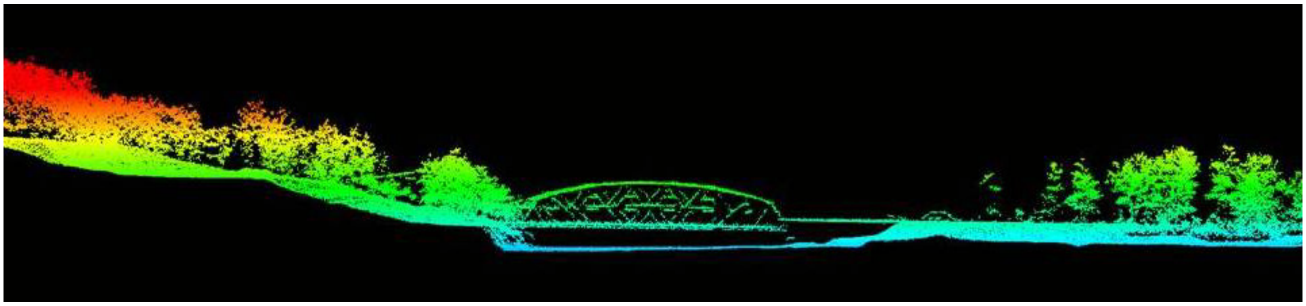

Matanuska-Susitna Borough LiDAR & Imagery Project Quality Assurance Report Point Mackenzie Block (V2)

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Contents

Study Area – Point Mackenzie Block

The study area for this report is the Point Mackenzie block, which includes 583 square miles covering the southern extent of the Susitna Valley. In the delivery blocks and tile map, it is shown in dark green (see Figure 1).

Basis for Evaluation

The Software used for the evaluation includes:

- ESRI ArcMap and ArcCatalog 10.0
- Applied Imagery Quick Terrain Modeler v7.1.5 64-bit
- Blue Marble Geographics, Global Mapper v13.1.2

Each block of LiDAR will be evaluated in the following ways:

- Check formatting and completeness of data delivery,
- Check completeness, clarity, and compliance of metadata,
- Assess the planimetric accuracy of the LiDAR data,
- Assess the vertical accuracy of the LiDAR data,
- Assess the LiDAR point cloud data of return density and classification accuracy,
- Assess the LiDAR bare-Earth and first-return surface data by mosaic and shaded relief analysis, identifying gaps, seams, anomalies, and hydro-flattening of data,
- Verify consistency of various derived products being provided by LiDAR contractor.

Itemized products to be evaluated include:

- Metadata
- Classified point cloud data in LAS format
- Bare-Earth surface (below canopy raster DEM)
- First-Return surface (top of canopy raster DSM)
- Intensity image composite
- Hydro-flattening breaklines (single and double line) and lake polygons
- Contours (elevation)
- Shaded relief mosaics
- Tile Index (full and quarter tile) and building feature classes (structures >400 square feet)

Format and Completeness of Data Delivery

Six separate data deliveries were required to correct all identified data anomalies. Each delivery provided data on an external computer disk organized by block and data type. The Point Mackenzie block deliveries included:

- Metadata – A single metadata file for each major product type including point clouds, raster bare-Earth DEM, raster first-return DSM, elevation contours, elevation contours in DXF.
- LiDAR DATA - LAS point cloud data for 269 quarter tiles covering 71 full tiles of data.
- Contours – DXF format contours for 260 quarter tiles covering 71 full tiles of data.
- Block Geodatabase which contained the following elements:
    - Bare-Earth DEM raster catalog,
    - Buildings feature dataset,
    - Contours feature dataset,
    - First-return DSM raster catalog,
    - Hydro features dataset including single and double breaklines and lake polygons,
    - Intensity Imagery raster catalog,
    - Tile index feature datasets including full and quarter tile,
    - Block boundary polygon.

The contents of the LiDAR point cloud files were verified to include the expected LiDAR classification layers. Then each layer was loaded into Quick Terrain Modeler (QTM) to verify coverage and extent of each classification layer. Each layer was captured to a computer graphic image in jpeg format for review. In some cases, the number of points within a classification layer needed to be separated into quarter block areas to keep within available memory (16 GB) to optimize RAM. In these cases up to four jpeg images were saved for the layer. Although this process was time consuming, it proved very useful in identifying omissions in coverage for particular classifications. By saving each layer in QTM, the number of points included in each classification layer was compiled to verify that the data was distributed appropriately between classification layers.

The contractor supplied GIS layers including block boundary, full and quarter tile indexes were displayed and evaluated to insure consistency with the original project coverage feature class (see Figure 2). The raster catalogs stored in the block geodatabase were combined into large scale raster mosaics and stored as geotiff products for evaluation purposes. Shaded relief images were produced from each of the surface elevation products to evaluate completeness of coverage, gaps, seams, or other data anomalies. The intensity image mosaic was also evaluated for completeness of coverage and quality of data.

Completeness, Clarity, and Compliance of Metadata

Each metadata file was examined for both content and clarity of the included metadata descriptions. Minor changes were requested when UAF spotted inaccuracies or omissions. In general, UAF found the metadata to be very good. To test for FGDC metadata format compliance, we used the USGS Metadata Parser (MP) program. Results of testing showed on the order of 70 to 71 errors per fundamental data type of which 34 were unrecognized, 35 were missing, and 2 were bad values. The MP program output was fairly consistent for each metadata file. These errors were reported to Aerometric and fixed and verified through subsequent testing. No metadata errors were reported with the revised metadata.

Planimetric Accuracy of the LiDAR Data

There were only two checkpoints for the developed classification in the Point Mackenzie block. The survey contractor, Lounsbury & Associates, identified and surveyed the corners of two small buildings in tile PM50NW as developed class checkpoints. The LiDAR intensity from the returns off the building roof did not provide enough contrast to the ground to be accurately identified. Viewing the point cloud data, the building roof could be easily identified. A marker (push pin) was created at each checkpoint coordinate using Quick Terrain Modeler (QTM) and several views were captured to show the alignment of the point with the returns from the roof. Both points showed good agreement with the LiDAR data. A PowerPoint file was compiled with a variety of screen shots to document this analysis along with information provided by the survey contractor for each checkpoint (see Figure 3-8).

Vertical Accuracy of the LiDAR Data

After the first version of this report was published, it was decided that a more comprehensive series of check points should be used for the vertical accuracy assessment. As a result, this section includes significant changes when compared to the first version. There were one hundred thirty four checkpoints within the Point Mackenzie block. These included one hundred and nine barren ground, five developed, six forested, three shrub, and eleven wetlands points in each land cover category. Using ArcMap, a Bare-Earth DEM mosaic was produced and elevation values for all checkpoints were extracted from the DEM. This was compiled into a spreadsheet and organized by land cover classification on separate worksheets (see Figure 9). A vertical accuracy assessment was done for each land cover classification and compared to accuracy requirements included in the LiDAR contract. UAF also looked at the combined class statistics which are included below. A root mean squared error at 95% confidence is used for barren ground, and a 95 percentile was used for all other land cover categories according to USGS methods. The contractual target vertical accuracies are listed to the right of each accuracy measurement. The accuracy measurement is colored green if it passed or red if it failed to meet the requirement. For Point Mackenzie block, all classes separately and combined were accurate enough to meet the target vertical accuracy requirements. **The Point Mackenzie block is very accurate data easily meeting the target vertical accuracy specifications.**

Barren Ground			**Target**
Statistical Summary:	**Feet**	**Meter**	**Accuracy**
Count = 109 pts			
Min =	-0.632	-0.193	
Max =	0.113	0.034	
Mean =	-0.318	-0.097	
RMSE =	0.342	0.104	
RMSE*1.96 (95%) =	0.670	0.204	< 0.245 m
Stddev =	0.126	0.039	

Table 1, Barren Ground Accuracy Assessment Summary

Developed			**Target**
Statistical Summary:	**Feet**	**Meter**	**Accuracy**
Count = 5 pts			
Min =	-0.293	-0.089	
Max =	0.011	0.003	
Mean =	-0.168	-0.051	
RMSE =	0.197	0.060	
95 Percentile =	0.281	0.086	< 0.363 m
Stddev =	0.102	0.031	

Table 2, Developed Land Accuracy Assessment Summary

Forested			**Target**
Statistical Summary:	**Feet**	**Meter**	**Accuracy**
Count = 6 pts			
Min =	-0.142	-0.043	
Max =	0.219	0.067	
Mean =	0.071	0.022	
RMSE =	0.158	0.048	
95 PERCENTILE =	0.213	0.065	< 0.363 m
Stddev =	0.141	0.043	

Table 3, Forested Land Accuracy Assessment Summary

Shrub			Target
Statistical Summary:	**Feet**	**Meter**	**Accuracy**
Count = 3 pts			
Min =	-0.212	-0.065	
Max =	-0.046	-0.014	
Mean =	-0.103	-0.031	
RMSE =	0.129	0.039	
95 PERCENTILE =	0.196	0.060	< 0.363 m
Stddev =	0.078	0.024	

Table 4, Shrub Accuracy Assessment Summary

Wetlands			Target
Statistical Summary:	**Feet**	**Meter**	**Accuracy**
Count = 11 pts			
Min =	-0.092	-0.028	
Max =	1.831	0.558	
Mean =	0.381	0.116	
RMSE =	0.619	0.189	
95 Percentile =	1.158	0.353	> 0.363 m
Stddev =	0.488	0.149	

Table 5, Wetlands Accuracy Assessment Summary

Combined Classes			Target
Statistical Summary:	**Feet**	**Meter**	**Accuracy**
Count = 134 pts			
Min =	-0.632	-0.193	
Max =	1.831	0.558	
Mean =	-0.233	-0.071	
RMSE =	0.360	0.110	
95 Percentile =	0.503	0.153	< 0.363 m
Stddev =	0.275	0.084	

Table 6, Combined Classes Accuracy Assessment Summary

LiDAR Point Cloud First-Return Density and Classification Accuracy

Point Density was determined using LAS tools provided by Aerometric. The application provides an ability to count point density creating ESRI ASCII GRID files for each tile. Global Mapper was used to read and display all of these grid files for the block (see Figure 10). We had to limit the point density per cell to a maximum of 10 points clamping values greater to that value so that the color map would show sufficient color variation at the low end. Point density is displayed using a color map from blue (low) to red (high). The grid spacing used for the evaluation was 4 feet per pixel, 2*NPS of 0.6 meter as specified in the contract. The First-Return of all valid classes (2-6, 8-11, and 13-14), excluding withheld bit data classes (1 and 7). At least 90% of the cells should contain at least one LiDAR point. Regions of no return are shown in dark blue which only occurs outside of the block boundary. For the Point Mackenzie block, first-return density was confirmed to exceed 90% for all interior cells of the combined point cloud data.

Each classification layer in the LAS point cloud was loaded into Quick Terrain Modeler to verify extent and completeness of coverage, number of points per class, and accuracy of classification. Given the number of points included in some of the larger classifications, it is necessary to split the block into quarters (i.e. SW, SE, NW, NE). Some classes such as the low, medium, and high vegetation are texture mapped using a solid color such as light, medium, and dark green respectively. Otherwise, the data is displayed with a color ramp for the elevation range of the block. In this way, the four blocks can be assembled into complete block coverage with a consistent color map for the height variation. During the assessments, UAF found and reported inconsistencies where data were omitted or regions where data were included over water that should have been excluded. **The LiDAR point cloud data was improved significantly by Aerometric including splitting class 1 into a new class 13 and refining the low vegetation class.**

The classifications included in the LAS point cloud data are listed below in order of class with point count totals per class:

Class # - Class Description	Point Count	Reference
Class 1 – Unclassified Data (marked as withheld)	431,683,318	Figure 11
Class 2 – Ground	1,397,508,138	Figure 12
Class 3 – Low Vegetation	1,395,986,038	Figure 13
Class 4 – Medium Vegetation	166,916,038	Figure 14
Class 5 – High Vegetation	963,545,923	Figure 15
Class 6 – Buildings	1,187,390	Figure 16
Class 7 – Error Points (Noise)	44,841,021	Figure 17
Class 8 – Ground Model Key Points	90,318,776	Figure 18
Class 9 – Water	205,746,217	Figure 19
Class 10 – Breakline Proximity	1,404,272	Figure 20
Class 11 – Power Transmission Lines	317,500	Figure 21
Class 13 – Ground Clutter (within foot of surface)	1,545,042,396	Figure 22
Class 14 – Bridge Decks	541	Figure 23

Table 7, LiDAR Point Cloud Classes Summary Table

Cross validation analysis was performed between each of the class layers and other source data. Quick Terrain Modeler was used initially to produce height profiles of multiple layers from a point cloud. This capability was used to verify issues with the low vegetation layer extending across rivers and streams (see Figure 24). This shows the presence of LiDAR returns from each vegetation layer, low, medium and high. Another example, a canopy height can be estimated by subtracting the bare-Earth surface DEM from the first-return DSM (see Figure 25). This product could then be colorized based on a number of classifications to match each of the three vegetation layers (see Figure 26), i.e. 1-6 feet for low vegetation (light green), 6-15 feet for medium vegetation (medium green), and greater than 15 feet for high vegetation (dark green). Barren ground could have height differences from -1 to 1 foot. Other classes could draw attention to outlier heights such as values less than one (red) and values greater than 100 feet (violet). The individual layer product could be compared to this classified product, keeping in mind that in high vegetation, there may also be returns for medium vegetation, low vegetation, or even ground. Other layers such as water can be compared to the lakes, single and double breakline files provided by the contractor. Similarly, the buildings layer can be compared to both the buildings feature class and to the ortho imagery for the block.

LiDAR Gridded Products

There are three gridded products being delivered for each block. These include the bare-Earth DEM, the first-return DSM, and the LiDAR intensity image. Each of these raster data sets are being delivered as raster catalogs within the block geodatabase. For each type of data, a mosaic product was produced from each raster catalog (see Figure 27, 28, and 29). Then for the two surface products, a shaded relief image is produced with consistent elevation and angle of the sun to provide consistency (see Figure 30 and 31). These derived images are then evaluated visually by zooming up to a tile per screen and panning through the mosaic, left to right, and top to bottom. Any height discontinuity between swaths or tiles would show up as a darker linear feature with a common orientation (to detect seams). Any regions of missing data will show up as dark edge to white interior of the missing data (to detect voids). Surface texture gives clues to intermittent vegetation (to detect corn rows) which may or may not be valid depending on the surface type. If anomalies are detected, then comparison to tile edges or swath edges can be made by bringing in other GIS layers for comparison.

For the Point Mackenzie block, seams were detected in two tiles of the bare-Earth DEM, and lots of seams were present in the LiDAR intensity image mosaic. These problems were reported and later fixed in subsequent deliveries. Careful examination of the shaded relief image produced from the first-return showed interpolation anomalies over water that helped determine that the first-return DSM was not a true first return from the LiDAR. We requested the contractor to not use interpolation to fill holes over water and to produce a true first-return product from the LiDAR as a gridded evaluation of all non-withheld returns. Several redeliveries were needed to get the right results, such that a canopy height assessment could be calculated from the two gridded products and classified to vegetation height. The resulting classification needed to hold up at full resolution and compare favorably with the point cloud layers assessment.

The bare-Earth gridded DEM is hydro flattened according to contract specifications. To verify this and to insure consistent heights were retained over water features, GIS analysis was performed on the contractor supplied data. The hydro breaklines include lake polygons, and either single for small streams and double breaklines for larger streams are included (see Figure 32). First the lake polygons were used to clip the bare-Earth DEM elevations for lake heights. This was compared to the water heights layer from the point cloud data. By loading consistent color map, contract stretch method to linear and minimum/maximum height range into both ArcMap and Quick Terrain Modeler the resulting images can be compared for consistency. Streams greater than 100 feet nominal width and a list of nineteen streams supplied by the Matanuska-Susitna Borough (appendix 4A) should be delineated with double breaklines. These polyline structures are combined to create polygons for each stream or river contained in the block. The hydro breaklines were delivered as polylines, so additional editing was needed to separate major rivers and streams from each other as individual polygons. Then the bare-Earth DEM was clipped for each river, stream, or slough, colorized and compared to the point cloud layer for that specific water body. A similar approach is taken within Quick Terrain Modeler for the specific water body so that the heights of the flattened water can be compared to the original LiDAR returns over that water surface. In this way, all streams could be checked for flow direction, magnitude, and consistency to the original LiDAR returns over that water body. For the Point Mackenzie block, we analyzed lakes (see Figure 33) and streams including the Susitna River (see Figure 34), the Little Susitna River (See Figure 35), Little Fish Creek (see Figure 36), and Upper Fish Creek (see Figure 37), from which all hydro flattening looked good.

LiDAR Derived Products

Derived products include a variety of GIS layers including tile index, hydro breaklines of lakes and streams, building feature class and topographic contours. These are delivered as elements in a block geodatabase. The tile index feature class provides both full tile and quarter tile. Aerometric was asked to include a block boundary feature class for each block that defines the geographic extent of each block. This should align where blocks join each other and provide a 100 meter buffer where no adjacent blocks are present. The boundary file is first checked against the original block definition provided with the LiDAR contract by Matanuska-Susitna Borough. The desired coverage and added buffer distance has been verified.

The building feature class is verified by performing a detailed examination of the quarter tile with the most buildings. Visual verification is performed on each building to the ortho imagery or canopy height difference classification (see Figure 38 and 39) looking for buildings that were missed or classified building that were incorrect identified (false positives). Buidings of greater than 400 square feet should be included at 97% success rate. Separate feature classes are created for new buildings and buildings that were misclassified (false positives). Areas are calculated for new buildings and the accuracy for this quarter tile is checked and reported. Given the limited time, the quarter tile with the highest building density was checked for accuracy and reported as representative of the block. For the Point Mackenzie block, there were 17 new buildings added of which 10 were greater than 400 square feet. Of the original building classification, it looked like two were incorrectly classified (false positive) as building when it was a forested location, with one building over 400 square feet. If you consider only buildings over 400 square feet in area, then 11 errors were made of 486 buildings at a 2.26% error rate or 97.74% success rate which meets the required accuracy of 97%. A final building figure (see Figure 40) is produced with accurate buildings (light blue), Incorrect buildings (red), and new buildings (dark blue) to document results from the analysis. Separate feature classes for each of the three categories are also produced for further analysis and provided to the Matanuska-Susitna Borough GIS staff.

The elevation contours are supplied in two different formats, one as a polyline feature for each tile in the block geodatabase, and the other is in AutoCAD format DXF format. A set of four contour tiles are displayed as an overlay to the bare-Earth DEM and visually examined for consistency. Due to limited time, only a statistical sample of the data is evaluated. The Matanuska-Susitna Borough GIS staff suggested that UAF pick contour tiles with the steepest slope as candidates for testing. A slope map in degrees was first generated from the bare-Earth DEM mosaic and colorized with a blue to red color map with steepest terrain in red (see Figure 41). From this map, tiles with the steepest terrain were selected. Each of four tiles were displayed and compared with the bare-Earth DEM elevations for that tile. The tighter the space between contours, the steeper the slope should be in the corresponding DEM. This can be visually compared to how rapid the change is color of the underlying DEM. Next, UAF created topologies for each of the selected tiles, testing for contour topology errors based on four selected rules. These rules include: there are no intersects, there are no overlaps, there are no dangles (except at tile edges), and must be single part. Each contour tile was then evaluated to these topology rules and errors were documented and reported to Aerometric. For Point Mackenzie block, three of four tiles tested showed topology errors that needed to be fixed. Using the topology edit tool, zooms of each error was captured in a graphic file and sent to Aerometric to be fixed. We requested that Aerometric test all tiles using the same methodology, not just the ones we reported. Upon redelivery of the data, we doubled the number of tiles tested to verify that everything was good (see Figure 42 and 43).

Quick Terrain Modeler has an ability to drape the AutoCAD contour files in DXF format over a corresponding DEM and visualize it in 3D. This capability was used to spot check the DXF files for problems (see Figure 44). The Point Mackenzie contour products were spot checked for completeness and accuracy.

Point Mackenzie Block Results and Recommendations

After significant effort testing, documenting data quality issues, consulting with Aerometric and the Matanuska-Susitna Borough GIS staff, and testing eight redeliveries. UAF is confident that the Point Mackenzie block is of acceptable quality. The spatial extent, coverage provided, horizontal and vertical accuracy, completeness and consistency of products makes this block the first of which we recommend acceptance. Aerometric has worked hard to address all of the identified quality issues to date. UAF has thoroughly documented the results of its assessments, including a complete record of all quality issues to date and what the solution was for each case. There were a few issues that the Matanuska-Susitna Borough staff accepted without modification. These include:

1) The spatial dimensions of both the LiDAR intensity and First Return DSM showed non-square pixels by a very small round off error. Aerometric assured us that the data was created with identical pixel dimensions.

Upon completion of writing this report and reviewing the results of our assessments, UAF recommends that the Point Mackenzie block be accepted. We are very pleased that the quality of data for this block. Aerometric is applying lessons learned from each reported data quality issue to subsequent block deliveries.

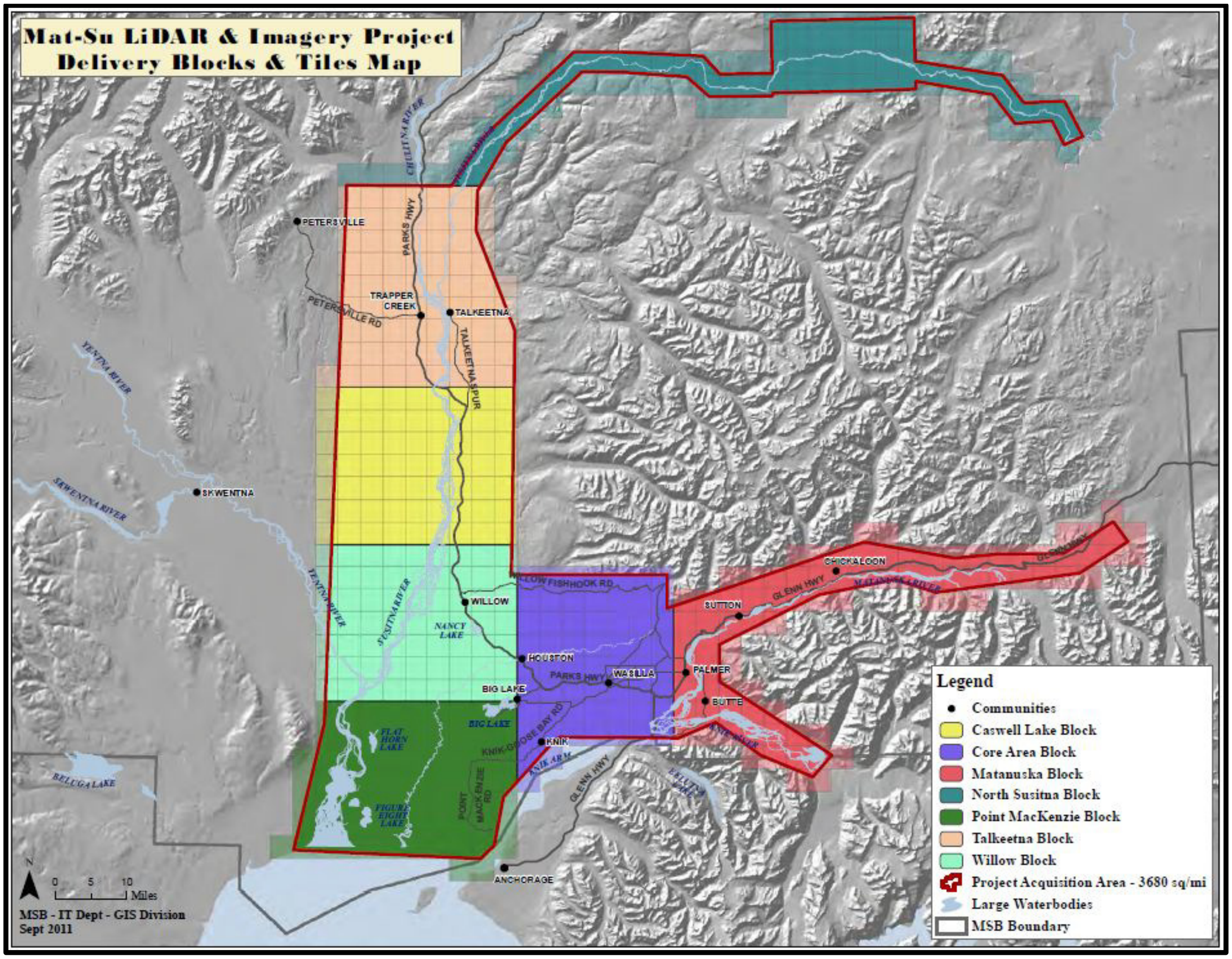


Figure 1, Mat-Su LiDAR & Imagery Project Delivery Blocks & Tiles Map

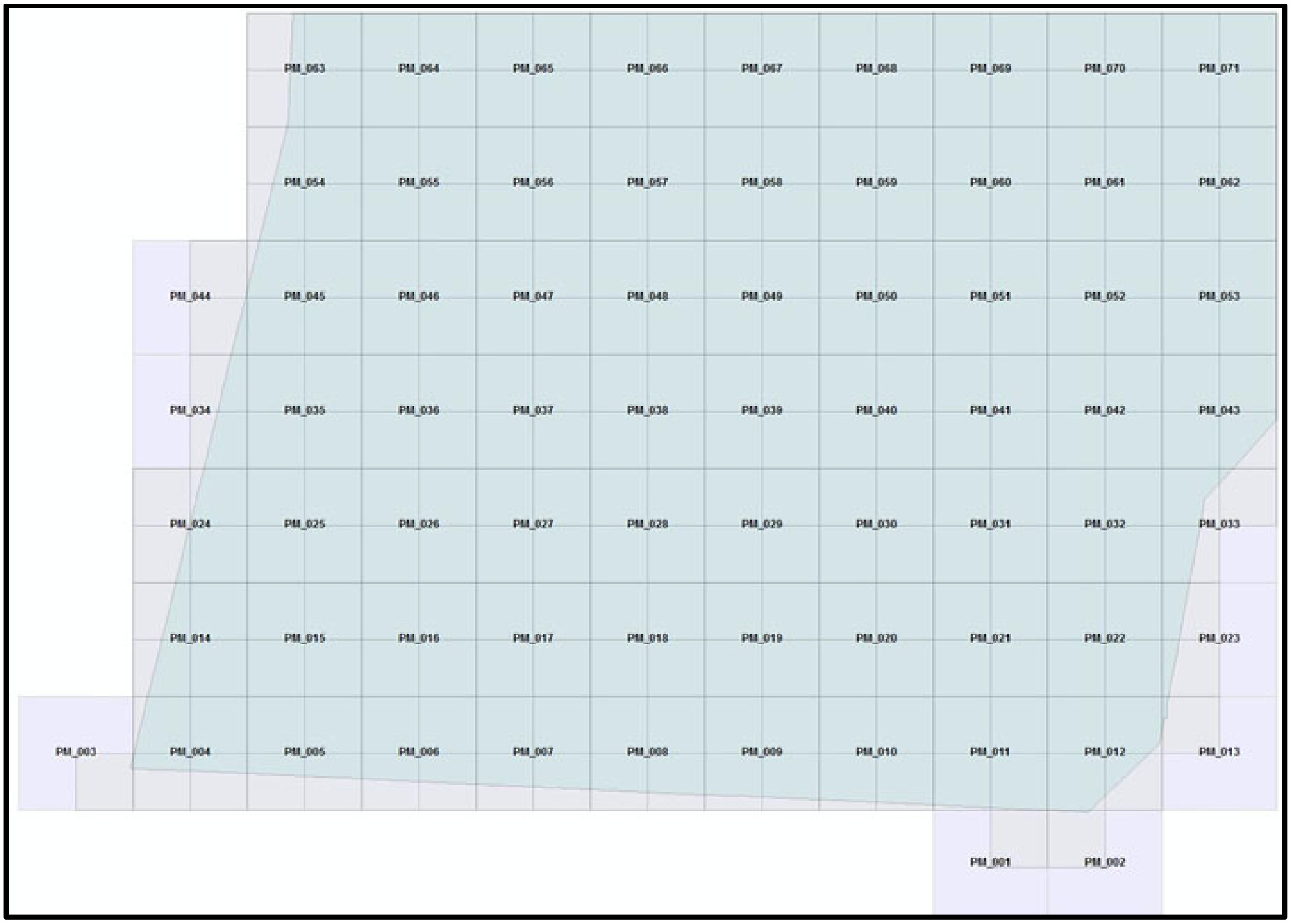


Figure 2, Contractor Supplied GIS Layers. Full tile (violet), quarter tile (tan), and block boundary (blue).

