Dauphin County, PA 2016
QL2 LiDAR Project Report

USGS Contract G16PC00016
Requisition # 0040267111
Task Order # G16PD00443

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1. Summary / Scope

1.1. Summary

This report contains a summary of the Dauphin County, Pennsylvania 2016 QL2 LiDAR acquisition task order, issued by USGS National Geospatial Technical Operations Center under their Geospatial Product and Services Contract on April 9, 2016. The task order yielded a project area covering approximately 555 square miles over Dauphin County, Pennsylvania. 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
2.26 pts / m^2	2,075 m	40°	30%	≤ 10 cm

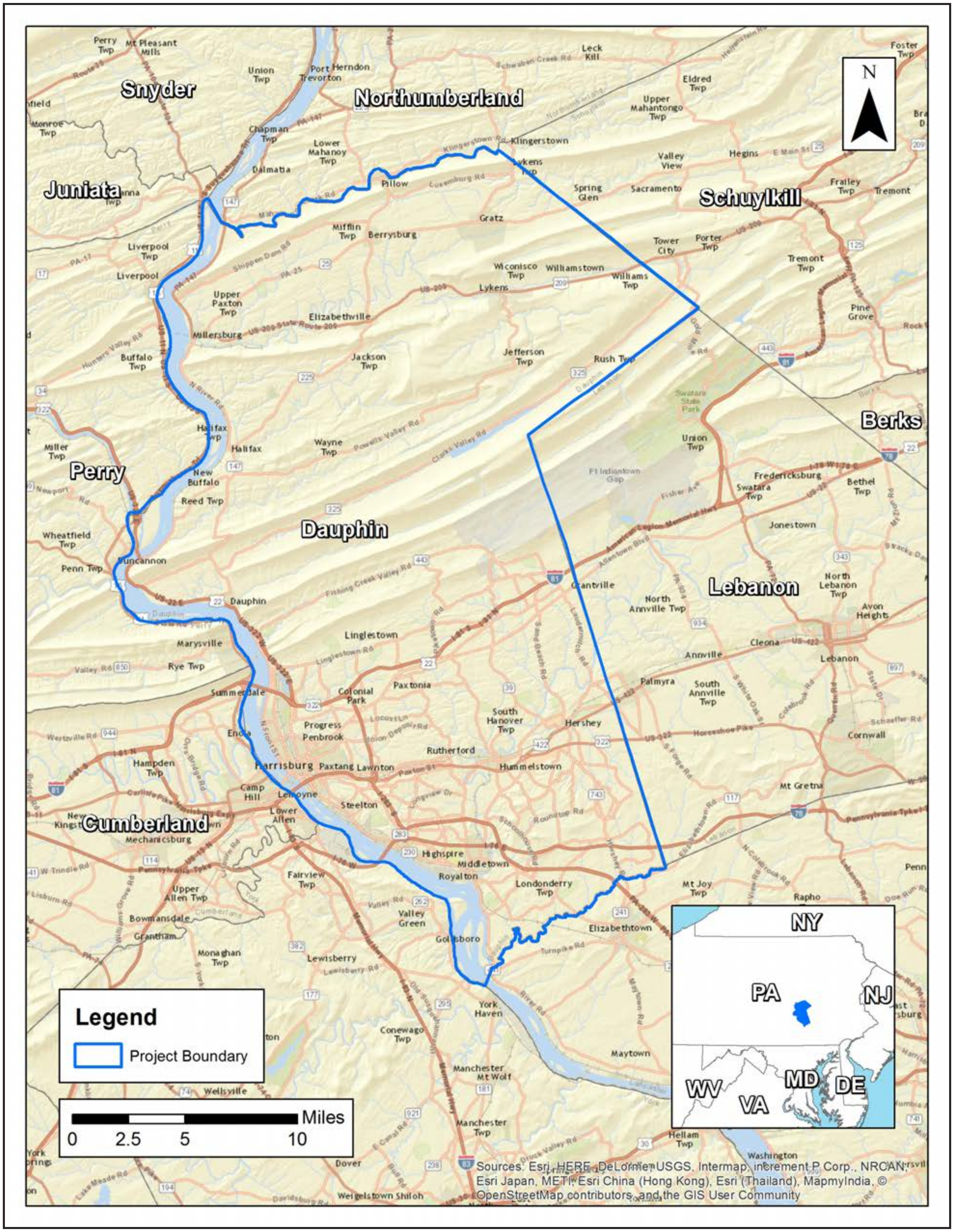
1.3. Coverage

The LiDAR project boundary covers approximately 555 square miles and encompasses Dauphin County in southeastern Pennsylvania. LiDAR extents are shown in Figure 1 on the following page. A buffer of 100 meters was created for the project boundary to meet task order specifications.

1.4. Duration

LiDAR data was acquired from March 24, 2016 to March 26, 2016 in four total lifts, with a re-flight on November 22, 2016. See “Section: 2.5. Time Period” for more details.

