Osceola, Florida QL2 LiDAR

Report Produced for U.S. Geological Survey

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Executive Summary

The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (LiDAR) technology for the Osceola 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 2,500 feet by 2,500 feet. A total of 7292 tiles were produced for the project encompassing an area of approximately 1,566 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.

Preble-Rish Inc.'s Frederick C. Rankin 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 for the Ground Control survey report and Appendix B for the Checkpoint survey report that were created for this portion of the project.

Aerial Cartographics of America, Inc (ACA) completed LiDAR data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the Florida counties of Osceola, Polk and Orange.

DATE OF SURVEY

The LiDAR aerial acquisition was conducted from January 21, 2016 and April 13, 2016.

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: Florida State Plane East (FIPS 0901)
Units: Horizontal units are in US Survey Feet, Vertical units are in US Survey Feet.
Geiod Model: Geoid12B (Geoid 12B was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the Osceola LiDAR Project, the tested $RMSE_z$ of the classified LiDAR data for checkpoints in non-vegetated terrain equaled **0.14ft (4.26cm)** compared with the 0.33 ft (10 cm) specification; and the NVA of the classified LiDAR data computed using $RMSE_z$ x 1.9600 was equal to **0.27ft (8.23cm)** , compared with the 0.64ft (19.6cm) specification.

For the Osceola LiDAR Project, the tested VVA of the classified LiDAR data computed using the 95^{th} percentile was equal to **0.45ft (13.7cm)** compared with the 0.96 ft (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. Raw Point Cloud Data (Swaths)
2. Classified Point Cloud Data (Tiled)
3. Bare Earth Surface (Raster DEM – IMG Format)
4. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
5. Breakline Data (File GDB)
6. Contours(File GDB, Tiled)
7. Low Confidence Polygons
8. Independent Survey Checkpoint Data (Report, Photos, & Points)
9. Calibration Points
10. Metadata
11. Project Report (Acquisition, Processing, QC)
12. Project Extents, Including a shapefile derived from the LiDAR Deliverable

PROJECT TILING FOOTPRINT

Seven thousand two hundred ninety two (7292) tiles were delivered for the project. Each tile's extent is 2,500 feet by 2,500 feet (see Appendix C for a complete listing of delivered tiles).

Figure 1 - Project Map

LiDAR Acquisition Report

Dewberry elected to subcontract the LiDAR acquisition and calibration activities to Aerial Cartographics of America Inc. (ACA). ACA was responsible for providing LiDAR acquisition, calibration and delivery of LiDAR data files to Dewberry.

Dewberry received calibrated swath data from ACA on May 9, 2016.

LIDAR ACQUISITION DETAILS

ACA planned 381 passes for the project area as a series of parallel flight lines with cross flight lines 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, ACA 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, ACA will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

ACA monitored weather and atmospheric conditions and conducted LiDAR missions only when no conditions existed below the sensor that would affect the collection of data. These conditions included 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. ACA 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, ACA 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.

ACA LiDAR sensors are calibrated at a designated site located at the Kissimmee Airport in Kissimmee, Florida and are periodically checked and adjusted to minimize corrections at project sites.

LIDAR SYSTEM PARAMETERS

ACA operated a Cessna T-206 (Tail # N948IT) outfitted with a Riegl LMS-Q680i LiDAR system during the collection of the study area. Table 1 illustrates ACA system parameters for LiDAR acquisition on this project.

Item	Parameter
System	Riegl LMS-Q680i
Altitude (AGL meters)	701 m/2300 Ft
Approx. Flight Speed (knots)	110 knots
Scanner Pulse Rate (kHz)	280 kHz
Scan Frequency (hz)	120 (1/s)
Pulse Duration of the Scanner (microseconds)	0.005553571
Pulse Width of the Scanner (m)	0.351 m
Swath width (m)	809.49 m
Central Wavelength of the Sensor Laser (nanometers)	1550
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	0.5 mrad
Nominal Swath Width on the Ground (m)	809.49 m
Swath Overlap (%)	55%
Total Sensor Scan Angle (degree)	60
Computed Down Track spacing (m) per beam	0.47 m
Computed Cross Track Spacing (m) per beam	0.429 m
Nominal Pulse Spacing (single swath), (m)	0.45 m
Nominal Pulse Density (single swath) (ppsm), (m)	4.94
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.45 m
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	4.94 m
Maximum Number of Returns per Pulse	7

Table 1: ACA 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 2 shows the combined trajectory of the flight lines.

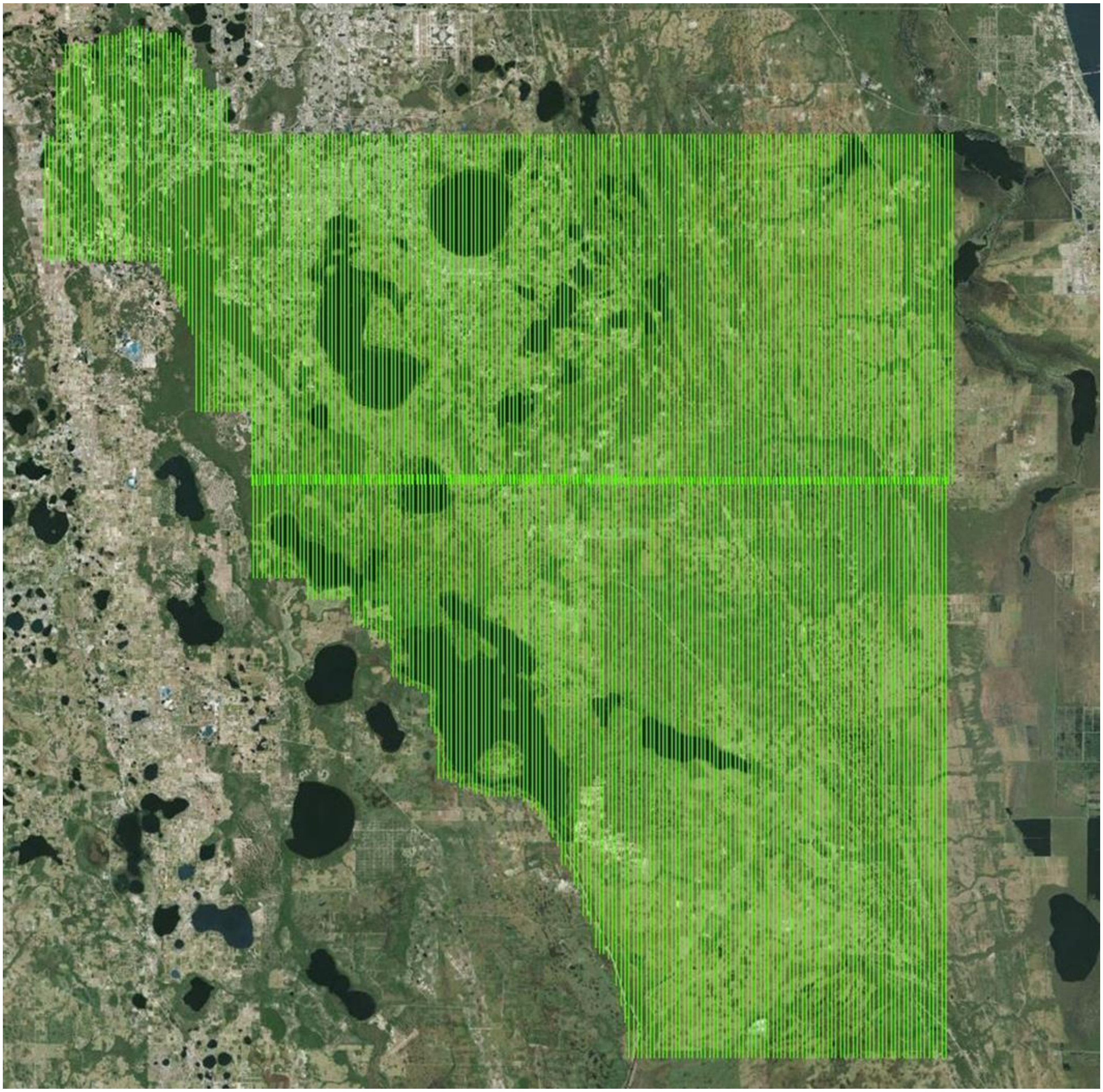


Figure 2: Trajectories as planned by ACA

LIDAR CONTROL

Two Leica GS14 base stations were used during each flight. Each base station was set on one of the closest of the sixteen NGS monuments recovered as part of the project. These base stations were used to control the LiDAR acquisition for the Osceola County QL2 LiDAR project area. The coordinates of all used base stations are provided in the table below.

Name	NAD83(2011) Florida State Plane East Zone		Orthometric Ht (NAVD88 Geoid12B,ft)
	Easting X (ft)	Northing Y (ft)	
AB5478	631573.38	1374800.82	75.141
AB5482	604549.95	1433053.94	69.412
AB5498	508908.72	1426446.69	78.999
AB5503	505940.89	1405986.06	74.881
AF6097	614001.26	1311079.64	68.714
AF6121	606515.82	1256753.59	60.579
AF6134	631895.46	1243075.86	69.502
AF7103	599246.59	1330578.47	75.376
AF7643	570148.21	1262168.84	61.564
AK6933	655130.15	1432707.69	65.986
AK6935	678778.58	1375220.92	50.157
AK7111	477009.28	1427522.14	86.404
CW6769	580462.92	1395969.10	72.956
DJ8307	697553.66	1217516.51	53.967
DL6642	515785.19	1440218.98	76.795
AK7134	493426.95	1475306.44	105.9

Table 2 – Base Stations used to control LiDAR acquisition

AIRBORNE GPS KINEMATIC

Airborne GPS data was processed using the Applanix MMS PosPac V7.2 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 25km.

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

GPS processing reports for each mission are included as a separate Appendix D so as not to add over 100 pages to this report.

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 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/Terramatch 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.

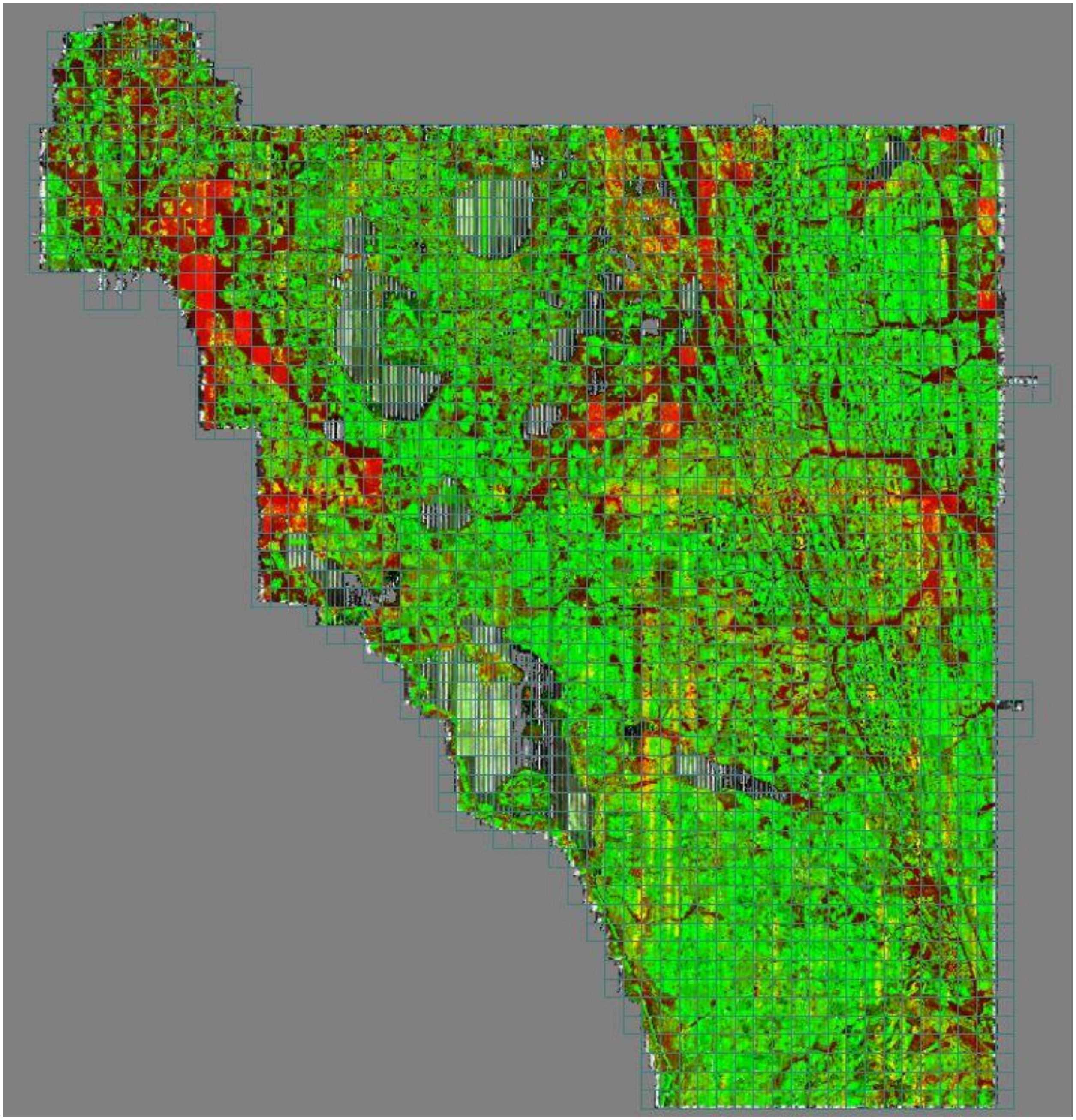


Figure 3 – LiDAR Swath output showing complete coverage.

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, heading, 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 <= 6cm RMSDz within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

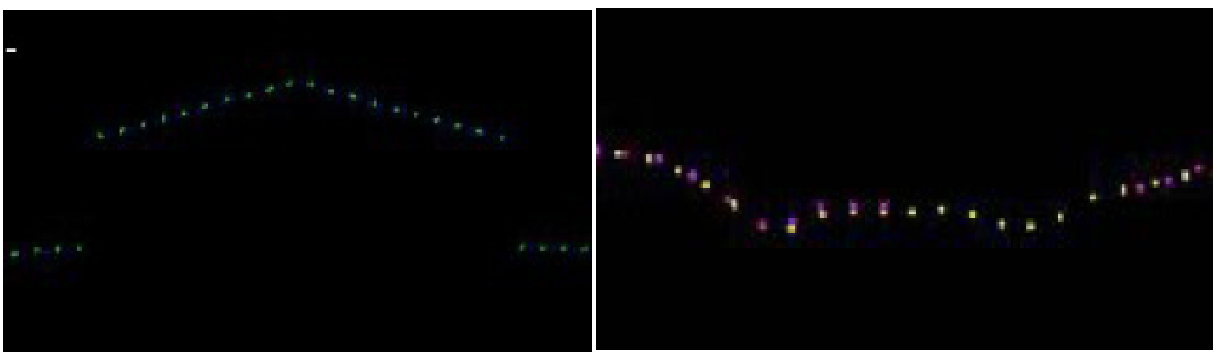


Figure 4 – Profile views showing correct roll and pitch adjustments.

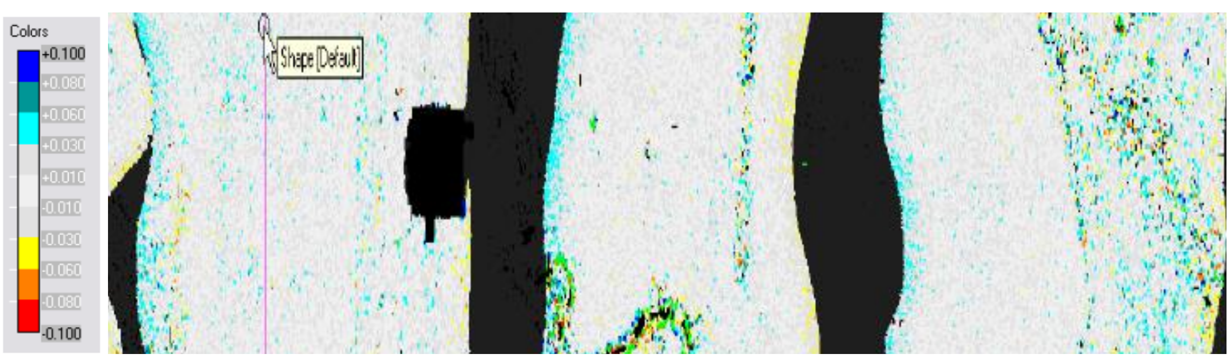


Figure 5 – QC block colored by distance to ensure accuracy at swath edges.

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

Dewberry

PRELIMINARY VERTICAL ACCURACY ASSESSMENT

A preliminary $RMSE_z$ error check is performed by ACA 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/0.33 ft and Accuracy at the 95% confidence level ≤ 19.6 cm/0.64 ft) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated Osceola County QL2 LiDAR dataset was tested to 0.188 FT vertical accuracy at 95% confidence level based on $RMSE_z$ (0.096 FT x 1.9600) when compared to 25 GPS static check points. The following are the final statistics for the GPS static checkpoints used by ACA to internally verify vertical accuracy.

Number	NAD83(2011) Florida State Plane East Zone		NAVD88 (Geoid 12B)	Laser Z (ft)	Delta Z
	Easting X (ft)	Northing Y (ft)	Known Z (ft)		
1	680191.877	1452296.979	40.410	40.440	+0.030
2	698276.228	1322140.535	34.814	34.770	-0.044
3	692661.909	1211402.002	69.153	69.070	-0.083
4	618197.017	1221056.935	55.706	55.710	+0.004
5	533875.931	1326659.484	52.388	52.390	+0.002
6	649572.831	1287863.477	70.849	70.910	+0.061
7	635371.914	1385010.711	76.048	75.950	-0.098
8	494342.953	1389521.856	71.943	71.860	-0.083
9	445328.454	1430756.615	192.147	192.390	+0.243
10	465100.214	1434611.408	106.965	107.100	+0.135
11	454218.150	1482342.163	130.943	131.170	+0.227
12	471486.710	1479657.440	97.054	97.040	-0.014
13	489034.678	1466499.464	98.750	98.800	-0.014
14	515232.165	1455748.200	84.815	84.740	-0.075
15	600059.199	1455463.458	64.891	64.720	-0.171
16	595538.905	1261643.809	56.731	56.720	-0.011
17	556025.484	1419419.156	73.098	73.190	+0.092
18	657725.716	1432623.766	67.133	67.030	-0.103
19	658221.704	1232725.191	69.599	69.650	+0.051
20	594718.403	1336001.148	71.980	71.980	+0.000
21	510923.280	1426934.560	66.280	66.290	+0.010
22	681573.632	1373748.832	55.865	55.860	-0.005
23	691348.461	1268127.684	60.964	60.870	-0.094
24	567514.711	1367373.382	66.612	66.550	-0.062
25	645796.080	1339420.971	67.008	67.010	-0.062

Table 3 - Static GPS Vertical Accuracy Results

Overall the calibrated LiDAR data products collected by ACA meet or exceed the requirements set out in the Statement of Work. The quality control requirements of ACA 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 ACA, 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 ninety-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 (0.64 ft) based on the $RMSE_z$ (10 cm/0.33 ft) x 1.96. The dataset for the Osceola 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 (0.33ft) $RMSE_z$ Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 8.8cm (0.29ft), equating to +/- 17 cm (0.56 ft) at 95% confidence level. The table below shows all calculated statistics for the raw swath data.

100 % of Totals	# of Points	RMSEz (ft) NVA Spec=0.33 ft	NVA- Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) Spec=0.64 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Min (ft)	Max (ft)	Kurtosis

Non-Vegetated Terrain	91	0.29	0.56	0.05	0.01	6.58	0.28	-0.33	2.42	55.00

Table 4: NVA at 95% Confidence Level for Raw Swaths

One checkpoint (NVA-38) was removed from the raw swath vertical accuracy testing due to its location outside the project boundary. Figure 6, below, shows the location of the LiDAR point outside the project boundary.

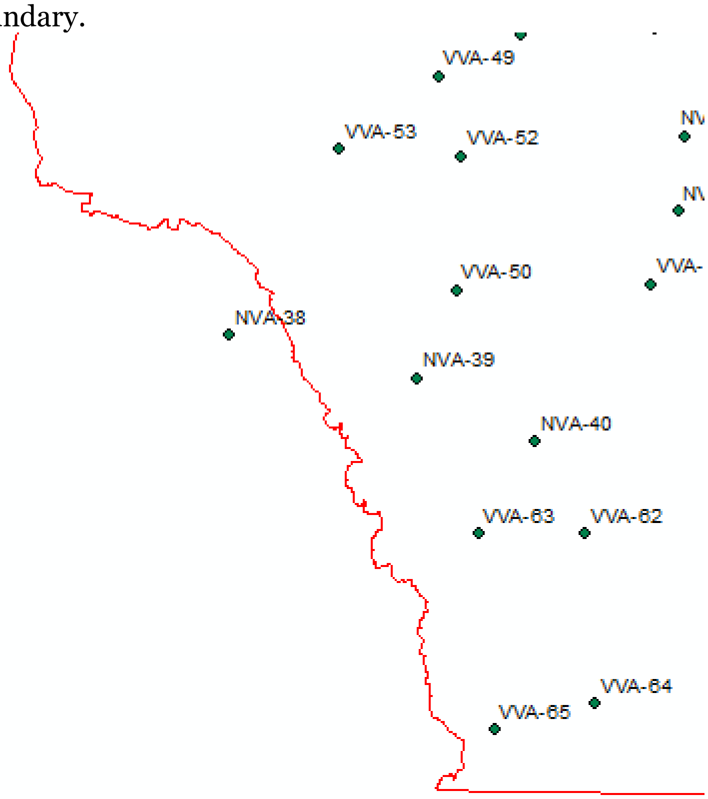


Figure 6 – Non- Vegetated checkpoint 38, shown outside the project boundary.

