AIRBORNE TOPOGRAPHIC LIDAR REPORT

SAN DIEGO, CA 2014 LIDAR

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1. Summary / Scope

1.1. Summary

This report contains a summary of the San Diego, CA 2014 LiDAR and Ortho acquisition task order, issued by the USGS National Geospatial Technical Operations Center (NGTOC), under their Geospatial Product and Services Contract (GPSC) on September 23, 2014 and amended December 12, 2014. The combined task orders yielded study areas covering a portion of San Diego County, Camp Pendleton, and Tijuana, Mexico. The intent of this document is to only provide specific validation information for the LiDAR data acquisition/collection work completed for the USGS NGTOC project.

1.2. Scope

The scope of the LiDAR task order included the acquisition of aerial topographic LiDAR using state of the art technology, along with necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems, for the San Diego County, Camp Pendleton, and Tijuana, Mexico project areas. The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Originally Planned LiDAR Specifications

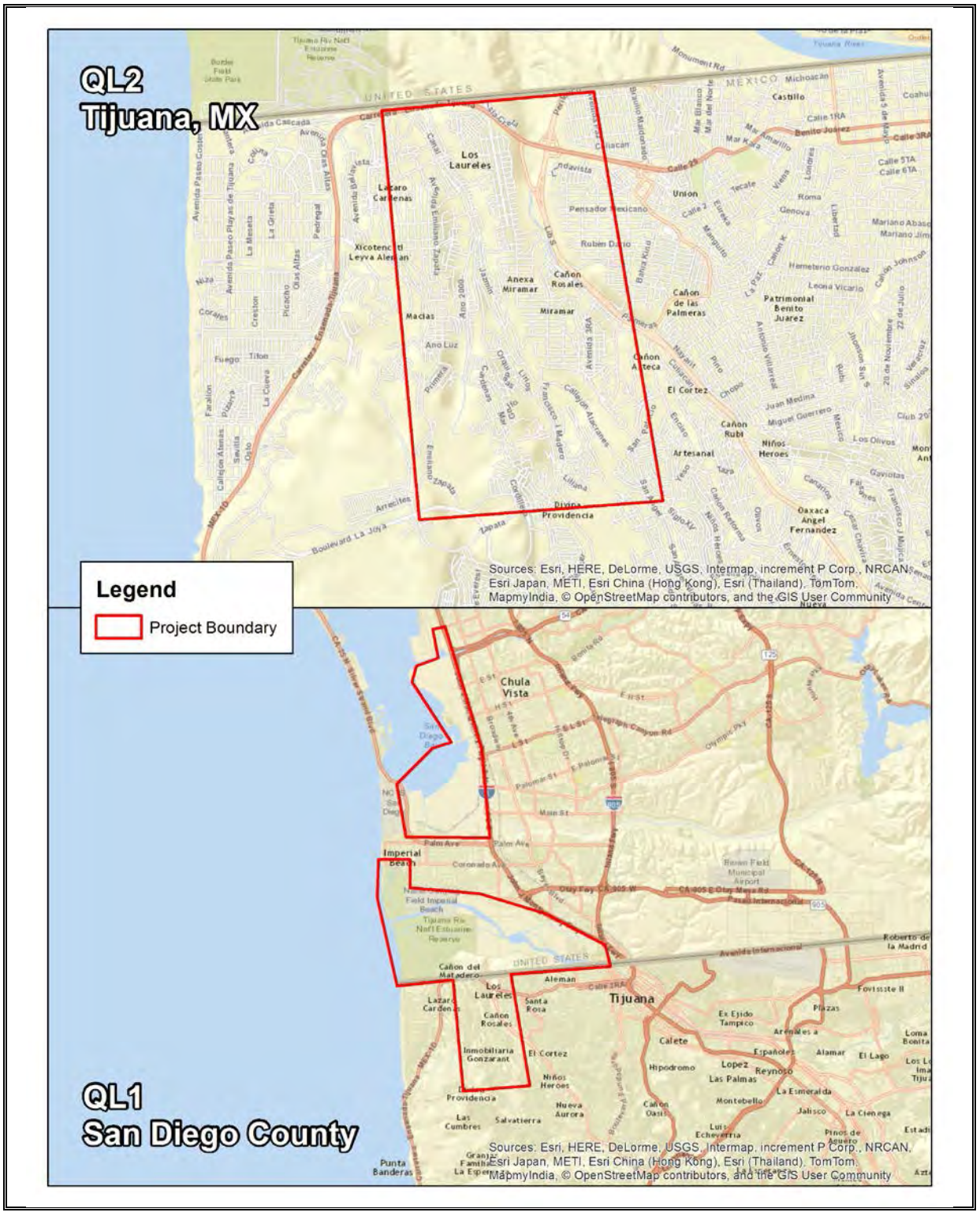
Coverage Area	Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
Main	2.43 pts / m^2	975.4 m	30.0°	26%	9.25 cm or better
Imperial Palms	11.12 pts / m^2	616.9 m	24.0°	26%	9.25 cm or better
SD QL1	11.12 pts / m^2	616.9 m	24.0°	51%	9.25 cm or better

1.3. Location / Coverage

The QL2 LiDAR project boundaries includes the western portion of San Diego County and the Camp Pendleton Marine Corps Base (approximately 1,388 square miles), as well as a section of Tijuana, Mexico (approximately 11 square miles). The QL1 LiDAR collection area covers the southern portion of San Diego County (approximately 40 square miles). These boundaries are shown in Figures 1 and 2.

Figure 1. San Diego County and Camp Pendleton QL2 LiDAR Project Boundaries

Figure 2. QL2 Tijuana, Mexico and QL1 San Diego County LiDAR Project Boundaries



1.4. Duration

The first LiDAR mission was flown on October 27, 2014 and it took 32 total lifts to complete coverage of the area.

1.5. Issues

Coordination with Mexican airspace was required. The LiDAR for the Camp Pendleton AOI had to be re-collected due to a sensor malfunction during the original flight.

2. Planning / Equipment

The entire LiDAR target area was comprised of 338 planned flight lines and approximately 6,912.928 flight line miles. Please refer to Figures 3 and 4 on the following pages, as well as Section 5.

Figure 3. San Diego County and Camp Pendleton Originally Planned LiDAR Flight Lines

