



# atlantic

## Project Report

**TASK ORDER NAME: 2018 Kansas QL2 LiDAR**  
**CONTRACT ID: 00000000000000000000039891**  
**EVENT ID: EVT0003259**  
**ATLANTIC PROJECT NUMBER: 18006**  
**PROJECT BLOCK NUMBER: Block 14**

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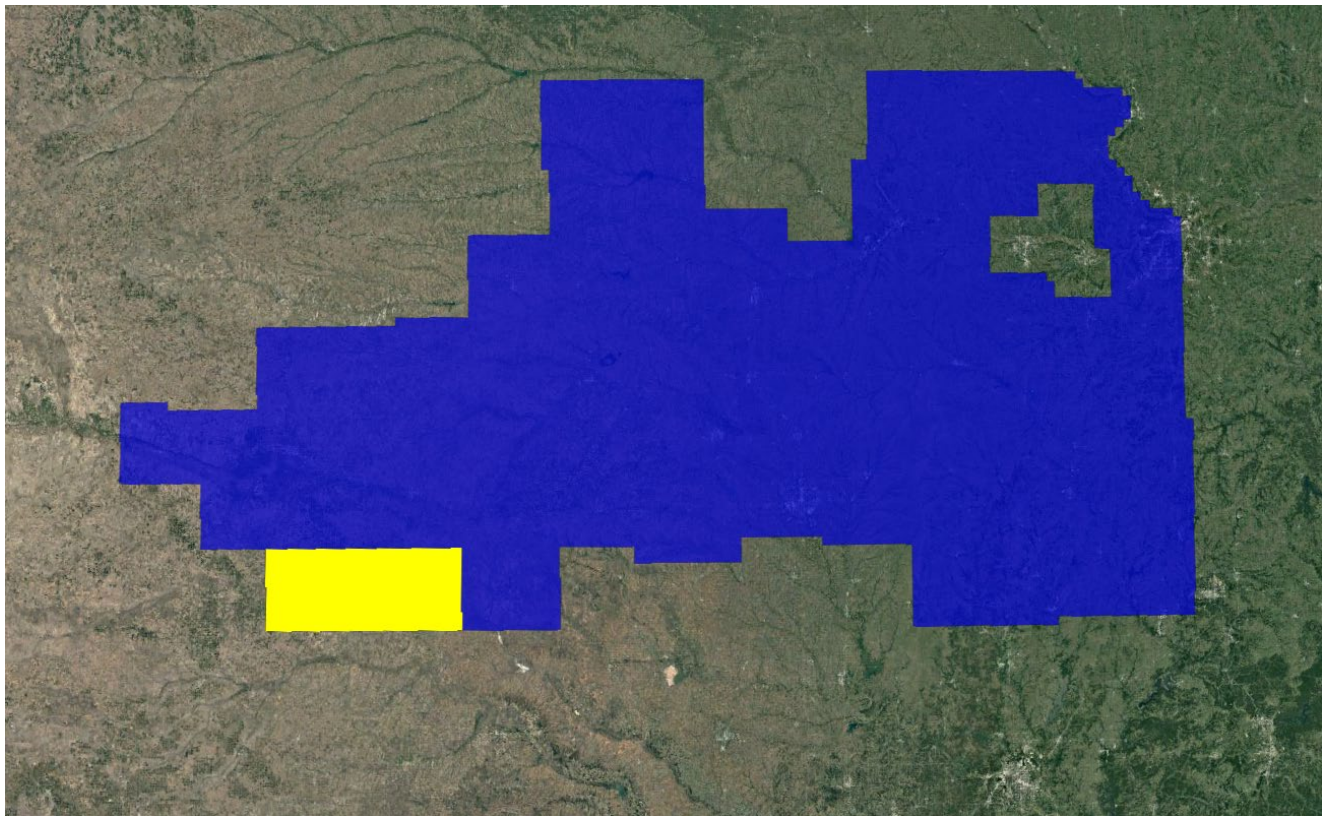
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## **SECTION I: PROJECT OVERVIEW & PURPOSE**

### ***1. Aerial LiDAR Project***

#### **a. Project Overview**

The State of Kansas Contract 0000000000000000000039891 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 14 encompasses part or all of 4 counties in Southern Kansas and covers approximately 2,323 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	
<b>Name of Contact</b>	Tara Lanzrath, CFM
<b>Organization</b>	Kansas Department of Agriculture
<b>Position</b>	Floodplain Mapping Coordinator
<b>Telephone</b>	785-296-2513
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<b>Mailing Address</b>	6531 SE Forbes Ave., Suite B
<b>City</b>	Topeka
<b>State or Province</b>	Kansas
<b>Postal Code</b>	66619