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 -12 cm are colored yellow, and areas in the dataset where overlapping flight lines have elevation differences in each pixel greater than 12 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 12 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 Osceola are shown in the figure below; this project meets inter-swath relative accuracy specifications.

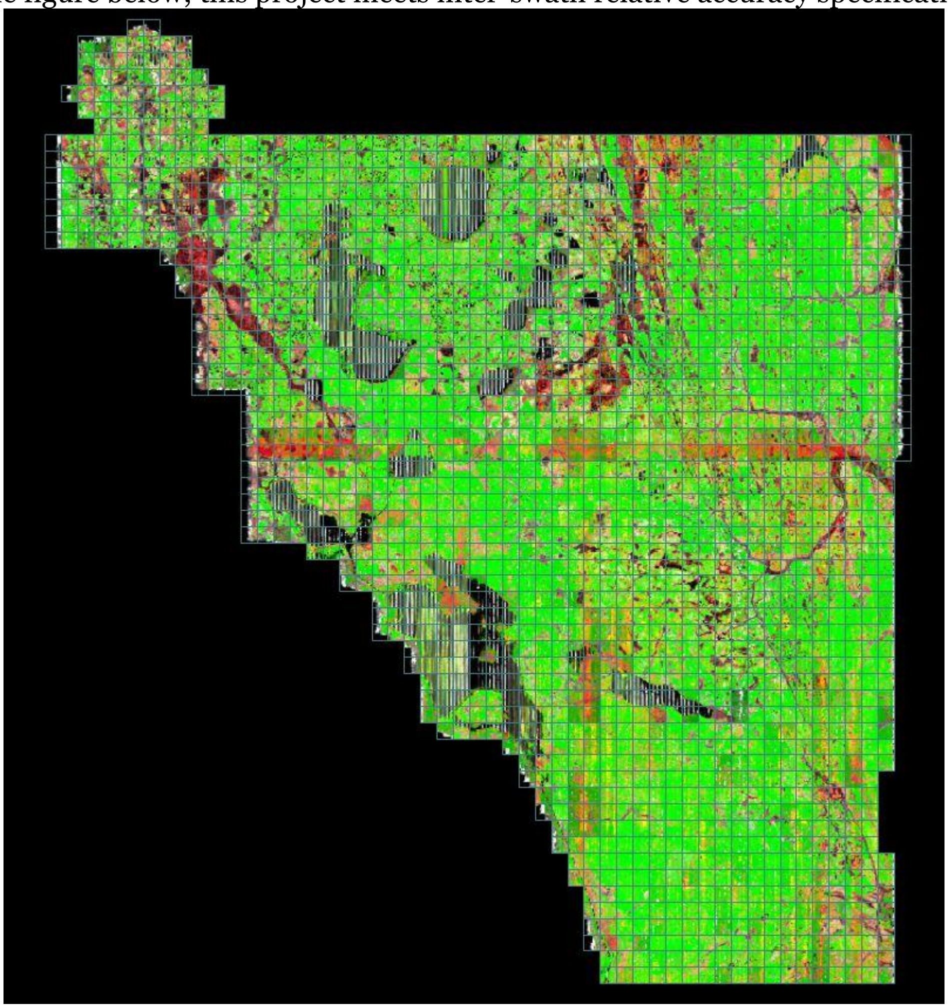


Figure 7–At full project scale, there are a few areas of red that appear to follow flight lines and suggest relative accuracy issues. Dewberry verified these areas and confirmed that water bodies, vegetation, and slope were the cause of higher DZ values in these locations. An example is shown in the figure below. Inter-swath relative accuracy for the Osceola Lidar Project meets specifications

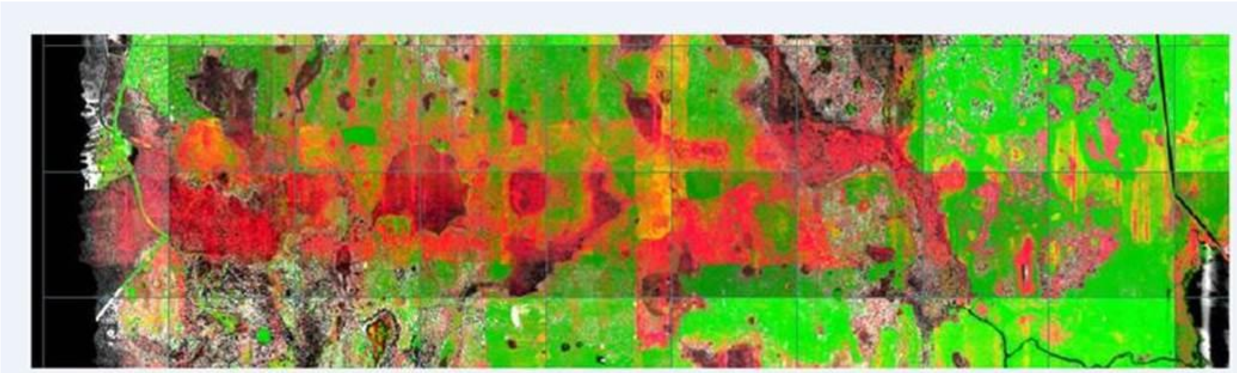


Figure 8- This image shows a close-up of one the red areas shown in the figure above where DZ values between swaths exceed 16 cm. Dewberry verified these areas and confirmed the differences are due to water bodies, vegetation, and sloped terrain.

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 Osceola; this project meets intra-swath relative accuracy specifications.

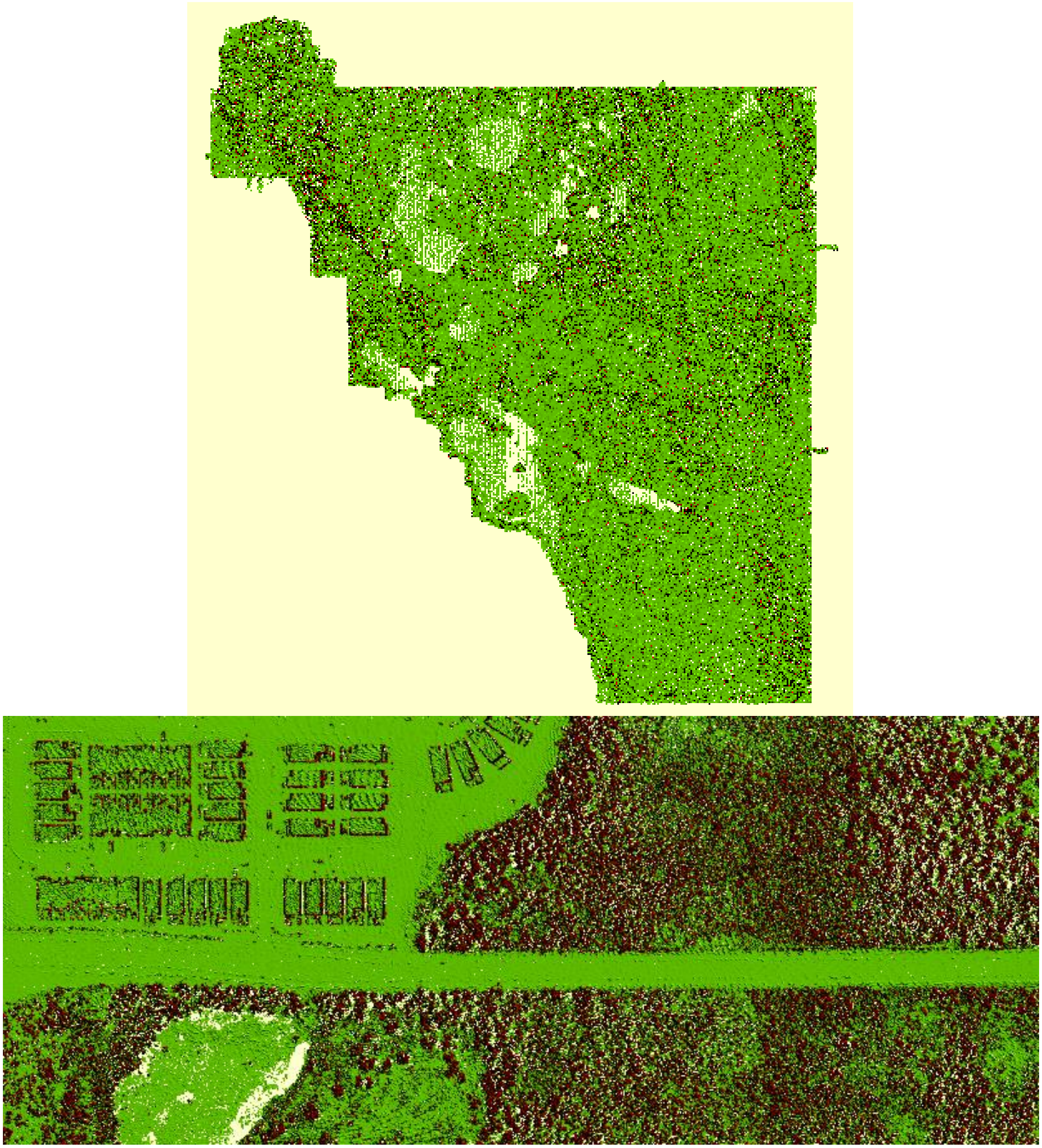


Figure 9–Intra-swath relative accuracy. The top image shows the full project area; areas where the maximum difference is ≤6 cm per pixel within each swath are colored green and areas exceeding 6 cm are colored red. The bottom image is a close-up of a flat area. With the exception of structures/forest (shown in red as the elevation/height difference in vegetated areas and along structures 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 Osceola; no horizontal alignment issues were identified.

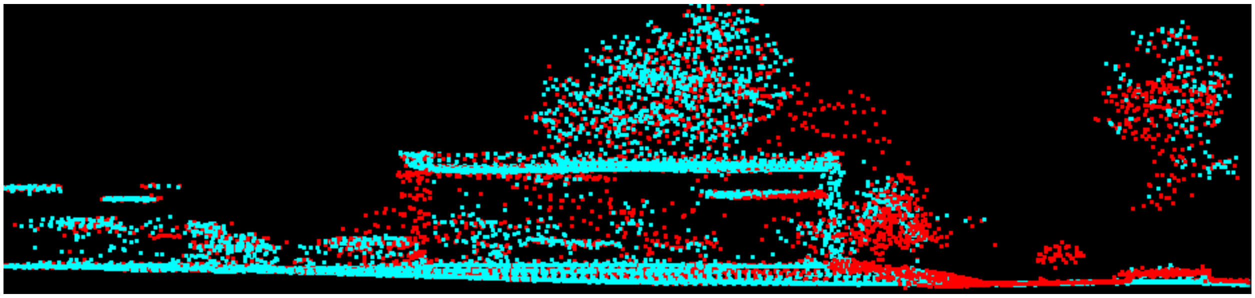


Figure 10– Horizontal Alignment. Two separate flight lines differentiated by color (Teal/Red) are shown in this profile. There is no visible offset between these two flight lines. No horizontal alignment issues were identified.

Point Density and Spatial Distribution

The required Aggregate Nominal Point Spacing (ANPS) for this project is no greater than 0.5 feet, which equates to an Aggregate Nominal Point Density (ANPD) of 4 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 0.31 feet or an ANPD of 10.4 points per square meter which satisfies the project requirements.

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. QTM scripting is then used to calculate the number of first return points of each swath within each grid cell. At least 90% 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.

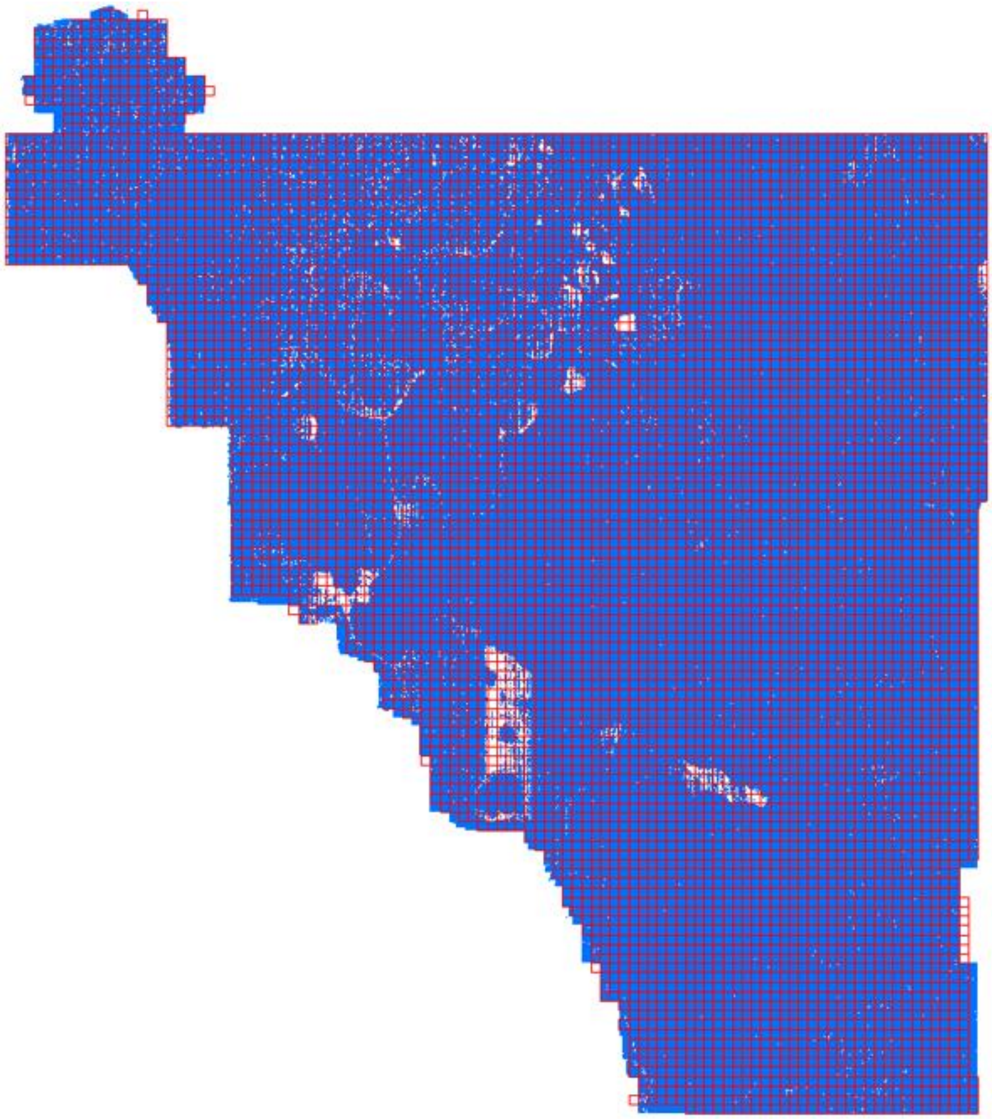


Figure 11– Spatial Distribution. The 2*NPS tile grid is shown in red and all tiles containing at least one LiDAR point are colored blue. The white areas of the project contain water bodies and are acceptable data voids.

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, the LAS files were then converted from LAS v1.2 to LAS v1.4 using GeoCue software. At this time, 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 Osceola.

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 Osceola 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 feet or less above the actual ground surface, and should not negatively impact the usability of the dataset.

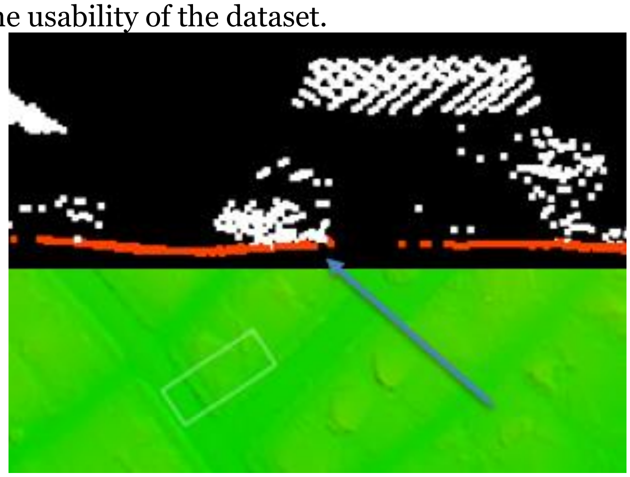


Figure 12– Tile LID2015_062864_E_C. Profile with points colored by class (class 1=white, class 2=orange) is shown in the top view and a TIN of the surface is shown in the bottom view. The arrow

identifies low vegetation points. 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.

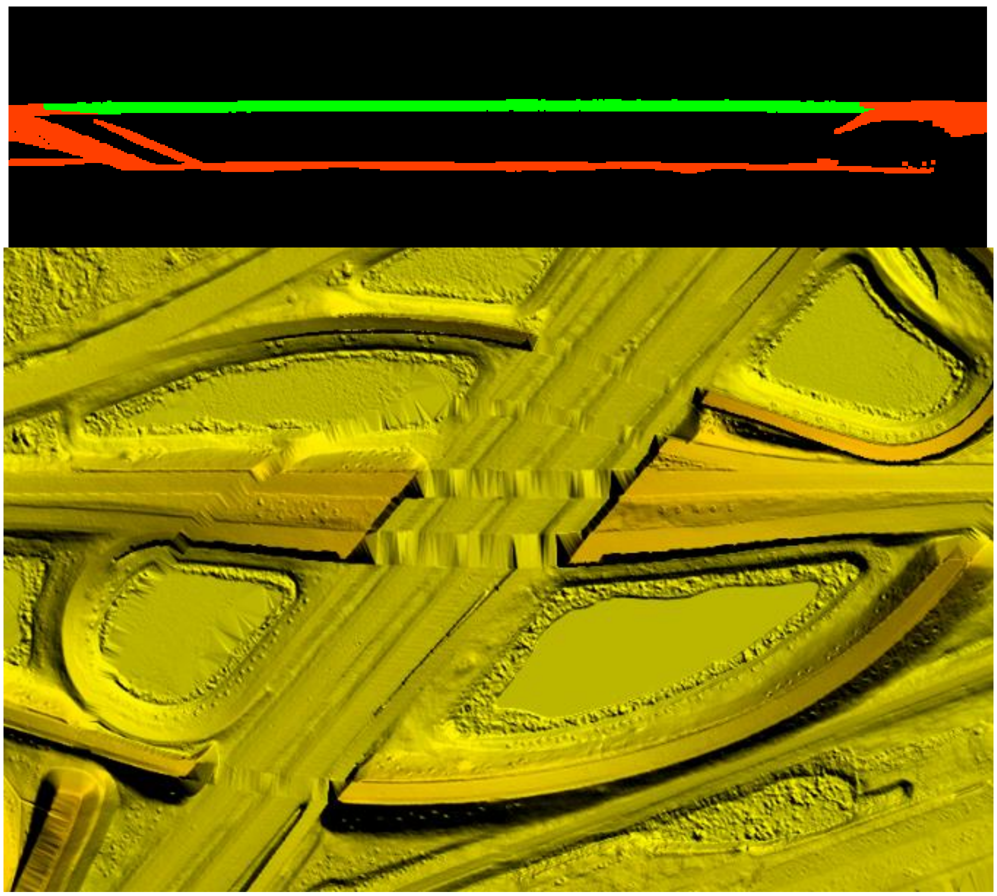


Figure 13 – Tile number LID2015_062863_E_A. The DEM in the bottom view shows an area where bridges have been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. The profile in the top view shows the LiDAR points of this particular feature colored by class. All bridge points have been removed from ground (orange) and are classified as bridge deck (green).

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.

