LiDAR QA/QC

- Quantitative and Qualitative Assessment Report -

Gloucester County

December 4, 2007

Prepared by:

Dewberry

Fairfax, VA

EXECUTIVE SUMMARY

This LiDAR project covered approximately 353 square miles for the entire county of Gloucester (New Jersey) in spring of 2007. The LiDAR data were acquired and processed by Terrapoint USA, as subcontractor to Leonard Jackson. The product is a mass point dataset with an average point spacing of 0.7m. The data is tiled, stored in LAS format, and LiDAR returns are classified in 4 ASPRS classes: non-ground (1), ground (2), noise (7) and water (9).

Terrapoint provided the vertical accuracy of these data and Dewberry reviewed their testing methodology. Dewberry also performed a quality assessment of these data including a completeness check and a qualitative review to ensure accuracy and usability for floodplain mapping.

First, based on acquisition survey data provided by Terrapoint (open terrain conditions along highways), the elevation meets the fundamental accuracy required for this project. It should be noted that the methodology used does not conform to FEMA Appendix A but complies to the NSSDA standard. This LiDAR dataset was tested 0.181m (0.596ft) fundamental vertical accuracy at 95% confidence level, based on consolidated RMSEz (0.304ft) x 1.9600.

Secondly, Dewberry inventoried the files and confirmed that all tiles were delivered by Terrapoint in the specified format and correctly geographically projected. We visually inspected 100% the data at a macro level; no remote-sensing data void was found and the data are free of major systematic errors. The cleanliness of the bare earth model was assessed on 25% of the tiles at the micro level and exhibits excellent quality and should meet most user's needs. Minor errors were found (such as cornrows, variation in the scan pattern, possible manmade structure remains, confusions between classes water and ground) but are not representative of the majority of the data.

In essence, this LiDAR dataset produced by Terrapoint is of good quality and meets the needs of FEMA and FEMA contractors for floodplain mapping.

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QAQC REPORT

1 Introduction

LiDAR technology data gives access to precise elevation measurements at a very high resolution, resulting in a detailed definition of the earth's surface topography. Dewberry's role is to provide and independent verification of this data using a vertical accuracy assessment, a completeness validation and a qualitative review of the derived bare earth surface.

First, the quantitative analysis addresses the quality of the data based on absolute accuracy of a limited collection of discrete checkpoint survey measurements. For this project, the data provider assessed the vertical accuracy of the data and Dewberry thoroughly reviewed it.

Then, the completeness verification is conducted at a project scale (files are considered as the entities). It consists in a file inventory and a validation of conformity to format, projection, georeference specifications. General statistics over all fields are computed per file and analyzed to identify anomalies especially in elevations and LAS classes.

Finally, to fully address the data for overall accuracy and quality, a qualitative review for anomalies and artifacts is conducted at the data level. As no automatic method exists yet, we perform a manual visualization process based on the knowledge of Dewberry's analysts. This includes creating pseudo image products such as 3-dimensional models. By creating multiple images and using overlay techniques, not only can potential errors be found, but we can also find where the data meets and exceeds expectations.

Within this Quality Assurance/Quality Control process, three fundamental questions were addressed:

- Did the LiDAR system perform to specifications?
- Was the data complete?
- Did the ground classification process yield desirable results for the intended bare-earth terrain product?

2 Vertical accuracy Assessment

Due to the limited budget for this project an independent ground-truth checkpoint survey was not performed. Typically for this type of data collection, a ground truth survey is conducted following the FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners Appendix A: Guidance for Aerial mapping and Surveying.* This methodology collects a minimum of 20 points for each of the predominant land cover types (i.e. bare-earth, weeds and crop, forest, urban etc.). By verifying the data in these different classes, the data accuracy is tested but it also tests whether the classification of the LiDAR has been performed correctly at those test point locations. However since this survey did not have an independent ground truth survey, the LiDAR provider internal checkpoints were utilized.

To test the accuracy Terrapoint utilized kinematic GPS techniques along two major highways (see *Figure **2***). A GPS receiver was attached to a vehicle and driven along the highway, and the position of the receiver was reduced down to the ground level. This process yielded over 2000 points spaced at one second intervals based on the vehicles velocity. This methodology in essence tests the fundamental vertical accuracy where the LiDAR is not influenced by any vegetation and there is no reason why the LiDAR should fail. Although this method did not test vegetated areas, the premise is that if the LiDAR system was accurate for the fundamental checks along the road then the same type of accuracy should be present in the vegetated areas. Since there are no survey checkpoints in the vegetated areas, an emphasis was to use the qualitative process to ensure the data was correctly classified. Using both these techniques provided enough information to ensure the data would meet the current FEMA accuracy and usability requirements.

To compute the accuracy, the checkpoints z-values are compared to z-values computed at the same horizontal locations from a TIN generated from the bare-earth LiDAR.
The statistics computed on the elevation differences between LiDAR and GPS are presented below.

Table 1 – RMSE statistics computed by Terrapoint

100 % of Totals	RMSE (ft) Spec=0.61ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Fundamental	0.304	-0.062	-0.177	0.702	0.298	2082	-0.686	0.763

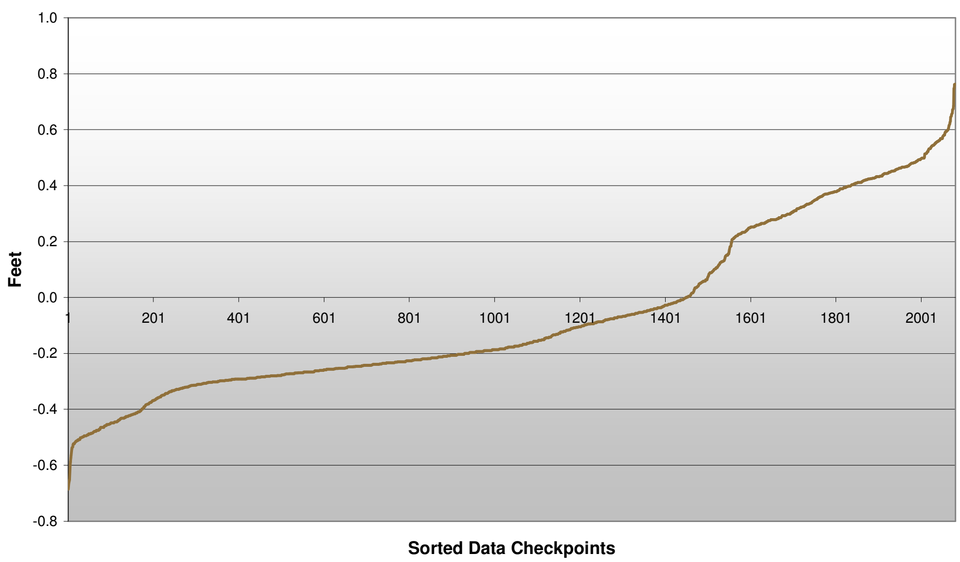


Figure 1 - Sorted checkpoint errors for 2082 GPS points

Based on these checkpoints, the data meets the accuracy specifications in accordance with the National Standard for Spatial Data Accuracy (NSSDA) guidance for 2ft equivalent contour interval (RMSE of 0.61ft). Detailed listing of these control points are provided as attached file (Final_GCR_SurveyFeet.txt).

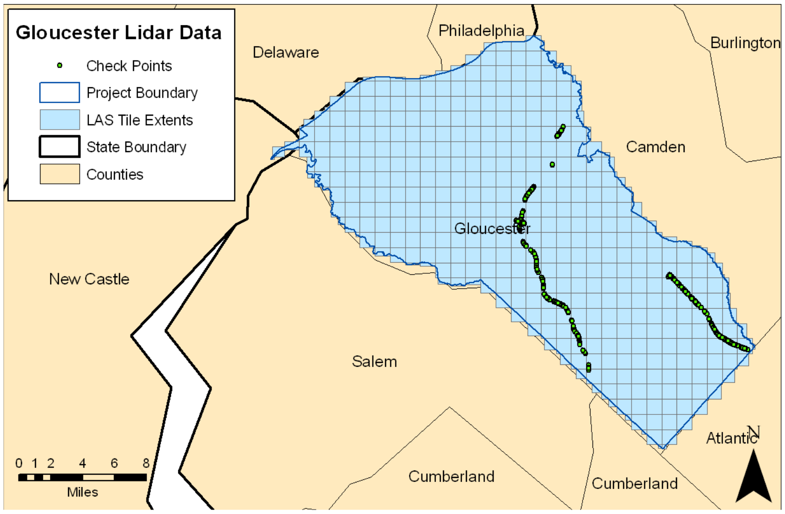


Figure** 2 **– Terrapoint checkpoints

Since the RMSE was pre-computed for us by Terrapoint, Dewberry tested 20 of the survey checkpoints to ensure we could derive the same interpolated value from the TIN. 20 points were randomly selected and compared. The answers did not change. Additionally the RMSE was computed from these random 20 points which equaled 0.362 ft. which is within the desired range and similar to the full project RMSE.

As an independent verification of the data, we utilized NGS control points as supplemental checkpoints. These checkpoints were selected based on the criteria of 2nd order or better for vertical and 3rd order or better for horizontal (http://www.ngs.noaa.gov). These points combined with Terrapoint check points produce a very good RMSE of 0.406 ft. The combined results are shown in Table 2. *Figure **4*** illustrates the distribution of the elevation differences between the LiDAR data and the surveyed points. Errors points are well distributed around 0.

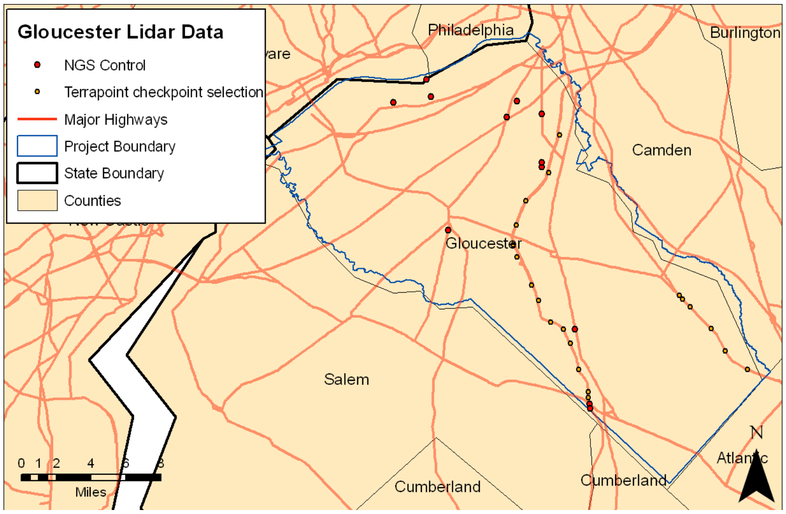


Figure 3 – Combined check points (Terrapoint sampling and NGS Controls)

Table 2 – Combined Results using 20 Terrapoint checkpoints and 12 NGS Controls

100 % of Totals	RMSE (ft) Spec=0.61ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Fundamental	0.406	0.149	0.150	-0.119	0.384	32	-0.572	0.662

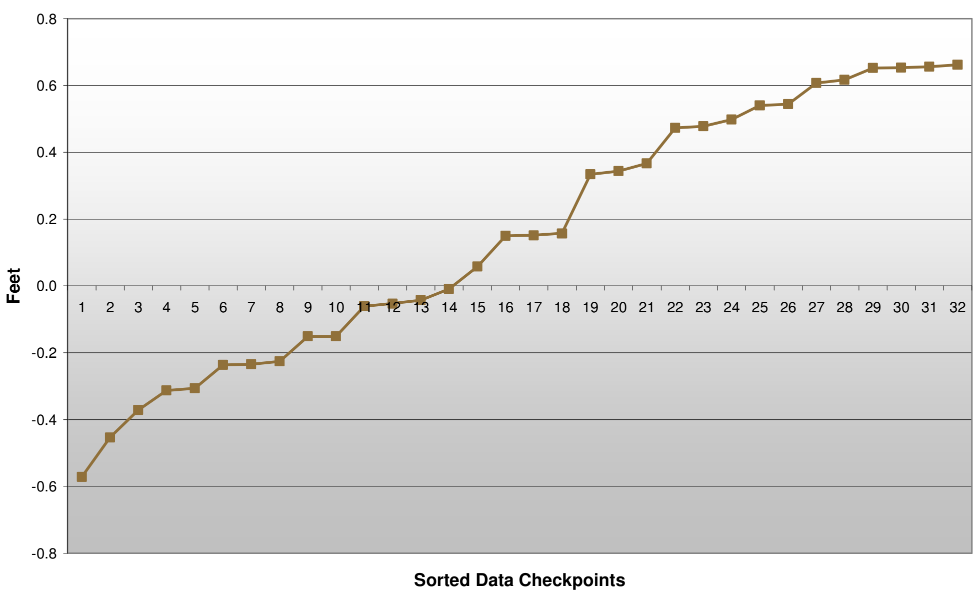


Figure 4 – Sorted checkpoint errors for combined dataset

3 Quality Assurance

3.1 Completeness of Lidar deliverables

The first step in our review is to inventory the data delivered, to validate the format, projection, georeferencing and verify the range of elevations.

