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Vertical Accuracy Assessment Report

Racine County Elevation Mapping Project

Prepared For:

STARR
(Strategic Alliance for Risk Reduction)

Prepared By:

Quantum Spatial
(Formerly Aero-Metric, Inc.)
4020 Technology Parkway
Sheboygan, WI 53083
P: 920.457.3631
F:920.457.0410

Quantum Spatial Project No: 1130103

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Vertical Accuracy Assessment

Contact Information:

Questions regarding the technical aspects of this report should be addressed to:
Quantum Spatial
4020 Technology Parkway
Sheboygan, WI 53083

Attention: Chris Guy (LiDAR Manager)
FAX: 920-457-0410
Email: cguy@quantumspatial.com

1. Background

The National Standard for Spatial Data Accuracy (NSSDA) defines guidelines for testing and reporting the accuracy of digital geospatial data. The NSSDA makes the assumption that all errors follow a normal error distribution where Root-Mean-Square (RMSE) procedures apply. The Federal Emergency Management Agency (FEMA) guidelines implement the NSSDA standards and recommend the survey of a minimum of 20 checkpoints per ground cover category representative of the area being tested. A minimum of three categories (60 checkpoints) is required. The National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing (ASPRS) provide a method for reporting the vertical accuracy whereby errors in vegetation categories are not assumed to follow a normal error distribution. The ASPRS guidelines are directly referenced to the assessment of LiDAR digital data. In addition to the ASPRS guidelines, the LiDAR must meet the specifications detailed in FEMA's Procedure Memorandum No 61 and the US Geological Survey (USGS) LiDAR Guidelines and Base Specifications - Version 13 so that the data is consistent across agencies and is updated to industry standards.

For the Racine County project, five major ground cover categories were defined by Quantum Spatial as representative of the project area (Hard Surface, Short Grass, Tall Grass, Brush, and Forest). A total of 223 checkpoints were collected over the entire project area.

Quantum Spatial's vertical accuracy assessment for the Racine County project was carried out in accordance with the method mentioned above. This method (defined by NDEP and ASPRS) assumes that errors in some land cover categories may not follow a normal error distribution. Comparing this method helps determine the amount of systematic errors that may exist in the five ground cover categories: Hard Surface, Short Grass, Tall Grass, Brush, and Forest. The following table summarizes the criteria used to evaluate the vertical data.

