# LiDAR Quality Assurance (QA) Report

## QA Report for Oahu LiDAR

## Produced for National Oceanic and Atmospheric Administration

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SUBMITTED BY:

**Dewberry**
1000 North Ashley Drive Suite 801
Tampa, FL 33602
813.225.1325

SUBMITTED TO:
**NOAA**
2234 S Hobson Ave
Charleston, SC 29405
843.740.1323

Dewberry

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# Executive Summary

The following LiDAR quality assurance report documents Dewberry's initial review of LiDAR data and derived products for the island of Oahu which was flown by Photo Science Inc (Quantum Spatial) for the NOAA Coastal Services Center. The data for Oahu covers approximately 602 square miles that consist of 694 tiles (1500 meters x 1500 meters). Each tile contains LAS point cloud data and a hydro-flattened DEM. Other deliverables include hydrographic breaklines and metadata. The figure below shows the locations of the project area *(Figure 1)*

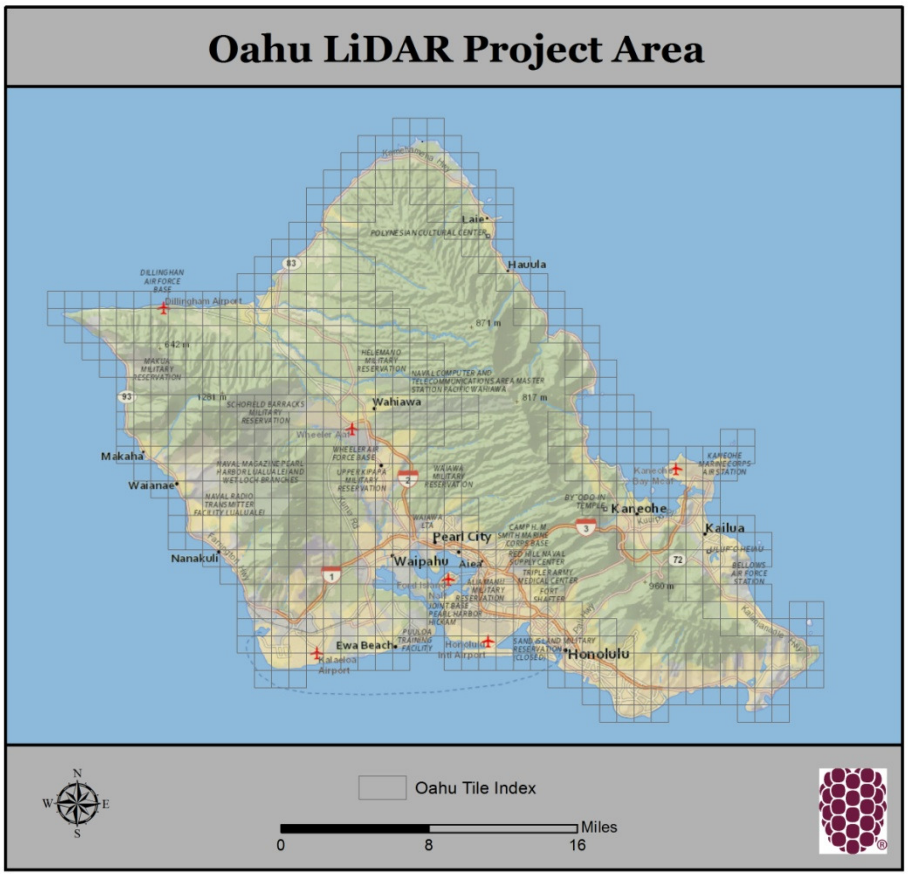


**Figure 1 - Location of the Oahu Project Area.**

| **Contract:** | **Production Contractor:** | **Delivery #:** | **Dewberry Recommendation:** |
|---|---|---|---|
| Oahu LiDAR | Photo Science Inc (Quantum Spatial) | 2 | It is Dewberry's recommendation to accept the data |
| **Data History:**<br>❑ Initial Full Delivery of Project Area<br>❑ Final Revisions (only revised tiles redelivered) | | | |

The LiDAR data and derived products were processed through Dewberry's comprehensive quantitative/qualitative review. This multipart analysis determines the degree to which the data met expectations for completeness, relative accuracy, and conformity to specific project requirements for each data product.

The LiDAR data for Oahu were thoroughly examined by Dewberry for completeness and conformity to project specifications. The data passes vertical accuracy requirements. However, there are a few qualitative issues that should be corrected by Photo Science Inc (PSI), including minor artifacts, eight (8) areas of aggressive misclassification, 110 areas of vegetation points remaining in ground, 47 flight line ridges, and vertical accuracy issues.

Photo Science Inc. discussed the best approach to revising the vegetation artifacts within the project area and in areas where no ground was visible the best effort was made to include points that were likely close to the actual ground. The result is that in some area minor vegetation may still be present but was preferred over large areas of no data. All issues commented in the geodatabase and report have been resolved in a sufficient manner.

There were no breakline issues identified in the review of the Oahu dataset. While 1.3% of the vertices on the breaklines were floating, a review of the hydro-flattened surface model identified that these were not impacting the DEM products.

Dewberry did identify five (5) locations with minor water surface issues as well as two areas where there was a hard line between DEM tiles. Also, modifications made to the LiDAR and breakline datasets will require some DEMs to be re-processed.

All water surface issues have been resolved in the updated deliverable.

Project metadata and metadata for each deliverable was reviewed to verify it contained sufficient content. All metadata files were verified against the MetaParser (MP) tool to ensure the files meet Federal Geographic Data Committee (FGDC) standards. Dewberry found no MP errors but recommend several modifications to the metadata files to improve the quality and completeness of the content described and reported. Only one set of metadata was delivered for all four counties.

## DELIVERABLES SUMMARY FOR OAHU LIDAR

| Deliverable | Applicable Acceptance Criteria | Dewberry Recommendation |
|---|---|---|
| **All-Return LAS Point Cloud Data** | **1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 23, 24, 25, 26** | [ ] Accept<br>[x] Accept with Comments<br>[ ] Return for Corrections<br>[ ] Reject |
| **Breakline Geodatabase** | **11, 12, 13, 14, 15, 30, 31, 32, 33, 34** | [x] Accept<br>[ ] Accept with Comments<br>[ ] Return for Corrections<br>[ ] Reject |
| **Bare Earth DEMs** | **11, 12, 13, 14, 15, 19, 20, 21, 23, 24, 25, 26** | [ ] Accept<br>[x] Accept with Comments<br>[ ] Return for Corrections<br>[ ] Reject |
| **LAS Metadata** | **22, 35** | [x] Accept<br>[ ] Accept with Comments<br>[ ] Return for Corrections<br>[ ] Reject |
| **Breakline Metadata** | **22, 35** | [x] Accept<br>[ ] Accept with Comments<br>[ ] Return for Corrections<br>[ ] Reject |
| **DEM Metadata** | **22, 35** | [x] Accept<br>[ ] Accept with Comments<br>[ ] Return for Corrections<br>[ ] Reject |

The applicable acceptance criteria refer to the numbered criteria found in "Appendix A-Acceptance Criteria." The acceptance criteria were also outlined in the final Quality Plan created by Dewberry.

# Overview

The goal of this LiDAR QAQC Project is to provide high accuracy elevation datasets of multiple deliverable products including LiDAR, hydro-flattened digital elevation models (DEMs), and 3D breaklines for National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center in partnership with the United States Geological Survey (USGS).

Dewberry's role is to provide Quality Assurance (QA) of the LiDAR data and supplemental deliverables provided by PSI that includes completeness checks, vertical accuracy testing, and a qualitative review of the bare earth surface. Each product is reviewed independently and against the other products to verify the degree to which the data meets expectations.

This report documents the quality of the deliverables for the island of Oahu.

# LiDAR Analysis

The LiDAR data are reviewed on project, tile, and point level to determine the relative accuracy, proper classification and conformity to project requirements. This review begins with a computational analysis of the points for completeness and to determine point data format, projection, classification scheme, number of returns per pulse, and intensity values of the points.

## LIDAR QUANTITATIVE REVIEW

One of the first steps in assessing the quality of the LiDAR is a vertical accuracy analysis of the ground models in comparison to surveyed checkpoints. NOAA CSC provided 100 checkpoints for the entire project area.

