

Forest Inventory

Building an elevation surface

—by Glen Jordan

Introduction

Problem

Elevation data is very useful in forestry and natural resources management, especially in more rugged landscapes. It's a basis for delineating watersheds; generating viewsheds; determining depth to the water table; modeling animal habitats; laying out, designing, and costing roads; and scheduling site-aware harvests and silviculture, to name a few.

Until recently, however, reliable elevation data was difficult to acquire, expensive, and typically not very accurate. Today, accurate digital elevation data is widely available, often for free download over the Internet. Federal, provincial, and state government websites are primary sources of the latter.

Typically, elevation data are made available as spot observations across a geographic area. Most often, these elevation observations are acquired through some form of remote sensing. In the past, laborious aerial photo interpretation methods were often used to capture spot elevations. Today, airborne sensor systems, such as LiDAR (Light Detection and Ranging), are commonly used. Regardless, the raw data produced takes the form of x, y, and z observations, termed *mass points* or a *point cloud*.

Mass points by themselves, however, are of little use in the aforementioned applications, where a continuous elevation surface, or digital elevation model (DEM), is required. The latter may be implemented as a raster or triangulated irregular network (TIN). You can find much more detail about DEMs at the [Wikipedia](#) website.

How does one build a DEM from mass points?

Location

A small 1,400-hectare (ha) Woodlot in the Acadian-New England forest region of North America

Keywords: mass points; DEM; raster; TIN; creating a DEM from mass points; calculating a hillshade raster; creating an elevation raster from a TIN; deriving slope rasters; calculating contours

Time to complete the lab

Approximately three hours

Prerequisites

A basic working knowledge of geographic information system (GIS) technology, and ArcGIS® software in particular (ArcScene™ experience is useful, and previous exposure to the 3D Analyst™ extension is good too. Familiarity with the Woodlot geodatabase inventory is essential.)

Data used in this lab

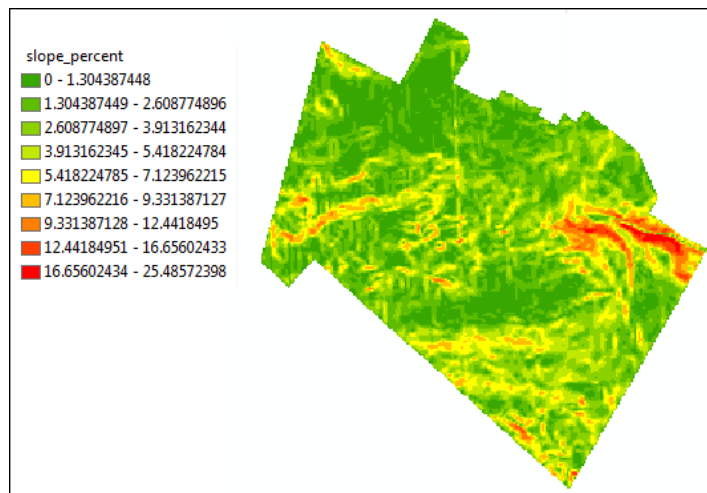
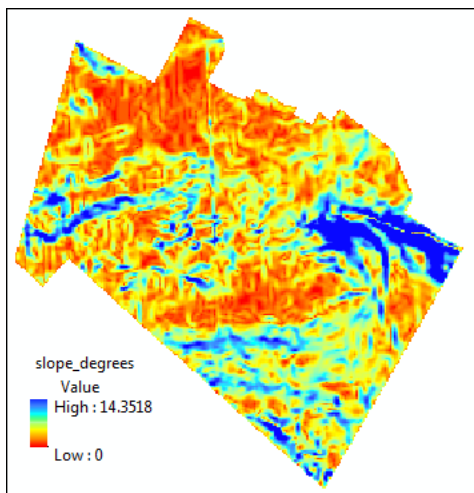
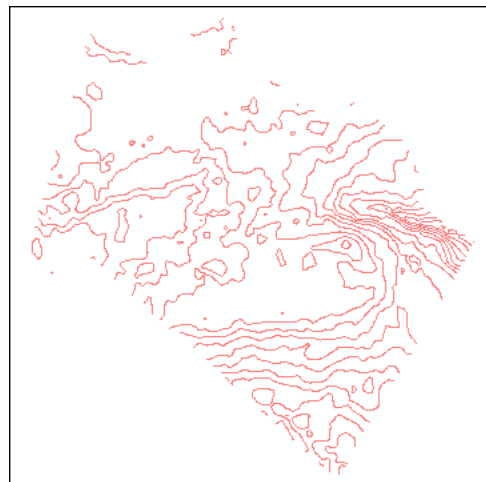
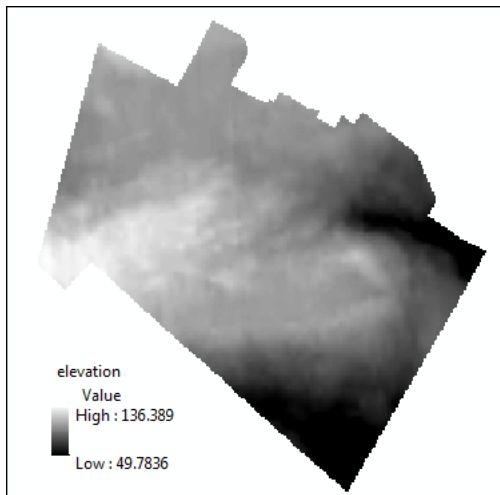
A mass points file and a personal geodatabase of several feature classes for a small (1,400 ha) Woodlot in the Acadian-New England forest region of North America (All data is NAD83 datum with New Brunswick Double Stereographic projection, unless otherwise stated.)

Student activity

In this exercise, you'll build a DEM raster from mass points, and from that, a hillshade raster. You'll map this data in 2D and 3D using ArcMap™ and ArcScene, respectively. You'll also compare the DEM raster with an existing Woodlot TIN derived from the same mass points. Last, you'll derive a DEM raster from the TIN and compile slope rasters, as well as a 5-meter (m) contours feature class.

Results expected

Rasters of elevation, slope, and a 5 m contours feature class



Data available

- Aerial photo-derived mass points for the Woodlot and surrounding area
- A TIN DEM for the Woodlot

Solution steps

1. Examine the mass points file.
2. Create a DEM raster from mass points.
3. View the DEM in 2D in ArcMap.
4. View the DEM in 3D in ArcScene.
5. Compare raster and TIN elevation surfaces.
6. View the Woodlot TIN in ArcScene.
7. Create an elevation surface raster from a TIN.
8. Create a slope surface and contours feature class.

EXAMINE THE MASS POINTS FILE

The Woodlot inventory holds a text file of comma-delimited mass points. Such files are commonly termed ASCII 3D files, since they contain not only x- and y-coordinate locations but also z-values (elevation, in this case) at the locations.

The mass points data was originally downloaded from the **Service New Brunswick** website as nine separate files, providing point elevations encompassing the Woodlot property and surrounding areas. The nine files were subsequently consolidated into a single large file for convenience.

RELATED CONCEPT: DIGITAL MAPPING—3D DATA

ArcCatalog™ cannot directly preview text files, but if you double-click a text file (.txt extension) in the catalog, it will open in Notepad.

