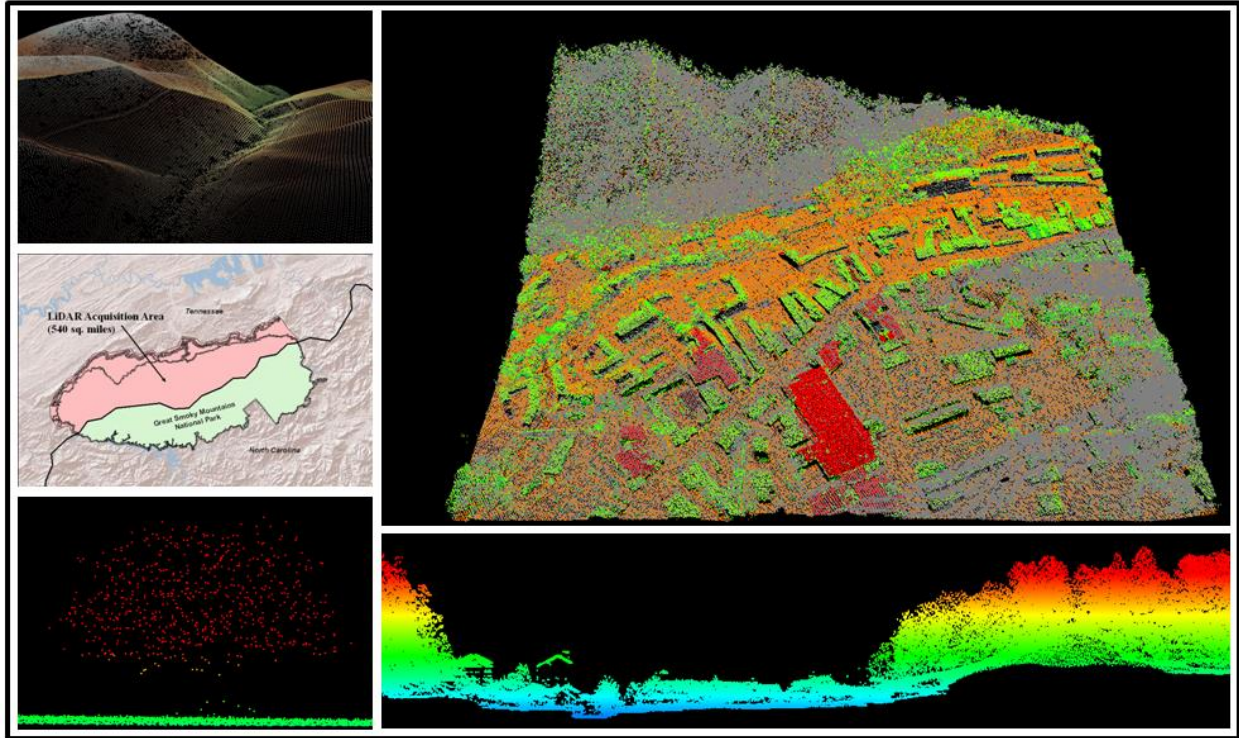


Acquisition of LiDAR for the Tennessee Portion of Great Smoky Mountains National Park and the Foothills Parkway



Final Report

by

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University of Georgia

and

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Gainesville State College

November 30, 2011

USGS Contract # G10AC0015

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National Mapping Program
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This LiDAR acquisition project was funded by the U.S. Geological Survey (USGS) through the American Recovery and Reinvestment Act (ARRA) of 2009, Contract #G10AC0015. The LiDAR data acquired, processed and compiled in this project adheres to the specifications of the USGS Grant Program Announcement No.10HQPA0014 for Proposal #NM-ARRA-0073. The authors would like to acknowledge with gratitude the contributions of the following organizations and individuals to the successful completion of this project.

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Acquisition of LiDAR for the Tennessee Portion of Great Smoky Mountains National Park and the Foothills Parkway

INTRODUCTION

The acquisition of approximately 1400 sq. km (540 sq miles) of LiDAR data for the Tennessee portion of the Great Smoky Mountains National Park (GRSM) and adjacent Foothills Parkway was completed by The Center for Remote Sensing and Mapping Science (CRMS), Department of Geography, University of Georgia (UGA) and Photo Science, Inc (PSI). Under the terms of Contract #G10AC0015, this LiDAR acquisition was funded by the U.S. Geological Survey (USGS) through the American Recovery and Reinvestment Act (ARRA) of 2009. The LiDAR data acquired, processed and compiled in this project adheres to the specifications of the USGS Grant Program Announcement No.10HQPA0014 for Proposal # NM-ARRA-0073.

The aim of this project was to collect and process high resolution LiDAR elevation data to complete the coverage of the Great Smoky Mountains National Park (GRSM). Previous to this project, high resolution LiDAR elevation data were only available for the North Carolina portion of the Park (971 sq km). Those data were acquired as part of the North Carolina Floodplain Mapping Project. The newly-acquired LiDAR data set includes leaf-off LiDAR data of the Tennessee portion of the GRSM and adjacent Foothills Parkway, acquired in the February-April, 2011 timeframe. This is a high priority area for national/global interests because: 1) it is one of the most biodiverse areas of the world; 2) it contains some of the most rare and endangered species in the world; 3) the parks protect some of the last remaining virgin forest in the U.S.; 4) the area is threatened by invasive exotic plants and animals, air pollution, overuse by park visitors and surrounding development; and 5) it is at high risk for flooding, fire and earthquake hazards.

Deliverables include 1) Classified LAS Point Cloud Data in LAS 1.2 format, organized as 1500x1500m tiles; 2) DEM bare earth grids in ERDAS Imagine (IMG) format, organized as 1500x1500m tiles; 3) Raw Unclassified LiDAR Point Clouds in LAS 1.2 format, organized by flight line; and 4) metadata. In all, there are 724 tiles covering 1399 sq. km (540 sq. miles) with 3.8 billion total points. Overall vertical accuracy was assessed to ± 16.5 cm for LiDAR points with an average point spacing of 0.62 m. LiDAR classes include 1 (unclassified), 2 (ground), 7 (noise) and 12 (overlap). All data sets were referenced to the UTM NAD83, Zone 17 North coordinate system and the NAVD88 Vertical Datum.

In a unique public/private partnership, Photo Science, Inc. (Norcross, GA and Lexington, KY) was contracted to acquire, process and classify the LiDAR data. Ground control and accuracy assessments points were surveyed by a ground crew supervised by a professional surveyor from Photo Science with support from UGA faculty and students. Data quality assurance and quality control (QA/QC), data inventory and metadata creation was conducted by a team of researchers, students, interns and employees at UGA. Overall supervision of the project was conducted by

UGA faculty. In this way, the U.S. workforce was strengthened via new jobs, continuity of existing jobs and the training of undergraduate and graduate students at two institutions for high skilled geospatial jobs.

PROJECT OVERVIEW

The aim of this project with the U.S. Geological Survey was to collect and process high resolution LiDAR data for the Tennessee portion of the Great Smoky Mountains National Park (GRSM) and adjacent Foothills Parkway. In a unique public/private partnership, the University of Georgia Center for Remote Sensing and Mapping Science (UGA-CRMS) coordinated with Photo Science, Inc. (Norcross, GA and Lexington, KY), with cooperation from the National Park Service, to develop the flight plans, collect ground control, coordinate flight timing with weather conditions, process and classify the LiDAR, perform QA/QC and accuracy analysis, write metadata and prepare the data for delivery.

Great Smoky Mountains National Park was established in 1934 in an attempt to halt the damage to forests caused by erosion and fires associated with logging activities of the 1800s and early 1900s. By the 1920s, nearly two-thirds of the lands that would become GRSM had been logged or burned (Walker, 1991). The Park now protects 2000 sq. km of forestland within the southern Appalachian Mountains – among the oldest mountain ranges on earth (Moore, 1988). Elevations in GRSM range from approximately 250 m along the outside boundary of the Park to 2,025 m at Clingman's Dome (Figure 1). Rock formations in the region are sedimentary, the result of silt, sand and gravel deposits into a shallow sea that covered the area between 900 and 600 million years ago. More than 900 km of streams and rivers that flow within the Park are replenished by over 200 cm of rain per year. As of 2004, 1,637 species (1,293 native and 344 exotic) of flowering plants, 10 percent of which are considered rare, and over 4,000 species of non-flowering plants are found in GRSM (Walker, 1991). The forestlands include over 100 different species of trees and contain the most extensive virgin hardwood forest in the eastern United States (Whittaker, 1956; Kemp, 1993; Houk, 2000). Scientists estimate that the flora and fauna currently identified in the Park represent only 10 percent of the total species that are likely present (Kaiser, 1999). Due to the range of relief, rugged terrain and extensive tree cover, the GRSM is an extremely difficult area to map (Welch, et al., 2000; Jordan, 2002; Welch et al., 2002). The acquisition of high resolution LiDAR will greatly enhance the existing map resources for this rich and valuable region.

The following figure shows areas of LiDAR acquisition in the Tennessee portion of the Great Smoky Mountains National Park and adjacent Foothills Parkway (Figure 1).

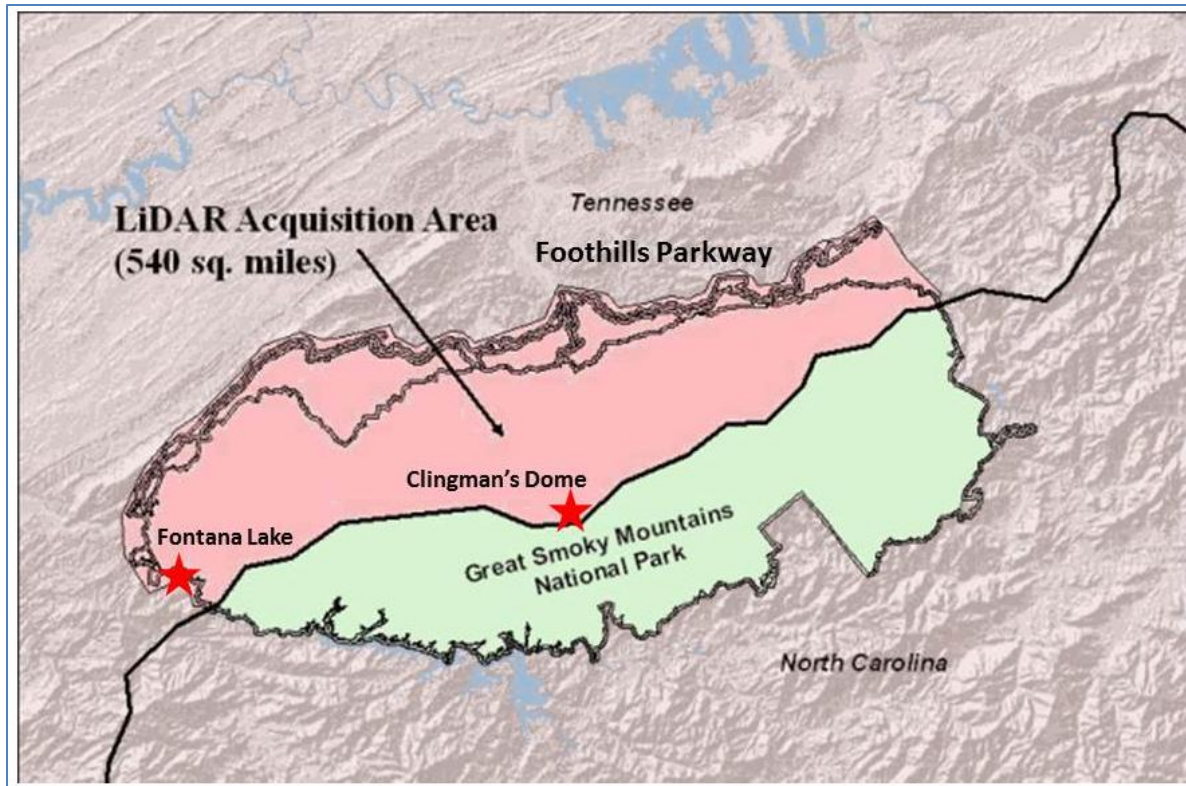


Figure 1: The Great Smoky Mountains National Park (GRSM) straddles the border of North Carolina and Tennessee in the Blue Ridge Mountains. LiDAR data were acquired for the Tennessee portion of GRSM and the adjacent Foothills Parkway.

DATA ACQUISITION

The project contract was signed on February 4, 2010 and scheduled to extend until April 30, 2011. Initial flights were conducted in April, 2010 and data covering approximately 25 to 30% of the westernmost (lower elevation) portion of the GRSM LiDAR study area in Tennessee was flown on April 22/23, 2010. However, flights were suspended and the mission was aborted due to continued snow cover at high elevations when leaf-out occurred.