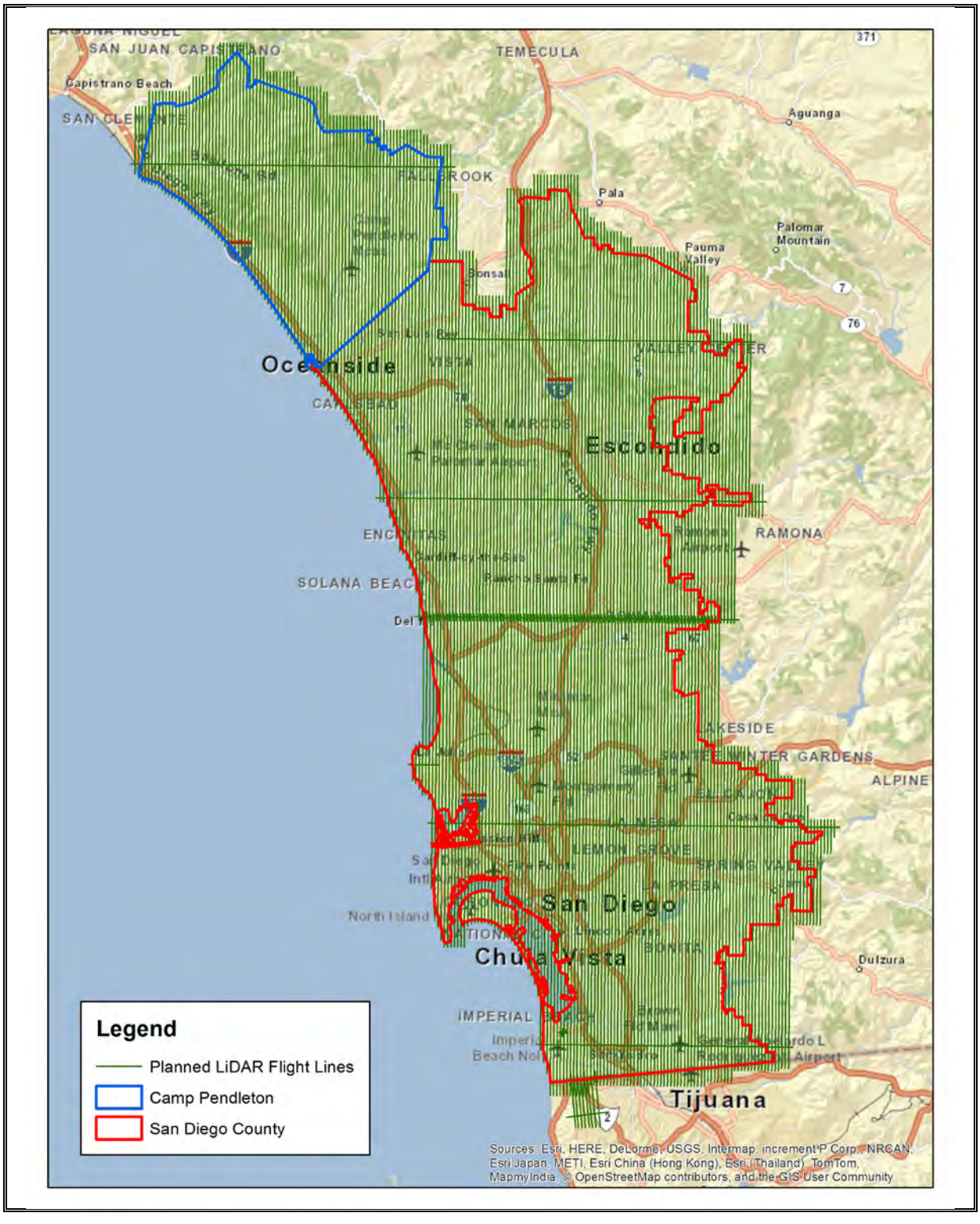
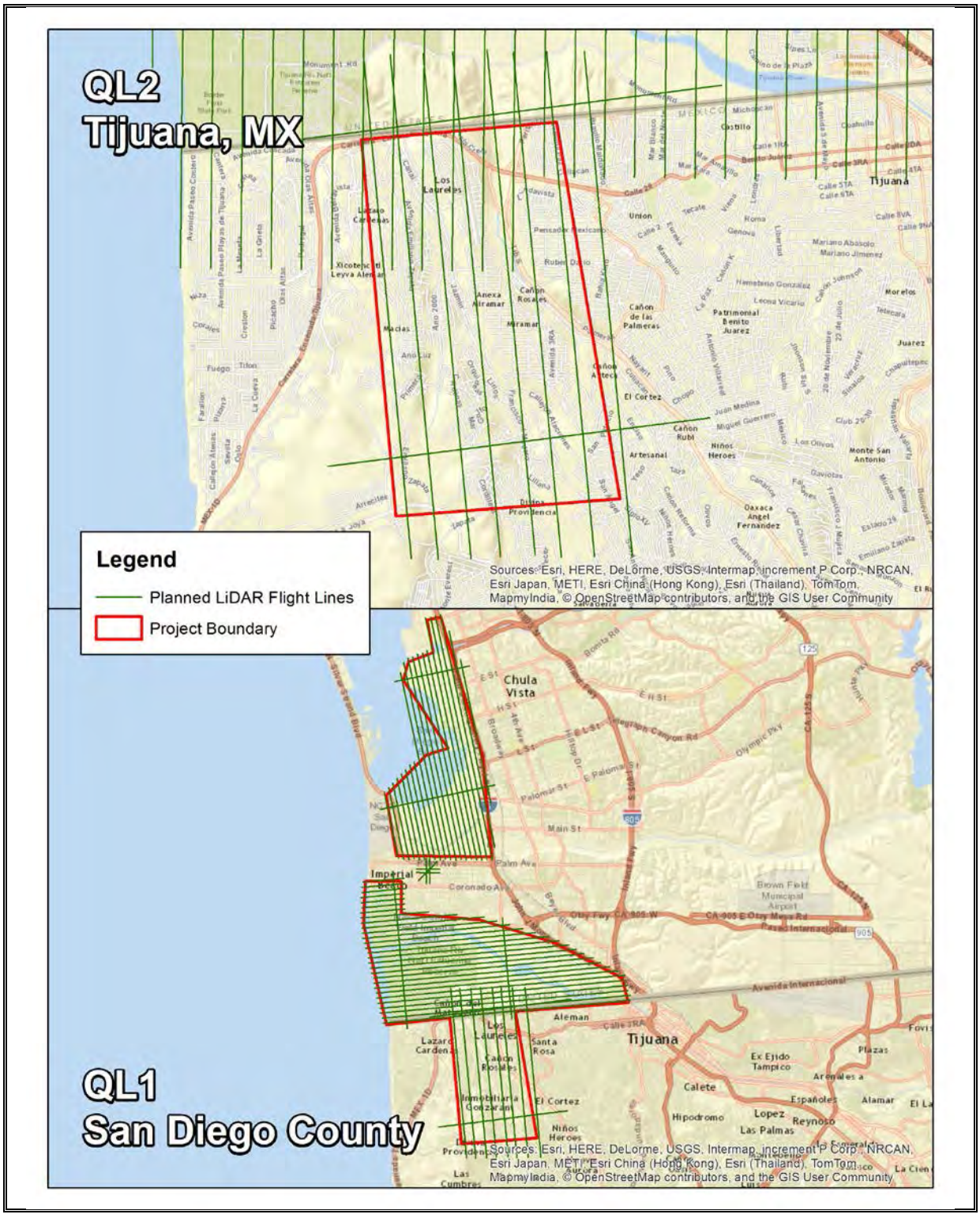


Figure 4. QL2 Tijuana, Mexico and QL1 San Diego County Originally Planned LiDAR Flight Lines



Detailed project flight planning calculations were performed for the San Diego, CA project using Optech ALTM Nav planning software. 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. Please note that certain values in the table below are listed as "Variable" due to the various flight plans used, as described in Section 1.5 of this document. A brief summary of the aerial acquisition parameters for the project are shown in the LiDAR System Specification Table 3 below.

Table 2. LiDAR System Specifications

		Main	Imperial Palms	SD QL1
Terrain and Aircraft	Flying Height AGL	975.4 m	616.9 m	616.9 m
	Recommended Ground Speed (GS)	115 kts	100 kts	100 kts
Scanner	Field of View (FOV)	30°	24°	24°
	Scan Rate Setting used (SR)	42.5 Hz	72.8 Hz	72.8 Hz
Laser	Laser Pulse Rate used	75 kHz	150 kHz	150 kHz
	Multi Pulse in Air Mode	Enabled	Enabled	Enabled
Coverage	Full Swath Width	522.70 m	262.26 m	262.26 m
	Line Spacing	350 m	120 m	175 m
Point Spacing and Density	Maximum Point Spacing Across Track	0.6973 m	0.3539 m	0.3539 m
	Maximum Point Spacing Along Track	0.6960 m	0.3533 m	0.3533 m
	Average Point Density	2.43 pts / m^2	11.12 pts / m^2	11.12 pts / m^2

2.1. Equipment: Aircraft

All flights for the LiDAR portion of the San Diego, CA project were accomplished through the use of customized planes, including a Cessna 206 Stationair (single-piston) (Tail Number: N7269T), a Piper Malibu Mirage (single-piston) (Tail Number: N146ZF), and a Cessna Caravan (single-turbo propeller) (Tail Number: N27DV). These aircraft provided an ideal, stable aerial base for LiDAR and orthoimagery acquisition. This aerial platform has relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using state-of-the-art Optech LiDAR systems. Some of the operating aircraft can be seen below in Figure 6.

