Project Report

TASK ORDER NAME: 2018 Kansas QL2 LiDAR
CONTRACT ID: 00000000000000000000039891
EVENT ID: EVT0003259
ATLANTIC PROJECT NUMBER: 18006
PROJECT BLOCK NUMBER: Block 1B

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SECTION I: PROJECT OVERVIEW & PURPOSE

1. Aerial LiDAR Project

a. Project Overview

The State of Kansas Contract 00000000000000000000039891 required Leaf-off 2018 QL 2 LiDAR surveys to be collected over 54,663 square miles covering part or all of 86 counties in Kansas in support of the Kansas Department of Agriculture and Kansas Data Access and Support Center. 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 1.2. Project Block 1B encompasses part or all of 9 counties in Southern Kansas and covers approximately 3990 square miles.

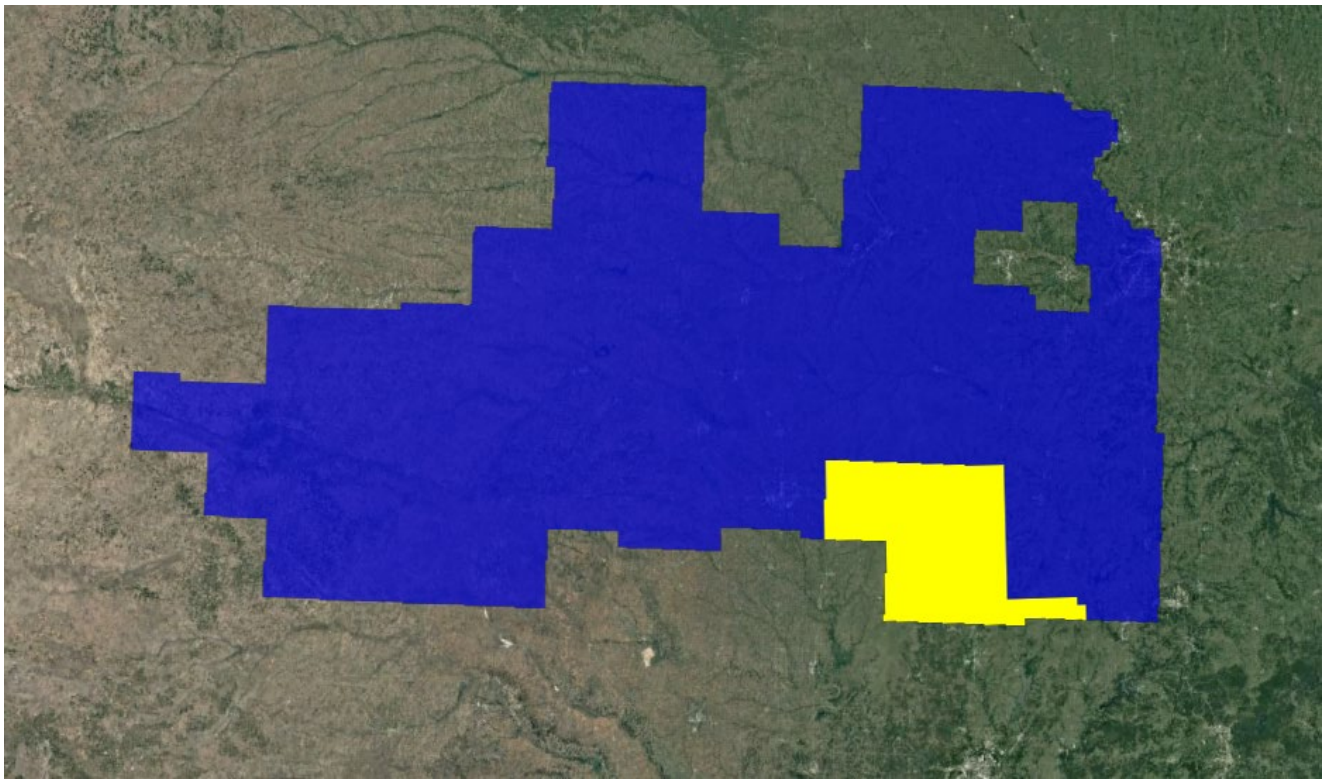


Figure 1: Aerial LiDAR Project Overview – Defined Project Area (DPA) and Associated Areas of Interest (AOIs)

b. Project Purpose

The State of Kansas, on behalf of the Kansas Department of Agriculture and Kansas Data Access and Support Center, has contracted with Atlantic for professional services related to the development of Light Detection and Ranging (LiDAR). Additional partners include the USDA Natural Resource Conservation Service, the U.S. Geological Survey, the Kansas GIS Policy Board, the Kansas Department of Transportation and the Kansas Water Office. These LiDAR elevation data will be used for conservation planning, design, research, floodplain mapping, wetlands identification, dam safety assessments, hydrologic modeling, and subsidence monitoring.

c. Client Contact Information

Client Contact Information	
Name of Contact	Tara Lanzrath, CFM
Organization	Kansas Department of Agriculture
Position	Floodplain Mapping Coordinator
Telephone	785-296-2513
E-Mail Address	Tara.Lanzrath@ks.gov
Mailing Address	6531 SE Forbes Ave., Suite B
City	Topeka
State or Province	Kansas
Postal Code	66619

Table 1: Aerial LiDAR Client Contact Information

d. Contract Deliverables

Item	Specification/Format
Metadata	FGDC compliant, xml format
Project Report	.pdf format
Raw Point Cloud	Swaths, LAS 1.4
Classified Point Cloud	LAS 1.4
Bare Earth DEM	ERDAS .IMG format, Hydroflattened
First Return DSM	ERDAS .IMG format
Hydro Polygon Breaklines	.gdb format
Intensity Imagery	ERDAS .IMG format