*Table 1: Aerial LiDAR Client Contact Information*

### d. Contract Deliverables

Item	Specification/Format
<b>Metadata</b>	FGDC compliant, xml format
<b>Project Report</b>	.pdf format
<b>Raw Point Cloud</b>	Swaths, LAS 1.4
<b>Classified Point Cloud</b>	LAS 1.4
<b>Bare Earth DEM</b>	ERDAS .IMG format, Hydroflattened
<b>First Return DSM</b>	ERDAS .IMG format
<b>Hydro Polygon Breaklines</b>	.gdb format
<b>Intensity Imagery</b>	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
<b>Model</b>	ALS70-HP
<b>Manufacturer</b>	Leica
<b>Platform</b>	Fixed-Wing
<b>Scan Pattern</b>	Sine, Triangle, Raster
<b>Maximum Scan Rate (Hz)</b>	Sine: 200 Triangle: 158 Raster: 120
<b>Field of View (°)</b>	0 – 75 (Full Angle, User Adjustable)
<b>Maximum Pulse Rate (kHz)</b>	500
<b>Maximum Flying Height (m AGL)</b>	3500
<b>Number of Returns</b>	Unlimited
<b>Number of Intensity Measurements</b>	3 (First, Second, Third)
<b>Roll Stabilization (Automatic Adaptive, °)</b>	75 - Active FOV
<b>Storage Media</b>	Removable 500 GB SSD
<b>Storage Capacity (Hours @ Max Pulse Rate)</b>	6
<b>Size (cm)</b>	Scanner: 37 W x 68 L x 26 H Control Electronics: 45 W x 47 D x 36 H
<b>Weight (kg)</b>	Scanner: 43 Control Electronics: 45
<b>Operation Temperature (°C)</b>	0 – 40
<b>Flight Management</b>	FCMS
<b>Power Consumption</b>	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
<b>System</b>	Leica ALS70-HP
<b>Nominal Pulse Spacing (m)</b>	0.71
<b>Nominal Pulse Density (pls/m<sup>2</sup>)</b>	2.2
<b>Nominal Flight Height (AGL meters)</b>	2000
<b>Nominal Flight Speed (kts)</b>	130
<b>Pass Heading (°)</b>	0
<b>Sensor Scan Angle (°)</b>	45
<b>Scan Frequency (Hz)</b>	33.9
<b>Pulse Rate of Scanner (kHz)</b>	256,400
<b>Line Spacing (m)</b>	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 76 passes of the AOI as a series of perpendicular and/or adjacent flight-lines executed in 5 flight missions conducted between December 16, 2018 and December 18, 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.

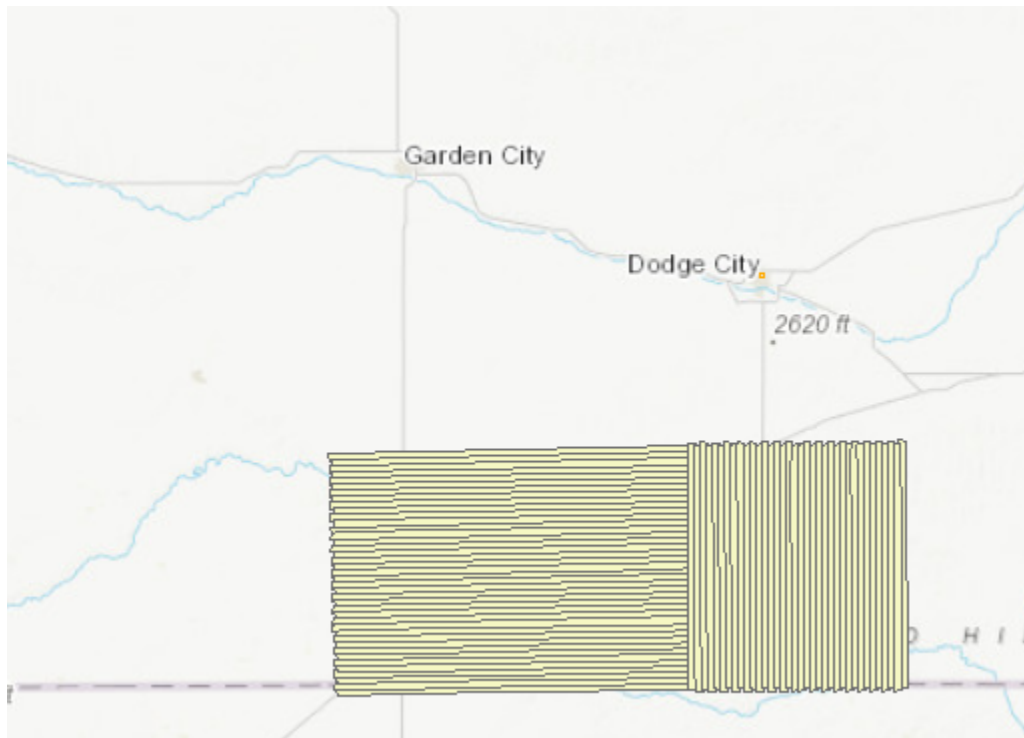


Figure 2: Orientation of Executed Flight-lines and LiDAR DPA

### d. GNSS Reference Stations

Six (6) 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
<b>KSBK</b>	CORS	KSBK	37°33'03.92856"	99°38'06.31395"	716.06
<b>KSCM</b>	CORS	KSCM	37°51'36.45801"	100°21'16.74776"	816.255
<b>KSGC</b>	CORS	KSGC	37°58'08.68604"	100°53'47.13442"	854.237
<b>KSMD</b>	CORS	KSMD	37°17'06.43096"	100°21'31.02753"	747.069
<b>KSSY</b>	CORS	KSSY	37°58'43.11412"	101°45'18.18782"	964.95
<b>OKBF</b>	CORS	OKBF	36°49'40.90136"	99°38'28.88468"	538.778

