Project Report

TASK ORDER NAME: GA_SW GEORGIA 22 COUNTY LIDAR_2017_B17
TASK ORDER NUMBER: G17PD00242
CONTRACT NUMBER: G16PC00042
ATLANTIC PROJECT NUMBER: 17017
BLOCK NUMBER: B1a, B1b, B2

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SECTION 1: PROJECT OVERVIEW AND PURPOSE

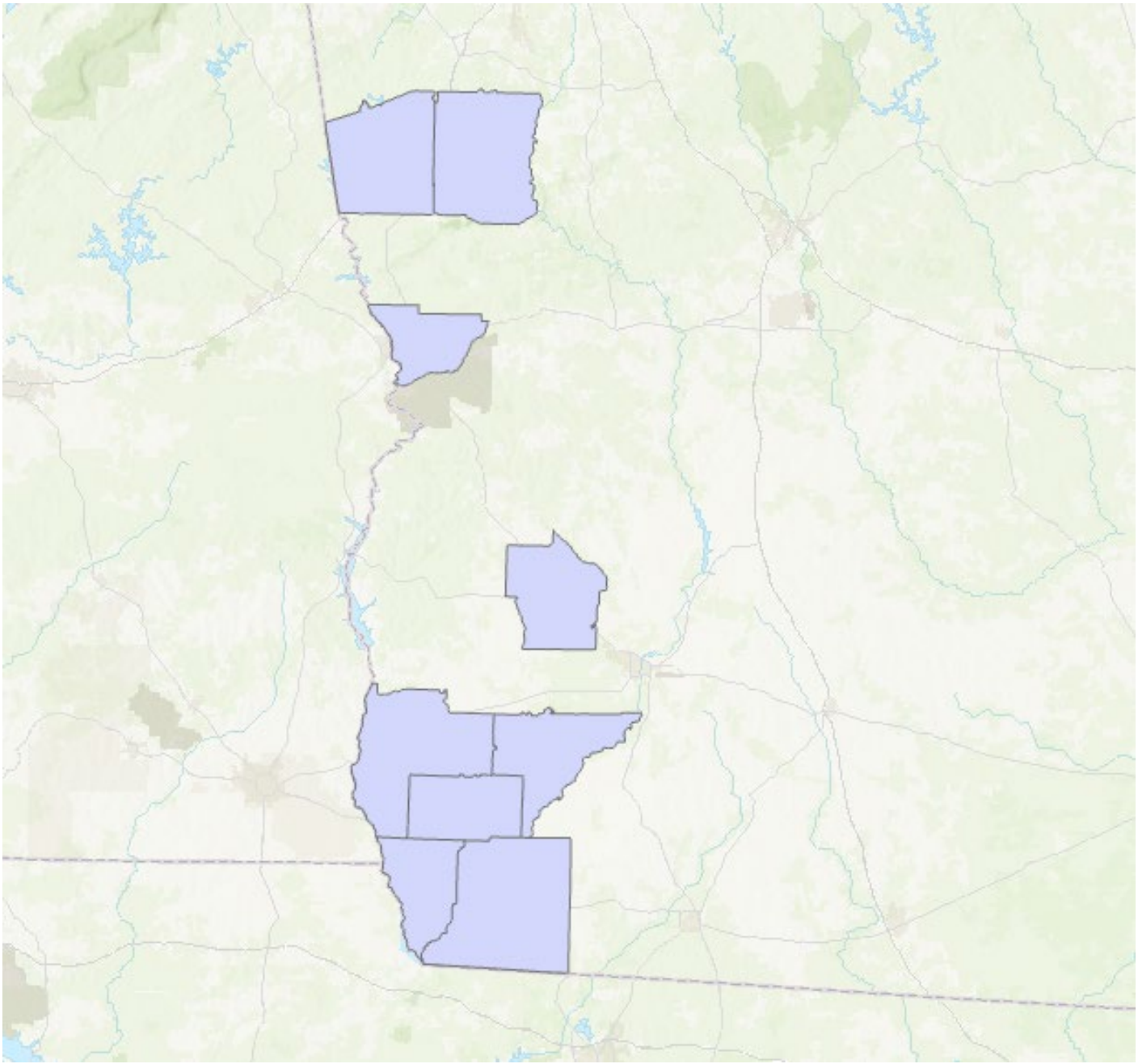
1.1 Aerial LiDAR Project

1.1.1 Project Overview

USGS NGTOC task order G17PD00242 required Spring 2017 LiDAR surveys to be collected over 7,931 square miles covering part or all of 22 counties in SW Georgia. These counties are Baker, Bleckley, Crawford, Crisp, Decatur, Dodge, Dooly, Early, Houston, Macon, Meriwether, Miller, Muscogee, Peach, Pulaski, Seminole, Telfair, Terrell, Troup, Turner, Twiggs, and Wilcox. Aerial LiDAR data for this task order was planned, acquired, processed, and produced at an aggregate nominal pulse spacing (ANPS) of 0.7 meters and in compliance with USGS National Geospatial Program LiDAR Base Specification version 1.2. This report is for blocks 1a, 1b, and 2 which covers 3,538 square miles.

Isolated gaps in GPS data were identified in several missions covering this project. As both, the IMU data and pulse data, were present across these gaps, using the fixed positions of the GPS on either end, the aircraft velocity across the gaps, and the IMU data, LiDAR calibration staff were able to reach an effective solution to address the GPS voids. Because these gaps were not uniform in size or correction, this extended the iterative LiDAR calibration efforts on this project. Subsequent rigorous data checking confirmed adequate results to meet the required accuracy specs. The USGS QA Team reviewed affected data (blocks) for this project and found no QA/QC discrepancies to report regarding those gaps.

In three missions 123_20190317_1, 123_20190318_1, and 123_20190318_2 there were symptoms of skunk striping present in the collected data. These artifacts are manifested by low noise points at nadir and are believed to have been caused by exhaust from the aircraft during collection. Atlantic isolated the points affected by channel and by intensity, and classed them out to noise and flagged them as withheld. We were able to maintain the integrity of the surface and still meet density requirements to meet spec.



1.1.2 Project Purpose

The produced data (DEMs and derivative products) will aid in planning and management purposes of the participating counties and participants.

1.1.3 Contract Deliverables

Item	Specification/Format
Classified LAS Point Cloud Data	LAS, V1.4, PRF 6,7,8,9 or 10
Bare Earth Surface (Raster DEM)	GIS-compatible, 32-bit floating point raster format (ERDAS Imagine .img)
Breaklines	ESRI .shp as PolylineZ and PolygonZ
Control	ESRI .shp
Metadata	FGDC compliant, product level
Flight Index	ESRI .shp
Project Report	This document
Tile Index	ESRI .shp
Intensity Image	8-bit, 256 color gray scale, GeoTIFF

Table 1: Aerial LiDAR Contract Deliverables

SECTION 2: FIELD OPERATIONS

2.1 Aerial LiDAR Project – Aerial Acquisition

2.1.1 Aircraft and Sensor Information

Atlantic operated a Cessna (N732JE) outfitted with a Leica ALS70-HP LiDAR system during the collection of the project area. The specifications of this system are presented in the following table:

Parameter	Specification
Model	ALS70-HP
Manufacturer	Leica
Platform	Fixed-Wing
Scan Pattern	Sine, Triangle, Raster
Maximum Scan Rate (Hz)	Sine: 200 Triangle: 158 Raster: 120
Field of View (°)	0 – 75 (Full Angle, User Adjustable)
Maximum Pulse Rate (kHz)	500
Maximum Flying Height (m AGL)	3500
Number of Returns	Unlimited
Number of Intensity Measurements	3 (First, Second, Third)
Roll Stabilization (Automatic Adaptive, °)	75 - Active FOV
Storage Media	Removable 500 GB SSD
Storage Capacity (Hours @ Max Pulse Rate)	6
Size (cm)	Scanner: 37 W x 68 L x 26 H Control Electronics: 45 W x 47 D x 36 H
Weight (kg)	Scanner: 43 Control Electronics: 45
Operation Temperature (°C)	0 – 40
Flight Management	FCMS
Power Consumption	927 @ 22.0 – 30.3 VDC

Table 2: System Specifications – ALS70-HP

2.1.2 Sensor Acquisition Information

The following table illustrates project specific system parameters for LiDAR acquisition on this project:

Parameter	Specification
System	Leica ALS70-HP
Nominal Pulse Spacing (m)	0.7
Nominal Pulse Density (pls/m²)	2.2
Nominal Flight Height (AGL meters)	2000

Parameter	Specification
Nominal Flight Speed (kts)	130
Pass Heading (°)	varies
Sensor Scan Angle (°)	45
Scan Frequency (Hz)	33.9
Pulse Rate of Scanner (kHz)	256,400
Line Spacing (m)	1373
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	YES
Beam Divergence (mrad)	0.15
Nominal Swath Width (m)	1740
Nominal Swath Overlap (%)	20
Scan Pattern	TRIANGLE

Table 3: Aerial LiDAR Sensor Acquisition Parameters

2.1.3 Flight Plan Execution

Atlantic acquired 220 passes of the AOI as a series of perpendicular and/or adjacent flight-lines executed in 32 flight missions conducted between March 15, 2017 and November 24, 2017. Onboard differential Global Navigation Satellite System (GNSS) unit(s) recorded sample aircraft positions at 2 hertz (Hz) or more frequency. LiDAR data was only acquired when a minimum of six (6) satellites were in view.

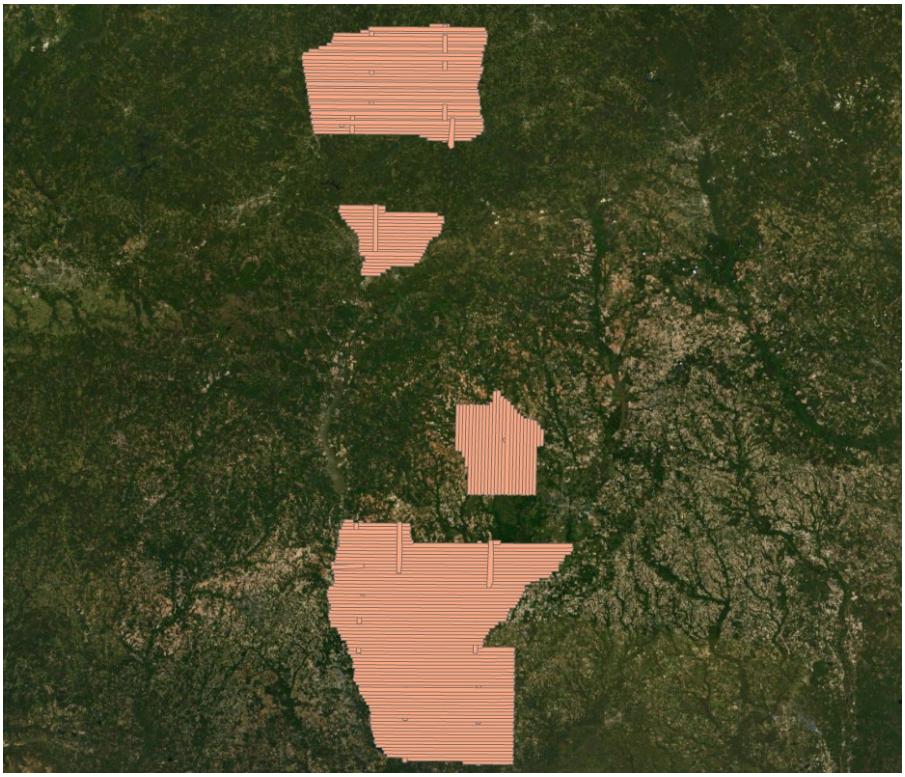


Figure 2: Orientation of Executed Flight-lines and LiDAR DPA

2.1.4 GNSS Reference Stations

Twenty-three (23) Continuously Operating Reference Stations (CORS) were used to control the LiDAR acquisition for the defined project area. The coordinates provided in below are in NAD83 (2011), Geographic Coordinate System, Ellipsoid, Meters.

Designation	Type	PID	Latitude (N)	Longitude (W)	Elevation
AL62	CORS	AL62	32°08'53.36550"	85°41'12.37851"	140.82
AL76	CORS	AL76	31°52'29.96038"	85°13'32.48298"	100.117
ALA1	CORS	ALA1	32°35'55.88725"	85°30'14.13593"	184.092
ALDO	CORS	ALDO	31°14'22.17386"	85°26'24.71278"	79.688
ALLA	CORS	ALLA	32°55'02.66332"	85°24'01.80526"	237.167
GACL	CORS	GACL	30°52'20.86349"	84°23'55.88509"	56.386
GACU	CORS	GACU	32°27'51.70352"	84°59'11.19498	53.13
GAED	CORS	GAED	31°36'01.14210"	84°51'42.39741"	103.834
GAFI	CORS	GAFI	31°16'25.02051"	84°32'47.71964"	34.114
GALC	CORS	GALC	31°14'37.74204"	84°55'13.36559"	38.447
GALG	CORS	GALG	33°01'14.63474"	84°59'51.19764"	217.568
GALU	CORS	GALU	31°33'48.73964"	83°50'12.23371"	107.063
GANW	CORS	GANW	33°18'20.82536"	84°46'02.50874"	259.999
GATF	CORS	GATF	31°27'06.88828"	83°30'32.85514"	96.084
GATH	CORS	GATH	30°57'42.69018"	84°54'54.63518"	23.638
P804	CORS	P804	32°57'47.83691"	84°13'32.72028"	216.378
P805	CORS	P805	32°57'47.83690"	84°13'32.72025"	216.378
P806	CORS	P806	32°57'47.92387"	84°13'33.05644"	215.885

Table 4: GNSS Reference Stations

2.2 Aerial LiDAR Project – Ground Acquisition

2.2.1 Ground Control Survey

A total of 156 ground survey points were collected in support of this project, including 32 LiDAR Control Points (LCP), 73 Non-vegetated Vertical Accuracy (NVA) and 51 Vegetated Vertical Accuracy (VVA) points.

Point cloud data accuracy was tested against a Triangulated Irregular Network (TIN) constructed from LiDAR points in clear and open areas. A clear and open area can be characterized with respect to topographic and ground cover variation such that a minimum of five (5) times the Nominal Pulse Spacing (NPS) exists with less than 1/3 of the RMSEZ deviation from a low-slope plane. Slopes that exceed ten (10) percent were avoided.

Each land cover type representing ten (10) percent or more of the total project area were tested and reported with a VVA. In land cover categories other than dense urban areas, the tested points did not have obstructions forty-five (45) degrees above the horizon to ensure a satisfactory TIN surface. The VVA value is provided as a target. It is understood that in areas of dense vegetation, swamps, or extremely difficult terrain, this value may be exceeded.

The NVA value is a requirement that must be met, regardless of any allowed "busts" in the VVA(s) for individual land cover types within the project. Checkpoints for each assessment (NVA and VVA) are required to be well-distributed throughout the land cover type, for the entire project area.