### Survey Vertical Accuracy Checkpoints

The following table lists all checkpoints surveyed for use in vertical accuracy testing.

| Point ID | NAD83 UTM Zone 04N | | Ellipsoid | LAND COVER |
|---|---|---|---|---|
| | Easting X (m) | Northing Y (m) | Elevation (m) | |
| A1 | 619743.7113 | 2354269.44 | 18.507 | Bare Earth |
| A3 | 619747.335 | 2354278.974 | 18.476 | Bare Earth |
| AA1 | 618829.8053 | 2384173.359 | 17.727 | Bare Earth |
| AB1 | 612010.3586 | 2391471.623 | 17.928 | Bare Earth |
| AC1 | 632992.0205 | 2365916.694 | 19.554 | Bare Earth |
| AD1 | 630339.1253 | 2372748.734 | 25.377 | Bare Earth |
| ADA3 | 630441.4488 | 2372838.724 | 24.933 | Bare Earth |
| ADB2 | 630211.2852 | 2372804.704 | 29.374 | Bare Earth |
| B08 | 622613.376 | 2351916.275 | 17.75 | Bare Earth |

| | | | | |
|---|---|---|---|---|
| B1 | 622566.099 | 2351864.347 | 17.968 | Bare Earth |
| B10 | 622581.681 | 2351915.549 | 17.912 | Bare Earth |
| B11 | 622522.472 | 2351893.758 | 18.102 | Bare Earth |
| B3 | 622550.1672 | 2351857.892 | 18.004 | Bare Earth |
| C07 | 624789.266 | 2351337.281 | 34.144 | Bare Earth |
| C1 | 624876.1261 | 2351379.508 | 34.051 | Bare Earth |
| C2 | 624893.04 | 2351385.062 | 34.184 | Bare Earth |
| D1 | 577888.466 | 2383748.136 | 20.973 | Bare Earth |
| DB05 | 577862.9321 | 2383715.682 | 18.613 | Bare Earth |
| F1 | 583143.3918 | 2374880.311 | 79.585 | Bare Earth |
| G1 | 583327.2511 | 2372175.413 | 18.423 | Bare Earth |
| GC05 | 583327.787 | 2372228.684 | 18.022 | Bare Earth |
| I1 | 592896.0579 | 2355248.443 | 17.109 | Bare Earth |
| IB01 | 592879.4312 | 2355207.89 | 16.858 | Bare Earth |
| J1 | 599797.8668 | 2359894.065 | 30.795 | Bare Earth |
| K1 | 604598.0909 | 2357388.098 | 16.869 | Bare Earth |
| M1 | 586282.0668 | 2379593.416 | 829.533 | Bare Earth |
| MA02 | 586228.7535 | 2379661.784 | 838.689 | Bare Earth |
| MA04 | 586272.688 | 2379606.008 | 830.768 | Bare Earth |
| MB01 | 586306.2008 | 2379593.342 | 826.809 | Bare Earth |
| N1 | 592792.552 | 2388841.723 | 16.959 | Bare Earth |
| O1 | 578941.1861 | 2386463.626 | 21.031 | Bare Earth |
| R1 | 608309.6601 | 2365253.147 | 18.804 | Bare Earth |
| RB02 | 608203.2828 | 2365171.242 | 18.72 | Bare Earth |
| S1 | 603854.267 | 2363769.032 | 22.64 | Bare Earth |
| SA01 | 603477.9427 | 2363669.805 | 27.226 | Bare Earth |
| T1 | 602165.63 | 2373329.234 | 227.17 | Bare Earth |
| TA01 | 602143.8106 | 2373355.009 | 227.383 | Bare Earth |
| TB03 | 602235.6211 | 2373400.924 | 226.773 | Bare Earth |
| U1 | 599301.239 | 2379193.727 | 314.586 | Bare Earth |
| UA03 | 599239.7054 | 2379169.123 | 312.803 | Bare Earth |
| VA03 | 617054.2118 | 2360579.022 | 61.155 | Bare Earth |
| W1 | 610722.3246 | 2360145.184 | 22.395 | Bare Earth |
| X1 | 630178.1982 | 2353564.88 | 18.039 | Bare Earth |
| YA01 | 638340.249 | 2354750.735 | 20.025 | Bare Earth |
| Z1 | 635492.5488 | 2359335.217 | 23.63 | Bare Earth |
| ZA03 | 635427.0219 | 2359380.71 | 22.873 | Bare Earth |
| A5 | 619813.0088 | 2354191.118 | 18.615 | Forest |
| ACA1 | 632992.0566 | 2365890.7 | 19.493 | Forest |
| B04 | 622578.721 | 2351855.2 | 17.926 | Forest |
| B05 | 622590.351 | 2351868.615 | 17.805 | Forest |
| B07 | 622608.512 | 2351893.843 | 17.713 | Forest |
| B09 | 622641.181 | 2351935.317 | 17.471 | Forest |
| B12 | 622467.89 | 2351838.997 | 17.788 | Forest |
| B13 | 622473.561 | 2351790.54 | 17.984 | Forest |
| C03 | 624876.488 | 2351399.376 | 34.444 | Forest |
| C05 | 624822.168 | 2351387.563 | 34.921001 | Forest |
| GC02 | 583396.929 | 2372213.874 | 18.305 | Forest |

| | | | | |
|---|---|---|---|---|
| GC04 | 583328.231 | 2372240.554 | 17.917 | Forest |
| MA03 | 586222.3815 | 2379699.072 | 843.14 | Forest |
| XA04 | 630220.2706 | 2353550.783 | 18.016 | Forest |
| ACB2 | 632992.7596 | 2365972.18 | 19.543 | Grass |
| DB03 | 577898.9438 | 2383718.369 | 20.244 | Grass |
| SA02 | 603510.6584 | 2363695.422 | 30.699 | Grass |
| SB03 | 603649.5037 | 2363825.666 | 25.478 | Grass |
| UB01 | 599316.6744 | 2379158.071 | 314.683 | Grass |
| Y1 | 638344.8681 | 2354743.135 | 20.368 | Grass |
| YA02 | 638311.7903 | 2354760.386 | 20.075 | Grass |
| DB02 | 577917.7307 | 2383760.655 | 21.592 | Scrub/Shrub |
| IA04 | 592911.9227 | 2355187.494 | 17.008 | Scrub/Shrub |
| KB02 | 604643.9905 | 2357410.574 | 17.24 | Scrub/Shrub |
| OA01 | 578922.0158 | 2386458.629 | 20.685 | Scrub/Shrub |
| RB03 | 608091.1242 | 2365172.939 | 17.728 | Scrub/Shrub |
| UB02 | 599337.7647 | 2379120.878 | 313.926 | Scrub/Shrub |
| WB03 | 610673.155 | 2360192.715 | 22.876 | Scrub/Shrub |
| YA03 | 638251.5219 | 2354741.602 | 19.807 | Scrub/Shrub |
| YA04 | 638255.7373 | 2354671.239 | 18.794 | Scrub/Shrub |
| A2 | 619707.0055 | 2354225.296 | 18.845 | Urban |
| A4 | 619471.0531 | 2354050.772 | 19.917 | Urban |
| ACA2 | 633051.4336 | 2365944.213 | 19.661 | Urban |
| ACB1 | 632972.0947 | 2365945.654 | 19.609 | Urban |
| ADA1 | 630340.4396 | 2372772.207 | 24.339 | Urban |
| AE1 | 623136.1632 | 2370677.572 | 19.532 | Urban |
| B06 | 622613.405 | 2351872.943 | 18.029 | Urban |
| C04 | 624855.165 | 2351447.324 | 36.452999 | Urban |
| C06 | 624786.842 | 2351374.634 | 35.388999 | Urban |
| DA06 | 577890.0955 | 2383779.567 | 21.83 | Urban |
| FA01 | 583150.307 | 2374889.527 | 80.07 | Urban |
| GC01 | 583388.169 | 2372190.408 | 18.56 | Urban |
| GC03 | 583372.01 | 2372217.59 | 18.381 | Urban |
| IA02 | 592883.5162 | 2355266.743 | 17.114 | Urban |
| KB01 | 604626.0241 | 2357396.197 | 16.864 | Urban |
| MA01 | 586265.8412 | 2379604.132 | 830.947 | Urban |
| MB02 | 586340.8071 | 2379573.762 | 825.326 | Urban |
| RB01 | 608281.4871 | 2365261.562 | 18.994 | Urban |
| SB02 | 603678.2132 | 2363796.412 | 24.716 | Urban |
| TA04 | 602208.5594 | 2373344.286 | 226.749 | Urban |
| TB01 | 602155.6261 | 2373318.403 | 226.467 | Urban |
| V1 | 617042.5117 | 2360456.316 | 57.636 | Urban |
| WB01 | 610701.5584 | 2360164.045 | 22.278 | Urban |
| XA01 | 630166.3778 | 2353588.656 | 19.132 | Urban |

