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Accuracy of Boulder County’s GIS Parcel Mapping:
An examination of GIS cadastral mapping compared to Land Surveys

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An examination of GIS cadastral mapping compared to Land Surveys

Abstract:
This research outlines land surveying in the State of Colorado and discusses the formation of parcel maps in the state. GIS continues to grow in various industries and government entities since it is able to best streamline copious amounts of geospatial information. Following suit, County Assessor Offices throughout the country have benefited from the use of a GIS to organize their data. The cost, implementation and maintenance of a GIS is a costly endeavor however it benefits both the County, State and the general public. County Assessor Office GIS systems have directly influenced the field of Land Surveying both positively and negatively. Now that the general public can go online in many counties to view their property, many feel that there is no need for a Land Survey despite the disclaimers attached to the County’s maps regarding accuracy. As this study shows, the accuracy of GIS parcel mapping is not as accurate as many may think. This field study shows that based on a sample of parcel shapefiles from Boulder County’s Assessor’s office accuracy is indeed lacking accuracy and precision.

Introductions:
Land surveying is the world’s second-oldest profession and dates back to ancient Egypt and Babylonia (Bagrow and Skelton, 37). In the past, land surveyors were the only profession to make maps. In centuries past, this profession very respected for many high profile people. Our former American presidents George Washington, Thomas Jefferson and Abraham Lincoln were all land surveyors by trade. Through the years, the profession has lost its prestige and in the eyes
of many, has become a dying industry. With the advent of new technologies leading to new areas of study such as Geographic Information Systems (GIS), Satellite Imagery, GPS (Global Positioning Systems), & Aerial Photography, the field of surveying continues to change. It appears that accuracy and precision have increased with the creation of these new technologies.

The accuracy and precision of on the ground measurements, both horizontal and vertical, provided by Land Surveyors has also improved greatly in the last couple decades. New equipment such as Total Station Robotics, Ground-based Scanners and Survey Grade GPS receivers, Land Surveyors are able to provide precise and accurate surveys with remarkable proficiency. They are, however, no longer the only ones create parcel maps. The new industry of GIS has flourished in the past two decades and is able to provide an affordable alternative for cadastral mapping since many government agencies are fiscally supporting them. GIS professionals speculate on the horizontal accuracy of their GIS parcel data however they typically test it. This paper suggests that an investigation into the horizontal accuracy is necessary so GIS professionals, in addition to the general public, have a better sense of how accurate the data is instead of speculating.

Background

The history for surveyors is a fascinating one that takes you on a journey dating back to the Babylonians and ancient Egypt. Originally surveys were performed using compasses and chains (Robillard, Wilson, and Brown, 55). Presently surveyors have new high precision and accuracy grade equipment such as Robotic Total Stations, centimeter grade GPS equipment and LiDAR
(Light Detection and Ranging) scanners. This technology is costly however it does provide Land Surveyors with a unique niche to precisely and accurately depict property boundaries.

Presently most large scale parcel mapping is generated by County Assessors Offices in the State of Colorado. The County Assessor Office is a great example of a Department which benefits greatly from the use of a GIS. Although County Assessor shows property boundaries, they are generally not accurate or precise. Colorado State law requires that you must be a PLS (Professional Land Surveyor) to survey in the state (CRS, 12.25). To create GIS cadastral mapping, there are currently no licensing requirements and a surveyor is not required.

Upon interviewing two GIS specialists with Boulder County Assessor’s Office, it is believed that the horizontal accuracy in the flatlands it is around six (6) feet (Braddock, 2011). In the mountains the relative accuracy is believed to be around thirty (30) feet in the mountains (Braddock, 2011). This study will be focusing on the flatlands of Boulder County since the estimated accuracy is directly related to the terrain according to the Assessor’s Office.