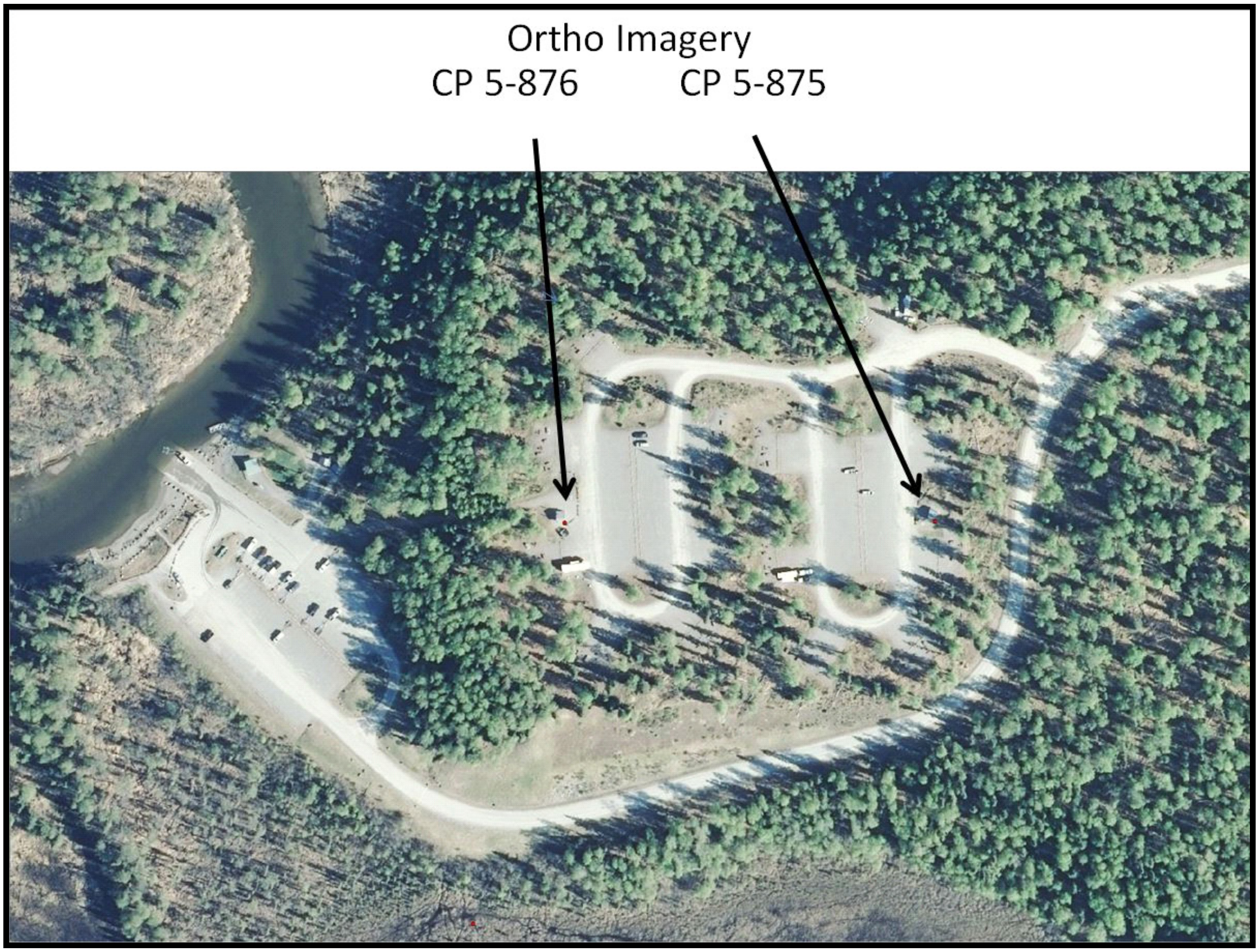


Figure 3, Ortho imagery with arrows pointing out two checkpoint locations in imagery.

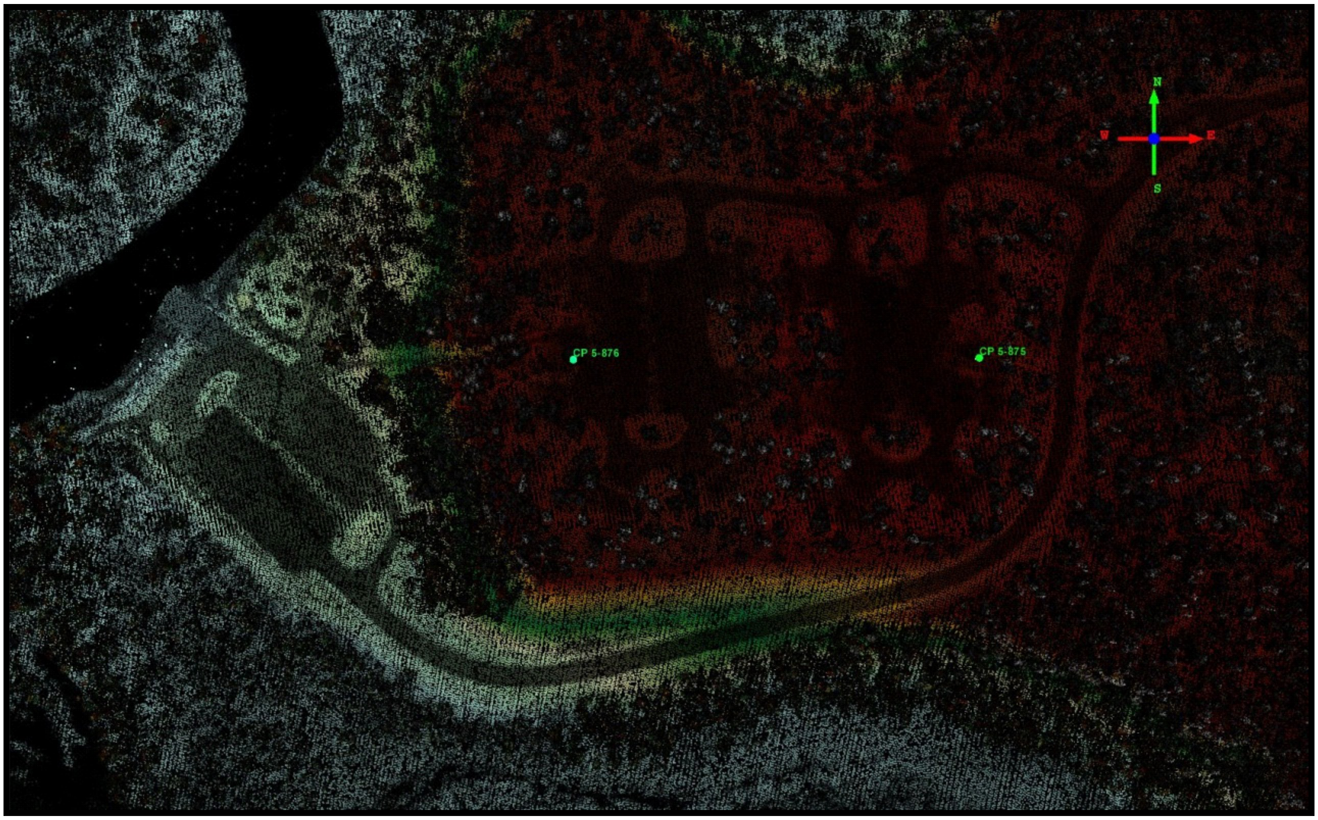


Figure 4, LiDAR Point Cloud Display of Bare Earth and intensity with checkpoints marked.

CP 5-875
Contractor Pictures

Check Point: 5-875
Latitude: 61 26 15.182543 N
Longitude: 150 10 05.628330 W
SPC-East: 1610967.4811
SPC-North: 2717395.3558
Ortho_HT_FT: 99.62
HZ_ACC_FT: 0.01
VT_ACC_FT: 0.02

Figure 5, Checkpoint survey contractor pictures of CP 5-875 at corner of outhouse.

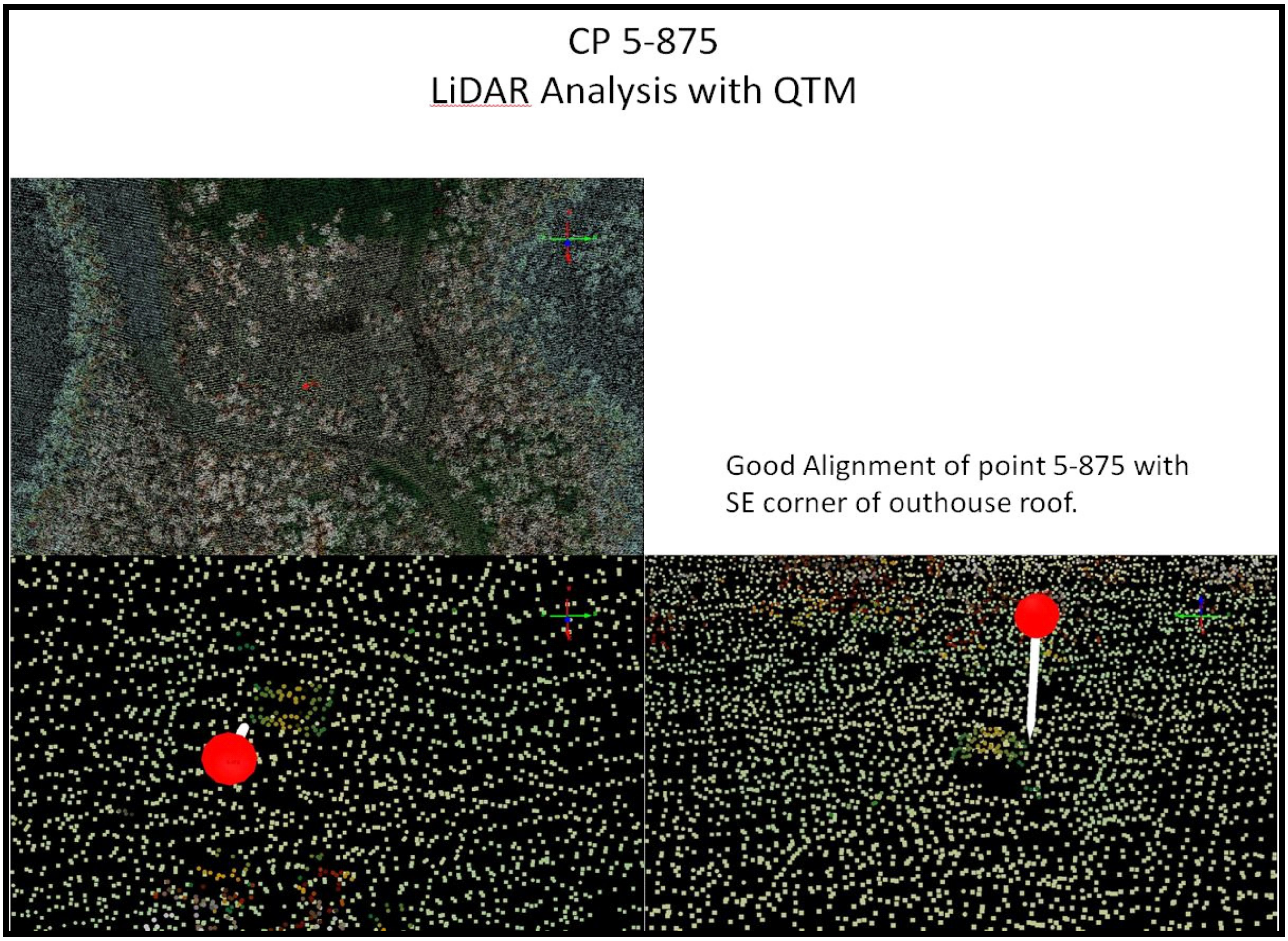


Figure 6, LiDAR point cloud assessment with QTM marking checkpoint location.

CP 5-876
Contractor Pictures

Check Point: 5-875
Latitude: 61 26 15.148276 N
Longitude: 150 10 16.365351 W
SPC-East: 1610445.3858 E
SPC-North: 2717393.1450 N
Ortho_HT_FT: 103.06
HZ_ACC_FT: 0.01
VT_ACC_FT: 0.02




Figure 7, Checkpoint Survey contractor pictures of CP 5-876 at corner of outhouse.

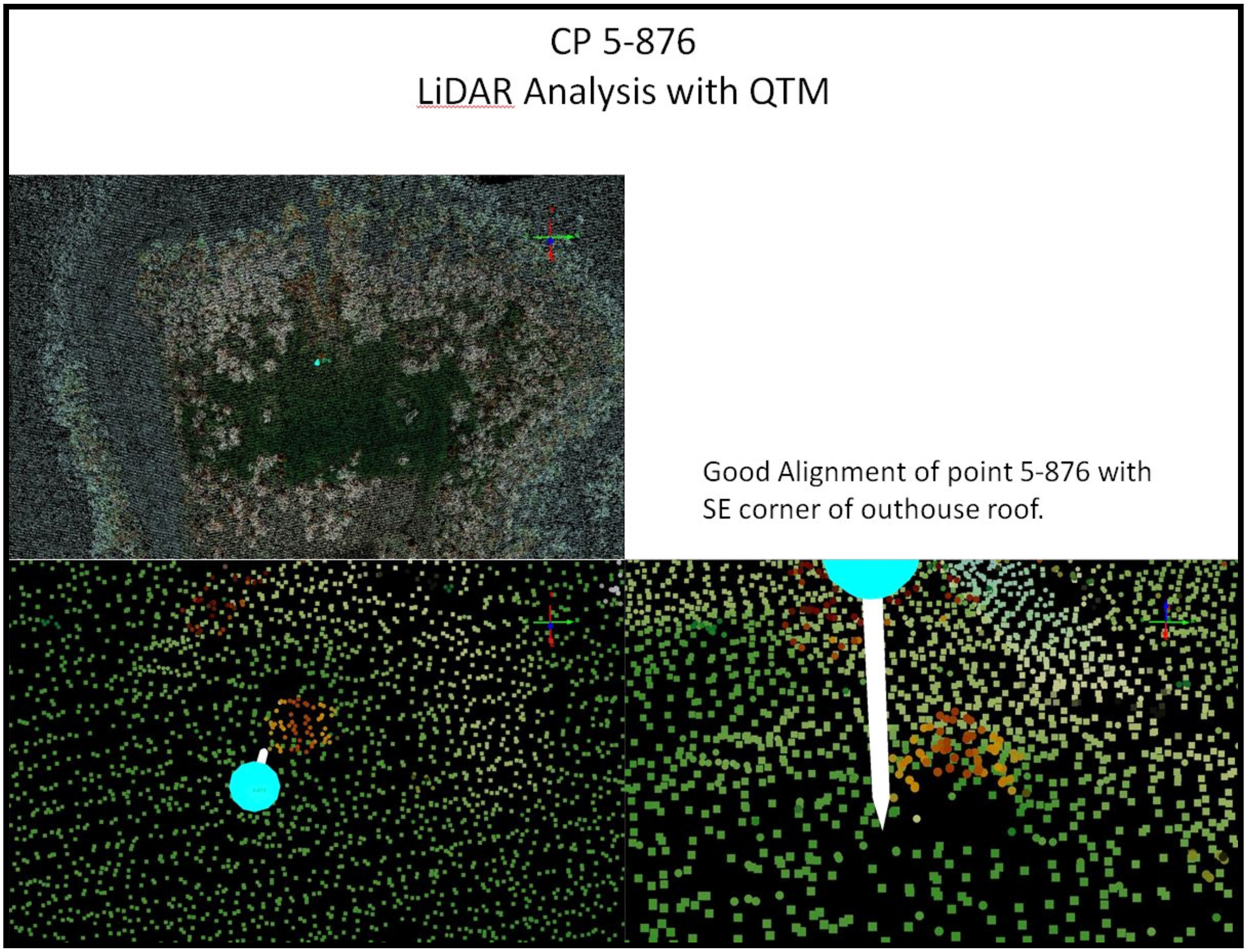
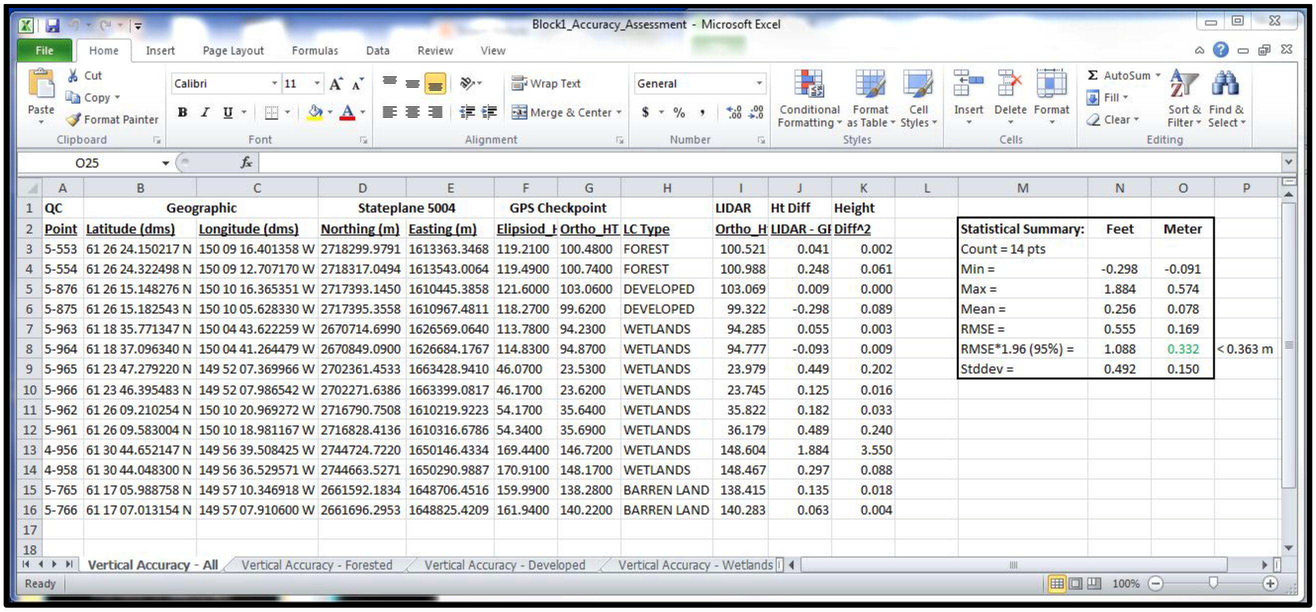


Figure 8, LiDAR point cloud assessment with QTM marking checkpoint location.



QC	Geographic		Stateplane 5004		GPS Checkpoint			LIDAR	Ht Diff	Height
Point	Latitude (dms)	Longitude (dms)	Northing (m)	Easting (m)	Elipsiod_H	Ortho_HT	LC Type	Ortho_H	LIDAR - GI	Diff^2
5-553	61 26 24.150217 N	150 09 16.401358 W	2718299.9791	1613363.3468	119.2100	100.4800	FOREST	100.521	0.041	0.002
5-554	61 26 24.322498 N	150 09 12.707170 W	2718317.0494	1613543.0064	119.4900	100.7400	FOREST	100.988	0.248	0.061
5-876	61 26 15.148276 N	150 10 16.365351 W	2717393.1450	1610445.3858	121.6000	103.0600	DEVELOPED	103.069	0.009	0.000
5-875	61 26 15.182543 N	150 10 05.628330 W	2717395.3558	1610967.4811	118.2700	99.6200	DEVELOPED	99.322	-0.298	0.089
5-963	61 18 35.771347 N	150 04 43.622259 W	2670714.6990	1626569.0640	113.7800	94.2300	WETLANDS	94.285	0.055	0.003
5-964	61 18 37.096340 N	150 04 41.264479 W	2670849.0900	1626684.1767	114.8300	94.8700	WETLANDS	94.777	-0.093	0.009
5-965	61 23 47.279220 N	149 52 07.369966 W	2702361.4533	1663428.9410	46.0700	23.5300	WETLANDS	23.979	0.449	0.202
5-966	61 23 46.395483 N	149 52 07.986542 W	2702271.6386	1663399.0817	46.1700	23.6200	WETLANDS	23.745	0.125	0.016
5-962	61 26 09.210254 N	150 10 20.969272 W	2716790.7508	1610219.9223	54.1700	35.6400	WETLANDS	35.822	0.182	0.033
5-961	61 26 09.583004 N	150 10 18.981167 W	2716828.4136	1610316.6786	54.3400	35.6900	WETLANDS	36.179	0.489	0.240
4-956	61 30 44.652147 N	149 56 39.508425 W	2744724.7220	1650146.4334	169.4400	146.7200	WETLANDS	148.604	1.884	3.550
4-958	61 30 44.048300 N	149 56 36.529571 W	2744663.5271	1650290.9887	170.9100	148.1700	WETLANDS	148.467	0.297	0.088
5-765	61 17 05.988758 N	149 57 10.346918 W	2661592.1834	1648706.4516	159.9900	138.2800	BARREN LAND	138.415	0.135	0.018
5-766	61 17 07.013154 N	149 57 07.910600 W	2661696.2953	1648825.4209	161.9400	140.2200	BARREN LAND	140.283	0.063	0.004

Statistical Summary:	Feet	Meter	
Count = 14 pts			
Min =	-0.298	-0.091	
Max =	1.884	0.574	
Mean =	0.256	0.078	
RMSE =	0.555	0.169	
RMSE*1.96 (95%) =	1.088	0.332	< 0.363 m
Stddev =	0.492	0.150	

Figure 9, Vertical Accuracy Assessment using Lounsbury Checkpoint Survey.

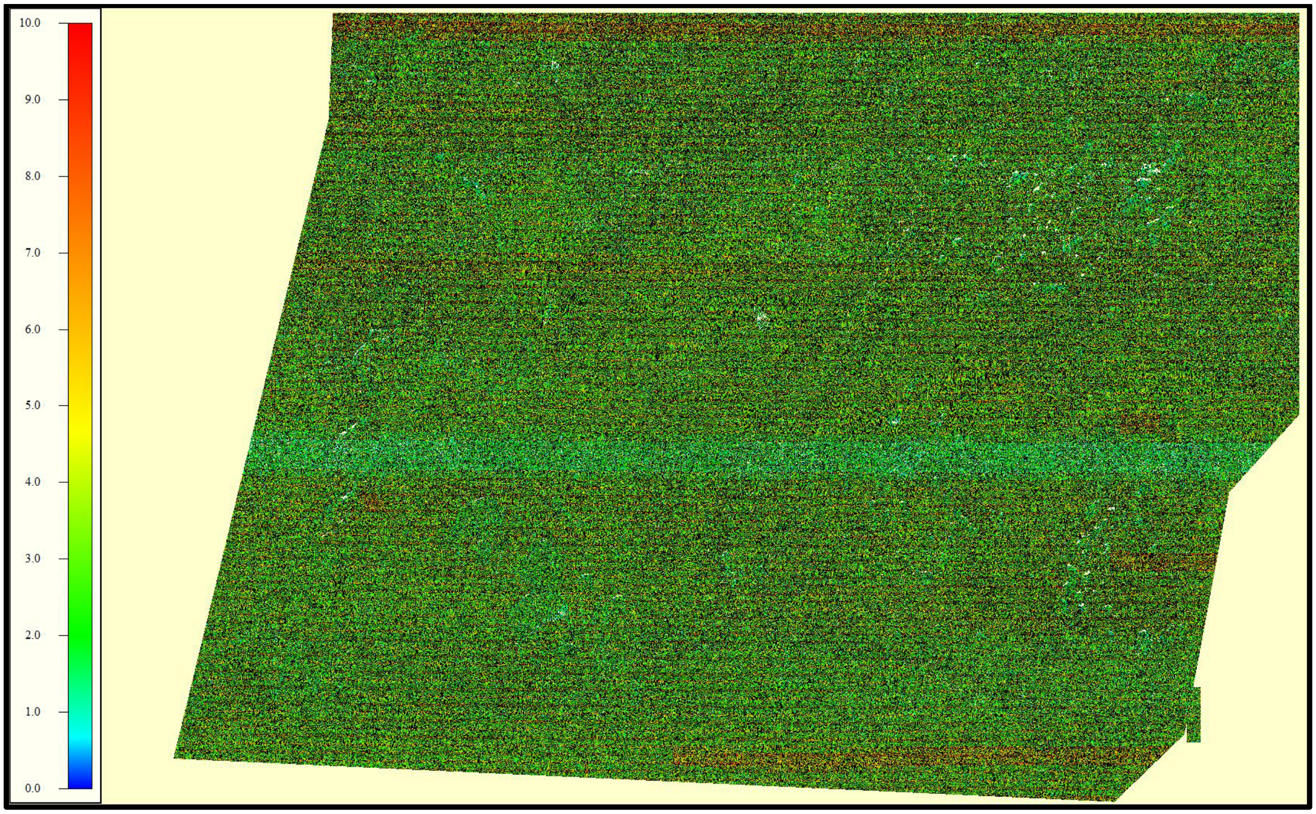


Figure 10, LiDAR First-Return Point Count

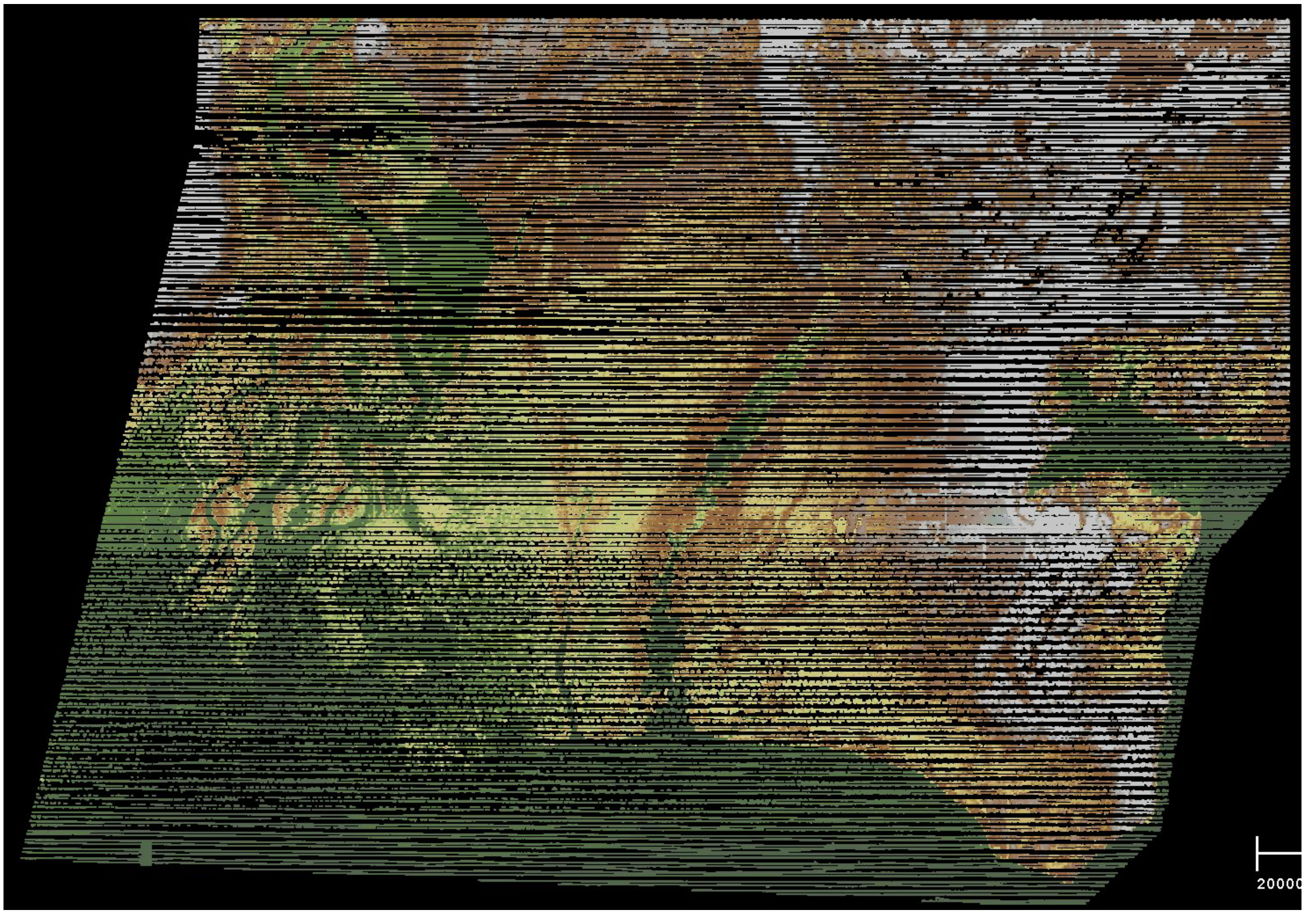


Figure 11, Class 1 – Unclassified.

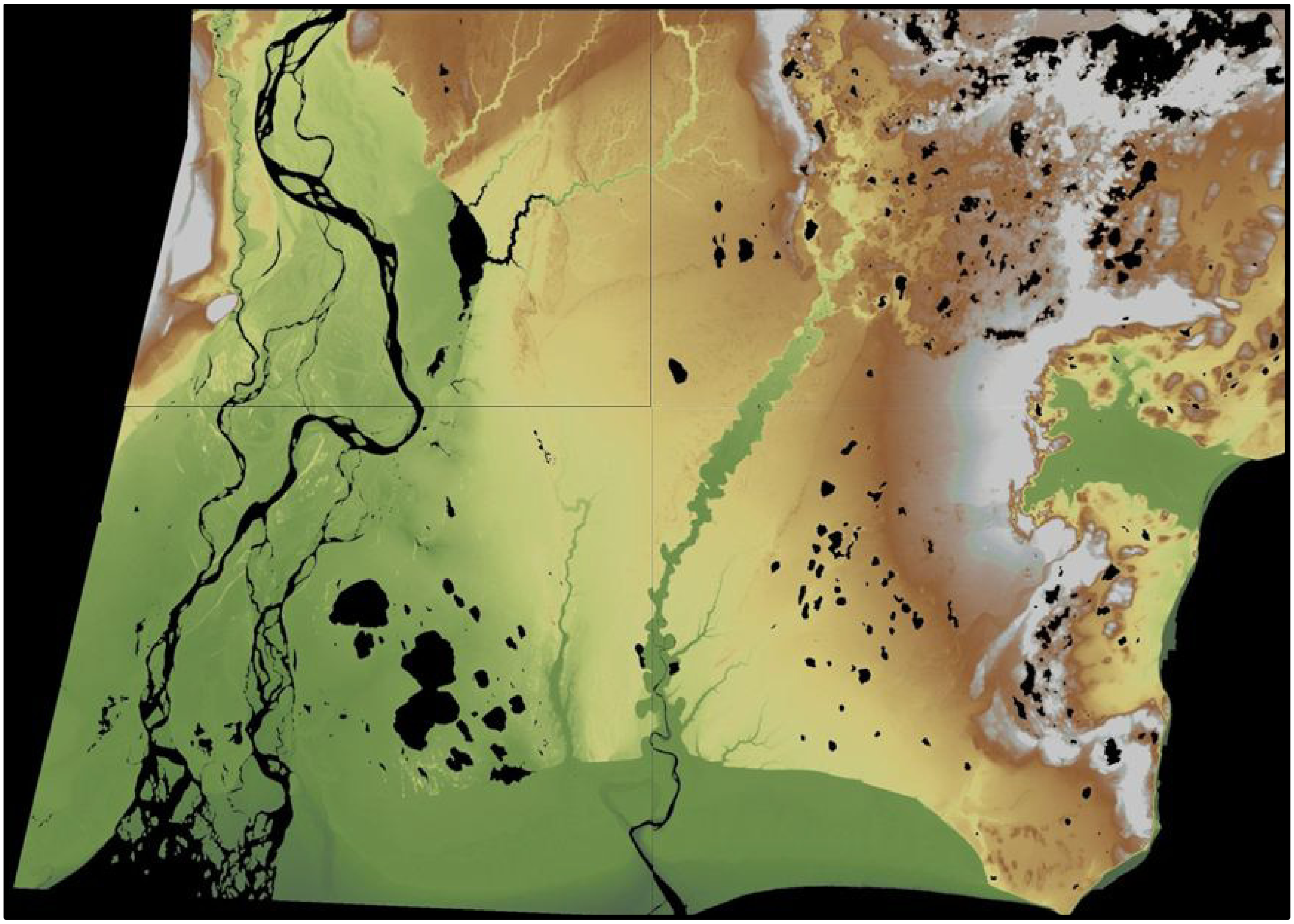


Figure 12, Class 2 – Ground.

