National Park Service
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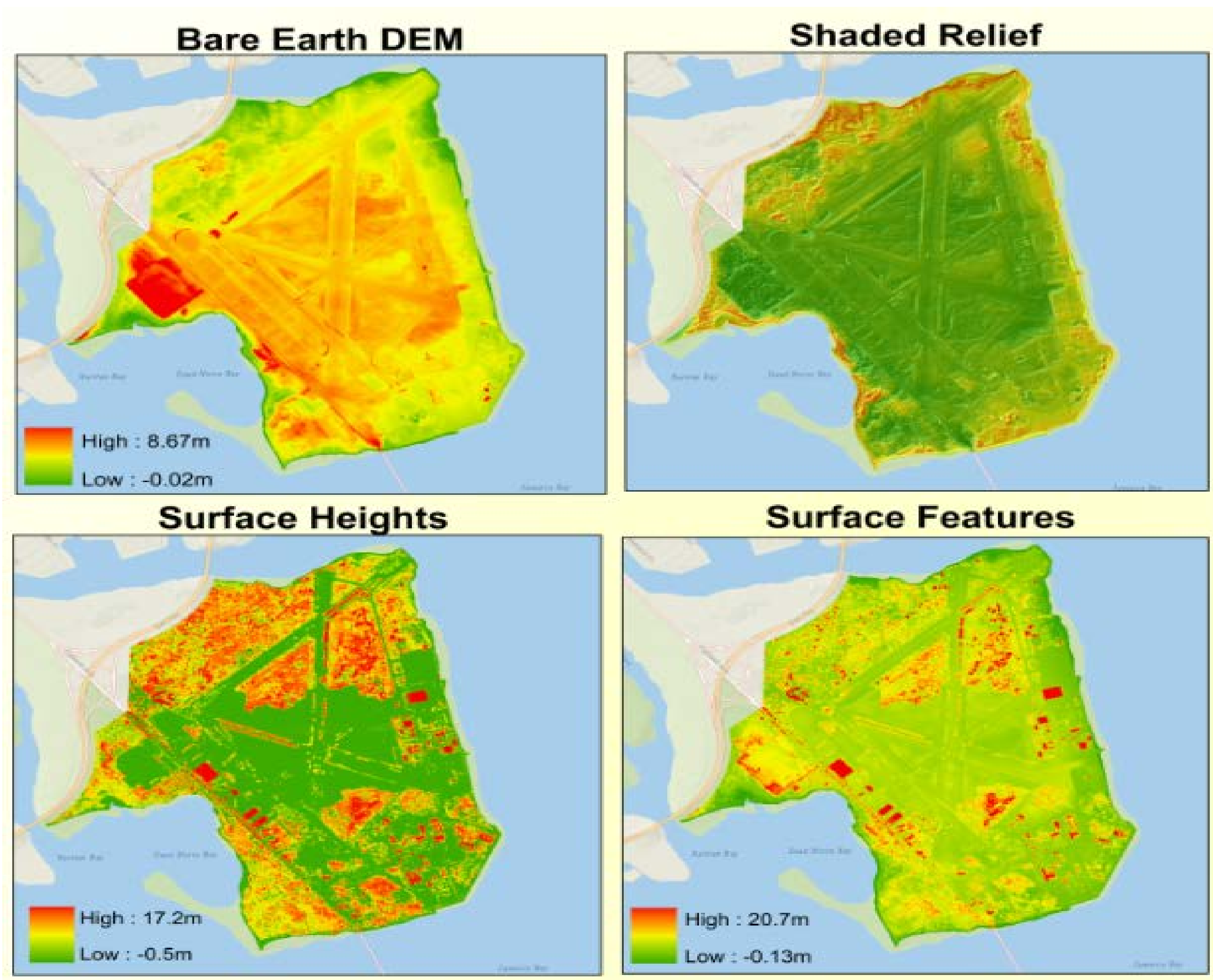
Natural Resource Stewardship and Science

Working with Elevation Data to Produce High-Quality Results

GIS workflows developed in response to Hurricane Sandy data processing needs – May 2017 Revision

Natural Resource Report NPS/NCBN/NRR—2017/1433



ON THE COVER

Various LiDAR derived products for Floyd Bennett Field in the Jamaica Bay Unit of Gateway National Recreation Area, New York City.

Photographs by: LiDAR collected by the U.S. Army Core of Engineers, featured derived products by Erica Tefft, Environmental Data Center at the University of Rhode Island.

Working with Elevation Data to Produce High-Quality Results

GIS workflows developed in response to Hurricane Sandy data processing needs – May 2017 Revision

Natural Resource Report NPS/NCBN/NRR—2017/1433

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U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Abstract

Access to high-quality elevation products can be critical in ensuring a quick and effective response to natural disasters, such as coastal storm events. For example, a high quality digital elevation model can assist with predicting areas that may be prone to inundation during a coastal storm event, as well as estimating the volume of sand lost or gained along a shoreline as a result of a storm. The workflows contained within this document walk Esri ArcGIS users through the steps necessary for creating high-quality LiDAR-derived products, such as Digital Elevation Models (DEMs), Esri mosaic datasets, and Esri LAS datasets. The first workflow introduces users to Esri LAS datasets, and how these can be used in the generation of DEMs and hillshade models. The next workflow is broken into two parts; the first section introduces users to utilizing mosaic datasets as a way to create high-quality DEMs and shaded relief models. The second section introduces users to viewing and analyzing surface features, creating surface height layers, as well as basic graphing via the ArcGIS 3D Analyst extension. These workflows provide users with not only detailed instructions, but also include annotated images for each step along the way. These procedures are intended to assist GIS analysts with expediting LiDAR data processing after a coastal storm event, and producing high-quality elevation data products that may be used as input for a wide variety of inundation modeling and change analysis techniques.

Acknowledgments

These workflows have been developed and tested by the Environmental Data Center at the University of Rhode Island with the support of a competitive grant (cooperative agreement number P09AC00212; task agreement number P13AC00875) from the National Park Service in partnership with the North Atlantic Coast Cooperative Ecosystems Studies Unit.

Glossary

Digital Elevation Model – Typically called a DEM, these are continuous representations of elevation values over a surface by a “regular array of z-values” to a common datum (or a standardized position from which measurements are made).

Footprints – Calculated based on each input raster image. Helps to determine which data is displayed in the mosaicked image. Footprints do not always represent the extent of the raster, but rather represent the valid raster data within the dataset.

Function – Processing operations that can perform on-the-fly processing to rasters within a mosaic dataset. There are over 30 pre-defined functions that a user can select to add to the function chain of their mosaic dataset.

Function Chain – Visual display of the “order of operations” in which the mosaic dataset carries out its on-the-fly processing. Function chains are applied from the bottom up, therefore any function added after the mosaic dataset is created appears higher up on the function chain than the Mosaic Function.

Hillshade – A grayscale 3 dimensional model of the surface, based off of a Digital Elevation Model, in which the angle of the sun is taken into account.

LAS Dataset – A system of storing references to a collection of LAS files, which allows the user to quickly examine the LAS file’s point cloud. These datasets also provide quick statistics on each input LAS file, and provide information on the footprint, or area covered, by each LAS file.

LAS File – The standard file formation in which LiDAR data is stored.

LiDAR – A shortened acronym for Light Detection and Ranging, LiDAR is a method used to remotely study the surface of the earth. Airborne LiDAR data is most commonly collected through the utilization of airplanes and helicopters; these carry the instrumentation necessary to collect these data. This specialized instrumentation consists of a laser, a scanner, a GPS receiver, and an inertial measurement unit (IMU). This equipment collects and records information about the surface of the earth through a series of pulses of light, creating a three-dimensional representation of the surface.

Mosaic Dataset – A powerful way to store and manage raster data that also provides the user with additional functionality to enhance imagery and produce polished, high-quality final products. Data is processed in two ways within a mosaic dataset, through dynamic mosaicking and on-the-fly processing making it extremely responsive to user-made changes. These datasets are ideal for easy viewing and sharing among colleagues or as an image service on ArcGIS Server.

Overviews – Lower-resolution images that increase display speed. The creation of overviews is very controlled within the mosaic dataset environment. This provides the user with a variety of options to control the areas in the imagery for which overview are created, the base-pixel size of the overview image and the resolution at which they appear.

Referenced Mosaic Dataset – A mosaic dataset that references an existing mosaic dataset and its imagery, overviews and footprints. Provides the user with quick processing as it eliminates many steps, but the user is unable to create overviews. Is typically used to create a mosaic dataset with a different derived product such as a hillshade through the use of the Hillshade Function.

Shaded Relief – A color raster image of elevation that is created by using the position of the sun to create light and shadows on the elevation surface. Similar concept to a hillshade, however a shaded relief is a color raster, while hillshades are represented in grayscale.

Introduction

Access to high-quality elevation products can be critical in ensuring a quick and effective response to a natural disaster. With derived elevation products in hand, emergency responders and park personnel will be able to easily assess areas in which there has been a significant loss of park infrastructure or natural landmarks. This will then allow first responders to determine areas that need potential search and rescue operations to occur, or areas that should be sequestered until fully inspected for safety hazards. These derived products will also be extremely useful to park personnel after a storm event has passed, as it will allow parks to conduct change analyses, such as the derivation of new shorelines that can then be compared with pre-storm shorelines. These products can also be used to determine volumetric changes; an example of where this might be useful would be Fire Island National Seashore, where the island experienced a breach following Hurricane (Superstorm) Sandy in October 2012.

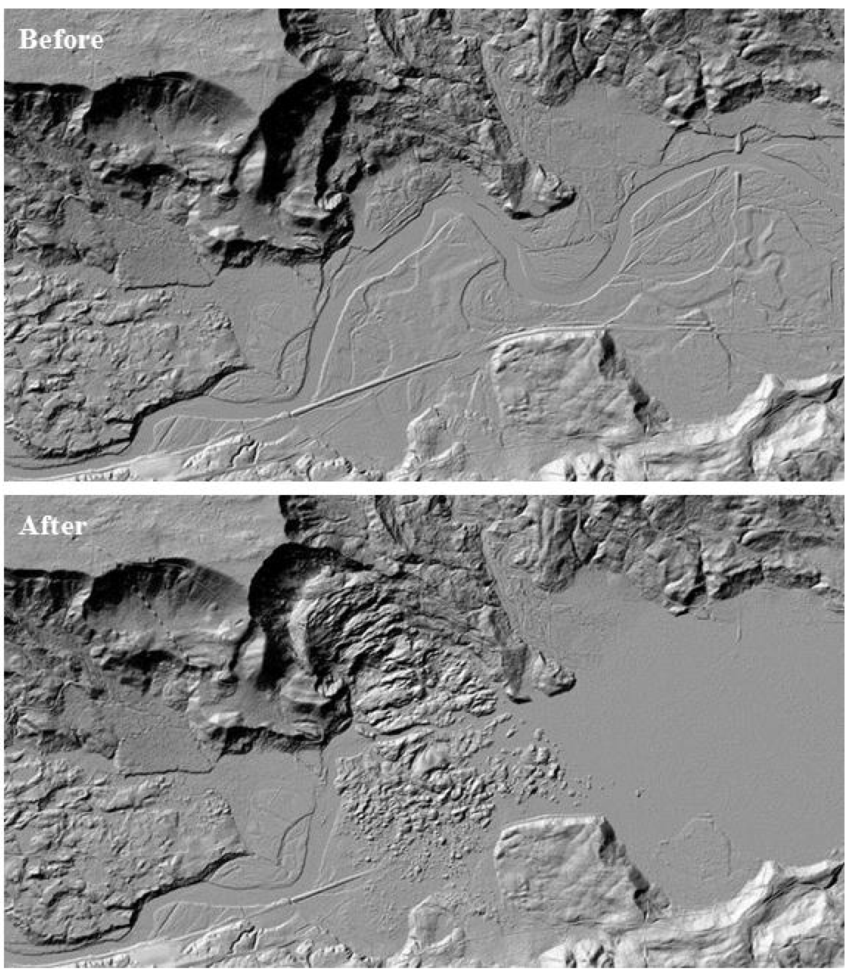


Figure 1. An example of two bare earth Digital Elevation Models for the Snohhomish County, Washington landslide that occurred in March 2014. The top image is what the river looked like before the landslide, while the bottom image is what the river looked like after the landslide. Images such as these truly illustrate the power of LiDAR and derived elevation products. Photograph Credits: The Seattle Times, the Puget Sound LIDAR Consortium, and the Washington Department of Transportation.

The following three workflows are intended for use by park personnel or emergency responders, both before and after a storm event. They provide easy to follow steps that will result in the creation of high-quality derived elevation products that can then be easily shared among the park staff and emergency responders. The first workflow will deal with the utilization of LAS datasets to visualize LiDAR data, and how derived elevation products can be produced from the LAS dataset. The second and third workflows will cover how to utilize mosaic datasets as a means for creating high-quality, shareable derived elevation products. The second workflow will detail how to create essential products such as digital elevation models and shaded reliefs, while the third workflow will go more in depth and explore using mosaic datasets in conjunction with the Image Analysis window.

Mosaic datasets are useful in situations where large datasets or large collections of data are in use. They provide the user with an easy way to catalog and store data, as well as providing the user with some quick processing. When LAS files are input into a mosaic dataset, the individual points are processed on-the-fly to create a raster surface. This cuts out the use of certain tools required to create a raster from a point cloud LAS dataset. Mosaic datasets also allow the user to apply further on-the-fly processing called Functions that further enhance the data. Although inputting the LAS files into the mosaic dataset require patience, the end result is quick versatile processing that allows for easy sharing.

It is the hope of the Environmental Data Center that these procedures will help expedite LiDAR processing before and after storm events take place. We believe that having access to high-quality derived elevation products before and after a storm can help responders to pinpoint areas that may be more susceptible to erosion or collapse before a storm, and critically hit areas that may need extra care and attention by responders in that area after a storm. By creating a seamless elevation product of an area, park personnel and first responders will have access to a high-quality view of the ground condition that will make these things possible. These seamless elevation products can also be used well after the storm event as a means to verify shoreline change, and carry out other types of change analysis.

