FEMA HQ - Shawano County, WI
QL2 2015 LiDAR Project Report

USGS Contract # G10PC00026
Requisition # 40225410
Task Order # G15PD00640

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1. Summary / Scope

1.1. Summary

This report contains a summary of the FEMA HQ - Shawano County, WI 2015 QL2 LiDAR acquisition task order, issued by the USGS National Geospatial Technical Operations Center (NGTOC) under their Geospatial Product and Services Contract on August 7, 2015. The task order yielded a project area covering 909 square miles over Shawano County, Wisconsin. The intent of this document is only to provide specific validation information for the data acquisition/ collection, processing, and production of deliverables 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
2.67 pts / m^2	1,700 m	30°	30%	≤ 10 cm

1.3. Coverage

The LiDAR project boundary covers 909 square miles over Shawano County in eastern Wisconsin. LiDAR extents are shown in Figure 1 on the following page.

1.4. Duration

LiDAR data was acquired from November 14, 2015 to November 15, 2015 in eight total lifts. See “Section: 2.5. Time Period” for more details.

1.5. Issues

There were no issues to report with this project.

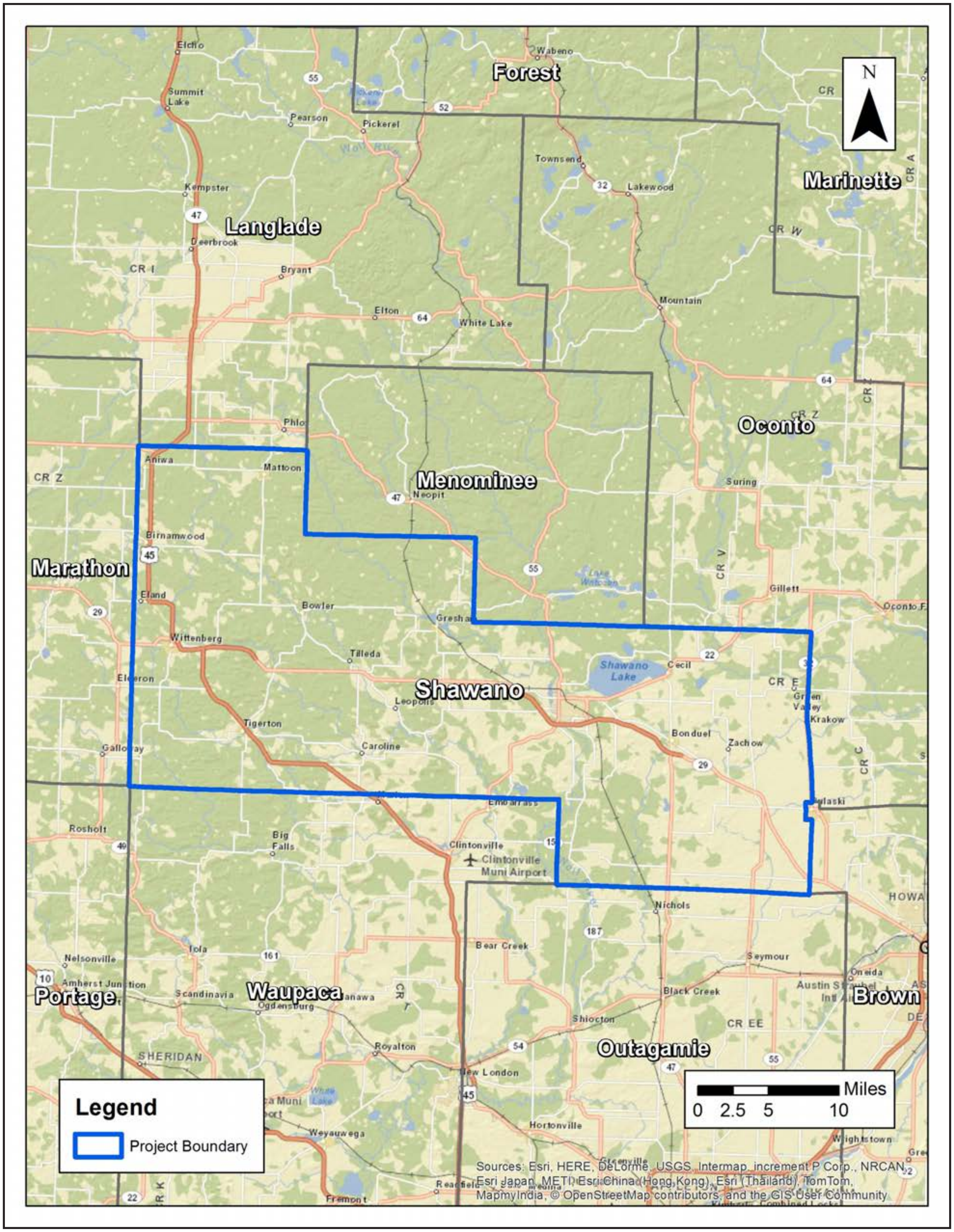
1.6. Deliverables

The following products were produced and delivered:

- Raw point cloud data, swath, in LAS 1.4 format
- Classified point cloud data, tiled, in LAS 1.4 format
- Hydro-flattened breaklines, single layer, in Esri file geodatabase format
- 1-meter hydro-flattened bare-earth raster DEM, tiled, in ERDAS .IMG format
- 1-meter intensity images, tiled, in GeoTIFF format
- Processing boundary in Esri shapefile format
- Tile index in Esri shapefile format
- Calibration control points and QC checkpoints in Esri shapefile format
- Project-, deliverable-, and lift-level metadata in .XML format
- Accuracy Analyst report in .XLS format

All geospatial deliverables were produced in NAD83 (2011), UTM Zone 16, Meters; NAVD88 (Geoid 12B), Meters. All tiled deliverables have a tile size of 1,500 meters x 1,500 meters and follow the US National Grid 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 Optech MissionNAV planning software. The entire target area was comprised of 66 planned flight lines measuring approximately total 1,914.2 flight line miles (Figure 2).