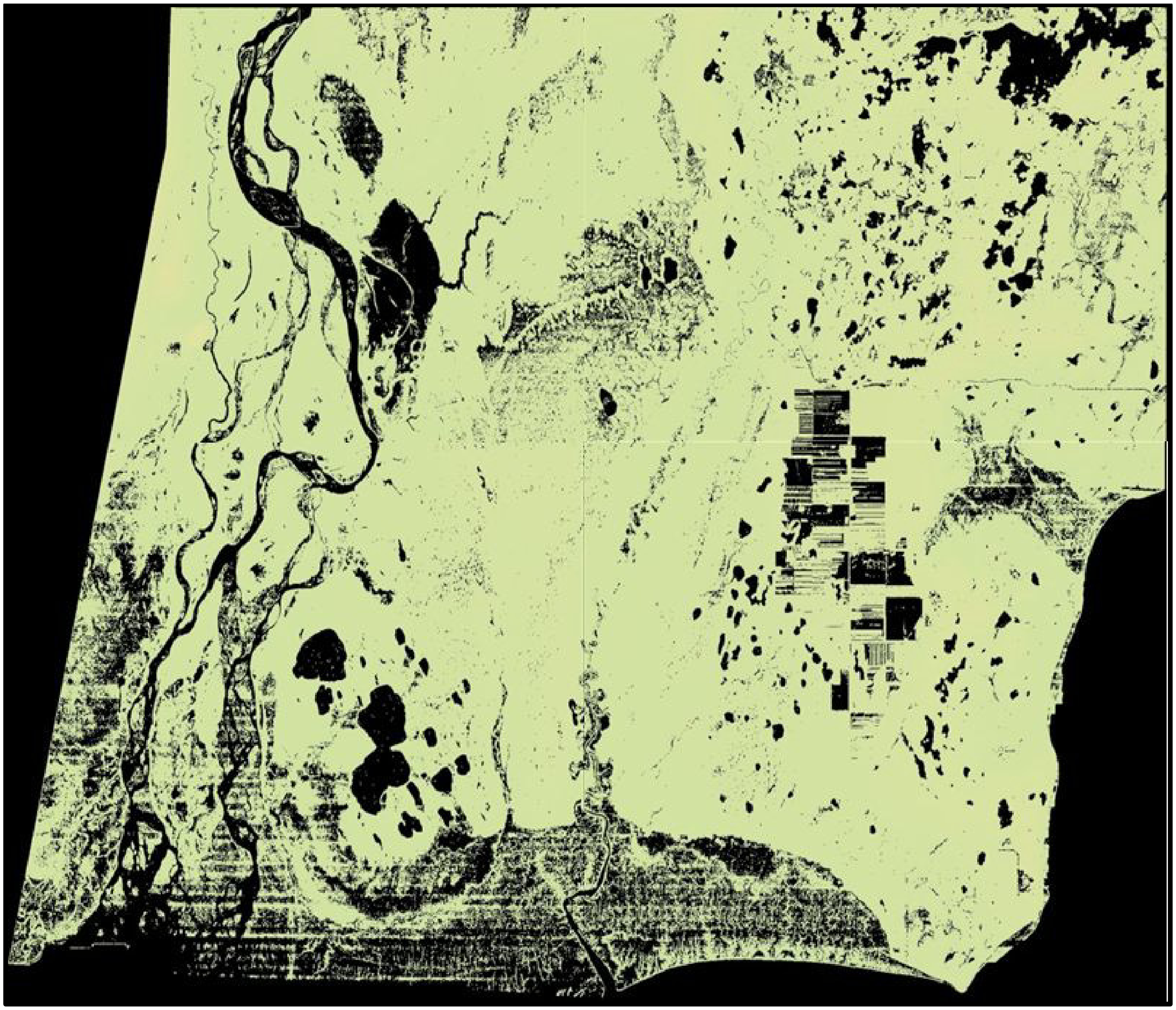


Figure 13, Class 3 – Low Vegetation.

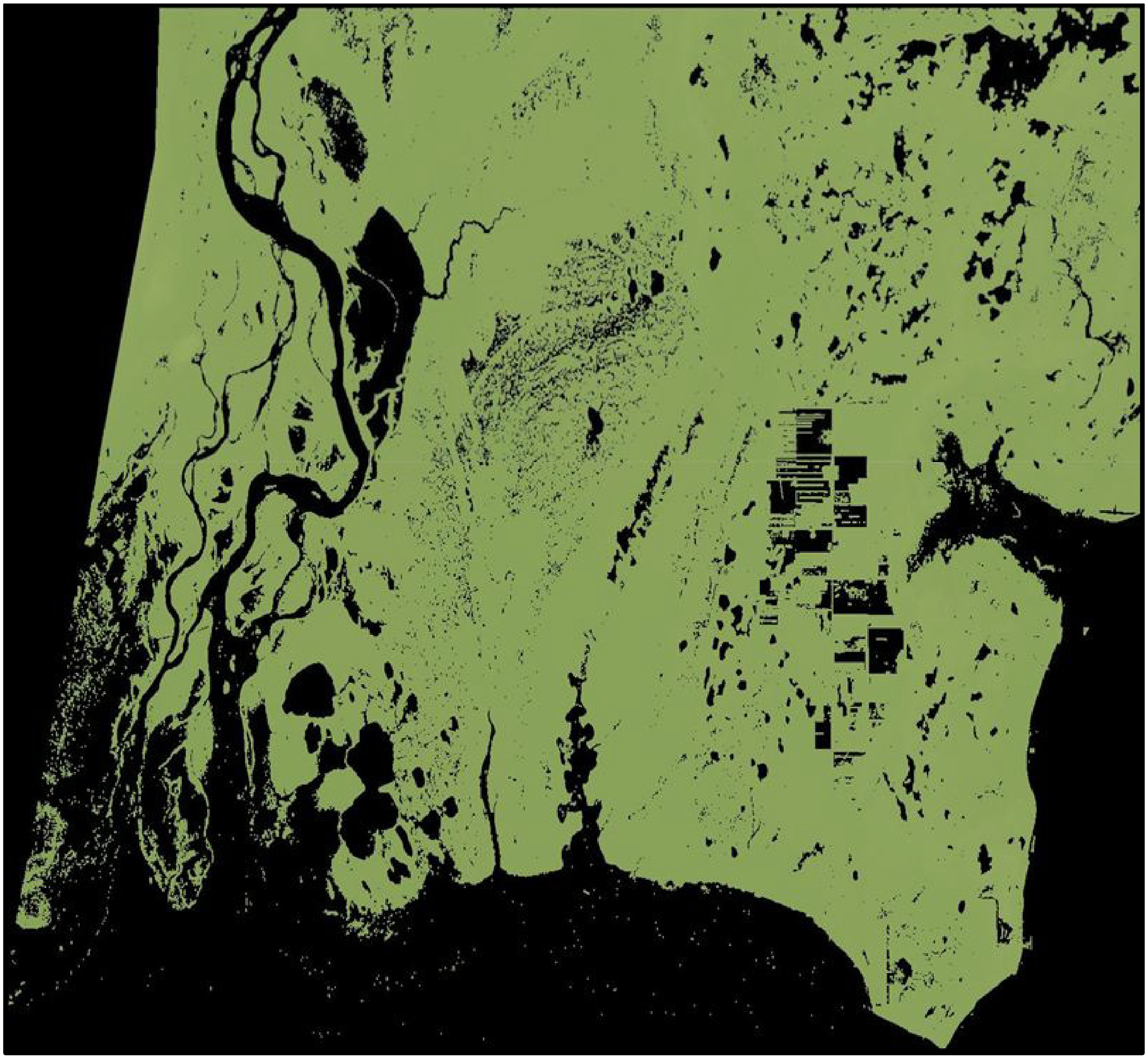


Figure 14, Class 4 – Medium Vegetation

.Figure 15, Class 5 – High Vegetation.

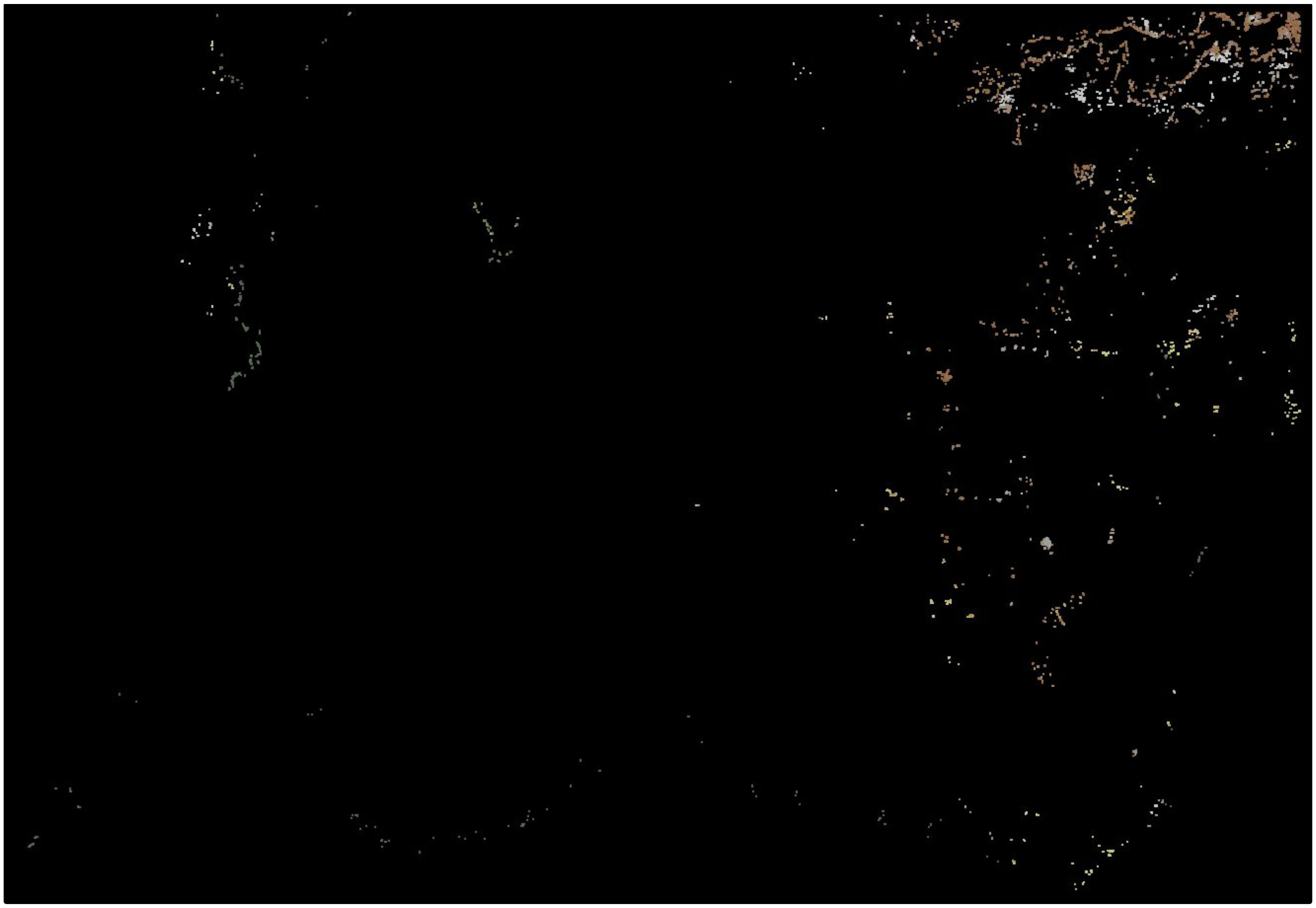


Figure 16, Class 6 – Buildings.

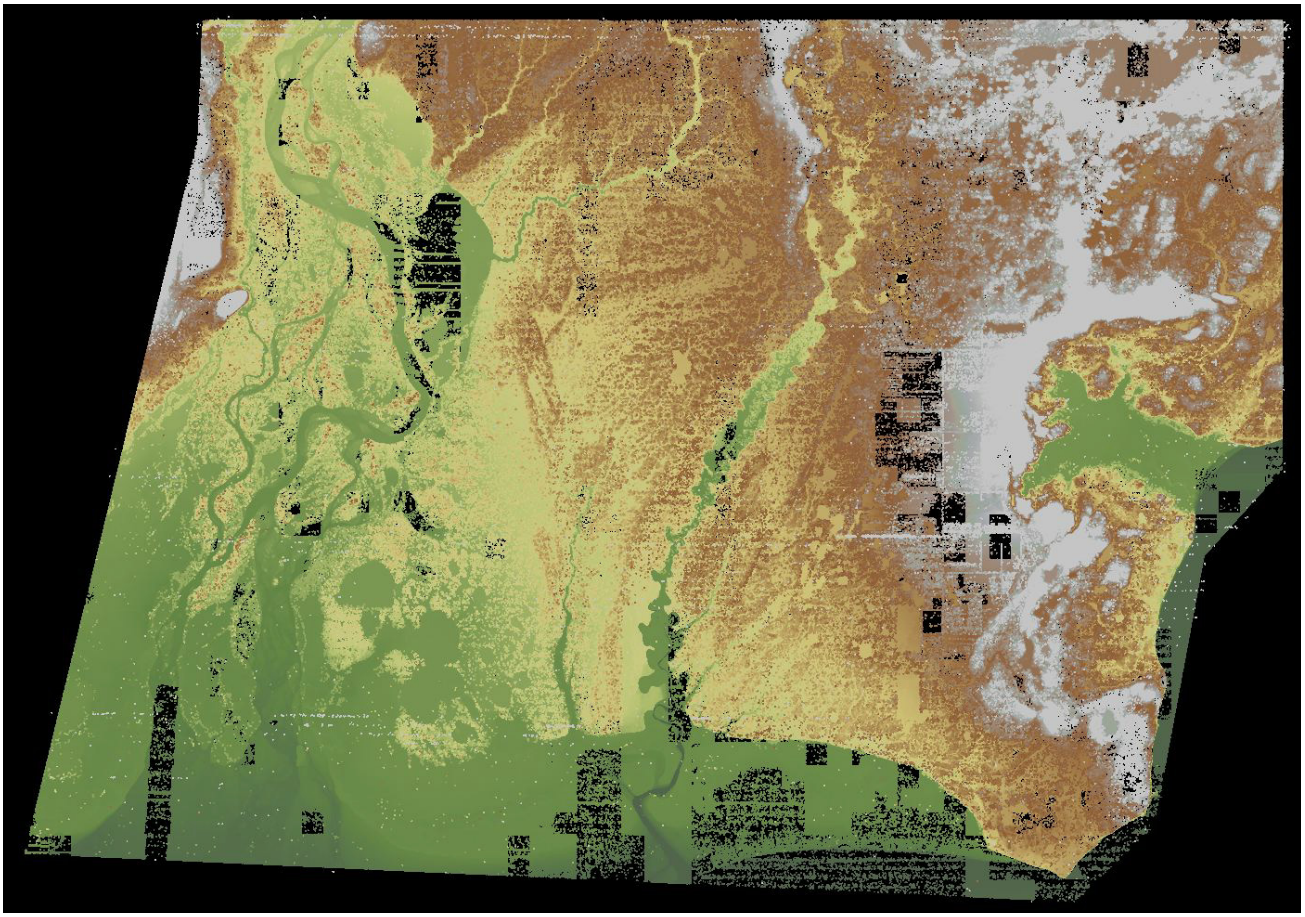


Figure 17, Class 7 – Error Points.

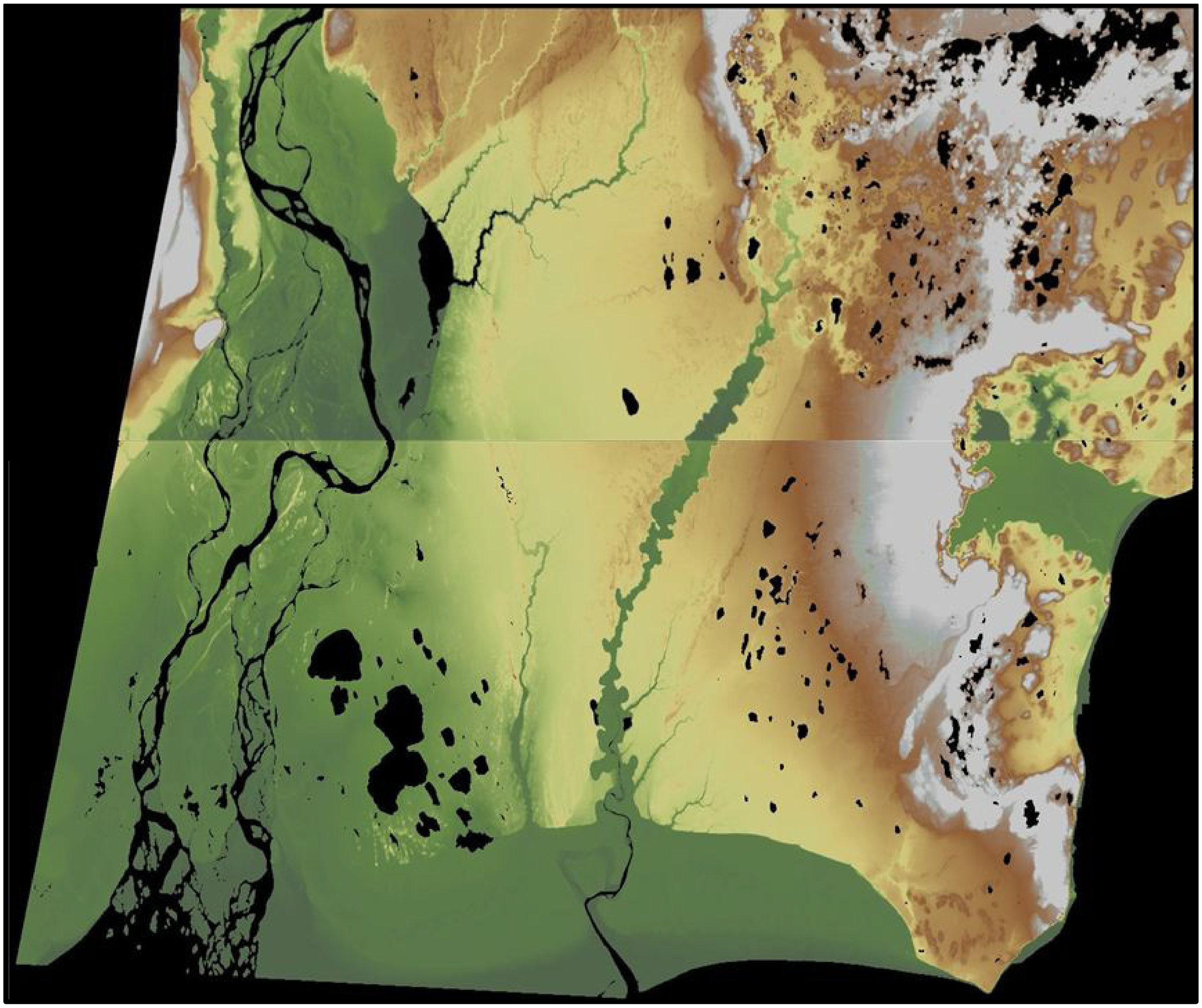


Figure 18, Class 8 – Ground Model Keypoints.

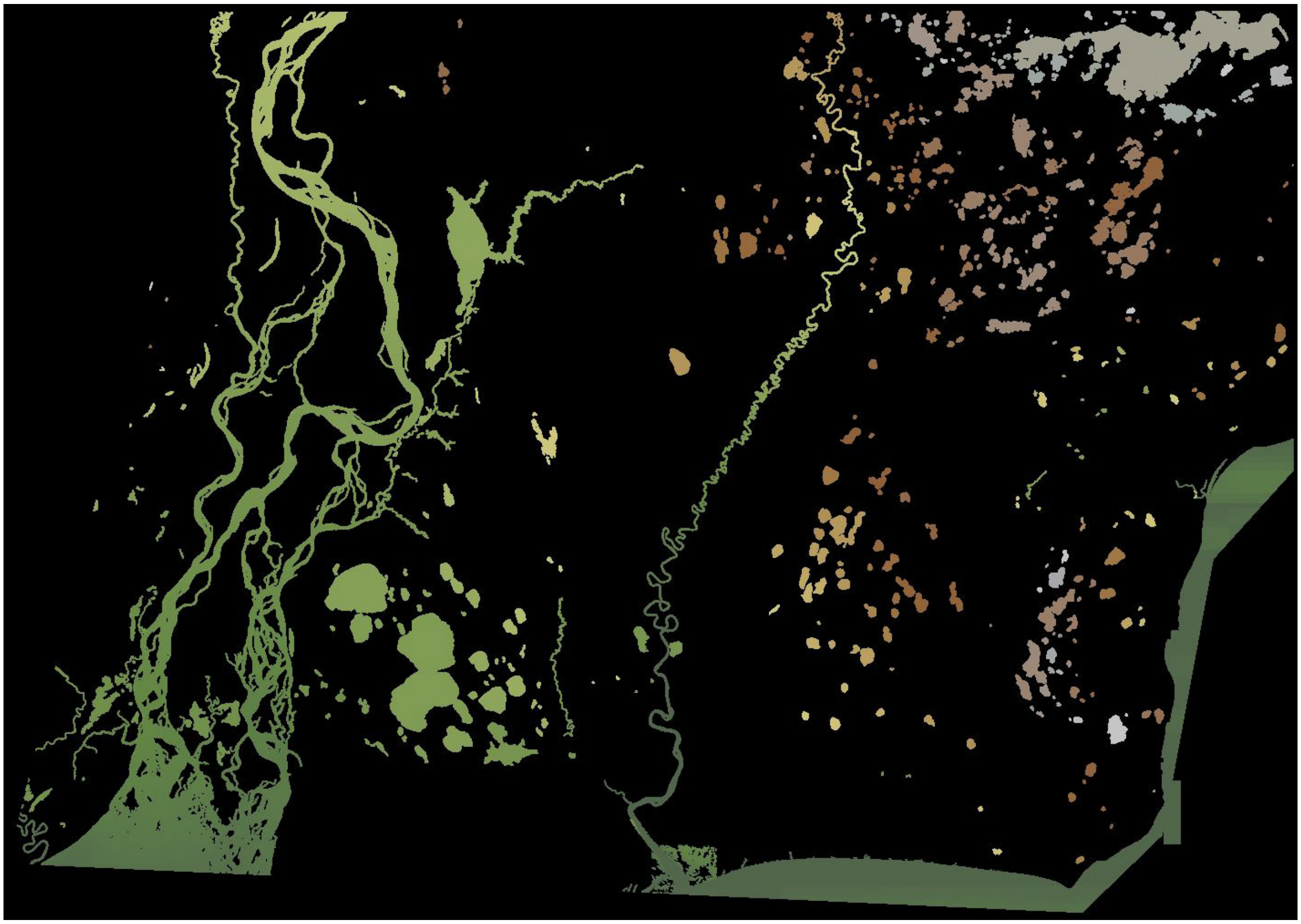


Figure 19, Class 9 – Water.

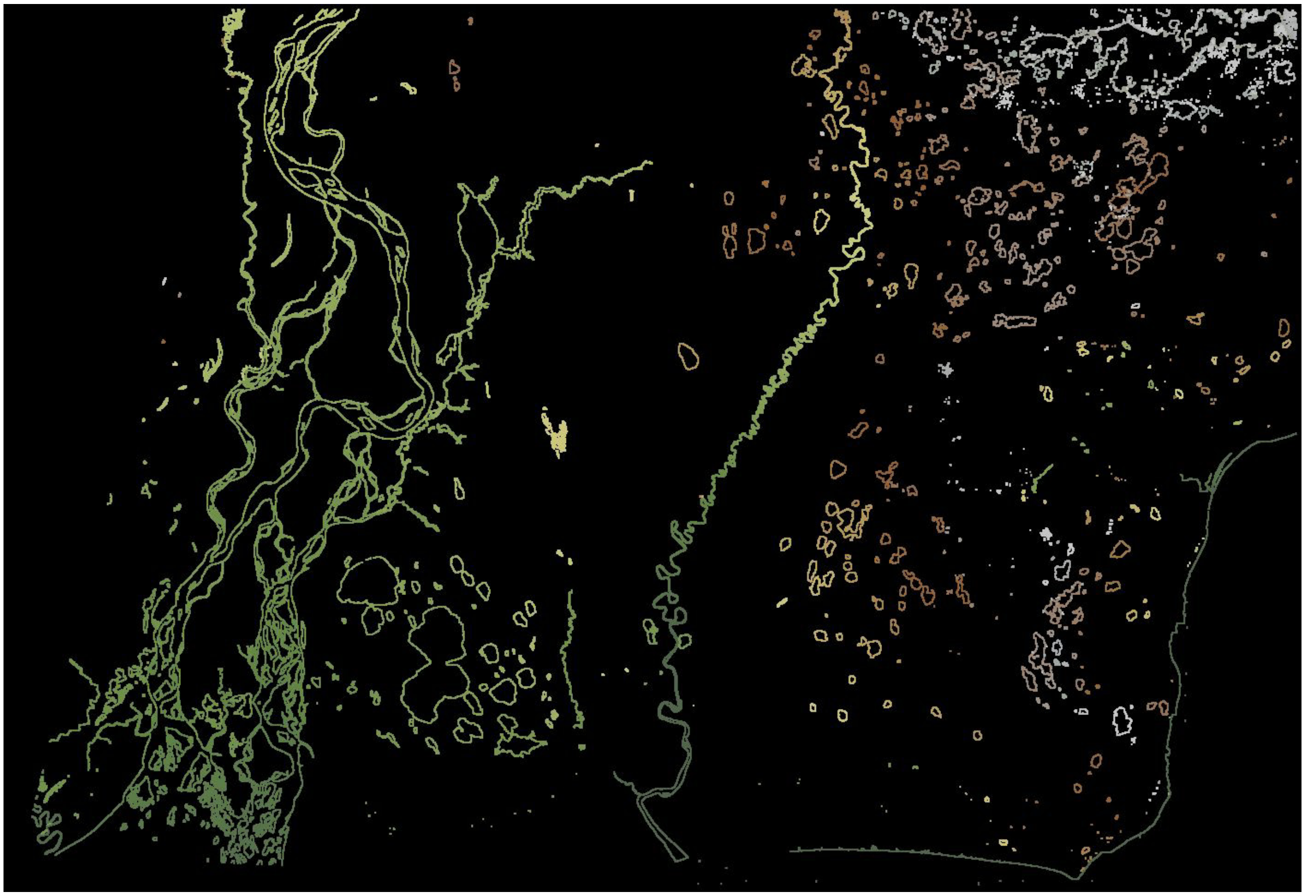


Figure 20, Class 10 – Breakline Proximity.

Figure 21, Class 11 – Power Transmission Lines.

