Evaluation of Survey Consistency

by Bob Myers

ABSTRACT

A study was conducted to evaluate field measurements made by survey crews using their standard procedures over a course designed to simulate actual survey conditions that may be encountered in a typical land survey. General instructions were provided for the measurements and specific requirements were set for reporting. For establishing "truth" , the Missouri Land Survey Program of the Department of Agriculture conducted a control network survey at the site consisting of almost 100 observations. After testing for internal consistency, the results from a rigorous adjustment following a least-squares analysis was used for the evaluations. The comparison of individual measurements for the same line was also used to evaluate consistency between surveyors. The variation in consistency in the measurement of direction was very evident. The evaluation of distances shows some measurements to be quite good, but on the other hand, distance measurements, especially of smaller length could not even achieve the previously held standard for chaining of one part in 10,000. Most surveys appeared to be largely in compliance with the Missouri Standards for Property Boundary Surveys but only half were able to achieve the positional accuracy required for the ALTA/NSPS Land Title Surveys. The results also showed some of the typical errors encountered in normal field results. The examples of the data comparison and implications for Missouri surveying practice are presented.

The Purpose of This Study

The St. Louis chapter of the Missouri Society of Professional Surveyors (MSPS) has actively strived to elevate the standards of the surveying profession in Missouri. The St. Louis chapter in the late 1960s sponsored a test survey to evaluate the accuracy of chaining with a steel tape as practiced at that time. The surveyors from several companies measured the distance between two points on an abandoned roadway. The results of that survey showed that the distance was being measured with an accuracy of one part in 10,000. That accuracy was considered the measurement standard of that time. The equipment used for that project was a 100-foot steel tape, plumb bobs and a transit to keep the measurements in line. Results of this project validated the current procedures before electronic distance measuring instruments (EDMI) were available.

The equipment and surveying technology used in the execution of surveys by the professional land surveyor has drastically changed in the last 45 years. The standards themselves have also changed from a surveying procedures specification to accuracy-based standards. Current standards rely on procedures and techniques designed by the surveyor that yield results of a specified accuracy.

This study attempts to answer the question "are the results obtained by current surveys consistent with the accuracy standards in place?". The St. Louis chapter is also interested in determining the relative consistency of measurements of their members. This study is not a contest between surveyors to see who could make the most accurate survey but to compare the actual survey measurements by one surveyor with the measurements from other surveyors.

The study is intended to compare the accuracy of the survey measurements with the accuracy standards currently being used with the intention to make recommendations for evaluating the survey standards if needed. The results of this study should provide information relative to the current standard of practice and may pinpoint needed changes in the Missouri's surveying statutes and regulations to consider modern procedures and technology.

There were no preconceived results of this study. It was recognized in the very beginning that the results of this study may have no tangible results and thus be inconclusive. It was also recognized that even if no earth-shattering results were found, the study would provide good information and insights into surveying technology in common use today.

Procedure for the Study

The plan is to conduct a survey at a location that was both realistic and accessible. The survey is intended to emulate a boundary survey in which the lines to be measured were property lines. Although the lines were not actual boundary lines they could have been boundaries. The site was selected to allow easy access to the interstate highway system, and thus accessibility to the survey crews in the area.

- The site selected was on property in the southwest quadrant of Missouri highway 141 and Interstate I-64. It was chosen because it had the following characteristics.
- The site had readily available parking for the surveyor's crew.

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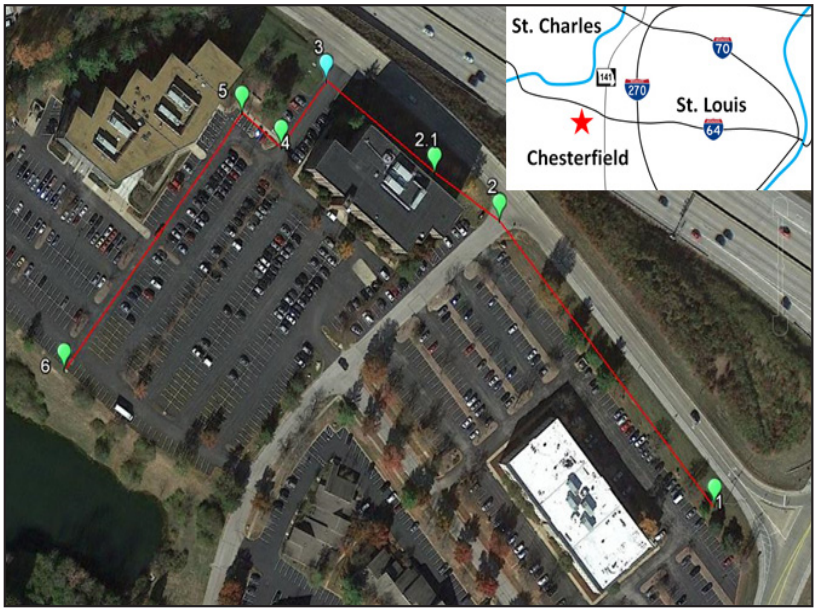
- The survey crews could come to the site any time during a normal working day.
- The measurement points are easy to monument and all the lines to be measured were visible and the corners could be occupied.
- The length of the lines varied so that the quality of the measurements could be evaluated with respect to distance.
- All the angles at the measurement points could be easily measured.
- Because there are some commercial buildings on the site the visibility (and non-visibility) of satellites provided a normal situation, with some blockages for the GPS satellites
- The configuration was such that the endpoints of the survey were not inter-visible.

