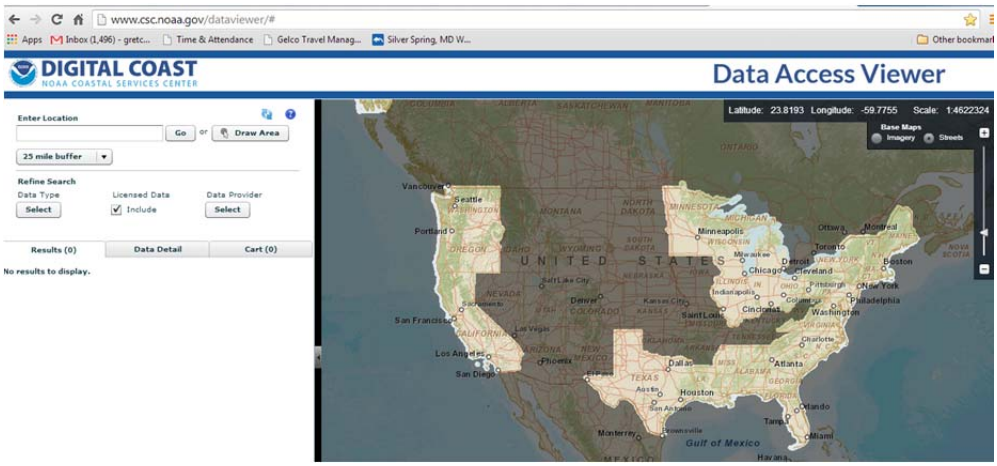
NCMP and Acoustic Processing Manual: Procedures to download, analyze and perform statistical analysis of NCMP bathymetric lidar data

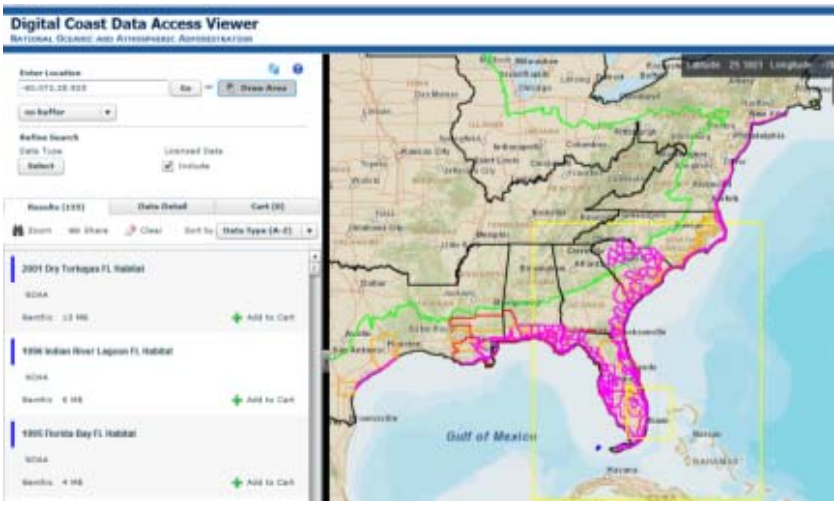
1. Pre-Processing

Finding Charts and Data

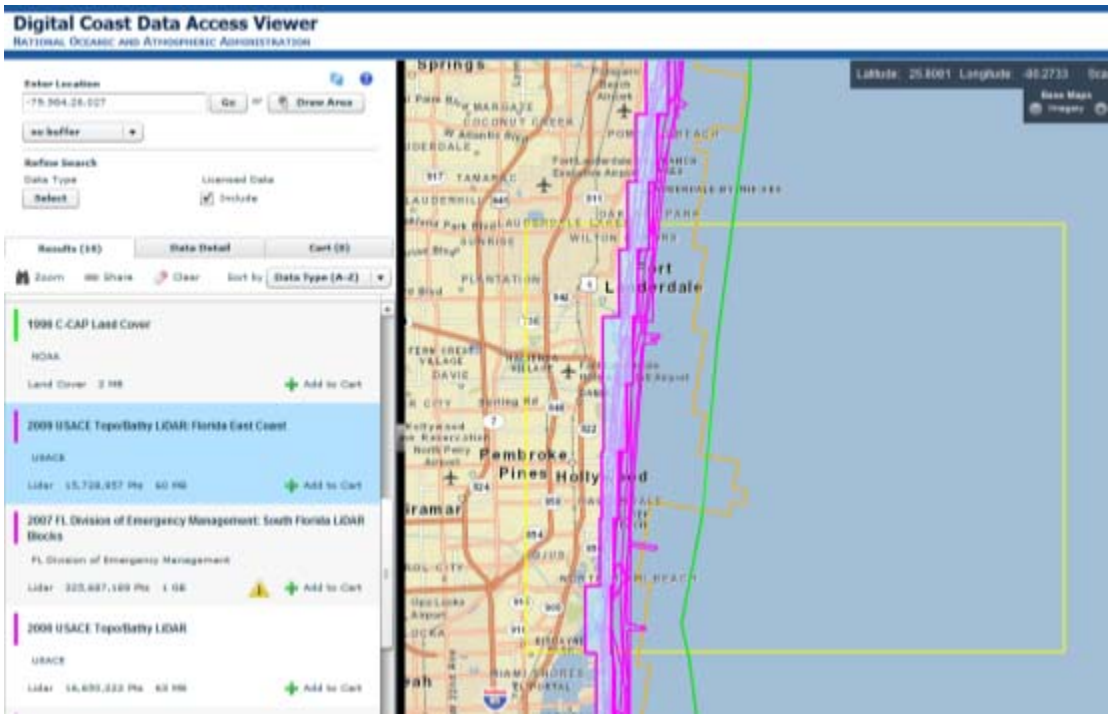
1.1. Open an Internet browser and navigate to http://www.csc.noaa.gov/dataviewer/#



1.2. Locate the desired area. Use ***Draw Area*** to focus the location. Use the smallest area for data to reduce wait time.

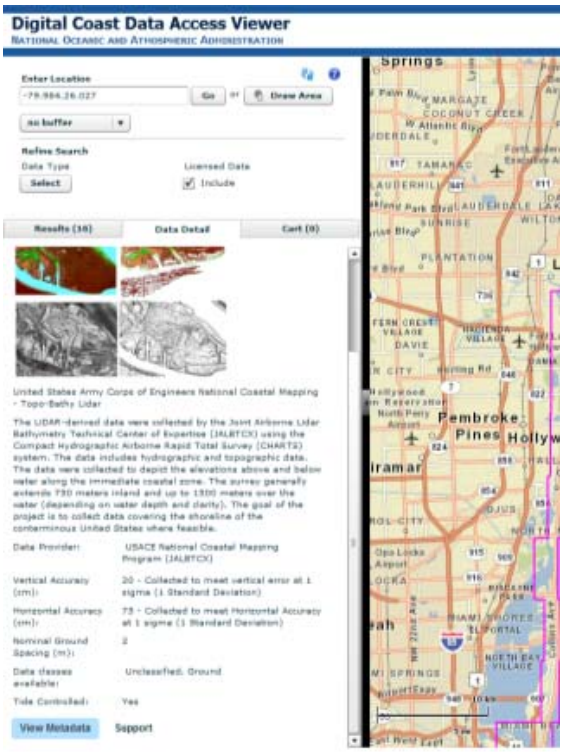


1.3. Search through ***Results*** for lidar data, which will appear in purple.



1.4. Click data to view ***Data Detail.***

1.5. Scroll down and click ***View Metadata.***



1.6. Search the ***Abstract*** within the ***Description*** for the word "Bathymetry" as an initial indication that you may have found bathymetric data. You may still have to examine the data directly to confirm that it is bathymetric.

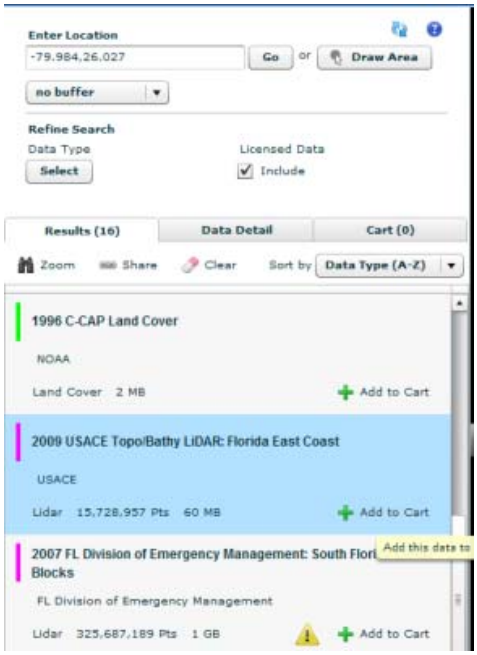
Identification_Information:
Citation:
Citation_Information:
Originator:
Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), Coastal Services Center (CSC)
Originator:
Joint Airborne Lidar Bathymetry Technical Center of eXpertise (JALBTCX)
Publication_Date: 201109
Title:
2009 US Army Corps of Engineers (USACE) Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) Lidar: East Coast of Florida
Publication_Information:
Publication_Place: Charleston, SC
Publisher: NOAA's Ocean Service, Coastal Services Center (CSC)
Online_Linkage:
<http://www.csc.noaa.gov/dataviewer/index.html?action=advsearch&qType=in&qFld=ID&qVal=1072>
Online_Linkage: <http://www.csc.noaa.gov/lidar>
Online_Linkage: <http://www.csc.noaa.gov>

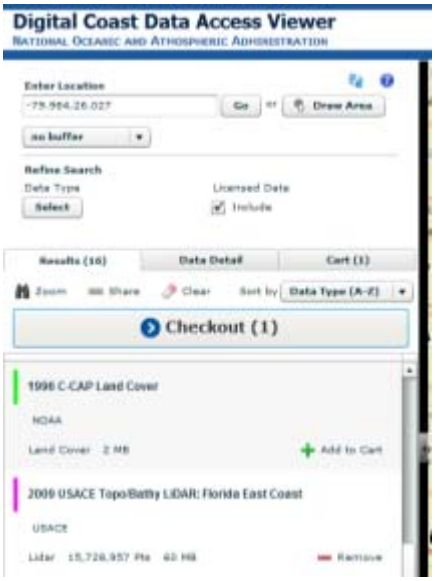
Description:
Abstract:
These files contain topographic lidar data classified as ground (2) and unclassified (1) in accordance with the American Society for Photogrammetry and Remote Sensing (ASPRS) classification standards. These data were collected by the Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system along the coast of Florida from August 31 - October 3, 2009. The area of coverage includes portions of the coastline in the following counties: Brevard, Broward, Indian River, Martin, Miami-Dade, Palm Beach, and Saint Lucie.
CHARTS integrates topographic and bathymetric lidar sensors, a digital camera and a hyperspectral imager on a single remote sensing platform for use in coastal mapping and charting activities. Data coverage generally extends along the coastline from the waterline inland 500 meters (topography) and offshore 1,000 meters or to laser extinction (bathymetry). Native lidar data is not generally in a format accessible to most Geographic Information Systems (GIS). Specialized in-house and commercial software packages are used to process the native lidar data into 3-dimensional positions that can be imported into GIS software for visualization and further analysis.
The data were provided to NOAA CSC in decimal degrees of latitude and longitude, referenced to the North American Datum of 1983 (NAD83). Vertical positions were referenced to the NAD83 ellipsoid and provided in meters. The National Geodetic Survey's (NGS) GEOID03 model was used to transform the vertical positions from ellipsoid to orthometric heights referenced to the North American Vertical Datum of 1988 (NAVD88). The format of the file was LAS version 1.1. For data storage and Digital Coast provisioning purposes, NOAA CSC converted the orthometric heights (NAVD88) back to ellipsoidal heights using GEOID03.
Purpose:
These data were collected as a part of the National Coastal Mapping Program (NCMP) to depict the elevations above the water in the Florida coastal zone.

Note: Metadata are not the most reliable indication of bathy; always check the data itself to confirm.

1.7. Go back to ***Results*** and select ***Add to Cart.***

1.8. Click ***Checkout.***





1.9. Click ***Next.***

1.10. For the outputs select the following:

1.10.1. Projection - UTM

1.10.2. Zone - May be auto filled. Verify that the selected zone is correct.

1.10.3. Horizontal Units - meters

1.10.4. Horizontal Datum - NAD83

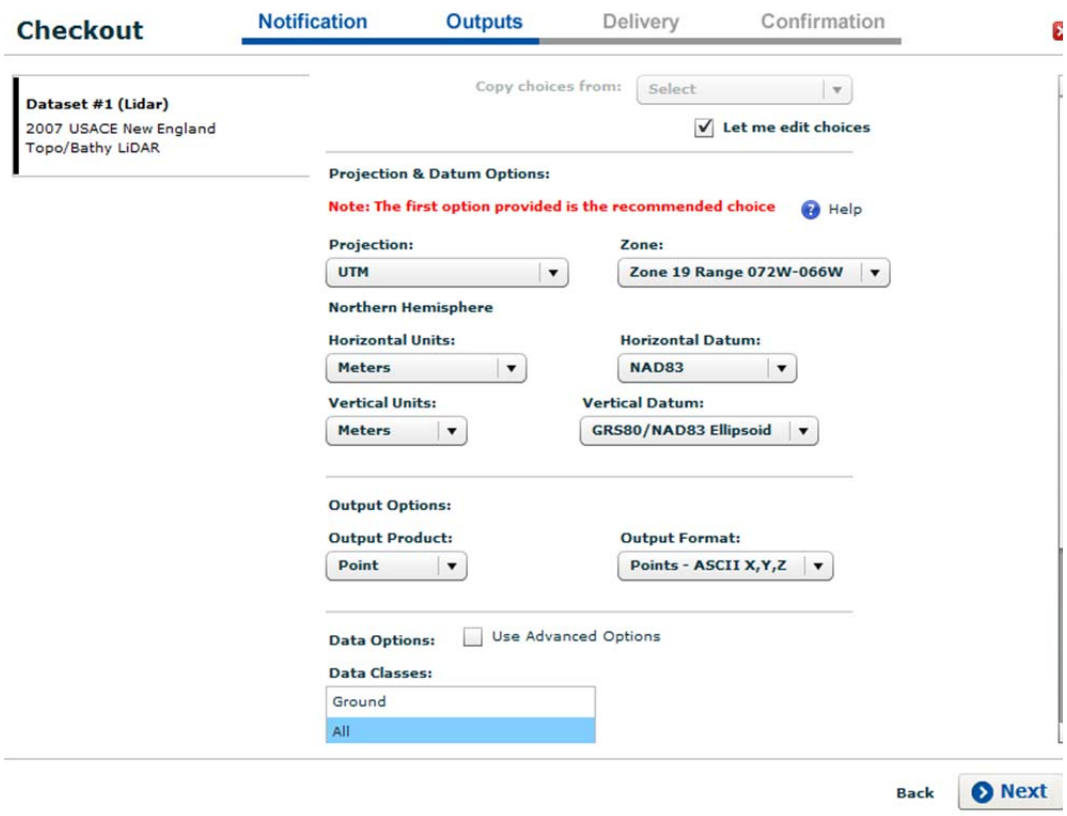
1.10.5. Vertical Units - meters

1.10.6. Vertical Datum - NAD83 Ellipsoid

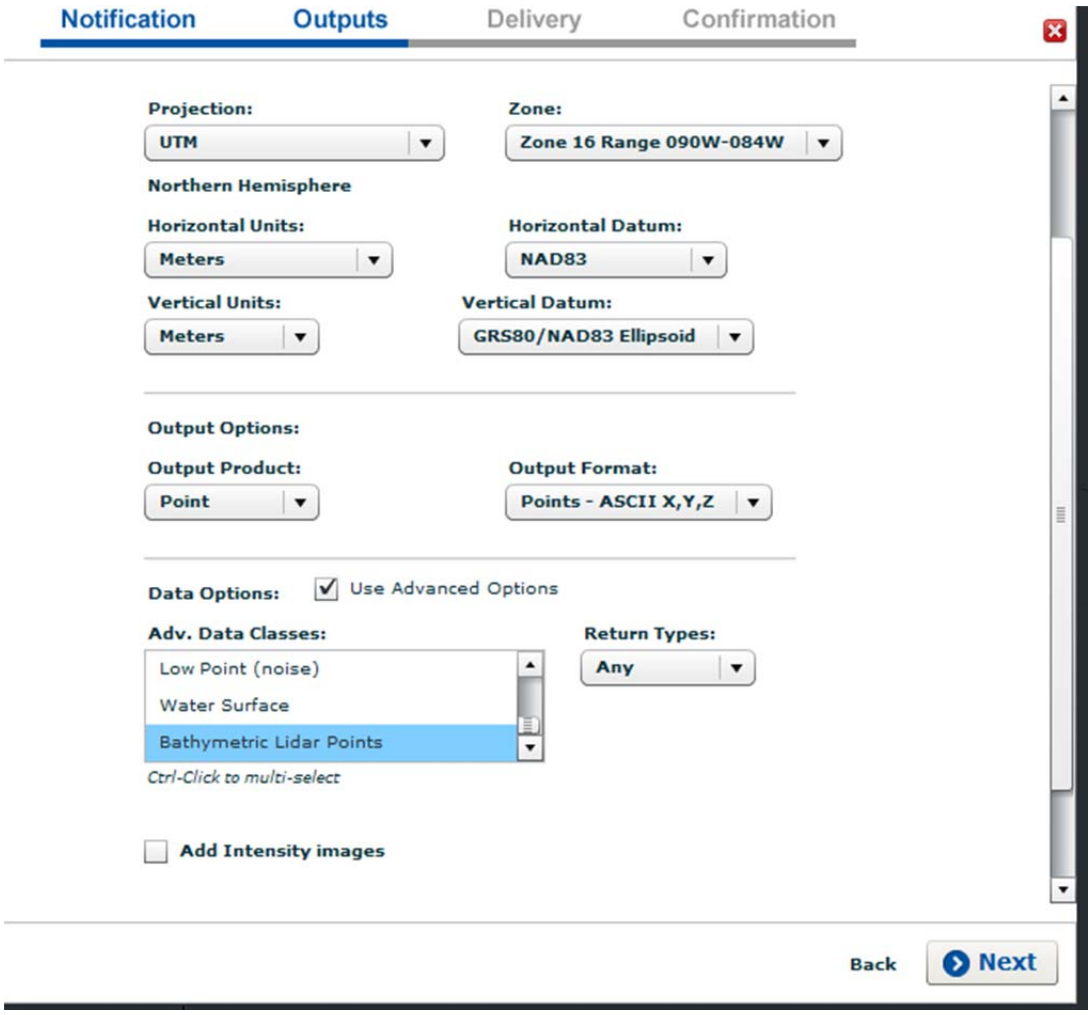
1.10.7. Output Products - Points

1.10.8. Output Format - Points- ASCII

1.10.9. Data Classes - All

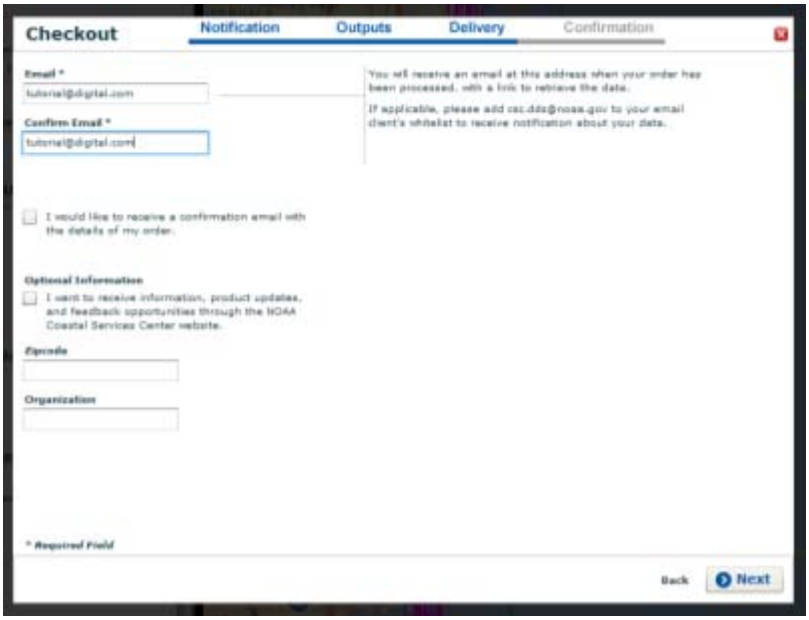


Note: You can also select LAS for the Output Format if, for example, you find there is no bathy in the ASCII. Alternately, select 'Advanced options' and select bathy points.



1.11. Click ***Next.***

1.12. Enter the email address to which the data should be delivered. Click ***Next***.



1.13. Click ***Next*** to confirm. Note that it may take several minutes or longer to receive the email containing the link to download your data.

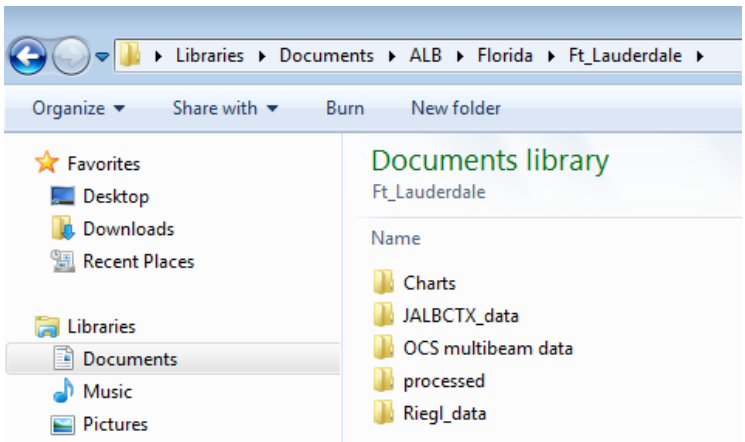
1.14. Once you receive the email, open it and copy the link within it to your browser's navigation bar.

1.15. Download and save the file.

1.16. Extract the files and save them in a designated folder.

Using ArcMap: Tips for Organizing Files

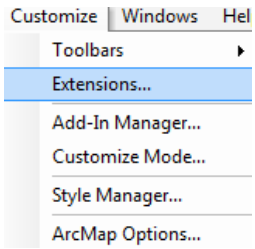
1.17. Consistent file structures and naming conventions are important for organizing your data. For example, one method of file structure is to separate the data you would like to analyze according to region and then store any grids or other files you create in a sub-folder within each region named "processed."

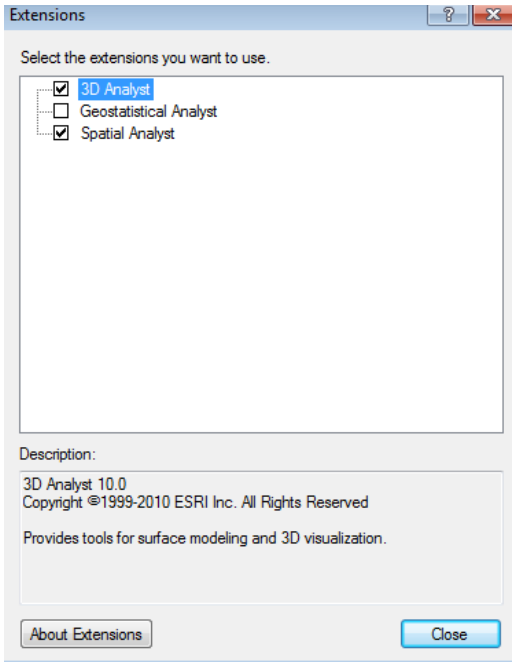


1.18. It may be helpful to use a file naming convention that indicates the region, data origin and action that you are performing (e.g., ftLauJALclip.shp)—just watch out for the 13-letter limit. The software applications Advanced Renamer (freeware with GUI) or Cygwin are capable of executing a batch rename of your files should you need it.

1.19. Avoid processing across the network – process on your PC. Save your downloaded ALB files on the server and other files you want to back up.

1.20. Set up ArcMap using the Spatial Analyst and 3D Analyst Extensions (modules):





1.21. When you begin a new project, follow the steps below to set the coordinate system to the local UTM zone of the study site (e.g., Ft. Lauderdale, FL):

- Right-click on ***Layers***.
- Select the ***Coordinate System*** tab.
- Select ***Predefined*** → ***UTM*** → ***NAD83*** → ***Northern Hemisphere*** and choose the zone where your data is located (e.g., Florida is zone 17N).

1.22. Go to Step 1.36 to add in Easting and Northing headers. If you have files in LAS format, follow the steps below to convert them.

Converting LAS files: Obtaining LAStools and converting files for use in ArcMap

1.23. Navigate to http://www.cs.unc.edu/~isenburg/lastools/.

1.24. Select ***download LAStools here***

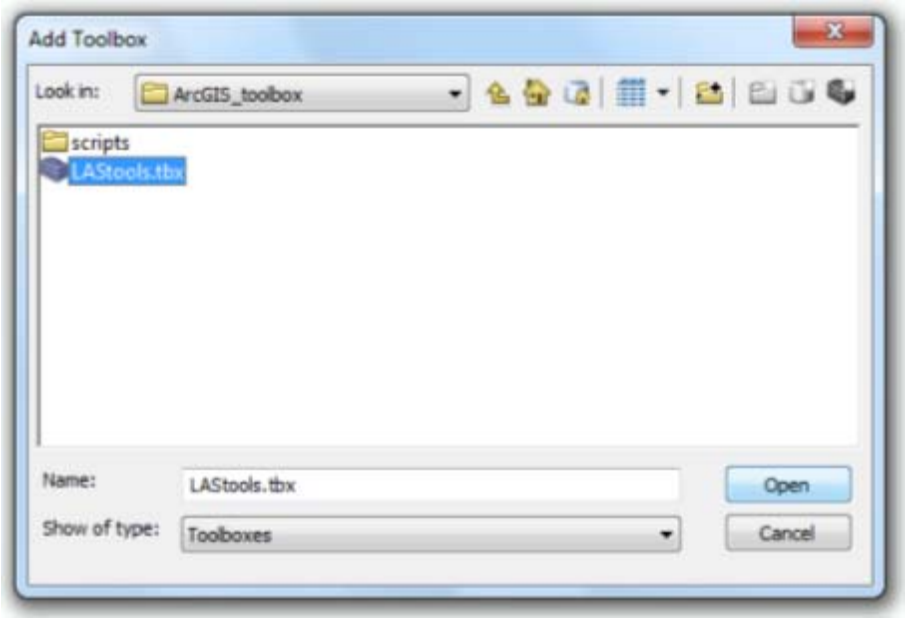
1.25. Extract the files and save to a folder.

1.26. Open ArcMap 10.

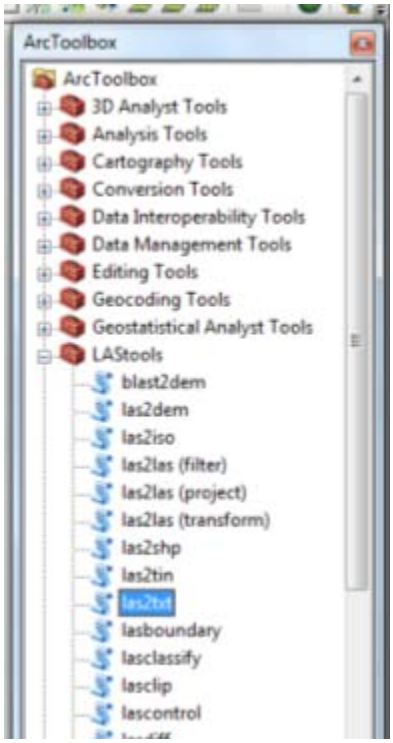
1.27. Open the ***ArcToolbox Window.***

1.28. Right-click on ***ArcToolbox.*** Click ***Add Toolbox.***

1.29. Select the ***LAStools*** folder, open the ***ArcGIS_toolbox***, select ***LAStools.tbx***, and click ***Open.***



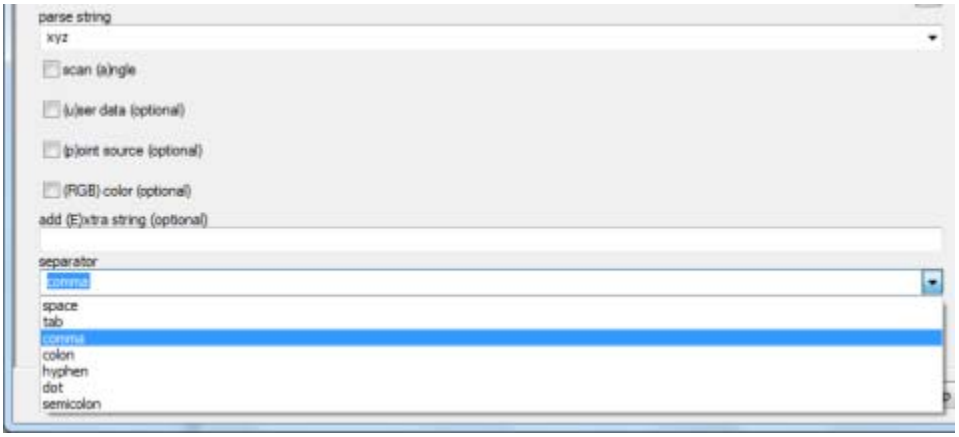
1.30. ***LAStools*** can now be used within ArcMap. Select ***las2txt.***



1.31. ***Input*** the Las file by selecting the folder icon. Make sure the file you select has the .las extension (i.e., *.las).

