TUTORIAL

Benthic Terrain Modeler v3.0 for ArcGIS 10.x

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Introduction

This tutorial will introduce the **Benthic Terrain Modeler (BTM)** toolbox for ArcGIS 10.x, a collection of Esri ArcGIS-based tools that coastal and marine resource managers can use in concert with bathymetric data sets to examine and classify the benthic environment. The BTM toolbox contains a set of customized scripts that allow users to create grids of bathymetric position index (BPI), standardized BPIs, slope, and rugosity from an input bathymetric data set. Additionally, two terrain classification scripts give users the freedom to create their own zone and structure classifications and define the relationships that characterize them.

The BTM toolbox for ArcGIS 10.x creates a user-defined classification system of benthic terrain. The BTM scripts transform digital elevation data into a classified product for use in research or natural resource management. However, the principles behind the tool are general enough that it can be used on any digital elevation data. The inclusion of flexible and customizable terrain classifications allows investigators and managers to create terrain maps in a variety of environments. To learn more about the original tool development and its applications in natural resource mapping and coastal management, refer to the document located at this link: *http://proceedings.esri.com/library/userconf/proc04/docs/pap1433.pdf*. More resources, including information on BTM product development and community support, can be found in the appendix.

The BTM was initially developed as a desktop extension for ArcGIS versions 8.x through 9.2 Service Pack 3. The version for ArcGIS 10.x consists of a series of ArcPy scripts combined in a custom toolbox that allows the user to run the individual processes as separate functions. The initial project was a partnership between the National Oceanic and Atmospheric

Administration (NOAA) Coastal Services Center and Oregon State University. The current version of the Benthic Terrain Modeler is a joint collaboration between the NOAA Coastal Services Center, the Massachusetts Office of Coastal Zone Management, and Esri. Contact information regarding technical support and product development is located in the appendix.

Benthic Terrain Modeler for ArcGIS 10.x Functions:

- **Build Bathymetric Position Index (BPI) Grids** creates BPI data sets at two different scales, which is central to the methods behind the benthic terrain classification process. BPI is a derivative of the input bathymetric data set and is used to define the location of specific features and regions relative to other features and regions within the same data set.
    - **Build Broad-Scale BPI** creates a broad-scale BPI data set that allows you to identify larger regions within the benthic landscape.
    - **Build Fine-Scale BPI** creates a fine-scale BPI data set that allows you to identify smaller features within the benthic landscape.
- **Standardize BPIs** creates standardized BPI data sets that may be classified to identify various benthic zones and/or structures.
- **Calculate Slope** creates a slope raster to be used in the classification tools.
- **Zone Classification Builder** creates a user-defined zones layer based on BPIs and slope. The benthic zones in the output layer include crests, depressions, flats, and slopes.
- **Structure Classification Builder** creates a user-defined structures layer based on BPIs, slope, standard deviation breaks, and depth. The benthic structures in the output layer will consist of narrow depression, local depression on flat, lateral midslope depression, depression on crest, broad depression, broad flat, shelf, open slopes, local crest in depression, local crest on flat, lateral midslope crest, narrow crest, and steep slope.
- **Terrain Ruggedness (VRM)** [“vector ruggedness measure”] measures terrain ruggedness, or rugosity, as the variation in three-dimensional orientation of grid cells within a neighborhood. Vector analysis is used to calculate the dispersion of vectors normal (orthogonal) to grid cells within the specified neighborhood. This method effectively captures variability in slope and aspect into a single measure. Ruggedness values in the output raster can range from 0 (no terrain variation) to 1 (complete terrain variation). Typical values for natural terrains range between 0 and about 0.4.

Note: The BPI, Slope, and Classification Builder scripts are all part of a single benthic terrain modeling process. The Terrain Ruggedness (VRM) script is an add-on for identifying rugosity in the benthic terrain environment that yields results unrelated to BPI.

Setup Instructions for Benthic Terrain Modeler for ArcGIS 10.x

The BTM for ArcGIS 10 is packaged as a .zip file. Unzip the contents to your computer's root **C:** drive in order to follow the tutorial steps below. The file location should read: **C:\BTM_Tutorial**. Within the **BTM_Tutorial** folder are two folders, one containing the BTM toolbox with scripts and another containing sample data that will be used throughout the tutorial.

Note: The program files may be saved anywhere the user prefers but in doing so the paths will differ for the following instructions.

1. To add the Benthic Terrain Modeler toolset into ArcMap, first open a new map project.
2. Open the ArcToolbox window by clicking **Geoprocessing > ArcToolbox** and pin it to the display if it is not already there. Right-click on the ArcToolbox top folder in the window and select **Add Toolbox**. Navigate to the **C:\BTM_Tutorial\scripts** folder and add **BTM.tbx**.
3. Expand the BTM toolset in ArcToolbox to see that it consists of seven python scripts. Note that the Spatial Analyst extension is required to run the BTM tools.
4. Confirm that the scripts are pointing to the correct source locations. Right-click on the **1. Build Broad-Scale BPI** script in the BTM toolset and select **Properties**. Click the **Source** tab. If you set up your toolbox as noted above, the script path should read **C:\BTM_Tutorial\scripts\broad_scale_bpi.py**. If you initially saved the files in another location, confirm that the script source path is correct. If not, click the folder icon and navigate to the script and select **Open**. Check the Source location for the other scripts and repeat this process if necessary.

