Lidar Quality Control Report

Task Order Name: QA Program for High Resolution Lidar Data, Multiple

Counties in North Dakota, Phase 7

Block Name(s): Ward

Acceptance Status: Third Delivery QC – Accepted

Date: 02/12/2018

Product: Lidar, Breaklines, DEMs, Intensity Imagery, and Metadata

Overview:

Dewberry conducted the evaluation of the 1,556 tiles of Light Detection and Ranging (lidar), breaklines, intensity data, DEM data, and metadata for Ward and will conduct an evaluation of 5,056 tiles of lidar, breaklines, intensity data, DEM data, and metadata for additional blocks submitted by Fugro Geospatial for the North Dakota Phase 7 project to ensure that the data have been produced to meet the required specifications in the SOW. The entire project area consists of Multiple Counties in North Dakota totaling approximately 6,612 square miles. Ward consists of parts of Ward, McLean, Mountrial, Burke, and Renville counties. These blocks must be produced to meet USGS Baseline Specification v1.2 for Quality Level 2 (QL2) Lidar products.

Fugro Geospatial delivered LAS, Breaklines, DEMs, Intensity imagery, and metadata templates for Ward and will deliver LAS, Breaklines, DEMs, Intensities, and Metadata for additional blocks which completes the extent of the QL2 project area. Each LAS file has been processed through an automated header validation routine to ensure that all fields have been appropriately set to meet the project requirements. Some issues were found in first delivery which required corrections: the File Source IDs should be 0 but have values. Upon re-delivery, Fugro Geospatial clarified that the defined File Source IDs are unique identifiers for each tiled LAS. These IDs are not the flight line or Point Source IDs, as Dewberry originally supposed. As tiled LAS are created from multiple flight lines or swaths, a single flight line ID cannot be set as the File Source ID. But as the defined File Source IDs are unique to each LAS tile, these identifiers are acceptable and no corrections were required.

After inspection of the intensity imagery, one corrupt tile was identified in the first delivery. Also, the intensity imagery did not have the NSRS 2007 update applied. The corrupt tile was re-generated and delivered to Dewberry as part of the second delivery. Fugro Geospatial also provided additional information with the second delivery stating that the IMG files were generated using ERDAS Imagine, and although the NSRS2007 tag does not show up in ArcMap, it displays correctly when IMG files are opened in ERDAS. Fugro Geospatial supplied screenshots from ERDAS Imagine showing the intensity imagery are in the correct horizontal datum of NAD83 (NSRS2007). However, as many end-users may rely on ArcGIS, Dewberry recommended the Coordinate Reference System (CRS) labels are re-defined using ArcGIS (Define Projection). Redefining the CRS labels processes very quickly and does not transform or

re-project the data as the data are already correctly projected. Redefining the labels will eliminate potential confusion from ArcGIS users. Upon the third delivery, the CRS labels were redefined to display the NSRS 2007 update in ArcGIS.

Dewberry reviewed the breaklines against intensity imagery and also ran several automated checks on the data to ensure completeness. All breaklines were reviewed for formatting, completeness, correct topology, and integrity of the breaklines. Additionally, 10% of the data was reviewed at a micro level requiring a highly detailed inspection of the data. If improvements to breaklines could be made, these were documented in the QA/QC file geodatabase in the breakline feature class that is being delivered along with this report. During the initial review several edit calls were placed for the following issues: a few features within specification collection requirements were not collected, parts of a river were sausage linked, and one pond had vertices that were at different elevations. Also, the horizontal units were in feet instead of meters. All breaklines were delivered in one shapefile as polygons and were not labeled as waterbody and river as they were in past deliverables. Upon re-delivery, the horizontal units were corrected from feet to meters. The features within specification collection requirements were also collected. The sausage link river was not modified, but has been deemed consistent with past deliveries so no additional modifications are requested by Dewberry. Upon additional request, the breaklines were delivered with feature labels, allowing Dewberry to verify the feature with vertices at different elevations is actually a river/stream, and does not require additional modifications.

