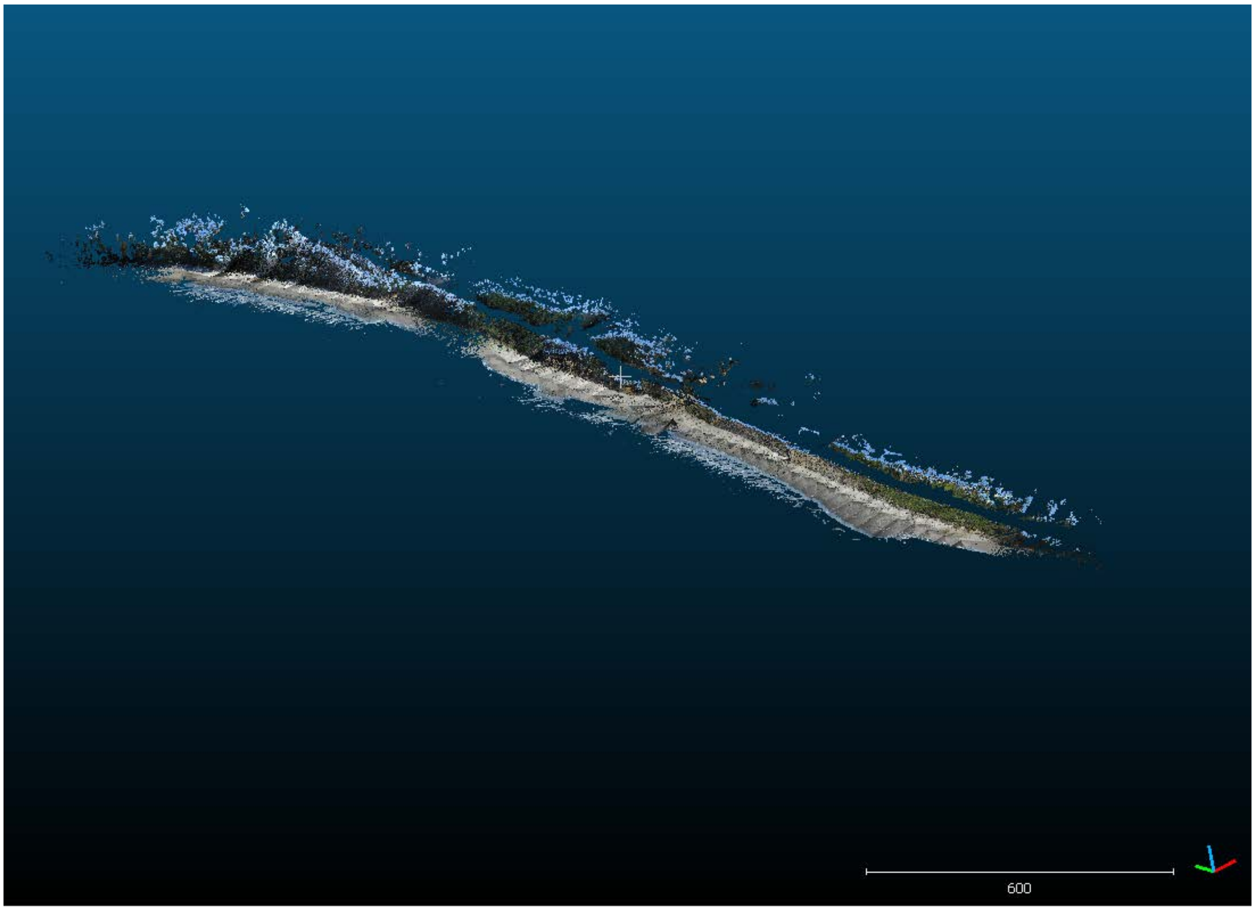

Generated LiDAR point cloud in CloudCompare
Data collected from a survey on Beverly Beach from October 10th, 2019

Cross section extraction for sea cliffs in Arc GIS Pro

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CE 560

Introduction:

This paper proposes a methodology to effectively capture cross sections of sea cliffs from LiDAR data. By extracting cross sections, coastal erosion analyses can be calculated including volumetric loss and retreat rates. The merit of this research is founded by the success of Topographical Compartment Analysis Tool (TopCAT) used to analyze sea cliff and beach change in GIS for the California and North Carolina coast. (Olsen et al. 2012) TopCAT is programmed in Visual Basic for Application (VBA) and ArcGIS Desktop no longer includes compatibility setup for VBA. The merit of this research is established by modernizing the central concepts of TopCAT given current programming in Python.

Background

Weather phenomena linked with climate change have been observed to shape the Oregon Coast. For the Pacific Northwest, Ruggiero et al. 2010 established statistically significant increases in significant wave heights between 1976 and 2007 annually, higher rates for the winter season (October through March) and the largest observed rate for significant wave heights generated by major storms. Barnard et al. 2017 showed that during the 2015-2016 El Nino, winter wave energy equalled or exceeded measured historical maxima across the US West Coast. This corresponded to large beach erosion across the region. Because the physical phenomena of climate change have proven to be key determinants of molding the Oregon coast, local and state governments and agencies must address the extent of change and its implications for coastal communities and landscapes.

The urgency of climate change research within Oregon is reflected in the creation of the Oregon Climate Change Research Institute (OCCRI) in 2007. Established under House Bill 3543 within the Oregon State Legislature, the institute publishes reports summarizing the current understandings of climate change phenomena in Oregon. The First Oregon Climate Assessment Report, created by OCCRI in 2010, emphasizes gaps in our knowledge regarding resilience and adaptation of the Oregon coast stating “we have limited ability to predict future trends in wave heights or coastal storms, but if the trend continues, impacts will be substantial” (pg. 19 Oregon Climate Assessment Report, 2010).

While three main landforms comprise the Oregon coast- beaches, sea cliffs and stacks, there is urgency to effectively monitor and reinforce sea cliffs. The physics of sea cliff failure is under researched within Oregon given local geologic, wave and precipitation conditions (SPR 807). Lack of sea cliffs research is problematic for coastal engineers because this landform comprises 53% of the Oregon coast. Additionally, Highway 101 borders the Oregon coast. Highway 101 facilitates economic activity for the region and serves as a single (and vulnerable) “lifeline route” for coastal communities.

Objectives

This research proposes a tool to extract cross sections from LiDAR data to strengthen ODOT’s capacity for climate change adaptation. Ability of coastal engineers to easily access cross sections facilitates analysis because cross sections serve as inputs for a number of metrics to measure coastal change. For example, retreat rate, distance along cross section, geospatial change and volumetric change may all be calculated. (Olsen et al. 2012)

The following tool utilizes georeferenced LiDAR data collected apart of existing ODOT SPR 807. The total area surveyed is cropped to focus on the area of interest. Manual refinement of the data is completed in CloudCompare, an open source point processing software. Automated refinement of the data is completed with Rockfall Activity Morphological Bigdata Optimizer (RAMBO). After refinement with these two softwares, the data is uploaded into ArcGIS for sea cliff extraction methodologies.

Methodology

The methodologies for this project were divided into two categories- preprocessing and processing. During the preprocessing stage, two softwares were used- CloudCompare and RAMBO. All methodologies for the processing stage were accomplished in Arc GIS Pro. Therefore the methodologies were separated into (1) Preprocessing in CloudCompare (2) Preprocessing in Rambo and (3) Processing in Arc GIS Pro.

(1) Preprocessing in Cloud Compare

The first step was to obtain the data from ODOT SPR 807 storage database. Because the principal investigators of this project, Dr. Michael Olsen and Dr. Ben Leshchinsky, are professors at Oregon State University, this was within the university's computer network system. In total 42 scans were collected on October 10th, 2019 for this location. The data was already georeferenced with the coordinate system "Oregon Coordinate Reference System: Oregon Coast OM (m)". Georeferencing refers to the process of linking each point within a point cloud to a specific x (longitudinal), y (latitude), and z (elevation) position. The coordinates (x, y, and z) were determined using Geographic Position System (GPS) or Global Navigation Satellite System (GNSS) technologies. GPS and GNSS technologies were used to determine the precise coordinates of the laser scan location. Knowing the precise location of the laser scans allows the technology to interpolate the precise coordinates of the surrounding points.