2.2. LiDAR Sensor

Quantum Spatial utilized a Optech Orion LiDAR sensor (Figure 3), serial numbers 324 and 329, during the project. This system is capable of collecting data at a maximum frequency of 167kHz, which affords elevation data collection of up to 167,000 points per second. The system utilizes a Multi-Pulse in the Air option (MPIA). This sensor is also equipped with the ability to measure up to 5 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd, 4th, and last returns. The intensity of the first four 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 LiDAR Flight Lines

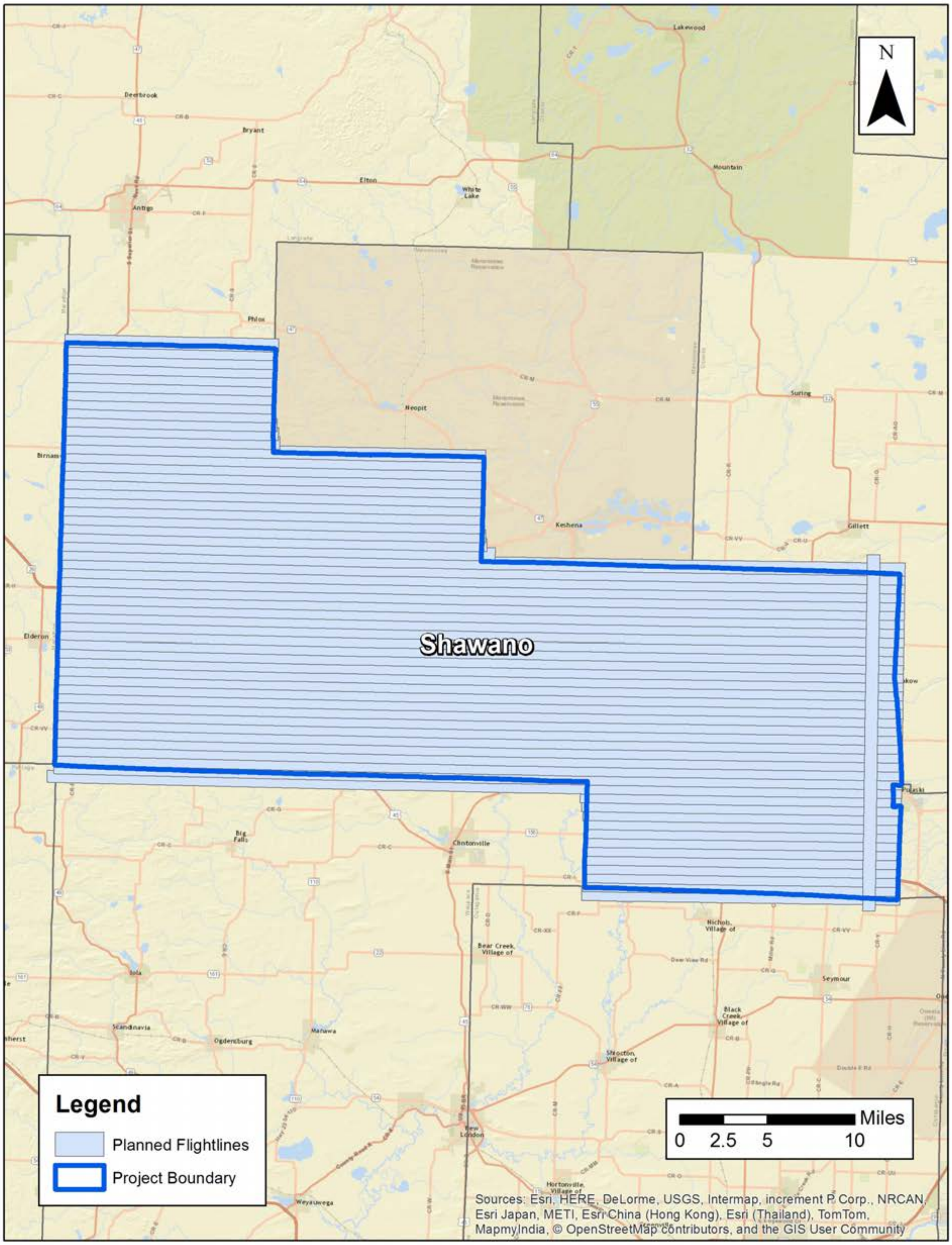


Table 2. Lidar System Specifications

		324, 329
Terrain and Aircraft Scanner	Flying Height	1,700 m
	Recommended Ground Speed	140 kts
Scanner	Field of View (deg)	38°
	Scan Rate Setting Used (Hz)	52 Hz
Laser	Laser Pulse Rate Used (kHz)	225 kHz
	Multi Pulse in Air Mode	Enabled
Coverage	Full Swath Width (m)	1,170.71 m
Point Spacing and Density	Maximum Point Spacing Across Track	0.658 m
	Maximum Point Spacing Along Track	0.6925 m
	Average Point Density	2.67 pts / m^2

Figure 3. Optech Orion LiDAR Sensor

2.3. Aircraft

All flights for the project were accomplished through the use of customized planes. Plane type and tail numbers are listed below.

- Piper PA-28 Cherokee (piston-single), Tail Number: N73TM
- Partenavia P68-TC (multi-engine piston), Tail Number: N300LF

These aircraft provided an ideal, stable aerial base for LiDAR and orthoimagery acquisition. These aerial platforms 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 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. 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

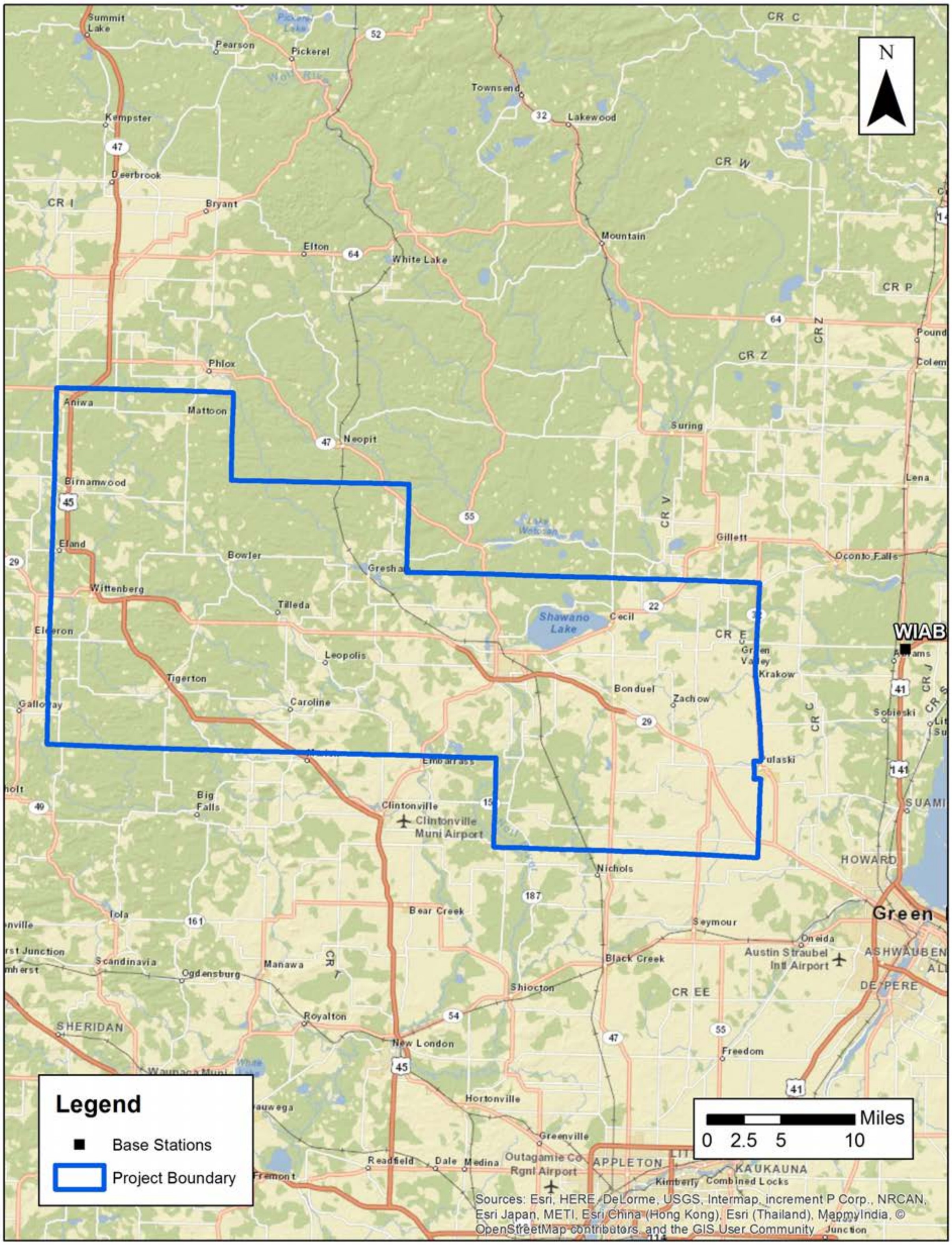
Base Station	Latitude	Longitude	Ellipsoid Height (m)
WIAB	44° 47' 27.29874"	88° 2' 42.18794"	167.06

