Airborne Lidar Report

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Lower Maumee 2016 Lidar Contract

Number: G16PC00022
Task Number: 0040270192

Contractor: Woolpert, Inc.
Woolpert Project # 76327

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Table of Contents

List of Figures

List of Tables

Section 1: Overview

TASK ORDER NAME: Lower Maumee 2016 Lidar

Project: # 76327

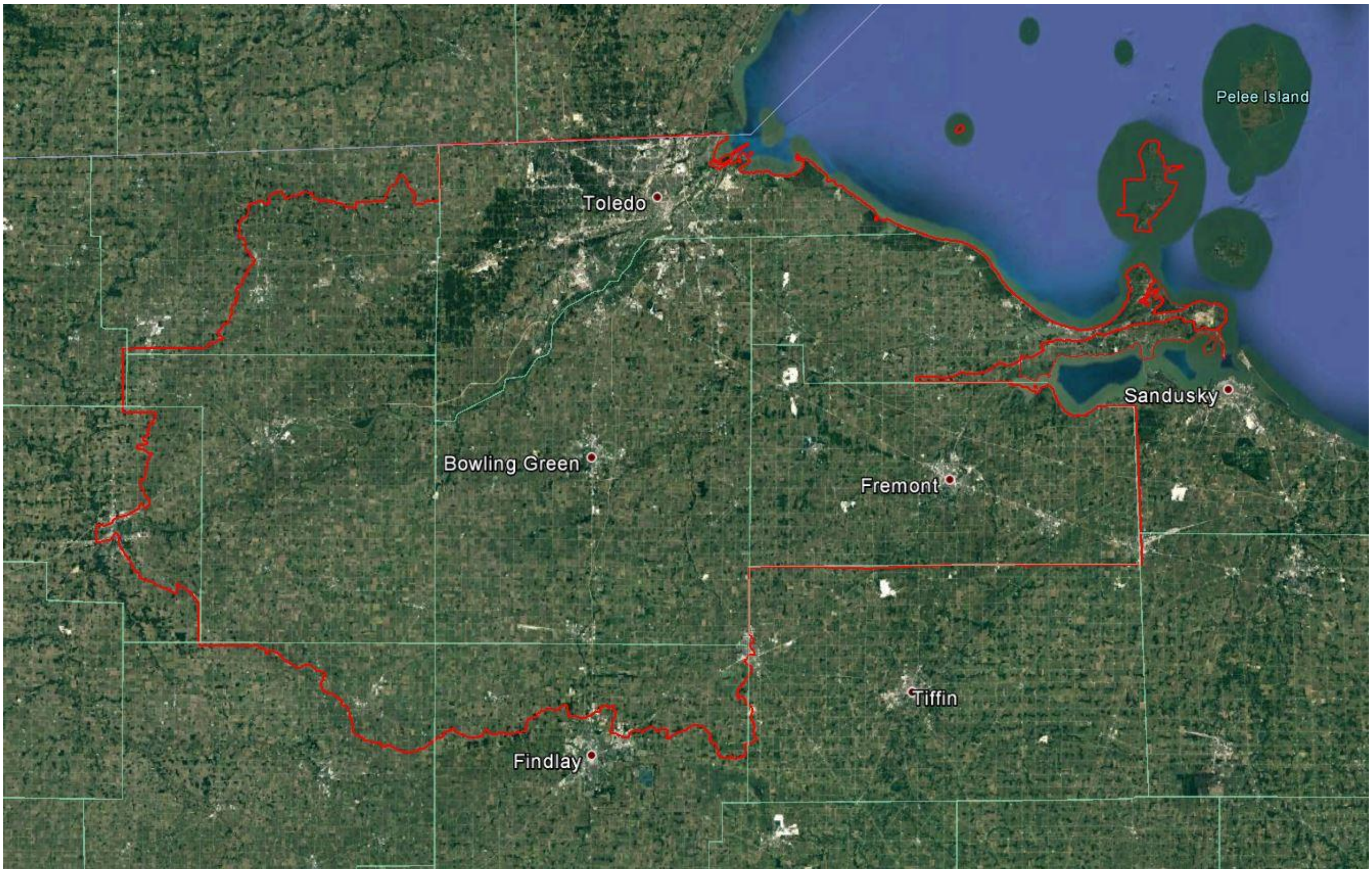
This report contains a comprehensive outline of the Lower Maumee 2016 Lidar Processing task order for the United States Geological Survey (USGS). This task is issued under USGS Contract No. G16PC00022, Task Order No. 0040270192. This task order requires lidar data to be acquired over 2,484 square miles of northwest Ohio that drains into Lake Erie collected at a nominal pulse spacing (NPS) of 0.7 meters. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

The data was collected using a Leica ALS80 HP 1000 kHz Multiple Pulses in Air (MPiA) lidar systems on board Woolpert aircraft. The ALS80 sensor collects up to four returns per pulse, as well as intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value. The aerial lidar was collected at the following sensor specifications:

Table 1.1: ALS80 Specifications	
Post Spacing	0.70 m
AGL (Above Ground Level) average flying height	1981m
Average Ground Speed:	150 knots
Field of View (full)	40 degrees
Pulse Rate	272 kHz
Scan Rate	50 Hz
Side Lap	26%

The LiDAR data was produced in NAD83(2011) StatePlane Ohio North FIPS3401, NAVD88 Geoid12B Survey Feet.

Figure 1.1: Lower Maumee 2016 Lidar Task Order AOI



Section 2: Acquisition

The lidar data was acquired with three Leica ALS80HP 1000 kHz Multiple Pulses in Air (MPiA) Lidar Sensor Systems. The ALS80 HP lidar system, developed by Leica Geosystems of Heerbrugg, Switzerland, includes the simultaneous first, intermediate and last pulse data capture module, the extended altitude range module, and the target signal intensity capture module.

The ALS80HP 1000 kHz Multiple Pulses in Air (MPiA) Lidar System has the following specifications:

Table 2.1: ALS80 HP Lidar System Specifications	
Operating Altitude	100 – 7,620 meters
Scan Angle	0 to 72° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 200 Hz (variable based on scan angle)
Maximum Pulse Rate	1000 kHz (Effective)
Range Resolution	Better than 1 cm
Elevation Accuracy	6 - 19 cm single shot (one standard deviation)
Horizontal Accuracy	5 – 43 cm (one standard deviation)
Number of Returns per Pulse	Unlimited
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control) level
MPiA (Multiple Pulses in Air)	8 bits @ 1nsec interval @ 50kHz
Laser Beam Divergence	0.22 mrad @ $1/e^2$ (~0.15 mrad @ 1/e)
Laser Classification	Class IV laser product (FDA CFR 21)
Eye Safe Range	400m single shot depending on laser repetition rate
Roll Stabilization	Automatic adaptive, range = 75 degrees minus current FOV
Power Requirements	28 VDC @ 25A
Operating Temperature	0-40°C
Humidity	0-95% non-condensing
Supported GNSS Receivers	Ashtech Z12, Trimble 7400, Novatel Millenium

Prior to mobilizing to the project site, flight crews coordinated with the necessary Air Traffic Control personnel to ensure airspace access.

Crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

The LiDAR data was collected in nine (9) mission, flown as close together as the weather permitted, to ensure consistent ground conditions across the project area. An initial quality control process was performed immediately on the LiDAR data to review the data coverage, airborne GPS data, and trajectory solution.