A less dense point cloud was used to determine the area of interest (Figure 1). The less dense point cloud was created by filtering and removing points within the point cloud. For example, the original point sizing was 0.02 m, however was increased to 0.11 m after decreasing density. By removing the number of points, it decreases the size of the file and allows the entire survey to be uploaded in CloudCompare without delay or crashing. No computational analysis was based on the less sense point cloud. Rather it was an optimal approach only for visually inspecting the entire point cloud and determing the ideal area of interest. Being able to see the entire survey was crucial for determining the area of interest. Without removing a meaningful number of points from the original point cloud, CloudCompare crashed and the entire survey was not be able to be visually inspected.

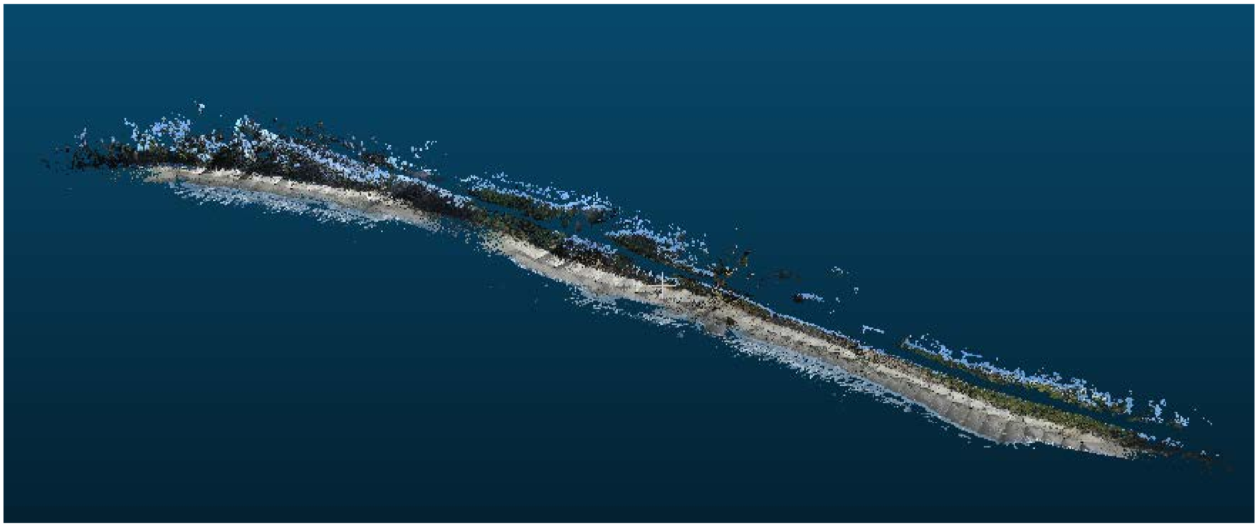

Figure 1: Less dense point cloud used to determine the area of interest

After generating the less dense point cloud, the “cross section” tool was used to determine the area of interest (Figure 2). Because this research seeks to establish the feasibility of methodologies, the area of interest was not choosen based on a specific criteria. The area of interest is 178 meters wide, 500 m long and 25 m tall. The length of 500 m was chosen because TopCAT- the study this research based its methodologies on- utilizes two site locations both 500 m long.

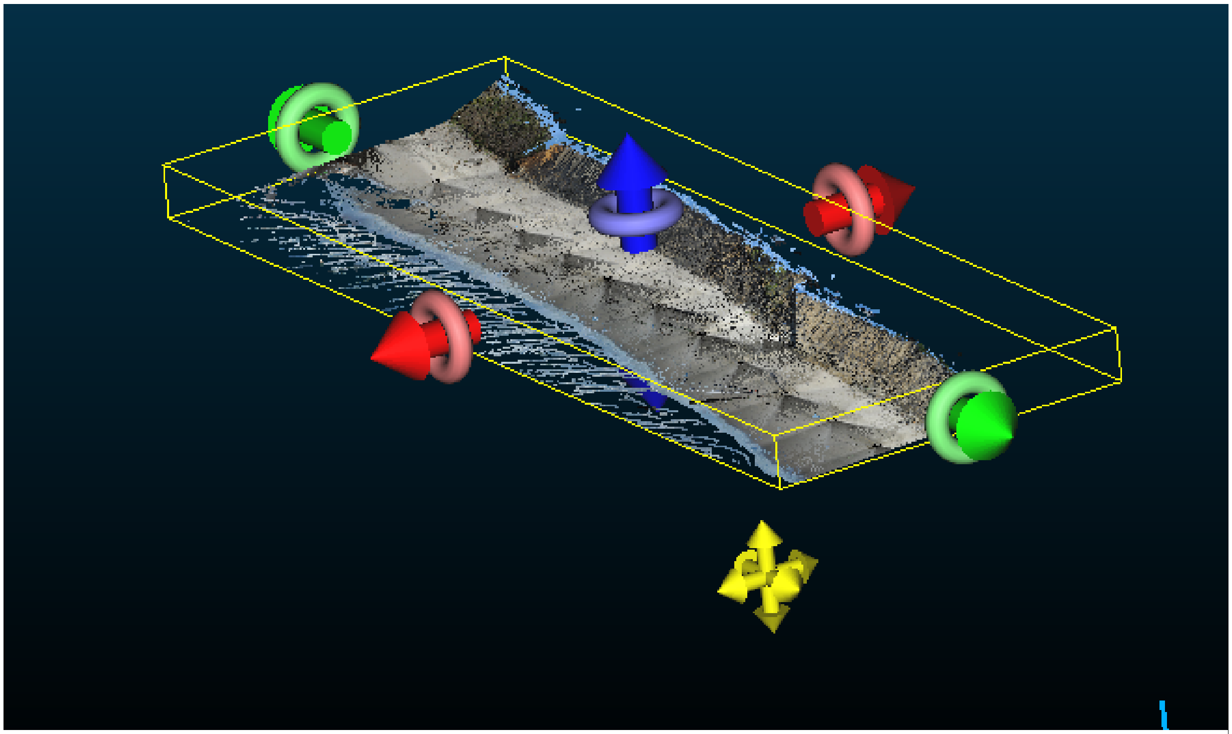

Figure 2: Cross section tool to isolate the area of interest

The benefit of the cross section tool was that it provided the x, y and z coordinates of the area of the interest (Table 1). Note these coordinates are within the OCRS Oregon Coast OM reference system. These coordinates were inputs for a batch file that cropped each of the files to an ouput LAS file only with points within the area of interest. For example, the batch file scans each of the 42 laser scan positions. While individually scanning each of these files, it checked to see if that scan contained points within the given coordinates for the area of interest. If the scan did contain these points, it returned a LAS file containing only those points with "CROPPED" in its name. If the scan did not contain these points, it returned the same file without "CROPPED" in its name. Of the 42 files in total, 27 contained "CROPPED" in its name indicating the former. These files were uploaded into CloudCompare and merged using the merge function (Figure 3). After this step, the less dense point cloud was no longer needed.

