Utah 2016 - Great Salt Lake AOI
QL1 & QL2 LiDAR Interim Project Report

Contract # AV2408

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1. Summary / Scope

1.1. Summary

This report contains a summary of the Utah 2016 - Great Salt Lake AOI QL1 and QL2 LiDAR acquisition task order, issued by State of Utah, Department of Technology Services, Division of Integrated Technology, Automated Geographic Reference Center (AGRC) under their contract signed on August 12, 2016. The task order yielded a project area covering approximately 7,536 square kilometers over western Utah and southern Idaho. 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

QL	Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
QL1	8 pts / m^2	1,200 - 1,550 m	40°	60%	≤ 10 cm
QL2	2 pts / m^2	1,400 - 1,900 m	40°	60%	≤ 10 cm

1.3. Coverage

The total LiDAR project boundary covers approximately 7,536 square kilometers. This report focuses on the Great Salt Lake QL1 and QL2 sub-AOIs, which cover approximately 3,684 km^2 total (1,537 km^2 for QL1, 2,147 km^2 for QL2). These AOIs include partial coverage of Box Elder, Davis, Salt Lake, Tooele, and Weber Counties in northern Utah.

A buffer of 100 meters was created to meet task order specifications. LiDAR extents are shown in Figure 1 and Figure 2.

1.4. Duration

QL1 LiDAR data was acquired on September 3, 2016 through November 4, 2016 in 22 total lifts. QL2 LiDAR data was acquired on September 3, 2016 through November 30, 2016 in 20 total lifts. See "Section: 2.5. Time Period" for more details.

1.5. Issues

There were no issues to report for this project.

1.6. Deliverables

The following products were produced and delivered:

- Raw LiDAR point cloud data swaths in LAS 1.4 format
- Classified LiDAR point cloud data, tiled, in LAS 1.4 format
- Hydro-flattened breaklines in Esri shapefile format
- 0.5-meter hydro-flattened bare-earth raster DEM, tiled, in ERDAS .IMG format - QL1
- 1-meter hydro-flattened bare-earth raster DEM, tiled, in ERDAS .IMG format - QL2
- 0.5-meter first return raster DSM, tiled, in ERDAS .IMG format - QL1
- 1-meter first return raster DSM, tiled, in ERDAS .IMG format - QL2
- 0.5-meter intensity images, tiled, in GeoTIFF format - QL1
- 1-meter intensity images, tiled, in GeoTIFF format - QL2
- Processing boundary in Esri shapefile format
- Tile index in Esri shapefile format
- Calibration and QC checkpoints in Esri shapefile format
- Accuracy assessment in .XLSX format
- Project-, deliverable-, and lift-level metadata in .XML format

All geospatial deliverables were produced in NAD83 UTM Zone 12, meters; NAVD88 (GEOID12B), meters. All .LAS tiled deliverables have a tile size of 1,000 meters x 1,000 meters. All other tiled deliverables have a tile size of 2,000 meters x 2,000 meters. All tile names follow US National Grid naming conventions. Tile names are based on the southwest corner of the tile.

Figure 1. Project Boundary - QL1

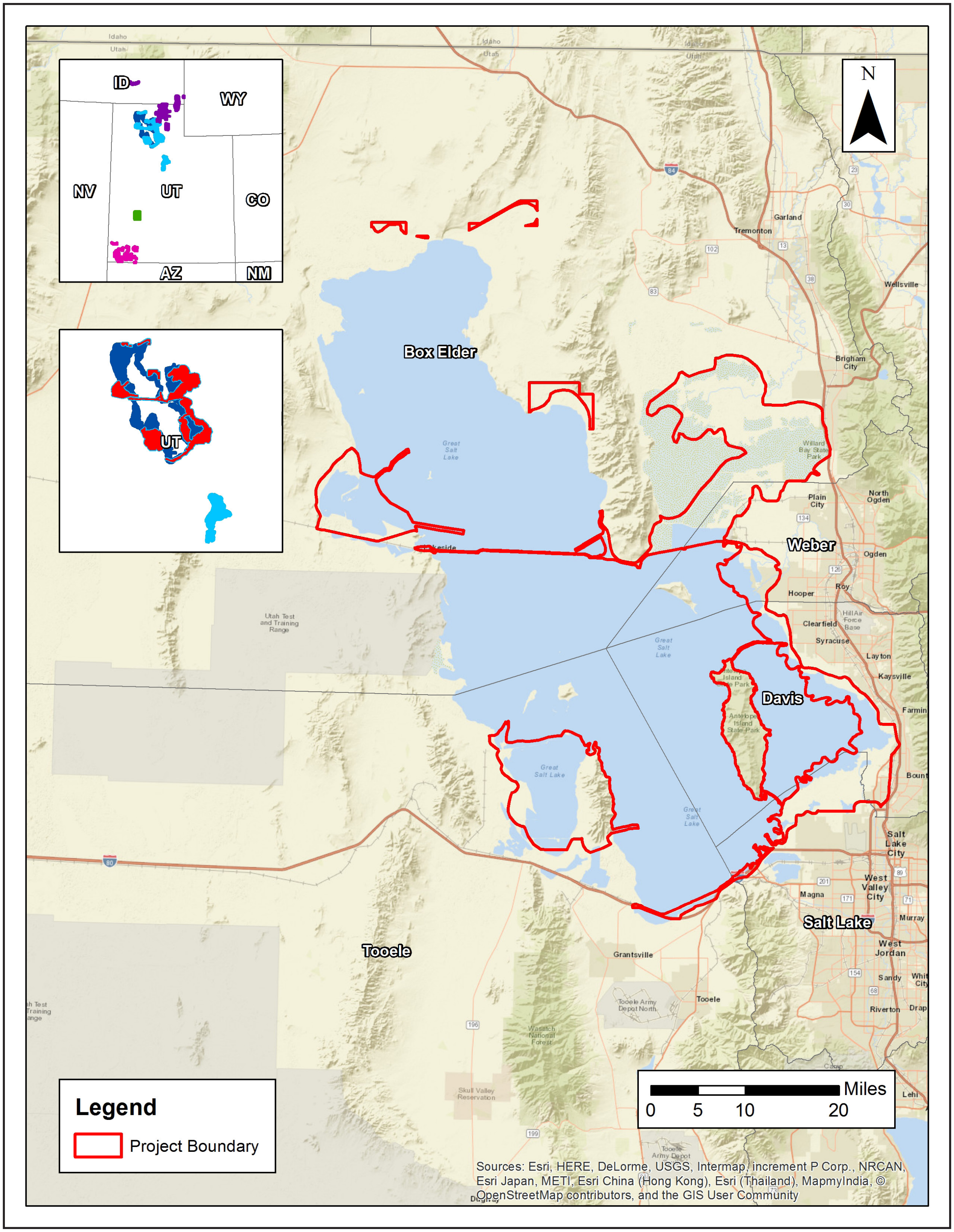
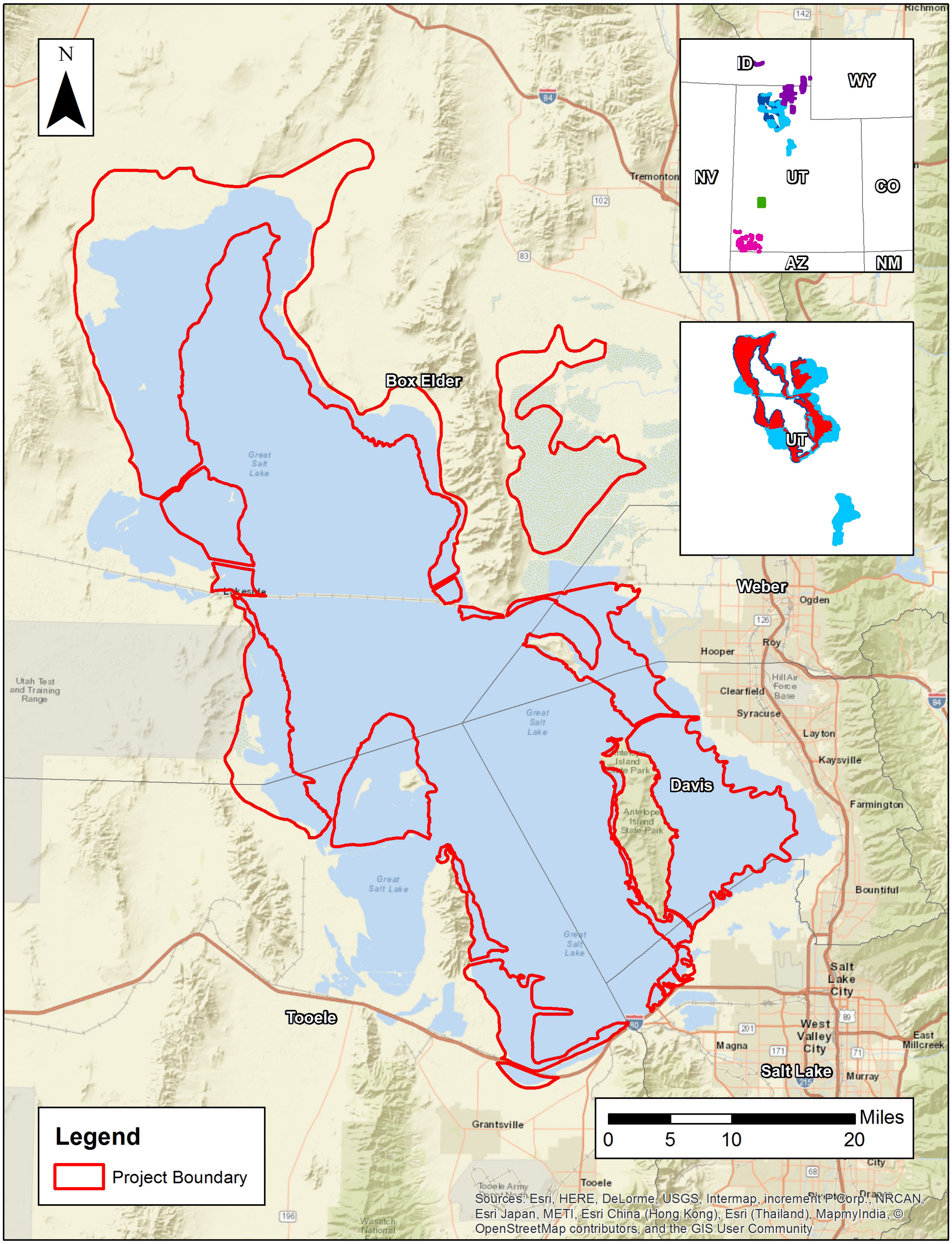


Figure 2. Project Boundary - QL2



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 QL1 target area was comprised of approximately 443 planned flight lines measuring approximately 5,168 total flight line miles (Figure 3). The entire QL2 target area was comprised of approximately 216 planned flight lines measuring approximately 3,103 total flight line miles (Figure 4).

