Standards and Guidelines for Cadastral Surveys Using Global Positioning Methods

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ABSTRACT

The development of high production GPS methods such as kinematic real time kinematic (RTK) , and fast static procedures have given rise to questions as to what are acceptable procedures for conducting cadastral surveys. This is due to the fact that these methods are radial survey methods. There are many standards and specifications that address how control surveys should be performed and to what accuracies but non that address acceptable procedures for the survey itself.

A team of U.S. Dept. Of Interior – Bureau of Land Management (BLM) and U.S. Department of Agriculture – Forest Service (FS) surveyors and geodesists have developed a new document titled *Standards and Guidelines for Cadastral Surveys Using Global Positioning Methods* (GPS Standards and Guidelines) to provide guidance to the cadastral surveyor in using GPS to conduct surveys. This document was developed from a combination of practical field procedures developed by team members, manufacturer guidelines, examination and review of existing standards and specifications, and review by government and private sector land surveyors. These Standards and Guidelines give an accuracy standard that are compatible with existing conventional survey methods and are easily achieved with current equipment. They are also in agreement with standards specified by the U.S. Federal Geodetic Control Committee (FGDC). Measurements are made by first establishing a project control network and then making corner measurements relative to this network. The procedures can be used with setups of two or more receivers.

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1. INTRODUCTION

The adoption of high production GPS techniques is changing how large scale cadastral surveys are performed. While the plats and field notes still constitute the basic returns and records; the use of GPS is changing how the surveys are conducted in the field, how the returns are being computed, and how the accuracy of the data and survey is evaluated.

For over 200 years the basic field procedures have changed very little. Originally lines were run using a solar compass and Gunter's chain. This later gave way to solar observations and angulation using transits and chain or electonic total stations. Lines wererun corner to corner and returns computed by direct measurement along true lines or inverses based on summation of latitudes and departures along random lines. Data quality was evaluated by the closure of travers loops around closed figures. These are techniques famliar to all surveyors.

The use of GPS has changed the ways surveys are conducted. GPS can be used in the same way as electonic total stations and direct measurements made between corners and returns directly computed from the observed baselines. It can also be used in a modified radial or network scheme to establish point positions relative to a control network and returns computed from inversing between corner positions. No longer is it necessary to measure directly corner to corner.

However with these new abilities have come new questions. What are acceptable field procedures? How do we evaluate data quality. Do we need ties and how many to single or multiple control points if radial techniques are used? These questions can be confusing to both the novice and expert user of GPS.

Many standards and specifications exist for the establish of geodetic control networks using GPS. However there are not any guidelines or standards that deal explicitly with production surveys. The FS and BLM have sought to provide guidance to their cadastral surveyors by jointly developing a set of accuracy standards and procederal guidelines that provide a set of minimally acceptable proceduresfor using GPS. By following these guidelines the new GPS surveyor can be assured of performing defensible surveys while the experienced user has set of accuracy standards and procederal guidelines which they can then use or modify as necesary to accommodate local practice or project needs.

This paper will provide a brief history of the development of the GPS Standards and Guidelines, their history, philosophy, and important aspects of their use.

2. HISTORY

The BLM and FS started to use GPS with the introduction of the first portable systems in the late 1980s. These initial efforts were mainly to make geodetic ties to conventional surveys, establishing project control networks, or running corner control orver long distances. During this time many surveyors started to explore the possibilities of using GPS as a production survey tool. Many field tests were run using a variety of observational schemes including direct measurements from corner to corner, fully networked observations, and modified radial observation schemes. A common thread was that all of the observation methods were static based and procedures were based on the specifications for creation of geodetic control networks. The results were mixed. The number of receivers, personnel requirred, and the length of observations required seemed to limit the utility of GPS to conduct surveys

With the advent of observational techniques such as kinematic, fast static, and especially RTK GPS the surveyor now had tools that could allow him or her to survey more points in less time. As more field tests were performed, many questions came up as to how the surveys should be performed. Many of the questions seemed to center on whether the observational requirements of geodetic control surveys should be followed or used or whether a lesser but still rigorous system could be used .

During this period Region Two of the FS (Colorado, Wyoming, South Dakota, and Nebraska) and the Wyoming BLM were among the most active in evaluating these new methods and developing the use of Fast Static and RTK GPS for cadastral surveys. The GPS leads for the two agencies often collaborated on projects to test new data collection procedures and shared information and thoughts regarding accuracy requirements, redundancy, observation times, control ties, and data evaluation needs. It was jointly recognized that different standards would be needed for GPS to become a high production survey tool.

During these discussions the GPS Leads for the FS Region Two and the Wyoming BLM had produced draft accuracy standards and procedural guidelines for use by surveyors and contractors in their respective region and state. These guidelines were based on personal experience and experimentation as well as reliance on the work of other surveyors and established standards and specifications. Continued discussions and joint projects brought about the recognition that since both agencies were performing the same type of surveys they should try formulate and use similar methods and procedures. At this time the leads started to merge their seperate documents into one that would cover the use of GPS for cadastral surveying in their region.

During the late 1990s the BLM and FS both started to widely implement GPS surveying based on RTK GPS use. Across the agencies the questions on how to use GPS wre being heard more and more. In 1998 a joint team of FS and BLM surveyors and geodesists was created for the task of developing a single set of GPS accuracy standards and guidelines that would guide the use of GPS for the respective agencies. The draft guidelines that had been developed by the FS in Region Two and the Wyoming BLM became the core of this new document. During the course of the next three years the philosophy, text, and procedures were repeatedly (and sometimes heatedly) discussed, reviewed, and modified as new

material was examined and technology was changing. Additional reviews were sought from both the government survey and private community. Especially helpful were reviews provided by the National Geodetic Survey. The final document was submitted to the respective Washington offices of the BLM and FS in March 2002 and issued on joint letterhead in July 2002 with the note that as we move to a fully integrated federal, state, local, and private mapping and land record system, there should be government wide standards and guidelines for using GPS technology on cadastral surveys of the public and Indian lands.

