Refinement of Topographic Lidar to Create a Bare Earth Surface

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Refinement of Topographic Lidar to Create a Bare Earth Surface

Introduction

Topographic lidar is a form of high-resolution, high-accuracy elevation data that is collected aerially. When the data set is collected, points are returned that indicate both the height of the land surface and the height of objects on the land surface, such as buildings and houses. For applications such as storm surge and flood modeling, a digital elevation model (DEM) that only uses points that hit the ground is necessary for showing water flow during an event. This surface, known as a "bare earth surface," shows the land surface and interpolates across areas where no bare earth points are found. Objects such as bridges, trees, and piers often look and act like walls and impervious obstructions in the model, which can change the speed, direction, and flow of the water; these objects must be removed from the bare earth surface. The process of removing points, or the features they represent, from lidar data is the subject of this paper.

Many lidar data collections are "classified," meaning the points are categorized according to the surface they strike (e.g., ground, not ground, water). For these data sets, it is relatively simple to create a bare earth surface. The user simply selects the bare earth points and creates a grid using an appropriate software package.

For unclassified data sets, the process is a bit more challenging. There are two main steps to refining a point data set so that only bare earth points are included: using an automated algorithm and editing manually. This document describes these steps and supports the explanation by using examples. The examples use a topographic lidar data collection from the U.S. Army Corps of Engineers and a freely available software package.

Automated Filtering

Refinement of topographic data requires an iterative process of point removal, and many automated algorithms are available to target non-bare-earth points. Each has benefits and drawbacks, so users must research algorithms and choose the appropriate method. The software packages that contain these algorithms often require licensing and purchase, with only a few available for free download. The most important consideration when choosing a software package is to balance the needs for usability and quality of end product with the cost, which can be significant.

The examples in this document use a free bare-earth-filtering software package developed by the International Hurricane Research Center (IHRC) at Florida International University. This software, called Airborne LIDAR Data Processing and Analysis Tools (ALDPAT), "provides a set of transparent and automatic filtering algorithms to classify ground and non-ground LIDAR measurements and a series of auxiliary tools such as thinning, tiling and gridding the point data set to assist the LIDAR data analysis." This software can also perform additional processing steps, including separation of first and last return measurements and extraction of points by a polygon. A graphical user interface provides a simple way for researchers with little programming experience to use the lidar processing tools.

The ALDPAT software and manual are available for download at the following Web location, http://lidar.ihrc.fiu.edu/lidartool.html. The manual provides the user with an explanation of the different filtering algorithms, the auxiliary tools, and the procedures to perform each. Please note that the point lidar data that are to be filtered need to be in ASCII text format and projected coordinates. The remainder of this document provides an example of using an automated filtering algorithm in ALDPAT to remove the non-bare-earth lidar points from a lidar data set.

Automated Filtering Example

An initial look at a digital elevation model (DEM) created from the entire data set (Figure 1) reveals that non-bare-earth features such as buildings, bridges, and trees are included in the data.

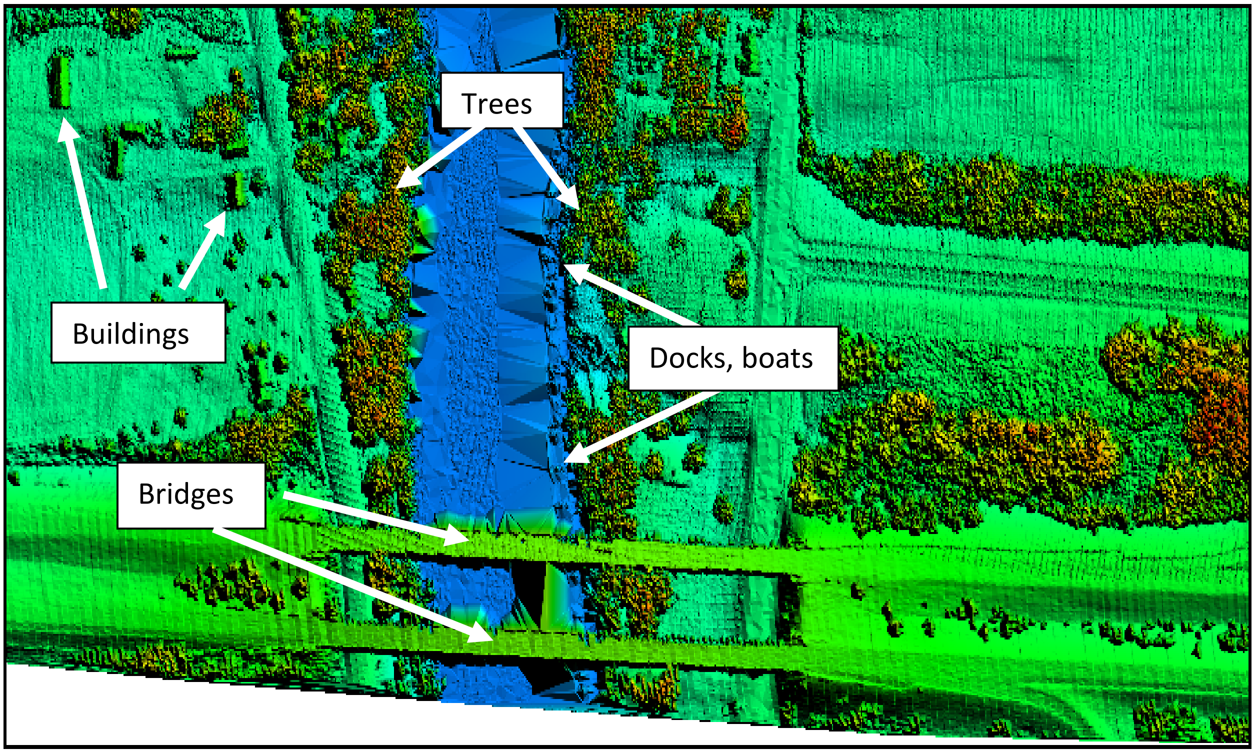


Figure 1. Digital elevation model (DEM) of lidar data, Orleans County, New York

The following steps detail the use of one of the automated filtering algorithms in ALDPAT to remove non-bare-earth points from a lidar data set in order to create a better model of the Earth's surface.

Review the lidar data

1. Examining the DEM in Figure 1 reveals that non-bare-earth points, specifically two bridges, buildings, trees, docks, and boats, are included in the lidar data set. Viewing the point data also reveals these features, as shown in Figure 2. The different colors represent different elevations; blue points have the lowest elevations and white points have the highest elevations.

