Allentown, PA 2016 LiDAR and Orthoimagery Project Report

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Requisition # 0040265899
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1. Summary / Scope

1.1. Summary

This report contains a summary of the Allentown, PA 2016 LiDAR and orthoimagery acquisition task order, issued by USGS National Geospatial Technical Operations Center (NGTOC) under their Geospatial Product and Services Contract on March 22, 2016. The task order yielded a project area covering 20 square miles over Allentown, Pennsylvania. 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
8 pts / m²	487.68 m	60°	35%	≤ 10 cm

High resolution 16-bit, 4-band (RGB-NIR) digital imagery was acquired and used for digital orthophoto production. Imagery data collection was planned using the specifications listed below in Table 2.

Table 2. Originally Planned Ortho Specifications

Raw GSD	Flight Altitude (AGL)	Min. Sun Angle	Side Overlap	Front Overlap
7 cm	3,773 ft	30°	30%	60%

1.3. Coverage

The project boundary covers 20 square miles and encompasses the city of Allentown in Lehigh County located in eastern Pennsylvania. Project extents are shown in Figure 1.

1.4. Duration

LiDAR data was acquired on March 26, 2016 in one total lift. Imagery was acquired in one lift on March 30, 2016. See "Section: 2.6. 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:

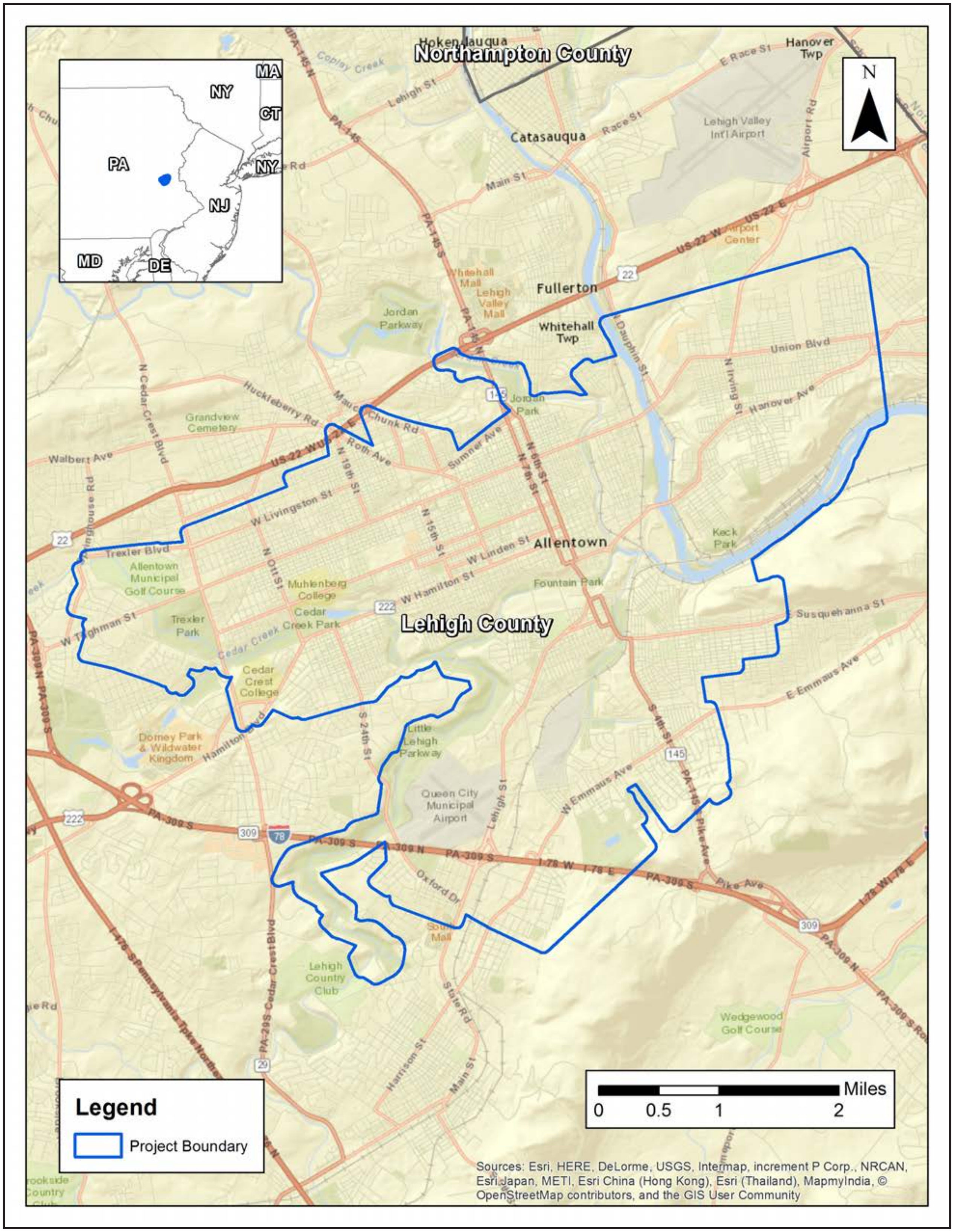
LiDAR

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

Imagery

- Non-orthorectified, uncompressed imagery in GeoTIFF format with Socet Set .sup files
- 7.5 cm digital orthorectified imagery, tiled, in GeoTIFF format
- 7.5 cm digital orthorectified imagery mosaic in MrSID Gen 4 format with a compression ratio of 80:1
- Photo centers in Esri shapefile format
- Seamlines in Esri shapefile format
- Processing boundary in Esri shapefile format
- Tile layout in Esri shapefile format
- QC checkpoints points in Esri shapefile format
- Project-, deliverable-, and tile-level metadata in .XML format

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.

The entire target area was comprised of 35 planned flight lines measuring approximately 148.32 total flight line miles for LiDAR acquisition (Figure 2) and 18 planned flight lines and 361 planned exposures for imagery acquisition (Figure 4).

2.2. LiDAR Sensor

Quantum Spatial utilized a Riegl Q680i LiDAR sensor (Figure 3) during the project. The system is capable of collecting data at a maximum frequency of 400 kHz, which affords elevation data collection of up to 266,000 points per second. The system utilizes a Multi-Pulse in the Air option (MPIA).

A brief summary of the aerial acquisition parameters for the project are shown in the LiDAR System Specifications in Table 3.

2.3. Orthoimagery Camera

Quantum Spatial also utilized a DMC IIe (Figure 5). This system has 4 channel (RGB & NIR) multi-spectral capability. The combination of the DMC's Forward Motion Compensation, along with the gyro stabilized mount, insures the best possible image collection. A single full resolution image is 15,552 by 14,144 pixels. This camera utilizes a 92mm lens focal distance.

A brief summary of the aerial acquisition parameters for the project are shown in the Camera System Specifications in Table 4.