Table 2: Aerial LiDAR Contract Deliverables

SECTION II: FIELD OPERATIONS

1. Aerial LiDAR Project – Aerial Acquisition

a. Aircraft & 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

Table3: System Specifications – ALS70-HP

b. 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)	0.71
Nominal Pulse Density (pls/m²)	2.2
Nominal Flight Height (AGL meters)	2000
Nominal Flight Speed (kts)	130
Pass Heading (°)	0
Sensor Scan Angle (°)	45
Scan Frequency (Hz)	33.9
Pulse Rate of Scanner (kHz)	256,400
Line Spacing (m)	1,171

Parameter	Specification
Pulse Duration of Scanner (ns)	4
Pulse Width of Scanner (m)	.35
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	2
Beam Divergence (mrad)	.15
Nominal Swath Width (m)	1,740
Nominal Swath Overlap (%)	20
Scan Pattern	TRIANGLE

Table 4: Aerial LiDAR Sensor Acquisition Parameters

c. Flight Plan Execution

Atlantic acquired 134 passes of the AOI as a series of perpendicular and/or adjacent flight-lines executed in 10 flight missions conducted between January 3, 2018 and January 28, 2018. 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

Fifteen (15) 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
ICT1	CORS	ICT1	N37°35'15.79517"	W97°18'32.00080"	363.340M
ICT3	CORS	ICT3	N37°45'09.33297"	W97°12'58.42230"	401.242M
ICT4	CORS	ICT4	N37°37'08.57671"	W97°37'57.00056"	392.172M
ICT5	CORS	ICT5	N37°47'12.04062"	W97°37'32.73360"	411.107M
KSBU	CORS	KSBU	N38°11'44.89654"	W95°44'17.09577"	289.926M
KSEM	CORS	KSEM	N38°24'14.61667"	W96°10'42.33265"	341.335M
KSEU	CORS	KSEU	N37°51'06.29431"	W96°17'23.77206"	344.298M
KSMA	CORS	KSMA	N38°21'35.67506"	W97°00'42.69506"	380.231M
KSOG	CORS	KSOG	N38°38'14.33271"	W95°49'49.98265"	307.468M
KSU1	CORS	KSU1	N39°06'02.70006"	W96°36'34.13595"	325.564M
MOA2	CORS	MOA2	N36°41'03.41544"	W94°26'18.28447"	268.313M
MOCA	CORS	MOCA	N37°10'39.18857"	W94°21'27.28200"	269.942M
MOMO	CORS	MOMO	N36°55'00.50847"	W93°58'59.05396"	380.618M
MONE	CORS	MONE	N37°51'56.74271"	W94°20'58.40827"	221.254M
ZKC1	CORS	ZKC1	N38°52'48.57351"	W94°47'27.00464"	305.466M

Table 5: GNSS Reference Stations

2. Aerial LiDAR Project – Ground Acquisition

a. Ground Control Survey

A total of 186 ground survey points were collected in support of this project, including 54 LiDAR Control Points (LCP), 75 Non-vegetated Vertical Accuracy (NVA) and 57 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 & 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
LCP172	675612.055	4163223.46	366.668
LCP174	686777.839	4190551.618	410.867
LCP183	749163.09	4185230.112	330.997
LCP184	742359.097	4180152.846	338.896
LCP185	757214.659	4146624.146	335.24
LCP186	743583.24	4149806.93	304.688
LCP187	726569.622	4127461.751	341.554
LCP188	730522.187	4133154.349	355.879
LCP189	749945.71	4100999.706	285.858
LCP190	759004.61	4099992.159	259.1
LCP191	759342.386	4109868.255	235.575
LCP307	696886.284	4161289.934	434.447
LCP308	702810.851	4174334.148	441.096
LCP309	688187.725	4165944.379	398.314
LCP310	701042.08	4188019.755	433.707
LCP527	687268.549	4155447.559	403.596
LCP532	748327.684	4191812.857	318.619
LCP533	739044.004	4174276.172	320.789

ID	Easting	Northing	Elevation
LCP534	725908.981	4133080.402	324.526
LCP535	744953.477	4105776.306	310.341
LCP639	726483.664	4179789.014	381.225
LCP640	727508.428	4184678.676	359.389
LCP641	733904.886	4186458.469	343.587
LCP642	715431.047	4150512.798	428.217
LCP643	708734.749	4154385.783	460.285
LCP644	734475.875	4163888.237	369.464
LCP645	731326.39	4162172.396	372.255
LCP646	728380.837	4153573.304	372.602
LCP647	735161.459	4142912.908	347.86
LCP648	734181.368	4116141.234	323.487
LCP649	746146.436	4120474.418	315.161
LCP650	753918.254	4128063.721	315.911
LCP651	723397.58	4188081.914	375.012
LCP652	714845.67	4177873.49	465.291
LCP653	708500.764	4148661.534	459.292
LCP654	747907.608	4139887.648	290.019
LCP655	758052.572	4141278.394	277.539
LCP656	719989.147	4105551.016	305.573
LCP657	743134.034	4125424.731	346.562
LCP01	250256.232	4150933.904	279.631
LCP02	243011.932	4154093.024	279.767
LCP03	241944.949	4107873.583	245.325
LCP04	239655.849	4109567.976	234.594
LCP108	235536.306	4130645.175	261.471
LCP109	249504.282	4162410.361	268.085
LCP110	257940.132	4163259.182	290.379
LCP111	255894.98	4179893.772	301.679
LCP112	278547.196	4106172.35	235.578
LCP136	239103.279	4177242.731	295.620
LCP147	296701.332	4103933.068	276.601
LCP40	250470.13	4187151.767	322.922
LCP41	257874.6	4187937.813	326.403
LCP42	257289.471	4128238.737	243.989
LCP51	303054.893	4098444.707	274.207