Generating Digital Elevation Models (DEMs) and Hillshade in LAS Datasets

Audience: This is an advanced workflow and assumes a working knowledge of the ArcGIS Platform and understanding of the management and creation of geospatial data types.

System Requirements: The following workflow was developed using a Windows 7 Professional operating system, and Esri ArcMap version 10.2.2. For best results, use these system specifications.

Data Requirements: LAS files for area of interest.

Products Produced: LAS Dataset, Bare Earth Digital Elevation Model, and Digital Surface Model.

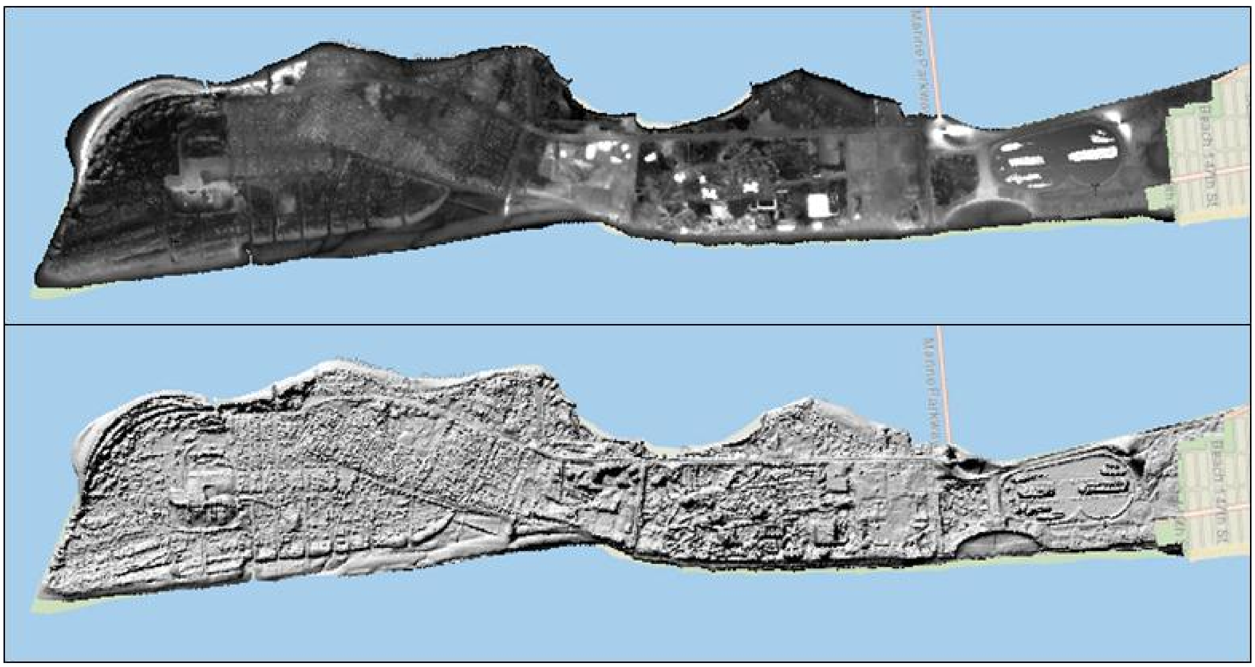


Figure 2. Close-up view of the Rockaway Peninsula in Jamaica Bay, Gateway National Recreation Area. The top photo is a Digital Elevation Model for the area, while the bottom photo is a hillshade for the area. Both were created using the following procedure.

First, designate a workspace in which the following steps will be carried out. Right click on this designated file folder in ArcCatalog, select New and click **LAS Dataset** in the context menu. The first step is to name the LAS dataset; the best practice to use here will be the National Park Service Layer Naming Conventions. While bulky at times, this naming convention will be the most transparent to future users, who may be unfamiliar with the data or the area.

Now, double click on the newly created LAS Dataset in the Catalog window; this will open the **LAS Dataset Properties** dialog box. To add your LAS files for your area of interest (AOI), see the steps below:

a) Select the **LAS Files** tab.

b) In the **Show** dropdown menu, select Folder (see green circle below).

c) Click the **Add Folders** button (see red circle below) and navigate to the folder containing the LAS files, and select the folder.

d) Click **OK** to add LAS files to the LAS Dataset.

e) Click **Apply** and **OK** to exit the dialog.

   i. In some cases it is not necessary to select an XY or Z coordinate system; this will automatically be determined from your data.

   ii. In other cases, the source LAS files will not come with a spatial reference. Before being input into a LAS dataset, it will be necessary to define the projections of each LAS file. To do this, follow these steps:

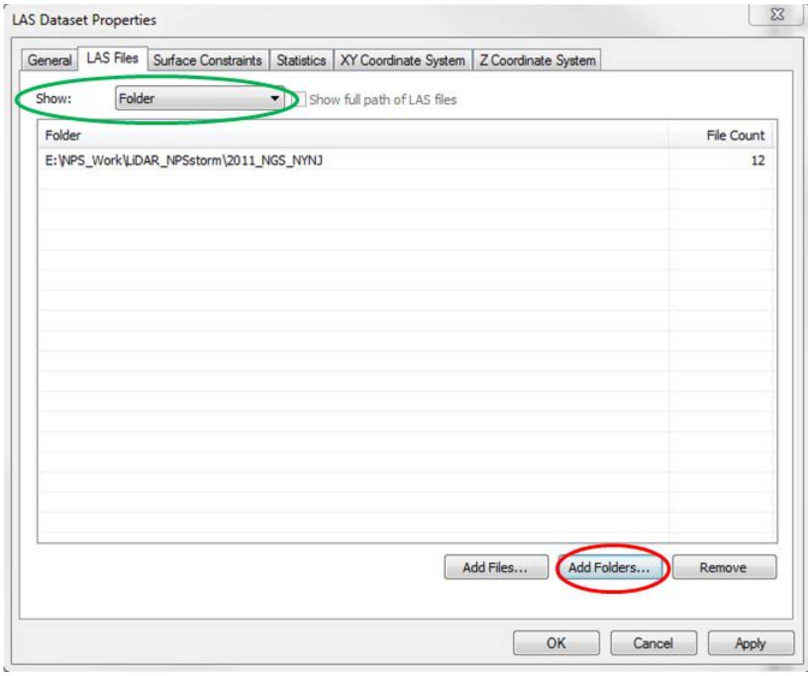
      a. Visit this link and download the toolbox.

      b. http://www.arcgis.com/home/item.html?id=d19c05deaf42447c9b4fc68fc4bb9c7a

      c. Open the **README.pdf** and follow instructions to install the toolbox. In ArcMap open your toolbox. Right click on the heading and select **Add Toolbox**.

      d. Navigate to the folder indicated in the README.pdf file and click **OK.**

      e. Next, open the **Lidar Tools toolbox**, and expand the **Manage toolset**. Open the **Create PRJ for LAS** and fill in the tool dialog. Once this is complete, please proceed with this workflow.



Next, open the LAS dataset in ArcMap. When this is done, only red outlines of the individual LAS files will show up. These are the footprints, or the area covered, by the LAS files. To see the individual points contained within the point cloud, zoom in.

To create a temporary layer from the LAS point cloud data, search for the **Make LAS Dataset Layer** tool within the Data Management toolbox. This allows the user to select which class of points will be visible. We will create two temporary outputs: one of ground returns, and one of all returns. Use the following specifications to fill in the tool:

Note: *It will be necessary to run this tool twice. Once to create the ground returns layer and one to create the all returns layer. See the two tool dialogs following the instructions below to verify parameters for each layer.*

a) Input LAS Dataset = LAS Dataset

b) Output Layer =

   i. One output name should specify if it is for ground returns, and the second output name should specify if it is for all returns. See the following two tool dialogs for an example of how this was done for this tutorial.

c) Class Codes =

   i. Ground returns: select class code **2**.

   ii. All returns: ***do not select any class codes***.

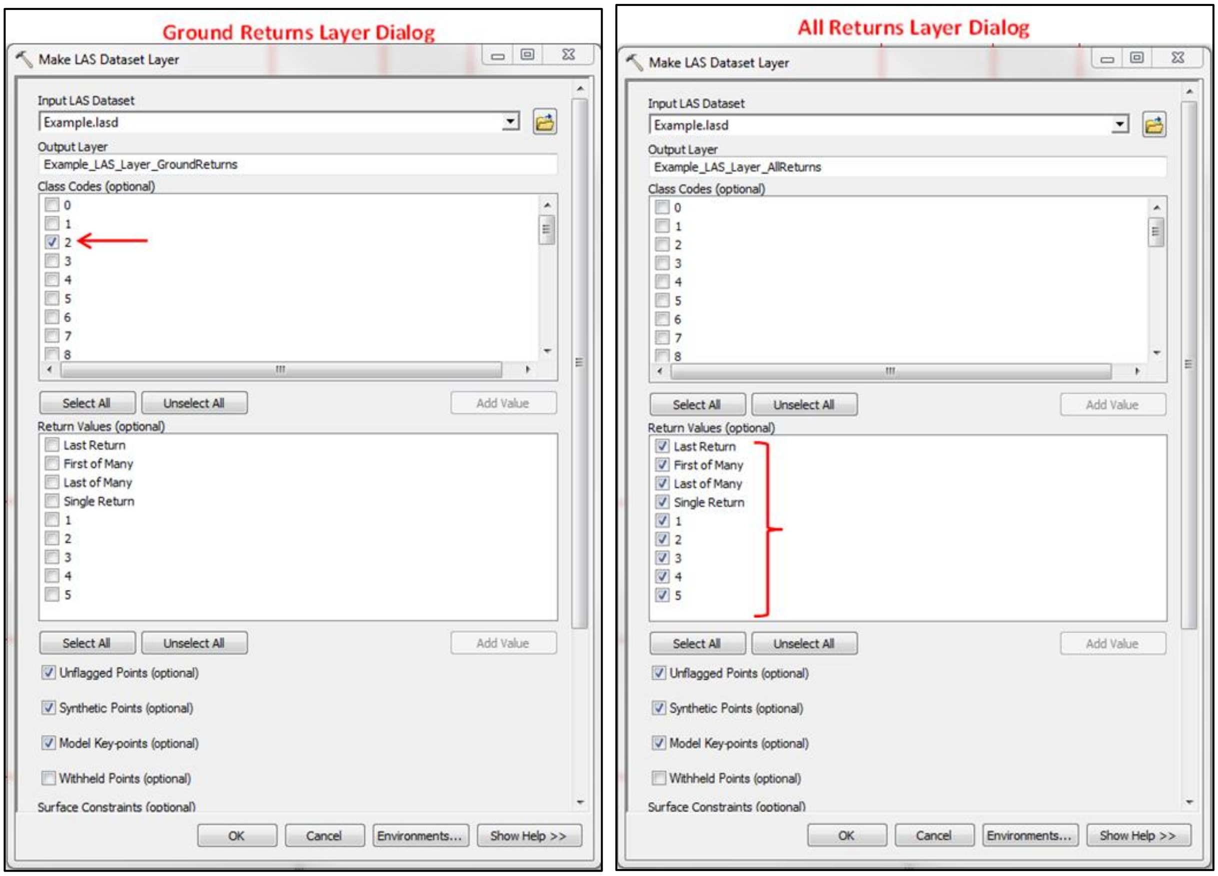
d) Return Values =

   i. Ground returns: ***do not select any return values***.

   ii. All returns: select **ALL** values within this area.

e) Leave the remainder of the tool as default values.

f) Click **OK** to run tool.



Next, search for the **LAS Dataset to Raster** tool within the Conversion toolbox. This will take the temporary layers created for the ground returns and all returns, and create a permanent raster dataset. The outputs of this tool will result in **Digital Elevation Models**.

Note: *It will be necessary to run this tool twice; once for each temporary layer created in the previous step.*

a) Input = Select one of the temporary layers.

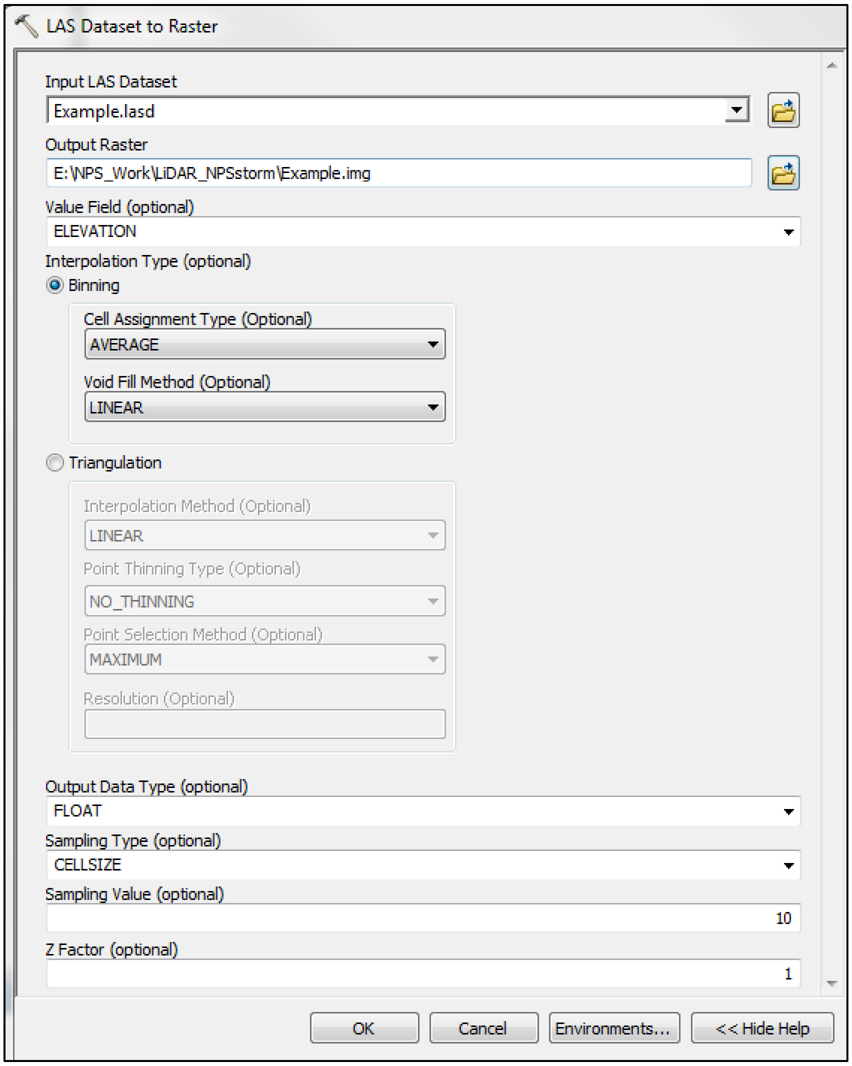
b) Output = Output location and file name with file extension specified.

   i. We recommend **.img** as a good file extension. Please note that if no file extension is specified, or if a different file extension is specified, the user may experience an ArcGIS error.

c) Sampling Value = desired cell size, the default is 10 (this will be 10 meters, or feet depending on the coordinate system of your data).

d) Leave the remainder of the tool as default values.

e) Click **OK** to run tool.



