Final Survey Report

USGS Mississippi NRCS East LIDAR

Task Order Name MS_NRCS_East_2018_D19

Contract Number G16PC00042

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Section 1. Executive Summary

1.1 Introduction

In support of the USGS NGTOC task order 140G0219F0262 LiDAR project, a geodetic control survey was performed for the collection of quality assurance and quality control (QA/QC) verification points. The importance of this survey was twofold; to ensure homogenous project meeting defined project accuracies, and to "tie" the mapping to existing Continually Operating Reference Stations (CORS) & National Geodetic Survey (NGS) framework used for aerial acquisition. This allows for repeatable measurements for current and future surveying and mapping needs.

The survey encompassed multiple areas of interest (AOI) across the states of Mississippi totaling 6,245 square miles of LIDAR. The survey was performed during the period of November 14th 2019 through November 17th 2020 with a total of four hundred and sixty-one (461) measured points. For LIDAR three hundred and seventy-eight (378) QA/QC points were subdivided into 3 main categories: non-vegetated, vegetated checkpoints, and Lidar calibration points.

Due to the rugged terrain and isolated pockets of cellular data coverage, Atlantic employed two methodologies' dynamically during the project. Real Time Network – Real Time Kinematic (RTN-RTK) was used when cellular data was available utilizing the Leica Smartnet RTN stations as this provides an instantaneous answer without any additional post processing. When cellular coverage was not available, static Global Navigation Satellite Survey System (GNSS) observations were conducted. These static sessions were postprocessed with the NGS Online Processing User Service (OPUS) using CORS data.

The final required accuracy of the Lidar calibration points (LCP's), QA/QC checkpoints were defined by the specified LiDAR for this project, the Lidar vertical accuracy is to meet a Root Mean Square Error ($RMSE_Z$) of 10 cm. Typically, QA/QC surveys should be at least three times as accurate as the final products being tested, therefore a $RMSE_{XY}$ of 10.0 cm or less & $RMSE_Z$ of 3.3 cm or less is required. Based on the analysis of the RTN-RTK checkpoints and OPUS network accuracy values, this geodetic control data meets this projects requirement for calibrating and testing the horizontal and vertical accuracies the acquired products.

Section 2. Survey Standards and Equipment

2.1 Applicable Standards

The accuracy standards for the QA/QC survey is to be approximately three times as accurate as the Lidar which required a vertical $RMSE_Z$ of 10 cm in non-vegetated areas. Although not specifically tested, the Lidar horizontal accuracy is defined to comply with the "compiled to meet" statement of having a $RMSE_R$ of 60cm or less. Therefore, the accuracy for the QA/QC survey was defined to have a horizontal $RMSE_R$ of <2cm and a $RMSE_Z$ of <3cm to meet and exceed project requirements.

2.2 Datum and Coordinate Systems

Horizontal: Universal Transverse Mercator (UTM) Zone 15N and 16N NAD83 (2011) meters.
Vertical: North American Vertical Datum 88 (NAVD88) Geoid12B meters.

2.3 Survey Equipment and Target Material

The following survey equipment was utilized to collect the survey coordinates:

- Trimble R8 GNSS Receiver S/N 46381-22371 (Dual Frequency)
- Trimble R10 GNSS Receiver S/N 5739470190 (Dual Frequency)
- Trimble TSC2 Data Collector S/N SS27A19346
- Trimble T10 Tablet S/N 01TT5B6X3745090
- Trimble VRS Now RTN (Trimble R8 Integrated GNSS Receivers)