- 1 In ArcCatalog, double-click the *DTM* file, located in the *Mass Points* folder.

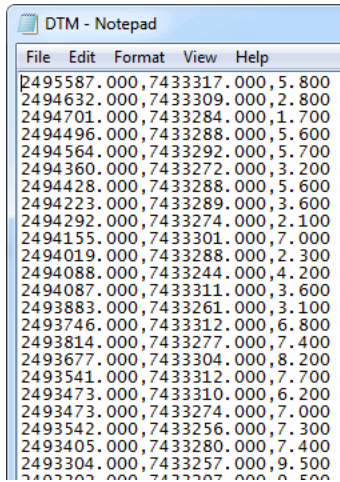


Figure 1. ArcCatalog uses Notepad to open text files.

The DTM file contains several thousand elevation observations for the Woodlot and surrounding area, interpreted from 1:10,000 aerial photography.

The underlying coordinate system, by the way, is the NAD83 New Brunswick Double Stereographic system. That and other details are found on the [Service New Brunswick](#) website.

How does one create a continuous elevation surface, or DEM, from these data? That's next.

CREATE A DEM RASTER FROM MASS POINTS

Of course, ArcGIS can't do much with text files of data, mass points or otherwise. It's built to process coverages, shapefiles, feature classes, rasters, and such. It's pretty straightforward, however, to create a 3D feature class from the mass point data. Once that's done, using it to build a DEM is easy.

RELATED CONCEPT: DIGITAL MAPPING—DEM RASTER

You'll need a couple of 3D Analyst tools.

- 1 Enable the 3D Analyst extension, if it isn't already, by clicking *Customize > Extensions*.

In rare cases, this may not make the 3D Analyst toolbox visible in ArcToolbox. If that happens, right-click in any blank space within ArcToolbox and select Add Toolbox. In the dialog box, navigate to C:\Program Files\ArcGIS\Desktop 10.0\ArcToolbox\Toolboxes and select 3D Analyst Tools.

- 2 If you haven't already, use *Environment Settings* to establish both your current and scratch workspaces as your *Woodlot* geodatabase.

- Now, using the *ASCII 3D To Feature Class* tool (*3D Analyst Tools » Conversion » From File*), create a feature class of mass points named *MassPoints* from the *DTM.txt* file.

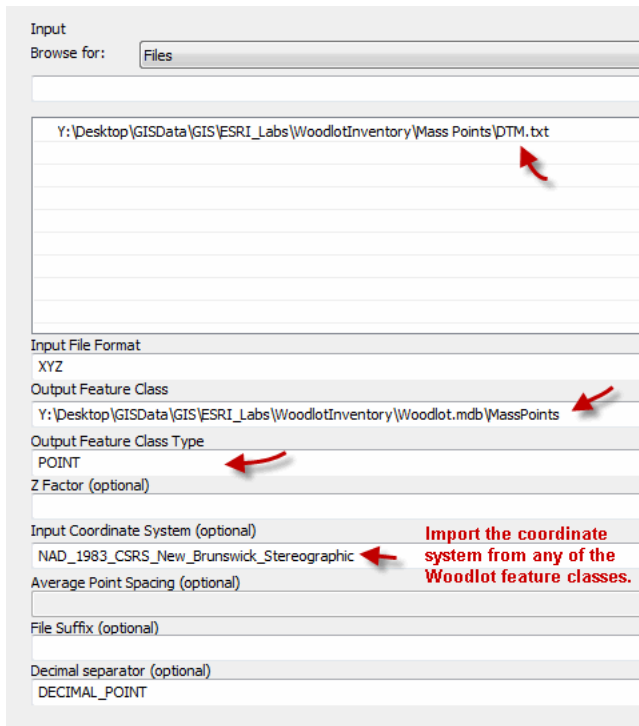


Figure 2. Create a 3D feature class from mass points data.

The tool may run for several minutes, depending on the processing speed of your computer.

In the end, it will produce a feature class that appears as a solid mass of points when previewed in ArcCatalog.

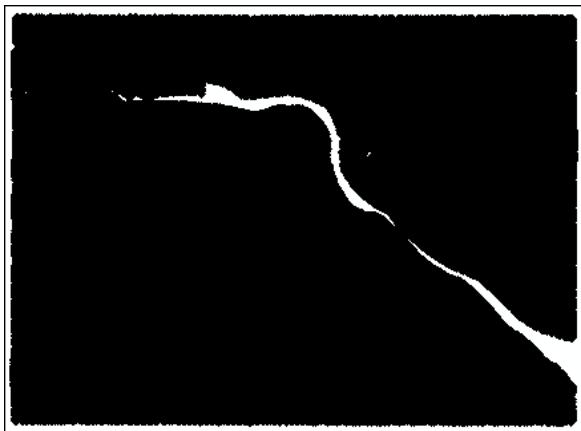


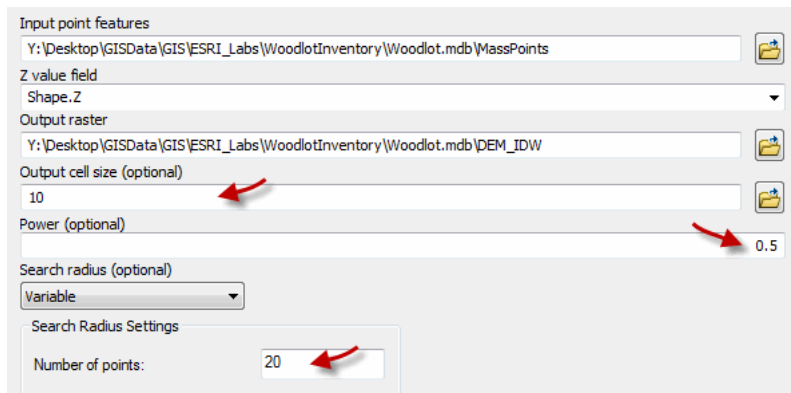
Figure 3. Preview the *MassPoints* feature class.

If you preview the attributes table, you'll note that there are more than 26,000 records. You'll also note that the Shape field contains entries of *Point Z*, indicating that features are 3D.

In any event, deriving a continuous elevation surface from these point elevations will require some form of interpolation. ArcGIS provides four different interpolation procedures for deriving raster surfaces from mass points—inverse distance weighted (IDW), natural neighbors, spline, and kriging. You can read more about these four at [ESRI Online Help](#).

Suffice it to say, IDW is particularly well suited for interpolating observations that are distance correlated and where the data are very dense. That fits your circumstance perfectly.

- 4 Run the *IDW* tool (*3D Analyst Tools » Raster Interpolation*) on the *MassPoints* shapefile, naming the output *DEM_IDW*. Enter a cell size of *10*, if necessary, and use a power value of *0.5*, with a variable search radius of *20* sample points.



Question 1: *Why are you using a cell size of 10 m by 10 m?*

Question 2: *What purpose does the Power value parameter serve?*

Figure 4. Create a DEM from mass points using the IDW interpolation method.

The result is an elevation surface, or DEM, containing elevation values for every 10 m by 10 m cell in the raster, calculated by interpolating across the array of more than 26,000 input elevation observations.

