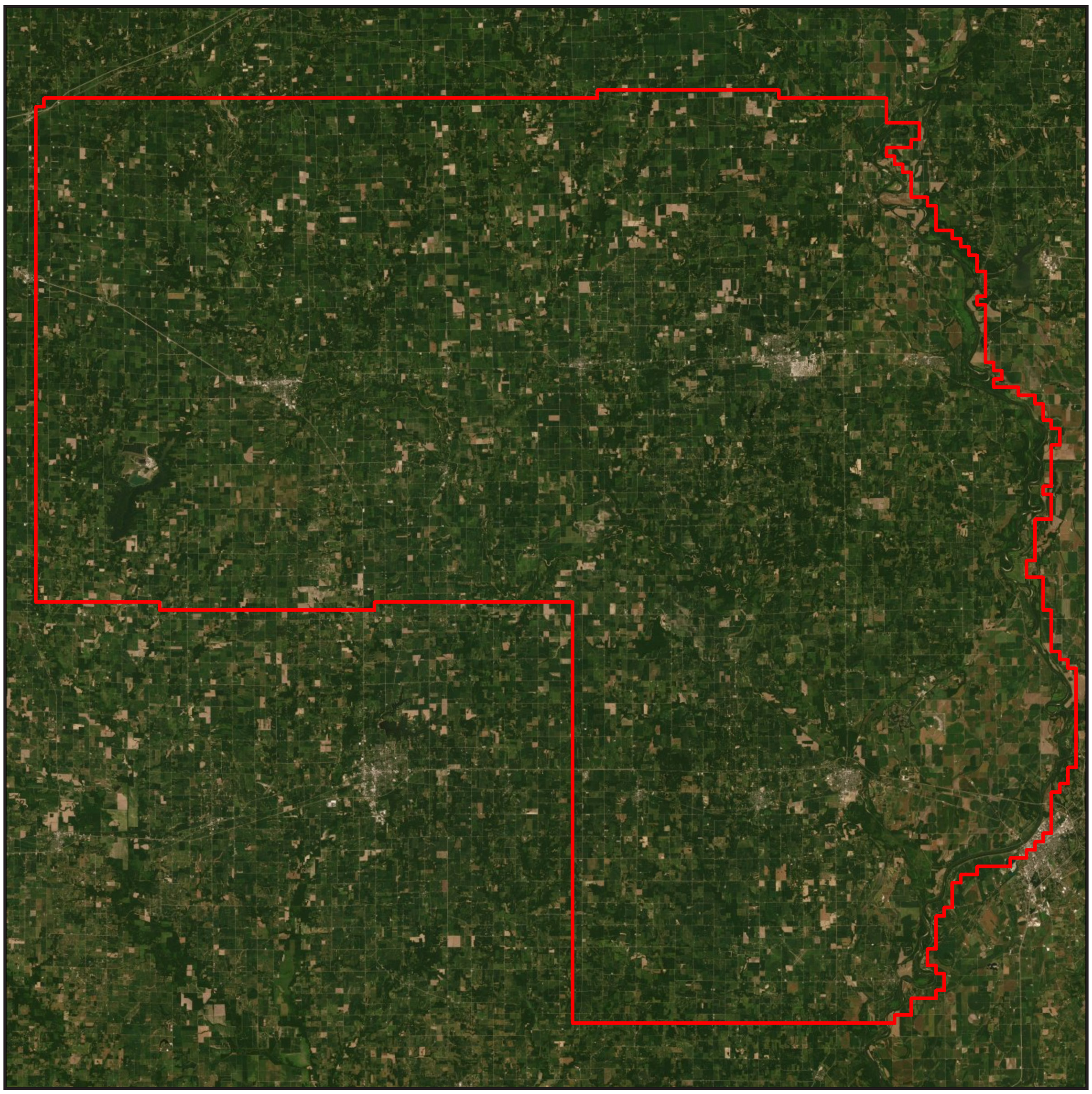
Lidar 2020 Data Acquisition of 3 Counties in Wabash and Embarrass Basin

Airborne Lidar Report

October 2020

Task Order # Univ of IL #U20066_R-1



Contractor Woolpert

Project # 80713

Table of Contents

Table of Contents

List of Figures

List of Tables

Appendix Documents

1. Overview

About

This project contains a comprehensive outline of the Lidar 2020 Data Acquisition of 3 Counties in Wabash and Embarrass Basin task order issued by the Illinois State Geological Survey. This task order called for the acquisition and processing of QL2+ data over one area of interest covering approximately 1,409 square miles in southeastern Illinois.