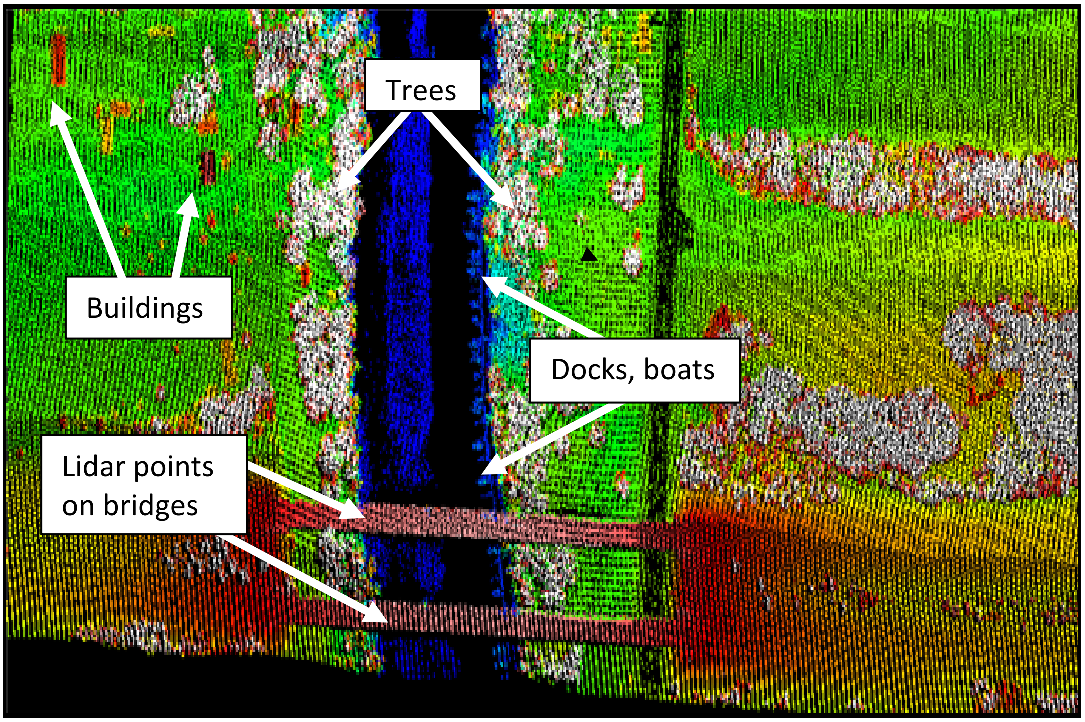


Figure 2. Lidar point data set

Verify features

2. Identification or verification of features can be done using imagery that was concurrently collected with the lidar (Figure 3) or other imagery for the area. The imagery can be very useful in identifying non-bare-earth features.

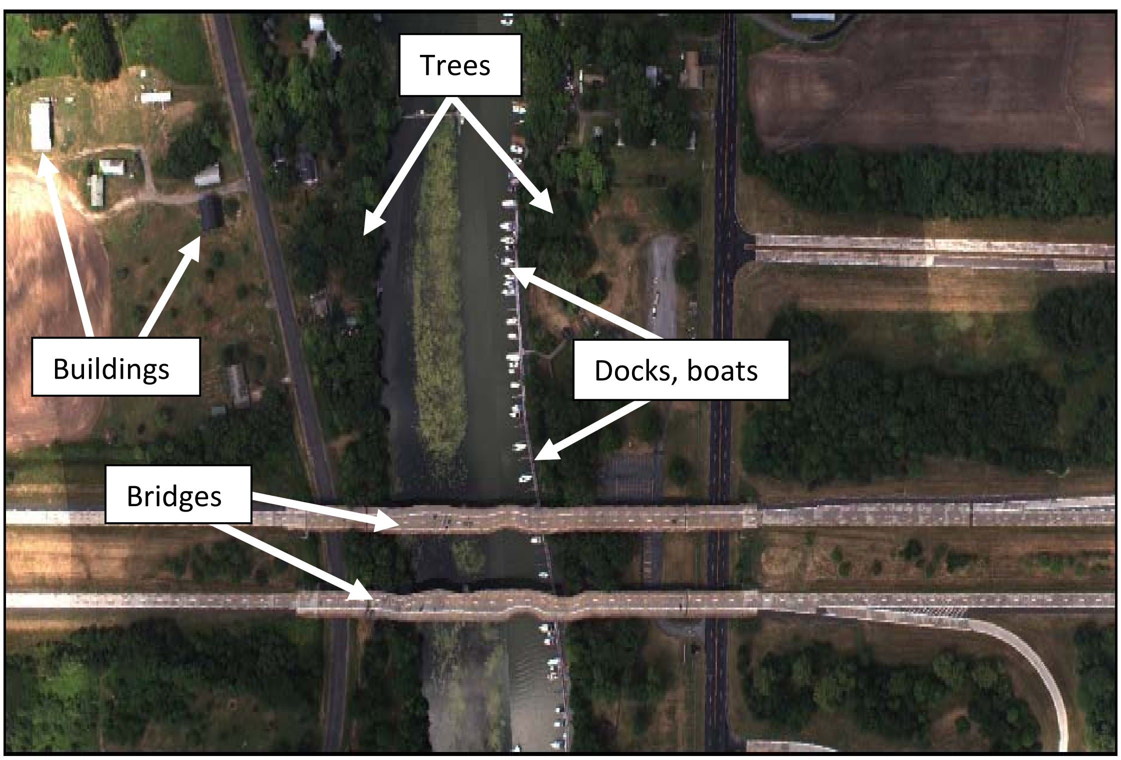


Figure 3. Concurrent imagery

Begin Using ALDPAT

3. To begin the bare earth process using ALDPAT, open **ALDPAT.exe**.

4. Click on **Settings** in the Main Menu, then **Preference**, and then the **I/O** tab to choose the correct delimiter (what separates the values in your ASCII txt file). The choices are comma, space, or tab (Figure 4). Click **OK**.