2.5. Time Period

Project specific flights were conducted in November. Eight sorties, or aircraft lifts were completed. Accomplished sorties are listed below.

- Nov 14, 2015-A (N73TM, SN324)
- Nov 14, 2015-B (N73TM, SN324)
- Nov 14, 2015-A (N300LF, SN329)
- Nov 14, 2015-C (N73TM, SN324)
- Nov 14, 2015-D (N73TM, SN324)
- Nov 14, 2015-B (N300LF, SN329)
- Nov 15, 2015-A (N73TM, SN324)
- Nov 15, 2015-A (N300LF, SN329)

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

Applanix + POSPac Mobile Mapping Suite 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. POSPac 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 Applanix POSPac 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 POSPac 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 Optech DashMap Post Processor 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 will manually be reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper will be 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 and the Bare Earth. In-house software will then used to perform final statistical analysis of the classes in the LAS files.

3.3. LAS Classification Scheme

The classification classes are determined by the USGS Version 1.2 specifications and are an industry standard for the classification of LIDAR point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

The classes used in the dataset are as follows and have the following descriptions:

- Class 1 – Processed, but Unclassified – These points would be the catch all for points that do not fit any of the other deliverable classes. This would cover features such as vegetation, cars, etc.
- Class 2 – Bare earth ground – This is the bare earth surface
- Class 7 – Low Noise – Low points, manually identified below the surface that could be noise points in point cloud.
- Class 9 – In-land Water – Points found inside of inland lake/ponds
- Class 10 – Ignored Ground – Points found to be close to breakline features. Points are moved to this class from the Class 2 dataset. This class is ignored during the DEM creation process in order to provide smooth transition between the ground surface and hydro flattened surface.
- Class 17 – Bridge Decks – Points falling on bridge decks.
- Class 18 – High Noise – High points, manually identified above the surface that could be noise points in point cloud.

3.4. Classified LAS Processing

The bare earth surface is then manually reviewed to ensure correct classification on the Class 2 (Ground) points. After the bare-earth surface is finalized, it is then used to generate all hydro-breaklines through heads-up digitization.

All ground (ASPRS Class 2) LiDAR data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 1 meter was also used around each hydro-flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 10). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed. All bridge decks were classified to Class 17.

All overlap data was processed through automated functionality provided by TerraScan to classify the overlapping flight line data to approved classes by USGS. The overlap data was identified using the Overlap Flag, per LAS 1.4 specifications.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper us used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for both the All Point Cloud Data and the Bare Earth. Quantum Spatial proprietary software was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

3.5. Hydro-Flattened Breakline Creation

Class 2 LiDAR was used to create a bare earth surface model. The surface model was then used to heads-up digitize 2D breaklines of inland streams and rivers with a 30 meter nominal width and Inland Ponds and Lakes of 2 acres or greater surface area.

Elevation values were assigned to all Inland Ponds and Lakes, Inland Pond and Lake Islands, Inland Stream and River Islands, using TerraModeler functionality.

Elevation values were assigned to all Inland streams and rivers using Quantum Spatial proprietary software.

All ground (ASPRS Class 2) LiDAR data inside of the collected inland breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 1 meter was also used around each hydro-flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 10).

The breakline files were then translated to Esri file geodatabase format using Esri conversion tools.

3.6. Hydro-Flattened Raster DEM Creation

Class 2 LiDAR in conjunction with the hydro breaklines were used to create a 1-meter Raster DEM. Using automated scripting routines within ArcMap, an ERDAS .IMG file was created for each tile. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

3.7. Intensity Image Creation

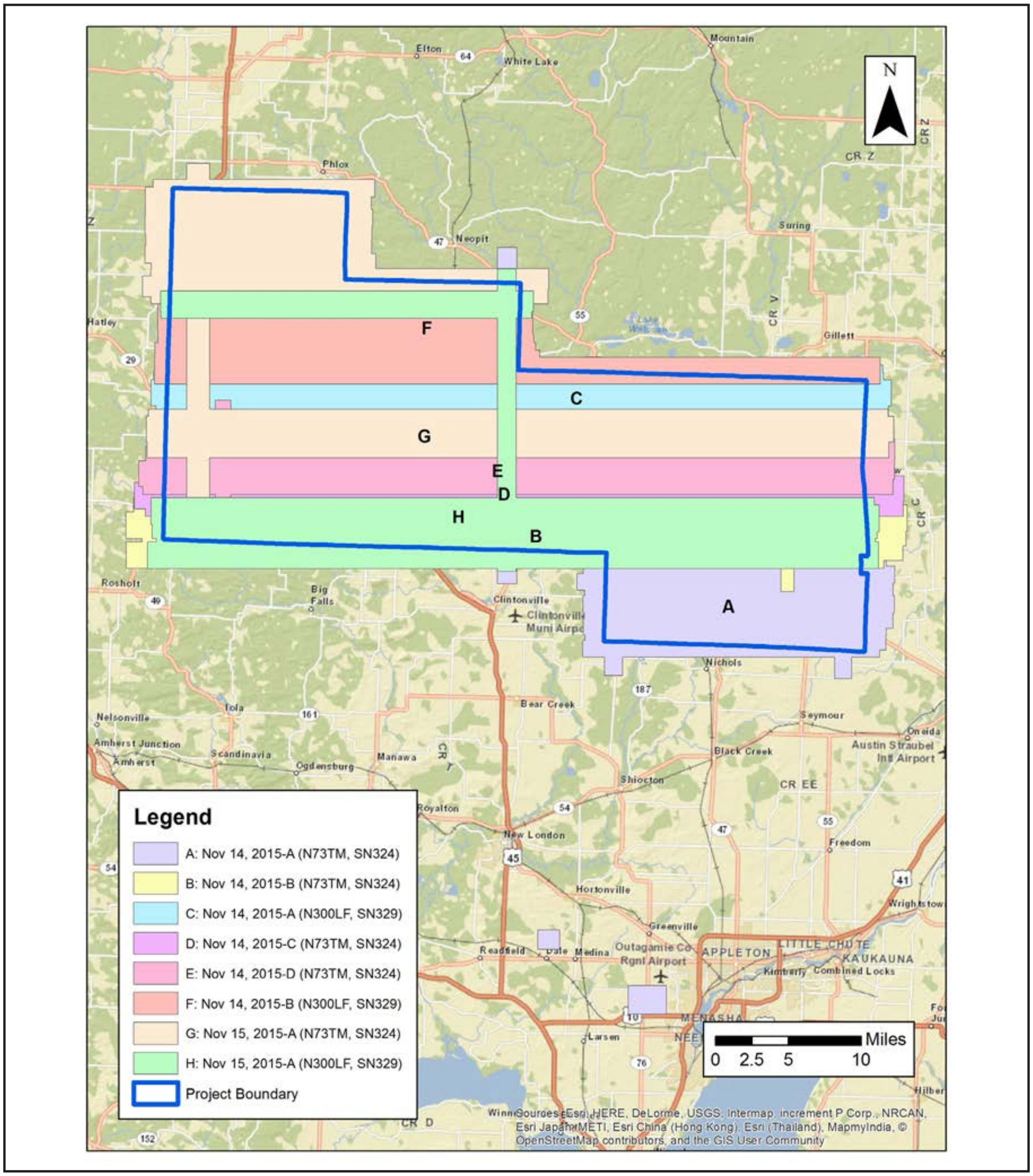
GeoCue software was used to create the deliverable Intensity Images with a 1-meter cell size. All overlap classes were ignored during this process. This helps to ensure a more aesthetically pleasing image.

