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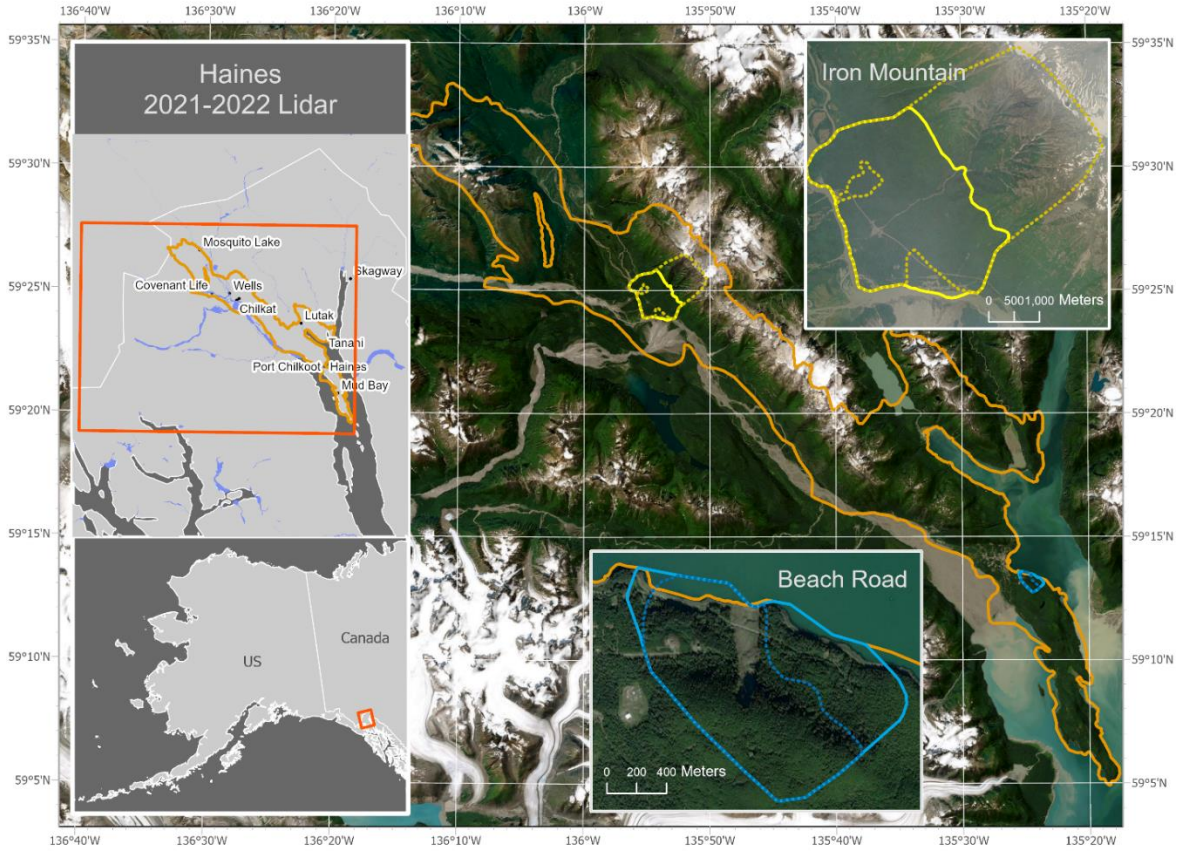
Raw Data File 2023-18



Location map of survey area.

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

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STATE OF ALASKA
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DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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LIDAR-DERIVED ELEVATION DATA FOR HAINES, SOUTHEAST ALASKA, COLLECTED OCTOBER 2021 AND OCTOBER 2022

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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 Haines, Southeast Alaska (cover figure) during snow-free ground conditions. The survey provides snow-free surface elevations for assessing landslide hazards and, in two active slide areas (dashed lines, cover figure), elevation changes between October 2021 and October 2022. Ground control data were collected November 1–3, 2021, and aerial lidar data were collected October 24–26, 2021, and October 2–4, 2022, 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/10.14509/201034.

LIST OF DELIVERABLES

Classified Points
DSM and DTMs
Intensity Image
Metadata

MISSION PLAN

Aerial Lidar Survey Details

DGGS used a Riegl VUX1-LR laser scanner integrated with a global navigation satellite system (GNSS) and Northrop Grumman LN-200C inertial measurement unit (IMU) designed by Phoenix LiDAR Systems. The sensor can collect up to 820,000 points per second at a range of up to 150 m. The scanner operated with a pulse refresh rate of 200,000–400,000 pulses per second over forested terrain, and 50,000–100,000 pulses per second over alpine terrain, with a scan rate between 80 and 220 lines per second. We used a Bell Jet Ranger helicopter to survey from an elevation of approximately 50–700 m above ground level, at a ground speed of approximately 30 m/s, and with a scan angle set from 80 to 280 degrees. The total survey area covers approximately 471 km^2 (cover figure).

Weather Conditions and Flight Times

The survey area was accessed by air from Haines Airport (fig. 1). See table 1 for data collection start and end times and weather conditions. The 2021 weather conditions were not ideal, and the resultant dataset was not complete. We revisited the area in 2022 to collect additional data in the areas with poor coverage.