Table 6: LiDAR Control Point Coordinates

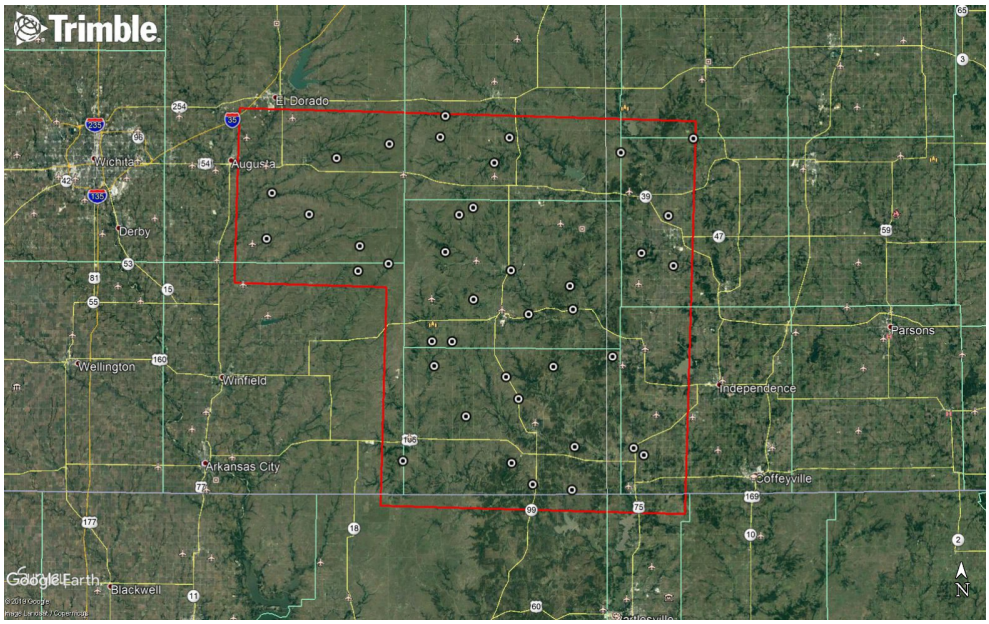


Figure 3: LiDAR Control Point Distribution

ID	Easting	Northing	Elevation
NVA1012	723418.22	4188076.689	375.835
NVA1013	742654.852	4160796.812	361.465
NVA1014	747895.699	4139872.13	290.672
NVA1015	746206.974	4117219.395	301.29
NVA1016	719878.47	4109963.245	297.522
NVA1017	730575.121	4176703.63	358.998
NVA1018	733900.158	4186457.859	343.502
NVA1019	734464.355	4163882.36	369.226
NVA1020	728380.616	4153583.022	373.072
NVA1021	740063.621	4137448.531	329.078
NVA1022	728752.716	4108105.557	306.065
NVA1023	760304.967	4124159.276	310.326
NVA439	686770.821	4190535.645	411.226
NVA440	701023.981	4188032.407	434.187
NVA441	742365.623	4180170.892	338.277
NVA442	749182.452	4185234.962	3330.309
NVA443	675622.995	4163220.283	366.21
NVA444	696897.259	4161272.799	434.67
NVA445	726573.551	4127432.842	341.765
NVA446	757199.032	4146630.93	335.14

ID	Easting	Northing	Elevation
NVA457	759017.876	4099998.852	259.088
NVA458	749963.222	4101005.314	285.796
NVA639	683146.905	4181905.176	411.336
NVA640	696916.898	4158041.376	435.957
NVA641	739074.512	4174288.576	319.341
NVA643	739576.254	4154329.759	328.075
NVA644	725891.729	4133085.508	324.025
NVA655	742517.691	4110881.326	325.282
NVA839	689831.778	4183702.809	409.098
NVA840	743501.349	4189221.106	333.056
NVA841	675643.491	4172128.736	375.976
NVA842	706312.088	4171190.199	452.962
NVA843	744443.59	4175395.645	346.928
NVA844	758877.832	4168425.702	291.805
NVA845	676071.291	4153340.006	368.168
NVA846	723372.558	4137788.094	357.88
NVA856	750448.223	4107858.72	278.881
NVA905	687433.357	4150430.916	382.259
NVA908	746896.447	4179489.327	311.544
NVA909	760578.179	4159606.257	290.166
NVA910	721843.523	4124899.542	330.551
NVA911	756218.025	4099928.13	244.348
NVA963	726485.323	4179775.149	381.285
NVA964	731334.039	4162175.024	372.4
NVA965	708741.249	4154389	460.267
NVA966	735129.178	4142921.851	348.331
NVA967	746148.193	4120476.11	315.16
NVA986	712747.052	4180480.252	472.782
NVA987	716837.309	4164470.141	492.42
NVA988	708513.613	4148662.411	459.277
NVA989	758059.921	4141277.152	277.532
NVA990	743137.692	4125416.764	346.329
NVA991	719989.552	4105555.29	305.611
NVA133	238591.21	4122879.178	289.329
NVA134	246983.295	4138268.371	269.602
NVA141	244474.98	4190566.771	316.351
NVA147	296682.135	4103929.88	276.335
NVA148	259160.609	4108812.88	268.263
NVA16	243019.75	4154073.022	279.752

ID	Easting	Northing	Elevation
NVA20	241953.218	4107896.792	246.088
NVA207	258979.556	4189518.102	324.062
NVA208	238796.073	4167615.33	301.673
NVA223	246650.326	4102360.955	268.492
NVA224	266230.469	4097732.484	226.980
NVA225	306390.083	4102409.477	259.433
NVA235	257278.651	4106074.702	232.835
NVA240	240461.088	4188532.799	303.065
NVA245	300359.362	4102629.616	266.204
NVA55	255894.946	4179887.997	301.568
NVA59	249506.355	4162420.168	268.217
NVA65	235533.342	4130642.67	261.372
NVA73	303034.614	4098432.324	274.221
NVA74	278541.889	4106161.344	235.354
NVA90	242190.305	4157738.013	264.031
NVA94	235224.168	4100453.681	224.205