Table 1. Coordinates of the area of interest

	X min	**Y min**	**Z min**	**X max**	**Y max**	**Z max**
Coordinates	82.52450562	-2203.339111333	0.62999725	260.51712036	-170.97705078	25.60026932

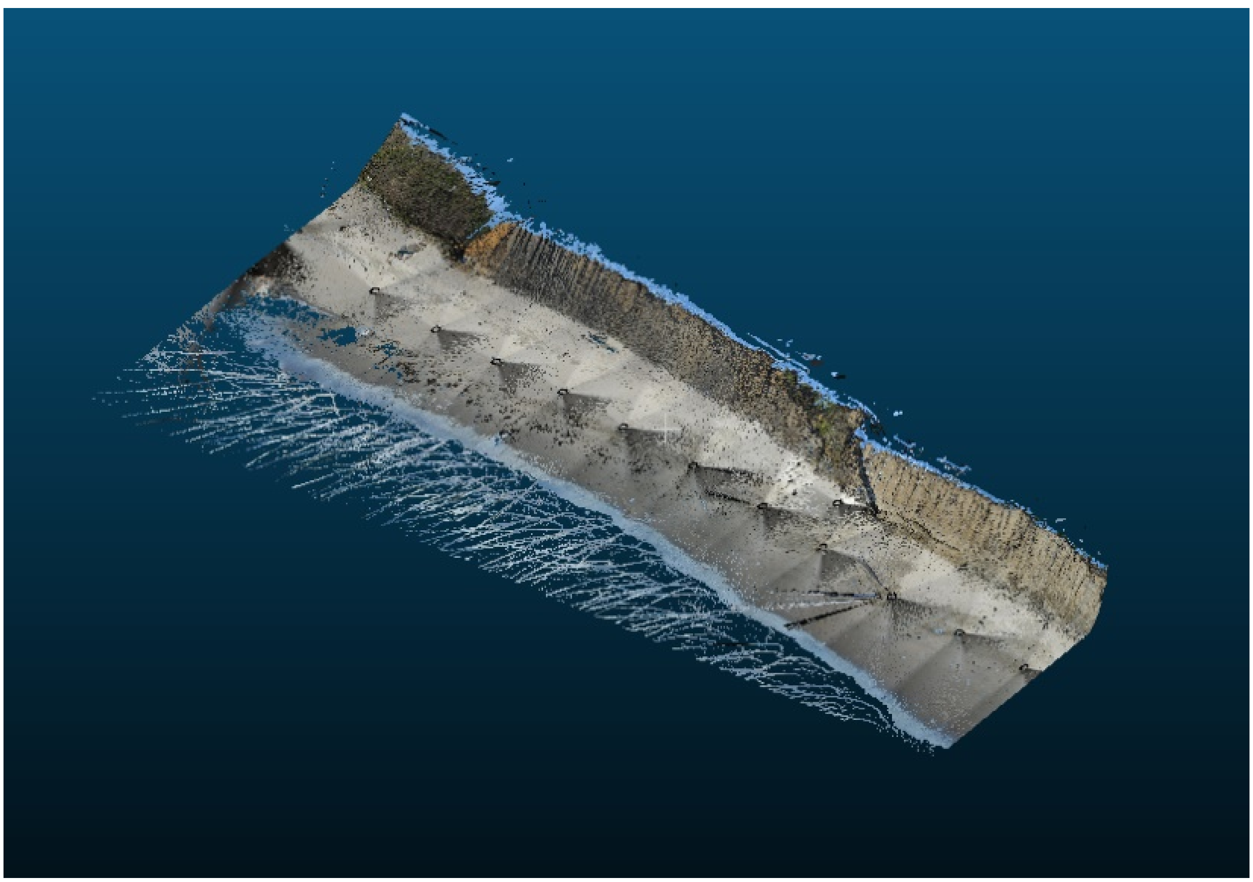

Figure 3: Merge of 27 scans containing points within the area of interest

Next, manual refine of the data is conducted in CloudCompare, namely removal of unrelated portions of the sea cliff. Because the purpose of this research is to extract sea cliff profiles, the beach as well as the area beyond the top of the sea cliff were removed. These sections were removed using the segment tool (Figure 4). A comparison between Figure 3 and Figure 4 visually displays the extent of segmentation.

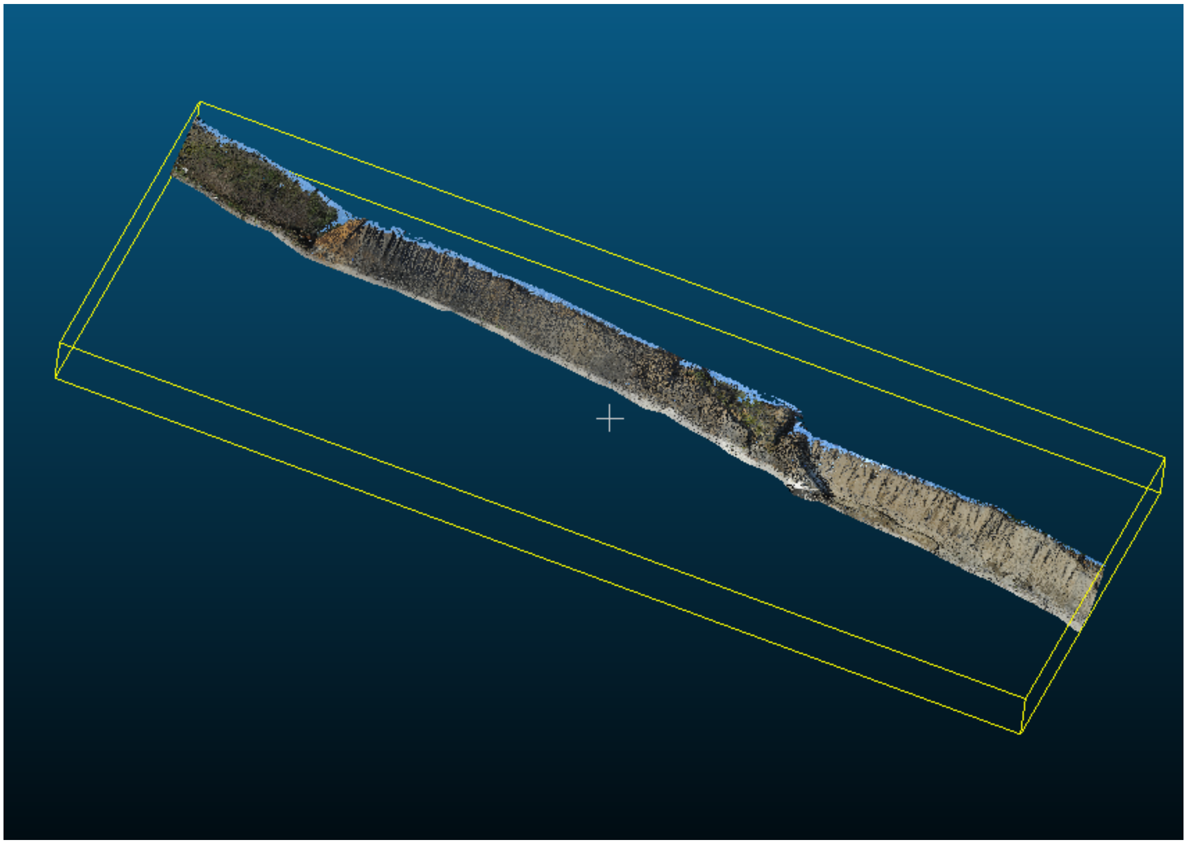

Figure 4: Product of segment tool after removing all surfaces other than the sea cliff profile

Determination of the cell size was crucial for obtaining high quality results. The cell size is a parameter used in sequent steps of automated refinement in RAMBO, as well as methodologies in Arc GIS Pro. LiDAR point clouds are converted to raster data formats for analysis. Raster or "gridded" data are stored as a grid of values which are rendered on a map as pixels. Each pixel value represents an area on the Earth's surface. A raster file is composed of regular grid cells, all the same size. The cell size represents the size of the pixel. Using the "point picking" tool, the "select 2 points and display segment information" feature was used. For the software used in the following section (RAMBO), a cell size of 0.05 or 0.1 meters must be used. Figure 5 displays three iterations of measuring the distance between points. It was determined 0.05 m was the appropriate cell size. The validity of this assumption is evaluated in the discussion section.

