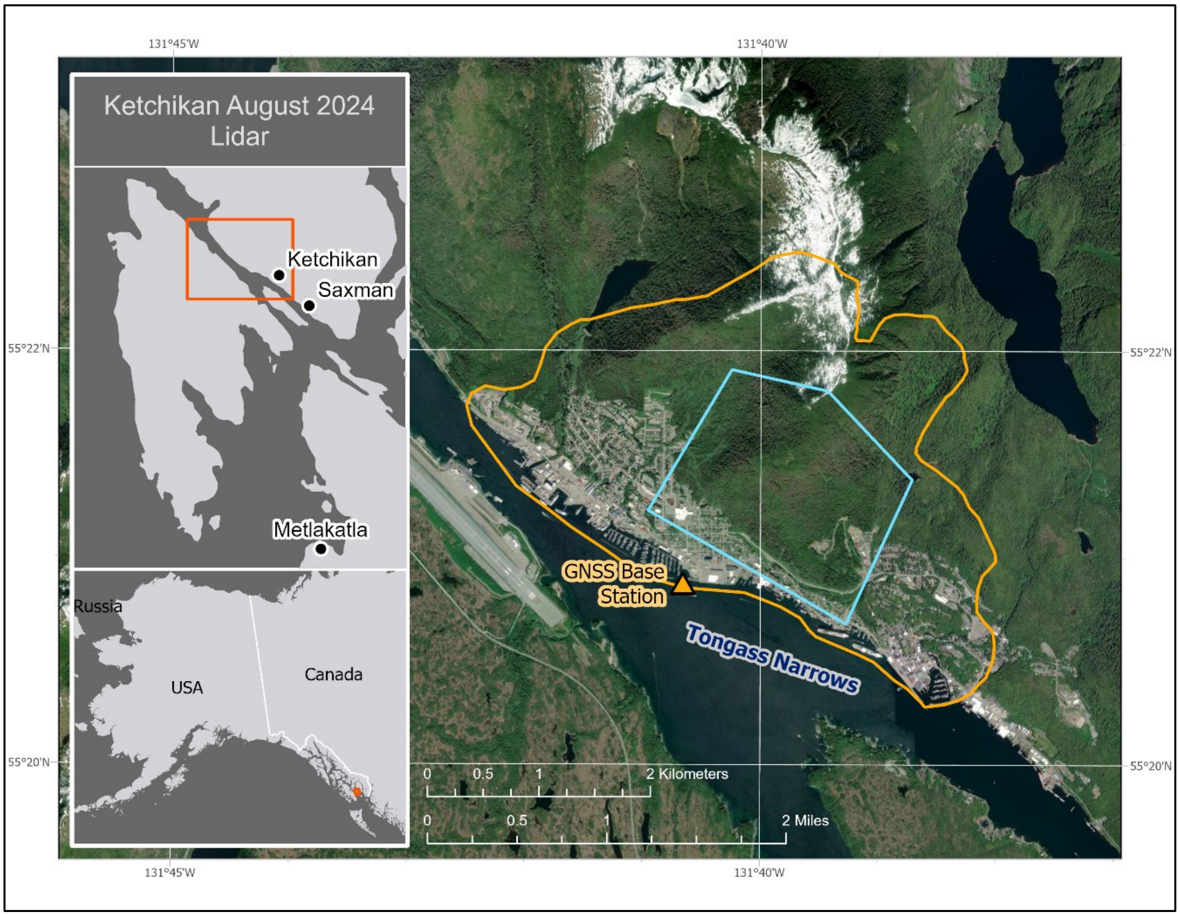
LIDAR-DERIVED ELEVATION DATA FOR KETCHIKAN, SOUTHEAST ALASKA, COLLECTED AUGUST 29, 2024

Jenna M. Zechmann, Martin C. Larsen, and Gabriel J. Wolken

Raw Data File 2024-31



Location map of survey area.

This report has not been reviewed for technical content or for conformity to the editorial standards of DGGS.

2024
STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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LIDAR-DERIVED ELEVATION DATA FOR KETCHIKAN, SOUTHEAST ALASKA, COLLECTED AUGUST 29, 2024

Jenna M. Zechmann[1], Martin C. Larsen[1], and Gabriel J. Wolken[1]

INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) used aerial lidar to produce a classified point cloud, digital surface model (DSM), digital terrain model (DTM), and an intensity model of Ketchikan, Southeast Alaska, during leaf-on conditions (cover figure). The survey provides snow-free surface elevations for use in landslide hazard analysis after a fatal landslide occurred in downtown Ketchikan on August 25, 2024. Aerial lidar data were collected on August 29, 2024, and ground control data were collected on August 30–31, 2024, and subsequently merged and processed using a suite of geospatial processing software. This data collection is released as a Raw Data File with an open end-user license. All files are available to download on the DGGS website at https://doi.org/10.14509/31453.