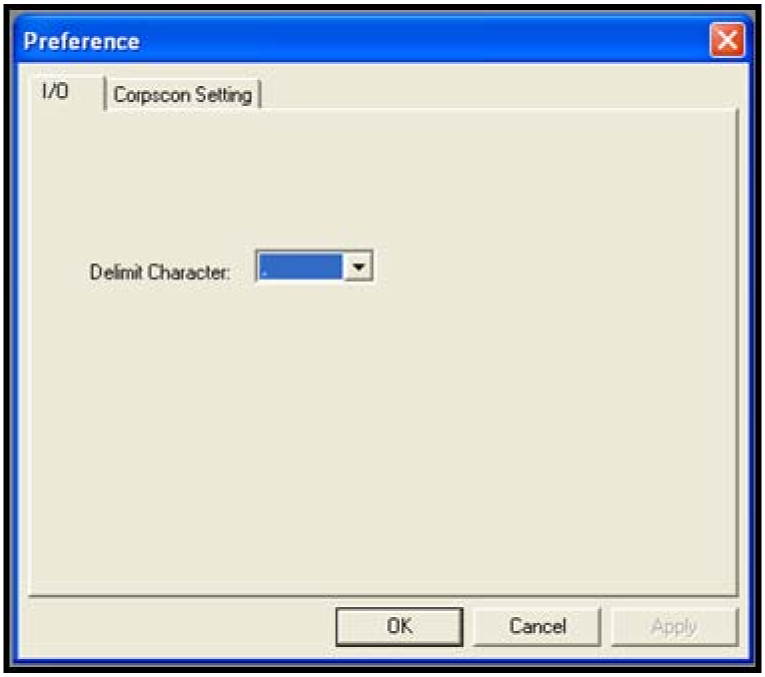


Figure 4. Delimiter preference

5. Click on **Tools** in the Main Menu, and then **Worksheet** (Figure 5).

   a. Input Files: Navigate to the file to be filtered.

   b. Output Path: Navigate to the file in which to save the output.

   c. Output File: Name your output file.

   d. Format: Choose the format to save your data. Choices: txt, asc, grd, bin, utm, sp.

   e. Method: Choose the filtering algorithm or lidar data task to perform. In this example, the ETEW (Elevation Threshold with Expand Window) filter was chosen. Please refer to the ALDPAT manual for a complete explanation of the six available filters to separate ground and nonground measurements. The user may also refer to two papers written by the creators of ALDPAT, comparing the algorithms and the results derived from each. Links to each paper are below.

      i. Zhang and Whitman. 2005. Comparison of Three Algorithms for Filtering Airborne Lidar Data. *Photogrammetric Engineering and Remote Sensing,* March 2005. Pages 313 to 324.

      ii. Zhang and others. 2003. A Progressive Morphological Filter for Removing Nonground Measurements from Airborne LIDAR Data. *IEEE Transactions on Geoscience and Remote Sensing*. Volume 41, Number 4. April 2003. Pages 872 to 882.

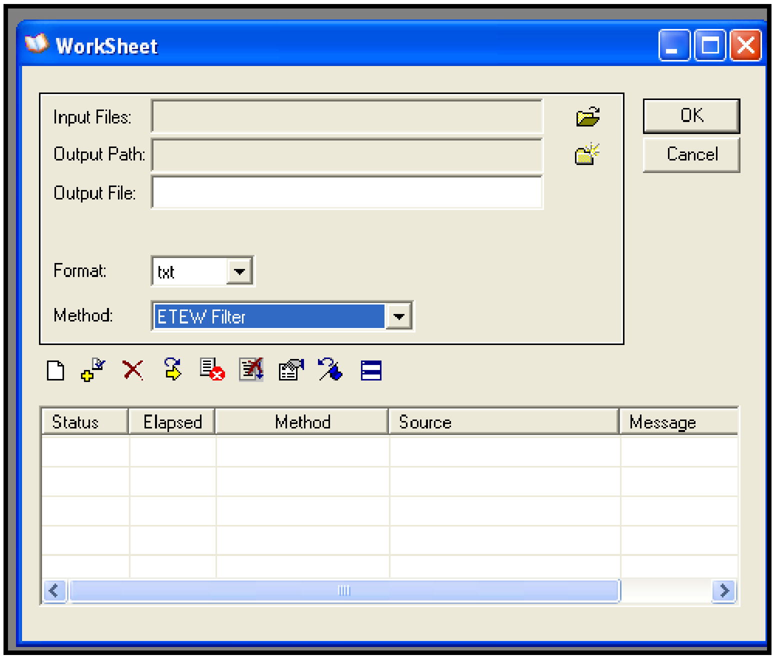
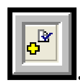


Figure 5. Worksheet dialog box

f. Click the **Add New Jobs** button . This will bring up the Parameter dialog box. The user may leave these values as is or change them. In this example, the Max Z and Min Z values were changed to the known maximum and minimum elevations in this data set (200 and 73). The slope was changed to 0.5 (decreasing the slope value removed more of the bridge points) and the Loop Times was changed to 10 (Figure 6).

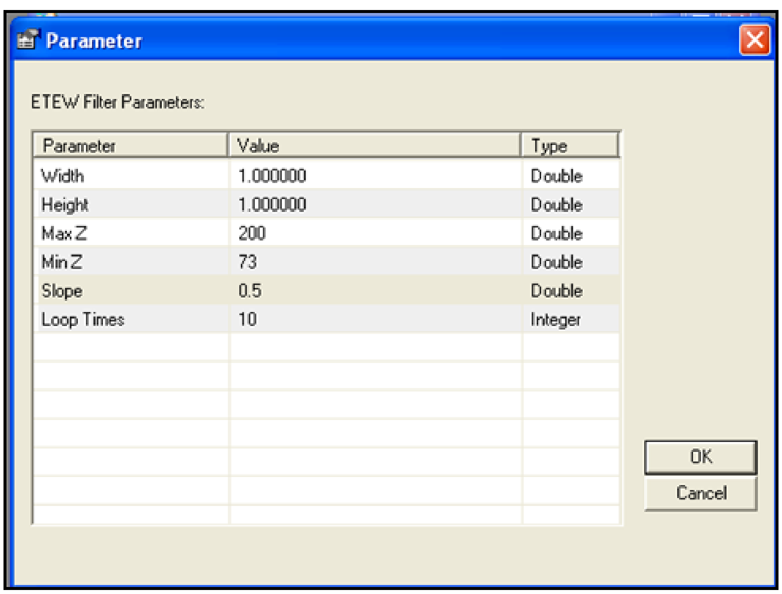


Figure 6. Elevation Threshold with Expand Window (ETEW) filter parameters

6. Once this is completed, the Status column will display "Ready." To start the task, click the **Run Jobs** button.  The Status column will change to "Running." The time the job runs will be listed in the Elapsed column (Figure 7).