The LiDAR data acquisition was then postponed. Based on experience with GRSM vegetation mapping and input from Keith Langdon and Tom Remaley, National Park Service Supervisory Biologist and Ecologist, respectively of GRSM, we knew the leaves typically begin to fall at the highest elevations in late October and at the lower elevations leaves should be down by the end of November. The plan was to re-fly the entire LiDAR study area in late November – first of December as soon as the leaves fell at the lower elevations. On November 30, Keith Langdon emailed to say there was no snow in the Smokies and leaves were considered down at all elevations. However there were severe winds described as “an intermittent mountain wave” wind event on November 29 with top wind speeds at Cove Mountain tower recorded at 95 mph and predicted 60 to 90 mph gusts predicted through the evening of November 30. On December 1 to 4 there was snow at the higher elevations and by December 6 there was 2-4

inches at the high elevations. It was hoped that this snow would melt and allow another window of LiDAR data collection, but unfortunately due to unusually severe weather of cold temperatures and winds, this window did not materialize. As of December 20th there was 5-7 inches of snow accumulation at higher elevations with drifts over 4 feet and 2-4 inches at lower elevations.

We advised the USGS of this delay and requested a telephone conference call on December 22, 2010 with USGS experts in LiDAR acquisition, representatives of Photo Science and UGA. As a result of this conference call, it was decided that the LiDAR should not be flown with snow on the ground, although a small amount of leaf coverage would be acceptable, if not optimal. Plans were made to continue to watch the weather and snow conditions in the Smokies so that data could be acquired at the earliest possible date in 2011.

Weather conditions cooperated and snow melted early due to a warming trend in the region. Thus, flights commenced in February and continued through April 2011, when data collection was completed (Figure 2; Table 1; Attachment A). The final data collection included reflighting the entire area originally acquired in April 2010. A total of 1658 flight miles of data were collected.

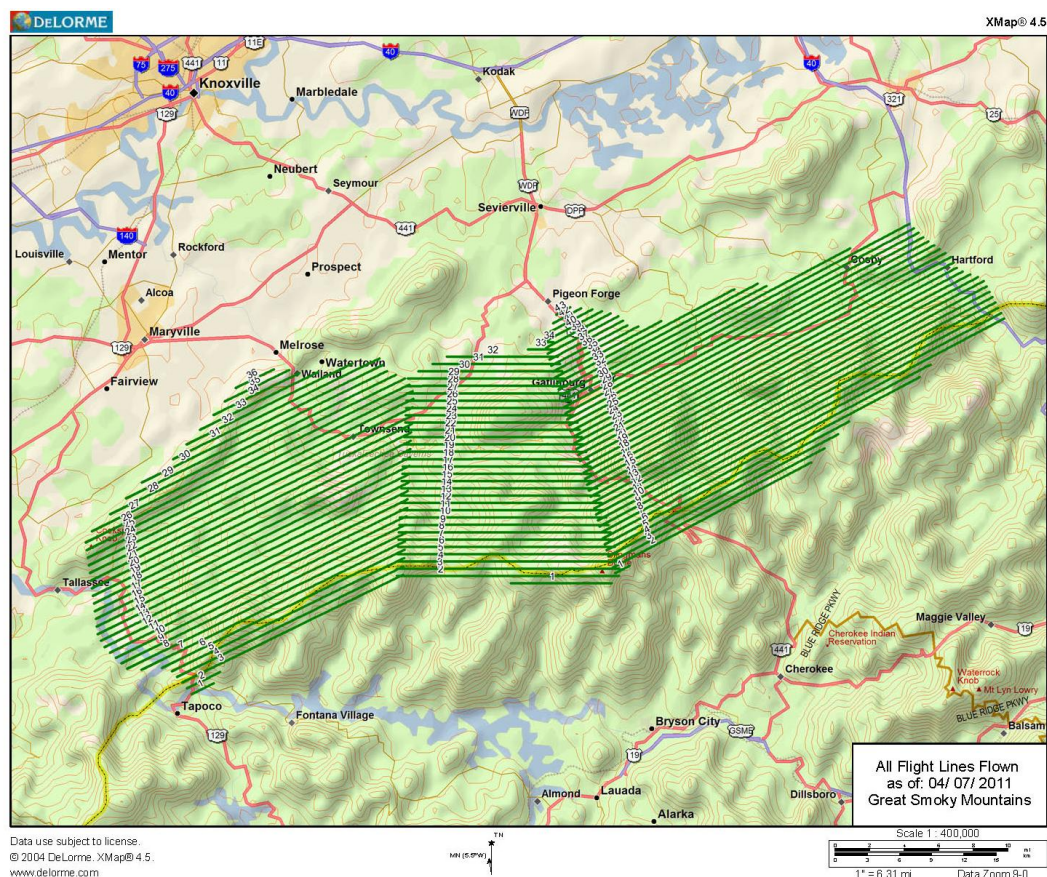


Figure 2: Flight lines in green show the extent of LiDAR data collection in April 2011. The data were acquired in sections: 1) west, 2) central, and 3) east.

Table 1: LiDAR Flight Dates, Miles Flown, Instruments and Aircraft. Full Flight details are provided in Attachment A.

Flight Date	FL_Km	Instrument	Aircraft	Tail Number
16-Feb-11	132.5	Optech Gemini ALTM (SN 240)	CESSNA U206G	N9471R
17-Feb-11	445.4	Optech Gemini ALTM (SN 240)	CESSNA U206G	N9471R
19-Feb-11	380.6	Optech Gemini ALTM (SN 240)	CESSNA U206G	N9471R
12-Mar-11	528.6	Leica ALS60 (SN 6156)	PIPER PA-31	N262AS
29-Mar-11	294.8	Leica ALS60 (SN 6156)	PIPER PA-31	N262AS
06-Apr-11	709.2	Leica ALS60 (SN 6156)	PIPER PA-31	N262AS
07-Apr-11	161.6	Leica ALS60 (SN 6156)	PIPER PA-31	N262AS
Total Miles	2652.6			

Two LiDAR instruments were employed for the data collection, an Optech Gemini ALTM (SN 240), and a Leica ALS60 (SN 6156), both owned and operated by Photo Science, Inc. (Lexington, KY). In both cases, four multiple discrete returns per pulse were collected at rates of 20.2 Hz. There was overlap of 40-50% between adjacent flight lines for a nominal flying height of 1981.2 m AGL. Scan angles were +/- 16 degrees for a swath width of 1134.7 m (Table 2).

Table 2: LiDAR Data Collection Statistics, by Survey Section and Sub-Area

Survey Section	Section 1	Section 2	Section 3	
Total Passes	36	34	50	
Total Length	924.773 km	549.845 km	1221.978 km	
Total Flight Time	7:53:30	5:42:49	10:49:47	
Total Laser Time	4:32:22	2:41:56	5:59:54	
Total Swath Area	629.604 km ²	374.345 km ²	693.289 km ²	
Total AOI Area	565.354 km ²	343.604 km ²	601.729 km ²	
Area Flight Profile			Sub-Area 3-1	Sub-Area 3-2
Total Length	924.773 km	549.845 km	1194.457 km	27.521 km
Flight Time	7:53:30	5:42:49	10:09:37	0:40:10
Laser Time	4:32:22	2:41:56	5:51:48	0:08:06
Swath Area	629.604 km ²	374.345 km ²	677.675 km ²	15.614 km ²
AOI Area	565.354 km ²	343.604 km ²	590.021 km ²	11.708 km ²
Altitude	1981.2 m AGL	1981.2 m AGL	1981.2 m AGL	1981.2 m AGL
Speed	110 kts	110 kts	110 kts	110 kts
Flight Lines	36	34	43	7
Pass Heading	64	90	62	241
Pass Spacing	680.82 m	680.82 m	567.35 m	567.35 m
Overlap	40% = 453.88 m	40% = 453.88 m	50% = 567.35 m	50% = 567.35 m
Turn Time	5 min	5 min	5 min	5 min

Area LIDAR Settings			Sub-Area 3-1	Sub-Area 3-2
Desired Res	1.134 m	1.134 m	1.134 m	1.134 m
Density	0.78 ppm^2	0.78 ppm^2	0.78 ppm^2	0.78 ppm^2
Cross Track Res	0.918 m	0.918 m	0.918 m	0.918 m
Down Track Res	1.401 m	1.401 m	1.401 m	1.401 m
Scan Frequency	20.2 Hz	20.2 Hz	20.2 Hz	20.2 Hz
Scan Angle	+/- 16 deg	+/- 16 deg	+/- 16 deg	+/- 16 deg
Scan Cutoff	+/- 0.02 deg	+/- 0.02 deg	+/- 0.02 deg	+/- 0.02 deg
Scan Offset	0 deg	0 deg	0 deg	0 deg
System PRF	50 kHz	50 kHz	50 kHz	50 kHz
Swath Width	1134.7 m	1134.7 m	1134.7 m	1134.7 m
DEM Estimates				
DEM Min Z	253.9 m	348.7 m	1011 m	1324 m
DEM Max Z	1685.5 m	2005.3 m	6607 m	3078 m

DATA PROCESSING

The project manager at CRMS coordinated with Photo Science, Inc. to acquire/process the LiDAR, while data post-processing, assessment, quality control assurance and the creation of useful products were conducted by a team of researchers, students, interns and employees at UGA and Photo Science Inc. The following pre- and post-processing steps were conducted for the LiDAR data.

- 1. Data Acquisition:** LiDAR data were acquired during a series of airborne LiDAR flights considering positioning, orientation, and laser point ranges. Differential Global Positioning System (DGPS) and Inertial Measurement Units (IMU) on-board the aircraft recorded precise position and orientation of the aircraft at all times.
- 2. Data Calibration:** The airborne LiDAR instruments were calibrated before and after each flight day in order to both calibrate and boresight the LiDAR sensor. The approach included flying both horizontally and perpendicular to established ground control points, usually adjacent to or on-site at any regional airport near Frankfort, KY. This process permitted the LiDAR data to be precisely georeferenced.
- 3. Data Classification:** The LiDAR data were classified using GeoCue Terrascan software. In this process, LiDAR points were identified as being members of one of the specified classes, including Unclassified (1), Ground (2), Noise (7) and Overlap (12) (Table 3). The LiDAR data were then split up into 1500x1500m adjacent and non-overlapping tiles according to the predetermined tiling scheme.
- 4. QA/QC:** Each tile was examined at high resolution using the QA/QC workflow incorporated into the QCoherent LP360 software package. The points classified as Ground were used to create a Triangular Irregular Network (TIN) that was displayed in shaded relief with the individual points overlaid. This procedure was designed to identify

points that were not correctly classified as Ground. A total of 2603 regions were identified as possible misclassifications or anomalies (Figure 3). Those points were return to PSI, examined and reclassified if needed. No points were deleted from the point cloud at any time.

5. **Final Data Sets:** After the QA/QC was completed, the classified point clouds were employed to create a bare-earth raster surface. A 32-bit floating point DEM with a spatial resolution of 1.5 m was created using ESRI ArcGIS software in order to maintain the detail provided by the very high resolution LiDAR point cloud. The 1500x1500-m tile scheme was enforced for the grid for consistency with the classified point cloud tiles. The DEM post-spacing of 1.5x1.5 m satisfies the USGS requirement for high resolution 1/9 arc-second (or better) bare-earth DEMs.
6. **Metadata:** Metadata files for each data type (one file for each RAW LiDAR, Classified LAS Tiles, Bare Earth DEM tiles) were created in the National Geospatial Data Committee (NGDC) Content Standard for Geospatial Metadata using metadata tools in ESRI ArcCatalog. These files are in XML-format (see Attachments C, D and E).
7. **Deliverables:** The deliverables for this project were created and assembled, including: Raw Point Cloud, a Classified Point Cloud, a Bare-Earth Surface (Raster DEM) and metadata.

Table 3: Classifications used in the LiDAR Data Set

Code	Description
1	Processed, but unclassified
2	Bare-earth ground
7	Noise (low or high, manually identified, if needed)
12	Overlap

Coordinate Systems and Datums

All data are cast on the following coordinate systems:

Horizontal : NAD83 - UTM Zone 17N, Meters

Vertical : NAVD88 - Geoid09, Meters

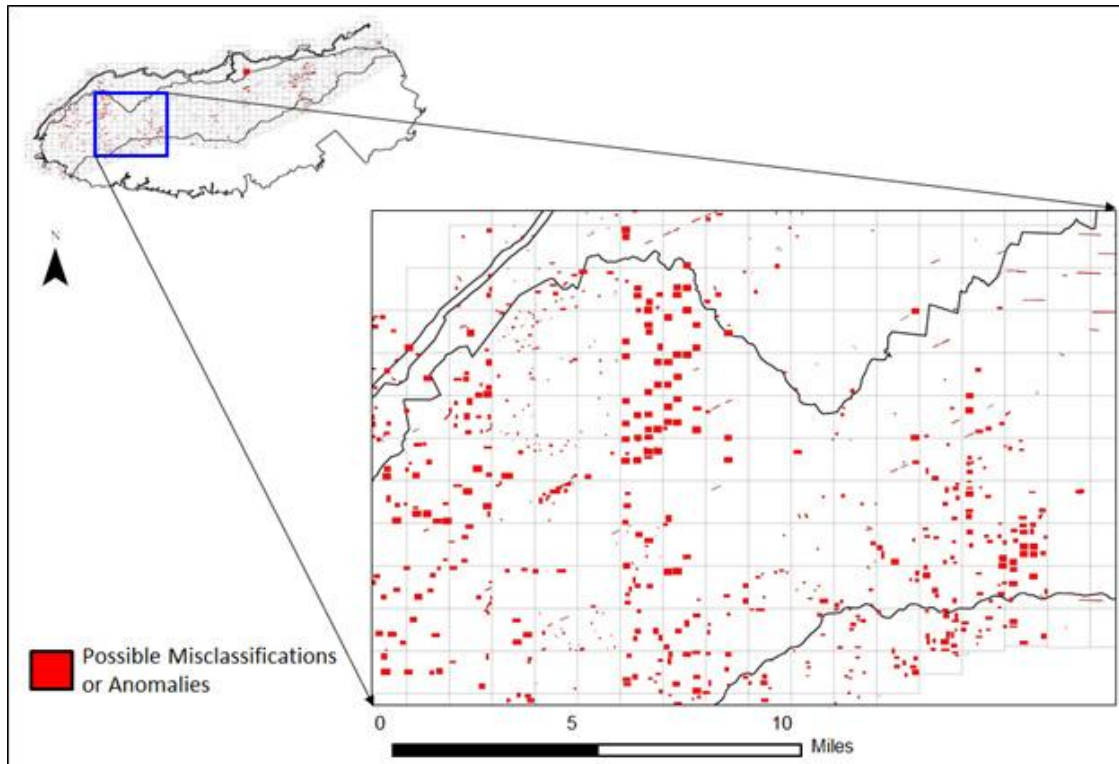


Figure 3: QA/QC points of interest. Possible misclassifications or anomalies are marked in red. A total of 2603 regions were identified as possible misclassifications or anomalies.

