TX West Central QL2 Lidar Project

Report Produced for U.S. Geological Survey

USGS Contract: G16PC00020

Task Order: 140G0218F0072

Report Date: 7/29/2019

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Executive Summary

The primary purpose of this project is to support the 3DEP mission and the Federal Emergency management Agency (FEMA) Risk Mapping, Assessment and Planning (MAP) program for the TX West Central 2018 D18 Project Area.

The lidar data were processed and classified according to project specifications. Detailed breaklines and bare-earth Digital Elevation Models (DEMs) were produced for the project area. Data was formatted according to tiles with each tile covering an area of 1500m by 1500m. A total of 50901 tiles were produced for the project encompassing an area of approximately 42,557 sq. miles.

THE PROJECT TEAM

Dewberry served as the prime contractor for the project. In addition to project management, Dewberry was responsible for LAS classification, all lidar products, breakline production, Digital Elevation Model (DEM) production, and quality assurance.

Dewberry's Gary D. Simpson, L.S. completed ground surveying for the project and delivered surveyed checkpoints. His task was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the lidar-derived surface model. He also verified the GPS base station coordinates used during lidar data acquisition to ensure that the base station coordinates were accurate. Please see Appendix A to view the separate Survey Report that was created for this portion of the project.

Airborne Imaging, AXIS, Eagle, LEG and Precision Aerial Reconnaissance completed lidar data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the New Mexico counties of Chaves, Lea and Roosevelt. Oklahoma counties of Bryan, Choctaw, Cotton, Crane, Jackson, Jefferson, Love, Marshall and Tillman. Texas counties of Andrews, Baylor, Borden, Brown, Clay, Cochran, Coke, Coleman, Concho, Cooke, Crosby, Dawson, Delta, Dickens, Ector, Fannin, Fisher, Gaines, Garza, Glasscock, Grayson, Haskell, Hockley, Hopkins, Howard, Hunt, Irion, Kent, King, Knox, Lamar, Lubbock, Lynn, Martin, Midland, Mitchell, Montague, Nolan, Reagan, Runnels, Scurry, Sterling, Stonewall, Taylor, Terry, Tom Green, Upton, Wichita, Wilbarger, Winkler, Wise and Yoakum.

DATE OF SURVEY

The lidar aerial acquisition was conducted from February 1, 2018 thru May 6, 2018.

COORDINATE REFERENCE SYSTEM

Data produced for the project were delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 with the 2011 Adjustment (NAD 83 (2011))

Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)

Coordinate System: UTM Zone 13, UTM 14 and UTM 15.

Units: Horizontal units are in meters, Vertical units are in meters.

Geiod Model: Geoid12B (Geoid 12B was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the TX West Central QL2 Lidar Project, the tested $RMSE_z$ of the classified lidar data for checkpoints in non-vegetated terrain equaled **4.7 cm** compared with the 10 cm specification; and the NVA of the classified lidar data computed using $RMSE_z$ x 1.9600 was equal to **9.1 cm,** compared with the 19.6 cm specification.

For the TX West Central QL2 Lidar Project, the tested VVA of the classified lidar data computed using the 95^{th} percentile was equal to **11.7 cm**, compared with the 29.4 cm specification.

Additional accuracy information and statistics for the classified lidar data, raw swath data, and bare earth DEM data are found in the following sections of this report.

PROJECT DELIVERABLES

The deliverables for the project are listed below.

1. Classified Point Cloud Data (Tiled)
2. Bare Earth Surface (Raster DEM – IMG Format)
3. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
4. Breakline Data (File GDB)
5. Independent Survey Checkpoint Data (Report, Photos, & Points)
6. Calibration Points
7. Metadata
8. Project Report (Acquisition, Processing, QC)
9. Project Extents, Including a shapefile derived from the lidar deliverable

PROJECT TILING FOOTPRINT

Fifty thousand nine hundred one (50901) tiles were delivered for the project. Each tile's extent is 1,500 meters by 1,500 meters.

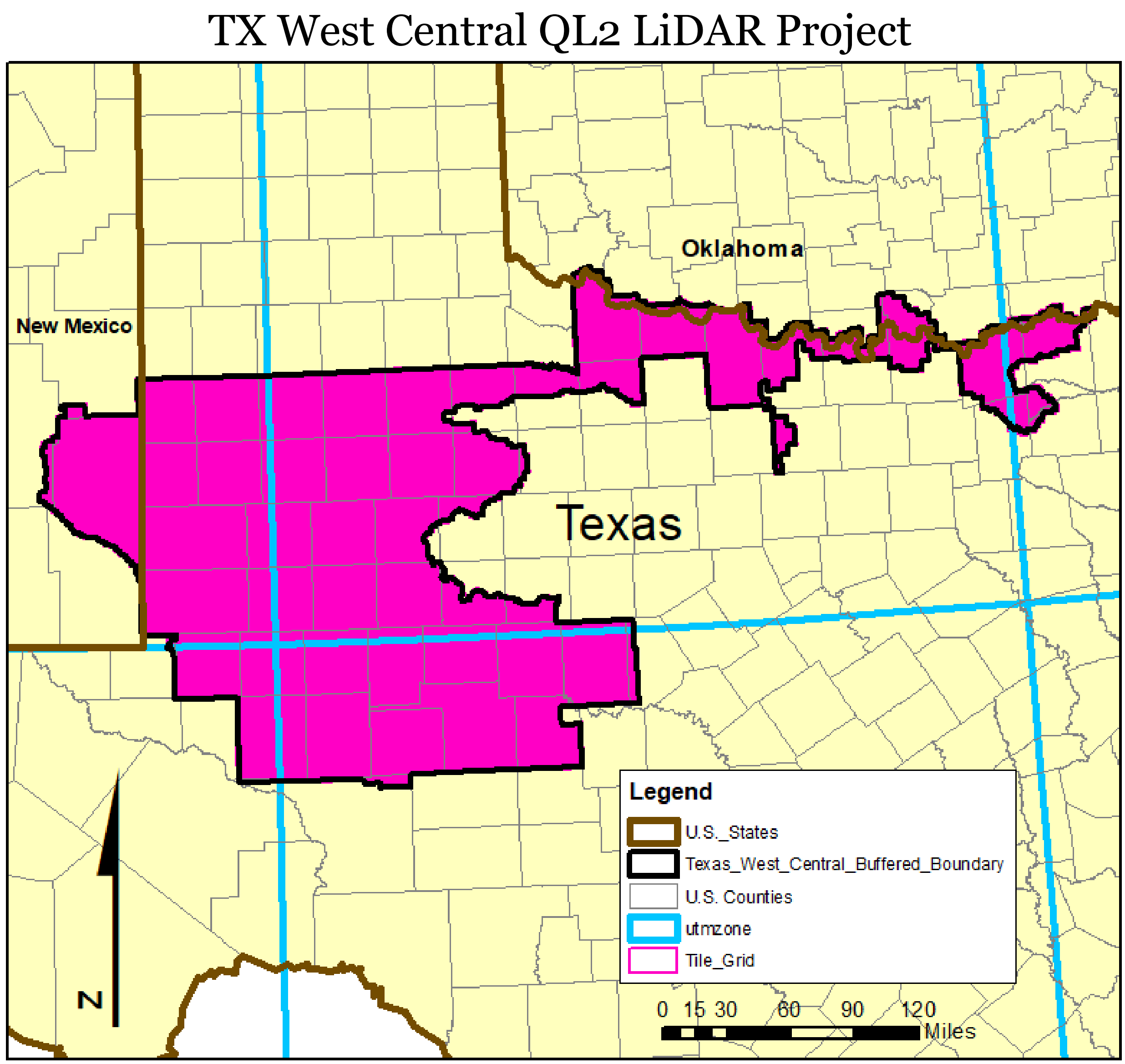


Figure 1 - Project Map

Lidar Acquisition Report

Dewberry elected to subcontract the lidar acquisition and calibration activities to Precision Aerial Reconnaissance (PAR), Airborne Imaging, AXIS Geospatial, LLC, Eagle Mapping Inc., Leading Edge Geomatics (LEG), Aerial Services Inc (ASI), and Intermap. Airborne Imaging, AXIS, Eagle, LEG, ASI, Intermap, and PAR were responsible for providing lidar acquisition, calibration and delivery of lidar data files to Dewberry.

Dewberry received calibrated swath data from:

- PAR on July 2, 2018.
- Airborne Imaging on February 12 and March 6, 2018
- AXIS on April 17, 2018
- Eagle Mapping on May 6, 2018
- LEG on February 1, 2018
- ASI on April 4, 2018
- Intermap on June 6, 2018

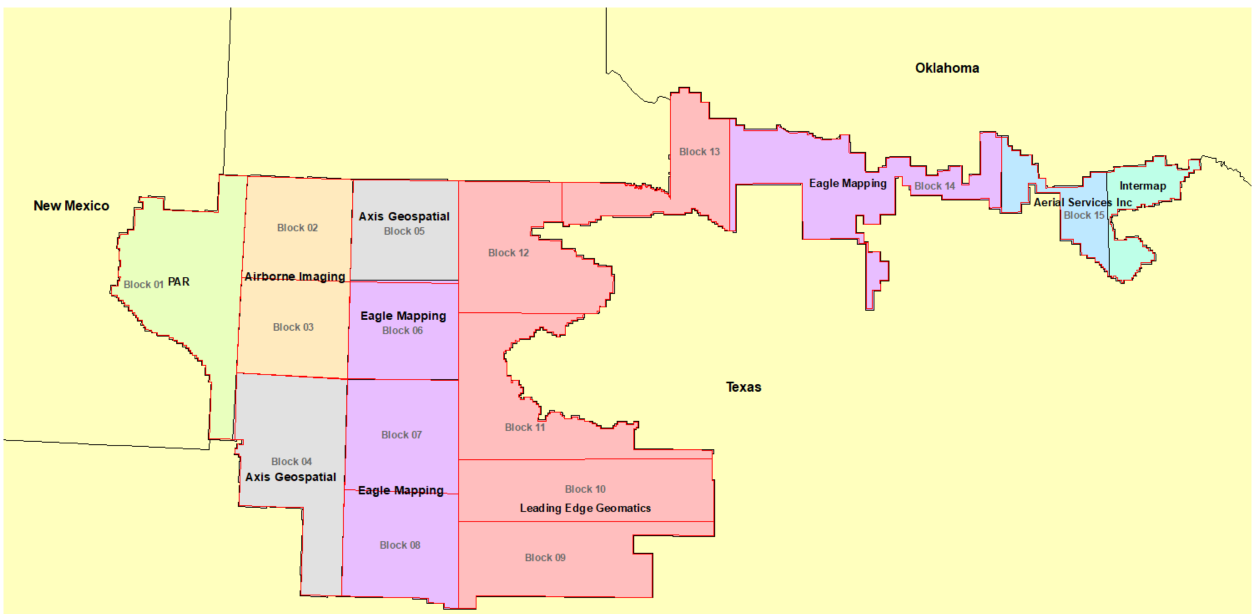


Figure 2 - Acquisition Map

PRECISION AERIAL RECONNAISSANCE- DELIVERY BLOCK 01

Lidar Acquisition Details

Precision Aerial Reconnaissance (PAR) planned 213 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, PAR followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using LEICA MISSION PRO flight design software for direct integration into the aircraft flight navigation system.

- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, PAR will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

PAR monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. PAR accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, PAR closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

PAR lidar sensors are calibrated at a designated site located at the Shreveport Downtown Airport in Shreveport, Louisiana and are periodically checked and adjusted to minimize corrections at project sites.

Lidar System parameters

Precision Aerial Reconnaissance (PAR) operated a Cessna U206G (Tail # N799AC), Cessna 206 (Tail # 6461Z), Cessna 206 (Tail # 8646Q), each outfitted with a LEICA ALS70-HP LiDAR system during the Texas West Central aerial survey. Table 1 illustrates PAR system parameters for lidar acquisition on this project.

Item	Parameter
System	Leica ALS-70 HP
Altitude (AGL meters)	1800
Approx. Flight Speed (knots)	150
Scanner Pulse Rate (kHz)	151.7
Scan Frequency (hz)	53.4
Pulse Duration of the Scanner (nanoseconds)	9
Pulse Width of the Scanner (m)	0.2
Swath width (m)	1310.29
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	0.22
Nominal Swath Width on the Ground (m)	1310.29
Swath Overlap (%)	30
Total Sensor Scan Angle (degree)	40

Item	Parameter
Computed Down Track spacing (m) per beam	1.22
Computed Cross Track Spacing (m) per beam	0.44
Nominal Pulse Spacing (single swath), (m)	0.7
Nominal Pulse Density (single swath) (ppsm), (m)	2
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.8
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2
Maximum Number of Returns per Pulse	7

Table 1: PAR lidar system parameters

Acquisition Status Report and Flightlines

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 3 shows the combined trajectory of the flightlines.

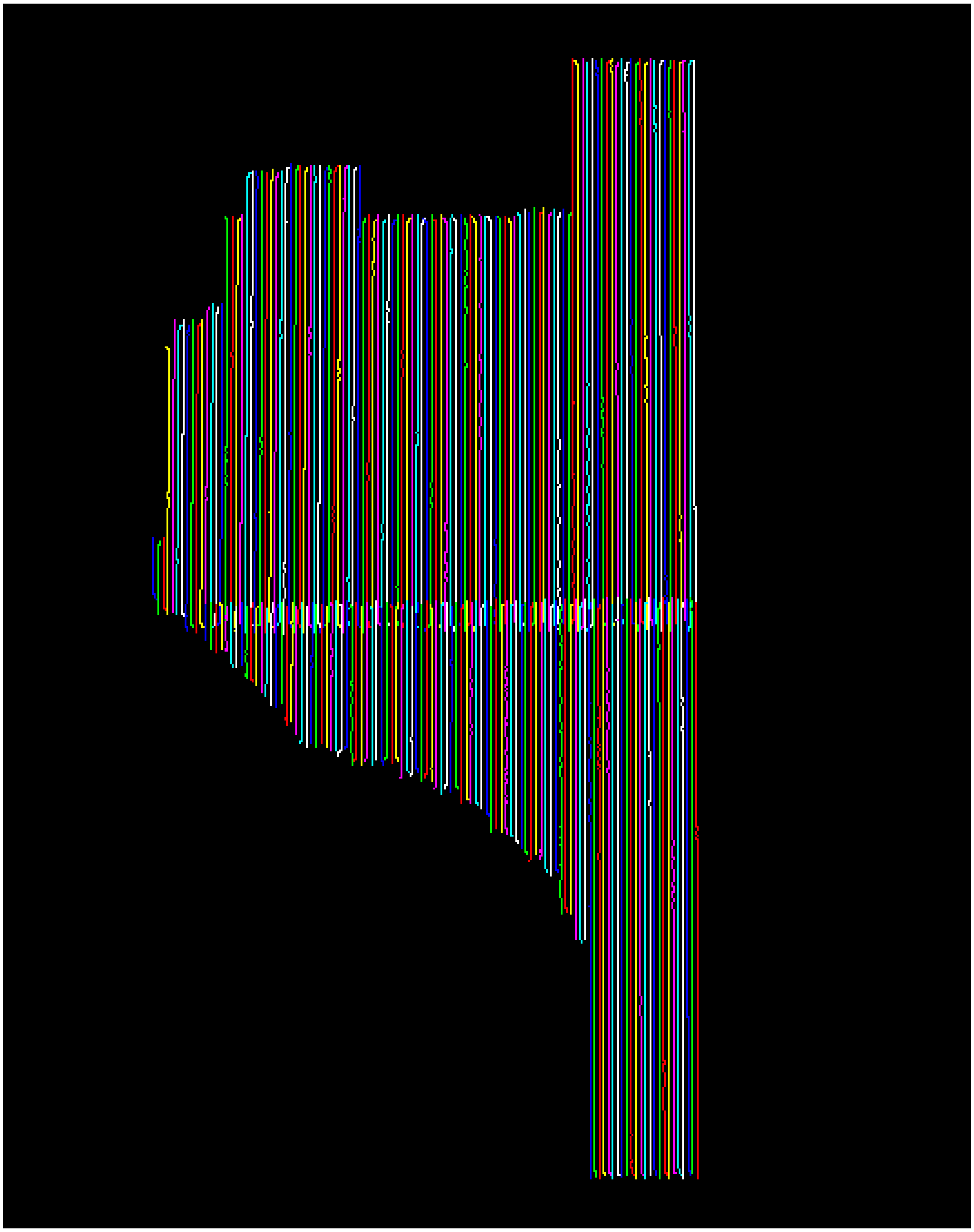


Figure 3: Trajectories as flown by PAR Inc.

Lidar Control

Four existing NGS monuments were used to control the lidar acquisition for the TX West Central Lidar project area. The coordinates of all used base stations are provided in the table below. All control and calibration points are also provided in shapefile format as part of the final deliverables.

Name	NAD83 (2011) UTM Zone 13N		Ellipsoid Ht (NAD83(2011), m)	Orthometric Ht (NAVD88 Geoid12B, m)
	Easting X (m)	Northing Y (m)		
Hobbs	667162	3618897	1090.582	1112.247
Lovington	649159	3646875	1187.250	1209.130
Lovington2	648061	3647668	1190.967	1212.790
Yoakum	701811	3677398	1098.861	1121.187

Table 2 – Base stations used to control lidar acquisition for delivery block 01.

Airborne GPS Kinematic

Airborne GPS data was processed using the Inertial Explorer software suite. Flights were flown with a minimum of 13 satellites in view (12° above the horizon) and with a PDOP of better than 3. Distances from base station to aircraft were kept to a maximum of 70km.

For all flights, the GPS data can be classified as excellent, no larger than 10cm being recorded.

GPS processing reports for each mission are included in Appendix B.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Leica Cloud Pro, initially with default values from Leica or the last mission calibrated for the system. Bayes StripAlign software (version 2.04B) was utilized for LiDAR calibration, assessment of calibration validity, and assessment of point cloud alignment to control. If a calibration error greater than specification is observed within the mission, roll, pitch and scanner, scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

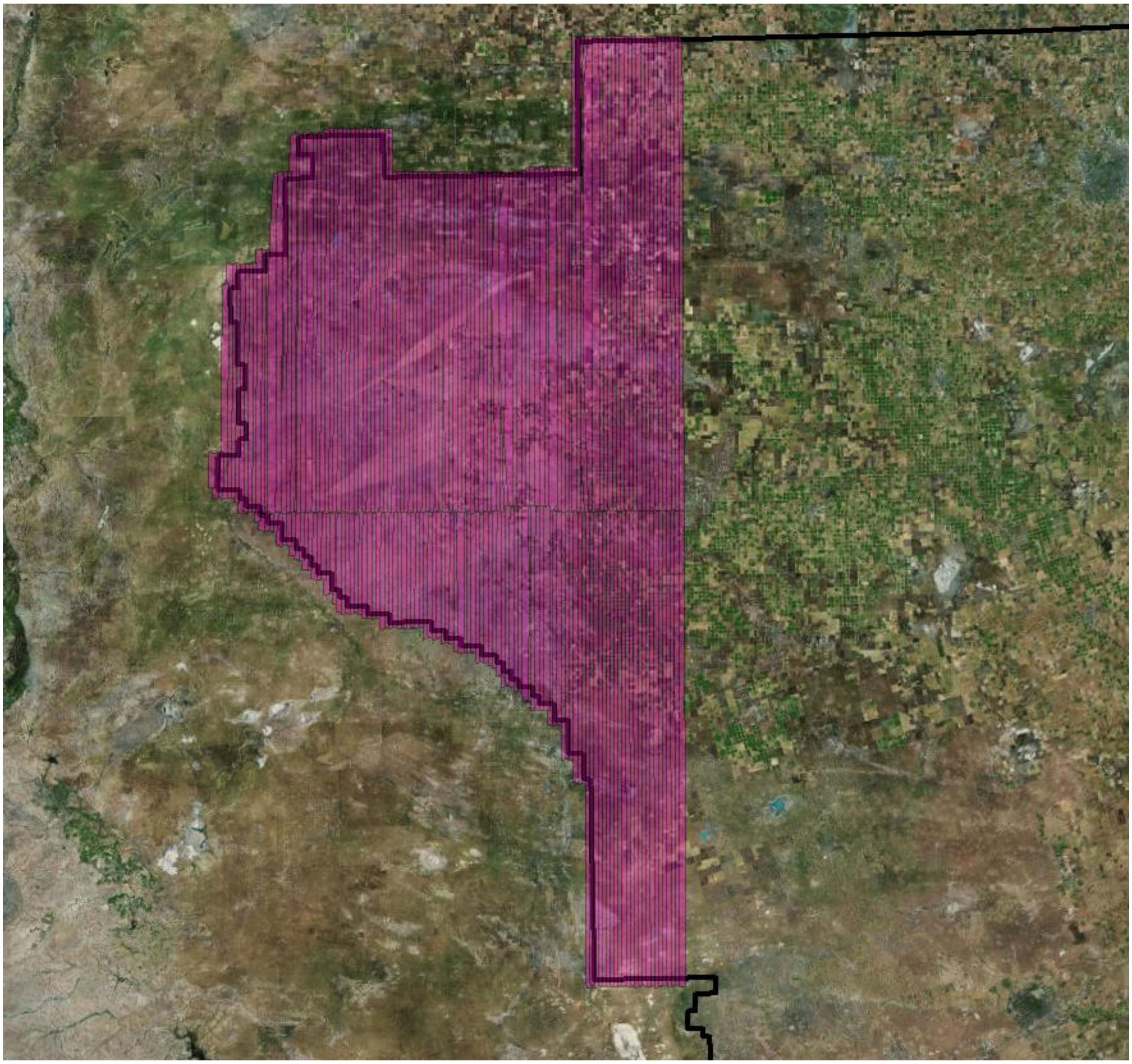


Figure 4 – Lidar swath output showing complete coverage for delivery block 01.

Boresight and Relative accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

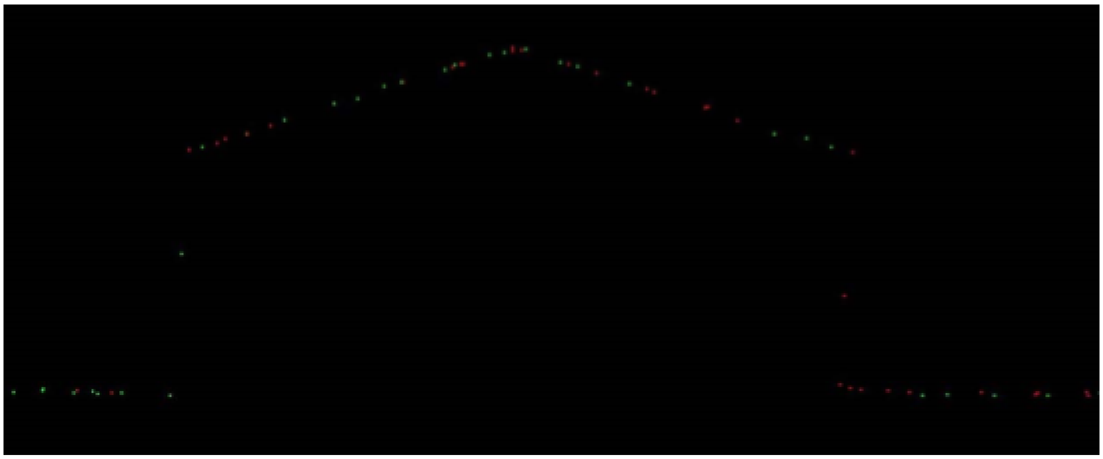


Figure 5 – Profile views showing correct roll and pitch adjustments.

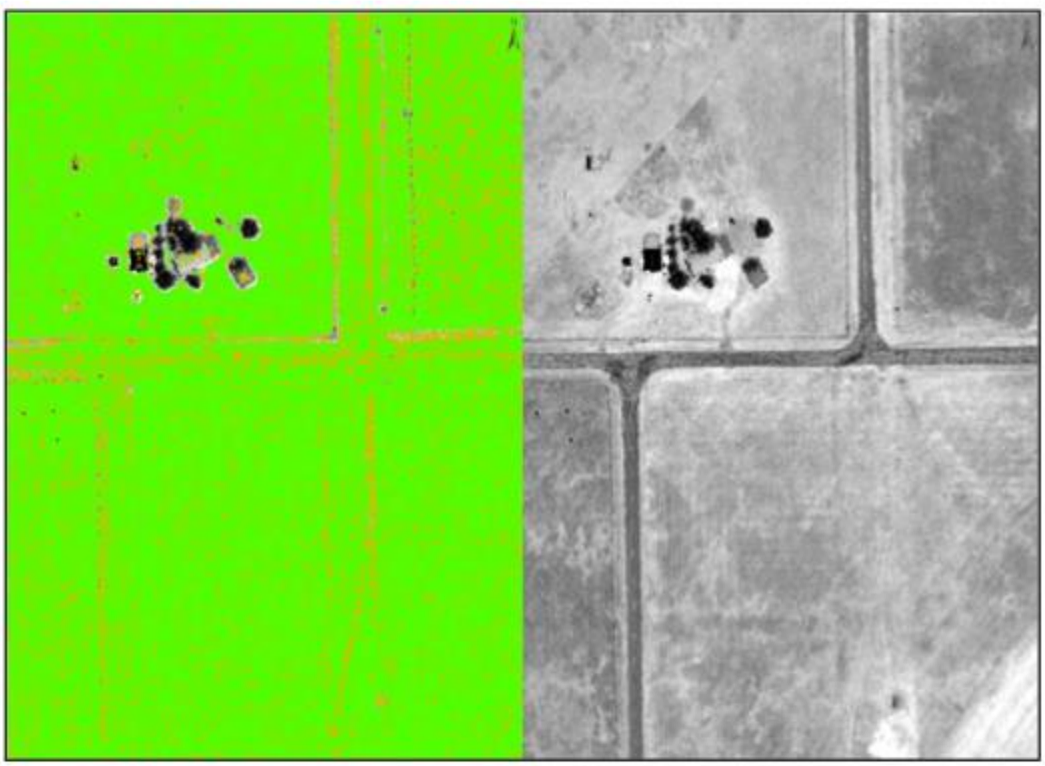


Figure 6 – Relative accuracy of swath data over road and pasture. Left view illustrates green points representing elevation offsets between adjacent points that are within 6 cm. Orange points represent elevation offsets greater than 6 cm. Right view shows LiDAR intensity of the left view.

A different set of QC blocks are generated for final review after all transformations have been applied.

Preliminary Vertical Accuracy Assessment

A preliminary $RMSE_z$ error check is performed by PAR at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq$ 10 cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

Unit Selection and Statistic Conversions		
Map Units	Meters	
Statistic	Feet	Meters
Average Δz =	0.015	0.005
Minimum Δz =	-0.423	-0.129
Maximimum Δz =	0.330	0.101
Median Δz =	-0.006	-0.002
Δz Skew =	-0.967	-0.295
Average Magnitude =	0.130	0.040
$RMSE_z$ =	0.164	0.050
Standard Deviation =	0.163	0.050
NVA(CAL) at 95% confidence =	0.321	0.098
Maximum Absolute Accuracy =	0.623	0.190

Table 3 - Static GPS Vertical Accuracy Results.

The calibrated TX West central Lidar dataset was tested to 0.098 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.050 m x 1.9600) when compared to 54 GPS static check points.

The following are the final statistics for the GPS static checkpoints used by PAR to internally verify vertical accuracy.

Number	NAD83 (2011) UTM Zone 13N		NAVD88 (Geoid 12B)	Laser Z (M)	Delta Z
	Easting X (M)	Northing Y (M)	Known Z (M)		
PAR-1	682645.854	3552494.250	940.145	940.187	0.042
PAR-2	697984.308	3557899.145	974.051	974.101	0.049
PAR-4	697607.639	3567492.714	996.976	997.022	0.046
PAR-3	682859.720	3567716.148	989.089	989.189	0.101
PAR-5	683035.863	3584733.906	1031.352	1031.432	0.080
PAR-6	698141.617	3584887.125	1025.520	1025.569	0.049
PAR-7	683052.252	3598559.719	1077.000	1077.036	0.036
PAR-8	699004.805	3598897.442	1034.185	1034.230	0.045
PAR-9	667738.867	3612590.620	1103.977	1103.969	-0.008

PAR-11	698849.953	3612140.435	1041.215	1041.205	-0.010
PAR-10	683067.006	3613617.962	1082.856	1082.809	-0.047
PAR-12	636975.595	3628993.318	1225.688	1225.689	0.001
PAR-14	668137.780	3628855.039	1127.953	1127.907	-0.046
PAR-15	681260.593	3628711.420	1108.466	1108.556	0.089
PAR-13	651844.858	3629361.957	1177.336	1177.280	-0.056
PAR-16	698233.262	3629305.489	1064.295	1064.345	0.050
PAR-17	624219.766	3643681.470	1291.098	1291.181	0.083
PAR-18	638056.184	3644395.843	1242.739	1242.828	0.089
PAR-20	667175.819	3644159.722	1151.044	1151.037	-0.008
PAR-22	698103.783	3643899.435	1083.808	1083.854	0.046
PAR-19	652595.847	3644690.162	1195.530	1195.553	0.023
PAR-21	682428.044	3645236.631	1119.009	1119.028	0.019
PAR-23	607961.944	3655336.805	1352.710	1352.694	-0.016
PAR-25	636771.362	3659163.268	1261.979	1262.008	0.029
PAR-27	666733.263	3659459.405	1171.052	1171.093	0.041
PAR-29	698127.297	3659037.879	1103.355	1103.324	-0.031
PAR-24	621619.600	3659779.487	1309.728	1309.728	0.001
PAR-26	651846.826	3660040.461	1213.939	1213.884	-0.055
PAR-28	682699.595	3660335.711	1135.874	1135.909	0.036
PAR-32	653596.429	3674821.830	1223.660	1223.630	-0.030
PAR-33	666444.859	3674753.081	1189.760	1189.723	-0.037
PAR-34	680791.856	3674813.861	1158.652	1158.635	-0.017
PAR-35	698551.452	3674240.084	1118.731	1118.726	-0.005
PAR-30	611796.571	3675412.801	1350.181	1350.130	-0.051
PAR-31	637249.813	3675664.665	1273.286	1273.342	0.057
PAR-40	669463.382	3686143.474	1193.312	1193.318	0.007
PAR-39	653392.543	3689055.683	1241.237	1241.231	-0.006
PAR-36	611767.073	3689695.354	1357.572	1357.484	-0.088
PAR-37	623264.500	3690036.603	1318.340	1318.211	-0.129
PAR-38	637642.706	3689961.906	1275.264	1275.253	-0.011
PAR-41	682903.613	3689529.266	1172.106	1172.116	0.010
PAR-42	698222.912	3689812.578	1142.724	1142.718	-0.006

Table 4 - Static GPS Points.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	54	0.050	0.098	0.002	0.005	-0.129	0.101

Table 5- Static GPS Vertical Accuracy Results for delivery block 01.

Overall the calibrated lidar data products collected by PAR meet or exceed the requirements set out in the Statement of Work. The quality control requirements of PAR quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

AIRBORNE IMAGINE- DELIVERY BLOCK 02 AND 03

Lidar Acquisition Details

Airborne Imaging planned 112 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, Airborne Imaging followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using LEICA MISSION PRO flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Airborne Imaging will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Airborne Imagery monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Airborne Imagery accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Airborne Imaging closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Airborne Imaging lidar sensors are calibrated at a designated site located at Red Deer, Alberta, Canada or St. Hubert, Quebec, Canada and are periodically checked and adjusted to minimize corrections at project sites.

Lidar System parameters

Airborne Imaging operated a Piper PA-31 Navajo (Tail # C-FFRY, and # N-44RL) outfitted with a Riegl Q-1560 lidar system during the collection of the study area. Table 6 illustrates Airborne Imaging system parameters for lidar acquisition on this project.

Item	Parameter
System	Riegl LMS-Q1560
Altitude (AGL meters)	2000
Approx. Flight Speed (knots)	150
Scanner Pulse Rate (kHz)	800
Scan Frequency (hz)	185
Pulse Duration of the Scanner (nanoseconds)	3
Pulse Width of the Scanner (m)	0.9
Swath width (m)	2241
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	0.25
Nominal Swath Width on the Ground (m)	2241
Swath Overlap (%)	30
Total Sensor Scan Angle (degree)	60
Computed Down Track spacing (m) per beam	0.85
Computed Cross Track Spacing (m) per beam	0.85
Nominal Pulse Spacing (single swath), (m)	0.7
Nominal Pulse Density (single swath) (ppsm), (m)	2
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.7
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2
Maximum Number of Returns per Pulse	4

Table 6: Airborne Imaging lidar system parameters

Acquisition Status Report and Flightlines

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 7 shows the combined trajectory of the flightlines.

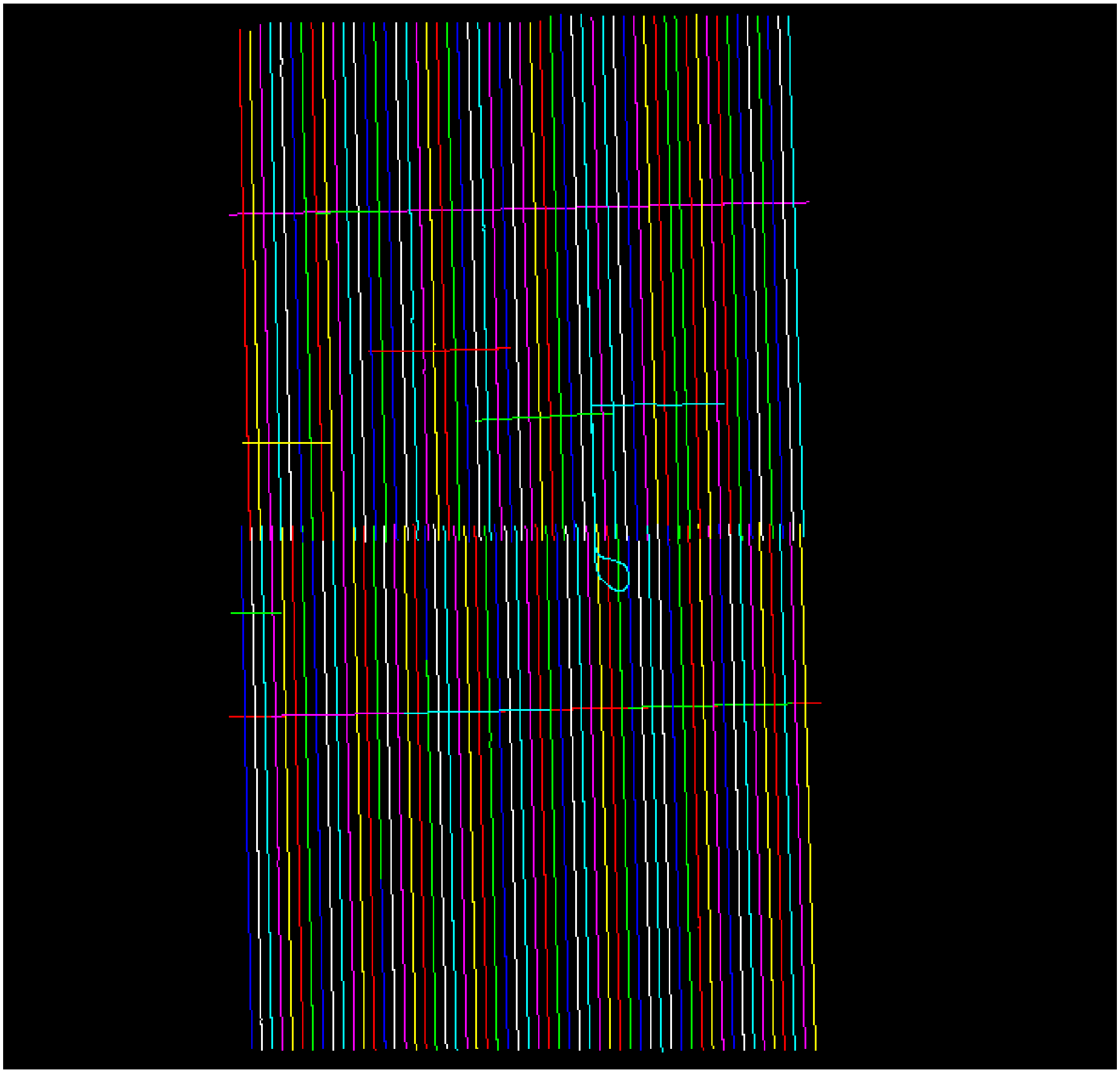


Figure 7: Trajectories as flown by Airborne Imaging.

Lidar Control

Seven Continuous Operating Reference Stations (CORS) were used to control the LiDAR acquisition for the Brownfield LiDAR project area. The coordinates of all used base stations are provided in the table 7 below. All control and calibration points are also provided in shapefile format as part of the final deliverables.

Name	NAD83(2011) UTM 13		Ellipsoid Ht (NAD83(2011), m)	Orthometric Ht (NAVD88 Geoid12B, m)
	Easting X (m)	Northing Y (m)		
TXAD	731272.142	3577227.206	947.962	971.461
TXL1	744975.701	3758490.343	1072.702	1097.294
TXLA	786307.460	3628966.290	892.759	916.881
TXLU	793194.360	3715110.976	957.122	981.962
TXM1	707543.355	3735341.408	1126.648	1149.976
TXP2	703419.357	3673602.278	1090.800	1113.110
TXS3	722158.860	3621819.740	978.869	1001.469

Table 7 – Base stations used to control lidar acquisition

Airborne GPS Kinematic

Airborne GNSS data was processed using the Applanix POSPac MMS software suite with SmartBase and Novatel's GrafNav software. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4. Distances from at least one base station to aircraft were kept to a maximum of 45km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix C.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Riegl's RiProcess, initially with default values calibration for the system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

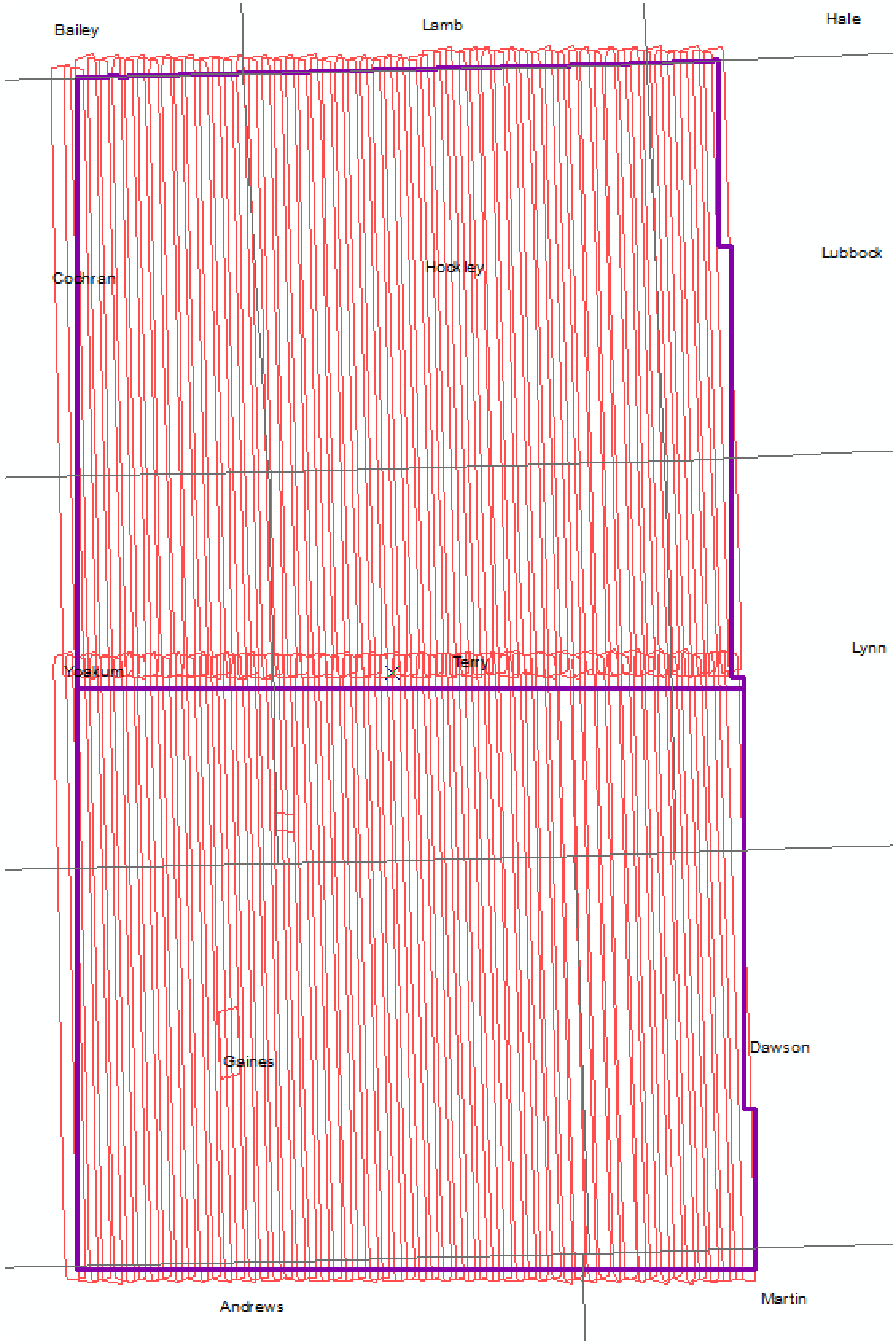


Figure 8 – Lidar swath output showing complete coverage of Block 02 and 03.

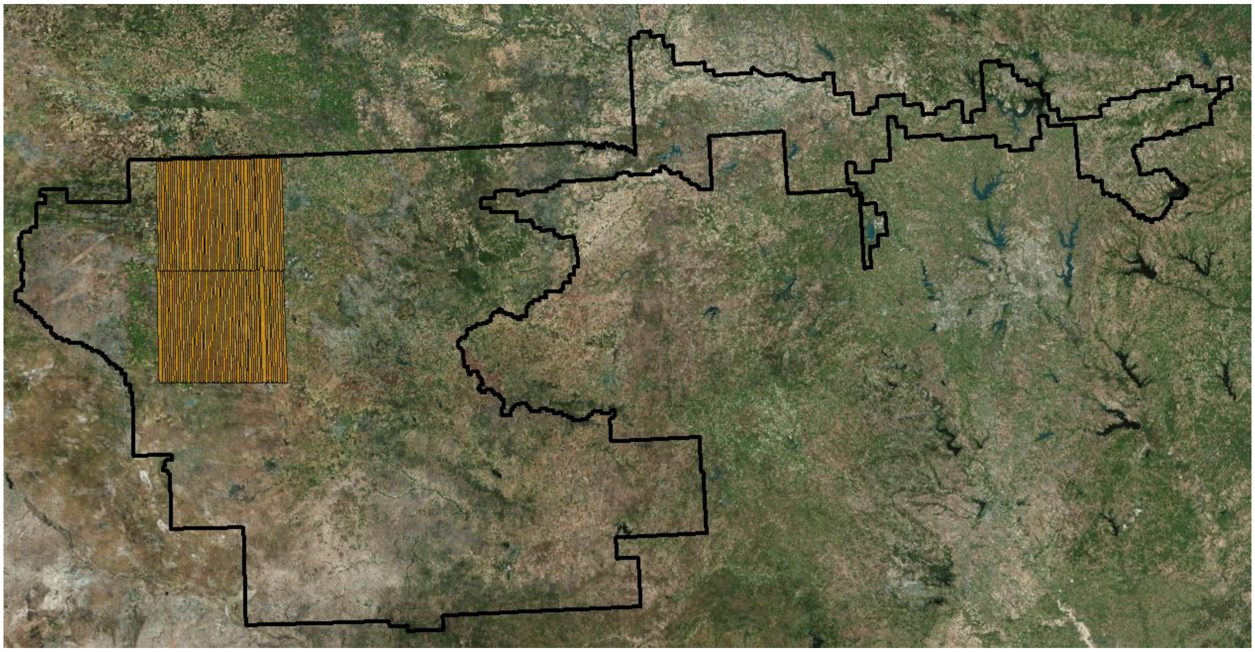


Figure 9 – Lidar swath output showing complete coverage for delivery blocks 2 and 3.

Boresight and Relative accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

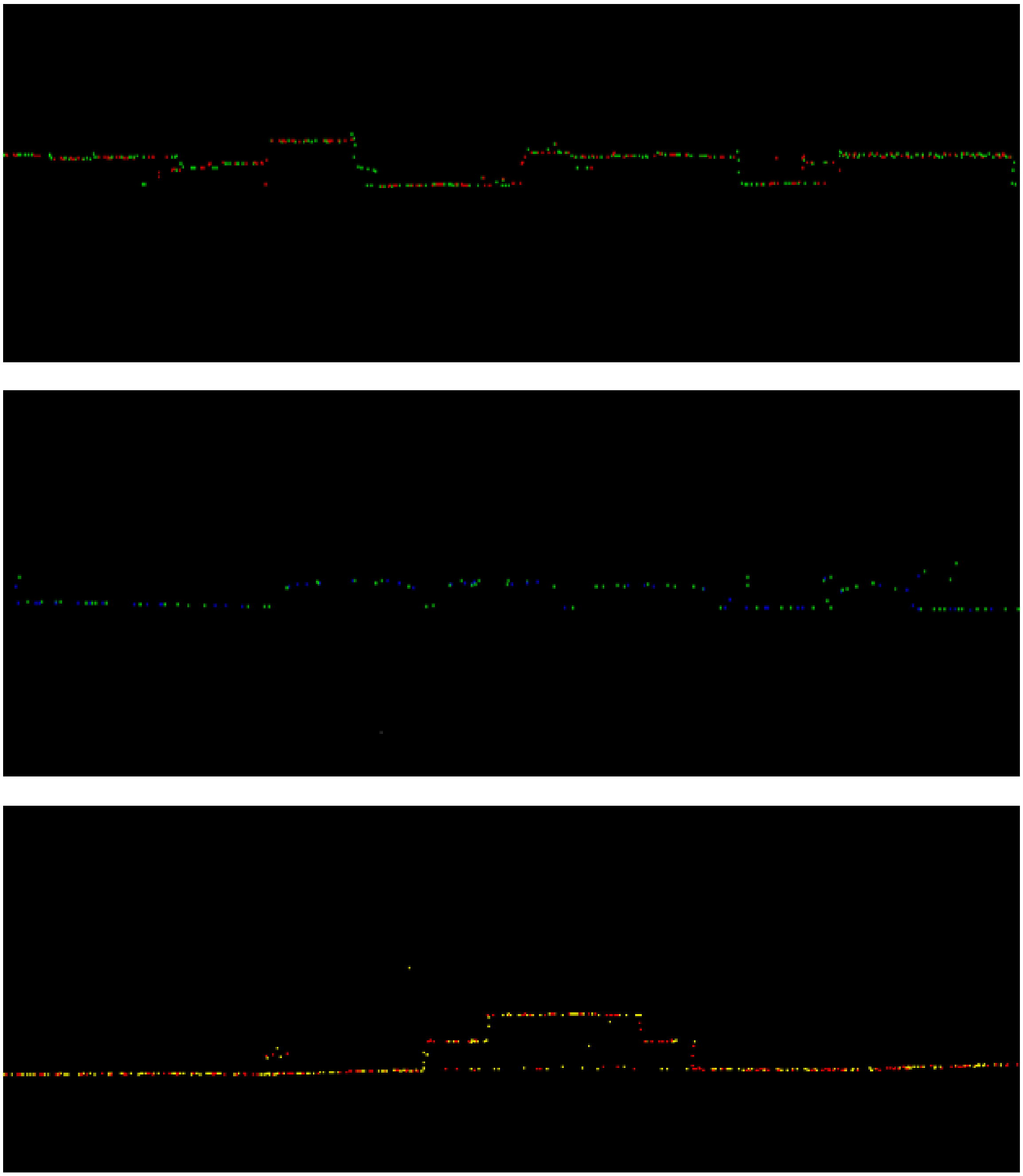


Figure 10 – Profile views showing correct roll and pitch adjustments.

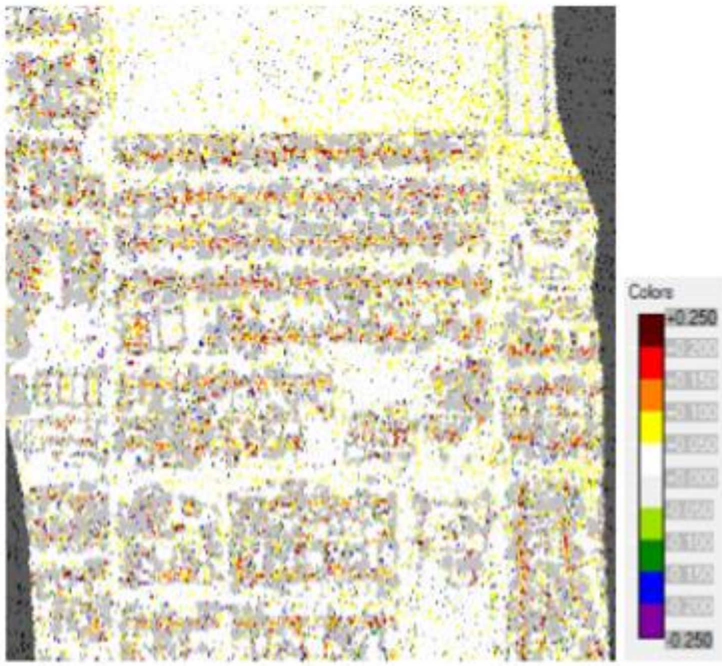


Figure 11 – QC block colored by distance to ensure accuracy at swath edges.

A different set of QC blocks are generated for final review after all transformations have been applied.

Preliminary Vertical Accuracy Assessment

A preliminary $RMSE_z$ error check is performed by Airborne Imaging at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq 10$ cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated TX West Central Lidar dataset was tested to 0.096 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.49 m x 1.9600) when compared to over 5000 GNSS kinematic checkpoints.

The following are the final statistics for the GNSS kinematic checkpoints used by Airborne Imaging to internally verify vertical accuracy.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	5172	0.049	0.096	-0.010	0.048	-0.258	0.176

Table 8 - Static GPS Vertical Accuracy Results

Overall the calibrated lidar data products collected by Airborne Imaging meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Airborne Imaging quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

AXIS GEOSPATIAL- DELIVERY BLOCK 04 AND 05

Lidar Acquisition Details

AXIS Geospatial, LLC planned 275 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, AXIS Geospatial, LLC followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using TrackAir flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, AXIS Geospatial, LLC will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

AXIS Geospatial, LLC monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. AXIS Geospatial, LLC accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, AXIS Geospatial, LLC closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

AXIS Geospatial, LLC lidar sensors are calibrated at a designated site located at the Easton Airport in Easton, Maryland and are periodically checked and adjusted to minimize corrections at project sites.

Lidar System parameters

AXIS Geospatial, LLC operated a Cessna 206H single engine aircraft (Tail # N223TC) and operating a Riegl VQ 1560i Lidar sensor during the collection of the study area. Table 9 illustrates AXIS Geomatics, LLC system parameters for lidar acquisition on this project.

Item	Parameter
System	Riegl VQ-Q1560i
Altitude (AGL meters)	5700
Approx. Flight Speed (knots)	147
Scanner Pulse Rate (kHz)	1000
Scan Frequency (hz)	201
Pulse Duration of the Scanner (nanoseconds)	3
Pulse Width of the Scanner (m)	.43
Swath width (m)	1947
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	.25
Nominal Swath Width on the Ground (m)	1947
Swath Overlap (%)	15
Total Sensor Scan Angle (degree)	58
Computed Down Track spacing (m) per beam	0.55
Computed Cross Track Spacing (m) per beam	0.55
Nominal Pulse Spacing (single swath), (m)	0.7
Nominal Pulse Density (single swath) (ppsm), (m)	2
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.7
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2
Maximum Number of Returns per Pulse	15

Table 9: AXIS Geospatial, LLC lidar system parameters

Acquisition Status Report and Flightlines

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 12 shows the combined trajectory of the flightlines.

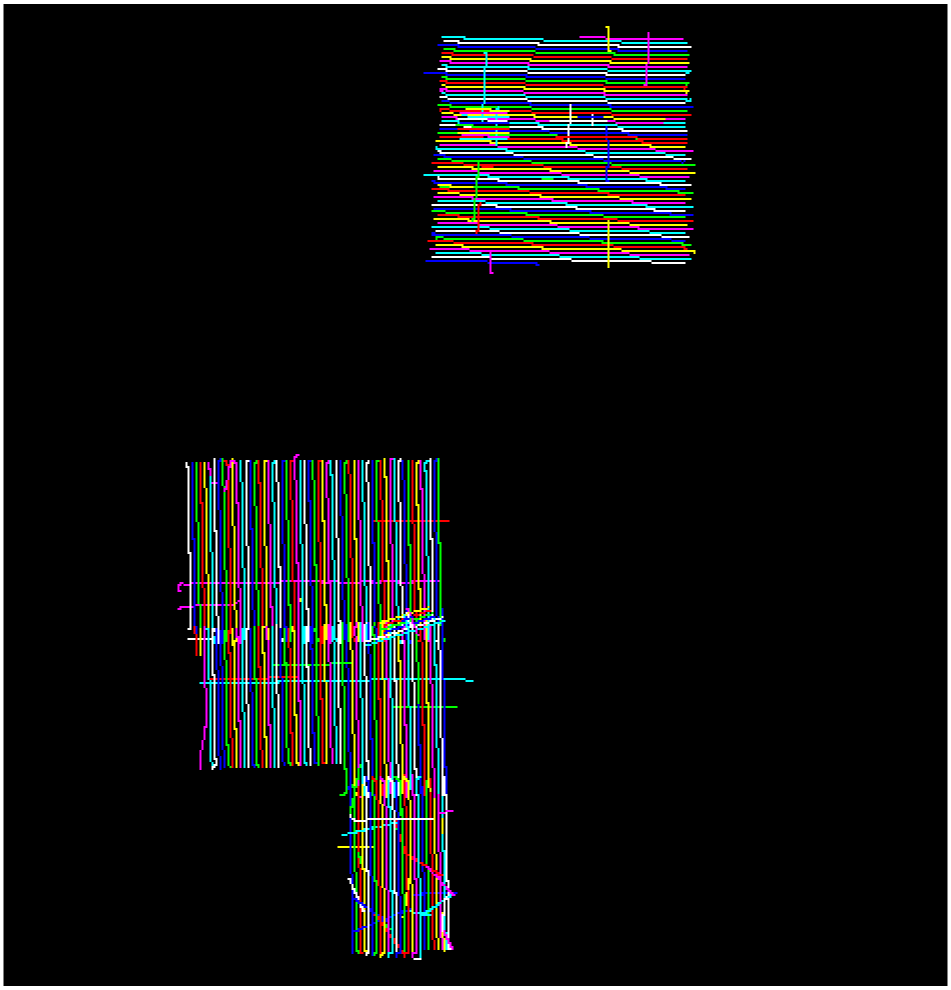


Figure 12: Trajectories as flown by AXIS Geospatial, LLC.

Lidar Control

NGS CORS, Texas DOT, and Leica Smartnet Base Stations were used to control the lidar acquisition for the TX West Central Lidar project area.

