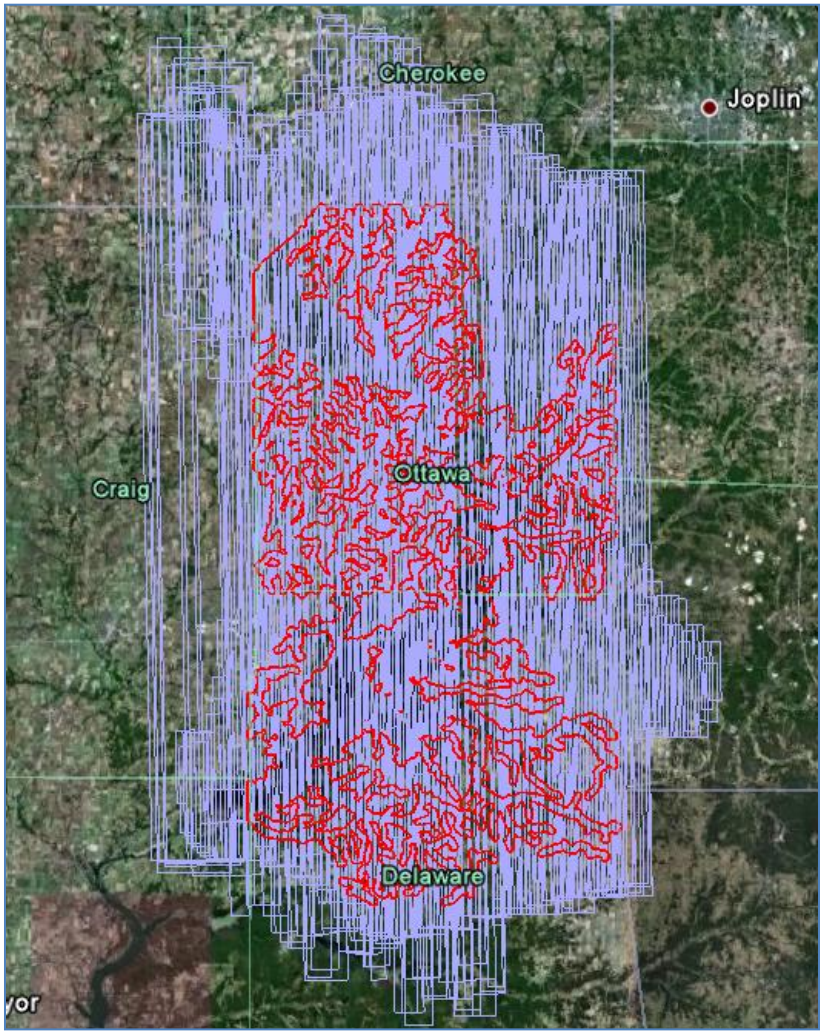
A JV of Dewberry, URS, and ESP
RAMPP
Risk Assessment, Mapping, and Planning Partners

Ottawa and Delaware Counties
Areas of Interest

INDEPENDENT QUALITY CONTROL REPORT



IDIQ Subcontract #: HSFEHQ-09-D-0369-U005
Task Order HSFE02-10-J-0004
Revised September 3, 2010

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Ottawa and Delaware Independent Quality Control Report

1 Executive Summary

RAMPP performed a limited review of the Ottawa/Delaware, OK dataset. 100% of the data was checked for completeness and 5% of the data was visually examined at the micro level for qualitative issues according to the scope of work. During the review, several issues that need to be addressed were identified. During the 5% visual review of the classified LAS a number of bridge artifacts and divots were identified in the bare-earth. RMSE Vertical Accuracy checks were run separately for the two AOIs. Both datasets meet FEMA's vertical accuracy specifications.

2 Overview

The Independent Quality Control for the Ottawa/Delaware, OK Areas of Interest (AOIs) was performed by RAMPP to validate the LiDAR data quality for use in support of developing new flood hazard information that will be used in the update and creation of accurate flood zone maps in support of the National Flood Insurance Program. This document reports on the Ottawa and Delaware Counties AOIs data delivery received from the RAMPP subcontractor Laser Mapping Specialists, Inc (LMSI) in March 2011.

2.1 Project Area

The LiDAR acquisition was conducted by LMSI for the AOI in Ottawa and Delaware Counties, Oklahoma. AOI1 covers approximately 1,030 square miles; the boresighted unclassified LAS data for AOI1 was delivered in full swath LAS format. A smaller area within AOI1 was identified and classified which became AOI2. The data collection included a 100 meter perimeter buffer. The area of AOI2 covers approximately 450 square miles and was delivered processed to a Level 2 which is a fully calibrated, classified point cloud LAS data set consisting of:

- Class 1 – Processed but unclassified
- Class 2 – Bare-earth ground
- Class 7 – Low points and noise
- Class 9 – Water
- Class 11 - Withheld

Figure 1 depicts the project area for each AOI that is included in this delivery. The purple line outlines the extent of AOI 1, and the red line depicts AOI2 processed to level 2.

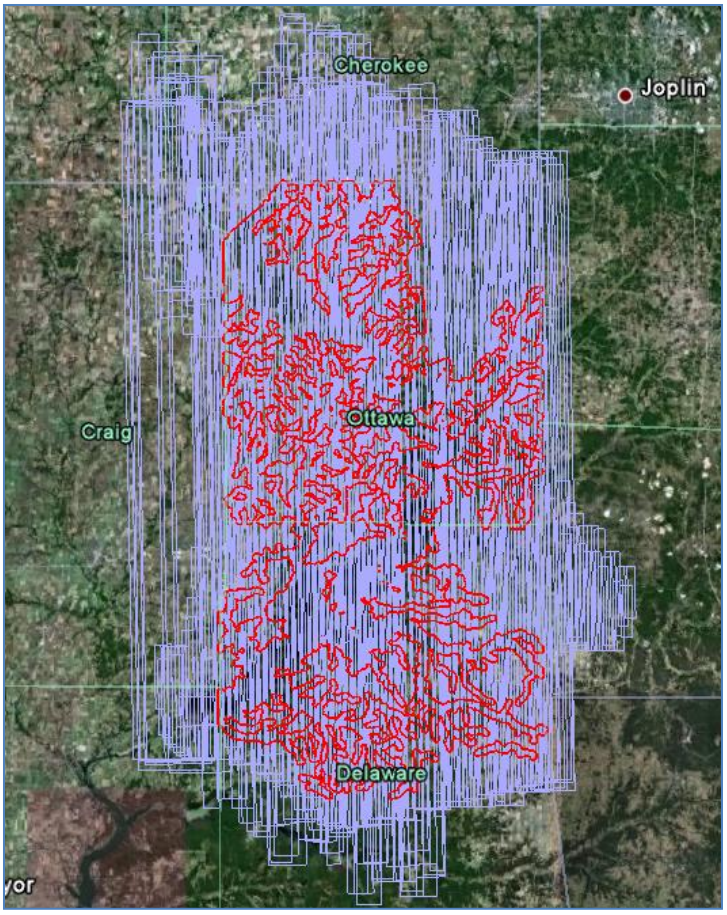


Figure 1: Ottawa and Delaware AOIs data coverage

2.2 Applicable Specifications & Guidelines

In addition, the following specifications/guidelines are applicable to this report:

A. Federal Emergency Management Agency, Procedure Memorandum No. 61 – Standards for LiDAR and Other High Quality Digital Topography, http://www.fema.gov/library/viewRecord.do?id=4345

3 Project Initiation Plan

The following quality control actions were taken prior to the aerial acquisition of LiDAR data for these AOIs and upon receipt of the Project Initiation Plan from LMSI.

3.1 Review of Project Initiation Plan

LMSI was required to submit a Project Initiation Plan for approval, prior to the commencement of data collection operations. The submitted Project Initiation Plan is dated March 10, 2010.