The site chosen to conduct this evaluation was owned by two property owners and included major office buildings. Before any work started these owners were contacted and permission was received for the work. The surveyors were particularly admonished to not block traffic unnecessarily or to cause any undue problems with access to the property by the public.

For specific detail of the site refer to the Site Plan. Corners 1 and 2 were relatively open and clear to receive GNSS satellite signals and not blocked by any other obstructions. Corner 2.1 was selected at a point close to the three-story building. That building blocked most GNSS satellites from the South. Corner 2.1 was visible to both the preceding and subsequent monument. i.e. they were inter-visible, as might be required for total station surveying by direct measurements. Corner 3 was clear for the observation to 2.1, 2 and 4. Corners 4 and 5 were selected between the three-story buildings although these buildings did not completely block satellite coverage. Corners 4 and 5 were selected so that the distance between them was less than 100 feet. Corner 6 was selected to give the greatest amount of difference in elevation between Corner 1 and Corner 6 and had good visibility to GNSS satellite signals. The line between Corner 1 and 6 was blocked by a building.



Participation in the special survey

A reasonable amount of participation from the surveyors in the St. Louis area was necessary to make this study a successful project. To provide an incentive for the participation of survey crews, a single cash award of $1000 was awarded to one of the participating crews. The winner of this cash prize was chosen by randomly drawing a name from those crews that had submitted their work. This award was made at a meeting of the St Louis chapter when the oral presentation of the results was given. The $1000 prize was money donated to the project by individuals interested in this study.

Participation in the study was not as high as expected. A total of 14 results were submitted. Three of the surveyors participating were listed as land surveyors in the St Louis Yellow Pages. One surveyor was from outside the St Louis area. Three consulting engineering companies and two state government agencies participated. Fourteen crews are a statistically small sample and represents a small percentage of the surveying profession. Although the deadline for submitting data was extended twice to solicit additional participation there seemed to be a reluctance to participate. The most common excuse was "that the company was too busy". Nevertheless, the participation did yield enough data for an analysis.

Instructions given to the surveyors

The primary purpose of this project was to evaluate the results of the field work obtained from the survey. The study was to compare values and results and leave the procedures up to the survey crews themselves. The crews were instructed to make that survey measurements just the way they normally would on a similar survey project in this area. There was no intention to use special procedures for this survey. Instructions were

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written for the survey crew that gave only general guidance on conducting the survey and specific instructions on reporting requirements.

By way of example the following is taken directly from the procedure given in the instructions:

Procedure: a series of points have been established in an area simulating an actual boundary survey. Survey crews are asked to determine ground distances and directions, state plane coordinates and elevations of selected lines and points. The survey crews are asked to use their normal or standard procedure to make these measurements. It is not intended that the survey crew will use special procedures. They should use procedures that they would normally use in conducting a survey for a client. For statistical purposes, the final report submitted by each survey crew will also include the estimated field and office time associated with the survey and a general description of the procedure and equipment used the names of the party chief and crew members must be included in the report, but those names will not be used in the comparison of measurements or included in the final analysis of the results.

Note that procedures were not specified, the term state plane coordinates was used without further identification and elevation was used without further identification. Interpretation of this information was left up to the individual crew.

Analysis of survey results

The low number of participants and thus the number of actual results were disappointing. Nevertheless, these results were analyzed and considered to be a representation of the surveying practice in the St. Louis metropolitan area. Although the results probably would not stand up under a rigorous academic standard the results are significant. It's important to keep in mind that this project was not intended to determine the most accurate survey possible but to evaluate and compare the results obtained by different surveyor's using their normal everyday procedures.