Name	NAD83(2011) UTM 13		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
TXP2	703418	3673603	1089.754
TXM1	707542	3735342	1125.576
TXL1	744975	3758491	1071.640
TXLD	746301	3720337	1052.166
TXBF	753390	3672900	990.369

Name	NAD83(2011) UTM 14		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
TXSC	309741	3524641	6279.312
TXPD	380919	3764270	533.175
TXP1	278112	3674045	767.614
TXLU	236007	3714266	956.030
TXLA	224200	3628669	891.650
TXTU	248585	3824746	1034.855
TXSL	287472	3817154	975.732
TXMT	330762	3764966	707.928
TXTO	239386	3674784	920.282
TXRA	278666	3728367	924.206
TXPW	248922	3782141	1006.097
TXDK	330230	3721932	762.791
TXSO	235167	3559537	801.531

Airborne GPS Kinematic

Airborne GPS data was processed using the PosPac Mobile Mapping System (MMS) version 8.1 software suite. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 40 km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix D.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Riegl's RiProsess, initially with default values from Riegl or the last mission calibrated for the system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

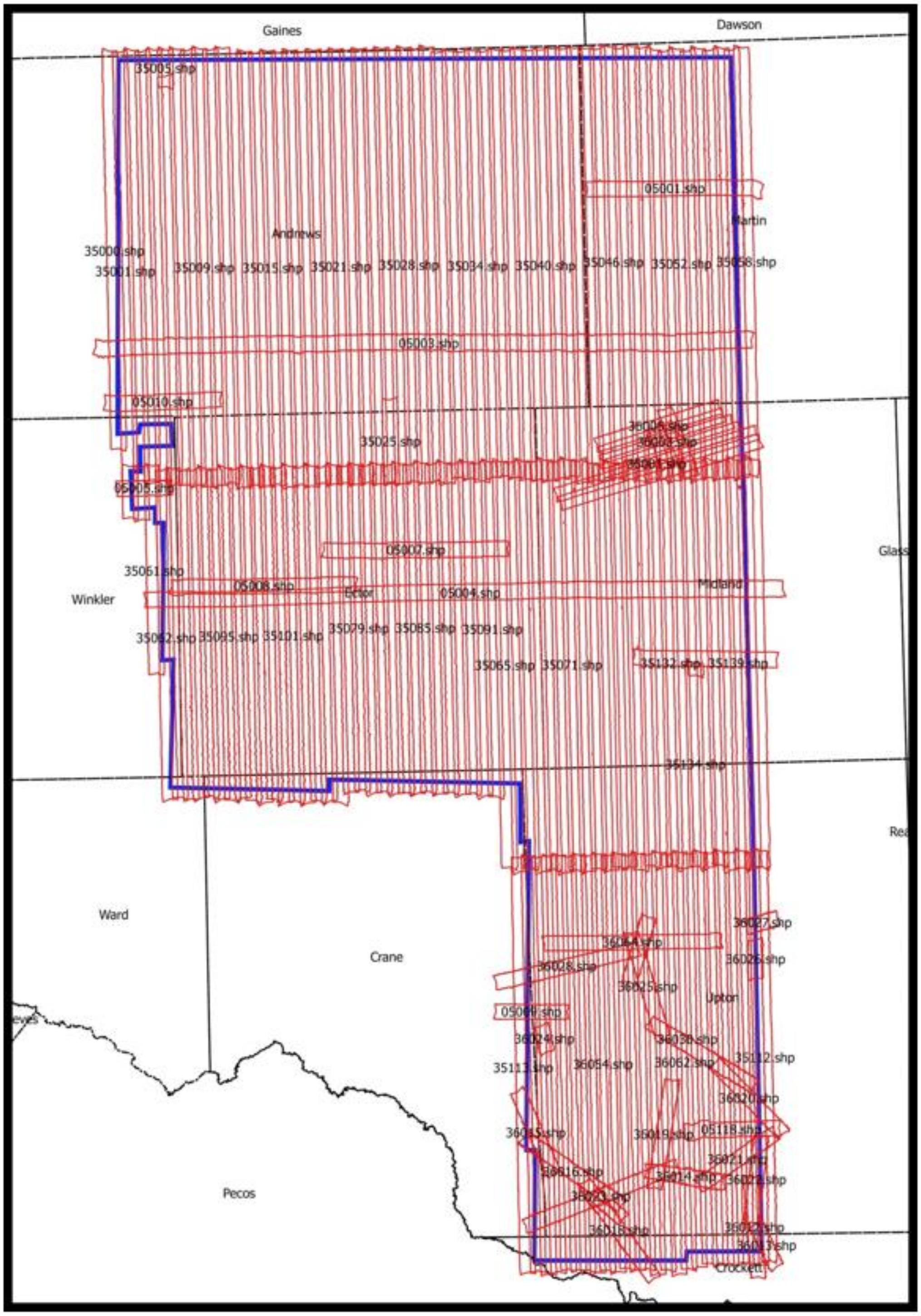


Figure 13 – Lidar swath output showing complete coverage of Block 04.

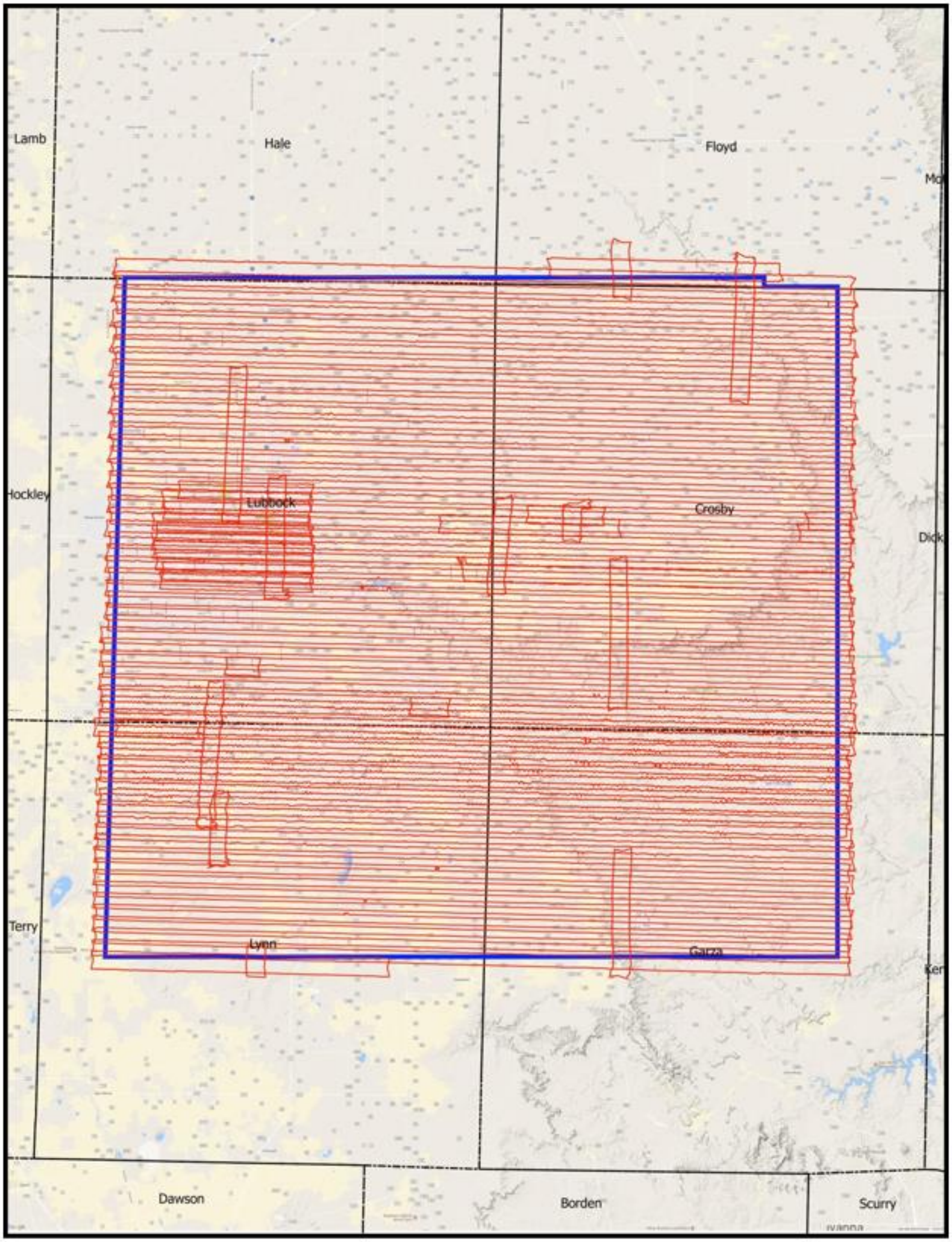


Figure 14 – Lidar swath output showing complete coverage of Block 05.

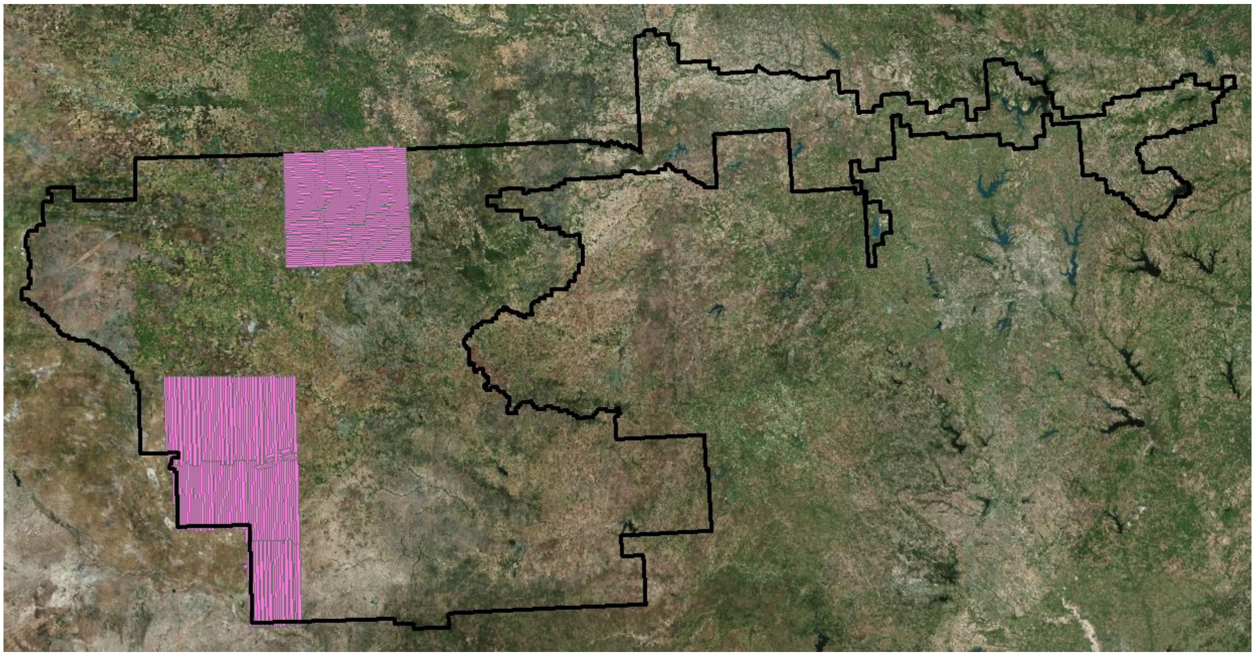


Figure 15 – Lidar swath output showing complete coverage for delivery blocks 04 and 05.

Boresight and Relative accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

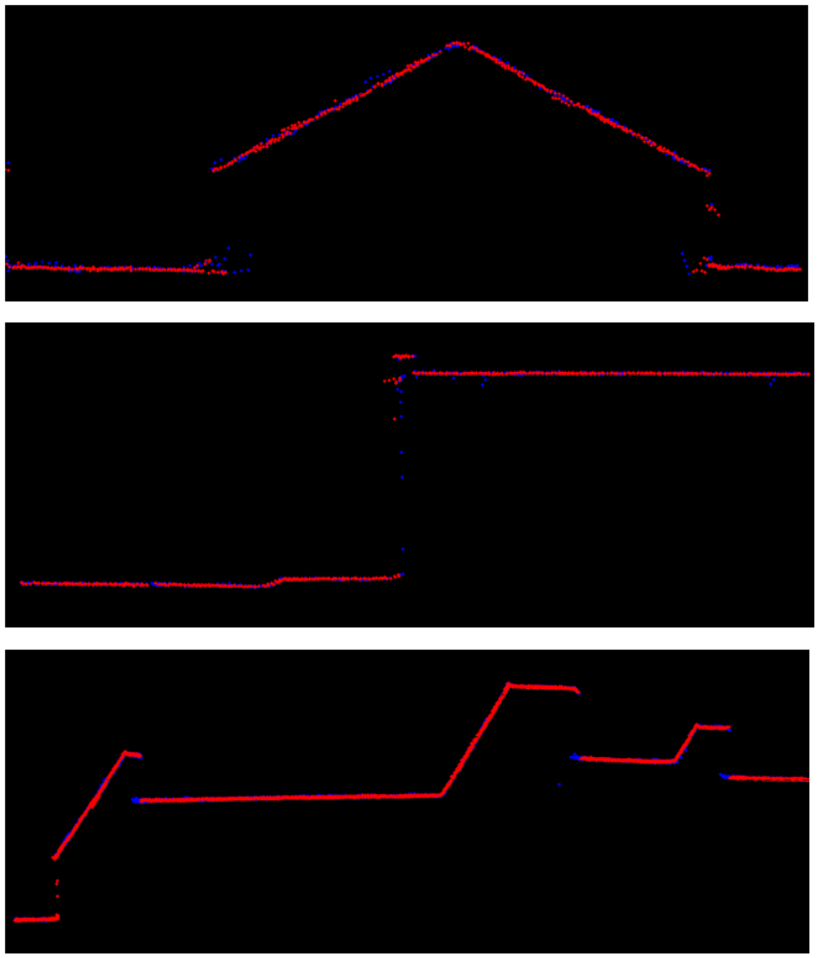


Figure 16 – Profile views showing correct roll and pitch adjustments.

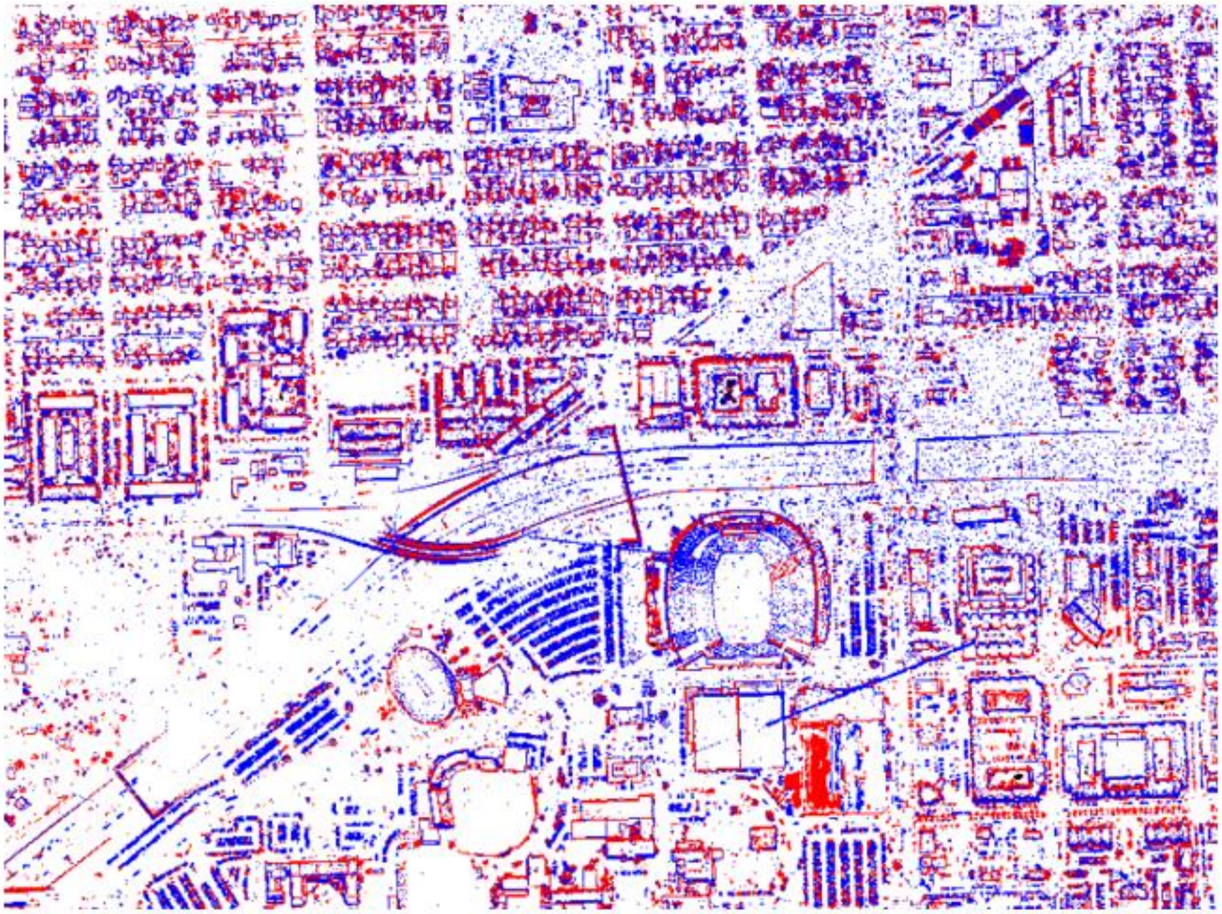


Figure 17 – QC block colored by distance to ensure accuracy at swath edges.

A different set of QC blocks are generated for final review after all transformations have been applied.

Preliminary Vertical Accuracy Assessment

Delivery Block 04

A preliminary $RMSE_z$ error check is performed by Axis Geospatial, LLC at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq 10$ cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated TX West Central Lidar dataset was tested to 0.114 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.058 m x 1.9600) when compared to 10 GPS static check points.

The following are the final statistics for the GPS static checkpoints used by Axis Geospatial, LLC to internally verify vertical accuracy.

Number	NAD83 (2011) UTM Zone 13N		NAVD88 (Geoid 12B)	Laser Z (M)	Delta Z
	Easting X (M)	Northing Y (M)	Known Z (M)		
AXG1	785429.823	3441396.799	711.624	711.64	0.016
AXG2	765181.588	3447019.832	742.686	742.67	-0.016
AXG3	781415.592	3473099.227	825.207	825.24	0.033
AXG4	757953.554	3487023.014	809.163	809.17	0.007
AXG5	783351.954	3512569.571	831.555	831.57	0.015
AXG6	748221.385	3510424.843	902.972	902.93	-0.042
AXG7	716983.479	3506247.2	877.593	877.61	0.017
AXG8	707816.305	3532064.987	974.587	974.65	0.063
AXG9	744778.7	3527940.104	891.989	891.96	-0.029
AXG10	781959.929	3534165.038	828.094	828.12	0.026
AXG11	712602.779	3540313.901	1010.84	1010.88	0.04
AXG12	736504.546	3544101.849	934.587	934.6	0.013
AXG13	772572.614	3544035.273	861.881	861.9	0.019
AXG14	704251.355	3556741.449	1008.25	1008.33	0.08
AXG15	750402.601	3561817.166	911.802	911.78	-0.022
AXG16	774674.288	3552826.924	857.942	857.96	0.018
AXG17	709492.84	3571532.104	1002.04	1002.08	0.042
AXG18	731975.104	3575358.694	967.802	967.76	-0.042
AXG19	759402.374	3573391	901.449	901.45	0.001
AXG20	779549.438	3575733.808	854.589	854.61	0.021
AXG21	708812.849	3584879.666	1004.3	1004.27	-0.029
AXG22	728649.539	3586326.699	973.651	973.55	-0.101
AXG23	766283.694	3579554.118	894.965	894.8	-0.165
AXG24	702280.105	3595115.707	1023.98	1024.11	0.134
AXG25	735043.699	3598713.253	954.517	954.49	-0.027
AXG26	774765.369	3596250.155	889.957	890.01	0.053
AXG27	780836.598	3498148.413	857.418	857.28	-0.138
AXG28	755476.253	3468798.377	859.636	859.61	-0.026
AXG29	759581.122	3539048.392	888.672	888.68	0.008
AXG30	738972.626	3558435.214	929.198	929.17	-0.028
AXG31	773046.502	3455812.098	810.387	810.38	-0.007

AXG32	766943.657	3499752.643	881.478	881.39	-0.088
AXG33	758201.136	3440103.379	701.622	701.64	0.018

Table 10 - Static GPS Points

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	33	0.058	0.114	-0.004	0.058	-0.165	0.134

Table 11 - Static GPS Vertical Accuracy Results for delivery block 04.

Overall the calibrated lidar data products collected by Axis Geospatial, LLC meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Axis Geospatial quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

Delivery Block 05

A preliminary $RMSE_z$ error check is performed by Axis Geospatial, LLC at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq 10$ cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated TX West Central Lidar dataset was tested to 0.099 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.051 m x 1.9600) when compared to 10 GPS static check points.

The following are the final statistics for the GPS static checkpoints used by Axis Geospatial, LLC to internally verify vertical accuracy.

Number	NAD83 (2011) UTM Zone 14N		NAVD88 (Geoid 12B)	Laser Z (M)	Delta Z
	Easting X (M)	Northing Y (M)	Known Z (M)		
GCP1	227621.642	3736900.108	1018.197	1018.19	-0.007
GCP2	245231.501	3737303.218	999.31	999.42	0.11
GCP3	259516.26	3737174.887	976.094	976.11	0.016
GCP4	278800.386	3735898.745	955.413	955.4	-0.013
GCP5	292376.207	3741559.789	871.471	871.64	0.169
GCP6	229164.411	3719277.881	988.8	988.81	0.01

GCP7	246479.966	3720367.287	962.744	962.7	-0.044
GCP8	260251.307	3720239.121	952.396	952.38	-0.016
GCP9	277878.484	3719599.564	935.945	935.92	-0.025
GCP10	292338.856	3719646.411	915.859	915.86	0.001
GCP11	228296.447	3704670.593	992.925	992.89	-0.035
GCP12	243274.362	3704316.31	959.607	959.58	-0.027
GCP13	259963.849	3708951.683	932.291	932.22	-0.071
GCP14	278021.847	3705096.694	847.641	847.67	0.029
GCP15	295396.518	3706613.436	809.64	809.67	0.03
GCP16	228953.74	3691311.673	986.872	986.83	-0.042
GCP17	245955.458	3690291.927	952.579	952.56	-0.019
GCP18	258752.7	3687750.599	916.101	916.17	0.069
GCP19	277241.879	3688730.113	768.868	768.82	-0.048
GCP20	290567.328	3689812.911	738.188	738.2	0.012
GCP21	228505.266	3673564.528	962.303	962.29	-0.013
GCP22	244772.878	3673018.12	935.099	935.1	0.001
GCP23	257952.802	3672742.729	903.686	903.69	0.004
GCP24	278041.981	3674385.097	793.94	793.89	-0.05
GCP25	291388.849	3676448.133	721.606	721.62	0.014

Table 12 - Static GPS Points

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	25	0.051	0.099	0.002	0.052	-0.071	0.169

Table 13 - Static GPS Vertical Accuracy Results for delivery Block 05.

Overall the calibrated lidar data products collected by Axis Geospatial, LLC meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Axis Geospatial quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

EAGLE MAPPING- DELIVERY BLOCK 06, 07, 08, AND 14

Lidar Acquisition Details

Eagle Mapping Inc. planned 346 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, Eagle Mapping Inc. followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Track" Air flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Eagle Mapping Inc. will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Eagle mapping Inc. monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Eagle Mapping Inc. accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Eagle Mapping Inc. closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Eagle Mapping Inc. lidar sensors are calibrated at a designated site located at the Chilliwack reginal Airport in Chilliwack BC, Canada and are periodically checked and adjusted to minimize corrections at project sites.

Lidar System parameters

A Riegl LMS-Q1560 dual-channel LiDAR system was used for acquisition of the LiDAR data. This system was installed in a Piper Navajo aircraft (Tail # N732JE) operated by Peregrine Aerial Surveys out of Abbotsford, BC. Table 14 illustrates Eagle Mapping Inc. system parameters for lidar acquisition on this project.

Item	Parameter
System	Riegl LMS-Q1560
Altitude (AGL meters)	2000
Approx. Flight Speed (knots)	150
Scanner Pulse Rate (kHz)	800
Scan Frequency (hz)	183
Pulse Duration of the Scanner (nanoseconds)	3
Pulse Width of the Scanner (m)	0.9
Swath width (m)	2217
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	<0.25
Nominal Swath Width on the Ground (m)	2217

Item	Parameter
Swath Overlap (%)	>25
Total Sensor Scan Angle (degree)	58
Computed Down Track spacing (m) per beam	0.77
Computed Cross Track Spacing (m) per beam	0.77
Nominal Pulse Spacing (single swath), (m)	0.77
Nominal Pulse Density (single swath) (ppsm), (m)	2
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.7
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2
Maximum Number of Returns per Pulse	15

Table 14: Eagle mapping Inc. lidar system parameters

Acquisition Status Report and Flightlines

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 18 shows the combined trajectory of the flightlines.

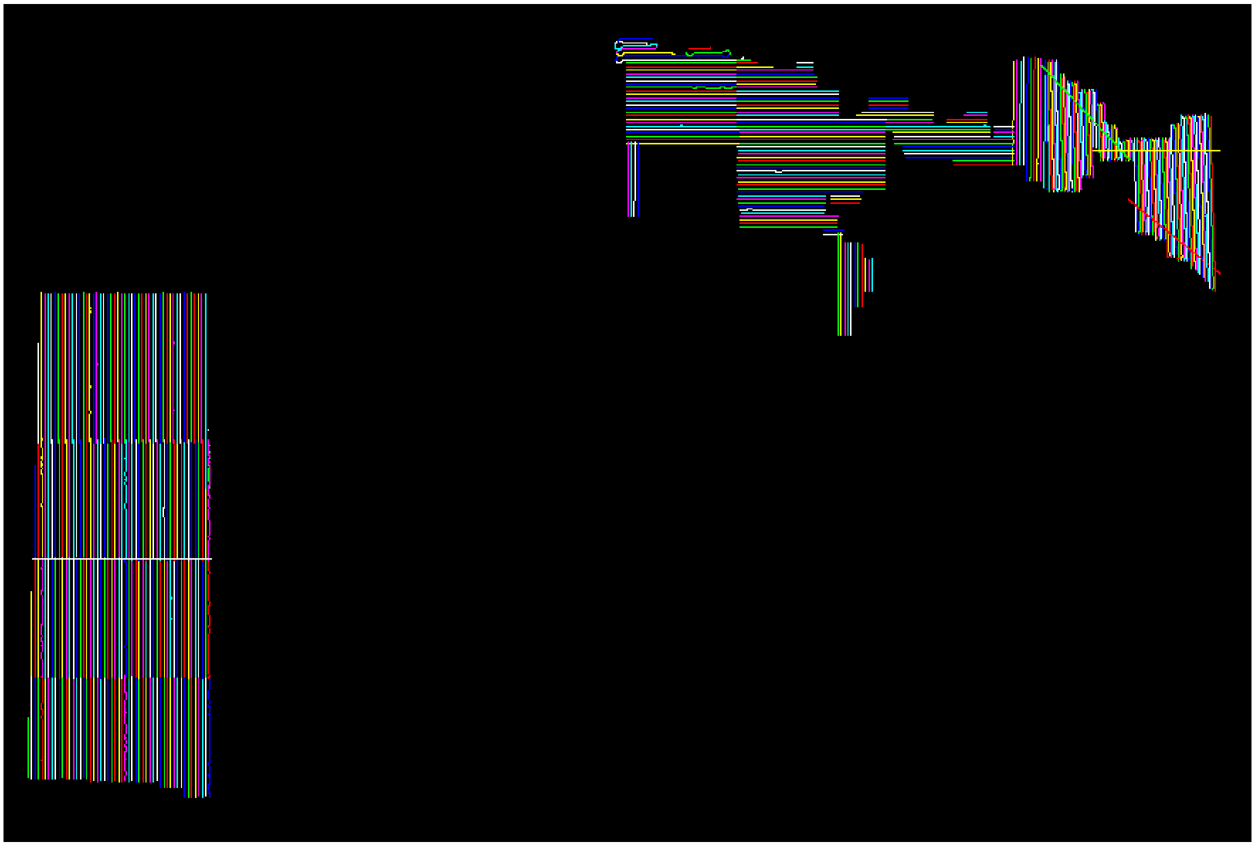


Figure 18: Trajectories as flown by Eagle Mapping Inc.

Delivery Block 06

Lidar Control

Eagle Mapping deployed static GPS base stations during the acquisition of the TX West Central project for Block 06. Considerations were made for location access and clear visibility of the horizon. Static sessions were recorded at 1 Hz samples for the highest quality post processed solution. These static base sessions were then incorporated during the kinematic post-processing of aircraft position. Additionally, CORS stations at 5 Hz were used to create an Applanix SmartBase for post-processing. This ensured that baseline length during acquisition was with the 35 mile specification required for this project. The coordinates of these base stations are provided in the table 15 below. All control and calibration points are also provided in shapefile format as part of the final deliverables.

Name	NAD83(2011) UTM 13		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
1000	763925	3537314	846.827
TXAD	731272	3577227	947.963
TXCE	751185	3479481	755.550
TXKM	678964	3524548	849.099
TXOE	754101	3529558	857.221

Name	NAD83(2011) UTM 14		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
2000	317476	3619761	711.772
TXLA	224201	3628668	892.759
TXLU	236008	3714265	957.122
TXMT	330763	3764965	709.029
TXP1	278113	3674044	768.729
TXSC	309742	3524640	680.437
TXSO	235168	3559537	802.648

Table 15 – Base stations used to control lidar acquisition for Block 06.

Airborne GPS Kinematic

Airborne GPS data was processed using the Applanix PosPAC v8.2 software suite and utilized a SmartBase trajectory solution. Flights were flown with a minimum of 7 satellites in view (12° above the horizon) and with a PDOP of better than 3. Distances from base station to aircraft were kept to a maximum of 35 miles.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix E.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Riegl's RiProcess, initially with default values from Riegl or the last mission calibrated for the system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

Figure 19 – Lidar swath output showing complete coverage for delivery Block 06.

Boresight and Relative accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 2 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

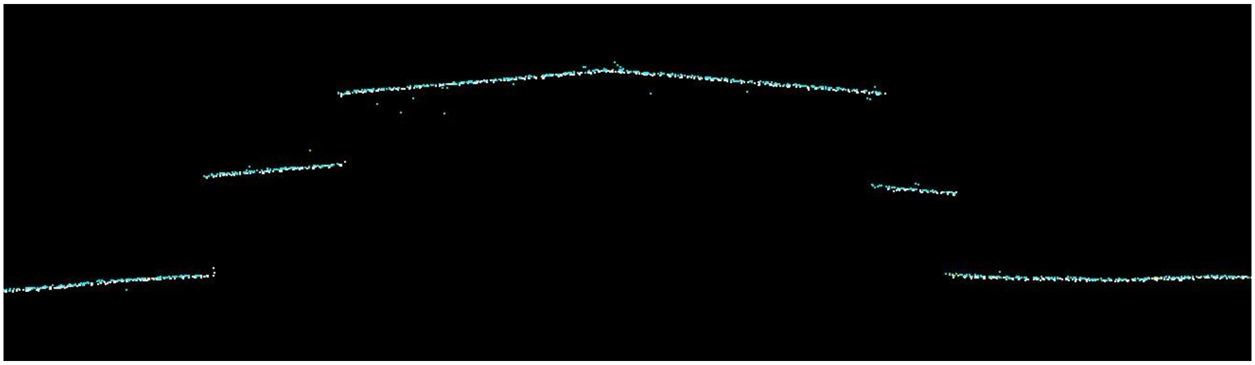


Figure 20 – Profile view showing correct roll and pitch adjustments.

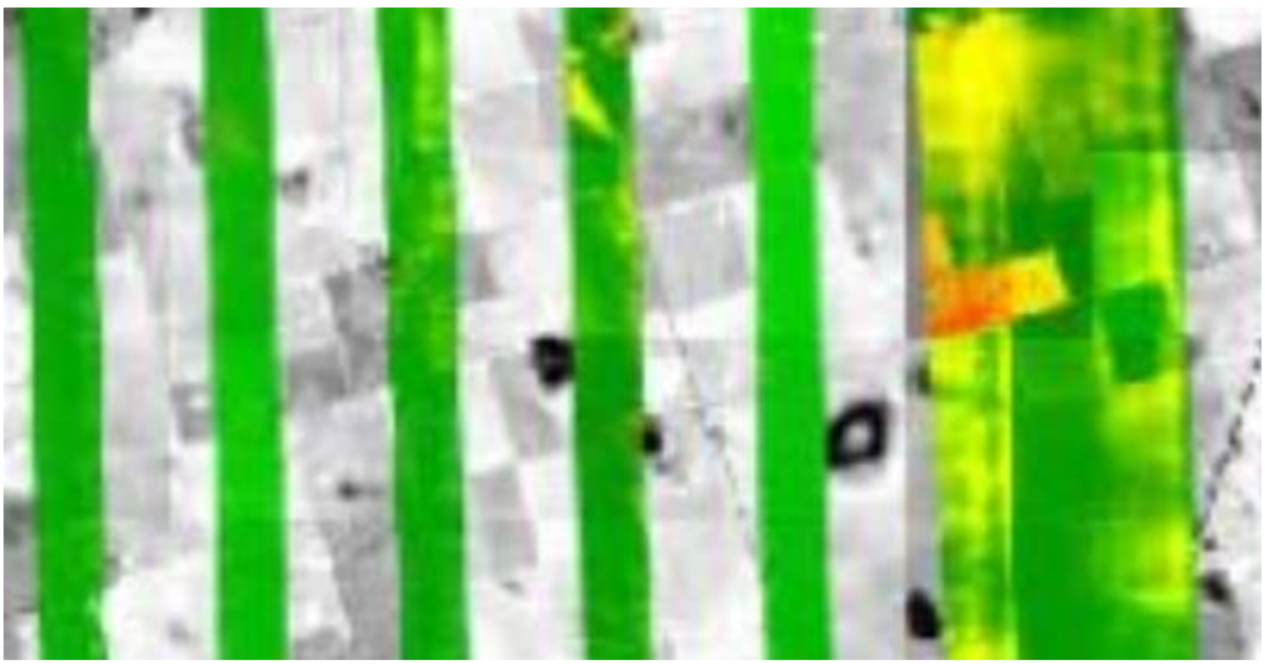


Figure 21 – QC block colored by distance to ensure accuracy at swath edges.

A different set of QC blocks are generated for final review after all transformations have been applied.

Preliminary Vertical Accuracy Assessment

A preliminary $RMSE_z$ error check is performed by Eagle Mapping Inc. at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq 10$ cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated TX West Central Lidar dataset was tested to 0.021 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.41 m x 1.9600) when compared to 21 GPS static check points.

The following are the final statistics for the GPS static checkpoints used by Eagle Mapping Inc. to internally verify vertical accuracy.

Number	NAD83(2011) UTM 14		NAVD88 (Geoid 12B)	Laser Z (m)	Delta Z
	Easting X (m)	Northing Y (m)	Known Z (m)		
GCP-21	228505.266	3673564.530	962.303	962.280	-0.023
GCP-22	244772.878	3673018.120	935.099	935.110	0.011
GCP-23	257952.802	3672742.730	903.686	903.780	0.094*
GCP-24	278041.981	3674385.097	793.940	outside**	N/A
GCP-25	291388.849	3676448.133	721.606	outside**	N/A
GCP-26	228001.548	3657484.530	942.753	942.750	-0.003
GCP-27	244316.163	3656852.960	916.523	916.530	0.007
GCP-28	275671.003	3657466.700	745.664	745.650	-0.014
GCP-29	293561.741	3659315.090	692.967	693.000	0.033
GCP-30	258142.259	3657882.570	879.664	879.690	0.026
GCP-31	230342.624	3641106.910	916.065	916.070	0.005
GCP-32	244575.171	3644392.650	912.528	912.540	0.012
GCP-33	255323.976	3640324.970	901.863	901.840	-0.023
GCP-34	274206.893	3638491.160	758.477	758.590	0.113*
GCP-35	290739.114	3639805.340	812.575	812.530	-0.045
GCP-36	229014.983	3625918.890	905.778	905.790	0.012
GCP-37	243983.907	3626101.780	890.061	890.020	-0.041
GCP-38	260121.407	3628562.610	793.477	793.480	0.003
GCP-39	275015.449	3628545.610	756.268	756.260	-0.008
GCP-40	292709.454	3625590.190	734.155	734.170	0.015
GCP-41	226713.245	3608873.430	871.399	871.380	-0.019
GCP-42	241052.92	3611029.840	872.986	872.980	-0.006
GCP-43	256847.161	3609606.550	775.726	775.730	0.004
GCP-44	291881.796	3612345.980	716.507	716.530	0.023
GCP-45	278456.438	3604645.660	749.731	749.760	0.029

**** GPSs 23 & 34 omitted from reporting as > 3-sigma outliers.**

***** GCPs 24 & 25 were located outside the project boundary and not covered by this Lidar collection.**

Table 16 - Static GPS Points

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	21	0.021	0.041	0.017	0.022	-0.045	0.033

Table 17 - Static GPS Vertical Accuracy Results for delivery block 6.

Delivery Block 07 and 08

Lidar Control

Eagle Mapping deployed static GPS base stations during the acquisition of the TX West Central project for Block 07 & 08. Considerations were made for location access and clear visibility of the horizon. Static sessions were recorded at 1 Hz samples for the highest quality post processed solution. These static base sessions were then incorporated during the kinematic post-processing of aircraft position. Additionally, CORS stations at 5 Hz were used to create an Applanix SmartBase for post-processing. This ensured that baseline length during acquisition was with the 35 mile specification required for this project. The coordinates of these base stations are provided in the table 18 below. All control and calibration points are also provided in shapefile format as part of the final deliverables.

Name	NAD83(2011) UTM 13		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
1000	763925	3537314	846.827
TXAD	731272	3577227	947.963
TXCE	751185	3479481	755.550
TXKM	678964	3524548	849.099
TXOE	754101	3529558	857.221
TXMC	763891	3447539	725.225
TXSN	749509	3338526	852.020

Name	NAD83(2011) UTM 14		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
2000	317476	3619761	711.772
TXLA	224201	3628668	892.759
TXP1	278113	3674044	768.729
TXSC	309742	3524640	680.437
TXSO	235168	3559537	802.648
TXAB	428907	3596472	489.758
TXOZ	289632	3401319	700.348
TXRL	361054	3530339	550.021
TXSA	359995	3476459	567.215

Table 18 – Base stations used to control lidar acquisition for Block 07 & 08.

Airborne GPS Kinematic

Airborne GPS data was processed using the Applanix PosPAC v8.2 software suite and utilized a SmartBase trajectory solution. Flights were flown with a minimum of 7 satellites in view (12° above the horizon) and with a PDOP of better than 3. Distances from base station to aircraft were kept to a maximum of 35 miles.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix E.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Riegl's RiProcess, initially with default values from Riegl or the last mission calibrated for the system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

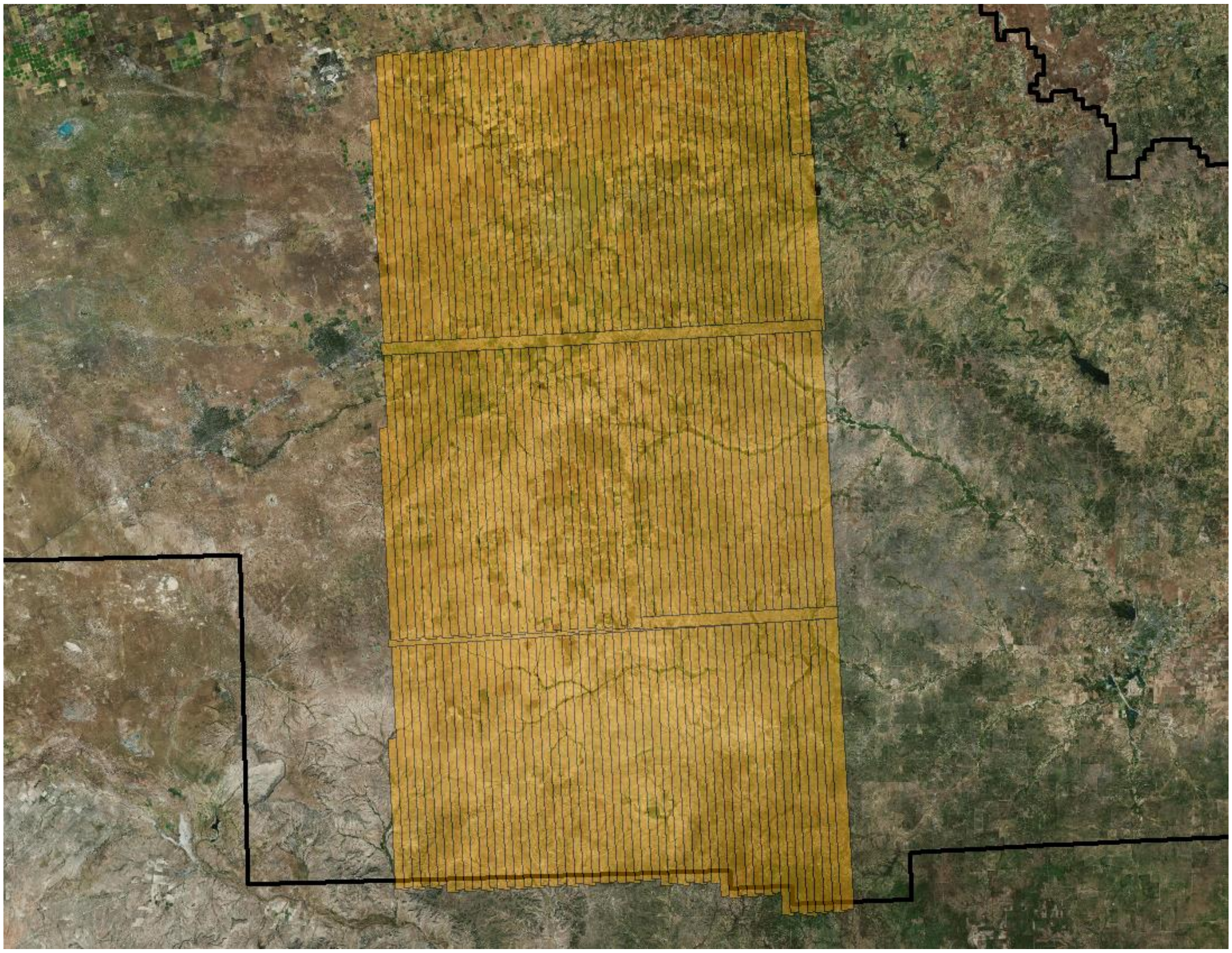


Figure 22 – Lidar swath output showing complete coverage for delivery Block 07 & 08.

Boresight and Relative accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 2 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

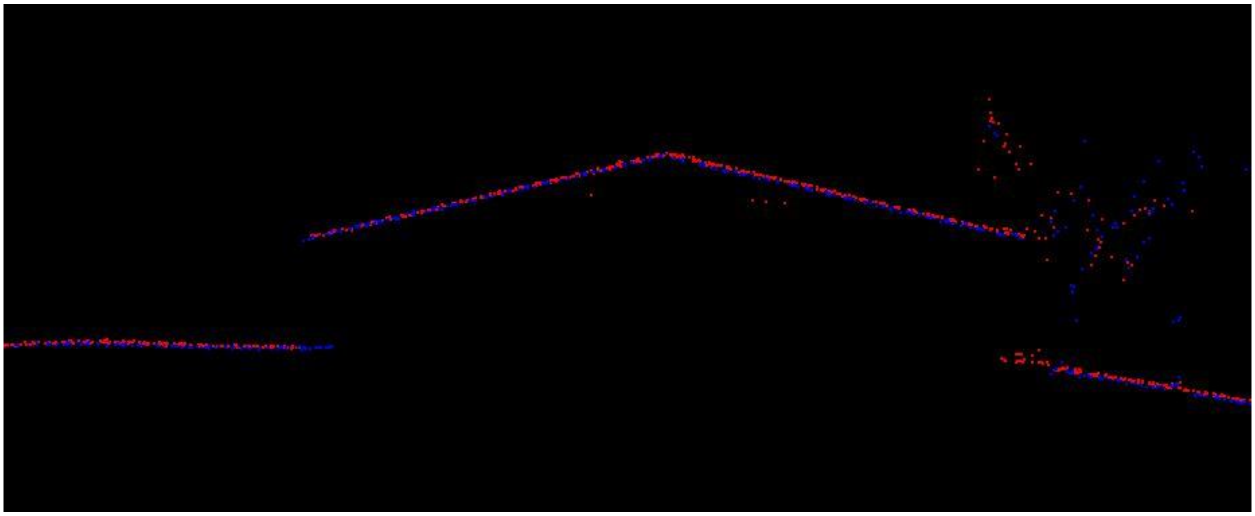


Figure 23 – Profile view showing correct roll and pitch adjustments.

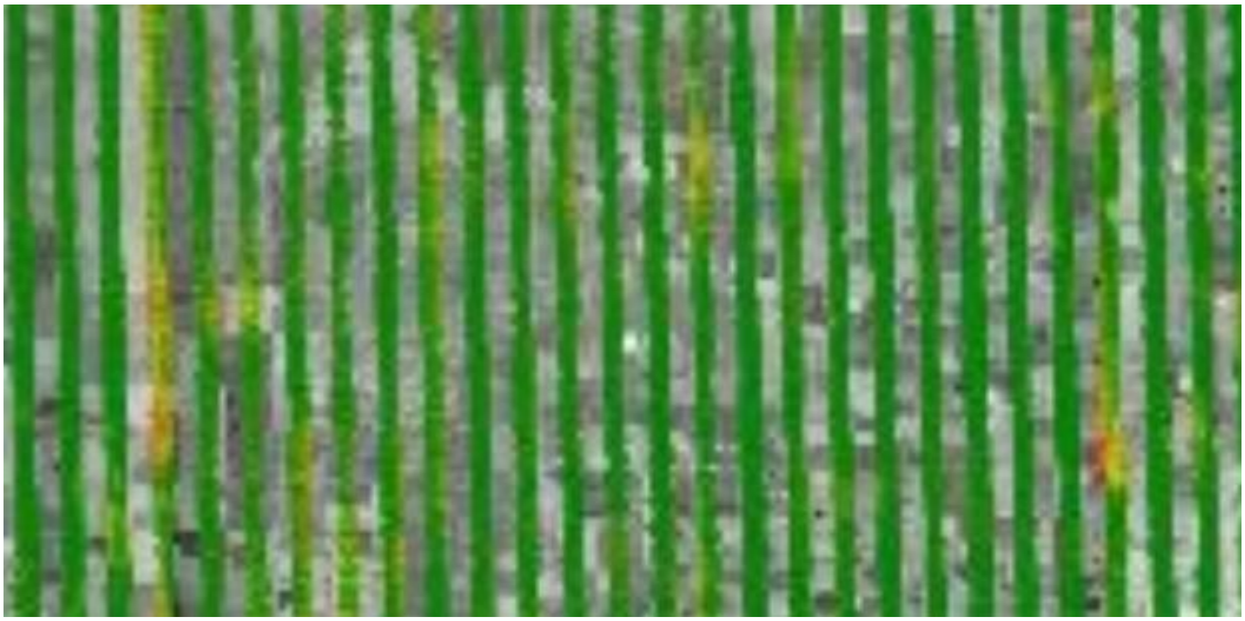


Figure 24 – QC block colored by distance to ensure accuracy at swath edges.

A different set of QC blocks are generated for final review after all transformations have been applied.

Preliminary Vertical Accuracy Assessment

A preliminary $RMSE_z$ error check is performed by Eagle Mapping Inc. at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks.

Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq 10$ cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated TX West Central Lidar dataset was tested to 0.074 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.38 m x 1.9600) when compared to 21 GPS static check points.

The following are the final statistics for the GPS static checkpoints used by Eagle Mapping Inc. to internally verify vertical accuracy.

Number	NAD83 (2011) UTM Zone 13N		NAVD88 (Geoid 12B)	Laser Z (M)	Delta Z
	Easting X (M)	Northing Y (M)	Known Z (M)		
EGM-1	299019.290	3598289.816	685.849	685.849	0.041
EGM-2	262838.153	3583143.209	812.737	812.680	-0.057
EGM-3	228844.084	3599436.977	846.335	846.330	-0.005
EGM-4	228873.357	3577734.598	865.573	865.560	-0.013
EGM-5	282871.619	3575452.014	732.985	732.970	-0.015
EGM-6	271083.994	3556245.303	840.400	840.370	-0.030
EGM-7	241731.773	3560208.172	785.437	785.410	-0.027
EGM-8	220070.329	3563950.892	843.323	843.310	-0.013
EGM-9	218055.061	3540671.736	836.863	836.890	0.027
EGM-10	243721.407	3531303.751	787.859	787.900	0.041
EGM-11	265057.055	3528313.174	813.284	813.220	-0.064
EGM-12	299934.959	3531709.963	732.138	732.070	-0.068
EGM-13	292332.706	3502154.274	804.091	803.950	-0.141**
EGM-14	264493.301	3498089.875	814.586	814.550	-0.036
EGM-15	243169.655	3492923.921	815.253	815.300	0.047
EGM-16	215591.981	3511238.614	839.906	839.300	0.044
EGM-17	221038.537	3486271.427	836.926	836.950	0.024
EGM-18	262578.501	3472128.750	797.483	797.490	0.007
EGM-19	276790.718	3465977.245	757.638	757.630	-0.008
EGM-20	298857.212	3471506.961	769.571	769.550	-0.021
EGM-21	299918.266	3449517.284	797.747	797.740	-0.007
EGM-22	264695.330	3440248.112	795.491	795.520	0.029
EGM-23	242528.397	3458323.634	821.625	821.580	-0.045
EGM-24	229605.401	3442958.570	815.055	815.100	0.045
EGM-25	214360.044	3454531.581	742.452	742.520	0.068

** EGM-13 omitted from reporting as a > 3-sigma outliers.

Table 19 - Static EGM Points

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	25	0.038	0.074	0.033	0.039	-0.068	0.068

Table 20 - Static GPS Vertical Accuracy Results for block 7 & 8.

Delivery Block 14

Lidar Control

CORS stations at 5 Hz were used to create an Applanix SmartBase for post-processing during the acquisition of the TX West Central project block 14. This ensured that baseline length during acquisition was with the 35 mile specification required for this project. The coordinates of these base stations are provided in the table below.

Name	NAD83(2011) UTM 14		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
OKAL	469813	3832312	401.595
OKAR	668743	3782349	236.923
OKDN	594900	3815787	315.460
OKLW	554125	3825825	314.702
TXDC	629631	3678337	256.452
TXJA	579638	3673210	327.216
TXNO	617961	3738010	259.433
TXOL	523289	3690783	332.944
TXQU	430523	3795614	455.215
TXVE	473891	3776930	352.771
TXTH	484348	3671140	373.060
TXWF	545740	3746069	281.316
OKAD	706907	3853233	293.274
TXDE	671230	3676122	179.961
TXSR	722066	3719438	195.513
TXWE	610208	3625171	338.556

Table 21 – Base stations used to control lidar acquisition for Block 14.

Airborne GPS Kinematic

Airborne GPS data was processed using the Applanix PosPAC v8.2 software suite and utilized a SmartBase trajectory solution. Flights were flown with a minimum of 7 satellites in view (12° above the horizon) and with a PDOP of better than 3. Distances from base station to aircraft were kept to a maximum of 35 miles.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix E.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Riegl's RiProcess software, with default values from Riegl or the last mission calibrated for the system. Data is then output in the proper projection and orthometric height and calibrated using BayesMap StripAlign software. This software uses a rigorous time-dependent approach to address effect such as IMU drifts and oscillations to correct both relative and absolute geometric errors. The missions with the new calibration values are regenerated and validated internally once again to ensure quality requirements are met.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

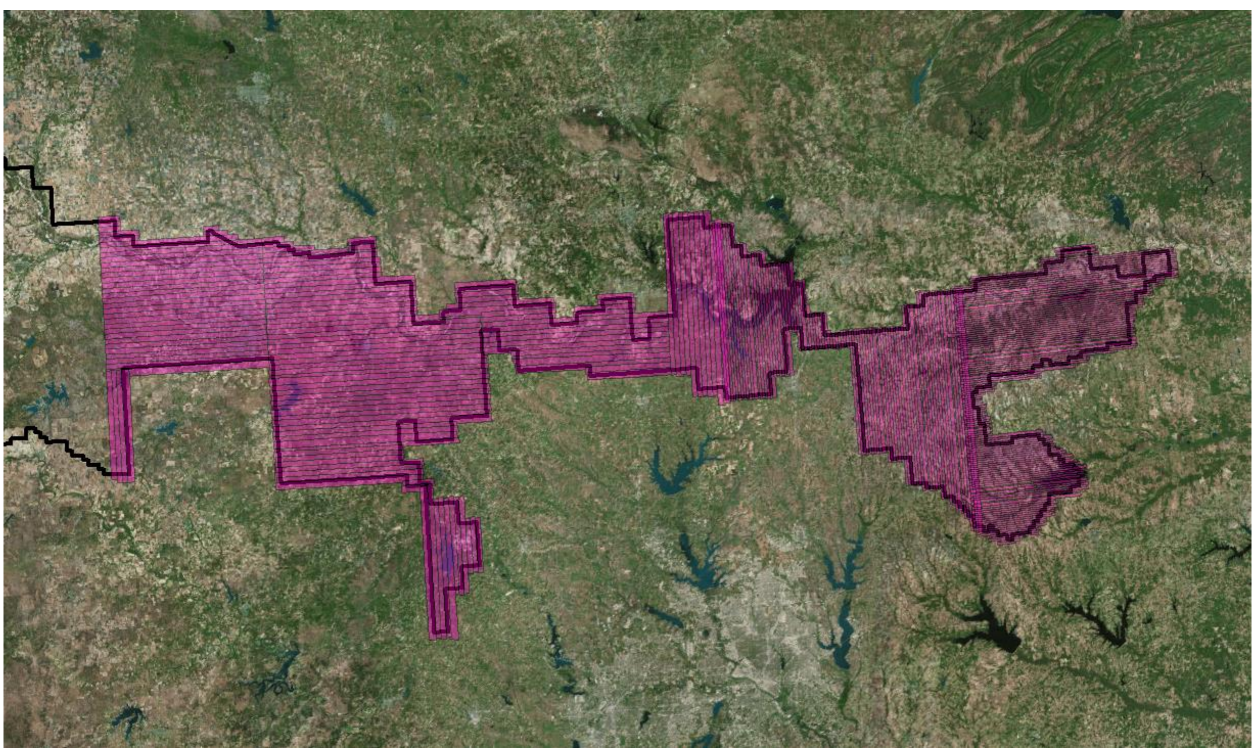


Figure 25 – Lidar swath output showing complete coverage for delivery Block 14

Boresight and Relative accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

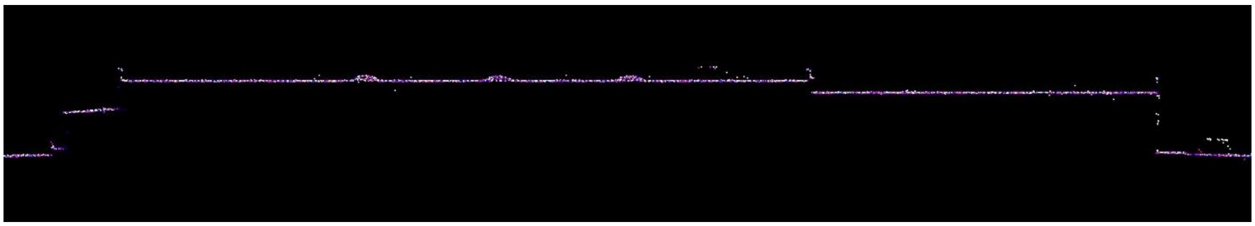


Figure 26 – Profile views showing correct roll and pitch adjustments.

