



atlantic

Project Report

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TASK ORDER NUMBER: 140G219F0006

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SECTION I: PROJECT OVERVIEW & PURPOSE

1. Aerial LiDAR Project

a. Project Overview

USGS task order 140G0219F0006-NM_SouthEast_2018_D19 required Fall 2018/Spring 2019 leaf-off LiDAR surveys to be collected over 23,650 square miles covering part or all of thirteen (13) counties in Southeast New Mexico. Aerial LiDAR data for this task order was planned, acquired, processed and produced at an aggregate nominal pulse spacing (ANPS) of 0.71 meters and in compliance with USGS National Geospatial Program LiDAR Base Specification version 1.3. The Block 5 portion of this project encompasses part of Lea, Eddy, Lincoln, and Chaves counties, covering approximately 4,113 square miles.

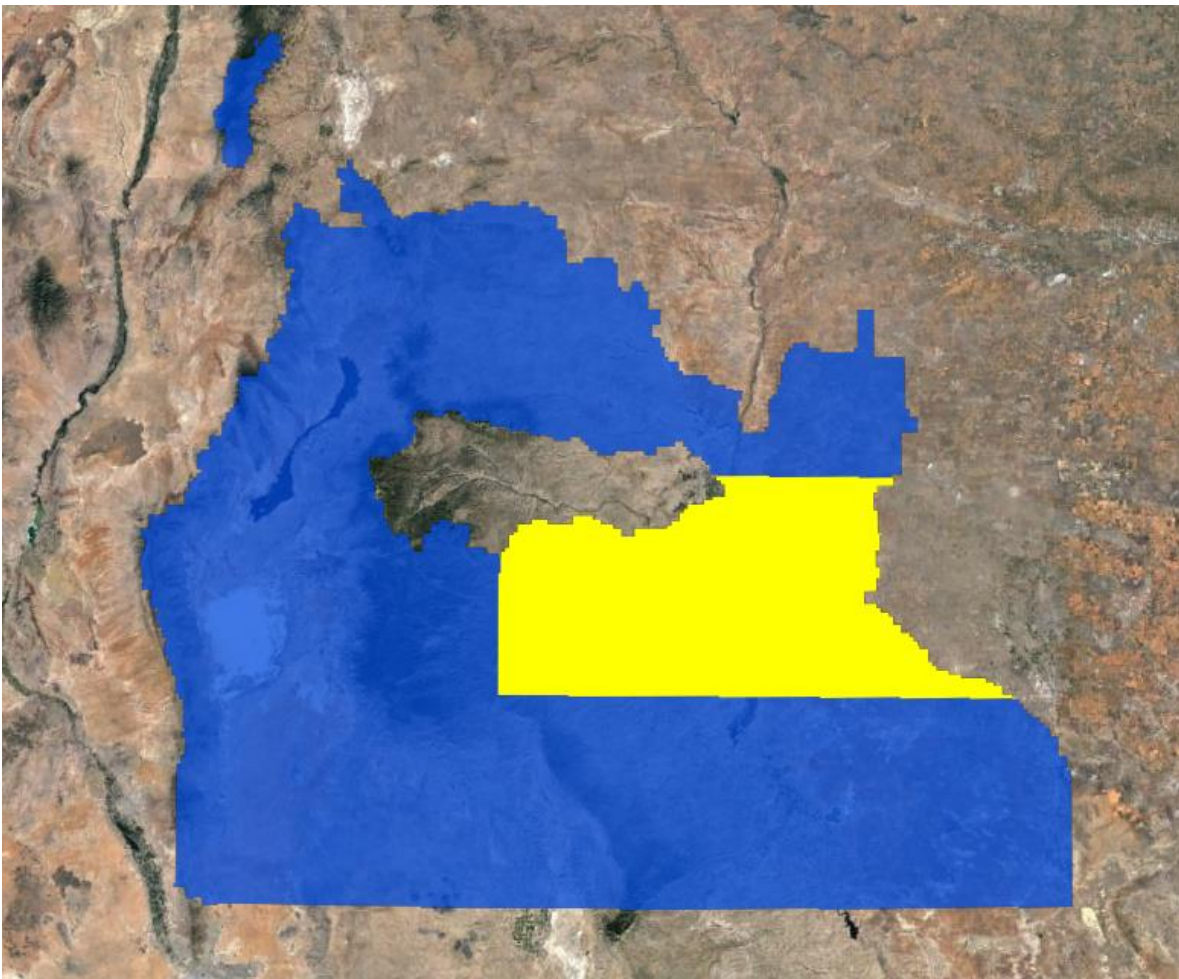


Figure 1: Aerial LiDAR Project Overview – Defined Project Area (DPA) and Associated Areas of Interest (AOIs) Block 5 is delineated in Yellow.

b. Project Purpose

The collected QL2 LiDAR data will support the 3DEP mission, the Natural Resources Conservation Services (NRCS) high resolution elevation enterprise program and the Federal Emergency Management Agency (FEMA) Risk Mapping, Assessment and Planning (MAP) program.

c. Contract Deliverables

Item	Specification/Format
Classified Point Cloud	LAS 1.4
Bare Earth Surface (Raster DEM)	1m cell size, GeoTIFF format, hydroflattened
Hydro Breaklines	.gdb format
Intensity Imagery	1m cell size, GeoTIFF format
Control	.txt
Delivery Diagram	ESRI Shapefile
Metadata	.xml format, FGDC compliant
Project Report	.pdf format

Table 1: Aerial LiDAR Contract Deliverables

SECTION II: FIELD OPERATIONS

1. Aerial LiDAR Project – Aerial Acquisition

a. Aircraft & Sensor Information

Atlantic operated a PACDV (N750DV) outfitted with an Optech Galaxy Prime LiDAR system during the collection of the project area. The specifications of this system are presented in the following table:

Parameter	Specification
Model	Galaxy Prime
Manufacturer	Optech
Performance Envelope	150 – 4700 m AGL, nominal
Absolute Horizontal Accuracy	1/10,000 x altitude
Absolute Elevation Accuracy	< 0.03 – 0.20 m RMSE from 150 – 4700 m AGL
Topographic Laser	1064-nm near-infrared
Laser Classification	Class IV
Pulse Repetition Frequency (Effective)	Programmable, 50 – 1000 kHz
Beam Divergence	0.25 mrad (1/e)
Laser Range Precision	< 0.008 m
Minimum Target Separation Distance	< 0.7 m (discrete)
Range Capture	Up to 8 range measurements, including last
Intensity Capture	Up to 8 intensity measurements, including last (12-bit)
Scan Angle (Fov)	10 – 60°
Swath Width	10 – 115% of altitude AGL
Scan Frequency	0 – 120 Hz advertised (0 – 240 scan lines/sec)
Scan Product	2000 maximum
Roll Compensation	±5° minimum
Data Storage	Internal solid-state drive (SSD)
Power Requirements	28 V; 300 W
Dimensions and Weight	Sensor: 0.34 x 0.34 x 0.25 m, 27 kg PDU: 0.42 x 0.33 x 0.10 m, 6.5 kg
Operation Temperature	0 to +35°C