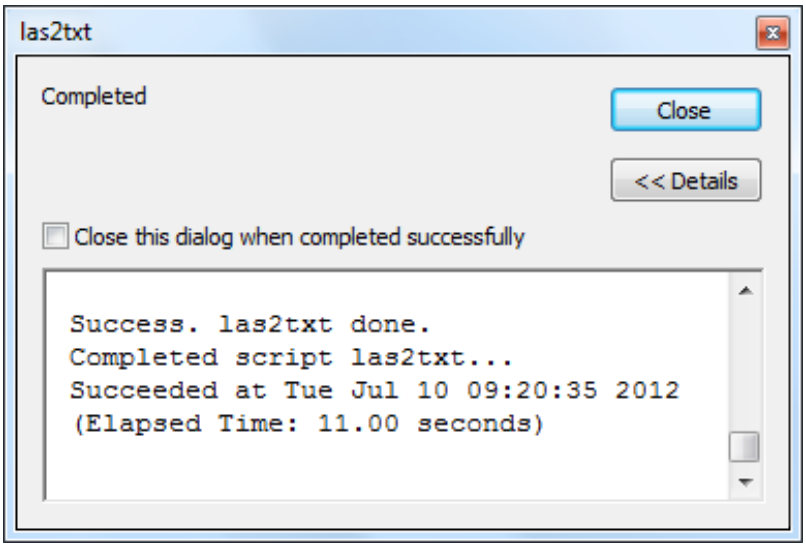
1.32. Set the ***parse string*** to ***xyz***.

1.33. Change the ***separator*** to ***comma***.

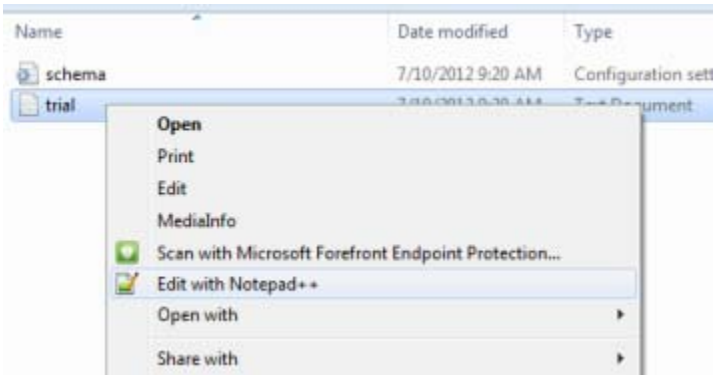


1.34. Select a desired location for the ***output file*** and select ***OK.*** When the execution box says ***completed***, the file can be accessed as a .txt file.

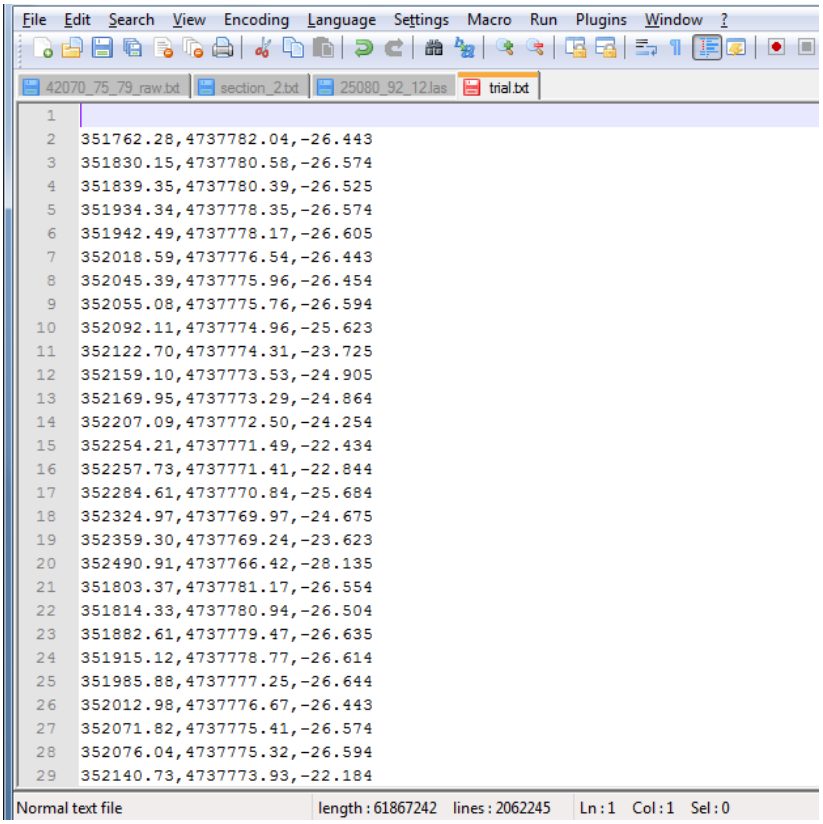
1.35. Click ***Close.***



1.36. Go to the converted .txt file. Right-click and select ***Edit with Notepad ++***.

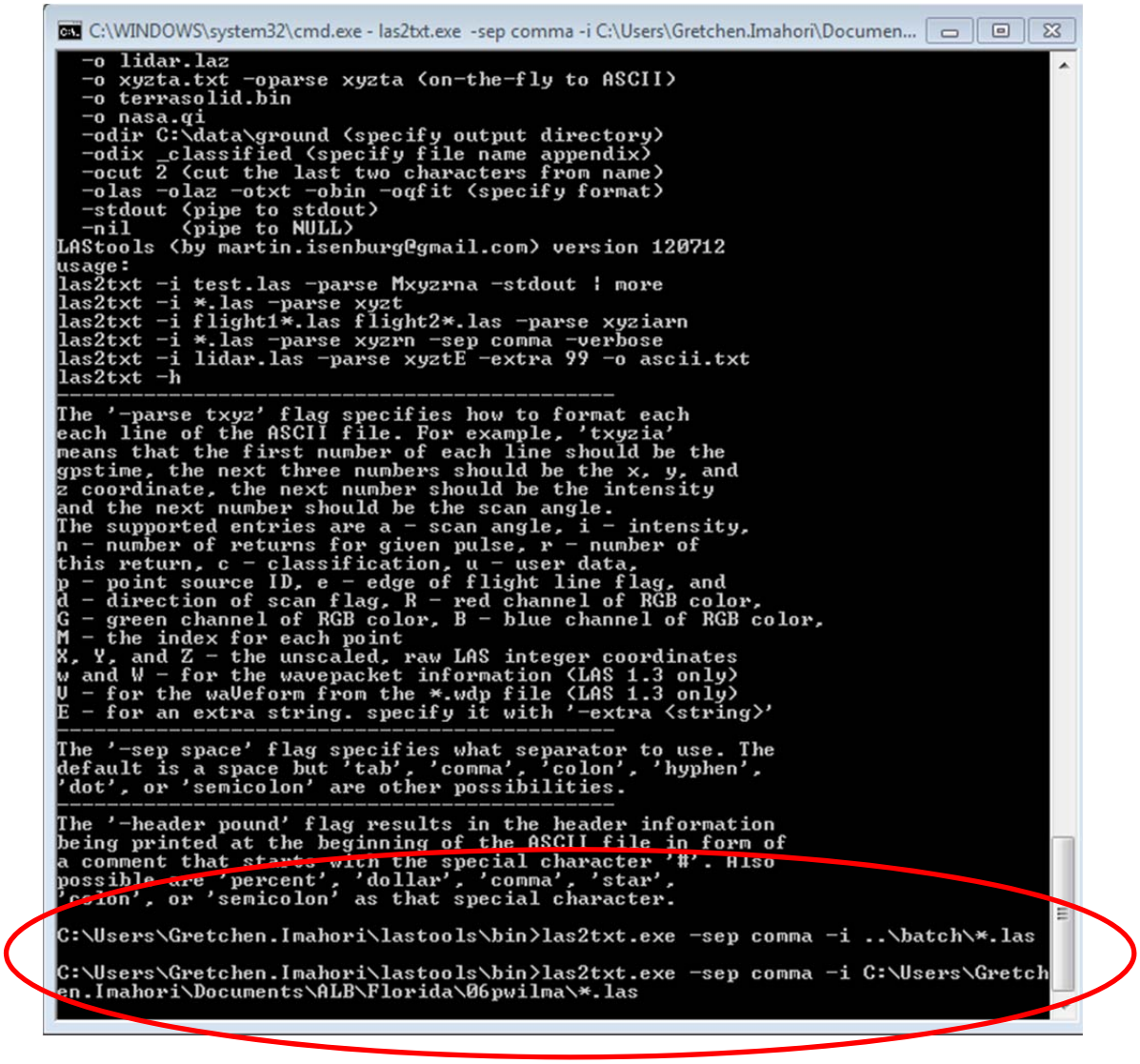


1.37. Add a row above the top layer of numbers by placing your cursor to the left of the topmost row of numbers, hitting ***Enter***, and typing ***Easting,Northing,Elevation*** in the newly created row.



To Batch-Converting LAS Files

1.38. Open up a command prompt window

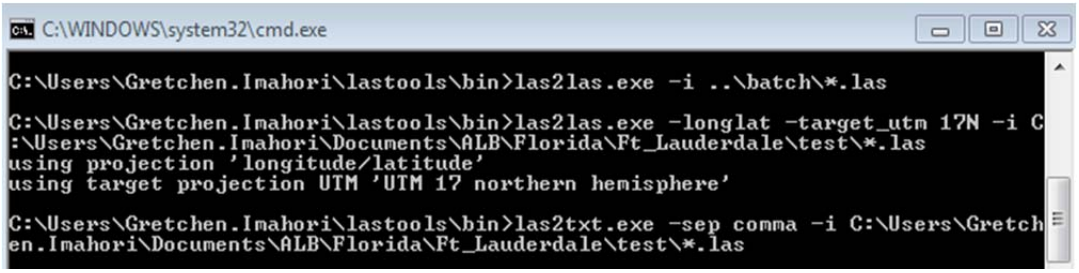


1.39. Use the ***cd*** command to change directories to get to the executable (e.g., cd lastools).

(See the circled area above if you need tips on how to use the command mode.)

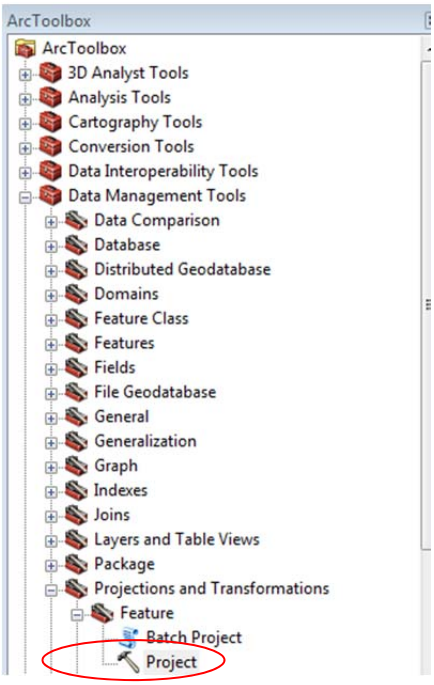
Make sure the data is comma delimited and that you type the correct directory where the .las files reside.

1.40. If your data are geographic coordinates (GC; long/lat) vice UTM (Easting/Northing) you will need to convert the long/lat to Easting/Northing (see image below):

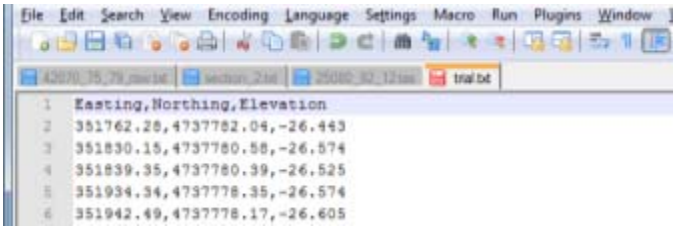


1.41. If you encounter an error trying to convert GC to UTM, first check to see that you have spelled everything correctly and that you have selected the correct directory. If both are correct, your .las file may contain only topo data not bathy and topo. If there is an option to get the ASCII files from Digital Coast (see 1.10.9), try those files—remember to add a comma and header. Open the files in ArcMap to see if they are in the water or on land.

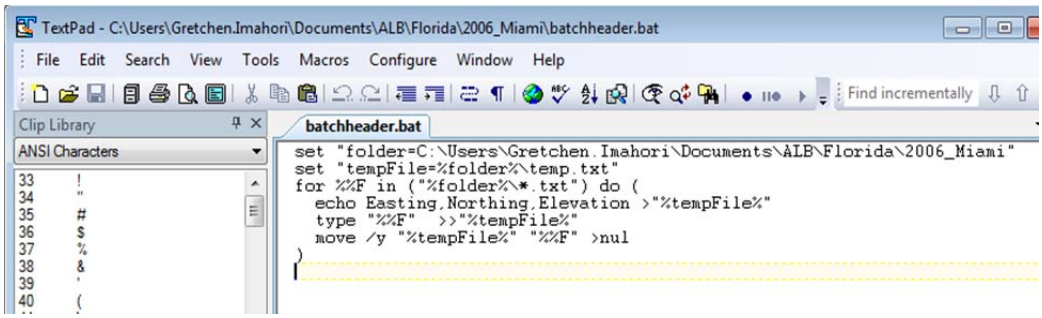
Note: You can also use ArcToolbox to convert GC to UTM:



1.42. Add **Easting,Northing,Elevation** to the top row. Then save the file.



Note that you can execute a batch process to add this header to multiple files (see below for example):



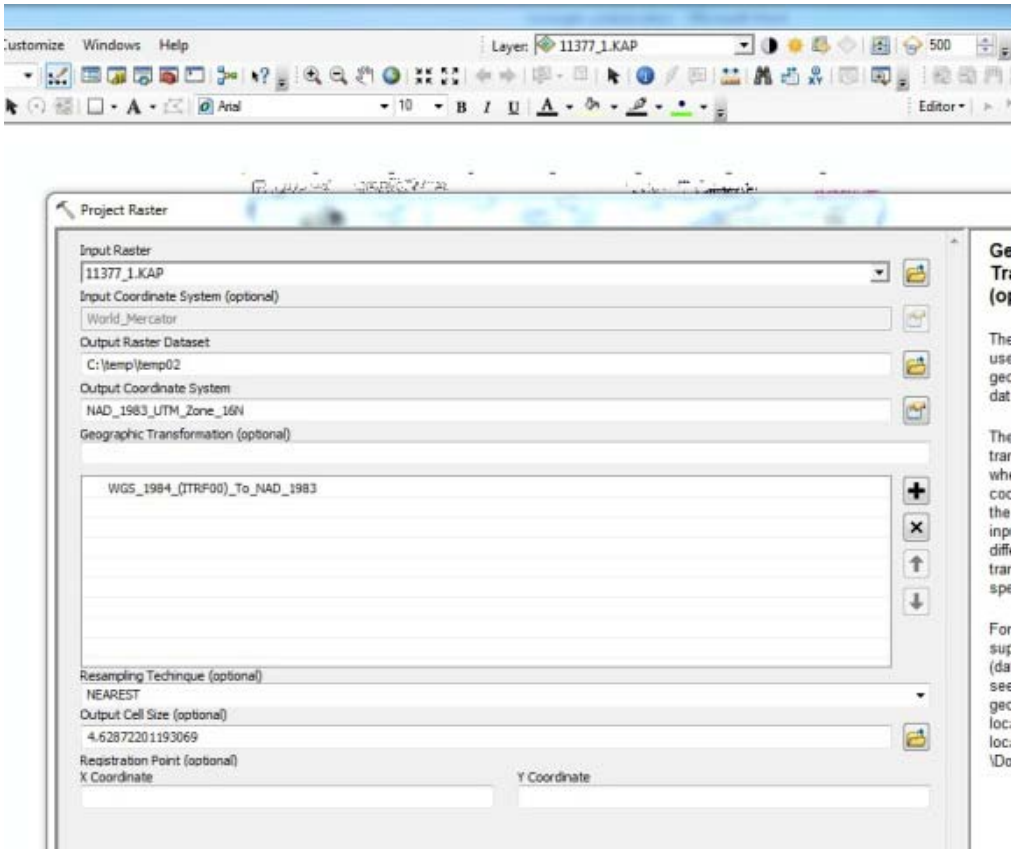
Following this example, you need only change the directory in the first line to your directory and ensure that the .bat file resides in the same directory as the files to which you are adding a header. Using TextPad to edit the .bat file is recommended instead of Notepad, which hangs when opening large files.

1.43. To add a Chart in ArcMap select ***Add Data.***

Note: Before beginning, save a separate copy of the chart on your hard drive, because the changes you are about to make to the projection will be permanent.

Set the projection (UTM NAD83 zone) and then change the chart projection. Go to

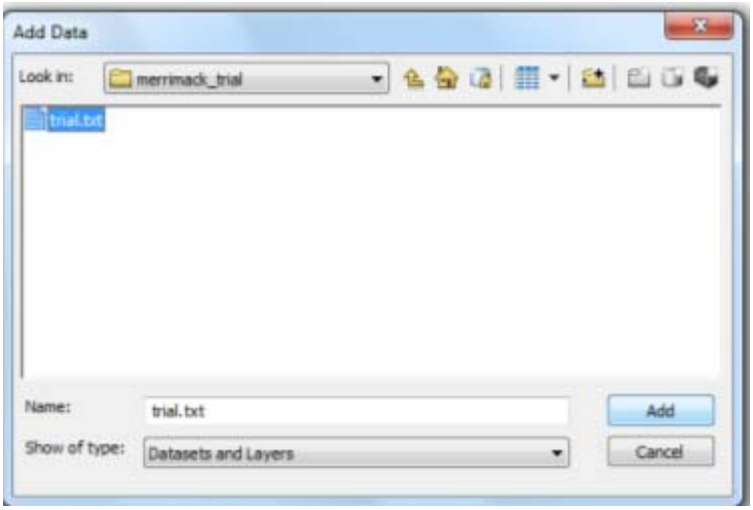
Arc Toolbox → Data Management → Projections and Transformations → Raster → Project Raster tool. If you have difficulty finding the tool, you can also conduct a Windows Search (see below for example):



Once the chart and project are in the correct projection, bring up the VDatum shape files to determine whether there is VDatum coverage for your area.

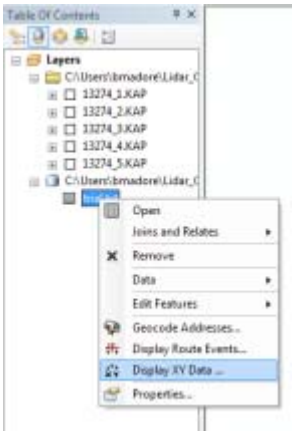
- If there is coverage, translate your data to mean lower low water (MLLW) before adding it to ArcMap (see SOP available at processing branches). If you aren't sure what geoid to select, pick the one closest to the time the data was acquired.
- If there isn't coverage, continue to follow the steps below and a later step will indicate how to determine the offset. Now add in the data.

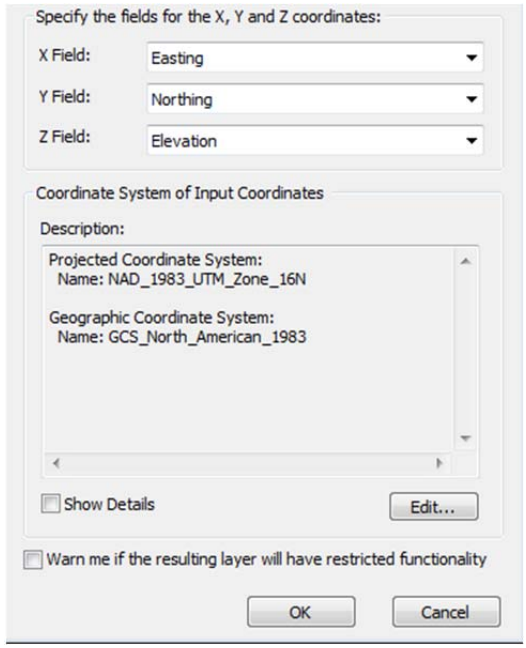
1.44. Insert the edited .txt file by clicking ***Add***.



Note: If you encounter a problem with creating an event file (when you translate the file in VDatum), open the text file to check whether ***Null*** *appears under the headings for Northing and Elevation. Most likely the commas for each of the columns will need to be added. Be sure there is no extra comma at the end of each row; if you are using TextPad, you can use* ***Batch control*** *under* ***Configure*** *to delete the comma or extra space(s).*

1.45. The layer will appear in the ***Table of Contents.***

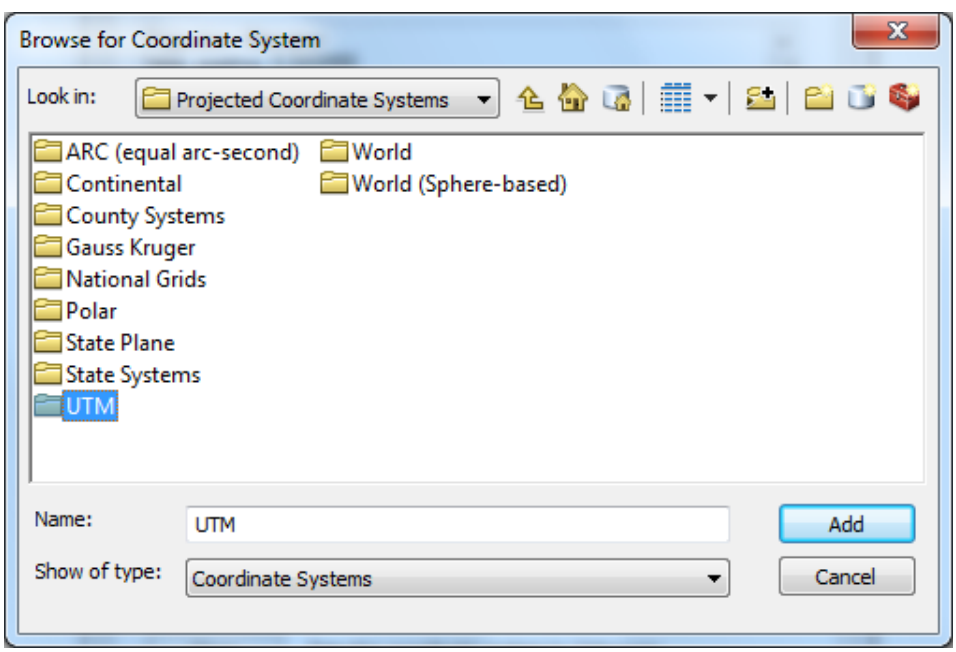




1.46. Right-click on .txt file and select ***Display XY Data***

1.47. Change the ***X Field, Y Field, and Z Field*** to ***Easting, Northing,*** and ***Elevation***, respectively.

1.48. Select ***Edit*** to choose a Coordinate System. Click ***Select***, then ***Projected Coordinate System***, then ***UTM***.

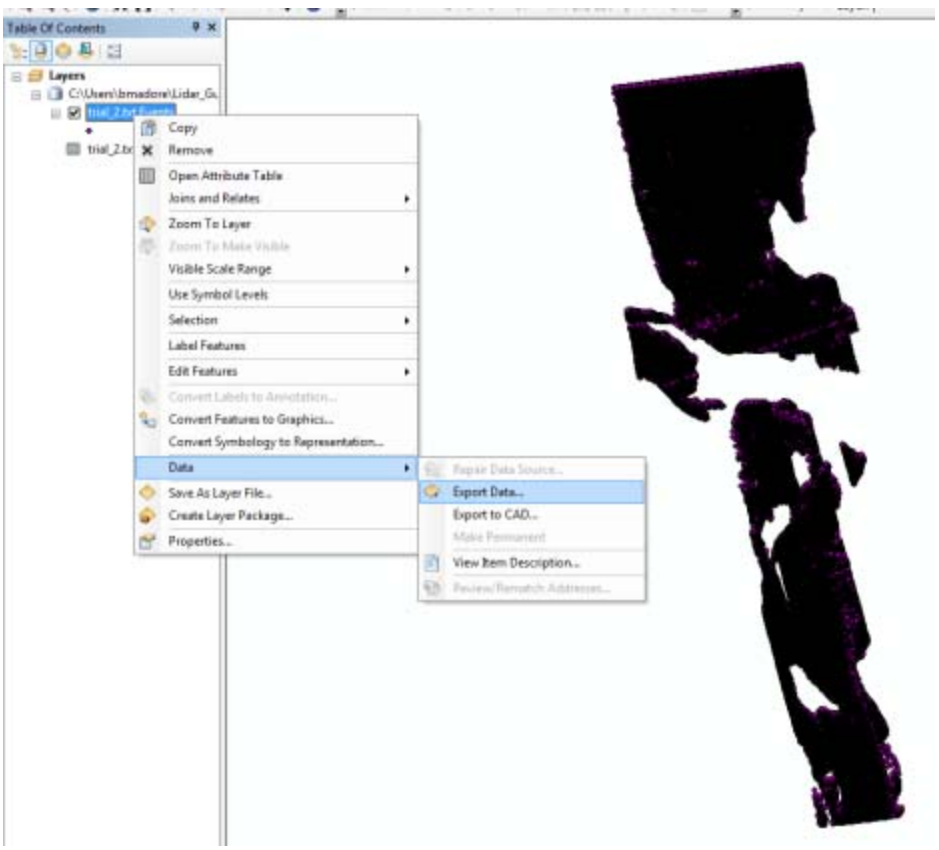


1.49. Select **NAD83** and choose the ***UTM Zone*** that corresponds to the area being examined. Click ***OK*** and ***OK*** again***.***

1.50. A message will appear about ***not having an Object-ID field***. Click ***OK***. Depending on the size of the file, it may take a few seconds to load the image.

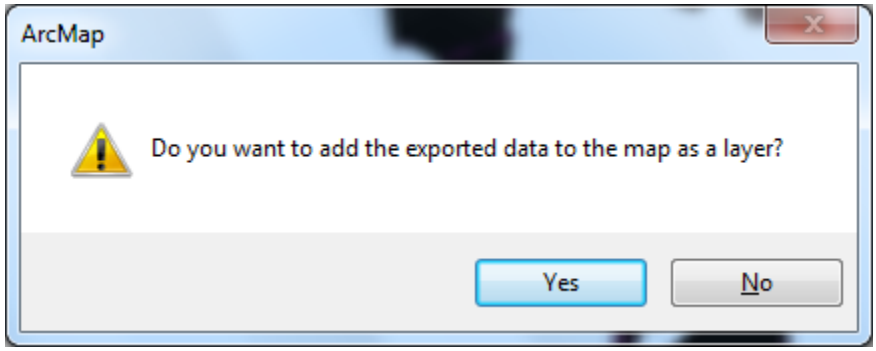
Note: For large datasets and to make it easier to see just the extents of the data, you can convert the data to a raster (Arctool box: conversion → to Raster → feature to raster).

1.51. Right-click on the ***event*** file that has been created. Select ***Data*** and then ***Export Data.***



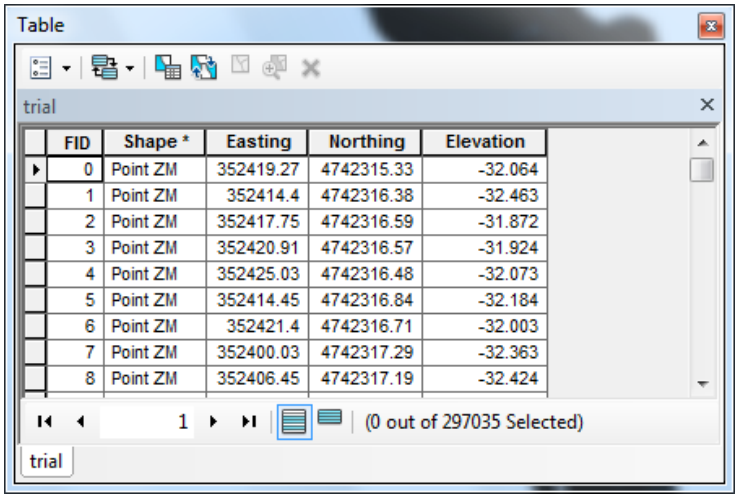
1.52. Select the coordinate system as ***this layer's source data***, select a destination to save the feature, and click ***OK.*** The export may take a few minutes depending on size of the export file.

