ARC HYDRO GROUNDWATER TUTORIALS

Subsurface Analyst – Creating GeoRasters from borehole data

Arc Hydro Groundwater (AHGW) is a geodatabase design for representing groundwater datasets within ArcGIS. The data model helps to archive, display, and analyze multidimensional groundwater data, and includes several components to represent different types of datasets, including representations of aquifers and wells/boreholes, 3D hydrogeologic models, temporal information, and data from simulation models. The *Arc Hydro Groundwater Tools* help to import, edit, and manage groundwater data stored in an AHGW geodatabase. *Subsurface Analyst* is a subset of the AHGW Tools that is used to manage 2D and 3D hydrogeologic data, and create subsurface models including generation of borehole representations, cross sections, surfaces, and volumes.

In this tutorial we will learn how to create raster surfaces from borehole data, and how to load and index the surfaces in the GeoRasters raster catalog.

1.1 Background

Data used in this tutorial are part of a project for developing a groundwater simulation model: The Sacramento Regional Model, which encompasses an area of approximately 1,360 square miles (871,000 acres) near the city of Roseville in the Sacramento valley, California. The model is bounded by the Bear River and Feather River to the north, the Mokelumne River to the south, the Sacramento River to the west and by bedrock of the Sierra Nevada to the east (Figure 1).

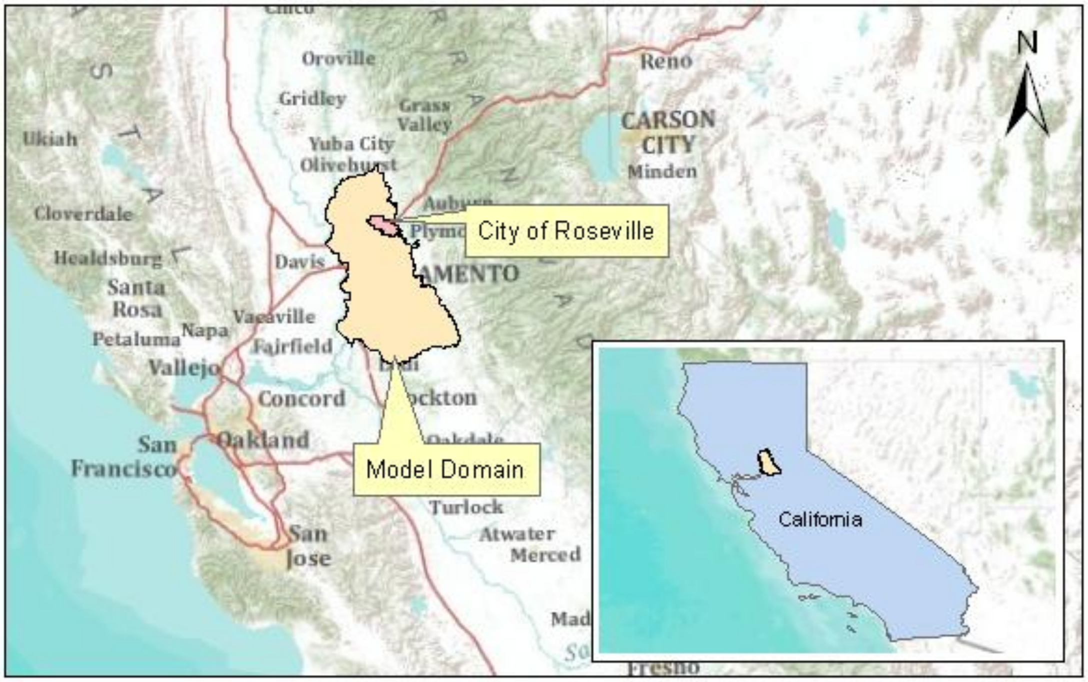


Figure 1 Location of the Roseville Model.

As part of the model development, a set of hydrogeologic units were defined. A simplified set of units were extracted from the original list and is used in this tutorial. Figure 2 shows the sequence of formations used in this tutorial. Each of the units is indexed by a hydrogeologic unit identifier (HGUID), and the unit properties are defined in the HydrogeologicUnit table. In addition, each of the units is indexed with a horizon ID.

The term "horizon" refers to the top of each stratigraphic unit that will be represented in the subsurface model. Horizons are numbered consecutively in the order that the strata are "deposited" (from the bottom up). Each contact that you wish to represent in the subsurface model must have a HorizonID. Horizons can be represented as rasters, one for each horizon ID. The rasters will typically be created by interpolating the borehole contact data for each horizon. When organized in a raster catalog, the rasters can be used to create 3D GeoSection and GeoVolume features based on an attribute field containing the horizon ID.

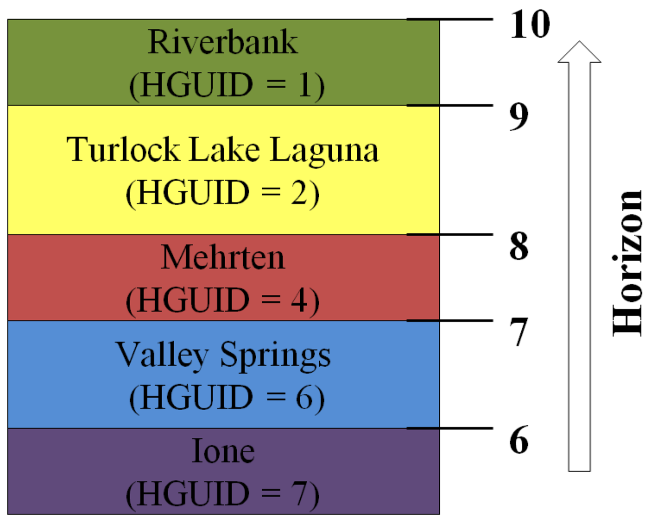


Figure 2 Hydrogeologic units indexed with a HGUID and a HorizonID.