3.1.1 Inventory and location of data

The project area is approximately 353 sq miles and covers the entire Gloucester County, New Jersey.

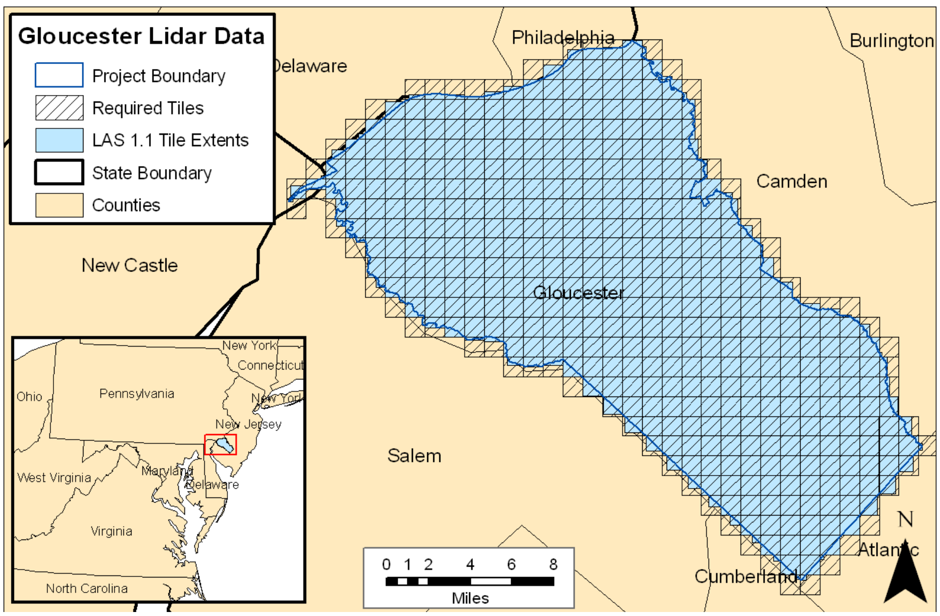


Figure** 5* ***- Delivered LiDAR tiles

A total of 440 files were delivered by Terrapoint for the entire project overlapping all the required area. We compared the actual LiDAR file extent with the required tile grid extent by creating the corresponding vector shape and overlaying it to the initial tile scheme. *Figure **5*** illustrates that the geographic extent of the LAS file is matching or is contained inside the extents of the project tile index defined for the project (based on the ortho state tile scheme). Moreover, a subsequent visual verification confirmed that points were clipped out by the project boundary for files intersecting the external boundary. Tile names conform to the proposed convention, giving the 3 first characters of the tile lower left corner (e.g. 270_345). No data issues were found.

We have verified that the data is in the correct projection:

- New Jersey State Plane
- Horizontal Datum: NAD83
- Vertical Datum: NAVD88 Geoid 03
- Units: US survey feet

Data were delivered in LAS (extension .las) version 1.1 with a point data format 1 including GPS time. Each record includes the following fields:

- XYZ coordinates
- Flightline
- Intensity
- Return number, Number of return, scan direction, edge of a flight line and scan angle
- Classification:
    - code 1 for non-ground,
    - code 2 for ground
    - code 7 for noise (low and high points)
    - code 9 for water
- GPS time

3.1.2 Statistical analysis of tile content

To verify the content of the data and to validate the data integrity, a statistical analysis was performed on all the data. This process allows us to statistically review 100% of the data to identify any gross outliers. This statistical analysis consists of:

1. Extract the header information
2. Read the actual records and compute the number of points, minimum, maximum and mean elevation for each class. Minimum and maximum for other relevant variables are also evaluated.

Each tile was queried to extract the number of LiDAR points and all tiles are within the anticipated size range, except for where fewer points are expected (near the project boundary) as illustrated in *Figure* ***6***.

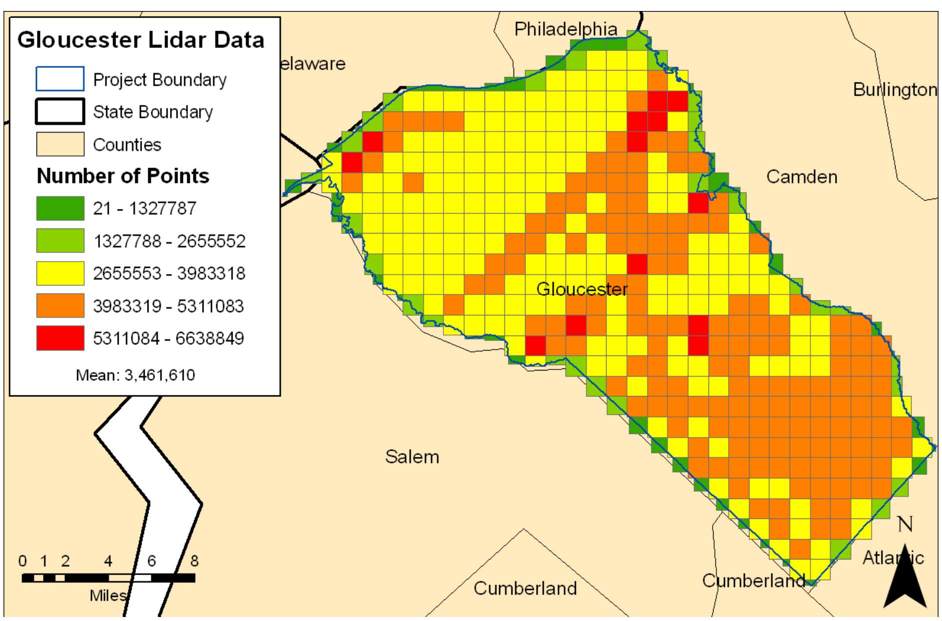


Figure** 6 **– Number of points in LAS files.

To first identify incorrect elevations, the z-minimum and z-maximum values for the ground class were reviewed. With maximum values between 5 and 250ft (2 tiles with only water excluded), no noticeable anomalies were identified. *Figure **7*** shows the spatial distribution of these elevations, following the anticipated terrain topography. Higher points were legitimate elevation on top of a mine heap. However, we noticed that several tiles with negative elevation minimum (*Figure **8***). These tiles are located along the Delaware River bordering our area to the Northwest. Several of the tiles that have an elevation below zero were investigated and it reveals that the lowest points are part of the drainage network (*Figure **9*** and *Figure **10***).

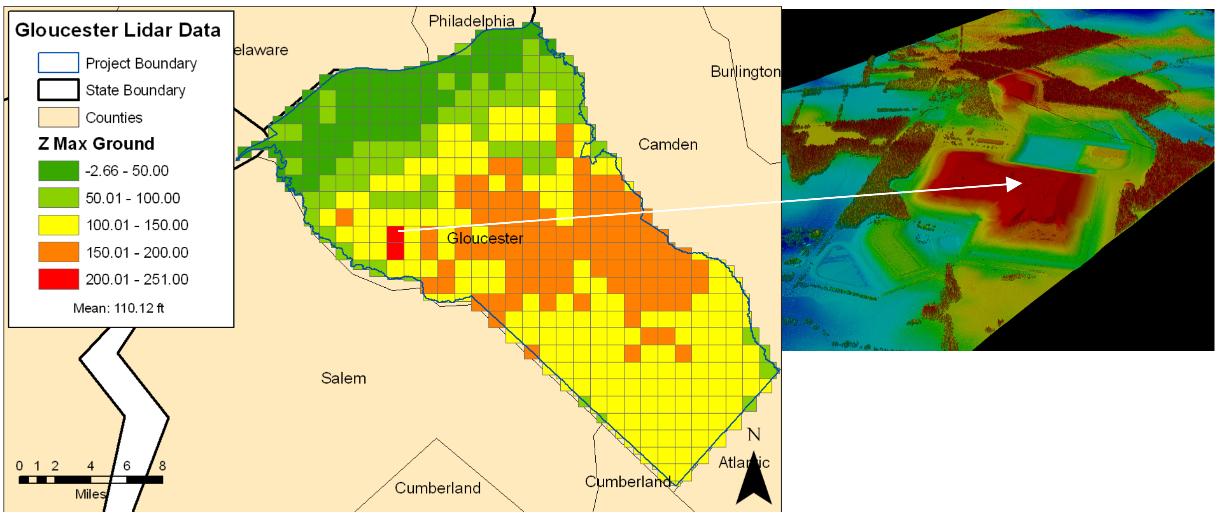


Figure** 7 **– Maximum elevation in feet for class 2 (ground) and detail of the highest points

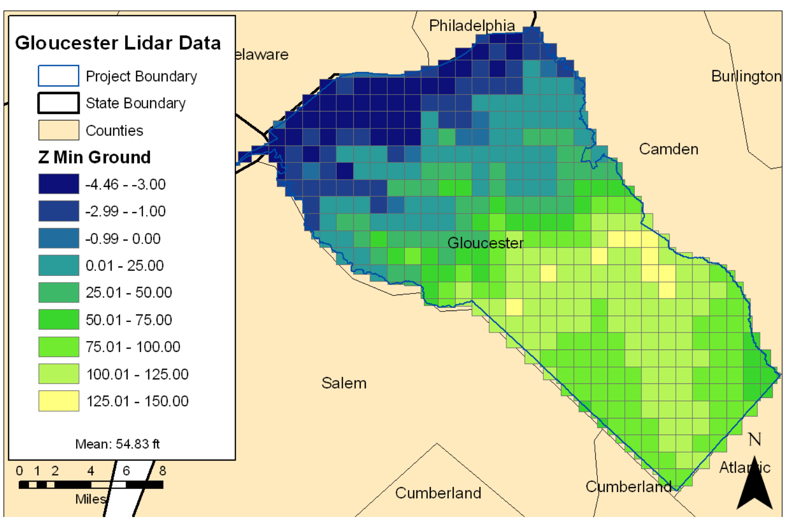
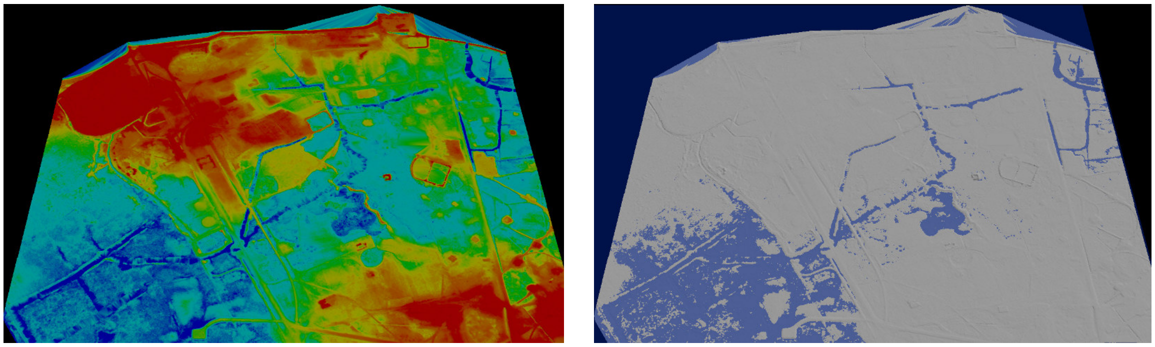