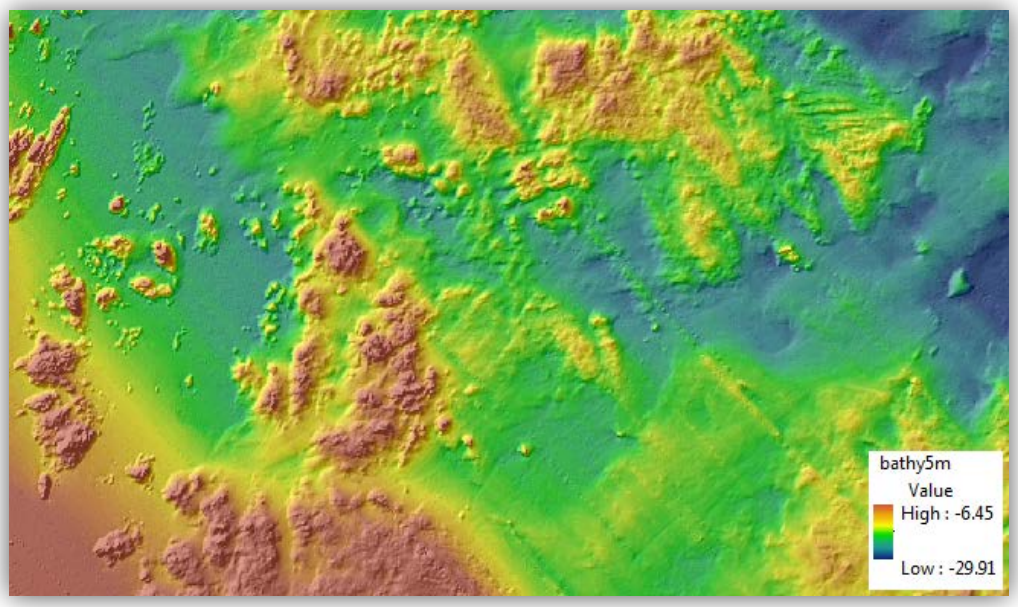
Note: This tutorial only guides the user on how to perform the BTM functions using the provided sample data and estimated input values. Bathymetric values and data ranges vary greatly from one area to another, and this should be noted when using the BTM with your own data sets.

Also, this tutorial also does not fully explain the processes that run the scripts in ArcMap. This tutorial is intended to guide the user on the script-based version of the BTM for ArcGIS 10.x. If interested in information on the initial product development and the processes that BTM utilizes, please refer to the original BTM for ArcGIS 8.x user documentation found at www.csc.noaa.gov/digitalcoast/tools/btm/index.html and click on the BTM Tutorial for ArcGIS 9.2 link.

BTM Tutorial

Add the Sample Data to Your Map

1. Click on **Add Data**, navigate to the **C:\BTM_Tutorial\sample_data** folder, and add the two raster layers **bathy5m** and **hillshade5m** to your map. Bathymetric data are the only data required for the BTM tools. The addition of a hillshade layer can be used to enhance the visualization of the results but does not affect the mechanics of the actual tools.
2. If necessary, drag the **bathy5m** layer beneath the **hillshade5m** layer in the table of contents.
3. Symbolize the **bathy5m** layer to a graduated color scheme representing changes in depth.
4. Change the transparency of the **hillshade5m** layer to **50%** in the layer properties. Your map should look similar to the following graphic, depending on color ramp selection.
5. Save your map as **BTM.mxd** in the **sample_data** folder.

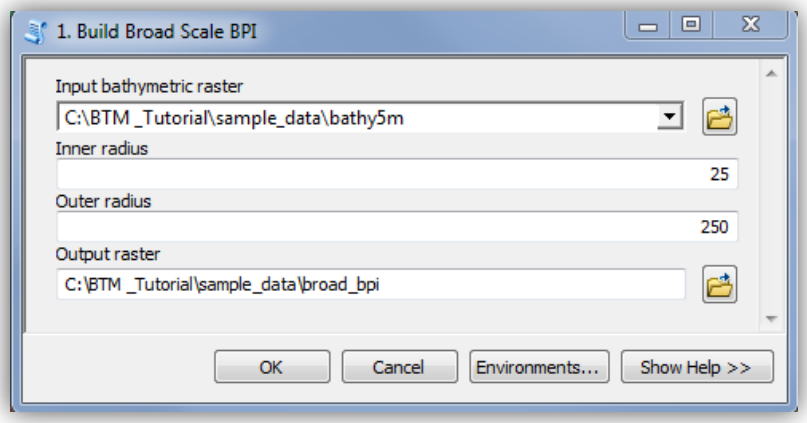


The bathymetric data used in this tutorial were collected by the U.S. Geological Survey and NOAA offshore of Massachusetts between Duxbury and Hull. These data are available as an ArcInfo 32-bit floating point binary grid in Esri format. The grid has a 5-meter horizontal resolution and the spatial reference is WGS_1984_UTM_Zone_19N. For more information on acquiring bathymetric data for use with the BTM, please visit *http://pubs.usgs.gov/of/2009/1072/html/appendix1.html*.

