U.S. Army Corps of Engineers – Tennessee LiDAR

Report Produced for U.S. Army Corps of Engineers

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Table of Contents

Executive Summary

The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (LiDAR) technology for portions of Western Tennessee. The U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) will use this data for tasks including conservation planning, design, research, floodplain mapping, dam safety assessments, and hydrologic modeling.

The LiDAR data were processed to a bare-earth digital terrain model (DTM). Detailed breaklines and bare-earth Digital Elevation Models (DEMs) were produced for the project area. Several LiDAR derived products, including intensity imagery, model key point LAS, first return LAS, last return LAS, and bare-earth LAS were produced for the project area. Data was formatted according to tiles with each tile covering an area of 1000 m by 1000 m. A total of 14, 822 tiles were produced for the project encompassing an area of approximately 14,395 sq. kilometers.

The LiDAR data, breaklines, bare-earth DEMs, and intensity imagery for this project were delivered in four separate deliveries. Delivery one (1) was shipped on December 29, 2011 and consisted of 331 tiles. Delivery two (2) was shipped on June 8, 2012 and consisted of 2,967 tiles. Delivery three (3) was shipped on July 16, 2012 and consisted of 5,023 tiles. Delivery four (4) was shipped on November 28, 2012 and contained the remaining 6,503 tiles. Please note that two tiles delivered in the first delivery were created to the original boundary. The project boundary changed to reflect the add-on area and these two tiles (16SBF8342 and 16SBF8442) have been processed to the final boundary and re-delivered as part of the fourth delivery.

While the data was delivered in four separate deliveries, all data were processed to the same specifications, accuracies, and methods to produce one seamless dataset. This project report describes all data for the entire Tennessee LiDAR project area.

THE PROJECT TEAM

Dewberry served as the prime contractor for the project. In addition to project management, Dewberry was responsible for LAS classification, all LiDAR products, breakline production, Digital Elevation Model (DEM) production, and quality assurance.

Dewberry's Gary Simpson completed ground surveying for the project and delivered surveyed checkpoints. His task was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the LiDAR-derived surface model. He also verified the GPS base station coordinates used during LiDAR data acquisition to ensure that the base station coordinates were accurate. Please see Appendix A to view the separate Survey Report that was created for this portion of the project.

Laser Mapping Specialist, Inc completed LiDAR data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the Tennessee counties of Lake, Obion, Weakley, Henry, Carroll, Gibson, Dyer, Lauderdale, Crockett, Haywood, Madison, Henderson, McNairy, and Chester. This project area also partially covers the Kentucky counties of Fulton, Hickman, Graves, and Calloway.

DATE OF LIDAR SURVEY

The LiDAR aerial acquisition was conducted from in two separate stages. The initial collect was conducted January 3, 2011 thru March 16, 2011 and the add-on area, or second area of collect, was conducted December 2, 2011 thru January 4, 2012. There was one re-flight that was conducted on June 13, 2012.

DATUM REFERENCE

Data produced for the project were delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 (NAD 83)

Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)

Coordinate System: UTM Zone 16

Units: Horizontal units are in meters, Vertical units are in meters.

Geiod Model: Geoid09 (Geoid 09 was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the USACE Tennessee LiDAR Project, the tested $RMSE_z$ of the classified LiDAR data for checkpoints in open terrain equaled **0.09 m** compared with the 0.0925 m specification; and the FVA of the classified LiDAR data computed using $RMSE_z$ x 1.9600 was equal to **0.18 m**, compared with the 0.18 m specification.

For the USACE Tennessee LiDAR Project, the tested CVA of the classified LiDAR data computed using the 95^{th} percentile was equal to **0.34 m,** compared with the 0.363 m target.

Additional accuracy information and statistics for the classified LiDAR data and raw swath data are found in the following sections of this report.

PROJECT DELIVERABLES

The deliverables for the project are listed below.

1. Classified Point Cloud Data (Tiled)
2. Bare Earth LiDAR Data (Tiled)
3. First Return LiDAR Data (Tiled)
4. Last Return LiDAR Data (Tiled)
5. Model Key Point LiDAR Data (Tiled)
6. Bare Earth Surface (Raster DEM – GRID Format)
7. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
8. Breakline Data (File GDB and Shapefiles)
9. Control & Accuracy Checkpoint Report & Points
10. Metadata
11. Project Report (Acquisition, Processing, QC)
12. Project Extents, Including a shapefile derived from the LiDAR Deliverable

PROJECT TILING FOOTPRINT

Fourteen thousand eight hundred twenty-two (14,822) tiles were delivered for the project. Each tile's extent is 1,000 meters by 1,000 meters (see Appendix B for a complete listing of delivered tiles). The project tile grid contains one extra tile (16SBF8549). A very small part of this tile intersects the project boundary. However, the geographic location of this tile is within a hydrographic feature and no LiDAR points were acquired within the tile. Thus, no data exists for this tile.

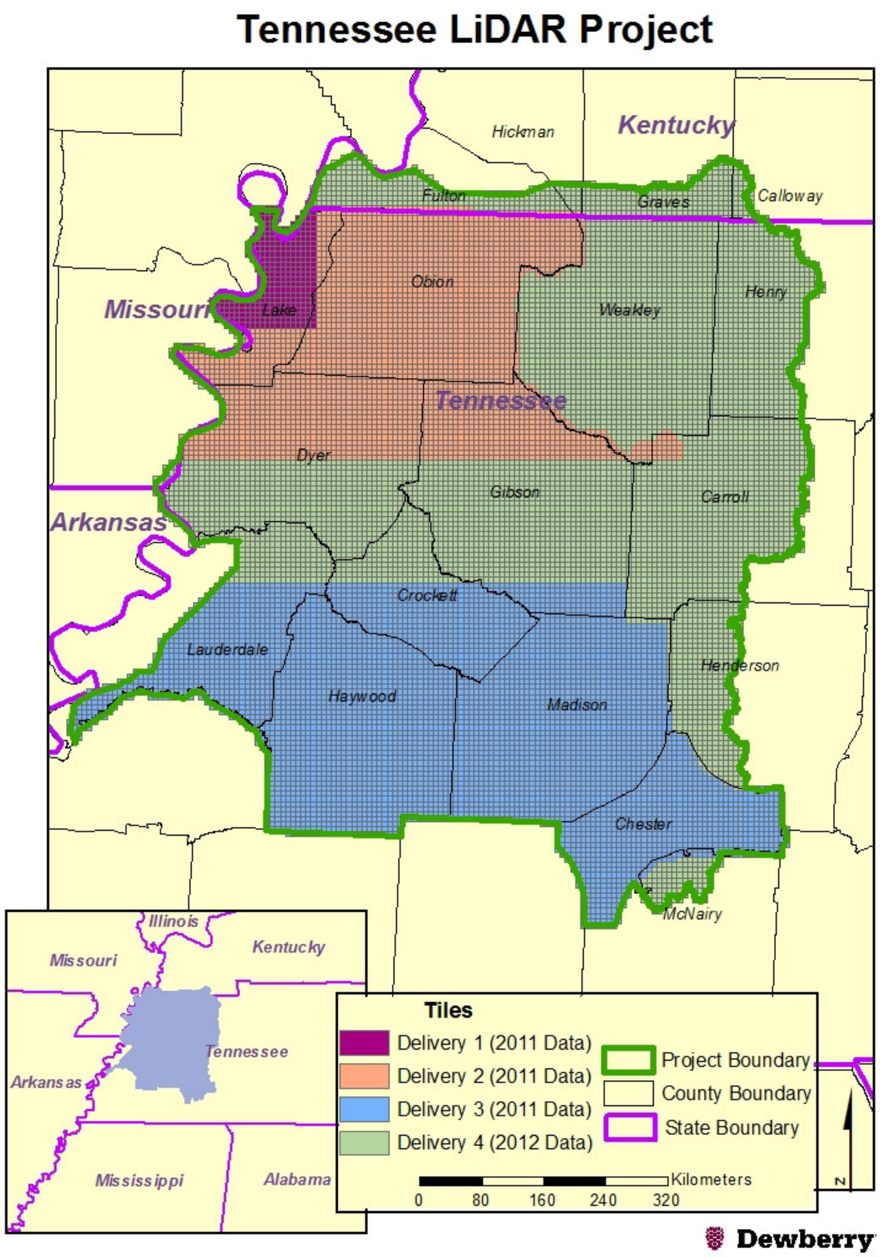


Figure 1 - Project Map

LiDAR Acquisition Report

LMSI provided high accuracy, calibrated multiple return LiDAR for roughly 14,395 square kilometers in Western Tennessee. Data was collected and delivered in compliance with the U.S. Geological Survey National Geospatial Program Base LiDAR Specifications, Version 13 – ILMF 2010 and FEMA Guidelines and Specifications for Flood Hazard Mapping, but project specific requirements supersede these guidelines and base specifications.

LIDAR ACQUISITION DETAILS

LIDAR acquisition for the Tennessee LiDAR project was completed in two stages. Acquisition for the initial task order began on January 3, 2011 and was completed on March 16, 2011. A total of 14 survey missions were flown to complete this area of the project. LiDAR acquisition for the add-on area of the Tennessee LiDAR project began on December 2, 2011 and was completed on January 4, 2012. A total of 29 survey missions were flown to complete the add-on area of the project. One re-flight was conducted on June 13, 2012. One survey mission was flown for this re-flight. For all survey missions, LMSI utilized an Optech ALTM3100EA for the acquisition. The flight plan was flown as planned with no modifications. There were no unusual occurrences during the acquisition and the sensor performed within specifications. There were 764 flight lines required to complete the project.

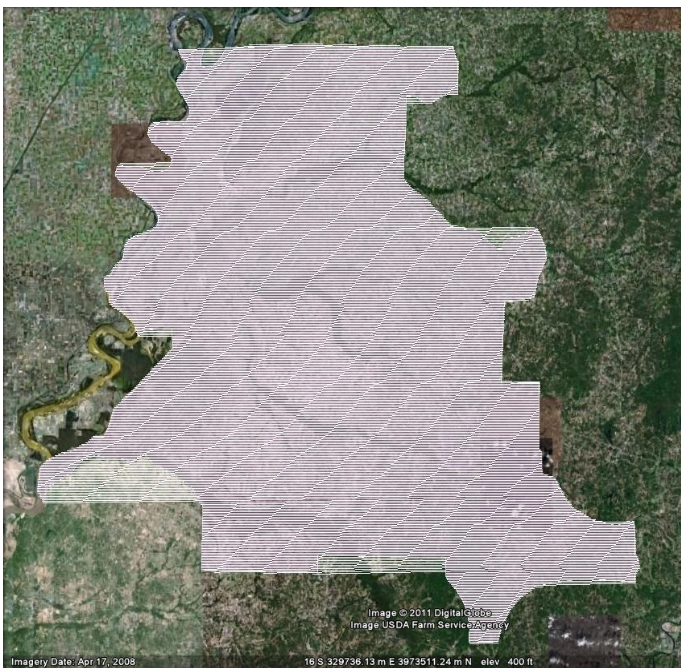


Figure 2 - Flight Layout for the initial collect area

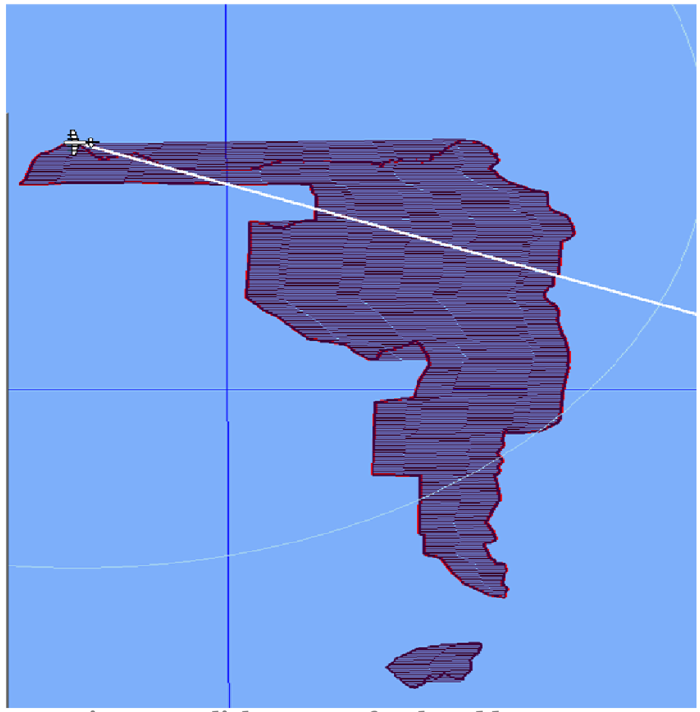


Figure 3 - Flight Layout for the add-on area

Laser Firing Rate: 70000
Altitude (mtr. AGL):1050
Swath Overlap (%): 50
Approx. Ground Speed (m/s): 77.2
Approx. Ground Speed (knots): 150
Scan Rate (Hz): 40
Scan Angle (°±): 21.5
Computed Along Track Spacing (mtr):0.965
Computed Cross Track Spacing (mtr): 0.945
Computed Swath Width (mtr): 743
Number of Lines Required: 764
Line Spacing (mtr): 361.54

LIDAR CONTROL

Seven existing NGS monuments and nine newly established base stations were used to control the LiDAR acquisition for the full Tennessee LiDAR project area. The coordinates of all used base stations are provided in the table below.

Name	Easting (m)	Northing (m)	Ellipsoid Ht (m)	Orthometric Ht (m)
E_MIDBA	364283.2068	4013695.1178	99.0790	127.3496
E_N_Base	322661.7378	4041480.1642	89.2047	117.2905
E_S_Base	358138.8853	3943017.0119	120.5380	148.6800
NE-Base	321799.245	4004728.178	66.846	95.100
NW-Base	277085.155	4013099.338	57.119	85.464
SE-Base	342507.455	3938330.008	112.902	141.126
SW-Base	275418.935	3948186.051	70.466	98.040
Mideast-Base	350043.1392	3988091.3502	83.7329	112.0315
Midwest-Base	294130.9230	3986069.8325	54.3586	82.5552

FE2747	335934.9935	3937739.0751	92.2562	120.4881
FE2748	296988.1182	3935296.1974	88.4935	116.3323
DF7942	367258.8151	4040593.2748	118.1898	146.5888
TN42	297714.8737	4001464.8858	95.5638	123.8688
TN44	326247.0999	3945762.5931	92.437	120.6349
DF7947	274354.743	3987588.238	51.867	80.10
GD1912	322076.246	4028129.628	66.985	95.23

Table 1 – Base Stations used to control LiDAR acquisition

AIRBORN GPS KINEMATIC

Airborne GPS data was processed using the GrafNav kinematic On-The-Fly (OTF) software suite. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 40km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3cm average or better but no larger than 10cm being recorded.

GPS processing statistics, charts, and graphs for each mission are provided in separate GPS processing reports, Appendix E and Appendix F. These reports are separate documents due to their size, but are delivered with this project report.

GENERATION AND CALIBRATION OF LASER POINTS (RAW DATA)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Optech's Dashmap, initially with default values from Optech or the last mission calibrated for the system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the LiDAR unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

BORESIGHT AND RELATIVE ACCURACY

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the LiDAR unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 7cm RMSEZ within individual swaths and <=10 cm RMSEZ or within swath overlap (between adjacent swaths).

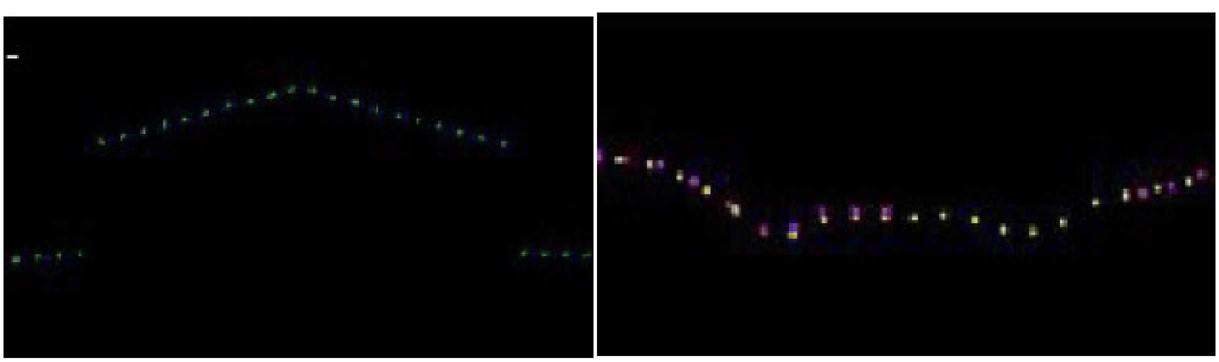


Figure 4 – Profile views showing correct roll and pitch adjustments.

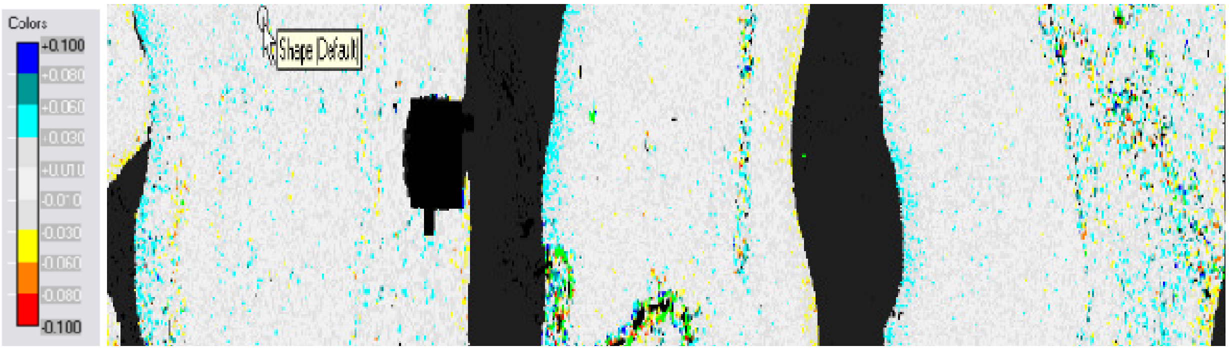


Figure 5 – QC block colored by distance to ensure accuracy at swath edges.

A different set of QC blocks are generated for final review after all transformations have been applied.

PRELIMINARY VERTICAL ACCURACY ASSESSMENT

A preliminary RMSEz error check is performed by LMSI at this stage of the project life cycle in the raw LiDAR dataset against GPS static and kinematic data and compared to RMSEz project specifications. The LiDAR data is examined in open, flat areas away from sharp elevation breaks. LiDAR ground points for each flight line generated by an automatic classification routine are used.

Results:
Prior to delivery to Dewberry the elevation data was verified internally by LMSI prior to delivery to ensure it met fundamental accuracy requirements (vertical accuracy NSSDA RMSEz = 9.25 cm (NSSDA AccuracyZ 95% = 18 cm) or better in open, non-vegetated terrain) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated Tennessee LiDAR dataset was tested to 0.039m vertical accuracy at 95% confidence level based on consolidated RMSEz (0.0198m x 1.9600) when compared to 19 GPS static check points.

The calibrated Tennessee LiDAR dataset was tested to 0.116m vertical accuracy at 95% confidence level based on consolidated RMSEz (0.059m x 1.9600) when compared to 12754 GPS kinematic checkpoints.

Overall the calibrated LiDAR data products collected by LMSI meet or exceed the requirements set out in the Statement of Work. The quality control requirements of LMSI's quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

FINAL SWATH VERTICAL ACCURACY ASSESSMENT

Once Dewberry received the calibrated swath data from LMSI, Dewberry tested the vertical accuracy of the open terrain swath data prior to additional processing. Dewberry tested the vertical accuracy of the swath data using the eighty-five open terrain independent survey check points. The vertical accuracy is tested by comparing survey checkpoints in open terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in open 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. Project specifications require a FVA of 0.18 m based on the RMSEz (0.0925 m) x 1.96. The dataset for the Tennessee LiDAR Project satisfies this criteria. The raw LiDAR swath data tested 0.18 m vertical accuracy at 95% confidence level in open terrain, based on RMSEz (0.09m) x 1.9600. The table below shows all calculated statistics for the raw swath data.

100 % of Totals	RMSE (m) Open Terrain Spec=0.0925 m	FVA – Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec=0.18 m	Mean (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Open Terrain	0.09	0.18	0.02	0.02	-0.13	0.09	85	-0.27	0.25

Table 2: FVA at 95% Confidence Level for Raw Swaths

LiDAR Processing & Qualitative Assessment

DATA CLASSIFICATION AND EDITING

LiDAR mass points were produced to LAS 1.2 specifications, including the following LAS classification codes:

- Class 1 = Unclassified, used for all other features that do not fit into the Classes 2, 7, 9, or 12, including vegetation, buildings, etc.
- Class 2 = Bare-Earth Ground
- Class 7 = Noise, low and high points
- Class 9 = Water, points located within collected breaklines
- Class 12 = Withheld, Points with scan angles exceeding +/- 20 degrees.

The data was processed using GeoCue and TerraScan software. The initial step is the setup of the GeoCue project, which is done by importing a project defined tile boundary index encompassing the entire project area. The acquired 3D laser point clouds, in LAS binary format, were imported into the GeoCue project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious outliers in the dataset to class 7 and points with scan angles exceeding +/- 20 degrees to class 12. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model.

This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

The following fields within the LAS files are populated to the following precision: GPS Time (0.000001 second precision), Easting (0.003 meter precision), Northing (0.003 meter precision), Elevation (0.003 meter precision), Intensity (integer value - 12 bit dynamic range), Number of Returns (integer - range of 1-4), Return number (integer range of 1-4), Scan Direction Flag (integer - range 0-1), Classification (integer), Scan Angle Rank (integer), Edge of flight line (integer, range 0-1), User bit field (integer - flight line information encoded). The LAS file also contains a Variable length record in the file header that defines the projection, datums, and units.

Once the initial ground routine has been performed on the data, Dewberry creates Delta Z (DZ) orthos to check the relative accuracy of the LiDAR data. These orthos compare the elevations of LiDAR points from overlapping flight lines on a 1 meter pixel cell size basis. If the elevations of points within each pixel are within 10 cm of each other, the pixel is colored green. If the elevations of points within each pixel are between 10 cm and 15 cm of each other, the pixel is colored yellow, and if the elevations of points within each pixel are greater than 15 cm in difference, the pixel is colored red. Pixels that do not contain points from overlapping flight lines are colored according to their intensity values. DZ orthos can be created using the full point cloud or ground only points and are used to review and verify the calibration of the data is acceptable. Some areas are expected to show sections or portions of red, including terrain variations, slope changes, and vegetated areas or buildings if the full point cloud is used. However, large or continuous sections of yellow or red pixels can indicate the data was not calibrated correctly or that there were issues during acquisition that could affect the usability of the data. Because data for the Tennessee LiDAR project area was collected during two separate time frames, Dewberry took extra care to ensure the add-on data matched the previously collected data within specifications. This was necessary to ensure a seamless data product. The add-on data was originally tied to control that was later identified to be erroneous. This resulted in very poor calibration between the add-on area (2012 collect) and the initial collect (2011 collect) and poor swath vertical accuracy of the 2012 data. The poor calibration between the 2011 and 2012 data collects is illustrated in Figure 6 below. LMSI re-calibrated the 2012 data by tying the data to the correct control. This re-calibration resulted in the 2011 and 2012 data edge-matching within relative accuracy specifications. The 2012 swath vertical accuracy also tested within project specifications. The DZ orthos for the final calibrated Tennessee LiDAR data are shown in Figure 7 below. All final Tennessee LiDAR data was calibrated correctly with no issues that would affect its usability.

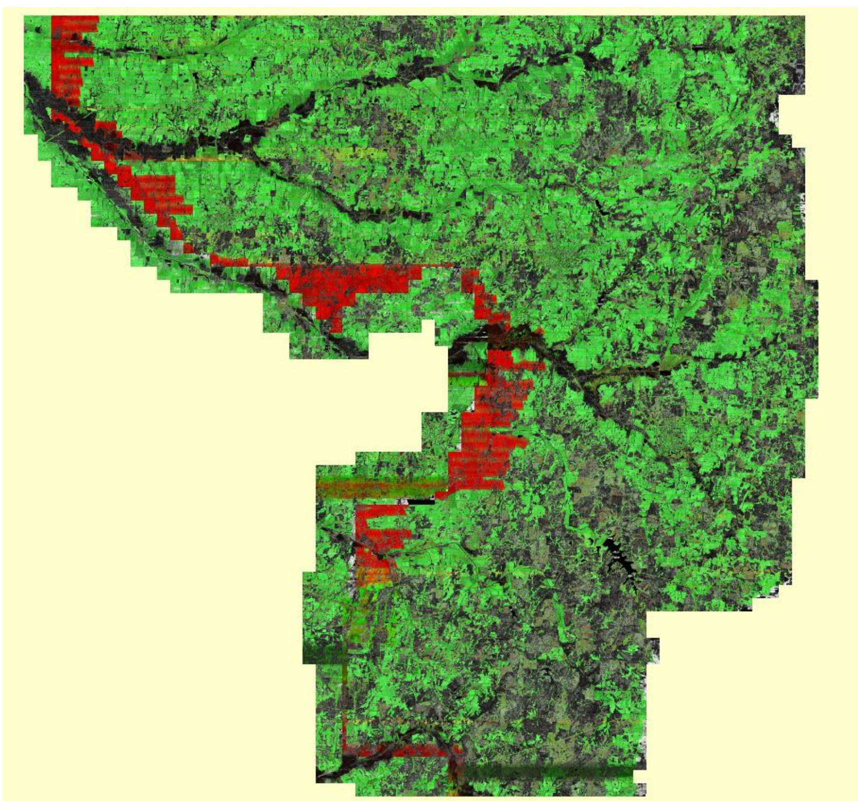


Figure 6 - DZ orthos created from the orginal full point cloud. Some red pixels are expected along embankments, sloped terrain, and in vegetated land cover. However, the red blocks following flight line patterns in areas where 2011 and 2012 data overlap were clear indications that the data were not calibrated properly and required corrections by the LiDAR provider.

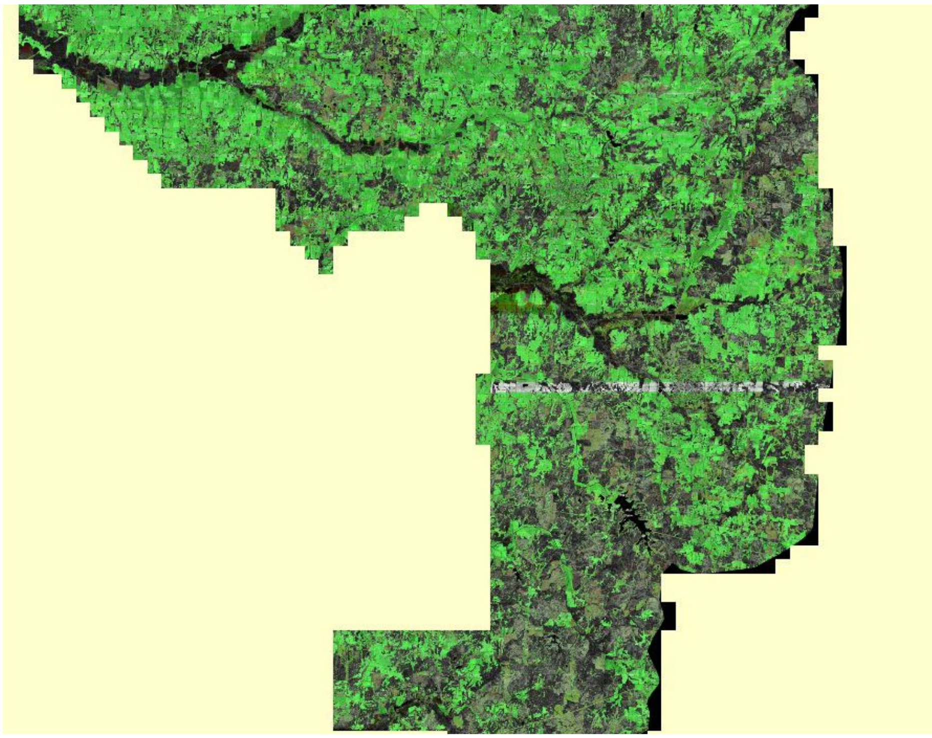


Figure 7 - DZ orthos created from the final full point cloud. All areas with overlapping 2011 and 2012 data are colored green, verifying that the relative accuracy of the 2011 and 2012 data are within specifications and that the calibration of the data is acceptable.

Dewberry utilized a variety of software suites for data processing. The LAS dataset was received and imported into GeoCue task management software for processing in Terrascan. Each tile was imported into Terrascan and a surface model was created to examine the ground classification. Dewberry analysts visually reviewed the ground surface model and corrected errors in the ground classification such as vegetation, buildings, and bridges that were present following the initial processing conducted by Dewberry. Dewberry analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points are removed from the ground classification. After the ground classification corrections were completed, the dataset was processed through a water classification routine that utilizes breaklines compiled by Dewberry to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water.

QUALITATIVE ASSESSMENT

Dewberry's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology to assess the quality of the data for a bare-earth digital terrain model (DTM). This process looks for anomalies in the data and also identifies areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model.