Section 3. Survey and Methodology

3.1 Real Time Network Survey – Real Time Kinematic

RTN-RTK use is a standard throughout the Geo-Spatial industry and was chosen to be the most efficient way to execute this survey when cell phone coverage was available. The Trimble VRS Now RTN is a system of established GNSS receivers that transmits real-time corrections which are sent to the GNSS rover receiver via cellular connections. The internal accuracy for the fixed ambiguity solutions pertaining to the RTN-RTK network results in a repeatable accuracy of <2cm horizontally and <3cm vertically at the 95% confidence level. All QA/QC points were surveyed utilizing a 2-meter rod leveled over each point coupled with Trimble's R8 or R10 GNSS receiver using the Trimble VRS Now RTN. The GNSS receivers are configured to log data at 1 Hz with an update rate of 10Hz, and at a 10° degrees' mask with a collection rate of 180 seconds or better. During collection, the field technician monitored standard field criteria to optimize each observation. These field criteria include but is not limited to number of SV's, PDOP, RMS, and status of ambiguity i.e. "fixed" or "float". RTN-RTK Root Mean Square values and digital field notes can be found in a separate appendix document - *19059_Survey_Report_Appendix.pdf*

In instances where cell phone coverage was not available, RTN-RTK was not an option and static GNSS observations were performed. Similar to RTN-RTK acquisition, a GNSS receiver was positioned with a fixed height tripod over the point and data was collected for a minimum of 30 minutes. The data was post processed using OPUS which utilizes the Trimble VRS Now RTN CORS stations.

3.2 QA/QC Survey Points

To initially control the Lidar during the calibration phase of production, calibration survey points were required. The LCP's were strategically positioned throughout the project area of interest. These LCP's are located on hard to semi-hard surfaces with flat or moderate slope to allow for a good sampling of ground surface types where the Lidar reflectivity would yield a good range.

To test the vertical accuracy of the Lidar point cloud, Lidar checkpoints were surveyed and used in an independent verification process, post calibration. These check points were collected in two different categories: Non-Vegetated Accuracy (NVA) and Vegetated Vertical Accuracy (VVA). Checkpoints serve to analyze or "ground truth" the accuracy of the LIDAR return with respect to surfaces types found within the project area of interest.

Figure 1 displays the survey collection of eighty-three (83) Lidar calibration points, two hundred ten (210) NVA, one hundred sixty-eight (168) VVA checkpoints. Final point coordinates summary, photographs of the LCP's, checkpoints & PIDs, observation digital Field notes, and static session forms can be found in the separate appendix document.