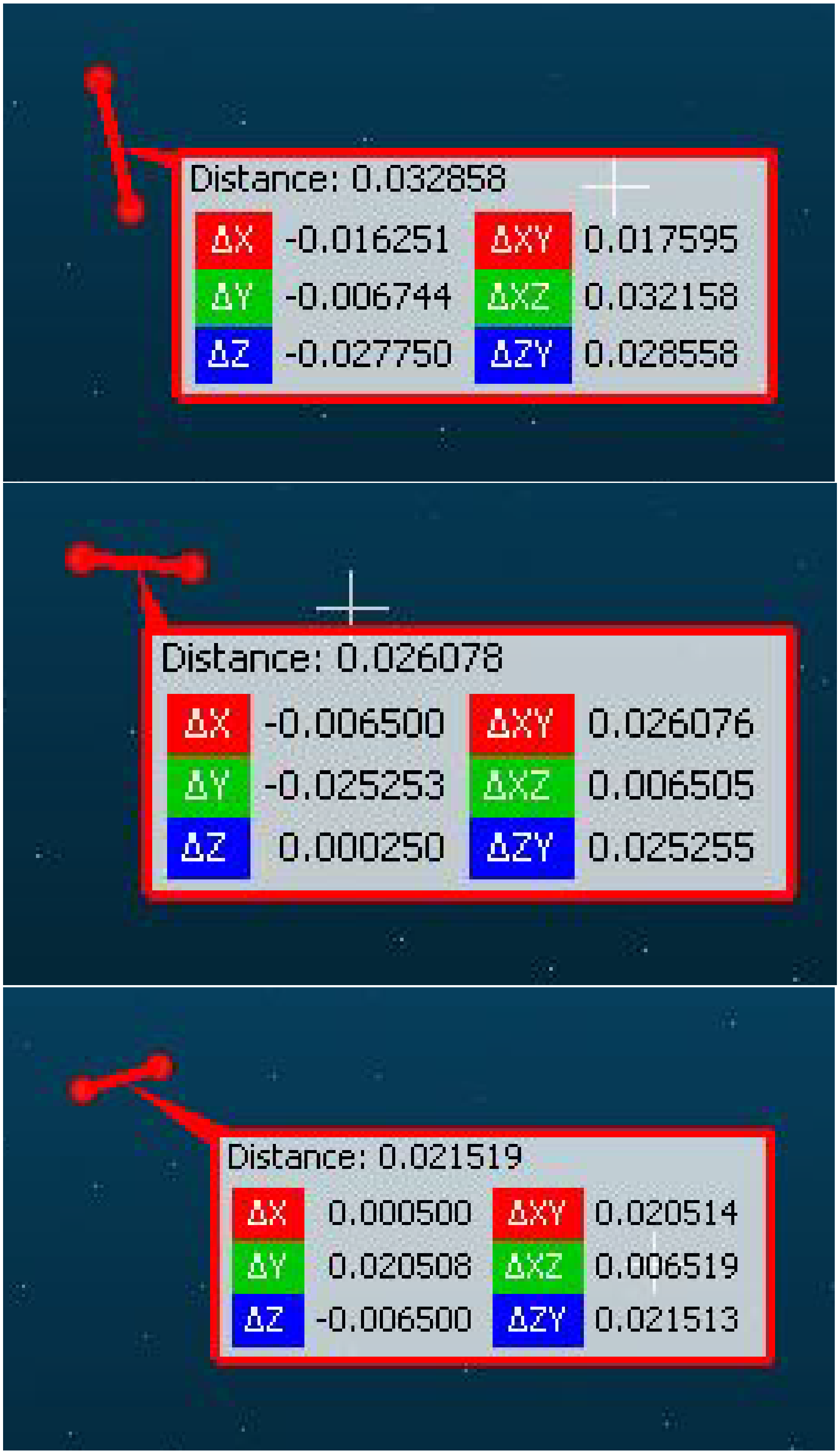

Figure 5: Point picking tool displaying multiple iterations to determine point spacing

(2) Preprocessing in RAMBO

Rockfall Activity Morphological Bigdata Optimizer (RAMBO) is also used to improve the quality of the DEM input for Arc GIS Pro. RAMBO performs two crucial tasks; removal of vegetation and filling of holes in the data. Before either of these tasks can be performed, the LAS file must first be converted to a BDP file format. The RAMBO software was able to perform this task.

After, the ground filter function is used. The software performs an automated ground filtering algorithm to create the ground filtered point cloud. It outputs a LAS 1.2 file with ground points classified as a 2. The default settings are used with a cell size of 0.05 m. Within the discussion section of this report, the choice in parameters as well as quality control checks for this step are discussed.

The output is a ground filtered point cloud with ground points classified as a 2 and non ground points classified as values other than 2. This classification systems allows the ground filtered point cloud to be uploaded into CloudCompare to be separated. For example, once uploaded under “properties” the “colors” characterization was changed to “scalar field” and the “active” scalar field was changed to “classification”. Figure 6 was generated that colored ground points as blue and colored all non ground points as green.

The next step was to create a LAS file that only contained ground points. This file served as an input for the next step of automated refinement in RAMBO; hole filing. Using CloudCompare, under the “edit” tab, “Scalar fields” then “Filter by value” was chosen. The range was changed from 1.9 to 2.1 then the split function was used. Two point clouds were created; one contained only ground points and one contained all other points. The point cloud containing ground points was saved as a LAS file (Figure 7).

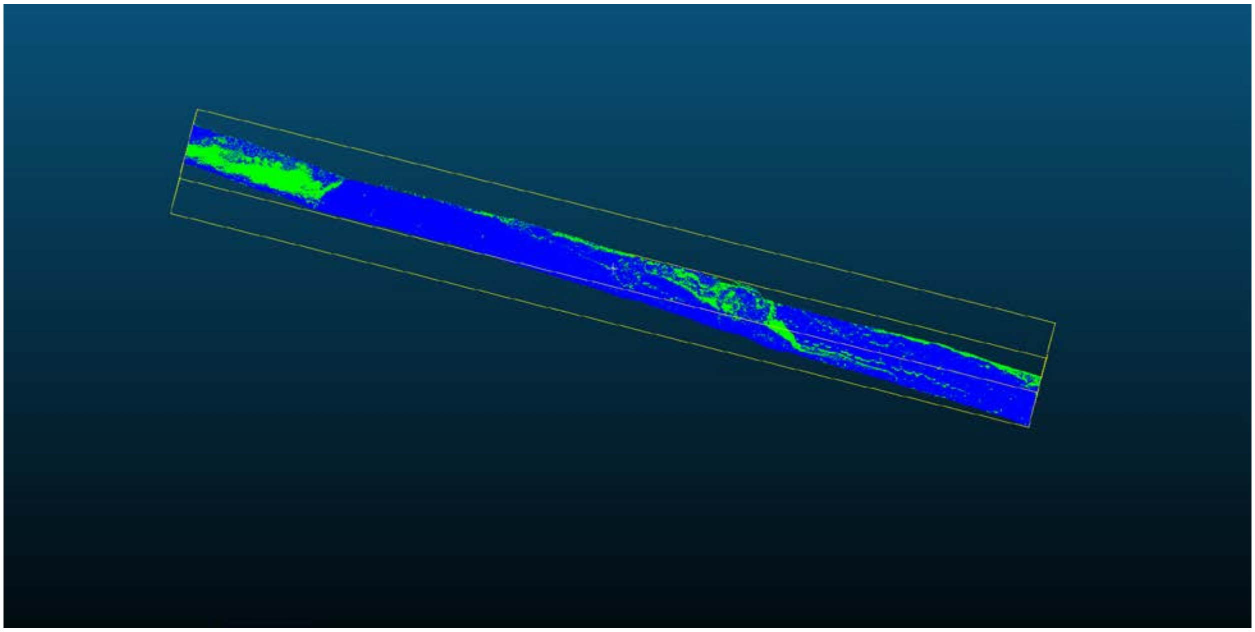

Figure 6: Point Cloud Classified (or colored) separating ground points from non-ground points