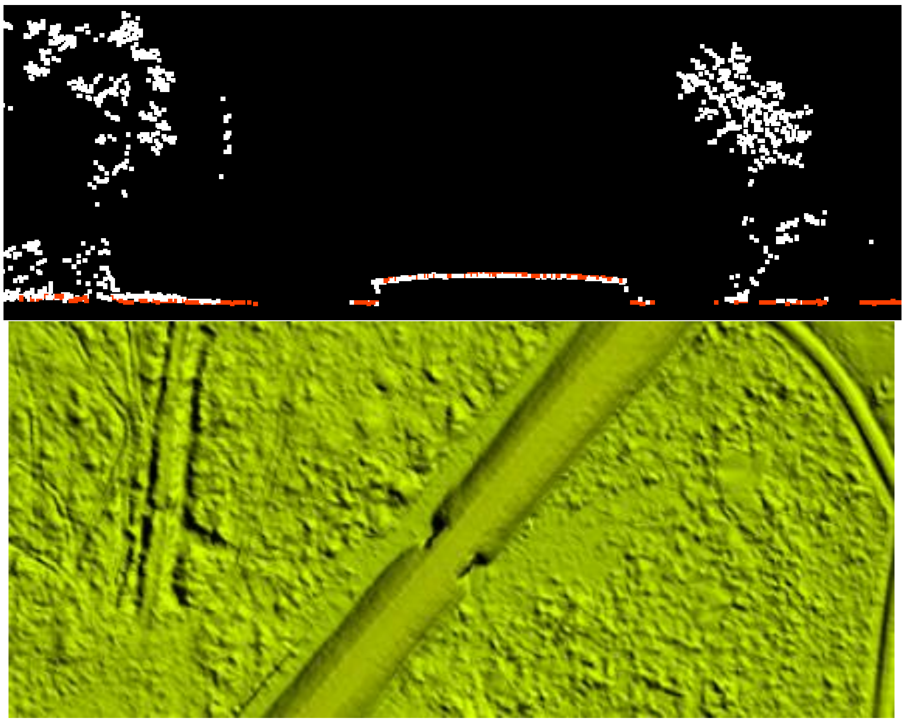


Figure 14– Tile number LID2015_064385_E_A. Profile with points colored by class (class 1=white, class 2=orange) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

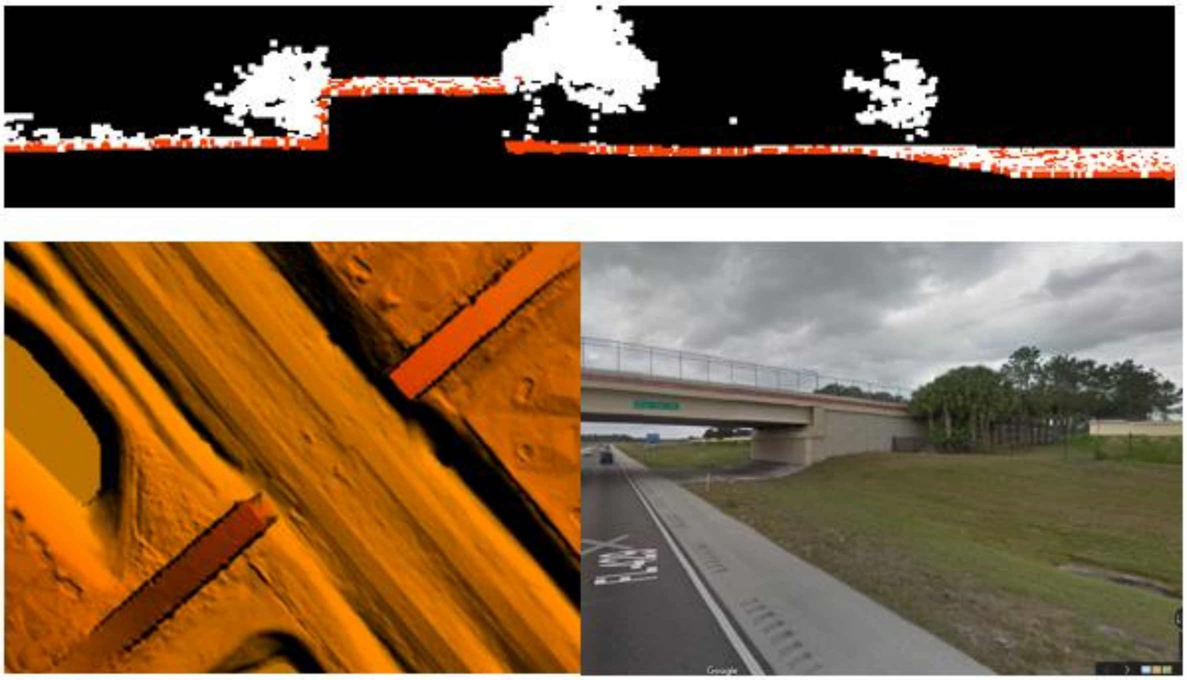


Figure 15– Tile LID2015_063158_E_B. Profile with points colored by class (class 1=white, class 2=orange) is shown in the top view, the DEM is shown in the middle and a google maps screenshot on the bottom. This area shows built up ground that resembles a bridge in the surface model. Only the actual bridge decks have been removed from the bare earth surface and classified to class 17.

In Ground Structures

In ground structures exist within the project area. These types of structures occur mainly within the Disney World Parks and surrounding resort area. These features are correctly included in the ground classification.

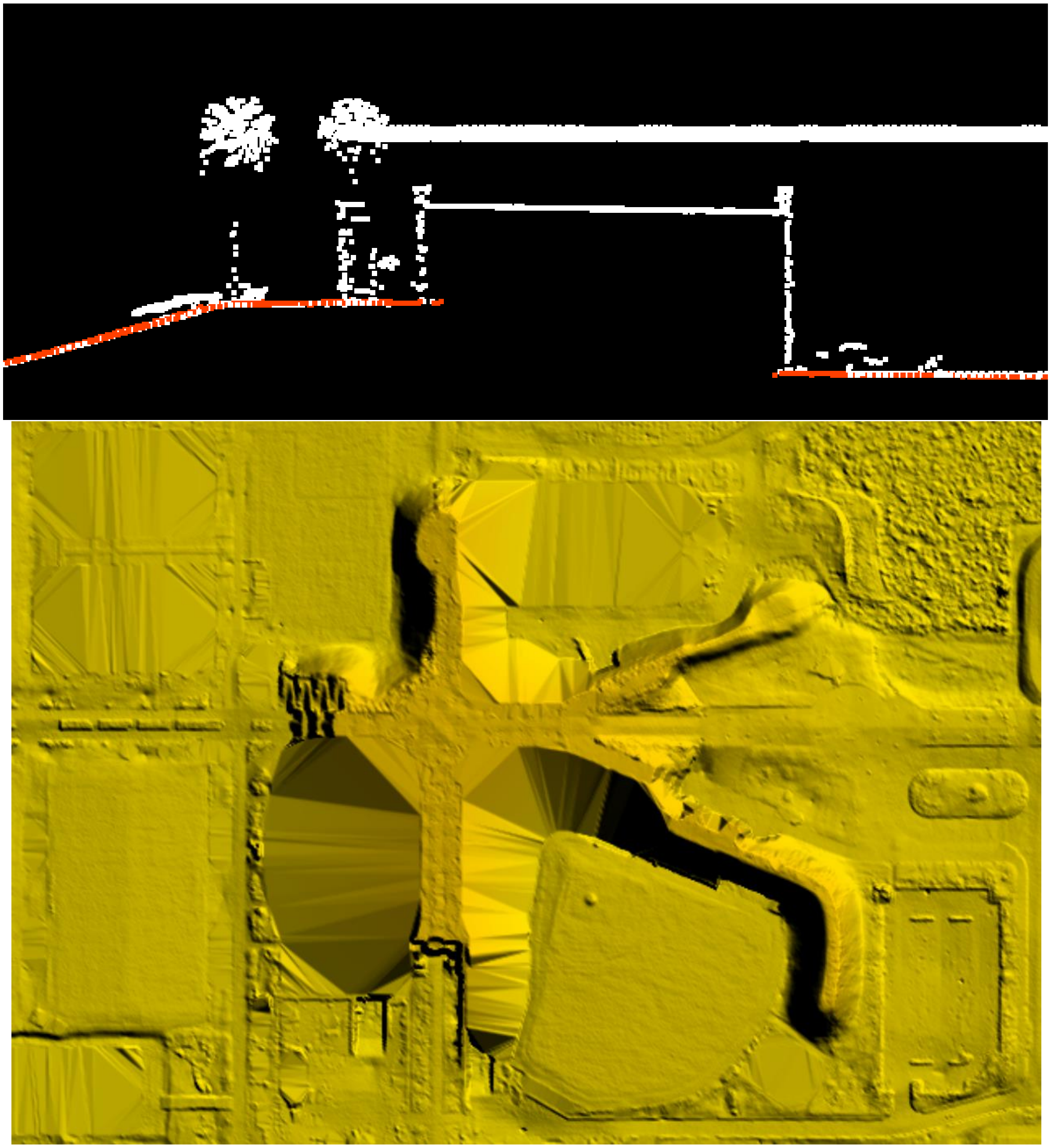


Figure 16 – Tile LID2015_062562_E_C. Profile with the points colored by class (class 1-white, class 2-orange) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

Divots

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

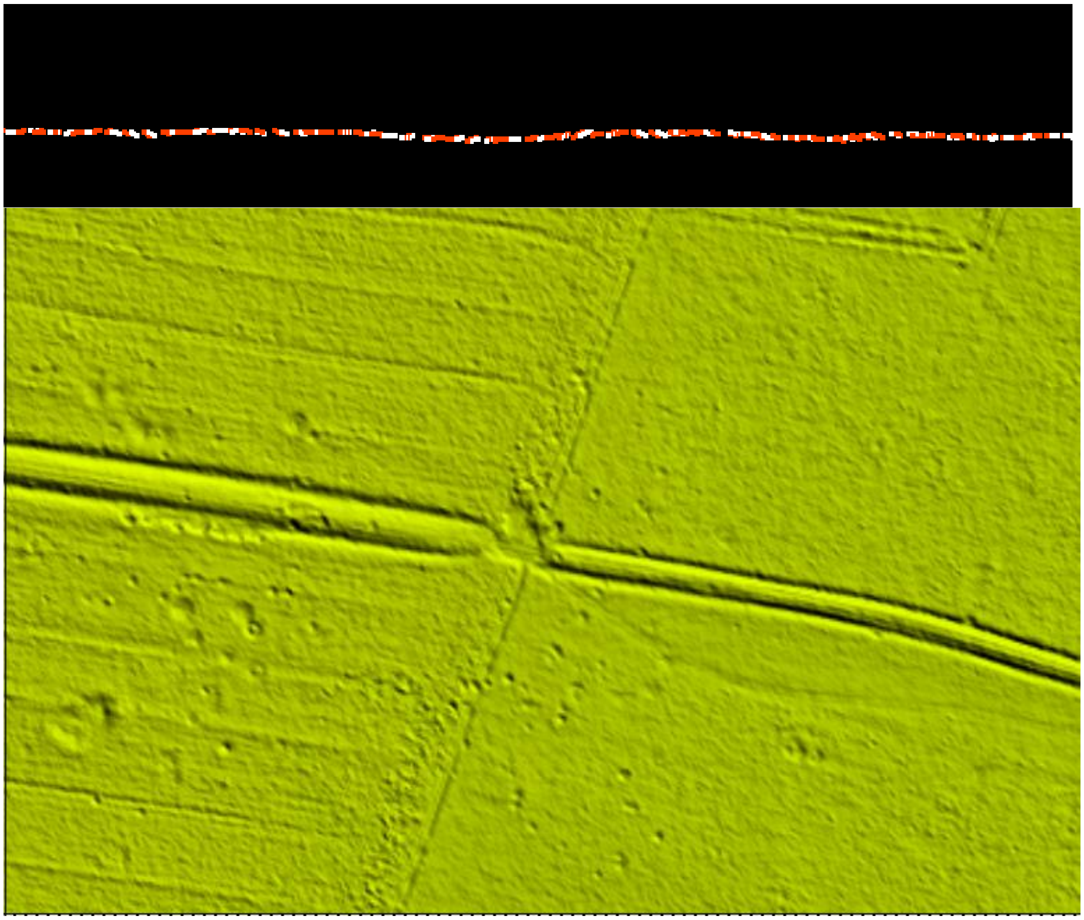


Figure 17 - Tile LID2015_075496_E_C. Profile with the points colored by class (class 1-white, class 2-orange) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

Dense Vegetation/Marsh

It is sometimes difficult to determine true ground in very densely vegetated/marshy area; the lowest points available are used to represent ground. Marsh areas are present within the project area and were not collected with breaklines as they are not open bodies of water. As these areas are not included in the collected breaklines, marsh areas were not flattened in the final DEMs. While low points are used to determine ground in marsh areas, there is often greater variation within the low points due to wet soils that cause greater interpolation between points, and undulating or uneven ground. An example is shown below.

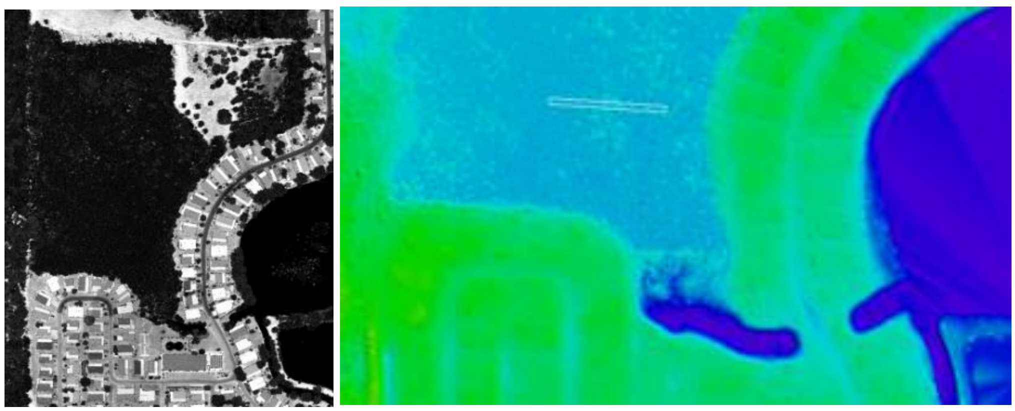


Figure 18 –Tile LID2015_062866_E_C. The intensity on the left shows a densely vegetated area that was not included in the collected breaklines. The same area is shown in the DEM on the right. Due to wet soils and broken terrain, the point density in marsh areas is sparser than surrounding areas and there is more variation in the low points representing ground.

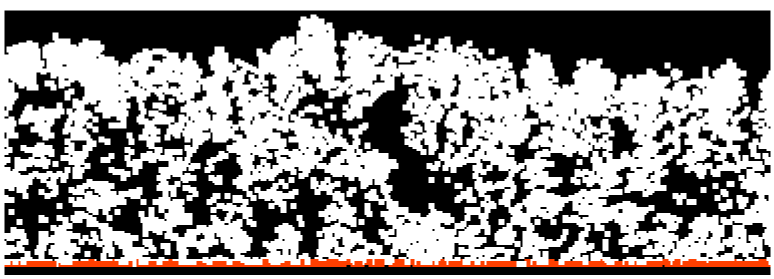


Figure 19- Tile LID2015_062866_E_C. This image shows a profile view of the Lidar points from the area above. This image shows the points colored by class (class 1=white, class 2=orange). Though the ground has variation, the Lidar is correctly portraying the ground surface.

Flight line Ridges

Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths. Some flight line ridges are visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of a visible ridge that is within tolerance is shown below.

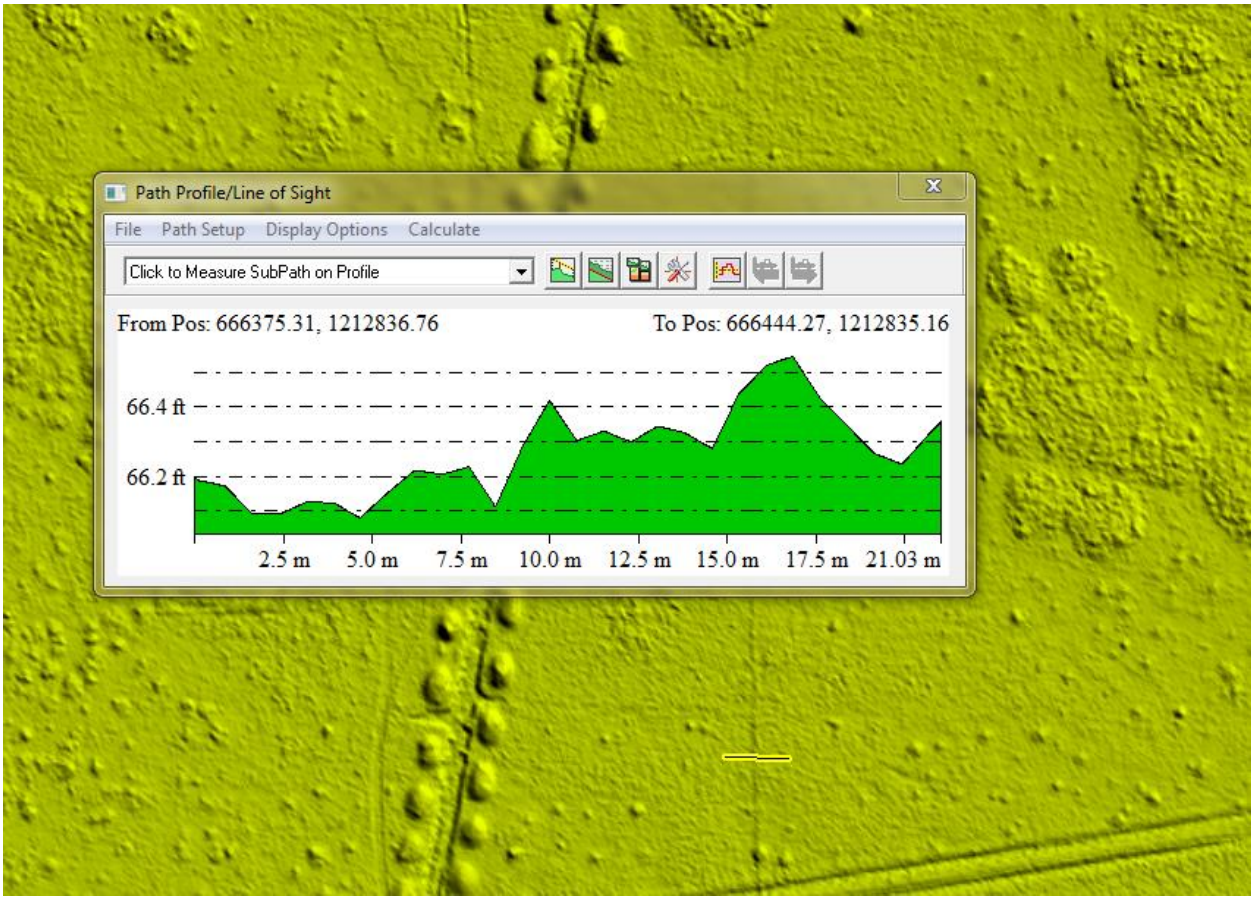


Figure 20– Tile LID2015_077300_E_A. The flight line ridge is less than 8 cm. Overall, the Osceola LiDAR data meets the project specifications for 8 cm RMSDz relative accuracy.

Temporal Differences

One flight line ridge exceeding specifications exists in Osceola County lidar project data due to temporal differences. Flightline 21211 is lower than its neighbors by approximately ½ foot to 1 foot in this area. This flightline and the adjacent flightlines cover a marshy area. Flightline 21211 was a re-flight/acquired on March 23, 2016 while the adjacent flightlines were acquired on February 12, 2016. The levels of water/moisture were different between the two time periods, which has had an impact on the level of lidar penetration. This difference, due to the difference in environmental conditions during the different acquisition dates, has resulted in this flight line ridge in this area. The flightline has been adjusted as much as possible for consistency with the adjacent flightlines.

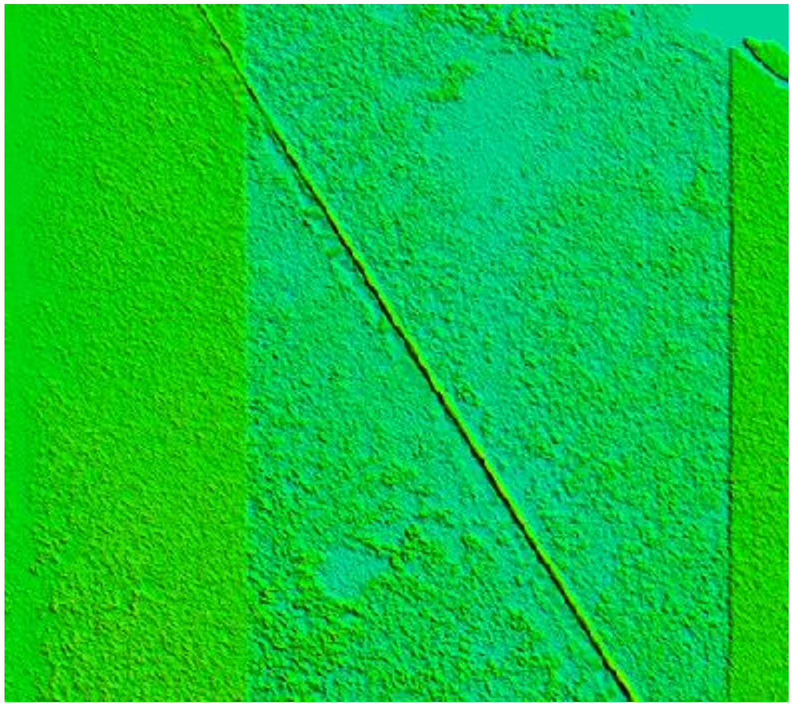


Figure 21– Tile DEM62606_A. This flightline ridge exceeds specifications but is the result of temporal changes in environmental conditions between two acquisition time periods.

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		
Validation	**Requirement**	**Pass/Fail**
LAS Version	1.4	Pass
Point Data Format	Format 6	Pass
Coordinate Reference System	NAD83(2011) StatePlane Florida East FIPS 0901 and NAVD88 (Geoid 12B), US Survey Feet 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

Derivative LiDAR Products

USGS required several derivative LiDAR products to be created. Each type of derived product is described below.

LOW CONFIDENCE POLYGONS

Low confidence areas occur with LiDAR where heavy vegetation greatly diminishes penetration of the LiDAR pulse. Areas of low confidence, where conformance to VVA standards may not be met, were delineated according to the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014).

