ADB

Project Number: 44214-024
Grant Number: 0357, 0358
July 2020

Nepal: Building Climate Resilience of Watersheds in Mountain Eco-Regions

Training Manual on Application of GIS in Watershed Management Planning

Asian Development Bank

Training manual on

Application of GIS in Watershed Management Planning

BCRWME KNOWLEDGE SERIES 8

BCRWME Knowledge Series

The BCRWME Knowledge Series cover publications under the **Building Climate Resilience of Watersheds Mountain Eco-regions** project in Nepal.

BCRWME is the first component of Nepal's Pilot Program for Climate Resilience (PPCR) under the National Strategic Program for Climate Resilience (SPCR), executed by the Department of Forestry and Soil Conservation (DFSC, previously DSCWM).

The Climate Investment Fund (CIF) is the primary donor of the project, with the grant being administered by the Asian Development Bank (ADB). The Nepal Government provides both financial and in kind support. A grant for technical assistance is provided by the Nordic Development Fund (NDF).

The overall objective of the SPCR is to build long-term climate resilience through an integrated water resource and ecosystem-based approach, and to yield lessons on how best to build resilience in vulnerable mountain regions.

The BCRWME pilot is implemented in six districts in the Far Western Development Region of Nepal between 2014-2020. It provides support to all participating communities to develop and protect their water sources (springs and streams) and construct water storages to help sustain the use of limited water during the dry season, to support domestic and agricultural uses. The spring or surface water sources are expected to become more reliable, and; the dry season water yield will either remain the same or increase.

In addition the project supports both the communities and the government to manage water and land in an integrated and inclusive manner within watersheds. Implementation of subprojects particularly addresses water conservation in catchments and shortage issues.

It being a pilot project it is essential that key stakeholders adopt knowledge-based approaches for integrated water and land management and improved water reliability and accessibility in the wake of climate change.

All participating communities are involved in a phased cycle of training and capacity building so that the knowledge they develop in integrated and inclusive watershed management can be used to apply best practice.

Research is conducted throughout the project on hydrological impacts of watershed management and interventions.

Training, capacity building, research and lessons learned are captured in these BCRWME Knowledge Series publications to support institutions and experts tasked with watershed management implementation in scaling up and scaling out activities based on best practice knowledge.

The complete series captures six years of work involving over thousands community members, Government staff at all levels, and technical assistance of 100+ (inter)national consultants.

BCRWME Knowledge Publications

1. User and training manual on Spring Water Assessment & Management
2. Gender Equality and Social Inclusion Training Manual
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4. Integrating GIS to Mapping of Groundwater Potential of Recharge Zones
5. Field Guide for Spring Development and Protection
6. A Seven-Step Approach for Springshed Development & Management
7. GIS based Watershed Management Planning: Sub-watershed Bio-physical Assessment and Prioritization
8. Training manual on Application of GIS in Watershed Management Planning
9. Guideline for Watershed Planning & Management
10. Field Manual on Spring Awareness (Nepali)
11. Community Organizer Training Manual (Nepali)
12. BCRWME - Lessons Learned from Project Design & Implementation

Training manual on Application of GIS in Watershed Management Planning
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Introduction

Technological advancement in earth observation technology such as remote sensing, GPS and GIS is proving to be a vital tool to improve our understanding of various attributes of the earth surface, including human activities, resultant environmental changes and indicators of climate change. Through the use of spatial tools and technologies such as GIS professionals and governmental officials can gain exposure and better understanding of issues related to climate change which can be useful in advocacy and development project planning, implementation, monitoring and evaluation.

GIS based watershed management and planning generally begins with an inventory of existing resources (an information base), followed by mapping and assessment which includes existing status of resources (issues or vulnerabilities). The base layers of data for carrying out GIS mapping and assessment for natural resource related studies typically include topographic data, climatic information, hydrologic information and associated infrastructures and services such as roads, schools, health posts and other information to facilitate orientation.