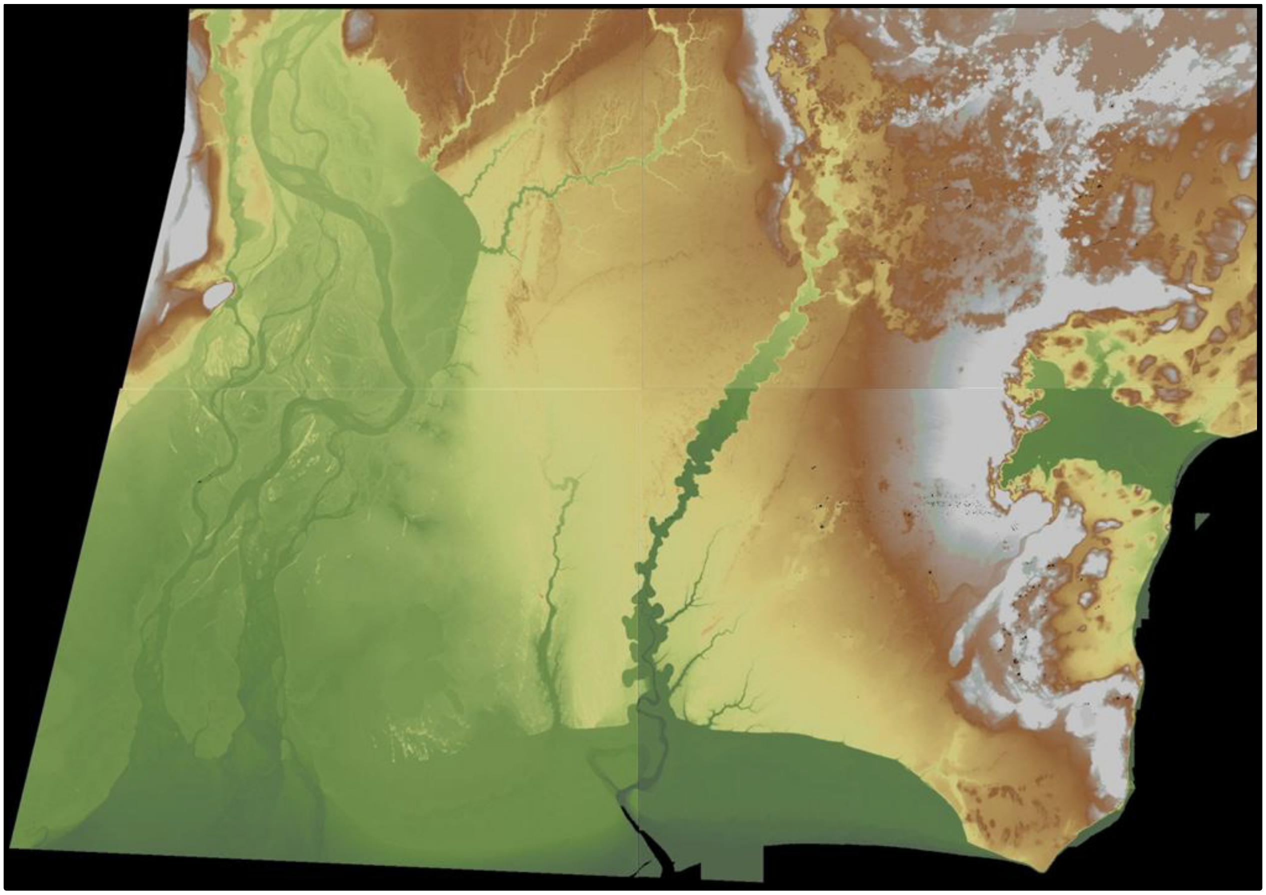


Figure 22, Class 13 – Surface Clutter.

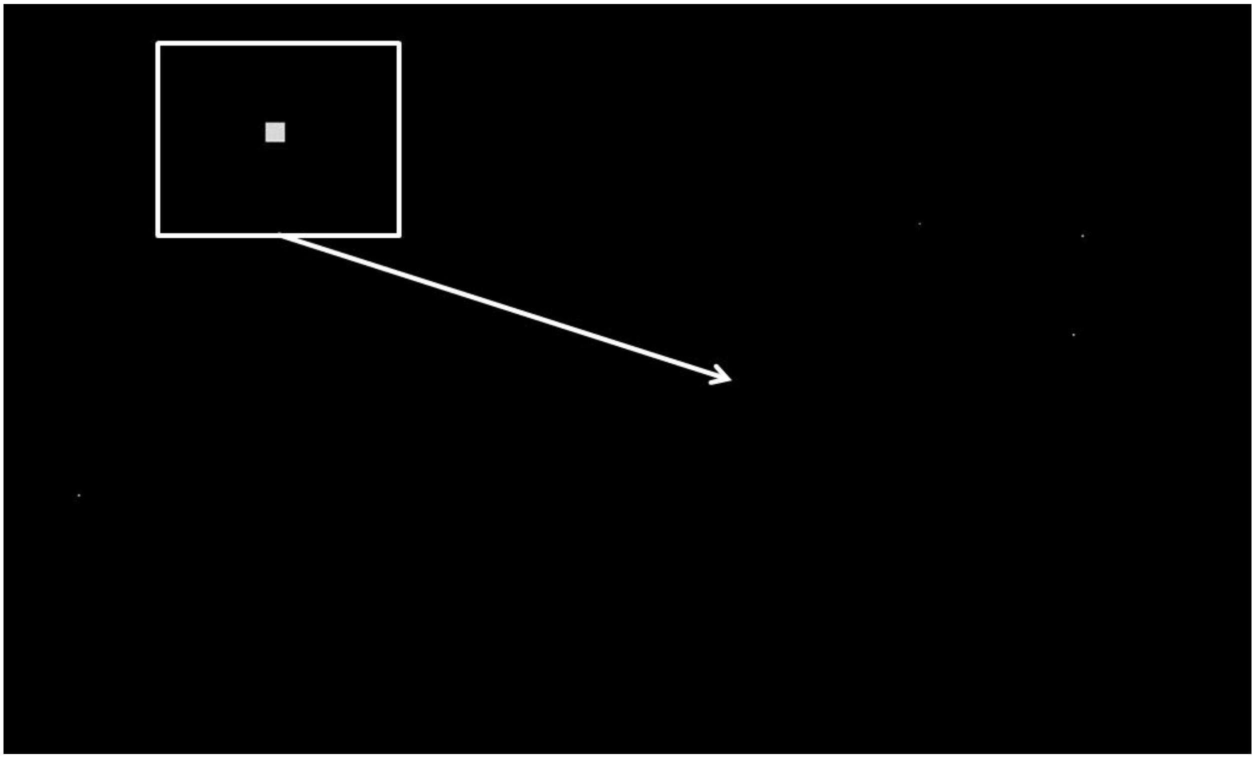


Figure 23, Class 14 – Bridge Decks with Zoom showing one Bridge Deck.

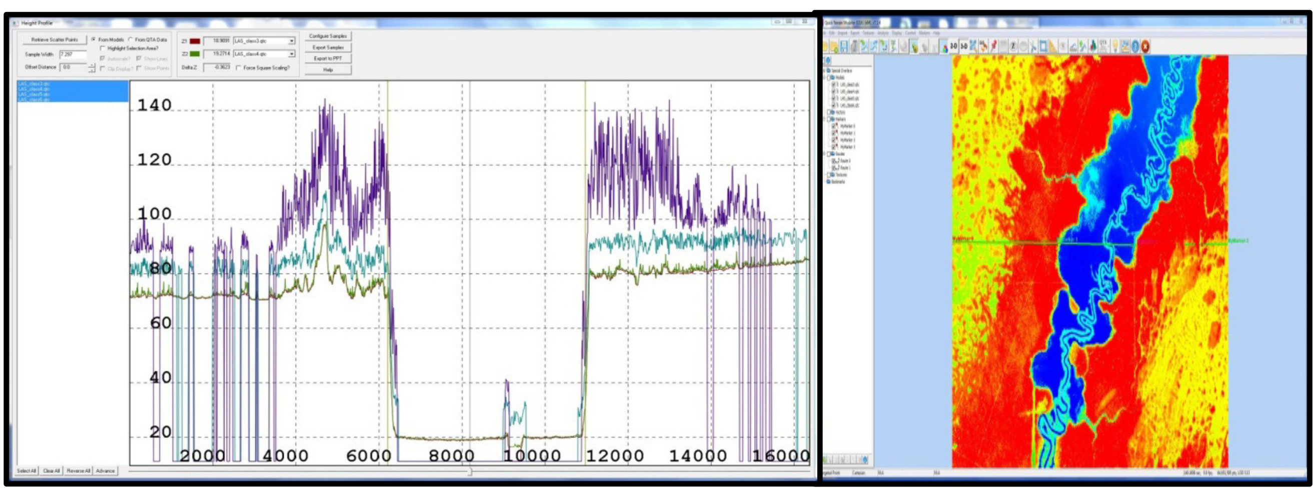


Figure 24, Vegetation Class Height Profile.

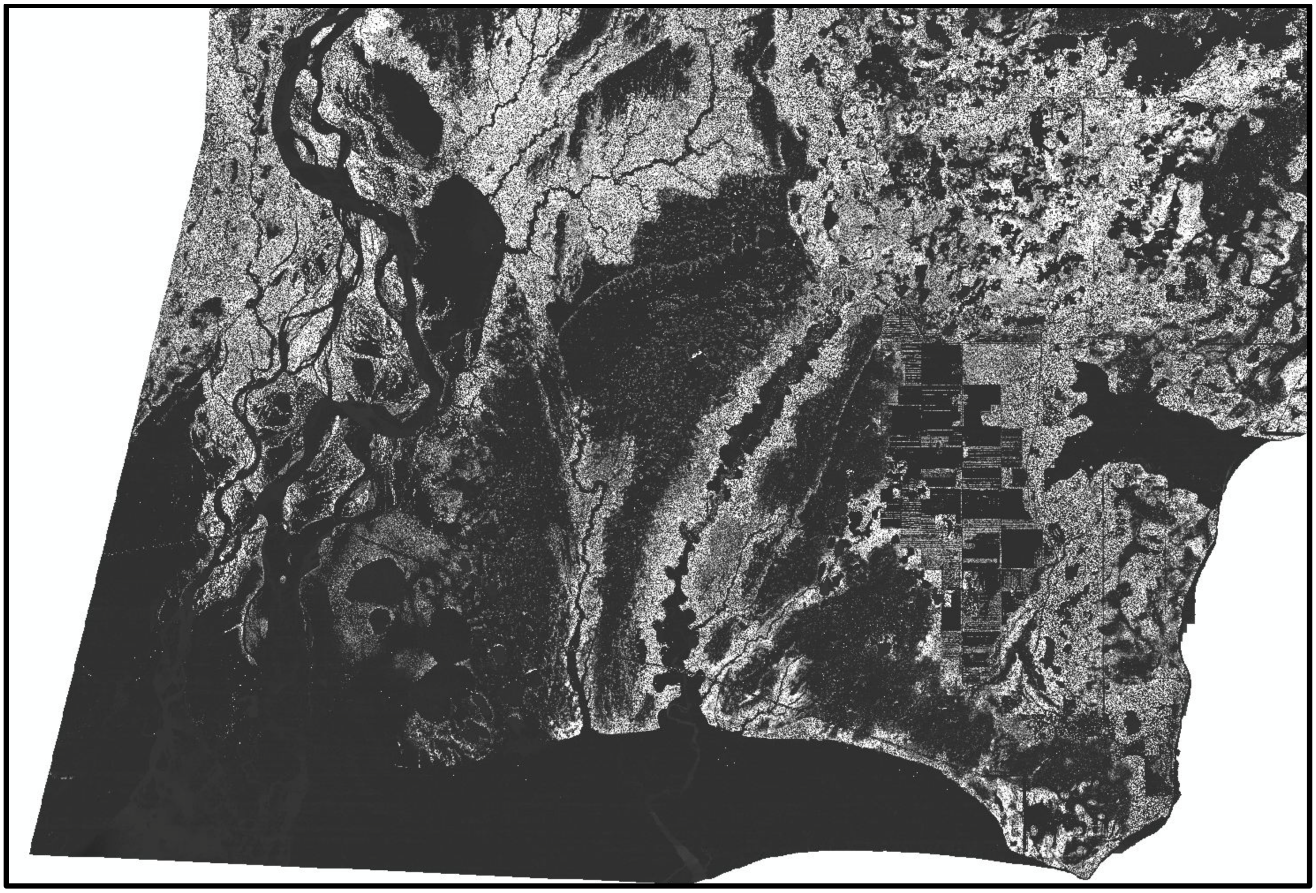


Figure 25, Canopy Height Difference (DSM –DEM).

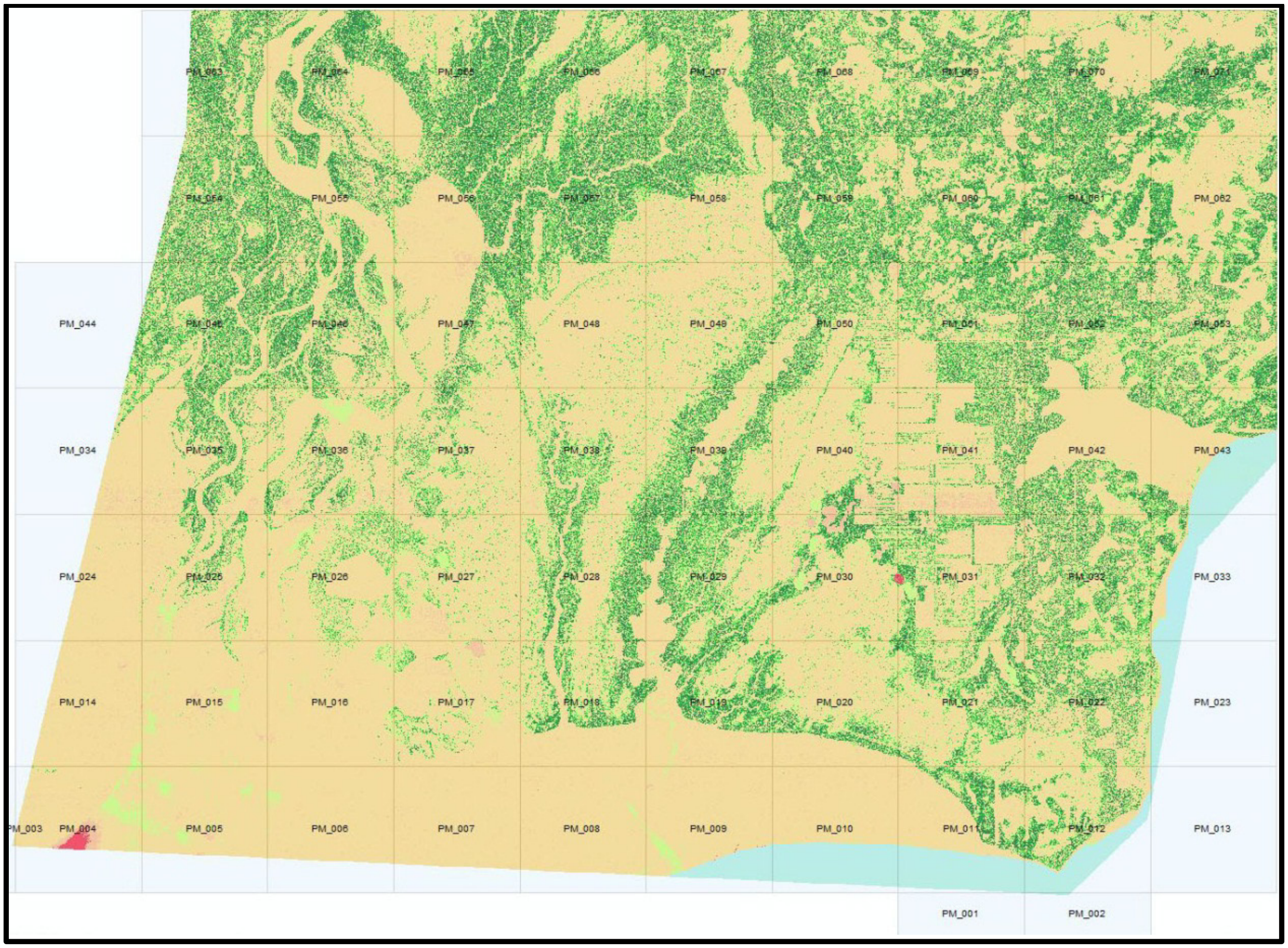


Figure 26, Canopy Height Classification.

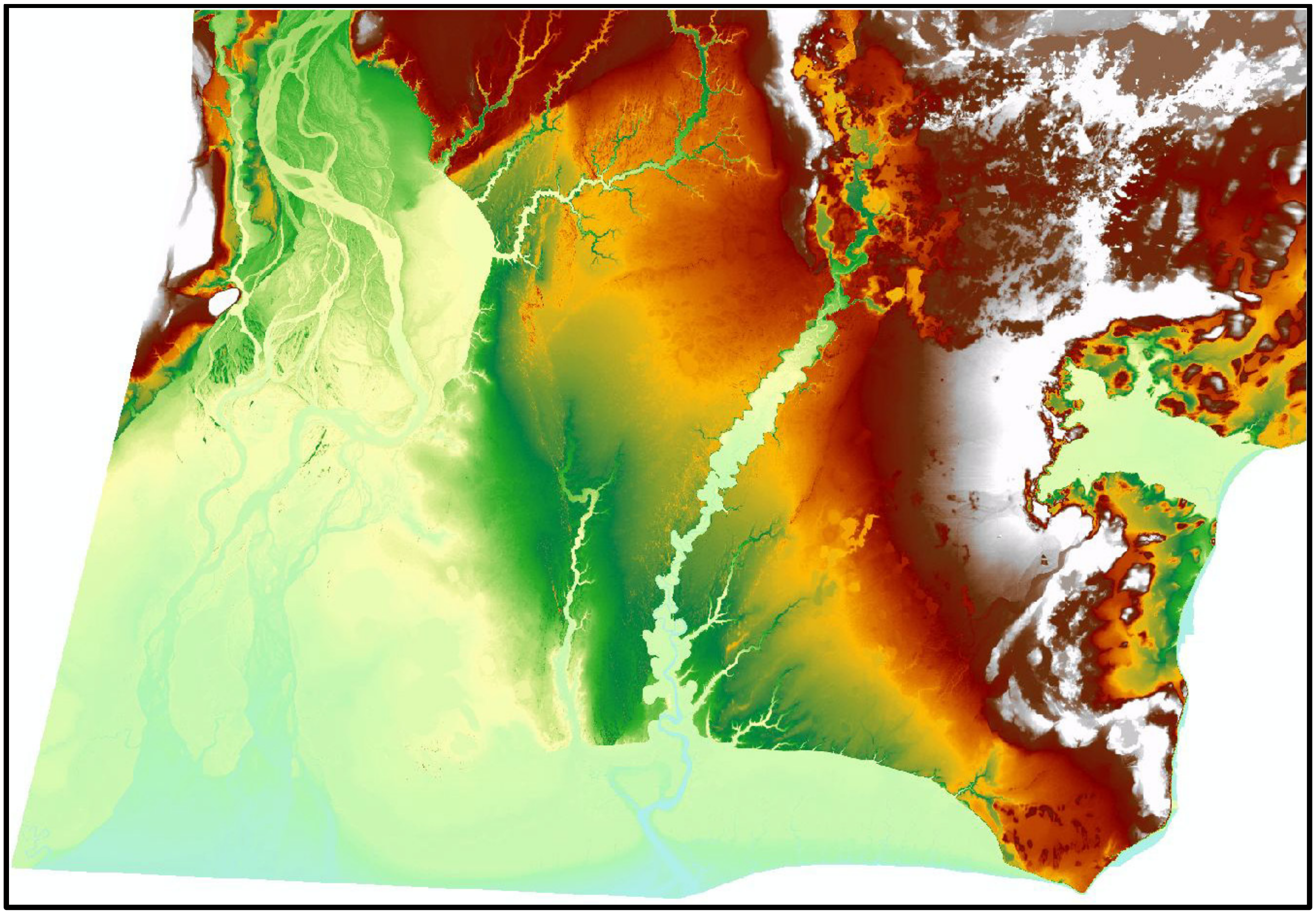


Figure 27, Bare-Earth Gridded DEM.

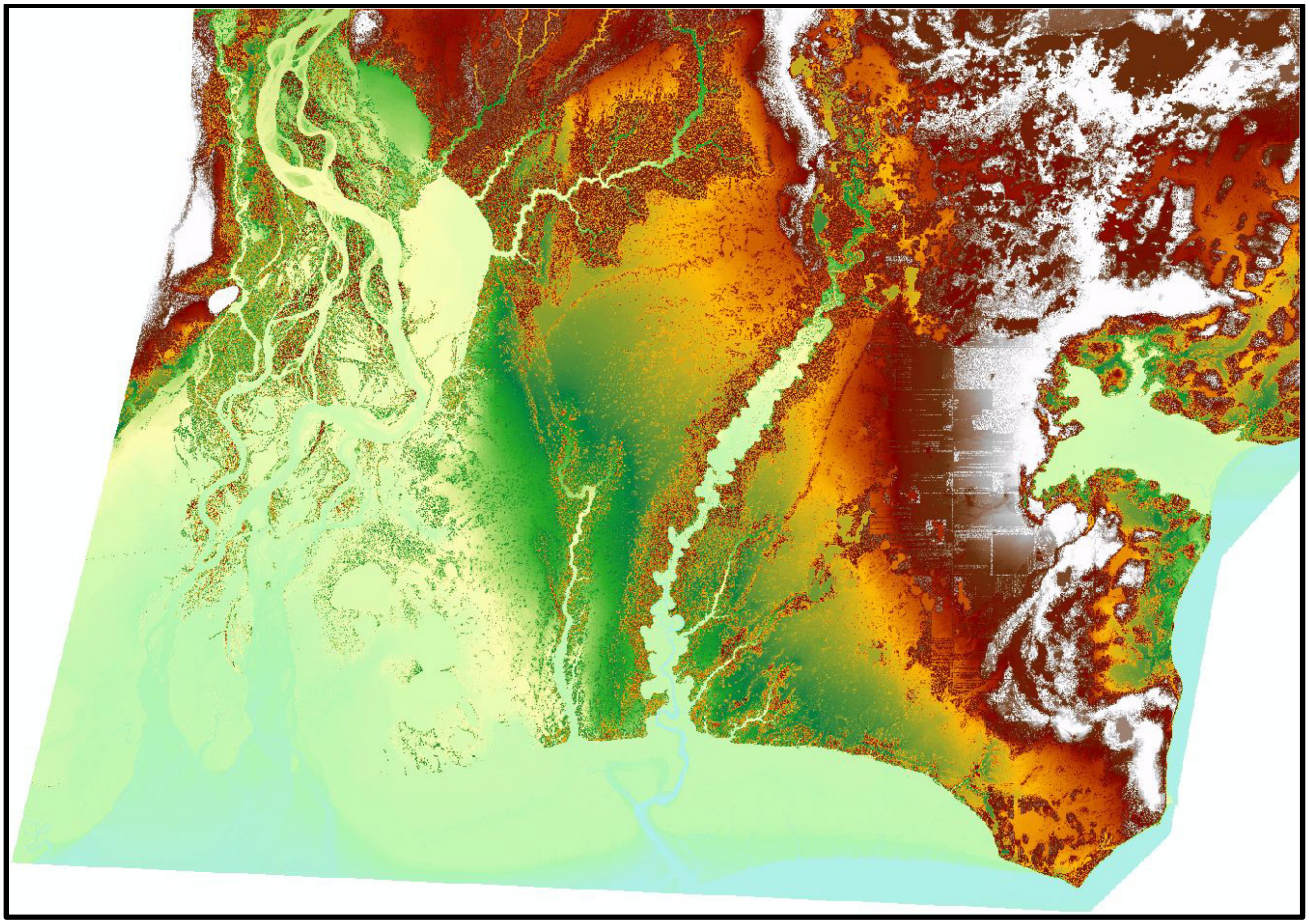


Figure 28, First-Return Gridded DSM.

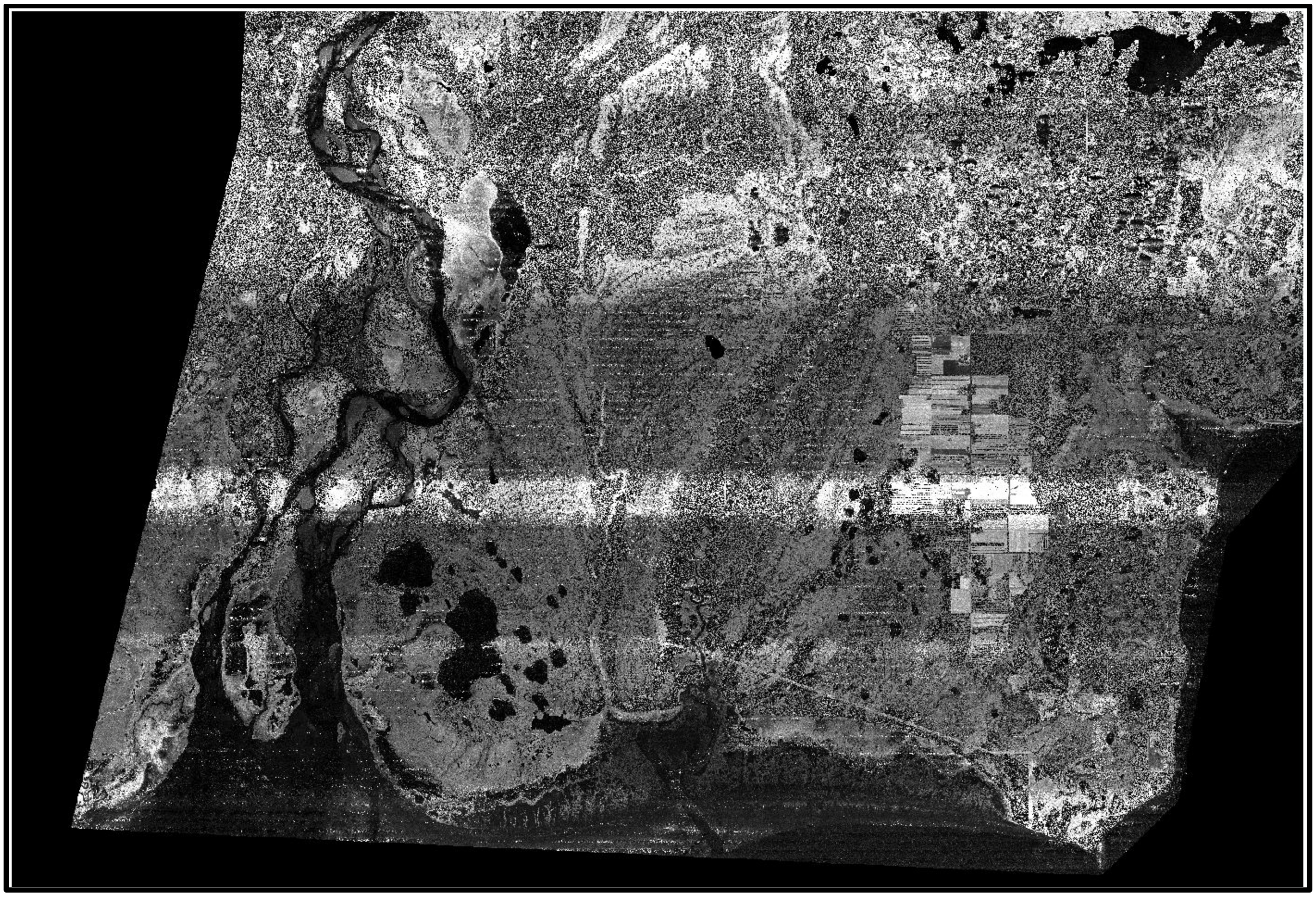


Figure 29, LiDAR Intensity Gridded Mosaic**.**

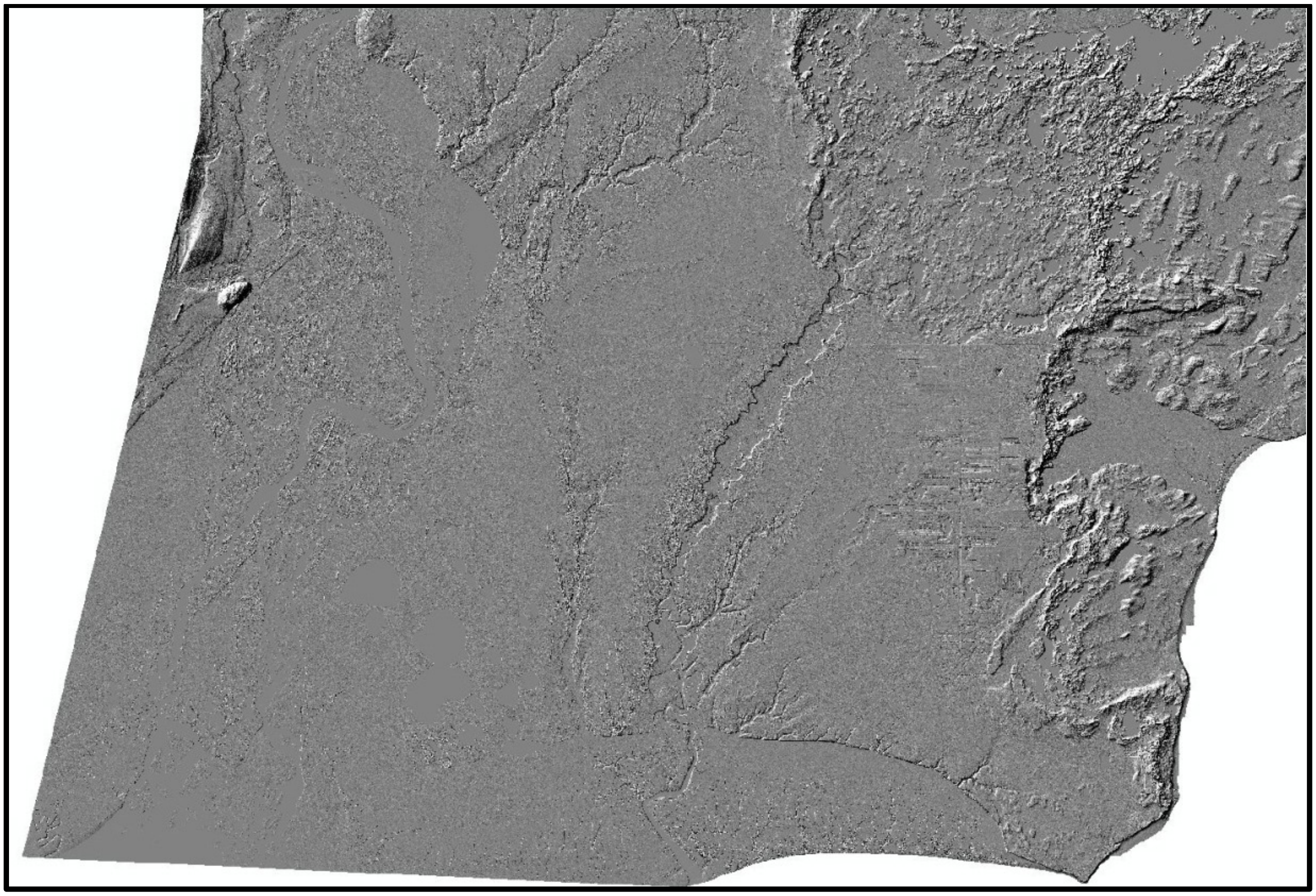


Figure 30, Shaded Relief Bare-Earth Gridded DEM.