1.2 Outline

The objective of this tutorial is to introduce the basic workflow and tools for creating raster surfaces from borehole data, and loading and indexing the rasters in the GeoRasters raster catalog. The tutorial includes the following steps:

1. Create BorePoints representing hydrogeologic units as contacts along boreholes.
2. Interpolate BorePoints to raster surfaces.
3. Load rasters into the GeoRasters raster catalog and index the rasters with appropriate attributes.
4. Visualize the resulting rasters in ArcScene.

1.3 Required Modules/Interfaces

You will need the following components enabled in order to complete this tutorial:

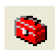
- Arc View license (or ArcEditor\ArcInfo)
- 3D Analyst
- Arc Hydro Groundwater Tools
- AHGW Tutorial Files

The AHGW Tools require that you have a compatible ArcGIS service pack installed. You may wish to check the AHGW Tools documentation to find the appropriate service pack for your version of the tools. The tutorial files should be downloaded to your computer and saved on a local drive.

2 Getting Started

Before opening the tutorial map, let’s ensure that the AHGW Tools are correctly configured.

1. If necessary, launch *ArcMap*.

2. If necessary, open the *ArcToolbox* window by clicking on the *ArcToolbox* icon .

3. Make sure the Arc Hydro Groundwater Toolbox is loaded. If it is not, add the toolbox by right-clicking anywhere in the *ArcToolbox* window and selecting the *Add Toolbox…* command. Browse to the top level of the *Catalog* and then browse down to the *Toolboxes|System Toolboxes* directory. Select the toolbox and select the *Open* button.

4. Expand the *Arc Hydro Groundwater Tools* item and then expand the *Subsurface Analyst* toolset to expose the tools we will be using in this tutorial.

We will also be using the *Arc Hydro Groundwater Toolbar*. The toolbar contains additional user interface components not available in the toolbox. If the toolbar is not visible, do the following:

5. Right-click on any visible toolbar and select the *Arc Hydro Groundwater Toolbar* item.

When using geoprocessing tools you can set the tools to overwrite outputs by default, and automatically add results to the map/scene. To set these options:

6. Select the *Geoprocessing | Options...* command.

7. Activate the option: “*Overwrite the outputs of geoprocessing operations*” as shown in Figure 3.

8. Enable the option to “*Add results of geoprocessing operations to the display*” as shown in Figure 3.

9. Select *OK* to exit the setup.

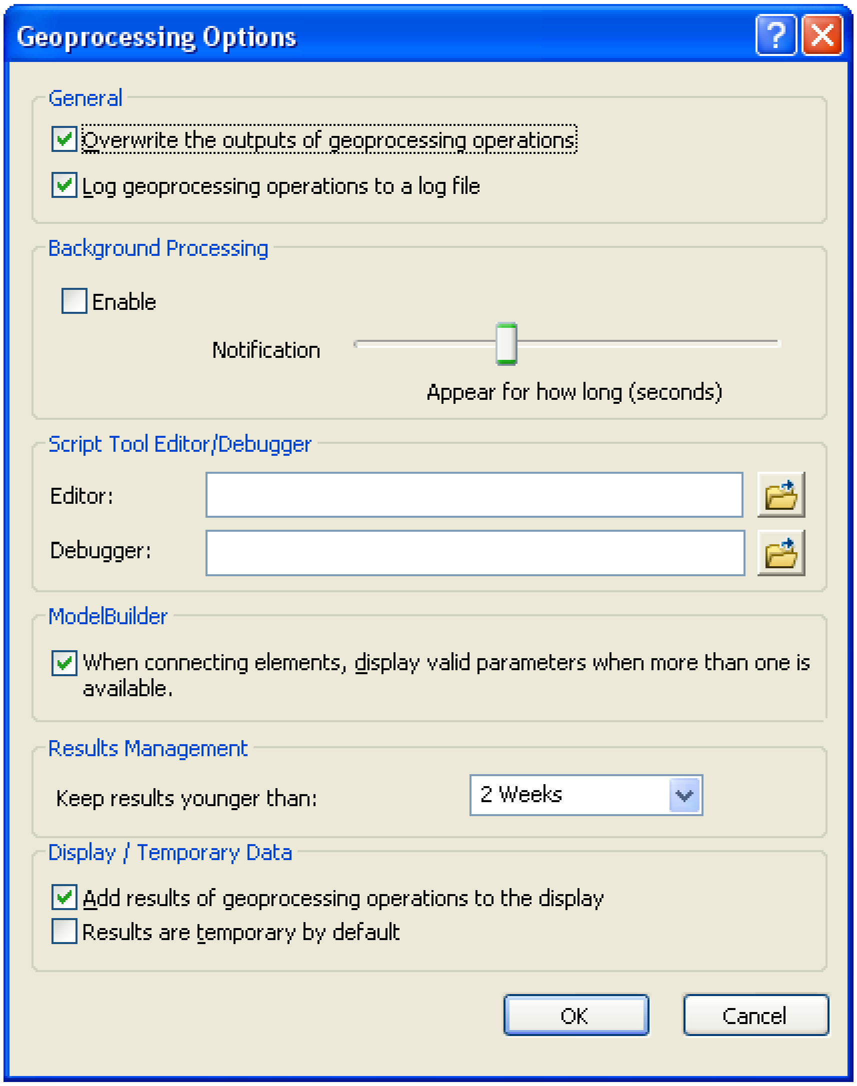


Figure 3 Setting Geoprocessing tools to overwrite outputs by default, and to add results of geoproceesing tools to the display.