**Table 1: Oahu LiDAR surveyed accuracy checkpoints**

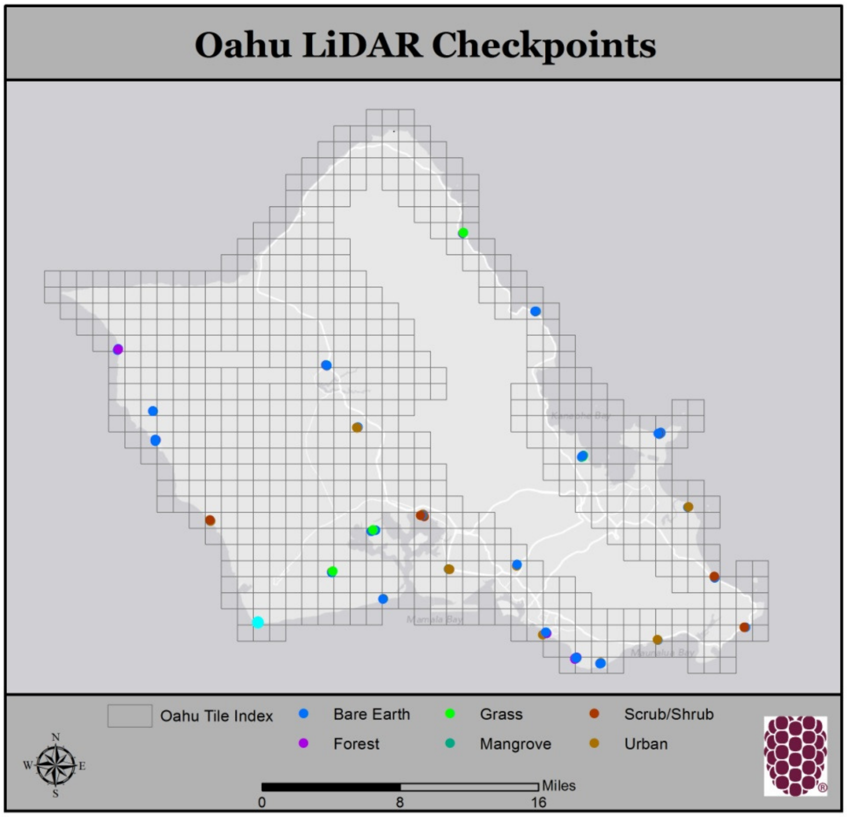


**Figure 3 – Checkpoint distribution for Oahu LiDAR data.**

The vertical accuracy assessment compares the measured survey checkpoint elevations with those of the TIN as generated from the bare-earth LiDAR. The X/Y locations of the survey checkpoints are overlaid on the TIN and the interpolated Z values of the LiDAR are recorded. These interpolated Z values are then compared with the survey checkpoint Z values and this difference represents the amount of error between the measurements. Once all the Z values are recorded, the FVA, CVA, and SVA are computed. 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.

**FVA** (Fundamental Vertical Accuracy) is determined with check points located only in the open terrain (grass, dirt, sand, and/or rocks) land cover category, 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 FVA 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 Oahu LiDAR project, vertical accuracy must be 24.5 cm or less based on an $RMSE_z$ of 12.5 cm x 1.9600.

**CVA** (Consolidated Vertical Accuracy) is determined with all checkpoints in all land cover categories combined where there is a possibility that the LiDAR sensor and post-processing may yield elevation errors that do not follow a normal error distribution. CVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all land cover categories combined. The Oahu LiDAR Project CVA standard is 36.0 cm at the 95% confidence level. The CVA is accompanied by a listing of the 5% outliers that are larger than the 95th percentile used to compute the CVA; these are always the largest outliers that may depart from a normal error distribution. Here, $Accuracy_z$ differs from CVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas CVA assumes LiDAR errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

**SVA** (Supplemental Vertical Accuracy) is determined for each land cover category other than open terrain. SVA at the 95% confidence level equals the 95th percentile error for all checkpoints in each land cover category. The Oahu LiDAR Project SVA target is 36.0 cm at the 95% confidence level. Target specifications are given for SVA's as individual land cover categories may exceed this target value as long as the overall CVA is within specified tolerances. Again, $Accuracy_z$ differs from SVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas SVA 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 2.

| Quantitative Criteria | Measure of Acceptability |
|---|---|
| Fundamental Vertical Accuracy (FVA) in open terrain only using $RMSE_z$ *1.9600 | 0.245 meters (based on $RMSE_z$ (0.125m) * 1.9600) |
| Consolidated Vertical Accuracy (CVA) in all land cover categories combined at the 95% confidence level | 0.360 meters (based on combined 95th percentile) |
| Supplemental Vertical Accuracy (SVA) in each land cover category separately at the 95% confidence level | 0.360 meters (based on 95th percentile for each land cover category) |

**Table 2 — Acceptance Criteria**

### Vertical Accuracy Results – Swath LiDAR

Table 3 outlines the calculated $RMSE_z$ and associated statistics, in meters, of the swath data as required by USGS V1 specificaitons.

| Swath Accuracy Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 100 % of Totals | # of Points | RMSEz (m) Open Terrain Spec=0.0925 m | FVA-Fundamental Vertical Accuracy ((RMSEz x 1.9600) Spec=0.181 m | Mean (m) | Median (m) | Skew | Std Dev (m) | Min (m) | Max (m) |
| Open Terrain | 46 | 0.10 | 0.20 | -0.01 | -0.01 | -0.32 | 0.10 | -0.25 | 0.21 |

**Table 3 - The table shows the calculated $RMSE_z$ values, in meters, as well as associated statistics of the errors for the LiDAR Swaths in the Oahu project area.**

## Vertical Accuracy Results – Classified LiDAR

Table 4 outlines the calculated $RMSE_z$ and associated statistics, in meters, while

**LiDAR Vertical Accuracy Results**

| Land Cover Category | # of Points | FVA – Fundamental Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.245 m | CVA – Consolidated Vertical Accuracy (95th Percentile) Spec=0.36 m | SVA – Supplemental Vertical Accuracy (95th Percentile) Target=0.36 m |
|---|---|---|---|---|
| Consolidated | 100 | | 0.268 | |
| Bare Earth-Open Terrain | 46 | 0.198 | | |
| Urban | 24 | | | 0.250 |
| Combined Vegetation | 30 | | | 0.332 |

Table 5 outlines vertical accuracy as computed by the different methods, in meters.

**Descriptive Statistics**

| 100 % of Totals | # of Points | RMSEz (m) Open Terrain Spec=0.125 m | Mean (m) | Median (m) | Skew | Std Dev (m) | Kurtosis | Min (m) | Max (m) |
|---|---|---|---|---|---|---|---|---|---|
| Consolidated | 100 | | -0.017 | -0.019 | 0.869 | 0.126 | 3.005 | -0.290 | 0.507 |
| Open Terrain | 46 | 0.101 | -0.007 | -0.004 | -0.482 | 0.102 | 0.504 | -0.267 | 0.202 |
| Urban | 24 | | -0.056 | -0.084 | 0.970 | 0.117 | 2.912 | -0.290 | 0.303 |
| Tall Weeds and Crops | 7 | | -0.018 | 0.022 | -0.296 | 0.090 | -2.523 | -0.129 | 0.076 |
| Brush Lands and Trees | 9 | | 0.128 | 0.107 | 0.019 | 0.224 | 0.870 | -0.275 | 0.507 |
| Forested and Fully Grown | 14 | | -0.071 | -0.075 | -0.592 | 0.075 | 1.257 | -0.244 | 0.060 |
| Combined Vegetation | 30 | | 0.001 | -0.018 | 1.306 | 0.160 | 3.012 | -0.275 | 0.507 |

**Table 4 - The table shows the calculated $RMSE_z$ values, in meters, as well as associated statistics of the errors for the Oahu project area for the final classified LiDAR deliverable.**

**LiDAR Vertical Accuracy Results**

| Land Cover Category | # of Points | FVA – Fundamental Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.245 m | CVA – Consolidated Vertical Accuracy (95th Percentile) Spec=0.36 m | SVA – Supplemental Vertical Accuracy (95th Percentile) Target=0.36 m |
|---|---|---|---|---|
| Consolidated | 100 | | 0.268 | |
| Bare Earth-Open Terrain | 46 | 0.198 | | |
| Urban | 24 | | | 0.250 |
| Combined Vegetation | 30 | | | 0.332 |

**Table 5 - The table shows the calculated FVA, CVA, and SVA, in feet, at the 95% confidence level.**

Table 6 lists the 5% outliers that are larger than the 95$^{th}$ percentile, or 0.616 feet.

| Point ID | NAD83 UTM Zone 04N | | Ellipsoid | LiDAR Z (m) | Delta Z | AbsDeltaZ |
|---|---|---|---|---|---|---|
| | Easting X (m) | Northing Y (m) | Survey Z (m) | | | |
| E1 | 579828.0295 | 2380581.60 | 18.946 | 19.8359 | 0.890 | 0.890 |
| JA01 | 599809.7605 | 2359896.26 | 32.291 | 30.9508 | -1.340 | 1.340 |
| ABA2 | 612038.1058 | 2391490.663 | 15.835 | 17.73010 | 1.895 | 1.895 |
| ZA04 | 635459.3668 | 2359482.417 | 22.510999 | 20.53620 | -1.975 | 1.975 |
| AEA3 | 623266.8992 | 2370776.838 | 19.722 | 17.04290 | -2.679 | 2.679 |

**Table 6 – 5% Outliers**

Figure 4 illustrates the magnitude of the differences between the QA/QC checkpoints and LiDAR data.