1.53. After the export is complete, you will be asked if you want to add the exported data to the map as a layer.



Select ***yes*** to save your lidar data as a shape file.

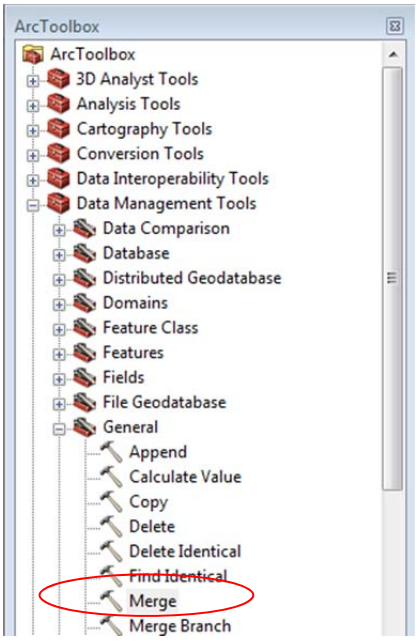
1.54. To view a table of the data points right-click on the shape file and select ***Open Attribute Table***.



FID	Shape *	Easting	Northing	Elevation
0	Point ZM	352419.27	4742315.33	-32.064
1	Point ZM	352414.4	4742316.38	-32.463
2	Point ZM	352417.75	4742316.59	-31.872
3	Point ZM	352420.91	4742316.57	-31.924
4	Point ZM	352425.03	4742316.48	-32.073
5	Point ZM	352414.45	4742316.84	-32.184
6	Point ZM	352421.4	4742316.71	-32.003
7	Point ZM	352400.03	4742317.29	-32.363
8	Point ZM	352406.45	4742317.19	-32.424

Note: Depending on the data source, it is possible that your data may export into multiple files. For example, when data is obtained from CSC's Digital Coast, it exports as a single file, but when data is obtained directly from JALBTCX, it exports into multiple files. If the data exports into multiple files, you will need to use the merge

function to combine the files.



1.55. Select the different datasets you would like to merge and the folder where you want the final file to be saved (e.g., process folder).

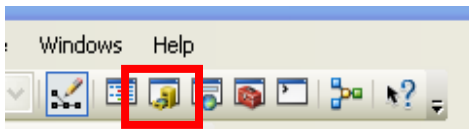
1.56. If the data includes land portions, you can clip these out to make loading and unloading the data easier and faster.

1.57. If you want to see the NCMP lidar and Office of Coast Survey (OCS) multibeam echosounder (MBES) overlap and you have a shape file of the OCS data, you can convert it to NAD83 UTM (it will be in Geographic). Go to ***Arc Toolbox*** → ***Data mgmt. tools*** → ***Projections and Transformation*** → ***feature*** → ***project*** and select the projection and the location where you want to save the new file. Once the file is created, you can change the transparency by right-clicking on ***File*** → ***Properties*** → ***Display*** → to bring up transparency settings. A transparency of 50% works well. You can also check for good overlap by creating a grid for the NCMP and OCS data (see

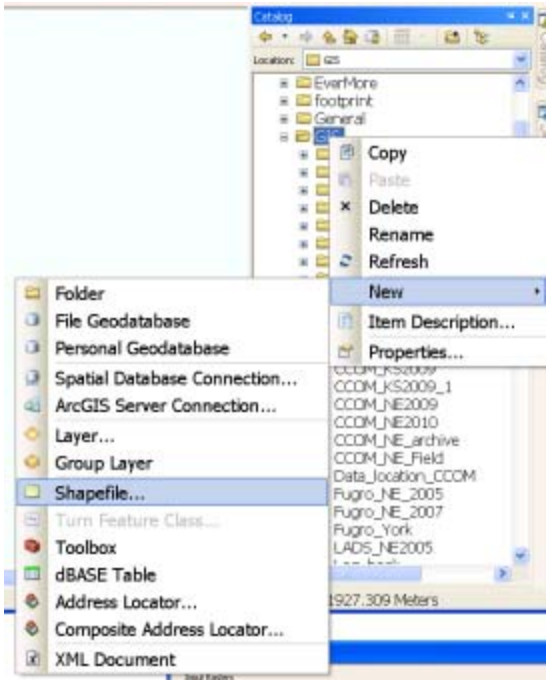
section 3).

2. Calculating Density

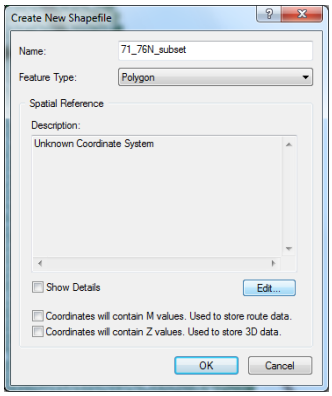
2.1. Activate ArcCatalog by clicking on the icon in the upper toolbar. Dock it by double-clicking on the ArcCatalog window.



2.2. Navigate in the ***ArcCatalog*** window to your GIS directory. Right-click on the directory and select ***New → Shapefile***.

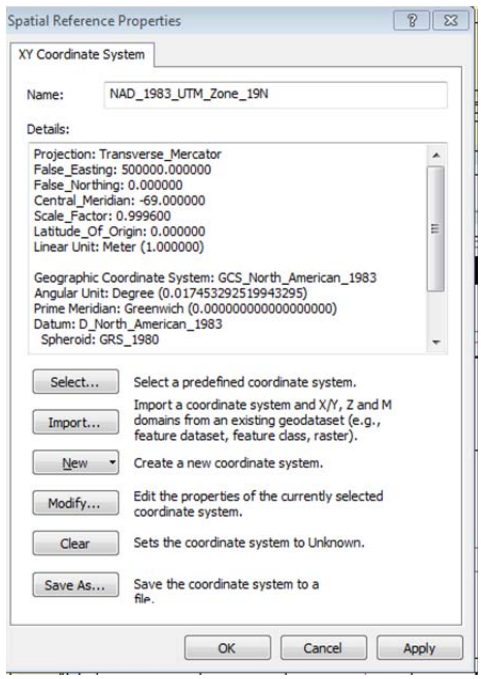


2.3. Type the name of your feature in the ***Create New Shapefile*** window and select ***Feature Type → Polygon.*** Click ***Edit*** to change the spatial reference.

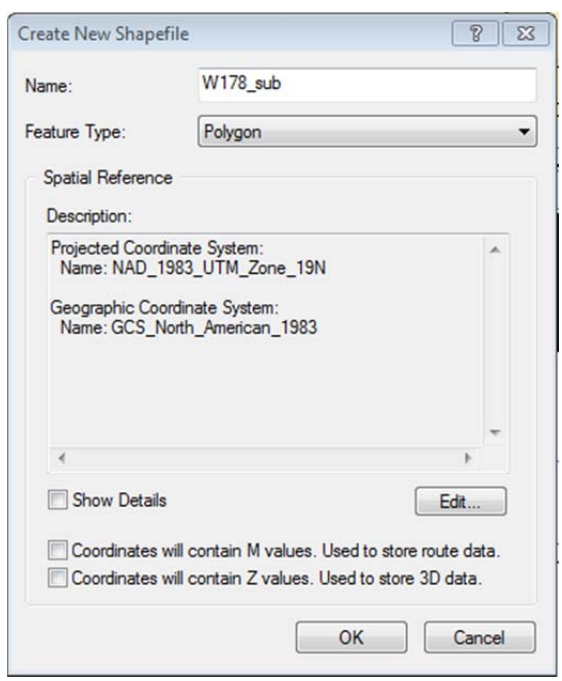


2.4. Select ***Projected Coordinate Systems → UTM → NAD83*** followed by the corresponding ***UTM Zone*** your data is using.

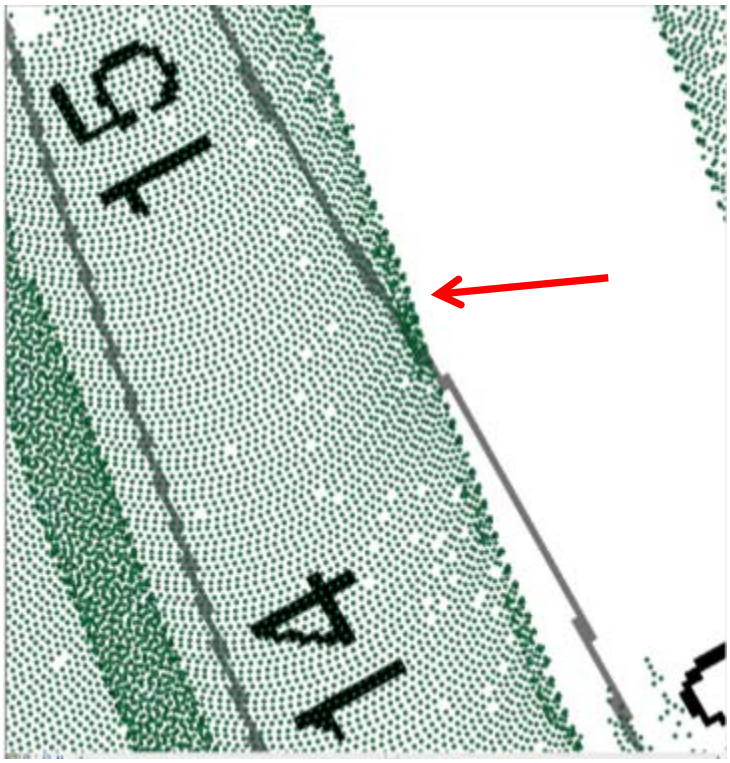
2.5. Click ***OK*** in the ***Spatial Reference Properties*** window.



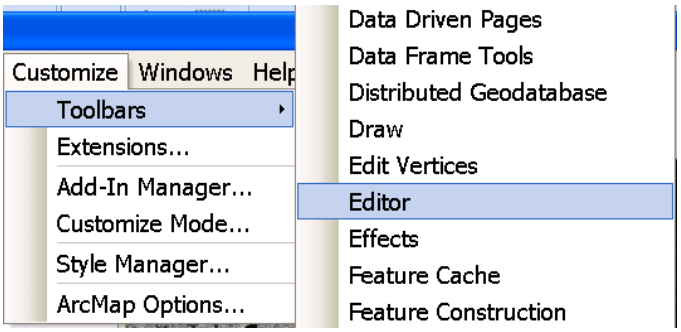
2.6. Click ***OK*** in the ***Create New Shapefile*** window.



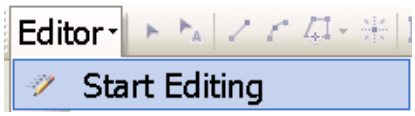
2.7. Zoom into a point cloud of the layering being analyzed where individual points can be seen, where there is no overlap, and where there are no big gaps in the data points. See below for example.



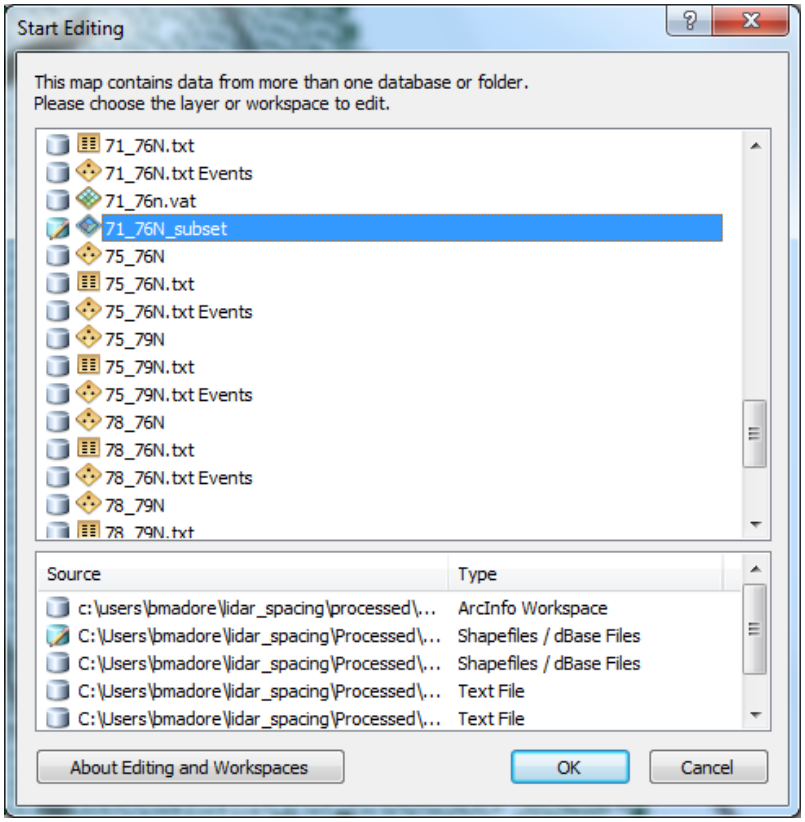
2.8. Activate the ***Editor*** toolbar by selecting ***Toolbars*** → ***Editor*** from the ***Customize*** tab.



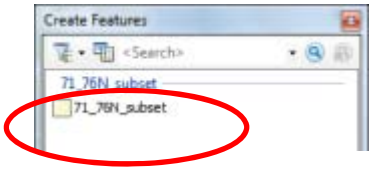
2.9. Select ***Start Editing*** in the Editor toolbar.

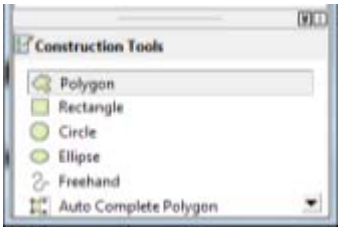


2.10. Select the shapefile created previously if there is more than one option and click ***OK.***



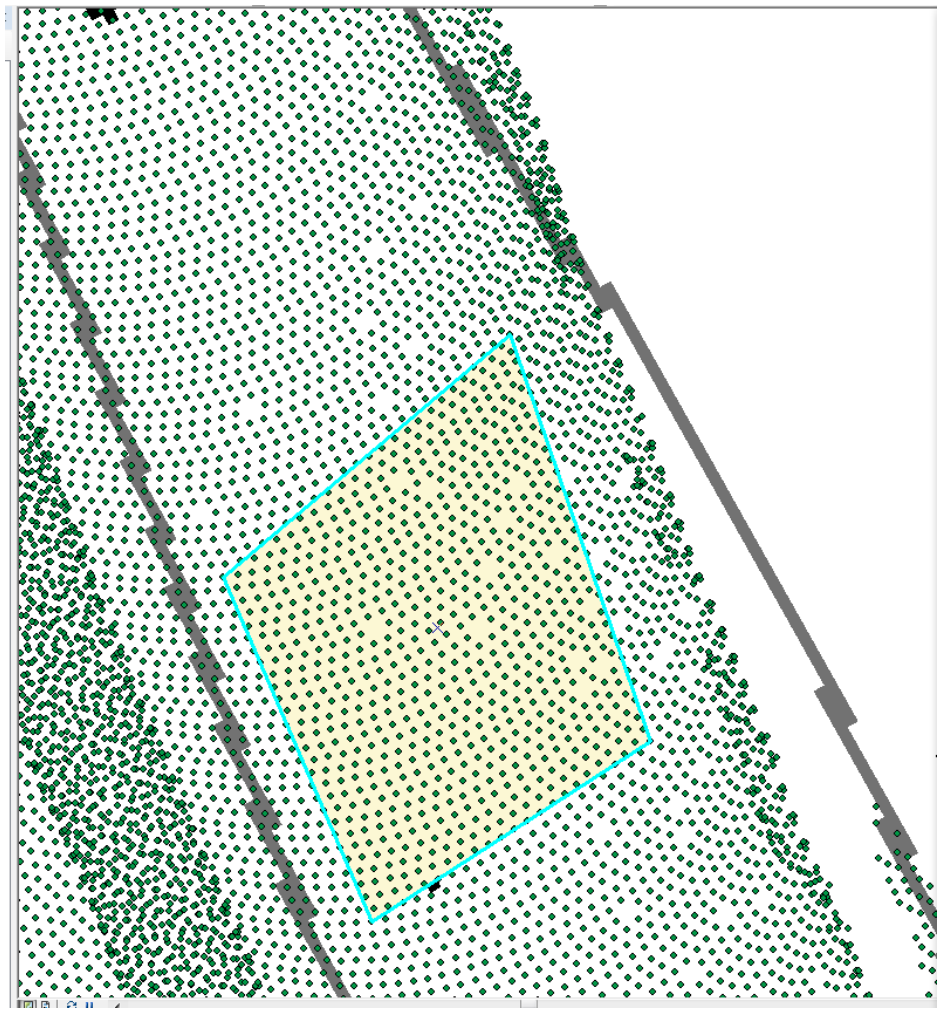
2.11. In the ***Create Features*** window, double-click on the shapefile (circled in red below) and then select ***polygon***.



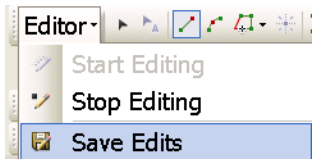


2.12. Create a polygon by left-clicking once on the image for a vertex point and twice when you are finished.

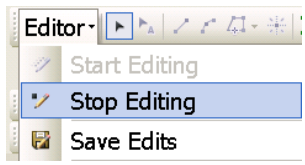
2.13. Select an area with good spacing, no overlap, and few to no holes missing in data (see the area outlined in blue below).



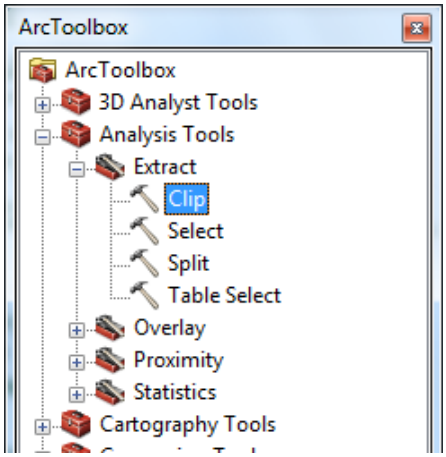
2.14. Select ***Save Edits*** in the ***Editor*** toolbar.



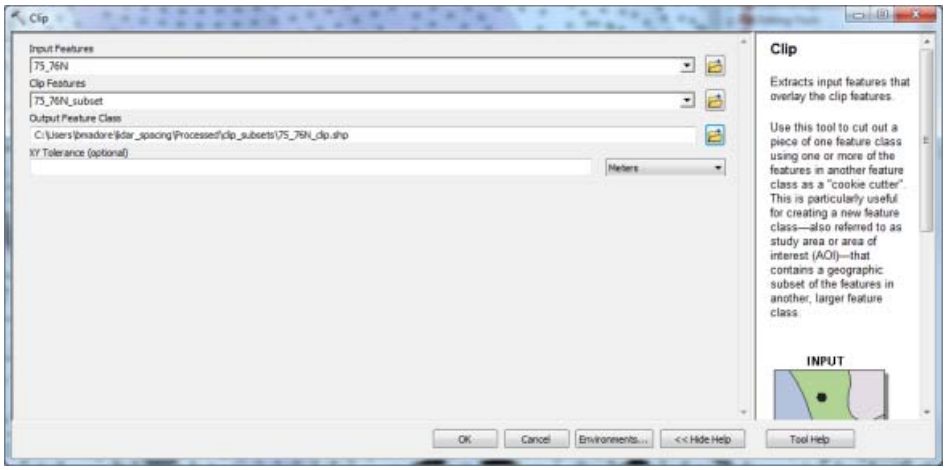
2.15. Select ***Stop Editing*** in the ***Editor*** toolbar.



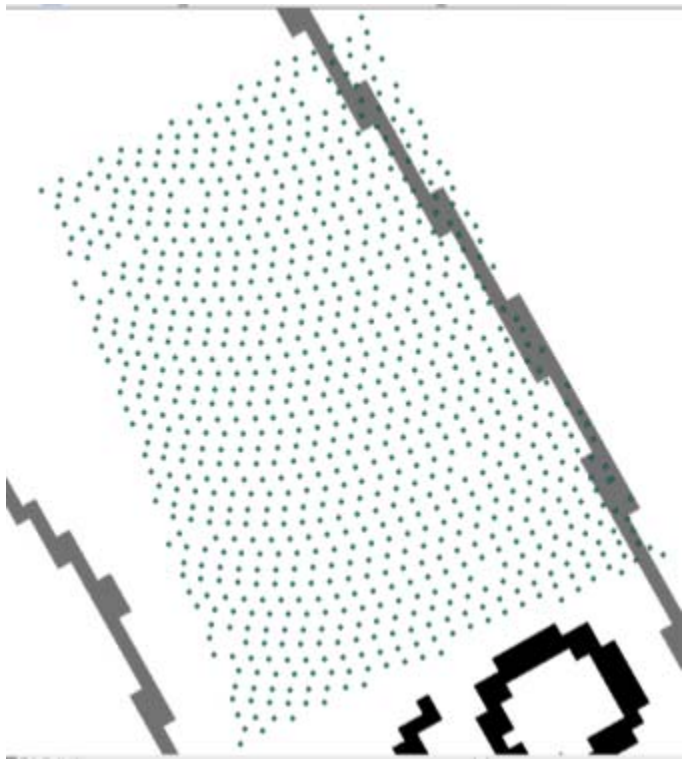
2.16. In ArcToolbox, select ***Analysis Tools → Extract → Clip***.



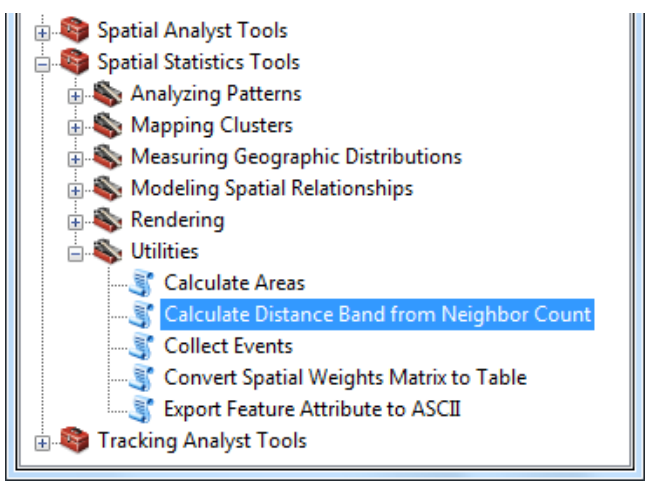
2.17. Input the feature or point cloud of the lidar data being examined. For ***Clip Features***, input the subset made of the small polygon. For ***Output Feature Class***, select a location where the layer will be saved.



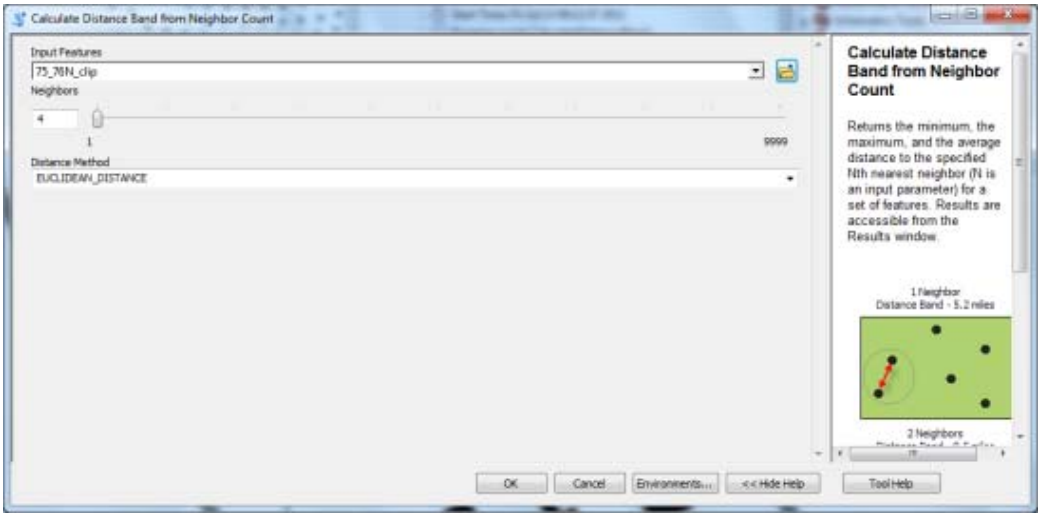
The resulting layer will appear similar to the point cloud but will only cover the area under the polygon. The new layer created is a cut out of points of only the region under the polygon.



2.18. Select ***Spatial Statistics Tools → Utilities → Calculate Distance Band from Neighbor Count***.

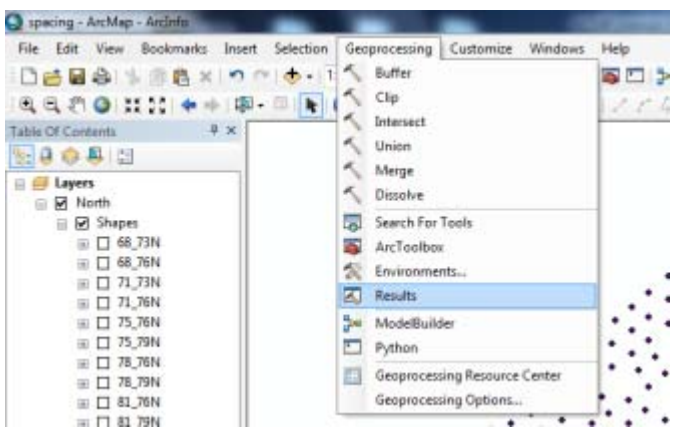


2.19. For ***Input Features***, select the newest layer you created from raster to point**.** Set ***Neighbors*** to 4 and select EUCLIDEAN_DISTANCE for ***Distance Method***.

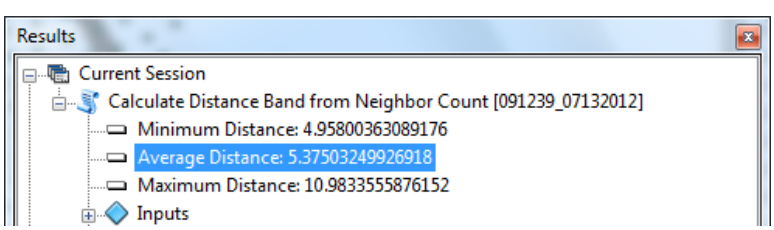


2.20. From the ***Geoprocessing*** menu, select ***Results***.

2.21. The most recent Results will include Minimum, Average, and Maximum Distances, in meters, for the set of data points. The distances are from each individual point to the nearest single point.

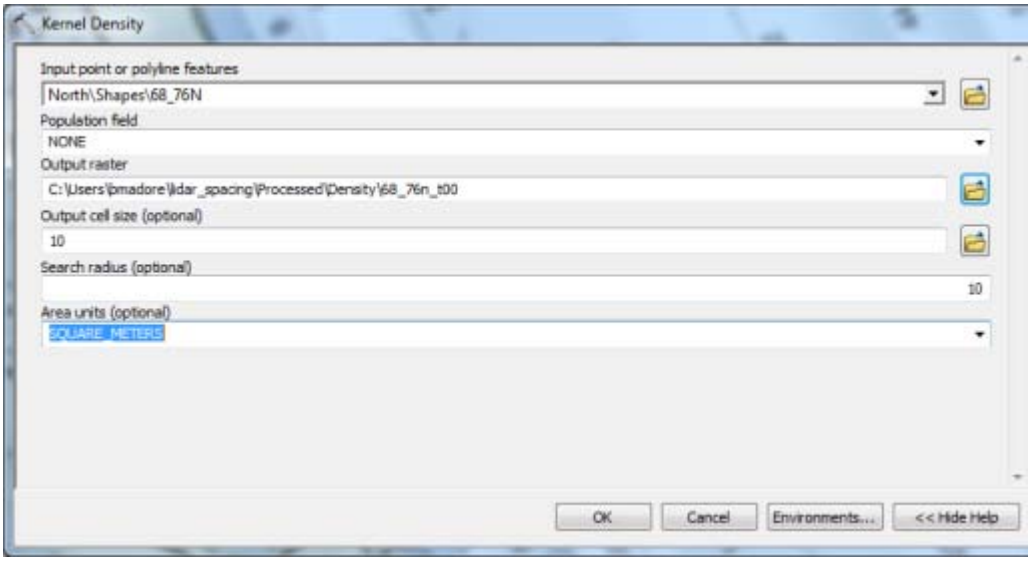


The Average Distance, to the closest integer, will be used to determine the grid spacing for the layers and calculations that follow.



