

Training Manual on

Application of Remote Sensing and Geographic Information Systems for Mapping and Monitoring of Glaciers

Part 2 - Glacier Database Generation using ArcGIS



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The International Centre for Integrated Mountain Development, ICIMOD, is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalaya – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.



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Training Manual on

Application of Remote Sensing and Geographic Information Systems for Mapping and Monitoring of Glaciers

Part 2 - Glacier Database Generation using ArcGIS

Authors

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Acronyms and Abbreviations

AM	Ante meridiem
BLOBs	Binary Large Objects
CAD	Computer-aided design
CGIAR	Consultative Group on International Agricultural Research
DB	Database
DEM	Digital Elevation Model
DHM	Department of Hydrology and Meteorology, Nepal
DMS	Degree Minutes Seconds
ESRI	Environmental Systems Research Institute
GCS	Geographic Coordinate System
GIS	Geographic Information Systems
GLIMS	Global Land Ice Measurement from Space
GPS	Global Positioning System
KU	Kathmandu University
NASA	National Aeronautics and Space Administration
OLE DB	Object Linking and Embedding Database
PCS	Projected Coordinate System
PM	Post meridiem
SRTM	Shuttle Radar Topography Mission
SQL	Structured Query Language
TM	Transverse Mercator
TU	Tribhuvan University
USAID	United States Agency for International Development
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WECS	Water and Energy Commission Secretariat, Nepal
WGS	World Geodetic System
λ	Longitude
Φ	Latitude
h	height
km	kilometres
m	metres
km ²	square kilometres

About the Manual

This manual provides an introduction to Geographic Information Systems (GIS) and ArcGIS software. The ArcGIS platform and tools are explained so that they can be used for generating glacier database, analysis on glacier database and preparing glacier maps. The manual is divided into three parts – first part includes the introduction of GIS and descriptions of some of the fundamental terms used in GIS. The second part includes the hands-on exercise on ArcGIS to make you familiar on the software and the third part includes the detail exercise for generating different attribute of the glacier polygon with some analysis.

Read the manual carefully before doing hands-on exercises. Step by step processes are explained in bullet point format and short introductions to the data processing steps are in normal format.

Practice data for this manual are available at this link:

http://www.icimod.org/glacierdata/glacier_training_data.zip

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1

Introduction to Geographic Information Systems (GIS)

1. Introduction to Geographic Information Systems (GIS)

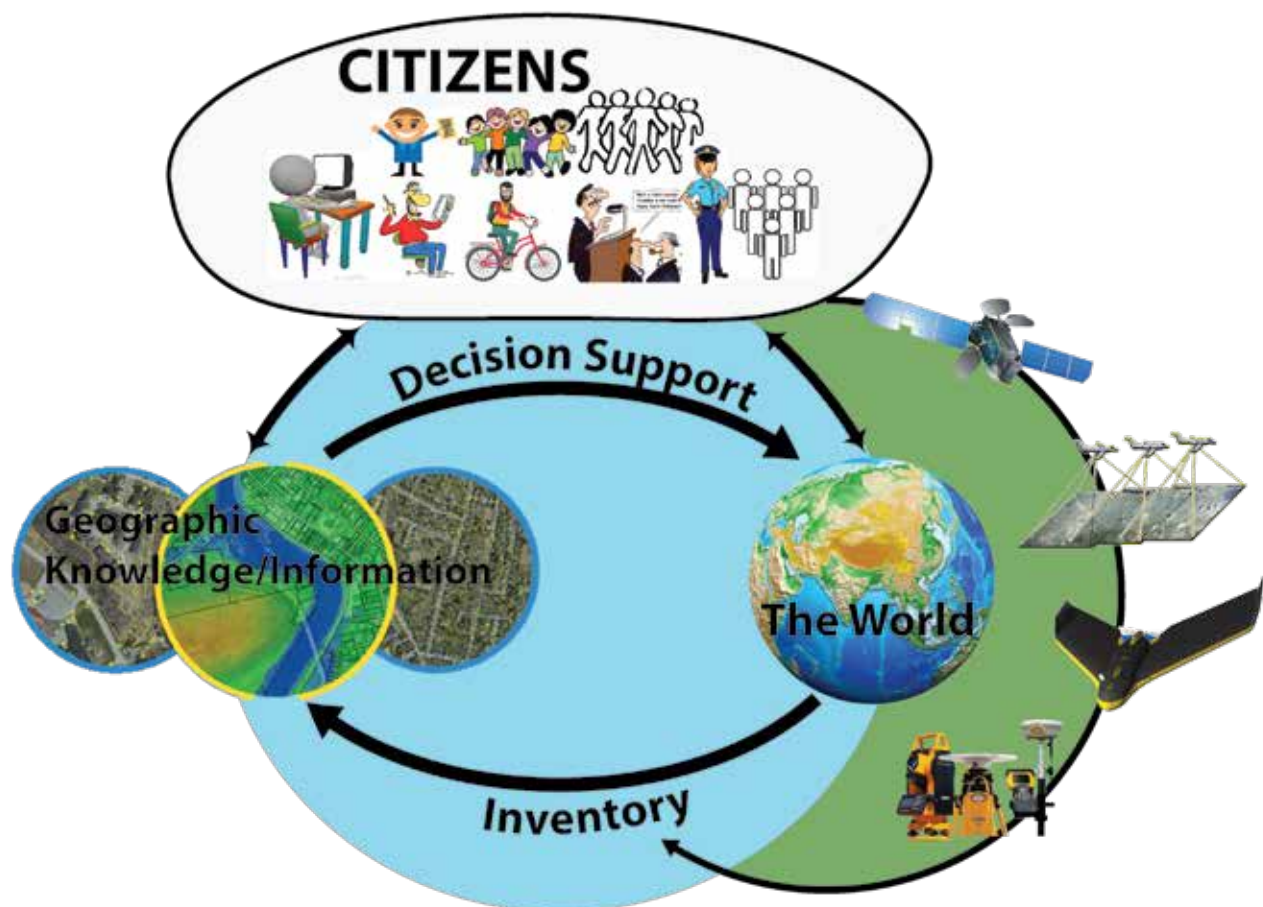
A geographic information system (GIS) is a system designed to capture, store, manipulate, analyse, manage, and present all types of geographically referenced data (Figure 1.1). Although the term GIS is commonly used to describe software packages, a true GIS includes knowledgeable staff, hardware, data, and software. GIS technology can be used in almost any geography-related discipline, from landscape, architecture, natural resource management to transportation routing. The main purpose of a GIS is to turn geographic data into useful information that can provide answers to real life questions.

Geographic – The key word is ‘geography’, which means that the data and information are associated with some location in space or referenced to locations on the earth.

Information – Tabular; attributes, or characteristics (data) can be used to symbolize and provide further insight into a given location.

Systems – a seamless operation linking the information to the geography – which requires hardware, networks, software, data, and operational procedures.

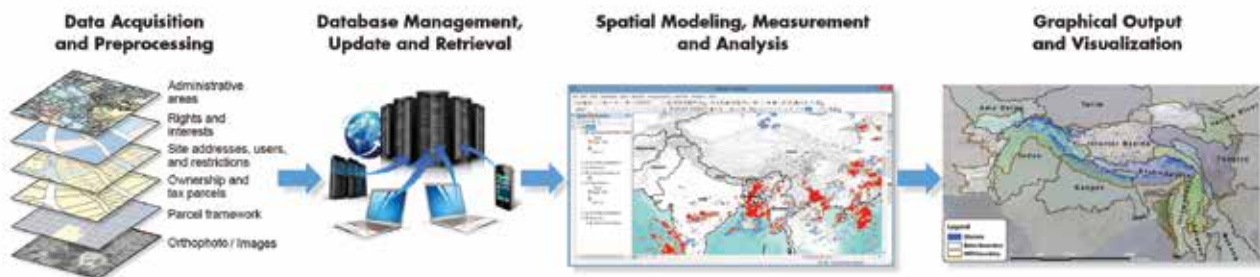
Figure 1.1: **Conceptual diagram showing how people from across the world use GIS to acquire knowledge and integrated it as a decision tools for development**



1.1 Functions of GIS

GIS uses the spatial and non-spatial attribute data to answer questions about the real world. Its spatial analysis function distinguishes it from other applications. Different authors or different GIS programmers may classify functions, manipulations, analyses and ways of data management in very different ways; in general the functions of GIS can be grouped into four processes: data acquisition and preprocessing; database management and retrieval; spatial modeling, measurement and analysis; and graphical output and visualization (Figure 1.2).

Figure 1.2: General functions of GIS



Data Acquisition and Preprocessing

Data used in GIS often come from different sources, are of many types, and are stored in different ways. A GIS provides tools and a method for integrating different data into a format to be compared and analysed. Data sources range from manual digitization and scanning of aerial photographs to paper maps and existing digital data sets. Remote-sensing satellite imagery and GPS are promising data input sources for GIS. It also provides a huge opportunity to interactively experiment with available data in order to obtain requisite map output or to confidently allow for any subsequent data analysis.

Database Management, Update and Retrieval

After data are collected and integrated, the GIS must provide facilities that can store and maintain data. Effective data management can be defined in many ways but should include all of the following aspects: data storage, data retrieval, data maintenance, data security and data integrity.

Spatial Modeling, Measurement and Analysis

Once data is acquired, assessed and stored, the collected information will be analysed and interpreted quantitatively and qualitatively. For example, satellite imagery can assist an agricultural scientist to project crop yield per hectare for a particular region. For the same region, the scientist also has the rainfall data for the past six months collected through weather station observations. The scientist also has a map of the soils in the region that shows the level of fertility and suitability for agriculture. These point data can be interpolated to get a thematic map showing isohyets, which are contour lines of rainfall. It can integrate various data sources and generate the final map which can help for decision makers. Some of the examples are – suitability map for settlement, agriculture and landslide susceptibility etc.

Presenting Results – Graphical Output and Visualization

One of the most exciting aspects of GIS technology is the variety of ways in which the information can be presented once it has been processed by GIS. Traditional methods of tabulating and graphing data can be supplemented by maps and three-dimensional images. Visual communication is one of the most fascinating aspects of GIS technology and is available in a diverse range of output options.

1.2 Fundamental Data Types Used in GIS

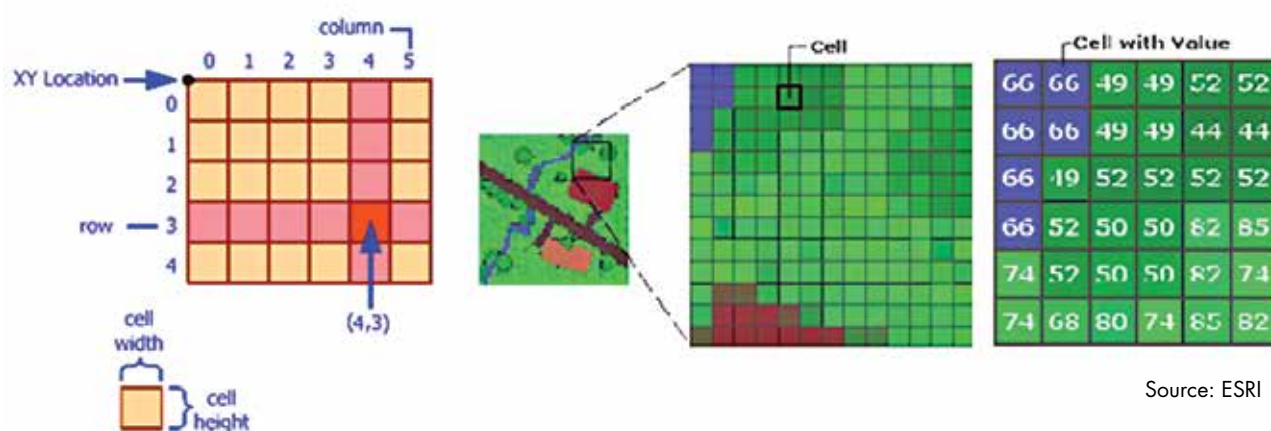
Spatial data in a GIS database are stored in either vector or raster format.

Raster Data

Raster data generalizes map features as cells or pixels in a grid matrix. The space is defined by a matrix of points or cells organized into rows and columns. In a raster data set, data values for a given parameter are stored in each cell – these values may represent an elevation in metres above sea level, a land use class, a plant biomass in grams per square metre, and so forth. The spatial resolution of the raster data set is determined by the size of the cell (Figure 1.3). For example, Landsat satellite imagery data are raster data that are corrected to have a cell size of approximately 30 metres on a side. However, spatial resolution can be much finer, or much coarser than 30 metres. In general, spatial resolution is a function of the data collection techniques used, and the desired outcomes.

The size of cells in a tessellated (highly symmetric, edge-to-edge tiling) data structure is selected on the basis of the data accuracy and the resolution needed by the user. There is no explicit coding of geographic coordinates required since that is implicit in the layout of the cells.

Figure 1.3: Structure of raster data model showing the matrix structure into row and column of the cells, cell structure and values of cells



Source: ESRI

Advantages of Raster Data

- The geographic location of each cell is implied by its position in the cell matrix. Accordingly, other than an origin point, e.g., bottom left corner, no geographic coordinates are stored.
- Due to the nature of the data storage technique, data analysis is usually easy to program and quick to perform.
- The inherent nature of raster maps, e.g., attribute maps, is ideally suited for mathematical modelling and quantitative analysis.
- Discrete data (e.g., landcover) is accommodated equally well as continuous data (e.g., elevation data) and facilitates the integration of the two data types.

Disadvantages of Raster Data

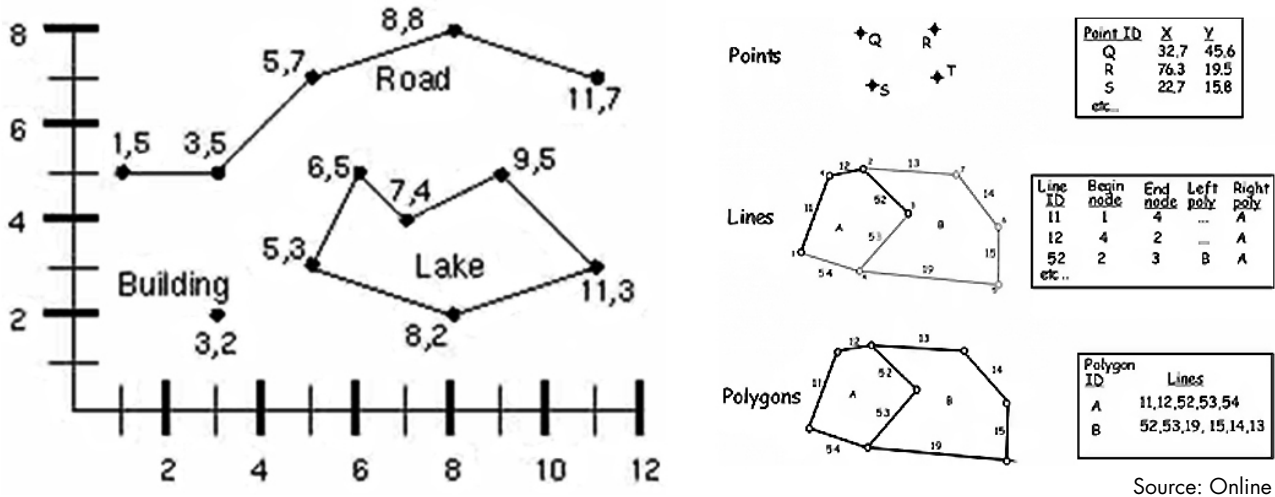
- The cell size determines the resolution at which the data is represented.
- It is especially difficult to adequately represent linear features depending on the cell resolution. Thus, network linkages of linear features are difficult to establish.
- Processing of associated attribute data may be cumbersome if large amounts of data exist. Raster maps inherently reflect only one attribute or characteristic for an area.
- Since most input data is in vector form, data must undergo vector-to-raster conversion. Besides increased processing requirements, this may introduce data integrity concerns due to generalization and the choice of inappropriate cell size.

Vector Data

In vector data, objects are represented as points, lines or areas, whose positions are precisely specified. The position of each object is defined by a (series of) coordinate pairs. A point is described by a single X-Y coordinate pair and by its name or label. A line is described by a set of coordinate pairs and by its name and label. In reality,

a line is described by an infinite number of points (Figures 1.4 and 1.5). In practice, this is not a feasible way of storing a line. Therefore, a line is built up of straight line segments. An area, also called a Polygon, is described by a set of coordinate pairs and by its name and label, with the difference that the coordinate pairs at the beginning and the end are the same.

Figure 1.4: Structures of vector data model showing the notation of points and representation of points, lines and polygons



Source: Online

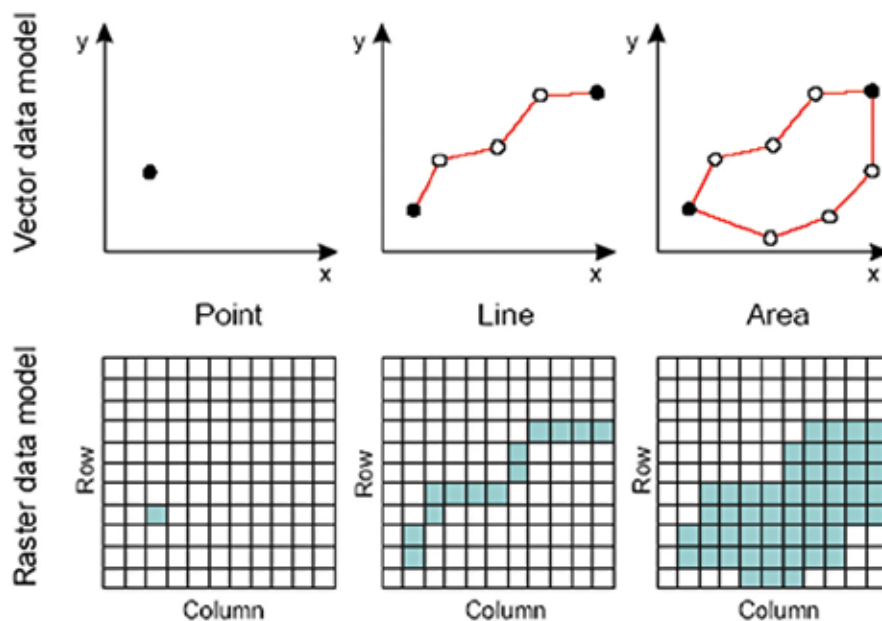
Advantages of Vector Data

- Data can be represented at its original resolution without generalization.
- Graphic output is usually more aesthetically pleasing.
- Since most data, e.g., hard copy maps are in vector form, no conversion is required.
- Accurate geographic location of data is maintained.
- Allows for efficient encoding of topology, and as a result more efficient operations that require topological information, e.g., proximity, network analysis.

Disadvantages of Vector Data

- The location of each vertex needs to be stored explicitly.
- Algorithms for manipulative and analysis functions are complex and may be processing intensive.
- Continuous data, such as elevation data, is not effectively represented in vector form.
- Spatial analysis and filtering within polygons is impossible.

Figure 1.5: Representation of vector and raster data



Source: Online

Attribute Data

Attribute data is information appended in tabular format to spatial features (Vector or Raster data). It provides the characteristics of spatial data. Attribute data can be stored as one of the five different field types in a table or database – character, integer, floating, date and binary large object (BLOB).

Character Data

The character property (or string) is for text-based values such as the name of a street or descriptive values such as the condition of a street. Character attribute data is stored as a series of alphanumeric symbols.

Aside from descriptors, character fields can contain other attribute values such as categories and ranks. For example, a character field may contain the categories for a street: avenue, boulevard, lane, or highway. A character field could also contain the rank, which is a relative ordering of features. For example, a ranking of the traffic load of the street with "1" being the street with the highest traffic.

Character data can be sorted in ascending (A to Z) and descending (Z to A) order. Since numbers are considered text in this field, those numbers will be sorted alphabetically, which means that a number sequence of 1, 2, 9, 11, 13, 22 would be sorted in ascending order as 1, 11, 13, 2, 22, 9. Because character data is not numeric, calculations (sum, average, median, etc.) can't be performed on this type of field, even if the value stored in the field are numbers (to do that, the field type would need to be converted to a numeric field). Character fields can be summarized to produce counts (e.g., the number of features that have been categorized as "avenue").

Numeric Data

Integer and floating are numerical values (see: the difference between floating and integer values). Within the integer type, it is a further division between short and long integer values. As would be expected, short integers store numeric values without fractional values for a shorter range than long integers. Floating point attribute values store numeric values with fractional values. Fractional values can be a float (single-precision floating-point number) or a double (double-precision floating-point numbers). These floating point values are for numeric values with decimal points (i.e., numbers to the right of the decimal point as opposed to whole values).

While choosing between a short or long integer or between a float or double, it is advisable to choose the data type that takes up the least storage space. This will not only minimize the amount of storage required but will also improve performance. For instance, if integers between -32,768 and 32,767 need to be stored, it is better to specify the short integer data type because it would take up only 2 bytes of storage, whereas the long integer data type takes up 4 bytes of storage. If fractional numbers between -3.4E38 and 1.2E38 need to be stored, it is good to specify the float data type because it takes 4 bytes of storage, whereas the double data type takes up 8 bytes of storage. The table lists data types, their ranges, and storage requirements. The ranges listed are for file and personal geodatabases (Table 1).

For a numeric field, the precision (i.e., the maximum length of the field) and scale (the maximum number of decimal places) need to be defined. For example, a float is specified with a precision of 4 and a scale of 2; the field could be 12.34.

Table 1: Details of various numeric data types

Data type	Storable range	Size (Bytes)	Applications
Short integer	-32,768 to 32,767	2	Numeric values without fractional values within specific range; coded values
Long integer	-2,147,483,648 to 2,147,483,647	4	Numeric values without fractional values within specific range
Float (single-precision floating-point number)	approximately -3.4E38 to 1.2E38	4	Numeric values with fractional values within specific range
Double (double-precision floating-point number)	approximately -2.2E308 to 1.8E308	8	Numeric values with fractional values within specific range

Numeric values will be sorted sequentially either in ascending (1 to 10) or descending (10 to 1) order. Numerical value fields can have operations performed such as calculating the sum or average value. Numerical field values can be a count (e.g., the total number of students at a school) or a ratio (e.g., the percentage of students that are girls at a school).

Date

The date data type can store dates, times, or dates and times. The default format in which the information is presented is 'mm/dd/yyyy hh:mm:ss' and a specification of AM or PM. When you enter date fields in the table through ArcGIS, they are converted to this format.

BLOBs

BLOB stands for binary large object and this attribute type is used for storing information such as images, multimedia, or bits of code in a field. A BLOB is data stored as a long sequence of binary numbers. ArcGIS stores annotation and dimensions as BLOBs, and items such as images, multimedia, or bits of code. You need a custom loader or viewer or a third-party application is needed to load items into a BLOB field or view the contents of a BLOB field.

1.3 Coordinate Systems

Coordinate systems enable geographic datasets to use common locations for integration. A coordinate system is a reference system used to represent the locations of geographic features, imagery, and observations such as GPS locations within a common geographic framework. Each coordinate system is defined by:

- Its measurement framework, which is either geographic (in which spherical coordinates are measured from the earth's centre) or planimetric (in which the earth's coordinates are projected onto a two-dimensional planar surface).
- Unit of measurement (typically feet or metres for projected coordinate systems or decimal degrees for latitude-longitude).
- The definition of the map projection for projected coordinate systems.
- Other measurement system properties such as a spheroid of reference, a datum, and projection parameters like one or more standard parallels, a central meridian, and possible shifts in the x- and y-directions.

There are two common types of coordinate systems used in GIS:

- A global or spherical coordinate system such as latitude-longitude. These are often referred to as geographic coordinate systems.
- A projected coordinate system based on a map projection such as transverse Mercator, Albers equal area, or Robinson, all of which (along with numerous other map projection models) provide various mechanisms to project maps of the earth's spherical surface onto a two-dimensional Cartesian coordinate plane. Projected coordinate systems are sometimes referred to as map projections.

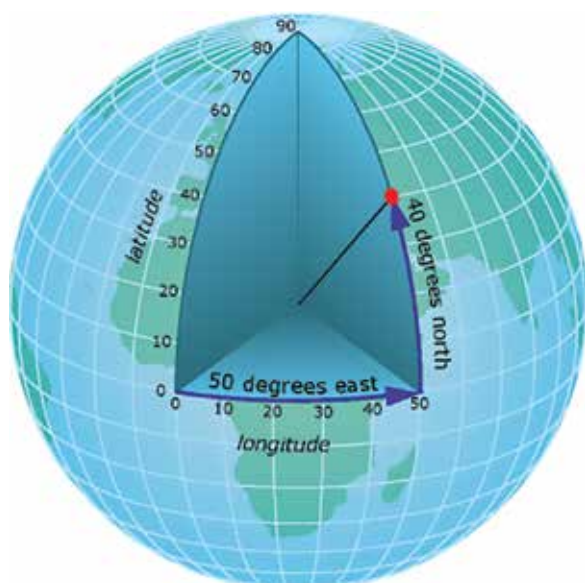
Coordinate systems (either geographic or projected) provide a framework for defining real-world locations. In ArcGIS, the coordinate system is used as the method to automatically integrate the geographic locations from different datasets into a common coordinate framework for display and analysis.

Geographic Coordinate System (GCS)

A geographic coordinate system (GCS) uses a three-dimensional spherical surface to define locations on the earth. A GCS is often incorrectly called a datum, but a datum is only one part of a GCS. A GCS includes an angular unit of measure, a prime meridian, and a datum (based on a spheroid).

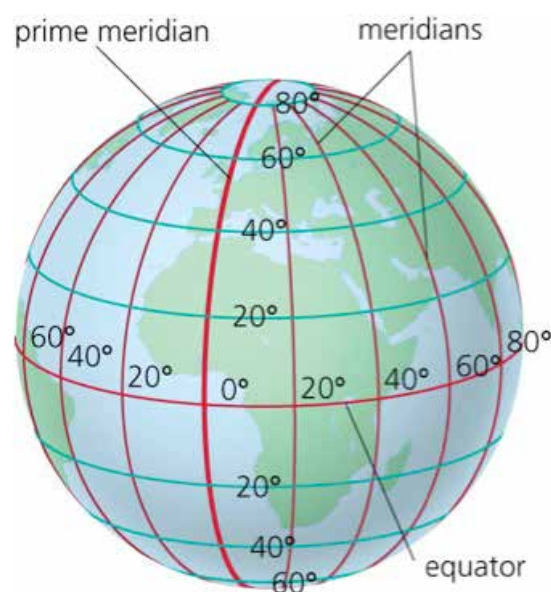
A point is referenced by its longitude and latitude values. Longitude and latitude are angles measured from the earth's centre to a point on the earth's surface. The angles are often measured in degrees (or in grads). The following illustration shows the world as a globe with longitude and latitude values (Figure 1.6).

Figure 1.6: Representation of the earth showing longitude and latitude of a point in globe



Source: ESRI

Figure 1.7: Representation of globe showing parallels and meridians lines



Source: ESRI

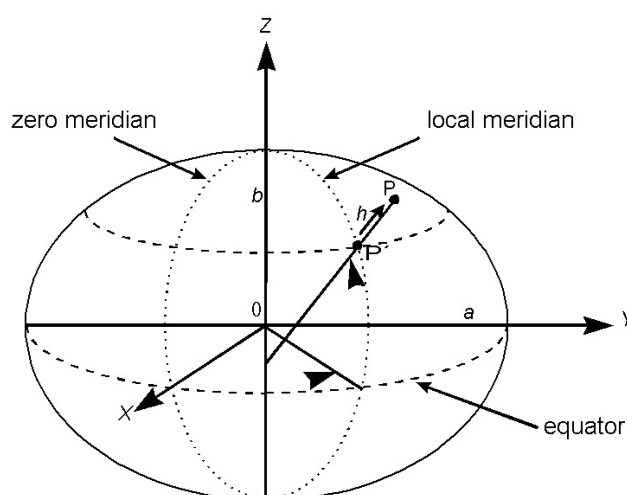
In the spherical system, horizontal lines, or east-west lines, are lines of equal latitude, or parallels. Vertical lines, or north-south lines, are lines of equal longitude, or meridians. These lines encompass the globe and form a gridded network called a graticule.

The line of latitude midway between the poles is called the equator. It defines the line of zero latitude. The line of zero longitude is called the prime meridian (Figure 1.7). For most geographic coordinate systems, the prime meridian is the longitude that passes through Greenwich, England. Other countries use longitude lines that pass through Bern, Bogota, and Paris as prime meridians. The origin of the graticule (0,0) is defined by where the equator and prime meridian intersect. The globe is then divided into four geographical quadrants that are based on compass bearings from the origin. North and south are above and below the equator, and west and east are to the left and right of the prime meridian.

Latitude and longitude values are traditionally measured either in decimal degrees or in degrees, minutes, and seconds (DMS). Latitude values are measured relative to the equator and range from -90° at the South Pole to $+90^\circ$ at the North Pole. Longitude values are measured relative to the prime meridian. They range from -180° when travelling west to 180° when travelling east.

The shape and size of a geographic coordinate system's surface is defined by a sphere or spheroid. Although the earth is best represented by a spheroid or ellipsoid (shapes that are generated by revolving an ellipsis around its minor axis), it is sometimes treated as a sphere to make mathematical calculations easier. The earth shape is represented by an ellipsoid of rotation (or called a spheroid) with the length of the major semi-axis (a) and minor semi-axis (b), as shown in the figure below (Figure 1.8).

Figure 1.8: Representation of the globe in ellipsoid showing major (a) and minor axis (b)



Source: ESRI

Projected Coordinate System (PCS)

A projected coordinate system is defined on a flat, two-dimensional surface. Unlike a geographic coordinate system, a projected coordinate system has constant lengths, angles, and areas across the two

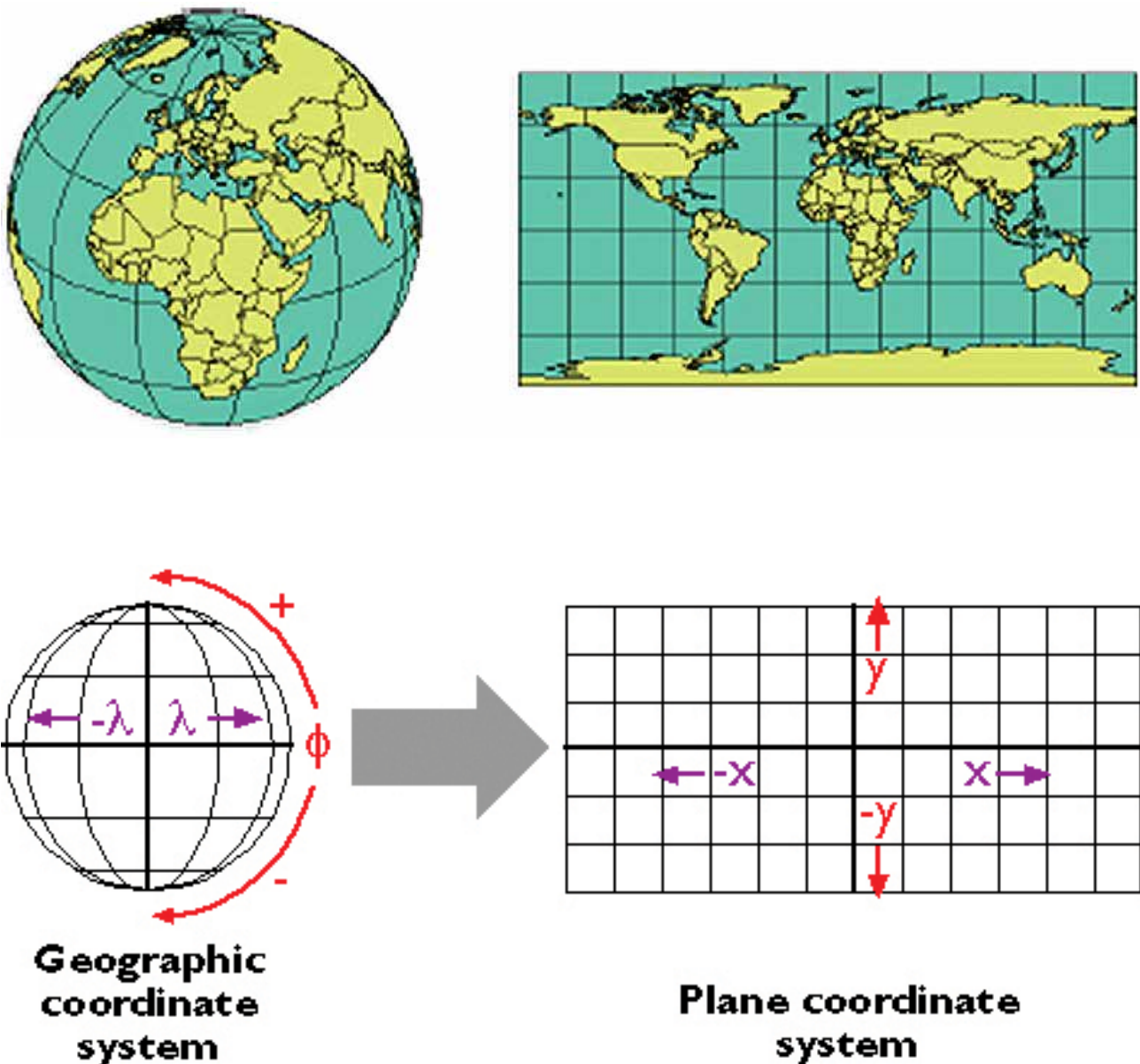
dimensions. A projected coordinate system is always based on a geographic coordinate system that is based on a sphere or spheroid.

In a projected coordinate system, locations are identified by x , y coordinates on a grid, with the origin at the centre of the grid (Figure 1.9). Each position has two values that reference it to that central location. One specifies its horizontal position and the other its vertical position. The two values are called the x -coordinate and y -coordinate. Using this notation, the coordinates at the origin are $x = 0$ and $y = 0$.

On a gridded network of equally spaced horizontal and vertical lines, the horizontal line in the centre is called the x -axis and the central vertical line is called the y -axis. Units are consistent and equally spaced across the full range of x and y . Horizontal lines above the origin and vertical lines to the right of the origin have positive values; those below or to the left have negative values. The four quadrants represent the four possible combinations of positive and negative X and Y coordinates.

When working with data in a geographic coordinate system, it is sometimes useful to equate the longitude values with the X axis and the latitude values with the Y axis.

Figure 1.9: **Geographic coordinate system (locations are expressed as longitude and latitude) on a globe and the projected coordinate system (locations are expressed as x , y coordinates on a map)**



1.4 Map Projection System

A map projection is the manner in which the spherical surface of the Earth is represented on a flat (two-dimensional) surface. It is a process of transferring location on the curved surface of the earth with the geodetic coordinate (MO) to planer map coordinates (XY). This can be accomplished by direct geometric projection or by a mathematically derived transformation. There are many kinds of projections, but all involve transfer of the distinctive global patterns of parallels of latitude and meridians of longitude onto an easily flattened surface, or developable surface.

The three most common developable surfaces are the cylinder, cone, and plane (Figure 1.10). A plane is already flat, while a cylinder or cone may be cut and laid out flat, without stretching. Thus, map projections may be classified into three general families: cylindrical, conical, and azimuthal or planar.

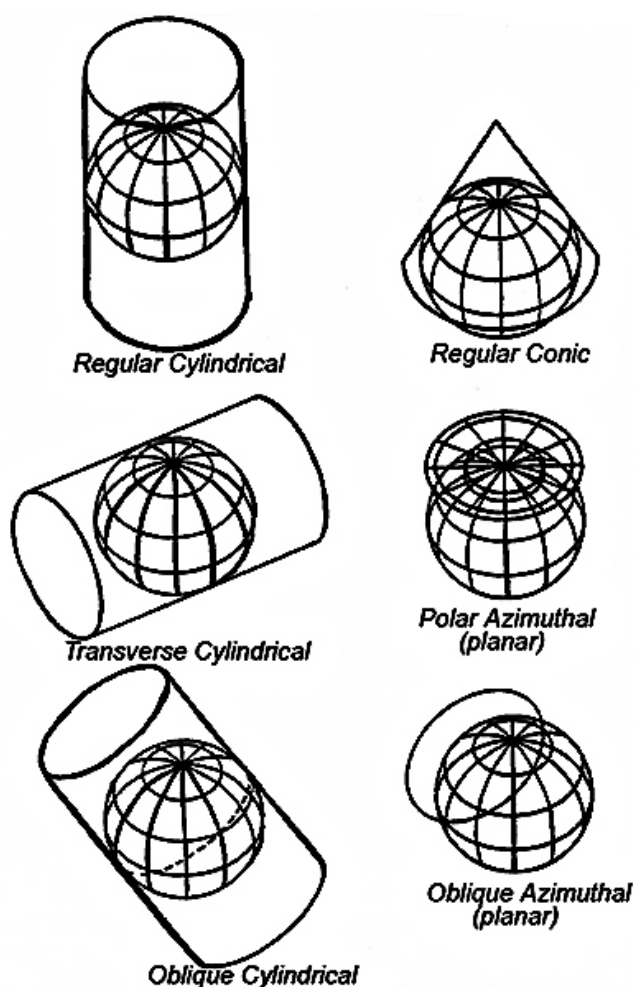
Properties of Map Projection

Regardless of what type of projection is used, some error or distortion is inevitable while transforming a spherical surface into a flat surface. Ideally, a distortion-free map has four valuable properties:

- Conformality
- Equivalence
- Equidistance
- True direction

Each of these properties is explained below. No map projection can be true in all of these properties. Therefore, each projection is devised to be true in selected properties, or most often, a compromise among selected properties. Projections that compromise in this manner are known as compromise projections.

Figure 1.10: Illustration of different types of map projection system



Conformality is the characteristic of true shape, wherein a projection preserves the shape of any small geographical area. This is accomplished by exact transformation of angles around points. One necessary condition is the perpendicular intersection of grid lines as on the globe. The property of conformality is important in maps which are used for analysing, guiding, or recording motion, as in navigation. A conformal map or projection is one that has the property of true shape.

Equivalence is the characteristic of equal area, meaning that areas on one portion of a map are in scale with areas in any other portion. Preservation of equivalence involves inexact transformation of angles around points and thus, is mutually exclusive with conformality except along one or two selected lines. The property of equivalence is important in maps that are used for comparing density and distribution data, as in populations.

Equidistance is the characteristic of true distance measurement. The scale of distance is constant over the entire map. This property can be fulfilled on any given map from one, or at most two, points in any direction or along certain lines. Equidistance is important in maps that are used for analysing measurements (i.e., road distances). Typically, reference lines such as the equator or a meridian are chosen to have equidistance and are termed standard parallels or standard meridians.

True direction is characterized by a direction line between two points that crosses reference lines (e.g., meridians) at a constant angle or azimuth. An azimuth is an angle measured clockwise from a meridian, going north to east. The line of constant or equal direction is termed a rhumb line.

The property of constant direction makes it comparatively easy to chart a navigational course. However, on a spherical surface, the shortest surface distance between two points is not a rhumb line, but a great circle, being an arc of a circle whose centre is the centre of the Earth. Along a great circle, azimuths constantly change (unless the great circle is the equator or a meridian). Thus, a more desirable property than true direction may be where great circles are represented by straight lines. This characteristic is most important in aviation. Note that all meridians are great circles, but the only parallel that is a great circle is the equator. flat, while a cylinder or cone may be cut and laid out flat, without stretching. Thus, map projections may be classified into three general families: cylindrical, conical, and azimuthal or planar.

Types of Projections

Although a great number of projections have been devised, the majority of them are geometric or mathematical variants of the basic direct geometric projection families described below. Choice of the projection to be used depends upon the true property or combination of properties desired for effective cartographic analysis.

Azimuthal or Planar or Perspective Projections

This projection is accomplished by drawing lines onto the plane tangent to the globe. This is conceptually equivalent to tracing a shadow of a figure cast by a light source. A tangent plane intersects the globe surface at only one point and is perpendicular to a line passing through the centre of the sphere. Thus these projections are symmetrical around a chosen centre or central meridian. So the characteristic outline of the world map would be circular. If the pole is the centre point, the meridians are straight lines, spaced at their true angles intersecting at the centre point. Parallels are represented as concentric circles.

This projections may be centred (Figure 1.11):

- On the poles (polar aspect);
- At a point on the equator (equatorial aspect);
- At any other orientation (oblique aspect).

Figure 1.11: Aspect wise classification of various types of azimuthal projections - on the poles (polar aspect); at a point on the equator (equatorial aspect) and at any other orientation (oblique aspect)

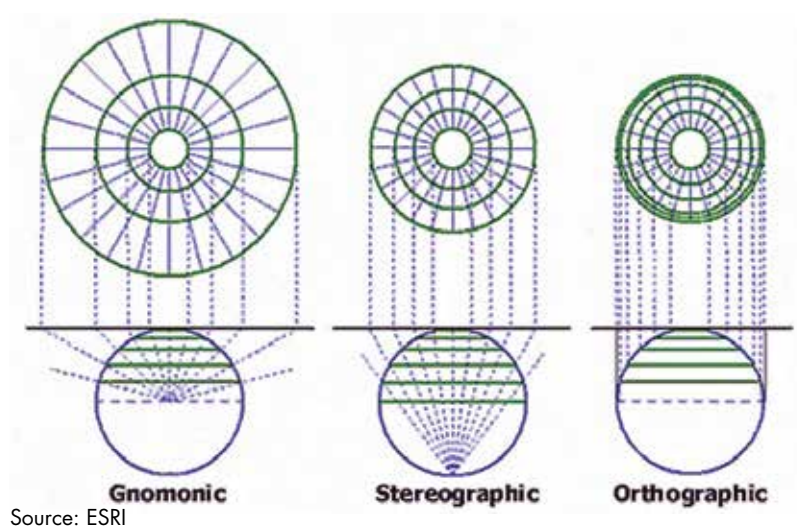


Source: ESRI

The origin of the projection lines – that is, the perspective point – may also assume to be at various positions (Figure 1.12):

- The centre of the Earth (gnomonic);
- An infinite distance away (orthographic);
- On the Earth's surface, opposite the projection plane (stereographic).

Figure 1.12: Types of Azimuthal projection based on the origin of the projection lines

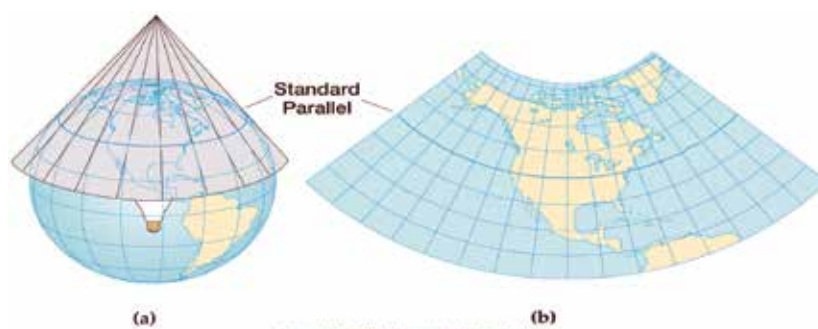


Source: ESRI

Conical Projection

This projection is accomplished by intersecting, or touching, a cone with the global surface and mathematically projecting lines into the developable area. It is wrapped like a cone around the globe and after unrolling the outline of the world would be fan shaped. The meridians are represented as straight lines and parallels as concentric circles. Only the parallels where the cone touches the global surface have the same lengths as on earth (Figure 1.13).

Figure 1.13: Illustration of a conical projection system

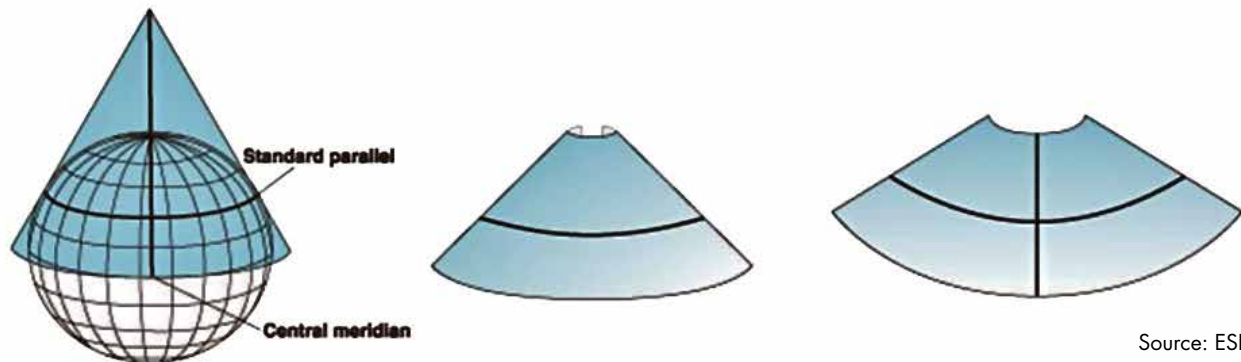


Copyright © 2005 Pearson Prentice Hall, Inc.

Source: ESRI

A tangent cone intersects the globe to form a circle. Along this line of intersection, the map is error-free and possesses equidistance. Usually this line is a parallel, termed 'the standard parallel' (Figure 1.14).

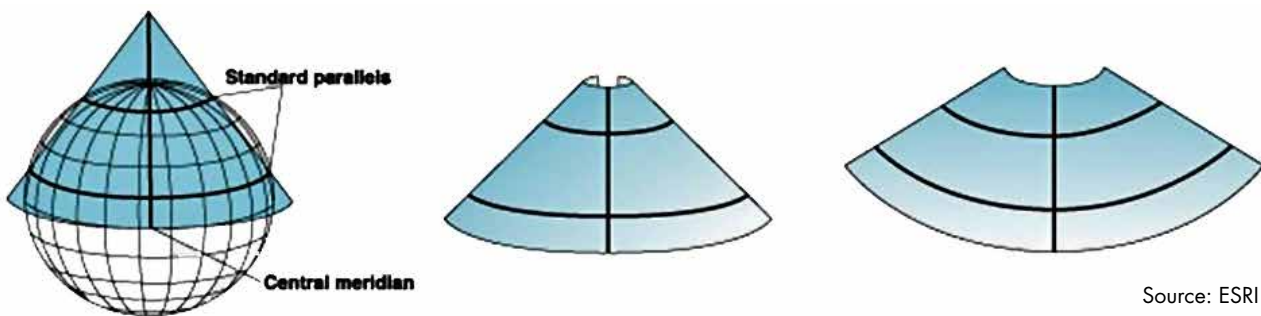
Figure 1.14: Illustration of a tangent cone intersecting the globe



Source: ESRI

A secant cone intersects the global surface forming two circles that possess equidistance. In this case the cone slices underneath the global surface, between the standard parallels (Figure 1.15). Note that the use of the word secant, in this instance, is only conceptual and not geometrically accurate.

Figure 1.15: Illustration of a secant cone intersecting the globe showing two parallels



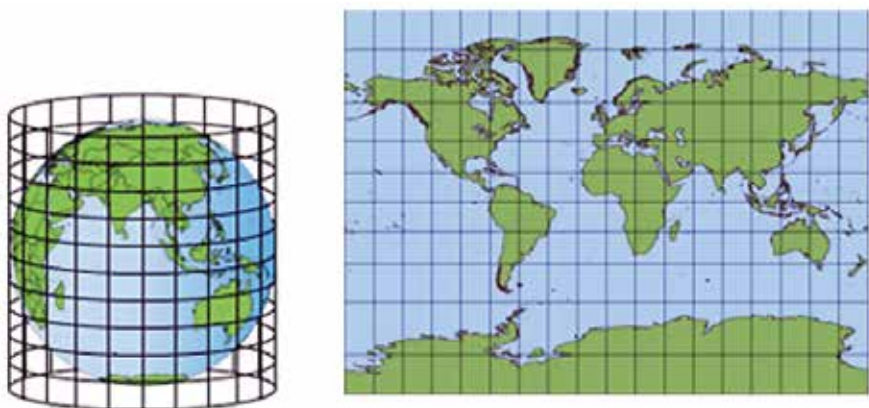
Source: ESRI

One of the popular conical projections is Lambert's conformal conic in which the angle is conformal with an equal angle and distance in an area of 300 km in east-west and 500 km in north-south.

Cylindrical Projection

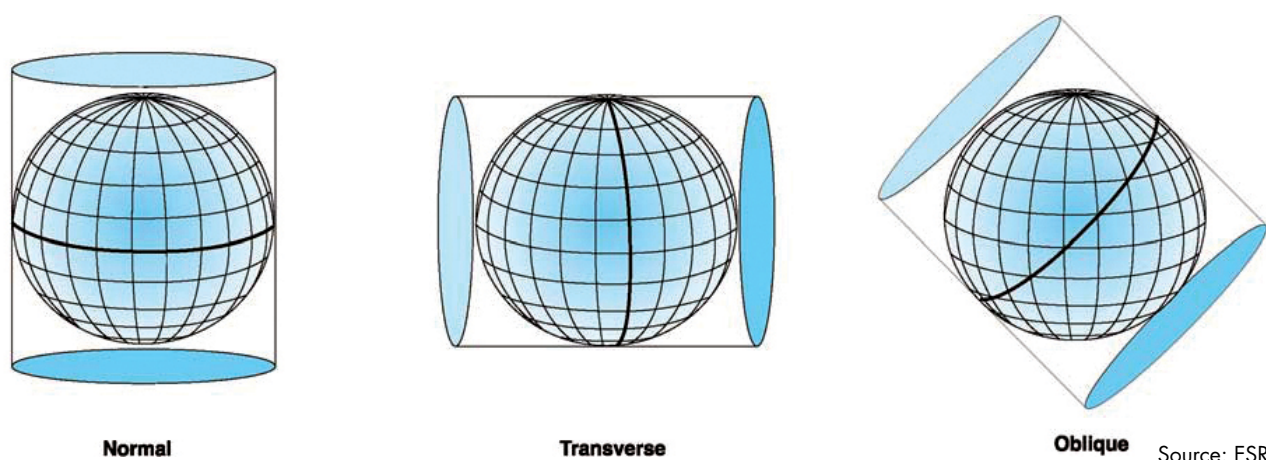
A projection to a plane that is wrapped around the globe in the form of a cylinder. The surface is mathematically projected onto the cylinder, which is then cut and unrolled. After unrolling, the outline of the globe would be rectangular in shape; the meridians are parallel straight lines that are crossed at right angles by parallel straight lines of latitude (Figure 1.16).

Figure 1.16: Illustration of a cylindrical projection system



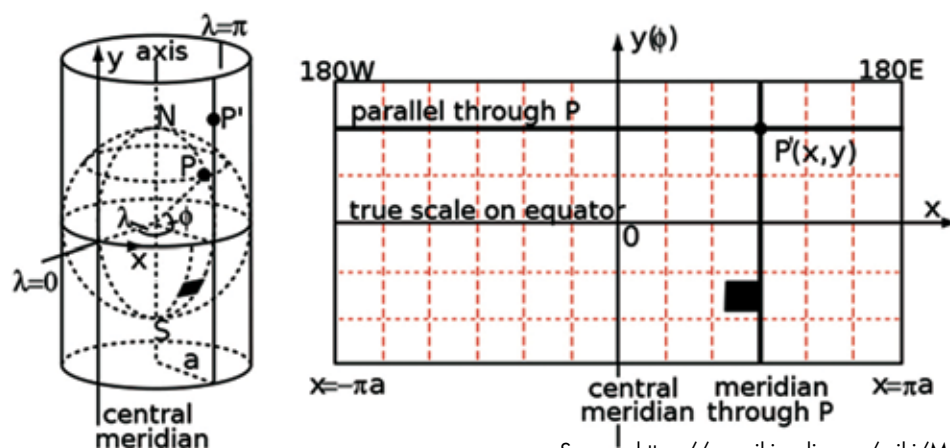
Like the conical projection system, the cylindrical projection is classified by aspect as well as cylinder size. The aspect wise cylindrical projections are normal, equatorial or transverse and oblique (Figure 1.17), and based on cylinder size it is inside, tangent and secant.

Figure 1.17: Types of cylindrical projections based on the aspect of cylinder



A tangent cylinder intersects the global surface on only one line to form a circle, as with a tangent cone. This central line of the projection is commonly the equator and possesses equidistance. If the cylinder is rotated 90 degrees from the vertical (i.e., the long axis becomes horizontal), then the aspect becomes transverse, wherein the central line of the projection becomes a chosen standard meridian as opposed to a standard parallel (Figure 1.18).

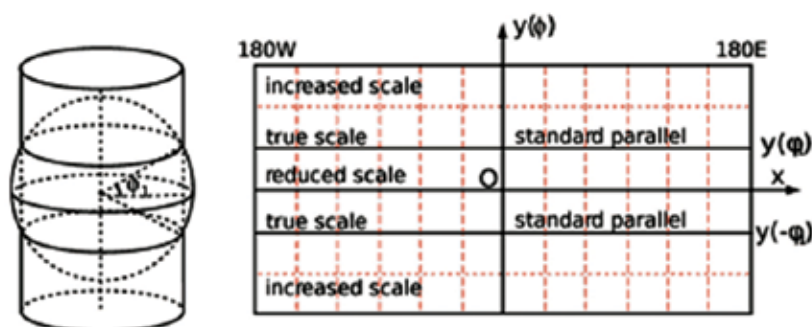
Figure 1.18: Illustration of tangent cylindrical projection showing single parallel line representation on map



A secant cylinder, only slightly smaller in diameter than the globe, has two lines possessing equidistance (Figure 1.19).

One of the most popular cylindrical projections is the Universal Transverse Mercator (UTM) with a transverse axis, secant cylinder and conformality (equal angle).

Figure 1.19: Illustration of secant cylindrical projection showing two parallel lines intersecting on the globe and representation it in planer map



Map Projection Parameters

Each map projection has a set of parameters that must be defined. The parameters specify the origin and customize a projection for the area of interest. Angular parameters use the geographic coordinate system units, while linear parameters use the projected coordinate system units.