This GIS training manual offers hands-on exercises enabling users to practice both the tools and the knowledge they gain to enhance their data management, mapping and analysis skills using GIS for watershed management planning. It presents the basics of GIS software operation, mapping and spatial analysis using sub-watershed level spatial and other data. Each section is detailed to be appropriate at a beginner's level. Major data, figure and information sources for the preparation of this manual include ESRI, ArcGIS Resource Center, GIS Geography, NRCS/USDA and Google Earth websites.

One expected output of the BCRWME project is that participating communities and government agencies manage water and land on a watershed basis in an improved integrated and inclusive manner. Access and reliability to water resources is expected to be improved through a participatory program of integrated watershed management with interventions in upland areas to increase surface water storage and groundwater recharge, and to deliver water to locations where the community can use it. The communities in the project area will have more reliable water supplies in the dry season. The project will demonstrate participatory watershed management planning and build the capacity of all levels of the government for integrated watershed development specifically focusing on water resources. The specific target is the adoption of the new watershed management planning approach by 2021. (PAM/BCRWME, 2015).

1. Defining GIS

A Geographic Information Systems (GIS) is defined as an information system that is used to enter, store, retrieve, manipulate, analyze and output geographically referenced data or geo-spatial data, in order to support decision-making for planning and management.

GIS is used to display and analyze spatial data which are tied to databases. This connection is what gives GIS its power: maps can be drawn from the database and data can be referenced from the maps. When a database is updated, the associated map will be updated as well. GIS databases include a wide variety of information including: geographic, social, political, environmental, and demographic (ESRI).

GIS elements include:

- Measurement of natural and human made phenomena and processes from a spatial perspective. These measurements emphasize three types of properties commonly associated with these types of systems: features, attributes, and relationships.
- Storage of measurements in digital form in a computer database. These measurements are often linked to features on a digital map, i.e. points, lines, and areas (polygons), which are identified as vector elements. Various data can also be represented as raster elements, pixel-type representations of discretized data.
- Analysis of collected measurements to produce more data and to discover new relationships.
- Depiction of measured or analyzed data in a visual display, most notably maps and similar map-like graphical representations. GIS tools can also generally produce or interface with other software visuals like graphs, tables of summary statistics, etc.

1.1 Understanding GIS Terms	
Altitude/Elevation	**The height of an object or point in relation to sea level or ground level**
Attribute Data	**Descriptive, non-graphic information recorded as digital map data or an associated database table. Examples of attributes are street names, street types (highway, side street, etc.), and pavement types**
Base Map	**A map containing visible surface features and boundaries, essential for locating additional layers or types of geo-referenced information**
Buffer	**A zone around a map feature measured in units of distance or time, used for proximity analysis**
Cartography	**The design, compilation, art or science of making maps.**
Coordinate System	**A reference system for defining precise locations on the earth's surface.**
Data Layer/Map Layer	**The visual representation of a geographic dataset in any digital map environment. Conceptually, a layer is a slice of the geographic reality in a particular area**
Database	**A logical collection of interrelated information managed and stored as a unit, usually on some form of mass storage system.**
Datum	**A mathematical model that provides a smooth approximation of the earth's surface.**
DEM/DTM	**A representation of the terrain in a given area, expressed as a rectangular array of regularly spaced elevation values. Also referred to as a Digital Terrain Model (DTM), or Digital Terrain Elevation Data.**
Feature	**An object or phenomena of the earth surface.**
Geo-referencing	**Assigning coordinates from a known reference system, such as latitude/longitude, UTM.**
Geo-processing	**Geo-processing is a framework and set of tools for processing geographic and related data. The comprehensive suite of geo-processing tools can be used to perform spatial analysis or manage GIS data in an automated way.**
Geodatabase	**The Geodatabase is the native data structure for ArcGIS and is the primary data format used for editing and data management. The Geodatabase is a "container" used to hold a collection of datasets. There are three types of Geodatabase: File, personal and enterprise Geodatabase.**
GIS Database	**A GIS database includes data about the Spatial locations and shape of geographic features recorded as points, lines, pixels, grid cells or tins as well as their attributes.**
Latitude	**The angular distance, usually measured in degrees, along a meridian north or south of the equator.**
Layout	**The arrangement or overall design of elements on a digital map display or printed map, possibly including a title, legend, north arrow, scale bar, and geographic data.**