Table 2: System Specifications – Galaxy Prime

b. Sensor Acquisition Information

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

Parameter	Specification
System	Optech Galaxy Prime
Nominal Pulse Density (pls/m²)	2.33
Nominal Flight Height (AGL meters)	4000

Parameter	Specification
Nominal Flight Speed (kts)	150
Pass Heading (°)	360/180
Sensor Scan Angle (°)	45
Scan Frequency (Hz)	60
Pulse Rate of Scanner (kHz)	350
Sensor Operated with Multiple Pulses	Yes
Nominal Swath Width (m)	1740
Nominal Swath Overlap (%)	20

Table 3: Aerial LiDAR Sensor Acquisition Parameters

c. Flight Plan Execution

Atlantic acquired one hundred forty-four (144) passes of the AOI as a series of perpendicular and/or adjacent flight-lines executed in ten (10) flight missions conducted between November 23, 2018 and January 10, 2019. 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.

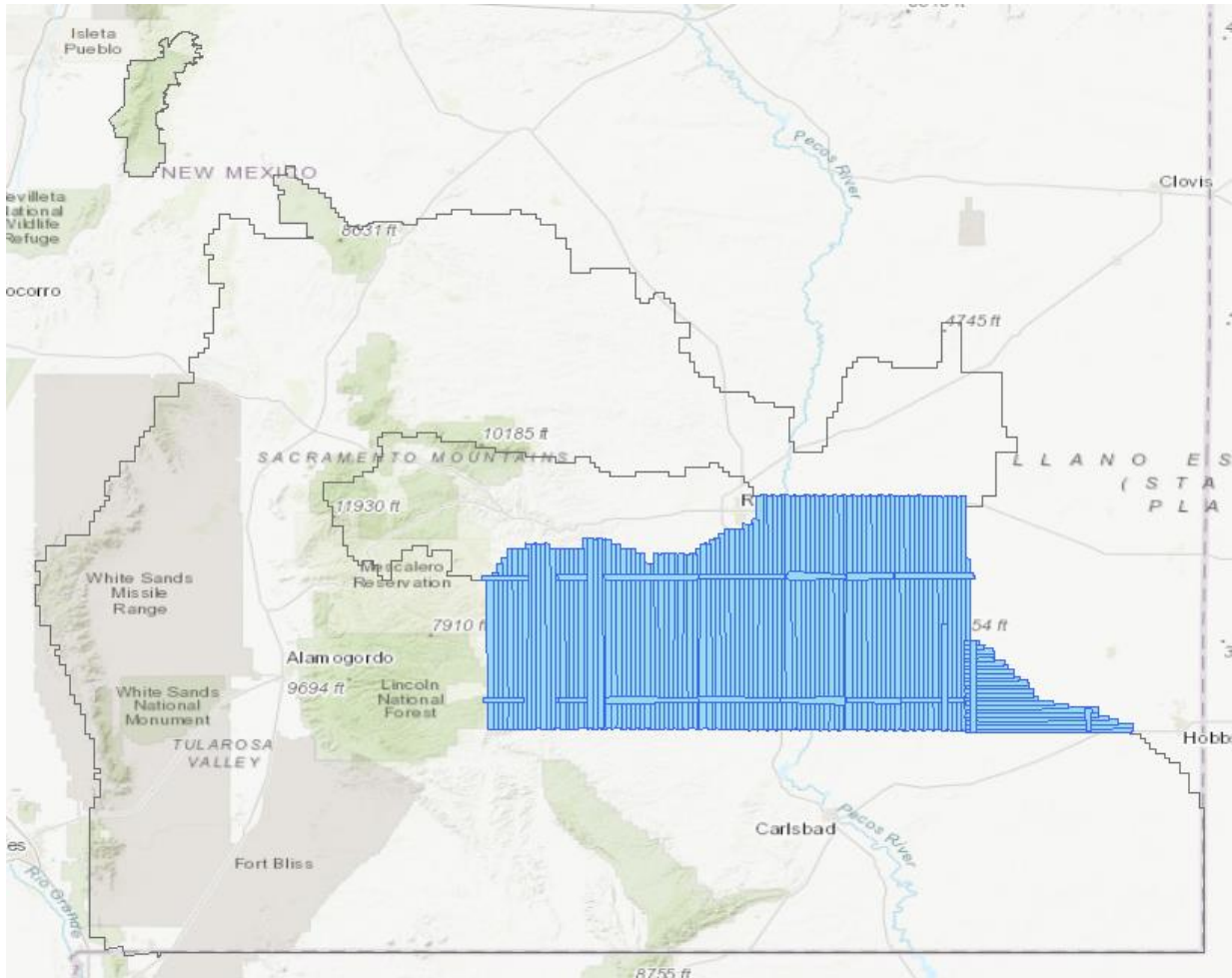


Figure 2: Orientation of Executed Flight-lines and LiDAR DPA

d. GNSS Reference Stations

Ten (10) 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
NMRO	CORS	NMRO	N33°23'41.84849"	W104°35'20.78287"	1094.692
P027	CORS	P027	N32°48'06.68835"	W105°48'14.98114"	2896.72
P034	CORS	P034	N34°56'44.22767"	W106°27'33.36616"	1810.899
P035	CORS	P035	N34°36'05.01237"	W105°11'00.97397"	1780.346
P038	CORS	P038	N34°08'50.11604"	W103°24'26.42481"	1212.964
TXAD	CORS	TXAD	N32°18'28.83144"	W102°32'36.98767"	946.85
TXKM	CORS	TXKM	N31°50'33.37093"	W103°06'31.30083"	847.989
TXP2	CORS	TXP2	N33°10'55.80241"	W102°49'05.38309"	1089.713
TXM1	CORS	TXM1	N33°44'16.18541"	W102°45'34.86097"	1125.573
TXS3	CORS	TXS3	N32°42'42.42331"	W102°37'47.28509"	977.768

Table 4: GNSS Reference Stations

2. Aerial LiDAR Project – Ground Acquisition

a. Ground Control Survey

A total of 160 ground survey points were collected in support of this project, including 37 LiDAR Control Points (LCP), 74 Non-vegetated Vertical Accuracy (NVA) and 49 Vegetated Vertical Accuracy (VVA).

