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Google Imagery Assessment
Shelby County, Alabama

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Purpose
This document has been developed for the purpose of assessing the horizontal accuracies of Google Imagery in the location of Shelby County, Alabama. The document provides the foundation for comparison of accuracy statistics between Google Imagery and other imagery datasets.

Background

Location
Shelby County is located in central Alabama. It is positioned southeast of Birmingham and composed of a mix of suburban and rural characteristics with some terrain relief. Shelby County has significant investments in mapping and geographic information systems (GIS) and has historically acquired high resolution orthoimagery every few years.

Imagery
The Shelby County orthoimagery used in this assessment was acquired in the winter of 2012 and is a natural color (RGB), 6-inch resolution dataset meeting all accuracy standards for 1”:100’ scale imagery put forth by the Alabama Department of Revenue (ADOR, 2010). This dataset was used for reference purposes only.

The Google Imagery was also acquired in the winter of 2012 and has the following specifications as reported by Google:

Table 1 - Google Imagery Product Specifications (Google, 2013)

Imagery Resolution	15 cm resolution
Positional Accuracy (CE90)	1 meter
Spectral Bands	Blue, Green, Red, (CIR licensing possible as add-on)
Processing	Orthorectified and mosaicked
Clouds	<1 percent
Bit Depth	8 bits per pixel (scaled from 12-bit source)
Snow and Ice	Only permanent snow or snow above timberline
Sun Angle	>=30 degrees
Smoke / Haze	<1 percent - Detail is visible
Format	JPEG2000
Tiling	4,096 by 4,096 pixels
Coordinate System	Geographic

Horizontal Accuracy Tests

While several horizontal accuracy tests exist, but the most prominent are the Circular Error of 90%, the Root Mean Square Error, and 1 Sigma. The following paragraphs describe each of these methods.

CE90

Circular Error of 90% (CE90) is commonly used for quoting and validating geodetic image registration accuracy. A CE90 value is the minimum diameter of the horizontal circle that can be centered on all photo-identifiable Ground Control Points (GCPs) and also contain 90% of their respective twin counterparts acquired in an independent geodetic survey. It can be stated as the radial error which 90% of all errors in a circular distribution will not exceed. Circular error may be defined as the circle radius, $\boldsymbol{R}$, that satisfies the conditions of the equation below, where $\boldsymbol{C.L.}$ is the desired confidence level (Ross, 2004).

Equation 1 - CE90 (Greenwalt and Shultz, 1962)

$$C.L. = \int_{-R}^{R} \int_{-\sqrt{R^2-x^2}}^{\sqrt{R^2-x^2}} \frac{1}{2\pi\sigma_x\sigma_y\left(1-\rho^2\right)} \exp\left[\frac{-1}{2\left(1-\rho^2\right)}\left[\left(\frac{x-\mu_x}{\sigma_x}\right)^2 - 2\rho\left(\frac{x-\mu_x}{\sigma_x}\right)\left(\frac{y-\mu_y}{\sigma_y}\right) + \left(\frac{y-\mu_y}{\sigma_y}\right)^2\right]\right] dydx$$

RMSE

Root Mean Square Error (RMSE) is commonly used for quoting and validating geodetic image registration accuracy. A RMSE value is a single summary statistic that describes the square-root of the mean horizontal distance between all photo-identifiable GCPs and their respective twin counterparts acquired in an independent geodetic survey.

RMSE is the square-root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or less than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product (FGDC, 1998).

Equation 2 - RMSE 1 Dimensional (Ross, 2004)

$$RMSE_x = \sqrt{\sum \frac{\Delta X_i^2}{n}} \qquad RMSE_y = \sqrt{\sum \frac{\Delta Y_i^2}{n}}$$

Equation 3 - RMSE 2 Dimensional (Ross, 2004)

$$RMSE_r = \sqrt{RMSE_x^2 + RMSE_y^2}$$

1-Sigma

1-Sigma (Standard Deviation Error) is used for quoting and validating geodetic image registration accuracy. 1-Sigma is the minimum diameter of the horizontal circle that, when centered on all of the photo-identifiable GCPs, would contain one Standard Deviation (i.e. ~68%) of the population of all available twin counterparts acquired in an independent geodetic survey. This is provided that the GCP population is sufficiently large for their relationship to be "normally" distributed (Congalton and Green, 2008).

Accuracy Standards

The use of certain standards ensures the consistency and dependability of geographic data. These standards exist to provide experiential unit, regardless of location, when using geographic data and to ensure compatibility between different datasets. Such standards must provide a foundation on which expectations can be measured. At present, the following standards represent the most prevalent criteria for assessing the accuracy of aerial photography and photogrammetry.