2.2. LiDAR Sensor

Quantum Spatial utilized a Leica ALS 70 LiDAR sensor (Figure 5), 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.

Quantum Spatial also utilized Leica ALS 80 LiDAR sensors (Figure 5), serial numbers 8227, 8121, and 8146 during the project. The Leica ALS 80 system is capable of collecting data at a maximum frequency of 1,000 kHz. The system utilizes a Multi-Pulse in the Air option (MPIA). The sensor is also equipped with the ability to measure up to 6 returns per outgoing pulse from the laser. 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 and Table 3.

Figure 3. Planned LiDAR Flight Lines - QL1

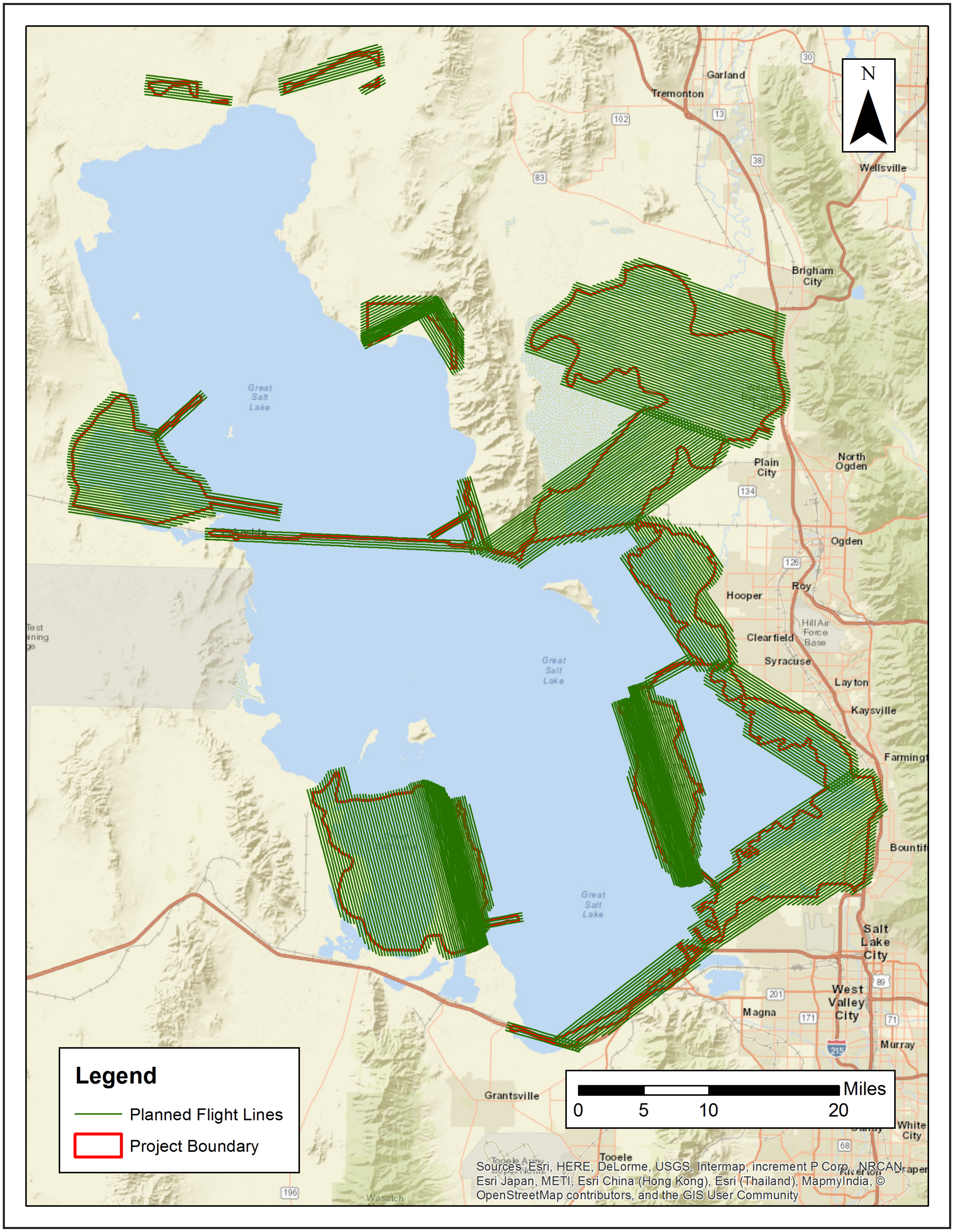


Figure 4. Planned LiDAR Flight Lines - QL2

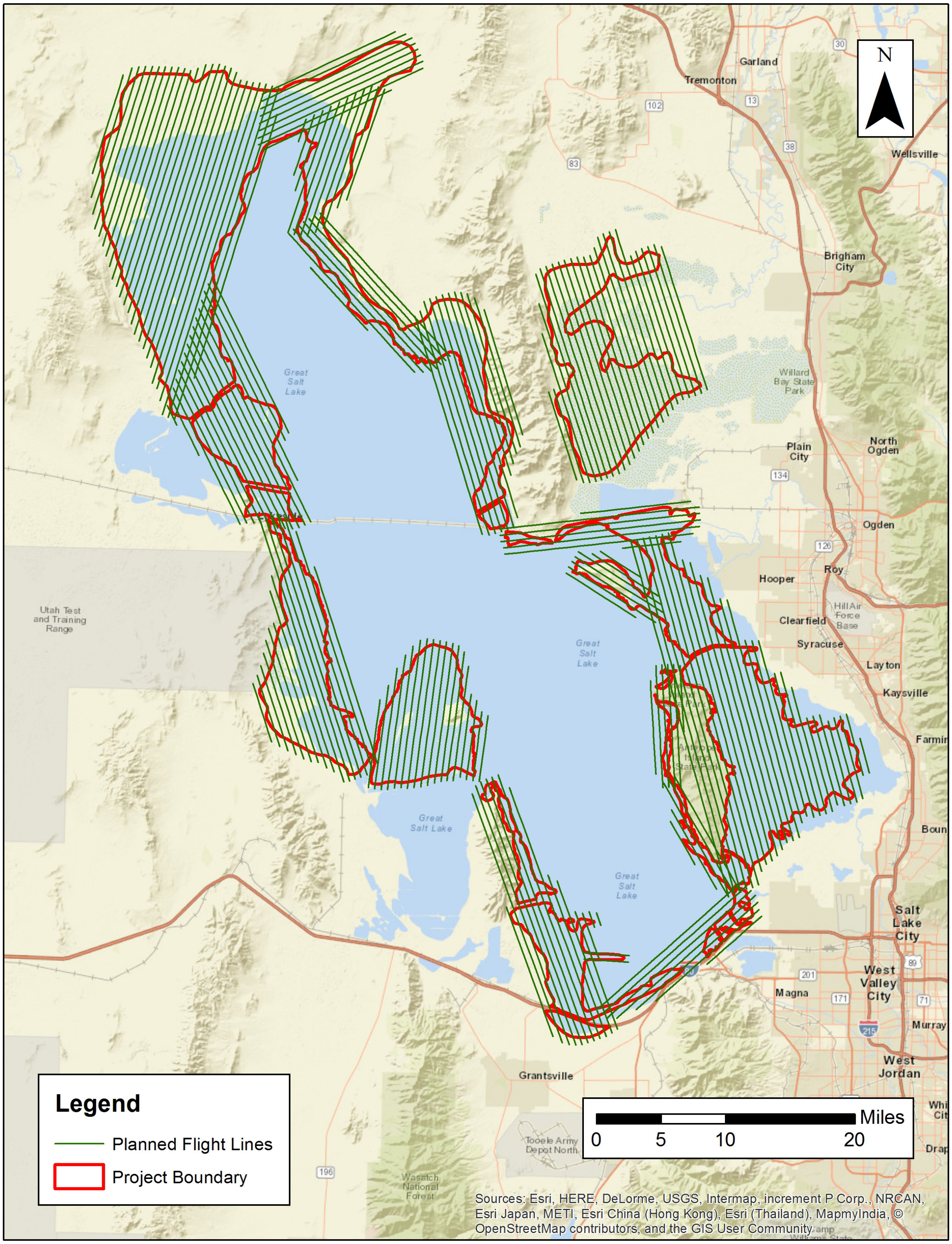


Table 2. Lidar System Specifications - QL1

		ALS 70	ALS 80
Terrain and Aircraft Scanner	Flying Height	1,200 m	1,550 m
	Recommended Ground Speed	145 kts	145 kts
Scanner	Field of View	40°	40°
	Scan Rate Setting Used	53.4 Hz	50 Hz
Laser	Laser Pulse Rate Used	215 kHz	330 kHz
	Multi Pulse in Air Mode	Disabled	Enabled
Coverage	Full Swath Width	874 m	1,128 m
Point Spacing and Density	Average Point Density	0.35 m	0.35 m
	Average Point Density	8 pts / m²	9.5 pts / m²

Table 3. Lidar System Specifications - QL2

		ALS 70 7161 (N704MD)	ALS 70 7161 (N22GE)	ALS 80 8146	ALS 80 8121
Terrain and Aircraft Scanner	Flying Height	1,600 m	1,400 m	1,900 m	1,800 m
	Recommended Ground Speed	105 kts	145 kts	150 kts	150 kts
Scanner	Field of View	40°	40°	40°	40°
	Scan Rate Setting Used	41 Hz	53.4 Hz	52 Hz	52 Hz
Laser	Laser Pulse Rate Used	160 kHz	193.6 kHz	288.2 kHz	288.2 kHz
	Multi Pulse in Air Mode	Disabled	Disabled	Enabled	Enabled
Coverage	Full Swath Width	1,164 m	1019 m	1,383 m	1,316 m
Point Spacing and Density	Average Point Density	0.7 m	0.7 m	0.7 m	0.7 m
	Average Point Density	2 pts / m²	2 pts / m²	2 pts / m²	2 pts / m²

Figure 5. Leica ALS 70 and 80 LiDAR Sensors

2.3. Aircraft

All flights for the project were accomplished through the use of the customized planes listed below.