Linear Parameters

False easting is a linear value applied to the origin of the x-coordinates. For instance, if the origin of projection (in latitude/longitude) is in the centre of the map, all areas west of the origin would be negative when false easting of zero is assigned. To make the coordinate positive for the entire map, set the false easting to a positive number.

False northing is a linear value applied to the origin of the Y-coordinates. For instance, if the origin of the projection (in latitude/longitude) is in the centre of the map, all area south of the origin would be negative unless a positive false northing is assigned.

False easting and northing values are usually applied to ensure that all x- and y-values are positive. You can also use the false easting and northing parameters to reduce the range of the x- or y-coordinate values. For example, if you know all y-values are greater than 5,000,000 metres, you could apply a false northing of -5,000,000.

Angular Parameters

- Azimuth defines the centre line of a projection. The rotation angle measures east from north. This is used with the azimuth cases of the Hotine Oblique Mercator, rectified skew orthomorphic, and Local projections.
- Central meridian defines the origin of the x-coordinates. The single line of longitude that is truly vertical on the map. It is usually in the middle of the map.
- Longitude of origin defines the origin of the x-coordinates. The central meridian and longitude of origin parameters are synonymous.
- Central parallel defines the origin of the y-coordinates.
- Latitude of origin defines the origin of the y-coordinates. This parameter may not be located at the centre of the projection. In particular, conic projections use this parameter to set the origin of the y-coordinates below the area of interest. In that instance, you don't need to set a false northing parameter to ensure that all y-coordinates are positive.
- Longitude of centre is used with the Hotine Oblique Mercator centre (both two-point and azimuth) cases to define the origin of the x-coordinates. This is usually synonymous with the longitude of origin and central meridian parameters.
- Latitude of centre is used with the Hotine Oblique Mercator centre (both two-point and azimuth) cases to define the origin of the y-coordinates. It is almost always the centre of the projection.

Standard parallel 1 and standard parallel 2 are used with conic projections to define the latitude lines where the scale is 1.0. When defining a Lambert conformal conic projection with one standard parallel, the first standard parallel defines the origin of the y-coordinates.

Unitless Parameters

Scale factor is a unitless value applied to the centre point or line of a map projection. The scale factor is usually slightly less than one. The Universal Transverse Mercator (UTM) coordinate system, which uses the Transverse Mercator projection, has a scale factor of 0.9996. Rather than 1.0, the scale along the central meridian of the projection is 0.9996. This creates two almost parallel lines approximately 180 kilometres, or about 1°, away where the scale is 1.0. The scale factor reduces the overall distortion of the projection in the area of interest.

2

Introduction to ArcGIS and Hands- on Exercises

2. Introduction to ArcGIS and Hands-on Exercises

ArcGIS comprises a set of integrated applications/software programs. It is used to create, display and analyse geospatial data and is developed by the Environmental Systems Research Institute (ESRI) of Redlands, California. It has three components: ArcCatalog, ArcMap and ArcToolbox.

- **ArcCatalog:** It is used for browsing maps and spatial data, exploring spatial data, viewing and creating metadata, and managing spatial data. It also allows users to search, preview and add data to ArcMap, use ArcToolbox for processing the data, and set up address locator services (geocoding).
- **ArcMap:** It is the main mapping application used for visualizing spatial data, performing spatial analysis, and creating maps to show the results of your work.
- **ArcToolbox:** It is an interface for accessing the data conversion and analysis function that comes with ArcGIS. Although it cannot be directly accessible from the Start menu as ArcCatalog and ArcMap, it is easily accessed and used within ArcMap and ArcCatalog. It contains tools for geoprocessing, data conversion, coordinate systems, projections and more.

ArcGIS comes in three software product levels: ArcView, ArcEditor, and ArcInfo. These products share a common architecture but provide increasing level of functionality.

- **ArcView:** it provides the base mapping and analysis tools.
- **ArcEditor:** it provides all ArcView capability and includes additional processing and advanced editing.
- **ArcInfo:** it provides all ArcEditor capability plus advanced analysis and processing.

While these levels should be carefully considered while purchasing software, it is also important to be aware of the limitations of the level you are using.

The common ArcGIS files are:

Geodatabase – The personal geodatabase, or geographic database, file is called the “modern container for GIS data” and is specific to ArcGIS. Geodatabases define, manage, process and store all the types of data that can be used in ArcGIS (i.e., feature, rasters, relationships, measurements, attributes, etc.) inside either a Microsoft Access database (.mdb) or a full relational database (SQL Server, Oracle, Informix or DB2).

Shapefiles – ArcGIS shapefile format is a widely adopted standard and comprises three or more associated files. It is a simple, non-topological format for storing geographic features with its attribute information. Geographic features in a shapefile can be represented by points, lines or polygons. Be careful while copying this data to a disk. You must get all of the files associated with a single layer. They will have a variety of file extensions: .shp, .shx, .dbf and sometimes others. If you are copying shapefiles, we recommend that you use the ‘File’ > ‘Data’ > ‘Export Data’ function in ArcMap or through ArcCatalog. This will automatically copy all files associated with a layer. Also, be aware that some of these files may be very large in size.

Layer – According to ESRI, the layer file (.lyr) stores symbology, symbology classifications, labelling properties, scale dependency, and definition. If you save something in this format it means that, unlike in shapefiles, colours and other characteristics are saved and will appear the same every time you open it.

Coverages – “A coverage stores a set of thematically associated data considered to be a unit. It usually represents a single layer, such as soils, streams, roads, or land use. In a coverage, features are stored as both primary features (points, arcs, polygons) and secondary features (tics, links, annotation).” Source: ESRI Data Dictionary.

CAD (computer-aided design) – “A computer-based system for the design, drafting, and display of graphical information.” Although most commonly used to support engineering, planning, and illustrating activities, these files can be used in a GIS. Source: ESRI Data Dictionary.

Image formats – ArcGIS accepts and uses a variety of image files (.tiff, .jpg, .jp2, .png, etc.).

Text files (with x, y coordinates)

2.1 ArcCatalog

ArcCatalog is an application for managing the spatial data holdings, database designs, and for recording and viewing metadata. It lets you find, preview, document, and organize geographic data and create a sophisticated geodatabase to store data. It provides a framework for organizing large and diverse repositories of GIS data.

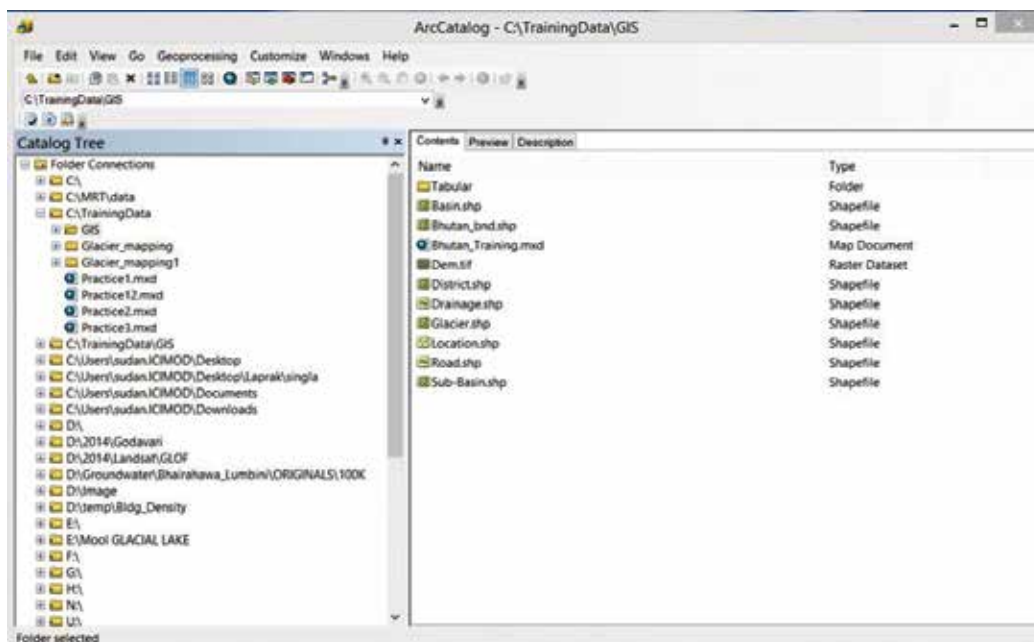
It is roughly equivalent to the Windows Explorer interface, in that it provides an interface from which to browse and manage geographic data and databases. Because Windows Explorer does not properly recognize all of the various components of geographic datasets, it is always best to use ArcCatalog to manage your data.

Exercise in ArcCatalog

In this exercise, you will explore the overview of the ArcCatalog, connect the data folder, visualize the various types of data, manage the folders and files, view metadata about the data and create new GIS shapefiles.

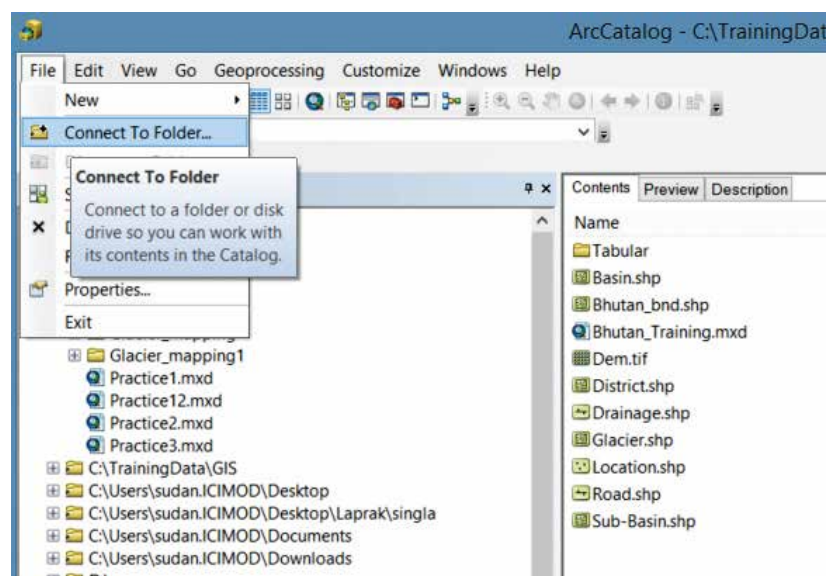
- **To start the ArcCatalog** – go to Windows Start menu > All Programs and select ArcCatalog from ArcGIS menu lists. Then the ArcCatalog window will open.

In the ArcCatalog window, the panel on the left side is the 'Catalog Tree' where you can browse folders on your system for geographic data. Note that only folders and files compatible with ArcGIS will displayed in the Catalog tree and the View Windows on the right.

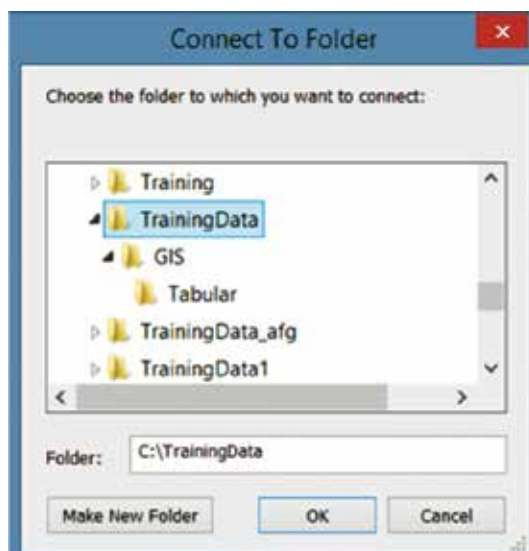


If your data folder is not shown or if you want to add quick access to your data folder, you need to connect your data folder.

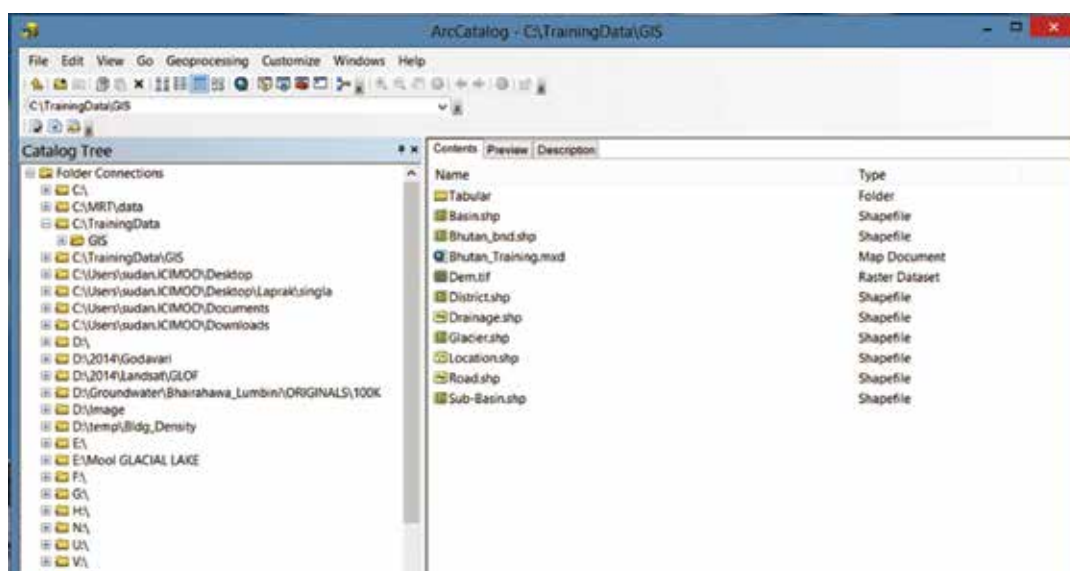
- To connect your data folder, go to file menu on top of the ArcCatalog > click 'Connect to Folder' in the file menu list.



The 'Connect to Folder' menu will open.



- Browse your training data folder in the folder tree menu and select TrainingData folder from the list > click OK to connect the folder.
- Now you can view your TrainingData folder connection list in the Folder Connection Tree list in the Catalog Tree.

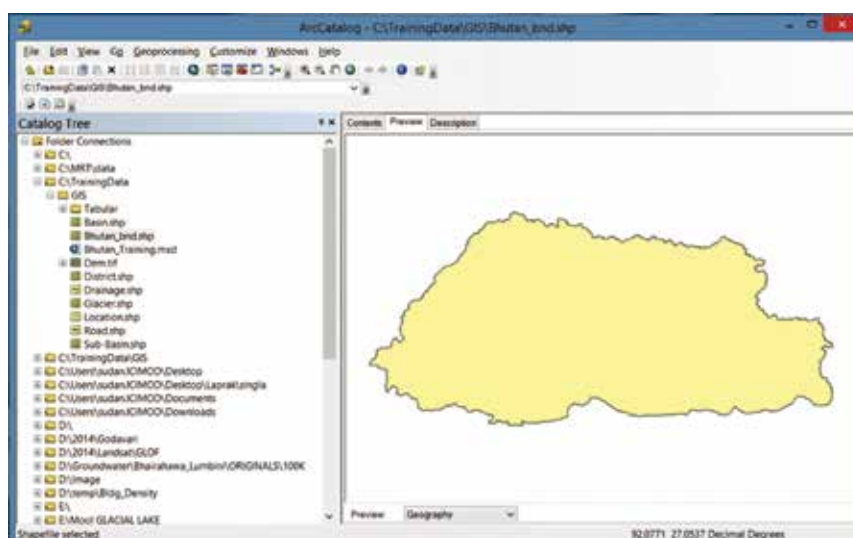


- Expand the C:\TrainingData in the Folder Connections in ArcCatalog Tree and click on GIS folder to display its contents in the Contents tab of the View window on the right side.

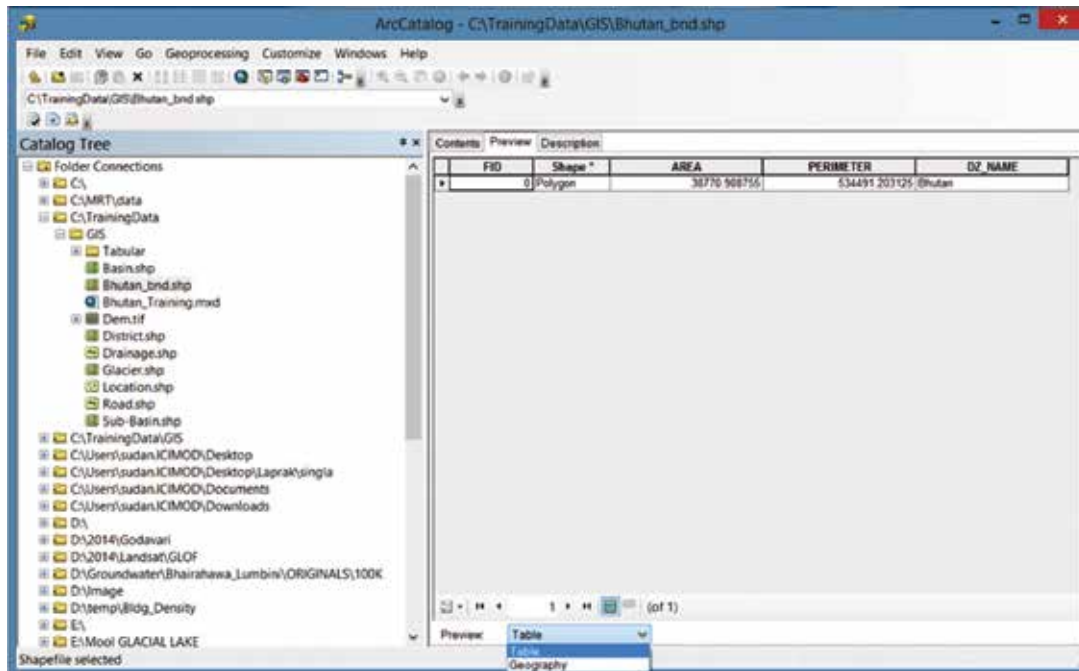
You will notice several files in this folder, not all of which are actually geographic data, but are in some way supported in ArcGIS.

- Click on the Bhutan_bnd.shp file in the list.
- Click on the Preview tab in the View window on the right of the ArcCatalog window.

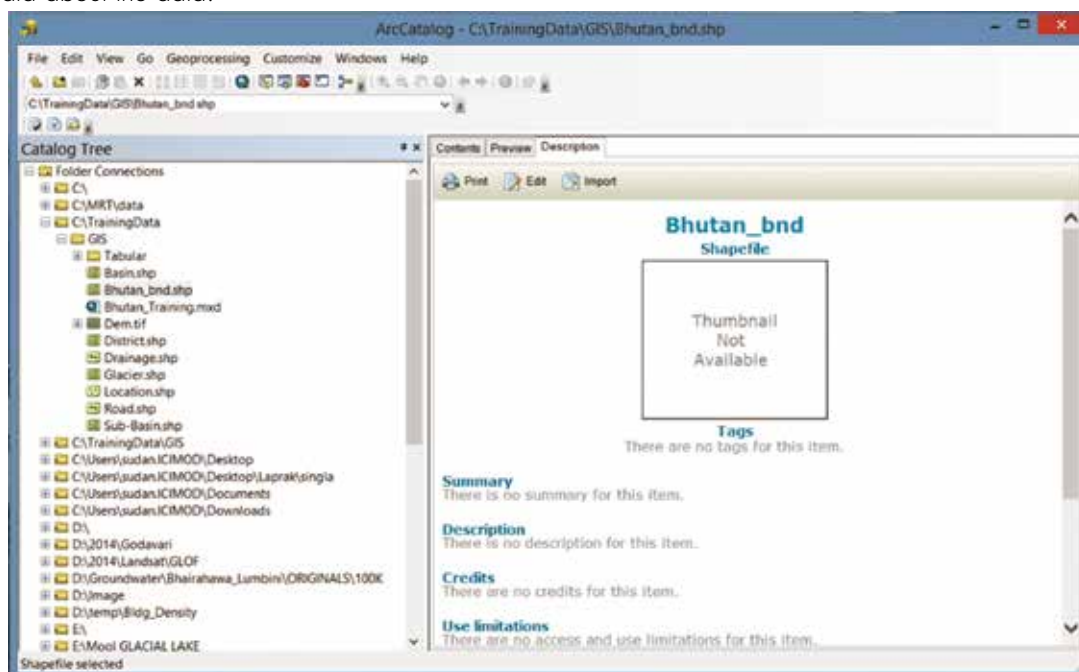
Now you can preview the geographic data (Bhutan boundary) in ArcCatalog.



- At the bottom of the Preview screen, change the Preview: Drop-down to Table, and examine the Table for this dataset.



- Change to the Description tab, at the top of the ArcCatalog view window to see the additional information/metadata about the data.

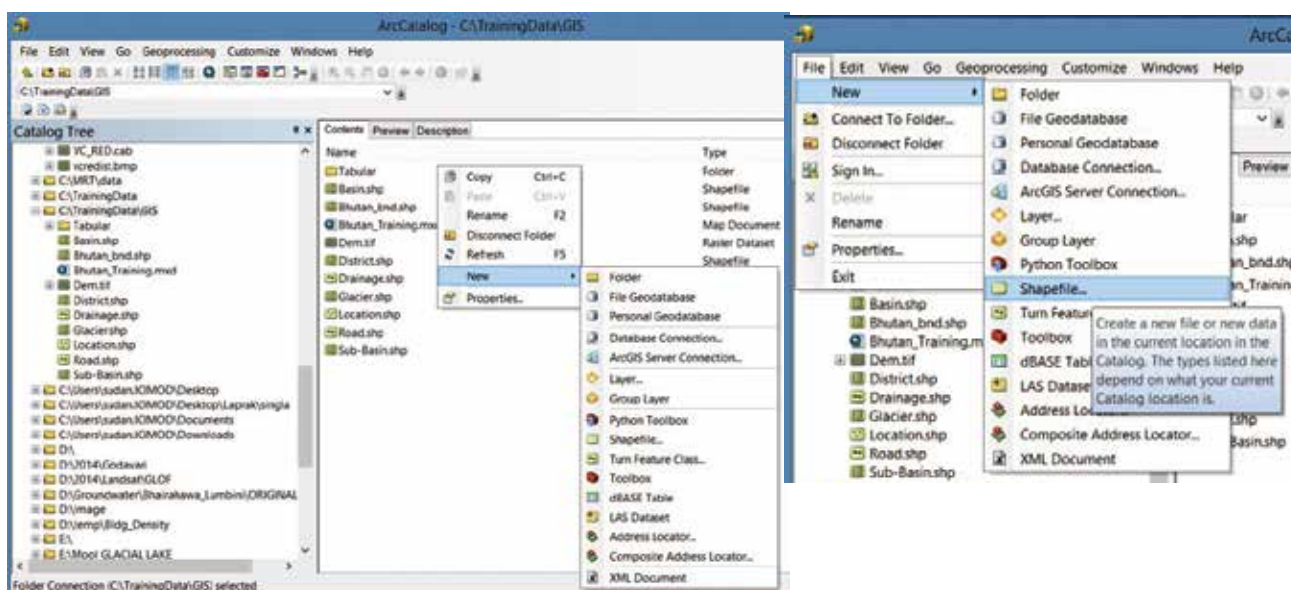


This section shows the metadata about the data, which is defined as 'data about data'. This information is important, especially in a geospatial context, because it gives information about the source, author, creation and geographic referencing. Here in the Description tab, it provides a description of the files, spatial information, and a list of all the attributes associated with the files, and allows you to edit, print and import the information on the data.

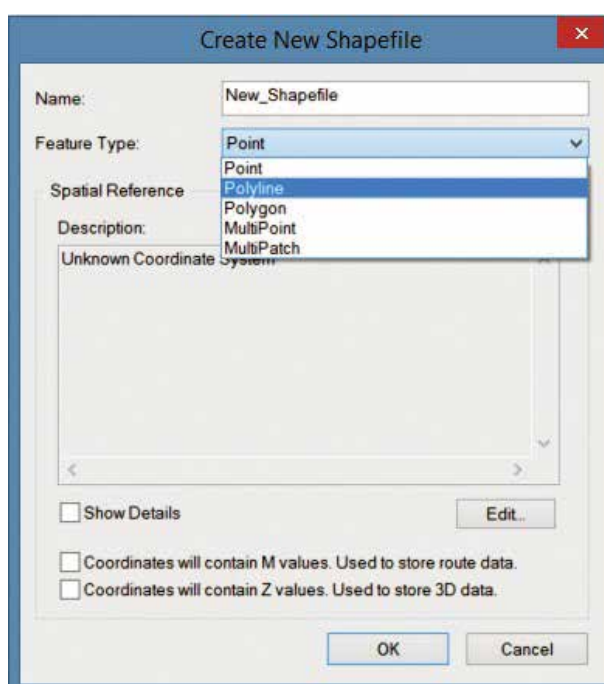
Create New Shapefile – ArcCatalog

A shapefile can be represented by different geographic features – points, polylines and polygons. In this exercise, you can create any one type of shapefile, as this exercise is only aimed at showing the process of creating a new shapefile. While creating a shapefile you can define the type of features as routes (m-values) or three-dimensional (z-values), and these properties cannot be modified after the shapefile has been created. You also need to define the coordinate system of the shapefile.

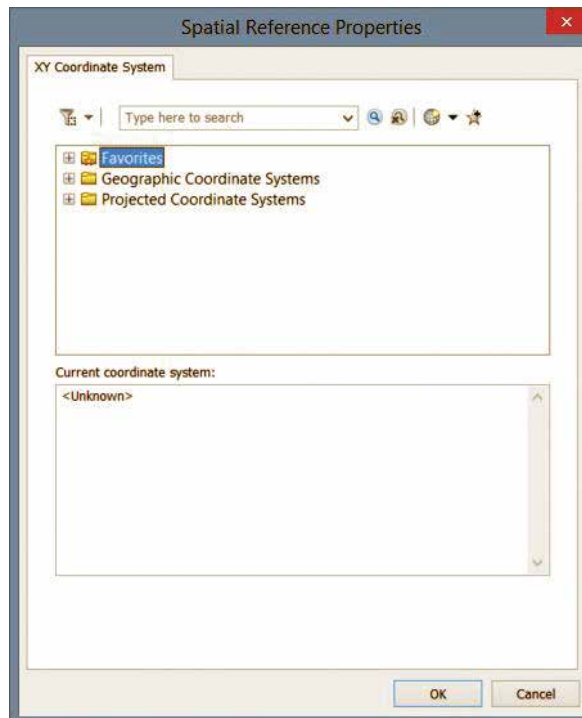
- Expand the C:\TrainingData in the Folder Connections in the ArcCatalog Tree and click on the GIS folder to display its contents in the Contents tab of the View window on the right side.
- To create a new shapefile, right click on the Folder in 'Catalog Tree' or in 'Contents View' window of the folder where you want to create the new shapefile or go to 'File Menu' at the top of the ArcCatalog window.
- Go to 'New' and select the shapefile from the list.



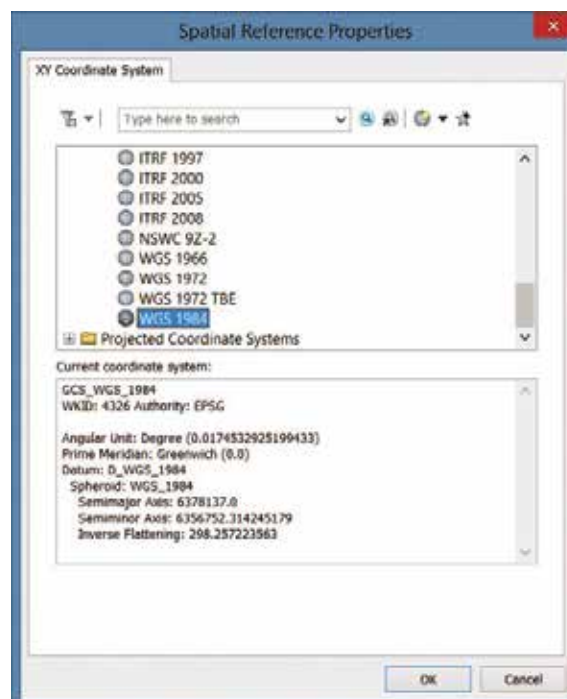
The 'Create New Shapefile' window will open.






- Type the name of the new shapefile in the Name textbox
- Select the type of the shapefile – point, polyline or polygon – from the dropdown Feature Type menu.
- Define the Spatial reference of the new shapefile – click the Edit button – the Spatial Reference Properties window will open.



- Expand the Geographic Coordinate Systems 'World' and select 'WGS 1984' from the list as Spatial Reference for the shapefile and click OK.



- Click OK.

Now you can see the new shapefile in the Contents list. Note that the icon of the new shapefile will be different for different feature types; for Point, the icon looks like ; for Polyline ; and for Polygon . At this point there will not be any feature data in the shapefile; to add the data in the shapefile you need to open it in ArcMap and add the data in it by enabling the editing mode.

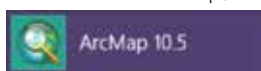
2.2 ArcMap

ArcMap is the main component of ArcGIS suite of geospatial processing programs, and is used to perform a wide range of common GIS tasks as well as specialized, user-specific tasks. It is used primarily to view, edit, create, and analyse geospatial data. It allows users to explore data within a data set, symbolize features accordingly, and create map layouts. The most common workflows that can be performed in ArcMap are:

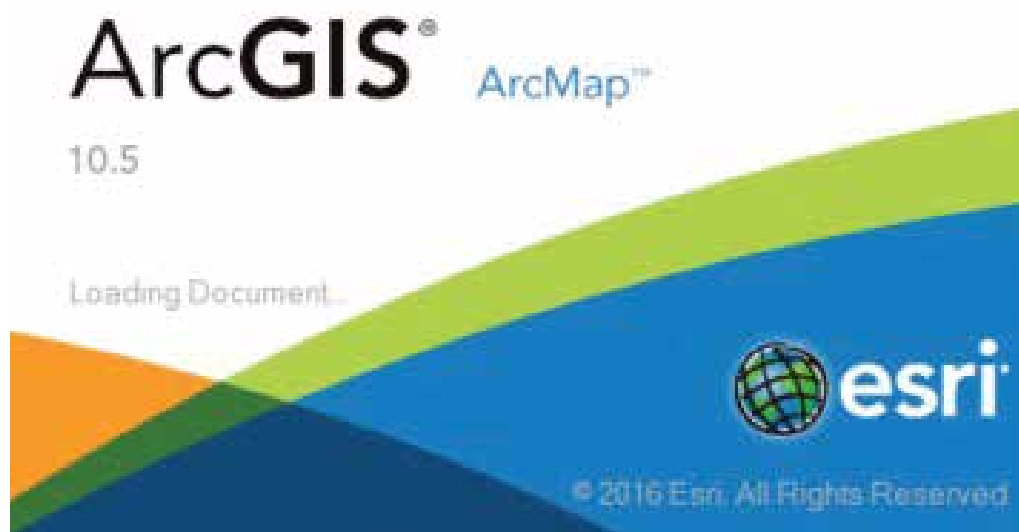
- Work with maps
- Print maps
- Compile and edit GIS datasets
- Use geo-processing to automate work and perform analysis
- Organize and manage geodatabases and ArcGIS documents
- Publish map documents as map services using ArcGIS Server
- Share maps, layers, geo-processing models, and geodatabases with other users
- Document geographic information
- Customize the user experiences

Getting Started with ArcMap

To start the ArcMap, click the Windows button and go to the programs list, then select the ArcMap icon from the list.

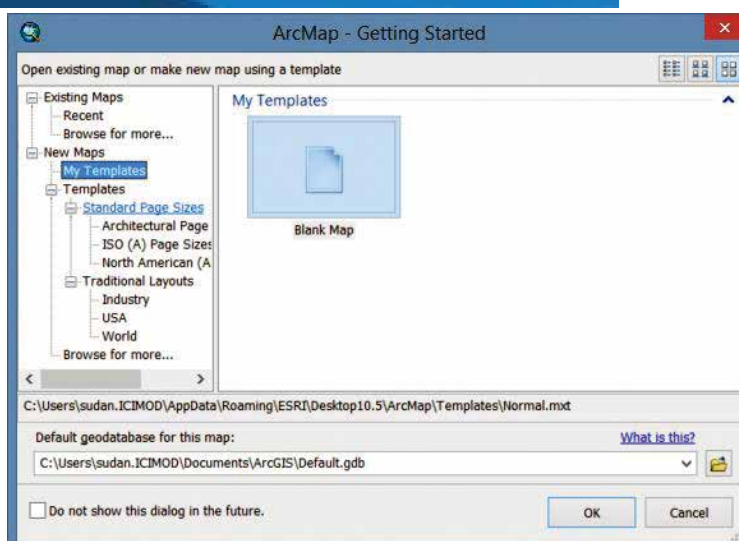


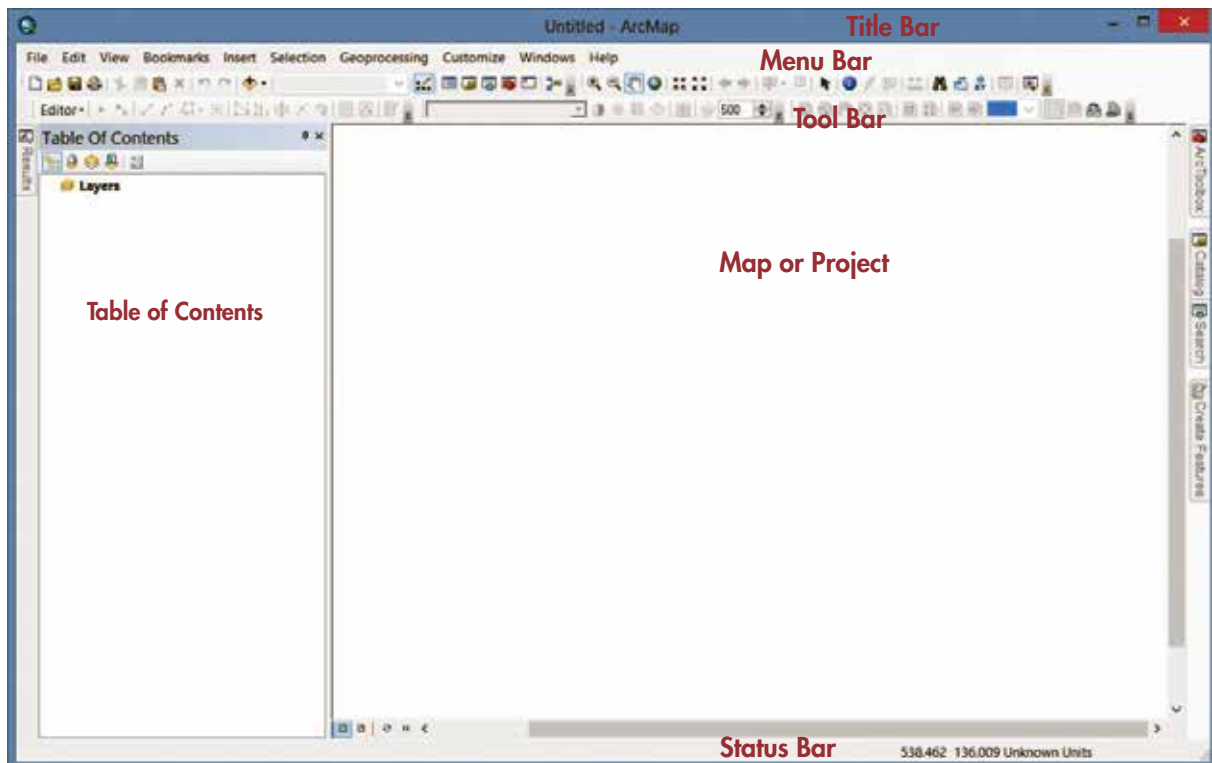
Upon opening ArcMap you may see the following startup window:



This is a new feature in version 10.x of ArcGIS software that allows you to make a shortcut to your most-used data location. Since we're just beginning, we are going to skip this option and simply use the default. Click **Cancel**.

Now, a new, blank ArcMap window will open.





The ArcMap contains the following features:

- Menu bar, toolbars and status bar
- Map or Project View.
- Table of contents.

Menu Bar

The menu bar is in the top row of the main window. It contains File, Edit, View, Bookmarks, Insert, Selection, Geoprocessing, Customize, Windows and Help options. Each option in the menu bar contains a drop-down menu.



Toolbar

Toolbars contain buttons or list boxes to help you view or analyse data. To check and modify the displayed toolbars, select 'View' > 'Toolbars' in the main menu bar. Alternatively, you can go to the Toolbars tab of the Customize dialog box.

Toolbars may be docked at the edges of the main window. Also, they may be undocked as floating toolbars. Holding Ctrl while dragging deactivates the magnetic snapping, allowing you to place the toolbars anywhere on your screen. Right-clicking anywhere inside the menu bar and toolbar area allows you to access a context menu which provides a selection of the View menu options.

Any changes made to the interface will be kept and applied every time you use ArcMap. Please note that some toolbars are dependent upon the license level. Some toolbars and extensions will be visible, but the user will not be able to access the functionality if they do not possess the required license.

Standard Toolbar

It appears at the top of the ArcMap and is used for creating a new project, opening an existing project or map, saving maps, adding data layers, redo and undo processes, opening Arctoolbox- ArcCatalog- Python command window and model builder, etc.



Tools Toolbar

It is used for map navigation and query within the active data frame. It allows you to adjust zooming level, restore the map extent, go forward or backward to previous view extent, select and deselect features on the map, view information on map features, set a hyperlink, carry out measurements on the map, and search the features and location points on the map. All these functions only apply in active map view.



Effects Toolbar

This toolbar is used for interactive display of layer in map view. It allows users to adjust contrast, brightness, transparency level of the layers in the active map view, as well as to swipe the selected layers.

Layout Toolbar

This toolbar consists of navigation tools used for navigating around the page of the map layouts. The tools will only be activated when you open the map layout view in the map view.



Draw Toolbar

This toolbar is used to add and edit graphical elements in the map layout page.



Editor Toolbar

It consists of various tools for editing the data in map view. This tool is used to enable/start, save and stop the editing mode in the map view. To add, modify and remove features/data in your data layers, you need to enable the 'start editing' mode in this toolbar and you can use various editing commands in this toolbar. You can also use additional editing toolbars available in ArcMap such as Advance Editing, COGO, Geometric Network Editing, Topology, Representation, Routing, etc.




Georeferencing Toolbar

Raster data commonly obtained by scanning maps or collecting aerial photographs does not normally contain spatial reference information. Sometimes the location information delivered from satellite imagery is inadequate and data does not align properly with other datasets. Thus, to use these datasets in conjunction with other datasets, you need to align or reference them to a map coordinate system. For that purpose we use this toolbar to align or georeference the data into a map coordinate system. To georeference the data you need to define its location using map coordinates and assign the coordinate system of the data frame. This toolbar allows you to georeference raster datasets, raster layers, images and raster products.




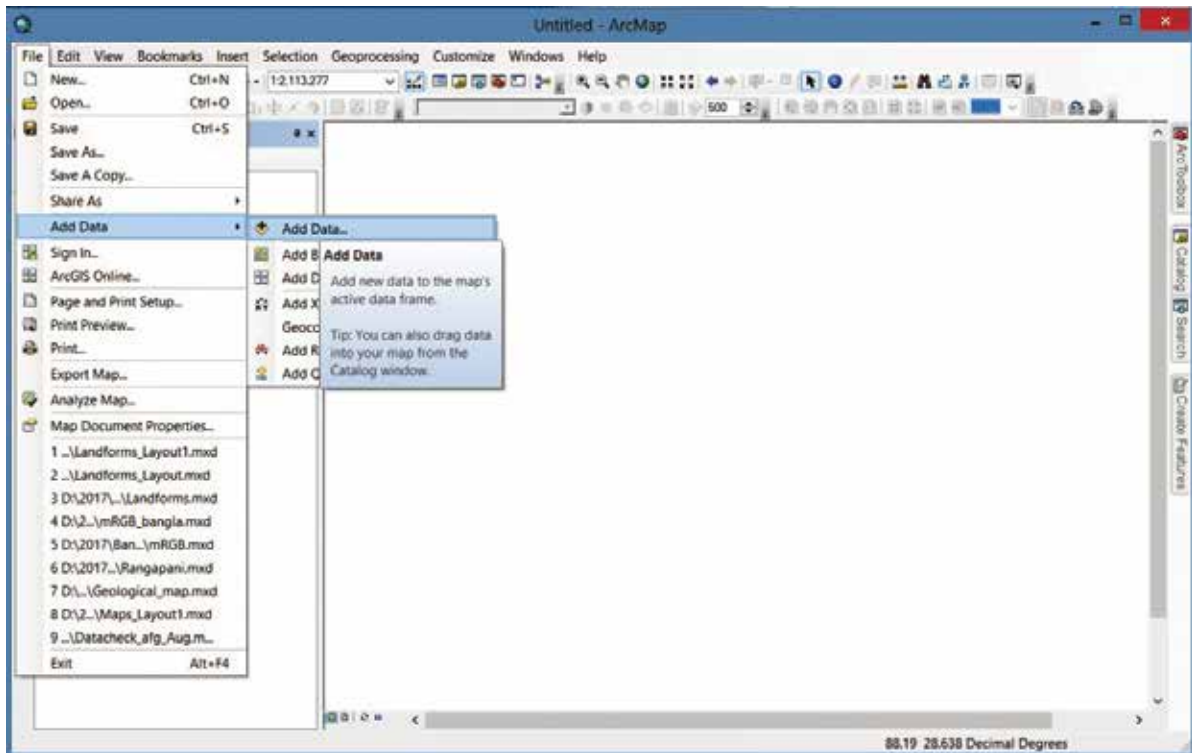
Adding Data to ArcMap

In ArcMap you can add data layers in two ways.

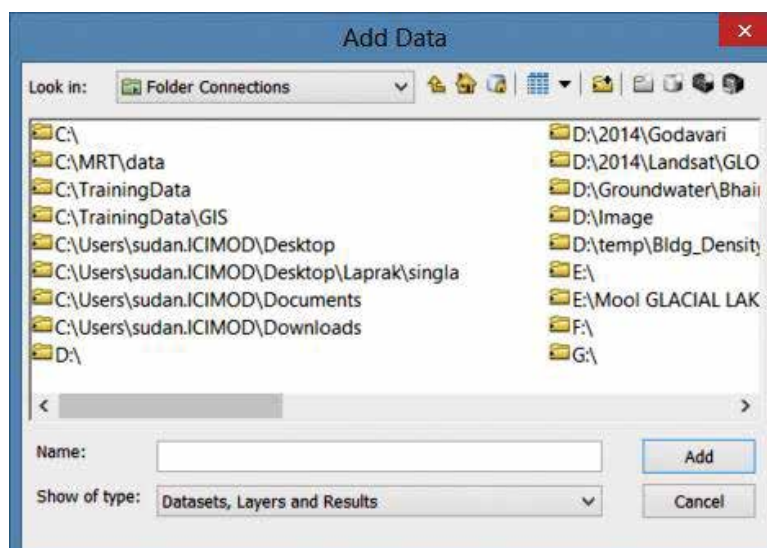
- Click on the ArcCatalog tab  in the Standard toolbar. You will see the catalog tree. Navigate to the data (c:\TrainingData\GIS) and drag and drop the data into the Table of Contents under Layers.


Or

- Click the add button  in the Standard toolbar or go to File menu in the menu bar and select 'Add Data' from the 'Add Data' list; or you can open the ArcCatalog from the standard menu bar - Then explore the location of the data and drag & drop the layer you want to add.

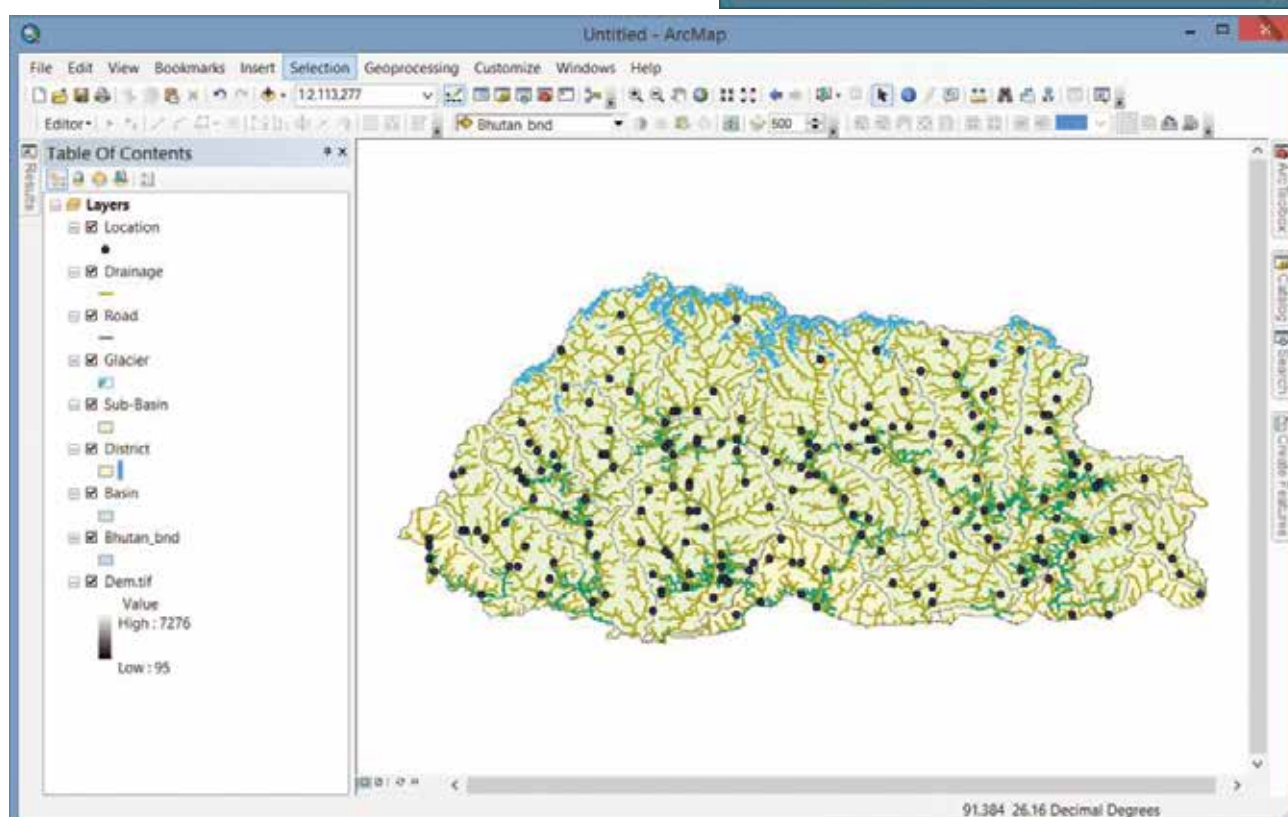


- The 'Add Data' sub-window will open.



- To connect the data folder, click on 'Connect To Folder'  icon in the 'Add Data' sub-window and select the data folder 'C:/TrainingData' from the folder list, then click the 'OK' button in the 'Connect To Folder' window. The 'TrainingData' folder is added to the list for quick access.
- Now open the GIS Data folder from the list. Select the '*Bhutan_bnd.shp*' data and click the 'Add' button to add the data.
- Again, explore the location of the data 'C:\trainingData' and select the data such as '*Basin.shp*', '*District.shp*', '*Sub-basin.shp*' and so on.

Now you can see the list of the added layers in the Table of Contents. Each layer has a check mark in the box to its left that indicates that they are turned on and displayed. Layers that are not checked are no longer visible in 'Map View'.



The color of the layers and their order may be different on each user screen. Each of these layers contains geometric objects that represent some real world entity. Points are used in the layer to represent the location of cities. Lines are used to represent the roads, and polygons are used to represent the country boundary, district boundary, and basin boundaries.

Notice how most of the button and toolbar functions are available now. Also notice the scale display next to the Add Data button **1:2,423,455**. This display tells you what the scale value of the current view is. If it displays the value '1: 2,423,455' it means each unit on the map is equal to 2,423,455 units in the real world. As you zoom in and out of the map, the scale will change dynamically. Scale is an important concept in computer mapping. The scale of the map often determines the amount of information that can be shown without the map becoming too crowded.

Also notice the position display at the bottom right (Status bar) of the screen. As you move the cursor around the view, these units change dynamically according to your cursor's position. Your map units will likely be in decimal

degrees **92.178 25.958 Decimal Degrees**. The first number in the display is longitude value and second number is latitude value.

Using the main tools

The toolbar contains buttons for zooming, panning, selection, identifying the features, Hyperlink, finding contents, input xy point and measuring on Map view. Some of the most useful ones are illustrated here.




Zoom In/Out

Zoom In  – zooms the view window in to a user-defined area. To use:


- Select the Zoom In tool with the left mouse button. Notice the cursor changes to a magnifying glass with a + sign icon.
- Go to a corner of the area you would like to zoom in on and click the left mouse button. While holding down the mouse button, move the cursor to the opposite corner that defines the area you want to magnify.
- Release the mouse and the view window should zoom in to your defined area and redraw.

Zoom Out  – zooms the view window out from the point clicked. To use:


- Select the Zoom Out tool with the left mouse button. Notice the cursor changes to a magnifying glass with a '-' sign icon.
- Using the left mouse button click on the area of the map you want to zoom out of. The view window should zoom out, centering on the area that you clicked on.

Pan  – moves all the view layer layers in the direction you move your mouse. It is a useful tool for viewing data that is larger than the view window, and you do not want to change your scale or loose detail by zooming out. To use:


- Select the Pan tool with the left mouse button. Notice the cursor changes to a hand.
- Click a spot on the view with the left mouse button, and while holding down the button move the mouse away from the direction you want to move the view and release the button. The view should move and redraw the view in the new location once the mouse button is released.

Full Extent  – zooms the view window to the full extent of all layers shown in the view. This is very handy when you want to get back to the way things looked when you first added the layer.

Zoom to Previous Extent  – zooms the view window back to the previous view window extent.

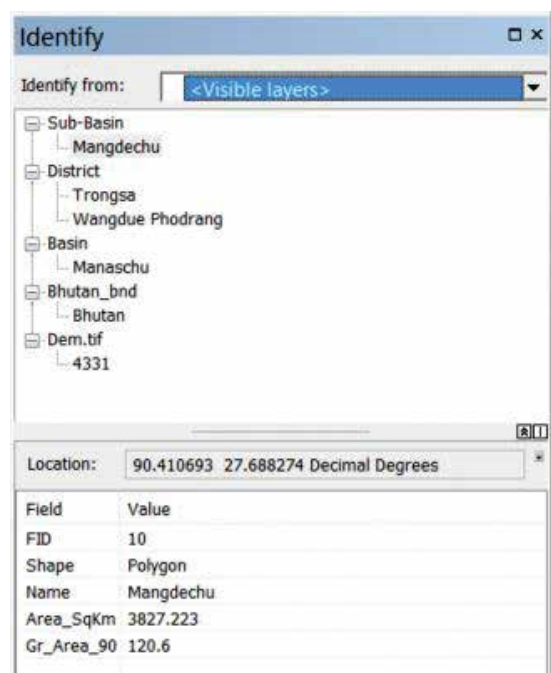
Practice using the zooming and panning tools to view data. You may also zoom in and out by using the wheel on your mouse and holding 'Ctrl' on your keyboard. You can always return to the initial view by pressing the 'Full Extent'  button; so don't be afraid to move around!

Identify Objects

The identify tool helps us to identify the objects of the layer. It is located on the Tools toolbar and it has the icon with the letter 'i' in a blue circle . This tool will display the attributes of a particular layer object. These attributes are actually located in a table of the layer. To use the identify tool:

- Click on the identify tool using the left mouse button. Your cursor changes to a selection with the 'i' icon.


When you click on a feature in the map, the 'Identify' window will open and you can choose what layers you would like to identify or see what you have identified.



Selecting Features

Selecting features allows you to identify or work with a subset of features. You'll most likely work with selected features when you are querying, exploring, analysing, or editing data. Applying a selection lets you specify the features you want to calculate statistics for, view attributes for, or edit or define the set of features that comprise a map layer.