Figure** 8 **– Minimum elevation in feet for class 2 (ground)



Ground model colored by elevation (blue: lower, red: higher)

Ground model with transparent water level set to 0ft. Surfaces in blue are bellow 0

Figure** 9 **– Tile 365_365 with elevations bellow 0 at project edge near the river

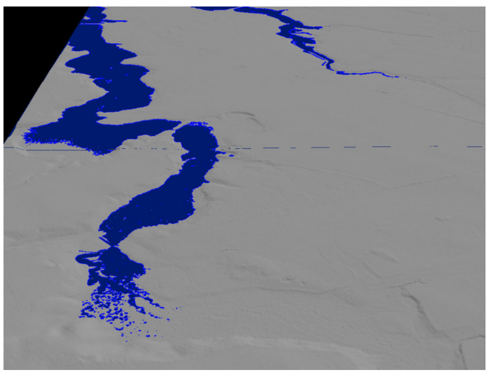


Figure** 10 **– Tile 370_345 with elevations bellow 0 in drainage network

By comparing extrema values for each classes we verified that class 7 really contains noise points (very low points under -5 feet and very high points around a few thousand feet) as illustrated in Figure 11 and Figure 12.

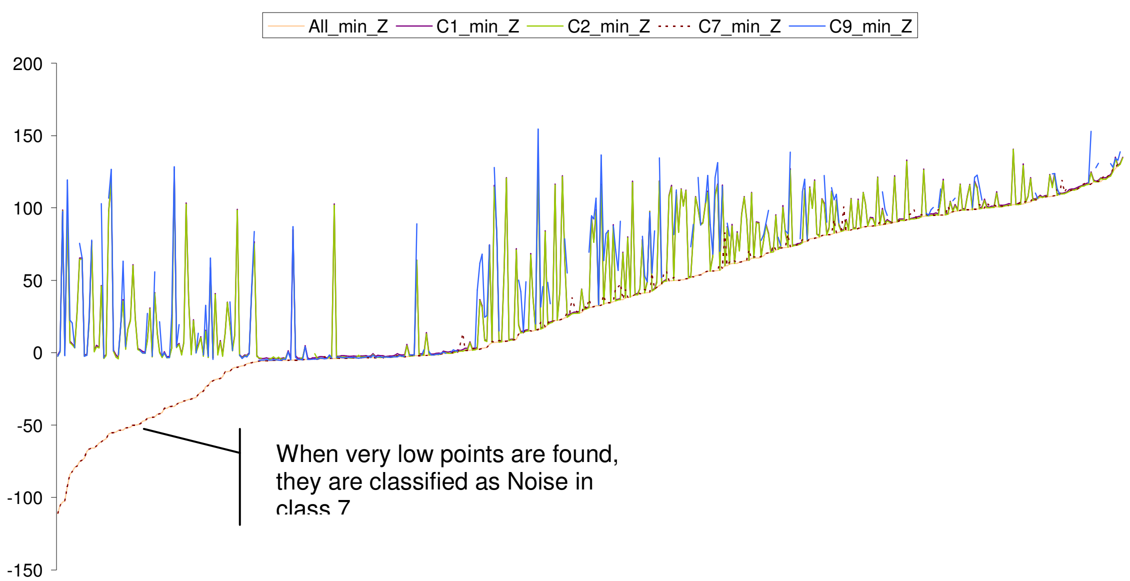


Figure** 11 **– Minimum elevation in feet for each tile sorted by Min_Z, each class is also plotted separately

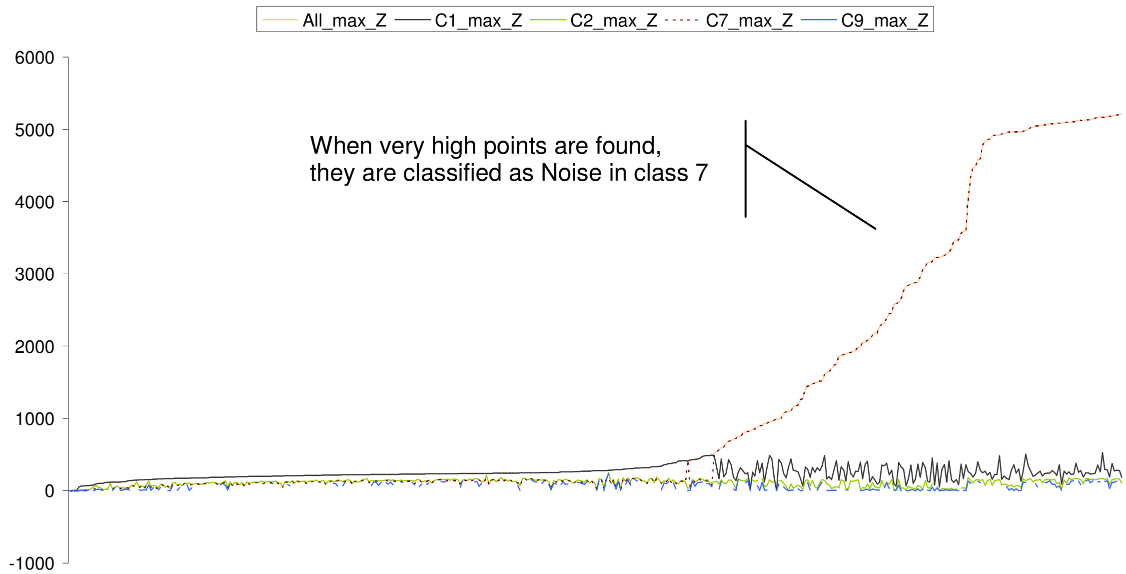


Figure** 12 **- Maximum elevation in feet for each tile sorted by Max_Z, each class is also plotted separately

Then, we reviewed the classification consistency. We noticed that 7 tiles do not contain any ground points as they are entirely over the Delaware River (265_370, 245_365, 225_340, 255_370, 260_370, 235_355 and 270_370) .

The general behavior of elevation for each class was logical, as illustrated in *Figure* ***13***, Class 2 (ground) maximum elevation is always lower than Class 1 (non-ground, which includes water and buildings) and higher Class 9 (water).

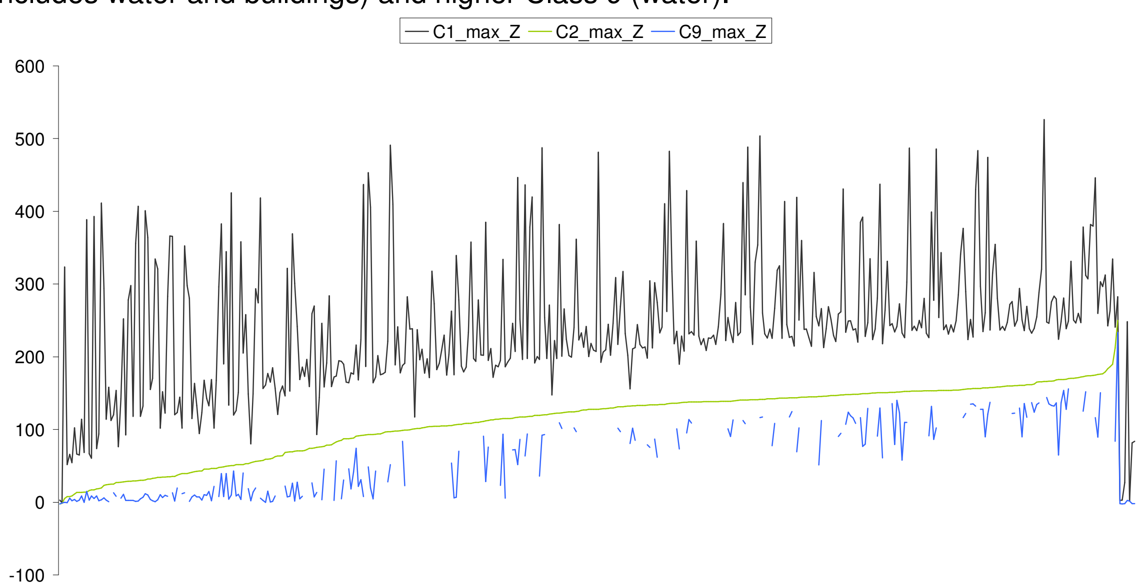


Figure** 13 **- Maximum elevation per class for each tile sorted by Max_Z in Class 2 (ground). Elevations in feet. Class 9 graph (blue) is interrupted as some files may not contain water.

Intensities values are not calibrated and are expressed in generic sensor units. Intensities averaged over each tile are generally under 80 units for class 2 and under 40 for class 1. Class 9 (water) exhibits really high spikes up to 15500 units indicating a possible saturation of the sensor over water (*Figure **14***).

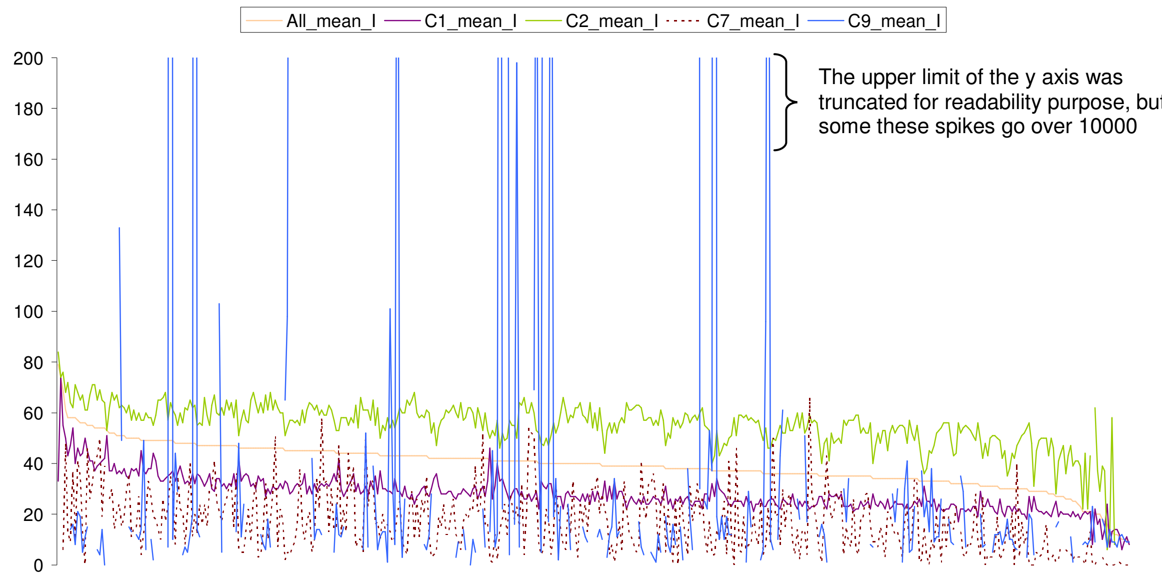


Figure** 14 **– Intensity average for each tile sorted by descending mean_Intensity, arbitrary units. Individual classes are also plotted separately.