Figure 5. Some of Quantum Spatial's planes

2.2. LiDAR Sensor

Quantum Spatial also utilized an Optech LiDAR sensor (see Figure 7), serial numbers 315 and 331 during the project. This system is capable of collecting data at a maximum frequency of 167 kHz, which affords elevation data collection of up to 167,000 points per second. The system utilizes a Multi-Pulse in the Air option (MPIA). This sensor is also equipped with the ability to measure up to 5 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd, 4th, and last returns. The intensity of the first four returns is also captured during aerial acquisition. During mission collection of the San Diego, CA project the LiDAR operator monitored point density and swath to ensure data integrity and desired coverage were obtained.

Figure 6. Optech Orion LiDAR System

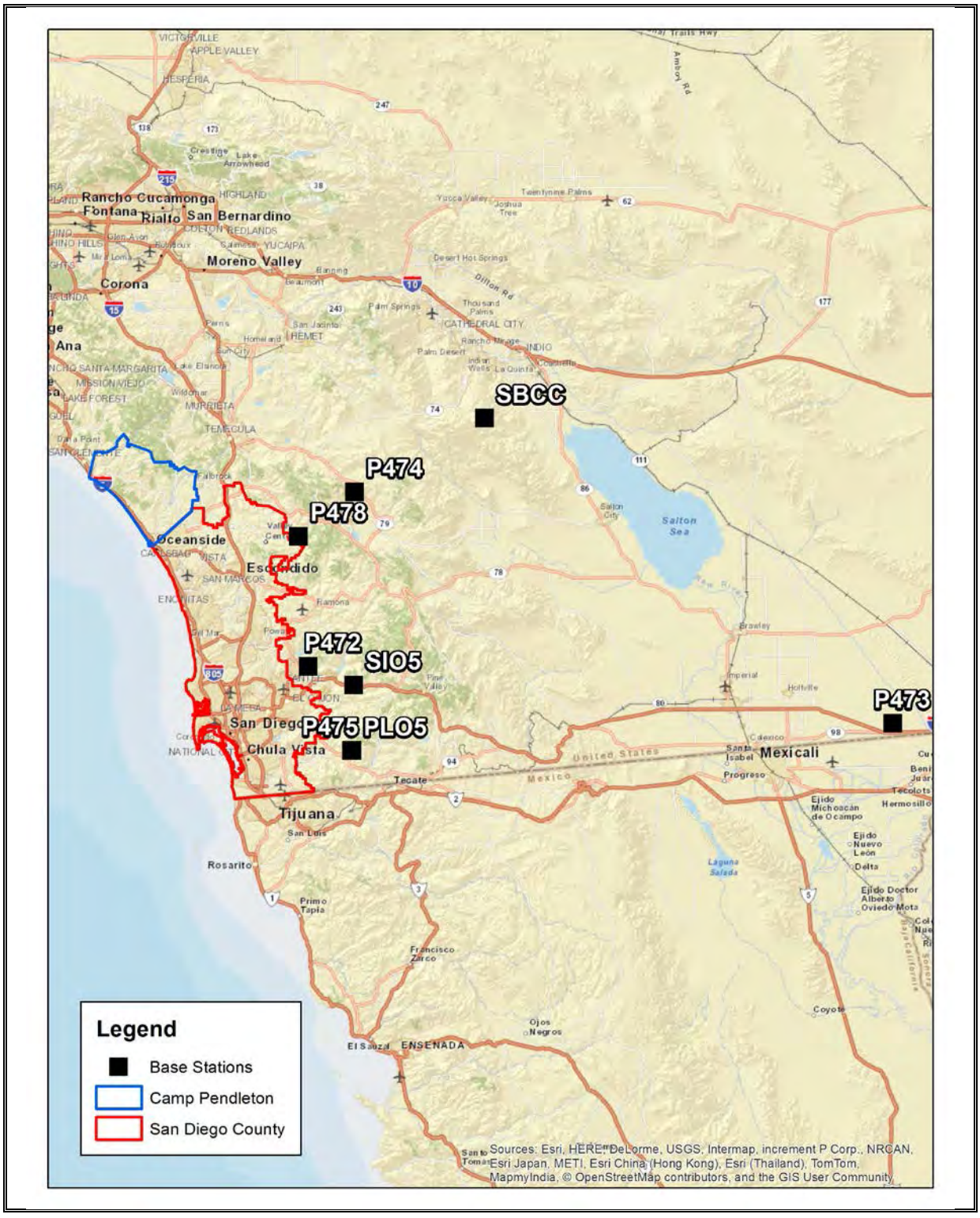
2.3. Base Station Information

GPS base stations were utilized during all phases of flight (see Table 3 below). 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)
SBCC	33° 33' 10.78852"	117° 39' 41.30293"	89.4060
P478	33° 14' 8.56044"	117° 4' 17.67752"	372.3260
P473	32° 44' 1.58057"	116° 56' 58.20691"	189.3280
P472	32° 53' 21.13975"	117° 6' 16.85407"	138.6030
P474	33° 21' 18.68099"	117° 14' 55.24202"	183.6530
SIO5	32° 50' 26.63269"	117° 14' 58.83411"	186.2840
P475	32° 39' 59.01141"	117° 14' 38.11759"	-24.2850
PLO5	32° 39' 55.50397"	117° 14' 34.85949"	-21.7740

Figure 7. Base Station Locations



2.4. Time Period

Project specific flights were conducted over several months. Thirty two LiDAR and nine ortho sorties, or aircraft lifts were completed. Accomplished sorties are listed below, and the type of acquisition is noted to the side:

LiDAR Sorties

- 20141023A_315
- 20141027A_315
- 20141028A_315
- 20141029A_315
- 20141030A_315
- 20141103A_315
- 20141112A_315
- 20141113A_315
- 20141116A_315
- 20141116B_315
- 20141117A_315
- 20141119A_315
- 20141121A_315
- 20141121B_315
- 20141122A_315
- 20141123A_315
- 20141123B_315
- 20141124A_315
- 20141124B_315
- 20141124A_331
- 20141125A_315
- 20141126A_315
- 20141126A_331
- 20141127A_315
- 20141127A_331
- 20141127B_331
- 20141204A_331
- 20141205A_331
- 20141228A_315
- 20150213A_315
- 20150216A_315
- 20150217A_315

3. Processing Summary

3.1. Flight Logs

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

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

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

3.2. LiDAR Processing

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

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

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

All data will manually be reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper will be used as a final check of the bare earth dataset. GeoCue was used to create the deliverable industry-standard LAS files for both the All Point Cloud Data and the Bare Earth. In-house software will then be used to perform final statistical analysis of the classes in the LAS files.

Metadata was generated for the project on a deliverable level.