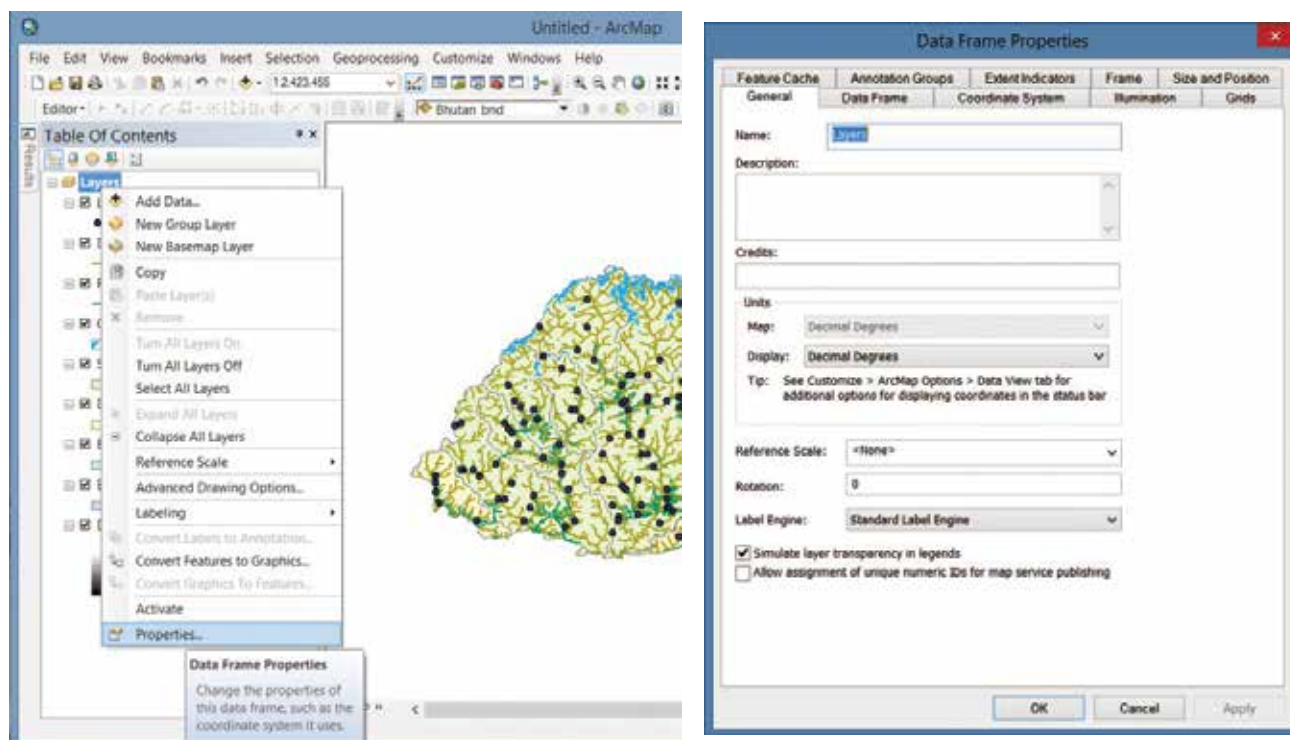
There are several ways you can select features. You can select features with your mouse pointer by clicking on them one at a time or by dragging a box around them on the map. There are two main ways to select features interactively on the map:

- Use the 'Select Features' tool  on the Tools toolbar.
- Select their records in the attribute table or Map window with your mouse pointer.

Setting Map Units, Display Units and Map Projection

One of the most important things that you should do after adding data is to set the map and display units. It is also a good idea to set the projection (if desired) at this stage as well. Setting these units will allow you to measure distances or compute areas. Display units should also be set if you are planning to create a map layout with a distance scale. To set the map and display units:

Right click on the data frame 'Layers' at the top of the legend and go down to 'Properties.'



The 'Data Frame Properties' dialog box pops up. You should go to the 'General' tab. Take a look at the 'Units' portion of the dialog box. As you can see, the map units are already determined in this case, but you can choose what units you would like to use for display. The map units here are 'decimal degrees' because all of the data added in the Layers are in decimal degrees. Not all data are in decimal degrees. Some data, especially images, are in other map units such as metres. To change the display units to metres, follow the steps described below.

- Select the 'Display' units in the Units columns of the 'General' tab and change into metres from the dropdown list.

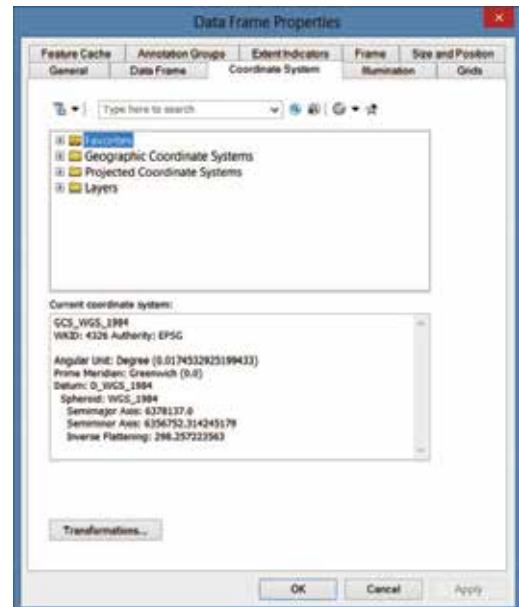
All our data are in Geographic WGS 1984 projection; the metres system that will display is not the correct one. So we want to give our view a standard and accurate projection. Bhutan displayed in 'UTM WGS 1984' projection would be separated into two regions – 'UTM WGS 1984 45N' and 'UTM WGS 1984 46N' but we can just use 'UTM WGS 1984 45N' in this exercise. To change the data frame projection follow the steps below:

- Click on the Coordinate System tab in the Data Frame Properties dialog box.

Notice that our current coordinate system 'GCS_WGS_1984' is a geographic coordinate system.


- Expand the 'Projected Coordinate System' by clicking on the + sign box.
- Scroll down and click on 'UTM'.
- Again expand 'UTM > WGS 1984 > Northern Hemisphere' folder and select 'WGS 1984 UTM Zone 45N' projection.
- Click 'Apply' and then 'OK'.

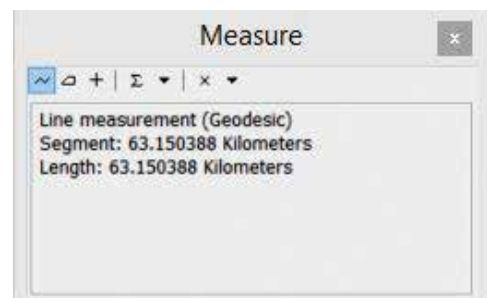
This will only change the projection of the data frame; it will not change the projection of the data.



Measuring in the Map Display

On the toolbar there is a button that allows you to measure the elements of the layers with a measuring tool. You can use this tool to draw a line or polygon on the map and get its length or area, or you can click directly on a feature and get measurement information after selecting the appropriate tab in the 'Measure' window that pops up.

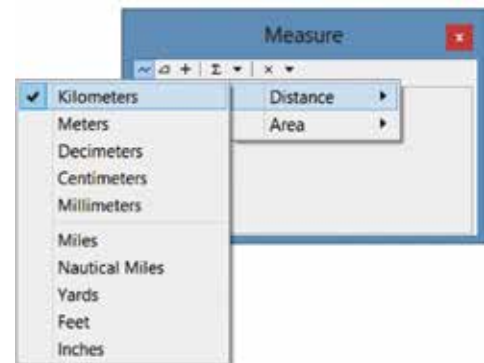
- Click on the measure tool  with the left mouse button. Your cursor changes to an L-shaped ruler with cross hairs and you get a pop-up window.
- Move the cursor to the point on the map where you want to start measuring and click.
- Now move the cursor to the point where you want to stop measuring and double-click.




The measurement is then displayed in the 'Measure' window. This measurement is composed of a segment length and total length, i.e., you can click and measure several different segments. It also indicates the display units of measurement. To change the units, click on the drop-down arrow next to the sum symbol.

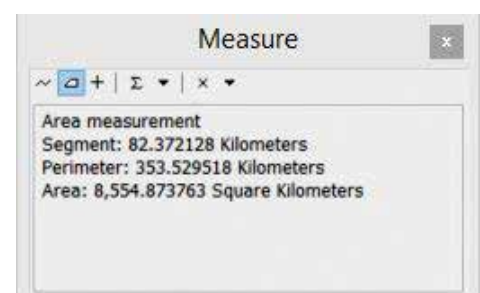
You can take measurements that are composed of multiple segments that do not follow a straight line. To do so:

- Click the measure tool with the left mouse button.
- Move the cursor to the point on the map where you want to start measuring and click once.
- Now move the cursor to the next point along your defined path and click once. The first segment is defined.
- Now move to the second point along your defined path and click once. The second segment is defined.
- Repeat this process until you reach the point where you want to stop, and click. Double-clicking makes the measurement lines disappear again and finishes the measurement.




You can also measure the area. To measure the area:

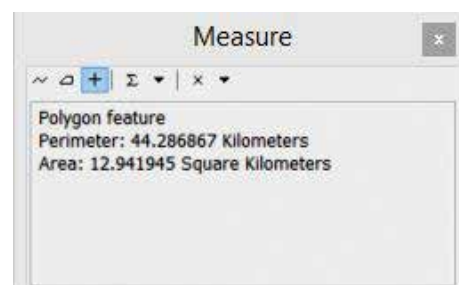
- Select the 'Measure an Area'  button from the 'Measure' dialog box.
- Move the cursor to the point on the map where you want to start measuring and click once.
- Now move the cursor to the next point along your defined path and click once. The first segment is defined.
- Now move to the second point along your defined path and click once. The second segment is defined.



- Follow this step and when done double click to complete the polygon. Now you will get the segment, perimeter and area of the polygon.

You can also quickly measure the length, perimeter and area of the features in the shapefile.

- Select the 'Measure A Feature'  button from the 'Measure' dialog box.
- Move the cursor to the feature on the map of which you want to measure and click on the feature you want to measure.
- Now you will get the perimeter and area of polygon (e.g. 'Basin') or length of the polyline feature, (e.g. Drainage).




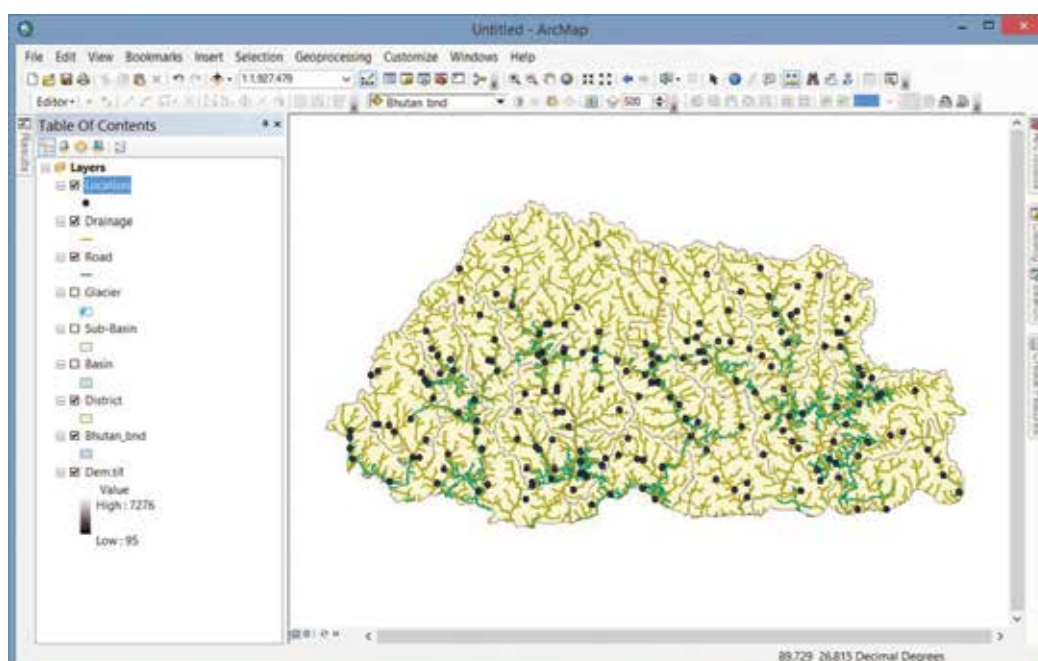
Symbolizing Features

Symbolizing features means assigning them colours, markers, sizes, widths, angles, patterns, transparency, and other properties by which they can be recognized on a map.

When data sets are added to ArcMap, the symbols and the colours of the features are assigned randomly by default. This symbology may not be (and usually is not!) the representation you wish to use for the map. You can modify the symbology so that the map is more presentable and readable. In this exercise, you will change the symbols and the colours of polygon, line and point features.

- Open the ArcMap and add the layers from 'C:\TrainingData\GIS'.

The colors and symbol of the layers and  their order may differ on each user screen. Now we will change the

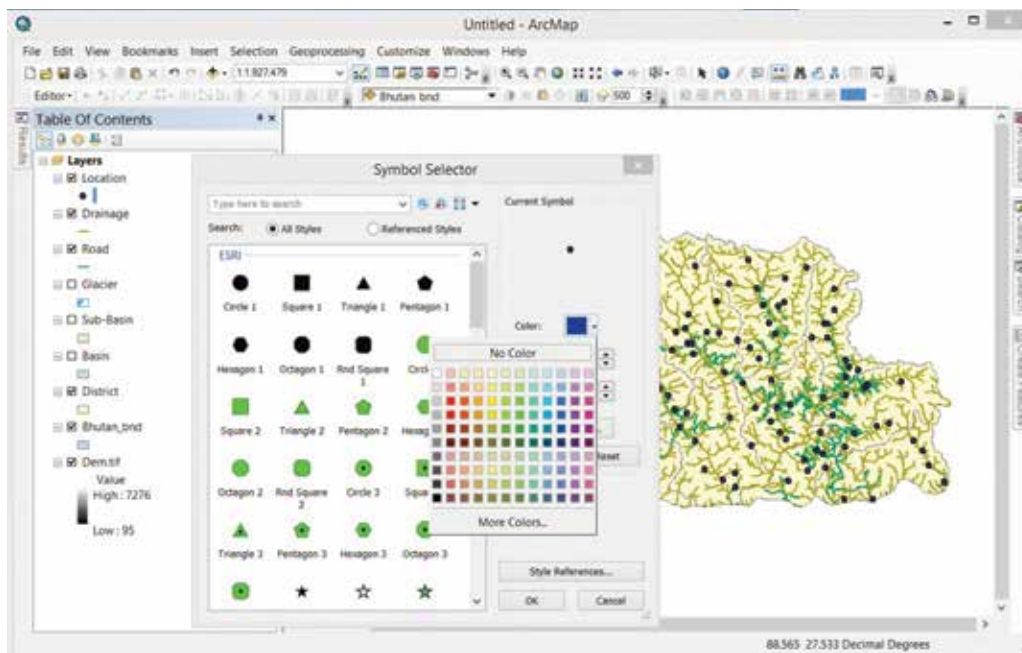


symbol and colors.

- In the 'Table of Contents' double-click on the circle of the 'Location' shapefile using the left mouse button to open the 'Symbol Selector' window.

You can change the symbol, colour, size, and angle or choose more specific symbols.

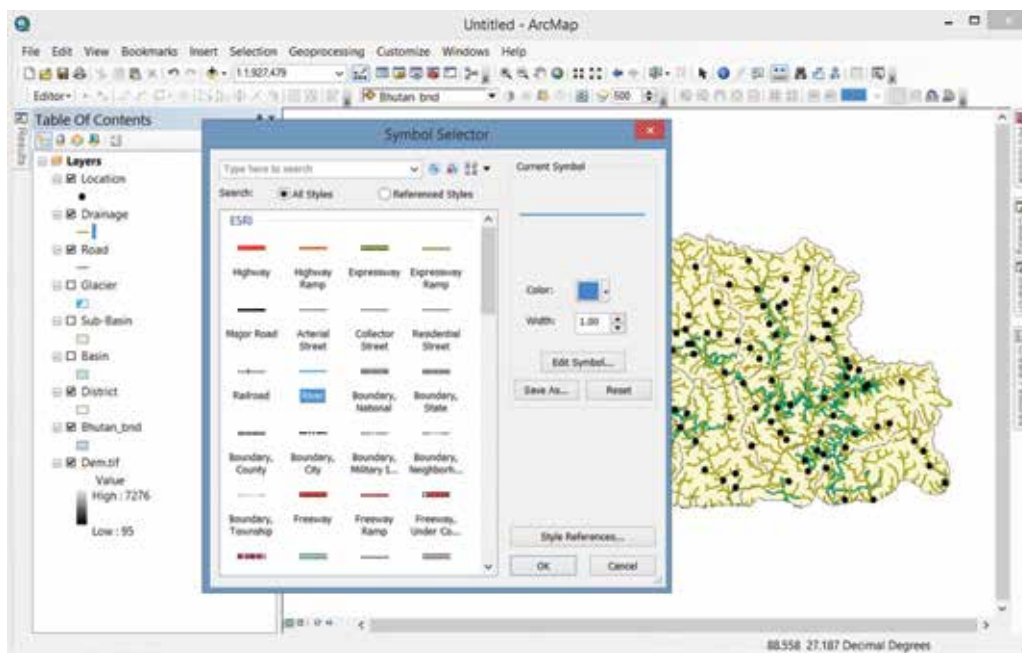
- Select the symbol 'circle 1' from the list.
- In the color option box, click the dropdown box and choose a dark blue color from the color panel.
- Change the size to 10.
- Click OK.



Now you can see the symbol and color of the location point in the Map View.

Repeat for other layers:

- Click on the line under Drainage layer name.
- Choose 'River'; you can also search for the name using the search bar at the top of the 'Symbol Selector'. Because this is already established as an accepted style, the colour and size of the line will be added automatically.




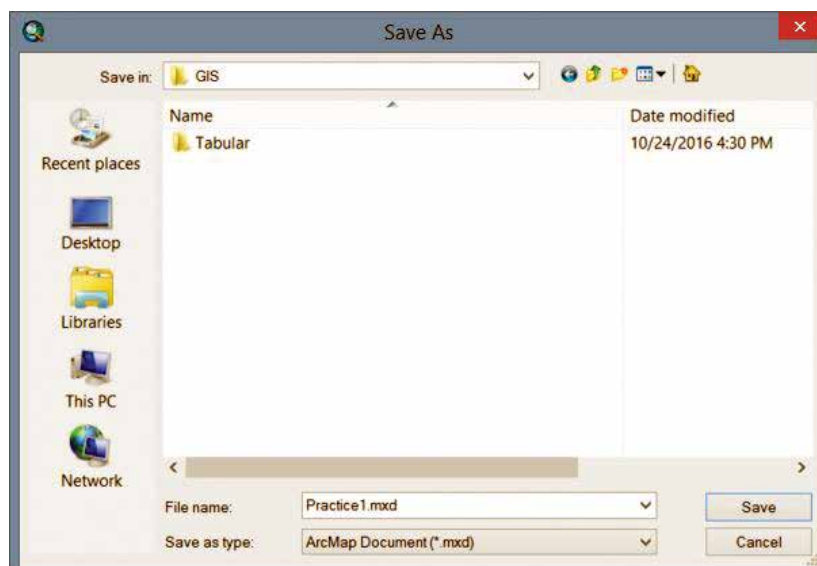
- Click OK to apply the change.
- Similarly, change the symbol of the 'Road' layer to 'Major Road'.
- Also click on the polygon under the 'District' layer name to change the color of the district boundary.
- Select a 'Hollow' from the list and change the outline color to 'Red' and Outline width to 1.
- Click OK to apply the change.
- Again click on the polygon under the 'Bhutan_bnd' layer name and select the 'Grey' symbol from the list.
- Change the Outline width to 1 and click OK to apply.

Now we have a much more attractive view. You can experiment with different colors and patterns until you find the right ones to suit your final map.

Saving ArcMap Projects


As in other program software, it is good idea to save your project work regularly.

- Go to File Menu and select 'Save' from the file menu, or you can click the 'Save'  icon in the main toolbar.
- Navigate to the folder 'C:\TrainingData' through the save in the drop-down menu at the top or click on 'This PC' and explore to the folder where you want to save the project
- Name the project file 'Practice1.mxd' and click 'Save' to save the project.



Now your project is saved as a '.mxd' extension. This stands for map document, and it is a GIS-specific file type. If you try to open this document without using the ArcGIS software, it won't work. This file instructs ArcGIS on what data to show and how to display it. The data layers are not stored with the .mxd file. If you copy your project file to another disk you must copy all the dataset files used in your project to that disk as well or reset the location from the layer properties.

If you copy the folder containing the .mxd project files and datasets to another drive and you want to link the project file and datasets as it is, you have to set the project file as the relative pathname of the datasets. To do this:

- Open the project file 'Practice1.mxd'.
 - To open it, go to the File menu and click on 'Open' from the File menu list, or directly click the 'Open' button (Folder icon) on the Standard toolbar.
 - Navigate to the folder where you saved your previous project file. (e.g., C:\TrainingData)
- Go to the File menu and select the 'Map Document Properties' from the list.
- Now the Map Document Properties window will open.
- Check the 'Store relative pathnames to data sources' and click OK to apply the document properties. This will preserve the relative path with data and your project file so that even when you copy your data folder and project file to another drive, it will not lose the link of the data in your project file.
- Now click the 'Save'  icon in the main toolbar or save the document from the File menu to save the document properties.

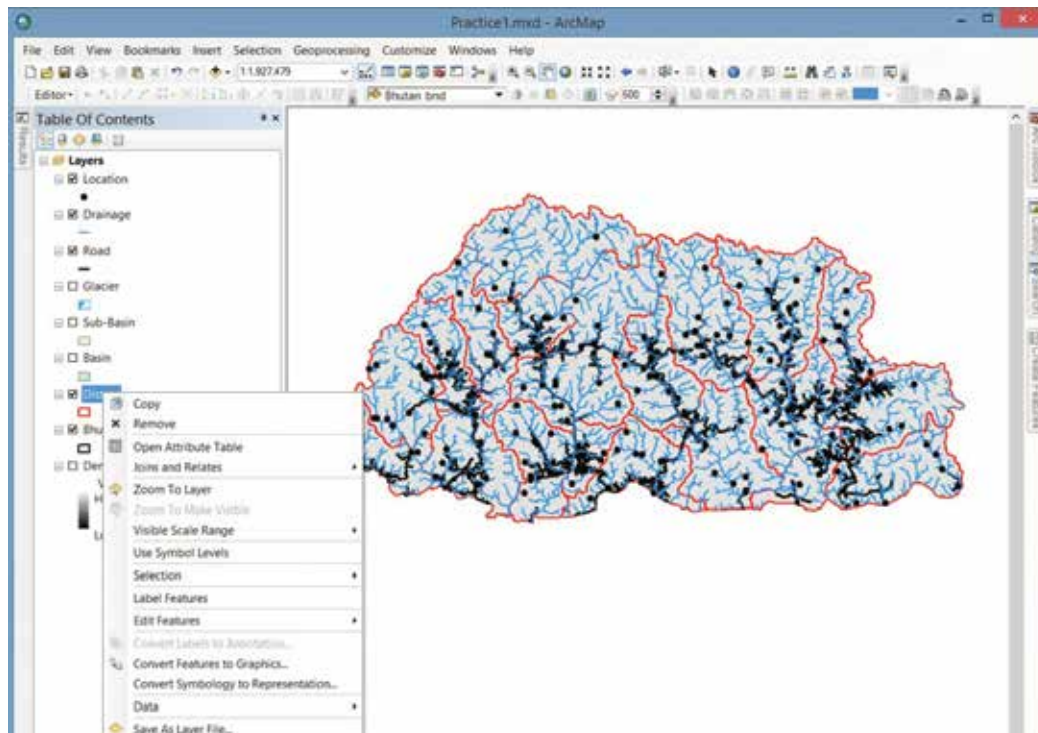
Now you can copy the folder containing the project file and datasets to another disk, and when you open the project file from another disk, the link of the datasets is not removed and you don't need to reset the link of the datasets.

Working with Attribute Table and Link to Other Tabular Data

Tabular information is the basis of geographic features, allowing you to visualize, quarry, and analyse data. In the simplest terms, tables are made up of rows and columns, and all rows have the same columns. In ArcGIS, rows are known as records and columns are fields. Each field can store a specific type of data such as number, date, and text.

Feature classes are really just tables with special fields that contain information about the geometry of the features. These include the shape field for point, line, and polygon feature classes and the BLOB field for annotation and dimension feature classes. Some fields, such as the unique identifier number (FID, OBJECTID) and Shape, are automatically added, populated, and maintained by ArcGIS. To check this information in GIS data:

- Open the project file 'Practice1.mxd'. If it is already opened, skip this step.
 - To open it, go to File menu and click on 'Open' from the File menu list, or directly click the 'Open' button (Folder icon) in the Standard toolbar.
 - Navigate to the folder where you saved your previous project file. (e.g., C:\TrainingData)
- Right click on the 'District' layer on the Table of Contents and click on 'Open Attribute Table' from list, or you can press the 'Ctrl' button on the keyboard and double click on the 'District' Layer.



Now you can see the tabular information of the feature 'District' of Bhutan. In the table, FID are the unique feature IDs which are automatically added and maintained by ArcGIS when you add new features to the layer. The shape field defines the type of the features. This is also automatically maintained by ArcGIS. Other Fields such as DIST_CODE, DIST_NAME, Shape_area, Shape_len, Pop_2005 can be changed, calculated and updated as per the requirements.

Sources of Tabular Information: There are lots of sources of tabular data, and ArcGIS can take advantage of many formats. Tabular information could be stored as tables in folders or databases, text files, queries on databases, and so on. In addition, if you have spatial data, you probably already have tabular attributes that describe those geographic features.



File-based tables are stored in folders on a disk. Some examples of file-based sources of tabular information include:

- dBASE, the format used with shapefiles;
- INFO, the format used with coverages;

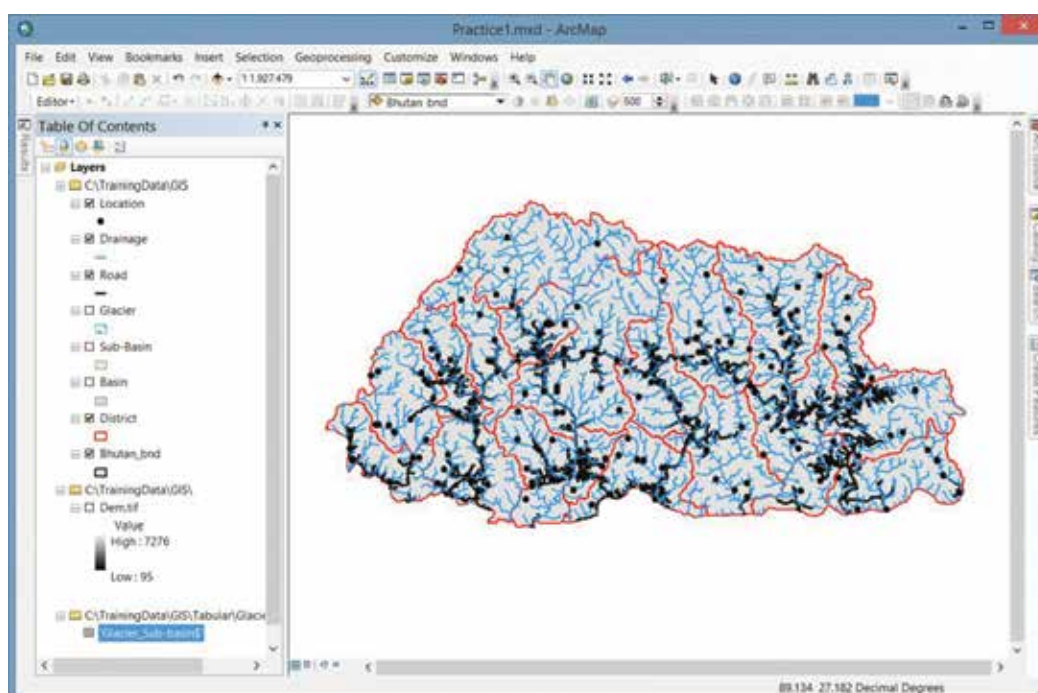
FID	Shape *	OBJECTID	DIST_CODE	DIST_NAME	Shape_area	Shape_len	Pop_2005
0	Polygon	1	01	Bumthang	2724.522520	282.943978	16116
1	Polygon	2	02	Chhukha	1881.522279	264.650335	74387
2	Polygon	3	03	Dagana	1725.269377	238.90829	18222
3	Polygon	4	04	Gasa	3138.860547	354.866463	3116
4	Polygon	5	05	Haa	1905.544147	225.199257	11648
5	Polygon	6	06	Lhuentse	2967.848397	305.403828	15395
6	Polygon	7	07	Monggar	1950.810334	248.968107	37069
7	Polygon	8	08	Paro	1287.978816	228.752615	36433
8	Polygon	9	09	Pema Gatsel	1025.701907	196.649219	13864
9	Polygon	10	10	Punakha	1111.072905	166.431496	17715
10	Polygon	11	11	Samdruk Jongkhar	1884.959148	233.755441	39961
11	Polygon	12	12	Samtse	1305.141473	251.658049	60100
12	Polygon	13	13	Sarpang	1619.039648	288.879614	41549
13	Polygon	14	14	Thimphu	1797.503237	320.921584	98876
14	Polygon	15	15	Trashigang	2213.060202	263.415902	48783
15	Polygon	16	16	Trongsa	1817.885586	250.308512	13419
16	Polygon	17	17	Tsuriang	838.989558	150.721026	18667
17	Polygon	18	18	Wangdue Phodrang	4042.904682	420.13771	31755
18	Polygon	19	19	Trashigang	1454.478084	221.110497	17740
19	Polygon	20	20	Zhemgang	2423.464048	290.62159	18636

- Text files such as those created in a text editor and delimited by commas or tabs; and
- Many other sorts of tables, including those generated in other programs, such as Excel, either accessed directly in ArcGIS or through the OLE DB functionality.

In ArcMap you can add these table data in the same way you add the GIS files such as Shapefile and raster images. For example:

- Open the project file 'Practice1.mxd'. If it is already opened, skip this step.
 - To open it, go to File menu and click on 'Open' from the File menu list, or directly click the 'Open' button (Folder icon) on the Standard toolbar.
 - Navigate to the folder where you saved your previous project file. (e.g., C:\TrainingData)
- Go to File menu > Add Data and click on Add Data  or directly click the Add  button in the Standard toolbar.
- Navigate to the folder 'C:\TrainingData\GIS\Tabular' and double click on 'Glacier_bhutan.xlsx' Excel file to open the table sheets in the excel file.
- Select 'Glacier_Sub-basin\$' table from the list and click the 'Add' button to add the selected table in the ArcMap project file.

Now you can see the Tabular data 'Glacier_Sub-basin\$' added to the Table of Contents. If you cannot see it in the Table of Contents, you have to change the view options of Table of Contents. To view all the tables and GIS data layers, switch the view of 'Table of Contents' to 'List by Source'.



Now in Table of Contents you will see the Table and all the other GIS data layers will be grouped in their respective locations (folder path).

- Right click on the added tabular data 'Glacier_Sub-basin\$' layer on the Table of Contents and select 'Open Attribute Table' from the list or you can press the 'Ctrl' button on the keyboard and double click on the 'Glacier_Sub-basin\$' layer.
- Now the new added table will open.

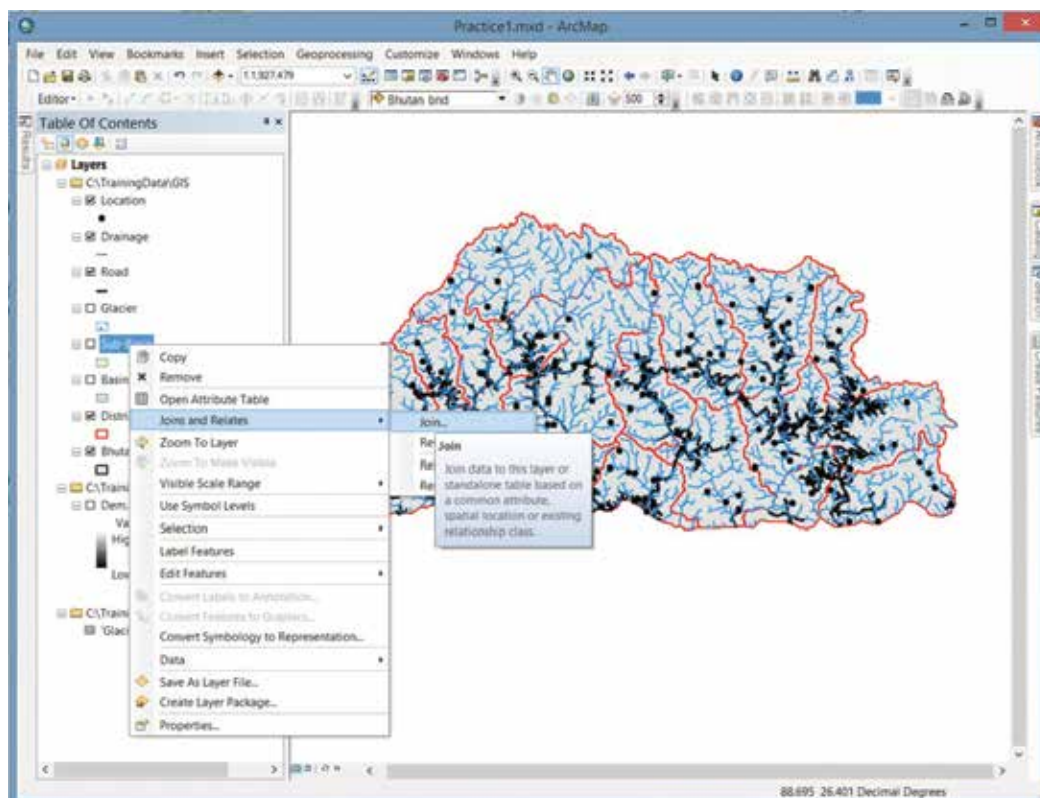
This table shows the number (num) and area of clean-ice (CI), debris-covered (DC) and total (Tot) glaciers, and largest (Large) glacier area in each glacier-fed sub-basin in Bhutan. The number in the field name represents the year ('80' represents 1980; '90' represents 1990, '00' represents 2000 and '10' represents 2010). For example, the field name 'DC_num_10' represents the number of debris-covered glaciers in 2010; similarly, 'CI_area_80' represents the area of clean-ice glacier in 1980. In ArcGIS, you can associate records in one table to record in

another table or table of GIS data through a common field, known as a key field. Here in our exercise we can associate our new added table to the table of 'Sub-Basin' layers. The steps are given below:

	DC_num_10	Tot_num_10	CI_area_10	DC_area_10	Tot_area_10	Large_area_10	Sub-Basin
0		19	5.2	0	5.2	1.5	Thimchu
2		37	22.2	5.4	27.6	7.2	Pachu
15		180	103.8	9.9	113.7	10.4	Mochu
15		256	201.1	46.9	247.9	36.6	Phochu
5		150	91.9	15.8	107.8	20.3	Mangdechu
7		125	62.1	9.8	71.9	15.6	Chamkharchu
6		96	57.8	3.6	61.4	12.5	Kurichu
0		22	6.7	0	6.7	1.5	Dangmechu

Joining the Table.

- Right click on the 'Sub-Basin' layer in the Table of Contents and go to 'Join and Relates' in the list then click on 'Join' from the sub-list of Joins and Relates.



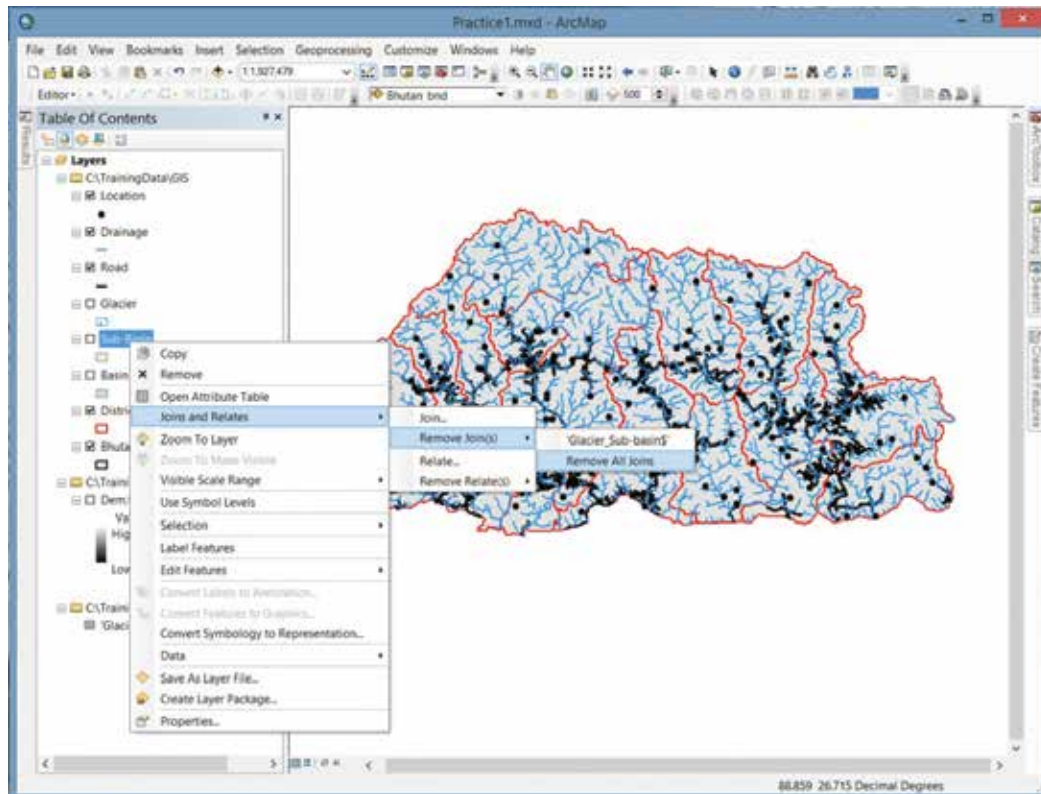
Now the 'Join Data' window will open.

- In the Join data window, select the option 'Name' in the field for the 'Sub-Basin' shapefile in which you are going to join the table.
- Select the table 'Glacier_Sub-basin\$' which you are going to join from the dropdown list.
- And in the third list, select the field of the Table 'Sub-Basin' which is the key field to join the table.
- Check 'Keep all records' in Join Options and Click 'OK' to join the table.
- Right click on the added tabular data 'Sub-Basin' layer on the Table of Contents and click on 'Open Attribute Table' from the list, or you can press the 'Ctrl' button on the keyboard and double click on the 'Sub-basin' layer.
- Now the table of 'Sub-basin' layer will open and you can see the joined tabular data in it.

FID	Shape	Name	Area_SqKm	Gr Area 90	Sub-Basin	CI num 80	DC num 80	Tot num 80	(
0	Polygon	Punatsangchu	5040.68	0	<Null>	<Null>	<Null>	<Null>	<Nt
1	Polygon	Nyere Amachu	1143.991	0	<Null>	<Null>	<Null>	<Null>	<Nt
2	Polygon	East	732.972	0	<Null>	<Null>	<Null>	<Null>	<Nt
3	Polygon	Amochu	2200.953	0	<Null>	<Null>	<Null>	<Null>	<Nt
4	Polygon	Wangchu	1359.913	0	<Null>	<Null>	<Null>	<Null>	<Nt
5	Polygon	Hachu	778.468	0	<Null>	<Null>	<Null>	<Null>	<Nt
6	Polygon	Pachu	1267.648	31.5	Pachu	34	2	34	
7	Polygon	Thimchu	1190.877	6.3	Thimchu	17	0	17	
8	Polygon	Phochu	2334.501	282.8	Phochu	209	15	209	
9	Polygon	Mochu	2365.231	135.8	Mochu	150	15	150	
10	Polygon	Mangdech	3827.223	120.6	Mangdech	121	4	121	
11	Polygon	Manaschu	1414.777	0	<Null>	<Null>	<Null>	<Null>	<Nt
12	Polygon	Chamkharchu	3180.617	85.3	Chamkharchu	117	5	117	
13	Polygon	Kurichu	3835.467	71	Kurichu	88	6	88	
14	Polygon	Dangmechu	3797.597	7.5	Dangmechu	35	0	35	

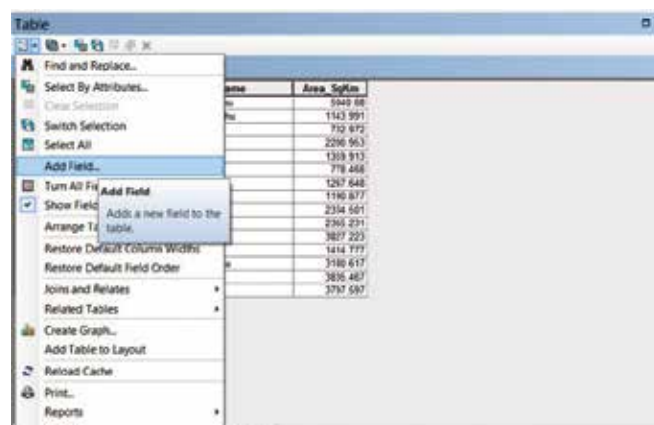
Here in the table you can see all the information in the 'Glacier_Sub-basin\$' table is joined with the table of 'Sub-Basin'. The information not contained in the joined table will show the <Null> values. The Join table shows the clean-ice, debris-covered, and total glaciers in the sub-basins of Bhutan from 1980 to 2010. This Join table is just temporary, which means that if you open the layer in another project you will not see this Join table in the layer. To make it permanent you need to either export this layer to a new file or add the new field in the layer and transfer these field values to the new added field. In this exercise, we will add a few new fields and transfer the values from Tabular data.

- First remove the joined table by right clicking on the 'Sub-Basin' layer in the Table of Contents and go to 'Join and Relates' in the list; then click on 'Remove Join > Remove All Joins' from the sub-list. This will remove all the joined tables.



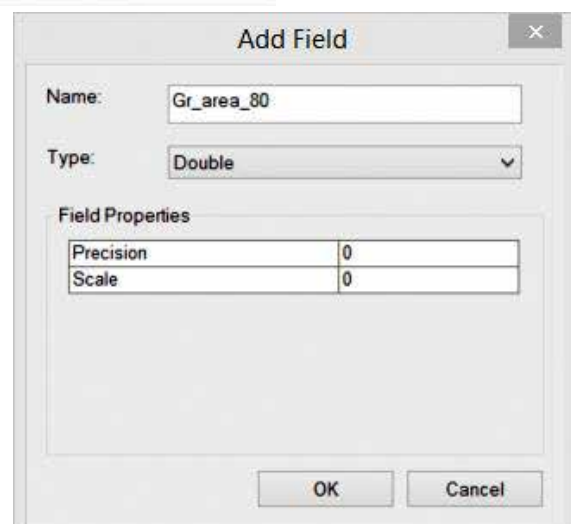
Add New Field in the Table

- Open the Attribute table of the 'Sub-Basin' layer.
- Click the Table Options dropdown button on the top left corner of the opened attribute table of the 'Sub-Basin' layer.
- Select 'Add Field' from the dropdown list of Table Options.



Now the 'Add Field' dialog box will open.

- In the Name field, type 'Gr_area_80'.
- For field type, select Double from the dropdown list.
- Leave the Field Properties as default. (Note: In the Field Properties, 'Precision' indicates the total number digits and 'Scale' indicates the number of digits after decimal degree.)
- Click 'OK' to add a new field.
- Similarly add other fields named 'Gr_area_10' and 'Gr_80_10' in the table.
- Now you can see three new fields added in the Sub-Basin layer.



FID	Shape	Name	Area_SqKm	Gr_area_80	Gr_area_10	Gr_80_10
0	Polygon	Punatsangchu	5040.68	0	0	0
1	Polygon	Nyere Amachu	1143.991	0	0	0
2	Polygon	East	732.972	0	0	0
3	Polygon	Amochu	2200.953	0	0	0
4	Polygon	Wangchu	1359.913	0	0	0
5	Polygon	Hachu	778.468	0	0	0
6	Polygon	Pachu	1267.648	0	0	0
7	Polygon	Thimchu	1190.877	0	0	0
8	Polygon	Phochu	2334.501	0	0	0
9	Polygon	Mochu	2365.231	0	0	0
10	Polygon	Mangdechu	3827.223	0	0	0
11	Polygon	Manaschu	1414.777	0	0	0
12	Polygon	Chamkharchu	3180.617	0	0	0
13	Polygon	Kunchu	3835.467	0	0	0
14	Polygon	Dangmechu	3797.597	0	0	0

Transferring Tabular Data to 'Sub-Basin' Layer

- Again Join the tabular data 'Glacier_Sub-basin\$' to the Sub-Basin layer.
- Then open the Attribute table of the Sub-basin layer; if it is already open, jump to the next step.
- Check whether the Tabular data is joined or not by scrolling horizontally.
- Right click on the title of the field named 'Gr_area_80' and click on 'Field Calculator' from the menu.
- Now the Field Calculator window will open.

FID	Shape	Name	Area_SqKm	Gr_area_80	Gr_area_10	Gr_80_10
0	Polygon	Punatsangchu	5040.68		0	
1	Polygon	Nyere Amachu	1143.991		0	
2	Polygon	East	732.972		0	
3	Polygon	Amochu	2200.953		0	
4	Polygon	Wangchu	1359.913		0	
5	Polygon	Hachu	778.468		0	
6	Polygon	Pachu	1267.648		0	
7	Polygon	Thimchu	1190.877		0	
8	Polygon	Phochu	2334.501		0	
9	Polygon	Mochu	2365.231		0	
10	Polygon	Mangdechu	3827.223		0	
11	Polygon	Manaschu	1414.777		0	
12	Polygon	Chamkharchu	3180.617		0	
13	Polygon	Kunchu	3835.467		0	
14	Polygon	Dangmechu	3797.597		0	

Parser

☒ VB Script
☐ Python

Fields:

'Glacier_Sub-basin\$.Sub-Basin'
'Glacier_Sub-basin\$.CI_num_80'
'Glacier_Sub-basin\$.DC_num_80'
'Glacier_Sub-basin\$.Tot_num_80'
'Glacier_Sub-basin\$.CI_area_80'
'Glacier_Sub-basin\$.DC_area_80'
'Glacier_Sub-basin\$.Tot_area_80'
'Glacier_Sub-basin\$.Large_area_80'
'Glacier_Sub-basin\$.CI_num_an

Type:

☒ Number
☐ String
☐ Date

Functions:

Abs ()
Atn ()
Cos ()
Exp ()
Fix ()
Int ()
Log ()
Sin ()
Sqr ()
Tan ()

☐ Show Codeblock

Sub-Basin.Gr_area_80 =
['Glacier_Sub-basin\$.Tot_area_80]

About calculating fields

Clear

Load...

Save...

OK

Cancel

- Leave Parser as default (check on VB Script).
- Double click on the field name ['Glacier_Sub-basin\$.Tot_area_80] in the Fields list. This will add the Field name in the Text area.
- Click 'OK' to transfer data in the new field.
- Now the value in the field 'Tot_area_80' of the joined tabular data 'Glacier_Sub-basin\$' will transfer to the new added field 'Gr_area_80' in the table of the 'Sub-basin' layer.
- Similarly transfer the value of the field 'Tot_area_10' from the joined tabular data 'Glacier_Sub-basin\$' to the field 'Gr_area_10' in the table of the 'Sub-Basin' layer.
- Remove the joined table by right clicking on the 'Sub-Basin' layer in the Table of Contents and go to 'Join and Relates > Remove Join > Remove All Joins' from the sub-list.
- Now you will get the Values in the field 'Gr_area_80' and 'Gr_area_10'. These values indicate the total glacier area in the sub-basins during 1980 and 2010.

FID	Shape	Name	Area Sqkm	Gr area 80	Gr area 10	Gr 80 10
0	Polygon	Punatsangchu	5040.98	0	0	0
1	Polygon	Nyire Amachu	1143.991	0	0	0
2	Polygon	East	732.972	0	0	0
3	Polygon	Amachu	2200.963	0	0	0
4	Polygon	Wangchu	1359.913	0	0	0
5	Polygon	Hachu	778.488	0	0	0
6	Polygon	Pachu	1267.648	36.3	27.6	0
7	Polygon	Thimchu	1190.877	6.9	5.2	0
8	Polygon	Phochu	2334.501	389.2	247.9	0
9	Polygon	Mochu	2366.231	152.9	113.7	0
10	Polygon	Mangdechhu	3827.223	134	907.8	0
11	Polygon	Manaschu	5414.777	0	0	0
12	Polygon	Chamkharchu	3180.617	99.6	71.9	0
13	Polygon	Kunchu	3835.467	79.5	61.4	0
14	Polygon	Dangmechu	3797.597	19.2	6.7	0

The glacier area change between 1980 and 2010 is calculated in the field 'Gr_80_10'. To calculate the glacier area change:

- Right click on title of the Field named 'Gr_80_10' and click on Field Calculator from the list.
- Field Calculator window will open.
- Leave Parser as default (check on 'VB Script').
- Double click on the field name 'Gr_area_80' in the Fields list. This will add the Field name in Text area.
- Then click on the 'subtract' button just above the Text area in the right corner of the window.
- Click on the field name 'Gr_area_10' in the Fields list.
- Now you see the expression in the Text area as '[Gr_area_80] - [Gr_area_10]'.
- Click 'OK' to calculate the field.
- You will see the glacier area change values in the field 'Gr_80_10' for each sub-basin of Bhutan.
- Similarly you can add other data from the tabular data to the shapefile and calculate change in clean-ice, debris-covered glacier area. Calculated results in this table stay permanently attached to the shapefile. For instance, the 'Sub-basin' layer (or shapefile?) can be opened in another ArcMap project and the added columns in the table will still be there.

Analysis in the Map Display

ArcMap can help in analysing data sets by mapping certain attributes of the layer data. Then each object in the layer is associated with a set of characteristics or attributes. These attributes, also called fields, are stored in the table, which is linked to the features or graphic object, which we view in the Map. Therefore, each object in the layer is associated with the records in the layer's attribute table. We will use this information for analysis.

Analysis within the Attribute Table

- Open the Attribute table of the Sub-Basin layer.
- Move the mouse to the top of the table. Right click on the 'Gr_area_80' field.
- Click, with the left mouse button, the 'Sort Descending' option on the menu bar.

FID	Shape	Name	Area SqKm	Gr area
0	Polygon	Pumatsangchu	5040.68	
1	Polygon	Nyere Amachu	1143.991	
2	Polygon	East	732.972	
3	Polygon	Amochu	2200.953	
4	Polygon	Wangchu	1359.913	
5	Polygon	Hachu	778.468	
6	Polygon	Pachu	1267.648	
7	Polygon	Thimchu	1190.877	
8	Polygon	Phochu	2334.501	
9	Polygon	Mocho	2365.231	
10	Polygon	Mangdech	3827.223	
11	Polygon	Manaschu	1414.777	
12	Polygon	Chamkharchu	3180.617	
13	Polygon	Kunichu	3835.467	
14	Polygon	Dangmechu	3787.697	

- Now you see the values in the field arranged in descending order.

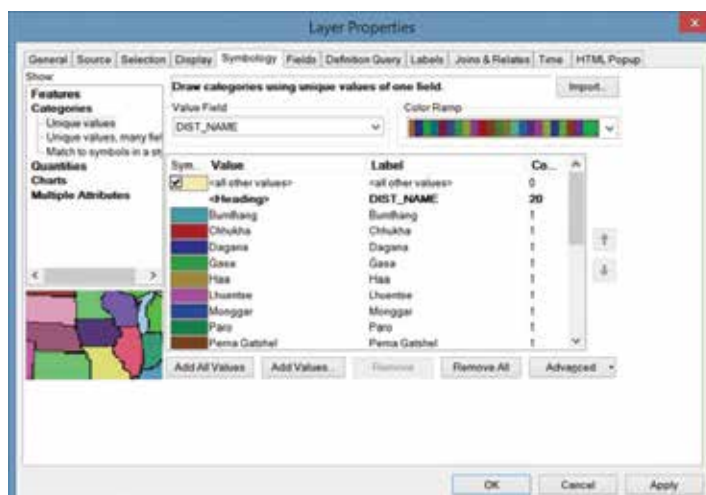
FID	Shape	Name	Area SqKm	Gr area 80	Gr area 10	Gr 80_10
8	Polygon	Phochu	2334.501	309.2	247.9	61.3
9	Polygon	Mocho	2365.231	152.9	113.7	39.2
10	Polygon	Mangdech	3827.223	134	107.8	26.2
12	Polygon	Chamkharchu	3180.617	99.6	71.9	27.7
13	Polygon	Kunichu	3835.467	79.5	61.4	18.1
6	Polygon	Pachu	1267.648	36.3	27.6	8.7
14	Polygon	Dangmechu	3787.697	19.2	6.7	12.5
7	Polygon	Thimchu	1190.877	6.9	5.2	1.7
0	Polygon	Pumatsangchu	5040.68	0	0	0
1	Polygon	Nyere Amachu	1143.991	0	0	0
2	Polygon	East	732.972	0	0	0
3	Polygon	Amochu	2200.953	0	0	0
4	Polygon	Wangchu	1359.913	0	0	0
5	Polygon	Hachu	778.468	0	0	0
11	Polygon	Manaschu	1414.777	0	0	0

Notice how the glacier area of 1980 of each sub-basin will arrange themselves in descending order. It thus shows which basin has the largest glacier area and which has the lowest. The table shows that the 'Phochu' basin has the largest glacier area and the 'Thimchu' basin has the smallest glacier area.

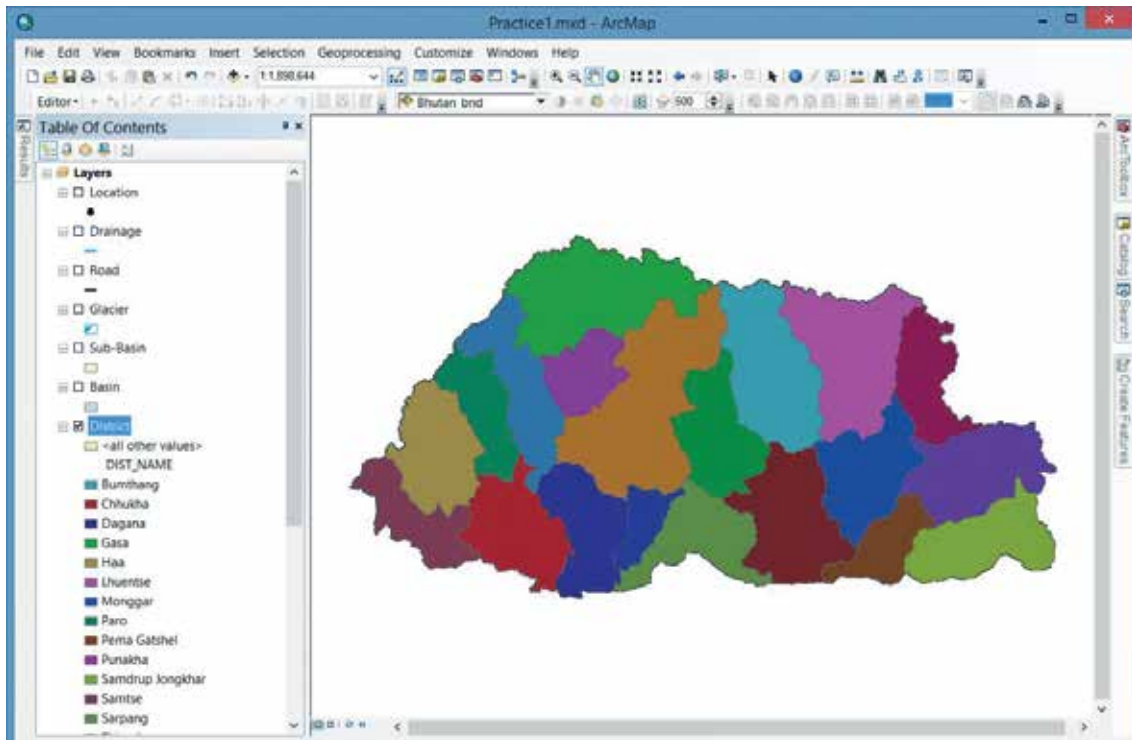
Mapping by Category

In ArcMap, you can make the view more informative by assigning a different symbol to each unique value, or to a distinct range of values, in the layers attribute table. Let's give a different colour to each districts of Bhutan.