LIST OF DELIVERABLES

Classified Points
DSM and DTM
Intensity Image
Metadata

MISSION PLAN

Aerial Lidar Survey Details

DGGS used a Riegl VUX1-LR22 laser scanner with a global navigation satellite system (GNSS) and Northrop Grumman LN-200C inertial measurement unit (IMU) integrated by Phoenix LiDAR Systems. The sensor can collect a maximum of 1,500,000 points per second at a range of 230 m, or a minimum of 50,000 points per second at 1,000 m (ranges assume ≥20 percent natural reflectance). The scanner operated with a pulse refresh rate of 800,000 pulses per second at a scan rate of 160 revolutions per second. We used a Bell 206 helicopter to survey from an elevation of approximately 100–300 m above ground level, at a ground speed of roughly 30 m/s, and with a scan angle set from 80 to 280 degrees. The total survey area covers approximately 11.1 km^2 (yellow outline in the cover figure), with a 3.1 km^2 portion of the block considered a priority area of interest (blue outline in the cover figure).

Weather Conditions and Flight Times

The survey area was accessed by air from Temsco Helicopters in Ketchikan (fig. 1). Data were collected from 12:05 pm to 1:05 pm and from 3:05 pm to 4:00 pm (AKST). The weather throughout the survey was overcast with scattered low-level clouds and no wind. For a GNSS base station occupation to later correct lidar survey flightlines, we set up a Trimble R10-2 on a jetty on Tongass Narrows (fig. 1).

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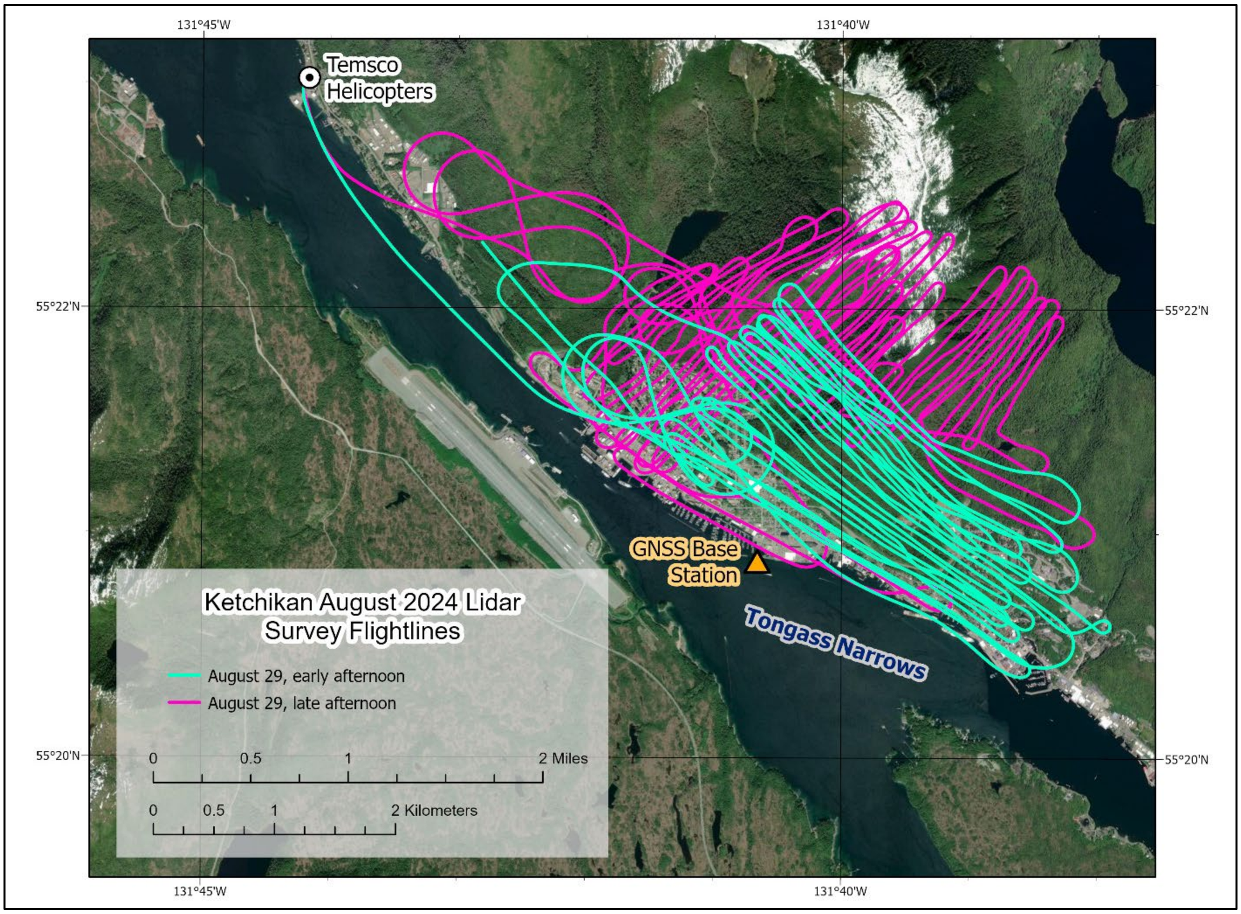