3.2 Qualitative assessment

3.2.1 Protocol

The goal of this qualitative review is to assess the continuity and the level of cleanliness of the bare earth product. The acceptance criteria we have reviewed are the following:

- If the density of point is homogeneous, correctly supported by flightline overlap and sufficient to meet the user needs.
- If the ground points have been correctly classified (no manmade structures and vegetation remains, no gap except over water bodies),
- If the ground surface model exhibits a correct definition (no aggressive classification, no over-smoothing, no inconsistency in the post-processing), in a context of flood modeling, special attention is given to the stream channels,
- If no obvious anomalies due to sensor malfunction or systematic processing artifact is present (data holidays, spikes, divots, ridges between tiles, cornrows…).

Dewberry analysts, experienced in evaluating LIDAR data, performed a visual inspection of the bare-earth digital elevation model (bare-earth DEM). LiDAR mass points were first gridded with a grid distance of 2x the full point cloud resolution. Then, a triangulated irregular network (TIN) was built based on this gridded DEM and displayed as a 3D surface. A shaded relief effect was applied which enhances 3D rendering. 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.
One of the variables established when creating the models is the threshold for missing data. For each individual triangle, the point density information is stored; if it meets the

threshold, the corresponding surface will be displayed in green, if not it will be displayed in red (see *Figure* ***15***).

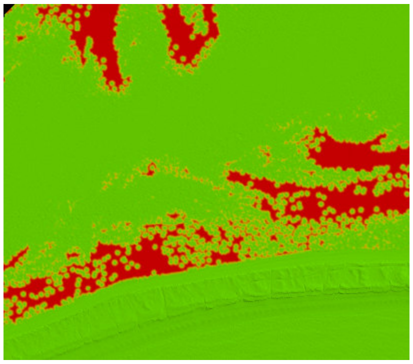


Figure** 15 **– Ground model with density information (red means no data)

The first step of our qualitative workflow was to verify the point distribution by systematically load a percentage of the tiles as mass points colored by class or by flightline. This particular type of display helps us visualize and better understand the scan pattern, the flight line orientation and coverage and gives an additional confirmation that all classes are present and seem to logically represent the terrain.

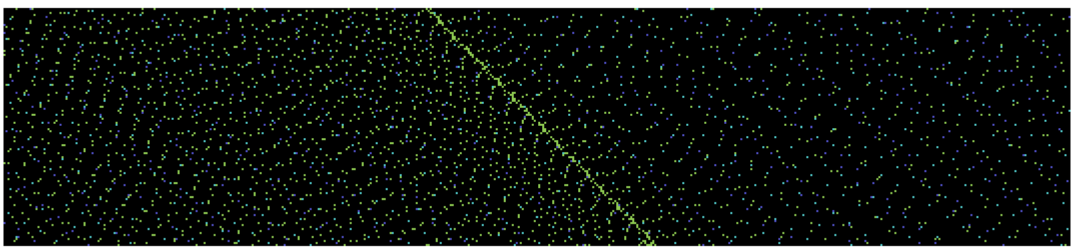


Figure** 16 **– Lidar points colored by flightline. Detail of the point distribution. Note the variations in the scan pattern

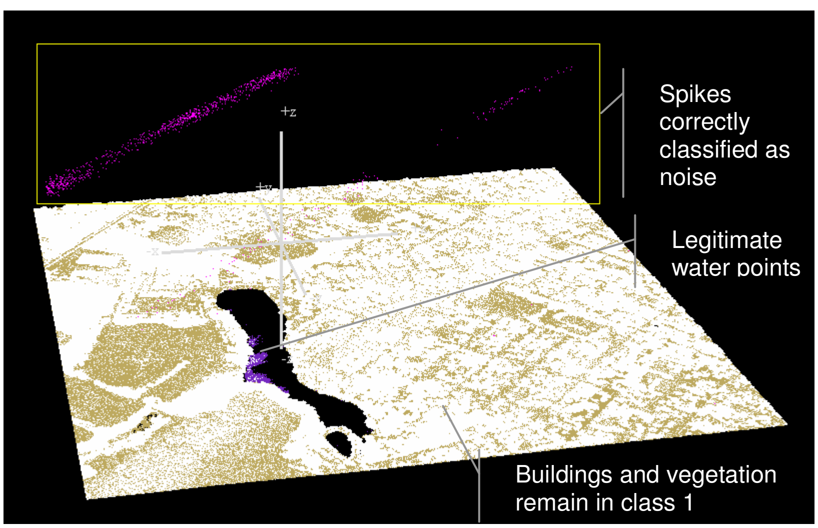


Figure** 17 **– Full point cloud colored by class (white: non ground, brown: ground, pink: noise, dark violet: water)

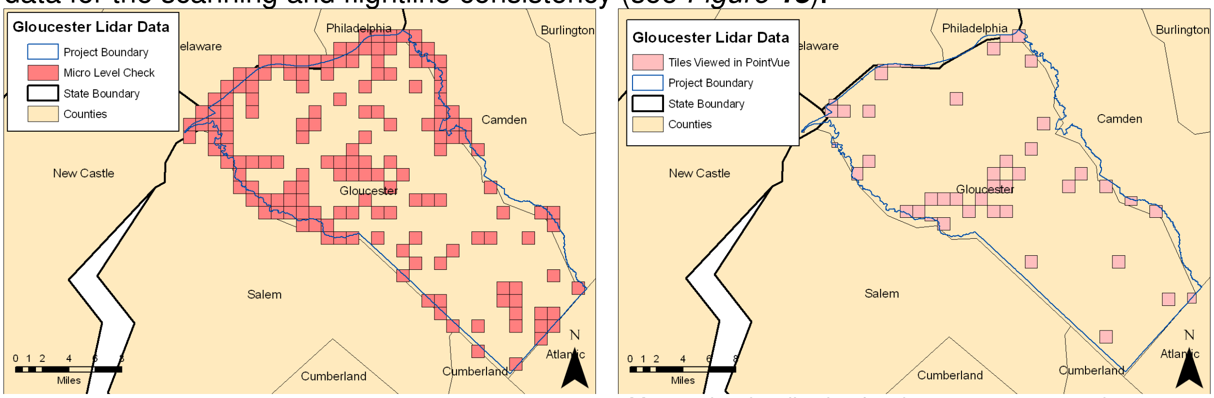
The second step was to verify data completeness and continuity using the bare-earth DEM with density information, displayed at a macro level. If, during this macro review of the ground models, we find potential artifacts or large voids, we use the digital surface model (DSM) based on the full point cloud including vegetation and buildings to help us better pinpoint the extent and the cause of the issue. Moreover, the intensity information stored in the LiDAR data can be visualized over this surface model, helping in interpretation of the terrain.

Finally, in case the analyst suspects a systematic errors relating to data collection, a visualization of the 3D raw mass points is performed, rather than visualizing as a surface.

The process of importing, comparing and analyzing these two later types of models (DSM with intensity and raw mass point), along with cross section extraction, surface measurements, density evaluation, constitutes our micro level of review.

3.2.2 Quality report

Contractually, our Qualitative review was to perform a macro visual inspection of all the tiles and to inspect a minimum of 25% at a micro level of detail. Actually, we reviewed all the data at a macro level and 30% at a micro level; additionally we reviewed 10% of the data for the scanning and flightline consistency (see *Figure **18***).



Micro level of qualitative analysis

Mass point visualization for class presence, scanning pattern consistency and flighline overlap

Figure** 18 **- evaluated tiles

Our professional judgment is that the bare earth model is of excellent quality (i.e. *Figure **19***). Generally speaking no void or significant anomalies were found in the data. The nominal point spacing of the ground mass points is approximately 2ft.

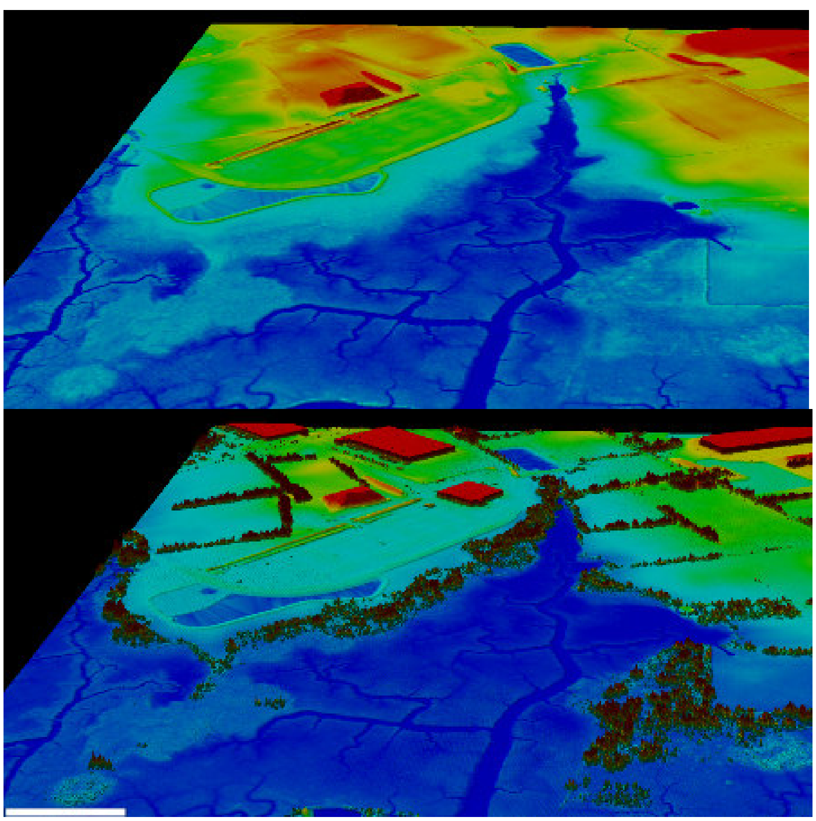
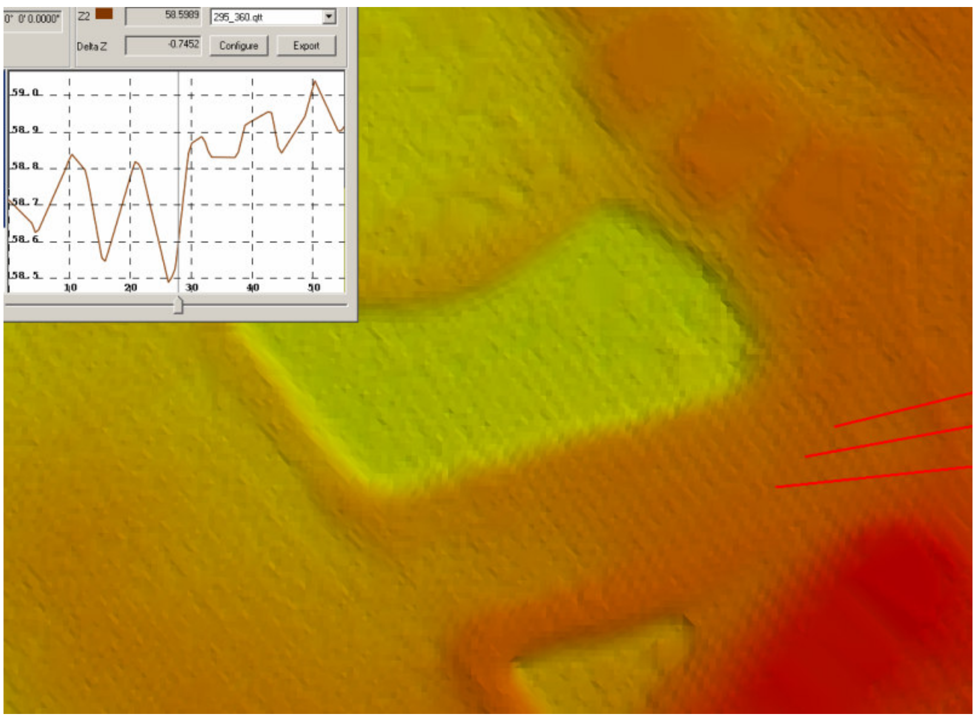


Figure** 19 **– Good example of the quality of the bare-earth (top) and corresponding surface model with intensity data (bottom) for tile 240_340

Dewberry did find a few minor errors in the data as outlined in the text and images below (contact sheets of all the errors found during the review are given in Appendix B). These errors are minor however and are not serious enough to render the data unusable.