Within this review of the LiDAR data, two fundamental questions were addressed:

- Did the LiDAR system perform to specifications?
- Did the vegetation removal process yield desirable results for the intended bare-earth terrain product?

Mapping standards today address the quality of data by quantitative methods. If the data are tested and found to be within the desired accuracy standard, then the data set is typically accepted. Now with the proliferation of LiDAR, new issues arise due to the vast amount of data. Unlike photogrammetrically-derived DEMs where point spacing can be eight meters or more, LiDAR nominal point spacing for this project is 2 points per 1 square meter. The end result is that millions of elevation points are measured to a level of accuracy previously unseen for traditional elevation mapping technologies and vegetated areas are measured that would be nearly impossible to survey by other means. The downside is that with millions of points, the dataset is statistically bound to have some errors both in the measurement process and in the artifact removal process.

As previously stated, the quantitative analysis addresses the quality of the data based on absolute accuracy. This accuracy is directly tied to the comparison of the discreet measurement of the survey checkpoints and 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 with DZ orthos. Once the absolute and relative accuracy has been ascertained, the next stage is to address the cleanliness of the data for a bare-earth DTM.

By using survey checkpoints to compare the data, the absolute accuracy is verified, but this also allows us to understand if the artifact removal process was performed correctly. To reiterate the quantitative approach, if the LiDAR sensor operated correctly over open terrain areas, then it most likely operated correctly over the vegetated areas. This does not mean that the entire bare-earth was measured; only that the elevations surveyed are most likely accurate (including elevations of treetops, rooftops, etc.). In the event that the LiDAR pulse filtered through the vegetation and was able to measure the true surface (as well as measurements on the surrounding vegetation) then the level of accuracy of the vegetation removal process can be tested as a by-product.

To fully address the data for overall accuracy and quality, the level of cleanliness (or removal of above-ground artifacts) is paramount. Since there are currently no effective automated testing procedures to measure cleanliness, Dewberry employs a combination of statistical and visualization processes. This includes creating pseudo image products such as LiDAR orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models. By creating multiple images and using overlay techniques, not only can potential errors be found, but Dewberry can also find where the data meets and exceeds expectations. This report will present representative examples where the LiDAR and post processing had issues as well as examples of where the LiDAR performed well.

ANALYSIS

Dewberry utilizes GeoCue software as the primary geospatial process management system. GeoCue is a three tier, multi-user architecture that uses .NET technology from Microsoft. .NET technology provides the real-time notification system that updates users with real-time project status, regardless of who makes changes to project entities. GeoCue uses database technology for sorting project metadata. Dewberry uses Microsoft SQL Server as the database of choice. Specific analysis is conducted in Terrascan and QT Modeler environments.

Following the completion of LiDAR point classification, the Dewberry qualitative assessment process flow for the Tennessee LiDAR project incorporated the following reviews:

1. *Format:* The LAS files are verified to meet project specifications. The LAS files for the Tennessee LiDAR project conform to the specifications outlined below.

- Format, Echos, Intensity
  - LAS format 1.2
  - Point data record format 1
  - Multiple returns (echos) per pulse
  - Intensity values populated for each point
- ASPRS classification scheme
  - Class 1 – unclassified
  - Class 2 – Bare-earth ground
  - Class 7 – Noise

  - Class 9 – Water
  - Class 12 – Withheld due to scan angles exceeding +/- 20 degrees
- Projection
  - Datum – North American Datum 1983 (NSRS2007)
  - Projected Coordinate System – UTM Zone 16
  - Units – Meters
  - Vertical Datum – North American Vertical Datum 1988, Geoid 09
  - Vertical Units - Meters
- LAS header information:
  - Class (Integer)
  - GPS Week Time (0.0001 seconds)
  - Easting (0.003 meters)
  - Northing (0.003 meters)
  - Elevation (0.003 meters)
  - Echo Number (Integer 1 to 4)
  - Echo (Integer 1 to 4)
  - Intensity (8 bit integer)
  - Flight Line (Integer)
  - Scan Angle (Integer degree)

2. *Data density, data voids:* The LAS files are used to produce Digital Elevation Models using the commercial software package "QT Modeler" which creates a 3-dimensional data model derived from Class 2 (ground) points in the LAS files. Grid spacing is based on the project density deliverable requirement for un-obscured areas. For the Tennessee LiDAR project it is stipulated that the minimum post spacing in un-obscured areas should be 2 points per 1 square meter.

   a. Acceptable voids (areas with no LiDAR returns in the LAS files) that are present in the majority of LiDAR projects include voids caused by bodies of water. These are considered to be acceptable voids. No unacceptable voids are present in the Tennessee LiDAR project.

3. *Bare earth quality:* Dewberry reviewed the cleanliness of the bare earth to ensure the ground has correct definition, meets the project requirements, there is correct classification of points, and there are less than 5% residual artifacts.

   a. Artifacts: Artifacts are caused by the misclassification of ground points and usually represent vegetation and/or man-made structures. The artifacts identified are usually low lying structures, such as porches or low vegetation used as landscaping in neighborhoods and other developed areas. These low lying features are extremely difficult for the automated algorithms to detect as non-ground and must be removed manually. The vast majority of these features have been removed but a small number of these features are still in the ground classification. The limited numbers of features remaining in the ground are usually 0.3 meters or less above the actual ground surface, and should not negatively impact the usability of the dataset.

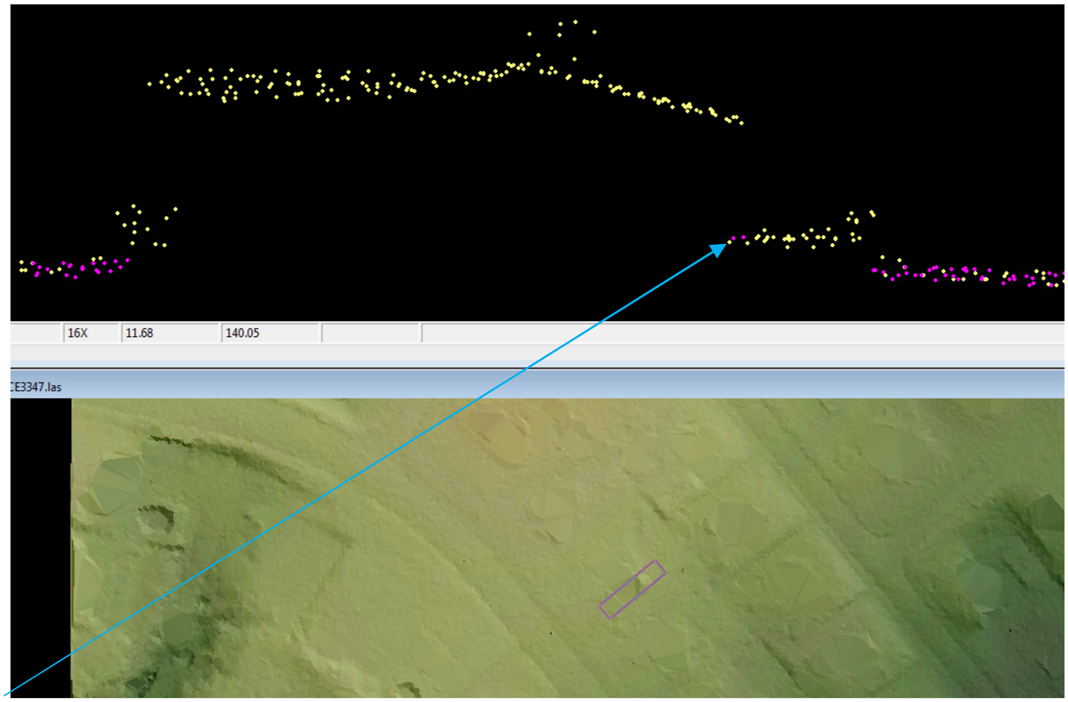


Figure 8 – Tile number 16SCE3347. Profile with points colored by class (class 1=yellow, class 2=pink) is shown in the top view and a TIN of the surface is shown in the bottom view. The arrow identifies points representing a low porch structure. A limited number of these small features are still classified as ground but do not impact the usability of the dataset.

b. *Bridge Removal Artifacts:* The DEM surface models are created from TINs or Terrains. TIN and Terrain models create continuous surfaces from the inputs. Because a continuous surface is being created, the TIN or Terrain will use interpolation to triangulate across a bridge opening from legitimate ground points on either side of the actual bridge. This can cause visual artifacts or "saddles." These "artifacts" are only visual and do not exist in the LiDAR points or breaklines.

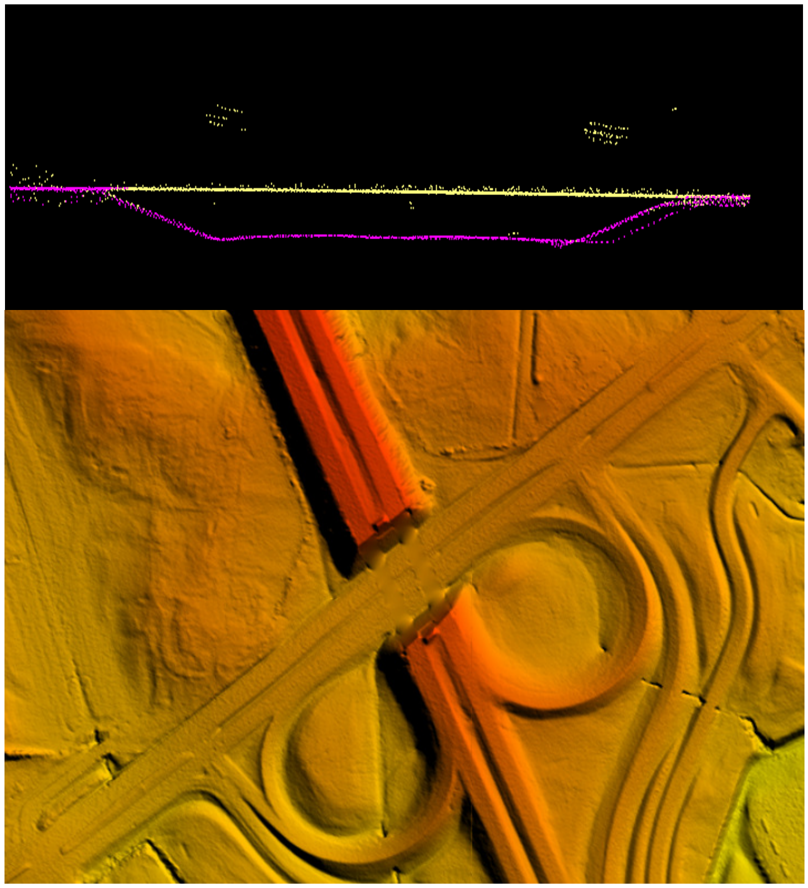


Figure 9 – Tile number 16SBE8893. The DEM in the bottom view shows a visual artifact because the surface model is interpolated from ground points on the slope leading to the bridge to the lower ground points on either side of the bridge. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This can cause visual artifacts when there are features with large elevation differences. The profile in the top view shows the LiDAR points of this particular feature colored by class. All bridge points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

c. *Culverts and Bridges:* Bridges have been removed from the bare earth surface while culverts remain in the bare earth surface. In instances where it is difficult to determine if the feature is a culvert or bridge, such as with some small bridges, Dewberry erred on assuming they would be culverts, especially if they are on secondary or tertiary roads. Below is an example of a culvert that has been left in the ground surface.

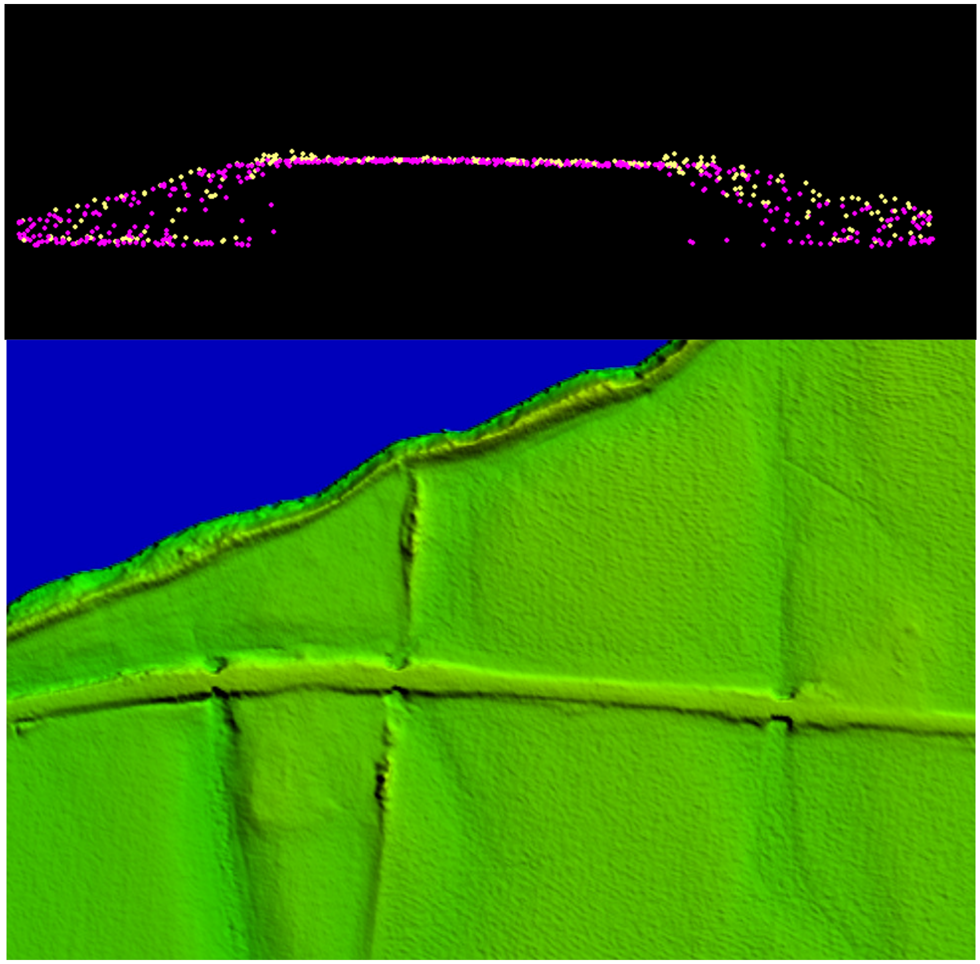


Figure 10– Tile number 16SBE6578. Profile with points colored by class (class 1=yellow, class 2=pink) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 1.

d. *Spoil Mounds*: Irregularities in the natural ground exist and may be misinterpreted as artifacts that should be removed. Small hills and dirt mounds are present throughout the project area, especially along irrigation canals. These features are correctly included in the ground.

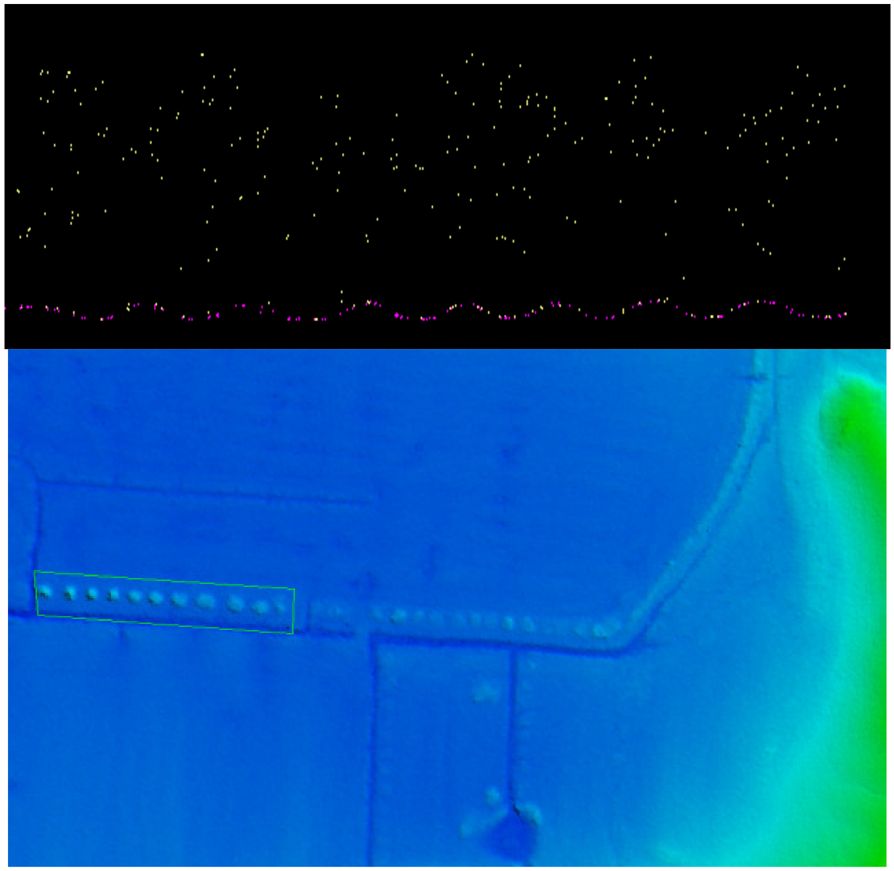


Figure 11 - Tile 16SCF2836. Profile with the points colored by class (class 1=yellow, class 2=pink) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

e. *Elevation Change Within Breaklines:* While water bodies are flattened in the final DEMs, other features such as linear hydrographic features can have significant changes in elevation within a small distance. In linear hydrographic features, this is often due to the presence of a structure that affects flow such as a dam or spillway. Dewberry has reviewed the DEMs to ensure that changes in elevation are shown from bank to bank. These changes are often shown as steps to reduce the presence of artifacts while ensuring consistent downhill flow. An example is shown below.

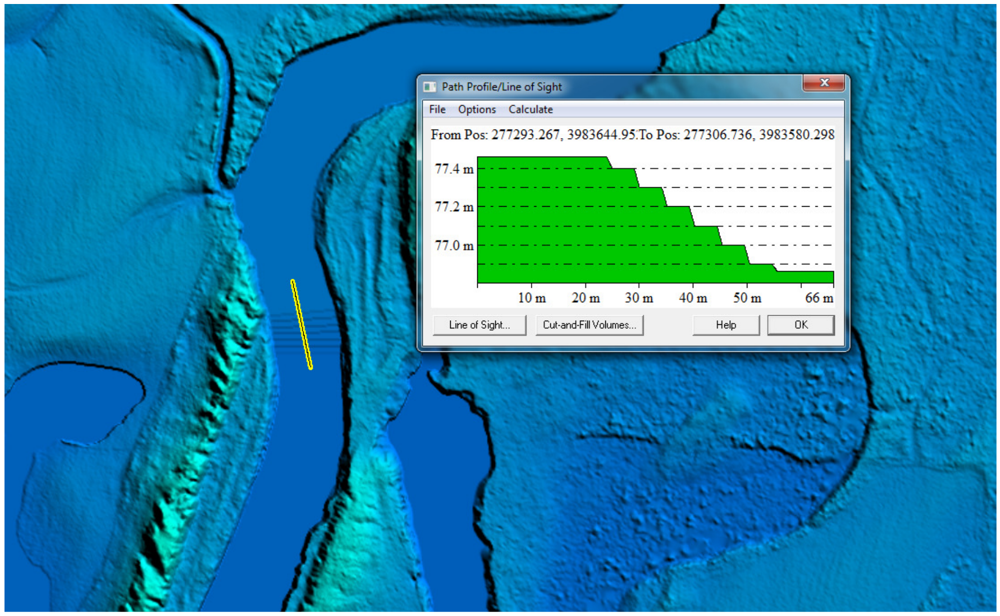


Figure 12 – Tile number 16SBE7783. Elevation change has been stair stepped. The steps are flat from bank to bank and flow consistently downhill.

f. *Marsh Areas*: It is sometimes difficult to determine true ground in low wet areas; the lowest points available are used to represent ground. Marsh areas are present within the project area and were not collected with breaklines as they are not open bodies of water. As these areas are not included in the collected breaklines, marsh areas were not flattened in the final DEMs. While low points are used to determine ground in marsh areas, there is often greater variation within the low points due to wet soils that cause greater interpolation between points, and undulating or uneven ground. An example is shown below.

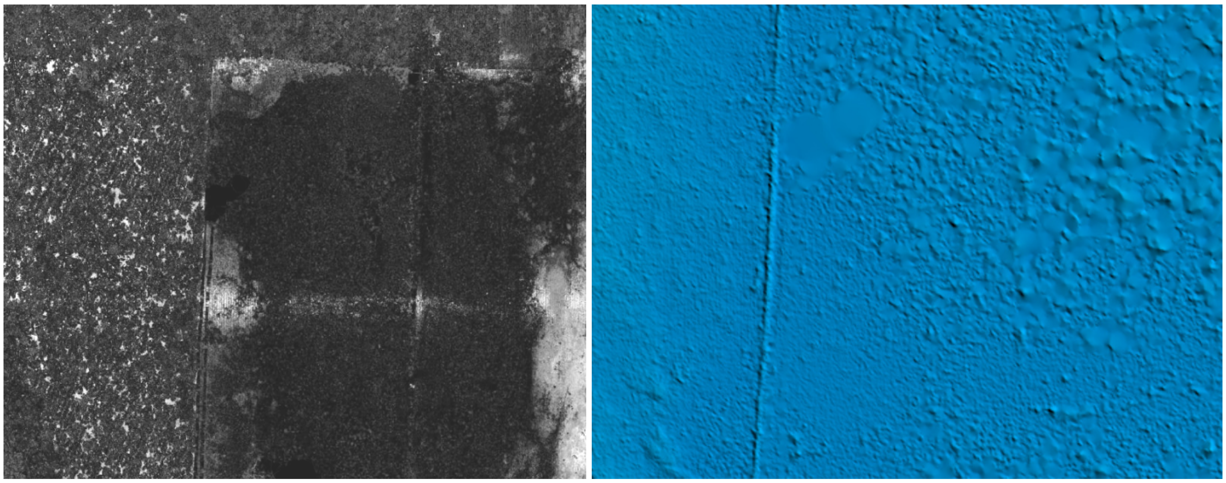


Figure 13 - Tiles 16SBE6390. The intensity on the left shows a marsh area that was not included in the collected breaklines. The same area is shown in the DEM on the right. Due to wet soils and broken terrain, the point density in marsh areas is sparser than surrounding areas and there is more variation in the low points representing ground.

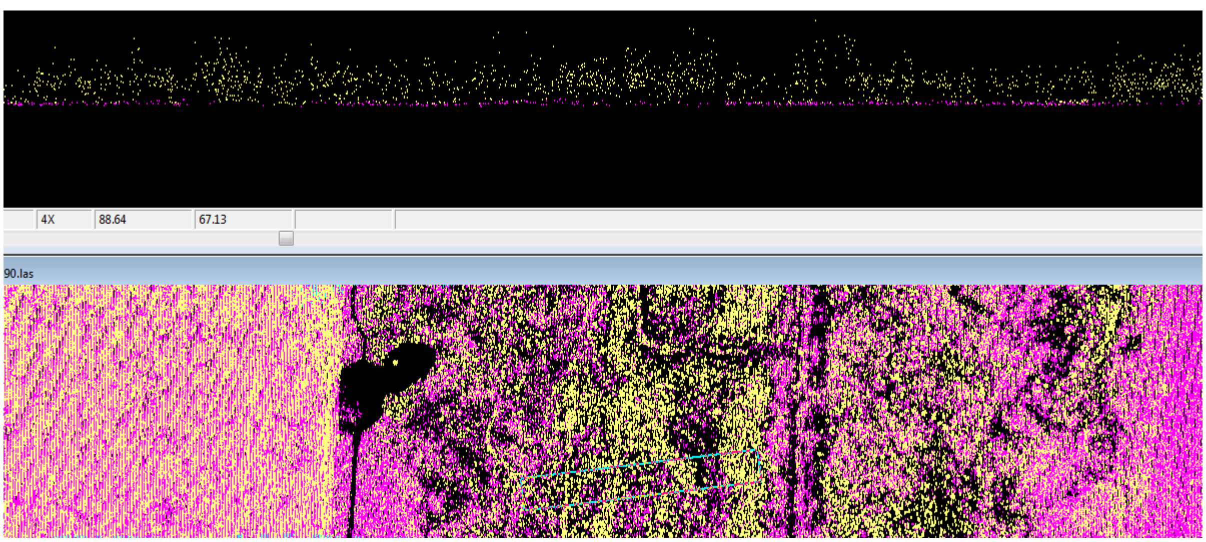


Figure 14 – Tile 16SBE6390. The same marsh area shown in the figure above is shown in this image with the points colored by class (class 1=yellow, class 2=pink). Though ground points are sparse they are present, indicating that the area is wet but should not be classified as water (class 9). Doing so would strip the detail from this area and result in incorrectly flattening ground as part of the hydro mask.

g. *Flight line Ridges:* Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths. Some flight line ridges are visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of a visible ridge that is within tolerance is shown below.

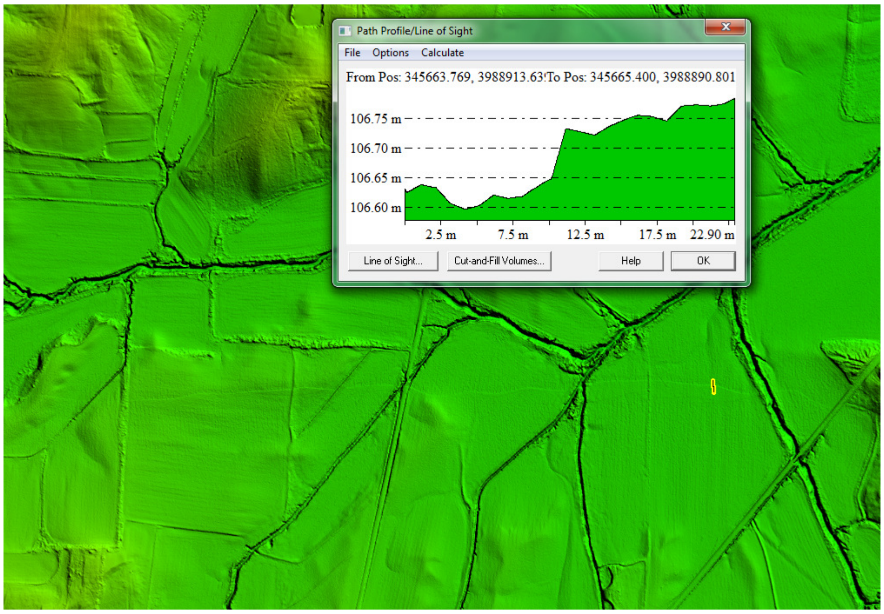


Figure 15– Tile number 16SCE4588. The flight line ridge is less than 8 cm. Overall, the LiDAR data meets the project specifications for 10 cm RMSE relative accuracy.

h. *Flight line Ridges along Tile Boundaries:* Because the Tennessee LiDAR project was acquired with two separate acquisition windows, there are some tiles that were completely created from the original 2011 collect and some tiles that were completely created from the add-on 2012 collect. In some areas along the boundary between the tiles created from different collects, there is a flight line ridge that follows the tile edge. While flight line ridges do not normally follow tile edges, some do in this instance because swaths were artificially clipped along tile boundaries where the data had to transfer from the 2011 collect to the 2012 collect. These ridges are within the project specifications for relative accuracy. These ridges do not represent edge-matching or seaming issues because there is no disconnect in terrain features or surface continuity and the ridges can be fully traced back to the original swaths used to create the final tiles. An example is shown below.

