# Airborne Topographic Lidar Report

## Wisconsin WROC - 3DEP

## Forest County Lidar 2017


Prime contractor: Ayres Associates
Airborne lidar acquisition completed by Quantum Spatial

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# 1. Summary / Scope

## 1.1. Summary

This report contains a summary of the Wisconsin WROC Forest QL2 2017 lidar acquisition task order, issued by Ayres under their Task Order # 24 on March 3, 2017. The task order yielded a project area covering 1,056 square miles over Forest County, Wisconsin. The intent of this document is only to provide specific validation information for the data acquisition/collection work completed as specified in the task order.

## 1.2. Scope

Aerial topographic lidar was acquired using state-of-the-art technology along with the necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems. The aerial data collection was designed with the following specifications listed in Table 1 below.

**Table 1. Originally Planned Lidar Specifications**

| Average Point Density | Flight Altitude (AGL) | Field of View | Minimum Side Overlap | RMSEz |
|---|---|---|---|---|
| 2 pts / m² | 1,800 m | 40° | 30% | ≤ 10 cm |

## 1.3. Coverage

The project boundary covers 1,056 square miles and encompasses the entirety of Forest County in northeastern Wisconsin. A buffer of 100 meters was created to meet task order specifications. Lidar extents are shown in Figure 1.

## 1.4. Duration

Lidar data was acquired from April 22, 2017 to April 25, 2017 in seven total lifts. See "Section: 2.5. Time Period" for more details.

## 1.5. Issues

There were no issues to report with this project.