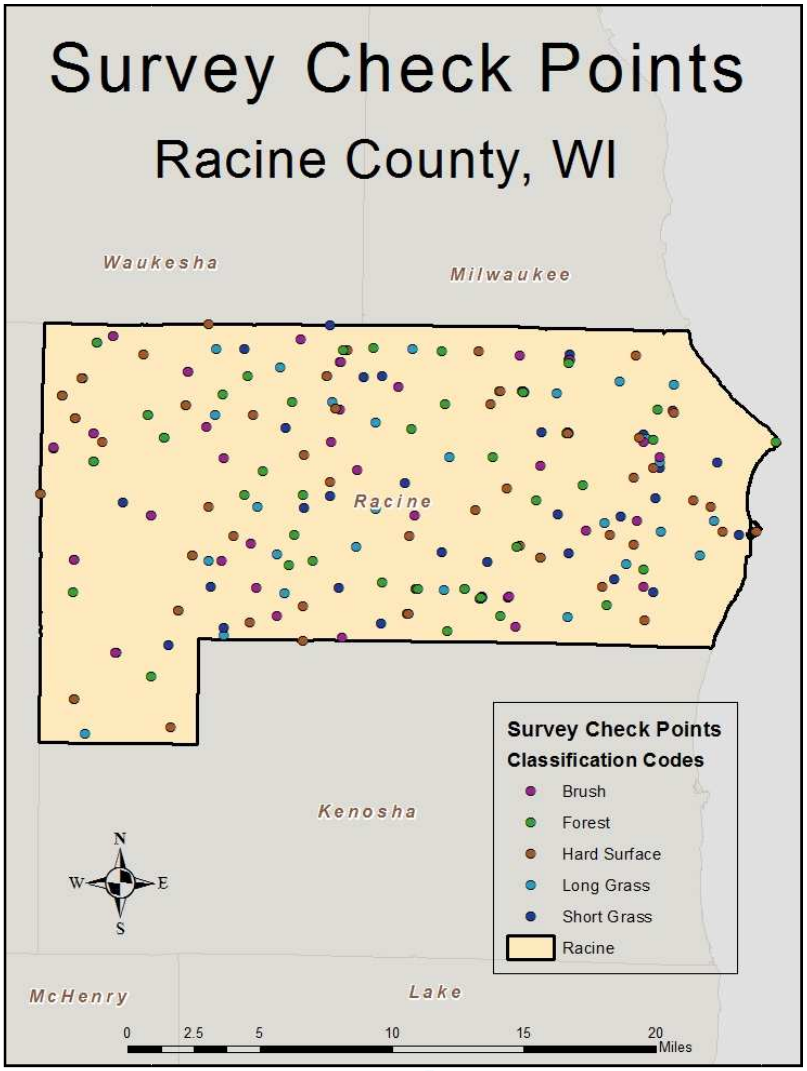
Table 1: DTM Acceptance Criteria

Criteria	Acceptable Value
Fundamental Vertical Accuracy (FVA) in open terrain only = 95% confidence level	1.19 ft ($RMSE_z$ x 1.9600) for open terrain only
Supplemental Vertical Accuracy (SVA) in individual ground cover categories = 95% confidence level	1.19 ft (based on 95th percentile per category; this is a target value only, not mandatory)
Consolidated Vertical Accuracy (CVA) in all ground cover categories combined = 95% confidence level	1.19 ft (based on combined 95th percentile)

2. Procedure

Quantum Spatial tested the digital vertical data using the following steps:

1. Quantum Spatial ground survey personnel collected and processed GPS data for each of the ground cover checkpoints. These points were distributed throughout ground cover category areas within the project limits.
2. The checkpoints were compared to the digital vertical data using the TerraSolid, LTD program TerraScan. The program creates a TIN surface from the digital vertical data and computes vertical differences between the surface and the surveyed checkpoints. An output file records the vertical differences and associated statistics.
3. The results were analyzed by Quantum Spatial to assess the quality of the data. Various accuracy parameters as defined by the ASPRS guidelines were used in the review process. Also, the overall descriptive statistics of each dataset were computed to assess any tendencies or inconsistencies. The tables, graphs, and figures in section 4 illustrate the data quality.



3. NDEP and ASPRS Guidelines

The required Fundamental Vertical Accuracy (FVA), the Supplemental Vertical Accuracy (SVA), and the Consolidated Vertical Accuracy (CVA) are specified by the ASPRS guidelines. FVA determines how well the digital data was collected in open terrain type ground cover where all errors are presumed to be random. The SVA determines how well the digital data represents the actual ground in each of the ground cover categories, tested separately. The CVA determines the overall accuracy of all the ground categories combined as one test.

FVA for this project is calculated using only the checkpoints in the Hard Surface ground cover category, where there is a very high probability that the sensor will have detected the ground surface. The digital data in this category is most likely to represent the actual ground surface (open terrain) and the random errors will follow a normal error distribution. The FVA shows how well the Photogrammetric process used to produce the digital vertical data represents the actual ground. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error ($RMSE_z$) of the checkpoints x 1.9600. As shown in Table 2, the FVA for this project (2 ft contours) is 1.19 ft.

CVA is calculated with all the checkpoints in all the ground cover categories combined. There is a possibility that the digital vertical data may yield errors that do not follow a normal distribution. CVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all ground cover categories combined. The CVA produces a listing of the 5% outliers that are larger than the 95th percentile and that may not follow the normal error distribution.