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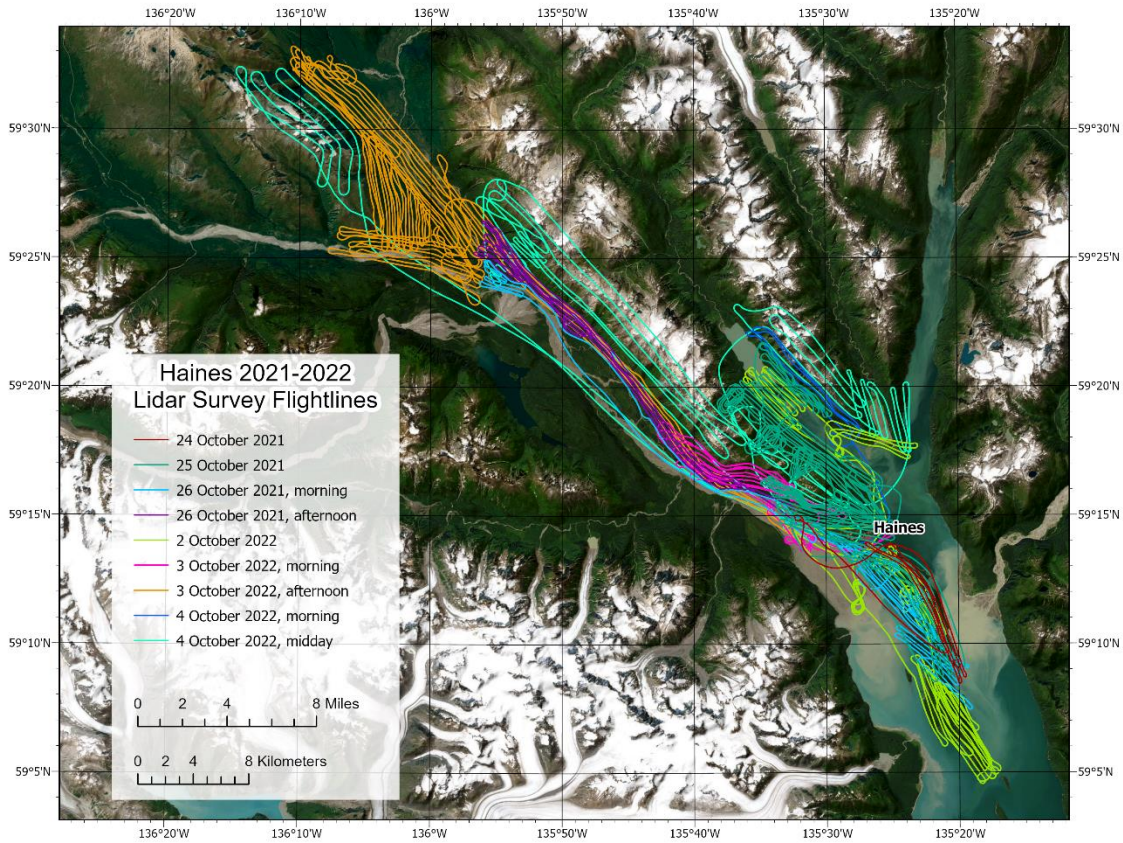

Figure 1. Lidar data collection flightlines.

Table 1. Data collection start and end times and weather conditions for the lidar collection survey.

Date	Start time (AKST)	End time (AKST)	Weather conditions
24 October 2021	3:41 pm	4:38 pm	Partly cloudy
25 October 2021	8:52 am	4:41 pm	Partly cloudy
26 October 2021	9:02 am	12:14 pm	Rain and snow showers
26 October 2021	2:24 pm	4:29 pm	Rain and snow showers
2 October 2022	12:00 pm	4:08 pm	Partly cloudy with wind
3 October 2022	9:51 am	10:41 am	Partly cloudy with wind
3 October 2022	11:41 am	4:54 pm	Partly cloudy with wind
4 October 2022	8:24 am	8:49 am	Partly cloudy with wind
4 October 2022	9:05 am	1:48 pm	Partly cloudy with wind

PROCESSING REPORT

Lidar Dataset Processing

To produce the final point cloud and whole-area DTM and DSM, we merged point data collected in 2021 with point data collected in 2022. Once data processing was complete, we

produced additional detail DTMs by extracting points by year from two specific locations, namely Beach Road and Iron Mountain (cover figure).

We processed point data in SDCimport software 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. We processed IMU and GNSS data in Inertial Explorer, and we used Spatial Explorer software to integrate flightline information with the point cloud. 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.

We created macros in Terrasolid software and classified points per 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.

We used ArcGIS Pro to derive raster products from the point cloud. A 50 cm DSM was interpolated from maximum return values from the ground, vegetation, bridge deck, and building classes using a binning method. A 50 cm DTM was interpolated from all ground class returns using a binning method and minimum values. Additionally, four closeup DTMs were created: a 20 cm DTM of the Iron Mountain area using 2021 lidar data; a 20 cm DTM of the Iron Mountain area using 2022 lidar data; a 20 cm DTM of the Beach Road slide using 2021 lidar data; and a 20 cm DTM of the Beach Road slide using 2022 lidar data. All closeup DTMs used triangulation for interpolation. We also produced an intensity image for the entire area using average binning in ArcGIS Pro.