Figure 1. LiDAR Project Boundary

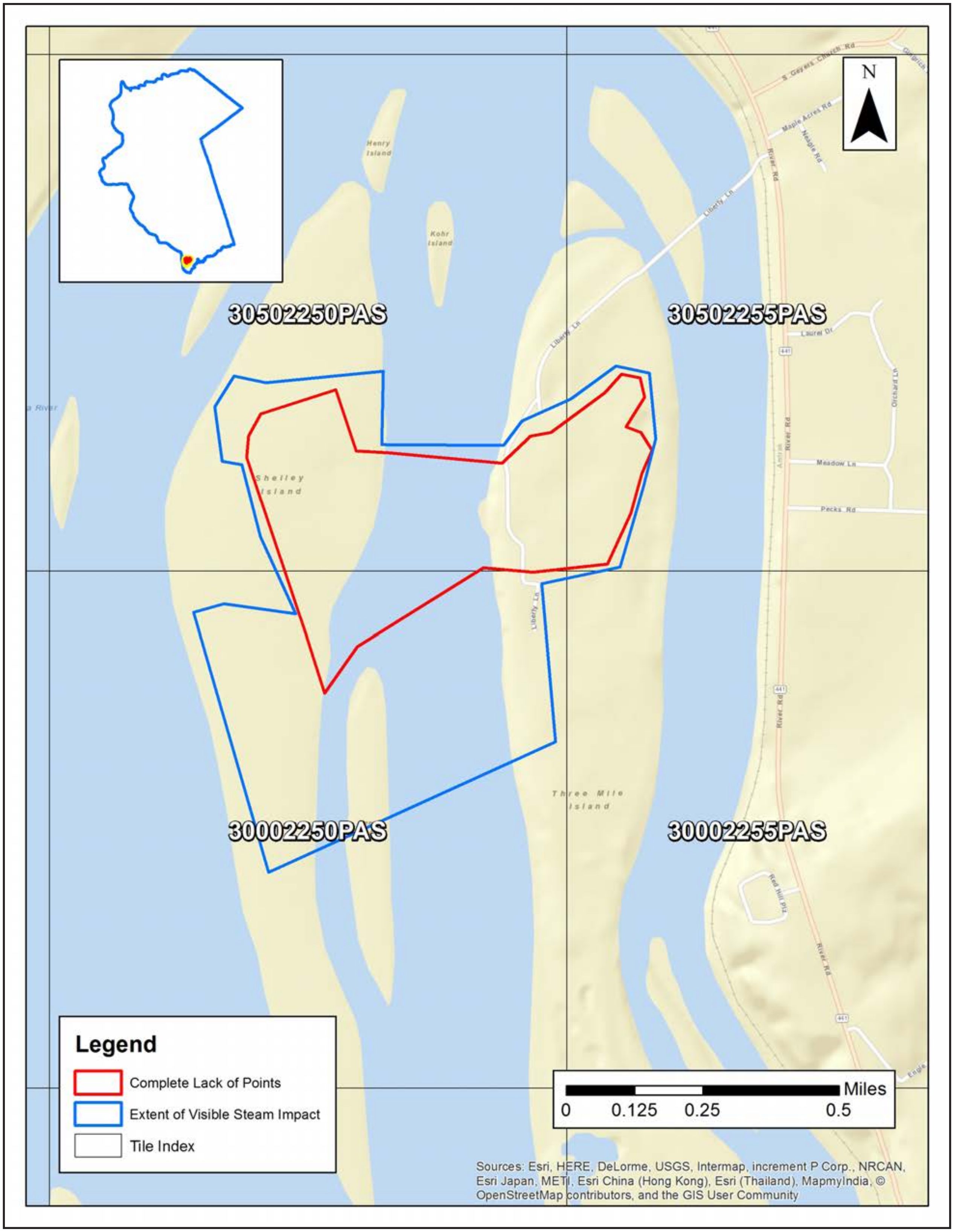


1.5. Issues

A four-tile area around Three Mile Island required a re-flight. Steam plumes over the area limited the amount of points returned, resulting in voids in the data set. Data falling within the following tiles was re-acquired on November 22, 2016: 30502250PAS, 30502255PAS, 30002250PAS, and 30002255PAS. See Figure 2 and Figure 3.

Figure 2. Three Mile Island Steam Obstruction

Figure 3. Three Mile Island Issue Area



1.6. Deliverables

The following products were produced and delivered:

- Raw LiDAR point cloud data swaths in LAS 1.4 format
- Classified LiDAR data, tiled, in LAS 1.4 format
- 2.5-foot bare earth raster DEMs, tiled, in ERDAS .IMG format
- Hydro-flattened breaklines in Esri file geodatabase format
- 2.5-foot intensity images, tiled, in GeoTIFF format
- 2-foot continuous contours in Esri file geodatabase format
- Accuracy Assessment in .XLS format
- Calibration control and QC checkpoints in Esri shapefile format
- Project-, deliverable-, and lift-level metadata in .XML format
- Processing boundary in Esri shapefile format
- Tile layout in Esri shapefile format

All geospatial deliverables were produced in NAD83 (2011) State Plane Pennsylvania South Zone, US survey feet; NAVD88 (Geoid 12B).

All tiled deliverables have a tile size of 5,000 feet x 5,000 feet. Tile names are derived from the upper left corner coordinate for the tile, formatted as YYYYXXXXPAd, where:

- YYYY = the first 4 characters of the tile’s upper left corner Y coordinate
- XXXX = the first 4 characters of the tile’s upper left corner X coordinate
- PA = Pennsylvania
- d = ‘N’ for North or ‘S’ for South

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 59 planned flight lines measuring approximately total 1,259.14 flight line miles for the LiDAR acquisition (Figure 4).

2.2. LiDAR Sensor

Quantum Spatial utilized a Leica ALS 70 LiDAR sensor (Figure 5), serial numbers 7178 and 7161, during the project. The 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 4. Planned LiDAR Flight Lines