The required content for this plan included:

- Schedule (data acquisition, data processing, data delivery) including contact information for the project and field operation manager(s)
- *Proposed flight lines in ESRI shapefile and graphic format*
- *GPS base station locations in ESRI shapefile and graphic format as well as supporting National Geodetic Survey (NGS) control information*
- *Proposed baseline lengths for aerial collection*
- *Calibration testing methodology*
- LiDAR collection parameters (flying height, scan field of view, angle, pulse rate, scanner frequency, side-lap percentage, point density, etc.)
- *Proposed acquisition windows including maximum position dilution of precision (PDOP) values*
- *Description of internal verification quality control processes:*
    - *Data validation*
    - *Pre-processing and accuracy check*
    - *Processing quality control*
    - *Product delivery quality control*
- *Communication of any issues that might affect the acquisition or processing of the intended project (such as restricted airspace)*

3.1.1 Results

The following table outlines the results of the QA review of the Project Initiation Plan:

QA of Project Initiation Plan – Ottawa, Delaware, OK		
Items Reviewed	**Pass / Fail**	**Comments**
Schedule provided for data acquisition, processing and delivery	Pass	None
Proposed flight lines submitted in GIS and graphic format	Pass	Flight lines provided in graphic format only
Base station location submitted in GIS and graphic format along with NGS control information	Pass	Base station locations provided in graphic format only
Proposed baseline lengths for aerial data collection	Pass	None
Calibration testing methodology(s) described	Pass	None
LiDAR collection parameters described	Pass	None
Proposed acquisition windows and maximum PDOP values outlined	Pass	None
Description of internal verification QC processes:		
Data validation	Pass	None
Pre-processing and accuracy check	Pass	None
Processing quality control	Pass	None
Product delivery quality control	Pass	None
Description of any potential issues that may affect the acquisition or processing of data	Pass	None

3.1.2 Notes and Comments

The Project Initiation Plan submitted by LMSI included several exceptions and clarifications to the specifications outlined by the Work Order. These exceptions and clarifications are outlined in sections 3.1.2 and 3.2.2 of this report.

4 Ground Survey and Data Acquisition

The following quality control actions were taken after the aerial acquisition of LiDAR data for these AOIs and upon receipt of the following reports:

- Acquisition Report – RAMPP LiDAR Acquisition, Ottawa and Delaware Counties, Oklahoma, dated February 23, 2011
- Report of Survey – Ottawa and Delaware Counties, Oklahoma, dated January 6, 2011

4.1 Review of Ground Survey Report

Laser Mapping Specialists, Inc. was tasked by LMSI to perform a ground control survey in support of data collections efforts in Ottawa and Delaware Counties.

The survey conducted in support of data collection efforts was required to meet the following specifications for this project:

- All surveys conducted shall be referenced to National Geodetic Survey (NGS) control monuments in the National Spatial Reference System (NSRS) using appropriate horizontal and vertical control
- Base station locations should be the “best” horizontal (second order or better) and vertical (third order or better) available and have a stability of “C” or better
- New control established where suitable monuments do not exist shall conform to the Standards and Specifications for Geodetic Control Networks (1984), Federal Geodetic Control Committee (FGCC)
- Primary control monuments established with GPS shall meet or exceed NOS NGS-58 “Guidelines for Establishing GPS-Derived Ellipsoidal Heights (Standards: 2 cm and 5 cm)” using the appropriate and latest geoid model and should be monumented to maintain stability and reoccupation if necessary
- Ground control stations are expected to have local network accuracy at the 95% accuracy level of 2 cm horizontally and vertically
- Supporting documentation such as processing reports, minimally and constrained 3-D least squares adjustment, pictures of the stations, etc.

4.1.1 Results

The following table outlines the results of the QA review of the Report of Survey for Ottawa and Delaware Counties, Ok:

QA of Report of Survey –Ottawa and Delaware, OK		
Items Reviewed	**Pass / Fail**	**Comments**
Survey is referenced to NGS control monuments in the National Spatial Reference System (NSRS) using appropriate horizontal and vertical control	Pass	None
Base station locations are the "best" horizontal (second order or better) and vertical (third order or better) available and have a stability of "C" or better	Pass	None
New control conforms to the Standards and Specifications for Geodetic Control Networks (1984), FGCC	Pass	None
Primary control monuments established with GPS meets or exceeds NOS NGS-58 "Guidelines for Establishing GPS-Derived Ellipsoidal Heights (Standards: 2 cm and 5 cm)" using the appropriate and latest geoid model and should be monumented to maintain stability and reoccupation if necessary	Pass	None
Ground control stations meet local network accuracy at the 95% accuracy level of 2 cm horizontally and vertically	Pass	None
Supporting documentation submitted such as processing reports, minimally and constrained 3-D least squares adjustment, pictures of the stations, etc.	Pass	None

4.1.2 Notes and Comments

The following exceptions and clarifications regarding the ground survey were submitted by LMSI in the Project Initiation Plan and approved by RAMPP:

1. New control will meet the NOS NGS-58 Standards for occupation only
2. A stable control point will be set; however, the NOS NGS-58 monumentation standards will not be met
3. Existing and/or new base station control points are expected to have a local network accuracy at the 95% confidence level of 2 cm horizontally and vertically

4.2 Data Acquisition Review

The following project specifications related to the data acquisition were checked for compliance:

- LiDAR is to be collected for two AOIs in Ottawa and Delaware Counties with a 100 meter buffer for a combined area of 1,030 square miles:
  - AOI # 1 – 1,030 square miles
  - AOI # 2 – 451 square miles
- LiDAR is to be collected using sensors capable of a minimum of 3 multiple discrete returns containing range and intensity values for first, intermediate and last returns for each emitted pulse
- The nominal post spacing (NPS) for all identified areas of interest within FEMA Regions II and VI will be 1 meter. Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically 90%) of each swath. Average along-track point spacing will be comparable

- Data Voids [areas => $(4*NPS)^2$, measured using 1st returns only] within a single swath will be deemed unacceptable, except where caused by water bodies, areas of low near infra-red reflectivity, or where filled appropriately by another swath
- Consistent with section 1.6 of the USGS LiDAR Guidelines and Specification, V.13, a regular grid with a cell size of equal to the design NPS*2 will be laid over the first return data within the geometrically usable center portion of each swath and at least 90% of the grid cells shall contain at least one LiDAR point
- The nominal side-lap between adjacent flight lines will be no less than 30%
- The scan angle total Field of View (FOV) shall not exceed 40º (+/- 20º off nadir) with an oscillating mirror scanner
- Relative accuracy shall be <=7cm RMSEz within individual swaths; <=10cm RMSEz within swath overlap areas
- The project area shall be fully and sufficiently covered with no data voids caused by gaps between flight lines and/or sensor malfunctions
- Acquisition window and constraints:
    - Leaf-off conditions required
    - Area shall be free of snow and of flood condition with rivers remaining in their channels and near average heights or lower
    - Extraneous environmental conditions such as rain, fog or smoke shall be avoided
- Base stations used in support of acquisition shall be set for collecting dual frequency data at 1 Hz intervals
- Baseline lengths of base stations shall not exceed 30 miles unless the LiDAR provider can provide definitive proof that longer baseline length for this project can support the project accuracy requirements
- Quality statistics from the airborne GPS/IMU processing shall be made available upon request
- Ground surveys conducted in support of the boresight and processing of the LiDAR shall be tied into the base stations used for acquisition
- All collected swaths shall be delivered as part of the raw data deliverable. Swaths shall be split into segments no greater than 2 GB each with each swath assigned a unique File Source ID.