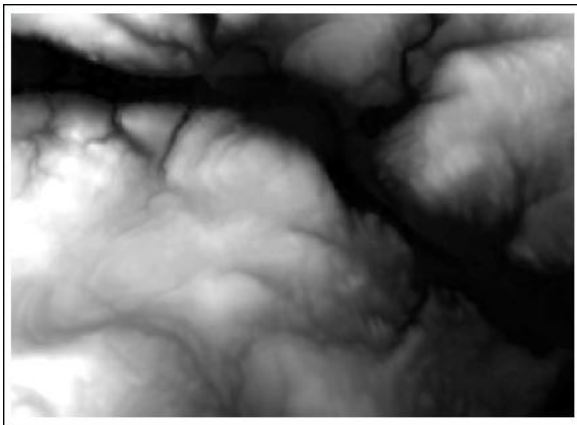


Figure 5. DEM for the Woodlot and surrounding areas.

Bear in mind, a DEM is indeed a model, in other words, a mimic of reality.

ArcCatalog is rather limited in displaying surfaces, even though it has a 3D preview option. ArcMap is more capable. We'll explore some of the possibilities next.

VIEW THE DEM IN 2D IN ARCMAP

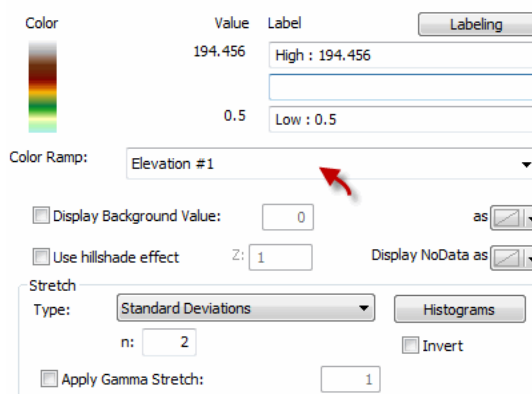
Even though ArcMap works only with 2D data, it is possible to fake a 3D perspective display. Here's how.

RELATED CONCEPT: DIGITAL MAPPING—DEM RASTER

- 1 Start ArcMap and add the *DEM_IDW* raster.

At this point, the display is no different than what you saw in ArcCatalog, except now a legend indicates that elevation values range from 0.5 m to 194.456 m. You can, however, add a 3D effect.

- 2 Symbolize *DEM_IDW* with the Elevation #1 stretched color ramp.



If you right-click the color ramp in the Symbology panel, you can switch between graphic and text views.

Figure 6. Select a color ramp by text name.

That gives your DEM a slight 3D perspective look.

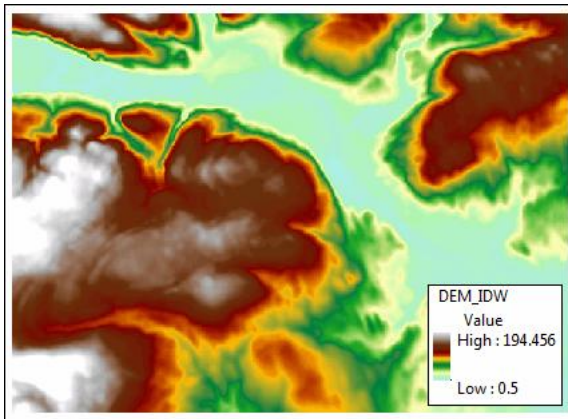
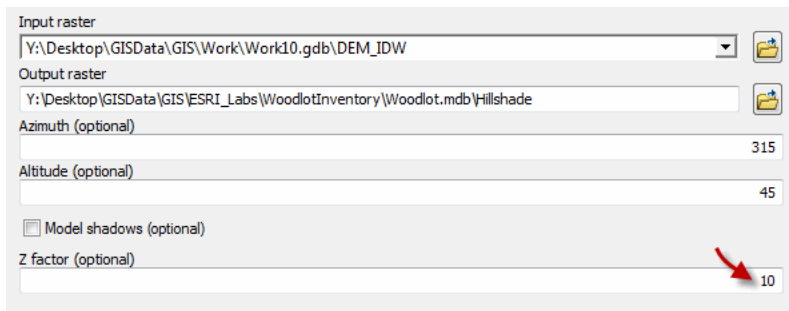


Figure 7. *DEM_IDW* displayed with Elevation #1 color ramp.

You can do better, though, by underlaying the DEM with a hillshade raster. Here's how that's done:

- Using the *Hillshade* tool (*3D Analyst Tools » Raster Surface*), build a hillshade raster for *DEM_IDW* named *Hillshade* with a vertical exaggeration (z-factor) of 10 m.



Question 3: What does the z-factor accomplish?

Figure 8. Create a hillshade raster from the DEM.

Shading definitely gives the *Hillshade* raster a 3D look, but its real utility is as an underlay for your DEM.

- Move the *Hillshade* layer below *DEM_IDW* and, so that the hillshade will show through, set the latter's transparency to 45 percent.

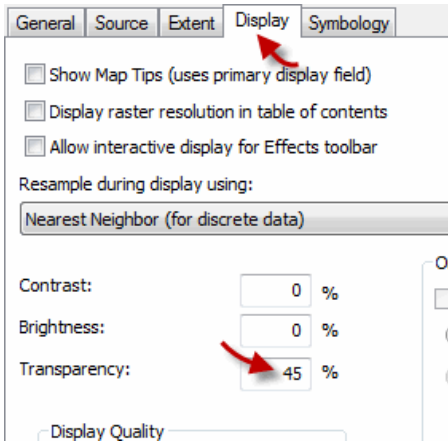


Figure 9. Set the *DEM_IDW* layer transparency to 45 percent.

That does a pretty good job of simulating a 3D perspective view.

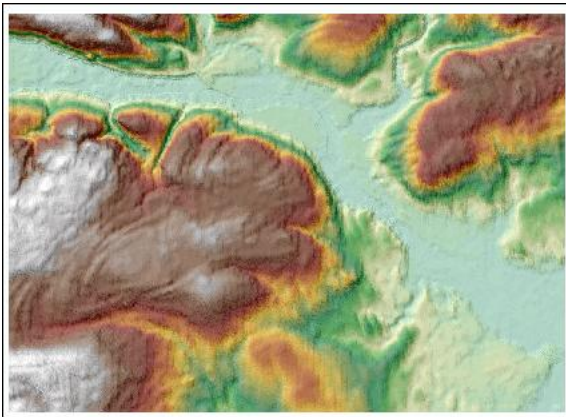


Figure 10. The hillshade effect simulates a 3D display.

Where, by the way, is the Woodlot property in all that?

- 5 Add the management compartments feature class (*compartment*) as a layer.

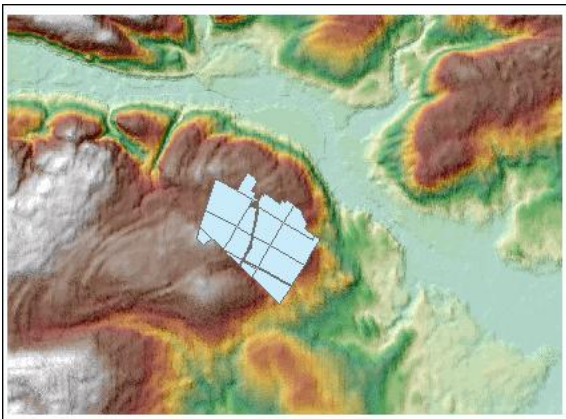



Figure 11. The location of the Woodlot property.