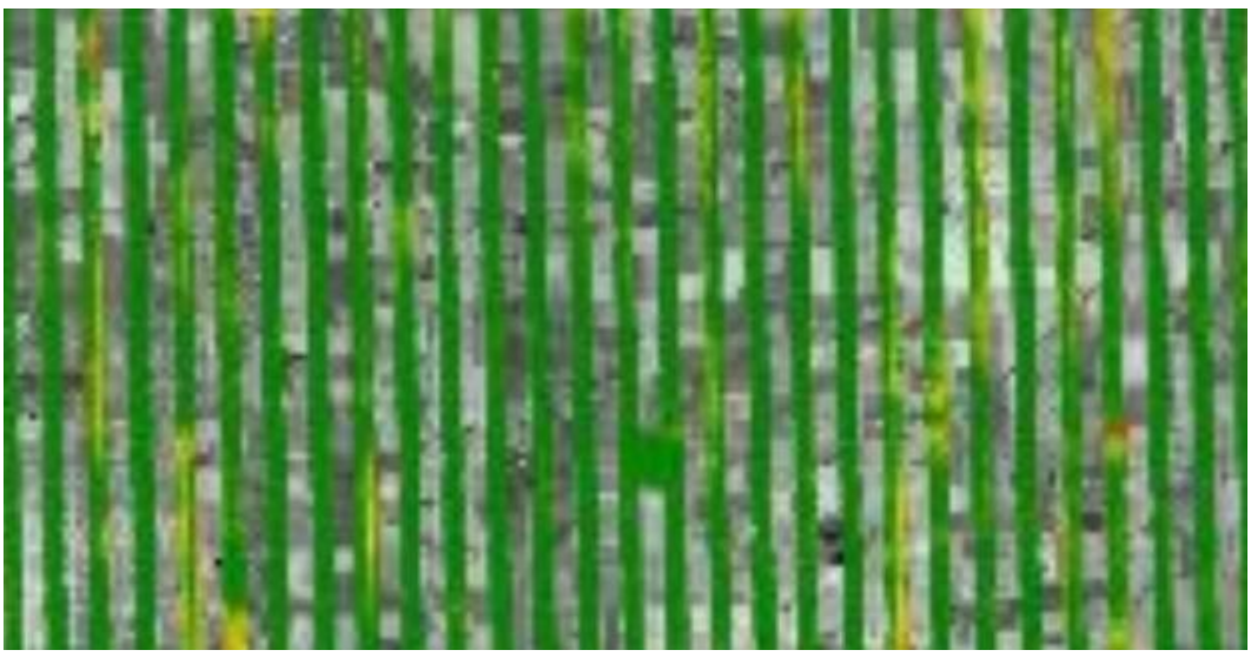


Figure 27 – QC block colored by distance to ensure accuracy at swath edges.

A different set of QC blocks are generated for final review after all transformations have been applied.

Preliminary Vertical Accuracy Assessment

A preliminary $RMSE_z$ error check is performed by Eagle Mapping Inc. at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq 10$ cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated TX West Central Lidar dataset was tested to 0.116 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.059 m x 1.9600) when compared to 45 GPS static check points.

The following are the final statistics for the GPS static checkpoints used by Eagle mapping inc. to internally verify vertical accuracy.

Number	NAD83 (2011) UTM Zone 14N		NAVD88 (Geoid 12B)	Laser Z (M)	Delta Z
	Easting X (M)	Northing Y (M)	Known Z (M)		
DAS-1	604378.514	3655501.727	325.900	325.780	-0.120
DAS-2	600455.917	3658085.694	309.147	309.030	-0.117
DAS-3	601472.839	3671032.926	264.794	264.720	-0.074
DAS-4	606065.164	3670901.306	255.952	255.870	-0.082
DAS-5	613718.113	3676151.781	244.731	244.650	-0.081
DAS-6	611983.872	3683637.950	286.674	286.620	-0.054
DAS-7	607066.893	3686264.559	274.513	274.440	-0.073
DAS-8	603848.847	3688340.379	293.066	292.870	-0.196**
DAS-9	601942.622	3692777.548	328.079	328.040	-0.039
DAS-10	650412.572	3736731.777	310.588	310.580	-0.008
DAS-11	599412.334	3699762.396	353.454	353.470	0.016
DAS-12	639811.317	3745442.329	271.049	271.090	0.041
DAS-13	648137.917	3740770.096	251.589	251.580	-0.009
DAS-14	672943.630	3736558.861	236.055	236.050	-0.005
DAS-15	638068.756	3741142.185	294.410	294.400	-0.010
DAS-16	598377.475	3742124.141	278.520	278.570	0.050
DAS-17	619573.616	3739453.983	294.957	295.080	0.123
DAS-18	601586.187	3726552.553	289.094	289.130	0.036
DAS-19	574169.683	3721866.863	297.495	297.610	0.115
DAS-20	693435.722	3726902.832	238.006	238.050	0.044
DAS-21	597372.077	3765682.738	285.311	285.380	0.069
DAS-22	570075.503	3765090.356	294.800	294.840	0.040
DAS-23	574338.834	3741741.831	281.130	281.200	0.070

DAS-24	507760.253	3772290.606	344.551	344.570	0.019
DAS-25	540727.546	3772363.374	313.042	313.020	-0.022
DAS-26	514940.549	3746400.256	311.172	311.200	0.028
DAS-27	521348.787	3759021.396	315.858	315.900	0.042
DAS-28	549242.188	3749701.835	299.092	299.140	0.048
DAS-29	501756.645	3728006.744	374.838	374.820	-0.018
DAS-30	590887.362	3721678.471	314.134	314.160	0.026
DAS-31	582186.254	3733880.209	290.522	291.460	+0.938***
DAS-32	574431.217	3711006.090	341.439	341.480	0.041
DAS-33	563280.004	3713068.670	316.447	316.520	0.073
DAS-34	563037.928	3732514.583	285.140	285.220	0.080
DAS-35	536693.631	3757265.742	306.916	306.960	0.044
DAS-36	557424.780	3765091.083	281.057	281.110	0.053
DAS-37	695702.890	3763878.863	229.202	229.240	0.038
DAS-38	686091.349	3762119.086	214.028	213.990	-0.038
DAS-39	671880.505	3741002.440	263.500	263.530	0.030
DAS-40	637744.863	3754598.587	234.370	234.290	-0.088
DAS-41	688454.449	3775173.586	256.021	256.050	0.029
DAS-42	523013.259	3772083.619	334.953	335.000	0.047
DAS-43	507597.809	3767016.498	364.221	364.210	-0.011
DAS-44	591328.287	3704203.139	309.205	309.260	0.055
DAS-45	696886.918	3741854.115	229.242	229.242	0.028

**** GCP 8 omitted from reporting as >3-sigma outlier**

***** GCP 31 did not have sufficient ground cover under vegetation to make an accurate assessment**

Table 22 - Static GPS Points

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	45	0.059	0.116	0.050	0.058	-0.120	0.123

Table 23 - Static GPS Vertical Accuracy Results for Block 14

Overall the calibrated lidar data products collected by Eagle Mapping Inc. meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Eagle mapping Inc. quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

LEADING EDGE GEOMATICS- DELIVERY BLOCK 09 THROUGH 13

Lidar Acquisition Details

Leading Edge Geomatics (LEG) planned 1,321 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, LEG followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Track Air flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, LEG will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

LEG monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. LEG accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, LEG closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

LEG lidar sensors are calibrated at a designated site located at a designated site located in downtown Fredericton, New Brunswick and are periodically checked and adjusted to minimize corrections at project sites.

Lidar System parameters

Leading Edge Geomatics (LEG) operated two different models of laser on three different aircraft for this project. Two Cessna 170 aircraft (UNB and CAU) were used to fly the Riegl VQ780i lasers, while a Cessna 206 aircraft (RBV) was used to fly the Riegl Q1560.

Table 24 illustrates LEG system parameters for lidar acquisition on this project.

Item	Parameter	Parameter
System	Riegl 780	Riegl 1560
Altitude (AGL meters)	1800	1600

Approx. Flight Speed (knots)	100	100
Scanner Pulse Rate (kHz)	280	700
Scan Frequency	68	80
Pulse Duration of the Scanner (nanoseconds)	5	5
Pulse Width of the Scanner (m)	1.5	.43
Swath width (m)	1996	1737
Central Wavelength of the Sensor Laser (nanometers)	1064	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes	Yes
Beam Divergence (milliradians)	0.25	0.25
Nominal Swath Width on the Ground (m)	1996	1737
Swath Overlap (%)	55	55
Total Sensor Scan Angle (degree)	60	57
Computed Down Track spacing (m) per beam	0.76	0.64
Computed Cross Track Spacing (m) per beam	0.76	0.64
Nominal Pulse Spacing (single swath), (m)	0.7	0.7
Nominal Pulse Density (single swath) (ppsm), (m)	2	2
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.7	0.7
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2	2
Maximum Number of Returns per Pulse	15	15

Table 24: LEG lidar system parameters

Acquisition Status Report and Flightlines

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 28 shows the combined trajectory of the flightlines.

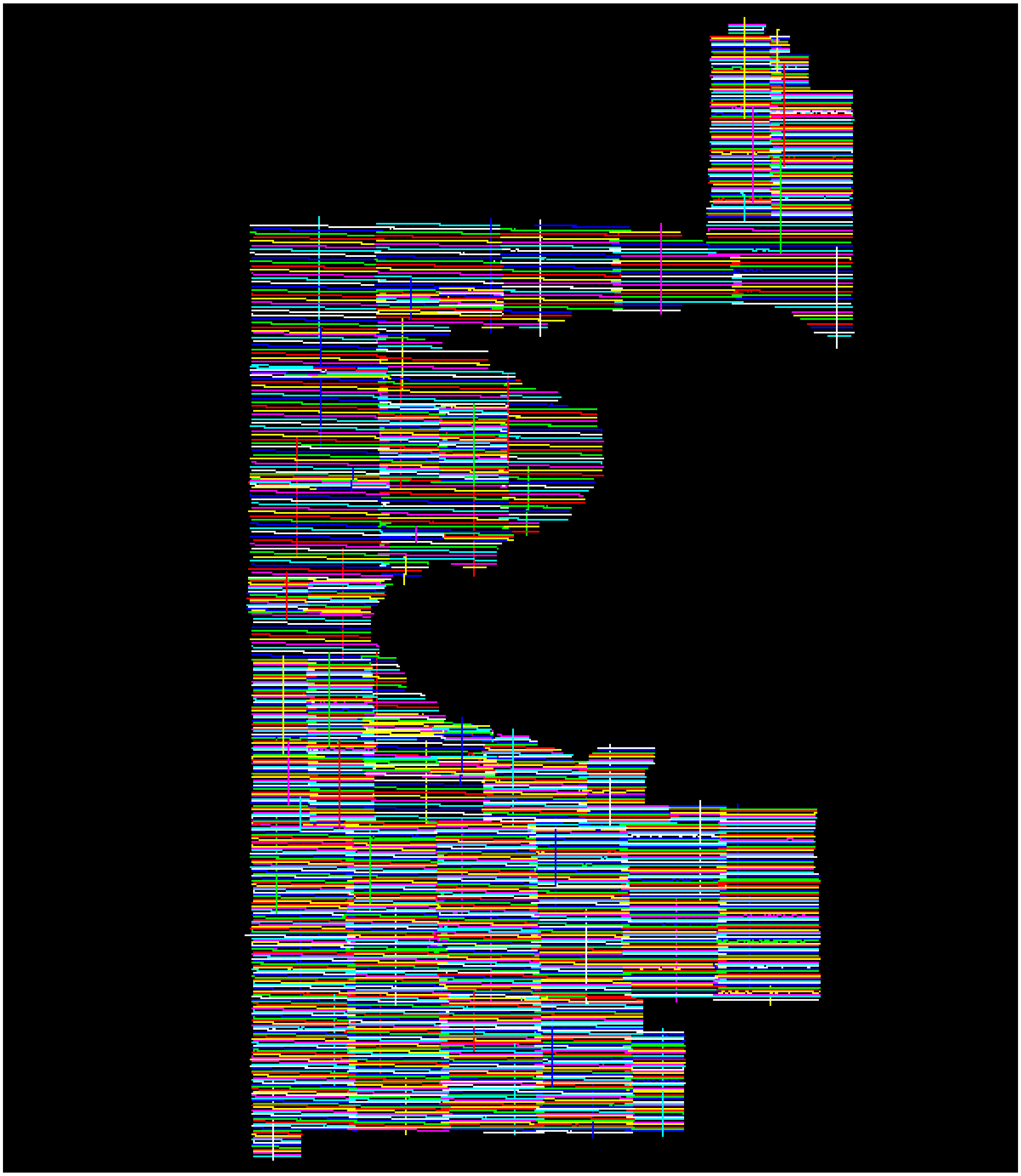


Figure 28- Trajectories as flown by LEG Inc.

Lidar Control

Fifty four base stations were employed by LEG for the collection. All stations coordinates were published in CORS (2011).The coordinates of all used base stations are provided in the table below. All control and calibration points are also provided in shapefile format as part of the final deliverables.

Network	Number	NAD83 (2011) UTM Zone 13N		NAVD88 (Geoid 12B)
		Easting X (M)	Northing Y (M)	Known Z (M)
NGS	TXAD	731272	3577227	947.962
NGS	TXOE	754101	3529558	857.221
Smartnet	TXML	770213	3538699	846.218
NGS	TXMC	763891	3447539	725.225
NGS	TXCE	751185	3479481	755.550

Network	Number	NAD83 (2011) UTM Zone 14N		NAVD88 (Geoid 12B)
		Easting X (M)	Northing Y (M)	Known Z (M)
NGS	TXAB	428907	3596472	489.758
NGS	TXB3	467966	3446221	504.665
NGS	TXBI	408323	3514323	501.912
NGS	TXC3	460050	3519432	499.494
NGS	TXCH	382591	3813858	565.075
NGS	TXEA	517969	3585096	408.658
NGS	TXEN	418086	3454021	608.350
NGS	TXGL	541041	3482013	461.050
NGS	TXLA	224201	3628668	892.759
NGS	TXLU	236008	3714265	957.122
NGS	TXME	359971	3843489	601.113
NGS	TXMT	330763	3764965	709.030
NGS	TXOL	523289	3690783	332.944
NGS	TXOZ	289632	3401319	700.349
NGS	TXP1	278113	3674044	768.729
NGS	TXPD	380920	3764270	534.287
NGS	TXQU	430523	3795614	455.215
NGS	TXRL	361054	3530339	550.021
NGS	TXSA	359995	3476459	567.214
NGS	TXSC	309742	3524640	680.437
NGS	TXSL	287472	3817154	976.803
NGS	TXSO	235168	3559537	802.648
NGS	TXSS	342357	3384337	637.021
NGS	TXSY	476024	3718105	368.469
NGS	TXTH	484348	3671140	373.060

NGS	TXVE	473891	3776930	352.771
NGS	TXWF	545740	3746069	281.316
NGS	TXWL	390105	3857038	589.207
NGS	OKAL	469813	3832312	401.595
NGS	OKAO	568751	3881776	340.446
NGS	OKCL	502589	3926625	470.693
NGS	OKLW	554125	3825825	314.702
NGS	OKSY	442034	3908161	567.147
LEG	LEG01	329241	3722493	763.198
LEG	LEG02	405070	3737174	482.608
LEG	LEG04	540716	3664401	308.812
LEG	LEG05	431775	3671507	460.844
LEG	LEG-HASKELL2	432974	3672799	460.902
LEG	LEG-STONE	388459	3669989	503.198
Smartnet	TXEY	505198	3511971	408.592
Smartnet	TXAL	431347	3590964	503.446
Smartnet	TXS8	363195	3482045	561.394
Smartnet	TXSI	311909	3524062	680.680
Smartnet	TXSD	320861	3620724	686.149
Smartnet	TXBG	264737	3574811	769.633
Smartnet	SMSW	368501	3593903	639.142
Smartnet	TXL2	223285	3626406	892.891
Smartnet	TXLB	232660	3712690	968.142
Smartnet	TXC0	501609	3584580	475.017

Table 25 – Base stations used to control lidar acquisition

Airborne GPS Kinematic

Airborne GPS data was processed using the PosPac kinematic On-The-Fly (OTF) software suite using Applanix Smartbase processing. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix F.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using either Riegl's RiProcess application or command-line versions of Riegl LiDAR processing software. System calibration was conducted prior to the aircraft departing for the project and the initial calibration values are used to position the point cloud.

As Leading Edge Geomatics was not tasked to perform calibration on the data, roll, pitch and yaw corrections were not applied. Checks were performed to verify that raw, uncalibrated LAS had height difference values within the expected range, and that no unusually large relative alignment errors were present.
Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

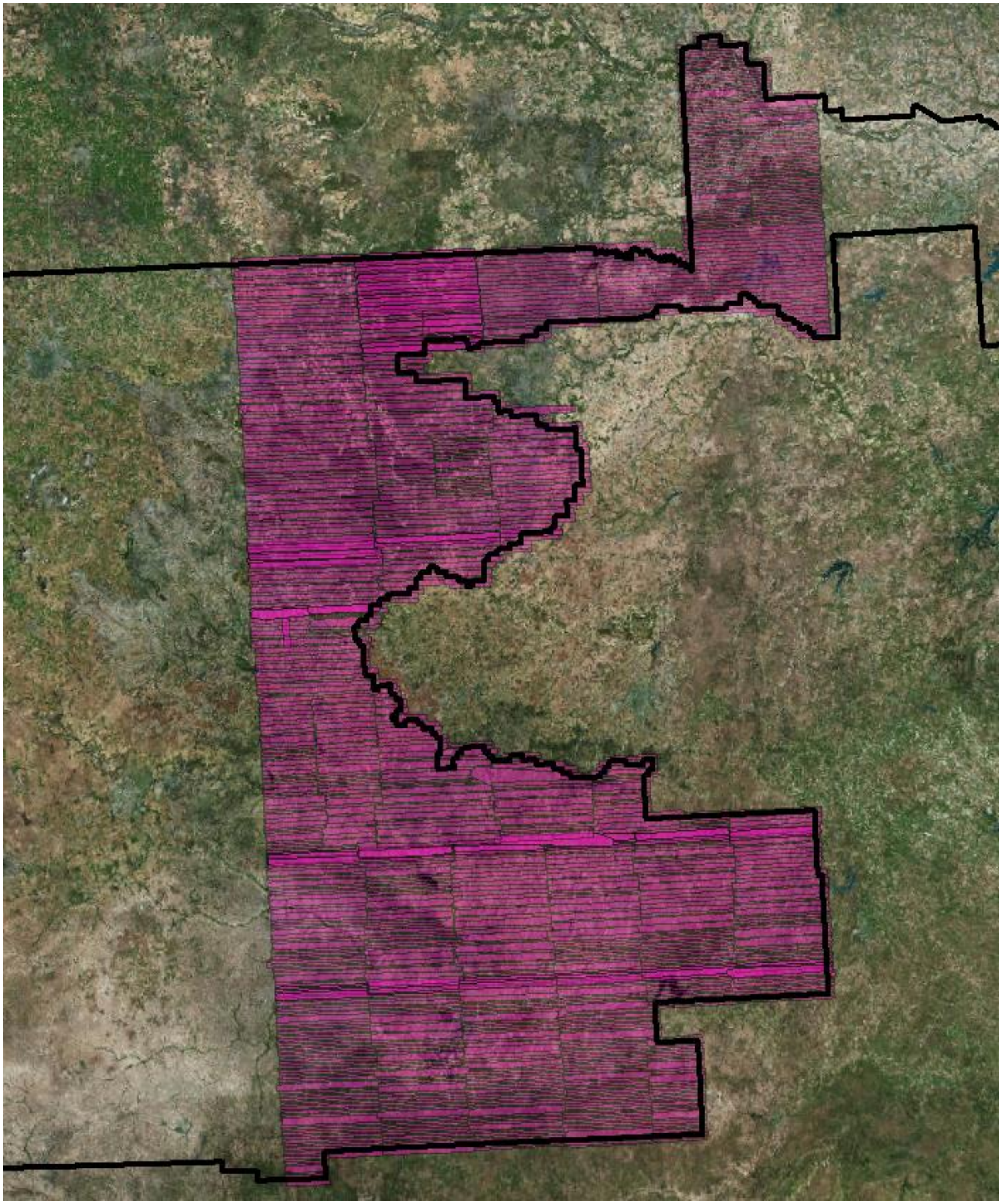


Figure 29 – Lidar swath output showing complete coverage.

Boresight and Relative accuracy

As described above, Leading Edge Geomatics was not tasked to perform a calibration on the collected data. However, checks were performed to verify that raw, uncalibrated LAS had height difference values within the expected range, and that no unusually large relative alignment errors were present.

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the LiDAR unit or GPS.

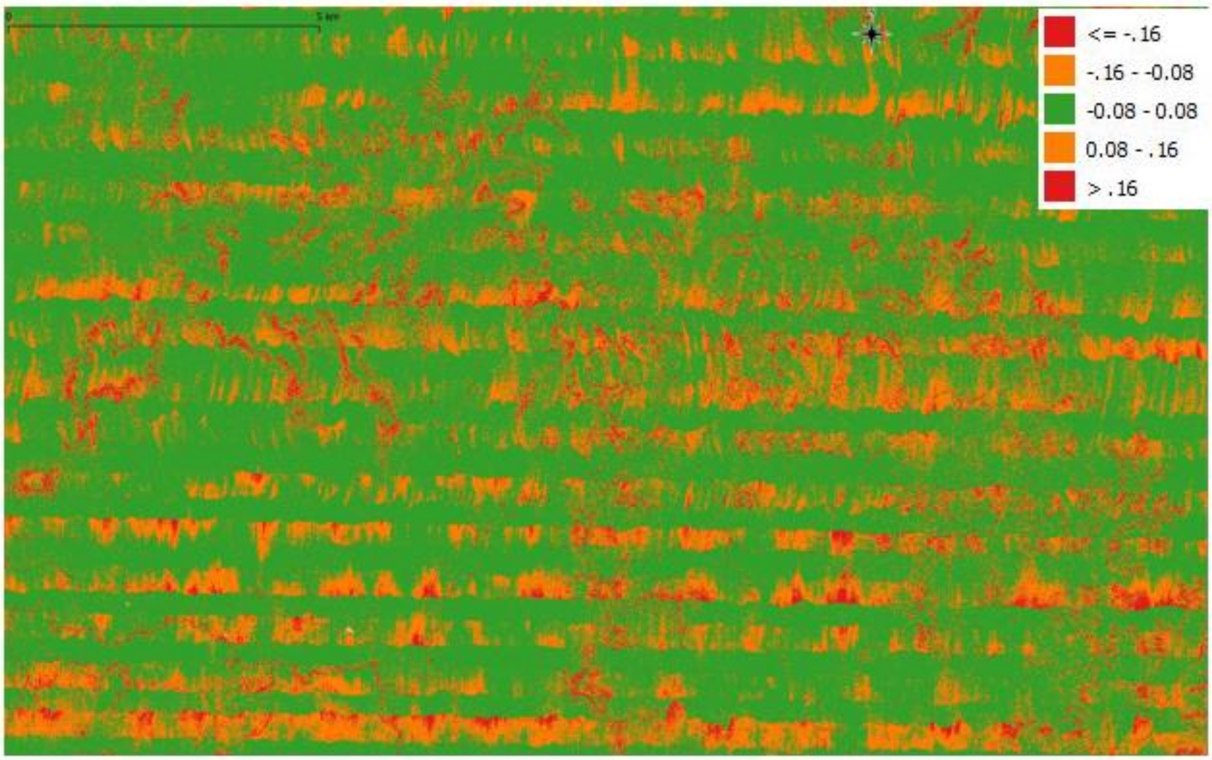


Figure 30 – QC block colored by separation demonstrating uncalibrated accuracy at swath edges (16cm max range).

Preliminary Vertical Accuracy Assessment

A preliminary $RMSE_z$ error check is performed by Dewberry at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \le 10$ cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated TX West Central dataset was tested to 0.079 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.051 m x 1.9600) when compared to 75 GPS static check points.

The following are the final statistics for the GPS static checkpoints used by Dewberry to internally verify vertical accuracy.

Number	NAD83 (2011) UTM Zone 14N		NAVD88 (Geoid 12B)	Laser Z (M)	Delta Z
	Easting X (M)	Northing Y (M)	Known Z (M)		
LEG-1	482725.053	3750790.860	366.346	366.370	0.024
LEG-2	473888.324	3780836.167	362.612	362.590	-0.022
LEG-3	469385.987	3814472.579	407.484	407.380	-0.104
LEG-4	455836.646	3765927.006	408.709	408.660	-0.049
LEG-5	499096.714	3770898.526	367.481	367.510	0.029
LEG-6	426854.553	3741802.040	420.292	420.330	0.038
LEG-7	421875.369	3735756.299	478.494	478.470	-0.024
LEG-8	462700.431	3729634.272	369.142	369.150	0.008
LEG-9	438268.586	3731720.106	456.797	456.790	-0.007
LEG-11	381866.002	3717196.569	530.773	530.790	0.017
LEG-12	376931.438	3744916.561	553.939	553.900	-0.039
LEG-13	341728.608	3735707.916	754.337	754.380	0.043
LEG-14	362474.465	3719519.488	580.578	580.550	-0.028
LEG-15	344398.971	3694283.330	644.016	644.070	0.054
LEG-16	383621.420	3694411.822	534.387	534.500	0.113
LEG-17	328655.710	3710977.146	707.442	707.450	0.008
LEG-18	305493.155	3729051.285	912.822	912.860	0.038
LEG-20	328883.204	3720314.618	759.482	759.510	0.028
LEG-21	336556.773	3672380.085	637.811	637.720	-0.091
LEG-22	300575.824	3676062.853	745.477	745.460	-0.017
LEG-23	304253.154	3705766.829	736.838	736.860	0.022
LEG-24	313340.782	3634343.609	766.476	766.380	-0.096
LEG-25	342734.456	3670060.457	612.818	612.870	0.052
LEG-26	337422.163	3599060.232	730.392	730.300	-0.092
LEG-27	360872.503	3644821.119	554.791	554.760	-0.031
LEG-28	369564.410	3675021.326	578.035	577.970	-0.065
LEG-29	373295.404	3658357.934	563.327	563.350	0.023
LEG-30	391415.845	3649545.716	538.937	538.940	0.003
LEG-31	401502.317	3667511.031	501.786	501.830	0.044
LEG-32	414949.543	3672512.707	515.821	515.760	-0.061

LEG-33	336693.223	3587360.195	682.568	682.500	-0.068
LEG-34	309090.271	3544519.249	756.526	756.510	-0.016
LEG-35	329457.133	3573146.281	653.927	653.960	0.033
LEG-36	303262.814	3558083.732	691.199	691.240	0.041
LEG-37	300994.492	3598922.313	670.005	670.100	0.095
LEG-38	352896.107	3543925.302	632.231	632.180	-0.051
LEG-39	378643.897	3544294.830	617.036	616.970	-0.066
LEG-40	378202.076	3570618.945	769.331	769.260	-0.071
LEG-41	410052.322	3543778.719	588.151	588.190	0.039
LEG-42	401840.713	3565819.303	744.291	744.280	-0.011
LEG-43	438032.594	3543379.615	604.445	604.470	0.025
LEG-44	429205.471	3564037.252	603.107	603.120	0.013
LEG-45	420015.970	3556537.190	625.701	625.820	0.119
LEG-45	420015.970	3556537.190	625.701	625.760	0.059
LEG-46	457545.253	3521475.627	559.508	559.440	-0.068
LEG-47	487216.179	3545137.140	482.945	483.040	0.095
LEG-48	466971.627	3500709.075	463.064	463.080	0.016
LEG-49	487345.558	3485110.417	426.141	426.110	-0.031
LEG-50	457966.740	3491401.838	474.653	474.630	-0.023
LEG-51	447977.118	3505000.943	548.915	548.930	0.015
LEG-52	425406.793	3488602.187	490.850	490.920	0.070
LEG-53	424134.424	3517971.640	541.854	541.870	0.016
LEG-54	409257.358	3528346.468	545.144	545.120	-0.024
LEG-55	412839.695	3484572.983	501.086	501.090	0.004
LEG-56	393946.175	3502774.549	528.337	528.350	0.013
LEG-57	361947.285	3530941.392	581.033	580.980	-0.053
LEG-58	378226.732	3512542.590	571.760	571.760	0.000
LEG-59	363074.483	3484377.766	576.307	576.340	0.033
LEG-60	336466.313	3506756.363	657.647	657.680	0.033
LEG-61	331039.100	3531182.939	785.836	785.900	0.064
LEG-62	306701.218	3528614.593	729.277	729.230	-0.047
LEG-63	301190.750	3484596.311	775.397	775.440	0.043
LEG-64	331647.670	3466689.691	642.851	642.920	0.069
LEG-65	306535.248	3450554.960	765.773	765.760	-0.013
LEG-66	326460.907	3457470.028	678.975	679.040	0.065
LEG-67	355776.503	3440764.412	653.135	653.150	0.015
LEG-68	363283.628	3468635.433	586.140	586.140	0.000

LEG-69	394767.811	3474358.572	551.975	551.990	0.015
LEG-70	371652.440	3440376.233	712.134	712.200	0.066
LEG-71	421657.409	3439260.472	661.790	661.740	-0.050
LEG-72	426344.763	3455313.243	609.203	609.140	-0.063
LEG-73	417442.459	3469116.557	576.035	575.950	-0.085
LEG-74	442881.166	3453852.398	572.785	572.770	-0.015
LEG-75	428102.549	3472239.996	502.750	502.770	0.020

Table 26- Static GPS Points

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	74	0.051	0.079	0.002	0.051	-0.104	0.119

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	74	0.051	0.079	0.002	0.051	-0.104	0.119

Table 27 - Static GPS Vertical Accuracy Results

Overall the calibrated lidar data products collected by Leading Edge Geomatics (LEG) meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Leading Edge Geomatics (LEG) quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

AERIAL SERVICES INC- DELIVERY BLOCK 15, UTM14

Lidar Acquisition Details

Aerial Services, Inc. planned 95 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, Aerial Services, Inc. followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using LEICA MISSION PRO flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.

- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Aerial Services, Inc. will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Aerial Services, Inc. monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Aerial Services, Inc. accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Aerial Services, Inc. closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Aerial Services, Inc. lidar sensors are calibrated at a designated site located at the Waverly Municipal Airport in Waverly, Iowa and are periodically checked and adjusted to minimize corrections at project sites.

Lidar System parameters

Aerial Services, Inc. operated a Piper Navajo PA-31 (Tail # N35AS) outfitted with a LEICA ALS70-HP lidar system during the collection of the study area. Table 28 illustrates Aerial Services, Inc. system parameters for lidar acquisition on this project.

Item	Parameter
System	Leica ALS-70 HP
Altitude (AGL meters)	1400
Approx. Flight Speed (knots)	150
Scanner Pulse Rate (kHz)	379.8
Scan Frequency (hz)	47
Pulse Duration of the Scanner (nanoseconds)	9
Pulse Width of the Scanner (m)	2.7
Swath width (m)	1300
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	0.22
Nominal Swath Width on the Ground (m)	1300
Swath Overlap (%)	30
Total Sensor Scan Angle (degree)	50
Computed Down Track spacing (m) per beam	1.6
Computed Cross Track Spacing (m) per beam	0.9
Nominal Pulse Spacing (single swath), (m)	0.7
Nominal Pulse Density (single swath) (ppsm), (m)	2

Item	Parameter
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.7
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2
Maximum Number of Returns per Pulse	4

Table 28: Aerial Services, Inc. lidar system parameters

Acquisition Status Report and Flightlines

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 31 shows the combined trajectory of the flightlines.

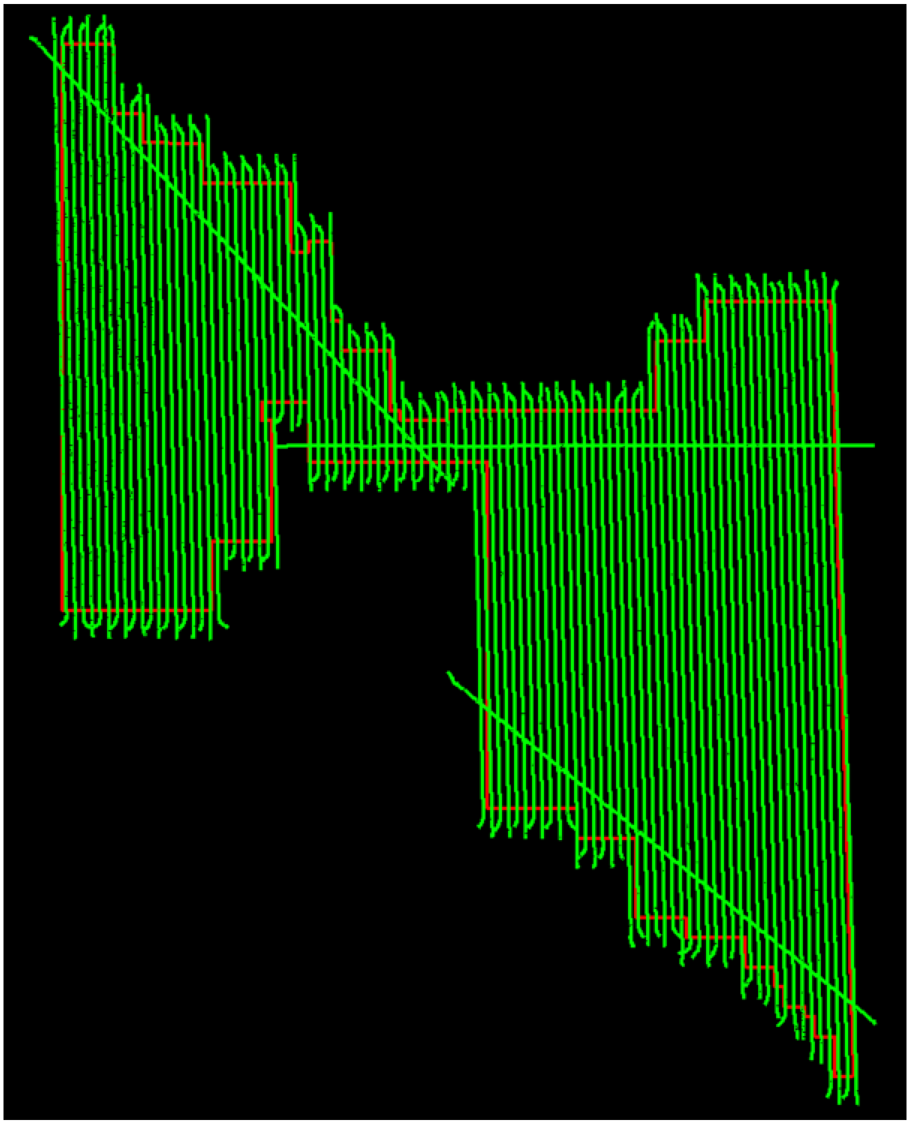


Figure 31: Trajectories as flown by Aerial Services, Inc.

Lidar Control

Aerial Services, Inc. conducted the survey which provided the established base stations that were used to control the lidar acquisition for the TX West Central area. The coordinates of the base station are provided in the table below.

Name	NAD83(2011) UTM 16		Ellipsoid Ht (NAD83(2011), m)	Orthometric Ht (NAVD88 Geoid12B, m)
	Easting X (m)	Northing Y (m)		
Perrin	8710059.844	8122083.676	199.487	226.457

Table 29 – Base stations used to control lidar acquisition

Airborne GPS Kinematic

Airborne GPS data was processed using the NovAtel Inertial Explorer software suite. Flights were flown with a PDOP of better than 2.3 (the instance of 2.6 was after data collection on the way back to the airport). Distances from base station to aircraft were kept to a maximum of 90 km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix G.

Generation and Calibration of Laser Points (raw data)

After processing the GNSS/GPS and IMU data in Inertial Explorer, the data is then exported to raw LAS files using Leica's CloudPro software. CloudPro combines the raw data collected with the ALS 70 HP sensor, combines it with the Airborne trajectory data, applies the sensor's calculated boresite correction angles, and then outputs the point cloud to the specified coordinate reference system and file format.

The initial step of calibration is to verify the complete coverage of the AOI with the 100 meter buffer with no internal voids present, as well as ensuring that minimum point density of 2.5 ppsm has been achieved.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

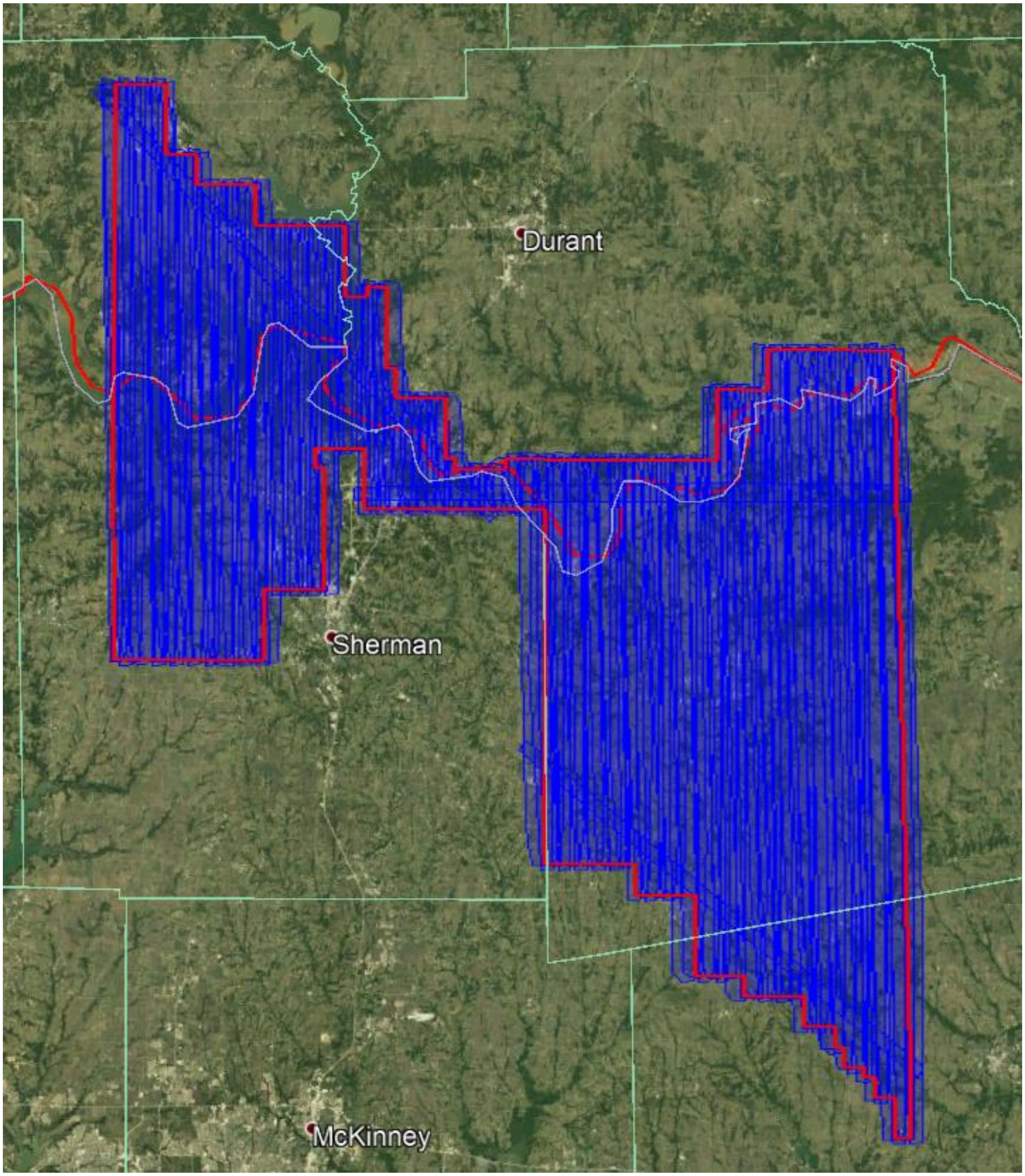


Figure 32 – Lidar swath output showing complete coverage.

Boresight and Relative accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

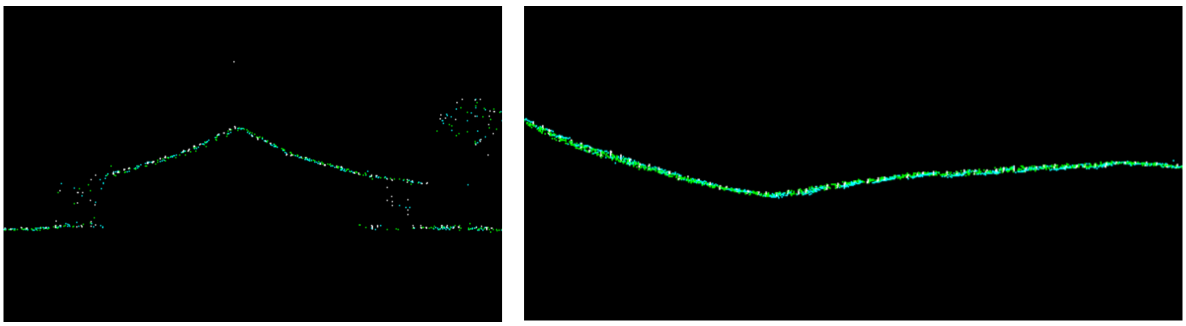


Figure 33 – Profile views showing correct roll and pitch adjustments.

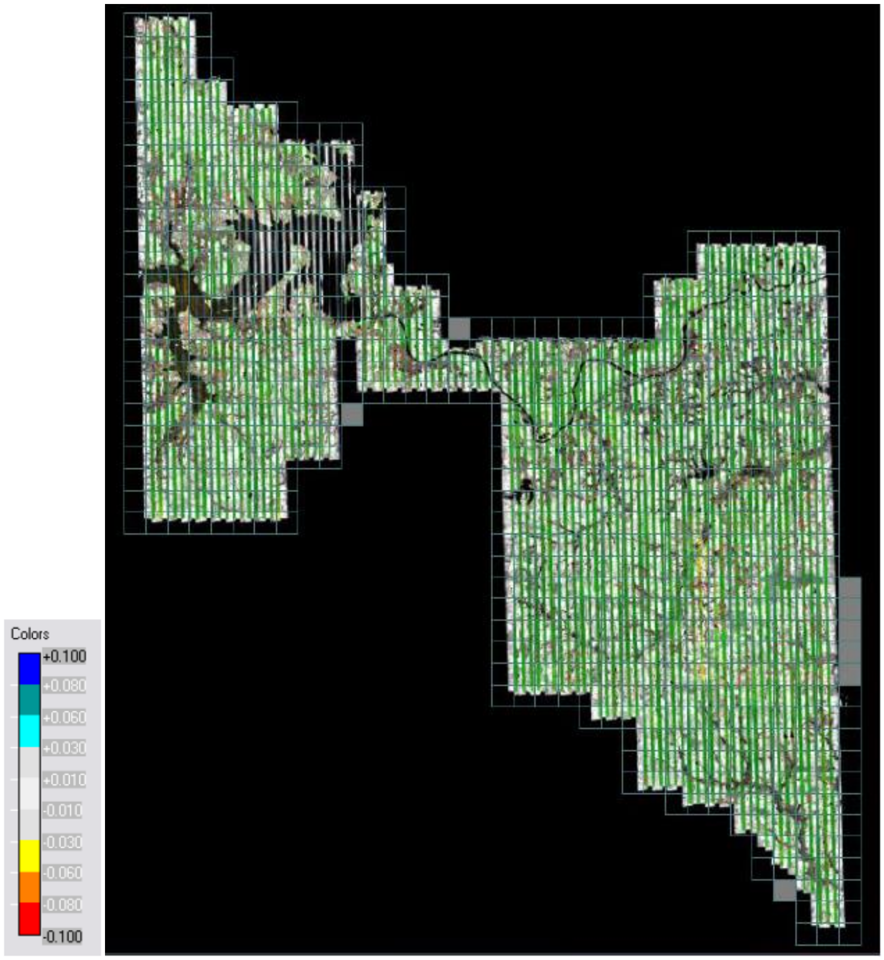


Figure 34 – QC block colored by distance to ensure accuracy at swath edges.

A different set of QC blocks are generated for final review after all transformations have been applied.

Preliminary Vertical Accuracy Assessment

A preliminary $RMSE_z$ error check is performed by Aerial Services, Inc. at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq 10$ cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints.

The following are the final statistics for the GPS static checkpoints used by Aerial Services, Inc. to internally verify vertical accuracy.

Number	NAD83(2011) UTM 14	NAVD88 (Geoid 12B)	Laser Z (m)	Delta Z

	Easting X (m)	Northing Y (m)	Known Z (m)		
ASI-01	713750.142	3722442.031	261.740	261.780	-0.04
ASI-02	700945.721	3724045.507	230.877	230.840	0.037
ASI-03	708275.869	3727959.062	221.388	221.440	-0.052
ASI-04	720494.556	3729233.929	248.286	248.240	0.046
ASI-05	715934.698	3738317.459	228.102	228.070	0.032
ASI-06	704670.691	3736146.265	196.347	196.360	-0.013
ASI-07	722600.326	3743701.658	219.421	219.320	0.101
ASI-08	717421.436	3752623.272	209.719	209.710	0.009
ASI-09	710425.349	3743597.810	235.533	235.540	-0.007
ASI-10	701788.705	3747829.892	216.613	216.630	-0.017
ASI-11	711295.109	3750338.671	200.247	200.250	-0.003
ASI-12	705422.185	3752926.847	216.990	216.970	0.02
ASI-13	703303.698	3762917.137	249.274	249.240	0.034
ASI-14	713889.679	3756497.773	200.896	200.870	0.026
ASI-15	711065.198	3764194.360	245.028	245.080	-0.052
ASI-16	703839.252	3772387.886	254.792	254.700	0.092
ASI-17	700511.447	3778207.900	280.597	280.480	0.117
ASI-18	722942.448	3764628.868	196.140	196.110	0.03
ASI-19	726733.155	3758256.383	194.560	194.540	0.02
ASI-20	725453.261	3738261.896	236.393	236.400	-0.007
ASI-21	728641.794	3746116.833	176.743	176.710	0.033
ASI-22	735785.000	3738453.524	189.109	189.060	0.049
ASI-23	742737.506	3738466.732	176.613	176.580	0.033
ASI-24	759855.932	3737974.100	161.206	161.240	-0.034
ASI-25	755694.819	3729280.697	183.379	183.420	-0.041
ASI-26	748968.723	3729599.335	167.257	167.260	-0.003
ASI-27	761299.415	3747788.267	155.283	155.380	-0.097
ASI-28	765521.138	3751883.694	158.842	158.820	0.022
ASI-29	776131.585	3738341.653	155.905	155.920	-0.015
ASI-30	776676.151	3752803.366	139.848	139.890	-0.042
ASI-31	769168.130	3740411.482	181.850	181.820	0.03
ASI-32	744329.184	3720933.722	205.659	205.590	0.069
ASI-33	760216.395	3721942.682	193.039	193.060	-0.021
ASI-34	768592.204	3729944.625	178.652	178.630	0.022
ASI-35	772986.665	3722304.139	190.108	190.020	0.088
ASI-36	752812.383	3713625.374	222.192	222.150	0.042
ASI-37	770853.830	3716652.159	199.413	199.440	-0.027
ASI-38	742890.361	3711165.381	230.569	230.540	0.029
ASI-39	763170.751	3711416.544	195.587	195.650	-0.063
ASI-40	751376.020	3705090.664	207.289	207.220	0.069
ASI-41	746324.156	3702095.654	230.258	230.290	-0.032
ASI-42	758441.626	3698988.659	217.210	217.130	0.08
ASI-43	766871.683	3701426.755	205.289	205.360	-0.071
ASI-44	772995.755	3696235.942	206.591	206.620	-0.029
ASI-45	777779.318	3683970.446	168.760	168.810	-0.05
ASI-46	779633.762	3675290.844	169.073	169.160	-0.087

ASI-47	770727.848	3687307.166	191.524	191.510	0.014
ASI-48	763944.011	3689427.607	205.389	205.430	-0.041
ASI-49	751232.458	3741890.144	188.603	188.550	0.053

Table 30 - Static GPS Points

Overall the calibrated lidar data products collected by Aerial Services, Inc. meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Aerial Services, Inc. quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

INTERMAP- DELIVERY BLOCK 15, UTM15

Lidar Acquisition Details

Intermap planned 140 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, Intermap followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Teledyne Optec flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Intermap will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Intermap monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Intermap accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Intermap closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Lidar System parameters

Intermap operated a Navajo aircraft; 1969 Piper Piper-PA31 outfitted with an ALTM Galaxy lidar system during the collection of the study area. Table 31 illustrates Intermap system parameters for lidar acquisition on this project.

Item	Parameter
System	Leica ALS-70 HP
Altitude (AGL meters)	1600
Approx. Flight Speed (knots)	145
Scanner Pulse Rate (kHz)	300
Scan Frequency (hz)	42.3
Pulse Duration of the Scanner (nanoseconds)	4
Pulse Width of the Scanner (m)	1.05
Swath width (m)	978
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	0.25
Nominal Swath Width on the Ground (m)	978
Swath Overlap (%)	30
Total Sensor Scan Angle (degree)	34
Computed Down Track spacing (m) per beam	0.57
Computed Cross Track Spacing (m) per beam	0.57
Nominal Pulse Spacing (single swath), (m)	0.7
Nominal Pulse Density (single swath) (ppsm), (m)	2
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.7
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2
Maximum Number of Returns per Pulse	4

Table 31: Intermap lidar system parameters

Acquisition Status Report and Flightlines

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 35 shows the combined trajectory of the flightlines.

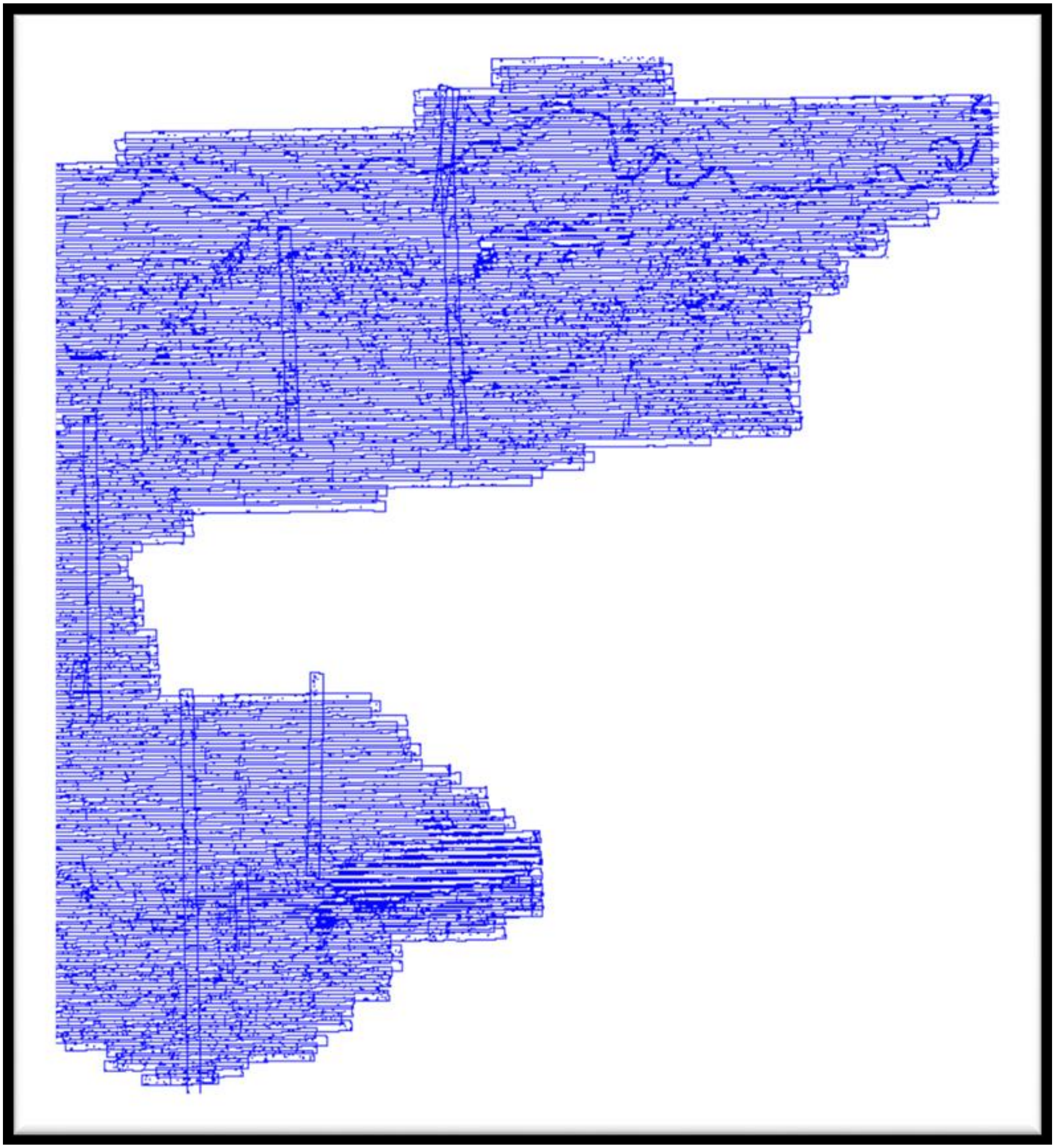


Figure 35: Trajectories as flown by Intermap

Lidar Control

Six existing NGS monuments were used to control the lidar acquisition for the Texas West Central lidar project area. The coordinates of all used base stations are provided in the table below. All control and calibration points are also provided in shapefile format as part of the final deliverables.

Name	NAD83(2011) UTM 14		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
TXBN	762090	3722129	161.789
TXGE	774699	3669776	136.166

Name	NAD83(2011) UTM 15		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
OKAN	258448	3786906	141.568
TXCR	307788	3720941	106.315
TXMV	292875	3671424	133.766
TXPA	262937	3728970	146.327

Table 32 – Base stations used to control lidar acquisition

Airborne GPS Kinematic

Airborne GPS data was processed using the Applanix PosPAC MMS 8.2 kinematic On-The-Fly (OTF) software suite. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 3.6. Distances from base station to aircraft were kept to a maximum of 27.2 miles.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 4 cm average or better but no larger than 15 cm being recorded.