Cornrows

Cornrows were typically seen throughout the project. There are multiple reasons as to why this happens but the end result is that adjacent scan lines are slightly offset from each other. This will give the effect that there are alternating rows of higher and then lower elevations. Although this is common with LiDAR data, as long as the elevation differences are less than 20 cm and the occurrences are minimized, it is acceptable because it is within the noise and accuracy levels. However this also can be an indication that the sensor is mis-calibrated, or offsets exist between adjacent flight lines so each area identified is analyzed. Our review found several negligible instances of the cornrow effect however only two or three were significant (see for instance Figure 20) and the remainder of this effect was within acceptable limits.

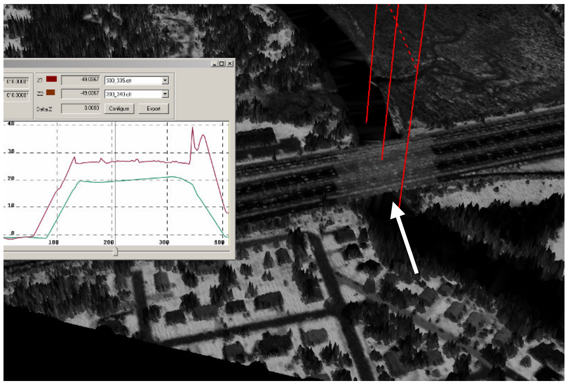


Bare earth model colored by elevation

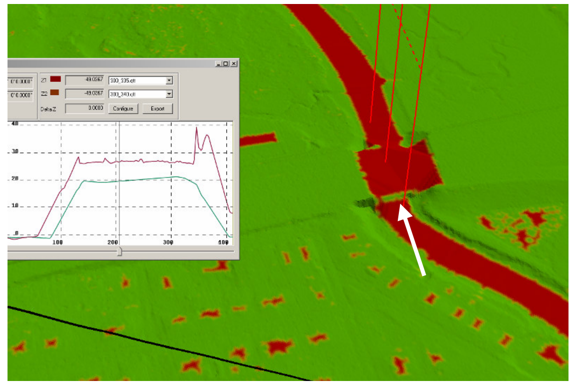
Figure** 20 **– tile 295_360. Cornrows under the acceptable limit (0.5feet)

Artifacts and bridges

One minor issue for the bare-earth terrain is the classification of bridges.. Some users may require bridges to be removed (classified to non-ground) while others may require them classified as ground. For the user community if this is an issue this is easily remedied because it is clearly identifiable and the data can be reclassified. In this dataset, the majority of them are removed from the ground but some instances of bridges partially removed were found. *Figure **21*** illustrates this case..



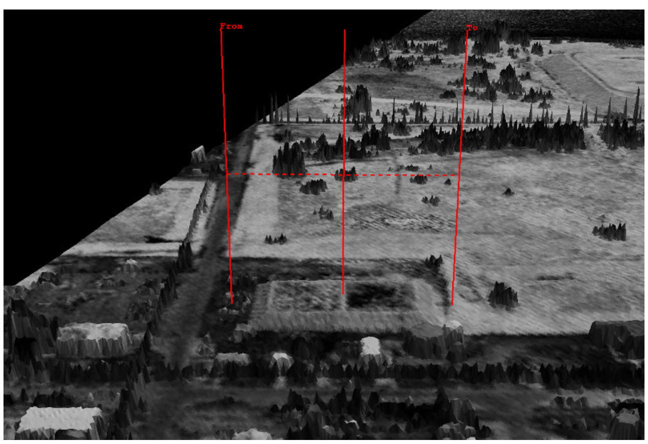
Full point cloud model colored by intensity



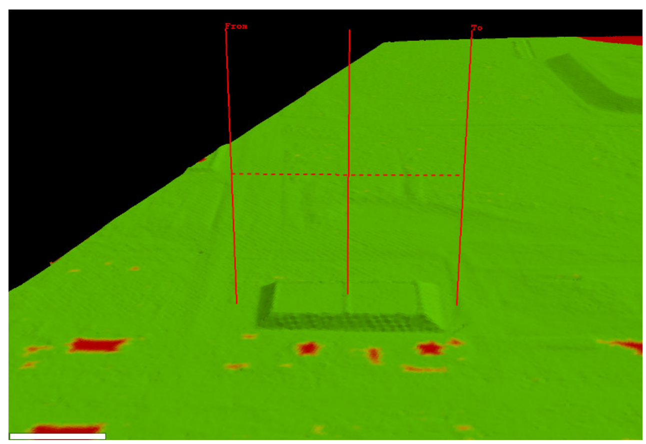
Bare earth model colored by density (red=no points)

Figure 21 – Tile 300_370: inconsistent Bridge editing. Bridges are sometimes removed, totally retained or sometimes portions of the bride remain in the bare earth terrain.

Due to the vast amounts of data and geographic phenomena, the classification algorithms can sometimes erroneously classify data. This misclassification results in artifacts which can be remnants of vegetation or manmade structures that do not represent the bare-earth terrain. *Figure* ***22*** illustrates potential artifacts based on the visual inspections of the bare-earth terrain. None of these tiles have been ground-truthed and therefore are identified only as potential issues. Moreover, it is evident that these potential areas are relatively small and easily within the specification of being 95% cleaned of artifacts.

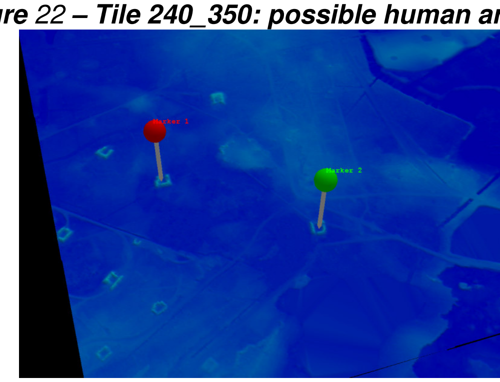


Surface model with intensity



Bare-earth model with density information (red = no data).

Figure 22 – Tile 240_350: possible human artifact in bare-earth model



Bare-earth colored by elevation

***Figure** 23 – Tile 270_365: possible man-made artifact in bare-earth model*

Scan Pattern

Sometimes scan pattern can vary along a flight line due to windy conditions or due to mirror acceleration. *Figure* ***24*** shows a tile with large variations. Note however that the point spacing along the scan line conform to the requirements. This type of irregular scan is recurrent but does not compromise the integrity of this data.
Concerning the flighltlines, the overlap appears to be of 50%, so every surface is scanned by at least two acquisitions, except for small slivers only covered once, no data holidays between adjacent flightlines were found.

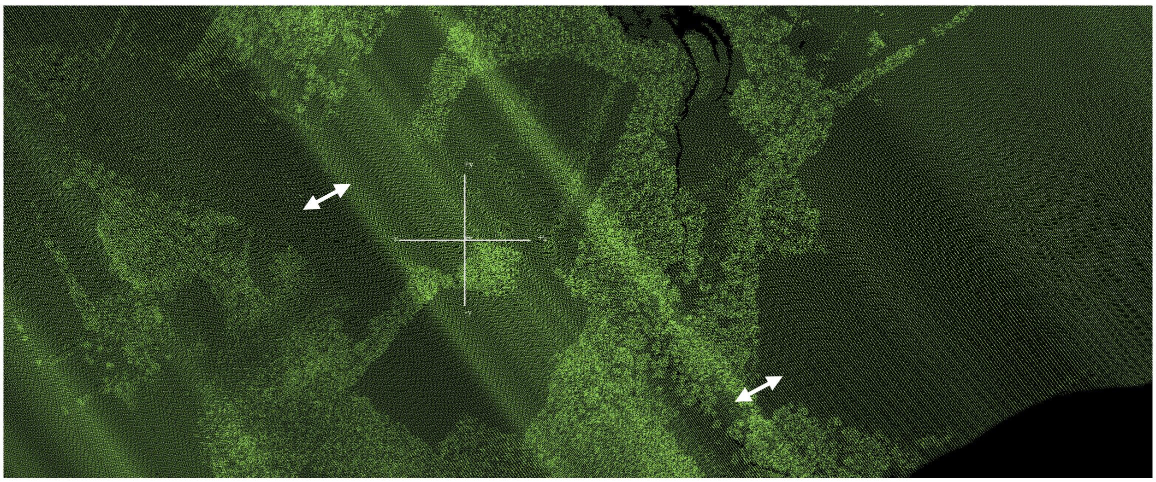
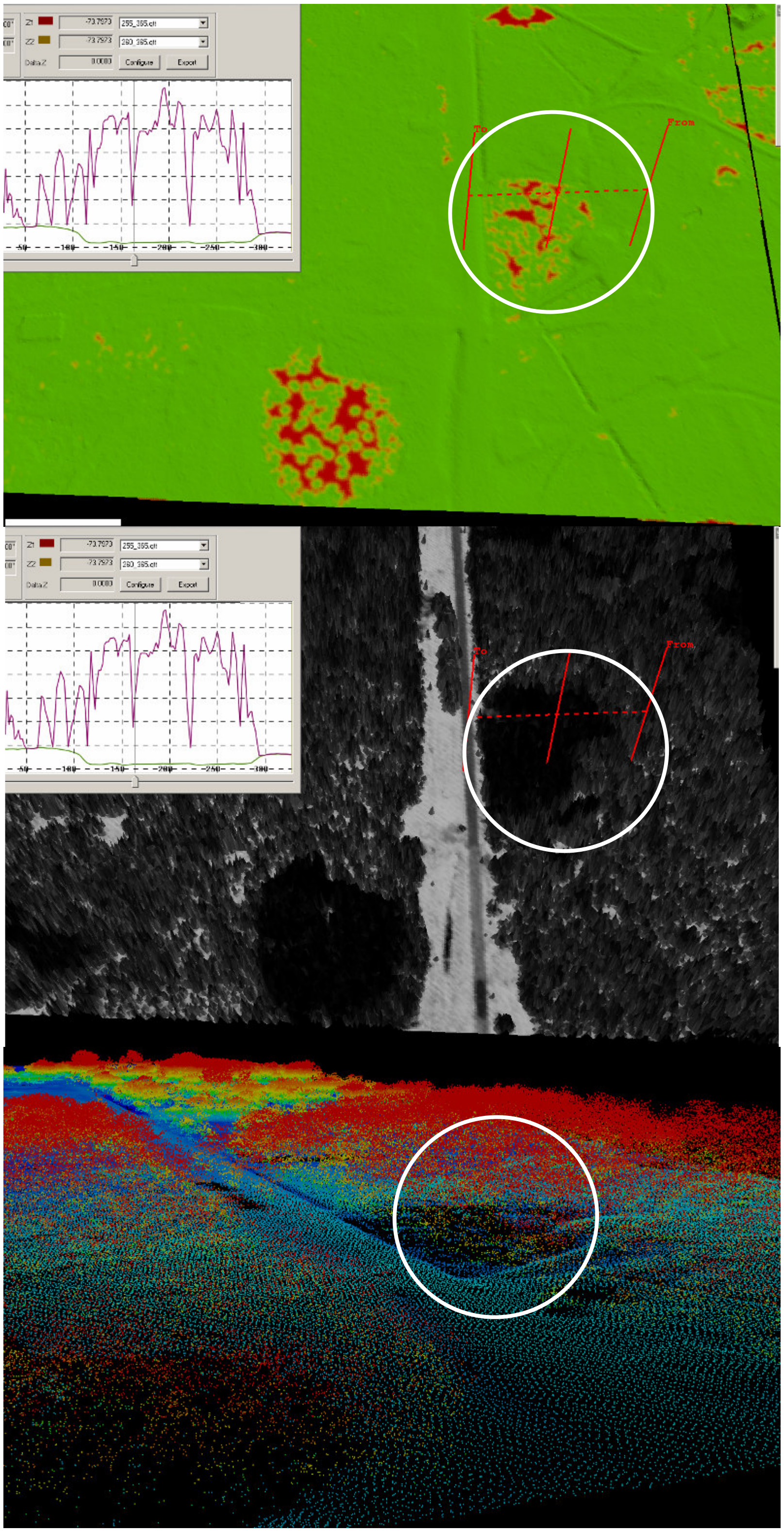