3.3. LAS Classification Scheme

The classification classes are determined by the USGS Version 1.0 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 – Noise – Low or high points, manually identified above or 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 that fall on bridge decks.
- Class 129 – Overlap Default (Unclassified) – Points found in the overlap between flight lines. These points are created through automated processing methods and not cleaned up during processing.
- Class 130 – Overlap Bare-earth ground – Points found in the overlap between flight lines. These points are created through automated processing, matching the specifications determined during the automated process, that are close to the Class 2 dataset (when analyzed using height from ground analysis)
- Class 137 – Overlap Water – Points found in the overlap between flight lines that are located inside hydro features. These points are created through automated processing methods and not cleaned up during processing.

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 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 to Class 129 (Overlap Default) and Class 130 (Overlap Ground). 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 is used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for all point cloud data. 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 Flattening Breakline Process

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, as well as all ocean shoreline features.

Elevation values were assigned to all Inland Ponds and Lakes, Inland Pond and Lake Islands, Inland Streams and Rivers and Inland Stream, River Islands and Ocean Shorelines 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 and ocean shoreline 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 breakline files were then translated to ESRI Shapefile format using ESRI conversion tools.

3.6. Hydro Flattening Raster DEM Process

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.

4. Deliverables

- Uncalibrated, unclassified raw point cloud swath LAS in version 1.2 format
- Classified point cloud tiled LAS in version 1.2 format
- Hydro flattened raster DEM in ERDAS .IMG format
- Intensity images
- 2-foot tiled Contours for QL1 and QL2 data (ArcGeodatabase format)
- Collection, survey, and processing reports
- Project and deliverable level metadata in XML format
- Project report

5. Project Coverage Verification

The San Diego, CA project area 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 Figures 8 and 9.

Figure 8. San Diego County and Camp Pendleton QL2 LiDAR Flightline Swath LAS File Coverage

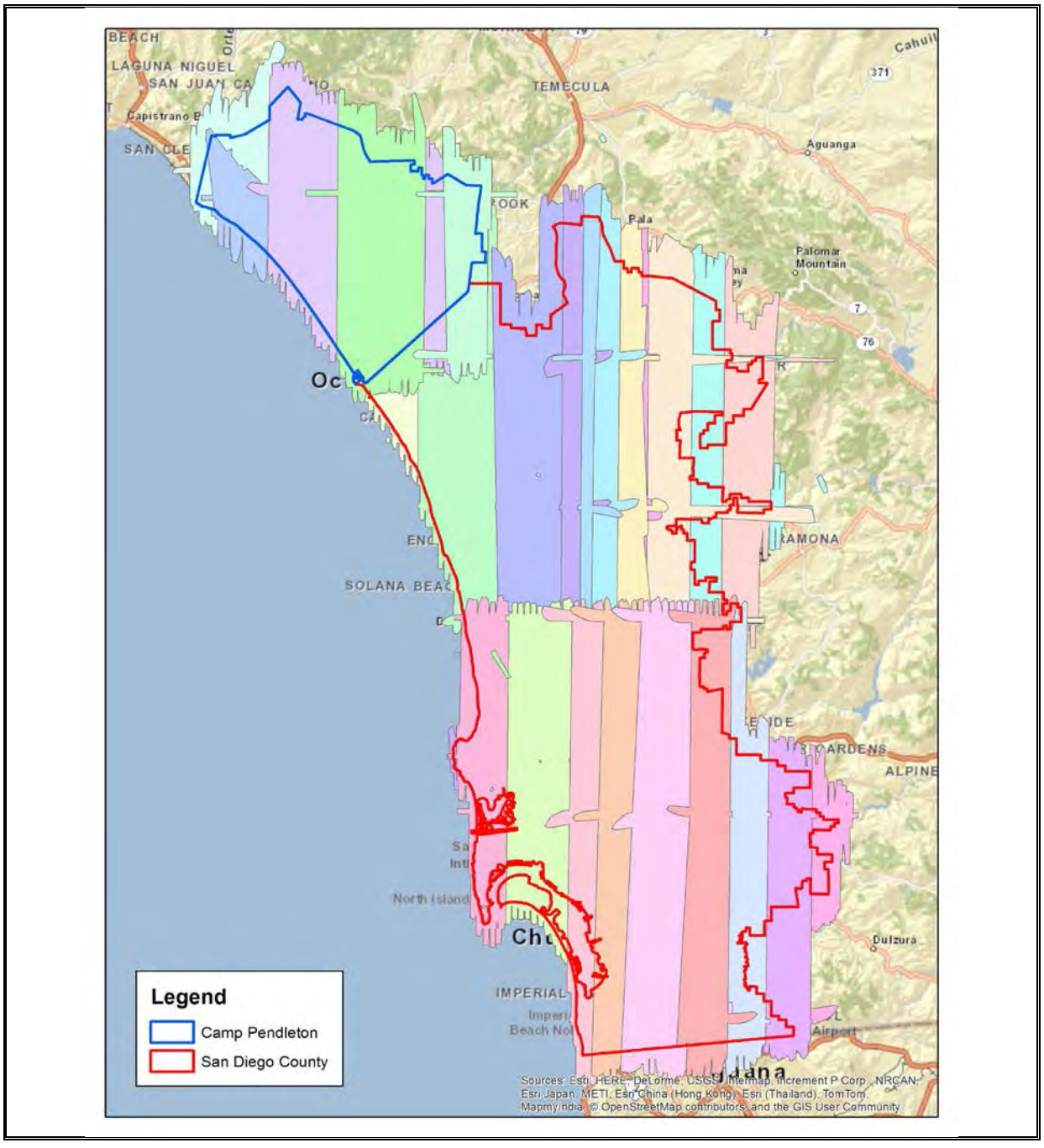
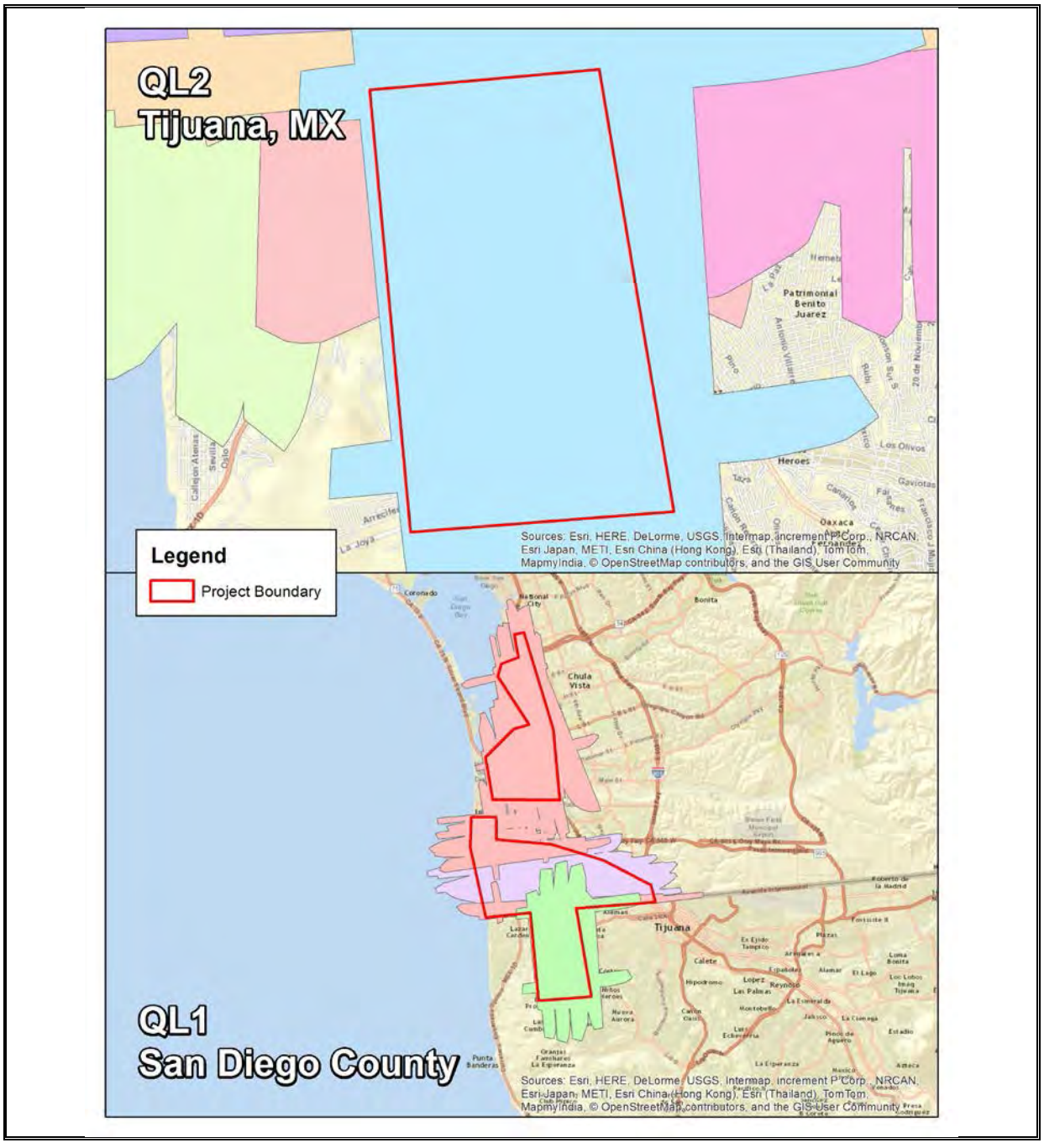