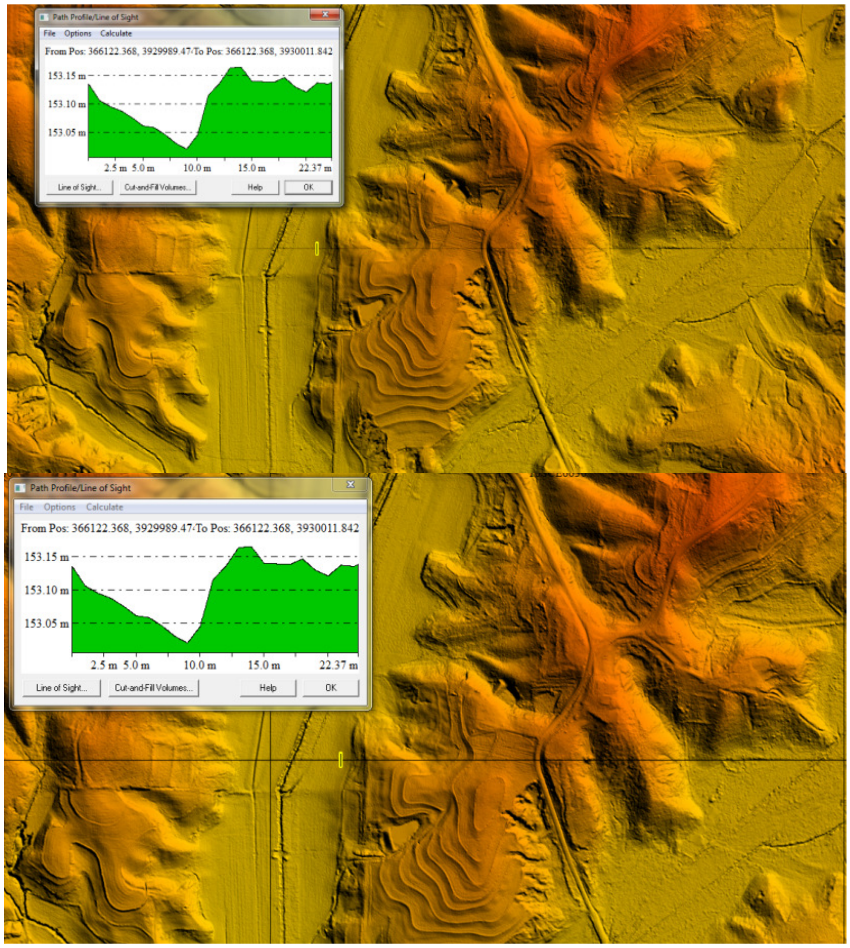


Figure 16-Tile numbers 16SCE6629 and 16SCE6630. The top image shows a flight line ridge without the tile grid overlaid. The bottom image shows the same area, but the tile grid (black outline) has been overlaid. The flight line ridge follows the tile boundary in some areas where tiles created solely from the original 2011 collect are adjacent to tiles created solely from the add-on 2012 collect. This flight line ridge is less than 10 cm. Overall, the LiDAR data meets the project specifications for 10 cm RMSE relative accuracy.

i. *Temporal Changes:* Because the Tennessee LiDAR project was collected during two different acquisition windows, there are some temporal differences between the areas collected at different times. The majority of temporal differences are found along water or hydrographic features, but some changes were noted on terrestrial features as well. The most common temporal changes was along hydrographic features, most notably the Mississippi River, where adjoining flight lines were from different collects and each flight line was flown at a different tide stage. While the Mississippi River is an inland river, it experiences large fluctuations in water surface elevations. To show continuous downhill flow, there were some portions of the river that while collected at a high tide stage, were arbitrarily lowered in the breaklines and final DEM. There was considerably more standing water in some areas of the add-on 2012 collect, which resulted in some farm fields and marsh areas being flooded. These flooded marsh areas have a higher ground surface compared to the drier areas and this difference is visible where a flooded marsh area edge-matches to a drier marsh area. Terrestrial temporal changes include construction and active changes to the landscape that occurred between the original 2011 collect and the add-on 2012 collect, such as building new irrigation canals or new ramps on a highway construction project. Several examples are provided below. A point shapefile, named "Temporal_Changes_AOI," has been delivered with the project data. This shapefile identifies locations where temporal changes occur.

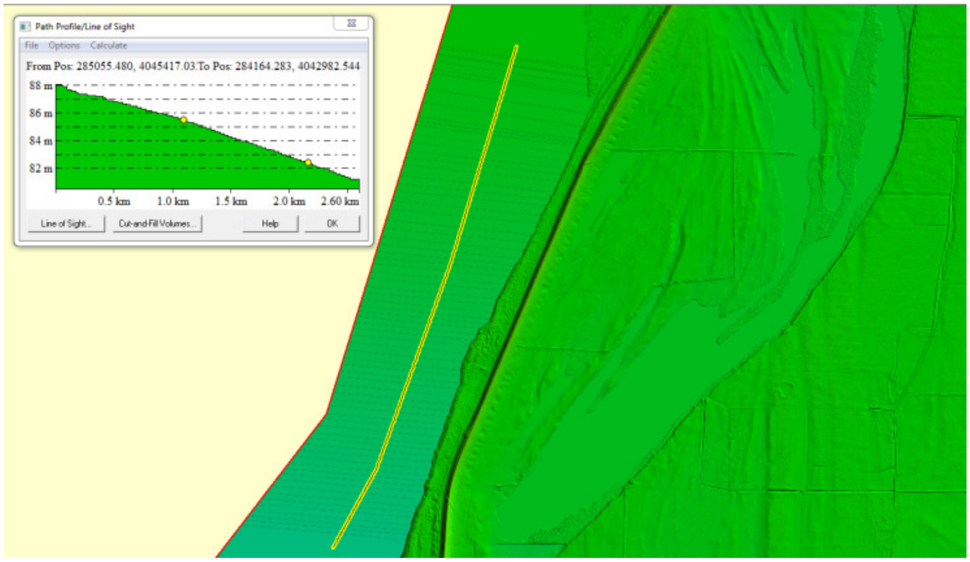


Figure 17-Tile numbers 16SBF8444, 16SBF8343, and 16SBF8443. In areas where flight lines were acquired at higher tide levels then surrounding flight lines, breaklines and the subsequent DEMs were artificially lowered through the "high" spots to ensure consistent downhill flow. The image above shows stair steps that were used to lower one flight line to match the adjacent, lower flight line to the south. Stair steps ensure consistent downhill flow, and that elevations are flat bank to bank.

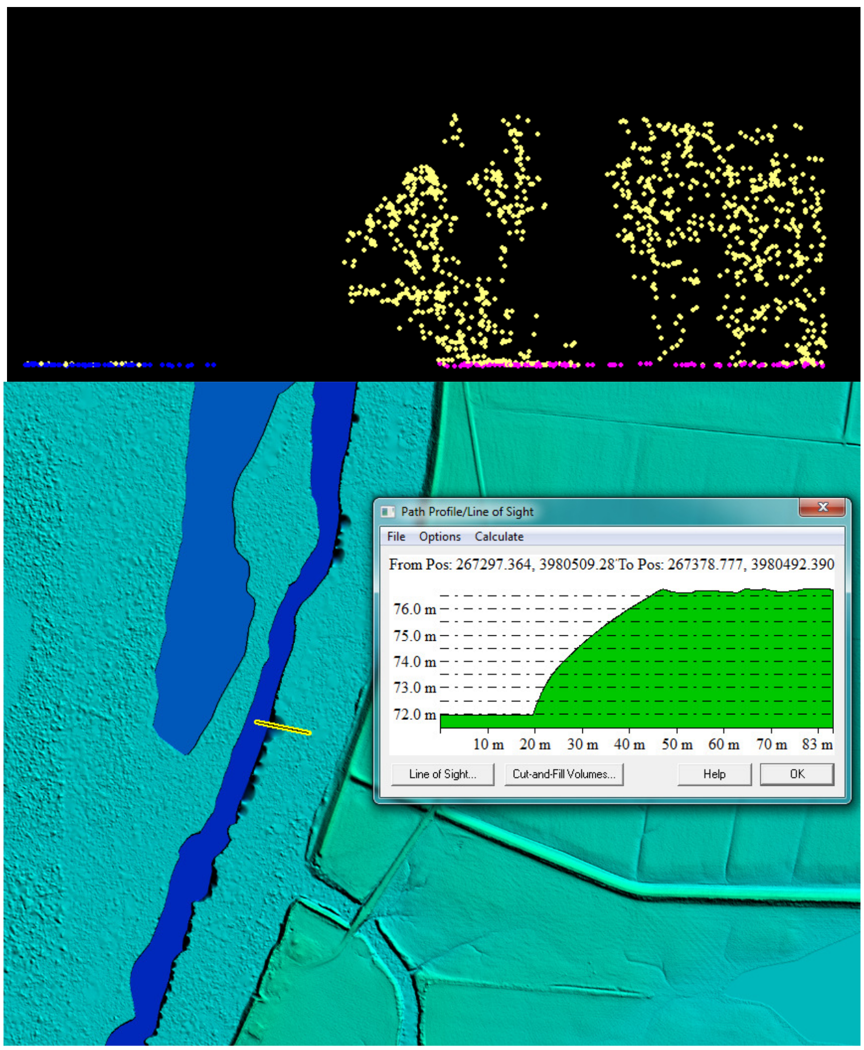


Figure 18-Tile number 16SBE6780. The profile on top shows points by class (water=blue, ground=pink, unclassified=yellow) and the DEM is shown on the bottom. Some interpolation artifacts occur along hydrographic features that have been lowered to show downhill flow through "high" flight lines and where there are large distances between water and ground points. The large linear distance combined with the steep elevation change is difficult for the surface model to interpolate and results in these visual artifacts. These artifacts are isolated along one or two small hydrographic features and do not occur throughout the dataset.

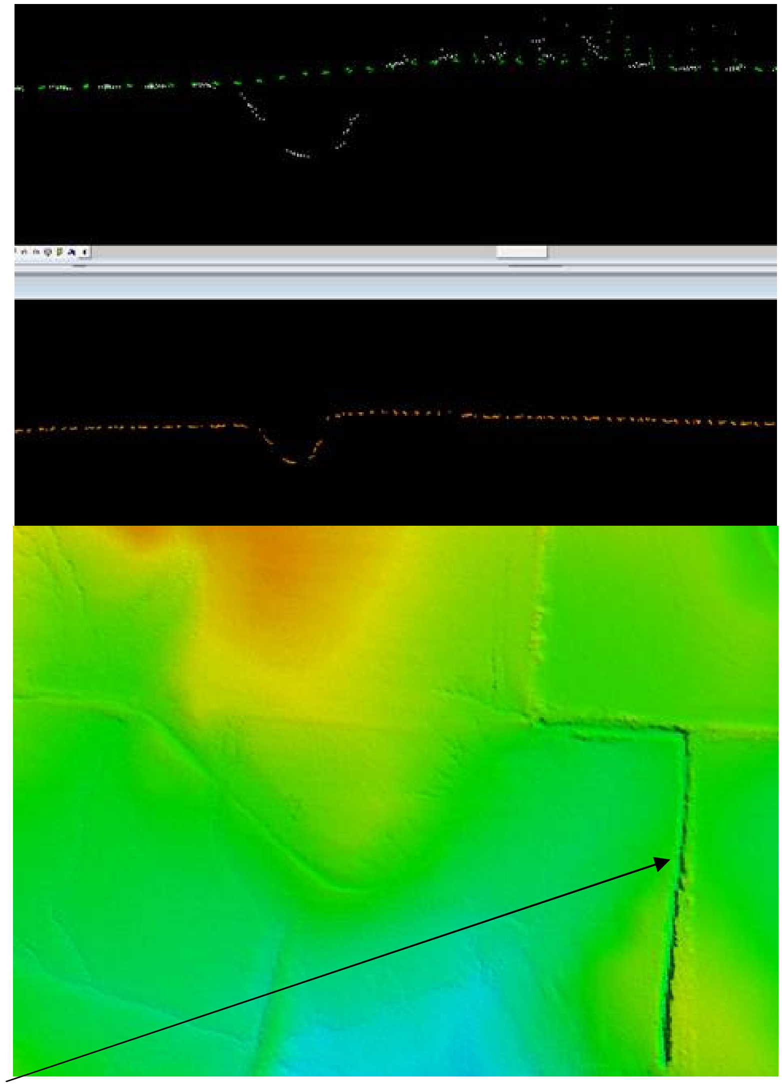


Figure 19-Tile number 16SCE0570. The top image shows a profile with points colored according to flight lines, the middle image shows a profile of ground only points, and the bottom image shows the final surface colored by elevation. No irrigation canal existed in this area during the original 2011 acquisition, as shown by the green flight line in the top image that is flat. By the add-on 2012 acquisition, however, this canal had been created, as seen by the white flight line in the top image that shows the depression in the cross section of the canal. Dewberry has classified points not representing the canal to unclassified so that this feature is represented in the final ground, shown with the black arrow. Any time flight lines showed conflicting representations of the surface, Dewberry manually classified points to consistently and most accurately represent the surface.

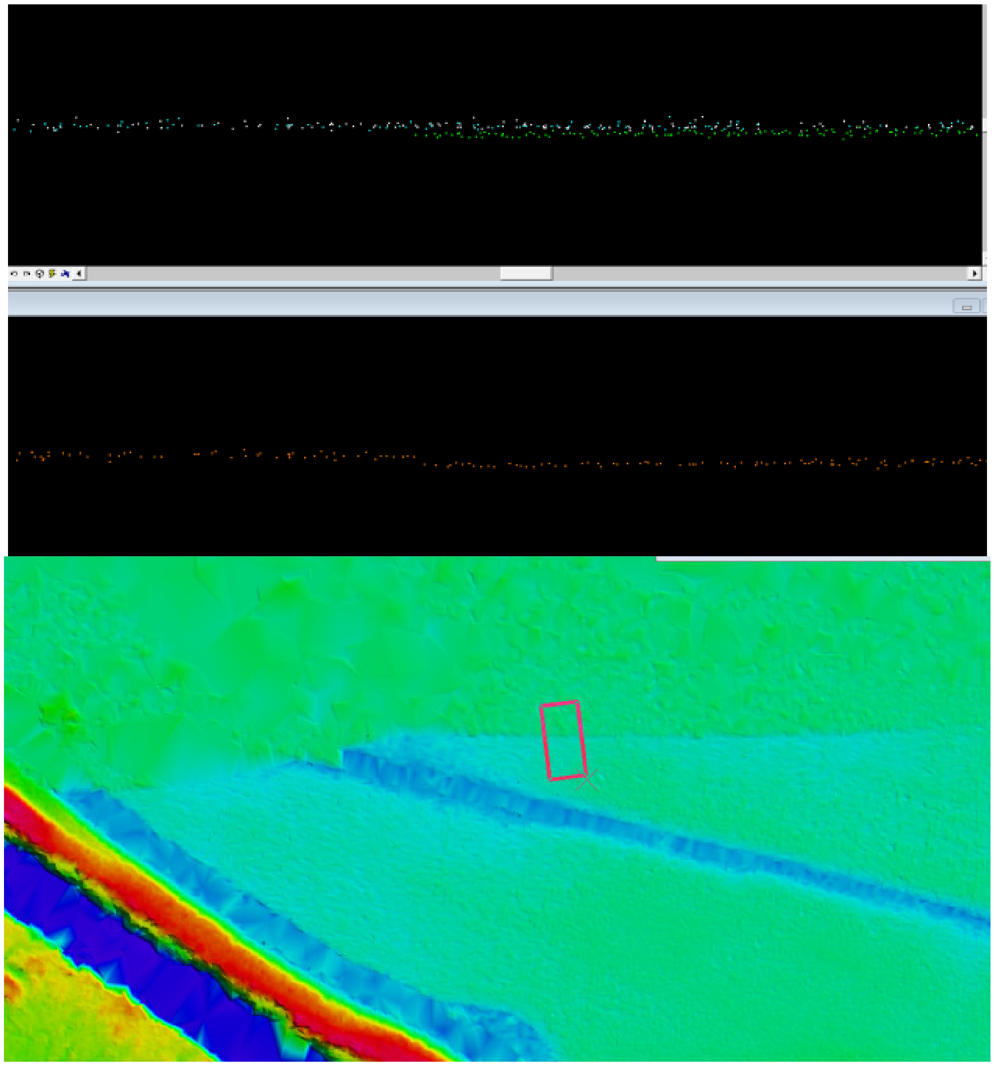


Figure 20-Tile number 16SCE1170. The top image shows a profile colored by flight line, the middle image shows a profile of ground only points, and the bottom image shows the surface colored by elevation. The top image shows that there are two separate flight lines in this area, represented by the colors blue and green. The blue flight line is higher in elevation than the green flight line and was collected as part of the add-on 2012 collect while the green flight line was collected as part of the original 2011 collect. The blue flight line is higher because this area contained more water during the 2012 collect, as shown in the intensity image below. As there are no lower points beneath the blue flight line, there is an elevation difference that exists in the final DEM surface. This temporal ridge is visible in the bottom image.

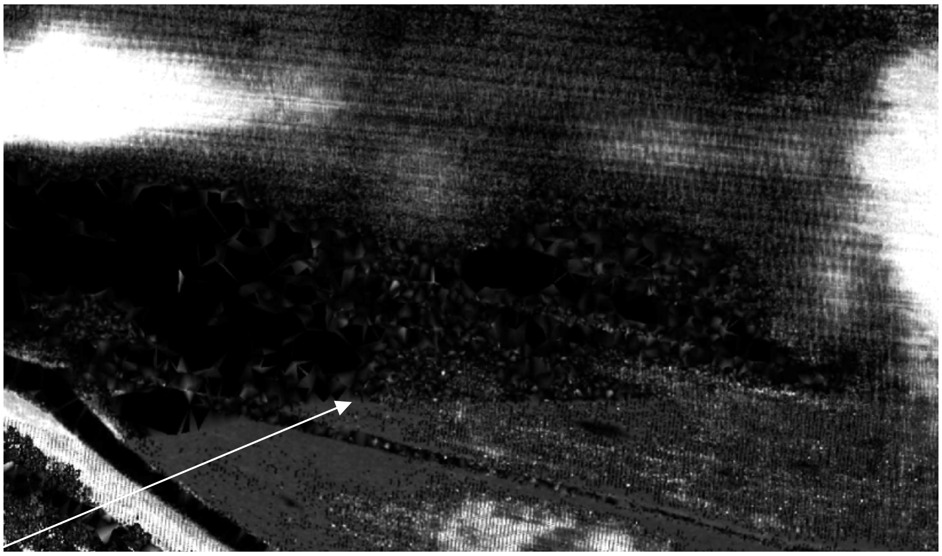


Figure 21-Tile number 16SCE1170. Differences in water levels between the original 2011 collect and the add-on 2012 collect resulted in some temporal elevation differences within hydrographic features and marsh areas. The presence of water results in higher ground compared to dry areas.

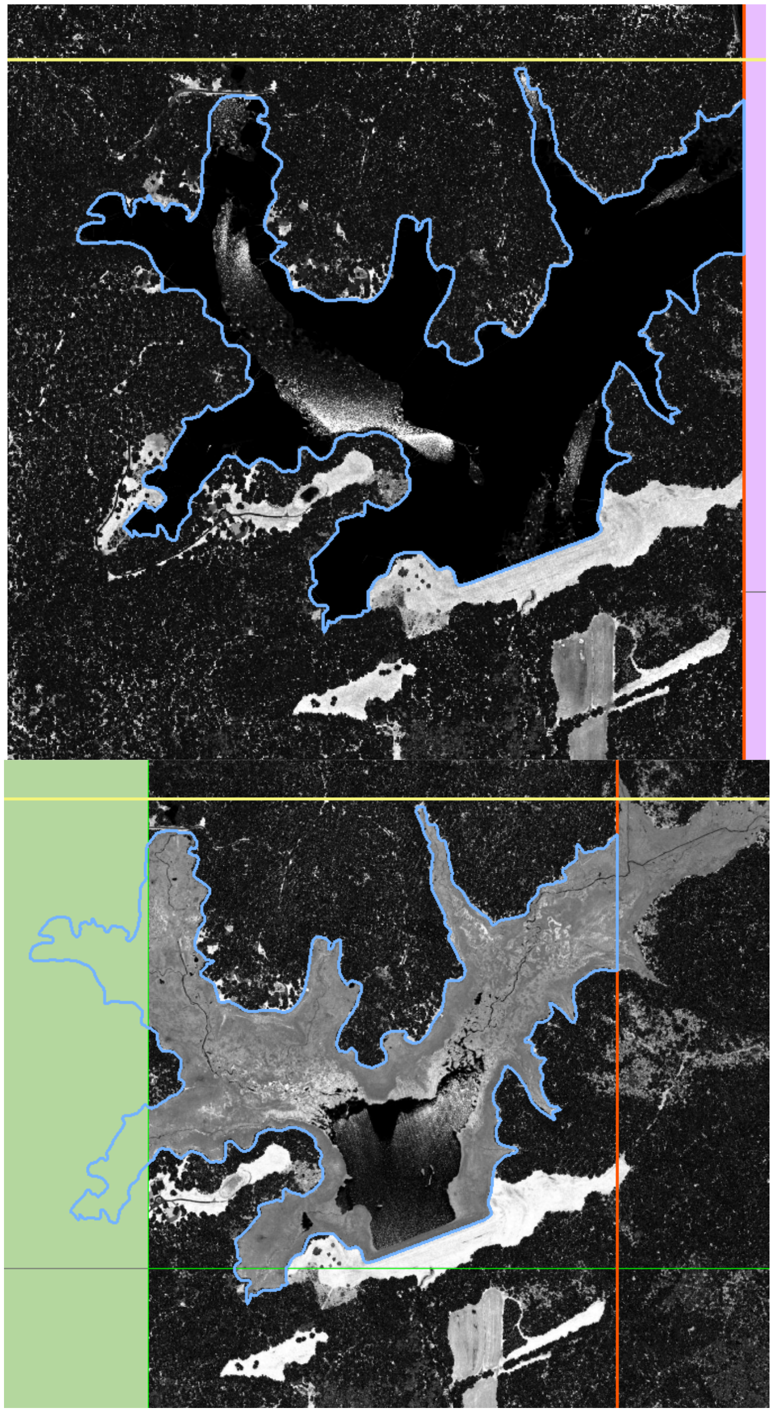


Figure 22-Tile number 16SCE5550. The top image shows a reservoir collected with a breakline to the extent of the original 2011 data. The bottom image shows the same breakline overlaid on intensity created from the add-on 2012 collect. The reservoir could not be completely captured from the extents of only one collection time period, but had to be captured using both the 2011 and 2012 datasets. Dewberry collected the reservoir as if it were full to show the full extent of area that could contain water. The reservoir extents are well defined; other water bodies whose extents are not as well defined were flattened to the most logical extent interpreted from the intensity imagery. The final DEM for the reservoir is shown below.

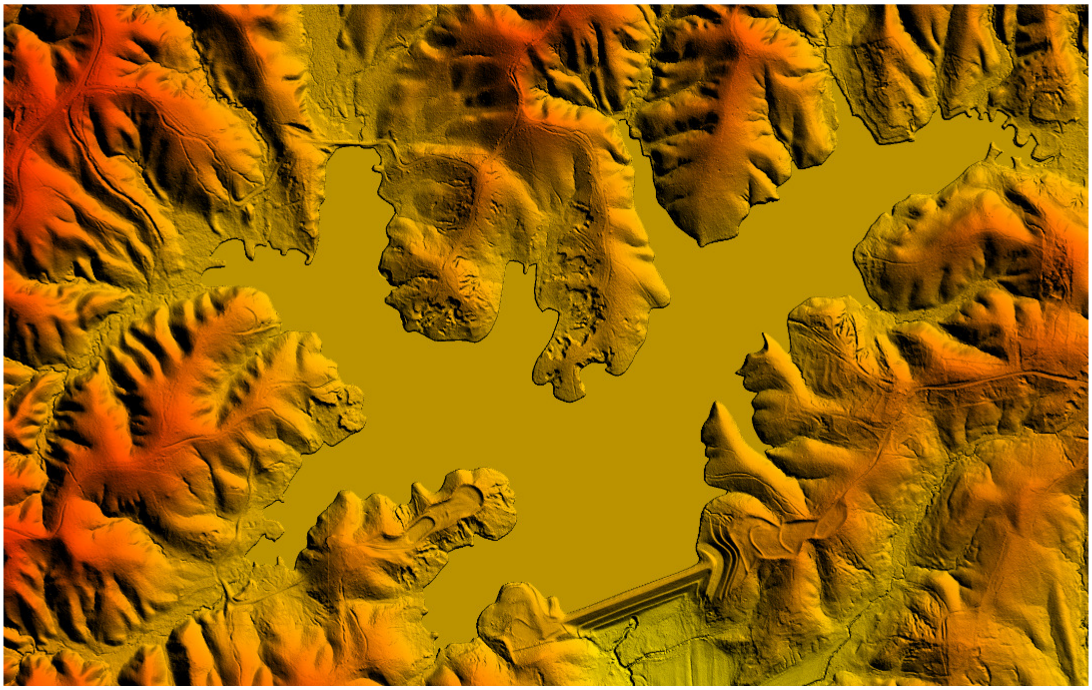


Figure 23-Tile numbers 16SCE5550, 16SCE5450, 16SCE5449, 16SCE5549, 16SCE5649, 16SCE5650, 16SCE5651, 16SCE5551, and 16SCE5451. This image shows the final DEM, colored by elevation, of the reservoir shown in the images above. The full extent of the reservoir has been modeled.

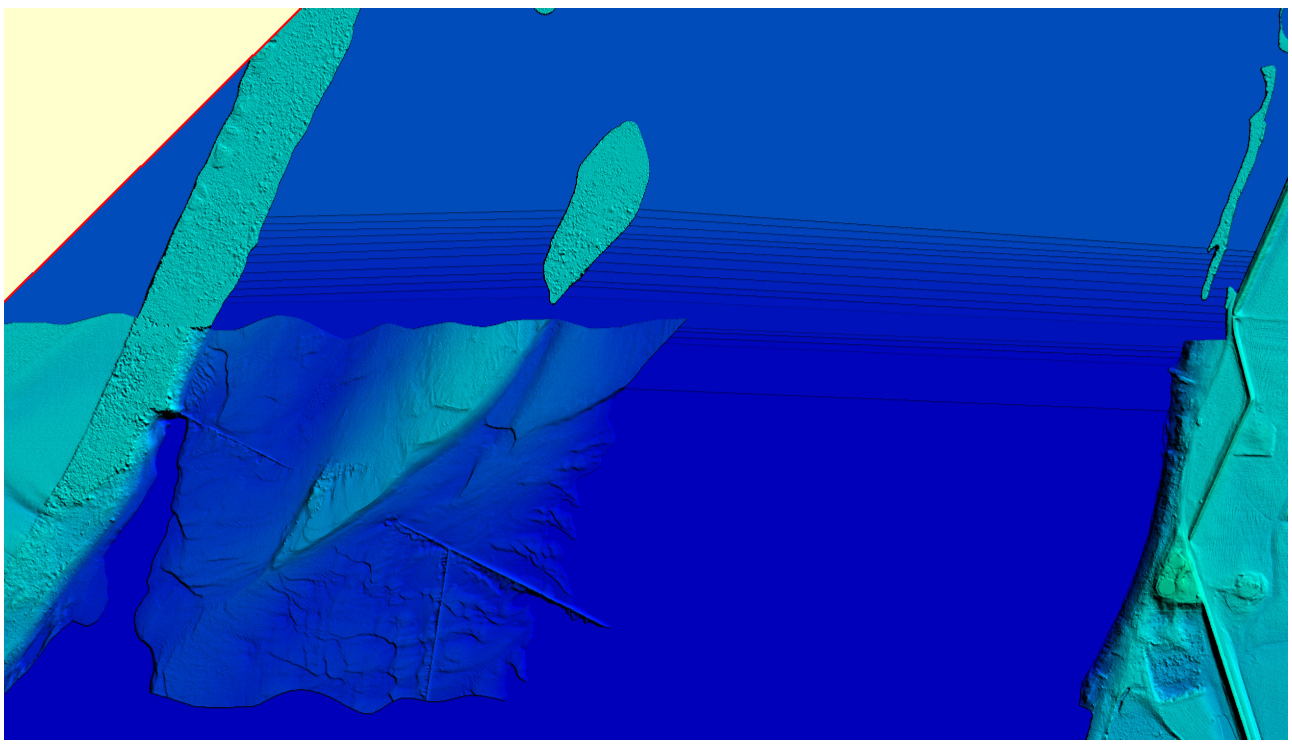


Figure 24-Tile numbers 16SBE5690, 16SBE5691, 16SBE5692, 16SBE5790, 16SBE5791, 16SBE5792, 16SBE5890, 16SBE5891, 16SBE5892, 16SBE5590, 16SBE5591. This DEM, colored by elevation, shows stair steps that lower the elevation from one flight line to a lower, adjacent flight line to the south. The flight line to the south was collected during a lower tidal stage when some tidal islands or shoals were exposed. However, because the flight line to the north was collected at a higher tide stage, these islands or shoals were inundated and the data does not exist to fully model these islands and shoals. These islands and shoals can only be partially modeled.

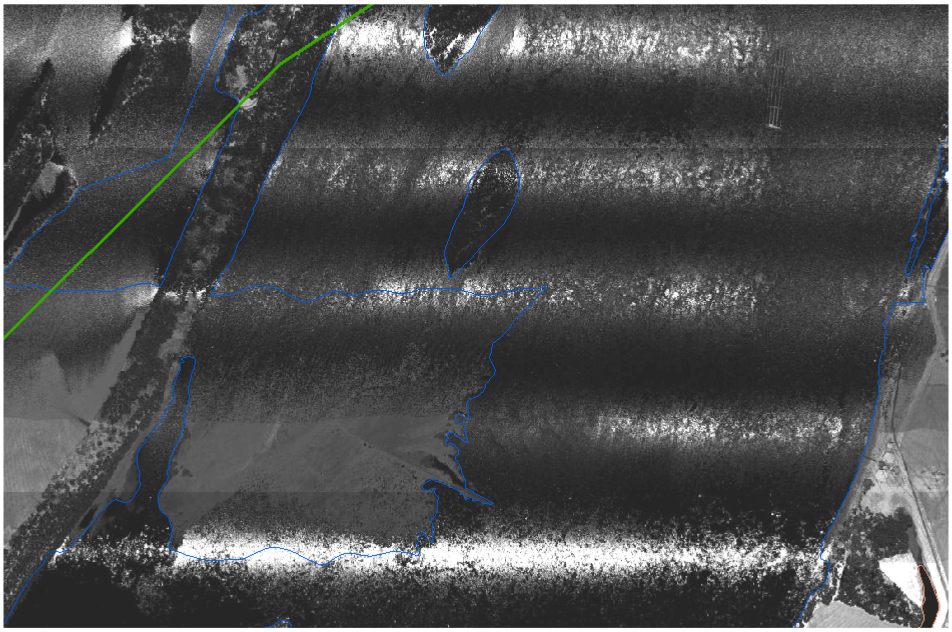


Figure 25-Tile numbers 16SBE5690, 16SBE5691, 16SBE5692, 16SBE5790, 16SBE5791, 16SBE5792, 16SBE5890, 16SBE5891, 16SBE5892, 16SBE5590, 16SBE5591. Intensity imagery overlaid with hydrographic breaklines (blue). The breaklines were collected in order to model the exposed islands and shoals to the fullest extent possible. However, these features can only be partially modeled because some data was collected at higher tide stages when these features were not exposed.