SVA is computed for each ground cover category separately. There again is a possibility that the digital vertical data may yield errors that do not follow a normal error distribution. Systematic errors per ground cover category are identified. For each category, the SVA at the 95% confidence level equals the 95th percentile error for all checkpoints in each individual ground cover category. The individual SVA statistics are used to analyze the data based on each of the ground cover categories.

4. Results

4.1 Summary of Vertical Accuracy by Fundamental, Consolidated, and Supplemental Methods

Table 2: FVA, CVA, SVA Vertical Accuracy at 95% Confidence Level

Ground Cover Category	# of Points	FVA Fundamental Vertical Accuracy Spec = 1.19 ft	CVA Consolidated Vertical Accuracy Spec = 1.19 ft	SVA Supplemental Vertical Accuracy Spec = 1.19 ft
Total Combined	223		0.920	
Hard Surface	46	0.980		0.936
Short Surface	44			0.751
Long Grass	45			0.977
Brush	43			0.748
Forest	45			0.862

The digital vertical data for the Racine County project meets all mandatory and target specifications as per the following vertical accuracy tests:

Compared with the 1.19 ft FVA specification, FVA tested 0.98 ft at the 95% confidence level on the open terrain (Hard Surface) ground cover category, based on $RMSE_z$ x 1.9600. The NDEP and ASPRS specifies that vertical accuracy at the 95% confidence level equals $RMSE_z$ x 1.9600; this method is valid only when random errors follow a normal error distribution, as in the Hard Surface category.

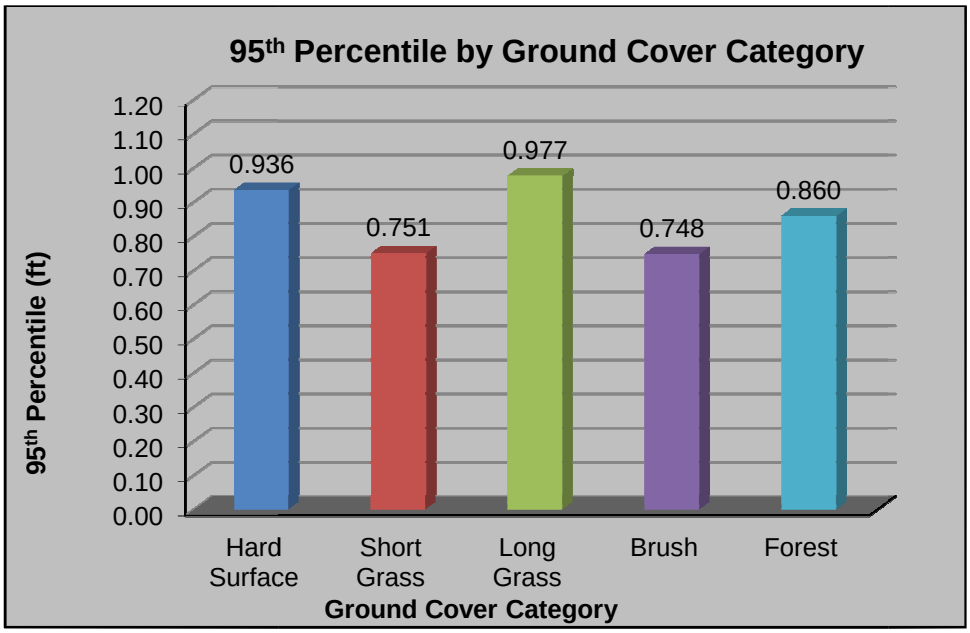
Compared with the 1.19 ft CVA specification, CVA tested 0.92 ft at the 95% confidence level on the Hard Surfaces, Short Grass, Long Grass, Brush, and Forest ground cover categories combined, based on the 95th Percentile. NDEP and ASPRS guidelines specify that vertical accuracy at the 95% confidence level equals the 95th percentile when random errors may not follow a normal error distribution, as in vegetated or obstructed areas. Table 3 lists the 5% outliers larger than the 95th percentile (0.92ft).

