Aerial Data Acquisition Report

2020 Lidar and Derivative Products for Cherokee, Chester, Fairfield, Lancaster, and Union Counties

Aerial Data Acquisition Report for 2020 Lidar: Flood Map Modernization Initiative Contract

November 12, 2020

Prepared for:

South Carolina Floodplain Mitigation Program
South Carolina Department of Natural Resources

Prepared by:

ESP Associates, Inc.

Overview

This Aerial Data Acquisition Report provides a comprehensive accounting of the lidar data collection conducted in support of flood modeling, contour generation and other uses as needed by the South Carolina Department of Natural Resources (SCDNR). The data acquisition for the project was performed under the "Flood Map Modernization Initiative" Contract (Contract) between ESP Associates, Inc. (formerly ESP Associates, P.A.) and the SCDNR Flood Mitigation Program, dated December 2015. Data was collected by team member Quantum Spatial, under contract to ESP.

The 2020 SCDNR Lidar project area was comprised of 5 Counties in South Carolina with an aerial acquisition extent of 3,021 square miles that included a 1,000 ft buffer from the county boundaries. The project area of interest (AOI) encompassed the required 5,000 ft X 5,000 ft deliverable tiles, including the tiles that intersect with the 1,000 ft buffer. The South Carolina counties included in this project were: Cherokee, Chester, Fairfield, Lancaster, and Union. All flights were completed between January 16 and February 15, 2020, during leaf-off conditions.

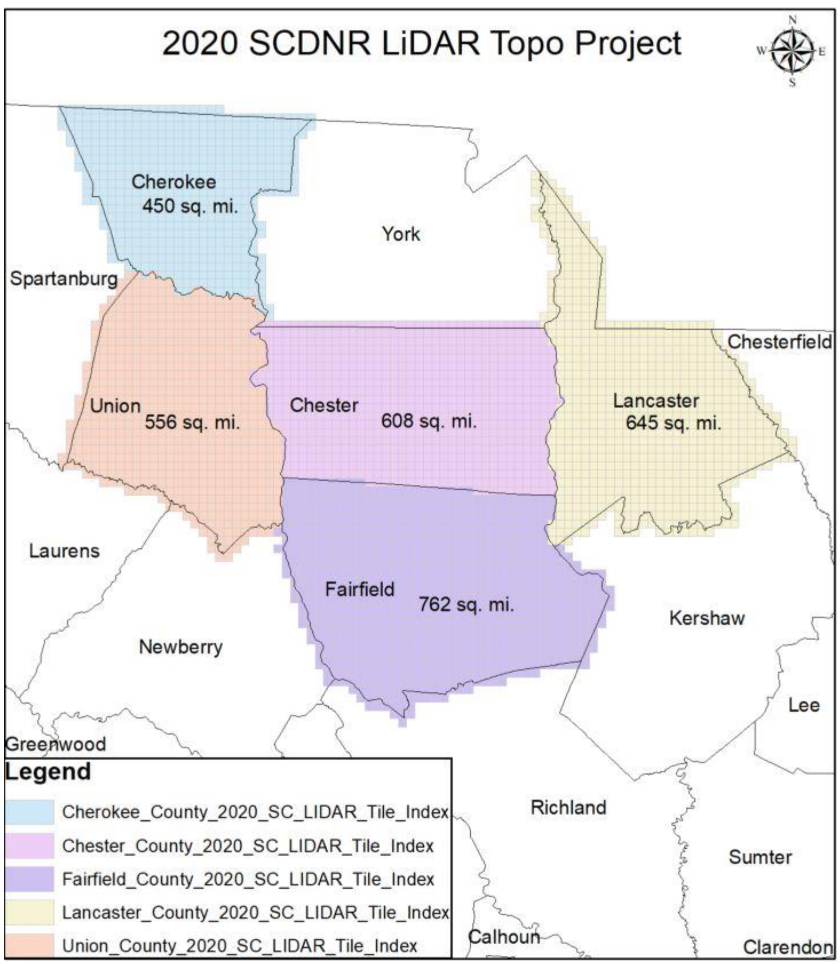


Figure 1. Project AOI

Scope of Work

All data collection complied with the specifications outlined in the SCDNR Scope of Services. The base specifications for this project are derived primarily from the USGS National Geospatial Program Base Lidar Specifications, Version 2.1, dated September, 2019 (BLS V2.1) and supplemented as appropriate by FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners, dated April 2003 and the American Society for Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0.0.