- Cessna Caravan (single-turboprop), Tail Numbers N704MD, N208NR
- Piper Navajo (twin-piston), Tail Number 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 state-of-the-art Leica LiDAR systems. Some of Quantum Spatial's 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. The base station locations were verified using NGS OPUS service and subsequent surveys. Base station locations, data sheets, graphical depiction of base station locations or log sheets used during station occupation will be available in the final report.

2.5. Time Period

Project specific flights were conducted over two months. Twenty two sorties, or aircraft lift was completed for the QL1 AOI; Twenty sorties were completed for the QL2 AOI. Accomplished sorties are listed below.

QL 1

- Sep 3, 2016-B2 (N704MD SN7161)
- Sep 4, 2016-A (N704MD, SN7161)
- Sep 5, 2016-A (N704MD, SN7161)
- Sep 6, 2016-A (N704MD, SN7161)
- Sep 7, 2016-A (N704MD, SN7161)
- Sep 8, 2016-A (N704MD, SN7161)
- Sep 10, 2016-A (N704MD, SN7161)
- Sep 11, 2016-A (N704MD, SN7161)
- Sep 12, 2016-A (N704MD, SN7161)
- Sep 13, 2016-A (N704MD, SN7161)
- Sep 13, 2016-C (N704MD, SN7161)
- Sep 14, 2016-A (N704MD, SN7161)
- Sep 17, 2016-A (N704MD, SN7161)
- Sep 18, 2016-A (N704MD, SN7161)
- Sep 19, 2016-A (N704MD, SN7161)
- Sep 19, 2016-B (N704MD, SN7161)
- Sep 24, 2016-A (N704MD, SN7161)
- Sep 25, 2016-A (N704MD, SN7161)
- Sep 26, 2016-A (N704MD, SN7161)
- Sep 27, 2016-A (N704MD, SN7161)
- Sep 28, 2016-A (N704MD, SN7161)
- Nov 4, 2016-A (N208NR, SN8227)

QL 2

- Sep 3, 2016-A (N704MD, SN7161)
- Sep 3, 2016-B1 (N704MD, SN7161)
- Sep 6, 2016-A (N704MD, SN7161)
- Sep 7, 2016-A (N704MD, SN7161)
- Sep 9, 2016-A (N704MD, SN7161)
- Sep 14, 2016-A (N704MD, SN7161)
- Sep 16, 2016-A (N704MD, SN7161)
- Sep 16, 2016-B (N704MD, SN7161)
- Sep 17, 2016-A (N704MD, SN7161)
- Sep 18, 2016-A (N704MD, SN7161)
- Sep 26, 2016-A (N704MD, SN7161)
- Sep 27, 2016-A (N704MD, SN7161)
- Sep 28, 2016-A (N704MD, SN7161)
- Oct 4, 2016-A2 (N22GE, SN7161
- Oct 4, 2016-B (N22GE, SN7161)
- Oct 5, 2016-A (N22GE, SN7161)
- Nov 4, 2016-A (N208NR, SN8227)
- Nov 6, 2016-A (N704MD, SN8121)
- Nov 6, 2016-B (N704MD, SN8121)
- Nov 30, 2016-A (N280NR, SN8146)

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 and B.

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 will be available in the full report.

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 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 point classification is performed as described below. 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-flattened 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 classified using standard LAS overlap bit. These classes were created through automated processes only and were not verified for classification accuracy. Due to software limitations within TerraScan, these classes were used to trip the withheld bit within various software packages. These processes were reviewed and accepted by USGS through numerous conference calls and pilot study areas.

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, Inc. 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 Processing

Class 2 (ground) lidar points 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, Inc. 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.

Breaklines are reviewed against lidar intensity imagery to verify completeness of capture. All breaklines are then compared to TINs (triangular irregular networks) created from ground only points prior to water classification. The horizontal placement of breaklines is compared to terrain features and the breakline elevations are compared to lidar elevations to ensure all breaklines match the lidar within acceptable tolerances. Some deviation is expected between breakline and lidar elevations due to monotonicity, connectivity, and flattening rules that are enforced on the breaklines. Once completeness, horizontal placement, and vertical variance is reviewed, all breaklines are reviewed for topological consistency and data integrity using a combination of Esri Data Reviewer tools and proprietary tools.

3.6. Hydro-Flattened Raster DEM Processing

Class 2 (Ground) lidar points in conjunction with the hydro breaklines were used to create hydro-flattened raster DEMs with a 0.5-meter cell size for the QL1 AOI and a 1-meter cell size for the QL2 AOI. 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. First Return Raster DSM Processing

First return lidar points were used to create a first-return raster DSMs with a 0.5-meter cell size for the QL1 AOI and a 1-meter cell size for the QL2 AOI. 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.

3.8. Intensity Image Processing

GeoCue software was used to create the deliverable Intensity Images with a 0.5-meter cell size for the QL1 AOI and a 1-meter cell size for the QL2 AOI. 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 7.

Figure 7. Flightline Swath LAS File Coverage - QL1

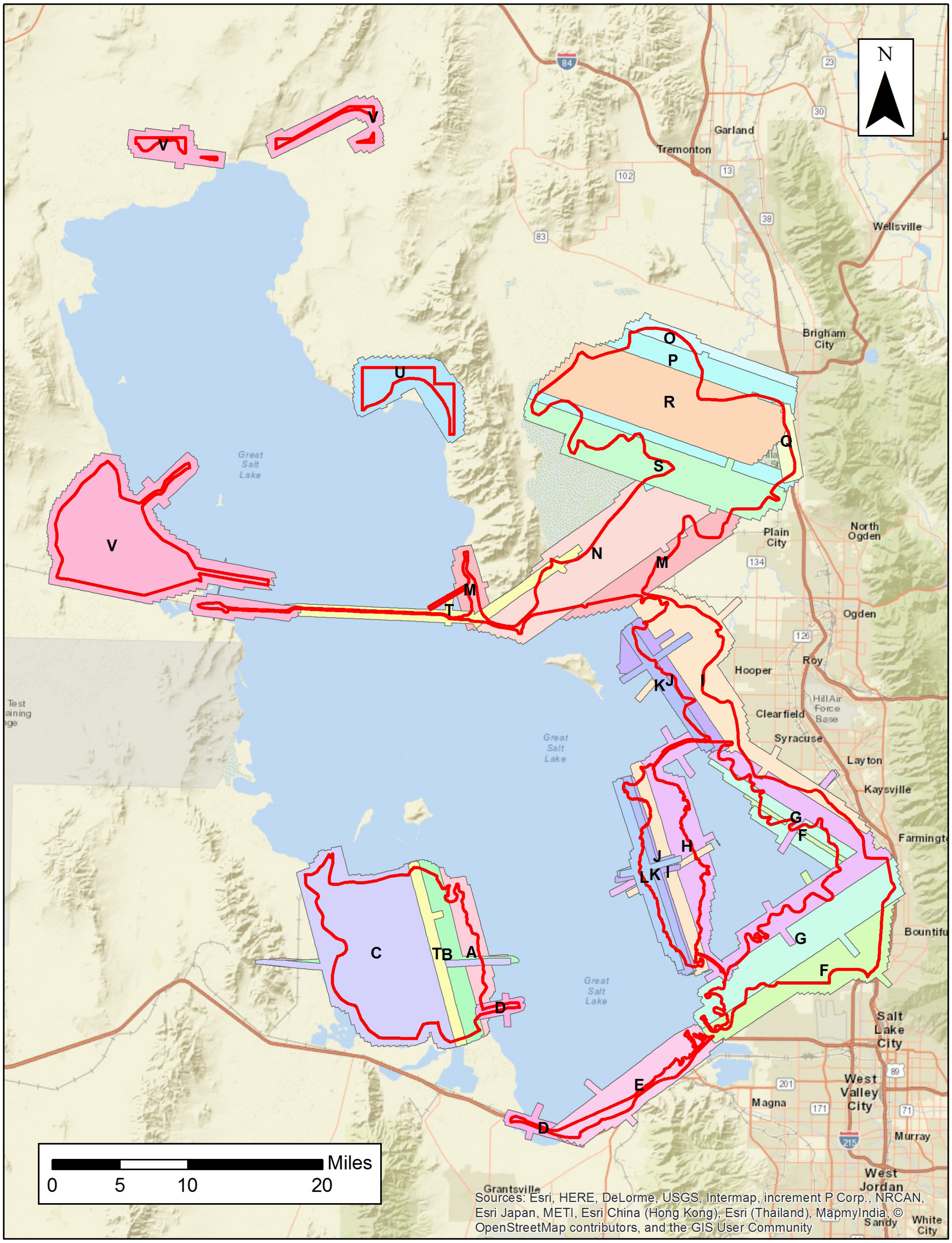
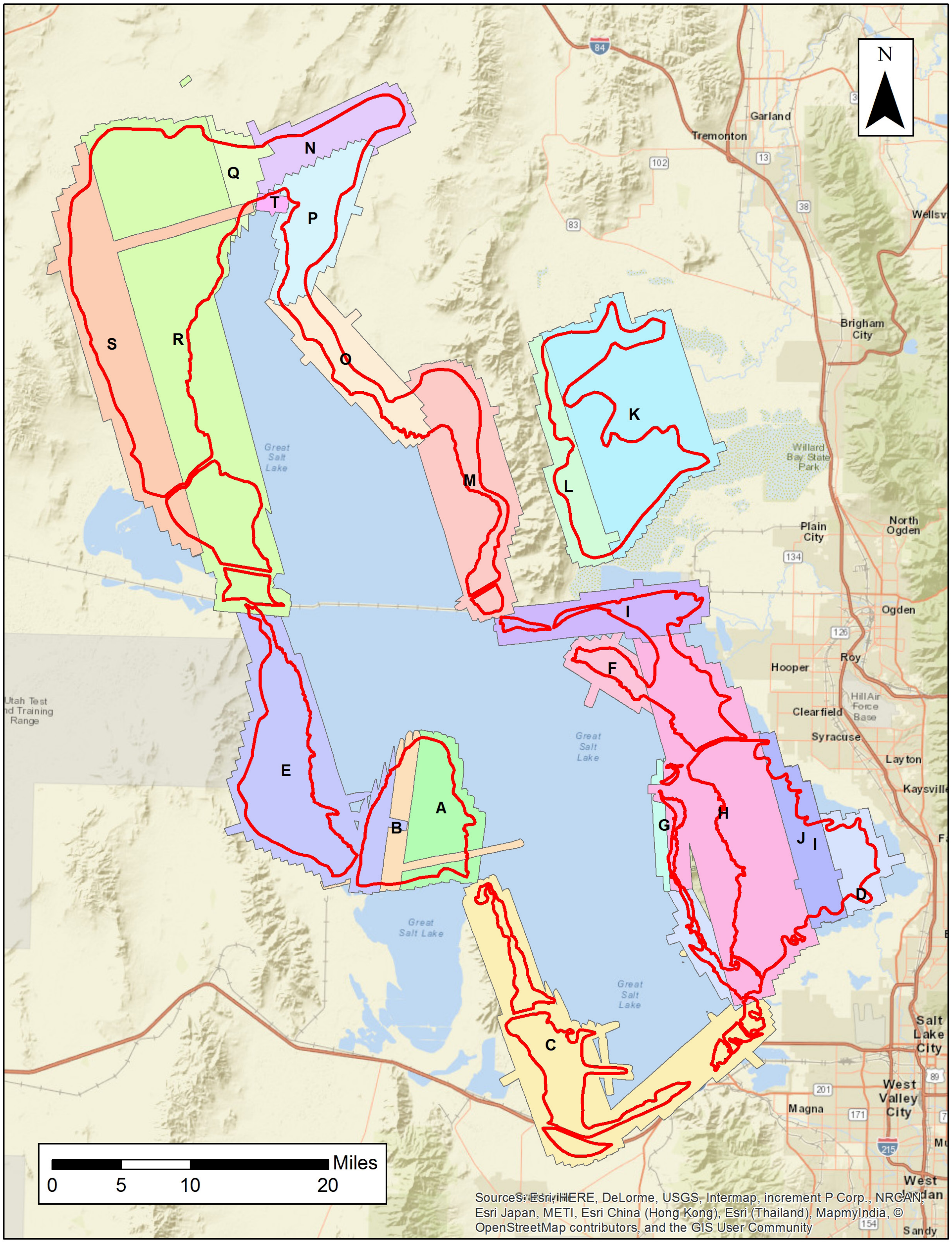