Analysis of the coordinate values

The instructions for this survey were to provides the state plane coordinates of points 1 and 6. There was no additional description of what was required. The surveyor had the responsibility to determine that he felt was the appropriate coordinate. Of the 14-surveyor's responding one surveyor chose not to provide coordinates at all stating that he did not normally provide coordinates on his surveys. Two surveyors responded with state coordinates in metric units only. Two surveyors responded with coordinates in both metric and English units. Nine surveyors responded with coordinates in English units only. One of the surveyors that provided coordinates in both English and metric units had an error in the conversion between the units.

The Missouri statutes specifically state that the Missouri state plane coordinate system (SPCS) will be reported in metric units. The intent of the statute is to provide a unique coordinate of specific locations unrelated to the dimensions or units of the survey itself. The use of metric coordinates is an additional way to make that apparent. The National Geodetic Survey (NGS) also publishes the coordinates of control stations in metric units. Since all the coordinates in the SPCS are based on the published coordinates of marks in the National Spatial Reference System (NSRS) maintained by in NGS, the metric system is the system to use. Some of the surveyor's made a statement in their reports that they would only publish the coordinates in metric units.

Most of the surveyors returned coordinates that were related to the Missouri Department of Transportation's Real-Time Network (RTN) and tied to NGS control station SL 33. Some surveyors submitted data to the NGS OPUS program and reported that result. The coordinate values reported are based on NAD 83 (2011).

The results of the analysis of coordinates are shown in Table A. The analysis clearly indicates that the average coordinate values obtained for points 1 and 6 are highly consistent. The average of 13 coordinates for Corner 1 was 311,727.762 m +/-4 mm North and 248,714.311 m +/- 22 mm East. The average coordinate for Corner 6 was 311,703.464 m +/- 4 mm North and 248,408.123 m +/-27 mm East. The precision of the average observations, i.e. the uncertainty indicated by the plus minus value, is given at the 68% confidence level. None of the observations were outside of the rejection limits of 3 sigma. The work of the surveyors who participated in this evaluation to determine the coordinate values was well within the accuracy of the network itself. In summary the level of consistency of the coordinate determination was very good. The ability of the surveyor to obtain consistent coordinates is demonstrated by the results of this part of the evaluation.

Analysis of the measured distances.

One of the primary items evaluated in this study is the quality of the measured distances. The measurements are given as ground distances in Table B. According to the Missouri standards, the accuracy of the fieldwork should be reflected in the number of significant figures shown in the measurements. One half of the survey crews reported distances measured to 100th of a foot and the other half reported distances to 1000th

of a foot. The results of this study would indicate that the field work is only accurate to 100th of a foot. Using distance of 1000th of a foot is appropriate for field results but should not be carried forward in the final survey plat and would be misleading to the client.

To evaluate the accuracy of the measurements the 14 measurements for each of the distances was averaged. That average distance is accurate with a standard deviation of .01 ft or less. To be able to state accuracy, a value needed to be measured that would serve as "truth". This was done by a survey conducted by the Missouri Land Survey Program (LSP). The LSP team measured a closed network that included the corners in the study area. The network was then adjusted using least squares with the Star Net Pro program. The average of the distances that was obtained from the observations by participating crews agreed very closely with the solutions obtained from the least squares solution. There were six distances measured and two agreed exactly, two differed by 0.01 ft, one by 0.02 ft and one by 0.03 ft. This analysis shows that the accuracy of the overall measurements was quite good and we consider the averages as a measure of the true value.

In this study we are particularly interested in how the Individual measurements compare between surveyors. When we look at the 14 individual observations of the lines we see a variation. The precision of these measurements is like the standard deviation of the measurements. Table B shows the standard deviation of Length A is +/-0.03 or 1:20,216, Length B is +/-0.04 or 1:3,173, Length C is +/-0.02 or 1:8,259, Length D is 0+/-.02 or 1:6,893, Length E is +/-0.02 or 1:3,944, and Length F is+/- 0.04 or 1:10,896. The old accepted standard for measurements using a steel tape was 1:10,000. The results would indicate that only Length A and F were better than the old taping measurements. The other lengths have accuracies that were below 1:10,000 and they are all less than 200 ft in length.

Another question to consider is how the 84 measurements compare with the current standards. All but one distance measurement is within the tolerance of the Missouri standards. That may say something about the standards and not the measurements. The analysis of the measurements shows that thirteen of the measurements are outside the tolerance of the ALTA/NSPS standards. Interestingly seven of the individual crews had no measurement outside that standards. Of the other seven crews four of them only had one measurement outside the standards. The length measurements in this study indicate good quality work but there is real concern about the lack of adherence to the ALTA/NSPS Land Title Survey Standard.