3 Opening the Map

We will begin by opening a map containing some background data for the project.

1. Select the *File| Open* command and browse to the location on your local drive where you have saved the AHGW tutorials. Browse to the ***creating georasters*** folder and open the file entitled ***GeoRasters.mxd***.

Once the file has loaded you will see a map of the model boundary with well features located within the model domain.

4 Creating BorePoints from borehole data

Borehole information is stored in the BoreholeLog table. Each row in the table represents a hydrogeologic unit observed along the borehole. Data in the BoreholeLog table are referenced to Well features. The WellID attribute in the BoreholeLog table relates to the HydroID of a Well feature. Figure 4 shows an example of a BoreholeLog table. Records in the table are indexed with a WellID to relate the vertical information with specific Wells. In addition, top and bottom elevations are defined for the different hydrogeologic units, and each unit is indexed with a hydrogeologic unit identifier (HGUID). Each of the units is also indexed with a HorizonID which defines the ordering of the units from bottom up and is used for indexing rasters.

Table

BoreholeLog

WellID	HGUID	TopElev	BottomElev	ElevUnits	LogType	HorizonID
6478	1	180.30075	155.30075	feet	Derived Borehole from GMS model	10
6478	2	155.30075	105.30075	feet	Derived Borehole from GMS model	9
6478	4	105.30075	-29.062442	feet	Derived Borehole from GMS model	8
6478	6	-29.062442	-180.303268	feet	Derived Borehole from GMS model	7
6478	7	-180.303268	-205.303268	feet	Derived Borehole from GMS model	6
6479	1	118.645248	33.930549	feet	Derived Borehole from GMS model	10
6479	2	33.930549	-196.842178	feet	Derived Borehole from GMS model	9
6479	4	-196.842178	-246.842178	feet	Derived Borehole from GMS model	8
6479	6	-246.842178	-400	feet	Derived Borehole from GMS model	7
6479	7	-400	-425	feet	Derived Borehole from GMS model	6
6480	2	193.57254	168.57254	feet	Derived Borehole from GMS model	9
6480	4	168.57254	118.572532	feet	Derived Borehole from GMS model	8
6480	6	118.572532	-66.23278	feet	Derived Borehole from GMS model	7
6480	7	-66.23278	-178.575439	feet	Derived Borehole from GMS model	6

0 (0 out of 1166 Selected)

BoreholeLog

Figure 4 BoreholeLog table containing information on hydrogeologic units along boreholes. The WellID attribute relates vertical logs to a Well feature.

In order to create a raster that defines a surface across the model domain we first need to create a set of points from which the raster will be interpolated. This is achieved by joining the Well features with the BoreholeLog table and creating a new set of points with the hydrogeologic information. You can use the *BoreholeLog Table To Points* tool to automate this process:

1. Open the ***BoreholeLog Table To Points*** tool located in the *Subsurface Analyst | Features* toolset.

2. Select the **Well** feature class as *the Input Well Features*.

3. Select **HydroID** as the *Well Unique Feature Identifier Field*.

4. Select the **BoreholeLog** table as the *Input BoreholeLog Table*.

5. Select **WellID** as the *BoreholeLog Related Feature Identifier Field*.

6. Specify the **GeoRasters.mdb\Data** dataset as the *Output Feature Class* location and name the feature class **BorePoint**.

7. Select all the fields in the *Copy Fields* list box.

8. Enable the *Create 3D Features* option.

9. Select the **TopElev** field as the *Elevation Field for 3D Features*.

At this point your inputs should be similar to the ones shown in Figure 5.

