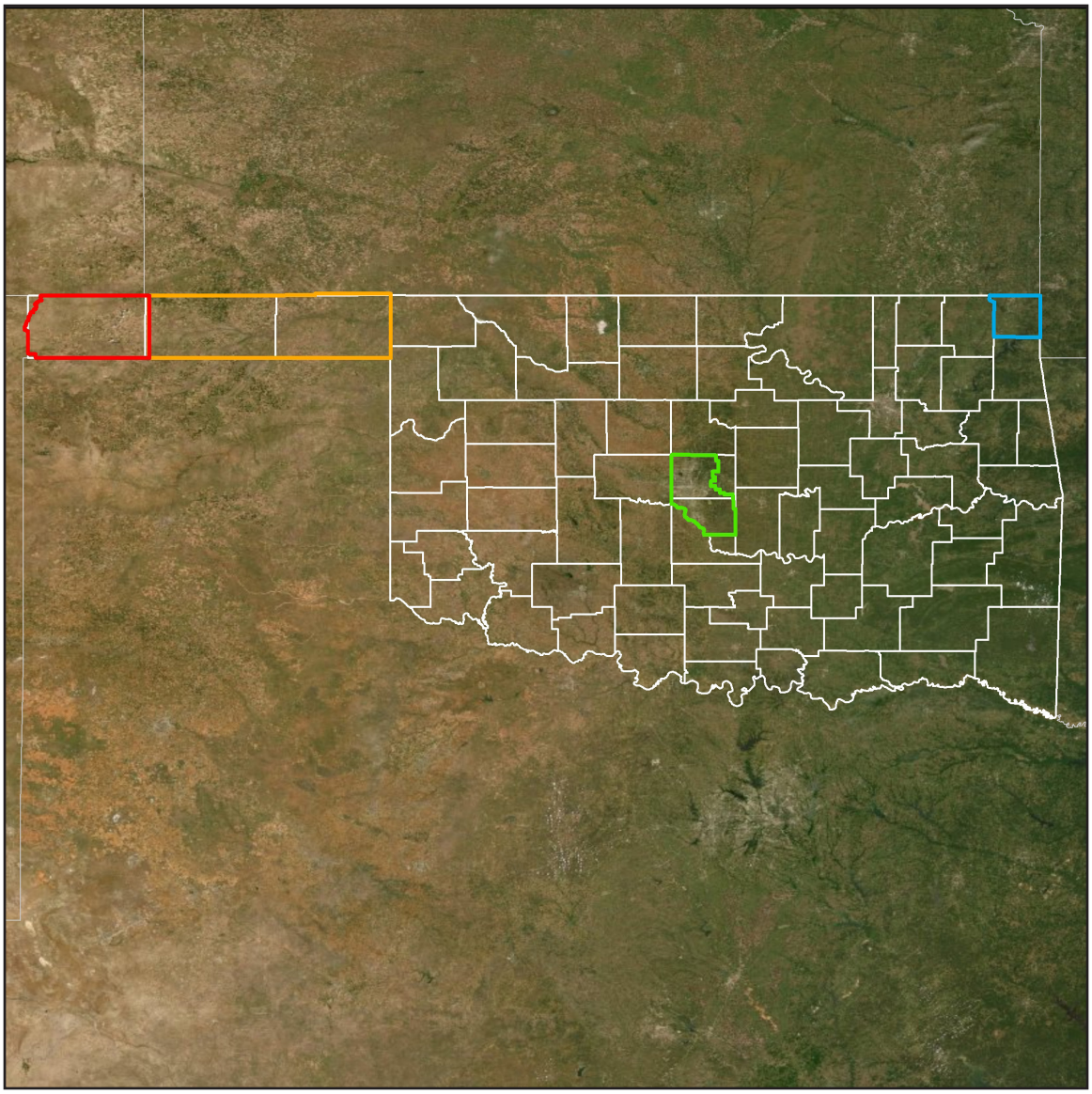
OK Panhandle 2018 D18

Airborne Lidar Report

February 2020



Contract # G16PC00022
Task Order # 140G0218F0438

Contractor Woolpert
Project # 78983

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1. Overview

About

This project contains a comprehensive outline of the 140G0218F0438 OK Panhandle 2018 D18 task order issued by the United States Geological Survey's National Geospatial Technical Operations Center (USGS-NGTOC). This task order called for the acquisition and processing of QL2 data over three areas of interest covering approximately 7,176 square miles in across the Oklahoma Panhandle region, Oklahoma City, and Ottawa County.

Data fully covers the following counties:

- Beaver
- Cimarron
- Ottawa
- Texas

Data partially covers the following counties:

- Cleveland
- Oklahoma

Purpose

The purpose of this project was to support the 3DEP mission, the Natural Resources Conservation Service (NRCS) high resolution elevation enterprise program and the Federal Emergency Management Agency (FEMA) Risk Mapping, Assessment and Planning (MAP) program.

Specifications

Data for this task order was acquired and produced to meet USGS Lidar Base Specification v1.3 standards and the American Society of Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0).

Spatial Reference

Geospatial data products were produced using the following horizontal and vertical spatial data reference systems.

Table 1-1. Spatial Reference System - UTM

Oklahoma Panhandle (Block 1)		
Horizontal	**EPSG Code**	6342
	Datum	NAD83 (2011)
	Projection	UTM Zone 13
	Units	Meters
Vertical	**Datum**	NAVD88
	Geoid	GEOID12B
	Units	Meters
	Height Type	Orthometric Heights

Oklahoma Panhandle (Block 2) + Oklahoma City (Block 1)		
Horizontal	**EPSG Code**	6343
	Datum	NAD83 (2011)
	Projection	UTM Zone 14
	Units	Meters
Vertical	**Datum**	NAVD88
	Geoid	GEOID12B
	Units	Meters
	Height Type	Orthometric Heights

Ottawa County (Block 1)		
Horizontal	**EPSG Code**	6344
	Datum	NAD83 (2011)
	Projection	UTM Zone 15
	Units	Meters
Vertical	**Datum**	NAVD88
	Geoid	GEOID12B
	Units	Meters
	Height Type	Orthometric Heights

After acceptance of the data by USGS NGTOC, a secondary data set was produced using the following horizontal and vertical spatial data reference systems.

Table 1-2. Spatial Reference System - State Plane

Oklahoma Panhandle, Oklahoma City North, Ottawa County		
Horizontal	**EPSG Code**	6553
	Datum	NAD83 (2011)
	Projection	State Plane Oklahoma North Zone
	Units	US Survey Feet
Vertical	**Datum**	NAVD88
	Geoid	GEOID12B
	Units	US Survey Feet
	Height Type	Orthometric Heights

Oklahoma City South		
Horizontal	**EPSG Code**	6555
	Datum	NAD83 (2011)
	Projection	State Plane Oklahoma South Zone
	Units	US Survey Feet
Vertical	**Datum**	NAVD88
	Geoid	GEOID12B
	Units	US Survey Feet
	Height Type	Orthometric Heights

Deliverables

All data products produced as part of this task order are listed below. All tiled deliverables had a tile size of 1,500-meters x 1,500-meters. Tile names are derived from the US National Grid.

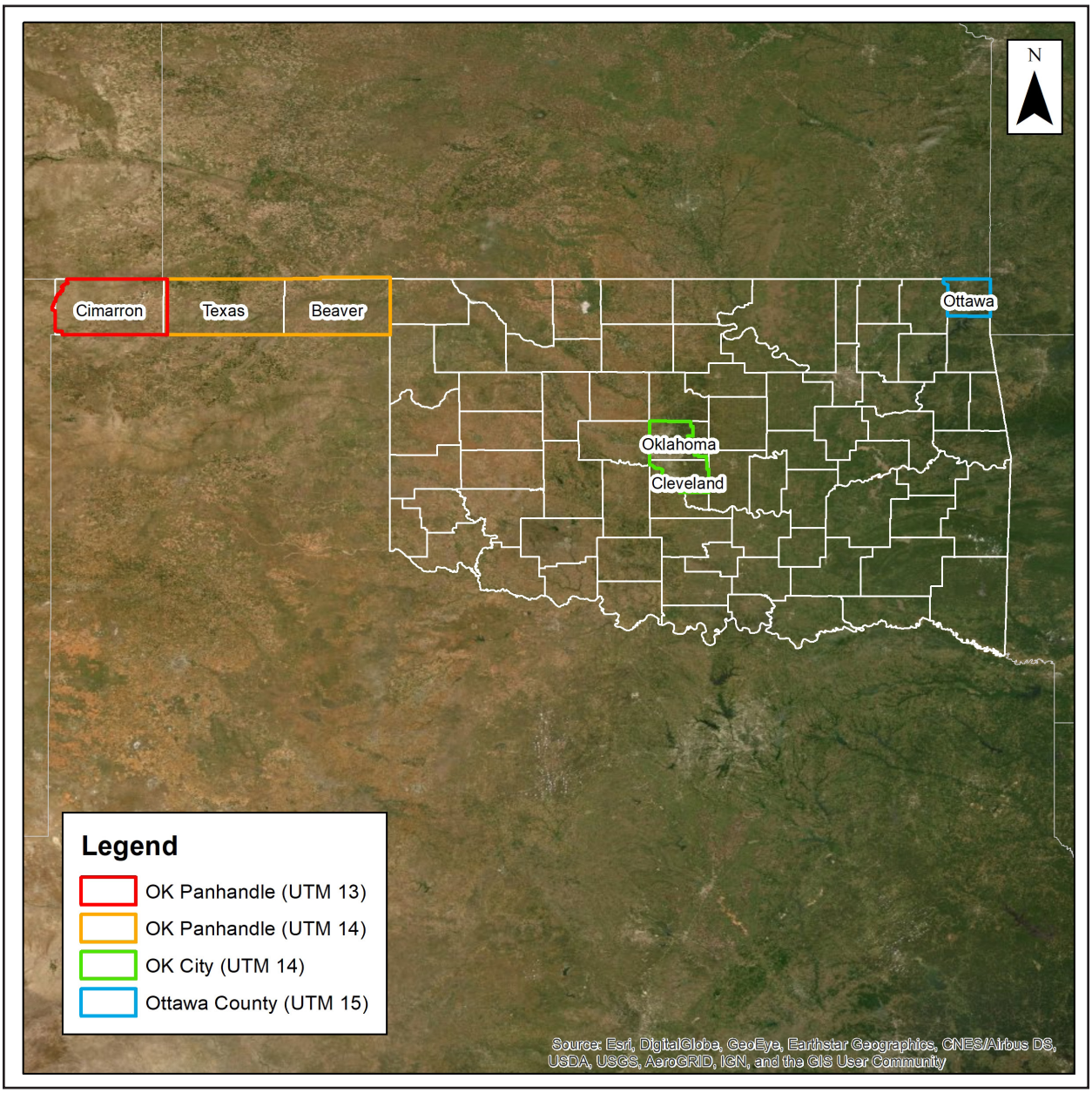
Table 1-3. Deliverables

Lidar Data	
Classified lidar point cloud data	Tiles in .las v1.4 format Classes • 1 – Processed, not Classified • 2 – Ground • 7 – Noise • 9 – Water • 17 – Bridge Decks • 18 – High Noise • 20 – Ignored Ground

Breaklines used for hydro-flattening	• Lake and River features as feature classes in an Esri file geodatabase
	  • Water bodies greater than 2 acres as polygon features
	  • Rivers 30.5 meters / 100 feet and greater in width as polyline features
	• Bridges used in DEM generation as point features in Esri shapefile format

Hydro-flattened bare earth digital elevation model (DEM)	1-meter pixel size, 32-bit floating-point; no bridges or overpass structures GeoTIFF format
Intensity Imagery	1-meter pixel size, 8-bit gray-scale (linear rescaling from 16-bit intensity) GeoTIFF format
Flight Line Index	Polygon features in an Esri file geodatabase
Control Data	
Lidar calibration points	Esri shapefile format
Lidar NVA checkpoints	Esri shapefile format
Lidar VVA checkpoints	Esri shapefile format
Other Data	
Data Extent	Esri shapefile format
Delivery Diagram	Esri shapefile format
Tile Index	Esri shapefile format
Metadata and Reports	
Metadata	Deliverable-level FGDC CSDGM/USGS MetaParser Compliant metadata in .xml format
Lidar Project Report	Project report with flight logs in .pdf format
Survey Report	Survey report in .pdf format

Figure 1-1. Project Area



2. Acquisition

Flight Planning

Aerial lidar data was collected using the specifications listed below.