Figure 9. QL2 Tijuana, Mexico and QL1 San Diego County LiDAR Flightline Swath LAS File Coverage



6. Ground Control and Check Point Collection

Quantum Spatial completed a field survey of 88 ground control (calibration) points along with 79 blind QA points in 4 different land cover classifications (total of 167 points) as an independent test of the accuracy of this project. The land cover classifications were selected from the dominant classifications for this project area. These included:

- Bare earth and low grass
- Brush Lands & Low Trees
- High grass, weeds, and crops
- Urban areas

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.

Figure 10 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 shown in Figure 10, 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.

The project was delivered using the following horizontal projection(s): NAD83 (2011) State Plane California Zone VI, US Feet; NAVD88 Geoid 12A. In this document, horizontal coordinates for ground control and QA points for all LiDAR classes are reported in State Plane California Zone VI, US Feet.

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 1.0 (2012). The locations for all tested blind QA points are shown in Figure 11. The summary below provides the results of this testing:

Point Cloud Testing

- Raw Fundamental Vertical Accuracy (Raw FVA): The tested Raw FVA for the dataset was found to be 0.195 ft (5.944 cm) in terms of the RMSEz. The resulting FVA stated as the 95% confidence level (RMSEz x 1.96) is 0.382 ft (11.64 cm). This dataset *meets* the required FVA of 0.597 ft (18.2 cm) at the 95% confidence level (according to the National Standard for Spatial Database Accuracy (NSSDA)), based on TINs derived from the final calibrated and controlled LiDAR swath data. This is summarized in Table 5.

Digital Elevation Model (DEM) Testing

- Fundamental Vertical Accuracy (FVA): The tested FVA for the dataset captured from the DEM using bi-linear interpolation to derive the DEM elevations was found to be 0.250 ft (7.62 cm) in terms of the RMSEz. The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is 0.490 ft (14.935 cm). This dataset *meets* the required FVA of 0.597 ft (18.2 cm) at the 95% confidence level (based on NSSDA). This is summarized in Table 6.

- Supplemental Vertical Accuracy (SVA): The tested SVA accuracies for the dataset for each of the land cover classes other than open ground are summarized below. These results are stated in terms of the 95th percentile error (based on ASPRS guidelines) for each of the land cover classes other than open ground.

  The following land cover classes were tested and the resulting 95th percentile error values are listed below:

  - Brush Lands & Low Trees: 0.648 ft (19.751 cm) (Table 7)
  - High Grass, Weeds, and Crops:0.824 ft (25.116 cm) (Table 8)
  - Urban Areas:.307 ft (9.357 cm0) (Table 9)

- Consolidated Vertical Accuracy (CVA): The tested CVA for the dataset captured from the DEM using bi-linear interpolation for all classes (including the bare earth class) was found to be 0.760 ft (23.164 cm), which is stated in terms of the 95th percentile error. Therefore the data *meets* the required CVA of 0.883 ft (26.9 cm). This test was based on the 95th percentile error (based on ASPRS guidelines) across all land cover categories

  This is also summarized in Table 10.