*Table 5: GNSS Reference Stations*

## 2. Aerial LiDAR Project – Ground Acquisition

### a. Ground Control Survey

A total of 125 ground survey points were collected in support of this project, including 34 LiDAR Control Points (LCP), 50 Non-vegetated Vertical Accuracy (NVA) and 41 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
LCP387	402798.489	4111813.15	675.648
LCP390	438994.153	4125164.752	692.125
LCP391	420944.373	4117938.961	638.81
LCP392	425004.381	4131735.06	742.013
LCP393	429862.334	4139486.101	744.243
LCP394	390217.542	4098161.265	707.318
LCP395	375712.923	4100163.892	748.354
LCP396	367031.392	4098670.135	723.961
LCP397	374893.339	4104485.395	762.954
LCP398	388721.712	4118778.618	735.349
LCP399	400416.947	4110588.909	684.364
LCP400	380971.55	4140276.018	793.816
LCP401	381558.754	4137057.984	794.271
LCP402	371923.78	4127573.593	817.689
LCP403	366171.875	4114639.29	812.408
LCP404	370872.965	4111487.741	760.947
LCP405	332540.839	4144383.884	892.348
LCP406	326452.356	4136467.628	890.146
LCP407	345009.765	4134301.48	865.328



ID	Easting	Northing	Elevation
LCP408	352375.125	4127904.474	848.464
LCP432	357765.645	4110094.897	824.737
LCP476	416149.486	4113670.513	614.713
LCP477	419315.97	4102184.332	586.45
LCP478	430916.864	4103900.871	566.74
LCP515	338644.297	4098223.918	841.984
LCP520	329353.089	4109043.274	878.168
LCP521	403062.255	4115713.827	673.321
LCP565	369277.457	4104257.614	761.708
LCP567	379523.049	4127377.86	769.373
LCP569	337473.166	4132919.621	873.69
LCP583	349182.404	4119194.312	847.494
LCP587	427604.949	4103589.141	572.058
LCP599	326059.877	4113221.292	885.454
LCP600	338088.919	4118583.403	839.387

Table 6: LiDAR Control Point Coordinates

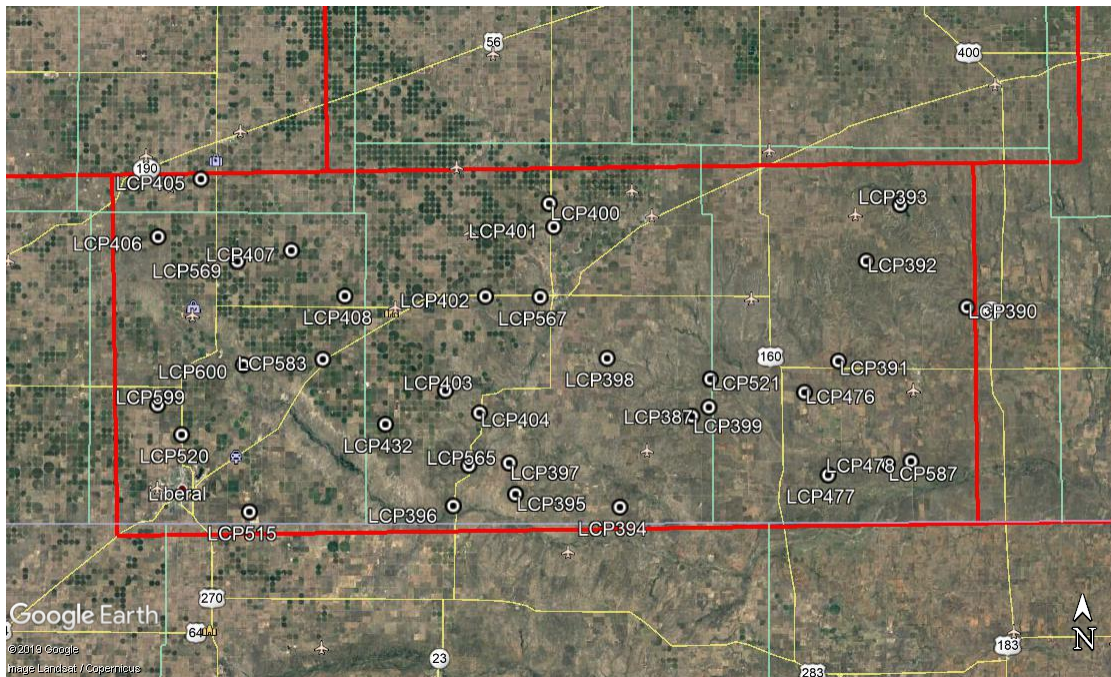


Figure 3: LiDAR Control Point Distribution

ID	Easting	Northing	Elevation
NVA264	429851.053	4139485.603	744.486
NVA265	429851.049	4139485.611	744.488
NVA266	424996.785	4131728.229	741.866
NVA267	371931.879	4127568.641	817.719
NVA419	326453.087	4136491.342	889.505