Finally search for the **Hillshade** tool within the 3D Analyst toolbox. Use the following inputs:

Note: *It will be necessary to run this tool twice; once for each DEM.*

a) Input = Select one of the newly created DEM rasters with the .img extension.

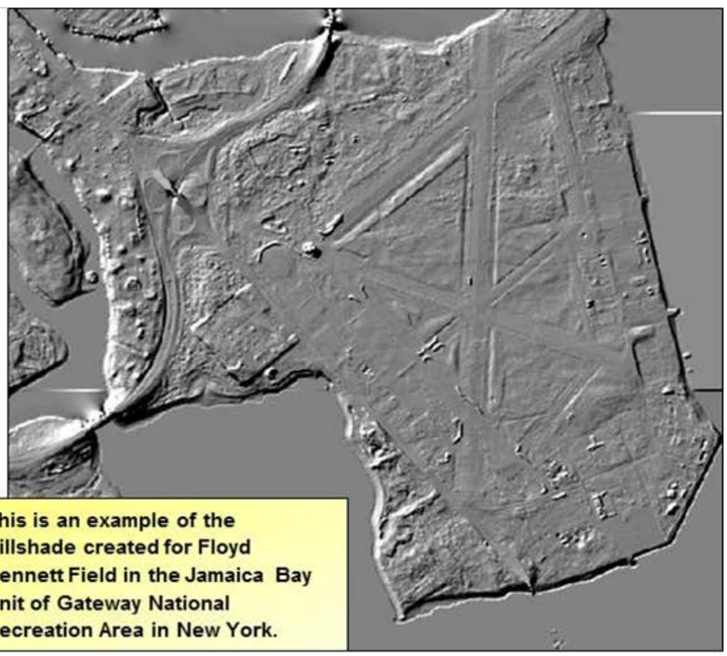
b) Output = Output location and file name with file extension specified.

   i. Again, please use **.img**.

c) Leave the remainder of the tool as default values.

d) Click **OK** to run tool.

This is an example of the Digital Elevation Model created for Floyd Bennett Field in the Jamaica Bay Unit of Gateway National Recreation Area in New York.



This is an example of the Hillshade created for Floyd Bennett Field in the Jamaica Bay Unit of Gateway National Recreation Area in New York.

Mosaic Datasets and LiDAR Data: Quick Processing and Versatile Results – Part 1: Digital Elevation Models and Shaded Reliefs

Audience: This is an advanced workflow and assumes a working knowledge of the ArcGIS Platform and understanding of the management and creation of geospatial data types.

System Requirements: The following workflow was developed using a Windows 7 Professional operating system, and Esri ArcMap version 10.2.2. For best results, use these system specifications.

Data Requirements: LAS files for area of interest.

Products Produced: Bare Earth Digital Elevation Model and Shaded Relief.

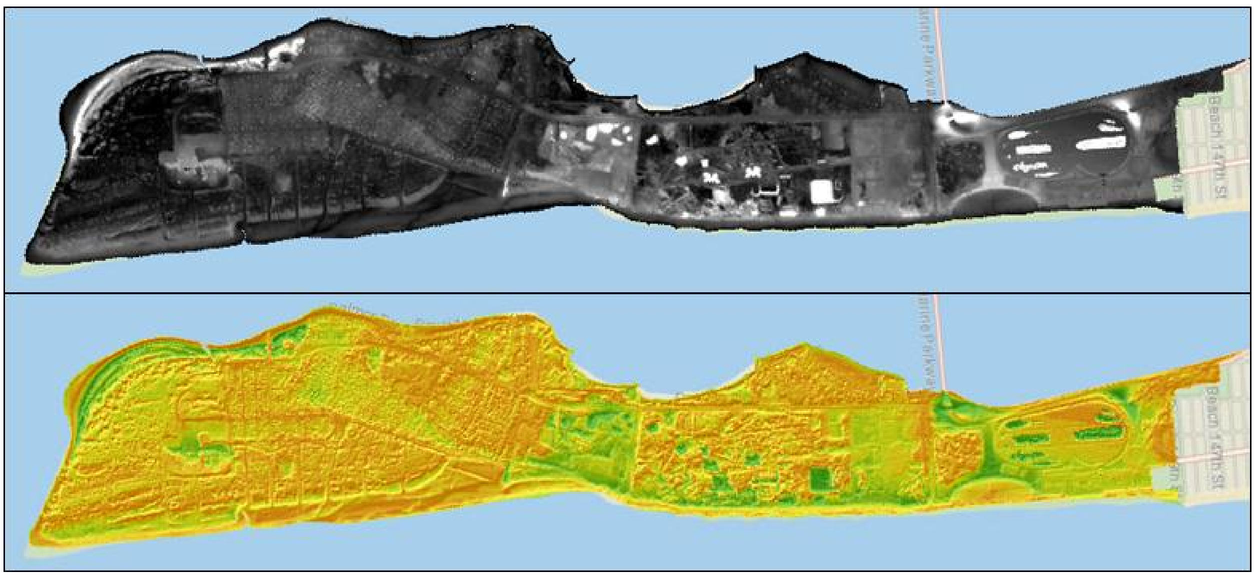
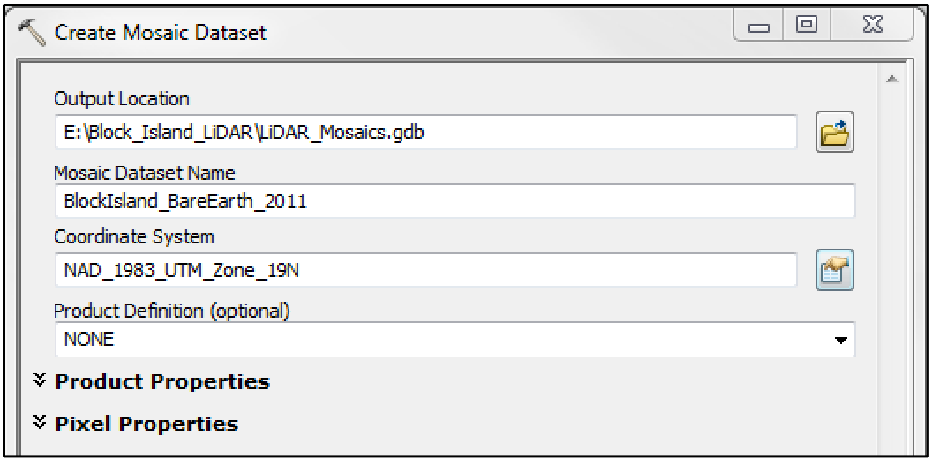


Figure 3. Digital Elevation Model (top) and Shaded Relief (bottom) for the Rockaway Peninsula in Jamaica Bay, Gateway National Recreation Area.

First, create new mosaic dataset within a file geodatabase. To do this, right click on the file geodatabase in ArcCatalog, select New and click **Mosaic Dataset** in the context menu. This will open the **Create Mosaic Dataset** tool where details about the input LAS fileswill be specified.

The first step is to name the mosaic dataset; the best practice to use here will be the National Park Service Layer Naming Conventions. While bulky at times, this naming convention will be the most transparent to future users, who may be unfamiliar with the data or the area. To fill out the rest of the tool, see the steps below:

a) Coordinate System = NAD 1983 UTM Zone 18N (for ASIS, FIIS, & GATE)
    i. This is the horizontal coordinate system.
b) Click OK to finish creating the mosaic dataset.



To determine the units in which the elevations will be represented, it is necessary to know the units of the vertical coordinate system. To determine this, use one of the following methods:

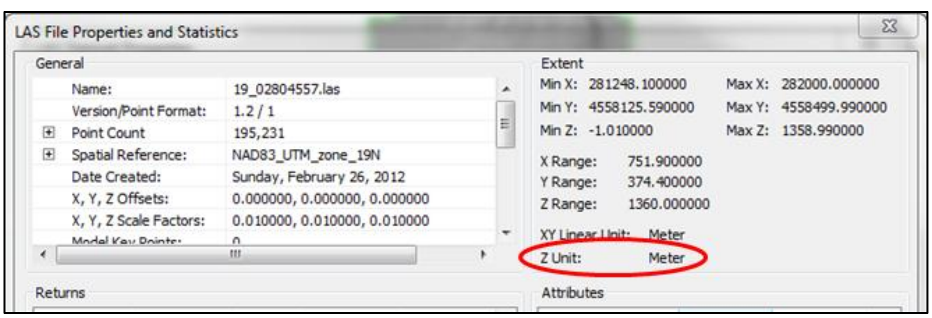
a) Check the metadata associated with the LiDAR data. If this is unavailable, continue on to the next option.

b) Create a temporary LAS Dataset and view the properties:

   i. Within a folder, create a new LAS Dataset. Do this by right clicking the folder in ArcCatalog and selecting New > **LAS Dataset**.

   ii. Double click on the new LAS Dataset in the Catalog window. Under the **LAS Files tab**, choose to **Add Files** by clicking the button near the bottom of the dialog box. Navigate to and select a single LAS file (.las) and click OK.

   iii. Once this appears in the LAS Files tab, click the  button. This opens the **LAS File Properties and Statistics** dialog which provides statistical information, in addition to information on the Z (elevation) units. Here, you can see that the vertical Z units are in meters (see below).



Note: *If you discover that the vertical coordinate system (Z units) is not the same as the horizontal coordinate system units, it is okay. We will address how to account for this later in the procedure.*

Next we will determine the average point spacing of the LAS files. It is important to do this, as you will need this information in the next step to determine the appropriate pixel size for the mosaic dataset. To do this, search for and open then **Point File Information** tool. Use the following specifications to fill out the tool:

a) Select all LAS files as inputs.

b) Select the output name and location for the new dataset.