As the Osceola project has a required NPD of 4 ppsm or a NPS of 0.5 m, a cell size and search radius of 1.5 m (3*NPS) was used to calculate the Nominal Ground Point Density (NGPD). All areas with a NGPD of 1 or less (less than or equal to 1/4 of the project NPD requirement) were identified as low confidence cells in our raster. The low confidence cells are exported to polygons and aggregated into larger shapes. Areas of expected low density in the ground, such as water or where buildings/structures have been removed, are deleted from the aggregated low confidence polygons. The size of all polygons are then calculated. For this project, all low confidence polygons greater than or equal to 5 acres were exported as the final low confidence polygon layer.

1-FT CONTOURS

One-foot (1ft) contours have been created for the full project area. The contour attributes include labeling as either Index or Intermediate and an elevation value. The contours are also 3D, storing the elevation value within its internal geometry. Some smoothing has been applied to the contours to enhance their aesthetic quality. No manual edits have been made to the contours. The contours have been tiled, named according to the final project tile grid, and located within one file GDB.

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 hundred sixty five (165) 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 B 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) Florida State Plane East		NAVD88 (Geoid 12B)
	Easting X (ft)	Northing Y (ft)	Elevation (ft)
NVA-01	565625.875	1426776.418	60.893
NVA-02	579330.214	1440994.188	78.979
NVA-03	580904.643	1459261.461	65.904
NVA-04	592213.745	1454084.174	74.37
NVA-05	581594.7885	1408943.436	71.882
NVA-06	598467.454	1424322.313	68.801
NVA-07	616905.552	1411173.529	72.494
NVA-08	680277.203	1458206.959	25.68
NVA-09	561863.587	1410057.983	73.245
NVA-10	560058.2535	1395918.311	69.167
NVA-11	546592.882	1411849.68	59.565
NVA-12	535074.6655	1405150.205	57.943
NVA-13	695832.6155	1366146.809	31.591
NVA-14	676234.735	1375728.254	51.593
NVA-15	689540.3355	1378938.4	50.503
NVA-16	629145.099	1381399.186	77.521
NVA-17	615284.547	1394069.206	75.873
NVA-18	641402.6085	1346758.725	67.203
NVA-19	655952.3705	1315830.771	59.815
NVA-20	682128.639	1426796.904	48.011
NVA-21	657491.3365	1300530.283	67.345
NVA-22	698328.515	1316040.228	38.465
NVA-23	692432.662	1348242.713	45.354
NVA-24	657499.425	1369469.061	55.481
NVA-25	676484.006	1361219.916	41.677
NVA-26	694693.508	1452992.737	14.201
NVA-27	522085.257	1443061.856	68.277
NVA-28	520681.603	1432771.431	61.516
NVA-29	515729.498	1422849.321	72.337
NVA-30	514358.051	1407837.663	70.349
NVA-31	583103.966	1388919.043	65.575
NVA-32	537140.612	1324361.607	54.296
NVA-33	575197.196	1338723.08	59.852
NVA-34	520814.726	1411998.048	61.07
NVA-35	698465.394	1268129.507	53.457
NVA-36	697937.786	1278664.008	48.414
NVA-37	676978.836	1280363.485	67.857
NVA-38	582923.719	1261947.171	55.381
NVA-39	607426.462	1256262.813	61.174

NVA-40	622714.472	1248094.582	65.61
NVA-41	508502.5335	1443236.958	76.963
NVA-42	524184.0045	1442117.045	63.163
NVA-43	539012.6725	1442156.82	70.917
NVA-44	550794.945	1443485.908	63.369
NVA-45	563616.429	1454137.853	75.846
NVA-46	545474.0685	1458870.857	82.048
NVA-47	504780.412	1458105.584	78.34
NVA-48	486615.226	1458408.447	88.93
NVA-49	466388.323	1458111.537	103.306
NVA-50	529685.335	1458719.529	83.649
NVA-51	445626.3035	1440753.617	140.08
NVA-52	530202.336	1384895.381	63.179
NVA-53	457199.649	1428683.554	126.294
NVA-54	506420.5635	1413568.098	74.231
NVA-55	466096.864	1442092.48	110.984
NVA-56	481064.3645	1442080.528	77.162
NVA-57	487711.142	1429032.22	70.086
NVA-58	505472.813	1425982.938	70.676
NVA-59	483617.6895	1415513.442	80.954
NVA-60	522397.991	1427635.232	58.59
NVA-61	499192.292	1396913.885	66.945
NVA-62	506972.824	1379598.758	63.631
NVA-63	514667.9265	1394884.673	74.372
NVA-64	470492.214	1489131.405	99.789
NVA-65	563248.1585	1379284.909	70.462
NVA-66	574467.193	1360744.562	63.77
NVA-67	597307.4855	1340812.641	78.836
NVA-68	612687.613	1331637.419	82.887
NVA-69	628955.0195	1313534.037	75.75
NVA-70	638519.767	1301928.177	72.662
NVA-71	655017.572	1268128.145	74.509
NVA-72	666636.1335	1251717.127	72.646
NVA-73	687923.8005	1223295.675	63.693
NVA-74	561780.82	1363535.858	59.92
NVA-75	620812.1875	1301209.082	69.836
NVA-76	642218.8725	1287855.762	71.905
NVA-77	660958.265	1285817.761	72.081
NVA-78	669585.975	1268738.621	75.227
NVA-79	680493.6115	1252539.825	63.744
NVA-80	696679.141	1202714.218	72.126
NVA-81	667316.1325	1231060.502	69.555
NVA-82	648549.1585	1235786.933	69.783
NVA-83	597747.756	1327127.568	73.868
NVA-84	593185.928	1317245.566	67.293
NVA-85	641411.6075	1278163.37	65.791

NVA-86	595102.265	1417968.1	70.783
NVA-87	653273.857	1380482.352	54.978
NVA-88	689079.578	1369571.53	48.589
NVA-89	680921.791	1435413.301	42.124
NVA-90	594959.849	1430319.164	70.748
NVA-91	514889.453	1388826.742	69.221
NVA-92	660094.227	1287734.408	70.951
VVA-01	543326.0335	1425707.697	64.333
VVA-02	581252.546	1425126.894	75.999
VVA-03	599294.972	1403963.199	76.005
VVA-04	598331.001	1411443.842	71.847
VVA-05	548563.6625	1400802.925	72.763
VVA-06	618620.792	1432971.276	70.18
VVA-07	641226.0005	1432616.081	75.784
VVA-08	657890.871	1430503.439	63.101
VVA-09	681840.6225	1442827.793	41.622
VVA-10	658314.138	1440702.752	54.508
VVA-11	646941.0495	1441659.775	71.223
VVA-12	603999.674	1442385.774	63.047
VVA-13	628343.362	1442353.535	75.266
VVA-14	625661.3265	1455936.039	72.324
VVA-15	647072.1225	1455012.577	68.697
VVA-16	657877.722	1457377.765	56.412
VVA-17	695603.4485	1438651.964	20.528
VVA-18	697486.584	1426945.715	16.593
VVA-19	696019.2945	1411629.635	17.269
VVA-20	685587.397	1407344.506	55.555
VVA-21	688659.291	1395428.951	35.381
VVA-22	677106.928	1397346.358	40.596
VVA-23	695781.0845	1400643.692	19.524
VVA-24	657543.5135	1379653.166	55.785
VVA-25	638656.494	1379389.604	67.345
VVA-26	633025.653	1408931.875	70.995
VVA-27	636173.3125	1399357.782	71.525
VVA-28	648197.2345	1411882.078	74.129
VVA-29	665173.3515	1406366.495	49.355
VVA-30	660244.734	1396894.809	62.779
VVA-31	633463.514	1362615.443	74.064
VVA-32	650062.3505	1331115.447	57.892
VVA-33	672635.59	1347677.308	55.624
VVA-34	665545.4295	1319636.502	47.784
VVA-35	676770.137	1299658.266	64.326
VVA-36	610688.671	1369377.81	81.419
VVA-37	447624.59	1452956.562	120.802
VVA-38	471771.3275	1428415.537	94.039
VVA-39	539046.9155	1382967.076	57.472

VVA-40	522220.9145	1365778.58	66.695
VVA-41	539629.635	1364856.993	55.063
VVA-42	473080.19	1470937.279	91.743
VVA-43	456734.308	1475254.645	105.157
VVA-44	584805.068	1348722.865	68.247
VVA-45	609810.7605	1316289.25	71.449
VVA-46	686274.317	1237097.447	58.328
VVA-47	675709.9405	1224032.945	65.751
VVA-48	584143.9475	1309732.693	55.112
VVA-49	610149.927	1295836.492	61.744
VVA-50	612462.319	1267891.513	60.859
VVA-51	648388.2945	1253168.11	67.266
VVA-52	613170.112	1285374.998	62.236
VVA-53	597176.447	1286265.027	51.827
VVA-54	561041.778	1348639.578	53.604
VVA-55	549406.096	1349168.662	55.113
VVA-56	557987.2095	1325094.298	53.9
VVA-57	544225.7855	1330862.393	62.675
VVA-58	525708.3585	1387129.728	68.789
VVA-59	637909.67	1268701.24	65.365
VVA-60	648753.259	1222007.138	62.581
VVA-61	648560.334	1207528.066	68.331
VVA-62	629363.122	1236125.572	67.05
VVA-63	615361.783	1236147.731	61.973
VVA-64	630542.693	1213924.531	60.639
VVA-65	617438.175	1210566.921	51.511
VVA-66	674929.437	1333605.899	42.7
VVA-67	653458.505	1352815.807	64.022
VVA-68	666680.437	1363256.799	66.487
VVA-69	692927.738	1299937.449	46.771
VVA-70	697741.349	1332998.684	32.698
VVA-71	616979.039	1374984.17	79.577
VVA-72	597452.297	1374945.635	67.514
VVA-73	619411.221	1363682.213	80.224

Table 5: Osceola County LiDAR surveyed accuracy checkpoints

One checkpoint (NVA-38) was removed from all vertical accuracy testing due to its location outside the project boundary. Figure 20, below, shows the location of the LiDAR point outside the project boundary.

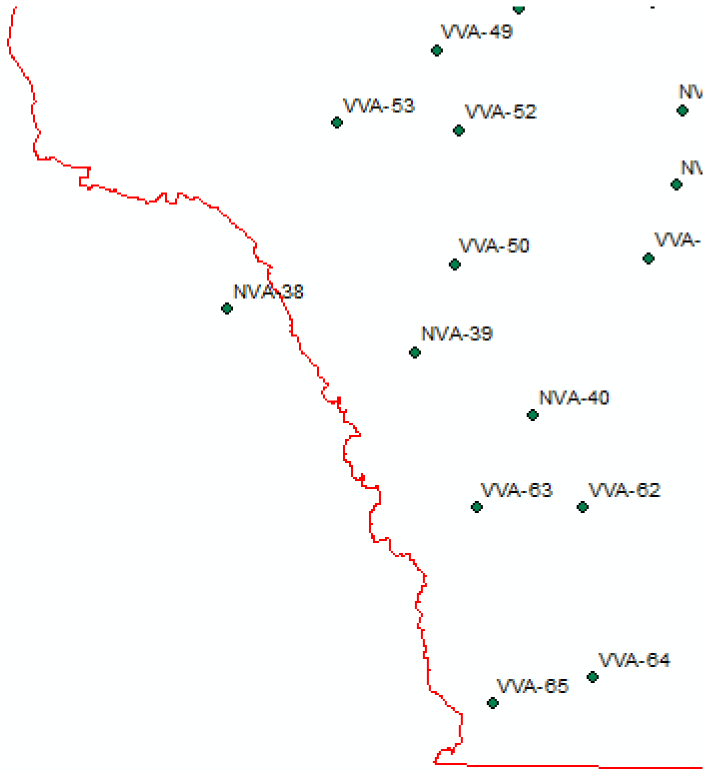


Figure 22 – Non- Vegetated checkpoint 38, shown outside the project boundary.

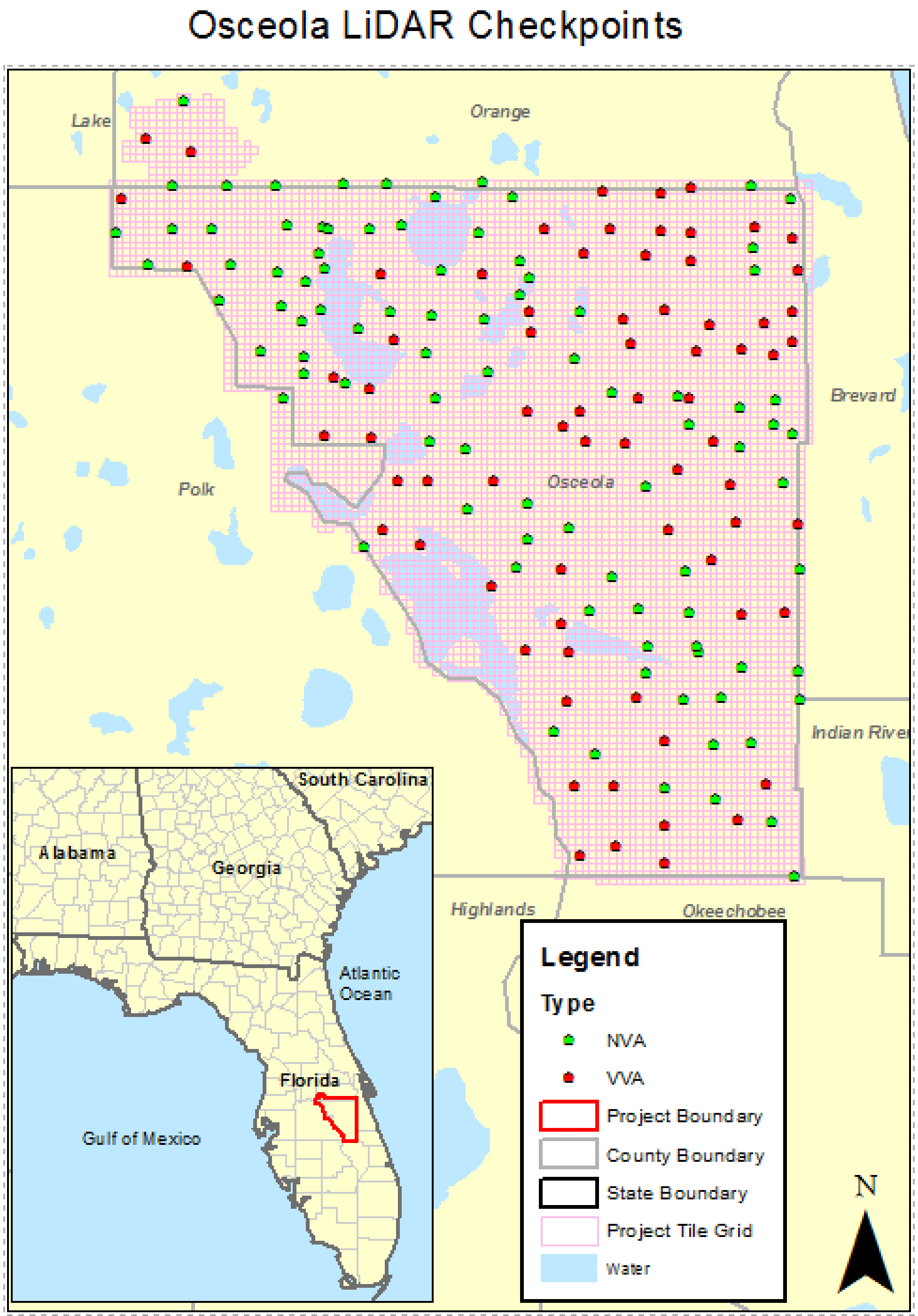


Figure 23 – Location of QA/QC Checkpoints

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 Osceola LiDAR project, vertical accuracy must be 0.64ft (19.6 cm) or less based on an $RMSE_z$ of 0.33ft (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 95^{th} percentile error for all checkpoints in all vegetated land cover categories combined. The Osceola LiDAR Project VVA standard is 0.96 ft (29.4 cm) based on the 95^{th} percentile. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95^{th} 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 6.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using $RMSE_z$ *1.9600	0.64 ft (based on $RMSE_z$ (0.33 ft) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	0.96 ft (based on combined 95^{th} percentile)

Table 6 — 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=0.64 ft	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.96 ft
NVA	91.00	0.27	
VVA	73.00		0.45

Table 7 – Tested NVA and VVA

This LiDAR dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 0.33 ft (10 cm) RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSE$_z$ =0.14 ft (4.26 cm), equating to +/- 0.27 ft (8.23 cm) at 95% confidence level. Actual VVA accuracy was found to be +/- 0.45 ft (13.7 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 +/- 0.20 ft of the checkpoints elevations, but there were some outliers where LiDAR and checkpoint elevations differed by up to +0.71 ft.

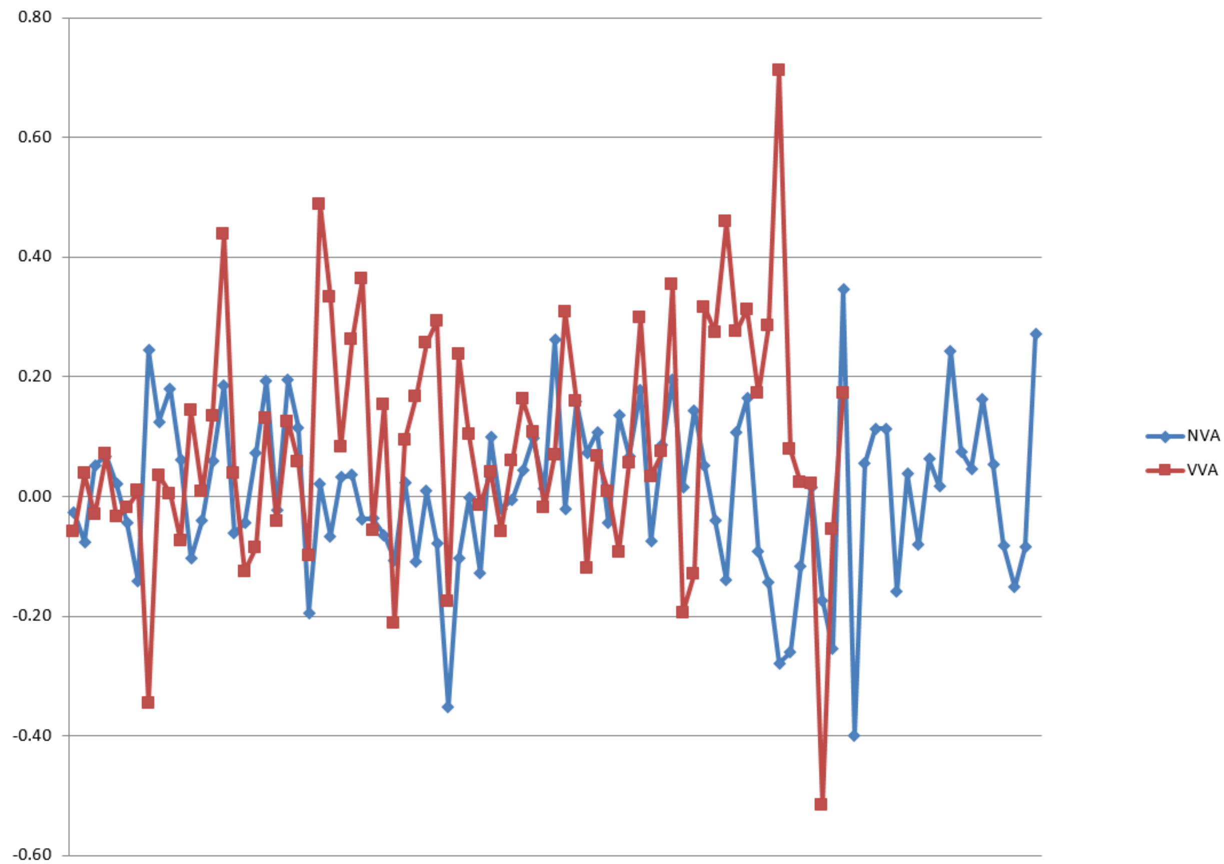


Figure 24 – Magnitude of elevation discrepancies per land cover category

Table 8 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83(2011) StatePlane Florida East FIPS 0901		NAVD88	LiDAR Z (ft)	Delta Z	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)			
VVA-67	653458.505	1352815.807	64.022	64.734	-0.712	0.712
VVA-24	657543.514	1379653.165	55.785	56.273	-0.488	0.488
VVA-62	629363.122	1236125.572	67.05	67.508	-0.458	0.458
VVA-71	616979.039	1374984.17	79.577	79.06	0.517	0.517

Table 8 — 5% Outliers

Table 9 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (ft) NVA Spec=0.33 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Kurtosis	Min (ft)	Max (ft)
NVA	91.00	0.14	0.01	0.02	-0.32	0.14	0.53	-0.40	0.35
VVA	73.00	N/A	0.09	0.07	0.19	0.20	1.45	-0.52	0.71

Table 9— 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 -0.52 feet and a high of +0.71 feet, 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 -0.15 feet to +0.35 feet.