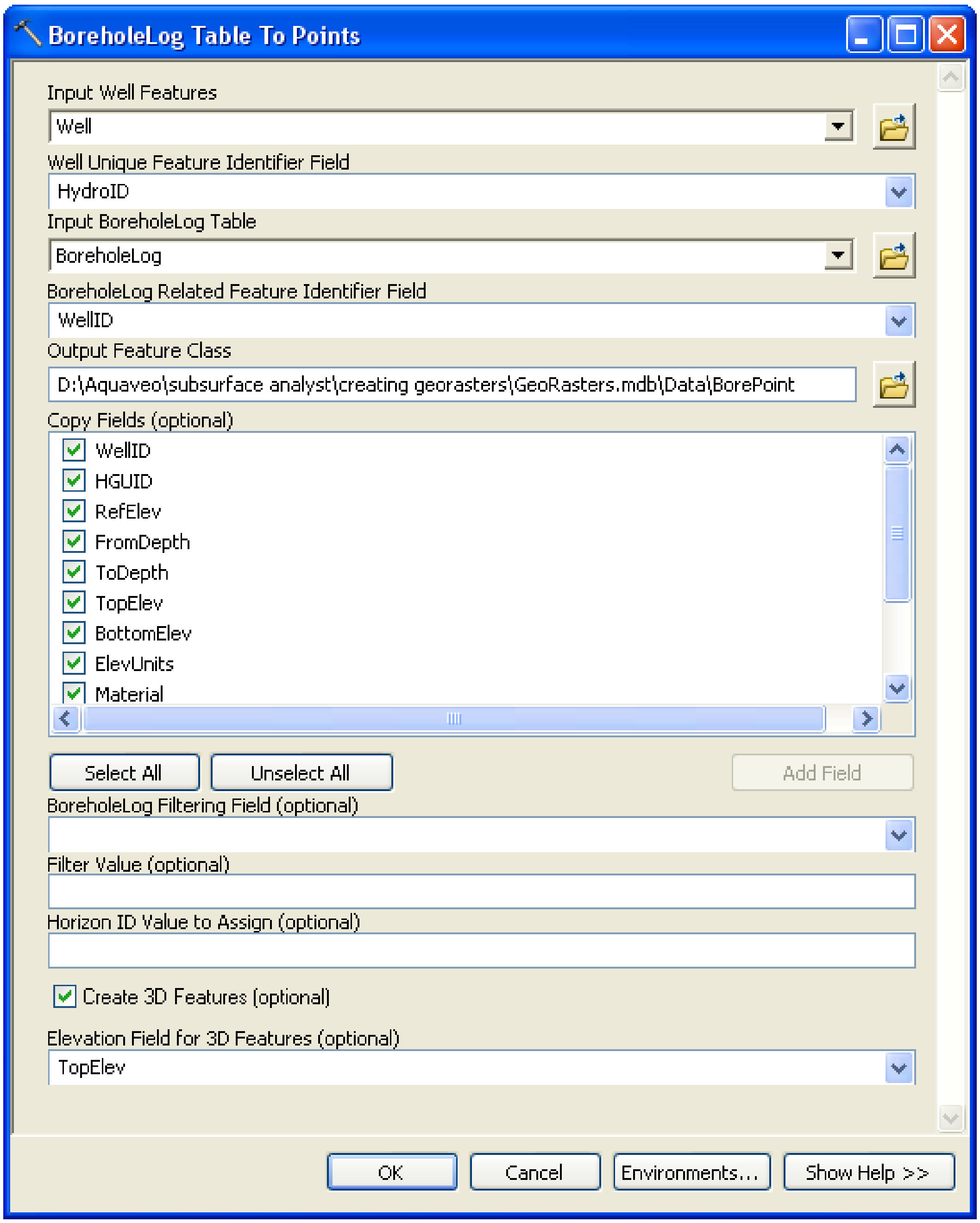


Figure 5 Inputs for the BoreholeLog Table To Points tool.

10. Select *OK* to run the tool.

At the end of this process you should have a new 3D point feature class that contains the BorePoints. Each point represents a horizon in the subsurface model. Next, we will interpolate a set of rasters based on the point features.

5 Interpolating rasters from points features

To create the rasters, you can use any of the interpolation tools available in the 3D Analyst and Spatial Analyst extensions.

Before the interpolation we will specify a query to define a HorizonID. This will ensure that only points representing a certain horizon in the model are included in the interpolation.

1. Make sure the BorePoint layer is selected in the table of contents.

2. Use the Field Filter available in the AHGW toolbar to define a query for points with a horizon of 6. Select the **HorizonID_BHL** filed in the first combo box. Select a **value of 6** in the second combo box.

For this tutorial we will use the IDW interpolation method.

3. Open the **IDW** tool located in the *Spatial Analyst Tools | Interpolation* toolset.

4. Specify the **BorePoint** point feature class as the *input point features*.

5. Select the **TopElev** field as the *Z value field*.

6. For the *Output raster*, browse to the **creating georasters\Rasters** folder and specify the raster as **idw_horizon06**.

7. Specify an *Output cell size* of **1000**.

At this point your inputs should be similar to the ones shown in Figure 6.