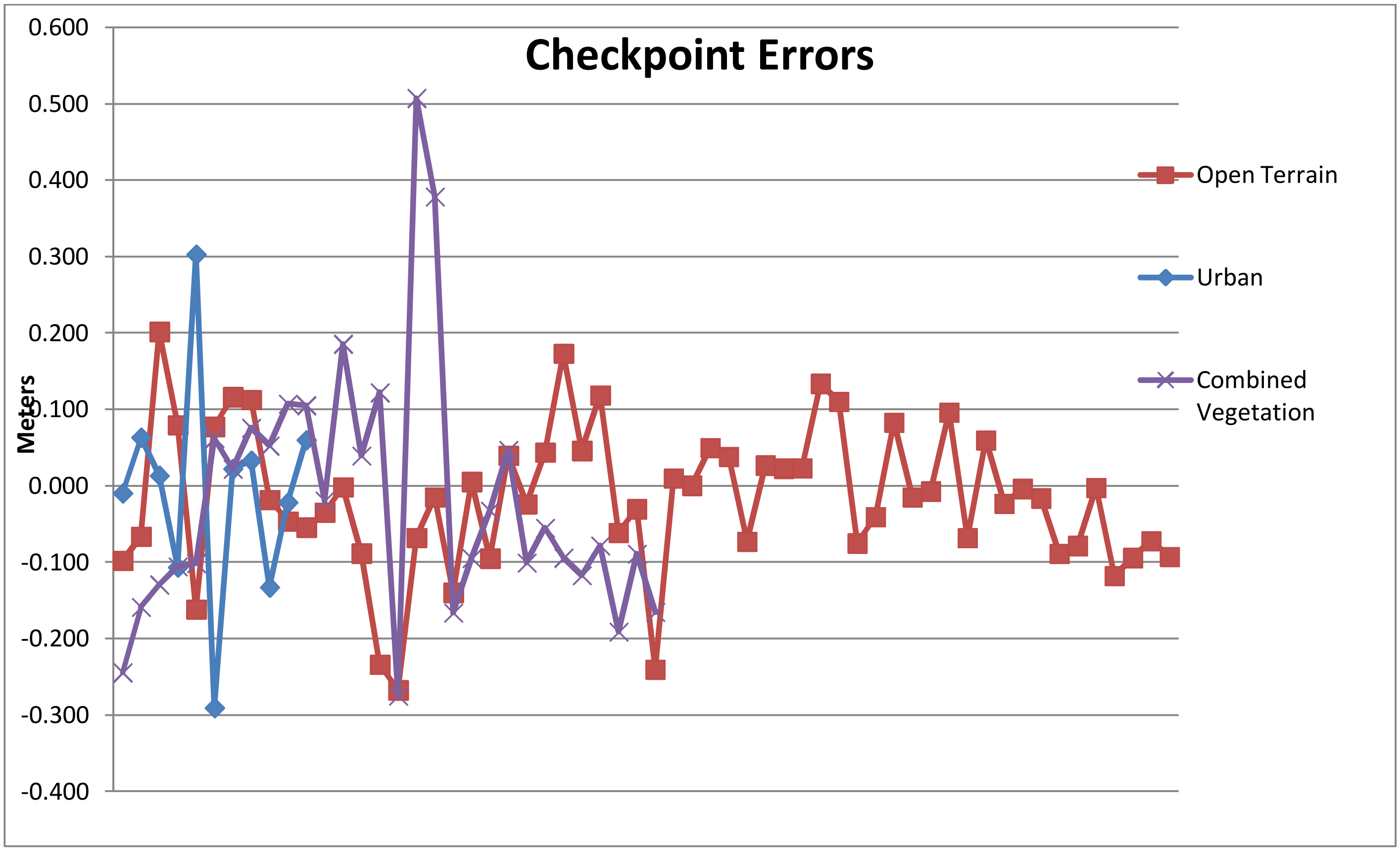


Figure 4 – Magnitude of Elevation Discrepancies

## LIDAR COMPLETENESS REVIEW

Dewberry received 637 LiDAR tiles for the project area. The LiDAR was delivered in LAS format 1.2, point data format 1 is used, and all data have intensity values. The LAS tiles are named appropriately according to the SOW and have correct extents (1500 m x 1500 m). The majority of all LiDAR tiles were within the specified combined scan angle of 40°. However, the maximum combined scan angle is 54°, but Dewberry has reviewed all tiles for relative accuracy and flight line ridge issues. No issues were identified that could be attributed to the high scan angles.

All spatial projection information was correct and is as follows:

- Horizontal Datum: NAD83 (PA11)
- Vertical Datum: Ellipsoid
- Projection: UTM 04N
- Horizontal and Vertical Units: Meters

Each record includes the following fields (among others):

- X, Y, Z coordinates
- Flight line data
- Intensity value
- Return number

- ❑ Number of returns
- ❑ Scan direction
- ❑ Edge of flight line
- ❑ Scan angle
- ❑ Classification
- ❑ Adjusted GPS time

The LiDAR data has been classified to contain the following classes:

Required Classes

- ❑ Class 1 (Unclassified)
- ❑ Class 2 (Bare Earth)
- ❑ Class 7 (Low Points and Outliers)
- ❑ Class 9 (Water)
- ❑ Class 10 (Ignored Ground)
- ❑ Class 17 (Unclassified Overlap)
- ❑ Class 18 (Filtered Bare-Earth Overlap)
- ❑ Class 25 (Water Overlap)

All tiles met the project requirement to have 20% overlap on adjoining swaths.

### Point Count/Elevation Analysis

To verify the content of the data and validate the data integrity, a statistical analysis was performed on each tile. This process allows Dewberry to review 100% of the data at a macro level to identify any gross outliers. The statistical analysis consists of first extracting the header information and then reading the actual records and computing the number of points, minimum, maximum, and mean elevation for each class. Minimum and maximum for other relevant variables are also evaluated. No major anomalies were identified.

Each tile was queried to extract the number of LiDAR points. The required nominal point spacing for the project is 1.0 meter. By utilizing the full point cloud, the Oahu project area was determined to have a nominal point spacing of greater than 1 point per square meter which satisfies the project requirements.

## LIDAR QUALITATIVE REVIEW

The goal of Dewberry's qualitative review is to assess the continuity and the level of cleanliness of the bare earth product. Each LiDAR tile is expected to meet the following acceptance criteria:

- ❑ The point density is homogenous and sufficient to meet the user's needs;
- ❑ The ground point have been correctly classified (no man-made structures or vegetation remains, no gaps except over water bodies);
- ❑ The ground surface model exhibits a correct definition (no aggressive classification, no over-smoothing, no inconsistency in the post-processing);
- ❑ No obvious anomalies due to sensor malfunction or systematic processing artifacts are present (data voids, spikes, divots, ridges between flight lines or tiles, cornrows, etc);
- ❑ Residual artifacts <5%

Dewberry analysts performed a visual inspection of 100% of the bare earth data digital terrain model (DTM). 100% of the project data was reviewed at the micro and macro levels. The DTMs are built by first creating a fishnet grid of the LiDAR masspoints with a grid distance equal to or better than the final DEM deliverables. Then a triangulated irregular network is built based on this gridded DTM and displayed as a 3D surface. A shaded relief effect was applied which enhances 3D rendering.

Quick Terrain Modeler, the software used for visualization allows the user to navigate, zoom and rotate models and to display elevation information with an adaptive color coding in order to better identify anomalies. Models can also be viewed by point density, in which areas meeting the specified point density threshold are displayed green and areas not meeting the point density threshold are displayed red. This can help to identify void areas and areas that are misclassified. As the surface model is created from ground only points, sparse or red areas are expected over buildings, water, and dense vegetation where there is poor LiDAR penetration. The table below shows a breakdown of the calls made during the first review of the project data.

| Issue | Number of Occurrences | Remaining Issues |
|---|---|---|
| Aggressive Misclassification | 9 | 0 |
| Artifacts | 5 | 0 |
| Divots | 1 | 0 |
| Corn Rows | 1 | 0 |
| Flight Line Ridges | 51 | 0 |
| Vegetation Artifacts in Ground | 129 | 0 |
| Voids | 7 | 0 |
| **Total** | 203 | 0 |

**Table 7 – Breakdown of LiDAR qualitative edit calls.**

## Aggressive Misclassification

Aggressive misclassification calls in this document imply that LiDAR points are unclassified in the delivered dataset when they should be classified to ground. This call indicates areas where some class 1 points could be reclassified to class 2, ground, to improve detail in the surface model and to more correctly model surface features. There are nine (9) instances of aggressive misclassification identified in this project area. An example of aggressive misclassification edit calls is found below and a geodatabase that contains the locations of all edit calls accompanies this report. The majority of these calls have been placed on the tops of ridges where points are present that would represent the peaks.

All areas marked for revisions have been addressed. While some minor misclassification still exists on the very tops of ridges they are within the 2% requirement for incorrectly classified data.