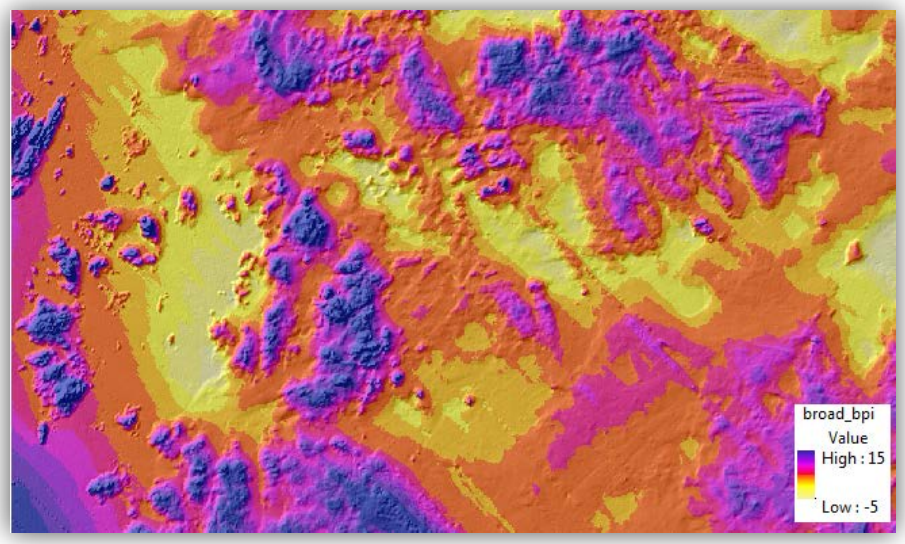
Build Broad-Scale BPI

1. Double-click the first script, **Build Broad-Scale BPI**, in the BTM toolset to open it. Populate the script with the following parameters:

   Input bathymetric raster: C:\BTM_Tutorial\sample_data\bathy5m
   Inner radius: 25
   Outer radius: 250
   Output raster: C:\BTM_Tutorial\sample_data\broad_bpi



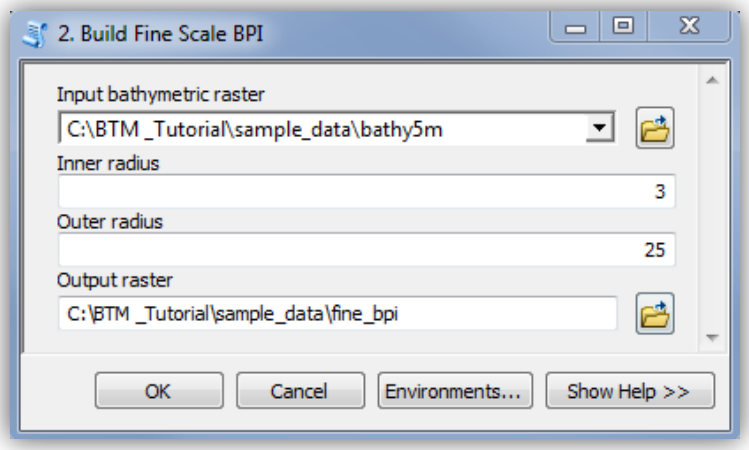
2. Click **OK** to run the script. Once the script runs, the symbology will need to be changed. Double-click the **broad_bpi** layer in the table of contents, select the **Symbology** tab, and then select the **Stretched** display option. Change the color ramp if necessary. Click **Apply** and then **OK**. Drag the layer beneath the hillsahde5m layer. Your results should look similar to the graphic below for the broad scale BPI.



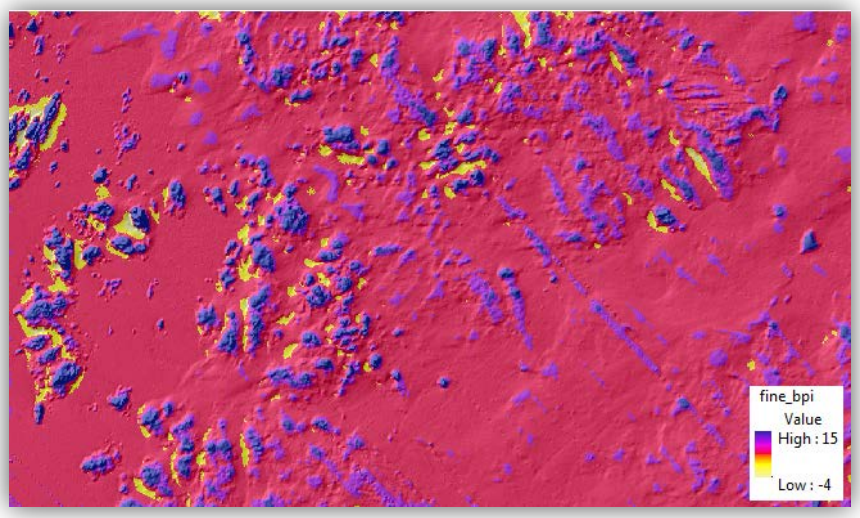
Build Fine-Scale BPI

1. Double-click the second script in the BTM toolset, **Build Fine-Scale BPI**, to open it. Populate the script with the following parameters:

   Input bathymetric raster: C:\BTM_Tutorial\sample_data\bathy5m
   Inner radius: 3
   Outer radius: 25
   Output raster: C:\BTM_Tutorial\sample_data\fine_bpi



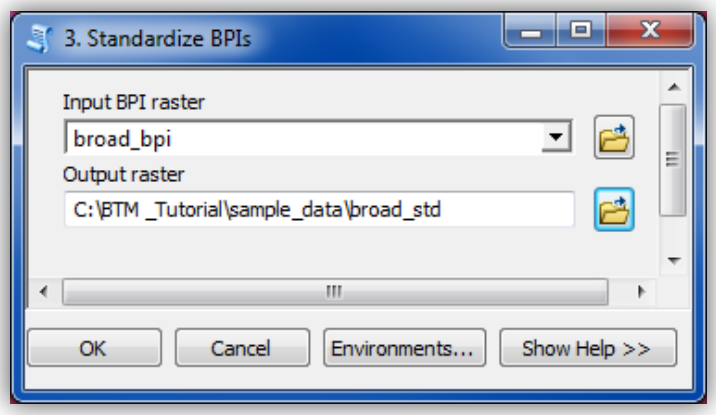
2. Click **OK** to run the script. Once the script runs, the symbology will need to be changed. Double-click the **fine_bpi** layer in the table of contents, select the **Symbology** tab, and then select the **Stretched** display option. Change the color ramp to match the **broad_bpi** color ramp. Click **Apply** and then **OK**. Drag the layer beneath the hillshade5m layer. Your results should look similar to the graphic below for the fine scale BPI.



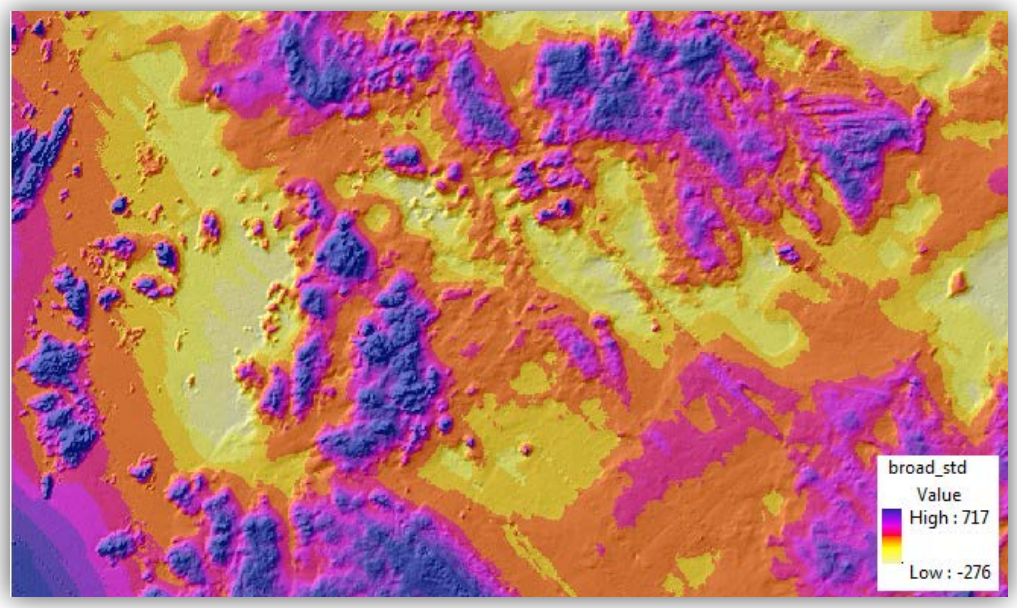
3. Toggle between the **broad_bpi** and **fine_bpi** layers to note the differences between the broad scale and fine scale BPI grids.

Standardize BPIs

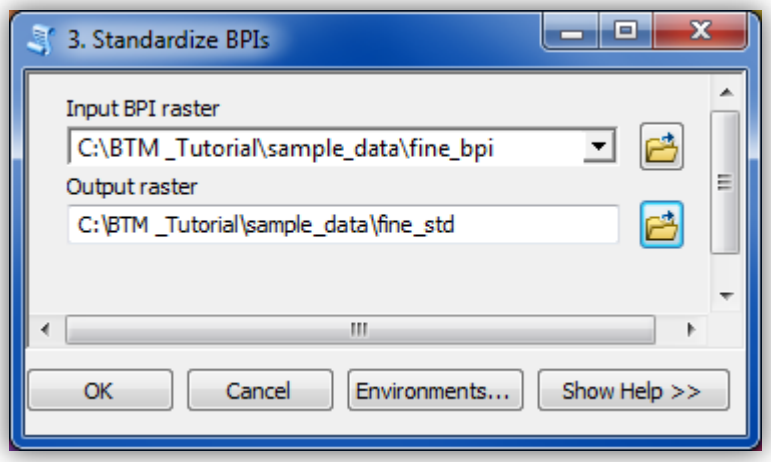
1. Double-click the **Standardize BPIs** script in the BTM toolset to open it. First standardize the broad-scale BPI. Select **broad_bpi** as the input raster, name the output **broad_std**, and save it to your **sample_data** folder.