Table 2-1. Acquisition Requirements

Specification	Target
Resolution	• 2 points per square meter • 0.71-meter nominal point spacing
Overlap	At contractor's discretion, but enough to ensure there are no data gaps between usable portions of the swath and nominal point density is achieved
Acquisition Window	Fall 2018/Spring 2019 (running through April 30, 2019)
Acquisition Conditions	• Cloud and fog-free between the aircraft and ground • Ground is snow free; very light undrafted snow may be acceptable in special cases, with prior approval • Ground has no unusual flooding or inundation, except in cases where the goal of the collection is to map the inundation • No tidal coordination is required for this project • Preference of vegetation is leaf-off
Data Voids	Not allowed except • Where caused by water bodies • Where caused by areas of low near infra-red (NIR) reflectivity (i.e. asphalt or composition roofing) • Where caused by lidar shadowing from buildings or other features • Where appropriately filled-in by another swath
Control	Airborne Global Positioning System (ABGPS) and Inertial Measurement Unit (IMU) data to be used along with differentially-corrected GPS ground control points

Lidar Sensor Information

Aerial lidar data was acquired using the Optech Galaxy Prime and Riegl Q1560 lidar sensor systems. A total of 338 flight lines were collected.

Table 2-2. Optech Galaxy PRIME Sensor Info

Sensor Performance	
Performance envelope [1, 2, 3, 4]	150-6000 m AGL, nominal
Absolute horizontal accuracy [2, 3]	1/10,000 × altitude; 1 σ
Absolute elevation accuracy [2, 3]	< 0.03-0.25 m RMSE from 150-6000 m AGL
Laser Configuration	
Topographic laser	1064-nm near-infrared
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Pulse repetition frequency (effective)	Programmable, 50-1000 kHz
Beam divergence	0.25 mrad (1/e)
Laser range precision [5]	< 0.008 m, 1 σ
Minimum target separation distance	< 0.7 m (discrete)
Range capture	Up to 8 range measurements, including last
Intensity capture	Up to 8 intensity measurements, including last (12-bit)
Sensor Configuration	
Position and orientation system	POS AV™ AP60 (OEM); 220-channel dual frequency GNSS receiver; GNSS airborne antenna with Iridium filters; high-accuracy AIMU (Type 57); non-ITAR
Scan angle (FOV)	10-60°
Swath width	10-115% of altitude AGL
Scan frequency	0-120 Hz advertised (0-240 scan lines/sec)
Scan product	2000 maximum
Flight management system	Optech FMS (Airborne Mission Manager and Nav) with operator console
SwathTRAK™	Dynamic FOV for fixed-width data swaths in variable terrain
PulseTRAK™	Multipulse tracking algorithm with no density loss across PIA transition zones
Roll compensation	±5° minimum
Data storage	Removable SSD (primary); internal SSD (spare)
Power requirements	28 V; 400 W
Dimensions and weight	Sensor: 0.34 × 0.34 × 0.25 m, 27 kg PDU: 0.42 × 0.33 × 0.10 m, 6.5 kg
Operating temperature	0 to +35°C

1. Target reflectivity ≥20%; 99% detection probability
2. Dependent on selected operational parameters; assumes nominal FOV of up to 40° in standard atmospheric conditions (i.e. 23-km visibility) and use of Optech LMS Professional software suite
3. Angle of incidence ≤20°
4. Target size ≥ laser footprint
5. Under Teledyne Optech test conditions, 1 sigma

Source: Optech Galaxy PRIME Airborne Lidar Terrain Mapper Specification Sheet
http://info.teledyneoptech.com/acton/attachment/19958/f-0278/1/-/-/-/-/Galaxy%20PRIME%20Brochure.pdf

Table 2-3. Riegl LMS-Q1560 Sensor Info

Full Laser Power				
Laser Power Level	100%			
Laser Pulse Repetition Rate (PRR)	200 kHz	400 kHz	600 kHz	800 kHz
Max. Measuring range [1, 3] natural targets ρ ≥ 20 % natural targets ρ ≥ 60 %	 4,100 m 5,800 m	 3,500 m 5,100 m	 3,000 m 4,500 m	 2,700 m 4,100 m
Max. Operating Flight Altitude Above Ground Level (AGL) [2, 3]	4,700 m 15,500 ft	4,200 m 13,700 ft	3,700 m 12,000 ft	3,300 m 11,000 ft
NOHD [4] ENOHD [5]	100 m 730 m	87 m 640 m	59 m 440 m	38 m 295 m

1. The following conditions are assumed: target is larger than the footprint of the laser beam; average ambient brightness; visibility 40 km; perpendicular angle of incidence; ambiguity resolved by multiple-time-around processing
2. Reflectivity ρ ≥ 60 %, max. scan angle 60°, additional roll angle ± 5°
3. In bright sunlight the operational range may be considerably shorter and the operational flight altitude may be considerably lower than under an overcast sky.
4. Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, for single pulse condition.
5. Extended Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, for single pulse condition.

Range Measurement Performance	
Minimum Range [11]	50 m
Accuracy [12, 13]	20 mm
Precision [12, 14]	20 mm
Laser Pulse Repetition Rate	up to 800 kHz
Effective Measurement Rate	up to 532 kHz @ 60° scan angle
Laser Wavelength	near infrared
Laser Beam Divergence [15]	≤ 0.25 mrad
Number of Targets per Pulse	digitized waveform processing: unlimited [16] monitoring data output: first pulse
Scanner Performance	
Scanning Mechanism	rotating polygon mirror
Scan Pattern	parallel scan lines per channel, crossed scan lines between channels
Tilt Angle of Scan Lines	± 14° = 28°
Forward/Backward Look in Non-Nadir Direction	± 8° at the edges
Scan Angle Range	60° total per channel, resulting in an effective FOV of 58°
Scan Speed	28 - 400 lines/sec [17] @ laser power level ≥ 50% 20 - 400 lines/sec [18] @ laser power level < 50%
Angular Step Width Δϑ [19]	Δϑ ≥ 0.012° @ laser power level ≥ 50% Δϑ ≥ 0.006° @ laser power level < 50%
Angle Measurement Resolution	0.001°

11. Limitation for range measurement capability, does not consider laser safety!
12. Standard deviation one sigma @ 250 m range under RIEGL test conditions
13. Accuracy is the degree of conformity of a measured quantity to its actual (true) value)
14. Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.
15. Measured at the $1/e^2$ points. 0.25 mrad correspond to an increase of 25 cm of beam diameter per 1,000 m distance.
16. Practically limited only by the maximum data rate allowed for the RIEGL Data Recorder.
17. Minimum scan speed increasing linearly to 106 lines/sec @ 800,000 Hz PRR @ laser power ≥ 50%
18. Minimum scan speed increasing linearly to 54 lines/sec @ 800,000 Hz PRR @ laser power < 50%
19. Angle between consecutive laser shots within a scan line, user adjustable.

Source: Riegl LMS-Q1560 Data Sheet
http://www.riegl.com/uploads/tx_pxpriegldownloads/DataSheet_LMS-Q1560_2015-03-19.pdf

GNSS and IMU Equipment

Prior to mobilizing to the project site, flight crews coordinated with the necessary air traffic control personnel to ensure airspace access. Crews were on-site, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

Flight navigation during acquisition was performed using IGI CCNS (Computer Controlled Navigation System). The pilots are skilled at maintaining their planned trajectory, while holding the aircraft steady and level. If atmospheric conditions are such that the trajectory, ground speed, roll, pitch and/or heading cannot be properly maintained, the mission is aborted until suitable conditions occur.

Base stations were set by acquisition staff and was used to support the aerial data acquisition. See the tables below for stations operated during acquisition.

Table 2-4. GNSS Base Stations

OK Panhandle AOI

Station Name	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height L1 Phase Center (Meters)
0056	36°24’49.13575”	100° 44’ 52.60265”	861.184
KPYX-Rebar	36° 24’ 49.13575”	100° 44’ 52.60265”	861.184
K17K-Rebar	36° 46’ 14.80714”	102° 30’ 59.01606”	1247.888
KGUY_Rebar	36° 40’ 44.52121”	101° 30’ 21.13157”	920.274
KGYM_Rebar	36° 40’ 44.52121”	101° 30’ 21.13157”	920.274
KPYX_Rebar	36° 24’ 49.13575”	100° 44’ 52.60265”	861.184

OK City AOI

Station Name	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height L1 Phase Center (Meters)
KPWA_Rebar	35° 31’ 57.67435”	97° 38’ 27.51724”	366.609

Ottawa County AOI

Station Name	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height L1 Phase Center (Meters)
KMIO_Rebar	36° 54’ 30.47548”	94° 53’ 20.891”	214.961

Timeline

Lidar data was collected from January 8, 2019 through March 7, 2019. Acquisition specifications are listed in the table below. An initial quality control process was immediately performed on to review the data coverage, airborne GPS data, and trajectory solution.

Table 2-5. Acquisition Specifications

Settings	Optech Galaxy PRIME	Riegl LMS-Q1560
Max. Number of Returns	8	12
Nominal Point Spacing	0.71 m	0.71 m
Nominal Point Density	3.64 ppsm	2.69 ppsm
Flying Height Above Ground Level	2,000 m	1,722 m
Flight Speed	145 knots	150 knots
Scan Angle	45°	58.52°
Scan Rate Used	66 Hz	175 Hz
Pulse Rate Used	450 kHz	600 kHz
Multi-Pulse in Air	Enabled	Enabled
Swath Width	1,657 m	1,930 m
Swath Overlap	30%	20%

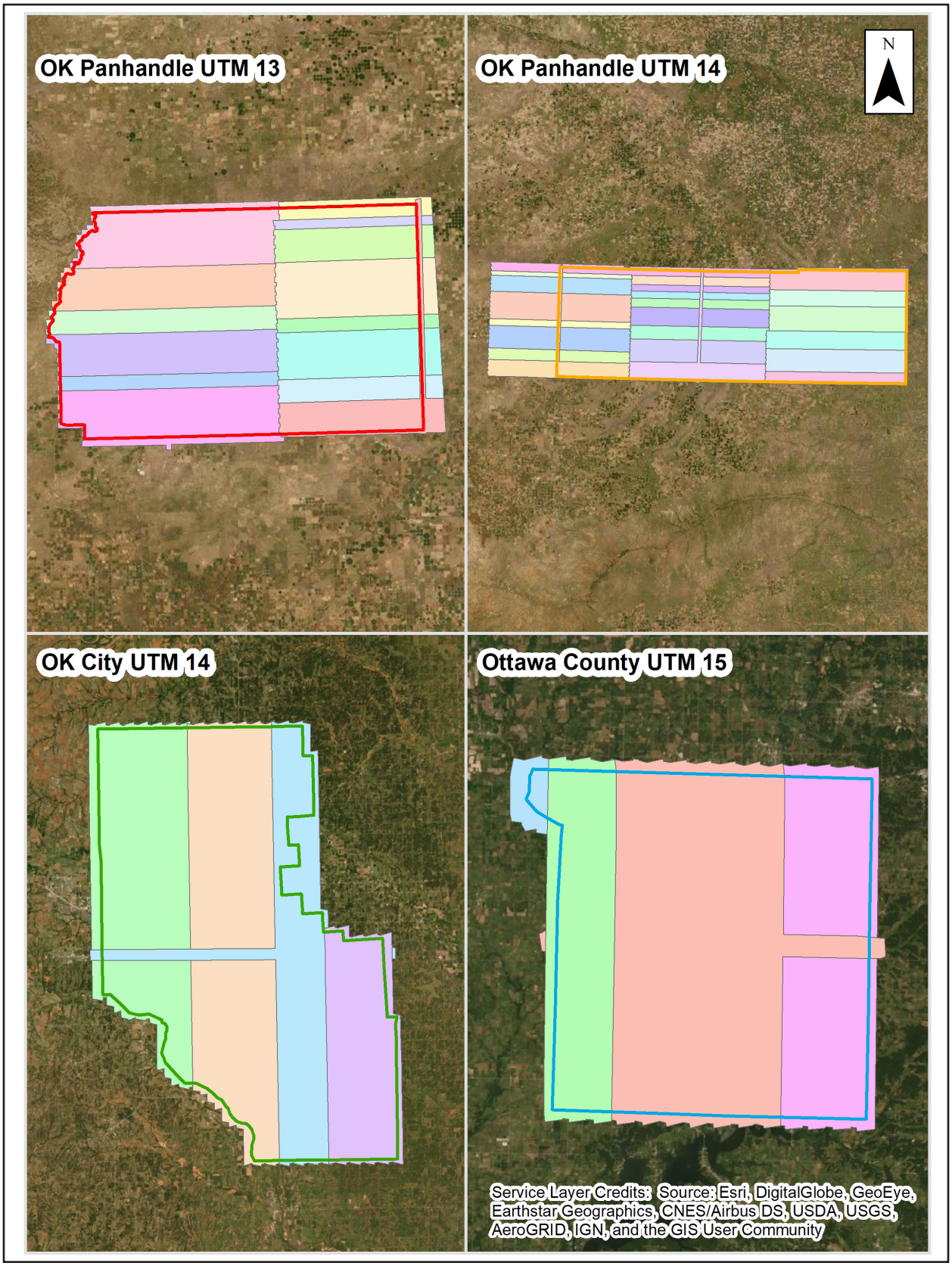
For more information, see the Flight Logs in Appendix 1.