Table 3: 5% Outliers Larger than 95th Percentile

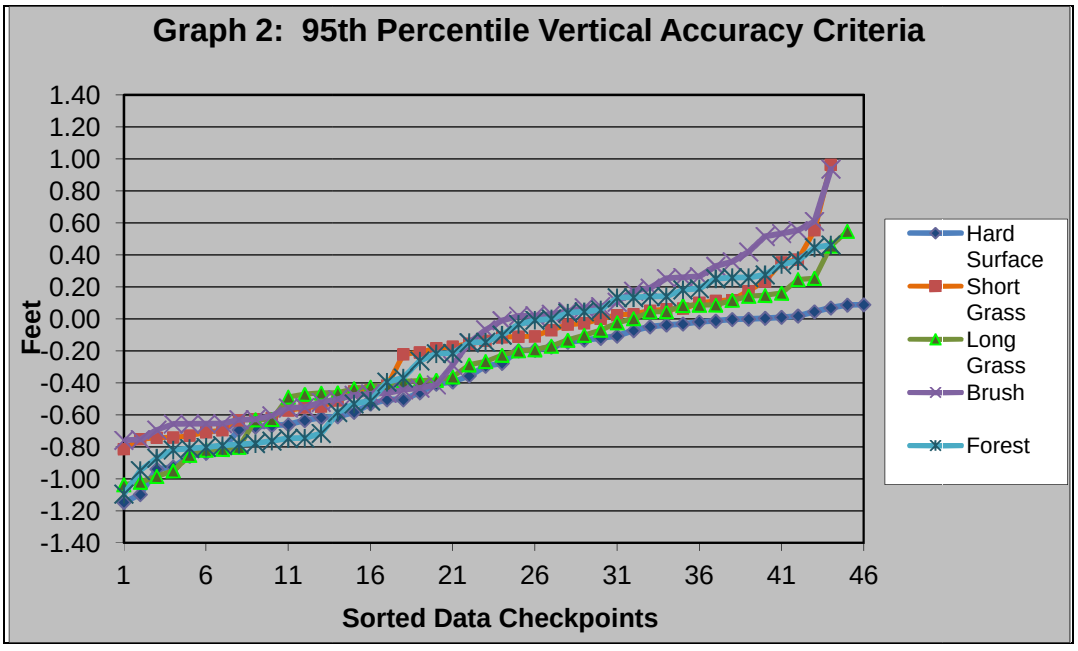
Ground Cover Category	Elevation Difference (ft.)
Long Grass	0.984
Hard Surface	1.147
Long Grass	1.036
Long Grass	1.021
Short Grass	0.963
Long Grass	0.95
Brush	0.936
Forest	0.947
Forest	1.095
Hard Surface	1.097
Hard Surface	0.939
Hard Surface	0.926

Compared with the 1.19 ft SVA target values, SVA tested 0.936 ft at the 95% confidence level on Hard Surfaces; 0.751 ft in Short Grass; 0.977 ft in Long Grass; 0.748 ft in Brush; and 0.860 ft in Forest ground cover categories, based on the 95th Percentile. None of the categories exceed the target value (1.19 ft).

Graph 1 illustrates the SVA by specific ground cover category:



Graph 2 illustrates the magnitude of the differences between the checkpoints and the digital vertical data by specific ground cover category and sorted from lowest to highest. None of the checkpoints are beyond the 1.19 ft criterion shown in graph 2. This exceeds the 95% requirement, where up to 5% of the checkpoints could be outside the 1.19 ft criteria.



4.2 Vertical Accuracy Testing in accordance with FEMA Procedures

In order to comply with FEMA's current requirements, $RMSE_z$ and other statistics were computed in all five ground cover categories, individually and combined. These statistics are shown in the figures below.

Graph 3 shows the RMSEz values as calculated for each ground cover category separately.