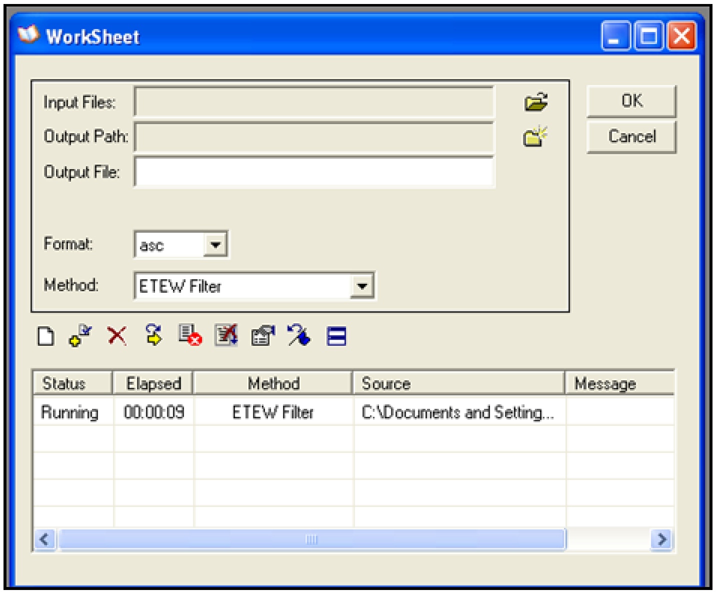


Figure 7. Worksheet dialog box

7. Once the task is complete, the user will see if the job succeeded in the Message column (Figure 8).

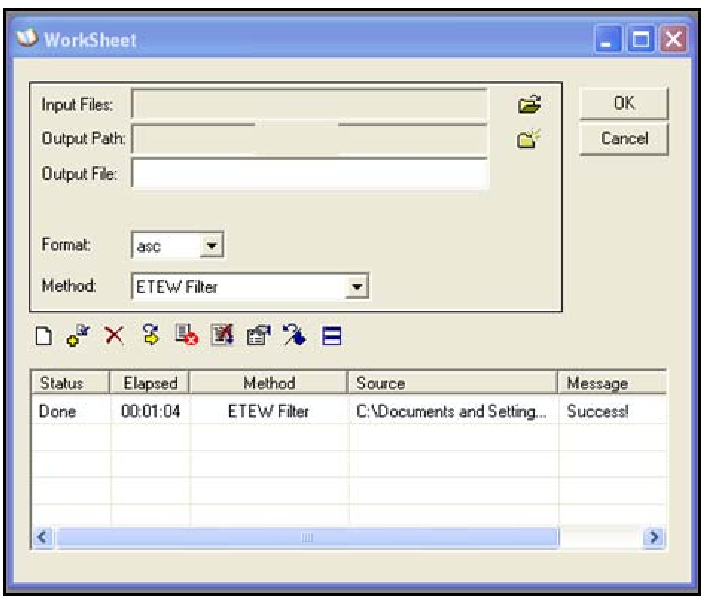


Figure 8. Worksheet dialog box status – Success

8. The filtered data set can now be reviewed to determine how well the procedure removed the non-bare-earth lidar points (Figure 9). The data show that many of the non-bare-earth points have been removed; these include the buildings, the bridges, and stands of trees. Notable, however, are the docks and boats still present in the data set. Removal of these points will be detailed in the "Manual Editing" section.

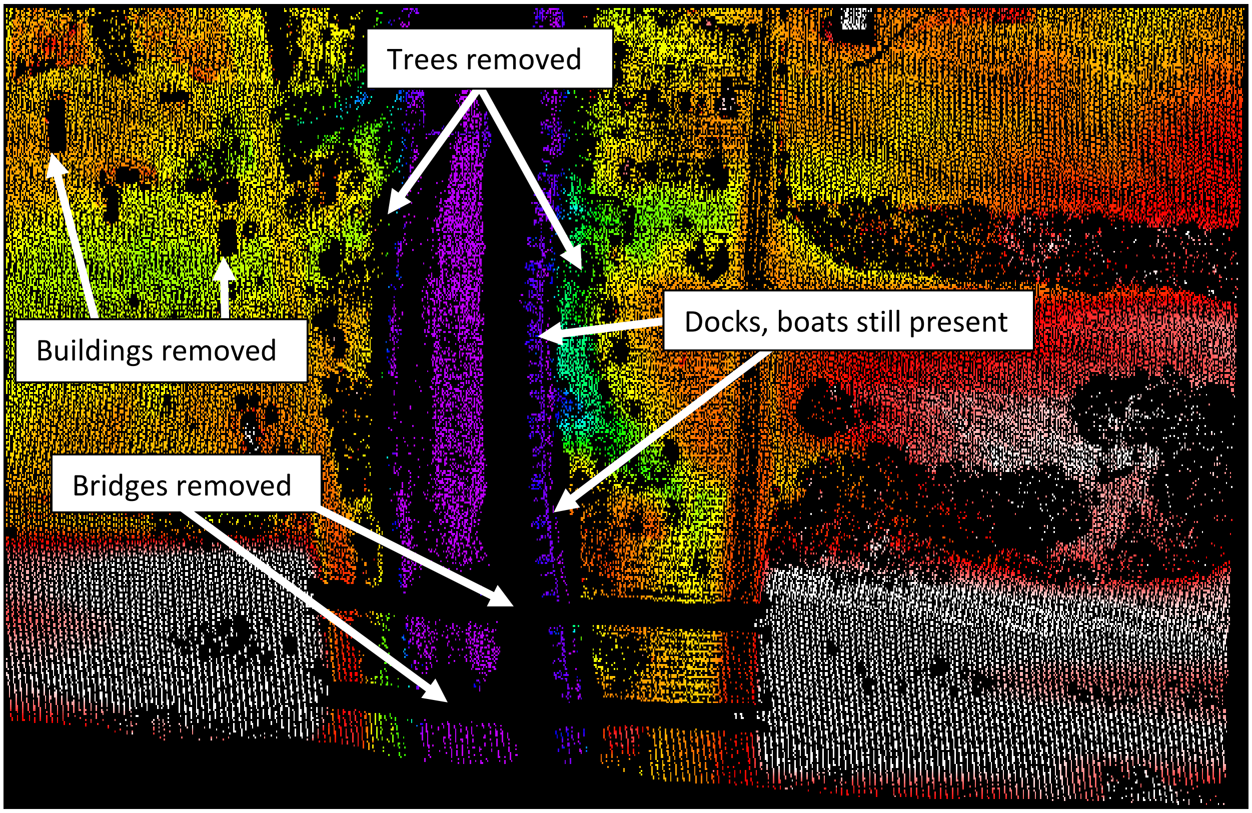


Figure 9. Lidar data set after filtering of non-bare-earth points

9. Creation of a DEM from the filtered data (Figure 10) shows that the removal of the buildings, bridges, and trees has provided a more accurate representation of the Earth's surface than the DEM created from the original unfiltered data set (Figure 11). However, boats and docks were not filtered from the data set and are still incorporated into this DEM. To further improve the model, these features can be removed from the data set using another task within ALDPAT. The procedure for removing these points from the data set follows in the next section.

