Working with Raster

Introduction: Raster Format

The second type of spatial data that is used in GIS is the raster format, which is one form of organization for spatial data. This type of format is suitable for continuous surfaces, such as temperature, elevation, moisture, and much others. Raster is a regular grid of mesh of cells (pixels) that laid over the landscape covering a specific area. The cells of the grid are organized in rows and columns.

Raster can be a satellite imagery, digital aerial photograph, digital picture, scanned map, and save image. The cell is the smallest unit of the raster and each cell has a value representing information, such as elevation. The cell is the fundamental unit of analysis in the raster system, and it represents a location in space. The condition of a given cell is recorded as a numeric value for each cell. The level of detail of features represented by a raster is often dependent on the cell size (spatial resolution).

Resolution means detail with which a map shows the shape and location of geometric feature such as a lake. Smaller cell sizes result in larger raster datasets to represent an entire surface; therefore, there is a need for greater storage space, which often results in longer processing time.

Feature Representation in Raster Format

A point in a vector representation can be approximately transformed to a single cell in a raster representation. Likewise, a vector line can be approximately transformed to a sequence of raster cells lying along that line, and a vector polygon can be approximately transformed to a zone of raster cells overlaying the polygon area. Like vector format, raster provides procedures for deriving new information by transforming or making associations of information from existing layers. GIS analysis using raster data is commonly used in environmental assessments. Raster processes are more commonly used because they can be significantly faster computationally than vector. This chapter consist of four sections and each section include different GIS exercises that deal with raster dataset.

Section 1: Data Download and Display in ArcMap

1.1. Downloading DEM Image from USGS Webpage
1.2. Explore the DEM image
1.3. Convert image from float to integer

Section 2: Projection and Processing Raster Dataset

2.1. Project an image
2.2. Clip an image
2.3. Merge raster datasets (Mosaic)
2.4. Resample an image
2.5. Classify an image
2.6. Convert Vector Feature into Raster

Section 3: Terrain Analysis

3.1. Create Hillshade
3.2. Create Contour
3.3. Create Vertical Profile
3.4. Create Visibility map
3.5. Create Line of Sight
3.6. Derive Slope and Aspect
3.7. Reclassify the Slope and Aspect
3.8. Combine the Slope and Geology

Section 1: Data Download and Display in ArcMap

Wisconsin

Statewide Data

Countywide Data

Douglas County, Wisconsin, United States

Digital Elevation Models (DEM) - 24K
Digital Line Graphs (DLG) - 100K

Download DEM Image from USGS Webpage

A popular site from where you can download images (DEM) and integrate directly into ArcGIS is the national map at USGS web page http://nationalmap.gov/. The national map from the USGS allows you to download a digital elevation map (DEM) that can be used directly in GIS.

Download Data from the National Map of USGS

1. Start the internet and in a web browser go to the web page: http://viewer.nationalmap.gov/
2. Under GIS Data title click Download GIS Data
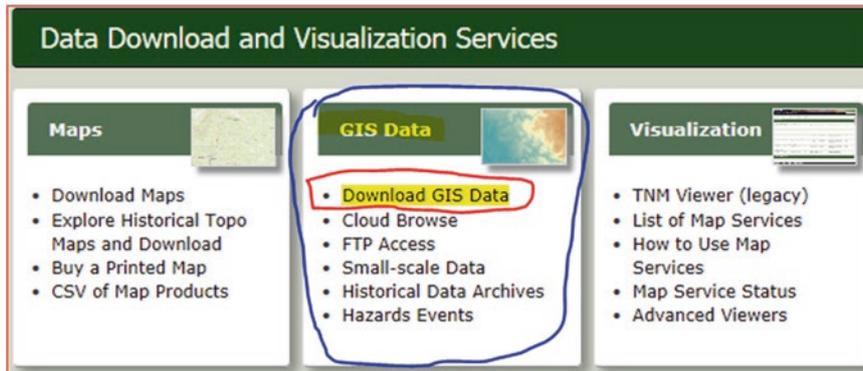
Result: USA map display with a menu and icons.
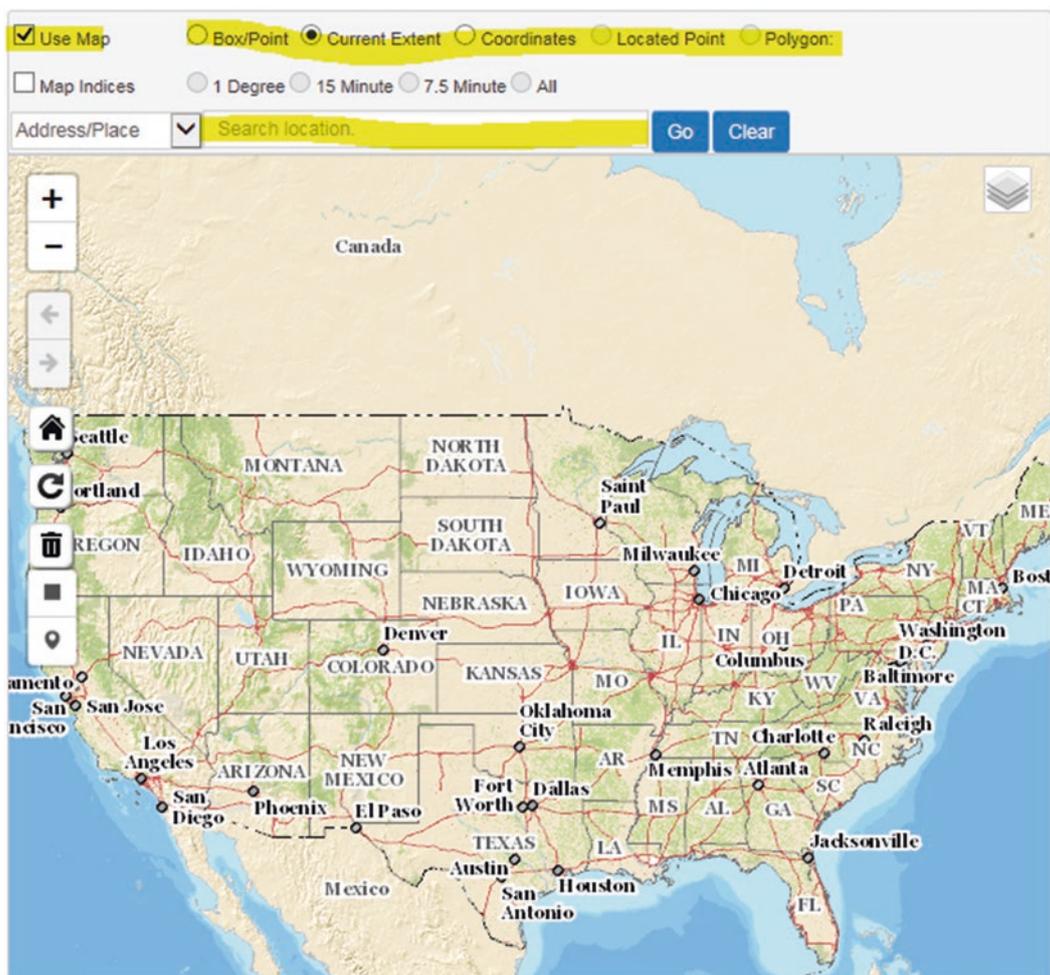
Note: Your area of interest can be found using different approaches, by drawing a box around your area of interest, or by coordinate location, but the easiest way is by search.

3. In the Search window type "Superior" and select Superior, WI, United States
4. The map zoom in the Superior, WI

Superior, Wisconsin, United States   Go   Clear

5. Click Go tab
6. A dialog box display shows the location of Superior, and its coordinates in Lon/Lat
7. On the left side of the screen, under Data, click the box next to **Elevation Products (3DEP)**
8. Click Find Product

Result: USGS NED 1/3 arc-second n47w093 1x1 degree ArcGrid 2016 displayed in the left panel.

9. Click **Download**
10. Browse and save it in \\Download\NED folder
11. Copy USGS_NED_13_n47w093_ArcGrid.zip from \\Download\NED folder
12. Paste it in \\Data01 folder

**Unzip the File**
13. R-click USGS_NED_13_n47w093_ArcGrid.zip/Point to WinZip*/Extract to here
*:- Or use any public domain free online unzip program (PeaZip or 7-Zip) to unzip the file

Explore the DEM Image

The "**grdn47w093_13**" DEM is a digital representation of cartographic information in a raster format. DEMs consist of a sampled array of elevations for a number of ground positions at regularly spaced intervals for the city of Superior, WI.

14. Launch ArcMap and call the data frame "**Raster**"
15. Integrate the "**grdn47w093_13**" from \\Data01\ folder (or \\Superior folder)
16. You will be asked to build pyramid
17. Click Yes to create the pyramid
18. The "**grdn47w093_13**" will display
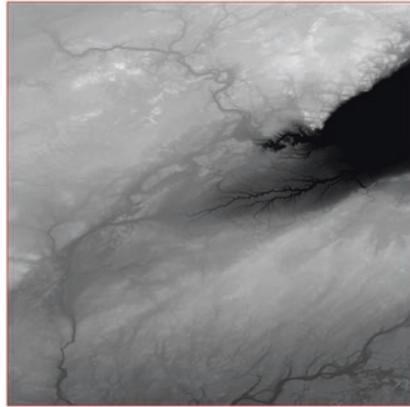
19. In the TOC, R-click the "**grdn47w093_13**"/Properties/click the Source tab
20. The raster property includes four sections that provide detail information about the raster:

First section: Raster Information: This shows that the DEM has 10812 columns and 10812 rows. It shows that the image consists of 1 band and the cell size (resolution) is $9.25.10^{-5} \times 9.25.10^{-5}$ decimal degree. It also indicates that the pixel type is a floating point, meaning that the attribute table of the raster can't be opened in ArcGIS. The pixel depth is 32 bit.