Figure 2. Planned LiDAR Flight Lines

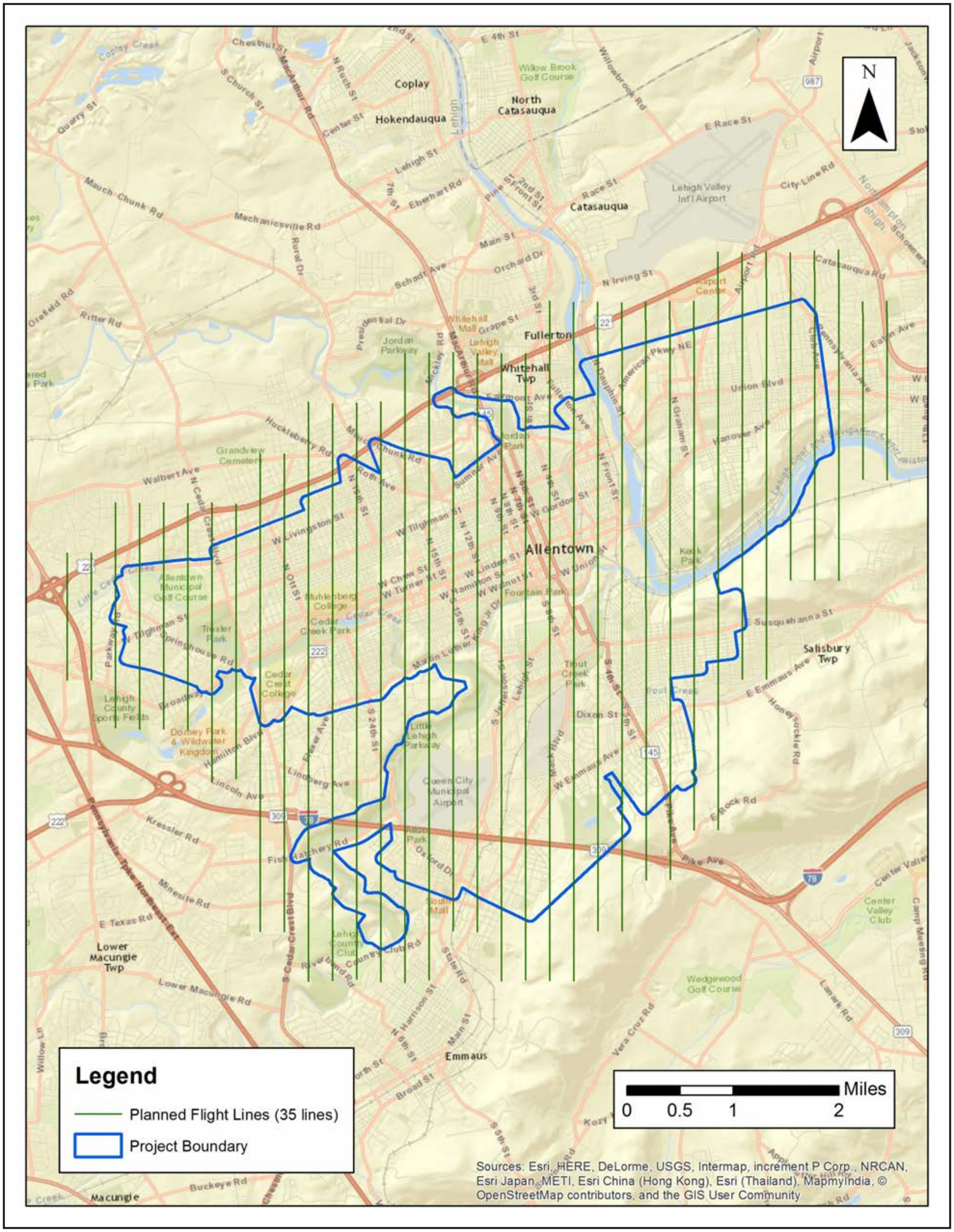


Table 3. Lidar System Specifications

Terrain and Aircraft Scanner	Flying Height	1,600 ft
	Recommended Ground Speed	125 kts
Scanner	Field of View	60°
	Scan Rate Setting Used	185 Hz
Laser	Laser Pulse Rate Used	400 kHz
	Multi Pulse in Air Mode	Enabled
Coverage	Full Swath Width	563.12 m
	Line Spacing	364.0 m
Point Spacing and Density	Maximum Point Spacing Along Track	0.348 m
	Maximum Point Spacing Along Track	0.350 m
	Average Point Density	8 pts / m^2

Figure 3. Riegl 680i LiDAR Sensor

Figure 4. Planned Ortho Flight Lines and Frames

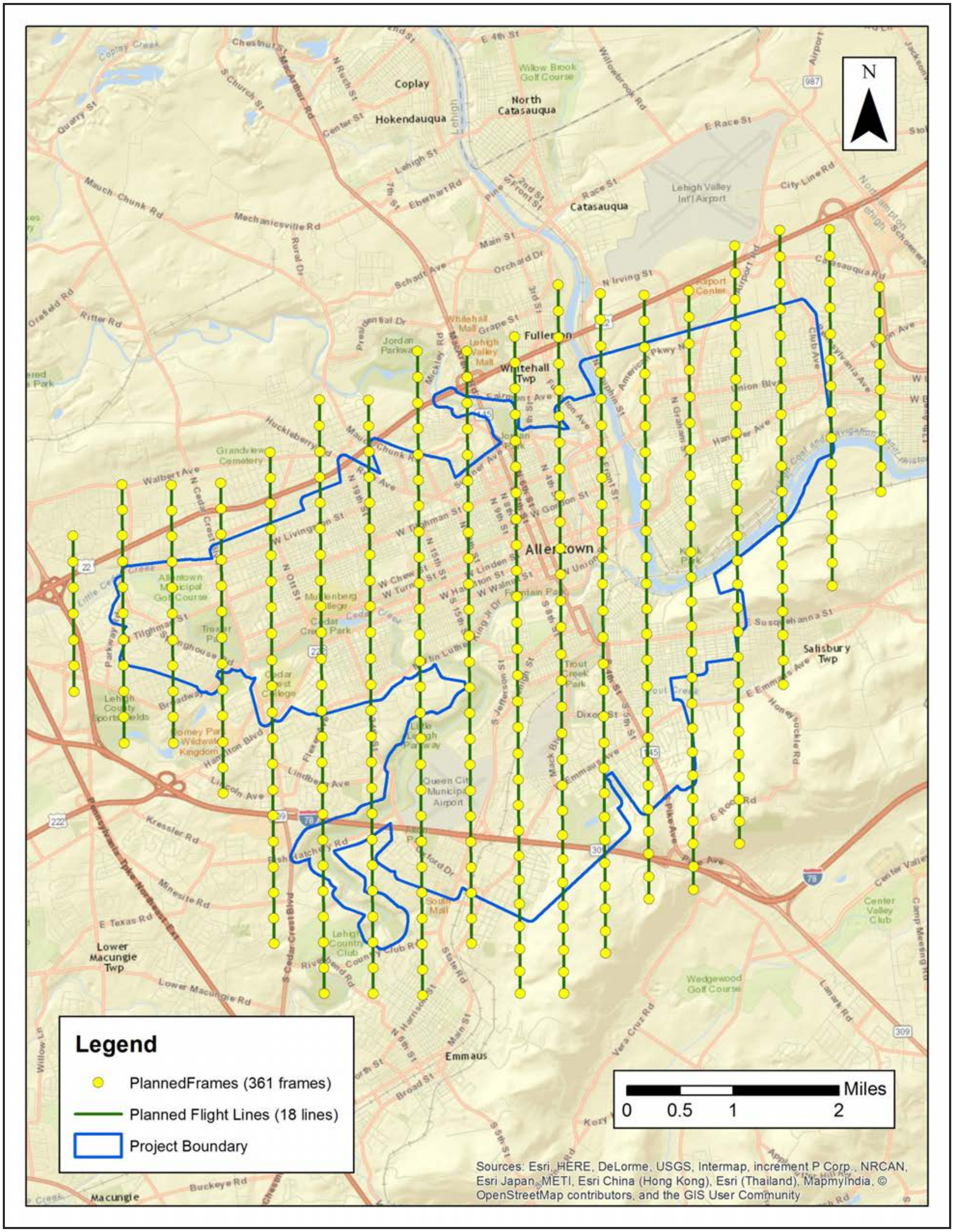


Table 4. Camera System Specifications

Terrain and Aircraft	Flying Height AGL	3,773 ft
	Recommended Ground Speed	160 kts
Overlap	Forward Overlap	60%
	Side Overlap	30%
Coverage	Strip Width	1,089 m
Resolution	GSD	7.5 cm