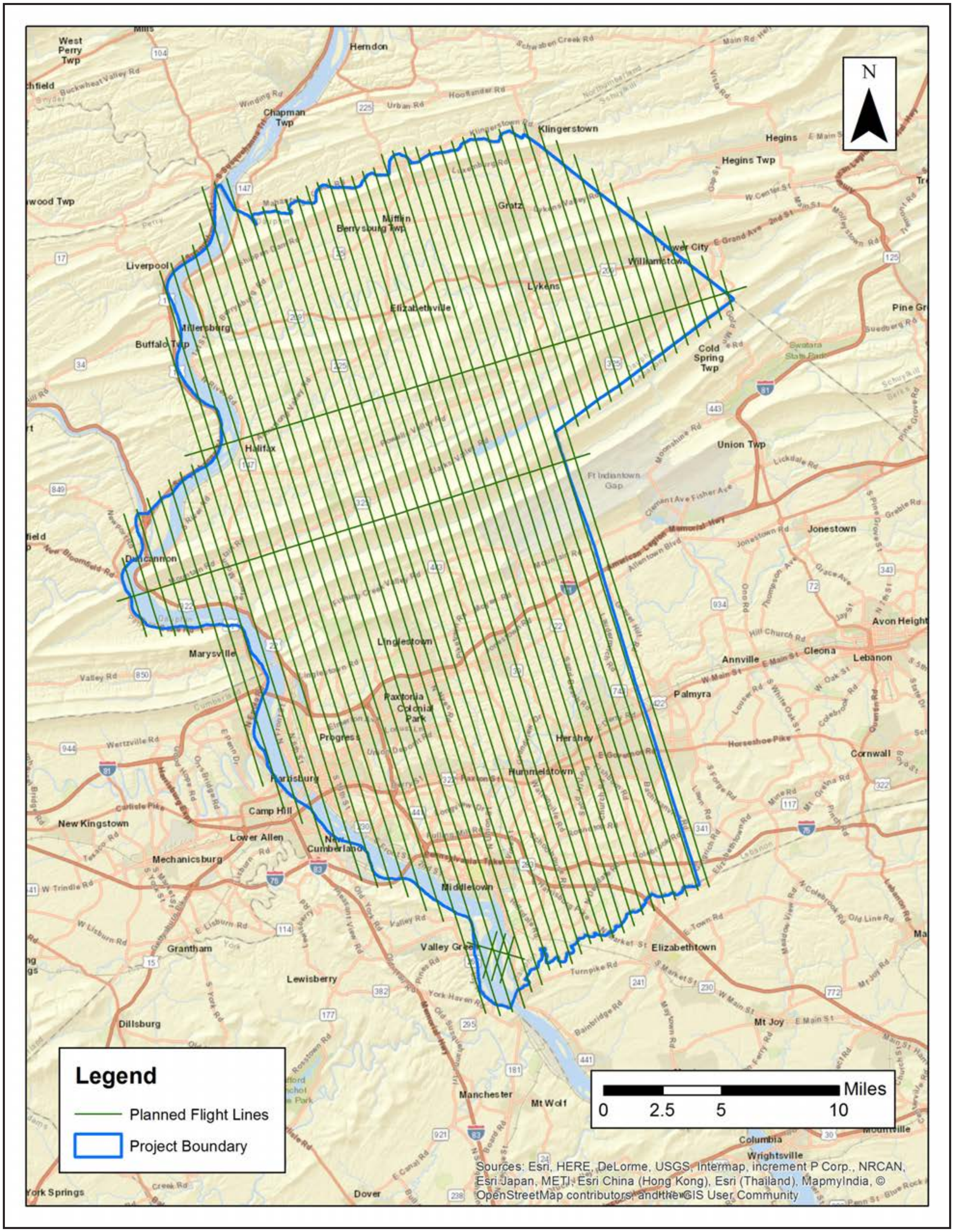


Table 2. Lidar System Specifications

		7178	7161
Terrain and Aircraft Scanner	Flying Height	1,596 - 2,075 m	2,080 - 2,100 m
	Recommended Ground Speed	150 kts	155 kts
Scanner	Field of View	40.0°	40.0°
	Scan Rate Setting Used	53.4 Hz	53.4 Hz
Laser	Laser Pulse Rate Used	263.4 kHz	260.4 kHz
	Multi Pulse in Air Mode	Enabled	Enabled
Coverage	Full Swath Width	1,510.48 m	1,528.67 m
	Line Spacing	1,018.43 m	1,351.74 m
Point Spacing and Density	Maximum Point Spacing Across Track	1.33 m	1.36 m
	Maximum Point Spacing Along Track (in phase)	1.44 m	1.49 m
	Maximum Point Spacing Along Track (out of phase)	0.72 m	0.75 m
	Average Point Density	2.26 pts / m^2	2.14 pts / m^2

Figure 5. Leica ALS 70 LiDAR Sensor

2.3. Aircraft

All flights for the project were accomplished through the use of two customized Piper Navajo (twin-piston) aircraft, tail numbers N73TM and N22GE. These aircraft provided an ideal, stable aerial base for LiDAR acquisition. These aerial platforms have 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 the operating aircraft can be seen in Figure 6 below.

Figure 6. 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 7. 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

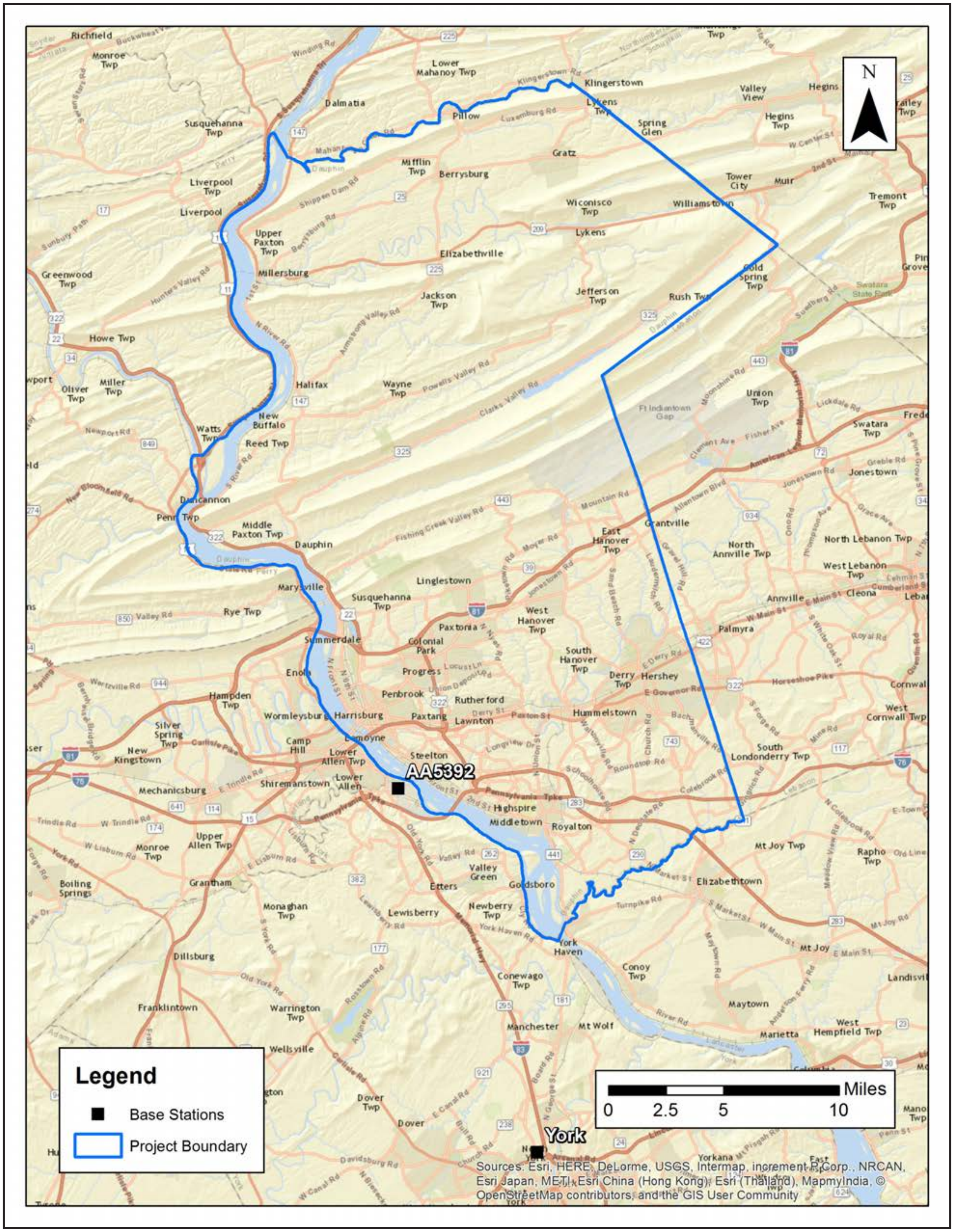
Base Station	Latitude	Longitude	Ellipsoid Height (m)
AA5392	40° 12′ 59.72438″	76° 51′ 2.17822″	69.111
York	39° 59′ 13.27663″	76° 44′ 24.53717″	99.616