- The topmost layer in the 'Table of Contents' will be displayed in the map view on the top of the layers. So if you need to view a specific layer, you need to uncheck the box adjacent to the name of the layer above the specific layer. Now hide all the layers above the District layer in the Table of Contents by unchecking the boxes next to the layer names.
- Right click on the 'District' layer and select Properties from the list or double-click on the 'District' layer to open the properties of the layer.
- The 'Layer Properties' window will open.
- Click on the 'Symbolization' tab in the layer properties window.
- In the 'Show' box on left side of the window, click on 'Categories' and then click on 'Unique values'.
- Choose 'DIST_NAME' in the dropdown box under the 'Value' field.
- Click the 'Add All Values' button on the bottom left corner of the window. This process will add all the district name values with their respective symbols in the category panels.



- You can choose any color ramp from the dropdown box under 'Color Ramp' at the top right corner.
- Click the 'Apply' button to apply the color code in each district polygon and check on the Map view. If you are not satisfied with the colors of the district, you can change them from the 'Color Ramp' dropdown list.
- Once you satisfy the symbology you assign to the district layer, click 'OK' to apply and close the window.



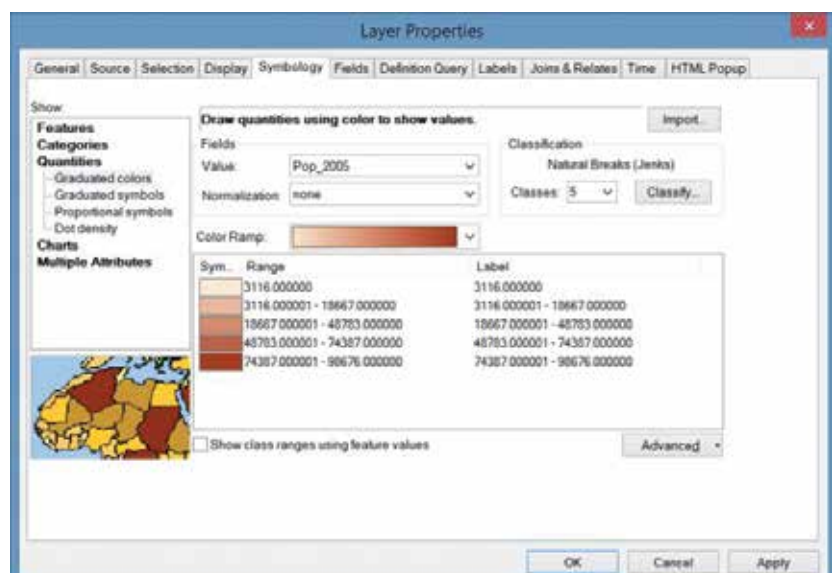
Now you will see different color codes for different district polygons. You can also apply this to Polyline layer 'Roads' by using the 'Type' field.

You can also control the colors assigned to each district by double clicking on the colored symbol. It will allow you to change the color individually.

Mapping by Quantity

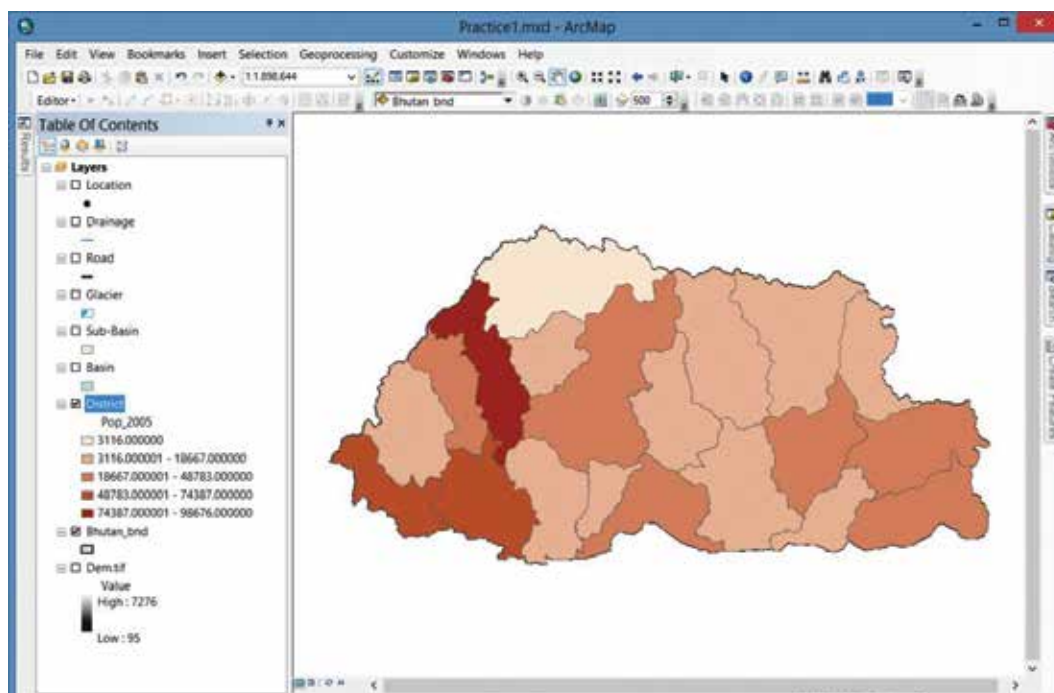
Now we will analyse data using a common mapping technique called colour maps. These maps are ideal for showing all sorts of data including both numerical and descriptive text. In this exercise, we again use the 'District' layer and prepare maps showing population distribution in the districts.

- Right click on the 'District' layer and select Properties from the list or double-click on the 'District' layer to open the properties of the layer.
- The 'Layer Properties' window will open.
- Click on the 'Symbology' tab in the Layer properties window.
- In the Show box on the left side of the window, click on 'Quantities' and then click on 'Graduated colors'.
- Choose 'Pop_2005' from the dropdown menu next to 'Value' under 'Fields'.
- Change the Color Ramp to Orange Light to Dark from the dropdown list.




- Click the 'OK' button at the bottom right corner of the layer properties window.

Now you will see the Map changes to display the districts according to population distribution.



In the map, the light colors represent the districts with a relatively small population and darker colors represent districts with a relatively large population (refer to actual numbers in the Table of Contents).

You can try this process again for the Sub-Basin layer with 'Gr_area_80' field to see the glacier area distribution in the sub-basin from 1980. To see the sub-basin layer, it needs to be moved above the district layer in the Table of Contents – in order to move it, switch to 'List by drawing order' .

You can also portray the data in different ways. You can choose your own classification range of value and display maps. To do this:

- Right click on the 'District' layer and open the 'Layer Properties.'
- It should automatically come up in symbology mode. If not, select the 'Symbology' tab.
- Also, there should automatically be in "Quantities > Graduated" mode and field value is "Pop_2005". If not, repeat the process.
- Now look at the Classification window at the upper left corner. It shows that the classification is in natural breaks and has 5 classes as default.
- Click on the 'Classify' button.
- The classification window will open.

In the classification window, the 'Classification Statistics' section in the upper right corner shows useful statistics that may help in analysis such as minimum, maximum, mean and standard deviation values. The

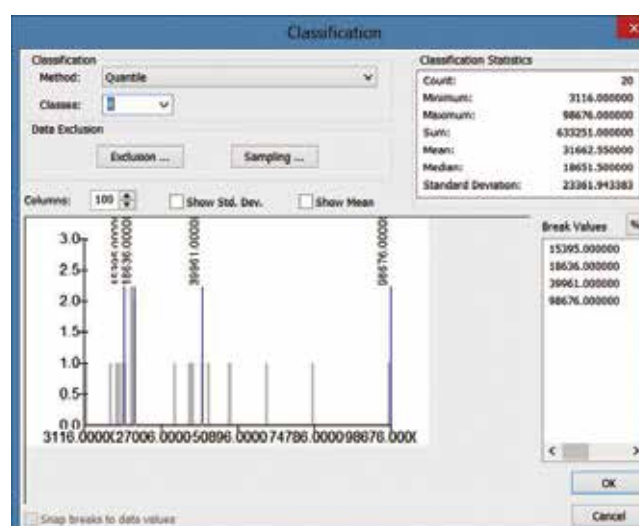
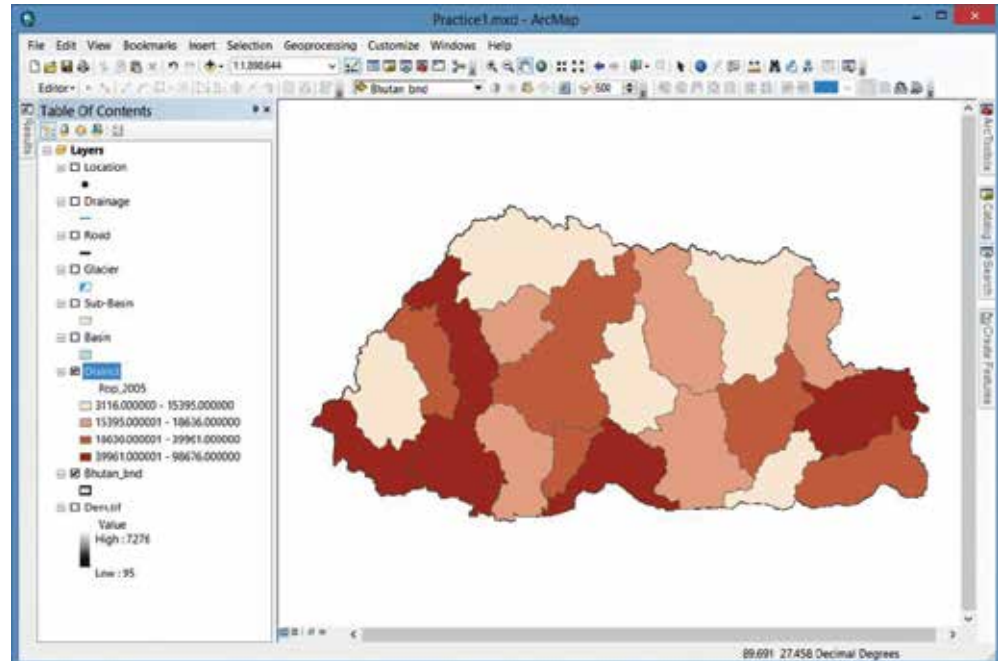


chart at the bottom left corner shows the break lines in blue color. These break lines can be changed manually by clicking on a line with the left mouse button, holding it, moving it to the new area and releasing it. The break values are also shown in the 'Break Values' box at the bottom right corner. You can also manually change these values. These values are synchronized with the charts.

- In the classification section, there are multiple methods for classifying the data in the dropdown menu of methods. This will automatically classify the value based on the statistics of the values. You need to choose the type of classification, number of classes and rounding values. Let's try this.
- For 'Method', select 'Quantile' from dropdown list and for 'Number of classes', select 4 from the dropdown list.
- Click 'OK' to apply and close the Classification window.
- Click 'OK' on the Layer Properties window to change the Map.

The view is now changed to display four colors representing four classes.

The new classification (Quantile) changes the color map into four categories with an equal number of features in each category. Test with different classification systems in the list to see their effect on the data view.



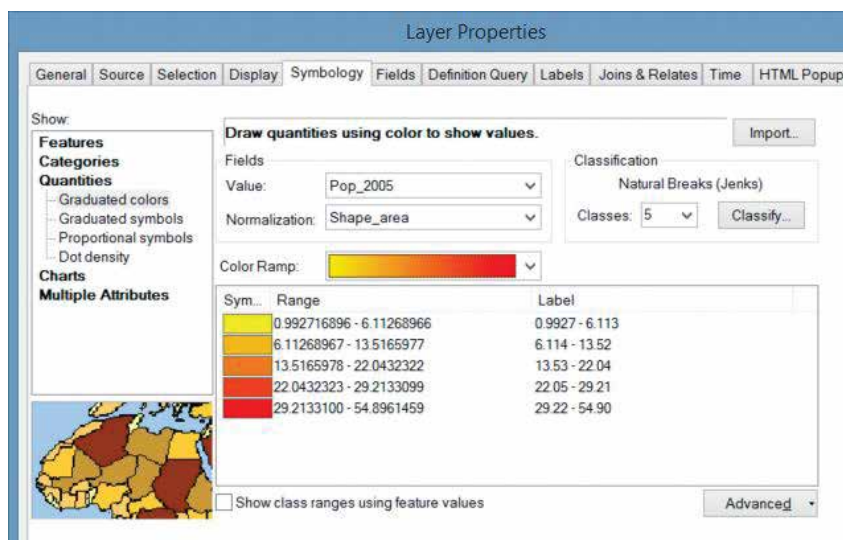
ESRI's definition of each classification option is given below:

- **Natural Breaks** - This is the default classification method in GIS. This method identifies breakpoints between classes using a statistical formula (Jenks optimization). Natural Breaks finds groupings and patterns inherent in your data.
- **Quantile** - In the quantile classification method, each class contains the same number of features.
- **Equal Interval** - The equal interval method divides the range of attribute values into equal sized sub-ranges. The features are classified based on those sub-ranges.
- **Standard Deviations** - ArcGIS finds the mean value and then places class breaks above and below the mean at intervals of either 1/4, 1/2, or 1 standard deviations until all the data values are contained within the classes.
- **Manual and Defined Interval** - it allows you to set your own classification methods.

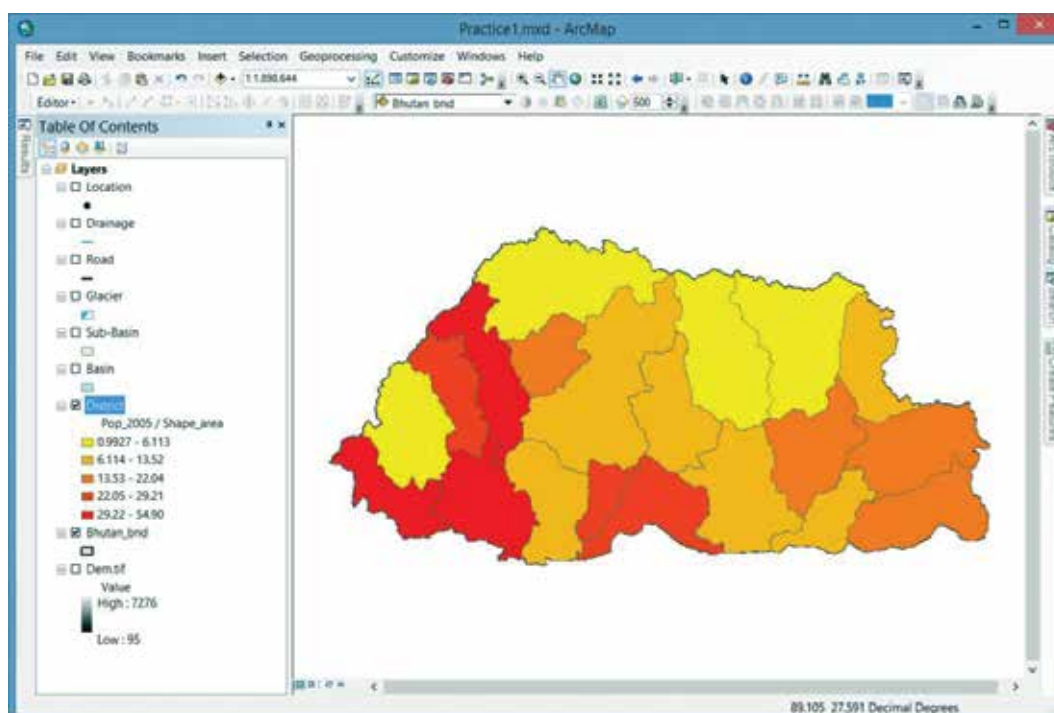
Density Mapping

The density map is prepared by dividing one attribute (numbers) by another attribute or area of the features. The process of dividing one attribute by another to find the ratio between them is called normalization. In this exercise, we will calculate the population density as we have the population of the district and area of the district calculated from district boundary features in ArcGIS. To calculate the population density, normalize the population data by the area of the districts and use graduate colors on the map.

- Double click on 'District' layers in the 'Table of Contents' to open the 'Layer Properties'.
- It should automatically come up in the Symbology mode. If not, select the 'Symbology' tab.
- Also, there should be automatically in 'Quantities > Graduated' mode and field value is 'Pop_2005'. If not, repeat the process as before.



- Now in the Normalization dropdown list, select 'Shape_area'. This field will divide the field value and give the ratio value.
- Set the color ramp to 'Yellow to Dark Red'.
- If necessary, you can also change the Classification mode.
- Click 'OK' to apply.



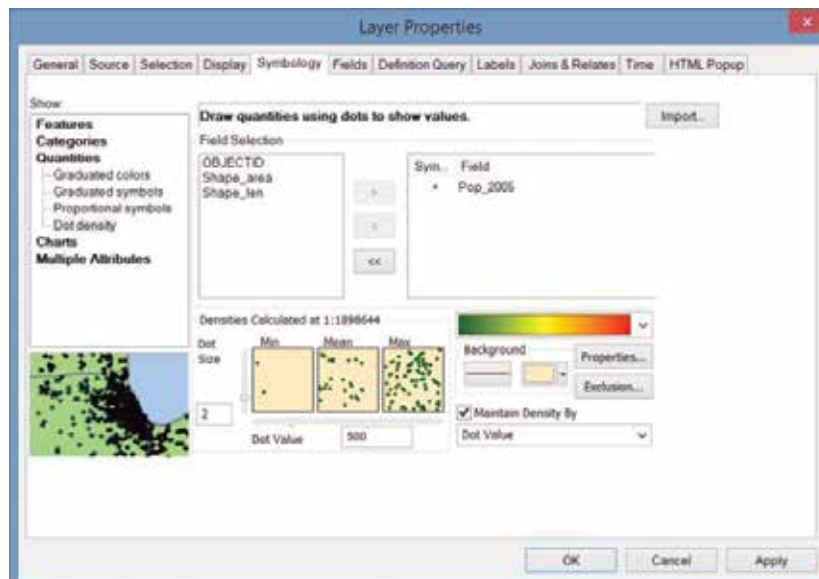
Now you can see the map showing the relatively higher population density district in red color and low population density district in yellow color.

You can also apply this for the number of glaciers in the sub-basin by adding data of total number glaciers in the sub-basin from the tabular data 'Glacier_Sub-basin\$'.

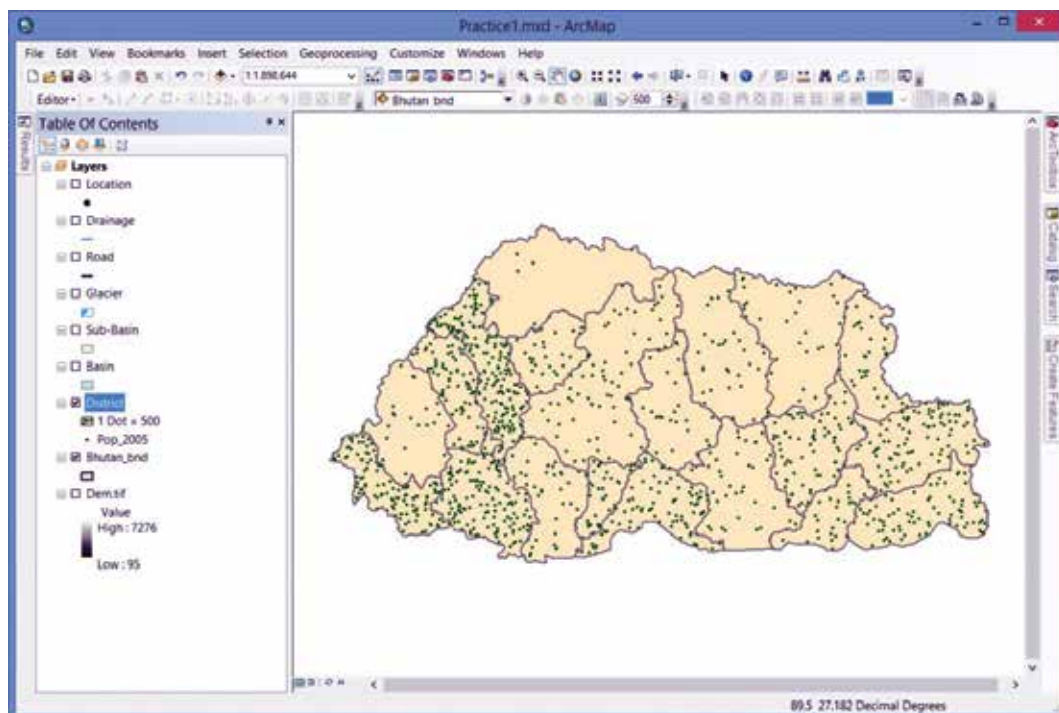
Another way to map density is by using a 'dot density map'. To prepare the dot density map:

- Double click on the 'District' layer in the 'Table of Contents' to open the Layer Properties.
- It should come automatically in the 'Symbology' tab; if not click on the 'Symbology' tab.
- Click on 'Quantities' and then select 'Dot Density' in the list.
- Under the 'Field Selection' list double click on 'Pop_2005' or select 'Pop_2005'; then click the right arrow button to add it to the box on the right.

- In the Densities Calculated section, notice the Dot Value and Dot Size. Change Dot Value to 500, which means that each dot in the map represents 500 people.
- Under the Background section, change the background color of the district to Olivine Yellow by selecting from the dropdown list in the square color box.



- Make sure your 'Layer Properties' window matches the above graphic and then click 'OK' to apply.
- Now you will see the dot density map in the Map view.



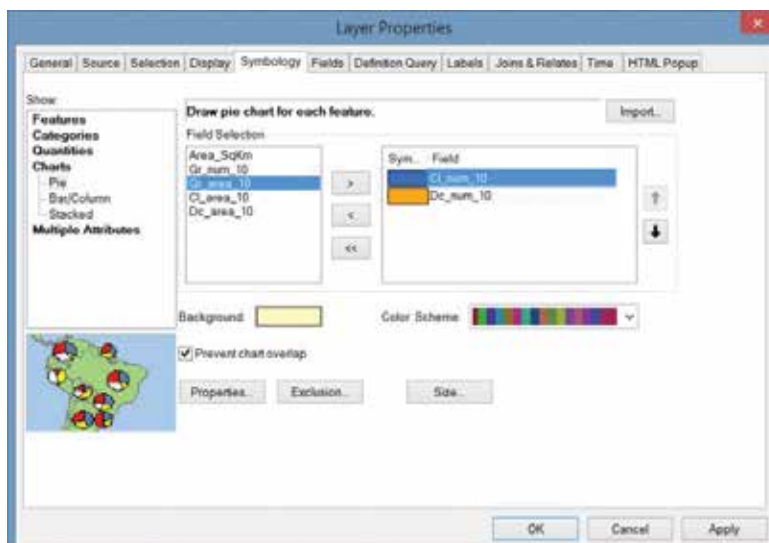
In the Map view, you will see that the density of the dots is higher in the western part than in the eastern part of Bhutan. Each dot in the map represents 500 people.

Chart Maps

Another type of analysis is involves overlaying a chart onto a map. It is a good mapping technique for displaying and comparing multiple values or values for each feature. In this exercise, you will analyse the distribution of clean-ice and debris-covered glaciers in the major basins of Bhutan.

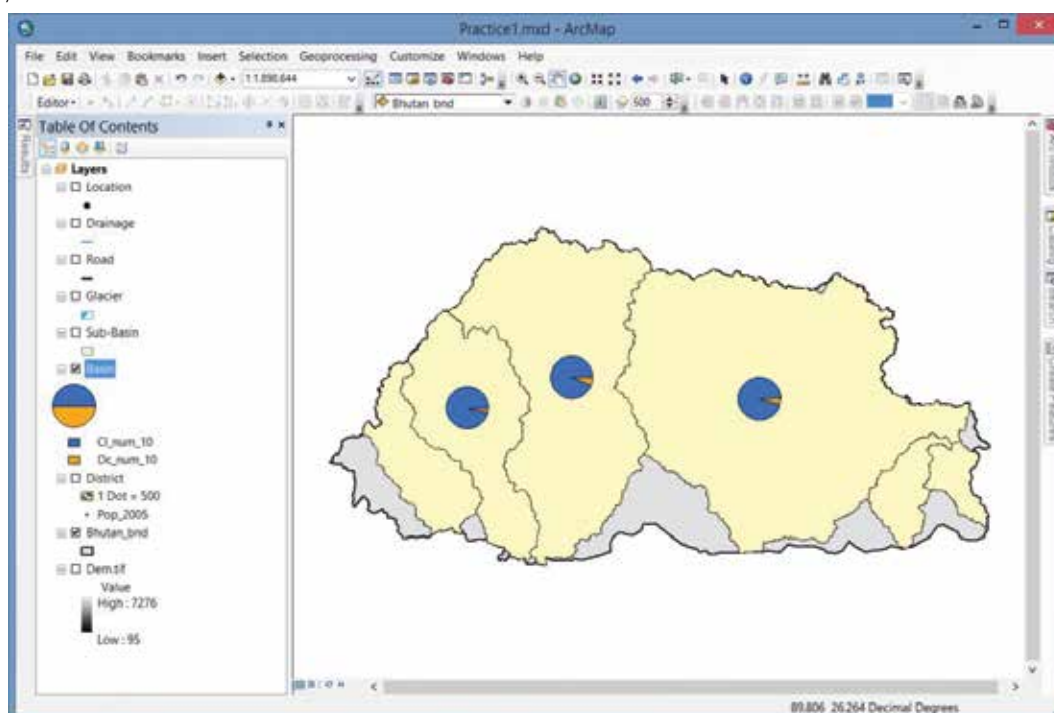
- To open the Layer Properties window, right-click on the 'Basin' layer and click on 'Properties' on the right-click menu or simply double-click on the 'Basin' layer and open the Layer Properties window.

- Click on the 'Symbology' tab.
- Click on 'Charts' in the Show list box on the left side of the window.
- Select 'Pie' in the chart list.
- From the 'Field Selection' list box on the left hand side, double click on the 'Cl_num_10' and 'Dc_num_10' or select both fields (by holding down the Ctrl button on the keyboard and clicking) then click on the right arrow button, to move the field on the right selection box.
- Right-click on the rectangular color box to Cl_num_10 to access a color palette. Then select the Ultra Blue color from the palette.
- Similarly change the color of Dc_num_10 to Electron Gold color.
- Click on the rectangular box next to 'Background' and select the Yellow color symbol from the symbol list and click OK.
- Check the box next to 'Prevent chart overlap'.
- Click OK to apply.



Now you can see the pie charts showing the distribution of clean-ice glaciers and debris-covered glaciers in the major basins.

You can change the size and display in 3D charts by clicking the 'Size.' Properties' in the Layer Properties – Symbology tab window.



Similarly you can also make a bar/column graph showing glacier area distribution in the basin.

Labeling Features

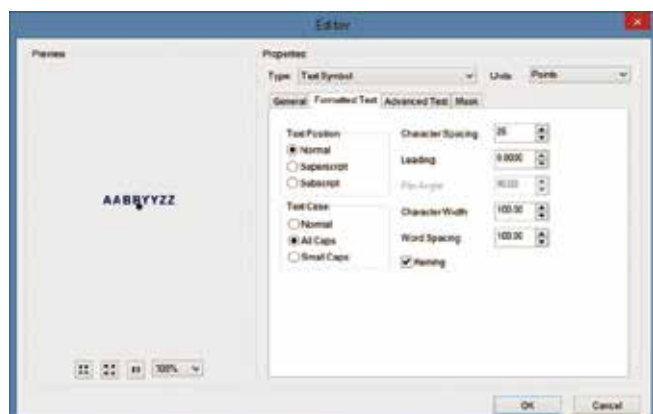
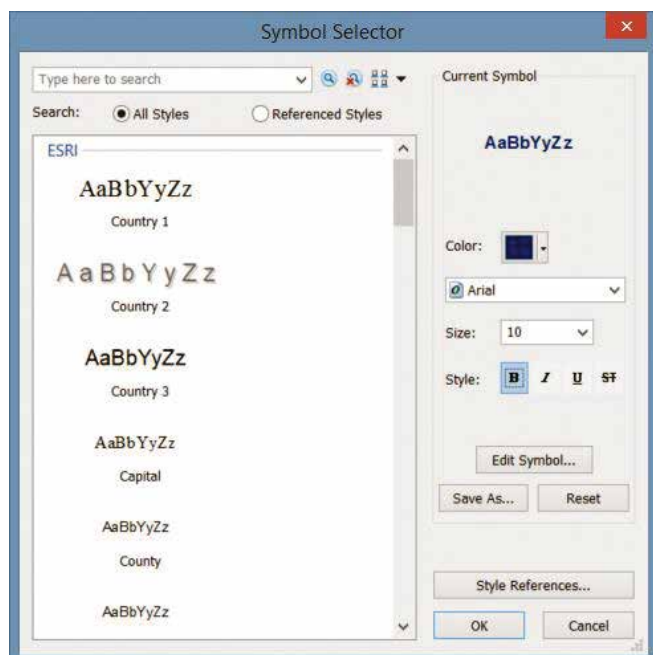
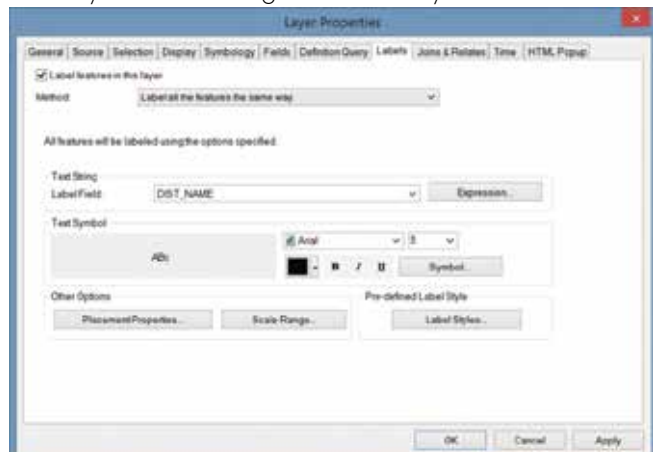
A label is any text that names or describes a feature on a map. In ArcMap, labels are often generated from values in the layer attribute table.

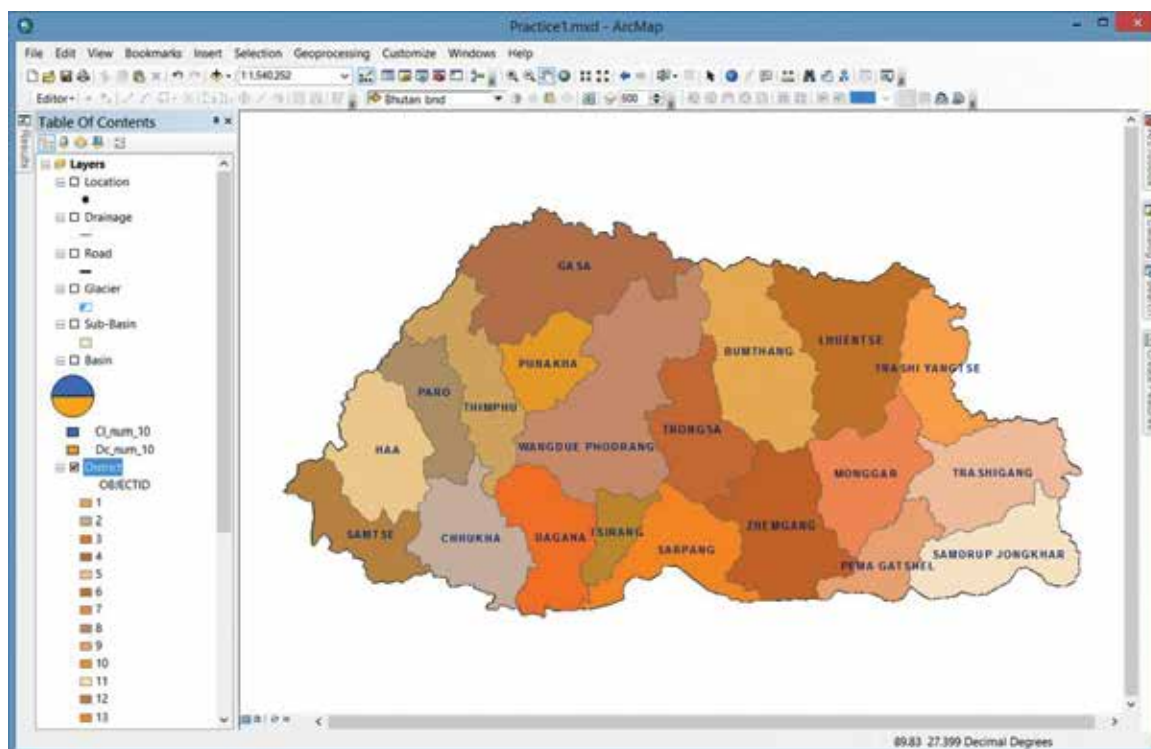
There are three types of labels available: dynamic, interactive, and annotation.

Dynamic Labeling

Dynamic labels are created at once and operate as a group. ArcMap will adjust the label according to the scale so that the labels are visible. Although you can set rules for display, ArcMap decides where to place them. As a default, labels will not overlap. In addition, you cannot individually select or change them unless you convert them to annotation.

- Right-click on 'District' and select 'Properties' from the list. This opens the 'Layer Properties' window. You can also double click on the layer to open the 'Layer Properties' window.
- Click on the 'Labels' tab and check the box next to 'Label features in this layer'.
- Select 'DIST_NAME' from the 'Label Field' dropdown menu.
- Click 'Apply' and check on the Map view.
- Each district is now labeled and ArcMap tries to place the labels at the centre of the polygon. You can change the font, color, shading and position of the labels.
- Stay on the 'Layer Properties' tab.
- Click the 'Symbol' button. The 'Symbol Selector' dialog box opens.
- In the 'Options' section of the 'Symbol Selector', click on the 'Color' dropdown palette and select the dark navy color. Choose font 'Arial' and Size '10' and make it 'B' (bold).
- Click the 'Edit Symbol' button on the 'Symbol Selector'. The Editor window will open.
- Select the 'Formatted Text' tab and click on 'All Caps' in the 'Text Case' section. Also change the 'Character Spacing' value to 25 and click 'OK' to apply the symbol properties.
- Click the 'OK' button on the 'Symbol Selector' window and then click 'OK' on the 'Layer Properties' window.
- Now you see the labeled map of the district.





You can also practise labeling the map of point data (Location layer), and explore the 'Placement Properties' in the Labeling Layer Properties.

Querying Data

In ArcGIS, we can find precise information quickly by using queries. This can help us to find patterns in the data.

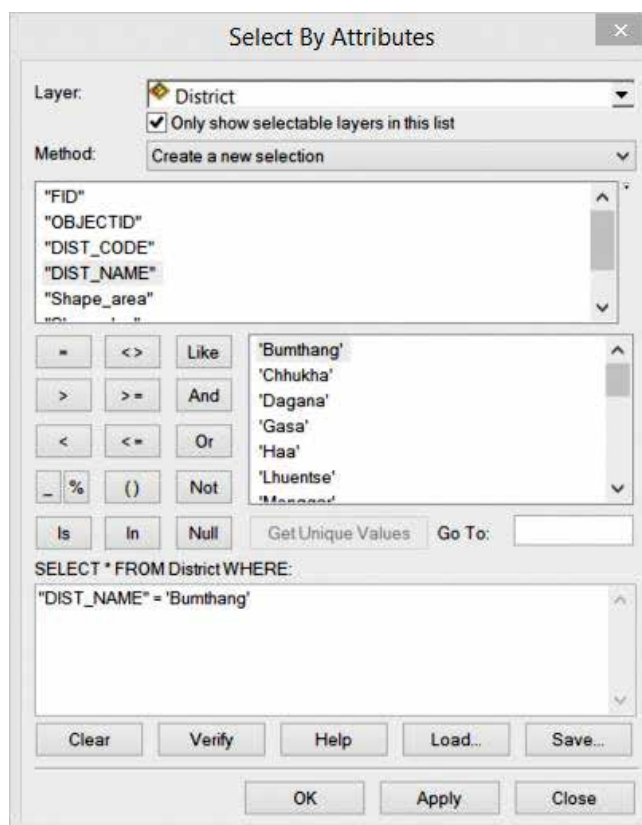
Querying By Attribute

- Click on the 'Selection' menu in the main menu bar and then 'Select by Attributes' from the list to open the 'Select by Attributes' window.

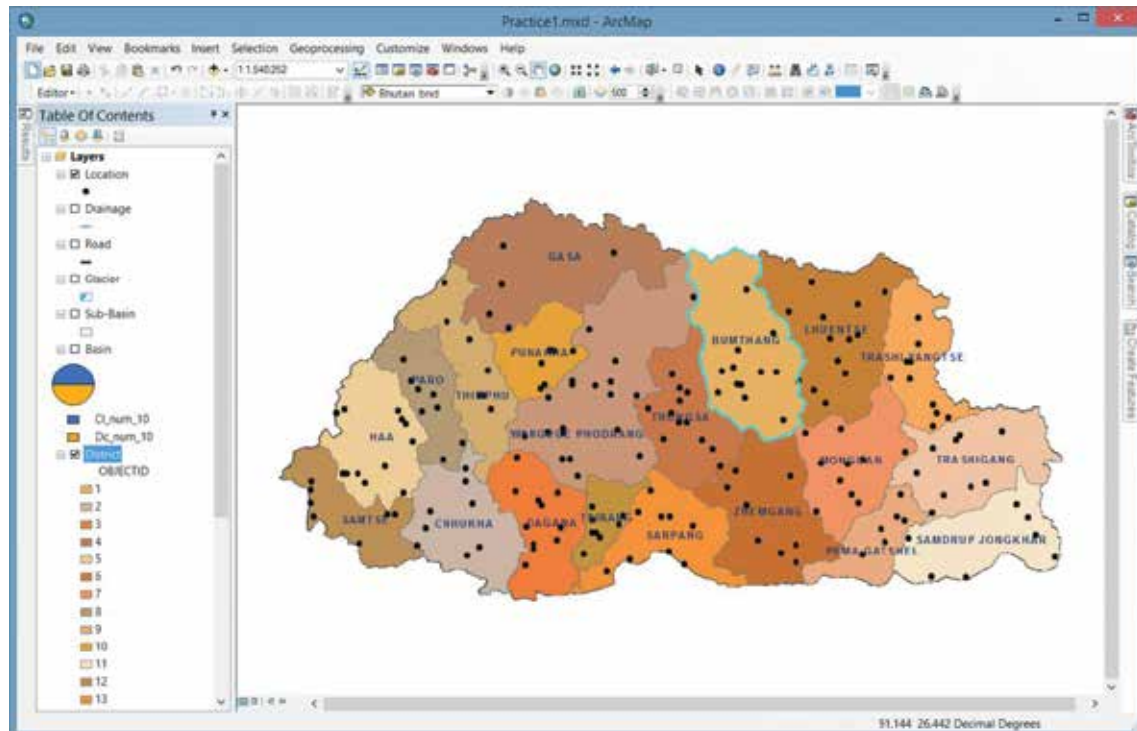
The query window allows you to choose the layer on which you would like to query and changes the list of layer attributes below depending on what you pick from the drop down menu. It also contains a set of operational tools in the left side of the middle section and all the table values for each attribute on the right side of the middle section. The operational tools including the standard mathematical ones =, >, <, etc. as well as the Boolean operators - 'and', 'or' and 'not'. To build a query, first select an attribute and then an operator to perform with its values.

Start the exercise with a simple query:

- Change the 'Layer' list drop down box to 'District'.
- Under 'Method', select 'Create new Selection'.
- Double-click on the attribute 'DIST_NAME'; this will add the field name in the expression box below.
- Then click on the '=' sign operation.
- Click on the 'Get Unique Values' button. A list of attributes will appear in the box on the right.
- Finally, in the box listing the attributes, double-click on 'Bumthang'. The name Bumthang appears in the query builder box.



- Verify that your query looks the same as the image above and click 'OK' to apply and close the "Select By Attribute" window.



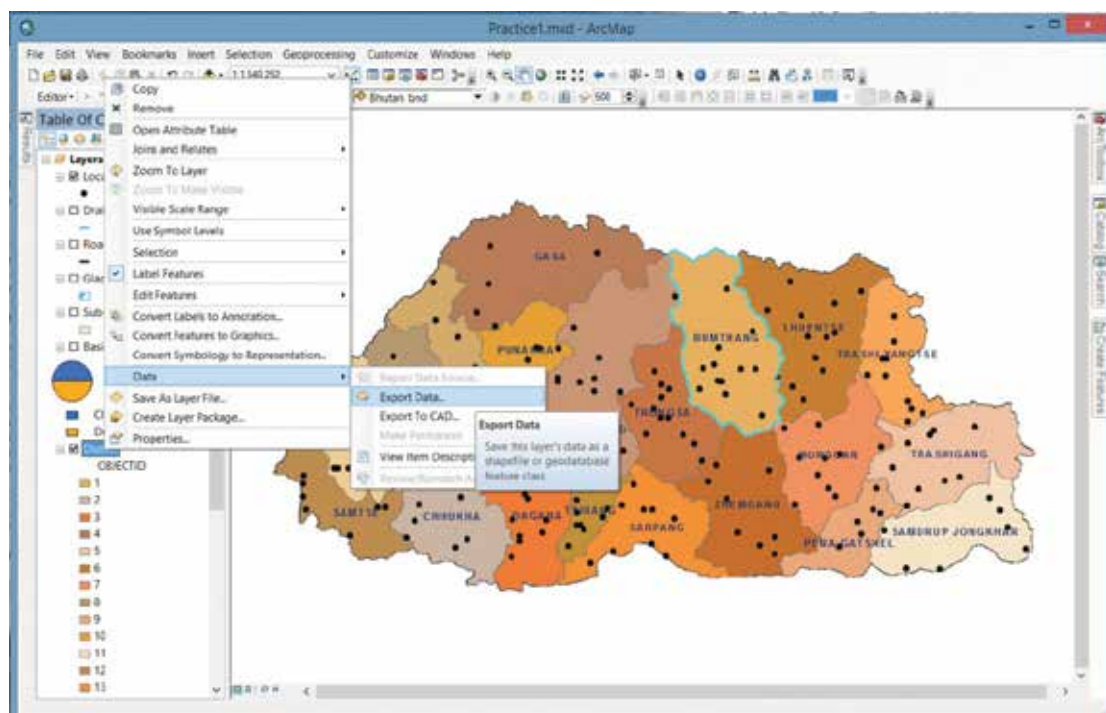
Now in the Map view, the boundary of 'Bumthang' district is highlighted in aqua color. Arcmap always highlights selected objects in aqua as the default.

Export the Selected Features as a New Map Layer

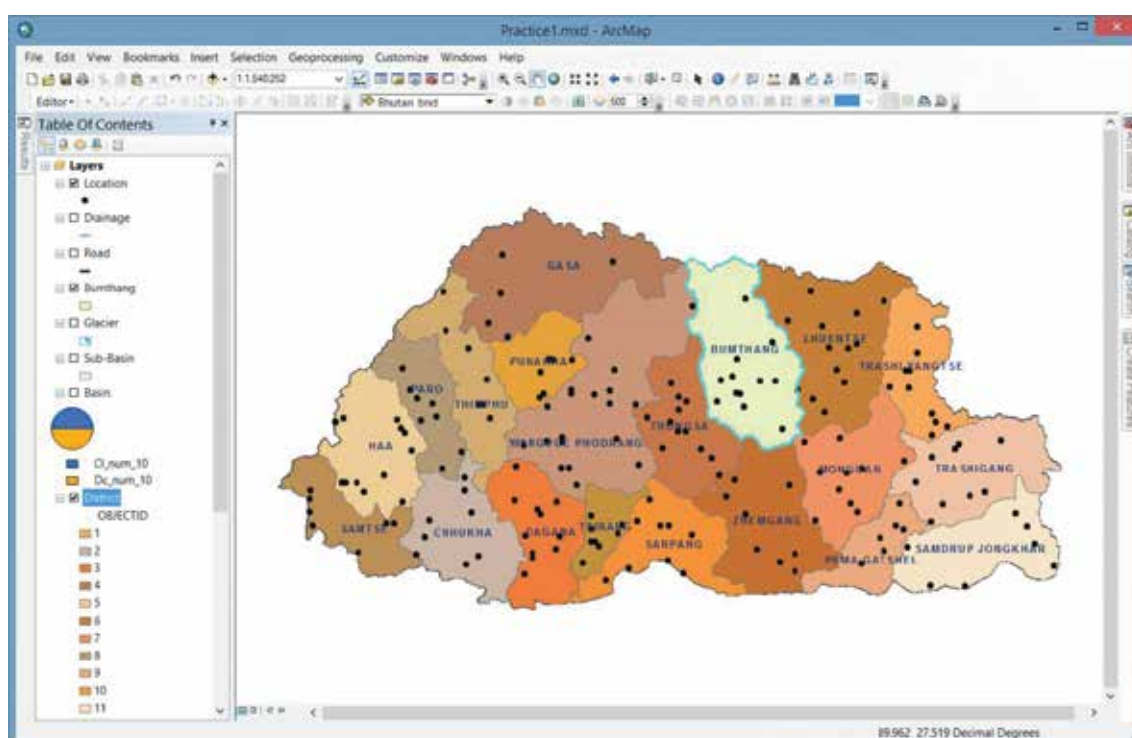
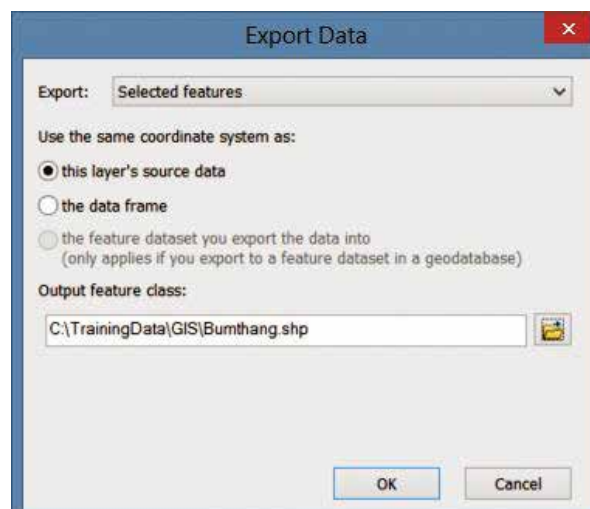
Now the selected Bumthang district boundary can be exported from the map as a new layer and added in the same project. This will help you define the area of interest for your work as well as extract other features from the larger database for the specific area 'Bumthang'.

- Right-click on the 'District' layer to open the right-click menu.
- Go to 'Data' and click on 'Export Data' on the menu.

Now the 'Export Data' menu will open.



- Choose 'Selected features' from the Export dropdown menu; under 'Use the same coordinate system as', select the option 'this layer's source data'.
- Click on the folder icon to choose the location and filename.
- Save the file in the appropriate folder (C:\TrainingData\GIS\temp, if there is no temp folder, create one) and name the file 'Bumthang' and select 'Shapefile' for 'Save as type'.
- Click 'OK' and then a dialog box will open. It will ask you if you wish to add the exported data to the map as a layer or not. Choose 'Yes' to add the exported data in ArcMap.
- Then the new layer 'Bumthang' will appear on the map and is added to the 'Table of Contents' at the bottom.



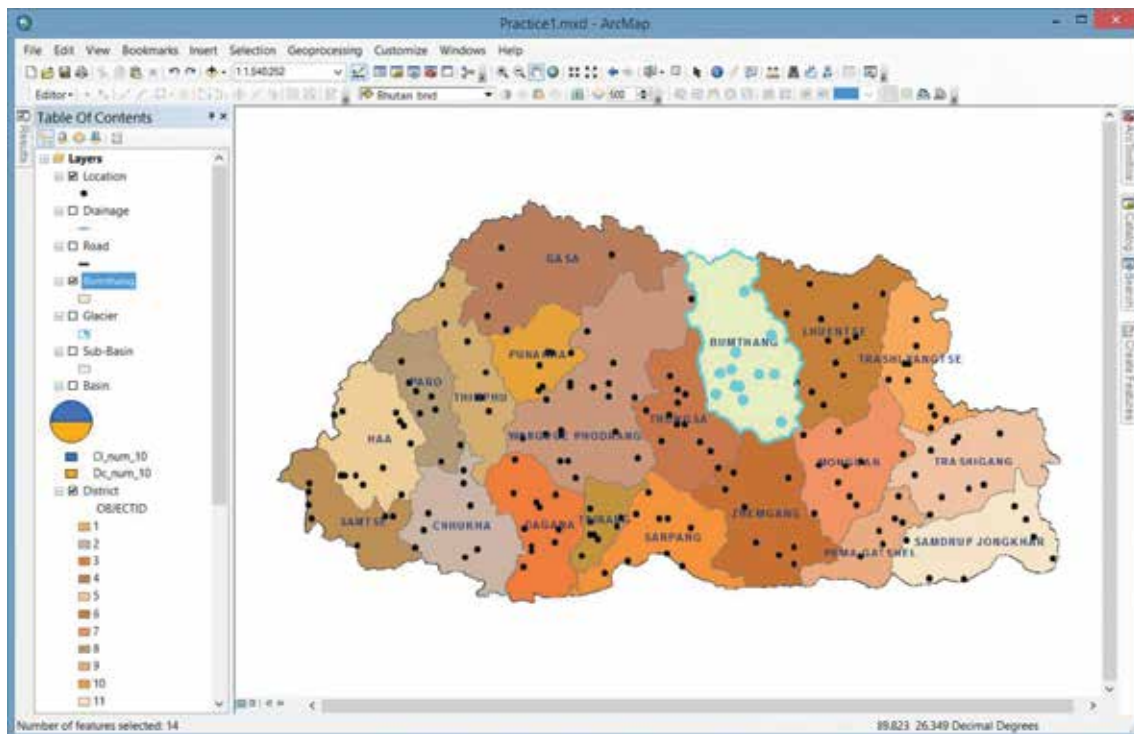
Spatial Queries: Select by Location

This exercise will let you select features based on their location relative to features in another layer. For example, if you want to know how many villages or major settlements lie within Bumthang district, you can select all the settlement location points that lie within the Bumthang district boundary.

- Click on the 'Selection' menu in the main menu bar and then 'Select by Location' from the list to open the 'Select by Location' window.
- From the dropdown list of 'Selection Method' options, choose 'select features from'.
- Check the box 'Location' under the option 'Target layer(s)'.
- Check the box next to 'only show selectable layers'.
- From the dropdown list for 'Source layer', select the 'Bumthang' layer.



- And select 'intersect the source layer feature' from the 'Spatial selection method for target layer feature(s)' dropdown list.
- Click 'Apply' and then 'OK'.
- Now you will see the selection of Location point only in Bhumthang district on the map.




Now you can export these selected points as new layers so that you will get only locations that lie within the Bhumthang district boundary.

Map Layout

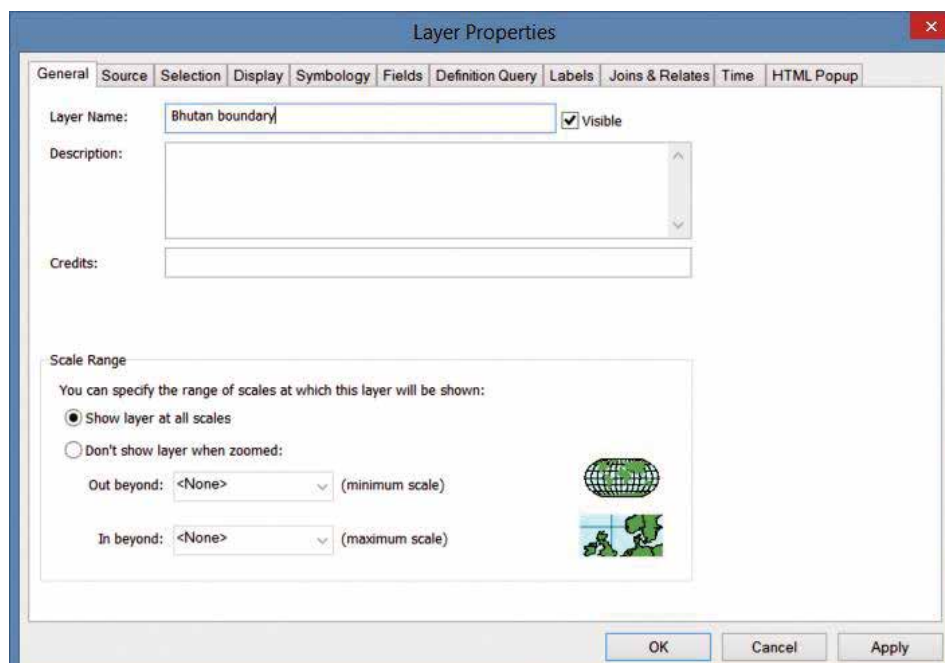
Map layout is a way of allowing you to make professional quality presentations. It is a collection of map elements laid out and organized on a page, designed for map printing. Common map elements that are arranged in the layout include one or more data frames (each containing an ordered set of layers), a scale bar, north arrow, map title, descriptive text and a symbol legend. In a map layout, we can also include tables and charts. We have thus far worked in 'Map View' and maps are created in 'Layout View'. To make the transition from map view to layout easier, a few things should be done in map display.