Classified Point Cloud

Classified point cloud data are provided in LAS format. Data are classified following ASPRS 2019 guidelines (table 2) and contain return and intensity information. For all ground points, the average point spacing is 57.0 cm, and the average density is 3.08 pts/m^2 (fig. 2).

For the 2021 Iron Mountain closeup (solid yellow line in the cover image), the average ground point spacing is 36.4 cm, and the average ground point density is 7.54 pts/m^2; for the Iron Mountain 2022 dataset (yellow dashed line in the cover image), the average ground point spacing is 58.2 cm, and the average ground point density is 2.95 pts/m^2.

The Beach Road 2021 closeup (blue solid line in the cover image) has an average ground point spacing of 36.8 cm and an average ground point density of 7.37 pts/m^2; for the 2022 Beach Road closeup (blue dashed line in cover image) the average ground point spacing and density were 50.3 cm and 3.95 pts/m^2, respectively.

Table 2. 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, ≤50m
6	Building
7	Low Noise
17	Bridge Deck
18	High Noise
30	Noise (manually classified)

Digital Surface Model

The DSM represents surface elevations, including heights of vegetation, buildings, powerlines, etc. The DSM is a single-band, 32-bit GeoTIFF file of 50-centimeter resolution. No Data value is set to -3.40282306074e+38 (32-bit, floating-point minimum).

Digital Terrain Model

The DTMs represent bare earth elevations, excluding vegetation, bridges, buildings, etc. We produced five DTMs, one 50-cm DTM named 'DTM' and four 20-cm DTMs named 'DTM_detail_iron_mountain_2021, 'DTM_detail_iron_mountain_2022,' 'DTM_detail_beach _road_2021,' and 'DTM_detail_beach_road_2022.' All DTMs are single-band, 32-bit float GeoTIFF files. The higher-resolution DTMs were identified as areas of significant ground surface elevation change between October 2021 and October 2022. No Data value is set to -3.40282306074e+38.

Lidar Intensity Image

The lidar intensity image describes the relative amplitude of reflected signals contributing to the point cloud. Lidar intensity is primarily a function of scanned object reflectance in relation to the signal frequency, is dependent on ambient conditions, and is not necessarily consistent between separate scans. The intensity image is a single-band, 16-bit unsigned GeoTIFF file of 0.5-meter resolution. No Data value is set to -3.40282306074e+38.

SURVEY REPORT

Ground Survey Details

Ground control points were collected by the Alaska Division of Mining, Land and Water (DMLW) during several sessions from November 1–3, 2021. They deployed a Trimble R12 GNSS receiver to provide a base station occupation and real-time kinematic (RTK) corrections to points surveyed with a rover Trimble R12i GNSS receiver (internal antenna). Each survey session covered a specific geographical area. The base station was moved to different sites to remain within 15 km and line-of-sight of the rover. The DMLW collected 322 ground control points and checkpoints to use for calibration and to assess the vertical accuracy of the point cloud. Points were collected in forest, shrubland, bare earth, and paved surfaces.