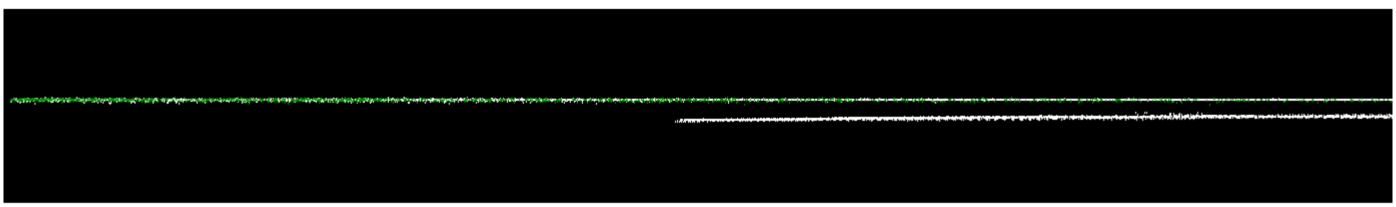


Figure 26-Tile numbers 16SBE5690, 16SBE5691, 16SBE5692, 16SBE5790, 16SBE5791, 16SBE5792, 16SBE5890, 16SBE5891, 16SBE5892, 16SBE5590, 16SBE5591. Profile showing points colored by flight line. The flight line with higher elevations, colored green, was collected at a higher tidal stage than the lower flight line, colored white. The white flight line does not fully extend across this area. The islands and shoals can only be modeled where data from the lower tide stage, i.e. the white flight line, exists. In areas where data can only come from the higher, green flight line, the data can only represent the water surface.

DERIVATIVE LIDAR PRODUCTS

Model Key Points

Terrascan software was used to create model key points. An algorithm is defined that intelligently thins bare earth ground points so that points necessary to define breaks and elevation changes in the terrain are kept while unnecessary or redundant points are not included in the model key points. The model key points are then written to a separate file, according to the project tile grid, with all points located in class 8. The model key point files follow all LAS formatting specifications outlined in the task order, including correct project information, versioning, and point data format. There were eighty-three files that did not contain enough model key points to create a file. Most of these are small tiles located along the boundary which have few ground points, if any, in the fully classified LiDAR tiles. The tiles that do not have corresponding model key points are identified in the attribute table of the final project tile grid and in Appendix C of this report.

Bare-Earth LiDAR

GeoCue software was used to create the bare earth only LAS files. For bare earth only LiDAR tiles, class 2 points are filtered from the full point cloud data and written to a separate file, according to the project tile grid. The bare earth LiDAR files follow all LAS formatting specifications outlined in the task order, including correct project information, versioning, and point data format. There were fifty-four files that did not contain enough bare earth points to create a file. Most of these are small tiles located along the boundary which have few or no ground points in the fully classified LiDAR tiles. The tiles that do not have corresponding bare earth points are identified in the attribute table of the final project tile grid and in Appendix D of this report.

First Return LiDAR

GeoCue software is used to filter the first return or echo for each laser pulse from the full point cloud and write this information to a separate file, according to the project tile grid. The first return files include the desired return from all classes. The first return LiDAR files follow all LAS formatting specifications outlined in the task order, including correct project information, versioning, and point data format.There is a first return LiDAR file for every fully classified LiDAR file within the Tennessee LiDAR project.

Last Return LiDAR

GeoCue software is used to filter the last return or echo for each laser pulse from the full point cloud and write this information to a separate file, according to the project tile grid. The last return files include the desired return from all classes. The last return LiDAR files follow all LAS formatting specifications outlined in the task order, including correct project information, versioning, and point data format.There is a last return LiDAR file for every fully classified LiDAR file within the Tennessee LiDAR project.

CONCLUSION

Overall the data meets project specifications. The dataset conforms to project requirements for format, header values, and spatial projection information. The classification of points is correct and the final ground points accurately represent the bare earth surface. Minor artifacts and small areas of misclassification are isolated and have minimal impact on the usability of the dataset. Temporal changes are well documented and have been minimized where possible.

Survey Vertical Accuracy Checkpoints

All checkpoints surveyed for vertical accuracy testing purposes are listed in the following table. A total of two hundred and fifty-three (253) checkpoints were surveyed for the USACE Tennessee LiDAR Project. The surveyor surveyed these points in two separate surveying windows; one survey was completed for the initial 2011 collect and a second survey was completed for the add-on 2012 collect. The final survey reports and point ID's did not distinguish between the two surveys. In order to avoid duplicate point ID's, Dewberry added "_AO" to all points surveyed for the add-on 2012 collect.

PT. #	NORTHING	EASTING	ELEVS.
	UTM North Zone 16		
POINT ID	**NORTHING (M)**	**EASTING (M)**	**ELEVATION (M)**
OT-9_AO	4017452.144	346136.297	127.363
OT-9	4039547.564	331994.844	128.507
OT-8_AO	4024706.928	367001.532	159.809
OT-8	4013076.155	310948.606	91.202
OT-7_AO	4033900.306	373227.887	148.984
OT-7	4023517.058	306282.181	106.165
OT-64	3922436.358	299253.551	104.123
OT-63	3924490.853	287735.715	101.822
OT-62	3927278.59	281932.972	103.772
OT-61	3928575.433	293765.812	94.153
OT-60	3925733.624	303041.794	118.101
OT-6_AO	4030094.056	349375.762	130.389

OT-6	4037120.111	298667.747	94.884
OT-59	3927656.877	312407.77	101.243
OT-58	3931271.649	319078.297	125.355
OT-57	3934013.677	334472.074	135.703
OT-56	3924704.365	330351.111	142.382
OT-55	3912235.144	340162.146	153.656
OT-54	3902698.799	339800.081	131.704
OT-53	3917103.157	350962.571	143.144
OT-52	3915491.168	375644.553	128.775
OT-51	3925254.831	375500.925	171.2
OT-50	3926553.328	362553.65	159.389
OT-5_AO	4025330.811	329817.948	112.5
OT-5	4022695.385	294023.454	144.07
OT-49	3928497.646	344070.899	116.614
OT-48	3937334.544	323739.578	152.751
OT-47	3939818.156	310647.008	122.954
OT-46	3942150.431	292750.5	113.608
OT-45	3944494.301	276559.234	96.896
OT-44	3951729.856	289114.835	92.169
OT-43	3950011.861	298026.269	103.257
OT-42	3947110.58	312939.152	132.728
OT-41	3946009.063	326257.625	105.351
OT-40	3941476.18	335947.629	108.585
OT-4_AO	4048546.271	367641.024	168.794
OT-4	4015724.769	296442.309	97.536
OT-39	3940422.841	352163.167	118.802
OT-38	3959090.838	348247.123	142.887
OT-37	3954834.903	340344.805	128.708
OT-36	3956116.366	332726.992	117.488
OT-35	3951621.47	319015.662	104.147
OT-34	3962515.328	313526.788	103.763
OT-33	3955671.517	301326.018	89.258
OT-32	3966481.237	299573.385	107.232
OT-31	3957570.151	281509.305	104.123
OT-30_AO	3971365.692	286780.324	83.869
OT-3_AO	4043755.984	343395.275	140.964
OT-3	4012062.526	271709.627	83.284
OT-29_AO	3973971.231	298681.561	102.855
OT-28	3963506.565	338849.133	140.239
OT-27	3967266.618	327135.948	110.173
OT-26_AO	3981988.941	308979.954	90.349
OT-25_AO	3981889.789	324883.081	114.191
OT-24_AO	3988172.53	337143.88	121.411
OT-23_AO	3985583.517	349059.702	114.038
OT-22_AO	3913981.45	354538.651	138.286
OT-22	3995783.499	350797.656	137.611
OT-21_AO	3933866.487	361680.219	156.057
OT-21	3997230.439	334246.876	107.162
OT-20_AO	3946196.752	365675.288	159.277
OT-20	3999819.369	319372.514	110.118
OT-2_AO	4047970.861	304368.957	112.505

OT-2	4027402.153	278235.146	87.051
OT-19_AO	3961394.052	361165.067	188.806
OT-19_AO	3991714.105	309624.227	94.226
OT-18_AO	3969755.295	350225.878	167.648
OT-18	4004264.196	305686.916	106.235
OT-17_AO	3977871.976	373230.811	141.456
OT-17_AO	3982839.472	289714.086	95.497
OT-16_AO	3983720.451	358096.711	128.291
OT-16_AO	3989345.13	289214.338	85.817
OT-15_AO	3990261.868	377117.831	140.939
OT-15	3999997.661	294580.307	103.44
OT-14_AO	3993443.767	368027.546	147.25
OT-14	4004929.737	277217.184	82.336
OT-13_AO	3999895.003	345662.642	142.549
OT-13_AO	3991973.651	274844.397	83.332
OT-12_AO	4006933.234	373346.052	160.29
OT-12_AO	3980343.005	278271.117	115.708
OT-11_AO	4009951.131	354721.756	124.11
OT-11_AO	3982131.429	262323.159	79.23
OT-10_AO	4002968.264	337927.239	129.605
OT-10	3997234.531	267044.128	89.435
OT-1_AO	4049907.64	289945.985	89.367
OT-1	4041087.152	276103.327	91.184
GWC-9_AO	4017498.35	351847.313	161.613
GWC-9	3923050.005	339435.166	142.491
GWC-8_AO	4017493.661	333407.271	105.673
GWC-7_AO	4027056.977	342845.684	116.24
GWC-7	3904903.596	338661.38	169.835
GWC-65	4040290.702	306081.415	116.897
GWC-64	4040911.974	287871.856	88.353
GWC-63	4033284.899	277782.855	90.239
GWC-62	4023129.303	269584.112	84.991
GWC-61	4030497.281	296073.266	135.085
GWC-60	4032248.108	309404.611	110.859
GWC-6_AO	4030264.404	365350.035	140.218
GWC-6	3909351.365	344465.27	195.54
GWC-59	4037141.096	323924.275	100.913
GWC-58	4031570.621	333509.706	104.696
GWC-57	4030481.328	320778.459	92.074
GWC-56	4021877.712	320101.89	112.849
GWC-55	4016504.284	305423.585	87.828
GWC-54	4012667.963	290103.633	97.597
GWC-53	4018351.687	282349.932	85.445
GWC-52_AO	4004183.649	265228.276	81.217
GWC-51	3998797.164	278870.793	145.722
GWC-50	4000906.001	284372.245	141.019
GWC-5_AO	4028824.765	379807.963	181.26
GWC-5	3918967.293	358457.162	130.144
GWC-49	4005565.536	297363.308	94.004
GWC-48	4008496.857	319839.844	89.913

GWC-47	3998073.553	313087.651	102.319
GWC-46	3998758.079	326631.438	122.883
GWC-45_AO	3990518.67	330329.517	107.354
GWC-44_AO	3990049.283	321786.35	109.804
GWC-43	3995869.951	297725.08	93.857
GWC-42_AO	3990629.258	269390.781	79.782
GWC-41_AO	3987804.719	258943.203	79.431
GWC-40_AO	3978071.208	264390.252	79.202
GWC-4_AO	4043417.818	361257.759	169.737
GWC-4	3922495.391	365378.918	171.42
GWC-39_AO	3984207.127	271267.474	79.047
GWC-38_AO	3978345.827	287604.356	91.897
GWC-37_AO	3983260.639	299977.351	83.68
GWC-36_AO	3974315.347	319582.85	99.783
GWC-35_AO	3982781.282	331802.624	115.163
GWC-34_AO	3985238.566	342517.965	145.948
GWC-33_AO	3991404.83	346786.068	116.635
GWC-32_AO	3990613.399	354680.042	113.41
GWC-31_AO	3980306.498	343088.755	114.636
GWC-30_AO	3973410.322	336500.141	109.326
GWC-3_AO	4038288.65	346717.463	136.383
GWC-3_AO	3928222.313	369155.847	193.036
GWC-29	3967520.408	312219.252	99.368
GWC-28	3968614.001	293676.78	114.358
GWC-27	3965493.239	282684.5	121.567
GWC-26	3950430.503	280092.403	95.564
GWC-25	3959490.989	290491.541	86.798
GWC-24	3954842.27	311510.781	107.037
GWC-23	3954482.061	326687.62	130.385
GWC-22_AO	3910737.871	359178.734	170.314
GWC-22	3959437.474	342858.482	116.522
GWC-21_AO	3941261.974	361687.862	129.442
GWC-21	3953796.5	352076.727	169.628
GWC-20_AO	3948127.949	358440.123	160.62
GWC-20	3948520.511	336948.377	148.255
GWC-2_AO	4043378.797	330471.153	125.883
GWC-2	3921069.587	375551.881	127.023
GWC-19_AO	3955372.908	365960.522	153.563
GWC-19	3944066.255	320990.491	128.419
GWC-18_AO	3971245.356	357881.823	138.358
GWC-18	3944235.277	302542.193	115.483
GWC-17_AO	3981010.623	364344.798	128.661
GWC-17	3940910.215	284565.916	108.652
GWC-16_AO	3987469.15	370400.878	134.777
GWC-16	3921870.024	278756.98	104.473
GWC-15_AO	3995244.448	360206.428	110.044
GWC-15	3924454.145	306517.827	132.445
GWC-14_AO	3996648.848	379411.701	126.872
GWC-14	3932104.849	309570.668	102.44

GWC-13_AO	4001587.357	353748.495	112.081
GWC-13	3926863.962	321068.68	146.173
GWC-12_AO	4008620.615	343036.177	117.702
GWC-12	3927419.615	332790.714	149.3
GWC-11_AO	4008864.861	360744.771	144.852
GWC-11	3939078.272	345081.098	115.721
GWC-10_AO	4016738.674	375743.968	149.31
GWC-10	3924474.758	352455.623	129.632
GWC-1_AO	4045825.528	296343.859	88.808
GWC-1	3916200.698	369265.95	125.572
FO-9_AO	3997503.242	371585.684	151.872
FO-9	4026663.188	299533.419	140.035
FO-8_AO	3988908.528	362614.675	142.846
FO-8	4026177.744	314587.659	121.134
FO-7_AO	3984265.939	376137.621	119.325
FO-7	4032602.856	302763.108	115.98
FO-61	3917582.852	334903.05	141.061
FO-60	3918376.106	346279.087	144.856
FO-6_AO	3979015.464	356518.959	144.062
FO-6	4034500.267	284824.94	86.448
FO-59	3922455.886	359008.124	152.824
FO-58	3924818.37	370028.519	166.461
FO-57	3929962.154	360127.548	136.395
FO-56	3934731.143	352735.545	145.615
FO-55	3929930.747	336714.611	147.77
FO-54	3932656.475	326711.635	137.782
FO-53	3931777.736	314343.491	121.637
FO-52	3921770.567	294821.19	119.375
FO-51	3927619.005	290759.198	92.873
FO-50	3928605.548	276955.662	87.289
FO-5_AO	3971479.695	365264.314	158.371
FO-5	4040446.348	295122.247	89.886
FO-49	3931891.762	278380.12	83.698
FO-48	3936400.327	284642.37	90.636
FO-47	3939416.009	275900.636	81.528
FO-46	3945015.639	286502.858	112.63
FO-45	3938291.792	300343.753	106.695
FO-44	3939605.365	318451.157	124.977
FO-43	3939514.683	331427.808	115.849
FO-42	3947804.949	349615.887	149.864
FO-41	3951863.595	346089.114	164.745
FO-40	3949774.704	325276.599	131.971
FO-4_AO	3964501.654	351271.451	145.57
FO-39	3951022.257	309707.389	93.333
FO-38	3955783.608	287113.361	88.828
FO-37	3962216.37	296940.927	91.465
FO-36	3960642.722	308276.706	118.476
FO-35	3962484.342	318542.092	110.935
FO-34	3959102.751	337467.082	120.914

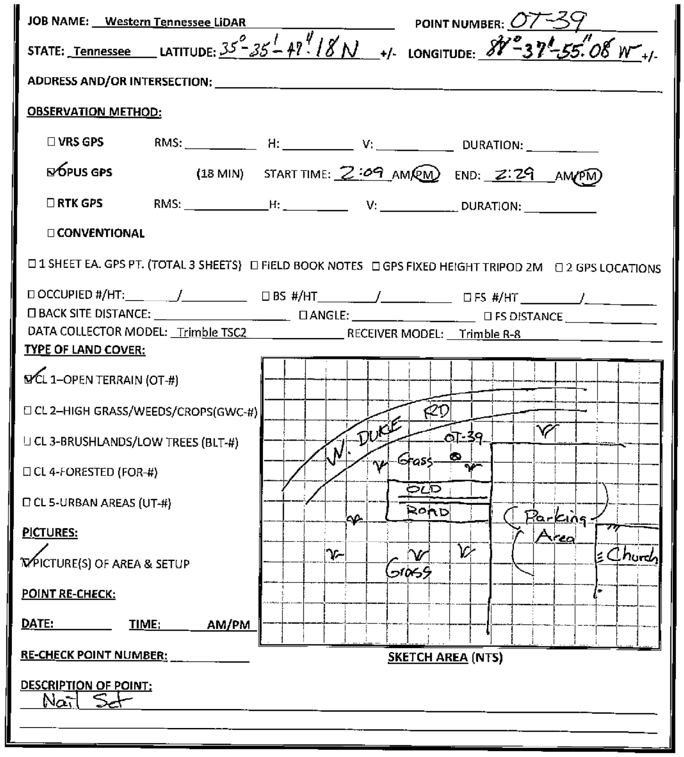
FO-33_AO	3969585.819	336677.136	119.226
FO-32_AO	3969485.916	304337.17	113.779
FO-31_AO	3974517.318	292068.927	86.265
FO-30_AO	3977797.491	276729.898	107.57
FO-3_AO	3952500.611	357458.634	171.513
FO-3	3998347.748	306346.074	105.613
FO-29	3993847.745	264908.788	77.991
FO-28_AO	3983576.367	282393.769	81.485
FO-27_AO	3978904.353	294098.422	89.179
FO-26_AO	3975341.158	310081.398	90.005
FO-25_AO	3980970.707	318775.175	104.303
FO-24_AO	3989400.789	342362.762	128.601
FO-23	3997061.354	355215.034	135.173
FO-22_AO	3996531.727	345213.569	126.602
FO-21_AO	4044818.368	299081.833	99.766
FO-21	3993114.914	339197.921	135.152
FO-20_AO	4043733.057	322747.653	108.728
FO-20	3994129.59	317856.871	102.258
FO-2_AO	3935149.828	366896.075	141.108
FO-2	4034153.343	326561.941	108.826
FO-19_AO	4045860.741	353120.22	163.329
FO-19_AO	3988473.187	298593.002	99.709
FO-18_AO	4038132.403	365888.51	124.507
FO-18	4006302.308	270703.396	80.908
FO-17_AO	4033164.195	341848.656	125.005
FO-17	4011052.684	261884.926	82.411
FO-16_AO	4023638.692	356088.513	149.606
FO-16	4011931.12	280215.409	83.387
FO-15_AO	4020196.111	379421.969	168.141
FO-15	4006559.263	288088.581	86.721
FO-14_AO	4012460.756	366040.808	130.483
FO-14	4008242.975	314091.271	95.22
FO-13_AO	4011902.706	346918.022	108.309
FO-13	4016600.984	322125.842	87.412
FO-12_AO	4010663.085	328464.954	103.159
FO-12	4016347.488	313172.668	88.097
FO-11_AO	4000595.381	340852.201	132.52
FO-11	4017596.839	289466.004	135.612
FO-10_AO	4005535.554	360764.578	139.161
FO-10	4026079.105	287368.616	95.098
FO-1_AO	3909569.952	351039.841	144.344
FO-1	4036329.644	334884.644	111.136

Table 3: USACE Tennessee LiDAR surveyed accuracy checkpoints

Two hundred and fifty-three checkpoints were surveyed for vertical accuracy testing. While reviewing the final coordinates of the provided survey checkpoints against the field sketches and intensity imagery created from the LiDAR, Dewberry identified issues with the location of some forest checkpoints. The location of checkpoints as recorded in field sketches did not match the location of the provided checkpoints. For example, a field sketch may have showed the checkpoint should be located west of a road, but the final coordinates showed the checkpoint east of a road. Upon discussion and review by the surveyor, it was determined that some forest checkpoints had erroneous coordinates and elevations. Forest points were collected using the conventional method and in some instances, the two points surveyed outside of the forest that are used to triangulate the point surveyed within the forest were reversed during calculations. All forest points were re-calculated by the surveyor and the new coordinates were used in the final vertical accuracy testing. Additionally, some checkpoints (from all land cover categories) had large delta Z errors during vertical accuracy testing that could not be attributed to characteristics of the LiDAR data. These checkpoints were reviewed by the surveyor to check for additional surveying issues. After reviewing and reprocessing the calculations, several checkpoints were modified with revised coordinates and elevations. The revised coordinates and elevations were used in the final vertical accuracy testing. Table 3, above, includes all revised coordinates and contains the final coordinates as used in the vertical accuracy testing. The revised coordinates provided by the surveyor can also be found in Appendix A.

There were two additional checkpoints that were reviewed by the surveyor for issues. Dewberry requested checkpoint FO-5_AO be reviewed by the surveyor because the Delta Z between the LiDAR and survey was over 7 meters and there was no issue in the LiDAR data to support this measurement. Other survey points within the same flight line tested within anticipated thresholds. Dewberry requested checkpoint OT-39 be reviewed by the surveyor because the field sketch and field photo show this checkpoint located within grass. However, the final coordinates of this checkpoint show it located on an asphalt driveway. Reprocessing the calculations for these two checkpoints resulted in no modifications to the coordinates and elevations of the points. However, in both cases the surveyor stated that all aspects of the survey for these two points could not be accounted for. As there was a low confidence in the survey of these two points, checkpoints FO-5_AO and OT-39 have been removed from the final vertical accuracy testing. Even with the removal of these two points, there are enough total checkpoints and enough checkpoints per land cover category to satisfy project requirements. The images below show the two checkpoints removed from final vertical accuracy testing.

Figure 27-Checkpoint FO-5_AO. The surveyed elevation of this forest checkpoint is over 7 meters above the ground surface in the LiDAR data. Review by the surveyor deemed this survey checkpoint erroneous and unsuitable to use in the final vertical accuracy testing.



JOB NAME: Western Tennessee LiDAR POINT NUMBER: OT-39

STATE: Tennessee LATITUDE: 35°-35'-47".18 N +/- LONGITUDE: 88°-37'-55".08 W +/-

ADDRESS AND/OR INTERSECTION:

OBSERVATION METHOD:

☐ VRS GPS RMS: H: V: DURATION:

☑ OPUS GPS (18 MIN) START TIME: 2:09 AM/PM END: 2:29 AM/PM

☐ RTK GPS RMS: H: V: DURATION:

☐ CONVENTIONAL

☐ 1 SHEET EA. GPS PT. (TOTAL 3 SHEETS) ☐ FIELD BOOK NOTES ☐ GPS FIXED HEIGHT TRIPOD 2M ☐ 2 GPS LOCATIONS

☐ OCCUPIED #/HT: / ☐ BS #/HT / ☐ FS #/HT /
☐ BACK SITE DISTANCE: ☐ ANGLE: ☐ FS DISTANCE
DATA COLLECTOR MODEL: Trimble TSC2 RECEIVER MODEL: Trimble R-8

TYPE OF LAND COVER:

☑ CL 1–OPEN TERRAIN (OT-#)

☐ CL 2–HIGH GRASS/WEEDS/CROPS(GWC-#)

☐ CL 3-BRUSHLANDS/LOW TREES (BLT-#)

☐ CL 4-FORESTED (FOR-#)

☐ CL 5-URBAN AREAS (UT-#)

PICTURES:

☑ PICTURE(S) OF AREA & SETUP

POINT RE-CHECK:

DATE: TIME: AM/PM

RE-CHECK POINT NUMBER:

SKETCH AREA (NTS)

DESCRIPTION OF POINT:
Nail Set

Figure 28-Field Sketch for checkpoint OT-39. Field sketch shows the checkpoint should be located within short grass, but final coordinates locate checkpoint in an asphalt driveway. Review by the surveyor deemed this survey checkpoint erroneous and unsuitable to use in the final vertical accuracy testing.

Figure 29-Field Photo for checkpoint OT-39. Field photo shows the checkpoint should be located within short grass, but final coordinates locate checkpoint in an asphalt driveway. Review by the surveyor deemed this survey checkpoint erroneous and unsuitable to use in the final vertical accuracy testing.

Figure 30-Tile 16SCE5240. Intensity imagery is shown with checkpoint OT-39 (red triangle) overlaid. Field sketch and field photo show the checkpoint should be located within short grass, but final coordinates locate checkpoint in an asphalt driveway. Review by the surveyor deemed this survey checkpoint erroneous and unsuitable to use in the final vertical accuracy testing.

LiDAR Vertical Accuracy Statistics & Analysis

BACKGROUND

Dewberry tests and reviews project data both quantitatively (for accuracy) and qualitatively (for usability).

For quantitative assessment (i.e. vertical accuracy assessment), two hundred and fifty-one (251) check points were surveyed for the project and are located within bare earth/open terrain, grass/weeds/crops, and forested/fully grown land cover categories. Please see appendix A to view the survey report which details and validates how the survey was completed for this project.

Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the "dispersed method" of placement.

VERTICAL ACCURACY TEST PROCEDURES

FVA (Fundamental Vertical Accuracy) is determined with check points located only in the open terrain (grass, dirt, sand, and/or rocks) land cover category, 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 FVA 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 USACE Tennessee LiDAR project, vertical accuracy must be 0.18 meters or less based on an RMSEz of 0.0925 meters x 1.9600.

CVA (Consolidated Vertical Accuracy) is determined with all checkpoints in all land cover categories combined where there is a possibility that the LiDAR sensor and post-processing may yield elevation errors that do not follow a normal error distribution. CVA at the 95% confidence level equals the 95^{th} percentile error for all checkpoints in all land cover categories combined. The USACE Tennessee LiDAR Project CVA standard is 0.363 meters based on the 95^{th} percentile. The CVA is accompanied by a listing of the 5% outliers that are larger than the 95^{th} percentile used to compute the CVA; these are always the largest outliers that may depart from a normal error distribution. Here, $Accuracy_z$ differs from CVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas CVA assumes LiDAR errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

SVA (Supplemental Vertical Accuracy) is determined for each land cover category other than open terrain. SVA at the 95% confidence level equals the 95th percentile error for all checkpoints in each land cover category. The USACE Tennessee LiDAR Project SVA target is 0.363 meters based on the 95th percentile. Target specifications are given for SVA's as individual land cover categories may exceed this target value as long as the overall CVA is within specified tolerances. Again, $Accuracy_z$ differs from SVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas SVA 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 4.

Quantitative Criteria	Measure of Acceptability
Fundamental Vertical Accuracy (FVA) in open terrain only using RMSEz *1.9600	0.18 meters (based on RMSEz (0.0925 meters) * 1.9600)
Consolidated Vertical Accuracy (CVA) in all land cover categories combined at the 95% confidence level	0.363 meters (based on combined 95th percentile)
Supplemental Vertical Accuracy (SVA) in each land cover category separately at the 95% confidence level	0.363 meters (based on 95th percentile for each land cover category)

Table 4 – Acceptance Criteria

VERTICAL ACCURACY TESTING STEPS

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 FVA, CVA, and SVA values.
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.

The figure below shows the location of the QA/QC checkpoints within the project area.