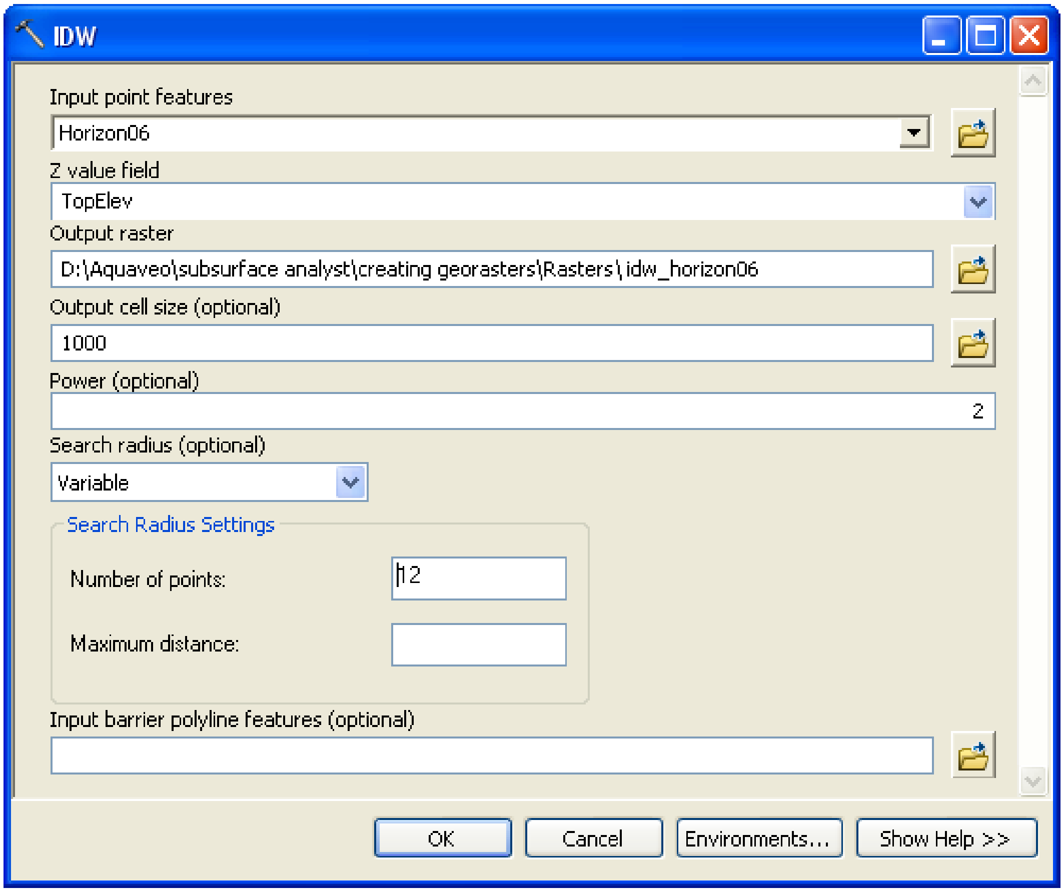


Figure 6 Inputs for the IDW interpolation tool.

Before running the tool we will also set the Environment Settings so the raster interpolation covers the whole model domain:

8. Select the Environments button 

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9. For the *Processing Extent* select the **Same as layer ModelBoundary** option.

10. From the *Raster Analysis* select the **ModelBoundary** layer as the *Mask.*

Your setting for ArcGIS 10 should be similar to the ones shown in Figure 7. If you are using ArcGIS 9.3 then the *Extent* can be found under the *General Settings* section.

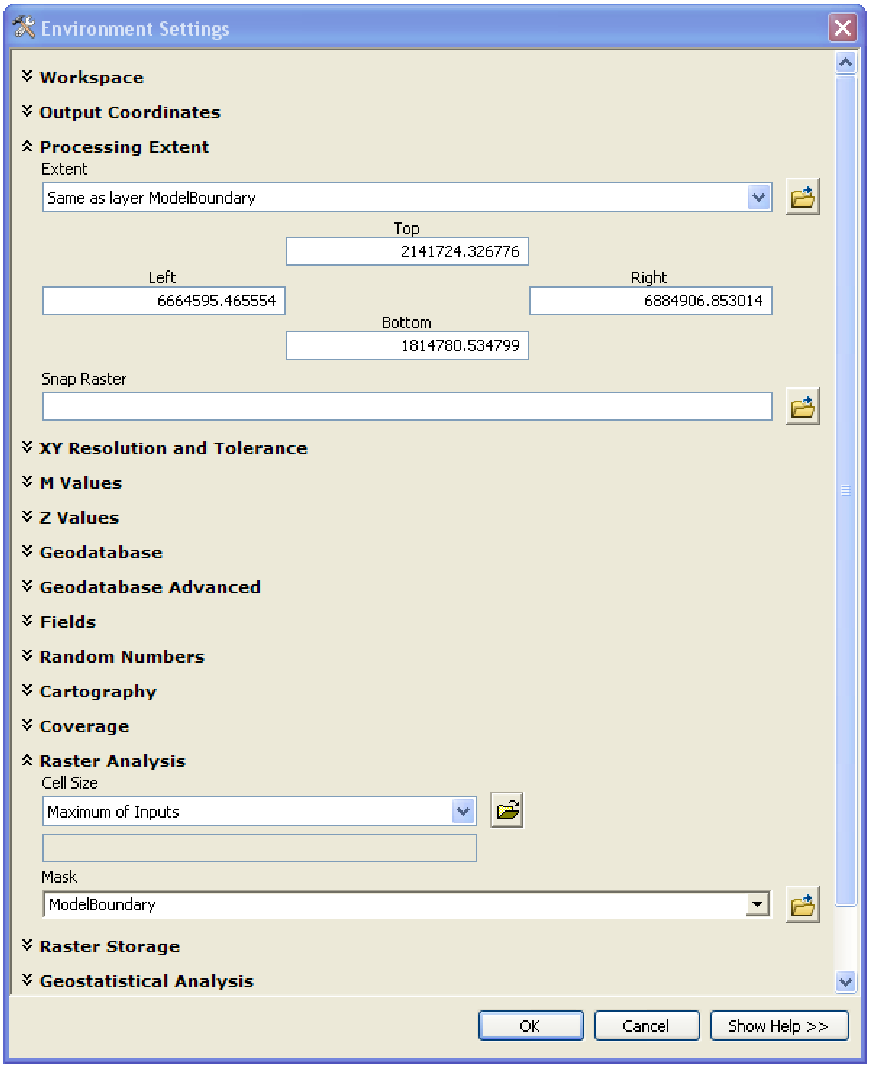


Figure 7 Environment Settings for the IDW tool.

11. Select **OK** to close the *Environment Settings* dialog.

12. Select **OK** to run the tool.

13. Repeat this process to create rasters for horizons 7, 8, 9, and 10. Make sure you specify the definition query each time before running the interpolation tool.

Tip: To save time you can access the results of a geoprocessing tool and edit the inputs. To access the geoprocessing results window in ArcGIS 9.3, select the *Results* tab at the bottom of the *Arc Toolbox* window; in ArcGIS 10, select *Geoprocessing* from the main ArcGIS menu and then select *Results*. Then expand the *Current Session* and double-click the *IDW* result. You can then edit any of the inputs you supplied previously and run the tool again.