Figure 31, Shaded Relief First-Return Gridded DSM.

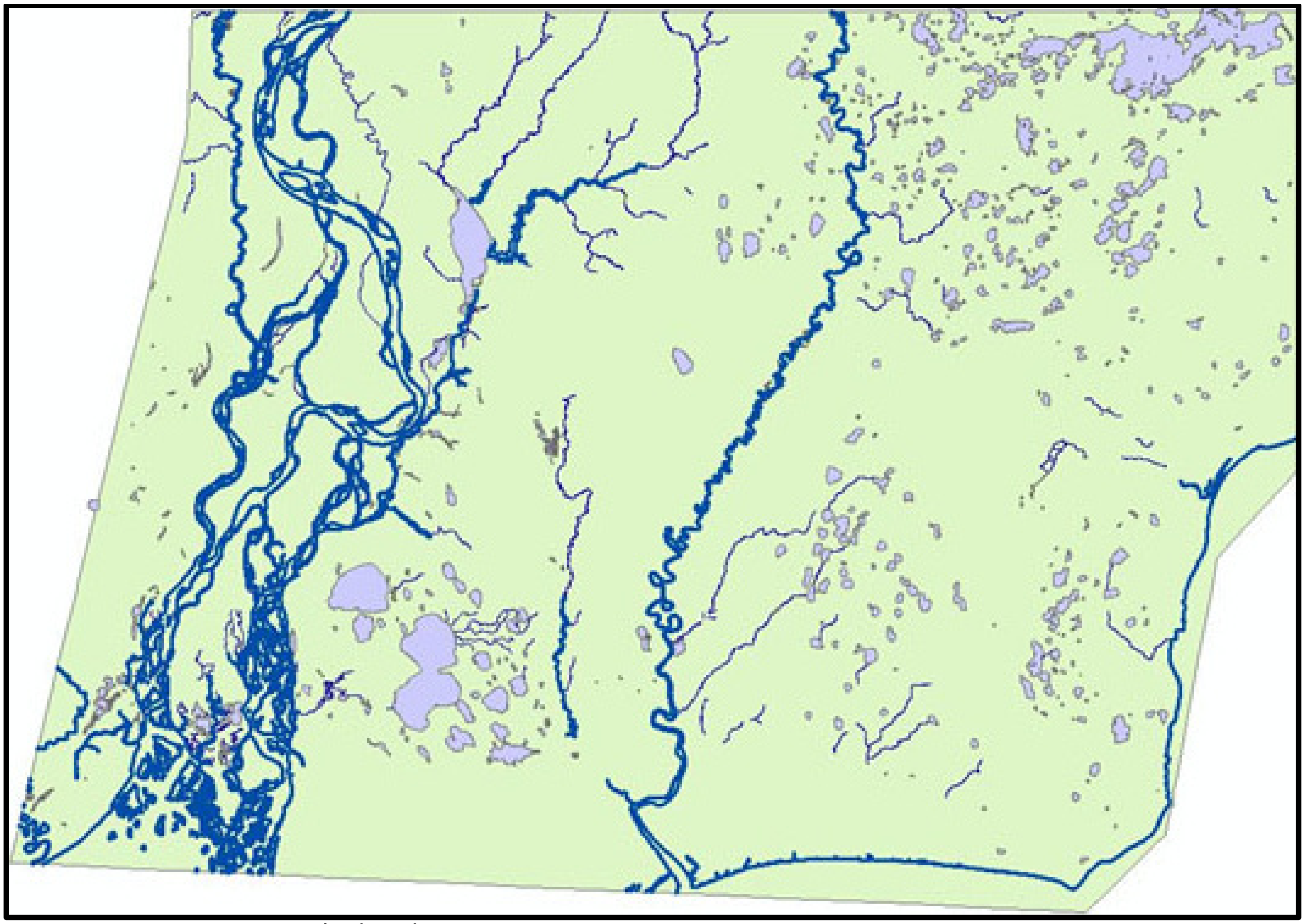


Figure 32, Contractor Supplied Hydro GIS Layers.

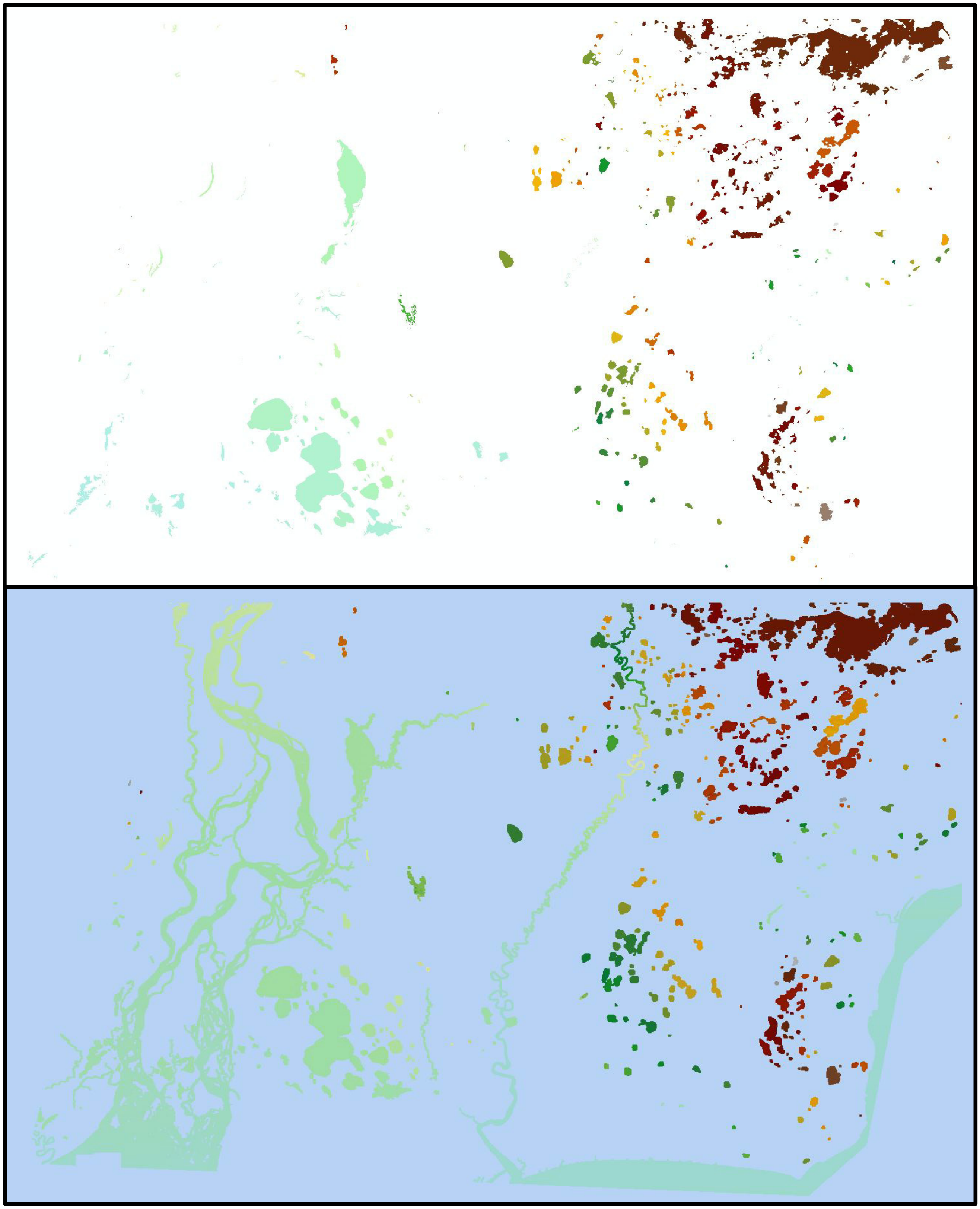


Figure 33, Lake Elevation Comparison (left GIS, right QTM).

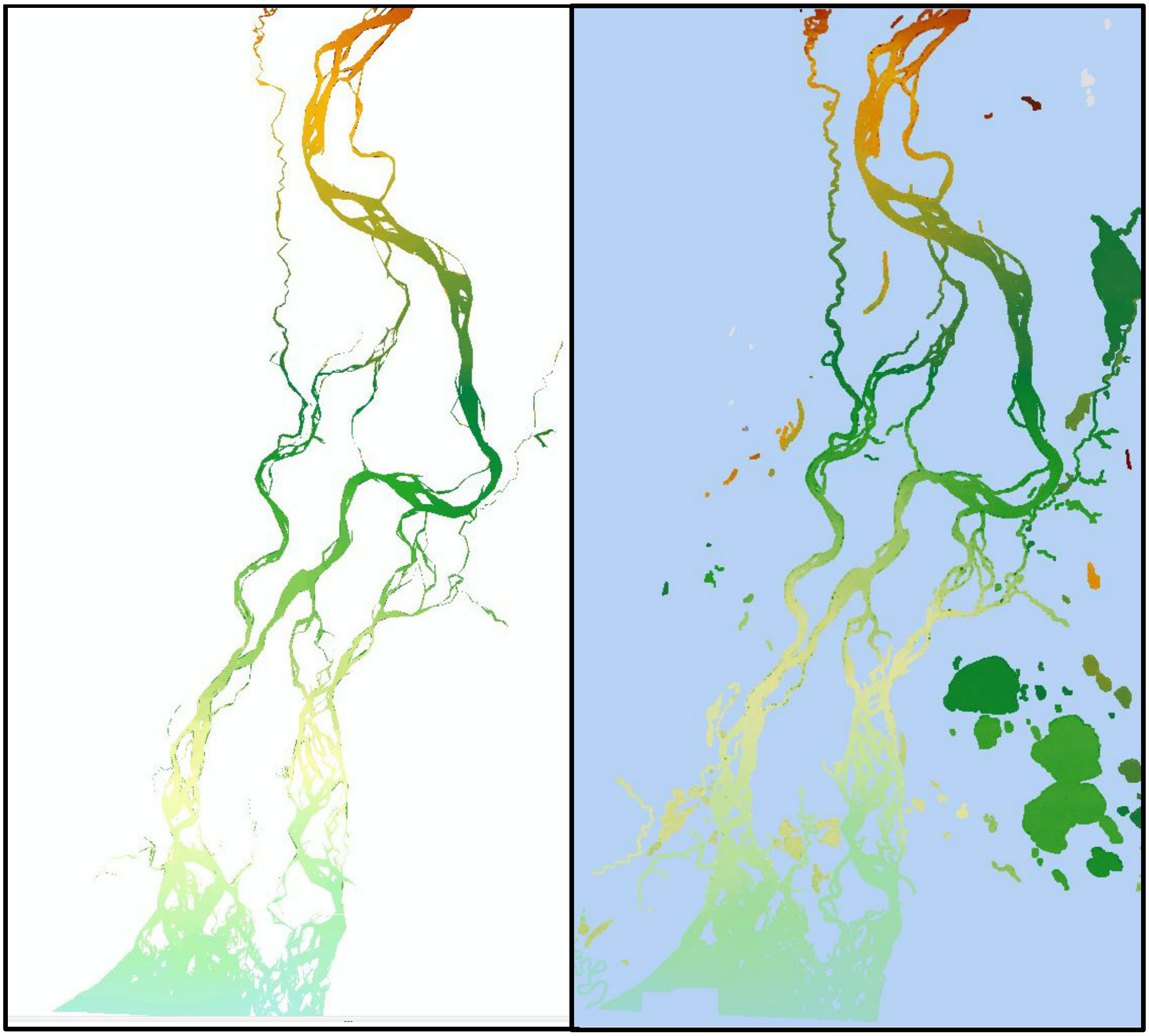


Figure 34, Susitna River Elevations (left GIS, right QTM).

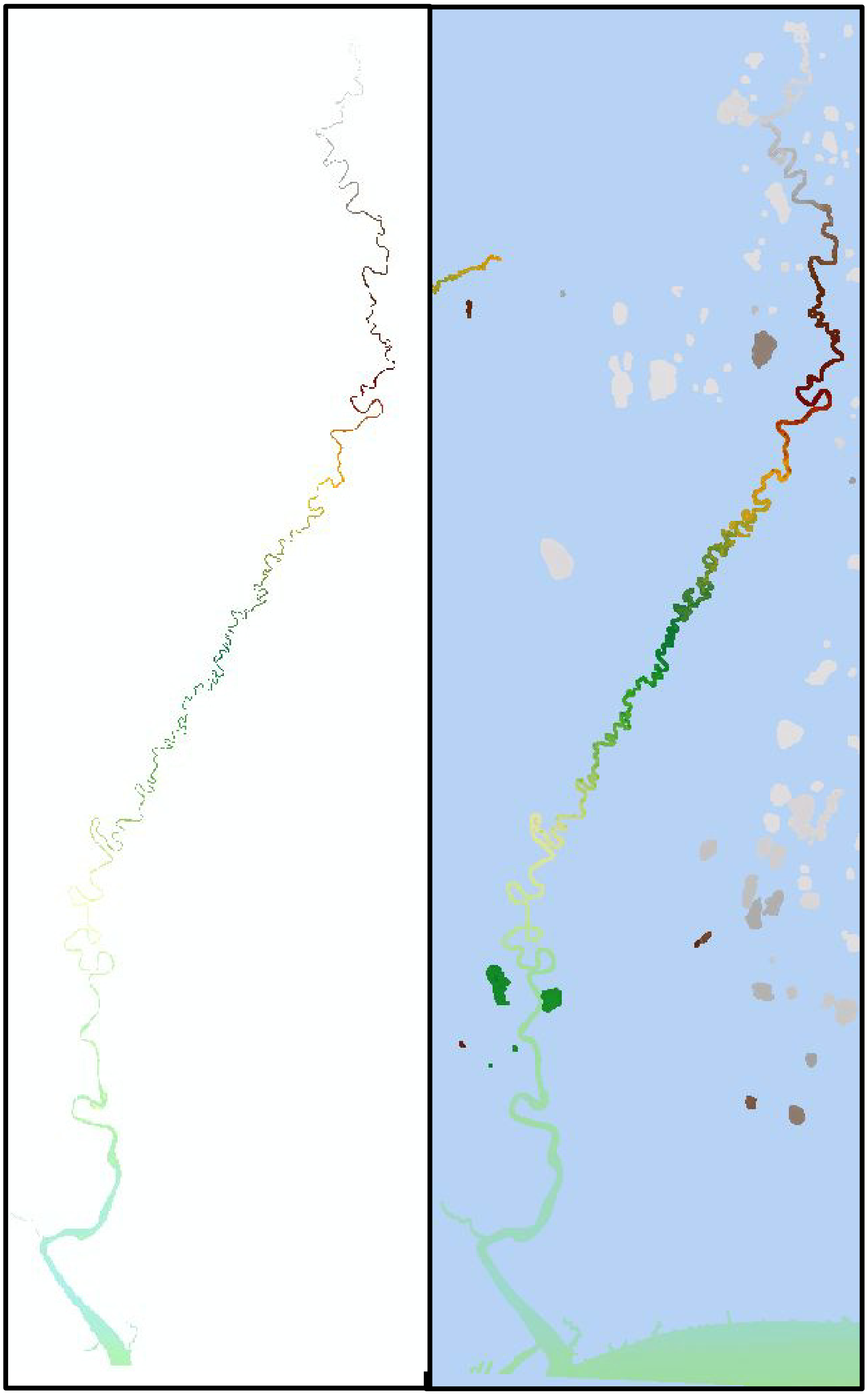


Figure 35, Little Susitna River Elevations (left GIS, right QTM).

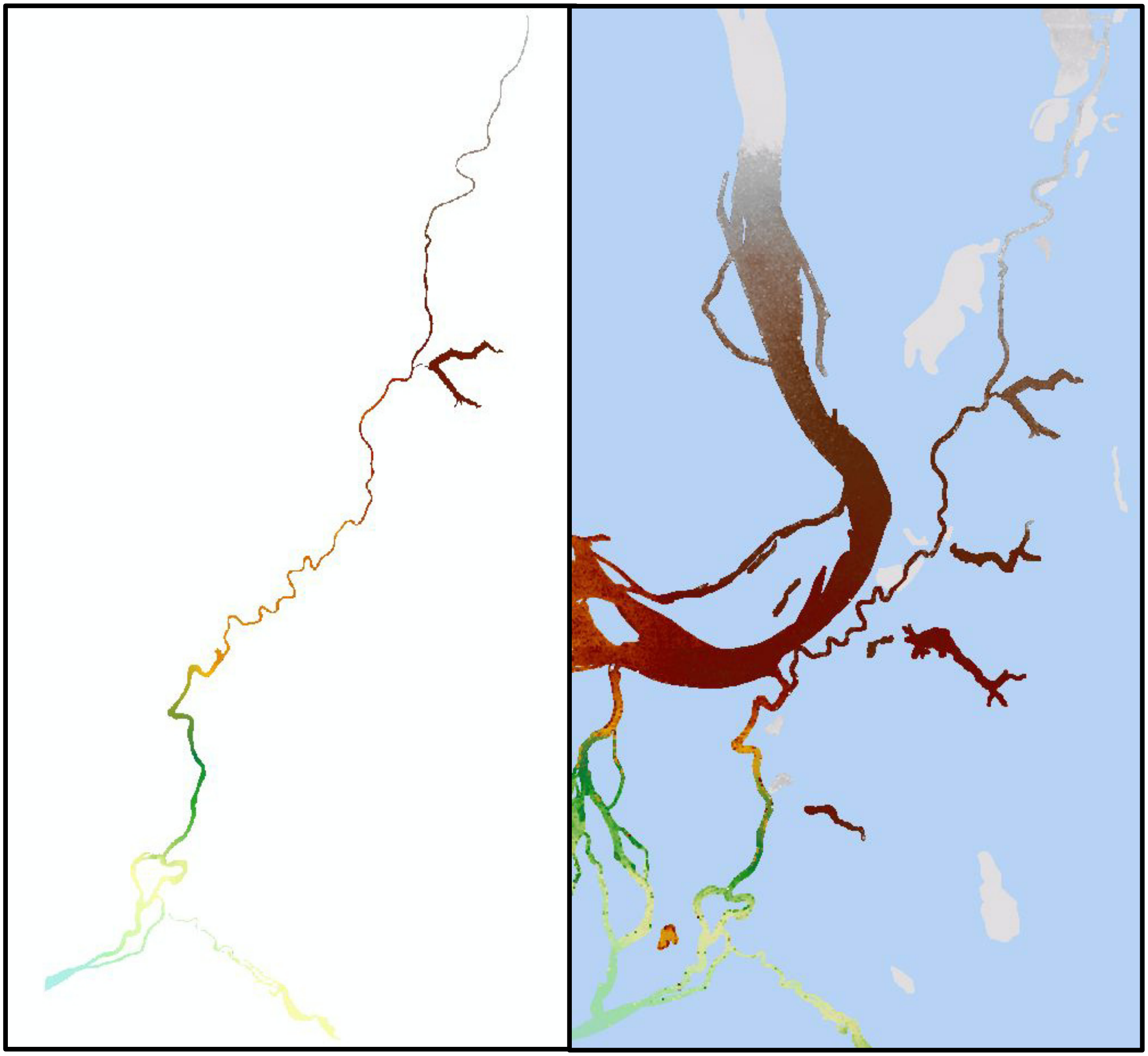


Figure 36, Little Fish Creek Elevations (left Hydro flattened DEM, right LiDAR Point Cloud).

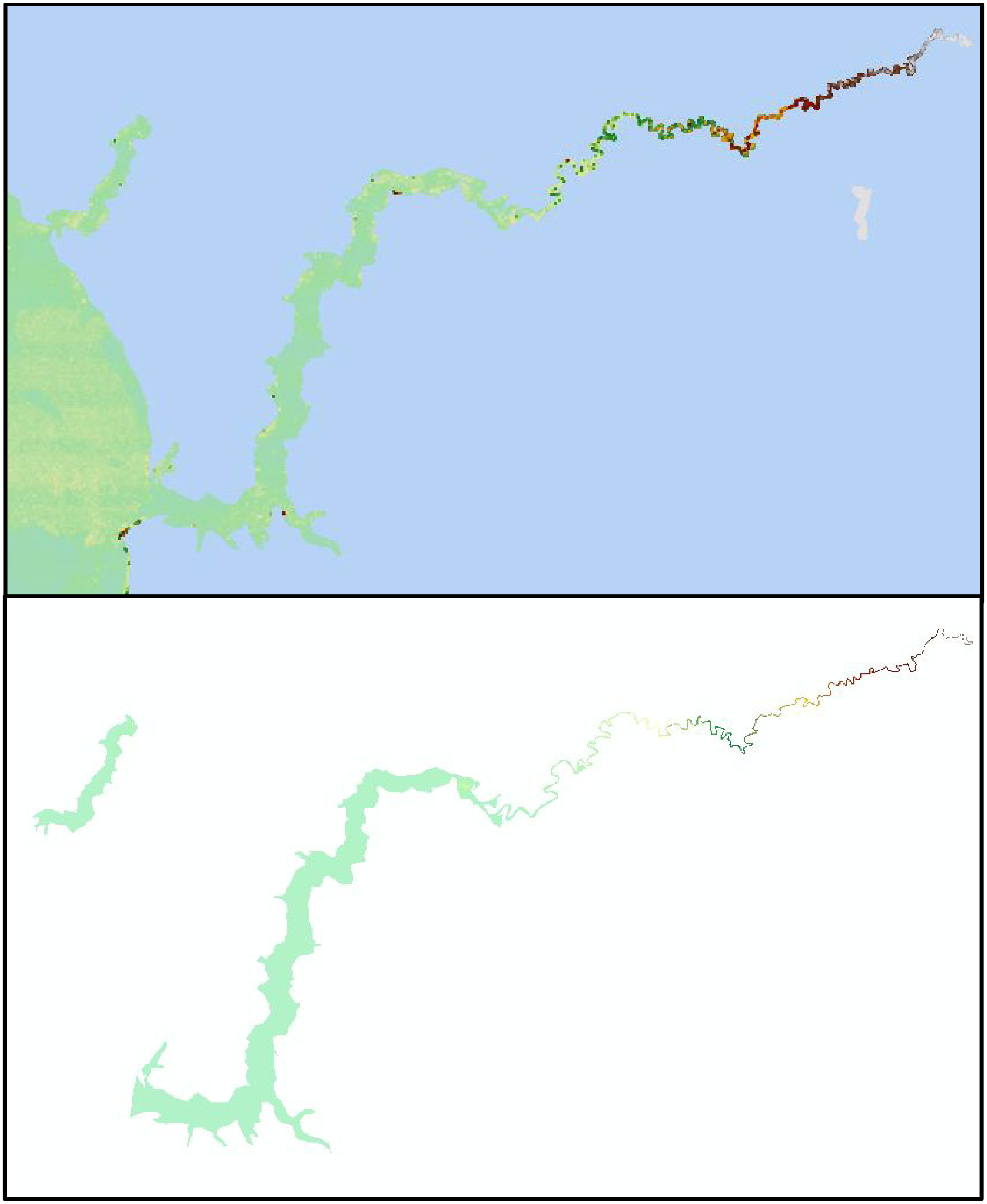


Figure 37, Upper Fish Creek (Top Hydro Flattened DEM, Bottom LiDAR Point Cloud)

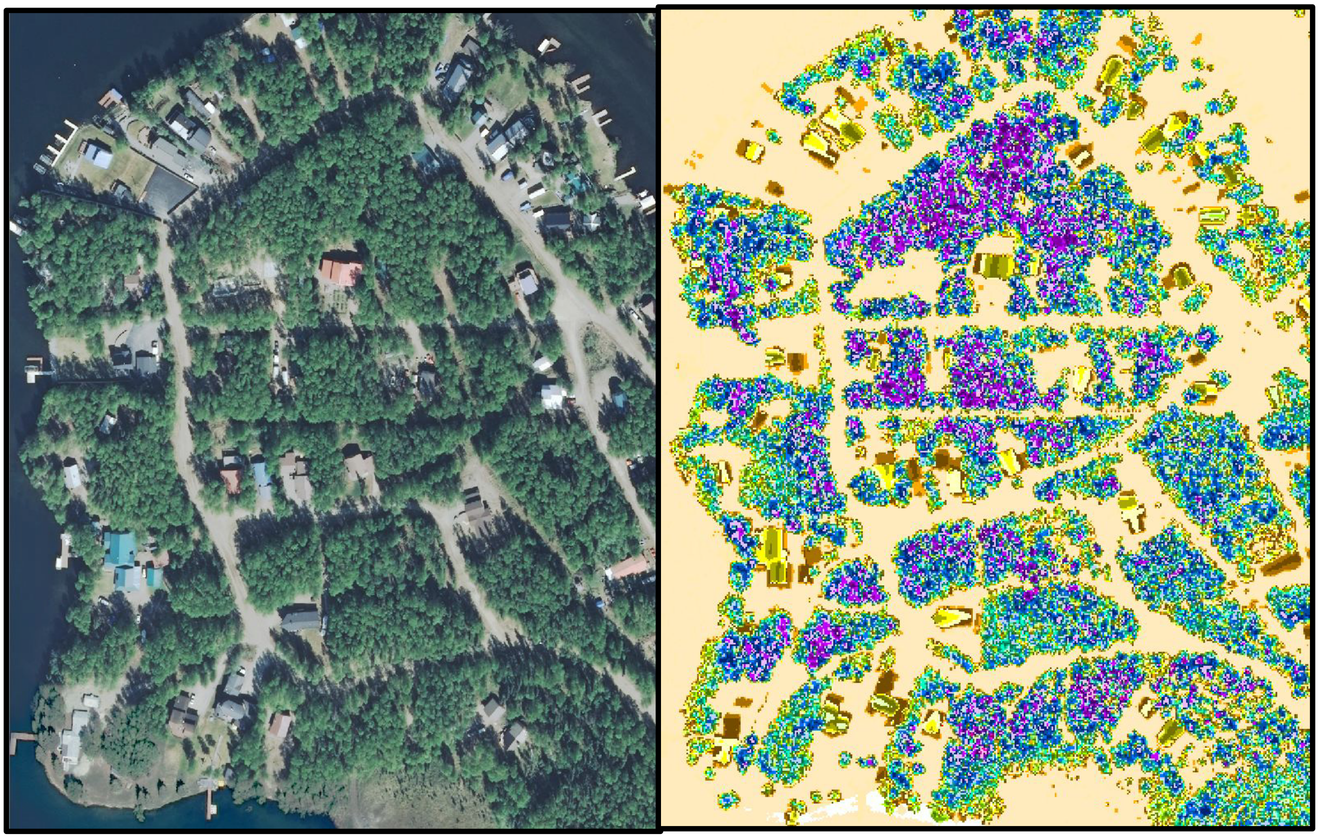


Figure 38, Building Analysis – Ortho vs. Canopy Height Classification.

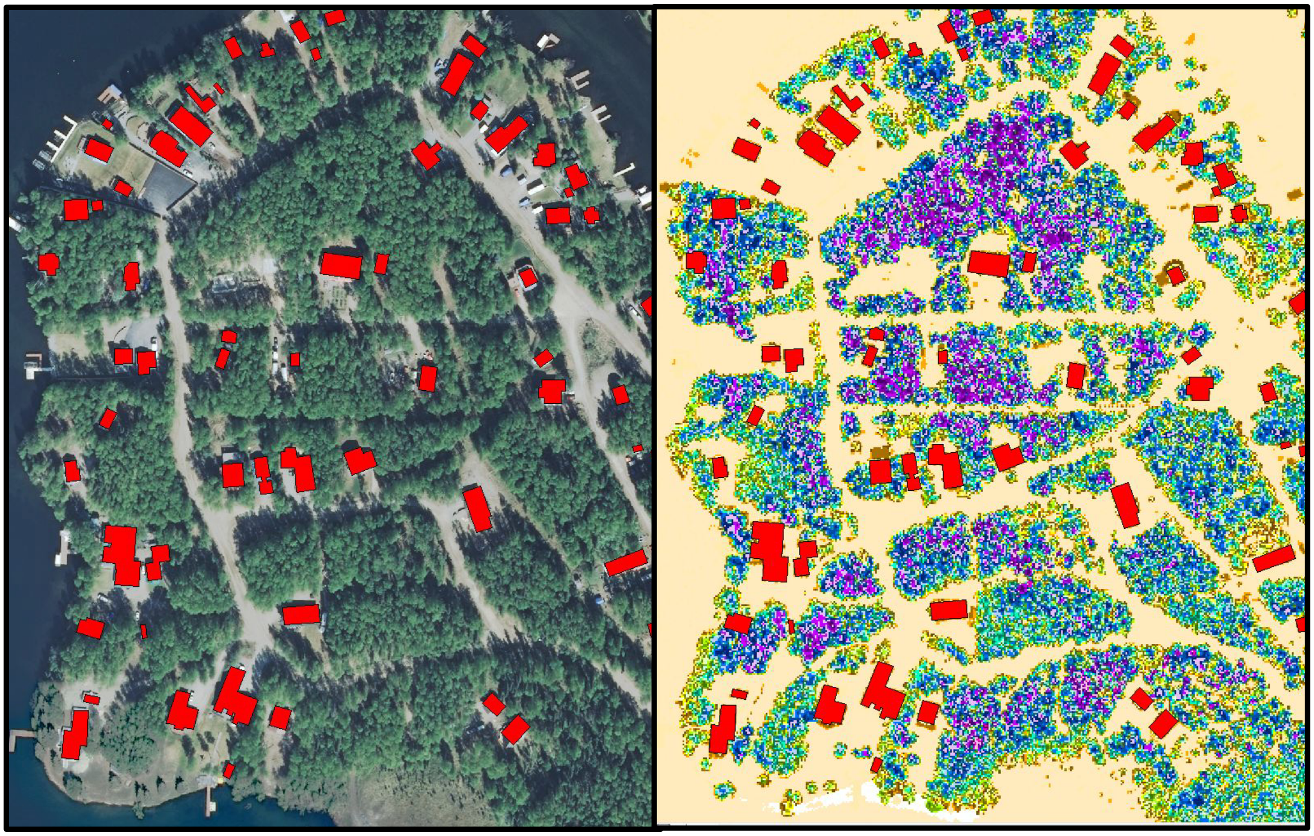


Figure 39, Building Analysis – Ortho vs. Canopy Height Classification with Building Footprint.

