Educational Corner "*Stones*"

Hanging Lines - Still a Problem for Surveyors

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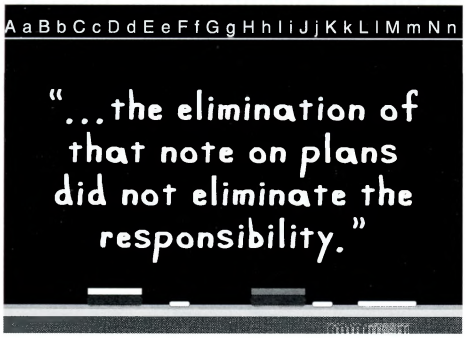
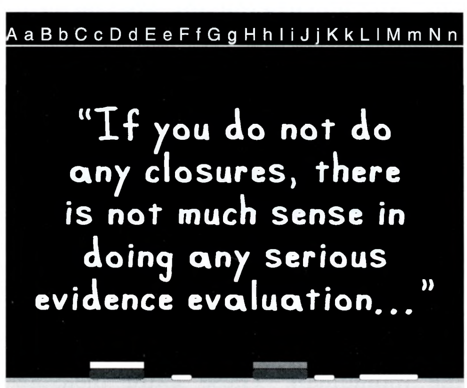


Sometime in the early 1970's, I attended a seminar on the subject of 'hanging lines' (unverified measurements) in field surveys. The problem has not gone away - even if the requirement to place the "All Hanging Lines Have Been Verified" note on our plans has. For those who thought otherwise, the elimination of that note on plans did not eliminate the responsibility.

This past year, I have had the privilege to assist with a few comprehensive reviews for the AOLS Survey Review Department. As part of that process, the consultants met with SRD manager David Norgrove and among other things, discussed some of the problems that all too often are found during those reviews. 'High-risk' technical survey practices are on that list. Given today's electronic equipment and sophisticated computer software, it is surprising that this is still a problem. The purpose of this article is not to delve into why this is occurring - there are a large number of factors ranging from economic pressures and naive reliance on the precision of total stations, to poor work habits by field and office staff. This article is an attempt to draw attention to the overall problem, highlight a few issues and provide a few ideas on better survey practice.

As a start, I will list some of the practices that I have observed during the comprehensive reviews:

- field traverse not closed in any manner;
- all or most objects (buildings, fences, survey monuments) tied in radially from only one traverse station with no check measurements between them or any dimensions of the buildings, etc.;
- short back-sights and long fore-sights and other 'weak' geometry;
- angles not doubled;
- traverse data not adjusted;
- survey monuments set from unadjusted traverse data;
- survey monuments set without any check measurements;
- little or no analysis to determine if any of the survey monuments were disturbed or to evaluate the evidence with respect to existing documents;
- field survey and evidence evaluation (if any) does not appear to be adequately supervised or reviewed by project surveyor;
- use of doubled angles and metric/imperial distances as the only method to verify radial ties;
- poor quality or non-existent field note sketches;
- measured angle and distance raw data not preserved in data collector (only co-ordinates are returned to office); and,
- measured angle and distance raw data not preserved with the field notes.

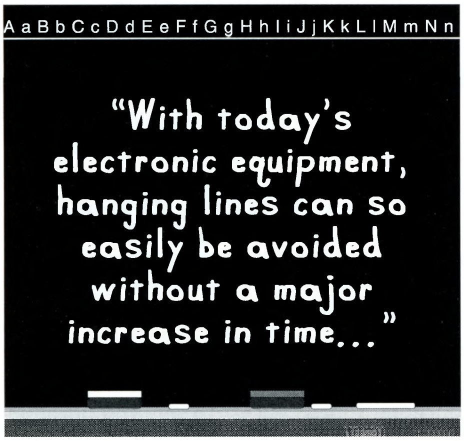


Many of the above problems stem from a process where the field staff tie in objects radially, co-ordinating everything as they go, including creating co-ordinates from plans, etc. for property corners. In this way, missing monuments can be set as the traverse proceeds around the project. Hopefully the traverse will not contain any substantial error, because the bars are already in the ground by the time the field crew is finished the traverse. If you are foolish enough to adjust the traverse in the office, everything ends up in the wrong place by small amounts (or worse) - better not to know! If you do not do any closures, there is not much sense in doing any serious evidence evaluation or resolve any differences with the dimensions published in deeds or plans because you really do not known where anything is.