2.5. Time Period

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

- Mar 24, 2016-A (N73TM, SN7178)
- Mar 26, 2016-A (N73TM, SN7178)
- Mar 26, 2016-B (N73TM, SN7178)
- Mar 26, 2016-C (N73TM, SN7178)
- Nov 22, 2016-B (N22GE, SN7161)

Figure 7. 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 and the Bare Earth. In-house software was 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 8 – Model Key – A thinned subset of the ground class created via an automated routine that takes into account changes in the terrain.
- 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 3 feet 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 was 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 100 foot 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 3 feet was also used around each hydro-flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 10).

The continuous 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 2.5-foot raster DEM. Using automated scripting routines within ArcMap, an ERDAS Imagine .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 2.5-foot 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.

3.8. Contour Creation

Using automated scripting routines within ArcMap, a terrain surface was created using the ground (ASPRS Class 2) LiDAR data as well as the hydro-flattening breaklines. This surface was then used to generate the final 2-foot continuous contour dataset in Esri file geodatabase format.

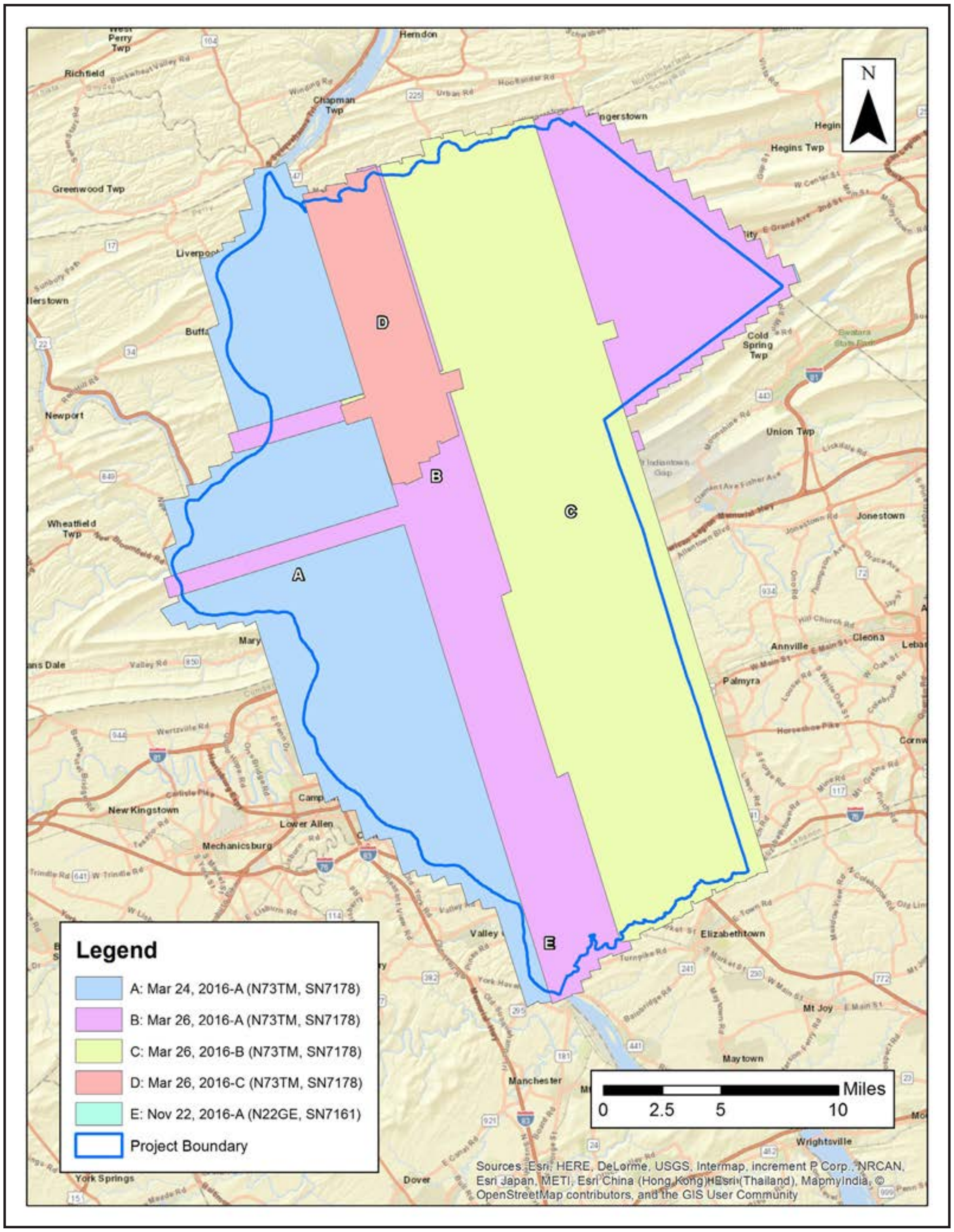
3.9. Esri Terrain Dataset Creation

Class 2 LiDAR along with the hydro-flattened breaklines were used to produce a multi-resolution, triangulated irregular network (TIN)-based surface. Each LAS file, overall hydro-flattened breakline file, and AOI was stored as a feature class in a feature dataset within an Esri file geodatabase.

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 8.

Figure 8. Flightline Swath LAS File Coverage



5. Ground Control and Check Point Collection

Quantum Spatial completed a field survey of 24 ground control (calibration) points along with 60 blind QA points in Vegetated and Non-Vegetated land cover classifications (total of 84 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.

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). In this document, horizontal coordinates for ground control and QA points for all LiDAR classes are reported in NAD83 Pennsylvania State Plane South Zone, US survey feet; NAVD88 (Geoid 12B), US survey feet.

5.1. Calibration Control Point Testing

Figure 9 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.