Figure 5. DMC IIe Camera

2.4. Aircraft

All flights for the project were accomplished through the use of two customized planes. LiDAR data was collected with a Piper Aztec (twin-piston), Tail Number N63868. Imagery was collected using a Piper Navajo (twin-piston), Tail Number N59848.

These aircraft provided an ideal, stable aerial base for LiDAR and imagery 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 state-of-the-art Riegl LiDAR and DMC imagery systems.

2.5. Base Station Information

GPS base stations were utilized during all phases of flight (Table 5). The base station locations were verified using NGS OPUS service and subsequent surveys. Base station locations are depicted in Figure 6. Data sheets, graphical depiction of base station locations or log sheets used during station occupation are available in Appendix A.

Table 5. Base Station Locations

Base Station	Latitude	Longitude	Ellipsoid Height (m)
LUMT	40° 36’ 5.74811”	75° 21’ 27.13397”	251.38

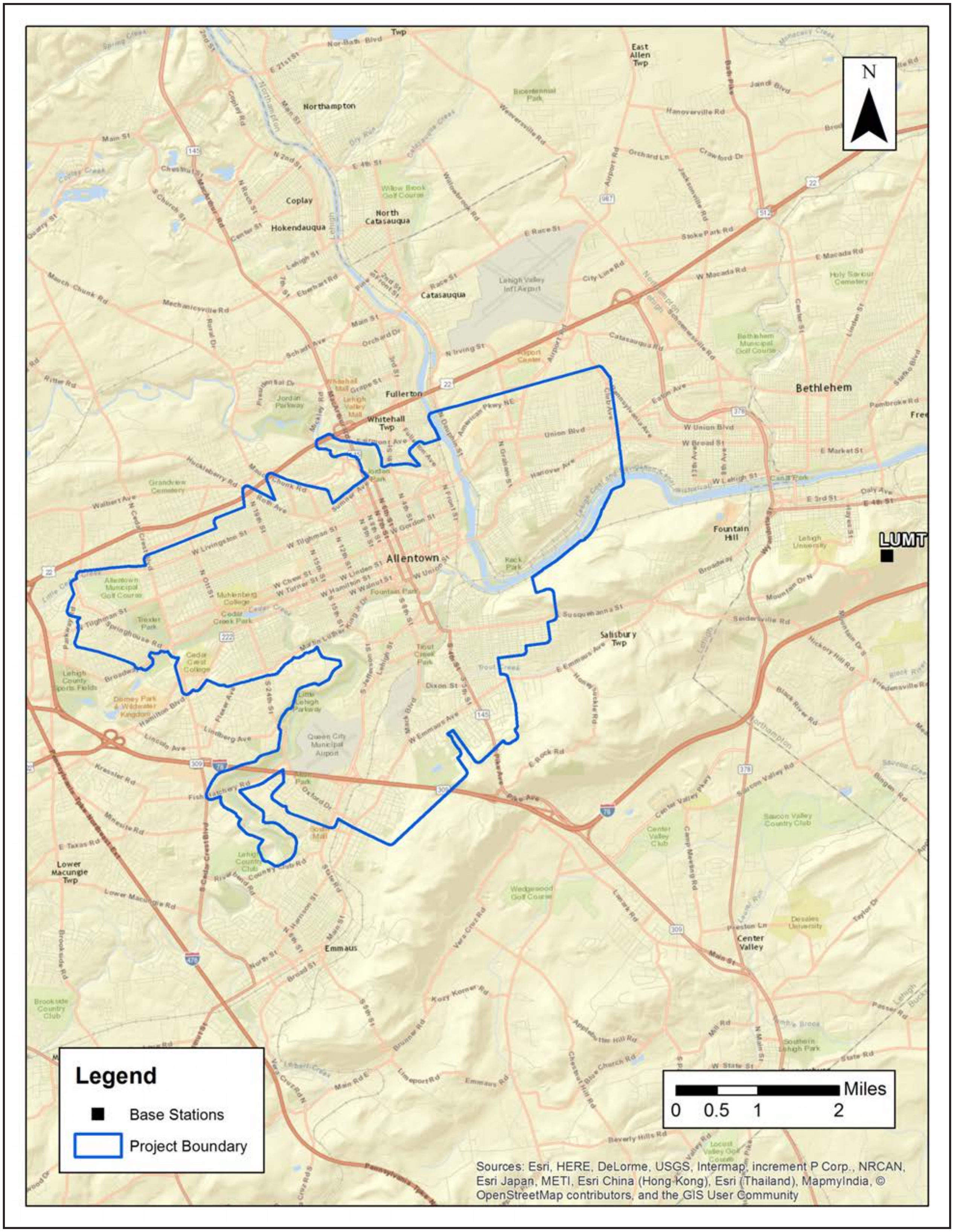
2.6. Time Period

Project specific flights were conducted over two days. One LiDAR sortie and one ortho sortie, or aircraft lift were completed. Accomplished sorties are listed below.

LiDAR Sorites
- Mar 26, 2016-A (N63868)

Ortho Sorties
- Mar 30, 2016-A (N59848)

Figure 6. 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

Similar information was also collected for imagery:

- Job / Project #
- System
- Flight Date / Lift Number
- Flight Line Number
- Flight Line Start Time
- Flight Line Stop Time
- Image Range
- F-Stop Setting
- Shutter Setting

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

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 B.

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 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 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 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 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 Bare Earth Raster DEM

Class 2 LiDAR in conjunction with the hydro breaklines were used to create a 1-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 1-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. Hydro-Flattened Bare Earth Raster DEM Mosaic Creation

After final surface acceptance, a mosaic of the 1-foot bare-earth raster DEM files was created using automated scripting routines within ArcMap, in ERDAS .IMG format. The surface was reviewed for completeness to ensure all tiles were included in the mosaic.

3.9. Imagery Processing Summary

There are five distinct processing steps. First, raw imagery is converted from the raw data collected in flight and post-processed to a "RAW" file that can be incorporated into orthophotography data. Second, Ground Control Points (GCPs) were collected and processed. Third, an additional set of raw data collected in flight from the Airborne GPS systems are processed to create an external orientation file. The processed RAW imagery, ground control and the external orientation file are used to create aerotriangulation data. And, finally, the merging of all of these, along with a surface, is done in order to create a digital orthophotograph.