ACCURACY ASSESSMENT

Field Survey

In February, 2011, personnel from PSI and UGA surveyed a total of 299 ground control points (GCPs) organized in 11 clusters distributed throughout the LiDAR project area (Figures 5 and 6). A combination of DGPS (real-time kinematic and static) coupled with total station survey methods was used to measure X, Y, and Z coordinates of the points in a variety of land cover conditions (see Attachment B) to be used to assess the accuracy of the LiDAR point cloud and raster DEM.



Total Station (TS) Surveying



Real Time Kenematic (RTK) GPS Surveying



Static GPS Surveying

Figure 4: Ground survey was conducted using a combination of DGPS and total station survey methods.

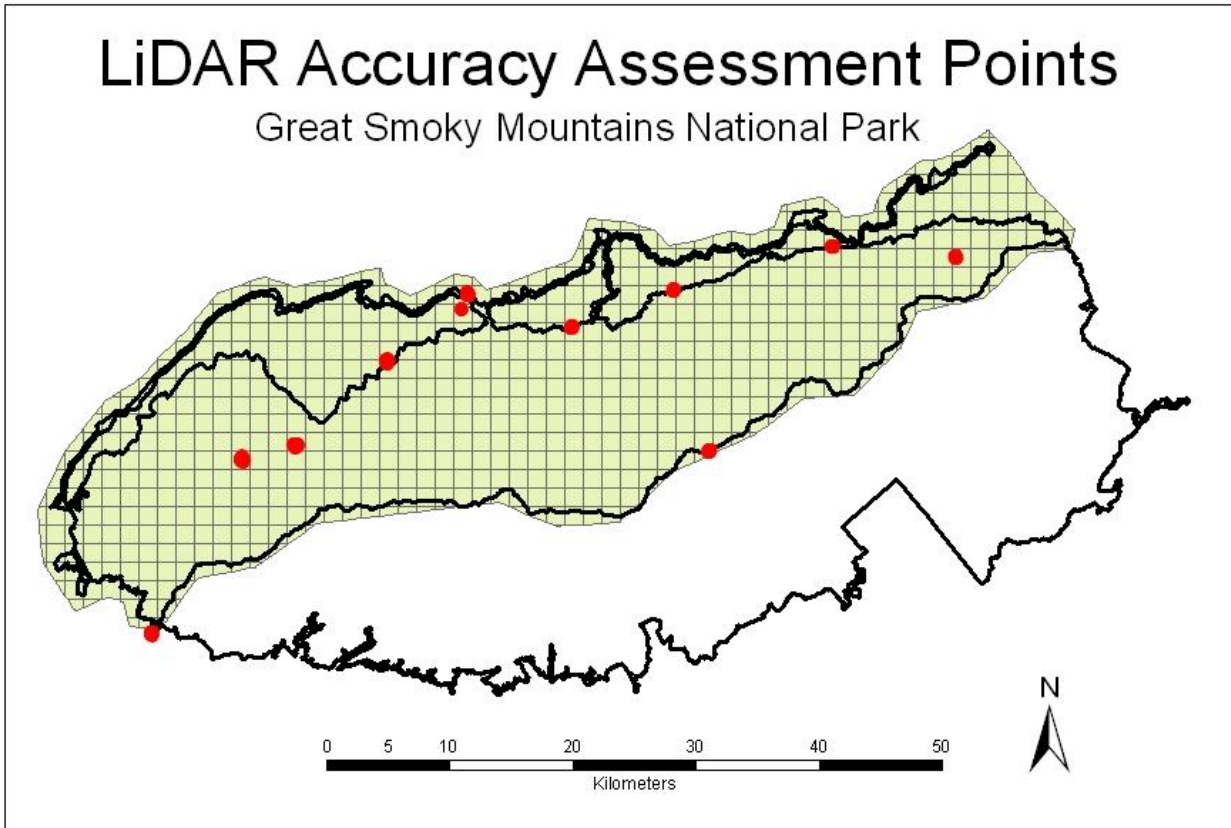


Figure 5: Distribution of points used for accuracy assessment of the LiDAR data. Each location (shown in red) represents a cluster of points measured by DGPS and total station survey. Each cluster averages 27 points for a total of 299 Accuracy Assessment (AA) points. The grid shows the data tiling scheme.

Accuracy Analysis

Using the 299 check points, the ground-classified points in the LiDAR data were evaluated in terms of elevation accuracy for the general categories of ground cover listed below.

1. Bare earth and low grass (plowed fields, lawns, golf courses)
2. High grass and crops (hay fields, corn fields, wheat fields)
3. Brush lands and low trees
4. Fully covered by trees (hardwoods, evergreens, mixed forests)
5. Urban areas (high, dense, manmade structures)

Overall accuracy was found to have a National Standard for Spatial Data Accuracy (NSSDA) $RMSE_z$ of ± 0.161 m, which exceeds the target accuracy of ± 0.185 m (FGDC, 1998). The minimum and maximum errors are -0.32 and 0.51 m, respectively. Finally, accuracy in the land cover sub-classes ranged from ± 0.12 to ± 0.20 m. A summary of these results is provided in Table 4 while the details for each point are given in Attachment B: Vertical Accuracy Report.

Table 4: Vertical Accuracy of the LiDAR Point Cloud

Statistical Analysis	Value
Average Dz	0 m
Minimum Dz	-0.32 m
Maximum Dz	0.51 m
RMSEz	± 0.161 m
Standard Deviation	0.162 m
Cover Class	RMSE
Overall Accuracy	± 0.161 m
Class 1 - Bare Earth	± 0.17 m
Class 2 - High grass and crops	± 0.12 m
Class 3 - Brush lands and low trees	± 0.16 m
Class 4 - Fully covered by trees	± 0.20 m
Class 5 - Urban areas	± 0.15 m

DELIVERABLE PRODUCTS

The following elevation data products were created as deliverables for this project. The final datasets were shipped to USGS on a portable hard drive on September 13, 2011. All horizontal data are referenced to the NAD83 UTM Coordinate System, Zone 17, while vertical coordinates are referenced to NAVD88, Geoid09.

No break line or contour deliverables were collected as part of this scope of work.

1. Raw LiDAR Point Clouds in LAS 1.2 format organized according to flight line (Base LiDAR Specification, Section IV, Outline 2). No wave form data were included in the collection.
2. Classified LiDAR Point Clouds in LAS 1.2 format organized in 1500x1500m tiles, with no overlap between tiles (Base LiDAR Specification, Section IV, Outline 3). The following classes were used: 1 – Unclassified; 2 – Ground; 7 – Noise; and 12 – Overlap.
3. Bare-Earth Surface (Raster DEMs) in 32-bit floating point ERDAS Imagine format, 1.5 m resolution, organized in 1500x1500m tiles, with no overlap between tiles (Base LiDAR Specification, Section IV, Outline 4). Georeferencing information is included in the header of each file. The Bare-Earth DEM was created from the Ground-classified LiDAR points to interpolate a regular grid. A 1.5-m grid spacing was employed so as to best represent the resolution of the LiDAR data without generalization.

4. Metadata for each data type (one file for each RAW LiDAR, Classified LAS Tiles, Bare Earth DEM tiles) are provided according to the NGDC Content Standard for Geospatial Metadata. Metadata files are provided in Attachments C, D and E.
5. Supporting documentation, including
 1. Control points
 2. Accuracy assessment table
 3. Study area shapefiles
 4. Tile layout index shapefile
 5. LAS analysis and flight logs
 6. Deliverable listing

Tile Referencing Scheme

All tiles are referenced to the NAD83, UTM Coordinate System, Zone 17, and are uniquely identified using a labeling system derived from the Military Grid Reference System (MGRS) at the 100-m level of precision for the lower-left corner of the tile.

The tile, 17SKV505540, is described as follows:

- | | |
|-----|--|
| 17S | Grid Zone designator, in this case, UTM Zone 17S |
| KV | The 100,000-m square MGRS identifier |
| 505 | The three digits of the easting coordinate of the lower-left corner of the tile. The last two digits (representing 100) of the coordinate are truncated. In this case, the full UTM Zone 17 easting coordinate would be 250,500. |
| 540 | The three digits of the northing coordinate of the lower-left corner of the tile. The last two digits (representing 100) of the coordinate are truncated. In this case, the full UTM Zone 17 northing coordinate would be 3,954,000. |

CONCLUSION

The acquisition of approximately 1400 sq. km (540 sq miles) of LiDAR data for the Tennessee portion of the Great Smoky Mountains National Park and adjacent Foothills Parkway was completed by a unique public/private partnership that included the Center for Remote Sensing and Mapping Science (CRMS), Department of Geography, University of Georgia (UGA) and Photo Science, Inc. (PSI), with cooperation from Gainesville State College and the National Park Service. Under the terms of Contract #G10AC0015, this LiDAR acquisition was funded by the USGS through American Recovery and Reinvestment Act (ARRA) of 2009. The LiDAR data acquired, processed and compiled in this project adhere to the specifications of the USGS Grant Program Announcement No.10HQPA0014 for Proposal # NM-ARRA-0073. Delivery of the data was made to the on September 13, 2011. Copies of the contract and data delivery letter are provided as Attachments F and G.

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Attachment A: LiDAR Flight Data

State	Proj_Num	Proj_Name	Pt_Spacing	Area_ID	No_FL	FL_NUM	FL_miles	Date_Flown	System_used	SN	AC	Begin_Lat	Begin_Long	End_Lat	End_Long
Tennessee	8114-001	TN	1.1	Section 1	36	1	1.412746	06-Apr-11	Leica	6156	N262AS	35.45975	-83.92195	35.46871	-83.89938
Tennessee	8114-001	TN	1.1	Section 1	36	2	2.142329	06-Apr-11	Leica	6156	N262AS	35.46458	-83.92697	35.47816	-83.89272
Tennessee	8114-001	TN	1.1	Section 1	36	3	14.24289	06-Apr-11	Leica	6156	N262AS	35.46939	-83.93202	35.55972	-83.70426
Tennessee	8114-001	TN	1.1	Section 1	36	4	14.59732	06-Apr-11	Leica	6156	N262AS	35.47414	-83.93721	35.56673	-83.70377
Tennessee	8114-001	TN	1.1	Section 1	36	5	14.95172	06-Apr-11	Leica	6156	N262AS	35.47889	-83.94241	35.57373	-83.70329
Tennessee	8114-001	TN	1.1	Section 1	36	6	15.61505	06-Apr-11	Leica	6156	N262AS	35.48169	-83.95253	35.58074	-83.70279
Tennessee	8114-001	TN	1.1	Section 1	36	7	16.96921	06-Apr-11	Leica	6156	N262AS	35.4801	-83.97371	35.58775	-83.7023
Tennessee	8114-001	TN	1.1	Section 1	36	8	17.93161	06-Apr-11	Leica	6156	N262AS	35.481	-83.98862	35.59475	-83.70181
Tennessee	8114-001	TN	1.1	Section 1	36	9	18.32145	06-Apr-11	Leica	6156	N262AS	35.48553	-83.99438	35.60176	-83.70132
Tennessee	8114-001	TN	1.1	Section 1	36	10	18.71124	06-Apr-11	Leica	6156	N262AS	35.49006	-84.00014	35.60877	-83.70083
Tennessee	8114-001	TN	1.1	Section 1	36	11	19.10099	06-Apr-11	Leica	6156	N262AS	35.49458	-84.0059	35.61577	-83.70034
Tennessee	8114-001	TN	1.1	Section 1	36	12	19.49069	06-Apr-11	Leica	6156	N262AS	35.49911	-84.01167	35.62278	-83.69984
Tennessee	8114-001	TN	1.1	Section 1	36	13	19.75347	06-Apr-11	Leica	6156	N262AS	35.50444	-84.0154	35.62979	-83.69936
Tennessee	8114-001	TN	1.1	Section 1	36	14	19.9892	06-Apr-11	Leica	6156	N262AS	35.50994	-84.01869	35.6368	-83.69887
Tennessee	8114-001	TN	1.1	Section 1	36	15	20.09411	17-Feb-11	Optech	240	N9471R	35.51628	-84.01991	35.6438	-83.69838
Tennessee	8114-001	TN	1.1	Section 1	36	16	20.17116	17-Feb-11	Optech	240	N9471R	35.52279	-84.02067	35.65081	-83.69788
Tennessee	8114-001	TN	1.1	Section 1	36	17	20.2643	17-Feb-11	Optech	240	N9471R	35.5292	-84.02169	35.65781	-83.6974
Tennessee	8114-001	TN	1.1	Section 1	36	18	20.35801	17-Feb-11	Optech	240	N9471R	35.5356	-84.02272	35.66482	-83.69691
Tennessee	8114-001	TN	1.1	Section 1	36	19	20.45172	17-Feb-11	Optech	240	N9471R	35.542	-84.02375	35.67183	-83.69641
Tennessee	8114-001	TN	1.1	Section 1	36	20	20.54541	17-Feb-11	Optech	240	N9471R	35.5484	-84.02478	35.67884	-83.69592
Tennessee	8114-001	TN	1.1	Section 1	36	21	20.63909	17-Feb-11	Optech	240	N9471R	35.55481	-84.02582	35.68584	-83.69543
Tennessee	8114-001	TN	1.1	Section 1	36	22	20.7341	17-Feb-11	Optech	240	N9471R	35.5612	-84.02687	35.69285	-83.69494
Tennessee	8114-001	TN	1.1	Section 1	36	23	20.8317	17-Feb-11	Optech	240	N9471R	35.56758	-84.02796	35.69986	-83.69445
Tennessee	8114-001	TN	1.1	Section 1	36	24	20.92929	16-Feb-11	Optech	240	N9471R	35.57396	-84.02905	35.70686	-83.69396
Tennessee	8114-001	TN	1.1	Section 1	36	25	20.96456	16-Feb-11	Optech	240	N9471R	35.58034	-84.03015	35.71347	-83.69447
Tennessee	8114-001	TN	1.1	Section 1	36	26	20.82553	16-Feb-11	Optech	240	N9471R	35.58672	-84.03124	35.71898	-83.69777

