LARIAC 4 – LiDAR Vertical Accuracy Assessment Report

Vertical Accuracy Assessment

FINAL SWATH VERTICAL ACCURACY ASSESSMENT

Once Dewberry received the calibrated swath data from Pictometry, Dewberry tested the vertical accuracy of the non-vegetated terrain swath data prior to additional processing. Dewberry tested the vertical accuracy of the swath data using the one hundred eighty nine (189) non-vegetated (open terrain and urban) independent survey check points. The vertical accuracy is tested by comparing survey checkpoints in non-vegetated terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in non-vegetated terrain can be tested against raw swath data because the data has not undergone classification techniques to remove vegetation, buildings, and other artifacts from the ground surface. Checkpoints are always compared to interpolated surfaces from the lidar point cloud because it is unlikely that a survey checkpoint will be located at the location of a discrete lidar point. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project. Project specifications require a NVA of 19.6 cm (0.64 ft) based on the $RMSE_z$ (10 cm) x 1.96. The dataset for the Lariac4 Lidar Project satisfies this criteria. This raw lidar swath data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm (0.33 ft) $RMSE_z$ Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 0.33 ft, equating to +/- 0.64 ft at 95% confidence level. The table below shows all calculated statistics for the **raw swath** data.

100 % of Totals	# of Points	$RMSE_z$ (ft) NVA Spec=0.33 ft	NVA –Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.64 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Min (ft)	Max (ft)	Kurtosis
NVA	189	0.33	0.64	0.21	0.25	-0.69	0.24	-0.63	0.74	0.55

Table 1: NVA at 95% Confidence Level for Raw Swaths

LIDAR POSITIONAL ACCURACY

Background

Dewberry quantitatively tested the dataset by testing the vertical accuracy of the lidar. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest lidar points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the lidar data is actually tested. However there is an increased level of confidence with lidar data due to the relative accuracy. This relative accuracy in turn is based on how well one lidar point "fits" in comparison to the next contiguous lidar measurement, and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to

test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in non-vegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the lidar sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated lidar sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error (RMSEz) of the checkpoints x 1.9600. For the Lariac4 lidar project, vertical accuracy must be 0.64 ft or less based on an RMSEz of 0.328 ft x 1.9600.

VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the lidar sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all vegetated land cover categories combined. The Lariac4 Lidar Project VVA standard is 0.96 ft based on the 95th percentile. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95th percentile used to compute the VVA; these are always the largest outliers that may depart from a normal error distribution. Here, $Accuracy_z$ differs from VVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas VVA assumes lidar errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

The relevant testing criteria are summarized in Table 2.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using $RMSE_z$ *1.9600	0.64 ft (based on $RMSE_z$ (10 cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	0.96 ft (based on combined 95th percentile)

Table 2 — Acceptance Criteria

The primary QA/QC vertical accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications.
2. Next, Dewberry interpolated the bare-earth lidar DTM to provide the z-value for every checkpoint.
3. Dewberry then computed the associated z-value differences between the interpolated z-value from the lidar data and the ground truth survey checkpoints and computed NVA, VVA, and other statistics.
4. The data were analyzed by Dewberry to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

Vertical Accuracy Results

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified lidar LAS files.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (RMSEz x 1.9600) Spec=0.64 ft	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.96 ft
NVA	189	0.63	
VVA	23		0.53

Table 3 – Tested NVA and VVA

This lidar dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 0.33 ft RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =0.32 ft, equating to +/- 0.63 ft at 95% confidence level. Actual VVA accuracy was found to be +/- 0.53 ft at the 95th percentile.

Table 4 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83 State Plane CA Zone 5 (FIPS 0405)		NAVD88 (Geoid 12B)		Delta Z	AbsDelta Z
	Easting X (ft)	Northing Y (ft)	Z-Survey (ft)	Z-LiDAR (ft)		
825GR	6421519.31	2116759.62	2671.66	2672.53	0.87	0.87

Table 4 – 5% Outliers

Table 5 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (ft) NVA Spec=0.33 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Kurtosis	Min (ft)	Max (ft)
NVA	189	0.32	0.21	0.24	-0.64	0.24	0.35	-0.65	0.71
VVA	23	N/A	0.19	0.18	0.40	0.25	1.38	-0.26	0.87

Table 5 – Overall Descriptive Statistics

DEM VERTICAL ACCURACY RESULTS

The same 212 checkpoints that were used to test the vertical accuracy of the lidar were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source lidar and final DEM deliverable. DEMs are created by averaging several lidar points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS, which does not average several lidar points together but may interpolate (linearly) between two or three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the surveyed elevations. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

Table 6 summarizes the tested vertical accuracy results from a comparison of the surveyed checkpoints to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (RMSEz x 1.9600) Spec=0.64 ft	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.96 ft
NVA	189	0.60	
VVA	23		0.52

Table 6 – DEM tested NVA and VVA

This DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm (0.33 ft) RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 0.31 ft, equating to +/- 0.60 ft at 95% confidence level. Actual VVA accuracy was found to be +/- 0.52 ft at the 95th percentile.