5.2. Point Cloud Testing

Raw Nonvegetated Vertical Accuracy (Raw NVA): The tested Raw NVA for the dataset was found to be 0.099 feet (0.030 meters) in terms of the RMSEz. The resulting NVA stated as the 95% confidence level (RMSEz x 1.96) is 0.193 feet (0.059 meters). This dataset meets the required NVA of 0.643 feet (0.196 meters) 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 10 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 0.089 feet (0.027 meters) in terms of the RMSEz. The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is 0.174 feet (0.053 meters). This dataset meets the required NVA of 0.643 feet (0.196 meters) at the 95% confidence level (based on NSSDA). See Figure 11 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 0.257 feet (0.078 meters), which is stated in terms of the 95th percentile error. Therefore the data meets the required VVA of 0.965 feet (0.294 meters). This test was based on the 95th percentile error (based on ASPRS guidelines) across all land cover categories. See Figure 12 and Table 7.

Figure 9. Calibration Control Point Locations

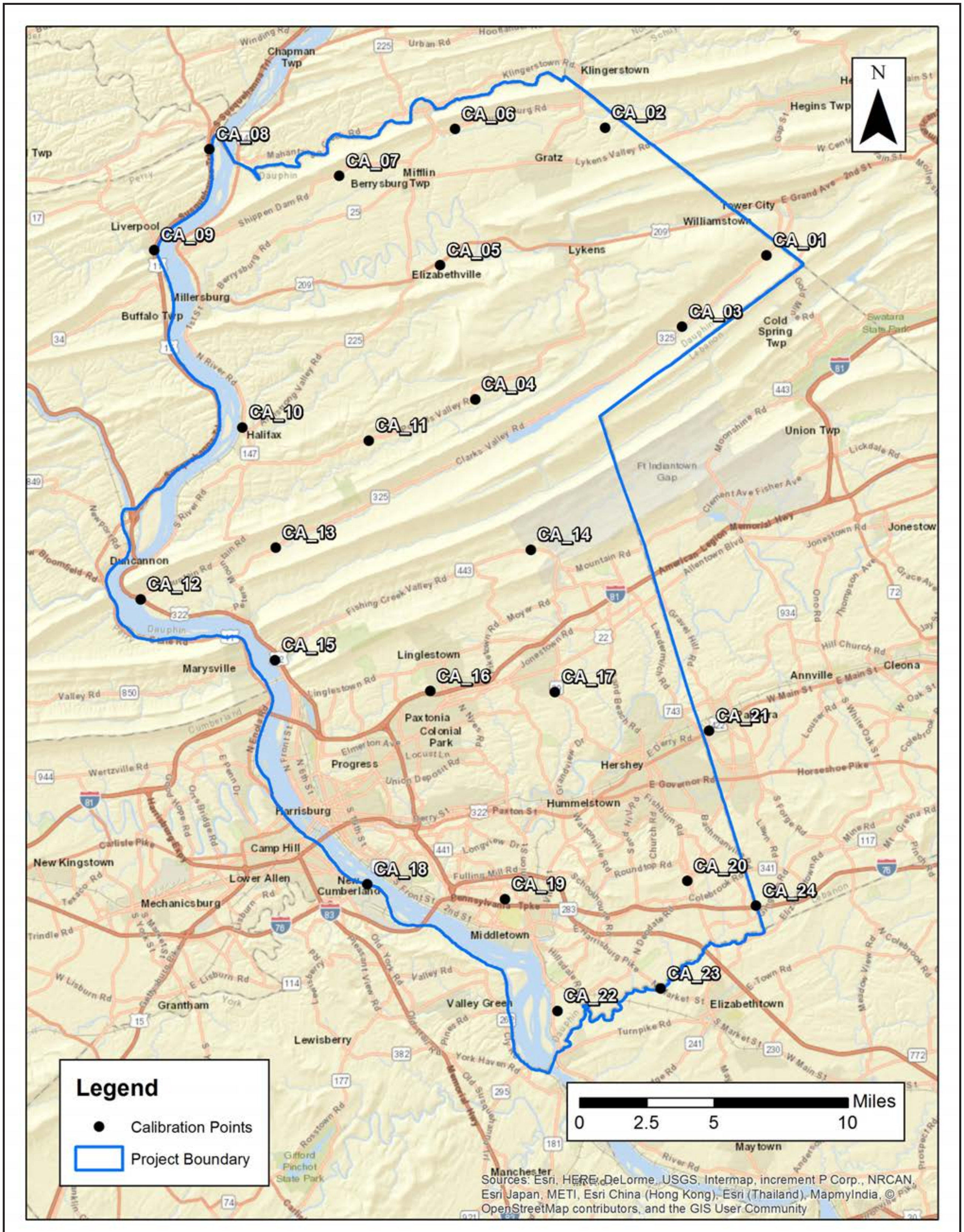


Table 4. Calibration Control Point Report

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
CA_01	2299135.810	449184.060	792.40	792.43	0.03
CA_02	2267325.580	474311.400	731.52	731.43	-0.09
CA_03	2282498.050	435122.920	722.99	722.78	-0.21
CA_04	2241746.320	420832.720	735.75	735.70	-0.05
CA_05	2234844.090	447239.570	647.29	647.22	-0.07
CA_06	2237761.080	474026.220	657.31	657.49	0.18
CA_07	2214983.180	464810.220	680.94	680.72	-0.22
CA_08	2189376.890	470061.250	414.30	414.18	-0.12
CA_09	2178514.290	450215.790	396.46	396.41	-0.05
CA_10	2195919.670	415269.140	387.19	387.28	0.09
CA_11	2220820.870	412692.510	667.57	667.64	0.07
CA_12	2175878.750	381429.060	366.39	366.29	-0.10
CA_13	2202458.750	391602.650	434.27	434.18	-0.09
CA_14	2252689.320	391195.980	564.74	564.85	0.11
CA_15	2202365.620	369482.050	324.56	324.55	-0.01
CA_16	2232892.750	363397.460	507.64	507.80	0.16
CA_17	2257451.070	363202.320	527.45	527.40	-0.05
CA_18	2220517.000	325334.560	307.99	308.07	0.08
CA_19	2247620.500	322410.260	409.39	409.43	0.04
CA_20	2283491.300	325993.920	582.32	582.48	0.16
CA_21	2287821.920	355535.050	446.17	446.16	-0.01
CA_22	2257948.240	300417.640	325.35	325.55	0.20
CA_23	2278265.510	304783.560	386.73	386.72	-0.01
CA_24	2297057.100	321129.320	493.03	493.02	-0.01
	Average Dz	0.000 ft			
	Minimum Dz	-0.220 ft			
	Maximum Dz	0.200 ft			
	Root Mean Square	0.112 ft			
	Std. Deviation	0.115 ft			