Figure 2.1: LiDAR Flight Layout, Lower Maumee 2016 Lidar

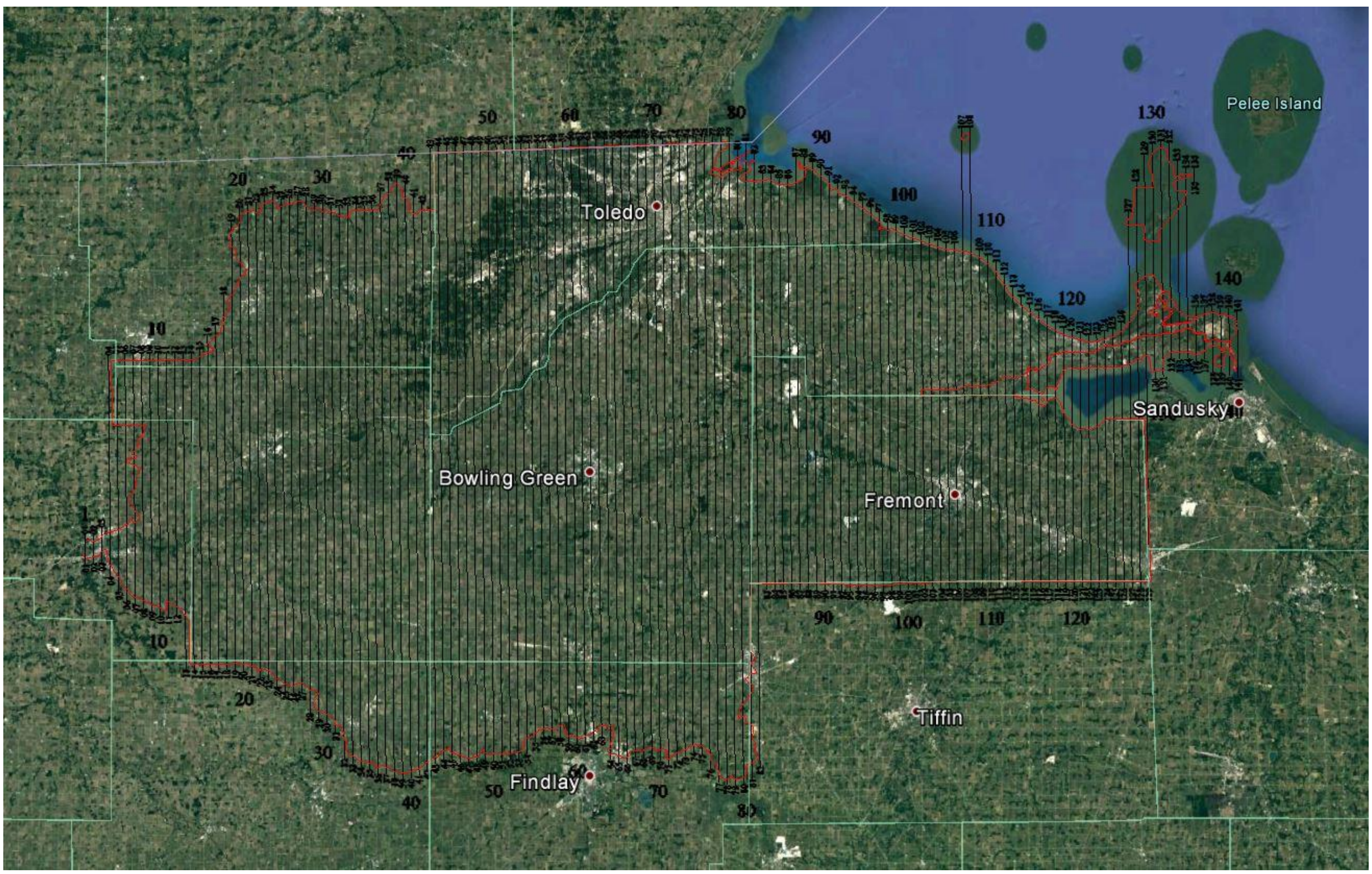


Table 2.2: Airborne Lidar Acquisition Flight Summary

Date of Mission	Lines Flown	Mission Time (UTC) Wheels Up/ Wheels Down
April 13, 2016	**130-141**	**17:45 – 19:04**
April 15, 2016	**125-129**	**14:33 – 16:59**
April 15, 2016	**1-22**	**14:57 – 19:04**
April 16, 2016	**75-90**	**13:35 - 20:27**
April 16, 2016	**91-124**	**13:19 – 21:17**
April 16, 2016	**44-55**	**13:28 – 17:45**
April 16, 2016	**37-42**	**19:17 – 21:11**
April 17, 2016	**23-36**	**13:16 - 19:14**
April 17, 2016	**56-75**	**14:23 – 21:55**

Section 3: LiDAR Data Processing

Applications and Work Flow Overview

1. Resolved kinematic corrections for three subsystems: inertial measurement unit (IMU), sensor orientation information and airborne GPS data. Developed a blending post-processed aircraft position with attitude data using Kalman filtering technology or the smoothed best estimate trajectory (SBET).
Software: POSPac Software v. 5.3, IPAS Pro v.1.35., Novatel Inertial Explorer v8.60.6129
2.Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey 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.
Software: ALS Post Processing Software v.2.75 build #25, Proprietary Software, TerraMatch v. 16.01., Add Leica Cloud Pro v1.2.3
3.Imported processed LAS point cloud data into the task order tiles. Resulting data were 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.
Software: TerraScan v.16.01.
4.The LAS files were evaluated through a series of manual QA/QC steps to eliminate remaining artifacts from the ground class.
Software: TerraScan v.16.01.

Global Navigation Satellite System (GNSS)–Inertial Measurement Unit (IMU) Trajectory Processing

Equipment

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 were used to support the LiDAR data acquisition. The GNSS base station operated during the Lidar acquisition missions is listed below:

Table 3.1: GNSS Base Station

Station (Name)	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase center) (Meters)
1G0_Arpt_Base	41°23'09.68786"	83°38'06.40796"	169.423m

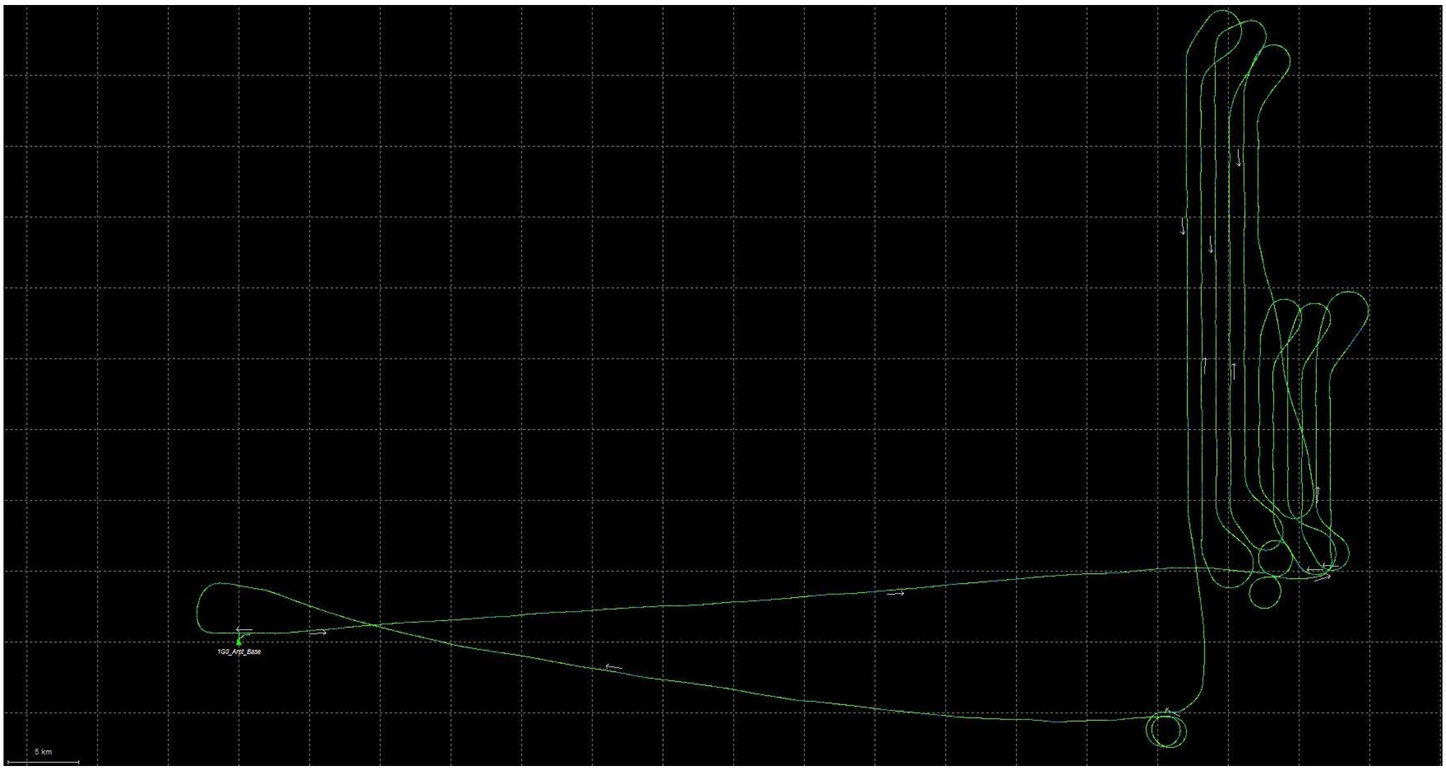
Data Processing

All airborne GNSS and IMU data was post-processed and quality controlled using Applanix MMS software. GNSS data was processed at a 1 and 2 Hz data capture rate and the IMU data was processed at 200 Hz.

Trajectory Quality

The GNSS Trajectory, along with 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).