Raster Information	
Columns and Rows	10812, 10812
Number of Bands	1
Cell Size (X, Y)	9.2592593e-005, 9.2592593e-005
Uncompressed Size	445.94 MB
Format	GRID
Source Type	Elevation
Pixel Type	floating point
Pixel Depth	32 Bit

Second section: Extent: This shows the coordinate extent in lat/long.

Third section: Spatial Reference: This shows that the coordinate of the image is registered in GCS_North_American_1983.

Extent	
Top	47.000555555
Left	-93.0005555555
Right	-91.9994444451
Bottom	45.9994444446
Spatial Reference	
XY Coordinate System	GCS_North_American_1983
Linear Unit	
Angular Unit	Degree (0.0174532925199433)

• **Statistics**: This shows the minimum and maximum elevation of the area.

Question: download another image of your interest from http://viewer.nationalmap.gov/. Integrate it in ArcMap and explore it in the source tab. What is the difference between this image and the first image "**grdn47w093_13**" in terms of resolution, format, pixel type, band, and coordinate?

Convert Image from Float to Integer

The values of cells in an integer raster dataset consists of whole numbers and the raster has an attribute table. In a floating point raster, the values of a cell's data consists of numbers with a decimal and the floating raster has no attribute table. Integer values usually represent categorical data, and floating-point values represent continuous surfaces. Note that when converting from floating-point to integer data the following is happening:

1. The value of each cell changes from decimal point to integer (the decimal is simply truncated)
2. The size of the raster dataset will be reduced.
3. If the floating raster values are between 0 and 1, the conversion leads to a loss of information.

The "**grdn47w093_13**" is a floating point and has no attribute table and its cell values is between 176.637 feet (lower elevation) and 490.935 feet (higher elevation).

Int Tool

This exercise will convert the pixel type of "**grdn47w093_13**" from floating point into integer using the "**Int**" tool. The "**Int**" tool will convert each cell value of a raster to an integer by truncation.

21. Insert Data Frame and call it "Integer"
22. Drag the "**grdn47w093_13**" from the **Raster** data frame into the **Integer** data frame
23. Launch ArcToolbox/r-click an empty place below ArcToolbox
24. Click the Environment and click Workspace
25. Current Workspace: \\Ch12\Data01
26. Scratch Workspace: \\Ch12\Result
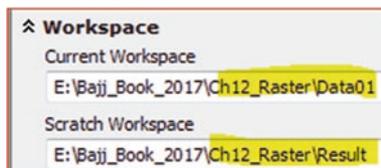
27. OK
28. ArcToolbox/Spatial Analyst Tools/Math/
29. D-click **Int** tool
30. Input Raster: **grdn47w093_13**
31. Output raster: **SupDEM_Int.tif**
32. OK
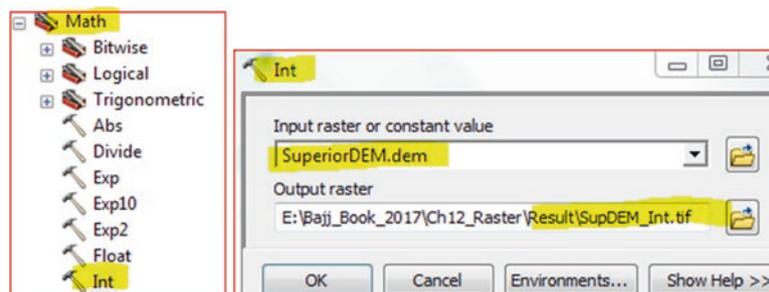
Question: What is the elevation of the "**SupDEM_Int**"?
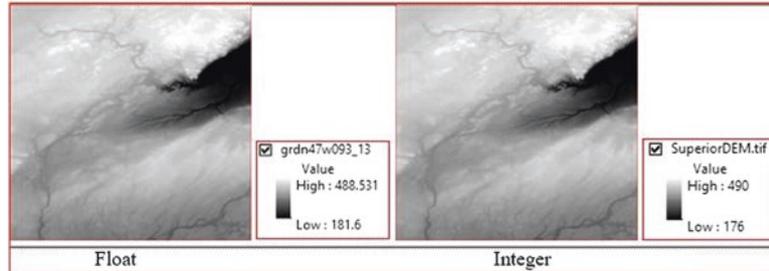

Section 2: Projection and Processing Raster Dataset

Project the DEM of an Area in the Amman-Zarqa Basin

ArcGIS can perform projection of vector and raster. This exercise deals with the international coordinate systems of Jordan. Jordan has specific datum and projected coordinate system. The projection is called the Palestine Projection, which is based on a custom "Transverse Mercator", and the parameters of the projection are listed below:

> False_Easting: 170251.55500000
> False_Northing: 1126867.90900000
> Central_Meridian: 35.21208056
> Scale_Factor: 1.00000000
> Latitude_Of_Origin: 31.73409694
> Linear Unit: meter

In ArcGIS the projection for Jordan is stored in the National Grids/Asia. In this exercise, you are going to project the image of AZ_DEM from GCS_WGS_1984 into Palestine Projection.

1. Insert Data Frame call it "Projection"
2. Integrate **az_dem** from \\Data02 folder
3. The **az_dem** has GCS_WGS_1984
4. Make sure that the ArcToolbox is active
5. ArcToolbox/Data Management Tools/Projections and Transformations\Raster
6. D-click Project Raster
7. Input Raster: az_dem
8. Output Raster Dataset: \\Result\AZ_DEM_PalUTM.tif
9. Output Coordinate System: Click the Spatial reference icon [icon], open Projected Coordinate Systems\open National Grids, open Asia\select Palestine 1923 Palestine Belt
10. OK
11. Geographic Transformation: select "**Palestine_1923_To_WGS_1984_1**"
12. Accept the default
13. OK
14. Save your map as Projection.mxd in \\Result
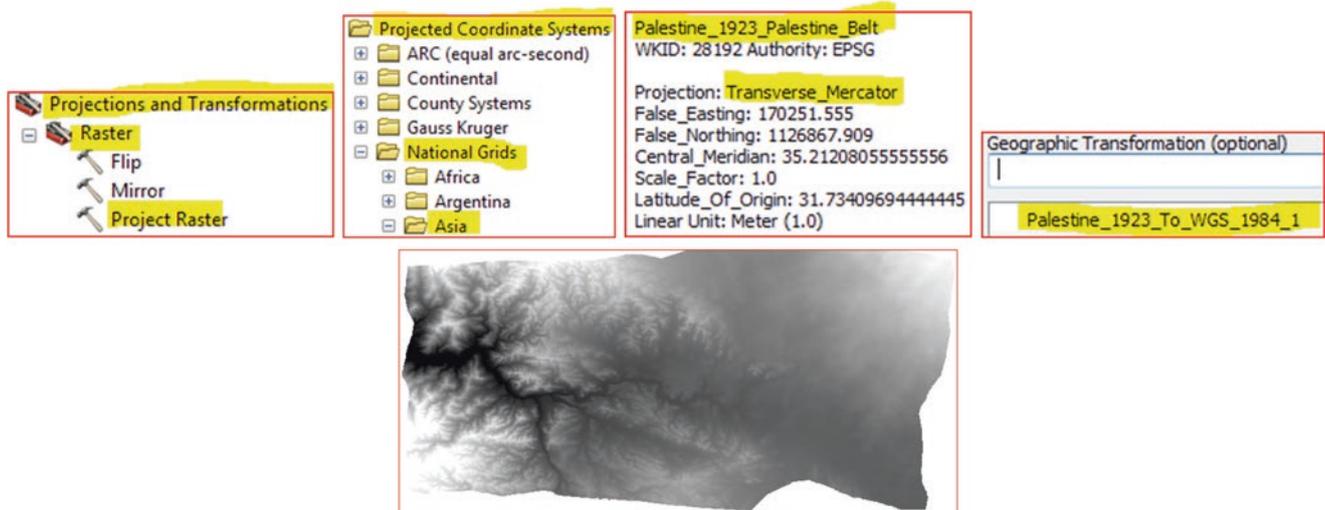
Question 1: What is the resolution of the AZ_DEM_PalUTM.tif?
Question 2: What is the Datum of the AZ_DEM_PalUTM.tif?

Clip an Image

The image (AZ_DEM_PalUTM.tif) that you projected in the previous section is covering a large area of the Amman-Zarqa Basin, and now you are interested in using the Clip Tool to cover only the Dhuleil area. In order to clip the image, you have created a shapefile (**StudyDhuleil.shp**) showing the area that you would like to use in order to clip the image.

1. Insert Data Frame and call it **Clip**
2. Drag **AZ_DEM_PalUTM** from the **Projection** data frame into the **Clip** data frame (or from \\Ch12\Output folder)
3. Add **StudyDhuleil.shp** from \\Data02
4. Click the symbol of the **StudyDhuleil.shp** in the TOC/select Hollow in Symbol Selector
5. Outline Width: 1, and Outline Color: red, click ok
6. ArcToolbox/Data Management Tools\Raster\Raster Processing\Clip
7. Input Raster: **AZ_DEM_PalUTM**
8. Output Extent: **StudyDhuleil**
9. Check Use Input Features for Clipping Geometry (Optional)
10. Output Raster Dataset: \\Result\Dhuleil.tif
11. Make Sure your Clip dialog box is filled as below
12. OK
13. Save your map as Clip.mxd in \\Result
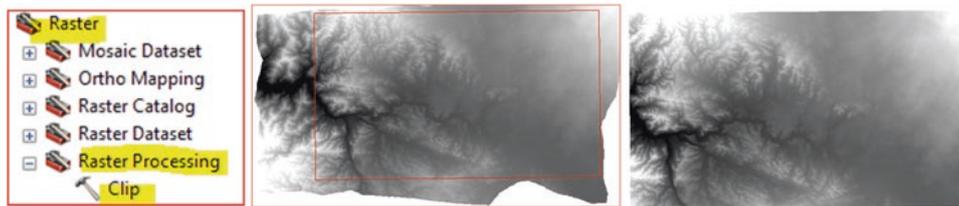
Result: The image is now clipped to the shape of the **StudyDhuleil**.**shp**.