4.2.1 Results

The following table outlines the results of the QA review of the data acquisition phase for Ottawa and Delaware Counties:

QA of Data Acquisition – Ottawa and Delaware, OK		
Items Reviewed	**Pass / Fail**	**Comments**
LiDAR is to be collected for the Ottawa and Delaware AOI1 and AOI 2 with a 100 meter buffer for a combined area of 1,029 square miles	Pass	None
LiDAR is to be collected using an approved, fully calibrated system capable of collecting multiple echoes per pulse with a minimum of first, last, and one intermediate echo	Pass	None

The system shall be capable of collecting the intensity (LiDAR pulse signal strength) for each echo signal at a minimum 8-bit depth	Pass	None
The nominal post spacing shall be no greater than 1 meter, Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath. Average along-track and cross-track point spacings should be comparable.	Pass	None
The nominal side-lap between adjacent flight lines will be no less than 30%	Pass	None
Total FOV shall not exceed 40º (+/- 20º off nadir) with an oscillating mirror scanner (60 º for Regal sensors)	Pass	None
The project area shall be fully and sufficiently covered with no data voids caused by gaps between flight lines and/or sensor malfunctions.	Pass	None
Data Voids [areas => $(4*NPS)^2$, measured using 1st returns only] within a single swath will be deemed unacceptable, except where caused by water bodies, areas of low near infra-red reflectivity, or where filled appropriately by another swath	Pass	None
Base stations used in support of acquisition shall be set for collecting dual frequency data at 1 Hz intervals	Pass	None
Baseline lengths of base stations shall not exceed 30 miles unless the LiDAR provider can provide definitive proof that longer baseline length for this project can support the project accuracy requirements	Pass	None
Quality statistics from the airborne GPS/IMU processing shall be provided	Pass	None
Relative accuracy – no flightline to flightline or point to point offsets present due to sensor anomalies or mismatches. •Relative accuracy shall be <=7cm RMSEz within individual swaths; <=10cm RMSEz within swath overlap areas	Pass	None
Ground surveys conducted in support of the boresight and processing of the LiDAR shall be tied into the base stations used for acquisition	Pass	None
Swaths split into segments no greater than 2 GB each with each having a unique File Source ID	Pass	None
Acquisition window and constraints:		
Leaf-off conditions required	Pass	None
Area shall be free of snow and of flood condition with rivers remaining in their channels and near average heights or lower (checked using stream gauges)	Pass	None
Extraneous environmental conditions such as rain, fog or smoke shall be avoided	Pass	None
Reports reviewed:		
Flight logs encompassing all collection dates	Pass	None
Aerial acquisition report	Pass	None
Ground survey report	Pass	None

4.2.2 Notes and Comments

No comments.

5 Project Data Deliverables

At this stage of the project none of the deliverables derived from LiDAR are required.

5.1 Review of AOIs Processed to Level 1

The AOI of 1,030 square miles were processed to Level 1. The data was delivered in full swath LAS. Only a statistical review was performed on the Level 1 data to make sure the data meets vertical accuracy specifications and that LAS header information is populated correctly. During the LAS header review it was discovered that vertical citation is not defined for all full swath LAS. Vertical accuracy assessment tables are provided further in the report.

5.2 Review of AOIs Processed to Level 2

The AOI of 450 square miles within Ottawa and Delaware Counties were processed to Level 2 which consists of post-processing to bare earth and other classifications.

The following graphic depicts the coverage of the data for the AOIs (red, shaded areas).

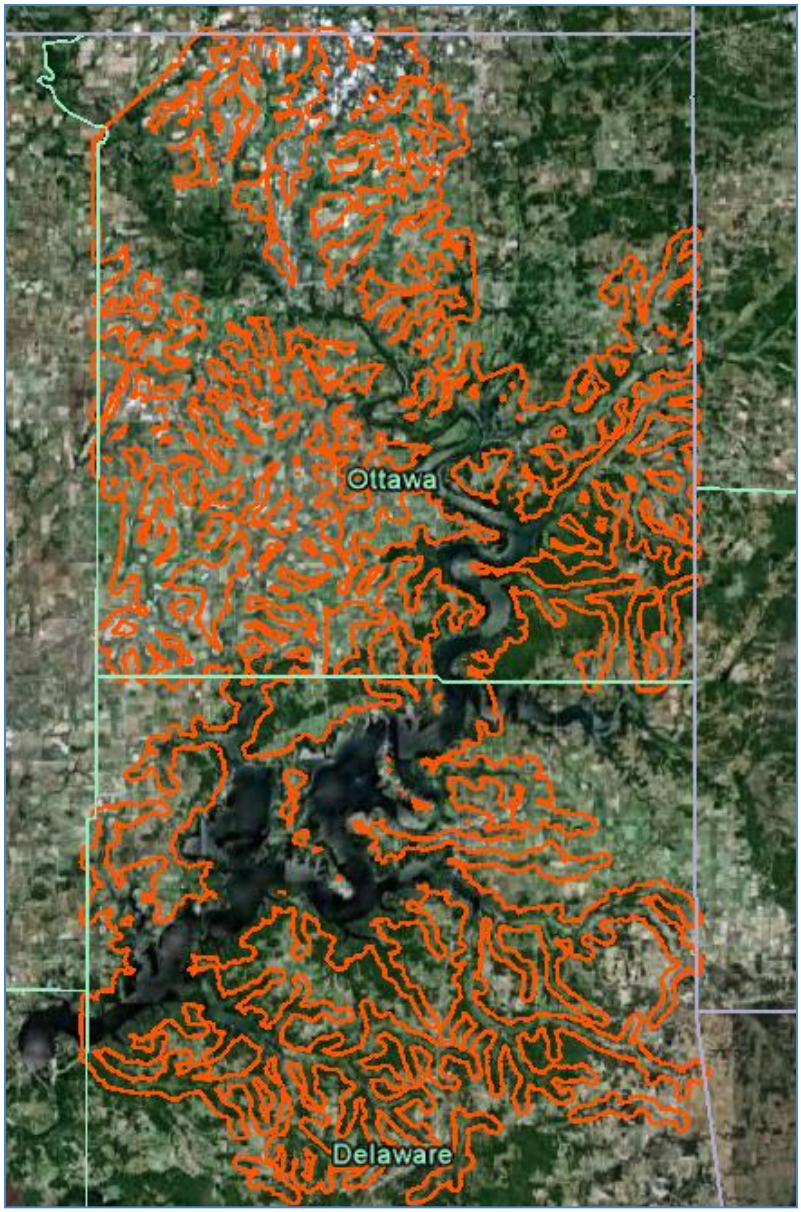


Figure 2 AOI depicted by the orange line

The following project specifications for the data delivery were checked for compliance using a combination of macro and micro checks (conducted on 5% of the data):

Macro checks (used to verify the following for 100% of the data)-

- Data will be processed and delivered in LAS 1.2, where all the required data structure is maintained by the LiDAR processing software, and the current version of Terrascan. All major fields will be maintained
- The header file shall contain, at a minimum, the “File Creation Year day” and “File Creation year” which shall represent the final deliverable LAS date.
- Projection information for the point data shall be specified in the Variable Length Record using the appropriate GeoTIFF tags

- The horizontal datum shall be referenced to the North American Datum NAD83 using the latest adjustment revision (NSRS 2007)
- The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD88)
- The most recent NGS-approved Geoid shall be used to convert ellipsoidal heights to orthometric heights
- The coordinate system used shall be UTM, NAD83, Meters using the predominant UTM Zone for the collection area
- All units will be to 1 cm resolution
- Tile shall align and contain no buffers or over-edges
- Classification codes for shall follow the ASPRS Standard LiDAR Point Classes utilizing only the following:
    - Class 1 – Processed but unclassified
    - Class 2 – Bare-earth ground
    - Class 7 – Low points and noise
    - Class 9 – Water
    - Class 11 - Withheld
- No points shall be deleted from the LAS file (all points must be included)

Micro checks (used to verify the following for 100% of the data)-

- Consistent with section 1.6 of the USGS LiDAR Guidelines and Specification, V.13, a regular grid with a cell size of equal to the design NPS*2 will be laid over the first return data within the geometrically usable center portion of each swath and at least 90% of the grid cells shall contain at least one LiDAR point
- Classifications shall adhere to the following guidelines through the use of automated and manual filtering routines:
    - 90% of artifacts classified
    - 95% of outliers classified
    - 95% of vegetation classified
    - 98% of buildings classified
- Channel geometry of streams and drainage features shall be maintained
- Dense vegetation data voids shall be minimized by the filtering process and “over smoothing” due to aggressive classification filters shall be avoided
- Outliers, blunders, noise points, etc. classified as Class 7 or 1 unless current version of Terrascan allows for use of Class 12 “Withheld”

5.2.1 Macro Check Results

Macro checks are conducted on 100% of the data. The following table outlines the results of the Macro Check QA review of the data set provided for the Pulaski County, AR, AOIs:

Macro Check QA of AOIs Ottawa and Delaware, OK		
Items Reviewed	**Pass / Fail**	**Comments**
Masspoint data delivered in LAS files utilizing the latest Las specification (currently LAS 1.2) containing all LAS items of point data record format 1	Pass	None