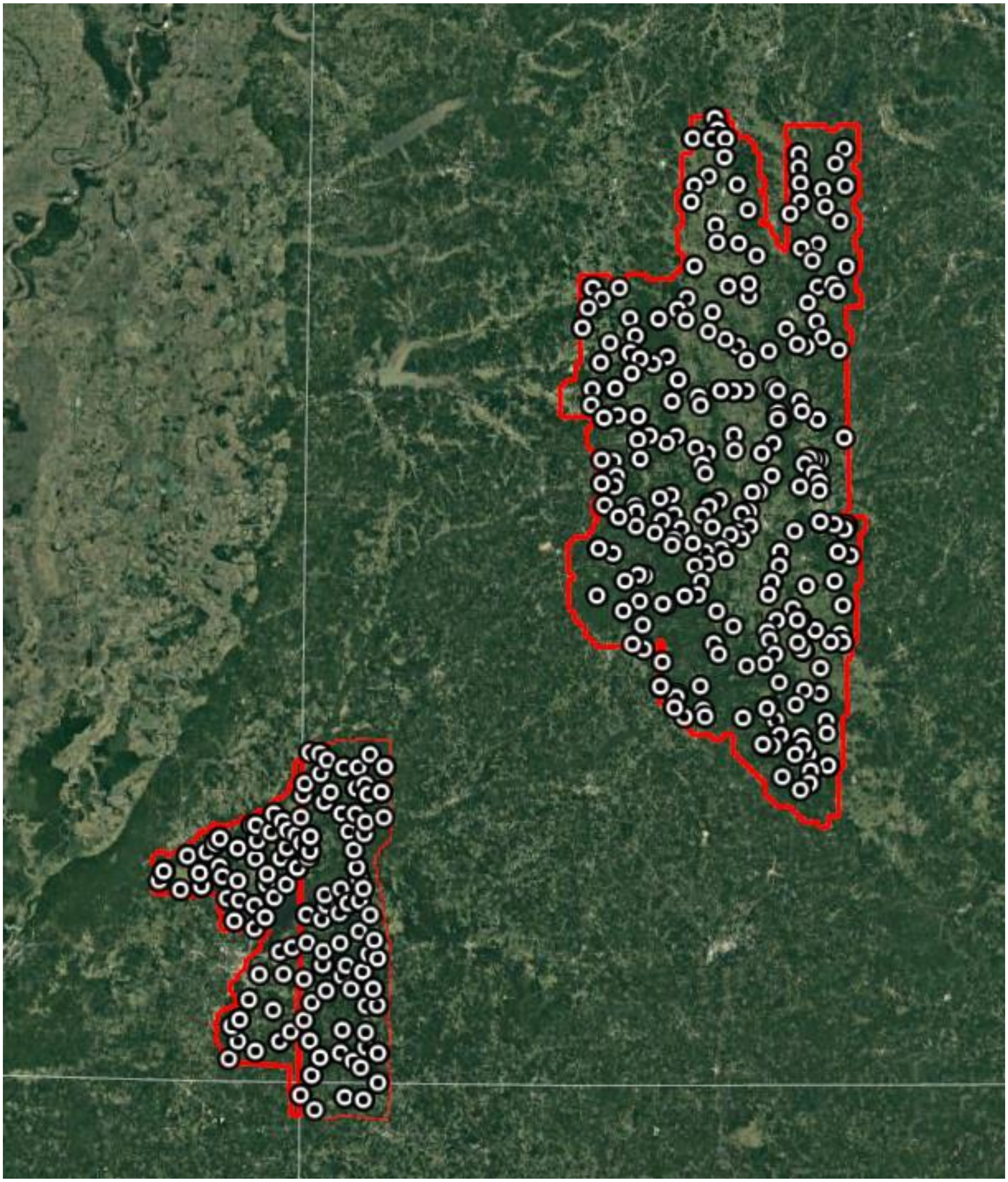

Figure 1: Project Survey Map

3.3 QA/QC Data Analysis

The advantages of using the RTN-RTK survey methodology is obtaining a real-time answer along with an estimate of its accuracy. However, to verify the system integrity and to provide a definitive check, Atlantic performs additional survey processes. Prior to the QA/QC survey, three (3) NGS monuments were recovered, statically observed, and processed using the National Geodetic Survey's (NGS) On-Line Positioning User Service (OPUS). OPUS uses a robust 3D least squares algorithm utilizing CORS within the vicinity of the survey point to provide a coordinate along with many metrics on the accuracy. The purpose of these points is to have a measured established coordinate which can be compared to the RTN-RTK coordinates. During each daily survey session, an NGS control monument or a temporary control point was occupied and compared with the OPUS network adjusted values. If the comparisons were within acceptable tolerances (good repeatability) then the GNSS unit and the system integrity was functioning properly.

To further verify the RTN-RTK data, observed coordinates for each checkpoint, and LCP were transferred into Trimble Business Center (TBC) software for QA/QC checks. During the analysis, the horizontal and vertical RMS values for each vector line between the RTN base and survey point were reviewed to ensure that they are within acceptable limits. For all static observations, the processing results and accuracy metrics are reviewed via the OPUS solution report. If the observations were weak, the data would have been re-observed, however no reobservations were required. The OPUS solutions, daily comparisons, and the QC observations can be found in a separate appendix document.

Section 4. Accuracy

4.1 Summary of Target Accuracies

The accuracy of this survey can be defined in multiple ways due to the methods for how the set verification monuments, Lidar calibration points, and checkpoints were derived. The accuracy of this survey was based on the analysis of the RTN-RTK final verification point checks at a 95% confidence level which statistically was <2cm horizontally and <3cm vertically. This was confirmed by the daily check measurements on the verification points. The static measurements also met the same accuracy based on the statistical data provided by the OPUS reports. The data easily exceeds the requirements for testing the vertical accuracy of the Lidar data.

Section 5. Custody Transfer Assurance

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