Clay County, Hiwassee, Little Tennessee and Savannah River Basins

The LIDAR accuracy assessment for Clay County was performed in accordance with section 1.5 of the *Guidelines for Digital Elevation Data*, Version 1.0, published by the National Digital Elevation Program (NDEP), see www.ndep.gov. The NDEP specifies the mandatory determination of Fundamental Vertical Accuracy (FVA) and the optional determination of Supplemental Vertical Accuracy (SVA) and/or Consolidated Vertical Accuracy (CVA). Consistent also with Appendix A, Aerial Mapping and Surveying, of the Federal Emergency Management Agency's (FEMA's) *Guidelines and Specifications for Flood Hazard Mapping Partners*, the North Carolina Floodplain Mapping Program (NCFMP) established mandatory acceptance standards for Fundamental and Consolidated Vertical Accuracy, utilizing five land cover categories listed in Table 1 below.

FVA is determined with check points located only in open terrain (grass, dirt, sand, and/or rocks) 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. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error ($RMSE_Z$) of the checkpoints x 1.9600, as specified in Appendix 3-A of the National Standard for Spatial Data Accuracy (NSSDA), FGDC-STD-007.3-1998, see www.fgdc.gov/standards/status/sub1_3.html. For the current Phase III of the North Carolina Floodplain Mapping Program (NCFMP), the FVA standard is 1.19 feet (ft) at the 95% confidence level, equivalent to the accuracy expected from 2 ft contours. This is a higher standard than the CVA and SVA described below.

CVA is determined with all checkpoints in all land cover categories combined where there is a possibility that the LIDAR sensor and post-processing may not have mapped the bare-earth ground surface and where random errors may not follow a normal error distribution. CVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all land cover categories combined. The CVA is accompanied by a listing of the 5% of the outliers that are larger than the 95th percentile. For Phase III of the NCFMP, the CVA standard is 1.61 ft at the 95% confidence level.

SVA is determined separately for each individual land cover category, recognizing that the LIDAR sensor and post-processing may not have mapped the bare-earth ground surface and where random errors may not follow a normal error distribution. For each land cover category, the SVA at the 95% confidence level equals the 95th percentile error for all checkpoints in that particular land cover category. For Phase III of the NCFMP, there is no SVA standard; nevertheless, the SVA target is 1.61 ft. SVA statistics are calculated individually for open terrain, weeds and crops, scrub, forests, and built-up areas in order to facilitate the analysis of the data based on each of these land cover categories that exist within the county watersheds.

The primary Quality Assurance/Quality Control (QA/QC) steps were as follows:

1. Watershed Concepts' LIDAR subcontractor (EarthData International) acquired the raw LIDAR data in early 2005 and performed post-processing to derive the bare-earth digital terrain model (DTM). EarthData also performed in-house QA/QC of its data.

2. An independent field survey contractor (Arcadis) surveyed "ground truth" county checkpoints in accordance with guidance received from the North Carolina Geodetic Survey (NCGS). See Figure 1 for the location of these QA/QC checkpoints for each land cover category.
3. NCGS provided the horizontal coordinates only for each checkpoint to Watershed Concepts which interpolated the bare-earth LIDAR DTM to provide the z-value for each of these checkpoint coordinates.
4. NCGS computed the associated z-value differences between the interpolated z-value from the LIDAR data and the ground truth survey checkpoints and computed the FVA and CVA. NCGS' Excel workbook, with FVA and CVA calculations, was submitted to Dewberry on November 13, 2006.
5. The NCGS data was reviewed by Dewberry and further analyzed to assess the quantitative quality of the data. The review process re-examined the various accuracy parameters as defined by NDEP guidelines. Also, the overall descriptive statistics of each dataset were computed to assess any trends or anomalies. The following tables, graphs and figures illustrate the data quality utilizing 100% of the checkpoints as per the vertical accuracy tests endorsed by the NCFMP.