GPS processing reports for each mission are included in Appendix H.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Intermap processed Lidar points using Lidar Mapping Suite (LMS) from Teledyne Optech; Version 5.3, initially with default values from Optech. Then the calibration points received from Dewberry were used. The initial point generation for each flight calibration was verified within Lidar Mapping Suite (LMS) and Global Mapper Lidar Module for calibration errors. If calibration errors greater than the project specification was observed within the flight, the roll, pitch and scanner scale corrections were re-calculated and applied. The flights with the new calibration values were regenerated and underwent additional internally quality control.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

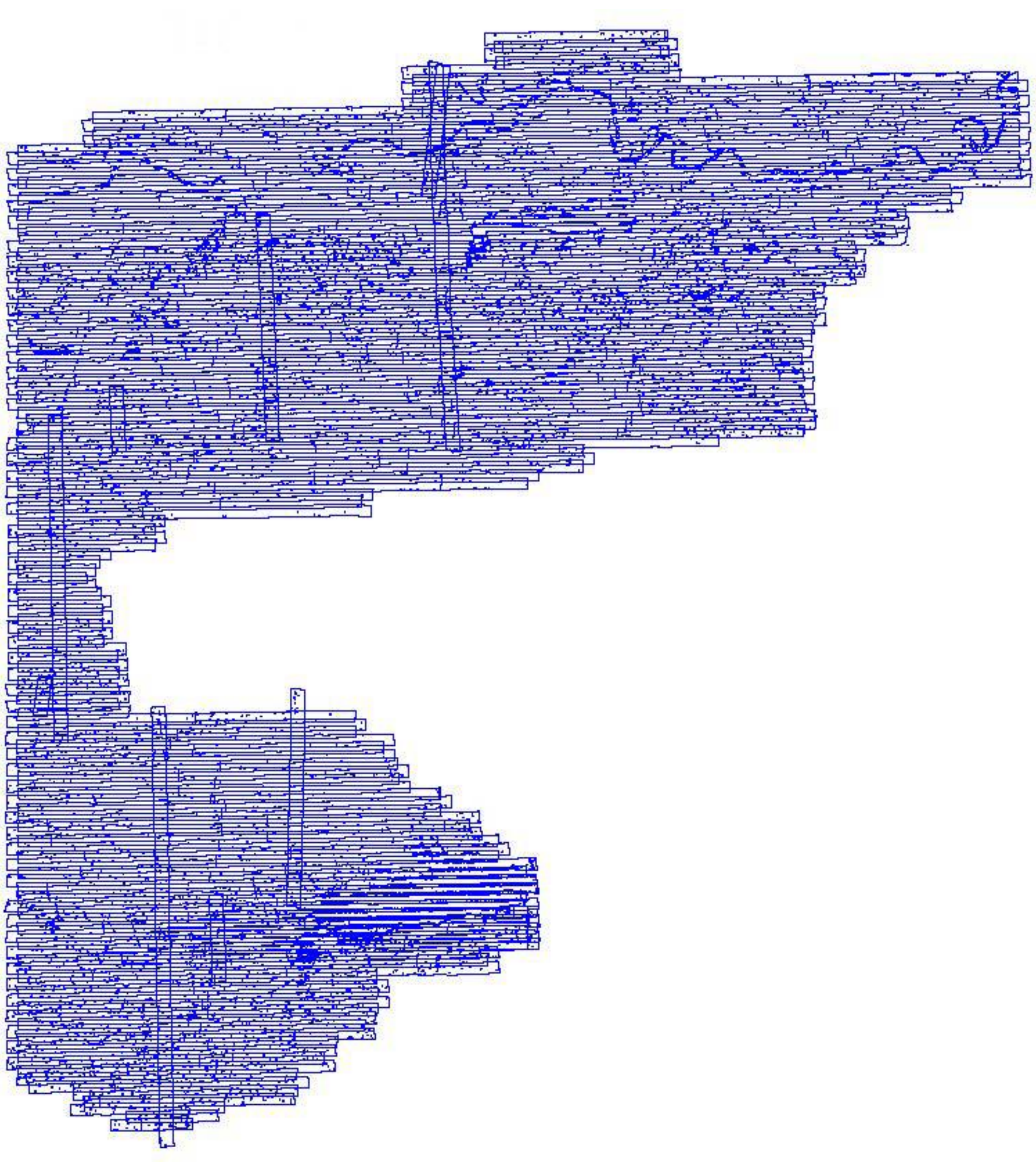


Figure 36 – Lidar swath output showing complete coverage.

Boresight and Relative accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

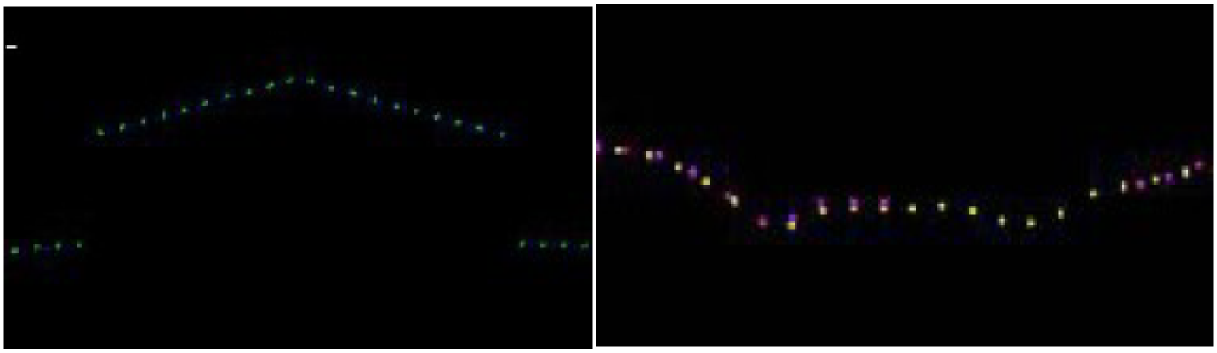


Figure 37 – Profile views showing correct roll and pitch adjustments.

Figure 38 – QC block colored by distance to ensure accuracy at swath edges.

A different set of QC blocks are generated for final review after all transformations have been applied.

Preliminary Vertical Accuracy Assessment

A preliminary $RMSE_z$ error check is performed by Intermap at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq 10$ cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated Texas Wesy Central Lidar dataset was tested to 0.096 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.049 m x 1.9600) when compared to 39 GPS static check points.

The following are the final statistics for the GPS static checkpoints used by Intermap to internally verify vertical accuracy.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	39	0.049	0.096	0.030	0.039	-0.033	0.120

Table 33 - Static GPS Vertical Accuracy Results

Overall the calibrated lidar data products collected by Intermap meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Intermap quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

Lidar Processing & Qualitative Assessment

INITIAL PROCESSING

Once Dewberry receives the calibrated swath data from the acquisition provider, Dewberry performs several validations on the dataset prior to starting full-scale production on the project. These validations include vertical accuracy of the swath data, inter-swath (between swath) relative accuracy validation, intra-swath (within a single swath) relative accuracy validation, verification of horizontal alignment between swaths, and confirmation of point density and spatial distribution. This initial assessment allows Dewberry to determine if the data are suitable for full-scale production. Addressing issues at this stage allows the data to be corrected while imposing the least disruption possible on the overall production workflow and overall schedule.

Final Swath Vertical Accuracy Assessment

Once Dewberry received the calibrated swath data from Precision Aerial Reconnaissance, Airborne Imaging, Axis Geospatially, Eagle Mapping Inc., Leading Edge Geomatics, Aerial

Services, Inc, and Intermap, Dewberry tested the vertical accuracy of the non-vegetated terrain swath data prior to additional processing. Dewberry tested the vertical accuracy of the swath data using the Seven hundred and one non-vegetated (open terrain and urban) independent survey check points. The vertical accuracy is tested by comparing survey checkpoints in non-vegetated terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in non-vegetated terrain can be tested against raw swath data because the data has not undergone classification techniques to remove vegetation, buildings, and other artifacts from the ground surface. Checkpoints are always compared to interpolated surfaces from the lidar point cloud because it is unlikely that a survey checkpoint will be located at the location of a discrete lidar point. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project. Project specifications require a NVA of 19.6 cm based on the $RMSE_z$ (10 cm) x 1.96. The dataset for the Texas West Central Lidar Project satisfies this criteria. This raw lidar swath data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm $RMSE_z$ Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 4.6 cm, equating to +/- 9 cm at 95% confidence level. The table below shows all calculated statistics for the raw swath data.

100 % of Totals	# of Points	$RMSE_z$ NVA Spec=0.10 m	NVA –Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.196 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
Non-Vegetated Terrain	701	0.046	0.090	0.004	0.003	0.206	0.046	-0.165	0.221	1.368

Table 34: NVA at 95% Confidence Level for Raw Swaths

Inter-Swath (Between Swath) Relative Accuracy

Dewberry verified inter-swath or between swath relative accuracy of the dataset by creating Delta-Z (DZ) orthos. According to the SOW, USGS Lidar Base Specifications v1.2, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class or QL2 data must meet inter-swath relative accuracy of 8 cm RMSDz or less with maximum differences less than 16 cm. These measurements are to be taken in non-vegetated and flat open terrain using single or only returns from all classes. Measurements are calculated in the DZ orthos on 1-meter pixels or cell sizes. Areas in the dataset where overlapping flight lines are within 8 cm of each other within each pixel are colored green, areas in the dataset where overlapping flight lines have elevation differences in each pixel between 8 cm to 16 cm are colored yellow, and areas in the dataset where overlapping flight lines have elevation differences in each pixel greater than 16 cm are colored red. Pixels that do not contain points from overlapping flight lines are colored according to their intensity values. Areas of vegetation and steep slopes (slopes with 16 cm or more of valid elevation change across 1 linear meter) are expected to appear yellow or red in the DZ orthos. If the project area is heavily vegetated, Dewberry may also create DZ Orthos from the initial ground classification only, while keeping all other parameters consistent. This allows Dewberry to review the ground classification relative accuracy beneath vegetation and to ensure flight line ridges or other issues do not exist in the final classified data.

Flat, open areas are expected to be green in the DZ orthos. Large or continuous sections of yellow or red pixels can indicate the data was not calibrated correctly or that there were issues during acquisition that could affect the usability of the data, especially when these yellow/red sections follow the flight lines and not the terrain or areas of vegetation. The DZ orthos for TX West Central Lidar are shown in the figures below; this project meets inter-swath relative accuracy specifications.

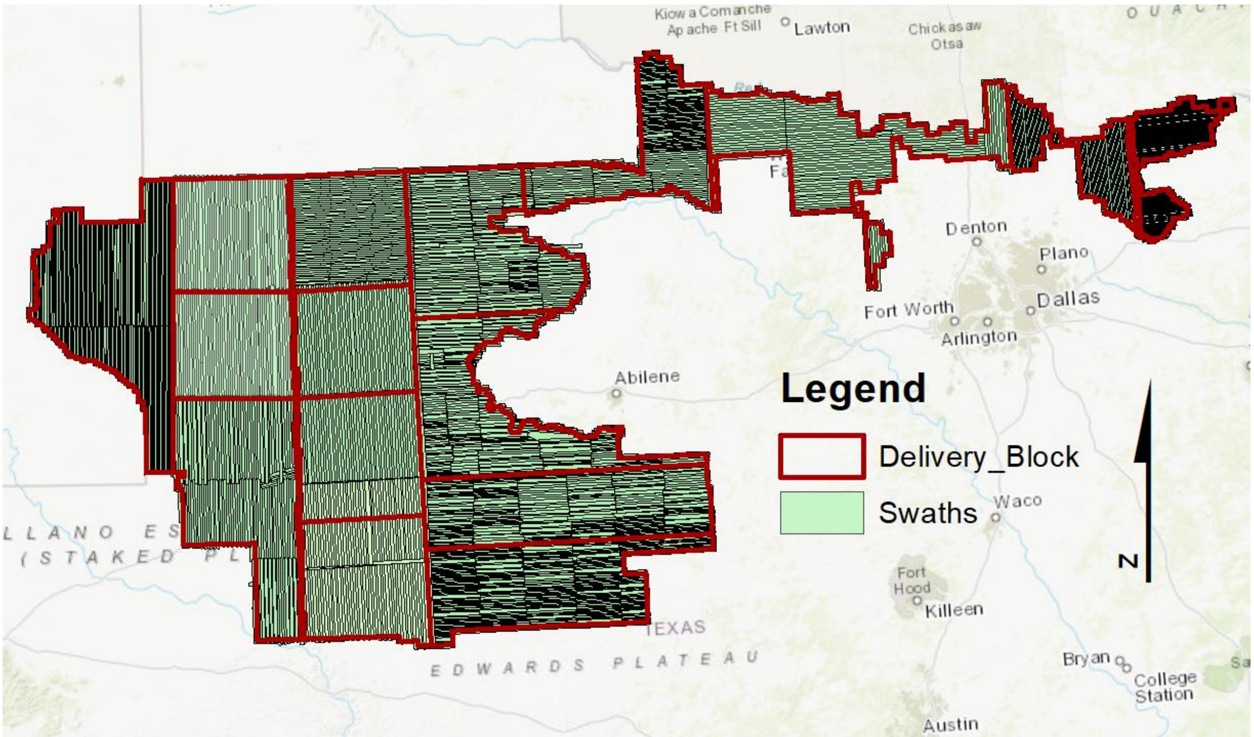


Figure 39– Diagram of the TX West Central Lidar project shows the swath coverage.

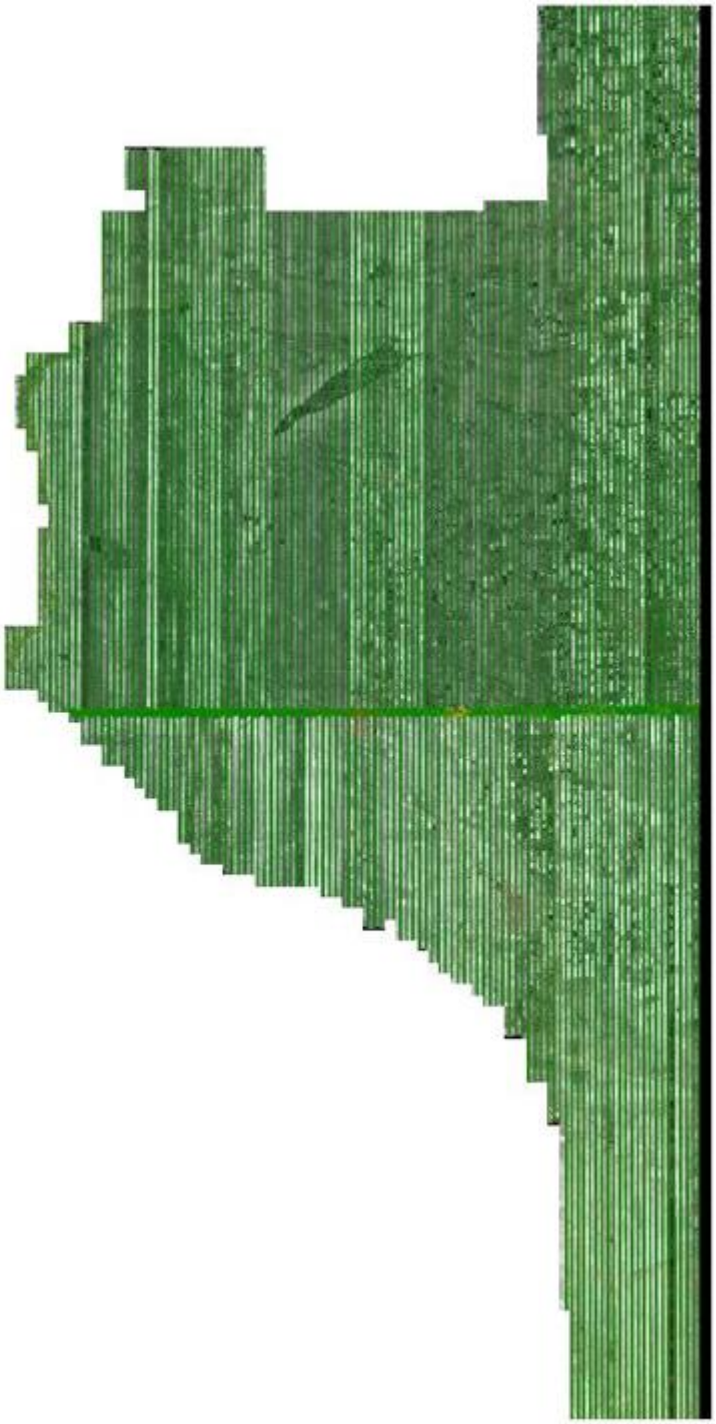


Figure 40– Single return DZ Orthos of delivery Block 01 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

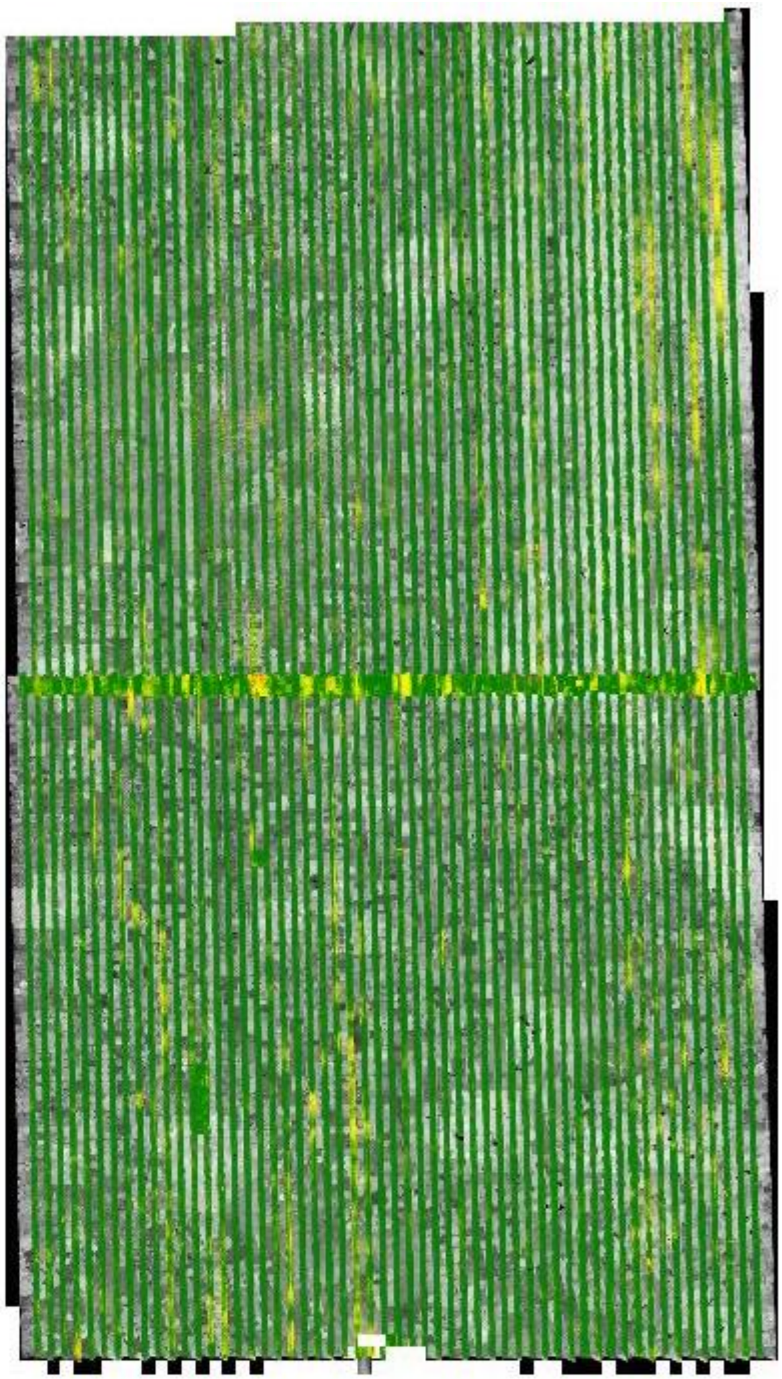


Figure 41– Single return DZ Orthos of delivery Block 02 and 03 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

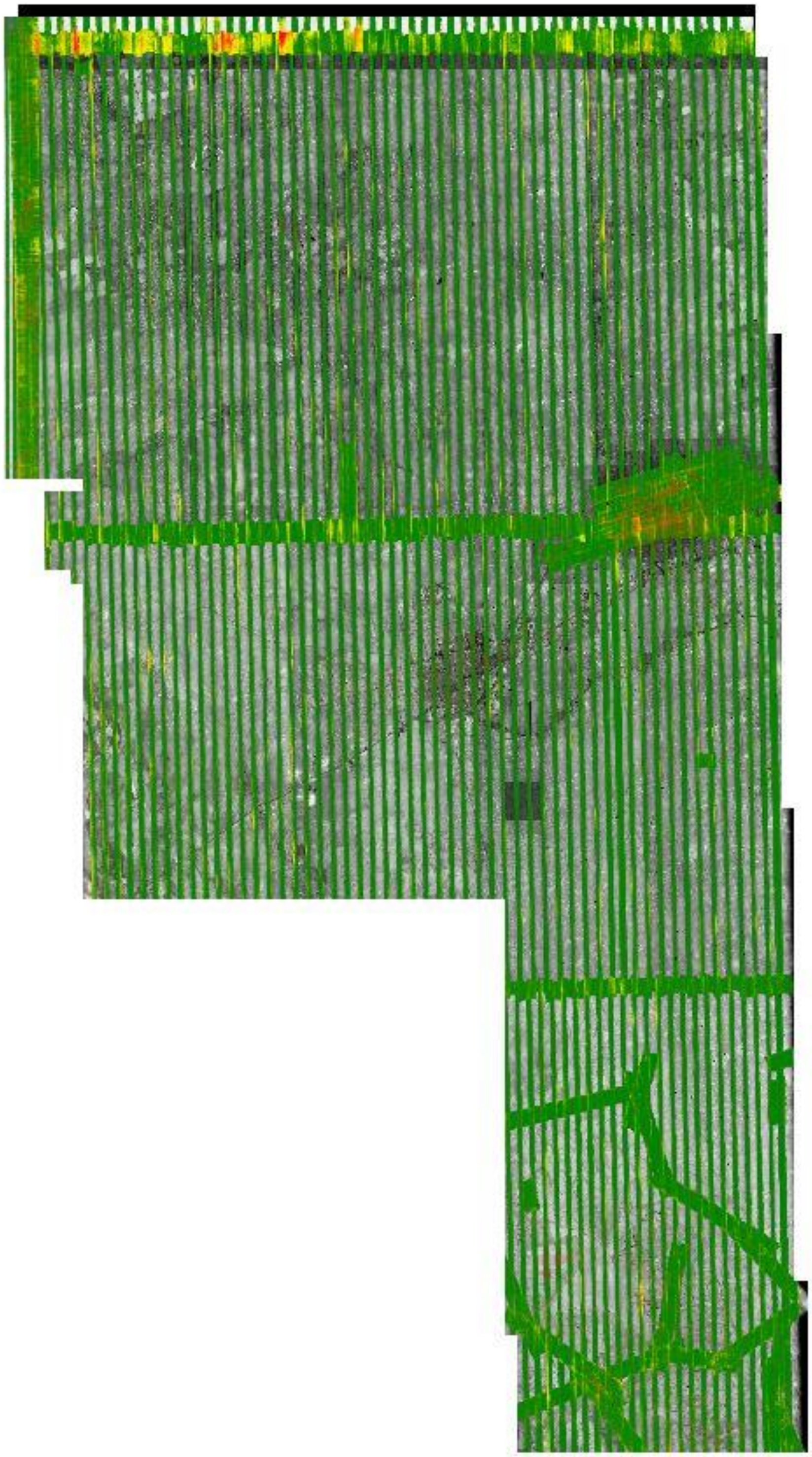


Figure 42– Single return DZ Orthos of delivery Block 04 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

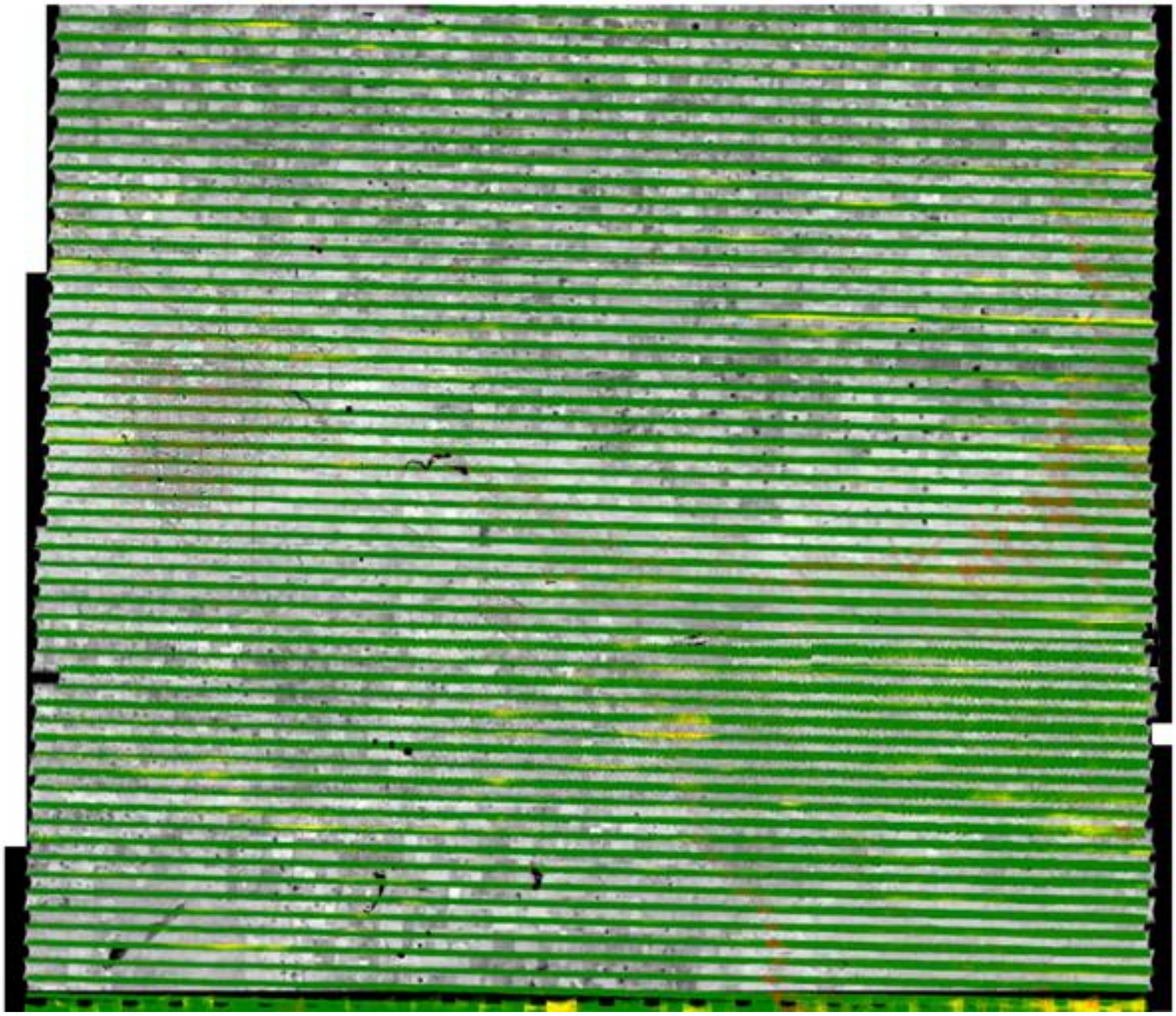


Figure 43– Single return DZ Orthos of delivery Block 05 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

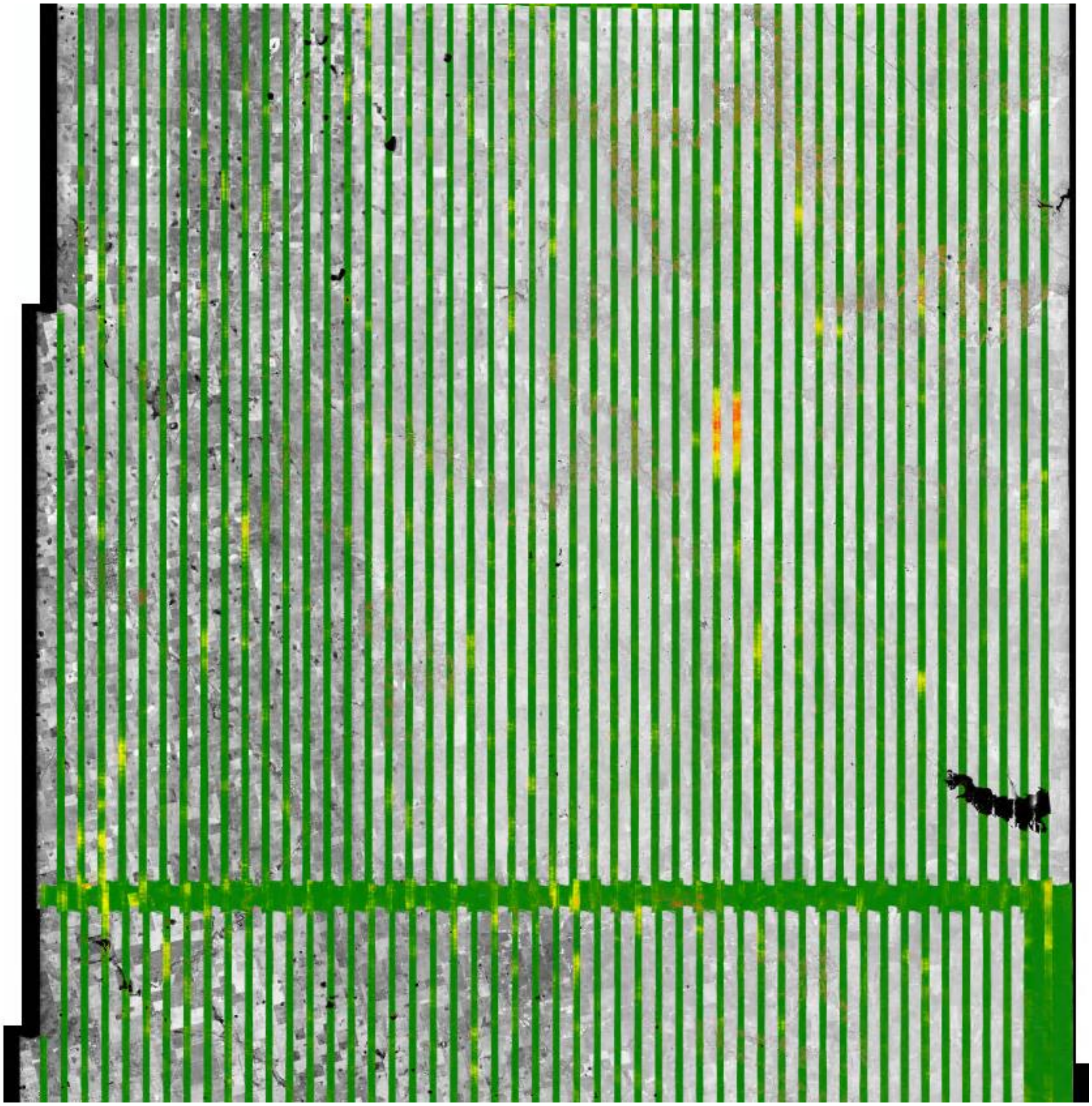


Figure 44– Single return DZ Orthos of delivery Block 06 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

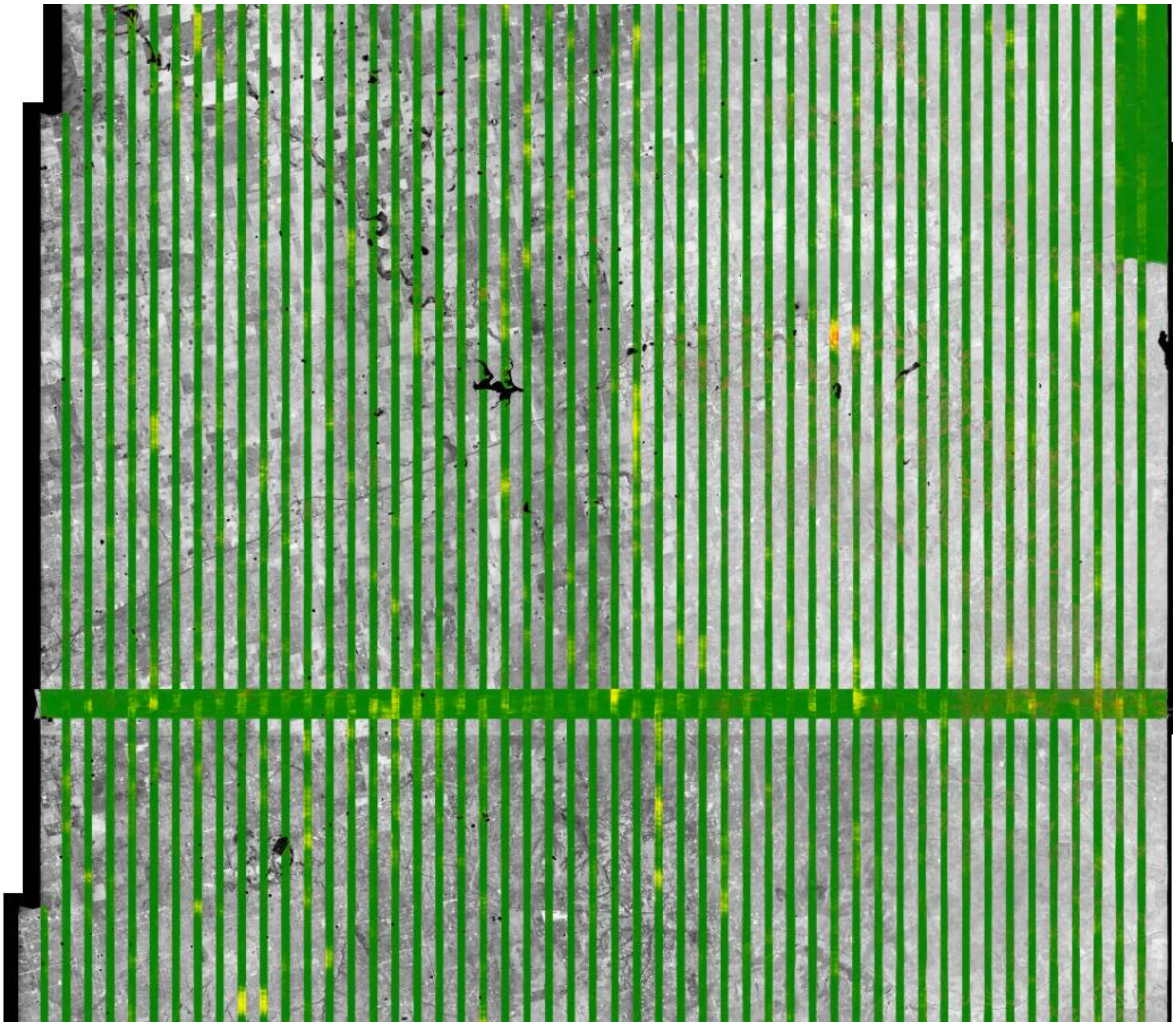


Figure 45– Single return DZ Orthos of delivery Block 07 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

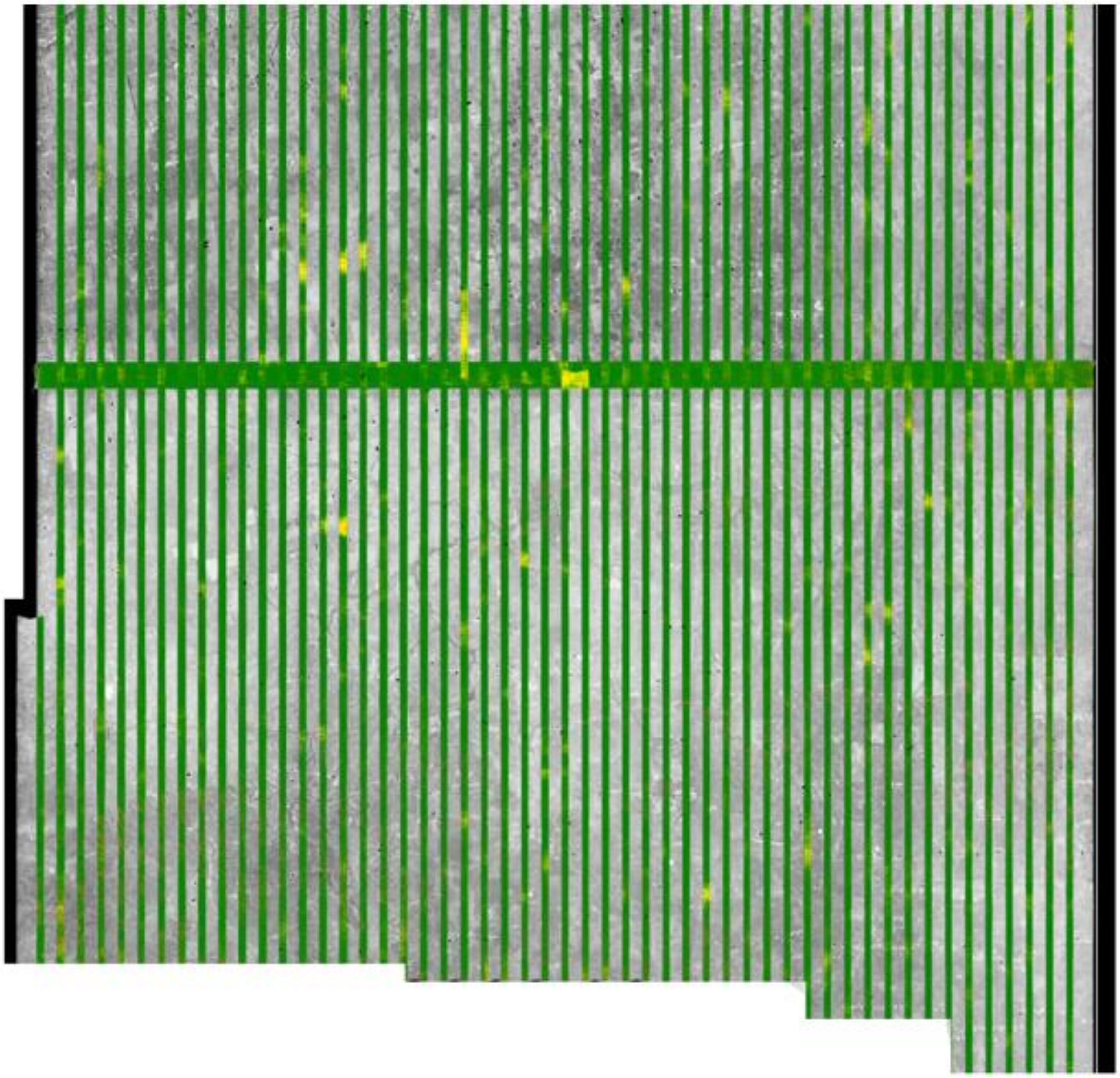


Figure 46– Single return DZ Orthos of delivery Block 08 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

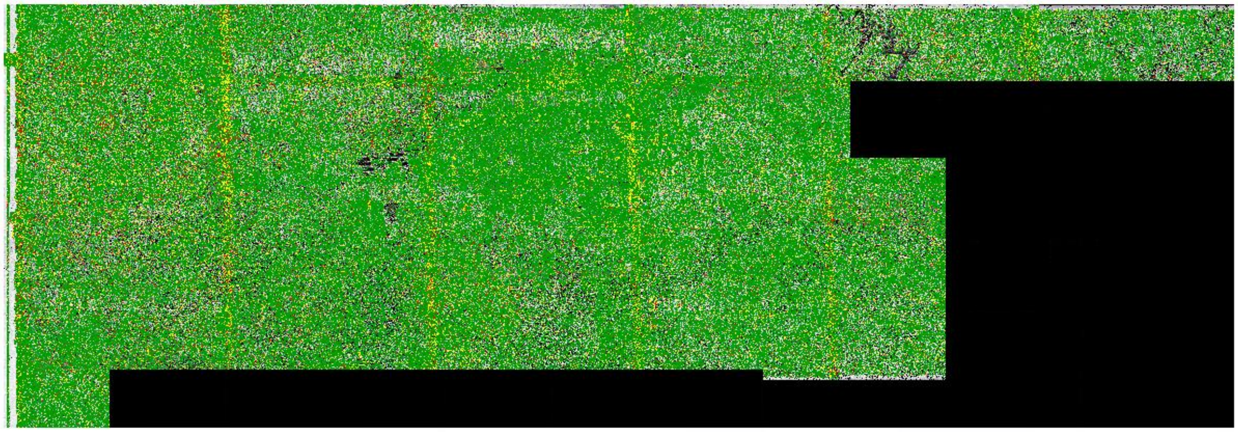


Figure 47– Single return DZ Orthos of delivery Block 09 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

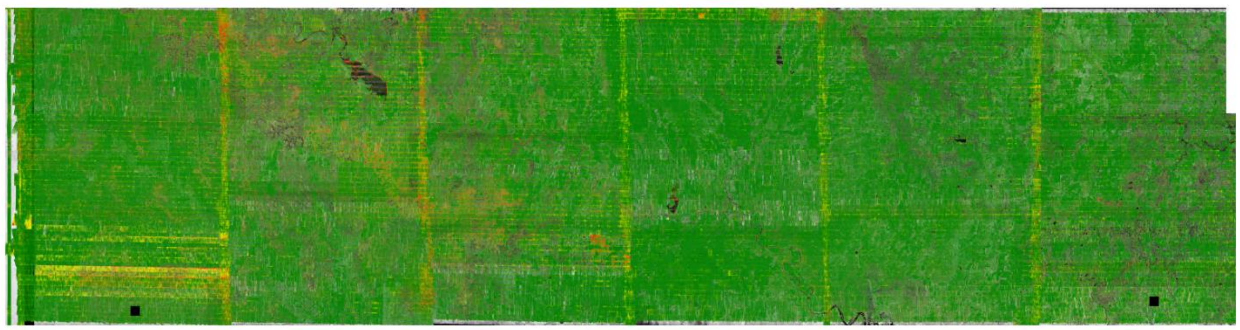


Figure 48– Single return DZ Orthos of delivery Block 10 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

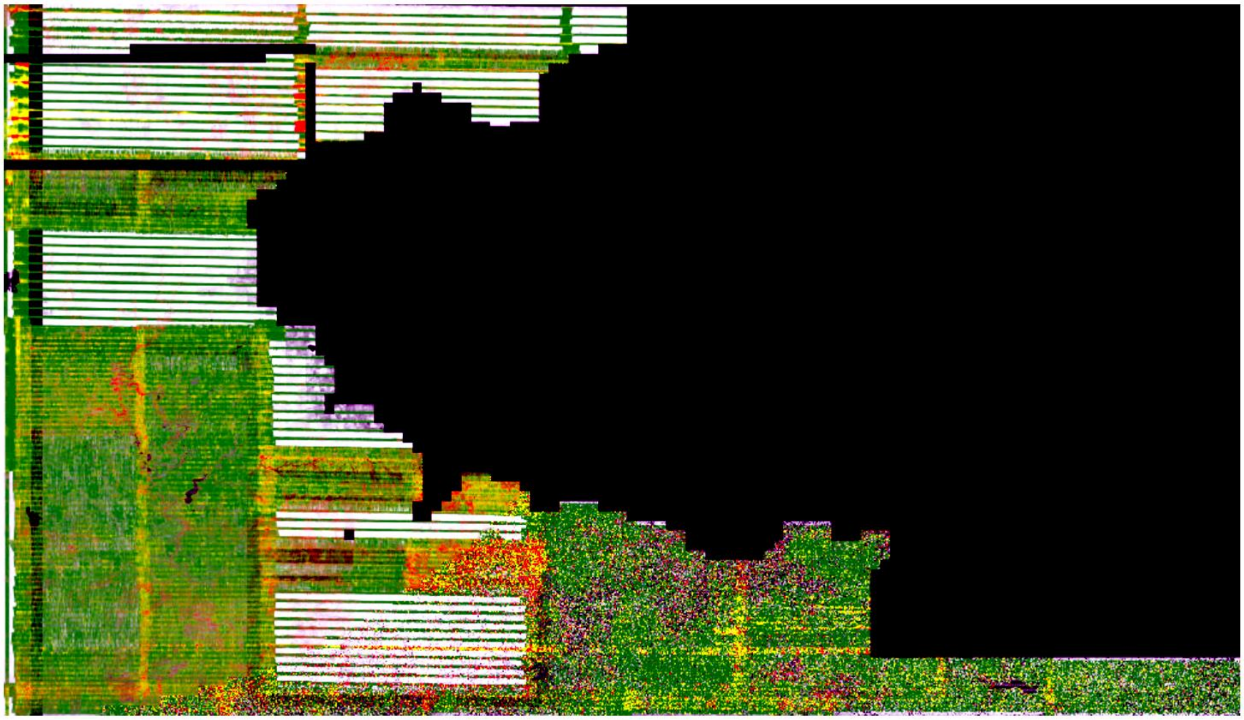


Figure 49– Single return DZ Orthos of delivery Block 11 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

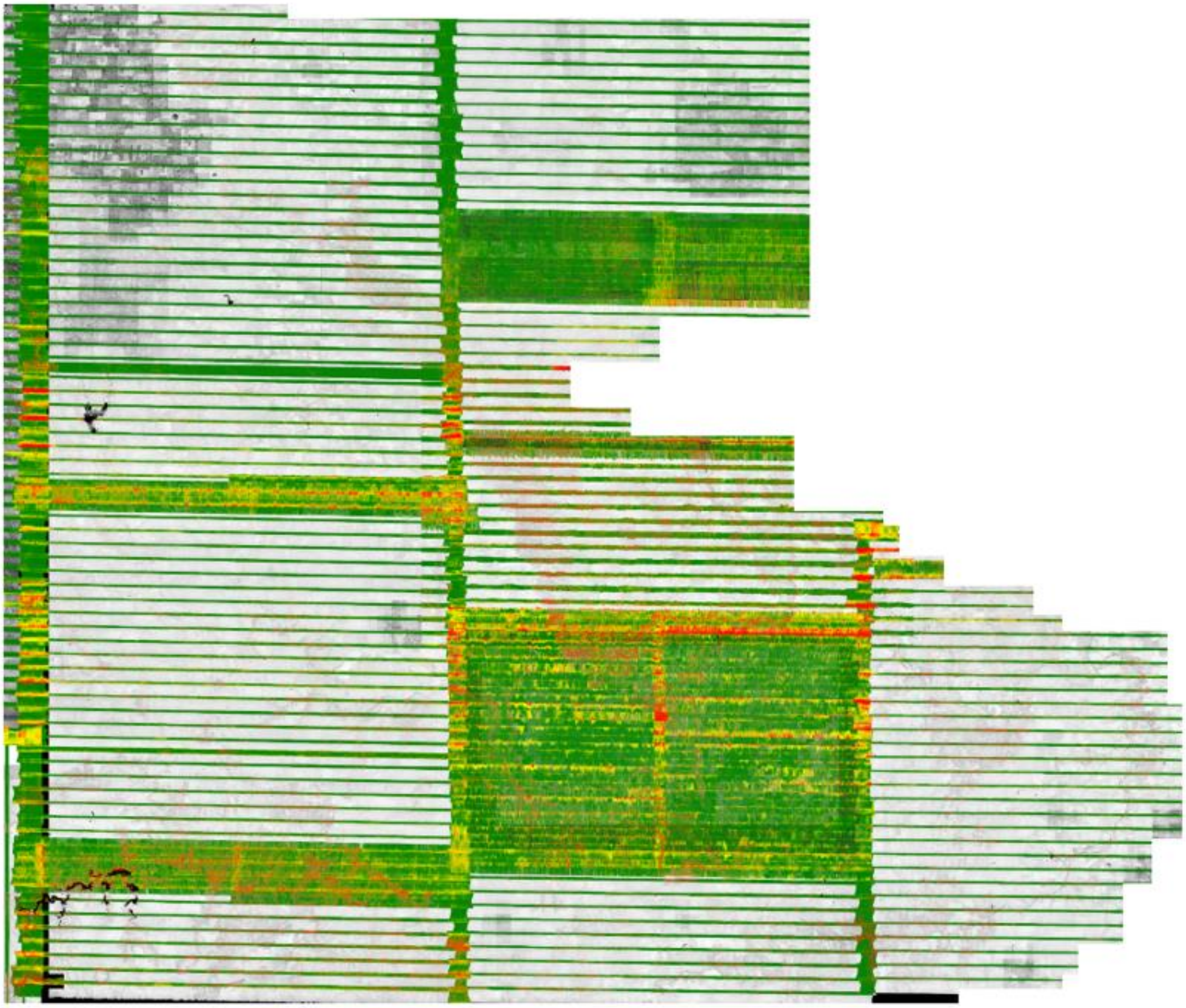


Figure 50– Single return DZ Orthos of delivery Block 12 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

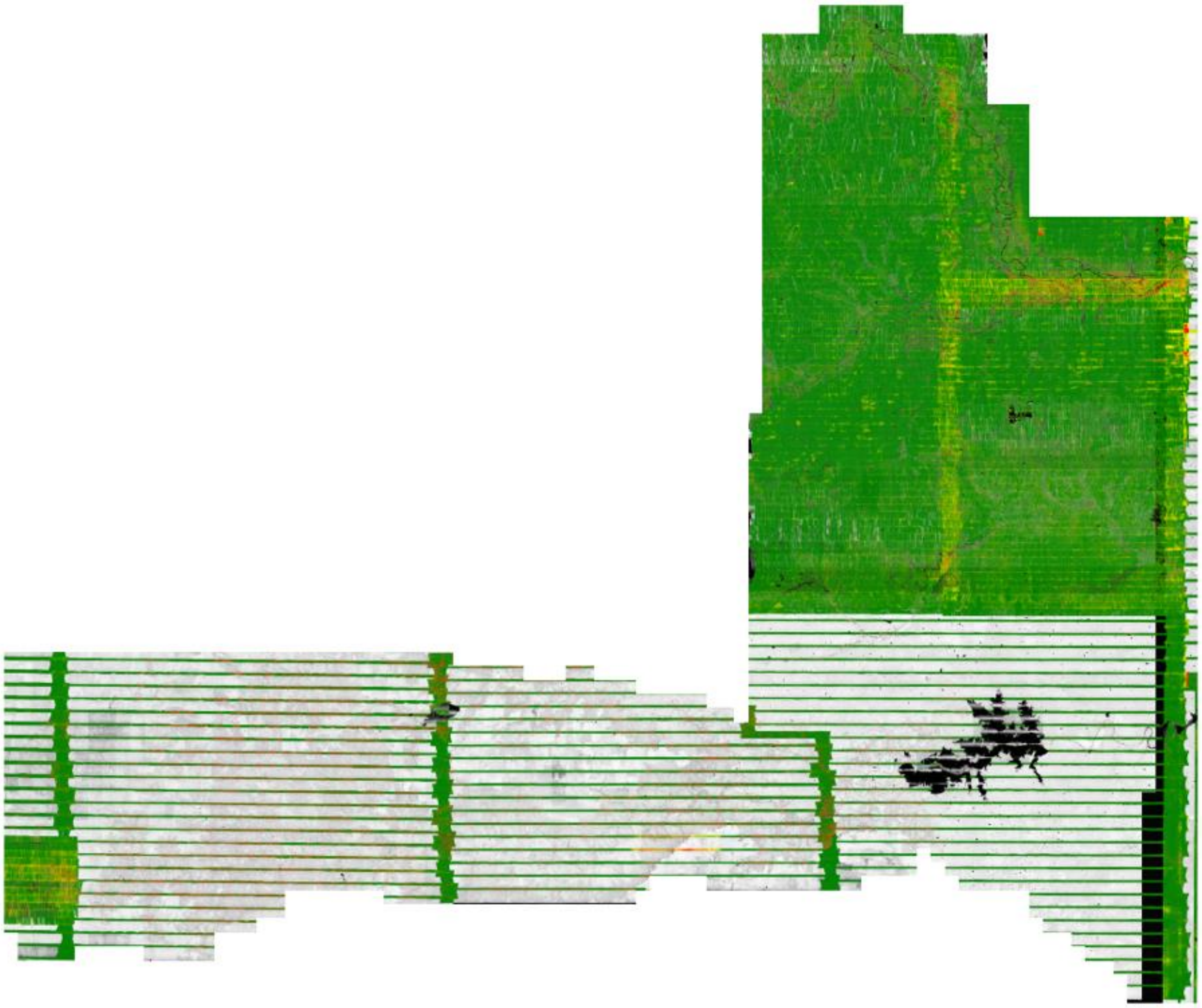


Figure 51– Single return DZ Orthos of delivery Block 13 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

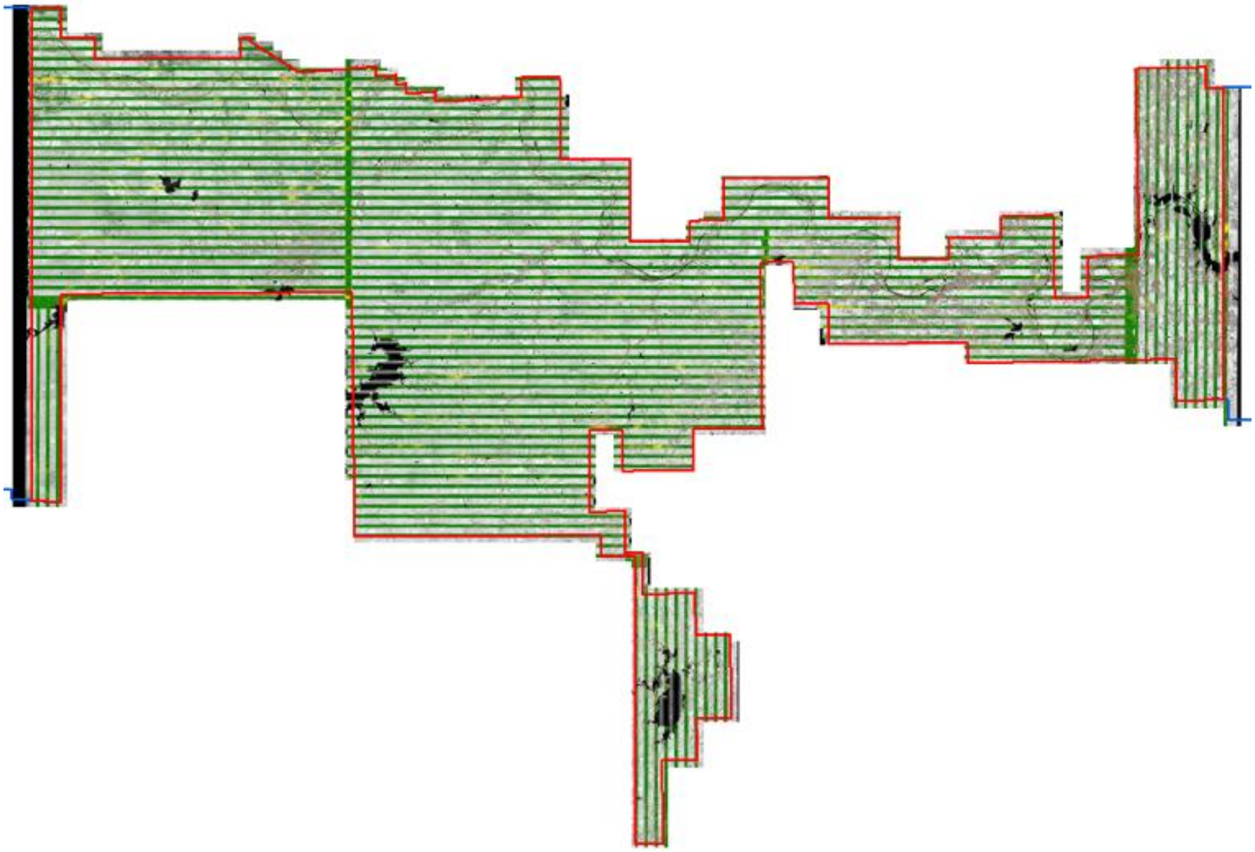


Figure 52– Single return DZ Orthos of delivery Block 14 for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

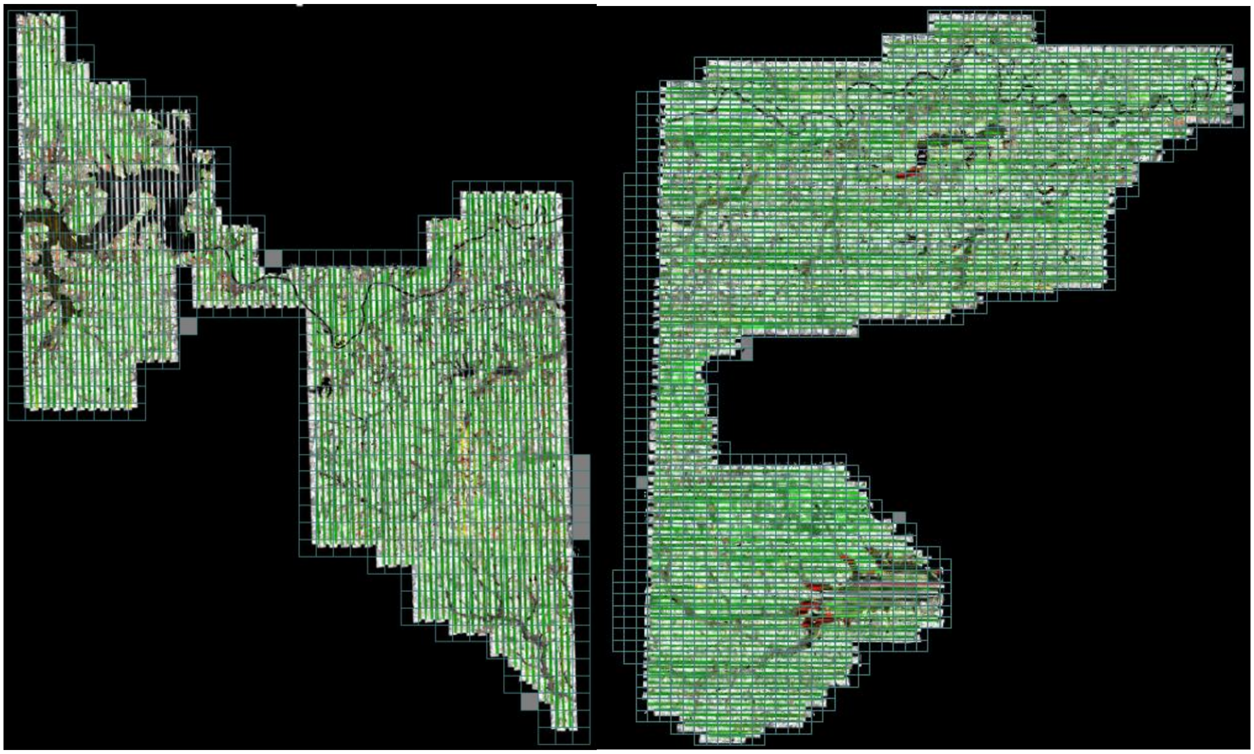


Figure 53– Single return DZ Orthos of delivery Block 15 (UTM14/15) for the TX West Central Lidar project. Inter-swath relative accuracy passes specifications.