Figure 1. Lidar data collection flightlines.

PROCESSING REPORT

Lidar Dataset Processing

We processed point data in Spatial Explorer for initial filtering and multiple-time-around (MTA) disambiguation. MTA errors, corrected in this process, result from ambiguous interpretations of received pulse time intervals and occur more frequently with higher pulse refresh rates. IMU and GNSS data were processed in Inertial Explorer, and flightline information was integrated with the point cloud in Spatial Explorer. We calibrated the point data at an incrementally precise scale of sensor movement and behavior, incorporating sensor velocity, roll, pitch, and yaw fluctuations throughout the survey. For the lidar data collection, the average pulse density is 218.7 pulses/m^2, and the average pulse spacing is 6.8 cm. Within the priority region, the average pulse density is 325.4 pulses/m^2, and the average pulse spacing is 5.6 cm.

We created a macro (an ordered list of point classification commands tailored to this dataset) in Terrasolid software and classified points in accordance with the American Society for Photogrammetry & Remote Sensing (ASPRS) 2019 guidelines (ASPRS, 2019). Once classified, we applied a geometric transformation and converted the points from ellipsoidal heights to GEOID12B (Alaska) orthometric heights.

Raster products were derived from the point cloud in ArcGIS Pro. A 50-cm DSM was interpolated from maximum elevations of the ground, vegetation, bridge deck, wire, and building classes using a binning method. A 50-cm DTM was interpolated from all ground-class returns using a binning method and minimum elevation values. We also produced a 20-cm intensity image using average binning in ArcGIS Pro, with no normalization or corrections applied.

Higher-resolution elevation products were also produced within the high-priority region. A 20-cm DSM was interpolated from elevation values in the ground, vegetation, bridge deck, wire, and building classes using a triangulation method. A 20-cm DTM was made using a triangulation interpolation from all ground-class returns.

Classified Point Cloud

Classified point cloud data are provided in LAZ format. Data are classified following ASPRS 2019 guidelines (table 1) and contain return and intensity information. For classified ground points, the average point density (fig. 2) is 12.4 pts/m^2 and the average spacing is 28.4 cm; within the high-priority region, the average ground point density is 11.5 pts/m^2 and the average spacing is 29.4 cm.

Table 1. Point cloud class code definitions.

Class Code	Description
1	Unclassified
2	Ground
3	Low Vegetation, ≥0.0m, <0.5m
4	Medium Vegetation, ≥0.5m, <3m
5	High Vegetation, ≥3m, ≤40m
7	Low Noise
14	Wire (Conductor)
17	Bridge Deck
18	High Noise
19	Overhead Structure
30	Noise (manually classified)

