Standards and Guidelines

For

CADASTRAL SURVEYS

Using

Global Positioning System Methods

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Forward

These Standards and Guidelines provide guidance to the Government cadastral surveyor and other land surveyors in the use of Global Positioning System (GPS) technology to perform Public Land Survey System (PLSS) surveys of the Public Lands of the United States of America.

Many sources were consulted during the preparation of this document. These sources included other GPS survey standards and guidelines, technical reports and manuals. Opinions and reviews were also sought from Public and private Professional Land Surveyors who use GPS for boundary and Cadastral Surveys.

The static and fast static survey procedures in these guidelines follow long established and well-documented industry and government survey practices. However, guidelines for real-time kinematic surveys of all types are in the early stages of development.

Manufacturer's technical manuals describe real-time kinematic GPS surveys as a topographic surveying method for small areas. It was not intended for surveying legal land boundaries or for large project areas. Therefore, the guidelines for performing land surveys using real-time kinematic GPS techniques require greater observational and occupational redundancies and checks than specified by the manufacturers.

These standards and guidelines do not require that Cadastral Surveys be performed to the higher accuracy and methodology requirements of geodetic control surveys. They are intended to provide sufficient observational and occupational redundancy to detect blunders and quantitatively demonstrate the stated accuracy of a survey has been achieved.

Cadastral Surveys are an important part of the National Spatial Data Infrastructure. The accuracy reporting requirements of this document are in accordance with accuracy reporting requirements of the Federal Geographic Data Committee's "Geospatial Positioning Accuracy Standards", July 1997.

Disclaimer Statement

This document is intended only for the purposed of providing the user with guidelines for planning, execution, and classification of PLSS surveys performed using GPS carrier phase methodology.

Note: Italicized words in bold font, i.e., ***independent occupation,*** indicate that a definition for that word appears in Appendix 1, Definitions.

Part One

Standards for Positional Accuracy

The following standards are for GPS technology only and shall be used to define the minimally acceptable levels of differential relative positional accuracy required of a Government cadastral survey.

TABLE ONE: **Local Accuracy Standards**

Local Accuracy	95% Confidence Circle	Application
0.050 meters (m)	Less than 0.050 (m)	*Cadastral Project Control*
0.100 meters (m)	Less than 0.100 (m)	*Cadastral Measurements*

Local Accuracy is an average measure (e.g. mean, median, etc.) of the relative accuracies of the coordinates for a point with respect to other adjacent points at the 95% confidence level.

TABLE TWO: **Network Accuracy Standards**

Network Accuracy	95% Confidence Circle	Application
0.100 meters (m)	Less than 0.100 (m)	*Cadastral Project Control*
0.200 meters (m)	Less than 0.200 (m)	*Cadastral Measurements*

The ***Network Accuracy*** of all Cadastral Measurements should be reported per the Federal Geographic Data Committee (FGDC) Geospatial Positioning Accuracy Standards to show the relationship of the cadastral survey relative to the National Spatial Reference System.

A least squares adjustment or other multiple baseline data analysis is performed to produce a weighted mean average to verify the required level of positional accuracy has been achieved.

Part Two

Guidelines

The guidelines outlined in this document consist of field data acquisition methods, field survey operations and procedures, data processing and analysis methodologies, and documentation. The use of these guidelines and the manufacturer's specifications provide a means for the surveyor to evaluate the survey and to verify the specified accuracy standard has been achieved.

These guidelines are designed to ensure a survey performed with GPS technology is repeatable, legally defensible and referenced to the ***National Spatial Reference System (NSRS)*** by providing the following:

- Elimination or reduction of known and potential systematic error sources.
- Occupational (station) and observational (baseline) redundancy to clearly demonstrate the stated accuracy.
- Baseline processing, data adjustment and data analysis to clearly demonstrate the stated accuracy.
- Documentation demonstrating verification of the results.
- Compliance with the Bureau of Land Management Manual of Instructions for the Survey of the Public Lands of the United States, 1973 and state laws.

GPS survey guidelines continually evolve with the advancements in equipment and techniques. Changes to these guidelines are expected as these advancements occur. The size, scope and site conditions of a project may also require variations from these guidelines.

Any variations from these guidelines should be designed to meet the above criteria and to achieve the accuracy standard of the survey as required by this document. All variations shall be documented in the project report.