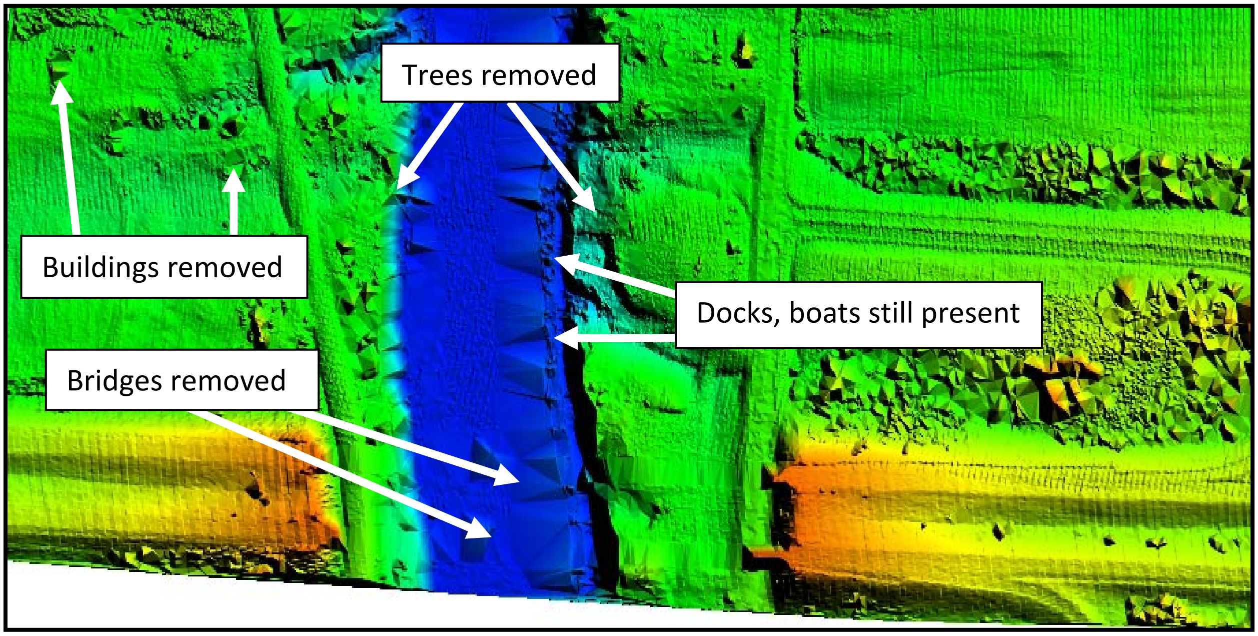


Figure 10. Digital elevation model (DEM) created from filtered data set

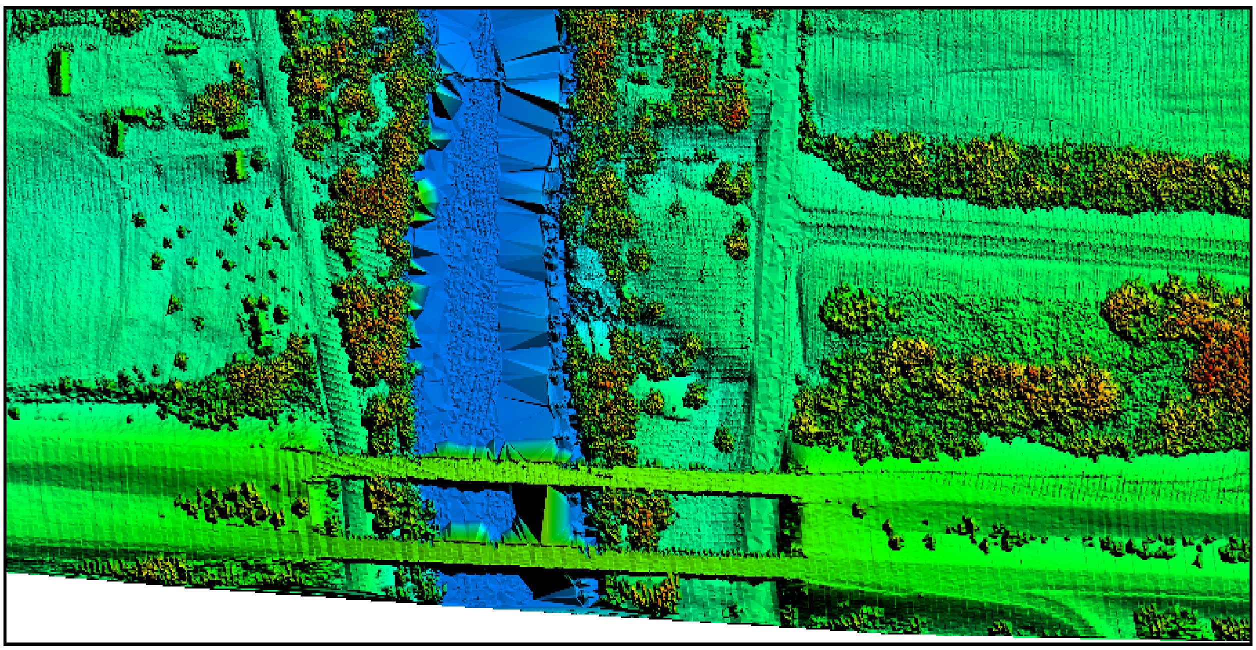


Figure 11. Digital elevation model (DEM) created from original data set

Manual Editing

Automated filtering processes can fail to remove part of a bridge, a stand of trees, or a pier on the coast, and when this happens, these features remain in the bare earth data. If inclusion of these features causes difficulty for analysis, further refinement using manual editing may be an option for improving the surface. Manual processing of lidar data uses software and labor resources, and the process can be very time-intensive, depending on the degree of surface refinement necessary. The manual process involves visually assessing the point data, comparing them with imagery, and eliminating points that do not represent the bare earth—or, alternately, adding points back in that do represent bare earth. Once this process is complete, the data set may be gridded to create a more accurate DEM.

In this example, the docks along the right shoreline of the river have not been removed by the filtering algorithm (Figures 9 and 10). This is a case where manual editing to remove these features from the data set is necessary to improve the surface. The likely reason these points were not removed is that their height was not that much different than the surrounding ground data points. The filtering algorithm uses the rationale of differences in elevation change to construct measures for separating ground from nonground measurements. The difference in elevation from the ground to the top of a tree or building is significantly larger than the difference between the docks and the bare earth points; therefore, these points may have been overlooked by the algorithm.