- Set the map and display units first. This needs to be done before a scale is placed on the layout.
- Choose appropriate colors for your map.
- Give names to map view and layers. These names will be used to title the map and label the legend.

In this exercise we will make a simple district map of Bhutan with road networks.


- First clear all of the selection of Objects or features by clicking on the 'Clear Selected Features' button  on the standard toolbar.
- Make sure that the layers that will be included in the Map Layout have appropriate colors and symbols.
 - Change the symbology of the 'District' layer to 'Categories > Unique values' of 'DIST_NAME' field with your appropriate 'Color Ramp'.
 - Similarly change the symbology of the 'Road' layers using the 'Type' field (black color and 1 to 2 point width for highway and dzongkhag roads, and dark grey color and 0.5 to 1 point width for other roads). You can change these properties by double-clicking on the 'Symbol' itself.
 - Also place the 'Bhutan_bnd' layer above the 'District' layer using drag and drop. And change the symbology to 'Hollow' and outline to 'Boundary National'.

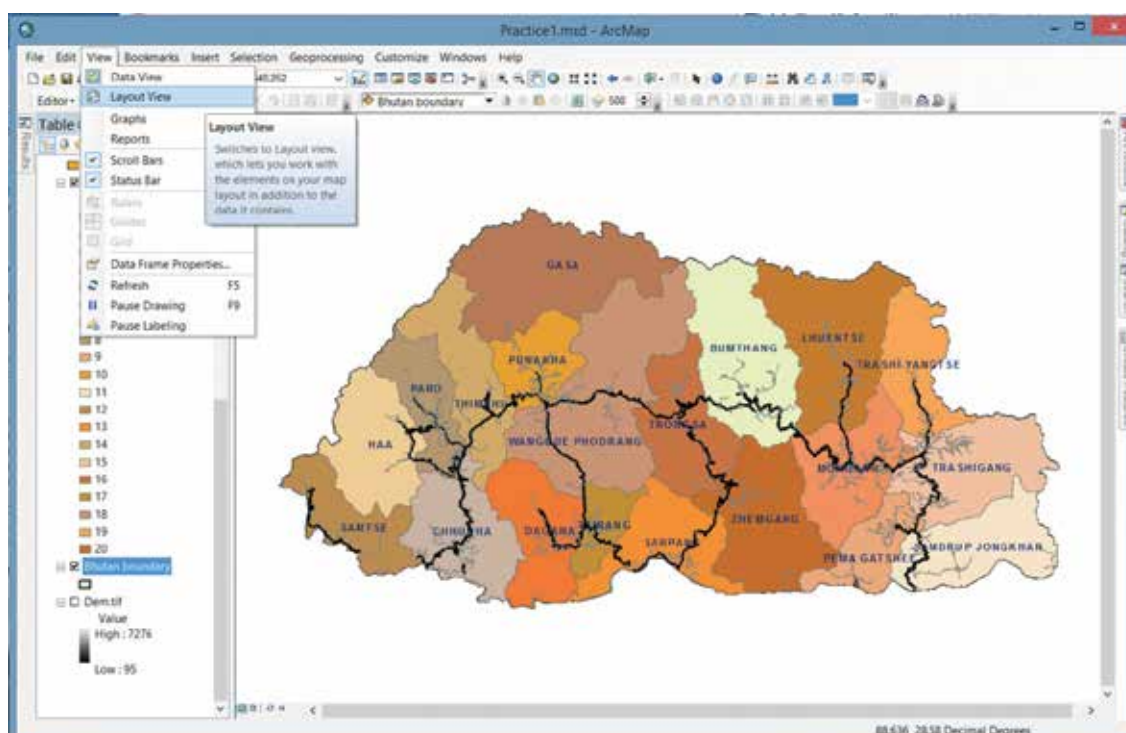
- Label the features that you want to put on the map.
- Provide meaningful names to the layers, so that they are nicely displayed in a legend on the map.
 - Right click on 'Bhutan_bnd' layer and click on 'Properties' in the list or double click on the 'Bhutan_bnd' layer to open the 'Layer Properties' window.
 - Click the 'General' tab.
 - Under the 'Layer Name' text box, change the name to 'Bhutan boundary' and keep 'Visible' checked.
 - Click 'OK' to apply the change and close the 'Layer Properties' window.



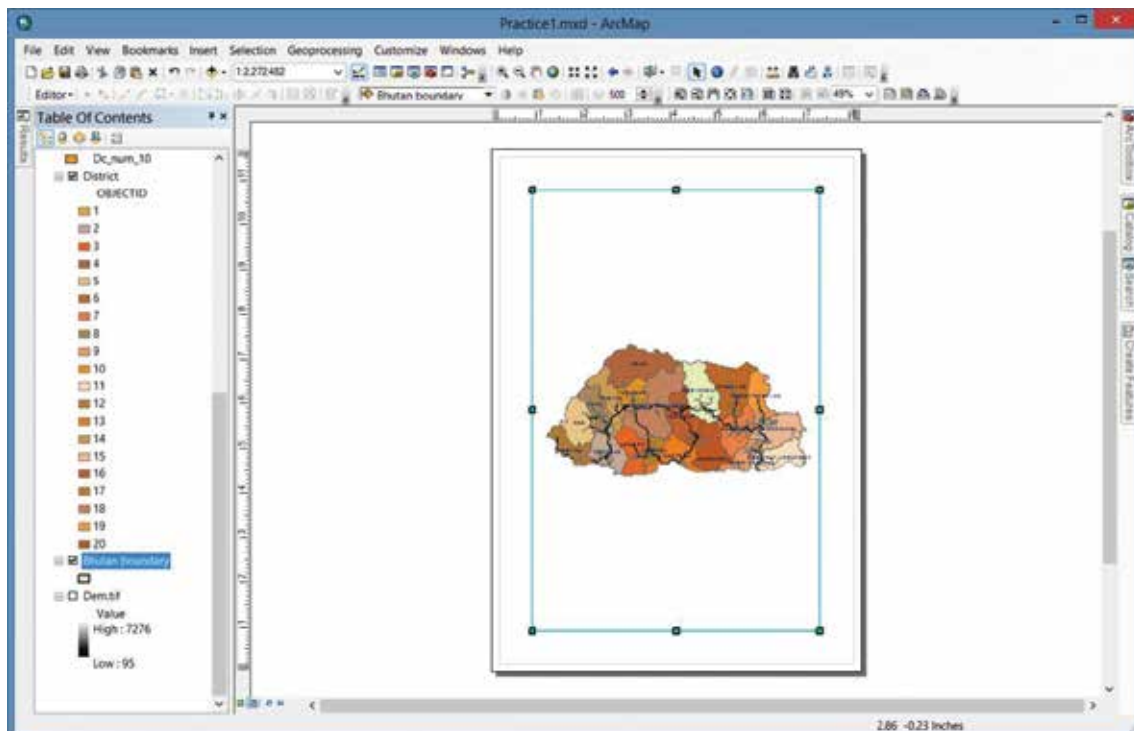
Repeat this process on other layers where changes are necessary.

If all the steps (changing colors, symbology, naming the layers and sequencing) have been completed satisfactorily, it's time for layout.

- Switch the 'Map View' mode to 'Layout' by clicking on the 'Layout' button at the bottom left corner of the 'Map View'  or go to the 'View' menu in the main menu bar and click on the 'Layout View' on the list.



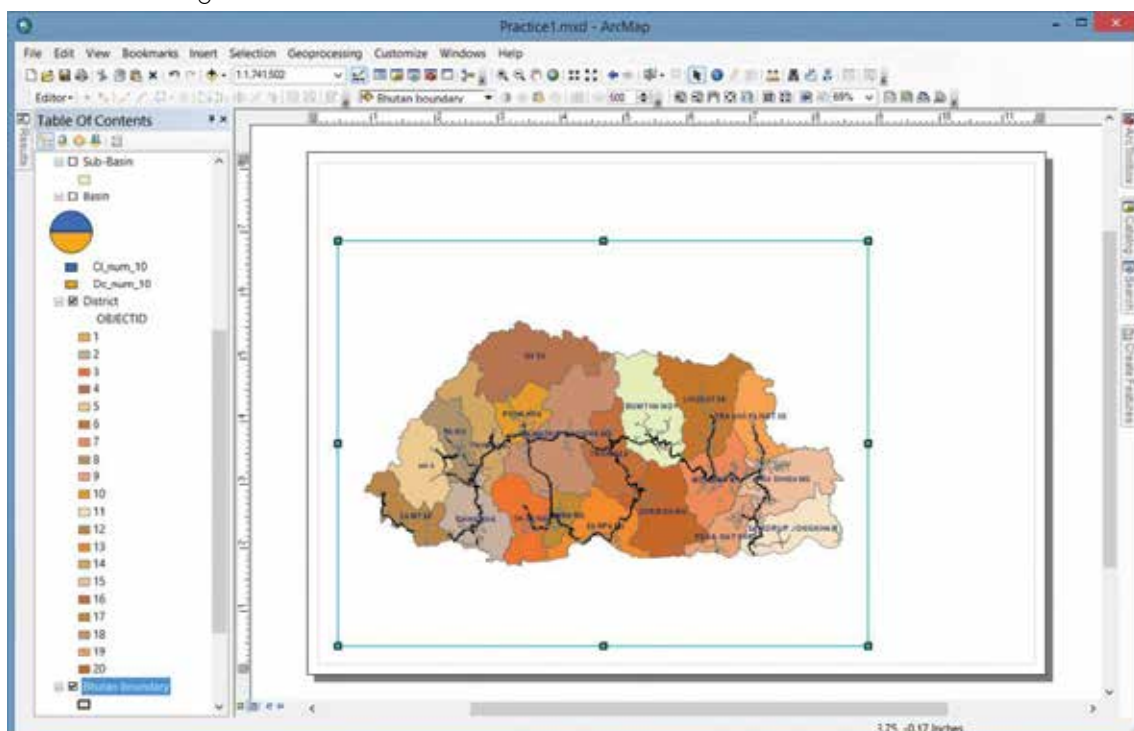
Now you can see the Layout view with box of data frame and page alignment. The alignment of the data frame boundary and page will not match. So you can change the data frame boundary by dragging the boundary node points. Before setting the data frame boundary, you have to set up the page format.



To Set up the Page Format

- Go to 'File' menu and click on the 'Page and Print Setup'. 'Page and Print Setup' window will open.
- In the Paper section, select the Paper size 'A4' from the dropdown menu and 'Automatically Select' for 'Source'.
- Select the 'Landscape' paper orientation for the present exercise.
- Check the box next to 'Use Printer Paper Settings' on the Map Page Size section and 'Scale Map Elements proportionally to change in Page Size' box on the bottom right corner of the window.
- Click 'OK' to apply the change and close the window.

As you will see, the page in the Layout view will now change to Landscape. You can set the boundary of the data frame to fit the page by dragging the node points of the data frame boundary. Make the data frame boundary fit the page, as shown in the figure below.



You can use Zoom and Pan tools to fix the Data view in the data frame.

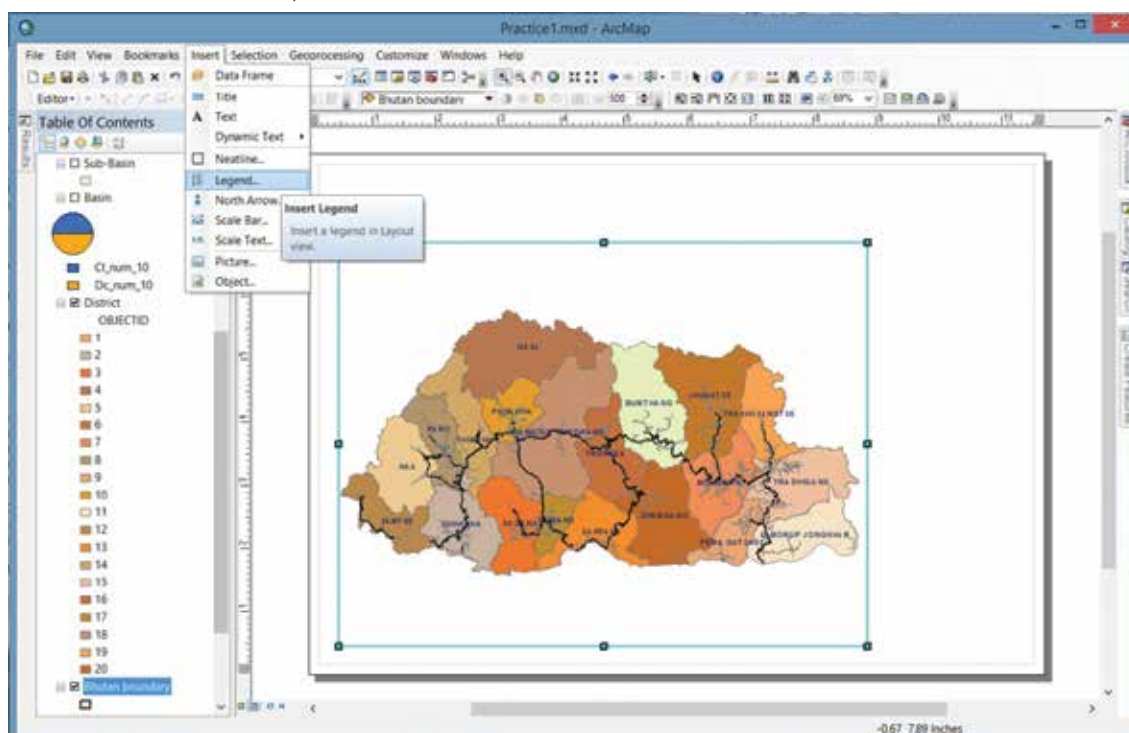
Also notice that the Layout toolbar is now activated.



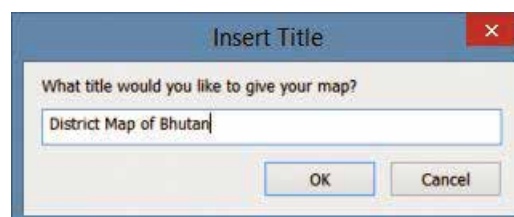
From here it is possible to zoom in, zoom out, pan, fixed zoom in, fixed zoom out, zoom to whole page, zoom to 100%, go back and forward between extents, and change the percentage of your zooming. If you want to quickly zoom in to the extent of the Bhutan boundary, just right click on the Bhutan boundary layer in 'Table of Contents' and select 'Zoom to Layer' from the list. Practise using these tools to become familiar with them.

Adding a Title, Scale Bar, North Arrow, and Legend

- In the Menu bar, click the 'Insert' menu. The list of options on the Insert menu will open. This menu allows you to add various elements to the layout.

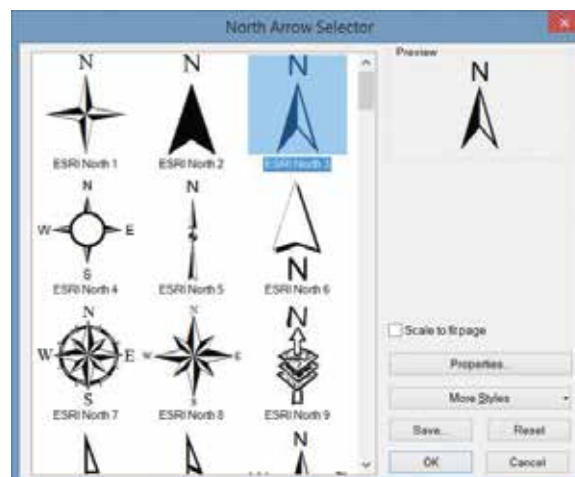


- Click on 'Title' and a 'Title' box will appear on the layout with the name you choose when you saved the project. It is possible to change the name by clicking on the box and typing in new text. Place the 'Title' at the top of the Map Layout by dragging and dropping in the right position.



Adding North Arrow

- Click the 'Insert' menu and select 'North Arrow' from the list. The 'North Arrow Selector' window will open.
- Select 'ESRI North 3' from the list and click 'OK' to add the North arrow.
- Click the North arrow and drag it to the right corner of the map layout within the data frame boundary. Or place it in a location you think is appropriate.

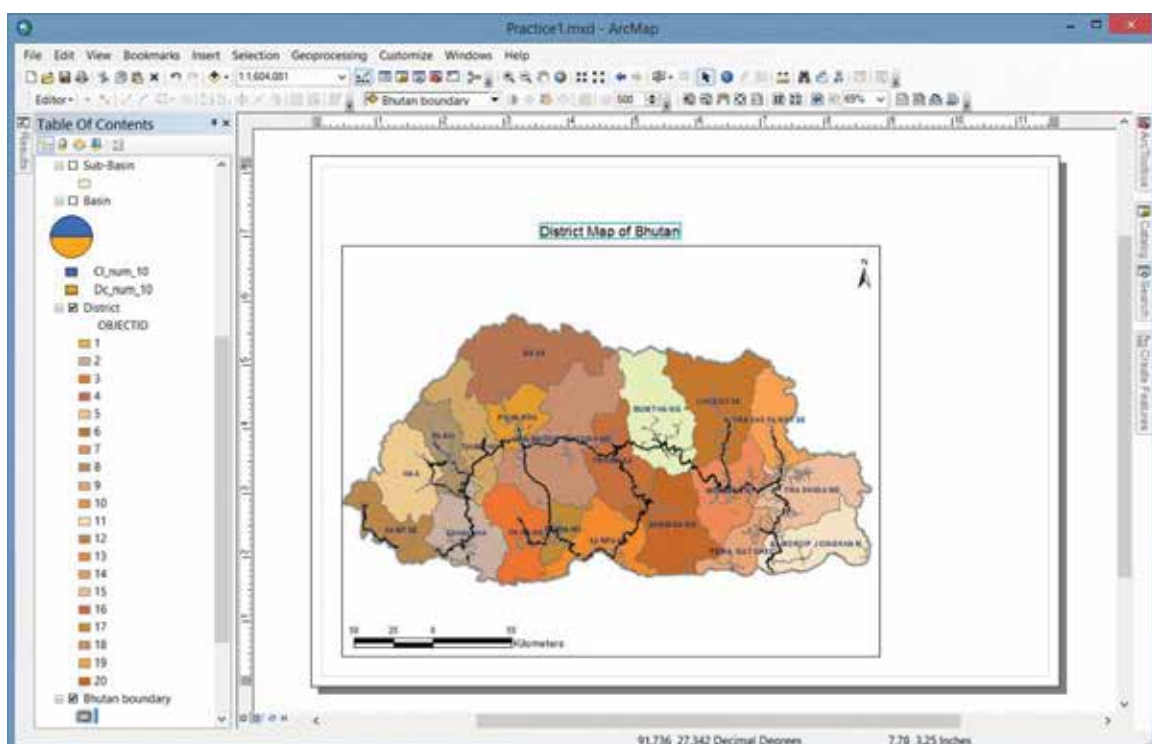
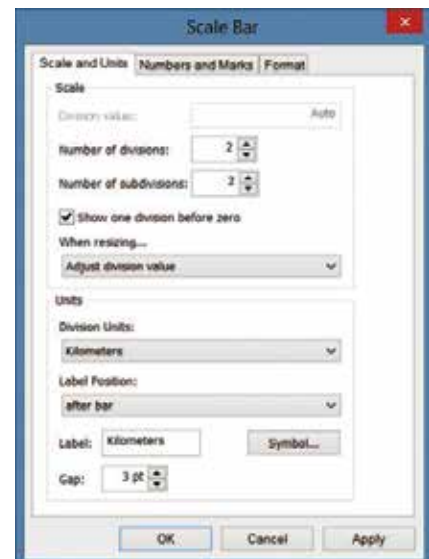


Adding a Scale Bar

- Click the 'Insert' menu and select 'Scale Bar'. The 'Scale Bar Selector' window will open.
- From the left box of the 'Scale Bar Selector' window, select 'Double Alternating Scale Bar1'.
- Then click the 'Properties' button on the right side of the window. The scale bar properties window will open.

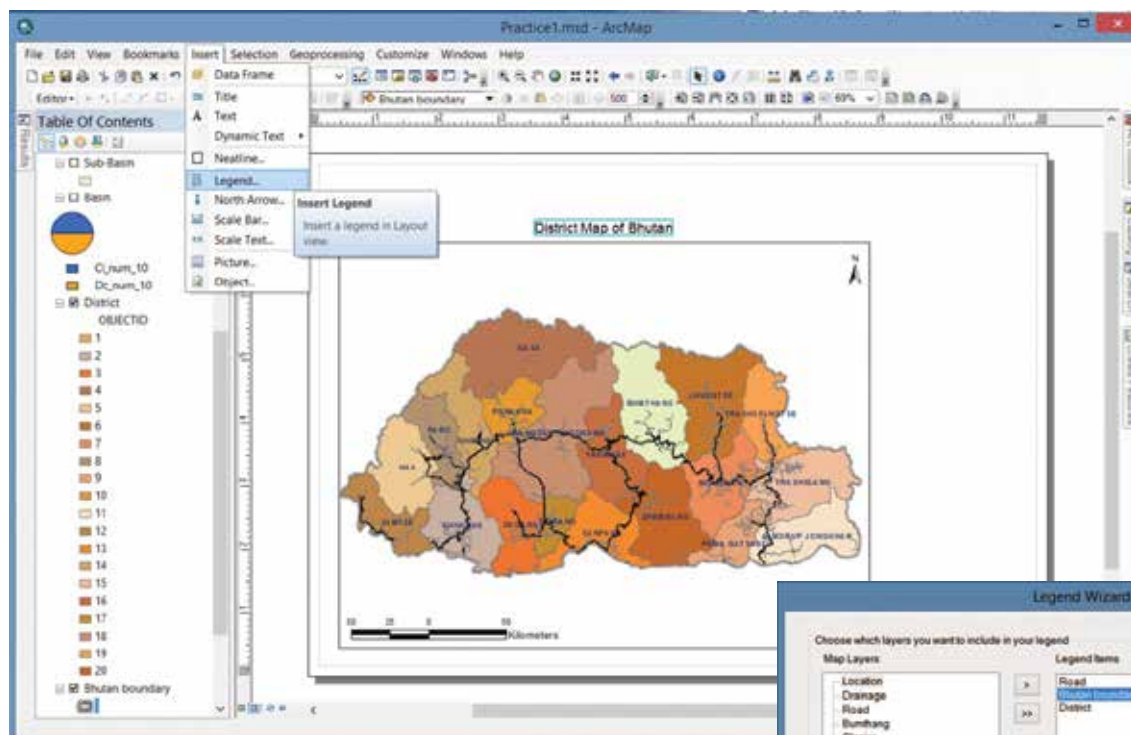


- On the 'Scale and Units' tab of the 'Scale Bar' window, set the values 'Number of Divisions' and 'Number of Subdivisions' to 2. Check the box next to 'Show one division before zero'. For 'Division Units', select 'Kilometres' from the dropdown list.
- Click 'OK' to apply the scale bar properties and to close the window.
- Click 'OK' on the 'Scale Bar Selector' window to apply and close the window.
- Now you will see the Scale Bar added in the Layout.
- By default the Scale Bar will appear in the middle of the page. So move the scale bar by selecting it and drag it to the lower left corner of the Map just inside the left corner of the Data Frame boundary.
- Also if you select the note point of the scale bar boundary and drag in/out, ArcGIS will automatically set the size and scale of the font and scale bar.



Adding Legend

- Before adding the Legend, you have set all the layer names and symbols as you would like them to be displayed on the Map.
- Click the 'Insert' menu and select and click on 'Legend'. The 'Legend Wizard' window will open.



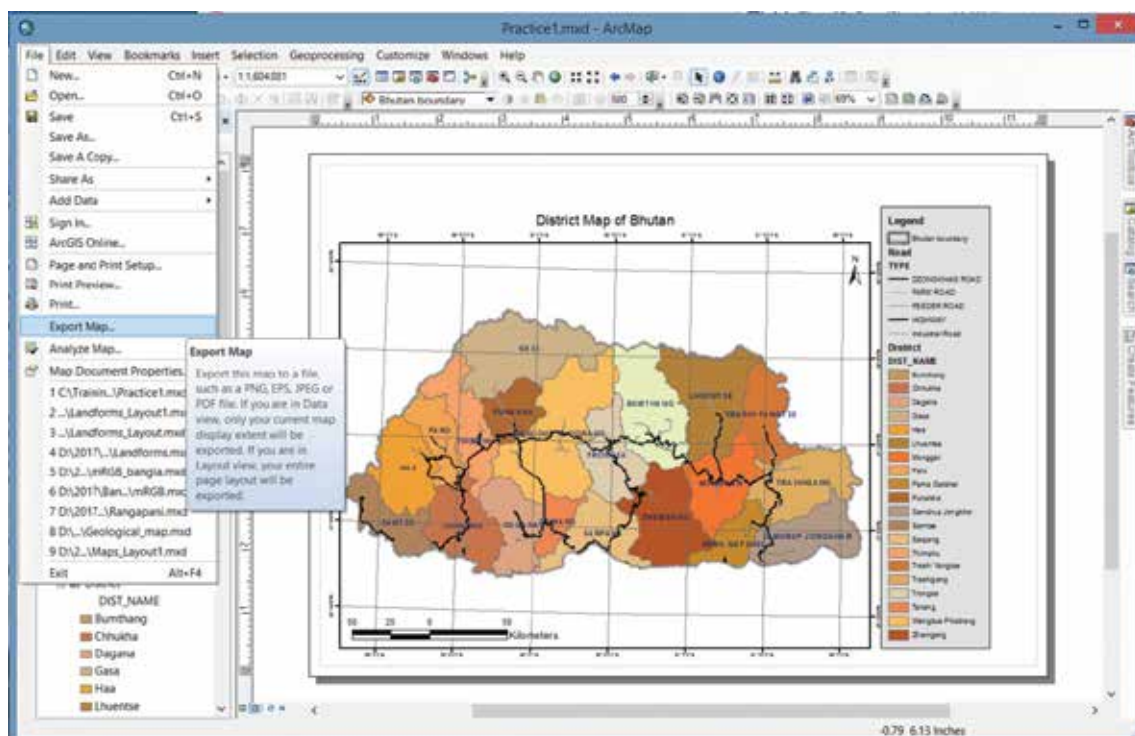
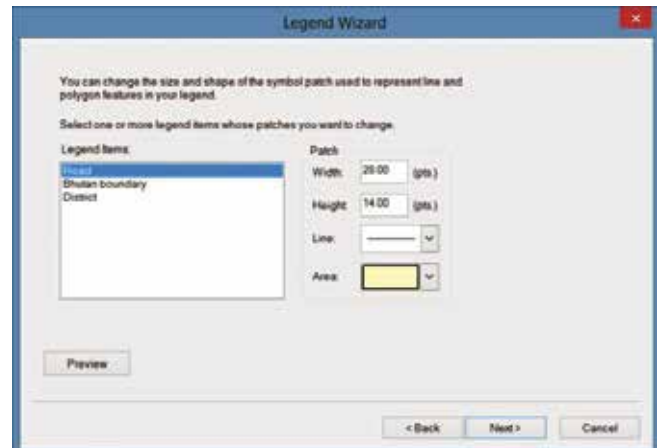
- In the 'Legend Wizard' window, there are two boxes – 'Map Layers' on the left and 'Legend Items' on the right and in between there are four arrow buttons. Now select the Layers from the 'Map Layers' box that you want to add in legend and move to the Legend Items box by clicking the single arrow button pointing towards the 'Legend Items'.
- Similarly for layers you do not want to display in the Legend on the Map, remove them from the Legend Items by selecting and clicking on the single arrow button pointing towards the Map Layers.



- On the right side of the Legend, there are four arrow buttons pointing downward and upward. You can use these buttons to arrange the sequence of the Layer one after another to show in the legend of the map.
- Once you select the Legend items and arrange them in the sequence you'd like to display on the map, click the 'Next' button. Now it will allow you to format the Legend title. Here you can change the Title name of the Legend and formats of the title name.
- Click 'Next'.
- In the next window, you can set the Legend Frame background and boundary. For 'Border' type, select '0.5point' from the dropdown list and for 'Background' select 'Grey 10%'. Then leave the others as default and click the 'Next' button.



- Now in the next window you can change the size and shape of the symbol patch used to represent the features in the legend. Select the items from the 'Legend Items' box on the left side and change the width, height, line type and area type in the 'Patch' section on the right side of the window. At the moment leave it as default and click the 'Next' button on the bottom right corner of the window.
- Again in the next window you can set the spacing between the parts of the legend. But for now leave it as default and click the 'Finish' button to add the Legend in the map and close the 'Legend Wizard' window.
- By default the legend will appear in the middle of the layout. You can move the legend by clicking on the legend box and dragging and dropping it on the right side of the layout, as shown in the figure below. You can also select the node corner point of the legend box and adjust the size of the box to fit the layout page. While you adjust the legend box size ArcGIS will automatically set the size and shape of the elements in the legend box.



Adding Grids and Graticules

A grid is a network of evenly spaced horizontal and vertical lines used to identify locations on a map. For example, you can place a grid that divides a map into a specified number of rows and columns by choosing the reference grid type. Often, the row and column labels of a reference grid identify locations listed in a map index.

You can also use grids to display measured locations using projected coordinates on the map. There are numerous ways to display measured grids.

Graticules are lines showing parallels of latitude and meridians of longitude for the earth. Graticules can be used to show location in geographic coordinates (degrees of latitude and longitude).

Usually, to add the grids or graticules in the layout you need to set the coordinate system of the data frame. For reference grids, you have to set the data frame as projected coordinate system and for the graticules line you have to set the coordinate system of the data frame as 'Geographic Coordinate System'. In the new version of ArcGIS (version 10.x), if you set the coordinate system of the data frame, the system will automatically set the grids and graticules, but it's better to set the respective coordinate system in the data frame. In this exercise, we will add the graticules on the map.

Double click on the data frame or right click on the data frame in the 'Table of Contents' and select 'Properties' from the list. The 'Data Frame Properties' window will open.



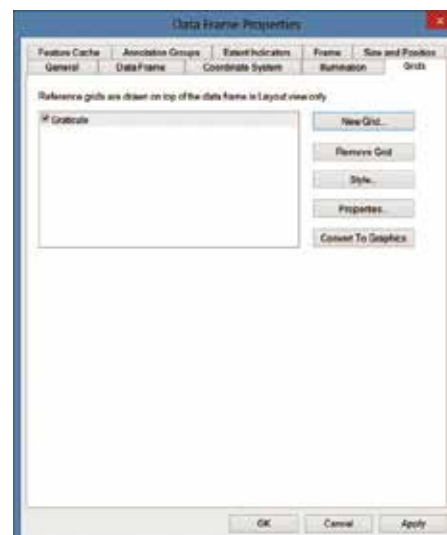
- Click on the 'Grids' tab.
- Click the 'New Grid' button on the left side of the 'Grid' tab window. The 'Grid and Graticules Wizard' will open.
- Here you have three options of grids you want to add on the map – Graticule, Measured Grid and Reference Grid. Check the radio button next to 'Graticule' and type the 'Grid name' if you want.
- Click the 'Next' button. In the next window you can change the Appearance and Intervals of the grids. Select the 'Graticule and labels' in the Appearance section and set the interval to 30 min in both the parallels and meridians.



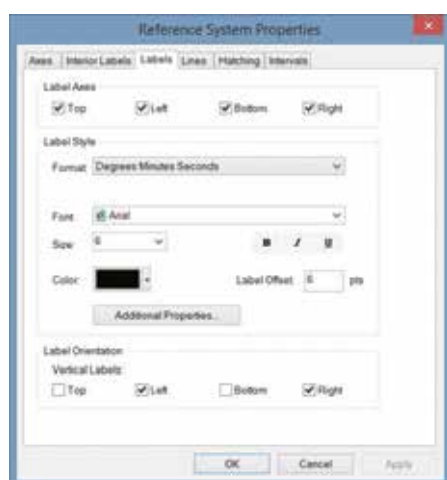
- Click the 'Next' button and it will allow you to format the axes and labels. For now leave it as default.
- Again click the 'Next' button and here it will allow you to create graticule line and its formats. You can leave this part also as default.



- Click 'Finish' to add the graticule lines and close the window.
- Now in the left box on the 'Grids' tab window of the 'Data Frame Properties' window, you will see an item named Graticule with box checked. On the right side of the window all the buttons are highlighted.

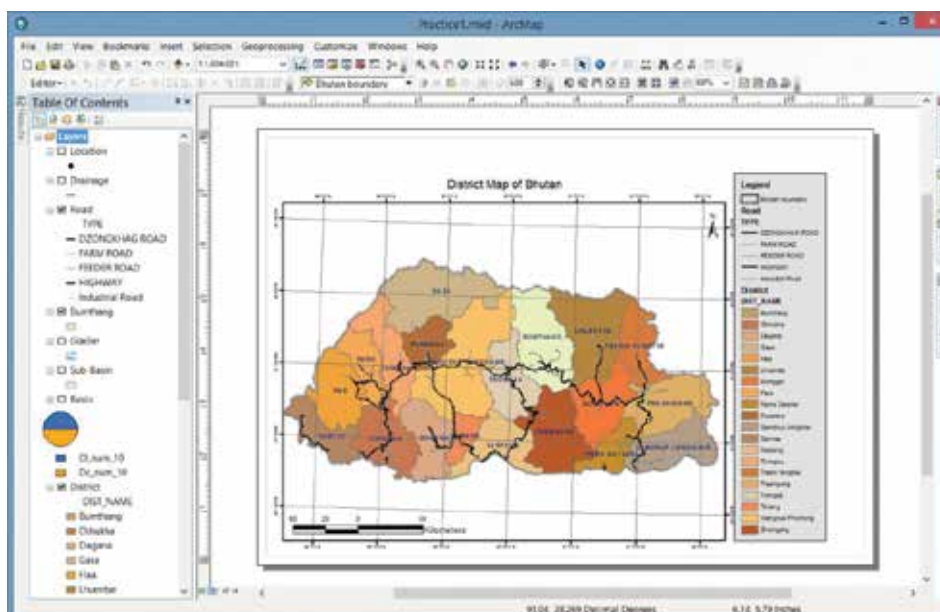


- Select the item in the left box and click the 'Properties' button. The 'Reference System Properties' window will appear, where you can again format the graticule lines and labels and display properties.



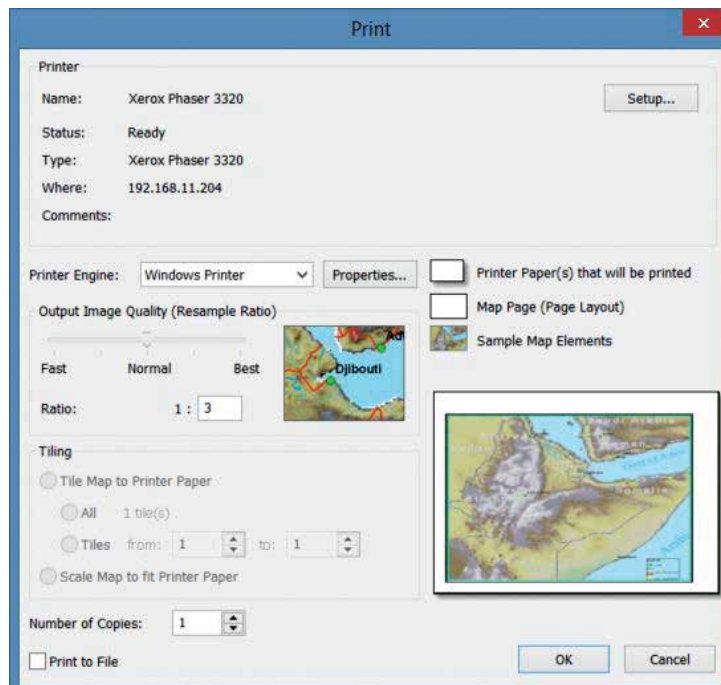
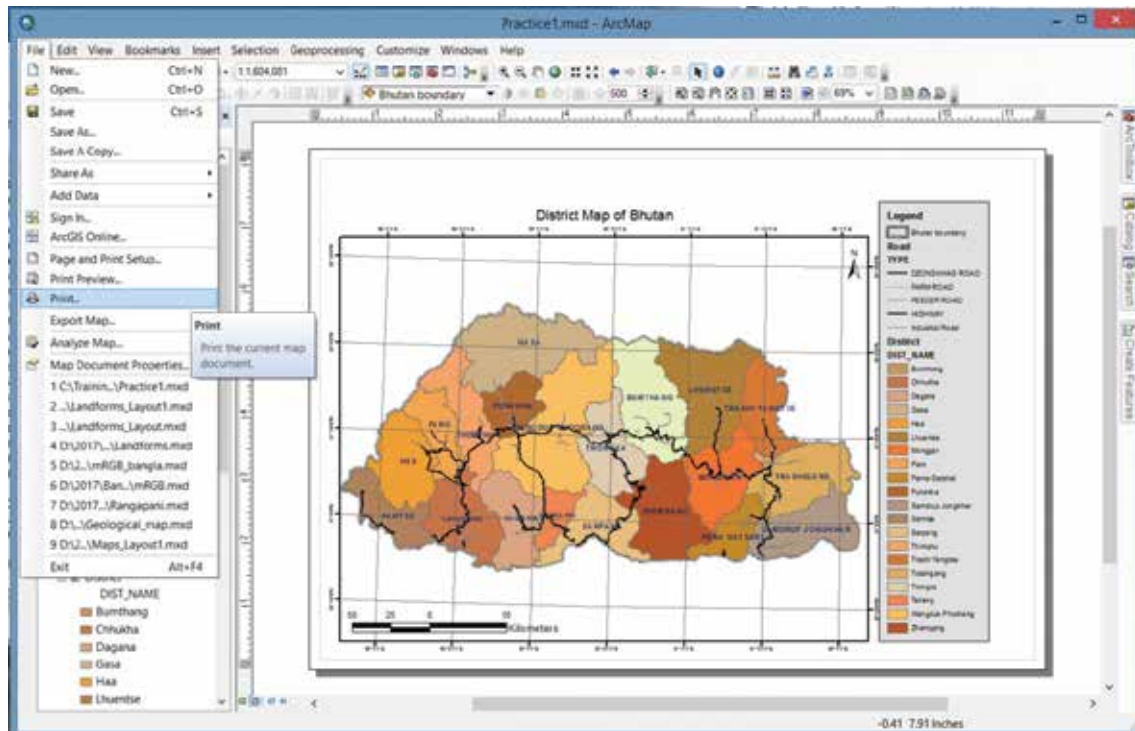
- Go to 'Labels' on the 'Reference System Properties' window and check the 'Left' and 'Right' check boxes in Vertical Labels Orientation section. Then click 'OK' to apply.
- Also click 'OK' on the 'Data Frame Properties' button to add the graticule lines on the map.
- Now you will see the graticule lines on the map. If the graticule lines are dense or do not appear clear or you are not satisfied with the view, you can change it by opening the Data frame properties > Grids tab and select 'Open the properties' of the graticules you added.

Now arrange the elements of the map layouts so that it looks good.



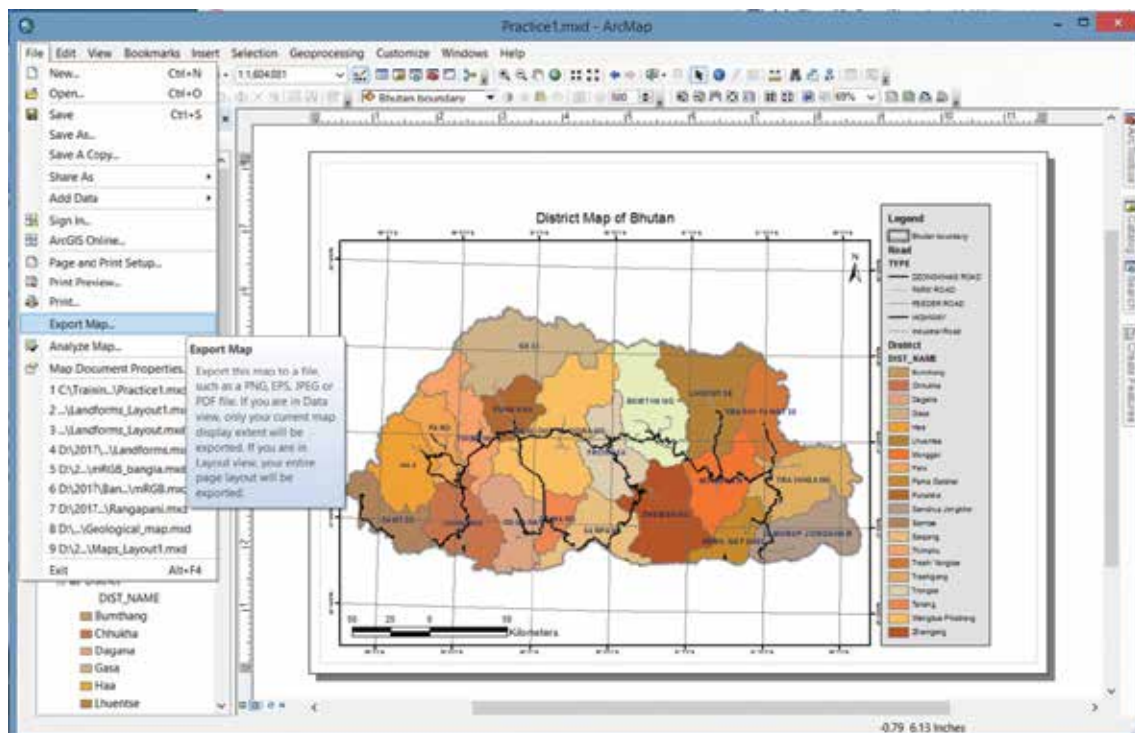
Export or Print the Map

- Once the layout is done, you can print it by pressing the print button in the standard toolbar or by selecting 'File > Print' from the menu bar.
- When the print window opens, set the printer and paper format then press the 'OK' button to print.

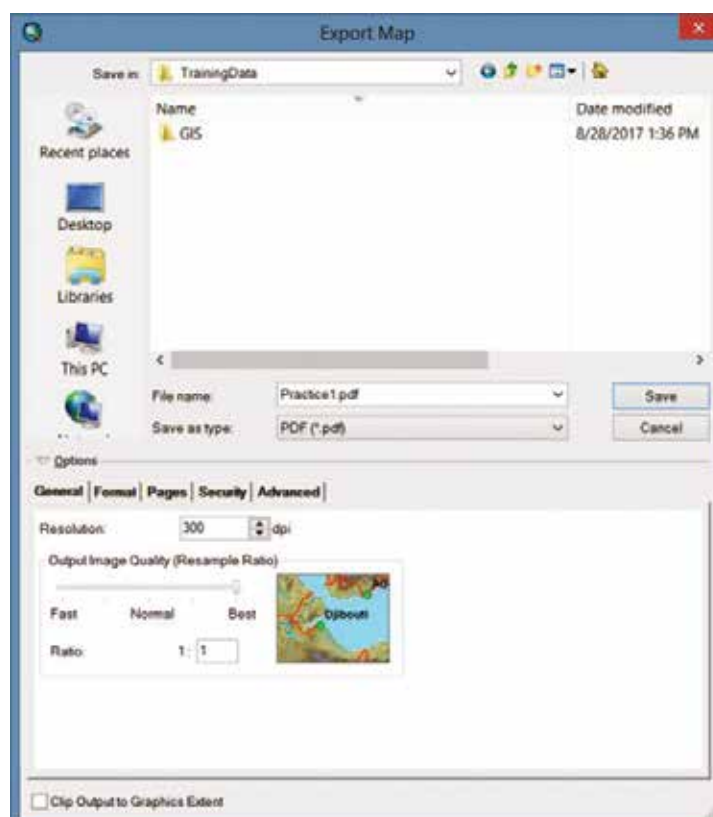


You can also export the map in a variety of file types.

- From the menu bar select 'File > Export Map'.
- The 'Export Map' window will open where you can choose the location, output filename and type, resolution and the extent of output map.



2.3 ArcToolbox and Extensions in ArcGIS



ArcToolbox

ArcToolbox is the third application of ArcGIS Desktop. Although it is not accessible from the start menu, it is easily accessed and used within ArcMap and ArcCatalog. ArcToolbox contains tools for geoprocessing, data conversion, coordinate systems, projections, and more.

The ArcToolbox is the central place where you find, manage, and execute geoprocessing tools. It contains toolboxes, which in turn contain tools and toolsets (a toolset is just an organizational device, like a system folder). Tools must be contained in a toolbox – they cannot exist outside a toolbox.

A toolbox is a file in a folder on a disk or a dataset in a geodatabase. Toolboxes in a folder have a .tbx extension. They can be easily copied and moved.


ArcGIS ships with a dozen or so toolboxes; the exact number depends on what extensions you have installed. Toolboxes installed with ArcGIS are referred to as system toolboxes. The organization of the system toolboxes—their names and the tools and toolsets they contain—has been carefully thought out to provide a logical and coherent collection of tools.

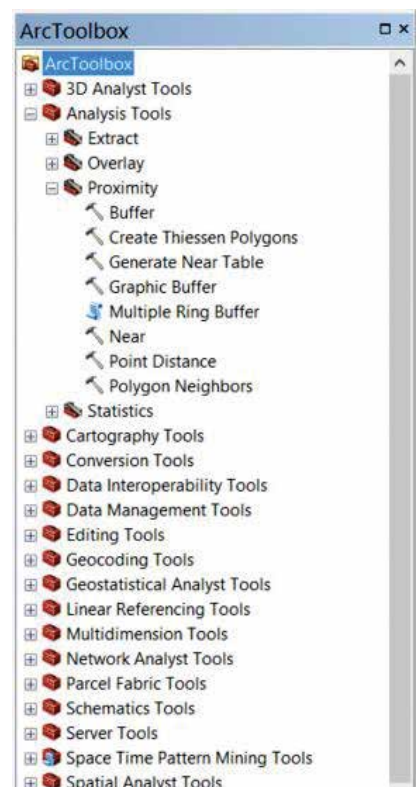
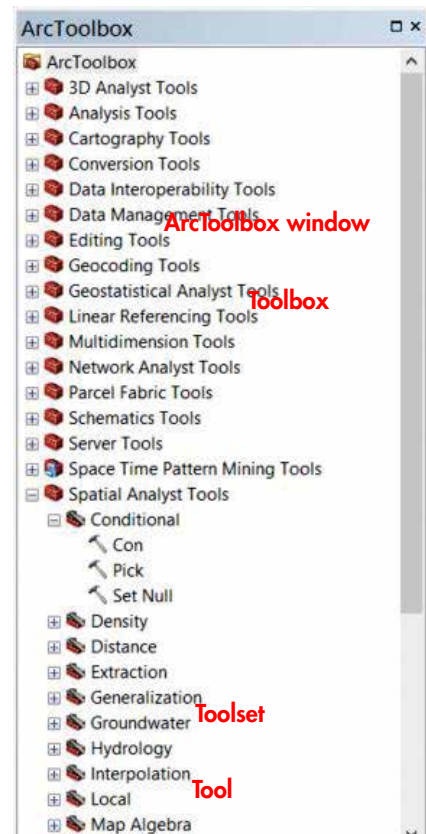
Geoprocessing through ArcToolbox

According to ESRI, geoprocessing refers to the tools and processes used to generate derived data sets. The derived data is a new file that results from taking a data layer and processing it.

There are many tools and ways to conduct geoprocessing in ArcGIS. But we only look at a few most common geoprocessing operations such as buffer, clip, dissolve, intersect and spatial join.

ArcToolbox allows us to perform these operations through sets of toolboxes. We will be using the Analysis and Data Management toolboxes. Within these main toolboxes, operations are grouped by the way that the derived data set is created.

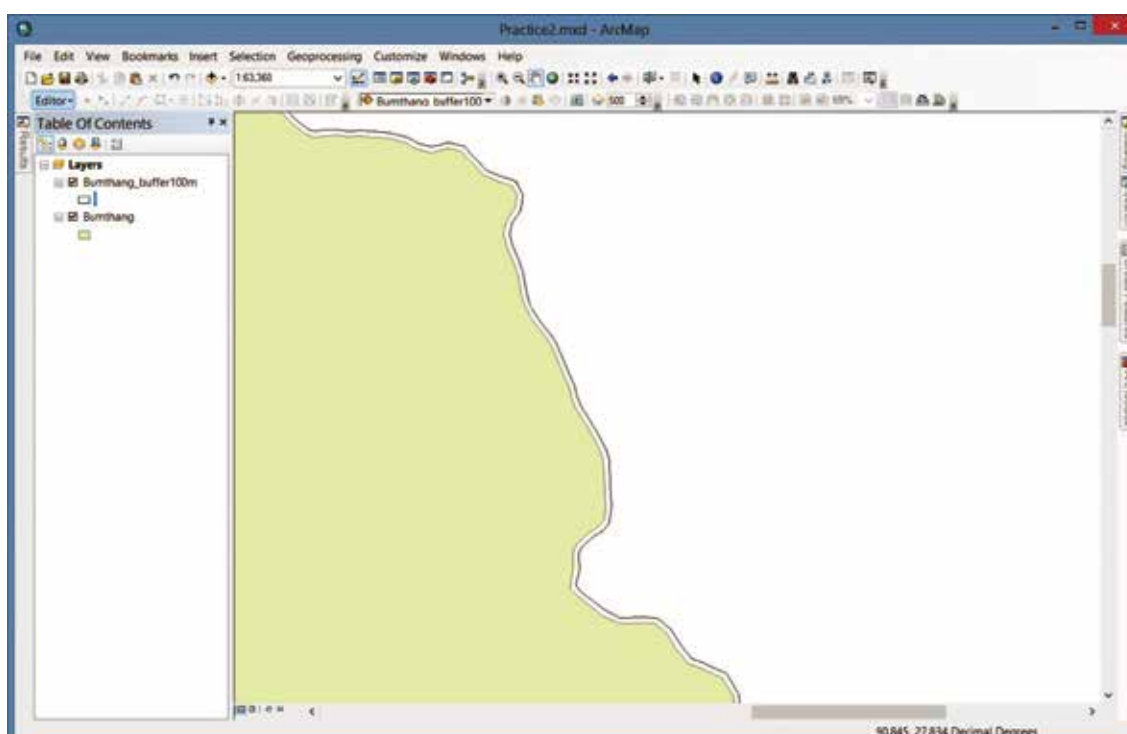
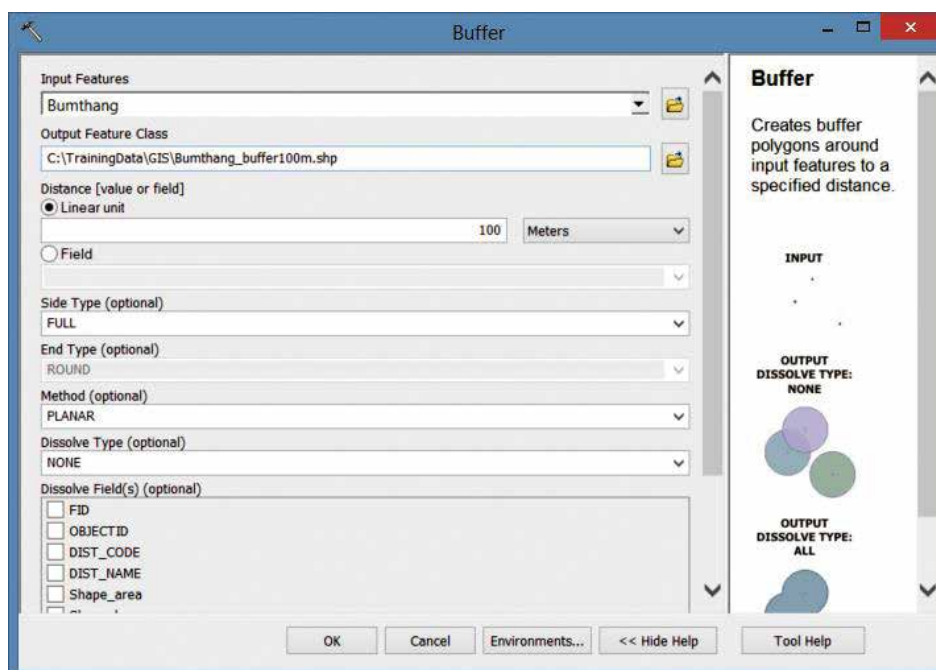
- Open new ArcMap projects.
- Add the 'Bhumthang' district layer from 'C:\TrainingData\GIS\temp', which was exported from the 'District' layer in the previous exercise, and 'Location', 'District' and 'Glacier' from the 'C:\TrainingData\GIS'.
- You can change the symbology as you like and save the project as 'Practice2.mxd' at 'C:\TrainingData'.
- Now open the ArcToolbox by clicking the 'ArcToolbox' button  in the standard toolbar. The ArcToolbox window will open.



Buffer

It is a zone around features measured in units of distance or time. It is useful for proximity analysis. It can also be defined as an area bounding the region determined by a set of points at a specified maximum distance from all nodes along the segments of an object. For instance, we will just use the Bhumthang district boundary to identify where the area lies within the 100 m distance from the Bhumthang district boundary.