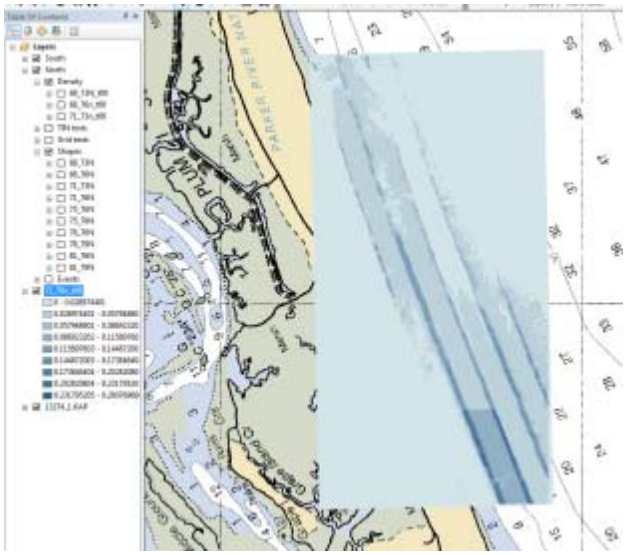
2.22. Select ***Spatial Analyst Tools → Density → Kernel Density*** from the **ArcToolbox.**

2.23. Select an ***Output cell size*** of 10 m, a ***Search radius*** of 10 m, and ***Area units*** of SQUARE_METERS and click ***OK***.



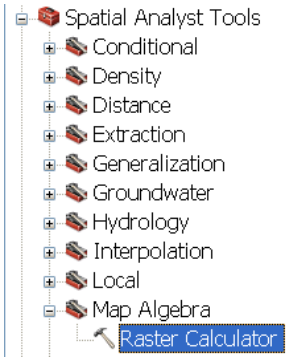
A distance of 10 meters is being utilized for these values because it is two times the average distance of each point to the next. This calculates a magnitude per unit area for each cell. A value of 0.01 is equivalent to 1 point per cell or 1 point per 100 m^2.

Note: You can use a smaller number if the average distance is less than 5 m, but you cannot use a number smaller than 10 for the raster calculator since 10 m is what is used to create the spline layer when doing the NCMP lidar and OCS bathy comparison. Lidar average distance of each point will not likely be less than 5 m, and you will need to keep these Spline layers the same for comparison purposes.

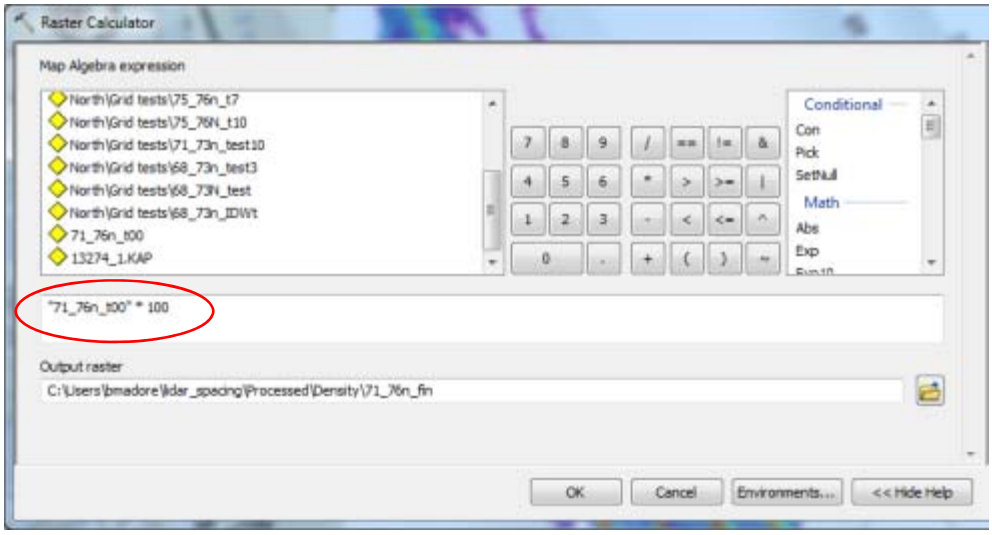


Results will appear like this.

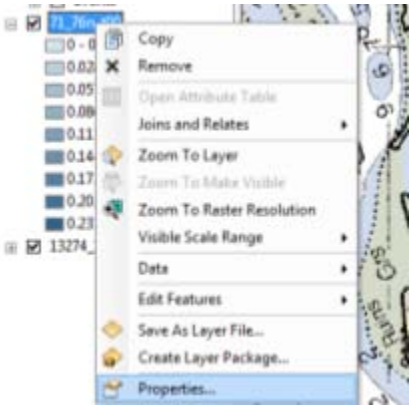
2.24. Select ***Spatial Analyst Tools*** → ***Map Algebra*** → ***Raster Calculator*** in the **Toolbox** window.



2.25. Type the following equation (see image below) in the **Raster Calculator**, select the density layer, multiply it by 10 * 10, and click ***OK***. The value is multiplied by 100 because that is the unit area of the square designated in an earlier step. If the cell size were 28 m, for example, this equation would be the layer 28 * 28.

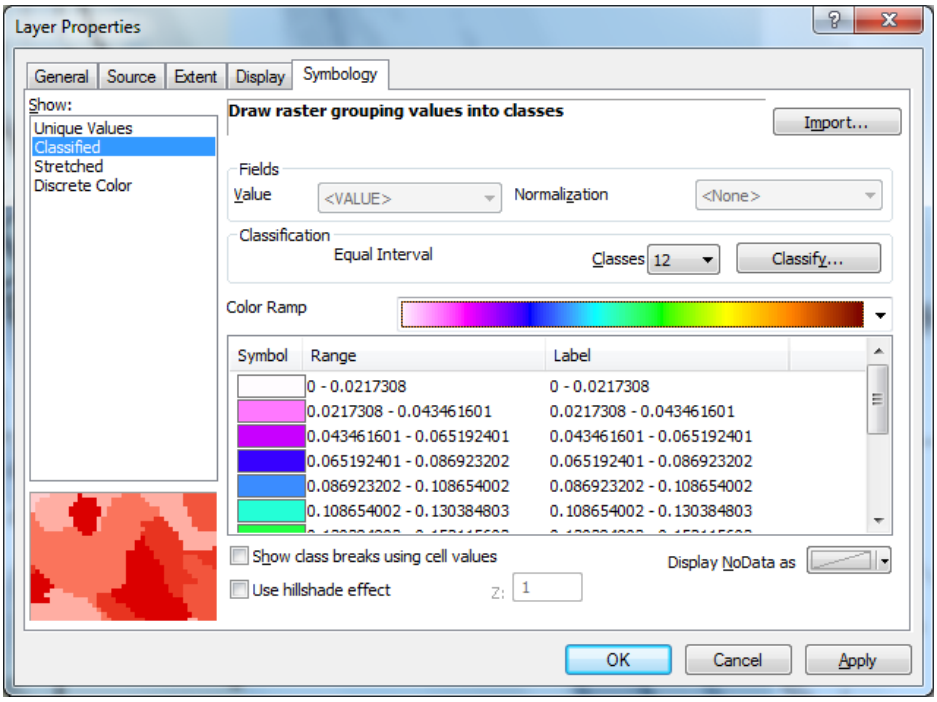


2.26. Right-click on the data and select ***Properties***.

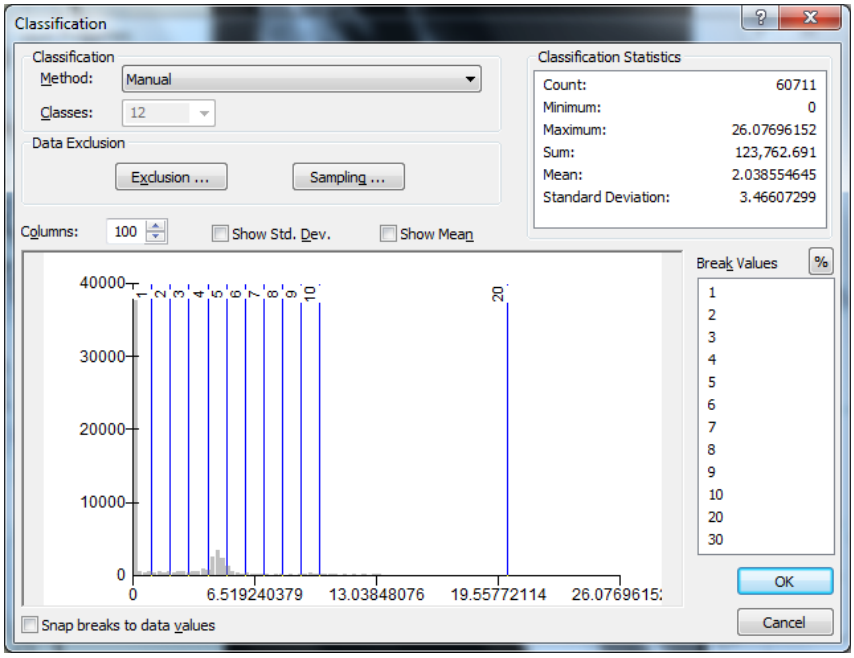


2.27. Select the ***Symbology*** tab and select ***Classified.***

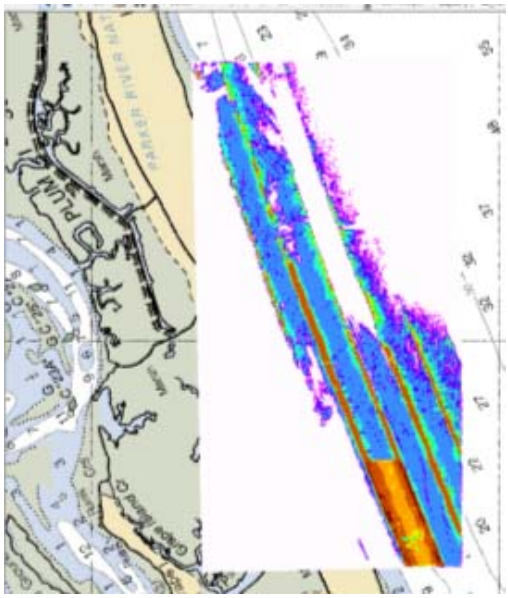
2.28. If you are prompted to, choose ***compute histograms***. Change ***classes*** to 12, and change ***Color Ramp*** to a colorful display with various colors.



2.29. Click ***Classify***. Click on the ***break values*** and manually input them as the following: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30.

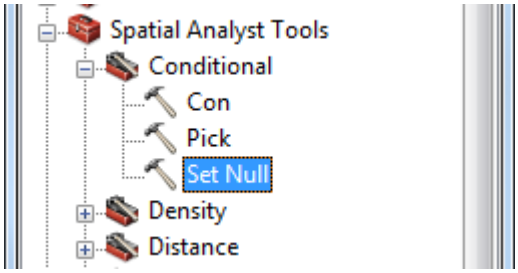


2.30. Click ***OK.*** Select ***OK***. The image will look like the following.



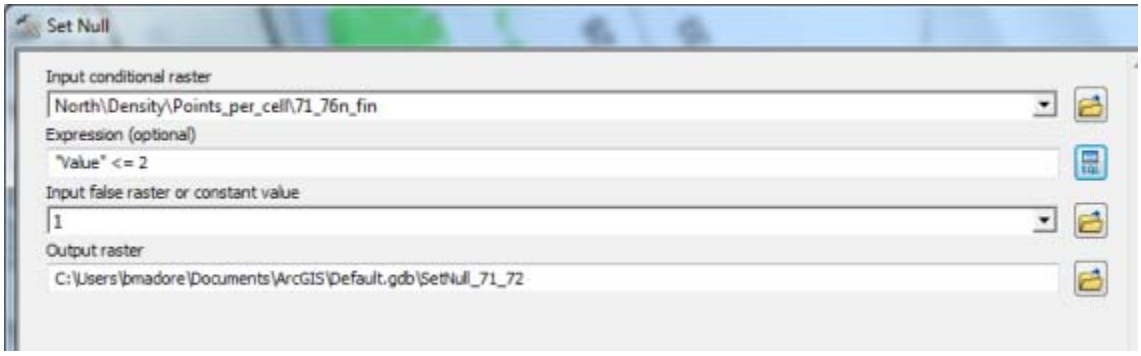
Depending on the number of data points present and the density of the points, the ***break values*** can be changed to various numbers to give the best results.

2.31. Cells with 2 points or less, for this NCMP lidar data, are not sufficient. Depending on the point density of the lidar data being used, this value (2) could change. This step will essentially allow you to keep only the data you want to use for your comparison. Select ***Spatial Analyst Tools → Conditional → Set Null.***

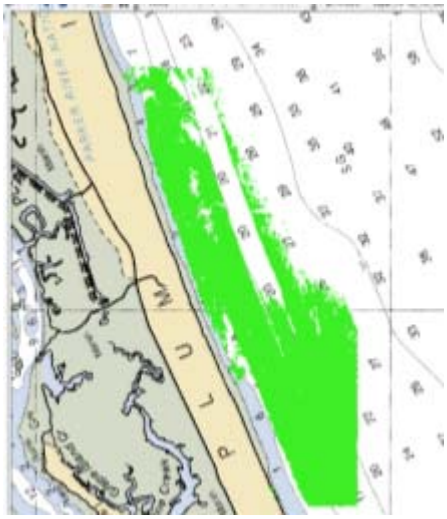


2.32. Input the data file received after ***raster calculation***.

Input the ***Expression*** “VALUE” <= 2 (make sure spaces are included). If a different cell value is being used as the threshold, insert that value instead. Use 1 for the ***constant value*** and designate an ***output raster.***

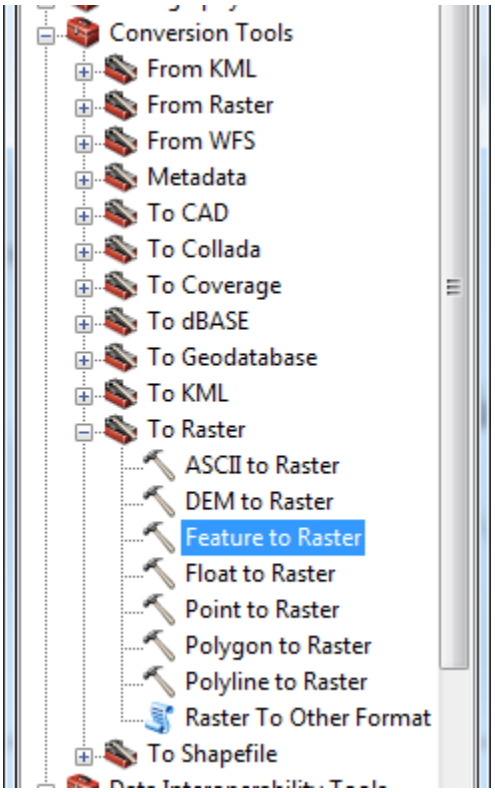


2.33. This creates a layer which later can be used to extract only the valid areas of data.



3. Creating Grids

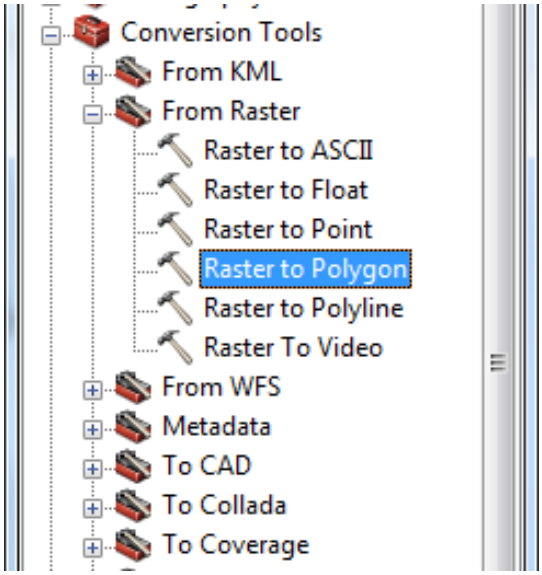
3.1. Select ***Conversion Tools → To Raster → Feature to Raster***.



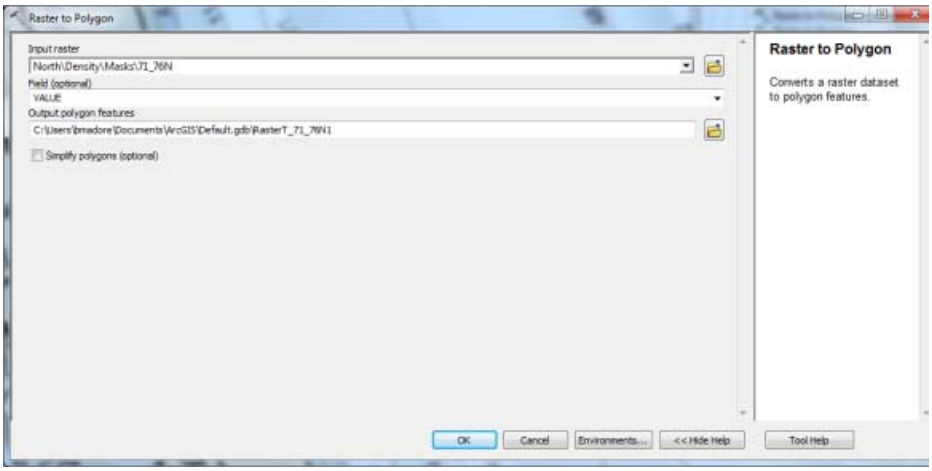
3.2. For the ***Input Features***, select the point cloud shapefile of the lidar data being examined. Select ***Elevation*** for the ***Field***. Select a destination to save for the ***Output raster*** and select an ***Output cell size*** that is twice the average distance from each point (calculated previously). Click ***OK.***

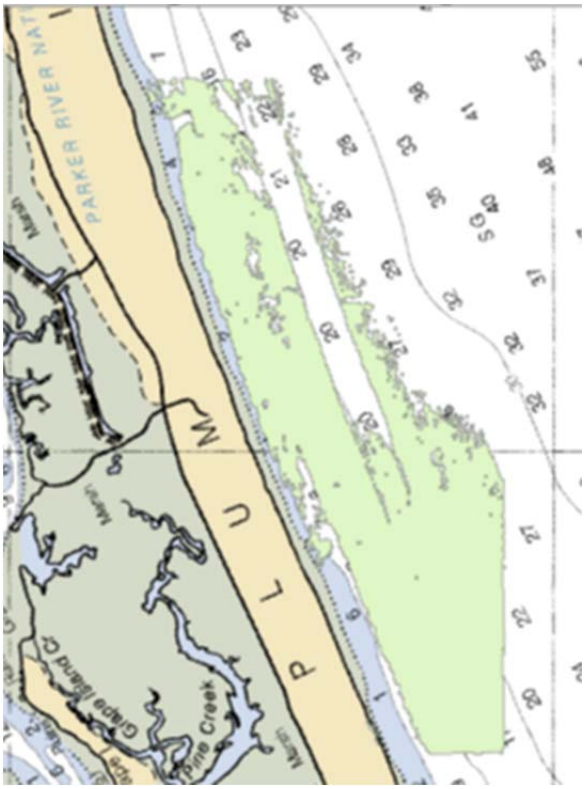
3.3. The bathymetry grid created has features that are not valid, because of an insufficient

number of data points. Using the layer created in steps 2.31 to 2.33 (*setnull mask),* the insufficient areas can be removed. Select ***Conversion Tools → From Raster → Raster to Polygon***.

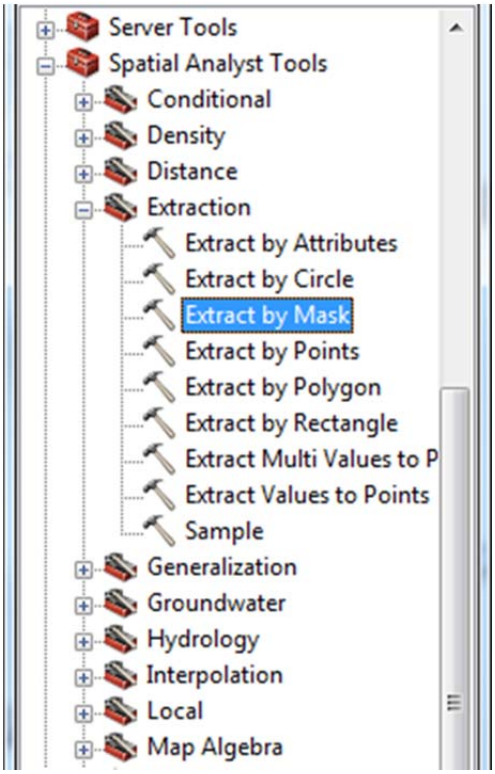


3.4. Select the layer created in steps 2.31-2.33 as the ***Input raster***. Set ***Field*** to ***VALUE***, select a save destination in the ***Output polygon features*****,** and uncheck the ***Simplify polygon*** box.

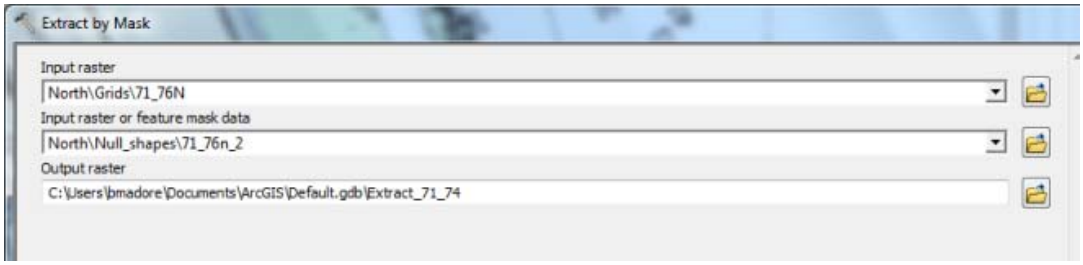




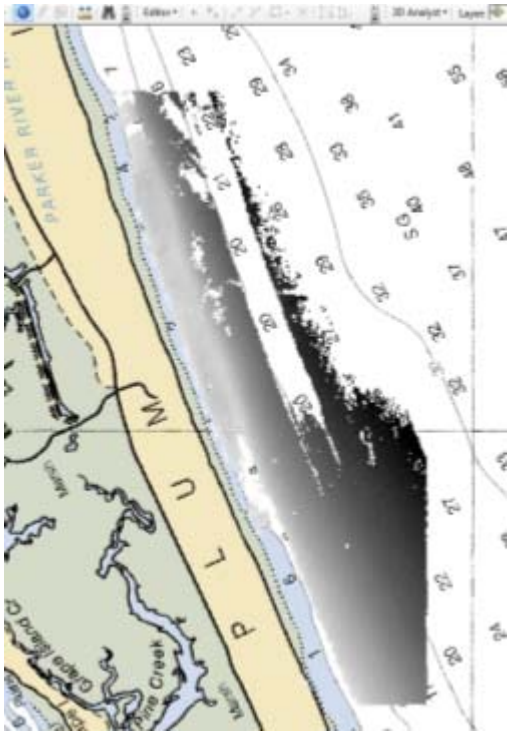
3.5. Select ***Spatial Analyst Tools → Extraction → Extract by Mask***



3.6. For the ***Input raster***, select the grid created in step 3.2. For the ***Input raster or feature mask data***, select the layer created in 3.4. Select a save destination for the ***Output raster.***

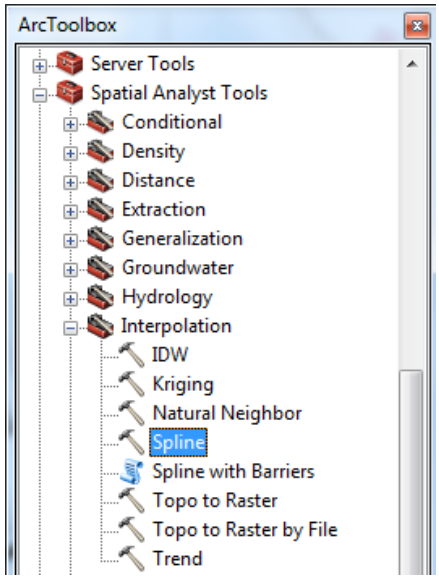


3.7. The resulting grid is the same as the original, but the areas with insufficient density of data points have been removed. To change the color scheme, select ***properties***, right-click on the layer's name, and select ***symbology***.



4. Working with Bathymetry (TIN and Spline)

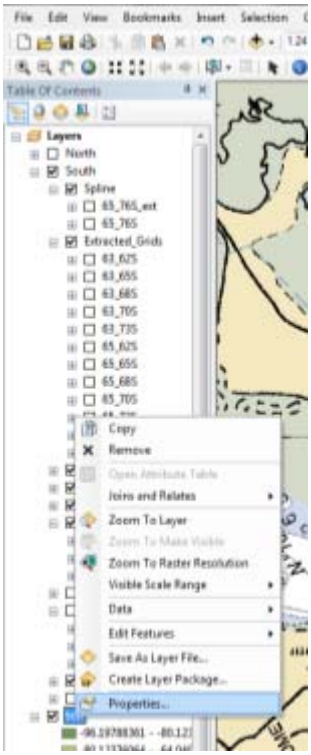
4.1. Select ***Spatial Analyst Tools → Interpolation → Spline***.



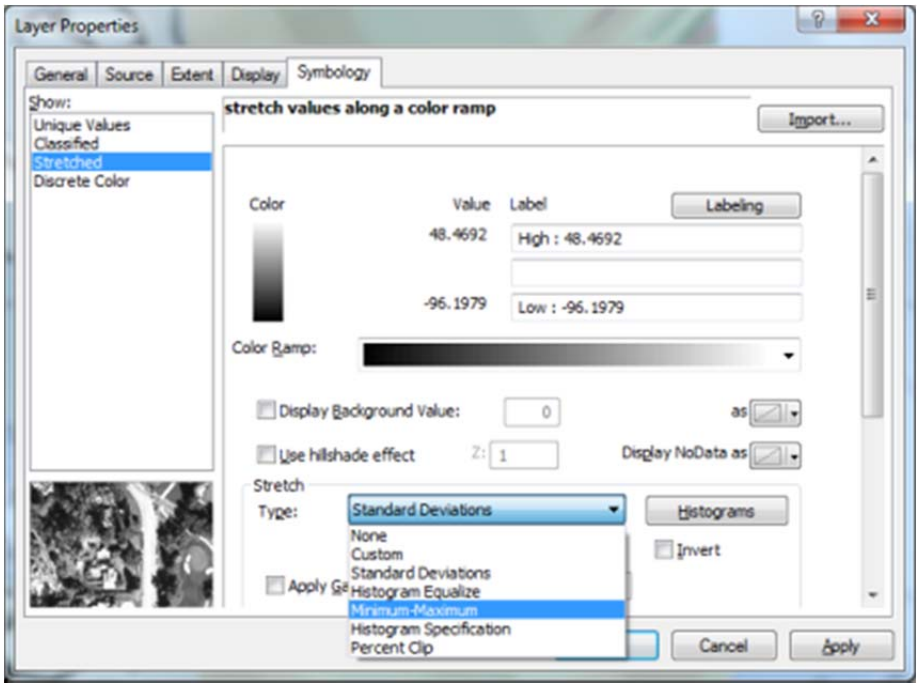
4.2. For the ***Input point features***, select the layer of the lidar point cloud. For the ***Z value field***, set ***Elevation***. Select a save destination for the file in the ***Output raster***. Set the ***Output cell size*** to 10, ***spline type*** to ***REGULARIZED***, ***Weight*** as 0.1, and ***Number of points*** as 12.

4.3. The resulting image may appear similar to the following.

4.4. To change the color scheme and data to more accurate values, right-click on the layer and select ***Properties.***

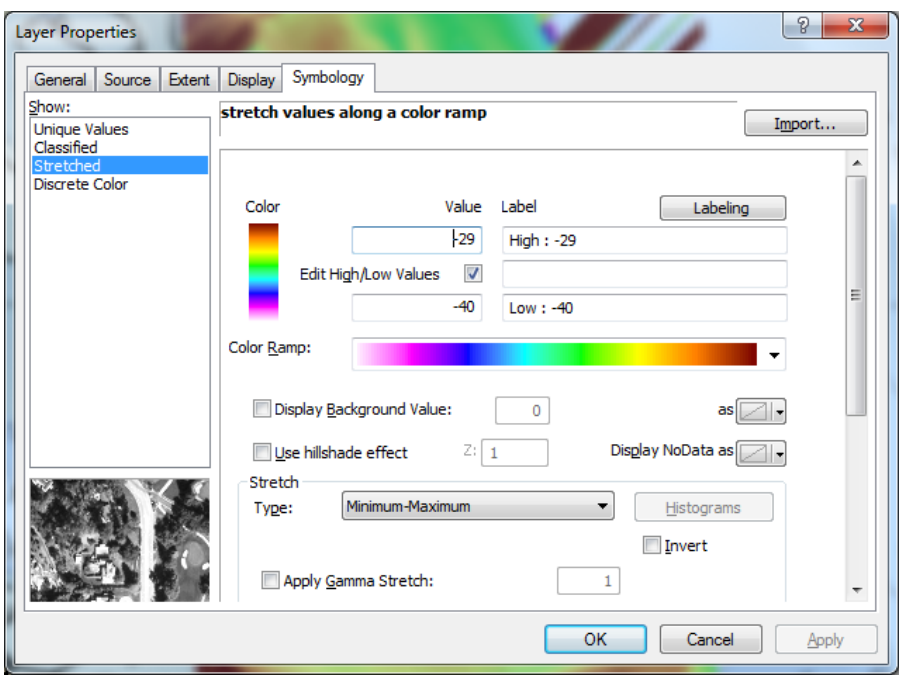


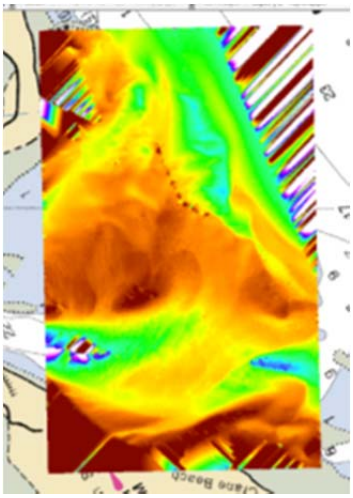
4.5. From the ***Symbology*** tab, select ***stretched.*** Change ***stretch*** to ***Minimum-Maximum***.