Analysis of the directions of the lines.

The instructions did not detail how the directions were to be reported so it was up to each individual crew to use their standard procedure. Of the 14 crews reporting six crews used azimuths the remainder used bearings. Each crew used a slightly different basis for their bearing. A comparison of the bearings or azimuth as reported was of no value to this analysis. To make a valid comparison the reported directions were used to compute the included angle at Corners 2, 2.1, 3, and 4. When the angles were computed it was apparent that there was an inconsistency in the angle at Corner 2. The bearing of line 2 to 2.1 reported by crew 10 was consistent with the other reported values but the value reported by crew 10 for line 1 to 2 was approximately 10 minutes different than the other reported values. When the results from crew 10 was used to compute the angle at point 2 that angle stands out as a possible blunder. For that reason, that bearing was rejected.

Table C shows the results of the analysis. The average of all computed interior angles at each point was in good agreement with the corresponding angles computed from the least-squares adjustment. The standard deviation of the average at Corner 2 was+/- 9 sec., at Corner 2.1 it was +/-20 sec., at Corner 3 it was +/-19 sec. and at Corner 4 it was +/- 12 sec. Consequently, we can conclude that the average angle is close to the actual angles.

Even though the average was good there was considerable variation in the reported individual angles. The standard deviation of the angles at Corner 2 was +/- 34 sec., at Corner 2.1 it was +/-1 minute 15 sec., at Corner 3 it was +/-1 minute 10 sec., and at Corner 4 it was +/-44 seconds. This variations in precision of the angles is larger than expected. Relating those variations to linear quantities may be more meaningful. Those variations are equivalent to 1:6,000 at 2, 1:2,750 at 2.1, 1:3,000 at 3 and 1:4,700 at 4. Although there is no actual angular error specification in current standards intuitively one can see that anything less than 1:10,000 is questionable. Whereas the average is fairly accurate the precision of the angle reflects on the method used to obtain the directions of the lines. There was no indication that actual angles were measured by any of the crews. Directions derived by computations over short distances such as those at Corners 2.1 and 3 may account for this lack of precision. These directions may result in some shortcomings in the written description of the property.

Survey Positional Accuracy Check

The surveyor needs to check positional accuracy. A positional accuracy standard is a yardstick by which surveyors can judge the quality of the survey work. One way to check the positional accuracy is to measure the distances between two points in a survey that have not been directly measured in

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the survey. This distance is one that is not usually or easily measured but can be determined indirectly from a precise survey or it can be directly measured as part of the fieldwork to serve as a check. In this project the distance between points 1 and 6 cannot be directly measured because of an intervening building. The survey conducted by the Land Survey Program serves as the source that provides the check on that distance. The network surveyed by LSP was composed of 98 Observations, 11 angles and 11 distances measured with recently calibrated instruments and adjusted by the least squares method in the STAR*NET-PRO program. The quality of the results of the network adjustment have been verified by the comparisons noted previously in this report

The survey positional accuracy of the 13 crews is being evaluated with respect to the published tolerance of the ALTA/NSPS standard at the 95% confidence level and at the 68% confidence level of the Missouri Standards for Property Boundary Surveys.

The following is an analysis of results as shown in Table D. All the distances were converted to grid distances using the combined grid factor from the least squares solution. The positional accuracy is computed by comparing the computed distance between Corners 1 and 6 and the distance resulting from the STAR*NET-PRO adjustment.

According to the Missouri Standards an error that exceeds 0.10 ft would not be acceptable. Of the 13 crews reporting three were not up to the Missouri standards. The other standard in general use is the ALTA/NSPS Land Title Survey standard. The computed accuracy value for this distance is +/-0.06 feet at the 68% confidence level which is +/-0.12 at the 95% confidence level. Of the 13 surveys crews, only 7 meet that much more stringent standard and the other 6 fails. The results of this positional accuracy evaluation show that if this study is representative of work done by Missouri surveyors, additional work should be done to strengthen the quality of their surveys to meet the ALTA/NSPS Land Title Survey standards. Certifying to the ALTA/NSPS standard when the survey is not in compliance with the accuracy standards may incur liability on the surveyor.

Evaluation of the elevations

The instructions for this project did not specify the vertical datum to be used. Each surveyor was able to determine what datum to use. One surveyor (crew 5) used an assumed datum and the others apparently used NAVD 88 orthometric heights based on Station SL 33. One crew reported the heights in reverse. The results are shown in Table E. The difference in elevation was good. The results of the 14 surveys shows that the average difference in elevation between 1 and 6 was 34.09 feet with a standard deviation of less than+/- 0.01 ft. The precision of the 14 observations of the orthometric height at Corner 1 was 0.05 ft and at Corner 6 was 0.06 ft.; none of the observations were outside of the rejection limits. This indicated that the elevation quality was quite acceptable and within the standard tolerance.