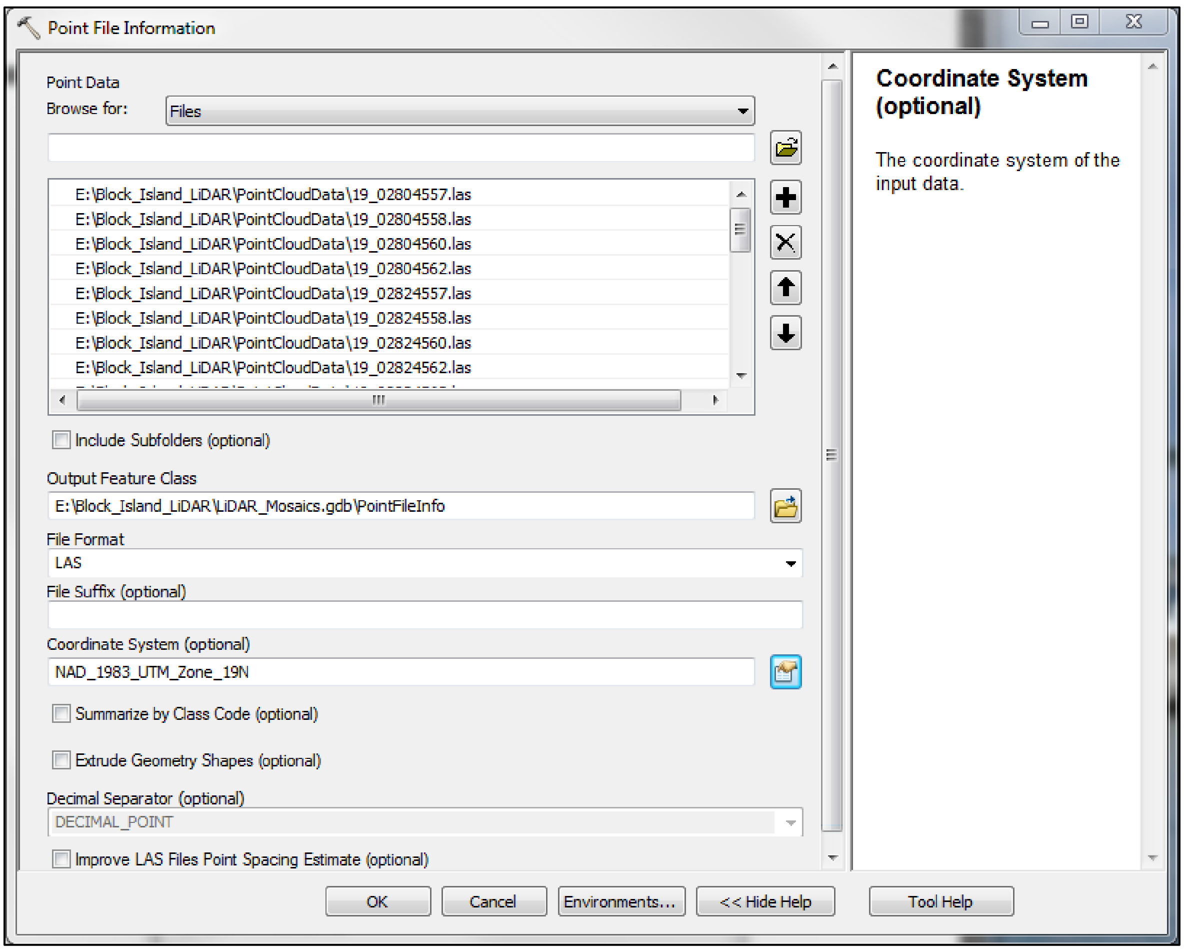
c) File Format = LAS

d) File Suffix = .las

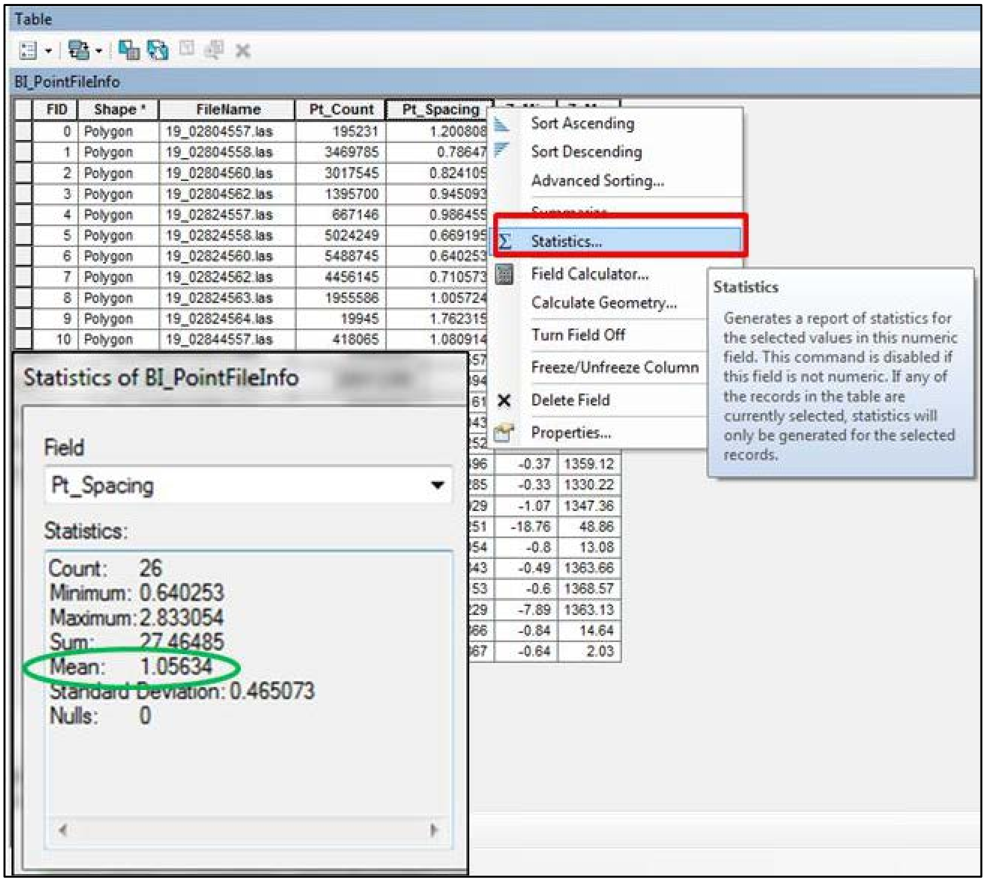
e) Select the coordinate system of the input data.

f) Check "Summarize by Class Codes" – this is optional. It will add an additional field to the output attributes table specifying return code. This will allow the user to determine the average point spacing for each different return code.

g) Click **OK** to run tool.

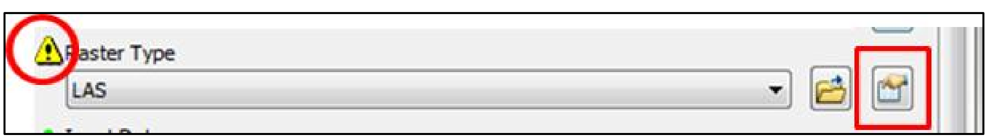


This will create a polygon shapefile. To determine the average point spacing, open the attribute table. Sort the **Class** field and select all records with the proper return code (2 = ground returns {based on ASPRS class code definitions}, and all records for "all" returns). Find the field labeled **Pt_Spacing**, right click on the heading and select **Statistics**. This will open a Statistics pop-up that will provide the **Mean** (or average) point spacing. ***Note this value***!



To add rasters to the mosaic dataset, right click on the mosaic dataset in the ArcCatalog window, and choose **Add Rasters** from the context menu. Use the following specifications to fill out the tool:

a) Select the Raster Type to be **LAS**.
   i. A warning icon will appear next to the Raster Type subsection; click the **Edit Raster Type Properties** button next to the raster type section box (see below).



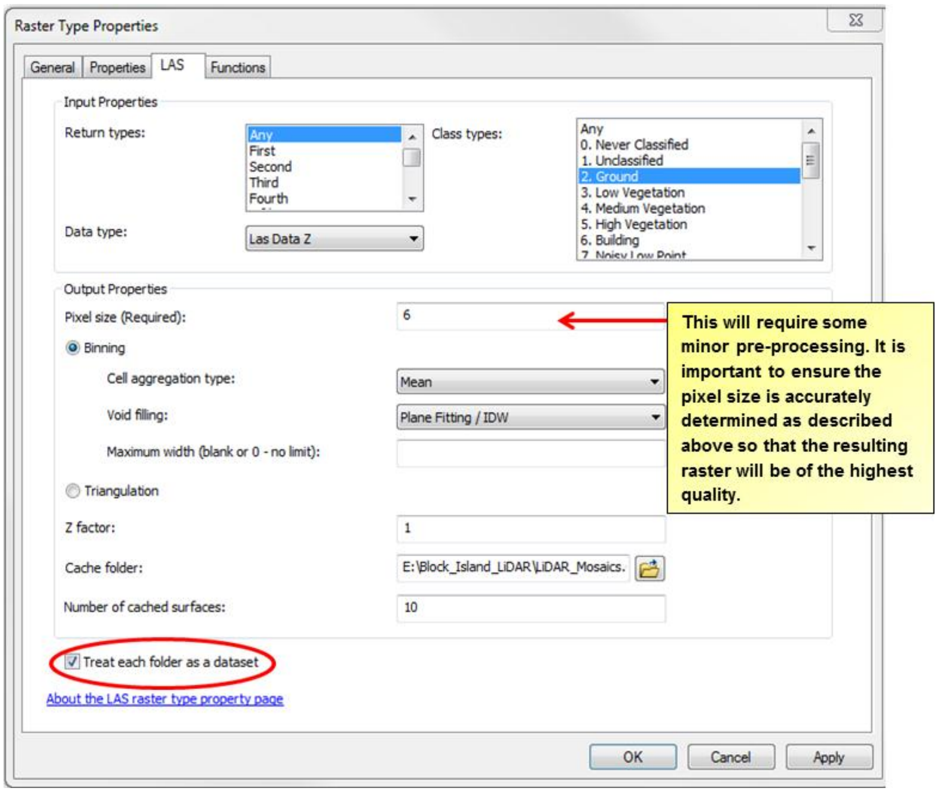
i. Click the LAS tab within the Raster Type Properties dialog box.
ii. Return Type = Any
iii. Class Type = 2. Ground
iv. Pixel Size = Calculated by multiplying the **average point spacing** by 3 or 4.
   1. This ensures that all gaps and voids and filled in the dataset.
   2. Enter the calculated pixel size into the appropriate field in the Raster Type Properties dialog box.
v. Void Filling = Plane Fitting/IDW

vi. To change from vertical units of meters to feet, the Z factor can be changed; refer to the table before for conversion factors.

From	To		
	Feet	Meters	Degrees
Feet	1	0.3048	0.000003
Meters	3.28084	1	0.00001

i. Check **Treat each folder as a dataset** box near the bottom of the dialog box.

ii. Click **OK** to return to the Add Rasters dialog box.



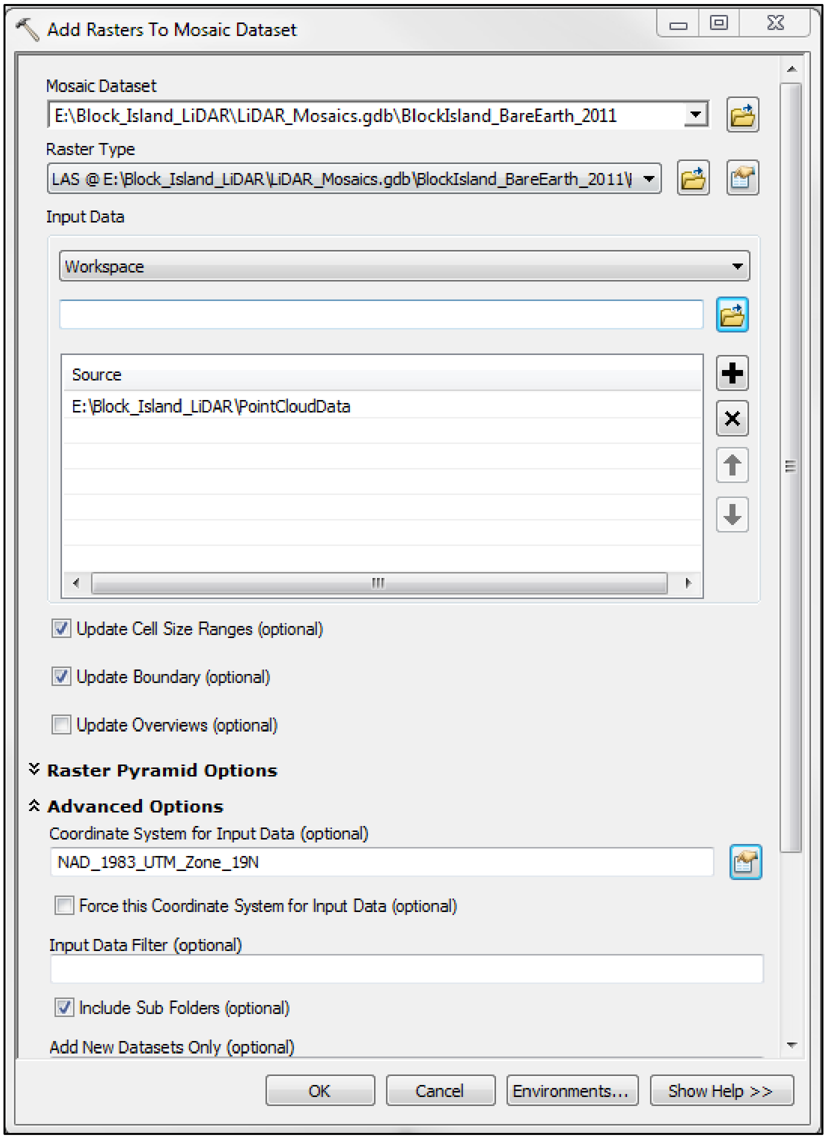
Next, finish filling out the **Add Rasters** dialog box:

a) Select **Workspace** in the Input Data dropdown menu and browse to, and select the folder containing the LAS files.

b) Under the **Advanced Options** section, select the same coordinate system as used in the **Create Mosaic Dataset** tool.

c) Leave the reminder of the tool as default values.

d) Click **OK** to finish adding LAS files (see below for the *completed* Add Rasters dialog).



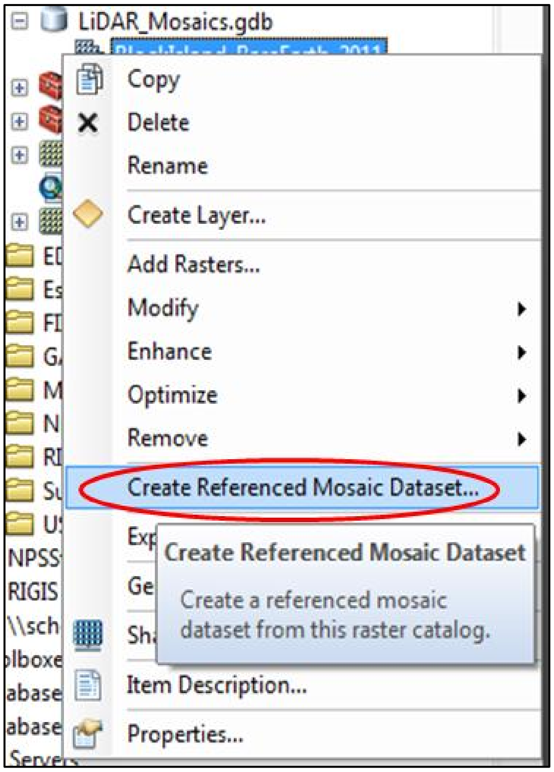
Next, right click on the mosaic dataset and choose **Optimize > Build Overviews**. Leave all values as default and click **OK** to run.

Note: Overviews are not built in the Add Raster dialog because this increases processing time, and doesn't result in proper display of the data. Running this step separately ensures the overviews will be built correctly and that the mosaicked image will appear to the highest quality.

You have just successfully created a Digital Elevation Model (DEM) mosaic dataset from LiDAR data. *If your data does not display to a high quality, it may be necessary to change the Stretch Type within the Properties dialog. This is dataset dependent and will sometimes be necessary.*

Now, we will work on creating a **Shaded Relief** mosaic dataset. This process will be much shorter as we will be creating a **referenced mosaic dataset**. This type of mosaic dataset will directly reference the Digital Elevation Model mosaic dataset that we just created, and will also use all of the specifications used to create it.

To begin, in the ArcCatalog window, right click the DEM mosaic dataset you have just created and select **Create Referenced Mosaic Dataset** from the context menu.



