**Dewberry**®

PROJECT REPORT

For the


**2011 South Carolina LiDAR Project**


**Project Number:**

**P24-N143-MJ**


**Prepared for:**

**South Carolina Department of Natural Resources**


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## 1 Executive Summary

The primary purpose of this project is to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (LiDAR) technology for the 2011 South Carolina LiDAR project area. The project encompasses four (4) counties in South Carolina: York, Pickens, Anderson, and Oconee. The deliverables, as required in the task order, are: classified point cloud data (LAS), hydro flattened bare earth DEM, intensity images, breaklines, terrain surfaces, supplemental metadata, and reports. This report documents the development of these deliverable products, including the planning, acquisition, and processing of the LiDAR data, as well as the derivation of LiDAR products.

Dewberry served as the primary contractor for the project. In addition to project management, Dewberry was responsible for LiDAR classification, breakline production, intensity image production, DEM development and quality assurance (QA/QC). Dewberry's staff performed the final post-processing of the LAS files for the project, produced the breaklines used to enhance the LiDAR-derived surface, generated the ten foot DEMs, and performed quality assurance inspections on all subcontractor generated data and reports. Towill Incorporated performed the LiDAR data acquisition including data calibration. Their reports can be found in the Appendices.

This report documents the tri county area deliverable, which includes Anderson County, Oconee County, and Pickens County. A report covering the York County deliverable was also created and submitted separately.

## 2 Project Tiling Footprint

The LiDAR delivery for the tri county area consists of two thousand and five hundred (2,500) tiles (Figure 1). 951 tiles were delivered for Anderson County, 872 for Oconee County, and 677 for Pickens County. Each tile's extent is 5,000 feet by 5,000 feet.
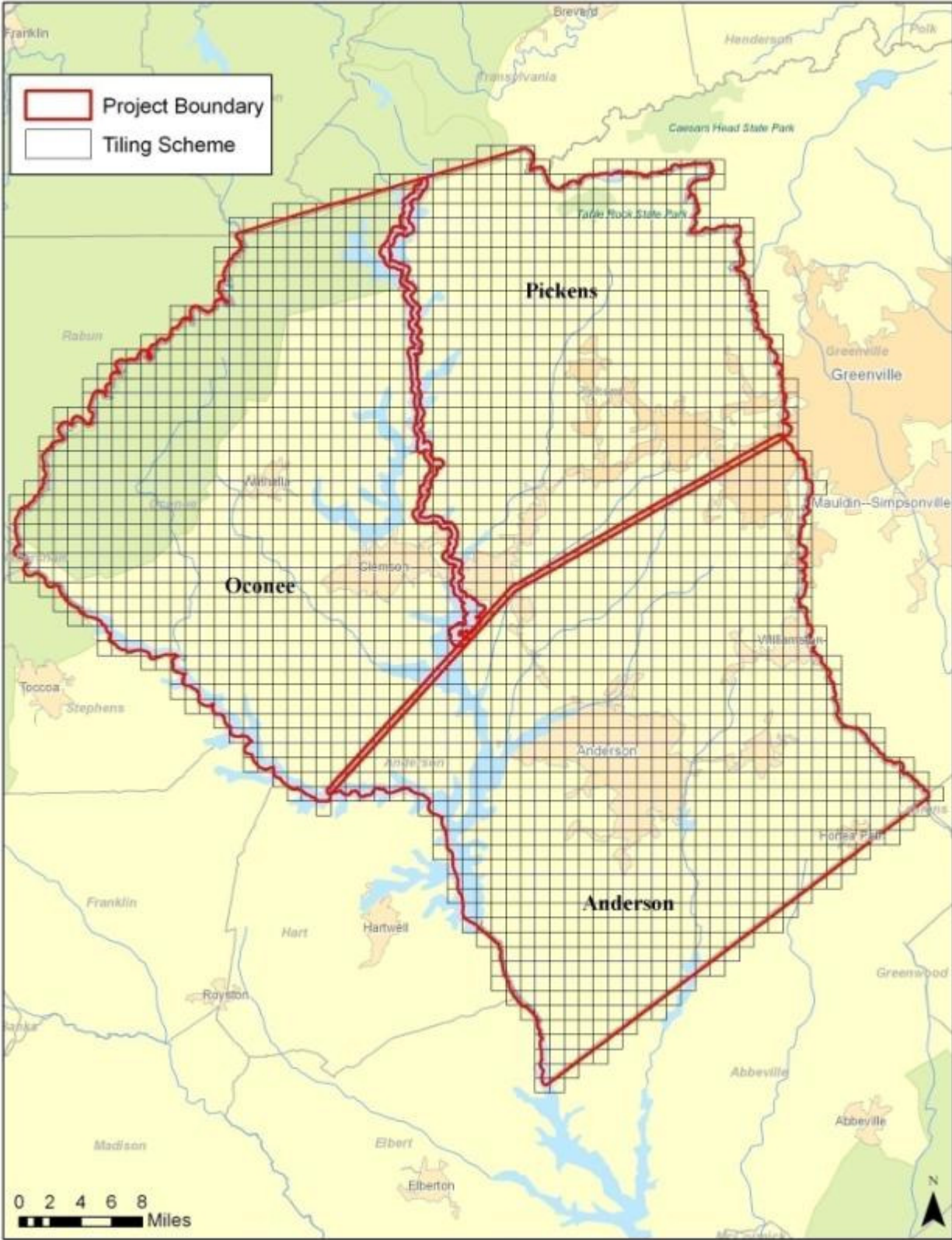
**Figure 1 - Project maps showing extent of project boundary and the delivered tiling scheme**