Table 7: Non-Vegetated Vertical Accuracy (NVA) Point Coordinates

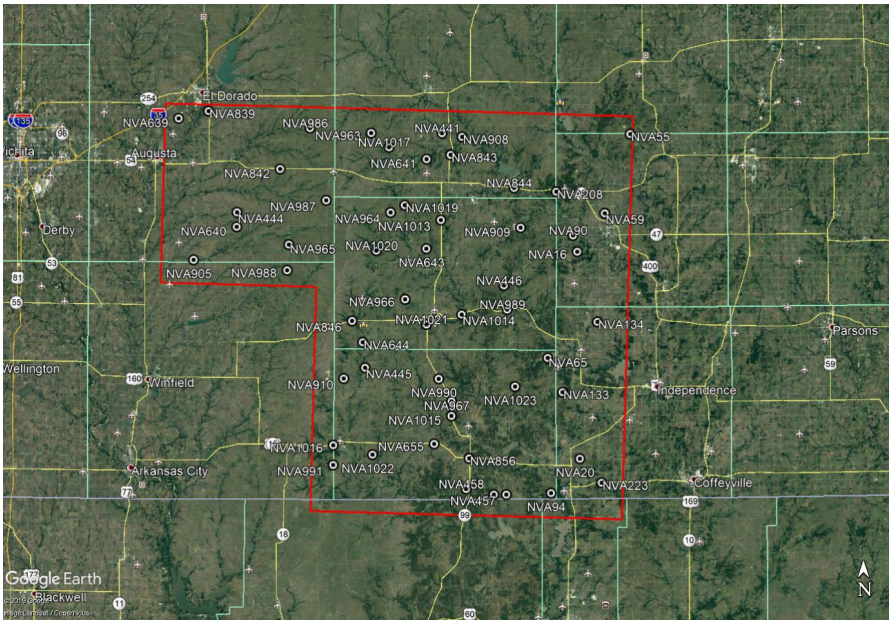


Figure 4: Non-Vegetated Vertical Accuracy (NVA) Point Distribution

ID	Easting	Northing	Elevation
VVA306	702813.518	4174328.872	440.938
VVA307	688195.823	4165954.569	398.531
VVA309	730542.367	4133147.783	355.876

ID	Easting	Northing	Elevation
VVA316	759342.516	4109886.391	235.643
VVA440	691717.065	4172657.092	411.148
VVA441	748312.929	4191826.919	318.322
VVA442	687413.848	4150423.352	382.016
VVA443	746924.022	4179474.402	311.512
VVA444	760586.343	4159596.075	289.629
VVA446	727523.348	4121739.845	336.272
VVA455	744939	4105783.856	309.805
VVA579	708915.02	4185808.888	458.013
VVA580	686878.377	4177204.204	387.074
VVA581	687280.308	4155445.367	403.712
VVA582	743577.349	4149794.835	308.618
VVA590	756210.308	4099949.461	244.387
VVA639	696964.625	4158053.491	435.114
VVA642	738512.009	4192734.23	368.964
VVA643	744452.851	4175403.037	352.411
VVA644	723400.65	4137795.682	356.252
VVA645	742546.089	4110871.45	324.577
VVA682	727500.452	4184668.574	360.742
VVA683	734471.231	4163895.725	369.561
VVA684	715411.71	4150523.87	430.362
VVA685	753924.448	4128083.13	316.165
VVA686	734148.769	4116135.737	323.192
VVA698	714853.545	4177877.269	465.61
VVA711	730551.605	4176717.885	358.814
VVA712	728387.696	4153528.221	370.305
VVA713	740069.782	4137465.173	328.984
VVA714	760307.713	4124150.524	310.364
VVA715	728762.603	4108112.509	306.459
VVA716	726472.39	4179773.726	381.433
VVA717	733908.093	4186448.028	343.044
VVA718	716832.933	4164463.512	492.44
VVA719	742645.834	4160798.565	361.002
VVA720	719909.958	4109986.183	299.844
VVA721	746182.611	4117221.414	301.455
VVA12	250235.264	4150938.867	280.349
VVA131	240474.196	4188537.759	302.929
VVA134	255183.715	4139632.157	251.816
VVA138	239107.49	4177254.413	295.737

ID	Easting	Northing	Elevation
VVA144	267577.195	4103587.872	223.578
VVA145	287101.327	4106394.835	272.181
VVA154	247005.325	4138270.838	269.247
VVA155	238832.719	4167612.51	305.215
VVA156	259147.162	4108831.841	266.750
VVA16	239658.334	4109584.585	234.590
VVA161	244451.108	4190549.912	316.166
VVA40	250476.455	4187163.222	322.938
VVA44	257280.673	4128233.133	244.018
VVA80	240006.778	4118045.39	250.006
VVA83	257888.002	4187925.971	325.845
VVA84	257944.376	4163243.674	290.432
VVA87	249741.869	4172806.023	262.575
VVA92	257302.499	4106049.989	232.099
VVA93	300371.363	4102603.336	265.825

Table 8: Vegetated Vertical Accuracy (VVA) Point Coordinates

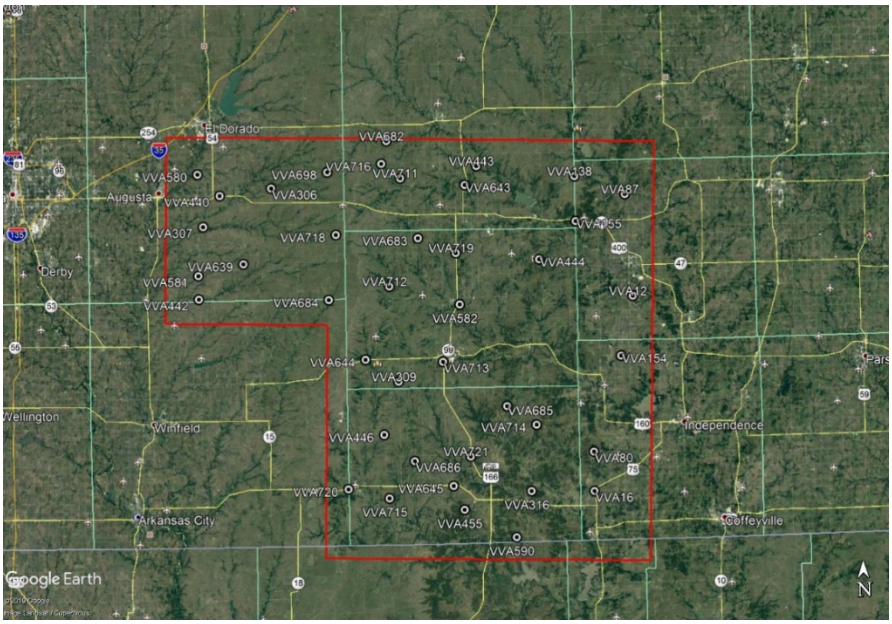


Figure 5: Vegetated Vertical Accuracy (VVA) Point Distribution

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(HARN)
Coordinate System: UTM, 14N/15N
Vertical Datum: NAVD88
Geoid Model: 12B
Units of Reference: Meter