Figure 8. Flightline Swath LAS File Coverage - QL2



QL1 AOI

Legend

Lift

- A: Sep 3, 2016-B2 (N704MD SN7161)
- B: Sep 4, 2016-A (N704MD, SN7161)
- C: Sep 5, 2016-A (N704MD, SN7161)
- D: Sep 6, 2016-A (N704MD, SN7161)
- E: Sep 7, 2016-A (N704MD, SN7161)
- F: Sep 8, 2016-A (N704MD, SN7161)
- G: Sep 10, 2016-A (N704MD, SN7161)
- H: Sep 11, 2016-A (N704MD, SN7161)
- I: Sep 12, 2016-A (N704MD, SN7161)
- J: Sep 13, 2016-A (N704MD, SN7161)
- K: Sep 13, 2016-C (N704MD, SN7161)
- L: Sep 14, 2016-A (N704MD, SN7161)
- M: Sep 17, 2016-A (N704MD, SN7161)
- N: Sep 18, 2016-A (N704MD, SN7161)
- O: Sep 19, 2016-A (N704MD, SN7161)
- P: Sep 19, 2016-B (N704MD, SN7161)
- Q: Sep 24, 2016-A (N704MD, SN7161)
- R: Sep 25, 2016-A (N704MD, SN7161)
- S: Sep 26, 2016-A (N704MD, SN7161)
- T: Sep 27, 2016-A (N704MD, SN7161)
- U: Sep 28, 2016-A (N704MD, SN7161)
- V: Nov 4, 2016-A (N208NR, SN8227)
- Project Boundary

QL2 AOI

Legend

Lift

- A: Sep 3, 2016-A (N704MD, SN7161)
- B: Sep 3, 2016-B1 (N704MD, SN7161)
- C: Sep 6, 2016-A (N704MD, SN7161)
- D: Sep 7, 2016-A (N704MD, SN7161)
- E: Sep 9, 2016-A (N704MD, SN7161)
- F: Sep 14, 2016-A (N704MD, SN7161)
- G: Sep 16, 2016-A (N704MD, SN7161)
- H: Sep 16, 2016-B (N704MD, SN7161)
- I: Sep 17, 2016-A (N704MD, SN7161)
- J: Sep 18, 2016-A (N704MD, SN7161)
- K: Sep 26, 2016-A (N704MD, SN7161)
- L: Sep 27, 2016-A (N704MD, SN7161)
- M: Sep 28, 2016-A (N704MD, SN7161)
- N: Oct 4, 2016-A2 (N22GE, SN7161
- O: Oct 4, 2016-B (N22GE, SN7161)
- P: Oct 5, 2016-A (N22GE, SN7161)
- Q: Nov 4, 2016-A (N208NR, SN8227)
- R: Nov 6, 2016-A (N704MD, SN8121)
- S: Nov 6, 2016-B (N704MD, SN8121)
- T: Nov 30, 2016-A (N280NR, SN8146)
- Project Boundary

5. Ground Control and Check Point Collection

Quantum Spatial completed a field survey of 202 ground control (calibration) points along with 105 blind QA points in Vegetated and Non-Vegetated land cover classifications (total of 307 points) as an independent test of the accuracy of this project. Accuracies were calculated for both the QL1 and QL2 areas as a whole.

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 C. The survey report will be include with the final report.

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 UTM Zone 12, meters; NAVD88 (GEOID 12B), meters.

5.1. Calibration Control Point Testing

Figure 6 shows the location of each bare earth calibration point for the project area. Table 3 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

The project specifications require that only Non-Vegetated Vertical Accuracy (NVA) be computed for raw lidar point cloud swath files. The required accuracy (ACCz) is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the "bare earth" and "urban" land cover classes. The NVA was tested with 58 checkpoints located in bare earth and urban (non-vegetated) areas. These check points were not used in the calibration or post processing of the lidar point cloud data. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See survey report for additional survey methodologies.

Elevations from the unclassified lidar surface were measured for the x,y location of each check point. Elevations interpolated from the lidar surface were then compared to the elevation values of the surveyed control points. AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASRPS Guidelines. See Figure 7 and Table 4.

Note: Point BE23 was obstructed between control point collection and LiDAR acquisition. Therefore, two sets of Raw NVA accuracy values can be found in this document and in the metadata - one including this point and one without.

5.3. Digital Elevation Model (DEM) Testing

The project specifications require the accuracy (ACCz) of the derived DEM be calculated and reported in two ways:

1. The required NVA is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the "bare earth" and "urban" land cover classes. This is a required accuracy. The NVA was tested with 49 checkpoints located in bare earth and urban (non-vegetated) areas. See Figure 8 and Table 5.

2. Vegetated Vertical Accuracy (VVA): VVA shall be reported for "shrubs" and "tall grass" land cover classes. The target VVA is: 29.4 cm at the 95th percentile, derived according to ASPRS Guidelines, Vertical Accuracy Reporting for Lidar Data, i.e., based on the 95th percentile error in all vegetated land cover classes combined. This is a target accuracy. The VVA was tested with 56 checkpoints located in shrubs and tall grass (vegetated) areas. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See Figure 9 and Table 6.

See survey report for additional survey methodologies. AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASRPS Guidelines.