Geodesy

After data calibration, the LAS files delivered to ESP were in horizontal coordinates of International Feet in two decimal places, State Plane Coordinate System, South Carolina zone, NAD83 (2011). Elevations were in U.S. Survey foot units to two decimal places, North American Vertical Datum of 1988 (NAVD88) and processed with the Geoid12B for all products

Data Acquisition

Data acquisition was executed under Task 3 of the project. The lidar data were acquired using linear mode Leica ALS-80 sensors, serial numbers 3061 and 3546. The project AOI, depicted in figure 1, was collected in its entirety, ensuring that full tiles are delivered along the AOI buffered boundary.

Quantum Spatial conducted flight operations management for the aerial Lidar collection and reported to ESP during all phases of the acquisition. Their responsibilities included data acquisition planning, ongoing flight plan management, crew coordination, issue mitigation, as well as daily progress reporting to ESP. Quantum Spatial acquired data covering the requested AOI measuring approximately 3,016 square miles of USGS QL2 data, shown in the reference map below. The planned buffered AOI was approximately 3,042 square miles.

Quantum Spatial utilized high-performance aircraft equipped Leica ALS80 sensors. Lidar data was collected at an Aggregated Nominal Pulse Spacing (ANPS) of no greater than 0.71 meters; as determined against the aggregated swath, first return data. The laser was configured to collect multiple returns per pulse. This included, at a minimum, first, last, and at least one intermediate return. The signal strength (intensity) of each return pulse was also be recorded, as well as GPS time in accordance with the project requirements.

The Lidar systems were comprised of roll-compensated sensors with GPS/IMU units. Calibration test flights were performed frequently to verify computation of lever arms and ultimately the relative and absolute accuracy of the system.

Project Standards Met

The project aerial collection design ensured an aggregate nominal pulse density (ANPD) of >4 points per square meter (PPSM) at an aggregate nominal post spacing (ANPS) of <0.7 meters. The data was equivalent to a RMSE of 10.0 cm or better for NVA based on current USGS specifications. Flight operations and design ensured that the following specifications in the scope of services were met:

Project Design Specifications

- The data acquisition for this project will provide an ANPS of <0.7 meters (excluding data from flight line overlap). Raw data or extraneous values are to be processed to provide ground-level, surface elevations or "bare-earth" DEMs devoid of vegetation or man-made and other above-ground structures. Data voids are unacceptable. Areas not within 2X the DEM posting of raw data points are considered data voids and will be resolved except for those removed intentionally to delete points that impinge on man-made structures.
- The aerial laser system will be configured to collect multiple returns per pulse, with a minimum of a first, last and intermediate returns collected. Point returns collected will be stored in the LAS point cloud.
- Minimum Flight line overlap of 20% or greater.
- Flight lines will include parallel flight lines with at least one cross path flight line. Data regarding mission date, time, flight altitude, airspeed, scan angle, laser pulse rate and other relevant flight characteristics and information will be included in a project report and in the supporting, FGDC-compliant metadata.
- Data acquisition is permitted only during vegetation leaf-off season that begins in late-December and ends in mid-March.
- ESP will assure that all parts of the project area are fully covered. It is important that no portion of the project area be omitted from collection and processing unless specified in the scope of services due to military operational areas (MOAs) or other sensitive or restricted areas
- Lidar data from different flight lines will be consistent across flight lines with vertical offset not to exceed RMSEz of 10cm between adjacent flight lines
- LAS point cloud data will include Adjusted GPS time, intensity/signal strength data, and the headers will include the date (day and year) of creation.