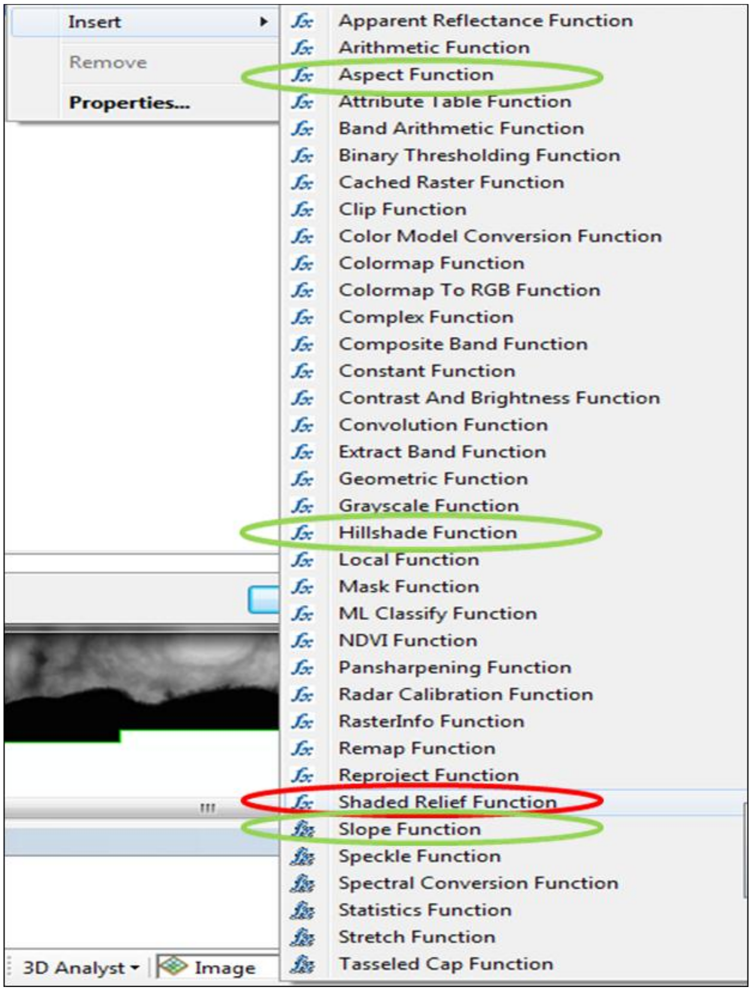
This opens the **Create Referenced Mosaic Dataset** tool. Change the name of the output mosaic dataset to specify that this will be a shaded relief. Click **OK**.

Next, in ArcCatalog, right click on the Shaded Relief mosaic dataset and open the **Properties** dialog box. Once open, click the **Functions** tab.

a) Right click Mosaic Function > Insert and select the Shaded Relief Function (circled in red below).

b) Accept all defaults and click **OK**.

c) Note: If you are interested in exaggerating the Z factor – you can do this here.

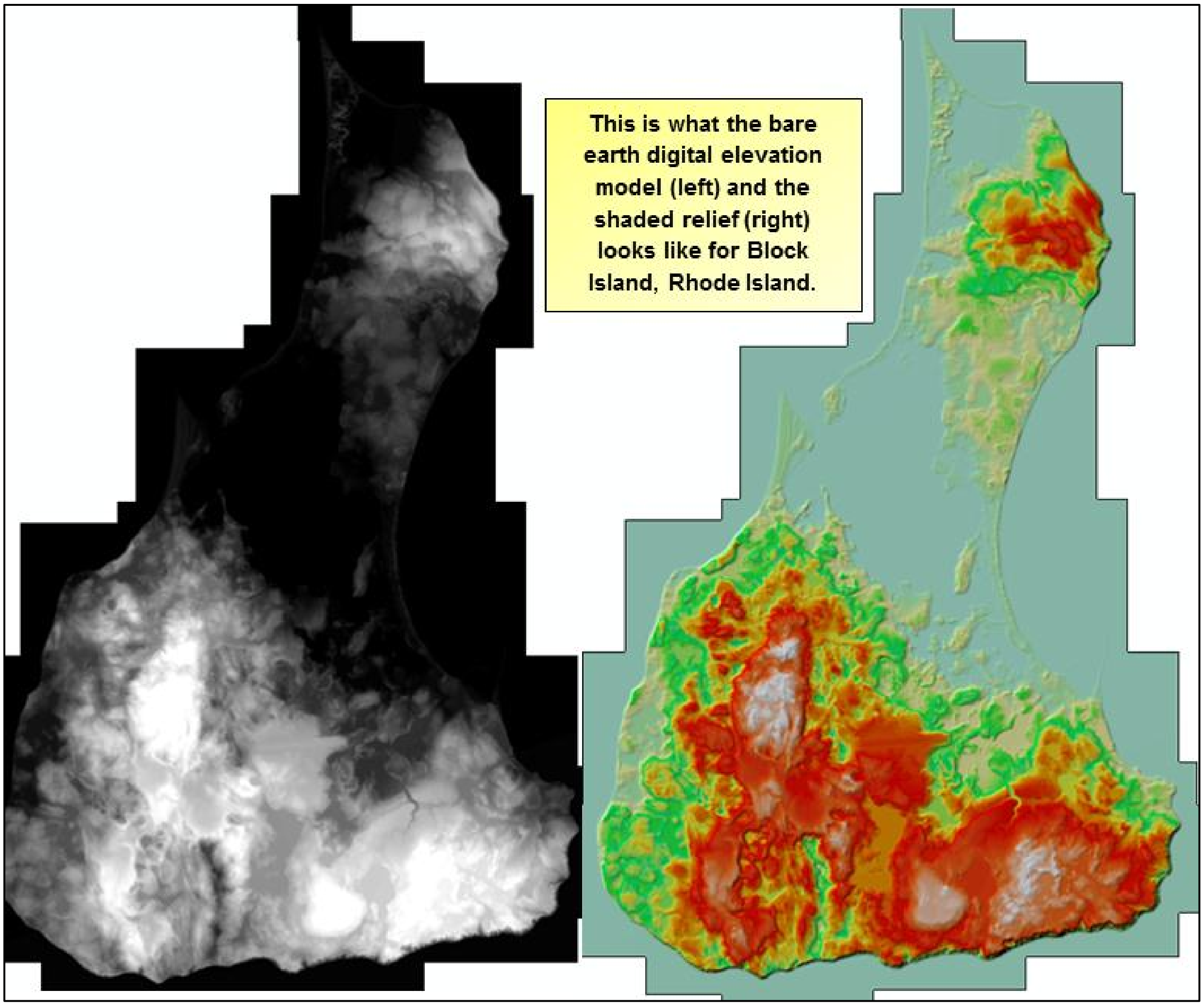


It is important to note that many other functions such as Slope, Aspect and Hillshade (circled in green above) can be added to separate mosaic datasets, or can be substituted in for the Shaded Relief Function.

There are also some important caveats to note when working with referenced mosaic datasets. They will *prohibit* the user from building overviews, adding new rasters and calculating pixel size ranges. While this may not be ideal in some situations, the use of referenced mosaic datasets can also help to significantly reduce the amount of time needed to work with data. Another important caveat is that if the original mosaic dataset that the referenced mosaic dataset refers to is **moved or deleted**, the referenced mosaic dataset will become **invalid**.

While creating a referenced mosaic dataset is useful in some cases, they may not be ideal in all situations. If a user does not want to create a referenced mosaic dataset, simply follow the first procedure and create a new mosaic dataset, then apply the Shaded Relief Function as described in the steps above.

Below, find some examples of the final products created from this procedure for Block Island, Rhode Island, an iconic landmark of distinct shape off the Rhode Island Coast.


This is what the bare earth digital elevation model (left) and the shaded relief (right) looks like for Block Island, Rhode Island.

Mosaic Datasets and LiDAR Data: Quick Processing and Versatile Results – Part 2: Viewing and Analyzing Surface Features

Audience: This is an advanced workflow and assumes a working knowledge of the ArcGIS Platform and understanding of the management and creation of geospatial data types.

System Requirements: The following workflow was developed using a Windows 7 Professional operating system, and Esri ArcMap version 10.2.2. For best results, use these system specifications.

Data Requirements: Bare Earth Digital Elevation Model created in Part 1 of Mosaic Datasets and LiDAR Data: Quick Processing and Versatile Results (the previous section).

Products Produced: Surface with Features raster and Surface Height raster.

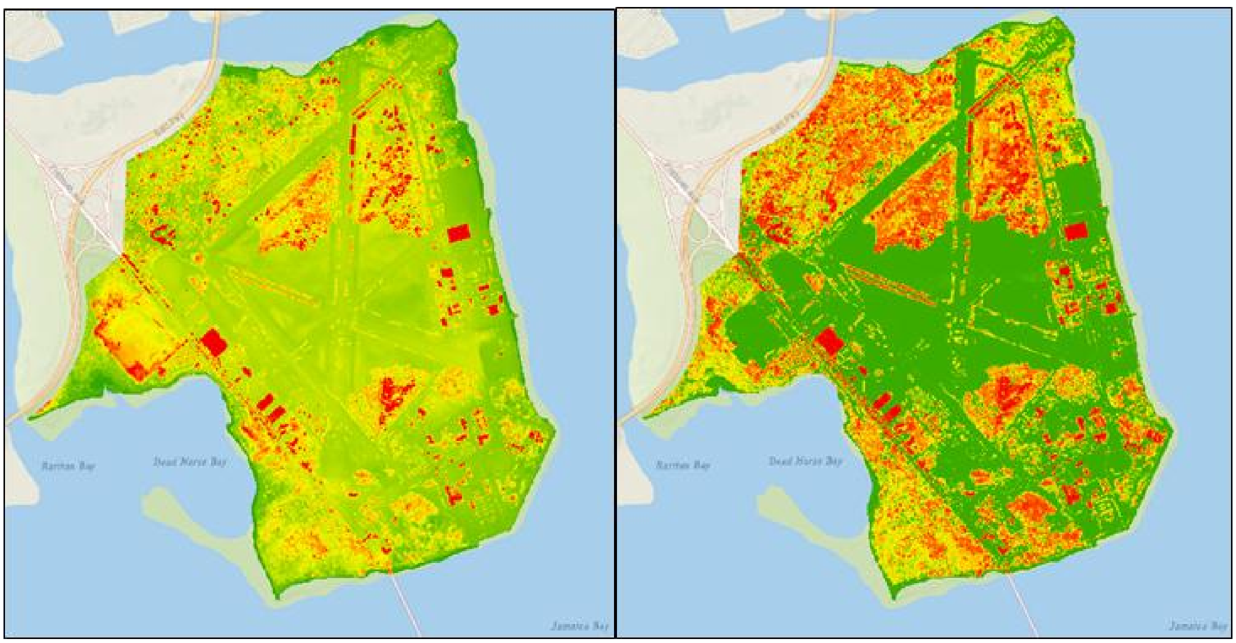


Figure 3. Surface Features (left) and Surface Height Differences (right) at Floyd Bennett Field in Jamaica Bay, Gateway National Recreation Area.

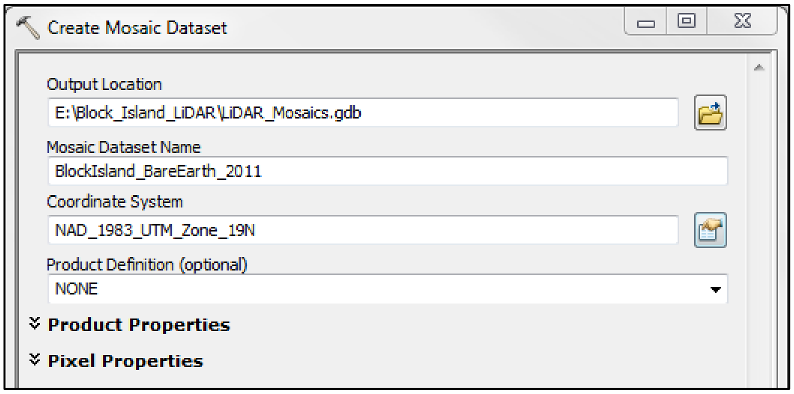
First, create new mosaic dataset within a file geodatabase. To do this, right click on the file geodatabase in ArcCatalog, select New and click **Mosaic Dataset** in the context menu. This will open the **Create Mosaic Dataset** tool where details about the input imagery will be specified.

The first step is to name the mosaic dataset (ie. TOPO_SurfacewithFeatures_USACE2012_ra); the best practice to use here will be the National Park Service Layer Naming Conventions. While bulky at times, this naming convention will be the most transparent to future users, who may be unfamiliar with the data or the area. To fill out the rest of the tool, see the steps below:

a) Coordinate System = NAD 1983 UTM Zone 18N (for ASIS, FIIS, & GATE)

i. This is the horizontal coordinate system.

b) Click OK to finish creating the mosaic dataset.



To determine the units in which the elevations will be represented, it is necessary to know the units of the vertical coordinate system. To determine this, use one of the following methods:

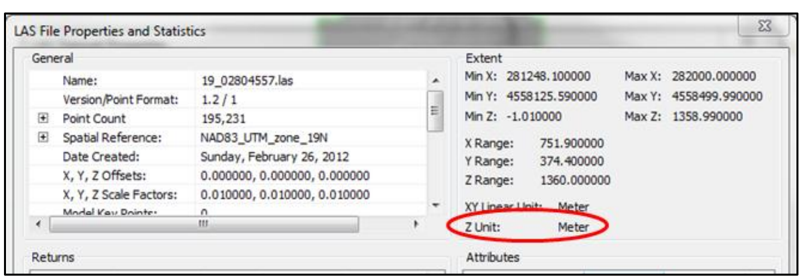
a) Check the metadata associated with the LiDAR data. If this is unavailable, continue on to the next option.

b) Create a temporary LAS Dataset and view the properties:

i. Within a folder, create a new LAS Dataset. Do this by right clicking the folder in ArcCatalog and selecting New > **LAS Dataset**.

ii. Double click on the new LAS Dataset in the Catalog window. Under the **LAS Files tab**, choose to **Add Files** by clicking the button near the bottom of the dialog box. Navigate to and select a single LAS file (.las) and click OK.

iii. Once this appears in the LAS Files tab, click the  button. This opens the **LAS File Properties and Statistics** dialog which provides statistical information, in addition to information on the Z (elevation) units. Here, you can see that the vertical Z units are in meters (see below).