The following tables and figures outline the coordinate values and distribution of LCP, NVA and VVA points collected in support of this project:

ID	Easting	Northing	Elevation
CTRL67	2138067	393593.7	133.469
CTRL32	1988535	1049880	595.479
CTRL31	2054314	1097386	803.961
CTRL77	2054627	883372.8	238.124
CTRL68	2172965	450759.3	179.296
CTRL30	2067744	1155204	705.304
CTRL28	2111724	1062938	858.589
CTRL54	2235263	666236.6	366.658
CTRL26	2084926	1151210	845.727
CTRL78	2130877	926450.5	460.352
CTRL61	2014405	427611.7	187.026
CTRL65	2186787	431969.8	134.832
CTRL69	2205007	372601.4	132.836
CTRL53	2218070	635512.9	314.897
CTRL70	2117981	357084.5	113.055
CTRL72	2163471	327587.4	85.225

ID	Easting	Northing	Elevation
CTRL79	2146260	380062.8	131.192
CTRL71	2129913	270088.6	286.614
CTRL29	2160019	1040487	885.268
CTRL25	2169995	1153742	767.991
CTRL66	2117787	426748.3	175.649
CTRL60	2124845	473028.2	223.754
CTRL58	2123078	520620.4	263.983
CTRL76	2094137	369340.2	144.237
CTRL63	2240376	477548.2	156.155
CTRL52	2188801	689250	460.632
CTRL27	2126048	1100502	881.079
CTRL64	2172149	500982.3	185.694
CTRL74	2071911	310239.5	97.31
CTRL62	2082432	471168.4	191.958
CTRL33	1979570	1107564	670.738
CTRL75	2072658	380018.3	142.469

Table 5: LiDAR Control Point Coordinates

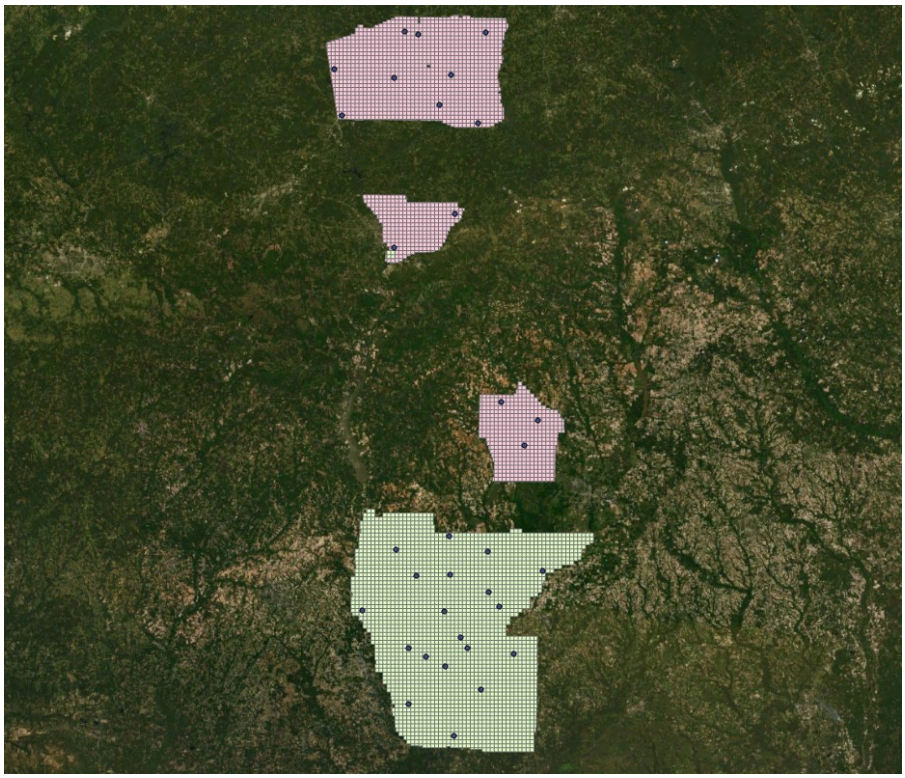


Figure 3: LiDAR Control Point Distribution

ID	Easting	Northing	Elevation
BE17	2172213	1125810	834.263
BE18	2158791	1040664	894.705
BE19	2120055	1168293	944.169
BE21	1978684	1107877	662.685
BE22	2028172	1137645	742.819
BE23	2016133	1100103	715.702
BE36	2198292	600872.4	282.341
BE37	2176542	663440.8	404.125
BE38	2234842	665848.5	369.416
BE41	2071807	532377.2	287.23
BE42	2039870	528966.5	318.288
BE43	2079433	509916.6	209.41
BE44	2172425	500690.2	186.587
BE45	2261984	520892	172.477

ID	Easting	Northing	Elevation
BE46	2185139	398502.4	136.217
BE47	2172980	449608.9	176.592
BE48	2071128	403632.9	158.834
BE49	2213814	318891.7	285.939
BE50	2175615	291419.5	309.925
BE51	2190440	382187.6	130.064
BE52	2083186	261104.5	238.444
BE53	2071299	310222.8	97.685
BE54	2073244	379659	142.481
BE55	2122828	938080.2	506.616
BE56	2052557	920983.7	474.355
OT17	2085837	1150842	869.131
OT18	2094060	1090399	848.49
OT19	2138732	1050521	972.916
OT20	2080788	1045784	911.757
OT21	2025940	1122155	687.883
OT22	2046702	1067528	809.349
OT36	2240570	624710.5	303.016
OT37	2208330	656627.2	367.935
OT40	2082922	470627	190.018
OT41	2015726	469856.2	217.255
OT42	2042491	397242.8	151.414
OT43	2125887	502289.7	235.972
OT44	2186826	433383.7	147.039
OT45	2253529	490182.8	146.231
OT46	2201054	489530.7	157.921
OT47	2165531	404214.1	146.445
OT48	2075152	428726	189.565
OT49	2157154	353075.4	128.904
OT50	2130097	269875.7	289.19
OT51	2145531	380134.1	129.961
OT52	2198630	273849.8	297.287
OT53	2094025	369241.4	143.621
OT54	2092609	356348.5	121.807
OT55	2043942	899161.7	253.584
UR17	2169879	1153361	770.228

ID	Easting	Northing	Elevation
UR18	2125844	1100369	890.044
UR19	2111933	1063370	859.47
UR20	2067650	1155680	704.022
UR21	2054546	1096837	785.451
UR22	1987895	1049579	581.882
UR36	2188813	689595.5	469.002
UR37	2218048	634999.2	317.512
UR40	2123230	520876.1	270.415
UR41	2057275	503629.4	259.195
UR43	2124418	472844.2	223.915
UR44	2239919	477440.7	164.14
UR45	2155266	485126.8	243.301
UR46	2118349	426845.9	179.297
UR47	2138668	392218.3	131.488
UR48	2204643	372686.7	134.143
UR49	2118246	357122.1	112.39
UR50	2118361	316110.4	123.193
UR51	2163544	327961.2	87.717
UR52	2226396	256807.9	258.673
UR53	2053655	377621.3	184.96
UR54	2084450	283883.3	94.259
UR55	2054947	882962.3	247.761
UR56	2131095	927294.2	454.165