Figure 9. Calibration Control Point Locations

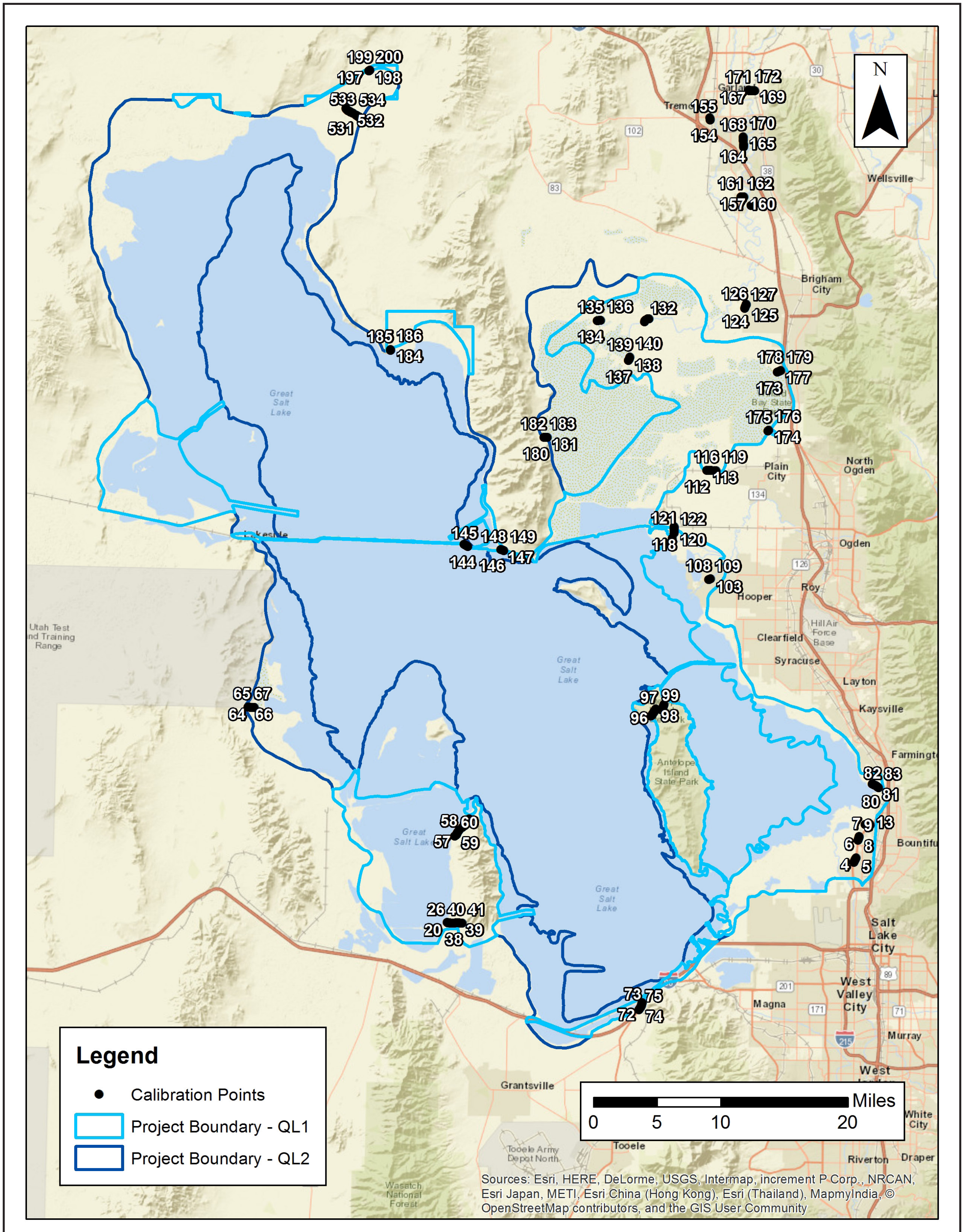


Table 4. Calibration Control Point Report

Units = Meters

Number	Easting	Northing	Known Z	Laser Z	Dz
1	420570.780	4524111.420	1288.59	1288.58	-0.01
2	420647.780	4524240.470	1287.84	1287.90	0.06
3	420724.660	4524381.380	1287.07	1287.08	0.01
4	420802.720	4524528.100	1288.10	1288.13	0.03
5	420884.030	4524672.470	1287.59	1287.60	0.01
6	421277.280	4527373.610	1286.08	1286.11	0.03
7	421255.800	4527320.590	1286.25	1286.24	-0.01
8	421206.040	4527204.480	1286.35	1286.33	-0.02
9	421159.730	4527072.970	1286.44	1286.38	-0.06
10	421113.290	4526942.720	1286.53	1286.50	-0.03
11	422450.550	4528861.640	1284.47	1284.49	0.03
12	422558.230	4528879.280	1284.41	1284.39	-0.02
13	422684.810	4528859.930	1284.81	1284.77	-0.04
14	422325.430	4528886.590	1284.11	1284.11	0.00
15	422180.730	4528888.140	1284.04	1284.03	-0.01
16	422031.540	4528889.370	1283.75	1283.78	0.03
19	369154.700	4516506.500	1282.97	1282.97	0.00
20	369201.450	4516500.340	1282.90	1282.89	-0.01
22	369303.550	4516486.650	1282.95	1282.95	0.00
25	369457.560	4516465.000	1283.09	1283.14	0.05
26	369513.150	4516457.550	1283.01	1283.00	-0.01
28	369634.540	4516442.060	1283.15	1283.16	0.01
29	369698.748	4516433.400	1283.19	1283.20	0.03
32	369891.316	4516425.100	1283.37	1283.40	0.00
33	369962.878	4516434.200	1283.47	1283.50	0.03
34	370102.994	4516451.600	1283.71	1283.80	0.05
35	370242.035	4516467.700	1283.84	1283.90	0.05
36	370374.183	4516477.500	1284.35	1284.40	0.09
37	370504.262	4516473.000	1284.44	1284.50	0.02
38	370641.924	4516465.100	1284.39	1284.40	0.02
39	370777.342	4516455.500	1284.35	1284.40	0.01
40	370918.994	4516446.900	1284.67	1284.70	0.04

Number	Easting	Northing	Known Z	Laser Z	Dz
41	371070.471	4516430.000	1285.08	1285.10	0.02
42	371887.690	4529379.600	1288.33	1288.30	-0.04
43	371929.750	4529487.300	1289.22	1289.20	0.01
44	371966.267	4529612.200	1291.35	1291.30	-0.04
45	371846.974	4529270.000	1289.23	1289.20	-0.03
46	371778.181	4529164.700	1289.88	1289.90	-0.03
47	371689.457	4529069.400	1289.64	1289.60	-0.05
48	371598.484	4528979.900	1289.47	1289.50	0.00
49	371498.160	4528882.900	1289.53	1289.50	-0.04
50	371392.958	4528788.600	1289.70	1289.60	-0.06
51	371286.701	4528702.600	1289.48	1289.40	-0.04
52	371177.682	4528616.200	1290.11	1290.00	-0.07
53	371070.074	4528532.500	1290.84	1290.70	-0.13
54	370694.599	4528209.100	1292.64	1292.60	-0.03
55	370528.520	4528008.600	1291.75	1291.70	-0.06
56	370466.259	4527881.200	1287.48	1287.40	-0.07
57	370400.501	4527752.100	1285.52	1285.50	-0.07
58	370339.867	4527636.300	1285.15	1285.10	-0.06
59	370238.278	4527541.100	1285.05	1285.00	-0.06
60	370135.868	4527446.400	1285.24	1285.20	-0.04
61	344791.556	4543719.800	1283.49	1283.50	0.01
62	344690.087	4543722.000	1283.64	1283.70	0.03
63	344563.870	4543725.600	1283.71	1283.70	0.00
64	344423.814	4543728.700	1283.56	1283.60	0.00
65	344282.150	4543733.100	1283.76	1283.80	0.00
66	344136.612	4543738.500	1283.78	1283.80	0.01
67	343985.407	4543742.600	1283.78	1283.80	0.00
68	393820.613	4506386.100	1291.18	1291.20	0.02
69	393788.229	4506269.800	1291.18	1291.20	0.01
70	393755.184	4506147.500	1290.87	1290.90	0.05
71	393720.097	4506016.900	1289.07	1289.10	0.05
72	393666.598	4505874.300	1288.29	1288.30	0.02
73	393583.968	4505747.200	1288.09	1288.10	0.01
74	393495.18	4505617.50	1288.18	1288.20	0.01
75	393408.43	4505482.90	1288.21	1288.20	0.02

Number	Easting	Northing	Known Z	Laser Z	Dz
76	422895.79	4534056.00	1285.32	1285.30	-0.02
77	422994.67	4533996.90	1285.16	1285.20	0.02
78	423098.98	4533946.90	1285.08	1285.10	0.02
79	423220.34	4533902.30	1285.23	1285.30	0.02
80	423349.38	4533842.50	1285.13	1285.10	0.01
81	423464.90	4533757.50	1284.99	1285.00	0.01
82	423581.58	4533667.30	1285.22	1285.20	0.00
83	423701.99	4533574.80	1285.11	1285.10	-0.01
84	396452.05	4543722.80	1355.66	1355.70	0.00
85	396500.91	4543833.50	1354.74	1354.80	0.01
86	396554.25	4543953.00	1351.70	1351.70	-0.01
87	396610.04	4544081.00	1341.58	1341.60	0.02
88	396452.34	4543720.60	1355.62	1355.60	0.00
89	396398.66	4543593.90	1349.44	1349.50	0.01
90	396325.79	4543476.30	1343.56	1343.60	0.01
91	396187.67	4543427.60	1342.00	1342.00	0.00
92	394926.47	4542605.90	1286.97	1287.00	-0.01
93	395056.35	4542712.40	1295.06	1295.10	0.00
94	395138.91	4542851.30	1297.74	1297.70	-0.01
95	395213.83	4542986.10	1305.13	1305.10	0.00
96	395293.03	4543112.40	1310.96	1311.00	-0.01
97	395370.18	4543245.10	1321.91	1321.90	0.01
98	395447.68	4543379.00	1331.29	1331.30	0.03
99	395529.65	4543522.10	1338.84	1338.90	0.02
100	397465.31	4564361.90	1282.74	1282.70	-0.03
101	397473.50	4564413.80	1282.70	1282.70	-0.03
102	397485.21	4564475.80	1282.78	1282.80	-0.03
103	402456.77	4559998.10	1284.30	1284.30	-0.03
104	402536.19	4573678.50	1284.52	1284.50	-0.03
105	397521.68	4564642.40	1282.85	1282.80	-0.02
106	402407.71	4573680.70	1284.53	1284.50	-0.02
107	397541.65	4564736.20	1283.11	1283.10	0.01
108	402287.27	4559894.90	1284.03	1284.00	-0.02
109	402252.02	4559872.70	1284.07	1284.10	0.00
110	402189.51	4573684.50	1284.86	1284.80	-0.02

Number	Easting	Northing	Known Z	Laser Z	Dz
111	402129.90	4573685.60	1284.88	1284.80	-0.06
112	402071.72	4573686.90	1284.47	1284.40	-0.03
113	402019.53	4573688.20	1284.62	1284.60	-0.06
114	397621.61	4565092.60	1282.90	1282.90	0.01
115	397866.75	4566562.60	1286.08	1286.10	-0.01
116	402990.67	4573670.10	1284.63	1284.60	-0.02
117	397864.86	4566448.30	1286.02	1286.00	-0.01
118	397863.89	4566385.20	1286.01	1286.00	0.02
119	403182.89	4573666.00	1284.76	1284.80	0.01
120	397860.66	4566136.70	1286.15	1286.20	0.00
121	397857.57	4565963.30	1284.17	1284.20	0.00
122	397853.85	4565791.60	1284.01	1284.00	0.02
123	406990.80	4594709.90	1285.09	1285.10	-0.02
124	406960.91	4594605.60	1284.91	1284.90	-0.03
125	406906.46	4594463.90	1284.98	1285.00	-0.02
126	406849.52	4594322.80	1285.21	1285.20	-0.04
127	406790.85	4594193.10	1285.30	1285.30	-0.05
128	394521.38	4592845.50	1284.39	1284.30	-0.05
129	394683.12	4592863.00	1284.47	1284.40	-0.04
130	394272.71	4592731.20	1284.39	1284.30	-0.05
131	394177.90	4592616.30	1283.50	1283.50	-0.02
132	394123.80	4592488.70	1283.62	1283.60	-0.04
133	388121.80	4592604.80	1283.78	1283.70	-0.06
134	388258.83	4592633.50	1283.78	1283.70	-0.06
135	388415.37	4592661.10	1283.78	1283.70	-0.05
136	388584.39	4592690.80	1283.78	1283.70	-0.05
137	392091.43	4587580.00	1283.59	1283.60	-0.03
138	392152.32	4587727.10	1283.66	1283.60	-0.02
139	392213.11	4587872.40	1283.71	1283.70	-0.02
140	392269.83	4588008.80	1283.76	1283.70	-0.04
141	371284.89	4564349.00	1283.91	1283.90	0.01
142	371441.08	4564275.70	1284.02	1284.00	0.00
143	371568.12	4564197.70	1284.09	1284.10	0.00
144	371682.15	4564124.00	1284.17	1284.20	0.00
145	371798.74	4564054.30	1284.28	1284.30	-0.02