Intra-Swath (Within a Single Swath) Relative Accuracy

Dewberry verifies the intra-swath or within swath relative accuracy by using Quick Terrain Modeler (QTM) scripting and visual reviews. QTM scripting is used to calculate the maximum difference of all points within each 1-meter pixel/cell size of each swath. Dewberry analysts then identify planar surfaces acceptable for repeatability testing and analysts review the QTM results in those areas. According to the SOW, USGS Lidar Base Specifications v1.2, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class or QL2 data must meet intra-swath relative accuracy of 6 cm maximum difference or less. The image below shows two examples of the intra-swath relative accuracy of TX West Central Lidar project; this project meets intra-swath relative accuracy specifications.

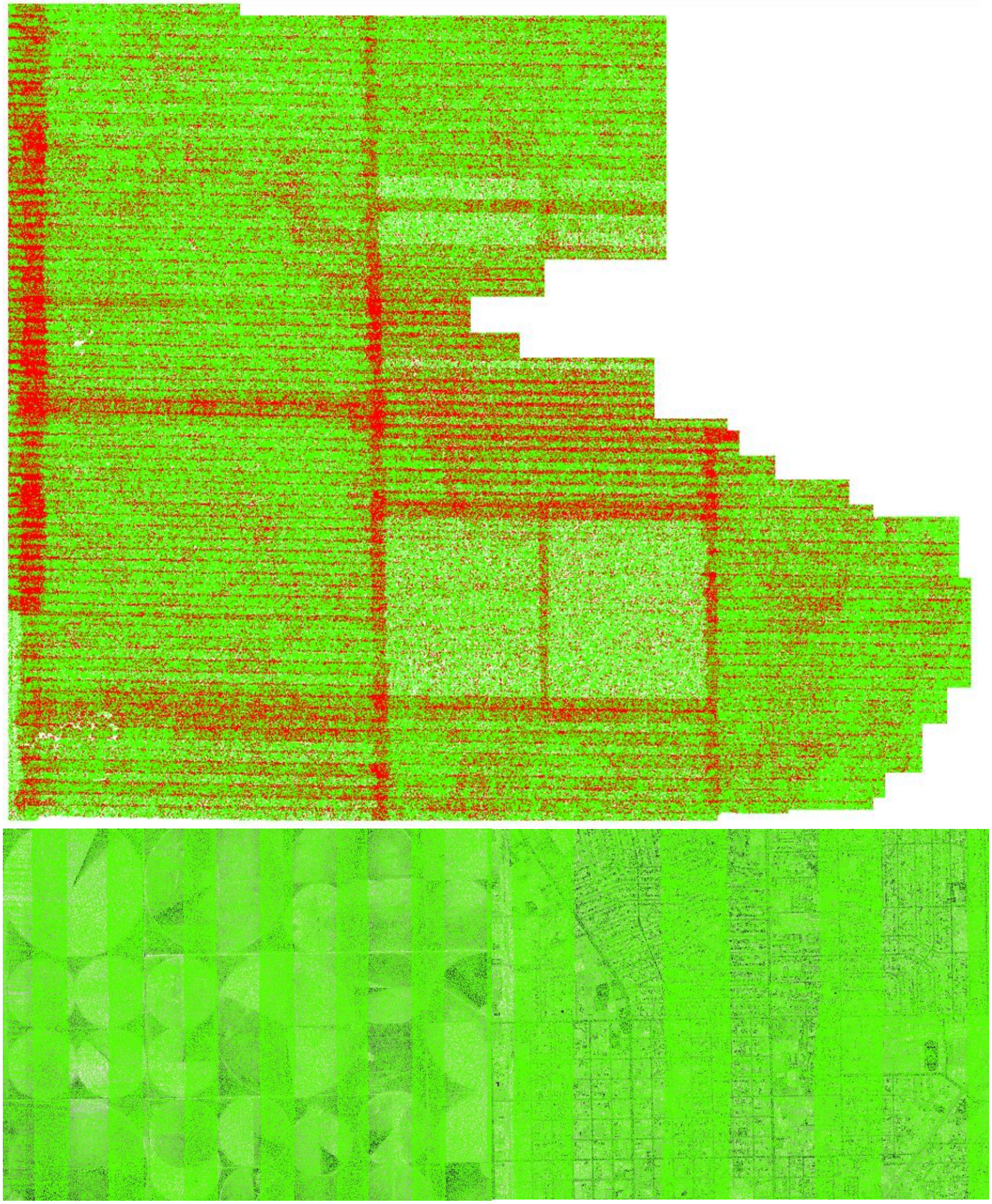


Figure 54–Intra-swath relative accuracy. The top image shows delivery Block 12 of project area; areas where the maximum difference is ≤6 cm per pixel within each swath are colored green and areas exceeding 6 cm are colored red. The bottom image is a close-up of a flat area. With the exception of few trees (shown in red as the elevation/height difference in vegetated areas will exceed 6 cm) this open flat area is acceptable for repeatability testing. Intra-swath relative accuracy passes specifications.

Horizontal Alignment

To ensure horizontal alignment between adjacent or overlapping flight lines, Dewberry uses QTM scripting and visual reviews. QTM scripting is used to create files similar to DZ orthos for each swath but this process highlights planar surfaces, such as roof tops. In particular, horizontal shifts or misalignments between swaths on roof tops and other elevated planar surfaces are highlighted. Visual reviews of these features, including additional profile verifications, are used to confirm the results of this process. The image below shows an example of the horizontal alignment between swaths for TX West central Lidar Project; no horizontal alignment issues were identified.

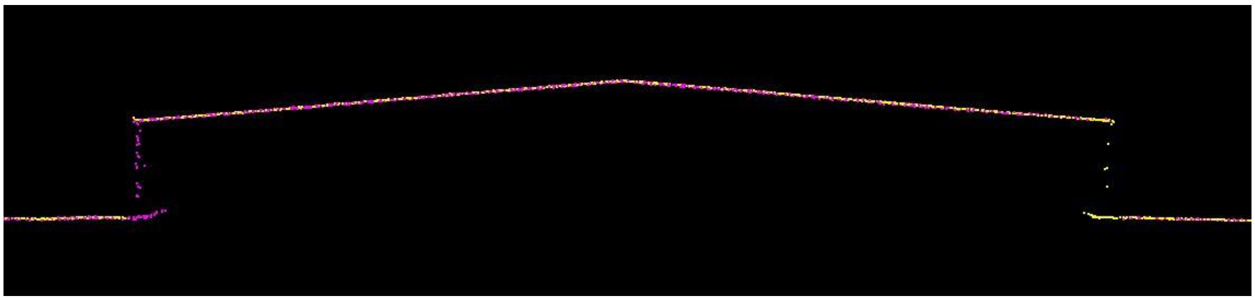


Figure 55– Horizontal Alignment. Two separate flight lines differentiated by color (Purple/Yellow) are shown in this profile. There is no visible offset between these two flight lines. No horizontal alignment issues were identified.

Point Density and Spatial Distribution

The required Aggregate Nominal Point Spacing (ANPS) for this project is no greater than 0.71 meters, which equates to an Aggregate Nominal Point Density (ANPD) of 2 points per square meter or greater. Density calculations were performed using first return data only located in the geometrically usable center portion (typically ~90%) of each swath. By utilizing statistics, the project area was determined to have an ANPS of 0.4 meters or an ANPD of 5.54 points per square meter which satisfies the project requirements. A visual review of a 1-square meter density grid (figure below) shows that there are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) and when density is viewed/analyzed by representative 1-square kilometer areas (to account for the irregular spacing of lidar point clouds), density passes with no issues.

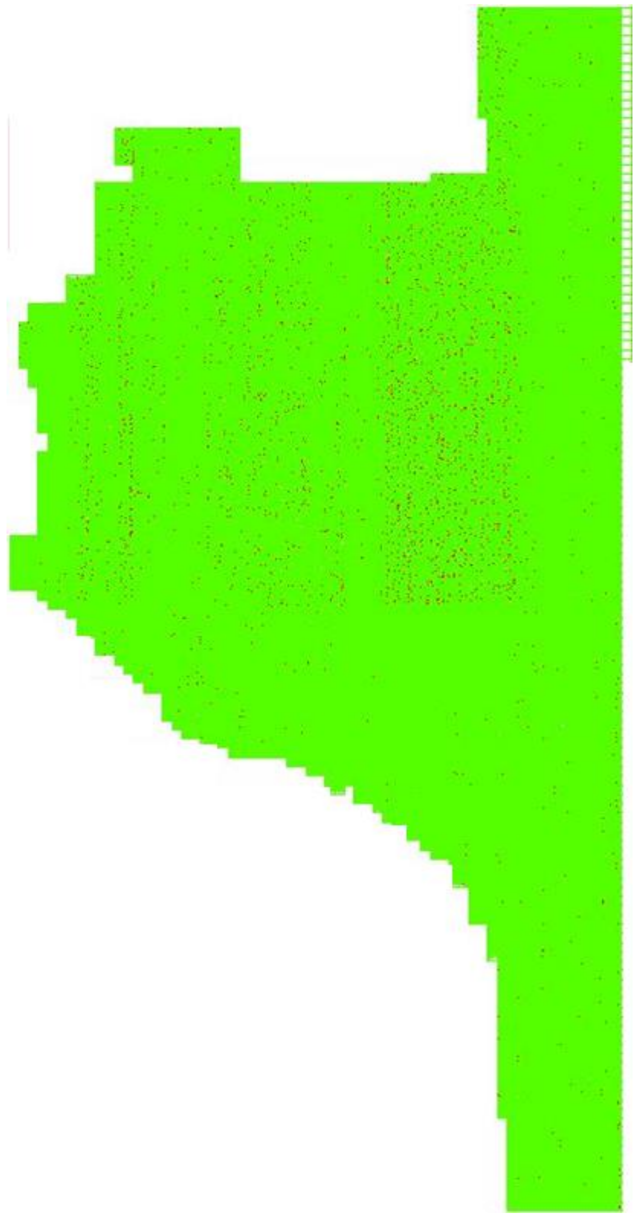


Figure 56– 1-square meter density grid for Block 01. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

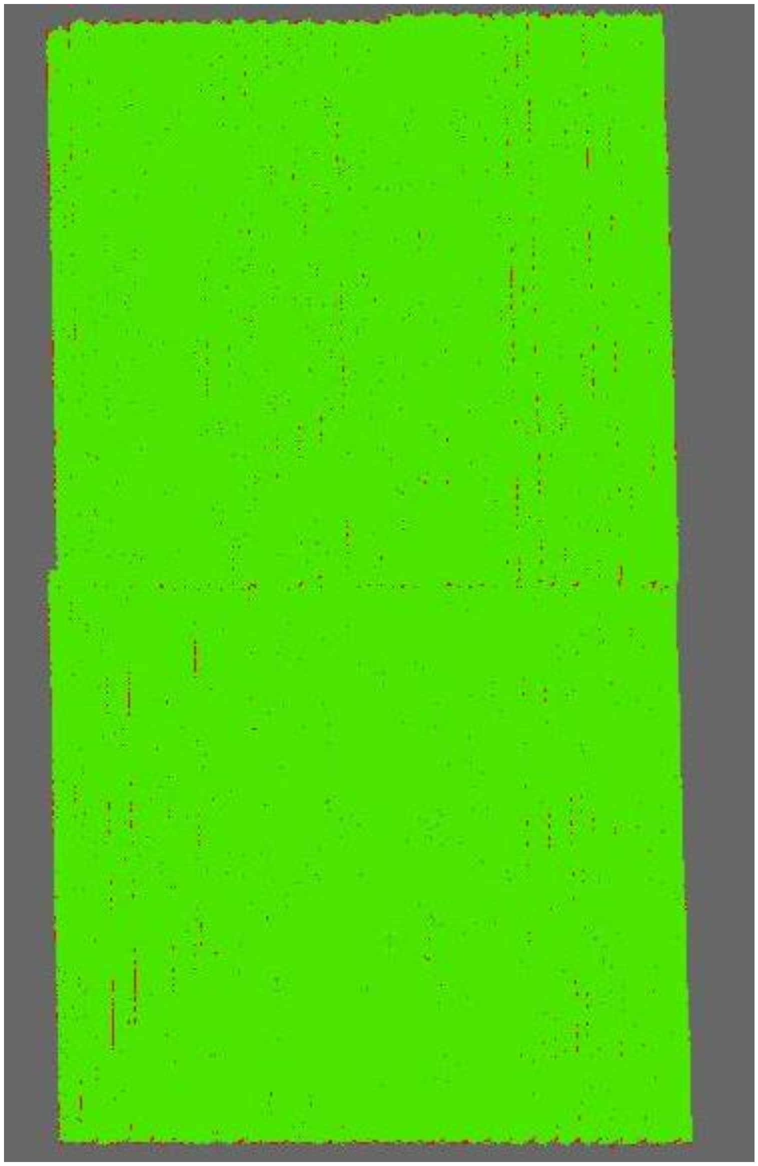


Figure 57– 1-square meter density grid for Block 02. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

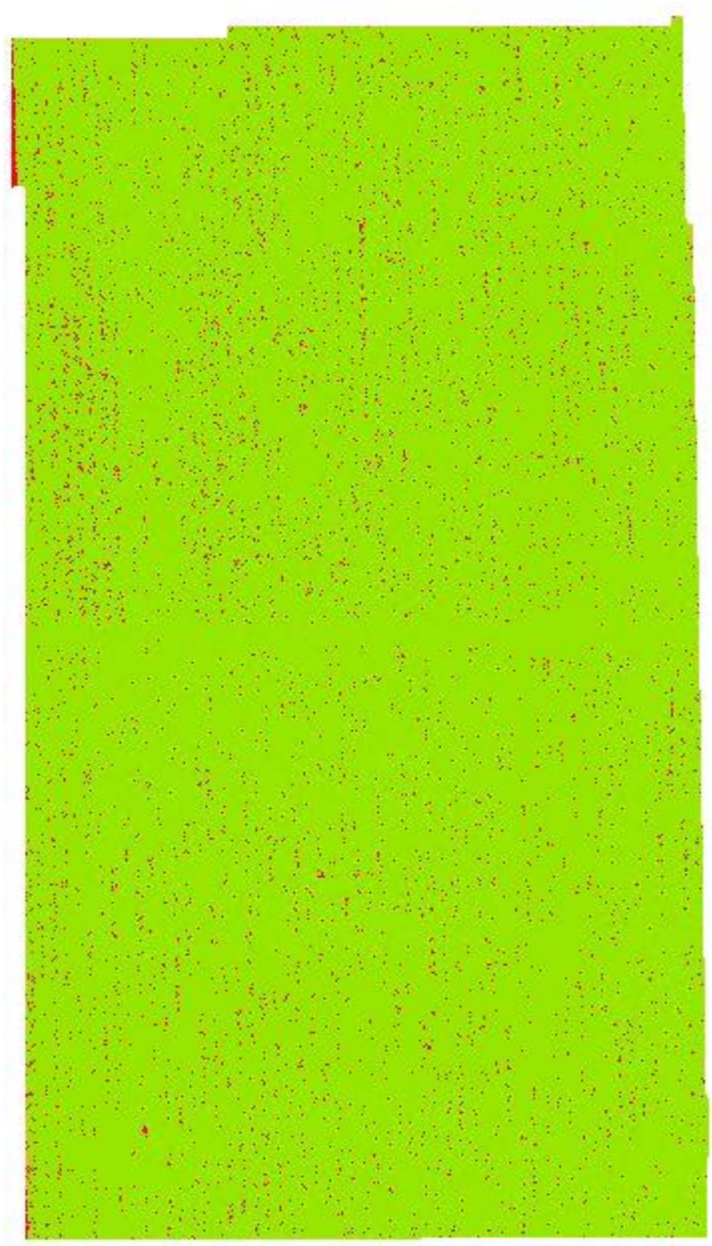


Figure 58– 1-square meter density grid for Block 03. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

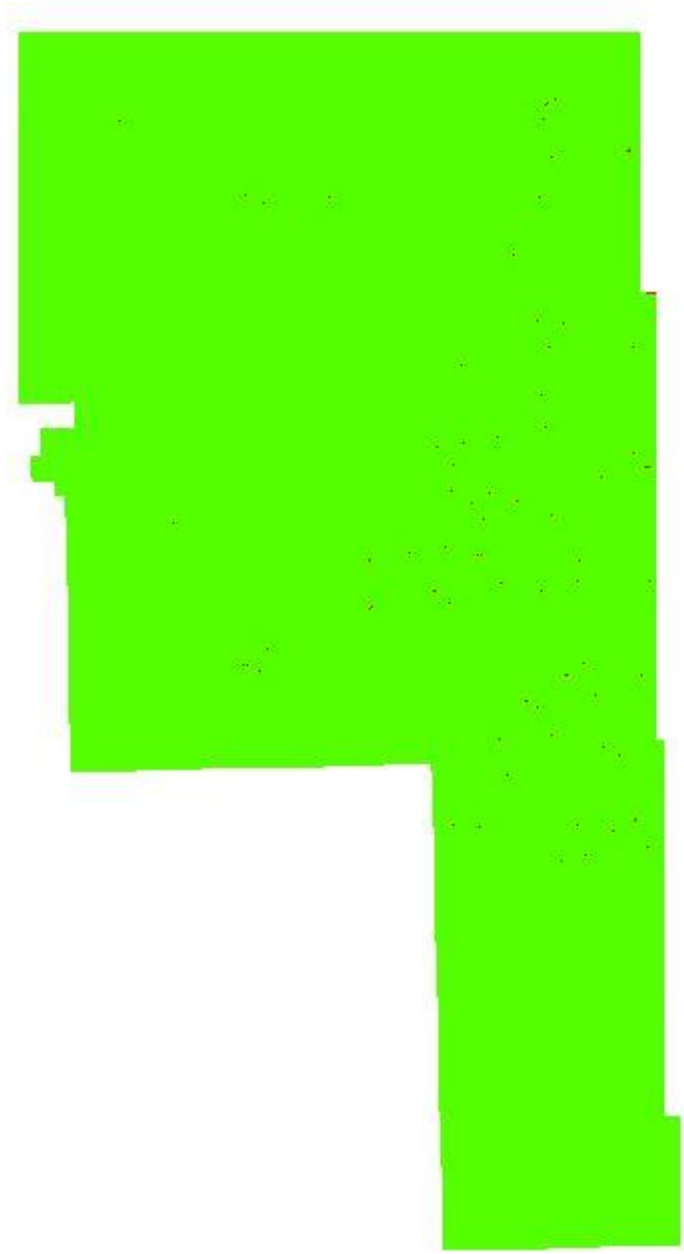


Figure 59– 1-square meter density grid for Block 04. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

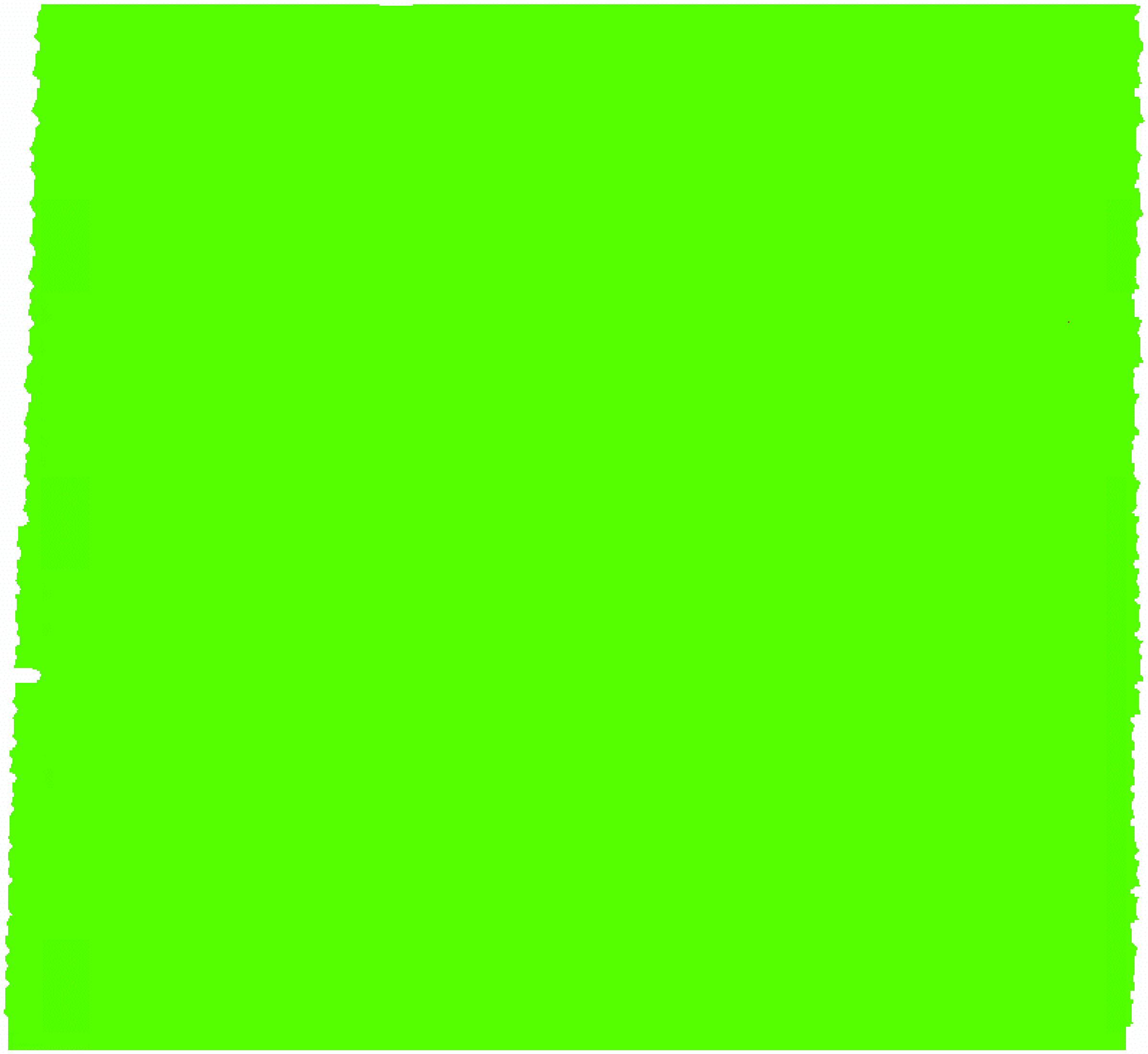


Figure 60– 1-square meter density grid for Block 05 and 06. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

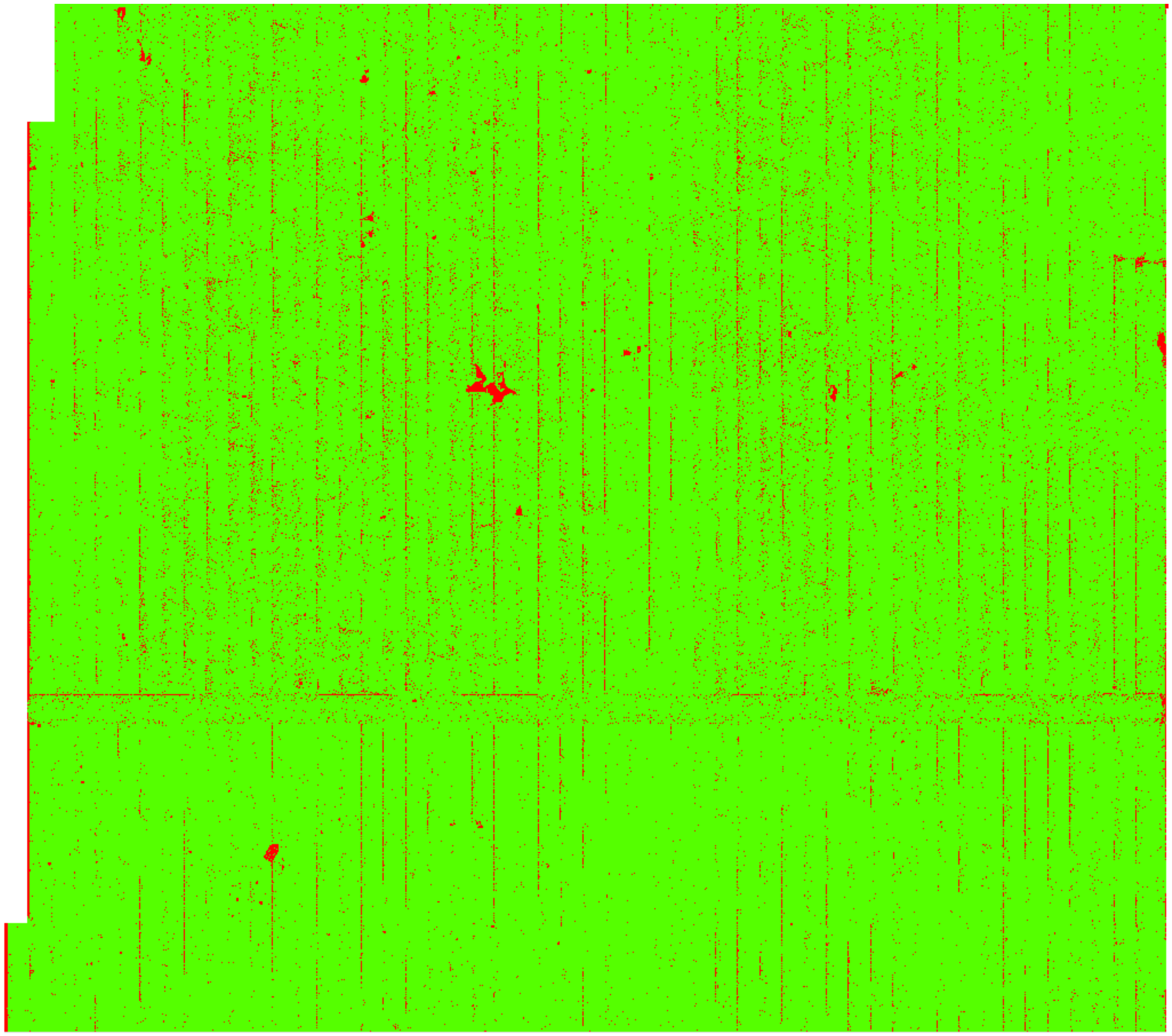


Figure 61– 1-square meter density grid for Block 07. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

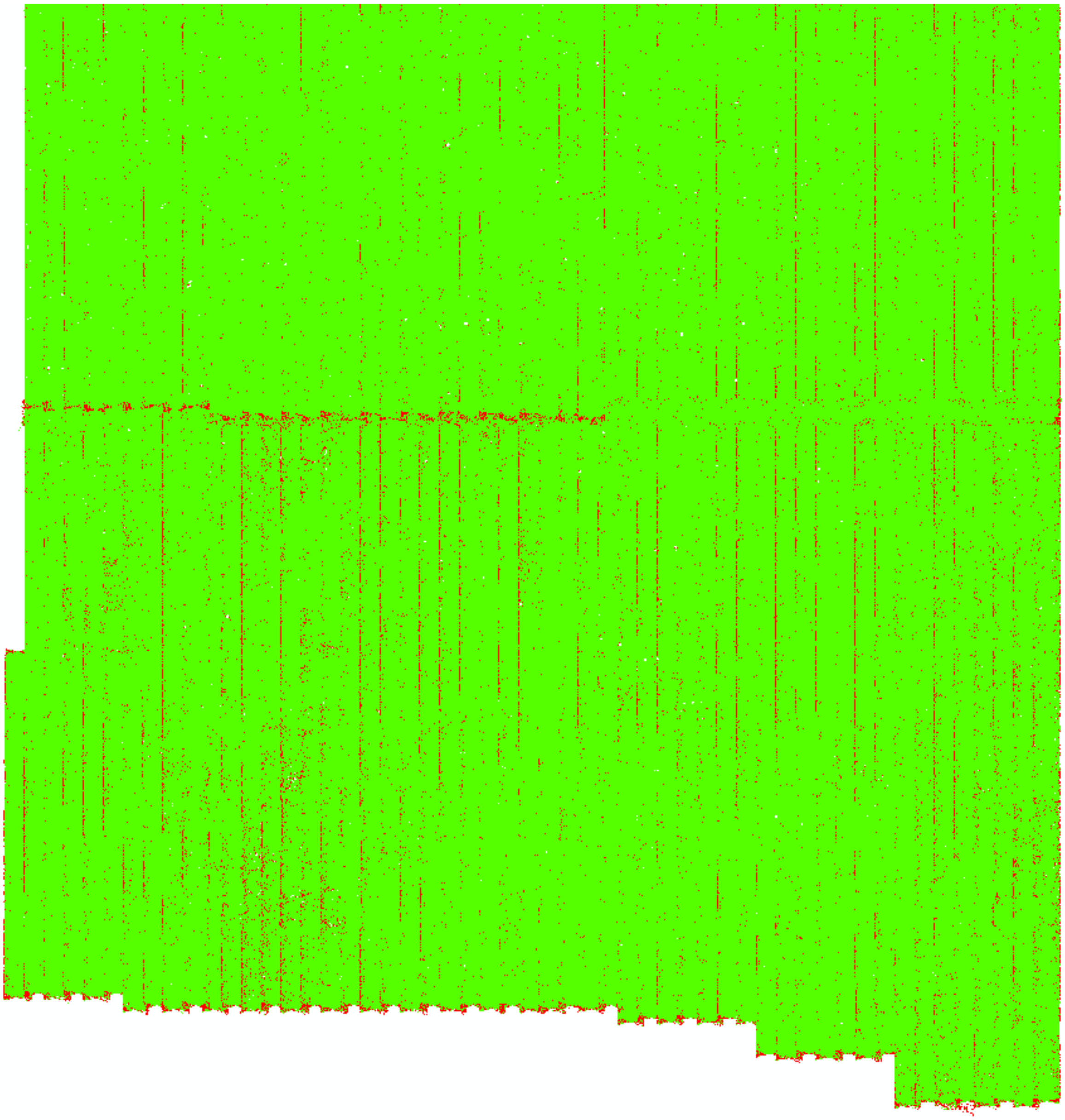


Figure 62– 1-square meter density grid for Block 08. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

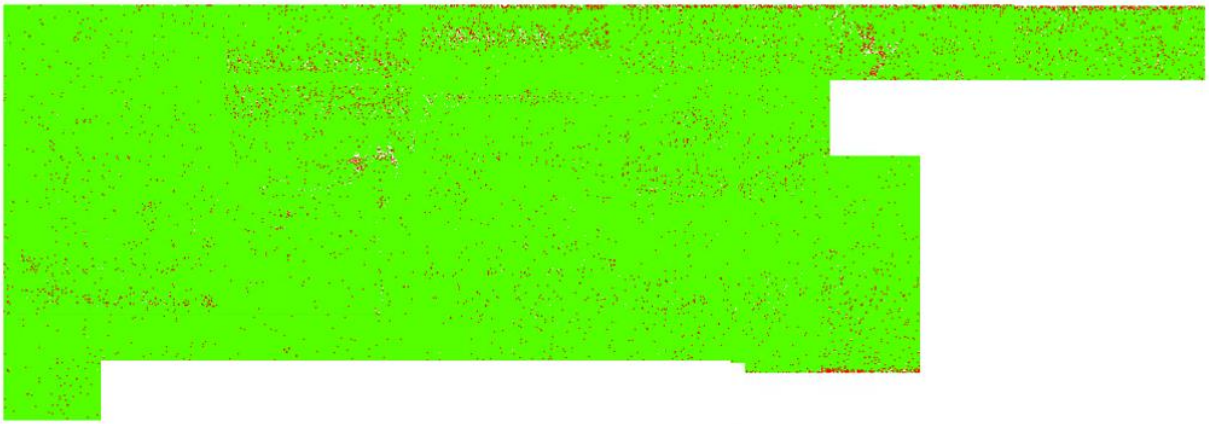


Figure 63– 1-square meter density grid for Block 09. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

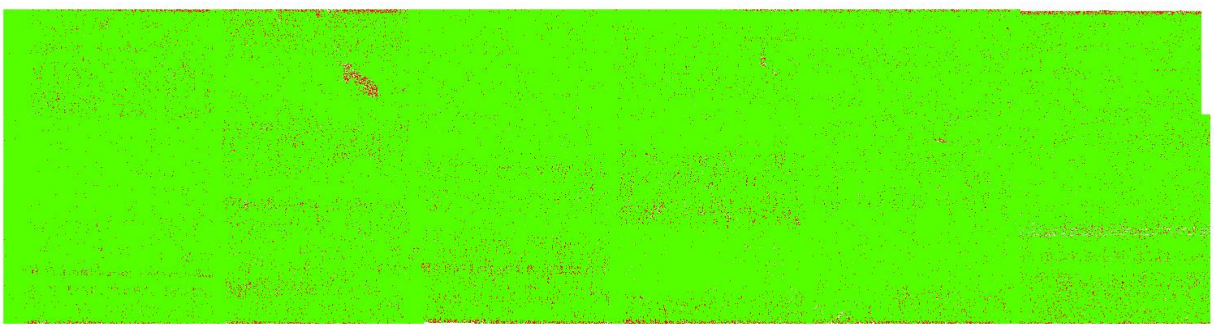


Figure 64– 1-square meter density grid for Block 10. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

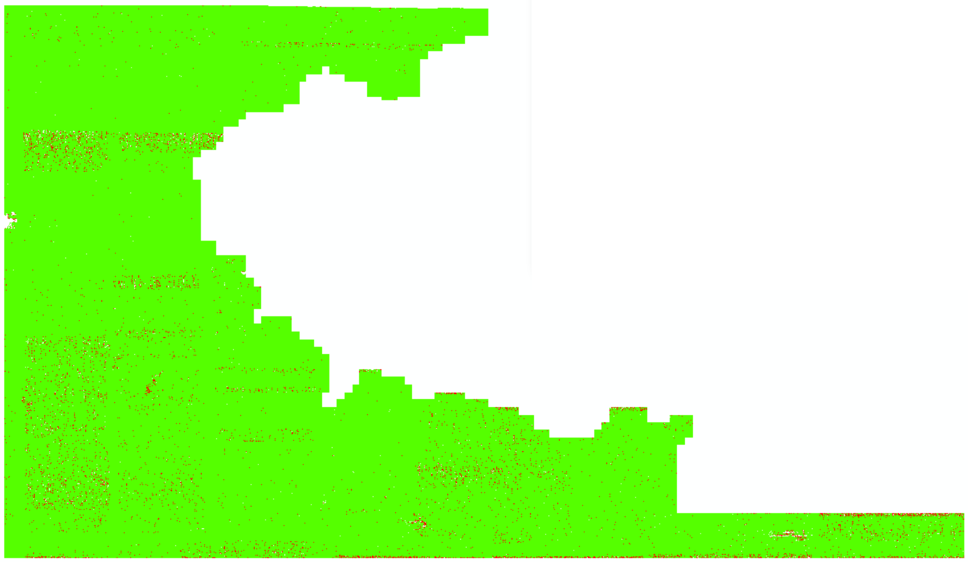


Figure 65– 1-square meter density grid for Block 11. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

Figure 66– 1-square meter density grid for Block 12. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

Figure 67– 1-square meter density grid for Block 13. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

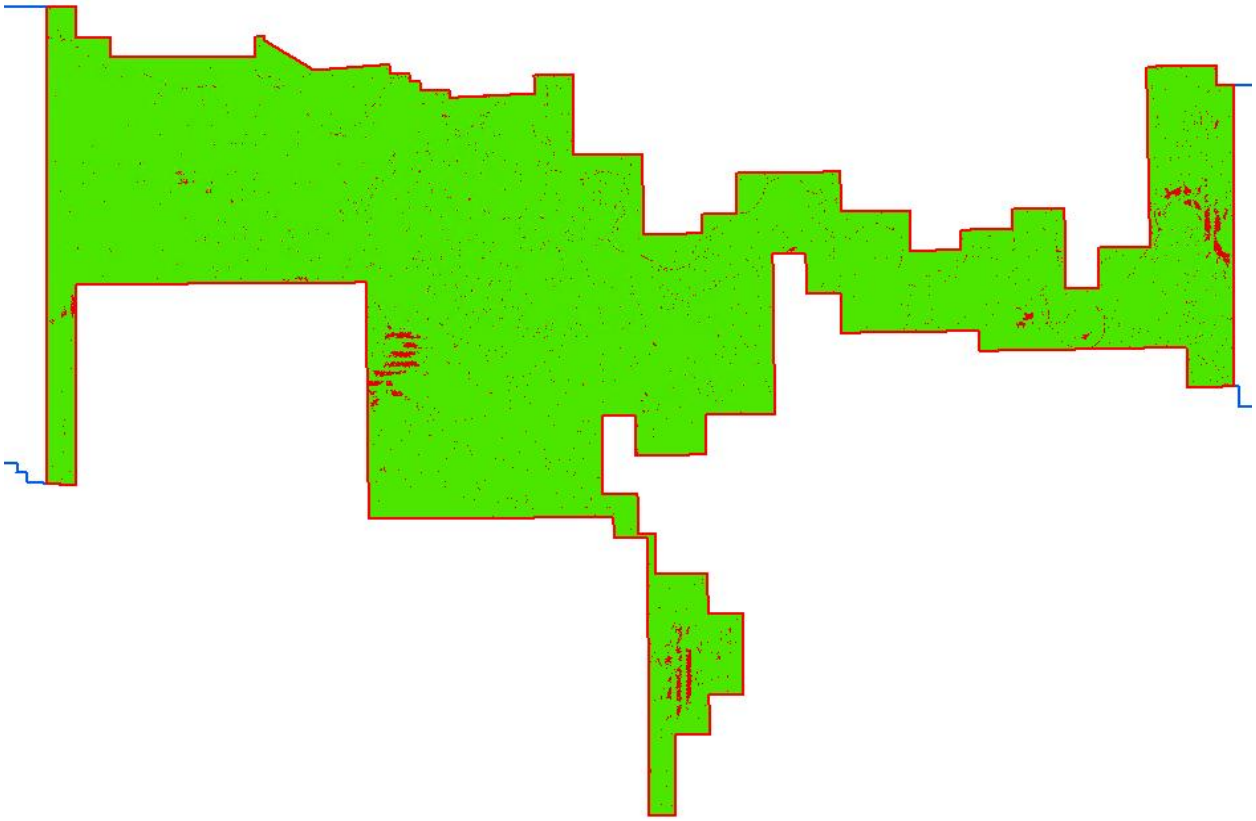


Figure 68– 1-square meter density grid for Block 14. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

Figure 69– 1-square meter density grid for Block 15. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

The spatial distribution of points must be uniform and free of clustering. This specification is tested by creating a grid with cell sizes equal to the design NPS*2. ArcGIS tools are then used to calculate the number of first return points of each swath within each grid cell. At least 98% of the cells must contain 1 lidar point, excluding acceptable void areas such as water or low NIR reflectivity features, i.e. some asphalt and roof composition materials. This project passes spatial distribution requirements, as shown in the image below.

Figure 70– Spatial Distribution for Block 01. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

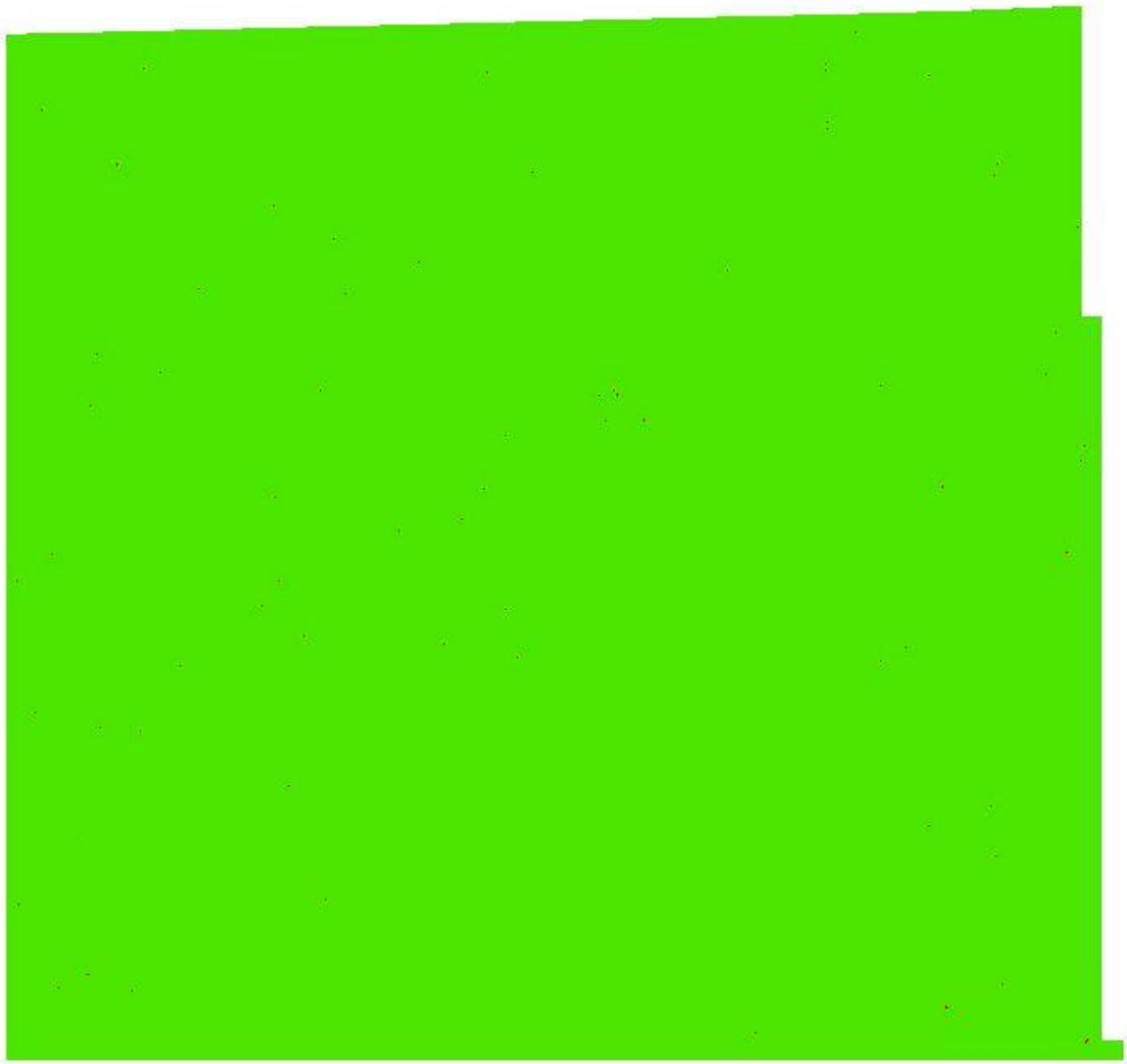


Figure 71– Spatial Distribution for Block 02. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

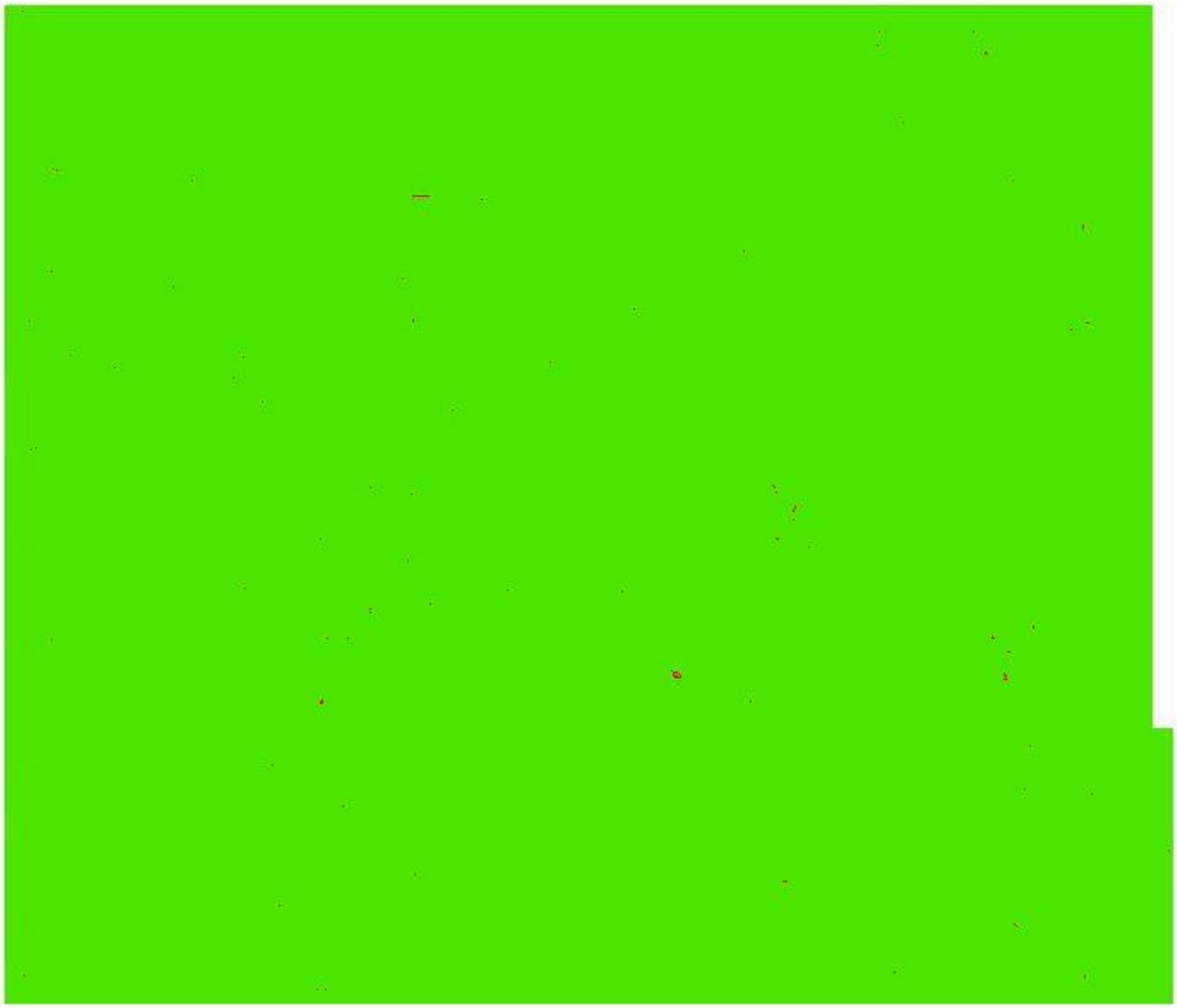


Figure 72– Spatial Distribution for Block 03. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

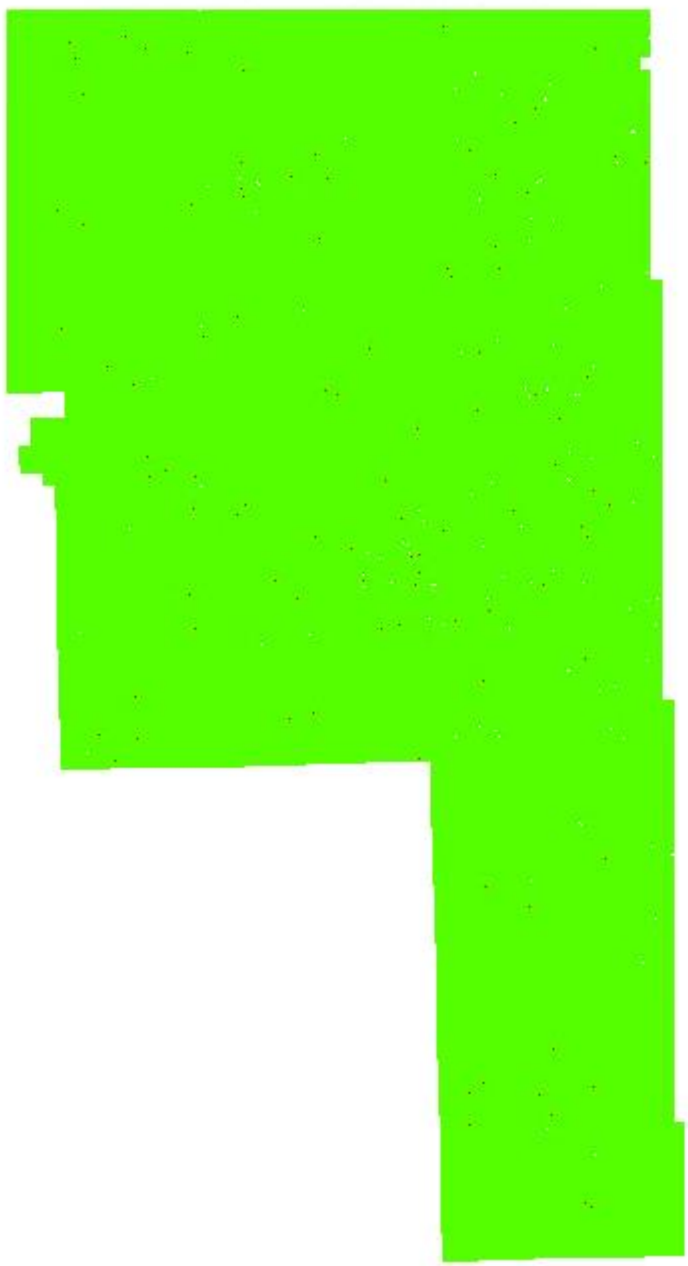


Figure 73– Spatial Distribution for Block 04. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

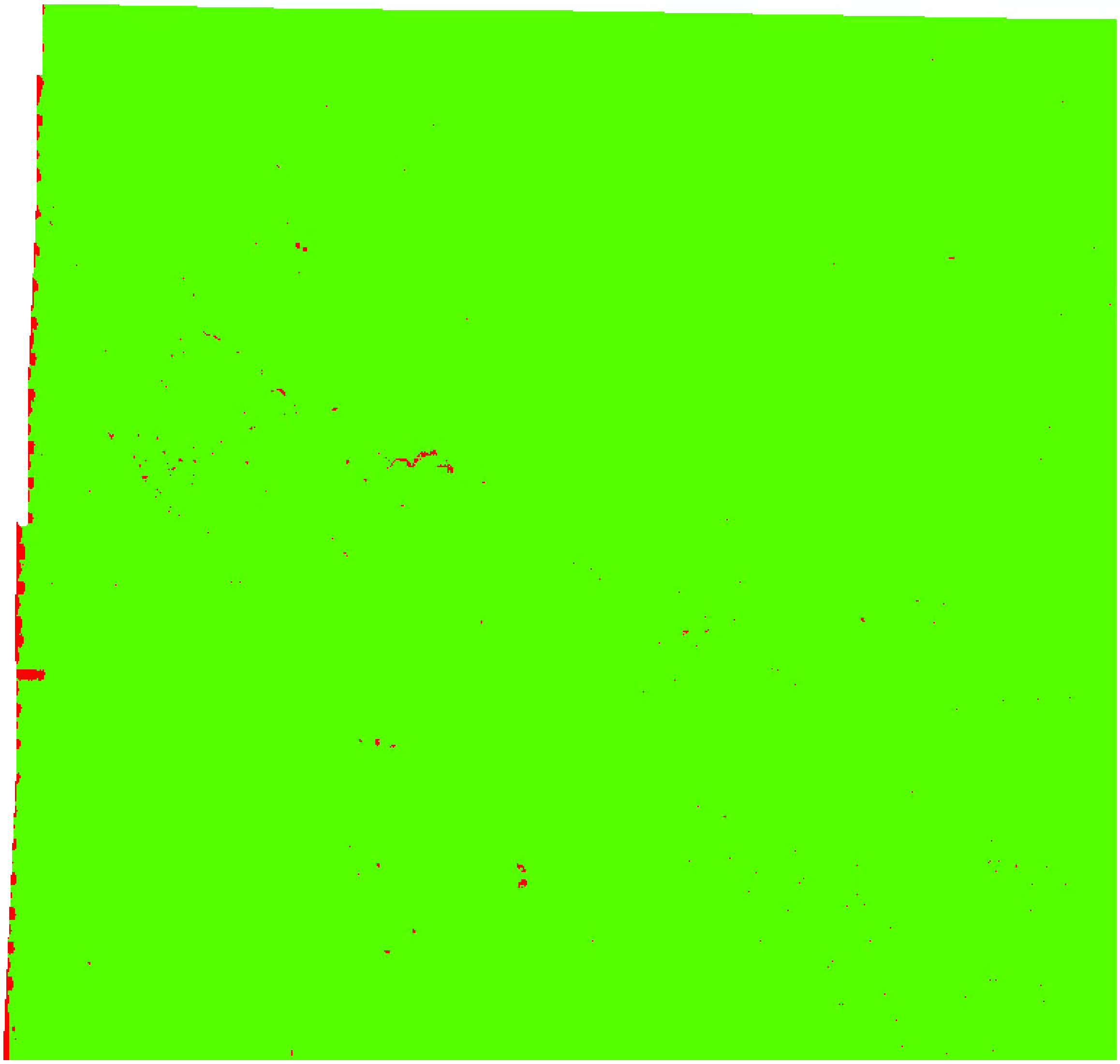


Figure 74– Spatial Distribution for Block 05 and 06. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