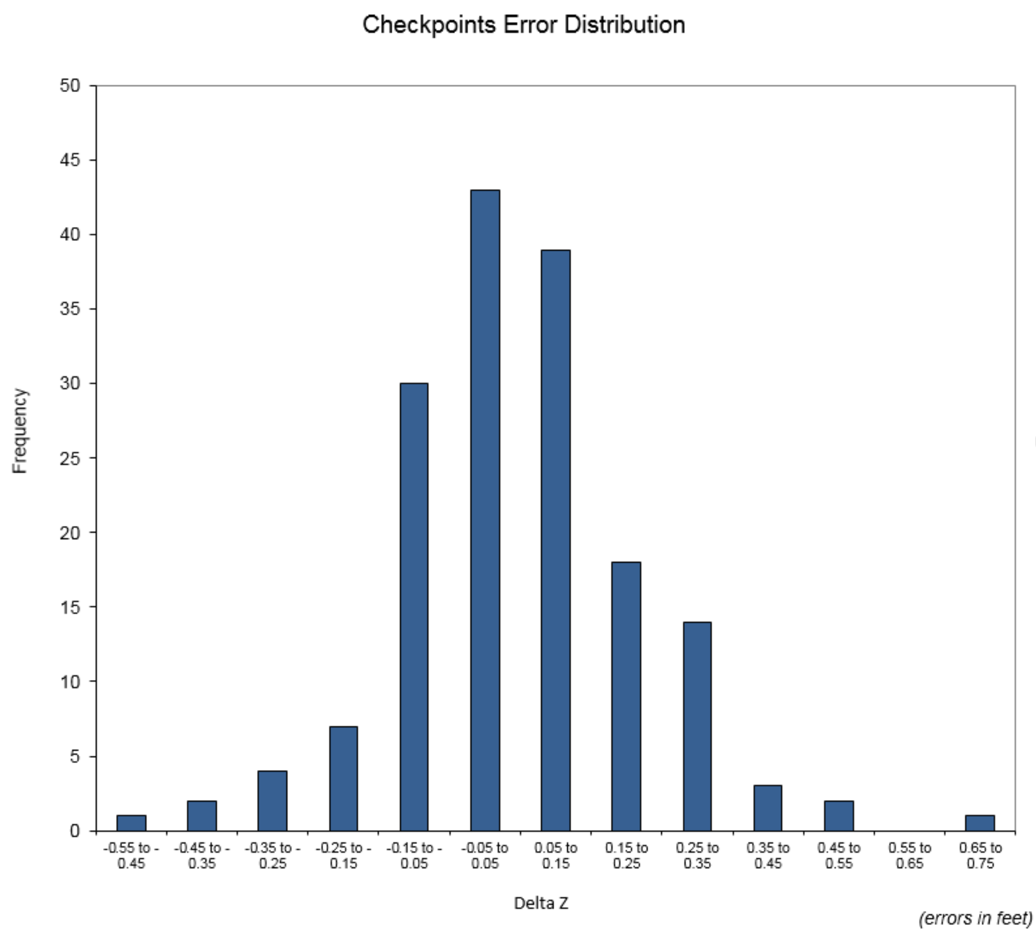


Figure 25 — Histogram of elevation discrepancies with errors in feet

Based on the vertical accuracy testing conducted by Dewberry, the LiDAR dataset for the USGS Osceola 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

Twenty–eight (28) 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.

No horizontal accuracy requirements or thresholds were provided for this project. However, LiDAR datasets are generally calibrated by methods designed to ensure a horizontal accuracy of 1 meter (3.28 ft) or less at the 95% confidence level.

# of Points	$RMSE_x$ (Spec=1.34 ft)	$RMSE_y$ (Spec=1.34 ft)	$RMSE_r$ (Spec=1.9 ft)	$ACCURACY_r$ ($RMSE_r$ x 1.7308) Spec=3.28 ft
28	0.66	0.84	1.07	1.85

Table 10-Tested horizontal accuracy at the 95% confidence level

Actual positional accuracy of this dataset was found to be RMSEx = 0.66ft (20cm) and RMSEy = 0.84ft (25.6cm) which equates to +/- 1.85ft (56.3cm) at 95% confidence level.

Breakline Production & Qualitative Assessment Report

BREAKLINE PRODUCTION METHODOLOGY

Dewberry used GeoCue software to develop LiDAR stereo models of the USGS Osceola LiDAR 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 developed by Dewberry to stereo-compile the two types of hard breaklines in accordance with the project's Data Dictionary.

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are reviewed in stereo and the lowest elevation is applied to the entire waterbody.

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.

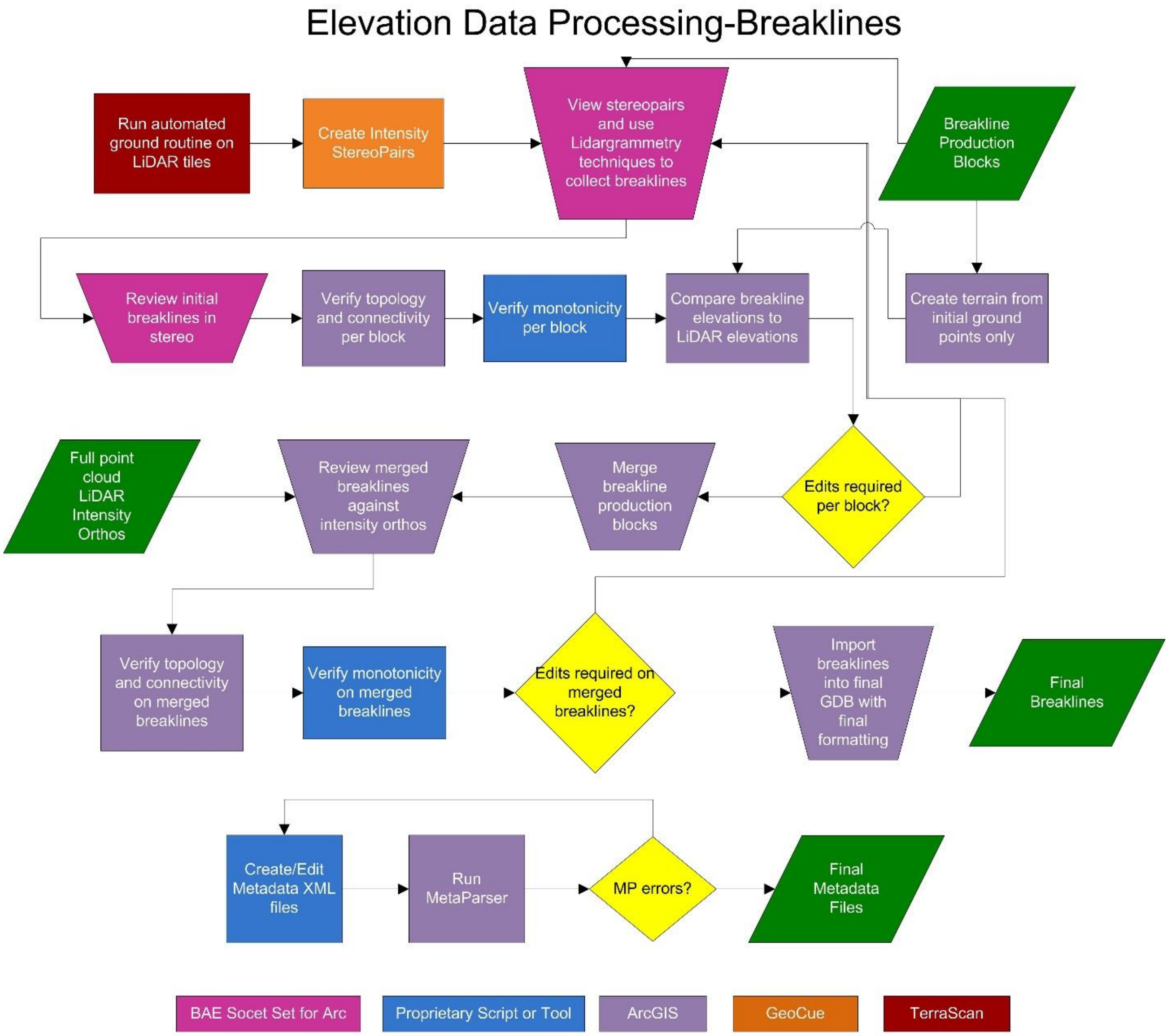


Figure 26-Breakline QA/QC workflow

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 intensity imagery, stereo pairs, 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 all checks-completeness, breakline variance, 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 11-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 US Survey Feet. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in US Survey Feet. Geoid12B shall be used to convert ellipsoidal heights to orthometric heights.

Coordinate System and Projection

All data shall be projected to NAD83 (2011) State Plane Florida East FIPS 0901

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. <u>The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body.</u> 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 2 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.

Beneath Bridge Breaklines

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

Feature Class: Bridge_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 Breaklines	Bridge Breaklines should be used where necessary to enforce terrain beneath bridge decks and to prevent bridge saddles in the bare earth DEMs.	Bridge breaklines should be collected beneath bridges where bridge saddles exist or are likely to exist in the bare earth DEMs. Bridge breaklines should be collected perpendicular to the bridge deck so that the endpoints are on either side of the bridge deck. Typically two bridge 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 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 27-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

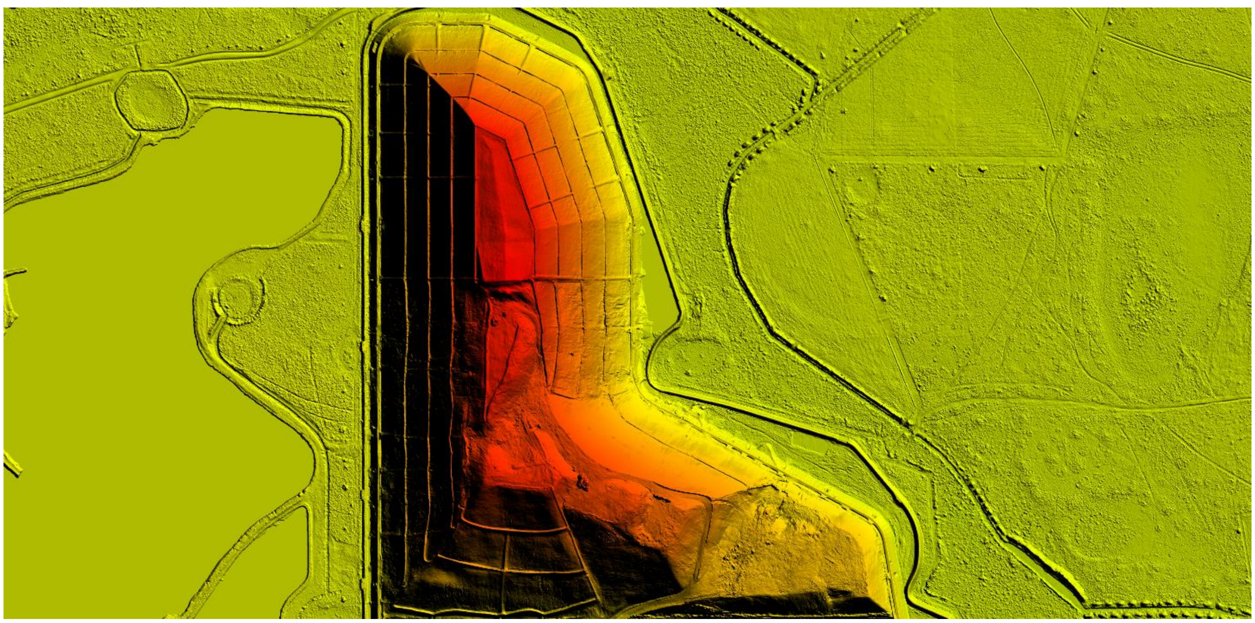


Figure 28- Tile LID2015_068591_E_D. The bare earth DEM.

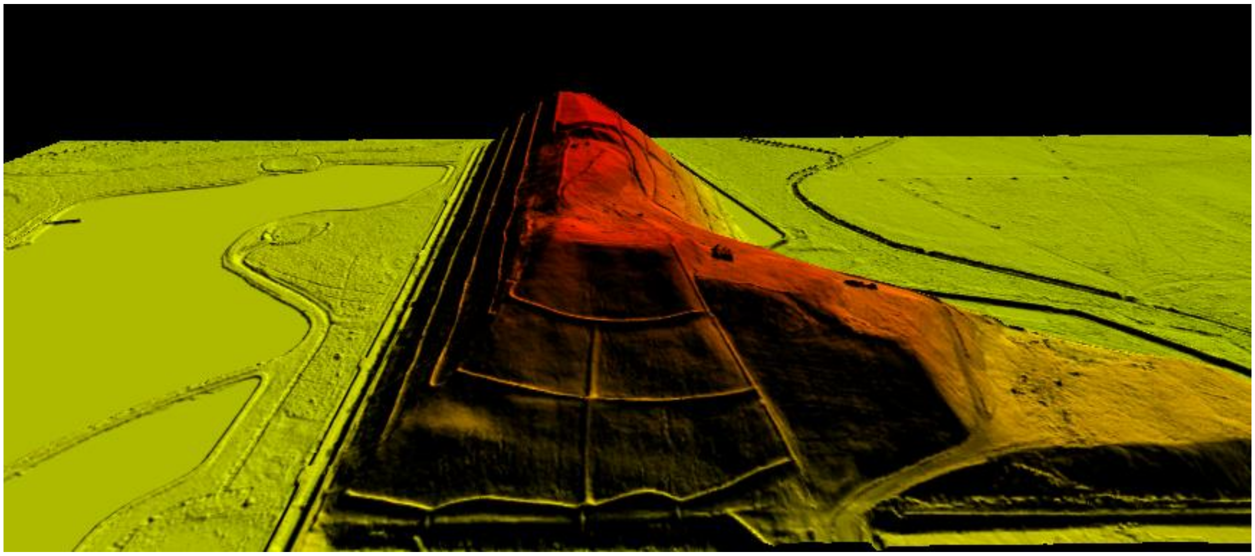


Figure 29-Tile LID2015_068591_E_D. 3D Profile view of the bare earth DEM

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.

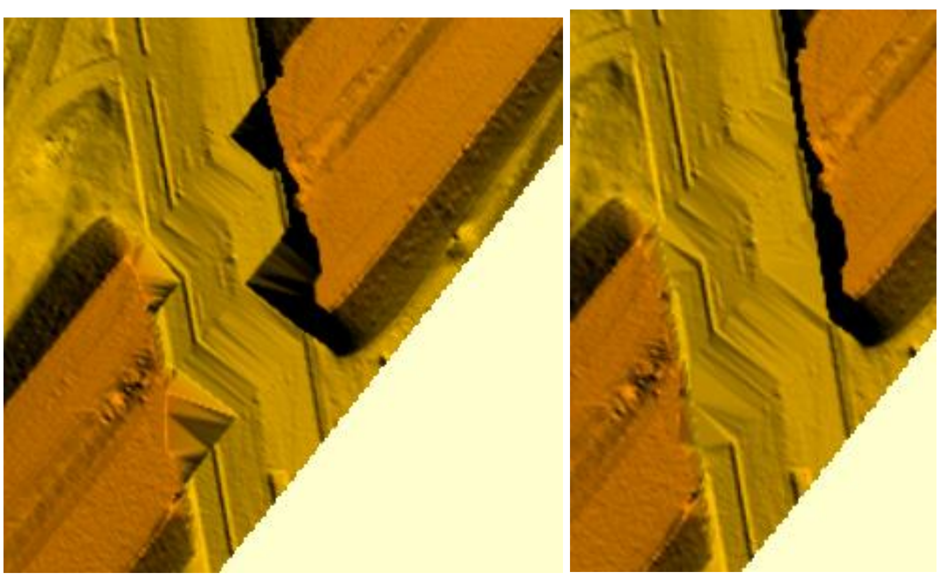


Figure 30- Tile LID2015_061665_E_D. The DEM on the left shows a bridge saddle artifact while the DEM on the right shows the same location after bridge breaklines have been enforced.

DEM VERTICAL ACCURACY RESULTS

The same 164 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 12 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=0.64 ft	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.96 ft
NVA	91.00	0.27	
VVA	73.00		0.45

Table 12 – DEM tested NVA and VVA

This DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 0.33 ft (10 cm) RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =0.14 ft (4.26 cm), equating to +/- 0.27 ft (8.23 cm) at 95% confidence level. Actual VVA accuracy was found to be +/- 0.45 ft (13.7 cm) at the 95th percentile.

Table 13 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83(2011) StatePlane Florida East FIPS 0901		NAVD88 (Geoid 12B)	DEM Z (ft)	Delta Z	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)			
VVA-71	616979.039	1374984.170	79.577	79.022	-0.555	0.555
VVA-62	629363.122	1236125.572	67.050	67.518	0.468	0.468
VVA-24	657543.514	1379653.166	55.785	56.275	0.490	0.490
VVA-67	653458.505	1352815.807	64.022	64.714	0.692	0.692

Table 13 – 5% Outliers

Table 14 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.33 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Kurtosis	Min (ft)	Max (ft)
NVA	91	0.14	0.01	0.01	-0.28	0.14	0.56	-0.40	0.37
VVA	73	N/A	0.10	0.09	-0.02	0.20	1.58	-0.56	0.69

Table 14 – Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Dewberry, the DEM dataset for the Osceola 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 15-A subset of the high-level steps from Dewberry's bare earth DEM Production and QA/QC checklist performed for this project.

EDGE-TIE ANALYSIS

Under the scope of work, Dewberry was tasked to evaluate how well the newly produced Osceola data ties spacially to preexisting data produced for Polk County, Florida. We received 673 Polk County tiles from the South Florida Water Management District for this task. There are 582 Osceola County tiles that overlap with the 673 Polk County tiles.

The Polk County data was first re-sampled to match the 2.5 ft DEM size specified for Osceola County so that the data were consistent. Dewberry then used the bare-earth DEMs for each dataset and created a difference raster by subtracting Polk County data from Osceola County data. This difference raster, along with the Osceola County and Polk County project boundaries, is shown on Figure 29 below.

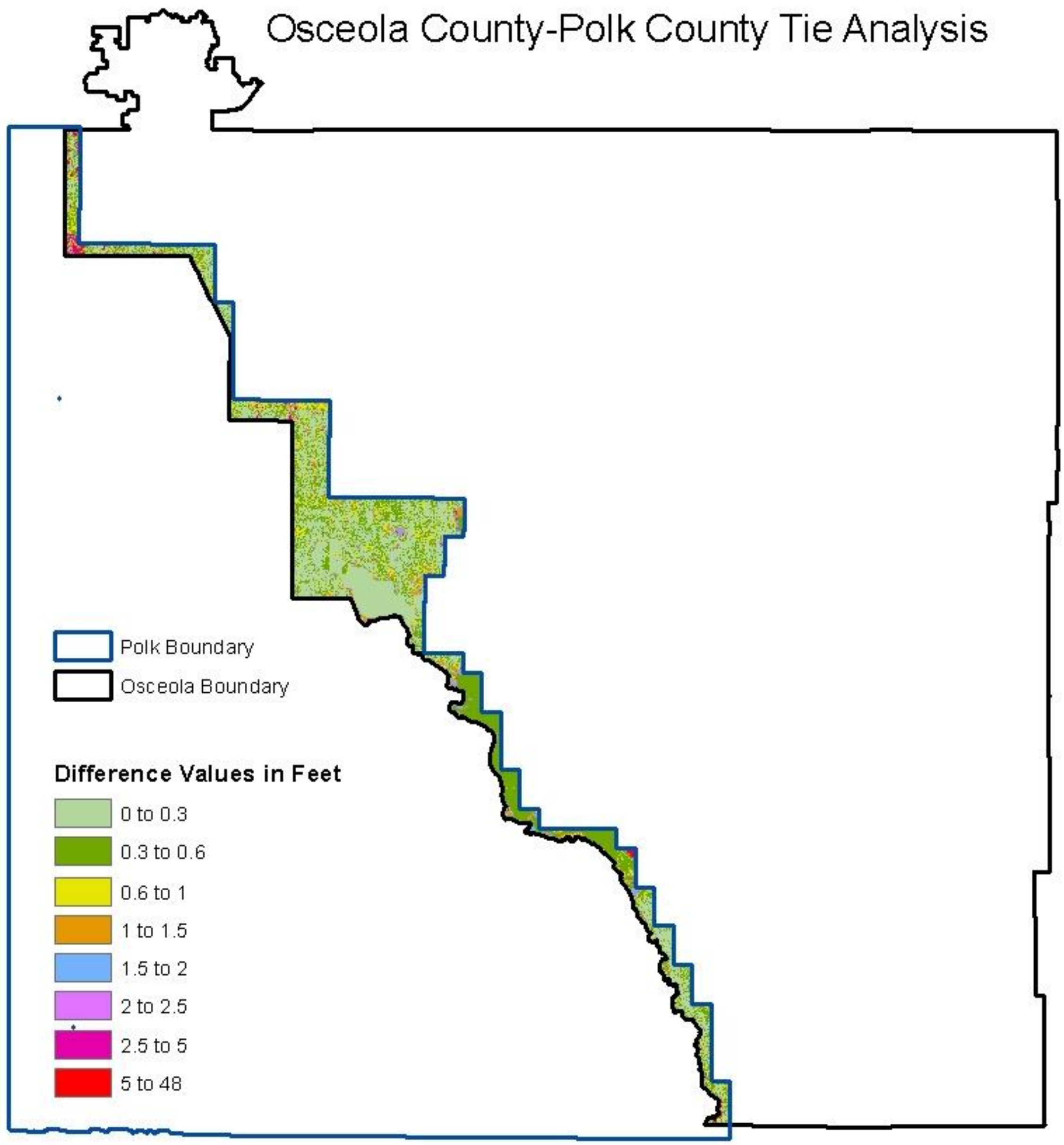


Figure 31-Difference raster created to analyze the edge-match/edge-tie area between Osceola County and previously collected Polk County.