Merge Raster Datasets (Mosaic)

This tool merges multiple raster dataset into a new raster dataset. To merge the raster datasets, they have to have the same number of bands, same pixel type, and the same pixel depth. When merging the raster dataset in a file format the extension should be specified. There are various extensions that users can choose from and the most popular formats are *.bil* (ESRI BIL), *.bmp* (BMP), *.gif* (GIF), *.png* (PNG), *.tif* (TIFF), *.jpg* (JPEG), *.img* (ERDAS IMAGINE). The extensions will not be added to the name of the raster when raster dataset stored in a geodatabase. In this example we are going to merge **Dhuleil. tif** raster with **KTDam** raster.

14. Insert Data Frame and call it **Mosaic**
15. Integrate into the **Mosaic** data frame **Dhuleil.tif** and **KTDam** raster from \\Data02 folder
16. In the Tools toolbar click Full Extent icon
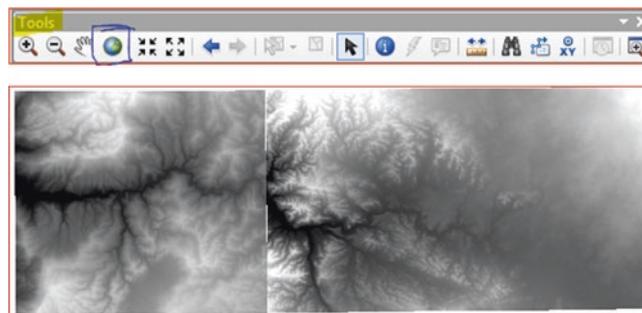
17. R-click the **Dhuleil** raster/Properties/Source and write down the following:
    a. Number of band:
    b. Pixel Type:
    c. Pixel Depth:
18. Repeat the same for the **KTDam** raster
    a. Number of band:
    b. Pixel Type:
    c. Pixel Depth
19. ArcToolbox/Data Management Tools/Raster/Raster Dataset/Mosaic To New Raster
20. Input Rasters: ktdam and Dhuleil.tif
21. Output Location: \\Result
22. Raster Dataset Name with Extension: Dhul_KTDam.tif
23. Spatial Reference for Raster: Click the Spatial reference/Click Add
    coordinate System drop down arrow 🌐 ▾, point to import/browse to \\Data02/select and select KTDam/Add/OK

Note: The coordinate is Palestine_1923_Palestine_Belt.

24. Pixel Type: 16_BIT_SIGNED

25. Number of Bands: 1
26. Accept the rest of the default
27. OK
28. Save your map as Mosaic.mxd in \\Result
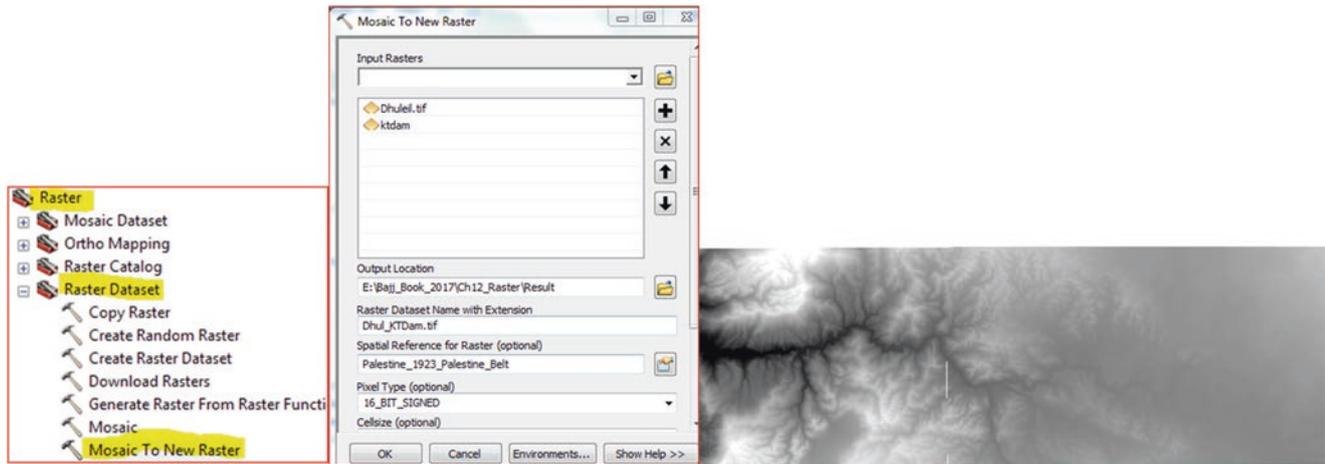
Result: The mosaic raster created from ktdam and Dhuleil.tif as both raster merge together and become one raster.

Resample an Image

Resample tool allows the user to change the resolution of the raster. The cell size can be changed either to a higher or lower resolution, but the extent of the raster dataset will remain the same. The output raster can be saved to any of these formats: BIL, BIP, BMP, BSQ, DAT, Esri Grid, GIF, IMG, JPEG, JPEG 2000, PNG, TIFF, or any geodatabase raster dataset.

There are four options for the Resampling Technique parameter: Nearest, Majority, Bilinear, and Cubic. In this exercise, you are going to use bilinear method and change the resolution (cell size from lower to higher) from 85.72 m into 5 m.

1. Insert Data Frame and call it **Resample**
2. Drag **ktdam** raster from the **Mosaic** data frame into the **Resample** data frame (or \\Data02)
3. R-click **ktdam** raster/Properties/Source
4. Under Raster Information you see that the Cell Size is 85.718 m

Raster Information	
Columns and Rows	377, 338
Number of Bands	1
Cell Size (X, Y)	85.71874745, 85.71874745

5. Close the Layer Properties dialog box
6. ArcToolbox/Data Management Tools/Raster/Raster Processing/Resample
7. Input Raster: **ktdam**
8. Ouput Raster Dataset: \\Result\ktdam_5
9. Output Cell Size: X = 5, Y = 5
10. Resampling Techniques: Bilinear
11. OK

12. R-click **ktdam_5** raster/Properties/Source
13. Under Raster Information you see that the Cell Size is 5 m
14. Save your map as Resample.mxd in \\Result folder
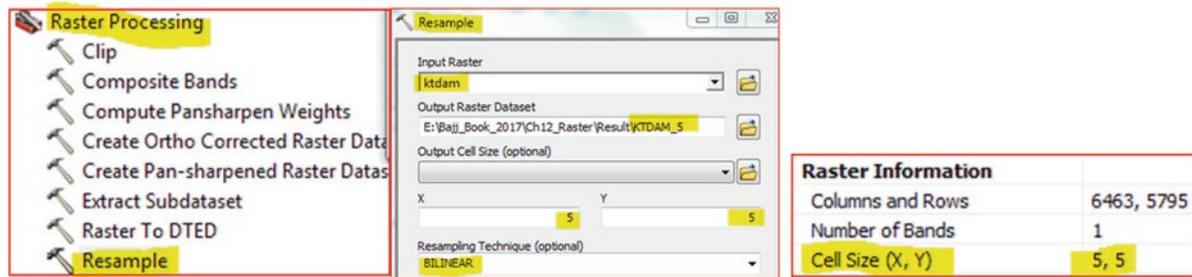
Classify an Image

The classification provides different color to the DEM image

15. D-click **ktdam_5** image/Symbology
16. Make sure the Stretched is selected under the Show:
17. R-click the Color Ramp/Uncheck the Graphic View
18. Scroll down and select Elevation 1
19. OK
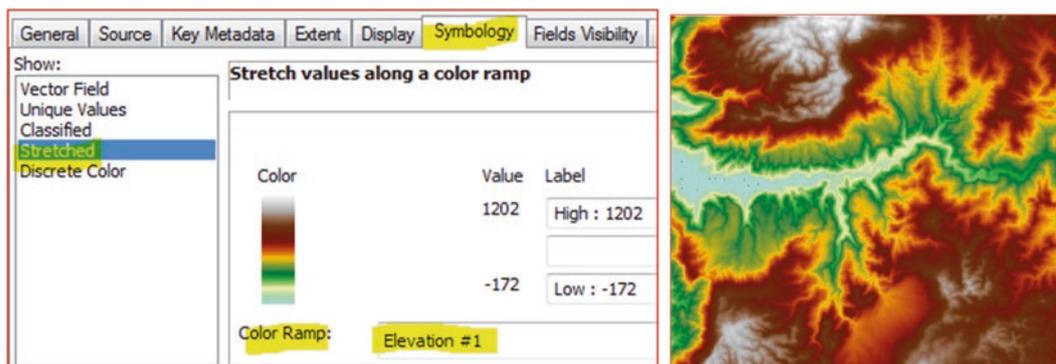
Convert Vector Feature into Raster

The Feature to Raster tool in the Conversion Tools converts features to a raster dataset. Any feature class (geodatabase, shapefile, or coverage) containing point, line, or polygon features can be converted to a raster dataset. This tool is similar to the Polygon to Raster and it always uses the cell center to decide the value of a raster pixel. The tool will be used to convert the geology of Dhuleil area into raster.