> Understanding GIS Terms	
Longitude	The angular distance, expressed in degrees, minutes, and seconds, of a point on the earth's surface east or west of an arbitrarily defined meridian: Greenwich prime meridian.
Map Extent	A map extent is the limit of area of a region show in a map. The limits of a map extent are defined in the coordinate system of the map. It is defined with a minimum and maximum width and height.
Meta Data/Data Dictionary	Metadata is structured description of data. Metadata summarizes basic information about data.
Overlay analysis	Overlay analysis allows to perform an analysis of multiple inputs that contain a variety of ranges. In general, there are two methods for performing overlay analysis—feature overlay (overlaying points, lines, or polygons) and raster overlay.
Projection	A method by which the curved surface of the earth is portrayed on a flat surface. This generally requires a systematic mathematical transformation
Raster data	Raster datasets represent geographic features by rectangular cells. Each cell has a value that is used to represent some characteristic of that location such as elevation or land-use type. Raster data are commonly used for representing and managing imagery.
Scale	The ratio or relationship between a distance or area on a map and the corresponding distance or area on the ground. 1:10, 000 means that one unit of measure on the map equals 10,000 of the same unit on the earth.
Shape file	A standard vector data storage format for storing the location, shape, and attributes of geographic features with .shp extension.
Spatial Data	Information in a digital map that records the physical position(lat/Long) and shape/ Geometry of a map feature.
Spatial Interpolation	Interpolation is a procedure used to predict the values of cells at locations based on sampled points. It is a method to predict unknown values for any geographic point data, such as elevation, rainfall, chemical concentrations.
Spatial Reference	A spatial reference system is a coordinate-based local, regional or global system used to locate geographical entities.
Symbology	Symbology is the application of graphic symbols like color, size, and other properties—to represent geographic features on a map.
Topology	A rule and description of the relationship between point, line, and polygon elements in a vector object.

1.2 GIS models and displays

Despite the heterogeneity of geographic information, there are two basic approaches to simplify and model space, so that spatial data can be stored and manipulated in a computer system. GIS represents objects using the vector model (i.e. points, lines, areas) and Raster model (i.e. grid cell or pixels).

The vector data model is based on the assumption that the earth’s surface is composed of discrete objects such as trees, rivers, ponds, etc. (ESRI, 2010). The raster structure is based on a matrix of cells represented in rows and columns. Each cell can store information about a given variable such as precipitation, temperature, relative humidity, solar radiation, radiance, reflectivity, etc. (Pucha-Cofrep et. al., 2018).

GIS uses graphic symbols to identify features. Features have attributes associated with them, for example a water source may be represented as a point. GIS features on a map are linked to their attributes in a table. For example, a water source represented on a map by a point could have name, discharge, and other information linked as associated attributes stored within an attribute table (i.e. database).

GIS utilizes a layer-based information model for characterizing and describing feature and its attributes.

Multiple layers of information can be overlaid and combined in various visual ways (Fig. 1). Mathematical calculations can also be performed on geo-referenced data to produce new layers of derived information.

For example: precipitation rate, land slope and surface roughness can be mathematically combined through various models to calculate estimated overland flow velocities on a geographically discretized basis.

Flow velocities across the known dimensions of the discrete unit can be converted to time, and time values for connected discrete units can be combined to calculate combined travel time to an identified point to create an event hydrograph.

Flow velocities and travel times can be displayed graphically, i.e. in bands of colors, which are much more intuitively comprehensible than hundreds of rows and columns of numerical values. The GIS displays can be immediately updated if input values are changed.