The purpose of the DMC post processing software is to take the raw image data and create final output images in a format that can be imported into a softcopy photogrammetric workflow. For each photo mission, raw image data is stored on the Solid State Device (SSD). The Digital Mapping Camera (DMC) has five cameras: panchromatic, near infrared, blue, red, and green. The final output from the post processing are high resolution panchromatic, color and color infrared images with a 5.6 micron resolution, and an image size of 15,552 x 14,144 pixels.

The post processing tasks include Radiometric corrections, lens distortion corrections, mosaicking of panchromatic images, reprojection of mosaicked panchromatic images to a central perspective, color fusion of multispectral imagery, generation of image overviews, and output of 8 or 12 bit imagery in compressed or uncompressed format.

There are two steps to the post processing, Radiometric and Geometric corrections.

3.9.1. Radiometric Processing

The Radiometric Processing involves the following functions:

- CCD Normalization or calibration of each CCD to ensure a uniform response across each CCD.
- Defect Pixel Correction which identifies and replaces defective pixels with interpolated values from neighboring pixels.
- Corrections for aperture, temperature, forward motion, and filter sensitivity effects.
- The radiometric processing produces a separate Tiff image output for each camera that are used as input to the geometric processing.

3.9.2. Geometric Processing

The Geometric Processing involves the following functions:

- Mosaicking of the four panchromatic images using automated tie point matching and a robust adjustment.
- Reprojection of the mosaicked panchromatic image into a single central perspective image.
- Application of the camera calibration parameters to compensate for lens distortion and platform calibration.
- Creation of pan-sharpened color images. This process involves registration of the lower resolution multispectral images to the high resolution panchromatic image, and then resampling the multispectral images to the same scale and alignment as the panchromatic image. The Red, Green, Blue, CIR bands are then transformed to Hue, Saturation, and Value. The Value band is discarded and replaced by the panchromatic image, and then transformed back to Red, Green, Blue, and CIR.
- Generated LUT is also applied in this step.

As part of the imagery processing phase, Quantum Spatial delivered sample imagery frames of various land cover types to the client for their review and acceptance prior to the processing of all imagery.

3.10. Airborne GPS and IMU Post Processing

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.

3.11. Aerotriangulation

Using RAW images, Airborne ABGPS/IMU external orientation parameters and ground control data the imagery control solution was further extended and densified using analytical aerotraingualtion adjustment techniques. This adjustment of the measurements was performed using a robust aerotriangulation software package, Image Station Aero Triangulation (ISAT) software, on softcopy photogrammetric workstations. A total of 1 aerotriangulation block was developed for the project. The final adjustment of these blocks was accomplished by using a rigorous simultaneous least squares bundle adjustment. For more information see the Aerotriangulation Report in Appendix D.

Maximum, minimum, and mean baseline lengths are as follows:

For Mar 30, 2016-A (N59848, DMC2-017), the max length was 16.89 km, min length was 4.56 km, and mean length was 10.725 km.

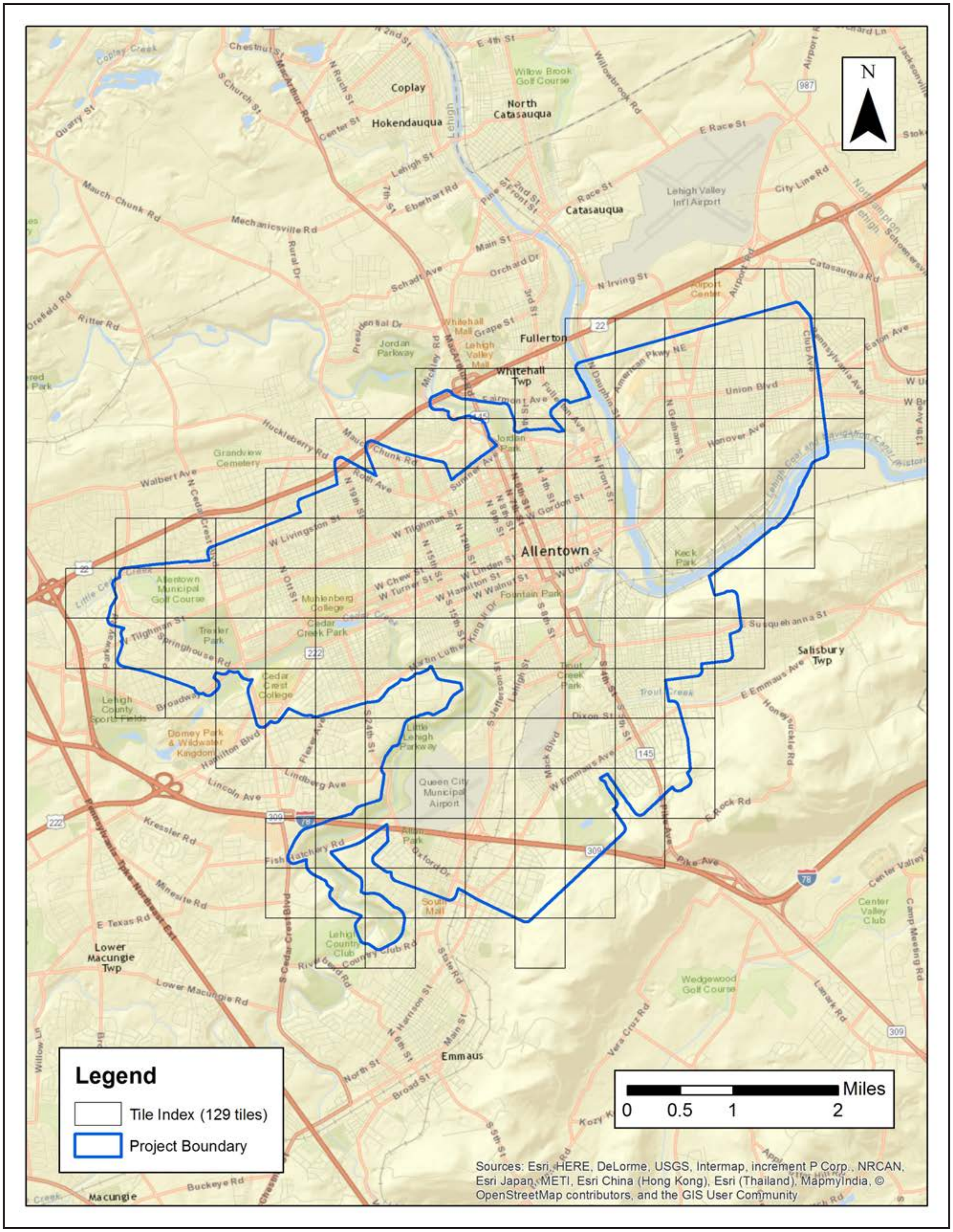
3.12. Orthophotography Creation

Digital orthophoto frames are created by using National Elevation Dataset (NED) Digital Elevation Models (DEM), which were in turn combined with processed RAW imagery and aerotriangulation data. Manual seamlines were drawn in MicroStation on every frame. Then, using the grid created with in-house software, a set of “base” mosaicked tiles were created in Intergraph OrthoPro using a bilinear interpolation method on the three data sources (processed RAW imagery, aerotriangulation data and surface data). At this stage, final color balancing is done to ensure a superior balance across the entire dataset.