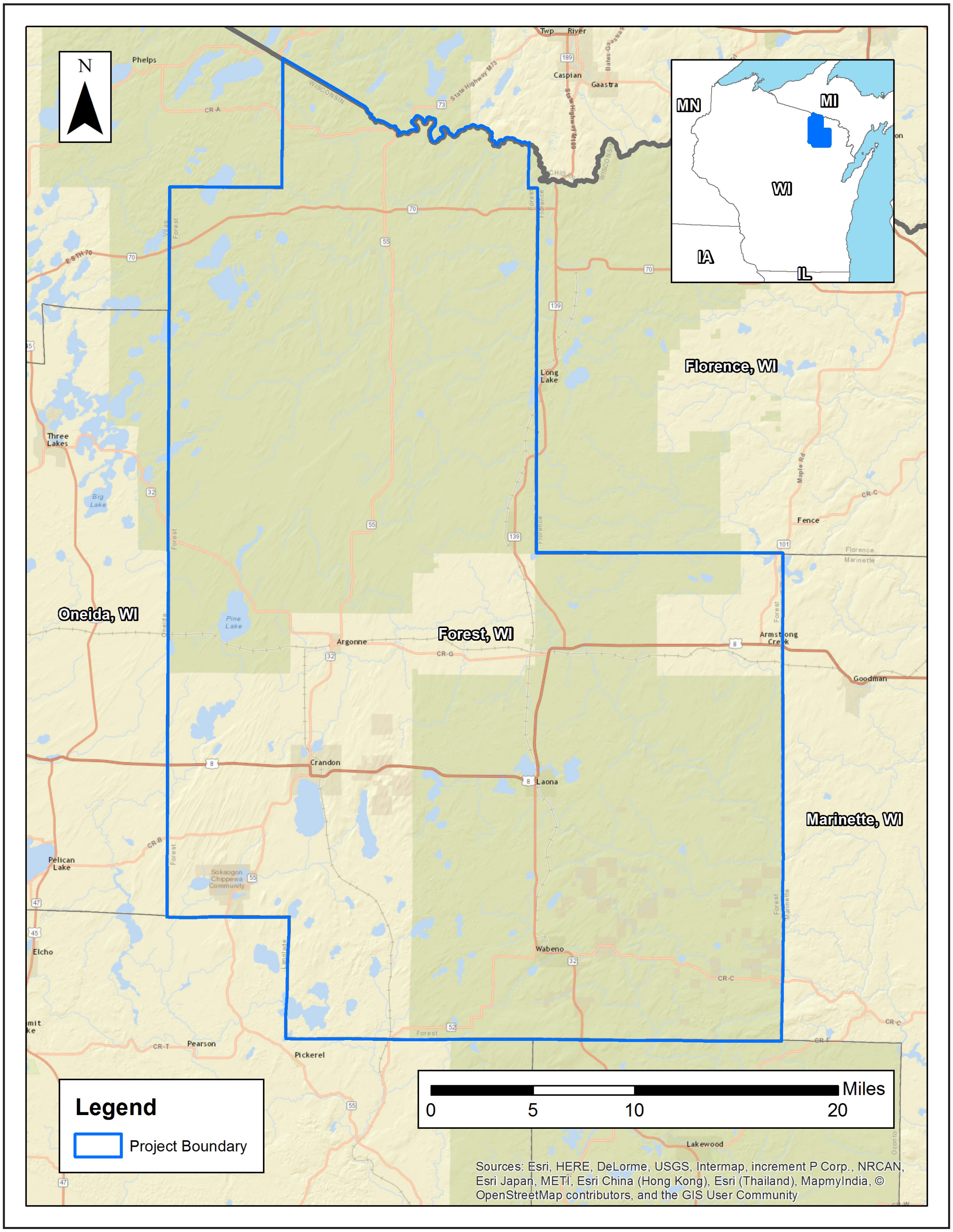
## 1.6. Deliverables

The following products were produced and delivered:

- Raw lidar point cloud data swaths in LAS 1.4 format
- Lidar point cloud data, tiled, in LAS 1.4 format
- SBETs in .SOL format
- Trajectories in .TRJ format
- Flight logs and GPS/IMU statistics in .PDF format
- Lift-level metadata in .XML format

All geospatial deliverables were produced in NAD83 (2011) WISCRS Forest County Coordinate System, US survey feet; NAVD88 (GEOID12B), US survey feet. All tiled deliverables have a tile size of 4,500-feet x 4,500-feet. Tile names follow a sequential naming schema.

**Figure 1. Project Boundary**



# 2. Planning / Equipment

## 2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity.

Detailed project flight planning calculations were performed for the project using Leica MissionPro planning software. The entire target area was comprised of 58 planned flight lines measuring approximately 2,111 total flight line miles (Figure 2).

## 2.2. Lidar Sensor

Quantum Spatial utilized a Leica ALS 70 lidar sensor (Figure 3), serial number 7161, during the project. The Leica ALS 70 system is capable of collecting data at a maximum frequency of 500 kHz, which affords elevation data collection of up to 500,000 points per second. The system utilizes a Multi-Pulse in the Air option (MPIA). The sensor is also equipped with the ability to measure up to 4 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd and last returns. The intensity of the returns is also captured during aerial acquisition.

A brief summary of the aerial acquisition parameters for the project are shown in the Lidar System Specifications in Table 2.