1.3 GIS in Watershed management

Watershed management interfaces with spatial planning, agriculture and forestry, nature and landscape conservation and many other sectors with spatial relevance. There are many different interdependencies and interactions between, for example, upper and lower reaches, surface water bodies and groundwater aquifers, water and land use and water balance.

In order to understand these connections, a watershed must be considered as a spatial system (FOEN, 2011). Computer technology and geographic information systems integrate a large amount of spatial information and knowledge from several disciplines and assist in understanding, modeling and managing natural resources (Schmidt et. al, 2001).

The increased availability and accessibility of geospatial tools such as GIS, Global Positioning Systems (GPS) and Remote Sensing Capabilities (RSC) has facilitated the development and implementation of dynamic assessment, monitoring, and management systems at sub-watershed, watershed and regional scales.

To be useful, information and data must be made available to decision makers in a rational framework (Ma, 2004). GIS has the advantage of assembling, developing, storing and analyzing and presenting vast amounts of spatial and other data from different sources and in different formats. The establishment of linkages between various types of processes such as relationships between the hydrological processes, soil erosion and vegetation cover, human activities in current climate change and vulnerability context is very possible through GIS and other integrating tools.

GIS technology has played critical roles in all aspects of watershed management; from assessing watershed conditions through modeling impacts of human activities on water quality to visualizing impacts of alternative management scenarios (Tim&Mallavaram, 2003).

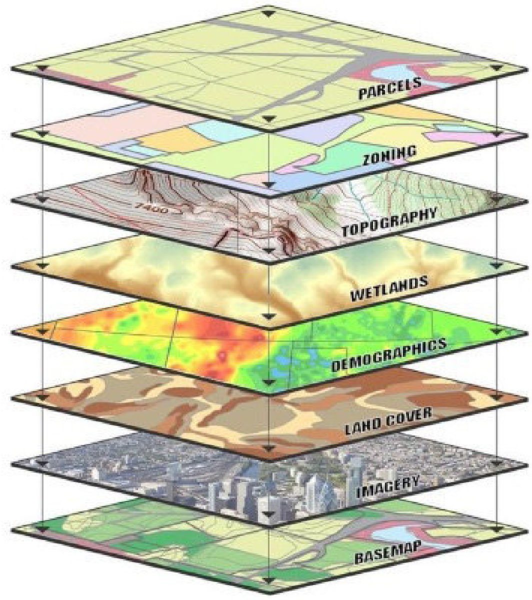


Figure 1: GIS data layer (Source: USGS)

1.3 GIS Application

Some of the common applications of GIS in watershed management planning include:

- Delineation and identification of spatial scales of watersheds
- Inventory preparation of resources within watershed
- Assessment of available water and land resources
- Characterization, prioritization, and feasibility analysis,
- Topographical analysis by extracting layers such as slope, aspect, drainage density,
- Thematic Mapping of resources and socio-economic aspects,
- Action Plan maps for land and water resources development by integrating the information obtained from various intermediate Analyses.

These applications are carried out during different steps of watershed planning processes. Integration of GIS application for atypical watershed planning processes is outlined in below 5 steps (Meltz, 2008):

Step 1 - Resource mapping: This includes identifying and inventorying the existing status of all relevant resources, trend mapping, temporal changes between past and existing conditions such as land use and land management practices. Most frequently used GIS data layers to facilitate orientation during this step include soil, land use, topographic and infrastructure maps, climatic and hydrologic (i.e. streams, rivers, lakes) data, and other information as relevant.

Step 2 & 3 - Characterization and prioritization mapping: Topographical and other analysis will be carried out based on the inventory prepared during step 1 for characterization and prioritization of watersheds and identification of problem/critical areas or high potential risk areas within a watershed. GIS allows relatively limited human and physical resources to focus on the highest risk areas. Based on identified problem areas and issues, an effective strategy with clear objectives can be developed.

Step 4 - Thematic Mapping: GIS is very useful as a visualization tool for watershed management plans. Application is mostly confined to thematic mapping. Map outputs include existing resources, socio-economic aspects such as population density, disadvantaged group cluster areas, intervention areas, conservation areas, buffer zones, etcetera.