Number	Easting	Northing	Known Z	Laser Z	Dz
146	375957.08	4563702.60	1285.77	1285.80	0.00
147	376095.40	4563655.10	1286.00	1286.00	-0.01
148	376219.65	4563604.60	1286.02	1286.00	-0.04
149	376346.04	4563555.40	1285.71	1285.70	-0.03
150	406633.42	4614605.50	1310.59	1310.50	-0.10
151	406629.18	4614801.00	1309.83	1309.80	-0.02
152	406627.34	4614964.80	1309.50	1309.50	-0.03
153	402398.54	4618271.40	1317.25	1317.20	-0.03
154	402400.22	4618125.30	1316.85	1316.90	0.00
155	402402.01	4618024.20	1316.28	1316.30	0.01
156	407613.87	4607200.10	1299.88	1299.90	0.00
157	407690.08	4607199.80	1299.49	1299.50	0.03
158	407783.00	4607195.10	1299.10	1299.10	0.02
159	407948.46	4607198.40	1298.47	1298.50	0.04
160	406675.75	4608264.40	1301.33	1301.30	0.01
161	406516.01	4608270.90	1300.70	1300.70	0.00
162	406336.92	4608275.90	1299.73	1299.70	-0.01
163	407364.37	4621731.00	1323.41	1323.40	-0.02
164	406616.77	4615482.40	1310.40	1310.40	-0.05
165	406618.57	4615391.40	1310.03	1310.00	-0.03
166	407630.20	4621730.60	1327.52	1327.50	-0.02
167	407722.74	4621728.60	1330.15	1330.10	-0.01
168	406613.02	4615708.00	1310.50	1310.50	0.03
169	407899.96	4621726.90	1332.98	1333.00	0.01
170	406611.22	4615875.30	1310.85	1310.90	0.02
171	408073.26	4621728.50	1336.49	1336.50	0.02
172	407290.92	4621804.90	1322.86	1322.90	0.00
173	410899.52	4586139.00	1283.26	1283.20	-0.03
174	409748.02	4578669.60	1292.66	1292.60	-0.06
175	409787.15	4578724.50	1292.60	1292.60	-0.05
176	409827.75	4578780.70	1292.63	1292.60	-0.06
177	411163.37	4586231.20	1284.88	1284.90	-0.02
178	411239.29	4586288.40	1285.64	1285.60	-0.02
179	411320.28	4586309.50	1286.68	1286.70	-0.03
180	381819.06	4577858.70	1287.47	1287.50	0.01

Number	Easting	Northing	Known Z	Laser Z	Dz
181	381673.62	4577852.90	1292.82	1292.80	0.00
182	381533.44	4577850.40	1297.86	1297.90	0.02
183	381402.52	4577849.10	1301.78	1301.80	0.05
184	361997.83	4588894.10	1293.35	1293.40	0.01
185	361998.39	4588887.20	1293.22	1293.20	-0.01
186	361995.66	4588987.60	1293.28	1293.30	-0.02
187	358100.68	4618335.40	1288.96	1289.10	0.09
188	358043.56	4618370.50	1288.78	1288.90	0.09
189	357989.61	4618403.20	1288.62	1288.70	0.08
190	357934.67	4618434.70	1288.48	1288.60	0.11
191	357881.42	4618466.80	1288.54	1288.70	0.11
192	357827.79	4618499.00	1288.24	1288.30	0.10
193	357774.61	4618531.00	1287.93	1288.10	0.12
194	357721.22	4618563.30	1287.83	1287.90	0.12
195	357668.82	4618595.30	1287.87	1288.00	0.12
196	357618.89	4618626.30	1287.98	1288.10	0.09
197	359251.45	4624204.70	1293.28	1293.30	0.02
198	359307.20	4624228.80	1293.58	1293.60	0.00
199	359353.81	4624263.30	1293.66	1293.70	0.01
200	359397.51	4624298.00	1293.35	1293.30	-0.01
525	356348.59	4619477.00	1288.25	1288.30	0.05
526	356421.48	4619389.70	1287.64	1287.70	0.05
527	356484.57	4619284.50	1287.34	1287.40	0.06
528	356588.50	4619209.70	1287.15	1287.20	0.06
529	356701.40	4619146.10	1287.01	1287.10	0.09
530	356816.16	4619084.00	1287.03	1287.10	0.02
531	356933.11	4619028.50	1286.89	1286.90	0.05
532	357048.71	4618978.80	1287.41	1287.50	0.07
533	357160.34	4618912.70	1287.17	1287.30	0.08
534	357266.48	4618842.70	1286.90	1287.00	0.11

Average Dz	0.000 m
Minimum Dz	-0.132 m
Maximum Dz	0.124 m
Root Mean Square	0.041 m
Std. Deviation	0.041 m