Table 6: Non-Vegetated Vertical Accuracy (NVA) Point Coordinates

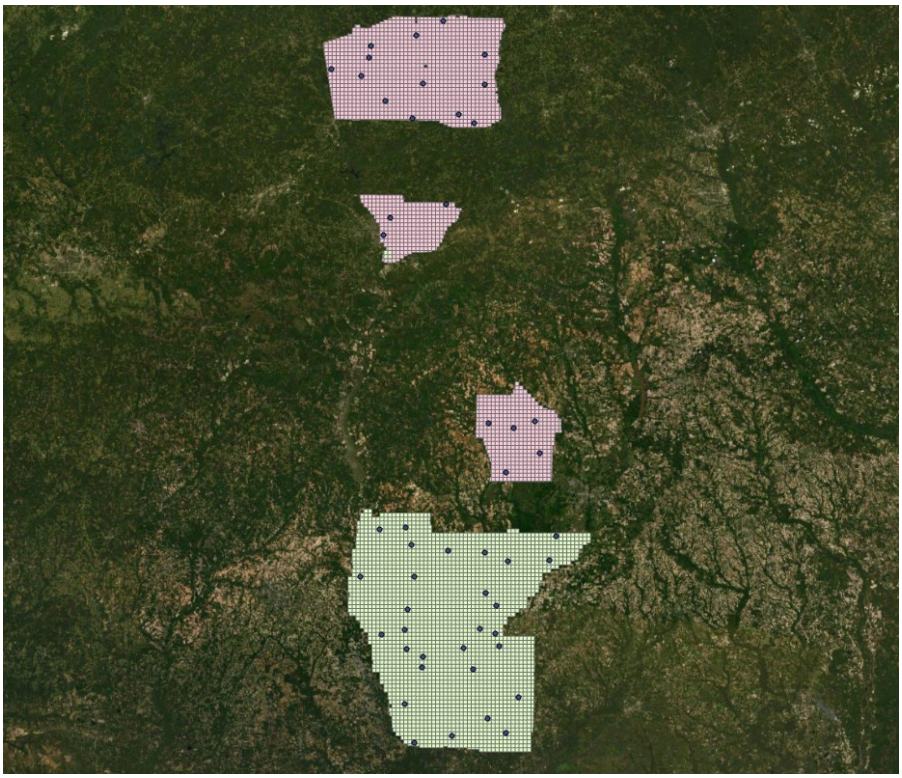


Figure 4: Non-Vegetated Vertical Accuracy (NVA) Point Distribution

ID	Easting	Northing	Elevation
BR14	2159458	1118843	732.831
BR15	2155530	1074566	788.417
BR24	2174349	644108.2	288.673
BR25	2215388	696947.5	307.28
BR27	2034857	445464.6	188.754
BR28	2110259	477204.7	175.019
BR30	2214715	487630.9	176.954
BR31	2200263	441655.8	133.793
BR32	2065017	450712.6	211.66
BR33	2210326	341321.4	142.389
BR34	2151579	309945.4	89.451
BR35	2181178	273264.6	262.941
BR36	2065263	340640.1	114.359
BR37	2083129	919303	336.291

ID	Easting	Northing	Elevation
BR38	2080225	1150053	846.076
BR39	2069369	1065010	857.986
BR40	2004275	1067209	613.545
HG13	2190924	1162544	788.334
HG14	2089563	1120663	829.287
HG15	2171222	1054667	988.857
HG24	2202094	646005.8	358.088
HG25	2217127	619155.4	306.604
HG27	2073997	490364.5	224.631
HG28	2054527	425931.5	202.553
HG29	2058207	543052.7	320.453
HG30	2232081	498738.7	166.802
HG31	2121225	455804.9	178.592
HG32	2139262	415067.4	147.194
HG33	2126711	387677.2	127.712
HG34	2218282	304735.7	262.789
HG35	2156358	286852.5	305.192
HG36	2096173	302839.7	100.207
HG37	2067375	904711	267.834
HG38	2068320	1118209	820.113
HG39	2022812	1046510	739.287
TR13	2136989	1134872	801.845
TR14	2129635	1080524	880.152
TR24	2239256	601275.5	245.073
TR27	2029619	501540.7	273.781
TR28	2094998	495007.4	221.194
TR29	2262248	510828.5	170.248
TR30	2200486	464577.1	140.426
TR31	2170586	430682	147.154
TR32	2184409	360181.4	128.052
TR33	2116405	290065.6	92.665
TR34	2175530	313816.4	119.196
TR35	2098466	326124.4	120.557
TR36	2098606	927291.7	444.358
TR37	2058225	943878.2	518.76
TR38	1984107	1135598	776.925

ID	Easting	Northing	Elevation
TR39	1988374	1089902	662.016

Table 7: Vegetated Vertical Accuracy (VVA) Point Coordinates

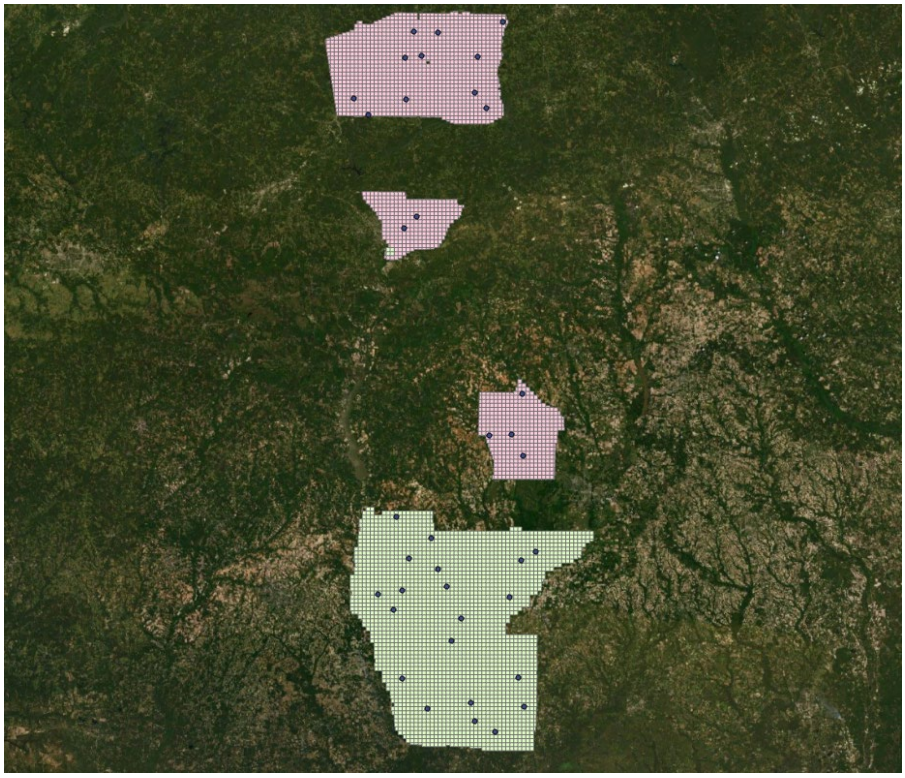


Figure 5: Vegetated Vertical Accuracy (VVA) Point Distribution

SECTION 3: DATA PRODUCTION

3.1 Aerial LiDAR Project – Calibration/Classification

3.1.1 LiDAR Point Cloud Generation

Atlantic used Leica software products to download the IPAS ABGNSS/IMU data and raw laser scan files from the airborne system. Waypoint Inertial Explorer is used to extract the raw IPAS ABGNSS/IMU data, which is further processed in combination with controlled base stations to provide the final Smoothed Best Estimate Trajectory (SBET) for each mission. The SBETs are combined with the raw laser scan files to export the LiDAR ASCII Standard (*.las) formatted swath point clouds.