Tennessee	8114-001	TN	1.1	Section 1	36	27	20.10845	16-Feb-11	Optech	240	N9471R	35.59615	-84.02464	35.72387	-83.70261
Tennessee	8114-001	TN	1.1	Section 1	36	28	18.3655	17-Feb-11	Optech	240	N9471R	35.61039	-84.00593	35.72704	-83.71179
Tennessee	8114-001	TN	1.1	Section 1	36	29	16.78019	17-Feb-11	Optech	240	N9471R	35.62362	-83.98974	35.73021	-83.72097
Tennessee	8114-001	TN	1.1	Section 1	36	30	15.49074	17-Feb-11	Optech	240	N9471R	35.63685	-83.97355	35.73526	-83.72541
Tennessee	8114-001	TN	1.1	Section 1	36	31	13.25561	17-Feb-11	Optech	240	N9471R	35.65654	-83.94107	35.74077	-83.72871
Tennessee	8114-001	TN	1.1	Section 1	36	32	10.66375	17-Feb-11	Optech	240	N9471R	35.66886	-83.92719	35.73662	-83.75636
Tennessee	8114-001	TN	1.1	Section 1	36	33	7.592743	17-Feb-11	Optech	240	N9471R	35.68118	-83.91331	35.72942	-83.79167
Tennessee	8114-001	TN	1.1	Section 1	36	34	5.505423	17-Feb-11	Optech	240	N9471R	35.69347	-83.89951	35.72845	-83.81129
Tennessee	8114-001	TN	1.1	Section 1	36	35	4.145722	17-Feb-11	Optech	240	N9471R	35.70477	-83.88818	35.73112	-83.82175
Tennessee	8114-001	TN	1.1	Section 1	36	36	2.470494	17-Feb-11	Optech	240	N9471R	35.71608	-83.87684	35.73178	-83.83725
Tennessee	8114-001	TN	1.1	Section 2	34	1	5.866334	29-Mar-11	Leica	6156	N262AS	35.55245	-83.59319	35.55245	-83.48887
Tennessee	8114-001	TN	1.1	Section 2	34	2	12.90011	29-Mar-11	Leica	6156	N262AS	35.55857	-83.71055	35.55857	-83.48112
Tennessee	8114-001	TN	1.1	Section 2	34	3	12.89913	29-Mar-11	Leica	6156	N262AS	35.5647	-83.71055	35.5647	-83.48112
Tennessee	8114-001	TN	1.1	Section 2	34	4	12.88441	29-Mar-11	Leica	6156	N262AS	35.57082	-83.71035	35.57082	-83.48116
Tennessee	8114-001	TN	1.1	Section 2	34	5	12.74004	29-Mar-11	Leica	6156	N262AS	35.57694	-83.70992	35.57694	-83.48328
Tennessee	8114-001	TN	1.1	Section 2	34	6	12.58805	29-Mar-11	Leica	6156	N262AS	35.58307	-83.70949	35.58307	-83.48554
Tennessee	8114-001	TN	1.1	Section 2	34	7	12.43608	29-Mar-11	Leica	6156	N262AS	35.58919	-83.70906	35.58919	-83.4878
Tennessee	8114-001	TN	1.1	Section 2	34	8	12.28413	29-Mar-11	Leica	6156	N262AS	35.59531	-83.70863	35.59531	-83.49006
Tennessee	8114-001	TN	1.1	Section 2	34	9	12.13221	29-Mar-11	Leica	6156	N262AS	35.60143	-83.70821	35.60143	-83.49232
Tennessee	8114-001	TN	1.1	Section 2	34	10	11.98031	29-Mar-11	Leica	6156	N262AS	35.60756	-83.70778	35.60756	-83.49458
Tennessee	8114-001	TN	1.1	Section 2	34	11	11.82843	07-Apr-11	Leica	6156	N262AS	35.61368	-83.70734	35.61368	-83.49683
Tennessee	8114-001	TN	1.1	Section 2	34	12	11.67658	07-Apr-11	Leica	6156	N262AS	35.6198	-83.70692	35.6198	-83.49909
Tennessee	8114-001	TN	1.1	Section 2	34	13	11.52475	07-Apr-11	Leica	6156	N262AS	35.62593	-83.70649	35.62593	-83.50135
Tennessee	8114-001	TN	1.1	Section 2	34	14	11.37294	07-Apr-11	Leica	6156	N262AS	35.63205	-83.70606	35.63205	-83.50361
Tennessee	8114-001	TN	1.1	Section 2	34	15	11.22115	07-Apr-11	Leica	6156	N262AS	35.63817	-83.70564	35.63817	-83.50587
Tennessee	8114-001	TN	1.1	Section 2	34	16	11.06939	07-Apr-11	Leica	6156	N262AS	35.64429	-83.7052	35.64429	-83.50813
Tennessee	8114-001	TN	1.1	Section 2	34	17	10.91765	07-Apr-11	Leica	6156	N262AS	35.65042	-83.70477	35.65042	-83.51038
Tennessee	8114-001	TN	1.1	Section 2	34	18	10.76593	07-Apr-11	Leica	6156	N262AS	35.65654	-83.70435	35.65654	-83.51264
Tennessee	8114-001	TN	1.1	Section 2	34	19	10.61424	07-Apr-11	Leica	6156	N262AS	35.66266	-83.70392	35.66266	-83.5149

Tennessee	8114-001	TN	1.1	Section 2	34	20	10.46256	19-Feb-11	Optech	240	N9471R	35.66879	-83.70349	35.66879	-83.51716
Tennessee	8114-001	TN	1.1	Section 2	34	21	10.31092	19-Feb-11	Optech	240	N9471R	35.67491	-83.70306	35.67491	-83.51942
Tennessee	8114-001	TN	1.1	Section 2	34	22	10.15929	19-Feb-11	Optech	240	N9471R	35.68103	-83.70263	35.68103	-83.52168
Tennessee	8114-001	TN	1.1	Section 2	34	23	10.00769	19-Feb-11	Optech	240	N9471R	35.68715	-83.7022	35.68715	-83.52393
Tennessee	8114-001	TN	1.1	Section 2	34	24	9.856103	19-Feb-11	Optech	240	N9471R	35.69328	-83.70177	35.69328	-83.52619
Tennessee	8114-001	TN	1.1	Section 2	34	25	9.70455	19-Feb-11	Optech	240	N9471R	35.6994	-83.70135	35.6994	-83.52845
Tennessee	8114-001	TN	1.1	Section 2	34	26	9.55301	19-Feb-11	Optech	240	N9471R	35.70552	-83.70092	35.70552	-83.53071
Tennessee	8114-001	TN	1.1	Section 2	34	27	9.4015	19-Feb-11	Optech	240	N9471R	35.71165	-83.70049	35.71165	-83.53297
Tennessee	8114-001	TN	1.1	Section 2	34	28	9.25001	19-Feb-11	Optech	240	N9471R	35.71777	-83.70006	35.71777	-83.53522
Tennessee	8114-001	TN	1.1	Section 2	34	29	9.098097	19-Feb-11	Optech	240	N9471R	35.72389	-83.69962	35.72389	-83.53748
Tennessee	8114-001	TN	1.1	Section 2	34	30	8.360334	19-Feb-11	Optech	240	N9471R	35.73001	-83.68874	35.73001	-83.53974
Tennessee	8114-001	TN	1.1	Section 2	34	31	7.407494	19-Feb-11	Optech	240	N9471R	35.73614	-83.67403	35.73614	-83.542
Tennessee	8114-001	TN	1.1	Section 2	34	32	6.454802	19-Feb-11	Optech	240	N9471R	35.74226	-83.65932	35.74226	-83.54426
Tennessee	8114-001	TN	1.1	Section 2	34	33	1.640596	19-Feb-11	Optech	240	N9471R	35.74838	-83.57576	35.74838	-83.54652
Tennessee	8114-001	TN	1.1	Section 2	34	34	0.4109287	19-Feb-11	Optech	240	N9471R	35.75451	-83.55618	35.75451	-83.54885
Tennessee	8114-001	TN	1.1	Section 3	43	1	0.914066	12-Mar-11	Leica	6156	N262AS	35.56105	-83.48485	35.56725	-83.47047
Tennessee	8114-001	TN	1.1	Section 3	43	2	12.99572	12-Mar-11	Leica	6156	N262AS	35.56556	-83.4878	35.65381	-83.2833
Tennessee	8114-001	TN	1.1	Section 3	43	3	14.03127	29-Mar-11	Leica	6156	N262AS	35.57029	-83.49023	35.66559	-83.26942
Tennessee	8114-001	TN	1.1	Section 3	43	4	15.02944	29-Mar-11	Leica	6156	N262AS	35.57527	-83.49207	35.67736	-83.25552
Tennessee	8114-001	TN	1.1	Section 3	43	5	15.85266	29-Mar-11	Leica	6156	N262AS	35.58026	-83.4939	35.68795	-83.24438
Tennessee	8114-001	TN	1.1	Section 3	43	6	20.5962	29-Mar-11	Leica	6156	N262AS	35.58524	-83.49574	35.72519	-83.17149
Tennessee	8114-001	TN	1.1	Section 3	43	7	21.41442	06-Apr-11	Leica	6156	N262AS	35.59023	-83.49758	35.73574	-83.16042
Tennessee	8114-001	TN	1.1	Section 3	43	8	26.32904	06-Apr-11	Leica	6156	N262AS	35.59521	-83.49942	35.77416	-83.08479
Tennessee	8114-001	TN	1.1	Section 3	43	9	26.25826	06-Apr-11	Leica	6156	N262AS	35.6002	-83.50126	35.77868	-83.08772
Tennessee	8114-001	TN	1.1	Section 3	43	10	26.18643	06-Apr-11	Leica	6156	N262AS	35.60519	-83.5031	35.78318	-83.09068
Tennessee	8114-001	TN	1.1	Section 3	43	11	26.11121	06-Apr-11	Leica	6156	N262AS	35.61017	-83.50494	35.78766	-83.09368
Tennessee	8114-001	TN	1.1	Section 3	43	12	26.03586	06-Apr-11	Leica	6156	N262AS	35.61516	-83.50677	35.79214	-83.09669
Tennessee	8114-001	TN	1.1	Section 3	43	13	25.96052	06-Apr-11	Leica	6156	N262AS	35.62014	-83.50861	35.79663	-83.09969
Tennessee	8114-001	TN	1.1	Section 3	43	14	25.88519	06-Apr-11	Leica	6156	N262AS	35.62513	-83.51045	35.80111	-83.1027