A manual editing process is required to remove these points, and ALDPAT provides a routine called Polygon Extraction to accomplish this task. The next section details the process for using Polygon Extraction to remove the boats and docks from the data set.

Manual Editing Example

Review the lidar data

1. After the automated filtering process has removed many of the non-bare-earth points, review of the filtered data set reveals that docks and boats along the right side of the river were not removed by the ETEW filtering algorithm (Figure 12).

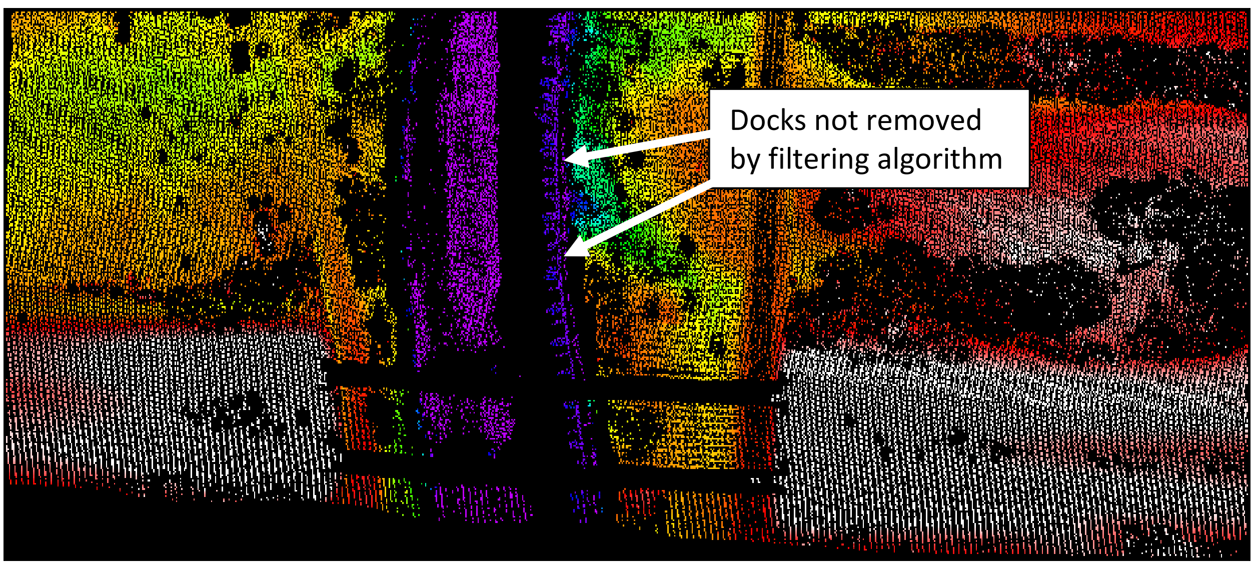


Figure 12. Docks remain in data set

Verify features

2. The imagery collected at the same time as the lidar, reviewed earlier in the automated processing procedure, confirms that these features are docks and boats (Figure 13).

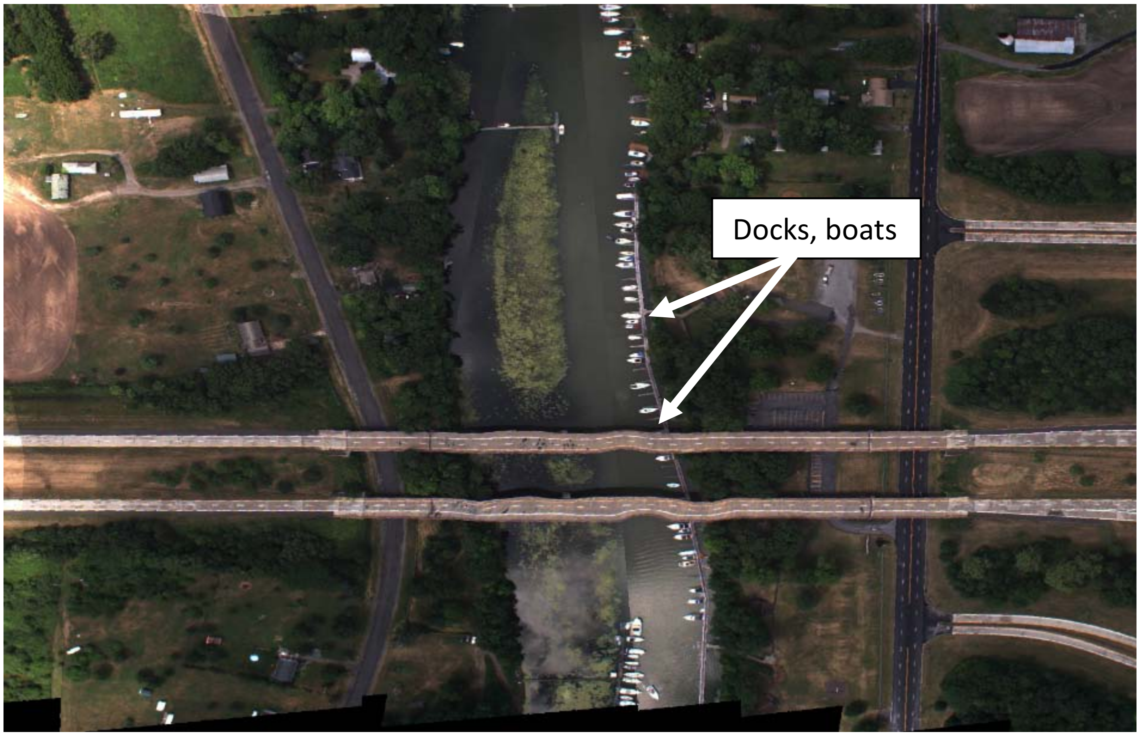


Figure 13. Aerial imagery showing docks and boats

Begin using ALDPAT

3. Within the ALDPAT software, use the Polygon Extraction task to remove these points. Please see the ALDPAT manual, page 68, for more information on this task.

   a. Click on **Tools** in the Main Task toolbar; then click on **Worksheet**.

   b. Enter the Input File and the Output Path, name the Output File, enter the format of your output data set, and choose Polygon Extraction for filtering (Figure 14).