3.1.2 Coordinate Reference System

Parameter	Specification
Horizontal Datum	NAD83 2011
Coordinate System	SPCS, Georgia West Zone
Vertical Datum	NAVD 88
Geoid Model	12B
EPSG Code	6647
Units of Reference	USFT

Table 8: Coordinate Reference System

3.1.3 LiDAR Point Cloud Statistics

Category	Value
Total Points (Nominal)	28,995,705,531
Nominal Pulse Spacing (FT)	1.5623
Nominal Pulse Density (PLS/FT^2)	0.4097
Total Points (Aggregate)	28,995,705,531
Aggregate Pulse Spacing (FT)	1.9352
Aggregate Pulse Density (PLS/FT^2)	0.2670

Table 9: LiDAR Point Cloud Statistics

3.1.4 Smooth Surface Repeatability (Interswath)

Departures from planarity of first returns within single swaths in non-vegetated areas were assessed at multiple locations with hard surface areas (parking lots or large rooftops) inside the project area. Each area was evaluated using signed difference rasters (maximum elevation – minimum elevation) at a cell size equal to 2 x ANPS, rounded to the next integer.

3.1.5 LiDAR Calibration

Using a combination of GeoCue, TerraScan and TerraMatch; overlapping swath point clouds are corrected for any orientation or linear deviations to obtain the best fit swath-to-swath calibration. Relative calibration was evaluated using advanced plane-matching analysis and parameter corrections derived. This process was repeated interactively until residual errors between overlapping swaths, across all project missions, was reduced to ≤2cm. A final analysis of the calibrated lidar is preformed using a TerraMatch tie line report for an overall statistical model of the project area. Individual control point assessments for this project can be found in Section VI of this report.

Upon completion of the data calibration, a complete set of elevation difference intensity rasters (dZ Orthos) are produced. A user-defined color ramp is applied depicting the offsets between overlapping swaths based on project specifications. The dZ orthos provide an opportunity to review the data calibration in a qualitative manner. Atlantic assigns green to all offset values that fall below the required RMSDz requirement of the project. A yellow color is assigned for offsets that fall between the RMSDz value and 1.5x of that value. Finally, red values are assigned to all values that fall beyond 1.5x of the RMSDz requirements of the project.

3.1.6 LiDAR Classification

Multiple automated filtering routines are applied to the calibrated LiDAR point cloud identifying and extracting bare-earth and above ground features. GeoCue, TerraScan, and TerraModeler software was used for the initial batch processing, visual inspection and any manual editing of the LiDAR point clouds. Atlantic utilized collected breakline data to preform classification for class 9 (Water).

Code	Description
1	Processed, but unclassified
2	Bare-earth ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
7	Low Point (“Low Noise”)
9	Water
10	Ignored Ground (Breakline Proximity)
17	Bridge Decks
18	High Point (“High Noise”)

Table 10: LiDAR Point Classification Codes and Descriptions

3.1.7 LiDAR Intensity Imagery

LiDAR intensity imagery was created from the final calibrated and classified lidar point cloud. Intensity images were produced from all classified points and posted to a 1.0-meter cell size. Intensity images were cut to match the tile index and its corresponding tile names and delivered in TIFF format.

3.1.8 Hydro-line Collection/Conflation

Hydro breaklines were compiled using LiDAR intensity data and surface terrain models of the entire project area. After the collection, all delineated hydro features were validated for monotonicity and vertical variance. This procedure ensures that no points were floating above ground. Hydro-lines were then encoded into the LiDAR surface and used to hydro-enforce/flatten all significant water bodies. These final hydro-lines were then used in the production of bare Earth digital models to hydro flatten significant water bodies. This product was delivered as an ESRI shapefile for the entire project area.

3.1.9 Bare-Earth Surface – Digital Elevation Model (DEM)

Bare earth Digital Elevation Models (DEMs) were derived using the hydro-lines and bare earth (ground) LiDAR points. All DEMs were created with a grid spacing of 2.5 US survey feet. DEMs for this project were cut to match the tile index and its corresponding tile names and delivered in 32-bit floating point .tiff format.

SECTION 4: ACCURACY ASSESSMENT

4.1 Aerial LiDAR Project – Vertical Accuracy Assessment

4.1.1 Requirements

Per the table below, the Vertical Accuracy Assessment utilized the required parameters for Vertical Data Accuracy Class IV.

Vertical Data Accuracy Class	RMSEz in Non-Vegetated Terrain (cm)	Non-Vegetated Vertical Accuracy (NVA) at 95% Confidence Level (cm)	Vegetated Vertical Accuracy (VVA) at 95th Percentile (cm)
I	1.0	2.0	2.9
II	2.5	4.9	7.4
III	5.0	9.8	14.7
IV	10.0	19.6	29.4
V	12.5	24.5	36.8
VI	20.0	39.2	58.8
VII	33.3	65.3	98.0
VIII	66.7	130.7	196.0
IX	100.0	196.0	294.0
X	333.3	653.3	980.0

Table 11: Vertical Accuracy Standards, Source: ASPRS Positional Accuracy Standards for Digital Geospatial Data v1.0 (2014)

*The terms NVA and VVA are from the American Society for Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data v1.0 (2014). The term NVA refers to assessments in clear, open areas (which typically produce only single LiDAR returns); the term VVA refers to assessments in vegetated areas (typically characterized by multiple return LiDAR).

4.1.2 Results

An overall statistical assessment of the check points can be found in the following two tables (values provided in meters):

Broad Land Cover Type	Points (#)	RMSEz	Confidence Level (95%)	Percentile (95th)
NVA (Point Cloud)	73	0.2160	0.4234	0.4251
NVA (DEM)	73	0.0000	0.0000	0.0000
VVA (Point Cloud)	51	0.4312	0.8451	0.8100
VVA (DEM)	51	0.3626	0.7107	0.2740

Table 12: NVA/VVA Accuracies

SECTION 5: CERTIFICATION STATEMENTS

5.1 Aerial LiDAR Project

This accuracy assessment confirms that the data may be used for the intended applications stated in Section I of this document. This dataset may also be used as a topographic input for other applications, but the user should be aware that this LiDAR dataset was designed with a specific purpose and was not intended to meet specifications and/or requirements of users outside of the United States Geological Survey.

It should also be noted that LiDAR points do not represent a continuous surface model. LiDAR points are discrete measurements of the surface and any values derived within a triangle of three LiDAR points are interpolated. As such, the user should not use the resultant LiDAR dataset for vertical placement of a planimetric feature such as a headwall, building footprint or any other planimetric feature unless there is an associated LiDAR point that can be reasonably located on this structure.

Consideration should be given by the end user of this dataset to the fact that this LiDAR dataset was developed differently and separately than previous LiDAR datasets that may be available for this geographic location. It is likely that the data in this project was created using different geodetic control, a different Geoid, newer LiDAR technology and more up-to-date processing techniques. As such, any direct comparative analysis performed between this dataset and previous datasets could result in misleading or inaccurate results. Users are encouraged to proceed with caution while performing this type of comparative analysis and to completely understand the variables that make each of these datasets unique and not corollary.

It is encouraged that the user refers to the full FGDC Metadata and project reports for a complete understanding on the content of this dataset.

I, hereby, certify to the extent of my knowledge that the statements and statistics represented in this document are true and factual.