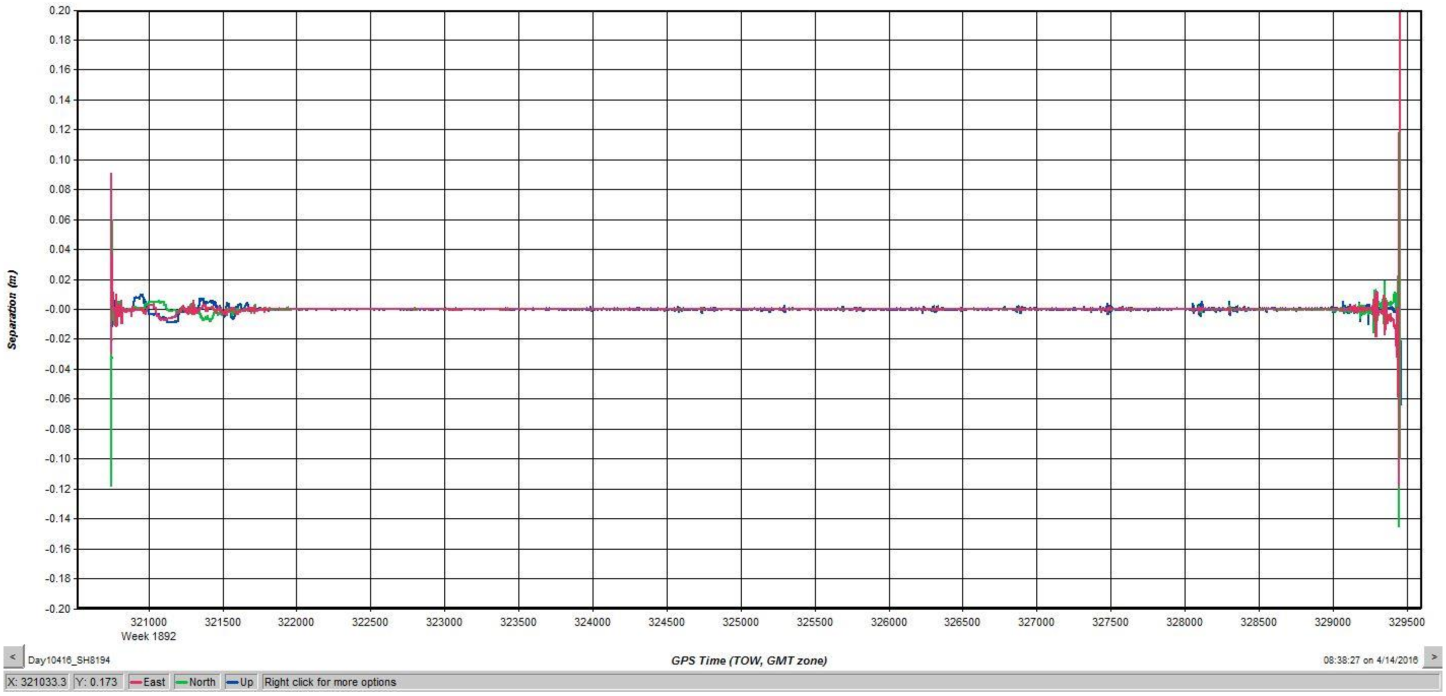
Figure 3.1: Trajectory, Day10416_SH8194



Combination Separation

The Combined Separation is a measure of the difference between the forward run and the backward run solution of the trajectory. The Kalman filter is processed in both directions to remove the combined directional anomalies. In general, when these two solutions match closely, an optimally accurate reliable solution is achieved.
Woolpert's goal is to maintain a Combined Separation Difference of less than ten (10) centimeters. In most cases we achieve results below this threshold.

Figure 3.2: Combined Separation, Day10416_SH8194

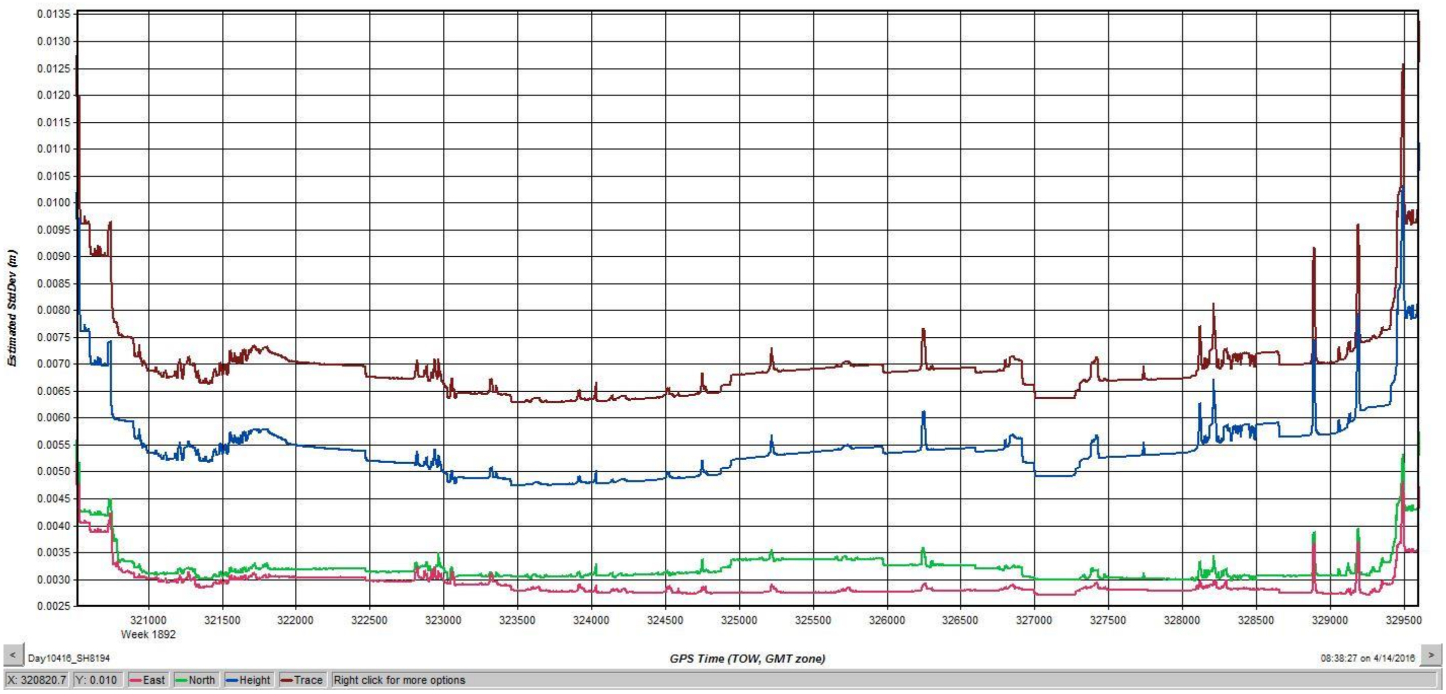


Estimated Positional Accuracy

The 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.

Woolpert's goal is to maintain an Estimated Positional Accuracy of less than ten (10) centimeters, often achieving results well below this threshold.

Figure 3.3: Estimated Positional Accuracy, Day10416_SH8194

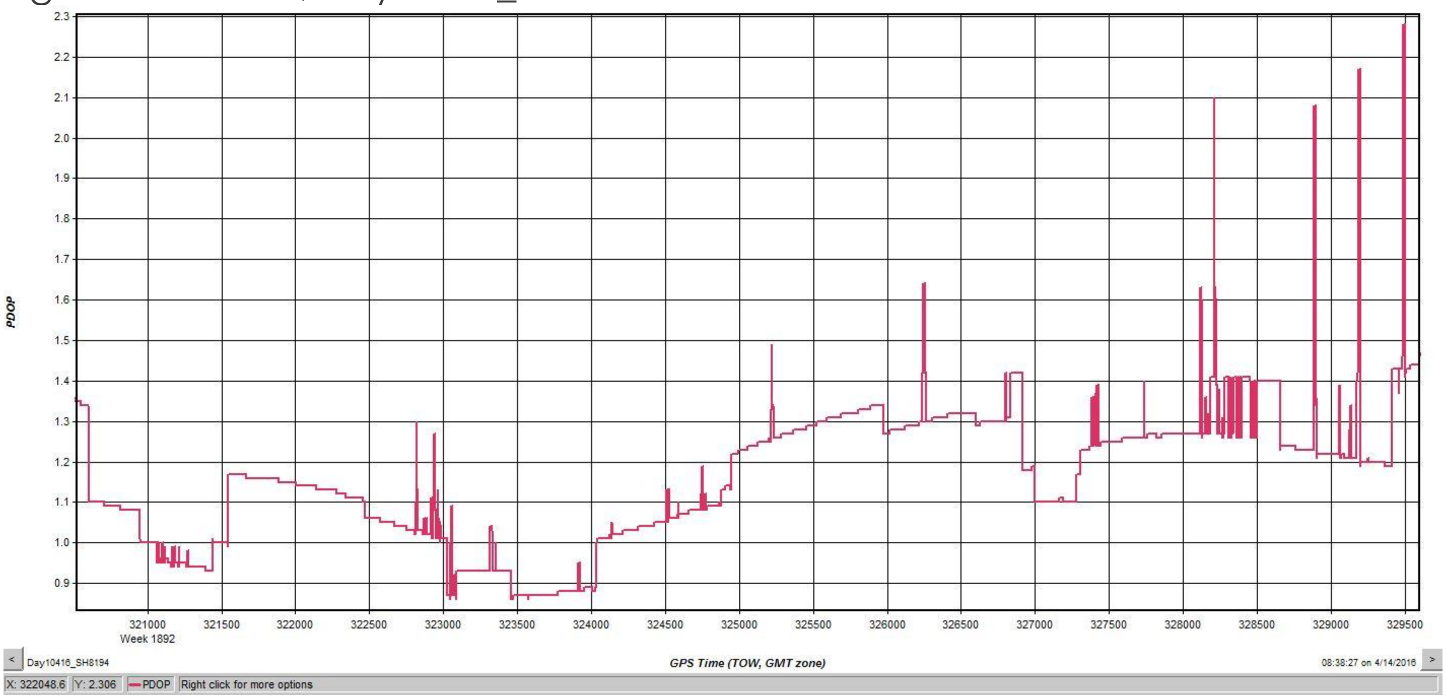


PDOP

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

Woolpert's goal is 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.