ID	Easting	Northing	Elevation
NVA420	345007.718	4134277.959	865.228
NVA447	329347.757	4109044.936	878.099
NVA448	357771.945	4110094.452	824.762
NVA449	402802.433	4111815.994	675.724
NVA450	388725.086	4118777.358	735.384
NVA451	403061.659	4115720.199	673.568
NVA452	370873.902	4111482.885	760.943
NVA453	416149.243	4113682.585	614.762
NVA454	419336.117	4102184.202	586.425
NVA455	375715.049	4100158.009	748.515
NVA456	430924.519	4103902.628	566.552
NVA459	376120.889	4136985.061	817.383
NVA616	334456.875	4134272.225	876.078
NVA617	358493.261	4139088.902	850.224
NVA645	343761.77	4117153.718	847.704
NVA646	343499.847	4100719.873	835.67
NVA647	371690.495	4122514.963	813.876
NVA648	398373.919	4119271.812	727.889
NVA649	362314.473	4108189.621	813.615
NVA650	387059.782	4104104.809	681.471
NVA651	410391.711	4115474.511	643.472
NVA652	429202.267	4120766.168	625.49
NVA653	408014.266	4101222.058	615.206
NVA654	428939.452	4099681.648	566.481
NVA656	379529.204	4127377.092	769.349
NVA657	410327.086	4143941.874	775.73
NVA658	393735.248	4137206.631	756.093
NVA659	359821.037	4124507.884	841.67
NVA818	331627.84	4126704.543	874.049
NVA819	358239.929	4126026.249	843.619
NVA847	329451.121	4104141.77	867.56
NVA848	349181.742	4119202.746	847.449
NVA849	362012.534	4119628.848	831.277
NVA850	380706.682	4119347.739	767.499
NVA851	424384.954	4109706.043	598.1
NVA852	393431.306	4105666.763	737.479
NVA853	369273.465	4104266.569	761.699
NVA854	388646.315	4112647.505	750.788
NVA855	412191.57	4099119.839	600.112
NVA858	432586.546	4116451.476	597.974

ID	Easting	Northing	Elevation
NVA877	406798.48	4127039.6	733.699
NVA879	381885.19	4111253.031	750.721
NVA880	369744.039	4137632.551	834.11
NVA888	348389.754	4114930.624	836.232
NVA900	417811.281	4110370.129	613.424

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

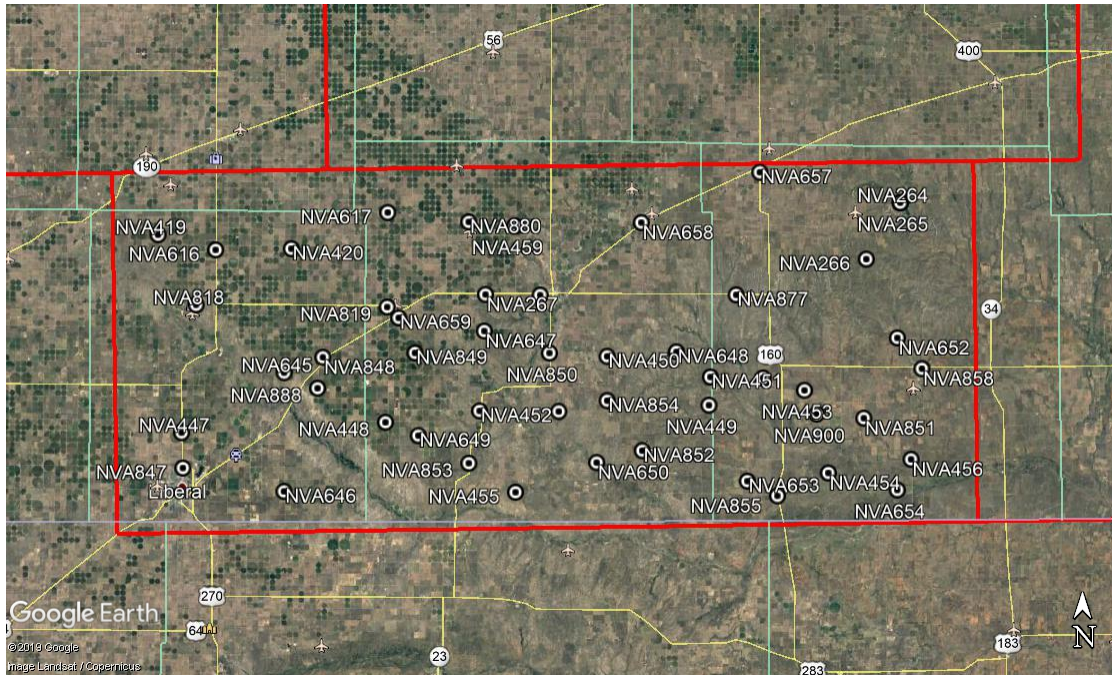


Figure 4: Non-Vegetated Vertical Accuracy (NVA) Point Distribution

ID	Easting	Northing	Elevation
VVA185	438999.997	4125158.357	692.536
VVA186	381544.054	4137059.068	794.479
VVA293	332530.104	4144392.382	892.466
VVA294	352360.233	4127932.327	847.824
VVA310	338646.84	4098232.293	841.828
VVA311	390229.088	4098141.042	707.195
VVA312	400430.757	4110599.727	683.698
VVA313	366163.789	4114654.256	812.877
VVA314	367024.696	4098697.06	724.318
VVA315	420928.028	4117956.221	639.096
VVA318	380980.37	4140295.672	793.624
VVA319	369750.296	4137629.89	834.103
VVA426	328029.6	4133325.589	876.697
VVA427	352101.067	4137532.654	853.611
VVA447	338080.9	4118591.249	839.738