Specific Goals & Research Question

The goal of this study is to gain a stronger understanding of the relationship around the accuracy of GIS parcel mapping using actual certified Land Surveys. Although GIS cadastral mapping is widely known and used, the accuracy in many instances is not discussed or reported. The research questions are as follows:

What is the relative accuracy for Boulder County Assessor parcel mapping in the flat region within their GIS when compared to a legal recorded Land Survey?

Benefits to Research
Presently, there are hardly any papers, articles or reports found on the subject of the accuracy of GIS parcel mapping. Once this study has been completed, it is believed that the relative accuracy of GIS parcel mapping will be off substantially more than anticipated. An analysis such as this could be a baseline for similar studies in the future. To understand what may happen in the future, it is important to find current trends. More discussion regarding benefits can be found at the Conclusion of this paper.

**Literature Review:**

**GIS Subsection:**

Increasingly organizations, such as County Assessor’s Offices and other government taxing agencies, across the country have been moving towards a GIS to manage their data since it is an excellent way to maintain and manage property information (Craglia, Massimo & Couclelis, 167). The creation and implementation of a GIS takes time, effort and money. Various costs with starting up a GIS: start up cost, data conversion costs, maintenance costs and of course other miscellaneous costs (Reeve and Petch, 61). Once the upfront investment has been made by a government entity to invest in a GIS the payback is generally quite rewarding (Reeve and Petch, 59). Once a GIS has been implemented, users can generate various spatial queries or analyzes. This has great advantages over a simple non-geographic Database Management System (DBMS) or simple filing system which is still in use to this day by various organizations (Martin, 168).

The primary purpose of the County Assessor is to calculate values of all real and personal property for tax purposes (CRS, Title 39). Since this is their primary purpose, accuracy is an inferior concern for their GIS. Also obtaining accuracy is incredibly time consuming, GIS
Technicians are forced to digitize boundaries, force closures and along with other manipulations to insure there are no gaps and overlaps (Hanousek, 3). Lay users are easily seduced into believing that data from a GIS are accurate (O’Looney, 31). Due to this fact, most County GIS systems have disclaimer on their online GIS mapping systems indicating that the information shown is approximate. For example, Boulder County Assessor’s Office uses the following disclaimer when accessing their county GIS:

_The data for this application have been developed solely for internal use by Boulder County, and Boulder County makes no warranties, representations or guarantees, either expressed or implied, as to the completeness, accuracy or correctness of the data, nor accepts or assumes any liability arising from or for any incorrect, incomplete or misleading data provided pursuant to the use of this application. There are no warranties and/or representations, either expressed or implied, of merchantability or fitness of the data for a particular purpose or use._

_These maps give approximate representations of property boundaries and other features. All GIS data have inherent spatial inaccuracies, including aerial photography. Only a licensed surveyor can create an exact depiction of property boundaries._ (Boulder County Assessor). [Emphasis added]

Although the County Assessor invests much money for a GIS they are, by law, only allowed to charge a minimal fee to recuperate their initial investment (Assessor’s Reference Library, 46). By state statutes, all public records or instruments shall be open to the general public (Assessor’s Reference Library, 46). The County Assessor can legally assign a ‘reasonable fee’ for the generation of a record (Assessor’s Reference Library, 47). In many counties throughout Colorado, the general public can gain a stronger understanding of their property using a free internet mapping service provided by County Assessor’s Office.
**Land Surveying Subsection:**

Presently in the State of Colorado, there are several types of boundary maps available to the public that are provided by a Professional Land Surveyor (PLS). First, there is the Improvement Location Certificate which is a simple map identifying improvements to the boundary lines. This is to be considered a certificate not a survey. It is merely the opinion of the PLS that buildings and other major improvements appear to be located on the subject property (CRS, 38-51-108). This type of map is not technically a survey, nor is it recorded with any government agency. These Certificates will not be considered in this study due to the difficult nature in locating the document and the inherent inaccuracies that exist within them.