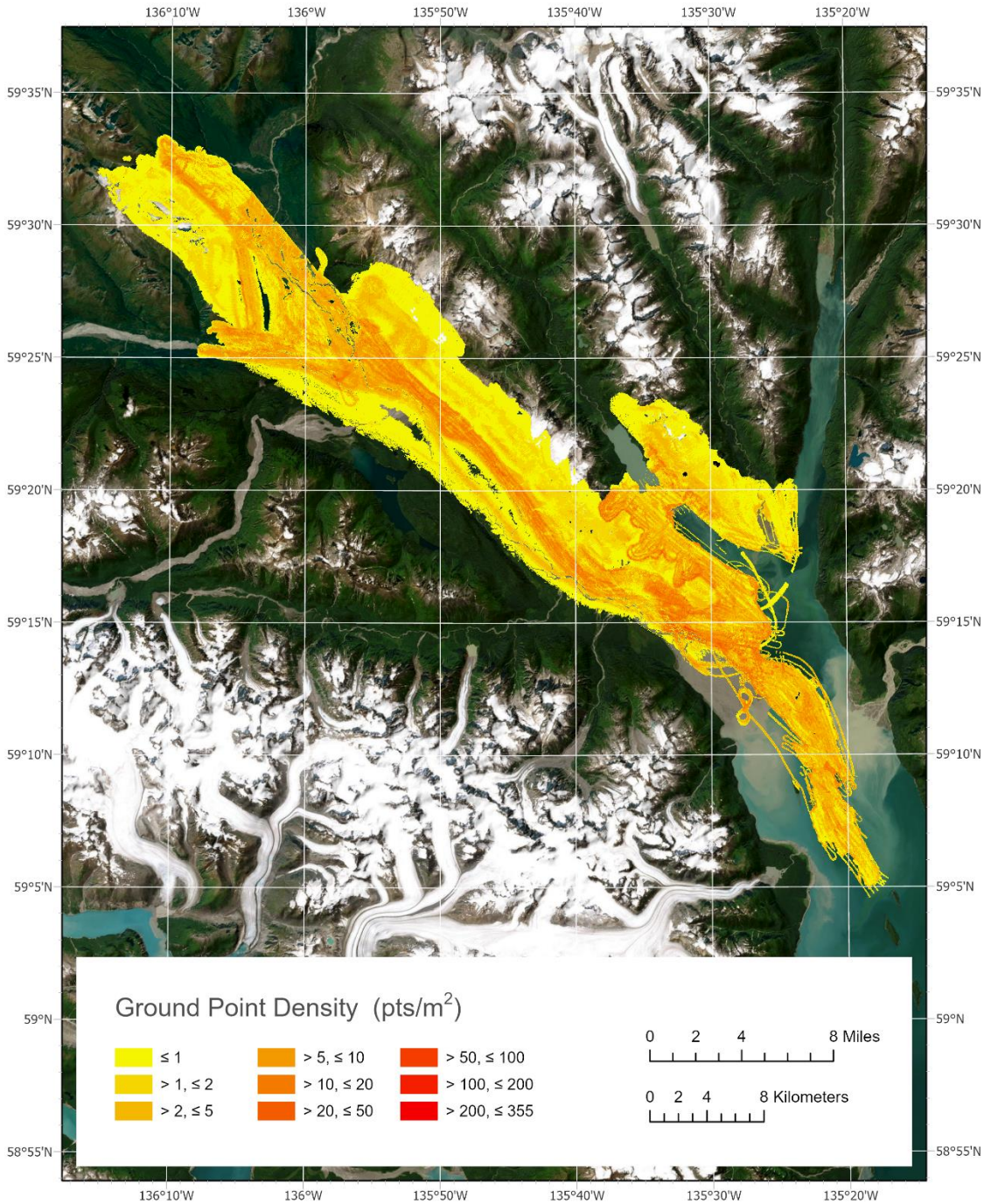

Figure 2. Ground point density for the survey displayed as a 10-meter raster.

Coordinate System and Datum

We processed and delivered all data in NAD83 (2011) UTM8N and vertical datum NAVD88 GEOID12B.

Horizontal Accuracy

We did not measure horizontal accuracy for this collection.

Vertical Accuracy

We measured a mean offset of -16.5 cm between 257 control points and the point cloud (app. 1). We reduced this offset to 0.8 cm by performing a rubber-sheet vertical correction of the lidar point data. We used 65 checkpoints to determine the vertical accuracy of the point cloud ground class using a Triangulated Irregular Network (TIN) approach. We calculated the project vertical accuracy to have a root mean square error (RMSE) of 6.4 cm (app. 2). We evaluated the relative accuracy for this dataset as the interswath overlap consistency and measured it at 8.6 cm RMSE.

Data Consistency and Completeness

This is a full-release dataset. There was no over-collect except for aircraft turns that were eliminated from the dataset. Data quality is consistent throughout the survey, save for a strip without coverage due to instrument error in the northern part of the study area, and over some glaciated areas where there were few returns due to ground cover conditions.

ACKNOWLEDGMENTS

This survey area is on the traditional homelands of the Tlingit people. This project was funded by the Federal Emergency Management Agency grant number EMS-2021-CA-00013. We thank Coastal Helicopters for their aviation expertise and contribution to these data products, and the Alaska Division of Mining, Land and Water for providing ground control points. Additionally, we thank Greg Palmeri of the Alaska Division of Forestry & Fire Protection for his help selecting survey area priorities. 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 U.S. Government.

REFERENCES

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

APPENDIX 1: GROUND CONTROL POINTS

GCP	Easting (m)	Northing (m)	GCP Z (m)	Pointcloud Z (m)	Dz (m)
1	474867.446	6570481.747	9.574	9.263	-0.311
2	474864.546	6570481.928	9.795	9.374	-0.421
3	450935.166	6583928.794	36.642	36.217	-0.425
4	476741.469	6564864.738	40.387	40.243	-0.144
5	476741.544	6564859.159	40.699	40.533	-0.166
6	476733.768	6564863.515	40.103	39.959	-0.144
7	476717.753	6564873.051	38.914	38.778	-0.136
8	476709.283	6564877.933	38.351	38.207	-0.144
9	476700.578	6564883.144	37.800	37.661	-0.139
10	476691.607	6564888.850	37.230	37.066	-0.164
11	476674.170	6564899.653	36.059	35.890	-0.169
12	476665.397	6564905.187	35.439	35.287	-0.152
13	476656.872	6564910.163	34.981	34.841	-0.140
14	476648.260	6564914.977	34.618	34.476	-0.142
15	476629.576	6564923.668	34.116	34.024	-0.092
16	476620.229	6564927.740	33.862	33.736	-0.126
17	476611.663	6564931.706	33.544	33.441	-0.103
18	476602.647	6564935.737	33.207	33.117	-0.090
19	476583.290	6564944.460	32.543	32.485	-0.058
20	476574.058	6564948.590	32.008	31.931	-0.077
21	476564.665	6564952.668	31.395	31.344	-0.051
22	476392.394	6565001.268	29.844	30.075	0.231
23	475189.380	6565381.975	8.667	8.355	-0.312
24	475268.710	6565298.715	10.369	10.095	-0.274
25	475203.335	6565351.064	8.792	8.614	-0.178
26	475202.894	6565343.308	8.762	8.364	-0.398
27	473968.497	6566311.037	13.638	13.480	-0.158
28	473954.045	6566333.677	12.780	12.615	-0.165
29	473945.895	6566344.749	12.937	12.749	-0.188
30	473955.269	6566345.809	12.889	12.732	-0.157
31	473974.913	6566343.830	13.805	13.659	-0.146
32	473984.040	6566341.868	14.203	14.056	-0.147
33	473993.186	6566340.571	14.659	14.509	-0.150
34	474002.597	6566339.552	15.175	15.018	-0.157
35	474017.625	6566348.087	15.718	15.574	-0.144
36	474020.982	6566355.861	15.372	15.234	-0.138
37	474022.547	6566363.715	14.845	14.706	-0.139
38	474023.711	6566372.014	14.265	14.137	-0.128
39	474025.988	6566388.620	13.614	13.493	-0.121
40	473752.437	6566439.428	11.248	11.333	0.085
41	472379.272	6567093.865	7.847	7.898	0.051
42	472383.203	6567126.103	9.325	9.197	-0.128