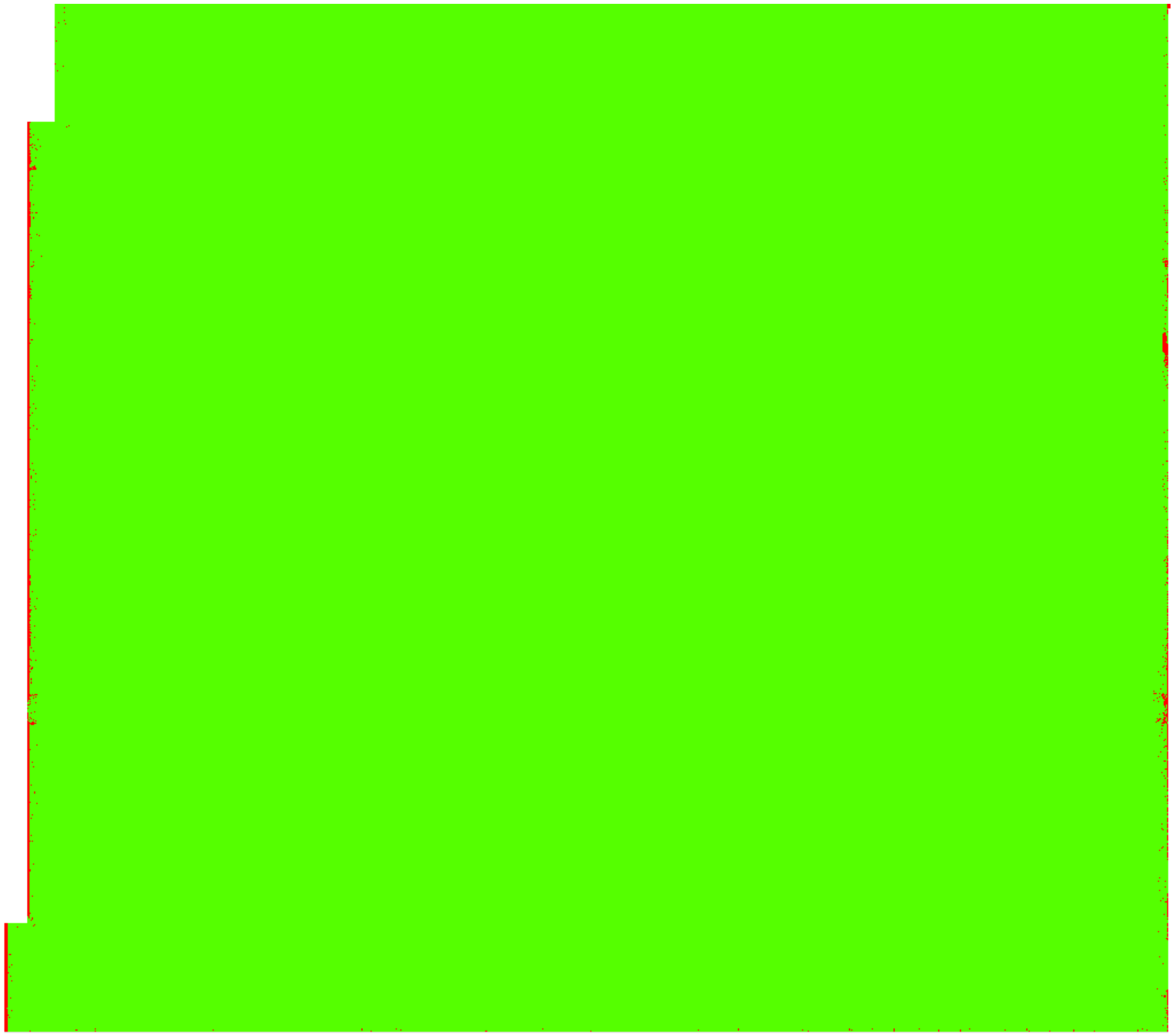


Figure 75– Spatial Distribution for Block 07. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

Figure 76– Spatial Distribution for Block 08. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

Figure 77– Spatial Distribution for Block 09. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

Figure 78– Spatial Distribution for Block 10. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

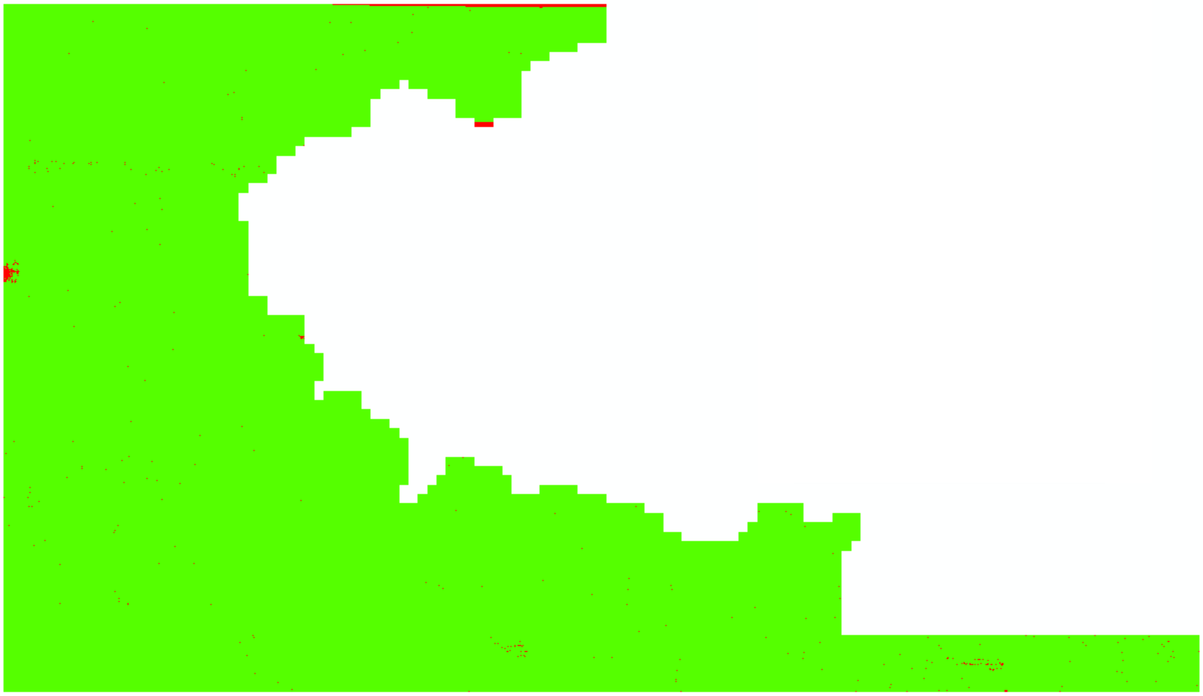


Figure 79– Spatial Distribution for Block 11. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

Figure 80– Spatial Distribution for Block 12. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

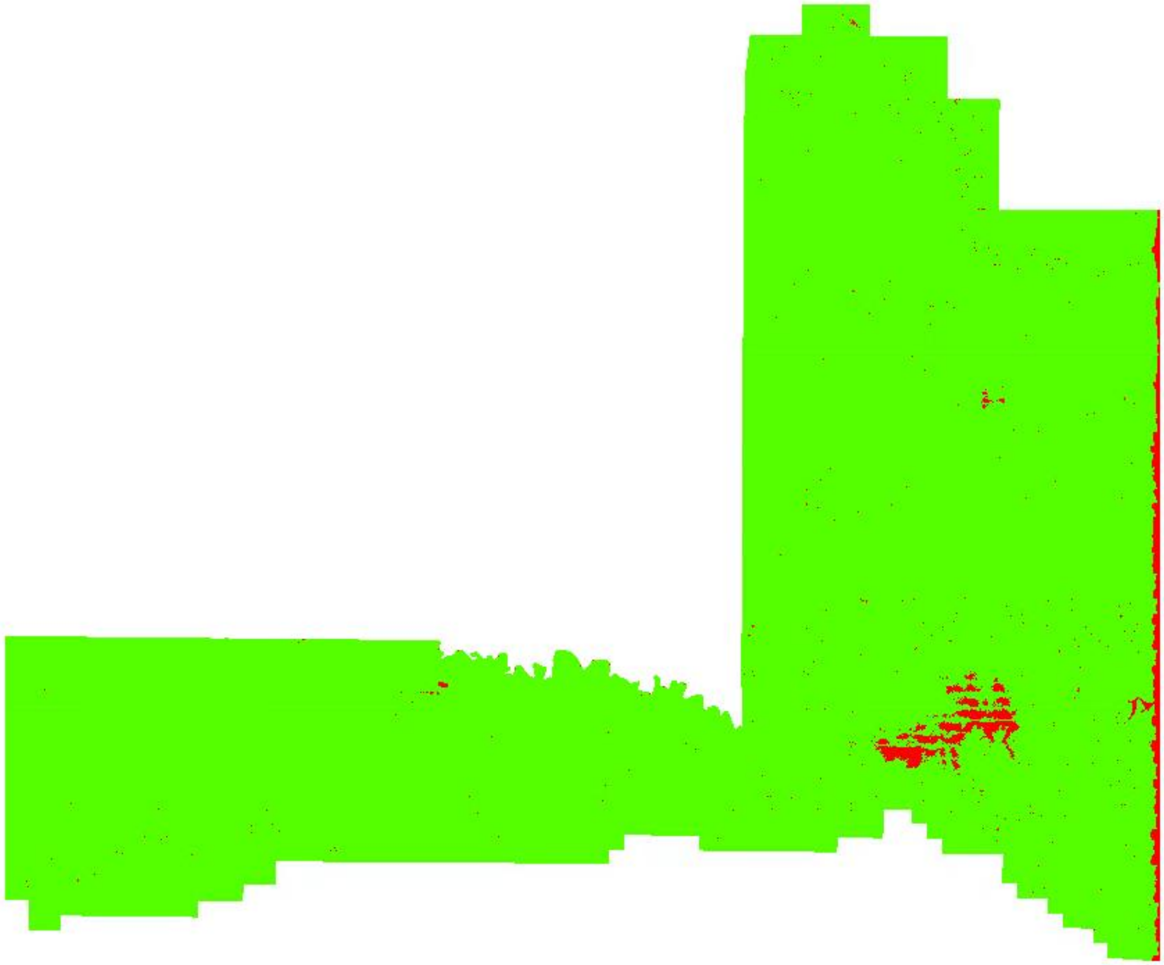


Figure 81– Spatial Distribution for Block 13. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

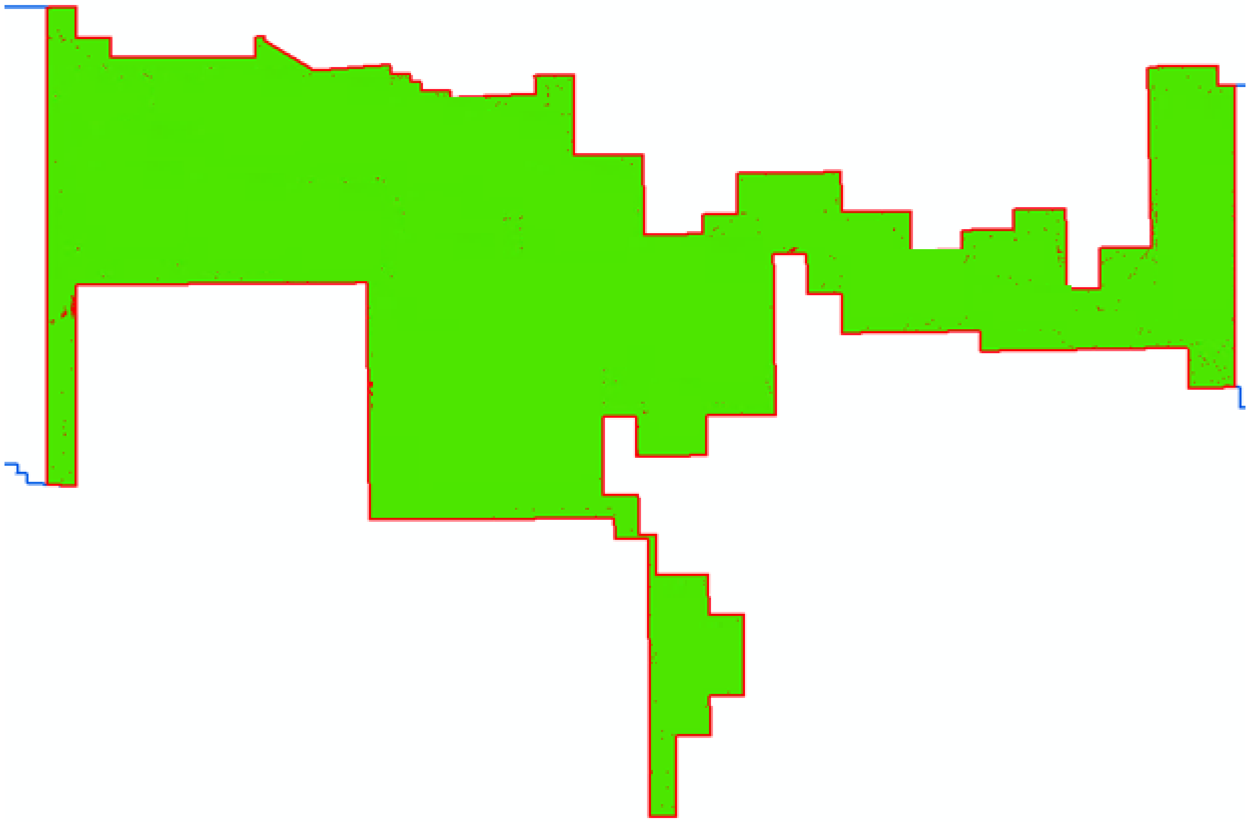


Figure 82– Spatial Distribution for Block 14. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

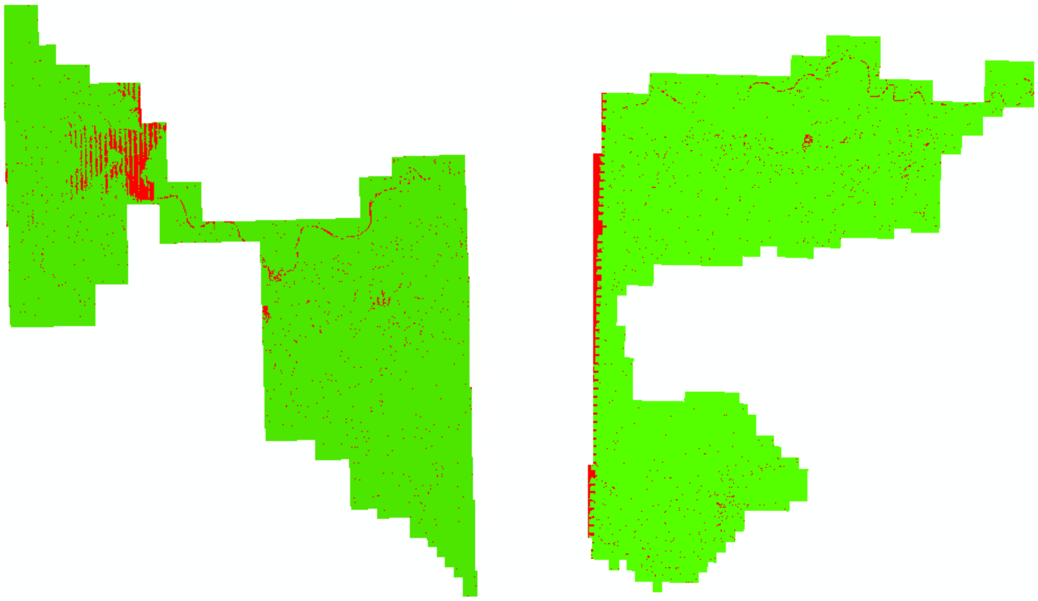


Figure 83– Spatial Distribution for Block 15. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, at least 98% of cells contain at least one lidar point.

DATA CLASSIFICATION AND EDITING

Once the calibration, absolute swath vertical accuracy, and relative accuracy of the data was confirmed, Dewberry utilized a variety of software suites for data processing. The data was processed using GeoCue and TerraScan software. The initial step is the setup of the GeoCue project, which is done by importing a project defined tile boundary index encompassing the entire project area. The acquired 3D laser point clouds, in LAS binary format, were imported into the GeoCue project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious low outliers in the dataset to class 7 and high outliers in the dataset to class 18. Points along flight line edges that are geometrically unusable are identified as withheld and classified to a separate class so that they will not be used in the initial ground algorithm. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model.

This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

Each tile was then imported into Terrascan and a surface model was created to examine the ground classification. Dewberry analysts visually reviewed the ground surface model and corrected errors in the ground classification such as vegetation, buildings, and bridges that were present following the initial processing conducted by Dewberry. Dewberry analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points are removed from the ground classification. Bridge decks are classified to class 17 using bridge breaklines compiled by Dewberry. After the ground classification corrections were completed, the dataset was processed through a water classification routine that utilizes breaklines compiled by Dewberry to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. During this water classification routine, points that are within 1x NPS or less of the hydrographic features are moved to class 10, an ignored ground due to breakline proximity. Overage points are then identified in Terrascan and GeoCue is used to set the overlap bit for the overage points and the withheld bit is set on the withheld points previously identified in Terrascan before the ground classification routine was performed.

The lidar tiles were classified to the following classification schema:

- Class 1 = Unclassified, used for all other features that do not fit into the Classes 2, 7, 9, 10, 17, or 18, including vegetation, buildings, etc.
- Class 2 = Bare-Earth Ground
- Class 7 = Low Noise
- Class 9 = Water, points located within collected breaklines
- Class 10 = Ignored Ground due to breakline proximity
- Class 17 = Bridge Decks
- Class 18 = High Noise

After manual classification, the LAS tiles were peer reviewed and then underwent a final QA/QC. After the final QA/QC and corrections, all headers, appropriate point data records, and variable length records, including spatial reference information, are updated in GeoCue software and then verified using proprietary Dewberry tools.

Lidar Qualitative Assessment

Dewberry's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology or visualization to assess the quality of the data for a bare-earth digital terrain model (DTM). This includes creating pseudo image products such as lidar orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models as well as reviewing the actual point cloud data. This process looks for anomalies in the data, areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model, and other classification errors. This report will present representative examples where the lidar and post processing had issues as well as examples of where the lidar performed well.

VISUAL REVIEW

The following sections describe common types of issues identified in lidar data and the results of the visual review for TX West Central Lidar project.

Data Voids

The LAS files are used to produce density grids using the commercial software package QT Modeler (QTM) which creates a 3-dimensional data model derived from Class 2 (ground) points in the LAS files. Grid spacing is based on the project density deliverable requirement for un-obscured areas. Acceptable voids (areas with no lidar returns in the LAS files) that are present in the majority of lidar projects include voids caused by bodies of water. No unacceptable voids are present in the TX West Central Lidar project.

Artifacts

Artifacts are caused by the misclassification of ground points and usually represent vegetation and/or man-made structures. The artifacts identified are usually low lying structures, such as porches or low vegetation used as landscaping in neighborhoods and other developed areas. These low lying features are extremely difficult for the automated algorithms to detect as non-ground and must be removed manually. The vast majority of these features have been removed but a small number of these features are still in the ground classification. The limited numbers of features remaining in the ground are usually 0.3 meters or less above the actual ground surface, and should not negatively impact the usability of the dataset.

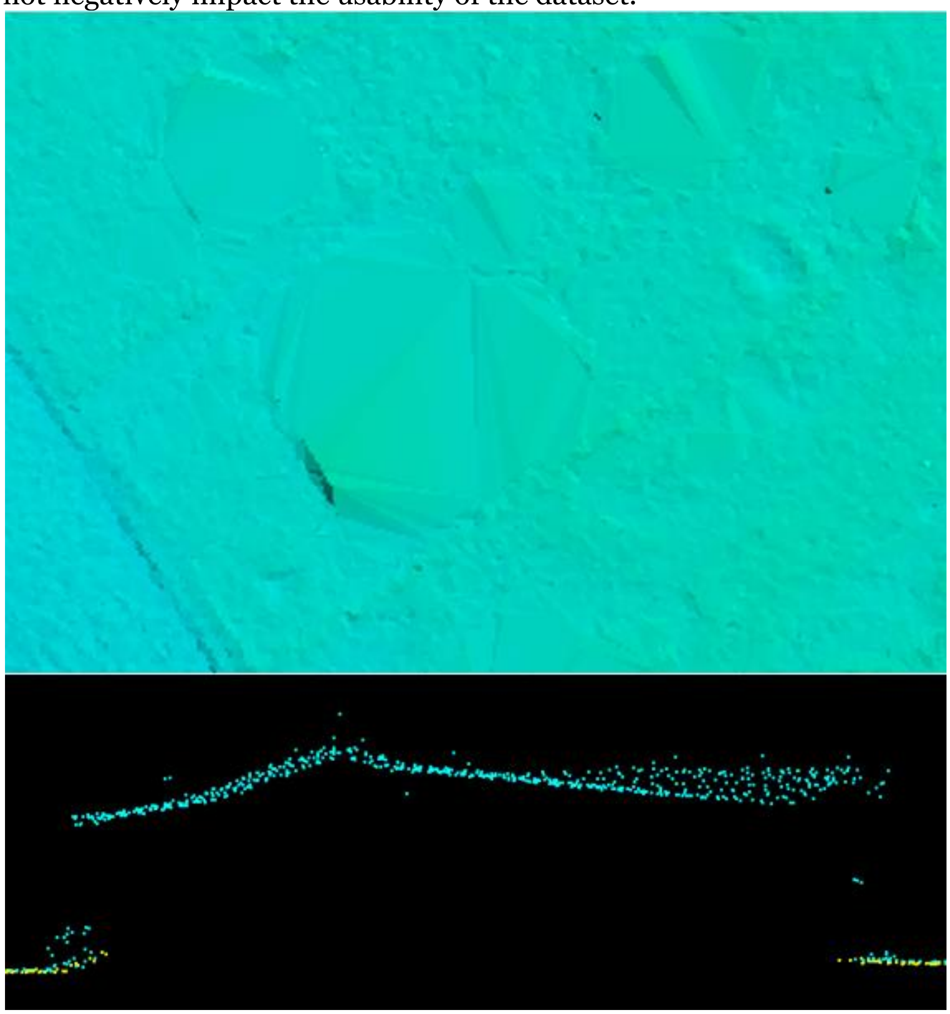
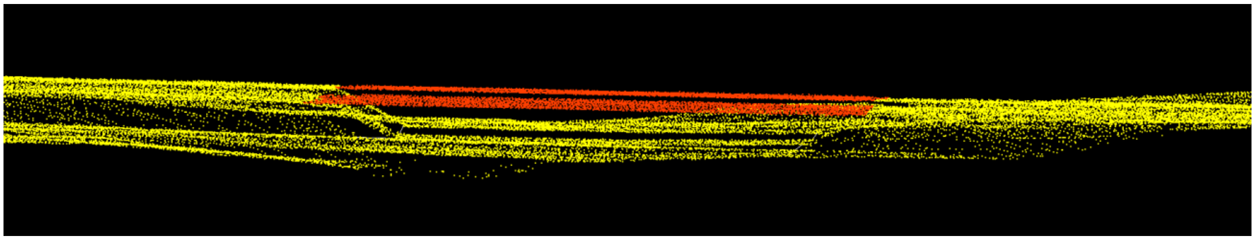
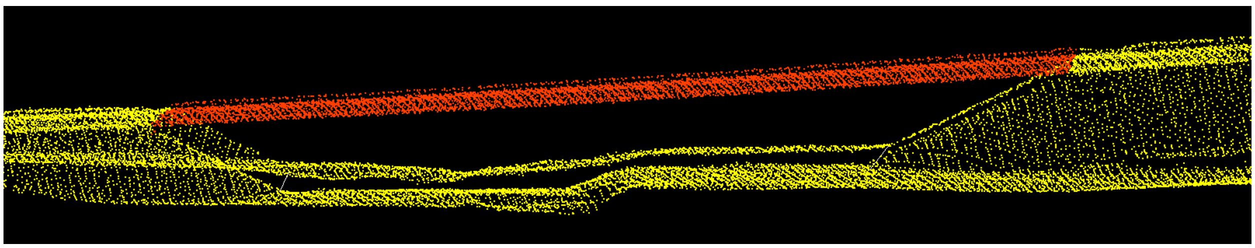


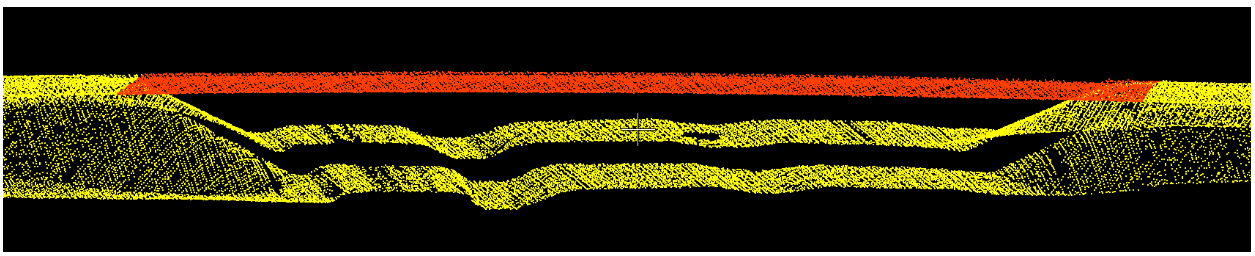
Figure 84 – Tile number 13RGR485235. Profile with points colored by class (class 2=yellow, class 1=cyan) is shown in the bottom view and a TIN of the surface is shown in the top view. A limited number of these small features are still classified as ground but do not impact the usability of the dataset.

Bridge Removal Artifacts

The DEM surface models are created from TINs or Terrains. TIN and Terrain models create continuous surfaces from the inputs. Because a continuous surface is being created, the TIN or Terrain will use interpolation to continue the surface beneath the bridge where no lidar data was acquired. Locations where bridges were removed will generally contain less detail in the bare-earth surface because these areas are interpolated.







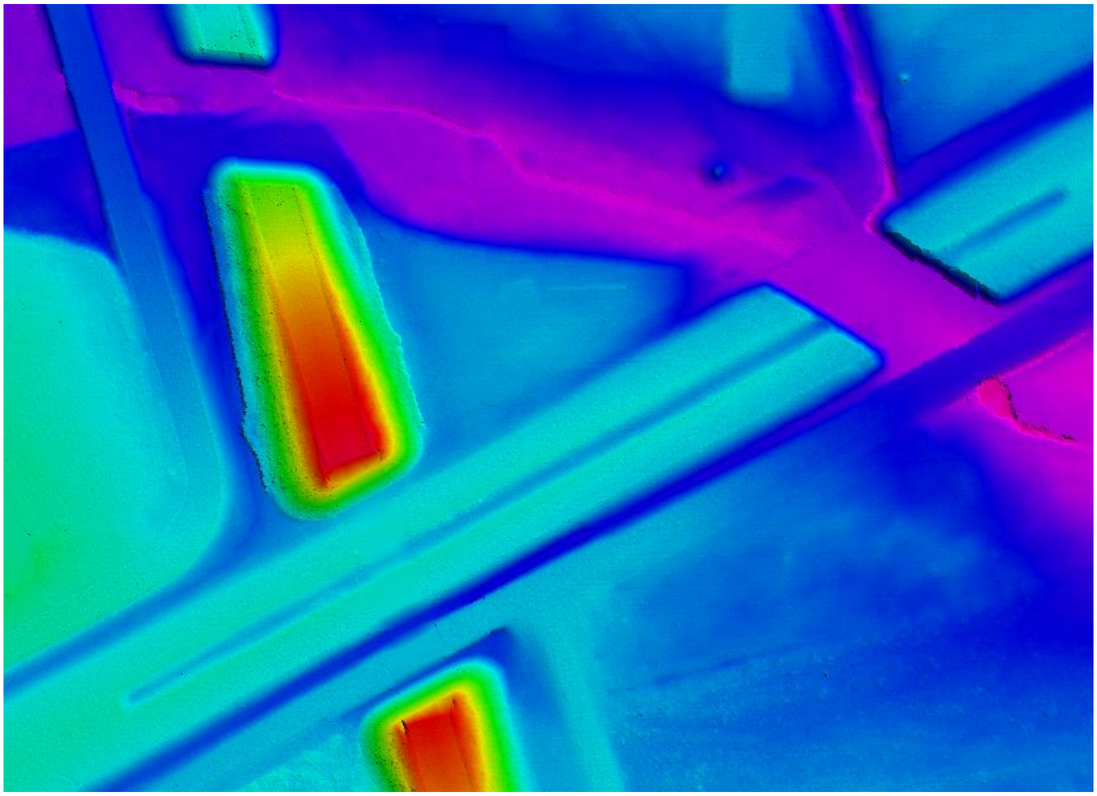
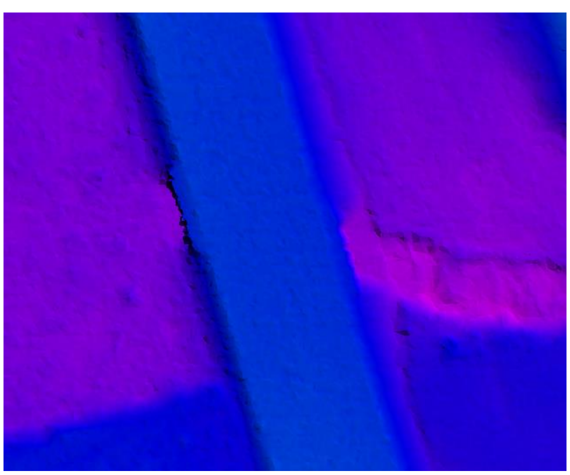


Figure 85 – Tile number 13RGR485235. The DEM in the bottom view shows an area where three bridges have been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. The profile in the top three views show the lidar points of this particular feature colored by class. All bridge points have been removed from Class 2-ground (yellow) and are Class 17- bridge deck (red).

Culverts and Bridges

Bridges have been removed from the bare earth surface while culverts remain in the bare earth surface. In instances where it is difficult to determine if the feature is a culvert or bridge, such as with some small bridges, Dewberry erred on assuming they would be culverts especially if they are on secondary or tertiary roads. Below is an example of a culvert that has been left in the ground surface.



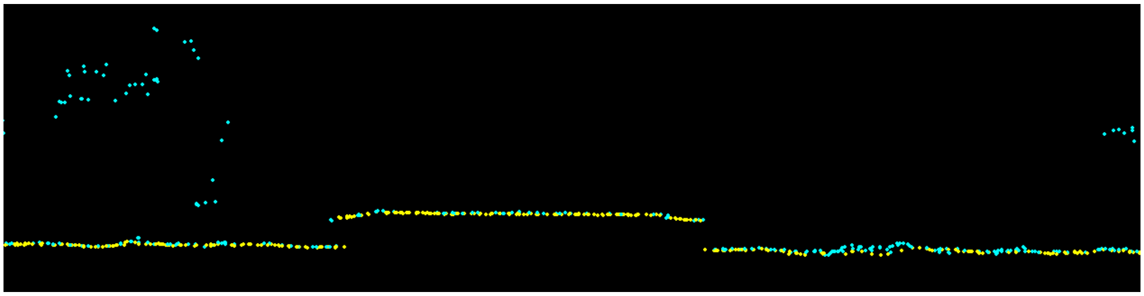


Figure 86– Tile number 13RGR485235. Profile with points colored by class (class 1=cyan, class 2=yellow) is shown in the bottom view, the DEM is shown in the top left view and an image is shown in the top right view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

Dirt Mounds

Irregularities in the natural ground exist and may be misinterpreted as artifacts that should be removed. Small hills and dirt mounds are present throughout the project area. These features are correctly included in the ground.

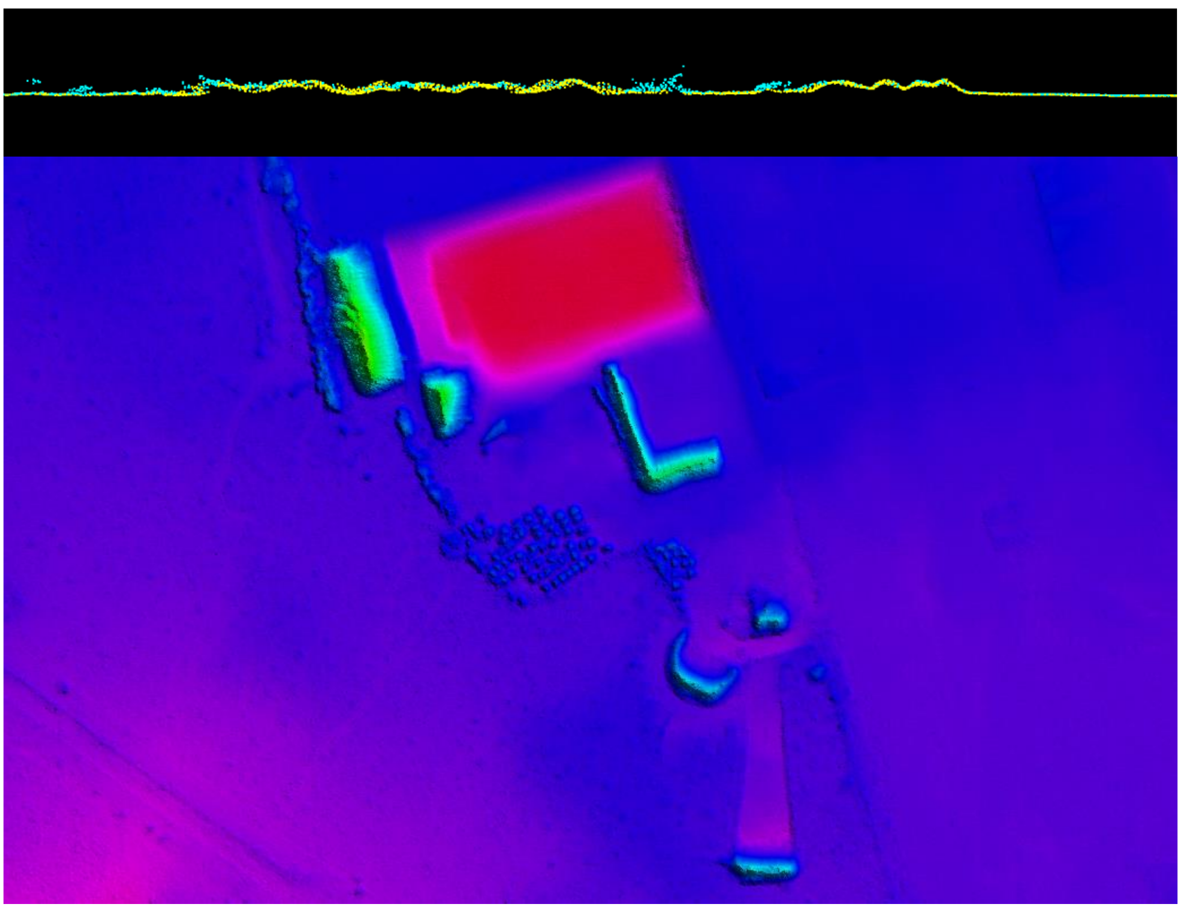


Figure 87 - Tile 13RGR500235. Profile with the points colored by class (class 1=cyan, class 2=yellow) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

Elevation Change Within Breaklines

While water bodies are flattened in the final DEMs, other features such as linear hydrographic features can have significant changes in elevation within a small distance. In linear hydrographic features, this is often due to the presence of a structure that affects flow such as a dam or spillway. Dewberry has reviewed the DEMs to ensure that changes in elevation are shown from bank to bank. These changes are often shown as steps to reduce the presence of artifacts while ensuring consistent downhill flow. An example is shown below.

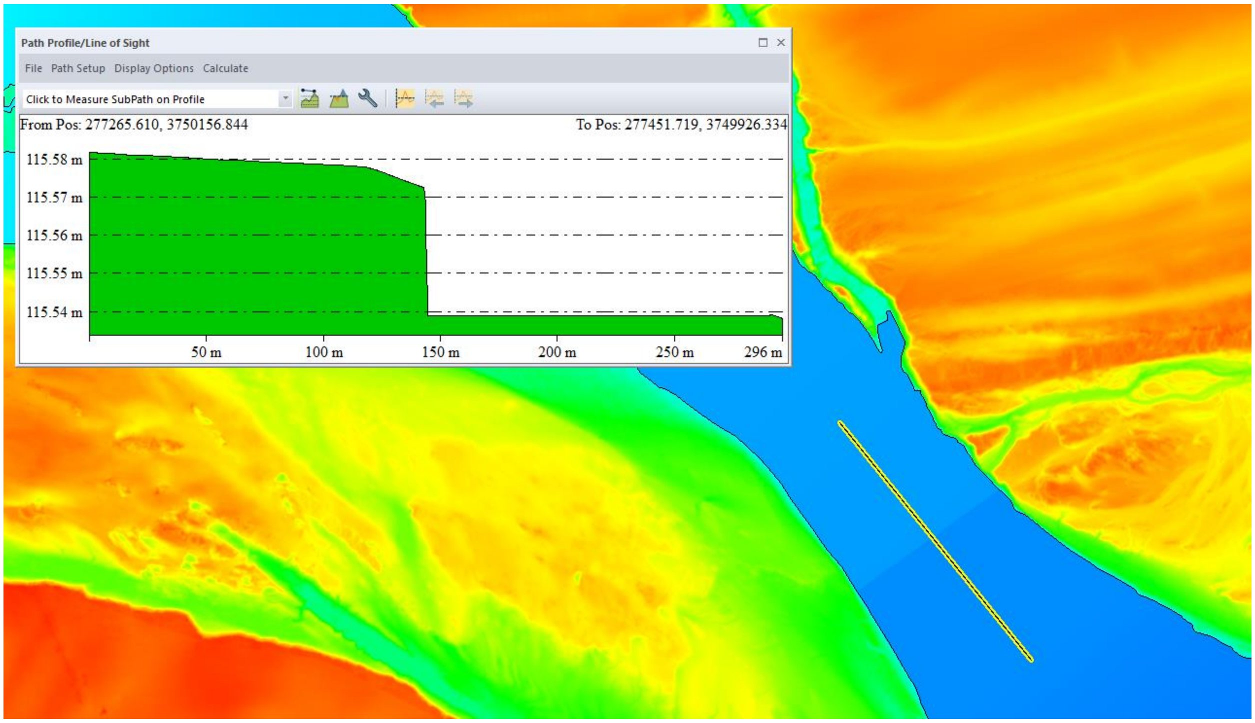


Figure 88 – Tile number 15STT760500. Elevation change has been stair stepped. The steps are flat from bank to bank and flow consistently downhill.

Precision Bombing Ranges

The TX West Central Lidar project has sites that were used until 1944 as a daytime precision bombing target by pilots and bombardiers stationed throughout New Mexico. Today, the properties are managed by the Bureau of Land management and the State of New Mexico. The U.S. Army Corps of Engineers is the organization responsible for environmental remediation of properties that were formerly owned by, leased to or otherwise possessed by the Department of Defense and transferred from DOD control prior to 17 October 1986. These properties are known as Formerly Used Defense Sites.

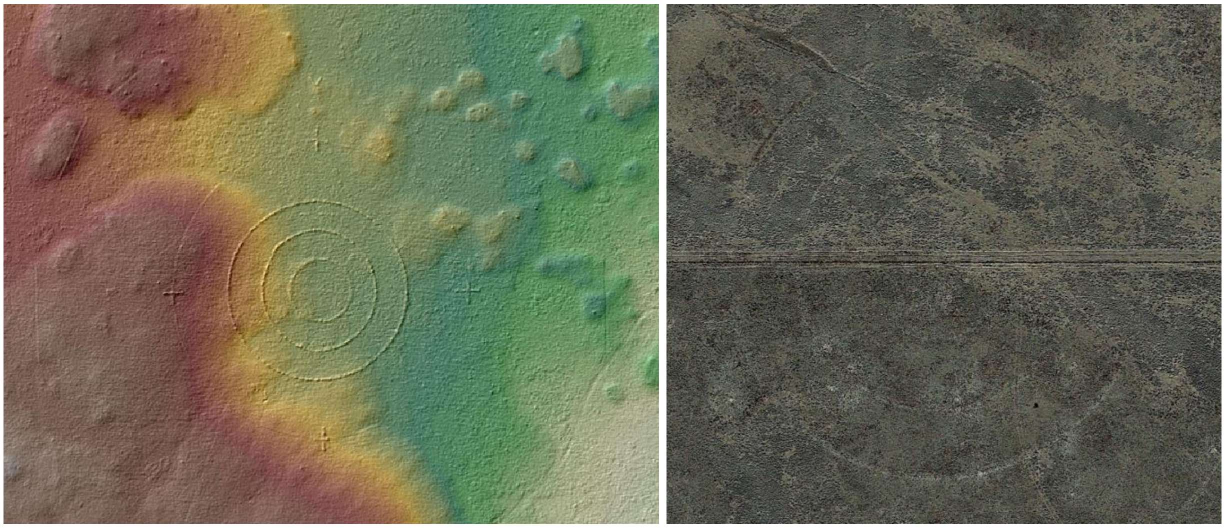


Figure 89 – Tile – 13SGS390660. The DEM on the left and the images on the right above represent a Precision Bombing Range (PBR).

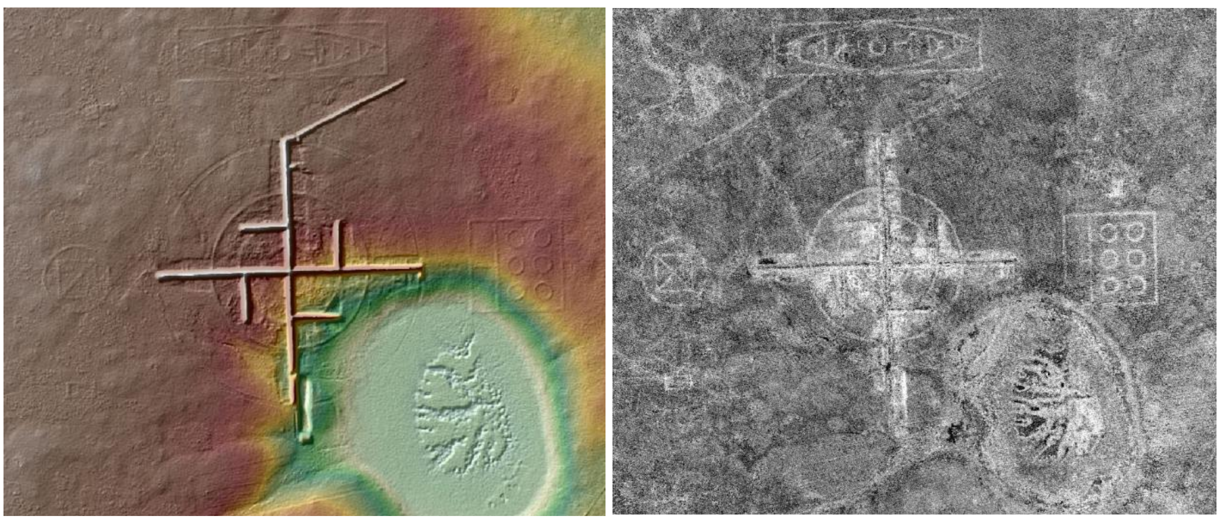


Figure 90 – Tile – 13RGR485235. The DEM on the left and the images on the right above represent a Precision Bombing Range (PBR).

Pipe Line Construction & Oil Production

The TX West Central Lidar project has a highly productive oil industry in the area. This is apparent throughout the project area due to the numerous small areas of drilling for oil in Texas. Also there is evidence of pipe construction for oil transportation. Examples are shown below.

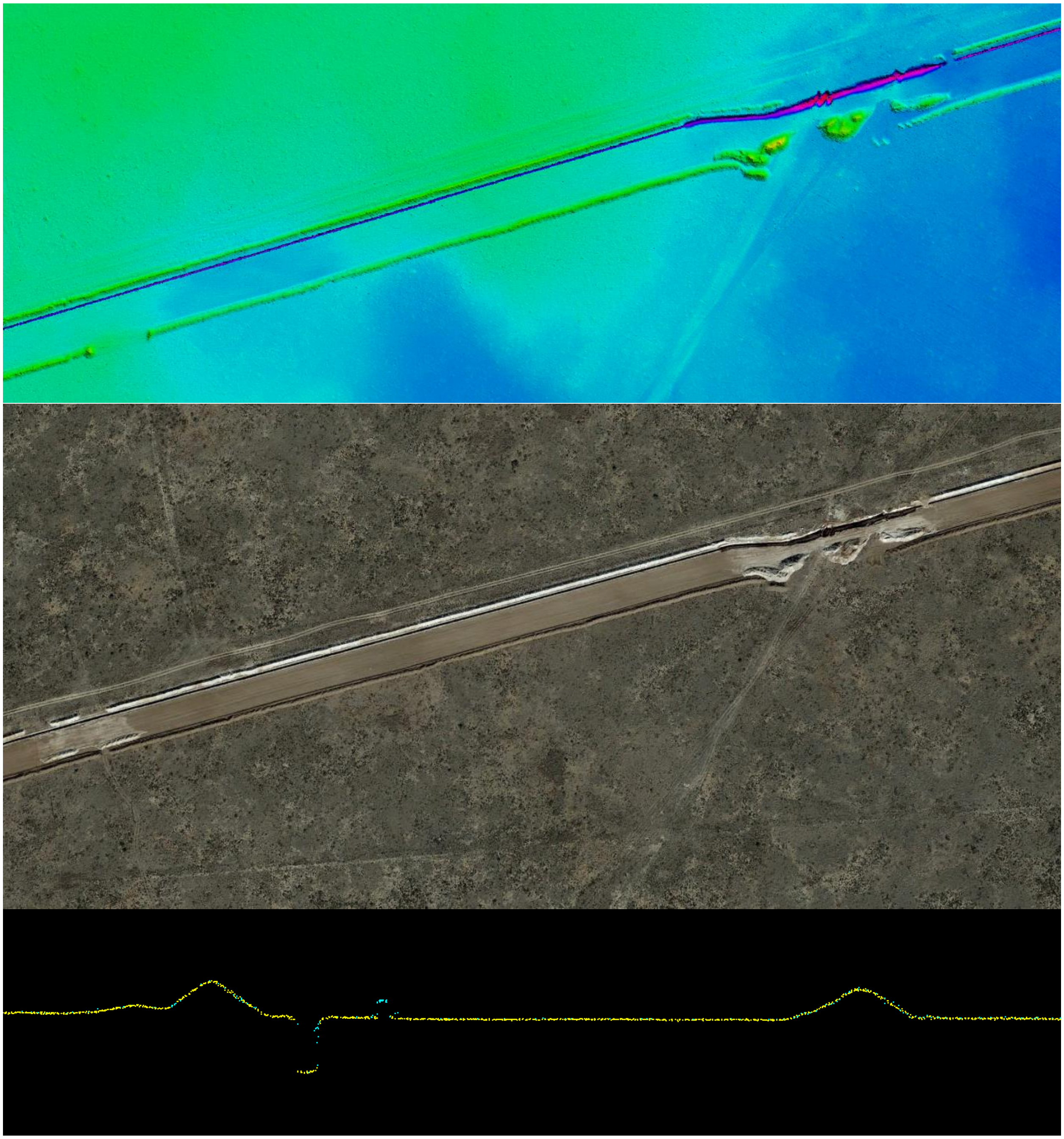


Figure 91 – Tile 13RGR140370. The top view is a tin surface that shows the pipeline construction, the image in the middle shows the pipeline construction in the aerial imagery, and a profile with the points colored by class (class 1=cyan, class 2=yellow) is shown in the bottom view.

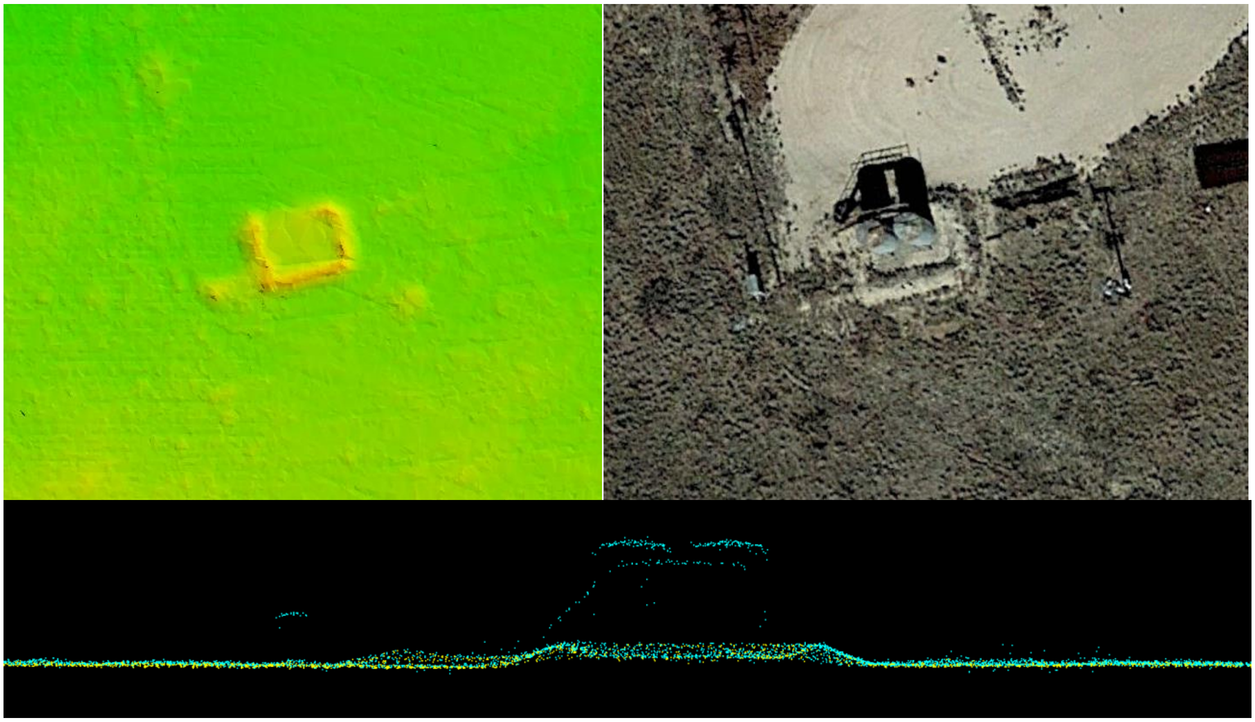


Figure 92 – Tile 13SGR125505. The tin surface upper left shows the berms where oil structures are located, the image on the upper right shows the working structures in the aerial imagery, and a profile with the points colored by class (class 1=cyan, class 2=yellow) is shown in the bottom view.

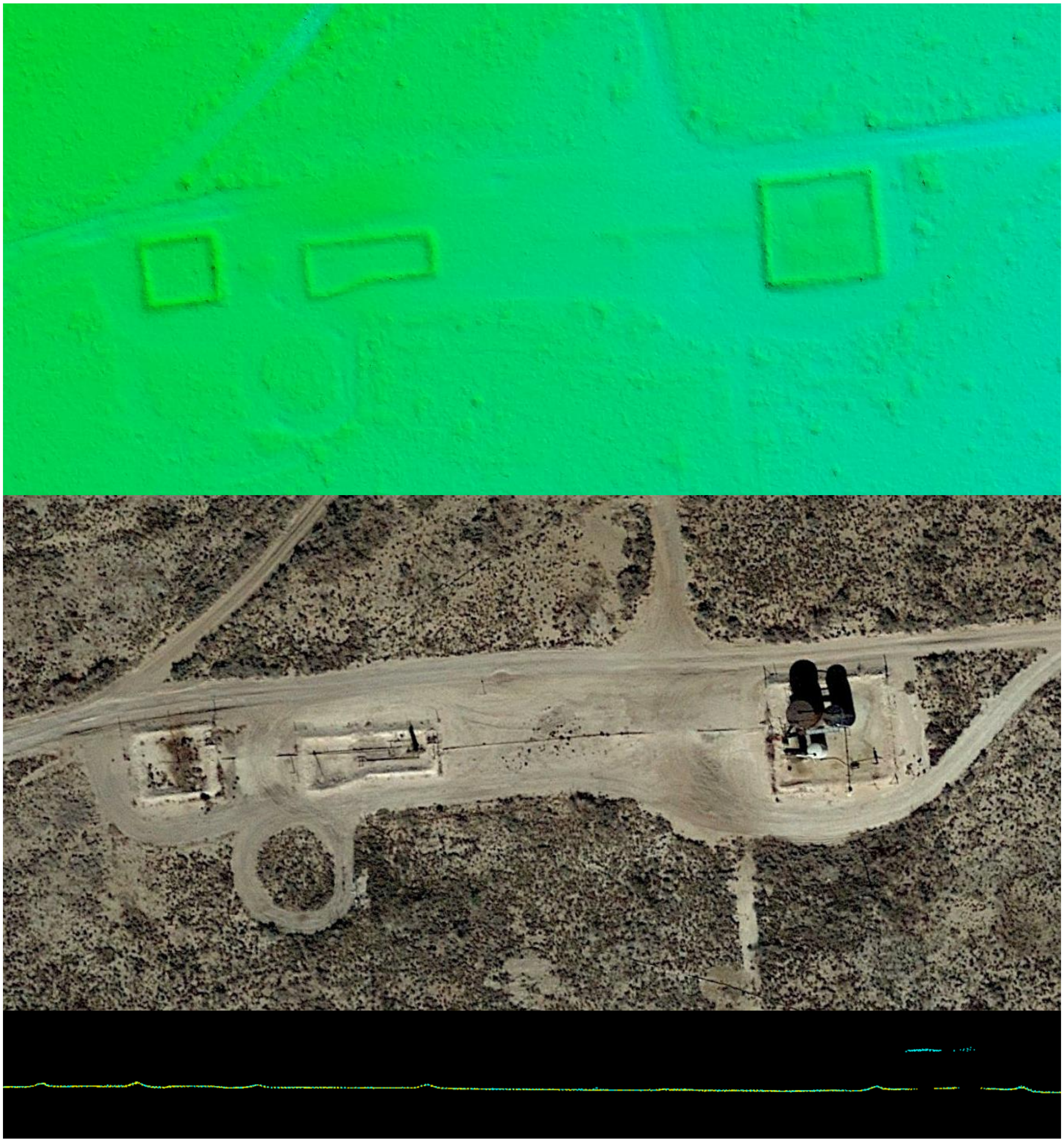


Figure 93 – Tile 13SGR110445. The top view is a tin surface that shows the berms created, the image in the middle shows the working structures in the area and a profile with the points colored by class (class 1=cyan, class 2=yellow) is shown in the bottom view.

