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ENCON Group Inc.
Telephone 613-786-2000
Facsimile 613-786-2001
Toll Free 800-267-6684
www.encon.ca

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Towards Achieving Measurement Redundancy*

by Fred S. Cheng, ALS

Background

During my review of land surveying practices, I have observed a serious lack of measurement redundancy. Measurement redundancy is a requirement of our Manual of Standard Practice (MSP).

Often, I am provided pages of printed co-ordinates and then expected to accept them as field notes of the survey. It appears that these co-ordinates were generated from either data collectors, or Global Positioning System (GPS) observations. At times, I receive the explanation that Real Time Kinematic (RTK) redundancy was achieved by gaining lock and logging followed immediately by losing lock, re-locking and re-logging.

I have often asked practitioners to provide their detailed in-house policy to demonstrate how the practitioner achieves measurement redundancy.

Once a statutory iron post is placed in the ground and the plan is registered at the Land Titles Office, the iron post governs the property corner wherever it is placed in accordance with the Surveys Act. As such, it is extremely important that the iron post is in the correct position. Land Surveyors should make every effort towards placing survey monuments with care and due diligence, by introducing stringent redundant measurements during the course of their surveys.

In my opinion, co-ordinate printouts are not field notes simply because a printout of a set of numbers could mean a lot of things, we do not know if they are raw data, adjusted data, co-ordinates generated from computation, and/or they could be altered. If the information is derived from conventional surveys using a theodolite and data collector, we require the practitioner to submit a copy of the raw data file of his field measurements.

As for GPS RTK redundancy, recording and losing lock, and immediately regaining lock is hardly considered redundant observations; even if done with an intervening time span. Re-measurement from the same base station set-up on the same day it was performed can only be considered a blunder check, and should not be considered to have eliminated any systematic errors or random errors. An independent set-up, preferably on a different day, is recommended. Also, proper written field notes are essential for keeping track of different field conditions for GPS observations at different epochs.

Some practitioners are hung up on technology and readily accepting "black box" solutions that come out of a GPS receiver. Without proper methods, sufficient checks and balances to ensure random, multipath, systematic and other errors are eliminated, the survey is not reliable.

One practitioner suggests that in RTK surveys potentially multipath, systematic, human, random, and other sources of error may be reduced by the following redundancy measures:

- perform the surveys again on a different day
- use different receivers for the base and rover (i.e., switch receivers)
- re-observe under different ionospheric conditions
- re-observe using different HI's (height of antenna in this instance)
- careful selection of a different base station location preferably with reduced multipath and improved field condition

- be aware of other surveyors working in the vicinity – their same frequency signals might interfere with yours
- use different procedures for blunder checks often during the surveys (i.e., using time change and/or dropping the integers to ensure multipath and poor PDOP conditions are remedied)

If you suspect the observations are not reliable, you should try some or a combination of the above-suggested procedures and see if the results would improve. After all, it is your name that stays on the plan and resides on public record for a long time.

Current Standards on Redundancy

Currently, Part C, Section 1.4 of our MSP calls for practitioners to provide redundant checks on their work as stated below:
All surveys conducted under the Surveys Act must be verified by one or more of the following:
- *closure on prior or current work*
- *closure on existing Alberta Survey Control*
- *check-measuring all observations*
- *other appropriate means*

Sufficient field measurements shall be made to ensure there are no errors of layout or measurement.

Also, as for measurements and accuracy for GPS surveys, MSP Part C, Section 2.4 states:
The position of every monument included in a GPS survey either found or placed shall be verified with sufficient redundant observations. This applies to both static and kinematic surveys.

Redundancy in Conventional Survey Measurements

With permission, I have reprinted a practitioner's field instructions and procedures for attaining redundancy in his field surveys.

"As with a conventional survey, your work must be checked. All important points must be checked, including all found evidence, any ASCM tied-in for horizontal control, all planted posts on an R/W survey and well centre on a wellsite survey ... Your check shot should be no more than 2.0 cm from your original.

An alternative technique is to tie it in conventionally. If you have to get your instrument out for a side shot anyway, this may be the most practical method.

When tying-in to Fd Is, you can check them to (against) plan. If they fit plan to 1:5000, they won't need any other work. However, if you are at a hard to get at location, do not have the other point tied-in yet, and you do not want to risk having to come back to it, consider double shooting it anyway.