GCP	Easting (m)	Northing (m)	GCP Z (m)	Pointcloud Z (m)	Dz (m)
43	472396.812	6567143.866	10.432	10.316	-0.116
44	470760.704	6567341.860	9.601	9.266	-0.335
45	470763.113	6567332.995	9.175	8.949	-0.226
46	470744.414	6567349.410	9.564	9.280	-0.284
47	470731.549	6567351.483	9.913	9.651	-0.262
48	470723.903	6567358.125	9.962	9.681	-0.281
49	470715.867	6567364.617	10.007	9.742	-0.265
50	470706.726	6567371.597	10.061	9.782	-0.279
51	470689.046	6567383.226	10.086	9.816	-0.270
52	470679.165	6567388.874	10.066	9.792	-0.274
53	470670.140	6567393.826	10.069	9.798	-0.271
54	470660.722	6567398.334	10.076	9.799	-0.277
55	470642.482	6567405.670	10.078	9.818	-0.260
56	470632.910	6567409.018	10.079	9.804	-0.275
57	470623.595	6567411.859	10.078	9.807	-0.271
58	470613.537	6567414.420	10.071	9.812	-0.259
59	470593.298	6567418.542	10.053	9.774	-0.279
60	470583.406	6567419.805	9.981	9.690	-0.291
61	470573.305	6567420.864	9.894	9.593	-0.301
62	470563.140	6567421.827	9.772	9.475	-0.297
63	470542.231	6567423.565	9.654	9.324	-0.330
64	469563.960	6567791.907	7.686	7.454	-0.232
65	469558.736	6567799.301	7.735	7.274	-0.461
66	469551.015	6567808.076	8.542	8.346	-0.196
67	466341.284	6569740.783	11.619	11.478	-0.141
68	466335.201	6569729.002	11.429	11.268	-0.161
69	466357.142	6569738.803	13.399	13.253	-0.146
70	466352.956	6569758.977	13.299	13.401	0.102
71	466329.188	6569726.005	11.310	11.175	-0.135
72	466320.641	6569731.104	11.301	11.161	-0.140
73	466311.967	6569736.259	11.339	11.205	-0.134
74	466303.436	6569741.642	11.369	11.235	-0.134
75	466286.053	6569752.205	11.501	11.346	-0.155
76	466277.307	6569757.701	11.555	11.383	-0.172
77	466268.209	6569763.205	11.627	11.496	-0.131
78	466259.543	6569768.575	11.721	11.577	-0.144
79	466241.676	6569778.355	11.817	11.659	-0.158
80	466232.604	6569782.862	11.845	11.686	-0.159
81	466223.669	6569786.983	11.881	11.722	-0.159
82	466214.431	6569790.916	11.897	11.768	-0.129
83	466195.799	6569798.023	11.974	11.842	-0.132
84	466186.001	6569801.026	12.001	11.806	-0.195
85	466176.500	6569803.750	12.021	11.884	-0.137