A Land Survey Plat (LSP) is a survey which shows all boundary lines, easements and rights-of-way, but no improvements unless they are within five (5) feet of the property line (CRS, 38-51-106). An ISP is basically a LSP but includes improvements (CRS, 38-51-106). Generally, Land Survey Plats are cheaper than an Improvement Survey Plat (ISP). There is no specific requirement regarding accuracy, however surveyors generally accept it as 1:10,000. Meaning for every 10,000 linear feet, a surveyor is allowed to have 1 foot of error. The Federal Geographic Data Committee (FGDC) and the National Geodetic Survey (NGS) are good sources for researching accuracies.

Presently, the most accurate and detailed survey you can get on a property is an American Land Title Association/American Congress on Surveying and Mapping (ALTA/ACSM) Land Title Survey. This type of survey was created as a national standard for surveys and is generally recommended for commercial properties. ISP, ISP and ALTA/ACSM Land Title Surveys must
be recorded with the County Clerk and Recorder’s office by law (CRS, 38-50-1b). In addition to these three types, Subdivision Plats, Condominium Maps, Annexation Maps, and a few other types are also of high accuracy and precision provided by land surveyors. These also must be filed with the County.

Research Methods:

The sample frame of this research is going to focus on flatlands of Boulder County, Colorado. In an attempt to simplify this study, it is necessary to focus in on one particular area of study. From a study in Boulder County, ideas and information can be extrapolated based on this study. Although it will not be completely representative (i.e. some counties still do not have a GIS installed for various reasons), it should provide valuable information regarding accuracy for cadastral mapping. The key construct of this non-experimental design is to investigate the accuracy of Boulder County’s parcel shapefile, which is shown on their online GIS, using surveying methods. The flatland areas in Boulder County include the following eight (8) townships (T), identified by Township and Range: T1S R70W, T1N R70W, T2N R70W, T3N R70W, T1S R69W, T1N R69W, T2N R69W, and T3N R69W. See Map below for a graphical representation of these sections.
Presently the Boulder County Assessor’s Office has all property boundaries in one GIS file, a shapefile. Said parcel shapefile is georeferenced and is on the following coordinate system:

Colorado State Plane, North Zone, NAD (North American Datum) 83, HARN (High Accuracy Reference Network) which is a specific projection for Northern Colorado. This shapefile can be obtained from the County for a nominal fee or in the case of scholastic endeavors, can be obtained for free. Boulder County Assessor’s Office has provided this file for this study.

Boulder County Clerk and Recorder’s Office (C & R) presently has access to recorded survey plats online however these maps only date back to 1987. Plats recorded prior to this date must be searched physically at the C & R’ office. Thousands of recorded plats can be found using this

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1 Plats and surveys are interchangeable terms (Brown, 444). Both derive from a performed land survey by a licensed professional.
online plat search function. Presently, this system is organized by Section, Township, Range, Surveyor, Firm, Survey No., Description, or Date Range (screen shot of site shown below).

Using C & R’s organizational platform, Townships and Ranges were divided out by their natural terrain and categorized as mountain townships and flatland townships (Townships of interest were previously identified in this section). Next, using this online system, a simple query determined how many recorded surveys were in each township. Using random sampling, six (6) parcels from the flatland townships will be selected to be studied. The map below identifies how many surveys (3556 total) were deposited in each township as of June 24th, 2011. Deposited surveys after this date were not considered.
Once these deposited surveys per township were queried, a spreadsheet aided in managing the data to aid in organizing all recorded surveys by township in an orderly numerical fashion. Once surveys were arranged in this format, the random number generator (http://www.random.org/) was used to select a random number between 1 and 3556. Using the spreadsheet, the random number determined which survey would be selected. The more a survey has been performed on a parcel, the more it is recorded; therefore that particular parcel would have a greater chance of being selected based on this methodology.

Recorded surveys deposited do not represent geodetic positions therefore field work was necessary to determine geodetic positions and to calculate boundaries. Once the parcels were selected, the researcher physically went onsite to locate a minimum of two survey corners referenced in the recorded survey plat. It was essential that it is the same monument found on the
Sample Sites:

Six (6) Sample sites were selected randomly for this study. Below is a map showing the sites within our flatlands sample area.