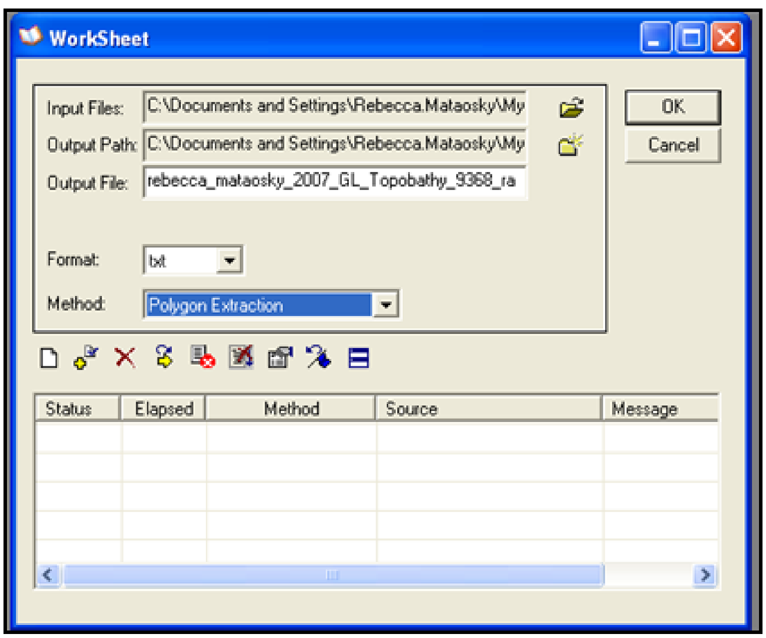
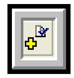


Figure 14. Input parameters for polygon extraction

c. Click the **Add New Jobs** button  .

4. This will bring up the Parameter dialog box. The coordinates may be imported as a text file or typed in using the Add button to add each vertex. In this example, the coordinates of the polygon are typed in manually. Input the X and Y coordinates of the vertices for the Polygon Extraction. The vertices need to be in either counter-clockwise or clockwise order. The first vertex does not need to be repeated as the last vertex. Once all vertices have been added, click the **OK** button (Figure 15). Please note that the Polygon Extraction task retains the elevation points within the polygon and removes those *outside* of the polygon.

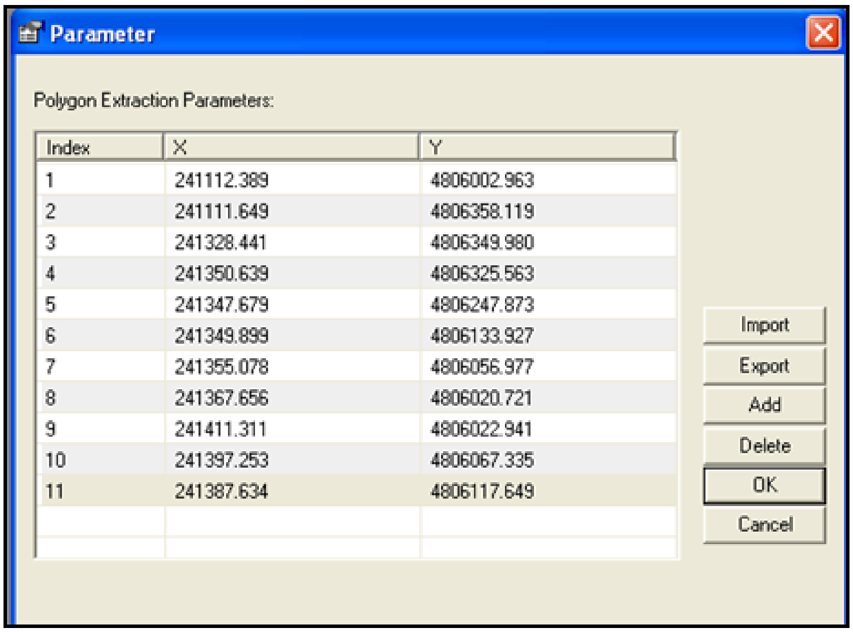


Figure 15. Vertices for polygon extraction

5. Once the vertices have been added, click the **Run Job** button  .

6. When the extraction is complete, the user will see that the job succeeded (Figure 16).

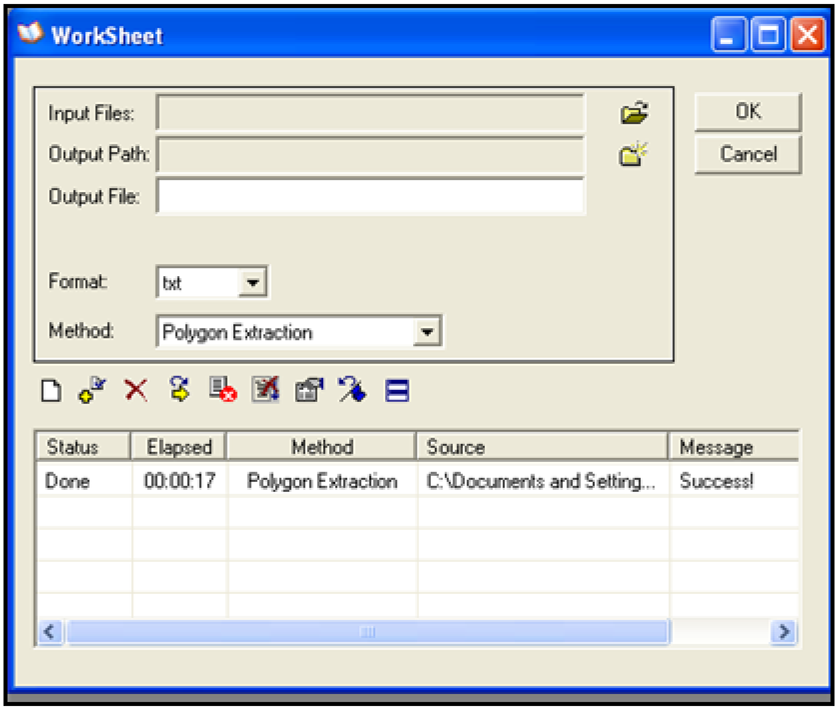


Figure 16. Polygon extraction Worksheet dialog box – Success

7. The data set with the docks and boats eliminated can now be reviewed to ensure that the elevation points that represented the docks and boats have been removed (Figure 17).