## 3   LiDAR Acquisition, Calibration and Control Survey Report

The LiDAR acquisition was completed in seven separate flight missions between March 8th and March 13th, 2011. Towill completed a separate report documenting all of the steps in their acquisition process. That document can be found in Appendix A. Their report includes: LiDAR collection parameters, planned flight path maps, flight line trajectories, forward/reverse or combined separation plots, flight logs, and GPS base log sheets. A control survey report is included in Appendix A and contains the details on the fully constrained control network and control station descriptions used by Towill.

## 4   Vertical Accuracy Assessment

Towill's LiDAR Acquisition and Control Survey Report (Appendix A) contains a thorough review of control used and also a LiDAR checkpoint quality assurance section. The checkpoint section documents how 40 check points and 6 existing National Geodetic Survey bench marks were used to calculated an RMS of all check points differences equaling 0.064 m or 0.21 feet. Figure 2 shows the distribution of check points throughout the dataset.
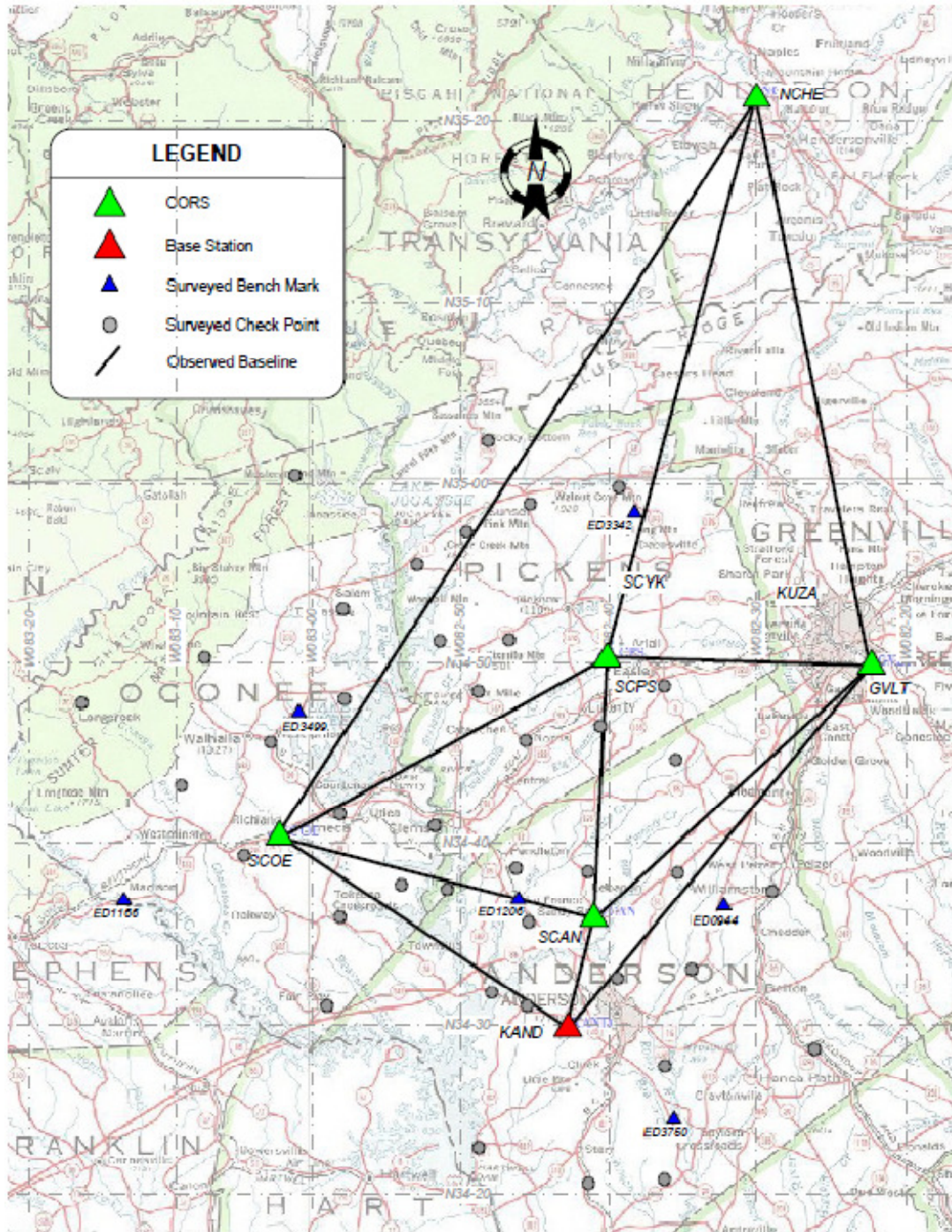
**Figure 2 – Checkpoint Map shows that checkpoints are well distributed throughout project area.**

The tables below show the vertical accuracy statistics and results based on calculations using the tested checkpoints. Fundamental Vertical Accuracy (FVA) is determined with check points located only in land cover category (1), open terrain (grass, dirt, sand, and/or rocks), where there is a very high probability that the LiDAR sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. 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.

Based on the vertical accuracy testing conducted by Towill and Dewberry, the LiDAR dataset for the 2011 South Carolina Project satisfies the project's pre-defined vertical accuracy criteria.

## 5   LiDAR Processing & Qualitative Assessment

The LiDAR is tiled into the 5,000 x 5,000 foot tiles, named using the South Carolina statewide tile scheme. The data were processed using GeoCue and TerraScan software. The initial step was the setup of the GeoCue project, which was done by importing the project defined tile boundary index.  The acquired 3D laser point clouds, in LAS binary format, were imported into the GeoCue project and divided into tiles.  Once tiled, the laser points were tested to ensure accuracy from flightline to flightline. This check is done by creating a set of deltaZ ortho images. This process measures the relative accuracy between flight lines by determining how well one flight line fits an overlapping flight line vertically.

After these checks, the data was classified using a proprietary routine in TerraScan. This routine classifies out any obvious outliers from the dataset following which the ground layer is extracted from the 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 low points 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.