- Click on the Plus sign next to 'Analysis Tools'.
- Single click on the plus sign next to the 'Proximity' toolset.
- Double click on the 'Buffer' tool. The buffer window will open.
- In the 'Input Features' box at the top choose the 'Bhumthang' layer from the dropdown list.
- Using the browse icon navigate to the 'C:\TrainingData\Gis\Temp' folder in the box for 'Output Feature Class' and name the new file 'Bhumthang_buffer100 m'.
- Under the 'Distance' section, type 100 in the 'Linear unit' box and select 'Meters' from the dropdown menu.
- Leave other functions as default and click the 'OK' button. You will see a little process window at the bottom of the screen, and when the process is complete a new layer will be added in the project.
- Select the new created layers and change the symbology to 'Hollow'. Zoom to the boundary of the new layers and measure the distance between the boundary of the 'Bhumthang' layer and new 'Bhumthang_buffer100 m' layer.

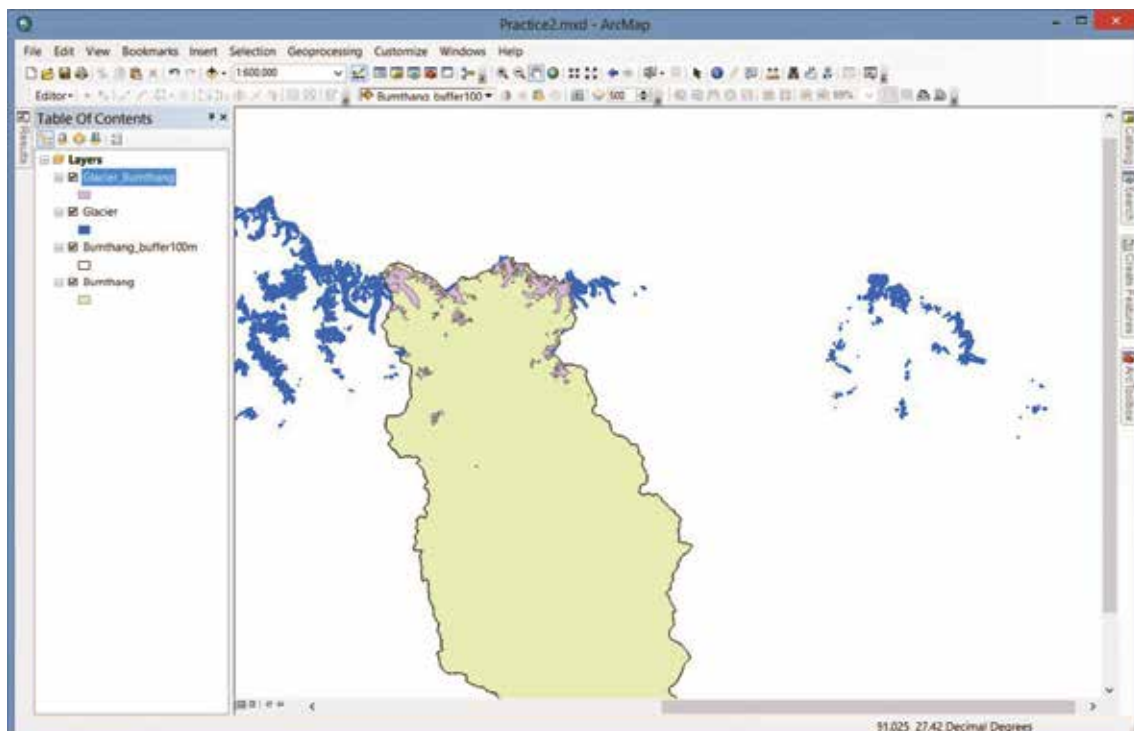
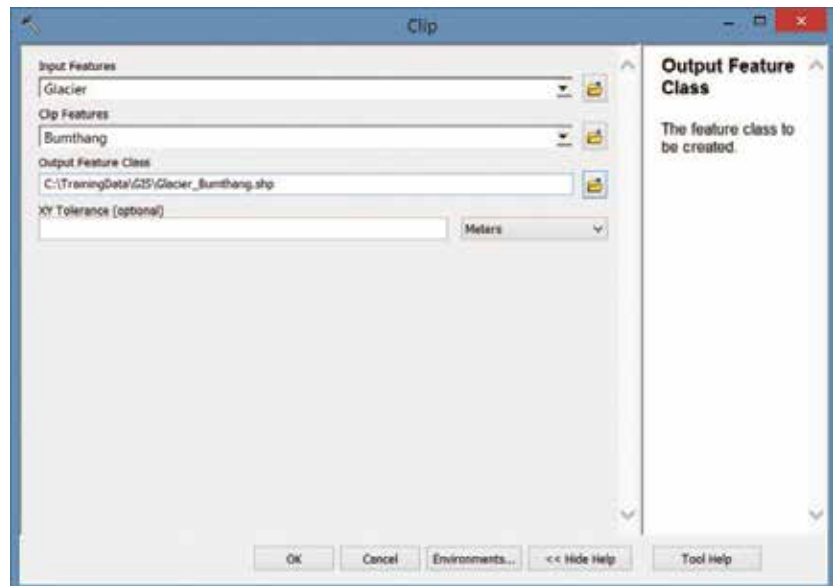


Here in the figure the pink filled polygon is the Bhumthang boundary and Black thick outline is boundary with 100 m buffer of the Bhumthang district boundary.

Clip Operation

This will cut out a feature using another feature. This is useful for creating a new feature class or a new shapefile of subset of feature in another, larger feature shapefile. In this exercise, you will use the Bumthang district boundary to cut out glaciers lies within Bumthang from the glacier shapefile of Bhutan.

- Re-open the ArcToolbox window if it is not already open.
- Under Analysis > Extract, double click on the 'Clip' tool in the ArcToolbox or click on Geoprocessing > Clip on the menu bar. The 'Clip' window will open.
- Under 'Input Features', select the 'Glacier' layer from the dropdown list.
- Under 'Clip Features', select the 'Bumthang' layer from the dropdown list.
- On the 'Output Feature Class', click on the folder icon and navigate to the folder 'C:\TrainingData\GIS\Temp', then name the output file 'Glacier_Bumthang.shp' and click the 'Save' button to close the window.
- Click the 'OK' button to process the command. You will see a little process window at the bottom of the screen, and when the process is complete a new layer will be added in the project.



You will see the new 'Glacier_Bumthang' layer in the map view. You can open the 'Attribute Table' of the layer. Then check the number of glaciers in Bumthang district and you can also summarize the area of glaciers to obtain the largest glacier area and total glacier area in Bumthang district. To summarize the area:

- Open the 'Attribute Table' of the layer 'Glacier_Bumthang'.
- Right click on the 'Area_SqKm' field and click on 'Statistics' on the list.

Table

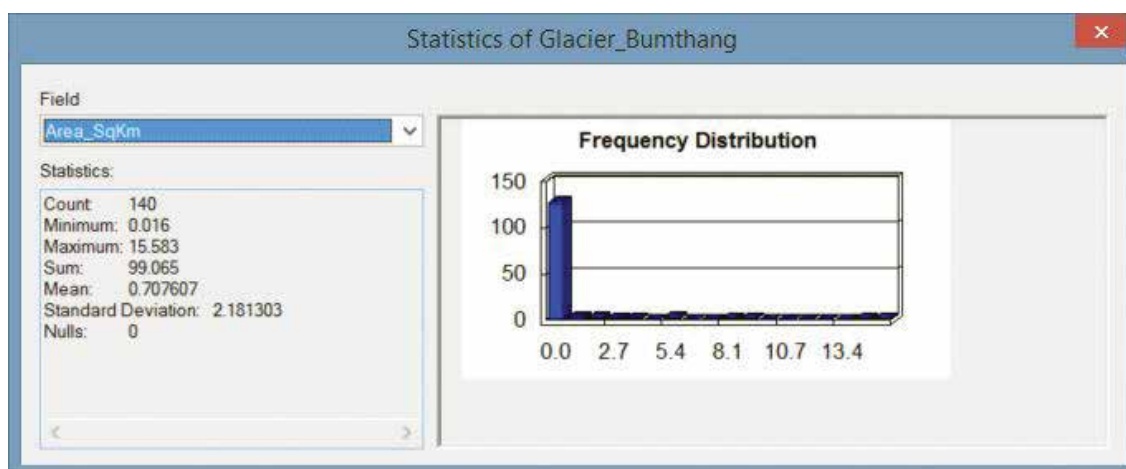
Glacier_Bumthang

Elv_max	Slope_min	Slope_mean	Slope_max	Aspect	Area_SqKm	Thickness	Reserve	Year
6706	0	17	54	174	14			010
5332	6	19	35	243	0			010
5372	4	15	26	206	0			010
5082	0	9	17	122	0			010
5166	2	15	25	129	0			010
5285	20	26	31	204	0			010
5209	14	18	21	285	0			010
5445	1	11	25	147	0			010
5367	2	16	36	111	0			010
5297	5	13	23	129	0			010
5980	1	14	49	140	8			010
5338	1	10	25	166	0			010
5785	15	30	48	238	0			010
5773	7	20	36	237	1			010
5477	7	24	36	206	0			010
5377	5	17	33	164	0			010
5710	0	11	38	127	4			010
5521	4	11	21	199	0.887			010

Statistics

Generates a report of statistics for the selected values in this numeric field. This command is disabled if this field is not numeric. If any of the records in the table are currently selected, statistics will only be generated for the selected records.

Now the 'Statistics of Glacier_Bumthang' window will open.

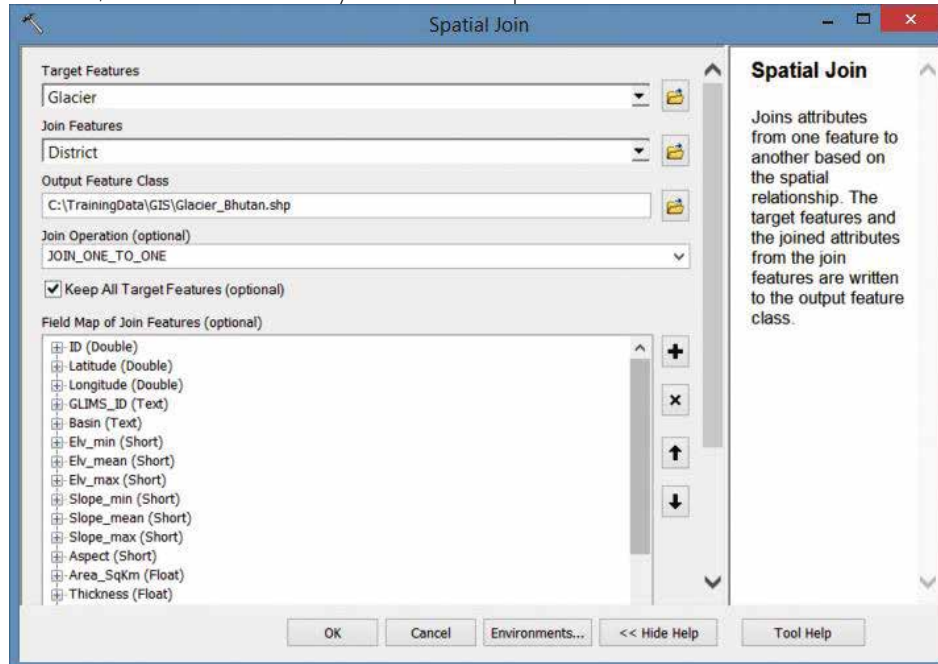


In the window, the left 'Statistics' box contains the summary of the field you selected from the 'Field' dropdown list. In the 'Statistics' box the count value represents the total number of glaciers, minimum value represents the smallest glacier area, maximum value represents the largest glacier area and the sum value represents the total glacier area in Bumthang district.

Spatial Join

This tool appends the attribute of one layer to another layer based on the relative locations of the features in the two layers. In this exercise, we will use the glacier shapefile and district shapefile of Bhutan and join as one-to-one operation taking glacier shapefile as the target layer. This will add all the district names including other attribute fields in the district shapefile in glacier features. Later we will summarize the area of glacier based on the added district name values in the field, which will give us the status of glaciers in each district.

- Re-open the ArcToolbox window if it is not already open.
- Under 'Analysis Tools' > 'Overlay' toolset, double click the 'Spatial Join' tool in the ArcToolbox. The 'Spatial Join' window will open.
- Under 'Target Features', select the 'Glacier' layer from the dropdown list.
- Under 'Join Features', select the 'District' layer from the dropdown list.



- On the 'Output Feature Class', click on folder icon and navigate to the folder 'C:\TrainingData\GIS\Temp', then name the output file 'Glacier_Bhutan.shp' and click the 'Save' button to close the window.
- Select 'JOIN_ONE_TO_ONE' in the 'Join Operation' and check the box for 'Keep All Target Features'.
- Click the 'OK' button to process the command. You will see a little process window at the bottom of the screen, and when the process is complete a new layer will be added in the project.
- Open the Attribute table of the new added layer 'Glacier_Bhutan' and scroll to the right side for the table to see the join table of the 'District' layer ('DIST_NAME').
- Now you can summarize the table to know the statistics of glaciers in each district of Bhutan. To do this follow these steps:

Table

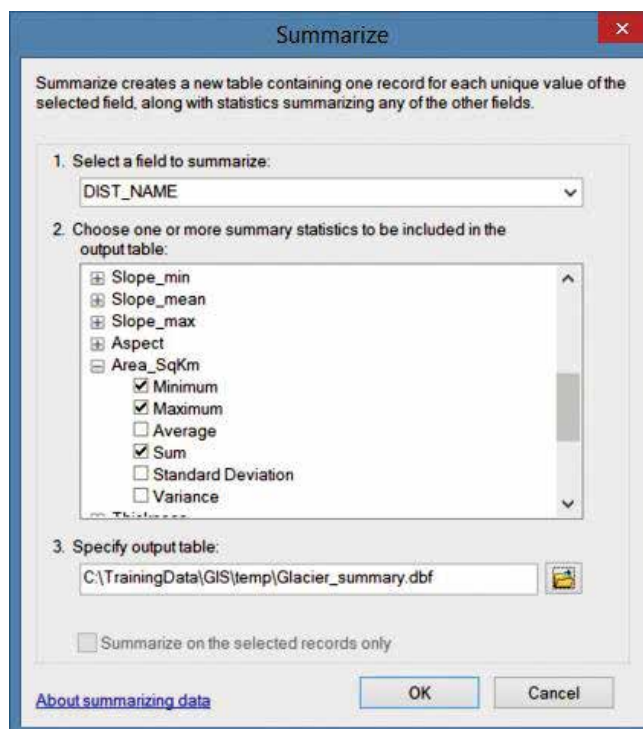
Glacier_Bhutan

Reserve	Year	OBJECTID	DIST_CODE	DIST_NAME	Shape_area	Shape_len	Pop_2005
0.07498	2010	8	08	Paro	515	36433	
0.03017	2010	8	08	Paro	515	36433	
0.02234	2010	8	08	Paro	515	36433	
0.01998	2010	8	08	Paro	515	36433	
0.00087	2010	14	14	Thimphu	584	98676	
0.00137	2010	14	14	Thimphu	584	98676	
0.00527	2010	4	04	Gasa			
0.01026	2010	4	04	Gasa			
0.00077	2010	14	14	Thimphu			
0.00009	2010	14	14	Thimphu			
0.00042	2010	14	14	Thimphu			
0.00405	2010	14	14	Thimphu			
0.00128	2010	14	14	Thimphu			
0.00021	2010	8	08	Paro			
0.00011	2010	14	14	Thimphu			
0.00024	2010	14	14	Thimphu			
0.00124	2010	14	14	Thimphu			
0.07343	2010	4	04	Gasa	3138.860647	354.866463	3116

(0 out of 886 Selected)

Glacier_Bhutan

- Right click on the 'DIST_NAME' file and click on 'Summarize' in the list. The 'Summarize' window will open.
- Select 'DIST_NAME' from the dropdown list under 'Select a field to summarize' at the top of the 'Summarize' window.
- Scroll down to the middle box to see the 'Area_SqKm' field. Click on the plus sign of the 'Area_SqKm' and check the boxes next to Minimum, Maximum and Sum under the 'Area_SqKm' tree menu.
- On the 'Specify output table', click on the folder icon and navigate to the folder 'C:\TrainingData\GIS\Temp', then name the output file 'Glacier_Summary.dbf' and select 'dBASE Table' in the 'Save as type' dropdown list, then click the 'Save' button to close the window.
- Click the 'OK' button to get the 'Summarize' table. A dialog box will open asking whether you'd like to add the result table on the map or not. Click the 'Yes' button to add the result table on the map.



- Now it will take some time to process and when it's done, the new summary table will be added to the 'Table of Contents'. Scroll down the 'Table of Contents' to view the new added table.
- Open the Table by right clicking on it and select Open from the list. Now the summary table will open. It shows the total number of glaciers in the each district in the 'Count_DIST_NAME' field, smallest glacier area in the 'Minimum_DIST_NAME' field, largest glacier area in the 'Maximum_DIST_NAME' field and total glacier area in the 'Sum_DIST_NAME' field. You can note down the names of the districts containing the highest glacier area and number, largest glacier.

Table						
Glacier_summary						
OID	DIST_NAME	Count_DIST_NAME	Minimum Area SqKm	Maximum Area SqKm	Sum Area SqKm	
0	Bumthang	140	0.016	15.583	99.065	
1	Gasa	464	0.011	36.551998	400.433998	
2	Lhuentse	91	0.022	12.548	49.152	
3	Paro	20	0.028	1.527	6.251	
4	Thimphu	51	0.019	7.176	36.556	
5	Trashig Yangtse	17	0.034	2.28	7.496	
6	Wangdue Phodrang	103	0.017	4.137	43.118	

Extensions in ArcGIS

ArcGIS has a suite of extensions that provide extended capabilities to the core product. The categories of extensions include analysis, data integration and editing, publishing, and cartography. With ArcGIS extensions, we can:

- Analyse data in a realistic perspective;
- Conduct advanced spatial analysis to get specific answers from data;
- Use advanced statistical tools to investigate data;
- Perform complex routing, closest facility, and service area analysis;
- Reveal and analyse time-based patterns and trends; and
- Represent and understand your network.

ArcGIS Network Analyst, ArcGIS StreetMap, ArcGIS 3D Analyst, ArcGIS Geostatistical Analyst, ArcGIS ArcScan, ArcGIS Tracking Analyst and ArcGIS Business Analyst are some of the examples of ArcGIS extensions. But in this exercise we only use some basic ArcGIS Spatial Analyst tools.

Spatial Analyst

The data structure used in the previous exercise is just vector data as discrete boundaries and location like district boundary, glacier boundary, and location point so on. But analysing continuous data models over space such as elevation, slope aspect, the raster data can be particularly useful in understanding the reasons for spatial patterns. As already described in the previous section, the raster data is composed of a two-dimensional matrix of grid cells, with numeric values assign to each cell. In this section we will work through some tools to analyse using raster data.

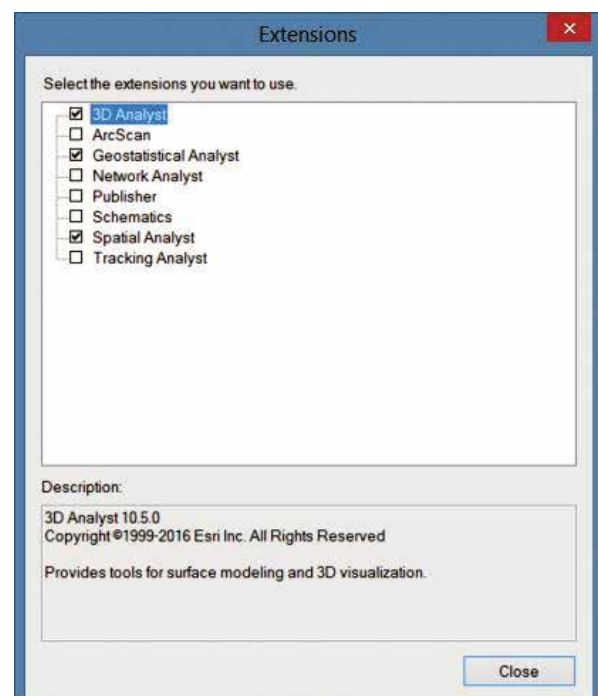
The spatial analyst provides a broad range of powerful spatial modelling and analysis tools. You can create, query, map, and analyse raster data; perform integrated raster/vector analysis; derive new information from existing data; query information across multiple data layers; and fully integrate raster data with traditional vector data sources. Integrated with the geoprocessing framework, ArcGIS Spatial Analyst provides easy access to numerous functions in ModelBuilder™, a graphic modelling tool.

With ArcGIS Spatial analyst, we can:

- Convert features (point, line, or polygon) to rasters;
- Create raster buffers based on distance from or proximity to features or rasters;
- Generate density maps and continuous surfaces from point features;
- Derive contour, slope, viewshed, aspect, and hill shades of these surfaces;
- Perform map algebra (Boolean queries and algebraic calculations);
- Conduct neighbourhood and zone analyses;
- Carry out discrete cell-by-cell analysis; and
- Perform classification and display.

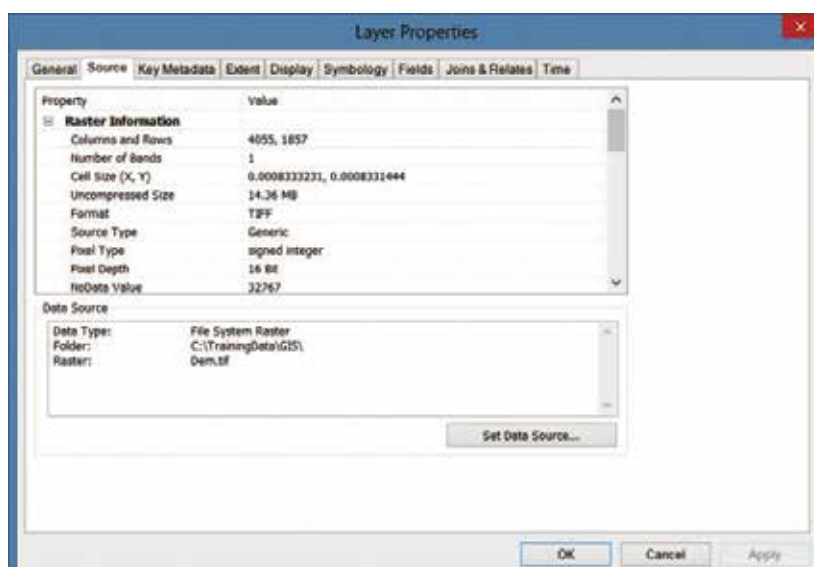
A license is required to activate the Spatial Analyst extension. To activate the extension:

- Open a new ArcMap Project.
- Click on the 'Customize' menu and select 'Extensions...' from the list. The extension window will open.
- Turn on 'Spatial Analyst' by checking the box next to 'Spatial Analyst'.
- Close the window by clicking the 'Close' button on the bottom right corner of the window.

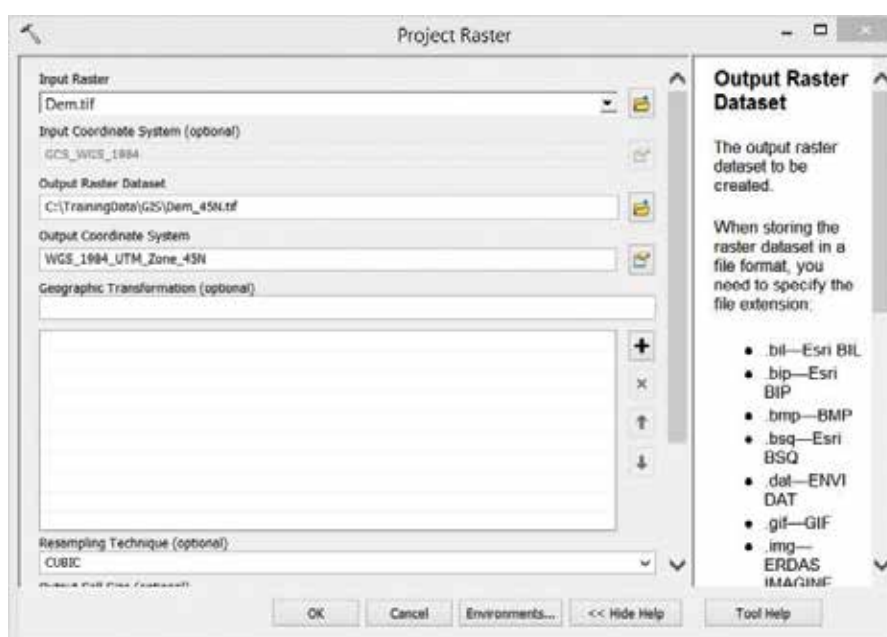



Now you can use Spatial Analyst to analyse the raster data. In this exercise, you will use DEM data (SRTM DEM) of Bhutan and generate various topographic features such as slope, aspect, hillshade, etc. and you will also use some mathematical operations for analysis using these raster data. Before generating different surface features and mathematical operations of DEM data, you need to project the data in a projected system. We generally use the UTM zone projections – for Bhutan we will use UTM 45N zones. So first check the coordinate system of the dem data by opening the properties of the data; if the coordinate system of the data is in geographic, you need to change the coordinate system into the UTM projected system. To change the projection system of DEM data perform the following steps:

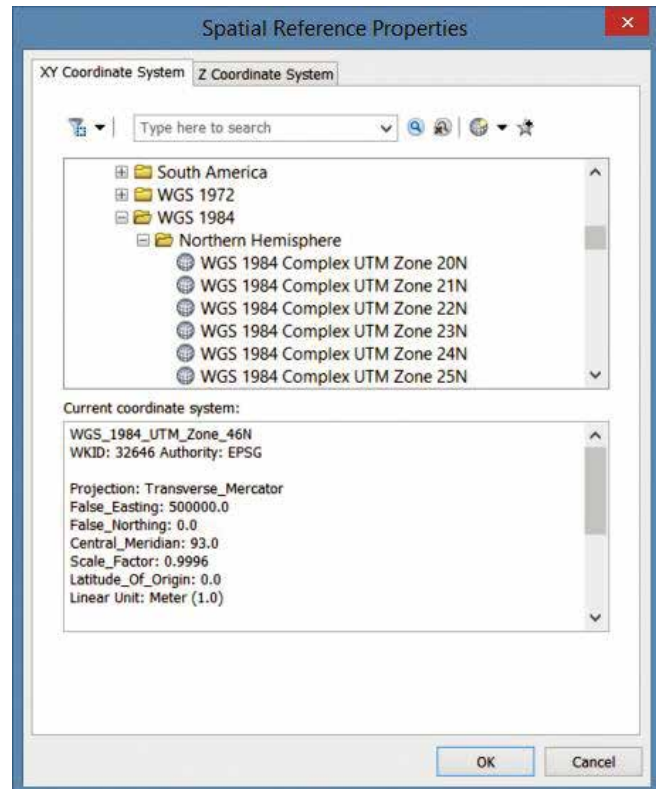
- Add the 'Dem.tif' raster data from 'C:\TrainingData\GIS'.
- Open the properties of the 'Dem.tif' by double clicking on it. The layer properties window will open.



- Click on the 'Source' tab. You can see the properties of the raster layer. You can scroll down the property box to see all the properties of the raster layer. Note the cell size, which represents the resolution of the layer and also note the spatial reference of the raster layer. This spatial reference of this layer is in Geographic Coordinate System (default of data frame?). So in order to analyse the raster data it is better to use a Projected Coordinate System. So the data need to change their spatial reference. To do this:
- Close the Layer properties window and Open ArcToolbox.
- Go to 'Data Management Tools' > 'Projections and Transformations' > 'Raster' and double click on 'Project Raster'. The Project Raster window will open.



- Under 'Input Raster', select 'Dem.tif' from the dropdown list.
- On the 'Output Raster Dataset', click on the folder icon and navigate to the folder 'C:\TrainingData\GIS', then name the output file 'Dem45N.tif' and click on 'Save' to close the window.
- Under 'Output Coordinate System', click on the icon  to open the 'Spatial Reference Properties' window.
- Click on the plus sign of the 'Projected Coordinate Systems' to expand the tree menu and again expand the tree menu of 'UTM > WGS 1984 > Northern Hemisphere'.
- Scroll down the Projection file list box and select the 'WGS 1984 UTM Zone 45N' projection and click 'OK' to apply and close the window.
- Note: Bhutan actually falls in two UTM projection zones – 'WGS 1984 UTM Zone 45N' and 'WGS 1984 UTM Zone 46N' but in this exercise we used the 'WGS 1984 UTM Zone 45N'. If you are going to do the real work, it is better to divide the area into two projections and process it.
- Under the 'Resampling Technique (optional)', select 'Cubic'.
- Leave all other functions as default and click 'OK' to process. You will see a little process window at the bottom of the screen, and when the process is complete a new layer 'Dem45N.tif' will be added in the project.
- You can change the symbology of the Dem layer by opening the Layer Properties > Symbology tab.
- Save the project as 'Practice3.mxd' in 'C:\Trainingdata\'.

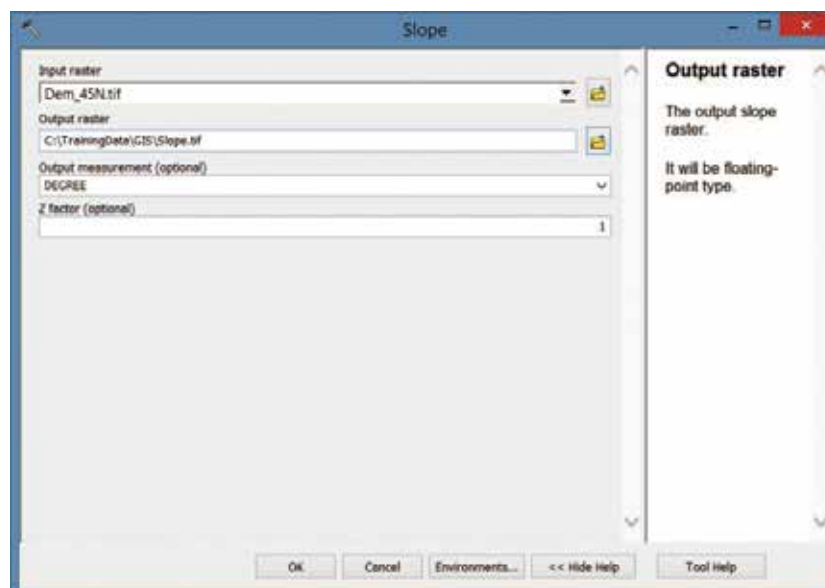


Now we will use this layer for further exercise.

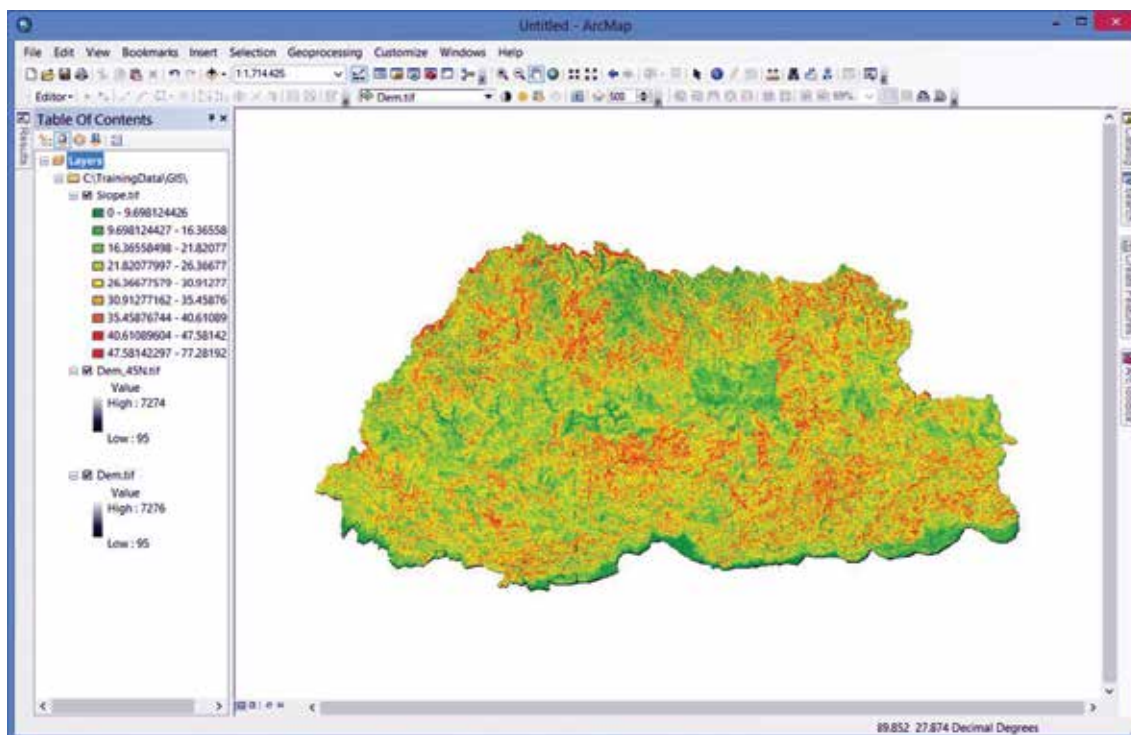
Slope Map

Slope data tells the steepness of the terrain. This data is useful for a variety of determinations such as likelihood of flooding, likelihood of occurrence of landslide, best places for settlements, and agriculture, possibility of occurrence of different types of glaciers and its characteristics, etc.

- In the ArcToolbox, go to 'Spatial Analyst Tools > Surface' and double click on 'Slope'. The 'Slope' window will open.



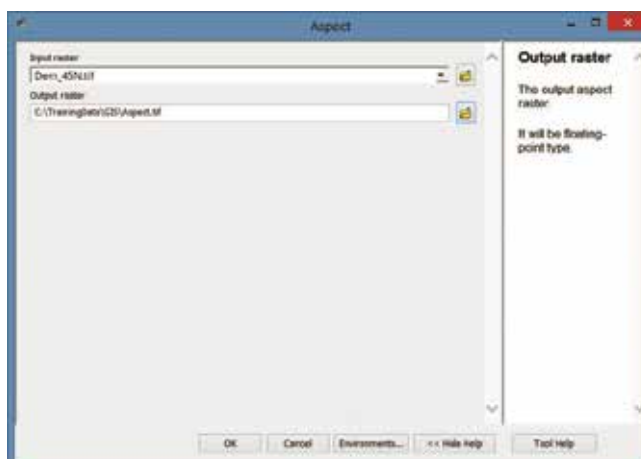
- Under the 'Input Raster', choose 'Dem45N.tif' from the dropdown list.
- Under the 'Output Raster', click on the folder icon and navigate to the folder 'C:\TrainingData\GIS', then name the output file 'slope.tif' and click the 'Save' button to close the window.
- Select 'DEGREE' from the 'Output Measurement' dropdown list.
- Set the 'Z factor' to '1'.
- Click the 'OK' button to process and close the window. You will see a little process window at the bottom of the screen, and when the process is complete a new layer 'slope. Tif' will be added in the project.
- Now you will see the new slope data added in the map view with its standard classified symbology, as shown in map below.

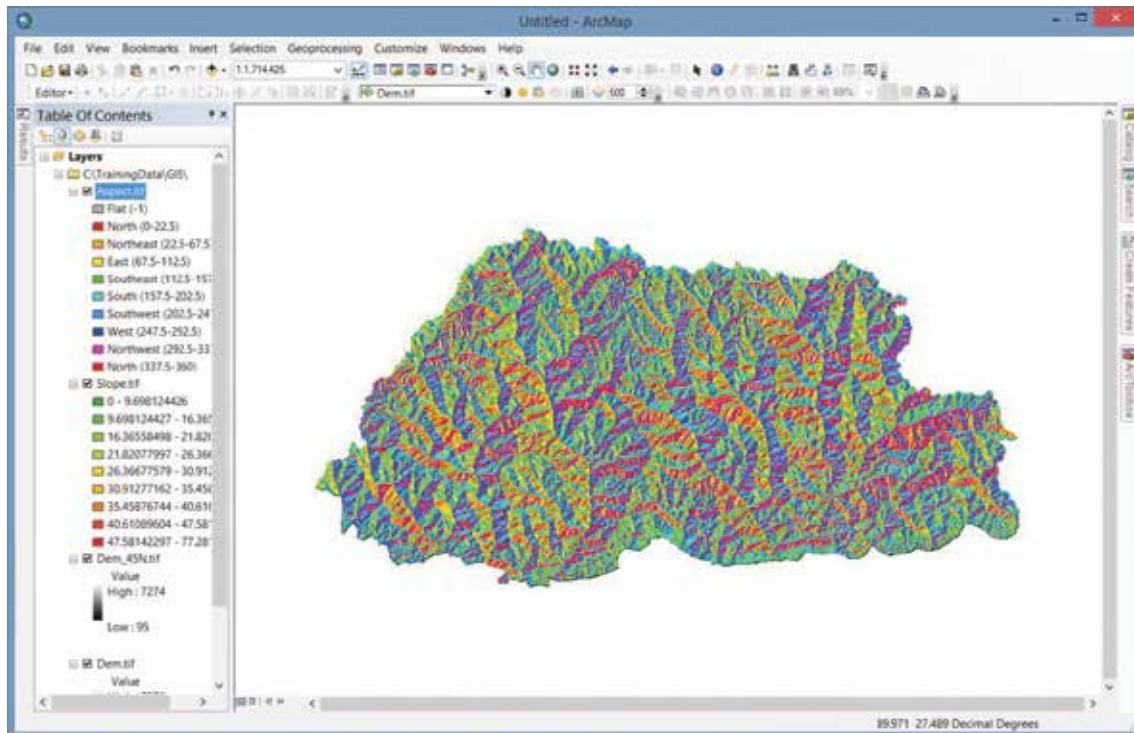


Aspect Map

It gives the directions faced by the topographic slopes, usually measured in degrees from north. It is useful for the identification of water flow direction, characterization of various features and various other flow modelling. It can be generated from DEM. The following steps will give you the aspect data.

- In the ArcToolbox, go to 'Spatial Analyst Tools > Surface' and double click on 'Aspect'. The 'Aspect' window will open.
- Under the 'Input Raster', choose the 'Dem45N.tif' layer from the dropdown list.
- Under the 'Output Raster', click on the folder icon and navigate to the folder 'C:\TrainingData\GIS', then name the output file 'Aspect.tif' and click the 'Save' button to close the window.
- Click the 'OK' button to process and close the window. You will see a little process window at the bottom of the screen, and when the process is complete a new layer 'Aspect.tif' will added in the project.
- Now you will see the new Aspect data added in the map view with it standard classified symbology as shown in map below.

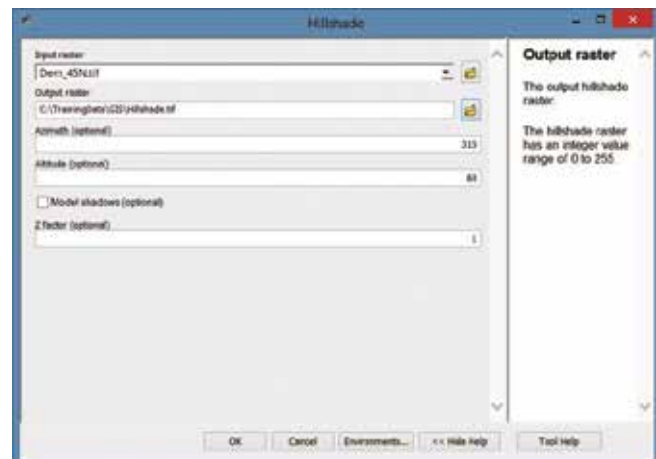


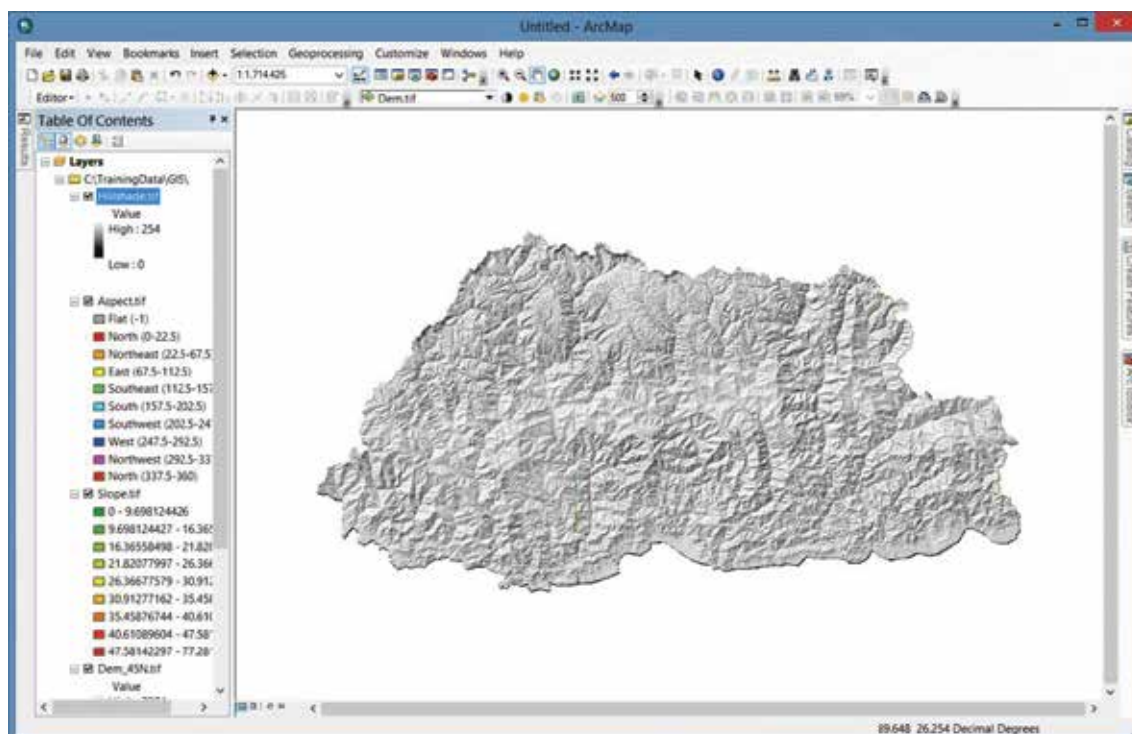


Hillshade

It is a grey scale 3D representation of the surface, with the sun's relative position taken into account for shading the images. It uses the altitude and azimuth properties to specify the sun's position. This data is useful for enhancing visualization of 2D surface data to 3D view, which will greatly aid visual analysis and graphical display of the data. Hillshade can also directly generated using DEM data and just changing the Azimuth angles and altitude of the sun's position in the tool.

- In the ArcToolbox, go to 'Spatial Analyst Tools > Surface' and double click on 'Hillshade'. The 'Hillshade' window will open.
- Under the 'Input Raster', choose 'Dem45N.tif' layer from the dropdown list.
- Under the 'Output Raster', click on the folder icon and navigate to the folder 'C:\TrainingData\GIS', then name the output file 'Hillshade.tif' and click the 'Save' button to close the window.
- Leave the Azimuth value as default and set the Altitude value to 60 degrees as the terrain of Bhutan is quite steep and if we increase the Altitude values it will decrease the shadow area in the output, as this altitude values represent the light source above the horizon.
- Leave other functions as default.
- Click the 'OK' button to process and close the window. You will see a little process window at the bottom of the screen, and when the process is complete a new layer 'Hillshade.tif' will be added in the project.
- Now you will see the new Hillshade layer added in the map view with its standard classified symbology, as shown in the map below.



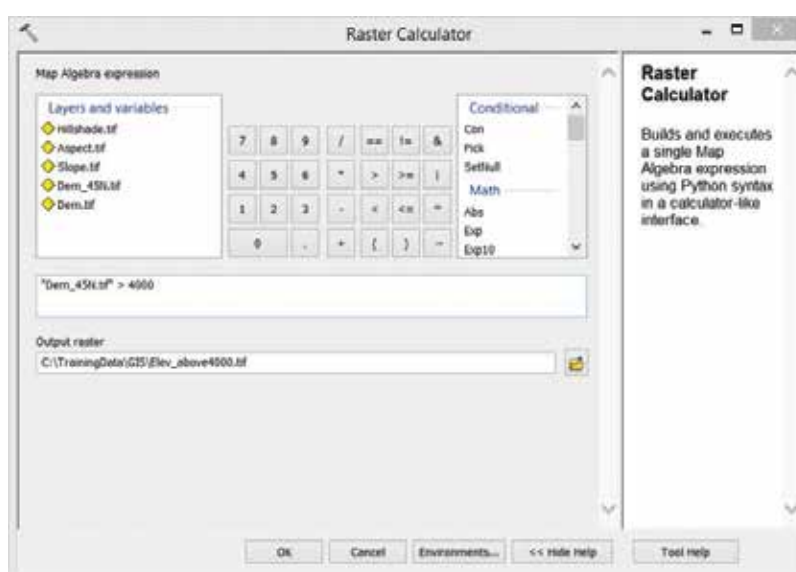


Spatial Analysis using Map Algebra

Map algebra uses a predefined, mathematical formula applied to the corresponding cells of overlaid themes to create a new theme with the numerical result assigned to the cell. The formula used in map algebra can be a simple mathematical operation like addition, multiplication, division or subtraction (arithmetic operators), Boolean operators ('and', 'or', or 'not') and it can also use a more complex operation involving logarithms, exponents, powers and trigonometric functions such as sine and cosine (mathematical functions).

In this exercise we will use some simple analysis to make the tool familiar.

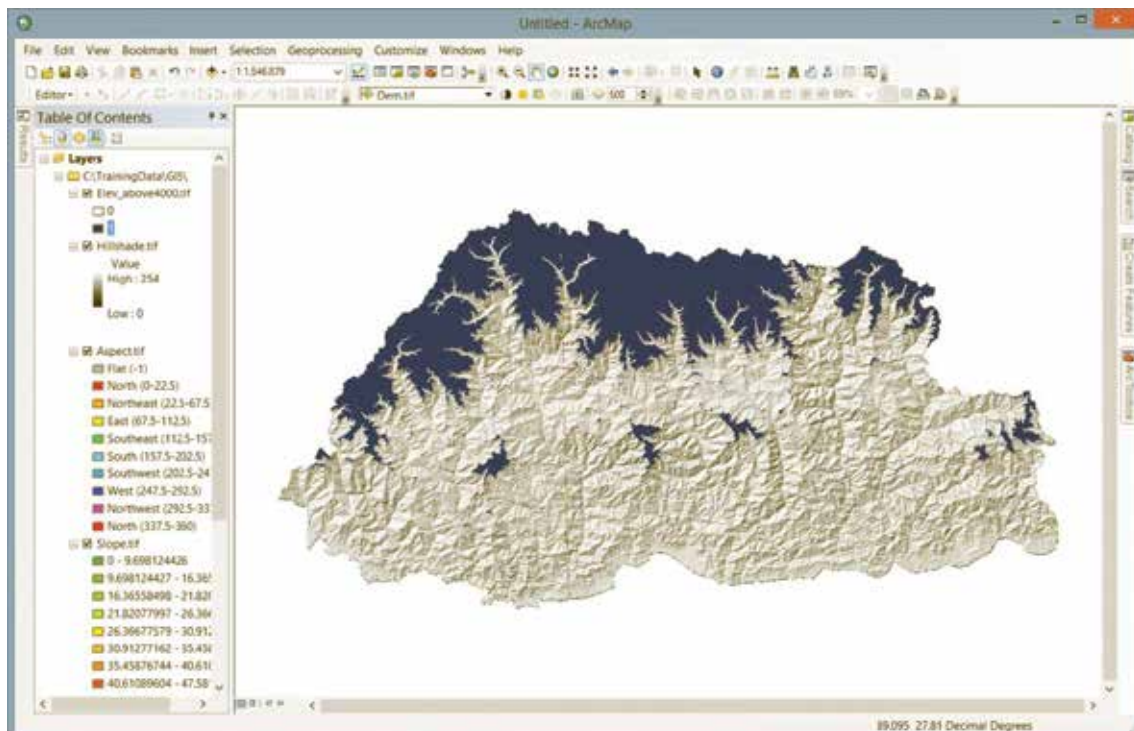
- In the ArcToolbox, go to 'Spatial Analyst Tools > Map Algebra' and double click on 'Raster Calculator'. The 'Raster Calculator' window will open.



Now we are just going to identify the higher elevation areas above 4,000 metres in Bhutan. To do this:

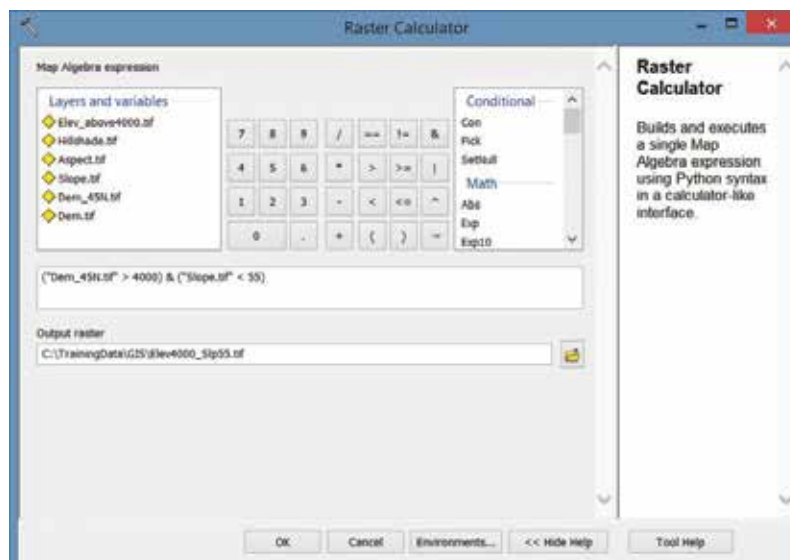
- In the 'Raster Calculator' window, double click on 'Dem45N.tif' in the Layers and Variables box on the left side of the window. This will add the 'Dem45n.tif' layer name in the expression box below the layers selection box.
- Click on the 'Greater Than' sign and type '4000' in the expression box as shown in the figure above.
- Under the 'Output Raster', click on the folder icon and navigate to the folder 'C:\TrainingData\GIS\temp', then name the output file 'Elev_above4000.tif' and click the 'Save' button to close the window.
- Click the 'OK' button to process and close the window. You will see a little process window at the bottom of the screen, and when the process is complete a new layer is added in the project.

Now you can see the 'Elev_above4000.tif' layer in the Map view, as shown in the figure below. The output data is categorised into two classes with the cell or pixel value of '0' and '1' respectively. Change the symbology of the value '0' to 'Hollow' and value '1' to 'dark blue' color. In the figure below, the value '1' is in dark blue color representing the area above 4,000 metre elevation.

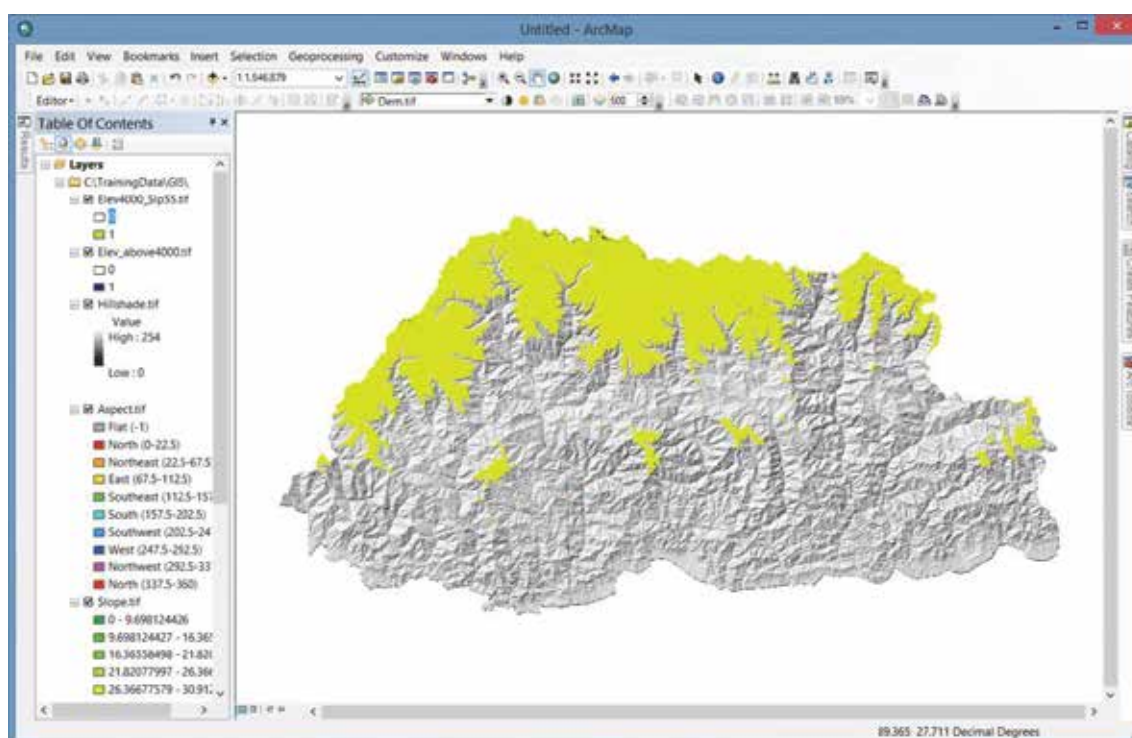


Let's combine the two raster with conditions for slope below 55 degrees and elevation above 4,000 metres. For example, just assume that glaciers mostly occur in elevations above the 4,000 metres and slopes below 55 degrees.

- Open the 'Raster Calculator' window by double clicking on the 'Raster Calculator' tool in the ArcToolbox.