Figure 40, Building Analysis Results (Lt.Blue – Correct, Red – Incorrect, Dark Blue – Added)

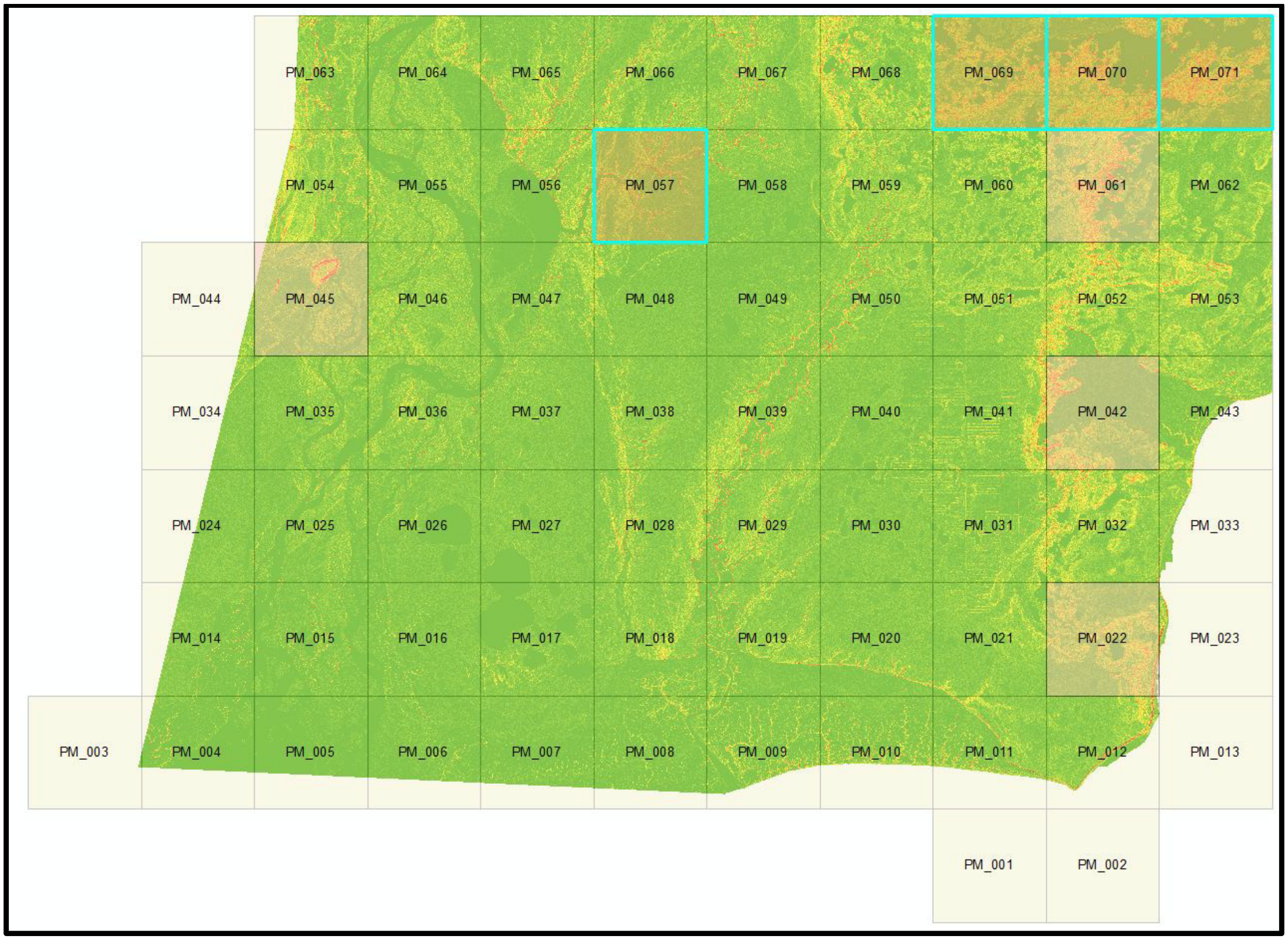


Figure 41, Degree Slope Selected Contour Tiles for Topology Testing.

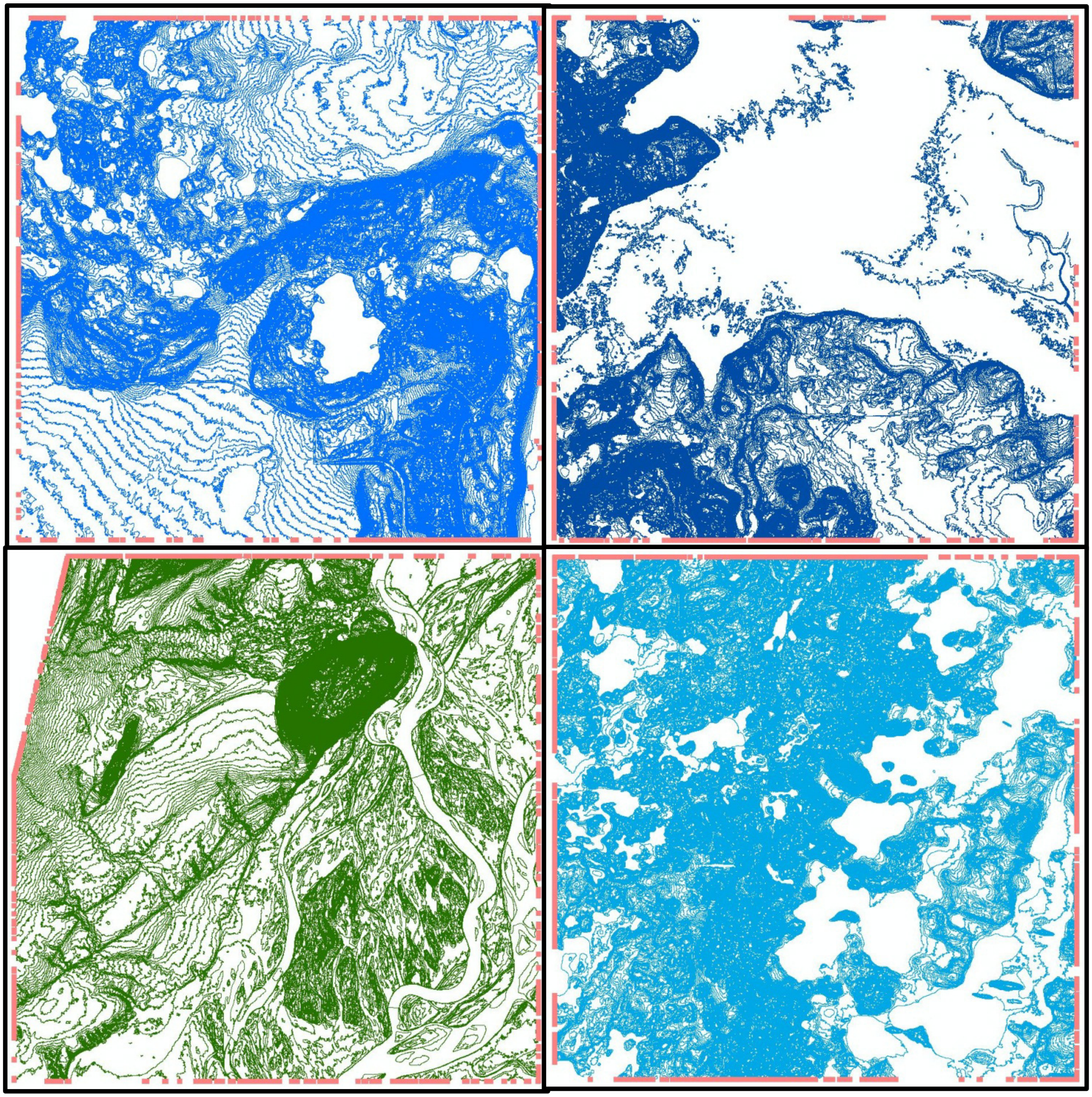


Figure 42, First Four Topology Checks .

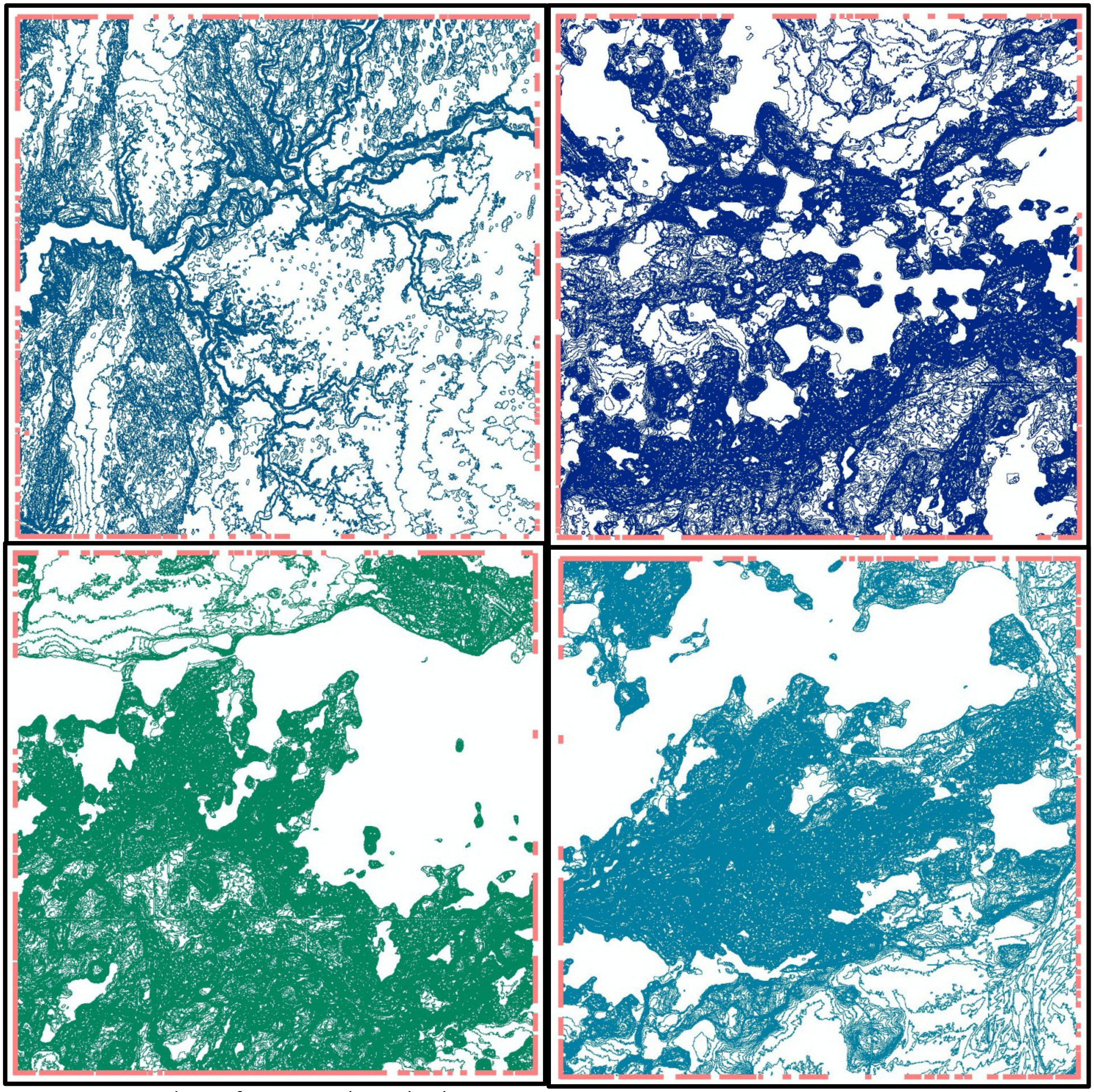


Figure 43, Second Set of Four Topology Checks.

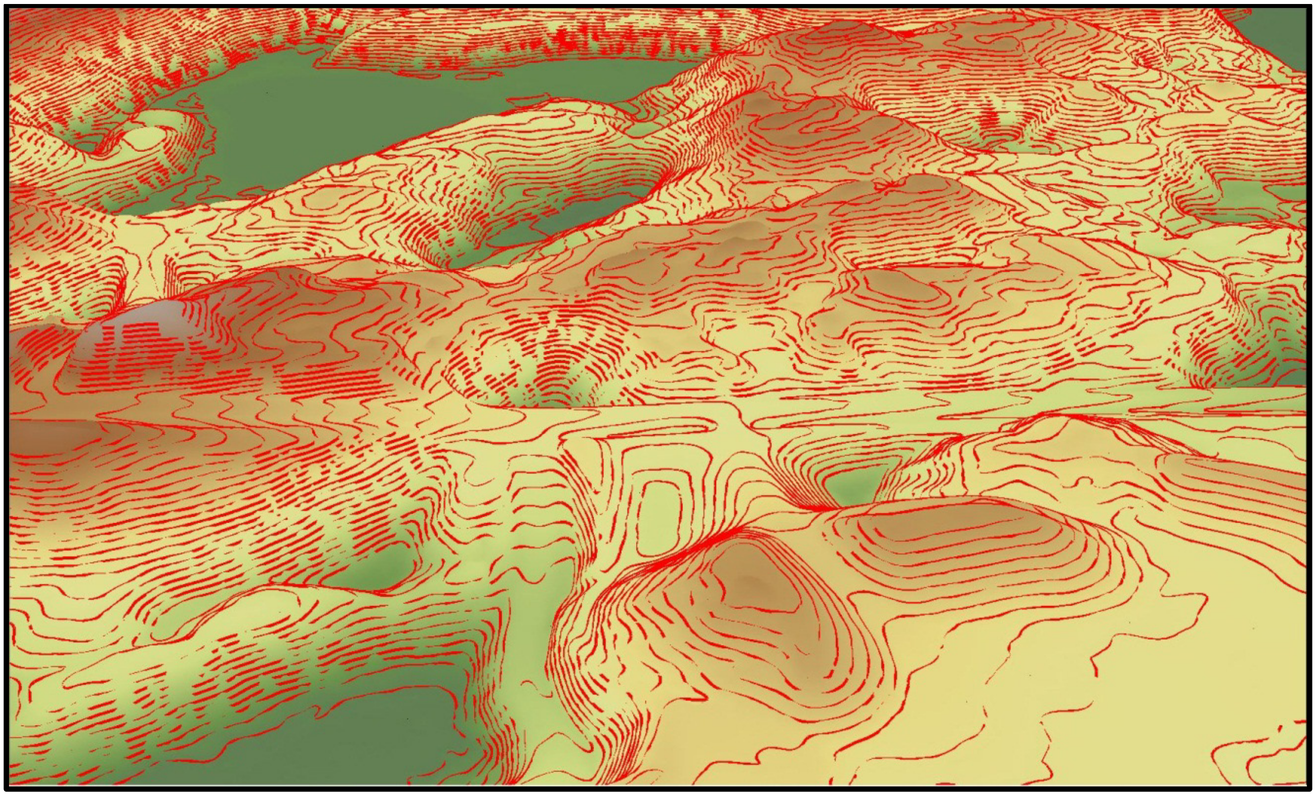


Figure 44, DXF Contour 3D Drape in QTM.

Delivery History and Reported Data Quality Issues

Delivery 1 & 2 - Aerometric delivered to UAF the first Point Mackenzie LiDAR data Oct. 21, 2011. This provided the LAS point cloud data so that UAF could start their evaluation. A second full delivery was received on Nov. 8, 2011 which included all LiDAR contract deliverables. Upon receipt of this complete delivery, we requested a copy of the corresponding ortho imagery for use in our quality assessments. UAF began its review of the LiDAR point cloud data with this first delivery and began reporting quality issues as problems were discovered. The following provides a brief description of each quality issue found in deliveries 1 & 2 and when they were reported.

Detected Seam in bare-Earth DEM – On 11/09/2011, an observed seam was reported when trying to mosaic bare-Earth DEM tiles. This seam was several pixels wide running west to East between two sets of tiles (see Figure 45).

Anomalies identified in single breaklines – On 11/10/2011, ten screen captures were provided to Aerometric identifying inconsistencies between single breaklines and either LiDAR intensity data or the bare-Earth DEM (see Figure 46-47). These were primarily over channels in the mud flats. After review, Aerometric decided to remove most of these breaklines because they were too difficult to determine accurately. The corrected hydro layers have very few breaklines in the mud flats (see Figure 48).

Anomalies in First Return DSM – On 11/11/2011, interpolation errors were observed in portions of the Little Susitna River (See Figure 49). In a true first return product, the LiDAR data should be evaluated on a cell by cell basis using the delivery grid as the basis for evaluation. All valid LiDAR returns (excluding points marked as withheld, class 1 and 7) should be evaluated for the highest return for that cell. For cells over water, there may not be a valid return for that cell, in which case the cell should be set to NoData. In discussion with Aerometric, they were using interpolation to fill holes over water which is undesirable. They were also using a gridding process that did not provide a true first return gridded product. After discussion, Aerometric was asked to change their processing methods to something that would provide a true first return product. This change was considered essential for a true canopy height product to be generated and for cross validation between gridded data and LiDAR point cloud data.

Detected Seams in LiDAR Intensity data – On 11/11/2011, observed seams were reported when trying to mosaic LiDAR Internsity data (see Figure 50). The seams were very obvious running from West to East and up to several pixels wide in places. After further investigation by Aerometric, they decided to use raster catalogs within the block geodatabase for all raster grids for future deliveries. This change eliminated the presence of seams in the data. It also was a much improved method for delivering raster data than what was initially used.

Clipping of Point Mackenzie Dock – On 11/11/2011, during visual assessment of the shaded relief product clipping of the Point Mackenzie dock was identified and reported (see Figure 51). An exception to the original block boundary was made to include the dock structure in both LiDAR intensity and first return DSM. This is an important structure that should be included in the resulting data. It should be noted that the original coverage requested by Matanuska-Susitna Borough GIS staff was the source of the error. Fortunately, the LiDAR coverage could be adjusted to cover the entire dock and breakwater.

Negative values in canopy height difference – On 11/22/2011, negative values greater than -1 foot was observed in two locations of the Point Mackenzie block (see Figure 52). One was in the Susitna River delta, which was attributed to tidal fluctuations. The other was an area near some agricultural fields. One of these errors was eliminated when the rigorous first return DSM product was generated (See Figure 53). For our evaluation, we expect noise levels to be on the order of plus or minus one foot. Any negative values greater than one foot are not real and should be eliminated in the data.

Low Vegetation not useful as initially defined 0-6 feet – On 11/23/2011, Aerometric was informed that the low vegetation class as initially defined with structures from 0-6 feet. There was no difference from the spatial extent of low vegetation and ground classes (See Figure 54). Given an accepted noise level in the data of one foot, UAF suggested that they redefine low vegetation as 1 to 6 feet. This should define a tighter spatial extent than ground and actually be useful, instead of redundant.

Delivery 3 - Aerometric delivered to UAF a third delivery disk on 12/14/2011. This disk included both Point Mackenzie and Willow blocks. It also combined both LiDAR and ortho imagery for the two blocks. This delivery was to address all of the reported quality issues to date. The following provides a brief description of each quality issue found in deliveries 3 and when they were reported.

Raster layers in block Geodatabase had no defined coordinate systems – On 12/16/2011, UAF reported that the bare-Earth and First-Return raster catalogs had unknown spatial reference. This was easily fixed in ArcCatalog by defining the spatial reference as NAD_1983_StatePlane_Alaska_4_FIPS_5004_Feet. We requested that Aerometric make sure that all layers have a defined spatial reference in future deliveries.

LiDAR Intensity has non-square pixel – On 12/16/2011, UAF reported the LiDAR Intensity data having a non-square pixel with dimensions of 3.2807999999999991 x 3.2808. This was discussed and Aerometric attributed this to the precision of ESRI software and how it handles round off. Matanuska-Susitna Borough finally decided that this was acceptable and no change was needed.

LiDAR intensity boarder not set to NoData - On 12/16/2011, UAF reported that fill values outside the block boundary were set to 249 or white and 0 or black (See Figure 55). UAF requested that these should be set to NoData to be similar to the bare-Earth and First-Return gridded products.

First-return in meters instead of feet - On 12/16/2011, UAF reported the new first-return DSM had a very different height range from the bare-Earth DEM. It looked like the first-return DSM was in meters instead of feet causing the very different elevation range.

Inconsistencies in Low Vegetation – On 12/19/2011, UAF reported several inconsistencies in the low vegetation class. There were four tiles over ocean that incorrectly included low vegetation in water (PM_033_NE, PM_043_SW, PM_043_NE, PM_009_SE). There was one tile which did not include low vegetation where it should (PM_009_SW). There were points along a line or breakline (PM_004_SE, PM_004_NE). There was a missing river section (PM_046_NE) and a missing lake section (PM_070_NE).

Bare-Earth DEM needs to be trimmed to block boundary – On 12/20/2011, UAF reported bare-Earth tile PM_063 needs to be trimmed to the block boundary (see Figure 56). With data extending beyond the block boundary, it made for large differences to be detected when subtracting the bare-Earth DEM from the first-return DSM. UAF encouraged Aerometric to produce and deliver a block boundary layer with its tile grids in future deliveries.

Contour topology errors – On 12/28/2011, UAF reported three tiles (PM022, PM042, and PM045) with contour topology errors (See Figure 57-59). This was determined after testing four tiles that contained the largest slopes and topology rules that were supplied by the Matanuska-Susitna Borough staff including: must not overlap, must not intersect, must not have dangles (except at tile edges), and must be single part.

Class 1 Unclassified point counts too high – On 12/30/2011, UAF reported point counts for unclassified (class 1) is larger than all other classes combined. The Matanuska-Susitna Borough GIS staff indicated that class 1 was in violation of the requirement to classify all LiDAR data according to the contract. In further discussion with Aerometric, it was learned that class 1 contained ends of swath data that was marked as withheld and surface clutter data that ranged from 1 to -1 feet of the surface. A compromise was reached asking Aerometric to create a new class 13 to contain the surface clutter data, and keeping the swath ends in the unclassified (class 1). This change made it easier to access either data given the separation into two different classes. It also made point density validation easier, allowing exclusion of class 1 and 7 from the point density counts.

Topology Error in breaklines – On 01/19/2012, UAF reported topology errors being detected in breaklines. UAF asked Aeometric to also test breaklines for topology errors prior to delivery.

Request for Metadata – On 01/25/2012, UAF requested Aerometric to provide metadata for Point Mackenzie and Willow blocks.

Delivery 4 - Aerometric delivered to UAF a fourth delivery disk on 12/08/2012, which provided fixes to all data quality issues reported to date. The disk provided only LiDAR data for Point Mackenzie block. Prior to this delivery, a list of issues was provided to Aerometric to verify that fixes were made for all identified data quality issues. Soon after the delivery was made, UAF reported confirmations to many of the reported data quality issues. The following provides a brief description of each quality issue found in deliveries 4 and when they were reported.

First-return pixel dimensions non-square – On 02/09/2012, UAF reported the latest first-return DSM had non-square pixel dimensions of 3.28079999999995 by 3.2808. I also reported that the bare-Earth DEM did have a consistent square pixel dimension. Similar to the LiDAR Intensity grids, this was thought to be an ESRI issue of round off. Aerometric assured us that they created the products with consistent pixel dimensions of 3.2808 by 3.2808.

Delivery 5 – Aerometric delivered to UAF a fifth delivery disk on 03/06/2012 containing LiDAR data for Point Mackenzie, Willow, and Caswell Lake blocks. For Point Mackenzie block, this delivery included fixed point cloud data that separated class 1 into class 1 and 13. It also included metadata for the block which was not provided previously. The following provides a brief description of each quality issue found in deliveries 5 and when they were reported.

Metadata not FGDC compliant – On 03/08/2012, UAF reported a number of metadata errors reported by the USGS MP software for checking FGDC format compliance. A summary of the errors detected was produced and supplied to Matanuska-Susitna Borough and Aerometric.

Low Vegetation errors – On 03/28/2012, UAF reported additional low vegetation errors that should be fixed (See Figure 60- 62). These include: the northern extent of cook inlet still has low vegetation over water (PM043), a block section of the Susitna River water classified as low vegetation (PM046NE and PM047NW), and a section of Big Lake that is classified as low vegetation (PM070).

Delivery 6 – Aerometric delivered to UAF by FTP on 03/29/2012 fixes to the requested tiles of new LAS point cloud data to fix the low vegetation errors that were reported. **This final delivery of data completed the final corrections that were needed for acceptance of the Point Mackenzie block.**

After the initial acceptance of this block, the data were delivered to USGS for review for inclusion into the National Elevation Dataset (NED). USGS identified some minor tinning issues in the hydro flattening of heavily braided streams that they considered unacceptable for inclusion into the NED. As a result, breaklines for hydro flattening, DEMs, and bare earth hillshades had to be reprocessed and redelivered for additional QC procedures. Deliveries 7 & 8 were a result of this unforeseen issue.

Delivery 7 – Aerometric delivered to UAF a fifth delivery disk on 02/07/2013 containing redelivery for Point Mackenzie block. This final delivery was required to fix some tinning issues that USGS found in the hydro flattened DEM that needed to be fixed to meet National Elevation Data (NED) requirements. The delivery included gridded bare-Earth DEM, gridded first return DSM and updated hydro layers.

Lake Height Error – On 2/11/2013, UAF reported a bad lake height that differed between first return DSM and bare earth DEM by -97 feet (PM_068_DEM). This was observed in the canopy height classification as red and also showed up in the shaded bare earth DEM (See Figure 63).

Delivery 8 – Aerometric staged to their ftp, a corrected bare earth DEM and shaded relief tile for PM_068_DEM.

On 2/11/2013, UAF completed verification of recently delivered fixes. **As a result, Point Mackenzie block passed the second and final quality assurance screening for submittal, to USGS.**

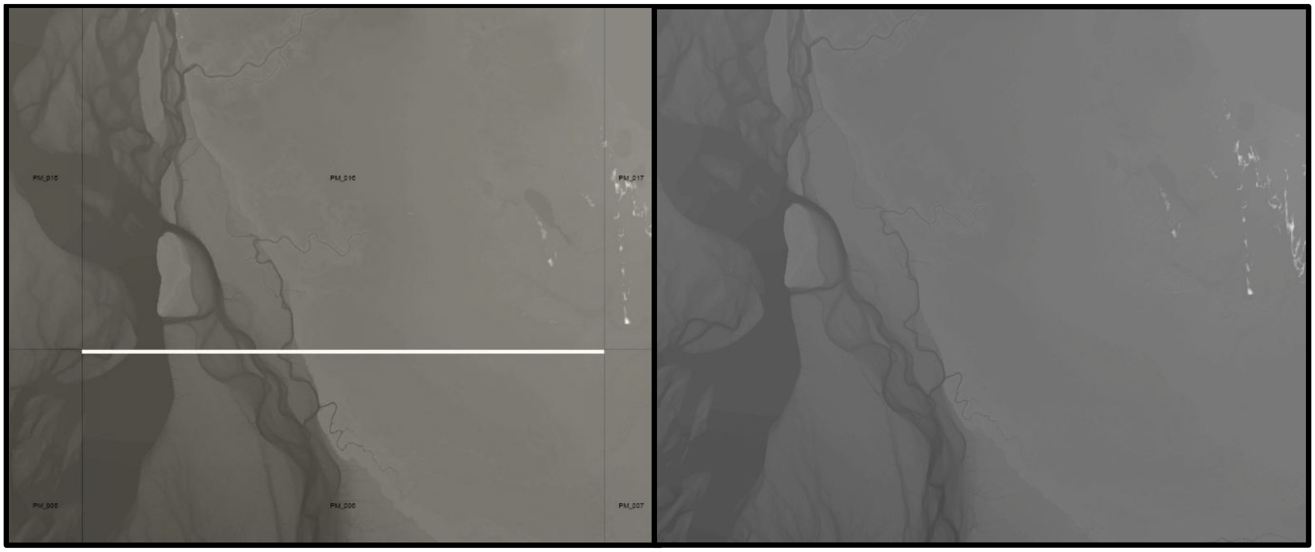


Figure 45, Seam in Bare-Earth DEM (Left) Corrected (Right).