Collection Environment

Acquisition was performed under leaf-off conditions during the winter of 2020. Acquisition commenced with the approval of the SCDNR and favorable flight conditions.

Parameter	Comment
Acquisition Dates	Start - January 16th
	End - February 15th
Atmospheric Conditions	Cloud and fog free
	Snow free
	No unusual flooding or inundation
	Leaf-off

Table 1: Acquisition Environment

Exceptions

An exception to the specifications was found during flight quality control. This consisted of a lift of data that had experience some winds aloft resulting in some, adjacent flight lines not achieving a full 20% overlap between lines. There were no gaps between flight lines identified and the data sufficiently covered the AOI. This was fully documented and SCDNR granted an exemption for this lift on February 20, 2020.

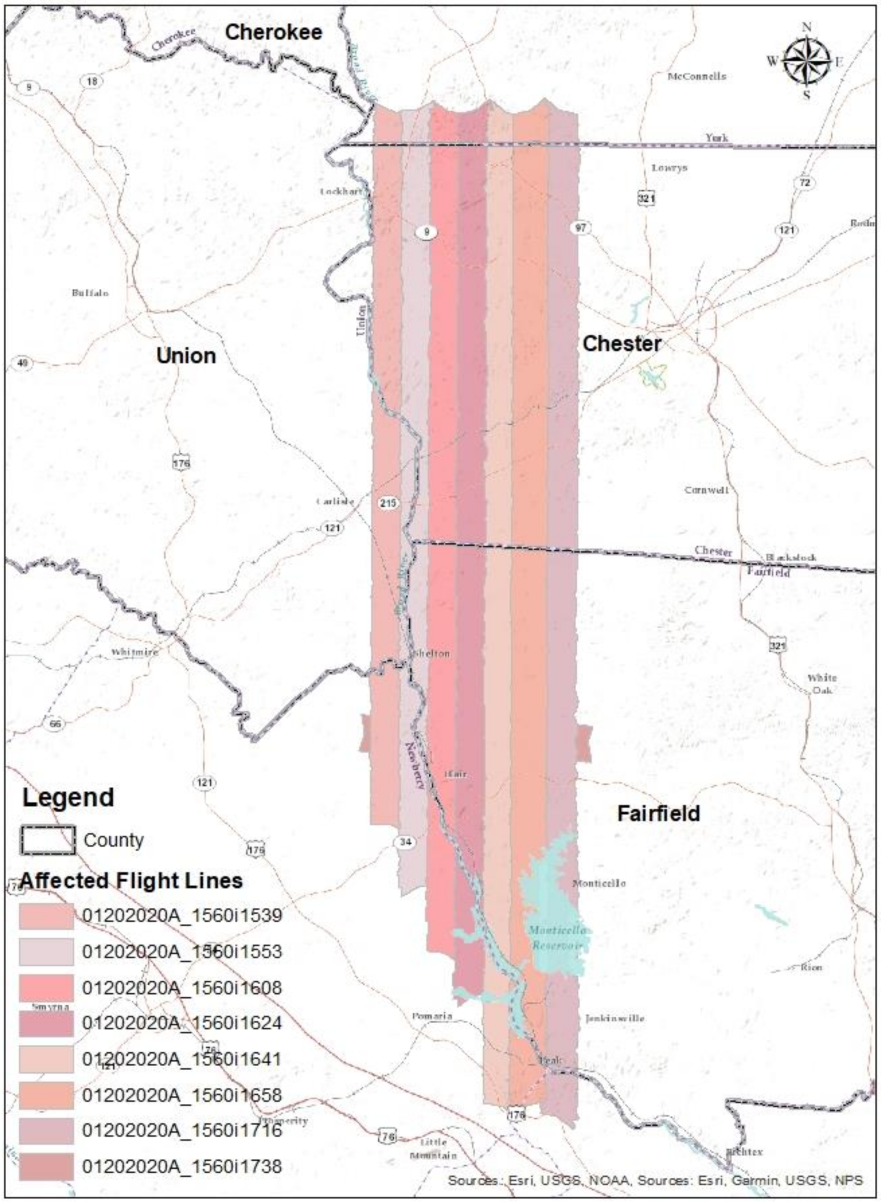


Figure 2: Exempted lift of data showing adequate coverage

Base Station Control

Quantum employed a number of methodologies to accomplish base stationing during acquisition. These typically included one or more of the following: setting base station locations at known NGS control located at basing airports that are within the maximum base line distance specified for any given mission, the utilization of the