**Figure 2. Planned Flight Lines**

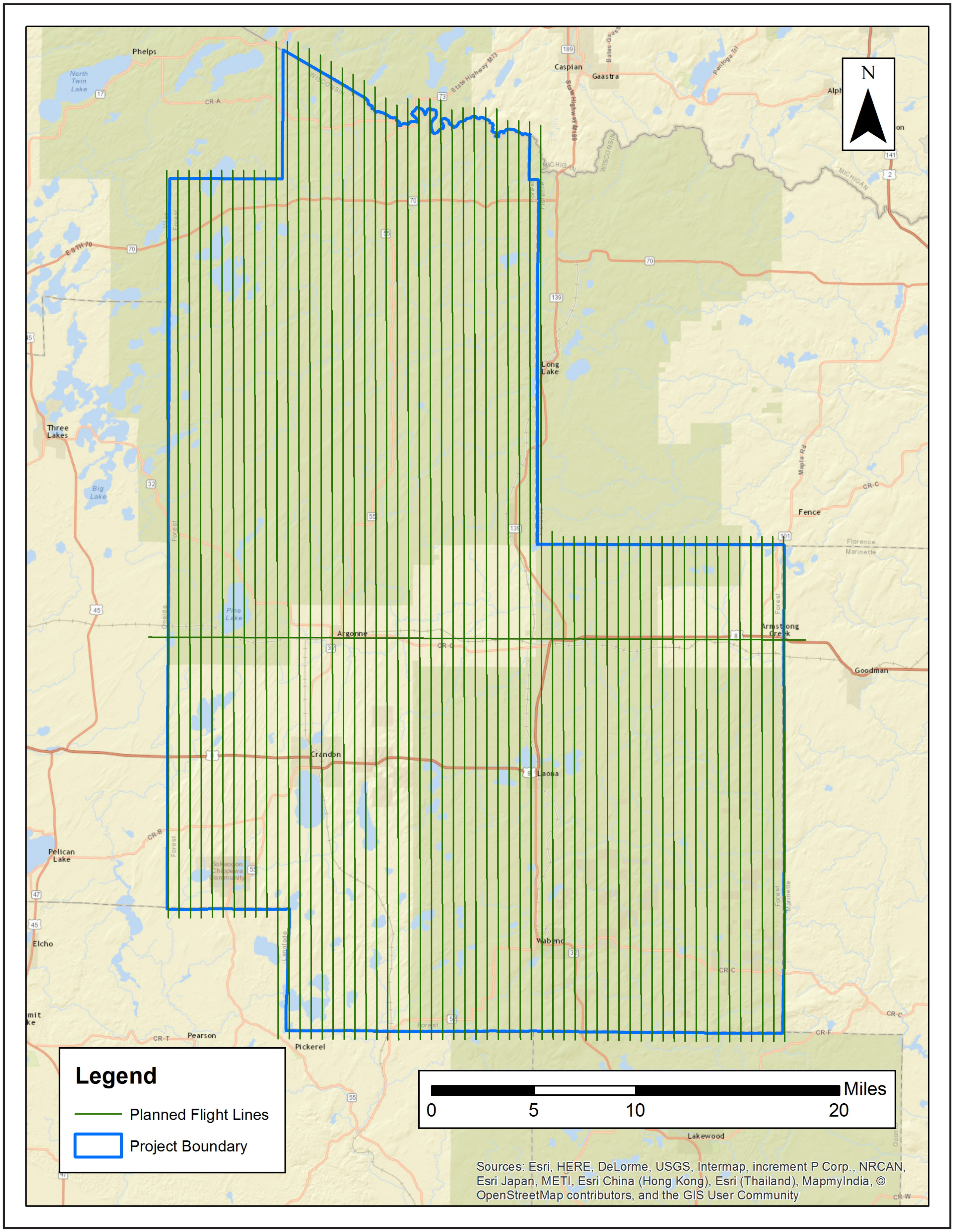
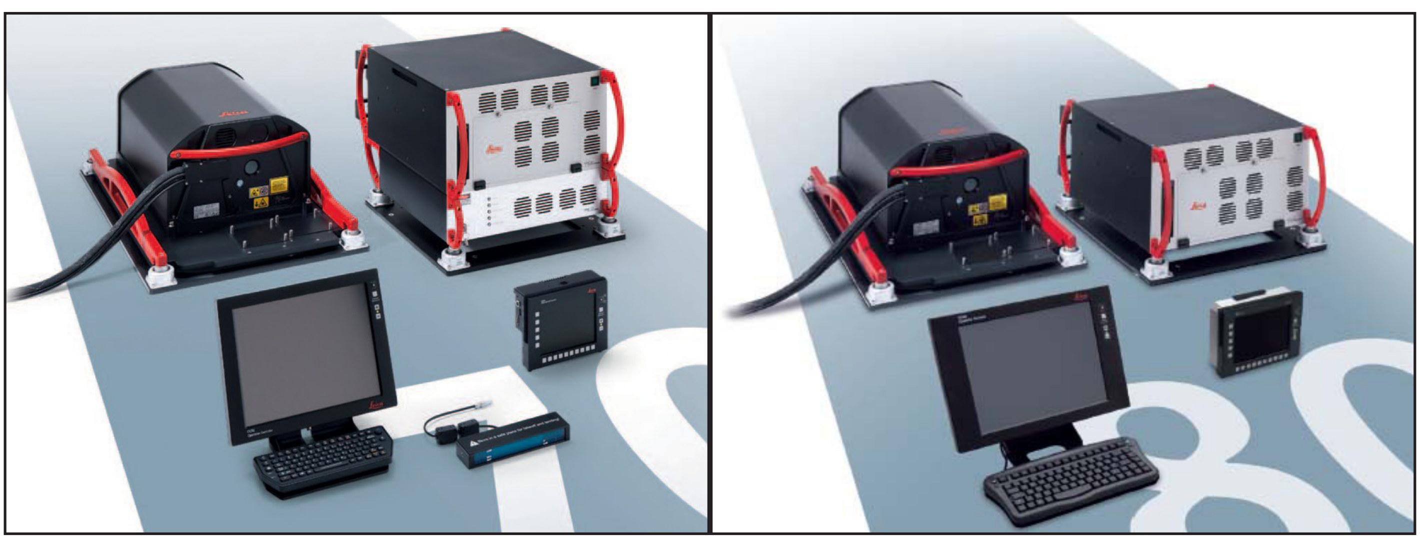