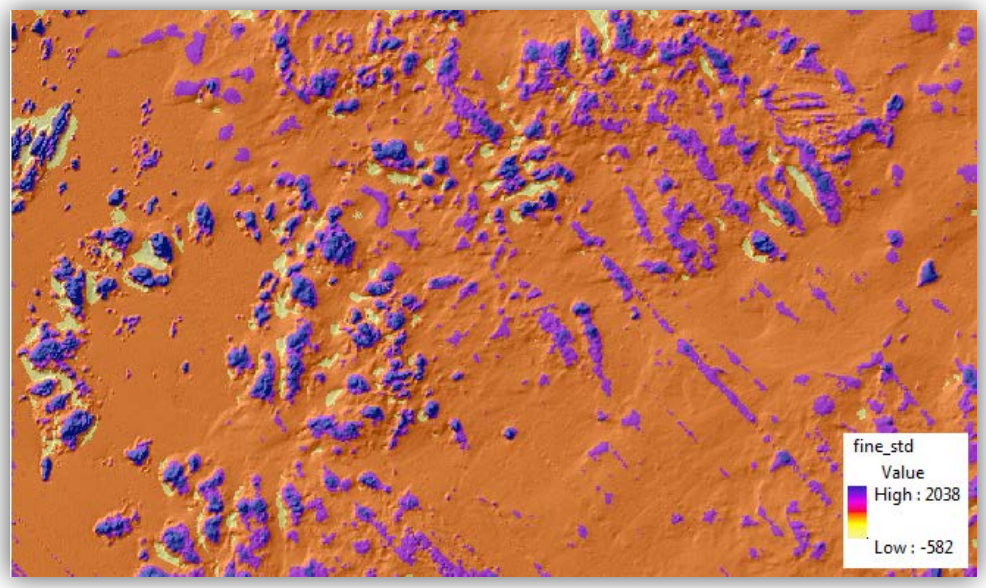
2. Click **OK** to run the script. Once the script runs, the symbology will need to be changed as in the previous steps. Drag the layer beneath the hillshade5m layer. Your results should look similar to the graphic below for the standardized broad-scale BPI.



3. Rerun the script to standardize the fine-scale BPI. Save the output layer as **fine_std**.

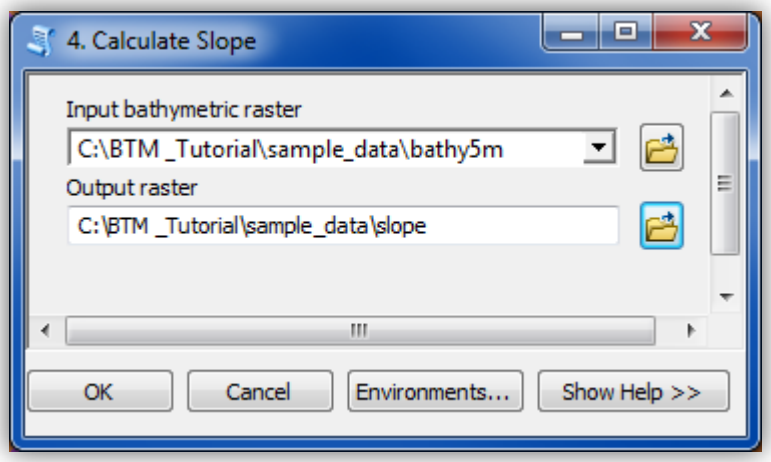


4. Once the script runs, the symbology will need to be changed as in the previous steps. Drag the layer beneath the hillshade5m layer. Your results should look similar to the graphic below for the standardized fine-scale BPI.