The GeoCue software was then used to verify full project coverage as well. TIF/TWF files were then provided as the deliverable for this dataset requirement.

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 completed a field survey of 40 ground control (calibration) points along with 100 blind QA points in Vegetated and Non-Vegetated land cover classifications (total of 140 points) as an independent test of the accuracy of this project.

A combination of precise GPS surveying methods, including static and RTK observations were used to establish the 3D position of ground calibration points and QA points for the point classes above. GPS was not an appropriate methodology for surveying in the forested areas during the leaf-on conditions for the actual field survey (which was accomplished after the LiDAR acquisition). Therefore the 3D positions for the forested points were acquired using a GPS-derived offset point located out in the open near the forested area, and using precise offset surveying techniques to derive the 3D position of the forested point from the open control point. The explicit goal for these surveys was to develop 3D positions that were three times greater than the accuracy requirement for the elevation surface. In this case of the blind QA points the goal was a positional accuracy of 5 cm in terms of the RMSE. For more information, see the survey report in Appendix B.

In this document, horizontal coordinates for ground control and QA points for all LiDAR classes are reported in NAD83 (2011) UTM Zone 16, Meters; NAVD88 (Geoid 12B), Meters.

The required accuracy testing was performed on the LiDAR dataset (both the LiDAR point cloud and derived DEM's) according to the USGS LiDAR Base Specification Version 1.2 (2014). The summaries below provide the results of this testing.

5.1. Calibration Control Points

TerraScan was used to perfomr a quality assurance check for each of the LiDAR bare earth calibration points. 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. See Figure 7 and Table 4.

5.2. Point Cloud Testing

Raw Nonvegetated Vertical Accuracy (Raw NVA): The tested Raw NVA for the dataset was found to be 0.045 m in terms of the RMSEz. The resulting NVA stated as the 95% confidence level (RMSEz x 1.96) is 0.088 m. This dataset meets the required NVA of 19.6 cm at the 95% confidence level (according to the National Standard for Spatial Database Accuracy (NSSDA)), based on TINs derived from the final calibrated and controlled LiDAR swath data. See Figure 8 and Table 5.

5.3. Digital Elevation Model (DEM) Testing

The tested Non-Vegetated Vertical Accuracy (NVA) for the dataset captured from the DEM using bi-linear interpolation to derive the DEM elevations was found to be 0.040 m in terms of the RMSEz. The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is 0.079 m. This dataset meets the required NVA of 19.6 cm at the 95% confidence level (based on NSSDA). See Figure 9 and Table 6.

The tested Vegetated Vertical Accuracy (VVA) for the dataset captured from the DEM using bi-linear interpolation for all classes (including the bare earth class) was found to be 0.278 m, which is stated in terms of the 95th percentile error. Therefore the data meets the required VVA of 29.4 cm. This test was based on the 95th percentile error (based on ASPRS guidelines) across all land cover categories. See Figure 10 and Table 7.