c. LiDAR Point Cloud Statistics

Category	Value
Total Points (Nominal)	22,149,939,534
Nominal Pulse Spacing (M)	0.6676
Nominal Pulse Density (PLS/M^2)	2.2439
Total Points (Aggregate)	36,259,946,944
Aggregate Pulse Spacing (M)	0.5921
Aggregate Pulse Density (PLS/M^2)	2.8524

Table 9: 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.

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 10 (Ignored Ground).

Code	Description
1	Unclassified
2	Ground
7	Low point (noise)
9	Water
10	Ignored ground (breakline proximity)
17	Bridge
18	High point (noise)

Table 10: LiDAR Point Classification Codes and Descriptions

g. 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 0.5-meter cell size. Intensity images were cut to match the tile index and its corresponding tile names and delivered in .img format.

h. 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.

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

j. Surface-Digital Elevation Model (DSM)

Surface digital elevation models (DSMs) were derived using all first return LiDAR points, excluding LiDAR points classified as high or low noise. All DSMs were created with a grid spacing of 1 meter. DSMs for this project were cut to match the tile index and its corresponding tile names and delivered in 32-bit floating point .img 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 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).

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	Points (#)	RMSEz	Confidence Level (95%)	Percentile (95th)
NVA (Point Cloud)	68	0.0923	0.1809	0.1524
NVA (DEM)	68	0.0855	0.1676	0.1392
VVA (Point Cloud)	48	0.1946	0.3815	0.2689
VVA (DEM)	48	0.1806	0.3540	0.4478