Many survey offices have automated with electronic distance and angle measurement and computers for survey calculations. What is also apparent is that there has been little serious rethinking to modify procedures to take advantage of the efficiency of this new equipment and still maintain the integrity of the data and the overall competence of the work.

CLOSING TRAVERSES / STRONG GEOMETRY / HANGING LINES

All field survey traverses, whether run on random lines or on the actual property line, must form a closed figure. This does not only mean the traditional closed traverse where each station is occupied. Certainly this is preferred, but on small projects such as an SRPR where a single traverse line is run into the back yard, use the building corners, etc. to close the traverse. Ties to building corners from the front and rear traverse stations will result in a closure sufficient to evaluate the work. More than one redundant tie is preferable and marking the tie point with a bit of washable crayon will improve the accuracy of the measurements by

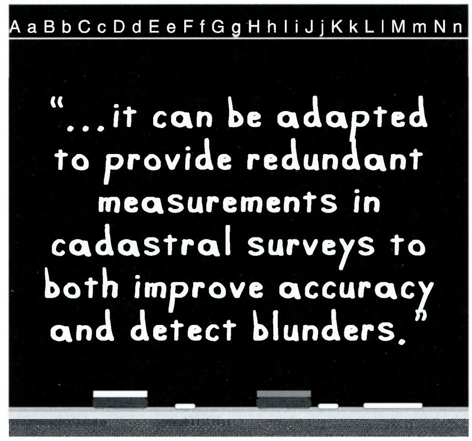


insuring that the ties are taken to the same point on the building.

Take advantage of 'distant sights' to improve traverse geometry. Occasionally, it is necessary to use a relatively short traverse leg. Look for distant sights (TV antennas, utility poles, building features, etc.) and set the traverse leg on that line thus providing the next set-up with a distant sight to help preserve angular accuracy. Another method is to use an extra traverse leg that bypasses the section with the weak geometry thus isolating any weakness in a portion of the survey. Adding in a few extra cross-ties in a traverse on a larger project is an excellent way of improving accuracy (always desirable when you are subdividing the property as it simplifies future layout) and isolating errors should any be discovered. Measuring the total distance as well as the individual partials on lines with multiple points improves accuracy and helps isolate errors. Measuring distances from both ends of a traverse line, particularly across water or when the line of sight is close to the ground, building or other object is always a help to isolate weak distances resulting from interference with the electronic distance meter signal. When carrying elevations using trigonometry, measuring the vertical angle from both ends of the traverse line will improve the accuracy of the resulting elevations.