20. Insert Data Frame and call it Geology

21. Integrate the Geology.shp from \\Data02 folder
22. D-click Geology layer/Symbology/Categories and select unique value
23. Value Field = Lithology/click Add All Values
24. Ok
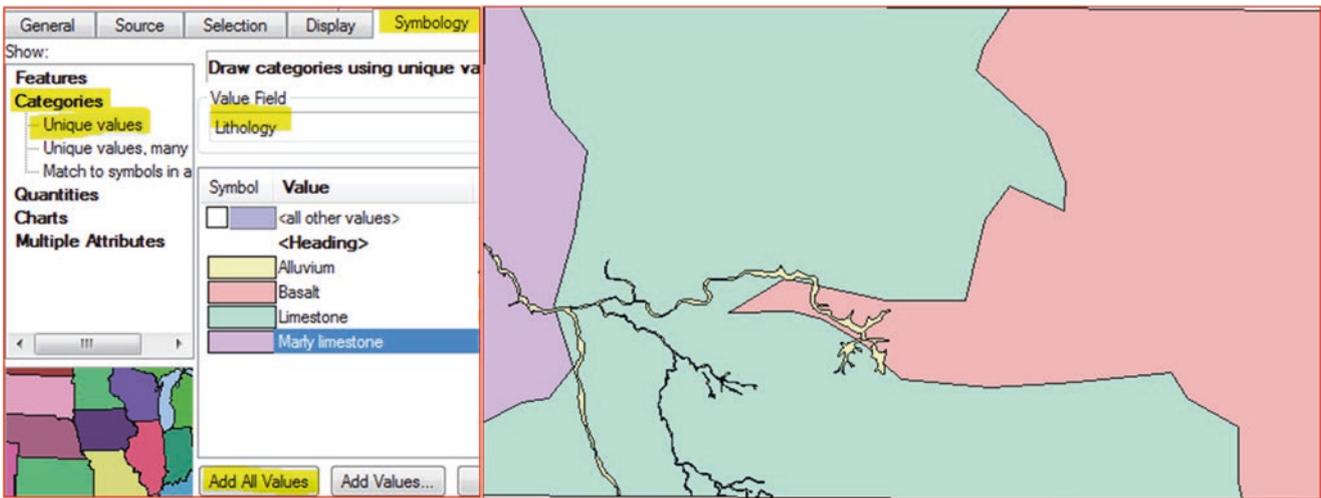
25. ArcToolbox/Conversion Tools/To Raster
26. D-Click Polygon to Raster
27. Input Features: Geology
28. Value field: Lithology
29. Output Raster Dataset: \\Result\Geology.tif
30. Cell assignment type Cell_Center
31. Cellsize: 100
32. OK
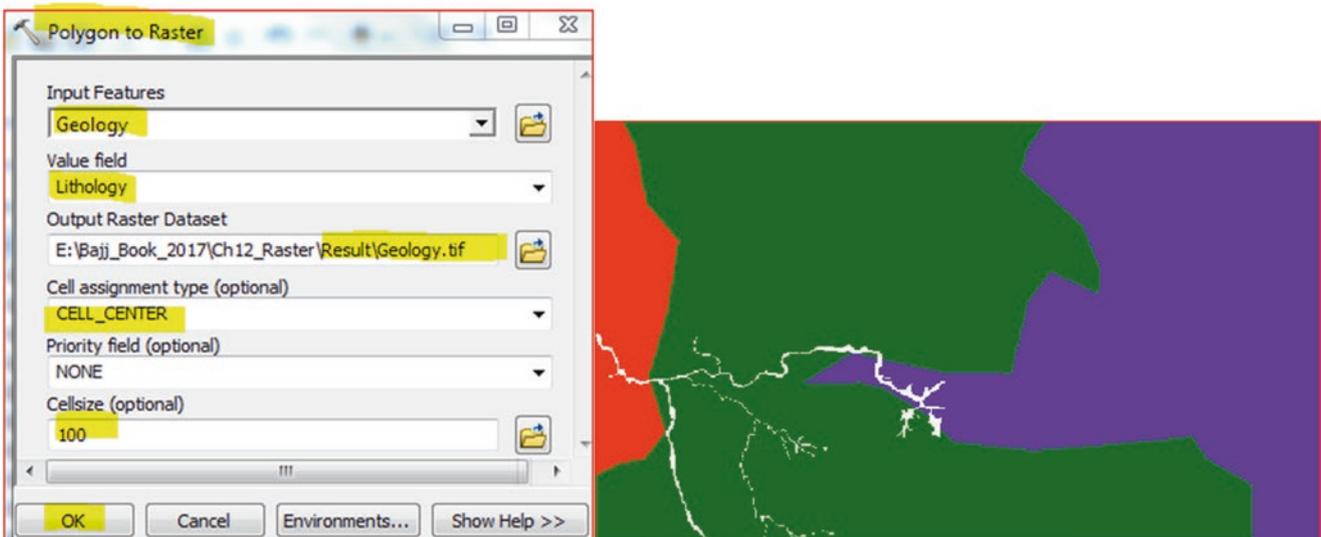
Result: The geology.tif is created with the lithology that consists of 4-geological formations.

## Section 3: Terrain Analysis

Create Hillshade

DEM is an excellent raster format that can be used for different terrain analysis. In this exercise you are given a DEM that covers the Dhuleil area. The area is part of the Amman-Zarqa Basin, which is considered one of the most important ground-water basins in Jordan. You have been asked to create a hillshade using the Dhuleil DEM.

The Hillshade tool in ArcGIS creates a shaded relief raster from a DEM raster. The DEM contains all the 3D information about the terrain, but it doesn't look like a 3D object. To get a better expression at the terrain, it is possible to calculate a hillshade, which is a raster format with a 3D-looking image. The Hillshade is a hypothetical illumination of a surface based on a given azimuth and altitude for the sun. It creates a 3-D effect that provides a sense of visual relief for the terrain and is considered the most common way to visualize texture. Using a hillshade enhance the topography of the landscape.

33. Insert Data Frame and call it Hillshade
34. Integrate the DEM of **Dhuleil.tif** from the \\Data02 folder
35. D-click **Dhuleil.tif** image/Symbology
36. Make sure the Stretched is selected under the Show:
37. R-click the Color Ramp/Uncheck the Graphic View
38. Scroll down and select Elevation 1
39. OK
40. Make sure Spatial Analysts are available (Customize/Extensions/check Spatial Analyst)
41. ArcToolbox/Spatial Analyst Tools/Surface/Hillshade
    a. Input Surface: **Dhuleil.tif**
    b. Output raster: \\Result\HillShade.tif
    c. Accept the Default 315 (azimuth), 45 (altitude), and 1 (Z factor)
42. Ok
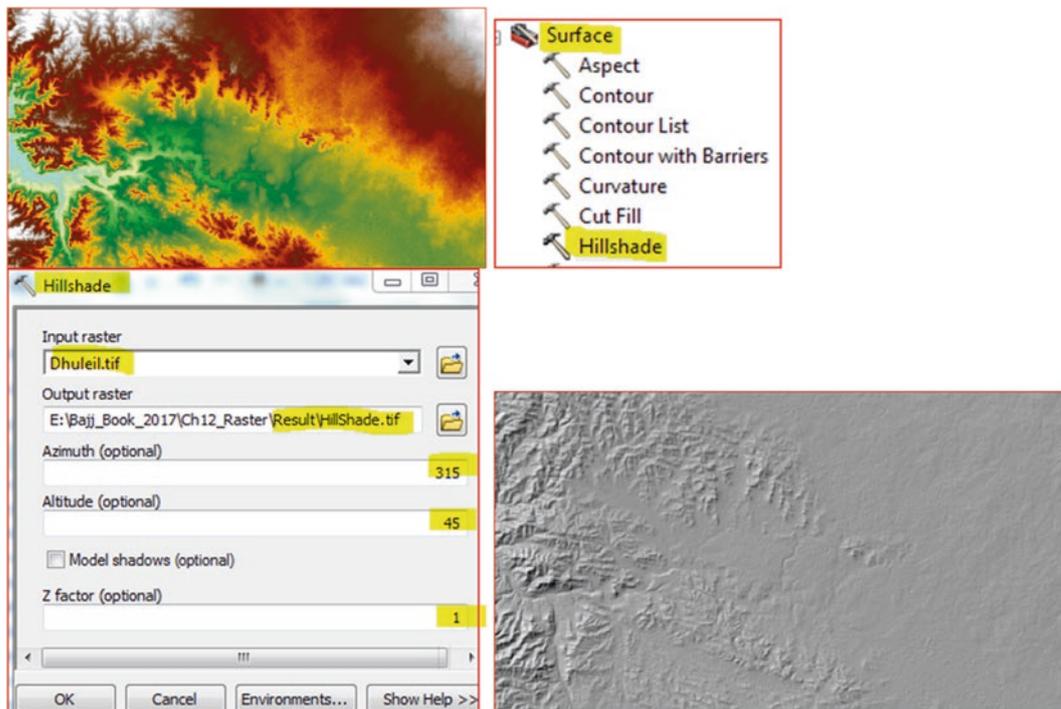
43. R-click Hillshade/Properties/click Display tab
44. Make Transparency (30%)
45. OK
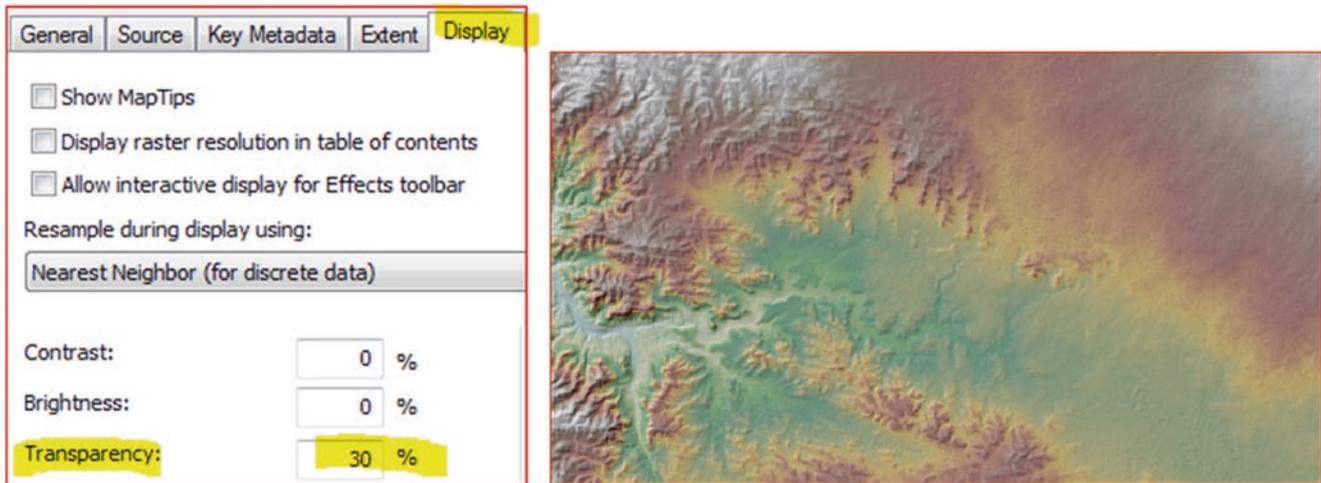
Result: The Transparency applied to the Hillshade raster allows you to see the symbology through the hillshade, yielding a three-dimensional effect.