Table 12: NVA/VVA Accuracies

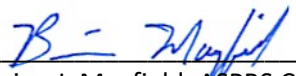
SECTION V: CERTIFICATION STATEMENTS

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	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
NVA1012	723418.2200	4188076.6890	375.8350	375.6250	-0.2100	NVA
NVA1013	742654.8520	4160796.8120	361.4650	361.3600	-0.1050	NVA
NVA1014	747895.6990	4139872.1300	290.6720	290.6190	-0.0530	NVA
NVA1015	746206.9740	4117219.3950	301.2900	301.2600	-0.0300	NVA
NVA1016	719878.4700	4109963.2450	297.5220	297.5050	-0.0170	NVA
NVA1018	733900.1580	4186457.8590	343.5020	343.5480	0.0460	NVA
NVA1019	734464.3550	4163882.3600	369.2260	369.1020	-0.1240	NVA
NVA1020	728380.6160	4153583.0220	373.0720	373.0800	0.0080	NVA
NVA1021	740063.6210	4137448.5310	329.0780	329.0900	0.0120	NVA
NVA1022	728752.7160	4108105.5570	306.0650	306.1380	0.0730	NVA
NVA1023	760304.9670	4124159.2760	310.3260	310.3860	0.0600	NVA
NVA133	238591.2100	4122879.1780	289.3290	289.3300	0.0010	NVA
NVA134	246983.2950	4138268.3710	269.6020	269.6350	0.0330	NVA
NVA141	244474.9800	4190566.7710	316.3510	316.3450	-0.0060	NVA
NVA147	296682.1350	4103929.8800	276.3350	276.2940	-0.0410	NVA
NVA16	243019.7500	4154073.0220	279.7520	279.8010	0.0490	NVA
NVA20	241953.2180	4107896.7920	246.0880	246.1040	0.0160	NVA
NVA207	258979.5560	4189518.1020	324.0620	324.1030	0.0410	NVA
NVA208	238796.0730	4167615.3300	301.6730	301.6570	-0.0160	NVA
NVA225	306390.0830	4102409.4770	259.4330	259.2860	-0.1470	NVA
NVA240	240461.0880	4188532.7990	303.0650	303.0400	-0.0250	NVA
NVA245	300359.3620	4102629.6160	266.2040	266.0720	-0.1320	NVA
NVA439	686770.8210	4190535.6450	411.2260	411.3680	0.1420	NVA
NVA440	701023.9810	4188032.4070	434.1870	434.2170	0.0300	NVA
NVA441	742365.6230	4180170.8920	338.2770	338.2890	0.0120	NVA
NVA442	749182.4520	4185234.9620	330.3090	330.4670	0.1580	NVA
NVA443	675622.9950	4163220.2830	366.2100	366.1987	-0.0113	NVA
NVA444	696897.2590	4161272.7990	434.6700	434.5690	-0.1010	NVA
NVA445	726573.5510	4127432.8420	341.7650	341.8010	0.0360	NVA
NVA446	757199.0320	4146630.9300	335.1400	335.1900	0.0500	NVA
NVA457	759017.8760	4099998.8520	259.0880	259.2030	0.1150	NVA
NVA458	749963.2220	4101005.3140	285.7960	285.9030	0.1070	NVA
NVA55	255894.9460	4179887.9970	301.5680	301.5570	-0.0110	NVA
NVA59	249506.3550	4162420.1680	268.2170	268.2080	-0.0090	NVA
NVA639	683146.9050	4181905.1760	411.3360	411.4290	0.0930	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
NVA640	696916.8980	4158041.3760	435.9570	436.2800	0.3230	NVA
NVA641	739074.5120	4174288.5760	319.3410	319.3730	0.0320	NVA
NVA643	739576.2540	4154329.7590	328.0750	328.1750	0.1000	NVA
NVA644	725891.7290	4133085.5080	324.0250	324.1220	0.0970	NVA
NVA65	235533.3420	4130642.6700	261.3720	261.4070	0.0350	NVA
NVA655	742517.6910	4110881.3260	325.2820	325.3790	0.0970	NVA
NVA73	303034.6130	4098432.3240	274.2210	274.3220	0.1010	NVA
NVA839	689831.7780	4183702.8090	409.0980	409.0040	-0.0940	NVA
NVA840	743501.3490	4189221.1060	335.0560	335.2660	-0.2103	NVA
NVA841	675643.4910	4172128.7360	375.9760	375.9102	-0.0658	NVA
NVA842	706312.0880	4171190.1990	452.9620	453.1390	0.1770	NVA
NVA843	744443.5900	4175395.6450	346.9280	346.8940	-0.0340	NVA
NVA844	758877.8320	4168425.7020	291.8050	291.8420	0.0370	NVA
NVA845	676071.2910	4153340.0060	368.1680	368.1074	-0.0606	NVA
NVA846	723372.5580	4137788.0940	357.8800	357.8780	-0.0020	NVA
NVA856	750448.2230	4107858.7200	278.8810	278.9130	0.0320	NVA
NVA90	242190.3050	4157738.0130	264.0310	263.9880	-0.0430	NVA
NVA905	687433.3570	4150430.9160	382.2590	382.3330	0.0740	NVA
NVA908	746896.4470	4179489.3270	311.5430	311.5440	-0.0010	NVA
NVA909	760578.1790	4159606.2570	290.1660	290.2450	0.0790	NVA
NVA910	721843.5230	4124899.5420	330.5510	330.5970	0.0460	NVA
NVA911	756218.0250	4099928.1300	244.3480	244.3890	0.0410	NVA
NVA94	235224.1680	4100453.6810	224.2050	224.2950	0.0900	NVA
NVA964	731334.0390	4162175.0240	372.4000	372.5250	0.1250	NVA
NVA965	708741.2490	4154389.0000	460.2670	460.2910	0.0240	NVA
NVA966	735129.1780	4142921.8510	348.3310	348.3550	0.0240	NVA
NVA967	746148.1930	4120476.1100	315.1600	315.0780	-0.0820	NVA
NVA986	712747.0520	4180480.2520	472.7820	472.8380	0.0560	NVA
NVA987	716837.3090	4164470.1410	492.4200	492.5140	0.0940	NVA
NVA988	708513.6130	4148662.4110	459.2770	459.3640	0.0870	NVA
NVA989	758059.9210	4141277.1520	277.5320	277.5810	0.0490	NVA
NVA990	743137.6920	4125416.7640	346.3290	346.4050	0.0760	NVA
NVA991	719989.5520	4105555.2900	305.6110	305.7960	0.1850	NVA
VVA12	250235.2640	4150938.8670	280.3490	280.4110	0.0620	VVA
VVA131	240474.1960	4188537.7590	302.9290	302.9910	0.0620	VVA
VVA134	255183.7150	4139632.1570	251.8160	251.7960	-0.0200	VVA
VVA138	239107.4900	4177254.4130	295.7370	295.8530	0.1160	VVA
VVA144	267577.1950	4103587.8720	223.5780	223.1430	-0.4350	VVA
VVA145	287101.3270	4106394.8350	272.1810	271.6950	-0.4860	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
VVA154	247005.3250	4138270.8380	269.2470	269.3240	0.0770	VVA
VVA155	238832.7190	4167612.5100	305.2150	305.2560	0.0410	VVA
VVA161	244451.1080	4190549.9120	316.1660	316.2720	0.1060	VVA
VVA306	702813.5180	4174328.8720	440.9380	441.1510	0.2130	VVA
VVA309	730542.3670	4133147.7830	355.8760	356.1260	0.2500	VVA
VVA316	759342.5160	4109886.3910	235.6430	236.0660	0.4230	VVA
VVA40	250476.4550	4187163.2220	322.9380	322.9520	0.0140	VVA
VVA44	257280.6730	4128233.1330	244.0180	243.5620	-0.4560	VVA
VVA440	691717.0650	4172657.0920	411.1480	411.3460	0.1980	VVA
VVA441	748312.9290	4191826.9190	318.3220	318.5260	0.2040	VVA
VVA442	687413.8480	4150423.3520	382.0160	382.1100	0.0940	VVA
VVA443	746924.0220	4179474.4020	311.5120	311.6460	0.1340	VVA
VVA444	760586.3430	4159596.0750	289.6290	289.9270	0.2980	VVA
VVA446	727523.3480	4121739.8450	336.2720	336.3490	0.0770	VVA
VVA455	744939.0000	4105783.8560	309.8050	310.0430	0.2380	VVA
VVA580	686878.3770	4177204.2040	387.0740	386.9860	-0.0880	VVA
VVA581	687280.3080	4155445.3670	403.7120	403.7670	0.0550	VVA
VVA590	756210.3080	4099949.4610	244.3870	244.4340	0.0470	VVA
VVA644	723400.6500	4137795.6820	356.2520	356.2140	-0.0380	VVA
VVA645	742546.0890	4110871.4500	324.5770	324.8060	0.2290	VVA
VVA682	727500.4520	4184668.5740	360.7420	360.9370	0.1950	VVA
VVA683	734471.2310	4163895.7250	369.5610	369.6670	0.1060	VVA
VVA684	715411.7100	4150523.8700	430.3620	430.5670	0.2050	VVA
VVA685	753924.4480	4128083.1300	316.1650	316.2070	0.0420	VVA
VVA686	734148.7690	4116135.7370	323.1920	323.2600	0.0680	VVA
VVA698	714853.5450	4177877.2690	465.6100	465.8150	0.2050	VVA
VVA712	728387.6960	4153528.2210	370.3050	370.3230	0.0180	VVA
VVA713	740069.7820	4137465.1730	328.9840	328.9820	-0.0020	VVA
VVA714	760307.7130	4124150.5240	310.3640	310.4740	0.1100	VVA
VVA715	728762.6030	4108112.5090	306.4590	306.6440	0.1850	VVA
VVA716	726472.3900	4179773.7260	381.4330	381.7120	0.2790	VVA
VVA717	733908.0930	4186448.0280	343.0440	343.1480	0.1040	VVA
VVA718	716832.9330	4164463.5120	492.4400	492.5540	0.1140	VVA
VVA719	742645.8340	4160798.5650	361.0020	360.9940	-0.0080	VVA
VVA720	719909.9580	4109986.1830	299.8440	300.0640	0.2200	VVA
VVA721	746182.6110	4117221.4140	301.4550	301.5730	0.1180	VVA
VVA80	240006.7780	4118045.3900	250.0060	250.0770	0.0710	VVA
VVA83	257888.0020	4187925.9710	325.8450	325.9390	0.0940	VVA
VVA84	257944.3760	4163243.6740	290.4320	290.4380	0.0060	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
VVA87	249741.8690	4172806.0230	262.5750	262.6900	0.1150	VVA
VVA92	257302.4990	4106049.9890	232.0990	231.7310	-0.3680	VVA
VVA93	300371.3620	4102603.3360	265.8250	265.9630	0.1380	VVA