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
LCP029	615639.29	3624269.083	1155.781
LCP040	577964.171	3631912.036	1092.018
LCP049	506313.04	3636405.02	1440.376
LCP050	486155.716	3643853.88	1593.854
LCP051	536979.789	3660222.817	1140.4
LCP053	591143.356	3698304.878	1185.735
LCP080	506733.241	3624396.922	1409.26
LCP081	483556.621	3638488.101	1616.853
LCP083	591630.681	3693614.61	1184.339
LCP109	524421.331	3635837.564	1240.976
LCP110	489033.839	3637837.144	1631.726
LCP116	485025.141	3648675.589	1652.766
LCP117	519211.917	3637579.241	1282.3
LCP132	479903.563	3621663.958	1753.811
LCP133	514972.222	3671756.406	1311.204
LCP134	514961.671	3671771.168	1311.39
LCP135	527302.22	3672249.911	1211.509
LCP136	529149.699	3656841.859	1214.216

ID	Easting	Northing	Elevation
LCP137	529155.47	3656865.899	1213.835
LCP138	557697.393	3689254.215	1060.757
LCP172	559369.232	3638843.612	1017.863
LCP173	583635.266	3656846.164	1109.597
LCP174	578958.537	3679174.869	1119.067
LCP175	558023.079	3679861.673	1062.632
LCP178	510372.009	3632297.169	1342.216
LCP179	506819.221	3643316.513	1399.714
LCP180	489438.668	3652987.8	1552.89
LCP181	478170.671	3639827.926	1663.606
LCP187	551867.889	3663586.419	1086.506
LCP188	541848.372	3646033.46	1085.22
LCP189	556467.979	3640469.328	1025.626
LCP190	555889.286	3622717.65	1040.546
LCP191	600515.316	3639875.612	1165.383
LCP192	573431.329	3662791.557	1047.386
LCP193	594200.785	3685779.221	1166.25
LCP215	570273.921	3678227.108	1087.753
LCP216	561981.079	3677435.423	1040.934

Table 5: LiDAR Control Point Coordinates

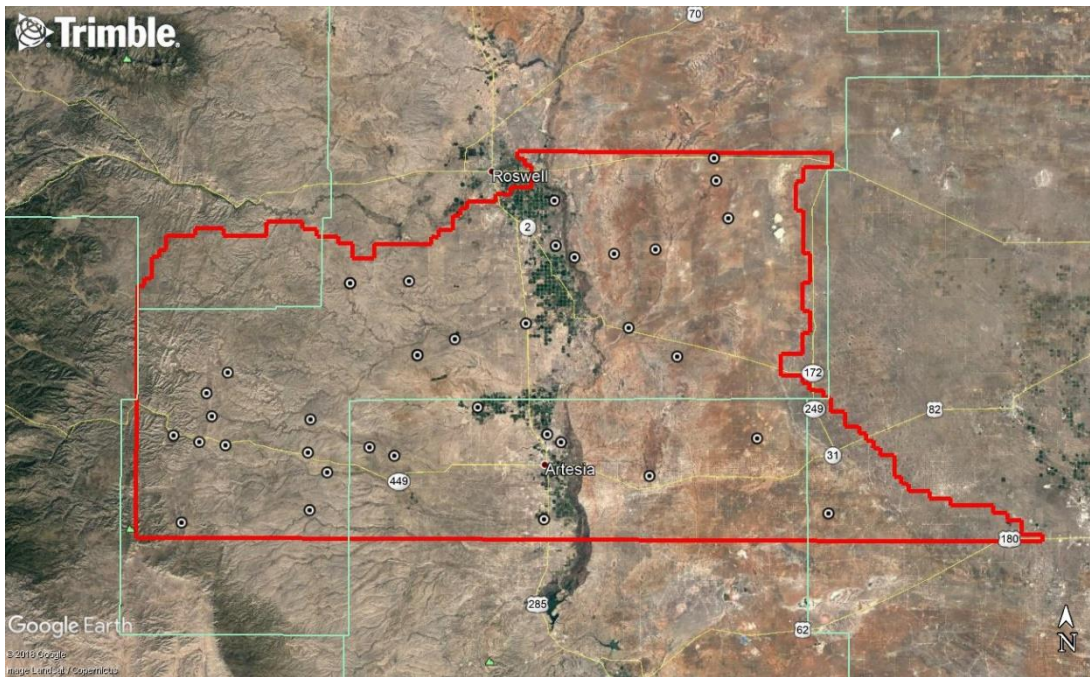


Figure 3: LiDAR Control Point Distribution

ID	Easting	Northing	Elevation
BE021	577953.356	3631906.773	1091.984
BE040	615625.042	3624258.429	1155.814
BE041	600531.856	3639887.51	1165.457
BE052	489183.834	3653158.156	1559.24
BE053	595075.32	3693896.904	1200.514
BE078	485387.355	3640450.735	1654.505
BE085	558047.821	3679858.809	1062.372
BE086	551879.464	3663594.766	1086.237
BE098	555883.841	3622713.097	1040.468
BE100	583621.449	3656844.895	1109.669
BE101	594206.777	3685776.01	1166.32
BE105	523036.559	3660162.539	1216.365
BE106	519201.495	3637591.005	1282.15
BE125	559371.136	3638846.159	1017.867
BE128	556476.226	3640467.225	1025.675
BE129	573439.033	3662797.685	1047.461
BE130	578966.106	3679210.39	1118.019
BE135	505453.453	3643347.426	1439.111
BE136	541852.914	3646039.685	1084.961
BE137	485068.95	3648747.304	1651.688
BE149	591445.116	3671522.033	1145.918
BE150	589375.059	3659449.749	1163.868
OT014	598883.529	3619783.448	1052.942
OT020	626547.376	3625576.649	1215.039
OT028	553981.683	3652259.912	1050.041
OT029	541625.415	3632671.912	1134.132
OT030	510893.035	3643322.95	1378.023
OT031	472778.229	3628203.735	1795.295
OT040	589207.252	3626411.69	1069.637
OT075	512775.169	3622122.196	1363.567
OT076	542749.385	3649007.751	1091.498
OT077	563274.228	3650315.788	1020.099
OT085	599786.953	3643195.372	1182.41
OT086	596829.924	3660768.331	1168.666
OT087	585288.54	3685737.585	1120.6
OT088	569458.06	3697301.827	1126.511
OT089	550794.975	3673344.621	1087.098
OT091	521862.123	3654633.302	1237.597