The first step in the quality control process is to draw circles on areas of concern. Reviewers look for mismatches at seamlines, smears caused by elevation discrepancies (building lean, bridge warping) and radiometric distortions. Then, a different technician edits the circles. Thus, images were thoroughly reviewed by the technician who circled errors as well as the editor, so that each image has been seen by at least three sets of eyes before submitted.

Tile layout is shown in Figure 7 on the following page.

Figure 7. Ortho Tile Layout



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.

The AOI project area imagery frame coverage (see Figure 9) and content verification was performed and validated by visual review. This action was performed in the field by flight crew during the acquisition phase as well as by imagery QA technicians at our processing center. The ABGPS/IMU and base station data was uploaded to the company FTP site after each flight for the INS processing team in Lexington, Kentucky to verify accuracy of data collected.

For more information, see the Flight Maps in Appendix E.

Figure 8. Flightline Swath LAS File Coverage

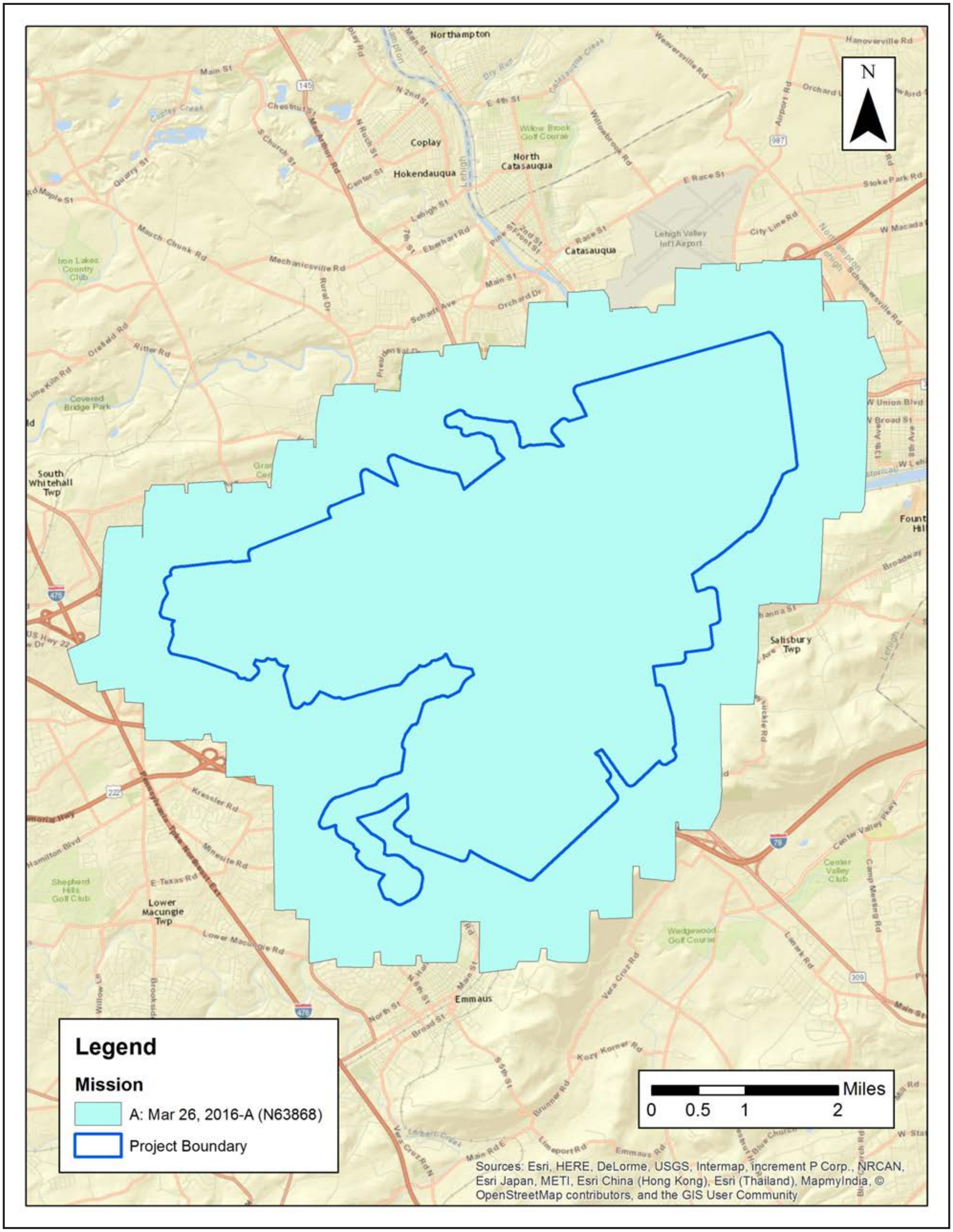
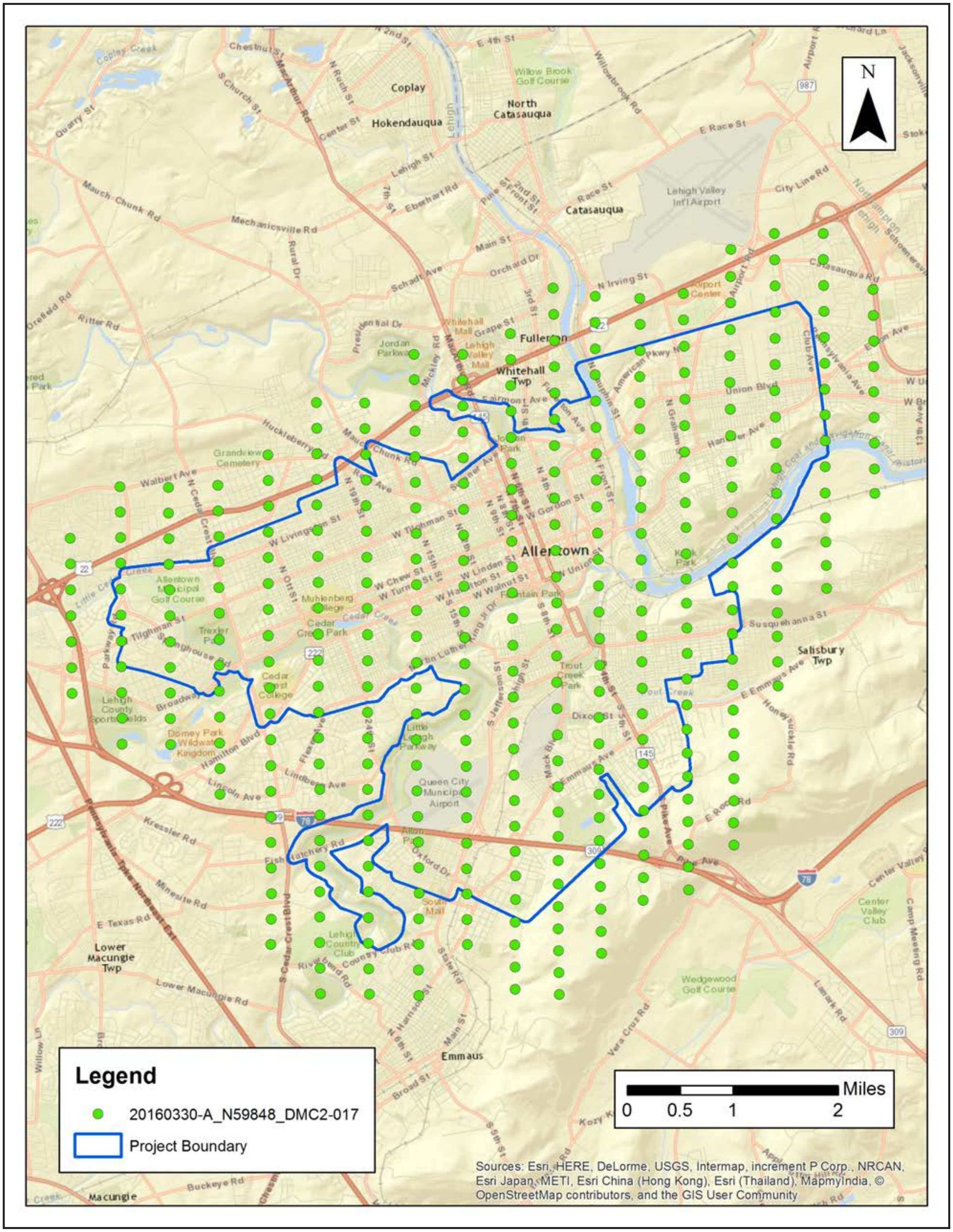