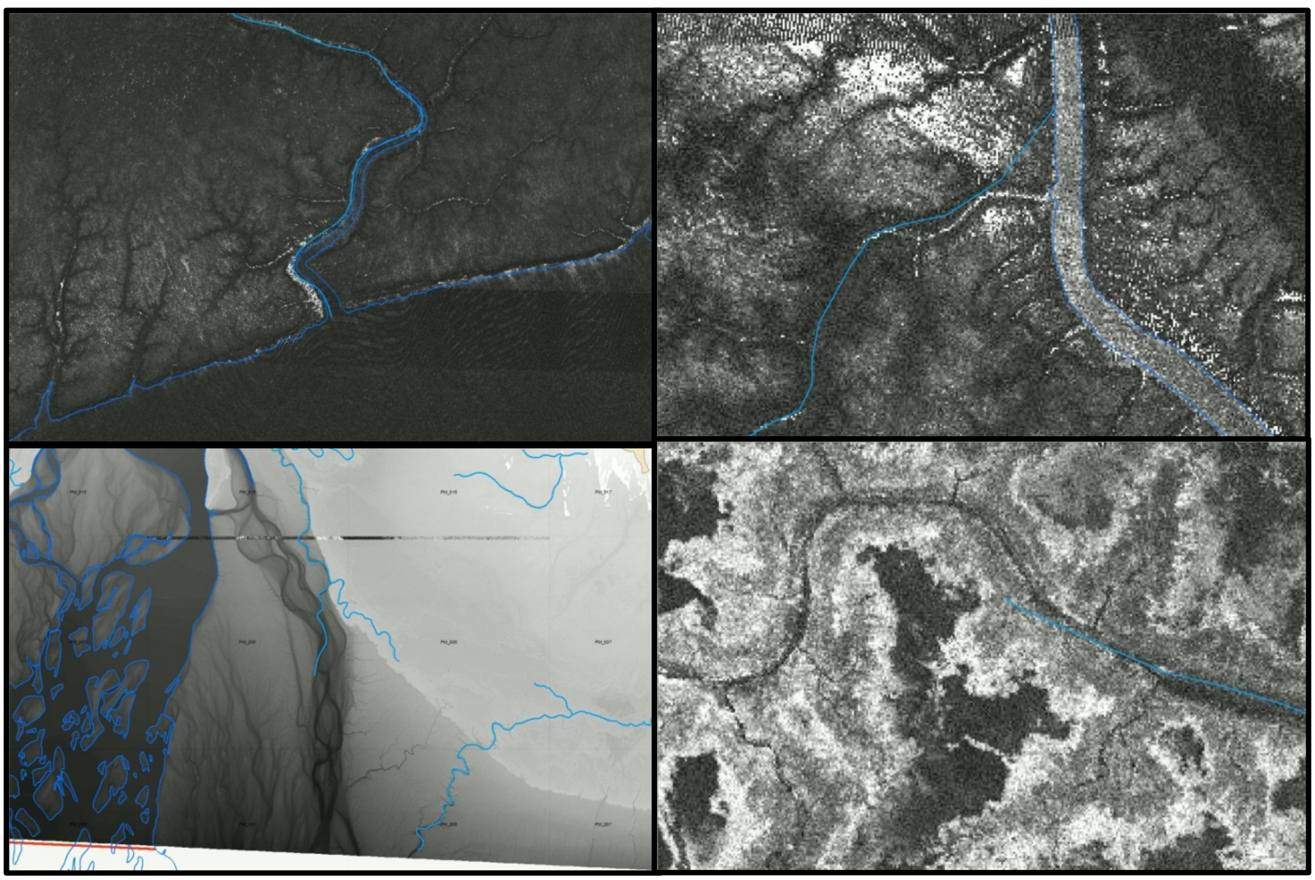


Figure 46, Single Hydro Breakline Inaccuracies.

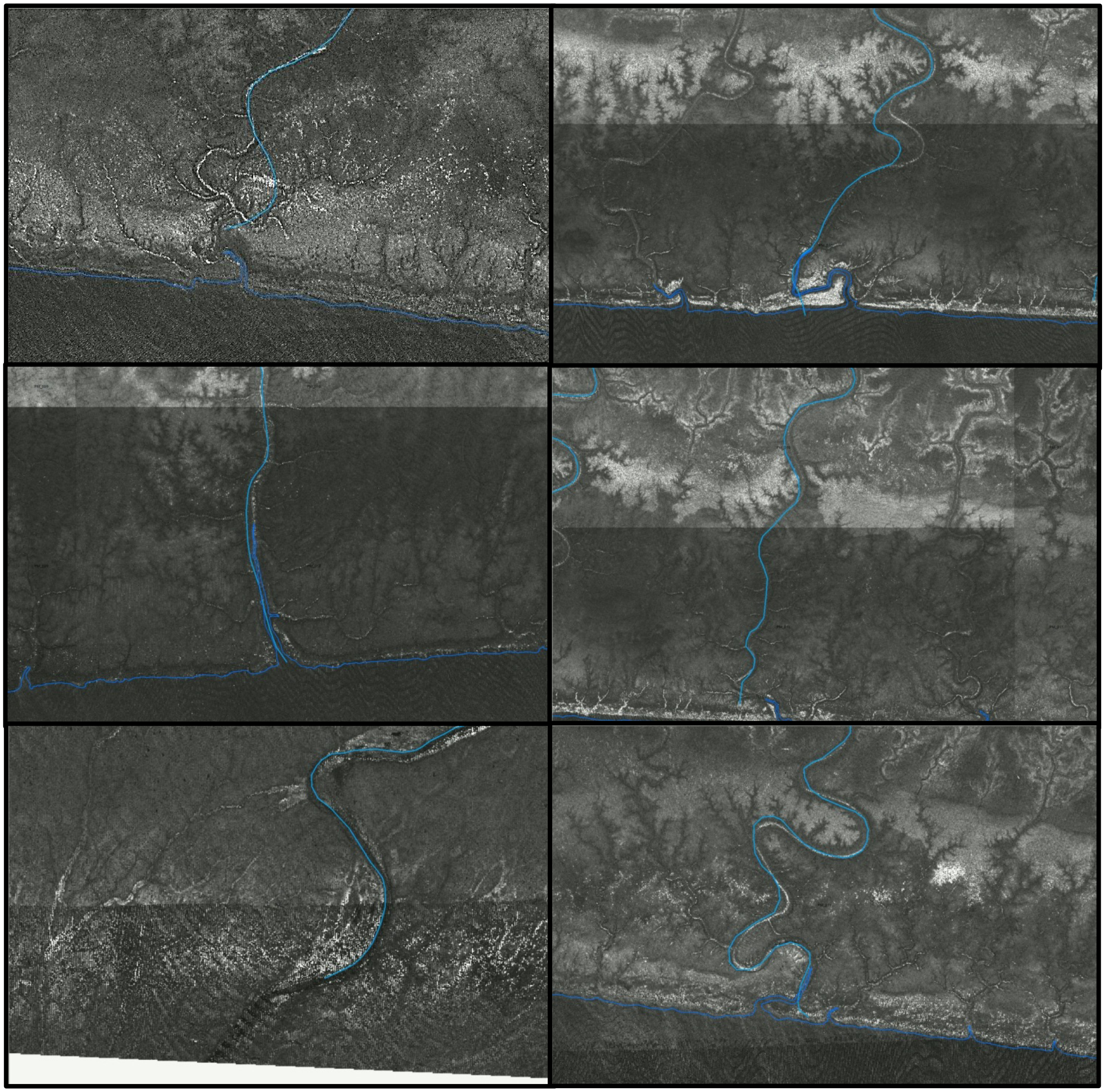


Figure 47, Single Hydro Breakline Inaccuracies.

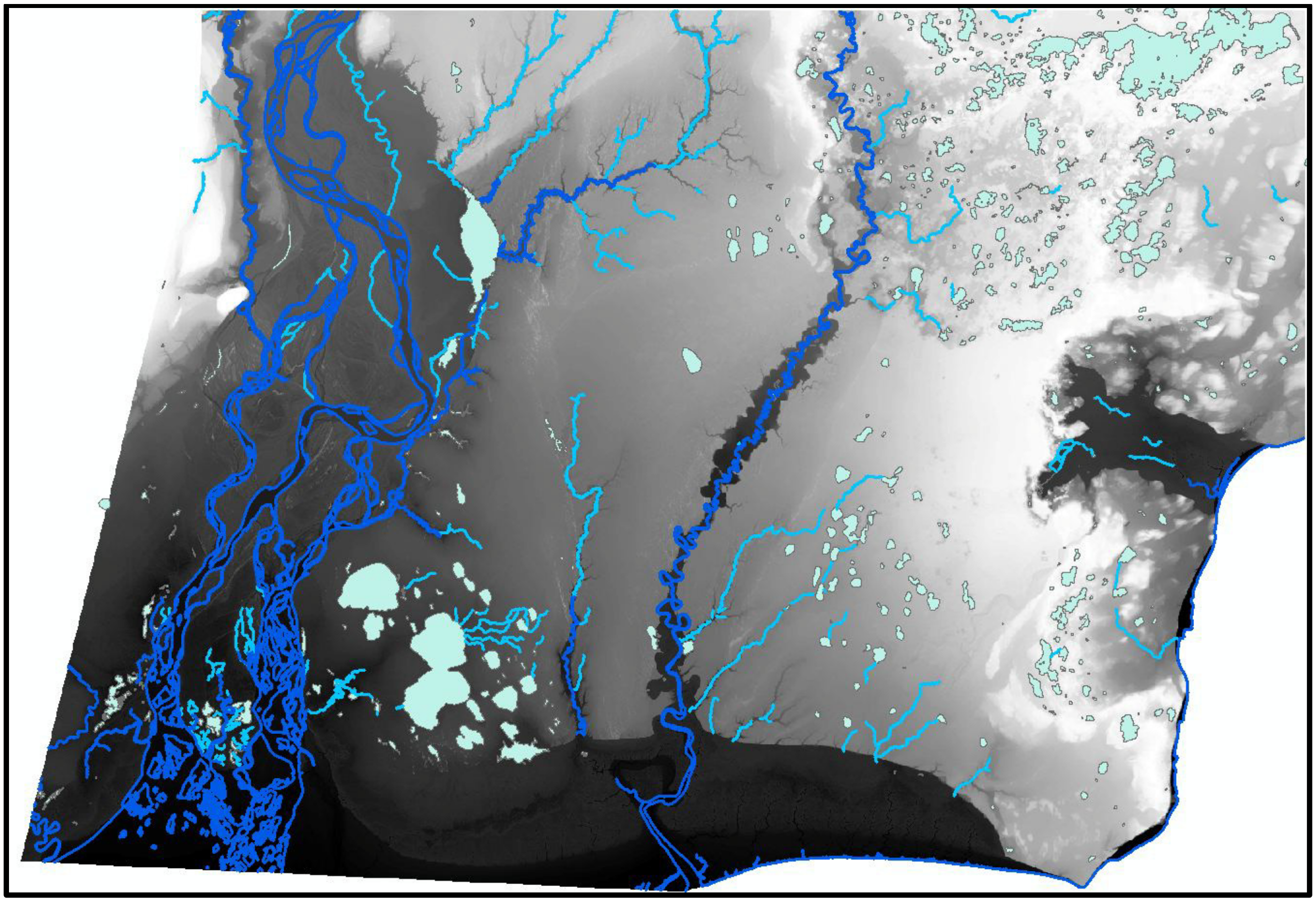


Figure 48, Corrected Hydro GIS Layers.

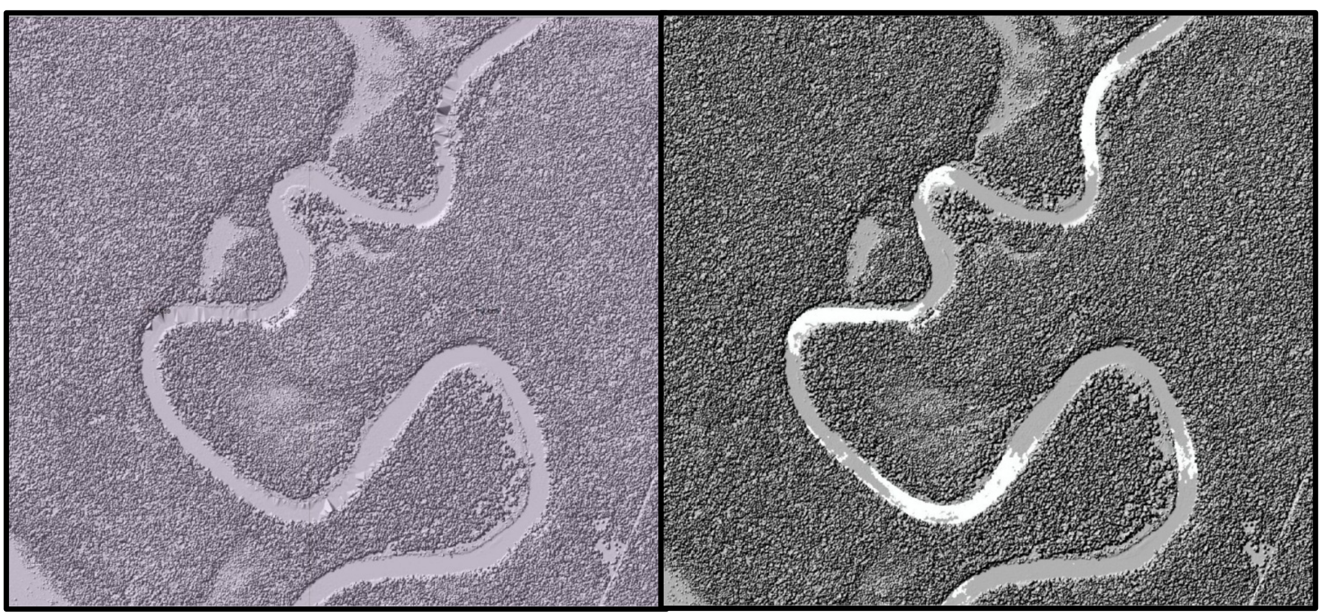


Figure 49, Interpolation Artifacts in First-Return DSM (Left), Corrected (Right).

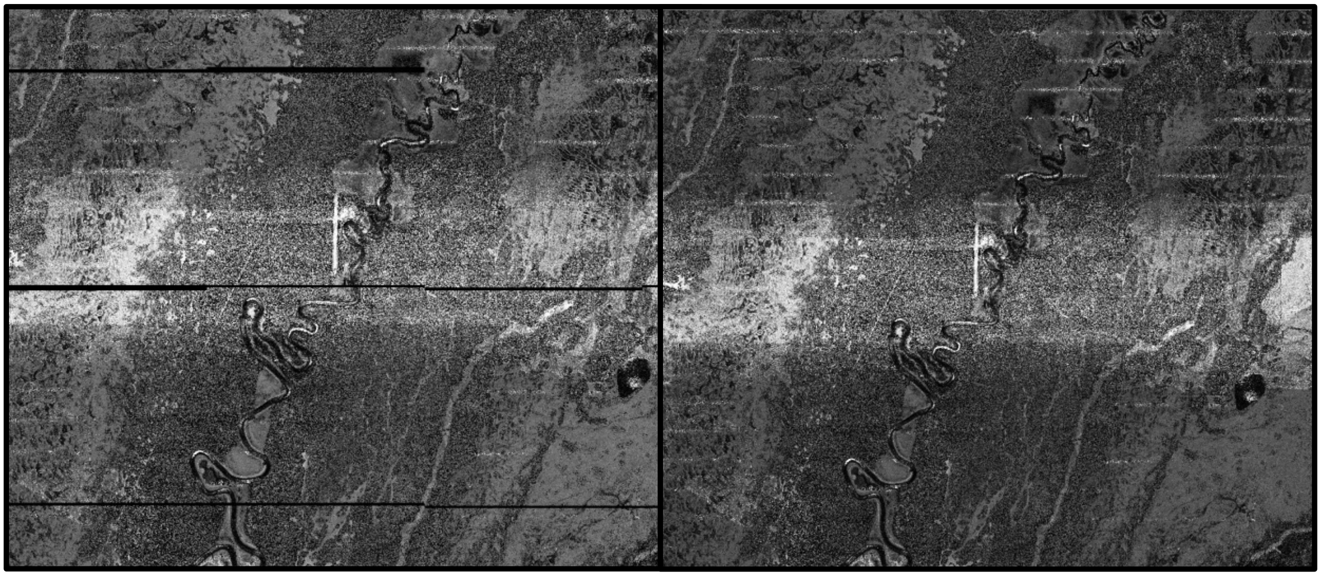


Figure 50, Seams in LiDAR intensity mosaic (Left), corrected (Right).

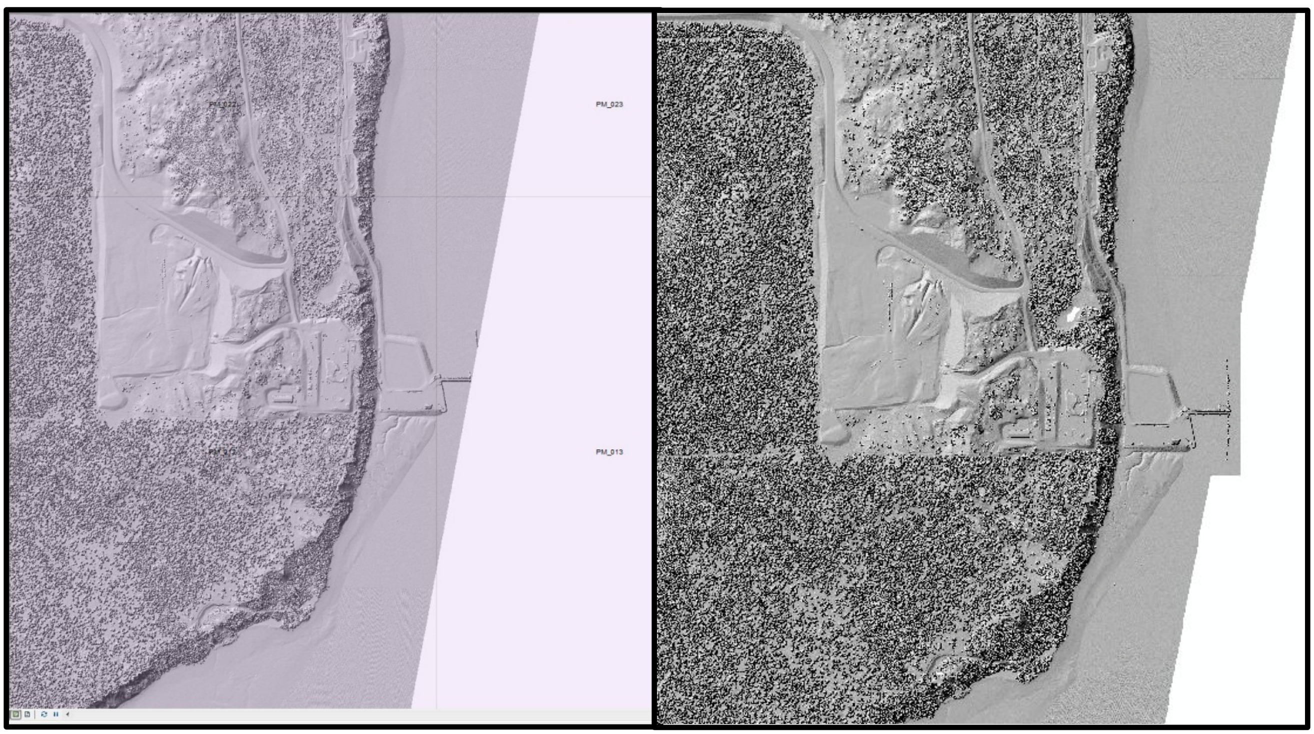


Figure 51, Coverage Gap (Port) in First Return (Left), Extended (Right).

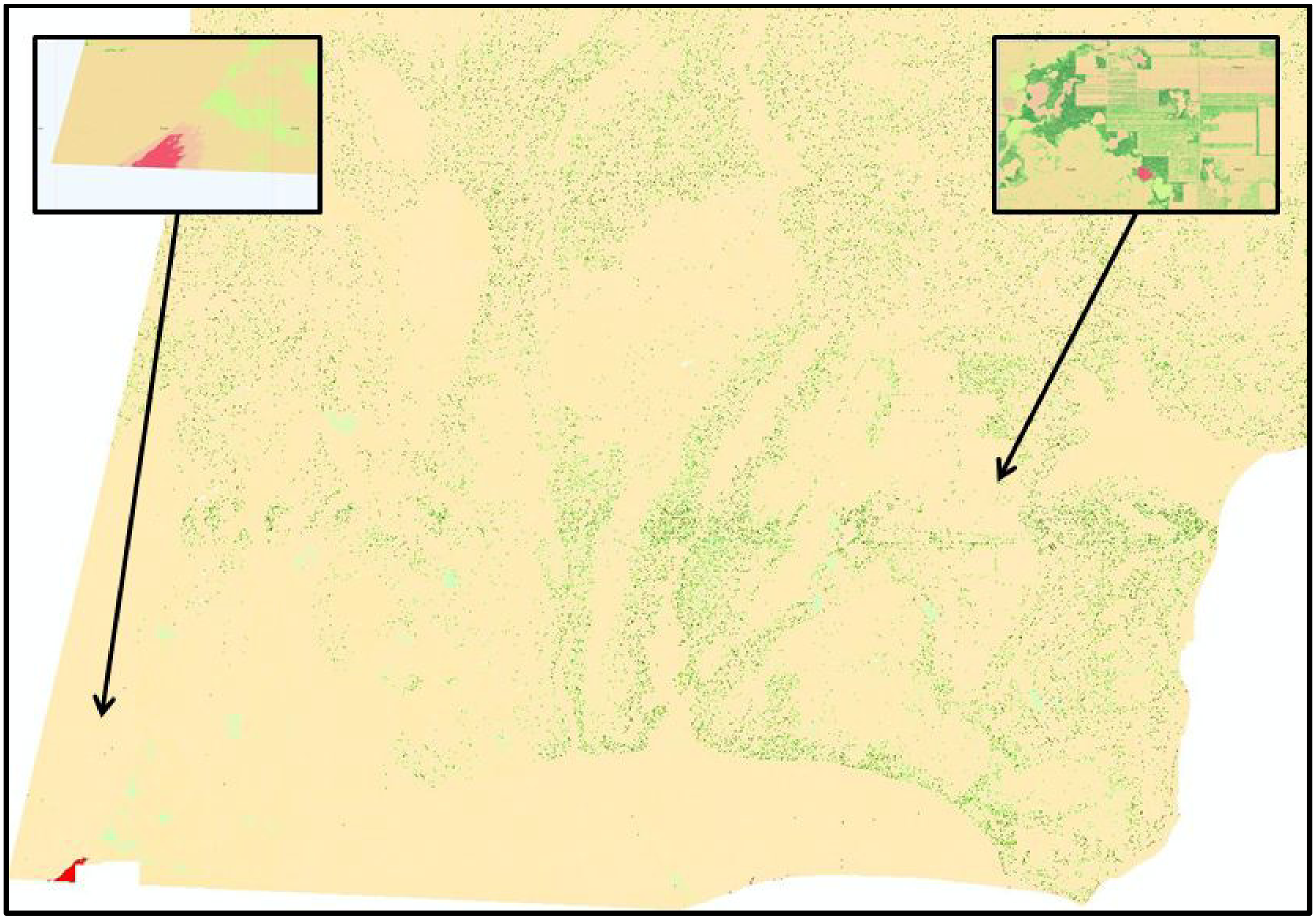


Figure 52, Canopy Height – FR minus BE, Regions of negative values over -1.

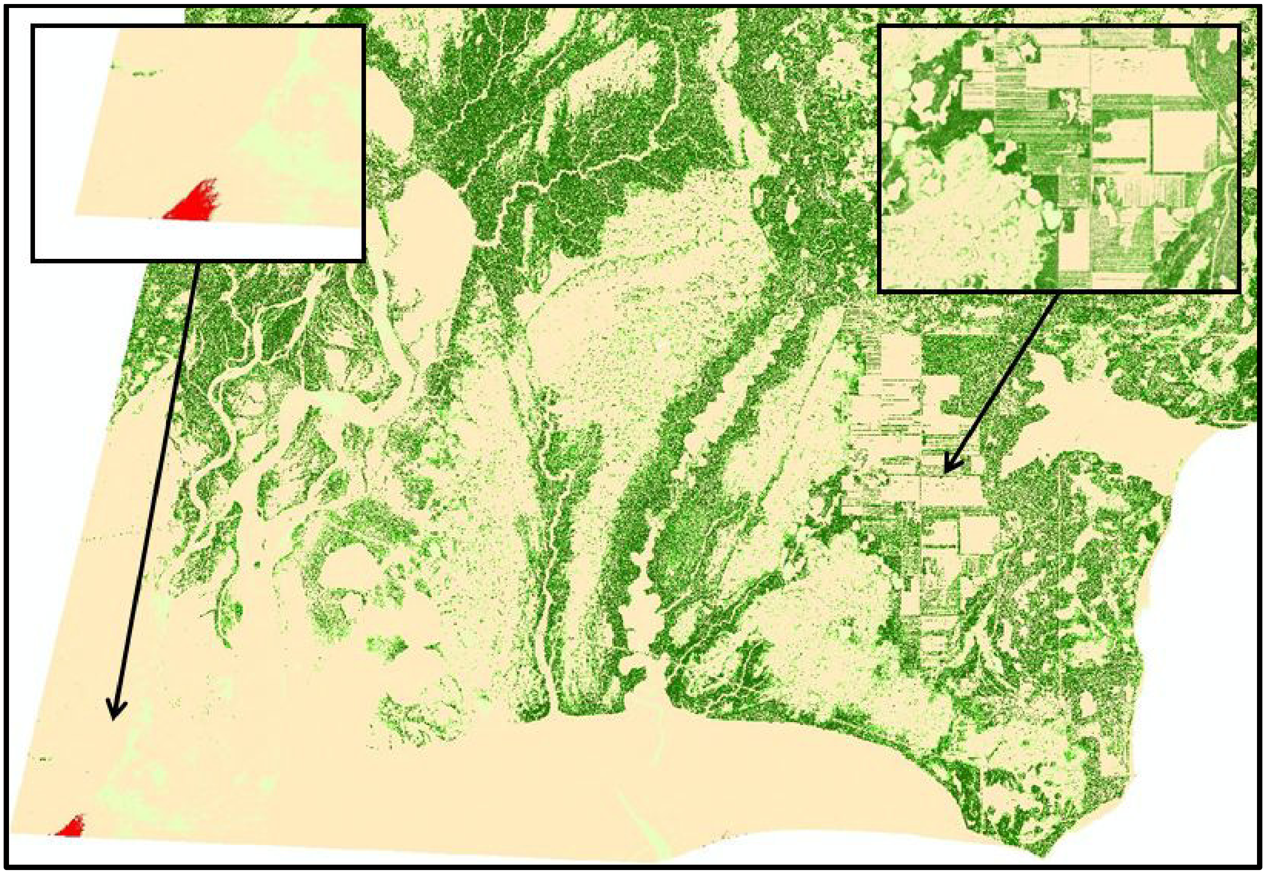


Figure 53, Corrected Canopy Height, Regions of negative values over -1.

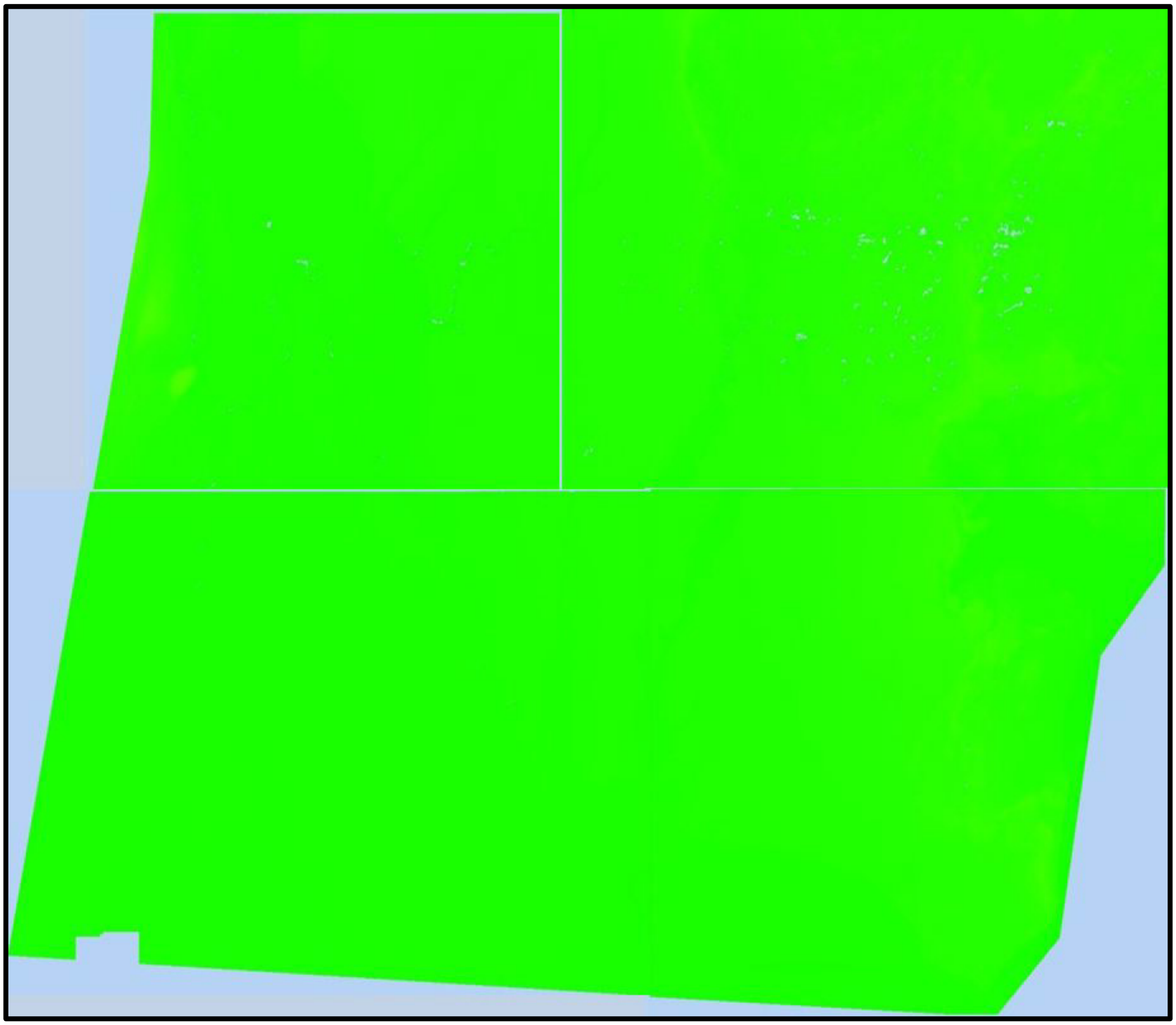


Figure 54, Initial low vegetation class not as useful at 0-6 feet because it includes ground noise.