NMAS

The National Map Accuracy Standards (NMAS) were published in 1941 by the U.S. Bureau of the Budget in an attempt to provide a foundation for maps generated throughout the U.S. The document was surprisingly short and was only revised twice since then, in 1943 and in 1947. The portions of the document that are relevant to this assessment are as follows (U.S. BUREAU OF THE BUDGET, 1947; Schuckman and Renslow, 2014; Falkner and Morgan, 2002):

"Horizontal accuracy. For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc."

"The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of the testing."

ASPRS

The American Society for Photogrammetry and Remote Sensing (ASPRS) created these standards in July of 1990 in a report titled "ASPRS Accuracy Standards for Large-Scale Maps". These standards were a response to the need for scale-independent accuracy standards.
The ASPRS standards explicitly used the statistical term, Root Mean Square Error (RMSE), and described a method of testing and reporting that related this more modern statistical language to map classes and contour intervals (ASPRS, 1990; Schuckman and Renslow, 2014; Falkner and Morgan, 2002).

Table 2 - ASPRS Standards for Maps in Feet (ASPRS, 1990)

	RMSE		
Map Scale	**Class I**	**Class II**	**Class III**
1:60	0.05	0.1	0.2
1:120	0.1	0.2	0.3
1:240	0.2	0.4	0.6
1:360	0.3	0.6	0.9
1:480	0.4	0.8	1.2
1:600	0.5	1.0	1.5
1:1200	1.0	2.0	3.0
1:2400	2.0	4.0	6.0
1:4800	4.0	8.0	12.0
1:6000	5.0	10.0	15.0
1:9600	8.0	16.0	24.0
1:12000	10.0	20.0	30.0
1:20000	16.7	33.4	50.1

NSSDA

The National Standard for Spatial Data Accuracy (NSSDA) implements a statistic and testing methodology for positional accuracy of maps and geospatial data derived from sources such as aerial photographs, satellite imagery, or maps. Accuracy is reported in ground units. The testing methodology consists of the comparison of dataset coordinate values with coordinate values from a higher accuracy source for points that represent features readily visible or recoverable from the ground. While this standard evaluates positional accuracy at points, it applies to geospatial datasets that contain point, vector, or raster spatial objects. Data content standards, such as FGDC Standards for Digital Orthoimagery and Digital Elevation Data, will adapt the NSSDA for particular spatial object representations.

The standard insures flexibility and inclusiveness by omitting accuracy metrics, or threshold values, that data must achieve. However, agencies are encouraged to establish "pass-fail" criteria for their product standards and applications and for contracting purposes. Ultimately, users must identify acceptable accuracies for their applications (FGDC, 2008; Schuckman and Renslow, 2014; Falkner and Morgan, 2002).

Methodology

The accuracy assessment approach was based on NSSDA guidelines for testing and evaluation. Initially the geographic extent of the assessment was determined. Shelby County, Alabama was selected based on the availability of recent high-quality orthoimagery and an extensive survey-grade control point network.

The standard’s guidelines require the testing of the sample dataset against an independent higher accuracy dataset. For this assessment the sample dataset was Google Imagery (referred to herein as the “test” set) and the independent higher accuracy dataset was Shelby

County’s control point network (referred to as the “independent” set) (FGDC, 1998).

The methodology used in this assessment of accuracy was a comparative process of associating chevrons on the “test” dataset with each control point on the “independent” dataset. Once identified, a point was placed in the interior crest of each chevron on the “test” and a measurement was made between the “independent” control point and the newly created “test” assessment sample point. The new assessment sample points were saved in an ESRI shapefile. NSSDA does not require that measurements be made, because the recorded coordinates are used to calculate the distances between the “test” and “independent” datasets. This extra step was added to aid with the summary statistics that are used in the narrative of this report.

To achieve a 95% confidence level NSSDA states the following:
“A minimum of 20 check points shall be tested, distributed to reflect the geographic area of interest and the distribution of error in the dataset. When 20 points are tested, the 95% confidence level allows one point to fail the threshold given in product specifications.” (FGDC, 1998)

In order to eliminate bias in this assessment, each control point in the “independent” dataset was assigned a number in sequence from 1 to 102. A random number generator was used to select 20 numbers. Control points in the “independent” dataset matching these random numbers were then used as the sample population for accuracy assessment.