Figure 9. Ortho Frame Coverage



5. Ground Control and Check Point Collection

Quantum Spatial partnered with Herbert, Rowland, and Grubic to complete a field survey of 18 ground control (calibration) points along with 25 QA points in Vegetated and Non-Vegetated land cover classifications (total of 43 points) as an independent test of the accuracy of this project. For more information, see the survey report in Appendix F.

The required accuracy testing was performed on the LiDAR dataset (both the LiDAR point cloud and derived DEMs) 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 (2011) State Plane Pennsylvania South Zone, US survey feet; NAVD88 (Geoid 12B), US survey feet.

5.1. Calibration Control Point Testing

Figure 10 shows the location of each bare earth calibration point for the project area. Table 6 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 0.051 feet (0.016 meters) in terms of the RMSEz. The resulting NVA stated as the 95% confidence level (RMSEz x 1.96) is 0.100 feet (0.030 meters). This dataset meets the required NVA of 0.643 ft (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 11 and Table 7.

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 0.057 feet (0.017 meters) in terms of the RMSEz. The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is 0.112 feet (0.034 meters). This dataset meets the required NVA of 0.643 ft (0.196 meters) at the 95% confidence level (based on NSSDA). See Figure 12 and Table 8.

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 0.146 feet (0.045 meters), which is stated in terms of the 95th percentile error. Therefore the data meets the required VVA of 0.965 ft (0.294 meters). This test was based on the 95th percentile error (based on ASPRS guidelines) across all land cover categories. See Figure 13 and Table 9.

5.4. Orthoimagery Testing

Upon completion of all production activities and prior to delivery of the final orthophoto dataset, Quantum Spatial used Accuracy Analyst QC software to compute the overall accuracy of the orthophoto data set using 33 surveyed control points that were established for the project.

The NSSDA value was calculated to be 0.199 meters (0.652 feet). This meets the target value of 0.38 meters (1.247 feet). Please see the Ortho Accuracy Analyst report in Appendix G for more information.

Figure 10. Calibration Control Point Locations

Table 6. Calibration Control Point Report

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
ALN_01	2577570.85	469597.02	411.81	411.79	-0.020
ALN_02	2586032.53	472786.00	380.26	380.35	0.090
ALN_03	2583295.07	468088.98	323.83	323.90	0.070
ALN_04	2581080.34	463313.25	404.62	404.62	0.000
ALN_05	2589166.45	464165.74	320.31	320.37	0.060
ALN_06	2589813.37	456030.81	289.02	289.02	0.000
ALN_07	2600618.92	452988.26	491.73	491.71	-0.020
ALN_08	2596701.24	457224.94	400.36	400.35	-0.010
ALN_09	2607448.43	457082.89	707.80	707.70	-0.100
ALN_10	2604625.84	464012.51	350.54	350.54	0.000
ALN_11	2612946.09	466166.89	513.47	513.39	-0.080
ALN_12	2598221.07	472369.33	355.72	355.73	0.010
ALN_13	2591950.49	477074.67	393.14	393.17	0.030
ALN_14	2601305.00	481083.82	350.34	350.36	0.020
ALN_15	2610917.81	476307.26	358.68	358.69	0.010
ALN_16	2610807.88	484307.75	362.68	362.68	0.000
ALN_17	2618593.99	477264.32	299.86	299.91	0.050
ALN_18	2614775.81	482806.55	349.90	349.87	-0.030
	Average Dz	0.00 ft			
	Minimum Dz	-0.1 ft			
	Maximum Dz	0.09 ft			
	Root Mean Square	0.046 ft			
	Std. Deviation	0.048 ft			