The header file contains, at a minimum, the "File Creation Year day" and "File Creation year" and represents the final deliverable LAS date	Pass	None
Projection information for the point data specified in the Variable Length Record using the appropriate GeoTIFF tags	Pass	None
The horizontal datum referenced to the North American Datum NAD83 using the latest adjustment revision (NSRS 2007)	Pass	None
The vertical datum referenced to the North American Vertical Datum of 1988 (NAVD88)	Pass	None
The latest geoid used to convert ellipsoidal heights to orthometric heights	Pass	None
The project data is in UTM, NAD83, Meters using the predominate UTM zone for the collection area	Pass	None
All units reported to 1 cm resolution or 1/100 of a foot	Pass	None
Tile shall align and contain no buffers or over-edges	Pass	None
Classification codes shall follow the ASPRS Standard LiDAR Point Classes utilizing only the following:		
Class 1 – Processed but not classified	Pass	None
Class 2 – Bare-earth ground	Pass	None
Class 7 – Low points and noise	Pass	None
Class 9 - Water	Pass	None
Class 11 - Withheld	Pass	None
No points shall be deleted from the LAS file (all points must be included)	Pass	None

5.2.2 Micro Check Results

Micro checks are conducted on 5% of the data. The following graphic depicts the 5% of the AOI checked:

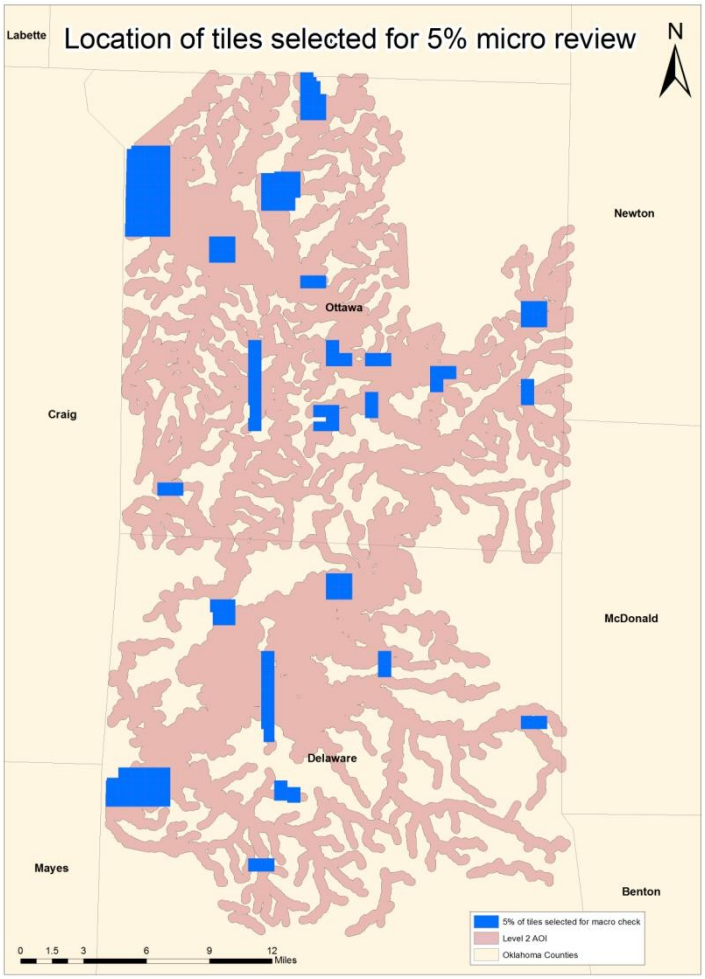


Figure 3:The figure depicts the location of tiles selected for 5% micro review

The following table outlines the results of the Macro Check QA review of the data set provided for the Ottawa and Delaware Counties, OK, AOIs:

Micro Check QA of AOIs – Ottawa and Delaware, OK		
Items Reviewed	**Pass / Fail**	**Comments**
Outliers, blunders, noise points, etc. classified as Class 7 or 1 unless current version of Terrascan allows for use of Class 11 "Withheld"	Pass	None
Classifications shall adhere to the following guidelines through the use of automated and manual filtering routines:		
90% of artifacts classified	Pass	See Below
95% of outliers classified	Pass	None
95% of vegetation classified	Pass	None
98% of buildings classified	Pass	None
Channel geometry of streams and drainage features shall be maintained	Pass	None

Dense vegetation data voids shall be minimized by the filtering process and "over smoothing" due to aggressive classification filters shall be avoided	Pass	None

5.2.3 Notes and Comments

A. RAMPP conducted a micro check QA review of 5%. 122 tiles were visually checked and the following were discovered:
   - 23 bridges artifacts
   - 26 divots
   - 8 building not completely removed
   - 1 misclassification call where waterbody over 2 acres in perimeter is not captured and thus incorrectly classified to ground

B. The 5% data review also determined that channel geometry and drainage features present within the Level 2 AOI were properly maintained and that no features were lost through overly-aggressive filtering.

5.3 Intensity Images

Intensity images derived from the LiDAR point cloud were not required for this scope of work. However, intensity values were provided in the LAS files.

5.4 3D Breaklines

Breakline (hydro-line) generation was conducted in order to classify water points in the LAS and to meet the USGS V.13 specifications for flattening. The following project specifications for the data delivery were checked for compliance by conducting a 5% review of the delivered line work:

- Inland ponds, lakes and boundary waters greater than 2-acres or greater surface area (~350' diameter for a round pond) at the time of collection will be collected in the appropriate hydro-line feature class
- Inland streams and rivers with a 100; nominal width will be collected in the appropriate hydro-line feature class
- Hydro-lines will be delivered as an ESRI feature class (Polyline or Polygon format as appropriate to the type of feature represented and the methodology used) in a geodatabase
- Each feature class or shape file will include properly formatted and accurate georeference information in the standard location. All feature classes must include a projection
- Breaklines must use the same coordinate reference system (horizontal and vertical) and units as the LiDAR points delivery
- Breakline delivery may be as a continuous layer or in tiles, at the discretion of the data producer. Tiled deliveries must edge-match seamlessly in both the horizontal and the vertical

Breakline Check QA of AOIs – Ottawa and Delaware County, OK		
Items Reviewed	**Pass /**	**Comments**

	Fail	
Inland ponds, lakes and boundary waters greater than 2-acres or greater surface area (~350' diameter for a round pond) at the time of collection collected in the appropriate hydro-line feature class	Pass	See Comments
Inland streams and rivers with a 100; nominal width collected in the appropriate hydro-line feature class	Pass	See Comments
Hydro-lines delivered as an ESRI feature class (Polyline or Polygon format as appropriate to the type of feature represented and the methodology used) in a geodatabase	Pass	See Comments
Each feature class or shape file includes properly formatted and accurate georeference information in the standard location. All feature classes include a projection	Pass	None
Breaklines use the same coordinate reference system (horizontal and vertical) and units as the LiDAR points delivery	Pass	None
Breaklines delivered as a continuous layer or in tiles. If tiled deliveries, tiles edge-match seamlessly in both the horizontal and the vertical	Pass	None
Topology rules were validated as specified in the FEMA Procedure Memorandum #61	Fail	See Below

5.4.1 Notes and Comments

FEM has no minimum breakline requirements. Breaklines for Ottawa and Delaware were delivered in a geodatabase.
The following feature classes were provided:

- Ponds and Lakes (Polyline ZM)
- Hydrographicfeature (Polyline ZM)
- Islands (Polyline ZM)

Topology rules were validated and the following topology errors were returned:

- Hydrographic feature – Must Not Intersect: 1 error
- Ponds and Lakes - Must Not Intersect: 11 errors
- Ponds and Lakes - Must Not Self-Intersect: 32 errors

5.5 Low Confidence Areas

Low Confidence Areas were compiled by the data provider in the areas where the vertical data may not meet the data accuracy requirements due to heavy vegetation even thought the specified nominal point spacing was met.
RAMPP made sure that low confidence area were delivered as polygons in accordance with a database schema.

Low Confidence Check for AOIs – Ottawa and Delaware County, OK		
Items Reviewed	**Pass / Fail**	**Comments**
Low confidence areas are captured as polygons in accordance with a database schema	Pass	None

6 QA Process

The following sections outline the general QA process used by RAMPP for this project.