Tennessee	8114-001	TN	1.1	Section 3	43	15	25.80986	06-Apr-11	Leica	6156	N262AS	35.63011	-83.51229	35.80559	-83.10571
Tennessee	8114-001	TN	1.1	Section 3	43	16	25.5568	12-Mar-11	Leica	6156	N262AS	35.6351	-83.51412	35.80886	-83.11152
Tennessee	8114-001	TN	1.1	Section 3	43	17	25.16915	12-Mar-11	Leica	6156	N262AS	35.64008	-83.51596	35.81121	-83.11945
Tennessee	8114-001	TN	1.1	Section 3	43	18	24.78152	12-Mar-11	Leica	6156	N262AS	35.64507	-83.5178	35.81357	-83.12738
Tennessee	8114-001	TN	1.1	Section 3	43	19	24.50779	12-Mar-11	Leica	6156	N262AS	35.65005	-83.51964	35.8167	-83.13351
Tennessee	8114-001	TN	1.1	Section 3	43	20	24.43607	12-Mar-11	Leica	6156	N262AS	35.65504	-83.52148	35.82121	-83.13647
Tennessee	8114-001	TN	1.1	Section 3	43	21	24.36226	12-Mar-11	Leica	6156	N262AS	35.66003	-83.52332	35.8257	-83.13945
Tennessee	8114-001	TN	1.1	Section 3	43	22	24.1162	12-Mar-11	Leica	6156	N262AS	35.66501	-83.52515	35.82902	-83.14516
Tennessee	8114-001	TN	1.1	Section 3	43	23	23.8636	12-Mar-11	Leica	6156	N262AS	35.67	-83.52699	35.83229	-83.15096
Tennessee	8114-001	TN	1.1	Section 3	43	24	23.61102	19-Feb-11	Optech	240	N9471R	35.67498	-83.52883	35.83556	-83.15676
Tennessee	8114-001	TN	1.1	Section 3	43	25	23.35846	19-Feb-11	Optech	240	N9471R	35.67997	-83.53067	35.83884	-83.16257
Tennessee	8114-001	TN	1.1	Section 3	43	26	23.13039	19-Feb-11	Optech	240	N9471R	35.68495	-83.53251	35.84228	-83.16798
Tennessee	8114-001	TN	1.1	Section 3	43	27	22.94393	19-Feb-11	Optech	240	N9471R	35.68994	-83.53435	35.846	-83.17274
Tennessee	8114-001	TN	1.1	Section 3	43	28	22.75748	19-Feb-11	Optech	240	N9471R	35.69492	-83.53619	35.84972	-83.17751
Tennessee	8114-001	TN	1.1	Section 3	43	29	22.57104	12-Mar-11	Leica	6156	N262AS	35.69991	-83.53802	35.85345	-83.18227
Tennessee	8114-001	TN	1.1	Section 3	43	30	18.82804	12-Mar-11	Leica	6156	N262AS	35.7049	-83.53986	35.83296	-83.24313
Tennessee	8114-001	TN	1.1	Section 3	43	31	13.47188	12-Mar-11	Leica	6156	N262AS	35.70988	-83.5417	35.8015	-83.32941
Tennessee	8114-001	TN	1.1	Section 3	43	32	13.01756	12-Mar-11	Leica	6156	N262AS	35.71487	-83.54354	35.8034	-83.33841
Tennessee	8114-001	TN	1.1	Section 3	43	33	11.59898	12-Mar-11	Leica	6156	N262AS	35.71985	-83.54538	35.79874	-83.3626
Tennessee	8114-001	TN	1.1	Section 3	43	34	6.953102	12-Mar-11	Leica	6156	N262AS	35.72483	-83.54722	35.77212	-83.43767
Tennessee	8114-001	TN	1.1	Section 3	43	35	5.55394	12-Mar-11	Leica	6156	N262AS	35.72982	-83.54906	35.76759	-83.46155
Tennessee	8114-001	TN	1.1	Section 3	43	36	4.959345	12-Mar-11	Leica	6156	N262AS	35.73481	-83.5509	35.76853	-83.47276
Tennessee	8114-001	TN	1.1	Section 3	43	37	4.785205	12-Mar-11	Leica	6156	N262AS	35.73979	-83.55273	35.77234	-83.47733
Tennessee	8114-001	TN	1.1	Section 3	43	38	4.61108	12-Mar-11	Leica	6156	N262AS	35.74478	-83.55457	35.77614	-83.48191
Tennessee	8114-001	TN	1.1	Section 3	43	39	4.229509	12-Mar-11	Leica	6156	N262AS	35.74976	-83.55641	35.77853	-83.48976
Tennessee	8114-001	TN	1.1	Section 3	43	40	3.580295	12-Mar-11	Leica	6156	N262AS	35.75607	-83.55518	35.78042	-83.49876
Tennessee	8114-001	TN	1.1	Section 3	43	41	2.747989	12-Mar-11	Leica	6156	N262AS	35.76319	-83.55207	35.78188	-83.50877
Tennessee	8114-001	TN	1.1	Section 3	43	42	1.828806	12-Mar-11	Leica	6156	N262AS	35.77031	-83.54897	35.78275	-83.52014
Tennessee	8114-001	TN	1.1	Section 3	43	43	0.9096907	12-Mar-11	Leica	6156	N262AS	35.77744	-83.54585	35.78363	-83.53151

Attachment B: Vertical Accuracy Report

LiDAR Check Point Coordinates, Landcover Classes and Elevation Errors

Point	Easting	Northing	Known Z	LIDAR Z	Dz	Landcover Class
129	254175.74	3950826.48	339.72	339.59	-0.13	100/5-tow-01
130	254196.12	3950754.82	342.21	342.09	-0.12	100/5-tow-02
179	254175.74	3950826.53	339.70	339.59	-0.11	100check
135	269123.67	3953531.47	898.44	898.27	-0.17	107/B57
136	269154.48	3953559.64	894.48	894.46	-0.02	108/PP25
278	269154.52	3953559.65	894.49	894.46	-0.03	108/PP25
138	280302.41	3943502.91	1538.01	1538.15	0.14	110/PP33
298	254196.13	3950754.78	342.22	342.10	-0.12	5-tow-02
12	300272.38	3959279.14	666.99	666.84	-0.15	ASPHALT
13	300296.44	3959271.98	666.81	666.71	-0.10	ASPHALT
19	300329.55	3959248.81	666.89	666.72	-0.17	ASPHALT
20	300258.38	3959275.27	667.15	667.02	-0.13	ASPHALT
22	300288.05	3959215.64	672.16	672.02	-0.14	ASPHALT
24	300311.15	3959174.61	675.91	675.82	-0.09	ASPHALT
26	300343.91	3959169.72	675.45	675.32	-0.13	ASPHALT
28	300372.44	3959192.02	670.79	670.69	-0.10	ASPHALT
29	300302.65	3959260.50	666.66	666.52	-0.14	ASPHALT
30	300303.43	3959258.37	666.61	666.48	-0.13	ASPHALT
31	300304.95	3959255.05	666.50	666.39	-0.11	ASPHALT
32	300306.69	3959262.57	666.70	666.56	-0.14	ASPHALT
33	300309.65	3959259.77	666.68	666.58	-0.10	ASPHALT
34	300312.81	3959254.73	666.67	666.52	-0.15	ASPHALT
35	300313.40	3959262.82	666.61	666.51	-0.10	ASPHALT
36	300316.76	3959260.13	666.61	666.50	-0.11	ASPHALT
37	300321.43	3959259.95	666.56	666.44	-0.12	ASPHALT
38	300323.15	3959252.11	666.74	666.61	-0.13	ASPHALT
39	300323.87	3959246.49	666.82	666.69	-0.13	ASPHALT
40	300324.37	3959240.82	666.87	666.75	-0.12	ASPHALT
50	290312.60	3960050.39	526.61	526.99	0.38	ASPHALT
51	290318.96	3960059.93	526.63	527.01	0.38	ASPHALT
53	290330.16	3960059.86	527.22	527.59	0.37	ASPHALT
54	290349.35	3960058.72	527.91	528.25	0.34	ASPHALT
58	290351.77	3960047.40	528.77	529.13	0.36	ASPHALT
65	235019.72	3928693.35	519.20	519.37	0.17	ASPHALT

66	235004.36	3928704.55	520.47	520.64	0.17	ASPHALT
90	277395.89	3956528.96	459.41	459.41	0.00	ASPHALT
91	277414.67	3956570.71	459.67	459.69	0.02	ASPHALT
92	277455.98	3956532.83	459.94	459.95	0.01	ASPHALT
93	277463.69	3956560.89	460.04	460.05	0.01	ASPHALT
94	260730.33	3956322.00	446.27	446.20	-0.07	ASPHALT
95	277417.22	3956557.26	459.40	459.41	0.01	ASPHALT
96	260704.54	3956340.14	447.43	447.36	-0.07	ASPHALT
97	260684.09	3956342.62	447.82	447.75	-0.07	ASPHALT
98	260661.89	3956362.83	449.22	449.16	-0.06	ASPHALT
99	260677.96	3956183.94	436.69	436.62	-0.07	ASPHALT
100	260233.36	3955017.58	438.98	438.92	-0.06	ASPHALT
139	254191.84	3950754.48	341.47	341.34	-0.13	ASPHALT
141	254190.40	3950791.38	341.58	341.47	-0.11	ASPHALT
150	254247.69	3950856.91	347.49	347.38	-0.11	ASPHALT
152	254095.92	3950812.30	337.47	337.35	-0.12	ASPHALT
154	254040.86	3950806.14	338.23	338.11	-0.12	ASPHALT
156	254062.30	3950751.33	337.77	337.66	-0.11	ASPHALT
158	254062.29	3950751.49	337.76	337.65	-0.11	ASPHALT
160	254071.21	3950724.63	337.99	337.86	-0.13	ASPHALT
162	254092.03	3950677.30	338.24	338.10	-0.14	ASPHALT
224	242400.96	3942793.00	522.44	522.34	-0.10	ASPHALT
225	242400.07	3942820.04	522.68	522.58	-0.10	ASPHALT
226	242399.68	3942840.91	522.87	522.77	-0.10	ASPHALT
259	269171.92	3953564.23	894.18	894.13	-0.05	ASPHALT
260	269179.23	3953573.88	892.52	892.44	-0.08	ASPHALT
277	269126.38	3953542.67	896.55	896.49	-0.06	ASPHALT
279	280311.85	3943477.76	1537.10	1537.24	0.14	ASPHALT
280	280298.66	3943475.43	1537.33	1537.47	0.14	ASPHALT
281	280282.22	3943462.06	1537.53	1537.66	0.13	ASPHALT
282	280254.39	3943451.22	1538.04	1538.17	0.13	ASPHALT
284	280230.34	3943458.61	1539.66	1539.83	0.17	ASPHALT
285	280183.01	3943427.84	1540.11	1540.12	0.01	ASPHALT
286	280250.00	3943473.46	1539.23	1539.38	0.15	ASPHALT
291	280301.08	3943520.84	1538.43	1538.59	0.16	ASPHALT
293	280312.88	3943517.04	1538.02	1538.17	0.15	ASPHALT
294	280321.08	3943493.03	1537.01	1537.15	0.14	ASPHALT
295	280302.06	3943479.26	1537.30	1537.43	0.13	ASPHALT
297	280281.86	3943507.93	1538.59	1538.73	0.14	ASPHALT

5	300346.16	3959230.01	668.11	668.00	-0.11	ASPHALT IN TREES
101	277391.66	3956563.93	459.35	459.39	0.04	BARE EARTH
102	277430.74	3956571.75	459.93	459.92	-0.01	BARE EARTH
103	277367.45	3956559.03	459.34	459.37	0.03	BARE EARTH
104	277349.71	3956534.38	458.77	458.78	0.01	BARE EARTH
105	277369.97	3956539.51	458.92	458.94	0.02	BARE EARTH
106	277397.19	3956547.27	459.27	459.29	0.02	BARE EARTH
140	254157.18	3950759.85	337.97	337.83	-0.14	BARE EARTH
145	254195.77	3950880.32	341.41	341.31	-0.10	BARE EARTH
187	242483.65	3942833.26	522.02	521.92	-0.10	BARE EARTH
190	242519.05	3942789.80	521.76	521.69	-0.07	BARE EARTH
191	242503.69	3942773.74	521.74	521.65	-0.09	BARE EARTH
192	242509.80	3942747.50	521.62	521.56	-0.06	BARE EARTH
193	242516.36	3942726.05	521.79	521.71	-0.08	BARE EARTH
194	242512.46	3942708.75	521.66	521.57	-0.09	BARE EARTH
195	242489.33	3942692.18	521.65	521.59	-0.06	BARE EARTH
196	242480.33	3942681.95	521.72	521.67	-0.05	BARE EARTH
197	242457.23	3942680.58	521.70	521.61	-0.09	BARE EARTH
198	242438.82	3942682.09	521.64	521.54	-0.10	BARE EARTH
199	242415.03	3942686.40	521.64	521.59	-0.05	BARE EARTH
209	242277.92	3942827.30	523.10	523.06	-0.04	BARE EARTH
210	242272.99	3942838.19	523.46	523.36	-0.10	BARE EARTH
211	242273.94	3942852.27	524.11	524.10	-0.01	BARE EARTH
218	242414.53	3942876.76	523.32	523.26	-0.06	BARE EARTH
219	242444.67	3942878.07	523.71	523.63	-0.08	BARE EARTH
220	242488.54	3942884.28	525.20	525.09	-0.11	BARE EARTH
233	246822.15	3943933.42	552.87	552.66	-0.21	BARE EARTH
240	246798.32	3943978.89	555.57	555.42	-0.15	BARE EARTH
241	246798.33	3943978.90	555.57	555.42	-0.15	BARE EARTH
275	269113.50	3953536.07	896.57	896.58	0.01	BARE EARTH
276	269119.38	3953547.99	895.89	895.89	0.00	BARE EARTH
165	254165.12	3950658.21	337.31	337.25	-0.06	BARE EARTH GRASS
178	254138.29	3950795.11	337.67	337.56	-0.11	BARE EARTH GRASS
287	280279.39	3943481.34	1538.28	1538.48	0.20	BARE EARTH GRASS
288	280295.16	3943494.83	1538.12	1538.27	0.15	BARE EARTH GRASS
289	280373.31	3943510.78	1537.10	1537.25	0.15	BARE EARTH GRASS
292	280310.42	3943506.05	1537.99	1538.18	0.19	BARE EARTH GRASS
290	280388.32	3943519.87	1542.56	1542.65	0.09	BARE EARTH ON TOP OF WALL