CORS network, and the use of TerraPos® Precise Point Positioning (PPP) and Trimble® CenterPoint™ Post-Processed Real-Time Extended (PP-RTX). Data was pre-processed before the crews left the area to assure that voids due to gaps between data swaths, instrument malfunction, insufficient return amplitude, or cloud cover or ground fog were re-captured to provide sufficient coverage. Unavoidable voids due to standing water or the exceptionally low reflectivity (shadowing by forest canopy) may be present.

Geodetic Control

The team utilized available GPS/GLONASS Continuously Operating Reference Station (CORS) sites as well as the VRS network in South Carolina where practical, in support of flight operations.

As-flown Flight Lines

As-flown flight lines are depicted in Figure 3 and are generated by converting the trajectory files into an ESRI shapefile. Cross flights are shown in red.

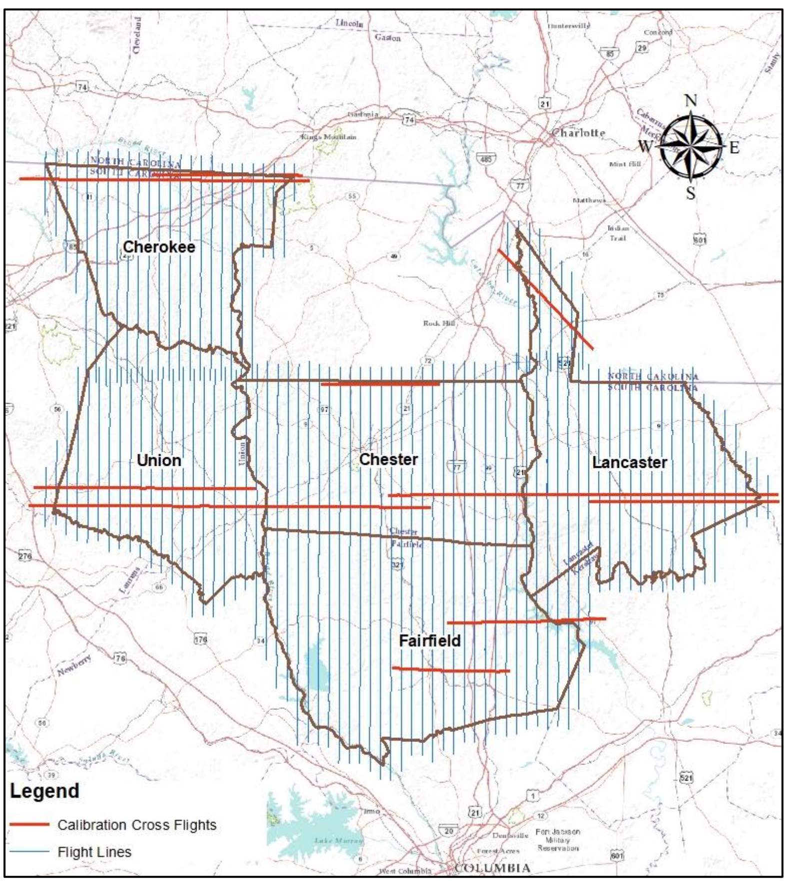


Figure 3: As-flown lidar flight lines and calibration cross flights

Data Processing, Calibration and Ground Survey Control

Data calibration processes and the establishment and use of ground survey control for the project and independent accuracy assessments are described and documented in the Report of Survey and Post-Processing Report documents.