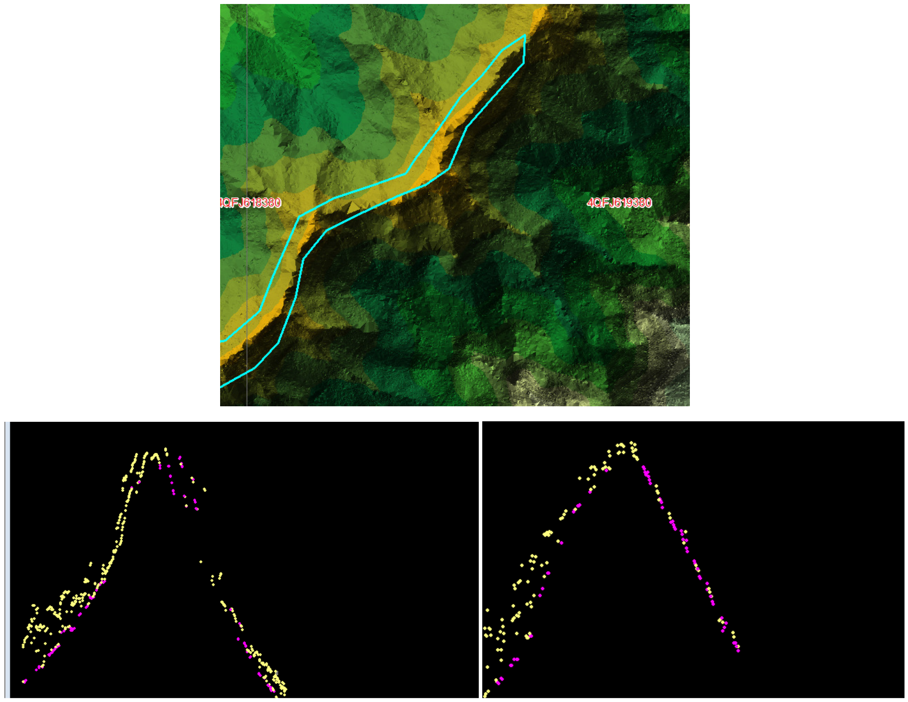


**Figure 5 – LAS Tile 4QFJ619380. The top image shows a view of the terrain with edit call highlighted. The bottom image shows a profile view of the LAS cloud colored by classification (ground-purple, unclassified-yellow) is shown on the bottom. Valid unclassified points should be reclassified to ground to improve the definition of the bare-earth surface. The image on the right shows the corrected area with additional point being classified to ground.**

## Artifacts

Artifacts are features that are left in the ground model that should be removed. There are five (5) artifacts identified in the project area and include bridges and structures. Vegetation has been separated out into a separate class for this project as the majority of issues were related to vegetation artifacts. These should be removed in order to improve the bare-earth surface model. Examples of artifact edit calls can be found below and a geodatabase that contains the locations of all edit calls accompanies this report.

All artifacts have been sufficient resolved.

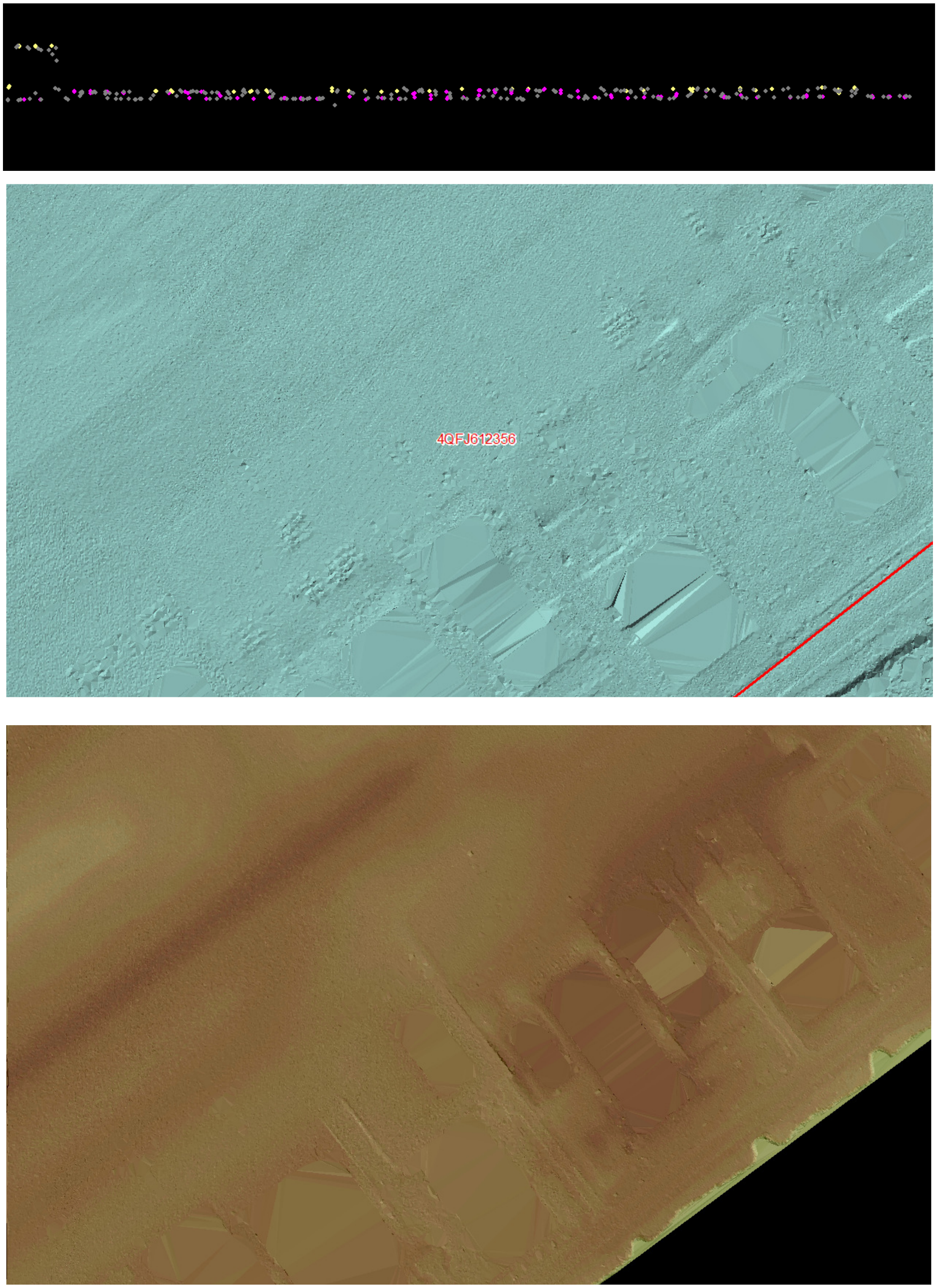


**Figure 6 - Tile 4QFJ612356 Profile view of the LAS cloud colored by classification (ground-pink) is shown on top while bare-earth TIN colored by elevation is shown on bottom. The features can be seen protruding from the ground and should be reclassified to unclassified (class 1). The area around the airport was highlighted for review of artifacts as a number of them were present on the surface. The bottom surface model shows all of these features have been removed from the ground.**

## Corn Rows

One area within the project area exists where corn rowing is prevalent throughout the area and is visible at the review scale. The extents of this area have been outlined in the LAS edit calls polygon. The edges of this area are also visible with a sharp change in elevation and overall LiDAR smoothness.

The issue regarding corn rows has been resolved and is no longer present in the dataset.


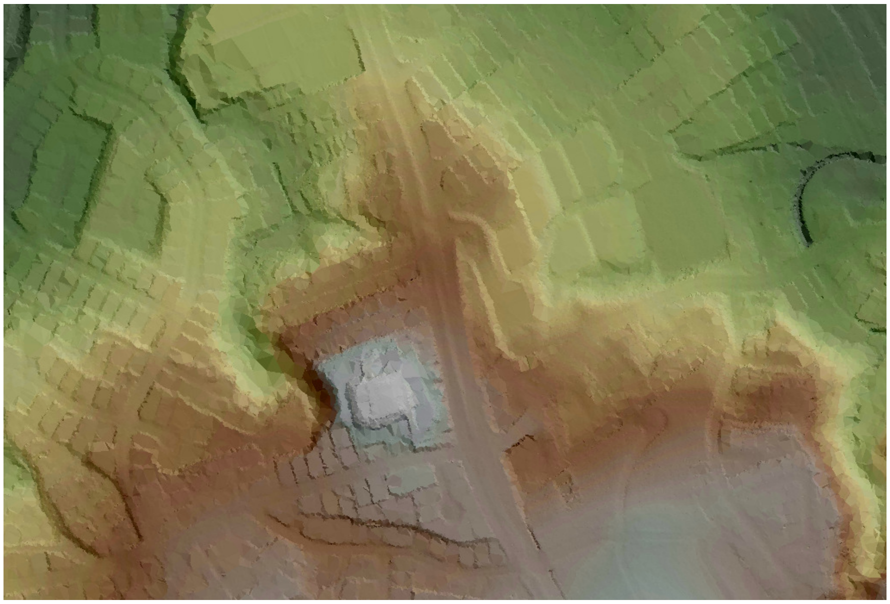

**Figure 7 – Tile 4QFJ624365. Example show visible corn row effect throughout this tile and surrounding area. The bottom image shows that the corn rows have been corrected.**

## Vegetation Artifacts in Ground

Vegetation artifact calls in this document imply that LiDAR points are incorrectly classified in the delivered dataset and should be re-classified to class 1 (unclassified). There are 123 instances of vegetation artifacts identified in this project area. Because this issue was prevalent in the dataset polygon edit calls were placed in areas where the issue was most visible.

All vegetation artifacts have been sufficiently addressed. In some cases minor vegetation does remain in the ground but based on input from NOAA CSC the limited vegetation was acceptable and does not negatively impact the use of the data.