Compared to surrounding areas, the Woodlot appears to be located at a relatively high elevation, above a large valley. A large North American river, the St. John, flows through the valley. How would you determine that?

A topographic map would make the river and other topographic features obvious, but the Woodlot inventory does not contain such. The map is available, however, via ArcGISSM Online.

- Using the *Add Data* drop-down arrow , select *Add Basemap*.

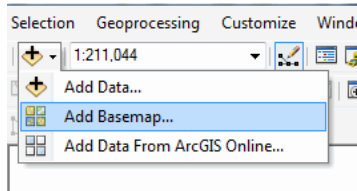


Figure 12. Access basemap data online from ArcMap.

That opens a window on imagery sources that you can add as layers.

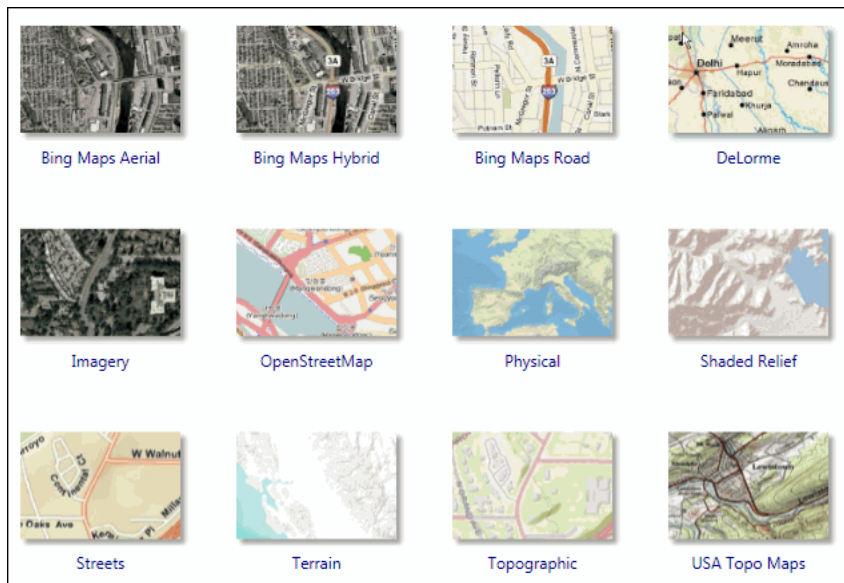


Figure 13. An array of basemap data can be added to an ArcMap document.

- 7 Select *Topographic*, then move the layer above *Hillshade* and zoom in a bit.

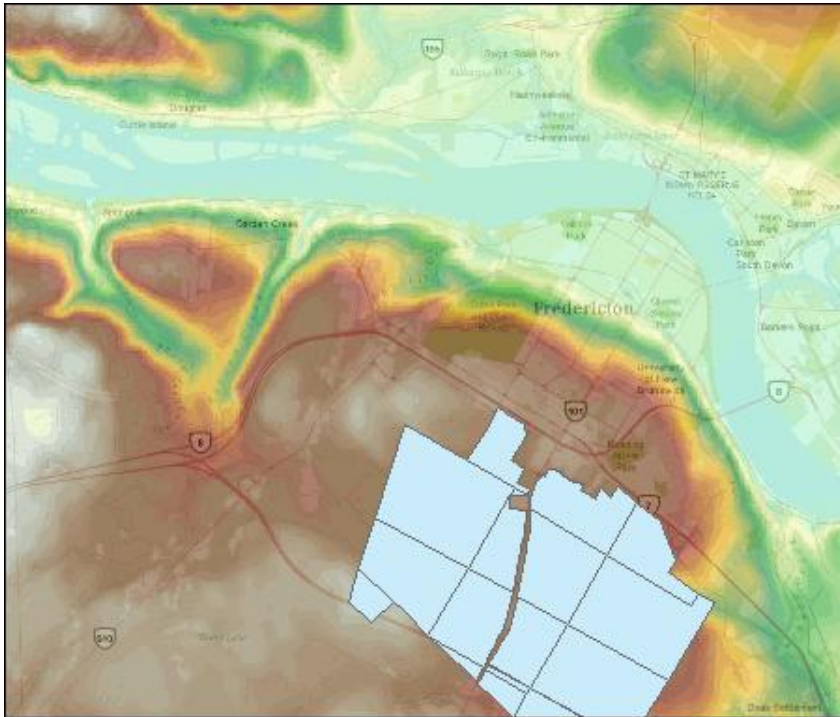


Figure 14. Woodlot property with an underlying hillshade and topographic map.

This gives you a better picture of the terrain surrounding the Woodlot and as close to 3D viewing as you can get in ArcMap.

If you want a real 3D perspective view, however, you'll have to use ArcScene.

VIEW THE DEM IN 3D IN ARCSCE

A specialty in ArcScene is displaying and processing 3D geographic data. That would include TINs, surface rasters like *DEM_IDW*, or 3D feature classes like the *MassPoints* feature class.

Have a 3D look at your *DEM_IDW* raster in ArcScene.

RELATED CONCEPT: DIGITAL MAPPING—DEM RASTER

- 1 Open ArcScene and add the *DEM_IDW* raster.

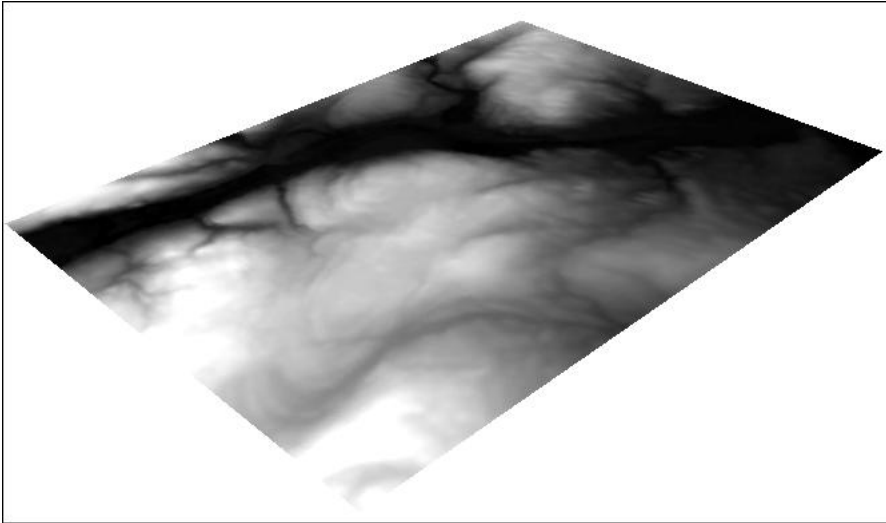



Figure 15. Display a DEM in 3D using ArcScene.

That's probably a big disappointment, even though the *Navigation* tool  will allow you to swivel the DEM in 3D. There's a relatively easy fix, though. First, double-click *DEM_IDW* and assign base heights using its elevation values.