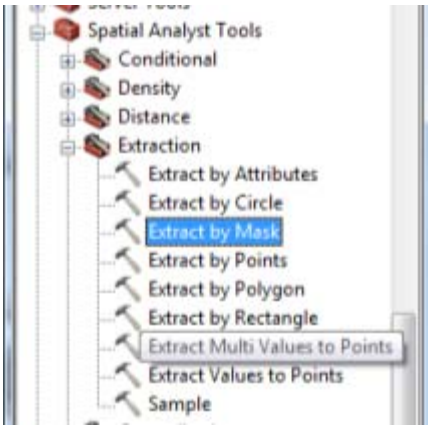
4.6. For ***Edit High/Low Values***, enter the minimum depth and maximum depth for your data set. Change ***Color Ramp*** to a more colorful bar.

4.7. The resulting image will now appear similar to the following.



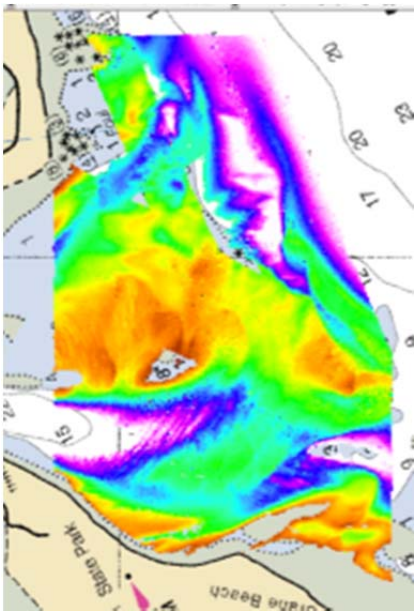


4.8. Select ***Spatial Analyst Tools → Extraction → Extract by Mask***.



4.9. ***Input*** the Spline layer from 4.7. For the ***feature mask data***, select the polygon created from step 3.6. Choose a save location for the file in the ***Output raster***.

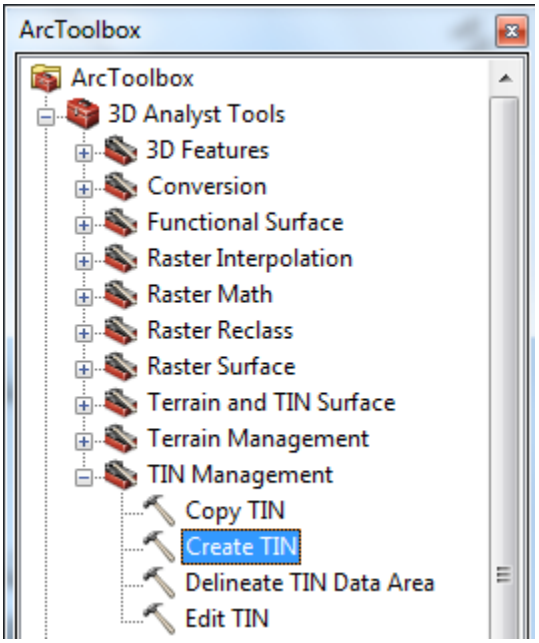
4.10. Once the ***Symbology*** has been changed, same as step 4.5 to 4.6, the image will now appear like the following.



4.11. **Triangulated Irregular Network (TIN) Creation**

Note: Skip to step 6 for statistical analysis steps unless you want to create a TIN to extract features or hazards to navigation.

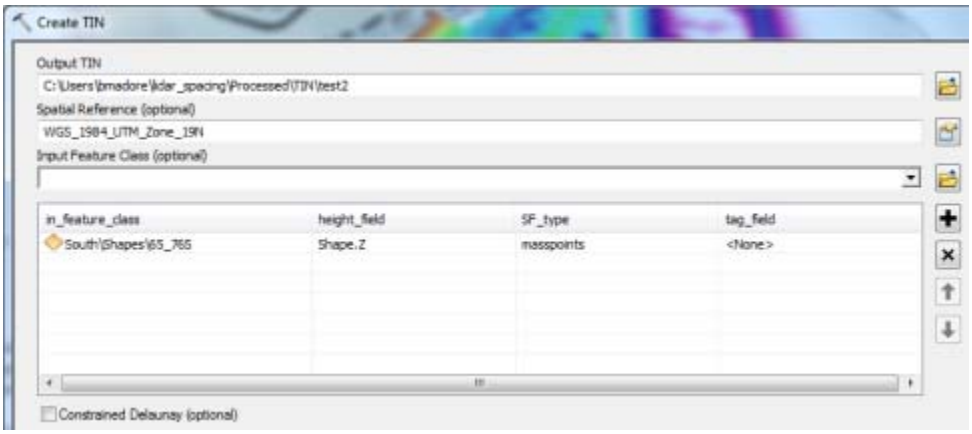
4.12. Select ***3D Analyst Tools → TIN Management → Create TIN***.



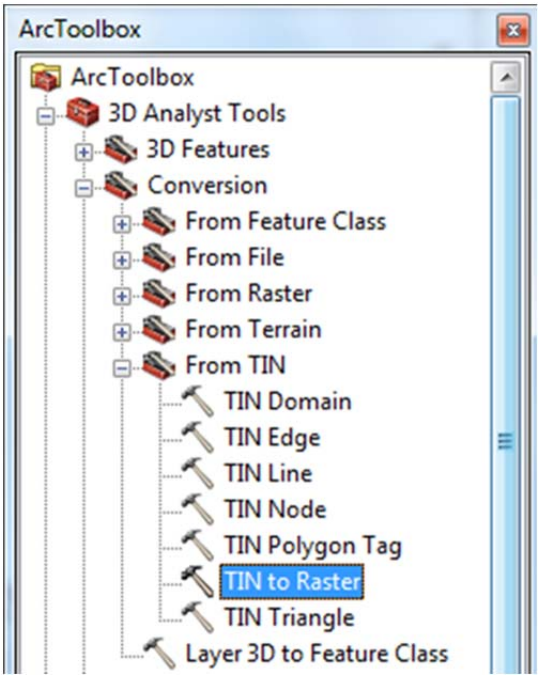
4.13. Select a name and save destination in ***Output TIN***.

4.14. Select a ***Spatial Reference*** that is the same as the lidar data. Click ***Select*** followed by ***Projected Coordinate Systems → UTM → NAD83*** followed by the corresponding hemisphere and zone of the data.

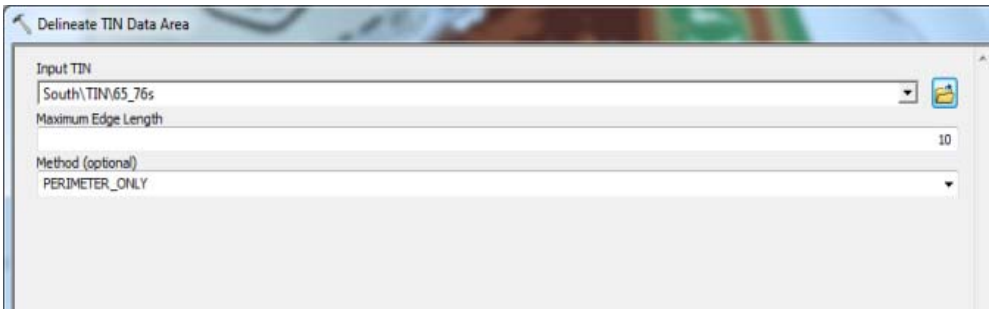
4.15. For ***Input Feature Class***, enter the feature class of the layer of the lidar point cloud. Click ***OK.*** The ***TIN*** may take a few minutes to create and load.



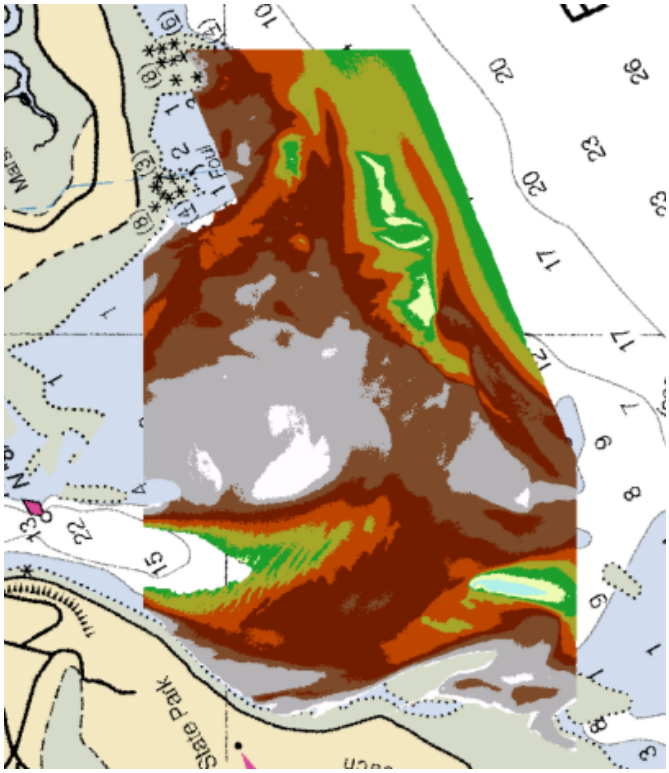
4.16. Select ***3D Analyst Tools → TIN Management → Delineate TIN Data Area***.



4.17. ***Input*** the newly created TIN. Select 10 as the ***Maximum Edge Length.*** Click ***OK***.



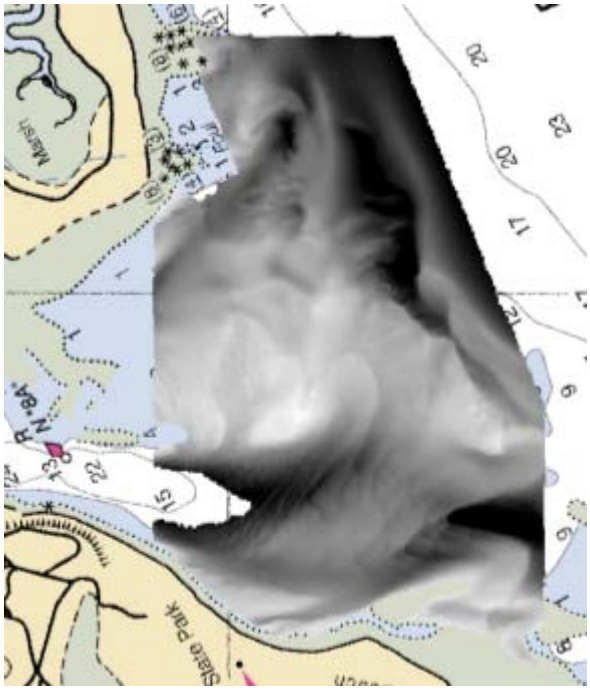
4.18. The image will appear similar to the following.



4.19. Select ***3D Analyst Tools Conversion → From TIN → TIN to Raster***.

4.20. Select the TIN as the ***Input TIN***. For the ***Output Raster***, select a save destination for the file. Select FLOAT for the ***Output Data Type*** and LINEAR for the ***Method***. Set the ***Sampling Distance*** to CELLSIZE 10 or use the value of the cellsize from step 2.23 to 2.26. Set the ***Z Factor*** to 1.

4.21. The results will look like the following.



4.22. Right-click the layer and select ***properties*** and then the ***symbology*** tab. The ***color ramp*** can now be changed to various colors.

5. Generating a Reference Data Set (MBES)

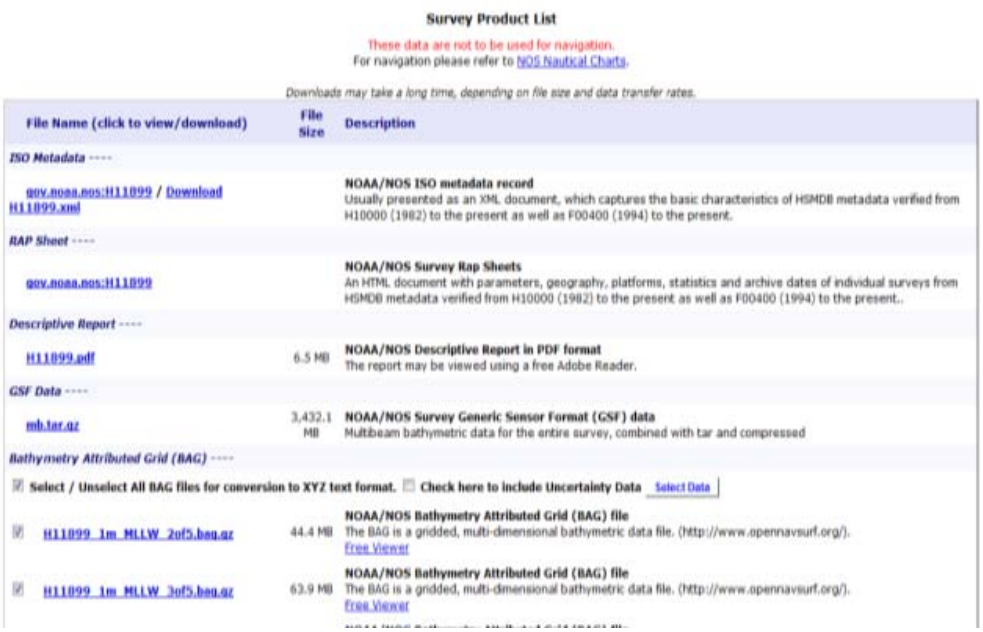
5.1. Navigate to the National Geophysical Data Center (http://maps.ngdc.noaa.gov/viewers/bathymetry/).

5.2. Zoom to the desired location. Click on the desired area. Select the most recent data set.

5.3. Select ***Survey ID*** number.

5.4. Select the PDF file of the ***Descriptive Report.***

5.5. Check the ***Select/Unselect All BAG files for conversion to XYZ text format*** box. Make



Survey Product List

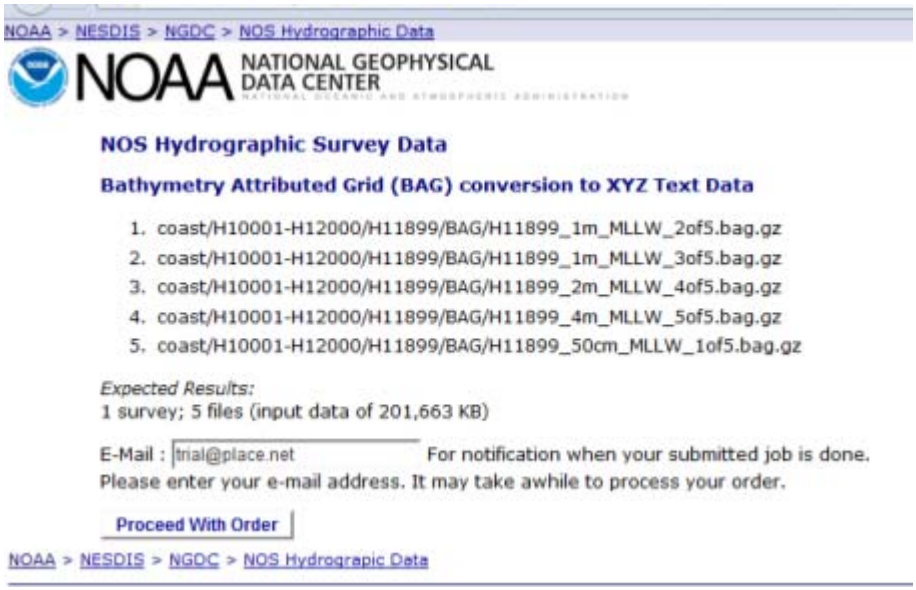
These data are not to be used for navigation.
For navigation please refer to NOS Nautical Charts.

Downloads may take a long time, depending on file size and data transfer rates.

File Name (click to view/download)	File Size	Description
ISO Metadata ----		
gov.noaa.nos:H11899 / Download H11899.xml		**NOAA/NOS ISO metadata record** Usually presented as an XML document, which captures the basic characteristics of HSMDB metadata verified from H10000 (1982) to the present as well as F00400 (1994) to the present.
RAP Sheet ----		
gov.noaa.nos:H11899		**NOAA/NOS Survey Rap Sheets** An HTML document with parameters, geography, platforms, statistics and archive dates of individual surveys from HSMDB metadata verified from H10000 (1982) to the present as well as F00400 (1994) to the present..
Descriptive Report ----		
H11899.pdf	6.5 MB	**NOAA/NOS Descriptive Report in PDF format** The report may be viewed using a free Adobe Reader.
GSF Data ----		
mb.tar.gz	3,432.1 MB	**NOAA/NOS Survey Generic Sensor Format (GSF) data** Multibeam bathymetric data for the entire survey, combined with tar and compressed
Bathymetry Attributed Grid (BAG) ----		
☑ **Select / Unselect All BAG files for conversion to XYZ text format.** ☐ **Check here to include Uncertainty Data** Select Data		
☑ H11899_1m_MLLW_2of5.bag.gz	44.4 MB	**NOAA/NOS Bathymetry Attributed Grid (BAG) file** The BAG is a gridded, multi-dimensional bathymetric data file. (http://www.opennavsurf.org/). Free Viewer
☑ H11899_1m_MLLW_3of5.bag.gz	63.9 MB	**NOAA/NOS Bathymetry Attributed Grid (BAG) file** The BAG is a gridded, multi-dimensional bathymetric data file. (http://www.opennavsurf.org/). Free Viewer

sure all the files are checked. Click ***Select Data***.

5.6. The following page will appear. Enter an email and select ***Proceed with Order.*** The



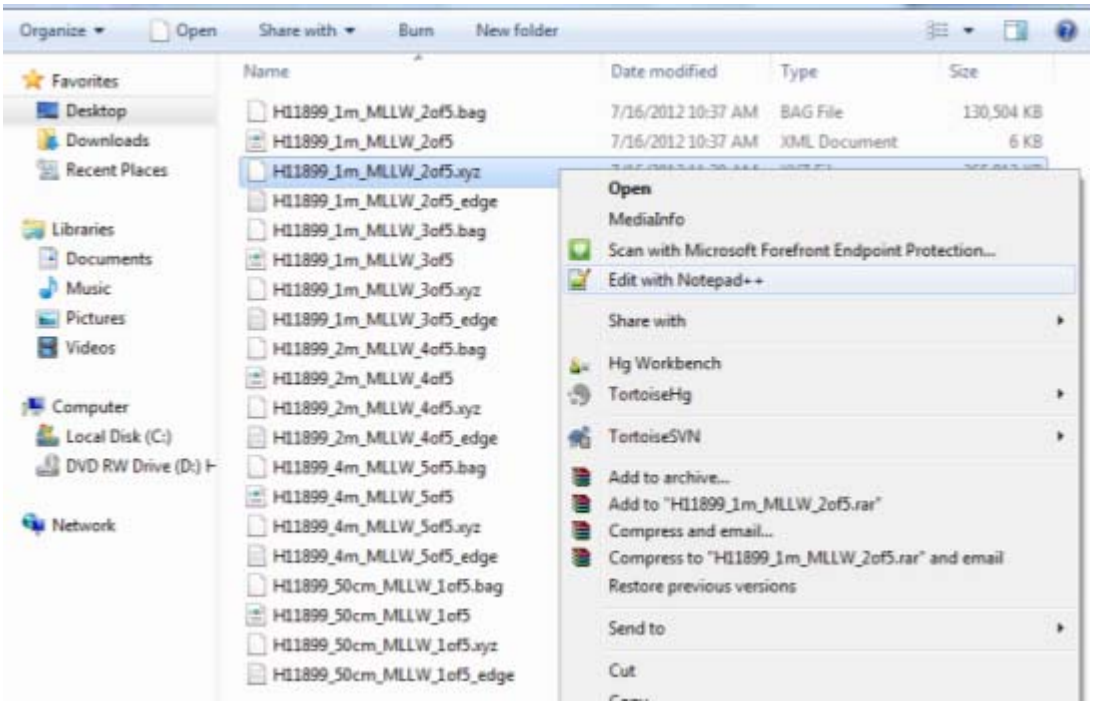
process will take a few minutes.

5.7. Once it is received, click the link provided in the email. Select ***Download your Data***.

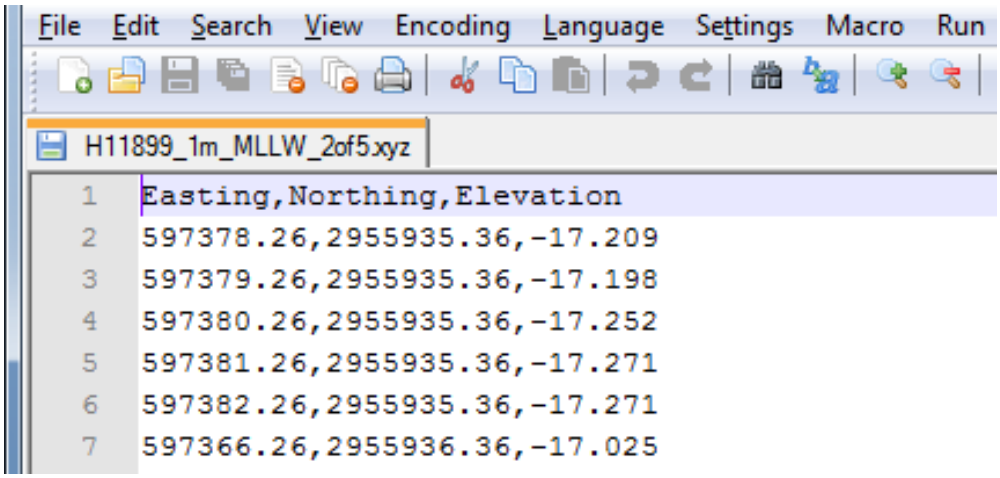
5.8. Select ***Save File*** and click ***OK***. This process may take a few minutes.

5.9. Once the data is downloaded, extract it and choose a save destination.

5.10. Open the folder to view the documents. For each XYZ file, right-click and select ***Edit with Notepad ++***.



5.11. To add a line, place the cursor at the far left of the top row and hit ***Enter***. Add ***Easting,Northing,Elevation*** to the new top row. Select ***File → Save As*** and save the file as a .txt file.

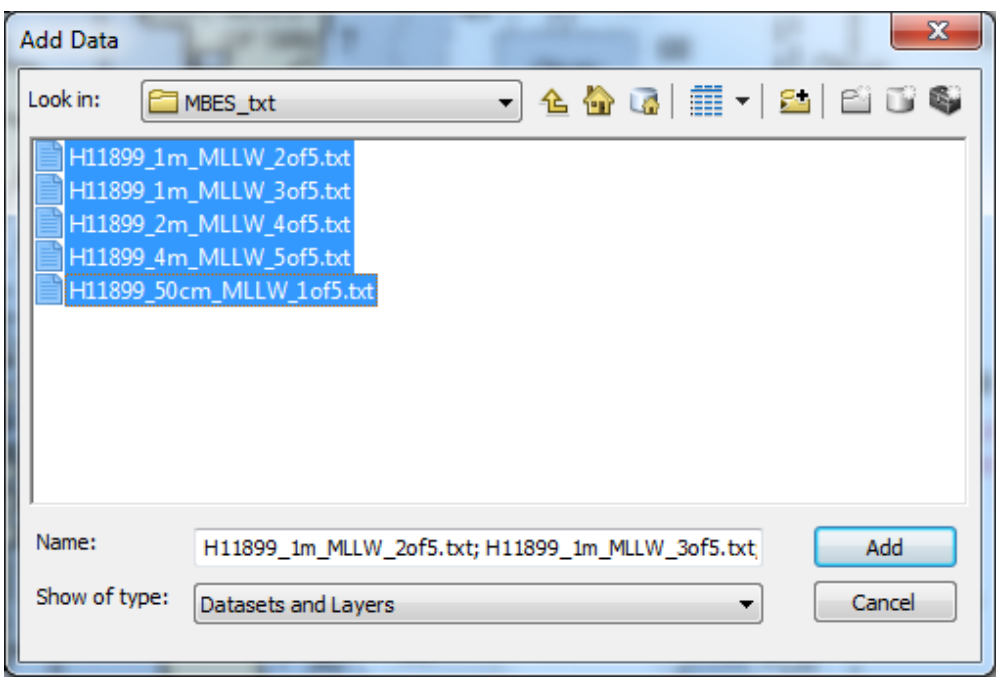


5.12. Repeat 5.10 and 5.11 for each ***XYZ File.*** Depending on the size of the file, it may be necessary to select ***File*** → ***Close All*** after each file.

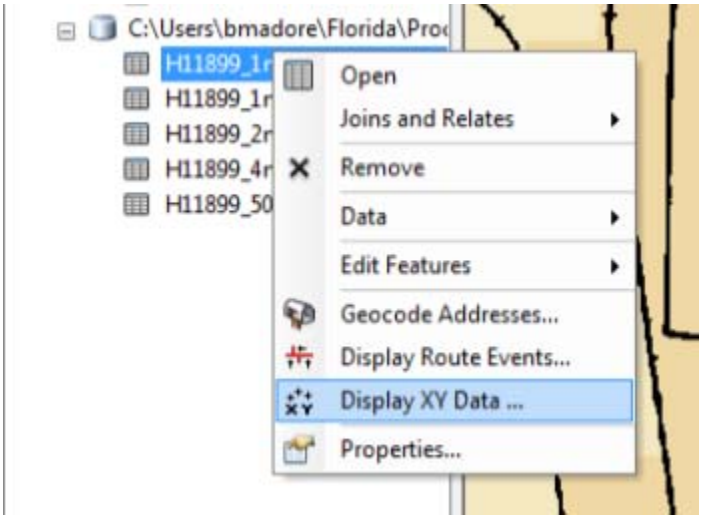
5.13. Open ArcMap with the lidar data from the earlier steps.

5.14. Select ***Add Data***.

5.15. Select each of the saved .txt files. Click ***Add***.



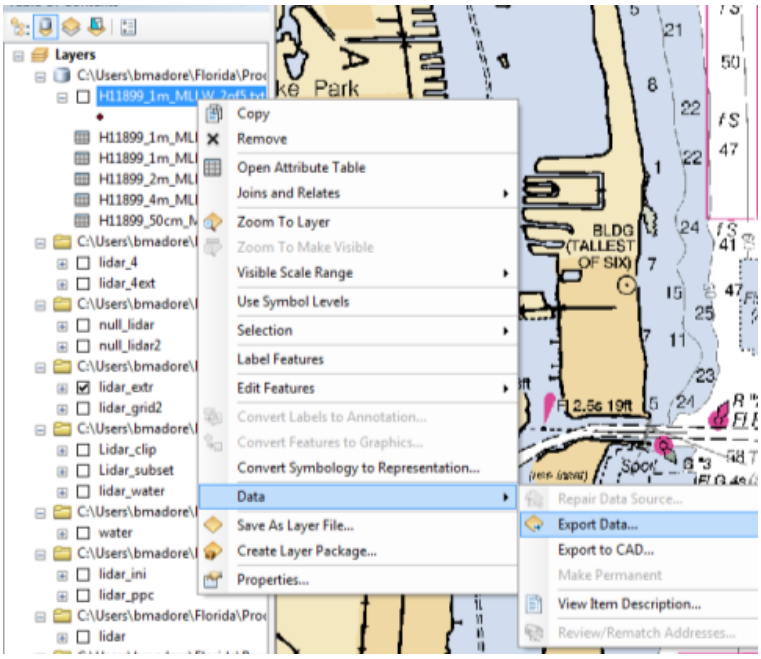
5.16. Right-click the imported .txt file and select ***Display XY Data***.