Conclusions to be reached from this study

The low number of participants and thus the number of actual results was disappointing. Nevertheless, these results were analyzed and considered to be a representation of the surveying practice in the St. Louis metropolitan area.

The surveyors reported state plane coordinates of points 1 and 6. These coordinates according to Missouri statutes should be in meters, but nine surveyors reported coordinates in English units only. The results of this study clearly show that the average coordinate values obtained for Corners 1 and 6 were extremely consistent. The ability of the surveyor to obtain quality coordinates is demonstrated quite well by the results of this study.

We are particularly interested in comparing the measurements of the distances made by each surveyor. The 14 individual observations of each of the six lines show some normal variation. The standard deviation of the measurements is a measure of the variation. The standard deviation ranges from +/- 0.02 feet to+/- 0.04 feet. Because the lengths of these lines varied from over 500 feet to less than 100 feet we reviewed the accuracy of each line. The accuracy ratio varied from 1 : 20,216 to 1 : 3,944. Only the two longer distances result in accuracy ratios that were better than 1: 10,000 (the normal accuracy of chaining). The average of the 14 observations for each distance agreed closely with the least-squares adjustment provided by the Missouri LSP and in turn shows the high accuracy of the LSP solution.

In this evaluation we computed the included angle at each of the angle points using the reported directions. One crew apparently made a 10-minute blunder in the bearing of the first line and those directions were rejected. The average of all computed interior angles at each corner was in good agreement with the angles computed from the least-squares adjustment. But the variation between the angles themselves left something to be desired. The variation between the angles ranged from 34 seconds to 1 minute and 15 seconds. A variation of more than 21 seconds would indicate poor quality. There is no indication that actual angles were measured by any of the crews. This may show up as a point of controversy in future legal descriptions written using the bearings.

Surveyors need to check the positional accuracy of their survey to see if they are within the accepted standards. In this study the positional accuracy was computed by comparing the computed grid distance between Corners 1 and 6 and the accurate grid distance computed by the least-squares adjustment determined by the LSP. Of the 13 crews reporting three were not up to Missouri standards. Only seven crews met the more stringent standard of the ALTA/NSPS Land Title Survey and six failed that standard altogether. The results of this positional accuracy evaluation indicate that additional work must be done to strengthen the quality of survey work to meet the standards for ALTA/NSPS Land Title Surveys.

The study shows that orthometric heights were adequately obtained. The difference in orthometric height between corners 1 and 6 was consistent and none of the observations were outside the rejection limits. The results show that for normal construction purposes the procedures used by the crews was sufficiently accurate for determining both the difference in elevation and orthometric height's. It is interesting that the city where this property is located requires the elevation to be in the "USGS Datum". The profession has not met its obligation to inform the public of the proper datum being used in the area.

Aside from the actual evaluation of measurements in this study it must be pointed out that there were numerous mistakes of one kind or another that occurred. Some were in the use of terminology as with Missouri state plane coordinates, one with the conversion between metric and English units, one was the possible copying error in recording a bearing, and one was with just a mistake in recording results in the wrong column of the prescribed report form. Mistakes are tolerable and expected in all kinds of work. But it must be clear to all surveyors that errors must be caught by having appropriate redundancy and checking of results before the error shows up as a **mistake** on the resulting survey report. For the surveyor as an expert in measurements to make a **mistake** represents an incompetence that needs to be guarded against in every surveyors practice.

INSTRUCTIONS & TABLES
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Project for Evaluation of Survey Consistency

Purpose: To compare survey measurements and the reporting of survey information between survey crews in the St. Louis area. This is not a competition but an evaluation of the accuracy of modern survey equipment and common field procedures. The results of individual crews will not be reported but will be kept confidential. The names of the crews will only be used to identify the crews that will be included in the final prize drawing

Procedure: A series of points have been established in an area simulating an actual boundary survey. Survey crews are asked to determine ground distances and directions, state plane coordinates and elevations of selected lines and points. The survey crews are ask to use their normal or standard procedure to make these measurements. It is not intended that the survey crews will use special procedures. They should use the procedures that they would ordinarily use in conducting a survey for a client. For statistical purposes, the final report submitted by each survey crew will also include the estimated field and office time associated with the survey and a general description of the procedure and equipment used. The names of the party chief and crew members must be included in the report but those names will not be used in the comparison of measurements or included in the final analysis of the results. These names will be used in the drawing for a monetary prize.