Once the automated classification finished, each tile was imported into TerraScan and a surface model was created to examine the ground classification. Often times, low lying buildings, porches, bridges, and small vegetation artifacts which are not caught during the automated classification are edited during this step. Dewberry analysts visually reviewed the ground surface model and corrected errors in the ground classification, such as vegetation and buildings that were present following the initial processing.  Dewberry analysts employed 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points were removed from the ground classification.

After the ground classification corrections were complete, 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 points within the breakline

polygon and automatically classifies them as class 9, water. The water classification routine also buffers the breakline polygon by 1 m and classifies points with that buffered polygon to class 10, ignored ground for DEM production. During this final classification step, a TerraScan routine was also used to select Model Key Points for class 8. The ground class for this data set was comprised of Class 2, ground, and Class 8, Model Key Points. Once the data classification was finalized, the LAS format 1.0 format points were converted to LAS 1.2 Point Data Record Format 1 and converted to the required ASPRS classification scheme. Below is a list of classifications used:

- Class 1 = Unclassified, and used for all other features that do not fit into the Classes 2, 7, 9, or 10, including vegetation, buildings, etc.
- Class 2 = Ground
- Class 7 = Noise
- Class 8 = Model Key Points
- Class 9 = Water
- Class 10 = Ignored Ground due to breakline proximity.

The following fields within the LAS files are populated to the following precision:

- GPS Time (0.000001 second precision),
- Easting (0.01 foot precision),
- Northing (0.01 foot precision),
- Elevation (0.01 foot 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.

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

1. Format: Using TerraScan, Dewberry verified that all points were classified into valid classes according to project specifications.
   a. LAS format 1.2, point data record format 1
   b. All points contain populated intensity values.
   c. All LAS files contain Variable Length Records with georeferencing information.
   d. All LiDAR points in the LAS files are classified in accordance with project specifications.

2. Spatial Reference Checks: The LAS files were imported into the GeoCue processing environment.   As part of the Dewberry process workflow, the GeoCue import produced a minimum bounding polygon for each data file. This minimum bounding polygon was one of the tools used in conjunction with the statistical analysis to verify spatial reference integrity.
   a. No issues were identified with the spatial referencing of this dataset.

3. 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 ground points in the LAS files. Grid spacing is based on the project density deliverable requirement for un-obscured areas.
   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 and large buildings. These are considered to be acceptable voids.
   b. There is one small data void within the tri-county deliverable. On the western side of Pickens County there is 11,000 square foot void in the data. This occurred because of an insufficient coverage between two swaths. The area has been filled with synthetic LAS points and possible resolution to the issue can be found in the June 23, 2011 memo from Dewberry to SCDNR. Appendix B.
4. Bare earth quality: Dewberry assured the cleanliness of the bare earth during classification by removing all artifacts, including vegetation, buildings, bridges, and other features not valid for inclusion in the ground surface model.

## LiDAR Processing Conclusion

Based on the procedures and quality assurance checks, the final classification conforms to the project specifications set by the scope of work. All issues found during the qualitative QC were fixed. The dataset follows project specifications for format and header values. The quality control steps taken by Dewberry to assure the classified LAS meet project specifications are detailed below.

## Classified LiDAR QA\QC Checklist

**Overview**

☒ Correct number of files delivered and all files adhere to project format specifications

☒ LAS statistics are run to check for inconsistencies

☒ Dewberry quantitative review process is completed

☒ Dewberry qualitative review process is completed

☒ Create LAS extent geometry

**Data Inventory and Coverage**

☒ All tiles present and labeled according to the project tile grid

Dewberry Quantitative Review Process

☒ LAS statistics review:

    ☒ LAS format 1.2

    ☒ Point data record format 1

    ☒ Georeference information is populated and accurate

        - NAD83 HARN StatePlane South Carolina FIPS 3900 Feet International
        - NAVD88, Feet