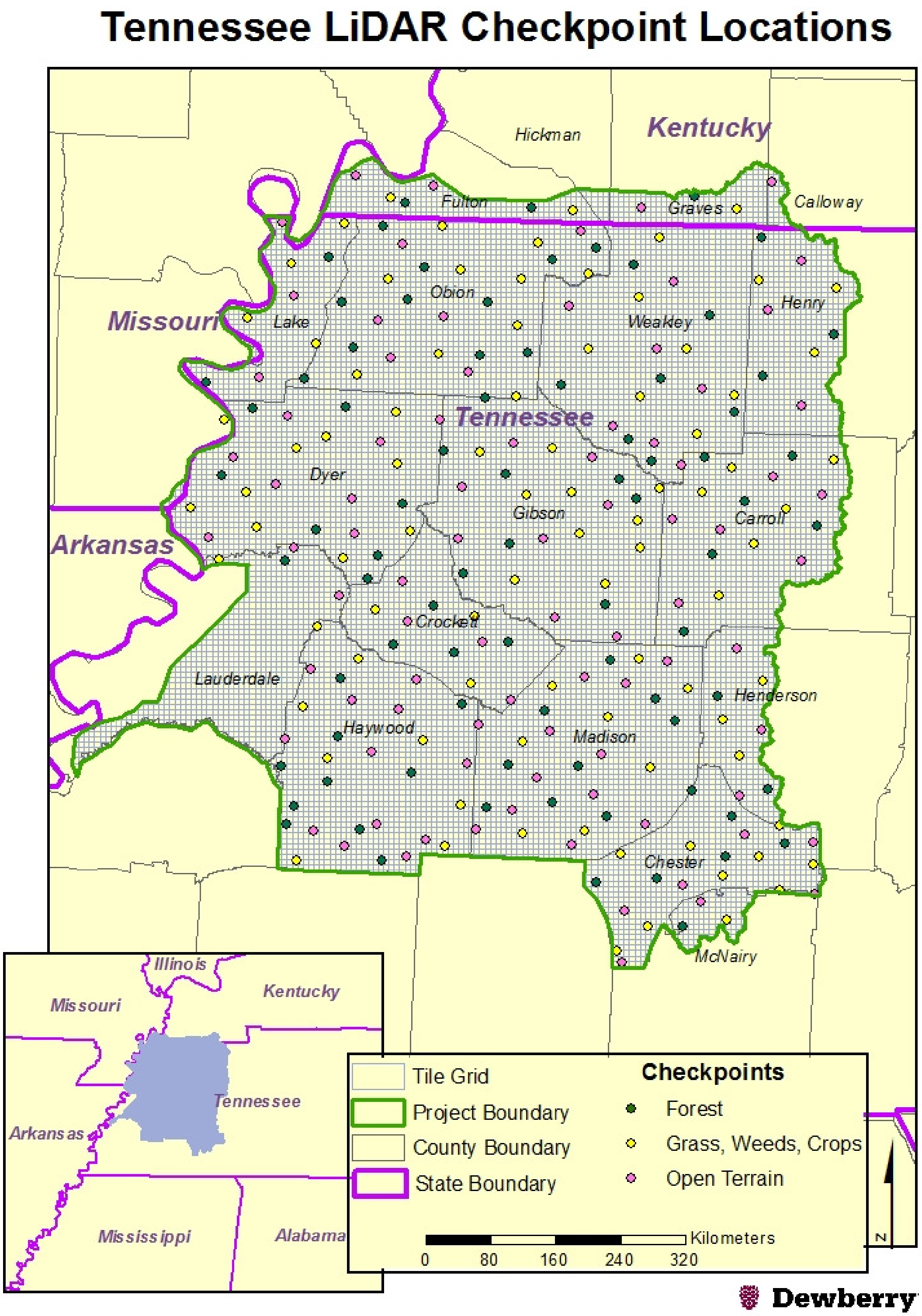


Figure 31 – Location of QA/QC Checkpoints

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	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec=0.18 m	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec=0.363 m	SVA — Supplemental Vertical Accuracy (95th Percentile) Target=0.363 m
Consolidated	251		0.34	
Bare Earth-Open Terrain	85	0.18		
Tall Grass, Weeds, and Crops	86			0.37
Forest	80			0.38

Table 5 — FVA, CVA, and SVA Vertical Accuracy at 95% Confidence Level

The $RMSE_z$ for checkpoints in open terrain only tested 0.09 meters, within the target criteria of 0.0925 meters. Compared with the 0.18 meters specification, the FVA tested 0.18 meters at the 95% confidence level based on $RMSE_z$ x 1.9600.

Compared with the 0.363 meters specification, CVA for all checkpoints in all land cover categories combined tested 0.34 meters based on the 95^{th} percentile.

Compared with target 0.363 specification, SVA for checkpoints in the tall grass, weeds, and crops land cover category tested 0.37 meters based on the 95^{th} percentile, and checkpoints in the forested land cover category tested 0.38 meters based on the 95^{th} percentile. Target specifications are given for SVA's as individual land cover categories may exceed this target value as long as the overall CVA is within specified tolerances.

The figure below illustrates the magnitude of the differences between the QA/QC checkpoints and LiDAR data. This shows that the majority of LiDAR elevations were within +/- 0.25 meters of the checkpoints elevations, but there were some outliers where LiDAR and checkpoint elevations differed by over +1.00 meters.

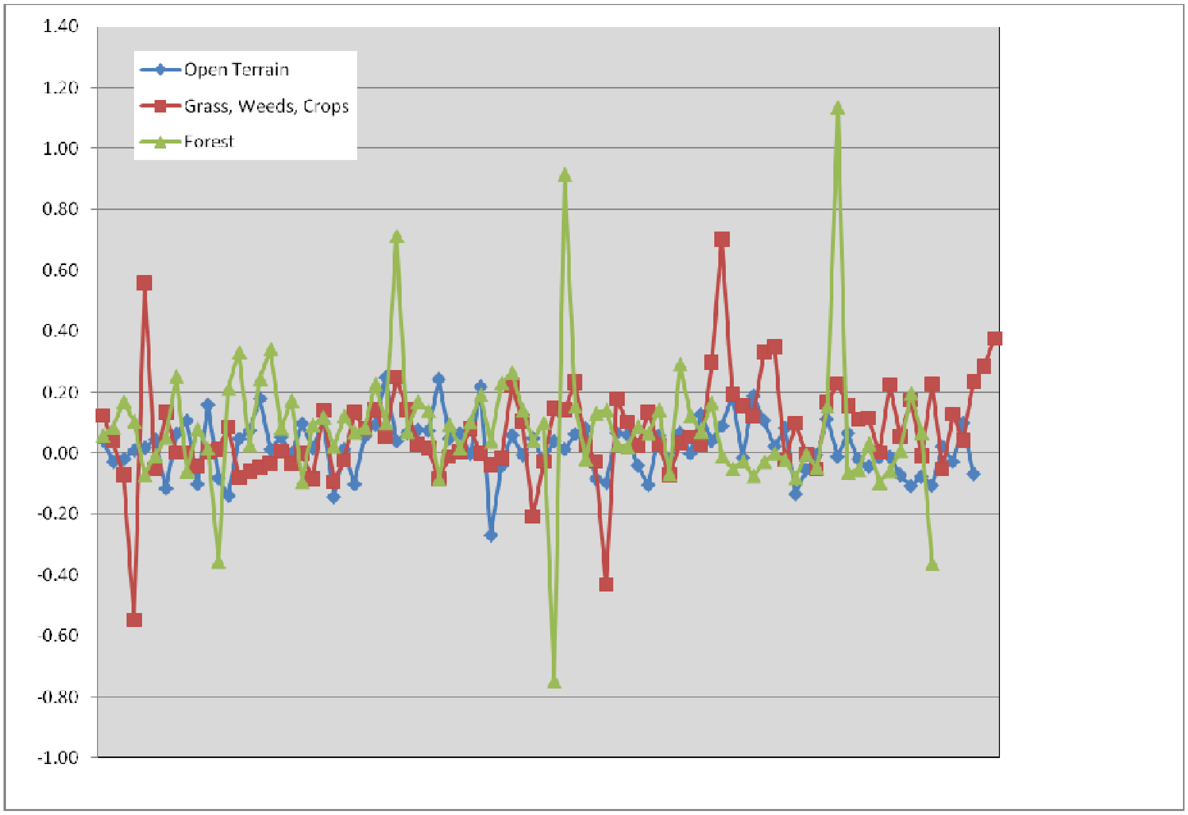


Figure 32 – Magnitude of elevation discrepancies per land cover category

Table 6 lists the 5% outliers that are larger than the 95th percentile.

Point ID	NAD83 UTM North Zone 15		NAVD88	LiDAR Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
GWC-7_AO	4027056.977	342845.684	116.24	115.693	-0.55	0.55
GWC-7	3904903.596	338661.38	169.835	170.394	0.56	0.56
GWC-3_AO	3928222.313	369155.847	193.036	192.605	-0.43	0.43
GWC-21	3953796.5	352076.727	169.628	170.331	0.70	0.70
GWC-19_AO	3955372.908	365960.522	153.563	153.910	0.35	0.35
GWC-1	3916200.698	369265.95	125.572	125.949	0.38	0.38
FO-58	3924818.37	370028.519	166.461	166.106	-0.36	0.36
FO-42	3947804.949	349615.887	149.864	150.577	0.71	0.71
FO-3	3998347.748	306346.074	105.613	104.864	-0.75	0.75
FO-29	3993847.745	264908.788	77.991	78.9061	0.92	0.92
FO-13	4016600.984	322125.842	87.412	88.548	1.14	1.14
FO-1	4036329.644	334884.644	111.136	110.773	-0.36	0.36

Table 6 — 5% Outliers

Table 7 provides overall descriptive statistics.

100 % of Totals	RMSE (m) Open Terrain Spec=0.0925m	Mean (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Consolidated		0.06	0.04	1.30	0.17	251	-0.75	1.14
Open Terrain	0.09	0.02	0.02	-0.13	0.09	85	-0.27	0.25
Tall Grass, Weeds, and Crops		0.07	0.04	0.18	0.17	86	-0.55	0.70
Forest		0.15	0.07	1.35	0.23	80	-0.75	1.14

Table 7 — Overall Descriptive Statistics

The figure below illustrates a histogram of the associated elevation discrepancies between the QA/QC checkpoints and elevations interpolated from the LiDAR triangulated irregular network (TIN). The frequency shows the number of discrepancies within each band of elevation differences. Although the discrepancies vary between a low of -0.75 meters and a high of +1.14 meters, the histogram shows that the majority of the discrepancies are skewed on the positive side. The vast majority of points are within the ranges of -0.15 meters to +0.25 meters.

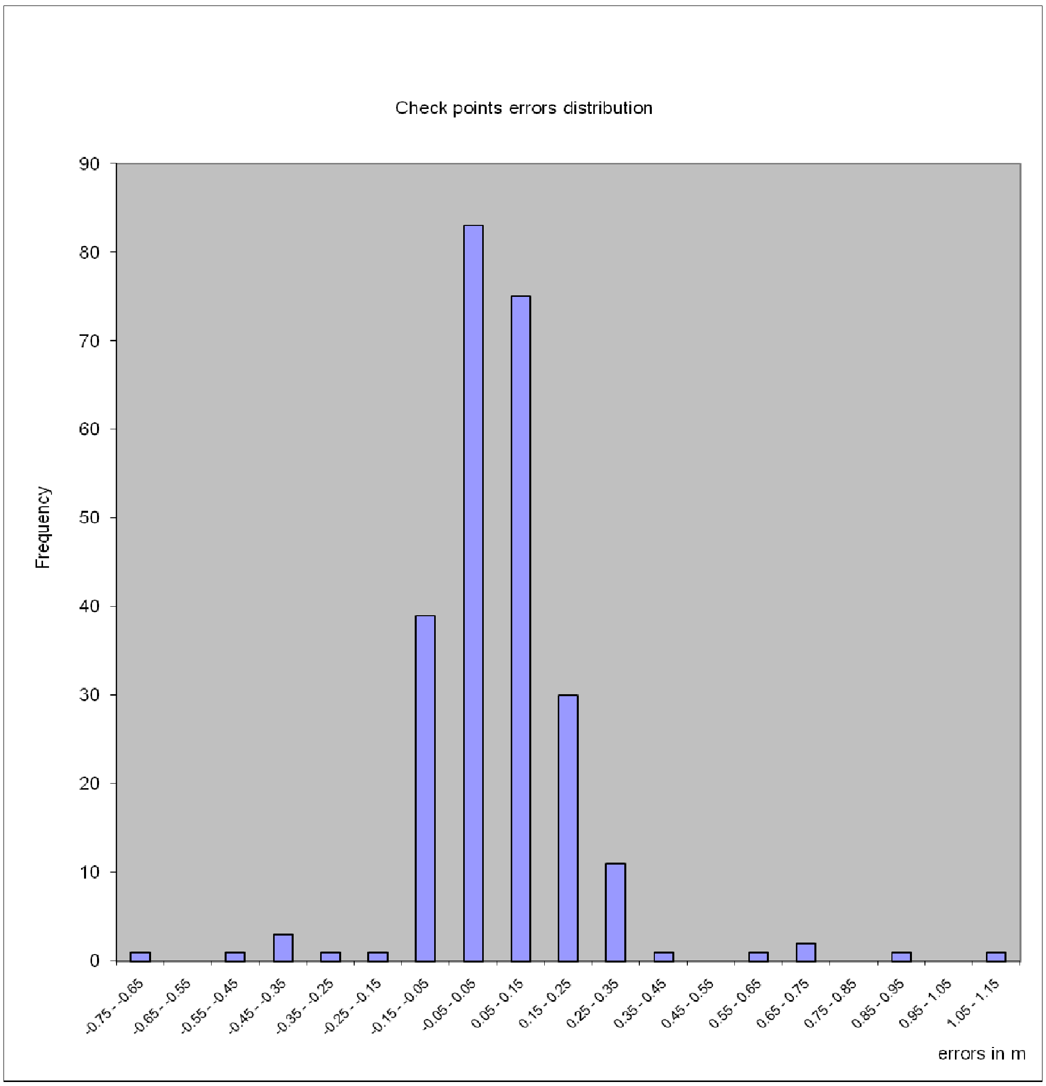


Figure 33 — Histogram of Elevation Discrepancies with errors in meters

CONCLUSION

Based on the vertical accuracy testing conducted by Dewberry, the LiDAR dataset for the USACE Tennessee LiDAR Project satisfies the project's pre-defined vertical accuracy criteria.

Breakline Production & Qualitative Assessment Report

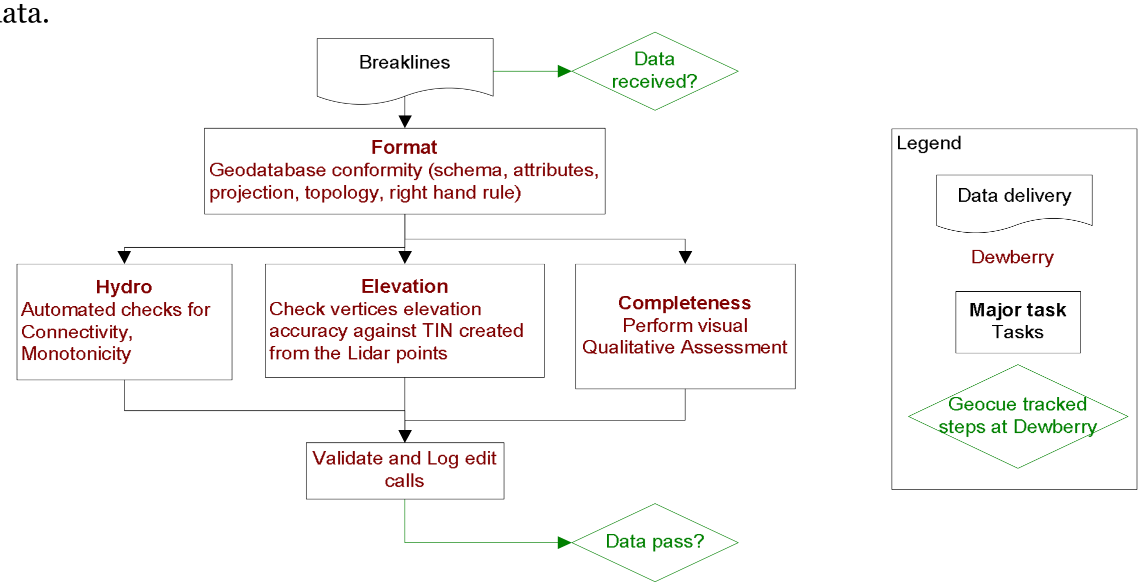
BREAKLINE PRODUCTION METHODOLOGY

Dewberry used GeoCue software to develop LiDAR stereo models of the USACE Tennessee LiDAR Project area so the LiDAR derived data could be viewed in 3-D stereo using Socet Set softcopy photogrammetric software. Using LiDARgrammetry procedures with LiDAR intensity imagery, Dewberry used the stereo models developed by Dewberry to stereo-compile the three types of hard breaklines in accordance with the project's Data Dictionary.

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are reviewed in stereo and the lowest elevation is applied to the entire waterbody.

BREAKLINE QUALITATIVE ASSESSMENT

Dewberry completed breakline qualitative assessments according to a defined workflow. The following workflow diagram represents the steps taken by Dewberry to provide a thorough qualitative assessment of the breakline data.



BREAKLINE TOPOLOGY RULES

Automated checks are applied on hydro features to validate the 3D connectivity of the feature and the monotonicity of the hydrographic breaklines. Dewberry's major concern was that the hydrographic breaklines have a continuous flow downhill and that breaklines do not undulate. Error points are generated at each vertex not complying with the tested rules and these potential edit calls are then visually validated during the visual evaluation of the data. This step also helped validate that breakline vertices did not have excessive minimum or maximum elevations and that elevations are consistent with adjacent vertex elevations.

The next step is to compare the elevation of the breakline vertices against the elevation extracted from the ESRI Terrain built from the LiDAR ground points, keeping in mind that a discrepancy is expected because of the hydro-enforcement applied to the breaklines and because of the interpolated imagery used to acquire the breaklines. A given tolerance is used to validate if the elevations differ too much from the LiDAR.

Dewberry's final check for the breaklines was to perform a full qualitative analysis. Dewberry compared the breaklines against LiDAR intensity images to ensure breaklines were captured in the required locations. The quality control steps taken by Dewberry are outlined in the QA Checklist below.

BREAKLINE QA/QC CHECKLIST

Project Number/Description: TO 0001 USACE Tennessee LiDAR

Date:______11/2/2012____

Overview

☒ All Feature Classes are present in GDB

☒ All features have been loaded into the geodatabase correctly. Ensure feature classes with subtypes are domained correctly.

☒ The breakline topology inside of the geodatabase has been validated. See Data Dictionary for specific rules

☒ Projection/coordinate system of GDB is accurate with project specifications

Perform Completeness check on breaklines using either intensity or ortho imagery

☒ Check entire dataset for missing features that were not captured, but should be to meet baseline specifications or for consistency (See Data Dictionary for specific collection rules). Features should be collected consistently across tile bounds within a dataset as well as be collected consistently between datasets.

☒ Check to make sure breaklines are compiled to correct tile grid boundary and there is full coverage without overlap

☒ Check to make sure breaklines are correctly edge-matched to adjoining datasets if applicable. Ensure breaklines from one dataset join breaklines from another dataset that are coded the same and all connecting vertices between the two datasets match in X,Y, and Z (elevation). There should be no breaklines abruptly ending at dataset boundaries and no discrepancies of Z-elevation in overlapping vertices between datasets.

Compare Breakline Z elevations to LiDAR elevations

☒ Using a terrain created from LiDAR ground points and water points, drape breaklines on terrain to compare Z values. Breakline elevations should be at or below the elevations of the immediately surrounding terrain. This should be performed before other breakline checks are completed.

Perform automated data checks using ESRI's Data Reviewer
The following data checks are performed utilizing ESRI's Data Reviewer extension. These checks allow automated validation of 100% of the data. Error records can either be written to a table for future correction, or browsed for immediate correction. Data Reviewer checks should always be performed on the full dataset.

☒ Perform "adjacent vertex elevation change check" on the Inland Ponds feature class (Elevation Difference Tolerance=.001 meters). This check will return Waterbodies whose vertices are not all identical. This tool is found under "Z Value Checks."

☒ Perform "unnecessary polygon boundaries check" on Inland Ponds and Lakes, Tidal Waters, and Islands (if delivered as a separate feature class) feature classes. This tool is found under "Topology Checks."

☒ Perform "different Z-Value at intersection check" (Inland Streams and Rivers to Inland Streams and Rivers), (Ponds and Lakes to Ponds and Lakes), (Tidal Waters to Tidal Waters), (Streams and Rivers to Ponds and Lakes), (Streams and Rivers to Tidal Waters), (Ponds and Lakes to Tidal Waters), (Island to Inland Ponds and Lakes), (Island to Tidal Waters), (Island to Island),and (Islands to Inland Streams and Rivers) (Elevation Difference Tolerance= .01 feet Minimum, 600 feet Maximum, Touches). This tool is found under "Z Value Checks." Please note that polygon feature classes will need to be converted to lines for this check.

☒ Perform "duplicate geometry check" on (Inland Streams and Rivers to Inland Streams and Rivers), (Inland Ponds and Lakes to Inland Ponds and Lakes), (Tidal Waters to Tidal Waters), (Islands to Islands-if delivered as a separate shapefile), (Inland Streams and Rivers to Inland Ponds and Lakes), (Inland Streams and Rivers to Tidal Waters), (Inland Ponds and Lakes to Tidal Waters), (Islands to Tidal Waters), and (Islands to Inland Ponds and Lakes). Attributes do not need to be checked during this tool. This tool is found under "Duplicate Geometry Checks."

☒ Perform "geometry on geometry check" (Inland Streams and Rivers to Inland Ponds and Lakes), (Inland Streams and Rivers to Tidal Waters), (Inland Ponds and Lakes to Tidal Waters), (Inland Streams and Rivers to Inland Streams and Rivers), (Inland Ponds and Lakes to Inland Ponds and Lakes), (Tidal waters to Tidal waters), (Islands to Tidal Waters), and (Islands to Inland Ponds and Lakes), (Islands to Islands). Spatial relationship is crosses, attributes do not need to be checked. This tool is found under "Feature on Feature Checks." Please note that "crosses" only works with line feature classes and not polygons. If the inputs are polygons, they will need to be converted to a line prior to running this tool.

☒ Perform "geometry on geometry check (Tidal Waters to Islands), and (Inland Ponds and Lakes to Islands), (Inland Streams and Rivers to Islands). Spatial relationship is contains, attributes do not need to be checked. This tool is found under "Feature on Feature Checks."

☒ Perform "geometry on geometry check" (Inland Streams and Rivers to Inland Ponds and Lakes), (Inland Streams and Rivers to Tidal Waters), (Inland Ponds and Lakes to Tidal Waters), (Inland

Streams and Rivers to Inland Streams and Rivers), (Inland Ponds and Lakes to Inland Ponds and Lakes), (Tidal waters to Tidal waters), (Islands to Tidal Waters), and (Islands to Inland Ponds and Lakes), (Islands to Islands). Spatial relationship is intersect, attributes do not need to be checked. This tool is found under "Feature on Feature Checks." Please note that false positives may be returned with this tool but that this tool may identify issues not found with "crosses."

☒ Perform "polygon overlap/gap is sliver check" on (Tidal Waters to Tidal Waters), (Island to Island), (Island to Inland Ponds and Lakes) and (Inland Ponds and Lakes to Inland Ponds and Lakes), (Inland Ponds and Lakes to Tidal Waters). Maximum Polygon Area is not required. This tool is found under "Feature on Feature Checks."

Perform Dewberry Proprietary Tool Checks

☒ Perform monotonicity check on (Inland Streams and Rivers) and (Tidal Waters to Tidal Waters if they are not a constant elevation) using "A3_checkMonotonicityStreamLines." This tool looks at line direction as well as elevation. Features in the output shapefile attributed with a "d" are correct monotonically, but were compiled from low elevation to high elevation. These features are ok and can be ignored. Features in the output shapefile attributed with an "m" are not correct monotonically and need elevations to be corrected. Input features for this tool need to be in a geodatabase and must be a line. If features are a polygon they will need to be converted to a line feature. Z tolerance is .01 feet.

☒ Perform connectivity check between (Inland Streams and Rivers to Inland Streams and Rivers), (Ponds and Lakes to Ponds and Lakes), (Tidal Waters to Tidal Waters), (Streams and Rivers to Ponds and Lakes), (Streams and Rivers to Tidal Waters), (Ponds and Lakes to Tidal Waters), (Island to Inland Ponds and Lakes), (Island to Tidal Waters), (Island to Island),and (Islands to Inland Streams and Rivers) using the tool "07_CheckConnectivityForHydro." The input for this tool needs to be in a geodatabase. The output is a shapefile showing the location of overlapping vertices from the polygon features and polyline features that are at different Z-elevation.

Metadata

☒ Each XML file (1 per feature class) is error free as determined by the USGS MP tool

☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc. Content should be consistent across all feature classes.

Completion Comments: Complete – Approved

Data Dictionary

HORIZONTAL AND VERTICAL DATUM

The horizontal datum shall be North American Datum of 1983, Units in Meters. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in Meters. Geoid09 shall be used to convert ellipsoidal heights to orthometric heights.

COORDINATE SYSTEM AND PROJECTION

All data shall be projected to UTM Zone 16, Horizontal Units in Meters and Vertical Units in Meters.

INLAND STREAMS AND RIVERS

Feature Dataset: BREAKLINES
Feature Class: STREAMS_AND_RIVERS
Feature Type: Polygon

Contains M Values: No
Contains Z Values: Yes
Annotation Subclass: None

XY Resolution: Accept Default Setting
Z Resolution: Accept Default Setting
XY Tolerance: 0.003
Z Tolerance: 0.001

Description

This polygon feature class will depict linear hydrographic features with a width greater than 50 feet.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Streams and Rivers	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 50 feet. In the case of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules.	Capture features showing dual line (one on each side of the feature). Average width shall be greater than 50 feet to show as a double line. Each vertex placed should maintain vertical integrity and data is required to show "closed polygon". Generally both banks shall be collected to show consistent downhill flow. There are exceptions to this rule where a small branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

		Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the feature is greater than ½ acre. The island feature will be represented as a "hole" in the hydrographic feature.

INLAND PONDS AND LAKES

Feature Dataset: BREAKLINES
Feature Class: PONDS_AND_LAKES
Feature Type: Polygon

Contains M Values: No
Contains Z Values: Yes
Annotation Subclass: None

XY Resolution: Accept Default Setting
Z Resolution: Accept Default Setting
XY Tolerance: 0.003
Z Tolerance: 0.001

Description

This polygon feature class will depict closed water body features that are at a constant elevation.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Ponds and Lakes	Land/Water boundaries of constant elevation water bodies such as lakes, reservoirs, ponds, etc. Features shall be defined as closed polygons and contain an elevation value that reflects the best estimate of the water elevation at the time of data capture. Water body features will be captured for features 2 acres in size or greater. "Donuts" will exist where there are islands within a closed water body feature greater than ½ acre in size.	Water bodies shall be captured as closed polygons with the water feature to the right. The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. An Island within a Closed Water Body Feature will also have a "donut polygon" compiled. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the

		water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

CONTACT INFORMATION

Any questions regarding this document should be addressed to:

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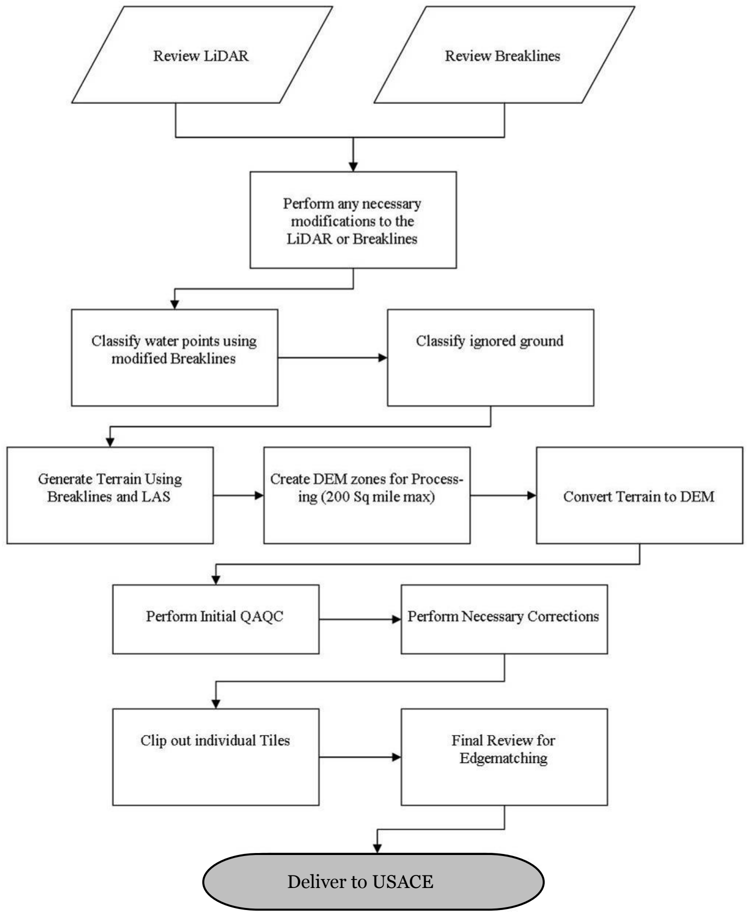
DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

Dewberry utilized ESRI software and Global Mapper for the DEM production and QC process. ArcGIS software is used to generate the products and the QC is performed in both ArcGIS and Global Mapper.