**Table 2. Lidar System Specifications**

| | | |
|---|---|---|
| Terrain and Aircraft Scanner | Flying Height | 1,800 m |
| | Recommended Ground Speed | 150 kts |
| Scanner | Field of View | 40° |
| | Scan Rate Setting Used | 53.4 Hz |
| Laser | Laser Pulse Rate Used | 302.6 kHz |
| | Multi Pulse in Air Mode | Enabled |
| Coverage | Full Swath Width | 1,310.29 m |
| | Line Spacing | 999.15 m |
| Point Spacing and Density | Maximum Point Spacing Along Track | 1.01 m |
| | Maximum Point Spacing Across Track (in phase) | 1.44 m |
| | Maximum Point Spacing Across Track (out of phase) | 0.72 m |
| | Average Point Density | 2.99 pts / m² |

**Figure 3. Leica ALS 70 LiDAR Sensor**



## 2.3. Aircraft

All flights for the project were accomplished through the use of a customized Piper Navajo (twinpiston), Tail # N262AS. This aircraft provided an ideal, stable aerial base for lidar acquisition. This aerial platform has relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using a state-of-the-art Leica lidar systems. Some of Quantum Spatial's operating aircraft can be seen in Figure 4 below.

Figure 4. Some of Quantum Spatial's Planes

## 2.4. Base Station Information

GPS base stations were utilized during all phases of flight (Table 3). The base station locations were verified using NGS OPUS service and subsequent surveys. Base station locations are depicted in Figure 5 (not all base stations fall within the map footprint). Data sheets, graphical depiction of base station locations or log sheets used during station occupation are available in Appendix A.