Data fully covers the following counties:

- Crawford
- Jasper
- Lawrence

Purpose

The purpose of this project was to obtain Lidar data for the Illinois Height Modernization Program.

Specifications

Data for this task order was acquired and produced to meet USGS Lidar Base Specification 2.1 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 system.

Table 1-1. Spatial Reference System

Horizontal	**EPSG Code**	6455
	Datum	NAD83 (2011)
	Projection	State Plane Illinois East Zone
	Units	US Survey Feet
Vertical	**Datum**	NAVD88
	Geoid	GEOID12B
	Units	US Survey Feet
	Height Type	Orthometric

Task Order Deliverables

All data products produced as part of this task order are listed below. All tiled deliverables had a tile size of 2,000-feet x 2,000-feet. Tile names follow the IGIS naming schema (ex.: 11858530).

Table 1-2. Deliverables

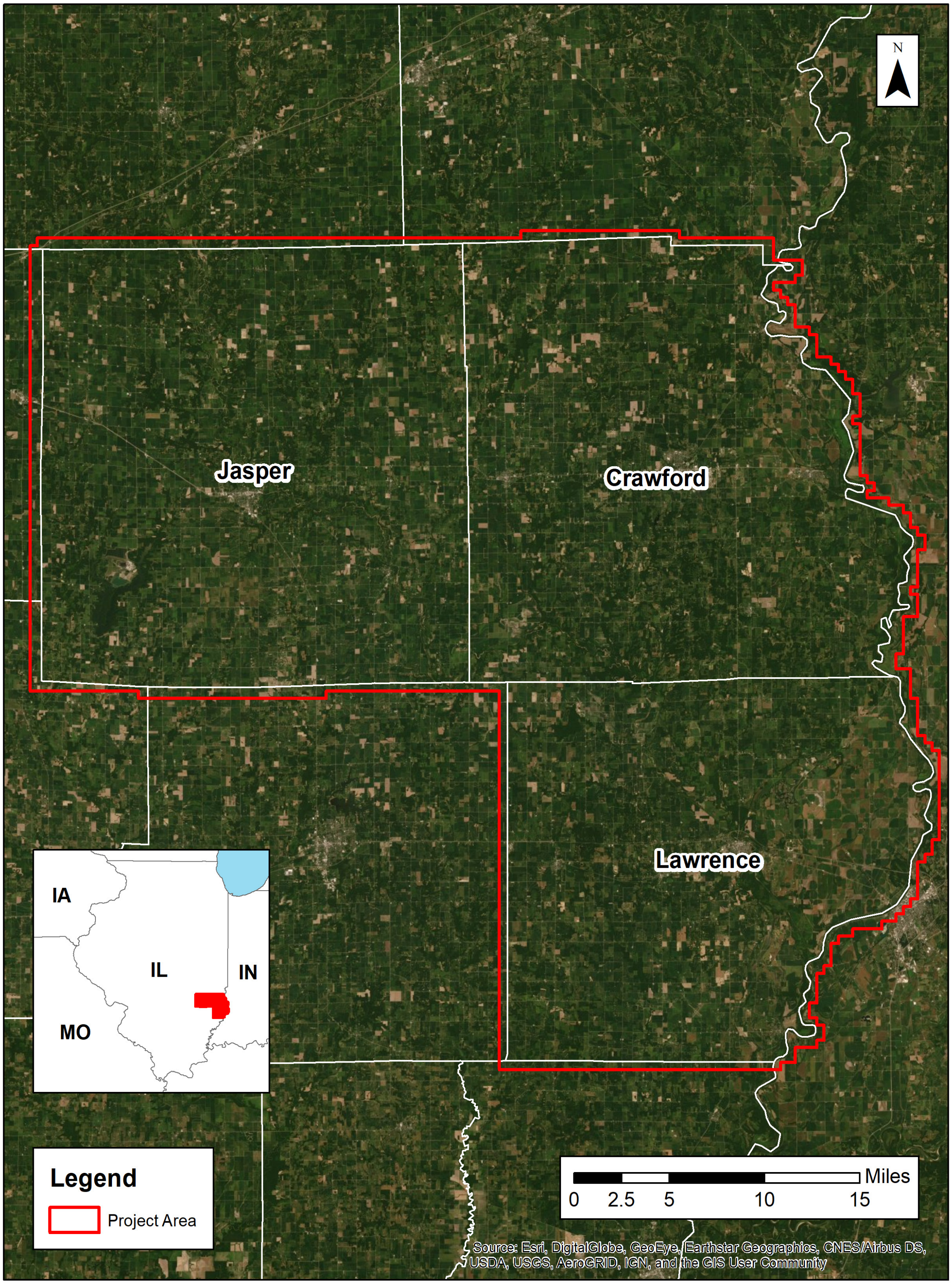
Lidar Data	
Classified lidar point cloud data	Tiles in .las v1.4 format Classes • 1 – Processed, not Classified • 2 – Ground • 3 – Low Vegetation (0.5 - 5 feet) • 4 – Medium Vegetation (5 - 20 feet) • 5 – High Vegetation (> 20 feet) • 6 – Buildings • 7 – Noise • 9 – Water • 17 – Bridge Decks • 18 – High 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 polyline features in Esri shapefile format