Figure 1 shows the location of the QA/QC checkpoints within the county, symbolized to reflect the five land cover categories used.
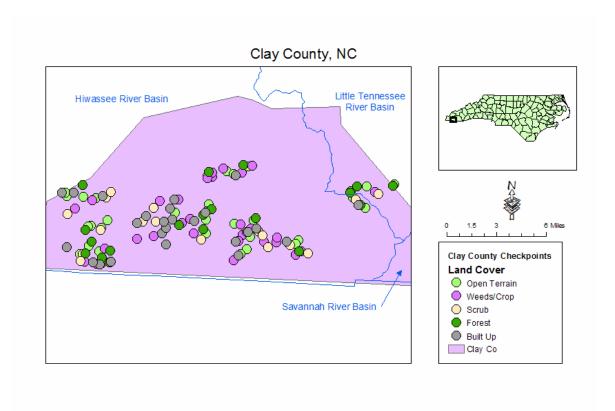

Figure 1

Table 1 summarizes the vertical accuracy by fundamental, consolidated and supplemental methods:

Table 1: Vertical Accuracy at 95% Confidence Level				
Land cover category	# of Points	Fundamental Vertical Accuracy Spec = 1.19 (ft)	Consolidated Vertical Accuracy Spec = 1.61 (ft)	Supplemental Vertical Accuracy (No specification, but target = 1.61 ft)
Total	124		**1.12**	
Open Terrain	29	**1.14**		0.91
Weeds/Crops	31			0.67
Scrub	18			1.46
Forest	19			1.46
Built Up	27			1.12

The LIDAR data of Clay County (Hiwassee, Little Tennessee and Savannah River Basins) meets the specifications as per the following vertical accuracy tests.

Compared with the 1.19 ft (36.3 cm) FVA specification, FVA tested 1.14 ft (34.75 cm) at the 95% confidence level in open terrain only, based on $RMSE_z$ x 1.9600. The NSSDA specifies that vertical accuracy at the 95% confidence level equals $RMSE_z$ x 1.9600, but this method is valid only when random errors follow a normal error distribution, as in open terrain.

Compared with the 1.61 ft (49.0 cm) CVA specification, CVA tested 1.12 ft (34.14 cm) at the 95% confidence level in open terrain, weeds and crops, scrub, forests, and built-up areas combined, based on the 95th Percentile. NDEP guidelines specify that vertical accuracy at the 95% confidence level equals the 95th percentile when random errors do not follow a normal error distribution, as in vegetated areas. Table 2 lists the 5% outliers larger than the 95th percentile (1.12 ft):

Table 2: 5% Outliers larger than 95th percentile		
Land cover category	Elev. Diff (ft)	
Scrub	-1.54	
Scrub	-1.45	The error in bold is the only error larger than the CVA standard (1.61 ft) which permits up to 5% of the checkpoints, normally 6 of 120, to be larger than 1.61 ft.
Forest	**-2.53**	
Forest	-1.34	
Forest	-1.18	
Built Up	-1.23	
Built Up	-1.13	

Figure 2 illustrates the SVA by specific land cover category.