GCP	Easting (m)	Northing (m)	GCP Z (m)	Pointcloud Z (m)	Dz (m)
86	466166.330	6569806.216	12.042	11.902	-0.140
87	462496.328	6570794.590	14.124	13.891	-0.233
88	462487.908	6570794.732	14.199	13.977	-0.222
89	462518.104	6570764.052	15.158	14.836	-0.322
90	459797.026	6573655.430	16.617	16.205	-0.412
91	459810.359	6573674.845	15.347	15.028	-0.319
92	459838.203	6573650.036	16.786	16.477	-0.309
93	457886.175	6576608.245	19.357	19.234	-0.123
94	457915.765	6576562.491	18.057	17.578	-0.479
95	457896.549	6576638.691	19.672	19.443	-0.229
96	457882.492	6576632.017	19.660	19.400	-0.260
97	457877.254	6576640.886	19.609	19.378	-0.231
98	457865.748	6576659.818	19.501	19.299	-0.202
99	457860.065	6576669.193	19.487	19.205	-0.282
100	457854.988	6576677.529	19.425	19.179	-0.246
101	457849.413	6576686.417	19.393	19.142	-0.251
102	457837.757	6576704.107	19.295	19.017	-0.278
103	457831.708	6576712.526	19.260	19.023	-0.237
104	457887.369	6576623.895	19.643	19.416	-0.227
105	457892.060	6576616.206	19.617	19.393	-0.224
106	457901.830	6576600.233	19.650	19.443	-0.207
107	457906.849	6576591.455	19.654	19.440	-0.214
108	457911.918	6576583.449	19.679	19.463	-0.216
109	457917.138	6576574.441	19.661	19.453	-0.208
110	457928.501	6576555.609	19.691	19.475	-0.216
111	457933.833	6576546.492	19.650	19.477	-0.173
112	474419.955	6565905.429	14.056	13.824	-0.232
113	474418.890	6565924.583	14.100	13.879	-0.221
114	474442.346	6565855.029	13.997	13.925	-0.072
115	474364.725	6563741.036	9.916	9.791	-0.125
116	474370.827	6563741.371	10.221	10.115	-0.106
117	474342.586	6563724.429	7.275	7.371	0.096
118	474373.720	6563744.665	10.519	10.357	-0.162
119	474376.729	6563735.138	10.524	10.386	-0.138
120	474380.080	6563724.822	10.569	10.428	-0.141
121	474383.205	6563714.841	10.580	10.468	-0.112
122	474389.463	6563693.963	10.560	10.463	-0.097
123	474392.677	6563683.977	10.568	10.483	-0.085
124	474395.823	6563673.683	10.599	10.531	-0.068
125	474399.114	6563662.941	10.618	10.513	-0.105
126	474405.842	6563642.240	10.656	10.539	-0.117
127	474409.547	6563632.414	10.668	10.585	-0.083
128	474413.582	6563622.534	10.717	10.648	-0.069

GCP	Easting (m)	Northing (m)	GCP Z (m)	Pointcloud Z (m)	Dz (m)
129	474418.025	6563612.994	10.726	10.658	-0.068
130	474428.562	6563595.419	10.579	10.472	-0.107
131	474434.793	6563587.196	10.551	10.434	-0.117
132	474441.410	6563579.450	10.514	10.387	-0.127
133	474448.626	6563571.925	10.456	10.306	-0.150
134	476631.319	6561223.324	8.109	8.046	-0.063
135	476577.619	6561268.893	8.145	8.062	-0.083
136	476556.739	6561286.850	7.749	7.749	0.000
137	477973.311	6559272.349	7.846	7.610	-0.236
138	478012.047	6559270.335	7.185	7.007	-0.178
139	478029.141	6559312.904	9.000	8.787	-0.213
140	478023.054	6559304.797	9.039	8.815	-0.224
141	478010.096	6559288.249	9.005	8.762	-0.243
142	478003.239	6559280.036	9.046	8.767	-0.279
143	477996.296	6559271.952	9.033	8.680	-0.353
144	477988.978	6559263.768	8.996	8.683	-0.313
145	477974.452	6559248.531	8.937	8.622	-0.315
146	477967.148	6559241.247	8.927	8.592	-0.335
147	477959.639	6559233.915	8.945	8.593	-0.352
148	477951.963	6559226.598	8.970	8.603	-0.367
149	477934.723	6559211.235	8.966	8.597	-0.369
150	477926.568	6559204.360	9.001	8.613	-0.388
151	477917.865	6559197.316	9.077	8.653	-0.424
152	477909.784	6559190.801	9.144	8.695	-0.449
153	477894.257	6559177.189	8.926	8.531	-0.395
154	477887.874	6559168.912	8.700	8.311	-0.389
155	477935.872	6558971.967	20.241	19.745	-0.496
156	478013.259	6558937.424	17.501	17.137	-0.364
157	478007.955	6558938.197	18.439	18.045	-0.394
158	477994.671	6558968.162	16.654	16.252	-0.402
159	474854.633	6570471.624	9.997	9.713	-0.284
160	474845.340	6570479.814	10.509	10.206	-0.303
161	474881.100	6570530.863	5.219	5.173	-0.046
162	474872.879	6570546.289	7.151	6.931	-0.220
163	474834.793	6570465.302	9.987	9.661	-0.326
164	474836.546	6570475.455	10.180	9.864	-0.316
165	474838.507	6570496.074	10.570	10.245	-0.325
166	474838.676	6570506.610	10.748	10.445	-0.303
167	474838.346	6570517.534	10.954	10.611	-0.343
168	474837.492	6570527.956	11.168	10.841	-0.327
169	474834.245	6570549.000	11.572	11.244	-0.328
170	474831.806	6570559.232	11.785	11.461	-0.324
171	474828.825	6570569.424	12.008	11.679	-0.329