Table 13: Point Cloud Check Point Assessment

b. Digital Elevation Model (DEM) Check Point Assessment

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
NVA1012	723418.2200	4188076.6890	375.8350	375.6812	0.1538	NVA
NVA1013	742654.8520	4160796.8120	361.4650	361.3544	0.1106	NVA
NVA1014	747895.6990	4139872.1300	290.6720	290.5890	0.0830	NVA
NVA1015	746206.9740	4117219.3950	301.2900	301.2119	0.0781	NVA
NVA1016	719878.4700	4109963.2450	297.5220	297.5394	-0.0174	NVA
NVA1018	733900.1580	4186457.8590	343.5020	343.5084	-0.0064	NVA
NVA1019	734464.3550	4163882.3600	369.2260	369.1226	0.1034	NVA
NVA1020	728380.6160	4153583.0220	373.0720	373.1002	-0.0282	NVA
NVA1021	740063.6210	4137448.5310	329.0780	329.0612	0.0168	NVA
NVA1022	728752.7160	4108105.5570	306.0650	306.1402	-0.0752	NVA
NVA1023	760304.9670	4124159.2760	310.3260	310.3300	-0.0040	NVA
NVA133	238591.2100	4122879.1780	289.3290	289.3271	0.0019	NVA
NVA134	246983.2950	4138268.3710	269.6020	269.5904	0.0116	NVA
NVA141	244474.9800	4190566.7710	316.3510	316.3464	0.0046	NVA
NVA147	296682.1350	4103929.8800	276.3350	276.2348	0.1002	NVA
NVA16	243019.7500	4154073.0220	279.7520	279.7817	-0.0297	NVA
NVA20	241953.2180	4107896.7920	246.0880	246.1074	-0.0194	NVA
NVA207	258979.5560	4189518.1020	324.0620	324.0323	0.0297	NVA
NVA208	238796.0730	4167615.3300	301.6730	301.6316	0.0414	NVA
NVA225	306390.0830	4102409.4770	259.4330	259.2921	0.1409	NVA
NVA240	240461.0880	4188532.7990	303.0650	303.0194	0.0456	NVA
NVA245	300359.3620	4102629.6160	266.2040	266.0602	0.1438	NVA
NVA439	686770.8210	4190535.6450	411.2260	411.2746	-0.0486	NVA
NVA440	701023.9810	4188032.4070	434.1870	434.2321	-0.0451	NVA
NVA441	742365.6230	4180170.8920	338.2770	338.2920	-0.0150	NVA
NVA442	749182.4520	4185234.9620	330.3090	330.4011	-0.0921	NVA
NVA443	675622.9950	4163220.2830	366.2100	366.1459	0.0641	NVA
NVA444	696897.2590	4161272.7990	434.6700	434.5780	0.0920	NVA
NVA445	726573.5510	4127432.8420	341.7650	341.7826	-0.0176	NVA
NVA446	757199.0320	4146630.9300	335.1400	335.1663	-0.0263	NVA
NVA457	759017.8760	4099998.8520	259.0880	259.1797	-0.0917	NVA
NVA458	749963.2220	4101005.3140	285.7960	285.9234	-0.1274	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
NVA55	255894.9460	4179887.9970	301.5680	301.5396	0.0284	NVA
NVA59	249506.3550	4162420.1680	268.2170	268.1798	0.0372	NVA
NVA639	683146.9050	4181905.1760	411.3360	411.4428	-0.1068	NVA
NVA640	696916.8980	4158041.3760	435.9570	436.2810	-0.3240	NVA
NVA641	739074.5120	4174288.5760	319.3410	319.3606	-0.0196	NVA
NVA643	739576.2540	4154329.7590	328.0750	328.0986	-0.0236	NVA
NVA644	725891.7290	4133085.5080	324.0250	324.0567	-0.0317	NVA
NVA65	235533.3420	4130642.6700	261.3720	261.4053	-0.0333	NVA
NVA655	742517.6910	4110881.3260	325.2820	325.3825	-0.1005	NVA
NVA73	303034.6130	4098432.3240	274.2210	274.2874	-0.0664	NVA
NVA839	689831.7780	4183702.8090	409.0980	408.9538	0.1442	NVA
NVA840	743501.3490	4189221.1060	335.0560	335.2416	-0.1856	NVA
NVA841	675643.4910	4172128.7360	375.9760	375.8547	0.1213	NVA
NVA842	706312.0880	4171190.1990	452.9620	453.0770	-0.1150	NVA
NVA843	744443.5900	4175395.6450	346.9280	346.9368	-0.0088	NVA
NVA844	758877.8320	4168425.7020	291.8050	291.7759	0.0291	NVA
NVA845	676071.2910	4153340.0060	368.1680	368.0542	0.1138	NVA
NVA846	723372.5580	4137788.0940	357.8800	357.7438	0.1362	NVA
NVA856	750448.2230	4107858.7200	278.8810	278.9271	-0.0461	NVA
NVA90	242190.3050	4157738.0130	264.0310	263.9912	0.0398	NVA
NVA905	687433.3570	4150430.9160	382.2590	382.2728	-0.0138	NVA
NVA908	746896.4470	4179489.3270	311.5430	311.4587	0.0843	NVA
NVA909	760578.1790	4159606.2570	290.1660	290.1720	-0.0060	NVA
NVA910	721843.5230	4124899.5420	330.5510	330.5538	-0.0028	NVA
NVA911	756218.0250	4099928.1300	244.3480	244.4142	-0.0662	NVA