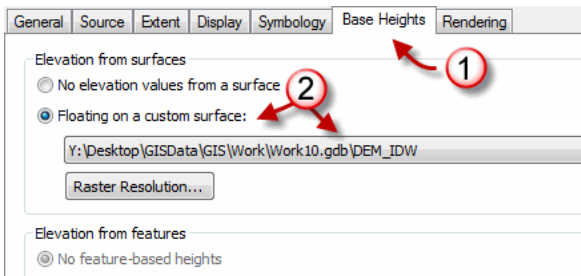


Figure 16. Add some 3D depth to the display of *DEM_IDW*.

That doesn't affect the display much, since there is very little variation in elevation in *DEM_IDW*. There's a fix for that too.

2 Double-click *Scene Layers* and set the z-value exaggeration to 10.

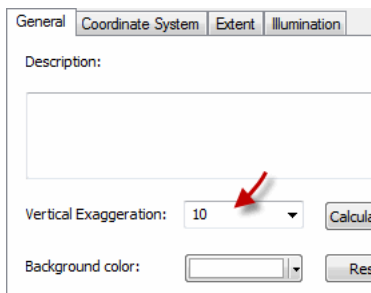


Figure 17. Set a vertical exaggeration of 10 for *DEM_IDW* display.

Now you have something that shows topographic relief.

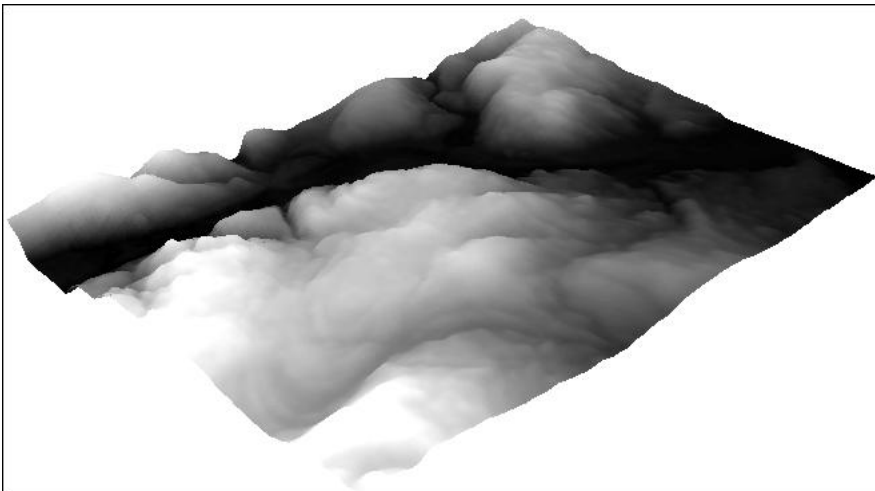


Figure 18. The vertical exaggeration effect.

The z-value exaggeration accomplishes the same thing the z-factor did earlier in constructing a hillshade raster: it exaggerates elevation values. This is useful where there is relatively little variation in elevation.

You can further enhance the display by symbolizing *DEM_IDW*, as you did earlier in ArcMap.

3 Symbolize *DEM_IDW* with the Elevation #1 stretched color ramp.

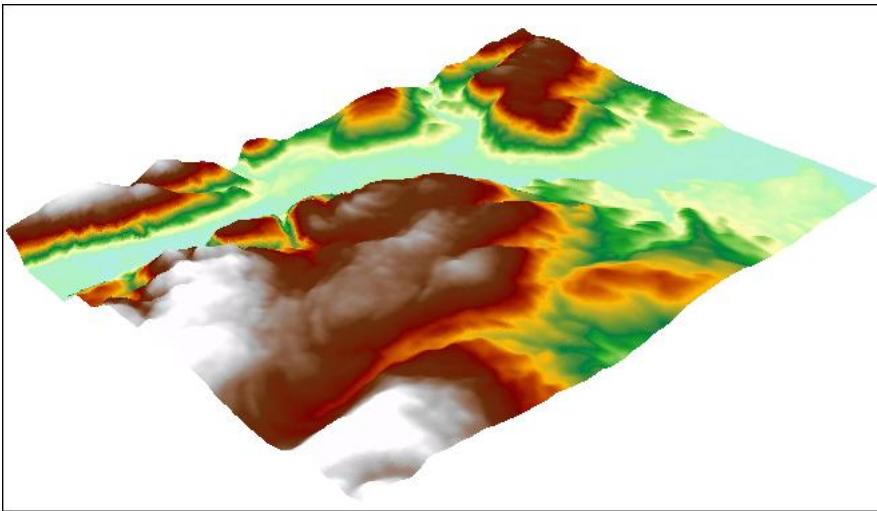


Figure 19. *DEM_IDW* symbolized with the Elevation #1 color ramp.

That's definitely superior to what you can achieve in ArcMap.

Now that you have the DEM nicely displayed in 3D, you can drape Woodlot 2D feature classes, or imagery, over it. Here's how that works:

4 Add the Woodlot management compartments feature class (*compart*).

Initially, the *Management Compartments* layer is hidden under the DEM, since it's a 2D feature class with no z-values (elevation, in this case) embedded.

What ArcScene will let you do, though, is assign z-values to *Management Compartments* using your DEM.

5 Simply double-click *Management Compartments* and assign base heights from *DEM_IDW*.

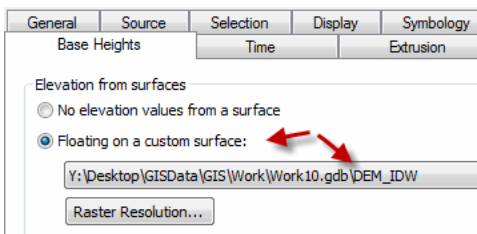


Figure 20. Draping *Management Compartments* over *DEM_IDW*.

If you zoom in, you'll see that this has the effect of draping *Management Compartments* over the DEM.

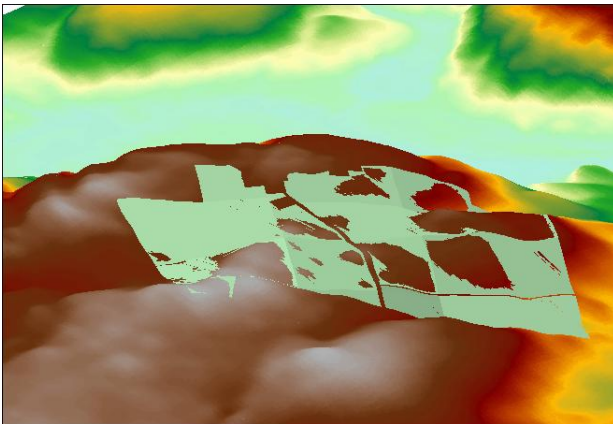


Figure 21. Woodlot management compartments draped over the DEM.

- 6 Symbolize *Management Compartments* with a hollow fill and a polygon border color of light blue.