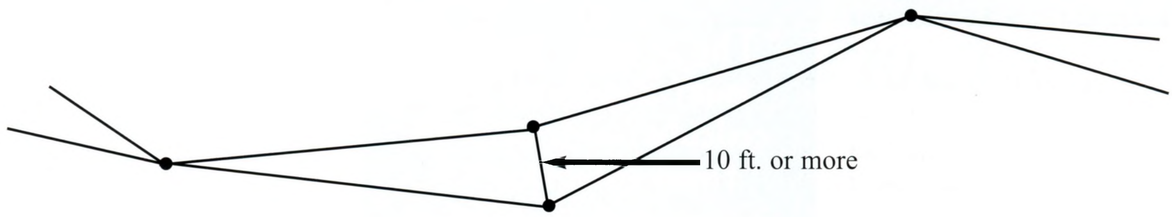
With today's electronic equipment, hanging lines can so easily be avoided without a major increase in time, it can only be laziness or ignorance that so many field surveys suffer from this problem. Planted survey monuments are the worst problem. I have examined surveys where monuments are set only a few metres apart and no check measurement is made between them! Get the old tape measure out of the truck! Measure all parts of the buildings. These dimensions provide verification for the radial ties. Obtain direct corner to corner dimensions if the corners have been radially tied in. Most buildings are square enough to check for blunders in radial tie measurements but they may be out of square enough to make it difficult to check for smaller errors. Obtain right angle ties from objects to traverse or property lines in addition to radial ties. Tape distances between building corners, fences, survey monuments, etc. will provide necessary check measurements. Radial ties to the same object from two or more traverse stations is highly recommended. Using survey monuments as traverse points is the most reliable method of locating them. One of my personal pet peeves, is reliance on doubled angles and metric and imperial distances to points tied in radially as the only method to provide measurement redundancy. This method does not always eliminate backsight errors, disturbed set-ups or other similar problems. It almost never detects a calculation error and provides little if any checks in the office that the person doing calculations has entered the data correctly. Redundant measurements not only check the field survey, they also check the calculation and data entry process. Where possible, set monuments should always be confirmed by measurements to other objects such as building corners or other monuments. On large projects such as a farm survey, monuments are often set on fence lines and tied in radially from traverse stations. Placing a nail a short distance from the traverse station and along a traverse line so that an equilateral triangle is formed between the monument, the traverse station and the nail and measuring with a tape between these points, provides an excellent check measurement system that takes very little time. Another efficient method is to turn a right angle from one or both traverse lines and obtain right angle ties to the monument. These extra measurements will confirm both the fieldwork and the office calculations.

The purpose of the survey should be reflected in the methods, equipment and traverse geometry used to locate the objects. A relative accuracy of 1:5,000 is not very difficult to obtain with today's electronic equipment, but a boundary survey for a plan of subdivision will likely need a relative accuracy of 1:20,000 or 1:30,000 to avoid problems during layout. Using more than one measurement technology (tape measurements, EDM measurements, GPS measurements, ties to existing control surveys, etc.) are all desirable methods of improving both the accuracy and confidence of field surveys. The primary purpose of redundant measurements in legal surveys is to improve the confidence of measurements (detect blunders).

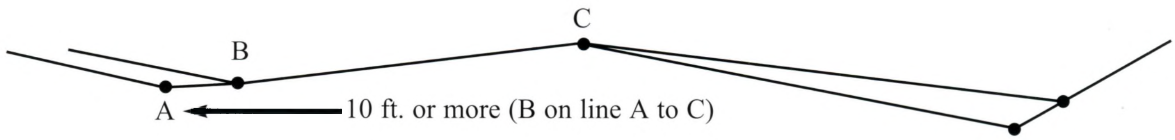


Redundant measurements can be of a lower precision than the primary ties. For control surveys or surveys of properties that are to be subdivided, the redundant ties also serve to improve the accuracy of the survey so the precision of all measurements should be as high as possible. Strong geometry is a must. When locating survey evidence, consideration of its use, can save time. Evidence that will be relied on to control a boundary for both distance and direction must be located with redundant measurements that confirm its position for both distance and direction. Evidence that is used only to control direction might not have a redundant distance to it. Thus monuments along a street line might be tied in radially from a traverse station. The monuments close to the property that control the distance along the street might have tape distances between them and right angle ties from the traverse line to them. Monuments further along the street that are only used to confirm the

Traditional 'Double Run' Traverse



'Double Run' Traverse in Forested Areas (requires less clearing)



street line direction might only have additional right angle ties to them.

There are a few unusual situations where closing traverses or obtaining redundant measurements is physically or economically very difficult. Surveys where all or a portion of the survey requires a traverse to a distant point(s) is an example. This can occur for ties to distant lot corners or for recreational properties - particularly in Northern Ontario. Doing this work with traditional closed traverse may require days of cutting additional traverse line through bush and /or traversing across other private property where permission has not been obtained to trim trees along traverse lines. For larger projects, surveyors need to consider the application of GPS technology. For distances under 10 km., observation times are from 5 to 15 minutes (5 minutes plus 1 minute for each kilometre is a rough rule of thumb). If you do not need to relate the survey to an existing datum, there is no need to use existing control monuments and the technology will still provide an accurate astronomic bearing reference. In situations were GPS is uneconomic or cannot be used because of obstructions to signal reception the method of 'double run' traverses (see sketch) should be considered. This technique was developed for geodetic control surveys of high accuracy but it can be adapted to provide redundant measurements in cadastral surveys to both improve accuracy and detect blunders. The method simply establishes two stations at every second traverse point thus forming a sequence of triangles. All lines are measured with angles and distances. In this type of traverse, the major time is spent travelling and clearing the traverse lines. The extra time spent making the redundant set-up and measurements is, in my experience, not more than an extra 10% to 25%. It is faster than re-measuring the traverse a second time.