5.17. Set the ***X Field*** to ***Easting***, ***Y Field*** to ***Northing***, and the ***Z Field*** to ***Elevation.*** Select ***edit.***

5.18. Click ***Select*** followed by ***Projected Coordinate Systems → UTM → NAD83*** followed by the corresponding ***UTM Zone*** your data is using. Click ***Add,*** then ***OK*** and ***OK.***

5.19. Right-click the new ***event*** layer that was created and select ***Data*** then ***Export Data***.



5.20. ***Export*** all features, ***use the same coordinate system as*** this layer's data source, and choose a save destination for the file. Click ***OK***. This process may take some time depending on the size of the file.

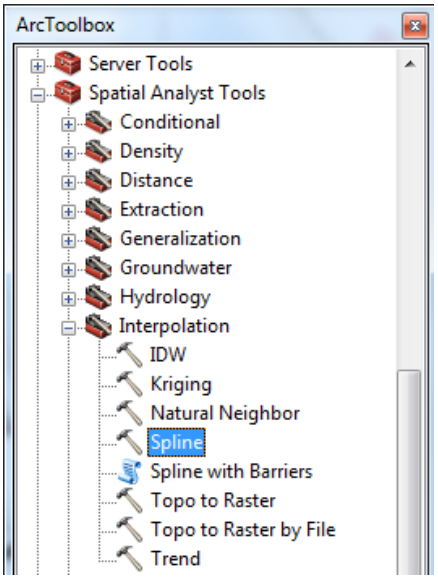
5.21. ***Repeat*** steps 5.13 to 5.20 for each .txt file that was imported.

Note: It may be more efficient to clip the MBES early since it is usually very high resolution and will take a long time to load. It is less memory intensive to change the files to a shape file → clip and then merge multiple MB files (if necessary) that lie within the range of the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) lidar.

5.22. Density Calculation – see section 2.0.

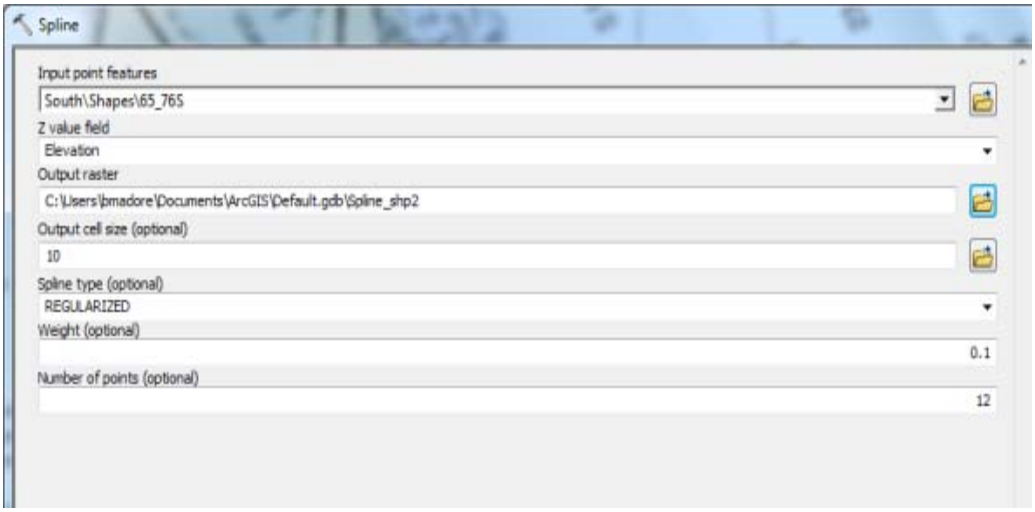
Note: Density calculation is only necessary for lidar and MBES datasets for which you are not sure of the measurement/sounding spacing.

5.23. Select ***Spatial Analyst Tools*** → ***Interpolation*** → ***Spline***.



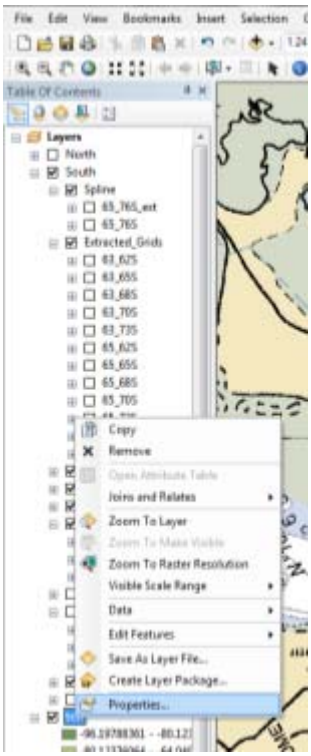
5.24. Select the layer of the MBES sounding data from step 5.21 for ***Input point features***. Set ***Elevation*** for the ***Z value field***. Select a save destination for the file in the ***Output raster***. Set the ***Output cell size*** to 10, ***spline type*** to REGULARIZED, ***weight*** as 0.1, and

number of points as 12.



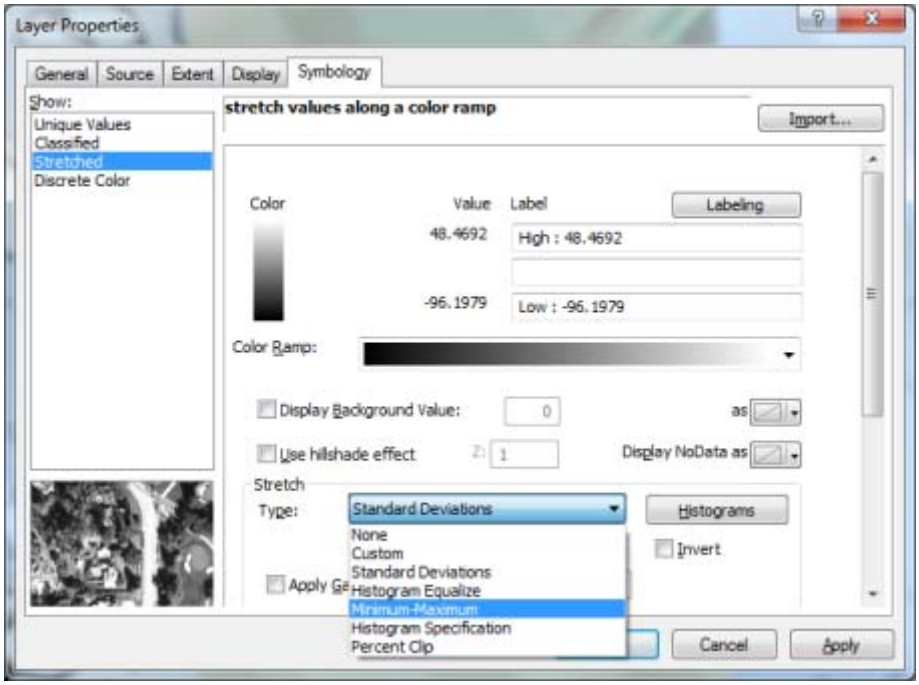
5.25. Repeat step 5.24, if necessary, for the additional layers created in step 5.21.

5.26. To change the color scheme and data to more accurate values, right-click on the layer and select ***Properties.***

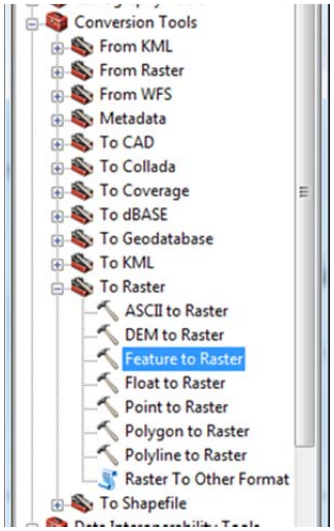


5.27. Go to the ***Symbology*** tab and select ***stretched.*** Change ***stretch*** to Minimum-Maximum.

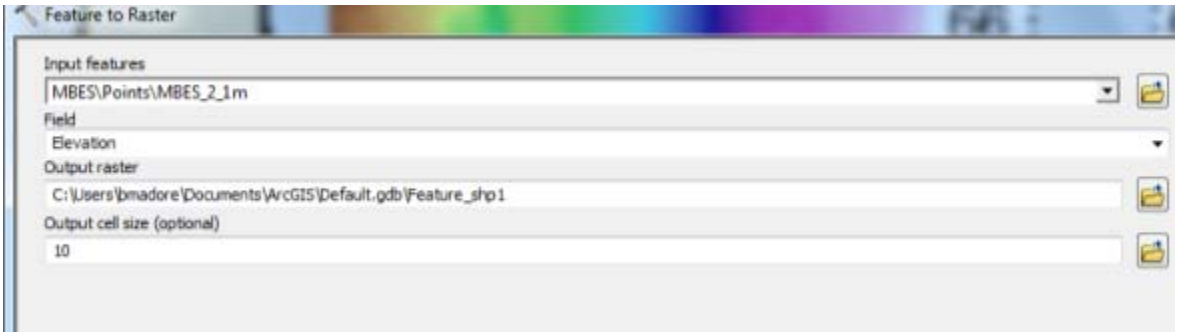
5.28. ***Edit High/Low Values*** with the minimum depth and maximum depth for your data set. Change ***Color Ramp*** to a more colorful bar.



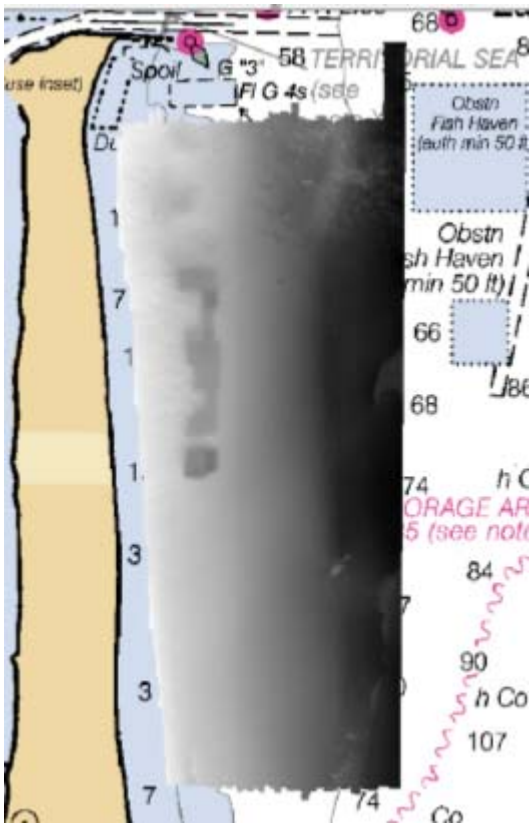
5.29. Select ***Conversion Tools → To Raster → Feature to Raster***.



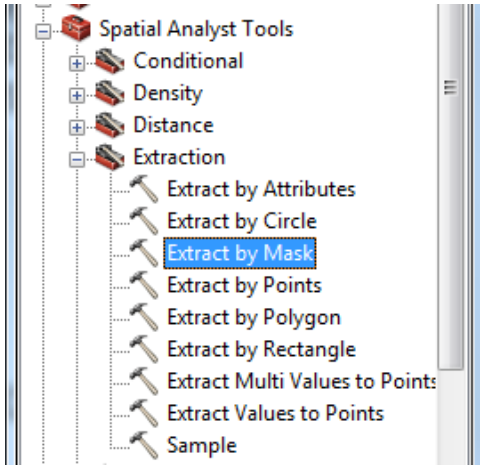
5.30. Select the MBES sounding data from step 5.21 for the ***Input features***. Select Elevation for the ***Field,*** choose a save destination in ***Output raster***, and set the ***Output cell size*** to 10.



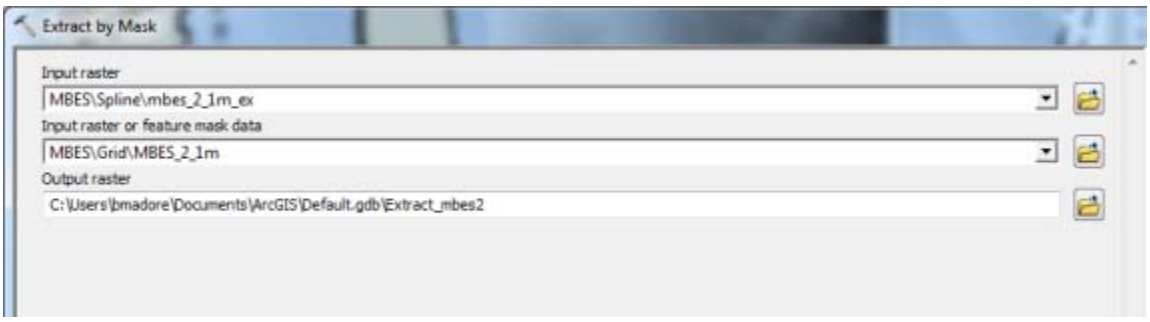
5.31. Results will resemble the following.



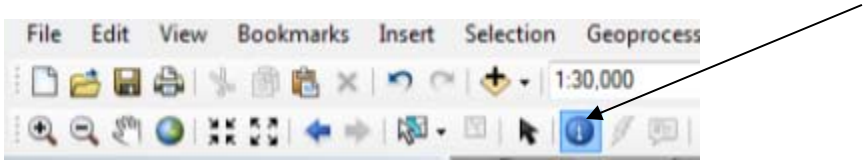
5.32. Select ***Spatial Analyst Tools*** → ***Extraction*** → ***Extract by Mask***.



5.33. For the ***Input raster*** select the spline layer from 5.24. For ***feature mask data***, select the grid from step 5.30 and for the ***Output raster*** choose a destination to save the file.



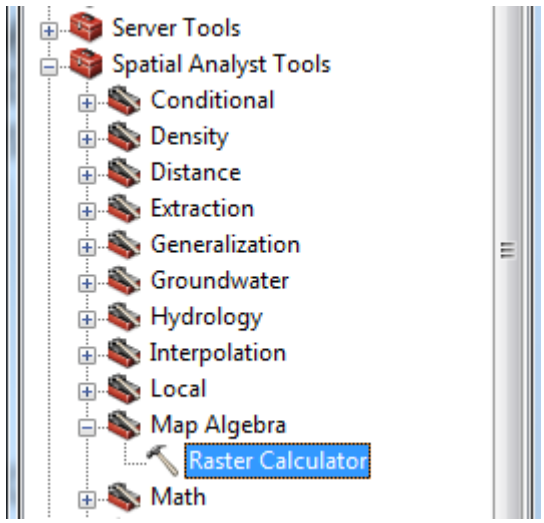
5.34. Compare the values from the chart of the area being examined and the values obtained from ***Identify***. This will determine whether the values of the ***Spline*** layer are in meters or feet.



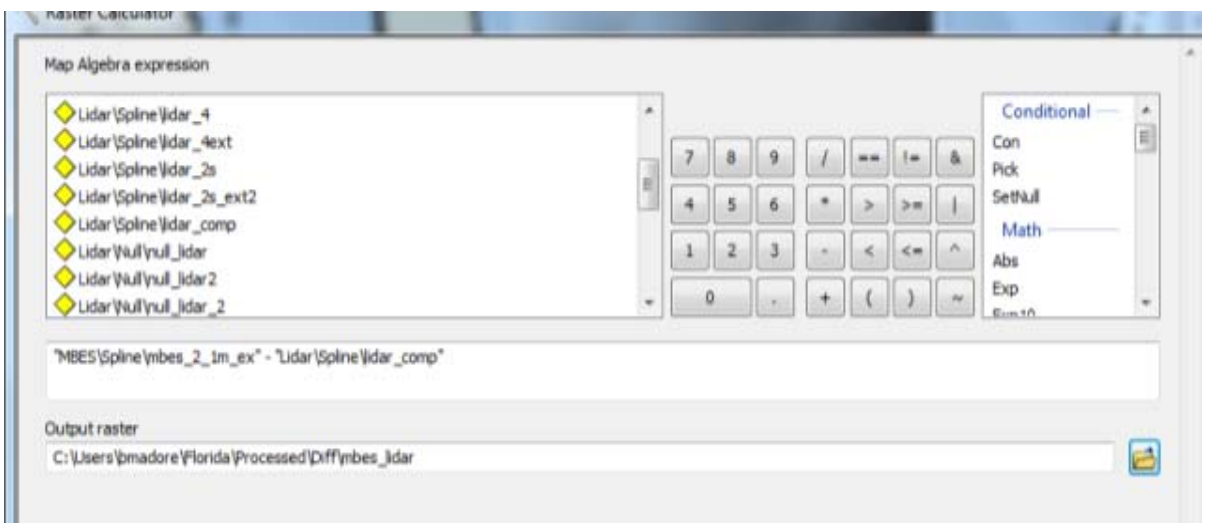
6. Performing Statistical Analysis

6.1. Difference Maps

6.1.1. Select ***Spatial Analyst Tools → Map Algebra → Raster Calculator***.

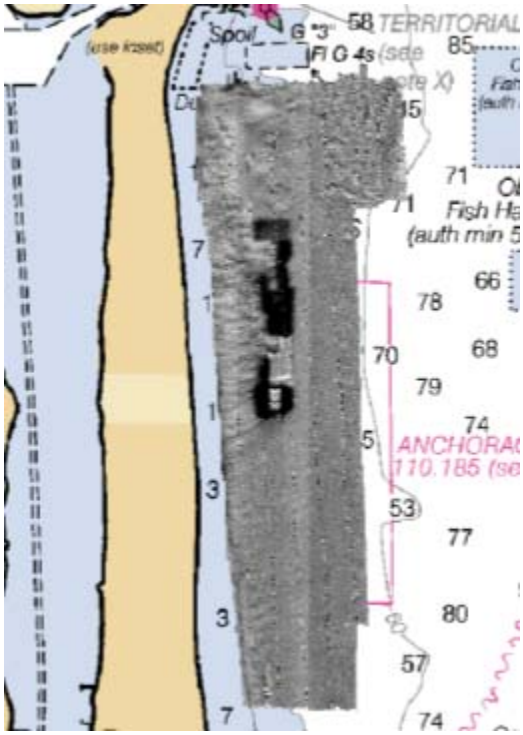


6.1.2. Select the ***Spline (e.g., H12extract by mask from spline file) MBES*** layer created in step 5.34. Select minus (-) and then the ***Spline lidar (extract mask file made from the Spline)*** layer from steps 4.9 to 4.10.



Note: Add a new group layer incorporating JALBTCX data files and save this as a different .mxb (project file) if you created the lidar and MBES data in separate .mxb files; you will need to redo the color map and min and max values for the spline file you are bringing in.

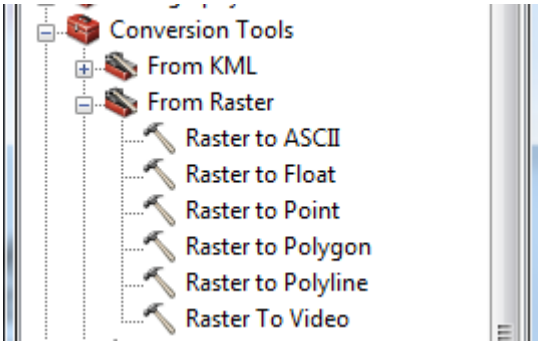
6.1.3. The new layer created is a difference map of the MBES and the lidar datasets. Results will appear similar to the following. It is a good practice to rename this file in the Table of Contents portion of ArcMap (e.g., OCS lidar minus JAL lidar). *Note: In ArcMap, if you right-click and go to* ***properties → classified → classify****,*



the right top corner will list the STD and mean, which will help you in doing calculations in Excel to verify your numbers. Also, if you notice a big difference between the two data sets (e.g., they are offset by 28m), you can enter a few points into VDatum to see if your offset is the difference between the ellipsoid and tidal datum.

6.2. Histograms

6.2.1. Select ***Conversion Tools → From Raster → Raster to ASCII***.

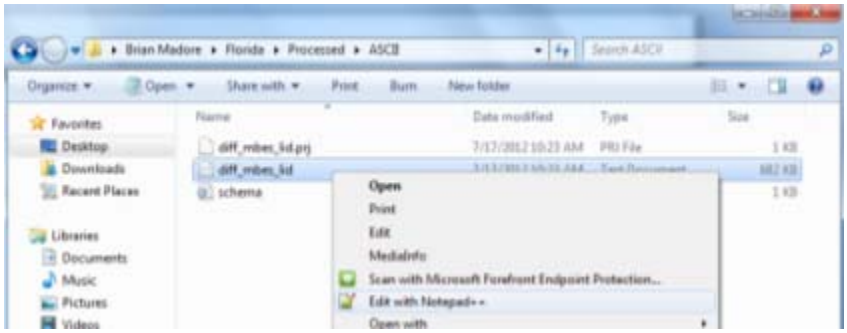


6.2.2. Select the difference layer created in step 6.1.2-3 for the ***Input raster***. Select a destination to save for the ***Output ASCII raster file*** (e.g., ***rast_diffmap.txt***).

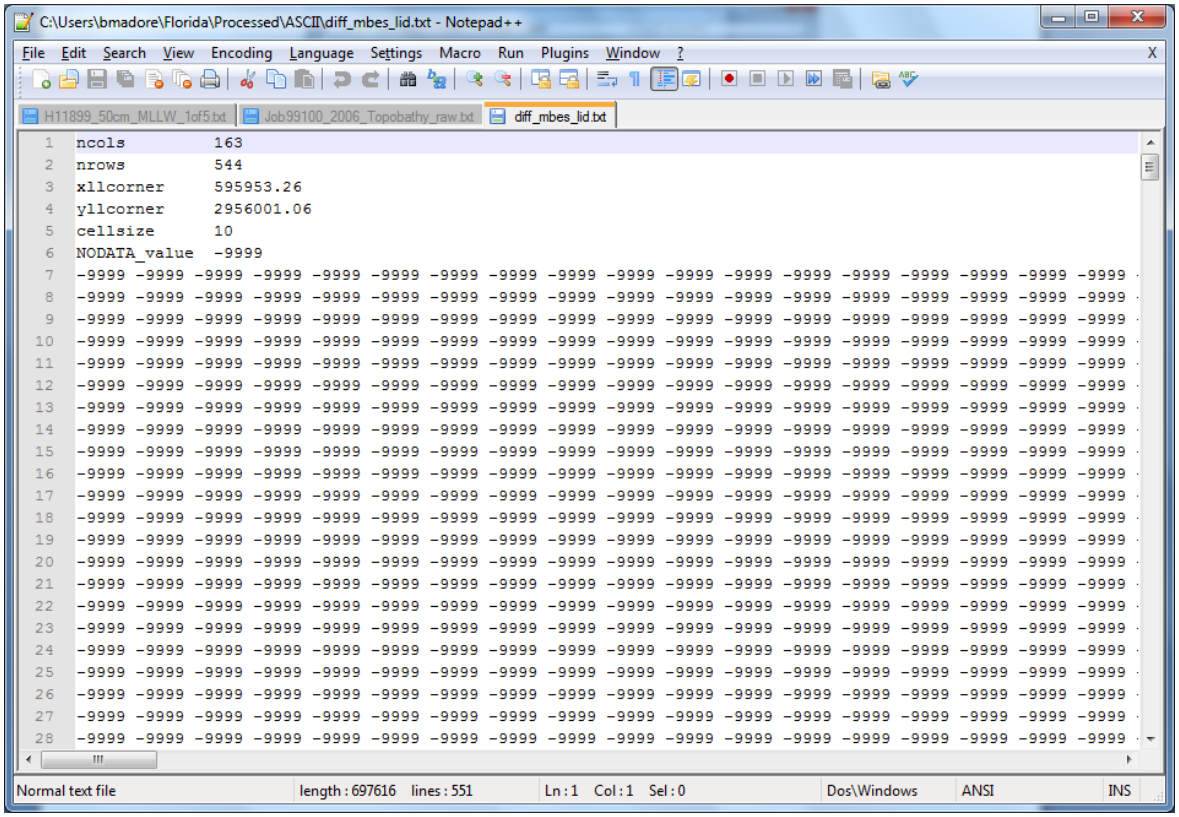
Click ***OK.***

Note: if you made a difference layer with the VDatum offset taken out you can export that instead.

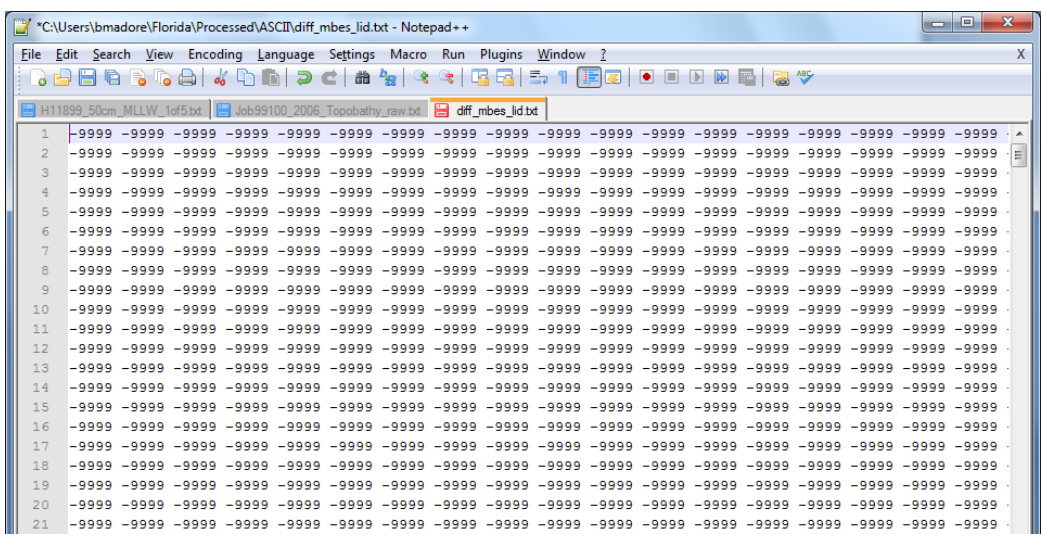
6.2.3. Go to the location of the saved ASCII file. Right-click on the file and select ***Edit with Notepad ++***.



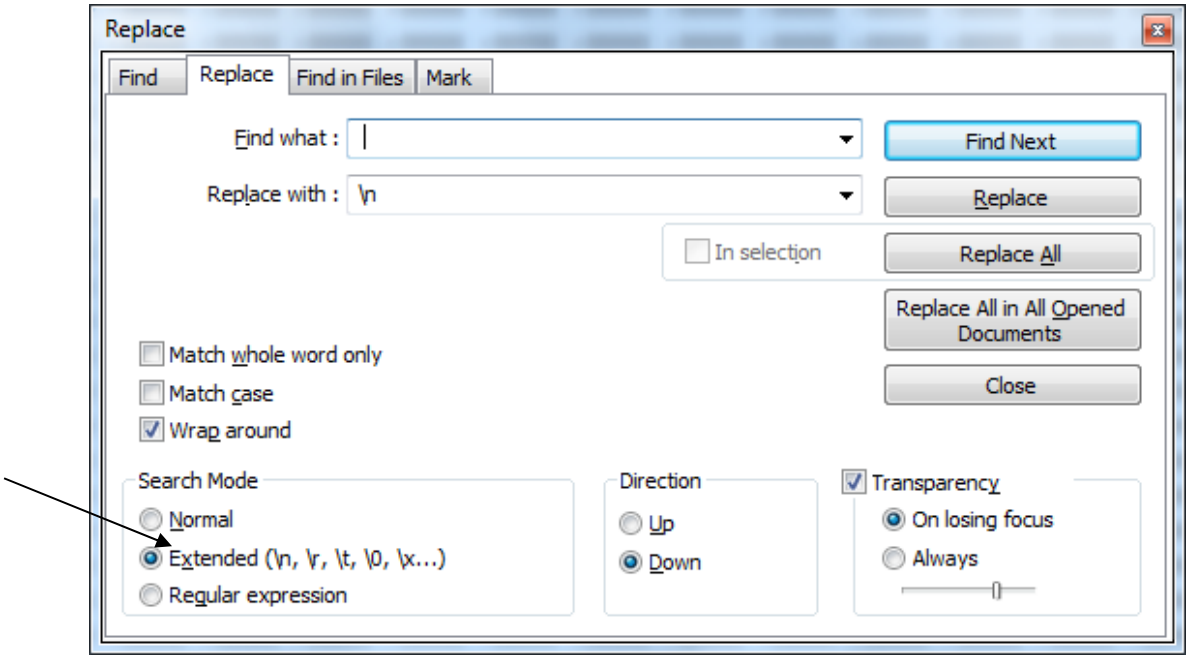
6.2.4. The file will appear similar to the following.