We are still having problems with insufficient check measurements with the field works.

I want to go through what evidence has to be checked, what is a suitable check and what is not.

The following evidence must always be checked:
- *all found posts*
- *all planted posts*
- *any tied-in in ASCM's*
- *well centre (both horizontally and vertically)*
- *any found spikes or I. bars if used for control*

The following are suitable checks:
- *checking found evidence to plan distance (if it fits 1:5000 for better)*
- *directly including in a loop that closes*
- *using other plans (1:5000 or better)*
- *using your own work or GPS to (1:7500 or better)*
- *double shooting with GPS (this GPS observation procedure is administered to support previous conventional measurements and simply used as a check)*
- *tie in with both GPS and conventional (use caution not to over control it)*
- *an angle and distance from different set-up*
- *an angle from different back sight and check chaining*
- *if placed on line, shooting the long distance and both short distances*
- *for elevation (if trig, vertical distance should be booked in both phases)*

The followings are not suitable checks:
- *a doubled angle is required to reduce horizontal collimation error and to avoid booking errors. It is not an independent check measurement*

- *shooting the same distance multiple times, booking either metres/feet or horizontal distance/slope distance/vertical angle are required but only to check booking error. These are not to be used as independent check measurements*
- *coming off or tying-off to evidence that has not been check measured itself is not a sufficient check*

In short, it is not checked until you have proven that it is where your field notes say it is. All these techniques have been discussed in detail. We appreciate your co-operation in ensuring the overall quality of our work."

The above is one of many good examples that we have observed. We anticipate that each and every practitioner observes similar examples and develops redundancy measurement procedures of their own which best cater to their resources.

Redundancy in GPS Survey Measurements

I have received several in-house GPS policies from different practitioners. They are professionally developed and can be used as yardsticks for other surveyor's practices.

It is interesting to note that the state government of Victoria, Australia has developed a set of formal guidelines towards GPS observations in legal surveying applications. The following are selected highlights from their GPS philosophy in legal surveying (Eddie Cichocki, Office of Surveyor-General, State Government of Victoria, Australia, 2006).

- "Legal Traceability" is the term used to describe the traceability of physical measurements back to a recognized-value standard.
- The National Measurement Act 1960 (of Australia) requires measurements made for legal purposes to be in terms of the Australian legal unit derived from reference to an appropriate standard of measurement.
- Measurements made for legal purposes are substantiated at law through a continuous chain of verifications from the recognized-value standard to a working standard being the device used to take the measurements.
- For GPS, an associated recognized-value standard is the Australian Fiducial Network (AFN). It was gazetted as a standard on April 22, 1998.
- There is currently no formally accepted process to provide legal traceability of GPS measurements. Despite this, GPS can, and is, being used for legal measurement on cadastral surveys.
- GPS should not be used as the sole method of determining length in cadastral surveys.
- A quality-assurance approach based on best practice guidelines for the use of GPS for surveying applications is recommended.
- General and specific requirements (for utilizing GPS in cadastral surveys):
  - The guidelines generally refer only to relative GPS positioning, which requires two or more GPS receivers.
  - Users should familiarize themselves with the procedures contained in the GPS equipment and software manuals.
  - Redundant observations should be built-in to detect errors.
  - Conventional observations of an appropriate accuracy to be included.
  - Connection, where possible, to at least two known Third Order or better markers in the Survey Control Network.
  - All ancillary equipment must be in good adjustment and repair.
  - Generally, GDOP no greater than 8 and elevation mask not less than 15 degree.
  - Occupation times should be increased where multipath is likely.
  - Rapid static:
    – attention to be paid to multipath errors
  - Post Processed Kinematics Baselines:
    – each point should be re-occupied in a different session with different satellite geometry
  - Real Time Kinematics:
    – base stations should be located in a low multipath environment
    – re-occupations of points should be made
    – new base stations on very large projects should be established using static or fast/rapid static GPS techniques
  - Analysis of Results:
    – least squares network adjustments for classic static and rapid static techniques
    – misclosure comparisons for techniques where there are no direct measurements between stations (i.e., RTK or rapid static)