**Table 3. Base Station Locations**

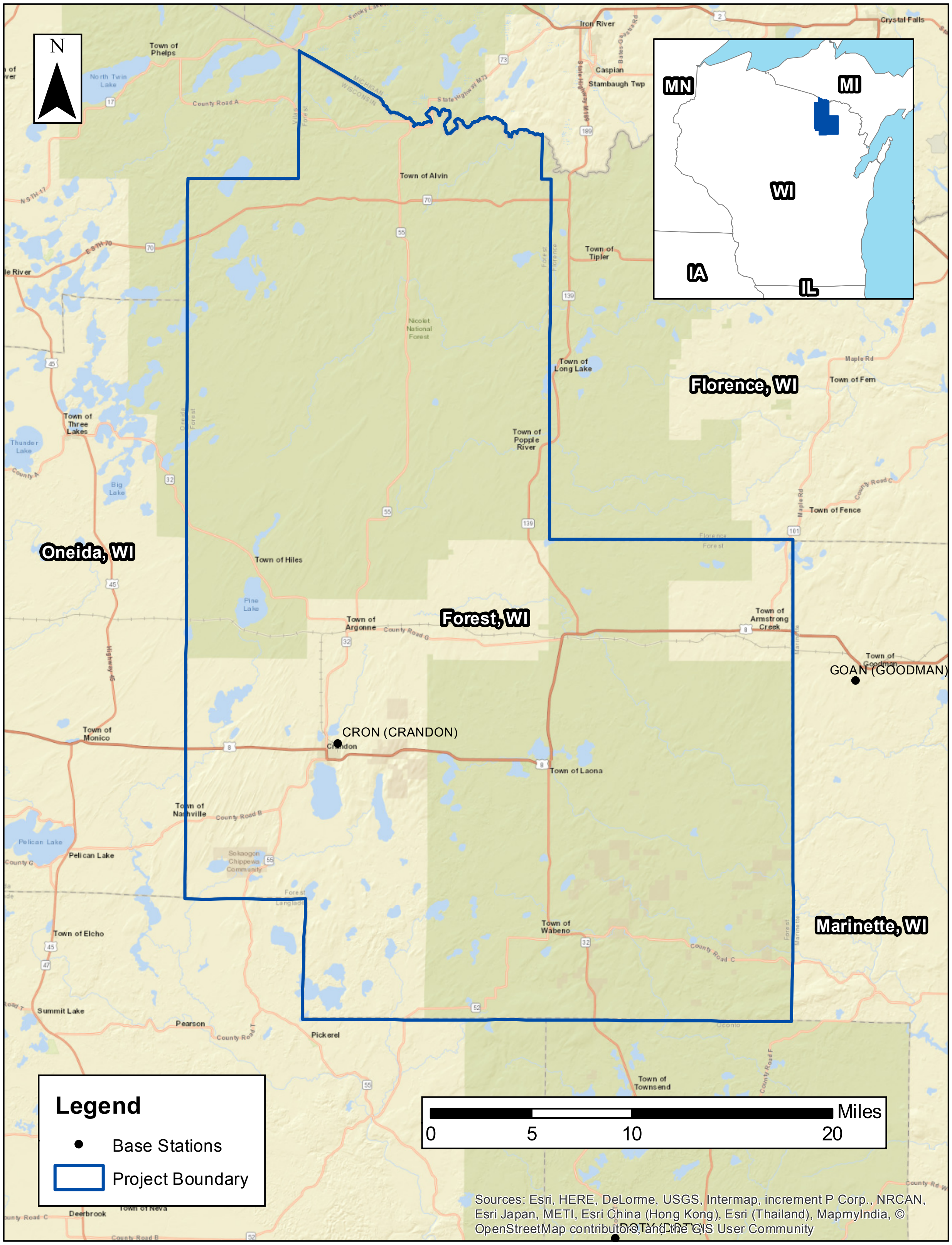
| Base Station | Longitude | Latitude | Ellipsoid Height (m) |
|---|---|---|---|
| CRON | -88.89178871 | 45.57639974 | 390.901 |
| DOTY | -88.60675199 | 45.21970869 | 419.362 |
| GOAN | -88.36004428 | 45.62136437 | 344.14 |
| RHER | -89.44384884 | 45.63284798 | 299.827 |
| PHPS | -89.07946161 | 46.06331337 | 387.702 |
| MIIR | -88.633364 | 46.080381 | 383.306 |

## 2.5. Time Period

Project specific flights were conducted over several days. Seven sorties, or aircraft lifts were completed. Accomplished sorties are listed below.

- April 22, 2017-B (N262AS, SN7161)
- April 24, 2017-A (N262AS, SN7161)
- April 24, 2017-A (N73TM, SN7178)
- April 24, 2017-B (N262AS, SN7161)
- April 24, 2017-C (N262AS, SN7161)
- April 25, 2017-A (N262AS, SN7161)
- April 25, 2017-B (N262AS, SN7161)

**Figure 5. Base Station Locations**



# 3. Processing Summary

## 3.1. Flight Logs

Flight logs were completed by lidar sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- Flight Date / Lift Number
- FOV (Field of View)
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Base Station
- PDOP avoidance times
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Returns
- Crab

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix A.