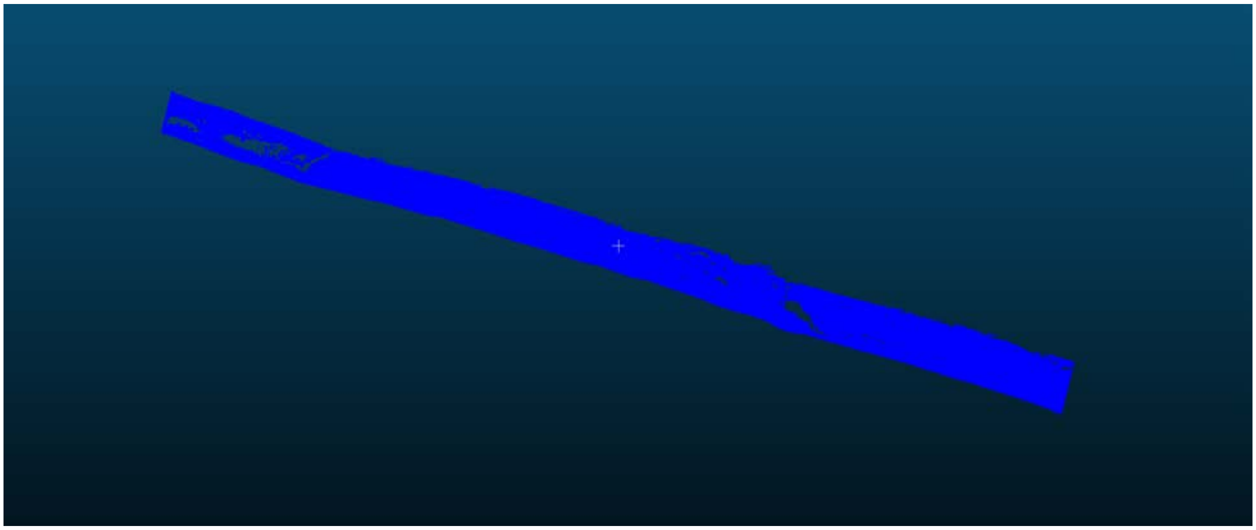

Figure 7: Point Cloud containing only ground points

The LAS file containing only ground points was uploaded in RAMBO. The hole filling function was applied after initially converting the file from LAS to BDP. This program implements a Thin Plate Spline (similar to bending a sheet of metal to fit the data points at a minimal energy state) to provide flexibility to follow the curvature of the surface when filling holes. This implementation is based on the approach of Olsen et al. 2015. The thin plate spline is ideal for surfaces with high levels of curvature and provides a more natural look to hole filling compared with other common methods. The output is a point cloud with holes filled (Figure 8).

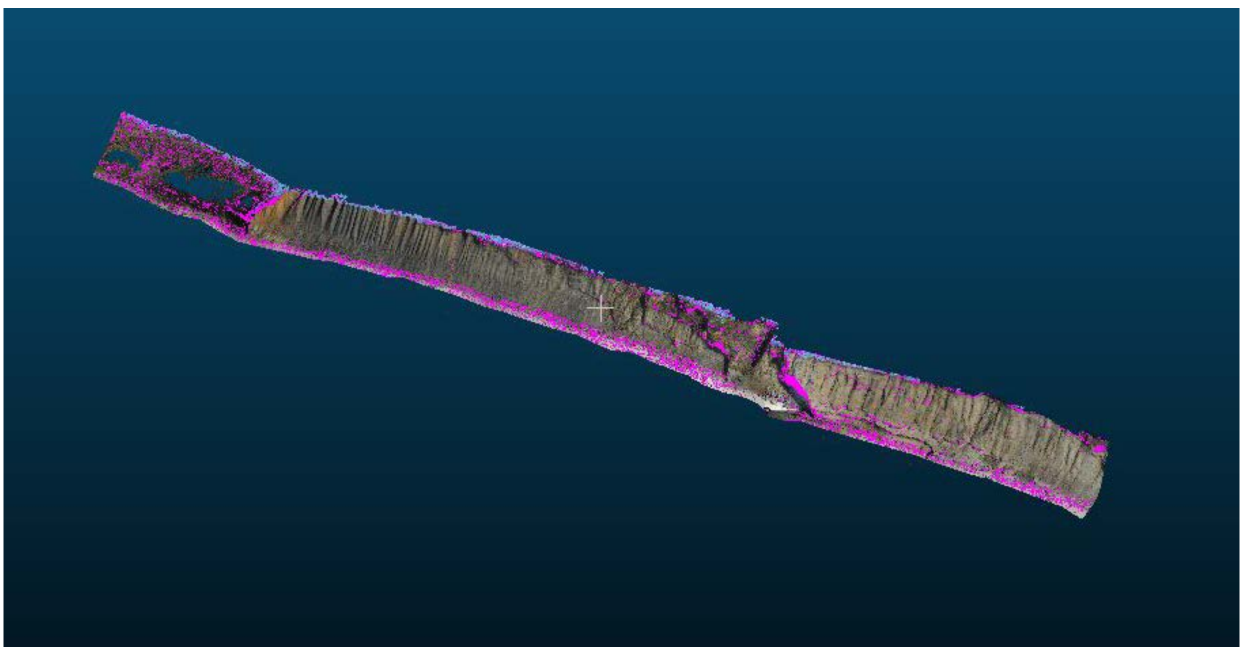

Figure 8: Point cloud with holes filled

An addition output was a Digital Elevation Model (DEM) of the data with both ground filtering and hole filling performed. Creation of this DEM was the final step within for preprocessing and the data was finally ready for sea cliff cross section analysis.

(3) Processing in Arc GIS Pro

The DEM is imported into Arc GIS Pro using the “Add Data” feature. Upon import, the build pyramids function was choosen. Pyramids are reduced resolution overviews of the data at different scales. They’re useful because they improve speed for raster datasets displayed at less than their full resolution. This is a common methodology for larger raster datasets.

Under the “Properties” of the map, the coordinate system was changed to “OCRS Oregon Coast NAD 1983 2011 OM Meters”. Because the earth is a sphere, there are always going to be tradeoffs when a spherical surface is represented on a flat surface such as a map. The OCRS is tailored to local topography and elevation and accordingly grid coordinate zones distances closely match the same distance measured on the group. The alternative is more generalized, less localized projection systems such as North American Datum of 1983 (NAD 83). After correcting the projection system, Figure 9 displays the initial map of the area of interest.