Acquisition Quality Assurance

Woolpert developed a quality assurance and validation plan to ensure the acquired lidar data meets the USGS Base Specification Version 1.3. For quality assurance purposes, the lidar data was processed immediately following acquisition to verify the coverage has appropriate density, distribution, and no unacceptable data voids. Accompanying GPS data was post processed using differential and Kalman filter algorithms to derive a best estimate of trajectory. The quality of the solution was verified to be consistent with the accuracy requirements of the task order. Any required re-flights were scheduled at the earliest opportunity.

The spatial distribution of the geometrically usable first return lidar points was reviewed for density requirements as well as regular and uniform point distribution - verifying the lidar data is spaced so that 90% of the cells in a 2*NPS grid placed over the data contain at least one lidar point. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath. Additionally, the data was reviewed for unacceptable data voids – verifying no area greater than or equal to $(4 \times ANPS)^2$ exhibited data coverage gaps.

Figure 2-1: Flown Flight Lines



3. Processing

Processing Summary

Once the lidar data passed initial QC, the dataset was corrected for aircraft orientation and movement. This process used airborne inertial, orientation, and GPS data collected during acquisition along with ground-based GPS data. The data went through a geometric calibration that further corrected each laser point. This calibrated data set was used to create the LAS point cloud. The LAS point data was initially classified into “ground” and “non-ground”, then further refined using the classes specified in this task order. Breaklines were drawn to denote hydrological features. After the hydro-flattening process, the final deliverables products were created.

GNSS-IMU Trajectory Processing

Kinematic corrections for the aircraft position were resolved using aircraft GPS and static ground GPS (1-Hz) for each geodetic control (base station) for three subsystems: inertial measurement unit (IMU), sensor orientation information, and airborne GPS data.

Post-processing of the IMU system data and aircraft position with attitude data was completed to compute an optimally accurate, blended navigation solution based on Kalman filtering technology, or the smoothed best estimate of trajectory (SBET).

Software: POSPac Software v. 5.3, IPAS Pro v.1.35., Novatel Inertial Explorer v8.60.6129

Trajectory Quality

The GNSS trajectory and high-quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the combined separation, the estimated positional accuracy, and the positional dilution of precision (PDOP).

Combination Separation

Combined separation is a measure of the difference between the forward-run and the backward-run solution of the trajectory. The Kalman filter was processed in both directions to remove the combined directional anomalies. In general, when these two solutions match closely, an optimally accurate and reliable solution is achieved.

The data for this task order was processed with a goal to maintain a combined separation difference of less than ten (10) centimeters.

Estimated Positional Accuracy

Estimated positional accuracy plots the standard deviations of the east, north, and vertical directions along a time scale of the trajectory. It illustrates loss of satellite lock issues, as well as issues arising from long baselines, noise, and/or other atmospheric interference.

PDOP

The PDOP measures the precision of the GPS solution in regard to the geometry of the satellites acquired and used for the solution.

The data for this task order was processed with a goal to maintain an average PDOP value below 3.0. Brief periods of PDOP over 3.0 are acceptable due to the calibration and control process if other metrics are within specification.

Geometric Calibration

After the initial phase was complete, a formal reduction process was performed on the data. Laser point position was calculated by associating the SBET position to each laser point return time, scan angle, intensity, etc. Raw laser point cloud data was created for the whole project area in LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift. Statistical reports were generated for comparison and used to make the necessary adjustments to remove any residual systematic error.

Software: Proprietary Software, TerraMatch v18, Leica CloudPro 1.2.4

Lidar Data Classification

LAS data was classified as ground and non-ground points with additional filters created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the lidar data was then adjusted to reduce the vertical bias when compared to the survey ground control of higher accuracy.

Calibrated LAS files were imported into the task order tiles and initially filtered to create a ground and non-ground class. Then additional classes were filtered as necessary to meet the following client-specified classes:

- Class 1 – Default / Processed, but not Classified
- Class 2 – Bare Earth Ground
- Class 7 – Low Noise
- Class 9 – Water
- Class 17 – Bridge Decks
- Class 18 – High Noise
- Class 20 – Ignored Ground

Classified LAS files were evaluated through a series of manual QA/QC steps as well as a peer-based review to eliminate remaining artifacts from the ground class. This included a review of the DEM surface to remove artifacts and ensure topographic quality.

Software: Proprietary Software, TerraScan v18

Hydrologic Flattening

The lidar task order required compilation of breaklines defining the following types of water body features:

Lakes, reservoirs, ponds	Minimum of 2-acres or greater Compiled as closed polygons, collected at a constant elevation
Rivers, streams	Nominal width of 30.5 meters / 100 feet Compiled in direction of flow, with both sides maintaining an equal elevation gradient
Bridge breaklines	Breaklines used to enforce a logical terrain surface below a bridge

Woolpert utilized the following steps to hydrologically flatten the water bodies and for gradient hydrologic flattening of the double line streams within the existing lidar data:

1. The newly acquired lidar data was utilized to manually compile the hydrologic features in a 2D environment using the lidar intensity and bare earth surface. Open Source imagery was used as reference when necessary.

2. An integrated software approach was applied to combine the lidar data and 2D breaklines. This process “drapes” the 2D breaklines onto the 3D lidar surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edges. The breaklines that characterize the closed water bodies are draped onto the 3D lidar surface and assigned a constant elevation at or just below ground elevation.

3. All classified ground points from inside the hydrologic feature polygons were reclassified to water, class nine (9).

4. All classified ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class twenty (20). The buffer distance was approximately the task order designed nominal pulse spacing distance.

5. Breaklines used for bridge removal during the hydrologic flattening were included with the hydrologic breakline geodatabase deliverable. The purpose of these breaklines is for a more aesthetically pleasing DEM appearance.

6. The lidar ground points and breaklines were used to generate a digital elevation model (DEM).

7. QA/QC for this task was performed by reviewing the hydrologically flattened DEM and hydrologic breakline features. Additionally, a combined approach utilizing commercial off the shelf software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

TerraScan was used to add the hydrologic breakline vertices and export the lattice models.

Breaklines defining the water bodies greater than 2-acres were provided as polygon features. Rivers and streams with a nominal minimum width of 30.5 meters (100 feet) were provided as polyline features. All lake and river breaklines compiled as part of the flattening process were provided in an Esri file geodatabase.

Breaklines used for DEM generation were provided as point features in Esri shapefile format.

Software: TerraScan v18, TerraModeler v18, Esri ArcMap v10.4, LP360 v2018.1.57.4

Digital Elevation Model

TerraScan was used to add the hydrologic breakline vertices and export the lattice models. Class 2 (ground) lidar points in conjunction with the hydro breaklines and bridge breaklines were used to create 1-meter hydro-flattened bare-earth raster DEM files. Using automated scripting routines within ArcMap, an 32-bit floating point raster GeoTIFF file was created for each tile. Files were clipped to the data extent. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

Intensity Imagery

Lidar intensity data derived from the acquired lidar data was linearly rescaled from 16-bit intensity and provided as 1-meter pixel, 8-bit, 256 gray scale GeoTIFF format intensity imagery files. Files were clipped to the data extent.

Software: TerraScan v18

Metadata

FGDC CSDGM/USGS MetaParser-compliant metadata was produced in XML format. The metadata includes a complete description of the task order client information, contractor information, project purpose, lidar acquisition and ground survey collection parameters, lidar acquisition and ground survey collection dates, spatial reference system information, data processing including acquisition quality assurance procedures, GPS and base station processing, geometric calibration, lidar classification, hydrologic flattening, intensity imagery development, and final product development.

Other metadata deliverables included Esri shapefiles of the ground control and QA/QC points, delivery tile index, delivery extent, and delivery diagram. A georeferenced, polygonal representation of the detailed extents of each acquired lidar swath was produced as a polygon feature class in an Esri file geodatabase.

4. Accuracy Assessment

Results Summary

The tables below show a summary of all test results. The following sections describe the testing methods used.

Software: TerraScan v18, Esri ArcMap v10.4

*Note: the Minimum Points required were calculated using the total project area. Accuracy testing was performed on data within each of the three UTM zones using points that fell within that zone.

There were 186 total NVA points used and 130 total VVA points used.

Horizontal Accuracy

For the Oklahoma Panhandle and Oklahoma City AOIs, the data sets were produced to meet ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (2014) for a 14.7 cm RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 36.0 cm at a 95% confidence level.

For the Ottawa AOI, the data set was produced to meet ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (2014) for a 12.8 cm RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 31.3 cm at a 95% confidence level.

Table 4-1. Vertical Accuracy Summary - OK Panhandle z13

Testing Categories	Target	Measured	Minimum Points	Points Used
Raw Swath NVA RMSEz 95% at Confidence Level	0.196 m	0.118 m	154*	43
DEM NVA RMSEz at 95% Confidence Level	0.196 m	0.116 m	154*	43
DEM VVA RMSEz at 95th Percentile	0.30 m	0.180 m	111*	15

Table 4-2. Vertical Accuracy Summary - OK Panhandle + OK City z14

Testing Categories	Target	Measured	Minimum Points	Points Used
Raw Swath NVA RMSEz 95% at Confidence Level	0.196 m	0.088 m	154*	124
DEM NVA RMSEz at 95% Confidence Level	0.196 m	0.092 m	154*	125
DEM VVA RMSEz at 95th Percentile	0.30 m	0.156 m	111*	80

Table 4-3. Vertical Accuracy Summary - Ottawa County z15

Testing Categories	Target	Measured	Minimum Points	Points Used
Raw Swath NVA RMSEz 95% at Confidence Level	0.196 m	0.098 m	154*	18
DEM NVA RMSEz at 95% Confidence Level	0.196 m	0.080 m	154*	18
DEM VVA RMSEz at 95th Percentile	0.30 m	0.230 m	111*	35

Raw Lidar Swath Testing

This project required Non-Vegetated Vertical Accuracy (NVA) to be tested on the raw lidar point cloud swath data. The dataset was required to meet a target value of 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600. Testing was assessed and reported using guidelines developed by the National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing (ASPRS).

The raw NVA was to be calculated with a minimum of 154 independent checkpoints that were not used in the calibration or post processing of the lidar point cloud data. Checkpoints were to be distributed throughout the project area and located in bare earth and urban (non-vegetated) land cover classes.