ID	Easting	Northing	Elevation
VVA448	343544.963	4104742.705	837.073
VVA449	381879.39	4111229.883	751.238
VVA450	362852.192	4104052.745	810.924
VVA451	361290.071	4115095.678	827.925
VVA452	407956.409	4105784.208	628.683
VVA453	437409.869	4111519.686	582.402
VVA454	437409.878	4111519.655	582.415
VVA457	417787.952	4110352.446	613.499
VVA458	406800.555	4127046.298	732.641
VVA461	407618.091	4134952.786	777.655
VVA462	423297.876	4141517.896	733.649
VVA565	337469.26	4132909.752	873.716
VVA583	326050.101	4113227.882	885.445
VVA584	348398.668	4114914.544	836.311
VVA585	372651.64	4114717.812	747.844
VVA586	374892.686	4104480.985	762.925
VVA587	390480.734	4107899.957	737.94
VVA588	407857.864	4109297.809	622.889
VVA589	427612.149	4103594.522	572.339
VVA591	410321.591	4143971.35	775.411
VVA612	387082.361	4104113.754	681.617
VVA613	380682.634	4119355.116	767.17
VVA621	343781.225	4117149.541	846.993
VVA623	428949.122	4099699.651	566.301
VVA624	424399.068	4109724.764	600.073
VVA635	331648.469	4126721.937	874.061

Table 8: Vegetated Vertical Accuracy (VVA) Point Coordinates

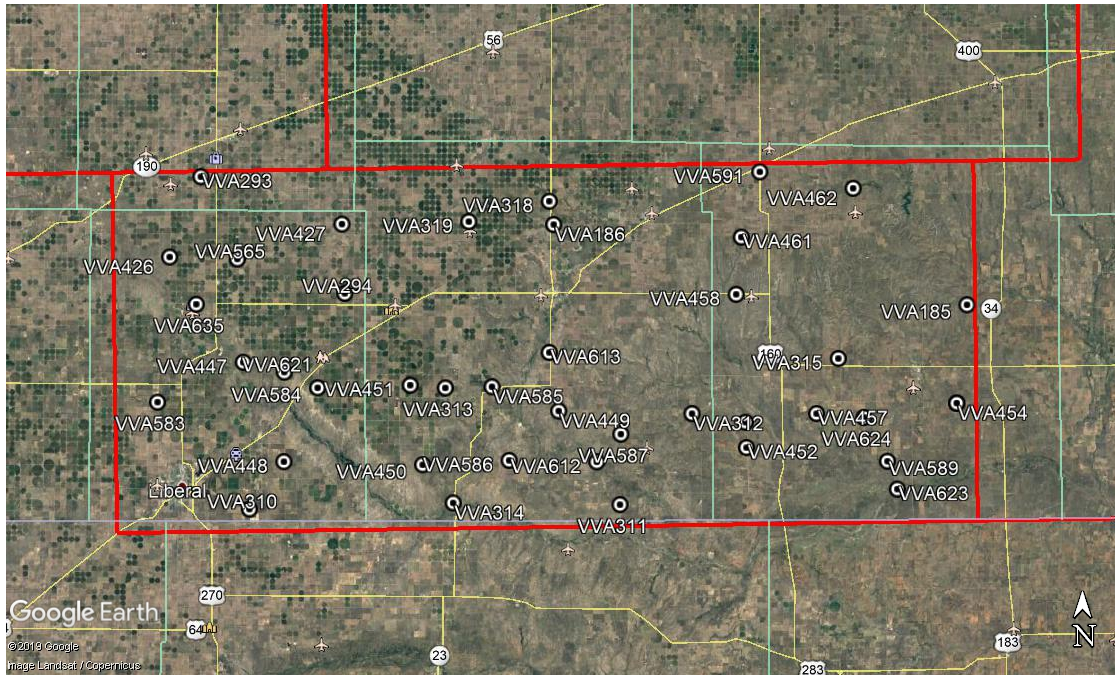


Figure 5: Vegetated Vertical Accuracy (VVA) Point Distribution

## 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(ITRF96)  
**Coordinate System:** UTM, 14N  
**Vertical Datum:** NAVD88  
**Geoid Model:** 12B  
**Units of Reference:** Meter

#### c. LiDAR Point Cloud Statistics

Category	Value
<b>Total Points</b>	17,603,466,746
<b>Nominal Pulse Spacing (m)</b>	0.5951
<b>Nominal Pulse Density (pls/m<sup>2</sup>)</b>	2.8236
<b>Aggregate Total Points</b>	16,590,927,634
<b>Aggregate Nominal Pulse Spacing (m)</b>	0.6022
<b>Aggregate Nominal Pulse Density (pls/m<sup>2</sup>)</b>	2.7575

*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. 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 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 95 <sup>th</sup> 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)	50	0.0855	0.1676	0.0834
NVA (DEM)	50	0.0819	0.1605	0.0845
VVA (Point Cloud)	39	0.1931	0.3785	0.4412
VVA (DEM)	39	0.1768	0.3465	0.2281