Figure 10. QC Checkpoint Locations - Raw NVA

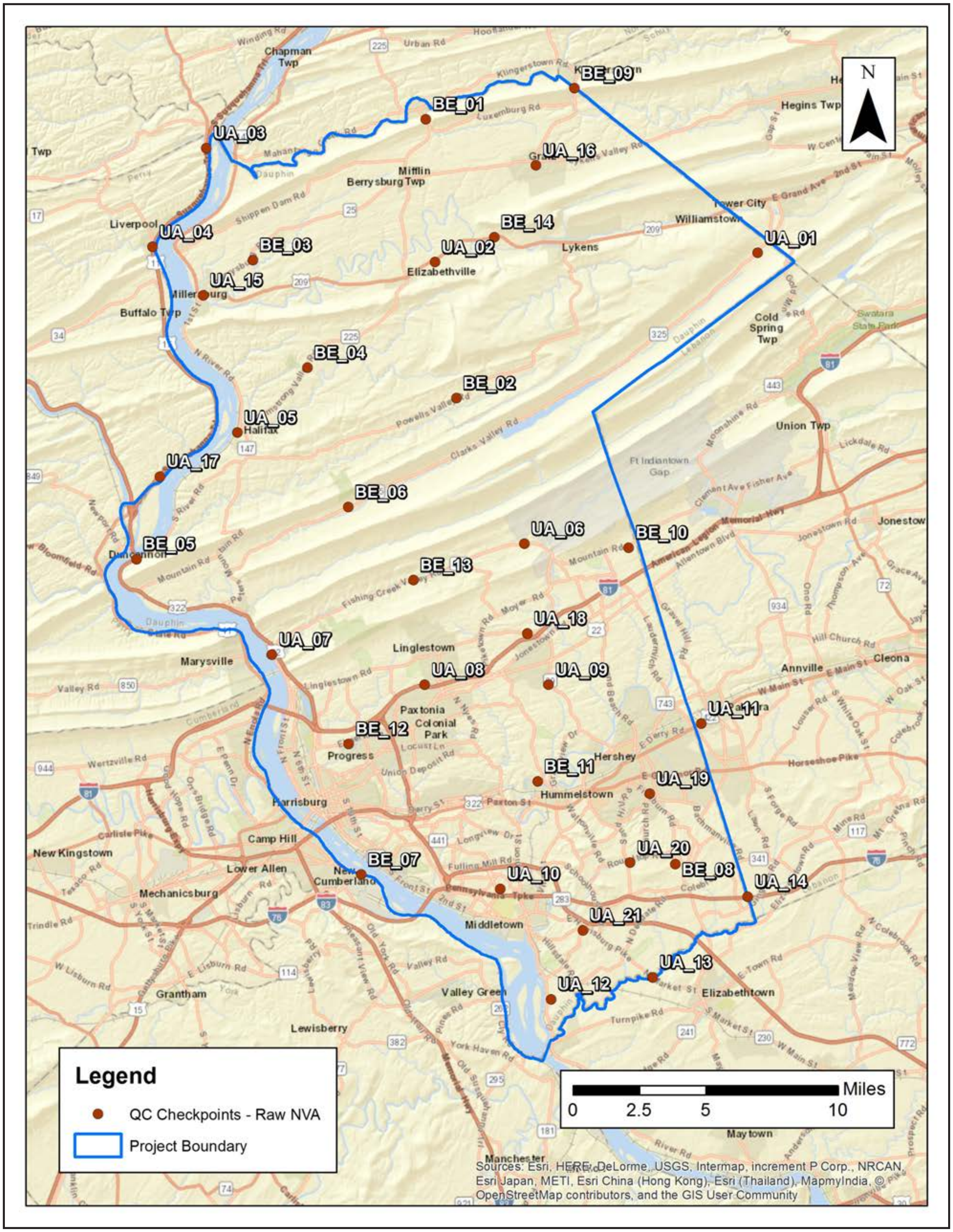


Table 5. QC Checkpoint Report - Raw NVA

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_01	2233016.520	475761.190	526.64	526.72	0.08
BE_02	2239114.000	420190.970	704.34	704.32	-0.02
BE_03	2198573.550	447717.330	550.78	550.79	0.01
BE_04	2209413.590	426246.710	615.73	615.88	0.15
BE_05	2175368.190	388102.890	361.71	361.63	-0.08
BE_06	2217547.450	398468.380	510.96	511.08	0.12
BE_07	2220126.630	325341.840	310.33	310.37	0.04
BE_08	2282681.110	327404.090	582.18	582.28	0.10
BE_09	2262624.240	481929.690	533.75	533.83	0.08
BE_10	2273434.200	390389.990	484.78	484.82	0.04
BE_11	2255317.990	343908.060	324.18	324.03	-0.15
BE_12	2217653.930	351360.820	447.37	447.47	0.10
BE_13	2230566.800	383933.070	505.44	505.58	0.14
BE_14	2246636.330	452295.180	726.07	726.15	0.08
UA_01	2299112.220	449165.600	792.30	792.24	-0.06
UA_02	2234834.490	447317.880	645.60	645.58	-0.02
UA_03	2189264.280	470024.430	420.49	420.49	0.00
UA_04	2178578.920	450331.600	396.72	396.74	0.02
UA_05	2195446.980	413334.900	394.25	394.31	0.06
UA_06	2252675.310	391149.430	566.17	566.12	-0.05
UA_07	2202367.290	369139.280	314.74	314.65	-0.09
UA_08	2232783.660	363143.760	501.39	501.51	0.12
UA_09	2257462.030	363169.140	527.78	527.85	0.07
UA_10	2247848.080	322492.600	416.69	416.87	0.18
UA_11	2287872.320	355451.860	448.99	448.84	-0.15
UA_12	2257956.100	300483.910	324.42	324.55	0.13
UA_13	2278215.690	304828.230	386.41	386.32	-0.09
UA_14	2297123.120	320934.280	491.13	491.11	-0.02
UA_15	2188634.160	440679.120	433.35	433.27	-0.08
UA_16	2254933.170	466592.650	815.27	815.29	0.02
UA_17	2180036.410	404559.610	370.86	371.01	0.15
UA_18	2253199.790	373293.110	514.73	514.61	-0.12