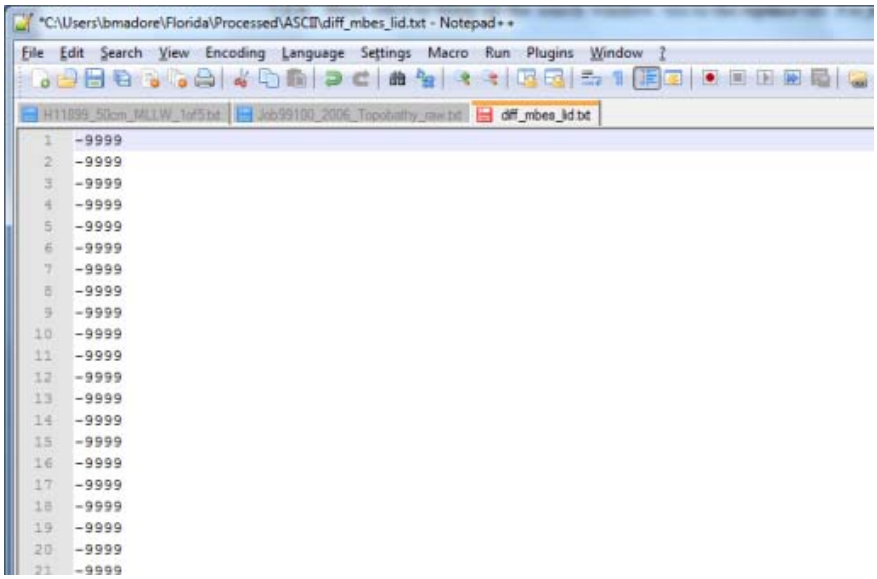
6.2.5. Select the first 6 rows, up to NODATA_value -9999, and delete those rows.



6.2.6. Press ***Ctrl-f*** to bring up the search window. Go to the ***Replace*** tab. In the ***Find what*** field, enter a ***space***. In the ***Replace with*** field, enter ***\n***. For ***Search Mode***, select ***Extended***. Click ***Replace All***.

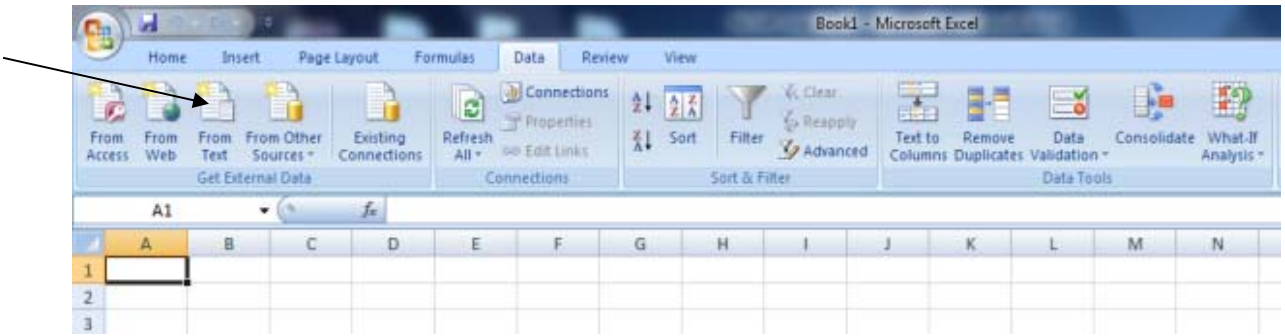


6.2.7. The file will now appear like the following.

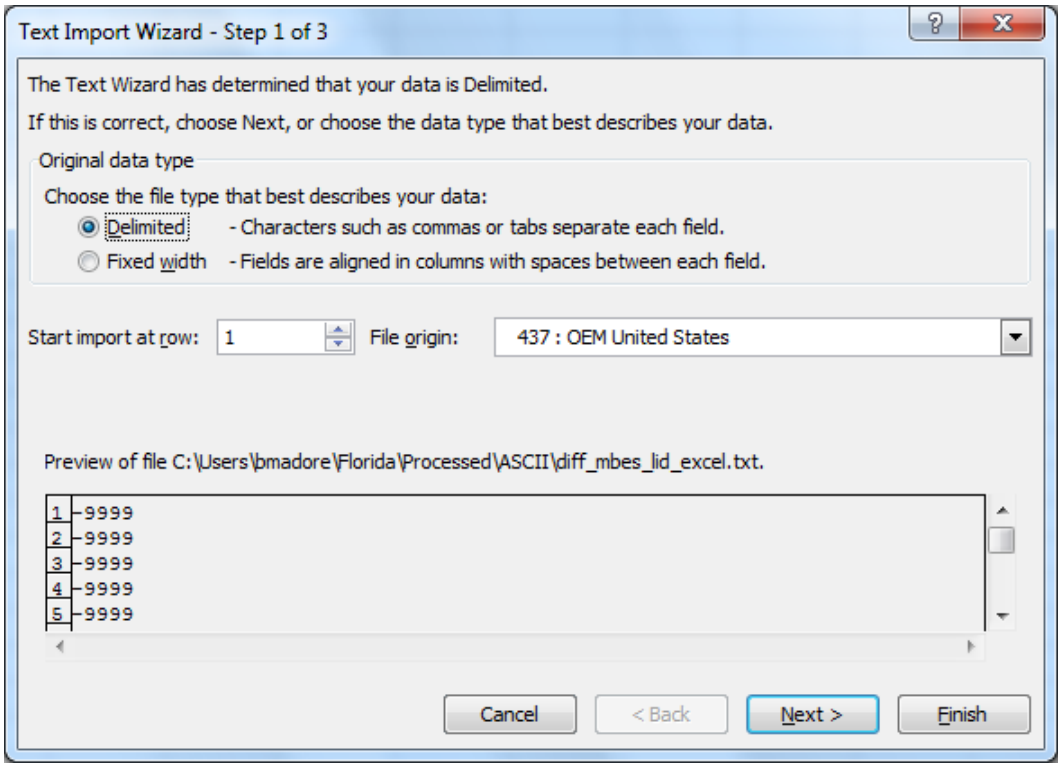


6.2.8. Save the file.

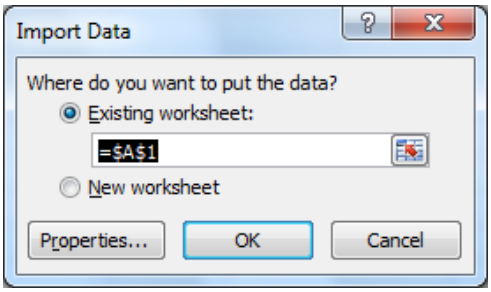
6.2.9. Open ***Excel***. On the ***Data*** tab, click ***From Text***.



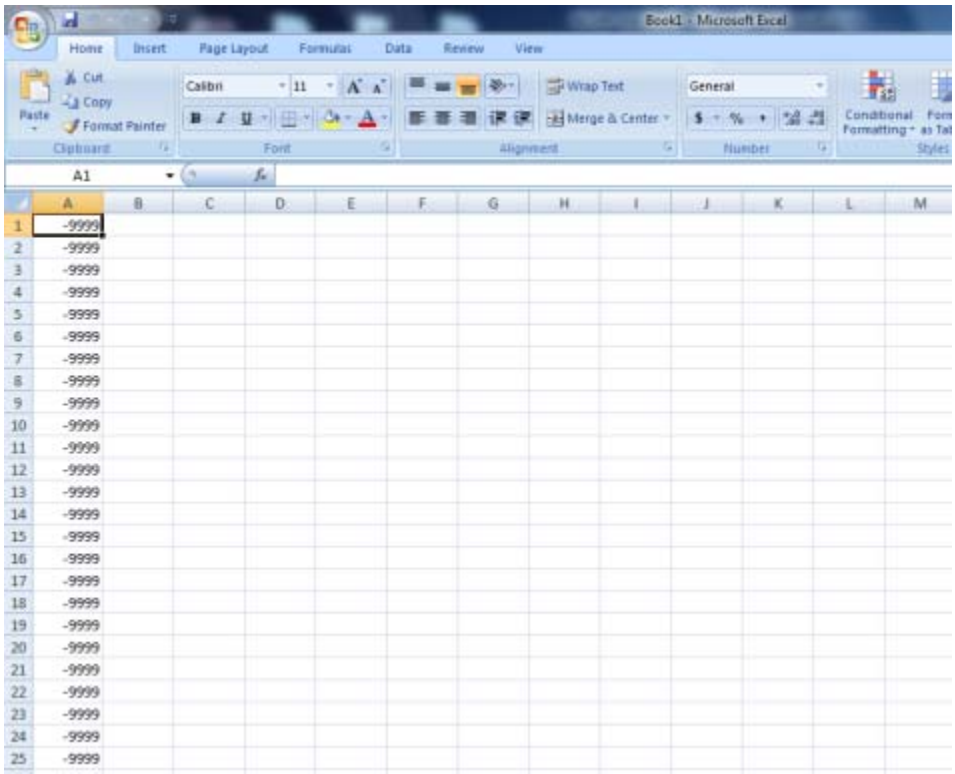
6.2.10. Select the file saved from step 6.2.8. The following window will appear.



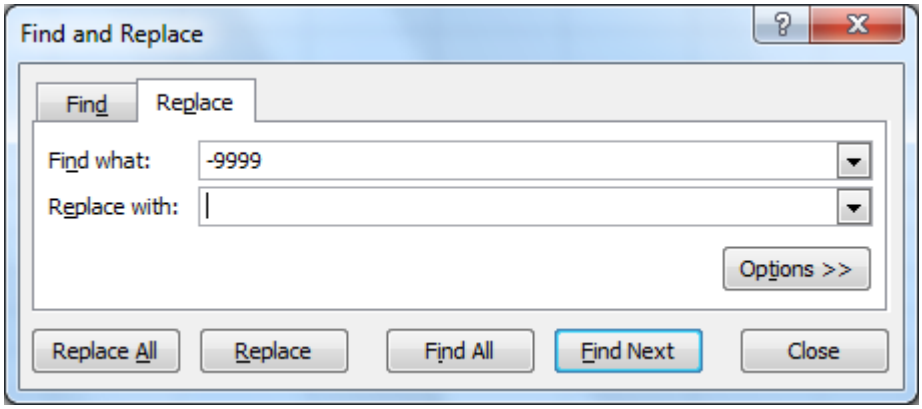
6.2.11. Click ***Finish***. The following window will appear. Click ***OK***.



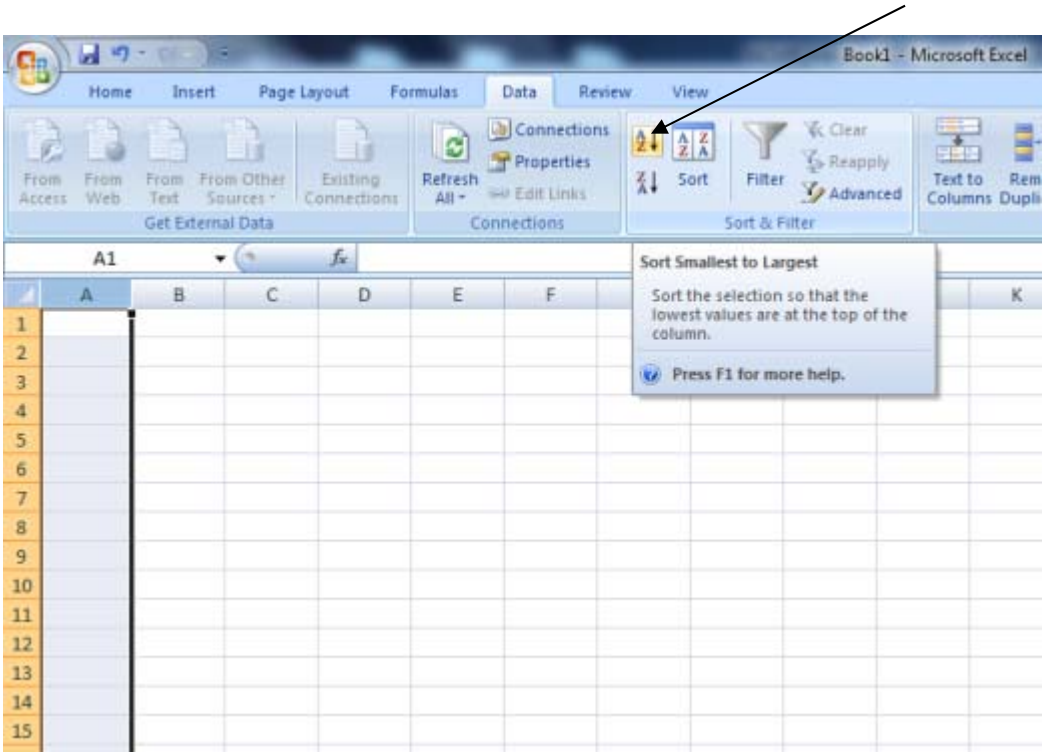
6.2.12. The Excel sheet will resemble the following.



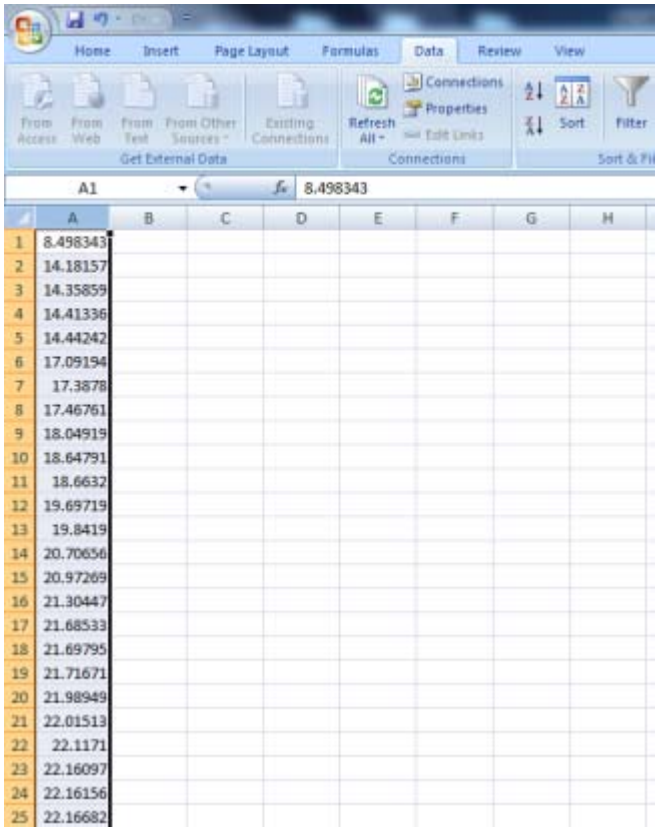
6.2.13. Press ***Ctrl-f*** to open a search window. Go to the ***Replace*** tab. In the ***Find what*** field, enter -9999. Do not enter anything in the ***Replace with*** field. Click ***Replace All.***



6.2.14. Select column ***A***. On the ***Data*** tab, click ***Sort Smallest to Largest.***

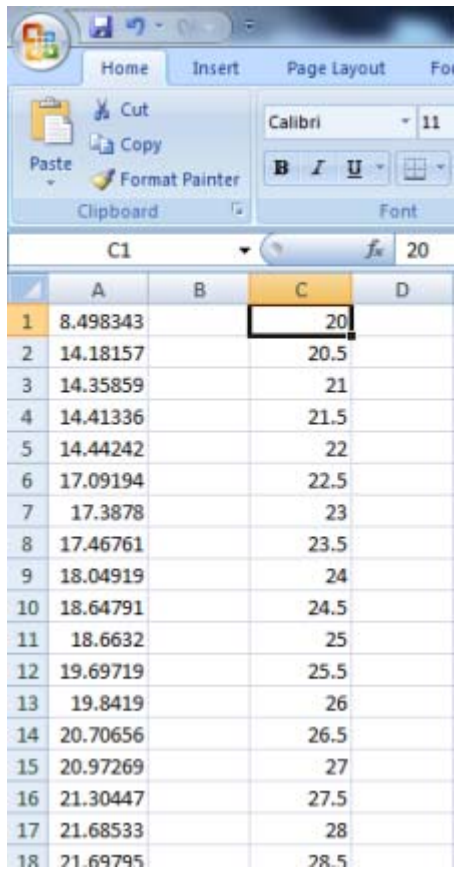


6.2.15. The worksheet should appear similar to the following.



6.2.16. Examine the range of the data for the minimum and maximum values. In the sample data, the minimum value is 8.49, but this value is an outlier. To best represent this sample data in a histogram, start at 20, and every 0.5 m create a section for the histogram.

In column C, start numbering from the smallest interval in your selected interval downward in the increments established in the previous step.



	A	B	C	D
1	8.498343		20	
2	14.18157		20.5	
3	14.35859		21	
4	14.41336		21.5	
5	14.44242		22	
6	17.09194		22.5	
7	17.3878		23	
8	17.46761		23.5	
9	18.04919		24	
10	18.64791		24.5	
11	18.6632		25	
12	19.69719		25.5	
13	19.8419		26	
14	20.70656		26.5	
15	20.97269		27	
16	21.30447		27.5	
17	21.68533		28	
18	21.69795		28.5	

Note: You can enter the first few numbers across (in top row) and use the transpose feature to copy the numbers in a column next to the values in column A (see column C below).

6.2.17. In column D, starting at D1, insert the following equation:

=COUNTIFS(A:A,">20",A:A,"<20.5"). The numbers can be replaced with other

values depending on the range of data. The first number will be the smallest value, followed by the smallest value + the interval. In cell D2, insert the following equation: **=COUNTIFS(A:A,">20.5",A:A,"<21")**. Continue this process until the entirety of the data being examined has been counted.

Note: the following macro can be used in Excel to count the data:

```
Public Sub Counter()

Dim goodcounter, badcounter, nullcounter, r1, r2 As Double
Dim num, minvalue, maxvalue As Double

r1 = 0
r2 = 0

Set ran1 = Range("$A:$A")
For n = 1 To ran1.Rows.Count
   If ActiveSheet.Cells(n, 1).Value <> "" Then
      r1 = n
   End If
Next

Set ran2 = Range("$C:$C")
For n = 1 To ran2.Rows.Count
   If ActiveSheet.Cells(n, 3).Value <> "" Then
      r2 = n
   End If
Next

For m = 1 To r2 - 1
   goodcounter = 0
   badcounter = 0
   nullcounter = 0
   minval = ActiveSheet.Cells(m, 3).Value
   maxval = ActiveSheet.Cells(m + 1, 3).Value
   For n = 1 To r1
      num = ActiveSheet.Cells(n, 1).Value
      If num = "" Then
         nullcounter = nullcounter + 1
      Else
         If num >= minval Then
            If num < maxval Then
            goodcounter = goodcounter + 1
            Else
            badcounter = badcounter + 1
```

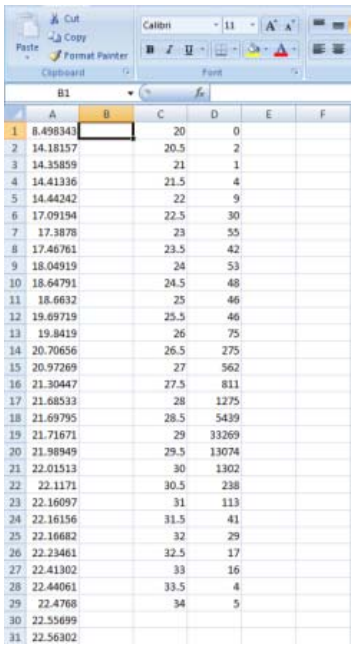
```
            End If
          Else
            badcounter = badcounter + 1
          End If
        End If
      Next
    ActiveSheet.Cells(m, 4).Value = goodcounter
    'ActiveSheet.Cells(m, 5).Value = badcounter
    'ActiveSheet.Cells(m, 6).Value = nullcounter
    Next

    End Sub
```

6.2.18. This process takes the number of data points that are between 20 and 20.5, counts them, and then enters the number of points into cell D1.

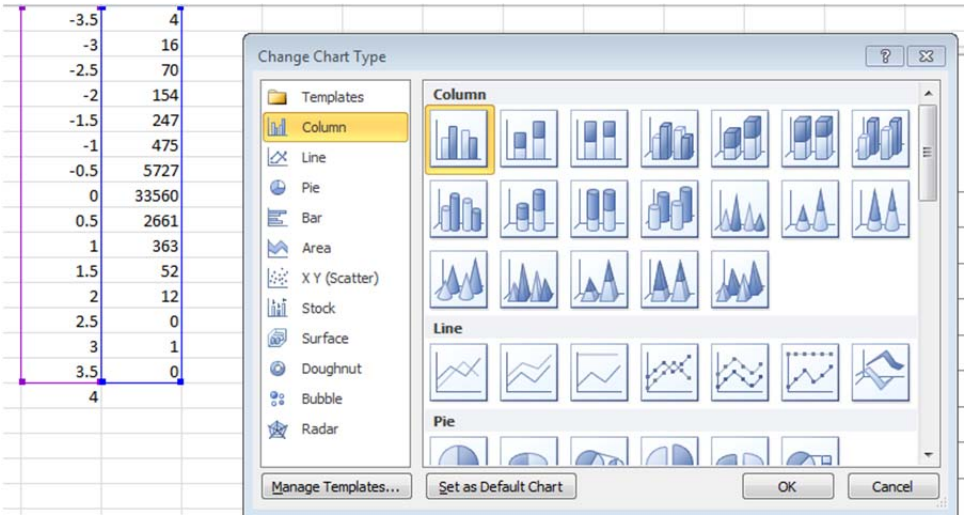
Correspondingly, cell D2 will display the number of points between the values of 20.5 and 21, etc.

6.2.19. Results will look similar to the following.

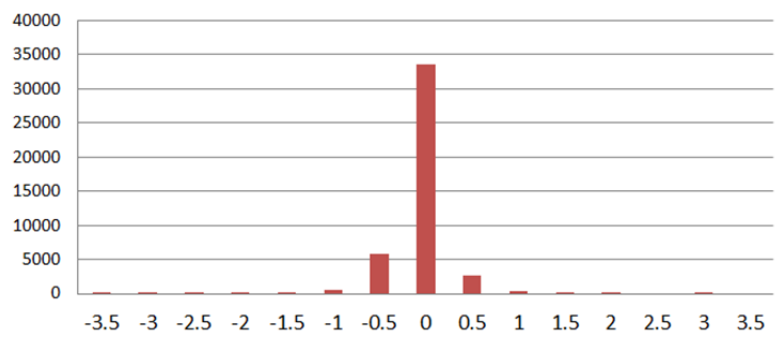


	A	B	C	D	E	F
1	8.498343		20	0		
2	14.18157		20.5	2		
3	14.35859		21	1		
4	14.41336		21.5	4		
5	14.44242		22	9		
6	17.09194		22.5	30		
7	17.3878		23	55		
8	17.46761		23.5	42		
9	18.04919		24	53		
10	18.64791		24.5	48		
11	18.6632		25	46		
12	19.69719		25.5	46		
13	19.8419		26	75		
14	20.70656		26.5	275		
15	20.97269		27	562		
16	21.30447		27.5	811		
17	21.68533		28	1275		
18	21.69795		28.5	5439		
19	21.71671		29	33269		
20	21.98949		29.5	13074		
21	22.01513		30	1302		
22	22.1171		30.5	238		
23	22.16097		31	113		
24	22.16156		31.5	41		
25	22.16682		32	29		
26	22.23461		32.5	17		
27	22.41302		33	16		
28	22.44061		33.5	4		
29	22.4768		34	5		
30	22.55699					
31	22.56302					

6.2.20. Select the cells with values from columns C and D. On the ***Insert*** tab, select ***Bar*** then ***all types.***



6.2.21. A graph similar to the following will appear.



6.2.22. You can add more bins between each 0.5-m increment and run the macro again to show more bars indicating the discrete histogram bins.

6.2.23. Go to the ***Design*** tab to add axis labels and title.

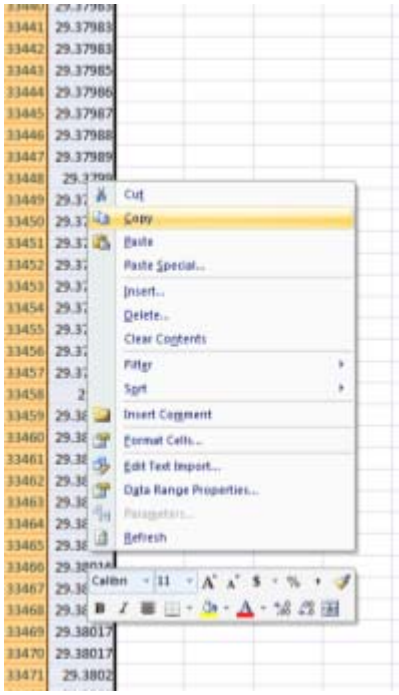
6.2.24. The values on the horizontal axis represent the value of the difference in bathymetry of the MBES and lidar datasets. The vertical axis indicates how many data points fall within that range.

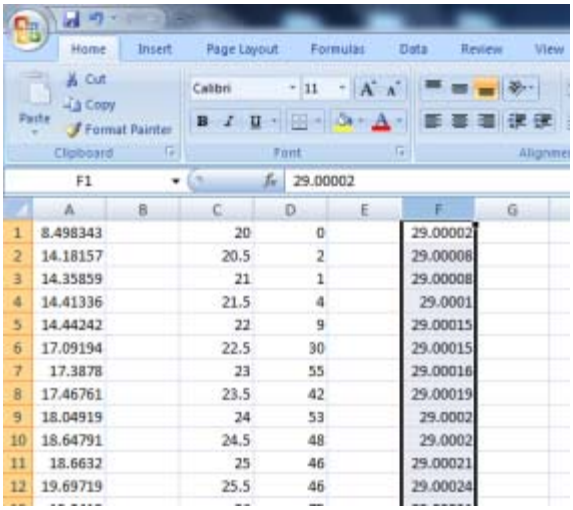
Note: If you have a large difference and the majority of the points are at for example 29 and not 0, this is most likely due to the datum of the lidar dataset. All of the values are offset by a specific amount, and this amount can be found by interpreting the above graph. If you already know what your offset is, skip to

step 6.3.

6.2.25. The peak of the graph is at 29 meters, which is roughly the offset of the lidar data. To obtain a more precise value, take the average of the data points from 29 to 29.5 m. Highlight these values in column A, right-click, and select ***Copy***.

6.2.26. Paste the values into the top of an empty column.

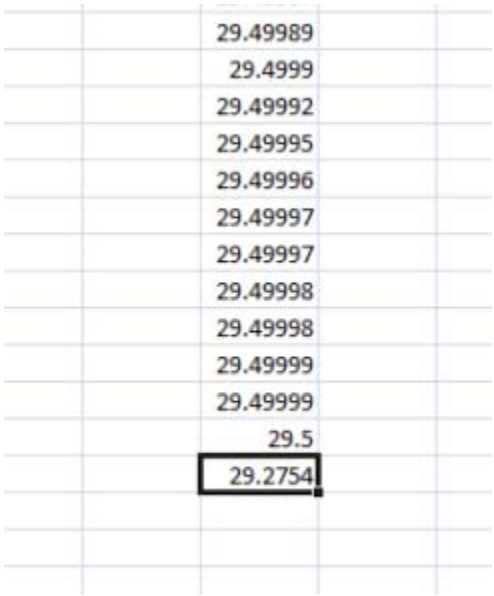




	A	B	C	D	E	F	G
1	8.498343		20	0		29.00002	
2	14.18157		20.5	2		29.00008	
3	14.35859		21	1		29.00008	
4	14.41336		21.5	4		29.0001	
5	14.44242		22	9		29.00015	
6	17.09194		22.5	30		29.00015	
7	17.3878		23	55		29.00016	
8	17.46761		23.5	42		29.00019	
9	18.04919		24	53		29.0002	
10	18.64791		24.5	48		29.0002	
11	18.6632		25	46		29.00021	
12	19.69719		25.5	46		29.00024	

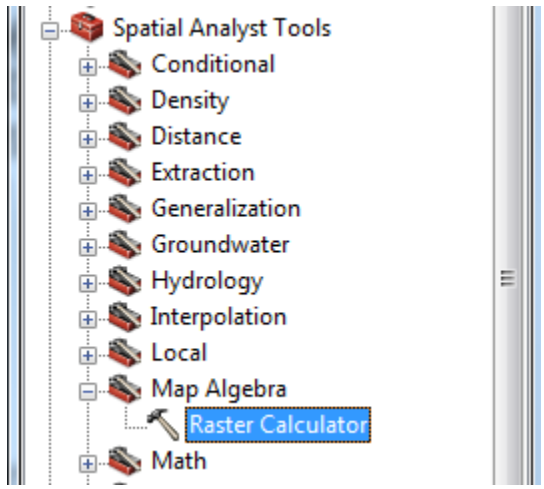
6.2.27. Select these values in the column and then select ***Average*** under ***Autosum***.

6.2.28. The average will appear under the last selected value in the column. This value is a more accurate representation of the datum offset for the lidar.