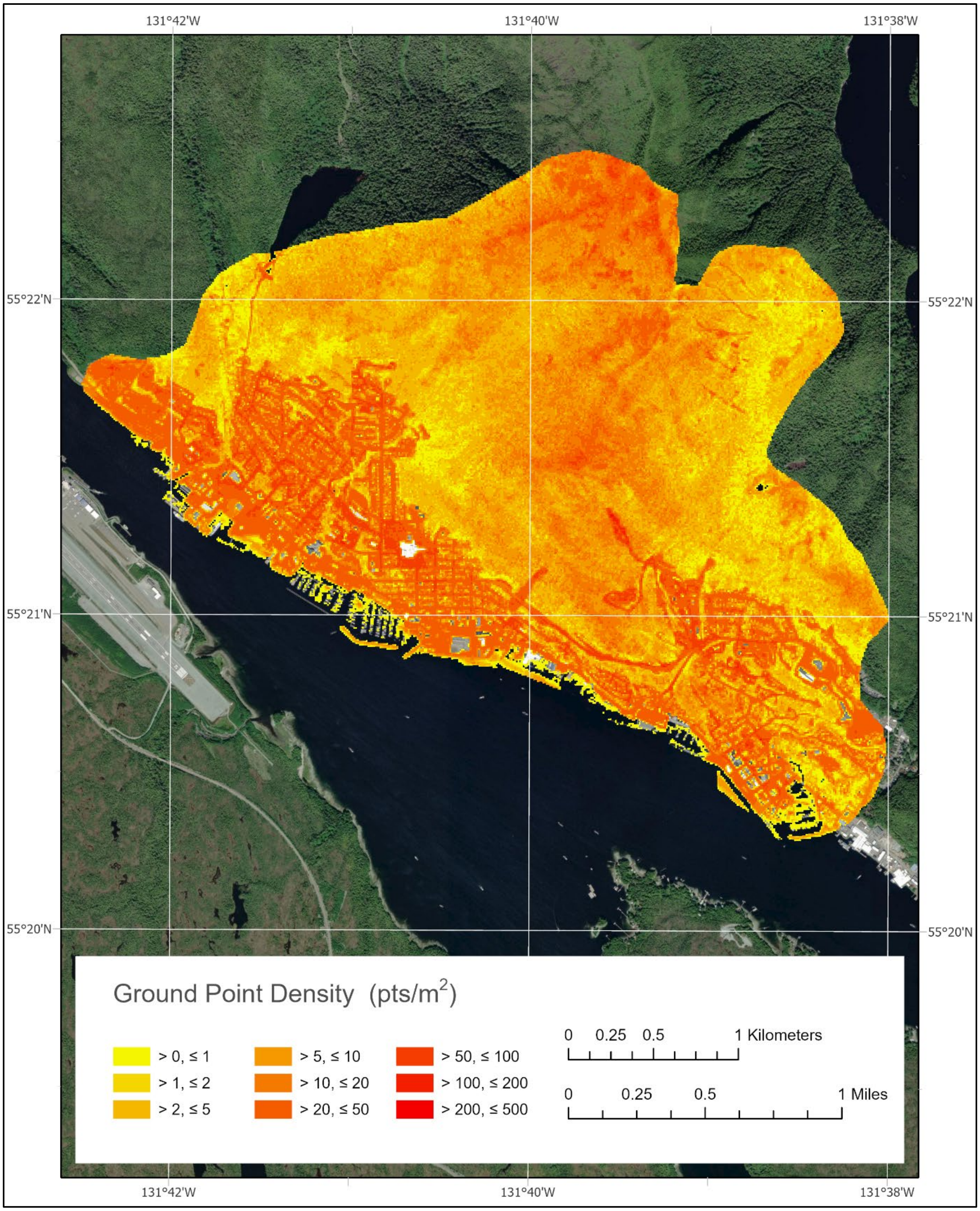

Figure 2. Ground point density for the survey displayed as a raster.

Digital Surface Model

The DSM represents surface elevations, including heights of vegetation, buildings, powerlines, bridge decks, etc. The DSM is a single-band, 32-bit GeoTIFF file of 50-cm resolution. No Data value is set to -3.40282306074e+38 (32-bit, floating-point minimum). The DSM from the high-priority area is a single-band, 32-bit GeoTIFF file of 20-cm resolution, with a No Data value of -3.40282306074e+38.

Digital Terrain Model

The DTM represents bare earth or snow surface elevations, excluding vegetation, bridge decks, buildings, etc. The DTM is a single-band, 32-bit GeoTIFF file of 50-cm resolution. No Data value is set to -3.40282306074e+38. The DTM from the high-priority area is a single-band, 32-bit GeoTIFF file of 20-cm resolution, with a No Data value of -3.40282306074e+38.

Lidar Intensity Image

The lidar intensity image illustrates the relative amplitude of reflected signals contributing to the point cloud. Lidar intensity is (1) primarily a function of scanned object reflectance in relation to the signal frequency, (2) dependent on ambient conditions, and (3) not necessarily consistent between separate scans. The intensity image is a single-band, 16-bit unsigned GeoTIFF file of 20-cm resolution. No Data value is set to 0.