Section One

Field Data Acquisition Methods

A variety of GPS field data acquisition methods may be used for ***Cadastral Measurements*** and ***Cadastral Project Control.***

Static Positioning:

Static positioning typically uses a network or multiple baseline approach for positioning. It may consist of multiple receivers, multiple baselines, multiple observational redundancies and multiple sessions. A least squares adjustment of the observations is required. This method provides the highest accuracy achievable and requires the longest observation times.

Static positioning is primarily used for ties to the National Spatial Reference System (NSRS) when

observing Cadastral Project Control. This method may also be used for the Cadastral Measurement portion of a cadastral survey.

Fast-Static Positioning:

This method requires shorter occupation times (i.e. 5 to 20+ minutes) than static positioning and may use a radial baseline technique, network technique, or a combination of the two. Fast static requires a least squares adjustment or other multiple baseline statistical analysis capable of producing a weighted mean average of the observations. Fast-static positioning may be used for observing both the Cadastral Project Control and the Cadastral Measurements of a cadastral survey.

Post-Processed Kinematic (PPK) Positioning:

Post processed kinematic survey methods provide the surveyor with a technique for high production Cadastral Measurements and can be used in areas with minimal obstructions of the satellites. PPK uses significantly reduced observation times compared to static or fast-static observations. This method requires a least squares adjustment or other multiple baseline statistical analysis capable of producing a weighted mean average of the observations. PPK positioning is used for observing the Cadastral Measurements of a cadastral survey.

Real-time Kinematic (RTK) Positioning:

Real-time kinematic positioning is similar to a PPK or a total station radial survey. RTK does not require post-processing of the data to obtain a position solution. This allows for real-time surveying in the field. This method allows the surveyor to make corner moves (stake out) similar to total station/data collector methods. RTK positioning is used for the Cadastral Measurement portion of a Cadastral Survey.

Real-time surveying technology may utilize dual-frequency (L1/L2) techniques for initialization, but the subsequent RTK survey is accomplished using the L1 carrier phase frequency. Therefore, all RTK surveys are currently subject to the limitations of the L1 frequency.

NOTE: Operations under a forest canopy using PPK or RTK methods are not recommended. However, these methods are acceptable if they result in a solution, which meets the survey standards. The surveyor must make an informed decision when choosing the appropriate methodology to be used in a particular project area. For survey projects in a forest canopy environment with marginal sky visibility, static, or fast-static GPS methods or even conventional optical methods should be considered in-lieu of using RTK or PPK.

Section Two

Field Survey Operations and Procedures

Field survey operations should be performed using the manufacturer's recommended receiver settings and observation times. Operations under adverse conditions, such as under a forest canopy, may require longer observation times than specified by the manufacturer.

Preset fixed height antenna tripods/bipods should be used for all rover GPS observations.

All plumbing/centering equipment should be periodically checked for proper adjustment.

The following topics are recommended procedures when using GPS measurement techniques for

Cadastral Surveys.

Cadastral Project Control

Cadastral Project Control is the network of the GPS stations, tied to the NSRS, which is surveyed to control all subsequent GPS Cadastral Measurements.

A Cadastral Project Control network shall be established by either static or fast-static survey methods.

The Cadastral Project Control network may be established at the same time the Cadastral Measurements are made. However, the points and resulting baseline vectors used in the Cadastral Project Control network shall be processed to derive the baseline solutions and be adjusted by least squares independently of the observed Cadastral Measurements.

The Cadastral Project Control network is designed to meet the following purposes:

- Provides a framework to reference the survey to a datum, a mapping projection, and the NSRS.
- Supports registration of the Cadastral Measurements into the ***Geographic Coordinate Data Base (GCDB)***.
- Serves as the basis for all subsequent GPS Cadastral Measurements.
- Allows for reporting of the Network Accuracy for the Cadastral Measurements per FGDC Geospatial Positioning Accuracy Standards.
- A well-designed Cadastral Project Control network will offer the surveyor more flexibility for using fast static, kinematic, and RTK survey methods for the Cadastral Measurement portion of a survey. It provides an adequate amount of reference (base) station locations, ties the Cadastral Measurement points together, allows for expanding area of the survey and provides accurate checks throughout survey project.
- The number of stations in the Cadastral Project Control network depends upon factors such as project size, topography, positioning method used, and access. A minimum of two or more Cadastral Project Control stations should be established as a reference for the Cadastral Measurements.
- All Cadastral Project Control networks should be referenced (tied) to at least two High Accuracy Reference Network (HARN) stations/ High Precision Geodetic Network (HPGN) or Continuous Operating Reference Station (CORS), of the NSRS.
- In the absence of HARN/HPGN or CORS stations, other GPS control stations which are referenced to the NSRS and published by or available through other Federal, state, or local agencies may be used. The use of such stations shall be evaluated by the surveyor regarding the relationship to the NSRS before inclusion into the Cadastral Project Control network and prior to any Cadastral Measurements occurring.
- The current national reference datum is the North American datum of 1983 (NAD83) of 1986. All control and project information should be referenced to the most current epoch of NAD 83 for

example: Wyoming NAD 1983 (1993).

All Cadastral Project Control networks shall conform to the following:

- Be referenced to two or more NSRS or other published horizontal control stations, located in two or more quadrants, relative to the cadastral project area.
- Points are established by two or more ***independent baselines***.
- Contain loops of a minimum of three baselines.
- Baselines have a fixed integer double difference solution or adhere to the manufacturer's specifications for baseline lengths exceeding the fixed solution criteria.
- Any station pair used as azimuth or bearing reference for use with conventional survey measurements during the course of a cadastral survey should be included in a network or measured with a minimum of two independent vectors.
- All stations in the cadastral project control network shall have two or more ***independent occupations***.
- The Cadastral Project Control network must be a geometrically closed figure; therefore, single radial (spur) lines or side shots to a point are not acceptable.

Cadastral Measurements

Cadastral Measurements are the measurements used to define the location of Public Land Survey System (PLSS) corners and boundaries. Cadastral Measurements are referenced to the Cadastral Project Control coordinates or by direct ties to the NSRS.

All Cadastral Measurement observations, except RTK, shall conform to the following:

- Be constrained to two or more Cadastral Project or NSRS stations which are located in two or more quadrants relative to the cadastral project area.
- Points are established by two or more independent baselines.
- Contain loops of a minimum of three independent baselines.
- Baselines have a fixed integer double difference solution or adhere to the manufacturer's specifications for baseline lengths exceeding the fixed solution criteria.
- Any station pair used as azimuth or bearing reference for use with conventional survey measurements during the course of a cadastral survey should be included in a network or measured with a minimum of two independent vectors.
- All stations in the cadastral measurements shall have two or more independent occupations.
- Single radial (spur) lines or side shots to a point are not acceptable.

Static Survey Methods

When using static methods as the sole measurement method for Cadastral Measurements, then the Cadastral Project Control and the Cadastral Measurements are considered to be the same. There is no need to establish a separate Cadastral Control Network. The ties the NSRS should be processed and adjusted independently of the Cadastral Measurements.

Static survey methods for Cadastral Measurements, uses a network or a multiple baseline observational scheme.

Fast-static Survey Methods

When using Fast-static methods as the sole measurement method for Cadastral Measurement, then the Cadastral Project Control and the Cadastral Measurements are separate.

One method uses one or more reference (base) receivers usually two located in two or more different quadrants and one or more rover receivers with adjustable fixed height antenna tripods/bipods for Cadastral Measurements.

Another method uses two or receivers in traverse or leapfrog observational scheme.

- Post-Processed Kinematic (PPK) Survey Methods

When using PPK survey methods, which include stop and go, continuous, leapfrog and other observation schemes as the sole measurement method for Cadastral Measurements, then the Cadastral Measurements and Cadastral Project Control are separate

This method uses one or more reference (base) receivers usually two located in two or more different quadrants and one or more rover receivers for Cadastral Measurements.

Real-Time Kinematic (RTK) Survey Methods

When using RTK survey methods, as the sole measurement method for Cadastral Measurement, then the Cadastral Project Control and the Cadastral Measurements are separate.

RTK uses a radial style survey scheme with one or more reference (base) receiver and one or more rover receivers for Cadastral Measurements.

The radial nature of RTK requires additional redundant measurements be made as part of the field survey operations and procedures as discussed in these guidelines.

There are four parts of an RTK survey which include:

- System check
- Corner measurements
- RTK calibrations
- Corner moves (stake-out)