Figure 10. LiDAR Ground Control Points Used in Calibration

Figure 11. All Final LiDAR QA Point Locations

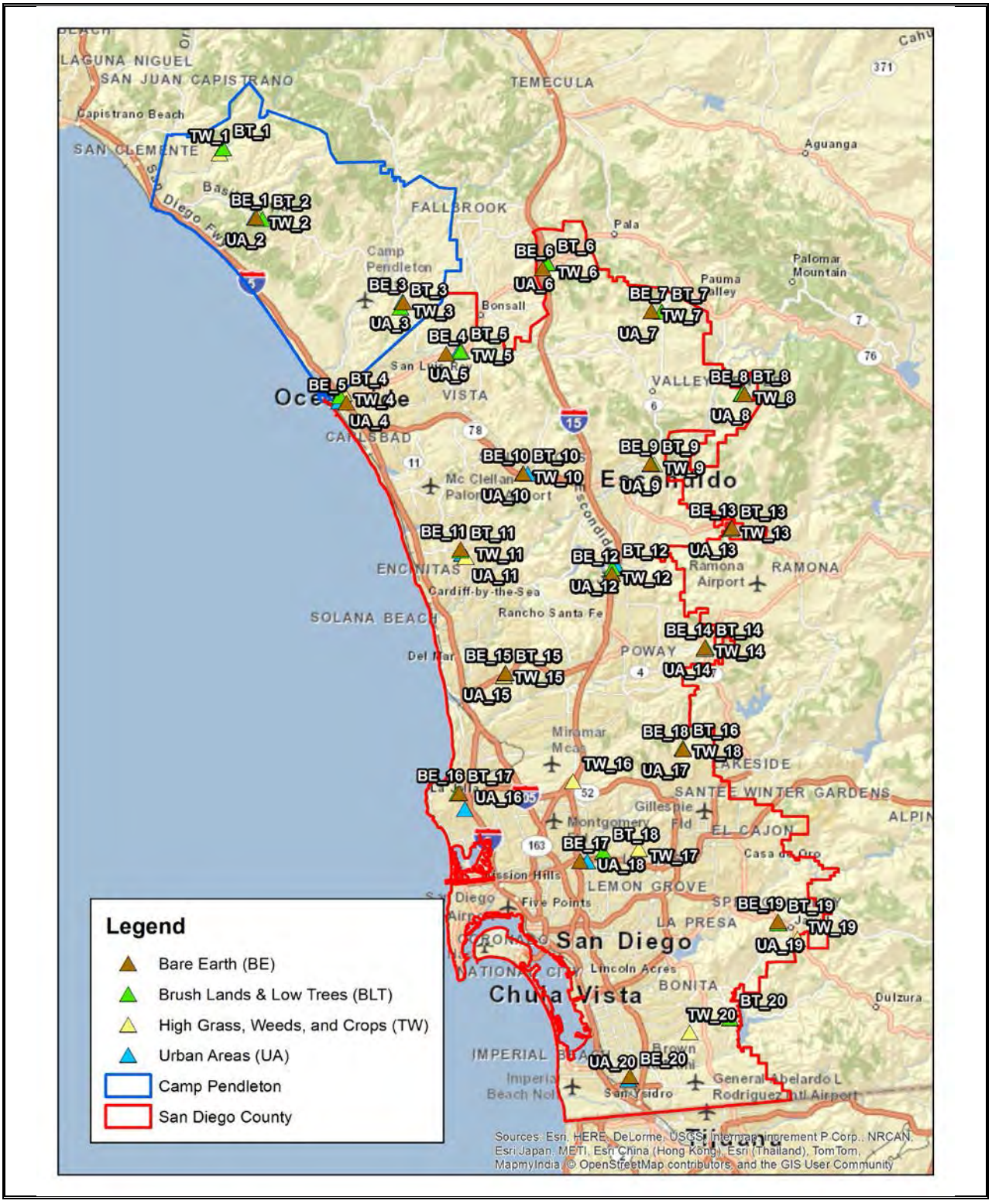


Figure 12. Bare Earth QA Point Locations

Figure 13. Brush Lands & Low Trees QA Point Locations

Figure 14. High Grass, Weeds, and Crops QA Point Locations

Figure 15. Urban Area QA Point Locations

Table 4. LiDAR Ground Control Point Report (Units = Survey Feet)

Number	Easting	Northing	Known Z	Laser Z	Dz
100P	6295119.57	1776166.58	11.9	12.03	0.13
101	6294702.05	1793941.18	22.19	22.31	0.12
102	6318296.65	1779411.5	55.04	55.16	0.12
103	6348225.12	1781880.57	528.17	528.31	0.14
104P	6354802.57	1794683.19	729.71	729.67	-0.04
105	6349989.27	1813196.36	596.16	596.27	0.11
106	6335452.23	1806759.72	475.83	476.19	0.36
107	6308082.44	1820997.45	50.34	50.48	0.14
108	6325804.77	1833877.5	444.27	444.51	0.24
109	6303186.64	1842388.65	213.33	213.58	0.25
110	6282877.72	1843714.83	157.9	158.2	0.3
111	6275880.66	1831136.99	24.39	24.43	0.04
112	6256275.2	1826897.33	351.79	351.5	-0.29
113	6258227.3	1855115.41	20.67	20.48	-0.19
114	6281397.5	1857459	60.07	60.06	-0.01
115	6310347.47	1863442.99	359.77	359.95	0.18
116	6339268.57	1851251.43	531.28	531.55	0.27
117	6365063.68	1858349.67	422.95	422.74	-0.21
118	6377991.92	1829351.62	808.88	808.44	-0.44
119	6364883.88	1884486.87	659	658.58	-0.42
120	6352449.83	1891973.74	394.41	394.52	0.11
121	6323156.32	1885261.6	336.2	336.3	0.1
122	6295020.95	1891231.63	449.04	449.11	0.07
123	6274653.05	1889918.71	315.25	315.19	-0.06
124	6248586.32	1887358.6	163.8	163.63	-0.17
125	6258703.39	1914678.82	17.87	17.55	-0.32
126	6281395.27	1923601.86	398.7	398.62	-0.08
127	6311847.71	1919816.31	650.33	650.33	0
128	6341555.59	1927092.01	1360.72	1360.91	0.19
129	6346106.26	1949232.58	1654.05	1654.1	0.05
130	6305588.46	1940948.91	716.34	716.58	0.24
131	6259111.12	1929314.9	263.84	263.42	-0.42
132	6246794.02	1957151.83	210.13	removed	*
133	6277894.38	1957539.65	254.52	254.64	0.12
136P	6385908.17	1860941.4	697.66	697.34	-0.32
137	6365400.04	1973308.09	1531.01	1531.1	0.09
138	6331934.86	1978456.03	414.83	414.55	-0.28
139	6299777.58	1989803.79	639.61	639.38	-0.23
140	6263819.860	1979871.39	512.16	512.15	-0.01
141	6235144.860	1982042.86	57.24	57.18	-0.06
142	6246943.160	1994078.06	296.69	296.76	0.07
143	6268661.130	2002253.97	446.2	446.36	0.16
144	6277283.670	2015477.31	798.7	798.7	0
145	6296902.900	2028591.79	1507.42	1507.52	0.1
146	6322039.150	2020766.52	1307.34	1307.67	0.33
147P	6352765.070	2015394.06	2313.21	2313.17	-0.04
148	6344925.920	2050597.03	1045.73	1045.67	-0.06
149	6311964.870	2045471.98	1321.6	1321.61	0.01

Number	Easting	Northing	Known Z	Laser Z	Dz
150	6286057.790	2052240.6	828.05	827.98	-0.07
152	6280668.080	2080718.22	563.51	563.54	0.03
153	6265768.810	2047946.6	166.44	166.42	-0.02
154	6241827.140	2044610.44	164.7	164.62	-0.08
155	6247049.460	2023948.27	387.05	387.17	0.12
156	6223788.600	2010093.17	72.11	71.63	-0.48
157	6226470.650	2024126.48	32.61	32.77	0.16
158	6199573.210	2043039.43	45.99	45.88	-0.11
159	6224198.860	2065817.19	193.68	193.85	0.17
160	6255304.300	2082122.9	686.72	686.96	0.24
161	6249430.160	2093827.29	871.27	871.35	0.08
165P	6187400.520	2116085.67	427.68	427.82	0.14
167	6208975.200	2072306.24	246.35	246.66	0.31
168	6197587.800	2083614.07	546.72	546.66	-0.06
169	6177491.480	2088368.15	201.88	202.09	0.21
170	6177578.350	2069229.02	157.56	157.48	-0.08
171	6155159.520	2085788.58	78.21	77.63	-0.58
172	6155436.940	2108478.1	452.07	451.49	-0.58
173P	6234374.760	2102486.53	364.84	365.18	0.34
174P	6185500.750	2124903.89	959.96	960.25	0.29
176QC	6313915.280	1789394.59	178.75	178.9	0.15
177QC	6364390.830	1843542.36	767.51	767.28	-0.23
179QC	6297334.290	1863713.38	100.81	100.76	-0.05
180QC	6258122.400	1881637.69	485.27	485.1	-0.17
181QC	6332473.610	1902183.37	466.2	466.32	0.12
182QC	6339877.330	1936595.16	1613.72	1613.83	0.11
183QC	6271967.730	1927855.04	213.66	213.56	-0.1
184QC	6257072.450	1968587.08	127.16	127.42	0.26
185QC	6309471.180	1964877.45	341.55	341.67	0.12
186QC	6348988.380	1977273.25	451.72	451.78	0.06
187QC	6353070.530	2023022.39	1999.38	1999.23	-0.15
188QC	6321865.920	1999043.08	721.61	721.74	0.13
189QC	6278664.800	1995192.7	558.7	559.18	0.48
190QC	6215231.680	2020414.36	32.36	32.53	0.17
191QC	6255978.730	2037118.15	190.52	190.32	-0.2
192QC	6284380.600	2065882.68	302.68	302.85	0.17
193QC	6325163.700	2051050.7	1683.03	1683.03	0
194QC	6236870.020	2054299.87	356.84	356.81	-0.03
195QC	6186932.900	2083009.89	377.56	377.6	0.04
196P	6174490.240	2105050.87	238.03	237.52	-0.51