Step 5 - Performance Mapping: GIS is utilized in a limited way at this stage, but could be used for performance mapping after a certain time period of implementation, to support monitoring and evaluation, i.e.: mapping changes in status of resources, quality, quantity, access, etcetera.

GIS is a very valuable and effective decision-making tool to plan, implement and manage various objects in a spatial context. For example: Watersheds vary in size and characteristics and watershed planning and management need to deal with different types of data. GIS is a very useful tool to analyze and visualize relationships between the various elements and factors within (and comparatively between) watersheds and how those elements interact.

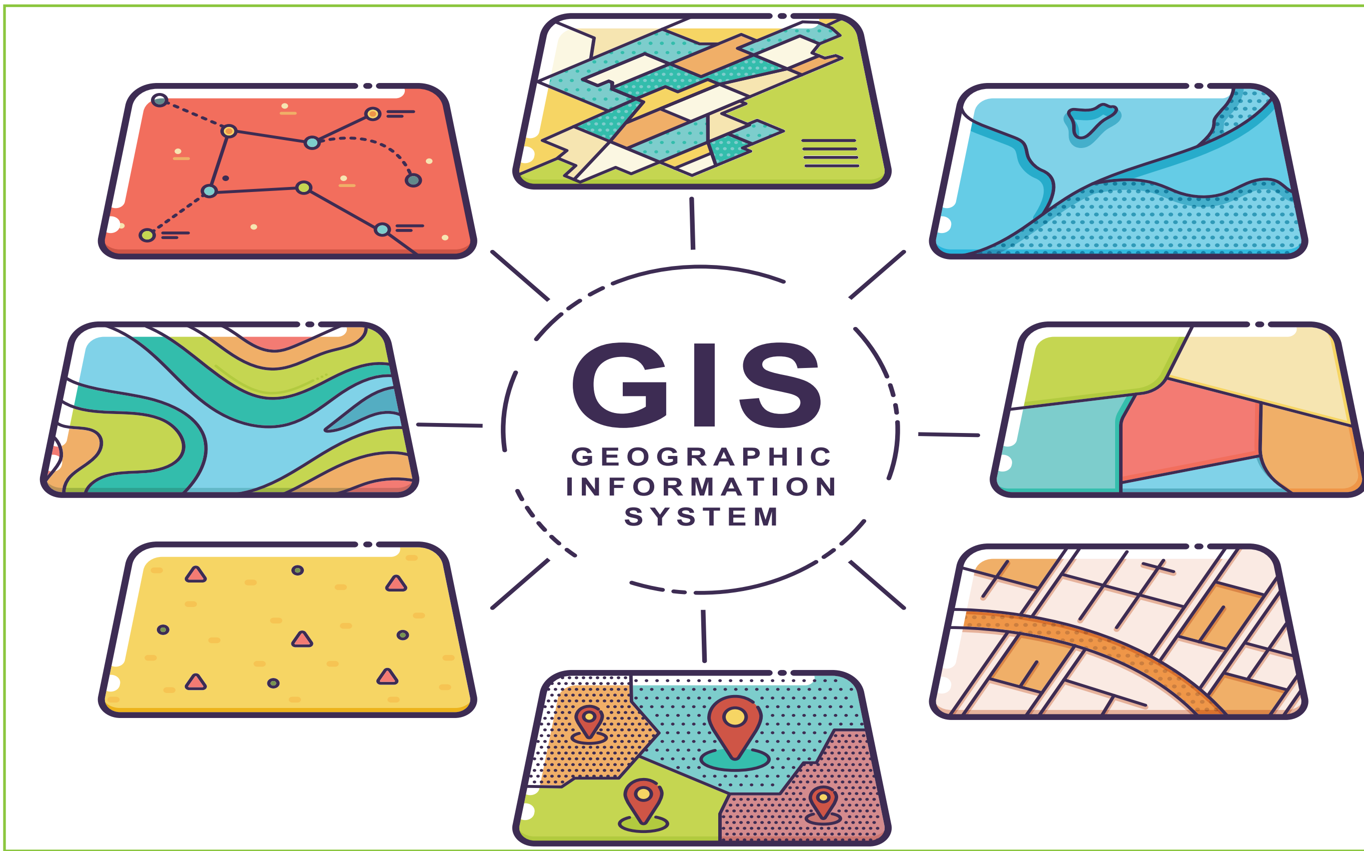
GIS furthermore delivers at high speed detailed and precise calculations of derived watershed characteristics, flow statistics, and debris flow probability. GIS software tools provide consistent and reliable methods for watershed analysis using Digital Elevation Models (DEMs) to delineating watershed boundaries and standardized datasets such as land cover, soil properties, gauging station locations, and climate variables (ESRI, 2015).