SURVEY REPORT

Ground Survey Details

Ground control points were collected from August 30–31, 2024. We deployed a Trimble R10-2 GNSS base receiver on a jetty along Tongass Narrows (cover figure) and surveyed points with a rover Trimble R10-2 GNSS receiver/Mesa controller within the survey area. We collected 115 ground control points and checkpoints, with 51 located on markers (crosswalks and other paint lines) with enough intensity contrast with their surroundings that they were visible in the lidar data. Surveyed points were used to correct the point cloud vertically and horizontally and to calculate the vertical and horizontal accuracy of the corrected point cloud. The checkpoints and ground control points were collected on bare earth (i.e., gravel, dirt, or pavement).

Coordinate System and Datum

We processed and delivered all data in NAD83 (2011) UTM9N and vertical datum NAVD88 GEOID12B.

Horizontal Accuracy

The offset between the intensity image and 25 ground control points was -115.6 cm measured west to east and +57.9 cm measured south to north (app. 1). This was reduced to +0.7 cm and +4.4 cm, respectively, by applying a constant horizontal correction (app. 2). We used 26 checkpoints to determine the horizontal accuracy of the corrected point cloud by measuring the offset between checkpoints and their respective locations in an intensity image produced from the corrected point cloud. The project horizontal accuracy has a root mean square error (RMSE) of 7.6 cm in the east-west direction and 15.9 cm in the north-south direction (app. 2).

Vertical Accuracy

We measured a mean elevation offset of -10.2 cm between 58 control points and the horizontally corrected point cloud (app. 3). This offset was reduced to -0.1 cm by applying a constant vertical correction to the lidar point data (app. 4). We used 57 checkpoints to determine the vertical accuracy of the point cloud ground class using a Triangulated Irregular Network (TIN) approach. The project vertical accuracy has a root mean square error (RMSE) of 6.4 cm (app. 4). We evaluated the relative accuracy for this dataset as the interswath overlap consistency and measured it at 7.6 cm RMSE.

Data Consistency and Completeness

This is a full-release dataset. There was no over-collect. Data quality is consistent throughout the survey.

ACKNOWLEDGMENTS

This survey area lies within the traditional homelands of the Tlingit peoples. This work was funded by the Alaska Department of Military and Veterans Affairs Division of Homeland Security and Emergency Management through emergency response funds from the Federal Emergency Management Agency. We thank Coastal Helicopters for their expertise and contribution to these data products and Temsco Helicopters for allowing us to use their facilities. We also thank the residents, first responders, and road clearing workers of Ketchikan for allowing us to operate in the landslide area. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of Alaska.

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The American Society for Photogrammetry & Remote Sensing (ASPRS), 2019, LAS Specification 1.4 - R15. https://www.asprs.org/wp-content/uploads/2019/07/LAS_1_4_r15.pdf

APPENDIX 1: HORIZONTAL GROUND CONTROL POINTS

GCP Name	GCP Easting (m)	GCP Northing (m)	Pointcloud Easting (m)	Pointcloud Northing (m)	Easting Offset (m)	Northing Offset (m)
gcp26	330065.795	6137300.681	330064.498	6137301.221	-1.297	0.540
gcp27	330065.932	6137304.355	330064.728	6137305.012	-1.204	0.657
gcp37	330377.609	6137290.617	330376.450	6137291.189	-1.159	0.572
gcp38	330386.519	6137290.223	330385.421	6137290.869	-1.098	0.646
gcp52	332324.715	6136971.172	332323.624	6136971.756	-1.091	0.584
gcp53	332329.887	6136965.179	332328.827	6136965.692	-1.060	0.513
gcp80	332189.378	6136197.652	332188.196	6136198.246	-1.182	0.594
gcp81	332169.400	6136174.649	332168.163	6136175.281	-1.237	0.632
gcp90	330702.871	6136808.789	330701.703	6136809.359	-1.168	0.570
gcp91	330691.121	6136826.873	330689.983	6136827.415	-1.138	0.542
gcp96	330319.693	6136850.522	330318.560	6136851.053	-1.133	0.531
gcp97	330322.351	6136849.937	330321.146	6136850.535	-1.205	0.598
gcp104	330323.719	6136843.420	330322.601	6136843.972	-1.118	0.552
gcp105	330321.024	6136843.964	330319.885	6136844.360	-1.139	0.396
gcp106	330318.358	6136844.536	330317.202	6136845.104	-1.156	0.568
gcp119	330603.194	6136750.865	330602.170	6136751.440	-1.024	0.575
gcp123	330596.193	6136754.571	330595.089	6136755.191	-1.104	0.620
gcp124	330596.094	6136751.860	330594.960	6136752.410	-1.134	0.550
gcp133	331630.019	6136314.722	331628.885	6136315.206	-1.134	0.484
gcp136	331629.519	6136315.046	331628.371	6136315.670	-1.148	0.624
gcp138	331621.365	6136316.084	331620.112	6136316.846	-1.253	0.762
gcp140	331624.152	6136319.001	331623.049	6136319.599	-1.103	0.598
gcp142	331625.061	6136322.910	331623.839	6136323.466	-1.222	0.555
gcp143	331625.558	6136322.675	331624.304	6136323.315	-1.254	0.640
gcp144	331626.628	6136325.504	331625.496	6136326.076	-1.132	0.572
				Average offset (m)	-1.156	0.579
				Minimum offset (m)	-1.297	0.396
				Maximum offset(m)	-1.024	0.762
				Average magnitude error (m)	1.156	0.579
				Root mean square error (m)	1.157	0.583
				Standard deviation (m)	0.063	0.066