46	290271.28	3960053.05	523.38	523.89	0.51	BRUSH
47	290271.96	3960060.15	523.63	524.08	0.45	BRUSH
48	290296.88	3960057.57	524.73	525.20	0.47	BRUSH
107	260745.07	3956175.82	433.74	433.78	0.04	BRUSH
108	260637.55	3956178.62	438.06	438.06	0.00	BRUSH
109	260614.78	3956182.30	439.70	439.68	-0.02	BRUSH
110	260648.29	3956187.65	437.65	437.69	0.04	BRUSH
111	260760.86	3956188.54	434.53	434.53	0.00	BRUSH
112	260218.51	3954990.33	438.65	438.60	-0.05	BRUSH
264	269175.68	3953540.90	891.22	891.18	-0.04	BRUSH
266	269152.27	3953537.40	893.88	893.82	-0.06	BRUSH
267	269159.78	3953544.80	894.43	894.40	-0.03	BRUSH
268	269140.28	3953534.73	896.12	896.08	-0.04	BRUSH
269	269135.55	3953525.48	896.32	896.22	-0.10	BRUSH
270	269126.64	3953520.02	896.78	896.73	-0.05	BRUSH
271	269112.21	3953512.19	895.80	895.78	-0.02	BRUSH
283	280244.85	3943456.03	1539.55	1539.49	-0.06	CONCRETE
PP12	284897.64	3930162.84	748.41	OUTSIDE	LIDAR	CORNER CONC TROUT RUN
PP37	250571.38	3925051.86	519.82	OUTSIDE	LIDAR	CORNER OF CONC BOAT RAMP
PP25	269154.48	3953559.64	894.48	894.46	-0.02	CORNER OF CONC PAD
PP34	282380.70	3956634.96	438.29	438.44	0.16	CORNER OF DRIVE
PP26	277413.90	3956553.37	459.35	459.36	0.01	CORNER STOP BAR
PP29	314442.55	3944526.46	1183.68	OUTSIDE	LIDAR	CRNR ASPH DR AT GRAVEL RD\NORTH BLOCKED BY HILL
PP38	268689.24	3924001.88	591.43	OUTSIDE	LIDAR	CRNR ASPHALT DR
PP13	246713.11	3943801.88	549.02	548.83	-0.19	CRNR OF PRKG STRIPE\MOVED FROM ORIG LOC
44	290292.55	3960039.32	525.67	526.04	0.37	EDGE OF PAVEMENT
57	290372.10	3960043.20	530.24	530.57	0.33	EDGE OF PAVEMENT
PP28	309718.30	3959627.71	475.53	475.55	0.02	EDGE OF PAVEMENT AT TANGENT POINT
PP11	294866.86	3939770.08	795.05	OUTSIDE	LIDAR	END OF FOG LINE AT BRIDGE
PP30	302275.87	3932341.92	1631.56	OUTSIDE	LIDAR	END OF YELLOW CL STRIPE
113	260716.60	3956228.23	438.95	439.04	0.09	FOREST
144	254211.82	3950876.46	342.86	342.76	-0.10	FOREST
147	254235.68	3950932.39	344.58	344.46	-0.12	FOREST
148	254210.40	3950949.74	343.36	343.09	-0.28	FOREST
149	254234.39	3950870.09	345.36	345.26	-0.10	FOREST

159	254098.55	3950879.72	336.71	336.50	-0.21	FOREST
164	254169.65	3950709.01	338.17	338.08	-0.09	FOREST
166	254199.97	3950648.67	338.35	338.45	0.10	FOREST
180	246846.67	3943972.72	556.85	556.70	-0.15	FOREST
181	246857.96	3943971.00	558.49	558.24	-0.25	FOREST
182	246868.88	3943972.52	560.55	560.24	-0.31	FOREST
183	246868.41	3943954.54	557.91	557.65	-0.26	FOREST
184	246843.55	3943996.69	559.35	559.22	-0.13	FOREST
201	242391.95	3942699.77	521.65	521.56	-0.09	FOREST
202	242377.40	3942720.59	521.86	521.73	-0.13	FOREST
203	242357.59	3942724.95	521.66	521.64	-0.02	FOREST
204	242344.13	3942729.49	521.57	521.52	-0.05	FOREST
205	242337.69	3942739.69	521.47	521.42	-0.05	FOREST
234	246846.46	3943939.95	553.16	553.05	-0.11	FOREST
235	246862.91	3943941.50	556.01	555.69	-0.32	FOREST
236	246868.74	3943952.90	557.79	557.57	-0.22	FOREST
237	246865.61	3943971.50	559.78	559.47	-0.31	FOREST
238	246857.70	3943969.81	558.40	558.09	-0.31	FOREST
239	246836.83	3943969.17	555.69	555.50	-0.19	FOREST
246	246664.02	3944004.38	553.12	553.01	-0.11	FOREST
247	246646.50	3944022.63	553.36	553.26	-0.10	FOREST
248	246616.98	3944030.34	557.69	557.86	0.17	FOREST
249	246604.29	3944019.25	565.96	565.93	-0.03	FOREST
250	246603.54	3944006.35	567.28	567.32	0.04	FOREST
251	246611.34	3943992.51	565.49	565.86	0.37	FOREST
252	246619.01	3943984.30	560.72	560.92	0.20	FOREST
253	246623.50	3943981.56	557.17	556.86	-0.31	FOREST
254	246633.90	3943982.22	552.15	551.97	-0.18	FOREST
255	246641.88	3943969.29	551.42	551.35	-0.07	FOREST
167	254207.30	3950644.27	342.77	342.79	0.02	FOREST ON SLOPE
168	254210.95	3950651.55	343.96	344.05	0.09	FOREST ON SLOPE
169	254213.95	3950642.72	347.47	347.48	0.01	FOREST ON SLOPE
170	254217.90	3950637.68	350.94	351.14	0.20	FOREST ON SLOPE
171	254203.06	3950643.77	340.13	340.16	0.03	FOREST ON SLOPE
21	300245.40	3959277.50	666.66	666.61	-0.05	FORESTED
23	300279.18	3959200.41	674.12	673.96	-0.16	FORESTED
25	300308.25	3959160.28	677.29	677.20	-0.09	FORESTED
60	290242.29	3960050.08	522.06	522.49	0.43	FORESTED
61	290249.43	3960052.87	522.37	522.85	0.48	FORESTED

68	234977.14	3928719.49	522.41	522.70	0.29	FORESTED
69	234963.49	3928728.64	524.83	525.04	0.21	FORESTED
70	234952.29	3928735.72	526.68	526.94	0.26	FORESTED
72	235012.06	3928735.99	528.29	528.59	0.30	FORESTED
73	235005.88	3928742.06	530.77	530.97	0.20	FORESTED
77	235062.81	3928791.38	520.88	520.80	-0.08	FORESTED
11	300269.88	3959270.34	667.64	667.59	-0.05	GRASS
45	290273.00	3960045.19	523.45	523.84	0.39	GRASS
49	290293.59	3960047.74	524.67	525.06	0.39	GRASS
52	290322.79	3960049.52	526.63	527.04	0.41	GRASS
56	290371.32	3960049.15	529.63	529.98	0.35	GRASS
59	290337.85	3960050.77	527.72	528.11	0.39	GRASS
67	234983.87	3928717.21	521.83	522.07	0.24	GRASS
71	234989.65	3928720.75	521.64	521.84	0.20	GRASS
114	260227.04	3954996.90	438.94	438.85	-0.09	GRASS
115	260727.85	3956182.48	435.05	435.02	-0.03	GRASS
116	277436.93	3956520.57	460.02	460.04	0.02	GRASS
117	277409.63	3956510.11	460.08	460.22	0.14	GRASS
118	260233.48	3955030.41	438.85	438.82	-0.03	GRASS
119	260785.89	3956216.25	437.94	437.92	-0.02	GRASS
120	277452.21	3956574.98	460.21	460.20	-0.01	GRASS
121	260666.48	3956176.69	436.40	436.34	-0.06	GRASS
122	260766.96	3956206.09	436.75	436.70	-0.05	GRASS
146	254187.59	3950884.12	340.93	340.83	-0.10	GRASS
296	280291.83	3943490.32	1538.02	1538.17	0.15	GRASS
55	290366.81	3960055.38	527.89	528.33	0.44	GRASS BY BLD
1	300346.30	3959271.92	662.59	662.53	-0.06	GRASS IN TREES
2	300356.16	3959253.67	665.09	665.09	0.00	GRASS IN TREES
3	300352.16	3959241.21	666.61	666.48	-0.13	GRASS IN TREES
6	300334.57	3959220.07	669.31	669.24	-0.07	GRASS IN TREES
7	300318.12	3959215.49	670.44	670.39	-0.05	GRASS IN TREES
8	300306.32	3959208.75	672.14	672.01	-0.13	GRASS IN TREES
9	300296.15	3959227.85	670.20	670.14	-0.06	GRASS IN TREES
10	300287.91	3959258.85	667.52	667.43	-0.09	GRASS IN TREES
14	300315.78	3959307.31	662.73	662.71	-0.02	GRASS IN TREES
16	300346.04	3959310.55	659.50	659.42	-0.08	GRASS IN TREES
17	300356.07	3959284.88	660.88	660.82	-0.06	GRASS IN TREES
18	300344.09	3959270.88	662.70	662.66	-0.04	GRASS IN TREES
27	300360.65	3959183.16	672.88	672.87	-0.01	GRASS IN TREES

15	300301.51	3959315.19	664.27	664.16	-0.11	GRASS IN TREES BY PAVILLION
123	260200.60	3954991.02	438.25	438.18	-0.07	GRAVEL
155	254149.79	3950881.41	339.27	339.17	-0.10	GRAVEL
157	254123.03	3950884.35	337.92	337.79	-0.13	GRAVEL
163	254108.40	3950844.49	337.18	337.04	-0.14	GRAVEL
172	254199.55	3950660.39	338.74	338.72	-0.02	GRAVEL
177	254152.89	3950782.14	337.87	337.82	-0.05	GRAVEL
258	269137.87	3953546.76	896.02	895.95	-0.07	GRAVEL
173	254203.77	3950704.22	341.15	341.11	-0.04	GRAVEL IN FOREST
PP15	278887.93	3926759.87	550.51	OUTSIDE	LIDAR	INSIDE INTRSX OF STRIPES
PP22	244878.11	3949461.37	614.09	613.94	-0.15	INTRSX OF DRIVE AT EP
PP21	235002.56	3947816.06	670.15	670.07	-0.08	INTRSX OF PVMNT CHG AT FOG LINE
PP33	280302.41	3943502.91	1538.10	1538.15	0.06	INTRSX OF SIDEWALKS
76	235051.74	3928790.34	520.50	520.68	0.18	LOW GRASS
78	235060.17	3928756.98	518.81	519.07	0.26	LOW GRASS
81	235064.74	3928581.63	512.29	512.55	0.26	LOW GRASS
82	235040.76	3928585.24	510.20	510.41	0.21	LOW GRASS
151	254185.30	3950888.50	340.73	340.62	-0.11	LOW GRASS
161	254102.18	3950857.45	337.16	337.03	-0.13	LOW GRASS
185	242408.15	3942842.99	522.72	522.64	-0.08	LOW GRASS
186	242430.08	3942849.37	522.75	522.67	-0.08	LOW GRASS
188	242519.44	3942827.73	521.87	521.82	-0.05	LOW GRASS
200	242406.33	3942685.72	521.65	521.54	-0.11	LOW GRASS
217	242412.51	3942894.59	524.40	524.33	-0.07	LOW GRASS
221	242500.63	3942872.55	524.66	524.58	-0.08	LOW GRASS
222	242479.70	3942850.62	522.58	522.52	-0.06	LOW GRASS
223	242446.91	3942833.80	522.17	522.09	-0.08	LOW GRASS
227	246713.67	3943812.89	549.47	549.29	-0.18	LOW GRASS
228	246733.30	3943833.42	550.24	550.09	-0.15	LOW GRASS
229	246746.35	3943852.32	551.59	551.41	-0.18	LOW GRASS
230	246745.80	3943870.27	551.78	551.68	-0.10	LOW GRASS
231	246747.10	3943892.10	550.68	550.58	-0.10	LOW GRASS
232	246770.39	3943909.41	552.31	552.14	-0.17	LOW GRASS
242	246769.60	3943985.14	555.67	555.56	-0.11	LOW GRASS
243	246738.02	3943994.70	555.55	555.33	-0.22	LOW GRASS
244	246709.47	3944001.52	555.15	555.01	-0.14	LOW GRASS
245	246678.01	3944001.94	553.26	553.10	-0.16	LOW GRASS
256	246678.85	3943952.52	551.99	551.84	-0.15	LOW GRASS