ID	Easting	Northing	Elevation
OT092	524421.11	3622529.755	1237.292
OT125	587154.094	3675999.702	1120.517
OT126	566731.175	3667006.238	1042.255
OT127	576029.393	3654663.14	1089.077
OT128	586917.466	3650838.922	1133.495
OT142	477501.412	3657932.34	1732.397
UR020	582626.639	3630559.976	1114.614
UR021	566404.106	3632559.746	1041.234
UR022	618830.103	3628663.478	1200.768
UR029	612769.459	3644965.215	1330.754
UR043	582435.648	3660024.019	1096.784
UR044	609887.726	3629792.081	1166.666
UR045	591787.378	3631737.692	1105.185
UR068	606172.717	3653649.392	1327.841
UR069	614282.986	3697670.988	1308.099
UR070	581737.272	3698307.546	1138.849
UR071	560786.239	3695788.419	1135.119
UR072	544354.526	3687296.809	1108.709
UR073	552504.729	3645263.554	1041.907
UR075	550565.966	3634791.015	1067.372
UR084	496643.879	3637524.252	1539.982
UR093	517301.266	3633424.018	1310.268
UR098	558772.683	3673623.483	1053.678
UR099	529160.048	3656861.772	1213.934
UR100	529161.177	3656869.994	1213.618
UR105	471014.648	3646213.476	1760.644
UR112	549655.781	3683025.803	1097.786
UR113	549786.067	3683016.519	1096.881
UR121	530770.354	3631783.721	1204.242
UR124	476235.737	3643951.316	1722.05
UR135	602422.389	3698280.408	1232.89
UR137	594727.901	3657072.331	1178.272
UR138	561981.211	3664082.141	1046.127
UR140	536440.319	3633950.91	1160.577
UR150	515309.519	3647628.46	1299.017
UR151	506323.188	3636405.218	1440.41

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

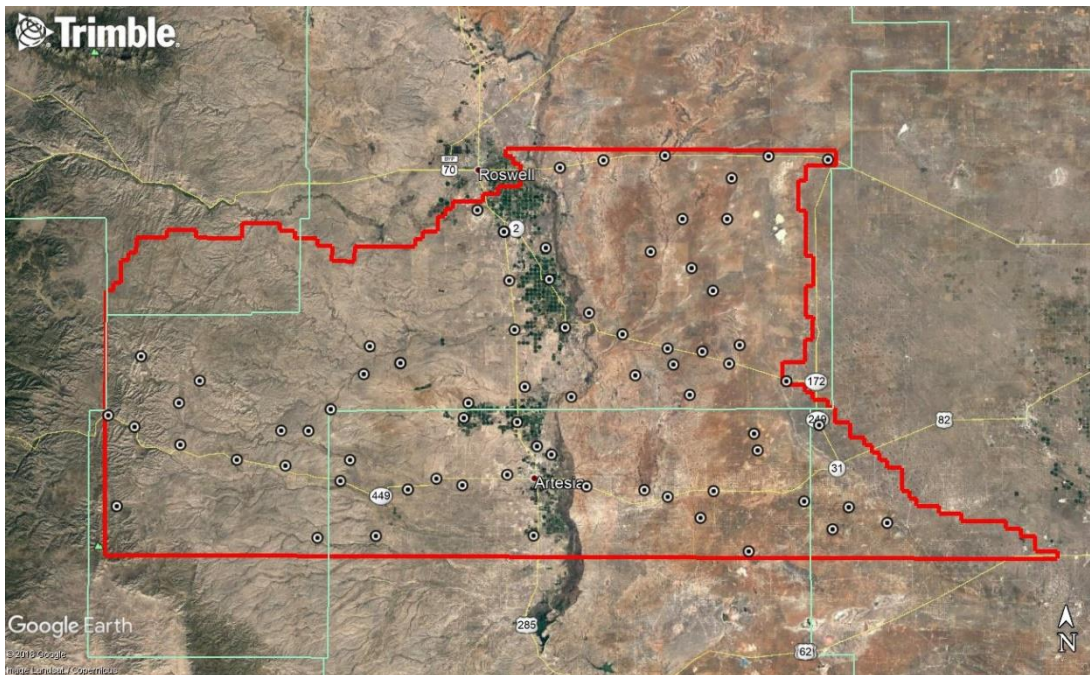


Figure 4: Non-Vegetated Vertical Accuracy (NVA) Point Distribution

ID	Easting	Northing	Elevation
BR016	623018.089	3620470.609	1148.565
BR017	569574.917	3621116.986	1064.069
BR044	479897.162	3621658.566	1753.937
BR059	531439.659	3628989.212	1202.849
BR060	526740.084	3632167.177	1232.397
BR066	542187.084	3660306.187	1132.762
BR067	570262.101	3678257.557	1087.734
BR068	591616.116	3693603.828	1184.688
BR076	595513.619	3632130.905	1113.369
BR081	477543.466	3673214.42	1806.339
BR084	480811.479	3629801.911	1666.547
BR089	585648.306	3653522.466	1132.297
BR090	540295.967	3640385.965	1112.752
BR107	587171.912	3676039.25	1121.083
BR108	589397.717	3659439.418	1163.629
HG013	602299.275	3621042.471	1105.299
HG020	596816.942	3620644.475	1068.098
HG023	644476.23	3621477.46	1189.601
HG024	644476.155	3621477.438	1189.625

ID	Easting	Northing	Elevation
HG054	474012.21	3666442.053	1853.406
HG055	506753.425	3624407.804	1409.052
HG065	531161.562	3628976.919	1204.563
HG066	534895.852	3651415.395	1155.131
HG067	550738.072	3653631.839	1071.196
HG070	559307.37	3642089.287	1013.89
HG080	545156.886	3625363.49	1101.141
HG081	545439.95	3622776.329	1101.591
HG082	562002.603	3677447.213	1040.606
HG083	589317.469	3658473.558	1149.446
HG084	555446.997	3660442.341	1067.79
HG086	591442.469	3671506.41	1146.375
HG087	588945.123	3687614.449	1142.793
HG090	530426.943	3665590.544	1193.675
HG091	585337.733	3642054.823	1113.254
HG103	570770.831	3638842.054	1046.559
HG104	514992.788	3671751.815	1311.122
HG107	499407.336	3636742.441	1501.982
HG108	516527.371	3660996.78	1257.687
TR023	561148.531	3626368.503	1003.955
TR030	579525.74	3644362.431	1086.412
TR031	571829.056	3657013.94	1041.24
TR032	470934.669	3659790.027	1844.634
TR047	609695.614	3663440.052	1280.495
TR048	560185.453	3664093.383	1054.55
TR049	497943.335	3650451.137	1467.817
TR065	553070.204	3682978.229	1082.47
TR084	524180.879	3630371.353	1251.09
TR085	484400.758	3680088.351	1713.063
TR099	480036.76	3652973.613	1665.828