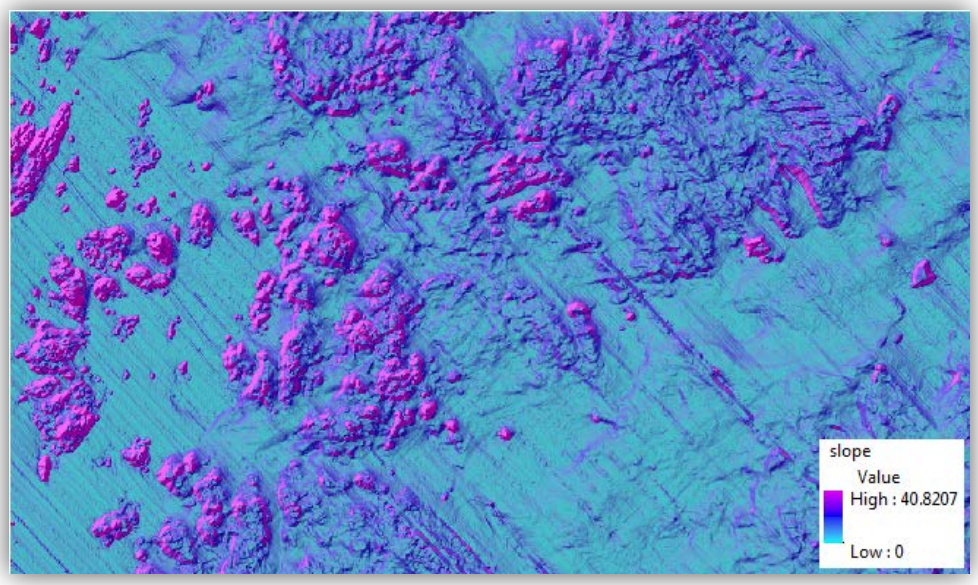
Calculate Slope

1. Double-click the **Calculate Slope** script in the BTM toolset to open it. The output slope raster will be used in the following scripts. Select the **bathy5m** raster as the input and name the output file **slope**, saving it to the **sample_data** folder.



2. Click **OK** to run the Calculate Slope script. Once the **slope** layer is added to the map, change the color ramp in the layer properties and then drag it beneath the hillshade5m layer in the table of contents. Your layer should have slope values similar to the graphic below.

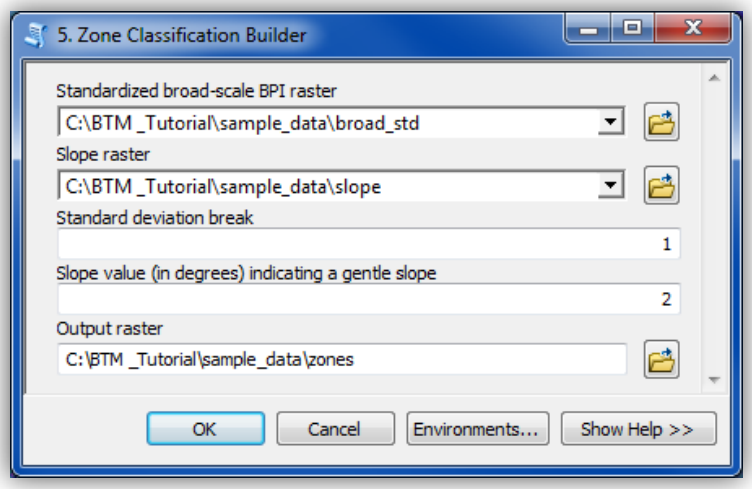
   Note: As seen below, artifacts in the bathymetry data may be magnified by some of the steps. In this case, small northwest to southeast changes in bathymetry are highlighted, caused by verging multibeam swathes.



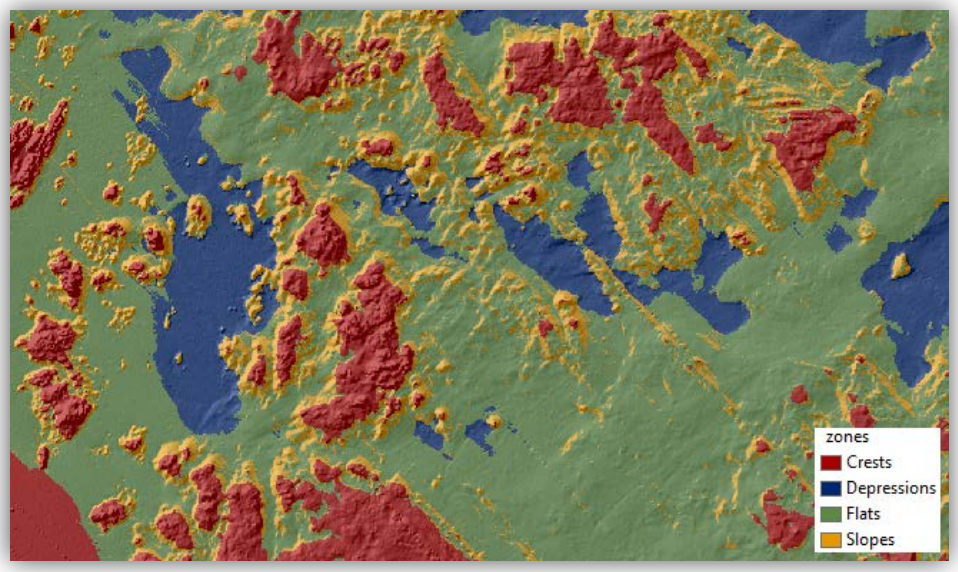
Zone Classification Builder

1. Double-click the **Zone Classification Builder** script in the BTM toolset to open it. Populate the script with the following input parameters:

   Standardized broad-scale BPI raster: C:\BTM_Tutorial\sample_data\broad_std
   Slope raster: C:\BTM_Tutorial\sample_data\slope
   Standard deviation break: 1
   Slope value indicating a gentle slope: 2
   Output raster: C:\BTM_Tutorial\sample_data\zones