Create Contour for Dhuleil DEM

The Contour tool creates isolines (contour lines) from the DEM raster. Contour lines are commonly used to represent surface elevations on maps. A contour is a line through all contiguous points with equal height values. The contour will be created for the DEM of Dhuleil.tif, which is registered in UTM coordinate system and the map unit is in meters. The elevation range is 404–905 m above sea level. In this exercise you want to create a 25-m interval from the DEM.

46. Insert Data Frame and call it Contour
47. Drag **Dhuleil.tif** from **Hillshade** data frame into the **Contour** Data Frame
48. ArcToolbox/Spatial Analyst/Surface/and d-click the Contour tool
    a. Input Surface: **Dhuleil.tif**
    b. Output polyline features: \\Result**Contour25.shp**
    c. Contour Interval: 25 m
    d. Base Contour: 405 m
49. OK
50. D-Click **Contour25.shp** in the TOC/Symbology/Quantities/Graduate Color
51. Set the Value to CONTOUR/4 classes/click Classify/Method select manual
52. Under Break Values type 500, 600, 700, and leave the last value (880)
53. Click an empty place in the Break Value
54. Click OK
55. Click shift and select all contours under Range and Label
56. Click Symbol tab/Properties for Selected Symbols/Width 0.75/OK/OK
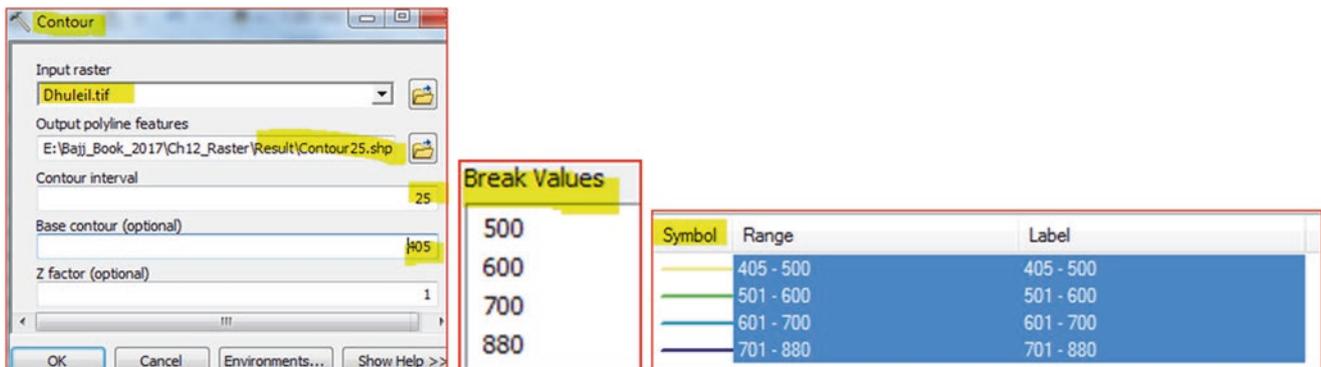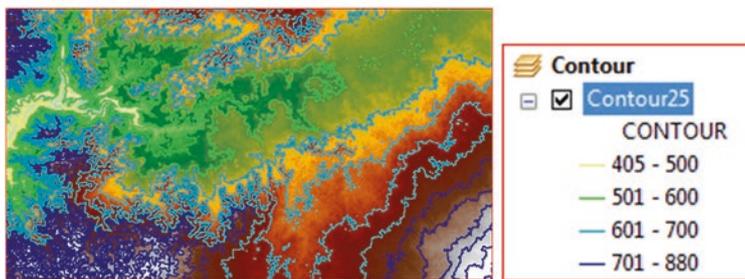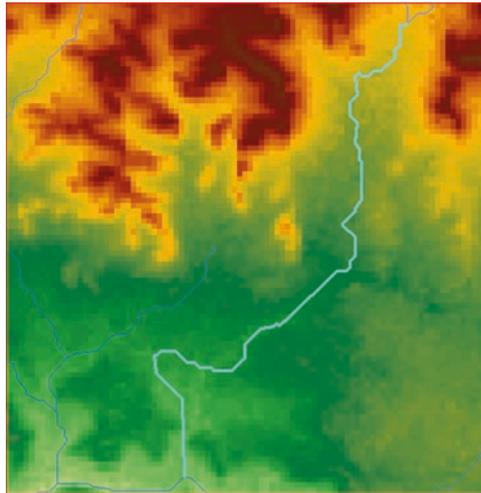
Create Vertical Profile

Profile is a useful GIS operation for terrain analysis, and is a very effective tool for viewing the landscape form. It is created by drawing a line across an elevation image, reading elevation along the line, and then plotting the shape of the terrain. In geology, creating a profile is very useful to understand the form of the land and the outcropping formations, the river morphology in terms of shape and form. In this exercise, you want to create a profile for one stream in the Dhuleil area.

1. Add **stream.shp** to the Contour data frame from \\Data02 folder
2. Uncheck the Countour25
3. Select the river symbol for the **stream.shp**
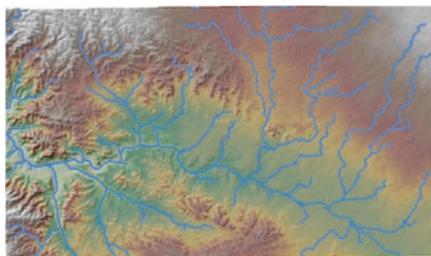
4. Open Attribute Table of **Stream.shp**/click Table Options/Select By Attribute
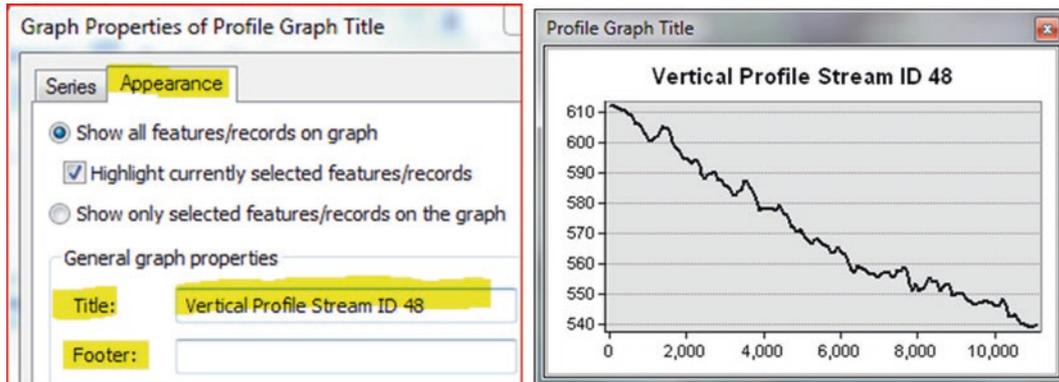5. Use the SQL "Stream_ID" = 48/Apply/Close

6. R-click stream in TOC/Selection/Zoom to Selected Feature
7. Customize/Toolbar/3-D

8. Click Interpolate Line ⬚ on the 3-D toolbar and digitize the selected stream
9. Click Create Profile Graph ⬚ tool on the 3-D toolbar

**Result**: A vertical Profile generated.

10. R-Click the title bar of the graph
11. Properties/Appearance tab/Title/enter new title" **Vertical Profile Stream ID 48**"
12. Remove the Footer
13. Click OK

Create Visibility Map

The Visibility tool can show what locations in the raster are visible from a specific location and how many observable locations it is visible from. The visibility map is based on two types of analysis:

a) Frequency visibility analysis: determines which raster surface locations are visible to a set of observers
b) Observer visibility analysis: identifies which observers are visible from each raster surface location

14. Insert Data Frame and call it Visibility
15. Drag **Dhuleil.tif** from the Contour data frame into the Visibility data frame
16. Integrate **KSCentroid.shp** from \\Data02 folder
17. ArcToolbox/Spatial Analyst Tool/Surface
18. D-click Visibility
19. Input raster: **Dhuleil.tif**
20. Input point or polyline observer features: KSCentroid
21. Output raster: \\Result\VisibFreq
22. Analysis type: Frequency
23. OK
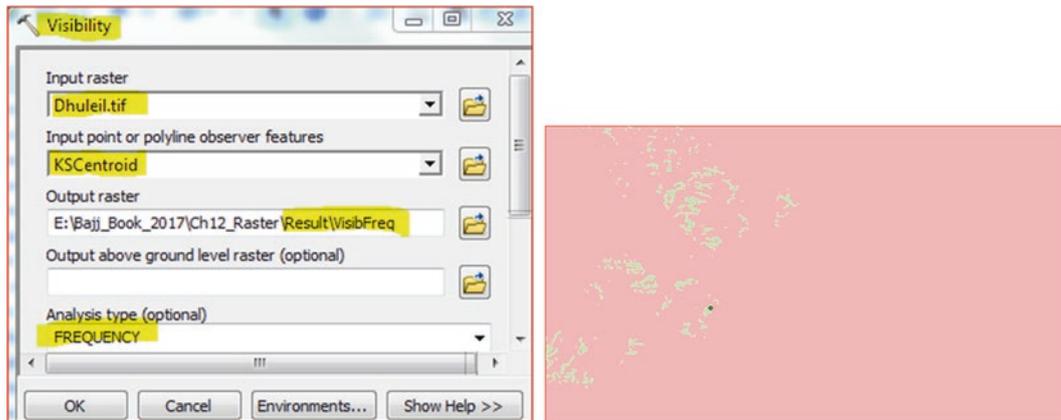
Result: The visibility output map shows the area that can be seen and not seen from the point location KSCentroid.