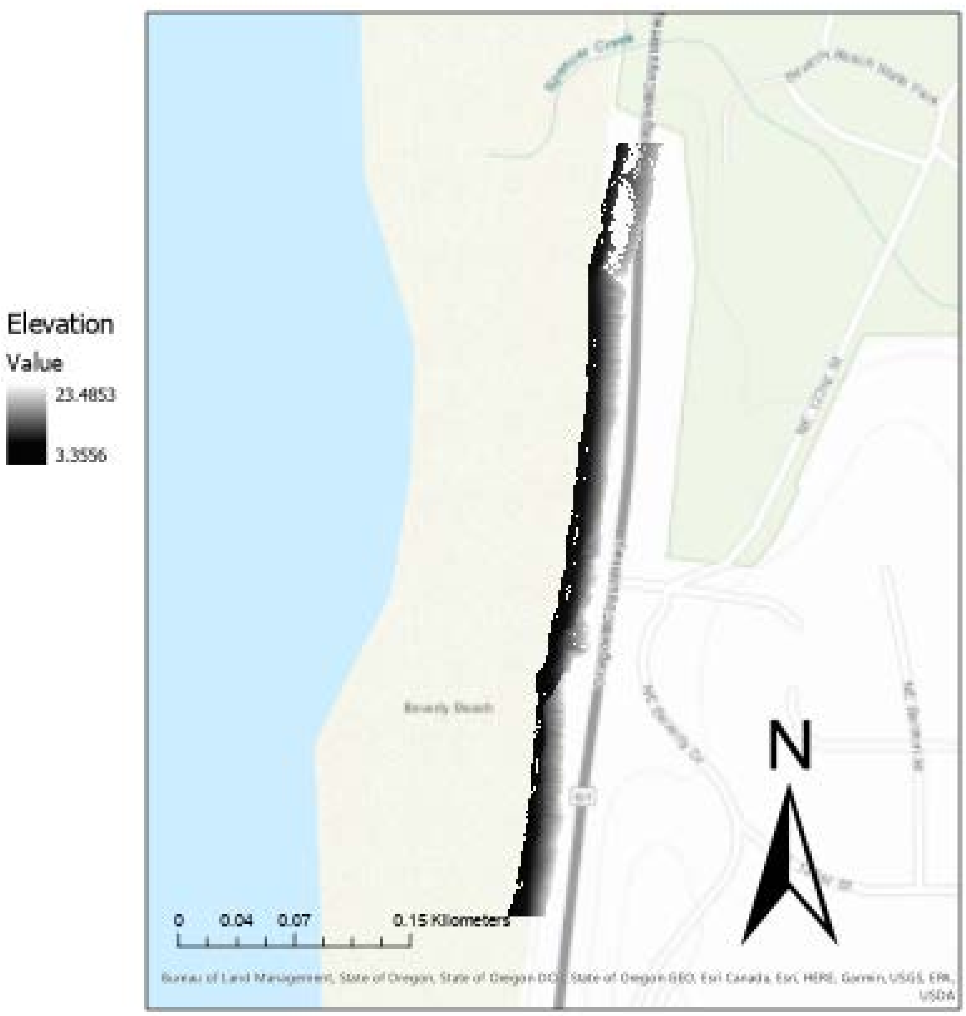

Figure 9: Map of the Digital Elevation Model

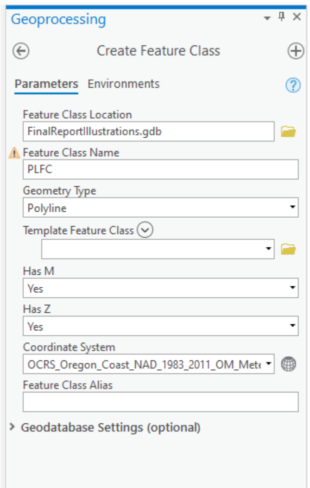

Figure 10:Parameters to create polyine feature class

Because the next step is to draw a polyline roughly across the middle of the sea cliff profile, a new feature class had to be created first. This created a folder to put the GIS polyline data in. Within tools "Create Feature Class" was used with the parameters outlined in Figure 10 with PLFC standing for Polyline Feature Class.

The next step is to create the polyline data within the feature class. With "PLFC" highlighted, within the "Edit" tab in the "Snapping" group, spanning preferences were enabled. In the "Edit" tab, in the "Features" group, the "Create" function was chosen. The "Create Features" pane appeared. With the "PLFC" layer highlighted, a line was created every 20 m for 500 m so 25 lines individual lines comprised the entire polyline.

Figure 11: Map of polyline roughly across the middle of the sea cliff

After creating the polyline, it was necessary to create a square buffer around it. Before creating the buffer, the distance from the polyline to limits of the buffer had to be deteremined. The "Measure" tool was used at three segments within the DEM; the southern most part (Figure 12), the middle (Figure 13) and the northern most part (Figure 14). In Figures 12, 13 and 14, the measure tool is the faint blue dotted line. The three segments indicated that on average, the outer limits of the DEM is 12 m with a maximum of 14 m. Because it does not disrupt the results for the buffer to overextend the DEM, a buffer distance of 15 meters was choosen. This ensures all DEM points were captured.

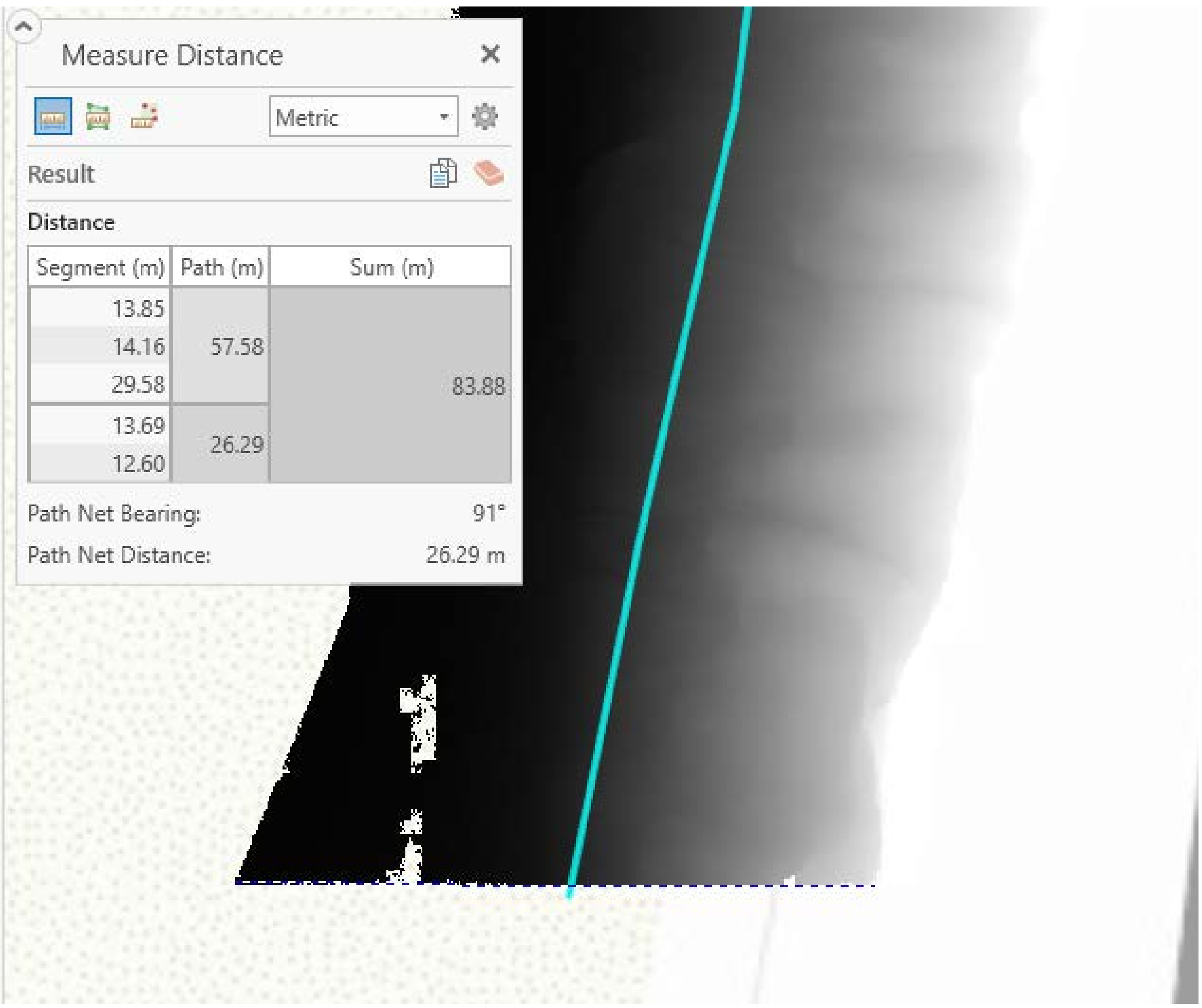

Figure 12: Use of measure tool to determine width of DEM at southern most segment of the DEM