Figure 3.4: PDOP, Day10416_SH8194



LiDAR Data Processing

When the sensor calibration, data acquisition, and GPS processing phases were complete, the formal data reduction processes by Woolpert lidar specialists included:

- Processed individual flight lines to derive a raw “Point Cloud” LAS file. Matched overlapping flight lines, generated statistics for evaluation comparisons, and made the necessary adjustments to remove any residual systematic error.
- 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 client specified classes.
- Once all project data was imported and classified, survey ground control data was imported and calculated for an accuracy assessment. As a QC measure, Woolpert has developed a routine to generate accuracy statistical reports by comparisons against the TIN and the DEM using surveyed ground control of higher accuracy. The lidar is adjusted accordingly to meet or exceed the vertical accuracy requirements.
- The lidar tiles were reviewed using a series of proprietary QA/QC procedures to ensure it fulfills the task order requirements. A portion of this requires a manual step to ensure anomalies have been removed from the ground class.
- The lidar LAS files are classified into the Default (Class 1), Ground (Class 2), Low noise (Class 7), Water (Class 9), Ignored ground (Class10), Bridge Decks (Class 17), High Noise (Class 18) classifications.
- FGDC Compliant metadata was developed for the task order in .xml format per product.
- The horizontal datum used for the task order was referenced to NAD83(2011), State Plane, zone Ohio North, Survey Feet. The vertical datum used for the task order was referenced to NAVD 1988, Survey Feet, GEOID12B.
- An occluded area exists at Sunoco Logistics Refinery, due to smoke from a smokestack. The area was flown on 3 separate occasions. Sunoco Logistics Refinery location coordinates are approximately 291400 E and 4611819N in UTM 17 meters.

Section 4: Hydrologic Flattening

HYDROLOGIC FLATTENING OF LIDAR DEM DATA

Lower Maumee 2016 Lidar processing task order required the compilation of breaklines defining water bodies and rivers. The breaklines were used to perform the hydrologic flattening of water bodies, and gradient hydrologic flattening of double line streams and rivers. Lakes, reservoirs and ponds, at a minimum size of 2-acre or greater, were compiled as closed polygons. The closed water bodies were collected at a constant elevation. Rivers and streams, at a nominal minimum width of 30 meters (100 feet), were compiled in the direction of flow with both sides of the stream maintaining an equal gradient elevation.

LIDAR DATA REVIEW AND PROCESSING

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. Woolpert used the newly acquired lidar data to manually draw 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. Woolpert utilizes an integrated software approach 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. The lakes, reservoirs and ponds, at a minimum size of 2-acre or greater and streams at a minimum size of 30 meters (100 feet) nominal width, were compiled to meet task order requirements. **Figure 4.1** illustrates an example of 30 meters (100 feet) nominal streams identified and defined with hydrologic breaklines. The breaklines defining rivers and streams, at a nominal minimum width of 30 meters (100 feet), were draped with both sides of the stream maintaining an equal gradient elevation.
4. All ground points were reclassified from inside the hydrologic feature polygons to water, class nine (9).
5. All ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class ten (10).
6. The lidar ground points and hydrologic feature breaklines were used to generate a new digital elevation model (DEM).

Figure 4.1: Example Hydrologic Breaklines

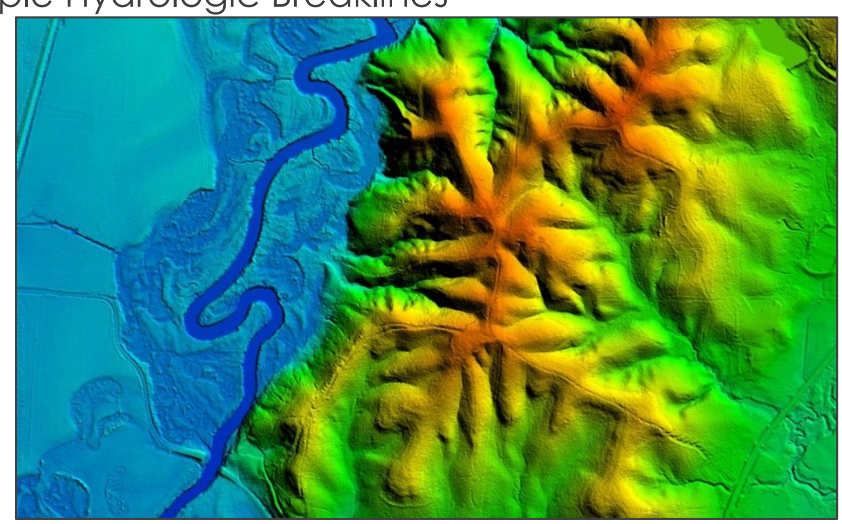


Figure 4.2 reflects a DEM generated from original lidar bare earth point data prior to the hydrologic flattening process. Note the "tinning" across the lake surface.

Figure 4.3 reflects a DEM generated from lidar with breaklines compiled to define the hydrologic features. This figure illustrates the results of adding the breaklines to hydrologically flatten the DEM data. Note the smooth appearance of the lake surface in the DEM.

Figure 4.2

Figure 4.3

Terrascan was used to add the hydrologic breakline vertices and export the lattice models. The hydrologically flattened DEM data was provided to USGS in ERDAS .IMG format.

The hydrologic breaklines compiled as part of the flattening process were provided to the USGS as an ESRI Shapefile The breaklines defining the water bodies greater than 2-acre and for the gradient flattening of all rivers and streams at a nominal minimum width of 30 meters (100 feet) were provided as a Polygon-Z and Polyline-Z shape file, respectively.

DATA QA/QC

Initial QA/QC for this task order was performed in Global Mapper v17, by reviewing the grids and hydrologic breakline features. Additionally, ESRI software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

Edits and corrections were addressed individually by tile. If a water body breakline needed to be adjusted to improve the flattening of the DEM data, the area was cross referenced by tile number, corrected accordingly, a new DEM file was regenerated and reviewed.

Section 5: ACCURACY ASSESSMENT

Accuracy Assessment

The vertical accuracy statistics were calculated by comparison of all lidar points to the ground surveyed QC points.

Table 5.1: Overall Vertical Accuracy Statistics		
Average error	0.014	Sv Feet
Minimum error	-0.220	Sv Feet
Maximum error	0.250	Sv Feet
Average magnitude	0.078	Sv Feet
Root mean square	0.094	Sv Feet
Standard deviation	0.093	Sv Feet

Table 5.2: RAW Swath Quality Check Point Analysis NVA

Point ID	Easting (Sv Feet)	Northing (Sv Feet)	Elevation (Sv Feet)	TIN Elevation (Sv Feet)	Dz (Sv Feet)
2001	1452522.980	596973.470	710.570	710.560	-0.010
2002	1475094.030	656155.420	735.700	735.650	-0.050
2003	1490295.080	582781.760	725.910	725.980	0.070
2004	1502708.540	646245.590	698.320	698.340	0.020
2005	1537018.480	687709.420	738.710	738.650	-0.060
2006	1554266.790	723313.160	755.630	755.590	-0.040
2007	1542546.510	632576.990	673.180	673.220	0.040
2008	1566782.910	523607.930	752.100	752.060	-0.040
2009	1567212.180	573680.040	707.790	707.590	-0.200
2010	1573665.410	668617.080	675.140	675.240	0.100
2011	1602925.750	733436.260	696.420	696.480	0.060
2012	1615376.730	618958.070	683.660	683.770	0.110
2013	1539474.130	598004.910	690.580	690.710	0.130
2014	1534402.960	546764.820	746.840	746.950	0.110
2015	1601873.060	565055.700	705.750	705.800	0.050
2016	1486465.170	631219.450	720.020	719.990	-0.030
2017	1614148.550	525884.720	771.340	771.220	-0.120
2018	1583295.910	607631.840	683.490	683.380	-0.110
2019	1554222.330	701939.450	723.500	723.280	-0.220
2020	1615353.720	711123.070	671.240	671.290	0.050
2021	1645982.290	580534.170	690.760	690.790	0.030
2022	1651062.960	551423.470	728.610	728.750	0.140
2023	1685077.500	526949.450	807.050	807.300	0.250
2024	1629199.020	675219.460	648.130	648.160	0.030

2025	1515414.750	629371.130	681.890	681.840	-0.050
2026	1511796.020	598313.310	683.290	683.380	0.090
2027	1710632.720	555787.560	749.970	750.080	0.110
2028	1677338.840	574638.610	702.700	702.770	0.070
2029	1664126.500	625274.670	670.310	670.400	0.090
2030	1684724.520	692626.090	627.040	627.100	0.060
2031	1642583.910	745578.960	660.760	660.590	-0.170
2032	1687960.410	746856.720	592.850	592.980	0.130
2033	1664355.430	712227.150	626.240	626.180	-0.060
2034	1677394.370	655182.170	656.870	656.960	0.090
2035	1717500.260	724529.950	590.530	590.640	0.110
2036	1727805.770	710908.730	596.910	596.960	0.050
2037	1757251.050	730440.040	572.240	572.250	0.010
2038	1781716.600	704990.180	576.880	576.830	-0.050
2039	1801531.180	706221.900	574.770	574.610	-0.160
2040	1731241.570	673745.930	626.770	626.660	-0.110
2041	1786589.000	677747.670	591.720	591.700	-0.020
2042	1776056.120	639985.850	613.640	613.720	0.080
2043	1715639.750	651012.470	651.710	651.630	-0.080
2044	1770726.250	687511.230	592.650	592.770	0.120
2045	1714973.820	606141.000	702.680	702.820	0.140
2046	1738134.120	623531.470	695.390	695.440	0.050
2047	1731531.610	590397.270	723.520	723.390	-0.130
2048	1774325.560	584320.940	682.520	682.710	0.190
2049	1793784.260	622414.220	622.050	621.980	-0.070
2050	1836180.800	594326.470	680.230	680.370	0.140
2051	1864448.510	588912.340	778.500	778.470	-0.030
2052	1815915.990	591453.440	642.240	642.290	0.050
2053	1860632.510	608237.470	693.150	693.130	-0.020
2054	1820292.060	637327.930	577.670	577.660	-0.010
2055	1843910.790	626446.310	594.420	594.360	-0.060
2056	1802258.090	648633.570	582.310	582.240	-0.070
2057	1909422.630	679120.730	585.030	585.120	0.090
2058	1897306.240	683158.910	605.350	605.350	0.000
2059	1877364.830	693504.580	590.500	590.520	0.020
2060	1881544.250	685151.990	583.050	583.140	0.090
2061	1892544.160	680312.550	599.250	599.360	0.110
2062	1870105.750	679634.270	607.260	607.350	0.090
2063	1817455.120	685214.460	576.150	576.080	-0.070
2064	1851279.170	670379.640	576.400	576.480	0.080
2065	1809230.410	673500.600	581.350	581.310	-0.040
2066	1528748.750	582231.810	705.950	705.800	-0.150
2067	1567128.070	555338.130	722.230	722.220	-0.010
2068	1616036.720	597387.000	693.690	693.640	-0.050
2069	1520824.930	667057.600	711.440	711.510	0.070

2070	1527759.930	723226.940	777.590	777.470	-0.120
2071	1544626.010	666733.890	682.030	681.940	-0.090
2072	1569459.080	650668.420	671.530	671.530	0.000
2073	1587071.080	693793.890	674.070	674.070	0.000
2074	1623839.040	652983.710	662.990	663.110	0.120
2075	1509566.940	564200.820	735.730	735.700	-0.030
2076	1598868.280	544272.110	723.910	723.930	0.020
2077	1673781.970	600968.370	676.420	676.570	0.150
2078	1660068.640	678513.420	643.490	643.400	-0.090
2079	1642362.560	722898.020	636.480	636.480	0.000
2080	1765408.520	674707.570	602.680	602.710	0.030
2081	1760195.300	656180.370	612.570	612.650	0.080
2082	1770178.670	618930.020	650.830	650.900	0.070
2083	1833149.780	616344.370	618.920	618.950	0.030

VERTICAL ACCURACY CONCLUSIONS

Raw Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.184 Survey Feet Non Vegetated Vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using all points.

LAS Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.186 Survey Feet Non vegetated vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using ground points.

Table 5.3: NVA Check Point Analysis DEM

Point ID	Easting (Sv Feet)	Northing (Sv Feet)	Elevation (Sv Feet)	DEM Elevation (Sv Feet)	Dz (Sv Feet)
2001	1452522.983	596973.474	710.574	710.613	-0.039
2002	1475094.027	656155.423	735.699	735.643	0.056
2003	1490295.084	582781.756	725.912	725.973	-0.061
2004	1502708.539	646245.590	698.322	698.313	0.009
2005	1537018.477	687709.421	738.705	738.583	0.122
2006	1554266.787	723313.157	755.628	755.563	0.065
2007	1542546.507	632576.985	673.178	673.203	-0.025
2008	1566782.912	523607.929	752.100	752.043	0.057
2009	1567212.180	573680.039	707.789	707.553	0.236
2010	1573665.411	668617.076	675.136	675.213	-0.077
2011	1602925.748	733436.262	696.418	696.493	-0.075
2012	1615376.727	618958.068	683.661	683.783	-0.122
2013	1539474.125	598004.911	690.575	690.713	-0.138
2014	1534402.956	546764.822	746.837	746.913	-0.076

2015	1601873.060	565055.699	705.753	705.783	-0.030
2016	1486465.173	631219.446	720.024	719.973	0.051
2017	1614148.554	525884.721	771.338	771.223	0.115
2018	1583295.910	607631.839	683.487	683.403	0.084
2019	1554222.331	701939.446	723.504	723.213	0.291
2020	1615353.715	711123.071	671.242	671.203	0.039
2021	1645982.293	580534.170	690.760	690.793	-0.033
2022	1651062.959	551423.471	728.611	728.733	-0.122
2023	1685077.497	526949.451	807.049	807.283	-0.234
2024	1629199.021	675219.463	648.130	648.133	-0.003
2025	1515414.749	629371.130	681.891	681.763	0.128
2026	1511796.024	598313.306	683.286	683.383	-0.097
2027	1710632.721	555787.559	749.971	750.093	-0.122
2028	1677338.841	574638.608	702.699	702.773	-0.074
2029	1664126.500	625274.668	670.307	670.363	-0.056
2030	1684724.518	692626.088	627.038	627.083	-0.045
2031	1642583.905	745578.962	660.763	660.623	0.140
2032	1687960.412	746856.720	592.854	592.932	-0.078
2033	1664355.427	712227.147	626.237	626.133	0.104
2034	1677394.366	655182.174	656.872	657.013	-0.141
2035	1717500.263	724529.946	590.530	590.632	-0.102
2036	1727805.768	710908.730	596.910	596.932	-0.022
2037	1757251.052	730440.042	572.236	572.212	0.024
2038	1781716.597	704990.182	576.876	576.832	0.044
2039	1801531.177	706221.903	574.770	574.612	0.158
2040	1731241.565	673745.933	626.768	626.733	0.035
2041	1786588.998	677747.668	591.720	591.732	-0.012
2042	1776056.120	639985.853	613.637	613.742	-0.105
2043	1715639.750	651012.471	651.714	651.683	0.031
2044	1770726.245	687511.234	592.650	592.702	-0.052
2045	1714973.820	606140.999	702.676	702.853	-0.177
2046	1738134.120	623531.468	695.386	695.413	-0.027
2047	1731531.614	590397.269	723.516	723.393	0.123
2048	1774325.563	584320.943	682.524	682.743	-0.219
2049	1793784.257	622414.219	622.051	621.932	0.119
2050	1836180.803	594326.468	680.233	680.433	-0.200
2051	1864448.505	588912.336	778.499	778.483	0.016
2052	1815915.986	591453.436	642.244	642.323	-0.079
2053	1860632.511	608237.474	693.153	693.133	0.020
2054	1820292.060	637327.927	577.672	577.682	-0.010
2055	1843910.787	626446.310	594.415	594.362	0.053
2056	1802258.091	648633.573	582.307	582.242	0.065
2057	1909422.630	679120.727	585.027	585.092	-0.065
2058	1897306.243	683158.905	605.350	605.352	-0.002
2059	1877364.834	693504.575	590.499	590.542	-0.043
2060	1881544.247	685151.986	583.049	583.142	-0.093
2061	1892544.160	680312.554	599.251	599.272	-0.021
2062	1870105.749	679634.272	607.255	607.282	-0.027

2063	1817455.122	685214.460	576.152	576.092	0.060
2064	1851279.174	670379.637	576.402	576.482	-0.080
2065	1809230.409	673500.599	581.353	581.302	0.051
2066	1528748.752	582231.812	705.949	705.873	0.076
2067	1567128.069	555338.126	722.227	722.293	-0.066
2068	1616036.721	597386.999	693.686	693.593	0.093
2069	1520824.930	667057.602	711.438	711.483	-0.045
2070	1527759.928	723226.943	777.591	777.473	0.118
2071	1544626.008	666733.890	682.025	681.943	0.082
2072	1569459.080	650668.415	671.526	671.593	-0.067
2073	1587071.076	693793.885	674.073	674.063	0.010
2074	1623839.039	652983.710	662.985	663.023	-0.038
2075	1509566.941	564200.820	735.733	735.703	0.030
2076	1598868.281	544272.110	723.914	723.913	0.001
2077	1673781.968	600968.367	676.422	676.533	-0.111
2078	1660068.641	678513.419	643.489	643.403	0.086
2079	1642362.564	722898.019	636.476	636.483	-0.007
2080	1765408.520	674707.574	602.680	602.692	-0.012
2081	1760195.295	656180.368	612.572	612.662	-0.090
2082	1770178.665	618930.018	650.833	650.953	-0.120
2083	1833149.779	616344.373	618.923	618.942	-0.019

VERTICAL ACCURACY CONCLUSIONS

Bare-Earth DEM Non-Vegetated Vertical Accuracy (NVA) Tested 0.096 Survey Feet Non-Vegetated vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM.

Table 5.4: VVA Quality Check Point Analysis DEM

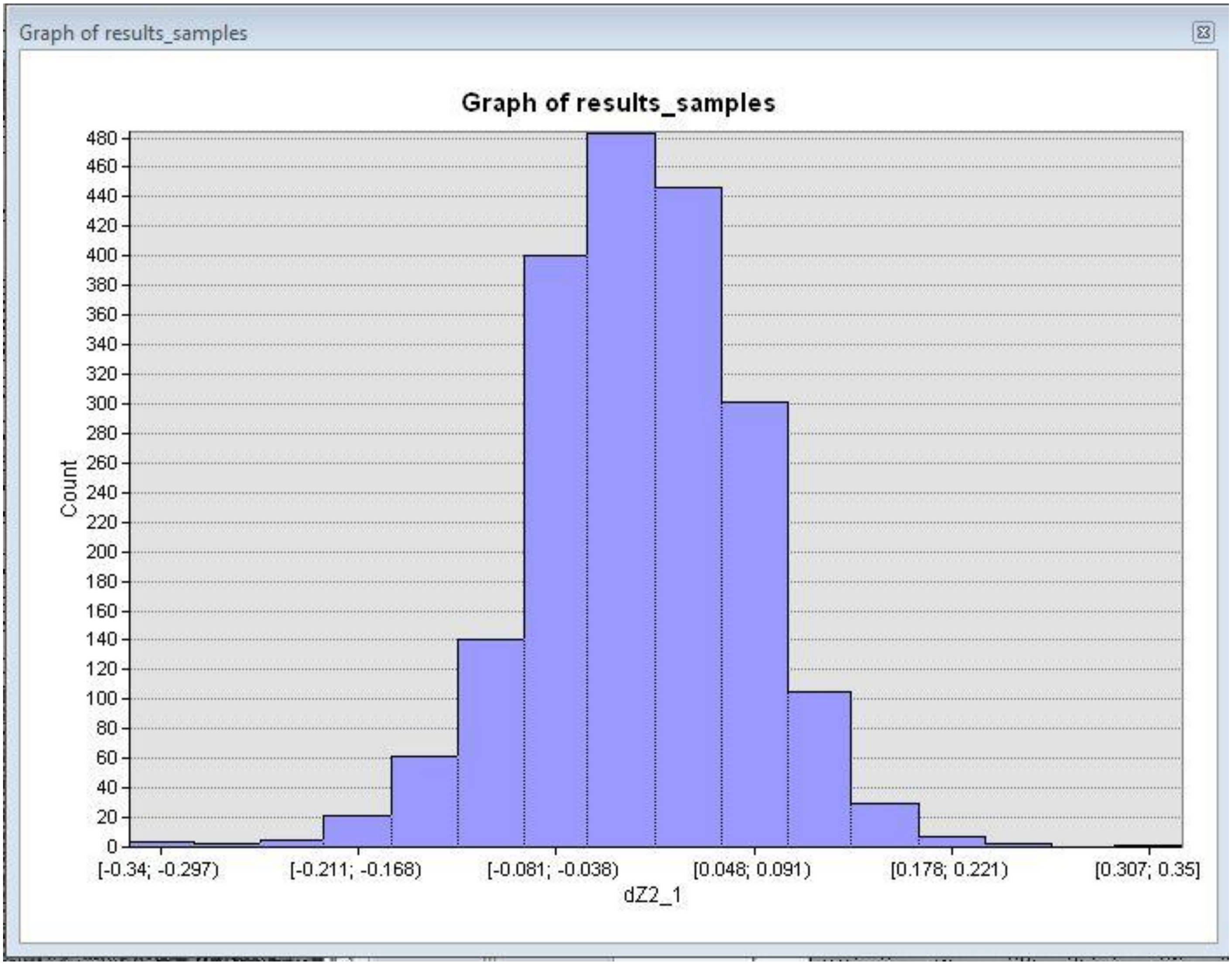
Point ID	Easting (Sv Feet)	Northing (Sv Feet)	Elevation (Sv Feet)	DEM Elevation (Sv Feet)	Dz (Sv Feet)
3001	1452593.308	596878.067	708.477	708.783	-0.306
3002	1475043.267	656195.755	737.549	737.573	-0.024
3003	1490368.143	582713.110	723.410	723.663	-0.253
3004	1502585.723	646179.355	697.269	697.253	0.016
3005	1536977.196	687700.209	737.211	737.333	-0.122
3006	1554219.216	723371.501	753.963	754.043	-0.080
3007	1542576.295	632516.334	671.303	671.443	-0.140
3008	1566680.259	523673.891	750.757	750.843	-0.086
3009	1567174.345	573813.987	706.624	706.543	0.081
3010	1573526.353	668680.229	674.974	675.343	-0.369
3011	1602795.894	733335.120	693.044	693.203	-0.159
3012	1615368.709	618899.135	682.565	682.803	-0.238
3013	1539469.602	598046.536	689.574	689.883	-0.309
3014	1534496.248	546704.956	745.524	745.923	-0.399
3015	1601912.975	565054.039	704.380	704.503	-0.123
3016	1486510.562	631222.332	718.884	719.013	-0.129
3017	1614207.057	525665.721	770.808	770.923	-0.115

3018	1583344.526	607568.057	681.008	681.083	-0.075
3019	1554156.300	701914.006	706.071	706.983	-0.912
3020	1615370.403	711052.366	672.489	672.693	-0.204
3021	1645915.388	580578.625	689.373	689.463	-0.090
3022	1651052.890	551537.581	727.354	727.573	-0.219
3023	1685054.505	527030.833	805.793	806.353	-0.560
3024	1628954.665	675146.088	645.830	646.133	-0.303
3025	1515743.128	629057.569	680.467	680.553	-0.086
3026	1511828.237	598243.206	677.124	677.623	-0.499
3027	1710593.919	555856.907	748.795	748.973	-0.178
3028	1677259.224	574540.035	701.633	702.023	-0.390
3029	1664070.008	625312.747	670.831	671.153	-0.322
3030	1684802.671	692650.153	624.346	624.623	-0.277
3031	1642526.573	745578.014	661.864	661.883	-0.019
3032	1687816.159	746875.715	592.760	593.022	-0.262
3033	1664332.037	712338.578	633.093	633.173	-0.080
3034	1677425.063	655223.226	655.092	655.433	-0.341
3035	1717604.607	724467.763	591.413	591.732	-0.319
3036	1727735.446	710883.356	597.032	597.032	0.000
3037	1757014.106	730211.904	570.221	570.412	-0.191
3038	1781632.770	705027.055	575.873	575.852	0.021
3039	1801507.127	706173.678	574.699	574.722	-0.023
3040	1731114.964	673743.613	627.240	627.293	-0.053
3041	1786666.270	677748.622	590.086	590.152	-0.066
3042	1776006.824	640100.464	612.138	612.682	-0.544
3043	1715673.337	651059.737	652.156	652.403	-0.247
3044	1770957.572	687471.039	582.226	582.542	-0.316
3045	1714998.571	606075.289	701.379	701.703	-0.324
3046	1738089.416	623491.564	694.501	694.633	-0.132
3047	1730858.073	590424.255	712.831	712.893	-0.062
3048	1774626.545	584424.147	679.268	679.543	-0.275
3049	1793723.594	622445.911	619.814	619.822	-0.008
3050	1836318.850	594201.409	680.244	680.473	-0.229
3051	1864340.162	588914.791	779.586	779.903	-0.317
3052	1815594.193	591652.567	636.075	636.443	-0.368
3053	1860680.022	608167.501	690.402	690.943	-0.541
3054	1820392.510	637276.543	575.060	575.222	-0.162
3055	1843873.044	626454.908	593.619	593.702	-0.083
3056	1802203.241	648648.101	581.268	581.342	-0.074
3057	1909335.838	679108.078	585.564	585.942	-0.378
3058	1897459.425	683144.868	605.748	605.882	-0.134
3059	1877538.637	693830.081	592.644	592.872	-0.228
3060	1881513.555	685226.650	582.046	582.092	-0.046
3061	1892627.576	679898.240	602.552	602.932	-0.380
3062	1869816.732	679570.183	600.167	600.562	-0.395
3063	1817549.864	685272.120	575.665	575.702	-0.037
3064	1851269.267	670329.883	576.577	576.532	0.045
3065	1809170.909	673502.419	581.144	581.152	-0.008

VERTICAL ACCURACY CONCLUSIONS

Vegetated Vertical Accuracy (VVA) Tested 0.543 Survey Feet at the 95th percentile reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. VVA Errors larger than 95th percentile include:
Point 3019, Easting 1554156.300, Northing 701914.006, Z-Error 0.912 Feet
Point 3023, Easting 1685054.505, Northing 527030.833, Z-Error 0.560 Feet
Point 3042, Easting 1776006.824, Northing 640100.464, Z-Error 0.544 Feet

Figure 5.1: Lidar Relative Accuracy Histogram



RELATIVE ACCURACY ASSESSMENT AND CONCLUSION

Relative accuracy also known as "between swath" accuracy was tested through a series of well distributed flight line overlap locations. The relative accuracy for the Lower Maumee 2016 Lidar measured at 0.071 Survey Feet RMSDz.

Approved by:	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		January 2017

Section 6: Flight Logs

Flight logs for the project are shown on the following pages:

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	4/13/2016	104	76269	2	Lower Maumee Portage SubBasin USGS

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
GALAMBOS	N111SD	404.1	1:45:00	17:45:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
FLOYD	OTHER	406.4	3:04:00	19:04:00	1GO

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
100 9 g15	10	Clear		11	0	30.38		Departing	1GO
								Arriving	1GO

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	50	272	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	X	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	7015	Ft	Yes		No	x	@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments	
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:	17:02:19
		↧ Times entered are Zulu / GMT ↧						Verify S-Turns Before Mission	Yes X No
141	N	17:45:01	17:46:58	11:42:21	19	0.6	1.1	SENSOR: 8194/1724z takeoff	
140	S	17:50:11	17:52:10	0:00:00	19	0.6	1.1		
139	N	17:55:07	17:57:06	0:00:00	19	0.6	1.1		
138	S	17:59:50	18:01:37	0:00:00	19	0.6	1.1		
137	N	18:05:20	18:07:00	0:00:00	19	0.6	1.1		
136	S	18:09:52	18:11:15	0:00:00	18	0.7	1.4		
135	N	18:18:05	18:18:36	0:00:00	18	0.7	1.4		
134	S	18:21:56	18:27:04	0:00:00	18	0.7	1.4		
133	N	18:30:12	18:35:36	0:00:00	18	0.7	1.4		
132	S	18:38:56	18:44:51	0:00:00	18	0.7	1.4		
131	N	18:48:40	18:55:01	0:00:00	19	0.6	1.1		
130	S	18:58:12	19:04:32	0:00:00	19	0.6	1.1		
				0:00:00				Short Lines Complete	
				0:00:00				Longer lines has some standing	
				0:00:00				water in the fields	
				0:00:00				Static: 19:31:05	
				0:00:00					
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				0:00:00					
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission	Yes X No

Additional Comments:	Drive #
	107

Leica LIDAR

MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
4/15/2016	106	76327	01	Lower Maumee Basin

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
SWAIN	N404CP	5436.9	10:33:00	14:33:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**ZULU Stop Time**	**PID**
SWAIN	ALS-8191	5439.8	12:59:00	16:59:00	Use Base from N111SD set up

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	KDAY
100/4	10	CLR	0	12	2	30.23		Arriving	KDAY

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	X	Mode		Threshold Values	
40	50	272	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	x	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	7008	Ft	Yes		No	X	@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	PDOP	GS	Alt	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a		GPS Began Logging At: 10:15:00
↕ Times entered are Zulu / GMT ↕									Verify S-Turns Before Mission Yes X No
North Canton Alliance									
129	359	15:37:10	15:47:42	0:10:32	17	1.1	156	6919	
128	179	15:50:50	16:00:59	0:10:09	17	1.1	154	6885	
127	359	16:03:06	16:12:24	0:09:18	16	1.3	160	6904	
126	179	16:16:23	16:22:58	0:06:35	17	1.3	158	6912	
125	359	16:25:36	16:31:56	0:06:20	17	1.3	162	6908	
124	179	16:34:47	16:41:00	0:06:13					VOID TMB1 Error close out over base shut down restart return to Dayton system running no errors
				0:00:00					
				0:00:00					
				0:00:00					
				0:00:00					
				0:00:00					
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↑ Times entered are Zulu / GMT ↑				Page		1			Verify S-Turns After Mission Yes X No

Additional Comments:

Drive #

Flew over base @ 15:17 closed out over base @ 16:54 "TMB1 Error on line 124 closed out over base shut down restart return to Dayton system running no errors"

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	4/15/2016	106	76269	2	Lower Maumee Portage SubBasin USGS

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
GALAMBOS	N111SD	411.4	10:57:00	14:57:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
FLOYD	OTHER	416.1	3:04:00	19:04:00	1GO

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	1GO
070 6	10	Clear		12	5	30.31		Arriving	1GO

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	50	272	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	X	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	7015	Ft	Yes		No	x	@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments	
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:	14:28:00
		↕ Times entered are Zulu / GMT ↕						Verify S-Turns Before Mission	Yes X No
								SENSOR: 8194/t/o:1435z	
1	S	14:57:17	14:58:09	0:00:00	18	0.6	1		
2	N	15:01:09	15:02:01	0:00:00	17	0.6	1.1		
3	S	15:05:03	15:06:06	0:00:00	17	0.6	1.1		
4	N	15:11:57	15:17:45	0:00:00	17	0.6	1.1		
5	S	15:21:08	15:28:14	0:00:00	17	0.6	1.1		
6	N	15:31:27	15:37:57	0:00:00	17	0.6	1.3		
7	S	15:41:09	15:48:39	0:00:00	17	0.6	1.2		
8	N	15:51:36	15:58:17	0:00:00	18	0.6	1.1		
9	S	16:04;15	16:09:48	0:00:00	16	0.7	1.3		
10	N	16:12:56	16:19:43	0:00:00	16	0.7	1.3		
11	S	16:23:16	16:31:13	0:00:00	16	0.7	1.3		
12	N	16:34:15	16:41:06	0:00:00	18	0.6	1		
13	S	16:4t5:29	16:54:50	0:00:00	18	0.6	1		
14	N	16:57:55	17:06:12	0:00:00	18	0.6	1		
15	S	17:09:37	17:19:10	0:00:00	18	0.6	1		
16	N	17:22:17	17:30:57	0:00:00	18	0.6	1		
17	S	17:34:33	17:44:50	0:00:00	18	0.6	1		
18	N	17:48:02	17:57:40	0:00:00	19	0.6	1		
19	S	18:03:06	17:16:26	0:00:00	20	0.6	1.2		
20	N	18:19:22	18:31:06	0:00:00	21	0.6	1		
21	S	18:34:40	18:48:36	0:00:00	16	0.7	1.2		
22	N	18:51:23	19:03:50	0:00:00	16	0.7	1.3		
				0:00:00				Landing 1920z	
				0:00:00				Static: 19:24:02	
				0:00:00					
				0:00:00					
				0:00:00					
				0:00:00					
				0:00:00					
				0:00:00					
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission	Yes X No

Additional Comments:	Drive #
	107

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	4/16/2016	107	76327		maumee

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
SMITH	N475RC	402.8	9:35:00	13:35:00	
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
ALBERS	OTHER	409.7	4:27:00	20:27:00	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	day
150/5	10					3033		Arriving	day

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
40	50	272	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	x	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts		Ft		Ft	Yes		No		@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:
		↕ Times entered are Zulu / GMT ↕						Verify S-Turns Before Mission Yes x No
90	n	15:26:00	15:37:00		16	0.7	1.3	
89	s	15:39:00	15:50:00		17	0.7	1.1	
88	n	15:52:00	16:04:00		17	0.7	1.2	
87	s	16:06:00	16:17:00		17	0.7	1.2	
86	n	16:19:00	16:30:00		17	0.7	1.3	
85	s	16:32:00	16:43:00		19	0.7	1.2	
84	n	16:45:00	16:56:00		18	0.7	1.2	
83	s	16:59:00	17:09:00		17	0.7	1.4	
82	n	17:17:00	17:32:00		20	0.7	1.1	
81	s	17:34:00	17:50:00		18	0.7	1.1	
80	n	17:53:00	18:09:00		17	0.7	1.3	
79	s	18:12:00	18:28:00		18	0.7	1.4	
78	n	18:30:00	18:47:00		19	0.7	1.1	
77	s	18:50:00	19:06:00		19	0.7	1.2	
76	n	19:09:00	19:25:00		16	0.7	1.7	
75	s	19:28:00	19:43:00		16	0.7	1.4	error **tm1b
				0:00:00				
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission Yes x No

Additional Comments:	Drive #

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	4/16/2016	107	76327	01	Lower Maumee Basin

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
BURKE	N404CP	5439.8	9:19:00	013:19:3	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**ZULU Stop Time**	**PID**
GEBHART	ALS-8191	5447.6	17:17:15	21:17:15	Use Base from N111SD set up

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	KDAY
140/8	10	CLR	0	14	4	30.33		Arriving	1G0

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	X	Mode		Threshold Values	
40	50	272	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	X	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	7008	Ft	Yes		No	X	@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	PDOP	GS	Alt	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a		GPS Began Logging At: 14:04 flew over N111SD Base
		↕ Times entered are Zulu / GMT ↕							Verify S-Turns Before Mission Yes X No
124	359	14:23:56	14:30:24	0:06:28	18	1	155	6864	Re-flight
123	179	14:33:57	14:40:38	0:06:41	17	1.1	153	6844	
122	359	14:43:38	14:49:56	0:06:18	17	1.1	152	6856	
121	179	14:53:09	14:59:48	0:06:39	17	1.1	150	6836	
120	359	15:03:18	15:09:44	0:06:26	17	1.1	159	6854	
119	179	15:13:18	15:20:07	0:06:49	16	1.2	148	6893	
118	359	15:23:19	15:29:55	0:06:36	16	1.3	160	6861	
117	179	15:33:28	15:40:36	0:07:08	17	1.1	148	6868	
116	359	15:43:33	15:50:26	0:06:53	18	1.1	154	6861	
115	179	15:53:57	16:01:23	0:07:26	17	1.2	147	6836	
114	359	16:04:41	16:12:00	0:07:19	16	1.3	154	6859	
113	179	16:15:57	16:23:51	0:07:54	17	1.3	150	6840	
112	359	16:26:54	16:34:50	0:07:56	17	1.3	161	6856	
111	179	16:38:17	16:46:40	0:08:23	18	1.2	147	6849	
110	359	16:49:51	16:58:36	0:08:45	18	1.2	154	6844	
109	179	17:01:33	17:10:23	0:08:50	17	1.4	144	6873	
108	359	17:13:16	17:25:08	0:11:52	20	1.1	149	6871	
107	179	17:27:29	17:39:48	0:12:19	19	1.1	146	6814	
106	359	17:42:52	17:51:45	0:08:53	17	1.3	150	6869	
105	179	17:54:10	18:03:15	0:09:05	17	1.3	146	6841	
104	359	18:06:35	18:15:37	0:09:02	18	1.4	151	6844	
103	179	18:18:19	18:27:21	0:09:02	20	1.1	149	6851	
102	359	18:29:58	18:39:04	0:09:06	19	1.1	156	6863	
101	179	18:41:31	18:50:53	0:09:22	19	1.2	147	6822	
100	359	18:53:43	19:03:18	0:09:35	18	1.2	159	6829	
99	179	19:05:47	19:15:39	0:09:52	17	1.3	148	6836	
98	359	19:18:39	19:28:09	0:09:30	16	1.7	151	6833	
97	179	19:30:30	19:40:50	0:10:20	17	1.4	144	6821	
96	359	19:43:35	19:53:28	0:09:53	17	1.3	152	6855	
95	179	19:55:51	20:06:25	0:10:34	21	1.4	144	6876	
94	359	20:09:00	20:19:07	0:10:07	20	1.2	149	6851	
93	179	20:21:31	20:32:21	0:10:50	20	1.2	145	6836	
92	359	20:35:11	20:45:36	0:10:25	19	1.3	155	6812	
91	179	20:47:32	20:58:42	0:11:10	19	1.2	148	6877	
				0:00:00					
				0:00:00					
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↑ Times entered are Zulu / GMT ↑				Page			1		Verify S-Turns After Mission Yes X No

Additional Comments:	Drive #
No sensor issues	00133

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	4/16/2016	107	76269	2	Lower Maumee Portage SubBasin USGS

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
GALAMBOS	N111SD	416.7	9:28:00	13:28:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
FLOYD	OTHER	421.4	1:45:00	17:45:00	1GO

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	1GO
060 5	10	Clear		10	7	30.37		Arriving	1GO

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	50	272	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	X	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	7015	Ft	Yes		No	x	@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments	
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:	13:05:18
		↓ Times entered are Zulu / GMT ↓						Verify S-Turns Before Mission	Yes X No
55	N	13:28:52	13:45:35		20	0.7	1.1	SENSOR: 8194	
54	S	13:48;31	14:04:46	0:00:00	19	0.7	1.2	"A" Flight	
53	N	14:08:06	14:25;20	0:00:00	18	0.7	1.2		
52	S	14:28:28	14:44:52	0:00:00	19	0.6	1		
51	N	14:48:36	15:05:51	0:00:00	16	0.7	1.2		
50	S	15:09:04	15:25:31	0:00:00	17	0.6	1.1		
49	N	15:28:49	15:45;50	0:00:00	17	0.6	1.3		
48	S	15:48:51	16:05:29	0:00:00	17	0.6	1.2		
47	N	16:08:47	16:25:50	0:00:00	18	0.6	1.1		
46	S	16:29:12	16:46:09	0:00:00	16	0.7	1.3		
45	N	16:49:13	17:05:52	0:00:00	18	0.7	1.3		
44	S	17:08:46	17:45:19	0:00:00	19	0.7	1.2	Landing: 1759z	
				0:00:00				Static: 1802:50 - 18:04:50	
				0:00:00					
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Additional Comments:	Drive #
	00129

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	4/16/2016	107	76269	2	Lower Maumee Portage SubBasin USGS

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
GALAMBOS	N111SD	421.4	3:17:00	19:17:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
FLOYD	OTHER	423.8	5:11:00	21:11:00	1GO

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
090 12	10	Clear		21	3	30.36		Departing	1GO
								Arriving	1GO

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	50	272	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	X	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode		Pre-Trigger Dist.
150	Kts	6500	Ft	7015	Ft	Yes		No	x	@	NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At: 18:54;40
		↓ Times entered are Zulu / GMT ↓						Verify S-Turns Before Mission Yes X No
42	S	19:17:08	19:32:48		19	0.7	1.2	SENSOR: 8194
41	N	19:36:06	19:51;14	0:00:00	19	0.7	1.2	"B" Flight+A24:L30
40	S	19:54:39	20:10:47	0:00:00	19	0.7	1.2	
39	N	20:13:56	20:29:39	0:00:00	19	0.7	1.2	
38	S	20:36:16	20:52:25	0:00:00	19	0.7	1.2	
37	N	20:55:26	21:10:32	0:00:00	17	0.6	1.1	
				0:00:00				Static: 21:26:53- 21:28:53
				0:00:00				
				0:00:00				
				0:00:00				
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Additional Comments:	Drive #
	107

Leica LIDAR	MM/DD/YEAR: 4/17/2016	Day of Year: 108	Project #: 76327	Phase #: 01	Project Name: Lower Maumee Basin
Operator: Other	Aircraft: N475RC	HOBBS Start: 7409.7	Local Start Time: 10:23:00	ZULU Start Time: 14:23:00	Base: WOOLPERT PIN
Pilot: ALBERS	Sensor Type: ALS-8170	HOBBS END: 4717.4	Local End Time: 17:54:00	ZULU Stop Time: 21:55:00	PID: Use Base from N111SD set up

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
140/8	10	CLR	0	18	6	30.33		Departing	1G0
								Arriving	1G0

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	X	Mode		Threshold Values	
40	50	272	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	X	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode		Pre-Trigger Dist.	
150	Kts	6500	Ft	7008	Ft	Yes		No	X	@	NS		Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	PDOP	GS	Alt	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a		GPS Began Logging At:
		↕ Times entered are Zulu / GMT ↕							Verify S-Turns Before Mission Yes X No
75	S	14:46:00	15:02:00	0:16:00	18	1.1	155	7000	
74	N	15:04:00	15:20:00	0:16:00	18	1.1	155	6950	
73	S	15:22:00	15:38:00	0:16:00	16	1.3	155	6950	
72	N	15:40:00	15:56:00	0:16:00	17	1.2	155	6950	
71	S	15:58:00	16:14:00	0:16:00	16	1.3	155	6980	
70	N	16:16:00	16:32:00	0:16:00	17	1.3	155	6950	
69	S	16:34:00	16:50:00	0:16:00	17	1.2	155	6980	
68	N	16:52:00	17:07:00	0:15:00	16	1.4	155	6950	
67	S	17:04:00	17:25:00	0:21:00	17	1.2	155	6940	
66	N	17:27:00	17:43:00	0:16:00	19	1.2	155	7000	
65	S	17:45:00	18:01:00	0:16:00	19	1.2	155	7000	
64	N	18:03:00	18:19:00	0:16:00	18	1.4	155	6980	
63	S	18:22:00	18:37:00	0:15:00	20	1.2	155	6950	
62	N	18:39:00	18:54:00	0:15:00	19	1.2	155	6925	
61	S	18:56:00	19:11:00	0:15:00	18	1.2	155	6900	
60	N	19:14:00	19:29:00	0:15:00	17	1.7	155	6950	
59	S	19:32:00	19:47:00	0:15:00	17	1.6	155	6950	
58	N	19:50:00	20:05:00	0:15:00	19	1.3	155	7000	
57	S	20:07:00	20:22:00	0:15:00	19	1.2	155	6920	
56	N	20:24:00	20:39:00	0:15:00	18	1.4	155	7020	
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Additional Comments:

No sensor issues

Drive #

Leica LIDAR

MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
4/17/2016	108	76327	01	Lower Maumee Basin

Operator	Aircraft	Hobbs Start	Local Start Time	ZULU Start Time	Base
BURKE	N404CP	5448.3	9:16:00	13:16:30	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**ZULU Stop Time**	**PID**
GEBHART	ALS-8191	5454.1	15:14:00	19:14:00	Use Base from N111SD set up

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
90/3	10	CLR	0	16	6	30.43		Departing	KDAY
								Arriving	KDAY

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	X	Mode		Threshold Values	
40	50	272	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	X	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	7008	Ft	Yes		No	X	@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	PDOP	GS	Alt	Line Notes/Comments	
Test	n/a			n/a	n/a	n/a	n/a		GPS Began Logging At:	flew over N111SD Base 14:01 / 18:25
		↕ Times entered are Zulu / GMT ↕							Verify S-Turns Before Mission	Yes X No
36	359	14:21:41	14:36:38	0:14:57	19	1	155	6929		
35	179	14:39:42	14:54:40	0:14:58	18	1.1	144	6868		
34	359	14:57:38	15:12:07	0:14:29	18	1.1	157	6868		
33	179	15:15:30	15:30:28	0:14:58	16	1.4	140	6862		
32	359	15:33:23	15:47:24	0:14:01	17	1.2	158	6898		
31	179	15:50:37	16:04:24	0:13:47	17	1.2	144	6906		
30	359	16:06:58	16:20:10	0:13:12	16	1.4	160	6893		
29	179	16:23:20	16:37:16	0:13:56	17	1.3	141	6896		
28	359	16:39:51	16:52:56	0:13:05	17	1.2	158	6896		
27	179	16:56:06	17:09:24	0:13:18	16	1.4	143	6873		
26	359	17:12:19	17:24:59	0:12:40	20	1.1	158	6894		
25	179	17:28:20	17:41:17	0:12:57	19	1.2	144	6915		
24	359	17:44:05	17:56:35	0:12:30	18	1.3	151	6836		
23	179	17:59:48	18:12:26	0:12:38	18	1.4	145	6847		
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Additional Comments:

No sensor issues

Drive #

00133

Section 7: Final Deliverables

The final lidar deliverables are listed below.

- LAS v1.4 classified point cloud
- LAS v1.4 raw unclassified point cloud flight line strips.
- Hydro Breaklines as ESRI shapefile
- Bridge Breaklines as ESRI shapefile
- Digital Elevation Model in ERDAS .IMG format
- 8-bit gray scale intensity images in .TIF format
- Tile layout provided as ESRI shapefile
- Control Points provided as ESRI shapefile
- FGDC compliant metadata per product in XML format
- Lidar processing report in pdf format
- Survey report in pdf format