Figure 7. Control Calibration Point Locations

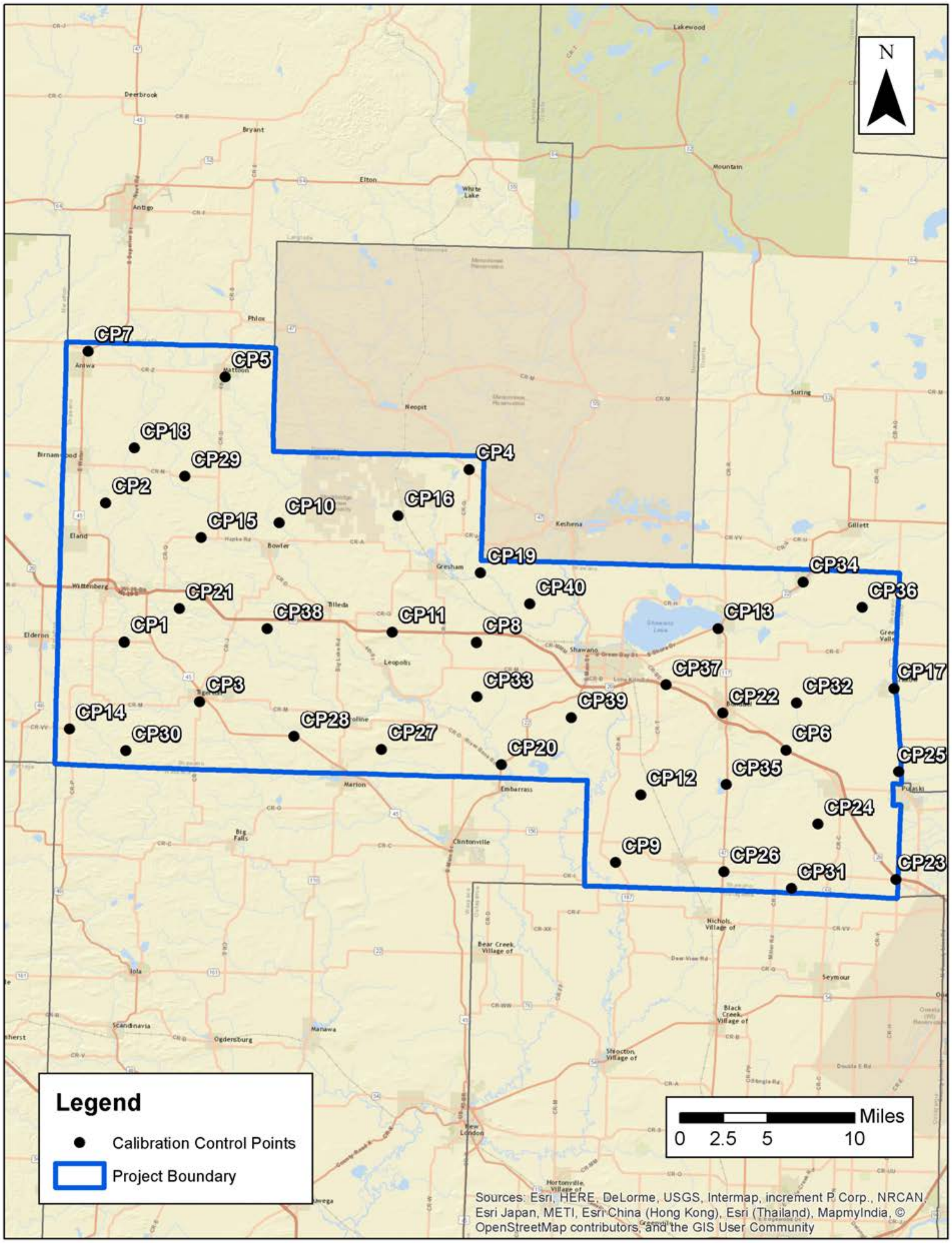


Table 4. Calibration Control Point Report

Units = Meters

Number	Easting	Northing	Known Z	Laser Z	Dz
CP1	330045.549	4961069.532	354.34	354.36	0.02
CP2	328343.541	4973871.868	383.66	383.57	-0.09
CP3	336983.880	4955594.371	312.95	312.97	0.02
CP4	361806.425	4976958.009	307.18	307.18	0.00
CP5	339357.019	4985494.813	382.69	382.66	-0.03
CP6	390990.174	4951128.360	261.54	261.55	0.01
CP7	326746.827	4987836.871	433.39	433.36	-0.02
CP8	362478.175	4961012.860	276.27	276.23	-0.04
CP9	375300.427	4940781.989	243.80	243.85	0.05
CP10	344320.393	4972032.548	336.50	336.48	-0.02
CP11	354726.252	4961972.353	279.03	279.06	0.04
CP12	377603.148	4947028.536	246.90	246.90	0.00
CP13	384716.692	4962284.075	248.08	248.09	0.01
CP14	325016.487	4953078.419	344.73	344.68	-0.05
CP15	337131.495	4970681.158	352.86	352.84	-0.02
CP16	355274.153	4972702.502	300.88	300.90	0.02
CP17	400937.157	4956820.179	238.97	239.04	0.07
CP18	330999.059	4978935.271	391.86	391.88	0.02
CP19	362855.962	4967430.115	269.36	269.33	-0.03
CP20	364784.069	4949819.070	246.58	246.57	-0.01
CP21	335124.191	4964134.457	341.47	341.38	-0.08
CP22	385153.880	4954544.134	263.51	263.62	0.11
CP23	401120.757	4939216.794	245.78	245.77	0.00
CP24	393929.786	4944325.149	272.41	272.42	0.01
CP25	401362.566	4949147.979	246.46	246.49	0.03
CP26	385272.289	4939916.242	247.43	247.41	-0.02
CP27	353740.045	4951198.605	270.68	270.72	0.04
CP28	345697.717	4952406.542	286.33	286.28	-0.05
CP29	335632.639	4976322.159	375.94	375.91	-0.03
CP30	330188.991	4951081.695	328.57	328.52	-0.05
CP31	391481.326	4938388.348	261.25	261.26	0.01
CP32	391967.030	4955496.220	272.00	272.07	0.07

Number	Easting	Northing	Known Z	Laser Z	Dz
CP33	362539.293	4956043.279	259.69	259.75	0.06
CP34	392552.101	4966580.473	241.19	241.13	-0.06
CP35	385473.760	4947967.384	257.35	257.30	-0.05
CP36	397988.901	4964245.644	249.46	249.44	-0.02
CP37	379953.950	4957150.366	308.80	308.89	0.09
CP38	343228.737	4962277.662	307.06	307.09	0.03
CP39	371214.221	4954143.595	248.54	248.58	0.04
CP40	367401.389	4964564.908	266.78	266.73	-0.04

Average Dz	0.00 m
Minimum Dz	-0.089 m
Maximum Dz	0.112 m
Root Mean Square	0.046 m
Std. Deviation	0.046 m