APPENDIX 2: HORIZONTAL CHECK POINTS

Check Point Name	Checkpoint Easting (m)	Checkpoint Northing (m)	Corrected Pointcloud Easting (m)	Corrected Pointcloud Northing (m)	Easting Offset (m)	Northing Offset (m)
gcp24	330056.195	6137301.106	330056.118	6137301.027	-0.077	-0.079
gcp25	330065.311	6137290.484	330065.259	6137290.514	-0.052	0.030
gcp28	330056.372	6137304.742	330056.403	6137304.830	0.031	0.088
gcp29	330069.417	6137299.854	330069.449	6137300.028	0.032	0.173
gcp36	330374.884	6137287.038	330375.102	6137287.087	0.218	0.049
gcp39	330387.199	6137286.516	330387.103	6137286.430	-0.097	-0.086
gcp40	330390.510	6137285.460	330390.595	6137285.462	0.085	0.002
gcp41	330390.281	6137278.495	330390.319	6137278.441	0.038	-0.054
gcp42	330386.845	6137276.288	330386.860	6137276.159	0.015	-0.129
gcp79	332194.922	6136224.364	332194.946	6136224.411	0.024	0.047
gcp82	332174.439	6136178.794	332174.404	6136178.899	-0.035	0.105
gcp98	330325.066	6136849.351	330324.991	6136849.401	-0.075	0.050
gcp99	330327.722	6136848.762	330327.734	6136848.651	0.012	-0.111
gcp101	330330.465	6136848.141	330330.490	6136848.164	0.025	0.023
gcp102	330329.085	6136842.282	330329.139	6136842.761	0.054	0.479
gcp103	330326.415	6136842.859	330326.545	6136843.355	0.130	0.496
gcp118	330603.124	6136748.116	330603.121	6136748.114	-0.003	-0.002
gcp120	330603.334	6136753.608	330603.284	6136753.501	-0.050	-0.107
gcp121	330603.234	6136756.352	330603.158	6136756.302	-0.076	-0.050
gcp122	330596.285	6136757.322	330596.403	6136757.275	0.118	-0.047
gcp126	330564.226	6136897.731	330564.135	6136897.679	-0.091	-0.052
gcp134	331628.052	6136311.658	331628.005	6136311.711	-0.047	0.053
gcp135	331627.522	6136311.972	331627.562	6136311.999	0.040	0.027
gcp139	331623.708	6136319.238	331623.667	6136319.215	-0.041	-0.024
gcp141	331621.851	6136315.742	331621.918	6136315.983	0.067	0.241
gcp145	331626.139	6136325.754	331626.078	6136325.764	-0.061	0.010
				Average offset (m)	0.007	0.044
				Minimum offset (m)	-0.097	-0.129
				Maximum offset (m)	0.218	0.496
				Average magnitude error (m)	0.061	0.101
				Root mean square error (m)	0.076	0.159
				Standard deviation (m)	0.075	0.153