    ☒ GPS time recorded as Adjusted GPS Time, with 0.01 precision

    ☒ Points have intensity values

    ☒ Files contain multiple returns (minimum First, Last, and one Intermediate)

    ☒ Scan angle < 40°

☒ Data meets Nominal Pulse Spacing requirement: <=1.2 meters

    ☒ Tested on single swath, first return data only

    ☒ Tested on geometrically usable portion (90%) of swath

☒ Data passes Geometric Grid Data Density Test

    ☒ Tested on 1 meter grid

    ☒ Tested on first return data only

    ☒ At least 90% of grid cells contain at least 1 point

☒ Data tested for vertical accuracy – Tested by Towill.

    ☒ Checkpoint inventory

    ☒ Vertical accuracy assessment.  LiDAR compiled to meet requirements.

**Completion Comments: Complete – Approved**

## *6 Breakline Production*

### **6.1 Breakline Production Methodology**

Dewberry used GeoCue software to develop LiDAR stereo models of the 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 stereo-compiled the five types of hard breaklines in accordance with the project's Data Dictionary. All drainage breaklines were monotonically enforced to show downhill flow. Water bodies were reviewed in stereo and the lowest elevation was applied to the entire waterbody.

## 6.2 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.
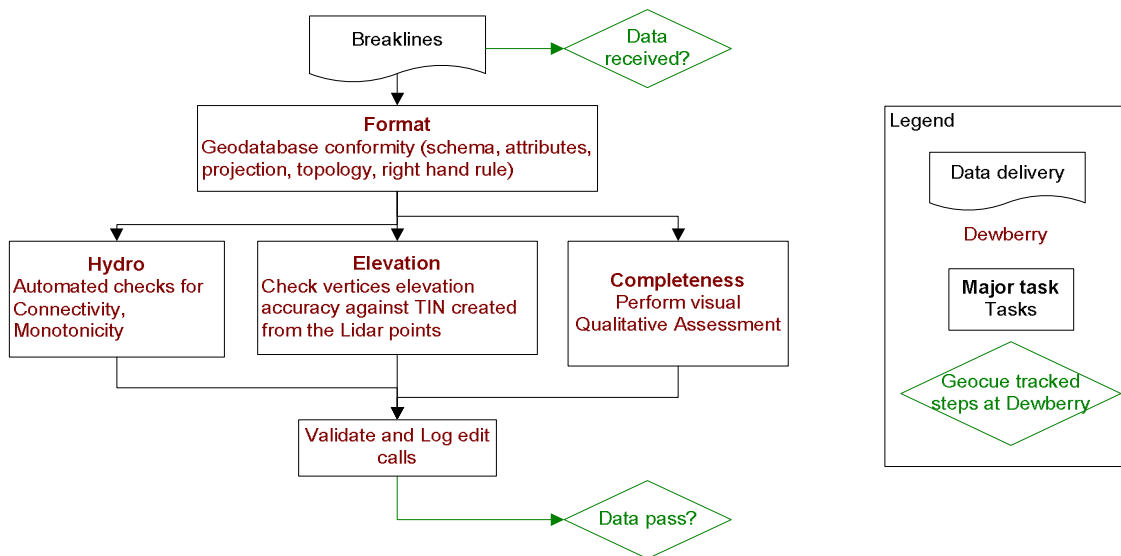


**Figure 3 – Breakline Workflow**

## 6.3 Breakline Topology Rules

Automated checks were applied on hydro features to validate the 3D connectivity of the feature and the monotonicity of the hydrographic breaklines. Two major concerns Dewberry checked for include ensuring hydrographic breaklines have a continuous flow downhill and that breaklines do not undulate. To perform these checks, error points were generated at each vertex not complying with the tested rules and these potential edit calls were then visually validated during the visual evaluation of the data. This step helped validate that breakline vertices did not have excessive minimum or maximum elevations and that elevations were consistent with adjacent vertex elevations.

The next step was 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 was used to validate if the elevations significantly differed 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.