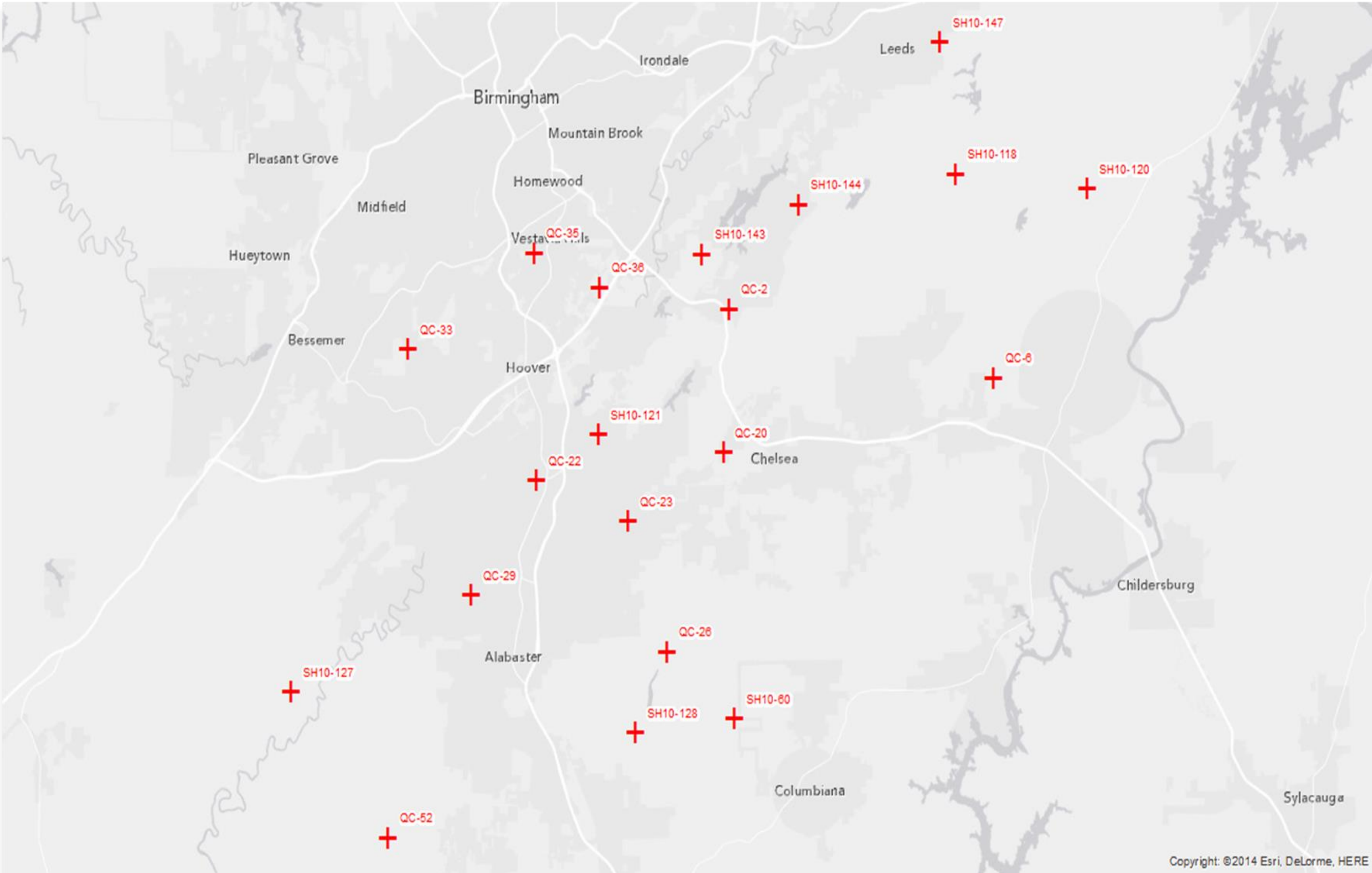

Figure 1 - 20 Randomly Selected Control Points

Assessment

The assessment was conducted in accordance with the NSSDA guidelines and the methodology stated above. The following software was used for the accuracy assessment:

1. ESRI ArcGIS Desktop v10.1
2. Microsoft Excel 2013
3. Microsoft Access 2013

The process of recording the position of each sample point is very repetitious and consists of the following steps in ArcGIS:

1. Zoom to the selected "independent" control point.
2. Load the "independent" orthoimagery for reference.
3. Identify the chevron on imagery.
4. Load the "test" orthoimagery.
5. Place the new "test" point in the crest of the chevron on the "test" orthoimagery.
6. Measure the planar distance in feet between the "independent" and the "test" control points
7. Record the measurement and analyst's notes in Microsoft Excel.