Figure 8. Raw NVA Point Locations

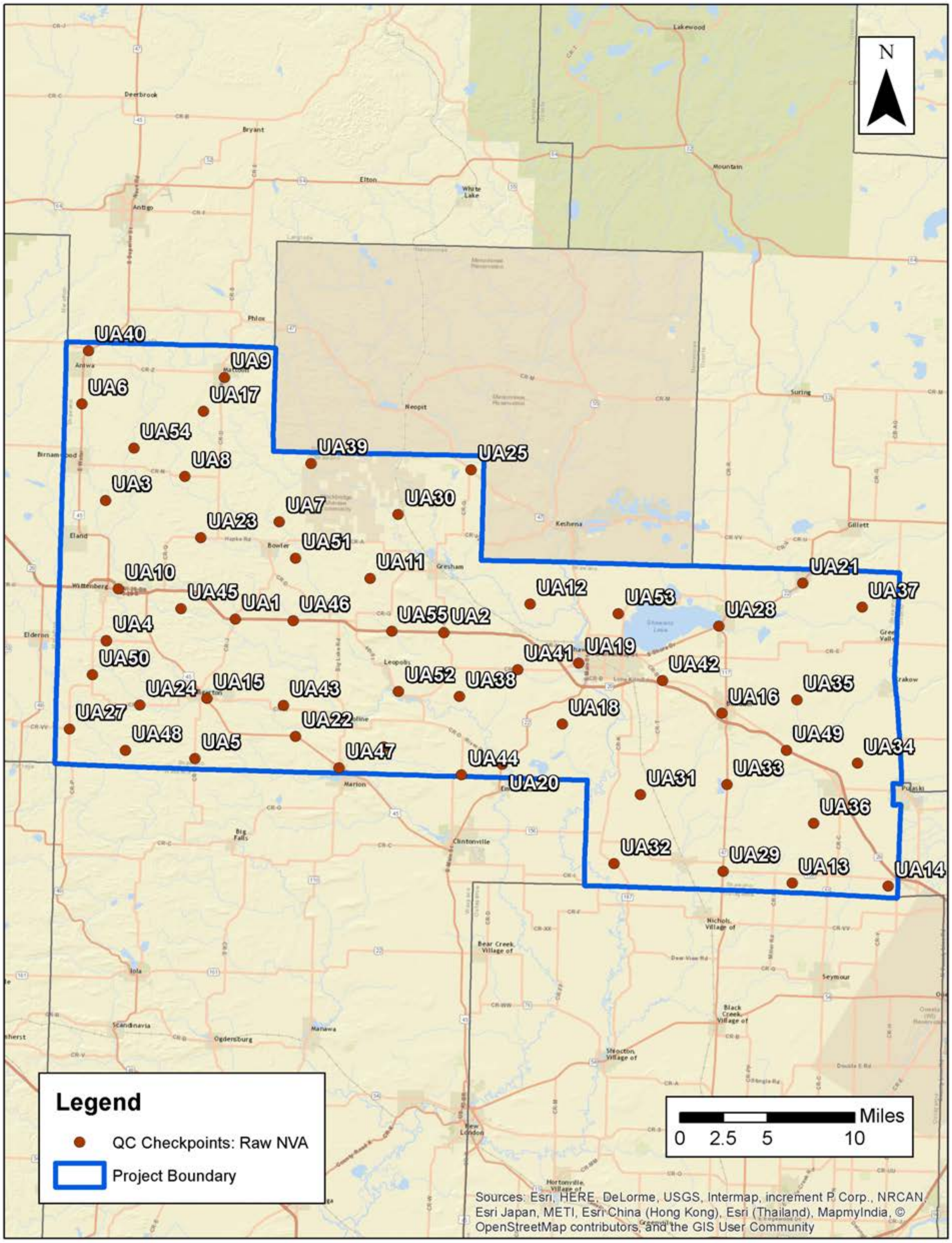


Table 5. Raw NVA Point Report

Units = Meters

Number	Easting	Northing	Known Z	Laser Z	Dz
UA1	340280.305	4963137.917	314.01	314	-0.007
UA2	359485.983	4961878.616	285.15	285.19	0.044
UA3	328347.163	4974077.042	379.15	379.09	-0.056
UA4	328422.804	4961183.174	343.65	343.66	0.011
UA5	336550.468	4950347.274	308.94	308.93	-0.007
UA6	326151.842	4982985.364	417.90	417.89	-0.009
UA7	344340.920	4972104.393	334.23	334.21	-0.021
UA8	335633.276	4976303.392	375.99	375.95	-0.035
UA9	339285.825	4985410.953	382.11	382.11	0.003
UA10	329525.656	4965940.069	367.52	367.51	-0.007
UA11	352674.431	4966885.387	297.98	298.01	0.029
UA12	367421.849	4964549.711	267.49	267.45	-0.036
UA13	391561.864	4938872.565	267.08	267.14	0.064
UA14	400397.776	4938564.403	248.75	248.72	-0.03
UA15	337676.962	4955897.912	313.80	313.77	-0.03
UA16	385099.986	4954505.932	263.99	264.07	0.08
UA17	337334.730	4982309.521	384.34	384.30	-0.04
UA18	370388.272	4953535.689	254.89	254.90	0.01
UA19	371879.323	4959128.439	245.62	245.70	0.08
UA20	364847.147	4949809.875	246.17	246.22	0.05
UA21	392542.213	4966472.373	235.06	234.94	-0.12
UA22	345826.812	4952370.294	286.55	286.52	-0.03
UA23	337106.962	4970662.865	351.60	351.55	-0.05
UA24	331474.331	4955289.702	330.12	330.18	0.06
UA25	361984.947	4976907.221	308.92	308.91	-0.01
UA26	353940.574	4951417.240	293.03	293.01	-0.02
UA27	325003.351	4953056.666	344.80	344.70	-0.10
UA28	384816.543	4962486.681	245.72	245.73	0.01
UA29	385185.059	4939929.715	246.05	246.01	-0.04
UA30	355281.084	4972782.621	302.33	302.33	0.00
UA31	377589.898	4946997.799	246.87	246.89	0.02
UA32	375139.466	4940660.592	241.19	241.19	0.00

Number	Easting	Northing	Known Z	Laser Z	Dz
UA33	385558.628	4947927.473	262.12	262.13	0.01
UA34	397550.777	4949893.791	254.98	254.97	-0.01
UA35	391976.021	4955742.531	269.55	269.55	0.00
UA36	393540.790	4944367.689	272.78	272.80	0.02
UA37	397997.981	4964234.106	249.78	249.75	-0.03
UA38	360920.245	4956067.687	267.63	267.68	0.046
UA39	347268.228	4977469.666	348.47	348.46	-0.007
UA40	326776.956	4987888.692	434.66	434.63	-0.029
UA41	366263.575	4958524.582	262.32	262.37	0.050
UA42	379608.803	4957523.981	286.32	286.38	0.063
UA43	344713.884	4955232.105	291.40	291.45	0.05
UA44	361110.355	4948852.280	274.58	274.50	-0.08
UA45	335293.998	4964117.238	341.69	341.58	-0.11
UA46	345594.589	4962986.632	307.24	307.24	0.01
UA47	349822.263	4949487.940	273.99	273.92	-0.07
UA48	330177.766	4951082.724	328.96	328.91	-0.05
UA49	391019.629	4951098.604	262.91	262.86	-0.05
UA50	327140.086	4958079.382	354.87	354.86	-0.01
UA51	345823.231	4968770.789	314.24	314.26	0.02
UA52	355305.741	4956538.177	269.51	269.50	-0.01
UA53	375556.182	4963639.625	256.71	256.74	0.03
UA54	330953.109	4978892.606	390.21	390.20	-0.01
UA55	354682.458	4962033.299	279.70	279.74	0.04

Average Dz	-0.01 m
Minimum Dz	-0.116 m
Maximum Dz	0.084 m
Root Mean Square	0.045 m
95% Confidence	0.088 m