Testing was performed using TINs created from the final calibrated and controlled swath data. For each NVA checkpoint, an elevation value was derived from the TIN at the point's x,y location. This value was compared to the checkpoint's surveyed elevation value.

The raw NVA was tested using 185 checkpoints. These checkpoints were surveyed using GPS techniques. See the survey report for acquisition methodologies. This dataset was tested to be the following:

- **UTM z13 (OK Pan.):** 0.118 meters, RMSEz of 0.060 meters x 1.9600; 43 checkpoints
- **UTM z14 (OK Pan. + OK City):** 0.088 meters, RMSEz of 0.045 meters x 1.9600; 124 checkpoints
- **UTM z15 (Ottawa Co.):** 0.098 meters, RMSEz of 0.050 meters x 1.9600; 18 checkpoints

For full checkpoint results, see the tables in Appendix 2.

Digital Elevation Model Testing

This project required Non-Vegetated Accuracy (NVA) and Vegetated Vertical Accuracy (VVA) testing of the digital elevation model (DEM) dataset. The calculated NVA value was required to meet 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600. VVA was required to meet 0.30 cm at the 95th percentile error. Testing was assessed and reported using guidelines developed by the National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing (ASPRS).

Testing was performed using the bare earth DEM created as part of this task order. For each checkpoint, an elevation value was derived from the DEM at the point's x,y location. This value was compared to the checkpoint's surveyed elevation value.

The NVA was to be calculated with a minimum of 154 independent checkpoints falling on bare earth and urban (non-vegetated) classes. VVA had a minimum requirement of 111 independent checkpoints falling in brush/tall grass/weeds (vegetated) land cover classes. These points were not used in the calibration or post processing of the lidar point cloud data and distributed throughout the project area. Checkpoints were surveyed using GPS techniques. See the survey report for acquisition methodologies.

The DEM NVA was tested using 186 checkpoints to be the following:

- **UTM z13 (OK Pan.):** 0.116 meters, RMSEz of 0.059 meters x 1.9600; 43 checkpoints
- **UTM z14 (OK Pan. + OK City):** 0.092 meters, RMSEz of 0.047 meters x 1.9600; 125 checkpoints
- **UTM z15 (Ottawa Co.):** 0.080 meters, RMSEz of 0.041 meters x 1.9600; 18 checkpoints

Table 4-4. VVA Errors - OK Panhandle z13

Point ID	Easting	Northing	Z-Error
3033_2018_OK	681351.1	4044711.624	0.240
3034_2018_OK	714423.087	4050300.026	0.180
3037_2018_OK	743984.587	4075234.47	0.180
3058_2018_OK	691324.124	4061021.97	0.180

Table 4-5. VVA Errors - OK Panhandle + OK City z14

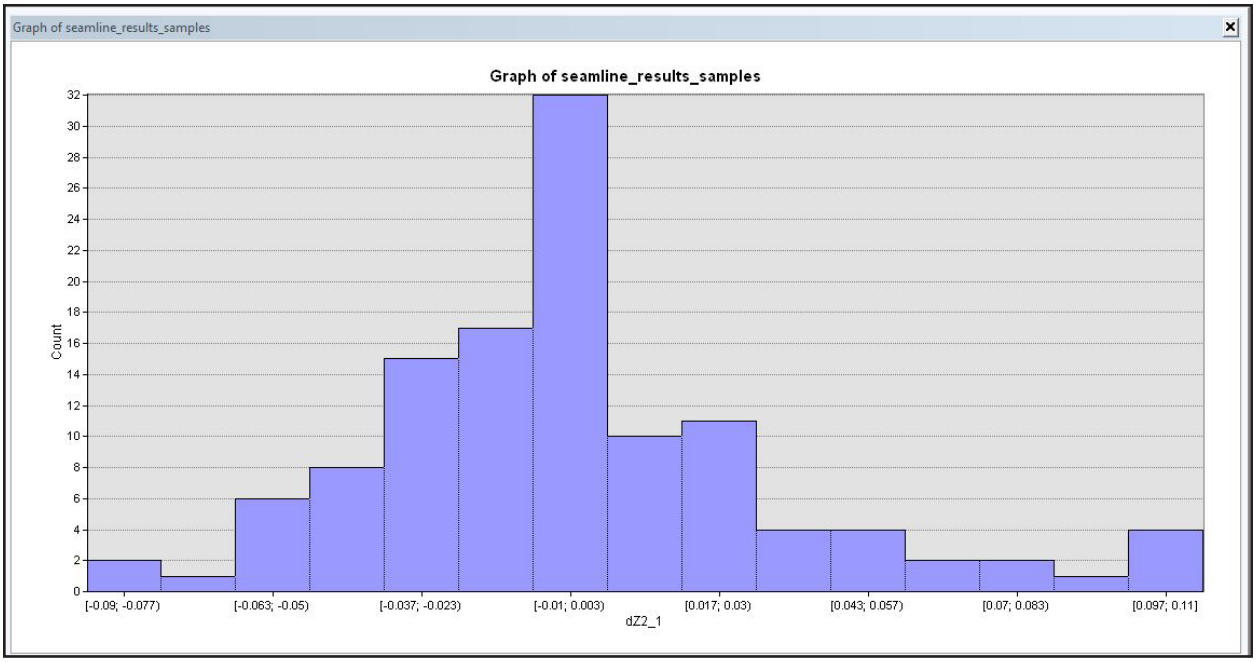
Point ID	Easting	Northing	Z-Error
3001_2018_OK	640934.872	3951594.544	0.157
3002_2018_OK	652869.615	3953146.961	0.189
3024_2018_OK	665908.832	3914716.58	0.176
3041_2018_OK	274568.228	4093928.618	0.192

Table 4-6. VVA Errors - Ottawa County z15

Point ID	Easting	Northing	Z-Error
3013_2018_OK	346811.772	4061651.992	0.244
3017_2018_OK	331033.424	4062570.74	0.252
3107_2018_OK	339087.692	4063667.865	0.242
3110_2018_OK	323428.202	4074659.873	0.232

Inter-Swath Testing - UTM z13

Inter-swath accuracy was tested against well-distributed flight line overlap locations. The relative accuracy for the lidar measured at 0.037 meters RMSE.



Values are in meters.

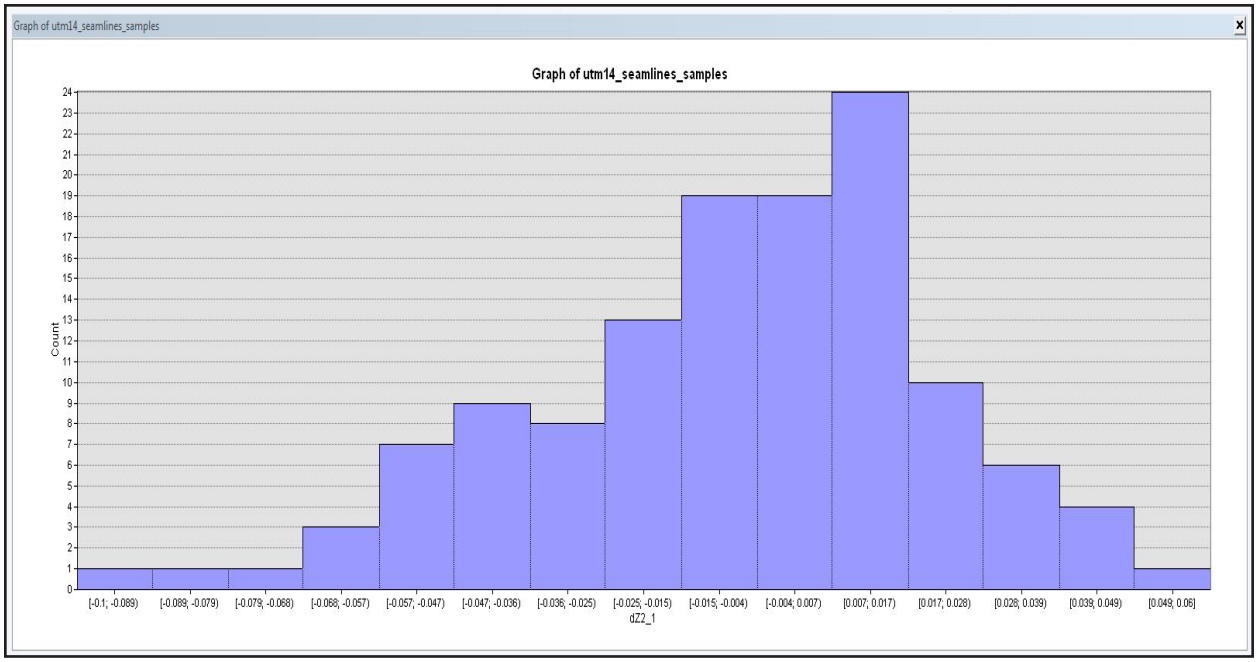
Approved By	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		November 2019

Intra-Swath Testing - UTM z13

Intra-swath accuracy, also known as “within swath” accuracy, was tested against single swath first return data located in flat open areas. The intra-swath accuracy for the lidar measured at 0.016 meters RMSDz.

Inter-Swath Testing - UTM z14

Inter-swath accuracy was tested against well-distributed flight line overlap locations. The relative accuracy for the lidar measured at 0.029 meters RMSE.



Values are in meters

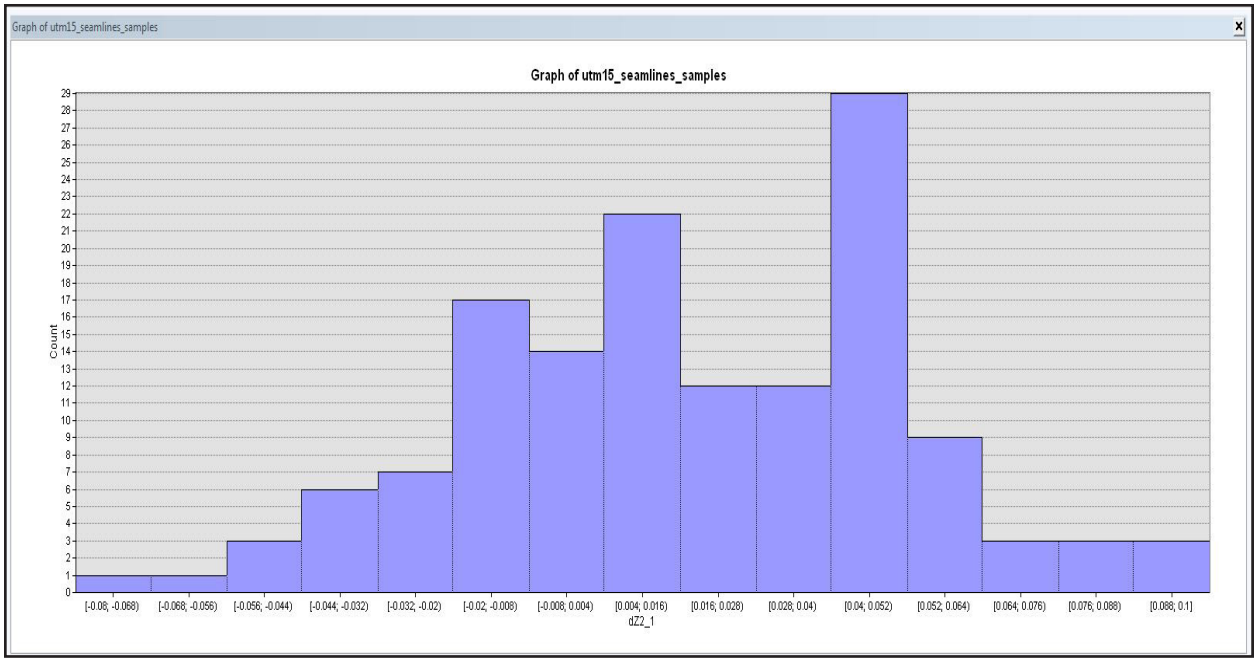
Approved By	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		November 2019

Intra-Swath Testing - UTM z14

Intra-swath accuracy, also known as “within swath” accuracy, was tested against single swath first return data located in flat open areas. The intra-swath accuracy for the lidar measured at 0.021 meters RMSDz.