At the end of this process you should have 5 rasters, one for each horizon (6, 7, 8, 9, and 10).

6 Loading the rasters into the GeoRasters raster catalog

Next, we will load the rasters into the GeoRasters raster catalog, and index them with the appropriate attributes.

1. Open the **Raster To Geodatabase (multiple)** tool located in the *Conversion Tools | To Geodatabase* toolset.

2. Select rasters for horizons 6, 7, 8, 9, and 10 as the *Input Rasters* by browsing to the **create georasters\Rasters** folder. Also select the **dem30m** raster that represents the surface terrain.

3. Select the **GeoRasters** raster catalog located in the GeoRasters.mdb geodatabase as the *Output Geodatabase*.

Your inputs should be similar to the ones shown in Figure 8.

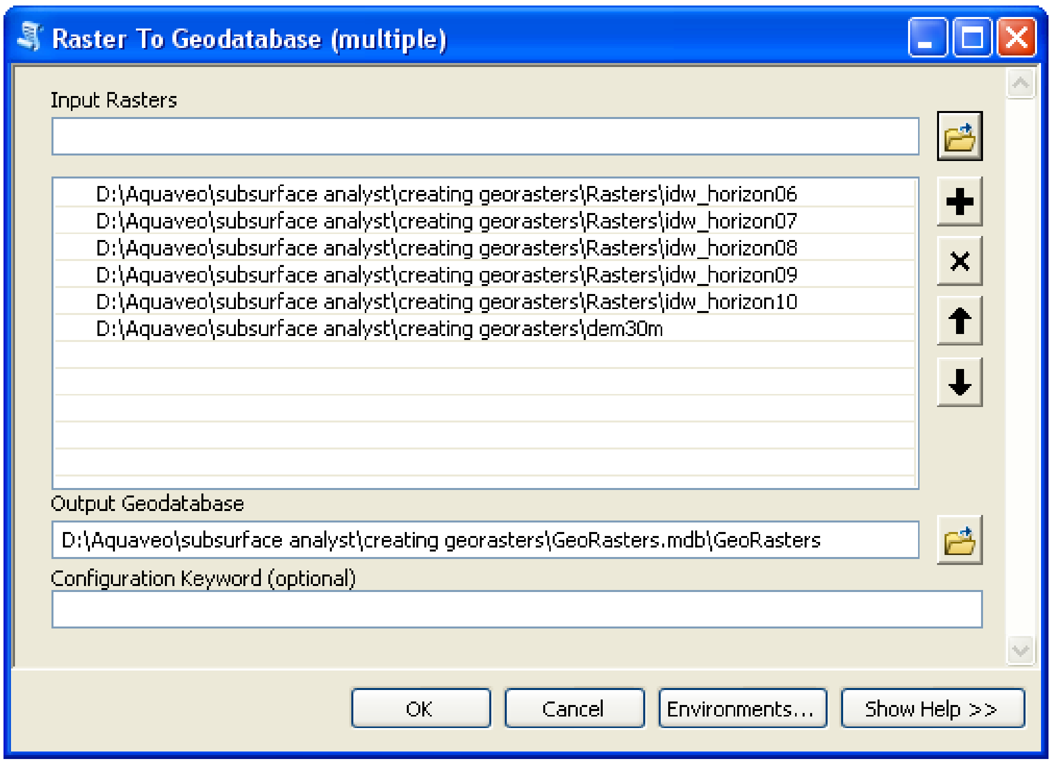
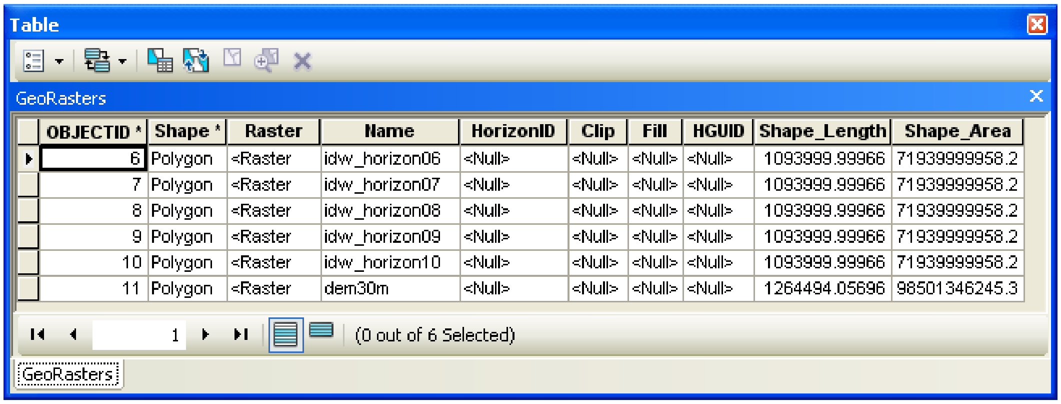


Figure 8 Inputs for the Raster To Geodatabase (multiple) tool.

4. Select **OK** to run the tool.

Once the tool has executed, you can open the GeoRasters raster catalog and see that the rasters were added to the raster catalog. Your raster catalog should be similar to the one shown in Figure 9.