Figure 10. QC Checkpoint Locations - Raw NVA

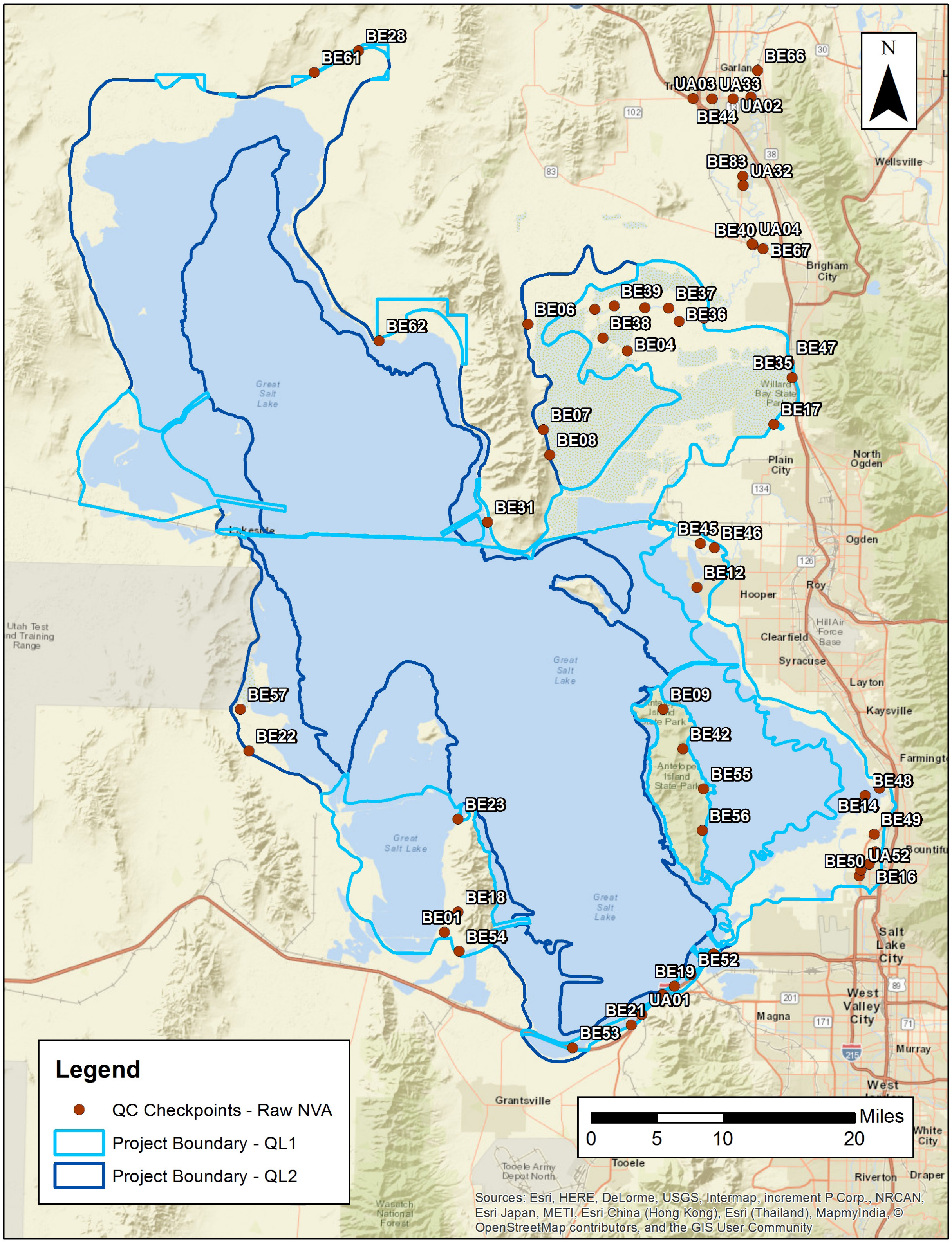


Table 5. QC Checkpoint Report - Raw NVA

Units = Meters

Number	Easting	Northing	Known Z	Laser Z	Dz
BE01	369735.724	4516467.140	1282.78	1282.76	-0.02
BE02	401449.276	4591474.630	1284.06	1283.97	-0.09
BE03	394210.756	4592783.730	1284.15	1284.12	-0.03
BE04	392073.184	4587518.960	1283.66	1283.66	0.00
BE05	388101.378	4592581.010	1283.56	1283.56	0.00
BE06	379927.646	4590780.690	1283.13	1283.15	0.02
BE07	381840.568	4577860.700	1286.42	1286.44	0.02
BE08	382594.338	4574804.920	1295.05	1295.11	0.06
BE09	396449.069	4543725.490	1355.68	1355.69	0.01
BE11	402617.451	4560092.000	1284.66	1284.63	-0.03
BE12	400568.440	4558632.990	1282.23	1282.20	-0.03
BE13	410933.016	4586146.900	1283.17	1283.17	0.00
BE14	422848.057	4534086.510	1285.18	1285.18	0.00
BE15	422362.040	4526284.620	1290.86	1290.84	-0.02
BE16	421569.120	4524790.830	1290.42	1290.43	0.01
BE17	409970.290	4578540.140	1291.76	1291.71	-0.05
BE18	371417.637	4518928.890	1286.57	1286.57	0.00
BE19	397837.249	4509881.560	1283.60	1283.57	-0.03
BE20	396382.460	4508844.090	1283.99	1283.97	-0.02
BE21	392542.400	4505143.310	1287.25	1287.25	0.00
BE22	345850.042	4538635.170	1285.02	1285.04	0.02
BE23	**371384.465**	**4530276.690**	**1284.20**	**1287.47**	**3.27**
BE28	359227.261	4624198.690	1293.66	1293.67	0.01
BE31	375018.904	4566590.320	1288.10	1288.07	-0.03
BE35	412192.265	4584250.260	1290.42	1290.36	-0.06
BE36	398372.553	4591121.290	1284.41	1284.36	-0.05
BE37	397103.784	4592741.110	1283.03	1282.97	-0.06
BE38	389102.445	4589052.320	1283.59	1283.61	0.02
BE39	390467.014	4592990.590	1283.95	1283.91	-0.04
BE40	407421.997	4600477.060	1290.32	1290.24	-0.08
BE42	398868.804	4538853.460	1378.57	1378.56	-0.01
BE44	402403.228	4618308.930	1317.12	1317.15	0.03

Number	Easting	Northing	Known Z	Laser Z	Dz
BE45	400991.789	4563952.940	1283.83	1283.80	-0.03
BE46	402688.494	4563443.610	1284.58	1284.54	-0.04
BE47	411831.713	4586079.310	1293.35	1293.34	-0.01
BE48	421115.760	4533183.450	1281.76	1281.76	0.00
BE49	422211.508	4528440.380	1283.85	1283.84	-0.01
BE50	420411.520	4523363.450	1287.24	1287.22	-0.02
BE51	402614.148	4513821.300	1286.35	1286.36	0.01
BE52	399863.006	4511323.600	1285.38	1285.38	0.00
BE53	385396.950	4502327.290	1284.23	1284.22	-0.01
BE54	371545.442	4514177.950	1286.64	1286.65	0.01
BE55	401396.527	4533974.380	1304.06	1304.09	0.03
BE56	401229.978	4528904.920	1298.37	1298.39	0.02
BE57	344820.235	4543720.700	1283.68	1283.68	0.00
BE61	353834.934	4621497.320	1301.99	1301.97	-0.02
BE62	361770.262	4588725.200	1295.15	1295.16	0.02
BE65	407152.099	4618514.660	1290.10	1290.12	0.02
BE66	407954.385	4621764.280	1333.93	1333.95	0.02
BE67	408660.077	4599970.700	1285.53	1285.55	0.02
BE83	406150.841	4608836.320	1299.82	1299.80	-0.02
UA01	393850.519	4506441.840	1291.50	1291.51	0.01
UA52	420611.926	4524068.620	1287.73	1287.76	0.03
UA02	404997.733	4618283.890	1318.46	1318.50	0.04
UA03	400078.637	4618354.570	1317.42	1317.49	0.07
UA04	407296.587	4600582.700	1290.45	1290.39	-0.06
UA32	406231.419	4607721.590	1298.79	1298.76	-0.03
UA33	402404.359	4618296.850	1317.24	1317.24	0.00

	With Point BE23	Without Point BE23
Average Dz	0.050 m	-0.010 m
Minimum Dz	-0.086 m	-0.086 m
Maximum Dz	3.273 m	0.069 m
Root Mean Square	0.431 m	0.032 m
95% Confidence Level	0.845 m	0.063 m

Figure 11. QC Checkpoint Locations - NVA

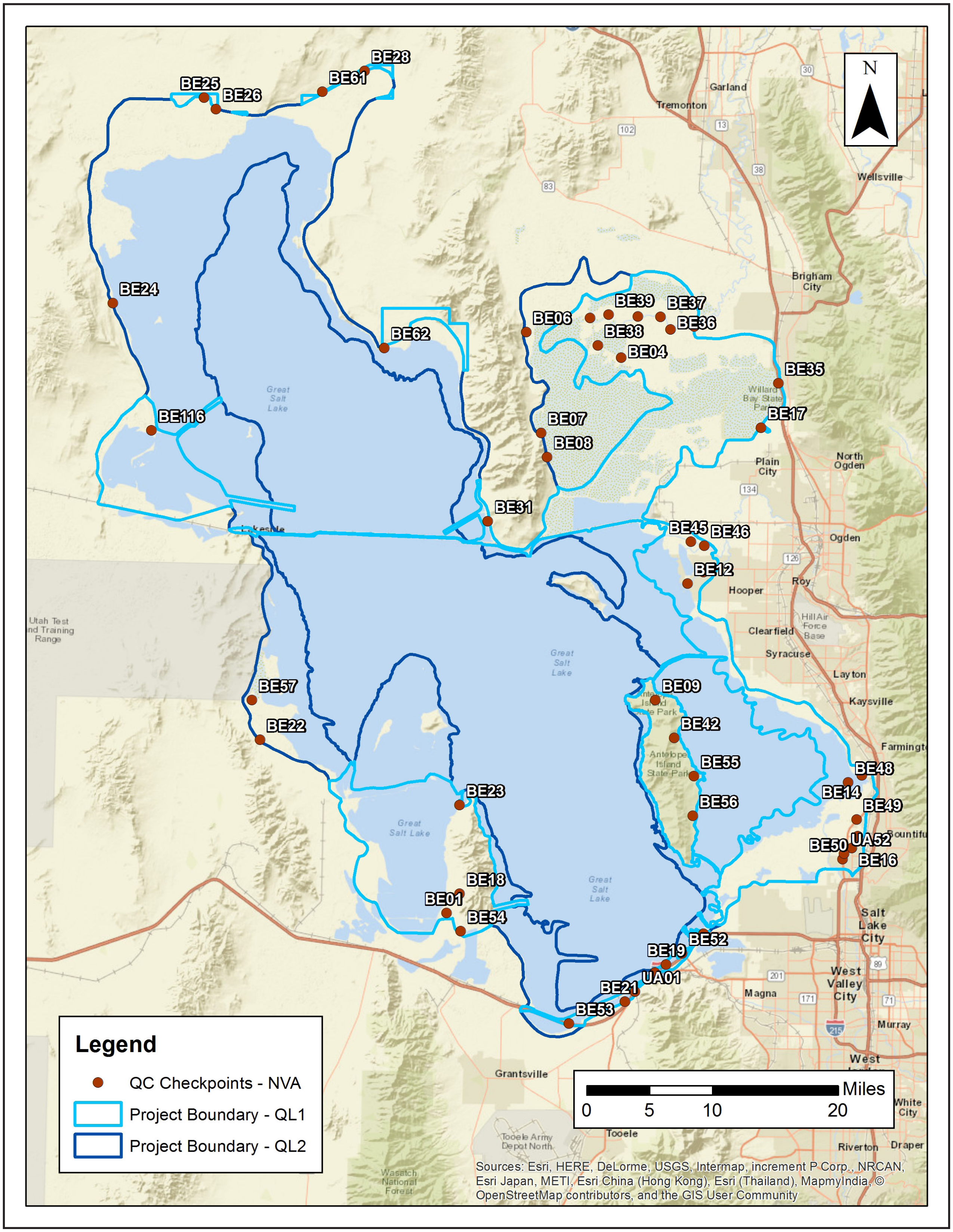


Table 6. QC Checkpoint Report - NVA

Units = Meters

Number	Easting	Northing	Known Z	Laser Z	Dz
BE01	369735.72	4516467.14	1282.78	1282.76	-0.02
BE02	401449.28	4591474.63	1284.06	1284.03	-0.03
BE03	394210.76	4592783.73	1284.15	1284.12	-0.03
BE04	392073.18	4587518.96	1283.66	1283.66	-0.01
BE05	388101.38	4592581.01	1283.56	1283.55	-0.02
BE06	379927.65	4590780.69	1283.13	1283.14	0.00
BE07	381840.57	4577860.70	1286.42	1286.44	0.03
BE08	382594.34	4574804.92	1295.05	1295.09	0.04
BE09	396449.07	4543725.49	1355.68	1355.69	0.01
BE11	402617.45	4560092.00	1284.66	1284.64	-0.02
BE116	331991.24	4578201.57	1287.23	1287.24	0.01
BE12	400568.44	4558632.99	1282.23	1282.20	-0.03
BE14	422848.06	4534086.51	1285.18	1285.18	0.00
BE15	422362.04	4526284.62	1290.86	1290.84	-0.03
BE16	421569.12	4524790.83	1290.42	1290.42	0.00
BE17	409970.29	4578540.14	1291.76	1291.71	-0.04
BE18	371417.64	4518928.89	1286.57	1286.55	-0.02
BE19	397837.25	4509881.56	1283.60	1283.57	-0.03
BE20	396382.46	4508844.09	1283.99	1283.97	-0.02
BE21	392542.40	4505143.31	1287.25	1287.25	0.00
BE22	345850.04	4538635.17	1285.02	1285.01	0.00
BE23	371384.47	4530276.69	1284.20	1284.16	-0.04
BE24	327034.14	4594469.56	1287.53	1287.51	-0.02
BE25	338726.18	4620740.71	1286.33	1286.32	-0.01
BE26	340213.75	4619305.48	1288.85	1288.87	0.02
BE28	359227.26	4624198.69	1293.66	1293.67	0.01
BE31	375018.90	4566590.32	1288.10	1288.06	-0.05
BE35	412192.27	4584250.26	1290.42	1290.35	-0.07
BE36	398372.55	4591121.29	1284.41	1284.37	-0.04
BE37	397103.78	4592741.11	1283.03	1282.96	-0.07
BE38	389102.45	4589052.32	1283.59	1283.59	0.00
BE39	390467.01	4592990.59	1283.95	1283.90	-0.05