Table 7: Vegetated Vertical Accuracy (VVA) Point Coordinates

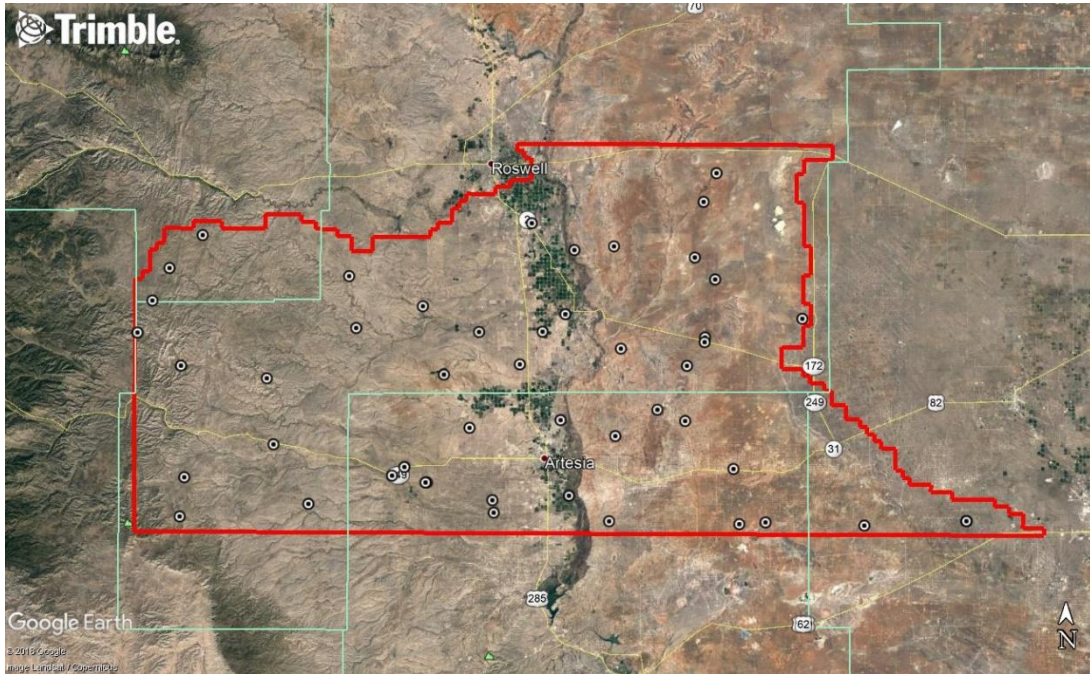


Figure 5: Vegetated Vertical Accuracy (VVA) Point Distribution

SECTION III: DATA PRODUCTION

3. Aerial LiDAR Project – Calibration/Classification

a. 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.

b. Coordinate Reference System

Horizontal Datum: NAD83(NSRS2011)
Coordinate System: UTM 13N
Vertical Datum: NAVD88
Geoid Model: 12B
Units of Reference: Meter

c. LiDAR Point Cloud Statistics

Category	Value
Total Points	35,350,714,085
Nominal Pulse Spacing (m)	0.6259
Nominal Pulse Density (pls/m²)	2.5525
Nominal Pulse Spacing (ft)	2.0535
Nominal Pulse Density (pls/ft²)	0.2371
Aggregate Total Points	33,342,487,865
Aggregate Nominal Pulse Spacing (m)	0.5596
Aggregate Nominal Pulse Density (pls/m²)	3.1929
Aggregate Nominal Pulse Spacing (ft)	1.8361
Aggregate Nominal Pulse Density (pls/ft²)	0.2966

Table 8: LiDAR Point Cloud Statistics

d. 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. The following figure depicts a sample of the assessment.

e. 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.

f. 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 classes 9 (Water) and 20 (Ignored Ground).

Code	Description
1	Processed, but unclassified
2	Bare-earth ground
7	Low Noise
9	Water
17	Bridge Decks
18	High Noise
20	Ignored Ground (breakline proximity)
21	Snow (if present and identifiable)
22	Temporal exclusion

Table 9: LiDAR Point Classification Codes and Descriptions

a. 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 .tif format.

b. 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 geodatabase for the entire project area.

c. 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 1.0 meter. DEMs for this project were cut to match the tile index and its corresponding tile names and delivered in 32-bit floating point .tif format.

SECTION IV: ACCURACY ASSESSMENT

1. Aerial LiDAR Project – Vertical Accuracy Assessment

a. 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 95 th 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 10: 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).

b. 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	# of Points	RMSEz	95% Confidence Level	95th Percentile
NVA of Point Cloud	49	0.0995	0.1950	0.1770
NVA of DEM	48	0.0998	0.1957	0.1740
VVA of Point Cloud	43	0.1959	0.3840	0.3656
VVA of DEM	42	0.1925	0.3773	0.3672

Table 21: NVA/VVA Accuracies

SECTION V: CERTIFICATION STATEMENTS

1. Aerial LiDAR Project

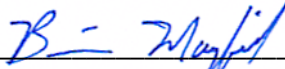
This accuracy assessment confirms that the data may be used for the intended applications stated in Section I of this document. This dataset may also be used as a topographic input for other applications, but the user should be aware that this LiDAR dataset was designed with a specific purpose and was 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 VI: CONTROL POINT ASSESSMENTS