Table

GeoRasters

	OBJECTID *	Shape *	Raster	Name	HorizonID	Clip	Fill	HGUID	Shape_Length	Shape_Area
▸	6	Polygon	<Raster	idw_horizon06	<Null>	<Null>	<Null>	<Null>	1093999.99966	71939999958.2
	7	Polygon	<Raster	idw_horizon07	<Null>	<Null>	<Null>	<Null>	1093999.99966	71939999958.2
	8	Polygon	<Raster	idw_horizon08	<Null>	<Null>	<Null>	<Null>	1093999.99966	71939999958.2
	9	Polygon	<Raster	idw_horizon09	<Null>	<Null>	<Null>	<Null>	1093999.99966	71939999958.2
	10	Polygon	<Raster	idw_horizon10	<Null>	<Null>	<Null>	<Null>	1093999.99966	71939999958.2
	11	Polygon	<Raster	dem30m	<Null>	<Null>	<Null>	<Null>	1264494.05696	98501346245.3

1 (0 out of 6 Selected)

GeoRasters

Figure 9 Example of a populated GeoRasters raster catalog.

Next, we will edit the attributes of the raster catalog to add the appropriate indexes.

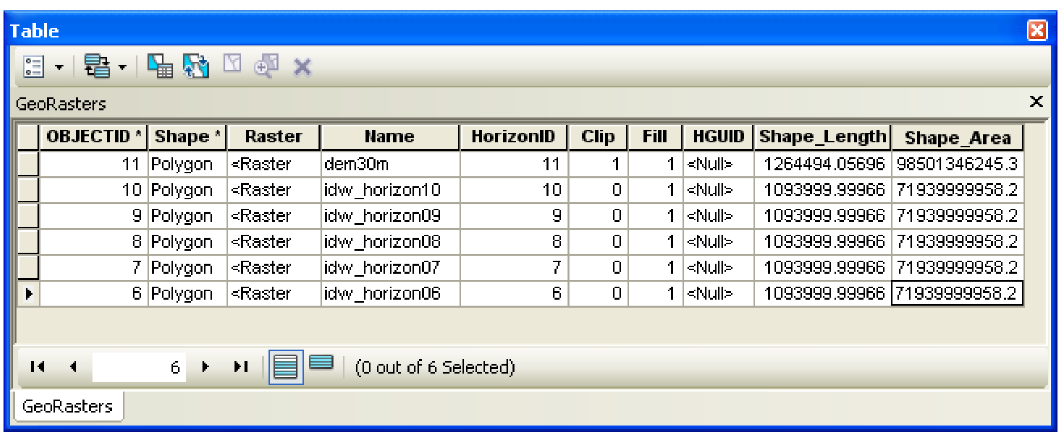
5. Start an edit session by selecting **Editor | Start Editing** command.

6. Edit the *HorizonID* attribute such that each raster is indexed with the appropriate horizon ID.

7. Edit the *Clip* and *Fill* attributes. Set the *Clip* attribute to 0 and the *Fill* attribute to 1.

8. For the DEM, set the *Clip* attribute to 1. A value of 1 means that when creating 3D fence diagrams and volumes features extending above the DEM will be clipped at the DEM elevation (for more details see a separate tutorial – Building 3D Models with the Horizons Method).

At this point your catalog attributes should be similar to the one shown in Figure 10.



Table

GeoRasters

	OBJECTID *	Shape *	Raster	Name	HorizonID	Clip	Fill	HGUID	Shape_Length	Shape_Area
	11	Polygon	<Raster	dem30m	11	1	1	<Null>	1264494.05696	98501346245.3
	10	Polygon	<Raster	idw_horizon10	10	0	1	<Null>	1093999.99966	71939999958.2
	9	Polygon	<Raster	idw_horizon09	9	0	1	<Null>	1093999.99966	71939999958.2
	8	Polygon	<Raster	idw_horizon08	8	0	1	<Null>	1093999.99966	71939999958.2
	7	Polygon	<Raster	idw_horizon07	7	0	1	<Null>	1093999.99966	71939999958.2
▸	6	Polygon	<Raster	idw_horizon06	6	0	1	<Null>	1093999.99966	71939999958.2

6 (0 out of 6 Selected)

GeoRasters

Figure 10 GeoRaster raster catalog after editing the HorizonID, Clip, and Fill attributes.

9. Save your edits by selecting the **Editor | Save Edits**.

10. Close the edit session by selecting the **Editor | Stop Editing** command.

7 Visualizing the rasters and points

To visualize the created rasters we will view them in ArcScene.

1. Close ArcMap.
2. Open the **GeoRasters.sxd** scene document.
3. Load the rasters previously interpolated in ArcMap into the scene.

To visualize the rasters based on the elevations, you will need to set the Base Heights for each raster.

4. Select a raster, right-click and select **Properties**.
5. In the *Base Heights* tab, for ArcGIS 10, select the option: *Floating on a custom surface.* In ArcGIS 9.3, select the option: *Obtain heights for layer from surface*. Then specify the appropriate raster (for each raster layer the custom surface is the raster itself, such that the raster will display in 3D using its values) as shown in Figure 11.