- Double click on the layers in the 'Layers and Variables' box, and using the buttons in the 'Raster Calculator' window enter the expression as ('Dem45N.tif' > 4000) & ('slope.tif' < 55) in the expression box.
- Under the 'Output Raster', click on the folder icon and navigate to the folder 'C:\TrainingData\GIS\temp', then name the output file 'Elev4000_slp55.tif' and click 'Save' to close the window.
- Click 'OK' to process and close the window. You will see a little process window at the bottom of the screen, and when the process is complete a new layer is added in the project.
- Now you can see the 'Elev4000_slp55.tif' layer in the Map view, as shown in the figure below. The output data is categorised into two classes with the cell or pixel value of '0' and '1' respectively. Change the symbology of the value '0' to 'Hollow' and value '1' to 'dark green' color and compare the result with the previous one.





3

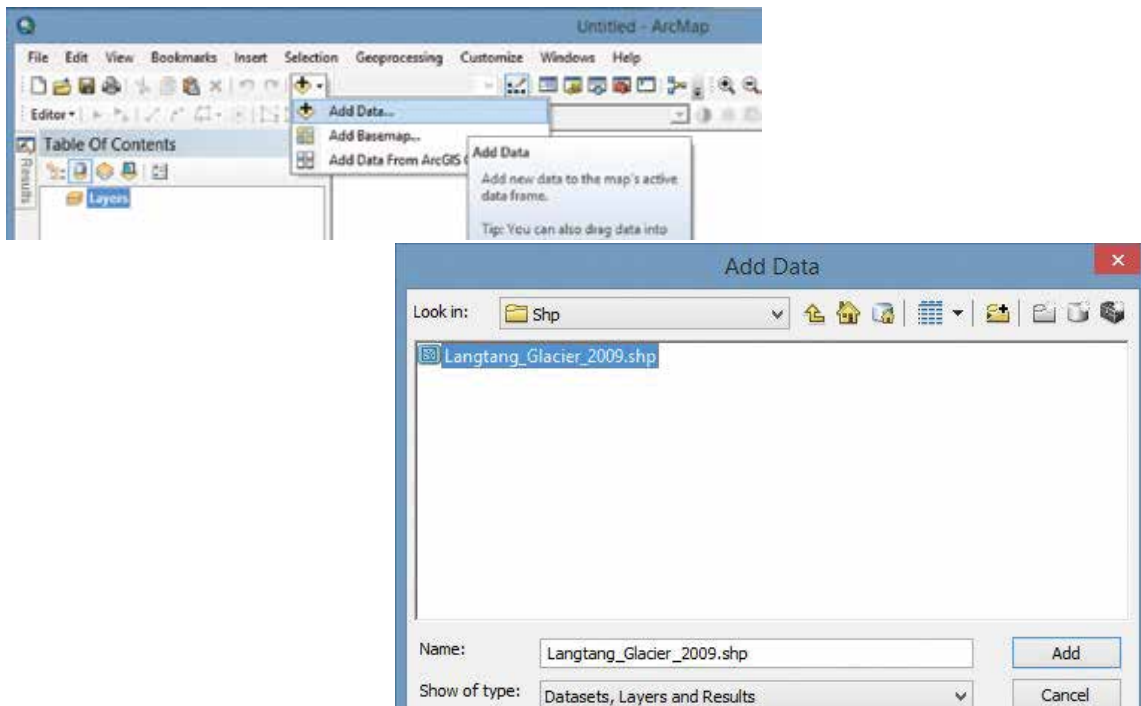
Calculation of
Geo-Statistical
Database of
Glaciers

3. Calculation of Geo-Statistical Database of Glaciers

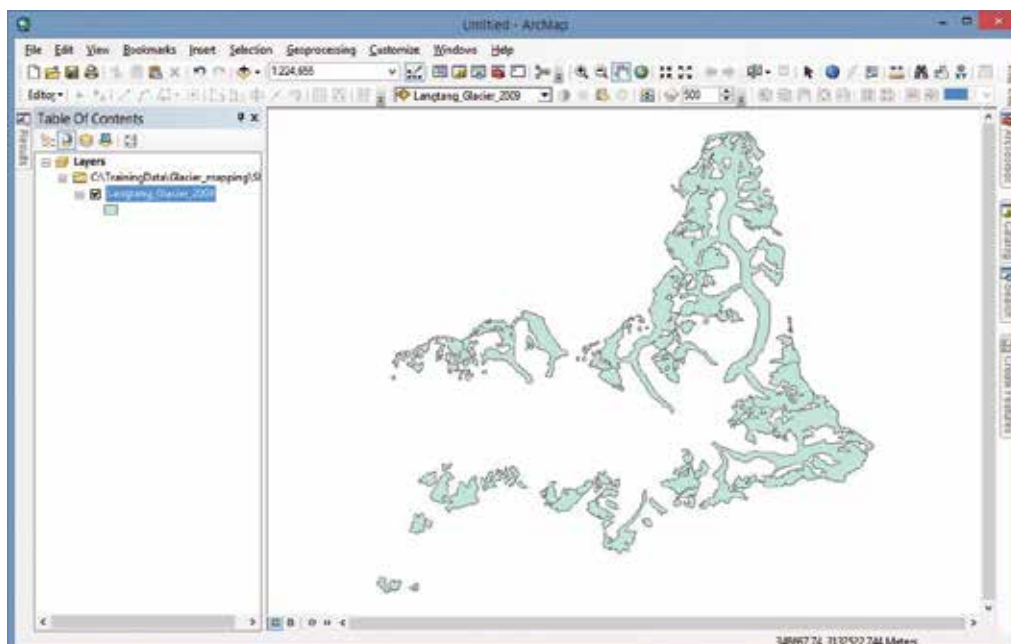
Before calculating the glacier database, the glaciers, which are mapped using the Definiens eCognition Software, are exported to the shapefiles and the polygons of the glaciers are prepared according to the standards of the World Glacier Inventory. For this exercise, we have provided the glacier polygon of Langtang area given in the training data folder including DEM of Langtang area. The glacier shapefile name is 'Langtang_Glacier_2009.shp'.

Add Glacier Layer

- To add a glacier polygon layer in the ArcMap, go to File > Add Data and click on  **Add Data...**, or alternatively, click the **Add Data** button  in the **Standard** toolbar. The Add Data dialog box appears.

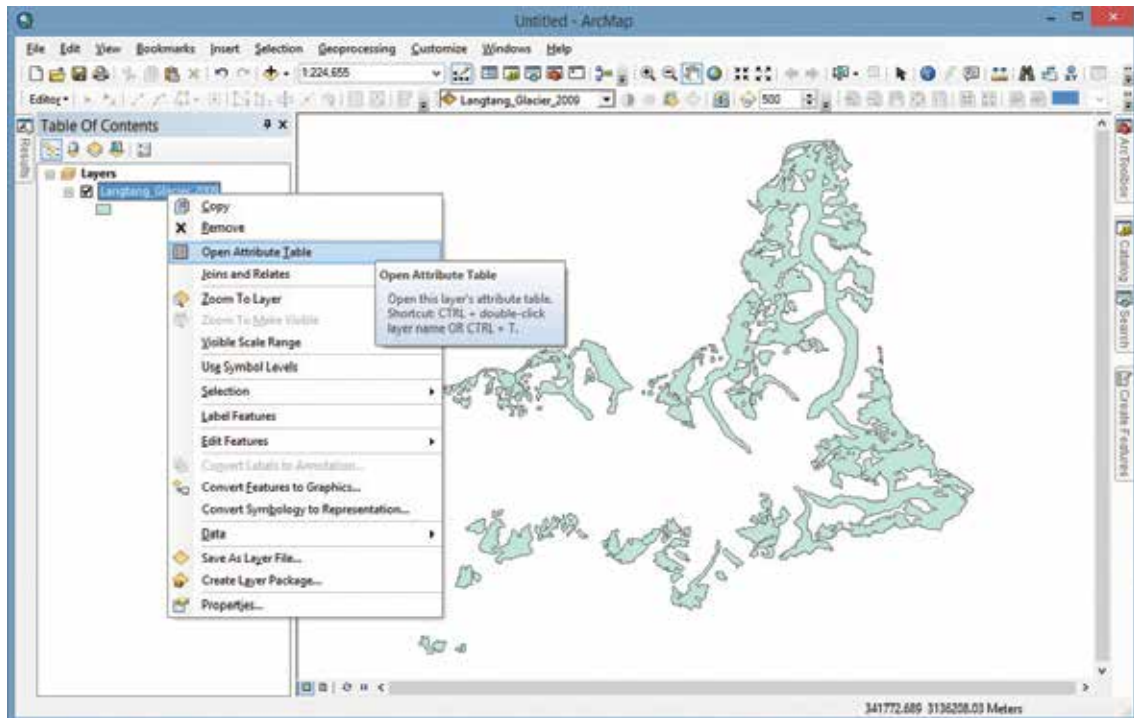


- Navigate the location (C:\TrainingData\Glacier_mapping\shp\) of the Glacier data and select the 'Langtang_Glacier_2009.shp' file and click the **Add** button. The glacier layer appears in the 'Data View' window.




Open Attribute Table

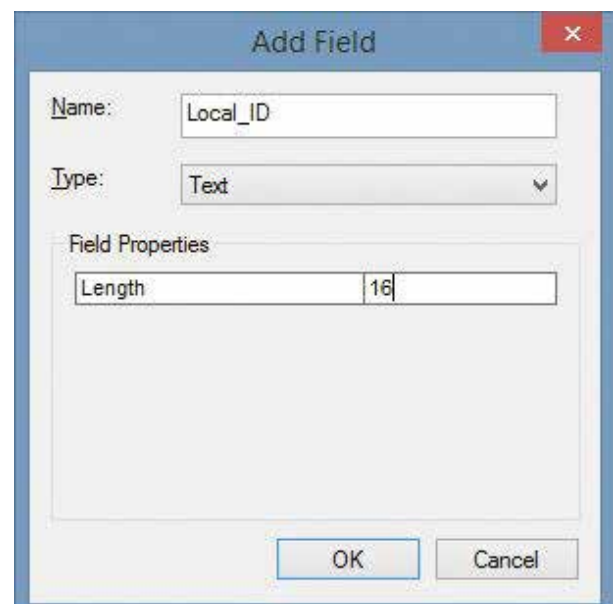
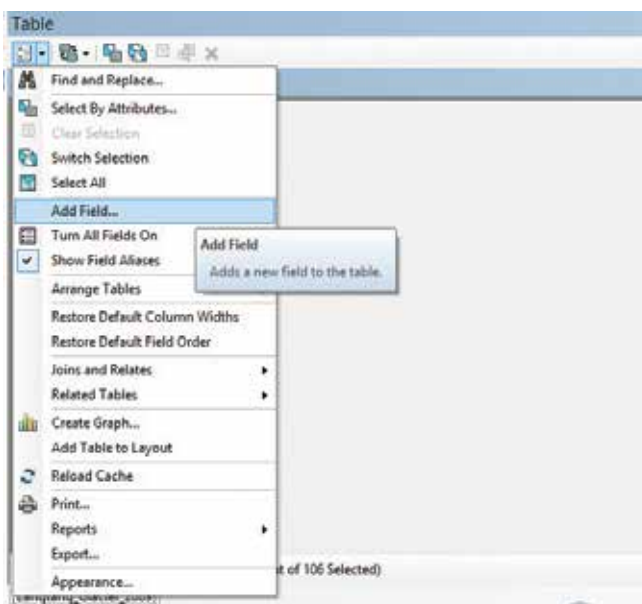
To open the 'Attribute Table' of the glacier layer, select the 'glacier' layer in the 'Table of Contents' window and right-click on the glacier layer. Then click on the 'Open Attribute Table' in the context menu. The Attribute Table of the glacier layer opens.



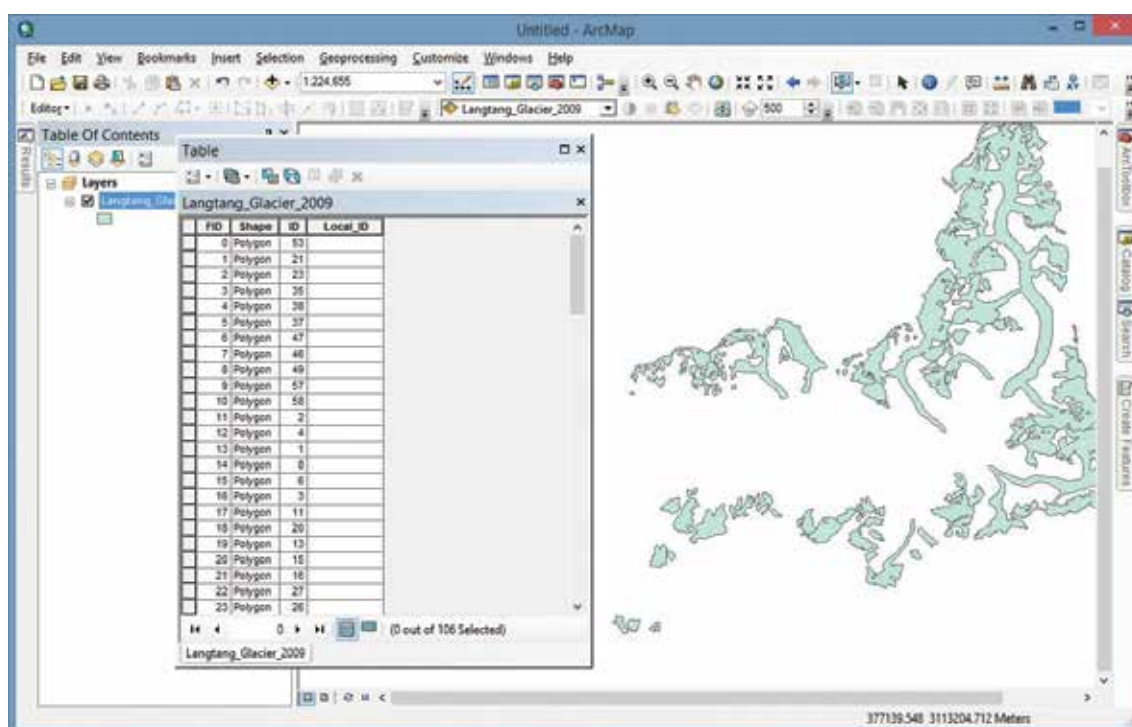
Assign the Local ID

The Local ID is given based on the basin and sub-basin name and counting starts from the outlet of the major stream of the sub-basin, then proceeds clockwise round the basin, as mentioned in Mool et al. 2001. For example, if the Local ID is 'Tlgr09_10', the first letter 'T' stands for Trishuli basin, 'la' stands for Langtang sub-basin, 'gr' stands for glacier, '09' represents year 2009 from which the glacier boundary was mapped and number '10' represents the number of glaciers in the Langtang sub-basin. The step-by-step process for assigning a local ID to each glacier is described below. This exercise is just to give you a sense of the Local ID but it is not in practice nowadays.

- Click the down arrow button in 'Table Options'  in the top row of the 'Attribute Table' window and click on 'Add Field' from the context menu of Table Options. The 'Add Field' dialog box appears.
- Enter '*Local_ID*' in the 'Name' textbox of the 'Add Field' sub-window.

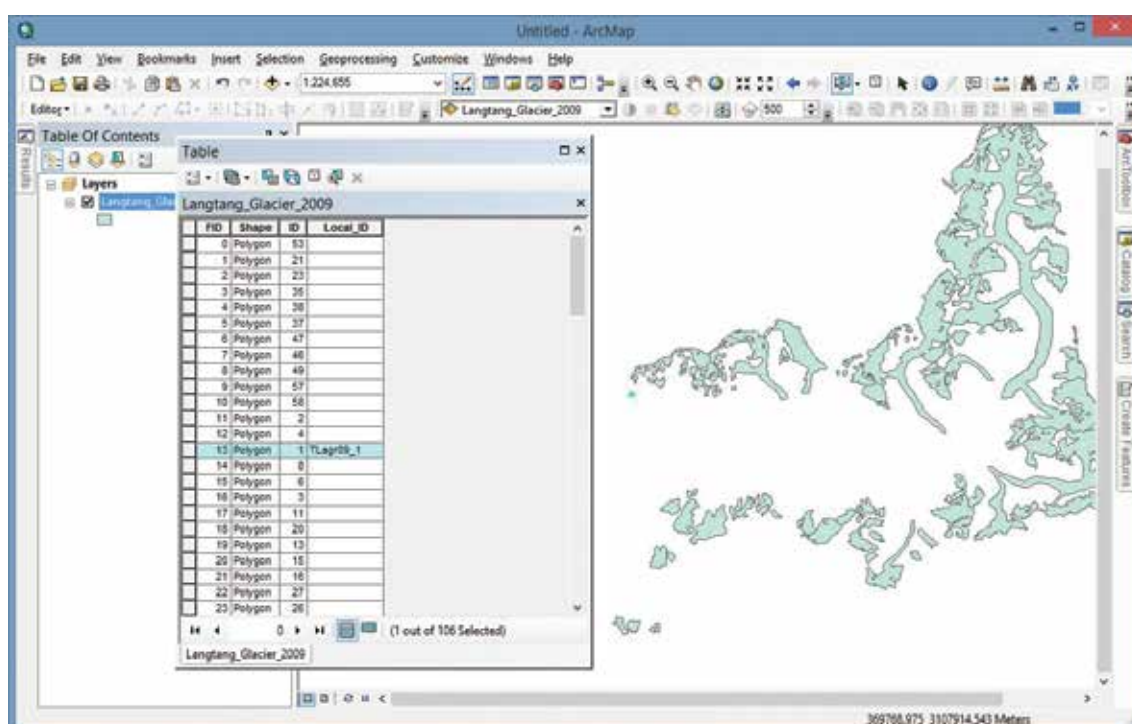


- For 'Type', select 'Text' from the dropdown menu.
- Assign the Length of the field in the 'Field Properties' column of the 'Add Field' window and click 'OK' to confirm. The new field 'Local_ID' appears in the last column of the attribute table of the glacier layer.



To Assign a Local ID to Each Glacier, Perform the Following Steps

- To assign the **Local_ID**, the data should be in **editing mode**. Click on **Customize** menu in the **Menu bar** and go to **Toolbars** then select the **Editor** from the list to open the **Editor Toolbar**.
- Click on down arrow in the 'Editor Toolbar' and click on the 'Start Editing' in the context menu. Now the data is in editing mode.
- Click on the 'Select Features' button in the 'Tools' toolbar and click on the individual glacier polygon in the 'Data View' window. The selected glacier is highlighted in the 'Data View' window as well as in the 'Attribute Table'.
- Assign the Local ID as 'TLagr09_1' in the highlighted cell of the 'Local_ID' field in Attribute Table, or alternatively click the Attribute button in the 'Editor' toolbar; when the 'Attributes' dialog box opens, assign the glacier a Local ID 'TLagr09_1' in the 'Local_ID' field in the 'Attributes' dialog box.



Note: First digit of Local ID: first letter of Basin; Second two digit: first two letter of the Sub-basin, gr indicates Glacier; 09 indicates Year and 1 indicates glacier number in clockwise rotation of drainage in the sub-basin.

- Likewise, select others glaciers in the basin and assign the each of them a Local ID.
- After all the glaciers have been assigned IDs, click on the **Editor** button in the **Editor** toolbar and click on the **Save Edits** to save the assigned data. Then click on **Editor** button again and click on **Stop Editing** to stop the editing mode.

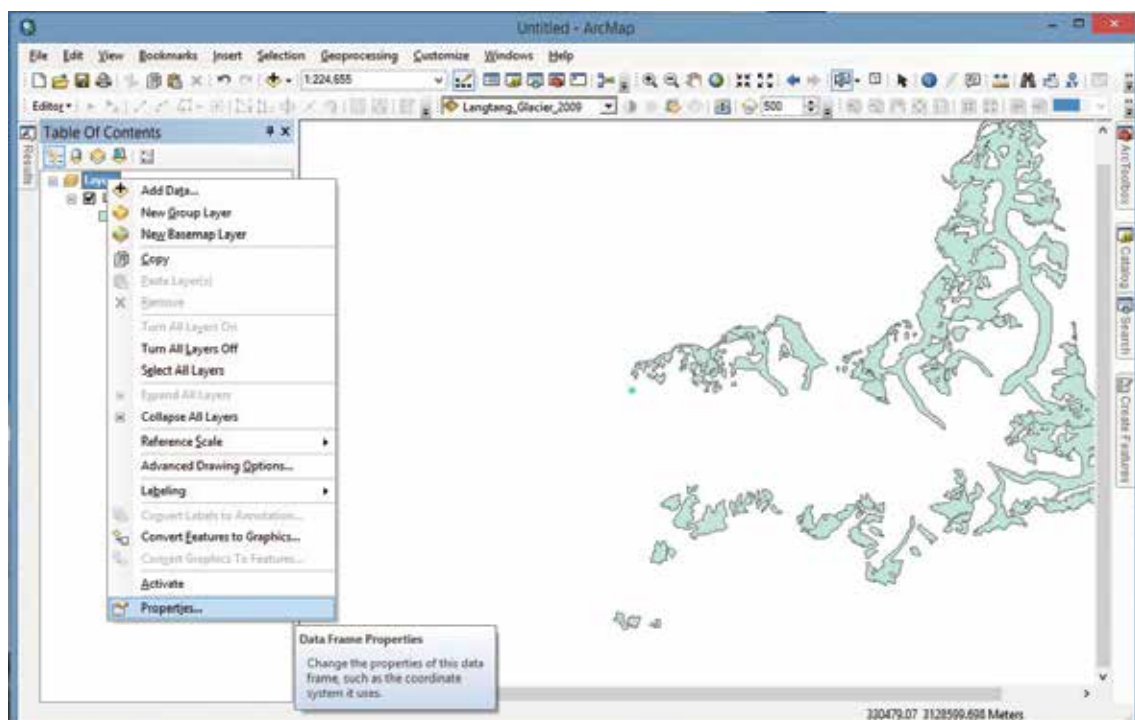
3.2 GLIMS ID

The GLIMS ID is based on the latitude and longitude location of a “centre point” on the glacier. The GLIMS ID is a 14-digit code where G stands for Global, E for East and N for North. The latitude and longitude should be in degrees defined to three decimal places. The format of the GLIMS ID is GXXXXXXEYYYYYN where G – Global, XXXXXX and YYYYY are longitude and latitude values defined to three decimal places after removing the decimal. For example, the GLIMS ID of the Lirung glacier is G085547E28252N.

To calculate the GLIMS ID, first we need to generate the points of the glaciers polygon by using “Feature to Point” tool in the toolbox “Data management tools>Features”. The point features generated were re-checked to confirm that the points lie at the centre of the glaciers. If the points are inside the glacier polygon rather than at the centre, activate the Editing mode and move the points manually to the centre or inside the glacier polygon. Once all the points are located at the centre of the glacier, calculate the longitude and latitude values of the points by adding the field named as Longitude and Latitude as field type ‘double’ and precision and scale properties of the fields as 8 and 3 respectively. This is the overall process for calculating the centre coordinates of the glacier polygons. But in this exercise we will directly calculate the longitude and latitude of the centroid of the glacier polygon, which is described step by step below.

Calculate the Latitude and Longitude

To calculate the Latitude and Longitude of the individual glaciers, the data (glacier shapefile) should be in geographic coordinate systems. But in the latest version (10.x) of ArcGIS, you can directly calculate the Latitude and Longitude by using the projection system of the data frame. So, to calculate the Latitude and Longitude of the glaciers, you have to either change the projection of the glacier shape file into geographic coordinate system or change the projection system of the data frame. To change the projection system of the data frame, perform the following steps:




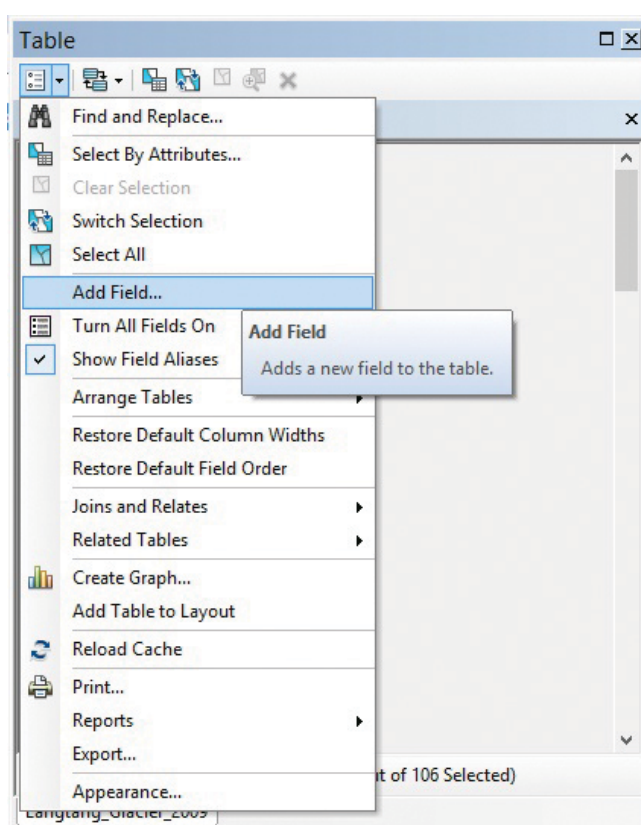
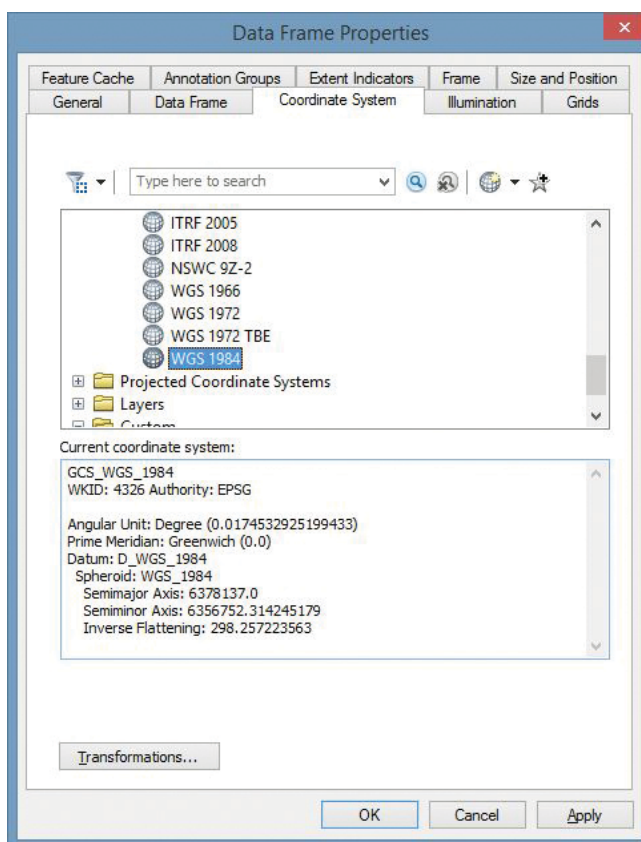
- Open the properties of the data frame by double clicking on the data frame name (Layers) or right clicking on the data frame (Layers) and select Properties from the list menu.

Now the 'Data Frame Properties' window will appear. Typically the coordinate system of the data frame is set by the coordinate system of the first dataset added to the map and all other added datasets will be projected on the fly to match the same coordinate system. You can review and change the coordinate system of the data frame. In this exercise, to set the coordinate system of the data frame is set to Geographic coordinate system.

- Select the 'Coordinate System' tab on the 'Data Frame Properties' window.
- Navigate to 'Geographic Coordinate Systems > World' in the list box of coordinate system and select the 'WGS 1984' from the world list.
- Click 'OK' to set the projection system of the data frame.

Now, you can calculate the longitude and latitude of the centroid of glacier polygon.

- If the 'Attribute Table' of the glacier layer is not opened, open it by right-clicking on the glacier layer in the 'Table of Contents' window and click on the 'Open Attribute Table' from the context menu.
- Click on the down arrow of the 'Table Options' button  in the top row of the 'Attribute Table' window and click on 'Add Field' from context menu. The 'Add Field' dialog box appears.
- Assign the field name 'Latitude' in the 'Name' textbox of 'Add Field' dialog box.
- Select field type as 'Double' from the 'Type' dropdown menu.



- Assign the 'Precision' as '6' and 'Scale' as '3' in the 'Field Properties' column of 'Add Field' dialog box and click the OK button to confirm. The new field 'Latitude' appears in the last column of the attribute table after 'Local ID' field.
- Similarly add the field 'Longitude'.
- To calculate the latitude of the glacier, right-click on the 'Latitude' field and click on the 'Calculate Geometry' from the context menu. The 'Calculate Geometry' dialog box appears.
- Select the 'Y Coordinate of Centroid' in the 'Property' dropdown menu.
- Click the 'OK' button to calculate the latitude of the glaciers.

Add Field

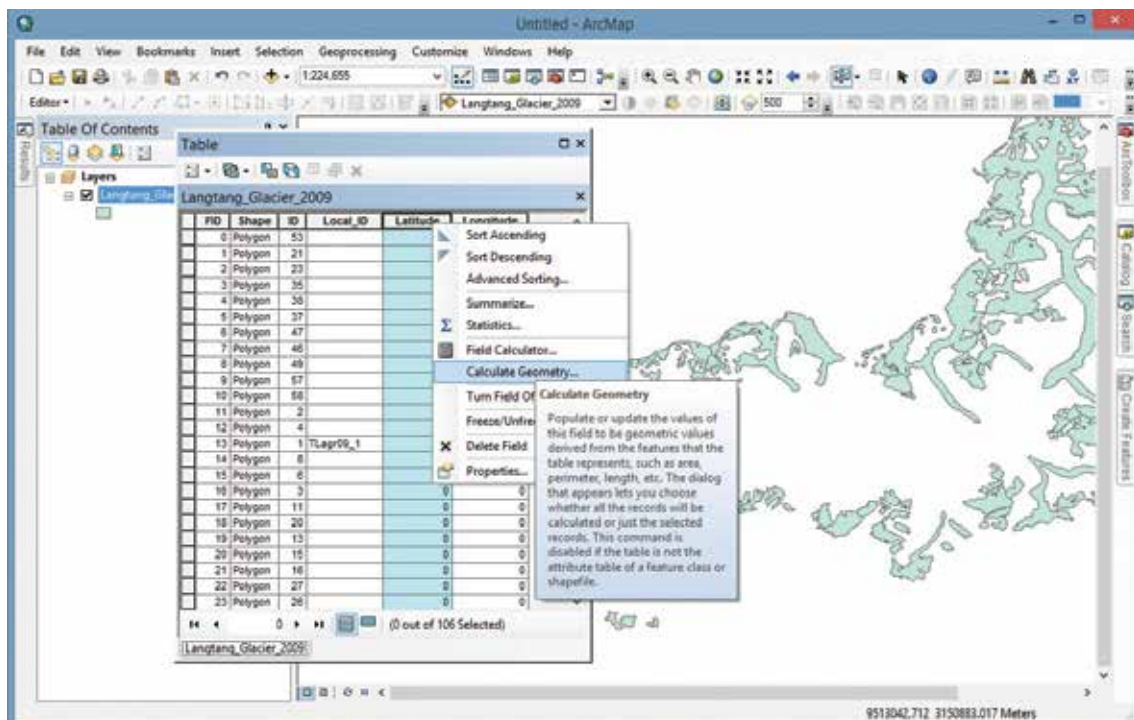
Name:

Type:

Field Properties

Precision	8
Scale	3

OK Cancel



- Similarly calculate the 'Longitude' of the glaciers.

Calculate Geometry

Property:

Coordinate System

☐ Use coordinate system of the data source:
PCS: UTM Zone 45, Northern Hemisphere

☒ Use coordinate system of the data frame:
GCS: WGS 1984

Units:

☐ Calculate selected records only

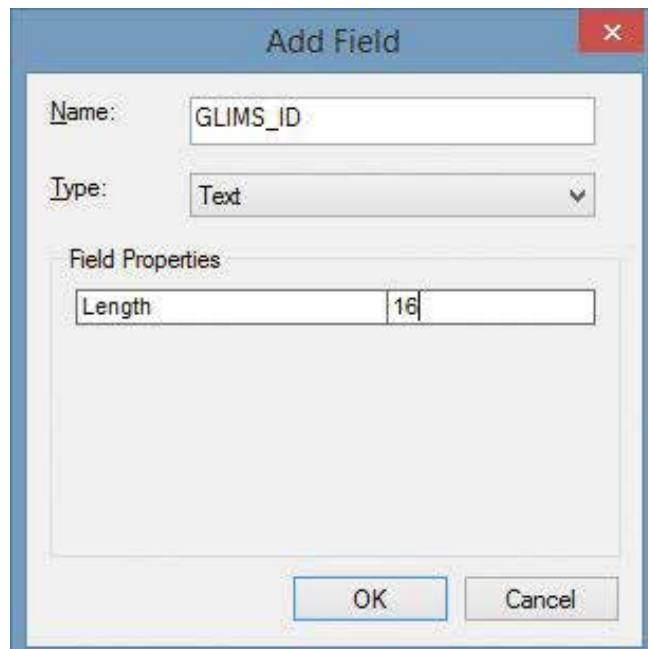
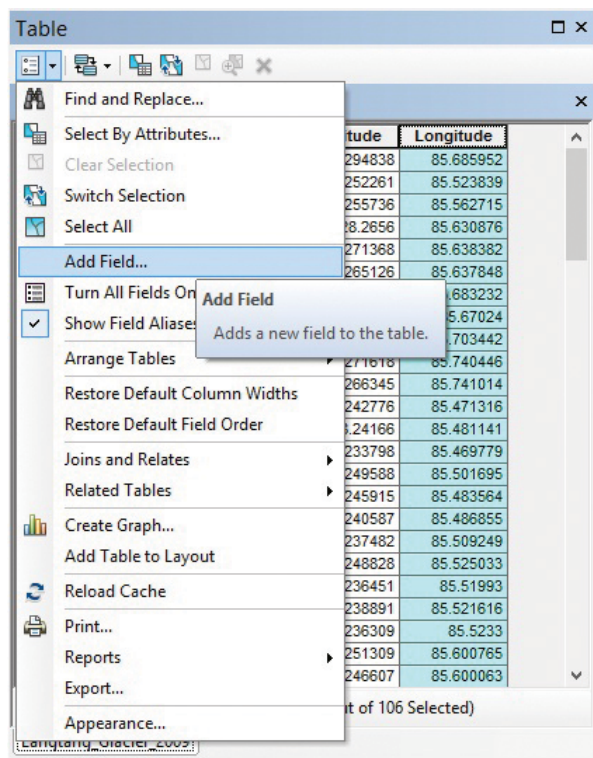
[About calculating geometry](#)


OK Cancel

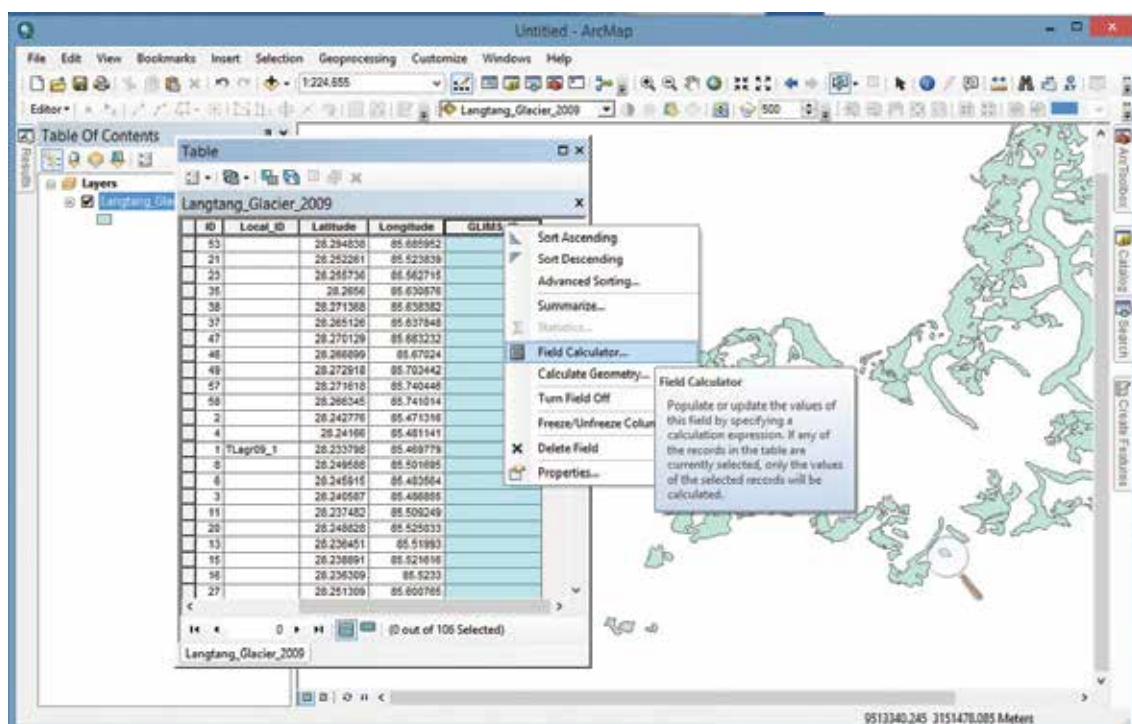
Assign GLIMS ID

Before assigning the GLIMS ID, calculation of Latitude and Longitude should be completed. To assign the GLIMS ID, perform the following steps:

- Click on the down arrow of the 'Table Options' button  in the top row of the 'Attribute Table' window and click on 'Add Field' from the context menu of 'Table Options'. The 'Add Field' sub-window will appear.



- Assign the field name 'GLIMS_ID' in the 'Name' textbox of Add Field sub-window.
- Select field type as 'Text' from the 'Type' dropdown menu.
- Set the field length to '16' in the 'Field Properties' column of the 'Add Field' dialog box and click on 'OK' to confirm. The new field 'GLIMS_ID' appears in the last column of the attribute table after the 'Longitude' field.
- To calculate 'GLIMS ID', right-click on the 'GLIMS_ID' field and click on 'Field Calculator'  in the context menu. The 'Field Calculator' dialog box appears.

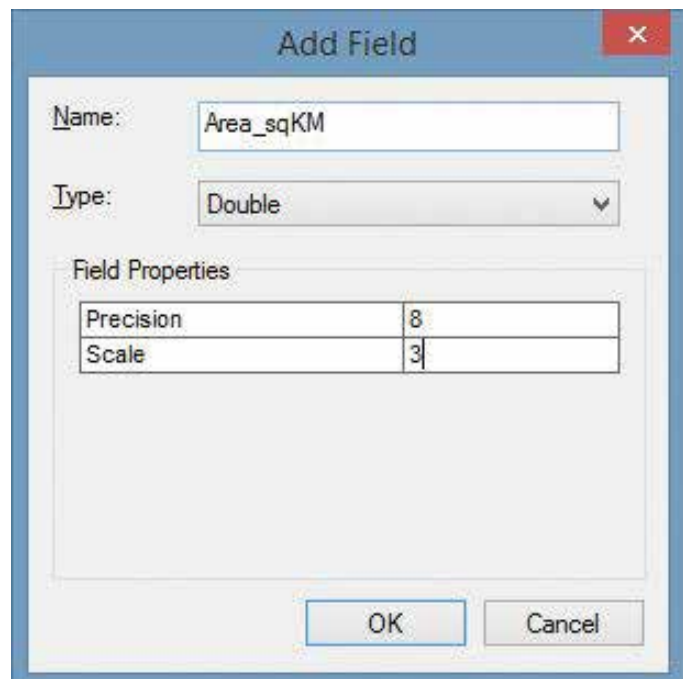
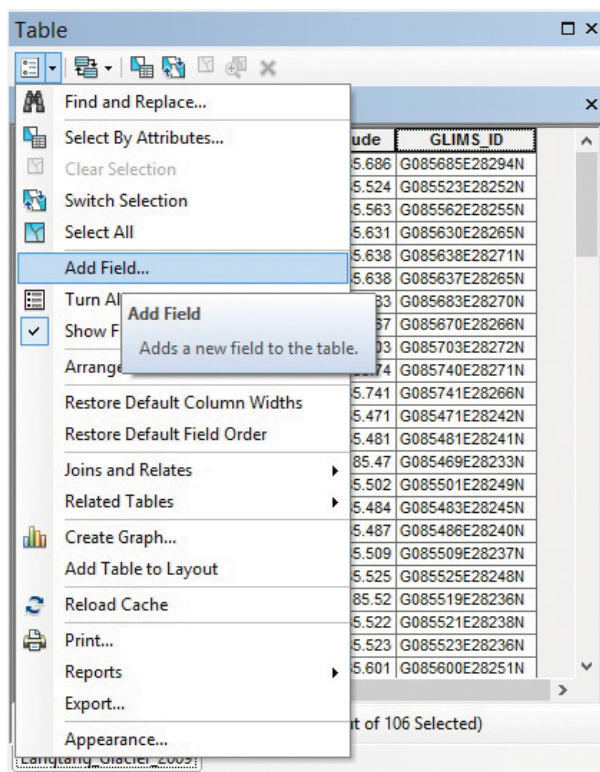
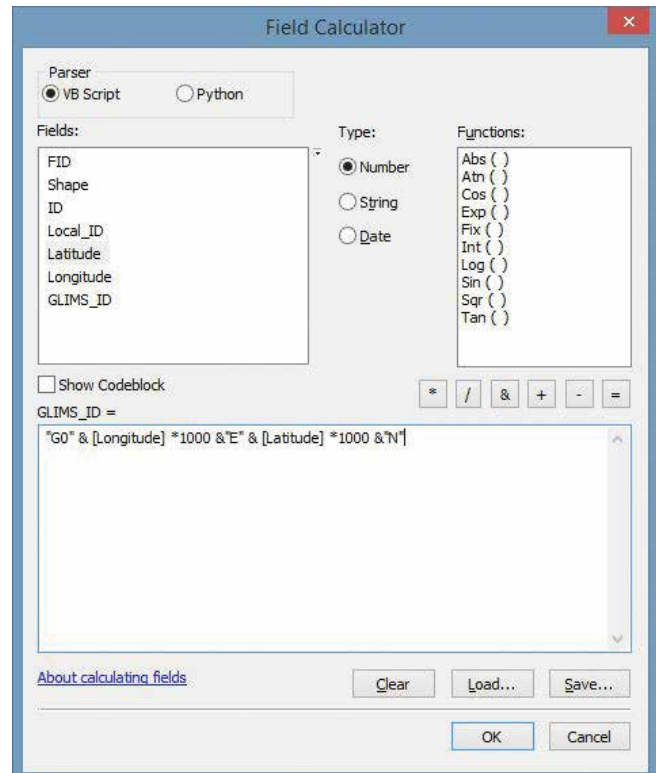


- Assign the formula "G0"& [Longitude]*1000&"E"& [Latitude]*1000&"N" in the 'GLIMS_ID' textbox in 'Field Calculator' dialog box using 'Mathematical Operator' buttons and Field name lists.
- Click 'OK' to calculate the 'GLIMS ID' of the glaciers.

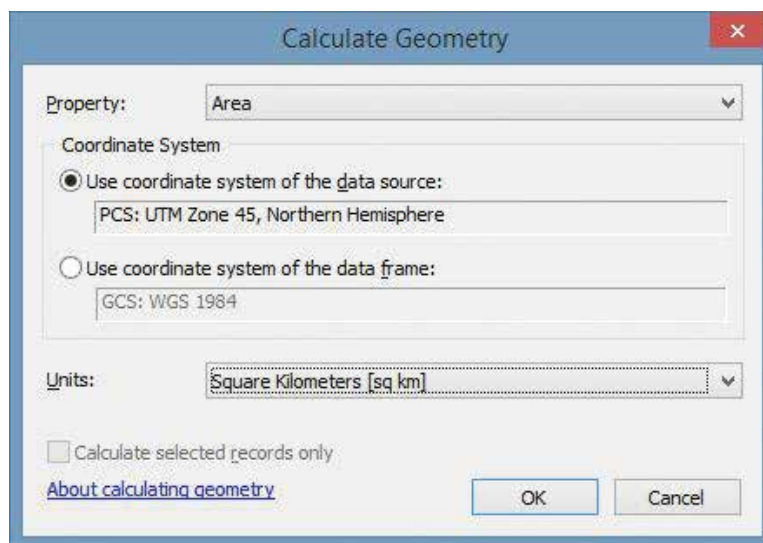
3.3 Glacier Area

It represents the aerial surface area covered on the ground. It will be calculated separately for clean ice (CI) and debris covered (DC) glaciers and later the area will be merged to obtain the total glacier area. The area of the polygon in ArcMap is calculated using calculate geometry function directly in the field properties. To calculate the area, the dataset needs to be projected into a projected coordinate system. For the exercise, the training data ("Langtang_Glacier_2009.shp") is already projected in UTM 45N zone, so you can directly calculate the area on it. If your data is not projected into a projected coordinate system, you need to either project your data or you can change the projection system of the data frame into a projected coordinate system, as in the previous exercise. To carry out the exercise, perform the following steps.

Click on the down arrow of the 'Table Options' button in the top row of the 'Attribute Table' window and click on 'Add Field' from the context menu of 'Table Options'. The 'Add Field' sub-window will appear.



- Assign the field name 'Area_sqKM' in the 'Name' textbox of 'Add Field' sub-window.
- Set 'field type' as 'Double' from the 'Type' dropdown menu.
- Set the 'Precision' to '8' and 'Scale' to '3' in the Field Properties column of 'Add Field' dialog box and click the 'OK' button to confirm. The new field 'Area_sqKM' appears in the last column of the attribute table after 'GLIMS_ID' field.
- To calculate the area of the glaciers, right-click on the 'Area_sqKM' field and click on the 'Calculate Geometry' from the context menu. The 'Calculate Geometry' dialog box appears.
- Select the 'Area' in the 'Property' dropdown menu and select the 'Square Kilometres (sq.km.)' from the 'Units' dropdown menu to calculate the area of the glacier in square kilometres.
- Click the 'OK' button to calculate the area of the glacier.




Now you can see the area of each glacier polygon in the Area_sqKm field. Double click on the Area_sqKm field; the values on the area field will be arranged in ascending order. Note down the first value of area in the first row, which is the smallest glaciers in the datasets. Again double click on the Area_sqKm field; the data will be arranged in descending order. Note down the largest glacier area from the first row in the table.

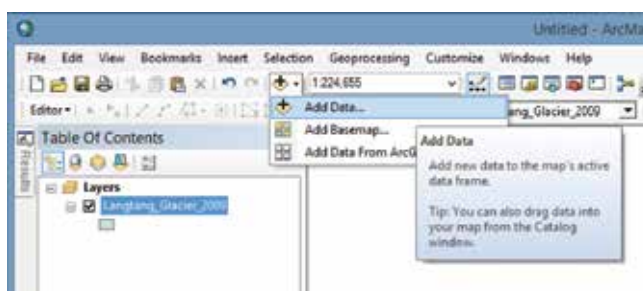
3.4 Glacier Elevation

The elevation of glacier represents the altitudinal extent of the glacier. It is calculated based on the SRTM DEM of spatial resolution of 90 m. Three levels of elevation data are calculated in the glacier inventory - highest elevation representing the highest elevation of the crown of the glacier mostly lies in the clean ice (CI) part; mean elevation is calculated as the average values of all the pixels associated with the glacier boundary in DEM; and lowest elevation representing the elevation of the tongue of the glacier derived from the debris covered ice. If the glacier is not debris covered, the tongue of the clean ice is considered to be the lowest elevation. It is measured in metres above sea level (masl).

In this exercise, we will use the SRTM DEM of the Langtang area provided in the training datasets. Zonal statistics tool built in the Spatial Analyst tool is used to calculate the statistics of each glacier polygon, using GLIMS ID as a reference. The elevation value of each glacier is calculated in a separate table, which will be joined later, and the required values (Min, Mean and Max) will be transferred to the glacier polygon dataset (shapefile). To calculate the elevation values of the glacier, follow the steps given below.

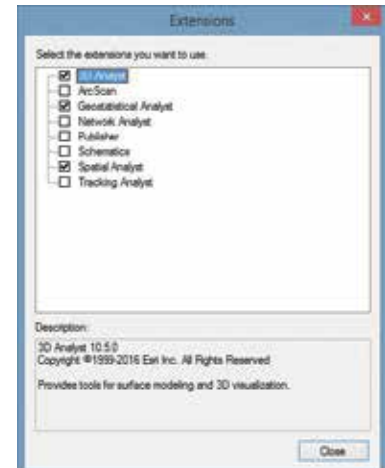
Add Dem

- Click on 'Add Data' button  in the 'Standard' toolbar. The Add Data dialog box appears.
- Navigate the location (C:\TrainingData\Glacier_mapping\Dem\) from 'Look in' dropdown menu and select the 'Dem' (Dem.img) file and click the 'Add' button. The 'Dem' layer appears in the 'Data View' window.



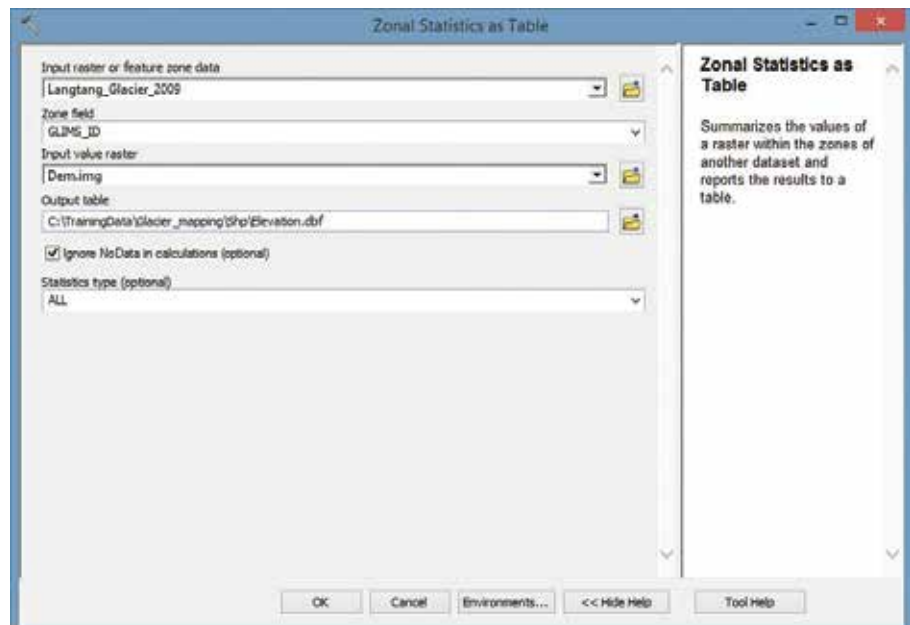
Activate Spatial Analyst Extension


- To calculate the elevation of the glacier from the raster elevation data, the 'Spatial Analyst' extension has to activate. Click on the 'Customize' menu in the Menu bar and click on the 'Extension...' menu from the context menu. The 'Extension' dialog box appears.
- Check the 'Spatial Analyst' from the list in the 'Extension' dialog box to activate the Spatial Analyst extension and click the 'Close' button to close the 'Extension' dialog box.



Calculate Elevation of the Glaciers

- Now click on 'ArcToolbox' icon  in the 'Standard' toolbar to open 'Arctoolbox'.
- Expand the 'Spatial Analyst Tools > Zonal' and click on 'Zonal Statistics as Table'. The 'Zonal Statistics as Table' dialog box opens.



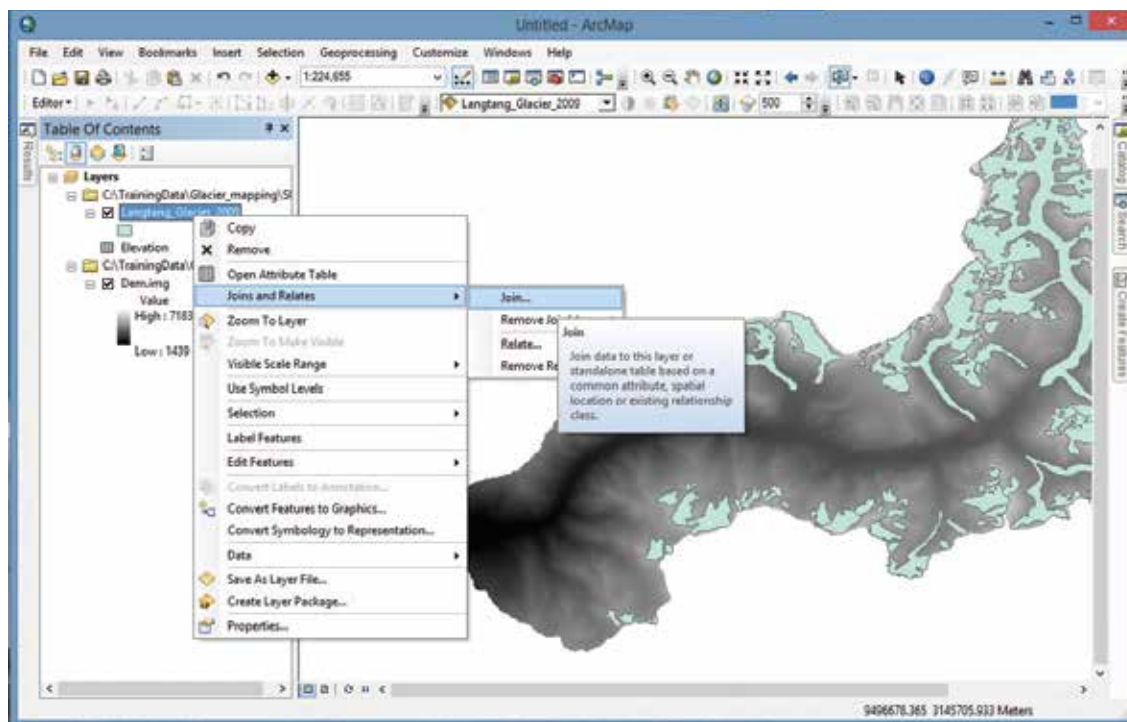
- In the 'Zonal Statistics as Table' Wizard, select 'glacier' layer in the 'Input Raster or feature zone data', 'GLIMS_ID' field in 'Zone Field' and select raster 'Dem' data in 'Input value raster' column.
- Click on the 'folder' icon  next to Output Table. The 'Output Table' dialog box appears. Locate the location for the file to be saved and name the file 'Elevation.dbf' and click 'OK' to confirm.
- Check 'Ignore NoData' in calculation.
- For 'Statistics Type', select 'All' and click 'OK' to calculate the elevation of glaciers.