6.1.1 Software

The main software programs used by RAMPP in performing the qualitative assessment are as follows:

- *GeoCue:* a geospatial data/process management system especially suited to managing large LiDAR data sets
- *TerraScan:* runs inside Bentley Microstation; used for point classification checks and points file generation
- *Proprietary tools:* developed in-house to conduct a statistical analysis of .LAS files
- *QT Modeler:* used for analysis and visualization

6.1.2 Qualitative Assessment Process

The following systematic approach was used for performing the qualitative assessment of this delivery.

Macro Checks

- Delivery was reviewed for completeness of content
- Proprietary tools were used to conduct a statistical analysis of delivery to check point classifications, variable-length record values, and maximum/minimum x,y,z ranges
- General reviews
    - Verified that tile naming conventions were followed
    - Verified that deliverable formats are correct
    - Verified relative accuracy looking at DZ Orthos created in GeoCue
    - Verified LAS extend against the provided project boundary

Micro Checks

- Reviewed 5% of the data for anomalies to include:
    - Buildings left in the bare-earth points
    - Vegetation left in the bare-earth points
    - Proper definition of roads and drainage patterns
    - Overpasses and bridges removed from bare-earth points
    - Areas that have been “shaved off’ or “over-smoothed” during filtering
    - Relative accuracy specification is met
    - Point density specification is met

A check of the swath overlap criteria was made by colorizing the LiDAR tiles by source identification (flight line) and making direct measurements in multiple locations of the tile. Figure 5 is an example from the AOIs.

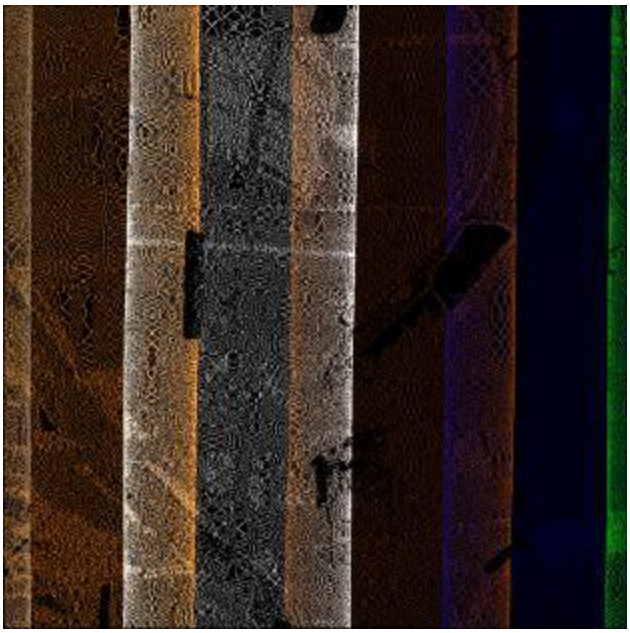


Figure 4 - Example of LiDAR points in tile colorized by source identification

Figure 5 depicts a data density check conducted on a tile (all-echo LAS). The .LAS files are used to produce digital elevation models using the commercial software package "QT Modeler" which creates a 3-dimensional data model derived from Class 2 (ground points) in the .LAS files.

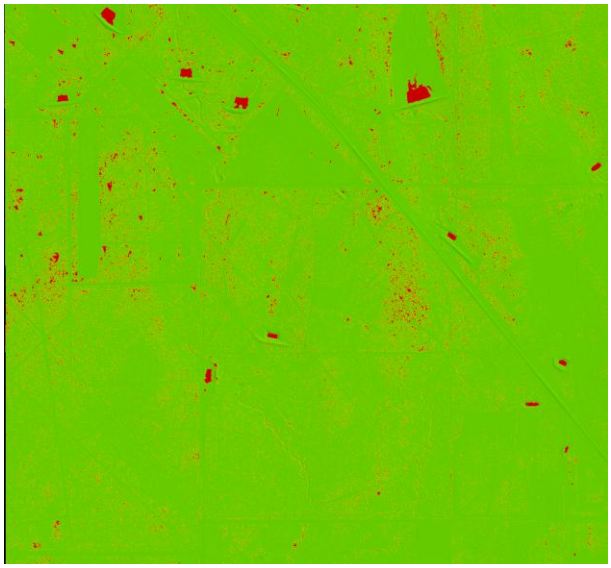


Figure 5 - Density grid of point cloud tile, created using a green to red color ramp. Green areas meet project specifications; red delineates areas not meeting minimum density requirements (primarily water and low-confidence areas)

The LiDAR orthos were one of the tools used to verify data coverage and point density, to check for data voids or gaps, and used as reference data during checks for data anomalies and artifacts. This product is not intended to be a project deliverable. The orthos were derived from the full point cloud elevations and LiDAR pulse return intensity values. Due to the point density of the original collection, the orthos were produced at a

1m pixel for the entire area of interest. Acceptable voids are those found over water features.

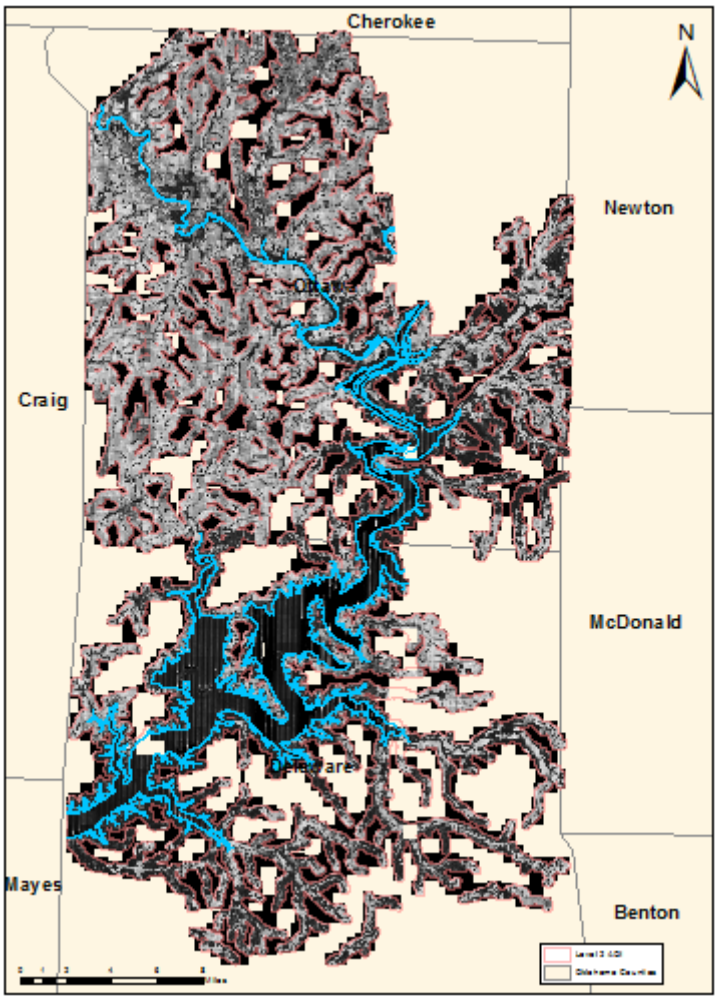


Figure 6 – Example of a void/gap check encompassing one of the Ottawa Delaware AOI2.

7 Metadata

The project metadata was reviewed and checked using the following methods:

- Structure of the metadata file was compared against FGDC standards by using the USGS Geospatial Metadata Validation Service: http://geo-nsdi.er.usgs.gov/validation/
- Metadata content was reviewed using a visual check

8 Data Accuracy Report

RAMPP performed the LiDAR vertical accuracy assessment for the Ottawa and Delaware Counties AOIs in accordance with ASPRS/NDEP and NSSDA/FEMA specifications and guidelines. Separate assessments were conducted for AOI 1 and AOI 2 as they were processed differently.

The LiDAR data produced for this project adheres to the ASPRS/NDEP and NSSDA/FEMA accuracy standards, as referenced in the accuracy section of the IDIQ Subcontract #: HSFEHQ-09-D-0369-U005, Task Order HSFE02-10-J-0004, September 3, 2010.

8.1 Data Accuracy Assessment

The data accuracy assessment for Ottawa and Delaware Counties was conducted for each of the two AOIs. AOI 2 was checked using the bare earth, forested and urban category checkpoints in order to assess the vertical accuracy of the data. AOI 1 was checked using only bare earth checkpoints due to the small area of the AOI and lack of other land cover categories.