Add a Height to an Observation Point

24. Open the attribute table of KSCentroid
25. Add field and call it OFFSETA/Short Integer
26. R-click OFFSETA/filed calculator/SQL statement OFFSETA = 25
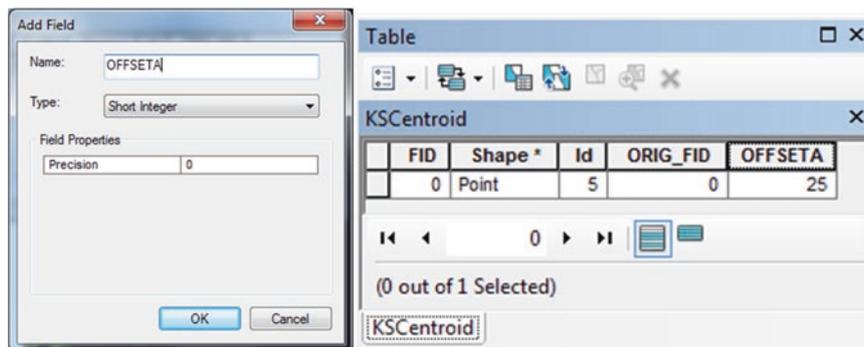
27. R-click KSCentroid/Data/Export Data/Save it as Height25.shp in the \\Result folder
28. Click Yes to add it to TOC
29. Run the visibility map again and call it VisbFreq25 using Dhuleil.tif and Height25.shp
30. OK
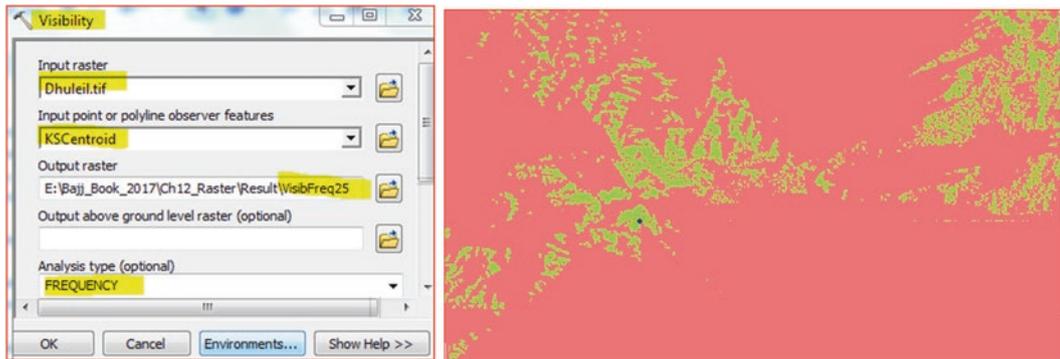
**Result**: When you added a 25m height the percentage of visible area increases.

Create Line of Sight

Line-of-sight analysis determines whether two points in the raster DEM are visible. To use ths tool a line should be drawn between two location. The Create Line of Sight button on the 3-D Analyst toolbar then divides the drawn line between the two points into segments that are visible (green) from the one point and segments that are invisible (red). The line of sight then can be compared with the visibility map that created in the visibility map section.

31. Integrate **Luhfi_Dam.shp** into the Visibility data frame from **\\Data02** folder
32. Provide the proper symbol to the dam
33. Make sure the 3-D Analyst toolbar is available in the Data View
34. Click Create Line of Sight on the 3-D Analyst toolbar (third icon)
35. The line of Sight dialog box display
36. Accept the default (observer and Target offset = 0)
37. Click the **Luhfi_Dam** and then click **KSCentroid**

Result: A red color line will be drawn, which mean the dam is not visible from KSCentroid.

38. Use select element button to select the line of sight and click delete on keyboard
39. Click Create Line of Sight on the 3-D Analyst toolbar again
40. The line of Sight dialog box display
41. Type 10 for the Observer offset and Target offset = 0)
42. Click the **Luhfi_Dam** and then click **KSCentroid**
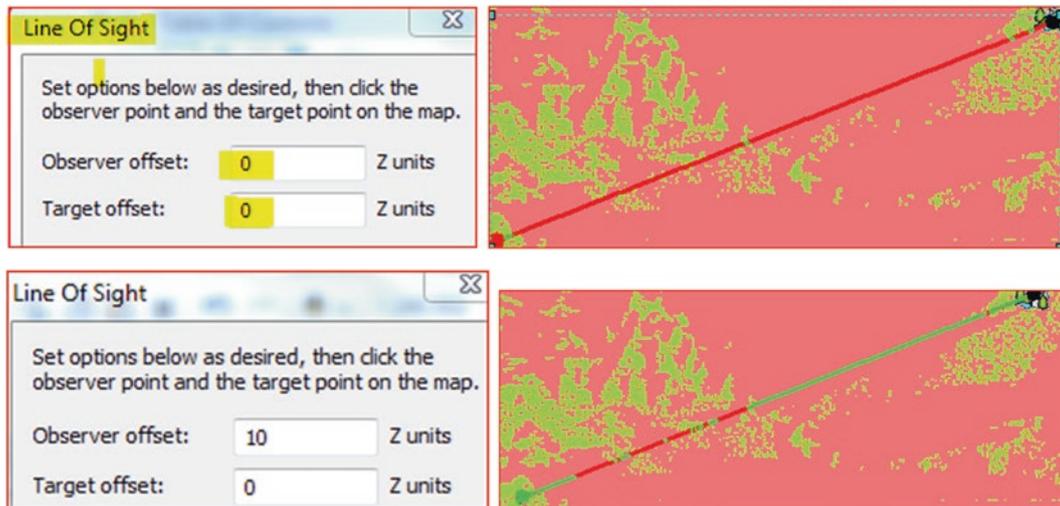
43. A color-coded line will be drawn, green color visible area and red color invisible

Result: The line of sight is correlated nicely with the visibility map.

Slope and Aspect

Slope: the slope is the incline or steepness of the ground surface of a terrain and it can be measured in degrees from horizontal (0–90), or percent slope (rise over run multiplied by 100). For example a slope of 45° equals 100% slope. As slope angle approaches vertical (90°), the percent slope approaches infinity. The slope for a cell in a raster is the steepest slope of a plane defined by the cell and its eight surrounding neighbors.
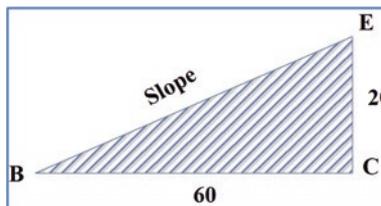
Slope: degree of angel CBE (α)

Slope = (Rise/Run) * 100 = (CE/BC) * 100%

Example: CE = 20, BC = 60; Slope = (20/60) * 100% = 33.3%

Note: If the rise > run, the slope will be more than 100%).

Aspect: The aspect raster map indicates the direction that slopes are facing. The compass direction that a topographic slope faces is usually measured in degrees starting from north. Aspect can be generated from continuous elevation surfaces. For example, the aspect recorded for a TIN face is the steepest downslope direction of the face, and the aspect of a cell in a raster is the steepest downslope direction of a plane defined by the cell and its eight surrounding neighbors.

Derive Slope Layer
44. Insert Data Frame, call it **Slope & Aspect**
45. Drag **Dhuleil.tif** from the **Visibility** data frame
46. ArcToolbox/Spatial Analyst tool/Surface/D-click Slope tool
47. Input raster: Dhuleil.tif

48. Output raster: \\Result\Dhuleil_Slope.tif
49. Output measurement: PERCENT_RISE
50. OK
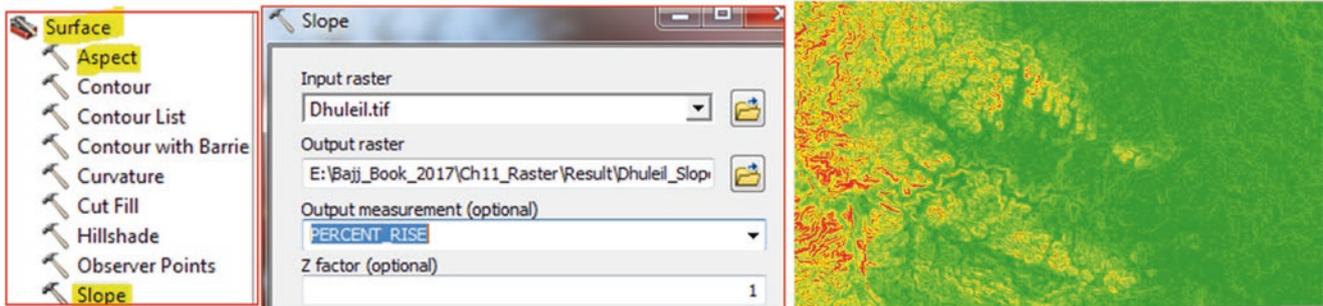
Q1: What is the range of percent slope values in **Dhuleil_Slope**?
Quiz: Can you run the slope again with "DEGREE" as output measurement?