Table 12: NVA/VVA Accuracies



## SECTION V: CERTIFICATION STATEMENTS

### *1. Aerial LiDAR Project*

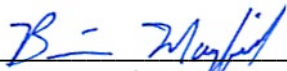
This accuracy assessment confirms that the data may be used for the intended applications stated in Section I of this document. This dataset may also be used as a topographic input for other applications, but the user should be aware that this LiDAR dataset was designed with a specific purpose and was 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)	Description
NVA264	429851.8010	4139484.8850	744.4860	744.4880	0.0020	NVA
NVA265	429851.7970	4139484.8930	744.4880	744.4880	0.0000	NVA
NVA266	424997.5340	4131727.5120	741.8660	741.9380	0.0720	NVA
NVA267	371932.6370	4127567.9230	817.7190	817.7210	0.0020	NVA
NVA419	326453.8520	4136490.6220	889.5050	889.5390	0.0340	NVA
NVA420	345008.4800	4134277.2400	865.2280	865.2670	0.0390	NVA
NVA447	329348.5230	4109044.2200	878.0990	878.1690	0.0700	NVA
NVA448	357772.7060	4110093.7370	824.7620	824.7740	0.0120	NVA
NVA449	402803.1860	4111815.2800	675.7240	675.7000	-0.0240	NVA
NVA450	388725.8420	4118776.6420	735.3840	735.3830	-0.0010	NVA
NVA451	403062.4120	4115719.4840	673.5680	673.5740	0.0060	NVA
NVA452	370874.6610	4111482.1700	760.9430	761.0080	0.0650	NVA
NVA453	416149.9940	4113681.8710	614.7620	614.8360	0.0740	NVA
NVA454	419336.8680	4102183.4900	586.4250	586.3250	-0.1000	NVA
NVA455	375715.8070	4100157.2960	748.5150	748.5820	0.0670	NVA
NVA456	430925.2680	4103901.9160	566.5520	566.3410	-0.2110	NVA
NVA459	376121.6460	4136984.3420	817.3830	817.4920	0.1090	NVA
NVA616	334457.6390	4134271.5050	876.0780	875.9890	-0.0890	NVA
NVA617	358494.0210	4139088.1820	850.2240	850.2800	0.0560	NVA
NVA645	343762.5330	4117153.0010	847.7040	847.5820	-0.1220	NVA
NVA646	343500.6110	4100719.1590	835.6700	835.6850	0.0150	NVA
NVA647	371691.2530	4122514.2460	813.8760	813.8700	-0.0060	NVA
NVA648	398374.6730	4119271.0960	727.8890	727.7900	-0.0990	NVA
NVA649	362315.2330	4108188.9060	813.6150	813.6560	0.0410	NVA
NVA650	387060.5380	4104104.0960	681.4710	681.4770	0.0060	NVA
NVA651	410392.4630	4115473.7960	643.4720	643.4010	-0.0710	NVA
NVA652	429203.0160	4120765.4530	625.4900	625.4800	-0.0100	NVA
NVA653	408015.0190	4101221.3450	615.2060	615.1960	-0.0100	NVA
NVA654	428940.2010	4099680.9360	566.4810	566.4560	-0.0250	NVA
NVA656	379529.9610	4127376.3740	769.3490	769.2670	-0.0820	NVA
NVA657	410327.8370	4143941.1540	775.7300	775.6770	-0.0530	NVA
NVA658	393736.0020	4137205.9120	756.0930	756.0910	-0.0020	NVA
NVA659	359821.7970	4124507.1670	841.6700	841.6820	0.0120	NVA
NVA818	331628.6050	4126703.8240	874.0490	874.0790	0.0300	NVA
NVA819	358240.6890	4126025.5310	843.6190	843.6760	0.0570	NVA

NVA847	329451.8870	4104141.0550	867.5600	867.6140	0.0540	NVA
NVA848	349182.5040	4119202.0290	847.4490	847.5010	0.0520	NVA
NVA849	362013.2940	4119628.1310	831.2770	831.3360	0.0590	NVA
NVA850	380707.4390	4119347.0230	767.4990	767.4910	-0.0080	NVA
NVA851	424385.7040	4109705.3290	598.1000	598.4760	0.3760	NVA
NVA852	393432.0610	4105666.0490	737.4790	737.3390	-0.1400	NVA
NVA853	369274.2240	4104265.8550	761.6990	761.6690	-0.0300	NVA
NVA854	388647.0710	4112646.7900	750.7880	750.6680	-0.1200	NVA
NVA855	412192.3220	4099119.1270	600.1120	600.0430	-0.0690	NVA
NVA858	432587.2940	4116450.7610	597.9740	598.0650	0.0910	NVA
NVA877	406799.2320	4127038.8830	733.6990	733.6450	-0.0540	NVA
NVA879	381885.9470	4111252.3160	750.7210	750.7240	0.0030	NVA
NVA880	369744.7970	4137631.8320	834.1100	834.1600	0.0500	NVA
NVA888	348390.5160	4114929.9080	836.2320	836.2100	-0.0220	NVA
NVA900	417812.0320	4110369.4150	613.4240	613.3260	-0.0980	NVA
VVA185	439000.7440	4125157.6410	692.5360	692.6270	0.0910	VVA
VVA186	381544.8100	4137058.3490	794.4790	794.7090	0.2300	VVA
VVA293	332530.8680	4144391.6610	892.4660	892.5940	0.1280	VVA
VVA294	352360.9940	4127931.6090	847.8240	848.2480	0.4240	VVA
VVA310	338647.6040	4098231.5790	841.8280	841.8200	-0.0080	VVA
VVA311	390229.8440	4098140.3300	707.1950	707.2470	0.0520	VVA
VVA312	400431.5110	4110599.0130	683.6980	683.7100	0.0120	VVA
VVA313	366164.5480	4114653.5400	812.8770	812.9740	0.0970	VVA
VVA314	367025.4560	4098696.3470	724.3180	724.3620	0.0440	VVA
VVA315	420928.7780	4117955.5060	639.0960	639.2100	0.1140	VVA
VVA318	380981.1260	4140294.9520	793.6240	793.6170	-0.0070	VVA
VVA319	369751.0540	4137629.1710	834.1030	834.2000	0.0970	VVA
VVA426	328030.3650	4133324.8690	876.6970	876.8060	0.1090	VVA
VVA427	352101.8280	4137531.9340	853.6110	853.7340	0.1230	VVA
VVA447	338081.6640	4118590.5320	839.7380	839.6680	-0.0700	VVA
VVA448	343545.7260	4104741.9900	837.0730	837.2850	0.2120	VVA
VVA449	381880.1470	4111229.1680	751.2380	751.1920	-0.0460	VVA
VVA450	362852.9520	4104052.0310	810.9240	811.0620	0.1380	VVA
VVA451	361290.8310	4115094.9620	827.9250	828.0260	0.1010	VVA
VVA452	407957.1620	4105783.4950	628.6830	628.6590	-0.0240	VVA
VVA453	437410.6170	4111518.9720	582.4020	583.0140	0.6120	VVA
VVA454	437410.6260	4111518.9410	582.4150	583.0110	0.5960	VVA
VVA457	417788.7030	4110351.7320	613.4990	613.5770	0.0780	VVA
VVA461	407618.8430	4134952.0680	777.6550	777.5460	-0.1090	VVA
VVA462	423298.6250	4141517.1770	733.6490	733.6110	-0.0380	VVA