Figure 11. QC Checkpoint Locations - Raw NVA

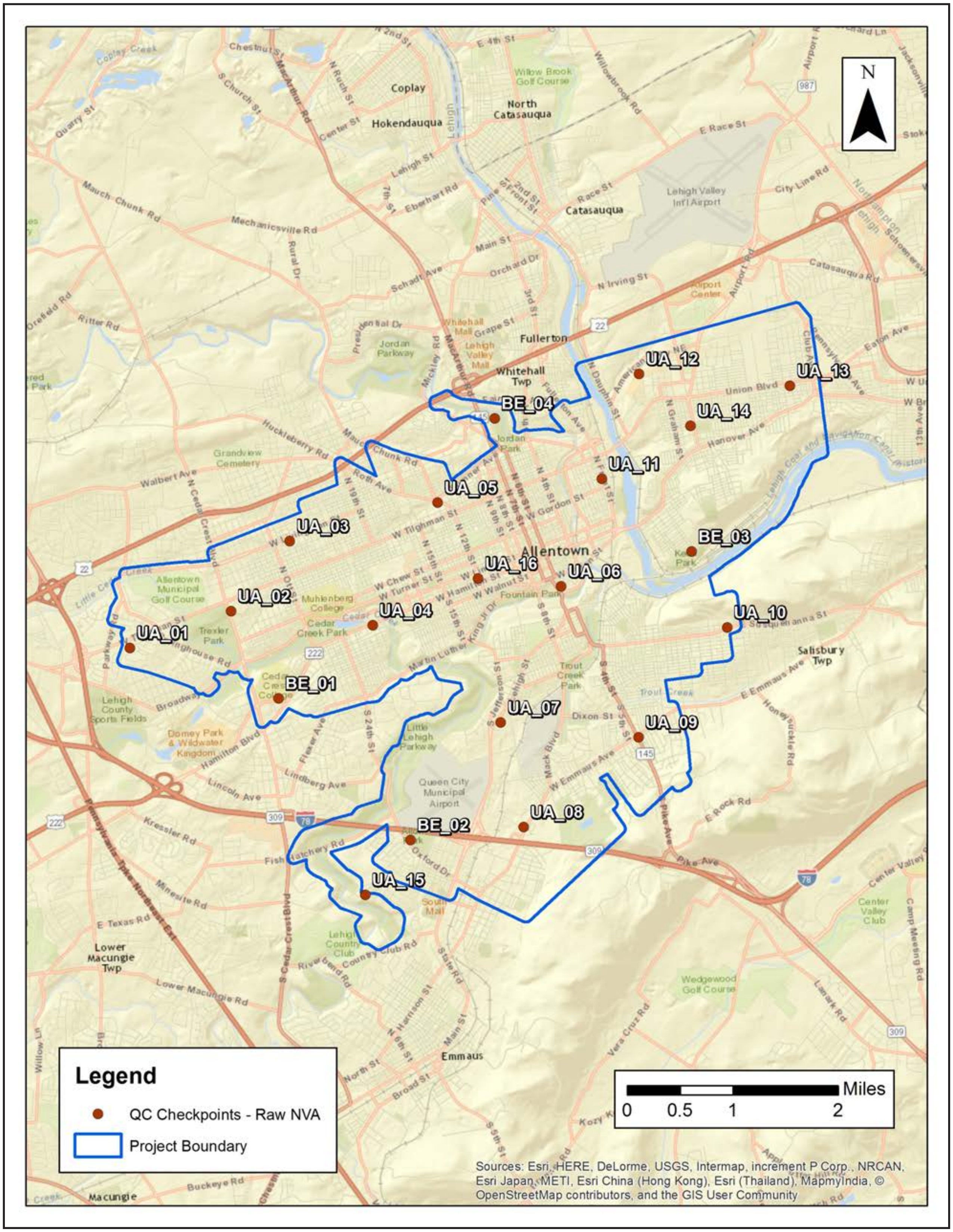


Table 7. QC Checkpoint Report - Raw NVA

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_01	2588159.14	463505.75	329.96	330.01	0.050
BE_02	2594774.56	456416.75	376.62	376.66	0.040
BE_03	2608849.11	470848.50	341.49	341.61	0.120
BE_04	2598983.57	477516.38	263.41	263.48	0.070
UA_01	2580720.31	466032.12	427.87	427.86	-0.010
UA_02	2585786.00	467852.94	364.25	364.19	-0.060
UA_03	2588730.80	471368.51	392.22	392.20	-0.020
UA_04	2592880.40	467152.92	277.16	277.19	0.030
UA_05	2596136.95	473289.00	311.36	311.33	-0.030
UA_06	2602320.63	469095.62	263.47	263.48	0.010
UA_07	2599289.54	462308.97	347.41	347.52	0.110
UA_08	2600449.33	457060.45	402.12	402.12	0.000
UA_09	2606191.84	461564.94	368.30	368.23	-0.070
UA_10	2610627.05	467031.72	502.68	502.67	-0.010
UA_11	2604363.27	474485.57	288.67	288.72	0.050
UA_12	2606220.36	479748.66	339.20	339.21	0.010
UA_13	2613781.14	479150.19	359.70	359.70	0.000
UA_14	2608800.36	477137.78	314.28	314.24	-0.040
UA_15	2592508.24	453671.30	395.83	395.80	-0.030
UA_16	2598164.83	469493.96	390.11	390.09	-0.020
	Average Dz	0.01 ft			
	Minimum Dz	-0.07 ft			
	Maximum Dz	0.12 ft			
	Root Mean Square	0.051 ft			
	95% Confidence Level	0.100 ft			