Classify the Slope into Six Classes

51. D-click **Dhuleil_Slope.tif/**Symbology/Classified (under Show:) 7 Classes/Click Classify/Method choose Manual
52. Under Break Values type 5, 10, 15, 20, 25, 30, and keep the last number 50.52
53. Click empty place below the last number and click OK
54. Click Label/Format label/Number of decimal places = 0/OK/OK
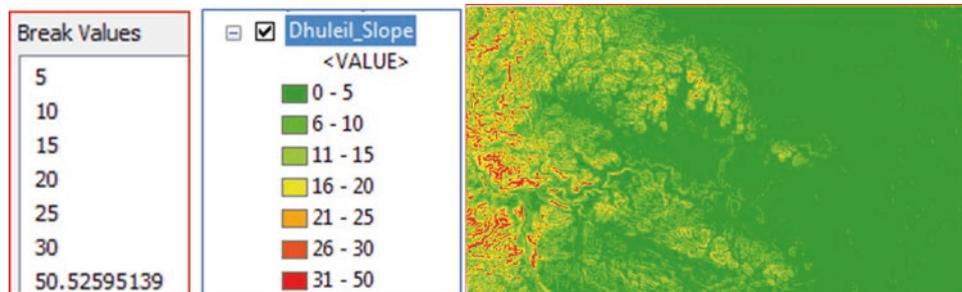
Question: Where is the highest and the gentle slope.

Answer:

Derive Aspect Layer

55. ArcToolbox/Spatial Analyst tool/Surface/Aspect
56. Input raster: Dhuleil.tif
57. Output raster: \\Result\Dhuleil_Aspect
58. OK

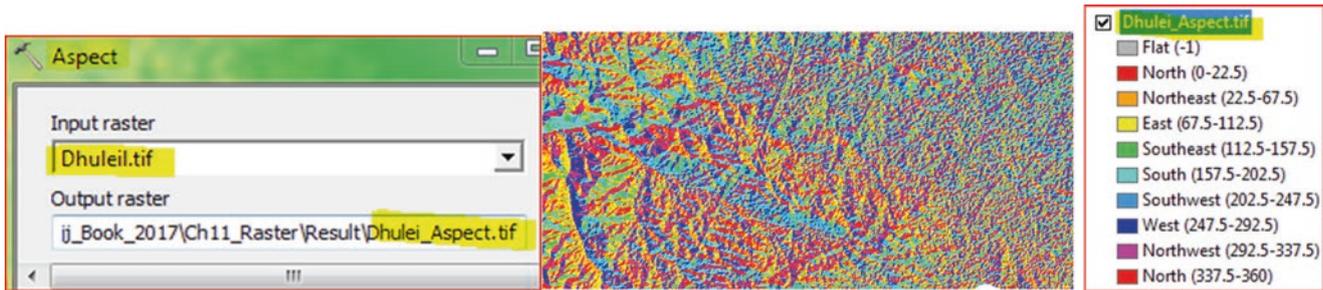**Result**: Nine principal directions and flat area (−1) are created for the **Dhuleil_Aspect.tif**.

Reclassify Slope and Aspect

The Reclassify tool allows you to change the range of values in the slope and aspect. At the same time it generate an integer raster, which will allows you to see the attribute table and perform further analysis.

Reclassify the Slope

Reclassify the **Dhul_Slope** into six classes

1. ArcToolbox/Spatial Analyst/Reclass/D-click Reclassify
2. Input raster: **Dhuleil_Slope.tif**
3. Reclass Field: **Value**
4. Output raster \\Result**Slope_Reclass.tif**
5. Click **Classify**
6. Classes: **6**
7. Method: **Manual**
8. Under **Break Values** enter **5, 10, 15, 20, 30,** and leave the last value **50.52**
9. OK
10. Click Precision button/Check Use "Format" Precision/Number of Decimal = 0/Ok
11. Check Change missing values to NoData
12. Ok
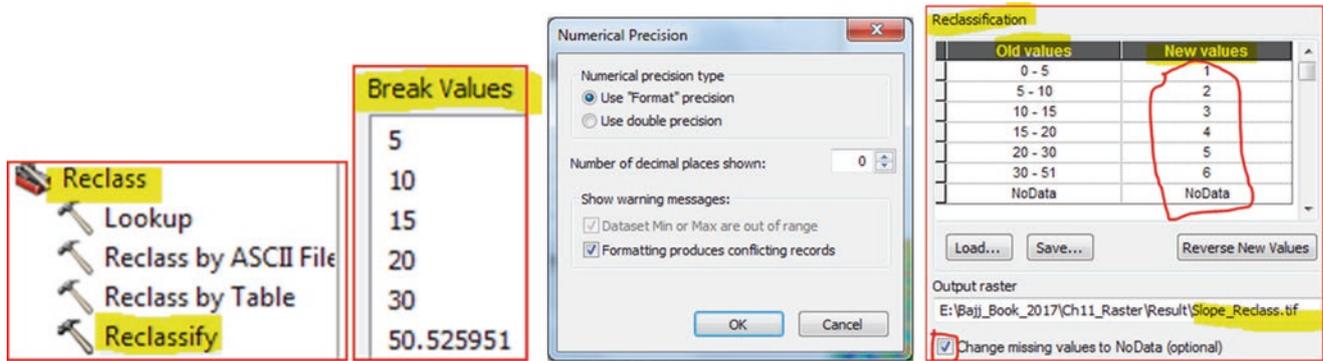
1. Open Attribute Table of **Slope_Reclass.tif**
2. Add Field and call it "Class"/Type Text/Length = 12/click OK
3. Populate the class as below by doing the following
4. Highlight the first row/R-click CLASS field/Field Calculator/Type **"0-5"**/OK
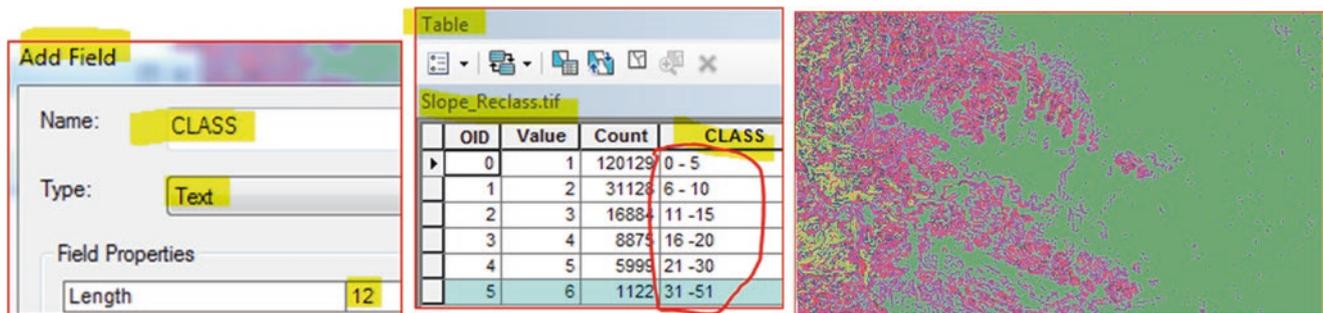5. Repeat for all the rows as seen in the table below

Reclassify the Aspect

Reclassify the **dhuleil_aspect** into 10 classes

1. ArcToolbox/Spatial Analyst/Reclass/Reclassify/
2. Input raster: **Dhuleil_Aspect.tif**
3. Reclass field: **Value**
4. Click **Classify (Classes 10)**
5. Method: **Manual**
6. Under **Break Values** highlight first value and replace it by **−1, then 22.5, 67.5, 112.5, 157.5, 202.5, 247.5, 292.5, 337.5, and 360**

Note: The difference is 45 with the exception the first class and last class.

7. Click Ok

Note: Now you are going to change the number under the New Values. This can be done by clicking the number and change as in the table below.

8. Click Save \\Result\Aspect_Reclass
9. OK

10. In TOC change the color of the flat area (−1) into white

Old values	New values
1	−1
2	1
3	2
4	3
5	4
6	5
7	6
8	7
9	8
10	1
No data	No data

Results:

1. The raster is an integer
2. The −1 is flat

Combine Two Images: Slope and Geology

The Combine tool takes multiple input rasters and assigns a new value for each unique combination of input values in the output raster. The original cell values from each of the inputs is recorded in the attribute table of the output raster. Additional items are added to the output raster's attribute table, one for each input raster.