VVA565	337470.0240	4132909.0330	873.7160	873.7400	0.0240	VVA
VVA583	326050.8670	4113227.1660	885.4450	885.4870	0.0420	VVA
VVA584	348399.4300	4114913.8280	836.3110	836.3160	0.0050	VVA
VVA585	372652.3980	4114717.0960	747.8440	747.7960	-0.0480	VVA
VVA586	374893.4440	4104480.2710	762.9250	762.9830	0.0580	VVA
VVA587	390481.4900	4107899.2430	737.9400	737.9100	-0.0300	VVA
VVA588	407858.6170	4109297.0950	622.8890	622.9250	0.0360	VVA
VVA589	427612.8980	4103593.8090	572.3390	571.8090	-0.5300	VVA
VVA591	410322.3420	4143970.6300	775.4110	775.3280	-0.0830	VVA
VVA612	387083.1170	4104113.0410	681.6170	681.6310	0.0140	VVA
VVA613	380683.3910	4119354.4000	767.1700	767.2230	0.0530	VVA
VVA621	343781.9880	4117148.8240	846.9930	846.9950	0.0020	VVA
VVA623	428949.8710	4099698.9390	566.3010	566.3290	0.0280	VVA
VVA635	331649.2340	4126721.2180	874.0610	874.0880	0.0270	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
NVA264	429851.8010	4139484.8850	744.4860	744.4694	-0.0166	NVA
NVA265	429851.7970	4139484.8930	744.4880	744.4696	-0.0184	NVA
NVA266	424997.5340	4131727.5120	741.8660	741.9437	0.0777	NVA
NVA267	371932.6370	4127567.9230	817.7190	817.6856	-0.0334	NVA
NVA419	326453.8520	4136490.6220	889.5050	889.5391	0.0341	NVA
NVA420	345008.4800	4134277.2400	865.2280	865.2554	0.0274	NVA
NVA447	329348.5230	4109044.2200	878.0990	878.1575	0.0585	NVA
NVA448	357772.7060	4110093.7370	824.7620	824.7693	0.0073	NVA
NVA449	402803.1860	4111815.2800	675.7240	675.6798	-0.0442	NVA
NVA450	388725.8420	4118776.6420	735.3840	735.3695	-0.0145	NVA
NVA451	403062.4120	4115719.4840	673.5680	673.5724	0.0044	NVA
NVA452	370874.6610	4111482.1700	760.9430	760.9801	0.0371	NVA
NVA453	416149.9940	4113681.8710	614.7620	614.7735	0.0115	NVA
NVA454	419336.8680	4102183.4900	586.4250	586.3303	-0.0947	NVA
NVA455	375715.8070	4100157.2960	748.5150	748.5748	0.0598	NVA
NVA456	430925.2680	4103901.9160	566.5520	566.3664	-0.1856	NVA
NVA459	376121.6460	4136984.3420	817.3830	817.4800	0.0970	NVA
NVA616	334457.6390	4134271.5050	876.0780	875.9887	-0.0893	NVA
NVA617	358494.0210	4139088.1820	850.2240	850.2516	0.0276	NVA
NVA645	343762.5330	4117153.0010	847.7040	847.5714	-0.1326	NVA
NVA646	343500.6110	4100719.1590	835.6700	835.7152	0.0452	NVA
NVA647	371691.2530	4122514.2460	813.8760	813.8774	0.0014	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
NVA648	398374.6730	4119271.0960	727.8890	727.7680	-0.1210	NVA
NVA649	362315.2330	4108188.9060	813.6150	813.6583	0.0433	NVA
NVA650	387060.5380	4104104.0960	681.4710	681.4571	-0.0139	NVA
NVA651	410392.4630	4115473.7960	643.4720	643.4131	-0.0589	NVA
NVA652	429203.0160	4120765.4530	625.4900	625.4652	-0.0248	NVA
NVA653	408015.0190	4101221.3450	615.2060	615.1890	-0.0170	NVA
NVA654	428940.2010	4099680.9360	566.4810	566.4569	-0.0241	NVA
NVA656	379529.9610	4127376.3740	769.3490	769.2851	-0.0639	NVA
NVA657	410327.8370	4143941.1540	775.7300	775.6665	-0.0635	NVA
NVA658	393736.0020	4137205.9120	756.0930	756.1034	0.0104	NVA
NVA659	359821.7970	4124507.1670	841.6700	841.6886	0.0186	NVA
NVA818	331628.6050	4126703.8240	874.0490	874.0903	0.0413	NVA
NVA819	358240.6890	4126025.5310	843.6190	843.6613	0.0423	NVA
NVA847	329451.8870	4104141.0550	867.5600	867.6221	0.0621	NVA
NVA848	349182.5040	4119202.0290	847.4490	847.5020	0.0530	NVA
NVA849	362013.2940	4119628.1310	831.2770	831.3348	0.0578	NVA