Inter-Swath Testing - UTM z15

Inter-swath accuracy was tested against well-distributed flight line overlap locations. The relative accuracy for the lidar measured at 0.038 meters RMSE.



Values are in meters

Approved By	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		November 2019

Intra-Swath Testing - UTM z15

Intra-swath accuracy, also known as “within swath” accuracy, was tested against single swath first return data located in flat open areas. The intra-swath accuracy for the lidar measured at 0.024 meters RMSDz.

Appendix 1: Flight Logs

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
78983	OK Panhandle 2018 D18 - OK City	Day065_111518_1	03/06/2019	065	1

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
JT	Cessna 401	N41GD	439	08:25:00	14:25:00	KPWA
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Kelly	Galaxy Prime	111518	443.9	13:19:00	19:19:00	KPWA

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
150	9	10	12,000	Clear	-3	-11	3043

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
145	6,500	7,720	1,300

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.56	3.2	45	66	450	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
29	180	15:10:43	15:23:30	00:12:47	27	0.95	
28	0	15:27:41	15:40:27	00:12:46	28	0.97	
27	180	15:46:14	15:59:51	00:13:37	26	1.03	
26	0	16:03:56	16:17:07	00:13:11	25	1.08	
25	180	16:24:11	16:38:49	00:14:38	25	1.01	
24	0	16:42:18	16:55:48	00:13:30	25	0.98	
23	180	17:02:11	17:16:43	00:14:32	24	0.99	
22	0	17:20:59	17:36:04	00:15:05	23	0.99	
21	180	17:43:27	17:58:17	00:14:50	26	0.9	
20	0	18:02:48	18:17:47	00:14:59	27	0.9	
19	180	18:23:45	18:38:47	00:15:02	29	0.92	
18	0	18:42:41	18:57:51	00:15:10	27	0.94	

Verify S-Turns After Mission: Yes

Additional Comments

LiDAR Drive #2

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
78983	OK Panhandle 2018 D18 - OK City	Day065_111518_2	03/06/2019	065	2

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
JT	Cessna 401	N41GD	443.9	14:15:00	20:15:00	KPWA
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Kelly	Galaxy Prime	111518	19:12	18:15:00	00:15:00	KPWA

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
170	22	10	12,000	Clear	12	-11	3021

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
145	6,500	7,720	1,300

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.56	3.2	45	66	450	100

Verify S-Turns Before Mission	Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
17	180	20:52:15	21:07:46	00:15:31	32	0.92	
16	0	21:11:52	21:27:04	00:15:12	32	0.98	
15	180	21:32:41	21:47:38	00:14:57	33	0.92	
14	0	21:51:22	21:55:55	00:04:33	32	0.88	got offline - going to re-intercept
14	0	22:04:11	22:14:59	00:10:48	32	0.88	gap in line - refly
13	180	22:20:58	22:36:03	00:15:05	29	0.91	
14	0	22:39:32	22:43:10	00:03:38	29	0.86	patch
12	0	23:00:26	23:14:32	00:14:06	27	0.94	
11	180	23:23:36	23:32:43	00:09:07	25	1.14	
44	270	23:44:16	23:55:31	00:11:15	25	1.2	crosstie

Verify S-Turns After Mission	Yes

Additional Comments

LiDAR Drive #Loaner

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
78983	OK Panhandle 2018 D18 - OK City	Day066_111518_1	03/07/2019	066	1

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
JT	Cessna 401	N41GD	447.9	11:45:00	17:45:00	KPWA
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Kelly	Galaxy Prime	111518	450.6	14:40:00	20:40:00	KPWA

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
200	14	10	12,000	Clear	12	0	2994

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
145	6,500	7,720	1,300

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.56	3.2	45	66	450	100

Verify S-Turns Before Mission	Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
1	180	18:25:58	18:31:06	00:05:08	26	0.92	
2	0	18:36:02	18:43:51	00:07:49	26	0.93	
3	180	18:47:53	18:55:53	00:08:00	25	1.01	
4	0	19:00:56	19:08:44	00:07:48	28	0.9	
5	180	19:12:51	19:20:36	00:07:45	30	0.88	
6	0	19:24:58	19:32:44	00:07:46	29	0.96	
7	180	19:36:40	19:44:30	00:07:50	29	1	
8	0	19:48:52	19:56:54	00:08:02	30	0.94	
9	180	20:01:00	20:09:03	00:08:03	31	0.94	
10	0	20:13:14	20:21:12	00:07:58	31	0.96	

Verify S-Turns After Mission	Yes

Additional Comments

LiDAR Drive #1

Appendix 2: Raw Swath NVA Checkpoint Results

Coordinate values are listed in the following spatial reference system:

Horizontal: NAD83 (2011) UTM zone 13 / 14 / 15, meters

Vertical: NAVD88 (GEOID12B) meters

Summary	UTM z13	UTM z14	UTM z14
Point Count	43	124	18
Average dZ	0.043 m	-0.004 m	0.026 m
Minimum dZ	-0.037 m	-0.124 m	-0.033 m
Maximum dZ	0.180 m	0.121 m	0.155 m
Average Magnitude	0.048 m	0.036 m	0.033 m
Root Mean Square	0.060 m	0.045 m	0.050 m
Standard Deviation	0.042 m	0.045 m	0.044 m

UTM z13 (OK Panhandle)

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2013_2018_OK	747674.170	4056008.663	1181.395	1181.410	0.015
2018_2018_OK	688829.933	4065817.059	1418.697	1418.770	0.073
2024_2018_OK	707631.599	4050913.511	1324.112	1324.190	0.078
2030_2018_OK	746308.709	4051770.751	1160.921	1160.980	0.059
2036_2018_OK	756779.144	4086909.868	1158.015	1158.060	0.045
2041_2018_OK	738304.777	4051668.493	1207.506	1207.580	0.074
2043_2018_OK	745909.051	4064004.826	1201.894	1201.890	-0.004
2044_2018_OK	730518.876	4058737.150	1238.950	1239.130	0.180
2057_2018_OK	702450.129	4051692.774	1345.078	1345.080	0.002
2059_2018_OK	718948.404	4048810.696	1269.598	1269.640	0.042
2061_2018_OK	737590.267	4071143.339	1221.797	1221.870	0.073
2064_2018_OK	729822.686	4062252.871	1244.974	1244.950	-0.024
2068_2018_OK	691878.541	4064271.485	1397.834	1397.880	0.046
2069_2018_OK	702513.005	4067753.411	1352.097	1352.150	0.053
2071_2018_OK	707395.939	4059985.258	1323.137	1323.150	0.013
2074_2018_OK	751055.751	4051258.927	1176.159	1176.250	0.091
2077A_2018_OK	722692.769	4067705.850	1266.380	1266.370	-0.010

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2077B_2018_OK	722685.072	4067705.571	1266.421	1266.480	0.059
2085_2018_OK	715196.802	4055134.217	1295.261	1295.280	0.019
2086_2018_OK	735651.464	4055770.389	1213.253	1213.330	0.077
2087_2018_OK	760220.790	4069176.667	1157.127	1157.090	-0.037
2102_2018_OK	726972.995	4076389.594	1255.146	1255.130	-0.016
2109_2018_OK	758813.163	4094729.139	1122.795	1122.910	0.115
2114_2018_OK	710309.597	4072755.609	1312.984	1313.020	0.036
2119_2018_OK	739974.898	4046038.509	1196.169	1196.250	0.081
2121_2018_OK	752466.754	4054524.379	1172.169	1172.230	0.061
2122_2018_OK	734206.199	4045993.098	1216.037	1216.060	0.023
2124_2018_OK	761107.038	4077336.911	1142.024	1142.020	-0.004
2125_2018_OK	732706.444	4074907.162	1236.138	1236.150	0.012
2126_2018_OK	745819.077	4067251.767	1204.912	1205.000	0.088
2129_2018_OK	765760.485	4045464.702	1123.780	1123.810	0.030
2130_2018_OK	697379.883	4048449.342	1355.959	1356.020	0.061
2131_2018_OK	708834.828	4067880.956	1313.217	1313.210	-0.007
2132_2018_OK	697637.632	4066019.119	1369.762	1369.790	0.028
2136_2018_OK	766504.163	4085546.791	1126.960	1126.980	0.020
2141_2018_OK	713546.602	4074220.850	1308.301	1308.360	0.059
2144_2018_OK	688444.117	4048046.541	1400.493	1400.520	0.027
2145_2018_OK	704492.254	4048156.183	1328.006	1328.030	0.024
2147A_2018_OK	745070.033	4077368.224	1200.775	1200.860	0.085
2147B_2018_OK	745070.335	4077358.171	1200.818	1200.890	0.072
2152_2018_OK	753456.167	4091619.043	1168.596	1168.660	0.064
2158_2018_OK	756369.954	4072359.989	1174.200	1174.200	0.000
2166_2018_OK	745081.438	4077326.864	1201.123	1201.190	0.067

UTM z14 (OK Panhandle + Oklahoma City)

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2001_2018_OK	345994.212	4045920.273	881.199	881.220	0.021
2002_2018_OK	626715.649	3925454.195	369.616	369.620	0.004
2003_2018_OK	242362.354	4078829.639	1088.395	1088.410	0.015
2004_2018_OK	274344.793	4082682.473	987.113	987.080	-0.033
2005_2018_OK	287801.426	4068300.567	883.942	883.970	0.028
2006_2018_OK	306034.880	4089949.022	908.903	908.870	-0.033
2007_2018_OK	387611.424	4092478.424	675.073	675.010	-0.063
2008_2018_OK	638152.682	3938437.027	343.851	343.850	-0.001
2009_2018_OK	243140.278	4051422.317	1053.633	1053.690	0.057
2010_2018_OK	384732.202	4061111.288	776.794	776.810	0.016
2011_2018_OK	378125.747	4088179.918	745.350	745.340	-0.010
2012_2018_OK	647041.190	3927204.881	372.776	372.730	-0.046
2014_2018_OK	402400.087	4052169.119	736.885	736.910	0.025
2015_2018_OK	377776.840	4091982.384	709.637	709.600	-0.037
2016A_2018_OK	264304.736	4053374.599	1003.795	1003.760	-0.035
2016B_2018_OK	264308.891	4053366.261	1003.765	1003.780	0.015
2017_2018_OK	313129.712	4073725.869	874.799	874.820	0.021
2019_2018_OK	250200.752	4088217.547	1070.221	1070.170	-0.051
2020_2018_OK	410572.405	4081876.062	664.991	664.970	-0.021
2021_2018_OK	366174.907	4052474.033	834.248	834.300	0.052
2022_2018_OK	333331.271	4060372.008	830.572	830.600	0.028
2023_2018_OK	317717.707	4081655.568	873.399	873.490	0.091
2023A_2018_OK	317750.885	4081647.347	873.714	873.810	0.096
2025_2018_OK	309191.355	4055594.918	869.053	869.030	-0.023
2026_2018_OK	237595.129	4080589.818	1107.072	1107.070	-0.002
2027_2018_OK	347977.573	4069770.279	802.188	802.220	0.032
2028_2018_OK	317104.418	4049071.438	825.662	825.600	-0.062
2029_2018_OK	371721.323	4043018.874	841.986	841.960	-0.026
2032_2018_OK	628072.116	3950348.281	314.081	314.040	-0.041
2033A_2018_OK	362877.878	4085637.607	790.177	790.250	0.073
2033B_2018_OK	362908.340	4085636.935	789.269	789.340	0.071
2034_2018_OK	290660.855	4045232.284	943.359	943.340	-0.019
2035A_2018_OK	302444.636	4081893.613	912.334	912.210	-0.124