Figure 9. NVA Point Locations

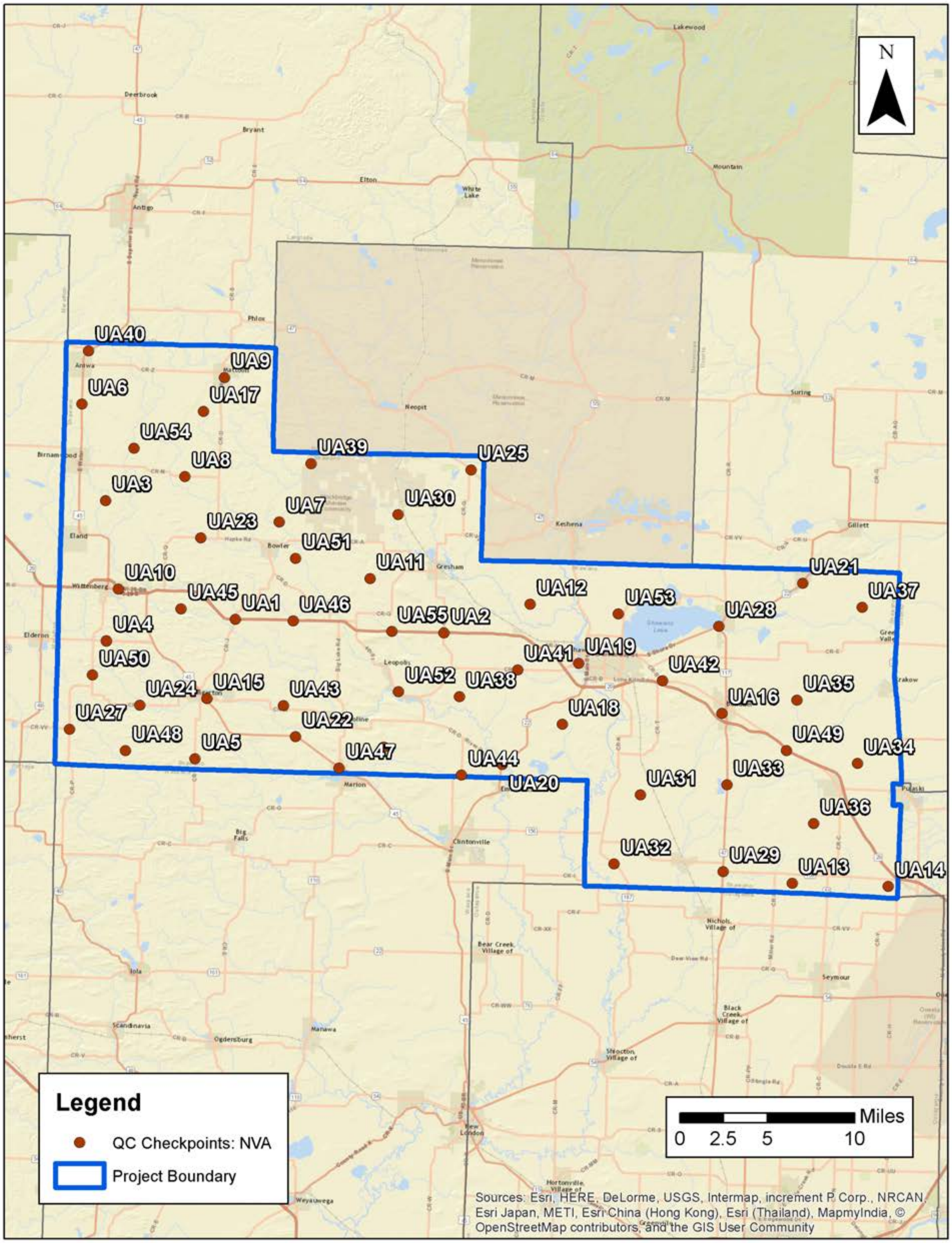


Table 6. NVA Point Report

Units = Meters

Number	Easting	Northing	Known Z	Laser Z	Dz
UA1	340280.31	4963137.92	314.01	314.01	0.00
UA2	359485.98	4961878.62	285.15	285.19	0.05
UA3	328347.16	4974077.04	379.15	379.08	-0.06
UA4	328422.80	4961183.17	343.65	343.67	0.02
UA5	336550.47	4950347.27	308.94	308.92	-0.01
UA6	326151.84	4982985.36	417.90	417.89	-0.01
UA7	344340.92	4972104.39	334.23	334.21	-0.02
UA8	335633.28	4976303.39	375.99	375.95	-0.04
UA9	339285.83	4985410.95	382.11	382.12	0.01
UA10	329525.66	4965940.07	367.52	367.51	-0.01
UA11	352674.43	4966885.39	297.98	298.01	0.02
UA12	367421.85	4964549.71	267.49	267.45	-0.03
UA13	391561.86	4938872.57	267.08	267.12	0.05
UA14	400397.78	4938564.40	248.75	248.71	-0.04
UA15	337676.96	4955897.91	313.80	313.77	-0.04
UA16	385099.99	4954505.93	263.99	264.07	0.08
UA17	337334.73	4982309.52	384.34	384.32	-0.02
UA18	370388.27	4953535.69	254.89	254.90	0.01
UA19	371879.32	4959128.44	245.62	245.70	0.08
UA20	364847.15	4949809.88	246.17	246.22	0.05
UA21	392542.21	4966472.37	235.06	234.99	-0.06
UA22	345826.81	4952370.29	286.55	286.51	-0.04
UA23	337106.96	4970662.87	351.60	351.54	-0.05
UA24	331474.33	4955289.70	330.12	330.18	0.06
UA25	361984.95	4976907.22	308.92	308.91	0.00
UA26	353940.574	4951417.24	293.03	293.00	-0.02
UA27	325003.35	4953056.67	344.80	344.74	-0.06
UA28	384816.54	4962486.68	245.72	245.72	0.00
UA29	385185.06	4939929.72	246.05	246.01	-0.04
UA30	355281.08	4972782.62	302.33	302.35	0.02
UA31	377589.90	4946997.80	246.87	246.87	0.00
UA32	375139.47	4940660.59	241.19	241.18	0.00

Number	Easting	Northing	Known Z	Laser Z	Dz
UA33	385558.63	4947927.47	262.12	262.12	-0.01
UA34	397550.78	4949893.79	254.98	254.97	-0.01
UA35	391976.02	4955742.53	269.55	269.55	0.00
UA36	393540.79	4944367.69	272.78	272.79	0.01
UA37	397997.98	4964234.11	249.78	249.75	-0.03
UA38	360920.25	4956067.69	267.63	267.68	0.04
UA39	347268.23	4977469.67	348.47	348.46	-0.01
UA40	326776.96	4987888.69	434.66	434.63	-0.03
UA41	366263.58	4958524.58	262.32	262.38	0.06
UA42	379608.80	4957523.98	286.32	286.38	0.06
UA43	344713.88	4955232.11	291.40	291.44	0.05
UA44	361110.36	4948852.28	274.58	274.50	-0.08
UA45	335294.00	4964117.24	341.69	341.58	-0.11
UA46	345594.59	4962986.63	307.24	307.24	0.01
UA47	349822.26	4949487.94	273.99	273.94	-0.06
UA48	330177.77	4951082.72	328.96	328.91	-0.05
UA49	391019.63	4951098.60	262.91	262.89	-0.01
UA50	327140.086	4958079.382	354.87	354.86	-0.01
UA51	345823.231	4968770.789	314.24	314.25	0.01
UA52	355305.741	4956538.177	269.51	269.50	-0.01
UA53	375556.182	4963639.625	256.71	256.75	0.04
UA54	330953.109	4978892.606	390.21	390.21	0.00
UA55	354682.458	4962033.299	279.70	279.74	0.03

Average Dz	0.00 m
Minimum Dz	-0.108 m
Maximum Dz	0.082 m
Root Mean Square	0.040 m
95% Confidence	0.079 m