Per the specifications, the Osceola County data must meet 0.64 ft vertical acccuracy at the 95% confidence level based on RMSEz (0.33 ft) x 1.9600 in Non-vegetated areas (NVA). After accuracy assessment testing using surveyed check points, the Osceola data achieved a 0.27 ft vertical accuracy at the 95% confidence level based on RMSEz (0.14 ft) x 1.9600. The Polk County metadata contained a statement that the data met 0.3 ft Fundamental Vertical Accuracy (FVA). This equates to a RMSEz of 0.15 ft. Statistically, these tested values should be regarded as a best case scenario applicable to well-defined locations and smooth, bare surfaces. Adjacent datasets should typically match within the combined tested RMSEz values for low slope, open terrain areas. For Osceola-Polk overlap, this would translate to 0.29 ft of allowable elevation differences between the two datasets in flat, open terrain. Dewberry rounded this value to 0.3 ft for visualization purposes in the difference raster.

When looking at all overlap areas consisting of all slopes and all land cover types, 48% of the Osceola-Polk overlap area matches within 0.3 feet of each other. As the Polk County FVA value of 0.3 feet was stated as best case scenario and a 0.3 ft FVA is very stringent, it is quite possible the Polk County data actually met 0.6 ft FVA based on RMSEz (0.3 ft) x 1.9600. This accuracy requirement would be very similar to the vertical accuracy requirement for Osceola County to meet USGS QL2 specifications. Consequently, Dewberry doubled the difference in elevation values threshold to 0.6 ft (0.3 ft required RMSEz for each dataset). While this threshold still only applies to flat, open areas 81% of all Osceola-Polk overlap areas (all slopes and land cover types) match within 0.6 feet of each other. Furthermore, 89% of all Osceola-Polk overlap areas (all slopes and land cover types) match within 1 foot of each other.

The areas of larger vertical differences between these two datasets occur due to temporal changes. There are clearly changes in the level of water in water bodies and streams, along shorelines,and within floodplains. And there are cultural or man-made changes including new housing developments. The figures below show a few examples of these temporal changes.

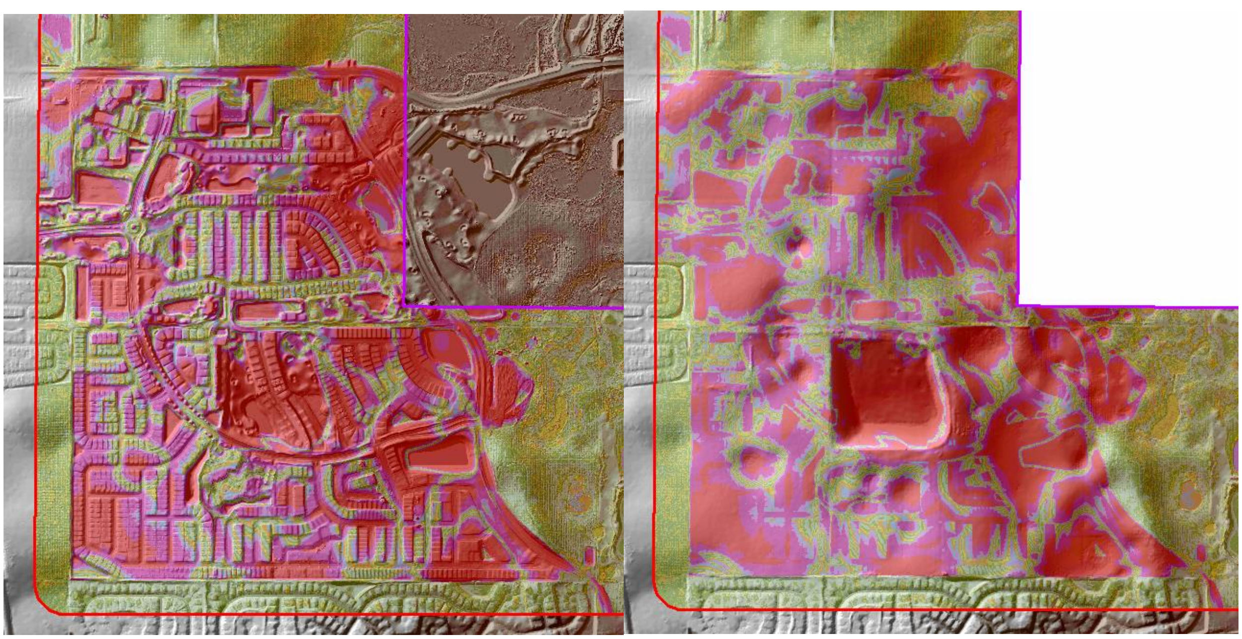


Figure 32-The image on the left shows the Osceola County bare earth DEM overlaid with the difference raster (partially transparent). The image on the right shows the Polk County bare earth DEM overlaid with the difference raster (partially transparent). The light and dark purple areas are between 2-5 feet different in elevation between the two datasets and the red areas are anywhere between 5-48 feet different in elevation. Most of the red areas in these images are between 5-20 feet different in elevation. These significant elevation differences occur because a housing development

exists in the Osceola County dataset (left image) but was not present when the Polk County data was previously acquired (right image).

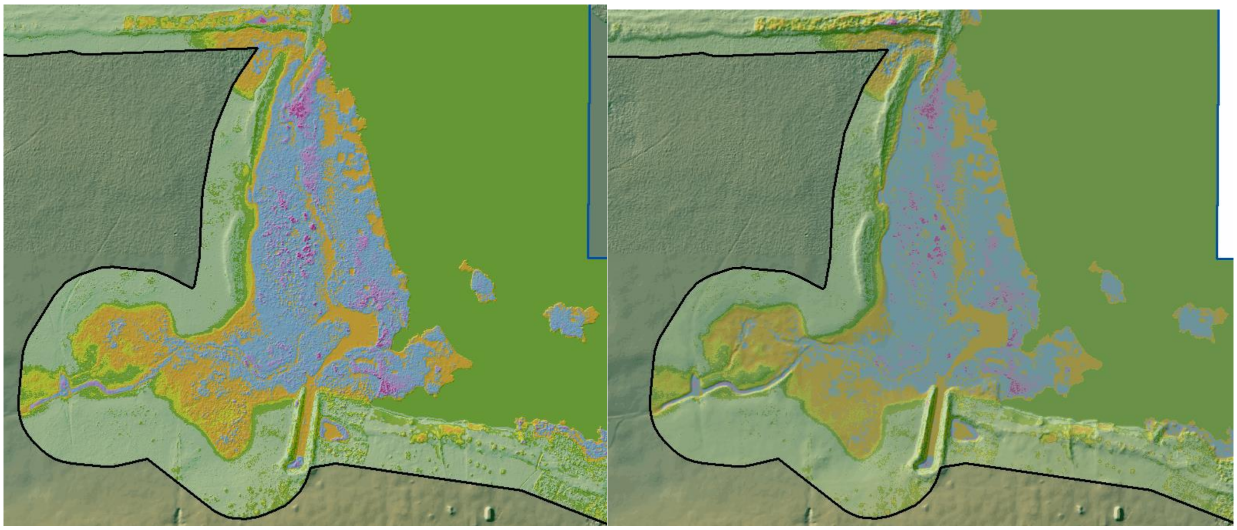


Figure 33 -The image on the left shows the Osceola County bare earth DEM overlaid with the difference raster (partially transparent). The image on the right shows the Polk County bare earth DEM overlaid with the difference raster (partially transparent). Areas of yellow and orange are 0.6 – 1.5 feet different in elevation. Areas of blue are 1.5 – 2 feet different in elevation. These changes in elevation occur because the shoreline has completely changed between the previously acquired Polk County dataset and the recently acquired Osceola dataset. Whereas open water existed in the Polk County dataset and was hydro-flattened (right image), this area is now bare earth in the Osceola County dataset and the shoreline has shifted east (left image).

Based on our analysis,the areas of significant vertical elevation change occur due to temporal differences. They include varying levels of water in hydrographic features, shoreline changes, changes in floodplains, and cultural or man-made changes. The Osceola County and Polk County datasets match quite well and match within the expected or allowable offset tolerances. No additional adjustments were applied to the Osceola County dataset for edge-matching purposes as none were needed.

Appendix A: Ground Control Point Survey Report

GROUND CONTROL SURVEY REPORT

ACA recovered 16 NAD83(2011) published NGS monuments throughout the project area to be used as set control locations during each lift. Before the collection started we covered the NGS points and shot them with a RTK unit to verify the published coordinate values. During each lift we set 2 Leica GS14 base stations within 25 miles of the lift recording 1 second static. The 16 NGS point values were used as the coordinates values for the base stations during the trajectory processing. After each mission was calibrated we then checked the mission to mission adjustment comparing horizontal and vertical offsets. Once all the mission to mission adjustments were finished we used the points Dewberry supplied to verify the vertical offset between the point cloud and the ground points. A final vertical adjustment was applied to overall point cloud after this assessment.


ACA
Osceola Control Points
GPS: OSCEOLA

AK7134 GIS146 RESET ORANGE CO. GEODETIC INFORMATION SYSTEM
Pmon w/ brass disc OPEN

AK7298 Not found

AK7111 FIR in box marked KOBI 1991
OPEN

AB5503 FMON 6X6 GPS 95-064 brass disc
OPEN

AB5498 PMON GPS 95-051
OPEN

DL6642 FIR in box Q733 2009
OPEN

AB5482 PMON 3/4" rod bent over

AK6933 FIR in box FLGPS 44 AZ MK 1999
OPEN

1-13-16

AK6935 FIR in box marked FLGPS 53 AZ MK 1989

AB5478 PMON w/ brass disc stamped 95-061A

CW6769 PMON BRICK 1960 AZ MARK US COAST GEODETIC SURVEY leaning westwordly

AF7103 PMON w/ brass disc FLORIDA DEPT NATURAL RESOURCES OSC1 1983
OPEN

AF6097 PMON w/ brass disc U.S. Coast & Geodetic Survey Jackson 1936
OPEN

G Thomas
J. McDonald
1-12-16
1-13-16
M157/23

Not found searched for
AK7298, AK7336, AF7663,

AW6687 Behind locked gates off of Hwy 523 & Boy Scout Camp Rd

DJ8307 FIR in box L687 2007
OPEN

AF6134 FMON 12x12 w/ brass disc US COAST & GEODETIC SURVEY stamped COON 1936

AF6121 PMON w/ brass disc US COAST & GEODETIC SURVEY stamped S197 1960 leaning slightly BENCH MARK
OPEN

AF7643 FIR in box K113 1991
OPEN

2016/01/13

Figure 1: Ground Control Field Notes

Appendix B: Checkpoint Survey Report

OSCEOLA FL QL2 LIDAR 2016
INDEPENDENT CHECK POINTS

SUBCONTRACT AGREEMENT NO. S/C-USGS-G10PC00013-PRI

Reference:

Client: USGS
Contract 3: G10PC00013
Task Order No.: G15PD00887
Task Name: Osceola FL QL2 Lidar

Prepared For:

Dewberry Consultants LLC
10003 Derekwood Lane, Suite 204
Lanham, Maryland, 20706
Phone (301)364-1855 Fax (301)731-0188

Prepared By:

Preble-Rish, Inc.
203 Aberdeen Parkway
Panama City, FL 32405

PREBLE-RISH INC
CONSULTING ENGINEERS & SURVEYORS

Dewberry

1. INTRODUCTION

1.1 Project Summary

Preble-Rish, Inc. is under subcontract to Dewberry Consultants, LLC, to provide a minimum of 65 Non-vegetated Vertical Accuracy (NVA – total number actually surveyed = 92), and 52 Vegetated Vertical Accuracy (VVA – total number actually surveyed = 73) check points for USGS in the State of Florida. A minimum of half (33) of the NVA points shall also be horizontal accuracy check points (total number actually surveyed = 35). Under the above referenced USGS Task Order, Preble-Rish is tasked to complete the quality assurance of high resolution LiDAR-derived elevation products. As part of this work, Preble-Rish, Inc. staff will complete checkpoint surveys that will be used to evaluate vertical accuracy on the bare-earth terrain derived from the LiDAR.

Existing NGS Control Points were recovered and surveyed to verify the accuracy of the RTK/GPS survey equipment with the results shown in Section 2.4 and Appendix 1 of this report.

As an internal QA/QC procedure, and to verify that the LiDAR check points meet the 95% confidence level, 68 of the NVA check points, and 53 of the VVA check points were resurveyed and are shown in Section 5 of this report. For check points that were surveyed twice, an average of the two observations was computed to generate final coordinates and elevations.

Final horizontal coordinates are referenced to the Florida State Plane Coordinate System, NAD83, East Zone, U.S. survey feet. Final vertical elevations are referenced to NAVD88 in feet using Geoid model 2012B (Geoid12B).

1.2 Points of Contact

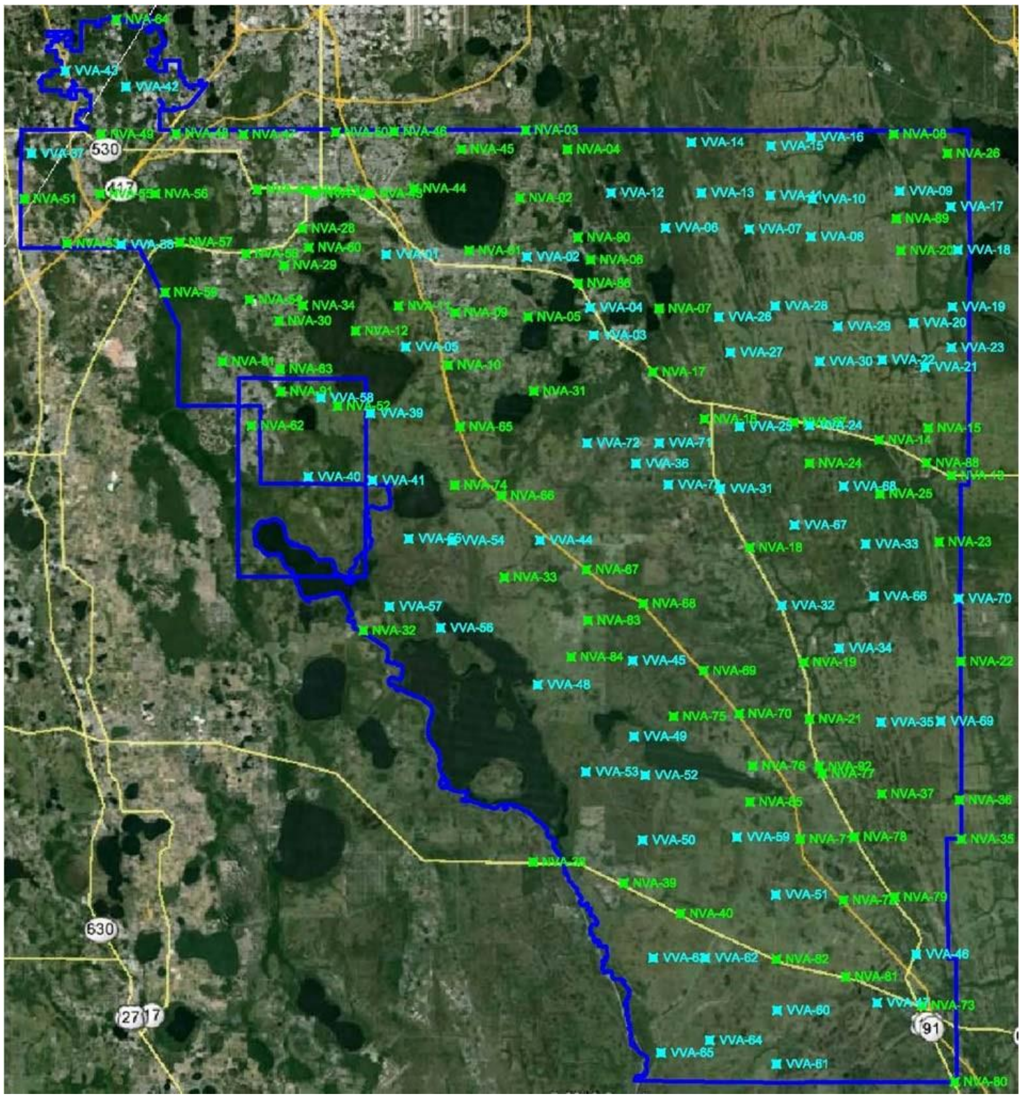
Questions regarding the technical aspects of this report should be addressed to:

Preble-Rish, Inc.

Frederick C. Rankin, P.S.M.
Professional Surveyor & Mapper
203 Aberdeen Parkway
Panama City, Florida 32405
(850) 522-0644 office

(850) 522-1011 fax

1.3 Project Area



OSCEOLA FL QL2 LIDAR 2016 – ICP LOCATIONS

2. PROJECT DETAILS

2.1 SURVEY EQUIPMENT

In performing the GPS observations, Spectra Precision Epoch 80 GNSS RTK GPS receiver/antenna attached to a 6.56 foot (2 meter) fixed height pole was used, together with a Spectra Precision Ranger Data Collector equipped with SurveyPro Software (version 5.5.2), to collect GPS raw data for the field surveys.

2.2 SURVEY POINT DETAIL

92 Non-vegetated Check Points, and 73 Vegetated Check Points were distributed throughout the project area.

A sketch was made for each location and a nail was set at the point where possible, unless said point was already located at a photo identifiable point. The LiDAR Check Point locations are detailed on the "Ground Control Point Documentation Report", which is delivered via electronic transfer, see appendix 5a on sheet 2.

2.3 NETWORK DESIGN

The GPS survey performed by Preble-Rish, Inc. was tied to the Florida Permanent Reference Network (FPRN), a Real Time Network (RTN) managed by the Florida Department of Transportation. The FPRN consists of a series of approximately 100 continuously operating dual-frequency reference stations (CORS) located throughout Florida, which are tied to the National Geodetic Survey's National CORS network. Each CORS site provides Global Positioning System (GPS) carrier phase and code range measurements in support of 3dimensional positioning activities through Florida and surrounding states. All of the reference stations have been linked together, creating a Virtual Reference Station System (VRS).

2.4 FIELD SURVEY PROCEDURES AND ANALYSIS

Preble-Rish, Inc. field surveyors used Spectra Precision Epoch 80 GNSS RTK GPS systems, which is a geodetic quality dual frequency GPS receiver, to collect data at each check point location.

Nineteen (19) existing NGS monuments were located as an additional QA/QC procedure, for the purpose of verifying the accuracy of the VRS network. All NGS monuments used are published in the NSRS database, and represent the primary project control for this survey. Field GPS observations are detailed in the "Project Network Control Monument Report", see appendix 1 on sheets 7-8.

A total of 68 of the NVA check point locations, and 53 of the VVA check point locations were occupied twice. All re-observations matched the initially derived station positions within the allowable tolerance of ± 5cm or within the 95% confidence level. Each occupation utilized the VRS network, was occupied for approximately three (3) minutes in duration, and measured to 180 epochs. Field GPS observations are detailed in the "Ground Control Point Documentation Report", and delivered via electronic transfer, see appendix 5a on sheet 2.

2.5 ADJUSTMENT

The survey data was collected using Virtual Reference Stations (VRS) methodology within a Virtual Reference System (VRS).

The system is designed to provide a true Network RTK performance, the RTK software enables high-accuracy positioning in real time across a geographic region. The RTK software package uses real-time data streams from the GPS system user and generates correction models for high-accuracy RTK GPS corrections throughout the network. Therefore, corrections were applied to the points as they were being collected, thus negating the need for a post process adjustment.

2.6 DATA PROCESSING PROCEDURES

After field data is collected the information is downloaded from the data collectors into the office software. Text files are created that show the point number, northing, easting, elevation, and description (PNEZD format) for each point surveyed. Points are then entered into a Microsoft Excell spreadsheet, which contains formulas for calculating differences between published and field survey data, as well as, comparing differences between points surveyed multiple times. This data is used to confirm point accuracy and precision.

After review of the point data, an "ASCII" or "txt" file (PNEZD format) is created, which is the industry standard. Point files are loaded into our CADD program (AutoCAD Civil 3D) to make a visual check of the point data (Pt. #, Coordinates, Elev. and Description). For check points that were surveyed twice, an average of the two observations was computed to generate final northings, eastings, and elevations. The data can now be imported into the final product.