Quality Control

This section of the report will cover the quality control procedures followed during acquisition as well as during a review of all flight data post-flight. The checks represent the steps necessary to ensure that the data collected meets or exceeds project specifications and to ensure that no additional reflights are needed before the flight season expires.

Flight Mission Checklist

Quantum completed Flight Mission Checklists that detailed general information for both Pre-flight and In-flight requirements. This ensured that a consistent quality control step process was followed prior to each flight.

Data Verification and Transfer

Upon completion of each mission, each aircrew executed additional responsibilities. First, they verified the integrity of the ABPS/IMU and Lidar data to ensure that a successful capture occurred. This step entailed using instrument-specific procedures and software. Next, a backup of all data occurred onto two independent transfer drives and the drives were shipped back to the Harris production facility as soon as possible.

Flight Data QA/QC

ESP reviewed daily reporting, flight logs, and initial trajectories after acquisition. Verification that proper environmental conditions were met during data collection was accomplished by reviewing flight logs and monitoring weather and ground conditions
Because calibration tasking was issued at a later date under DO35, the more comprehensive data checks conducted at ESP post-calibration will not begin until October of 2017.

Data Integrity Check

Initial reviews were conducted by Quantum flight and quality control staff. Upon receipt of the data at ESP, a review was conducted on each shipment to check for abnormally sized, corrupt, or missing files. After this initial review, the integrity and completeness of each LAS tile record was checked using an automated tool reporting on the following per tile:

Report Contents		
Project ID 1	Minor Version	Y Limits (actual)
Project ID 2	Number of Variable Length Records	Z Limits (header)
Project ID 3	Record Type	Z Limits (actual)
Generating Software	Number of Records	X/Y/Z Scale

Creation Day	Intensity	X/Y/Z Offset
Creation Year	Angle	Classes present and number of points per class
Source File ID	X Limits (header)	Returns present and number of points per return
Global Encoding	X Limits (actual)	
Major Version	Y Limits (header)	

Table 2: Data Integrity Report Contents

Coverage and Void Check

The data were checked for any potential coverage or unacceptable void issues at several stages in the QA process. The initial review was done by visually inspecting the data to ensure that any voids were acceptable (such as those caused by water bodies) and that the coverage encompassed the full extents of the project tile layout.

During other QA steps such as relative accuracy checks and review of intensities, a cursory review of coverage and voids was added to the workflow. This ensured a redundant approach of review to reduce or eliminate the potential for error.

ABGPS and IMU Data Review

During acquisition, monitoring ensured that proper Airborne GPS (ABGPS) surveying techniques were followed (including pre-and post-mission static initializations) and in-air Inertial Measurement Unit (IMU) alignment (proper self-calibration of IMU accelerometers and gyros) was conducted. After acquisition, as-flown trajectories and ABGPS quality plots were reviewed to ensure that no potential issues were missed and that all lines were flown to plan. ABGPS quality plots are included as part of the digital deliverable for this report.