Dewberry Hydro-Flattening Workflow



1. Classify Water Points: LAS point falling within hydrographic breaklines shall be classified to ASPRS class 9 using TerraScan. Breaklines must be prepared correctly prior to performing this task.
2. Classify Ignored Ground Points: Points in close proximity to the breaklines can be classified from Ground to class 10 (Ignored Ground), if desired by the client. Close proximity will be defined as no more than 1x the nominal point spacing on the landward side of the breakline. Ignored ground points were not created for the USACE Tennessee LiDAR project.
3. Terrain Processing: A Terrain will be generated using the Breaklines and LAS data that has been imported into Arc as a Multipoint File.
4. Create DEM Zones for Processing: Create DEM Zones that are buffered around the edges. Zones should be created in a logical manner to minimize the number of zones without creating zones too large for processing. Dewberry will make zones no larger than 200 square miles (taking into account that a DEM will fill in the entire extent not just where LiDAR is present). Once the first zone is created it must be verified against the tile grid to ensure that the cells line up perfectly with the tile grid edge.
5. Convert Terrain to Raster: Convert Terrain to raster using the DEM Zones created in step 4. In the environmental properties set the extents of the raster to the buffered Zone. For each subsequent zone, the first DEM will be utilized as the snap raster to ensure that zones consistently snap to one another.
6. Perform Initial QAQC on Zones: During the initial QA process anomalies will be identified and corrective polygons will be created.

7. Correct Issues on Zones: Dewberry will perform corrections on zones following Dewberry's correction process.
8. Extract Individual Tiles: Dewberry will extract individual tiles from the zones utilizing a Dewberry proprietary tool.
9. Final QA: Final QA will be performed on the dataset to ensure that tile boundaries are seamless.

DEM QUALITATIVE ASSESSMENT

Dewberry performed a comprehensive qualitative assessment of the DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained the proper referencing information. This process was performed in ArcGIS software with the use of a tool set Dewberry has developed to verify that the raster extents match those of the tile grid and contain the correct projection information. The DEM data was reviewed at a scale of 1:5000 to review for artifacts caused by the DEM generation process and to review the hydro-flattened features. To perform this review Dewberry creates HillShade models and overlays a partially transparent colorized elevation model to review for these issues. Upon completion of this review the DEM data is loaded into Global Mapper to ensure that all files are readable and that no artifacts exist between tiles.

DEM QA/QC CHECKLIST

Project Number/Description: TO 0001 USACE Tennessee LiDAR
Date:______11/16/2012_____

Overview

☒ Correct number of files is delivered and all files are in ESRI GRID format
☒ Verify Raster Extents
☒ Verify Projection/Coordinate System

Review

☒ Manually review bare-earth DEMs with a hillshade to check for issues with the hydro-flattening process or any general anomalies that may be present. Specifically, water should be flowing downhill, water features should NOT be floating above surrounding terrain and bridges should NOT be present in bare-earth DEM. Hydrologic breaklines should be overlaid during review of DEMs.
☒ DEM cell size is 1 meter
☒ Perform final overview in Global Mapper to ensure seamless product.

Metadata

☒ Project level DEM metadata XML file is error free as determined by the USGS MP tool

☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc.

Completion Comments: Complete – Approved

Appendix A: Survey Reports

FINAL SURVEY REPORT FOR ORIGINAL TENNESSEE TASK ORDER

Control Point Survey Report
"WESTERN TENNESSEE LiDAR QA"
USACE CONTRACT NUMBER: W912P9-10-D-0534
TASK ORDER NUMBER: 0001
JANUARY, 2011

Prepared for:
United States Army Corps of Engineers
St. Louis District

Dewberry

Prepared By:

Dewberry & Davis, LLC
10003 Derekwood Lane, Suite 204
Lanham, Maryland, 20706
Phone (301)364-1855 Fax (301)731-0188

1. INTRODUCTION

1.1 *Project Summary*

Dewberry & Davis, LLC is under contract to United States Army Corps of Engineers, USACE to provide 189 QA/QC Check Points for all or parts of Obion, Dyer, Gibson, Crockett, Lauderdale, Carroll, Haywood, Madison & Chester counties in Tennessee. These points will be used as an independent verification of the LiDAR to meet the minimum requirements of the NSSDA and as part of the FEMA requirement to verify LiDAR data.

Existing NGS Control Points were located and surveyed to check the accuracy of the RTK/GPS survey equipment with the results shown in Section 2.4 of this Report.

As an internal QA/QC procedure and to verify that the Check Points meet the 95% confidence level one hundred eight (108) points were re-observed and are shown in Section 5 of this report.

Final horizontal coordinates are referenced to UTM, Zone 16, NAD83 (NSRS 2007), Meters. Final Vertical elevations are referenced to NAVD 88 Meters, orthometric heights, using Geoid 09.

1.2 *Points of Contact*

Questions regarding the technical aspects of this report should be addressed to:

Dewberry & Davis, LLC

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Associate
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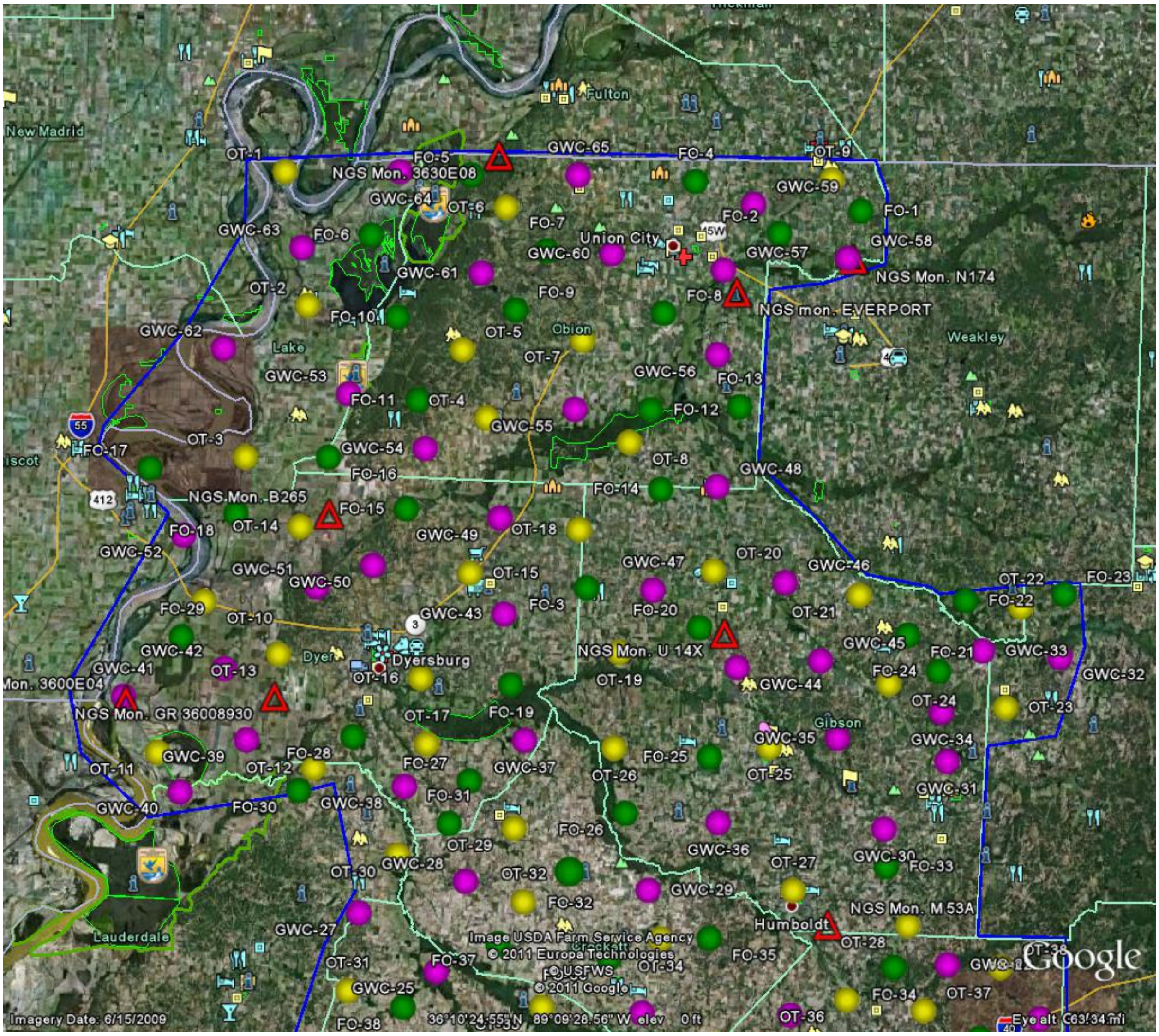
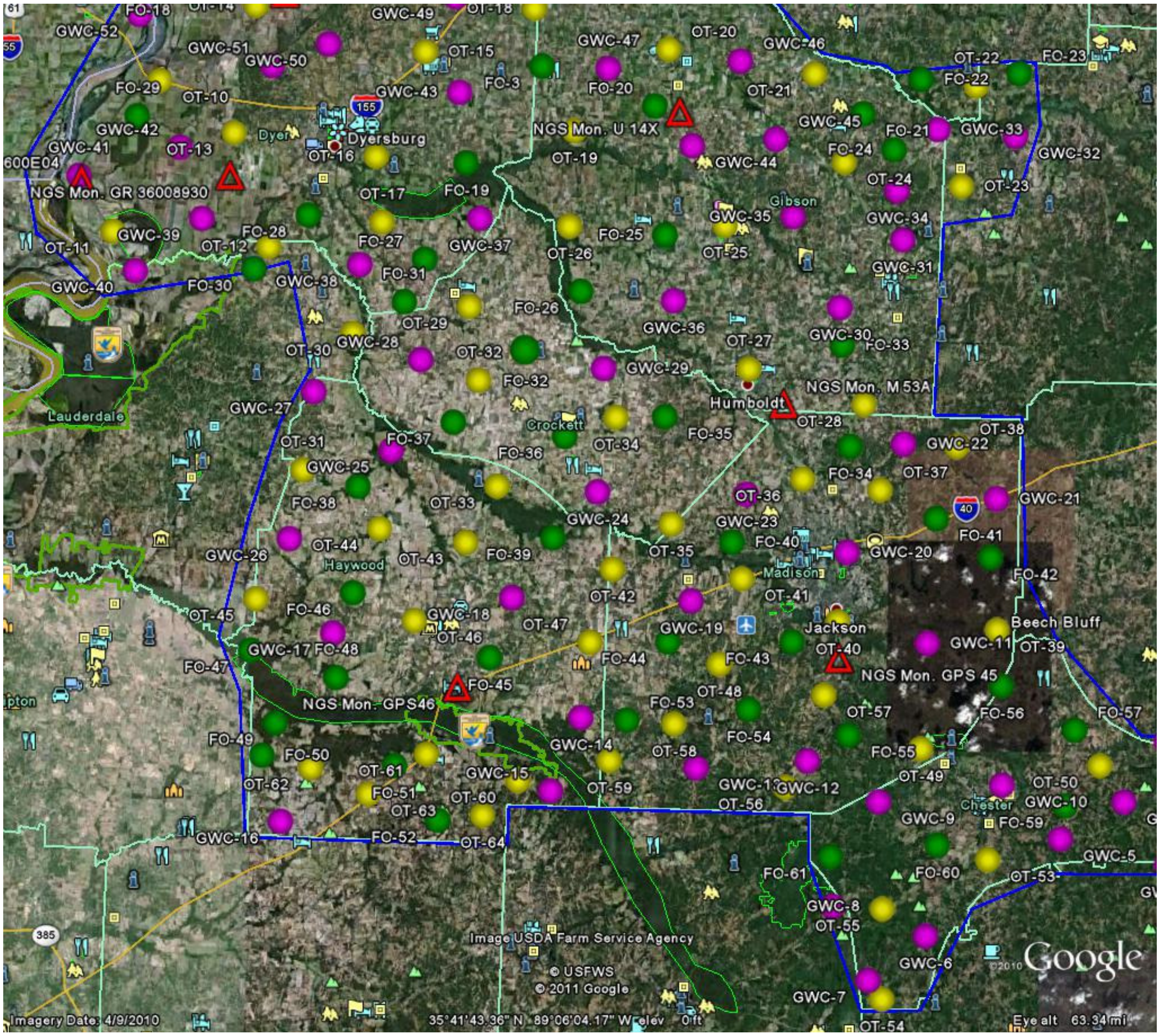
Suite 204
Lanham, Maryland 20706
(301) 364-1855 direct
(301) 731-0188 fax

1.3 *Project Area(s)*

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GWC-49
OT-18
GWC-51
GWC-50
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FO-22
FO-29
OT-10
GWC-43
FO-3
FO-20
OT-21
GWC-42
Dyer
Dyersburg
NGS Mon. U 14X
GWC-45
FO-21
GWC-33
GWC-41
OT-13
OT-16
OT-19
GWC-44
FO-24
GWC-32
600E04
NGS Mon. GR 36008930
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FO-19
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Gibson
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FO-32
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NGS Mon. M 53A
Humboldt
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Jackson
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Image USDA Farm Service Agency
© USFWS
© 2011 Google
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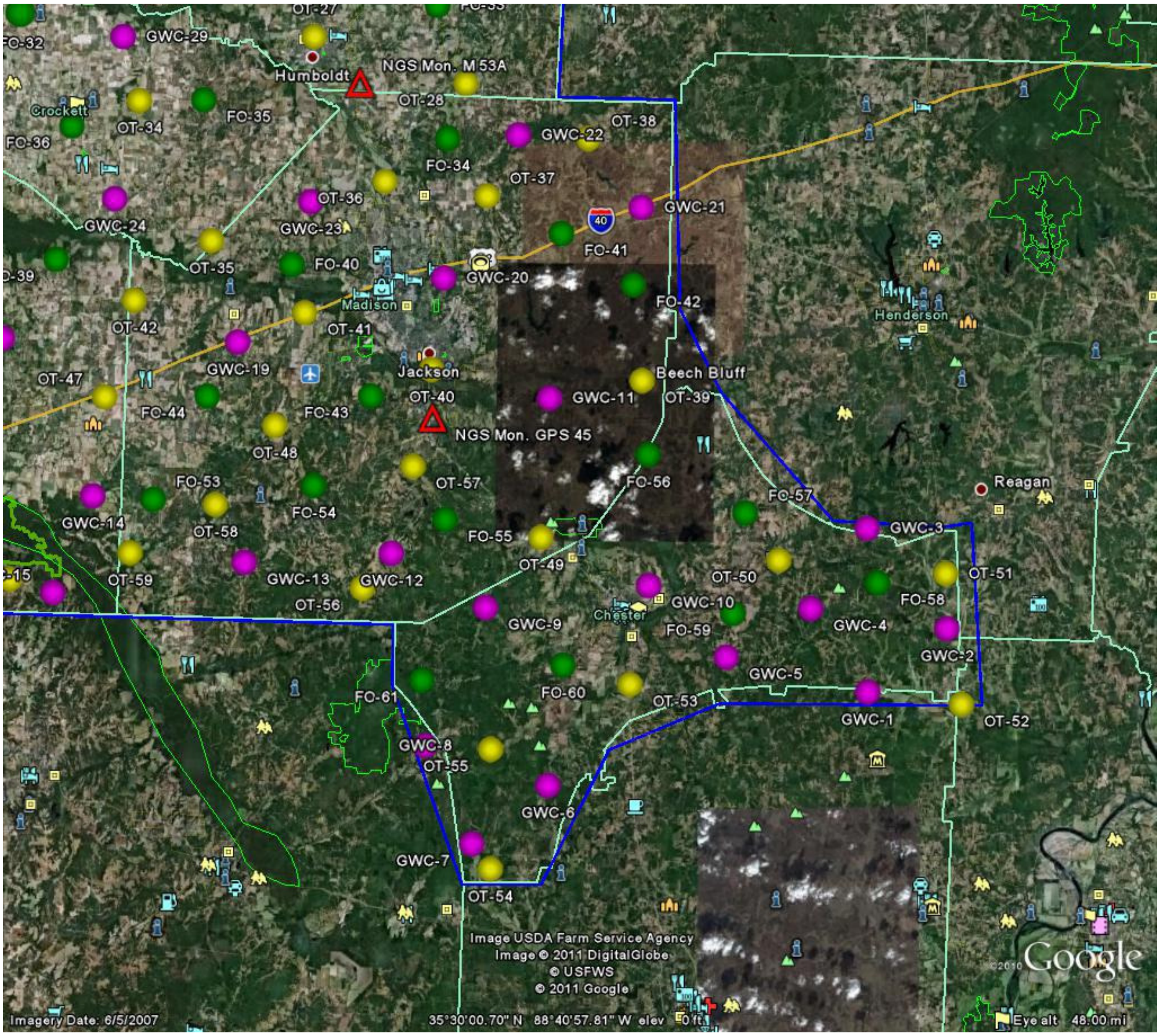
Eye alt 63.34 mi
Google



2.0 Project Details

2.1 *Survey Equipment*

In performing the GPS observations, Trimble R-8 GNSS receiver/antenna attached to a two meter fixed height pole with a Trimble TSC2 Data Collector to collect raw data were used to perform the field surveys.

2.2 *Survey Point Detail*

The 189 Check Points were well distributed throughout the project area so as to cover as many flight lines as possible using the "dispersed method" of placement.

A sketch was made for each location and a nail was set at the point where possible or at an identifiable point. The Check Point locations are detailed on the "Ground Control Point Documentation Report" sheets attached to this report.

2.3 *Network Design*

The GPS survey performed by Dewberry & Davis, LLC office located in Lanham, Maryland was tied to a Real Time Network (RTN) managed by Earl Dudley, Inc. The network is a series of continuously operating, high precision GPS reference stations. All of the reference stations have been linked together using Trimble GPSNet software, creating a Virtual Reference Station System (VRS).

The Trimble NetR5 Reference Station is a multi-channel, multi-frequency GNSS (Global Navigation Satellite System) receiver designed for use as a stand-alone reference station or as part of a GNSS infrastructure solution. Trimble R-Track technology in the NetR5 receiver supports the modernized GPS L2C and L5 signals as well as GLONASS L1/L2 signals.

2.4 *Field Survey Procedures and Analysis*

Dewberry & Davis, LLC used Trimble R-8 GNSS receivers, which is a geodetic quality dual frequency GPS receiver, to collect data at each surveyed location.

All locations were occupied once with approximately 57% of the locations being re-observed. All re-observations matched the initially derived station positions within the allowable tolerance of ± 5cm or within the 95% confidence level. Each occupation which utilized the VRS network was occupied for three (3) minutes in duration.

Each occupation which utilized OPUS (if used) was occupied between 18 and 20 minutes.

Field GPS observations are detailed on the “Ground Control Point Documentation Reports” submitted as part of this report.

Five (5) existing NGS monuments listed in the NSRS database were located as an additional QA/QC method to check the accuracy of the VRS network as well as being the primary project control monuments designated as PID FE2747, DG5302, GD1912, DF7947 AND DH3700. The results are as follows:

	As Surveyed (UTM16)			Published (UTM 16)			Differences (ft)		
NGS Name	Northing(ft)	Easting(ft)	Elev.(ft)	Northing(ft)	Easting(ft)	Elev.(ft)	Δ N	Δ E	Δ Elev.
GPS 45	12919065.740	1102146.720	395.154	12919065.76	1102146.88	395.1	-0.02	-0.16	+0.05
U 14X	13101878.015	1051137.146	355.700	13101878.01	1051137.06	355.8	+0.01	+0.09	-0.10
EVERPORT	13215622.160	1056677.821	312.479	13215622.23	1056677.73	312.4	-0.07	+0.09	+0.08
GR 36008930	13082612.410	900112.134	262.690	13082612.51	900112.25	262.8	-0.10	-0.12	-0.11
3600E04	13081770.200	850146.544	278.102	13081770.29	850146.64	278.2	-0.09	-0.10	-0.10

The above results indicate that the VRS network is providing positional values within the 5cm parameters for this survey.

2.5 *Adjustment*

The survey data was collected using Virtual Reference Stations (VRS) methodology within a Virtual Reference System (VRS).

The system is designed to provide a true Network RTK performance, the RTKNet software enables high-accuracy positioning in real time across a geographic region. The RTKNet software package uses real-time data streams from the GPSNet system user and generates correction models for high-accuracy RTK GPS corrections throughout the network. Therefore, corrections were applied to the points as they were being collected, thus negating the need for a post process adjustment.

2.6 *Data Processing Procedures*

After field data is collected the information is downloaded from the data collectors into the office software. The Software program used is called TGO or Trimble Geomatics Office.

Downloaded data is run through the TGO program to obtain the following reports; points report, point comparison report and a point detail report. The reports are reviewed for point accuracy and precision.

After review of the point data an “ASCII” or “txt” file which is the industry standard is created. Point files are loaded into our CADD program (Carlson Survey 2010) to make a visual check of the point data (Pt. #, Coordinates, Elev. and Description). The data can now be imported into the final product.

3. FINAL COORDINATES

WESTERN TENNESSEE LiDAR - FINAL COORDINATES			
	UTM ZONE 16 (NAD83)		NAVD 88
OPEN TERRAIN			
POINT ID	NORTHING (M)	EASTING (M)	HEIGHT (M)
OT-1	4041087.152	276103.327	91.184
OT-2	4027402.153	278235.146	87.051
OT-3	4012062.526	271709.627	83.284
OT-4	4015724.769	296442.309	97.536
OT-5	4022695.385	294023.454	144.070
OT-6	4037120.111	298667.747	94.884
OT-7	4023517.058	306282.181	106.165
OT-8	4013076.155	310948.606	91.202
OT-9	4039547.564	331994.844	128.507
OT-10	3997234.531	267044.128	89.435
OT-11	3982131.429	262323.159	79.230
OT-12	3980343.005	278271.117	115.708
OT-13	3991973.651	274844.397	83.332
OT-14	4004929.737	277217.184	82.336
OT-15	3999997.661	294580.307	103.440
OT-16	3989345.130	289214.338	85.817

OT-17	3982839.472	289714.086	95.497
OT-18	4004264.196	305686.916	106.235
OT-19	3991714.105	309624.227	94.226
OT-20	3999819.369	319372.514	110.118
OT-21	3997230.156	334246.500	108.271
OT-22	3995783.499	350797.656	137.611
OT-23	3985583.517	349059.702	114.038
OT-24	3988172.530	337143.880	121.411
OT-25	3981889.789	324883.081	114.191
OT-26	3981988.941	308979.954	90.349
OT-27	3967266.618	327135.948	110.173
OT-28	3963506.565	338849.133	140.239
OT-29	3973971.231	298681.561	102.855
OT-30	3971365.692	286780.324	83.869
OT-31	3957570.151	281509.305	104.123
OT-32	3966481.237	299573.385	107.232
OT-33	3955671.517	301326.018	89.258
OT-34	3962515.328	313526.788	103.763
OT-35	3951621.470	319015.662	104.147
OT-36	3956116.366	332726.992	117.488
OT-37	3954834.903	340344.805	128.708
OT-38	3959090.838	348247.123	142.887
OT-39	3940422.841	352163.167	118.802
OT-40	3941476.180	335947.629	108.585
OT-41	3946009.063	326257.625	105.351
OT-42	3947110.580	312939.152	132.728
OT-43	3950011.861	298026.269	103.257
OT-44	3951729.856	289114.835	92.169
OT-45	3944494.301	276559.234	96.896
OT-46	3942150.431	292750.500	113.608
OT-47	3939818.156	310647.008	122.954
OT-48	3937334.544	323739.578	152.751
OT-49	3928497.646	344070.899	116.614
OT-50	3926553.328	362553.650	159.389
OT-51	3925262.681	375501.676	171.200
OT-52	3915491.168	375644.553	128.775
OT-53	3917103.157	350962.571	143.144
OT-54	3902698.799	339800.081	131.704
OT-55	3912235.144	340162.146	153.656
OT-56	3924704.365	330351.111	142.382
OT-57	3934013.677	334472.074	135.703
OT-58	3931271.649	319078.297	125.355
OT-59	3927656.877	312407.770	101.243

OT-60	3925733.624	303041.794	118.101
OT-61	3928575.433	293765.812	94.153
OT-62	3927278.590	281932.972	103.772
OT-63	3924490.853	287735.715	101.822
OT-64	3922436.358	299253.551	104.123
GRASS, WEEDS, CROPS			
GWC-1	3916200.698	369265.950	125.572
GWC-2	3921069.587	375551.881	127.023
GWC-3	3928222.313	369155.847	193.036
GWC-4	3922495.391	365378.918	171.420
GWC-5	3918967.293	358457.162	130.144
GWC-6	3909359.183	344465.959	195.542
GWC-7	3904903.596	338661.380	169.835
GWC-8	3912708.043	334606.419	127.885
GWC-9	3923050.005	339435.166	142.491
GWC-10	3924474.758	352455.623	129.632
GWC-11	3939078.272	345081.098	115.721
GWC-12	3927419.615	332790.714	149.300
GWC-13	3926863.962	321068.680	146.173
GWC-14	3932104.849	309570.668	102.440
GWC-15	3924454.145	306517.827	132.445
GWC-16	3921870.024	278756.980	104.473
GWC-17	3940910.215	284565.916	108.652
GWC-18	3944235.277	302542.193	115.483
GWC-19	3944066.255	320990.491	128.419
GWC-20	3948520.511	336948.377	148.255
GWC-21	3953796.500	352076.727	169.628
GWC-22	3959437.474	342858.482	116.522
GWC-23	3954482.061	326687.620	130.385
GWC-24	3954842.270	311510.781	107.037
GWC-25	3959490.989	290491.541	86.798
GWC-26	3950430.503	280092.403	95.564
GWC-27	3965493.239	282684.500	121.567
GWC-28	3968614.001	293676.780	114.358
GWC-29	3967520.408	312219.252	99.368
GWC-30	3973410.322	336500.141	109.326
GWC-31	3980306.498	343088.755	114.636
GWC-32	3990613.399	354680.042	113.410
GWC-33	3991404.830	346786.068	116.635
GWC-34	3985238.566	342517.965	145.948
GWC-35	3982781.282	331802.624	115.163
GWC-36	3974315.347	319582.850	99.783

GWC-37	3983260.639	299977.351	83.680
GWC-38	3978345.827	287604.356	91.897
GWC-39	3984207.127	271267.474	79.047
GWC-40	3978071.208	264390.252	79.202
GWC-41	3987804.719	258943.203	79.431
GWC-42	3990629.258	269390.781	79.782
GWC-43	3995869.951	297725.080	93.857
GWC-44	3990049.283	321786.350	109.804
GWC-45	3990518.670	330329.517	107.354
GWC-46	3998758.079	326631.438	122.883
GWC-47	3998073.553	313087.651	102.319
GWC-48	4008496.857	319839.844	89.913
GWC-49	4005565.536	297363.308	94.004
GWC-50	4000906.001	284372.245	141.019
GWC-51	3998797.164	278870.793	145.722
GWC-52	4004183.649	265228.276	81.217
GWC-53	4018351.687	282349.932	85.445
GWC-54	4012667.963	290103.633	97.597
GWC-55	4016504.284	305423.585	87.828
GWC-56	4021877.712	320101.890	112.849
GWC-57	4030481.328	320778.459	92.074
GWC-58	4031570.621	333509.706	104.696
GWC-59	4037141.096	323924.275	100.913
GWC-60	4032248.108	309404.611	110.859
GWC-61	4030497.281	296073.266	135.085
GWC-62	4023129.303	269584.112	84.991
GWC-63	4033284.899	277782.855	90.239
GWC-64	4040911.974	287871.856	88.353
GWC-65	4040290.702	306081.415	116.897
FOREST			
FO-1	4036329.644	334884.644	111.136
FO-2	4034153.343	326561.941	108.826
FO-3	3998347.748	306346.074	105.613
FO-5	4040446.348	295122.247	89.886
FO-6	4034500.267	284824.940	86.448
FO-7	4032602.856	302763.108	115.980
FO-8	4026177.744	314587.659	121.134
FO-9	4026663.188	299533.419	140.035
FO-10	4026079.105	287368.616	95.098
FO-11	4017596.839	289466.004	135.612
FO-12	4016347.488	313172.668	88.097
FO-13	4016600.984	322125.842	87.347

FO-14	4008242.975	314091.271	95.220
FO-15	4006430.085	287984.766	86.722
FO-16	4011931.120	280215.409	83.387
FO-17	4011071.948	261873.890	83.003
FO-18	4006270.677	270748.424	80.909
FO-19	3988473.187	298593.002	99.709
FO-20	3994129.590	317856.871	102.258
FO-21	3993114.914	339197.921	135.152
FO-22	3996531.727	345213.569	126.602
FO-23	3997061.354	355215.034	135.173
FO-24	3989400.789	342362.762	128.601
FO-25	3980970.707	318775.175	104.303
FO-26	3975341.158	310081.398	90.005
FO-27	3978904.353	294098.422	89.179
FO-28	3983576.367	282393.769	81.485
FO-29	3993858.099	264865.767	78.023
FO-30	3977799.758	276769.932	107.570
FO-31	3974517.318	292068.927	86.265
FO-32	3969485.916	304337.170	113.779
FO-33	3969585.819	336677.136	119.226
FO-34	3959102.751	337467.082	120.914
FO-35	3962484.342	318542.092	110.935
FO-36	3960642.722	308276.706	118.476
FO-37	3962216.370	296940.927	91.465
FO-38	3955783.608	287113.361	88.828
FO-39	3951022.257	309707.389	93.333
FO-40	3949782.601	325277.250	131.973
FO-41	3951863.595	346089.114	164.745
FO-42	3947804.949	349615.887	149.864
FO-43	3939514.683	331427.808	115.849
FO-44	3939605.365	318451.157	124.977
FO-45	3938291.792	300343.753	106.695
FO-46	3945015.639	286502.858	112.630
FO-47	3939416.009	275900.636	81.528
FO-48	3936400.327	284642.370	90.636
FO-49	3931891.762	278380.120	83.698
FO-50	3928605.548	276955.662	87.289
FO-51	3927619.005	290759.198	92.873
FO-52	3921770.567	294821.190	119.375
FO-53	3931777.736	314343.491	121.637
FO-54	3932656.475	326711.635	137.782
FO-55	3929930.747	336714.611	147.770
FO-56	3934731.143	352735.545	145.615