Below are our selected sites. First showing the GIS shapefile with aerial background and the second showing the recorded survey associated with the selected parcel. In this format, they are not to scale for comparison.
Parcel 1 (aka Oak):
Parcel 2 (aka Nissan):
Parcel 3 (aka Lefthand):
Parcel 4 (aka Bluff):
Parcel 5 (aka Baseline):
Parcel 6 (aka NIST):
Equipment

For this study, Trimble Navigation provided the researcher with a Trimble R8 Receiver (with accessories) enabled with VRS. VRS, or Virtual Reference Station, is a method used by surveyors to achieve sub-centimeter grade accuracy. Typical GPS Base/Rover configuration uses a Radio Frequency to transmit corrections to the Rover GPS. VRS uses a modem to connect with a CORS (Continuing Operating Reference Station). The CORS then act as the base station and provide corrections through the modem. This methodology will save time by eliminating the need for a Base Station Setup. VRS is not available everywhere however it does cover the sample area of this study. Below is a map of the coverage area.

![Coverage Map](Trimble Navigation, website)

A TSC3 data collector was also provided by Trimble Navigation for this study. For the purposes of this study, only point data was be collected. That point data is the physical monument found at the property corner. Land surveyors are required by law to set a monument when performing a survey if one was not found. Sometimes, offset monuments are set in instances where the
Physical corner cannot be set due to the field conditions. There are laws set forth for what surveyors must set for property corners. The data collector used for this project has the capability to implement a data dictionary. Unlike your typical recreational grade that simply captures points, lines and polygons, this data collector has the ability to collect additional information with the feature being collected. The GIS industry refers to this as attribute data. The data dictionary takes into account requirements for set monumentation and also environment often found when locating points. The table below outlines data dictionary created for this study.

<table>
<thead>
<tr>
<th>Name</th>
<th>Entry Mode</th>
<th>Attribute Type</th>
<th>Values Listed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monument Cap Type</td>
<td>Required</td>
<td>Menu</td>
<td>YPC, RPC, Alum Cap, Brass Cap, Brass Tag, Alum Tag, Chiseled X, No Cap, Other</td>
<td>Type of Cap on Monument</td>
</tr>
<tr>
<td>Cap Size</td>
<td>Required</td>
<td>Menu</td>
<td>¼&quot;, ½&quot;, 1&quot; ½&quot;, 2&quot;, 3&quot;, 3 ¼&quot;, N/A, Other</td>
<td>Cap Size (Diameter of Cap)</td>
</tr>
<tr>
<td>Monument Type</td>
<td>Required</td>
<td>Menu</td>
<td>½&quot; Pipe, ¾&quot; Pipe, 1&quot; Pipe, No. 4 Rebar, No. 5 Rebar, No. 6 Rebar, Concrete Monument, Other, Unknown</td>
<td>Type of Monument Found</td>
</tr>
<tr>
<td>Range Box</td>
<td>Required</td>
<td>Menu</td>
<td>Range Box, No Range Box</td>
<td>Indication of if a Range Box is present</td>
</tr>
<tr>
<td>Offset</td>
<td>Optional</td>
<td>Menu</td>
<td>Offset Monument, Not Offset Monument</td>
<td>Depicting if the monument found is an offset from the property corner or not.</td>
</tr>
<tr>
<td>Text on Monument</td>
<td>Required</td>
<td>Text, Max Length 40 Characters</td>
<td>N/A</td>
<td>Text on monument cap</td>
</tr>
<tr>
<td>Date and Time of Shot</td>
<td>Auto-generated</td>
<td>Date</td>
<td>N/A</td>
<td>Date and Time of shot.</td>
</tr>
<tr>
<td>Photo</td>
<td>Required</td>
<td>Photo</td>
<td>N/A</td>
<td>Photo of monument shot</td>
</tr>
</tbody>
</table>

The above outlined attributes were collected for every point collected in the field.