Table 1:

Project Network Control Monument Report

95 061A (AB5478)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z		
3/16/2016	1374800.6940	631573.4030	75.129	1374800.6600	631573.4700	75.1900	-0.03		0.06	rmse$_N$	0.055 0.048
3/16/2016	1374800.7300	631573.4750	75.14	1374800.6600	631573.4700	75.1900	0.07 -0.07	-	0.05	rmse$_E$	**0.073**
							0.01			**Hrmse$_r$**	0.056
										Vrmse	

OSC 1 FLDNR (B2 AK7103)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z		
3/13/2016	1330578.438	599246.504	75.43	1330578.4200	599246.5000	75.4100	-0.02	0.00	-0.02	rmse$_N$	0.015
3/13/2016	1330578.411	599246.506	75.266	1330578.4200	599246.5000	75.4100	0.01	-	0.14	rmse$_E$	0.040
3/12/2016	1330578.44	599246.503	75.568	1330578.4200	599246.5000	75.4100	0.01	-0.02	-0.16	**Hrmse$_r$**	**0.043**
3/10/2016	1330578.437	599246.567	75.443	1330578.4200	599246.5000	75.4100	0.00 -0.02	-	-0.03	**Vrmse**	0.111
3/14/2016	1330578.418	599246.428	75.283	1330578.4200	599246.5000	75.4100	0.07	0.00	0.13		
3/15/2016	1330578.436	599246.503	75.309	1330578.4200	599246.5000	75.4100	0.07		0.10		
							-0.02	0.00			

K 113 (B3 AF7643)-H

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z		
3/13/2016	1262168.927	570148.143	61.923	1262168.9200	570148.1500		-0.01	0.01	-61.92	rmse$_N$	0.026
3/16/2016	1262168.9560	570148.1010	61.871	1262168.9200	570148.1500		-0.04	0.05	-61.87	rmse$_E$	0.035
										Hrmse$_r$	**0.044**

Q 733 (B4 DL6642)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z		
3/7/2016	1440218.9888	515785.2659	76.821	1440218.9700	515785.2200	76.8200	-0.02	-0.05	0.00	rmse$_N$	0.033
3/7/2016	1440218.9760	515785.2550	76.799	1440218.9700	515785.2200	76.8200	-0.01	-0.04	0.02	rmse$_E$	0.040
3/8/2016	1440218.9960	515785.2280	76.784	1440218.9700	515785.2200	76.8200	-0.03	-0.01	0.04	**Hrmse$_r$**	**0.052**
3/11/2016	1440218.9990	515785.2530	76.858	1440218.9700	515785.2200	76.8200	-0.03 -0.03 -0.05	-	-0.04	**Vrmse**	0.050
3/16/2016	1440219.0240	515785.2630	76.7370	1440218.9700	515785.2200	76.8200	0.04		0.08		
3/16/2016	1440219.0110	515785.2780	76.7510	1440218.9700	515785.2200	76.8200	-0.04	-0.06	0.07		

FLGPS 44 AZ MK (B5 AK6933)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z		
3/9/2016	1432707.6550	655130.0730	66.008	1432707.6800	655130.0800	65.9900	0.02	0.01	-0.02	rmse$_N$	0.023
3/10/2016	1432707.642	655130.085	65.979	1432707.6800	655130.0800	65.9900	0.04	-0.01	0.01	rmse$_E$	0.020
3/10/2016	1432707.669	655130.119	66.052	1432707.6800	655130.0800	65.9900	0.01	-0.04	-0.06	**Hrmse$_r$**	**0.030**
3/11/2016	1432707.649	655130.069	65.918	1432707.6800	655130.0800	65.9900	0.03 0.01 0.01		0.07	**Vrmse**	0.062
3/12/2016	1432707.672	655130.064	66.108	1432707.6800	655130.0800	65.9900	0.02		-0.12		
3/13/2016	1432707.678	655130.099	65.99	1432707.6800	655130.0800	65.9900	0.00	-0.02	0.00		

95 056A (B7 AB5482)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z	

3/7/2016	1433053.737	604549.893	69.592	1433053.7800	604549.9500	69.8800	0.04		0.29	$rmse_N$	0.036
3/9/2016	1433053.75 604549.99		69.567	1433053.7800	604549.9500	69.8800	0.06 0.03	-	0.31	$rmse_E$	0.048
							0.04			**$Hrmse_r$**	**0.060**
										Vrmse	0.301

95 064 (B8 AB5503)-H

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z		
3/7/2016	1405986.015	505940.911	74.79	1405985.9800	505940.8900		-0.03	-0.02 N.A. -0.04		$rmse_N$	0.038
3/7/2016	1405986.021	505940.913	74.828	1405985.9800	505940.8900			-0.02 N.A.		$rmse_E$	0.022
										$Hrmse_r$	**0.044**
										Vrmse	N.A.

FLGPS 53 AZ MK (B9 AK6935)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z		
3/11/2016	1375220.924	678778.547	50.142	1375220.8300	678778.5200	50.1400	-0.09	-0.03	0.00	$rmse_N$	0.090
3/12/2016	1375220.936	678778.582	50.098	1375220.8300	678778.5200	50.1400	-0.11	-0.06	0.04	$rmse_E$	0.047
3/13/2016	1375220.866	678778.586	50.162	1375220.8300	678778.5200	50.1400	-0.04 -	-0.07 -	-0.02	**$Hrmse_r$**	**0.102**
3/15/2016	1375220.886	678778.581	50.137	1375220.8300	678778.5200	50.1400	0.06 -0.09	0.06	0.00	**Vrmse**	0.054
3/15/2016	1375220.923	678778.559	50.008	1375220.8300	678778.5200	50.1400	-0.11 -	-0.04	0.13		
3/14/2016	1375220.937	678778.522	50.159	1375220.8300	678778.5200	50.1400	0.11	0.00 -	-0.02		
3/16/2016	1375220.9390	678778.5330	50.132	1375220.8300	678778.5200	50.1400	-0.09	0.01	0.01		
3/16/2016	1375220.9250	678778.5780	50.198	1375220.8300	678778.5200	50.1400		-0.06	-0.06		

95 058A (AB5489)-H

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z		
3/7/2016	1409017.102	577659.624	76.725	1409017.0300	577659.5900		-0.07	-0.03 N.A.		$rmse_N$	0.072
										$rmse_E$	0.034
										$Hrmse_r$	**0.080**
										Vrmse	N.A.

Table 2 1:

Project Network Control Monument Report (Cont.)

JACKSON (AF6097)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z	$rmse_N$	0.027
3/12/2016	1311079.552	614001.222	68.881	1311079.5900	614001.2300	68.8500	0.04	0.01	-0.03	$rmse_E$	0.032
3/12/2016	1311079.591	614001.275	68.861	1311079.5900	614001.2300	68.8500	0.00	-0.05	-0.01	**$Hrmse_r$**	**0.042**
										Vrmse	0.023

BREVARD GPS1051 (AF7746)-H

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
	Northing	Easting	Elevation	Northing	Easting	Elevation	Delta N	Delta E	Delta Z	$rmse_N$	0.044
3/13/2016	1268022.72	698733.451	51.868	1268022.7400	698733.4700		0.02 0.02 N.A. -0.06 -0.01 N.A.			$rmse_E$	0.014
3/16/2016	1268022.7990 698733.4760		51.656	1268022.7400	698733.4700					**$Hrmse_r$**	**0.046**
										Vrmse	N.A.

COON (AF6134)-HV

Date	Field Survey Data (F)	Published Data (F)	Differences (F)	RMSE

3/16/2016	**Northing**	**Easting**	**Elevation**	**Northing**	**Easting**	**Elevation**	**Delta N**	**Delta E**	**Delta Z**	rmse$_N$	0.035
3/16/2016	1243075.8490	631895.4220	69.541	1243075.8200	631895.4400	69.6600	-0.03	0.02	0.12	rmse$_E$	0.016
	1243075.8600	631895.4260	69.544	1243075.8200	631895.4400	69.6600	-0.04	0.01	0.12	**Hrmse$_r$**	**0.038**
										Vrmse	0.118

L 512 (DF6696)-V

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
3/7/2016	**Northing**	**Easting**	**Elevation**	**Northing**	**Easting**	**Elevation**	**Delta N**	**Delta E** N.A.	**Delta Z**	rmse$_N$	N.A.
3/8/2016	1439418.2830	528917.6810	57.999			58.0900	N.A.	N.A.	0.09	rmse$_E$	N.A.
	1439418.275 528917.652		58.065			58.0900	N.A.		0.03	**Hrmse$_r$**	**N.A.**
										Vrmse	0.067

F 512 (DF6691)-V

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
3/7/2016	**Northing**	**Easting**	**Elevation**	**Northing**	**Easting**	**Elevation**	**Delta N**	**Delta E** N.A.	**Delta Z**	rmse$_N$	N.A.
3/8/2016	1425023.0350	550821.7920	61.245			61.3000	N.A.	N.A.	0.05	rmse$_E$	N.A.
	1425023.0200	550821.8070	61.209			61.3000	N.A.		0.09	**Hrmse$_r$**	**N.A.**
										Vrmse	0.075

P 59 RESET (AK2011)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
3/8/2016	**Northing**	**Easting**	**Elevation**	**Northing**	**Easting**	**E evation**	**Delta N**	**Delta E**	**Delta Z**	rmse$_N$ rmse$_E$	0.036
3/8/2016	1422295.1640	561801.3390	75.146	1422295.1400	561801.3400	75.2300	-0.02	0.00	0.08	**Hrmse$_r$**	0.012
3/9/2016	1422295.1510	561801.3430	75.145	1422295.1400	561801.3400	75.2300	-0.01 -0.05	0.00	0.09	**Vrmse**	**0.038**
3/9/2016	1422295.186	561801.345	75.191	1422295.1400	561801.3400	75.2300	-0.03	-0.01	0.04		0.091
3/14/2016	1422295.169	561801.341	75.153	1422295.1400	561801.3400	75.2300	-0.03	0.00	0.08		
3/15/2016	1422295.169	561801.312	75.233	1422295.1400	561801.3400	75.2300	-0.04 -0.06	0.03	0.00		
3/16/2016	1422295.177	561801.322	75.383	1422295.1400	561801.3400	75.2300	-0.03	0.02 0.00	-0.15		
3/17/2016	1422295.2020	561801.3370	75.0890	1422295.1400	561801.3400	75.2300		0.00	0.14		
	1422295.1660	561801.3410	75.2070	1422295.1400	561801.3400	75.2300			0.02		

K081 (AK7111)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
3/9/2016	**Northing**	**Easting**	**Elevation**	**Northing**	**Easting**	**Elevation**	**Delta N**	**Delta E**	**Delta Z**	rmse$_N$ rmse$_E$	0.004
3/9/2016	1427522.1930	477009.2950	86.421	1427522.1900	477009.2700	86.4500	0.00	-0.02	0.03	**Hrmse$_r$**	0.030
	1427522.186 477009.304		86.459	1427522.1900	477009.2700	86.4500	0.00	-0.03	-0.01	**Vrmse**	**0.030**
											0.021

95 051 (AB5498)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
3/9/2016	**Northing**	**Easting**	**Elevation**	**Northing**	**Easting**	**Elevation**	**Delta N**	**Delta E**	**Delta Z**	rmse$_N$ rmse$_E$	0.034
3/10/2016	1426446.7460	508908.7550	79.068	1426446.7100	508908.7400	79.1400	-0.04	-0.02 -0.03 -	0.07	**Hrmse$_r$**	0.011
	1426446.741 508908.745		79.13	1426446.7100	508908.7400	79.1400		0.01	0.01	**Vrmse**	**0.035**
											0.051

L 687(DJ8307)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
3/11/2016	**Northing**	**Easting**	**Elevation**	**Northing**	**Easting**	**Elevation**	**Delta N**	**Delta E**	**Delta Z**	rmse$_N$ rmse$_E$	0.060
3/12/2016	1217516.464	697553.604	53.974	1217516.4100	697553.5600	53.9500	-0.05	-0.04	-0.02 -	**Hrmse$_r$ Vrmse**	0.063
3/12/2016	1217516.444	697553.648	54.02	1217516.4100	697553.5600	53.9500	-0.03	-0.09	0.07		**0.087**
	1217516.492	697553.609	53.932	1217516.4100	697553.5600	53.9500	-0.08	-0.05	0.02		0.044

R 513(DF6726)-HV

Date	Field Survey Data (F)			Published Data (F)			Differences (F)			RMSE	
3/14/2016	**Northing**	**Easting**	**Elevation**	**Northing**	**Easting**	**Elevation**	**Delta N**	**Delta E**	**Delta Z**	rmse$_N$ rmse$_E$	0.079
3/14/2016	1363436.403	566567.497	62.575	1363436.32	566567.51	62.6500	-0.08	0.01	0.07	**Hrmse$_r$ Vrmse**	0.010
	1363436.394	566567.504	62.54	1363436.32	566567.51	62.6500	-0.07	0.01	0.11		**0.079**
											0.094

Table 3:

Final Check Point Coordinates

Osceola FL QL2 LiDAR POINTS 2016			
POINT #	NORTHING (F)	EASTING (F)	ELEV. (F)
NVA-01	1426776.418	565625.875	60.893
NVA-02	1440994.188	579330.214	78.979
NVA-03	1459261.461	580904.643	65.904
NVA-04	1454084.174	592213.745	74.370
NVA-05	1408943.436	581594.789	71.882
NVA-06	1424322.313	598467.454	68.801
NVA-07	1411173.529	616905.552	72.494
NVA-08	1458206.959	680277.203	25.680
NVA-09	1410057.983	561863.587	73.245
NVA-10	1395918.311	560058.254	69.167
NVA-11	1411849.680	546592.882	59.565
NVA-12	1405150.205	535074.666	57.943
NVA-13	1366146.809	695832.616	31.591
NVA-14	1375728.254	676234.735	51.593
NVA-15	1378938.400	689540.336	50.503
NVA-16	1381399.186	629145.099	77.521
NVA-17	1394069.206	615284.547	75.873
NVA-18	1346758.725	641402.609	67.203
NVA-19	1315830.771	655952.371	59.815
NVA-20	1426796.904	682128.639	48.011
NVA-21	1300530.283	657491.337	67.345
NVA-22	1316040.228	698328.515	38.465
NVA-23	1348242.713	692432.662	45.354
NVA-24	1369469.061	657499.425	55.481
NVA-25	1361219.916	676484.006	41.677
NVA-26	1452992.737	694693.508	14.201
NVA-27	1443061.856	522085.257	68.277
NVA-28	1432771.431	520681.603	61.516
NVA-29	1422849.321	515729.498	72.337
NVA-30	1407837.663	514358.051	70.349
NVA-31	1388919.043	583103.966	65.575
NVA-32	1324361.607	537140.612	54.296
NVA-33	1338723.080	575197.196	59.852
NVA-34	1411998.048	520814.726	61.070
NVA-35	1268129.507	698465.394	53.457
NVA-36	1278664.008	697937.786	48.414
NVA-37	1280363.485	676978.836	67.857

NVA-38	1261947.171	582923.719	55.381
NVA-39	1256262.813	607426.462	61.174
NVA-40	1248094.582	622714.472	65.610
NVA-41	1443236.958	508502.534	76.963
NVA-42	1442117.045	524184.005	63.163
NVA-43	1442156.820	539012.673	70.917
NVA-44	1443485.908	550794.945	63.369
NVA-45	1454137.853	563616.429	75.846
NVA-46	1458870.857	545474.069	82.048
NVA-47	1458105.584	504780.412	78.340
NVA-48	1458408.447	486615.226	88.930
NVA-49	1458111.537	466388.323	103.306
NVA-50	1458719.529	529685.335	83.649

Final Check Point Coordinates (Cont.)

Osceola FL QL2 LiDAR POINTS 2016			
POINT #	NORTHING (F)	EASTING (F)	ELEV. (F)
NVA-51	1440753.617	445626.304	140.080
NVA-52	1384895.381	530202.336	63.179
NVA-53	1428683.554	457199.649	126.294
NVA-54	1413568.098	506420.564	74.231
NVA-55	1442092.480	466096.864	110.984
NVA-56	1442080.528	481064.365	77.162
NVA-57	1429032.220	487711.142	70.086
NVA-58	1425982.938	505472.813	70.676
NVA-59	1415513.442	483617.690	80.954
NVA-60	1427635.232	522397.991	58.590
NVA-61	1396913.885	499192.292	66.945
NVA-62	1379598.758	506972.824	63.631
NVA-63	1394884.673	514667.927	74.372
NVA-64	1489131.405	470492.214	99.789
NVA-65	1379284.909	563248.159	70.462
NVA-66	1360744.562	574467.193	63.770
NVA-67	1340812.641	597307.486	78.836
NVA-68	1331637.419	612687.613	82.887
NVA-69	1313534.037	628955.020	75.750
NVA-70	1301928.177	638519.767	72.662
NVA-71	1268128.145	655017.572	74.509
NVA-72	1251717.127	666636.134	72.646
NVA-73	1223295.675	687923.801	63.693
NVA-74	1363535.858	561780.820	59.920
NVA-75	1301209.082	620812.188	69.836
NVA-76	1287855.762	642218.873	71.905
NVA-77	1285817.761	660958.265	72.081
NVA-78	1268738.621	669585.975	75.227
NVA-79	1252539.825	680493.612	63.744
NVA-80	1202714.218	696679.141	72.126
NVA-81	1231060.502	667316.133	69.555
NVA-82	1235786.933	648549.159	69.783
NVA-83	1327127.568	597747.756	73.868
NVA-84	1317245.566	593185.928	67.293
NVA-85	1278163.370	641411.608	65.791
NVA-86	1417968.100	595102.265	70.783
NVA-87	1380482.352	653273.857	54.978
NVA-88	1369571.530	689079.578	48.589
NVA-89	1435413.301	680921.791	42.124
NVA-90	1430319.164	594959.849	70.748
NVA-91	1388826.742	514889.453	69.221
NVA-92	1287734.408	660094.227	70.951

Final Check Point Coordinates (Cont.)

Osceola FL QL2 LiDAR POINTS 2016			
POINT #	**NORTHING (F)**	**EASTING (F)**	**ELEV. (F)**
VVA-01	1425707.697	543326.034	64.333
VVA-02	1425126.894	581252.546	75.999
VVA-03	1403963.199	599294.972	76.005
VVA-04	1411443.842	598331.001	71.847
VVA-05	1400802.925	548563.663	72.763
VVA-06	1432971.276	618620.792	70.180
VVA-07	1432616.081	641226.001	75.784
VVA-08	1430503.439	657890.871	63.101
VVA-09	1442827.793	681840.623	41.622
VVA-10	1440702.752	658314.138	54.508
VVA-11	1441659.775	646941.050	71.223
VVA-12	1442385.774	603999.674	63.047
VVA-13	1442353.535	628343.362	75.266
VVA-14	1455936.039	625661.327	72.324
VVA-15	1455012.577	647072.123	68.697
VVA-16	1457377.765	657877.722	56.412
VVA-17	1438651.964	695603.449	20.528
VVA-18	1426945.715	697486.584	16.593
VVA-19	1411629.635	696019.295	17.269
VVA-20	1407344.506	685587.397	55.555
VVA-21	1395428.951	688659.291	35.381
VVA-22	1397346.358	677106.928	40.596
VVA-23	1400643.692	695781.085	19.524
VVA-24	1379653.166	657543.514	55.785
VVA-25	1379389.604	638656.494	67.345
VVA-26	1408931.875	633025.653	70.995
VVA-27	1399357.782	636173.313	71.525
VVA-28	1411882.078	648197.235	74.129
VVA-29	1406366.495	665173.352	49.355
VVA-30	1396894.809	660244.734	62.779
VVA-31	1362615.443	633463.514	74.064
VVA-32	1331115.447	650062.351	57.892
VVA-33	1347677.308	672635.590	55.624
VVA-34	1319636.502	665545.430	47.784
VVA-35	1299658.266	676770.137	64.326
VVA-36	1369377.810	610688.671	81.419
VVA-37	1452956.562	447624.590	120.802

VVA-38	**1428415.537**	**471771.328**	**94.039**
VVA-39	**1382967.076**	**539046.916**	**57.472**
VVA-40	**1365778.580**	**522220.915**	**66.695**
VVA-41	**1364856.993**	**539629.635**	**55.063**
VVA-42	**1470937.279**	**473080.190**	**91.743**
VVA-43	**1475254.645**	**456734.308**	**105.157**
VVA-44	**1348722.865**	**584805.068**	**68.247**
VVA-45	**1316289.250**	**609810.761**	**71.449**
VVA-46	**1237097.447**	**686274.317**	**58.328**
VVA-47	**1224032.945**	**675709.941**	**65.751**
VVA-48	**1309732.693**	**584143.948**	**55.112**
VVA-49	**1295836.492**	**610149.927**	**61.744**
VVA-50	**1267891.513**	**612462.319**	**60.859**

Final Check Point Coordinates (Cont.)