1. Aerial LiDAR Project

a. Point Cloud Check Point Assessment

Point ID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
UR044	609887.726	3629792.081	1,166.6660	1,166.6690	URBAN TERRAIN	0.0030
BE105	523036.559	3660162.539	1,216.3650	1,216.3700	BARE EARTH	0.0050
UR137	594727.901	3657072.331	1,178.2720	1,178.2660	URBAN TERRAIN	(0.0060)
UR029	612769.459	3644965.215	1,330.7540	1,330.7610	URBAN TERRAIN	0.0070
BE100	583621.449	3656844.895	1,109.6690	1,109.6810	BARE EARTH	0.0120
OT020	626547.376	3625576.649	1,215.0390	1,215.0530	OPEN TERRAIN	0.0140
OT086	596829.924	3660768.331	1,168.6660	1,168.6810	OPEN TERRAIN	0.0150
UR022	618830.103	3628663.478	1,200.7680	1,200.7880	URBAN TERRAIN	0.0200
BE150	589375.059	3659449.749	1,163.8680	1,163.8940	BARE EARTH	0.0260
UR045	591787.378	3631737.692	1,105.1850	1,105.2140	URBAN TERRAIN	0.0290
UR112	549655.781	3683025.803	1,097.7860	1,097.8150	URBAN TERRAIN	0.0290
UR121	530770.354	3631783.721	1,204.2420	1,204.2130	URBAN TERRAIN	(0.0290)
UR150	515309.519	3647628.460	1,299.0170	1,299.0460	URBAN TERRAIN	0.0290
BE041	600531.856	3639887.510	1,165.4570	1,165.4240	BARE EARTH	(0.0330)
UR021	566404.106	3632559.746	1,041.2340	1,041.2710	URBAN TERRAIN	0.0370
OT085	599786.953	3643195.372	1,182.4100	1,182.4480	OPEN TERRAIN	0.0380
OT092	524421.110	3622529.755	1,237.2920	1,237.2520	OPEN TERRAIN	(0.0400)
UR099	529160.048	3656861.772	1,213.9340	1,213.9750	URBAN TERRAIN	0.0410
UR100	529161.177	3656869.994	1,213.6180	1,213.6650	URBAN TERRAIN	0.0470
OT127	576029.393	3654663.140	1,089.0770	1,089.1300	OPEN TERRAIN	0.0530
UR070	581737.272	3698307.546	1,138.8490	1,138.9020	URBAN TERRAIN	0.0530
UR043	582435.648	3660024.019	1,096.7840	1,096.7260	URBAN TERRAIN	(0.0580)
UR069	614282.986	3697670.988	1,308.0990	1,308.0360	URBAN TERRAIN	(0.0630)
OT014	598883.529	3619783.448	1,052.9420	1,053.0160	OPEN TERRAIN	0.0740
UR020	582626.639	3630559.976	1,114.6140	1,114.6890	URBAN TERRAIN	0.0750
BE021	577953.356	3631906.773	1,091.9840	1,092.0660	BARE EARTH	0.0820
BE130	578966.106	3679210.390	1,118.0190	1,118.1110	BARE EARTH	0.0920
OT089	550794.975	3673344.621	1,087.0980	1,087.1910	OPEN TERRAIN	0.0930
BE149	591445.116	3671522.033	1,145.9180	1,146.0180	BARE EARTH	0.1000
UR073	552504.729	3645263.554	1,041.9070	1,042.0070	URBAN TERRAIN	0.1000
BE129	573439.033	3662797.685	1,047.4610	1,047.5680	BARE EARTH	0.1070
UR075	550565.966	3634791.015	1,067.3720	1,067.4830	URBAN TERRAIN	0.1110
BE106	519201.495	3637591.005	1,282.1500	1,282.2620	BARE EARTH	0.1120
BE040	615625.042	3624258.429	1,155.8140	1,155.7000	BARE EARTH	(0.1140)
OT040	589207.252	3626411.690	1,069.6370	1,069.7510	OPEN TERRAIN	0.1140

Point ID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
OT125	587154.094	3675999.702	1,120.5170	1,120.6320	OPEN TERRAIN	0.1150
UR093	517301.266	3633424.018	1,310.2680	1,310.3880	URBAN TERRAIN	0.1200
OT075	512775.169	3622122.196	1,363.5670	1,363.4440	OPEN TERRAIN	(0.1230)
OT076	542749.385	3649007.751	1,091.4980	1,091.6300	OPEN TERRAIN	0.1320
UR072	544354.526	3687296.809	1,108.7090	1,108.8460	URBAN TERRAIN	0.1370
BE135	505453.453	3643347.426	1,439.1110	1,439.2580	BARE EARTH	0.1470
BE053	595075.320	3693896.904	1,200.5140	1,200.6620	BARE EARTH	0.1480
UR135	602422.389	3698280.408	1,232.8900	1,233.0560	URBAN TERRAIN	0.1660
OT030	510893.035	3643322.950	1,378.0230	1,378.1910	OPEN TERRAIN	0.1680
UR105	471014.648	3646213.476	1,760.6440	1,760.4740	URBAN TERRAIN	(0.1700)
OT077	563274.228	3650315.788	1,020.0990	1,020.2700	OPEN TERRAIN	0.1710
UR140	536440.319	3633950.910	1,160.5770	1,160.7580	URBAN TERRAIN	0.1810
UR151	506323.188	3636405.218	1,440.4100	1,440.5940	URBAN TERRAIN	0.1840
OT091	521862.123	3654633.302	1,237.5970	1,237.7900	OPEN TERRAIN	0.1930
HG054	474012.210	3666442.053	1,853.4060	1,853.4090	HIGH GRASS	0.0030
TR084	524180.879	3630371.353	1,251.0900	1,251.0860	TREE	(0.0040)
HG023	644476.230	3621477.460	1,189.6010	1,189.5690	HIGH GRASS	(0.0320)
BR090	540295.967	3640385.965	1,112.7520	1,112.7850	BRUSH	0.0330
HG055	506753.425	3624407.804	1,409.0520	1,409.0900	HIGH GRASS	0.0380
BR068	591616.116	3693603.828	1,184.6880	1,184.7350	BRUSH	0.0470
HG087	588945.123	3687614.449	1,142.7930	1,142.8410	HIGH GRASS	0.0480
HG024	644476.155	3621477.438	1,189.6250	1,189.5730	HIGH GRASS	(0.0520)
HG090	530426.943	3665590.544	1,193.6750	1,193.7360	HIGH GRASS	0.0610
TR048	560185.453	3664093.383	1,054.5500	1,054.4810	TREE	(0.0690)
BR108	589397.717	3659439.418	1,163.6290	1,163.7020	BRUSH	0.0730
HG086	591442.469	3671506.410	1,146.3750	1,146.4510	HIGH GRASS	0.0760
BR016	623018.089	3620470.609	1,148.5650	1,148.6470	BRUSH	0.0820
HG104	514992.788	3671751.815	1,311.1220	1,311.2160	HIGH GRASS	0.0940
HG020	596816.942	3620644.475	1,068.0980	1,068.1980	HIGH GRASS	0.1000
HG083	589317.469	3658473.558	1,149.4460	1,149.5680	HIGH GRASS	0.1220
HG108	516527.371	3660996.780	1,257.6870	1,257.8090	HIGH GRASS	0.1220
BR066	542187.084	3660306.187	1,132.7620	1,132.8860	BRUSH	0.1240
TR032	470934.669	3659790.027	1,844.6340	1,844.5070	TREE	(0.1270)
BR107	587171.912	3676039.250	1,121.0830	1,121.2120	BRUSH	0.1290
HG013	602299.275	3621042.471	1,105.2990	1,105.4330	HIGH GRASS	0.1340
TR031	571829.056	3657013.940	1,041.2400	1,041.3760	TREE	0.1360
BR060	526740.084	3632167.177	1,232.3970	1,232.5340	BRUSH	0.1370
HG065	531161.562	3628976.919	1,204.5630	1,204.7090	HIGH GRASS	0.1460
BR017	569574.917	3621116.986	1,064.0690	1,064.2190	BRUSH	0.1500