Number	Easting	Northing	Known Z	Laser Z	Dz
UA_19	2277577.970	341489.880	436.57	436.62	0.05
UA_20	2273707.720	327717.180	620.37	620.37	0.00
UA_21	2264287.950	314201.300	538.20	537.98	-0.22

Average Dz	0.020 ft
Minimum Dz	-0.220 ft
Maximum Dz	0.180 ft
Root Mean Square	0.099 ft
95% Confidence Level	0.193 ft

Figure 11. QC Checkpoint Locations - NVA

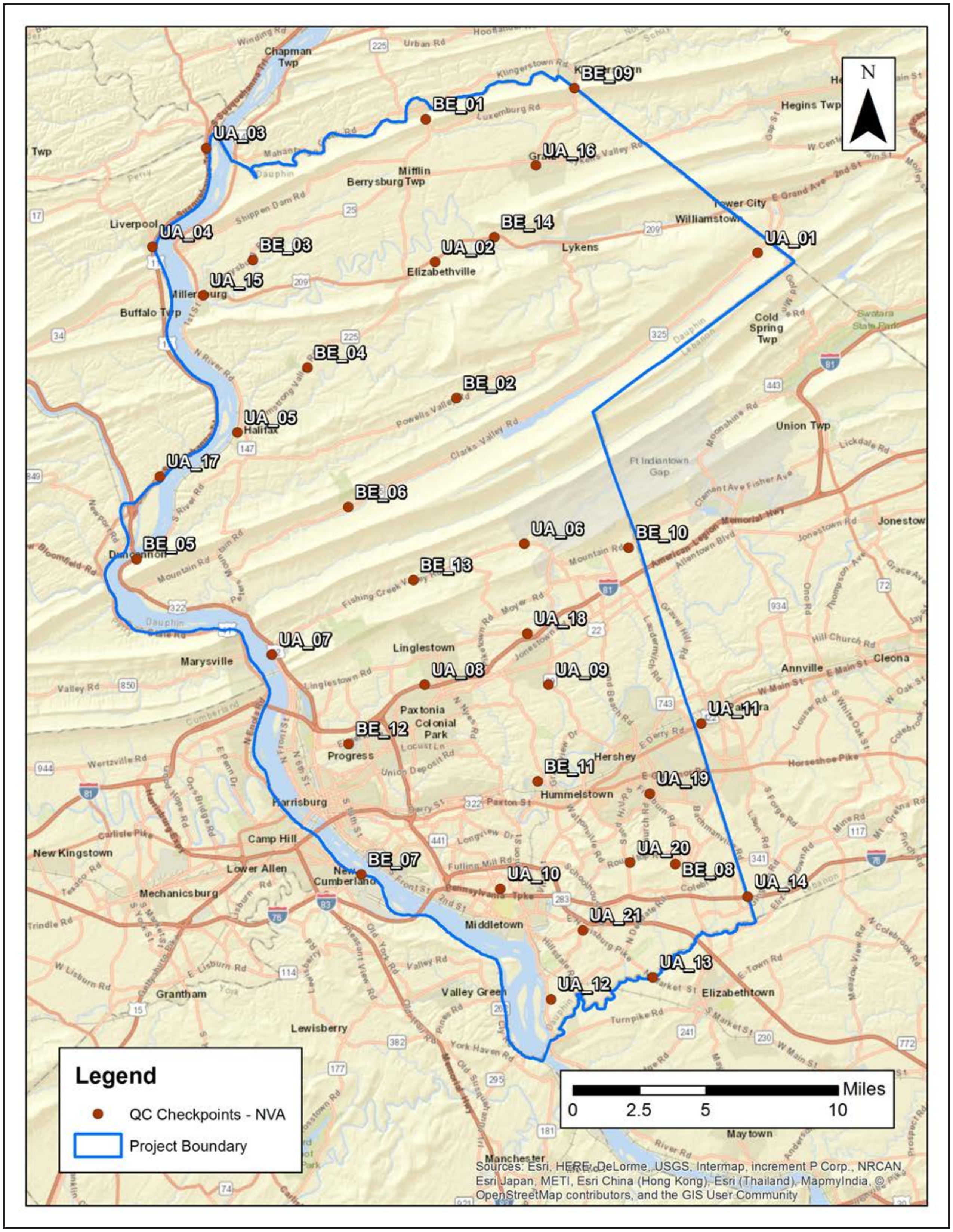


Table 6. QC Checkpoint Report - NVA

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_01	2233016.52	475761.19	526.64	526.73	0.09
BE_02	2239114.00	420190.97	704.34	704.31	-0.03
BE_03	2198573.55	447717.33	550.78	550.77	-0.01
BE_04	2209413.59	426246.71	615.73	615.88	0.15
BE_05	2175368.19	388102.89	361.71	361.70	-0.01
BE_06	2217547.45	398468.38	510.96	511.02	0.06
BE_07	2220126.63	325341.84	310.33	310.38	0.05
BE_08	2282681.11	327404.09	582.18	582.30	0.12
BE_09	2262624.24	481929.69	533.75	533.84	0.09
BE_10	2273434.20	390389.99	484.78	484.90	0.12
BE_11	2255317.99	343908.06	324.18	324.06	-0.12
BE_12	2217653.93	351360.82	447.37	447.46	0.09
BE_13	2230566.80	383933.07	505.44	505.58	0.14
BE_14	2246636.33	452295.18	726.07	726.15	0.08
UA_01	2299112.22	449165.60	792.30	792.23	-0.08
UA_02	2234834.49	447317.88	645.60	645.58	-0.02
UA_03	2189264.28	470024.43	420.49	420.44	-0.05
UA_04	2178578.92	450331.60	396.72	396.75	0.03
UA_05	2195446.98	413334.90	394.25	394.26	0.01
UA_06	2252675.31	391149.43	566.17	566.15	-0.02
UA_07	2202367.29	369139.28	314.74	314.67	-0.07
UA_08	2232783.66	363143.76	501.39	501.51	0.12
UA_09	2257462.03	363169.14	527.78	527.83	0.05
UA_10	2247848.08	322492.60	416.69	416.86	0.17
UA_11	2287872.32	355451.86	448.99	448.92	-0.07
UA_12	2257956.10	300483.91	324.42	324.55	0.14
UA_13	2278215.69	304828.23	386.41	386.34	-0.07
UA_14	2297123.12	320934.28	491.13	491.20	0.07
UA_15	2188634.16	440679.12	433.35	433.24	-0.11
UA_16	2254933.17	466592.65	815.27	815.20	-0.07
UA_17	2180036.41	404559.61	370.86	370.99	0.13
UA_18	2253199.79	373293.11	514.73	514.61	-0.13