APPENDIX 3: VERTICAL GROUND CONTROL POINTS

GCP Name	Easting (m)	Northing (m)	GCP Z (m)	Pointcloud Z (m)	Elevation Difference (Pointcloud Z – GCP Z) (m)
gcp5	329089.354	6137897.341	8.605	8.452	-0.153
gcp8	329310.137	6138023.540	42.138	41.980	-0.158
gcp9	329303.077	6138180.179	58.582	58.443	-0.139
gcp10	329262.600	6138306.011	69.057	68.950	-0.107
gcp14	329444.576	6138425.676	88.572	88.489	-0.083
gcp17	329998.231	6138240.238	116.552	116.479	-0.073
gcp23	330080.751	6137800.068	78.474	78.369	-0.105
gcp26	330065.795	6137300.681	31.849	31.701	-0.148
gcp27	330065.932	6137304.355	31.972	31.749	-0.223
gcp30	330068.997	6137290.321	31.851	31.719	-0.132
gcp31	330299.779	6137493.758	62.827	62.689	-0.138
gcp34	330353.058	6137393.047	53.636	53.488	-0.148
gcp35	330358.094	6137370.693	53.803	53.689	-0.114
gcp37	330377.609	6137290.617	44.846	44.703	-0.143
gcp38	330386.519	6137290.223	45.005	44.854	-0.151
gcp43	330234.415	6137327.663	49.994	49.841	-0.153
gcp44	330590.049	6137273.451	58.361	58.167	-0.194
gcp46	330595.226	6137190.211	44.960	44.792	-0.168
gcp47	331133.759	6136797.276	38.440	38.286	-0.154
gcp50	331990.692	6136950.375	54.517	54.332	-0.185
gcp52	332324.715	6136971.172	45.873	45.611	-0.262
gcp53	332329.887	6136965.179	45.776	45.553	-0.223
gcp76	332108.655	6136301.560	44.593	44.438	-0.155
gcp78	332196.093	6136222.427	31.178	31.056	-0.122
gcp80	332189.378	6136197.652	32.580	32.445	-0.135
gcp81	332169.400	6136174.649	32.397	32.256	-0.141
gcp83	332110.008	6135977.098	6.138	5.951	-0.187
gcp84	332118.977	6135954.520	5.898	5.741	-0.157
gcp86	332169.228	6135885.727	5.887	5.711	-0.176
gcp90	330702.871	6136808.789	5.802	5.614	-0.188
gcp91	330691.121	6136826.873	5.849	5.657	-0.192
gcp94	330530.694	6136754.094	5.696	5.501	-0.195
gcp96	330319.693	6136850.522	5.626	5.585	-0.041
gcp97	330322.351	6136849.937	5.630	5.594	-0.036
gcp100	330330.463	6136848.154	5.668	5.635	-0.033
gcp104	330323.719	6136843.420	5.593	5.581	-0.012
gcp105	330321.024	6136843.964	5.511	5.498	-0.013
gcp106	330318.358	6136844.536	5.490	5.480	-0.010

GCP Name	Easting (m)	Northing (m)	GCP Z (m)	Pointcloud Z (m)	Elevation Difference (Pointcloud Z – GCP Z) (m)
gcp107	329299.913	6137604.269	5.965	5.948	-0.017
gcp108	329270.760	6137601.775	5.992	5.989	-0.003
gcp109	329248.269	6137586.108	6.000	5.981	-0.019
gcp111	329323.136	6137594.309	5.888	5.879	-0.009
gcp113	329907.187	6137199.647	5.569	5.539	-0.030
gcp119	330603.194	6136750.865	5.634	5.576	-0.058
gcp123	330596.193	6136754.571	5.588	5.535	-0.053
gcp124	330596.094	6136751.860	5.618	5.563	-0.055
gcp127	330615.960	6136821.327	5.556	5.523	-0.033
gcp128	331612.182	6136298.352	6.210	6.152	-0.058
gcp129	331590.091	6136303.469	6.235	6.169	-0.066
gcp130	331595.468	6136319.093	6.249	6.219	-0.030
gcp133	331630.019	6136314.722	6.218	6.173	-0.045
gcp136	331629.519	6136315.046	6.209	6.180	-0.029
gcp138	331621.365	6136316.084	6.147	6.122	-0.025
gcp140	331624.152	6136319.001	6.120	6.071	-0.049
gcp142	331625.061	6136322.910	6.115	6.068	-0.047
gcp143	331625.558	6136322.675	6.107	6.065	-0.042
gcp144	331626.628	6136325.504	6.071	6.013	-0.058
gcp146	331626.509	6136326.078	6.059	6.016	-0.043
Average elevation difference (dZ) (m)	-0.102				
Minimum dZ (m)	-0.262				
Maximum dZ (m)	-0.003				
Average magnitude error (m)	0.102				
Root mean square error (m)	0.123				
Standard deviation (m)	0.069				