Hydro-flattened bare earth digital elevation model (DEM)	2.5-foot pixel size, 32-bit floating-point; no bridges or overpass structures GeoTIFF format
Intensity Imagery	2.5-foot 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
Checkpoint tabular data	Excel XLSX spreadsheet
Other Data	
Tile Index	Esri shapefile format
Data Extent	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 for this project was collected using the specifications listed below.

Table 2-1. Acquisition Requirements

Specification	Target
Resolution	• 4 points per square meter • 0.5-meter nominal point spacing
Overlap	Minimum sidelap of 30 degrees
Acquisition Window	Winter or Spring of 2020, with the ultimate goal of acquiring data before Summer 2020
Acquisition Conditions	• Leaf-off vegetative conditions • Without snow cover • Prior to Spring flooding or advanced foliage development

Lidar Sensor Information

Aerial lidar data was acquired for this project using the Leica TerrainMapper lidar sensor system. A total of 73 flight lines were collected for this project.

Table 2-2. Leica Terrain Mapper Sensor Info

Sensor Specifications	
Operating Altitude (m AGL)	300 - 5,500 at 10% reflective target
Maximum Measurement Rate (kHz)	2,000
Scan Angle	20 - 40
Scan Width	Up to 70% of flight altitude
Scan Frequency	Programmable up to 125 Hz (7,500 RPM), 250 scan lines per second
Number of Returns	15
Number of intensity measurements	15
Pulse Mode(s)	Up to 35 pulses in air
Laser Specifications	
Laser Beam Divergence	0.25 mrad (1/e)
Laser Classification	Class 4 laser product
Accuracy	
Range Resolution	< 1 cm RMS
Elevation Accuracy	< 5 cm 1 σ
Horizontal Accuracy	< 13 cm 1 σ
Physical Specifications	
Size (cm), Weight (kg) • Scanner • Control Electronics	 • 37 W x 68 L x 26 H cm, 47 kg • 45 W x 47 D x 25 H cm, 33 kg
Operating Temperature • Scanner • Control Electronics	 • 0 - 40°C cabin-side temperature • 0 - 40°C
Flight Management	Leica FlightPro
Power Consumption	922 W @ 22.0 – 30.3 VDC

Source: Leica TerrainMapper Data Sheet
https://leica-geosystems.com/en-US/products/airborne-systems/topographic-lidar-sensors/leica-terrainmapper

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 table below for stations operated during acquisition.

Table 2-3. GNSS Base Stations

Station Name	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height L1 Phase Center (Meters)
INAS_CORS	39° 23' 22.22912"	87° 06' 39.62936"	154.523
INLN_CORS	39° 01' 46.98731"	87° 09' 12.11433"	129.502
INVI_CORS	38° 37' 38.55557"	87° 31' 50.13557"	102.258

Timeline

Lidar data was collected March 30, 2020 through April 10, 2020. 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.

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

Table 2-4. Project Acquisition Specifications

Settings	Leica TerrainMapper
Max. Number of Returns	15
Nominal Point Spacing	0.35 m
Nominal Point Density	4 ppsm
Flying Height Above Ground Level	2,377 m
Flight Speed	150 knots
Scan Angle	40°
Scan Rate Used	115 Hz
Pulse Rate Used	950 kHz
Multi-Pulse in Air	Enabled
Swath Width	1,730 m
Swath Overlap	30%

Acquisition Quality Assurance

Woolpert developed a quality assurance and validation plan to ensure the acquired lidar data meets the USGS Base Specification Version 2.1. 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.

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 v20, 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:

- 1 – Processed, not Classified
- 2 – Ground
- 3 – Low Vegetation (0.5 - 5 feet)
- 4 – Medium Vegetation (5 - 20 feet)
- 5 – High Vegetation (> 20 feet)
- 6 – Buildings
- 7 – Noise
- 9 – Water
- 17 – Bridge Decks
- 18 – High Noise
- 20 – Ignored Ground

Model Key Points were identified from the ground (Class 2) points using the Key-Point Classification Flag (Bit 1). All overlap data was processed through automated functionality provided by TerraScan to classify the overlapping flight line data to approved classes by USGS. The overlap data was classified using standard LAS overlap bit. These classes were created through automated processes only and were not verified for classification accuracy. Due to software limitations within TerraScan, these classes were used to trip the withheld bit within various software packages.

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 v20

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 PolygonZ and PolylineZ feature classes in an Esri file geodatabase.

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

Software: TerraScan v20, TerraModeler v20, Esri ArcMap v10.7, LP360 v2019.1.30.4

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 2.5-foot 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 produced to the full extents of the tile boundaries. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

Software: TerraScan v20, Esri ArcMap v10.7, Global Mapper v20.0

Intensity Imagery

Lidar intensity data derived from the acquired lidar data was linearly rescaled from 16-bit intensity and provided as 2.5-foot pixel, 8-bit, 256 gray scale GeoTIFF format intensity imagery files. Files were produced to the full extents of the tile boundaries.

Software: TerraScan v20, Esri ArcMap v10.7

Metadata

FGDC CSDGM/USGS MetaParser-compliant metadata was produced in XML format. This 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 ground control and checkpoint data in tabular format, ground control and checkpoints in Esri shapefile format, data extent in Esri shapefile format, and delivery tile index in Esri shapefile format. 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

Horizontal Accuracy

The data sets was produced to meet ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (2014) for a 17.6 cm RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 43.2 cm at a 95% confidence level.

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 using 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 67 checkpoints. These checkpoints were surveyed using GPS techniques. The dataset was tested to be 0.07 meters using an RMSEz of 0.035 meters x 1.9600.

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 using independent checkpoints falling on bare earth and urban (non-vegetated) classes. VVA was to be calculated using 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 measured 0.0686 meters using an RMSEz of 0.035 meters x 1.9600 using 67 checkpoints. VVA tested 0.167 meters at the 95th percentile using 54 checkpoints.

Appendix 1: Flight Logs

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80713	Wabash Basin	Day090_90511_A	03/30/2020	090	A

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
Costanzo	Cessna 404 Titan - N404CP	7641.4	12:57:00	16:57:00	DAY
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
DeHart	Leica Terrain Mapper - 90511	7649.3	06:04:00	22:04:00	DAY

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
290	23	10	12,000	Overcast	7.8	0.6	30.1

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
160	7,000	8,000	1,009

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35	10	40	81	600	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
1	S	16:57:00	17:06:00	00:09:00	21	1.2	
2	N	17:09:00	17:18:00	00:09:00	21	1.2	
3	S	17:22:00	17:31:00	00:09:00	19	1.5	
4	N	17:34:00	17:43:00	00:09:00	21	1.3	
5	S	17:46:00	17:55:00	00:09:00	20	1.3	
6	N	17:58:00	18:07:00	00:09:00	21	1.2	
7	S	18:10:00	18:19:00	00:09:00	23	1.1	
8	N	18:22:00	18:30:00	00:08:00	23	1.1	
9	S	18:33:00	18:42:00	00:09:00	22	1.4	
10	N	18:45:00	18:54:00	00:09:00	22	1.3	
11	S	18:57:00	19:06:00	00:09:00	20	1.3	
12	N	19:09:00	19:19:00	00:10:00	21	1.2	
13	S	19:22:00	19:30:00	00:08:00	21	1.1	
14	N	19:33:00	19:43:00	00:10:00	16	1.4	
15	S	19:46:00	19:54:00	00:08:00	17	1.3	
16	N	19:56:00	20:06:00	00:10:00	17	1.3	
17	S	20:09:00	20:17:00	00:08:00	16	1.3	
18	N	20:20:00	20:29:00	00:09:00	17	1.2	
19	S	20:32:00	20:41:00	00:09:00	18	1.1	
20	N	20:44:00	20:53:00	00:09:00	19	1	
21	S	20:56:00	21:05:00	00:09:00	19	1	
22	N	21:07:00	21:17:00	00:10:00	17	1.2	
23	S	21:19:00	21:28:00	00:09:00	19	1.2	
24	N	21:30:00	21:40:00	00:10:00	19	1.2	
25	S	21:42:00	21:51:00	00:09:00	21	1.2	

Verify S-Turns After Mission: Yes

Additional Comments

Further notes on second page

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80713	Wabash Basin	Day090_90511_A	03/30/2020	90	A

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
Costanzo	Cessna 404 Titan - N404CP	7641.4	12:57:00	16:57:00	DAY
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
DeHart	Leica Terrain Mapper - 90511	7649.3	06:04:00	22:04:00	DAY

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
290	23	0,010	12,000	Overcast	7.8	0.6	30.1

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
160	7,000	8,000	1,009

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35	10	40	81	600	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
26	N	21:54:00	22:04:00	00:10:00	18	1.1	

Verify S-Turns After Mission:

Additional Comments

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80713	Wabash Basin LiDAR	Day093_90511	04/02/2020	093	

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
Costanzo	Cessna 404 Titan - N404CP	7649.3	10:30:00	14:30:00	KDAY
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
Nardone	Leica Terrain Mapper - 90511	7656.8	06:00:00	22:00:00	KDAY

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	5	7		Clear	7	4	30.19

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	7,800	8,094	1,009

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		40	115	950	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
S	27	15:44:00	15:53:00	00:09:00	22	1.2	
N	28	15:56:00	16:04:00	00:08:00	23	1.1	
S	29	16:08:00	16:16:00	00:08:00	24	1	
N	30	16:19:00	16:28:00	00:09:00	20	1.2	
S	31	16:31:00	16:40:00	00:09:00	21	1.3	
N	32	16:42:00	16:51:00	00:09:00	21	1.3	
S	33	16:54:00	17:02:00	00:08:00	22	1.1	
N	34	17:05:00	17:14:00	00:09:00	20	1.3	
S	35	17:17:00	17:31:00	00:14:00	19	1.5	
N	36	17:35:00	17:49:00	00:14:00	20	1.4	
S	37	17:53:00	18:07:00	00:14:00	21	1.3	
N	38	18:11:00	18:25:00	00:14:00	24	1.1	
S	39	18:29:00	18:44:00	00:15:00	23	1.2	
N	40	18:48:00	19:02:00	00:14:00	23	1.1	
S	41	19:05:00	19:19:00	00:14:00	22	1.2	
N	42	19:23:00	19:38:00	00:15:00	21	1.4	
S	43	19:41:00	19:56:00	00:15:00	20	1.3	
N	44	19:59:00	20:14:00	00:15:00	19	1.2	
S	45	20:17:00	20:32:00	00:15:00	20	1.1	

Verify S-Turns After Mission

Additional Comments

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80713	Wabash Basin LiDAR	Day094_90511	04/03/2020	094	

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
Costanzo	Cessna 404 Titan - N404CP	7656.8	09:45:00	13:45:00	KDAY
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
Nardone	Leica Terrain Mapper - 90511	7660.8	01:45:00	17:45:00	KMGY

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
290	6	9	1,900	Clear	9	3	30.19

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	7,800	8,094	1,009

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		40	115	950	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
46	S	14:56:00	15:09:00	00:13:00	22	1.2	
47	N	15:14:00	15:29:00	00:15:00	22	1.2	
48	S	15:32:00	15:47:00	00:15:00	21	1.2	
49	N	15:50:00	16:05:00	00:15:00	21	1.2	
50	S	16:08:00	16:23:00	00:15:00	20	1.2	
51	N	16:26:00	16:41:00	00:15:00	20	1.3	

Verify S-Turns After Mission

Additional Comments

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80713	Wabash Basin LiDAR	Day101_90511	04/10/2020	101	

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
Costanzo	Cessna 404 Titan - N404CP	7661	10:45:00	14:45:00	KDAY
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
Nardone	Leica Terrain Mapper - 90511	7666.6	04:22:00	20:22:00	KDAY

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
300	18	10	2,800	Clear	4	-3	29.99

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	7,800	8,094	1,009

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		40	115	950	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
68	W	16:02:00	16:18:00	00:16:00	19	1.3	
69	S	16:21:00	16:28:00	00:07:00	21	1.2	
70	E	16:43:00	16:48:00	00:05:00	19	1.4	
52	N	17:01:00	17:19:00	00:18:00	19	1.4	
53	S	17:26:00	17:42:00	00:16:00	22	1.3	
54	N	17:45:00	18:03:00	00:18:00	22	1.2	
55	S	18:06:00	18:22:00	00:16:00	23	1.1	
56	N	18:24:00	18:41:00	00:17:00	21	1.2	
57	S	18:44:00	18:59:00	00:15:00	20	1.2	
58	N	19:02:00	19:18:00	00:16:00	17	1.2	

Verify S-Turns After Mission

Additional Comments

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80713	Wabash Basin Lidar	Day101_90513	04/10/2020	101	

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Dar Perl	Reims 406 - N406SD	298.6	10:48:00	14:48:00	DAY
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90513	304.7	15:42:00	19:42:00	DAY

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
300	18	10	2,800	Broken	4	-3	29.99

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	7,800	8,094	1,009

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35	4	40	115	950	100

Verify S-Turns Before Mission Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
73	W	16:09:00	16:15:00	00:06:00	18	1.4	
72	N	16:19:00	16:26:00	00:07:00	20	1.2	
71	W	16:32:00	16:36:00	00:04:00	19	1.2	
59	N	16:48:00	17:02:00	00:14:00	18	1.5	
60	S	17:05:00	17:16:00	00:11:00	19	1.4	
61	N	17:20:00	17:31:00	00:11:00	22	1.4	
62	S	17:34:00	17:43:00	00:09:00	22	1.2	
63	N	17:46:00	17:56:00	00:10:00	22	1.2	
64	S	17:59:00	18:07:00	00:08:00	23	1.2	
65	N	18:10:00	18:19:00	00:09:00	23	1.1	
66	S	18:22:00	18:29:00	00:07:00	22	1.1	
67	N	18:32:00	18:36:00	00:04:00	21	1.2	

Verify S-Turns After Mission Yes

Additional Comments

Maint hobbs 5277.9