Figure 94 – The image above shows a wide area of oil production that is common throughout the TX West Central Lidar project.

FORMATTING

After the final QA/QC is performed and all corrections have been applied to the dataset, all lidar files are updated to the final format requirements and the final formatting, header information, point data records, and variable length records are verified using Dewberry proprietary tools. The table below lists some of the main lidar header fields that are updated and verified.

Classified Lidar Formatting		
Parameter	**Requirement**	**Pass/Fail**
LAS Version	1.4	Pass
Point Data Format	Format 6	Pass
Coordinate Reference System	NAD83 (2011) UTM Zone 13, 14 & 15, meters and NAVD88 (Geoid 12B), meters in WKT Format	Pass

Global Encoder Bit	Should be set to 17 for Adjusted GPS Time	Pass
Time Stamp	Adjusted GPS Time (unique timestamps)	Pass
System ID	Should be set to the processing system/software and is set to NIIRS10 for GeoCue software	Pass
Multiple Returns	The sensor shall be able to collect multiple returns per pulse and the return numbers are recorded	Pass
Intensity	16 bit intensity values are recorded for each pulse	Pass
Classification	Required Classes include: Class 1: Unclassified Class 2: Ground Class 7: Low Noise Class 9: Water Class 10: Ignored Ground Class 17: Bridge Decks Class 18: High Noise	Pass
Overlap and Withheld Points	Overlap (Overage) and Withheld points are set to the Overlap and Withheld bits	Pass
Scan Angle	Recorded for each pulse	Pass
XYZ Coordinates	Unique Easting, Northing, and Elevation coordinates are recorded for each pulse	Pass

Table 35: Main lidar header fields that are updated and verified.

Lidar Positional Accuracy

BACKGROUND

Dewberry quantitatively tested the dataset by testing the vertical accuracy of the lidar. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest lidar points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the lidar data is actually tested. However there is an increased level of confidence with lidar data due to the relative accuracy. This relative accuracy in turn is based on how well one lidar point "fits" in comparison to the next contiguous lidar measurement, and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

Dewberry also tests the horizontal accuracy of lidar datasets when checkpoints are photo-identifiable in the intensity imagery. Photo-identifiable checkpoints in intensity imagery typically include checkpoints located at the ends of paint stripes on concrete or asphalt surfaces or checkpoints located at 90 degree corners of different reflectivity, e.g. a sidewalk corner adjoining a grass surface. The XY coordinates of checkpoints, as defined in the intensity imagery, are compared to surveyed XY coordinates for each photo-identifiable checkpoint. These differences are used to compute the tested horizontal accuracy of the lidar. As not all projects contain photo-identifiable checkpoints, the horizontal accuracy of the lidar cannot always be tested.

SURVEY VERTICAL ACCURACY CHECKPOINTS

For the vertical accuracy assessment, one thousand one hundred seventy six (1176) check points were surveyed for the project and are located within bare earth/open terrain, grass/weeds/crops, and forested/fully grown land cover categories. Please see appendix A to view the survey report which details and validates how the survey was completed for this project.

Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the "dispersed method" of placement.

All checkpoints surveyed for vertical accuracy testing purposes are listed in the following table.

Point ID	NAD83(2011) UTM Zone 13, 14, & 15		NAVD88 (Geoid 12B)
	Easting X (m)	Northing Y (m)	Elevation (m)
NVA-1	683409.755	3737093.684	1201.762
NVA-2	697685.141	3741527.179	1172.569
NVA-3	693629.723	3722367.066	1178.894
NVA-4	689502.137	3708305.624	1182.525
NVA-5	671718.753	3712849.805	1218.401
NVA-6	654187.874	3709339.451	1255.744
NVA-7	638288.486	3709666.863	1315.625
NVA-8	631417.719	3719269.171	1337.171
NVA-9	625287.374	3709622.643	1319.841
NVA-10	625288.129	3698922.303	1318.432
NVA-11	635185.118	3701121.701	1282.238
NVA-12	666343.247	3696657.011	1211.129
NVA-13	680763.267	3700147.698	1191.636
NVA-14	694467.930	3699513.978	1160.438
NVA-15	691711.115	3691284.777	1165.092
NVA-16	680763.817	3692486.757	1179.818
NVA-17	656537.811	3692106.866	1231.354
NVA-18	643742.583	3690479.840	1263.024
NVA-19	634144.886	3689089.774	1285.351
NVA-20	619608.726	3691809.835	1334.735
NVA-21	611640.953	3686260.590	1358.734
NVA-22	611732.614	3678641.611	1348.264
NVA-23	629427.045	3679025.375	1300.959
NVA-24	639818.785	3682138.770	1269.384

NVA-25	656797.764	3681320.309	1219.530
NVA-26	669489.343	3684469.924	1190.936
NVA-27	680793.299	3681491.772	1154.749
NVA-28	695343.737	3679907.696	1130.962
NVA-29	697091.991	3665451.124	1116.124
NVA-30	680790.636	3668576.375	1153.122
NVA-31	672944.313	3671652.194	1176.622
NVA-32	656898.046	3671381.098	1210.879
NVA-33	644019.474	3669569.924	1249.629
NVA-34	630317.529	3673204.413	1291.371
NVA-35	621262.235	3670639.595	1314.184
NVA-36	611860.254	3667807.594	1346.568
NVA-37	611971.798	3653444.577	1341.188
NVA-38	629619.423	3661346.983	1282.877
NVA-39	644126.520	3661564.920	1240.313
NVA-40	656999.390	3663348.443	1204.384
NVA-41	668264.827	3663510.424	1171.046
NVA-42	687422.254	3660422.063	1130.593
NVA-43	697379.670	3649327.032	1094.710
NVA-44	680885.252	3649024.795	1132.058
NVA-45	663645.560	3650572.785	1169.398
NVA-46	653133.470	3648267.275	1197.725
NVA-47	637894.229	3648509.990	1246.834
NVA-48	626605.323	3648313.768	1284.479
NVA-49	625056.623	3640813.902	1283.465
NVA-50	644342.386	3638107.160	1213.009
NVA-51	659909.096	3638430.322	1162.129
NVA-52	675205.149	3638518.043	1128.626
NVA-53	691635.993	3639343.200	1093.681
NVA-54	692025.265	3629180.490	1078.117
NVA-55	687889.162	3622099.584	1078.982
NVA-56	671576.629	3624970.917	1114.665
NVA-57	654463.854	3625011.484	1166.470
NVA-58	639981.472	3630447.645	1216.682
NVA-59	695613.202	3611481.332	1054.217
NVA-60	678005.406	3607973.750	1090.260
NVA-61	670724.891	3616326.170	1099.556
NVA-62	699852.936	3593910.011	1018.190
NVA-63	684855.988	3603642.659	1067.014
NVA-64	691309.371	3587233.374	1042.511
NVA-65	690127.849	3579345.341	1022.143
NVA-66	700365.938	3569130.481	996.048
NVA-67	684017.924	3555740.299	951.984
NVA-68	698342.005	3558040.259	976.281
NVA-69	707445.088	3740231.892	1146.679
NVA-70	726762.188	3739554.120	1110.943
NVA-71	740547.780	3739774.632	1060.038

NVA-72	753488.899	3739964.830	1049.583
NVA-73	768230.700	3739940.238	1027.869
NVA-74	774063.009	3728915.118	1019.929
NVA-75	761934.002	3729744.523	1039.214
NVA-76	751938.659	3729666.668	1056.256
NVA-77	739065.130	3729512.841	1094.894
NVA-78	729446.320	3731326.153	1107.883
NVA-79	714171.256	3727975.379	1139.359
NVA-80	707517.822	3733405.774	1147.329
NVA-81	707948.605	3716231.981	1144.830
NVA-82	721427.744	3720311.640	1121.489
NVA-83	738014.489	3719370.639	1080.162
NVA-84	755513.048	3720377.110	1047.100
NVA-85	771150.890	3719749.458	1019.760
NVA-86	774491.470	3709584.102	1011.741
NVA-87	761750.342	3708073.255	1033.530
NVA-88	743850.130	3707315.530	1056.573
NVA-89	730098.457	3706468.371	1087.255
NVA-90	717846.099	3706467.652	1115.081
NVA-91	707272.019	3707221.560	1144.324
NVA-92	702900.418	3696373.841	1143.810
NVA-93	730160.270	3699261.930	1082.074
NVA-94	746378.683	3699950.190	1055.861
NVA-95	764878.488	3697662.370	1014.133
NVA-96	772263.411	3688097.269	995.015
NVA-97	758418.538	3687680.539	1008.922
NVA-98	744196.797	3685774.182	1040.672
NVA-99	724102.069	3683739.979	1078.080
NVA-100	707975.772	3685076.817	1114.827
NVA-101	702981.267	3674328.295	1107.347
NVA-102	717797.520	3677096.947	1087.883
NVA-103	737980.387	3679239.429	1039.715
NVA-104	753786.420	3674545.605	1009.625
NVA-105	768522.545	3679117.423	989.514
NVA-106	775304.041	3667260.452	975.749
NVA-107	755959.716	3666896.499	993.073
NVA-108	739751.106	3667938.851	1026.833
NVA-109	726051.604	3665981.014	1059.997
NVA-110	709968.787	3667289.568	1090.786
NVA-111	703701.794	3655893.585	1097.849
NVA-112	718204.741	3656163.467	1064.270
NVA-113	732664.341	3656460.263	1032.788
NVA-114	748774.050	3656882.390	994.399
NVA-115	777123.363	3659255.641	948.715
NVA-116	774491.120	3648507.203	944.935
NVA-117	760880.066	3647611.063	960.687
NVA-118	748018.100	3646626.435	982.837

NVA-119	728659.306	3647742.203	1017.842
NVA-120	706295.234	3647238.412	1072.111
NVA-121	708545.080	3636927.106	1049.527
NVA-122	730253.805	3636495.127	1007.370
NVA-123	746658.065	3636896.611	960.672
NVA-124	759624.670	3637488.307	937.494
NVA-125	775829.621	3638788.552	931.030
NVA-126	705064.774	3622956.435	1042.667
NVA-127	720337.578	3622720.693	1009.611
NVA-128	742084.184	3625480.328	975.127
NVA-129	757024.711	3626871.759	956.785
NVA-130	773091.715	3627729.664	920.962
NVA-131	772739.292	3615916.527	906.681
NVA-132	758290.425	3616659.182	915.642
NVA-133	742188.698	3616831.465	955.342
NVA-134	727291.319	3615130.005	980.470
NVA-135	708418.783	3616579.323	1018.624
NVA-136	714683.288	3605220.965	1008.329
NVA-137	731050.981	3606374.127	982.707
NVA-138	744018.365	3605616.091	934.158
NVA-139	759473.718	3605550.607	907.320
NVA-140	779815.692	3606328.676	893.937
NVA-141	778115.902	3601796.902	887.639
NVA-142	754981.814	3590931.755	909.889
NVA-143	746528.043	3596022.453	929.496
NVA-144	728744.047	3596884.935	963.139
NVA-145	719762.824	3593316.923	978.839
NVA-146	706255.116	3593215.672	1013.774
NVA-147	705878.268	3583368.458	1008.249
NVA-148	720461.359	3579832.262	973.617
NVA-149	730955.203	3579901.267	967.111
NVA-150	742722.809	3585983.146	932.368
NVA-151	751699.643	3579609.694	917.257
NVA-152	768569.429	3593505.302	881.988
NVA-153	771176.865	3583798.262	882.844
NVA-154	780328.700	3573194.485	850.272
NVA-155	767871.032	3574040.796	881.477
NVA-156	755397.579	3572397.066	895.897
NVA-157	746350.501	3574140.540	924.414
NVA-158	738412.412	3571764.720	943.474
NVA-159	732255.623	3574074.236	968.085
NVA-160	722764.471	3572194.794	974.896
NVA-161	703960.761	3569837.852	1015.085
NVA-162	706432.268	3559734.638	1020.296
NVA-163	717798.956	3560581.541	980.512
NVA-164	725913.077	3563595.734	970.271
NVA-165	743486.423	3563780.697	934.087

NVA-166	761507.598	3561943.731	882.332
NVA-167	772165.865	3560927.017	878.622
NVA-168	775570.921	3550020.236	853.101
NVA-169	761442.165	3547055.556	877.753
NVA-170	750815.781	3548412.813	900.462
NVA-176	730735.379	3542396.651	951.297
NVA-177	742223.602	3536338.984	915.308
NVA-178	754145.510	3532291.994	883.840
NVA-179	763038.078	3535369.398	876.625
NVA-180	777913.609	3536538.186	844.635
NVA-181	781121.231	3525594.267	834.760
NVA-182	765830.712	3525634.371	861.738
NVA-183	756110.948	3524535.143	869.229
NVA-184	747547.516	3519355.318	885.444
NVA-185	735311.406	3525147.425	907.687
NVA-186	729673.098	3527098.351	949.297
NVA-187	711513.047	3519696.770	908.350
NVA-188	721549.479	3509520.019	872.283
NVA-189	732540.193	3505845.447	862.179
NVA-190	745738.465	3507456.888	895.241
NVA-191	758555.233	3509990.870	890.264
NVA-192	774771.945	3510023.897	863.518
NVA-193	783805.388	3500114.431	854.733
NVA-194	755639.050	3489280.149	809.658
NVA-195	757062.624	3477623.011	792.668
NVA-196	775437.089	3478636.318	860.297
NVA-197	781265.278	3464827.495	778.473
NVA-198	758570.869	3467998.665	877.470
NVA-199	758289.690	3453097.683	768.850
NVA-200	767080.745	3448993.465	756.999
NVA-201	783182.043	3452622.733	736.346
NVA-202	785209.362	3443614.294	720.730
NVA-203	765556.125	3444954.211	728.274
NVA-204	237392.646	3736660.411	1006.835
NVA-205	253063.579	3738022.695	989.376
NVA-206	267577.937	3737780.102	965.820
NVA-207	278930.498	3742188.131	953.518
NVA-208	293324.620	3737169.621	935.397
NVA-209	291618.354	3726522.597	923.199
NVA-210	282858.131	3727805.834	941.852
NVA-211	264854.340	3728360.126	965.821
NVA-212	248244.827	3727184.967	972.212
NVA-213	236319.952	3726447.684	974.381
NVA-214	225758.958	3719047.309	998.942
NVA-215	239296.313	3718647.443	968.895
NVA-216	253473.677	3720179.297	956.333
NVA-217	273118.202	3719710.024	944.844

NVA-218	292226.512	3715443.399	911.871
NVA-219	282441.735	3709753.722	917.950
NVA-220	266422.473	3708593.952	928.809
NVA-221	252926.947	3709270.040	944.387
NVA-222	237748.340	3707695.437	967.521
NVA-223	228607.637	3708484.660	993.440
NVA-224	224275.935	3697882.529	994.917
NVA-225	238676.787	3697530.737	969.827
NVA-226	258036.901	3697727.520	932.304
NVA-227	278113.747	3697525.266	787.250
NVA-228	295643.470	3698567.854	741.030
NVA-229	292091.501	3686469.624	707.632
NVA-230	273078.412	3687315.590	810.107
NVA-231	252947.955	3687901.061	937.576
NVA-232	238580.237	3684673.810	954.829
NVA-233	222398.203	3686645.994	984.886
NVA-234	239325.925	3674454.931	943.296
NVA-235	253116.537	3676209.333	920.820
NVA-236	268194.891	3677544.833	894.052
NVA-237	278800.359	3675267.589	791.420
NVA-238	297457.531	3676644.520	759.132
NVA-239	294132.181	3667122.850	702.541
NVA-240	283556.144	3669265.286	757.516
NVA-241	268685.088	3665716.922	872.591
NVA-242	257796.509	3667762.324	895.926
NVA-243	244558.643	3664885.373	919.271
NVA-244	233078.379	3662001.648	946.130
NVA-245	223360.902	3664058.199	953.220
NVA-246	224571.004	3651124.439	931.278
NVA-247	235269.740	3650961.666	928.551
NVA-248	250837.051	3655042.890	910.002
NVA-249	252711.901	3644687.046	900.595
NVA-250	271714.488	3649720.834	772.133
NVA-251	294221.182	3658119.097	685.726
NVA-252	298154.138	3653573.077	695.430
NVA-253	296952.580	3632232.758	769.501
NVA-254	285932.016	3639966.115	785.970
NVA-255	270445.877	3628353.494	789.857
NVA-256	256978.372	3634093.968	898.590
NVA-257	250709.220	3632501.991	843.490
NVA-258	236734.562	3642622.611	893.442
NVA-259	222764.491	3627320.406	915.104
NVA-260	224306.793	3618215.349	897.843
NVA-261	235556.499	3619185.770	883.310
NVA-262	245353.021	3619804.916	883.560
NVA-263	253776.079	3620079.271	806.159
NVA-264	268681.011	3620784.963	767.845

NVA-265	287181.036	3622403.581	720.890
NVA-266	297786.291	3623557.040	718.845
NVA-267	297532.502	3612068.116	712.462
NVA-268	284972.622	3604517.802	715.076
NVA-269	276152.511	3610868.890	733.530
NVA-270	266507.351	3605770.035	758.902
NVA-271	249026.394	3605751.787	852.643
NVA-272	238333.079	3609842.630	873.697
NVA-273	222311.228	3606190.320	879.788
NVA-274	290764.232	3595166.238	717.909
NVA-275	279610.825	3596572.357	782.817
NVA-276	270220.046	3594201.986	823.945
NVA-277	256575.812	3595769.751	836.183
NVA-278	246468.553	3595193.509	821.176
NVA-279	236659.721	3594521.218	819.707
NVA-280	223718.744	3593211.918	834.474
NVA-281	224061.277	3578262.545	862.662
NVA-282	234290.571	3583997.803	796.049
NVA-283	244509.906	3583092.060	783.030
NVA-284	256267.494	3582663.573	780.357
NVA-285	266915.893	3587045.158	813.635
NVA-286	276616.714	3580835.114	773.980
NVA-287	291105.759	3582544.771	692.858
NVA-288	295299.322	3571924.594	698.447
NVA-289	283253.552	3576354.454	738.679
NVA-290	270451.335	3571144.031	731.086
NVA-291	263801.272	3568872.317	784.716
NVA-292	248771.723	3572515.587	749.989
NVA-293	235710.227	3571095.707	837.613
NVA-294	223542.815	3567697.530	851.576
NVA-295	221916.257	3559507.146	830.788
NVA-296	235572.557	3558249.907	818.548
NVA-297	250120.551	3559559.211	761.905
NVA-298	258652.994	3559941.310	765.935
NVA-299	272113.644	3557790.199	852.028
NVA-300	285487.469	3556853.287	740.611
NVA-301	295050.130	3556365.943	733.183
NVA-302	290832.218	3538262.357	756.808
NVA-303	281171.572	3545923.757	787.809
NVA-304	265474.110	3544246.217	795.788
NVA-305	252714.582	3541961.497	775.473
NVA-306	242216.540	3551020.287	807.447
NVA-307	234211.748	3543028.205	807.431
NVA-308	220983.652	3545736.525	835.307
NVA-309	217011.675	3531081.697	822.170
NVA-310	229342.324	3528722.430	799.907
NVA-311	242055.034	3524813.735	805.982

NVA-312	251809.164	3528428.337	830.426
NVA-313	262887.861	3527974.966	806.317
NVA-314	276173.386	3532579.161	831.002
NVA-315	282090.979	3523811.920	797.558
NVA-316	296239.183	3525607.434	744.891
NVA-317	3515512.779	288296.971	807.975
NVA-318	3515647.011	279884.471	821.569
NVA-319	3515402.847	266473.602	828.022
NVA-320	3516612.853	257911.481	824.618
NVA-321	3517303.876	247200.617	821.765
NVA-322	236180.841	3517807.839	804.543
NVA-323	3515417.047	225950.612	845.246
NVA-324	3501608.513	219876.932	849.125
NVA-325	3502390.942	230808.072	835.088
NVA-326	3506211.263	243150.172	826.280
NVA-327	3501495.438	257784.107	814.261
NVA-328	3501810.023	270623.798	819.566
NVA-329	3502651.485	281686.973	809.891
NVA-330	3506970.752	293187.818	763.516
NVA-331	3499090.567	292206.718	796.889
NVA-332	3481861.107	278990.461	746.150
NVA-333	3488563.760	264522.003	808.065
NVA-334	3486110.228	256413.869	812.070
NVA-335	3490138.978	245392.163	811.309
NVA-336	3489701.750	233069.757	823.550
NVA-337	3489097.008	220618.372	837.230
NVA-338	3474121.874	220223.233	824.921
NVA-339	3472563.578	234609.674	811.184
NVA-340	3470458.639	244936.579	795.121
NVA-341	3477961.622	249738.833	783.821
NVA-342	3474110.326	268569.008	796.983
NVA-343	3473922.451	280331.777	736.382
NVA-344	3470809.757	287128.849	736.084
NVA-345	3464815.017	294164.467	757.362
NVA-346	3454530.699	280812.578	823.166
NVA-347	3455503.062	264922.635	812.974
NVA-348	3463603.936	255517.503	807.857
NVA-349	3457463.620	246872.984	832.266
NVA-350	3461975.671	233025.955	823.886
NVA-351	3458580.613	220026.173	786.209
NVA-352	3450697.318	215468.699	758.497
NVA-353	3451957.524	226638.341	903.477
NVA-354	3454786.507	238468.432	857.701
NVA-355	3448535.723	246988.869	895.208
NVA-356	3447768.210	264746.312	814.014
NVA-357	3443452.007	282385.620	820.831
NVA-358	3444852.800	293189.058	789.093

NVA-359	310747.065	3436141.031	783.578
NVA-360	303799.396	3444700.912	750.659
NVA-361	316030.710	3447693.214	711.250
NVA-362	330460.693	3445890.489	698.062
NVA-363	347403.122	3441251.846	718.487
NVA-364	355812.492	3442767.020	645.157
NVA-365	364205.432	3444881.935	682.856
NVA-366	371389.318	3447629.422	672.738
NVA-367	364205.432	3444881.935	682.856
NVA-368	402532.188	3447227.446	680.500
NVA-369	421273.572	3444025.638	642.561
NVA-370	436197.492	3443886.910	617.490
NVA-371	436294.993	3455444.898	581.129
NVA-372	424745.768	3454615.923	606.013
NVA-373	408344.800	3454098.116	652.717
NVA-374	401104.781	3461760.980	579.618
NVA-375	381507.671	3458203.932	642.136
NVA-376	367085.674	3455133.176	650.595
NVA-377	358268.033	3456427.266	618.589
NVA-378	345446.191	3460875.223	624.356
NVA-379	326948.681	3459091.926	675.258
NVA-380	320283.988	3464308.417	734.392
NVA-381	316861.226	3451598.963	734.344
NVA-382	305420.323	3474845.359	696.489
NVA-383	315331.905	3471451.012	672.729
NVA-384	328307.175	3470355.951	671.112
NVA-385	343960.547	3467798.274	609.306
NVA-386	356573.092	3470793.399	577.851
NVA-387	369348.004	3473275.653	568.425
NVA-388	376563.230	3471805.413	569.890
NVA-389	389679.613	3469775.015	564.659
NVA-390	396309.147	3472708.312	553.088
NVA-391	411400.511	3469874.246	568.806
NVA-392	428086.720	3466917.518	534.211
NVA-393	437939.428	3465155.970	527.781
NVA-394	482894.133	3490211.979	457.142
NVA-395	464448.891	3486859.218	454.756
NVA-396	452969.330	3487962.360	471.240
NVA-397	439681.857	3487181.032	484.743
NVA-398	421744.492	3479163.797	520.468
NVA-399	412646.691	3486368.158	496.744
NVA-400	396572.945	3484221.130	529.881
NVA-401	382383.832	3484710.710	553.514
NVA-402	371139.843	3487903.481	564.488
NVA-403	353295.123	3486012.810	595.449
NVA-404	343292.710	3479308.841	634.578
NVA-405	333173.632	3483400.649	647.531

NVA-406	319749.621	3476680.240	711.677
NVA-407	301543.022	3487753.623	782.572
NVA-408	303742.647	3500382.295	791.215
NVA-409	317498.509	3497585.931	729.811
NVA-410	330221.389	3502905.858	654.473
NVA-411	344063.616	3497904.174	616.653
NVA-412	353125.147	3495014.519	606.232
NVA-413	364554.802	3501793.391	650.023
NVA-414	384940.450	3497845.746	563.031
NVA-415	401178.685	3495936.783	514.978
NVA-416	418882.521	3498201.842	486.095
NVA-417	434185.803	3499538.162	506.420
NVA-418	447750.885	3499387.066	514.945
NVA-419	459708.471	3498782.756	491.284
NVA-420	481735.592	3501897.483	448.428
NVA-421	487468.546	3508667.427	486.985
NVA-422	468988.218	3511628.734	530.188
NVA-423	455174.389	3513782.061	507.382
NVA-424	434899.541	3511124.579	590.212
NVA-425	416908.979	3511610.457	523.281
NVA-426	409214.014	3512468.042	506.756
NVA-427	388553.817	3512549.153	529.844
NVA-428	377513.136	3510794.145	571.906
NVA-429	364252.798	3511556.461	654.197
NVA-430	337599.063	3515460.680	770.796
NVA-431	323985.704	3516477.425	668.896
NVA-432	306792.205	3512434.440	732.079
NVA-433	311699.839	3524548.908	699.091
NVA-434	326495.314	3530234.720	791.116
NVA-435	349082.216	3524800.648	637.113
NVA-436	360178.663	3527623.494	553.915
NVA-437	377609.536	3528371.089	546.833
NVA-438	397274.679	3521836.826	548.409
NVA-439	410721.398	3522458.888	520.210
NVA-440	428634.351	3522655.470	568.685
NVA-441	443765.554	3524022.932	599.602
NVA-442	461521.559	3524655.878	523.618
NVA-443	483981.894	3527020.824	457.641
NVA-444	471786.527	3534042.987	489.633
NVA-445	461554.181	3536843.102	502.528
NVA-446	448624.817	3535991.241	605.969
NVA-447	429771.787	3536178.800	615.602
NVA-448	419603.173	3532182.162	546.454
NVA-449	409296.065	3537382.762	566.551
NVA-450	395329.567	3536367.184	594.985
NVA-451	379574.789	3537993.365	606.304
NVA-452	367996.968	3535871.145	633.075

NVA-453	355603.029	3536272.689	626.052
NVA-454	342945.338	3534290.839	618.467
NVA-455	325532.150	3538079.499	692.913
NVA-456	335447.262	3543280.956	611.772
NVA-457	316776.163	3532339.902	801.991
NVA-458	306959.131	3536776.468	756.885
NVA-459	309408.758	3550629.266	709.481
NVA-460	324939.247	3554342.415	665.723
NVA-461	337533.871	3554491.402	633.740
NVA-462	341152.187	3549542.736	640.853
NVA-463	350471.525	3546306.851	641.647
NVA-464	369862.408	3544327.479	684.245
NVA-465	374978.556	3550469.745	642.614
NVA-466	395617.237	3545016.485	608.892
NVA-467	412699.249	3548352.822	581.351
NVA-468	423747.929	3545448.083	581.481
NVA-469	435081.833	3546876.081	603.044
NVA-470	450313.682	3546400.500	590.095
NVA-471	460076.381	3546315.436	553.572
NVA-472	480252.419	3545842.694	503.383
NVA-473	423864.868	3559724.691	615.472
NVA-474	411440.664	3557759.161	629.881
NVA-475	398747.719	3558324.770	680.154
NVA-476	384593.581	3560258.237	724.834
NVA-477	375170.268	3559636.825	665.562
NVA-478	365355.499	3555617.765	700.083
NVA-479	354203.432	3563107.492	751.984
NVA-480	332921.797	3564317.657	629.408
NVA-481	321854.525	3566299.309	608.424
NVA-482	309963.863	3561179.097	649.786
NVA-483	300198.102	3560915.081	692.444
NVA-484	304701.758	3574160.814	678.329
NVA-485	318855.312	3576731.339	644.830
NVA-486	328626.563	3577254.673	638.517
NVA-487	340161.241	3573251.485	703.290
NVA-488	348519.828	3576584.751	717.320
NVA-489	358096.113	3578559.415	767.398
NVA-490	363010.896	3567366.712	782.588
NVA-491	373879.181	3574471.603	773.605
NVA-492	390808.024	3569146.454	757.849
NVA-493	345306.879	3584181.490	739.235
NVA-494	343396.946	3593707.294	723.629
NVA-495	338969.685	3586714.484	699.976
NVA-496	330463.666	3592771.521	666.812
NVA-497	322975.120	3586890.974	646.409
NVA-498	307661.751	3589799.666	658.046
NVA-499	310409.311	3582024.774	662.843

NVA-500	305349.722	3600795.058	685.984
NVA-501	314781.970	3595267.581	672.857
NVA-502	323010.885	3605563.743	678.825
NVA-503	333662.506	3602725.158	732.807
NVA-504	334763.162	3612415.784	745.689
NVA-505	324797.462	3613598.465	717.175
NVA-506	315507.736	3610955.525	697.094
NVA-507	304334.029	3615162.203	710.662
NVA-508	304195.072	3627904.538	750.620
NVA-509	312790.041	3622955.786	740.407
NVA-510	320358.962	3628243.877	747.439
NVA-511	328984.950	3623128.920	746.410
NVA-512	334283.889	3628984.593	692.867
NVA-513	372502.410	3638057.350	569.399
NVA-514	343946.363	3641258.168	658.278
NVA-515	327129.728	3638148.878	706.571
NVA-516	307855.454	3640813.450	767.959
NVA-517	314246.988	3652637.004	736.565
NVA-518	324762.194	3651985.969	721.815
NVA-519	344801.243	3651755.333	634.286
NVA-520	365097.280	3652155.947	565.897
NVA-521	384175.586	3647415.014	544.349
NVA-522	400828.179	3657241.603	491.595
NVA-523	387009.593	3659142.830	551.143
NVA-524	369175.653	3662304.456	582.617
NVA-525	350985.373	3663033.409	624.009
NVA-526	330456.882	3667557.294	693.327
NVA-527	306494.786	3661590.212	712.605
NVA-528	310574.113	3672839.398	716.979
NVA-529	321210.589	3677255.100	650.146
NVA-530	336737.971	3677110.796	588.326
NVA-531	345407.982	3670000.119	596.108
NVA-532	365338.320	3671021.397	549.970
NVA-533	383405.357	3671775.314	524.864
NVA-534	405139.664	3674589.149	502.104
NVA-535	393861.007	3685859.473	539.934
NVA-536	377285.798	3684866.587	542.858
NVA-537	366647.545	3684316.538	522.518
NVA-538	349802.651	3686910.461	626.179
NVA-539	335313.923	3686425.078	656.126
NVA-540	315157.146	3689607.194	699.114
NVA-541	305005.046	3698658.264	755.318
NVA-542	322064.622	3697100.856	690.411
NVA-543	342675.817	3697747.081	654.166
NVA-544	385334.777	3691122.273	528.463
NVA-545	333744.005	3702137.793	674.312
NVA-546	343970.736	3704972.789	683.538

NVA-547	337124.160	3709845.983	707.004
NVA-548	327099.580	3708353.636	698.421
NVA-549	313744.771	3705212.601	745.344
NVA-550	305152.649	3704428.460	734.765
NVA-551	308631.348	3721399.413	893.877
NVA-552	316910.221	3714068.139	744.122
NVA-553	329602.242	3721753.712	776.068
NVA-554	352420.878	3713716.642	676.048
NVA-555	343494.562	3721018.289	669.982
NVA-556	358252.258	3719096.404	601.613
NVA-557	369309.334	3721631.527	564.023
NVA-558	376886.372	3719917.988	530.098
NVA-559	389929.443	3714676.894	550.981
NVA-560	390822.081	3725370.542	547.179
NVA-561	426271.095	3720379.507	440.761
NVA-562	425794.545	3726176.560	424.456
NVA-562A	425814.630	3725722.100	421.615
NVA-563	425803.733	3726654.527	427.582
NVA-563A	438154.582	3721312.632	402.219
NVA-564	452789.101	3724117.688	434.320
NVA-565	480097.313	3721417.501	409.558
NVA-566	500204.260	3716723.324	354.130
NVA-567	489976.295	3718590.981	395.082
NVA-568	502766.653	3728754.073	375.308
NVA-569	487846.534	3730486.098	385.711
NVA-570	487351.401	3728442.947	410.208
NVA-570A	476486.928	3729605.399	373.118
NVA-571	468814.232	3726930.404	391.657
NVA-572	460979.595	3731618.328	377.224
NVA-573	456642.893	3737594.436	385.676
NVA-574	445883.794	3734056.501	434.943
NVA-575	438015.019	3727931.280	456.689
NVA-576	425815.770	3733706.956	465.825
NVA-577	413911.581	3736457.142	521.877
NVA-578	402941.303	3737040.230	507.572
NVA-579	387821.094	3737035.160	560.760
NVA-580	375276.148	3730906.174	560.932
NVA-581	364553.407	3730487.403	606.860
NVA-582	358556.695	3736855.388	656.733
NVA-583	347777.462	3735452.967	745.243
NVA-584	340417.137	3731920.380	748.024
NVA-585	328928.022	3737759.122	797.300
NVA-586	314028.757	3728978.616	904.613
NVA-587	305616.589	3737692.690	919.499
NVA-588	314187.879	3741938.505	919.584
NVA-589	337066.089	3741895.960	726.803
NVA-590	359644.922	3741705.186	628.900

NVA-591	394268.332	3739413.699	514.730
NVA-592	426511.979	3740223.484	450.408
NVA-593	478114.166	3749346.358	382.400
NVA-594	484953.834	3743779.859	383.143
NVA-595	505475.418	3745405.052	335.027
NVA-596	495496.721	3751042.669	355.481
NVA-597	480695.978	3757310.149	346.629
NVA-598	465286.889	3754630.337	395.027
NVA-599	458950.143	3764209.537	407.623
NVA-600	476831.649	3765441.477	374.293
NVA-601	499749.660	3761522.888	358.050
NVA-602	499490.247	3775994.100	366.020
NVA-603	485137.798	3776501.403	371.489
NVA-604	472941.312	3778169.980	377.912
NVA-605	464134.954	3774282.681	381.600
NVA-606	459476.471	3786127.519	409.365
NVA-607	474467.996	3788180.230	379.781
NVA-608	485603.369	3781903.339	358.457
NVA-609	493022.279	3788947.827	355.335
NVA-610	477204.120	3797157.374	364.013
NVA-611	462368.725	3797426.415	423.810
NVA-612	460511.931	3807294.406	405.507
NVA-613	470775.159	3802917.022	411.007
NVA-614	476605.509	3808882.721	388.502
NVA-615	507780.070	3777155.191	348.473
NVA-616	523117.747	3779911.233	342.142
NVA-617	535665.298	3775986.704	315.326
NVA-618	544321.590	3775157.652	322.571
NVA-619	553116.552	3764887.691	295.965
NVA-620	540937.027	3765737.224	319.309
NVA-621	529583.349	3769387.394	334.203
NVA-622	519158.218	3768650.468	358.277
NVA-623	507766.617	3765443.057	370.319
NVA-624	510443.167	3752647.501	337.577
NVA-625	516188.111	3761025.427	326.212
NVA-626	521886.003	3749074.948	306.513
NVA-627	529921.093	3757906.061	318.527
NVA-628	538873.993	3748244.724	312.649
NVA-629	547797.081	3755922.258	296.701
NVA-630	556333.295	3771517.491	311.933
NVA-631	574656.198	3769607.125	305.567
NVA-632	585795.289	3778191.831	295.422
NVA-633	588433.590	3759365.737	284.269
NVA-634	578836.696	3758910.690	293.946
NVA-635	563283.956	3757840.717	297.459
NVA-636	555572.454	3753539.431	302.291
NVA-637	560379.712	3743709.940	281.241

NVA-638	572671.014	3746975.522	279.234
NVA-639	590029.328	3746400.877	277.292
NVA-640	598676.983	3735919.247	262.941
NVA-641	585893.115	3737894.413	284.019
NVA-642	568683.259	3732458.745	291.900
NVA-643	563247.149	3720812.456	290.784
NVA-644	579703.188	3719252.093	306.110
NVA-645	590875.906	3728290.227	307.537
NVA-646	589068.184	3709944.667	335.871
NVA-647	574578.053	3705088.736	325.851
NVA-648	562775.434	3706499.195	323.243
NVA-649	608305.805	3692210.399	299.069
NVA-650	609143.973	3674066.218	279.037
NVA-651	603155.211	3659658.168	315.540
NVA-652	602491.776	3749642.958	262.988
NVA-653	603086.336	3720248.112	292.654
NVA-654	618628.808	3725160.549	327.237
NVA-655	617601.000	3739087.705	296.652
NVA-656	618008.564	3751050.988	267.597
NVA-657	630675.711	3751156.525	243.613
NVA-658	644680.722	3741070.297	259.839
NVA-659	647579.651	3747799.107	248.665
NVA-660	664347.451	3749775.194	260.759
NVA-661	660878.821	3736308.312	224.307
NVA-662	670289.791	3739354.548	254.771
NVA-663	685839.954	3740279.175	243.927
NVA-664	694248.006	3736153.486	223.367
NVA-665	691778.102	3749541.021	227.741
NVA-666	693145.113	3762328.616	209.010
NVA-667	687352.546	3770316.196	218.552
NVA-668	694600.143	3779279.558	299.051
NVA-669	703458.580	3768985.080	264.500
NVA-670	718077.190	3764316.740	212.030
NVA-671	702454.700	3752858.940	200.920
NVA-672	714832.930	3747870.180	231.040
NVA-673	728124.250	3743824.200	164.720
NVA-674	713089.020	3737263.640	214.200
NVA-675	713377.300	3728868.200	226.720
NVA-676	702916.970	3727947.190	219.840
NVA-677	702225.340	3740239.690	203.680
NVA-678	748091.530	3734559.000	153.900
NVA-679	765386.080	3739362.380	189.690
NVA-680	772033.020	3750066.680	142.770
NVA-681	769575.250	3724435.000	180.630
NVA-682	752534.690	3723813.590	183.070
NVA-683	747908.050	3709696.290	204.070
NVA-684	761929.830	3718399.330	173.750

NVA-685	763507.740	3702748.760	216.690
NVA-686	773998.910	3709527.820	191.330
NVA-687	772324.100	3696728.050	207.820
NVA-688	777645.950	3688123.250	181.420
NVA-689	228941.695	3742832.624	150.753
NVA-690	250376.585	3748210.673	150.114
NVA-691	268979.574	3752064.409	125.432
NVA-692	279300.406	3748840.604	125.946
NVA-693	270994.652	3738143.139	131.715
NVA-694	263303.638	3731244.469	169.056
NVA-695	246416.841	3735140.980	166.324
NVA-696	234144.885	3736006.603	176.830
NVA-697	235184.942	3727808.860	176.636
NVA-698	221742.323	3717941.380	211.323
NVA-699	224849.922	3706012.384	162.996
NVA-700	226491.231	3697070.069	171.711
NVA-701	238036.368	3696759.184	155.831
NVA-702	249297.375	3684562.245	169.399
NVA-703	240794.683	3681892.592	142.506
NVA-704	228587.923	3681246.658	158.905
VVA-1	689236.408	3741411.540	1194.832
VVA-2	693564.881	3727893.957	1176.616
VVA-3	689501.678	3711652.879	1184.605
VVA-4	680753.129	3713037.074	1206.552
VVA-5	663808.020	3712751.080	1236.041
VVA-6	643080.301	3706973.576	1292.296
VVA-7	630746.183	3713470.086	1338.174
VVA-8	625172.685	3702946.055	1319.667
VVA-9	613636.285	3692573.751	1356.204
VVA-10	635044.919	3696133.216	1279.661
VVA-11	652011.913	3698027.317	1238.065
VVA-12	663823.087	3692052.553	1211.971
VVA-13	683844.314	3698900.747	1182.818
VVA-14	698240.181	3707498.060	1161.501
VVA-15	698236.016	3694703.073	1146.504
VVA-16	689861.584	3679872.267	1140.764
VVA-17	666348.061	3681179.442	1193.274
VVA-18	653807.533	3677760.154	1223.694
VVA-19	643828.066	3684802.018	1259.551
VVA-20	627802.569	3684609.463	1306.600
VVA-21	620212.874	3684519.556	1340.285
VVA-22	615970.924	3678837.286	1337.690
VVA-23	639173.962	3671151.109	1263.908
VVA-24	655283.020	3669759.651	1213.970
VVA-25	666624.323	3668342.293	1181.444
VVA-26	686456.075	3673325.537	1156.209
VVA-27	696328.162	3671744.888	1124.698

VVA-28	692412.057	3655732.651	1114.402
VVA-29	680785.615	3654088.798	1137.927
VVA-30	668756.143	3645179.555	1149.012
VVA-31	657088.176	3658592.217	1199.161
VVA-32	644216.973	3655056.401	1233.811
VVA-33	619684.473	3657985.125	1316.080
VVA-34	629608.355	3637574.674	1264.064
VVA-35	647802.972	3640542.563	1207.274
VVA-36	668802.120	3635167.704	1134.033
VVA-37	685674.351	3637218.434	1113.170
VVA-38	695498.839	3617958.776	1058.750
VVA-39	681370.800	3617731.388	1089.749
VVA-40	664276.093	3618173.847	1118.773
VVA-41	681636.248	3606087.292	1079.518
VVA-42	684982.703	3589627.699	1062.060
VVA-43	687002.913	3579282.588	1011.853
VVA-44	689003.189	3562951.060	983.206
VVA-45	693521.437	3556578.124	963.070
VVA-46	687880.574	3555811.579	964.996
VVA-47	3734289.688	713508.879	1133.841
VVA-48	3734397.951	731928.628	1095.587
VVA-49	3734756.625	753615.480	1046.131
VVA-50	3736285.339	770658.518	1006.322
VVA-51	3724850.648	765240.422	1029.860
VVA-52	3724466.110	749485.332	1061.630
VVA-53	3722674.021	729546.017	1103.250
VVA-54	3723426.279	711238.003	1144.404
VVA-55	3711900.682	709904.797	1138.182
VVA-56	3713428.156	728278.989	1098.363
VVA-57	3712570.799	746211.684	1061.135
VVA-58	3716174.464	763349.337	1029.282
VVA-59	3700981.888	773221.534	1003.106
VVA-60	3701738.313	754322.873	1042.143
VVA-61	3701413.250	734978.476	1071.692
VVA-62	3702771.906	704195.780	1142.534
VVA-63	3693508.746	722259.853	1098.277
VVA-64	3690433.180	737577.233	1049.805
VVA-65	3693991.221	753535.242	1032.162
VVA-66	3693469.784	774885.906	995.739
VVA-67	3682928.886	761938.355	993.175
VVA-68	3680772.244	744322.405	1035.437
VVA-69	3679209.249	729908.572	1069.184
VVA-70	3680159.191	708087.192	1116.507
VVA-71	713171.330	3668953.932	1088.766
VVA-72	736515.767	3669399.824	1037.935
VVA-73	767214.815	3668042.793	968.722
VVA-74	760204.233	3658822.108	970.811

VVA-75	742256.557	3660152.824	1001.174
VVA-76	724608.171	3659536.941	1047.899
VVA-77	703826.527	3658871.626	1097.406
VVA-78	720631.501	3649767.926	1046.031
VVA-79	739283.786	3650194.801	1008.550
VVA-80	758626.278	3650658.232	961.438
VVA-81	763778.720	3640364.405	947.210
VVA-82	751393.610	3640242.539	965.051
VVA-83	735267.814	3641501.601	1000.924
VVA-84	712736.714	3640924.317	1047.755
VVA-85	710702.976	3629554.238	1038.349
VVA-86	741876.917	3633515.351	970.509
VVA-87	764955.299	3630667.160	943.271
VVA-88	770093.962	3622306.571	912.388
VVA-89	746963.764	3621731.478	947.692
VVA-90	705102.311	3619775.229	1038.046
VVA-91	706658.154	3608670.856	1021.328
VVA-92	729691.621	3609593.670	977.291
VVA-93	749269.607	3611458.329	940.446
VVA-94	777039.293	3610432.954	889.653
VVA-95	771856.214	3591005.355	886.369
VVA-96	755153.890	3596227.338	922.392
VVA-97	739224.289	3591167.136	941.402
VVA-98	718332.301	3597856.646	989.960
VVA-99	713460.347	3587555.552	998.455
VVA-100	708080.794	3576154.734	1004.557
VVA-101	730133.277	3578436.997	966.252
VVA-102	740336.294	3579106.622	939.413
VVA-103	759753.399	3578074.854	906.293
VVA-104	778728.177	3578590.522	859.937
VVA-105	769484.557	3568779.823	866.884
VVA-106	757045.170	3566552.563	891.661
VVA-107	749117.953	3564853.224	908.692
VVA-108	739865.227	3568212.241	943.531
VVA-109	724761.125	3567576.342	975.728
VVA-110	712327.781	3562838.851	997.958
VVA-113	725413.051	3554489.892	950.019
VVA-114	740331.264	3553911.771	930.522
VVA-115	753128.371	3556753.976	893.031
VVA-116	773994.271	3554848.599	866.416
VVA-118	748633.277	3546022.839	901.439
VVA-119	741189.747	3539771.112	920.009
VVA-120	725096.807	3541401.323	966.534
VVA-121	709285.669	3538048.240	1019.321
VVA-122	715977.020	3527632.738	992.553
VVA-123	735029.879	3529960.063	919.543
VVA-124	756045.294	3521714.166	865.601

VVA-125	775634.422	3532812.465	835.590
VVA-126	775705.276	3515100.220	848.635
VVA-127	762320.072	3514578.498	882.237
VVA-128	750594.613	3514015.250	889.643
VVA-129	732867.729	3515789.882	940.105
VVA-130	724562.476	3511690.267	879.821
VVA-131	760036.221	3505563.664	882.085
VVA-132	768594.443	3494378.912	866.880
VVA-133	762351.732	3479160.219	807.414
VVA-134	773947.414	3460421.804	845.987
VVA-135	759266.893	3445929.925	731.564
VVA-136	768861.591	3441131.234	717.866
VVA-137	226165.488	3741791.378	1016.656
VVA-138	249931.888	3741446.975	985.982
VVA-139	262643.334	3733049.712	972.482
VVA-140	291769.494	3745016.099	938.093
VVA-141	284326.727	3730906.125	936.959
VVA-142	265576.879	3722464.728	952.015
VVA-143	248131.659	3721958.280	962.811
VVA-144	237409.299	3718978.137	963.337
VVA-145	226313.171	3709575.874	997.547
VVA-146	260152.993	3715349.323	943.668
VVA-147	277233.372	3712499.412	925.859
VVA-148	294280.835	3714634.064	910.021
VVA-149	282303.999	3700773.209	794.532
VVA-150	264004.702	3700485.566	901.670
VVA-151	246612.378	3702649.320	953.976
VVA-152	227557.185	3701196.443	992.454
VVA-153	235498.641	3691188.160	971.514
VVA-154	249870.093	3693744.204	946.582
VVA-155	262698.728	3694676.741	920.894
VVA-156	286037.733	3692203.485	742.230
VVA-157	295487.138	3684068.855	736.090
VVA-158	263303.045	3680913.484	899.631
VVA-159	246647.403	3681111.754	935.816
VVA-160	222176.573	3679111.733	979.005
VVA-161	231504.010	3665342.502	956.109
VVA-162	247863.095	3668088.414	924.731
VVA-163	269261.282	3667412.261	871.847
VVA-164	288561.455	3665344.223	735.805
VVA-165	291845.790	3658603.743	689.866
VVA-166	275664.472	3659518.218	760.150
VVA-167	255859.295	3658455.204	886.481
VVA-168	239960.822	3658581.857	927.067
VVA-169	221576.982	3659247.917	948.802
VVA-170	222452.198	3645898.343	925.287
VVA-171	253967.860	3650347.912	888.149

VVA-172	272068.942	3646587.248	819.020
VVA-173	290956.141	3644551.117	824.615
VVA-174	285748.484	3634249.668	780.651
VVA-175	270606.501	3633075.689	784.367
VVA-176	248475.424	3641867.612	904.592
VVA-177	227726.445	3635573.885	919.671
VVA-178	229831.619	3622415.215	890.809
VVA-179	252243.145	3626274.838	777.460
VVA-180	273289.925	3622267.614	756.280
VVA-181	285298.317	3624701.426	727.472
VVA-182	285040.020	3609394.336	700.582
VVA-183	269224.744	3612414.228	722.218
VVA-184	255488.358	3613874.646	784.977
VVA-185	234132.558	3603906.649	851.800
VVA-186	222907.321	3596603.213	834.175
VVA-187	240578.535	3598779.153	838.320
VVA-188	264384.790	3597998.502	828.044
VVA-189	276426.105	3595664.195	794.376
VVA-190	287253.727	3589652.617	721.554
VVA-191	272026.062	3586384.000	800.259
VVA-192	256684.608	3587732.256	796.605
VVA-193	243015.372	3587728.550	789.827
VVA-194	221192.888	3589962.146	865.406
VVA-195	223844.049	3575442.196	858.361
VVA-196	242824.218	3576633.655	762.511
VVA-197	270989.880	3577858.875	778.958
VVA-198	289309.142	3576350.879	703.815
VVA-199	291083.373	3568408.164	700.763
VVA-200	268208.425	3563811.110	845.338
VVA-201	244910.920	3567671.739	762.786
VVA-202	229233.968	3562918.904	838.151
VVA-203	232797.135	3548809.586	807.706
VVA-204	246141.253	3548647.337	795.393
VVA-205	265670.652	3549497.013	790.355
VVA-206	284759.156	3547727.986	795.238
VVA-207	290673.786	3535223.325	762.679
VVA-208	264669.205	3534073.722	809.920
VVA-209	254750.997	3534063.433	790.634
VVA-210	242624.549	3535992.116	782.428
VVA-211	224954.540	3538179.904	817.115
VVA-212	228871.574	3521393.789	814.572
VVA-213	250710.115	3523134.995	827.531
VVA-214	275884.237	3524128.895	770.293
VVA-215	290955.928	3521711.464	750.605
VVA-216	3505681.740	284306.231	810.718
VVA-217	3510558.382	274886.939	820.508
VVA-218	3507596.101	249503.561	820.274

VVA-219	3508984.988	227539.672	841.376
VVA-220	3493359.858	224398.702	838.946
VVA-221	3497096.921	242154.736	812.696
VVA-222	3493013.643	273903.598	808.777
VVA-223	3495294.975	286854.073	760.357
VVA-224	3480344.642	282453.587	727.901
VVA-225	3478854.633	267791.508	752.270
VVA-226	3484815.966	243304.948	799.793
VVA-227	3482764.601	225665.019	824.175
VVA-228	3468554.715	224613.976	823.233
VVA-229	3467705.847	238546.292	791.845
VVA-230	3464797.302	252734.973	809.300
VVA-231	3466103.194	273879.825	751.679
VVA-232	3464441.079	286590.751	757.988
VVA-233	3457339.526	292738.624	769.992
VVA-234	3454599.212	274320.995	830.242
VVA-235	3449684.095	255928.301	847.757
VVA-236	3451577.680	247111.025	861.393
VVA-237	3455541.613	225619.273	817.113
VVA-238	3447376.112	215205.214	757.301
VVA-239	3442590.674	250046.525	852.419
VVA-240	3445047.657	265549.034	812.124
VVA-241	3443027.710	286852.407	805.385
VVA-242	298119.883	3446248.903	771.372
VVA-243	311839.308	3444555.866	730.413
VVA-244	333049.239	3449551.608	671.296
VVA-245	349732.593	3442663.706	679.906
VVA-246	366194.911	3442890.787	681.105
VVA-247	385146.986	3452071.107	710.575
VVA-248	385743.946	3441510.340	696.564
VVA-249	414641.556	3443978.704	650.267
VVA-250	432901.296	3450487.402	617.271
VVA-251	408245.046	3450388.050	649.211
VVA-252	389206.872	3453723.152	644.562
VVA-253	377615.625	3461858.822	620.669
VVA-255	346756.650	3457390.272	657.984
VVA-256	329959.240	3459046.757	690.559
VVA-257	323603.046	3454121.226	685.957
VVA-258	305621.776	3463695.540	773.881
VVA-259	308518.104	3472562.226	683.256
VVA-260	322930.162	3477289.674	679.867
VVA-261	338167.166	3468484.372	623.890
VVA-262	348588.992	3469801.395	595.795
VVA-263	365091.554	3465675.021	603.555
VVA-264	394567.303	3469647.155	561.313
VVA-265	407391.105	3468916.005	562.470
VVA-266	423172.692	3465344.913	565.371

VVA-267	415220.452	3482494.398	530.664
VVA-268	404644.630	3480773.029	526.244
VVA-269	385099.885	3480955.639	542.868
VVA-270	371872.355	3482595.735	551.802
VVA-271	350961.556	3485636.971	609.011
VVA-272	339429.942	3489210.730	698.677
VVA-273	300675.177	3479738.891	709.318
VVA-274	303493.733	3496580.378	782.747
VVA-275	304570.096	3506343.628	738.687
VVA-276	325013.082	3503098.359	730.050
VVA-277	345143.491	3498905.119	632.409
VVA-278	364454.379	3498320.218	633.618
VVA-279	378593.505	3497907.711	580.392
VVA-280	411453.004	3497374.954	515.757
VVA-281	436405.442	3496201.215	499.932
VVA-282	447593.893	3493714.311	487.103
VVA-283	475415.756	3494957.452	429.352
VVA-284	476592.961	3510176.618	479.966
VVA-285	454583.593	3507562.657	507.658
VVA-286	442047.735	3512567.662	597.992
VVA-287	419035.974	3508592.552	503.562
VVA-288	393199.139	3509765.918	518.997
VVA-289	371554.433	3514820.029	595.121
VVA-290	345229.318	3520038.747	765.160
VVA-291	315750.571	3514468.222	708.804
VVA-292	301667.630	3511591.597	735.655
VVA-293	300193.852	3526457.289	738.986
VVA-294	324173.878	3520621.851	701.829
VVA-295	344461.679	3529368.956	622.659
VVA-296	362144.888	3519995.731	577.421
VVA-297	385743.230	3522005.266	529.311
VVA-298	406186.655	3524392.673	543.555
VVA-299	432670.030	3525794.021	597.703
VVA-300	448761.338	3521807.344	576.558
VVA-301	477382.112	3519995.846	476.045
VVA-302	478913.587	3534782.874	488.580
VVA-303	452408.824	3531214.935	587.360
VVA-304	436534.530	3535609.078	619.513
VVA-305	418263.991	3538524.581	547.989
VVA-306	387349.121	3537289.928	574.892
VVA-307	371997.197	3534142.190	587.948
VVA-308	353091.946	3536702.280	586.227
VVA-309	339348.267	3538510.895	628.480
VVA-310	320064.480	3532182.121	802.127
VVA-311	308810.741	3539127.934	760.604
VVA-312	300059.543	3557655.942	703.990
VVA-313	328489.146	3541283.253	657.977