GCP	Easting (m)	Northing (m)	GCP Z (m)	Pointcloud Z (m)	Dz (m)
172	474825.376	6570579.368	12.199	11.864	-0.335
173	474816.741	6570599.298	12.671	12.394	-0.277
174	474811.836	6570608.540	12.975	12.644	-0.331
175	474806.546	6570617.304	13.289	12.972	-0.317
176	474801.034	6570625.658	13.602	13.281	-0.321
177	474789.572	6570642.450	14.374	14.056	-0.318
178	474783.940	6570650.597	14.779	14.467	-0.312
179	471843.899	6572571.569	8.106	8.104	-0.002
180	471848.637	6572575.716	7.989	8.194	0.205
181	470749.301	6573400.343	9.341	9.283	-0.058
182	470749.297	6573400.347	9.313	9.283	-0.030
183	468906.709	6575134.270	5.691	5.510	-0.181
184	468889.362	6575130.331	8.517	8.081	-0.436
185	468883.979	6575123.876	8.188	8.167	-0.021
186	468846.547	6575213.591	7.830	7.603	-0.227
187	468410.243	6575454.558	7.454	7.311	-0.143
188	468406.821	6575464.085	7.391	7.304	-0.087
189	468404.115	6575473.867	7.474	7.330	-0.144
190	468401.932	6575483.868	7.455	7.354	-0.101
191	468399.275	6575504.121	7.413	7.294	-0.119
192	468398.300	6575514.626	7.439	7.266	-0.173
193	468397.408	6575524.756	7.369	7.207	-0.162
194	468396.558	6575535.263	7.447	7.255	-0.192
195	468394.959	6575555.494	7.590	7.424	-0.166
196	468394.223	6575565.304	7.670	7.468	-0.202
197	468393.396	6575575.305	7.756	7.560	-0.196
198	468392.605	6575585.582	7.910	7.775	-0.135
199	468391.030	6575606.106	8.201	8.064	-0.137
200	468390.142	6575616.027	8.326	8.172	-0.154
201	468389.535	6575625.654	8.449	8.300	-0.149
202	469430.792	6576365.624	7.465	7.391	-0.074
203	469438.596	6576352.701	6.220	6.328	0.108
204	468041.462	6577581.955	18.729	18.630	-0.099
205	468037.165	6577581.362	18.635	18.615	-0.020
206	475468.171	6567064.314	6.156	6.075	-0.081
207	475485.701	6567092.500	5.768	5.620	-0.148
208	475449.835	6567069.823	9.310	9.082	-0.228
209	474745.869	6566176.287	11.897	11.857	-0.040
210	474750.958	6566193.663	10.393	10.504	0.111
211	474756.185	6566147.192	10.336	10.198	-0.138
212	450952.682	6583934.765	35.675	35.600	-0.075
213	450918.280	6584004.530	36.241	36.166	-0.075
214	450911.389	6584000.044	36.854	36.770	-0.084

GCP	Easting (m)	Northing (m)	GCP Z (m)	Pointcloud Z (m)	Dz (m)
215	450918.847	6583992.799	36.823	36.759	-0.064
216	450933.236	6583979.303	36.753	36.653	-0.100
217	450940.697	6583972.583	36.729	36.640	-0.089
218	450947.912	6583966.212	36.638	36.604	-0.034
219	450955.508	6583959.685	36.604	36.564	-0.040
220	450971.070	6583946.961	36.509	36.388	-0.121
221	450979.077	6583940.757	36.455	36.393	-0.062
222	450987.139	6583934.794	36.400	36.365	-0.035
223	450995.489	6583928.868	36.413	36.362	-0.051
224	451012.359	6583917.187	36.339	36.237	-0.102
225	451020.863	6583911.465	36.348	36.202	-0.146
226	451029.251	6583905.982	36.307	36.233	-0.074
227	451038.211	6583900.246	36.296	36.227	-0.069
228	451055.060	6583889.691	36.321	36.209	-0.112
229	451063.732	6583884.299	36.324	36.198	-0.126
230	453448.963	6581130.430	39.300	39.150	-0.150
231	453512.409	6581115.740	39.434	39.334	-0.100
232	453492.577	6581138.990	39.816	39.750	-0.066
233	456300.538	6578835.085	20.336	20.213	-0.123
234	456294.774	6578830.070	20.523	20.393	-0.130
235	456337.888	6578818.412	19.264	19.315	0.051
236	448098.375	6585831.735	87.098	86.993	-0.105
237	448106.327	6585836.244	87.654	87.521	-0.133
238	448097.079	6585895.874	89.030	88.872	-0.158
239	448242.598	6585793.597	93.690	93.627	-0.063
240	444994.674	6586036.148	49.087	49.188	0.101
241	445017.620	6586083.016	51.461	51.485	0.024
242	445027.584	6586082.674	51.305	51.381	0.076
243	445048.131	6586082.239	51.137	51.177	0.040
244	445058.391	6586082.177	50.985	51.044	0.059
245	445068.460	6586082.215	50.777	50.899	0.122
246	445078.437	6586082.264	50.720	50.781	0.061
247	445098.006	6586082.602	50.459	50.557	0.098
248	445108.243	6586082.800	50.344	50.425	0.081
249	445118.241	6586083.021	50.185	50.282	0.097
250	445128.323	6586083.282	50.062	50.154	0.092
251	445147.889	6586083.684	49.773	49.914	0.141
252	445158.358	6586083.957	49.714	49.805	0.091
253	445168.694	6586084.175	49.596	49.663	0.067
254	445179.078	6586084.441	49.436	49.538	0.102
255	445200.472	6586084.843	49.107	49.273	0.166
256	445212.253	6586085.118	49.007	49.136	0.129
257	445222.390	6586085.308	48.912	49.018	0.106