NVA94	235224.1680	4100453.6810	224.2050	224.2907	-0.0857	NVA
NVA964	731334.0390	4162175.0240	372.4000	372.5067	-0.1067	NVA
NVA965	708741.2490	4154389.0000	460.2670	460.2776	-0.0106	NVA
NVA966	735129.1780	4142921.8510	348.3310	348.3727	-0.0417	NVA
NVA967	746148.1930	4120476.1100	315.1600	315.0651	0.0949	NVA
NVA986	712747.0520	4180480.2520	472.7820	472.7917	-0.0097	NVA
NVA987	716837.3090	4164470.1410	492.4200	492.4712	-0.0512	NVA
NVA988	708513.6130	4148662.4110	459.2770	459.3217	-0.0447	NVA
NVA989	758059.9210	4141277.1520	277.5320	277.5417	-0.0097	NVA
NVA990	743137.6920	4125416.7640	346.3290	346.3607	-0.0317	NVA
NVA991	719989.5520	4105555.2900	305.6110	305.7525	-0.1415	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
VVA12	250235.2640	4150938.8670	280.3490	280.4587	-0.1097	VVA
VVA131	240474.1960	4188537.7590	302.9290	303.0279	-0.0989	VVA
VVA134	255183.7150	4139632.1570	251.8160	251.8175	-0.0015	VVA
VVA138	239107.4900	4177254.4130	295.7370	295.8252	-0.0882	VVA
VVA144	267577.1950	4103587.8720	223.5780	223.0685	0.5095	VVA
VVA145	287101.3270	4106394.8350	272.1810	271.6749	0.5061	VVA
VVA154	247005.3250	4138270.8380	269.2470	269.2841	-0.0371	VVA
VVA155	238832.7190	4167612.5100	305.2150	305.1813	0.0337	VVA
VVA161	244451.1080	4190549.9120	316.1660	316.0995	0.0665	VVA
VVA306	702813.5180	4174328.8720	440.9380	441.0276	-0.0896	VVA
VVA309	730542.3670	4133147.7830	355.8760	355.9305	-0.0545	VVA
VVA316	759342.5160	4109886.3910	235.6430	235.8713	-0.2283	VVA
VVA40	250476.4550	4187163.2220	322.9380	322.7390	0.1990	VVA
VVA44	257280.6730	4128233.1330	244.0180	243.5029	0.5151	VVA
VVA440	691717.0650	4172657.0920	411.1480	411.1438	0.0042	VVA
VVA441	748312.9290	4191826.9190	318.3220	318.5520	-0.2300	VVA
VVA442	687413.8480	4150423.3520	382.0160	382.0909	-0.0749	VVA
VVA443	746924.0220	4179474.4020	311.5120	311.5629	-0.0509	VVA
VVA444	760586.3430	4159596.0750	289.6290	289.9175	-0.2885	VVA
VVA446	727523.3480	4121739.8450	336.2720	336.3879	-0.1159	VVA
VVA455	744939.0000	4105783.8560	309.8050	310.0133	-0.2083	VVA
VVA580	686878.3770	4177204.2040	387.0740	387.0744	-0.0004	VVA
VVA581	687280.3080	4155445.3670	403.7120	403.6966	0.0154	VVA
VVA590	756210.3080	4099949.4610	244.3870	244.4045	-0.0175	VVA
VVA644	723400.6500	4137795.6820	356.2520	356.2365	0.0155	VVA
VVA645	742546.0890	4110871.4500	324.5770	324.6791	-0.1021	VVA
VVA682	727500.4520	4184668.5740	360.7420	360.8990	-0.1570	VVA
VVA683	734471.2310	4163895.7250	369.5610	369.6057	-0.0447	VVA
VVA684	715411.7100	4150523.8700	430.3620	430.5904	-0.2284	VVA
VVA685	753924.4480	4128083.1300	316.1650	316.1568	0.0082	VVA
VVA686	734148.7690	4116135.7370	323.1920	323.3004	-0.1084	VVA
VVA698	714853.5450	4177877.2690	465.6100	465.5698	0.0402	VVA
VVA712	728387.6960	4153528.2210	370.3050	370.3640	-0.0590	VVA
VVA713	740069.7820	4137465.1730	328.9840	328.9612	0.0228	VVA
VVA714	760307.7130	4124150.5240	310.3640	310.4742	-0.1102	VVA
VVA715	728762.6030	4108112.5090	306.4590	306.6230	-0.1640	VVA
VVA716	726472.3900	4179773.7260	381.4330	381.7230	-0.2900	VVA
VVA717	733908.0930	4186448.0280	343.0440	343.1213	-0.0773	VVA
VVA718	716832.9330	4164463.5120	492.4400	492.5339	-0.0939	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
VVA719	742645.8340	4160798.5650	361.0020	360.9643	0.0377	VVA
VVA720	719909.9580	4109986.1830	299.8440	300.0503	-0.2063	VVA
VVA721	746182.6110	4117221.4140	301.4550	301.5600	-0.1050	VVA
VVA80	240006.7780	4118045.3900	250.0060	250.0576	-0.0516	VVA
VVA83	257888.0020	4187925.9710	325.8450	325.9275	-0.0825	VVA
VVA84	257944.3760	4163243.6740	290.4320	290.4293	0.0027	VVA
VVA87	249741.8690	4172806.0230	262.5750	262.6513	-0.0763	VVA
VVA92	257302.4990	4106049.9890	232.0990	231.7593	0.3397	VVA
VVA93	300371.3620	4102603.3360	265.8250	265.9420	-0.1170	VVA

Table 14: DEM Check Point Assessment