Note: *If you discover that the vertical coordinate system (Z units) is not the same as the horizontal coordinate system units, it is okay. We will address how to account for this later in the procedure. Alternatively, you can specify the coordinate system of your mosaic dataset (which is the horizontal coordinate system) to be in the same units as the vertical coordinate system.*

To add rasters to the mosaic dataset, right click on the mosaic dataset in the ArcCatalog window, and choose **Add Rasters** from the context menu. Use the following specifications to fill out the tool:

a) Raster Type = Table

b) Input Data = Bare Earth DEM mosaic created in the previous tutorial.

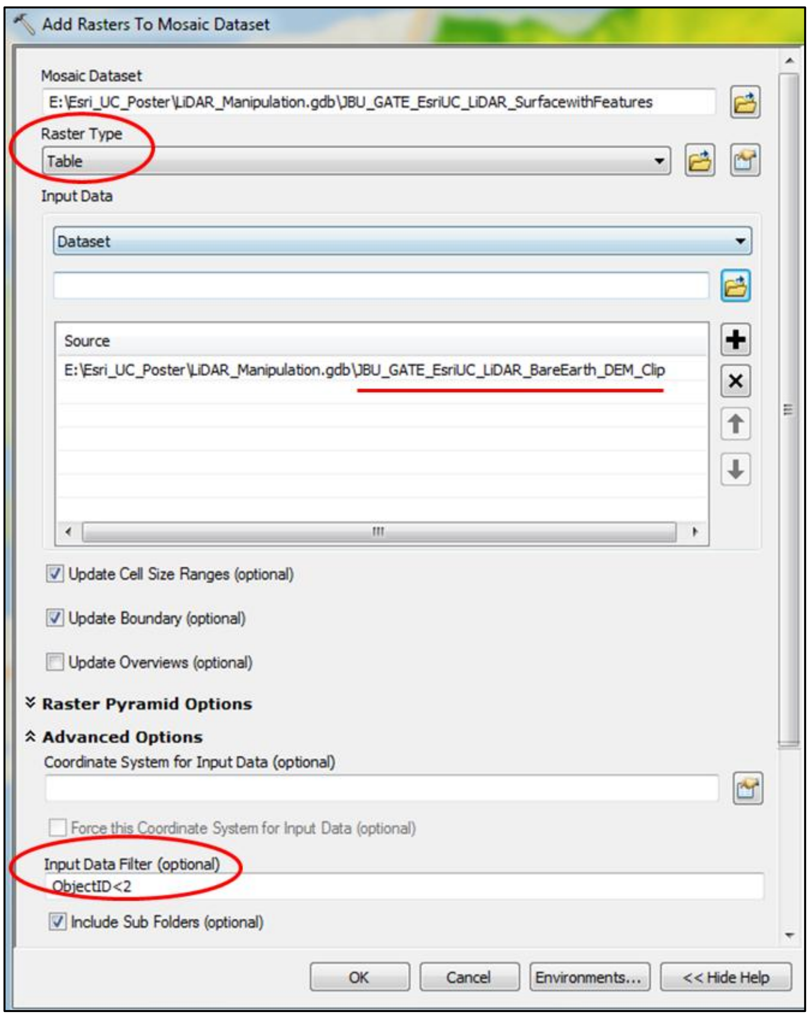
c) Advanced Options:

   i. Input Data Filter = ObjectID<2.

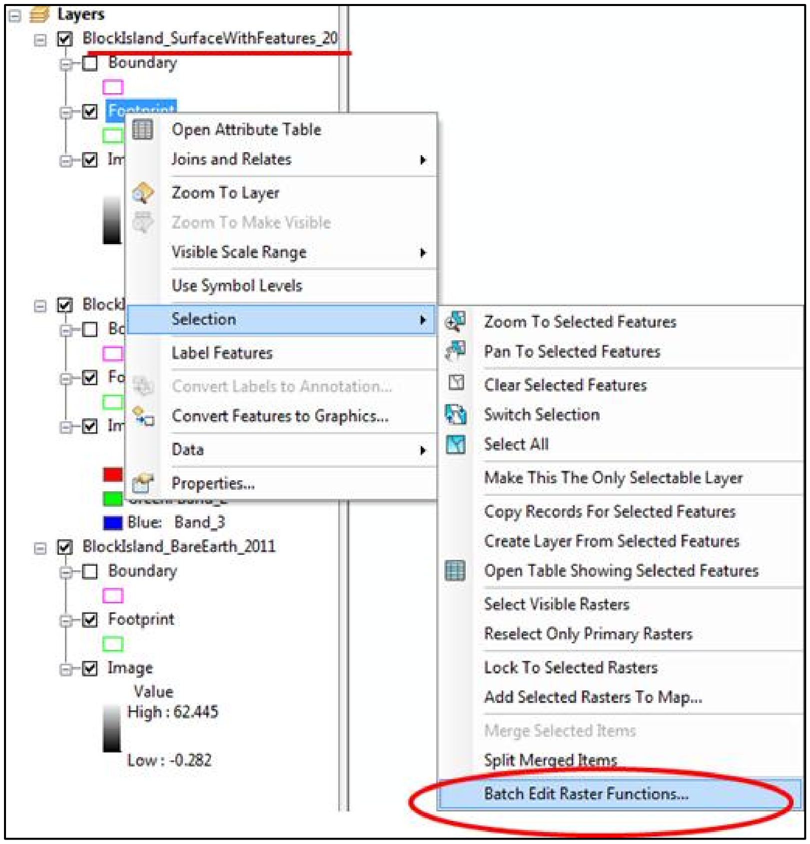
      1. This will select the mosaic dataset and exclude the overviews of the Bare Earth DEM dataset. This will work as long as your overviews are the second row of your attribute table.

d) Leave the remainder of the tool as defaults values.

e) Click **OK** to run tool.



Select the Footprint feature by opening the **Attribute Table** of the Footprint layer of the Surface with Features mosaic layer tree in the **Table of Contents**. Select the first row in the Attribute Table for the Point Cloud Data, and then close the window.



Now, right click the Surface with Features Footprint layer in the Table of Contents and click Selection > **Batch Edit Raster Functions** in the context menu. Follow the steps below:

a) Select **Edit Raster Function** and click next.

b) Click Search next to the Find location by: **Function Name**, and select the **LASToRaster** function and click next.

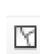
c) Click **LAS To Raster** in the **Edit raster function properties** list and select the following options:

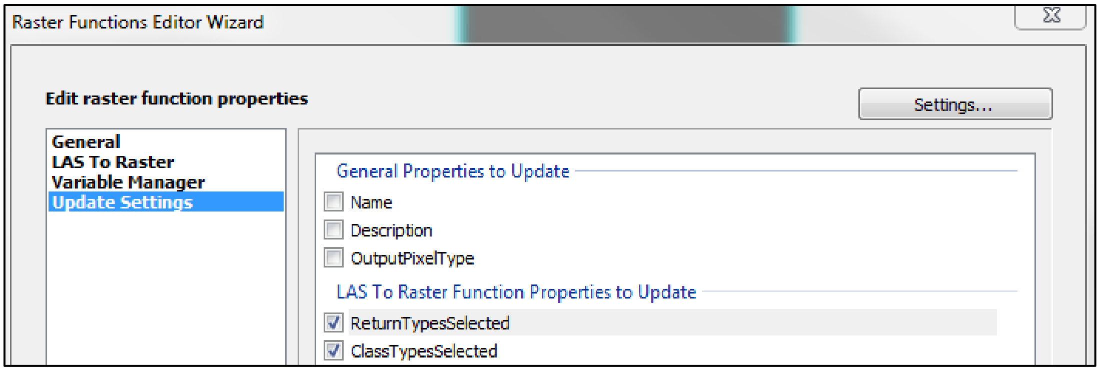
  i. Return Types = Any

  ii. Class Types = Any

d) Now, click on **Update Settings** in the **Edit raster function properties** list and check boxes for **ReturnTypesSelected** and **ClassTypesSelected**.

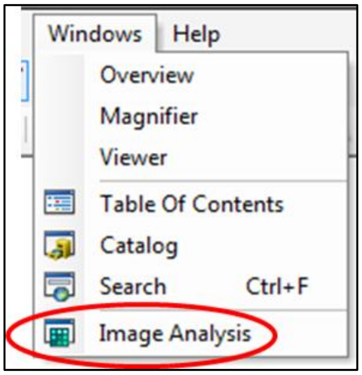
e) Click Next, then **Finish**.

f) Clear the selected features with the  button from your toolbar.



Next, right click on the Surface with Features mosaic dataset in ArcCatalog and choose **Optimize > Build Overviews**. You may need to refresh the view first to see the Optimize function. Leave all values as default and click **OK** to run the tool.

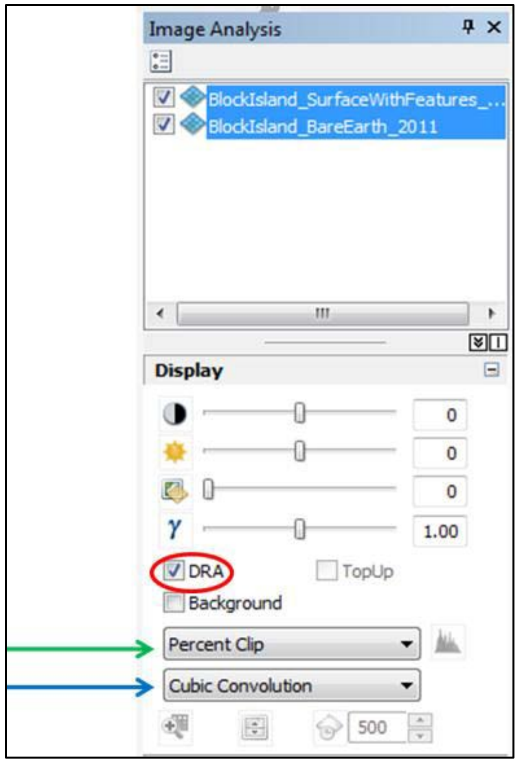
Now we will examine how to enhance the appearance of the mosaicked image using the **Image Analysis Window**. To open this window, go to the **Windows** dropdown at the top of ArcMap and select **Image Analysis** from the context menu.



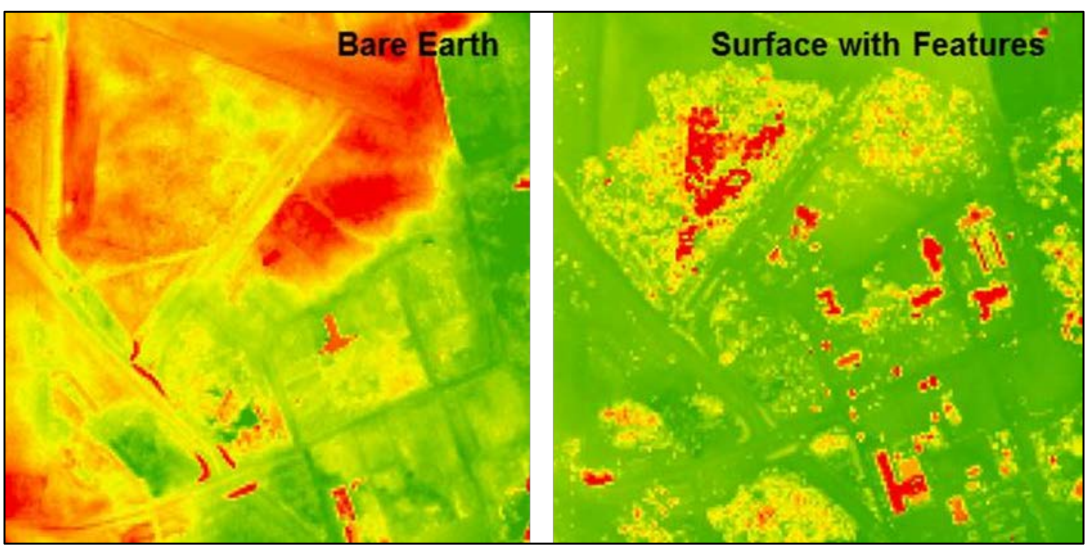
It is important to note that the changes made in the **Display section** of the Image Analysis Window are **NOT** permanent, but we will discuss this in more detail shortly. While many changes can be made to the image through the use of the Image Analysis Window, only changes made in the **Processing section** can be saved and exported. This can be done by right clicking on the raster generated by the Image Analysis Window in the Table of Contents and clicking Data > **Export Data**. Once exported, the file will be saved in raster format.

First, bring the **Surface with Features layer** and the **Bare Earth DEM** into the Table of Contents, with the Surface with Features layer on top. Next, zoom in on an area of interest (AOI).

a) Check boxes next to, and then select both the Bare Earth DEM and the Surface with Features layer in the Image Analysis layers then check **DRA** (see image below for more details.
b) Change the Interactive Stretch method to Percent Clip (green arrow below).
c) Change the Resample method to **Cubic Convolution** (blue arrow below)



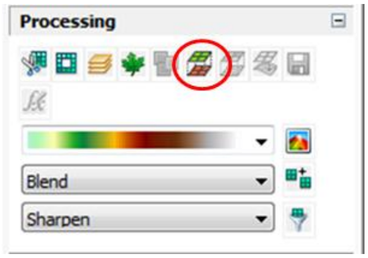
Now, toggle the Surface with Features layer on and off to see the surface with and without features (such as buildings). As you can see below, you should be able to see a distinct difference between the two layers.



Now we will begin to create a **Surface Height layer**. To do this, we will essentially subtract two rasters from one another.