GCP	Easting (m)	Northing (m)	GCP Z (m)	Pointcloud Z (m)	Dz (m)
Average dz (m)	-0.165				
Minimum dz (m)	-0.496				
Maximum dz (m)	0.231				
Average magnitude error (m)	0.185				
Root mean square error (m)	0.213				
Standard deviation	0.136				

APPENDIX 2: CHECKPOINTS

Check Point	Easting (m)	Northing (m)	Checkpoint Z (m)	Corrected Pointcloud Z (m)	Dz (m)
1	450936.952	6583925.422	35.876	35.882	0.006
2	476726.040	6564867.994	39.514	39.513	-0.001
3	476682.761	6564894.272	36.647	36.591	-0.056
4	476639.463	6564918.977	34.344	34.376	0.032
5	476592.212	6564940.249	32.883	32.942	0.059
6	476359.890	6565014.460	27.715	27.932	0.217
7	473968.565	6566291.712	13.434	13.391	-0.043
8	473965.445	6566345.600	13.363	13.340	-0.023
9	474011.509	6566341.665	15.629	15.619	-0.010
10	474024.958	6566380.682	13.740	13.737	-0.003
11	472356.704	6567137.427	8.577	8.724	0.147
12	470734.760	6567354.566	9.824	9.791	-0.033
13	470698.399	6567377.337	10.083	10.094	0.011
14	470651.371	6567402.257	10.074	10.086	0.012
15	470603.620	6567416.681	10.085	10.092	0.007
16	470552.932	6567422.682	9.699	9.659	-0.040
17	469600.825	6567874.651	10.815	10.870	0.055
18	466337.575	6569720.689	11.321	11.357	0.036
19	466294.649	6569747.019	11.433	11.440	0.007
20	466250.847	6569773.509	11.795	11.796	0.001
21	466205.098	6569794.547	11.911	11.942	0.031
22	466155.985	6569808.580	12.089	12.063	-0.026
23	459790.441	6573650.333	15.316	15.296	-0.020
24	457893.423	6576613.699	19.621	19.648	0.027
25	457871.197	6576650.768	19.555	19.581	0.026
26	457843.829	6576695.043	19.334	19.286	-0.048
27	457896.693	6576608.503	19.626	19.648	0.022
28	457922.654	6576565.229	19.634	19.665	0.031
29	474394.779	6565909.854	13.143	13.044	-0.099
30	474339.144	6563742.387	7.837	7.990	0.153
31	474386.503	6563703.917	10.584	10.596	0.012
32	474402.440	6563652.472	10.654	10.642	-0.012
33	474422.976	6563604.068	10.680	10.669	-0.011
34	474456.320	6563564.504	10.408	10.398	-0.010
35	478010.917	6559308.737	7.976	8.083	0.107
36	478016.684	6559296.521	9.002	9.095	0.093
37	477981.653	6559255.932	8.975	8.990	0.015
38	477944.330	6559219.635	8.976	8.954	-0.022
39	477901.768	6559184.150	9.069	9.008	-0.061
40	478018.588	6558941.600	17.790	17.641	-0.149
41	474852.582	6570515.311	10.785	10.901	0.116
42	474837.755	6570485.367	10.364	10.355	-0.009

Check Point	Easting (m)	Northing (m)	Checkpoint Z (m)	Corrected Pointcloud Z (m)	Dz (m)
43	474836.136	6570538.492	11.384	11.359	-0.025
44	474821.389	6570589.318	12.417	12.377	-0.040
45	474795.255	6570634.161	13.965	13.933	-0.032
46	471831.557	6572553.702	8.349	8.352	0.003
47	468415.087	6575443.629	7.494	7.526	0.032
48	468400.414	6575494.062	7.444	7.466	0.022
49	468395.746	6575545.435	7.432	7.396	-0.036
50	468391.818	6575595.739	8.100	8.042	-0.058
51	469448.698	6576373.755	7.450	7.387	-0.063
52	475442.398	6567032.248	9.401	9.385	-0.016
53	474773.116	6566155.933	9.139	9.067	-0.072
54	450899.377	6583993.883	36.980	37.059	0.079
55	450926.117	6583985.911	36.806	36.800	-0.006
56	450963.248	6583953.258	36.560	36.604	0.044
57	451003.742	6583923.069	36.381	36.393	0.012
58	451047.061	6583894.670	36.305	36.301	-0.004
59	453489.621	6581144.204	40.202	40.410	0.208
60	456281.895	6578869.904	19.845	19.871	0.026
61	445005.274	6586035.154	48.614	48.576	-0.038
62	445037.518	6586082.441	51.272	51.200	-0.072
63	445088.236	6586082.419	50.609	50.594	-0.015
64	445138.324	6586083.494	49.917	49.945	0.028
65	445189.821	6586084.651	49.314	49.338	0.024
Average dz (m)	0.008				
Minimum dz (m)	-0.149				
Maximum dz (m)	0.217				
Average magnitude error (m)	0.044				
Root mean square error (m)	0.064				
Standard deviation (m)	0.064				