Figure** 24 **- Tile 487500_4663500: Lidar points. Note the variation in point spacing between scans inside a same flightline.

Swamp

We did find some isolated spots of sparse density of points in the bare earth model with no apparent change in the vegetation density at these locations; however the intensity image is characterized by a darker tone. After carefully inspecting the full point cloud, which really shows presence of Lidar points inside the vegetation but very few at ground level and based on the dark coloration of the intensity images we assumed that these are swamp areas where the Lidar is not reflected by the wet ground surface. Indeed, except at angles close to nadir, the Near Infrared Lidar beam is usually not reflected by water.



Bare-earth (class 2) model with density information (red = no points),

Surface model with intensity (all classes

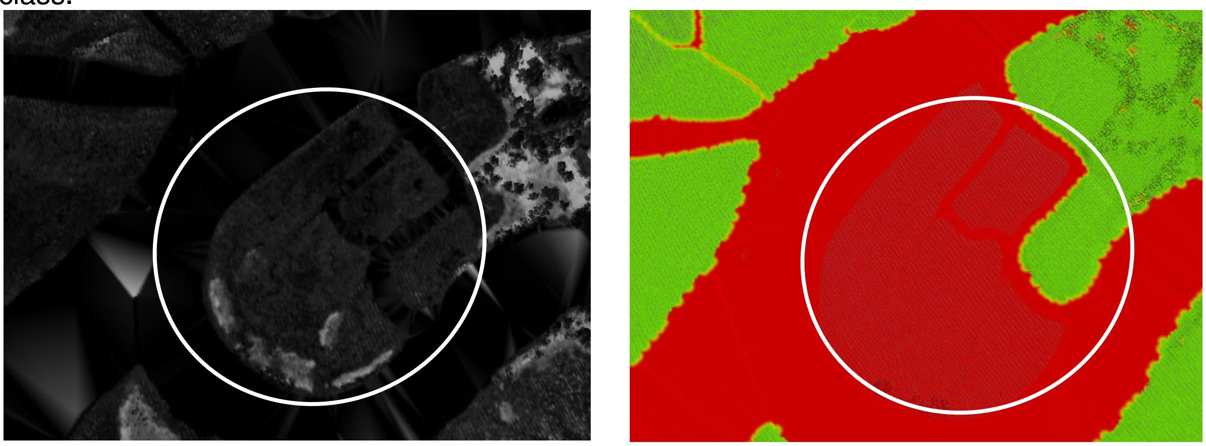
Full point cloud colored by elevation

Figure** 25 – **Poor LiDAR reflection in swamp area, the cross section and the full point cloud show the presence of vegetation but the Lidar do not seem to be reflected by the underlying surface.

Misclassification

In addition, users should be aware that the contract for acquisition and processing identified only two classes: Class “1” for unclassified and Class “2” for ground. However Terrapoint did classify water points in a separate category using breaklines developed with the intensity images. Globally the classification of water was satisfactory. We found few instances of ground points wrongly classified as water, mainly islands or sand bars (see example in *Figure* ***26***). In addition, some sections of water bodies remained in the ground class, most of the time they were portions of rivers looking like salt and pepper noise in the intensity image as illustrated in *Figure* ***27***.

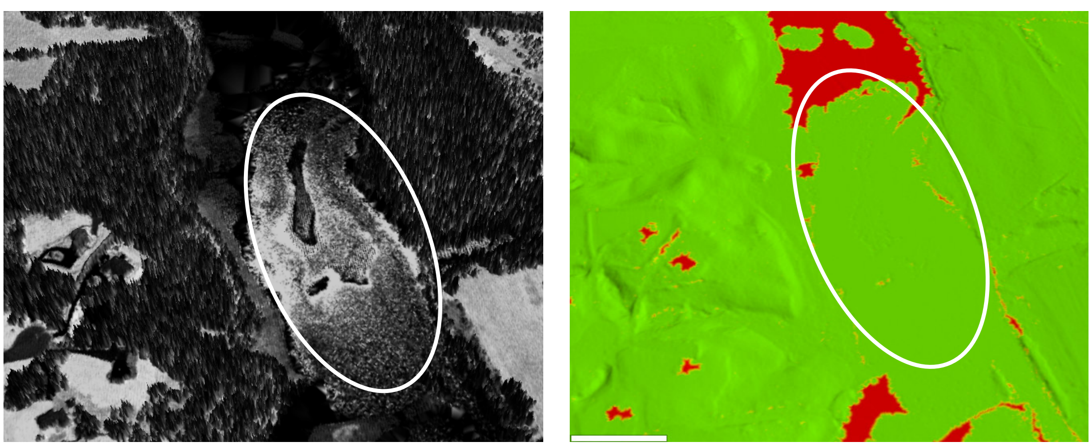
Once again, as the classification of water was not required in the scope of work, this is not something we consider as an issue, the end user should just be aware that further processing may be needed to completely remove the water points from the ground class.



Surface model with intensity (all classes)

Bare-earth (class 2) model with density information (red = no points), with full point cloud as overlay

Figure** 26 **– Islands classified as water (tile 250_350)

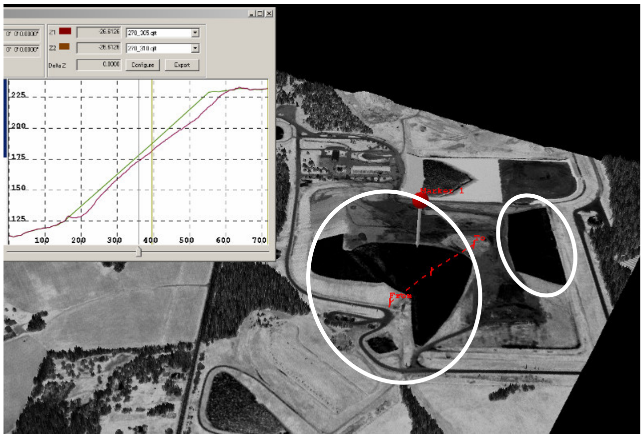


Surface model with intensity (all classes)

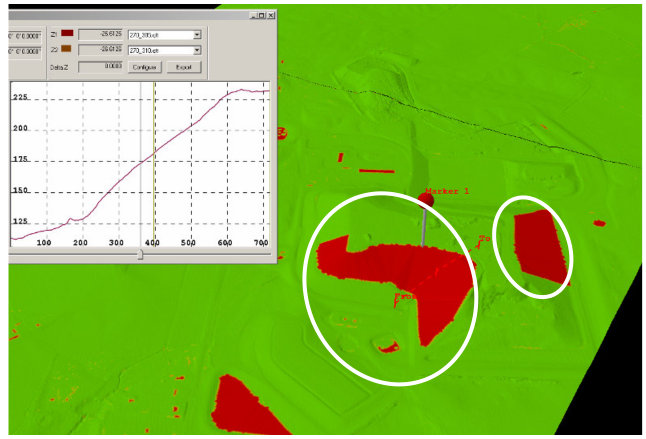
Bare-earth model with density information (red = no points), class 2

Figure** 27 **– Tile 295_350, river section with bright reflections remains in the ground class

Finally, one occurrence of misclassification of ground was encountered in the data (see *Figure **28***). Two large slope sections of this mine heap are removed from the ground class leaving gaps in the bare earth surface, however the summit of the hill is still there leaving the general surface profile fairly unaffected. Therefore, we do not consider this as a critical issue but users of this data in this area may need to reclassify to suit there intended need and use.



Surface model with intensity (all classes); green line in cross section



Bare-earth model with density information (red = no points), class 2; purple line in cross section

Figure** 28 **– Tile 270_315 misclassification of ground

In summary, the types of issues more frequently encountered are (in order of occurrence):

- Cornrows (mostly under 20cm)
- Inconsistencies in bridge processing (either removed, not removed or partially removed)

A few instances of the following issues were found:

- Possible building remains
- Localized sparse density possibly due to swamps
- Misclassification of water

To reiterate, these errors were minor. Dewberry believes that the overall quality of the data is excellent. It should be noted that these data may have unidentified errors at a local scale as we are not performing an exhaustive review at micro level. It also may require slight modifications to fit specific application needs. For example, transportation groups may need the bridge deck elevations whereas the hydrologist would prefer the bridges removed. However, this data will meet the needs of the general users of elevations data and is good for floodplain mapping.