APPENDIX 4: VERTICAL CHECK POINTS

Check Point Name	Easting (m)	Northing (m)	Checkpoint Z (m)	Corrected Pointcloud Z (m)	Elevation Difference (Corrected Pointcloud Z –Checkpoint Z) (m)
gcp1	330287.300	6136844.582	5.626	5.558	-0.068
gcp3	330339.865	6136840.053	5.838	5.784	-0.054
gcp4	329095.964	6137890.317	8.759	8.705	-0.054
gcp6	329239.829	6138132.389	47.242	47.194	-0.048
gcp11	329281.128	6138341.312	70.630	70.629	-0.001
gcp12	329291.888	6138597.183	91.144	91.138	-0.006
gcp13	329305.624	6138595.433	89.723	89.621	-0.102
gcp16	329883.789	6138243.825	102.449	102.487	0.038
gcp20	330018.363	6138390.323	136.650	136.632	-0.018
gcp22	330249.117	6137997.620	114.701	114.704	0.003
gcp24	330056.195	6137301.106	31.820	31.774	-0.046
gcp25	330065.311	6137290.484	31.781	31.741	-0.040
gcp28	330056.372	6137304.742	32.008	31.973	-0.035
gcp29	330069.417	6137299.854	31.820	31.737	-0.083
gcp36	330374.884	6137287.038	44.729	44.664	-0.065
gcp39	330387.199	6137286.516	45.086	45.040	-0.046
gcp40	330390.510	6137285.460	45.221	45.174	-0.047
gcp41	330390.281	6137278.495	44.839	44.790	-0.049
gcp42	330386.845	6137276.288	44.465	44.406	-0.059
gcp45	330609.112	6137261.675	60.231	60.185	-0.046
gcp48	331148.746	6136801.674	40.385	40.330	-0.055
gcp51	332097.385	6137053.964	49.755	49.644	-0.111
gcp54	332337.736	6136970.535	45.922	45.798	-0.124
gcp55	332351.841	6136892.238	53.298	53.196	-0.102
gcp77	332132.185	6136317.657	43.030	42.988	-0.042
gcp79	332194.922	6136224.364	31.167	31.135	-0.032
gcp82	332174.439	6136178.794	32.341	32.308	-0.033
gcp85	332131.820	6135936.917	5.864	5.807	-0.057
gcp87	332189.109	6135864.184	5.484	5.425	-0.059
gcp88	331591.306	6136373.033	5.878	5.813	-0.065
gcp89	331573.851	6136372.332	5.977	5.911	-0.066
gcp93	330560.414	6136750.948	5.623	5.529	-0.094
gcp98	330325.066	6136849.351	5.644	5.717	0.073
gcp99	330327.722	6136848.762	5.656	5.728	0.072
gcp101	330330.465	6136848.141	5.670	5.737	0.067
gcp102	330329.085	6136842.282	5.656	5.739	0.083
gcp103	330326.415	6136842.859	5.629	5.716	0.087
gcp110	329302.522	6137599.225	5.907	5.994	0.087
gcp112	329896.116	6137186.556	5.303	5.377	0.074

Check Point Name	Easting (m)	Northing (m)	Checkpoint Z (m)	Corrected Pointcloud Z (m)	Elevation Difference (Corrected Pointcloud Z –Checkpoint Z) (m)
gcp114	329889.321	6137206.908	5.592	5.663	0.071
gcp115	329911.544	6137201.370	5.674	5.737	0.063
gcp116	330599.149	6136747.068	5.652	5.693	0.041
gcp117	330600.247	6136760.276	5.497	5.557	0.060
gcp118	330603.124	6136748.116	5.640	5.674	0.034
gcp120	330603.334	6136753.608	5.611	5.652	0.041
gcp121	330603.234	6136756.352	5.564	5.622	0.058
gcp122	330596.285	6136757.322	5.543	5.592	0.049
gcp125	330570.713	6136754.561	5.412	5.471	0.059
gcp126	330564.226	6136897.731	5.607	5.704	0.097
gcp131	331582.647	6136331.529	6.280	6.327	0.047
gcp132	331595.776	6136380.374	5.584	5.648	0.064
gcp134	331628.052	6136311.658	6.241	6.308	0.067
gcp135	331627.522	6136311.972	6.227	6.284	0.057
gcp137	331629.512	6136315.051	6.214	6.282	0.068
gcp139	331623.708	6136319.238	6.086	6.144	0.058
gcp141	331621.851	6136315.742	6.142	6.209	0.067
gcp145	331626.139	6136325.754	6.080	6.136	0.056
Average elevation difference (dZ) (m)	-0.001				
Minimum dZ (m)	-0.124				
Maximum dZ (m)	0.097				
Average magnitude error (m)	0.059				
Root mean square error (m)	0.064				
Standard deviation (m)	0.064				