Table 7 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83 State Plane CA Zone 5 (FIPS 0405)		NAVD88 (Geoid 12B)	DEM Z (ft)	Delta Z	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)			
824Base	6410855.558	2104729.923	2820.031	2820.565	0.534	0.534
825GR	6421519.306	2116759.621	2671.658	2672.438	0.780	0.780

Table 7 – 5% Outliers

Table 8 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (ft) NVA Spec=0.33 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Kurtosis	Min (ft)	Max (ft)
NVA	189	0.31	0.19	0.25	-0.67	0.24	0.26	-0.65	0.64
VVA	23	N/A	0.16	0.19	0.30	0.25	0.64	-0.27	0.78

Table 8 – Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Dewberry, the DEM dataset for the Lariac4 Lidar Project satisfies the project's pre-defined vertical accuracy criteria.

QA/QC Checkpoint Location Map

The figure below shows the location of the QA/QC checkpoints used to test the positional accuracy of the dataset.

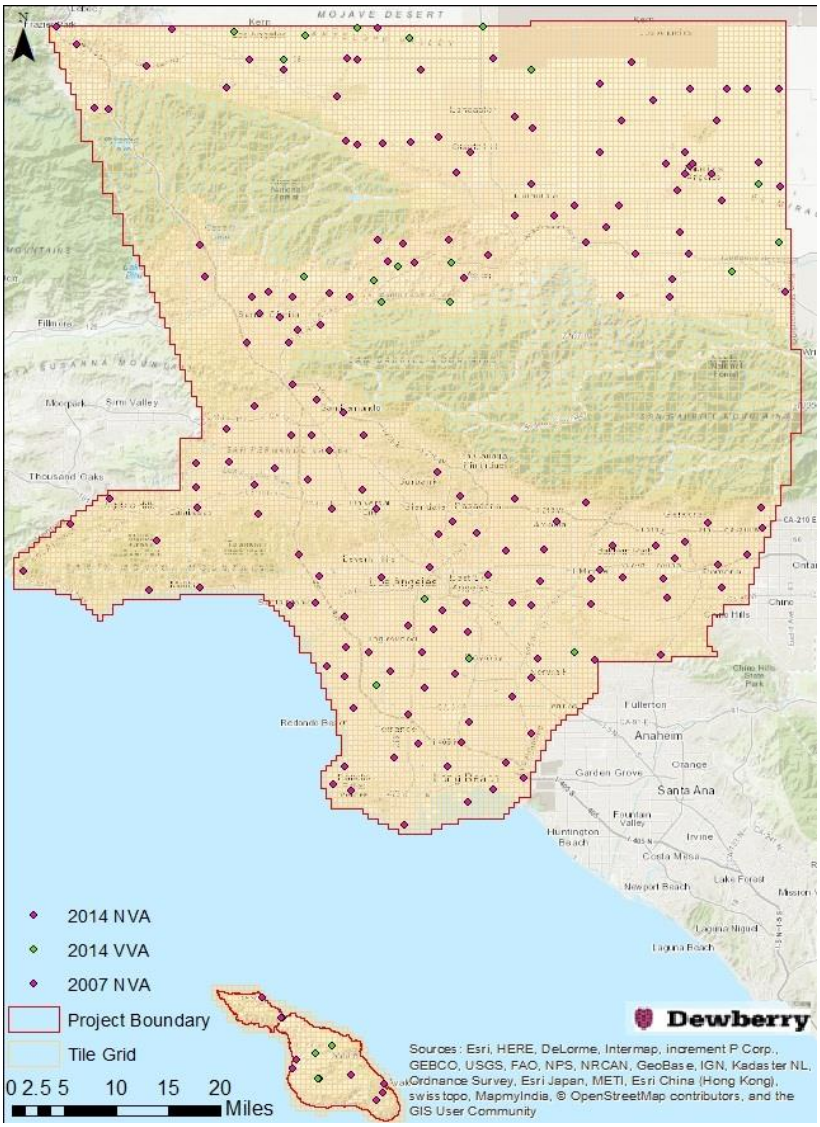

Figure 1 – Location of QA/QC Checkpoints