Average dz	0.009 ft
Minimum dz	-0.580 ft
Maximum dz	0.480 ft
Root Mean Square	0.220 ft
Std Deviation	0.221 ft

Table 5. Raw FVA - Bare Earth and Low Grass QA – Unclassified Points (Units = Survey Feet)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
BE-01	6186831.01	2083107.59	375.08	375.33	0.25
BE-02	6237022.27	2054205.80	360.84	360.93	0.09
BE-03	6251650.15	2036697.37	145.31	145.42	0.11
BE-04	removed				
BE-05	6284579.19	2065721.04	301.23	301.50	0.27
BE-06	6321625.48	2051274.52	1624.46	1624.56	0.10
BE-07	6353399.42	2022901.73	2004.47	2004.34	-0.13
BE-08	6321334.36	1999193.21	715.82	716.01	0.19
BE-09	6277885.40	1995948.12	564.24	564.04	-0.20
BE-10	6256598.09	1970116.68	122.88	123.08	0.20
BE-11	6308215.53	1961619.83	358.33	358.51	0.18
BE-12	6349058.56	1977362.55	448.90	448.90	0.00
BE-13	6339911.92	1936649.06	1619.10	1619.13	0.03
BE-14	6271970.82	1927842.18	212.58	212.80	0.22
BE-15	6256101.36	1886944.45	791.02	790.67	-0.35
BE-16	6297356.65	1863832.73	99.16	99.39	0.23
BE-17	6332485.60	1902011.23	463.00	463.28	0.28
BE-18	6364770.67	1843333.26	772.26	772.16	-0.10
BE-19	6314311.70	1790517.04	205.26	205.54	0.28
BE-20	11654473.93	6904866.24	456.81	456.82	0.01

Average dz	0.382 ft
Minimum dz	-0.350 ft
Maximum dz	0.280 ft
Root Mean Square	0.195 ft
95% Confidence	0.382 ft

Table 6. FVA - Bare Earth and Low Grass QA – Derived DEMs Classified (Units = Survey Feet)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
BE_1	6186831.010	2083107.590	375.080	375.352	0.272
BE_3	6237022.270	2054205.800	360.840	360.936	0.096
BE_4	6251650.150	2036697.370	145.310	145.378	0.068
BE_5	6217594.500	2020041.410	123.880	123.224	-0.656
BE_6	6284579.190	2065721.040	301.230	301.518	0.288
BE_7	6321625.480	2051274.520	1624.460	1624.556	0.096
BE_8	6353399.420	2022901.730	2004.470	2004.408	-0.062
BE_9	6321334.360	1999193.210	715.820	716.001	0.181
BE_10	6277885.400	1995948.120	564.240	564.045	-0.195
BE_11	6256598.090	1970116.680	122.880	123.093	0.213
BE_12	6308215.530	1961619.830	358.330	358.510	0.180
BE_13	6349058.560	1977362.550	448.900	448.917	0.017
BE_14	6339911.920	1936649.060	1619.100	1619.154	0.054
BE_15	6271970.820	1927842.180	212.580	212.852	0.272
BE_16	6256101.360	1886944.450	791.020	790.661	-0.359
BE_17	6297356.650	1863832.730	99.160	99.394	0.234
BE_18	6332485.600	1902011.230	463.000	463.276	0.276
BE_19	6364770.670	1843333.260	772.260	772.153	-0.107
BE_20	6314311.700	1790517.040	205.260	205.536	0.276

Average dz	0.06 ft
Minimum dz	-0.656 ft
Maximum dz	0.288 ft
Root Mean Square	0.250 ft
95% Confidence	0.490 ft

Table 7. SVA Brush Lands & Low Trees QA – Derived DEMs (Units = Survey Feet)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
BT_1	6175659.940	2106639.440	274.180	274.234	0.054
BT_2	6189012.180	2082618.690	394.550	394.780	0.230
BT_3	6236084.110	2052505.520	333.890	333.967	0.077
BT_4	6215465.550	2022193.480	58.650	58.473	-0.177
BT_5	6256507.050	2037414.560	139.560	139.505	-0.055
BT_6	6286185.730	2067476.910	265.560	266.843	1.283
BT_7	6325065.070	2050975.170	1677.200	1677.708	0.508
BT_8	6352550.800	2023024.220	2052.080	2052.366	0.286
BT_9	6321832.580	1999071.790	722.820	723.417	0.597
BT_10	6277851.200	1995977.580	564.990	565.604	0.614
BT_11	6256447.400	1969700.000	120.310	120.265	-0.045
BT_12	6308362.880	1963602.390	404.240	404.400	0.160
BT_13	6348566.280	1976912.700	461.240	461.514	0.274
BT_14	6340219.110	1936670.660	1625.270	1625.429	0.159
BT_15	6271876.940	1927737.910	210.550	211.007	0.457
BT_16	6332352.960	1902491.800	469.440	469.234	-0.206
BT_17	6255470.650	1886863.390	754.800	754.546	-0.254
BT_18	6305176.400	1867008.850	222.630	223.079	0.449
BT_19	6364830.320	1842688.850	838.200	838.489	0.289
BT_20	6348429.140	1810299.390	527.550	528.105	0.555

Average dz	0.26 ft
Minimum dz	-0.254 ft
Maximum dz	1.283 ft
Root Mean Square	0.439 ft
95th Percentile	0.648 ft

Table 8. SVA High Grass, Weeds, and Crops QA – Derived DEMs (Units = Survey Feet)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
TW_1	6174392.610	2104906.930	235.390	236.149	0.759
TW_2	6187609.600	2083035.140	378.460	379.042	0.582
TW_3	6236990.840	2054127.010	359.600	360.275	0.675
TW_4	6216794.550	2023114.620	23.320	23.500	0.180
TW_5	6256952.830	2037418.900	143.880	144.282	0.402
TW_6	6286084.710	2067484.840	264.610	265.844	1.234
TW_7	6321622.350	2051233.100	1621.680	1622.455	0.775
TW_8	6353139.720	2023447.670	1984.090	1984.271	0.181
TW_9	6322485.320	1999074.590	738.690	738.976	0.286
TW_10	6277849.430	1995955.480	564.110	564.003	-0.107
TW_11	6258228.950	1967400.860	178.360	178.688	0.328
TW_12	6307993.470	1962140.030	358.900	359.702	0.802
TW_13	6348601.490	1976973.590	455.580	455.617	0.037
TW_14	6339868.470	1936119.810	1609.020	1609.059	0.039
TW_15	6271354.170	1926784.950	135.700	135.440	-0.260
TW_16	6294849.460	1891062.350	445.490	446.047	0.557
TW_17	6317423.710	1867899.570	548.000	548.304	0.304
TW_18	6332346.990	1902456.930	469.370	469.028	-0.342
TW_19	6371398.350	1837311.510	966.220	966.177	-0.043
TW_20	6334640.730	1805489.920	469.270	469.569	0.299

Average dz	0.36 ft
Minimum dz	-0.342 ft
Maximum dz	1.234 ft
Root Mean Square	0.398 ft
95th Percentile	0.824 ft