This process is repeated for each of the points in the randomly selected sample set.

Once all of the points were recorded, the following procedure was conducted to extract the X and Y coordinates for each point in the "independent" and "test" populations.

1. In ArcGIS, X and Y fields were added to the "independent" and "test" datasets using the "Add Field" tool in ArcToolbox.
2. The "Calculate Geometry" function was then used to populate the X and Y fields of each dataset.
3. The table for each dataset was then exported to Dbase III (.dbf) file.
4. Each Dbase file was imported into Microsoft Access.
5. A "Query" was created and the two tables were joined based on the PointID field to produce a single table.
6. The output of the query was exported to Microsoft Excel to allow for the NSSDA calculations to be performed (Table 3).

Results

The assessment yielded the following results:

$RMSE_r$ = 1.651781346

NSSDA (95%) = 2.858903153 ft

The assessment revealed that 70% of points tested were off by less than 1 foot, and 35% of the points tested were off by less than 6 inches.

The conclusion to be derived from these statistics is that the assessed Google Imagery meets or exceeds NMAS standards. In addition, the assessed Google Imagery meets or exceeds ASPRS Class II standards for map scale 1”:100’.

Table 3 - Accuracy Assessment Worksheet (FGDC, 2008)

Point number	x (independent)	x (test)	diff in x	(diff in x) ^{2}	y (independent)	y (test)	diff in y	(diff in y) ^{2}	(diff in x)^2 + (diff in y)^2
QC-33	2154786.413	2154786.807	-0.39416	0.15536211	1236180.391	1236181.126	-0.73515	0.54044552	0.695807628
QC-52	2150477.155	2150477.499	-0.34433	0.11856315	1148674.353	1148673.972	0.38097	0.14513814	0.26370129
QC-35	2182129.684	2182130.005	-0.32044	0.10268179	1253355.306	1253355.547	-0.24095	0.0580569	0.160738696
SH10-121	2196070.488	2196070.488	0	0	1220838.341	1220838.341	0	0	0
QC-23	2202555.758	2202556.169	-0.41135	0.16920882	1205405.675	1205406.868	-1.19317	1.42365465	1.592863472
QC-2	2224310.674	2224310.874	-0.20023	0.04009205	1243320.554	1243320.603	-0.04854	0.00235613	0.042448185
QC-6	2281645.77	2281645.618	0.15224	0.02317702	1231069.961	1231070.412	-0.45102	0.20341904	0.226596058
SH10-118	2273483.71	2273486.239	-2.52888	6.39523405	1267581.068	1267581.004	0.06353	0.00403606	6.399270114
SH10-144	2239406.114	2239402.831	3.28314	10.7790083	1262041.847	1262042.903	-1.05638	1.1159387	11.89494696
SH10-127	2129454.384	2129454.384	0	0	1174816.583	1174816.583	0	0	0
QC-26	2210890.646	2210891.154	-0.50816	0.25822659	1182000.799	1182000.846	-0.04678	0.00218837	0.260414954
SH10-147	2270076.781	2270076.781	0	0	1291145.116	1291145.116	0	0	0
SH10-120	2301915.35	2301920.356	-5.00599	25.0599359	1264931.888	1264931.034	0.85425	0.72974306	25.78967894
QC-20	2223117.198	2223116.415	0.78278	0.61274453	1217738.172	1217738.149	0.02331	0.00054336	0.613287885
QC-29	2168406.058	2168405.779	0.27867	0.07765697	1192149.388	1192149.818	-0.42955	0.1845132	0.262170171
QC-36	2196388.908	2196389.142	-0.23347	0.05450824	1247278.468	1247278.454	0.01338	0.00017902	0.054687265
SH10-128	2204036.023	2204037.668	-1.64473	2.70513677	1167514.856	1167514.95	-0.09435	0.00890192	2.714038696
QC-22	2182534.73	2182536.274	-1.54353	2.38248486	1212634.621	1212634.353	0.26783	0.07173291	2.45421777
SH10-143	2218513.993	2218514.459	-0.46562	0.21680198	1253184.513	1253184.124	0.38867	0.15106437	0.367866353
SH10-60	2225502.487	2225501.713	0.77342	0.5981785	1169970.976	1169971.396	-0.42038	0.17671934	0.774897841
								sum	54.56763228
								average	2.728381614
								RMSE	**1.651781346**
								NSSDA	**2.858903153**

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