Number	Easting	Northing	Known Z	Laser Z	Dz
BE42	398868.80	4538853.46	1378.57	1378.57	0.00
BE45	400991.79	4563952.94	1283.83	1283.80	-0.03
BE46	402688.49	4563443.61	1284.58	1284.55	-0.03
BE48	421115.76	4533183.45	1281.76	1281.76	0.00
BE49	422211.51	4528440.38	1283.85	1283.83	-0.02
BE50	420411.52	4523363.45	1287.24	1287.22	-0.02
BE51	402614.15	4513821.30	1286.35	1286.36	0.01
BE52	399863.01	4511323.60	1285.38	1285.36	-0.02
BE53	385396.95	4502327.29	1284.23	1284.22	-0.01
BE54	371545.44	4514177.95	1286.64	1286.65	0.02
BE55	401396.53	4533974.38	1304.06	1304.08	0.02
BE56	401229.98	4528904.92	1298.37	1298.38	0.02
BE57	344820.24	4543720.70	1283.68	1283.68	0.00
BE61	353834.93	4621497.32	1301.99	1301.97	-0.01
BE62	361770.26	4588725.20	1295.15	1295.16	0.02
UA01	393850.52	4506441.84	1291.50	1291.52	0.02
UA52	420611.93	4524068.62	1287.73	1287.76	0.03

Average Dz	-0.010 m
Minimum Dz	-0.074 m
Maximum Dz	0.038 m
Root Mean Square	0.026 m
95% Confidence Level	0.052 m

Figure 12. QC Checkpoint Locations - VVA

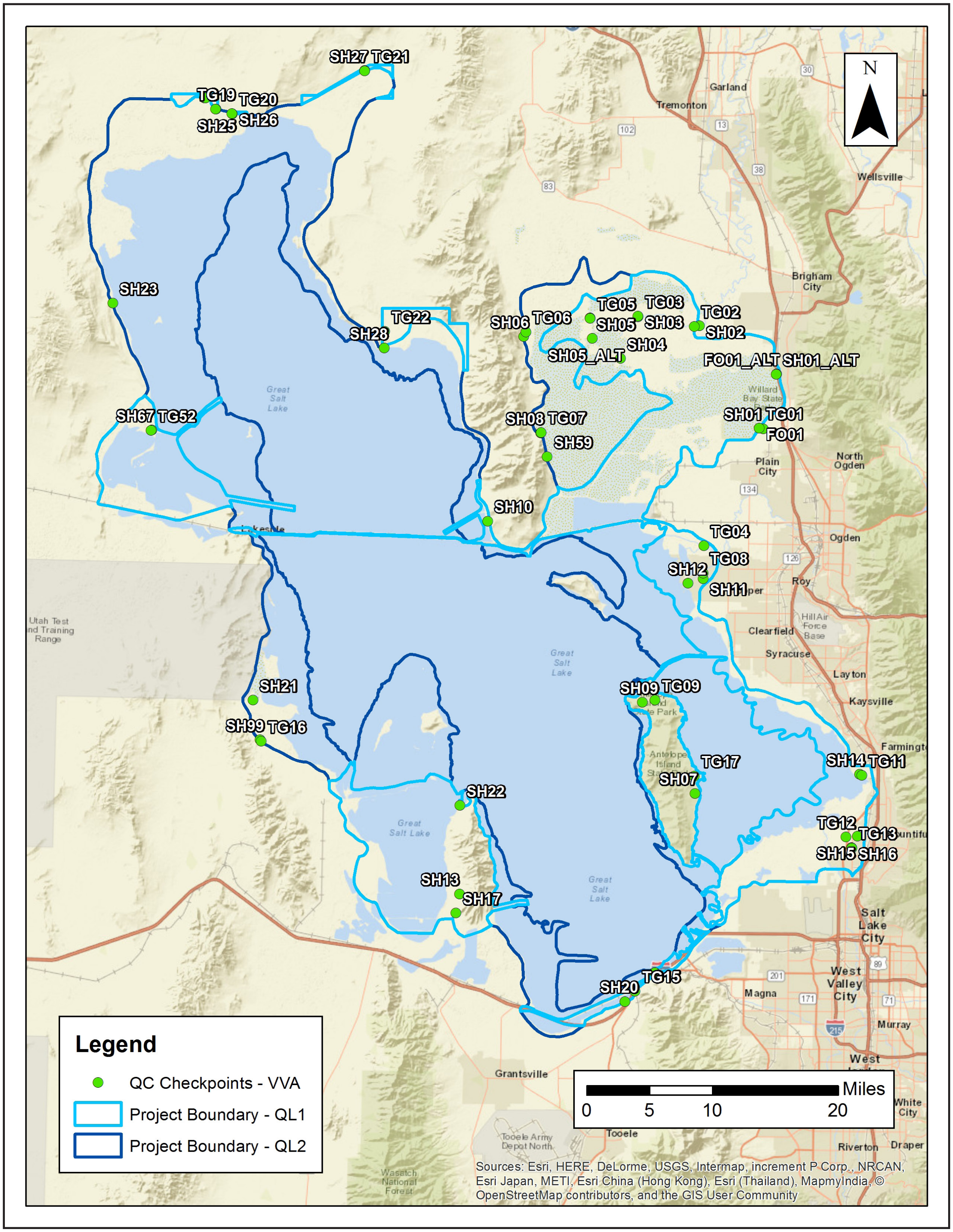


Table 7. QC Checkpoint Report - VVA

Units = Meters

Number	Easting	Northing	Known Z	Laser Z	Dz
FO01	409746.19	4578484.62	1286.32	1286.24	-0.09
FO01_ALT	411943.15	4585393.69	1290.25	1290.22	-0.03
SH01	410271.63	4578406.94	1287.99	1288.18	0.18
SH01_ALT	411891.32	4585363.14	1289.61	1289.66	0.05
SH02	402079.28	4591566.14	1283.88	1283.89	0.02
SH03	394228.52	4592728.84	1284.21	1284.49	0.28
SH04	391991.25	4587427.66	1281.95	1282.02	0.07
SH05	388087.39	4592590.33	1282.17	1282.07	-0.10
SH05_ALT	388371.79	4589950.21	1281.78	1281.81	0.02
SH06	379606.25	4590188.95	1292.56	1292.61	0.05
SH07	401541.33	4531768.13	1323.43	1323.49	0.07
SH08	381771.28	4577870.59	1289.38	1289.44	0.07
SH09	394797.90	4543411.03	1345.56	1345.58	0.02
SH10	374994.69	4566589.13	1286.64	1286.56	-0.08
SH11	402565.68	4559243.15	1284.97	1285.08	0.10
SH12	400598.30	4558635.13	1281.39	1281.42	0.02
SH13	371404.26	4518917.95	1286.16	1286.22	0.06
SH14	422606.12	4534208.65	1283.79	1283.82	0.03
SH15	422311.80	4526285.28	1290.31	1290.50	0.19
SH16	421566.45	4524830.16	1290.45	1290.49	0.04
SH17	370932.84	4516460.45	1284.55	1284.53	-0.02
SH19	396394.29	4508836.28	1286.49	1286.49	0.00
SH20	392544.51	4505162.17	1286.71	1286.74	0.03
SH21	344955.80	4543710.46	1284.80	1284.82	0.02
SH22	371424.85	4530222.58	1282.96	1282.98	0.02
SH23	327026.02	4594470.14	1287.63	1287.61	-0.02
SH24	338740.47	4620724.98	1286.32	1286.37	0.06
SH25	340222.79	4619290.33	1288.87	1288.90	0.02
SH26	342330.72	4618690.27	1287.04	1287.10	0.06
SH27	359230.49	4624203.89	1293.38	1293.40	0.02
SH28	361782.15	4588720.10	1294.91	1294.98	0.07
SH59	382612.25	4574832.91	1293.85	1293.90	0.05

Number	Easting	Northing	Known Z	Laser Z	Dz
SH67	331995.41	4578232.47	1286.72	1286.83	0.10
SH99	345869.31	4538628.27	1285.10	1285.19	0.09
TG01	409716.77	4578476.98	1286.44	1286.43	0.00
TG02	401450.06	4591488.91	1284.14	1284.36	0.22
TG03	394236.91	4592798.20	1283.38	1283.49	0.11
TG04	402670.27	4563432.77	1284.36	1284.32	-0.04
TG05	388113.62	4592524.73	1282.44	1282.56	0.12
TG06	379867.10	4590784.81	1283.22	1283.27	0.06
TG07	381821.06	4577928.63	1282.63	1282.72	0.08
TG08	402571.88	4559951.15	1284.30	1284.27	-0.03
TG09	396393.95	4543702.83	1354.02	1354.04	0.02
TG11	422851.35	4534064.90	1282.26	1282.49	0.24
TG12	420854.40	4526198.72	1285.75	1285.72	-0.03
TG13	421585.88	4524784.92	1290.61	1290.84	0.23
TG14	396391.59	4508866.83	1282.52	1282.76	0.24
TG15	393848.16	4506475.94	1291.55	1291.61	0.06
TG16	345998.01	4538443.04	1286.04	1286.07	0.03
TG17	401438.78	4534004.99	1302.39	1302.42	0.04
TG18	338907.10	4620724.34	1286.13	1286.17	0.05
TG19	340194.95	4619297.37	1288.34	1288.42	0.08
TG20	342284.74	4618704.20	1286.86	1286.94	0.09
TG21	359249.51	4624197.37	1293.64	1293.73	0.09
TG22	361814.62	4590852.52	1304.55	1304.61	0.06
TG52	331933.39	4578203.14	1286.54	1286.56	0.02

Average Dz	0.060 m
Minimum Dz	-0.101 m
Maximum Dz	0.276 m
Root Mean Square	0.098 m
95th Percentile	0.031 m