Table 9. SVA Urban Areas QA Points – Derived DEMs (Units – Survey Feet)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
UA_1	6186388.780	2083130.520	367.740	367.512	-0.228
UA_2	6187590.820	2082974.640	379.370	379.245	-0.125
UA_3	6236675.270	2054483.390	362.350	361.917	-0.433
UA_4	6215222.780	2020341.610	34.720	34.278	-0.442
UA_5	6255676.640	2037120.170	191.800	191.570	-0.230
UA_6	6286016.040	2067771.600	275.000	275.704	0.704
UA_7	6325146.800	2051054.070	1683.190	1683.157	-0.033
UA_8	6352399.340	2023107.770	2050.860	2050.760	-0.100
UA_9	6321609.100	1999037.990	715.630	715.818	0.188
UA_10	6279362.440	1995822.460	563.520	563.497	-0.023
UA_11	6257049.730	1968582.740	128.100	128.386	0.286
UA_12	6309341.120	1964874.860	334.490	334.556	0.066
UA_13	6348920.530	1977290.620	451.240	451.111	-0.129
UA_14	6339921.500	1936545.660	1614.660	1614.739	0.079
UA_15	6271850.350	1927847.500	213.230	213.282	0.052
UA_16	6258085.360	1881553.120	486.010	485.614	-0.396
UA_17	6332415.740	1902214.650	467.070	467.147	0.077
UA_18	6299855.600	1863766.740	88.100	88.050	-0.050
UA_19	6365207.200	1842677.620	868.690	868.430	-0.260
UA_20	6313871.440	1789412.500	180.070	180.276	0.206

Average dz	-0.04 ft
Minimum dz	-0.442 ft
Maximum dz	0.704 ft
Root Mean Square	0.268 ft
95th Percentile	0.307 ft

Table 10. CVA for the 4 Classified Land Cover Classes (Units = Survey Feet)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
BE_1	6186831.010	2083107.590	375.080	375.352	0.272
BE_3	6237022.270	2054205.800	360.840	360.936	0.096
BE_4	6251650.150	2036697.370	145.310	145.378	0.068
BE_5	6217594.500	2020041.410	123.880	123.224	-0.656
BE_6	6284579.190	2065721.040	301.230	301.518	0.288
BE_7	6321625.480	2051274.520	1624.460	1624.556	0.096
BE_8	6353399.420	2022901.730	2004.470	2004.408	-0.062
BE_9	6321334.360	1999193.210	715.820	716.001	0.181
BE_10	6277885.400	1995948.120	564.240	564.045	-0.195
BE_11	6256598.090	1970116.680	122.880	123.093	0.213
BE_12	6308215.530	1961619.830	358.330	358.510	0.180
BE_13	6349058.560	1977362.550	448.900	448.917	0.017
BE_14	6339911.920	1936649.060	1619.100	1619.154	0.054
BE_15	6271970.820	1927842.180	212.580	212.852	0.272
BE_16	6256101.360	1886944.450	791.020	790.661	-0.359
BE_17	6297356.650	1863832.730	99.160	99.394	0.234
BE_18	6332485.600	1902011.230	463.000	463.276	0.276
BE_19	6364770.670	1843333.260	772.260	772.153	-0.107
BE_20	6314311.700	1790517.040	205.260	205.536	0.276
BE_1	6186831.010	2083107.590	375.080	375.352	0.272
BT_1	6175659.940	2106639.440	274.180	274.234	0.054
BT_2	6189012.180	2082618.690	394.550	394.780	0.230
BT_3	6236084.110	2052505.520	333.890	333.967	0.077
BT_4	6215465.550	2022193.480	58.650	58.473	-0.177
BT_5	6256507.050	2037414.560	139.560	139.505	-0.055
BT_6	6286185.730	2067476.910	265.560	266.843	1.283
BT_7	6325065.070	2050975.170	1677.200	1677.708	0.508
BT_8	6352550.800	2023024.220	2052.080	2052.366	0.286
BT_9	6321832.580	1999071.790	722.820	723.417	0.597
BT_10	6277851.200	1995977.580	564.990	565.604	0.614
BT_11	6256447.400	1969700.000	120.310	120.265	-0.045
BT_12	6308362.880	1963602.390	404.240	404.400	0.160
BT_13	6348566.280	1976912.700	461.240	461.514	0.274
BT_14	6340219.110	1936670.660	1625.270	1625.429	0.159
BT_15	6271876.940	1927737.910	210.550	211.007	0.457
BT_16	6332352.960	1902491.800	469.440	469.234	-0.206
BT_17	6255470.650	1886863.390	754.800	754.546	-0.254
BT_18	6305176.400	1867008.850	222.630	223.079	0.449
BT_19	6364830.320	1842688.850	838.200	838.489	0.289
BT_20	6348429.140	1810299.390	527.550	528.105	0.555
TW_1	6174392.610	2104906.930	235.390	236.149	0.759
TW_2	6187609.600	2083035.140	378.460	379.042	0.582
TW_3	6236990.840	2054127.010	359.600	360.275	0.675
TW_4	6216794.550	2023114.620	23.320	23.500	0.180
TW_5	6256952.830	2037418.900	143.880	144.282	0.402
TW_6	6286084.710	2067484.840	264.610	265.844	1.234
TW_7	6321622.350	2051233.100	1621.680	1622.455	0.775
TW_8	6353139.720	2023447.670	1984.090	1984.271	0.181

Number	Easting	Northing	Known Z	LiDAR Z	Dz
TW_9	6322485.320	1999074.590	738.690	738.976	0.286
TW_10	6277849.430	1995955.480	564.110	564.003	-0.107
TW_11	6258228.950	1967400.860	178.360	178.688	0.328
TW_12	6307993.470	1962140.030	358.900	359.702	0.802
TW_13	6348601.490	1976973.590	455.580	455.617	0.037
TW_14	6339868.470	1936119.810	1609.020	1609.059	0.039
TW_15	6271354.170	1926784.950	135.700	135.440	-0.260
TW_16	6294849.460	1891062.350	445.490	446.047	0.557
TW_17	6317423.710	1867899.570	548.000	548.304	0.304
TW_18	6332346.990	1902456.930	469.370	469.028	-0.342
TW_19	6371398.350	1837311.510	966.220	966.177	-0.043
TW_20	6334640.730	1805489.920	469.270	469.569	0.299
UA_1	6186388.780	2083130.520	367.740	367.512	-0.228
UA_2	6187590.820	2082974.640	379.370	379.245	-0.125
UA_3	6236675.270	2054483.390	362.350	361.917	-0.433
UA_4	6215222.780	2020341.610	34.720	34.278	-0.442
UA_5	6255676.640	2037120.170	191.800	191.570	-0.230
UA_6	6286016.040	2067771.600	275.000	275.704	0.704
UA_7	6325146.800	2051054.070	1683.190	1683.157	-0.033
UA_8	6352399.340	2023107.770	2050.860	2050.760	-0.100
UA_9	6321609.100	1999037.990	715.630	715.818	0.188
UA_10	6279362.440	1995822.460	563.520	563.497	-0.023
UA_11	6257049.730	1968582.740	128.100	128.386	0.286
UA_12	6309341.120	1964874.860	334.490	334.556	0.066
UA_13	6348920.530	1977290.620	451.240	451.111	-0.129
UA_14	6339921.500	1936545.660	1614.660	1614.739	0.079
UA_15	6271850.350	1927847.500	213.230	213.282	0.052
UA_16	6258085.360	1881553.120	486.010	485.614	-0.396
UA_17	6332415.740	1902214.650	467.070	467.147	0.077
UA_18	6299855.600	1863766.740	88.100	88.050	-0.050
UA_19	6365207.200	1842677.620	868.690	868.430	-0.260
UA_20	6313871.440	1789412.500	180.070	180.276	0.206

Average dz	0.16 ft
Minimum dz	-0.656 ft
Maximum dz	1.283 ft
Root Mean Square	0.385 ft
95th Percentile	0.760 ft