Add Fields in Glacier Layer

Open 'attribute table' of the glacier layer and 'Add Fields' – 'Elv_min', 'Elv_mean' and 'Elv_Max' in the attribute table of the glacier layer.


Join Elevation Table

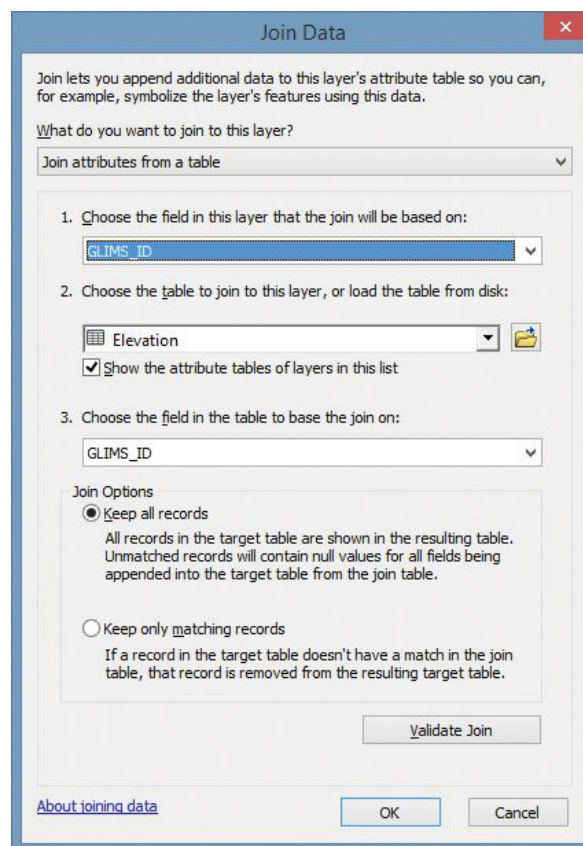
- Join the '*Elevation.dbf*' table to glacier layer.
- To join the table right click on 'Glacier File' and select 'Join and Relates' from the context menu and click on 'Join'. The 'Join Data' dialog box appears.



- Select the 'GLIMS_ID' field in '1' dropdown menu. Select table '(Elevation.dbf)' layer in the '2' dropdown menu and select the same field 'GLIMS_ID' in the '3' dropdown menu.
- Under 'Join options', select 'Keep all records' and click the 'OK' button to join the table.

Shifting Elevation Data of the Glacier into the Glacier Layer from the Joined Table

- Now right-click on 'Elv_min' field in the Attribute Table of glacier layer and click on 'Field Calculator'  in the context menu. The 'Field Calculator' dialog box appears.
- Assign the Field 'MIN' of the joined table '*Elevation.dbf*' in the 'Elv_min' textbox from the 'Field Name' lists in the 'Field Calculator' dialog box.
- Click 'OK' to confirm. The 'Minimum elevation' of the glacier is assigned from the joined table into the glacier layers.
- Similarly assign the 'Mean' and 'Maximum' elevation of glacier from the joined table to the glacier layer.
- Remove the joined table from the glacier layer. To remove the joined table, right click on glacier layer and select 'Join and Related' from the context menu. Select 'Remove Joins' from the 'Join and Related' context menu and click on the joined table 'Elevation'. The joined table removed from the glacier layer.



Arrange the maximum elevation values in descending order by double clicking on "Elv_Max" twice and note down the respective GLIMS ID and elevation value from the topmost row in the arranged attribute table as the highest elevation extent glaciers. Find out the lowest elevation glacier by clicking on the "Elv_min" field. Similarly, find out the extent of the glaciers in the Langtang sub-basin.

3.5 Glacier Slope


Slope of the glacier is also an important parameter as it helps us characterize various morphological conditions of the glacier. It is derived for each glacier from the DEM. Slope is generated using the slope model built in the Spatial Analyst tools in arcgis using SRTM DEM.

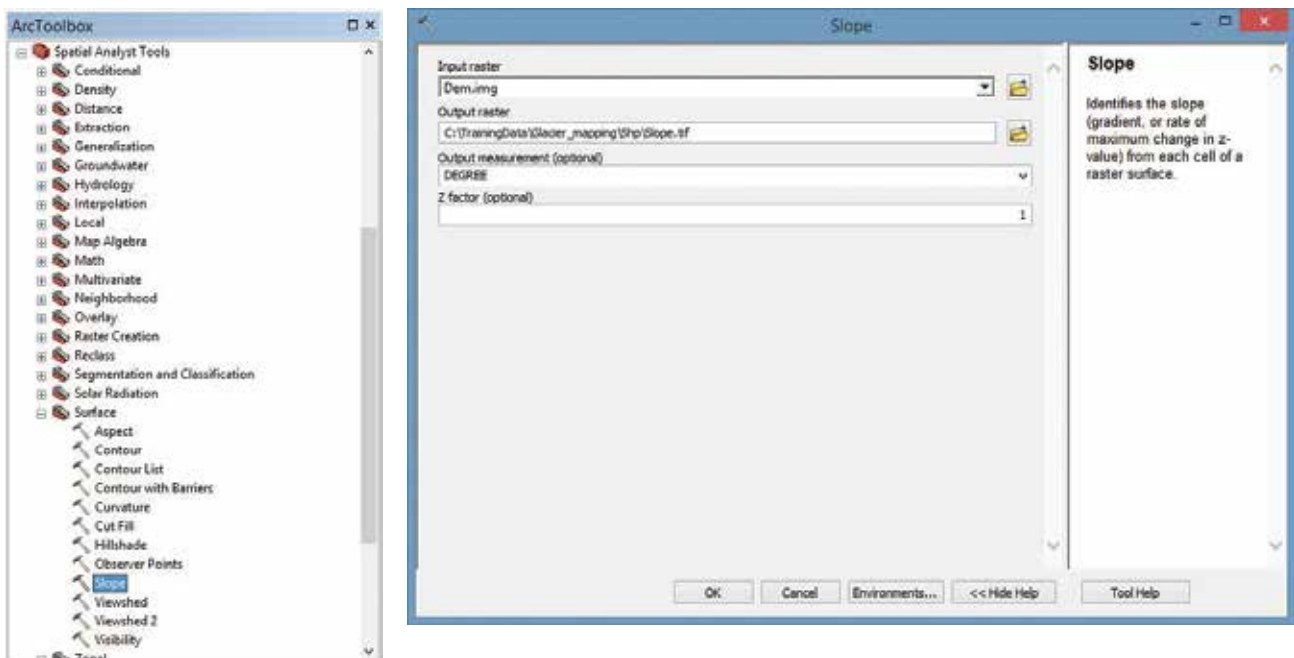
Activate Spatial Analyst Extension


To generate the slope and calculate the slope of glacier from the raster slope data, the '**Spatial Analyst**' extension has to activate. If you have already activated the Spatial Analyst, you don't need to follow these steps.

- Click on '**Customize**' menu in the Menu bar and click on Extension... menu from the context menu. The Extension dialog box appears.
- Check on '**Spatial Analyst**' on the list in the 'Extension' dialog box to activate the Spatial Analyst extension and click the 'Close' button to close the 'Extension' dialog box.

Create Slope Data from DEM

- Click on 'Arc Toolbox'  in the standard toolbar to open Arctoolbox
- Expand the 'Spatial Analyst Tools > Surface' and double click on 'Slope'. The Slope wizard opens.




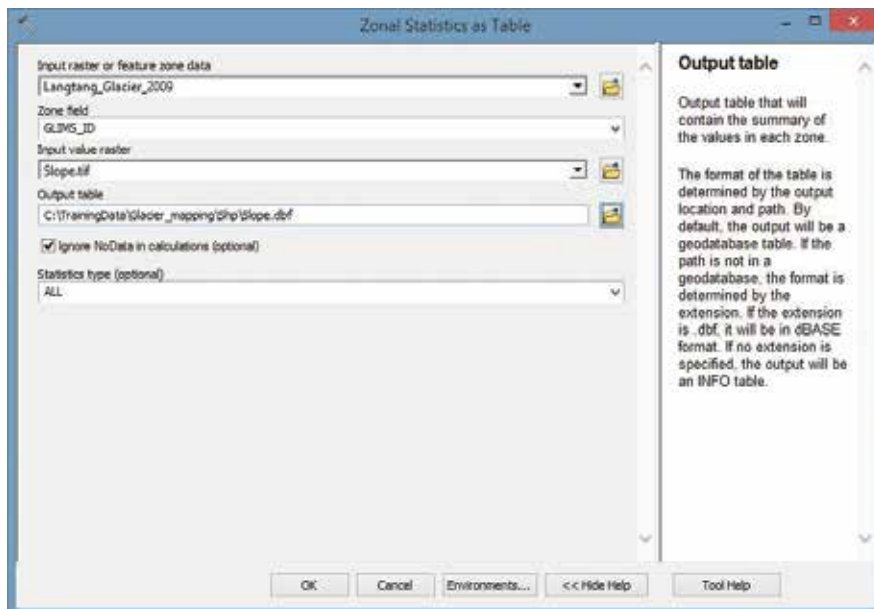
- In the slope wizard, select 'Dem' in 'Input Raster', click on 'Folder' icon  next to 'Output Raster'. The Output Raster dialog box opens. Select the location of the file to be saved and name the file 'Slope.tif' and click the 'OK' button to confirm.


Note that if you 'Dem' data in a geographic coordinate system, you have to first change it into a projected coordinate system. For this exercise, change the projection of the "Dem" to "UTM WGS 1984 45N". Then create the slope and aspect data.

- Select 'Output Measurement' as 'DEGREE' and 'Z-factor' as '1'.
- Click the 'OK' button in the Slope wizard to calculate Slope. The Slope layer appears in the Data View window.

Calculate Slope of the Glaciers

- Now click on the 'ArcToolbox' icon  in the 'Standard' toolbar to open 'Arctoolbox'.
- Expand the 'Spatial Analyst Tools > Zonal' and click on 'Zonal Statistics as Table'. The 'Zonal Statistics as Table' dialog box opens.



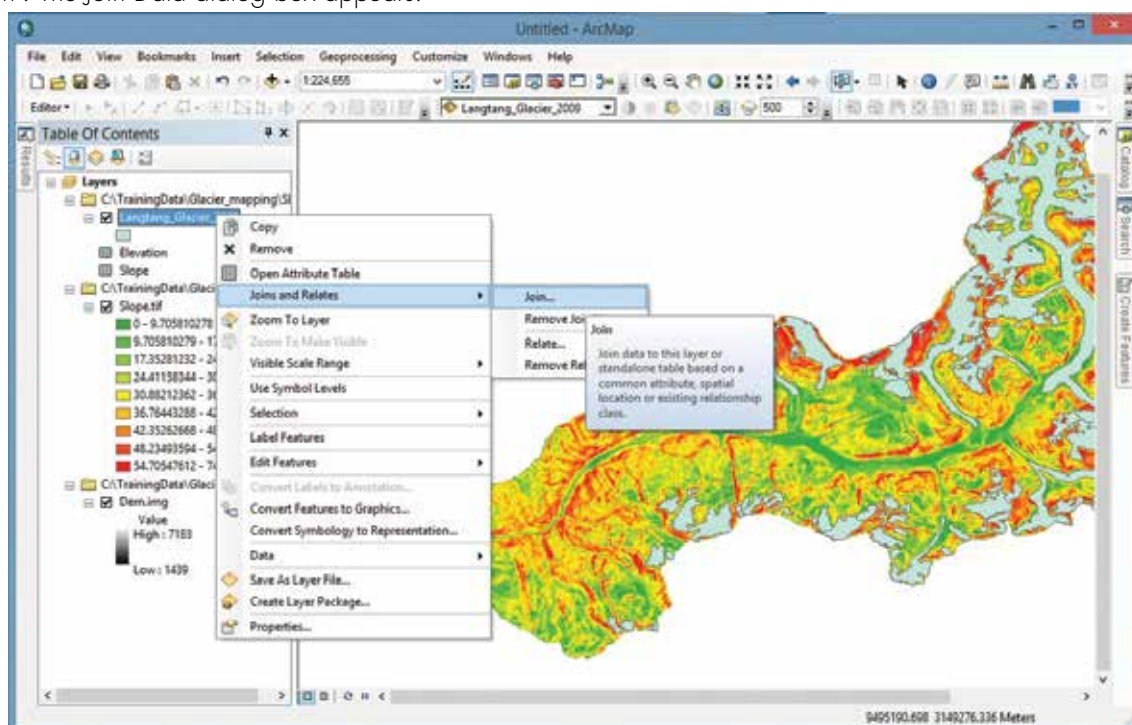
- In the 'Zonal Statistics as Table' wizard, Select 'glacier layer' in the 'Input Raster or feature zone data', '*GLIMS_ID*' field in 'Zone Field' and select raster 'Slope' data in 'Input value raster' column.
- Click on 'Folder' icon  next to 'Output Table'. The Output Table dialog box appears. Select the location of the file to be saved and name the file 'Slope.dbf' and click 'OK' to confirm.
- Check 'Ignore NoData in calculation'
- Select 'Statistics Type' as 'Mean' and click 'OK' to calculate the Slope of glaciers.

Add Fields in Glacier Layer

- Open 'attribute table' of the glacier layer and 'Add Fields' - '*Slp_min*', '*Slp_mean*' and '*Slp_Max*' in the 'Attribute table' of the glacier layer.


Join Elevation Table

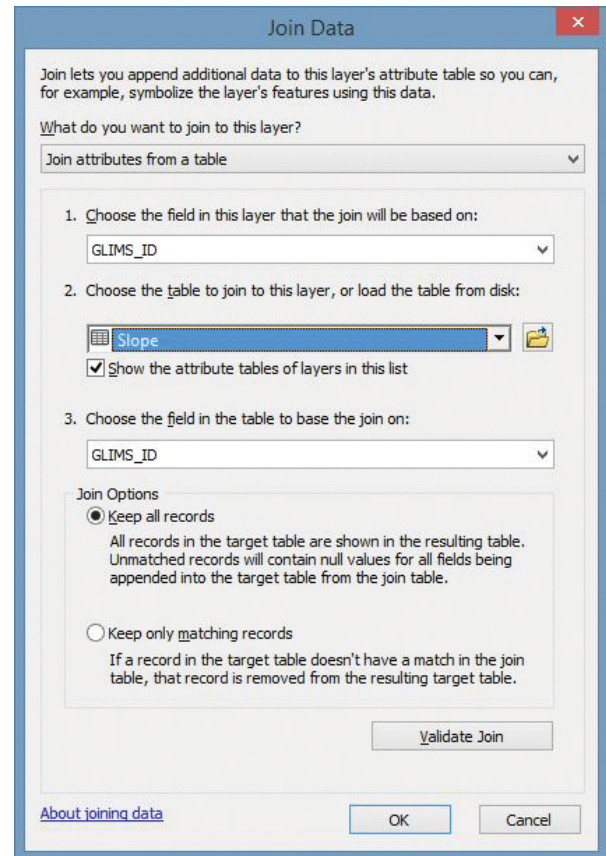
- Join the '*Slope.dbf*' table to glacier layer.
- To join the table right click on 'Glacier File' and select 'Join and Relates' from the context menu and click on 'Join'. The Join Data dialog box appears.



- Select the 'GLIMS_ID' field in '1' dropdown menu. Select Table ('Slope.dbf') layer in '2' dropdown menu and select the same field 'GLIMS_ID' in '3' dropdown menu.
- Under 'Join options', select 'Keep all records' and click the 'OK' button to join the table.

Shifting Slope Data of Glacier into the Glacier Layer from Joined Table

- Now right-click on 'Slp_min' field in the Attribute Table of glacier layer and click on 'Field Calculator'  in the context menu. The 'Field Calculator' dialog box appears.
- Assign the Field 'MIN' of the joined table 'Slope.dbf' in the 'Slp_min' textbox from the 'Field Name' lists in the 'Field Calculator' dialog box.
- Click 'OK' to confirm. The 'Minimum' slope of glacier is assigned from the joined table into the glacier layers.
- Similarly assign the 'Mean' and 'Maximum' slope of glacier from the joined table to the glacier layer.
- Remove the joined table from the glacier layer. To remove the joined table, right click on glacier layer and select 'Join and Related' from the Context menu. Select 'Remove Joins' from the 'Join and Related' context menu and click on the joined table 'Slope'. The joined table is removed from the glacier layer.

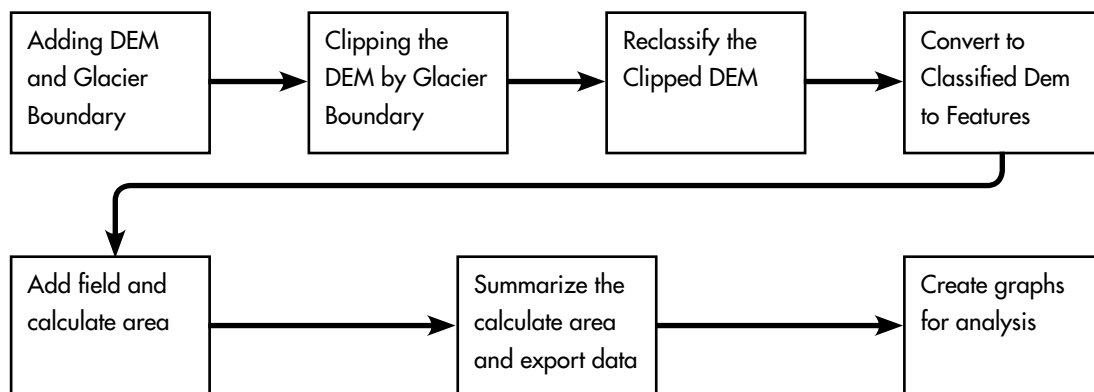


Similarly calculate the 'mean' aspect value of the glaciers.

3.6 Hypsography of Glaciers

Hypsography is the study of the distribution of elevations on the surface of the earth (glacier/lands). The term originates from the Greek word ὕψος 'hypsos', which means height. It is the calculation of glacier specific area-elevation distribution and can be easily obtained by combining glacier outlines with the DEM. This information would greatly improve the calculation of future glacier response to climate change, as glacier melt (and precipitation) is largely elevation dependent. A 100 m binning is recommended to have some consistency in the database and to cover the large range of possible values without losing relevant information on smaller glaciers.

Methodology




Detailed Steps for Hypsography Analysis of Glaciers Using ARCGIS 10

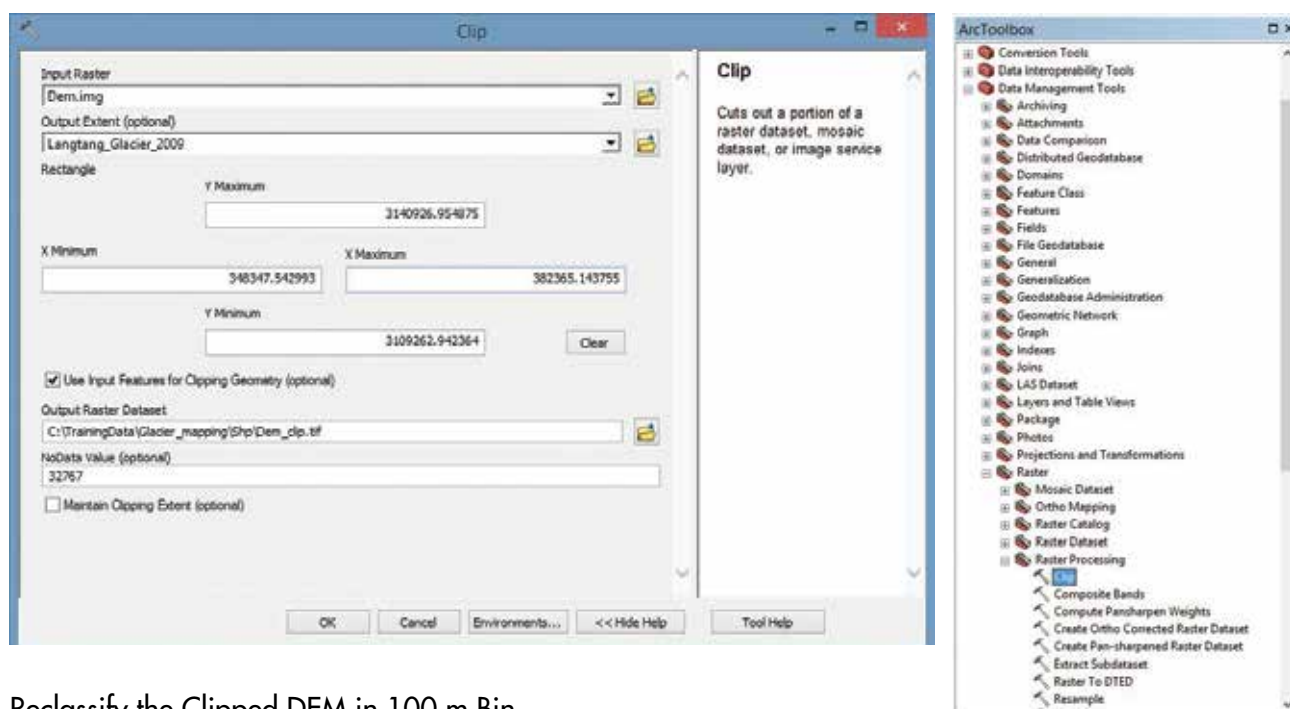
Add Raster Data (DEM) and Feature Data (Shape file) of Glacier Boundary

- Go to 'File > Add Data > Add Data...' Or click on 




Clip DEM by Glacier Boundary

- In order to clip the 'DEM', open the 'Arc Toolbox' .
- Go to 'Data Management Tools > Raster > Raster Processing' and double click on Clip.
- In the clip panel, 'add DEM in Input Raster columns' and add 'glacier boundary file in Output Extent'.
- Check 'Use input Feature for Clipping Geometry (Optional)'.
- Select the output path in 'Output Raster Dataset'.
- Then click 'OK'.

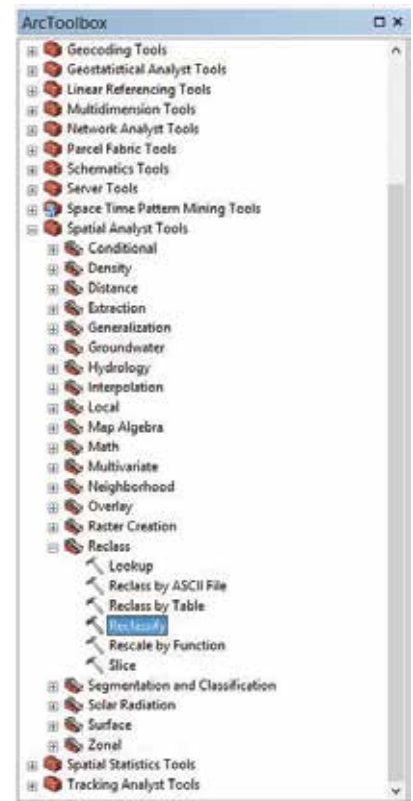
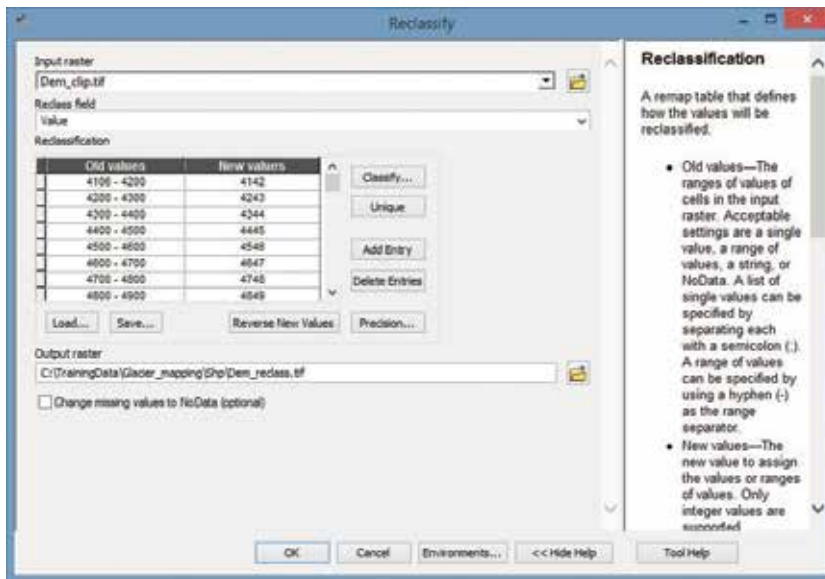


Reclassify the Clipped DEM in 100 m Bin


- Open 'Arc Toolbox'  and go to 'Spatial Analyst Tools > Reclass'.
- Double click on 'Reclassify' to open 'Reclassify' sub-window.
- Add clipped DEM in Input 'Raster' column and select 'Reclass' Field from the 'Reclass' field dropdown menu.
- Now define the 100 m class interval in 'Old values' column and also the 'New values' in Reclassification to reclassify the DEM. Define the 'Old Values' and 'New Values' as follows

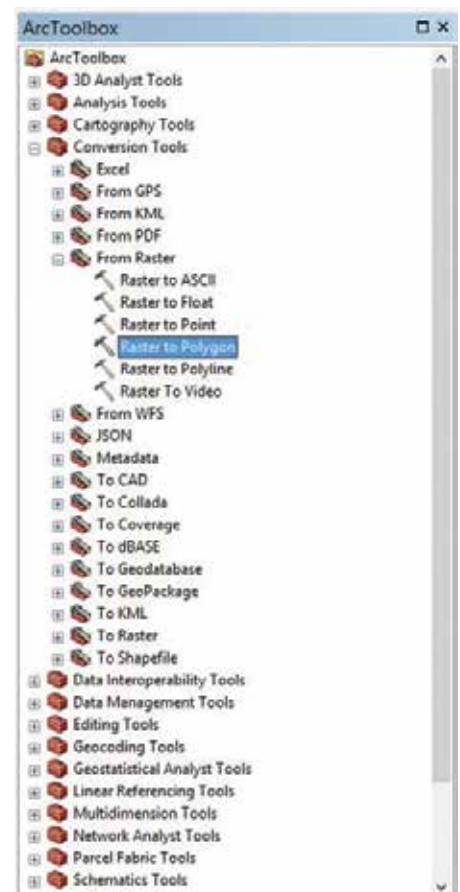
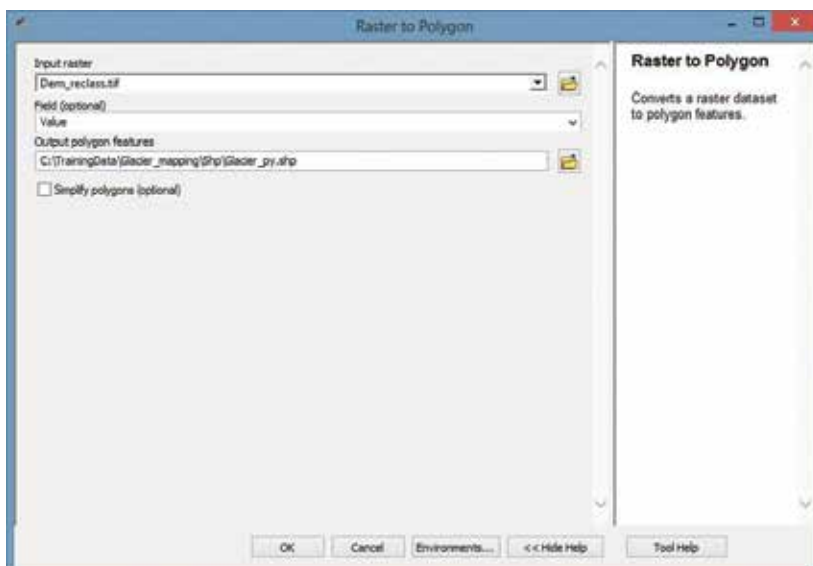
S.N.	Old values	New values
1	4,000–4,100	4,041
2	4,100–4,200	4,142
3	4,200–4,300	4,243
4	4,300–4,400	4,344
5	No Values	No Values

- And define the output file path in 'Output Raster'.
- Then click 'OK'.



Convert Classified DEM into Features

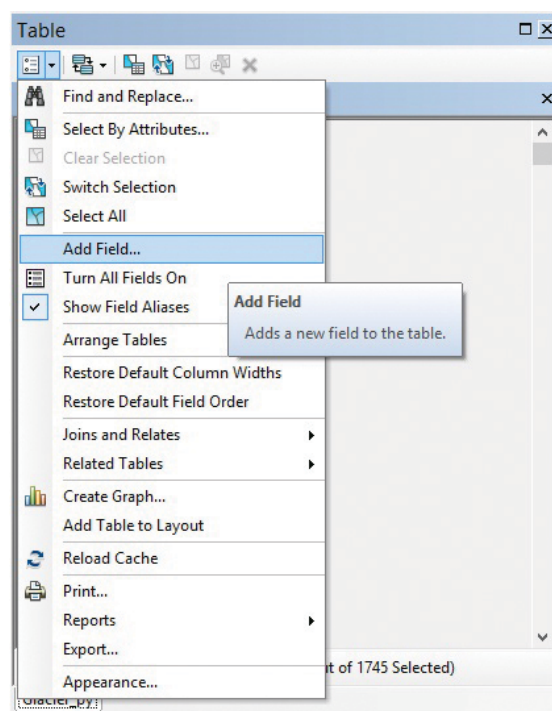
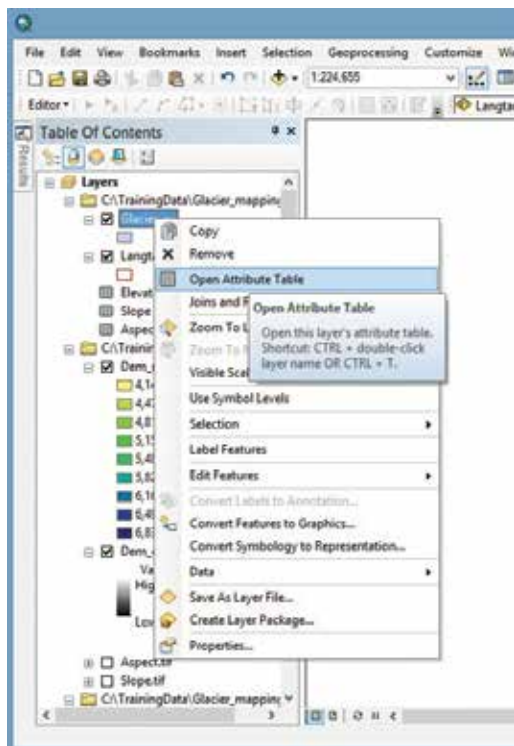
- Open 'Arc Toolbox' .
- Go to 'Conversion Tools > From Raster'.
- Double click on 'Raster to Polygon' to open the sub window.
- Add Reclassified 'DEM' in 'Input Raster' and specify the output polygon file in 'Output Polygon Features'.
- Click 'OK'.



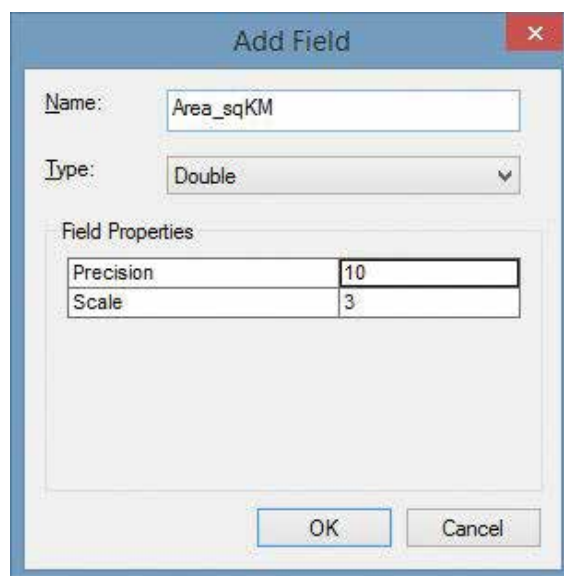
Add Field and Calculate Area in Feature

Adding Field in Attribute Table

- Add the 'Reclassified polygon' feature data 
- Right click on the 'Reclassified Polygon' feature in the 'Table of Contents' Column and click on 'Open Attribute Table'.
- Go to 'Table Option'  in the 'Attribute table' and click on 'Add Field'.

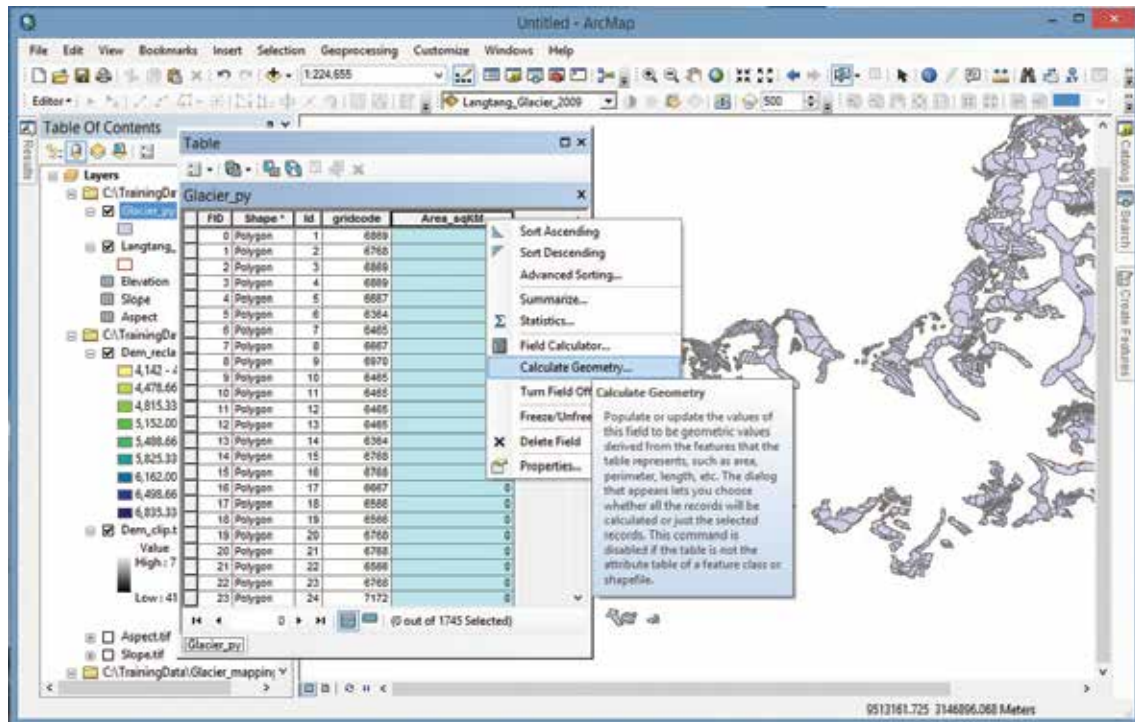


- Type 'Name' of the 'Field' (Area) in the 'Name' textbox in Add field window and select 'Double' under 'Field Type'; then set the 'Precision' to '10' and 'Scale' to '3' in the Field Properties column.
- And click 'OK'.



Calculate Area

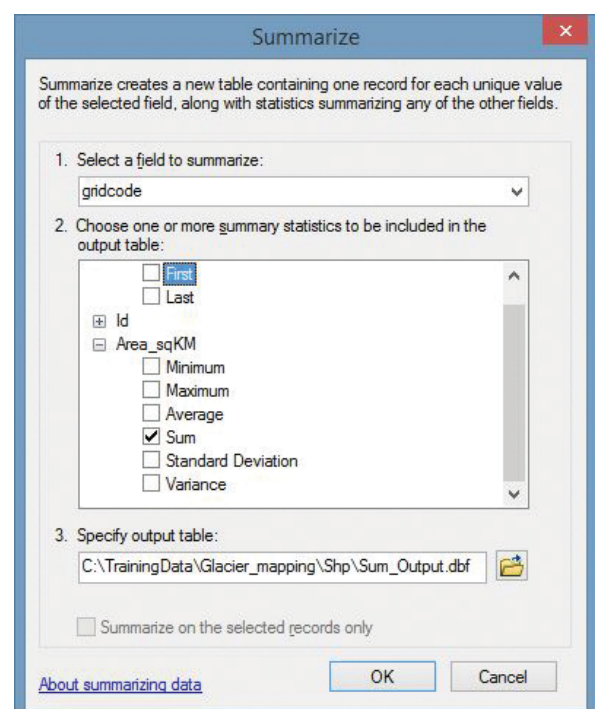
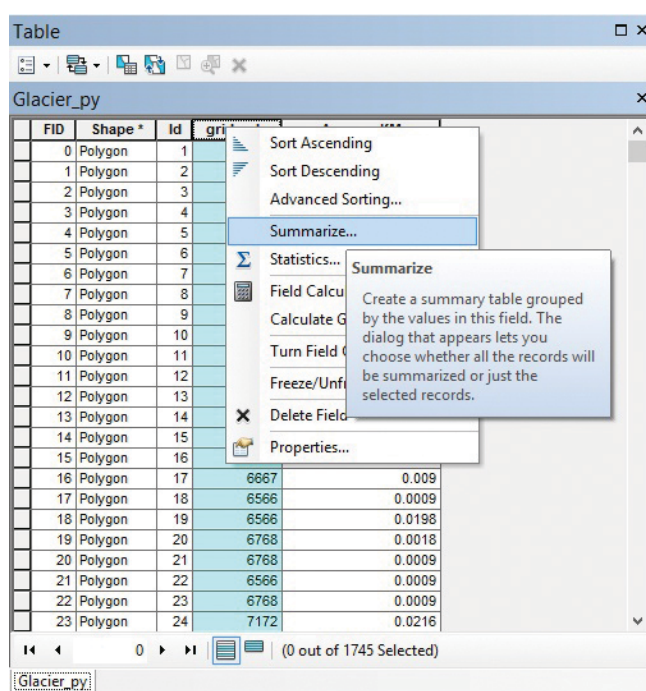
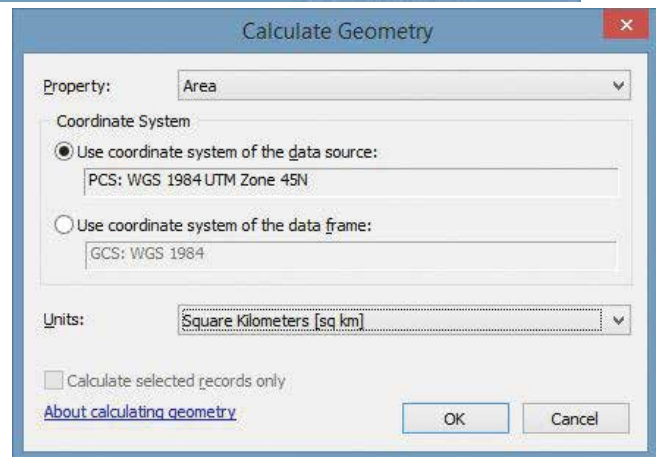
- Right click on the 'Field Title' (area) in the attribute table.
- Go to 'Calculate Geometry'.
- Select 'Area' from the 'Properties' dropdown menu and specify the unit from the 'Units' dropdown menu and click 'OK'.



Note: To calculate area the data should be in a projected coordinate system. So first the data should be converted into a projected coordinate system as "UTM WGS 1984 45N".




Export the Summarize Attribute Data

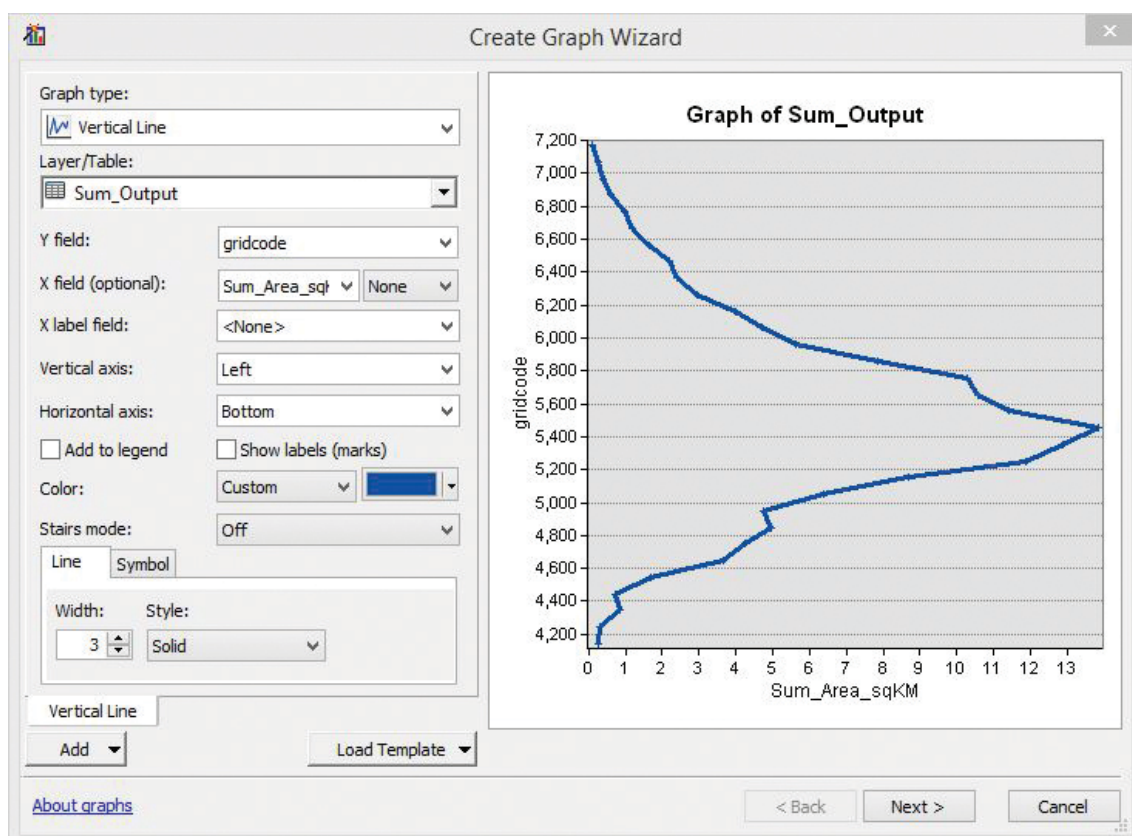
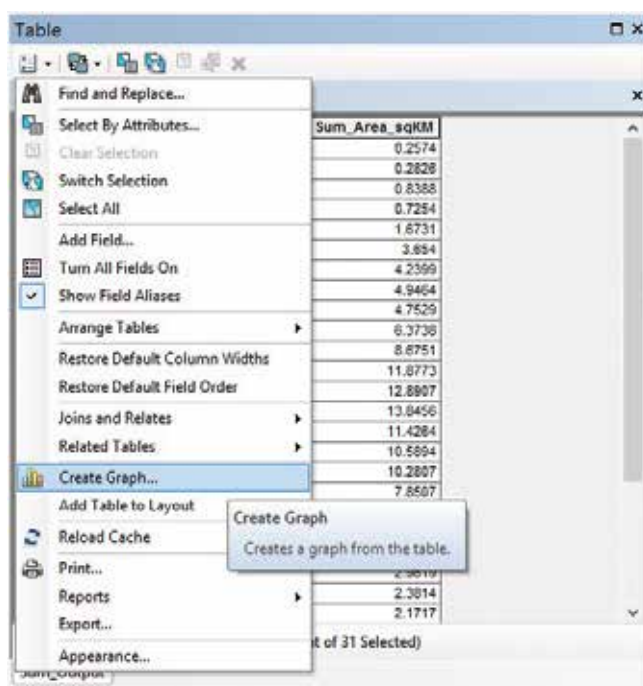
- Open the 'Attribute Table' of the 'Polygon Feature' data.
- Right click on 'GRIDCODE' field and click on 'Summarize' menu.
- In the 'Summarize' window, select 'GRIDCODE' field to summarize.



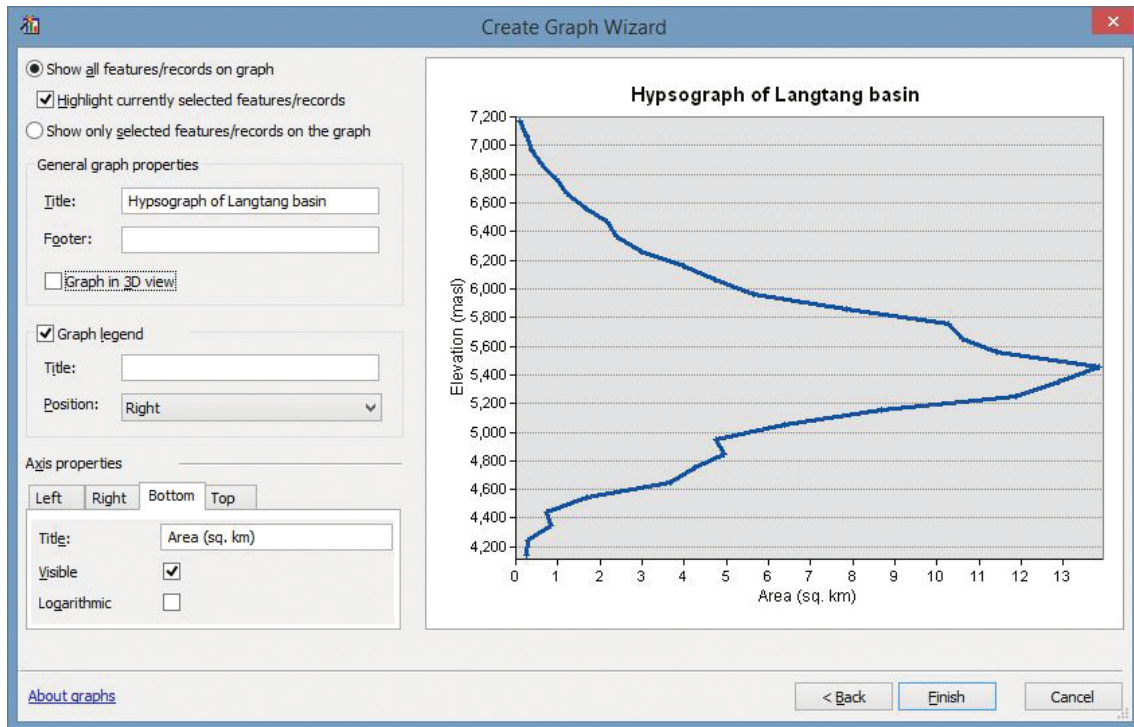
- Check the 'SUM' into the Area field in the selection menu.
- Specify the output table path and click 'OK'.

Create and Export Charts

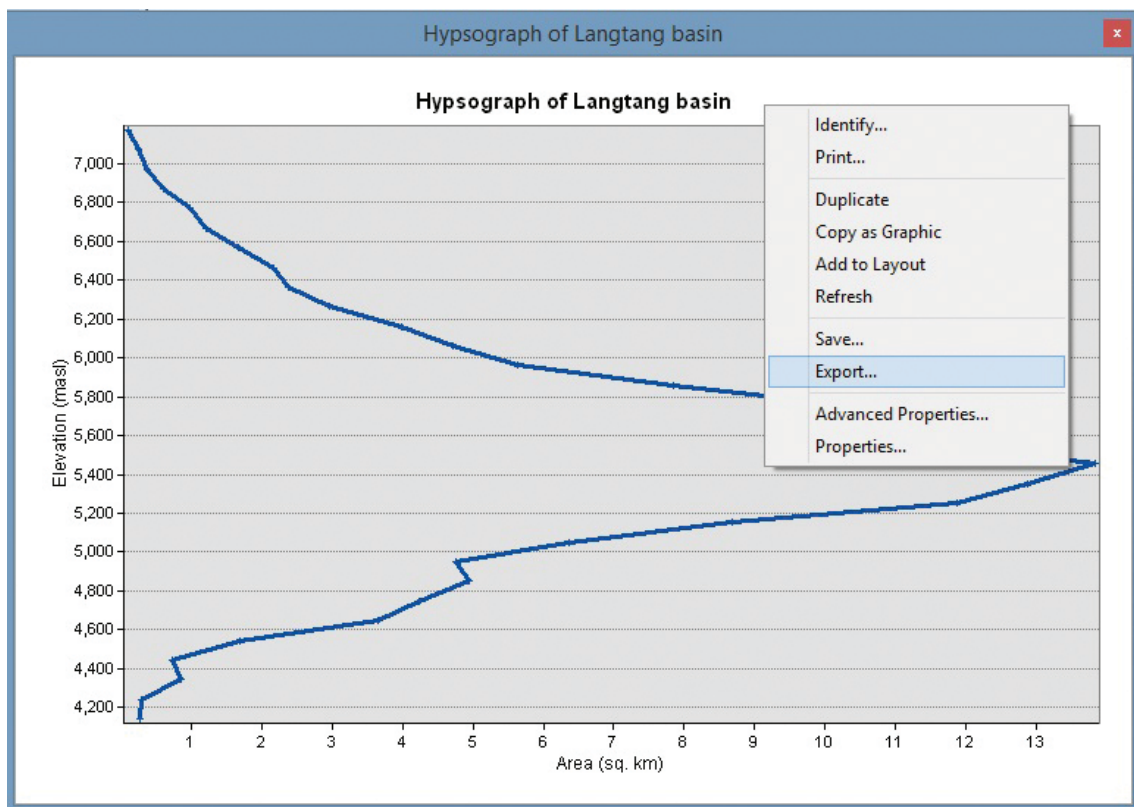
- Add summarized data 
- Open the 'Attribute Table'.
- Click the down arrow in 'Table Option'  and go to 'Create Graph'  **Create Graph...**
- In the 'Create Graph' Wizard, select the following items in their respective columns.
- For 'Graph Type', select 'Vertical Line'.
- Select 'Layer/Table' that will be used to create a graph.
- Select 'Y field' as 'GRIDCODE' and 'X field' as 'Area'.
- Then click 'Next'.

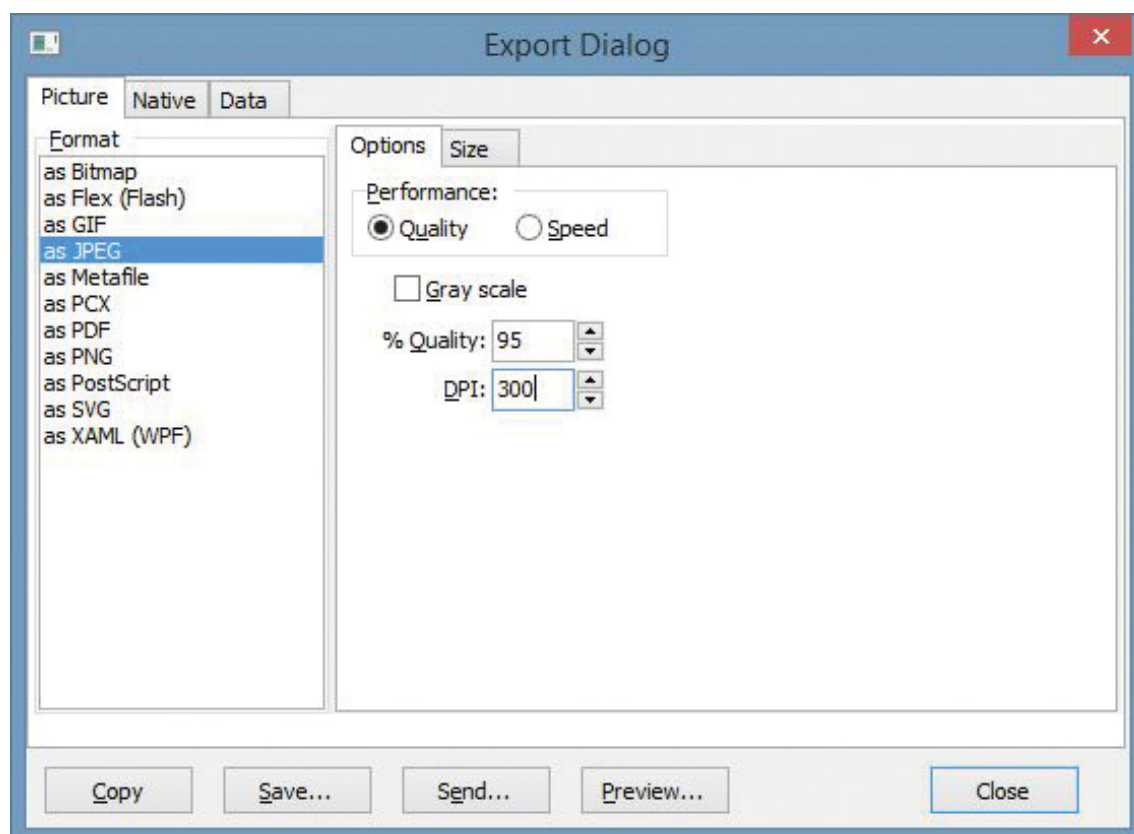


- In the next panel define the 'Graph Title' in 'General Graph Properties' column and 'Axis Title' in 'Axis Properties' column by selecting Left and Bottom Tab.



- Then click 'Finish'.
- Right-click on the 'Graph' and choose 'Advanced Properties...' to further refine the graph;
- OR choose 'Export...' to export it into JPEG format;
- OR choose 'Add to Layout' to add it in a layout; and
- OR choose 'Print...' to print it.





4. References

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