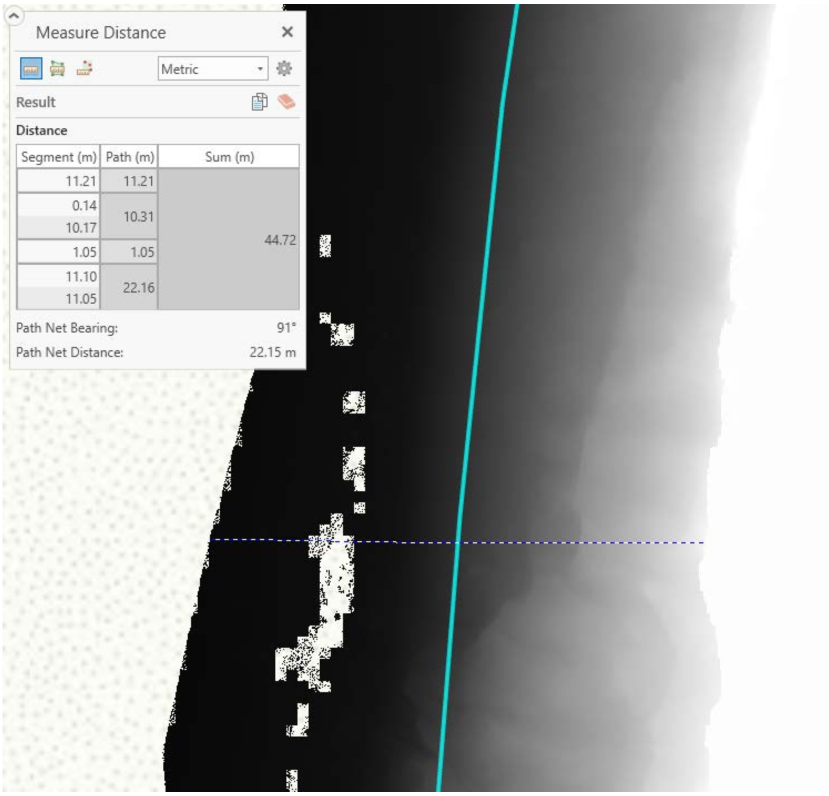

Figure 13: Use of measure tool to determine width of DEM at middle segment

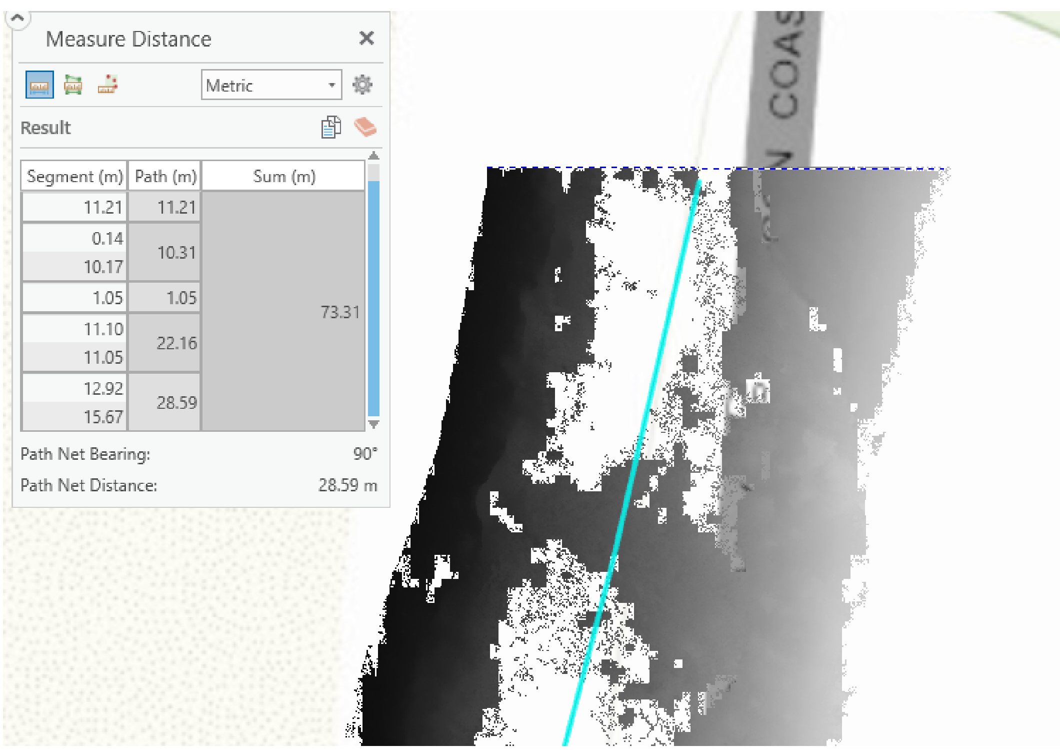

Figure 14: Use of measure tool to determine width of DEM at northern most segment

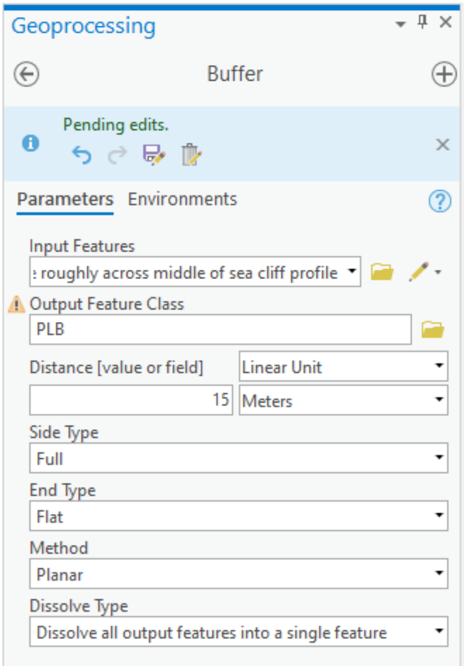

Figure 15: Parameters for "Buffer" tool

With the size of the buffer determined from the "Measure" tool, the "Buffer" tool was used with the parameters provided in Figure 15. The name "PLB" stands for Polyline Buffer. Side Type "Full" was chosen because it was desired to create a buffer on both sides of the polyline (versus left or right). End type was "Flat" because it was easier to compartmentalize (or segment) square features. Method "Planar" was chosen because it's a local DEM, geoseic (planar preserving) is not an issue. Dissolve type was "Dissolve all output features into a single feature" because it was desirable to create one buffer to later be compartmentalized or segment. Figure 15 displays a map with the added buffer.