257	246699.71	3943941.32	552.49	552.37	-0.12	LOW GRASS
142	254187.49	3950829.08	340.38	340.23	-0.15	LOW TREES
143	254186.69	3950834.06	340.36	340.32	-0.04	LOW TREES
153	254159.32	3950884.34	339.54	339.43	-0.11	LOW TREES
261	269188.25	3953577.97	891.51	891.59	0.08	LOW TREES
262	269182.80	3953565.65	893.63	893.65	0.02	LOW TREES
265	269166.38	3953539.65	892.34	892.32	-0.02	LOW TREES
272	269105.72	3953506.93	894.63	894.66	0.03	LOW TREES
273	269103.42	3953512.51	894.69	894.65	-0.04	LOW TREES
274	269102.80	3953520.72	894.98	894.94	-0.04	LOW TREES
263	269181.19	3953551.78	892.64	892.54	-0.10	LOW TREES AND BRUSH
64	235038.55	3928678.27	517.04	517.25	0.21	NAIL
89	260712.69	3956335.61	447.08	447.01	-0.07	NAIL
131	246729.64	3943939.74	553.87	553.70	-0.17	NAIL 103
133	242406.31	3942817.90	522.46	522.38	-0.08	NAIL 105
134	242415.73	3943091.34	534.17	534.00	-0.17	NAIL 106
137	280342.68	3943532.71	1537.55	1537.65	0.10	NAIL 109
43	290328.77	3960046.72	526.92	527.31	0.39	NAIL PP27B
PP14	273762.11	3937631.88	1923.58	1923.66	0.09	NORTHERN CORNER OF HANDICAP SYMBOL
PP27	290309.95	3960065.12	526.71	527.02	0.32	NW CORNER OF PARKING LOT
74	235050.11	3928698.32	516.36	516.53	0.17	PAVEMENT
75	235060.34	3928742.56	518.21	518.41	0.20	PAVEMENT
79	235051.02	3928661.35	514.89	515.10	0.21	PAVEMENT
80	235060.06	3928620.88	513.77	513.97	0.20	PAVEMENT
132	246713.11	3943801.88	549.02	548.83	-0.19	PP13/104
88	235052.29	3928612.27	513.08	513.30	0.22	PP17
87	235038.45	3928675.20	517.27	517.44	0.17	PP17A
299	254200.99	3950833.27	341.40	341.32	-0.08	PP23 chk
62	290309.92	3960065.12	526.71	527.02	0.31	PP27
63	290362.19	3960047.78	529.21	529.56	0.35	PP27A
41	300295.29	3959270.40	666.82	666.70	-0.12	PP36A
42	300337.14	3959241.22	667.25	667.19	-0.06	PP36B
PP19	227313.67	3939025.73	271.04	270.97	-0.07	SE CORNER OF STOP BAR
PP35	308306.13	3944007.20	847.74	OUTSIDE	LIDAR	SE CORNER OF WOODEN BRIDGE
4	300348.43	3959236.34	667.65	667.61	-0.04	SIDEWALK IN TREES
PP23	254201.07	3950833.21	341.39	341.34	-0.05	SW CORNER OF GRASS MEDIAN
124	260714.20	3956313.95	448.36	448.33	-0.03	TALL GRASS

125	260701.70	3956322.29	448.36	448.39	0.03	TALL GRASS
126	277381.81	3956497.27	459.83	460.02	0.19	TALL GRASS
127	277472.29	3956539.40	460.25	460.35	0.10	TALL GRASS
128	260764.01	3956197.24	435.64	435.62	-0.02	TALL GRASS
189	242529.01	3942795.48	521.74	521.68	-0.06	TALL GRASS
206	242332.96	3942748.82	521.63	521.63	0.00	TALL GRASS
207	242326.25	3942767.86	521.80	521.83	0.03	TALL GRASS
208	242313.42	3942788.39	522.18	522.22	0.04	TALL GRASS
212	242286.31	3942858.96	524.14	524.21	0.07	TALL GRASS
213	242303.87	3942858.53	524.03	523.99	-0.04	TALL GRASS
214	242317.58	3942876.51	524.41	524.39	-0.02	TALL GRASS
215	242331.53	3942882.26	524.53	524.61	0.08	TALL GRASS
216	242359.79	3942889.09	524.25	524.25	0.00	TALL GRASS
PP17	235052.29	3928612.27	513.08	513.30	0.22	TIP OF LEFT TURN ARROW
83	235063.01	3928715.36	517.04	517.26	0.22	URBAN
84	235060.20	3928656.22	514.66	514.89	0.23	URBAN
85	235065.49	3928645.90	514.65	514.81	0.16	URBAN
86	235056.30	3928644.24	514.29	514.50	0.21	URBAN
176	254229.13	3950784.06	345.73	345.76	0.03	URBAN FOREST
175	254236.81	3950765.58	348.53	348.54	0.01	URBAN GRASS
174	254226.92	3950750.41	346.86	346.81	-0.05	URBAN GRAVEL
PP36	300304.62	3959264.77	666.69	666.58	-0.11	VERT PNT IN PARKING LOT\VERY HIGH TREES
PP31	256467.01	3947416.90	412.27	412.48	0.21	VERTICAL POINT IN FIELD
PP32	265860.47	3947515.13	737.37	737.46	0.09	VERTICAL POINT IN PASTURE

Attachment C: Metadata – Raw Point Cloud

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      <citeinfo>
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University of Georgia</origin>
        <pubdate>September 1, 2011</pubdate>
        <title>
          Acquisition of LiDAR for the Tennessee Portion of Great Smoky Mountains National Park (GRSM)
          and the Foothills Parkway ARRA LIDAR Task Order - GRSM Raw Flight Line Metadata; USGS
          Contract: G10AC0015;
          Proposal Number: NM-ARRA-0073
        </title>
        <geoform>model</geoform>
      </citeinfo>
    </citation>
  <descript>
    <abstract>
      Raster DEM files, Raw Las Files, and Classified Las Files
      LiDAR was collected at a 0.69 meter average post spacing (0.69m GSD) for approximately 540 square miles
      of NPS-managed lands in eastern Tennessee including the Tennessee half of Great Smoky Mountain
      National Park (GRSM) (373 mi2), the adjacent Foothills Parkway (167 mi2), and a 300-m buffer
      surrounding the GRSM/Foothills Parkway study area, as part of the American Recovery and Reinvestment
      Act (ARRA) of 2009. Data were acquired while no snow was on the ground. This project meets U.S.
      Geological Survey National Geospatial Program Base LiDAR Specification, Version 1.2.
      Data sets include Raw LAS files organized by flightline, Classified LAS files organized in 1500x1500m tiles,
      and raster DEM files at 1.5-m resolution in 1500x1500-m tiles. An associated project collected 0.30m
      resolution 4-band color orthophotos of the entire GRSM organized along the same tiling scheme.
    </abstract>
    <purpose>
      Airborne LiDAR collection missions are planned to meet project specifications and are flown under cloud-
      free conditions in order to collect LIDAR points (X,Y,Z) at an average of 1.0 meter point spacing or
      better(dependent on collection area.)
      This allows the user to create Intensity Images, Break Lines, and fully Classified LiDAR LAS files. Classified
      LAS files can then be used to create raster gridded bare earth digital elevation models (DEMs).
    </purpose>
  </descript>
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        <enddate>20110430</enddate>
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  </timeperd>
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</status>
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  </bounding>
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    <themekey>DEM</themekey>
    <themekey>Raster</themekey>
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    <themekey>remote sensing</themekey>
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    <placekey>Blount County</placekey>
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  </place>
</keywords>
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  None. However, users should be aware that temporal changes may have occurred since this data set was
  collected and that some parts of this data may no longer represent actual surface conditions. Users
  should not use this data for critical applications without a full awareness of it's limitations.
  Acknowledgement of the U.S. Geological Survey would be appreciated for products derived from these
  data.
</useconst>
<datacred>Photo Science, Inc. flew the LiDAR and processed the data.</datacred>
<native>
  MicroStation Version 8; TerraScan Version 11; Optech DASHMap 5.100; TerraModeler Version 11; GeoCue
  Version 7.0.34.5; ESRI ArcGIS 10.1; QT Modeler v 7.1.0; ALS Post Processor 2.70 Build #15; Global Mapper
  12; Windows XP Operating System
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</idinfo>
<dataqual>
  <attracc>
    <attraccr>The project specifications require LiDAR to be collected on 1.5 meter GSD

```

or better and vertical accuracy of 18.5 centimeters RMSE or better to support 2' contour generation when combined with breaklines. No breaklines were required for this project.

</attraccr>

</attracc>

<logic>Raw Flightlines were processed by Photo Science to meet both vertical and horizontal accuracy specifications.</logic>

<complete>Datasets contain complete coverage of tiles.</complete>

<posacc>

<vertacc>

<vertaccr>Raw Flightlines were processed by Photo Science to meet both vertical and horizontal accuracy specifications. Flightlines, when combined, cover the entire project area with overlap. The vertical unit of the data file is in decimal meters with 2-decimal point precision.</vertaccr>

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</posacc>

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<pubdate>2011</pubdate>

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<timeinfo>

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</srctime>

<srccitea>LiDAR</srccitea>

<srccntr>LiDAR points were used to produce the deliverables.</srccntr>

</srcinfo>

<procstep>

<procdesc>

Applanix software was used in the post processing of the airborne GPS and inertial data that is critical to the positioning and orientation of the sensor during all flights. POSPac MMS provides the smoothed best estimate of trajectory (SBET) that is necessary for Optech's post processor to develop the point cloud from the LiDAR missions. The point cloud is the mathematical three dimensional collection of all returns from all laser pulses as determined from the aerial mission. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above ground features are removed from the data set. The point cloud was manipulated within the Optech or Leica software; GeoCue, TerraScan, and TerraModeler software was used for the automated data classification, manual cleanup, and bare earth generation from

this data. Project specific macros were used to classify the ground and to remove the side overlap between parallel flight lines.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler.

Each tile is stored as 32-bit floating-point. ESRI Products were used to create the 1.5 meter resolution ERDAS Imagine (IMG) files.

Optech DASHMap software and Leica ALS Post Processor software were used to create the Raw LIDAR Flight Line strips.

```
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<denflat>298.257223563000030000</denflat>
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</horizsys>
</spref>
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University of Georgia</cntorg>
        <cntper>Thomas R. Jordan; Marguerite Madden</cntper>
      </cntorgp>
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Department of Geography
The University of Georgia</address>
        <city>Athens</city>
        <state>GA</state>
        <postal>30602</postal>
        <country>USA</country>
      </cntaddr>
      <cntvoice>706-542-2372;706-542-2379</cntvoice>
      <cntemail>tombob@uga.edu; mmadden@uga.edu</cntemail>
    </cntinfo>
    <cntinfo>
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        <cntper>Mark Meade</cntper>
      </cntorgp>
      <cntaddr>
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        <city>Lexington</city>
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      </cntaddr>
      <cntvoice>859-277-8700</cntvoice>
      <cntemail>mmeade@photoscience.com</cntemail>
    </cntinfo>
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Attachment D: Metadata – Tiled, Classified LiDAR Point Cloud

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      <citeinfo>
        <origin>Center for Remote Sensing and Mapping Science (CRMS), the Department of Geography at the
University of Georgia</origin>
        <pubdate>September 1, 2011</pubdate>
        <title>
          Acquisition of LiDAR for the Tennessee Portion of Great Smoky Mountains National Park and the Foothills
          Parkway; USGS Contract: G10AC0015; Proposal Number: NM-ARRA-0073
        </title>
        <geoform>model</geoform>
      </citeinfo>
    </citation>
    <descript>
      <abstract>
        Raster DEM files, Raw Las Files, and Classified Las Files
        LiDAR was collected at a 0.69 meter average post spacing (0.69m GSD) for approximately 540 square miles
        of NPS-managed lands in eastern Tennessee including the Tennessee half of Great Smoky Mountain
        National Park (GRSM) (373 mi2), the adjacent Foothills Parkway (167 mi2), and a 300-m buffer
        surrounding the GRSM/Foothills Parkway study area, as part of the American Recovery and Reinvestment
        Act (ARRA) of 2009. Data were acquired while no snow was on the ground. This project meets U.S.
        Geological Survey National Geospatial Program Base LiDAR Specification, Version 1.2.