3. PHILOSOPHY

Several philosophies and viewpoints are central to the GPS Standards and Guidelines and their use. These philosophies affect both the accuracy standards and the data collection procedures. Much of the discussion and many of the procedures are aimed at the use of RTK GPS since it is the method of choice but the document is applicable to all data collection procedures.

The basis of the data collection scheme is through the use of modified radial survey techniques. This holds for both RTK or fast static based data collection. The use of a project control network is necessary to support these types of observations and provide for possible checks and efficiency in data collection. A primary consideration is to be able to support the two receiver RTK system as well as multi-receiver data collection.

Data evaluation is based on point accuracies as opposed to loop closures. This is necessary given the radial nature of the data collection and non networked or lack of direct corner to corner measurements. The point accuracy can be derived from least squares analysis, weighted mean position averages, or considerations of the control point accuracy and manufacturer specifications. The accuracy standards are designed such that bearings and distances obtained from inversing between corner positions will be the equal or better than thos eobtained from conventional surveys.

The GPS Standards and Guidelines need to be flexible and modifications allowed to accomodate local practice and surveyor preference. They shoud be viewed as the minimum procedures that should be followed in using GPS to do cadastral surveys. In the same manner they should be applicable to multi-township sized surveys or one section subdivisions. While designed with RTK data collection in mind , they can also cover fast static or kinematic collection.

The GPS Standards and Guidelines had to be surveyor and production oriented. The document had to be understandable by both the beginning and experienced GPS surveyor. A central view is that the projects do not constitute geodetic control work and that it is not necessary the field and observation procedures to be as stringent and still be able to achieve accurate results.

Lastly the document needed to fulfill a multifunctional role. Besides giving direction to surveyors using GPS, it also needed to be a teaching document covering basics of data collection and project control design. It also needed to be a document that spelling out

requirements for contractors or cooperators submitting data to the respective agencies. These demands account for the structure and content of the work.

4. IMPORTANT POINTS

This section of the paper will discuss in more detail some of the points outlined in the above sections that are integral to successful application of the GPS Standards and Guidelines. Every possible data collection scheme or check for RTK GPS and the other collection methods have not been listed or described in the document. The methods and procedures that are discussed are intended to be guidelines to what could constitute good practice. The flexibility built into the guidelines allow the surveyor to develop and apply data collection methods and checks that are harmonious with the documents.

The positional accuracy standards shown below in Tables One and Two are based on data analysis and manufacturer specifications. They reference the positional accuracy of the points relative to external control.

Table 1. 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 2. 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.

This requires that the local accuracy of the Cadastral Project Control should be less than 5 cm 95 % of the time. The Cadastral Measurements should then have a maximum relative accuracy relative to the project control of 5 cm . This results in the overall 10 cm (95% confidence) shown in Table One.

These values are used so that bearings and distances returned from inverses between corner positions will be as good or better than that of conventional surveys.

The accuracy bands are also set up to be in accordance with FGDC Geospatial Positioning Standards. This is to be consistent with developing federal guidelines and metadata development.

Project Control Networks are central to the application of the GPS Standards and Guidelines. The project networks could be as small as two points for small projects or number as many as four or more for large township sized projects. The number of points will depend on a number of factors such as as access, topography, minimizing baseline lengths when possible, opportunities for checks, and spacing necessary for efficient operations. Project Control Networks are not intended to be densifications of the National Spatial Reference System (NSRS). However good observation practices such as ties to two or more high accuracy NSRS stations, multiple point occupations, good network design, and adjustment to obtaining high quality control. This is vital since the Project Control Network is the framework that holds the project together and allows observations, such as RTK, based on two receiver systems to work.

GPS surveying in the FS and BLM is built around two receiver systems. The predominant Cadastral Measurement data collection method is by RTK GPS. The a major concern is providing sufficient redundant measurements at a corner position. Traditionally one would tie a point to two separate control points. However this is sometimes not practical due to point access, terrain problems, or other considerations. The GPS Standards and Guidelines accepts multiple measurements to a single control point as checks. In the case of RTK GPS loss of satellite lock and reinitialization between measurements is required regardless of time or distance seperation. Additional checks (based on changing the observation environment) such as waiting a specified period time, reinitializing in a different location, or changing the antenna height could be integrated. Testing has shown that this is a viable technique when used with a well design Project Control Network. Even though there is not a required redundancy factor built into the GPS Standards and Guidelines, the user is encouraged to check points by observations relative to different control points.

5. SUMMARY

The GPS Standards and Guidelines is intended to provide guidance to the surveyor using GPS to perform Cadastral or other types of boundary surveys. In a short time this document has gained wide circulation and acceptance. Copies of draft and the final versions have been requested by other federal agencies, state and local government groups, GPS equipment manufacturers. and private surveyors and organizations in the United States and overseas.

The electronic version of the document *Standards and Guidelines for Cadastral Surveys Using Global Positioning System Methods* is available for downloading at http://www.fs.fed.usdatabase/gps/gpsusfs.htm in a PDF format.

6. ACKNOWLEDGEMENTS

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BIOGRAPHICAL NOTES

Dr. Michael D. Londe is a Geodesist with Wyoming BLM in the United States for the last 10 years. He has been involved with GPS instruction, implementation, field surveying and mapping, and testing since 1987.