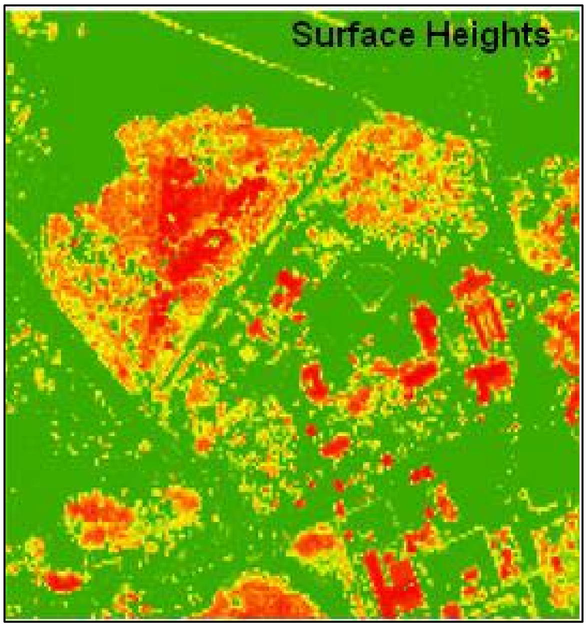
First, double check to make sure the Bare Earth DEM layer is still below the Surface with Features layer (it should be already since we did this in the previous step). Next, open the Image Analysis window.

a) Select both of the layers mentioned above in the Image Analysis layer panel at the top of the window.



b) Under the Processing section, click the **Difference Button** (circled in red above).
c) Change the symbology on the newly created layer to an easy to visualize color scheme of your preference.
d) Remember, to save this raster it is necessary to **<u>export</u>** it from the Table of Contents.
    i. To do this, right click the "Diff_Image" and select **Data > Export Data**.

Below is a sample of the Surface Heights layer (also called the "Diff_Image"). This essentially subtracts the *Bare Earth DEM* layer from the *Surface with Features* layer and shows the heights of features in the area of interest. The area shown below is the difference between the two images on the previous page for the Bare Earth DEM and the Surface with Features. Areas shown in red and orange indicate features with greater height differences.



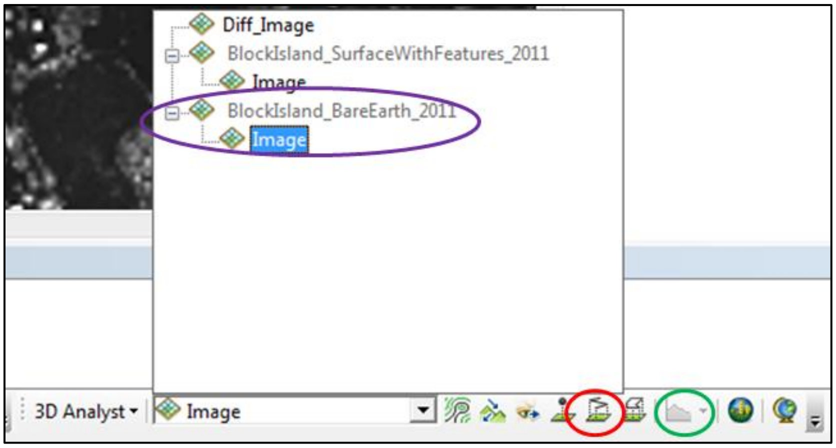
Lastly, we will determine how to examine and compare profile graphs of elevation data.

First, zoom in to an area of interest. Next, in the Image Analysis window, select the "Diff_Image" and check **DRA**.

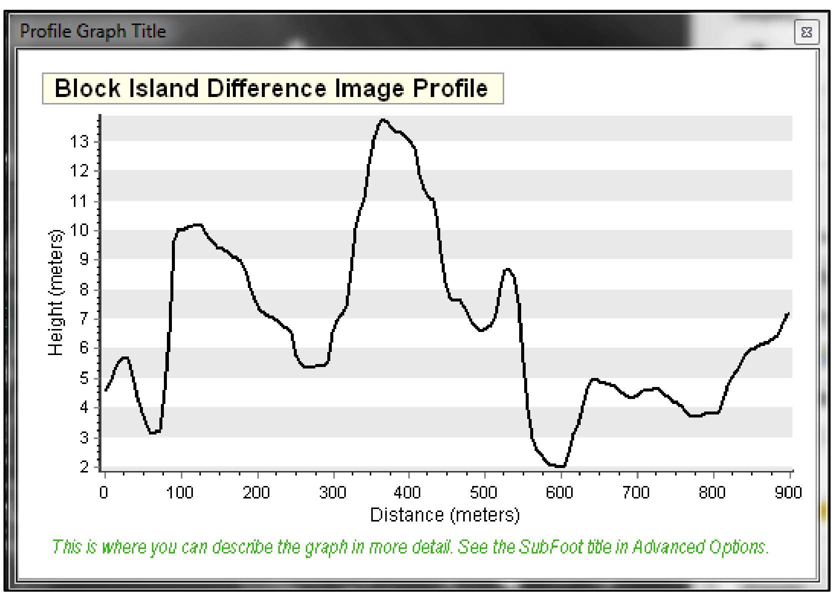
a) Open the **3D Analyst** toolbar and select the Bare Earth DEM image in the dropdown window (purple circle).

b) Click the **Interpolate Line** button (red circle) on the 3D Analyst toolbar and draw a line across the AOI.

c) Click the **Profile Graph** (green circle) button to view the graph of the profile.



To compare this profile graph, to the profile graphs of other layers for the same AOI, select a different image in the 3D Analyst dropdown window and follow the same procedure. This graph provides you with elevation data for the chosen transect.



All graphs can be edited by right clicking a graph and selecting **Advanced Options**. This is where the user can control the appearance of the graph, the text of the graph (title, subtitle, footer, axis labels, etc.), font options, 3D graph view, and many other options.

Developing Topobathy Digital Elevation Models (DEMs) in LAS Datasets

Audience: This is an advanced workflow and assumes a working knowledge of the ArcGIS Platform and understanding of the management and creation of geospatial data types.

System Requirements: The following workflow was developed using a Windows 7 Professional operating system, and Esri ArcMap version 10.3.1. For best results, use these system specifications.

Data Requirements: 2014 NOAA NGS Post Hurricane Sandy Topobathymetric LiDAR - LAS files for area of interest (or other topobathymetric LiDAR).

Products Produced: LAS Dataset, Topobathy Digital Elevation Model.

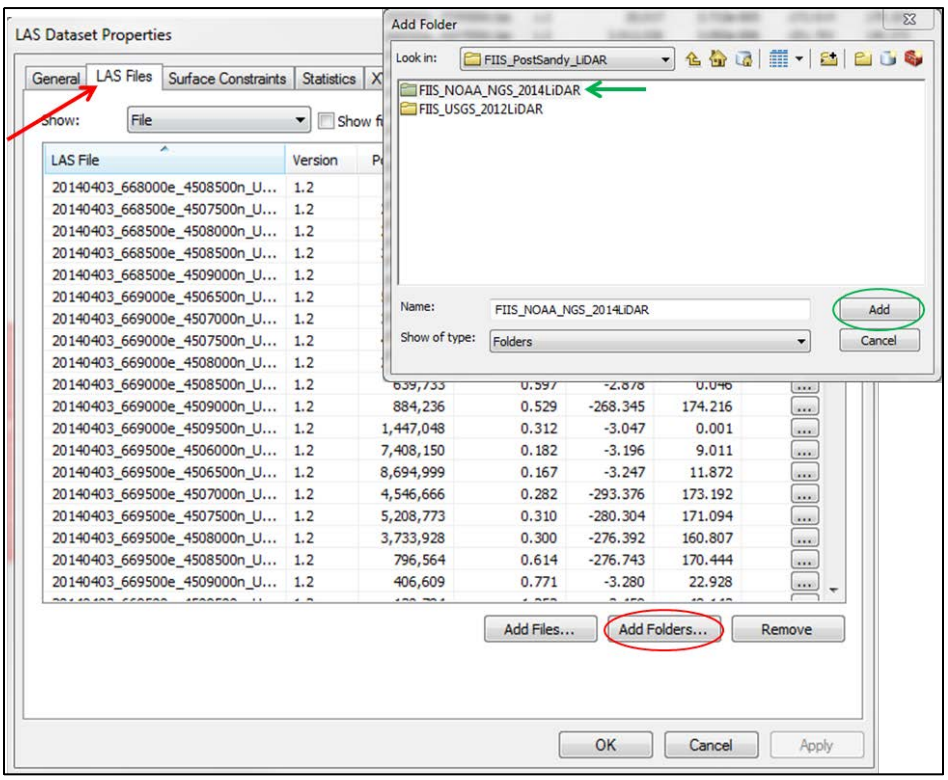
Figure 5. Topobathy Digital Elevation Model of Jamaica Bay in Gateway National Recreation Area. Here both ground returns (bare earth) and bathymetric bottom and submerged topography returns are displayed. This was created using the procedures detailed in this document.

First, designate a workspace in which the following steps will be carried out. Right click on this designated file folder in your ArcCatalog window within ArcMap. Select **New** and click **LAS Dataset** in the context menu. The first step is to name the LAS dataset; the best practice to use here will be the National Park Service Layer Naming Conventions. While it may seem cumbersome at times, this naming convention will be the most transparent to future users, who may be unfamiliar with the data or the area (i.e. for the Fire Island NS topobathy DEM – TOPO_TopobathyDEM_NGS_2014LiDAR_ra).

Now, double click on the newly created LAS Dataset (LASD) in the Catalog window; this will open the **LAS Dataset Properties** dialog box. To add your LAS files for your area of interest (AOI), see the steps below:

a) Select the **LAS Files** tab.
b) Click the **Add Folders** button (see red circle below) and navigate to the folder containing the LAS files, and select the folder.
c) Click **OK** to add LAS files to the LAS Dataset.
d) Once these have been added, click **Apply**.

Note: When adding a folder, select only the folder containing the LAS data (see green arrow below) and click **Add** (see green circle below).



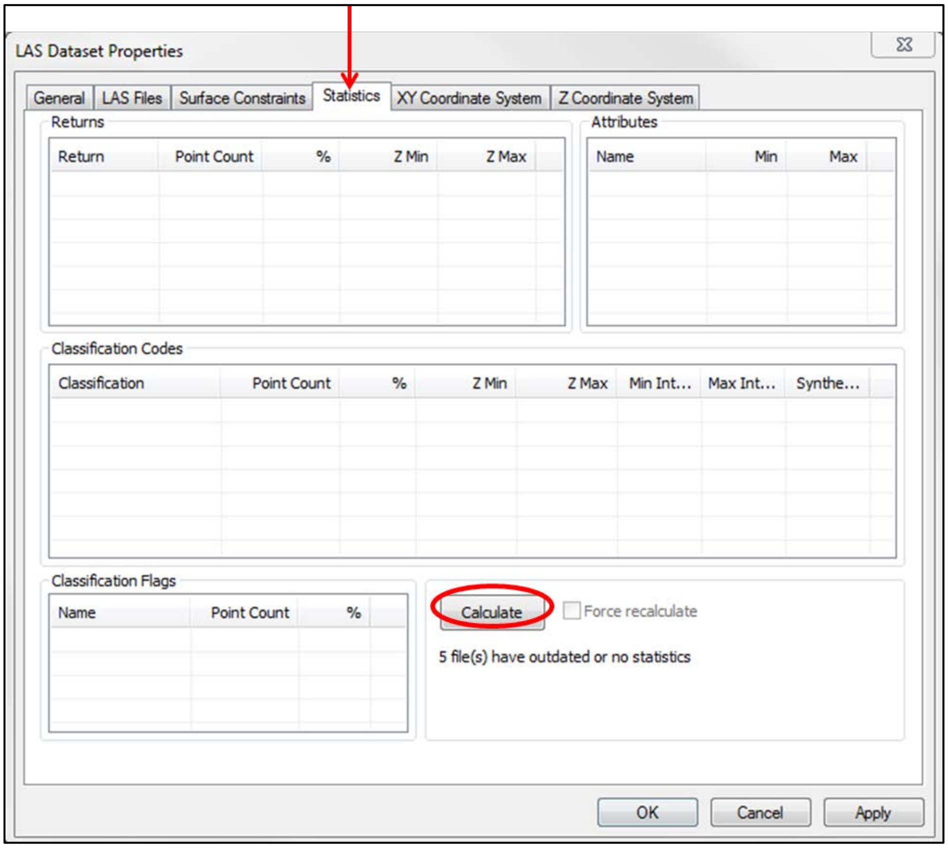
Next, navigate to the **XY Coordinate System** tab to check the projection information of your data. For the NOAA NGS 2014 Topobathy LiDAR, this is *NAD 1983*.

Now, we need to calculate statistics for the LAS files.

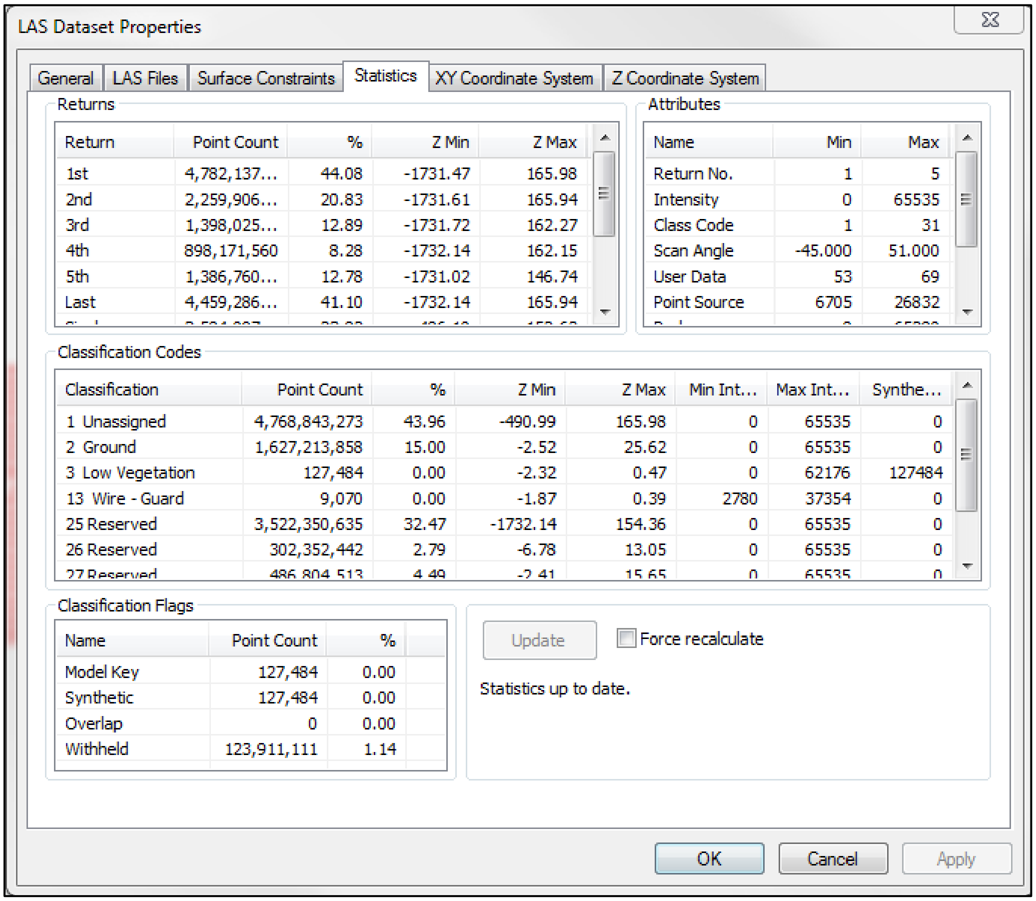
This will provide information on point counts per classification and return, minimum and maximum elevation values for each classification and return, as well as many other useful statistics. *It is necessary to do this, so that the vendor-specified classification codes are properly associated with the data.*

Navigate to the **Statistics tab**. In the bottom right corner, click **Calculate**. Depending on the number of input LAS files, this can take some time.