Figure 12. QC Checkpoint Locations - NVA

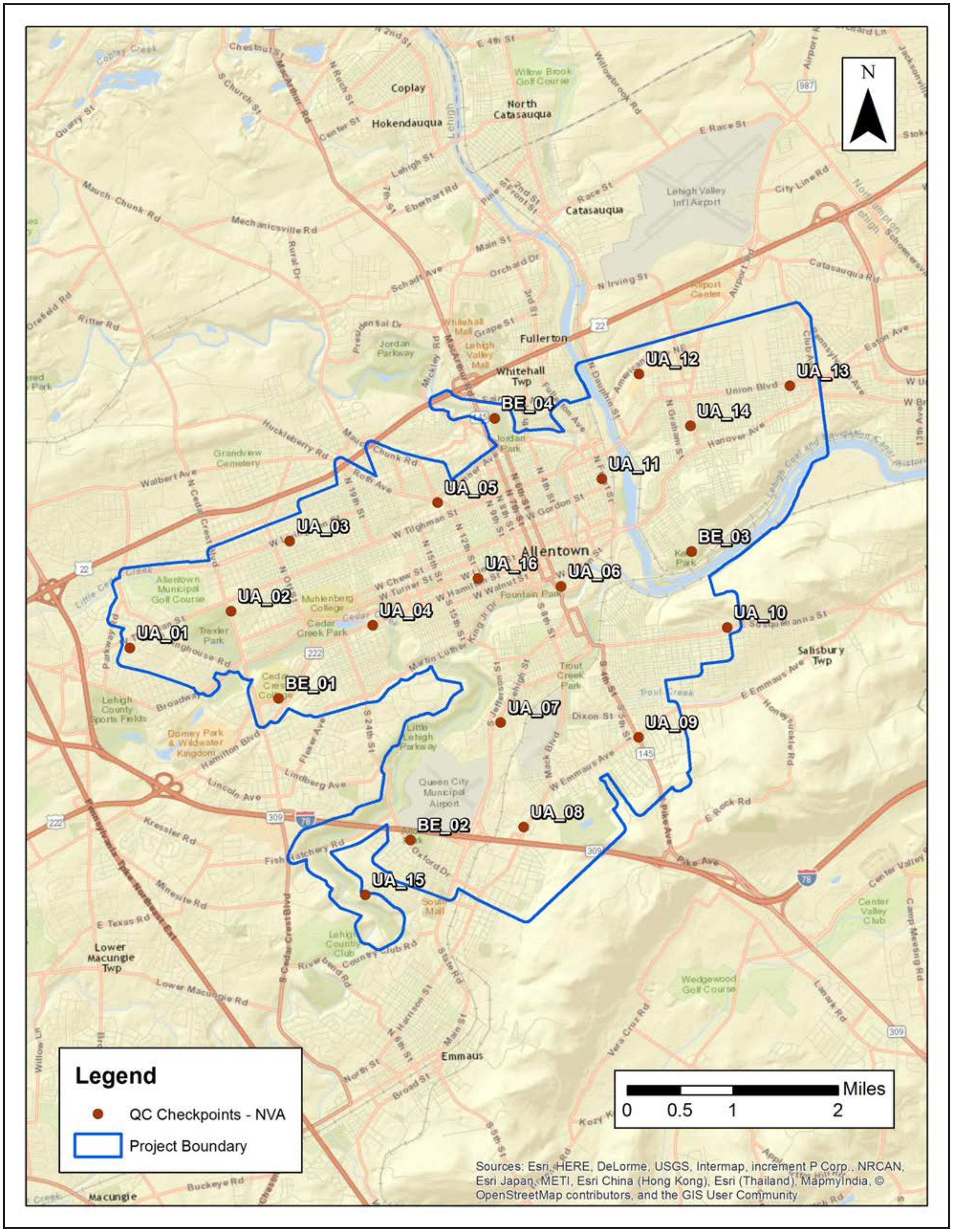


Table 8. QC Checkpoint Report - NVA

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_01	2588159.14	463505.75	329.960	330.040	0.078
BE_02	2594774.56	456416.75	376.620	376.690	0.069
BE_03	2608849.11	470848.50	341.490	341.610	0.120
BE_04	2598983.57	477516.38	263.410	263.480	0.073
UA_01	2580720.31	466032.12	427.870	427.870	-0.002
UA_02	2585786.00	467852.94	364.250	364.200	-0.054
UA_03	2588730.80	471368.51	392.220	392.220	-0.004
UA_04	2592880.40	467152.92	277.160	277.180	0.022
UA_05	2596136.95	473289.00	311.360	311.380	0.016
UA_06	2602320.63	469095.62	263.470	263.470	-0.004
UA_07	2599289.54	462308.97	347.410	347.550	0.140
UA_08	2600449.33	457060.45	402.120	402.130	0.005
UA_09	2606191.84	461564.94	368.300	368.230	-0.069
UA_10	2610627.05	467031.72	502.680	502.650	-0.031
UA_11	2604363.27	474485.57	288.670	288.720	0.055
UA_12	2606220.36	479748.66	339.200	339.210	0.007
UA_13	2613781.14	479150.19	359.700	359.710	0.014
UA_14	2608800.36	477137.78	314.280	314.240	-0.037
UA_15	2592508.24	453671.30	395.830	395.810	-0.020
UA_16	2598164.83	469493.96	390.110	390.090	-0.020
	Average Dz	0.02 ft			
	Minimum Dz	-0.069 ft			
	Maximum Dz	0.14 ft			
	Root Mean Square	0.057 ft			
	95% Confidence Level	0.112 ft			

Figure 13. QC Checkpoint Locations - VVA

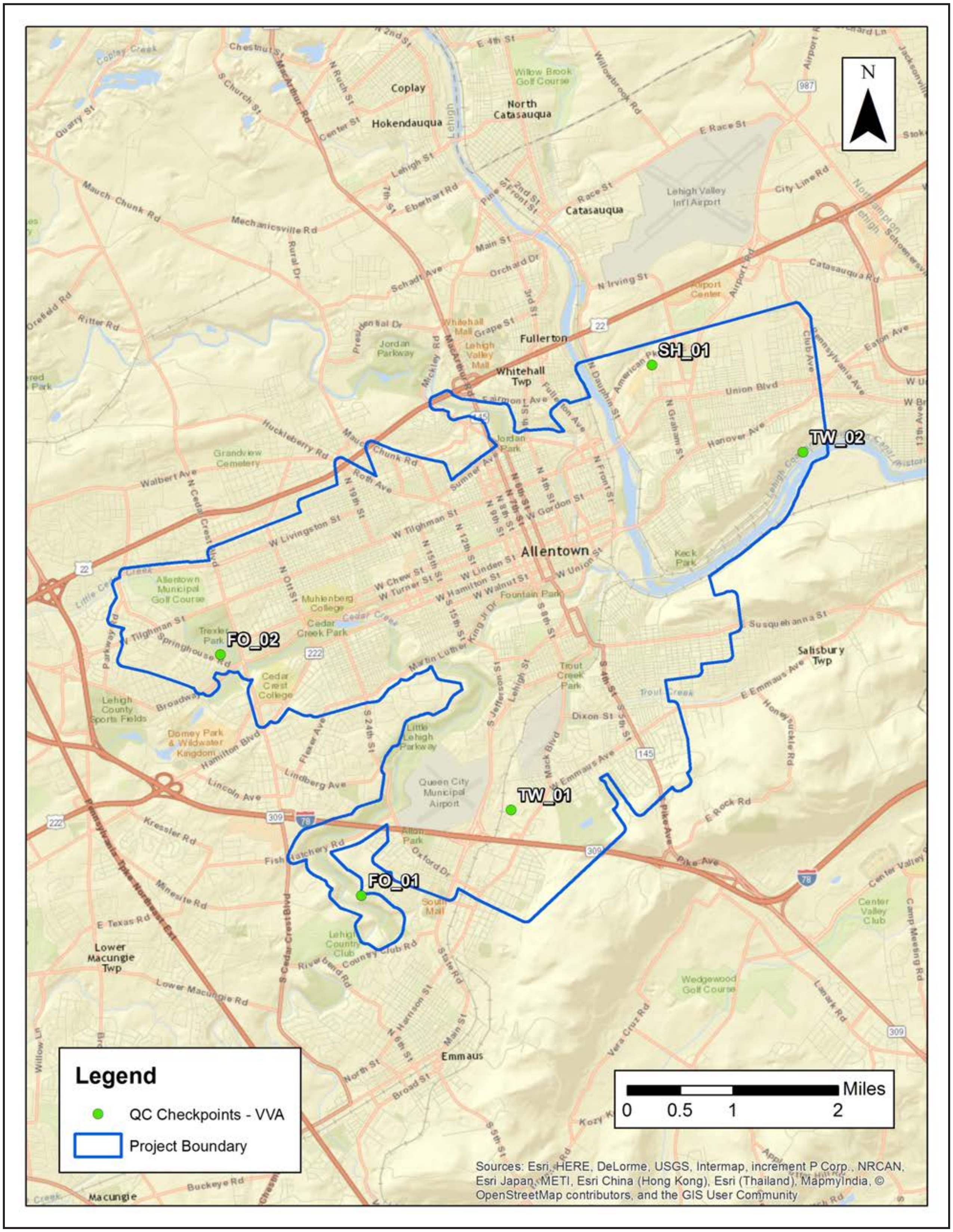


Table 9. QC Checkpoint Report - VVA

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
FO_01	2592314.88	453627.28	385.72	385.76	0.037
FO_02	2585245.67	465699.64	322.77	322.81	0.041
SH_01	2606862.22	480182.37	344.88	345.03	0.147
TW_01	2599800.66	457923.01	382.75	382.83	0.085
TW_02	2614432.47	475831.58	245.51	245.86	0.350

Average Dz	0.13 ft
Minimum Dz	0.037 ft
Maximum Dz	0.35 ft
Root Mean Square	0.176 ft
95th Percentile	0.146 ft

Figure 14. Imagery Checkpoint Locations

Table 10. Photo Checkpoint Report

Units = US survey feet

Number	Survey X	Survey Y	Photo X	Photo Y	dX	dY
ALN_01	2577570.85	469597.02	2577570.939	469597.3	0.089	0.28
ALN_03	2583295.07	468088.98	2583295.278	468088.991	0.208	0.011
ALN_04	2581080.34	463313.25	2581080.957	463313.037	0.617	-0.213
ALN_05	2589166.45	464165.74	2589166.467	464165.566	0.017	-0.174
ALN_06	2589813.37	456030.81	2589813.503	456030.743	0.133	-0.067
ALN_07	2600618.92	452988.26	2600619.018	452988.249	0.098	-0.011
ALN_08	2596701.24	457224.94	2596701.5	457224.755	0.26	-0.185
ALN_09	2607448.43	457082.89	2607448.259	457082.655	-0.171	-0.235
ALN_10	2604625.84	464012.51	2604625.487	464012.229	-0.353	-0.281
ALN_12	2598221.07	472369.33	2598221.441	472369.746	0.371	0.416
ALN_13	2591950.49	477074.67	2591950.794	477075.303	0.304	0.633
ALN_15	2610917.81	476307.26	2610917.731	476307.518	-0.079	0.258
ALN_16	2610807.88	484307.75	2610807.85	484308.004	-0.03	0.254
ALN_18	2614775.81	482806.55	2614775.639	482806.644	-0.171	0.094

RMSEx	0.26 ft
RMSEy	0.273 ft
RMSEh	0.377 ft
NSSDA	0.652 ft