## 6.4    Breakline QA/QC Checklist

**Overview**

☒    All Feature Classes are present in geodatabase (GDB)

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

☒    The breakline topology inside of the GDB 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 should be captured in order to meet baseline specifications or for consistency (See Data Dictionary for specific collection rules).  NHD data will be used to help evaluate completeness of collected hydrographic features.  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 with GeoFIRM tools 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.  Z value differences should generally be limited to within 1 foot.  This should be performed before other breakline checks are completed.

**Perform automated data checks using PLTS**

The following data checks were performed utilizing ESRI's PLTS 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.  PLTS 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 feet).  This check will return water bodies where vertices are not all identical.  This tool is found under "Z Value Checks."

☒ Perform "unnecessary polygon boundaries check" on water bodies and streams feature classes. This tool is found under "Topology Checks."

☒ Perform "duplicate geometry check".  Attributes do not need to be checked during this tool. This tool is found under "Duplicate Geometry Checks."

☒ Perform "geometry on geometry check".   Spatial relationship is contains, attributes do not need to be checked.  This tool is found under "Feature on Feature Checks."

☒ Perform "polygon overlap/gap is sliver check".   Choose 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 features 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 errors 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.  Z tolerance is .01 feet. Polygons need to be exported as lines for the monotonicity tool.

☒ Perform connectivity check between (tidal waters to inland streams), (tidal waters to inland ponds), (inland ponds to inland streams) 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.  The unnecessary polygon boundary check must be run and all errors fixed prior to performing connectivity check.  If there are exceptions to the polygon boundary rule then that feature class must be checked against itself, i.e. inland streams to inland streams.

**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**

# 7  DEM Production & Qualitative Assessment

## DEM Production Methodology

Dewberry utilized ESRI software and Global Mapper for DEM production and the QC process. ArcGIS software was used to generate the products and the QC was performed in both ArcGIS and Global Mapper. The DEM workflow is shown in Figure 4 and described in further detail below.
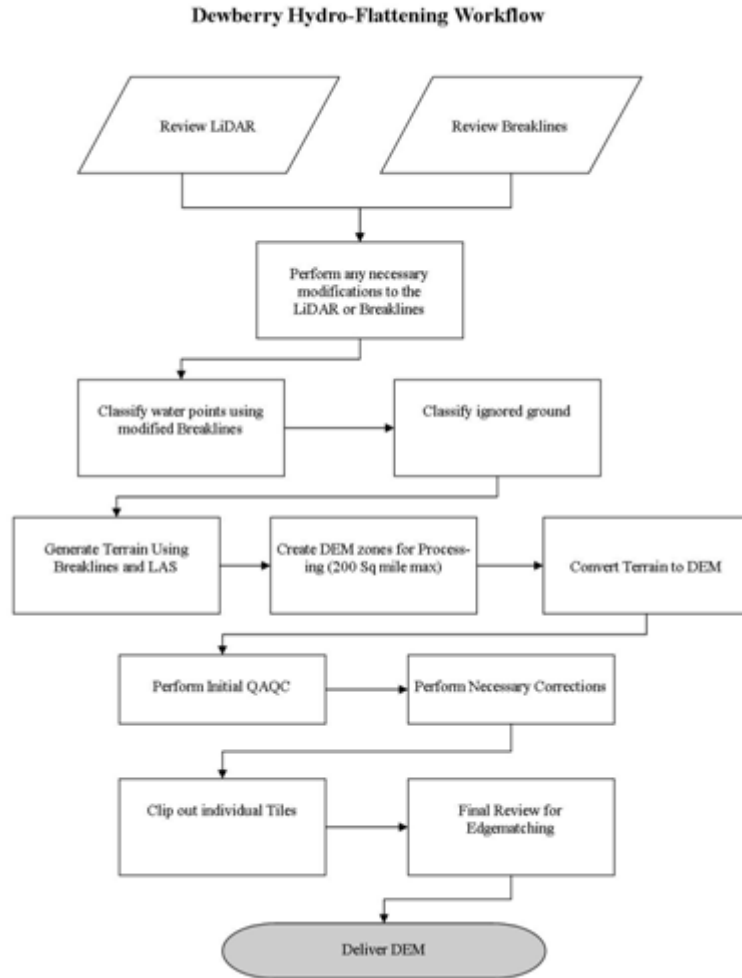
**Dewberry Hydro-Flattening Workflow**