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2035B_2018_OK	302458.308	4081892.667	912.264	912.150	-0.114
2037_2018_OK	642900.829	3928894.067	354.654	354.640	-0.014
2038_2018_OK	354260.045	4058381.571	842.488	842.470	-0.018
2039_2018_OK	635055.736	3916404.354	391.541	391.540	-0.001
2042_2018_OK	651544.546	3896078.015	323.292	323.260	-0.032
2045_2018_OK	259223.656	4050938.705	1024.647	1024.620	-0.027
2046_2018_OK	290423.288	4068572.819	902.522	902.520	-0.002
2047_2018_OK	314586.589	4044682.708	834.045	833.990	-0.055
2048_2018_OK	248549.363	4071480.557	1053.878	1053.83	-0.048
2049_2018_OK	351601.828	4082619.955	799.82	799.83	0.01
2050_2018_OK	325023.011	4083997.225	854.965	855.04	0.075
2051_2018_OK	309079.654	4051129.186	866.975	866.95	-0.025
2052A_2018_OK	642678.56	3902145.75	357.187	357.17	-0.017
2052B_2018_OK	642687.039	3902145.861	357.48	357.43	-0.05
2053_2018_OK	292926.368	4047355.622	936.968	936.99	0.022
2054_2018_OK	286707.896	4054917.122	931.608	931.61	0.002
2055_2018_OK	274359.978	4044056.543	985.128	985.14	0.012
2056_2018_OK	387018.122	4090400.77	727.907	727.88	-0.027
2058_2018_OK	648316.244	3896226.65	347.299	347.29	-0.009
2060_2018_OK	253954.691	4086487.214	1057.816	1057.81	-0.006
2062_2018_OK	324141.438	4077904.235	850.675	850.63	-0.045
2063_2018_OK	343838.353	4082749.655	820.109	820.23	0.121
2065_2018_OK	395959.942	4052914.641	711.103	711.12	0.017
2065A_2018_OK	395957.862	4052875.497	710.576	710.59	0.014
2066_2018_OK	298371.209	4074779.789	913.122	913.11	-0.012
2067_2018_OK	313649.023	4055967.55	860.89	860.82	-0.07
2070_2018_OK	343176.198	4068221.733	828.105	828.1	-0.005
2072_2018_OK	285050.654	4052521.418	934.125	934.1	-0.025
2073_2018_OK	264572.062	4070156.094	987.313	987.36	0.047
2075_2018_OK	633258.669	3948127.425	326.59	slope	*
2076_2018_OK	393705.058	4081591.522	771.861	771.87	0.009
2078_2018_OK	378340.557	4078911.305	769.062	769.11	0.048
2079_2018_OK	400683.266	4092408.966	636.734	636.68	-0.054
2080_2018_OK	400601.654	4083909.601	699.385	699.4	0.015

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2081_2018_OK	315809.776	4091628.889	891.403	891.29	-0.113
2082A_2018_OK	332678.28	4081824.476	838.626	838.61	-0.016
2082B_2018_OK	332709.247	4081823.935	838.489	838.48	-0.009
2083_2018_OK	265625.836	4090939.692	1021.875	1021.85	-0.025
2084_2018_OK	396850.329	4040011.397	772.23	772.26	0.03
2088A_2018_OK	625846.191	3943783.17	328.988	328.93	-0.058
2088B_2018_OK	625834.995	3943795.877	329.067	329.02	-0.047
2089_2018_OK	291658.267	4062289.224	916.094	916.12	0.026
2090_2018_OK	389347.575	4080499.092	770.418	770.4	-0.018
2091_2018_OK	336418.74	4049879.009	886.174	886.21	0.036
2092_2018_OK	295037.71	4062828.724	902.219	902.31	0.091
2093_2018_OK	379655.416	4043479.942	813.661	813.68	0.019
2094_2018_OK	259493.942	4057379.673	1027.697	1027.6	-0.097
2095_2018_OK	410417.394	4096433.757	602.951	602.9	-0.051
2096_2018_OK	320884.144	4076314.014	856.7	856.7	0
2097_2018_OK	332909.67	4095837.611	855.698	855.6	-0.098
2098_2018_OK	320244.496	4045449.077	866.235	866.21	-0.025
2099_2018_OK	241879.003	4063528.305	1068.221	1068.26	0.039
2101_2018_OK	320107.111	4080254.349	863.848	863.8	-0.048
2103_2018_OK	248380.942	4065780.283	1046.757	1046.73	-0.027
2104_2018_OK	405568.715	4069686.54	696.391	696.43	0.039
2105_2018_OK	339716.245	4054653.784	874.589	874.55	-0.039
2106_2018_OK	246513.734	4056703.218	1016.302	1016.26	-0.042
2107_2018_OK	653788.681	3949292.4	323.194	323.24	0.046
2108_2018_OK	234997.227	4072617.123	1098.37	1098.4	0.03
2110_2018_OK	383192.862	4083733.243	784.242	784.27	0.028
2111_2018_OK	342929.719	4054202.126	880.2	880.18	-0.02
2112_2018_OK	344876.001	4073014.49	779.978	780	0.022
2112A_2018_OK	344874.913	4073044.827	779.894	779.91	0.016
2113_2018_OK	278588.51	4094635.923	987.636	987.67	0.034
2115_2018_OK	635864.029	3907512.025	365.292	365.2	-0.092
2116_2018_OK	291326.266	4089325.64	952.64	952.73	0.09
2117_2018_OK	626373.763	3953189.118	323.23	323.21	-0.02
2118_2018_OK	642659.28	3945405.924	320.315	320.37	0.055

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2120_2018_OK	263141.048	4076568.991	1011.072	1011.09	0.018
2123_2018_OK	262262.547	4085516.586	1027.713	1027.69	-0.023
2127_2018_OK	369036.172	4050080.844	844.192	844.19	-0.002
2128_2018_OK	308714.865	4086127.192	901.1	901.14	0.04
2133_2018_OK	314939.723	4094579.563	895.854	895.85	-0.004
2134_2018_OK	355636.84	4043486.813	873.387	873.38	-0.007
2137_2018_OK	300961.142	4077190.231	907.845	907.82	-0.025
2138_2018_OK	310902.114	4063495.494	863.41	863.37	-0.04
2139A_2018_OK	634158.226	3929724.571	360.457	360.52	0.063
2139B_2018_OK	634158.273	3929715.256	360.615	360.64	0.025
2140_2018_OK	336644.378	4063116.299	841.707	841.71	0.003
2142_2018_OK	397660.448	4062267.129	744.449	744.44	-0.009
2146_2018_OK	400871.853	4095706.208	691.379	691.35	-0.029
2148_2018_OK	397440.045	4088405.3	677.105	677.1	-0.005
2150_2018_OK	651394.761	3949113.168	327.067	327.1	0.033
2151_2018_OK	302723.113	4054614.439	892.289	892.26	-0.029
2153_2018_OK	336815.268	4087703.29	836.669	836.71	0.041
2154_2018_OK	292845.896	4043547.951	940.914	940.87	-0.044
2155_2018_OK	342185.323	4044103.12	889.328	889.36	0.032
2157_2018_OK	641521.68	3940136.359	341.626	341.59	-0.036
2159_2018_OK	337976.063	4046541.284	890.339	890.37	0.031
2160_2018_OK	233500.779	4053297.538	1093.442	1093.47	0.028
2161_2018_OK	650753.05	3923848.55	393.787	393.75	-0.037
2162_2018_OK	409409.727	4077826.383	656.193	656.14	-0.053

UTM z15 (Ottawa County)

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2031A_2018_OK	324988.421	4062921.075	238.033	238.060	0.027
2031B_2018_OK	324991.871	4062914.764	238.015	238.170	0.155
2040_2018_OK	323105.482	4068215.541	242.234	242.310	0.076
2100_2018_OK	333768.925	4083390.854	235.129	235.170	0.041
2135_2018_OK	345656.306	4075544.829	255.558	255.560	0.002
2143_2018_OK	348357.800	4069400.507	235.306	235.320	0.014
2149_2018_OK	353827.622	4063379.961	291.137	291.140	0.003
2156_2018_OK	343914.942	4086459.087	261.596	261.570	-0.026
2156A_2018_OK	344657.505	4083626.226	236.099	236.140	0.041
2163_2018_OK	327475.491	4065959.040	249.284	249.310	0.026
2164_2018_OK	338827.558	4071324.569	242.201	242.250	0.049
2165A_2018_OK	332659.704	4084464.774	241.123	241.090	-0.033
2165B_2018_OK	332658.962	4084437.274	241.087	241.090	0.003
2167_2018_OK	330544.074	4096462.708	259.310	259.310	0.000
2168_2018_OK	327753.790	4090344.877	248.912	248.910	-0.002
2169_2018_OK	339393.545	4094962.339	251.924	252.000	0.076
2170_2018_OK	348573.663	4096077.116	243.776	243.790	0.014
2171_2018_OK	354695.759	4094859.986	281.915	281.920	0.005

Appendix 3: DEM NVA Checkpoint Results

Coordinate values are listed in the following spatial reference system:

Horizontal: NAD83 (2011) UTM zone 13 / 14 / 15, meters

Vertical: NAVD88 (GEOID12B) meters

Summary	UTM z13	UTM z14	UTM z15
Point Count	43	125	18
Root Mean Square Error	0.059 m	0.047 m	0.041 m
95% Confidence Level	0.116 m	0.092 m	0.080 m
Mean of Residuals	0.048 m	0.038 m	0.033 m
Standard Deviation	0.035 m	0.029 m	0.025 m

UTM z13 (OK Panhandle)

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2013_2018_OK	747674.17	4056008.663	1181.395	1181.400	0.005
2018_2018_OK	688829.933	4065817.059	1418.697	1418.750	0.053
2024_2018_OK	707631.599	4050913.511	1324.112	1324.190	0.078
2030_2018_OK	746308.709	4051770.751	1160.921	1160.980	0.059
2036_2018_OK	756779.144	4086909.868	1158.015	1158.060	0.045
2041_2018_OK	738304.777	4051668.493	1207.506	1207.580	0.074
2043_2018_OK	745909.051	4064004.826	1201.894	1201.870	0.024
2044_2018_OK	730518.876	4058737.15	1238.950	1239.130	0.180
2057_2018_OK	702450.129	4051692.774	1345.078	1345.050	0.028
2059_2018_OK	718948.404	4048810.696	1269.598	1269.650	0.052
2061_2018_OK	737590.267	4071143.339	1221.797	1221.860	0.063
2064_2018_OK	729822.686	4062252.871	1244.974	1244.960	0.014
2068_2018_OK	691878.541	4064271.485	1397.834	1397.880	0.046
2069_2018_OK	702513.005	4067753.411	1352.097	1352.130	0.033
2071_2018_OK	707395.939	4059985.258	1323.137	1323.170	0.033
2074_2018_OK	751055.751	4051258.927	1176.159	1176.240	0.081
2077A_2018_OK	722692.769	4067705.85	1266.380	1266.380	0.000
2077B_2018_OK	722685.072	4067705.571	1266.421	1266.500	0.079
2085_2018_OK	715196.802	4055134.217	1295.261	1295.270	0.009