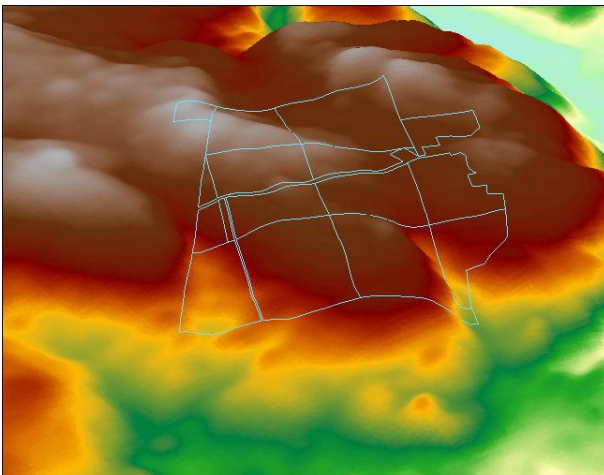


Figure 22. The Woodlot management compartment boundaries draped over the DEM.

- 7 Using the same procedure, you could drape other Woodlot feature classes, like *streams* and *basemap*.



Figure 23. Drape other Woodlot feature classes over the DEM.

As you can see, you don't necessarily have to display the DEM, even though it's the source of base heights.

ArcScene certainly adds another dimension to map display where surfaces are involved, but the greatest value of surfaces, like the raster DEM in this instance, is in the additional analyses that they allow when used with 3D Analyst or Spatial Analyst tools.

There is a problem, though.

A raster DEM might be fine for 3D display as illustrated previously, but where analysis of elevation data—contouring, cut and fill, slope, and aspect, for example—are required, a TIN is superior. Exploring that alternative is next.

COMPARE RASTER AND TIN ELEVATION SURFACES

The TIN is a fundamentally different way of modeling elevation surfaces. Rather than a regular grid of equal-sized cells, a TIN is composed of a myriad of triangles of various sizes, giving it the name "triangulated irregular network." However, each triangle has a constant slope and aspect. Elevation values vary from place to place within a triangle and must be interpolated from the known values at each of a triangle's three corners.

It might sound weird. Take a look and see for yourself.

RELATED CONCEPT: DIGITAL MAPPING—RASTER AND TIN

- 1 Start ArcMap and add the Woodlot *tin*.

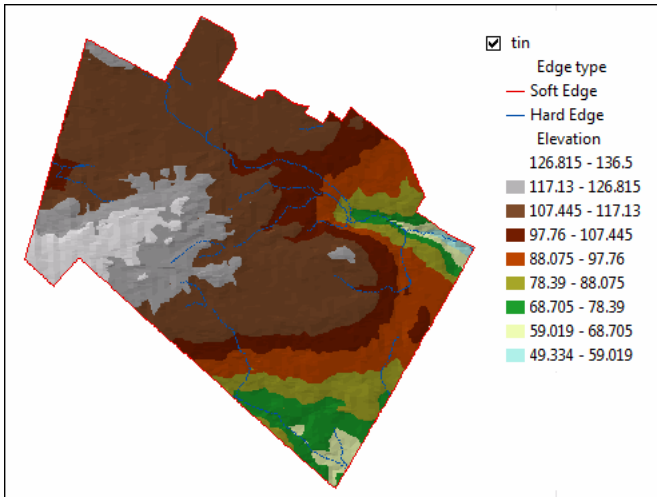


Figure 24. Woodlot *tin* displayed with default symbolism for elevation in ArcMap.

That produces a nice map of elevation, but aside from the smaller spatial extent and map symbolism, this doesn't appear much different from what you observed when displaying the *DEM_IDW* raster you created earlier.

Underneath, though, the TIN structure is very different.

- 2 Double-click *tin* and map just its edges, or triangle sides.

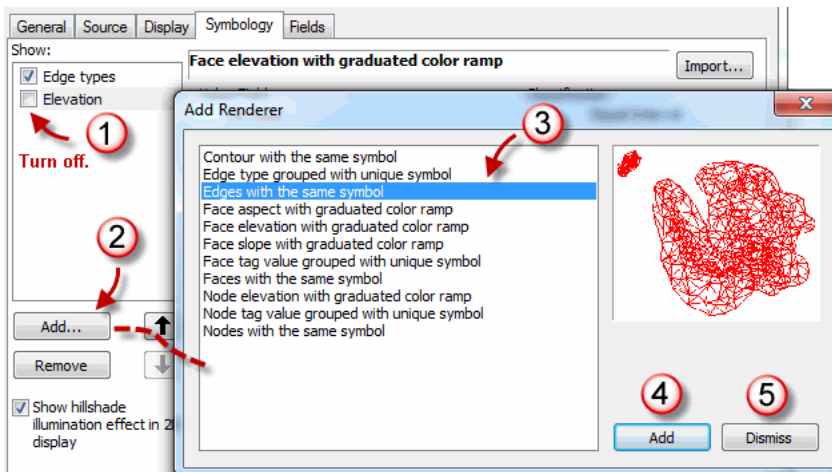


Figure 25. Map a TIN's edges.

If you zoom in, you'll see the thousands of triangles that make up the Woodlot's TIN.

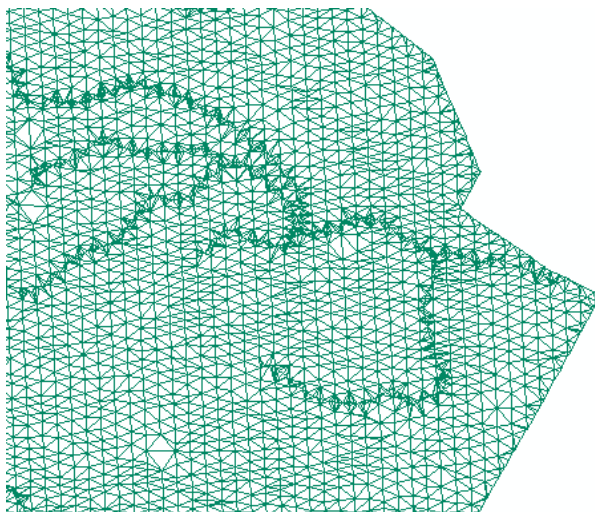


Figure 26. The triangles that make up the Woodlot TIN.

The TIN was created by joining the thousands of mass points in the *MassPoints* feature class. But, in the TIN-building process, Woodlot stream features were used as special edges whereby triangles never cross. This ensures that streams flow downslope in the DEM. Fully zoomed in, these special triangles are evident. Likewise, although it's not readily evident in the TIN display, Woodlot bog, marsh, and pond features were used to ensure that the areas they occupy have constant elevations.

These special construction features hint at the principal advantage TINs have over rasters when building a DEM. They build much better elevation models. Yet they may be viewed and mapped as easily as rasters in ArcMap or ArcScene.

VIEW THE WOODLOT TIN IN ARCSCE

Of course, like DEM rasters, TINs are most informative when displayed in 3D using ArcScene rather than in 2D in ArcMap.

RELATED CONCEPT: DIGITAL MAPPING—TIN DEM

- 1 In ArcScene, add the *tin* file, turn the *Management Compartments* layer off, and zoom in on the Woodlot *tin*.

The default display in ArcScene simply symbolizes the Woodlot TIN with red for soft triangle edges around the perimeter, blue for hard edges that define streams, and a graduated color ramp for all triangle faces.