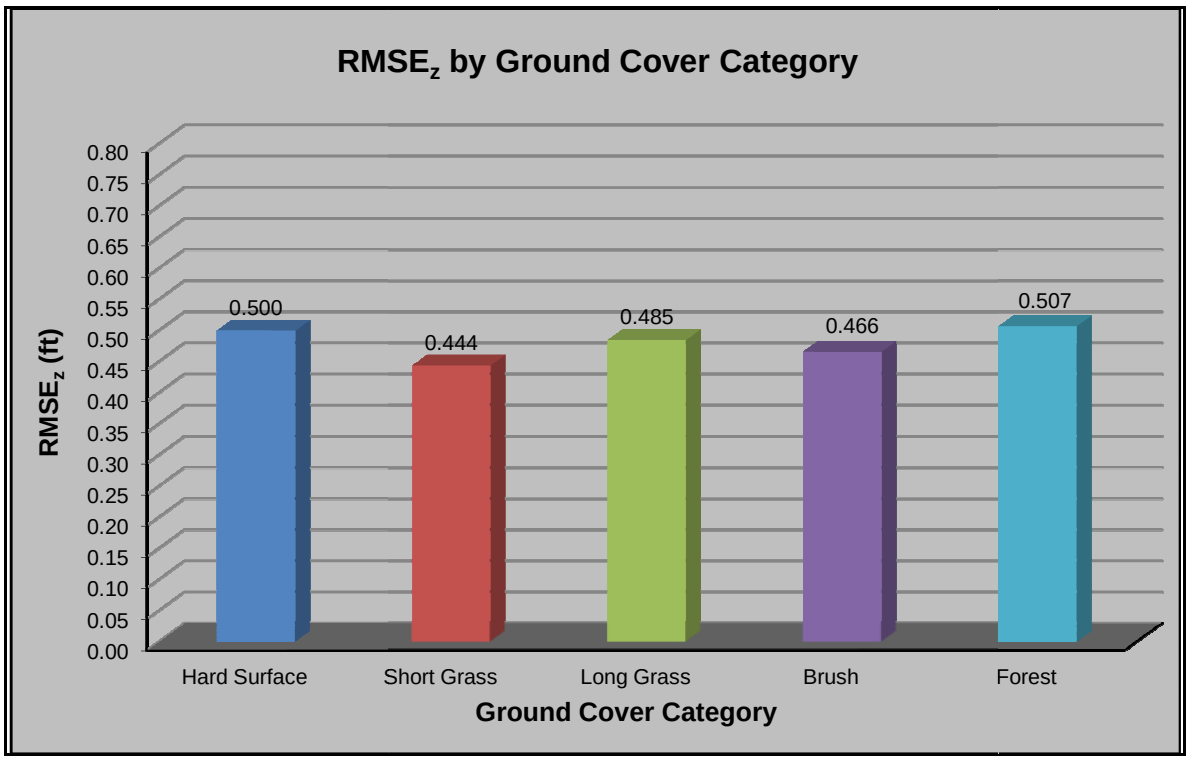
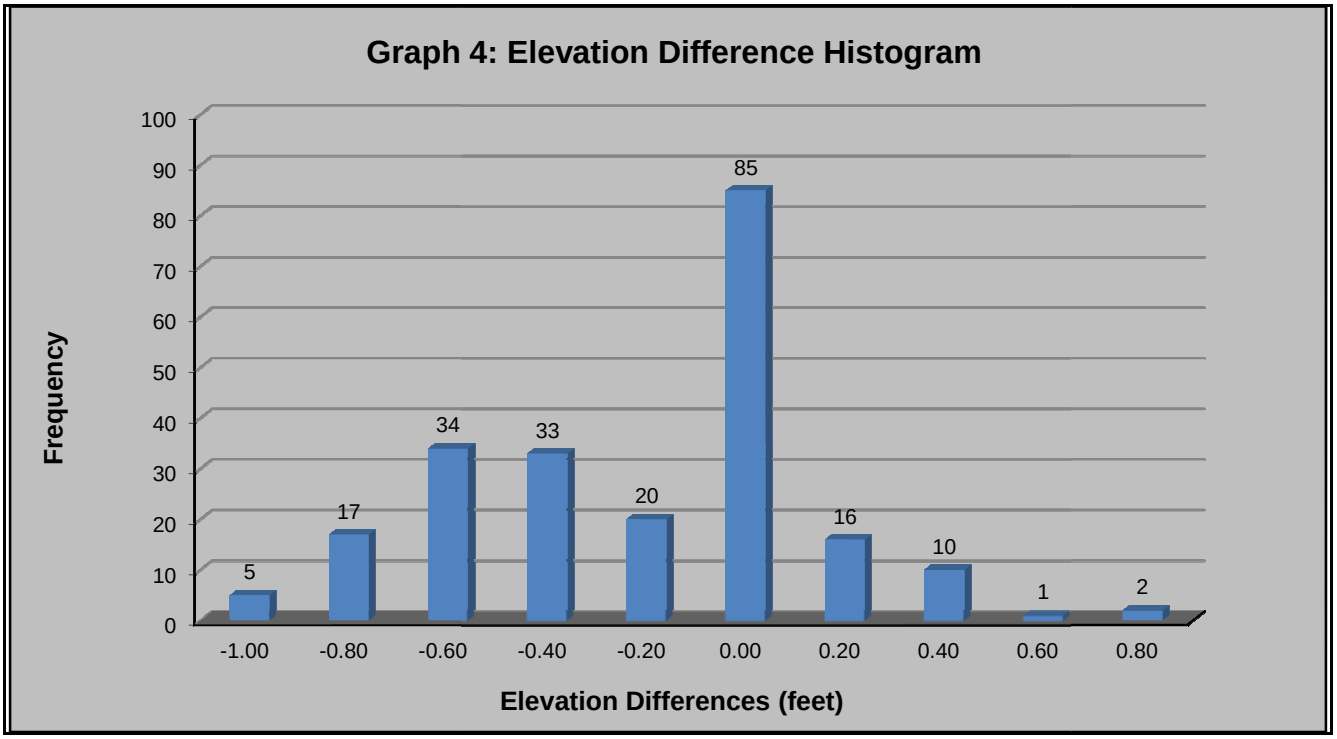


Table 4: Overall Descriptive Statistics by Ground Cover Category

Land Cover Category	$RMSE_z$ (ft.)	Mean (ft.)	Median (ft.)	Skew	Std. Dev (ft.)	# of Points	Min. (ft.)	Max (ft.)
Consolidated	0.481	-0.240	-0.193	0.08	0.418	223	-1.147	0.963
Hard Surface	0.5	-0.358	-0.287	-0.519	0.353	46	-1.147	0.088
Short Grass	0.444	-0.202	-0.147	0.445	0.4	44	-0.813	0.963
Long Grass	0.485	-0.277	-0.266	-0.174	0.402	45	-1.036	0.548
Brush	0.466	-0.131	-0.068	0.335	0.453	43	-0.758	0.936
Forest	0.507	-0.223	-0.145	-0.23	0.461	45	-1.095	0.465

Figure 4 shows a histogram of the elevation differences between the field surveyed checkpoints and the TIN surface computed from the digital vertical data. The histogram shows the number of occurrences (frequency) along the vertical axis that fell within the 0.20 ft ranges shown along the horizontal axis.



5. Conclusions

The vertical accuracy testing methods derived from the NSSDA/FEMA and NDEP/ASPRS guidelines, when applied to the Racine County project, verify that the digital vertical data provided by Quantum Spatial is well suited for the production of 2 ft contours.

Per NSSDA/FEMA guidelines: $RMSE_z$ x 1.9600 = 95% confidence level

0.481 x 1.9600 = **0.943 ft**

Per NDEP/ASPRS guidelines: 95^{th} percentile (CVA) = 95% confidence level

= **0.92 ft**

Both of the 95% confidence level test results exceed the required 1.19 ft accuracy level to support the generation of 2 ft contours.