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2086_2018_OK	735651.464	4055770.389	1213.253	1213.340	0.087
2087_2018_OK	760220.79	4069176.667	1157.127	1157.120	0.007
2102_2018_OK	726972.995	4076389.594	1255.146	1255.130	0.016
2109_2018_OK	758813.163	4094729.139	1122.795	1122.910	0.115
2114_2018_OK	710309.597	4072755.609	1312.984	1313.020	0.036
2119_2018_OK	739974.898	4046038.509	1196.169	1196.250	0.081
2121_2018_OK	752466.754	4054524.379	1172.169	1172.230	0.061
2122_2018_OK	734206.199	4045993.098	1216.037	1216.060	0.023
2124_2018_OK	761107.038	4077336.911	1142.024	1142.010	0.014
2125_2018_OK	732706.444	4074907.162	1236.138	1236.170	0.032
2126_2018_OK	745819.077	4067251.767	1204.912	1204.970	0.058
2129_2018_OK	765760.485	4045464.702	1123.780	1123.810	0.030
2130_2018_OK	697379.883	4048449.342	1355.959	1356.020	0.061
2131_2018_OK	708834.828	4067880.956	1313.217	1313.180	0.037
2132_2018_OK	697637.632	4066019.119	1369.762	1369.790	0.028
2136_2018_OK	766504.163	4085546.791	1126.960	1126.980	0.020
2141_2018_OK	713546.602	4074220.85	1308.301	1308.360	0.059
2144_2018_OK	688444.117	4048046.541	1400.493	1400.500	0.007
2145_2018_OK	704492.254	4048156.183	1328.006	1328.050	0.044
2147A_2018_OK	745070.033	4077368.224	1200.775	1200.850	0.075
2147B_2018_OK	745070.335	4077358.171	1200.818	1200.900	0.082
2152_2018_OK	753456.167	4091619.043	1168.596	1168.670	0.074
2158_2018_OK	756369.954	4072359.989	1174.200	1174.200	0.000
2166_2018_OK	745081.438	4077326.864	1201.123	1201.200	0.077

UTM z14 (OK Panhandle + Oklahoma City)

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2001_2018_OK	345994.212	4045920.273	881.199	881.200	0.001
2002_2018_OK	626715.649	3925454.195	369.616	369.620	0.004
2003_2018_OK	242362.354	4078829.639	1088.395	1088.410	0.015
2004_2018_OK	274344.793	4082682.473	987.113	987.080	0.033
2005_2018_OK	287801.426	4068300.567	883.942	883.970	0.028
2006_2018_OK	306034.880	4089949.022	908.903	908.880	0.023
2007_2018_OK	387611.424	4092478.424	675.073	675.020	0.053
2008_2018_OK	638152.682	3938437.027	343.851	343.850	0.001
2009_2018_OK	243140.278	4051422.317	1053.633	1053.690	0.057
2010_2018_OK	384732.202	4061111.288	776.794	776.800	0.006
2011_2018_OK	378125.747	4088179.918	745.350	745.360	0.010
2012_2018_OK	647041.190	3927204.881	372.776	372.700	0.076
2014_2018_OK	402400.087	4052169.119	736.885	736.900	0.015
2015_2018_OK	377776.840	4091982.384	709.637	709.590	0.047
2016A_2018_OK	264304.736	4053374.599	1003.795	1003.760	0.035
2016B_2018_OK	264308.891	4053366.261	1003.765	1003.770	0.005
2017_2018_OK	313129.712	4073725.869	874.799	874.810	0.011
2019_2018_OK	250200.752	4088217.547	1070.221	1070.180	0.041
2020_2018_OK	410572.405	4081876.062	664.991	664.970	0.021
2021_2018_OK	366174.907	4052474.033	834.248	834.280	0.032
2022_2018_OK	333331.271	4060372.008	830.572	830.600	0.028
2023_2018_OK	317717.707	4081655.568	873.399	873.500	0.101
2023A_2018_OK	317750.885	4081647.347	873.714	873.810	0.096
2025_2018_OK	309191.355	4055594.918	869.053	869.020	0.033
2026_2018_OK	237595.129	4080589.818	1107.072	1107.070	0.002
2027_2018_OK	347977.573	4069770.279	802.188	802.220	0.032
2028_2018_OK	317104.418	4049071.438	825.662	825.610	0.052
2029_2018_OK	371721.323	4043018.874	841.986	841.980	0.006
2032_2018_OK	628072.116	3950348.281	314.081	314.030	0.051
2033A_2018_OK	362877.878	4085637.607	790.177	790.260	0.083
2033B_2018_OK	362908.340	4085636.935	789.269	789.340	0.071
2034_2018_OK	290660.855	4045232.284	943.359	943.350	0.009
2035A_2018_OK	302444.636	4081893.613	912.334	912.190	0.144
2035B_2018_OK	302458.308	4081892.667	912.264	912.140	0.124

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2037_2018_OK	642900.829	3928894.067	354.654	354.630	0.024
2038_2018_OK	354260.045	4058381.571	842.488	842.460	0.028
2039_2018_OK	635055.736	3916404.354	391.541	391.550	0.009
2042_2018_OK	651544.546	3896078.015	323.292	323.270	0.022
2045_2018_OK	259223.656	4050938.705	1024.647	1024.610	0.037
2046_2018_OK	290423.288	4068572.819	902.522	902.520	0.002
2047_2018_OK	314586.589	4044682.708	834.045	833.990	0.055
2048_2018_OK	248549.363	4071480.557	1053.878	1053.820	0.058
2049_2018_OK	351601.828	4082619.955	799.820	799.820	0.000
2050_2018_OK	325023.011	4083997.225	854.965	855.040	0.075
2051_2018_OK	309079.654	4051129.186	866.975	866.950	0.025
2052A_2018_OK	642678.560	3902145.750	357.187	357.190	0.003
2052B_2018_OK	642687.039	3902145.861	357.480	357.460	0.020
2053_2018_OK	292926.368	4047355.622	936.968	936.990	0.022
2054_2018_OK	286707.896	4054917.122	931.608	931.630	0.022
2055_2018_OK	274359.978	4044056.543	985.128	985.160	0.032
2056_2018_OK	387018.122	4090400.770	727.907	727.850	0.057
2058_2018_OK	648316.244	3896226.650	347.299	347.290	0.009
2060_2018_OK	253954.691	4086487.214	1057.816	1057.810	0.006
2062_2018_OK	324141.438	4077904.235	850.675	850.630	0.045
2063_2018_OK	343838.353	4082749.655	820.109	820.220	0.111
2065_2018_OK	395959.942	4052914.641	711.103	711.140	0.037
2065A_2018_OK	395957.862	4052875.497	710.576	710.590	0.014
2066_2018_OK	298371.209	4074779.789	913.122	913.110	0.012
2067_2018_OK	313649.023	4055967.550	860.890	860.830	0.060
2070_2018_OK	343176.198	4068221.733	828.105	828.090	0.015
2072_2018_OK	285050.654	4052521.418	934.125	934.090	0.035
2073_2018_OK	264572.062	4070156.094	987.313	987.350	0.037
2075_2018_OK	633258.669	3948127.425	326.590	326.620	0.030
2076_2018_OK	393705.058	4081591.522	771.861	771.870	0.009
2078_2018_OK	378340.557	4078911.305	769.062	769.110	0.048
2079_2018_OK	400683.266	4092408.966	636.734	636.680	0.054
2080_2018_OK	400601.654	4083909.601	699.385	699.390	0.005
2081_2018_OK	315809.776	4091628.889	891.403	891.320	0.083

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2082A_2018_OK	332678.280	4081824.476	838.626	838.610	0.016
2082B_2018_OK	332709.247	4081823.935	838.489	838.430	0.059
2083_2018_OK	265625.836	4090939.692	1021.875	1021.830	0.045
2084_2018_OK	396850.329	4040011.397	772.230	772.260	0.030
2088A_2018_OK	625846.191	3943783.170	328.988	328.940	0.048
2088B_2018_OK	625834.995	3943795.877	329.067	329.020	0.047
2089_2018_OK	291658.267	4062289.224	916.094	916.120	0.026
2090_2018_OK	389347.575	4080499.092	770.418	770.410	0.008
2091_2018_OK	336418.740	4049879.009	886.174	886.220	0.046
2092_2018_OK	295037.710	4062828.724	902.219	902.320	0.101
2093_2018_OK	379655.416	4043479.942	813.661	813.680	0.019
2094_2018_OK	259493.942	4057379.673	1027.697	1027.610	0.087
2095_2018_OK	410417.394	4096433.757	602.951	602.900	0.051
2096_2018_OK	320884.144	4076314.014	856.700	856.690	0.010
2097_2018_OK	332909.670	4095837.611	855.698	855.590	0.108
2098_2018_OK	320244.496	4045449.077	866.235	866.210	0.025
2099_2018_OK	241879.003	4063528.305	1068.221	1068.290	0.069
2101_2018_OK	320107.111	4080254.349	863.848	863.780	0.068
2103_2018_OK	248380.942	4065780.283	1046.757	1046.730	0.027
2104_2018_OK	405568.715	4069686.540	696.391	696.430	0.039
2105_2018_OK	339716.245	4054653.784	874.589	874.540	0.049
2106_2018_OK	246513.734	4056703.218	1016.302	1016.250	0.052
2107_2018_OK	653788.681	3949292.400	323.194	323.240	0.046
2108_2018_OK	234997.227	4072617.123	1098.370	1098.370	0.000
2110_2018_OK	383192.862	4083733.243	784.242	784.270	0.028
2111_2018_OK	342929.719	4054202.126	880.200	880.160	0.040
2112_2018_OK	344876.001	4073014.490	779.978	780.000	0.022
2112A_2018_OK	344874.913	4073044.827	779.894	779.930	0.036
2113_2018_OK	278588.510	4094635.923	987.636	987.660	0.024
2115_2018_OK	635864.029	3907512.025	365.292	365.190	0.102
2116_2018_OK	291326.266	4089325.640	952.640	952.740	0.100
2117_2018_OK	626373.763	3953189.118	323.230	323.220	0.010
2118_2018_OK	642659.280	3945405.924	320.315	320.370	0.055
2120_2018_OK	263141.048	4076568.991	1011.072	1011.110	0.038

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2123_2018_OK	262262.547	4085516.586	1027.713	1027.690	0.023
2127_2018_OK	369036.172	4050080.844	844.192	844.190	0.002
2128_2018_OK	308714.865	4086127.192	901.100	901.150	0.050
2133_2018_OK	314939.723	4094579.563	895.854	895.860	0.006
2134_2018_OK	355636.840	4043486.813	873.387	873.360	0.027
2137_2018_OK	300961.142	4077190.231	907.845	907.810	0.035
2138_2018_OK	310902.114	4063495.494	863.410	863.340	0.070
2139A_2018_OK	634158.226	3929724.571	360.457	360.480	0.023
2139B_2018_OK	634158.273	3929715.256	360.615	360.580	0.035
2140_2018_OK	336644.378	4063116.299	841.707	841.700	0.007
2142_2018_OK	397660.448	4062267.129	744.449	744.440	0.009
2146_2018_OK	400871.853	4095706.208	691.379	691.350	0.029
2148_2018_OK	397440.045	4088405.300	677.105	677.080	0.025
2150_2018_OK	651394.761	3949113.168	327.067	327.100	0.033
2151_2018_OK	302723.113	4054614.439	892.289	892.250	0.039
2153_2018_OK	336815.268	4087703.290	836.669	836.720	0.051
2154_2018_OK	292845.896	4043547.951	940.914	940.860	0.054
2155_2018_OK	342185.323	4044103.120	889.328	889.360	0.032
2157_2018_OK	641521.680	3940136.359	341.626	341.590	0.036
2159_2018_OK	337976.063	4046541.284	890.339	890.350	0.011
2160_2018_OK	233500.779	4053297.538	1093.442	1093.460	0.018
2161_2018_OK	650753.050	3923848.550	393.787	393.740	0.047
2162_2018_OK	409409.727	4077826.383	656.193	656.140	0.053

UTM z15 (Ottawa County)

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2031A_2018_OK	324988.421	4062921.075	238.033	238.060	0.027
2031B_2018_OK	324991.871	4062914.764	238.015	238.060	0.045
2040_2018_OK	323105.482	4068215.541	242.234	242.290	0.056
2100_2018_OK	333768.925	4083390.854	235.129	235.140	0.011
2135_2018_OK	345656.306	4075544.829	255.558	255.580	0.022
2143_2018_OK	348357.800	4069400.507	235.306	235.310	0.004
2149_2018_OK	353827.622	4063379.961	291.137	291.130	0.007
2156_2018_OK	343914.942	4086459.087	261.596	261.590	0.006
2156A_2018_OK	344657.505	4083626.226	236.099	236.130	0.031
2163_2018_OK	327475.491	4065959.040	249.284	249.290	0.006
2164_2018_OK	338827.558	4071324.569	242.201	242.250	0.049
2165A_2018_OK	332659.704	4084464.774	241.123	241.050	0.073
2165B_2018_OK	332658.962	4084437.274	241.087	241.090	0.003
2167_2018_OK	330544.074	4096462.708	259.310	259.270	0.040
2168_2018_OK	327753.790	4090344.877	248.912	248.850	0.062
2169_2018_OK	339393.545	4094962.339	251.924	252.000	0.076
2170_2018_OK	348573.663	4096077.116	243.776	243.720	0.056
2171_2018_OK	354695.759	4094859.986	281.915	281.900	0.015