Software:

Several different types of software were used for this study. The software on the TSC3 Data Collector is a survey-specific software titled Survey Controller. For data download, data
processing and data manipulation, Trimble Business Center (TBC) was utilized. This software is specific for processing various types of survey data including survey-grade GPS. Accurate conversions from ‘Ground to Grid’ can be made in a precise and accurate way.

ArcMap was used to generate geo-tiffs and manage Boulder County’s parcel shapefiles. Subject properties were extracted and exported from ArcMap to AutoCAD Civil 3D/Map3D for a more precise analysis. Using ArcGIS to analyze the survey grade data obtained is not appropriate since it is not a survey-grade software. TBC and Civil 3D are meant to handle survey grade data and therefore were utilized for the geospatial data manipulations, comparisons and analysis.

**Data Collection**

It is essential to the project that GPS is used in this project. Survey Grade GPS has the ability to obtaining a georeferenced position for all corners precisely and accurately. If georeferenced locations for property corners are not obtained on the selected sites, analysis would be impossible.

Although it is specified that GPS is necessary in this process, it is quite probable that many property corners will be under trees or another area where multipathing will prove problematic and a quality GPS position cannot be generated. In these situations, alternate corners will be located. A minimum of two corners must be located to place the survey boundary in the proper location (more information under Office Calculations and Data Manipulation Section).
When in the field, a project (or job) in the data collector will be set up for each site. This is necessary to generate an onsite combined scale factor. Combine scale factors are necessary when converting data from ‘ground to grid’. When ‘ground’ is referenced, this simply means, measurements actually made on the ground; on our earth’s round surface. When ‘grid’ is referenced, this means that it is projected onto a particular projection. In the case of this study, the projection will always be Colorado State Plane, North Zone, NAD 83 (hereon referred to as grid). Data is always distorted when projecting; this is why surveyors almost always present georeferenced data on ground. Ground is what happens in the ‘real world’. In our area of interest when converting from ‘Ground to Grid’, the data is always shrunk by a small amount. In small sites, you’ll only see a couple hundredths of a foot difference, whereas with larger parcels, you could see a foot or more. Typical combined factors for this area is typically more than 0.999 and less than 1.0. To get from ‘Ground to Grid’, you must multiply your data by this combined scale factor (or the inverse to get from ‘Grid to Ground’). Details of ground to grid are common to Land Surveyors however aren’t known by many in the GIS community. Below is a graphical representation of what is taking place.

(AshTech Solutions, 2)
It is necessary to investigate the collected data in both systems. When data is on 'ground', we can compare that data with the recorded survey in the office. Once data is converted to grid, we can compare it to the GIS parcel shapefile. Let it be noted that ground coordinates in this study is always a modified version of grid coordinates.

Office Calculations and Data manipulation:

After data is collected, two different projects were created in TBC for each site; one for ground and one for grid. Ground was investigated first. Data was first brought straight into TBC in its original format; ground coordinates. From this, a comma-separated values (csv) file is exported and then brought straight into AutoCAD Civil 3D. Office work was necessary to generate the remainder of corners not collected in the field, referred to as calculated points. Using coordinate geometry (COGO), all boundaries of the recorded survey were determined. COGO, simply means that you're generating lines based on bearings and distances. First, the survey was verified that it did indeed close; meaning that after you used COGO to generate all the boundary lines, that the beginning point and ending point are the same. All parcels used in this study did close. The boundary lines that were generated by COGO from the deposited survey will be here forth referred to as the 'survey boundary'.