## 3.2. Lidar Processing

Inertial Explorer software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the lidar sensor during all flights. Inertial Explorer combines aircraft raw trajectory data with stationary GPS base station data yielding a "Smoothed Best Estimate Trajectory (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the lidar missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Inertial Explorer processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: Max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory. All relevant graphs produced in the Inertial Explorer processing environment for each sortie during the project mobilization are available in Appendix A.

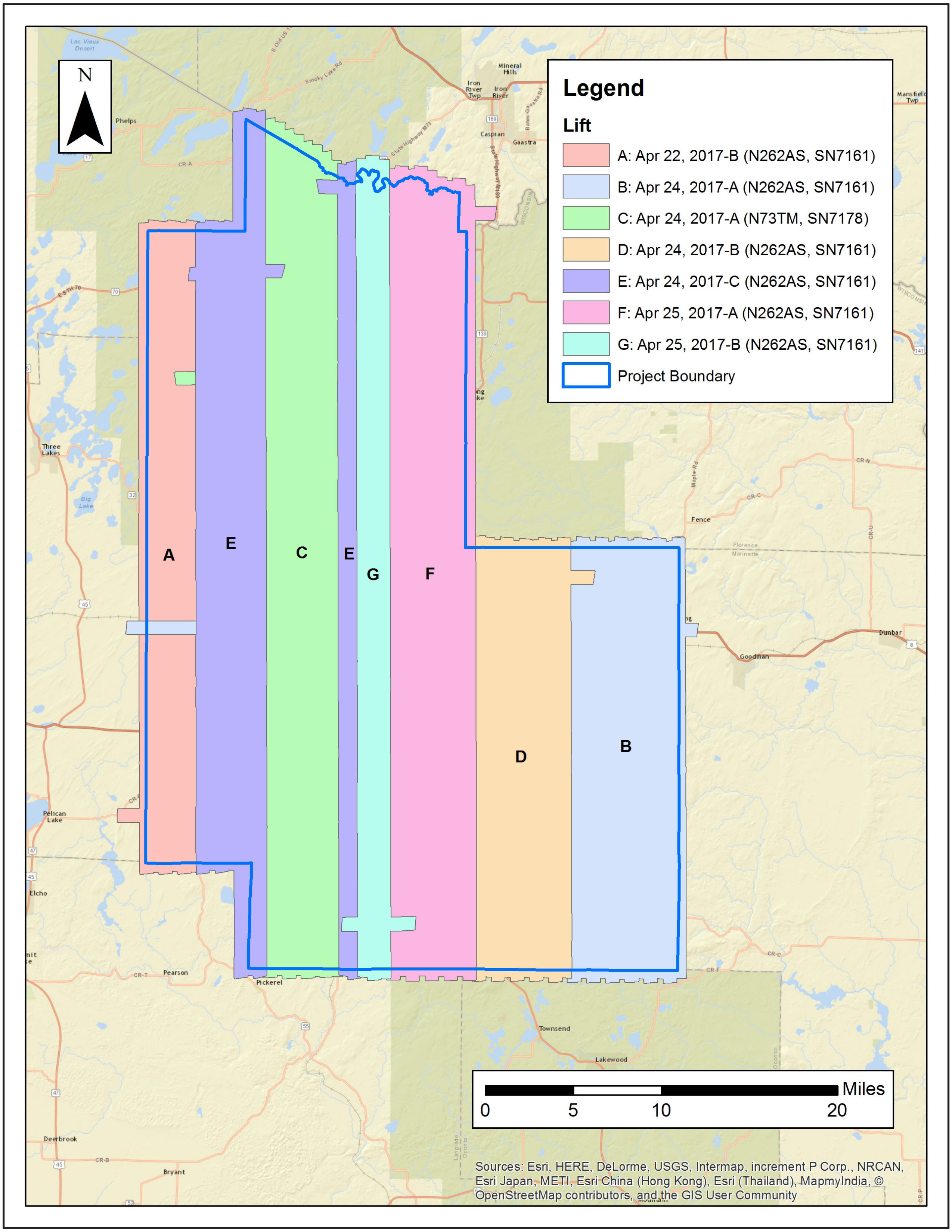
The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. Laser point data are imported into TerraScan and a manual calibration is performed to assess the system offsets for pitch, roll, heading and scale. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above-ground features are removed from the data set. Point clouds were created using the Leica CloudPro software. GeoCue distributive processing software was used in the creation of some files needed in downstream processing, as well as in the tiling of the dataset into more manageable file sizes. TerraScan and TerraModeler software packages were then used for the automated data classification, manual cleanup, and bare earth generation. Project specific macros were developed to classify the ground and remove side overlap between parallel flight lines.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper was used as a final check of the bare earth dataset. GeoCue was used to create the deliverable industry-standard LAS files for both the All Point Cloud Data.