Appendix 4: DEM VVA Checkpoint Results

Coordinate values are listed in the following spatial reference system:

Horizontal: NAD83 (2011) UTM zone 13 / 14 / 15, meters

Vertical: NAVD88 (GEOID12B) meters

Summary	UTM z13	UTM z14	UTM z15
Point Count	15	80	35
Root Mean Square Error	0.147 m	0.075 m	0.115 m
95th Percentile	0.180 m	0.150 m	0.230 m
Mean of Residuals	0.139 m	0.060 m	0.090 m
Standard Deviation	0.050 m	0.046 m	0.073 m

UTM z13 (OK Panhandle)

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3033_2018_OK	681351.100	4044711.624	1440.760	1441.000	0.240
3034_2018_OK	714423.087	4050300.026	1293.990	1294.170	0.180
3036_2018_OK	730031.671	4069988.500	1243.560	1243.610	0.050
3037_2018_OK	743984.587	4075234.470	1203.150	1203.330	0.180
3038_2018_OK	753339.461	4094830.503	1161.750	1161.890	0.140
3057_2018_OK	697815.355	4054732.955	1361.520	1361.620	0.100
3058_2018_OK	691324.124	4061021.970	1406.400	1406.580	0.180
3059_2018_OK	685623.821	4056017.809	1392.680	1392.820	0.140
3060_2018_OK	736631.488	4053392.633	1207.220	1207.360	0.140
3061_2018_OK	736787.033	4044388.092	1210.030	1210.100	0.070
3083_2018_OK	733100.339	4079771.878	1246.330	1246.480	0.150
3084_2018_OK	724294.508	4068374.821	1257.000	1257.170	0.170
3085_2018_OK	757688.714	4046604.747	1152.530	1152.650	0.120
3094_2018_OK	750338.383	4086650.079	1190.700	1190.850	0.150
3095_2018_OK	752453.879	4060979.531	1166.860	1166.940	0.080

UTM z14 (OK Panhandle + Oklahoma City)

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3001_2018_OK	640934.872	3951594.544	343.073	343.2300	0.1570
3002_2018_OK	652869.615	3953146.961	344.791	344.9800	0.1890
3003_2018_OK	637452.291	3935418.328	348.551	348.5900	0.0390
3004_2018_OK	664742.294	3887428.750	340.085	340.0900	0.0050
3005_2018_OK	656356.215	3892799.951	358.027	358.1100	0.0830
3006_2018_OK	657883.722	3900328.715	324.600	324.5900	0.0100
3007_2018_OK	663809.732	3917358.833	352.120	352.2500	0.1300
3008_2018_OK	650759.462	3923834.729	393.561	393.6800	0.1190
3019_2018_OK	657979.024	3890624.078	359.210	359.2800	0.0700
3020_2018_OK	649026.990	3900090.320	357.029	357.0200	0.0090
3021_2018_OK	638838.304	3904783.437	354.075	354.1100	0.0350
3022_2018_OK	641238.533	3912719.458	383.218	383.2500	0.0320
3023_2018_OK	664846.415	3909893.062	344.989	344.9300	0.0590
3024_2018_OK	665908.832	3914716.580	341.014	341.1900	0.1760
3025_2018_OK	655057.868	3922685.448	382.988	383.0800	0.0920
3026_2018_OK	409180.952	4062435.931	672.232	672.3300	0.0980
3027_2018_OK	405608.567	4073494.255	665.053	665.0700	0.0170
3028_2018_OK	277271.294	4061703.064	940.591	940.5300	0.0610
3029_2018_OK	621901.797	3941145.980	344.456	344.5100	0.0540
3039_2018_OK	233635.576	4096806.370	1116.394	1116.4600	0.0660
3040_2018_OK	245602.457	4091577.058	1091.318	1091.3900	0.0720
3041_2018_OK	274568.228	4093928.618	1001.538	1001.7300	0.1920
3042_2018_OK	294513.569	4090833.916	945.833	945.8600	0.0270
3043_2018_OK	312356.761	4093824.862	903.060	903.1600	0.1000
3044_2018_OK	334731.216	4089329.230	847.993	848.0300	0.0370
3045_2018_OK	351853.373	4084251.892	809.896	809.9900	0.0940
3046_2018_OK	398274.417	4089915.776	641.512	641.5500	0.0380
3047_2018_OK	387925.564	4051114.103	769.482	769.5200	0.0380
3048_2018_OK	403504.788	4043124.326	771.273	771.3200	0.0470
3049_2018_OK	371742.227	4048414.132	822.120	822.1900	0.0700
3050_2018_OK	355646.885	4044674.930	873.347	873.3700	0.0230
3051_2018_OK	331546.596	4047140.223	876.092	876.1400	0.0480
3052_2018_OK	323669.981	4054128.234	829.447	829.4800	0.0330

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3053_2018_OK	308763.802	4072195.070	881.017	881.1300	0.1130
3054_2018_OK	290378.680	4077469.336	928.184	928.1900	0.0060
3055_2018_OK	256412.786	4065736.344	984.931	984.9500	0.0190
3056_2018_OK	238362.512	4059609.019	1079.529	1079.6100	0.0810
3062_2018_OK	256376.001	4049390.400	1037.978	1038.0000	0.0220
3063_2018_OK	267927.010	4044209.373	996.809	996.8400	0.0310
3064_2018_OK	287461.519	4044903.375	945.517	945.5700	0.0530
3065_2018_OK	315226.026	4060621.553	816.068	816.1500	0.0820
3066_2018_OK	343552.183	4056947.120	865.922	865.9000	0.0220
3067_2018_OK	370369.278	4066041.690	741.494	741.5400	0.0460
3068_2018_OK	388006.766	4067652.092	735.645	735.6700	0.0250
3068A_2018_OK	388010.575	4067577.558	734.962	734.9600	0.0020
3069_2018_OK	373729.909	4080776.231	789.402	789.3400	0.0620
3070_2018_OK	390208.122	4096573.689	718.596	718.6600	0.0640
3071_2018_OK	405276.102	4084978.472	649.503	649.5400	0.0370
3072_2018_OK	389345.538	4083558.701	788.149	788.2900	0.1410
3073_2018_OK	377739.917	4094123.589	692.658	692.6600	0.0020
3074_2018_OK	326064.971	4073403.057	837.603	837.6200	0.0170
3075_2018_OK	378979.271	4073145.547	707.967	708.1000	0.1330
3076_2018_OK	352315.049	4063256.027	834.923	834.9000	0.0230
3077_2018_OK	333597.002	4073601.349	831.263	831.2400	0.0230
3077A_2018_OK	333639.090	4073569.798	831.063	831.1700	0.1070
3078_2018_OK	329035.180	4083040.595	845.368	845.4600	0.0920
3079_2018_OK	321570.717	4089649.765	872.806	872.8100	0.0040
3080_2018_OK	323641.785	4094163.351	876.104	876.0800	0.0240
3080A_2018_OK	327012.247	4096481.242	869.299	869.2100	0.0890
3081_2018_OK	269480.684	4084407.843	1004.695	1004.7500	0.0550
3082_2018_OK	274478.992	4076352.997	958.161	958.1900	0.0290
3086_2018_OK	300918.898	4048206.981	904.738	904.7800	0.0420
3087_2018_OK	383017.204	4044974.931	769.187	769.2200	0.0330
3088_2018_OK	369331.292	4090346.318	766.283	766.2800	0.0030
3089_2018_OK	361562.891	4097468.802	731.257	731.2200	0.0370
3090_2018_OK	344390.149	4087698.705	831.870	831.8700	0.0000
3091_2018_OK	273539.723	4071510.573	948.514	948.6000	0.0860

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3092_2018_OK	307246.617	4081847.899	900.026	900.0500	0.0240
3093_2018_OK	317730.298	4078435.004	867.283	867.3500	0.0670
3096_2018_OK	232646.896	4075922.332	1112.917	1113.050	0.1330
3097_2018_OK	620365.000	3952682.541	355.758	355.8000	0.0420
3098_2018_OK	652163.241	3942500.902	353.736	353.7300	0.0060
3099_2018_OK	626507.758	3944785.113	331.033	331.1300	0.0970
3100_2018_OK	647399.140	3885581.947	333.361	333.4200	0.0590
3101_2018_OK	647859.957	3893666.939	338.777	338.7700	0.0070
3102_2018_OK	635374.031	3900713.034	343.525	343.5000	0.0250
3103_2018_OK	627132.509	3912561.432	375.975	376.1100	0.1350
3104_2018_OK	621478.176	3926557.356	378.262	378.3500	0.0880
3105_2018_OK	623628.990	3917340.593	394.628	394.7100	0.0820
3106_2018_OK	645266.724	3933762.576	352.815	352.8900	0.0750

UTM z15 (Ottawa County)

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3009_2018_OK	353782.601	4063388.526	294.221	294.300	0.079
3010_2018_OK	345586.548	4065481.434	237.572	237.680	0.108
3011_2018_OK	354717.462	4094872.424	281.413	281.520	0.107
3012_2018_OK	330905.784	4059996.459	236.719	236.840	0.121
3013_2018_OK	346811.772	4061651.992	325.376	325.620	0.244
3014_2018_OK	351963.378	4086753.366	288.481	288.510	0.029
3014A_2018_OK	351997.376	4086710.677	290.758	290.790	0.032
3015_2018_KS	348582.744	4096096.220	244.239	244.270	0.031
3015A_2018_KS	348599.455	4096099.378	244.426	244.420	0.006
3016_2018_OK	320954.077	4094023.699	237.704	237.790	0.086
3016A_2018_OK	320990.333	4094084.158	238.015	238.160	0.145
3017_2018_OK	331033.424	4062570.740	253.068	253.320	0.252
3018_2018_OK	351991.732	4064539.323	334.938	335.110	0.172
3030_2018_OK	331093.133	4084279.370	239.124	239.220	0.096
3031_2018_OK	339368.944	4094975.373	251.825	252.010	0.185
3031A_2018_OK	339410.953	4094974.446	251.981	252.030	0.049
3032_2018_OK	353315.749	4079121.919	281.160	281.140	0.020
3032A_2018_OK	353304.703	4079155.685	278.910	278.870	0.040

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3107_2018_OK	339087.692	4063667.865	276.038	276.280	0.242
3108_2018_OK	339041.654	4082800.435	250.096	250.140	0.044
3109_2018_OK	327747.231	4090354.668	249.026	249.100	0.074
3109A_2018_OK	324046.292	4095206.486	247.643	247.740	0.097
3110_2018_OK	323428.202	4074659.873	237.938	238.170	0.232
3111_2018_OK	336170.233	4077997.979	235.564	235.630	0.066
3111A_2018_OK	336162.590	4078083.993	235.925	235.920	0.005
3112_2018_OK	344657.259	4083636.919	236.994	237.120	0.126
3112A_2018_OK	343885.317	4086426.367	261.731	261.720	0.011
3113_2018_OK	343131.890	4090088.661	249.354	249.430	0.076
3113A_2018_OK	343049.187	4090076.191	251.018	251.020	0.002
3114_2018_OK	330537.769	4096444.677	259.654	259.670	0.016
3114A_2018_OK	330579.199	4096475.575	258.661	258.620	0.041
3115_2018_OK	331179.757	4069648.556	243.540	243.660	0.120
3115A_2018_OK	331220.212	4069635.645	243.328	243.420	0.092
3116_2018_OK	342497.023	4075683.791	251.292	251.350	0.058
3116A_2018_OK	342452.136	4075691.923	251.156	251.190	0.034