VVA-314	342759.845	3549519.417	640.448
VVA-315	364193.333	3550579.478	699.559
VVA-316	388712.598	3549815.211	644.561
VVA-317	413938.433	3541850.209	583.216
VVA-318	432128.755	3546947.755	592.295
VVA-319	450242.393	3539960.731	594.723
VVA-320	469185.227	3546004.225	482.785
VVA-321	418013.995	3565983.502	629.559
VVA-322	404410.267	3556281.636	653.844
VVA-323	393118.388	3563233.721	696.263
VVA-324	375322.411	3566424.654	728.682
VVA-325	363892.540	3561700.705	747.278
VVA-326	345755.461	3559146.687	712.046
VVA-327	335539.749	3557799.045	620.053
VVA-328	312463.077	3556441.016	680.077
VVA-329	310233.382	3565272.463	635.143
VVA-330	310197.688	3578826.476	670.405
VVA-331	319971.775	3570950.269	628.272
VVA-332	336154.508	3580672.643	688.749
VVA-333	345331.360	3575928.275	708.760
VVA-334	367944.653	3571159.803	786.532
VVA-335	350098.445	3585151.834	744.137
VVA-336	340210.437	3593055.215	702.716
VVA-337	334252.970	3590196.441	694.055
VVA-338	321628.796	3595953.124	687.090
VVA-339	300587.969	3589805.090	661.554
VVA-340	299717.178	3605007.055	692.612
VVA-341	318073.601	3605752.565	675.479
VVA-342	330972.750	3603731.092	716.071
VVA-343	329627.124	3613332.498	721.623
VVA-344	317992.955	3615489.371	723.217
VVA-345	307713.323	3618259.325	708.913
VVA-346	306549.496	3628599.981	786.233
VVA-347	316280.669	3627412.136	730.141
VVA-348	335270.591	3624575.410	729.311
VVA-349	377308.666	3634993.370	605.808
VVA-350	350346.647	3637812.050	646.172
VVA-351	337095.240	3637934.832	659.881
VVA-352	324805.924	3636645.773	698.803
VVA-353	311185.061	3638963.518	765.878
VVA-354	303009.011	3640941.613	811.732
VVA-355	321426.520	3648007.278	757.253
VVA-356	326064.321	3653855.627	717.885
VVA-357	357061.726	3649744.719	650.939
VVA-358	373615.604	3650750.616	525.044
VVA-359	401755.484	3661925.118	501.824
VVA-360	380673.996	3661997.634	559.765

VVA-361	356786.651	3661011.776	606.403
VVA-362	335019.017	3659581.334	659.880
VVA-363	318813.423	3670685.744	705.045
VVA-364	306073.879	3673596.029	727.113
VVA-365	348792.892	3675712.888	581.417
VVA-366	361378.878	3675196.871	588.938
VVA-367	388275.437	3674811.874	521.527
VVA-368	400373.349	3677942.408	492.546
VVA-369	377521.613	3690737.250	525.096
VVA-370	355674.093	3686199.919	543.930
VVA-371	335363.542	3689715.527	634.522
VVA-372	309926.249	3693743.715	692.436
VVA-373	318742.298	3697137.273	689.307
VVA-374	337031.761	3693694.221	667.445
VVA-375	351658.369	3694697.250	637.894
VVA-376	338752.005	3706620.972	691.923
VVA-377	317089.807	3712732.243	748.711
VVA-378	311415.245	3722477.380	896.636
VVA-379	336629.773	3721609.944	694.903
VVA-380	354387.656	3720064.489	616.073
VVA-381	376868.412	3722679.695	529.028
VVA-382	387422.739	3720529.882	531.362
VVA-383	425593.579	3723241.034	411.576
VVA-384	492787.173	3718647.211	398.693
VVA-385	487051.029	3725307.511	388.699
VVA-386	476463.759	3727875.755	368.317
VVA-387	444146.777	3734091.772	438.885
VVA-388	416066.238	3736056.244	491.088
VVA-389	408764.107	3736743.377	506.962
VVA-390	387743.195	3732399.179	534.112
VVA-391	365000.679	3736325.818	633.892
VVA-392	349309.596	3730931.537	746.405
VVA-393	312852.779	3734529.844	913.092
VVA-394	325801.263	3741030.471	821.446
VVA-395	354974.159	3738980.325	669.080
VVA-396	399589.438	3738793.020	481.971
VVA-397	431161.742	3732638.658	466.050
VVA-398	458222.563	3735470.892	394.157
VVA-399	485675.203	3741504.090	365.685
VVA-400	491242.531	3743294.615	371.417
VVA-401	501203.400	3753460.700	320.553
VVA-402	487471.849	3756701.651	367.587
VVA-403	468138.101	3753521.244	384.691
VVA-404	462501.455	3763606.537	393.852
VVA-405	486278.022	3764069.915	345.458
VVA-406	498831.836	3765372.224	355.284
VVA-407	491325.346	3774143.242	382.055

VVA-408	478015.429	3774090.390	379.104
VVA-408A	466703.113	3771767.949	391.129
VVA-409	469383.540	3788597.553	385.780
VVA-410	479091.554	3783769.127	380.983
VVA-411	503077.655	3782010.561	338.106
VVA-412	485765.999	3789625.261	361.167
VVA-413	463276.168	3793990.851	437.369
VVA-414	483004.617	3799223.695	367.484
VVA-415	467251.800	3803537.545	415.916
VVA-416	468588.160	3813693.565	390.558
VVA-417	512869.794	3775463.579	326.473
VVA-418	531698.015	3781475.925	321.183
VVA-419	549627.103	3776706.672	308.318
VVA-420	550203.674	3762295.985	315.188
VVA-421	529832.643	3764341.246	332.617
VVA-422	515065.244	3765353.380	336.323
VVA-423	508663.273	3760775.735	352.010
VVA-424	507508.972	3751629.314	314.961
VVA-425	527200.236	3748104.013	303.152
VVA-426	551248.105	3745824.316	293.672
VVA-427	563536.595	3770738.495	293.232
VVA-428	584267.231	3770678.675	275.562
VVA-429	592433.271	3757279.262	283.887
VVA-430	576155.308	3755382.430	276.891
VVA-431	562207.070	3756089.967	287.167
VVA-432	567172.377	3737420.602	284.149
VVA-433	582667.697	3743083.551	279.402
VVA-434	597025.194	3737596.517	278.800
VVA-435	583799.314	3730767.642	284.953
VVA-436	559341.303	3726679.563	299.025
VVA-437	559354.691	3708824.113	319.669
VVA-438	583290.848	3713281.725	308.160
VVA-439	606862.612	3690910.673	302.093
VVA-440	603094.189	3667166.441	259.669
VVA-441	612486.930	3728411.995	300.144
VVA-442	613549.409	3747254.473	263.176
VVA-443	624967.835	3756860.150	243.323
VVA-444	636742.170	3746014.380	278.335
VVA-445	655670.969	3743127.635	298.857
VVA-446	668431.001	3753855.263	234.124
VVA-447	681758.056	3737101.473	210.821
VVA-448	699261.774	3731776.061	211.270
VVA-449	687117.051	3743768.309	252.463
VVA-450	681296.971	3749222.804	200.266
VVA-451	690861.906	3756171.157	234.742
VVA-452	694392.638	3767229.287	202.731
VVA-453	690740.765	3777841.253	285.402

VVA-454	701890.850	3766867.270	244.100
VVA-455	711647.660	3761109.230	215.820
VVA-456	708853.500	3741879.990	220.740
VVA-457	707712.000	3725056.310	211.450
VVA-458	717389.940	3741044.310	229.410
VVA-459	731402.520	3743818.990	170.420
VVA-460	754649.790	3735226.620	165.280
VVA-461	768140.140	3744728.880	149.430
VVA-462	763830.880	3729302.370	180.170
VVA-463	748949.080	3719416.110	184.960
VVA-464	747427.100	3705382.530	222.210
VVA-465	768241.330	3711546.180	213.120
VVA-466	762528.670	3696532.760	204.640
VVA-467	775234.700	3689709.080	178.340
VVA-468	228997.955	3747641.626	145.425
VVA-469	243116.658	3740751.518	149.413
VVA-470	261338.189	3751823.124	128.939
VVA-471	275938.659	3745993.665	126.076
VVA-472	255992.970	3734766.285	153.359
VVA-473	238915.845	3731857.855	172.448
VVA-474	224040.541	3729981.700	155.974
VVA-475	225658.668	3690170.002	166.233
VVA-476	238143.779	3700607.438	164.394
VVA-477	236982.170	3684748.444	145.010
VVA-478	229595.896	3676271.941	150.165

Table 36: TX West Central Lidar project surveyed accuracy checkpoints

One checkpoint was surveyed for vertical accuracy testing. While reviewing the final coordinates of the provided survey checkpoints, Dewberry identified two checkpoints with the same name (NVA-562). Upon discussion and review with the surveyor, it was determined that one of the NVA-562 would be renamed NVA-562A. Additionally it was also noted that the earlier delivered report stated that there were 1185 checkpoints. After review it was determined there were 1177 checkpoints and that was revised on the report. Table 36, above, includes the revised name changed for NVA-562A. The revised coordinates provided by the surveyor can also be found in Appendix A.

The figure below shows the location of the QA/QC checkpoints used to test the positional accuracy of the dataset.

USGS FEMA VI - TX West Central Checkpoint Locations

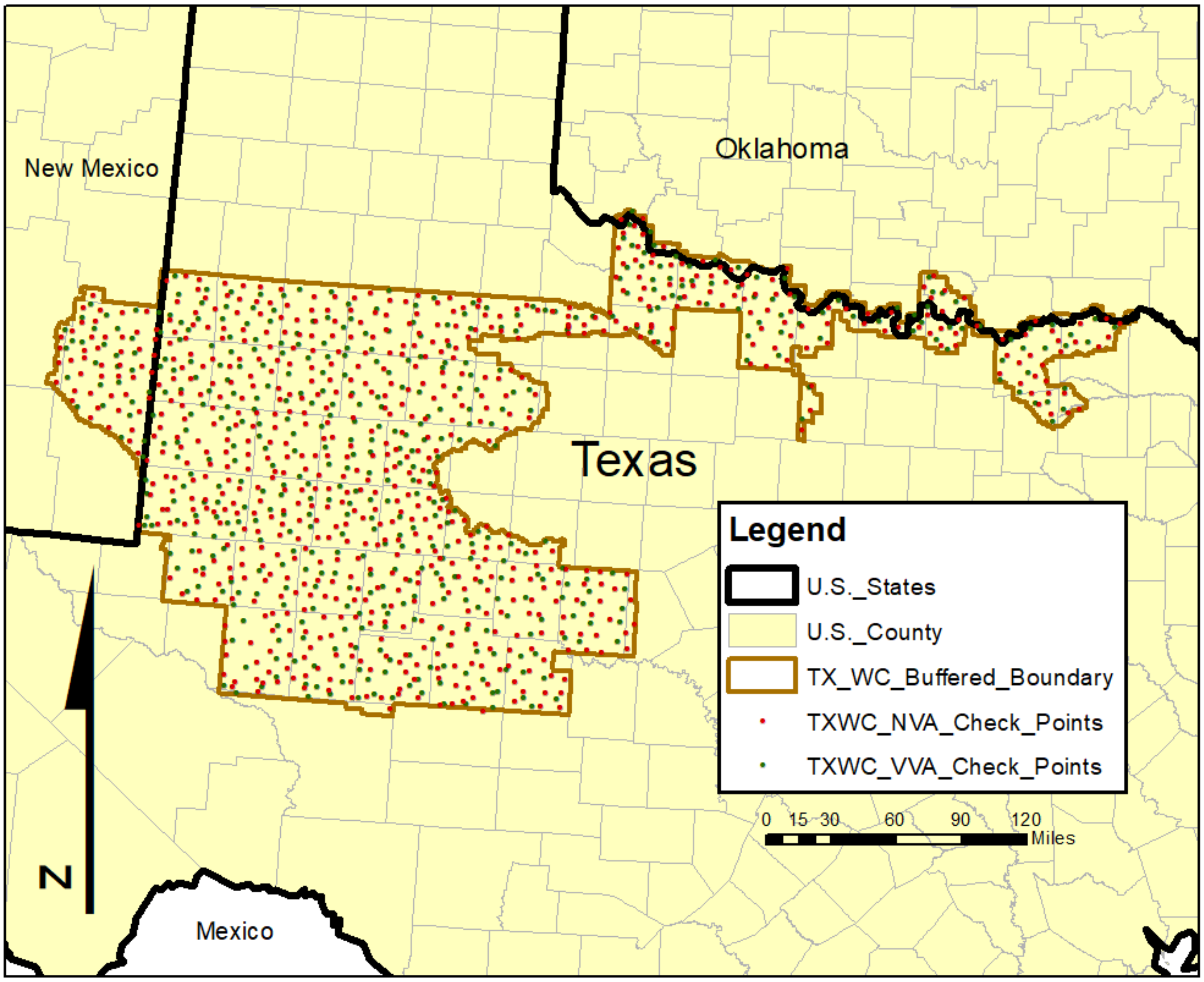


Figure 95 – Location of QA/QC Checkpoints

VERTICAL ACCURACY TEST PROCEDURES

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in non-vegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the lidar sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated lidar sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error ($RMSE_z$) of the checkpoints x 1.9600. For the TX West Central Lidar project, vertical accuracy must be 19.6 cm or less based on an $RMSE_z$ of 10 cm x 1.9600.

VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the lidar sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all vegetated land cover categories combined. The TX West Central Lidar project VVA standard is 29.4 cm based on the 95th percentile. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95th percentile used to compute the VVA; these are always the largest outliers that may depart from a normal error distribution. Here, $Accuracy_z$ differs from VVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas VVA assumes lidar errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

The relevant testing criteria are summarized in Table 37.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using $RMSE_z$ *1.9600	19.6 cm (based on $RMSE_z$ (10 cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	29.4 cm (based on combined 95th percentile)

Table 37 – Acceptance Criteria

The primary QA/QC vertical accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications.
2. Next, Dewberry interpolated the bare-earth lidar DTM to provide the z-value for every checkpoint.
3. Dewberry then computed the associated z-value differences between the interpolated z-value from the lidar data and the ground truth survey checkpoints and computed NVA, VVA, and other statistics.
4. The data were analyzed by Dewberry to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

VERTICAL ACCURACY RESULTS

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified lidar LAS files.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=29.4 cm
NVA	701	9.1	
VVA	475		11 .7

Table 38 – Tested NVA and VVA

This lidar dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be

$RMSE_z$ =4.7 cm, equating to +/- 9.1 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 11.7 cm at the 95th percentile.

The figure below illustrates the magnitude of the differences between the QA/QC checkpoints and lidar data. This shows that the majority of lidar elevations were within +/- 5 cm of the checkpoints elevations, but there were some outliers where lidar and checkpoint elevations differed by up to +20 cm.

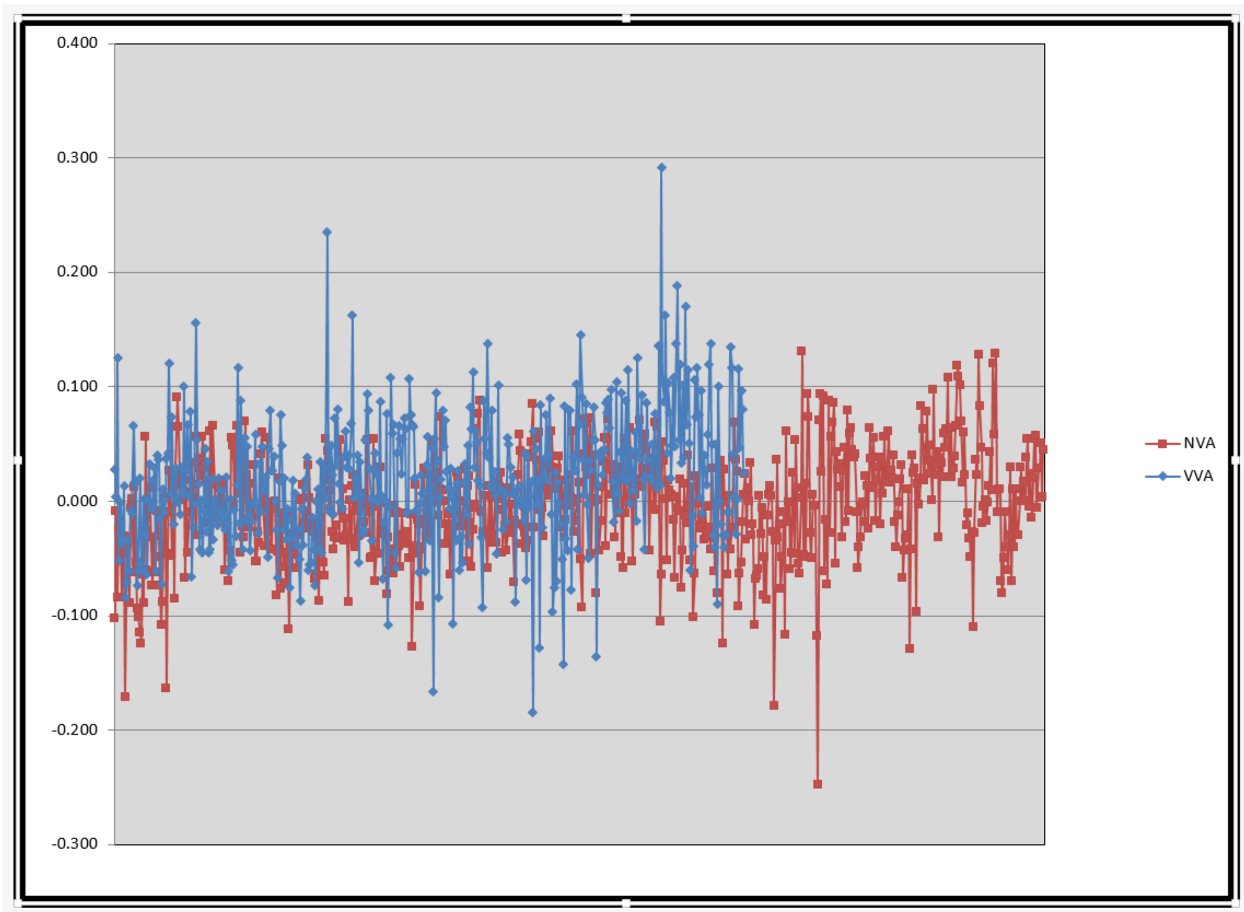


Figure 96 – Magnitude of elevation discrepancies per land cover category

Table 39 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83(2011) UTM Zone 13, 14 & 15N		NAVD88 (Geoid 12B)		DeltaZ	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Z-Survey (m)	Z-LiDAR (m)		
VVA-3	689501.678	3711652.879	1184.605	1184.730	0.125	0.125
VVA-62	704195.780	3702771.906	1142.534	1142.690	0.156	0.156
VVA-468	228997.955	3747641.626	145.425	145.560	0.135	0.135
VVA-164	288561.455	3665344.223	735.805	736.040	0.235	0.235

VVA-183	269224.744	3612414.228	722.218	722.380	0.162	0.162
VVA-244	333049.239	3449551.608	671.296	671.130	-0.166	0.166
VVA-286	442047.735	3512567.662	597.992	598.130	0.138	0.138
VVA-320	469185.227	3546004.225	482.785	482.600	-0.185	0.185
VVA-325	363892.540	3561700.705	747.278	747.150	-0.128	0.128
VVA-343	329627.124	3613332.498	721.623	721.480	-0.143	0.143
VVA-356	326064.321	3653855.627	717.885	718.030	0.145	0.145
VVA-368	400373.349	3677942.408	492.546	492.410	-0.136	0.136
VVA-399	485675.203	3741504.090	365.685	365.810	0.125	0.125
VVA-414	483004.617	3799223.695	367.484	367.620	0.136	0.136
VVA-416	468588.160	3813693.565	390.558	390.850	0.292	0.292
VVA-419	549627.103	3776706.672	308.318	308.480	0.162	0.162
VVA-427	563536.595	3770738.495	293.232	293.370	0.138	0.138
VVA-428	584267.231	3770678.675	275.562	275.750	0.188	0.188
VVA-430	576155.308	3755382.430	276.891	277.010	0.119	0.119
VVA-434	597025.194	3737596.517	278.800	278.970	0.170	0.170
VVA-469	243116.658	3740751.518	149.413	149.530	0.117	0.117
VVA-452	694392.638	3767229.287	202.731	202.850	0.119	0.119
VVA-453	690740.765	3777841.253	285.402	285.540	0.138	0.138

Table 39 — 5% Outliers

Table 40 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) Spec=0.100 m NVA Spec=0.1 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	701	0.047	-0.005	-0.004	-0.342	0.046	1.383	-0.248	0.131
VVA	475	N/A	0.019	0.017	0.293	0.056	1.718	-0.185	0.292

Table 40 — Overall Descriptive Statistics

The figure below illustrates a histogram of the associated elevation discrepancies between the QA/QC checkpoints and elevations interpolated from the lidar triangulated irregular network (TIN). The frequency shows the number of discrepancies within each band of elevation differences. Although the discrepancies vary between a low of -0.248 meters and a high of +0.292 meters, the histogram shows that the majority of the discrepancies are skewed on the positive side. The vast majority of points are within the ranges of -0.05 meters to +0.05 meters.

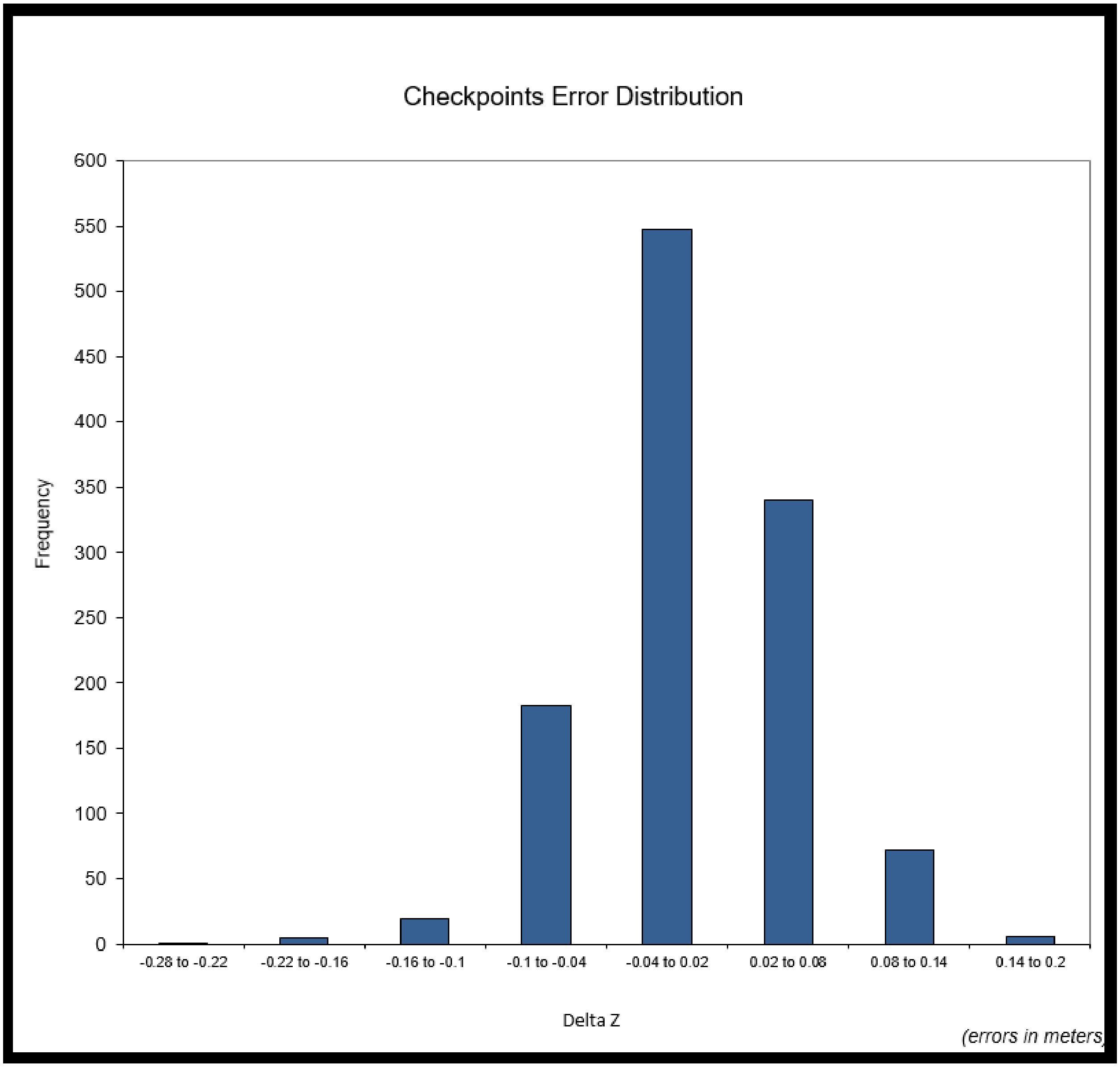


Figure 97 – Histogram of Elevation Discrepancies with errors in meters

Based on the vertical accuracy testing conducted by Dewberry, the lidar dataset for the TX West Central Lidar project satisfies the project's pre-defined vertical accuracy criteria.

HORIZONTAL ACCURACY TEST PROCEDURES

Horizontal accuracy testing requires well-defined checkpoints that can be identified in the dataset. Elevation datasets, including lidar datasets, do not always contain well-defined checkpoints suitable for horizontal accuracy assessment. However, the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) recommends at least half of the NVA vertical check points should be located at the ends of paint stripes or other point features visible on the lidar intensity image, allowing them to double as horizontal check points.

Dewberry reviews all NVA checkpoints to determine which, if any, of these checkpoints are located on photo-identifiable features in the intensity imagery. This subset of checkpoints are then used for horizontal accuracy testing.

The primary QA/QC horizontal accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications and tried to locate half of the NVA checkpoints on features photo-identifiable in the intensity imagery.
2. Next, Dewberry identified the well-defined features in the intensity imagery.
3. Dewberry then computed the associated xy-value differences between the coordinates of the well-defined feature in the lidar intensity imagery and the ground truth survey checkpoints.
4. The data were analyzed by Dewberry to assess the accuracy of the data. Horizontal accuracy was assessed using NSSDA methodology where horizontal accuracy is calculated at the 95% confidence level. This report provides the results of the horizontal accuracy testing.

HORIZONTAL ACCURACY RESULTS

One hundred ten checkpoints were determined to be photo-identifiable in the intensity imagery and were used to test the horizontal accuracy of the lidar dataset.

Using NSSDA methodology (endorsed by the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014)), horizontal accuracy at the 95% confidence level (called ACCURACYr) is computed by the formula RMSEr * 1.7308 or RMSExy * 2.448.

# of Points	$RMSE_x$ (Target=41 cm)	$RMSE_y$ (Target=41 cm)	$RMSE_r$ (Target=58 cm)	$ACCURACY_r$ ($RMSE_r$ x 1.7308) Target=100 cm
110	26.5	23.5	35.5	61.4

Table 41-Tested horizontal accuracy at the 95% confidence level

Breakline Production & Qualitative Assessment Report

BREAKLINE PRODUCTION METHODOLOGY

Dewberry used GeoCue software to develop lidar stereo models of the project area so the lidar derived data could be viewed in 3-D stereo using Socet Set softcopy photogrammetric software. Using lidargrammetry procedures with lidar intensity imagery, Dewberry used the stereo models to stereo-compile the three types of hydrographic breaklines in accordance with the project's Data Dictionary.

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are at a constant elevation where the lowest elevation of the water body has been applied to the entire water body.

BREAKLINE QUALITATIVE ASSESSMENT

Dewberry completed breakline qualitative assessments according to a defined workflow. The following workflow diagram represents the steps taken by Dewberry to provide a thorough qualitative assessment of the breakline data.

Completeness and horizontal placement is verified through visual reviews against lidar intensity imagery. Automated checks are applied on all breakline features to validate topology, including the 3D connectivity of features, enforced monotonicity on linear hydrographic breaklines, and flatness on water bodies.

The next step is to compare the elevation of the breakline vertices against the ground elevation extracted from the ESRI Terrain built from the lidar ground points, keeping in mind that a discrepancy is expected because of the hydro-enforcement applied to the breaklines and because of the interpolated imagery used to acquire the breaklines. A given tolerance is used to validate if the elevations differ too much from the lidar.

After all corrections and edits to the breakline features, the breaklines are imported into the final GDB and verified for correct formatting.

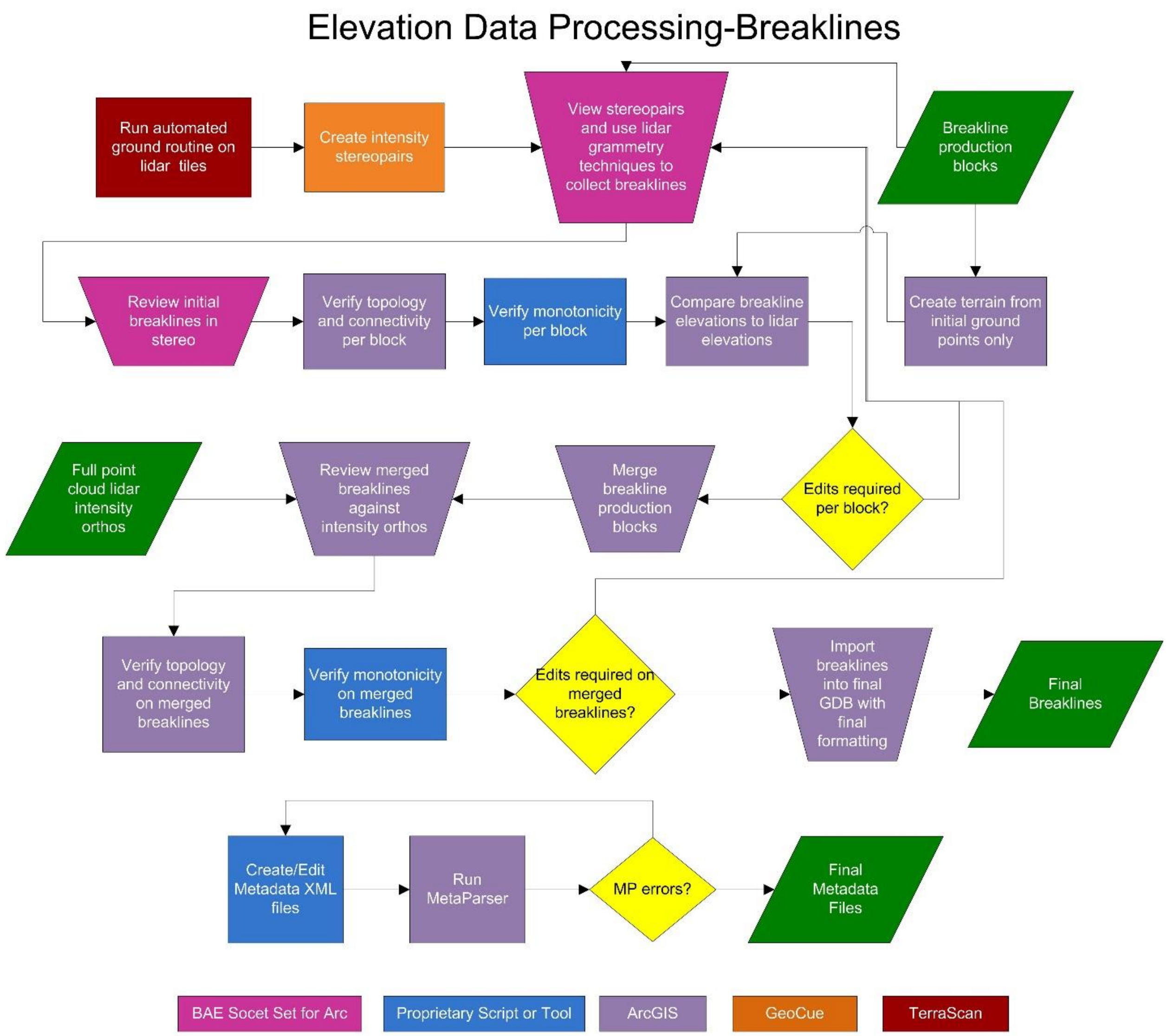


Figure 98-Breakline QA/QC workflow

BREAKLINE CHECKLIST

The following table represents a portion of the high-level steps in Dewberry's Production and QA/QC checklist that were performed for this project.

Pass/Fail	Validation Step
Pass	Use lidar-derived data, which may include intensity imagery, stereo pairs, bare earth ground models, density models, slope models, and terrains, to collect breaklines according to project specifications.
Pass	In areas of heavy vegetation or where the exact shoreline is hard to delineate, it is better to err on placing the breakline *slightly* inside or seaward of the shoreline (breakline can be inside shoreline by 1x-2x NPS).

Pass	After each producer finishes breakline collection for a block, each producer must perform a completeness check, breakline variance check, and all automated checks on their block before calling that block complete and ready for the final merge and QC
Pass	After breaklines are completed for production blocks, all production blocks should be merged together and completeness and automated checks should be performed on the final, merged GDB. Ensure correct snapping-horizontal (x,y) and vertical (z)-between all production blocks.
Pass	Check entire dataset for missing features that were not captured, but should be to meet baseline specifications or for consistency. Features should be collected consistently across tile bounds. Check that the horizontal placement of breaklines is correct. Breaklines should be compared to full point cloud intensity imagery and terrains
Pass	Breaklines are correctly edge-matched to adjoining datasets in completion, coding, and horizontal placement.
Pass	Using a terrain created from lidar ground (all ground including 2, 8, and 10) and water points (class 9), compare breakline Z values to interpolated lidar elevations.
Pass	Perform all Topology and Data Integrity Checks
Pass	Perform hydro-flattening and hydro-enforcement checks including monotonicity and flatness from bank to bank on linear hydrographic features and flatness of water bodies. Tidal waters should preserve as much ground as possible and can include variations or be non-monotonic.

Table 42-A subset of the high-level steps from Dewberry's Production and QA/QC checklist performed for this project.

DATA DICTIONARY

The following data dictionary was used for this project.

Horizontal and Vertical Datum

The horizontal datum shall be North American Datum of 1983(2011), Units in Meters. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in Meters. Geoid12B shall be used to convert ellipsoidal heights to orthometric heights.

Coordinate System and Projection

All data shall be projected to UTM Zone 13, 14 & 15, Horizontal Units in Meters and Vertical Units in Meters.

Inland Streams and Rivers

Feature Dataset: BREAKLINES
Feature Type: Polygon
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Feature Class: STREAMS_AND_RIVERS
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will depict linear hydrographic features with a width greater than 100 feet.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software

SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Streams and Rivers	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 100 feet. In the case of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules. Other natural or manmade embankments will not qualify for this project.	Capture features showing dual line (one on each side of the feature). Average width shall be greater than 100 feet to show as a double line. Each vertex placed should maintain vertical integrity. Generally both banks shall be collected to show consistent downhill flow. There are exceptions to this rule where a small branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the island is greater than 1 acre. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

Inland Ponds and Lakes

Feature Dataset: BREAKLINES
Feature Type: Polygon
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Feature Class: PONDS_AND_LAKES
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will depict closed water body features that are at a constant elevation.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Ponds and Lakes	Land/Water boundaries of constant elevation water bodies such as lakes, reservoirs, ponds, etc. Features shall be defined as closed polygons and contain an elevation value that reflects the best estimate of the water elevation at the time of data capture. Water body features will be captured for features 2 acres in size or greater. "Donuts" will exist where there are islands within a closed water body feature.	Water bodies shall be captured as closed polygons with the water feature to the right. The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. An Island within a Closed Water Body Feature that is 1 acre in size or greater will also have a "donut polygon" compiled. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath

		the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

Tidal Waters

Feature Dataset: BREAKLINES
Feature Type: Polygon
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Feature Class: TIDAL_WATERS
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will outline the land / water interface at the time of lidar acquisition.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
TIDAL_WATERS	The coastal breakline will delineate the land water interface using lidar data as reference. In flight line boundary areas with tidal variation the coastal shoreline may show stair stepping as no feathering is allowed. Stair stepping is allowed to show as much ground as the collected data permits.	The feature shall be extracted at the apparent land/water interface, as determined by the lidar intensity data, to the extent of the tile boundaries. Differences caused by tidal variation are acceptable and breaklines delineated should reflect that change with no feathering. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock

		or pier as it is adjacent to the water, at the measured elevation of the water. Breaklines shall snap and merge seamlessly with linear hydrographic features.

Bridge Saddle Breaklines

Feature Dataset: BREAKLINES
Feature Type: Polyline
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003
Feature Class: Bridge_Saddle_Breaklines
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polyline feature class is used to enforce terrain beneath bridge decks where ground data may not have been acquired. Enforcing the terrain beneath bridge decks prevents bridge saddles.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Bridge Saddle Breaklines	Bridge Saddle Breaklines should be used where necessary to enforce terrain beneath bridge decks and to prevent bridge saddles in the bare earth DEMs.	Bridge saddle breaklines should be collected beneath bridges where bridge saddles exist or are likely to exist in the bare earth DEMs. Bridge saddle breaklines should be collected perpendicular to the bridge deck so that the endpoints are on either side of the bridge deck. Typically two bridge saddle breaklines are collected per bridge deck, one at either end of the bridge deck to enforce the terrain under the full bridge deck. The endpoints of the bridge saddle breaklines will match the elevation of the ground at their xy position to enforce the ground/bare earth elevations beneath the bridge deck and prevent bridge saddles from forming.

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

Dewberry utilized ESRI software and Global Mapper for the DEM production and QC process. ArcGIS software is used to generate the products and the QC is performed in both ArcGIS and Global Mapper. The figure below shows the entire process necessary for bare earth DEM production, starting from the lidar swath processing.

The final bare-earth lidar points are used to create a terrain. The final 3D breaklines collected for the project are also enforced in the terrain. The terrain is then converted to raster format using linear interpolation. For most projects, a single terrain/DEM can be created for the whole project. For very large projects, multiple terrains/DEMs may be created. The DEM(s) is reviewed for any issues requiring corrections, including remaining lidar mis-classifications, erroneous breakline elevations, poor hydro-flattening or hydro-enforcement, and processing artifacts. After corrections are applied, the DEM(s) is then split into individual tiles following the project tiling scheme. The tiles are verified for final formatting and then loaded into Global Mapper to ensure no missing or corrupt tiles and to ensure seamlessness across tile boundaries.

Figure 99-DEM Production Workflow

DEM QUALITATIVE ASSESSMENT

Dewberry performed a comprehensive qualitative assessment of the bare earth DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained the proper referencing information. This process was performed in ArcGIS software with the use of a tool set Dewberry has developed to verify that the raster extents match those of the tile grid and contain the correct projection information. The DEM data was reviewed at a scale of 1:5000 to review for artifacts caused by the DEM generation process and to review the hydro-flattened features. To perform this review Dewberry creates HillShade models and overlays a partially transparent colorized elevation model to review for these issues. All corrections are completed using Dewberry's proprietary correction workflow. Upon completion of the corrections, the DEM data is loaded into Global Mapper for its second review and to verify corrections. Once the DEMs are tiled out, the final tiles are again loaded into Global Mapper to ensure coverage, extents, and that the final tiles are seamless.

The images below show an example of a bare earth DEM.

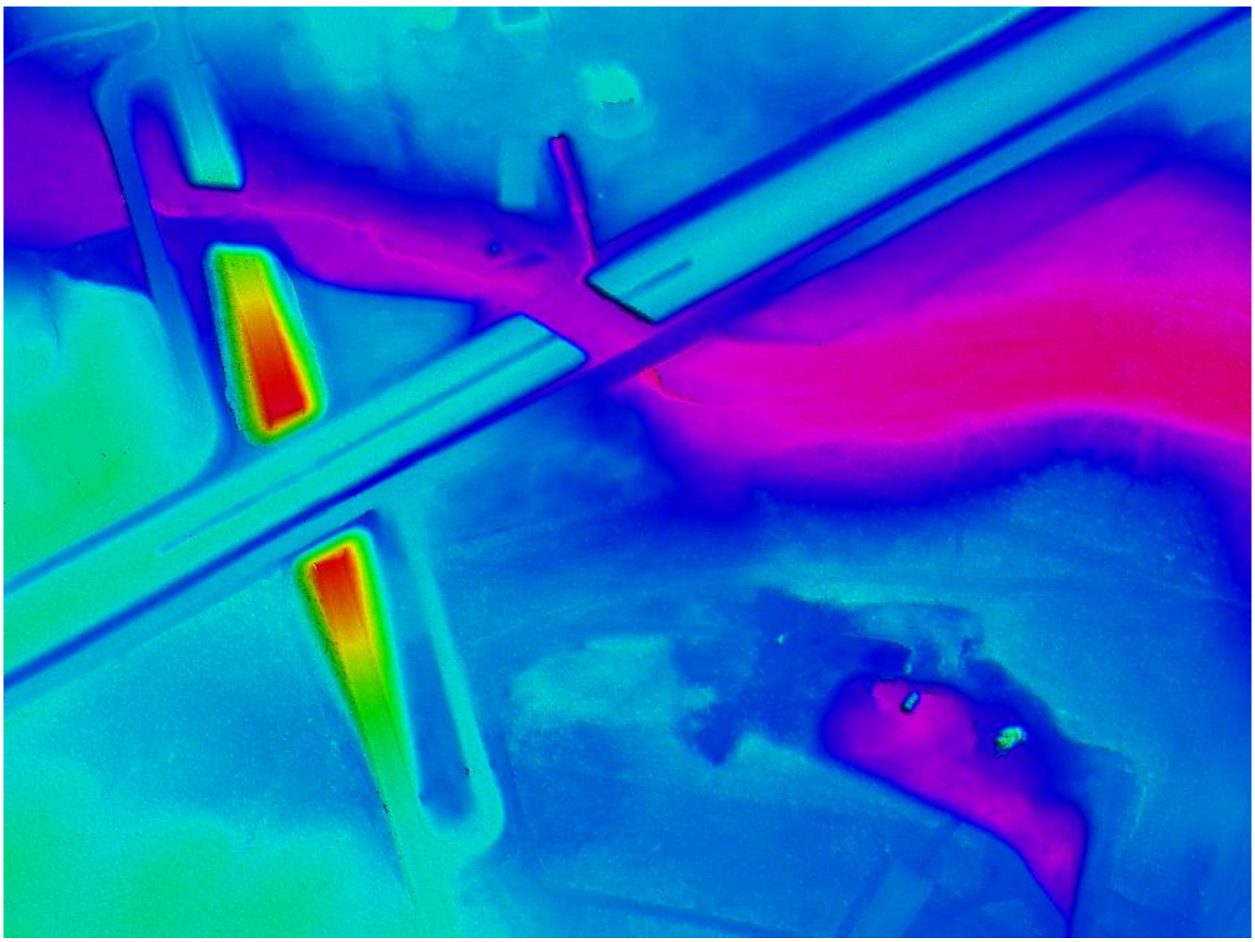


Figure 100-Tile 13RGR485235. The bare earth DEM is shown above.

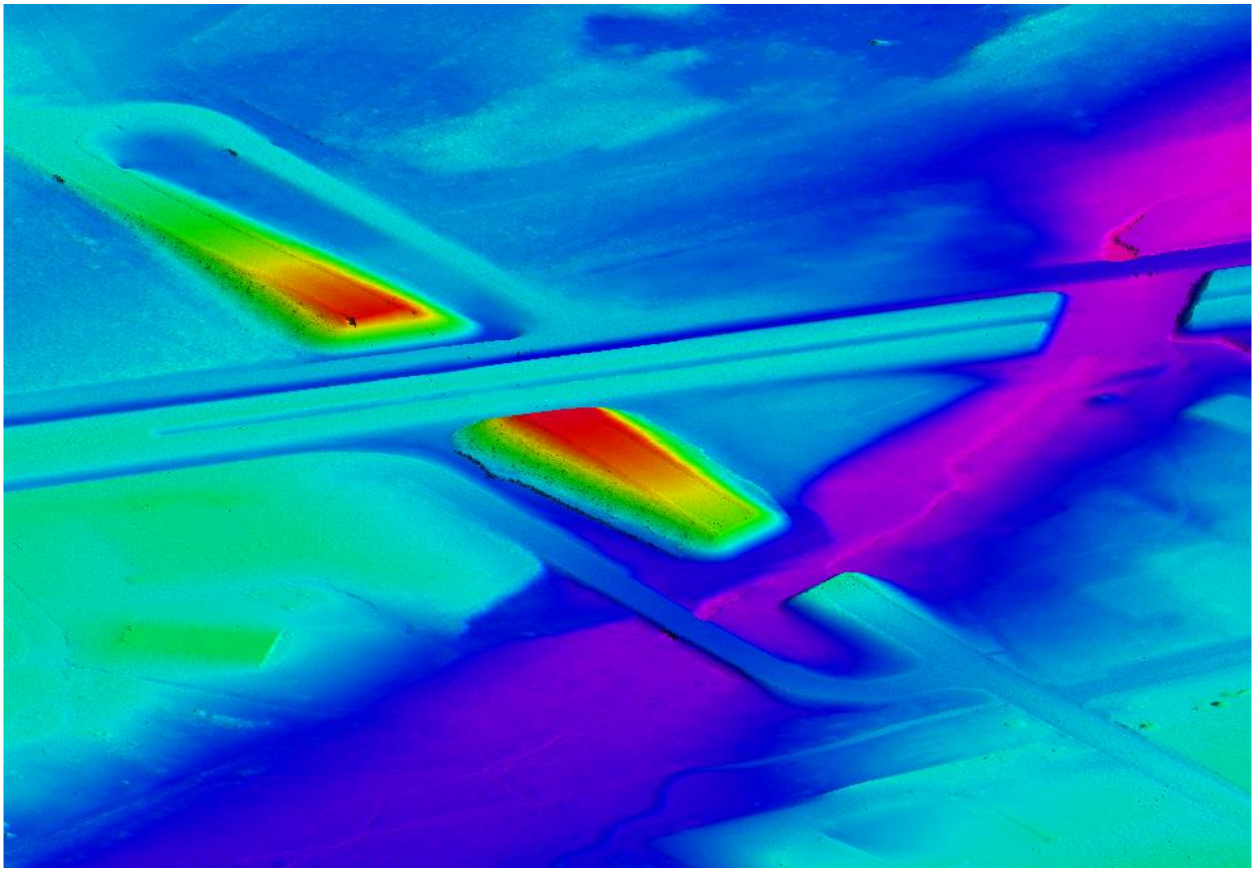


Figure 101-Tile 13RGR485235. 3D Profile view of the bare earth DEM

When some bridges are removed from the ground surface, the distance from bridge abutment to bridge abutment is small enough that the DEM interpolates across the entire bridge opening, forming 'bridge saddles.' Dewberry collected 3D bridge breaklines in locations where bridge saddles were present and enforced these breaklines in the final DEM creation to help mitigate the bridge saddle artifacts. The image below on the left shows a bridge saddle while the image below on the right shows the same bridge after bridge breaklines have been enforced.

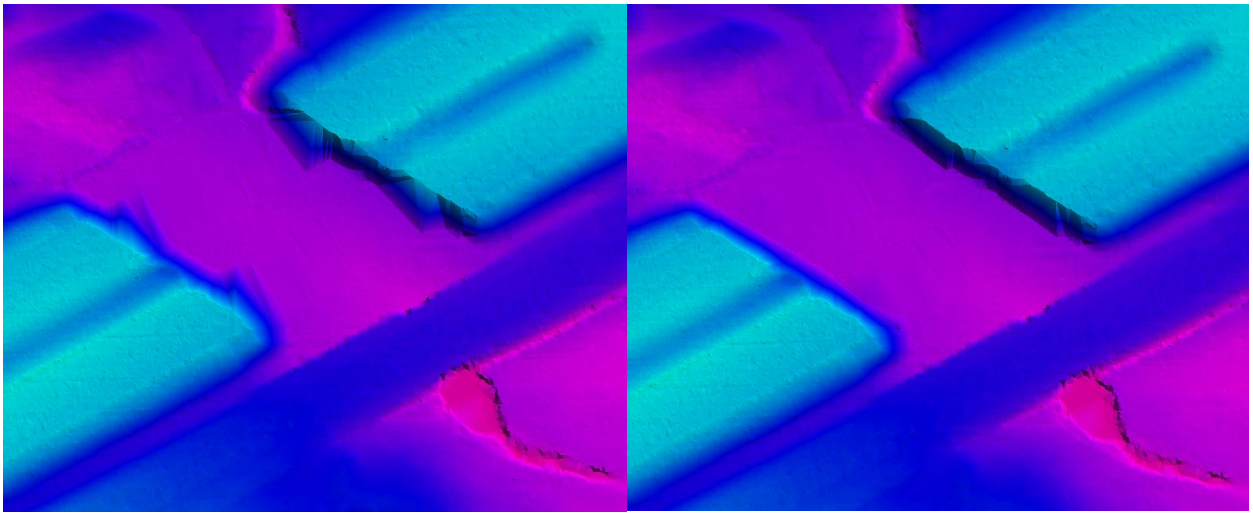


Figure 102-Tile 13RGR485235. The DEM on the left shows a bridge saddle artifact while the DEM on the right shows the same location after bridge saddle breaklines have been enforced.

DEM VERTICAL ACCURACY RESULTS

The same 1176 checkpoints that were used to test the vertical accuracy of the lidar were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source lidar and final DEM deliverable. DEMs are created by averaging several lidar points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS, which does not average several lidar points together but may interpolate (linearly) between two or three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the surveyed elevations. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

Table 43 summarizes the tested vertical accuracy results from a comparison of the surveyed checkpoints to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=29.4 cm
NVA	701	9	
VVA	475		11.5

Table 43 – DEM tested NVA and VVA

This DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =4.5 cm, equating to +/- 9 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 11.5 cm at the 95th percentile.

Table 44 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83(2011) UTM Zone 13, 14 & 15N		NAVD88 (Geoid 12B)		DeltaZ	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Z-Survey (m)	Z-LiDAR (m)		
NVA-9	625287.374	3709622.643	1319.841	1319.687	-0.154	0.154
NVA-18	643742.583	3690479.840	1263.024	1262.887	-0.137	0.137
VVA-468	228997.955	3747641.626	145.425	145.558	0.133	0.133
NVA-40	656999.390	3663348.443	1204.384	1204.213	-0.171	0.171
NVA-132	758290.425	3616659.182	915.642	915.525	-0.117	0.117
NVA-489	358096.113	3578559.415	767.398	767.262	-0.136	0.136
NVA-504	334763.162	3612415.784	745.689	745.520	-0.169	0.169
NVA-512	334283.889	3628984.593	692.867	692.752	-0.115	0.115
NVA-525	350985.373	3663033.409	624.009	624.144	0.135	0.135
NVA-537	366647.545	3684316.538	522.518	522.264	-0.254	0.254
VVA-62	3702771.906	704195.780	1142.534	1142.723	0.189	0.189
VVA-94	3610432.954	777039.293	889.653	889.800	0.147	0.147
VVA-127	762320.072	3514578.498	882.237	882.115	-0.122	0.122
VVA-164	288561.455	3665344.223	735.805	736.065	0.260	0.260
VVA-183	269224.744	3612414.228	722.218	722.373	0.155	0.155
VVA-244	333049.239	3449551.608	671.296	671.143	-0.153	0.153
VVA-320	469185.227	3546004.225	482.785	482.629	-0.156	0.156
VVA-325	363892.540	3561700.705	747.278	747.153	-0.125	0.125
VVA-343	329627.124	3613332.498	721.623	721.488	-0.135	0.135
VVA-356	326064.321	3653855.627	717.885	718.028	0.143	0.143
VVA-368	400373.349	3677942.408	492.546	492.394	-0.152	0.152
VVA-414	483004.617	3799223.695	367.484	367.655	0.171	0.171
VVA-416	468588.160	3813693.565	390.558	390.856	0.298	0.298
VVA-417	512869.794	3775463.579	326.473	326.594	0.121	0.121
VVA-419	549627.103	3776706.672	308.318	308.491	0.173	0.173
VVA-474	224040.541	3729981.700	155.974	156.096	0.122	0.122
VVA-427	563536.595	3770738.495	293.232	293.371	0.139	0.139
VVA-428	584267.231	3770678.675	275.562	275.770	0.208	0.208
VVA-434	597025.194	3737596.517	278.800	278.968	0.168	0.168
VVA-469	243116.658	3740751.518	149.413	149.532	0.119	0.119
VVA-452	694392.638	3767229.287	202.731	202.862	0.131	0.131
VVA-453	690740.765	3777841.253	285.402	285.543	0.141	0.141

Table 44 – 5% Outliers

Table 45 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	701	0.046	-0.005	-0.004	-0.328	0.046	1.665	-0.254	0.135
VVA	475	N/A	0.021	0.018	0.383	0.056	2.156	-1.156	0.298

Table 45 — Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Dewberry, the DEM dataset for the TX West Central Lidar project satisfies the project's pre-defined vertical accuracy criteria.

DEM CHECKLIST

The following table represents a portion of the high-level steps in Dewberry's bare earth DEM Production and QA/QC checklist that were performed for this project.

Pass/Fail	Validation Step
Pass	Masspoints (LAS to multipoint) are created from ground points only (class 2 and class 8 if model key points created, but no class 10 ignored ground points or class 9 water points
Pass	Create a terrain for each production block using the final bare earth lidar points and final breaklines.
Pass	Convert terrains to rasters using project specifications for grid type, formatting, and cell size
Pass	Create hillshades for all DEMs
Pass	Manually review bare-earth DEMs in ArcMap with hillshades to check for issues
Pass	DEMs should be hydro-flattened or hydro-enforced as required by project specifications
Pass	DEMs should be seamless across tile boundaries
Pass	Water should be flowing downhill without excessive water artifacts present
Pass	Water features should NOT be floating above surrounding
Pass	Bridges should NOT be present in bare-earth DEMs.
Pass	Any remaining bridge saddles where below bridge breaklines were not used need to be fixed by adding below bridge breaklines and re-processing.
Pass	All qualitative issues present in the DEMs as a result of lidar processing and editing issues must be marked for corrections in the lidar These DEMs will need to be recreated after the lidar has been corrected.
Pass	Calculate DEM Vertical Accuracy including NVA, VVA, and other statistics
Pass	Split the DEMs into tiles according to the project tiling scheme
Pass	Verify all properties of the tiled DEMs, including coordinate reference system information, cell size, cell extents, and that compression has not been applied to the tiled DEMs

Pass	Load all tiled DEMs into Global Mapper to verify complete coverage to the (buffered) project boundary and that no tiles are corrupt.

Table 46-A subset of the high-level steps from Dewberry's bare earth DEM Production and QA/QC checklist performed for this project.

Appendix A: Survey Report

Appendix A is a separate document located in the reports folder of the deliverables.

Appendix B-F: GPS Processing

Appendix B through H are separate documents located in the reports folder of the deliverables.