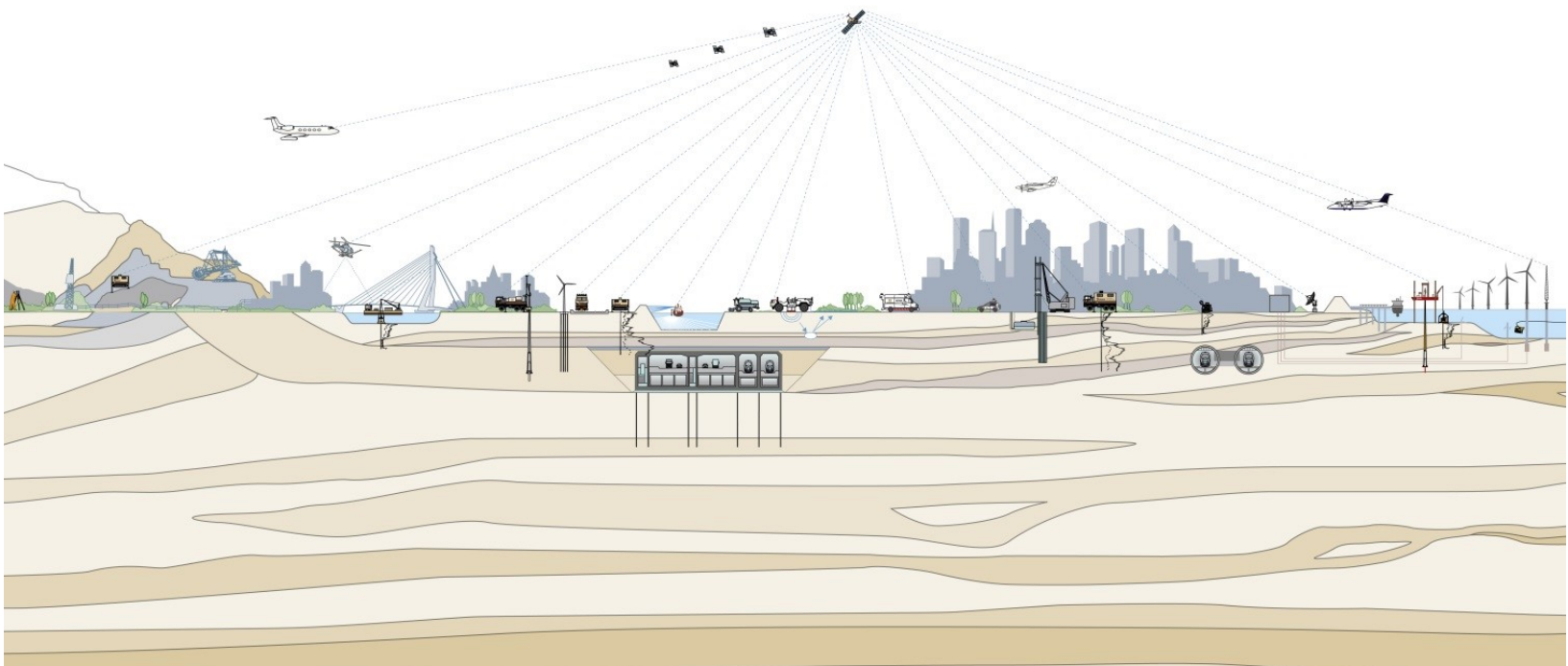**FUGRO GEOSPATIAL, INC.**

Accuracy Report – Virginia Counties Collection

Prepared for:

United States Geological Survey
1400 Independence Road
Rolla, MO 65401
(573) 308-3689

July 27, 2020

USGS Contract: G17PC00015
USGS Task Order: 140G0218F0449

1.   ACCURACY REPORTING

Data collected under this Task Order meets the National Standard for Spatial Database Accuracy (NSSDA) accuracy standards. The NSSDA standards specify that vertical accuracy be reported at the 95 percent confidence level for data tested by an independent source of higher accuracy.

1.1   Positional Accuracy

Before classification and development of derivative products from the point cloud, the absolute and relative vertical accuracies of the point cloud were verified.

1.2   Absolute Vertical Accuracy

Unclassified Lidar Point Cloud Data: The Non-Vegetated Vertical Accuracy (NVA) of the Lidar Point Cloud data was calculated against TINs derived from the final calibrated and controlled swath data. The required accuracy (ACC_Z) is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on $RMSE_Z$ of 10 cm in the "open terrain" and/or "Urban" land cover categories. This is a required accuracy. Please refer to the table below for the achieved accuracies. The raw swath point cloud data met the required accuracy levels before point cloud classification and derivative product generation.

Table 1: Accuracy of the Lidar Point Cloud Data

Raw Flight Lines	$RMSE_Z$ (non-vegetated)	NVA at 95-percent confidence level
Specification (cm)	≤ 10	≤ 19.6
Calculated Values (cm)	5.2	10.2
Specification (m)	*≤ 0.100*	*≤ 0.196*
Calculated Values (m)	*0.052*	*0.102*
Number of points	107	107

Bare Earth Surface: The accuracy (ACC_Z) of the derived DEM was calculated and is being reported in three (3) ways:

1. **$RMSE_Z$ (Non-Vegetated):** The required $RMSE_Z$ is ≤ 10 cm.
2. **Non-Vegetated Vertical Accuracy (NVA):** The required NVA is: ≤ 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on $RMSE_Z$ of 10 cm in the "open terrain" and/or "Urban" land cover categories. This is a required accuracy.
3. **Vegetated Vertical Accuracy (VVA):** The required VVA is: ≤ 29.4 cm at a 95th percentile level, derived according to ASPRS Guidelines, Vertical Accuracy for Reporting LiDAR Data, i.e. based on the 95th percentile error in Vegetated land cover categories combined (Tall Grass, Brush, Forested Areas). This is a required accuracy.

Please refer to the table below for the achieved accuracies.

Table 2: Accuracy of the Derived DEM

DEM	RMSE$_z$ (non-vegetated)	NVA at 95-percent confidence level	VVA at 95th percentiles
Specification (cm)	≤ 10	≤ 19.6	≤ 29.4
Calculated Values (cm)	5.5	10.9	18.5
Specification (m)	*≤ 0.100*	*≤ 0.196*	*≤ 0.294*
Calculated Values (m)	*0.055*	*0.109*	*0.185*
Number of points	107	107	81

1.3   Relative Accuracy

Smooth Surface Repeatability: In ideal theoretical conditions, smooth surface repeatability is a measure of variations documented on a surface that would be expected to be flat and without variation. Users of lidar technology commonly refer to these variations as "noise." Single-swath data was assessed using only single returns in non-vegetated areas. Repeatability was evaluated by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns was then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops).

Each sample area was evaluated using a signed difference raster (maximum elevation − minimum elevation) at a cell size equal to twice the ANPS, rounded up to the next integer. Sample areas were approximately 50 square meters (m²) or larger. The maximum acceptable variations within sample areas for this project is 6 cm. Isolated noise is expected within the sample areas and was disregarded.

The evaluation was done on 22 flat open sample areas over the Virginia Counties AOI. The results are shown in the table below, please also refer to:

USGS_VA_Counties_Lidar_Relative_Accuracy_Smooth_Surface_Repeatability.shp

Table 3: Relative Accuracy, Smooth Surface Repeatability

RMSDZ_Corr	Area_m2
0.026269	78
0.043907	78
0.042600	78
0.054901	78

0.033294	78
0.018535	78
0.022494	78
0.022272	78
0.031660	78
0.024872	78
0.024429	78
0.029437	78
0.043756	78
0.035253	78
0.021768	78
0.043352	78
0.042923	78
0.020381	78
0.048020	78
0.058672	78
0.051215	78
0.022142	78

Overlap Consistency: Overlap consistency is a measure of geometric alignment of two overlapping swaths; the principles used with swaths can be applied to overlapping lifts and projects as well. Overlap consistency is the fundamental measure of the quality of the calibration or boresight adjustment of the data from each lift, and is of particular importance as the match between the swaths of a single lift is a strong indicator of the overall geometric quality of the data, establishing the quality and accuracy limits of all downstream data and products.

Overlap consistency was assessed at multiple locations within overlap in non-vegetated areas of only single returns.

Each overlap area was evaluated using a signed difference raster with a cell size equal to twice the ANPS, rounded up to the next integer. The difference rasters are visually examined using a bicolor ramp from the negative acceptable limit to the positive acceptable limit. Although isolated excursions beyond the limits are expected and accepted, differences in the overlaps shall not exceed the following limits:

1. Swath overlap difference, RMSDz ≤ 8 cm
2. Swath overlap difference, maximum ± 16 cm

The difference rasters are also statistically summarized to verify that root mean square difference in z (RMSDz) values do not exceed the 8 cm maximum. Consideration will be given for the effect of the expected isolated excursions over limits.

The evaluation was completed at 52 sample areas throughout the Virginia Counties AOI. A sample of the results can be seen in the table below. Please also refer to the shapefile below for the complete analysis:

USGS_VA_Counties_Lidar_Relative_Accuracy_Swath_Overlap.shp

Table 4: Relative Accuracy, Overlap Consistency

RMS_DZ	Max_DZ	Min_DZ	Area sq m
0.0285	-0.0028	-0.0596	222
0.0396	0.1008	-0.0032	219
0.0241	0.0294	-0.0636	138
0.0236	0.0640	-0.0339	165
0.0329	0.0829	-0.0801	139
0.0318	0.0117	-0.0644	152
0.0300	0.0584	-0.0475	131
0.0469	0.1243	-0.0316	222
0.0243	0.0454	-0.0548	122
0.0394	0.1243	-0.0229	116
0.0188	0.0359	-0.0403	174
0.0377	0.0896	-0.0472	111
0.0393	-0.0084	-0.0764	117
0.0137	0.0227	-0.0426	128
0.0200	0.0450	-0.0620	108
0.0285	-0.0028	-0.0596	222