Figure 10. VVA Point Locations

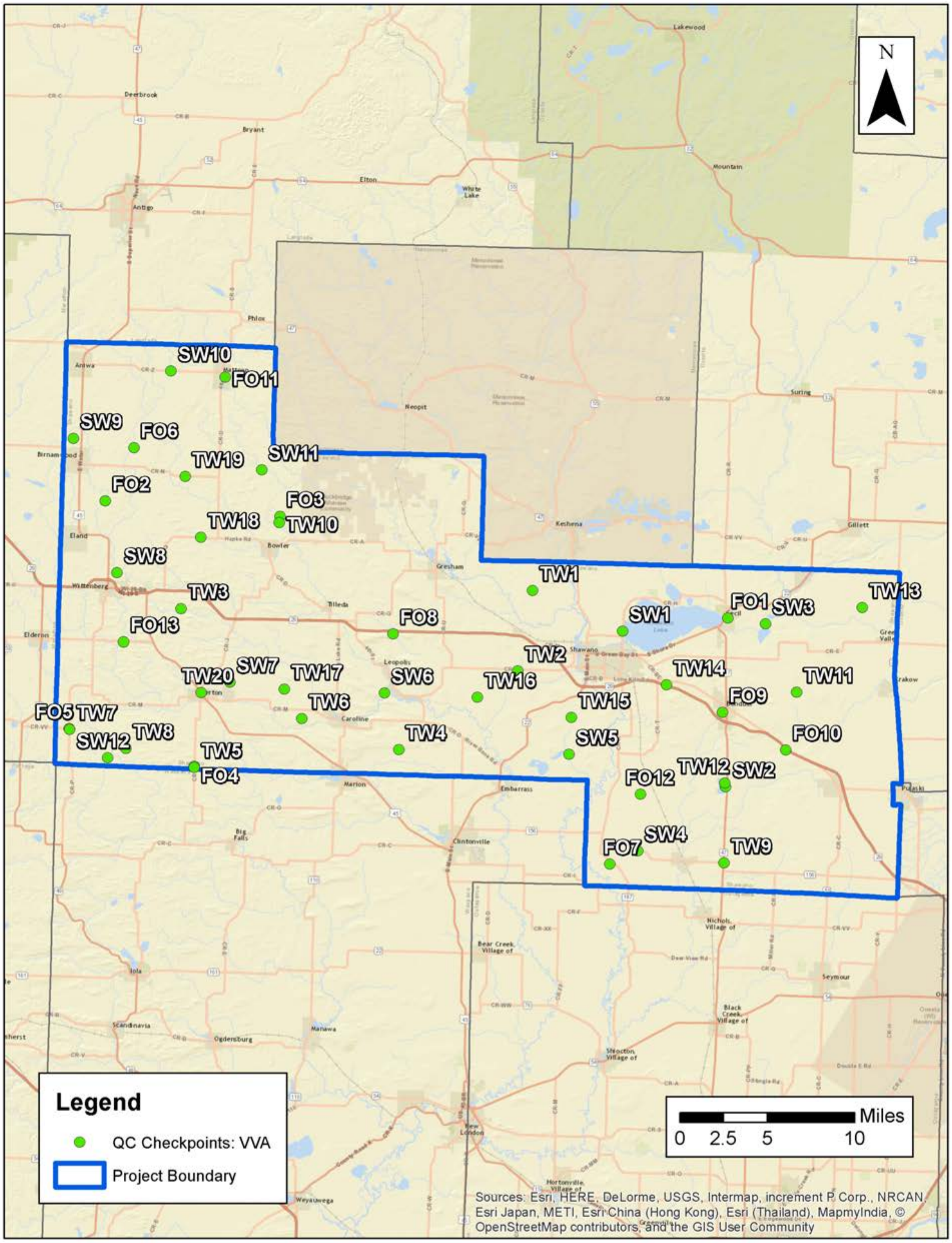


Table 7. VVA Point Report

Units = Meters

Number	Easting	Northing	Known Z	Laser Z	Dz
FO1	385630.16	4963257.99	246.82	246.87	0.05
FO2	328312.82	4974059.35	378.05	378.06	0.02
FO3	344379.01	4972608.50	345.71	345.66	-0.05
FO4	336495.51	4949626.19	301.05	301.04	-0.01
FO5	324963.36	4953077.88	343.70	343.67	-0.03
FO6	330936.50	4978930.71	389.78	389.83	0.05
FO7	374745.84	4940621.74	241.32	241.35	0.03
FO8	354802.95	4961777.37	284.11	284.20	0.09
FO9	385115.49	4954594.21	262.00	262.14	0.14
FO10	390966.63	4951134.11	260.71	260.72	0.01
FO11	339367.05	4985465.65	381.81	381.80	-0.01
FO12	377562.84	4947034.94	246.84	246.93	0.09
FO13	329982.53	4961063.33	356.48	356.50	0.02
SW1	375930.96	4962015.44	244.92	245.02	0.10
SW2	385423.51	4947717.17	252.30	252.46	0.16
SW3	389094.07	4962703.47	249.80	250.14	0.34
SW4	377329.28	4941839.64	243.45	243.58	0.13
SW5	371015.08	4950746.29	243.46	243.65	0.19
SW6	354017.36	4956379.91	264.06	264.15	0.09
SW7	339770.62	4957397.14	305.45	305.71	0.26
SW8	329384.28	4967416.90	354.49	354.66	0.17
SW9	325365.33	4979802.42	402.87	403.13	0.26
SW10	334357.50	4986018.24	401.48	401.75	0.27
SW11	342699.02	4976892.67	350.58	350.84	0.26
SW12	328524.07	4950416.06	321.29	321.47	0.18
TW1	367650.16	4965768.61	283.04	283.18	0.14
TW2	366277.86	4958408.75	260.13	260.37	0.24
TW3	335286.90	4964101.94	341.27	341.27	0.00
TW4	355319.12	4951152.48	270.92	271.01	0.08
TW5	336499.07	4949516.73	299.85	299.86	0.01
TW6	346388.05	4954028.65	285.13	285.23	0.10
TW7	325019.99	4953033.46	344.38	344.46	0.08

Number	Easting	Northing	Known Z	Laser Z	Dz
TW8	330192.89	4951267.82	327.89	327.90	0.01
TW9	385264.56	4940704.14	249.40	249.52	0.11
TW10	344332.52	4972036.08	335.66	335.66	0.01
TW11	391952.84	4956463.78	268.08	268.61	0.53
TW12	385346.96	4948085.85	254.99	255.07	0.08
TW13	397986.00	4964202.19	249.12	249.22	0.10
TW14	379967.64	4957132.35	308.45	308.72	0.28
TW15	371224.11	4954139.84	248.38	248.58	0.20
TW16	362558.67	4956004.89	259.58	259.76	0.19
TW17	344803.70	4956749.36	295.23	295.26	0.02
TW18	337088.96	4970683.16	352.98	352.97	-0.01
TW19	335653.20	4976291.62	374.45	374.48	0.03
TW20	337144.98	4956398.89	308.69	308.84	0.15

Average Dz	0.12 m
Minimum Dz	-0.053 m
Maximum Dz	0.529 m
Root Mean Square	0.116 m
95th Percentile	0.278 m