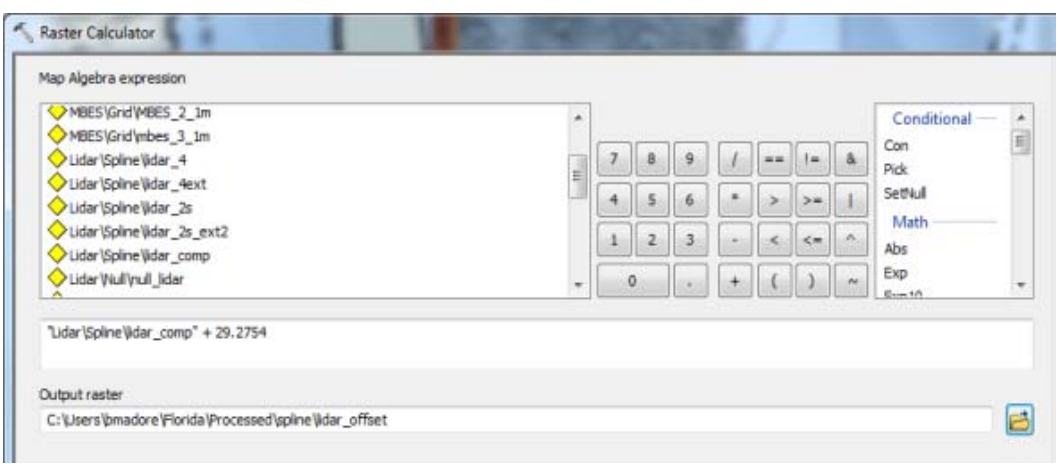


6.3. Difference Maps, Part 2

6.3.1. In ArcMap, select ***Spatial Analyst Tools → Map Algebra → Raster Calculator*** in the ***Arc Toolbox***.

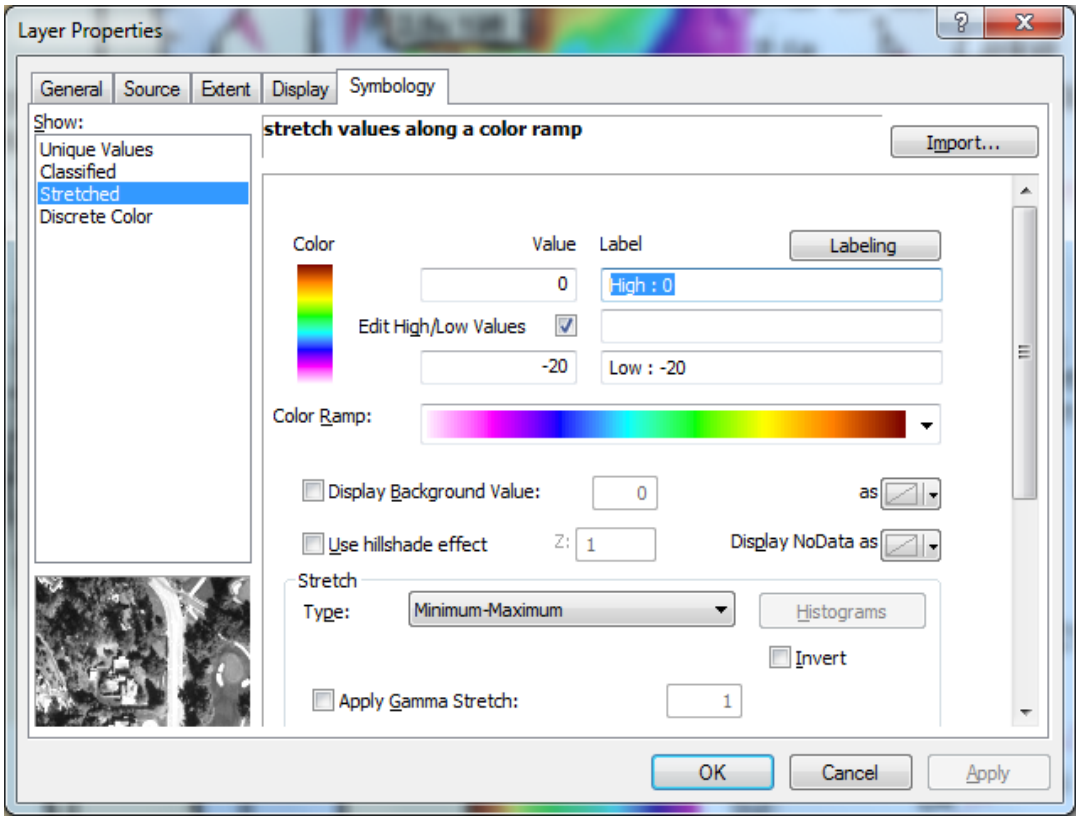


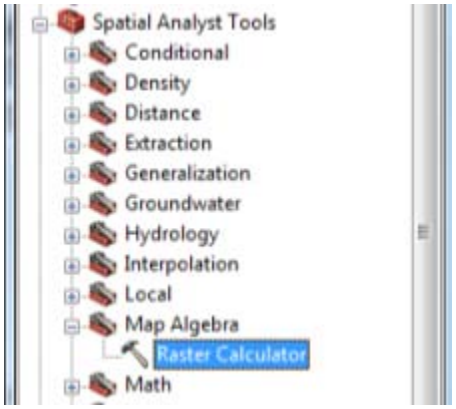
6.3.2. Select the lidar ***Spline*** layer from step 4.9 and 4.10. Then select ***add*** (+) and enter the value from step 6.2.28. Choose a save destination for the file and click ***OK***.



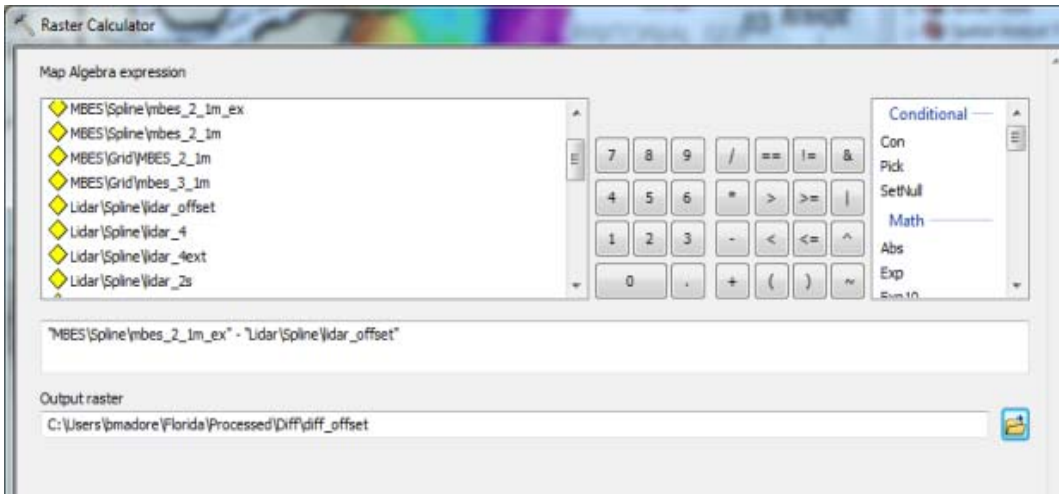
6.3.3. Right-click and select ***Properties***. On the ***Symbology*** tab, change ***Stretch Type*** to ***Minimum-Maximum. Edit*** the ***High/Low Values*** and select a different ***Color Ramp***, if desired.

6.3.4. Select ***Spatial Analyst Tools → Map Algebra → Raster Calculator*** in the ***Arc Toolbox.***





6.3.5. Select the ***MBES Spline*** layer from steps 5.33-5.34. Subtract (-) the ***lidar Spline*** layer from step 6.3.2. Select a save destination, and click ***OK***.

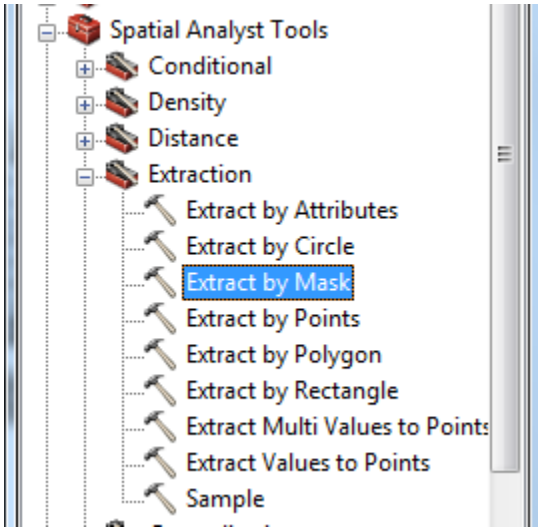


6.3.6. The new difference map accounts for the offset in the lidar data and gives the absolute difference between the two data sets now.

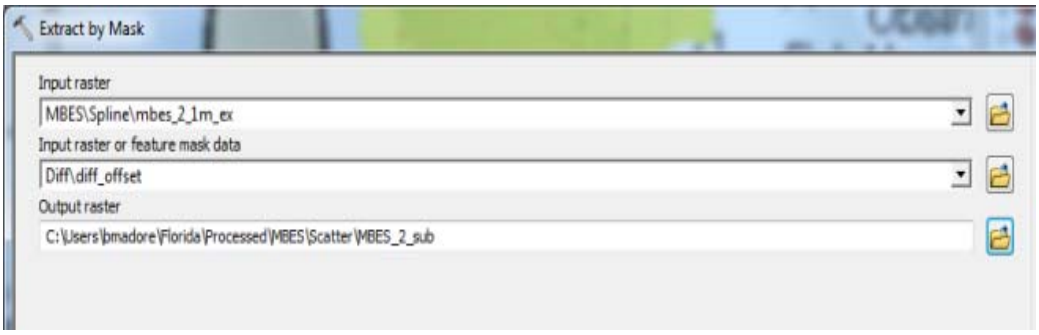
6.4. Scatter Plots

Note: Scatter plots will show the difference between the reference data set (OCS lidar/mbes) and the JALBTCX data.

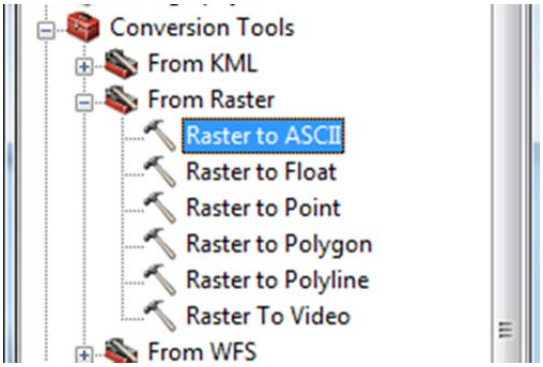
6.4.1. Select ***Spatial Analyst Tools → Extraction → Extract by Mask*** in the Toolbox.



6.4.2. Select the ***MBES Spline*** layer from step 5.34 for the ***Input raster***. Select the difference layer from step 6.3.5 for the ***feature mask*** and choose a save destination for the new layer in the ***Output raster.*** Click ***OK.***

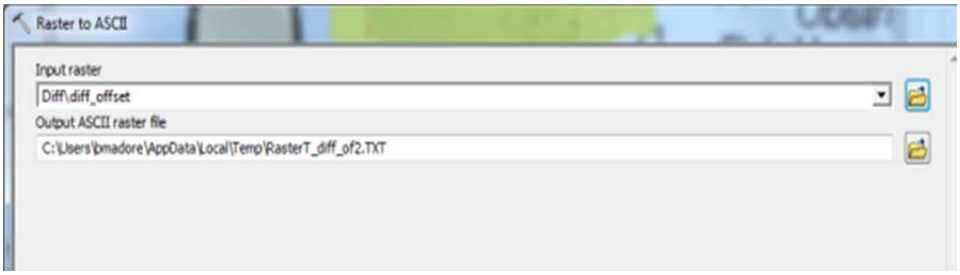


6.4.3. Select ***Conversion Tools → From Raster → Raster to ASCII***.



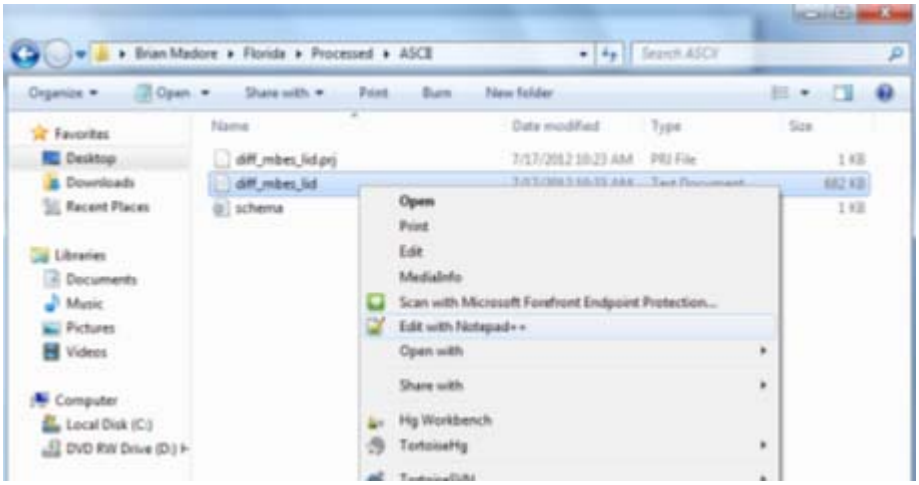
6.4.4. ***Input*** the difference layer from step 6.3.5 and choose a save destination in the ***Output*** field.

Note: Select file type.txt.

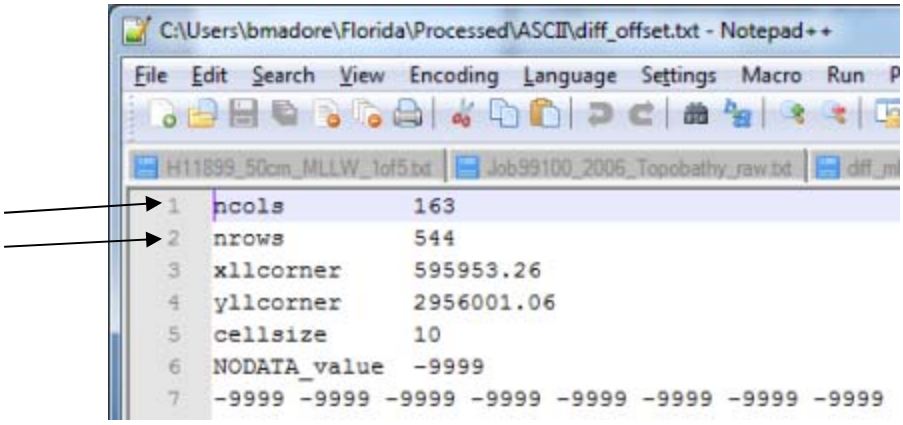


6.4.5. Repeat step 6.4.4 but insert the layer from step 6.4.2 instead.

6.4.6. Go to the location of the saved ASCII file. Right-click on the file and select ***Edit with Notepad ++.*** Open both files (from step 6.4.4 and 6.4.5).



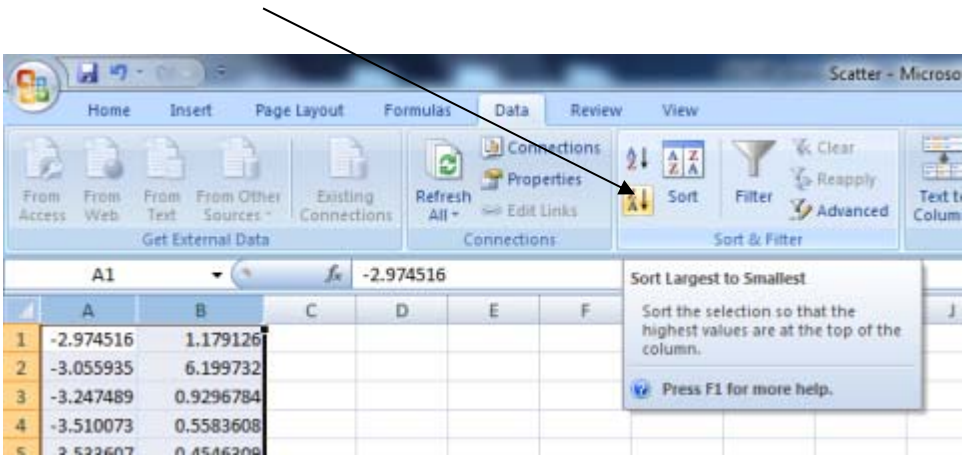
6.4.7. Compare the row and column values given to confirm that they are equal.



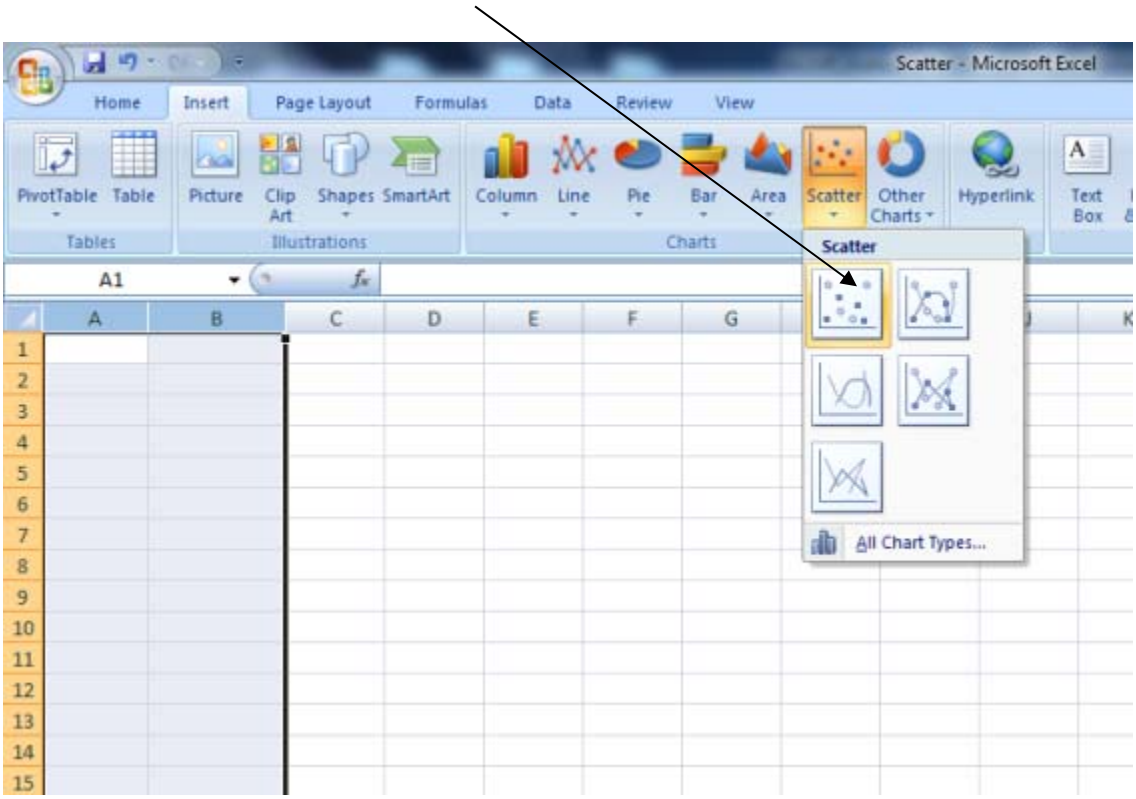
6.4.8. Repeat steps 6.2.5 to 6.2.11 for both files. Put the MBES values in column A and the Difference values in column B. Check the columns to ensure they are even. If they are not even, delete the -9999 that are longer.

6.4.9. Press ***Ctrl-f*** to open a search window. Select the ***Replace*** tab. In the ***Find what*** field, enter -9999; do not enter anything in the ***Replace with*** field. Click ***Replace All.***

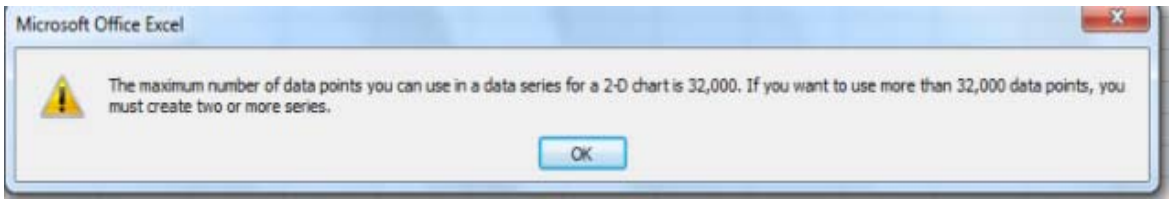
6.4.10. Select columns A and B. On the ***Data*** tab, select ***Sort Largest to Smallest***.



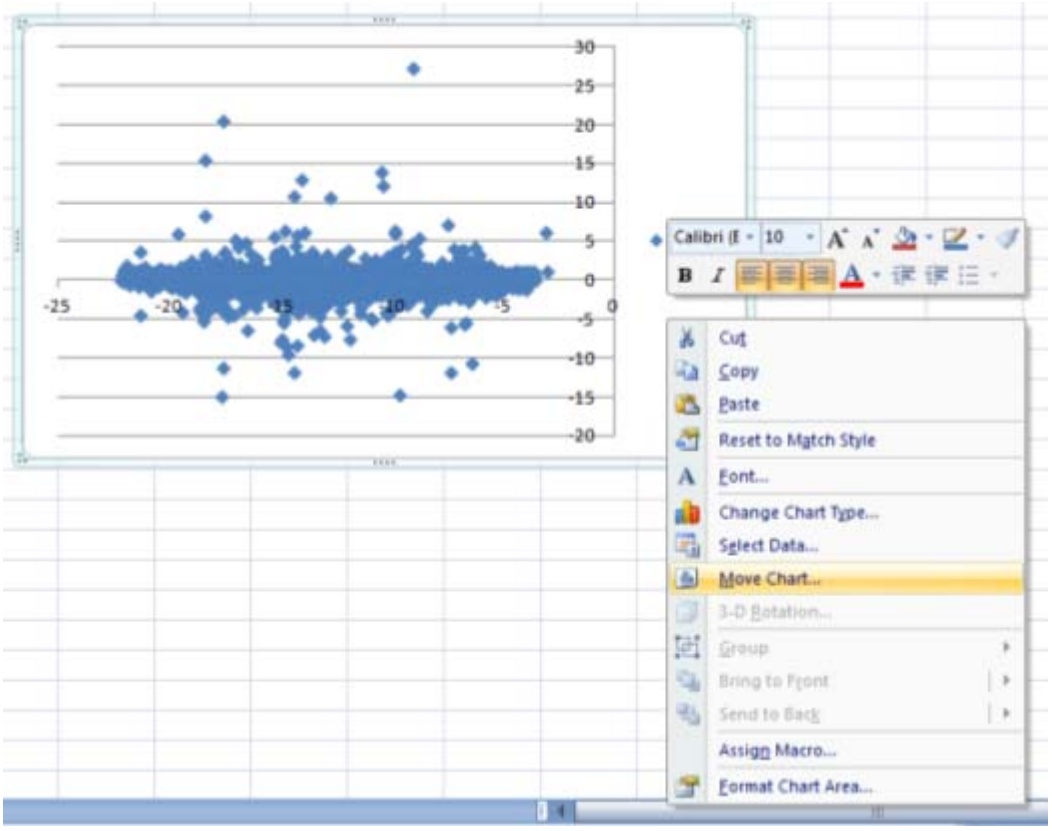
6.4.11. Select columns A and B. On the ***Insert*** tab, select ***Scatter*** then ***Scatter with only Markers***



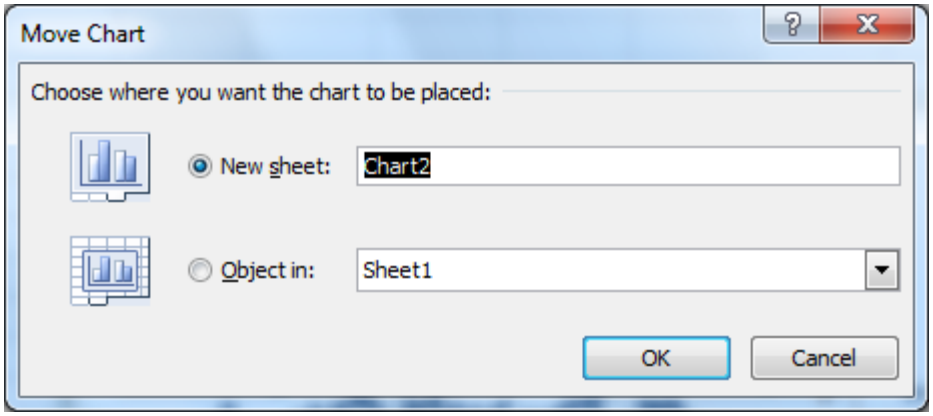
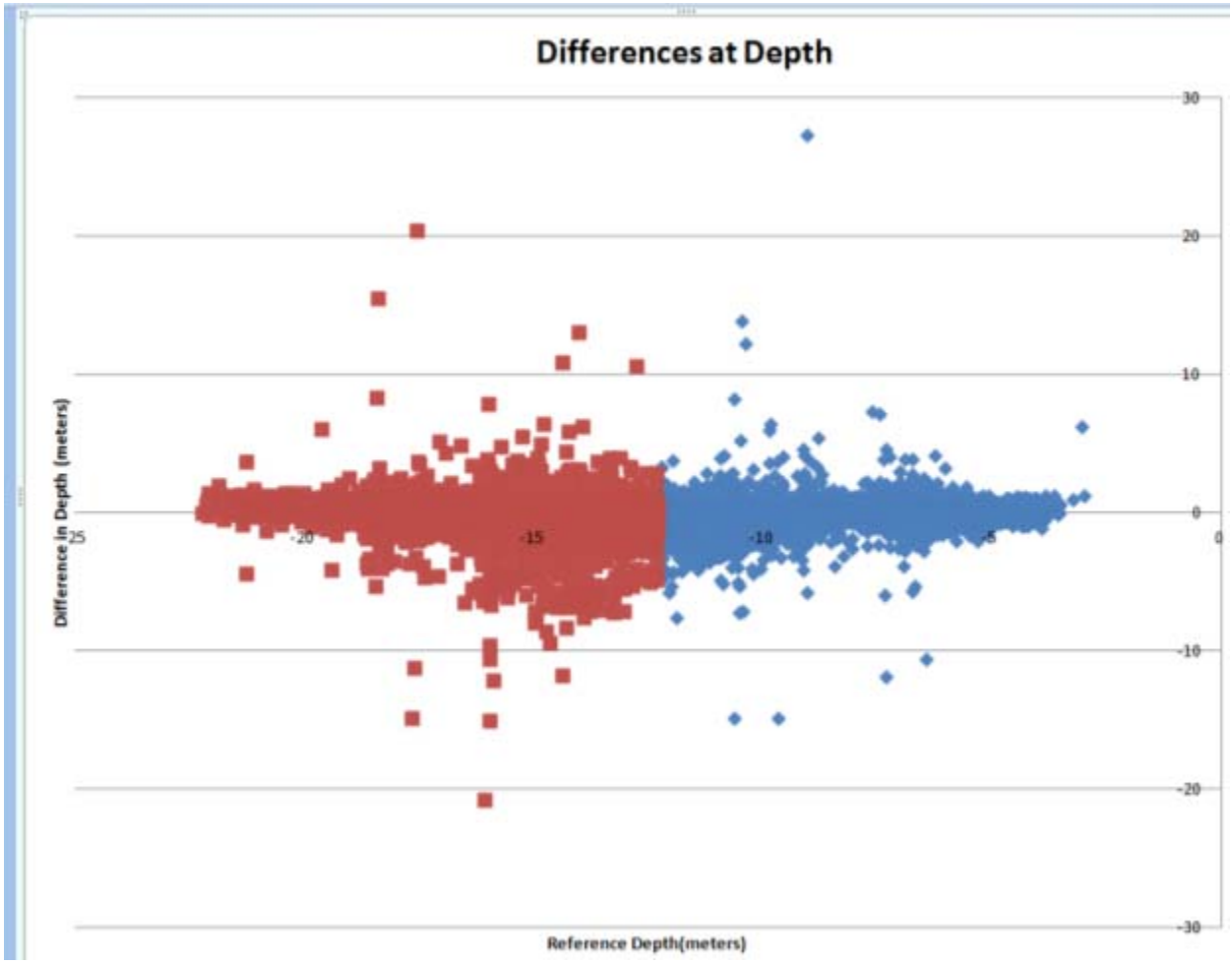
6.4.12. If the following window appears, click ***OK***.



6.4.13. A graph will appear. Right-click and select ***Move Chart***.



6.4.14. Select ***New Sheet***. Click ***OK***.



6.4.15. Select ***Design*** tab and ***Chart Layout*** to add title and axis labels.