), data logger, or portable computer. As technology evolves, GLKN will continually try to use equipment which maximizes spatial accuracy; reduces hardware weight and user fatigue; and reduces database development, data manipulation, and transformation.

There are three major types of GPS units that are based on the level of accuracy to which spatial data can be collected. Survey-grade GPS units are used for surveying tasks that require very high accuracy (1 cm or less). Mapping-grade units can map features from sub-meter to less than 5m accuracy, employing differential correction. Recreational-grade GPS units are sold primarily for

outdoor sports and recreational activities. Accuracy using recreational GPS units ranges from 5 to 30 m. Most natural resource-related data collection requirements correspond to either the recreational-grade or mapping-grade. Figure A1 shows some of the major differences between these two types.

Deciding which type of unit to use is an essential part of project planning, and depends on the end product needed. Mapping-grade GPS units are recommended for most GLKN field work; however, for some projects recreational-grade units can meet a project's accuracy requirements and reduce the cost of field operations. The choice of GPS unit should be made by the program manager after consulting with the GLKN data management and GIS staff.

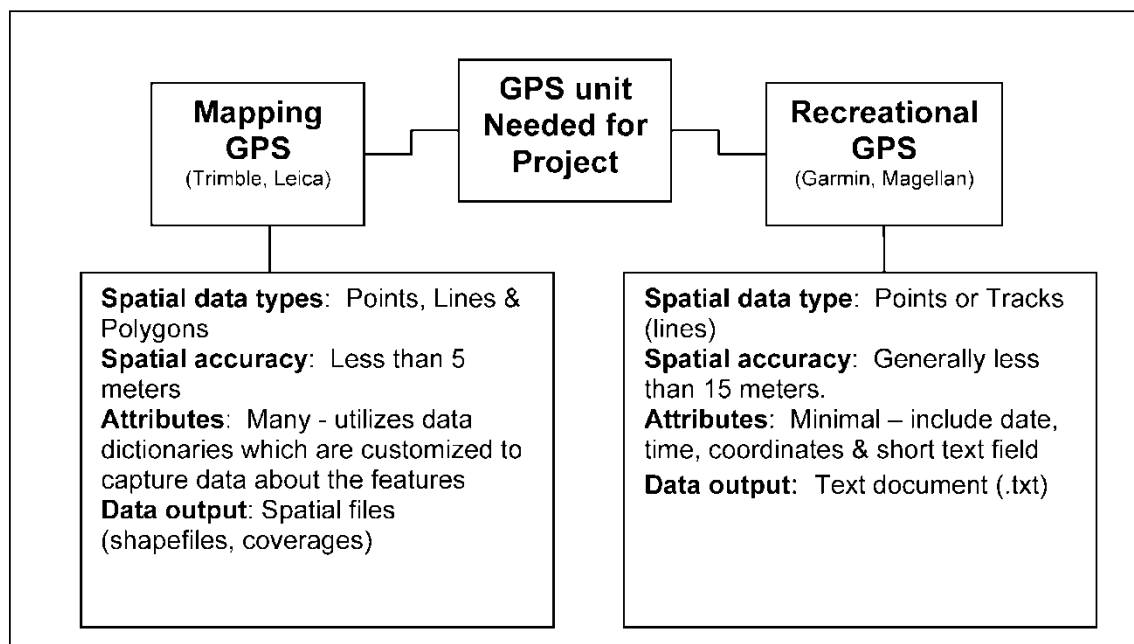


Figure A1. Differences between different grades of GPS units.

All resulting GIS data layers need to meet or exceed the National Map Accuracy Standards for a 1:24,000 product (NPS GIS Data Standards, 2002 http://www.nps.gov/gis/data_info/standards.html). Table A1 provides the allowable horizontal accuracy for some common scales.

Table A1. Map scales and allowable error.

Scale	Allowable Error	Scale	Allowable Error
1:40,000	33.8 meters (111 feet)	1:9,600	4.9 meters (16 feet)
1:31,680	16.1 meters (53 feet)	1:4,800	2.4 meters (8 feet)
1:24,000	12.2 meters (40 feet)	1:2,400	1.2 meters (4 feet)
1:20,000	10.1 meters (33 feet)	1:1,200	0.6 meters (2 feet)
1:12,000	6.1 meters (20 feet)		