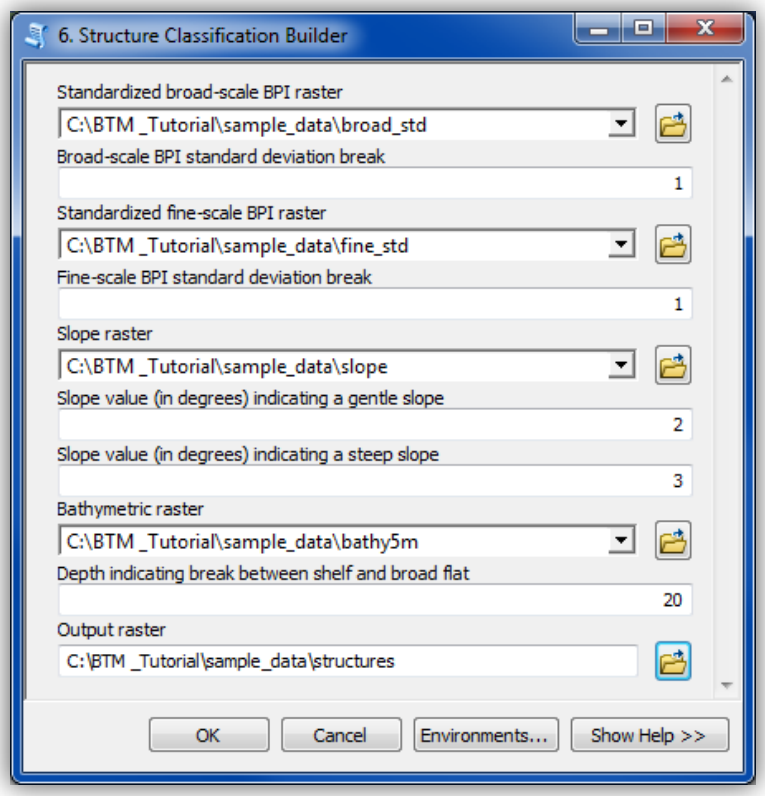
2. Click **OK** to run the script. Drag the **zones** layer beneath the hillshade5m layer in the table of contents and change the ramp color to your preference. Your **zones** layer should look similar to the graphic below.



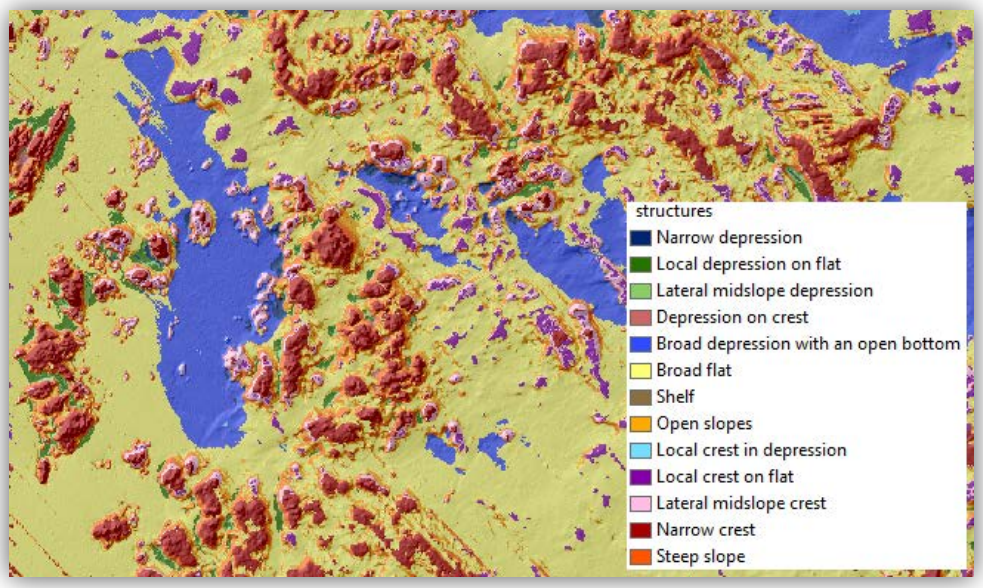
Structure Classification Builder

1. Double-click the **Structure Classification Builder** script in the BTM toolset to open it. Populate the script with the following input parameters:

   Standardized broad-scale BPI raster: C:\BTM_Tutorial\sample_data\broad_std
   Broad-scale BPI standard deviation break: 1
   Standardized fine-scale BPI raster: C:\BTM_Tutorial\sample_data\fine_std
   Fine-scale BPI standard deviation break: 1
   Slope raster: C:\BTM_Tutorial\sample_data\slope
   Slope value indicating a gentle slope: 2
   Slope value indicating a steep slope: 3
   Bathymetric raster: C:\BTM_Tutorial\sample_data\bathy5m
   Depth indicating break between shelf and broad flat: 20
   Output raster: C:\BTM_Tutorial\sample_data\structures