8.1.1 Software Used

- *GeoCue:* a geospatial data/process management system especially suited to managing large LiDAR data sets
- *QT-Modeler:* used for direct comparison of the QC checkpoints against the LiDAR Class 2 or ground points
- *Microsoft Excel:* used to calculate accuracy values and statistics from the measurements

8.1.2 Vertical Accuracy Testing Process

The primary quantitative assessment steps were as follows:

1. LMSI acquired new raw LiDAR data from December 3 to December 29, 2010 and performed post-processing to derive the bare-earth digital terrain model.
2. Laser Mapping Specialists, Inc. surveyed 80 ground checkpoints, in 4 land cover categories in accordance with FEMA specifications and guidelines. All project survey work performed by Laser Mapping Specialists, Inc. adhered to the rules and regulations for providing professional land surveying services.
3. Laser Mapping Specialists, Inc. provided RAMPP with a table of horizontal coordinates and orthometric heights for all surveyed checkpoints, classified by land cover category. RAMPP created a triangulated irregular network (TIN) from the bare-earth LiDAR points, and interpolated a z-value at each of the survey point locations.
4. RAMPP compared the LiDAR-derived elevations of the check points to the surveyed check point orthometric heights and computed the vertical accuracy assessment according to FEMA/NSSDA and ASPRS/NDEP specifications.

The spatial distribution of ground checkpoints surveyed by Laser Mapping Specialists, Inc. is shown in Figure 7.

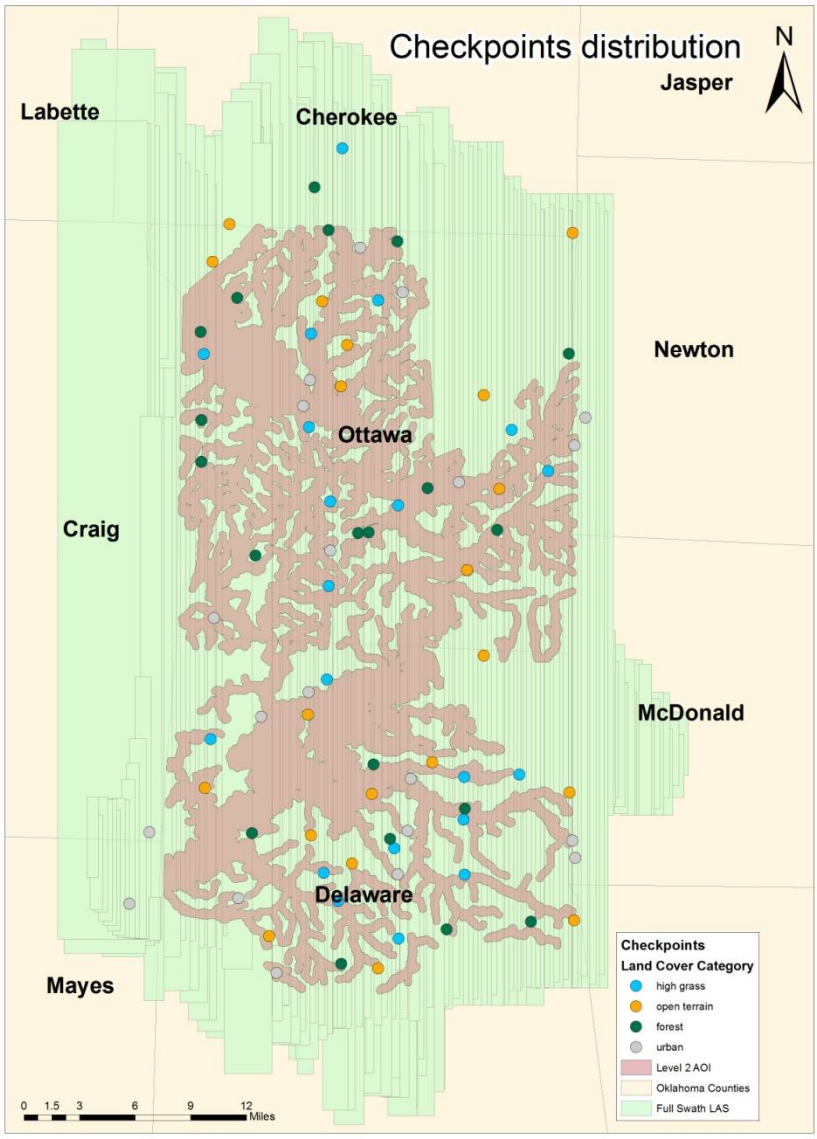


Figure 7 Ottawa Delaware AOIs checkpoints

8.1.3 Vertical Accuracy Testing – NDEP and ASPRS Procedures

Testing was conducted to determine how well the LiDAR sensor performed in the various land cover categories present within the Ottawa/Delaware project area. AOI 1 in Ottawa, Delaware consisted of only the bare earth/low grass category land cover and was therefore only tested for Fundamental Vertical Accuracy (FVA).

FVA was determined across the entire acquisition area using checkpoints located only in land cover areas consisting of bare-earth and low grass, due to the high probability of detecting the ground surface, yielding a normal error distribution. The FVA is reported at a 95% confidence level, which is computed as the root mean square error of the

checkpoint elevations (RMSEz) x 1.96. For this project this project the FVA requirement was 1.19 ft RMSE.

Supplemental Vertical Accuracy (SVA), though not a requirement for this project, was calculated separately for each land cover category that exists within AOI 2; bare earth, urban, high grass and forested. SVA illustrates the quality of the post processing (filtering) of the LiDAR used to determine ground within each land cover category. Post processing may yield elevation errors that do not follow a normal error distribution; therefore the SVA at the 95% confidence level equals the 95th percentile error for all checkpoints in each individual land cover category.

Consolidated Vertical Accuracy (CVA) within the entire AOI was determined by using all checkpoints in all land cover categories combined. CVA assumes LiDAR errors may not follow a normal distribution error in vegetated categories and, at the 95% confidence level, equals the 95th percentile error for all checkpoints in all land cover categories combined.

Tables 1 and 2 summarize the vertical accuracy by fundamental, consolidated, and supplemental methods within each AOI:

AOI 1 - Vertical Accuracy at 95% Confidence Level and 95th Percentile				
Land Cover Category	**# of Points**	**Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec = 0.245 m**	**Consolidated Vertical Accuracy (95th Percentile) Spec = 0.363 m**	**Supplemental Vertical Accuracy (95th Percentile) Spec = 0.365 m**
Consolidated			0.11	
BE & Low Grass	19	0.12		0.11
High Grass				
Brush				
Forest				
Urban				

Table 1 FVA at the 95% confidence level for AOI 1

AOI 2 - Vertical Accuracy at 95% Confidence Level and 95th Percentile				
Land Cover Category	**# of Points**	**Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec = 0.245 m**	**Consolidated Vertical Accuracy (95th Percentile) Spec = 0.363 m**	**Supplemental Vertical Accuracy (95th Percentile) Spec = 0.365 m**
Consolidated	29		0.14	
BE & Low Grass	5	0.15		0.11
High Grass	5			0.13
Brush	0			
Forested	8			0.13
Urban	11			0.15

Table 2 FVA at the 95% confidence level for AOI 2

Figures 9 and 10 illustrate the magnitude of differences between the QC checkpoints and the processed LiDAR data by specific land cover category in each AOI:

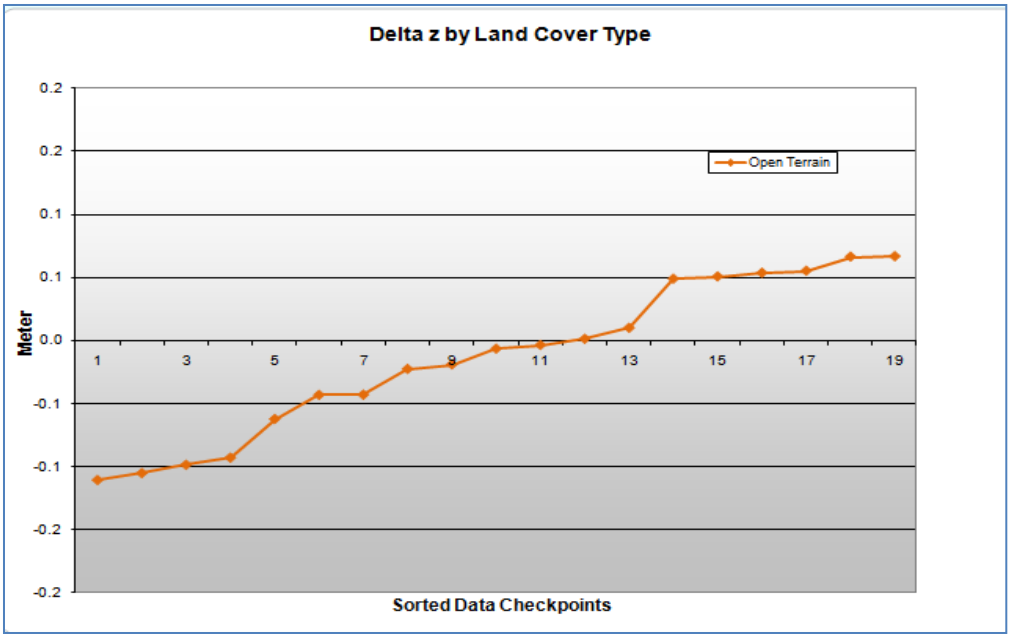


Figure 9 Magnitude of elevation discrepancies by land cover category for AOI 1

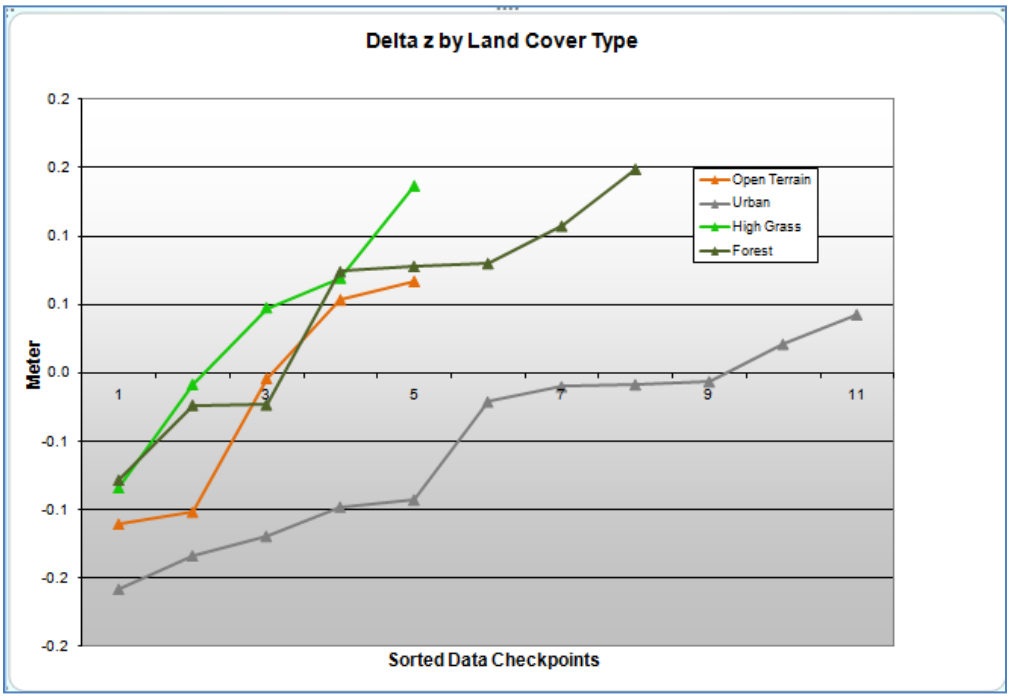


Figure 10 Magnitude of elevation discrepancies by land cover category for AOI 2

8.1.3.1 Analysis of the 95th Percentile

The list of checkpoints used to calculate the RMSE that exceeded the 95th percentile in AOI 1:

Point No	Easting	Northing	Elevation	Z LiDAR	Delta Z, m
O_OD_A_17	355252.1179	4047473.305	297.0367	296.9259	-0.111

The list of checkpoints used to calculate the RMSE that exceeded the 95th percentile in AOI 2:

Point No	Easting	Northing	Elevation	Z LiDAR	Delta Z, m
U_OD_E_62	355685.376	4077629.431	258.586224	258.4525	-0.134
U_OD_E_59	345635.158	4074439.436	236.31144	236.1532	-0.158
H_OD_B_47	323498.910	4085554.451	234.433872	234.5702	0.136

8.1.4 Vertical Accuracy Testing – NSSDA and FEMA Procedures

To comply with current FEMA guidelines, RMSEz statistics were computed in the relevant land cover categories, individually and combined, as well as other recommended statistics for each AOI. This process assists in the analysis to help check for any anomalous characteristics that may be present in the LiDAR data. These statistics are summarized in Tables 3 and 4 below.

AOI 1 - Descriptive Statistics							
100% of Totals	**Points**	**RMSE Spec=0.125 m**	**Mean Error (m)**	**Median Error (m)**	**SKEW**	**STDEV (m)**	**95th Percentile Spec=0.363 m**
Consolidated	19	0.06	-0.01	-0.01	-0.22	0.06	0.11
BE & Low Grass	19	0.06	-0.01	-0.01	-0.22	0.06	0.11
High Grass							
Brush							
Forest							
Urban							

Table 3: Descriptive statistics for AOI 1

AOI 2 - Descriptive Statistics							
100% of Totals	**Points**	**RMSE Spec=0.125 m**	**Mean Error (m)**	**Median Error (m)**	**SKEW**	**STDEV (m)**	**95th Percentile Spec=0.363 m**
Consolidated	29	0.08	-0.01	-0.01	-0.04	0.08	0.14
BE & Low Grass	5	0.08	-0.02	0.00	-0.21	0.08	0.11
High Grass	5	0.08	0.03	0.05	-0.32	0.08	0.08
Forest	8	0.09	0.05	0.08	-0.44	0.08	0.13
Urban	11	0.08	-0.05	-0.02	0.07	0.07	0.15

Table 4: Descriptive statistics for AOI 2

Figures 13 and 14 illustrate histograms of the associated elevation discrepancies between the QC checkpoints and elevations as interpolated from the LiDAR triangulated irregular network (TIN) for each AOI. The frequency of elevation differences is distributed within each band of elevation differences.