Dewberry's review also included reviewing the classification of the lidar between ground and non-ground. This review was conducted by reviewing the LAS Dataset (LASD) in ArcMap at a scale of 1:25,000. In areas where the LASD showed issues, cross sections in the lidar were drawn to ensure the points were properly classified. Additionally, 10% of the data was reviewed at a micro level which requires a highly detailed inspection of the data. Some issues were found in the initial review and a polygon feature class identifying specific locations was delivered along with this report. These issues included four culverts classified to class 1, low points mis-classified to ground, and a few areas where vegetation was not removed. Upon re-delivery, all corrections were made or addressed.

Hydro-flattened bare-earth DEMs were reviewed for correct formatting and completeness. This review was conducted through reviewing the elevation models in ArcMap at a scale of 1:25,000. In areas where the model showed issues, cross sections in the lidar were drawn to ensure the points were properly classified. Additionally, 10% of the data was reviewed at a micro level. No DEM-specific issues were identified in the first delivery, but updates to the breaklines and lidar required some DEMs to be rerun. Upon re-delivery, all DEMs were verified to correctly model updates in the breaklines and lidar.

Tile-based metadata for each deliverable product is required. Dewberry reviewed the three metadata templates delivered for the LAS, Intensity, and DEMs. Issues were identified in the first delivery of metadata files which required corrections. A few additional updates were still required in the metadata templates upon re-delivery. All metadata calls were located in the

metadata QC spreadsheet. All corrects were made upon the third delivery. An updated metadata QC spreadsheet is included with the report.

Dewberry recommended the dataset to be returned for corrections to the metadata along with a recommendation to re-define the intensity CRS labels for correct display within ArcGIS. Upon re-delivery all metadata corrects were made and the intensity CRS labels were redefined to correctly display in ArcGIS. Dewberry accepts all items of this dataset.

Classified Lidar Formatting				
Parameter	**Requirement**	**First Delivery Pass/Fail**	**Second Delivery Pass/Fail**	**Third Delivery Pass/Fail**
Overlap and Withheld Points	SOW did not require either overlap or withheld points to be flagged. SOW specifies withheld points to be classified to class 11.	Pass		
Coordinate Reference System	LAS files should have the coordinate reference system properly defined using Well Known Text (WKT) format (OGC 2001 dialect).	Pass		
Project Identifier	A project identifier should be recorded in GUID fields 1, 2, and 3	Pass		
Point Data Format	Should be format 6	Pass		
Global Encoder Bit	Should be 17 for Adjusted GPS Time	Pass		
System ID	Should be recorded in the LAS header for determination of processing system	Pass		
Major Version	Should be 1 (for LAS 1.4)	Pass		
Minor Version	Should be 4 (for LAS 1.4)	Pass		
Classes	Required Classes include: Class 1: Unclassified Class 2: Ground Class 7: Low Noise Class 9: Water Class 11: Withheld	Pass- Classification also includes class 6 for buildings		
Time Stamp	Should be documented and meet the project requirement for Adjusted GPS Time	Pass		

Multiple Returns	The sensor shall be able to collect multiple returns per pulse and the return numbers are recorded	Pass		
Intensity	16 bit intensity values are recorded for each pulse	Pass		
Edge of Flight line	The edge of flight line field records a value of 1 for points on the end of a scan line prior to the scan changing direction (oscillating mirror scan mechanisms only and not rotating mirror scan mechanisms)	Pass-Not Applicable to Riegl sensors		
Resolution of Coordinates	All coordinates should be recorded to 1 cm (0.01) resolution, as defined in the SOW	Pass		
File Source ID	Should be set to 0 for tiled lidar data and should be set to the flight line ID for swath data	Fail-Values are defined for the File Source ID in the tiled lidar but this field should be set to 0	Pass – Fugro clarified the defined File Source IDs do not correlate to flight lines or swaths, as tiled las are created from multiple swaths, but are unique values assigned to each LAS tile for overall project identification purposes.	