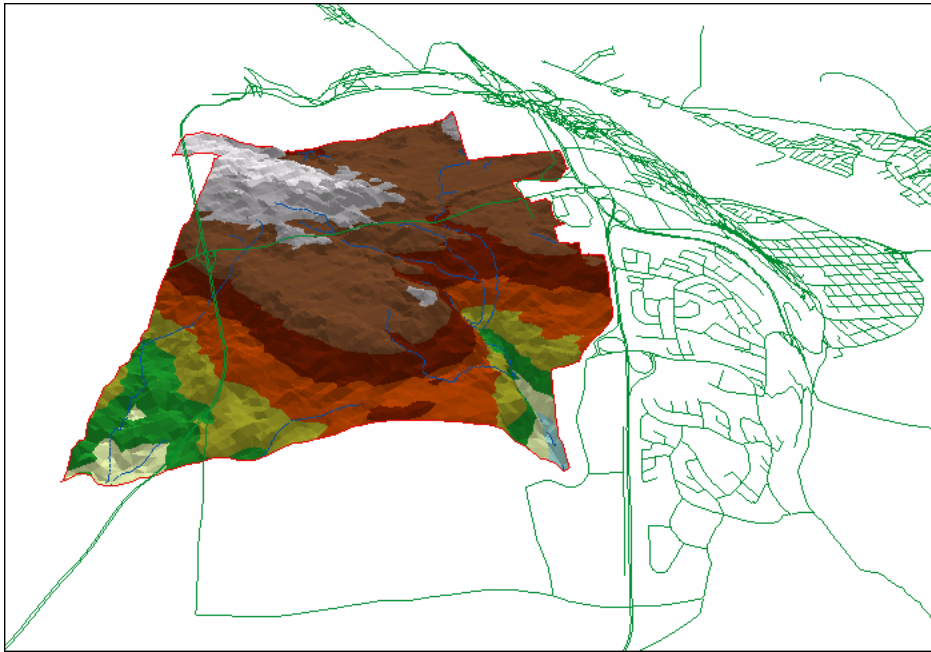


Figure 27. The Woodlot TIN displayed in ArcScene with default symbology.

You'll immediately notice that the display of elevation is not as smooth as your display of the *DEM_IDW* raster earlier. The irregular size and positioning of the TIN's triangles produce this effect. The regular grid of relatively small cells in a raster produces a smoother surface.

You may recall that the Woodlot TIN was constructed with constant elevations in areas where ponds, marshes, and bogs occur. So, if these features are draped over the TIN, they should lie flat.

- 2 Add the *cover* feature class and, using Definition Query, limit it to ponds, duck marshes, and treed bogs using the *TYPE* field.
- 3 Assign the *Cover Types* layer base heights from *tin*, not *DEM_IDW*.

- 4 Zoom in closer, and you'll see that the water bodies appear to lay flat, as they do in reality.

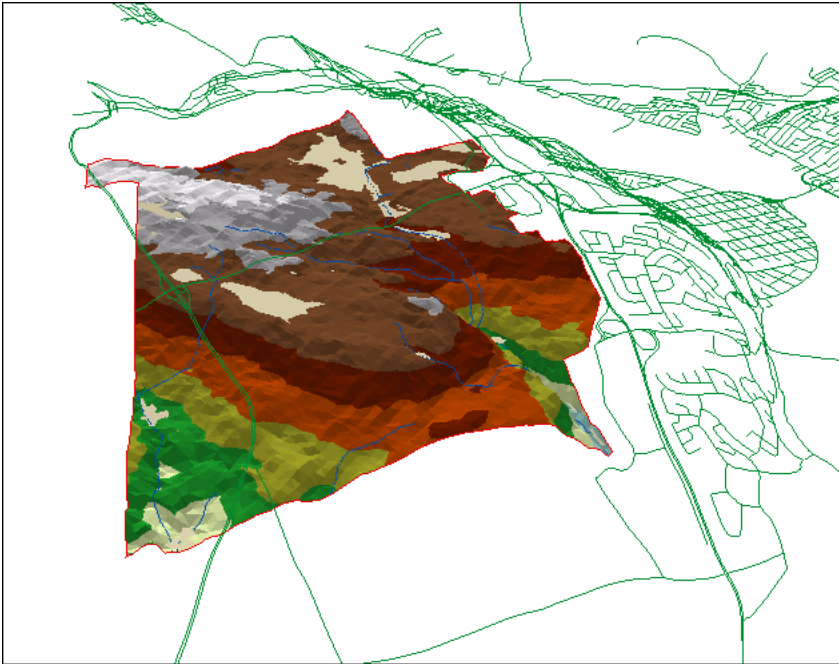


Figure 28. Woodlot water features draped over the TIN.

A TIN, unlike a raster DEM, also contains slope and aspect values for its triangle faces, as well as elevation values. They are easily displayed in 3D. Try doing that if you wish.

It seems there isn't anything that you can't do with a TIN in ArcMap or ArcScene that you can with a raster, but that's not exactly true.

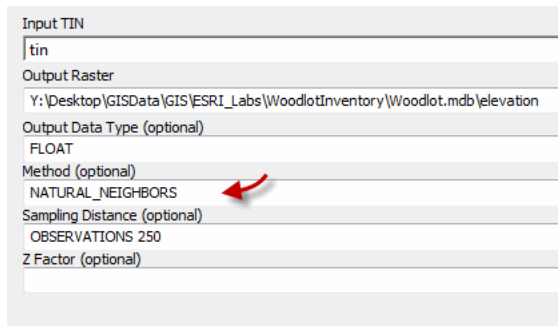
Unfortunately, whereas rasters support a rich array of spatial analysis tools available via 3D Analyst or Spatial Analyst, TINs do not. Fortunately, you can convert a TIN to a raster and have the best of both worlds.

CREATE AN ELEVATION SURFACE RASTER FROM A TIN

Deriving an elevation raster from a TIN is simple using a 3D Analyst tool.

RELATED CONCEPT: DIGITAL MAPPING—TIN TO RASTER

- Using the *TIN To Raster* tool in ArcToolbox (*3D Analyst Tools » Conversion » From TIN*), create a Woodlot raster DEM named *elevation*. Use the natural neighbors interpolation method.



The *TIN To Raster* tool will use a default cell size for the result raster.

Question 4: How would you determine what cell size it used?

Question 5: How could you force a specific cell size on the tool, such as 10 m?

Figure 29. Derive a raster DEM from the Woodlot's TIN.

That produces an elevation raster that reflects the more accurate TIN model yet may be manipulated with additional tools in Spatial Analyst.

The elevation raster isn't displayed in 3D at the moment, since it hasn't had base heights assigned.

- Assign *elevation* its own values as base heights.

If you turn *tin* off, you'll see the 3D display of elevation. It's apparent that it's much smoother than the TIN. That arose in interpolating *tin* elevations to arrive at raster cell values.