Point ID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
BR089	585648.306	3653522.466	1,132.2970	1,132.4500	BRUSH	0.1530
TR047	609695.614	3663440.052	1,280.4950	1,280.6550	TREE	0.1600
TR030	579525.740	3644362.431	1,086.4120	1,086.5840	TREE	0.1720
HG066	534895.852	3651415.395	1,155.1310	1,155.3080	HIGH GRASS	0.1770
HG091	585337.733	3642054.823	1,113.2540	1,113.4410	HIGH GRASS	0.1870
BR059	531439.659	3628989.212	1,202.8490	1,203.0410	BRUSH	0.1920
TR065	553070.204	3682978.229	1,082.4700	1,082.6680	TREE	0.1980
HG082	562002.603	3677447.213	1,040.6060	1,040.8060	HIGH GRASS	0.2000
HG080	545156.886	3625363.490	1,101.1410	1,101.3920	HIGH GRASS	0.2510
BR067	570262.101	3678257.557	1,087.7340	1,087.9960	BRUSH	0.2620
HG103	570770.831	3638842.054	1,046.5590	1,046.8580	HIGH GRASS	0.2990
HG067	550738.072	3653631.839	1,071.1960	1,071.4990	HIGH GRASS	0.3030
BR081	477543.466	3673214.420	1,806.3390	1,806.6550	BRUSH	0.3160
HG081	545439.950	3622776.329	1,101.5910	1,101.9090	HIGH GRASS	0.3180
TR085	484400.758	3680088.351	1,713.0630	1,713.4070	TREE	0.3440
HG070	559307.370	3642089.287	1,013.8900	1,014.2580	HIGH GRASS	0.3680
HG084	555446.997	3660442.341	1,067.7900	1,068.1600	HIGH GRASS	0.3700
TR099	480036.760	3652973.613	1,665.8280	1,666.3300	TREE	0.5020

Table 32: Point Cloud Check Point Assessment

b. Digital Elevation Model (DEM) Check Point Assessment

Point ID	Easting	Northing	KnownZ	DEMZ	Description	DeltaZ
BE021	577953.356	3631906.773	1,091.9840	1,092.0759	BARE EARTH	0.0919
BE040	615625.042	3624258.429	1,155.8140	1,155.7010	BARE EARTH	(0.1130)
BE041	600531.856	3639887.510	1,165.4570	1,165.4199	BARE EARTH	(0.0371)
BE053	595075.320	3693896.904	1,200.5140	1,200.6781	BARE EARTH	0.1641
BE100	583621.449	3656844.895	1,109.6690	1,109.6981	BARE EARTH	0.0292
BE105	523036.559	3660162.539	1,216.3650	1,216.3750	BARE EARTH	0.0100
BE106	519201.495	3637591.005	1,282.1500	1,282.2631	BARE EARTH	0.1131
BE129	573439.033	3662797.685	1,047.4610	1,047.5765	BARE EARTH	0.1154
BE130	578966.106	3679210.390	1,118.0190	1,118.1142	BARE EARTH	0.0952
BE135	505453.453	3643347.426	1,439.1110	1,439.2568	BARE EARTH	0.1458
BE149	591445.116	3671522.033	1,145.9180	1,146.0216	BARE EARTH	0.1036
BE150	589375.059	3659449.749	1,163.8680	1,163.9030	BARE EARTH	0.0350
OT014	598883.529	3619783.448	1,052.9420	1,052.9553	OPEN TERRAIN	0.0133
OT020	626547.376	3625576.649	1,215.0390	1,215.0554	OPEN TERRAIN	0.0165
OT030	510893.035	3643322.950	1,378.0230	1,378.1961	OPEN TERRAIN	0.1732
OT040	589207.252	3626411.690	1,069.6370	1,069.7535	OPEN TERRAIN	0.1165
OT076	542749.385	3649007.751	1,091.4980	1,091.6223	OPEN TERRAIN	0.1243