        Data sets include Raw LAS files organized by flightline, Classified LAS files organized in 1500x1500m tiles,
        and raster DEM files at 1.5-m resolution in 1500x1500 m tiles. An associated project collected 0.30m
        resolution 4-band color orthophotos of the entire GRSM organized along the same tiling scheme.
      </abstract>
      <purpose>
        Airborne LiDAR collection missions are planned to meet project specifications and are flown under cloud-
        free conditions in order to collect LiDAR points (X,Y,Z) at an average of 1.0 meter point spacing or
        better(dependent on collection area.) This allows the user to create Intensity Images, Break Lines, and
        fully Classified LiDAR LAS files. Classified LAS files can then be used to create raster gridded bare earth
        digital elevation models (DEMs).
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    <themekey>Raster</themekey>
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    <themekey>remote sensing</themekey>
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  collected and that some parts of this data may no longer represent actual surface conditions. Users
  should not use this data for critical applications without a full awareness of it's limitations.
  Acknowledgement of the U.S. Geological Survey would be appreciated for products derived from these
  data.
</useconst>
<datacred>Photo Science, Inc. flew the LiDAR and processed the data.</datacred>
<native>
  MicroStation Version 8; TerraScan Version 11; Optech DASHMap 5.100; TerraModeler Version 11;
  GeoCue Version 7.0.34.5; ESRI ArcGIS 10.1; QT Modeler v 7.1.0; ALS Post Processor 2.70 Build #15; Global
  Mapper 12; Windows XP Operating System
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</idinfo>
<dataqual>
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    <attraccr>

```

The project specifications require LiDAR to be collected on 1.5 meter GSD or better and vertical accuracy of 18.5 centimeters RMSE or better to support 2' contour generation when combined with breaklines. No breaklines were required for this project.

</attraccr>

</attracc>

<logic>

Classified LAS files were tested by Photo Science for both vertical and horizontal accuracy. All data is seamless from one tile to the next, no gaps or no data areas.</logic>

<complete>Datasets contain complete coverage of tiles.</complete>

<posacc>

<vertacc>

<vertaccr>

Classified LAS files were tested by Photo Science for both vertical and horizontal accuracy. All data is seamless from one tile to the next, no gaps or no data areas. The vertical unit of the data file is in decimal feet with 2-decimal point precision.</vertaccr>

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<pubdate>2011</pubdate>

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<srctr>LiDAR points were used to produce the deliverables.</srctr>

</srcinfo>

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<procdesc>

Applanix software was used in the post processing of the airborne GPS and inertial data that is critical to the positioning and orientation of the sensor during all flights. POSpac MMS provides the smoothed best estimate of trajectory (SBET) that is necessary for Optech's post processor to develop the point cloud from the LiDAR missions. The point cloud is the mathematical three dimensional collection of all returns from all laser pulses as determined from the aerial mission. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above ground features are

removed from the data set. The point cloud was manipulated within the Optech or Leica software; GeoCue, TerraScan, and TerraModeler software was used for the automated data classification, manual cleanup, and bare earth generation from this data. Project specific macros were used to classify the ground and to remove the side overlap between parallel flight lines.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Each tile is stored as 32-bit floating-point. ESRI Products were used to create the 1.5 meter resolution ERDAS Imagine (IMG) files.

Optech DASHMap software and Leica ALS Post Processor software were used to create the Raw LIDAR Flight Line strips.

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</horizsys>
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</eainfo>
<metainfo>
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    <cntinfo>
      <cntorgp>
        <cntorg>Center for Remote Sensing and Mapping Science (CRMS), Department of Geography at the
University of Georgia</cntorg>
        <cntper>Thomas R. Jordan; Marguerite Madden</cntper>
      </cntorgp>
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          Department of Geography
          The University of Georgia</address>
        <city>Athens</city>
        <state>GA</state>
        <postal>30602</postal>
        <country>USA</country>
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    <cntinfo>
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        <cntper>Mark Meade</cntper>
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        <city>Lexington</city>
        <state>KY</state>
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        <country>USA</country>
      </cntaddr>
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      <cntemail>mmeade@photoscience.com</cntemail>
    </cntinfo>
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  <metstdv>FGDC-STD-001-1998</metstdv>
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Attachment E: Metadata – Raster DEM

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University of Georgia</origin>
        <pubdate>September 1, 2011</pubdate>
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          Acquisition of LiDAR for the Tennessee Portion of Great Smoky Mountains National Park (GRSM) and the
          Foothills Parkway ARRA LIDAR Task Order-GSM RasterDEM Metadata;
          USGS Contract: G10AC0015;
          Proposed Number: NM-ARRA-0073
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        Raster DEM files, Raw Las Files, and Classified Las Files
        LiDAR was collected at a 0.69 meter average post spacing (0.69m GSD) for approximately 540 square miles
        of NPS-managed lands in eastern Tennessee including the Tennessee half of Great Smoky Mountain
        National Park (GRSM) (373 mi2), the adjacent Foothills Parkway (167 mi2), and a 300-m buffer
        surrounding the GRSM/Foothills Parkway study area, as part of the American Recovery and Reinvestment
        Act (ARRA) of 2009. Data were acquired while no snow was on the ground. This project meets U.S.
        Geological Survey National Geospatial Program Base LiDAR Specification, Version 1.2.
        Data sets include Raw LAS files organized by flightline, Classified LAS files organized in 1500x1500m tiles,
        and raster DEM files at 1.5-m resolution in 1500x1500-m tiles. An associated project collected 0.30m
        resolution 4-band color orthophotos of the entire GRSM organized along the same tiling scheme.
      </abstract>
      <purpose>
        Airborne LiDAR collection missions are planned to meet project specifications and are flown under cloud-
        free conditions in order to collect LIDAR points (X,Y,Z) at an average of 1.0 meter point spacing or
        better(dependent on collection area.) This allows the user to create Intensity Images, Break Lines, and
        fully Classified LiDAR LAS files. Classified LAS files can then be used to create raster gridded bare earth
        digital elevation models (DEMs).
      </purpose>
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</keywords>
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  None. However, users should be aware that temporal changes may have occurred since this data set was
  collected and that some parts of this data may no longer represent actual surface conditions. Users
  should not use this data for critical applications without a full awareness of it's limitations.
  Acknowledgement of the U.S. Geological Survey would be appreciated for products derived from these
  data.
</useconst>
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  MicroStation Version 8; TerraScan Version 11; Optech DASHMap 5.100; TerraModeler Version 11; GeoCue
  Version 7.0.34.5; ESRI ArcGIS 10.1; QT Modeler v 7.1.0; ALS Post Processor 2.70 Build #15; Global Mapper
  12; Windows XP Operating System
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    <attraccr>

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The project specifications require LiDAR to be collected on 1.5 meter GSD or better and vertical accuracy of 18.5 centimeters RMSE or better to support 2' contour generation when combined with breaklines. No breaklines were required for this project.

```

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</attracc>
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    Deliverables were tested by Photo Science for both vertical and horizontal accuracy.
    All data is seamless from one tile to the next, no gaps or no data areas.</logic>
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<vertacc>
    <vertaccr>Deliverables were tested by Photo Science for both vertical and horizontal
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    The vertical unit of the data file is in decimal feet with 2-decimal point precision.</vertaccr>
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    Applanix software was used in the post processing of the airborne GPS and inertial data that is critical to
    the positioning and orientation of the sensor during all flights. POSpac MMS provides the smoothed best
    estimate of trajectory (SBET) that is necessary for Optech's post processor to develop the point cloud from
    the LiDAR missions. The point cloud is the mathematical three dimensional collection of all returns from
    all laser pulses as determined from the aerial mission. At this point this data is ready for analysis,
    classification, and filtering to generate a bare earth surface model in which the above ground features are
    removed from the data set.

```

The point cloud was manipulated within the Optech or Leica software; GeoCue, TerraScan, and TerraModeler software was used for the automated data classification, manual cleanup, and bare earth generation from this data. Project specific macros were used to classify the ground and to remove the side overlap between parallel flight lines.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Each tile is stored as 32-bit floating-point. ESRI Products were used to create the 1.5 meter resolution ERDAS Imagine (IMG) files.

Optech DASHMap software and Leica ALS Post Processor software were used to create the Raw LIDAR Flight Line strips.

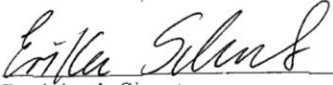
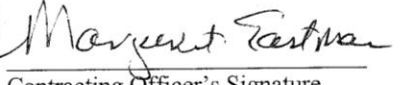
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Department of Geography
The University of Georgia</address>
        <city>Athens</city>
        <state>GA</state>
        <postal>30602</postal>
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      <cntemail>tombob@uga.edu; mmadden@uga.edu</cntemail>
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Attachment F: ARRA Assistance Award Contract

9-2092 OPS/OAFA (Rev 1/2000)		U.S. DEPARTMENT OF THE INTERIOR U.S. GEOLOGICAL SURVEY ARRA ASSISTANCE AWARD			
1	AWARD TYPE	2	AWARD NUMBER	3	REQUISITION NUMBER
	☐ Grant ☒ Cooperative Agreement		G10AC0015		10-RA03-CE28 Proposal No. NM-ARRA-0073 ATN: ARRA-NM0004W
4	RECIPIENT		5	ISSUED BY	
	Name & Address: University of Georgia 617 Boyd GSRC Athens, GA 30602 Erika Schwabe schwabe@uga.edu 706-542-5856 HHS PMS Subaccount Code: G10AC00115			Name & Address: U.S. Geological Survey Office of Acquisition & Grants 12201 Sunrise Valley Drive, MS 205 Reston, VA 20192 Margaret Eastman, Contracting Officer Phone: 703/648-7366 Fax: 703/648-7901 E-Mail: mrussell@usgs.gov	
6	APPLICATION TITLE & DATE				
	Acquisition of Lidar for the Tennessee Portion of Great Smoke Mountains National Park, dated December 1, 2009				
7	AWARD PERIODS		8	FISCAL DATA	
	Budget Period: Date of Award through 04/30/2011 Total Project Period: Date of Award through 04/30/2011 Effective Date: Date of Award			Federal Share: \$389,481.00 Non-Federal Share: \$117,757.00 Total Project Cost: \$507,238.00 Appropriation/Object Class: Obligated: 2009/2010-RA03-00M01 SARAD 411C \$389,481.00 DCN: G10AC00115	
9	PRINCIPAL INVESTIGATOR		10	USGS PROGRAM OFFICE	
	Dr. Marguerite Madden, Dr. Thomas Jordan Center for Remote Sensing and Mapping Science Dept. of Geography The University of Georgia Athens, GA 30602-2305 678-717-3594 mmadden@uga.edu tombob@uga.edu			Teresa Dean tdean@usgs.gov U.S. Geological Survey National Mapping Program 12201 Sunrise Valley Drive, MS511 Reston, VA 20192 (703) 648-4825	
11	ADMINISTRATIVE DATA		12	FAADS DATA	
	CFDA Number: 15.817 Program: National Map - ARRA Legislative Authority: 43 USC 36d and the American Recovery and Reinvestment Act of 2009			City Code: 03436 County Code: 059 State Code: 13 Congressional District: 010	
13	AUTHORIZED SIGNATURES				
	 Recipient's Signature Erika Schwabe Assistant Grants Officer TYPED NAME AND TITLE			 Contracting Officer's Signature Margaret Eastman, Contracting Officer TYPED NAME AND TITLE	
	Date: 2-1-2010			Date: 2-4-10	

Attachment G: Data Delivery Transmittal Letter

Center for Remote Sensing and Mapping Science (CRMS)

Marguerite Madden, Ph.D., Director
Thomas R. Jordan, Ph.D., Associate Director



September 13, 2011

Michael D. Jones
U. S. Geological Survey
1400 Independence Road, MS-702
Rolla, MO 65401

Dear Mr. Jones,

With reference to Contract # G10AC0015, please find enclosed a portable USB hard drive containing the deliverable products for the LiDAR Data Collection for the Tennessee portion of the Great Smoky Mountains National Park and Foothills Parkway. We are very pleased with the results and the overall vertical accuracy of 0.161m. Included on the hard drive are the following datasets and documents:

1. Raw LiDAR Point clouds in LAS format organized according to flight line
2. Classified LiDAR Point Clouds in LAS format organized in 1500x1500m tiles
3. Bare earth DEMS in ERDAS Imagine format, 1.5 m resolution, organized in 1500x1500m tiles
4. Metadata for each data type (one file for each RAW Lidar, Classified LAS Tiles, Bare Earth DEM)
5. Supporting documentation, including
 - a. Control points
 - b. Accuracy assessment
 - c. Study Area shapefiles
 - d. Tile layout index shapefile
 - e. LAS Analysis
 - f. Deliverable listing

Please feel free to contact me (tombob@uga.edu) or Marguerite Madden (mmadden@uga.edu) if you have any further questions.

Center for Remote Sensing and Mapping Science (CRMS)

Marguerite Madden, Ph.D., Director
Thomas R. Jordan, Ph.D., Associate Director



Thank you very much for this opportunity. It was a great project and many students received unsurpassed training in geospatial technologies as a result.

Sincerely,



Thomas R. Jordan, Ph.D.
Associate Director, CRMS
ASPRS Certified Photogrammetrist #1308
ASPRS Certified Mapping Scientist-GIS/LIS
#GS184



Marguerite Madden
Director, CRMS
Professor, Department of Geography
University of Georgia