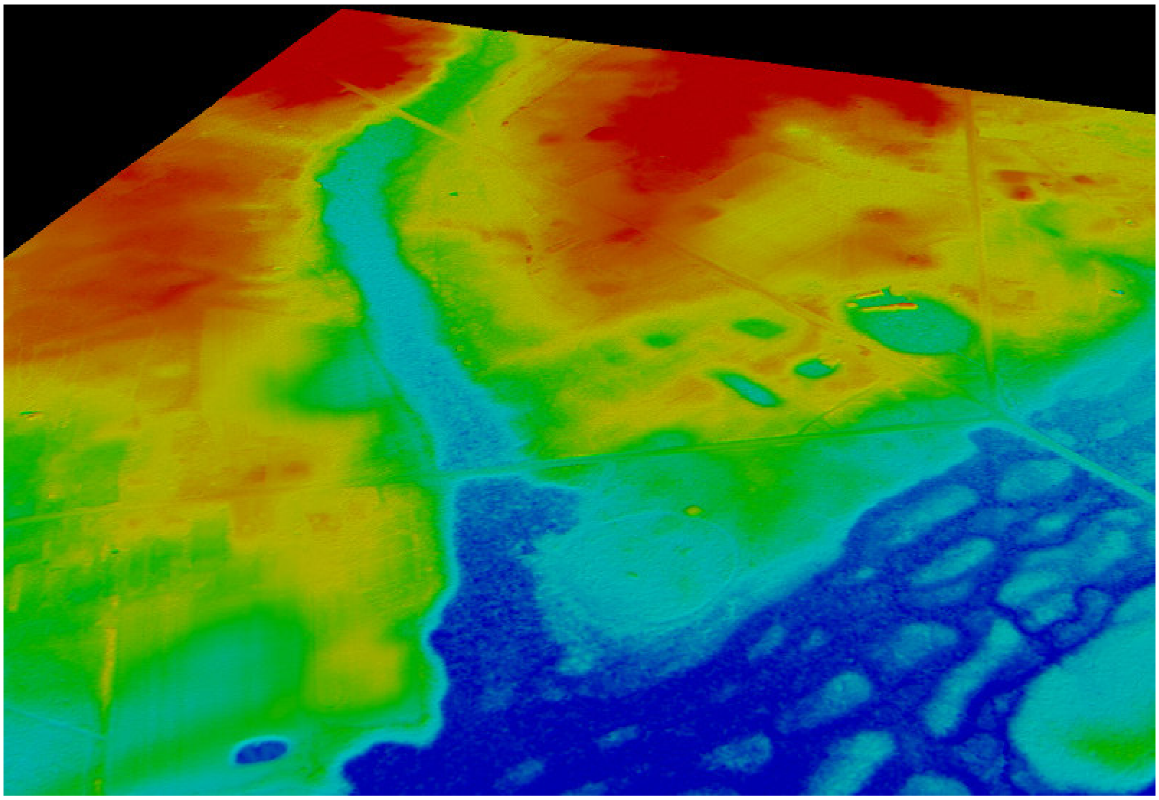


Figure** 29 **– Illustration of the cleanliness of the bare earth surface

4 Conclusion

Overall the data exhibit excellent detail and meet both the absolute and relative accuracy. Even though the accuracy testing does not conform to FEMA Appendix A, the testing methodology we employed complies with the NSSDA for test vertical accuracy. Additionally there were sufficient fundamental checkpoints coupled with the qualitative review which indicates that the RMSE of 0.304 ft is valid for this dataset and this data will meet the requirements for the use in hydrologic and hydraulic studies. The level of cleanliness for a bare-earth terrain is of the highest quality and no major anomalies were found. The figures highlighted above are a sample of the minor issues that were encountered and are not representative of the vast majority of the data, which is of excellent quality.

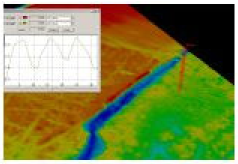
Appendix A Control points

20 randomly selected points from Terrapoint GPS survey and 12 NGS controls

pointNo	easting	northing	elevation	zLidar	DeltaZ	AbsDeltaZ
20	378899.684	283026.687	86.634	86.0623	-0.572	0.572
19	361503.678	301904.367	136.453	135.9993	-0.454	0.454
18	359351.205	304148.58	143.625	143.2535	-0.371	0.371
17	323147.025	295206.211	117.464	117.1507	-0.313	0.313
16	330720.617	276138.171	98.323	98.0165	-0.307	0.307
15	367890.101	295242.19	113.71	113.4729	-0.237	0.237
JU3228	331347.655	271178.839	94.235	94.0001	-0.235	0.235
14	358228.703	305311.84	143.917	143.6911	-0.226	0.226
13	319371.51	297203.839	116.604	116.453	-0.151	0.151
JU0671	308978.419	364134.879	33.373	33.222	-0.151	0.151
12	372103.921	288609.159	102.273	102.2123	-0.061	0.061
11	327883.489	283032.397	95.909	95.8562	-0.053	0.053
10	330767.961	274448.418	96.043	96.0003	-0.043	0.043
9	325207.318	290885.916	109.954	109.9447	-0.009	0.009
JU3229	331139.465	272444.853	98.966	99.0238	0.058	0.058
8	308924.577	326564.691	126.988	127.1378	0.150	0.150
JU0668	283057.212	365494.593	10.692	10.8431	0.151	0.151
AI4333	305998.983	359215.3	32.841	32.9978	0.157	0.157
7	315696.212	303806.6	128.687	129.0208	0.334	0.334
AI4363	271676.492	363707.99	4.836	5.1792	0.343	0.343
6	313472.581	308516.584	130.22	130.5863	0.366	0.366
5	321966.581	353742.79	66.772	67.2446	0.473	0.473
4	311834.383	333886.78	69.4	69.8773	0.477	0.477
3	309058.42	316945.748	149.222	149.7194	0.497	0.497
2	318799.213	342455.748	64.472	65.0119	0.540	0.540
AI4354	326714.989	295102.735	128.123	128.6665	0.544	0.544
1	307985.07	320611.074	148.28	148.8871	0.607	0.607
AI4334	281722.354	370637.614	21.801	22.4179	0.617	0.617
AI4361	316506.15	345515.669	75.334	75.9862	0.652	0.652
AI4357	316583.958	344230.475	73.264	73.9174	0.653	0.653
AI4340	316645.554	360245.391	44.039	44.6952	0.656	0.656
AI4356	288285.598	324976.393	83.396	84.058	0.662	0.662

Appendix B Qualitative issues contact sheets

Gloucester County, NJ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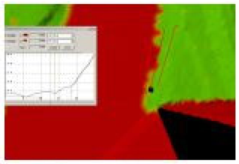
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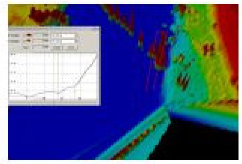
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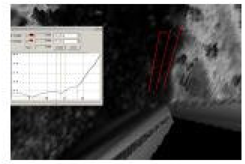
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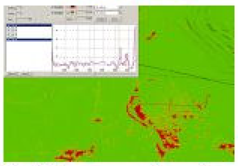
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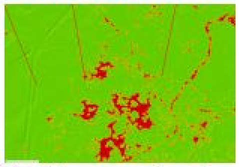
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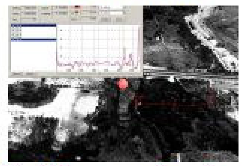
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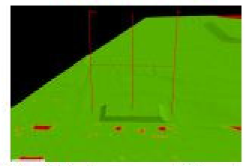
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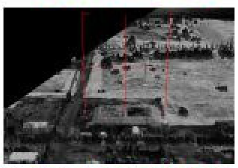
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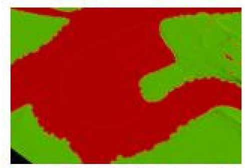
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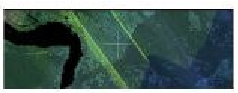
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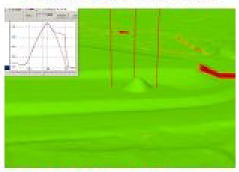
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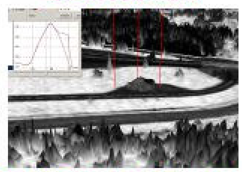
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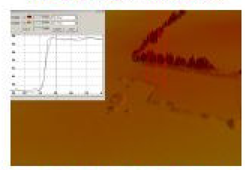
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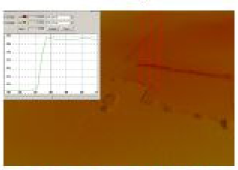
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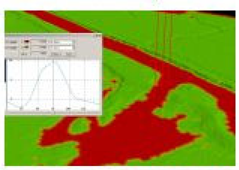
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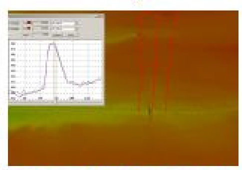
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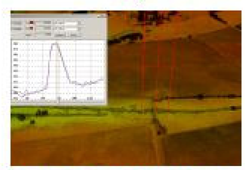
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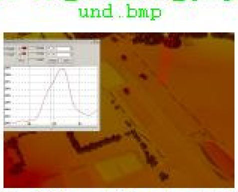
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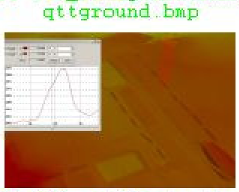
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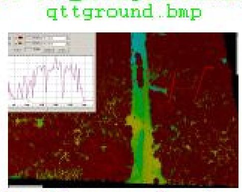
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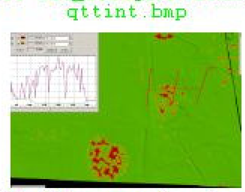
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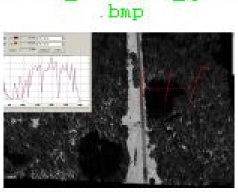
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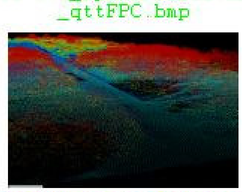
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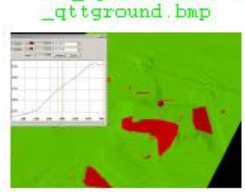
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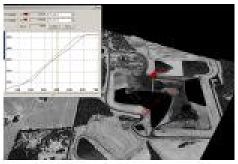
Gloucester County, NJ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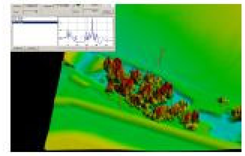
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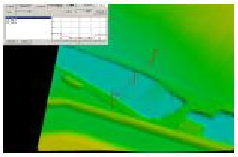
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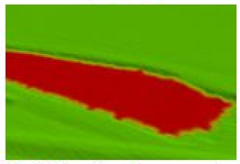
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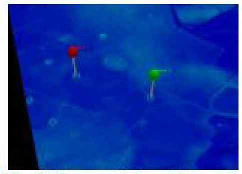
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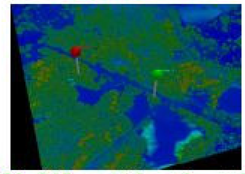
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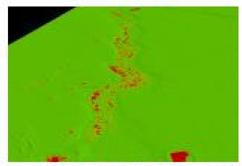
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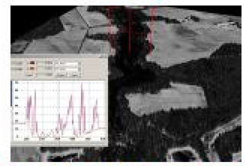
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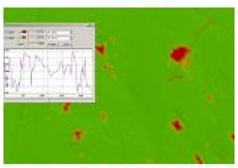
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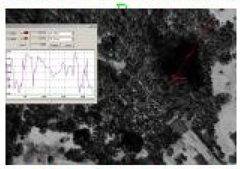
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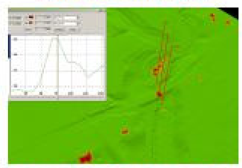
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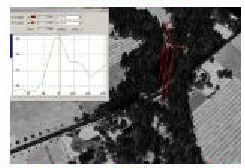
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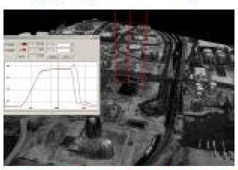
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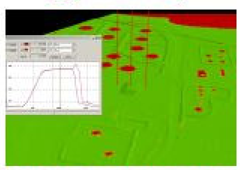
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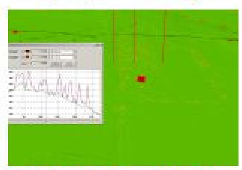
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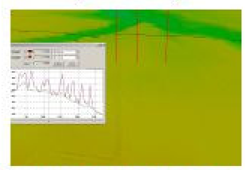
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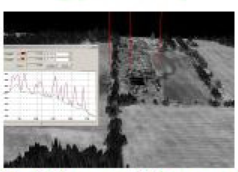
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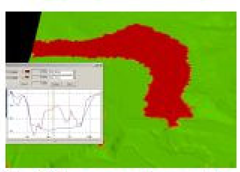
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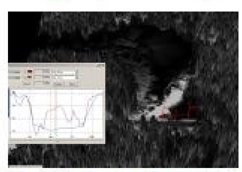
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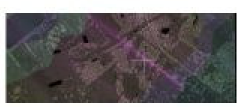
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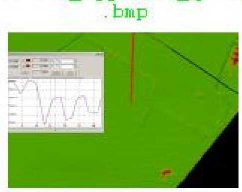
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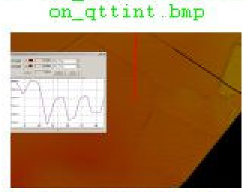
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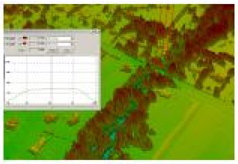
Gloucester County, NJ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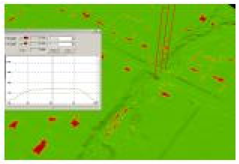
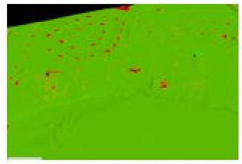
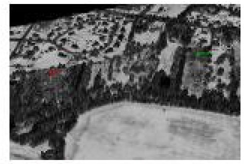
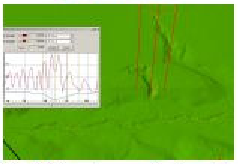
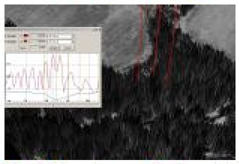
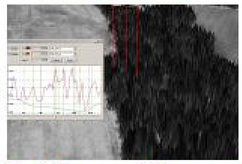