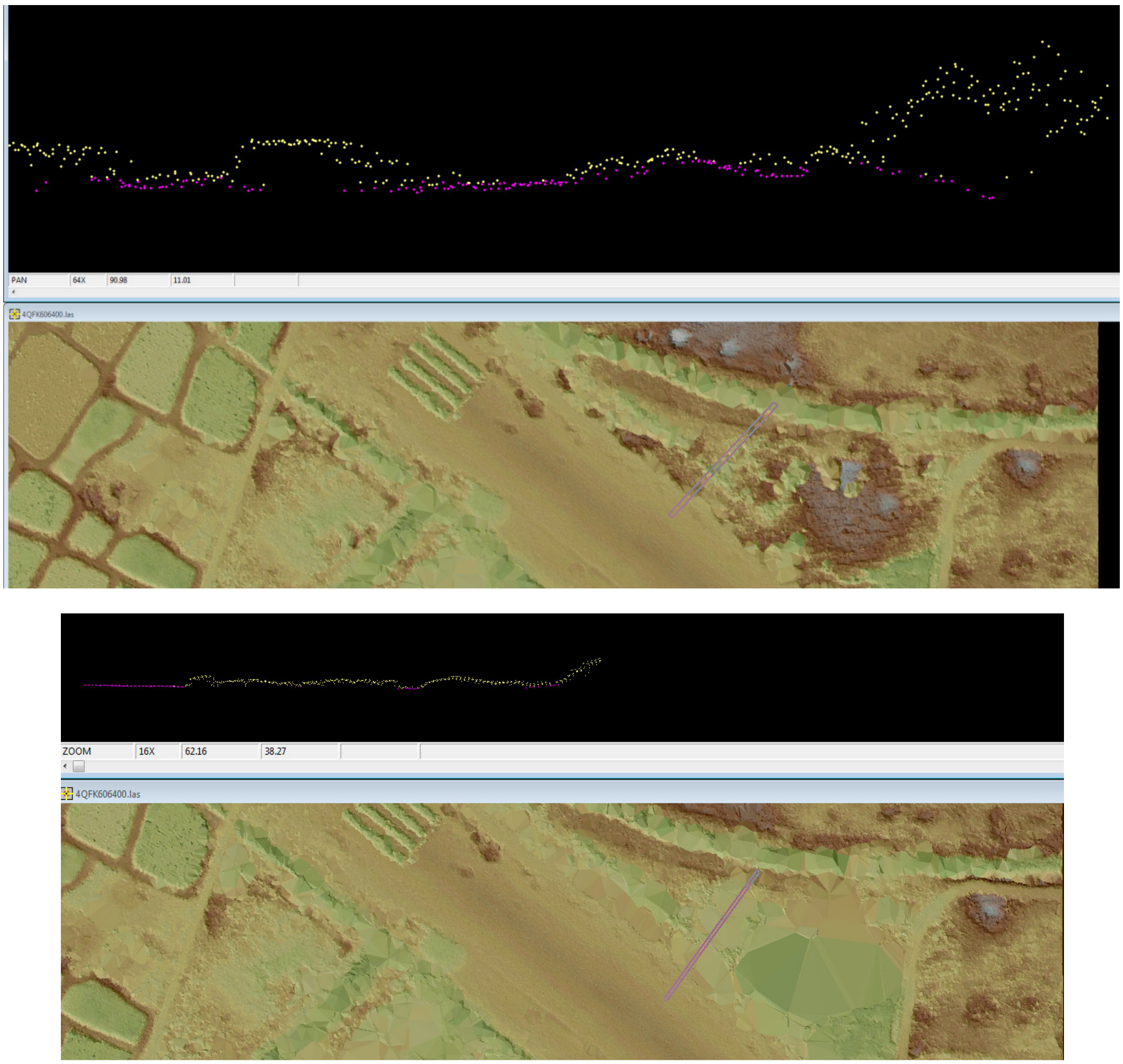


**Figure 8 & 9 – Tile 4QFK606400. The top image is a profile view of the LAS cloud colored by classification (unclassified-yellow, ground - pink). In this example ground points start to move to the lower extent of the vegetation and should be reclassified as class 1. The second images show the corrected area.**

### LIDAR RECOMMENDATION

Dewberry recommends the LiDAR be accepted by NOAA CSC.

## Breakline Analysis

A qualitative/quantitative review was completed on the project area breaklines. The comprehensive review consisted of a visual review of the breaklines for completeness in compilation and horizontal placement as well as proper feature coding. This visual analysis was followed by several automated tests for hydro-flattening and topology using ESRI Data Reviewer tools and proprietary tools developed by Dewberry. The breakline review followed the Breakline QA/QC Checklist provided in Appendix B. This QA/QC checklist was also provided in Dewberry's Quality Plan.

### BREAKLINE DATA OVERVIEW

The Breakline qualitative review starts with an overview. First, the ESRI geodatabase is reviewed in ArcCatalog for correct spatial projections, data organization, and to ensure all necessary feature classes are present and are properly populated.

The delivered geodatabases contained the correct feature classes, shown below:

- TIDAL_WATERS
- STREAMS_AND_RIVERS
- PONDS_AND_LAKES

The coordinate system of the delivered breaklines is correct and is as defined below:

- Horizontal Datum: NAD83 (PA11)
- Vertical Datum: Ellipsoid
- Projection: UTM 04N
- Horizontal and Vertical Units: Meters

### BREAKLINE QUALITATIVE REVIEW

The breakline qualitative review includes reviewing data for completeness, validating the horizontal placement of breaklines, and verifying the coding and attribution of breaklines.

The breaklines were reviewed against intensity imagery Dewberry creates for its QC process. A review was performed on 100% of the data in an ESRI environment to validate data collection consistency and to validate all necessary features were collected. There were no edit calls requiring revisions by Photo Science to the breakline dataset.

### BREAKLINE QUANTITATIVE REVIEW

The Quantitative Vertical Analysis compares the breakline vertices against the bare-earth LiDAR data. Dewberry begins this process by converting all breakline vertices to points. At the same time an ESRI Terrain is created from the LiDAR using ground and water points. The LiDAR elevation, extracted from the terrain, is recorded for every breakline vertex. An analysis of the differences in elevation between the breakline vertices and LiDAR is conducted to determine the vertical accuracy of the breakline collection.

Dewberry found no issues in this portion of the review.

## TOPOLOGY

One of the requirements of hydro breaklines intended for modeling is valid topology. Dewberry tested the topology using ESRI's Data Reviewer extension and proprietary tools to ensure that the breakline vertices are snapped together, that hydro-lines fulfill monotonicity requirements within a specified tolerance, that all water bodies are flat within a tolerance, and that all breaklines have elevations defined. These data checks allow automated validation of 100% of the data and are used on every delivery of data to ensure consistent data integrity. The data checks used are listed in detail in Appendix B-The Breakline QA/QC Checklist. The Breakline QA/QC Checklist was also provided in Dewberry's Quality Plan. Dewberry found no issues in this portion of the review.

### Monotonicity

All stream/river breaklines should show continuous downhill flow. Some exceptions may occur at confluences of rivers or where tributaries or other off-shoots of a river exist. Monotonic breaklines are necessary to produce hydro-flattened DEMs. Dewberry found no issues in this portion of the review.

### Connectivity

Connectivity, or different Z at intersections, ensures that all overlapping vertices that have the same X-Y coordinates also have the same Z-elevations. While some exceptions can occur for vertical structures, such as sea walls or dams, most overlapping vertices should have the same Z-elevation. This means that the first and last vertices for a closed feature should have the same elevation and that vertices from one feature that connect to vertices from another feature, such as a stream that drains into a water body, should have the same elevation. Connectivity issues can cause false waterfalls within a feature or between two features. Dewberry found no issues in this portion of the review.

## BREAKLINE RECOMMENDATION

Dewberry recommends accepting the breakline data as delivered

# Hydro-flattened Digital Elevation Model Analysis

Dewberry received 637 hydro-flattened bare earth DEMs as part of the deliverables for the project area. Dewberry used proprietary scripts and tools to ensure all DEMs have the correct formatting, cell size, projection, and extents. Dewberry used ESRI ArcMap and Global Mapper software to review all DEMs for completeness and qualitative analysis.

## OVERVIEW

Dewberry ran proprietary tools on all delivered DEMs to verify formatting, cell size, extents, and projection information.

All DEMs were correctly formatted:

- DEM type: IMG
- Cell Size: 1 meter
- Extents: 1500 m x 1500 m tiles

The coordinate system of the delivered DEMs is correct and is as defined below:

- Horizontal Datum: NAD83 (PA11)
- Projection: UTM 04N
- Horizontal Units: Meters

## DEM QUANTITATIVE REVIEW

### Vertical Accuracy Results – Digital Elevation Model (DEM)

Table 8 outlines the calculated $RMSE_z$ and associated statistics, in meters, while

**LiDAR Vertical Accuracy Results**

| Land Cover Category | # of Points | FVA – Fundamental Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.245 m | CVA – Consolidated Vertical Accuracy (95th Percentile) Spec=0.36 m | SVA – Supplemental Vertical Accuracy (95th Percentile) Target=0.36 m |
|---|---|---|---|---|
| Consolidated | 100 | | 0.268 | |
| Bare Earth-Open Terrain | 46 | 0.198 | | |
| Urban | 24 | | | 0.250 |
| Combined Vegetation | 30 | | | 0.332 |

Table 9 outlines vertical accuracy as computed by the different methods, in meters.