# 4. Project Coverage Verification

Coverage verification was performed by comparing coverage of processed .LAS files captured during project collection to generate project shape files depicting boundaries of specified project areas. Please refer to Figure 6.

**Figure 6. Flightline Swath LAS File Coverage**



# 5. Ground Control and Check Point Collection

Quantum Spatial utilized 22 ground control (calibration) points collected by Ayres Associates as an independent test of the accuracy of this project. In this document, horizontal coordinates for ground control and QA points for all lidar classes are reported in NAD83 (2011) WISCRS Forest County Coordinate System, US survey feet; NAVD88 (GEOID12B), US survey feet.

## 5.1. Calibration Control Point Testing

Figure 7 shows the location of each bare earth calibration point for the project area. Table 4 depicts the Control Report for the lidar bare earth calibration points, as computed in TerraScan as a quality assurance check. Note that these results of the surface calibration are not an independent assessment of the accuracy of these project deliverables, but the statistical results do provide additional feedback as to the overall quality of the elevation surface.

**Figure 7. Calibration Control Point Locations**

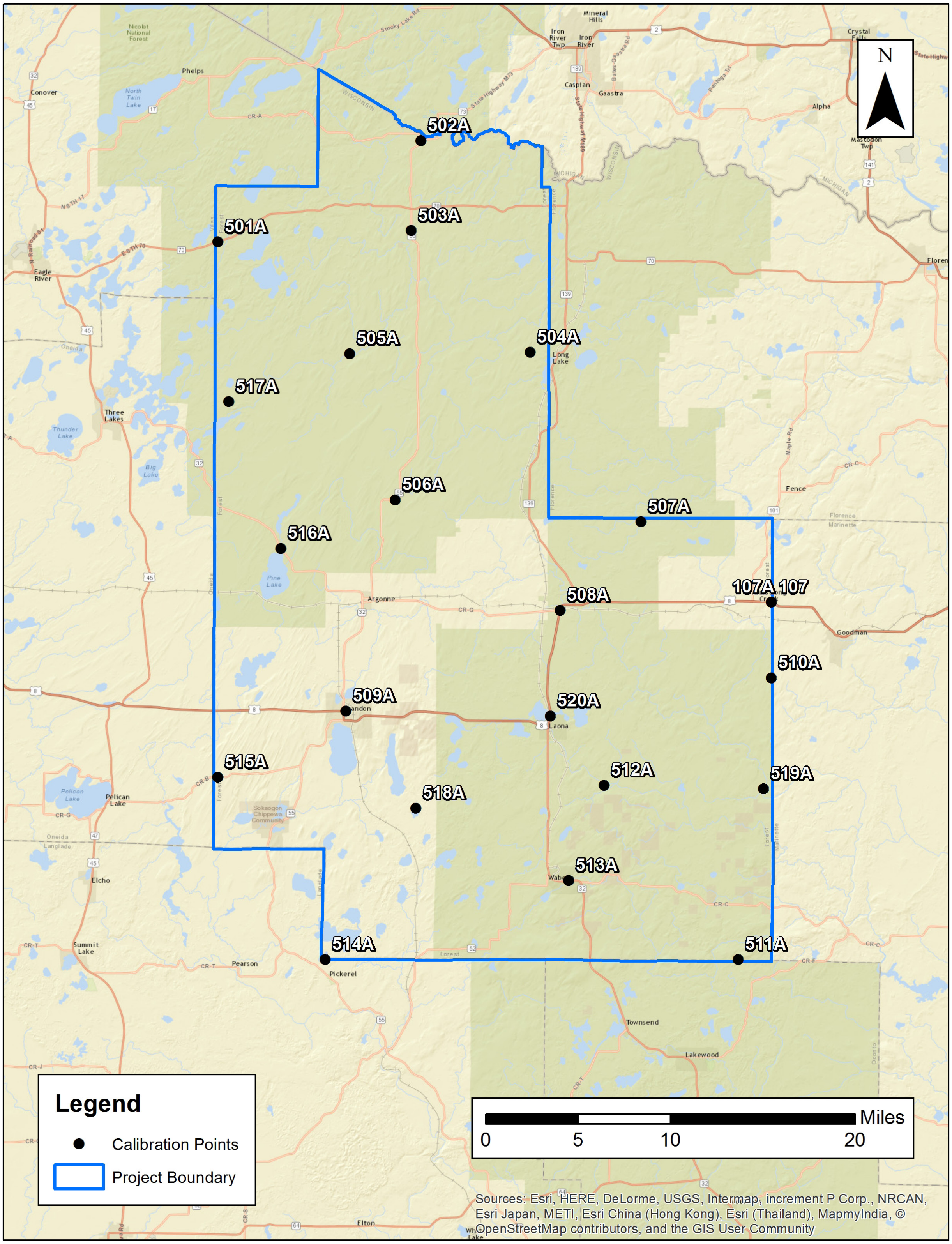


**Table 4. Calibration Control Point Report**
**Units = US survey feet**

| Number | Easting | Northing | Known Z | Laser Z | Dz |
|---|---|---|---|---|---|
| 507A | 920766.105 | 625417.629 | 1472.26 | 1472.48 | 0.22 |