NVA850	380707.4390	4119347.0230	767.4990	767.4782	-0.0208	NVA
NVA851	424385.7040	4109705.3290	598.1000	598.4582	0.3582	NVA
NVA852	393432.0610	4105666.0490	737.4790	737.3341	-0.1449	NVA
NVA853	369274.2240	4104265.8550	761.6990	761.6522	-0.0468	NVA
NVA854	388647.0710	4112646.7900	750.7880	750.6472	-0.1408	NVA
NVA855	412192.3220	4099119.1270	600.1120	600.0765	-0.0355	NVA
NVA858	432587.2940	4116450.7610	597.9740	598.0641	0.0901	NVA
NVA877	406799.2320	4127038.8830	733.6990	733.6851	-0.0139	NVA
NVA879	381885.9470	4111252.3160	750.7210	750.7410	0.0200	NVA
NVA880	369744.7970	4137631.8320	834.1100	834.1625	0.0525	NVA
NVA888	348390.5160	4114929.9080	836.2320	836.2534	0.0214	NVA
NVA900	417812.0320	4110369.4150	613.4240	613.3533	-0.0707	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
VVA185	439000.7440	4125157.6410	692.5360	692.6274	0.0914	VVA
VVA186	381544.8100	4137058.3490	794.4790	794.6301	0.1511	VVA
VVA293	332530.8680	4144391.6610	892.4660	892.5842	0.1182	VVA
VVA294	352360.9940	4127931.6090	847.8240	847.9545	0.1305	VVA
VVA310	338647.6040	4098231.5790	841.8280	841.8091	-0.0189	VVA
VVA311	390229.8440	4098140.3300	707.1950	707.2599	0.0649	VVA
VVA312	400431.5110	4110599.0130	683.6980	683.6765	-0.0215	VVA
VVA313	366164.5480	4114653.5400	812.8770	812.9795	0.1025	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
VVA314	367025.4560	4098696.3470	724.3180	724.3598	0.0418	VVA
VVA315	420928.7780	4117955.5060	639.0960	639.1032	0.0072	VVA
VVA318	380981.1260	4140294.9520	793.6240	793.6270	0.0030	VVA
VVA319	369751.0540	4137629.1710	834.1030	834.1975	0.0945	VVA
VVA426	328030.3650	4133324.8690	876.6970	876.8003	0.1033	VVA
VVA427	352101.8280	4137531.9340	853.6110	853.7804	0.1694	VVA
VVA447	338081.6640	4118590.5320	839.7380	839.6697	-0.0683	VVA
VVA448	343545.7260	4104741.9900	837.0730	837.2596	0.1866	VVA
VVA449	381880.1470	4111229.1680	751.2380	751.1880	-0.0500	VVA
VVA450	362852.9520	4104052.0310	810.9240	811.0579	0.1339	VVA
VVA451	361290.8310	4115094.9620	827.9250	828.0210	0.0960	VVA
VVA452	407957.1620	4105783.4950	628.6830	628.6686	-0.0144	VVA
VVA453	437410.6170	4111518.9720	582.4020	583.0175	0.6155	VVA
VVA454	437410.6260	4111518.9410	582.4150	583.0163	0.6013	VVA
VVA457	417788.7030	4110351.7320	613.4990	613.5286	0.0296	VVA
VVA461	407618.8430	4134952.0680	777.6550	777.5426	-0.1124	VVA
VVA462	423298.6250	4141517.1770	733.6490	733.6192	-0.0298	VVA
VVA565	337470.0240	4132909.0330	873.7160	873.7431	0.0271	VVA
VVA583	326050.8670	4113227.1660	885.4450	885.4663	0.0213	VVA
VVA584	348399.4300	4114913.8280	836.3110	836.2809	-0.0301	VVA
VVA585	372652.3980	4114717.0960	747.8440	747.8010	-0.0430	VVA
VVA586	374893.4440	4104480.2710	762.9250	763.0157	0.0907	VVA
VVA587	390481.4900	4107899.2430	737.9400	737.8985	-0.0415	VVA
VVA588	407858.6170	4109297.0950	622.8890	622.9398	0.0508	VVA
VVA589	427612.8980	4103593.8090	572.3390	571.8525	-0.4865	VVA
VVA591	410322.3420	4143970.6300	775.4110	775.3181	-0.0929	VVA
VVA612	387083.1170	4104113.0410	681.6170	681.6346	0.0176	VVA
VVA613	380683.3910	4119354.4000	767.1700	767.2239	0.0539	VVA
VVA621	343781.9880	4117148.8240	846.9930	847.0030	0.0100	VVA
VVA623	428949.8710	4099698.9390	566.3010	566.2915	-0.0095	VVA
VVA635	331649.2340	4126721.2180	874.0610	874.1060	0.0450	VVA

Table 14: DEM Check Point Assessment