Once the survey boundary was created, simple rotation and translation was used to place the polygon in the correct position based on points found in the field hence why a minimum of two points were needed per site. If in the case of three points, the third point was used as a mathematical check for accuracy. Next, a comparison of the survey boundary was made with the points collected in the field. It was found that all points collected were within an acceptable
tolerance (less than 0.15 feet). Once the parcel was properly compared to the survey and determined to meet acceptable error tolerances, the grid coordinates were investigated. It is necessary to check the survey to ground coordinates to verify the accuracy of the survey and points found on the ground.

Subsequent to checking the quality of the deposited survey, data was next explored in Grid. Using TBC, a simple project changing can change our coordinate system from ground (modified grid), into grid. This is a simple mathematical procedure that this program can implement in a seamless fashion. New projects were generated for all sites and converted into grid. After this, the combined scale factor was noted and a csv file was exported for further analysis.

Upon exporting grid coordinates for all sites, data was imported into Civil 3D. The survey boundaries were not quite ready for comparison; these parcels needed to be scaled by the combined scale factor so they can be properly placed on grid. Once all the survey boundaries have been scaled by their appropriate combined scale factor (different per site), they were then rotated and translated onto the grid points that were brought into the software. Next the sites from Boulder County parcel shapefiles were then imported into Civil 3D using a Map 3D function. A simple comparison of all boundary corners were investigated to determine the mathematical difference between the shape file compared to the GPS located points or calculated points.

Analysis:

Below is an example of what was done on each site. The site below is parcel 1 (Oak).
The survey boundary is in red, Boulder County’s parcel shapefile is in green, points located are in blue.
<table>
<thead>
<tr>
<th>Site</th>
<th>Site Description</th>
<th>Type of map</th>
<th>Number of Parcels</th>
<th>Shape</th>
<th>Closest Corner (feet)</th>
<th>Farthest Corner (feet)</th>
<th>Average (feet)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parcel 1</td>
<td>Oak Street Plat</td>
<td>Land Survey</td>
<td>2</td>
<td>Accurate</td>
<td>32</td>
<td>47</td>
<td>39</td>
<td>Analyzed entire boundary (no interior corners existed).</td>
</tr>
<tr>
<td>Parcel 2</td>
<td>Nissan Dealership</td>
<td>ALTA/ACSM</td>
<td>8</td>
<td>Accurate</td>
<td>56</td>
<td>107</td>
<td>79</td>
<td>Analysis is only boundary of all lots on north side of alley.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land Title Survey</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Southern portion not included in study.</td>
</tr>
<tr>
<td>Parcel 3</td>
<td>Lefthand Circle</td>
<td>ALTA/ACSM</td>
<td>1</td>
<td>Accurate</td>
<td>79</td>
<td>143</td>
<td>108</td>
<td>Easterly line does not reflect jog which is shown on Condominium map</td>
</tr>
<tr>
<td>Parcel 4</td>
<td>Bluff S</td>
<td>Condominium Map</td>
<td>1</td>
<td>Not Accurate</td>
<td>20</td>
<td>53</td>
<td>34</td>
<td>Analysis is only boundary of subdivision.</td>
</tr>
<tr>
<td>Parcel 5</td>
<td>Baseline</td>
<td>Subdivision</td>
<td>4</td>
<td>Accurate</td>
<td>35</td>
<td>90</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Parcel 6</td>
<td>NST</td>
<td>Land Survey</td>
<td>1</td>
<td>Not Accurate</td>
<td>18</td>
<td>106</td>
<td>56</td>
<td>Small jog on south side that is not reflected on GIS.</td>
</tr>
</tbody>
</table>

Above is a table for each site reflecting the physical difference between Boulder County’s parcel shapefile corners verses points located at the time of this study. In instances where there was more than one parcel surveyed, the boundary of the entire parcel was investigated.
Quality Analysis Quality Control (QAQC):

One way accuracy was verified was by comparing the data collected to the survey boundary while everything was in ground. This verifies the survey is consistent with findings on the ground and that two independent resources come to similar conclusions. Checking the closure of all survey boundaries also aids in verifying that the survey published doesn’t contain obvious blunders. The largest error used between monuments and survey boundary was less than fifteen hundredths (0.15’). Reasons for this error are outlined in the Errors Section.