Results: An analysis of the survey measurements will be made in order to compare the consistency of the measurements. The results will be presented to the membership at a forthcoming St. Louis MSPS chapter meeting and Individual results will be kept confidential. If a participating company would like to have the results of their crew in order to compare it with the overall results that information can be provided, however no individual crews results will be shared publicly.

Incentive: Each crew that submits their measurements in the correct form will be entered into a drawing for a monetary prize. The prize drawing will take place at the meeting where the result of the consistency analysis is presented.

Qualification: Only one entry per survey crew will be allowed and there must be at least 15 crews submitting valid and complete data before the drawing will take place. Participants do not need to be a member of either MSPS or the St Louis Chapter of MSPS.

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Detailed instructions for the survey crew

The Survey Crew should consider this survey as they would a normal survey that they would execute for a client in this location.

THE SCENARIO: The client is requesting some specific measurements of lines and the bearings of those lines. The client is also going to record the final survey and will therefore need to meet the requirements for state plane coordinates of two of the points called for in the survey. The client is also going to design some streets and sewers that will match existing streets and sewers already in existence. For this reason the surveyor is asked to give elevation data on two specific points in the survey.

The survey crew is to report the data on the attached Survey Results Report Form. The surveyor is also request to give the estimated amount of field time and office time used in developing these measurements. It is important that the survey crew describe the equipment that was used in the survey and the procedure that was used. This information will be utilized to make a comparison in the survey measurements. Survey crew should include all of the basic data which would be necessary to reproduce the survey in the future.

Each survey crew should keep in mind that this survey is taking place on private property with the permission of the owners. But the survey crew should use utmost care not to cause any problems for the tenants using this facility. Survey crews should conduct themselves in a courteous and competent manner. There should be no need to cause traffic to be blocked or delayed while making the surveys and any questions ask by the tenants or clients using these buildings should be answered as clearly as possible by the survey crews.

The **completed survey report must be returned to**;

Robert E. Myers
705 S. Laclede Station Rd Apt 365
Webster Groves MO 63119

Before January 15, 2015

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Survey Results Report Form

The name of the Company Performing the Survey-_______________________________
Name of Survey Crew Chief ____
Name of Crew Members____
Phone Number____
Email Address____

>>

Survey Crew number (assigned by committee)____________________

Refer to the attached survey diagram (page 14) showing the test survey area.

Length and direction of line between point 1 and point 2 ____________________

Length and direction of line between point 2 and point 2.1 ____________________

Length and direction of the line between point 2.1 and point 3 ____________________

Length and direction of line between point 3 and point 4 ____________________

Direction and length of line between Point 4 and point 5 ____________________

Direction and length of line between Point 5 and Point 6 ____________________

State plane coordinates of Point 1 ____________________,____________________

State plane coordinates of Point 6 ____________________,____________________

Elevation of Point 1 ____________________

Elevation of Point 6 ____________________

Date of the field work ____________________

Time of day of the field Work ____________________

Tables; Evaluation of Survey Consistency *(continued)*

TABLE A

COORDINATES OF POINTS 1 AND 6

(MISSOURI COORDINATE SYSTEM OF 1983, EAST ZONE)

	Coordinate of Point 1		Coordinate of Point 6	
	Northing (meters)	Easting (meters)	Northing (meters)	Easting (meters)
Land Survey Pogram STAR*NET Result	311727.755	248714.307	311703.456	248408.124
Crew				
5	0.000	0.000	0.000	0.000
1	311,727.765	248,714.297	311,703.460	248,408.118
2	311,727.753	248,714.335	311,703.466	248,408.154
3	311,727.765	248,714.296	311,703.460	248,408.115
4	311,727.763	248,714.299	311,703.470	248,408.108
6	311,727.756	248,714.325	311,703.469	248,408.138
7	311,727.765	248,714.316	311,703.461	248,408.146
8	311,727.764	248,714.269	311,703.463	248,408.082
9	311,727.761	248,714.347	311,703.462	248,408.144
10	311,727.761	248,714.301	311,703.459	248,408.111
11	311,727.764	248,714.298	311,703.472	248,408.124
12	311,727.760	248,714.335	311,703.457	248,408.146
13	311,727.764	248,714.298	311,703.466	248,408.065
14	311,727.765	248,714.332	311,703.465	248,408.143
Standard Deviation of the meaurements	0.004	0.022	0.004	0.027
Arithmetic mean	311,727.762	248,714.311	311,703.464	248,408.123
Standard Deviation of the mean	0.001	0.006	0.001	0.007
Average - LSP Value	0.007	0.004	0.008	-0.001
Rev 4/14/2018				