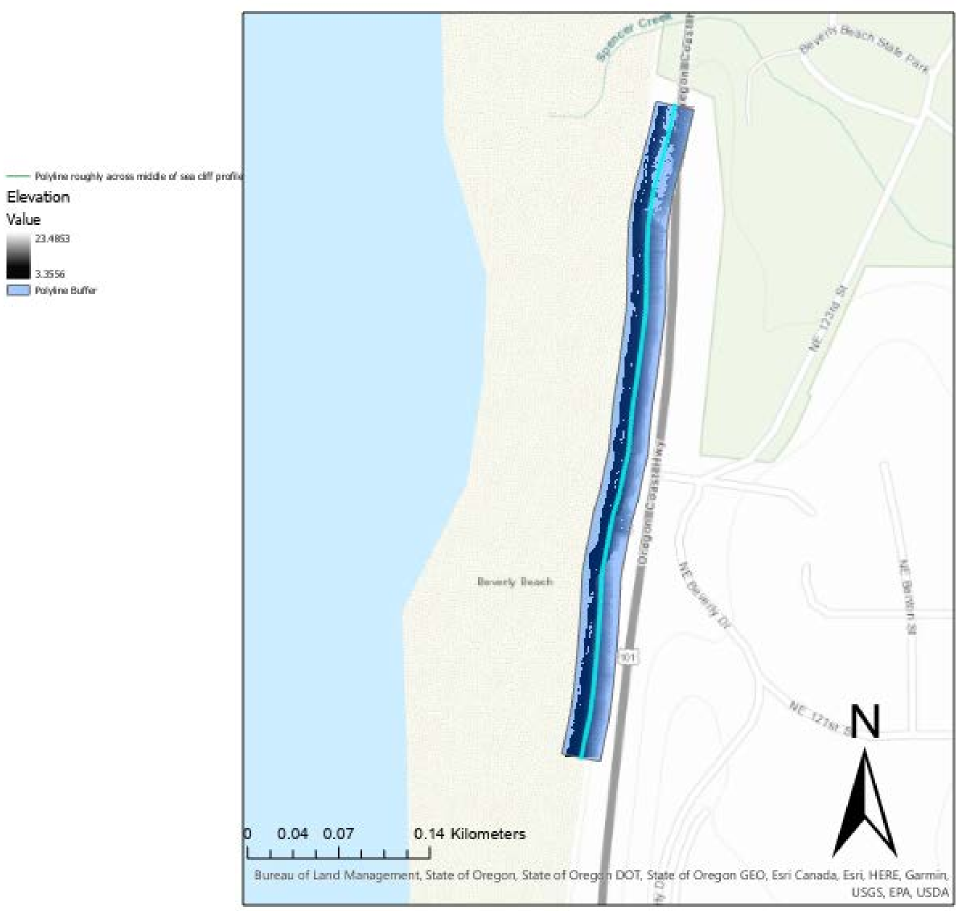

Figure 16: Map with polyline buffer

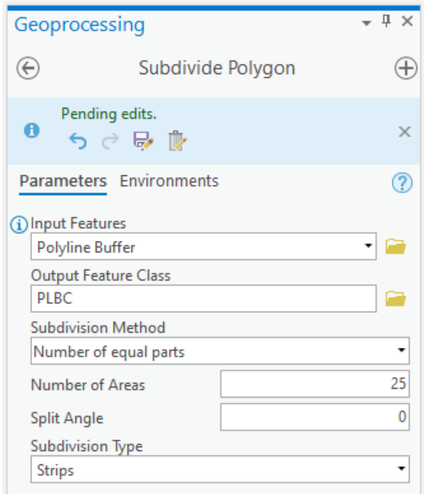

Figure 17: Parameters for "Subdivide Polygon" tool

To create compartments, the “Subdivide Polygon” tool was used with the parameters outlined in Figure 17. “PLBC” stands for polyline buffer compartments. The subdivision method is “number of equal parts” with 25 equal parts shaped as “Strips”. When the polyline was drawn, 25 lines individual lines comprised the entire polyline. Therefore this value was an appropriate fraction to divide the entire buffer by. Figure 18 displays the map with the added polyline buffer compartments.

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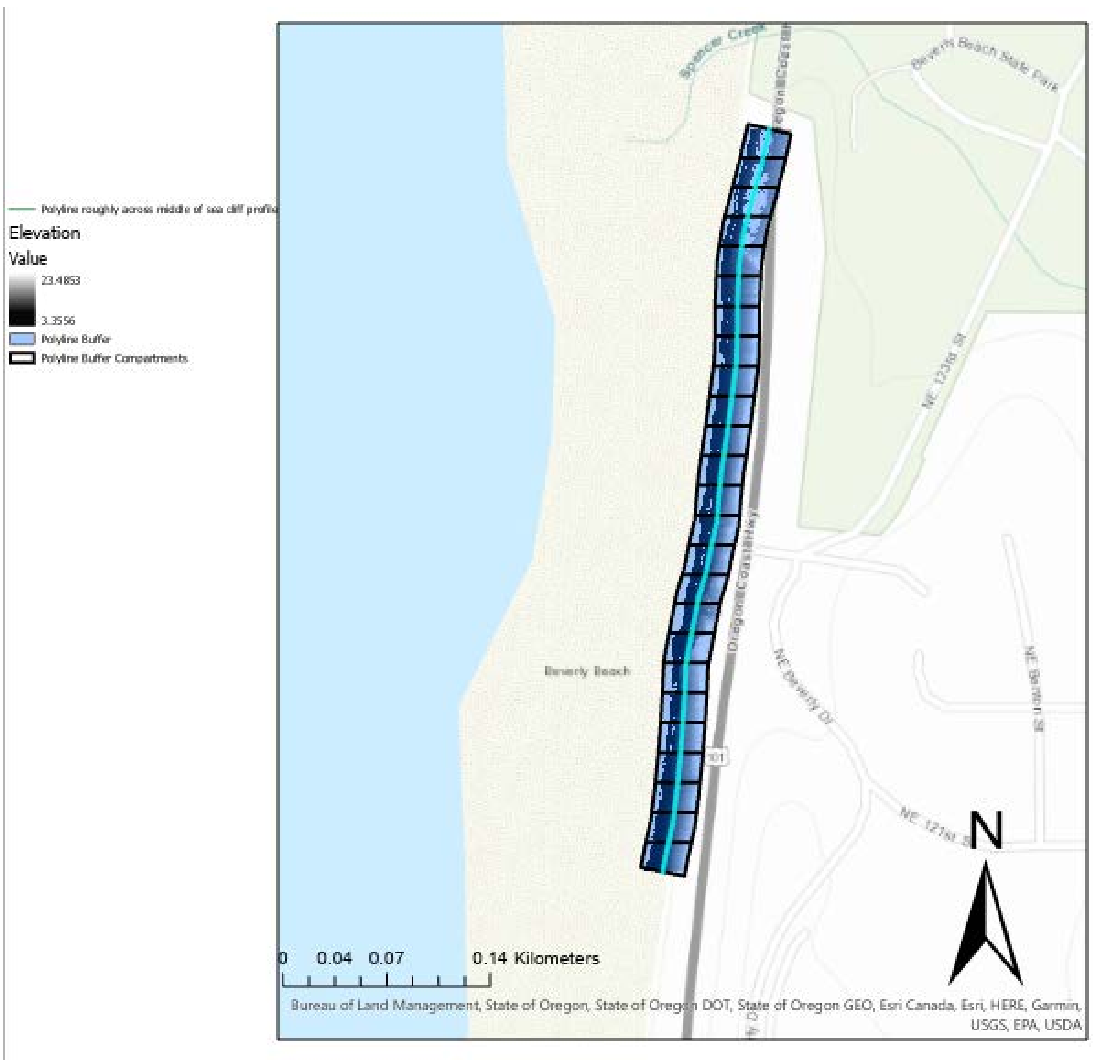

Figure 18: Map with Polyline Buffer Compartments added

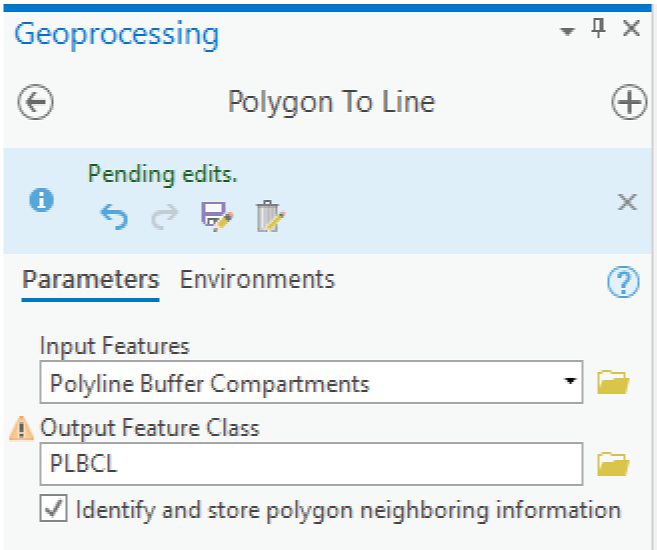

Figure 19: Parameters for polygon to line tool

In order to extract cross sections, the polygon had to be separated into lines with the “Polygon to Line” tool. Figure 19 summarizes the parameters. “PLBCL” stands for Polyline Buffer Compartment Lines. This tool separates the compartments at the vertices. Once this step was completed, an individual line can be choosen and under the “Feature Layer” tab then “Create Chart” then “Profile graph”. The cross section can be displayed.

Conclusion

Above summarizes the methodologies to extract sea cliff cross sections using LiDAR data, CloudCompare, RAMBO and Arc GIS Pro. While there are an infinite number of ways to improve both the quality and the speed of the methodologies, the purpose of this research was simply to provide proof of concept.

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