95th Percentile by Land Cover Type

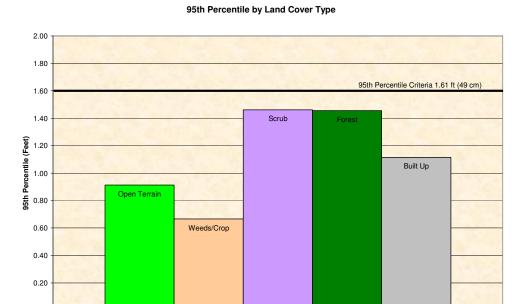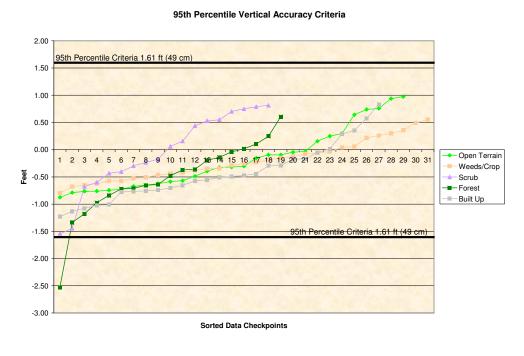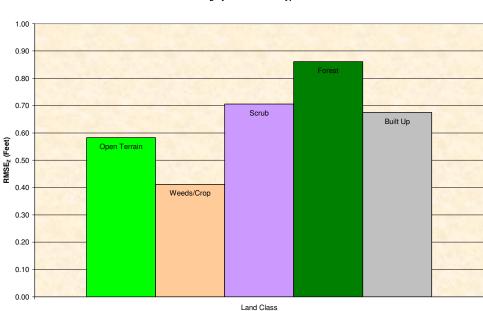**Figure 2**

Figure 3 illustrates the magnitude of the differences between the checkpoints and LIDAR data by specific land cover category and sorted from lowest to highest.

95th Percentile Vertical Accuracy Criteria

Figure 3

Although the NCFMP uses standards different from those specified in Appendix A of the FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, Figure 4 and Table 3 below document $RMSE_Z$ and other statistics that analyze error frequency distribution by land cover category, per Section A.8.6.3 of Appendix A.

$RMSE_Z$ by Land Cover Type

Figure 4

Table 3: Overall Descriptive Statistics								
Land cover category	$RMSE_Z$ (ft)	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Consolidated	0.64	-0.28	-0.33	-0.16	0.57	124	-2.53	0.97
Open Terrain	0.58	-0.18	-0.32	0.77	0.56	29	-0.88	0.97
Weeds/Crops	0.41	-0.21	-0.26	0.49	0.36	31	-0.80	0.55
Scrub	0.71	-0.06	-0.06	-0.64	0.72	18	-1.54	0.82
Forest	0.86	-0.54	-0.48	-1.16	0.69	19	-2.53	0.60
Built Up	0.67	-0.44	-0.51	0.74	0.52	27	-1.23	0.83

Figure 5 illustrates a histogram of the associated delta errors (discrepancies) between the data checkpoints and the interpolated TIN values. The frequency shows the number of discrepancies within each band of elevation differences.
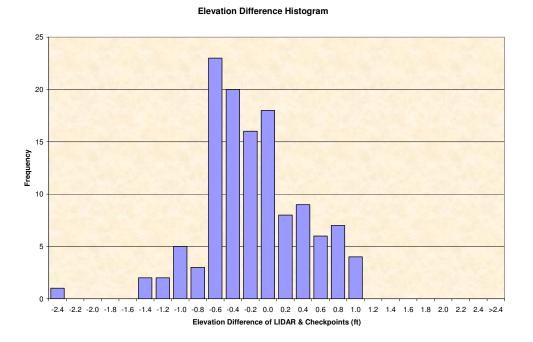
Elevation Difference Histogram

Figure 5

Based on the vertical accuracy testing methodology and the number of checkpoints, the data is of good quality.

Although not tested independently because LIDAR DTM points are not clearly defined points on the ground, the LIDAR provider was required to perform daily calibration checks to ensure that the horizontal (radial) accuracy was equal to or better than 5.68 ft at the 95% confidence level, equivalent to a radial root mean square error ($RMSE_r$) of 3.28 ft (1 meter).

Function	Responsible Organization
LIDAR Data Collection and Processing	EarthData International
QA/QC Surveys	Arcadis
TIN Interpolation	Watershed Concepts
Initial LIDAR Accuracy Assessment	North Carolina Geodetic Survey
Final LIDAR Accuracy Assessment and Report	Dewberry

Users are encouraged to review the associated metadata for additional details of the county's LIDAR dataset.