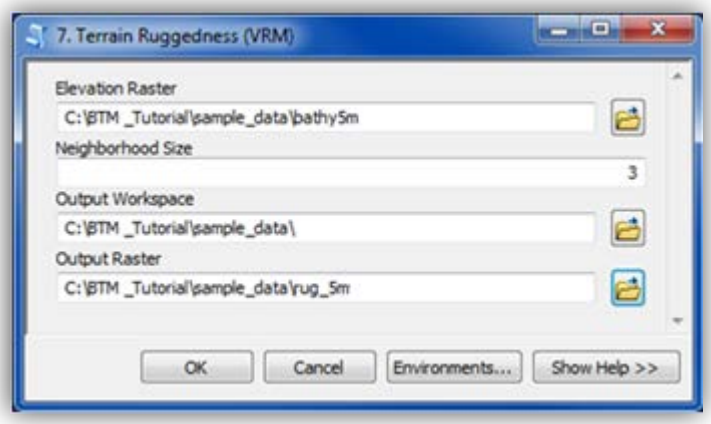
2. Click **OK** to run the script. Drag the **structures** layer beneath the hillshade5m layer in the table of contents and change the ramp color to your preference. Your **structures** layer should look similar to the graphic below.



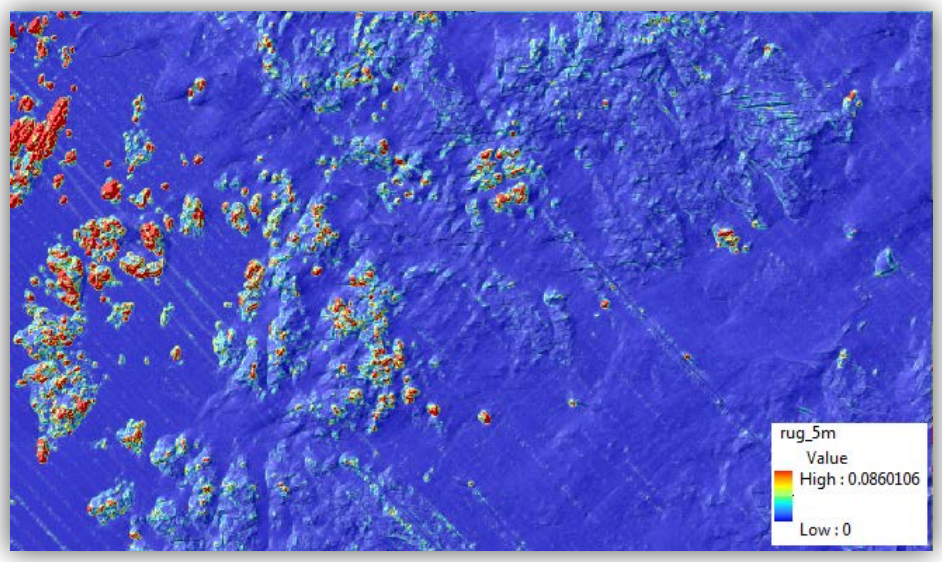
Terrain Ruggedness (VRM) [Vector Ruggedness Measure]

1. Double-click the **Terrain Ruggedness (VRM)** script in the BTM toolset to open it. Populate the script with the following input parameters:

   Elevation Raster: C:\BTM_Tutorial\sample_data\bathy5m
   Neighborhood Size: 3
   Output Workspace: C:\BTM_Tutorial\sample_data
   Output raster: C:\BTM_Tutorial\sample_data\rug_5m



2. Click **OK** to run the script. Drag the **rug_5m** layer beneath the hillshade5m layer in the table of contents and change the ramp color to your preference. Your **rug_5m** layer should look similar to the graphic below.



3. Ruggedness values in the output raster can range from 0 (no terrain variation) to 1 (complete terrain variation). Typical values for natural terrains range between 0 and about 0.4. However, it is important to understand that the number is unitless and not directly comparable between study sites. This script, originally created by Mark Sappington, was adapted for ArcGIS v10 by the Massachusetts Office of Coastal Zone Management. For more information about the script processes please refer to

   Sappington, J.M., K.M. Longshore, and D.B. Thompson. 2007. "Quantifying Landscape Ruggedness for Animal Habitat Analysis: A Case Study Using Bighorn Sheep in the Mojave Desert." *Journal of Wildlife Management*. Volume 71, Issue 5. Pages 1,419 to 1,426.

Appendix

Contact Information and Technical Assistance:

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BTM Development and Support Information:

Wright, D. J., E. R. Lundblad, E. M. Larkin, R. W. Rinehart, J. Murphy, L. Cary-Kothera, and K. Draganov. 2005. ArcGIS Benthic Terrain Modeler [a collection of tools used with bathymetric data sets to examine the deepwater benthic environment]. Oregon State University, Davey Jones' Locker Seafloor Mapping/Marine GIS Laboratory and NOAA Coastal Services Center. Accessible online at *www.csc.noaa.gov/digitalcoast/tools/btm*.

Alternate BTM Tutorial for ArcGIS 8.x, 9.x:
http://dusk.geo.orst.edu/buffgis/Arc9Labs/lab3_analysis_modelsS09.pdf

Seafloor Mapping/Marine and Coastal GIS (Davey Jones' Locker) – Oregon State University:
http://marinecoastalgis.net