| 520A | 894972.61 | 569919.004 | 1575.916 | 1576.09 | 0.174 |
| 516A | 817932.829 | 617817.173 | 1641.554 | 1641.72 | 0.166 |
| 506A | 850582.18 | 631618.764 | 1650.886 | 1651.05 | 0.164 |
| 503A | 855160.033 | 708721.785 | 1717.347 | 1717.48 | 0.133 |
| 512A | 910267.236 | 550119.585 | 1478.725 | 1478.85 | 0.125 |
| 509A | 836493.699 | 571294.345 | 1620.143 | 1620.18 | 0.037 |
| 517A | 803002.547 | 659762.763 | 1683.549 | 1683.58 | 0.031 |
| 504A | 889151.025 | 673887.673 | 1568.854 | 1568.88 | 0.026 |
| 514A | 830563.54 | 500326.138 | 1559.88 | 1559.9 | 0.02 |
| 501A | 799903.393 | 705420.803 | 1750.945 | 1750.95 | 0.005 |
| 513A | 900116.969 | 522896.087 | 1534.301 | 1534.29 | -0.011 |
| 519A | 955866.27 | 549139.81 | 1267.984 | 1267.93 | -0.054 |
| 107A | 958075.423 | 602457.632 | 1438.282 | 1438.22 | -0.062 |
| 508A | 897717.247 | 600143.495 | 1507.442 | 1507.38 | -0.062 |
| 518A | 856445.249 | 543514.034 | 1639.055 | 1638.94 | -0.115 |
| 510A | 958085.4 | 580790.357 | 1437.957 | 1437.82 | -0.137 |
| 511A | 948618.505 | 500321.623 | 1331.985 | 1331.84 | -0.145 |
| 505A | 837581.789 | 673484.131 | 1646.004 | 1645.83 | -0.174 |
| 515A | 799941.628 | 552477.31 | 1701.44 | 1701.26 | -0.18 |
| 107 | 958052.648 | 602464.359 | 1438.752 | 1438.53 | -0.222 |
| 502A | 857944.31 | 734310.319 | 1565.104 | 1564.83 | -0.274 |

| | |
|---|---|
| Average Dz | -0.015 |
| Minimum Dz | -0.274 |
| Maximum Dz | 0.22 |
| Average Magnitude | 0.115 |
| Root Mean Square | 0.138 |
| Std Deviation | 0.141 |