TABLE B

Measured Ground Distances in Feet

	LENGTH A FROM POINT 1 TO POINT 2			LENGTH B FROM POINT 2 TO POINT 2.1			LENGTH C FROM POINT 2.1 TO POINT 3			LENGTH D FROM POINT 3 TO POINT 4			LENGTH E FROM POINT 4 TO POINT 5			LENGTH F FROM POINT 5 TO POINT 6		
LSP STAR*NET Results (in feet)	506.016			141.370			187.525			136.378			64.452			450.023		
Crew	Distance	Residual		Distance	Residual		Distance	Residual		Distance	Residual		Distance	Residual		Distance	Residual	
1	506.03	0.004		141.31	0.056	**	187.56	-0.040	**	136.35	0.018		64.43	-0.006		449.92	0.075	**
2	506.06	-0.026		141.35	0.016		187.50	0.020		136.36	0.008		64.42	0.004		449.99	0.005	
3	506.01	0.022		141.47	-0.106	*	187.57	-0.054	**	136.32	0.048	**	64.43	-0.009		450.08	-0.087	**
4	506.03	0.004		141.35	0.016	**	187.52	0.000		136.36	0.008		64.43	-0.006		449.99	0.005	
5	506.05	-0.016		141.41	-0.039		187.51	0.012		136.38	-0.008		64.44	-0.015		449.99	0.003	
6	506.05	-0.016		141.36	0.006		187.52	0.000		136.36	0.008		64.43	-0.006		449.99	0.005	
7	506.05	-0.015		141.37	0.000		187.51	0.011		136.38	-0.016		64.43	-0.005		450.02	-0.023	
8	506.05	-0.019		141.36	0.011		187.51	0.006		136.37	-0.004		64.40	0.023		450.04	-0.040	
9	506.03	0.005		141.36	0.008		187.52	0.004		136.35	0.014		64.43	-0.001		450.00	-0.004	
10	506.03	0.004		141.37	-0.004		187.52	0.000		136.40	-0.032		64.45	-0.026		450.03	-0.035	
11	506.05	-0.018		141.28	0.087	**	187.52	-0.001		136.39	-0.025		64.42	0.006		449.97	0.026	
12	506.03	0.004		141.38	-0.014		187.52	0.000		136.37	-0.002		64.39	0.034		449.93	0.065	**
13	506.04	-0.001		141.40	-0.037	**	187.48	0.037	**	136.38	-0.009		64.41	0.019		449.98	0.020	
14	505.96	0.074	**	141.36	0.006		187.51	0.010		136.37	-0.002		64.44	-0.016		450.01	-0.015	
Standard Deviation of the meaurements	0.03			0.04			0.02			0.02			0.02			0.04		
Precision	1:20,216 (±50 ppm)			1:3,173 (±315 ppm)			1:8,260 (±120 ppm)			1:6,894 (±145 ppm)			1:3,944 (±255 ppm)			1:10,896 (±90 ppm)		
Arithmetic mean	506.03			141.37			187.52			136.37			64.42			450.00		
Standard Deviation of the mean	0.007			0.012			0.006			0.005			0.004			0.011		
Precision	1:75,641 (±13 ppm)			1:11,871 (±85 ppm)			1:30,903 (±30 ppm)			1:25,793 (±40 ppm)			1:14,757 (±70 ppm)			1:40,768 (±25 ppm)		
* Exceeds Missouri Standard and ALTA/NSPS Standard																		
** Exceeds ALTA/NSPS Standard																		
Residual: the difference between the distance measurement and the arithmetic mean.																		

(continued on page 37)