**Descriptive Statistics**

| 100 % of Totals | # of Points | RMSEz (m) Open Terrain Spec=0.125 m | Mean (m) | Median (m) | Skew | Std Dev (m) | Kurtosis | Min (m) | Max (m) |
|---|---|---|---|---|---|---|---|---|---|
| Consolidated | 100 | | -0.017 | -0.019 | 0.869 | 0.126 | 3.005 | -0.290 | 0.507 |
| Open Terrain | 46 | 0.101 | -0.007 | -0.004 | -0.482 | 0.102 | 0.504 | -0.267 | 0.202 |
| Urban | 24 | | -0.056 | -0.084 | 0.970 | 0.117 | 2.912 | -0.290 | 0.303 |
| Tall Weeds and Crops | 7 | | -0.018 | 0.022 | -0.296 | 0.090 | -2.523 | -0.129 | 0.076 |
| Brush Lands and Trees | 9 | | 0.128 | 0.107 | 0.019 | 0.224 | 0.870 | -0.275 | 0.507 |
| Forested and Fully Grown | 14 | | -0.071 | -0.075 | -0.592 | 0.075 | 1.257 | -0.244 | 0.060 |
| Combined Vegetation | 30 | | 0.001 | -0.018 | 1.306 | 0.160 | 3.012 | -0.275 | 0.507 |

**Table 8 - The table shows the calculated $RMSE_z$ values, in meters, as well as associated statistics of the errors for the Oahu project area for the final DEM deliverable.**

| LiDAR Vertical Accuracy Results | | | | |
|---|---|---|---|---|
| **Land Cover Category** | **# of Points** | **FVA – Fundamental Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.245 m** | **CVA – Consolidated Vertical Accuracy (95th Percentile) Spec=0.36 m** | **SVA – Supplemental Vertical Accuracy (95th Percentile) Target=0.36 m** |
| Consolidated | 100 | | 0.268 | |
| Bare Earth-Open Terrain | 46 | 0.198 | | |
| Urban | 24 | | | 0.250 |
| Combined Vegetation | 30 | | | 0.332 |

**Table 9 - The table shows the calculated FVA, CVA, and SVA, in feet, at the 95% confidence level.**

## QUALITATIVE REVIEW

Dewberry performed a visual analysis on 100% of the delivered DEMs. The DEMs were reviewed in Global Mapper or ESRI ArcMap software. The DEMs were reviewed with hillshades, which allow the viewer to see the DEMs as if in 3D. This helps with the identification of issues and anomalies. The DEM is required to be free of artifacts, gaps, and artificial smoothing. A breakdown of the edit calls made during the review can be seen in the table below.

| Issue | Number of Occurrences | Remaining Issue |
|---|---|---|
| Artifacts | 7 | 0 |
| **Total** | 7 | **0** |

**Table 6 – Breakdown of DEM qualitative edit calls**

### Artifacts

Dewberry found seven tiles that contained minor artifacts in the DEM surface likely from processing either within a single tile or between two adjacent tiles. All artifacts have been addressed in the redelivery of the dataset.

## DEM RECOMMENDATION

It is Dewberry's recommendation that the DEMs be accepted by NOAA CSC.

# Metadata

Photo Science delivered five project level metadata files, in XML format for the raw swaths, final classified LAS, breaklines, and DEMs. As well as a single project level metadata file. Additionally, metadata was provided for each lift as required by USGS. Dewberry reviewed the metadata files for correct formatting and for sufficient content. All metadata files meet FGDC standards and were deemed error free by the MetaParser (MP) tool developed by the United States Geological Survey.

All metadata files have similar abstracts. Each lineage step has the beginning and end dates of acquisition and provides detailed information for the acquisition and processing of the LiDAR and the breakline collection process. However, the LiDAR metadata should include references to the additional overlap classes that were used in the LiDAR dataset.

The metadata files have been updated based on the recommendations.

### METADATA RECOMMENDATION

Dewberry recommends the metadata be accepted by NOAA CSC.

# Other Comments

Along with this report, Dewberry is providing a GDB named Oahu_D1_QC_20140321.gdb" that contains all LiDAR, breakline, and DEM edit calls from our review of the Oahu deliverable. PSI should comment for each call whether or not the issue was corrected. If no corrections are made, the reason why should be documented in the feature class. This GDB will provide a record of the review, modification, and response process used on the Oahu data.

# Recommendations Summary

The following represents a summary of Dewberry's recommendations for Photo Science Inc (Quantum Spatial). These recommendations can be found throughout the various sections of this report but are summarized here for convenience.

### LIDAR:

1. Recommended for acceptance.

### BREAKLINES:

1. Recommended for acceptance.

### DEMS:

1. Recommended for acceptance.

### METADATA:

1. Recommended for acceptance.

# APPENDIX A – ACCEPTANCE CRITERIA

| Criteria | Tested Characteristic | Measure of Acceptability |
|---|---|---|
| | | **LiDAR Data Acquisition Acceptance Criteria** |
| 1. | Returns per pulse | LiDAR sensor shall be capable of recording up to 3 (or more) returns per pulse, including 1st and last returns |
| 2. | Scan angle | ≤ ±20 degrees on each side of nadir, i.e., maximum Field of View = 40 degrees |
| 3. | Swath overlap | Nominal sidelap of 15% on adjoining swaths. Any data gaps between the geometrically usable portions of the swaths will be rejected. |
| 4. | Design pulse density (nominal) | ≥ 1 pulse/$m^2$ per swath; assessment to be made against single swath, first return located within the geometrically usable center portion of each swath. |
| 5. | GPS procedures | Base stations for GPS surveys shall be based on first or second order survey control stations that are part of the National Geodetic Survey's National Spatial Reference System (NSRS). New control stations will be sufficiently monumented to hold their position. |
| 6. | Collection Conditions | Ground is snow free unless approved and documented by NOAA and its partners<br>Streams must be within their banks |
| | | **LiDAR Accuracy Acceptance Criteria** |
| 7. | Vertical Accuracy | Fundamental Vertical Accuracy (FVA) 12.5cm $RMSE_z$ or 24.5 cm at the 95% confidence level<br>Consolidated Vertical Accuracy (CVA) for 3 land cover classes that are TBD, should have an $Accuracy_z$ of 36cm<br>There shall be minimal vertical offset (7cm RMSE) between adjacent flight lines |
| 8. | Horizontal Accuracy | $RMSE_{xy}$ shall ≤ 4.0' |
| | | **Geographic Coverage and Continuity Acceptance Criteria** |
| 9. | Coverage | No voids between swaths. No voids because of cloud cover or instrument failure. Voids within a single swath ≥ $(4*NPS)^2$ will not be acceptable except for voids caused by water bodies, low reflectivity or where appropriately filled-in by an overlapping swath. |
| 10. | Aggregate 1st return density | Barring non-scattering areas (e.g., open water, wet asphalt); no voids of more than 4*NPS^2; point spacing (1st return) within each swath must have an average of 1 m, not including overlap points. Acceptable data voids identified in Acceptance Criterion #9 above are excluded from this requirement. |
| | | **Spatial Reference Framework** |
| 11. | Vertical Datum | NAVD 88, processed with Geoid12 – Gridded products shall be Local Mean Sea Level as defined by the NOAA tide station in Honolulu Harbor (#1612340) |
| 12. | Horizontal Datum | NAD 83 (PA11) |
| 13. | Projection | UTM Zone 4 |
| 14. | Vertical Units | Meters (orthometric heights), 3 decimal places |
| 15. | Horizontal Units | Meters, 3 decimal places |
| | | **Deliverables** |
| 16. | Report of Survey | Text report that describes survey methods; x,y,z results; file formats; file naming schemes; tiling schemes., *.pdf, .doc, or .odt format*. The survey data and report shall be delivered on the same media as the actual data. |