**Figure 4 – Dewberry's DEM 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: Classify points in close proximity to the breaklines from Ground to class 10 (Ignored Ground). Close proximity will be defined as equal to the nominal point spacing on either side of the breakline. Breaklines will be buffered using this specification and the subsequent file will need to be prepared in the same manner as the water breaklines for classification. This process will be performed after the water points have been classified and only run on remaining ground points.
3. Terrain Processing: A Terrain will be generated using the Breaklines and LAS data that has been imported into ArcGIS as a Multipoint File. If the final DEMs are to be clipped to a project boundary that boundary will be used during the generation of the Terrain.
4. Create DEM Zones for Processing: Create DEM Zones that are buffered by 14m around the edges. Zones should be created in a logical manner to minimize the number of zones without creating zones to 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. *No zones were needed for the York County deliverable. The client allowed a full county DEM.*

5. Convert Terrain to Raster:  Convert Terrain to raster using the DEM Zones created in step 4. Utilizing the natural neighbors interpolation method. 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.  *No zones were needed for the York County deliverable. The client allowed a full county DEM.*
7. Correct Issues on Zones:  Corrections on zones will be performed following Dewberry's in-house correction process. *No zones were needed for the York County deliverable. The client allowed a full county DEM.*
8. Extract Individual Tiles:  Individual Tiles will be extracted from the zones utilizing the Dewberry created 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 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 scan for artifacts caused by the DEM generation process and to analyze the hydro-flattened features.  To perform this review, Dewberry created HillShade models and overlayed a partially transparent colorized elevation model.  Upon completion of this review, the DEM data was loaded into Global Mapper to ensure that all files were readable and that no artifacts existed between tiles.

The quality control steps taken by Dewberry are outlined in the QA Checklist below.

## DEM QA/QC Checklist

**Overview**

☒ Correct number of files is delivered and all files are in ESRI Grid Format

☒ All files are visually inspected to be free of artifacts and processing anomalies.

☒ DEM extent geometry shapefile is created

**Review**

☒ All files are tiled with a 10 foot cell size

☒ Georeference information is populated and accurate

- NAD83 HARN StatePlane South Carolina FIPS 3900 Feet International

☒ Vertical accuracy is verified by comparing the LAS to the DEM.

⊠ Water Bodies, wide streams and rivers and other non-tidal water bodies as defined in Section III are NOT to be hydro-flattened within the DEM.

⊠ Manually review bare-earth DEMs with a hillshade to check for processing issues or any general anomalies enforcement process or any general anomalies that may be present.

**Completion Comments: Complete – Approved**

## 8    Conclusion

Dewberry was tasked by the client to collect LiDAR data and create derived LiDAR products for Anderson, Oconee, and Pickens counties in South Carolina. In summary, Towill Inc. was subcontracted to perform the LiDAR acquisition and calibration. Once Dewberry received the LiDAR data, initial QA/QC checks on the raw LAS swaths were performed. The LiDAR data were compiled to meet a vertical accuracy of 15 cm and based on Towill's vertical accuracy tests the data meets that criterion. Dewberry then classified the data according to project specifications and the classification was checked to ensure its accuracy. Intensity images were then generated from the LiDAR. In addition, 3D breaklines were collected for the area. These breaklines and the LiDAR ground points were used to generate a DEM with hydro-flattened water bodies. Finally, metadata were created for all deliverables. Based on the scope of work, all delivered products for the tri county project conform to project specifications.