FO-57	3929962.154	360127.548	136.395
FO-58	3924818.370	370028.519	166.461
FO-59	3922455.886	359008.124	152.824
FO-60	3918376.106	346279.087	144.856
FO-61	3917590.688	334903.718	141.062

4. GPS OBSERVATION & RE-OBSERVATION SCHEDULE

POINT ID	Observ. Date	Julian Date	Time of Day	Re-Observ. Date	Re-Observ. Time
OT-1	2/2/2011	33	10:30	2/6/2011	17:04
OT-2	2/2/2011	33	12:15	2/6/2011	17:48
OT-3	2/2/2011	33	14:40	2/6/2011	16:30
OT-4	2/3/2011	34	14:00	2/6/2011	12:10
OT-5	2/4/2011	35	14:27	2/6/2011	17:29
OT-6	2/6/2011	37	7:29	2/8/2011	10:50
OT-7	2/2/2011	33	9:00	2/3/2011	17:09
OT-8	2/2/2011	33	8:20	N/A	N/A
OT-9	2/5/2011	36	14:53	2/6/2011	9:20
OT-10	2/4/2011	35	17:24	2/5/2011	17:23
OT-11	2/4/2011	35	13:24	2/5/2011	16:32
OT-12	2/4/2011	35	11:27	2/5/2011	14:53
OT-13	2/4/2011	35	16:13	2/5/2011	17:04
OT-14	2/2/2011	33	15:50	2/6/2011	13:33
OT-15	2/2/2011	33	14:20	2/6/2011	9:50
OT-16	2/4/2011	35	6:40	2/5/2011	10:30
OT-17	2/4/2011	35	9:07	2/5/2011	10:03
OT-18	2/2/2011	33	12:51	N/A	N/A
OT-19	2/5/2011	36	13:15	2/6/2011	9:20
OT-20	2/2/2011	33	14:20	2/5/2011	17:45
OT-21	2/4/2011	35	17:15	N/A	N/A
OT-22	2/4/2011	35	9:45	2/4/2011	9:40
OT-23	2/4/2011	35	8:10	2/4/2011	9:05
OT-24	2/4/2011	35	16:20	2/4/2011	10:25
OT-25	2/5/2011	36	11:20	2/5/2011	10:40
OT-26	2/5/2011	36	12:50	2/5/2011	9:00
OT-27	2/3/2011	34	10:20	2/5/2011	7:45
OT-28	2/3/2011	34	8:45	N/A	N/A
OT-29	2/3/2011	34	14:25	2/5/2011	11:31
OT-30	2/3/2011	34	13:02	2/5/2011	14:08

OT-31	2/3/2011	34	8:16	2/5/2011	13:22
OT-32	2/3/2011	34	13:33	2/5/2011	12:10
OT-33	2/3/2011	34	14:30	2/5/2011	12:38
OT-34	2/3/2011	34	12:30	N/A	N/A
OT-35	2/3/2011	34	11:00	N/A	N/A
OT-36	2/2/2011	33	8:36	N/A	N/A
OT-37	2/2/2011	33	9:39	2/5/2011	12:15
OT-38	2/2/2011	33	10:40	N/A	N/A
OT-39	2/2/2011	33	14:09	2/5/2011	9:15
OT-40	2/2/2011	33	15:28	2/2/2011	16:50
OT-41	2/4/2011	35	10:10	2/4/2011	10:41
OT-42	2/3/2011	34	13:17	2/5/2011	8:15
OT-43	2/3/2011	34	9:30	2/5/2011	8:51
OT-44	2/2/2011	33	17:50	N/A	N/A
OT-45	2/2/2011	33	15:55	2/5/2011	9:20
OT-46	2/3/2011	34	8:50	2/5/2011	9:45
OT-47	2/3/2011	34	13:44	2/5/2011	10:21
OT-48	2/4/2011	35	9:06	2/5/2011	10:55
OT-49	2/2/2011	33	8:20	2/4/2011	11:20
OT-50	2/3/2011	34	17:15	2/4/2011	11:52
OT-51	2/3/2011	34	16:34	N/A	N/A
OT-52	2/3/2011	34	15:33	2/5/2011	11:45
OT-53	2/3/2011	34	13:21	2/5/2011	12:20
OT-54	2/3/2011	34	11:49	N/A	N/A
OT-55	2/3/2011	34	10:45	N/A	N/A
OT-56	2/2/2011	33	17:31	2/5/2011	13:20
OT-57	2/2/2011	33	16:23	2/5/2011	13:45
OT-58	2/4/2011	35	7:56	2/5/2011	11:20
OT-59	2/3/2011	34	15:21	N/A	N/A
OT-60	2/2/2011	33	9:46	N/A	N/A
OT-61	2/2/2011	33	8:20	2/6/2011	11:45
OT-62	2/2/2011	33	12:44	2/6/2011	8:15
OT-63	2/2/2011	33	11:54	N/A	N/A
OT-64	2/2/2011	33	10:46	2/6/2011	9:20

POINT ID	Observ. Date	Julian Date	Time of Day	Re-Observ. Date	Re-Observ. Time
GWC-1	2/3/2011	34	15:00	2/5/2011	17:55
GWC-2	2/3/2011	34	16:06	N/A	N/A
GWC-3	2/4/2011	35	8:21	N/A	N/A
GWC-4	2/3/2011	34	14:44	N/A	N/A
GWC-5	2/3/2011	34	14:19	2/5/2011	14:15
GWC-6	2/3/2011	34	12:23	2/5/2011	14:50

GWC-7	2/3/2011	34	11:20	N/A	N/A
GWC-8	2/3/2011	34	10:16	2/5/2011	15:20
GWC-9	2/2/2011	33	8:50	2/5/2011	15:45
GWC-10	2/3/2011	34	13:41	N/A	N/A
GWC-11	2/2/2011	33	14:20	N/A	N/A
GWC-12	2/2/2011	33	17:08	N/A	N/A
GWC-13	2/4/2011	35	7:28	2/5/2011	16:21
GWC-14	2/3/2011	34	14:51	2/5/2011	7:01
GWC-15	2/2/2011	33	10:15	2/5/2011	7:35
GWC-16	2/2/2011	33	12:16	N/A	N/A
GWC-17	2/3/2011	34	8:20	2/5/2011	16:45
GWC-18	2/3/2011	34	11:46	N/A	N/A
GWC-19	2/3/2011	34	17:36	N/A	N/A
GWC-20	2/2/2011	33	7:49	2/3/2011	11:20
GWC-21	2/2/2011	33	11:19	2/6/2011	6:52
GWC-22	2/2/2011	33	10:15	2/6/2011	7:20
GWC-23	2/2/2011	33	8:18	2/6/2011	8:20
GWC-24	2/3/2011	34	11:20	N/A	N/A
GWC-25	2/3/2011	34	10:20	2/5/2011	13:01
GWC-26	2/2/2011	33	16:26	2/6/2011	8:45
GWC-27	2/3/2011	34	13:44	2/5/2011	13:52
GWC-28	2/3/2011	34	13:18	2/5/2011	11:52
GWC-29	2/3/2011	34	13:45	2/6/2011	8:10
GWC-30	2/3/2011	34	7:30	2/6/2011	7:25
GWC-31	2/4/2011	35	7:40	2/5/2011	8:05
GWC-32	2/4/2011	35	8:40	2/5/2011	9:25
GWC-33	2/4/2011	35	10:10	2/5/2011	10:00
GWC-34	2/5/2011	36	8:35	N/A	N/A
GWC-35	2/4/2011	35	15:30	N/A	N/A
GWC-36	2/3/2011	34	16:08	2/6/2011	8:30
GWC-37	2/4/2011	35	8:40	N/A	N/A
GWC-38	2/3/2011	34	15:25	2/5/2011	14:32
GWC-39	2/4/2011	35	12:18	N/A	N/A
GWC-40	2/4/2011	35	13:20	2/5/2011	15:20
GWC-41	2/4/2011	35	14:19	2/5/2011	16:28
GWC-42	2/4/2011	35	15:56	2/5/2011	16:45
GWC-43	2/2/2011	33	14:42	N/A	N/A
GWC-44	2/4/2011	35	14:15	2/5/2011	16:05
GWC-45	2/4/2011	35	14:45	2/5/2011	16:40
GWC-46	2/4/2011	35	13:15	2/5/2011	17:30
GWC-47	2/5/2011	36	14:30	2/6/2011	9:40
GWC-48	2/2/2011	33	12:20	N/A	N/A
GWC-49	2/2/2011	33	12:30	N/A	N/A

GWC-50	2/5/2011	36	6:50	N/A	N/A
GWC-51	2/5/2011	36	7:15	2/6/2011	9:03
GWC-52	2/2/2011	33	16:52	N/A	N/A
GWC-53	2/2/2011	33	13:54	2/6/2011	16:32
GWC-54	2/4/2011	35	14:28	2/6/2011	12:59
GWC-55	2/5/2011	36	7:00	2/6/2011	11:49
GWC-56	2/5/2011	36	7:56	N/A	N/A
GWC-57	2/5/2011	36	10:19	2/6/2011	11:15
GWC-58	2/5/2011	36	11:52	2/6/2011	12:42
GWC-59	2/5/2011	36	15:29	2/6/2011	14:08
GWC-60	2/6/2011	37	10:28	N/A	N/A
GWC-61	2/6/2011	37	8:09	2/8/2011	10:00
GWC-62	2/2/2011	33	13:07	N/A	N/A
GWC-63	2/2/2011	33	11:23	2/6/2011	16:29
GWC-64	2/4/2011	35	10:15	N/A	N/A
GWC-65	2/5/2011	36	17:05	2/6/2011	15:02

POINT ID	Observ. Date	Julian Date	Time of Day	Re-Observ. Date	Re-Observ. Time
FO-1	2/5/2011	36	14:01	2/6/2011	14:30
FO-2	2/5/2011	36	13:03	N/A	N/A
FO-3	2/5/2011	36	13:45	N/A	N/A
FO-5	2/4/2011	35	9:26	N/A	N/A
FO-6	2/4/2011	35	11:02	N/A	N/A
FO-7	2/4/2011	35	9:45	N/A	N/A
FO-8	2/5/2011	36	8:45	N/A	N/A
FO-9	2/6/2011	37	8:57	N/A	N/A
FO-10	2/4/2011	35	12:14	N/A	N/A
FO-11	2/4/2011	35	13:22	2/6/2011	10:15
FO-12	2/2/2011	33	9:29	N/A	N/A
FO-13	2/2/2011	33	11:20	N/A	N/A
FO-14	2/2/2011	33	13:10	N/A	N/A
FO-15	2/5/2011	36	14:30	2/6/2011	10:15
FO-16	2/4/2011	35	15:12	N/A	N/A
FO-17	2/3/2011	34	17:00	N/A	N/A
FO-18	2/6/2011	37	14:07	N/A	N/A
FO-19	2/4/2011	35	8:45	N/A	N/A
FO-20	2/5/2011	36	15:00	N/A	N/A
FO-21	2/4/2011	35	11:55	N/A	N/A
FO-22	2/4/2011	35	11:05	N/A	N/A
FO-23	2/4/2011	35	9:05	N/A	N/A
FO-24	2/4/2011	35	16:50	N/A	N/A
FO-25	2/5/2011	36	12:00	N/A	N/A

FO-26	2/3/2011	34	14:30	N/A	N/A
FO-27	2/3/2011	34	16:05	2/5/2011	15:42
FO-28	2/4/2011	35	10:30	N/A	N/A
FO-29	2/4/2011	35	16:43	N/A	N/A
FO-30	2/4/2011	35	12:05	N/A	N/A
FO-31	2/3/2011	34	16:06	N/A	N/A
FO-32	2/3/2011	34	14:05	N/A	N/A
FO-33	2/3/2011	34	8:00	N/A	N/A
FO-34	2/3/2011	34	9:06	N/A	N/A
FO-35	2/3/2011	34	12:50	2/6/2011	15:50
FO-36	2/3/2011	34	11:45	N/A	N/A
FO-37	2/3/2011	34	12:15	N/A	N/A
FO-38	2/3/2011	34	10:30	N/A	N/A
FO-39	2/3/2011	34	10:20	2/4/2011	7:20
FO-40	2/4/2011	35	11:30	N/A	N/A
FO-41	2/2/2011	33	11:59	N/A	N/A
FO-42	2/2/2011	33	13:04	N/A	N/A
FO-43	2/4/2011	35	9:50	N/A	N/A
FO-44	2/3/2011	34	16:40	N/A	N/A
FO-45	2/3/2011	34	12:36	N/A	N/A
FO-46	2/3/2011	34	13:15	N/A	N/A
FO-47	2/2/2011	33	16:20	N/A	N/A
FO-48	2/3/2011	34	7:55	N/A	N/A
FO-49	2/2/2011	33	14:04	N/A	N/A
FO-50	2/2/2011	33	13:35	2/6/2011	14:21
FO-51	2/2/2011	33	8:45	N/A	N/A
FO-52	2/2/2011	33	11:26	N/A	N/A
FO-53	2/3/2011	34	16:00	N/A	N/A
FO-54	2/4/2011	35	8:43	N/A	N/A
FO-55	2/2/2011	33	16:41	N/A	N/A
FO-56	2/4/2011	35	10:03	N/A	N/A
FO-57	2/4/2011	35	9:02	N/A	N/A
FO-58	2/4/2011	35	7:23	N/A	N/A
FO-59	2/3/2011	34	14:04	N/A	N/A
FO-60	2/3/2011	34	13:02	N/A	N/A
FO-61	2/3/2011	34	9:14	2/6/2011	12:20

5. POINT COMPARISON REPORT

POINT ID NO.	Point Check	Delta North (ft)	Delta East (ft)	Vert. (ft)
OT-1	OT-1CK	0.03	0.08	0.15

OT-2	OT-2CK	0.09	0.03	0.15
OT-3	OT-3CK	0.01	0.03	0.15
OT-4	OT-4CK	0.04	0.07	0.15
OT-5	OT-5CK	0.06	0.02	0.03
OT-6	OT-6CK	0.05	0.01	0.15
OT-7	OT-7CK	0.01	0.03	0.08
OT-9	OT-9CK	0.03	0.03	0.04
OT-10	OT-10CK	0.00	0.02	0.06
OT-11	OT-11CK	0.05	0.10	0.15
OT-12	OT-12CK	0.02	0.01	0.11
OT-13	OT-13CK	0.01	0.02	0.03
OT-14	OT-14CK	0.05	0.04	0.11
OT-15	OT-15CK	0.02	0.15	0.09
OT-16	OT-16CK	0.01	0.05	0.06
OT-17	OT-17CK	0.02	0.01	0.13
OT-19	OT-19CK	0.01	0.01	0.12
OT-20	OT-20CK	0.02	0.04	0.10
OT-22	OT-22CK	0.04	0.01	0.02
OT-23	OT-23CK	0.06	0.04	0.02
OT-24	OT-24CK	0.15	0.03	0.15
OT-25	OT-25CK	0.10	0.02	0.06
OT-26	OT-26CK	0.01	0.02	0.09
OT-27	OT-27CK	0.02	0.03	0.15
OT-29	OT-29CK	0.02	0.09	0.15
OT-30	OT-30CK	0.15	0.03	0.14
OT-31	OT-31CK	0.09	0.05	0.09
OT-32	OT-32CK	0.04	0.03	0.07
OT-33	OT-33CK	0.15	0.01	0.10
OT-37	OT-37CK	0.03	0.05	0.06
OT-39	OT-39CK	0.02	0.03	0.05
OT-40	OT-40CK	0.10	0.09	0.06
OT-41	OT-41CK	0.11	0.09	0.08
OT-42	OT-42CK	0.05	0.06	0.06
OT-43	OT-43CK	0.08	0.08	0.06
OT-45	OT-45CK	0.09	0.06	0.07
OT-46	OT-46CK	0.07	0.07	0.06
OT-47	OT-47CK	0.06	0.03	0.02
OT-48	OT-48CK	0.08	0.09	0.10
OT-49	OT-49CK	0.00	0.06	0.03
OT-50	OT-50CK	0.07	0.06	0.05
OT-52	OT-52CK	0.02	0.03	0.09
OT-53	OT-53CK	0.09	0.06	0.06
OT-56	OT-56CK	0.08	0.06	0.06

OT-57	OT-57CK	0.06	0.02	0.03
OT-58	OT-58CK	0.08	0.09	0.03
OT-61	OT-61CK	0.10	0.11	0.15
OT-62	OT-62CK	0.03	0.05	0.06
OT-64	OT-64CK	0.09	0.07	0.04
GWC-1	GWC-1CK	0.03	0.02	0.06
GWC-5	GWC-5CK	0.09	0.00	0.06
GWC-6	GWC-6CK	0.03	0.01	0.01
GWC-8	GWC-8CK	0.09	0.01	0.05
GWC-9	GWC-9CK	0.09	0.11	0.15
GWC-13	GWC-13CK	0.06	0.05	0.03
GWC-14	GWC-14CK	0.08	0.09	0.06
GWC-15	GWC-15CK	0.01	0.02	0.06
GWC-17	GWC-17CK	0.08	0.09	0.02
GWC-20	GWC-20CK	0.08	0.06	0.04
GWC-21	GWC-21CK	0.09	0.07	0.08
GWC-22	GWC-22CK	0.09	0.05	0.06
GWC-23	GWC-23CK	0.10	0.15	0.14
GWC-25	GWC-25CK	0.01	0.08	0.07
GWC-26	GWC-26CK	0.02	0.06	0.03
GWC-27	GWC-27CK	0.03	0.04	0.08
GWC-28	GWC-28CK	0.06	0.02	0.13
GWC-29	GWC-29CK	0.10	0.03	0.04
GWC-30	GWC-30CK	0.05	0.09	0.05
GWC-31	GWC-31CK	0.05	0.00	0.15
GWC-32	GWC-32CK	0.10	0.04	0.03
GWC-33	GWC-33CK	0.02	0.03	0.03
GWC-36	GWC-36CK	0.07	0.01	0.05
GWC-38	GWC-38CK	0.06	0.02	0.01
GWC-40	GWC-40CK	0.09	0.11	0.14
GWC-41	GWC-41CK	0.00	0.02	0.15
GWC-42	GWC-42CK	0.02	0.02	0.10
GWC-44	GWC-44CK	0.01	0.00	0.15
GWC-45	GWC-45CK	0.08	0.06	0.04
GWC-46	GWC-46CK	0.08	0.04	0.15
GWC-47	GWC-47CK	0.04	0.00	0.01
GWC-51	GWC-51CK	0.15	0.10	0.06
GWC-53	GWC-53CK	0.08	0.10	0.14
GWC-54	GWC-54CK	0.00	0.05	0.11
GWC-55	GWC-55CK	0.02	0.04	0.06
GWC-57	GWC-57CK	0.01	0.04	0.10
GWC-58	GWC-58CK	0.03	0.02	0.14

GWC-59	GWC-59CK	0.06	0.00	0.05
GWC-61	GWC-61CK	0.03	0.03	0.10
GWC-63	GWC-63CK	0.02	0.05	0.15
GWC-65	GWC-65CK	0.00	0.03	0.08
FO-1	FO-1CK	0.11	0.12	0.06
FO-11	FO-11CK	0.08	0.06	0.12
FO-15	FO-15CK	0.09	0.08	0.05
FO-27	FO-27CK	0.06	0.08	0.06
FO-35	FO-35CK	0.00	0.01	0.05
FO-39	FO-39CK	0.06	0.07	0.06
FO-50	FO-50CK	0.05	0.06	0.10
FO-61	FO-61CK	0.08	0.06	0.07

FINAL SURVEY REPORT FOR THE ADD-ON PORTION OF THE TENNESSEE TASK ORDER

Check Point Survey Report
“Western Tennessee LiDAR Quality Assurance”
USACE, St. Louis Contract: W912P9-10-D-0534
Task Order Number: 0001

Prepared for:
UNITED STATES ARMY CORPS OF ENGINEERS

Prepared By:
Dewberry & Davis, LLC
10003 Derekwood Lane, Suite 204
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1. INTRODUCTION

1.1 *Project Summary*

Dewberry & Davis, LLC is under contract to the United States Army Corps of Engineers to provide 65 QA Check Points for portions of western Tennessee. Under the above referenced USACE Task Order, Dewberry is tasked to complete the quality assurance of high resolution LiDAR-derived elevation products. As part of this work Dewberry staff will complete checkpoint surveys that will be used to evaluate vertical accuracy on the bare-earth terrain derived from the LiDAR.

Existing NGS Control Points were located and surveyed to check the accuracy of the RTK/GPS survey equipment with the results shown in Section 2.4 of this Report.

As an internal QA/QC procedure and to verify that the Check Points meet the 95% confidence level approximately 50% of the points were re-observed and are shown in Section 5 of this report.

Final horizontal coordinates are referenced to UTM, Zone 16, NAD83 (NSRS 2007), in meters. Final Vertical elevations are referenced to NAVD 88 in meters, orthometric heights, using Geoid 09.

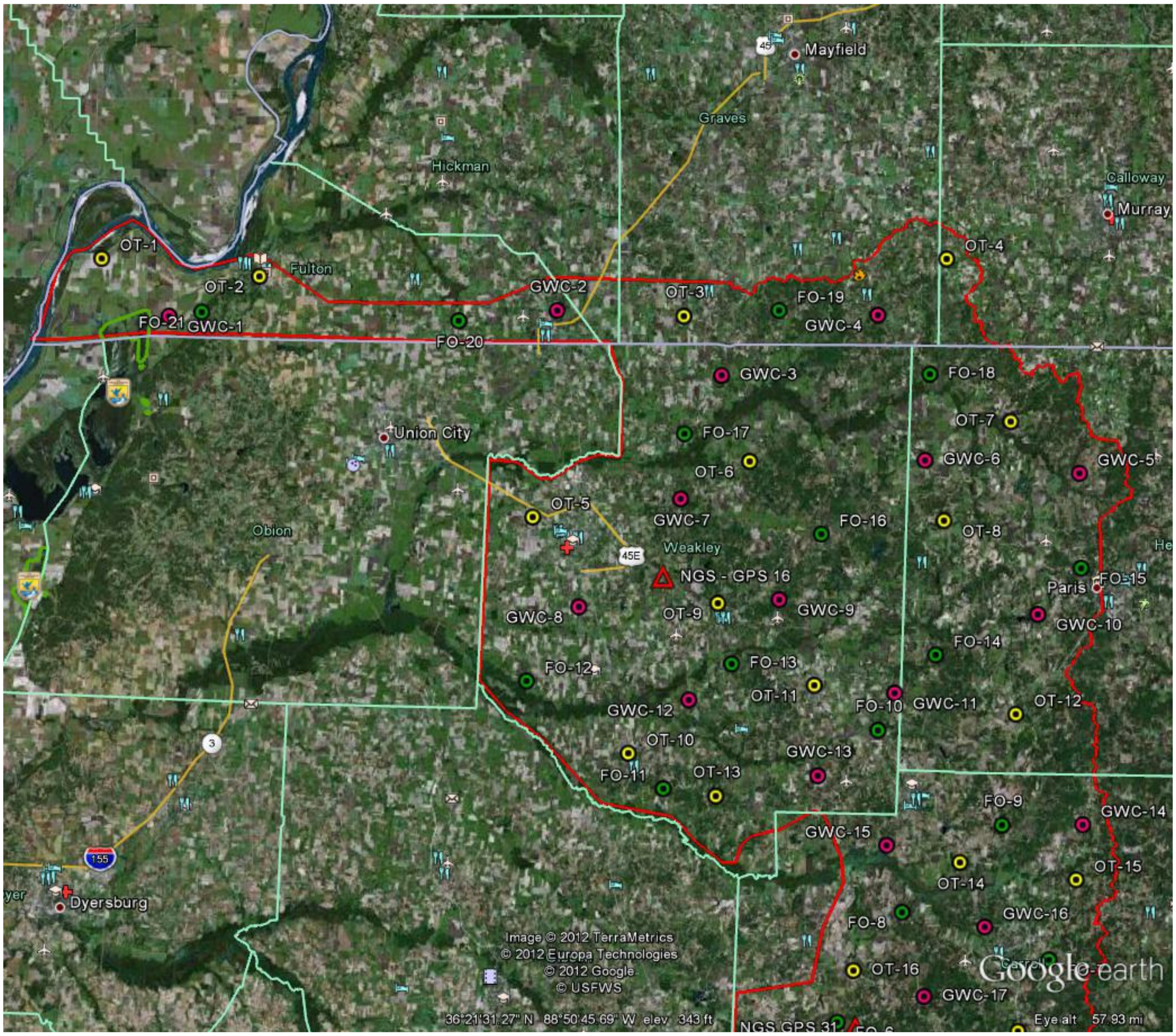
1.2 *Points of Contact*

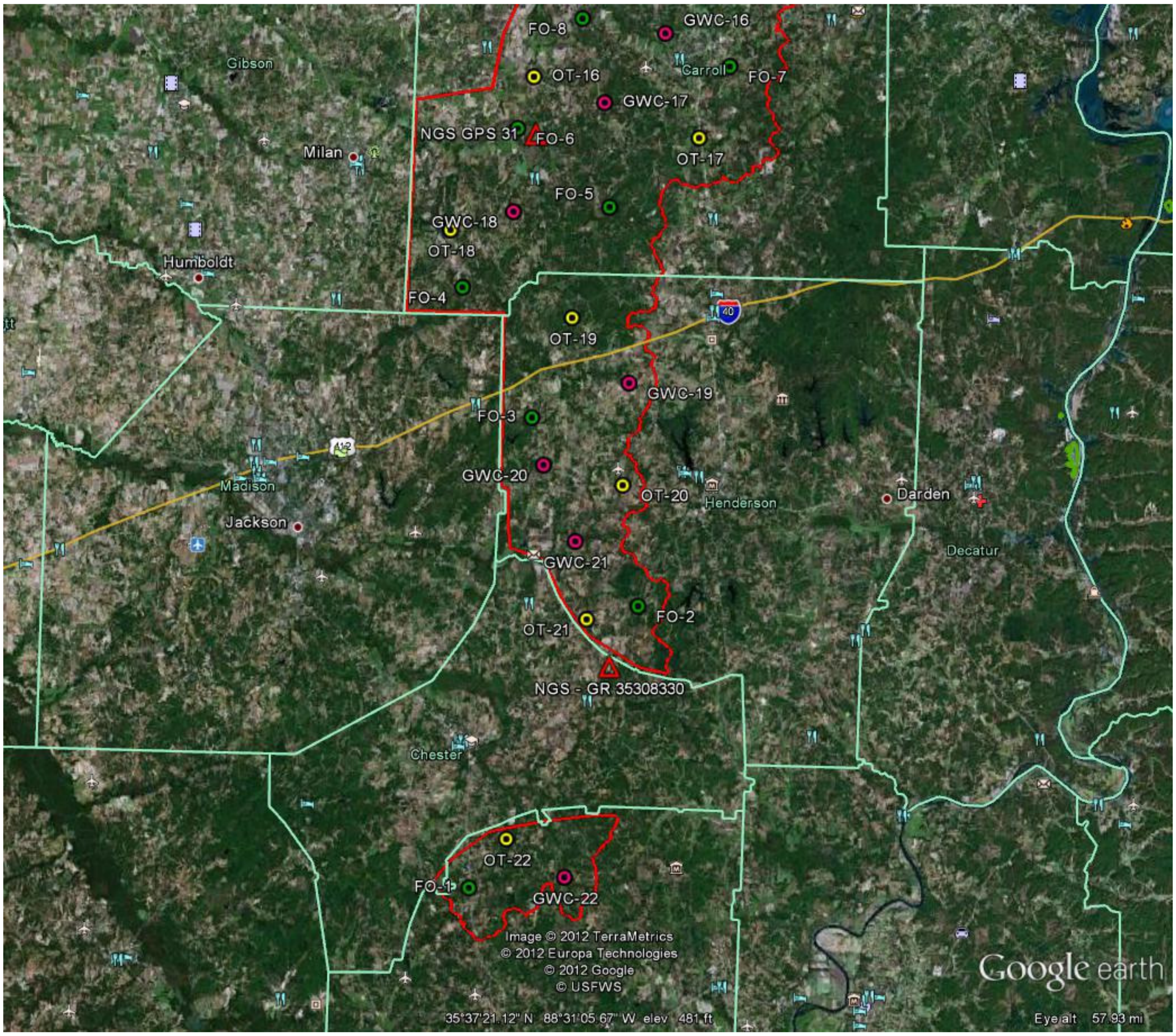
Questions regarding the technical aspects of this report should be addressed to:

Dewberry & Davis, LLC

Gary Simpson, L.S.
Associate
10003 Derekwood Lane
Suite 204
Lanham, Maryland 20706
(301) 364-1855 direct
(301) 731-0188 fax

1.3 *Project Area*




FO-8
GWC-16
Gibson
OT-16
Carroll
FO-7
GWC-17
NGS GPS 31
FO-6
Milan
OT-17
FO-5
GWC-18
OT-18
Humboldt
FO-4
OT-19
GWC-19
FO-3
Madison
GWC-20
OT-20
Henderson
Darden
Jackson
Decatur
GWC-21
FO-2
OT-21
NGS - GR 35308330
Chester
OT-22
FO-1
GWC-22
Image © 2012 TerraMetrics
© 2012 Europa Technologies
© 2012 Google
© USFWS
Google earth
35°37'21.12" N 88°31'05.67" W elev 481 ft
Eye alt 57.93 mi

2 Project Details

2.1 *Survey Equipment*

In performing the GPS observations, Trimble R-8 GNSS receiver/antenna attached to a two meter fixed height pole with a Trimble TSC2 Data Collector to collect GPS raw data were used to perform the field surveys.