Brian J. Mayfield, ASPRS Certified Photogrammetrist #R1276

SECTION 6: CONTROL POINT ASSESSMENTS

6.1 Aerial LiDAR Project

6.1.1 Point Cloud Check Point Assessment

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
BE17	2172212.5780	1125809.6860	834.2630	834.4873	0.2243	NVA
BE18	2158790.6690	1040663.7850	894.7050	894.8684	0.1634	NVA
BE19	2120055.3100	1168293.3910	944.1690	944.1223	-0.0467	NVA
BE21	1978683.8450	1107876.6940	662.6850	663.0730	0.3880	NVA
BE22	2028172.2150	1137644.7250	742.8190	742.8110	-0.0080	NVA
BE23	2016132.5010	1100103.2000	715.7020	715.7950	0.0930	NVA
BE36	2198291.7100	600872.3690	282.3410	282.2663	-0.0747	NVA
BE37	2176542.4840	663440.8050	404.1250	404.2359	0.1109	NVA
BE38	2234841.6330	665848.4590	369.4160	369.4577	0.0417	NVA
BE41	2071807.2550	532377.1990	287.2300	287.2499	0.0199	NVA
BE42	2039869.6440	528966.4500	318.2880	318.4729	0.1849	NVA
BE43	2079432.6380	509916.6240	209.4100	209.7707	0.3607	NVA
BE44	2172425.0390	500690.2060	186.5870	186.7429	0.1559	NVA
BE45	2261983.9670	520891.9660	172.4770	173.0411	0.5641	NVA
BE46	2185139.0840	398502.3870	136.2170	136.0478	-0.1692	NVA
BE47	2172979.8480	449608.8960	176.5920	176.2813	-0.3107	NVA
BE48	2071128.1350	403632.8640	158.8340	158.9401	0.1061	NVA
BE49	2213814.2140	318891.7200	285.9390	285.9182	-0.0208	NVA
BE50	2175614.9080	291419.4940	309.9250	309.7046	-0.2204	NVA
BE51	2190440.4920	382187.6450	130.0640	129.7810	-0.2830	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
BE52	2083185.5150	261104.4780	238.4440	238.2690	-0.1750	NVA
BE53	2071299.2180	310222.7900	97.6850	97.3628	-0.3222	NVA
BE54	2073244.3390	379659.0110	142.4810	142.9605	0.4795	NVA
BE55	2122828.1460	938080.1740	506.6160	506.9591	0.3431	NVA
BE56	2052556.9260	920983.6700	474.3550	474.5878	0.2328	NVA
BR14	2159457.5530	1118842.6010	732.8310	733.3084	0.4774	VVA
BR15	2155530.3280	1074565.9510	788.4170	788.5010	0.0840	VVA
BR24	2174348.6670	644108.2080	288.6730	289.1440	0.4710	VVA
BR25	2215387.7170	696947.5130	307.2800	307.2912	0.0112	VVA
BR27	2034856.5290	445464.5980	188.7540	189.3534	0.5994	VVA
BR28	2110259.3800	477204.7270	175.0190	175.8453	0.8263	VVA
BR30	2214714.8990	487630.8970	176.9540	177.4480	0.4940	VVA
BR31	2200263.1960	441655.7570	133.7930	133.7968	0.0038	VVA
BR32	2065017.2750	450712.5910	211.6600	212.1808	0.5208	VVA
BR33	2210325.7280	341321.3950	142.3890	142.8342	0.4452	VVA
BR34	2151579.3600	309945.3980	89.4510	89.8845	0.4335	VVA
BR35	2181177.9810	273264.5570	262.9410	263.9317	0.9907	VVA
BR36	2065262.6500	340640.1370	114.3590	114.4113	0.0523	VVA
BR37	2083128.6890	919302.9930	336.2910	336.5010	0.2100	VVA
BR38	2080224.9090	1150052.8700	846.0760	846.6780	0.6020	VVA
BR39	2069368.8340	1065009.7630	857.9860	858.5253	0.5393	VVA
BR40	2004274.9730	1067209.4300	613.5450	614.3388	0.7938	VVA
HG13	2190923.9100	1162544.4600	788.3340	788.5389	0.2049	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
HG14	2089563.2600	1120662.6060	829.2870	829.6615	0.3745	VVA
HG15	2171222.2050	1054667.1900	988.8570	988.9480	0.0910	VVA
HG24	2202094.4110	646005.7630	358.0880	358.6382	0.5502	VVA
HG25	2217126.7860	619155.4400	306.6040	306.8128	0.2088	VVA
HG27	2073996.9870	490364.5020	224.6310	224.9961	0.3651	VVA
HG28	2054527.3630	425931.4990	202.5530	202.8314	0.2784	VVA
HG29	2058206.5230	543052.6540	320.4530	320.9536	0.5006	VVA
HG30	2232080.8610	498738.6970	166.8020	167.7892	0.9872	VVA
HG31	2121224.5610	455804.9020	178.5920	178.7983	0.2063	VVA
HG32	2139262.1850	415067.4440	147.1940	147.4031	0.2091	VVA
HG33	2126711.2760	387677.2070	127.7120	127.8634	0.1514	VVA
HG34	2218281.5700	304735.6950	262.7890	263.3277	0.5387	VVA
HG35	2156358.3500	286852.5250	305.1920	305.7633	0.5713	VVA
HG36	2096172.9280	302839.6690	100.2070	100.3270	0.1200	VVA
HG37	2067374.8020	904711.0070	267.8340	268.2959	0.4619	VVA
HG38	2068320.1250	1118209.0910	820.1130	820.6537	0.5407	VVA
HG39	2022811.8990	1046510.4810	739.2870	739.1266	-0.1604	VVA
OT17	2085836.9480	1150842.4320	869.1310	869.2884	0.1574	NVA