This calculates statistics for each input LAS file. Within the directory containing the LAS files, a new LASX (.lasx) file will be created for each input LAS file; these files house the statistics information.



Once statistics have been calculated, the **Statistics tab** will look like this:



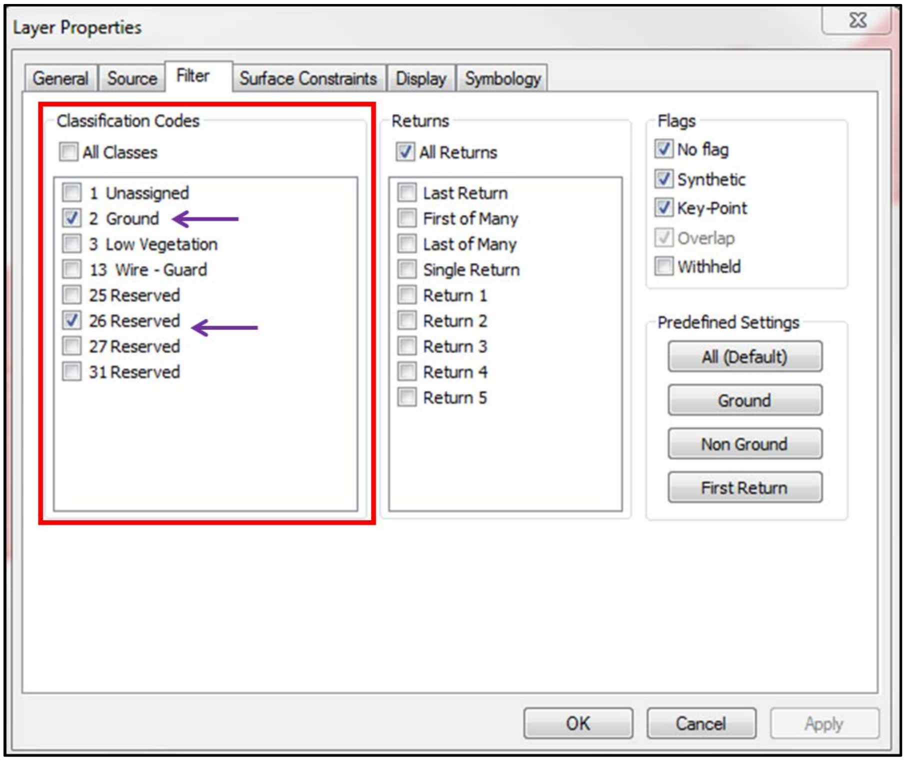
Click **Apply**, and **OK** to save these changes and exit the LASD dialog box. Drag and drop the LASD into your ArcMap document.

Next, in the **Table of Contents**, double click the LASD to open the Properties dialog box. Navigate to the **Filter tab**.

Within the **Classification Codes** portion of the dialog, check the boxes for "**2 Ground"** and "**26 Reserved"** (or other appropriate codes if using different topobathy LiDAR data as an input). This will filter out any return that does not fall within these two classifications.

The classification code "2 Ground" corresponds to all ground returns, also commonly referred to as bare earth. To determine which classification code(s) correspond to the bathymetric data, consult the metadata provided with the original LAS files (in this case, by NOAA NGS). Within the first process step (contained within the *Data Quality Information* section), find the list of all the classification code definitions. In this case, code "26 Reserved" is "bathymetric bottom and submerged topography."

Selecting these two classification codes enables us to create a topobathy raster displaying both bare earth (ground) elevation values and bathymetric (submerged topography) elevation values.



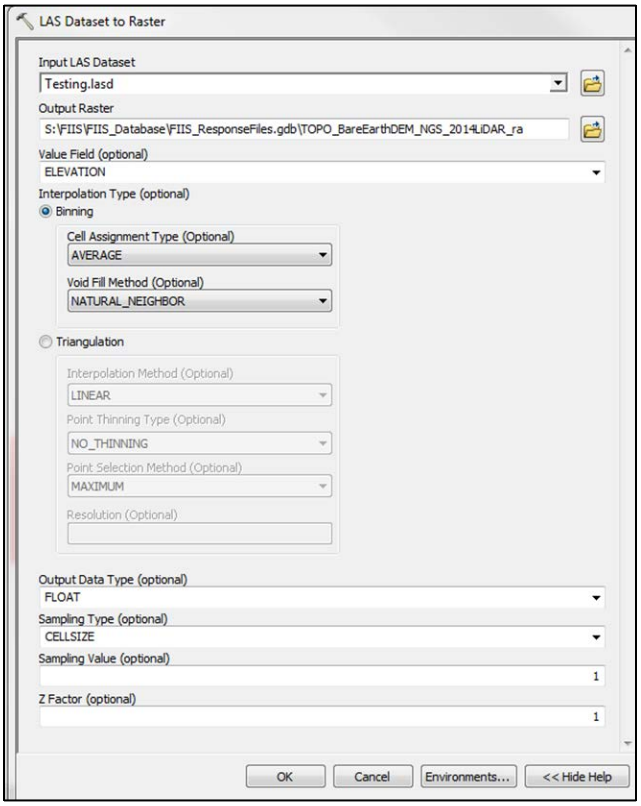
Once you have selected classification codes 2 and 26 (or other appropriate codes), click **Apply** and **OK** to exit the dialog.

Within the **Search window** of ArcMap, search for the **LAS Dataset to Raster tool** (alternatively, this can be found within the Conversion Toolbox). Using the following parameters, fill in the tool dialog (see below for example):

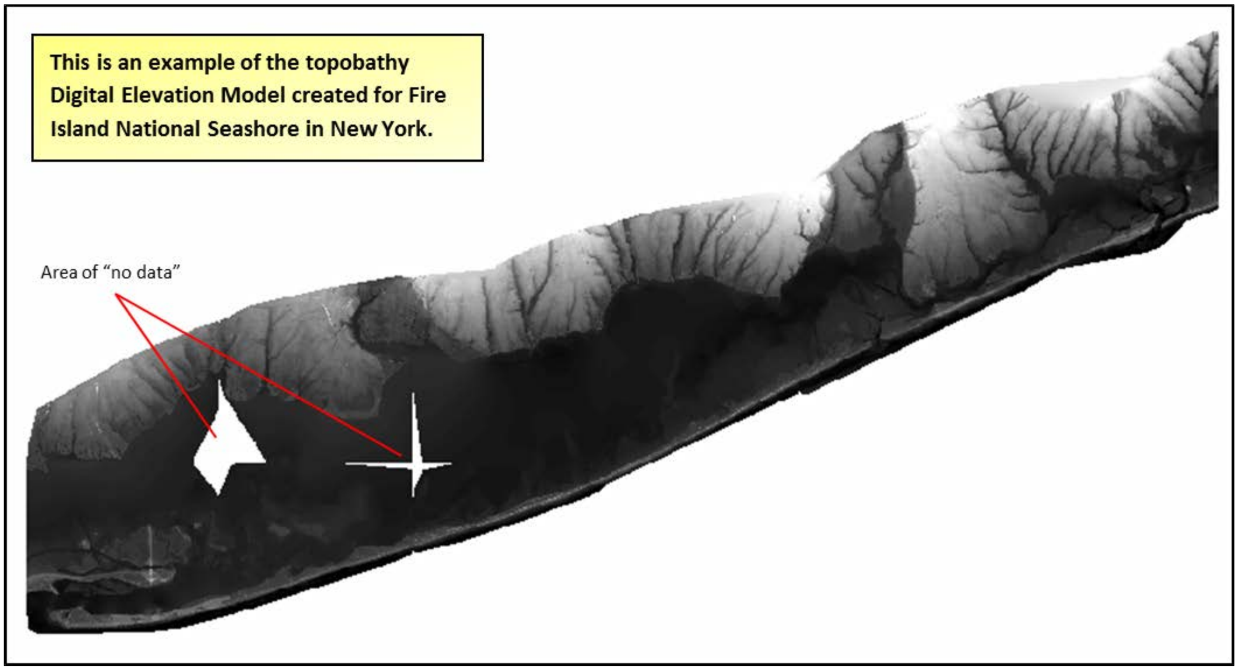
Note: *These parameters have been determined to be the best for the creation of bare earth Digital Elevation Models by Esri. These selections and other combinations of parameters have been tested by the authors of this workflow, and these provided the best results.*

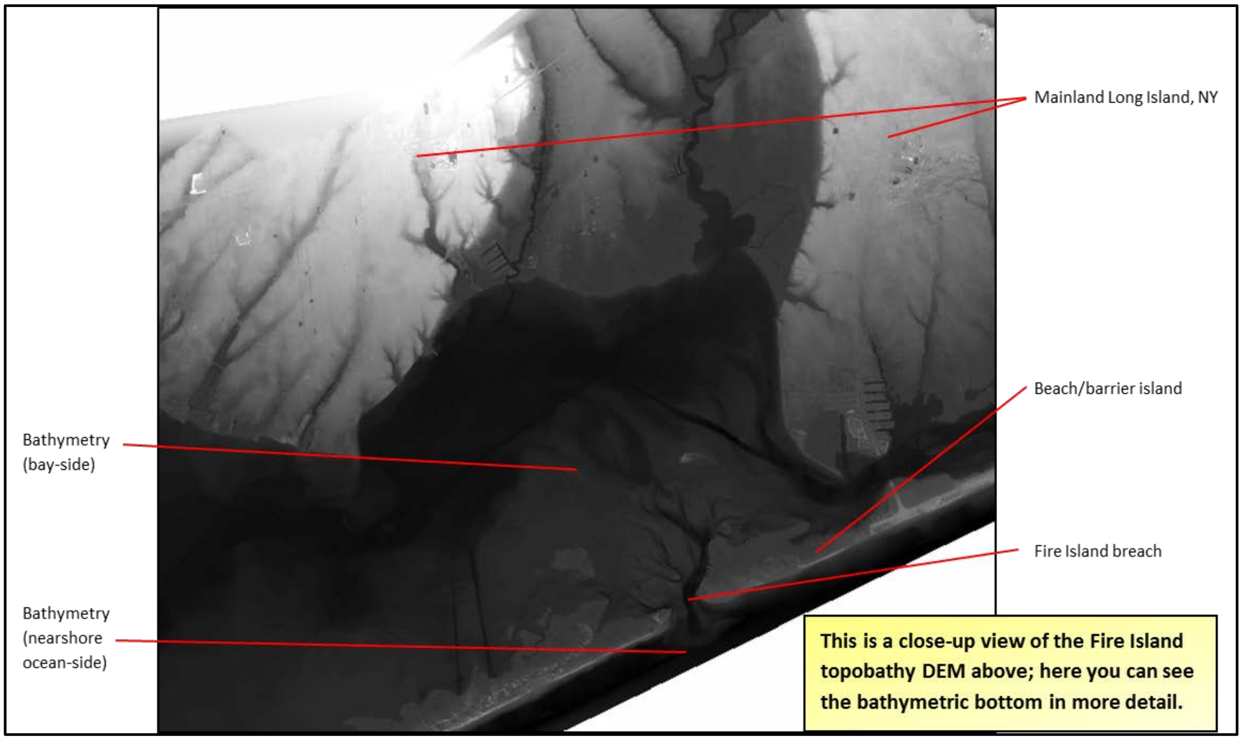
a) Input LAS Dataset = LAS dataset
b) Output Raster = Select output location & filename
    i. If writing raster to a file geodatabase, no file extension is needed. Other output options can be found in the tool help.
c) Interpolation Type - Binning
    i. Cell Assignment Type = Average
    ii. Void Fill Method = Natural Neighbor
d) Output Data Type = FLOAT
e) Sampling Type = CELLSIZE
f) Sampling Value = 1

Once the dialog is completed, click **OK** to run. *It could take a few hours to output a raster dataset (depending on size of dataset and processing speed of computer).*



Once completed, add the raster to ArcMap to ensure it was output correctly.




Mainland Long Island, NY
Beach/barrier island
Bathymetry
(bay-side)
Fire Island breach
Bathymetry
(nearshore
ocean-side)
This is a close-up view of the Fire Island topobathy DEM above; here you can see the bathymetric bottom in more detail.

References

Esri (2012). ArcGIS 10.1 Lidar Workshop. International Civil Aviation Organization (ICAO). Available at http://gis.icao.int/icaoetod/lidar_workshop_exercises.pdf (accessed June 2014).

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 962/138139, May 2017

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