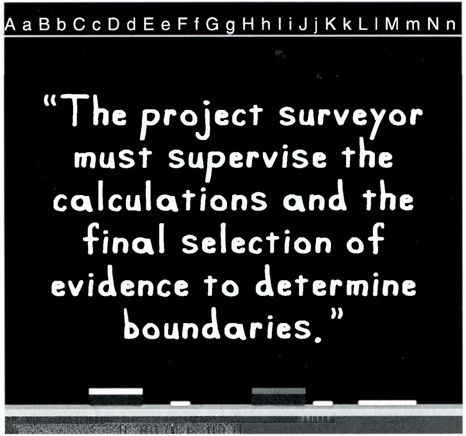
OFFICE CALCULATIONS AND SUPERVISION

Extensive field check measurements are of little use if no one reviews the data. Traverses must be closed and adjusted and inverses (missing courses) calculated to confirm that the check measurements are within expected accuracy. Few cadastral survey offices appear to be using least square adjustment software for their adjustment and data analysis. This software is readily available and is not expensive. This software allows all data (building dimensions, survey data from earlier surveys, etc.) to be simultaneously adjusted. The adjustment provides extensive measurement analysis - both relative and absolute and perhaps most importantly, clearly identifies what object locations are confirmed by redundant measurements and which are 'hanging lines'.

Part of the calculator or party chief responsibilities should be the preservation of the raw measurement data. The data should be printed out in unmodified form and retained as part of the field notes. Photocopying the print out onto the back of your standard field note paper is one method. Getting it into the field note record usually helps ensure that it is preserved and is available to other surveyors when they request the information for that project. Our standards and regulations require that the original angles and distances be preserved along with a field note sketch sufficient to relate the tabular data to the sketch and sufficient to illustrate how the field survey progressed.

Other than point number identifiers (to relate tabular data to the sketch), office calculations should be illustrated on a separate sketch or a photocopy of the original notes. If these calculation sketches are made part of the field note record (an excellent place to preserve this valuable information), these pages should be clearly identified as being calculation pages. Additional measurements made during field work after the office calculations to set bars or obtain check measurements, etc. should be made on a new page or very clearly identified as to the date, crew, what measurements were made and how the work was done.

After the data is adjusted and any blunders eliminated, there needs to be an analysis of the evidence to select the best evidence for each boundary. Too often, I have noted that bars are held as best evidence of a corner when there are clear indications that it is disturbed - a new fence post jammed beside it and the distance to neighbouring monuments are long and short by similar amounts. In my opinion, this is lazy surveying and taking the legal premise that survey monuments govern to its illogical conclusion. The rule is that survey monuments ***in their original position*** govern (my emphasis). Determining that a monument is in its original position does take some analy-



sis. Sometimes we must select the best evidence to determine boundaries from conflicting evidence. In situations where the evidence is inconsistent by small amounts (several building ties along a street), consider the use of 'best fit' routines found in many co-ordinate geometry packages rather than selecting the two points furthest apart and calling everything else off by small amounts. A best fit analysis may find a solution that places most of the evidence on the line within legal accuracy and only one or two that remain conflicting.

The project surveyor must supervise the calculations and the final selection of evidence to determine boundaries. In my experience, it provides the surveyor with an excellent review of the competence of both the field and office staff and identifies areas where additional training is required. Surveyors too often forget that students from Community Colleges and Universities are trainable but not fully trained. It is the project surveyor's responsibility to ensure that the work is taking place in an accurate and reliable manner.