Point ID	Easting	Northing	KnownZ	DEMZ	Description	DeltaZ
OT077	563274.228	3650315.788	1,020.0990	1,020.2735	OPEN TERRAIN	0.1745
OT085	599786.953	3643195.372	1,182.4100	1,182.4450	OPEN TERRAIN	0.0350
OT086	596829.924	3660768.331	1,168.6660	1,168.6876	OPEN TERRAIN	0.0216
OT089	550794.975	3673344.621	1,087.0980	1,087.1842	OPEN TERRAIN	0.0862
OT091	521862.123	3654633.302	1,237.5970	1,237.7911	OPEN TERRAIN	0.1941
OT092	524421.110	3622529.755	1,237.2920	1,237.2451	OPEN TERRAIN	(0.0469)
OT125	587154.094	3675999.702	1,120.5170	1,120.6387	OPEN TERRAIN	0.1217
OT127	576029.393	3654663.140	1,089.0770	1,089.1285	OPEN TERRAIN	0.0515
UR020	582626.639	3630559.976	1,114.6140	1,114.6950	URBAN TERRAIN	0.0810
UR021	566404.106	3632559.746	1,041.2340	1,041.2478	URBAN TERRAIN	0.0138
UR022	618830.103	3628663.478	1,200.7680	1,200.7800	URBAN TERRAIN	0.0121
UR029	612769.459	3644965.215	1,330.7540	1,330.7721	URBAN TERRAIN	0.0181
UR043	582435.648	3660024.019	1,096.7840	1,096.7173	URBAN TERRAIN	(0.0668)
UR044	609887.726	3629792.081	1,166.6660	1,166.6635	URBAN TERRAIN	(0.0025)
UR045	591787.378	3631737.692	1,105.1850	1,105.2147	URBAN TERRAIN	0.0296
UR069	614282.986	3697670.988	1,308.0990	1,308.0421	URBAN TERRAIN	(0.0569)
UR070	581737.272	3698307.546	1,138.8490	1,138.8999	URBAN TERRAIN	0.0509
UR072	544354.526	3687296.809	1,108.7090	1,108.8551	URBAN TERRAIN	0.1461
UR073	552504.729	3645263.554	1,041.9070	1,042.0178	URBAN TERRAIN	0.1108
UR075	550565.966	3634791.015	1,067.3720	1,067.4814	URBAN TERRAIN	0.1095
UR093	517301.266	3633424.018	1,310.2680	1,310.3886	URBAN TERRAIN	0.1207
UR099	529160.048	3656861.772	1,213.9340	1,213.9673	URBAN TERRAIN	0.0333
UR100	529161.177	3656869.994	1,213.6180	1,213.6697	URBAN TERRAIN	0.0517
UR105	471014.648	3646213.476	1,760.6440	1,760.4735	URBAN TERRAIN	(0.1705)
UR112	549655.781	3683025.803	1,097.7860	1,097.8220	URBAN TERRAIN	0.0360
UR121	530770.354	3631783.721	1,204.2420	1,204.2058	URBAN TERRAIN	(0.0361)
UR135	602422.389	3698280.408	1,232.8900	1,233.0560	URBAN TERRAIN	0.1660
UR137	594727.901	3657072.331	1,178.2720	1,178.2704	URBAN TERRAIN	(0.0016)
UR140	536440.319	3633950.910	1,160.5770	1,160.7589	URBAN TERRAIN	0.1819
UR150	515309.519	3647628.460	1,299.0170	1,299.0432	URBAN TERRAIN	0.0262
UR151	506323.188	3636405.218	1,440.4100	1,440.5768	URBAN TERRAIN	0.1668
BR016	623018.089	3620470.609	1,148.5650	1,148.6479	BRUSH	0.0830
BR017	569574.917	3621116.986	1,064.0690	1,064.1884	BRUSH	0.1194
BR059	531439.659	3628989.212	1,202.8490	1,202.9037	BRUSH	0.0547
BR060	526740.084	3632167.177	1,232.3970	1,232.5483	BRUSH	0.1513
BR066	542187.084	3660306.187	1,132.7620	1,132.8324	BRUSH	0.0704
BR067	570262.101	3678257.557	1,087.7340	1,087.9753	BRUSH	0.2413
BR068	591616.116	3693603.828	1,184.6880	1,184.7138	BRUSH	0.0258
BR081	477543.466	3673214.420	1,806.3390	1,806.6719	BRUSH	0.3329

Point ID	Easting	Northing	KnownZ	DEMZ	Description	DeltaZ
BR089	585648.306	3653522.466	1,132.2970	1,132.4553	BRUSH	0.1583
BR090	540295.967	3640385.965	1,112.7520	1,112.7714	BRUSH	0.0194
BR107	587171.912	3676039.250	1,121.0830	1,121.2205	BRUSH	0.1375
BR108	589397.717	3659439.418	1,163.6290	1,163.6836	BRUSH	0.0546
HG013	602299.275	3621042.471	1,105.2990	1,105.4358	HIGH GRASS	0.1368
HG020	596816.942	3620644.475	1,068.0980	1,068.2047	HIGH GRASS	0.1067
HG023	644476.230	3621477.460	1,189.6010	1,189.5630	HIGH GRASS	(0.0380)
HG024	644476.155	3621477.438	1,189.6250	1,189.5630	HIGH GRASS	(0.0620)
HG054	474012.210	3666442.053	1,853.4060	1,853.3647	HIGH GRASS	(0.0413)
HG055	506753.425	3624407.804	1,409.0520	1,409.0924	HIGH GRASS	0.0404
HG065	531161.562	3628976.919	1,204.5630	1,204.6950	HIGH GRASS	0.1320
HG066	534895.852	3651415.395	1,155.1310	1,155.2914	HIGH GRASS	0.1604
HG067	550738.072	3653631.839	1,071.1960	1,071.4745	HIGH GRASS	0.2785
HG070	559307.370	3642089.287	1,013.8900	1,014.2579	HIGH GRASS	0.3679
HG080	545156.886	3625363.490	1,101.1410	1,101.3815	HIGH GRASS	0.2405
HG081	545439.950	3622776.329	1,101.5910	1,101.8968	HIGH GRASS	0.3059
HG082	562002.603	3677447.213	1,040.6060	1,040.8177	HIGH GRASS	0.2117
HG083	589317.469	3658473.558	1,149.4460	1,149.5715	HIGH GRASS	0.1255
HG084	555446.997	3660442.341	1,067.7900	1,068.1762	HIGH GRASS	0.3862
HG086	591442.469	3671506.410	1,146.3750	1,146.4531	HIGH GRASS	0.0781
HG087	588945.123	3687614.449	1,142.7930	1,142.8385	HIGH GRASS	0.0455
HG090	530426.943	3665590.544	1,193.6750	1,193.7307	HIGH GRASS	0.0557
HG091	585337.733	3642054.823	1,113.2540	1,113.4294	HIGH GRASS	0.1754
HG103	570770.831	3638842.054	1,046.5590	1,046.8522	HIGH GRASS	0.2932
HG104	514992.788	3671751.815	1,311.1220	1,311.2173	HIGH GRASS	0.0954
HG108	516527.371	3660996.780	1,257.6870	1,257.8008	HIGH GRASS	0.1138
TR030	579525.740	3644362.431	1,086.4120	1,086.5891	TREE	0.1771
TR031	571829.056	3657013.940	1,041.2400	1,041.3899	TREE	0.1499
TR047	609695.614	3663440.052	1,280.4950	1,280.6675	TREE	0.1725
TR048	560185.453	3664093.383	1,054.5500	1,054.4609	TREE	(0.0891)
TR065	553070.204	3682978.229	1,082.4700	1,082.6553	TREE	0.1853
TR084	524180.879	3630371.353	1,251.0900	1,251.0993	TREE	0.0093
TR085	484400.758	3680088.351	1,713.0630	1,713.4167	TREE	0.3537
TR099	480036.760	3652973.613	1,665.8280	1,666.3083	TREE	0.4803

Table 43: DEM Check Point Assessment