In the image below, two rasters were input into the Combine function. Notice that each unique combination of values from the two input rasters receives a unique value in the output raster. Two additional fields are added to the output raster attribute table containing the original values from the two input rasters that created the unique combination. Thus, the parentage of the output values can be traced back to the original rasters. Notice that if a cell contains NoData in any of the input rasters, that location will receive NoData for the output. There is no limit to the number of rasters that can be combined; however, there is a practical limit. If there are many rasters all having many different zones, a greater number of unique combinations will be created, resulting in a large attribute table.
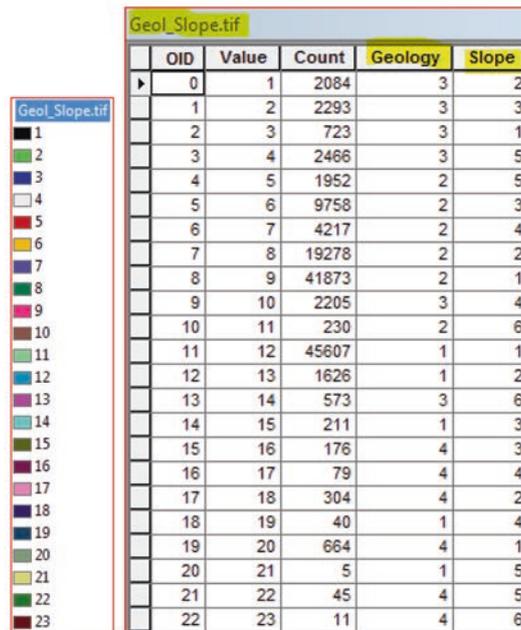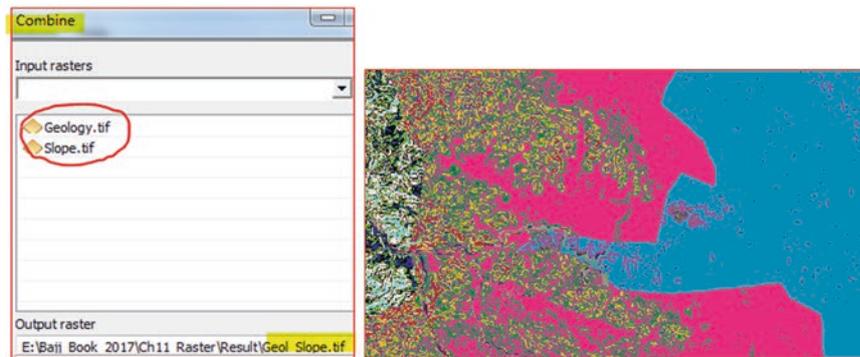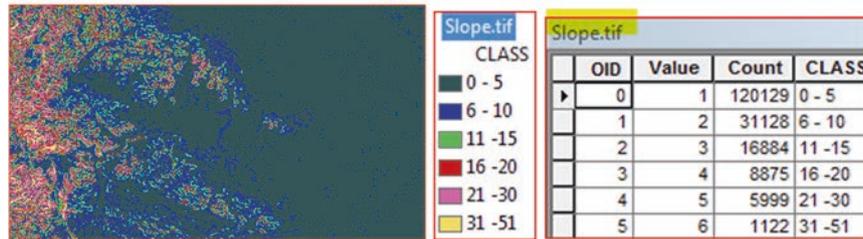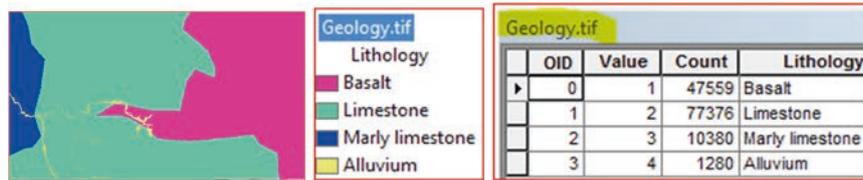
	Raster01				Raster02				Output Raster		
1	1	0	0	0	1	1	0	1	2	3	4
	1	2	2	3	3	1	2		5	6	7
4	0	0	2		0	0	2		4	4	7
4	0	1	1	3	2	1	0	8	9	2	1

Raster 01	Raster 02	Output Raster
1	0	1
1	1	2
0	1	3
0	0	4
1	3	5
2	1	6
2	2	7
0	0	4
0	0	4
2	2	7
4	3	8
0	2	9
1	1	2
1	0	1

Scenario: The Water Authority decided to install a Lysimeter to estimate the infiltration rate in Dhuleil area. The greatest factor controlling infiltration is the amount and characteristics of the precipitation that falls as rain or snow. In general, rain falling on steeply-sloped land runs off more quickly and infiltrates less than water falling on flat land. In addition to that, some outcropping formations allow water to infiltrate at a higher downgradient and recharge the subsurface geology. Alluvium and limestone are more permeable layers that allow portions of the rain to infiltrate into the aquifers and recharge them. Therefore, the aim is to find an area with a slop less than 10% and consists of limestone and alluvium. Slope with value 1 and 2 has a slope less than 10%.

To perform the analysis, the first step is to combine the two rasters: **Slope.tif** and **Geology.tif** together

59. Insert Data Frame call it **Best Location**
60. Integrate **Slope.tif** & **Geology.tif** \\Data03 folder
61. ArcToolbox/Spatial Analyst Tools/Local/D-click Combine
62. Input rasters: **Slope.tif** & **Geology.tif**
63. Output raster: \\Result\Geol_Slope.tif
64. OK

Geology.tif — Lithology

	Basalt
	Limestone
	Marly limestone
	Alluvium

Geology.tif

	OID	Value	Count	Lithology
▶	0	1	47559	Basalt
	1	2	77376	Limestone
	2	3	10380	Marly limestone
	3	4	1280	Alluvium

Slope.tif — CLASS

	0 - 5
	6 - 10
	11 -15
	16 -20
	21 -30
	31 -51

Slope.tif

	OID	Value	Count	CLASS
▶	0	1	120129	0 - 5
	1	2	31128	6 - 10
	2	3	16884	11 -15
	3	4	8875	16 -20
	4	5	5999	21 -30
	5	6	1122	31 -51

Combine

Input rasters

Geology.tif
Slope.tif

Output raster
E:\Baji_Book_2017\Ch11 Raster\Result\Geol_Slope.tif

Geol_Slope.tif

	OID	Value	Count	Geology	Slope
▶	0	1	2084	3	2
	1	2	2293	3	3
	2	3	723	3	1
	3	4	2466	3	5
	4	5	1952	2	5
	5	6	9758	2	3
	6	7	4217	2	4
	7	8	19278	2	2
	8	9	41873	2	1
	9	10	2205	3	4
	10	11	230	2	6
	11	12	45607	1	1
	12	13	1626	1	2
	13	14	573	3	6
	14	15	211	1	3
	15	16	176	4	3
	16	17	79	4	4
	17	18	304	4	2
	18	19	40	1	4
	19	20	664	4	1
	20	21	5	1	5
	21	22	45	4	5
	22	23	11	4	6

Geol_Slope.tif

	1
	2
	3
	4
	5
	6
	7
	8
	9
	10
	11
	12
	13
	14
	15
	16
	17
	18
	19
	20
	21
	22
	23

Result: The combine output raster unites the geology and the slope in one map.

To find the areas of limestone and alluvium outcropping formations that have slopes less than 10% slope, you should do spatial analysis and this can be performed using two different approaches: Extract by Attribute or Raster Calculator. Both approaches can be used to find the best location to install the Lysimeter.

Extract by Attribute Tool

This approach allows you to extract the cells of a raster based on a logical query.

65. Spatial Analyst Tools/Extraction/D-click Extract by Attributes
66. In the Extract by Attributes dialog box fill it as follow:
67. Input raster: Geol_Slope.tif
68. Where clause ("Slope" <= 2) AND ("Geology" = 2) OR ("Geology" = 4)
69. Output raster: \\Result\BestLocation.tif
70. OK

**Result**: The result is BestLocation1.tif that consist of eight records.
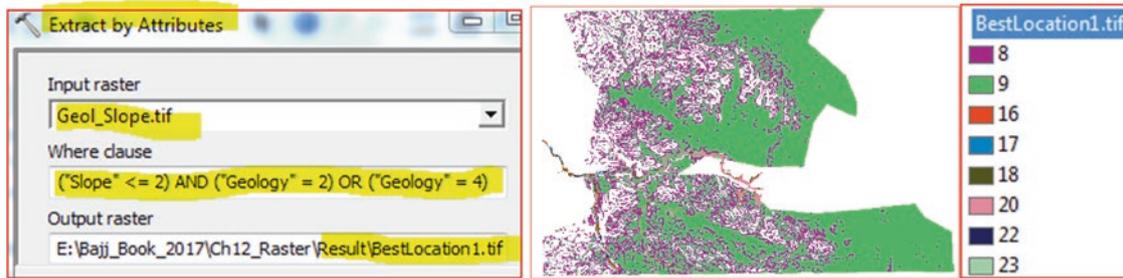
Raster Calculator Tool

In this particular case we have to use the Raster Calculator in the Map Algebra to select the land that has a slope less than 10% and consist of limestone and alluvium using the two rasters: Geology.tif and Slope.tif

71. Spatial Analyst Tools/Map Algebra/D-click Raster Calculator
72. In the Raster Calculator dialog box, type the SQL statement as below

Combine("Slope.tif" <= 2) & ("Geology.tif" == 2) | ("Geology.tif" == 4)

73. Output raster: \\Result\Lys_Location
74. OK
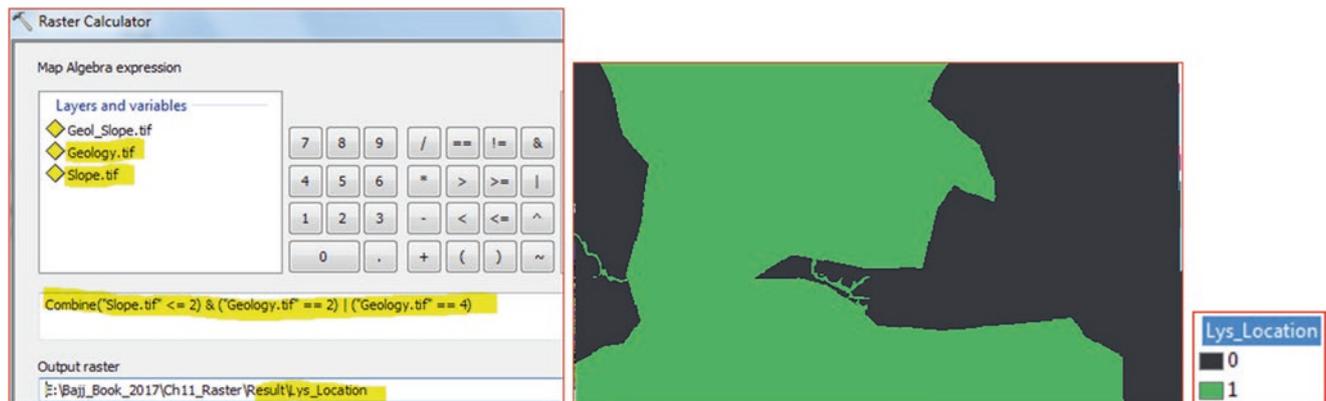
Result: Lys_Location is a raster with two records. Class no. 1 is the location where the lysometer will be installed and the class 0 is the area that are not suitable for lysometer installation.

Calculate the Percent of the Area That Suitable for Installation the Lysimeter

75. Open the attribute table of **Lys_Location** (two records)
76. How many cells value of 1 of the **Lys_Location** raster have?
77. Table Options/Add field/called it "Percentage"/Type = Double) OK
78. R-click field "Percentage" point to Field Calculator
79. Write the following statement: ([COUNT]/(57827 + 78546)) * 100

Result: Value 1 is 57.63%.

Result: The percentage of area that are suitable for building a Lysimeter is 57.59%.