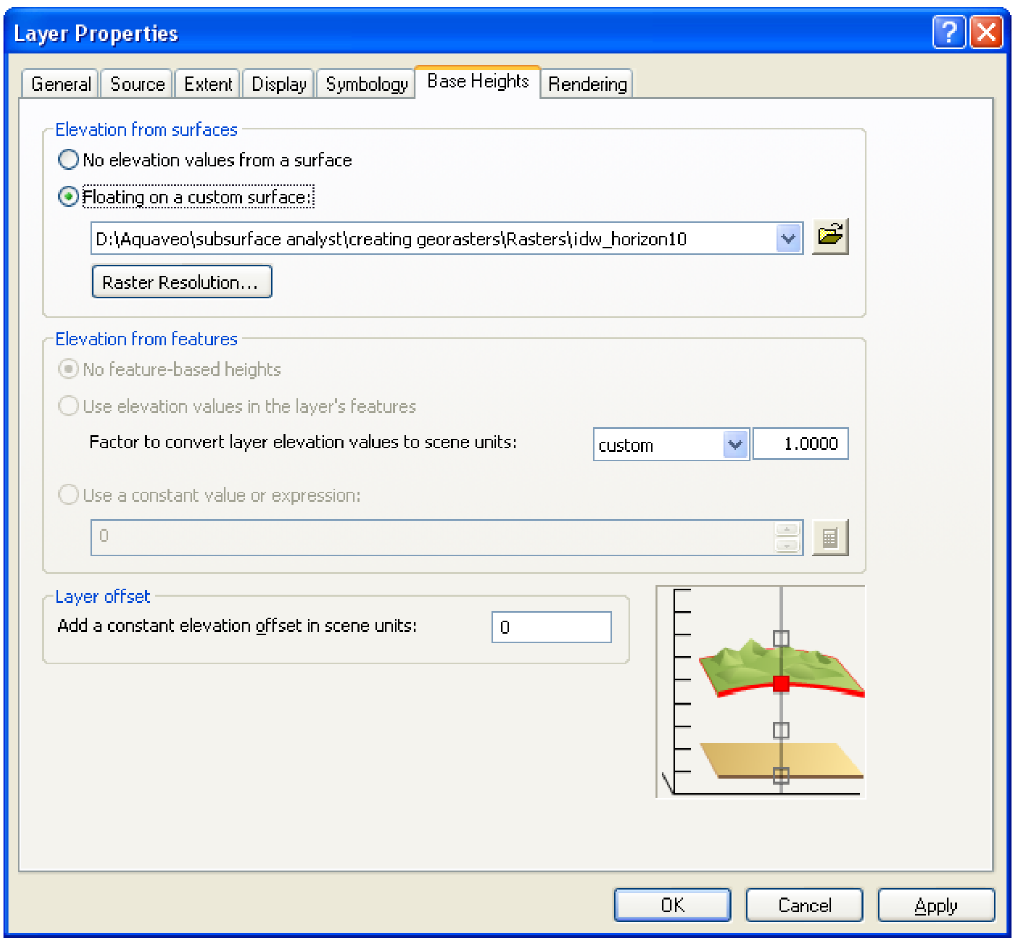


Figure 11 Setting the base heights for rasters in ArcScene.

6. Repeat steps 4 and 5 for each of the rasters representing horizons (if necessary also for the DEM raster).

7. Add the point features representing the horizons.

You can also change the colors of the rasters and points using the Symbology tab to better visualize the different horizons. At the end of this process you will be able to visualize the raster layers and points together as shown in Figure 12.

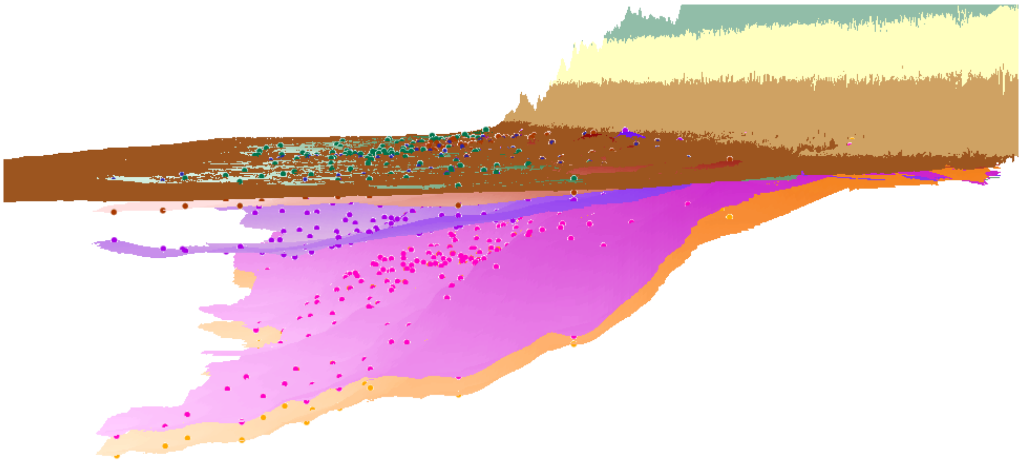


Figure 12 Visualizing rasters and points in ArcScene.

Based on the GeoRasters raster catalog 3D fence diagrams and volume models can be constructed. The creation of the 3D features is demonstrated in a separate tutorial.

8 Conclusion

This concludes the tutorial. Here are some of the key concepts in this tutorial:

- 3D BorePoint features can be created from tabular bore log data associated with well features.
- The *BoreholeLog Table To Points* tool is used to create 3D point features from tabular bore log data – a set of points can be created for each horizon in the subsurface model.
- The *Field Filter* is used to query for specific sets of points based on a HorizonID.
- Rasters representing top/bottom of units can be interpolated from the BorePoints.
- The rasters are loaded into the GeoRasters raster catalog and indexed with the appropriate HorizonID, Clip, and Fill attributes.
- The rasters and points created can be visualized in ArcScene.