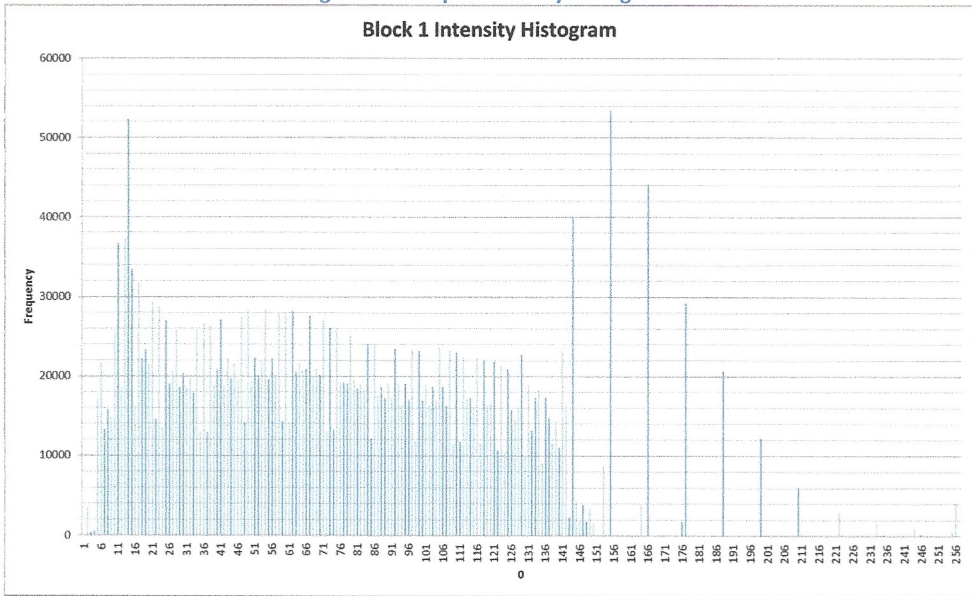
Relative Accuracy Check

Relative accuracy was achieved by adding a minimum of one cross-flight throughout each project block area across all flight lines and over roadways where possible. The cross-flights provided a common control surface used to remove any vertical discrepancies in the Lidar data between flight lines and aided in the bundle adjustment process with review of the roll, pitch, heading (omega, phi, kappa). The cross-flight was critical to ensure flight line ties across the sub-blocks and the entire project area.
The areas of overlap between flight lines are later used to calibrate (aka boresight) the Lidar point cloud to achieve proper flight line to flight line alignment in all 6 degrees of freedom. This includes adjustment of IMU and scanner-related variables such as roll, x, y, z, pitch, heading, and timing interval (calibration range bias by return)

Review of Intensity Values

Intensity values were inspected across the project area to ensure that no anomalous ranges of values were present and to ensure that it would be possible to achieve a minimal level of homogeneity across the project during the production phase. The intensity values of each lift of data were visually inspected and histograms were processed to review the actual range of values present in a given area. Figure 16 depicts an example of a test histogram.

Figure 4: Sample intensity histogram.



Recommendations for Future Projects

The following recommendations are being made for future LiDAR acquisition tasks commissioned by the SCDNR:

1. Recommend a review of the latest USGS Lidar Base Specification 2020, Rev. A and adaption of current SCDNR specifications to the latest USGS guidelines if appropriate.

Report Prepared by:

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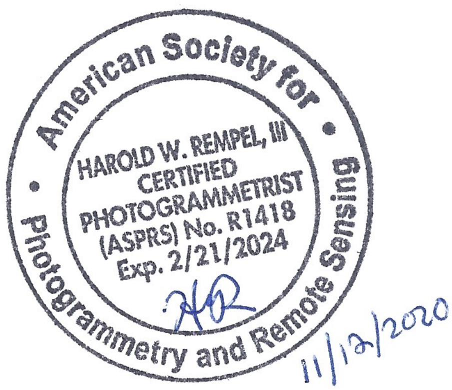

Post-Acquisition Report

Appendixes

Appendix A – Digital Attachments

The following digital attachments have been provided as part of this report:

- 2020 Lidar Flight Logs: contains all flight logs generated for this project (PDF format)
- 2020 Lidar GPS Reports: contains the GPS quality plots associated with each lift of data, by Block (PNG or BMP)
- 2020 Lidar Trajectory Files: contains as-flown trajectories for each sensor serial # (ESRI Shapefile format)
- 2020 Lidar Flight Plan: Google Earth KMZ file of original flight plan layout