OT18	2094060.3880	1090398.5070	848.4900	848.5158	0.0258	NVA
OT19	2138731.6590	1050520.5510	972.9160	972.8647	-0.0513	NVA
OT20	2080788.0990	1045784.1450	911.7570	911.4691	-0.2879	NVA
OT21	2025939.9230	1122154.8760	687.8830	688.0371	0.1541	NVA
OT22	2046702.0930	1067527.5950	809.3490	809.3161	-0.0329	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
OT36	2240570.3740	624710.4560	303.0160	303.1029	0.0869	NVA
OT37	2208329.8820	656627.1740	367.9350	367.6775	-0.2575	NVA
OT40	2082921.8650	470626.9940	190.0180	190.3662	0.3482	NVA
OT41	2015725.8270	469856.1580	217.2550	217.2113	-0.0437	NVA
OT42	2042491.1090	397242.8420	151.4140	151.9536	0.5396	NVA
OT43	2125887.1000	502289.6630	235.9720	236.3094	0.3374	NVA
OT44	2186825.7210	433383.6500	147.0390	146.7925	-0.2465	NVA
OT45	2253529.3890	490182.7700	146.2310	146.7193	0.4883	NVA
OT46	2201054.3890	489530.7120	157.9210	158.3099	0.3889	NVA
OT47	2165530.9640	404214.0780	146.4450	146.4792	0.0342	NVA
OT48	2075152.0510	428725.9880	189.5650	189.4332	-0.1318	NVA
OT49	2157154.2800	353075.3780	128.9040	128.9205	0.0165	NVA
OT50	2130097.2040	269875.7150	289.1900	289.1239	-0.0661	NVA
OT51	2145531.1980	380134.1140	129.9610	130.0602	0.0992	NVA
OT52	2198630.0500	273849.7560	297.2870	297.5694	0.2824	NVA
OT53	2094024.8350	369241.3880	143.6210	143.4565	-0.1645	NVA
OT54	2092609.0110	356348.5230	121.8070	121.9087	0.1017	NVA
OT55	2043941.7660	899161.7370	253.5840	253.5311	-0.0529	NVA
TR13	2136988.6060	1134872.3430	801.8450	802.0160	0.1710	VVA
TR14	2129635.1280	1080523.9080	880.1520	879.9300	-0.2220	VVA
TR24	2239256.3940	601275.5480	245.0730	245.2970	0.2240	VVA
TR27	2029618.8690	501540.6880	273.7810	273.9990	0.2180	VVA
TR28	2094997.6250	495007.3850	221.1940	221.3950	0.2010	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
TR29	2262248.1830	510828.5200	170.2480	170.6240	0.3760	VVA
TR30	2200486.2110	464577.0910	140.4260	140.2670	-0.1590	VVA
TR31	2170585.5200	430681.9930	147.1540	146.9430	-0.2110	VVA
TR32	2184409.3480	360181.3840	128.0520	128.6097	0.5577	VVA
TR33	2116405.3230	290065.5600	92.6650	92.3450	-0.3200	VVA
TR34	2175529.8050	313816.3850	119.1960	119.3300	0.1340	VVA
TR35	2098466.3770	326124.3760	120.5570	120.2400	-0.3170	VVA
TR36	2098606.4330	927291.7170	444.3580	444.5770	0.2190	VVA
TR37	2058224.9330	943878.1860	518.7600	518.5330	-0.2270	VVA
TR38	1984107.1910	1135597.9630	776.9250	776.8690	0.5600	VVA
TR39	1988374.2140	1089902.3680	662.0160	661.6260	-0.3900	VVA
UR17	2169879.4200	1153361.3770	770.2280	770.0465	-0.1815	NVA
UR18	2125844.1040	1100369.3780	890.0440	889.9724	-0.0716	NVA
UR19	2111932.7200	1063370.1020	859.4700	859.5489	0.0789	NVA
UR20	2067649.6110	1155680.1400	704.0220	703.8330	-0.1890	NVA
UR21	2054546.3040	1096836.6780	785.4510	785.3293	-0.1217	NVA
UR22	1987895.1070	1049579.3860	581.8820	581.6722	-0.2098	NVA
UR36	2188812.5400	689595.5400	469.0020	468.9857	-0.0163	NVA
UR37	2218048.1630	634999.2290	317.5120	317.6025	0.0905	NVA
UR40	2123229.6910	520876.0510	270.4150	270.2735	-0.1415	NVA
UR41	2057274.9900	503629.4390	259.1950	259.2276	0.0326	NVA
UR43	2124417.5120	472844.1550	223.9150	223.8422	-0.0728	NVA
UR44	2239919.1620	477440.6600	164.1400	164.2426	0.1026	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
UR45	2155266.2870	485126.8310	243.3010	243.3694	0.0684	NVA
UR46	2118349.2380	426845.9160	179.2970	179.1071	-0.1899	NVA
UR47	2138667.8040	392218.2980	131.4880	131.1659	-0.3221	NVA
UR48	2204642.6130	372686.7030	134.1430	134.0602	-0.0828	NVA
UR49	2118245.6530	357122.1480	112.3900	112.3047	-0.0853	NVA
UR50	2118361.4440	316110.3900	123.1930	122.9697	-0.2233	NVA
UR51	2163544.1810	327961.1620	87.7170	87.5301	-0.1869	NVA
UR52	2226395.8920	256807.9190	258.6730	258.6991	0.0261	NVA
UR53	2053655.4620	377621.2570	184.9600	185.0326	0.0726	NVA
UR54	2084450.4230	283883.3420	94.2590	94.0163	-0.2427	NVA
UR55	2054947.4400	882962.3010	247.7610	247.7142	-0.0468	NVA
UR56	2131094.9570	927294.1580	454.1650	454.1101	-0.0549	NVA