Number	Easting	Northing	Known Z	Laser Z	Dz
UA_19	2277577.97	341489.88	436.57	436.61	0.04
UA_20	2273707.72	327717.18	620.37	620.42	0.05
UA_21	2264287.95	314201.30	538.20	538.11	-0.09

Average Dz	0.020 ft
Minimum Dz	-0.125 ft
Maximum Dz	0.172 ft
Root Mean Square	0.089 ft
95% Confidence Level	0.174 ft

Figure 12. QC Checkpoint Locations - VVA

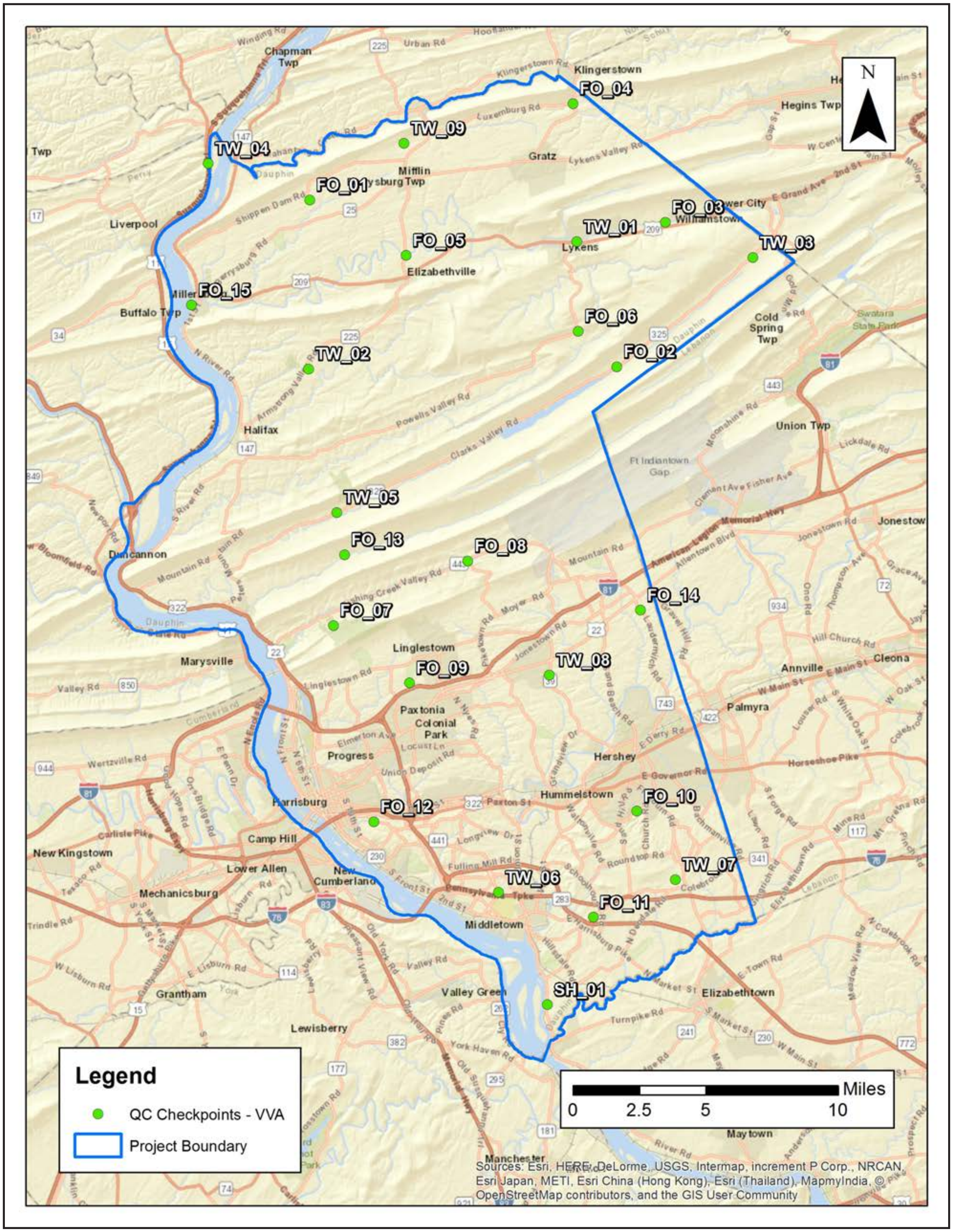


Table 7. QC Checkpoint Report - VVA

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
FO_01	2209867.64	459676.89	651.36	651.55	0.19
FO_02	2271067.40	426421.07	692.00	692.04	0.04
FO_03	2280681.61	455251.62	692.32	692.20	-0.12
FO_04	2262335.93	478896.50	537.10	537.23	0.13
FO_05	2229090.05	448627.46	515.13	515.23	0.10
FO_06	2263360.64	433528.65	1161.24	1161.21	-0.04
FO_07	2214588.98	374874.02	581.49	581.76	0.27
FO_08	2241373.68	387712.23	565.30	565.33	0.03
FO_09	2229753.70	363526.62	414.23	414.31	0.08
FO_10	2275056.34	337961.84	522.71	522.88	0.17
FO_11	2266347.83	316828.42	446.94	447.06	0.12
FO_12	2222619.14	335879.15	332.98	333.07	0.09
FO_13	2216825.18	388990.35	481.04	481.20	0.16
FO_14	2275741.62	377932.23	431.14	431.19	0.05
FO_15	2186338.82	438715.42	378.80	378.65	-0.15
SH_01	2257186.02	299424.39	333.82	334.13	0.31
TW_01	2263055.51	451357.12	699.52	699.26	-0.26
TW_02	2209628.61	425984.75	614.43	614.58	0.15
TW_03	2298146.29	448192.44	785.91	786.02	0.11
TW_04	2189612.81	466969.09	389.65	389.97	0.32
TW_05	2215247.99	397407.13	520.28	520.26	-0.02
TW_06	2247469.65	321786.59	401.61	401.84	0.23
TW_07	2282694.47	324338.56	542.41	542.55	0.14
TW_08	2257596.76	365088.97	507.67	507.84	0.17
TW_09	2228609.11	470962.93	723.83	723.99	0.16

Average Dz	0.100 ft
Minimum Dz	-0.257 ft
Maximum Dz	0.320 ft
Root Mean Square	0.166 ft
95th Percentile	0.257 ft