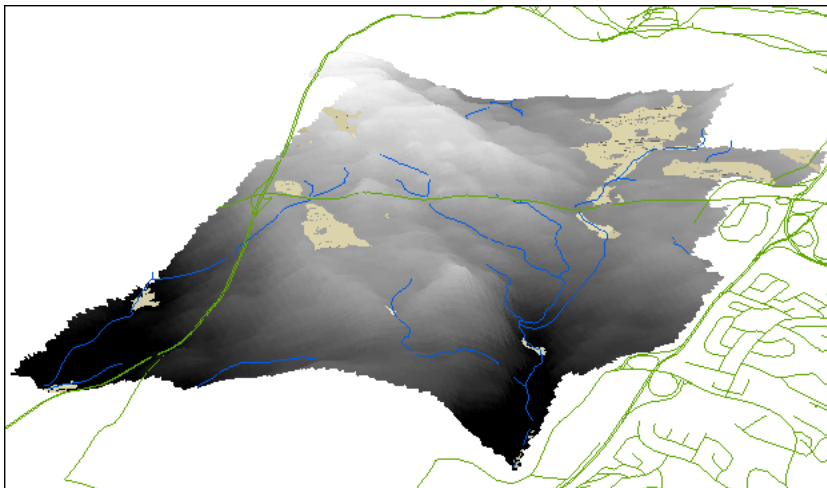


Figure 30. The *elevation* raster displayed in 3D appears smoother than the *tin* it was derived from.

As a result, the elevation raster is not an exact copy of *tin*. For example, you'll note that the range of elevation values is slightly different from the TIN—50 to 136.28 versus 49.33 to 136.5.

Slope and aspect surfaces are easily derived from the elevation raster. These are convenient to have on hand, as they prove useful from time to time in some forestry analyses such as habitat modeling.

CREATE A SLOPE SURFACE AND CONTOURS FEATURE CLASS

Compiling slope and aspect surfaces is a cinch using 3D Analyst or Spatial Analyst tools. Slope is perhaps the most useful in forestry applications.

Slope can be compiled in two ways—degrees and percent. Depending on the application, one or the other will be best or preferred, so it might be good to have both on hand.

RELATED CONCEPT: DIGITAL MAPPING—RASTER

- 1 Using the *Slope* tool in ArcToolbox (*3D Analyst Tools » Raster Surface*) and the *elevation* raster as input, create a slope surface in degrees. Name it *slope_degrees*.

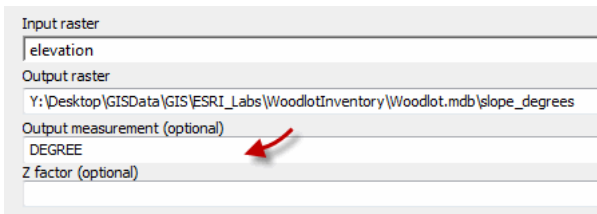


Figure 31. Create a slope raster from a DEM.

The slope raster again illustrates that the Woodlot is relatively flat except for an area in the northeast corner.

- 2 Repeat the process, but create a slope surface in percent this time. Name it *slope_percent*.

While you're at it, you might as well create a feature class of contours.

- 3 Using the *Contour* tool (*3D Analyst Tools » Raster Surface*), create a feature class called *contours* at 5 m intervals.

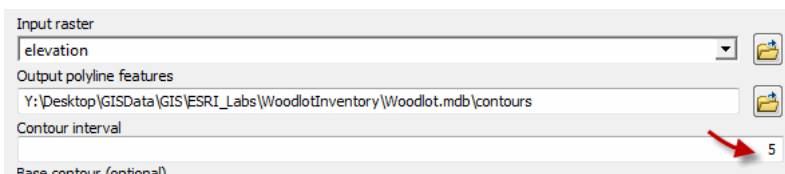


Figure 32. Create a 5 m contours feature class.

4 Assign base heights from *elevation* to display the contours in 3D.

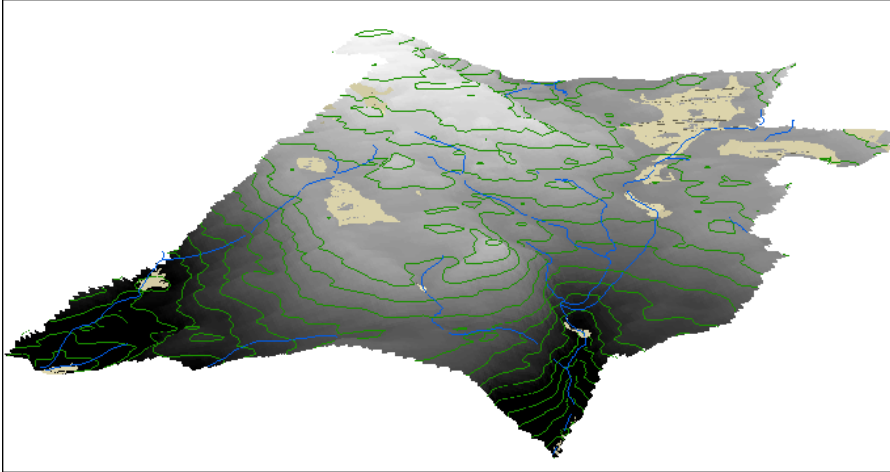


Figure 33. Contours (5 m) draped over the *elevation* surface.

Conclusion

The Woodlot inventory now has everything you'll likely need for spatial analysis involving terrain—watershed analysis, viewshed analysis, road construction cut and fill and grade analysis, animal habitat analysis, harvest and silviculture scheduling, and more.

Submit your work

Suggested student deliverables

- A DEM derived from mass points
- A DEM derived from the Woodlot inventory TIN
- Slope surfaces in degrees and percent derived from the DEM
- A 5 m contours feature class
- A paragraph describing the differences between a TIN DEM and a raster DEM
- A short paragraph discussing the pros and cons of TINs and rasters
- A short paragraph explaining the significance of the word *model* in DEM
- Answers to the questions posed in the exercise:
 - Why, when running the *IDW* tool, were you instructed to use a cell size of 10 m?
 - What purpose does the *Power* value parameter serve when running the *IDW* tool?
 - What does a z-factor, or vertical exaggeration, accomplish?
 - In the *TIN To Raster* tool, how would you determine what cell size it used?
 - How would you force a specific cell size on the tool, such as 10 m?
- A DEM constructed by locating and using a source of mass points data, or LiDAR data

Credits

Sources of supplied data

Course Data

Data\cover, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\highway, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\newprop, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\tin, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Woodlot.mdb, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Codes\Woodlot_Codes.xls, courtesy of University of New Brunswick UNB Faculty of Forestry and Environmental Management

Data\Coordinate Systems\ATS 1977 New Brunswick Stereographic.prj, courtesy of ESRI

Data\Coordinate Systems\NAD 1983 CSRS New Brunswick Stereographic.prj, courtesy of ESRI

Data\GPS\Knowledge.shp, courtesy of University of New Brunswick

Data\GPS\towers.xls, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Layer Files\Age Classes.lyr, courtesy of Glen Jordan

Data\Layer Files\Air Photo Centre Points.lyr, courtesy of Glen Jordan

Data\Layer Files\Main Roads.lyr, courtesy of Glen Jordan

Data\Layer Files\Mgt Compartments.lyr, courtesy of Glen Jordan

Data\Layer Files\Non-forested.lyr, courtesy of Glen Jordan

Data\Layer Files\Secondary Roads.lyr, courtesy of Glen Jordan

Data\Layer Files\Streams.lyr, courtesy of Glen Jordan

Data\Mass Points\DTM.txt, courtesy of Service New Brunswick

Data\Models\Clearcutting.tbx, courtesy of Glen Jordan

Data\Models\Forest Analysis.tbx, courtesy of Glen Jordan

Data\Models\Forest Values.tbx, courtesy of Glen Jordan

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