Tables; Evaluation of Survey Consistency *(continued)*

TABLE C

INTERIOR ANGLES

(ANGLE RIGHT)	AT POINT 3	AT POINT 2.1	AT POINT 3	AT POINT 4	AT POINT 5
LSP STAR*NET	154° 59' 33"	205° 17' 17"	81° 54' 36"	266° 48' 25"	89° 02' 17"
Crew					
1	154° 59' 42"	205° 17' 06"	81° 54' 34"	266° 47' 06"	89° 03' 29"
2	154° 59' 37"	205° 17' 29"	81° 53' 57"	266° 47' 53"	89° 03' 40"
3	155° 00' 06"	205° 17' 42"	81° 53' 40"	266° 47' 35"	89° 03' 15"
4	154° 59' 55"	205° 16' 51"	81° 54' 58"	266° 48' 39"	89° 02' 42"
5	154° 59' 53"	205° 17' 28"	81° 54' 02"	266° 48' 34"	89° 02' 30"
6	154° 59' 36"	205° 17' 35"	81° 54' 15"	266° 48' 01"	89° 02' 59"
7	155° 00' 07"	205° 17' 12"	81° 55' 12"	266° 48' 03"	89° 02' 00"
8	155° 00' 08"	205° 16' 20"	81° 55' 06"	266° 48' 52"	89° 02' 00"
9	154° 59' 55"	205° 17' 20"	81° 54' 24"	266° 49' 34"	89° 01' 18"
10	(OMITTED)	205° 17' 31"	81° 54' 02"	266° 48' 31"	89° 02' 03"
11	155° 01' 46"	205° 12' 51"	81° 58' 16"	266° 48' 20"	89° 00' 42"
12	155° 00' 22"	205° 17' 4"	81° 55' 02"	266° 48' 06"	89° 01' 45"
13	155° 00' 07"	205° 17' 49"	81° 54' 50"	266° 47' 03"	89° 03' 16"
Arithmetic mean	155° 00' 06"	205° 16' 58"	81° 54' 41"	266° 48' 16"	89° 02' 24"
Standard Deviation	0° 00' 33"	0° 01' 15"	0° 01' 10"	0° 00' 32"	0° 00' 44"
Standard Deviation of the mean	0° 00' 33"	0° 00' 20"	0° 00' 19"	0° 00' 12"	0° 00' 20"

TABLE D

SURVEY ACCURACY CHECK

THE ACCURATE GRID DISTANCE* IS 1007.70 ft.

				Missouri Standards**	ALTA/NSPS Land Title Standards***
CALCULATED MAXIMUM ALLOWABLE				0.10'	0.06' (2cm)
RELATIVE POSITIONAL PRECISION OF GRID DISTANCE 1 TO 6				1:10,077 (±100ppm)	1:17,374 (±58ppm)
Crew	(Feet)	ERROR (in Feet)	Precision		
1	1007.592	-0.10	1:9,820 (±100 ppm)	Fail	Fail
2	1007.688	-0.01	1:147,559 (±07 ppm)		
3	1007.808	0.11	1:8,957 (±112 ppm)	Fail	Fail
4	1007.763	0.07	1:14,718 (±70 ppm)		Fail
5	1007.739	0.04	1:22,974 (±44 ppm)		
6	1007.700	0.01	1:187,574 (±05 ppm)		
7	1007.754	0.06	1:17,211 (±58 ppm)		Fail
8	1007.710	0.02	1:65,056 (±15 ppm)		
9	1007.671	-0.02	1:42,248 (±24 ppm)		
11	1007.680	-0.02	1:66,134 (±15 ppm)		
12	1007.639	-0.06	1:17,995 (±56 ppm)		
13	1007.767	0.07	1:13,985 (±70 ppm)		Fail
14	1007.519	-0.18	1:5,715 (±175 ppm)	Fail	Fail

* The Accuarate Grid Distance from Point 1 to Point 6 taken from the LSP Detail Survey and Adjustment by STAR*NET

** The Missouri Standards are set at a 1-Sigma (68%) Confidence Level .

*** The ALTA/NSPS Standards at set at a 2-Sigma (95%) Confidence Level.

(Crew 10's data was rejected and eliminated from these results.)

(continued on next page)

Tables; Evaluation of Survey Consistency *(continued)*

TABLE E						
ELEVATION DATA						
	Elevation of Point 1		Elevation of Point 6		Difference	
LSP STAR*NET Result	598.09		564.00		34.09	
		Avg- Mea				
Crew		Star*net - Mea		Star*net - Mea		
5	100.00		65.88		34.12	
1	597.99	0.10	563.89	0.11	34.11	
2	597.96	0.13	563.85	0.15	34.11	
3	597.98	0.11	563.86	0.14	34.12	
4	598.04	0.06	563.95	0.05	34.09	
6	597.96	0.13	563.86	0.14	34.10	
7	598.08	0.01	563.96	0.04	34.12	
8	598.00	0.09	563.87	0.13	34.13	
9	598.05	0.05	563.94	0.06	34.11	Reversed
10	598.01	0.08	563.94	0.06	34.07	
11	598.07	0.02	564.00	0.00	34.07	
12	598.06	0.03	563.93	0.07	34.13	
13	598.08	0.01	563.95	0.05	34.13	
14	598.16	-0.06	564.09	-0.09	34.07	
Arithmetic mean	598.03	0.06	563.93	0.07	34.10	
Standard Deviation	0.05		0.06		0.02	