| Criteria | Tested Characteristic | Measure of Acceptability |
|---|---|---|
| 17. | Flight Lines as-flown | ESRI geodatabase format (vector) with attribution for start and stop time as well as dates. Dates must be in Julian date format with times generated using either a 12 or 24 hour cycle. GPS time is not acceptable. |
| 18. | All-return point cloud | List of all valid returns in LAS 1.2 format. For each return: GPS week, GPS second, easting, northing, elevation, intensity, return#, return classification. May include additional attributes that are outlined in the LiDAR SOW. No duplicate entries. GPS second shall be reported to the nearest microsecond (or better). Easting, northing, and elevation shall be reported to nearest 0.01 m (nearest 0.01 ft). Classification of returns shall be as complete as is feasible (including classes: 1. Unclassified, 2. Ground, 7. Noise, 9. Water, 10. Breakline Proximity points, 17. Unclassified overlap, 18. Ground overlap, 25. Water overlap) without avoidable return misclassification. |
| 19. | File naming convention | LAS Files -1500m x 1500m on even boundaries.<br>Naming shall conform to nomenclature provided by NOAA and its partners. |
| 20. | Digital Elevation Model (DEM) of bare-earth w/ breaklines | DEM of bare-earth terrain surface (1 meter grid), interpolated using a triangulated irregular network (TIN) from identified ground points and hydro-flattened, 2.5 and 3D breaklines. DEM deliverables will be in IMG format |
| 21. | DEM Artifacts | DEM shall have no tiling artifacts, no gaps and no artificial smoothing at tile boundaries. Areas outside survey boundary shall be coded as NoData. Internal voids (e.g., open water areas) may be coded as NoData. |
| 22. | Formal metadata | See SOW instructions on formal metadata |
| 23. | Ground Points (Bare Earth) | Post-processed to remove structures and vegetation with <5% residual artifacts |
| 24. | Inconsistent Post-Processing, Editing | No visible variations in LiDAR data caused by alternating processing techniques. Bare earth surface must be consistent in both the removal of features and the features left in the ground. |
| 25. | Over-Smoothing | Smoothing techniques shall not remove topographic features necessary to define drainage structures. |
| 26. | LAS Artifacts | No obvious artifacts, spikes, holes or blunders; no cornrows |
| | | **Usability Acceptance Criteria** |
| 27. | Internal file formats | Files shall have consistent internal formats |
| 28. | Compressed files | Files shall not be compressed, unless documented by NOAA and partners |
| 29. | Ancillary geographic feature data | Ancillary geographic feature data represented as vector data types shall have complete and correct associated projection files. |
| | | **Breakline Acceptance Criteria** |
| 30. | Completeness | 3D Breaklines collected for:<br>• Streams and Rivers<br>• Ponds and Lakes<br>• Tidal Waters |
| 31. | Monotonicity | • Double Line Streams shall generally maintain a consistent down-hill flow and be collected in the direction of flow – some natural exceptions will be allowed. |
| 32. | Vertical Consistency | • Closed Waterbodies shall maintain a constant elevation at all vertices.<br>• Vertices should not have excessive min or max z-values when compared to adjacent vertices<br>•Vertical variance between breaklines & LiDAR DTM: Continuous segments shall not float above existing terrain >0.3 ft. Features should not be excessively buried compared to surrounding terrain.<br>• Intersecting features shall maintain connectivity in X,Y,Z planes |

| Criteria | Tested Characteristic | Measure of Acceptability |
|---|---|---|
| 33. | Topology | • Streams and Rivers must not self-intersect or intersect<br>• Lakes and Ponds must not overlap or have gaps<br>• Features must not have unnecessary dangles or boundaries |
| 34. | Horizontal Placement | Breaklines are required to meet a tolerance of 2x the nominal post spacing for the horizontal placement when breaklines are compared to intensity imagery. The requirement applies only to the inside placement of the hydrographic feature, or inside the shoreline. If the feature intersects the bank of the feature so that ground is captured as water, it will still be considered an error. |
| 35. | Metadata | Metadata must be FGDC compliant and contain sufficient detail to document source materials, projections, datums, processing steps, etc. |

# Appendix B- QA/QC Checklists

## LiDAR Checklist

**Overview**

☒ Correct number of files is delivered and all files are in LAS format 1.2 - Passed
☒ LiDAR Swaths have been delivered and are in LAS format 1.2 – Passed
☒ LAS statistics have been run

**Quantitative Review/Accuracy Assessment**

Absolute and relative accuracy of data (vertical and horizontal) should be verified prior to classification and subsequent product development

☒ Control Points and Checkpoints in ASCII format
☒ FVA: RMSEz = 12.5cm or ACCURACYz at 95% = 24.5 cm
☒ CVA: ACCURACYz at 95% =36 cm
☒ Horizontal Accuracy: 4' at 95%
☒ Final accuracy report has been produced

**Project Requirements for LAS**

☒ Nominal Pulse spacing no greater than 1 meter, assessment made against single swath- Passed
☒ LiDAR is free from data voids, $4m^2$, except for over water bodies, areas of low NIR - Passed reflectivity such as asphalt or composition roofing, and where appropriately filled-in by another swath
☒ Distribution of points is uniform and free of clustering: A rectangular grid with 1m cell size overlaid on data shows at least 90% of the cells in the grid contain at least 1 LiDAR point when tested against 1st return only data- Passed
☒ Scan angle does not exceed 40° Passed
☒ Flightline overlap of 20% or greater- Passed
☒ Data collected to cover project area shapefiles- Passed. Project does not cover full extent but has been approved by Client.
☒ LAS header includes all required fields according to the ASPRS LAS 1.2 specifications- Passed with some minor inconsistencies in the GUID files
☒ LAS files include the mandatory GeoKey DirectoryTag variable length header - Passed
☒ Point Data Record Format 1 is used - Passed
☒ Intensity field is required - Passed
☒ Classification is as follows: Class 1-Unclassified, Class 2-Ground, Class 7-Low Points/Noise, Class 9-Water, Class 11 - withheld. Within any 1km x 1km area, no more than 2% of points will possess an erroneous classification value. – Passed, also includes classes 10, 17, 18, 25.
☒ LiDAR data is referenced to NAD83 (PA11), UTM Zone 4 and NAVD88, using latest GEOID model (GEOID12). All units shall be in meters to 2 decimal places – Passed. Data was submitted in ellipsoid heights but that has been accepted by Client.
☒ LiDAR data gaps between adjacent flight lines larger than 2 meters are not acceptable, but overlap points will be supplied. - Passed
☒ Bridge removal is consistent across the project area following the bridge collection guidelines- Passed. One edit call has been placed for a single bridge to be removed.

**Qualitative Review**

☒ LiDAR tiles reviewed for errors, anomalies, and incorrect project specifications – Passed
☒ Bare earth surface has been consistently classified, processed, and edited - Passed
☒ Profiles should be used to confirm every potential issue can be modified or corrected prior to marking it with an edit call. Dewberry's LiDAR SOP and standardized calls should be used during QC. - Passed
☒ If tiles are a re-submittal, corrections are verified to be acceptable Passed

**Metadata**

☒ Project level LiDAR metadata XML file is error free as determined by the USGS MP tool
☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc. – Passed

## Breakline Checklist

**Overview**

☒ All Feature Classes are present in GDB
☒ All features have been loaded into the geodatabase correctly.

☒ The breakline topology inside of the geodatabase has been validated (No Self-Intersection, No Overlap/Gaps, No Dangles).
☒ The correct project level metadata is provided for each feature class within the geodatabase – Passed
☒ If geodatabase is a re-submittal, verify all edit calls placed in the QAQC database have been corrected and comment fields are filled out correctly.
☒ Projection/coordinate system of GDB is accurate with project specifications (NAD83 – PA11, UTM Zone 4 and Ellipsoid Heights). All units in meters to 2 decimal places

**Perform Completeness check on breaklines using intensity imagery**
☒ Check entire dataset for missing features that were not captured, but should be to meet baseline specifications or for consistency
☒ Breaklines are compiled to correct tile grid boundary and there is full coverage without overlap
☒ Breaklines are correctly edge-matched to adjoining datasets.

**Compare Breakline Z elevations to LiDAR elevations**
☒ Compare all breakline vertex elevations to the LiDAR to ensure they are within the project tolerance. The impact the breaklines have on the final DEMs should be the deciding factor as to if there is an issue that requires corrections. Delta Z differences caused by noise within the LiDAR is expected and are not considered errors. – Some floating and digging vertices exist in the dataset. However, the impact on the DEM was minimal and any changes to the elevations would have caused the majority of the breakline to either dig or float greater than the existing feature.

**Perform automated data checks using PLTS**
The following data checks are performed utilizing ESRI's PLTS extension. These checks allow automated validation of 100% of the data. Error records can either be written to a table for future correction, or browsed for immediate correction. PLTS checks should always be performed on the full dataset.

☒ Perform "adjacent vertex elevation change check" on the Waterbody feature class (Elevation Difference Tolerance=.001 feet).
☒ Perform "unnecessary polygon boundaries check" on Waterbody and Coastal shoreline feature classes.
☒ Perform "different Z-Value at intersection check"
☒ Perform "duplicate geometry check"
☒ Perform "geometry on geometry check"
☒ Perform "polygon overlap/gap is sliver check"

**Perform Dewberry Proprietary Tool Checks**
☒ Perform monotonicity check on stream banks to ensure consistent downhill flow on hydrographic features
☒ Perform connectivity check for intersecting or touching features

**Metadata**
☒ Each XML file (1 per feature class) is error free as determined by the USGS MP tool
☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc. Content should be consistent across all feature classes.

## DEM Checklist

**Overview**
☒ Correct number of files is delivered and all files are in IMG format
☒ Run "QCRaster" script to ensure all files are tiled 1500m x 1500m with a 1 meter resolution
☒ Check sample of rasters to ensure projection/coordinate is accurate with project specifications (NAD83 – PA11, UTM Zone 4 and Ellipsoid Heights). All units shall be in meters to 2 decimal places.

**Review**
☒ Manually review bare-earth DEMs with a hillshade to check for issues with hydro-flattening process or any general anomalies that may be present. Specifically, water should be flowing downhill, water features should NOT be floating above surrounding terrain and bridges/box culverts should NOT be present in bare-earth DEM. Hydrologic breaklines should be used during review of DEMs to ensure features are carried through bridges to ensure all hydrographic features are flattened in the DEM. However, breaklines should be flipped off and on for each window display as breaklines turned on will hide floating hydrographic features. The tile grid should usually be turned off as well as it can hide anomalies along borders between tiles.
☒ Dewberry's DEM QC SOP and standardized DEM edit calls should be used.

**Metadata**

- ☒ Project level DEM metadata XML file is error free as determined by the USGS MP tool
- ☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc.