Appendix H. NCPN specifications for using global positioning systems

The National Park Service
Inventory & Monitoring
NORTHERN COLORADO PLATEAU NETWORK

GPS Field Data Collection Guide

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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 28 Department of Defense satellites orbiting 11,000 miles above the Earth approximately every 12 hours, emitting 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.

This guide supplements the National Park Service *Field Data Collection with Global Positioning Systems Standard Operating Procedures and Guidelines, 03/02/2007.* (http://science.nature.nps.gov/nrgis/pdfs/NPS_GISSpecs_20070302.pdf) Readers should be familiar with and follow both sets of guidelines, as well as individual project specifications or protocols that may contain additional detailed procedures. Users must also be familiar with the operation of their particular GPS unit before entering the field to collect data or navigate to points.

This guide addresses GPS instruments, instrument settings, field operation, data collection, data processing, and a standardized method for acquiring and managing location data. It contains the procedures and considerations that GPS users should follow when collecting geospatial data or navigating to locations in Northern Colorado Plateau Network (NCPN) parks.

Types of GPS units

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 5-meter 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 – 30 meters. Most natural resource-related data collection requirements correspond to either the recreational-grade

or mapping-grade. Figure 1 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. NCPN encourages the use of the mapping-grade GPS units (NCPN prefers and uses the Trimble line of GPS products); however, for some projects recreational-grade units (NCPN prefers and uses Garmin GPS units) can meet a project's accuracy requirements. The choice of GPS unit should be made by the project leader after consulting with the NCPN GIS technician and data manager.

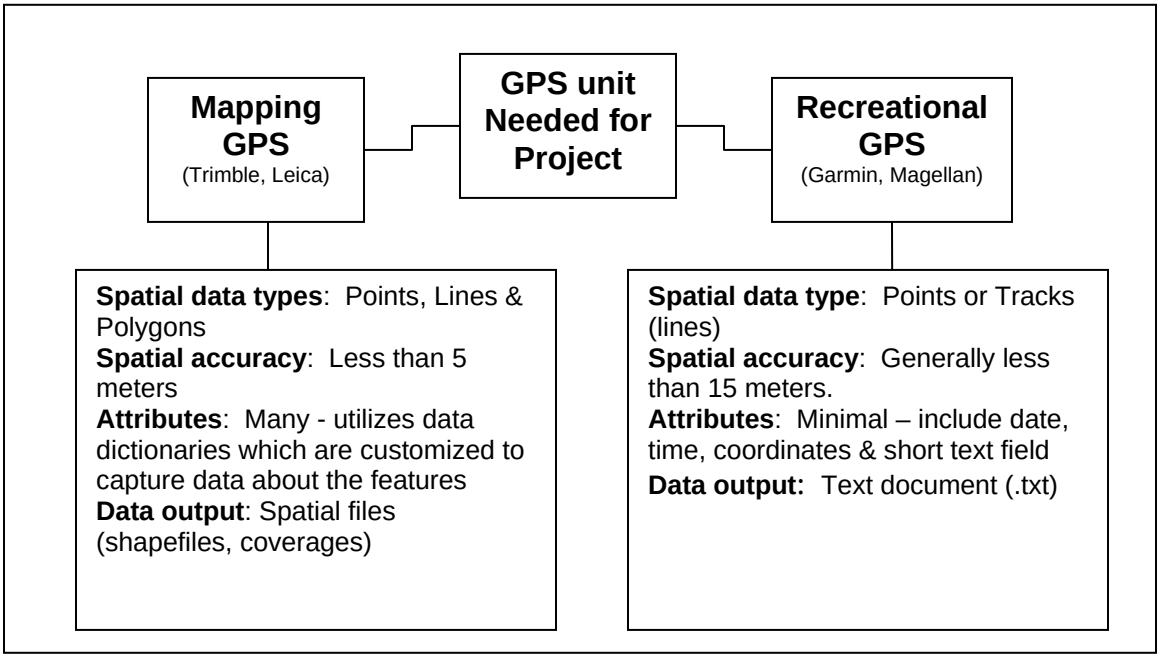

Figure 1. Differences between different grades of GPS units

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 1 provides the allowable horizontal accuracy for some common scales.

Table 1. 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)		

Mapping-grade GPS

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

Data dictionaries

Mapping-grade GPS units have the capability of using data dictionaries. Data dictionaries store attribute information about the feature being mapped and are customized for each project. The NCPN GIS technician should be directly involved in the creation of data dictionaries. Basic steps include:

1. Identify the features to be mapped. These features are real world physical locations of objects which are categorized as point, line or polygon features.

2. Identify the data to be collected about each feature while in the field and create a data dictionary. Part of this process is assigning a unique identifier to each feature. (For example, if a survey plot is mapped as both a point and a polygon, one feature should be named plotname_poly and the other plotname_pt.)

3. Implement and test the data dictionary. NPCN recommends a complete trial run for newly-created data dictionaries before beginning field work. Corrections and refinements are inevitable after such a trial.

GPS settings

Positional accuracy can be affected by several factors which mapping-grade GPS units can track and to some extent, compensate for. Table 2 lists these functions, their definitions, and the standard settings. All spatial data collected shall be analyzed for spatial accuracy and shall meet or exceed the National Map Accuracy Standards (see http://erg.usgs.gov/isb/pubs/factsheets/fs17199.html#Map%20Accuracy). Table 3 indicates the coordinate system settings for data collection.

Table 2. Minimum GPS Receiver Settings Standards

Name	Definition	Standard
Almanac	GPS unit collects data containing estimated position of satellites, time corrections, and atmospheric delay parameters.	Acquired within 10 days prior to data collection or navigating.
Altitude reference	Ellipsoid model	Height above Ellipsoid (HAE) [preferred] or Mean Sea Level (MSL); if MSL is used, indicate Geoid Model
Antenna heights	GPS unit height above the ground.	1.0 – 2.0 meters
Datum	Geodetic model designed to fit a point on the earth's surface to	NAD 83

Name	Definition	Standard
	the ellipsoid.	
Elevation mask	The minimum angle at which a GPS receiver will track satellite vehicles.	15 degrees
Feature types	The physical location and geometry of spatial data.	point, line, area (polygon)
Logging intervals	Time interval between positions gathered.	Point: 1 second, Line and Polygon: 5 seconds
Minimum number of positions for a point feature	Number of positions received then averaged to create a point feature.	10 - 20
Mode	2-Dimensional or 3-Dimensional	3-Dimensional (4 satellites)
PDOP Mask	Positional Dilution of Precision is a measurement of the geometry of the satellites.	6.0 or less
Satellite vehicles	Number of satellites, currently a constellation of 28 DOD satellites.	4
SNR Mask	Signal-to-Noise Ratio is a measure of the strength of the satellite signal relative to background noise.	4.0 minimum, 6.0 or greater preferred
Unit of Measure	Units of measure.	Meters

Table 3. Coordinate settings for Northern Colorado Plateau Network parks

Park	UTM Zone	Datum
ARCH	12	NAD 1983 (Conus)
BLCA	13	NAD 1983 (Conus)
BRCA	12	NAD 1983 (Conus)
CANY	12	NAD 1983 (Conus)
CARE	12	NAD 1983 (Conus)
CEBR	12	NAD 1983 (Conus)
COLM	12	NAD 1983 (Conus)
CURE	13	NAD 1983 (Conus)
DINO	12	NAD 1983 (Conus)
FOBU	12	NAD 1983 (Conus)
GOSP	12	NAD 1983 (Conus)
HOVE	12	NAD 1983 (Conus)
NABR	12	NAD 1983 (Conus)
PISP	12	NAD 1983 (Conus)
TICA	12	NAD 1983 (Conus)
ZION	12	NAD 1983 (Conus)

Before beginning data collection, the NCPN GIS technician needs to provide the most current almanac available. The almanac is a set of data that is used to predict the timing

and path of satellite orbits over approximately a one-month period, which is then used to determine if or when satellite reception could hamper data collection.

If navigation to preset waypoints is applicable to a project, waypoints must be loaded onto the GPS unit before departure to the field. NCPN also recommends having printed topographic maps of the waypoint locations to maximize field time and efficiently navigate between waypoints.

Many mapping-grade GPS units have the capability of storing and displaying background maps or layers, which can be very helpful when navigating in the field. The NCPN GIS technician can help identify and load these layers onto a unit before field work begins.

GPS units create files to store data during a field session using a prefix and date-time stamp as file names:

RMMDDHHx
R – Unit prefix
MM – Month
DD – Day
HH – Hour
X – a, b, c, etc. order of files created in an hour.

If multiple GPS units are used on a project, a unique prefix (letter) should be assigned to each unit, which will ensure that downloaded files for each unit contain a unique identifier within the filename. For example, with three GPS units, the unique letters for the units could be N, G, and A. Those letters would serve as a prefix for the file names (e.g., N102715A, G102715A and A102715A would indicate units N, G, and A, October, 27, 15 hour, A first in hour).

Each user should be familiar with the data capacity of their GPS unit. All units have limited battery and memory resources, and a balance needs to be reached that will allow the most efficient use of these resources.

Data Collection

Data collection is accomplished by using the data dictionary customized for a project. Users should keep in mind the following key concepts:

- If using a GPS unit that gives an approximate 5 meter horizontal (XY) accuracy, the user cannot map anything as a polygon that is less than 4-6 meters in width. The object must be captured as a point feature.
- If a GPS user is collecting a line or polygon feature and then stops moving, the GPS unit will continue to collect data (Figure 2, ex. 1 and 2). Users need to be familiar with the *Pause/Resume* toggle key and use it liberally.
- Another way to avoid errors is to collect point features that represent the beginning and end points of a line transect (Figure 2). Having these reference point locations will mean easier editing of any zig-zagging line features.

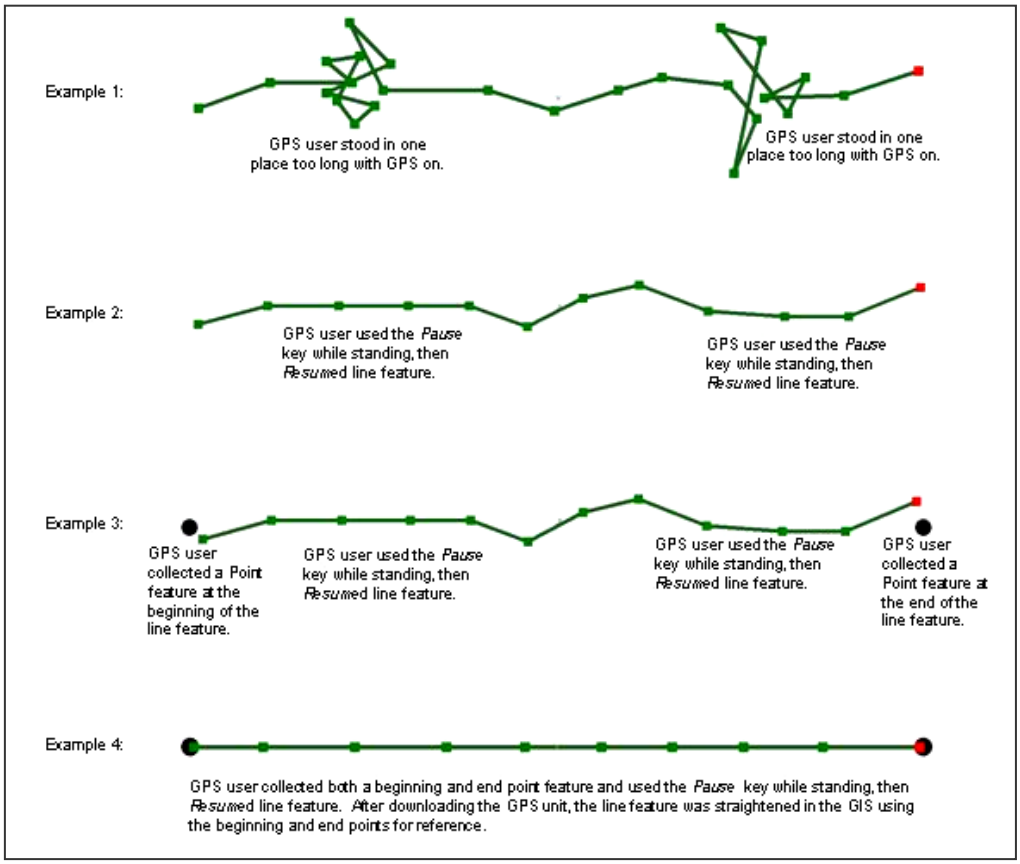

Figure 2. Examples of GPS point feature data collection

Mapping-grade GPS units have additional features that aid in data collection. These include:

- *Nested Features* – Allows user to collect a point while collecting a line or polygon feature. For example, while surveying potential amphibian habitat along a stream (line feature), the user can pause the line feature, take a point a specific observation, then resume the line feature collection.
- *Offset Feature* – Allows user to collect a feature when topography is such that getting next to or over the feature is impossible. For example, a GPS point could be collected for a hanging garden while standing to the side of the actual garden.
- *Between-feature Positions* – the GPS unit collects positions without any feature or attribute data. This feature is useful for tracking areas traveled during a day. For example, while surveying for presence or absence of invasive plants, a user could collect data on the area surveyed in addition to specific plants found.

Data Processing:

When data collection is complete for the day or field stint, data are downloaded from the GPS unit to a computer. For Trimble GPS units, the proprietary software Pathfinder Office is used to download, differentially correct and then export the data to a GIS format. Differential correction is a post processing procedure to improve upon raw GPS positions using base station data. Base stations consist of a GPS antenna and receiver positioned at a known location specifically to collect data from satellites. The distance between the base station and the remote GPS receiver should be kept to a minimum, preferably less than 150 miles.

Once the data are differentially corrected, they can be verified and edited. Unintentional features can be deleted and attributes can be reviewed. The last step is exporting the data set to GIS (ArcGIS or ArcView). Additional data elements can be included in the data exports. Data elements recommended by NCPN are listed in Table 4.

Table 4. 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 NCPN include:

- Download all data to a computer that is regularly backed up.
- Keep GPS data and GIS data separate
- Directories and files names should not contain non-alpha-numeric characters and/or spaces.
- Keep incoming GPS data in well-organized and identified directories (Figure 3).

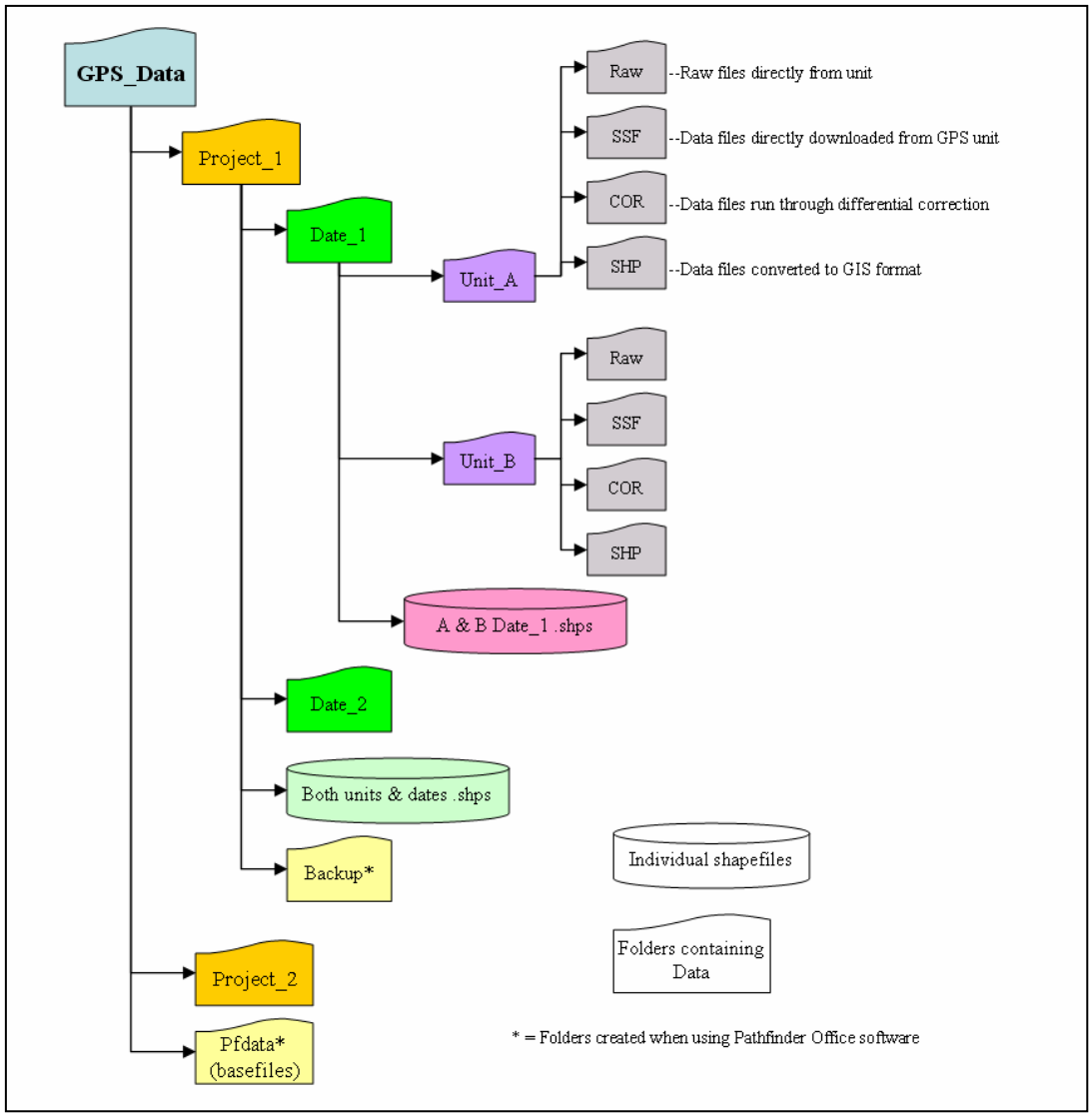

Figure 3. Suggested directory structure for GPS data and resulting GIS files

At the end of a project, all data and background files should be removed from the GPS unit. Data files should not be left on a unit if they have been properly downloaded and verified.

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

Recreational-grade GPS

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.

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. This 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. NCPN data and GIS staff can assist in creating unique IDs on a project by project basis.

Data Collection

Location data are captured by recreational-grade GPS units as *waypoints*. When taking a waypoint, enter the Location ID in the text field provided. NCPN also recommends that reference points be collected every so often. These reference point positions should be taken at known locations (e.g., trailheads, parking lots, stream confluences) which can later be used in GIS to QC the accuracy of waypoint data.

If navigation to preset waypoints is applicable to a project, they must be loaded onto the GPS unit before departure to the field. NCPN also recommends having printed topographic maps of the waypoint locations to maximize field time and efficiently navigate between waypoints.

Data Processing

GPS units should be downloaded once a day or after each field session. NCPN suggests each file name include the download date. The downloaded data should then be converted to a spatial file and projected to UTM NAD83. Figure 3 shows a suggested directory structure for downloaded data. Points should be checked for reasonable spatial accuracy and errors and all subsequent downloads should be error-checked in the same manner. When data collection is finished, all files should be compiled into one spatial file to be submitted along with all raw downloads to the Northern Colorado Plateau Network.

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, there isn't a standardized method for project documentation. 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.

The NCPN recommends formal metadata be written by the data collectors as they are the ones familiar with the project and resulting data. However, GIS staff are usually the ones documenting someone else's work. 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 & zone)
- Type (or types) of GPS units used
- The range of field collection dates
- Name of Base Station used for correction
- Name and version of software used for downloading and any corrections
- Any editing performed on the raw data
- All versions of data dictionaries should be saved

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 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 continuous from community base stations, local base stations, or Continually operating Stations (CORS). Gather 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 North American Datum (NAD) 1927, 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 five meters of accuracy 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 3 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.