Table 13: Point Cloud Check Point Assessment

6.1.2 Digital Elevation Model (DEM) Check Point Assessment

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
BE17	2172212.5780	1125809.6860	834.2630	834.1110	0.1520	NVA
BE18	2158790.6690	1040663.7850	894.7050	894.7280	-0.0230	NVA
BE19	2120055.3100	1168293.3910	944.1690	943.9410	0.2280	NVA
BE21	1978683.8450	1107876.6940	662.6850	663.0680	-0.3830	NVA
BE22	2028172.2150	1137644.7250	742.8190	742.8020	0.0170	NVA
BE23	2016132.5010	1100103.2000	715.7020	715.8080	-0.1060	NVA
BE36	2198291.7100	600872.3690	282.3410	282.1710	0.1700	NVA
BE37	2176542.4840	663440.8050	404.1250	404.1060	0.0190	NVA
BE38	2234841.6330	665848.4590	369.4160	369.2740	0.1420	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
BE41	2071807.2550	532377.1990	287.2300	287.2420	-0.0120	NVA
BE42	2039869.6440	528966.4500	318.2880	318.3450	-0.0570	NVA
BE43	2079432.6380	509916.6240	209.4100	209.8030	-0.3930	NVA
BE44	2172425.0390	500690.2060	186.5870	186.7270	-0.1400	NVA
BE45	2261983.9670	520891.9660	172.4770	172.7020	-0.2250	NVA
BE46	2185139.0840	398502.3870	136.2170	136.0490	0.1680	NVA
BE47	2172979.8480	449608.8960	176.5920	176.3500	0.2420	NVA
BE48	2071128.1350	403632.8640	158.8340	158.9840	-0.1500	NVA
BE49	2213814.2140	318891.7200	285.9390	285.8880	0.0510	NVA
BE50	2175614.9080	291419.4940	309.9250	309.6460	0.2790	NVA
BE51	2190440.4920	382187.6450	130.0640	129.7900	0.2740	NVA
BE52	2083185.5150	261104.4780	238.4440	238.2480	0.1960	NVA
BE53	2071299.2180	310222.7900	97.6850	97.3040	0.3810	NVA
BE54	2073244.3390	379659.0110	142.4810	142.6830	-0.2020	NVA
BE55	2122828.1460	938080.1740	506.6160	506.7780	-0.1620	NVA
BE56	2052556.9260	920983.6700	474.3550	474.4950	-0.1400	NVA
OT17	2085836.9480	1150842.4320	869.1310	868.9320	0.1990	NVA
OT18	2094060.3880	1090398.5070	848.4900	848.4560	0.0340	NVA
OT19	2138731.6590	1050520.5510	972.9160	972.8770	0.0390	NVA
OT20	2080788.0990	1045784.1450	911.7570	911.5260	0.2310	NVA
OT21	2025939.9230	1122154.8760	687.8830	687.8570	0.0260	NVA
OT22	2046702.0930	1067527.5950	809.3490	809.1300	0.2190	NVA
OT36	2240570.3740	624710.4560	303.0160	303.1010	-0.0850	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
OT37	2208329.8820	656627.1740	367.9350	367.6080	0.3270	NVA
OT40	2082921.8650	470626.9940	190.0180	190.2940	-0.2760	NVA
OT41	2015725.8270	469856.1580	217.2550	217.2100	0.0450	NVA
OT42	2042491.1090	397242.8420	151.4140	151.8560	-0.4420	NVA
OT43	2125887.1000	502289.6630	235.9720	236.3370	-0.3650	NVA
OT44	2186825.7210	433383.6500	147.0390	146.7380	0.3010	NVA
OT45	2253529.3890	490182.7700	146.2310	146.7260	-0.4950	NVA
OT46	2201054.3890	489530.7120	157.9210	158.2480	-0.3270	NVA
OT47	2165530.9640	404214.0780	146.4450	146.4630	-0.0180	NVA
OT48	2075152.0510	428725.9880	189.5650	189.4360	0.1290	NVA
OT49	2157154.2800	353075.3780	128.9040	128.8610	0.0430	NVA
OT50	2130097.2040	269875.7150	289.1900	288.9810	0.2090	NVA
OT51	2145531.1980	380134.1140	129.9610	130.0470	-0.0860	NVA
OT52	2198630.0500	273849.7560	297.2870	297.5070	-0.2200	NVA
OT53	2094024.8350	369241.3880	143.6210	143.3160	0.3050	NVA
OT54	2092609.0110	356348.5230	121.8070	121.9080	-0.1010	NVA
OT55	2043941.7660	899161.7370	253.5840	253.5080	0.0760	NVA
UR17	2169879.4200	1153361.3770	770.2280	769.8960	0.3320	NVA
UR18	2125844.1040	1100369.3780	890.0440	889.9630	0.0810	NVA
UR19	2111932.7200	1063370.1020	859.4700	859.5280	-0.0580	NVA
UR20	2067649.6110	1155680.1400	704.0220	703.8080	0.2140	NVA
UR21	2054546.3040	1096836.6780	785.4510	785.3160	0.1350	NVA
UR22	1987895.1070	1049579.3860	581.8820	581.6500	0.2320	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
UR36	2188812.5400	689595.5400	469.0020	468.8420	0.1600	NVA
UR37	2218048.1630	634999.2290	317.5120	317.5200	-0.0080	NVA
UR40	2123229.6910	520876.0510	270.4150	270.2100	0.2050	NVA
UR41	2057274.9900	503629.4390	259.1950	259.1540	0.0410	NVA
UR43	2124417.5120	472844.1550	223.9150	223.7890	0.1260	NVA
UR44	2239919.1620	477440.6600	164.1400	164.2050	-0.0650	NVA
UR45	2155266.2870	485126.8310	243.3010	243.3320	-0.0310	NVA
UR46	2118349.2380	426845.9160	179.2970	179.1170	0.1800	NVA
UR47	2138667.8040	392218.2980	131.4880	131.1900	0.2980	NVA
UR48	2204642.6130	372686.7030	134.1430	133.9280	0.2150	NVA
UR49	2118245.6530	357122.1480	112.3900	112.2330	0.1570	NVA
UR50	2118361.4440	316110.3900	123.1930	122.9860	0.2070	NVA
UR51	2163544.1810	327961.1620	87.7170	87.5240	0.1930	NVA
UR52	2226395.8920	256807.9190	258.6730	258.5020	0.1710	NVA
UR53	2053655.4620	377621.2570	184.9600	184.9390	0.0210	NVA
UR54	2084450.4230	283883.3420	94.2590	94.0170	0.2420	NVA
UR55	2054947.4400	882962.3010	247.7610	247.4670	0.2940	NVA
BR14	2159457.5530	1118842.6010	732.8310	733.0900	-0.2590	VVA
BR15	2155530.3280	1074565.9510	788.4170	788.5650	-0.1480	VVA
BR24	2174348.6670	644108.2080	288.6730	289.1430	-0.4700	VVA
BR25	2215387.7170	696947.5130	307.2800	307.7140	-0.4340	VVA
BR27	2034856.5290	445464.5980	188.7540	189.0420	-0.2880	VVA
BR28	2110259.3800	477204.7270	175.0190	175.5550	-0.5360	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
BR30	2214714.8990	487630.8970	176.9540	177.4340	-0.4800	VVA
BR31	2200263.1960	441655.7570	133.7930	133.8030	-0.0100	VVA
BR32	2065017.2750	450712.5910	211.6600	212.0830	-0.4230	VVA
BR33	2210325.7280	341321.3950	142.3890	142.8730	-0.4840	VVA
BR34	2151579.3600	309945.3980	89.4510	89.4190	0.0320	VVA
BR35	2181177.9810	273264.5570	262.9410	263.7990	-0.8580	VVA
BR36	2065262.6500	340640.1370	114.3590	114.3930	-0.0340	VVA
BR37	2083128.6890	919302.9930	336.2910	336.5020	-0.2110	VVA
BR38	2080224.9090	1150052.8700	846.0760	846.6310	-0.5550	VVA
BR39	2069368.8340	1065009.7630	857.9860	858.3930	-0.4070	VVA
BR40	2004274.9730	1067209.4300	613.5450	613.9830	-0.4380	VVA
HG13	2190923.9100	1162544.4600	788.3340	788.0990	0.2350	VVA
HG14	2089563.2600	1120662.6060	829.2870	829.5860	-0.2990	VVA
HG15	2171222.2050	1054667.1900	988.8570	988.9000	-0.0430	VVA
HG24	2202094.4110	646005.7630	358.0880	358.5890	-0.5010	VVA
HG25	2217126.7860	619155.4400	306.6040	306.7950	-0.1910	VVA
HG27	2073996.9870	490364.5020	224.6310	225.0000	-0.3690	VVA
HG28	2054527.3630	425931.4990	202.5530	202.8000	-0.2470	VVA
HG29	2058206.5230	543052.6540	320.4530	320.9560	-0.5030	VVA
HG30	2232080.8610	498738.6970	166.8020	167.7880	-0.9860	VVA
HG31	2121224.5610	455804.9020	178.5920	178.7230	-0.1310	VVA
HG32	2139262.1850	415067.4440	147.1940	147.2510	-0.0570	VVA
HG33	2126711.2760	387677.2070	127.7120	127.8660	-0.1540	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
HG34	2218281.5700	304735.6950	262.7890	263.0480	-0.2590	VVA
HG35	2156358.3500	286852.5250	305.1920	305.4190	-0.2270	VVA
HG36	2096172.9280	302839.6690	100.2070	100.3420	-0.1350	VVA
HG37	2067374.8020	904711.0070	267.8340	268.2000	-0.3660	VVA
HG38	2068320.1250	1118209.0910	820.1130	820.2640	-0.1510	VVA
HG39	2022811.8990	1046510.4810	739.2870	739.0150	0.2720	VVA
TR13	2136988.6060	1134872.3430	801.8450	801.9680	-0.1230	VVA
TR14	2129635.1280	1080523.9080	880.1520	879.9230	0.2290	VVA
TR24	2239256.3940	601275.5480	245.0730	245.2380	-0.1650	VVA
TR27	2029618.8690	501540.6880	273.7810	273.9860	-0.2050	VVA
TR28	2094997.6250	495007.3850	221.1940	221.4810	-0.2870	VVA
TR29	2262248.1830	510828.5200	170.2480	170.6210	-0.3730	VVA
TR30	2200486.2110	464577.0910	140.4260	140.2730	0.1530	VVA
TR31	2170585.5200	430681.9930	147.1540	146.9510	0.2030	VVA
TR32	2184409.3480	360181.3840	128.0520	128.8490	-0.7970	VVA
TR33	2116405.3230	290065.5600	92.6650	92.3890	0.2760	VVA
TR34	2175529.8050	313816.3850	119.1960	119.3300	-0.1340	VVA
TR35	2098466.3770	326124.3760	120.5570	120.2390	0.3180	VVA
TR36	2098606.4330	927291.7170	444.3580	444.5490	-0.1910	VVA
TR37	2058224.9330	943878.1860	518.7600	518.5230	0.2370	VVA
TR38	1984107.1910	1135597.9630	776.9250	776.8560	0.0690	VVA

Table 14: DEM Check Point Assessment