- Digital Data Storage:
  – raw observational data, results from baseline processing and final adjustments, should be archived (RTK or rapid static)
- GPS measurements are being supported/validated by comparison with "known" ground markers, multiple occupancy of stations and comparison with conventional measurements.
- Abstract of field records (proposed) needs to clearly show or state:
  – the method used to perform the survey
  – the base stations and co-ordinates of the origin of the GPS datum control (if appropriate)
  – the measurements that have been derived from GPS observations
- Survey report (proposed) to include:
  – details of the equipment used
  – the process used to validate the equipment
  – an indication of the integrity of the measurements
  – details of the base stations used and their co-ordinates (if appropriate)
  – the observation technique employed
  – the method of reduction and software used
  – a statement of the precision obtained

The above excerpts are highlighted from the guidelines to be utilized in Victoria, Australia and are contained in their GPS Best Practice Guidelines that were produced by ICSM (Intergovernmental Committee on Surveying and Mapping). Further details regarding the Victoria government recommended procedures for the use of GPS in legal surveys are now included in their publications entitled, *Standards and Practices for Control Surveys (publication SP1),* and *Survey Practice Handbook.* They can be found in the following websites respectively: *www.icsm.gov.au/icsm/publications* and *www.land.vic.gov.au/surveying.*

Similar guidelines regarding GPS in cadastral surveying can be found in the New South Wales government document entitled, *Surveyor General's Directions (Document no. 9) GPS Surveys,* within which, it refers to another ICSM document entitled, *Best Practice Guidelines – Use of the Global Positioning System For Surveying Applications.* This can be found in the following web link: *www.icsm.gov.au/icsm/publications/sp1/sp1.htm.*

A Private Practitioner's Opinion on GPS Redundancy

I had lengthy discussions with one of our members who has been practicing extensively with GPS since its introduction to land surveying in Alberta. This private practice member is of the opinion the method of initialization – loss of lock – re-initialization or time interval methods do produce redundant observations if performed under the right conditions. "Under the right conditions" is difficult to quantify and, as a result, less experienced individuals may find they are not achieving accurate positions when they have mistakenly accepted confirmation of position using this technique.

The above initialization – loss of lock – re-initialization method is perceived to almost always produce a precise confirmation measurement (i.e., two co-ordinated observations that are within 0.02m of each other); while the (initialization – loss of lock – time interval method) might appear to provide a less precise confirmation measurement, it in fact provides a lot more confidence in the position.

This same individual is of the opinion that, as a profession we should be placing less emphasis on precision and more on reliability (i.e., accuracy and detection of blunders) in our work.

His rankings from best to worst redundancy technique to confirm a GPS position is tabulated as follows:

1. GPS position confirmed by conventional or other completely independent positioning technique
2. position confirmed by being part of a closed GPS network, consisting of static observations, wherein the position is occupied at least a second time on a different day
3. multibase observations (i.e., not two bases with one-point observation but two separate occupations of the monument)
4. time separation with new GPS satellite constellation
5. time separation (30 minutes or less)
6. observation – loss of lock – re-initialization

The second procedure puts the most emphasis on GPS accuracy, and blunder detection. For additional reference, please consult the "Guardpost" article on RTK and Measurement Closures published in the December 2005 issue of *ALS News.*

All of the above discussions assume that the GPS personnel has undergone rigorous trainings and that GPS system, procedures, and techniques have been verified through calibration/validation on the Alberta Government's GPS Three Dimensional Positioning Basenet (*ALS News* Winter Issue 1990 Vol. XIX-1). As section 11(2)(b) of the Surveys Act stipulates that electronic linear measuring equipment used by land surveyors be calibrated against this standard of measure periodically.

Conclusion

The above excerpts and discussions for achieving redundant measurements in GPS (and conventional) surveys are, in my opinion, good references. It should be noted though they are not considered to be Practice Review Board or Systematic Practice Review directives.

As I understand, the current MSP standard for achieving redundancy measurement is under review by the Standards Committee. In the meantime, I urge every practitioner to develop their own policy to achieve reliable survey results based on their resources such that redundancy can be achieved in a consistent fashion within their own practice.

Please note that redundancy is not just confined to field practices and procedures. If proper checks and balances are in place in both the field and office, getting it done right the first time is achievable. For example, in some instances, field errors can be identified during a stringent plan examination process. In addition, good records and note keeping is key to achieving communication between field and office staff to further detect and resolve potential errors.

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Facsimile 613-786-2001
Toll Free 800-267-6684
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