Every day the researcher was in the field, NGS monuments were found and shot in. Once imported into TBC, a point was generated at its published coordinates and compared to the field coordinates. Errors between published data verses collected data was less than six hundredths (0.05’). Using these two independent methods as QAQC verifies that the data collected accurate and precise.

Errors

There are many several sources for error in the parcel shapefile provided by Boulder County. Their shapefile began back in the mid 80’s (Braddock) and has progressively improved through the years due. This shapefile was primarily based on digitizing old tax maps and using COGO to generate boundaries. Years later they received geodetic positions on all section corners provided by the BLM. They completely revamped their data to match the provided data. Later georeferenced imagery came through and they once again did a complete overhaul of their shapefile to make it more accurate. Due to the interconnectedness of the parcels, it’s impossible to
just work on one piece, the entire set must be considered. To make sure parcels close, on the spot, stretching and shrinking took place to verify sound topology. This file continues to become more accurate as more data and iterations take place.

Inherently surveys don't always match up perfectly when comparing field measurements to the published survey. This could be due to acceptable errors within the profession or perhaps errors made in the field. Monuments can also move in the field either by man or natural processes (freeze/thaw cycle for example).

Error also exists in the GPS set up. Though it is incredibly accurate (less than 0.10, checked into NGS points within 0.05°), the signal can bounce off of buildings or trees, atmospheric conditions could become adverse, or satellite geometry could become unfavorable. In the field, precautions were made to ensure quality data.

Conclusion:

This study shows Boulder County's Parcel Mapping isn't as accurate as their office predicted. The importance of this study is to show the importance of field verification for QAQC. It's nearly impossible to claim certain accuracies without any actual field measurements. Boulder County has one of the more sophisticated online GIS systems however that doesn't change the fact that their data isn't that accurate. They believed that their parcel shapefiles in the flat regions of Boulder County were within six (6) feet. My findings indicated errors over twice that speculated amount, with one property corner at 14.3 feet off. This is a fascinating finding and helps give authority to surveyors for what they do. Although my research question was regarding
mathematical differences, the primary inquiry can't be answered right away. This question is ‘What’s going to happen to the old practice of Land Surveying?’ As the accuracy of GIS cadastral mapping gets better, how will this affect the profession of Land Surveying? As indicated in the introduction, history shows us that accuracy will continue to increase as time passes. One could logically deduce that all County GIS parcel maps could one day be to a survey-grade accuracy. If this speculation regarding GIS and accuracy is true, what will happen to one of the world’s oldest professions? Will these two industries end up merging together? Will this ancient profession simply die out as many suspects?

It is important for both industries to have an analysis shown in this study so future researchers are have a baseline for the forthcoming studies. It’s possible that upcoming researchers could provide a developmental design (time-series) experiment to view alternate trends and provide statistical predictors. This investigation would certainly answer some questions regarding previously mentioned variables for these two industries but more importantly, it has a great potential provoke more inquiries regarding what the future will hold for these two professions.
**List of Abbreviations:**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALTA/ACSM</td>
<td>American Land Title Association/American Congress on Surveying and Mapping</td>
</tr>
<tr>
<td>CRS</td>
<td>Colorado Revised Statutes</td>
</tr>
<tr>
<td>CORS</td>
<td>Continuing Operating Reference Station</td>
</tr>
<tr>
<td>DBMS</td>
<td>Database Management System</td>
</tr>
<tr>
<td>HARN</td>
<td>High Accuracy Reference Network</td>
</tr>
<tr>
<td>FGDC</td>
<td>Federal Geographic Data Committee</td>
</tr>
<tr>
<td>GLONASS</td>
<td>Global Navigation Satellite System (Russian Satellite constellation)</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
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<td>Virtual Reference Station</td>
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References:


http://maps.bouldercounty.org/boco/emapping/