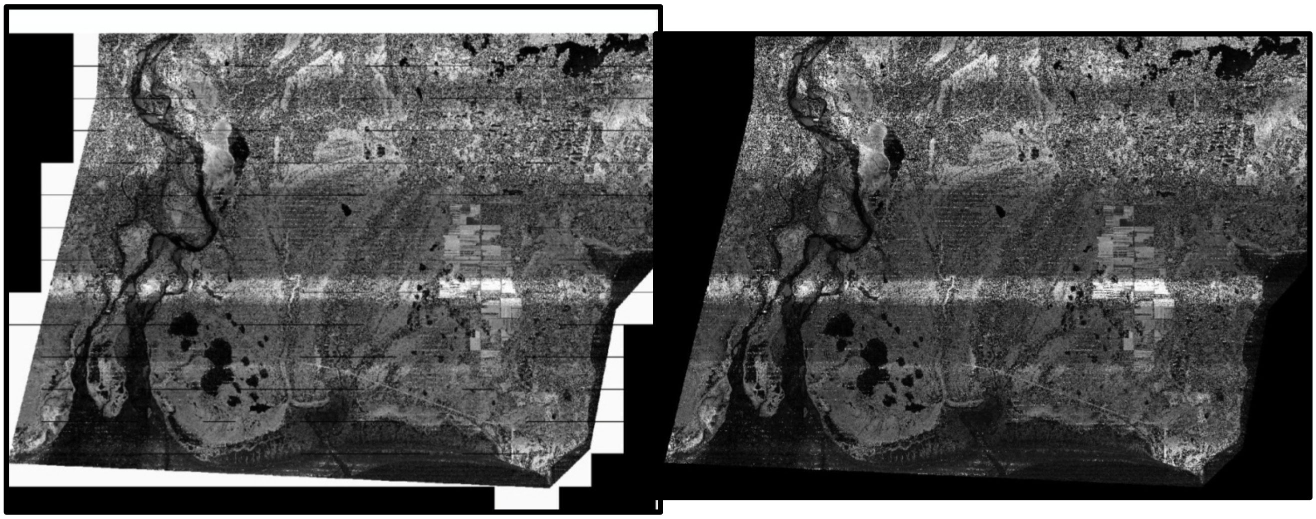


Figure 55, Fill values around good data inconsistent (Left), corrected (Right).

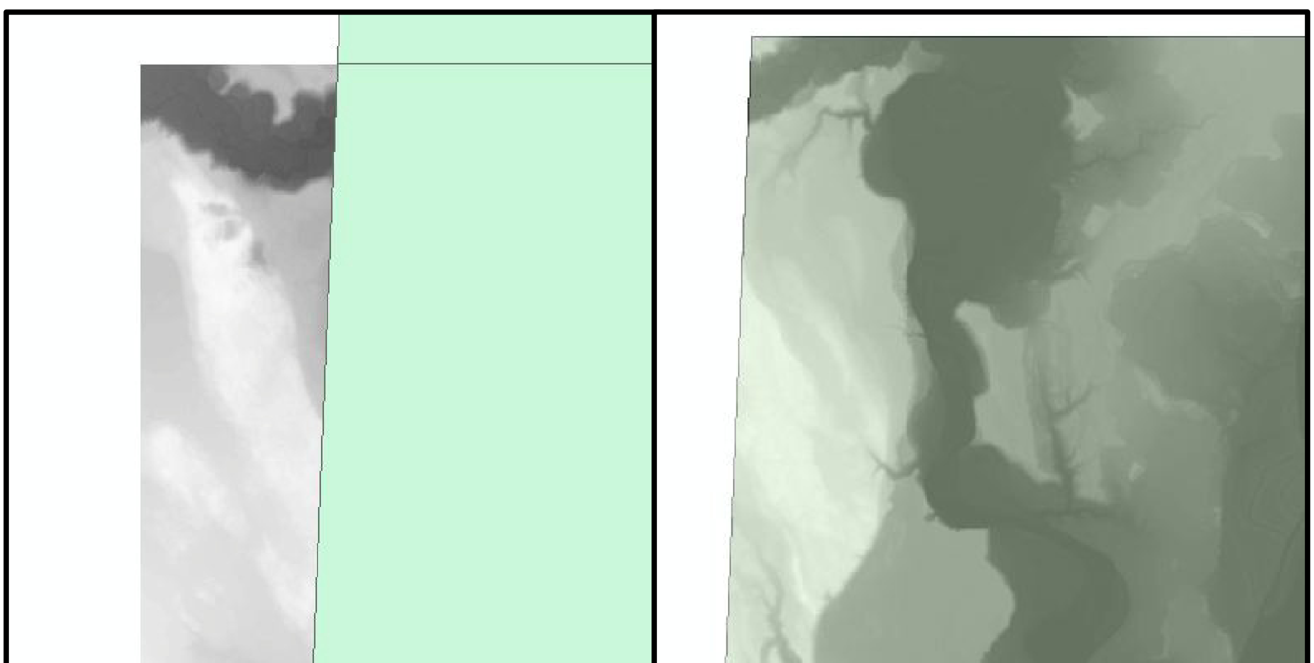


Figure 56, Bare-Earth DEM needs trimming (Left), corrected (Right).

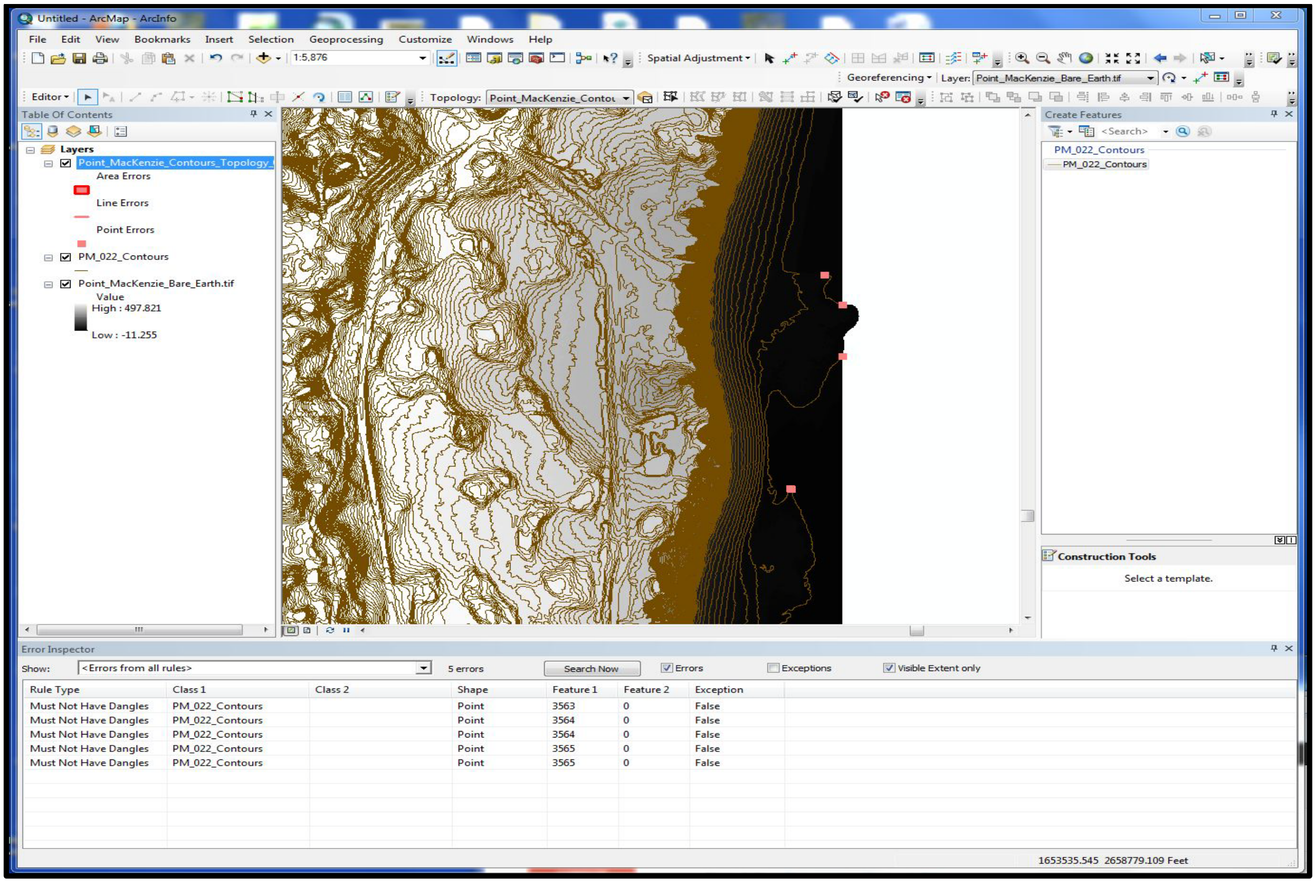


Figure 57, Topology Errors in Contours (PM022).

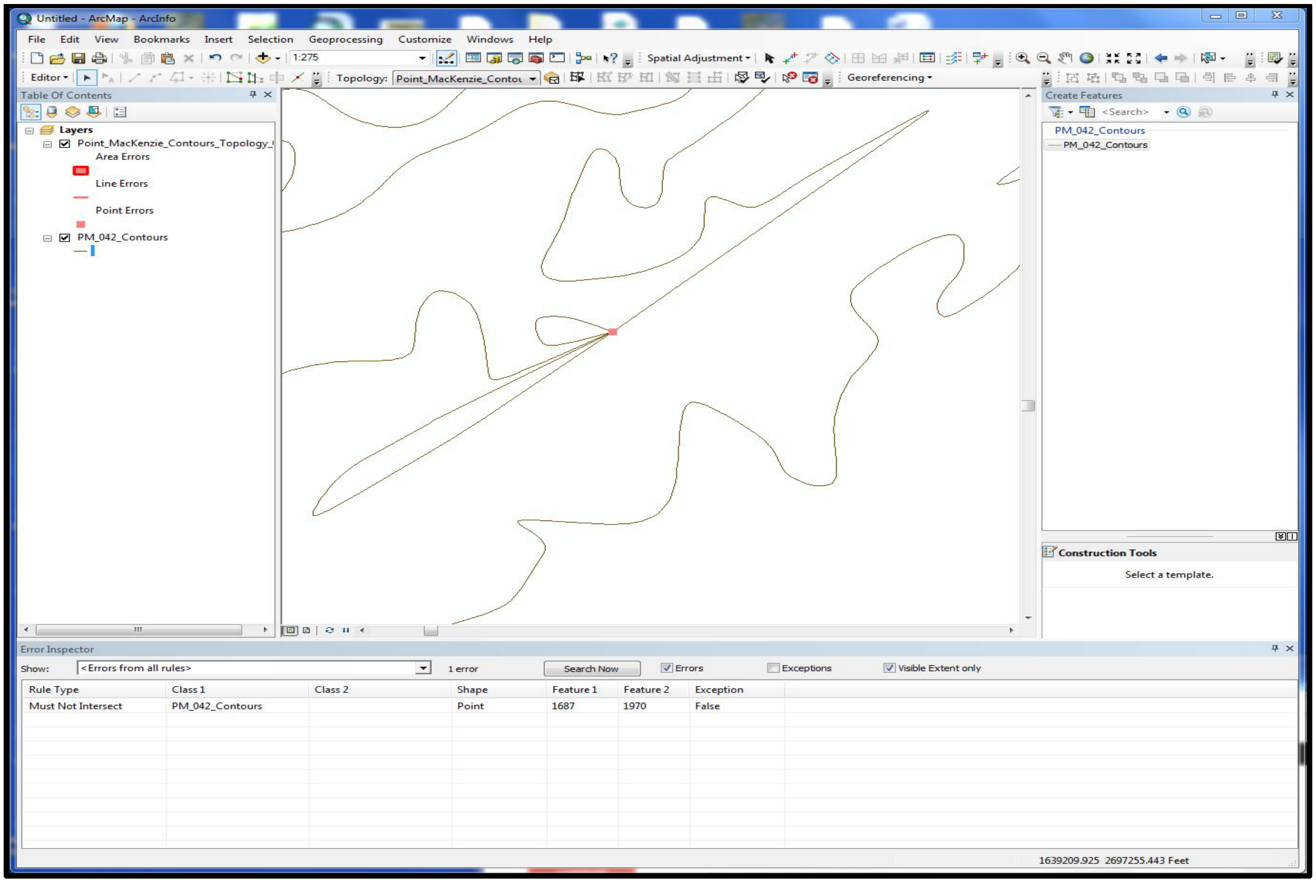


Figure 58, Topology Errors in Contours (PM042).

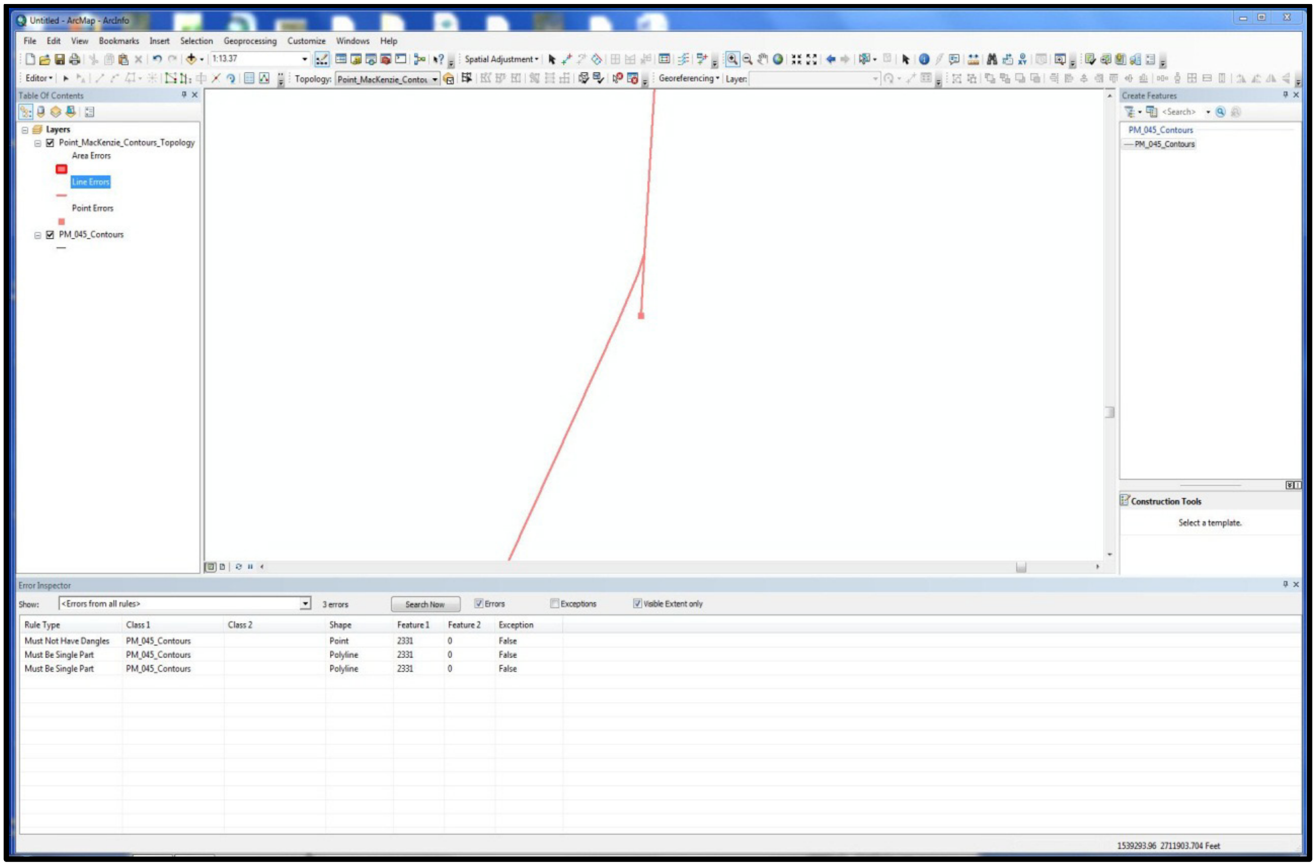


Figure 59, Topology Errors in Contours (PM045).

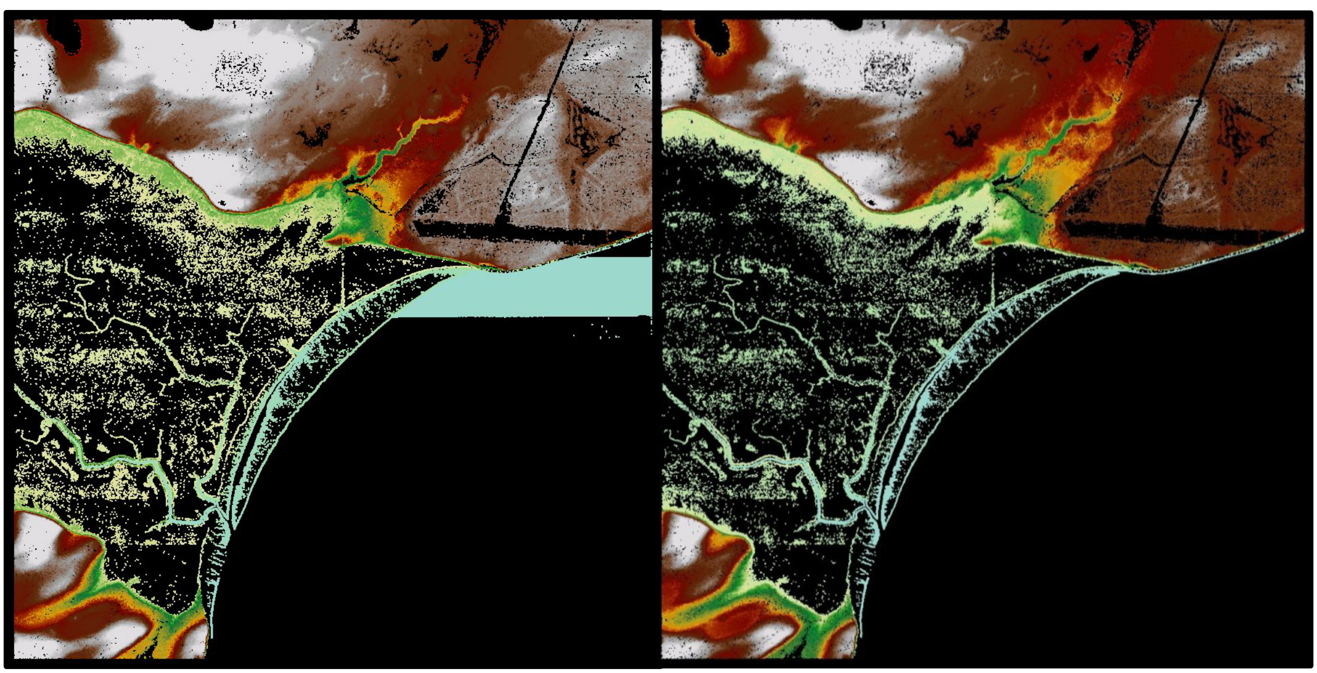


Figure 60, Low vegetation (PM043) Left, corrected Right.

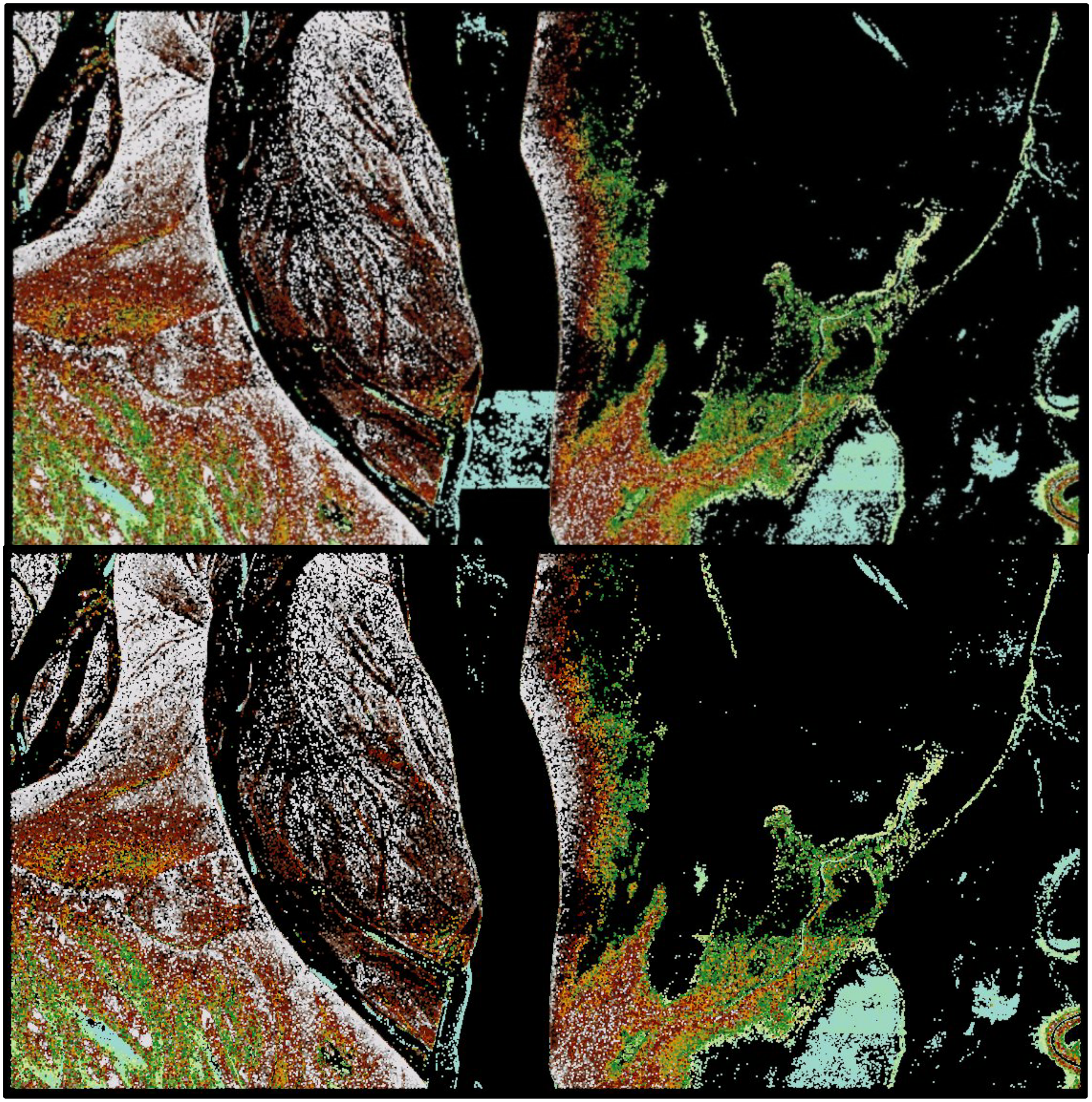


Figure 61, Low Vegetation (PM046-47) Top, corrected Bottom.

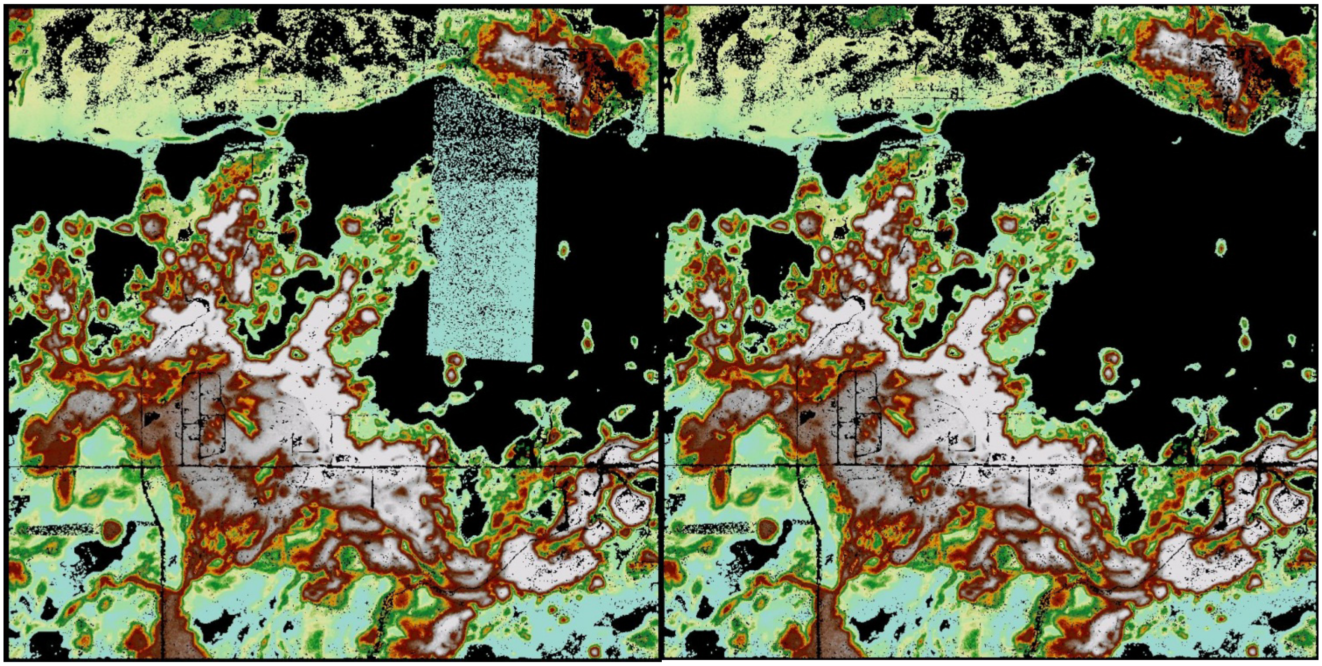


Figure 62, Low Vegetation (PM070) Left, corrected Right.

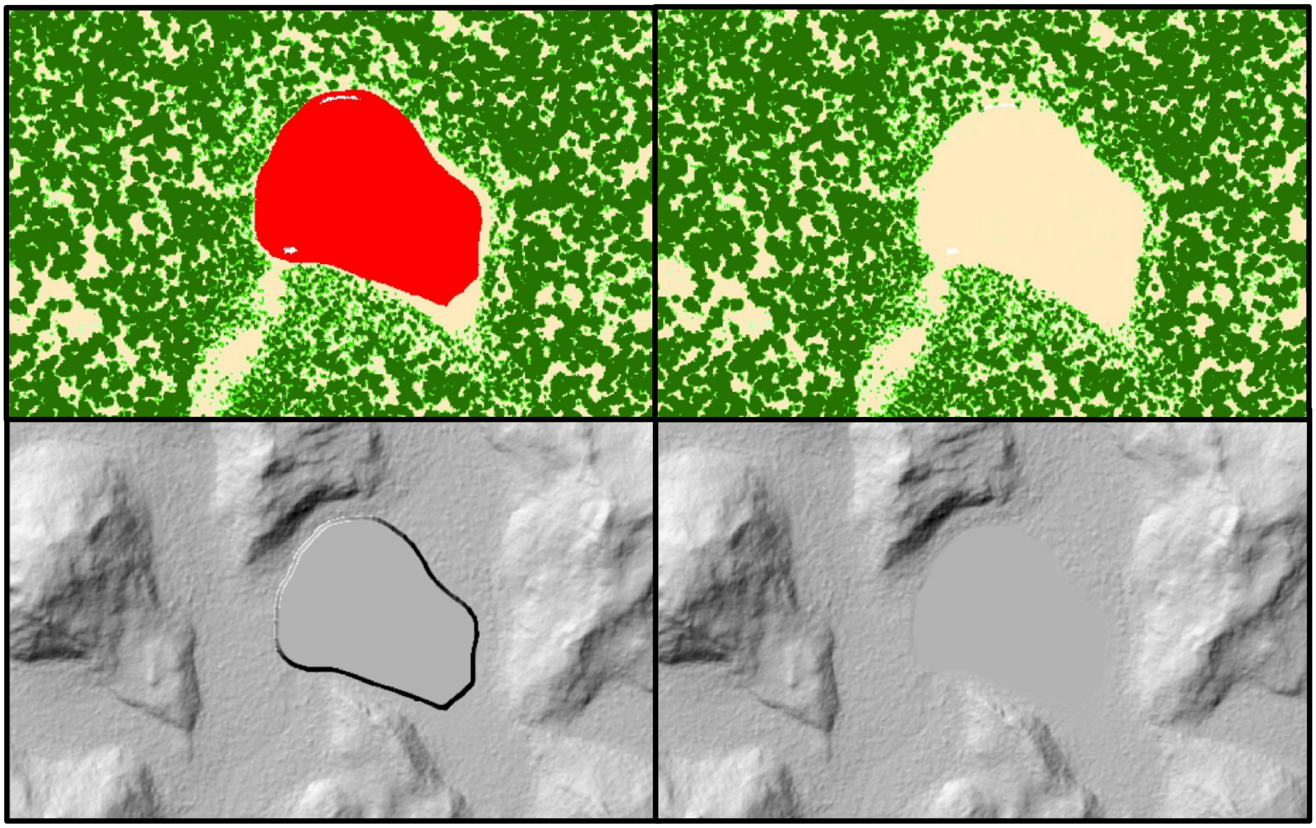


Figure 63, Lake Height Error (PM068) Left, corrected Right.