2.2 *Survey Point Detail*

The 65 Check Points were well distributed throughout the project area so as to cover as many flight lines as possible using the “dispersed method” of placement.

A sketch was made for each location and a nail was set at the point where possible or at an identifiable point. The Check Point locations are detailed on the “Ground Control Point Documentation Report” sheets attached to this report.

2.3 *Network Design*

The GPS survey performed by Dewberry & Davis, Inc office located in Charlotte, NC was tied to a Real Time Network (RTN) managed by Earl Dudley, Inc. The network is a series of “real-time” continuously operating, high precision GPS reference stations. All of the reference stations have been linked together using Trimble GPSNet software, creating a Virtual Reference Station System (VRS).

The Trimble NetR5 Reference Station is a multi-channel, multi-frequency GNSS (Global Navigation Satellite System) receiver designed for use as a stand-alone reference station or as part of a GNSS infrastructure solution. Trimble R-Track technology in the NetR5 receiver supports the modernized GPS L2C and L5 signals as well as GLONASS L1/L2 signals.

2.4 *Field Survey Procedures and Analysis*

Dewberry & Davis, Inc used Trimble R-8 GNSS receivers, which is a geodetic quality dual frequency GPS receiver, to collect data at each surveyed location.

All locations were occupied once with approximately 50% of the locations being re-observed. All re-observations matched the initially derived station positions within the allowable tolerance of ± 5cm or within the 95% confidence level. Each occupation which utilized the VRS network was occupied for approximately three (3) minutes in duration and measured to 180 epochs.

Each occupation which utilized OPUS (if used) was occupied between 18 and 20 minutes.

Field GPS observations are detailed on the "Ground Control Point Documentation Reports" submitted as part of this report.

Three (3) existing NGS monuments listed in the NSRS database were located as an additional QA/QC method to check the accuracy of the VRS network as well as being the primary project control monuments designated as PID GD1864, FE2743 and DF7952. The results are as follows:

	As Surveyed (m)			Published (m)			Differences (m)		
NGS PT. ID	Northing(m)	Easting(m)	Elev.(m)	Northing(m)	Easting(m)	Elev.(m)	Δ N	Δ E	Δ Elev.
GPS-16	4019915.117	341042.783	123.765	4019915.158	341042.843	123.810	0.041	0.044	0.045
GPS-31	3978322.256	358119.153	160.080	3978322.214	358119.138	160.060	0.042	0.015	0.020
GR35308830	3929542.576	364127.095	177.676	3929542.518	364127.066	177.760	0.045	0.029	0.045

The above results indicate that the VRS network is providing positional values within the 5cm parameters for this survey.

2.5 *Adjustment*

The survey data was collected using Virtual Reference Stations (VRS) methodology within a Virtual Reference System (VRS).

The system is designed to provide a true Network RTK performance, the RTKNet software enables high-accuracy positioning in real time across a geographic region. The RTKNet software package uses real-time data streams from the GPSNet system user and generates correction models for high-accuracy RTK GPS corrections throughout the network. Therefore, corrections were applied to the points as they were being collected, thus negating the need for a post process adjustment.

2.6 *Data Processing Procedures*

After field data is collected the information is downloaded from the data collectors into the office software. The Software program used is called TGO or Trimble Geomatics Office.

Downloaded data is run through the TGO program to obtain the following reports; points report, point comparison report and a point detail report. The reports are reviewed for point accuracy and precision.

After review of the point data an “ASCII” or “txt” file which is the industry standard is created. Point files are loaded into our CADD program (Carlson Survey 2010) to make a visual check of the point data (Pt. #, Coordinates, Elev. and Description). The data can now be imported into the final product.

3. FINAL COORDINATES

Western Tennessee LiDAR QA			
UTM ZONE 16 COORDINATE SYSTEM			
	NAD83 (m)		NAVD88 (m)
POINT ID	NORTHING (m)	EASTING (m)	ORTHO HEIGHT (m)
OPEN TERRAIN POINTS			
OT-1	4049907.640	289945.985	89.367
OT-2	4047970.861	304368.957	112.505
OT-3	4043755.984	343395.275	140.964
OT-4	4048546.271	367641.024	168.794
OT-5	4025330.811	329817.948	112.500
OT-6	4030094.056	349375.762	130.389
OT-7	4033900.306	373227.887	148.984
OT-8	4024706.928	367001.532	159.809
OT-9	4017452.144	346136.297	127.363
OT-10	4002968.264	337927.239	129.605
OT-11	4009951.131	354721.756	124.110
OT-12	4006933.234	373346.052	160.290
OT-13	3999895.003	345662.642	142.549
OT-14	3993443.767	368027.546	147.250
OT-15	3990261.868	377117.831	140.939
OT-16	3983720.451	358096.711	128.291
OT-17	3977871.976	373230.811	141.456
OT-18	3969755.295	350225.878	167.648
OT-19	3961394.052	361165.067	188.806
OT-20	3946196.752	365675.288	159.277
OT-21	3933866.487	361680.219	156.057
OT-22	3913981.450	354538.651	138.286
GRASS, WEEDS, CROPS POINTS			
GWC-1	4045825.528	296343.859	88.808
GWC-2	4043378.797	330471.153	125.883
GWC-3	4038288.650	346717.463	136.383
GWC-4	4043417.818	361257.759	169.737
GWC-5	4028824.765	379807.963	181.260
GWC-6	4030264.404	365350.035	140.218

GWC-7	4027056.977	342845.684	116.240
GWC-8	4017493.661	333407.271	105.673
GWC-9	4017498.350	351847.313	161.613
GWC-10	4016738.674	375743.968	149.310
GWC-11	4008864.861	360744.771	144.852
GWC-12	4008620.615	343036.177	117.702
GWC-13	4001587.357	353748.495	112.081
GWC-14	3996648.848	379411.701	126.872
GWC-15	3995244.448	360206.428	110.044
GWC-16	3987469.150	370400.878	134.777
GWC-17	3981010.623	364344.798	128.661
GWC-18	3971245.356	357881.823	138.358
GWC-19	3955372.908	365960.522	153.563
GWC-20	3948127.949	358440.123	160.620
GWC-21	3941261.974	361687.862	129.442
GWC-22	3910737.871	359178.734	170.314
FOREST POINTS			
FO-1	3909569.952	351039.841	144.344
FO-2	3935149.828	366896.075	141.108
FO-3	3952500.611	357458.634	171.513
FO-4	3964501.654	351271.451	145.570
FO-5	3971479.694	365264.316	158.371
FO-6	3979015.464	356518.959	144.062
FO-7	3984265.939	376137.621	119.325
FO-8	3988908.528	362614.675	142.846
FO-9	3997503.242	371585.684	151.872
FO-10	4005535.554	360764.578	139.161
FO-11	4000595.381	340852.201	132.520
FO-12	4010663.085	328464.954	103.159
FO-13	4011902.706	346918.022	108.309
FO-14	4012460.756	366040.808	130.483
FO-15	4020196.111	379421.969	168.141
FO-16	4023638.692	356088.513	149.606
FO-17	4033164.195	341848.656	125.005
FO-18	4038132.403	365888.510	124.507
FO-19	4045860.741	353120.220	163.329
FO-20	4043733.057	322747.653	108.728
FO-21	4044818.368	299081.833	99.766

4. GPS OBSERVATION & RE-OBSERVATION SCHEDULE

Western Tennessee LiDAR QA

POINT ID	OBSERV. DATE	JULIAN DATE	TIME OF DAY	RE-OBSERV. DATE	RE-OBSERV. TIME
OPEN TERRAIN POINTS					
OT-1	2/15/2012	46	8:35	N/A	N/A
OT-2	2/15/2012	46	7:38	N/A	N/A
OT-3	2/15/2012	46	16:51	N/A	N/A
OT-4	2/17/2012	48	7:11	N/A	N/A
OT-5	2/16/2012	47	11:01	2/19/2012	12:09
OT-6	2/17/2012	48	14:05	2/19/2012	13:17
OT-7	2/16/2012	47	15:01	2/19/2012	15:05
OT-8	2/16/2012	47	14:30	2/19/2012	14:40
OT-9	2/16/2012	47	9:14	2/18/2012	13:56
OT-10	2/19/2012	50	7:20	2/14/2012	8:50
OT-11	2/16/2012	47	7:13	2/19/2012	9:49
OT-12	2/16/2012	47	16:35	2/19/2012	16:13
OT-13	2/19/2012	50	7:50	2/19/2012	15:55
OT-14	2/17/2012	48	13:45	2/18/2012	16:25
OT-15	2/17/2012	48	12:20	N/A	N/A
OT-16	2/17/2012	48	15:05	2/18/2012	11:40
OT-17	2/17/2012	48	10:00	N/A	N/A
OT-18	2/16/2012	47	15:15	2/18/2012	6:20
OT-19	2/16/2012	47	14:35	2/17/2012	7:20
OT-20	2/15/2012	46	13:20	2/16/2012	12:15
OT-21	2/15/2012	46	11:10	2/16/2012	10:44
OT-22	2/15/2012	46	8:50	N/A	N/A
GRASS, WEEDS, CROPS POINTS					
GWC-1	2/15/2012	46	9:53	N/A	N/A
GWC-2	2/15/2012	46	15:54	N/A	N/A
GWC-3	2/16/2012	47	13:15	N/A	N/A
GWC-4	2/17/2012	48	8:35	N/A	N/A
GWC-5	2/16/2012	47	15:29	2/19/2012	15:26:00
GWC-6	2/16/2012	47	14:05	N/A	N/A

GWC-7	2/16/2012	47	11:47	2/18/2012	16:46
GWC-8	2/16/2012	47	10:04	2/18/2012	11:39
GWC-9	2/16/2012	47	8:42	N/A	N/A
GWC-10	2/16/2012	47	16:00	2/19/2012	15:50
GWC-11	2/16/2012	47	6:37	2/19/2012	9:26
GWC-12	2/16/2012	47	7:51	2/19/2012	10:19
GWC-13	2/19/2012	50	16:25	N/A	N/A
GWC-14	2/17/2012	48	12:45	2/19/2012	14:20
GWC-15	2/17/2012	48	14:30	N/A	N/A
GWC-16	2/17/2012	48	11:25	2/18/2012	14:00
GWC-17	2/17/2012	48	15:20	N/A	N/A
GWC-18	2/16/2012	47	15:45	2/18/2012	7:20
GWC-19	2/16/2012	47	14:00	N/A	N/A
GWC-20	2/15/2012	46	14:20	2/17/2012	6:40
GWC-21	2/15/2012	46	12:20	N/A	N/A
GWC-22	2/15/2012	46	7:30	N/A	N/A
FOREST POINTS					
FO-1	2/16/2012	47	8:30	N/A	N/A
FO-2	2/16/2012	47	11:30	N/A	N/A
FO-3	2/16/2012	47	13:15	N/A	N/A
FO-4	2/17/2012	48	8:00	2/19/2012	14:21
FO-5	2/18/2012	49	8:00	N/A	N/A
FO-6	2/17/2012	48	9:20	N/A	N/A
FO-7	2/18/2012	49	14:40	N/A	N/A
FO-8	2/18/2012	49	12:45	2/19/2012	9:45
FO-9	2/19/2012	50	13:20	N/A	N/A
FO-10	2/19/2012	50	12:30	N/A	N/A
FO-11	2/19/2012	50	9:45	N/A	N/A
FO-12	2/18/2012	49	12:49	N/A	N/A
FO-13	2/18/2012	49	9:00	2/19/2012	13:22
FO-14	2/18/2012	49	6:20	N/A	N/A
FO-15	2/18/2012	49	7:30	N/A	N/A
FO-16	2/18/2012	49	14:15	N/A	N/A
FO-17	2/17/2012	48	14:56	N/A	N/A
FO-18	2/17/2012	48	12:12	N/A	N/A
FO-19	2/17/2012	48	10:15	2/19/2012	16:44
FO-20	2/15/2012	46	14:10	N/A	N/A
FO-21	2/15/2012	46	10:31	N/A	N/A

5. POINT COMPARISON REPORT

Western Tennessee LiDAR QA				
POINT ID NO.	POINT CK NO.	DELTA NORTH (m)	DELTA EAST (m)	VERT. DIFF (m)
OT-5	OT-5CK	0.029	0.032	0.041
OT-6	OT-6CK	0.041	0.043	0.032
OT-7	OT-7CK	0.005	0.000	0.020
OT-8	OT-8CK	0.026	0.029	0.011
OT-9	OT-9CK	0.032	0.035	0.010
OT-10	OT-10CK	0.014	0.004	0.005
OT-11	OT-11CK	0.011	0.043	0.043
OT-12	OT-12CK	0.002	0.007	0.003
OT-13	OT-13CK	0.022	0.002	0.008
OT-14	OT-14CK	0.017	0.018	0.044
OT-16	OT-16CK	0.044	0.013	0.044
OT-18	OT-18CK	0.043	0.045	0.045
OT-19	OT-19CK	0.038	0.022	0.045
OT-20	OT-20CK	0.012	0.016	0.014
OT-21	OT-21CK	0.025	0.027	0.045
GWC-5	GWC-5CK	0.042	0.018	0.014
GWC-7	GWC-7CK	0.046	0.045	0.045
GWC-8	GWC-8CK	0.045	0.045	0.043
GWC-10	GWC-10CK	0.022	0.000	0.018
GWC-11	GWC-11CK	0.011	0.005	0.020
GWC-12	GWC-12CK	0.025	0.045	0.044
GWC-14	GWC-14CK	0.044	0.043	0.045
GWC-16	GWC-16CK	0.007	0.008	0.006
GWC-18	GWC-18CK	0.022	0.033	0.045
GWC-20	GWC-20CK	0.003	0.030	0.045
FO-4	FO-4CK	0.025	0.035	0.021
FO-8	FO-8CK	0.012	0.019	0.009
FO-13	FO-13CK	0.034	0.025	0.026
FO-19	FO-19CK	0.029	0.038	0.022

REPROCESSED CHECKPOINTS

The following checkpoints were re-processed by the surveyor and the review/re-verification resulted in revision to the final coordinates and elevation values.

POINT #	NORTHING	EASTING	ELEVS.
FO15	4006559.263	288088.581	86.721
FO17	4011052.684	261884.926	82.411
FO18	4006302.308	270703.396	80.908
FO29	3993847.745	264908.788	77.991
FO30	3977797.491	276729.898	107.570
FO-13	4016600.984	322125.842	87.412
FO-40	3949774.704	325276.599	131.971
FO-5	3971479.695	365264.314	158.371
FO-61	3917582.852	334903.050	141.061
OT-21	3997230.439	334246.876	107.162
OT-51	3925254.831	375500.925	171.200
GWC-6	3909351.365	344465.270	195.540

Appendix B: Complete List of Delivered Tiles

16SBE3639	16SBE4145	16SBE4850	16SBE5450	16SBE5648
16SBE3640	16SBE4146	16SBE4947	16SBE5451	16SBE5649
16SBE3641	16SBE4147	16SBE4948	16SBE5452	16SBE5650
16SBE3737	16SBE4242	16SBE4949	16SBE5453	16SBE5651
16SBE3738	16SBE4243	16SBE4950	16SBE5454	16SBE5652
16SBE3739	16SBE4244	16SBE4951	16SBE5455	16SBE5653
16SBE3740	16SBE4245	16SBE5047	16SBE5456	16SBE5654
16SBE3741	16SBE4246	16SBE5048	16SBE5457	16SBE5655
16SBE3742	16SBE4247	16SBE5049	16SBE5483	16SBE5656
16SBE3743	16SBE4342	16SBE5050	16SBE5484	16SBE5657
16SBE3744	16SBE4343	16SBE5051	16SBE5485	16SBE5658
16SBE3745	16SBE4344	16SBE5147	16SBE5486	16SBE5659
16SBE3838	16SBE4345	16SBE5148	16SBE5487	16SBE5681
16SBE3839	16SBE4346	16SBE5149	16SBE5488	16SBE5682
16SBE3840	16SBE4347	16SBE5150	16SBE5489	16SBE5683
16SBE3841	16SBE4348	16SBE5151	16SBE5546	16SBE5684
16SBE3842	16SBE4443	16SBE5246	16SBE5547	16SBE5685
16SBE3843	16SBE4444	16SBE5247	16SBE5548	16SBE5686
16SBE3844	16SBE4445	16SBE5248	16SBE5549	16SBE5687
16SBE3845	16SBE4446	16SBE5249	16SBE5550	16SBE5688
16SBE3846	16SBE4447	16SBE5250	16SBE5551	16SBE5689
16SBE3940	16SBE4448	16SBE5251	16SBE5552	16SBE5690
16SBE3941	16SBE4544	16SBE5252	16SBE5553	16SBE5691
16SBE3942	16SBE4545	16SBE5346	16SBE5554	16SBE5692
16SBE3943	16SBE4546	16SBE5347	16SBE5555	16SBF5613
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16SBF5713	16SBE5946	16SBE6046	16SBF6010	16SBE6194
16SBF5714	16SBE5947	16SBE6047	16SBF6011	16SBE6195
16SBF5715	16SBE5948	16SBE6048	16SBF6012	16SBE6196
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16SCE7416	16SCF7402	16SCE7519	16SCF7505	16SCE7623
16SCE7417	16SCF7403	16SCE7520	16SCF7506	16SCE7624
16SCE7418	16SCF7404	16SCE7521	16SCF7507	16SCE7625
16SCE7419	16SCF7405	16SCE7522	16SCF7508	16SCE7626
16SCE7420	16SCF7406	16SCE7523	16SCF7509	16SCE7627
16SCE7421	16SCF7407	16SCE7524	16SCF7510	16SCE7628
16SCE7422	16SCF7408	16SCE7525	16SCF7511	16SCE7673
16SCE7423	16SCF7409	16SCE7526	16SCF7512	16SCE7674
16SCE7424	16SCF7410	16SCE7527	16SCF7513	16SCE7675
16SCE7425	16SCF7411	16SCE7528	16SCF7514	16SCE7676
16SCE7426	16SCF7412	16SCE7573	16SCF7515	16SCE7677
16SCE7427	16SCF7413	16SCE7574	16SCF7516	16SCE7678
16SCE7428	16SCF7414	16SCE7575	16SCF7517	16SCE7679
16SCE7473	16SCF7415	16SCE7576	16SCF7518	16SCE7680
16SCE7474	16SCF7416	16SCE7577	16SCF7519	16SCE7681
16SCE7475	16SCF7417	16SCE7578	16SCF7520	16SCE7682
16SCE7476	16SCF7418	16SCE7579	16SCF7521	16SCE7683
16SCE7477	16SCF7419	16SCE7580	16SCF7522	16SCE7684
16SCE7478	16SCF7420	16SCE7581	16SCF7523	16SCE7685
16SCE7479	16SCF7421	16SCE7582	16SCF7524	16SCE7686
16SCE7480	16SCF7422	16SCE7583	16SCF7525	16SCE7687
16SCE7481	16SCF7423	16SCE7584	16SCF7526	16SCE7688
16SCE7482	16SCF7424	16SCE7585	16SCF7527	16SCE7689
16SCE7483	16SCF7425	16SCE7586	16SCF7528	16SCE7690
16SCE7484	16SCF7426	16SCE7587	16SCF7529	16SCE7691
16SCE7485	16SCF7427	16SCE7588	16SCF7530	16SCE7692
16SCE7486	16SCF7428	16SCE7589	16SCF7531	16SCE7693
16SCE7487	16SCF7429	16SCE7590	16SCF7532	16SCE7694
16SCE7488	16SCF7430	16SCE7591	16SCF7533	16SCE7695
16SCE7489	16SCF7431	16SCE7592	16SCF7534	16SCE7696
16SCE7490	16SCF7432	16SCE7593	16SCF7535	16SCE7697

16SCE7698	16SCE7718	16SCF7713	16SCE7890	16SCF7832
16SCE7699	16SCE7719	16SCF7714	16SCE7891	16SCF7833
16SCF7600	16SCE7720	16SCF7715	16SCE7892	16SCF7834
16SCF7601	16SCE7774	16SCF7716	16SCE7893	16SCF7835
16SCF7602	16SCE7775	16SCF7717	16SCE7894	16SCF7836
16SCF7603	16SCE7776	16SCF7718	16SCE7895	16SCF7837
16SCF7604	16SCE7777	16SCF7719	16SCE7896	16SCE7975
16SCF7605	16SCE7778	16SCF7720	16SCE7897	16SCE7976
16SCF7606	16SCE7779	16SCF7721	16SCE7898	16SCE7977
16SCF7607	16SCE7780	16SCF7722	16SCE7899	16SCE7978
16SCF7608	16SCE7781	16SCF7723	16SCF7800	16SCE7979
16SCF7609	16SCE7782	16SCF7724	16SCF7801	16SCE7980
16SCF7610	16SCE7783	16SCF7725	16SCF7802	16SCE7981
16SCF7611	16SCE7784	16SCF7726	16SCF7803	16SCE7982
16SCF7612	16SCE7785	16SCF7727	16SCF7804	16SCE7983
16SCF7613	16SCE7786	16SCF7728	16SCF7805	16SCE7984
16SCF7614	16SCE7787	16SCF7729	16SCF7806	16SCE7985
16SCF7615	16SCE7788	16SCF7730	16SCF7807	16SCE7986
16SCF7616	16SCE7789	16SCF7731	16SCF7808	16SCE7987
16SCF7617	16SCE7790	16SCF7732	16SCF7809	16SCE7988
16SCF7618	16SCE7791	16SCF7733	16SCF7810	16SCE7989
16SCF7619	16SCE7792	16SCF7734	16SCF7811	16SCE7990
16SCF7620	16SCE7793	16SCF7735	16SCF7812	16SCE7991
16SCF7621	16SCE7794	16SCF7736	16SCF7813	16SCE7992
16SCF7622	16SCE7795	16SCF7737	16SCF7814	16SCE7993
16SCF7623	16SCE7796	16SCF7738	16SCF7815	16SCE7994
16SCF7624	16SCE7797	16SCE7874	16SCF7816	16SCE7995
16SCF7625	16SCE7798	16SCE7875	16SCF7817	16SCE7996
16SCF7626	16SCE7799	16SCE7876	16SCF7818	16SCE7997
16SCF7627	16SCF7700	16SCE7877	16SCF7819	16SCE7998
16SCF7628	16SCF7701	16SCE7878	16SCF7820	16SCE7999
16SCF7629	16SCF7702	16SCE7879	16SCF7821	16SCF7900
16SCF7630	16SCF7703	16SCE7880	16SCF7822	16SCF7901
16SCF7631	16SCF7704	16SCE7881	16SCF7823	16SCF7902
16SCF7632	16SCF7705	16SCE7882	16SCF7824	16SCF7903
16SCF7633	16SCF7706	16SCE7883	16SCF7825	16SCF7904
16SCF7634	16SCF7707	16SCE7884	16SCF7826	16SCF7905
16SCF7635	16SCF7708	16SCE7885	16SCF7827	16SCF7906
16SCF7636	16SCF7709	16SCE7886	16SCF7828	16SCF7907
16SCF7637	16SCF7710	16SCE7887	16SCF7829	16SCF7908
16SCF7638	16SCF7711	16SCE7888	16SCF7830	16SCF7911
16SCE7717	16SCF7712	16SCE7889	16SCF7831	16SCF7912

16SCF7913	16SCE8086	16SCF8023	16SCF8122	16SCF8427
16SCF7914	16SCE8087	16SCF8024	16SCF8123	
16SCF7915	16SCE8088	16SCF8025	16SCF8124	
16SCF7916	16SCE8089	16SCF8026	16SCF8125	
16SCF7917	16SCE8090	16SCF8027	16SCF8126	
16SCF7918	16SCE8091	16SCF8028	16SCF8127	
16SCF7919	16SCE8092	16SCF8029	16SCF8128	
16SCF7920	16SCE8093	16SCF8030	16SCF8129	
16SCF7921	16SCE8094	16SCF8031	16SCF8130	
16SCF7922	16SCE8095	16SCF8032	16SCF8131	
16SCF7923	16SCE8096	16SCF8033	16SCF8132	
16SCF7924	16SCE8097	16SCE8183	16SCE8289	
16SCF7925	16SCE8098	16SCE8184	16SCE8290	
16SCF7926	16SCE8099	16SCE8186	16SCE8291	
16SCF7927	16SCF8000	16SCE8187	16SCE8292	
16SCF7928	16SCF8001	16SCE8189	16SCE8293	
16SCF7929	16SCF8002	16SCE8190	16SCE8294	
16SCF7930	16SCF8003	16SCE8191	16SCE8295	
16SCF7931	16SCF8004	16SCE8192	16SCF8225	
16SCF7932	16SCF8005	16SCE8193	16SCF8226	
16SCF7933	16SCF8006	16SCE8194	16SCF8227	
16SCF7934	16SCF8007	16SCE8195	16SCF8228	
16SCF7935	16SCF8012	16SCE8196	16SCF8229	
16SCF7936	16SCF8013	16SCE8197	16SCF8230	
16SCF7937	16SCF8014	16SCE8198	16SCF8231	
16SCE8075	16SCF8015	16SCE8199	16SCF8325	
16SCE8076	16SCF8016	16SCF8115	16SCF8326	
16SCE8078	16SCF8017	16SCF8116	16SCF8327	
16SCE8079	16SCF8018	16SCF8117	16SCF8328	
16SCE8082	16SCF8019	16SCF8118	16SCF8329	
16SCE8083	16SCF8020	16SCF8119	16SCF8330	
16SCE8084	16SCF8021	16SCF8120	16SCF8331	
16SCE8085	16SCF8022	16SCF8121	16SCF8426	

Appendix C: Model Key Point Tiles Not Created

16SBE3639	16SBF5910	16SBF6500	16SBF7135	16SBF8327
16SBE3745	16SBF5915	16SBF6505	16SBF7241	16SBF8343
16SBE3846	16SBE6078	16SBF6520	16SBF7242	16SBF8445
16SBE5483	16SBE6098	16SBF6525	16SBF7325	16SBF8446
16SBE5484	16SBF6009	16SBF6601	16SBF7330	16SBF8630
16SBE5485	16SBF6015	16SBF6602	16SBF7338	16SBF8650
16SBE5582	16SBE6198	16SBF6603	16SBF7738	16SBF8729
16SBE5587	16SBF6108	16SBF6625	16SBF7740	16SBF8851
16SBE5681	16SBF6115	16SBF6719	16SBF7838	16SBF8931
16SBE5780	16SBE6298	16SBF6725	16SBF7938	16SBF9253
16SBE5781	16SBE6299	16SBF6818	16SBF8039	16SBF9353
16SBE5880	16SBF6207	16SBF6825	16SBF8129	16SBF9650
16SBE5895	16SBE6399	16SBF6915	16SBF8140	16SBF9749
16SBE5896	16SBF6406	16SBF6917	16SBF8227	16SBF9949
16SBE5897	16SBF6414	16SBF7124	16SBF8228	16SCF0049
16SBF5811	16SBF6422	16SBF7133	16SBF8229	
16SBE5979	16SBF6424	16SBF7134	16SBF8241	

Appendix D: Bare Earth Tiles Not Created

16SBE3639	16SBE5896	16SBF6115	16SBF6725	16SBF8228
16SBE3745	16SBE5897	16SBE6299	16SBF6818	16SBF8229
16SBE3846	16SBF5811	16SBE6399	16SBF6825	16SBF8327
16SBE5483	16SBE5979	16SBF6406	16SBF6915	16SBF8445
16SBE5484	16SBF5910	16SBF6414	16SBF6917	16SBF8446
16SBE5485	16SBF5915	16SBF6500	16SBF7124	16SBF8650
16SBE5582	16SBE6078	16SBF6505	16SBF7738	16SBF8851
16SBE5681	16SBE6098	16SBF6601	16SBF7838	16SBF9253
16SBE5780	16SBF6009	16SBF6602	16SBF7938	16SBF9353
16SBE5880	16SBF6015	16SBF6603	16SBF8129	16SBF9949
16SBE5895	16SBF6108	16SBF6625	16SBF8227	