290-325_bridgeartifact_qttground.bmp

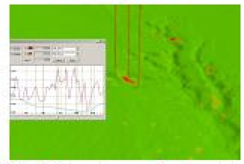

290-330_poorlidarpenetr_qttground.bmp

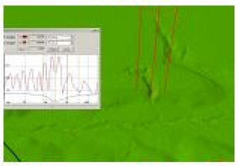

290-330_poorlidarpenetr_qttint.bmp

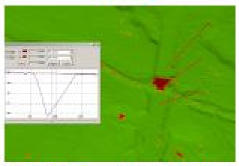

290-330_streamDef_qttground.bmp

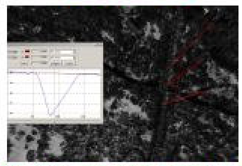

290-330_streamDef_qttint.bmp

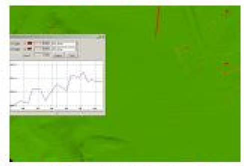

290-335_poorlidarpenetr_qttFPC.bmp

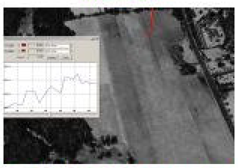

290-335_streamDef_qttground.bmp

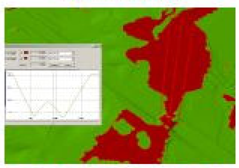

295-330_aggrclas_qttground.bmp

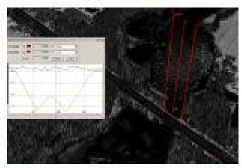

295-340_aggrremoval_qttground.bmp

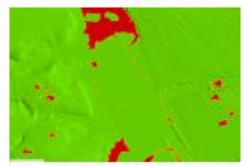

295-340_aggrremoval_qttint.bmp


295-340_cornrows_qttground.bmp

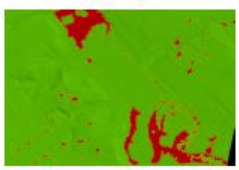

295-340_cornrows_qttint.bmp

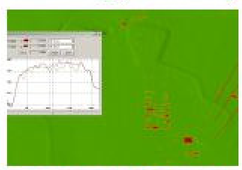

295-350_incompleteBridgeRemoval_qttground.bmp

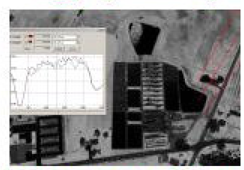

295-350_incompleteBridgeRemoval_qttint.bmp

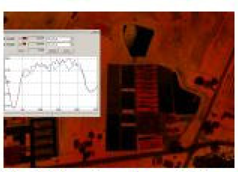

295-350_misclassification_qttground.bmp

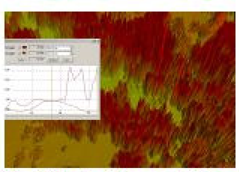

295-350_misclassification_qttint.bmp

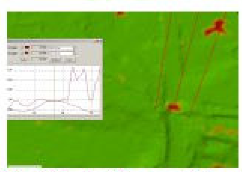

295-350_misclass-waterSHP_qttground.bmp

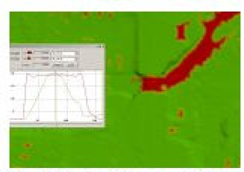

300-300_misclassificationWater1_qttground.bmp

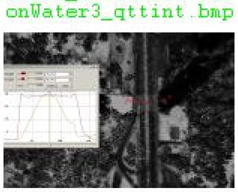

300-300_misclassificationWater2_qttint.bmp

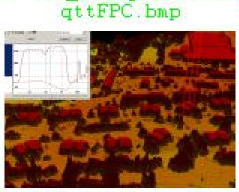

300-300_misclassificationWater3_qttint.bmp

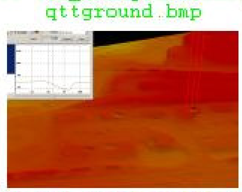

300-325_bridgeartifact_qttFPC.bmp


300-325_bridgeartifact_qttground.bmp


300-350_bridgeartifact_qttground.bmp

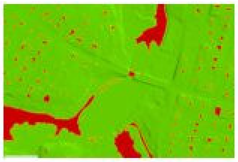

300-350_bridgeartifact_qttint.bmp


300-350_divot_qttFpc.bmp

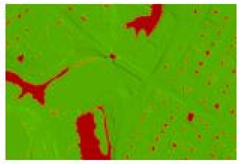

300-350_divot_qttGd.bmp


300-365_misclassification_qttFPC.bmp

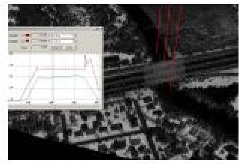
Gloucester County, NJ



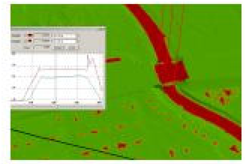
300-365_misclassification_qttground.bmp



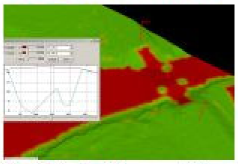
300-365_misclass-waterSHP_qttground.bmp



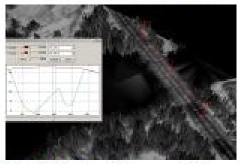
300-370_bridgeartifact1_qttint.bmp



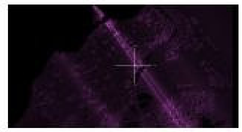
300-370_bridgeartifact2_qttground.bmp



300-370_bridgeartifact3_qttground.bmp

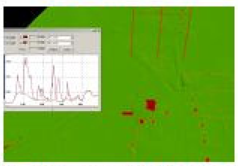


300-370_bridgeartifact4_qttint.bmp

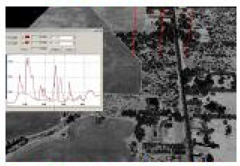


300-375_sensorAnomaly_FPC.bmp

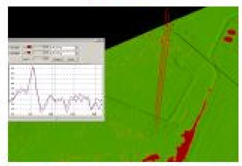
305-310_flightlineOverlap_FPC.bmp



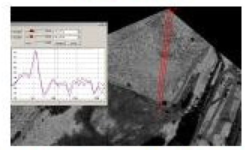
305-320_vegartifact_qttground.bmp



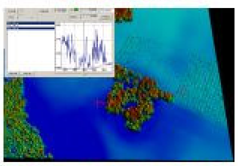
305-320_vegartifact_qttint.bmp



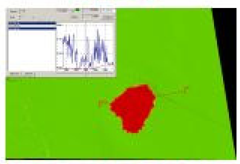
305-375_vegartifact_qttground.bmp



305-375_vegartifact_qttint.bmp



310-295_misclassification_qttFPC.bmp



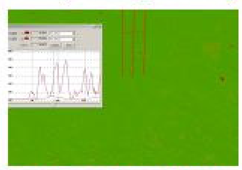
310-295_misclassification_qttground.bmp

310-295_misclassification-byreturn_FPC.bmp

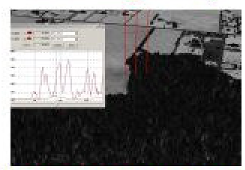
310-295_misclassification-class_FPC.bmp

310-295_misclassification-depth_FPC.bmp

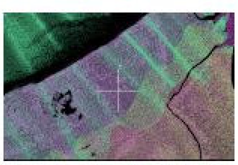
310-295_misclassification-int_FPC.bmp



310-295_poorlidarpenetr_qttground.bmp

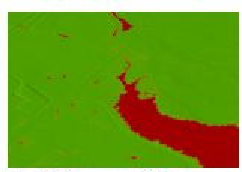


310-295_poorlidarpenetr_qttint.bmp



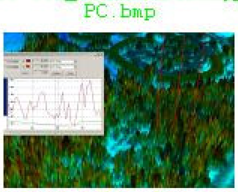
310-380_sensorAnomaly_FPC.bmp

315-290_sensorAnomaly_FPC.bmp

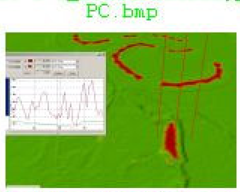


315-300_poorlidarpenetr_qttground.bmp

315-300_poorlidarpenetr_qttint.bmp

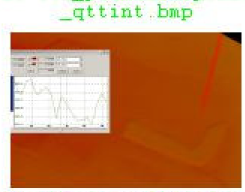


315-360_streamDef_qttFPC.bmp



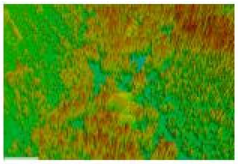
315-360_streamDef_qttground.bmp

315-370_sensorAnomaly_FPC.bmp

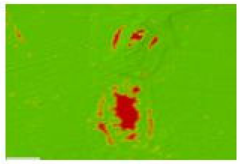


320-315_scannerissues_qttground.bmp

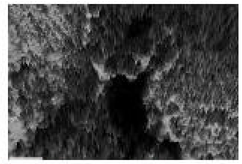
Gloucester County, NJ



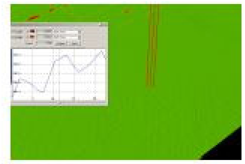
320-345_poorlidarpenetr_qttFPC.bmp



320-345_poorlidarpenetr_qttground.bmp

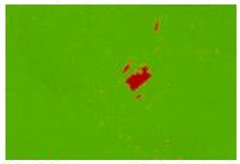


320-345_poorlidarpenetr_qttint.bmp

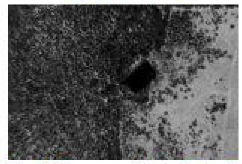


325-315_cornrows_qttground.bmp

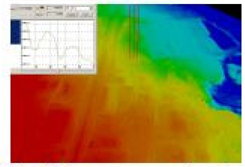
330-295_possibleDataHoliday_qttFPC.bmp



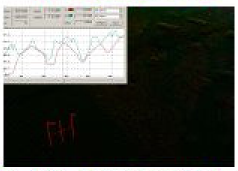
330-295_possibleDataHoliday_qttground.bmp



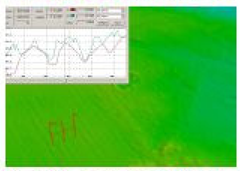
330-295_possibleDataHoliday_qttint.bmp



350-310_cornrowsNegl_qttGd.bmp



360-300_cornrowsNegl_qtcFpc.bmp



360-300_cornrowsNegl_qttGd.bmp

365-310_sensorAnomaly_FPC.bmp