Lidar/DEM Quality Control				
Parameter	**Requirement**	**First Delivery Pass/Fail**	**Second Delivery Pass/Fail**	**Third Delivery Pass/Fail**
Returns per pulse	Lidar sensor shall be capable of recording up to 3 (or more) returns per pulse, including 1st and last returns	Pass		

Swath overlap	Any data gaps between the geometrically usable portions of the swaths will be rejected.	Pass		
Design pulse density (nominal)	≥ 2 points/m²; assessment to be made against single swath, first return located within the geometrically usable center portion of each swath.	Pass		
Scan Angle	Total FOV ≤ ± 45 degrees	Pass		
Collection Conditions	Ground is snow free and no unusual flooding	Pass		
Vertical Accuracy	Non- Vegetated Vertical Accuracy (NVA) at the 95% confidence level is ≤ 19.6 cm based on $RMSE_z \leq 10$ cm x 1.9600. Vegetated Vertical Accuracy (VVA) at the 95th percentile is ≤30 cm	Pass – See Vertical Accuracy Testing Results tables below		
Coverage	No voids between swaths. No voids because of cloud cover or instrument failure. Voids within a single swath ≥ (4*NPS)² will not be acceptable except for voids caused by water bodies, low reflectivity or where appropriately filled-in by an overlapping swath.	Pass		
Spatial Distribution	Spatial distribution of geometrically usable points will be uniform and regular. Spatial distribution will be assessed against individual swaths using first return points only. A grid shall be generated with a cell size 2x the ANPS and 90% of all cells shall contain at least one lidar point.	Pass		
Vertical Datum	NAVD 88, processed with Geoid12B	Pass		
Horizontal Datum	NAD 83 (NSRS 2007)	Fail – intensity imagery did not have NSRS 2007 update	Recommendation- As the images are in the correct horizontal datum of NAD83 (NSRS2007), Dewberry recommends simply defining the CRS label in ArcGIS to show the NSRS 2007 adjustment in order to reduce potential confusion and	Pass

			questions by ArcGIS users.	
Projection	UTM, Zone 14 North	Pass		
Vertical Units	Meters (Orthometric Heights, NAVD88)	Fail – Breaklines delivered in feet instead of meters	Pass	
Horizontal Units	Meters	Pass		
File naming convention	Tiles shall be named according to the provided nomenclature	Pass		
Tile Size	2000 m x 2000 m, no added overlap, used for all tiled deliverables, edgematch seamlessly both horizontally and vertically.	Pass		
Digital Elevation Model (DEM) of bare-earth w/ breaklines	DEM of bare-earth terrain surface (1.0 m cell size) created from lidar ground points and breaklines. DEMs shall be tiled without overlaps or gaps, shall show no edge artifact or mismatch, DEM deliverables will be .img format	Pass		
DEM Compression	DEMs should not be compressed	Pass		
Ground Points (Bare Earth)	Post-processed to remove structures and vegetation with <10% residual artifacts	Fail- 4 culverts are currently classified as bridges and need to be re-classified as ground, a few porches need to be classed to default, and some vegetation needs to be removed; see attached GDB	Pass	
Inconsistent Post-Processing, Editing	No visible variations in lidar data caused by alternating processing techniques. Bare earth surface must be consistent in both the removal of features and the features left in the ground.	Pass		

LAS Artifacts	No obvious artifacts, spikes, holes or blunders; no cornrows	Pass		
Over-Smoothing	Smoothing techniques shall not remove topographic features necessary to define drainage structures.	Pass		
Misclassification	All points within water bodies and double-line streams that have accompanying breaklines must be classified to class 9 (water). 90% of all other ground points must be appropriately classified in class 2 ground. Gross misclassifications shall be avoided.	Pass		
Intensity Imagery	Produced for each tile, 16-bit, 256 Grayscale, IMG format, with world files, and should match the project tiling scheme.	Fail-One tile (03545316) is partially corrupt and does not load. This tile needs to be re-created.	Pass	
DEM Artifacts	DEM shall have no tiling artifacts, no gaps or overlap, and no artificial smoothing at tile boundaries. Areas outside survey boundary shall be coded as NoData. Internal voids (e.g., open water areas) may be coded as NoData.	Pass		
Formal metadata	Metadata shall be FGDC compliant in XML Format containing all requirements outlined in the SOW and include Project, Lift and Tiled Data products.	Fail – Metadata will need to be corrected; see attached Metadata QC spreadsheet	Fail-a few metadata corrections remain to be addressed; see attached Metadata QC spreadsheet	Pass
Tile Grid	Extent shapefiles, including tile grid and boundary are included in the deliverables. Tile grid must contain the tile names in the attribute table.	Pass		

Breakline Quality Control

Parameter	Requirement	First Delivery Pass/Fail	Second Delivery Pass/Fail	Third Delivery Pass/Fail
Monotonicity	Double line streams shall generally maintain a consistent down-hill flow and be collected in the direction of flow – some natural exceptions will be allowed	Pass		
Vertical Consistency	Waterbodies shall maintain a constant elevation at all vertices Vertices should not have excessive min or max z-values when compared to adjacent vertices Intersecting features should maintain connectivity in X, Y, Z planes Double stream lines shall have the same elevation at any given cross-section of the stream	Fail – one pond/lake have vertices at different elevations: see attached GDB	Pass – Once breaklines with feature labels were delivered, Dewberry verified this feature was actually a stream/river	
Completeness	Breaklines collected for: Inland Ponds and Lakes, Inland Streams and Rivers. For Inland ponds and lakes water bodies greater than 2.0 acres shall be captured as polygons. For Inland streams and rivers average width shall be greater than 100 feet to show as a double line.	Fail – One pond/lake within specification collection requirments not collected, and a two rivers/streams need to be either extended or deleted to prevent sausage links; see attached GDB	Pass – the rivers/streams which were not extended or deleted to prevent sausage links are consistent with past deliveries; see attached GDB	
Topology	Features must not overlap or have gaps Features must not have unnecessary dangles or boundaries	Fail – Three features not merged to create one feature; see attached GDB.	Pass – Features not merged because there is a drop at the spillway; see attached GDB	

Lidar Vertical Positional Accuracy Results

Table 1 outlines the calculated $RMSE_z$ and associated statistics, in meters, while table 2 outlines vertical accuracy as computed by the different methods, in meters.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.100 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	59	0.027	0.002	0.000	-0.148	0.027	0.516	-0.060	0.070
VVA	41	N/A	0.053	0.040	0.636	0.061	0.814	-0.040	0.230

Table 1 - The table shows the calculated $RMSE_z$ values, in meters, as well as associated statistics of the errors for the QL2 Ward block of the North Dakota Phase 7 project area.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.196 m	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.300 m
NVA	59	0.053	
VVA	41		0.160

Table 2 - The table shows the calculated NVA and VVA, in meters, at the 95% confidence level.

Table 3 lists the 5% outliers that are larger than the 95th percentile, or 0.160 meters.

Point ID	NAD83 (2007) UTM 14N		NAVD88 (Geoid 12B)	LiDAR Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
5B	288608.100	5398742.243	562.380	562.570	0.190	0.190
7B	274984.779	5386344.790	621.410	621.640	0.230	0.230

Table 3 – 5% Outliers

This lidar dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =2.7 cm, equating to +/- 5.3 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 16.0 cm at the 95th percentile.

DEM Vertical Positional Accuracy Results

Table 4 outlines the calculated $RMSE_z$ and associated statistics, in meters, while Table 5 outlines vertical accuracy as computed by the different methods, in meters.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.100 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	59	0.027	0.002	0.003	-0.025	0.027	0.463	-0.062	0.070
VVA	41	N/A	0.053	0.039	0.720	0.058	-0.201	-0.038	0.195

Table 4 - The table shows the DEM calculated $RMSE_z$ values, in meters, as well as associated statistics of the errors for the QL2 Ward block of the North Dakota Phase 7 project area.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (RMSEz x 1.9600) Spec=0.196 m	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.300 m
NVA	59	0.052	
VVA	41		0.158

Table 5 - The table shows the DEM calculated NVA and VVA, in meters, at the 95% confidence level.

Table 6 lists the 5% outliers that are larger than the 95th percentile, or 0.158 meters.

Point ID	NAD83 (2007) UTM14N		NAVD88 (Geoid 12B)	LiDAR Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
7B	274984.779	5386344.790	621.410	621.605	0.195	0.195
14A	309137.102	5360270.200	511.760	511.922	0.162	0.162

Table 6 – DEM 5% Outliers

This DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 2.7 cm, equating to +/- 5.2 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 15.8 cm at the 95th percentile.