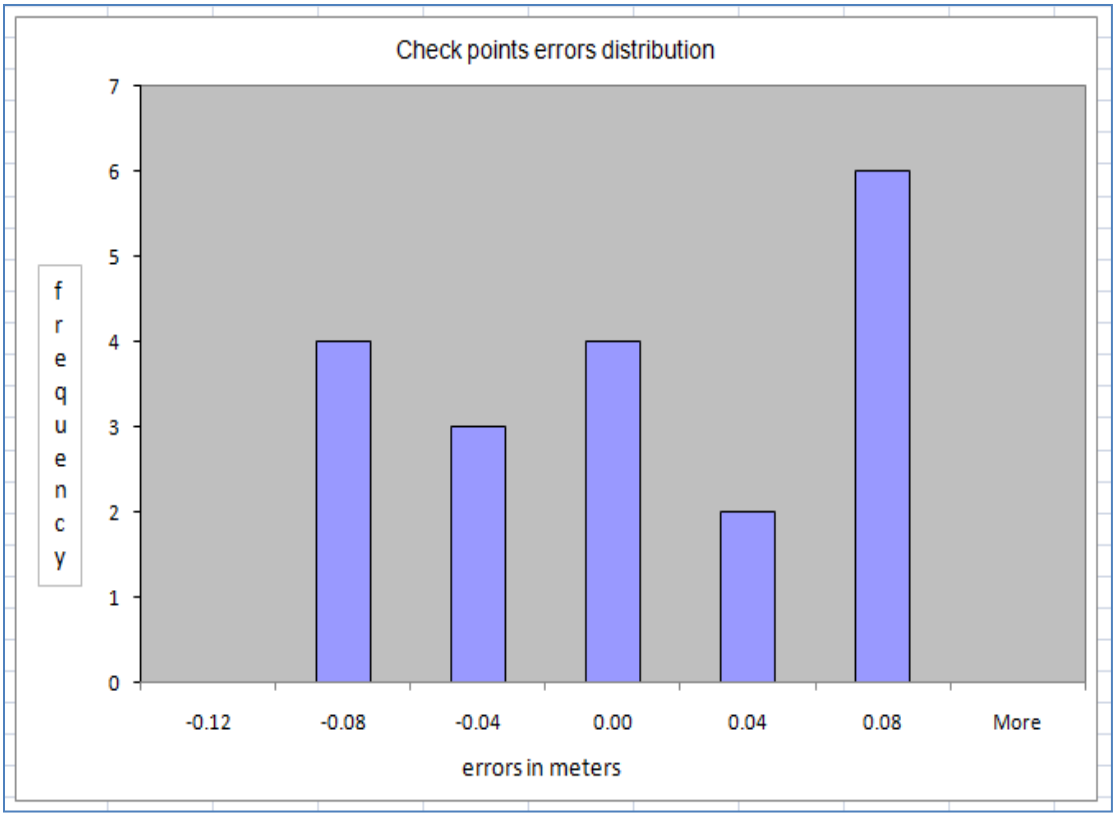


Figure 13 Histogram of elevation discrepancies for AOI 1

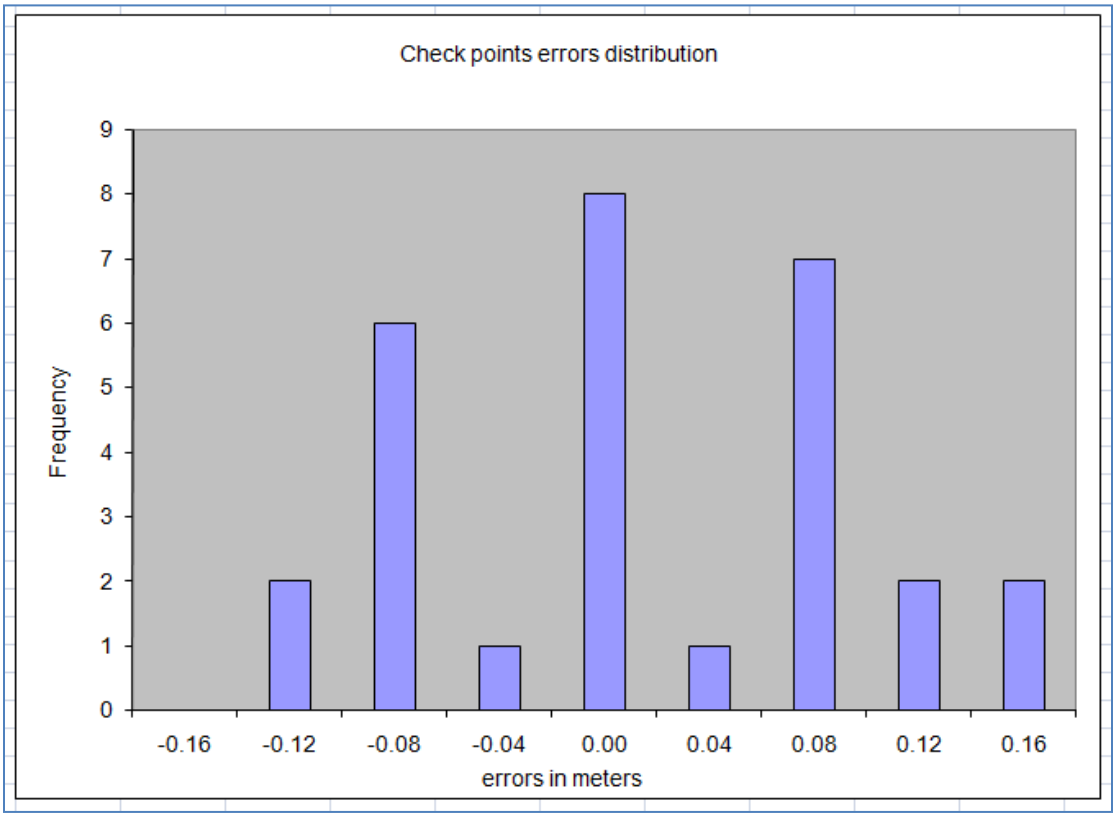


Figure 14 Histogram of elevation discrepancies for AOI 2

8.1.5 Checkpoints not used

The checkpoint was investigated and was legitimately removed from the quotation. Therefore, the Ottawa and Delaware, OK LiDAR dataset passes the final NDEP/ASPRS accuracy assessment test for both AOIs.

The coordinated of the point removed from the RMSE calculations for the AOI 1 are listed below:

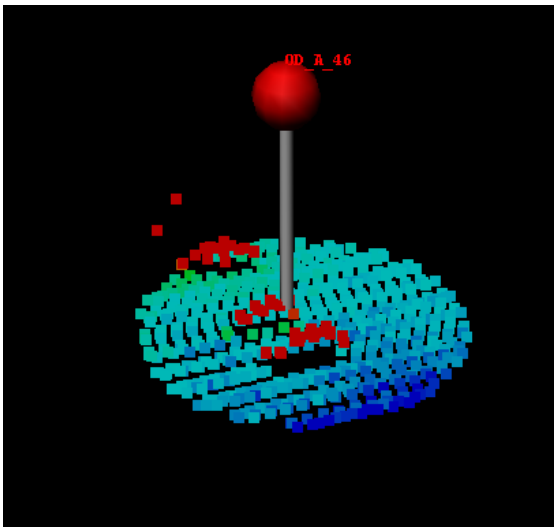
Error larger than 95th percentile

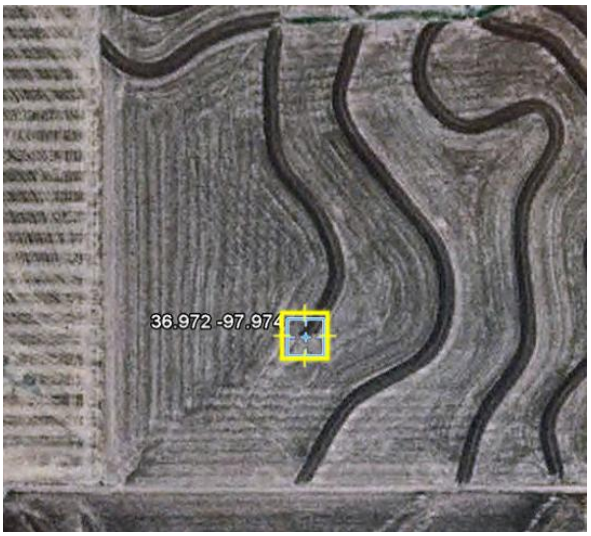
Point No	Easting	Northing	Elevation	Z LiDAR	Delta Z, m
OD_A_46	324259.2581	4093587.122	240.6548	242.0694	1.405

The picture for the point OD_A_46 provided by the LMSI indicates an open terrain.

Figure 8: Picture provided for the checkpoint OD_A_46 by the LMSI. Checkpoint is classified to Open Terrain Land Cover Category.

When the checkpoint was further investigated and QTC from LAS and Google Earth locations for the checkpoint were checked, it became clear that the checkpoint is located on the seasonal agricultural feature. The checkpoint was removed from the final computation for the AOI 1.





8.2 Credits

Organizations involved in the procurement, acquisition, processing, and quality control of the Ottawa and Delaware AOIs LiDAR dataset are identified below.

Function	Responsible Organization
LiDAR procurement	FEMA
LiDAR acquisition and processing	Laser Mapping Specialists, Inc
Checkpoint surveys	Laser Mapping Specialists, Inc
Accuracy assessment and reporting	RAMPP
Independent Technical Review	

8.3 References

Federal Emergency Management Agency, Procedure Memorandum No. 61 – Standards for Lidar and Other High Quality Digital Topography, http://www.fema.gov/library/viewRecord.do?id=4345

9 Conclusions

Based on the limited qualitative and vertical accuracy assessments conducted by RAMPP on the data delivered, the Ottawa/Delaware OK delivery meets the applicable project specifications as set forth by the IDIQ Subcontract # HSFEHQ-09-D-0369_U005, Task Order HSFE02-10-J-0004, revised September 3,2010.

Vertical Accuracy Assessment Conducted by:

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Tim Blak
Project Manager

Qualitative Assessment Conducted by:

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Polina Lyamtseva
GIS Analyst