Osceola FL QL2 LiDAR POINTS 2016			
POINT #	NORTHING (F)	EASTING (F)	ELEV. (F)
VVA-51	1253168.110	648388.295	67.266
VVA-52	1285374.998	613170.112	62.236
VVA-53	1286265.027	597176.447	51.827
VVA-54	1348639.578	561041.778	53.604
VVA-55	1349168.662	549406.096	55.113
VVA-56	1325094.298	557987.210	53.900
VVA-57	1330862.393	544225.786	62.675
VVA-58	1387129.728	525708.359	68.789
VVA-59	1268701.240	637909.670	65.365
VVA-60	1222007.138	648753.259	62.581
VVA-61	1207528.066	648560.334	68.331
VVA-62	1236125.572	629363.122	67.050
VVA-63	1236147.731	615361.783	61.973
VVA-64	1213924.531	630542.693	60.639
VVA-65	1210566.921	617438.175	51.511
VVA-66	1333605.899	674929.437	42.700
VVA-67	1352815.807	653458.505	64.022
VVA-68	1363256.799	666680.437	66.487
VVA-69	1299937.449	692927.738	46.771
VVA-70	1332998.684	697741.349	32.698
VVA-71	1374984.170	616979.039	79.577
VVA-72	1374945.635	597452.297	67.514
VVA-73	1363682.213	619411.221	80.224

Table 4: *GPS Observation & Re-Observation Schedule*

Osceola FL QL2 LiDAR POINTS 2016					
POINT #	SURVEY DATE	JULIAN DATE	TIME	RE-SURVEY DATE	RE-SURVEY TIME
NVA-01	3/7/2016	67	14:14	3/8/2016	7:36
NVA-02	3/7/2016	67	15:15	3/8/2016	6:03
NVA-03	3/7/2016	67	15:45	3/8/2016	9:33
NVA-04	3/7/2016	67	16:11	3/8/2016	9:49
NVA-05	3/7/2016	67	16:51	3/8/2016	10:14
NVA-06	3/8/2016	68	11:57	3/9/2016	10:56
NVA-07	3/8/2016	68	13:00	3/9/2016	9:51
NVA-08	3/9/2016	69	14:40	3/10/2016	9:47
NVA-09	3/8/2016	68	14:37	3/9/2016	8:34
NVA-10	3/8/2016	68	15:02	3/9/2016	8:52
NVA-11	3/8/2016	68	15:40	3/9/2016	7:30
NVA-12	3/8/2016	68	16:46	3/9/2016	7:50
NVA-13	3/12/2016	72	13:23	3/13/2016	10:47
NVA-14	3/12/2016	72	13:58	3/13/2016	11:03
NVA-15	3/12/2016	72	14:22	3/13/2016	10:35
NVA-16	3/13/2016	73	13:07	3/14/2016	8:29
NVA-17	3/13/2016	73	13:27	3/14/2016	7:55
NVA-18	3/14/2016	74	13:44	3/15/2016	9:16
NVA-19	3/14/2016	74	14:50	3/15/2016	10:00
NVA-20	3/11/2016	71	14:12	3/12/2016	9:20
NVA-21	3/14/2016	74	15:38	3/15/2016	10:19
NVA-22	3/15/2016	75	14:07	N/A	N/A
NVA-23	3/15/2016	75	13:37	N/A	N/A
NVA-24	3/15/2016	75	12:43	N/A	N/A
NVA-25	3/15/2016	75	17:55	N/A	N/A
NVA-26	3/12/2016	72	8:08	3/13/2016	8:44
NVA-27	3/17/2016	77	8:17	N/A	N/A
NVA-28	3/17/2016	77	8:37	N/A	N/A
NVA-29	3/17/2016	77	8:52	N/A	N/A
NVA-30	3/17/2016	77	9:03	N/A	N/A
NVA-31	3/16/2016	76	9:06	N/A	N/A
NVA-32	3/14/2016	74	12:54	3/14/2016	17:00
NVA-33	3/15/2016	75	9:57	N/A	N/A
NVA-34	3/9/2016	69	12:56	3/10/2016	12:45
NVA-35	3/13/2016	73	18:15	N/A	N/A
NVA-36	3/13/2016	73	17:53	N/A	N/A

NVA-37	3/13/2016	73	17:45	N/A	N/A
NVA-38	3/13/2016	73	14:23	N/A	N/A
NVA-39	3/13/2016	73	13:33	N/A	N/A
NVA-40	3/13/2016	73	13:25	N/A	N/A
NVA-41	3/7/2016	67	9:53	3/8/2016	7:20
NVA-42	3/7/2016	67	10:35	3/8/2016	7:52
NVA-43	3/7/2016	67	11:16	3/8/2016	8:10
NVA-44	3/7/2016	67	11:38	3/8/2016	8:25
NVA-45	3/7/2016	67	12:01	3/8/2016	8:46
NVA-46	3/7/2016	67	12:35	3/8/2016	8:59
NVA-47	3/7/2016	67	14:25	3/8/2016	10:05
NVA-48	3/7/2016	67	14:10	3/8/2016	9:15
NVA-49	3/7/2016	67	15:40	3/8/2016	10:34
NVA-50	3/7/2016	67	13:46	3/8/2016	9:30

GPS Observation & Re-Observation Schedule (Cont.)

Osceola FL QL2 LiDAR POINTS 2016					
POINT #	SURVEY DATE	JULIAN DATE	TIME	RE-SURVEY DATE	RE-SURVEY TIME
NVA-51	3/8/2016	68	11:22	3/9/2016	7:40
NVA-52	3/17/2016	77	9:50	N/A	N/A
NVA-53	3/8/2016	68	12:30	3/9/2016	8:51
NVA-54	3/9/2016	69	13:20	3/10/2016	11:28
NVA-55	3/8/2016	68	14:14	3/9/2016	9:38
NVA-56	3/8/2016	68	14:48	3/9/2016	10:00
NVA-57	3/8/2016	68	15:44	3/9/2016	10:30
NVA-58	3/8/2016	68	16:13	3/9/2016	11:43
NVA-59	3/9/2016	69	14:00	3/10/2016	13:40
NVA-60	3/8/2016	68	16:57	3/9/2016	11:09
NVA-61	3/9/2016	69	15:00	3/10/2016	8:39
NVA-62	3/9/2016	69	15:41	3/10/2016	8:08
NVA-63	3/9/2016	69	16:11	3/10/2016	12:13
NVA-64	3/11/2016	71	10:16	3/11/2016	14:17
NVA-65	3/11/2016	71	16:05	3/12/2016	13:40
NVA-66	3/11/2016	71	16:35	3/12/2016	13:24
NVA-67	3/11/2016	71	16:50	3/12/2016	13:14
NVA-68	3/11/2016	71	17:05	3/12/2016	13:08
NVA-69	3/11/2016	71	17:19	3/12/2016	12:59
NVA-70	3/11/2016	71	17:29	3/12/2016	12:53
NVA-71	3/11/2016	71	17:41	3/12/2016	12:45
NVA-72	3/11/2016	71	17:52	3/12/2016	13:36
NVA-73	3/11/2016	71	18:15	3/12/2016	11:58
NVA-74	3/12/2016	72	8:14	3/12/2016	14:17
NVA-75	3/12/2016	72	9:32	3/12/2016	15:11
NVA-76	3/12/2016	72	9:45	3/12/2016	15:25
NVA-77	3/12/2016	72	10:07	3/12/2016	15:43
NVA-78	3/12/2016	72	10:19	3/12/2016	15:52
NVA-79	3/12/2016	72	10:35	3/12/2016	16:00
NVA-80	3/12/2016	72	11:40	3/12/2016	16:30
NVA-81	3/12/2016	72	16:55	3/13/2016	16:53
NVA-82	3/12/2016	72	17:14	3/13/2016	16:47
NVA-83	3/13/2016	73	9:38	3/13/2016	7:35
NVA-84	3/13/2016	73	10:46	3/13/2016	7:29
NVA-85	3/13/2016	73	12:49	3/15/2016	11:10
NVA-86	3/17/2016	77	7:58	N/A	N/A
NVA-87	3/17/2016	77	8:30	N/A	N/A
NVA-88	3/17/2016	77	8:47	N/A	N/A
NVA-89	3/17/2016	77	9:46	N/A	N/A
NVA-90	3/17/2016	77	10:21	N/A	N/A
NVA-91	3/17/2016	77	9:20	N/A	N/A
NVA-92	3/16/2016	76	15:36	N/A	N/A

GPS Observation & Re-Observation Schedule (Cont.)

Osceola FL QL2 LiDAR POINTS 2016					
POINT #	SURVEY DATE	JULIAN DATE	TIME	RE-SURVEY DATE	RE-SURVEY TIME
VVA-01	3/7/2016	67	13:25	3/8/2016	7:01
VVA-02	3/7/2016	67	14:45	3/8/2016	8:45
VVA-03	3/8/2016	68	10:51	3/9/2016	9:11
VVA-04	3/8/2016	68	12:30	3/9/2016	9:35
VVA-05	3/8/2016	68	16:15	3/9/2016	8:05
VVA-06	3/9/2016	69	11:45	3/10/2016	8:07
VVA-07	3/9/2016	69	12:23	3/10/2016	8:28
VVA-08	3/9/2016	69	13:25	3/10/2016	9:00
VVA-09	3/9/2016	69	14:00	3/10/2016	9:37
VVA-10	3/9/2016	69	13:40	3/10/2016	10:42
VVA-11	3/9/2016	69	16:35	3/10/2016	16:15
VVA-12	3/9/2016	69	12:23	3/11/2016	7:55
VVA-13	3/10/2016	70	13:40	3/11/2016	8:58
VVA-14	3/10/2016	70	14:45	3/11/2016	9:16
VVA-15	3/10/2016	70	15:45	3/11/2016	10:06
VVA-16	3/10/2016	70	16:00	3/11/2016	10:40
VVA-17	3/11/2016	71	12:36	3/12/2016	8:45
VVA-18	3/11/2016	71	15:00	3/12/2016	9:55
VVA-19	3/11/2016	71	16:29	3/12/2016	11:17
VVA-20	3/11/2016	71	17:13	3/12/2016	11:46
VVA-21	3/12/2016	72	14:45	3/13/2016	10:26
VVA-22	3/12/2016	72	15:24	3/13/2016	9:30
VVA-23	3/12/2016	72	17:04	3/13/2016	10:12
VVA-24	3/13/2016	73	12:07	3/14/2016	8:57
VVA-25	3/13/2016	73	12:50	3/14/2016	8:21
VVA-26	3/13/2016	73	15:03	3/14/2016	12:00
VVA-27	3/13/2016	73	16:00	3/14/2016	11:30
VVA-28	3/13/2016	73	17:14	3/14/2016	10:55
VVA-29	3/13/2016	73	17:36	3/14/2016	10:35
VVA-30	3/13/2016	73	18:03	3/14/2016	10:01
VVA-31	3/14/2016	74	13:20	3/15/2016	8:55
VVA-32	3/14/2016	74	14:30	3/15/2016	9:49
VVA-33	3/16/2016	76	10:03	N/A	N/A
VVA-34	3/14/2016	74	16:13	3/15/2016	11:35
VVA-35	3/14/2016	74	17:08	3/15/2016	12:10
VVA-36	3/16/2016	76	13:33	N/A	N/A

VVA-37	3/7/2016	67	16:38	3/8/2016	10:55
VVA-38	3/8/2016	68	12:57	3/9/2016	9:10
VVA-39	3/9/2016	69	16:58	3/10/2016	11:37
VVA-40	3/10/2016	70	9:40	3/10/2016	14:20
VVA-41	3/10/2016	70	11:10	3/10/2016	15:15
VVA-42	3/11/2016	71	9:23	3/11/2016	13:25
VVA-43	3/11/2016	71	9:50	3/11/2016	13:15
VVA-44	3/12/2016	72	8:33	3/12/2016	14:29
VVA-45	3/12/2016	72	9:05	3/12/2016	14:54
VVA-46	3/12/2016	72	11:04	3/12/2016	16:11
VVA-47	3/12/2016	72	17:42	3/13/2016	16:22
VVA-48	3/13/2016	73	10:11	3/13/2016	19:21
VVA-49	3/13/2016	73	10:45	3/15/2016	10:39
VVA-50	3/13/2016	73	14:45	N/A	N/A

GPS Observation & Re-Observation Schedule (Cont.)

Osceola FL QL2 LiDAR POINTS 2016					
POINT #	SURVEY DATE	JULIAN DATE	TIME	RE-SURVEY DATE	RE-SURVEY TIME
VVA-51	3/13/2016	73	12:30	3/15/2016	12:50
VVA-52	3/13/2016	73	15:08	N/A	N/A
VVA-53	3/13/2016	73	14:36	N/A	N/A
VVA-54	3/14/2016	74	9:25	3/14/2016	14:38
VVA-55	3/14/2016	74	10:05	3/14/2016	14:23
VVA-56	3/14/2016	74	10:35	3/14/2016	15:19
VVA-57	3/14/2016	74	11:16	3/14/2016	15:49
VVA-58	3/9/2016	69	16:33	3/10/2016	11:48
VVA-59	3/15/2016	75	12:05	N/A	N/A
VVA-60	3/15/2016	75	13:55	N/A	N/A
VVA-61	3/15/2016	75	14:09	N/A	N/A
VVA-62	3/15/2016	75	14:50	N/A	N/A
VVA-63	3/15/2016	75	14:29	N/A	N/A
VVA-64	3/15/2016	75	16:11	N/A	N/A
VVA-65	3/15/2016	75	16:46	N/A	N/A
VVA-66	3/16/2016	76	10:35	N/A	N/A
VVA-67	3/16/2016	76	13:42	N/A	N/A
VVA-68	3/15/2016	75	15:23	N/A	N/A
VVA-69	3/15/2016	75	13:26	N/A	N/A
VVA-70	3/15/2016	75	15:10	N/A	N/A
VVA-71	3/16/2016	76	9:45	N/A	N/A
VVA-72	3/16/2016	76	11:50	N/A	N/A
VVA-73	3/16/2016	76	12:55	N/A	N/A

Table 5:

Point Comparison Report

Osceola FL QL2 LiDAR POINTS 2016				
POINT ID	POINT CHK	DELTA N (F)	DELTA E (F)	VERT DIFF (F)
NVA-01	NVA-01CHK	0.025	0.040	0.122
NVA-02	NVA-02CHK	0.000	0.014	0.094
NVA-03	NVA-03CHK	0.028	0.026	0.105
NVA-04	NVA-04CHK	0.005	0.036	0.032
NVA-05	NVA-05CHK	0.004	0.001	0.074
NVA-06	NVA-06CHK	0.019	0.030	0.000
NVA-07	NVA-07CHK	0.011	0.008	0.119
NVA-08	NVA-08CHK	0.019	0.028	0.027
NVA-09	NVA-09CHK	0.031	0.002	0.080
NVA-10	NVA-10CHK	0.068	0.019	0.083
NVA-11	NVA-11CHK	0.029	0.004	0.077
NVA-12	NVA-12CHK	0.008	0.017	0.054
NVA-13	NVA-13CHK	0.003	0.035	0.103
NVA-14	NVA-14CHK	0.017	0.024	0.026
NVA-15	NVA-15CHK	0.026	0.003	0.004
NVA-16	NVA-16CHK	0.001	0.008	0.047
NVA-17	NVA-17CHK	0.023	0.034	0.084
NVA-18	NVA-18CHK	0.104	0.029	0.101
NVA-19	NVA-19CHK	0.002	0.001	0.091
NVA-20	NVA-20CHK	0.018	0.058	0.102
NVA-21	NVA-21CHK	0.066	0.029	0.119
NVA-26	NVA-26CHK	0.023	0.044	0.118
NVA-32	NVA-32CHK	0.024	0.036	0.034
NVA-34	NVA-34CHK	0.025	0.040	0.080
NVA-41	NVA-41CHK	0.006	0.037	0.003
NVA-42	NVA-42CHK	0.059	0.009	0.026
NVA-43	NVA-43CHK	0.001	0.037	0.048
NVA-44	NVA-44CHK	0.029	0.002	0.026
NVA-45	NVA-45CHK	0.018	0.034	0.020
NVA-46	NVA-46CHK	0.019	0.059	0.057
NVA-47	NVA-47CHK	0.010	0.004	0.028
NVA-48	NVA-48CHK	0.001	0.038	0.038
NVA-49	NVA-49CHK	0.035	0.028	0.086
NVA-50	NVA-50CHK	0.021	0.032	0.020
NVA-51	NVA-51CHK	0.019	0.031	0.070

NVA-53	NVA-53CHK	0.012	0.022	0.008
NVA-54	NVA-54CHK	0.035	0.007	0.034
NVA-55	NVA-55CHK	0.002	0.006	0.138
NVA-56	NVA-56CHK	0.041	0.029	0.051
NVA-57	NVA-57CHK	0.036	0.044	0.043
NVA-58	NVA-58CHK	0.003	0.014	0.031
NVA-59	NVA-59CHK	0.060	0.049	0.119
NVA-60	NVA-60CHK	0.042	0.066	0.025
NVA-61	NVA-61CHK	0.004	0.014	0.103
NVA-62	NVA-62CHK	0.025	0.052	0.038
NVA-63	NVA-63CHK	0.055	0.033	0.111
NVA-64	NVA-64CHK	0.030	0.058	0.095
NVA-65	NVA-65CHK	0.079	0.035	0.067
NVA-66	NVA-66CHK	0.019	0.010	0.121
NVA-67	NVA-67CHK	0.050	0.015	0.026

Point Comparison Report (Cont.)

Osceola FL QL2 LiDAR POINTS 2016				
POINT ID	POINT CHK	DELTA N (F)	DELTA E (F)	VERT DIFF (F)
NVA-68	NVA-68CHK	0.055	0.004	0.049
NVA-69	NVA-69CHK	0.035	0.033	0.140
NVA-70	NVA-70CHK	0.020	0.002	0.038
NVA-71	NVA-71CHK	0.026	0.010	0.066
NVA-72	NVA-72CHK	0.065	0.011	0.010
NVA-73	NVA-73CHK	0.021	0.019	0.053
NVA-74	NVA-74CHK	0.018	0.022	0.022
NVA-75	NVA-75CHK	0.023	0.061	0.001
NVA-76	NVA-76CHK	0.047	0.055	0.132
NVA-77	NVA-77CHK	0.023	0.038	0.023
NVA-78	NVA-78CHK	0.022	0.008	0.038
NVA-79	NVA-79CHK	0.002	0.011	0.152
NVA-80	NVA-80CHK	0.028	0.014	0.155
NVA-81	NVA-81CHK	0.055	0.027	0.063
NVA-82	NVA-82CHK	0.057	0.031	0.133
NVA-83	NVA-83CHK	0.029	0.032	0.144
NVA-84	NVA-84CHK	0.008	0.016	0.080
NVA-85	NVA-85CHK	0.041	0.033	0.006

Point Comparison Report (Cont.)

Osceola FL QL2 LiDAR POINTS 2016				
POINT ID	POINT CHK	DELTA N (F)	DELTA E (F)	VERT DIFF (F)
VVA-01	VVA-01CHK	0.028	0.089	0.147
VVA-02	VVA-02CHK	0.007	0.054	0.047
VVA-03	VVA-03CHK	0.022	0.016	0.088
VVA-04	VVA-04CHK	0.077	0.006	0.018
VVA-05	VVA-05CHK	0.002	0.015	0.114
VVA-06	VVA-06CHK	0.048	0.002	0.110
VVA-07	VVA-07CHK	0.025	0.013	0.015
VVA-08	VVA-08CHK	0.082	0.114	0.126
VVA-09	VVA-09CHK	0.116	0.047	0.007
VVA-10	VVA-10CHK	0.036	0.052	0.013
VVA-11	VVA-11CHK	0.000	0.041	0.127
VVA-12	VVA-12CHK	0.014	0.008	0.075
VVA-13	VVA-13CHK	0.040	0.046	0.051
VVA-14	VVA-14CHK	0.050	0.095	0.132
VVA-15	VVA-15CHK	0.024	0.013	0.025
VVA-16	VVA-16CHK	0.135	0.082	0.037
VVA-17	VVA-17CHK	0.030	0.037	0.115
VVA-18	VVA-18CHK	0.052	0.012	0.013
VVA-19	VVA-19CHK	0.043	0.043	0.027
VVA-20	VVA-20CHK	0.023	0.046	0.152
VVA-21	VVA-21CHK	0.069	0.026	0.130
VVA-22	VVA-22CHK	0.014	0.000	0.048
VVA-23	VVA-23CHK	0.008	0.025	0.158
VVA-24	VVA-24CHK	0.041	0.031	0.048
VVA-25	VVA-25CHK	0.047	0.018	0.042
VVA-26	VVA-26CHK	0.028	0.076	0.044
VVA-27	VVA-27CHK	0.041	0.049	0.061
VVA-28	VVA-28CHK	0.061	0.049	0.103
VVA-29	VVA-29CHK	0.116	0.009	0.086
VVA-30	VVA-30CHK	0.072	0.022	0.090
VVA-31	VVA-31CHK	0.035	0.002	0.005
VVA-32	VVA-32CHK	0.023	0.013	0.152
VVA-34	VVA-34CHK	0.077	0.111	0.035
VVA-35	VVA-35CHK	0.003	0.016	0.128
VVA-37	VVA-37CHK	0.042	0.012	0.077
VVA-38	VVA-38CHK	0.015	0.041	0.049
VVA-39	VVA-39CHK	0.014	0.007	0.110
VVA-40	VVA-40CHK	0.082	0.023	0.114
VVA-41	VVA-41CHK	0.045	0.114	0.021
VVA-42	VVA-42CHK	0.014	0.056	0.004
VVA-43	VVA-43CHK	0.048	0.056	0.048

VVA-44	VVA-44CHK	0.012	0.050	0.015
VVA-45	VVA-45CHK	0.034	0.019	0.143
VVA-46	VVA-46CHK	0.049	0.008	0.059
VVA-47	VVA-47CHK	0.096	0.109	0.123
VVA-48	VVA-48CHK	0.060	0.071	0.043
VVA-49	VVA-49CHK	0.016	0.014	0.018
VVA-51	VVA-51CHK	0.049	0.091	0.133
VVA-54	VVA-54CHK	0.034	0.048	0.094
VVA-55	VVA-55CHK	0.072	0.052	0.128
VVA-56	VVA-56CHK	0.109	0.019	0.025
VVA-57	VVA-57CHK	0.020	0.015	0.020
VVA-58	VVA-58CHK	0.015	0.149	0.022

Appendix C: Complete List of Delivered Tiles

LID2015_060460_E_D
LID2015_060461_E_C
LID2015_060462_E_D
LID2015_060757_E_C
LID2015_060757_E_D
LID2015_060758_E_C
LID2015_060758_E_D
LID2015_060759_E_A
LID2015_060759_E_B
LID2015_060759_E_C
LID2015_060759_E_D
LID2015_060760_E_A
LID2015_060760_E_B
LID2015_060760_E_C
LID2015_060760_E_D
LID2015_060761_E_A
LID2015_060761_E_B
LID2015_060761_E_C
LID2015_060761_E_D
LID2015_060762_E_A
LID2015_060762_E_B
LID2015_060762_E_C
LID2015_060762_E_D
LID2015_060763_E_A
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LID2015_060763_E_D
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Appendix D: GPS Processing

Appendix D is a separate document located in the Reports folder of the deliverables.