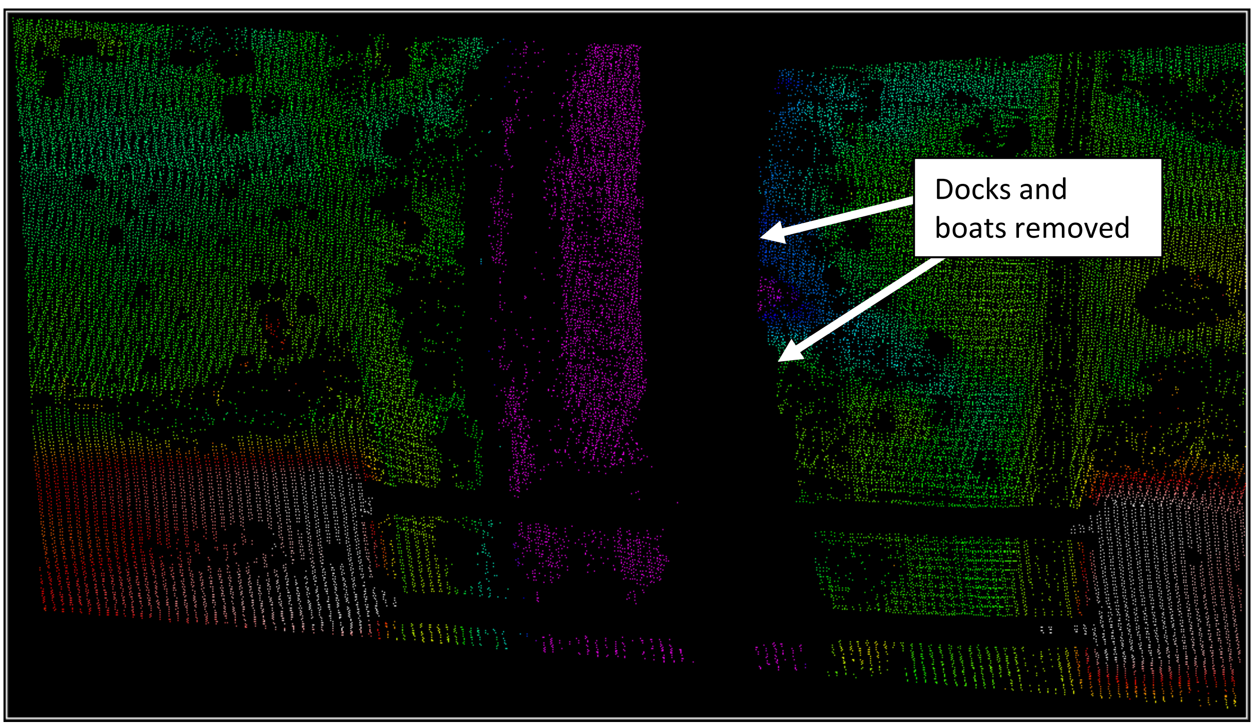


Figure 17. Data set with docks and boats removed

8. Once satisfied with the removal of the non-bare-earth lidar points, grid the new filtered lidar data set to required parameters. Gridding may be done in ALDPAT. Refer to the ALDPAT manual, page 57, for this procedure. In this example, the GIS software, Global

Mapper, version 10, was used to create the DEM from the filtered lidar data set. The new DEM, shown in Figure 18, created from the filtered data, does not incorporate docks and boats, so it is a more accurate model that can be used for storm surge and flood modeling.

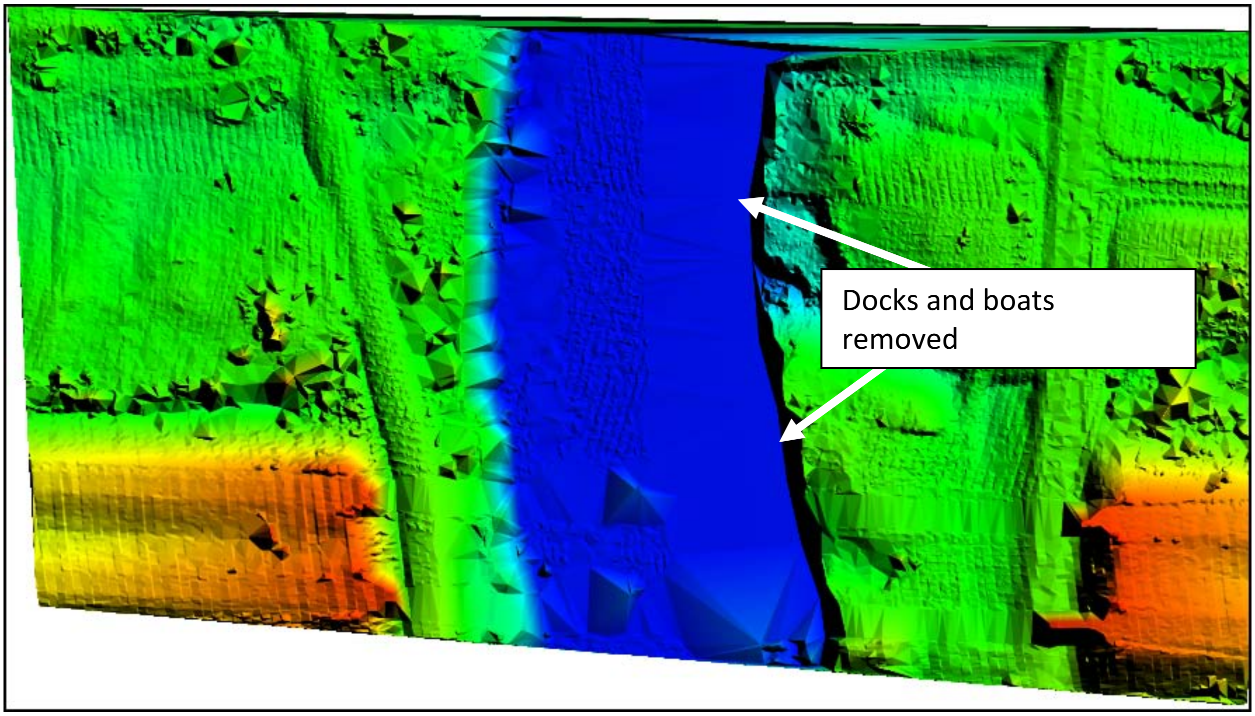


Figure 18. Digital elevation model (DEM) with docks and boats removed

Conclusion

Automated lidar classification processes use various algorithms to determine which points are "bare earth" and which are "non–bare earth." Sometimes the process fails to completely classify or filter out features such as vegetation or structures. When these "artifacts" remain in the data set, they degrade the resulting DEM by assimilating these features into the Earth's surface. When the automated filtered product does not meet the specified needs, these remaining artifacts may require manual editing to create a more accurate model of the Earth's surface.

In this example, a lidar data set that included both bare earth and non-bare-earth points was filtered using automated processing to remove the non-bare-earth points. Review of the resulting filtered data showed that while many of the structures and trees were removed, features such as the boats and docks remained. These features were removed using a manual editing process to create a DEM more representative of the Earth's surface for flood modeling.