Other examples of GIS application include:

- Exploring both geographical and thematic components of data in a holistic way
- Stressing geographical aspects of a research question
- Handling and exploration of large volumes of data
- Integration of data from widely disparate sources
- Analysis of data to explicitly incorporate location
- Visualization offering a wide variety of forms

1.3 Challenges of using GIS

GIS is a very useful tool for application in multi-disciplinary and integrated sectors such as watershed management planning, but there are challenges because GIS is data dependent. Data must be fundamentally appropriate and accurate, data management processes must be properly developed and maintained, and analytical methodologies must be properly selected and applied from both technical and institutional perspectives, for GIS to serve as a reliable decision-making tool. Other major challenges at institutional level include; Familiarity with the tools, familiarity with watershed management concepts, and tool integration into the planning process, in particular to facilitating the effective linkages among technical, social and ecological components of watershed management and planning through GIS.



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2. Preparation and collection of data

GIS depends on data. Data are therefore the basic building blocks for GIS based watershed management and planning. Two different types of data are fundamental to GIS application: Spatial/ Geographic (location based) data and Non-spatial (Socio-economic, environmental, demographic, etc.) data.

Data of various characteristics, of different time scale and from various sources are used and analyzed for informed and better management and planning decisions. The physical and natural features of a sub-watershed are the base data which must be gathered for management planning which will allow characterizing sub-watershed and learning about the complexities (Prah & Lisec, 2013).

Even if existing data from secondary sources appear sufficient, systematic compilation and assessment of existing data can identify data gaps and reduce the cost of the data collection. The data requirement varies from regional to local level of analysis and output. Pre-analysis of data requirement is thus essential prior to any sub-watershed level (or other) data collection exercise. The requirement analysis should consider components like essential GIS data layers, a scale and spatial reference system and GIS data structure.

In order to set standardization of data and mapping and to maintain work consistency, it is important that a uniform and homogenous method of presentation can easily and effectively be followed by all involved in baseline data preparation and collection. The data should meet the basic minimum standards in its organization and format, internal detail, data content and representation.

2.1 Data collection procedures

For the preparation and collection of a spatial database for watershed management and planning, the following procedures should be considered:

- Careful and thorough assessment of information requirements. Preparatory work on what is required, how it can be collected and where to get it should be considered.
- Data required for watershed planning varies for different management objectives, watershed problems, existing conditions and available resources. Data collection and studies can be divided into three phases; i) collection and use of existing information, which should be used to the greatest extent possible; ii) New data and information vital to watershed planning and iii) Long-term monitoring to fill additional data gap (FAO, 1997).

- Data acquisition is among the most time-consuming aspects of any GIS project. Generally two types of data are collected from the field. Primary data refer to data that are obtained via direct observation or measure, and Secondary data refer to existing data collected and/or documented by others.
- Identifying the data sources is the starting point for collection of data. Before data collection, a list of data sources should be prepared and related organization/institutions approached for data collection/sharing. A central collection of relevant maps, reports and records can be created and regularly updated.
- Collection and review of existing data is the first step toward comprehensive survey and planning of a watershed.
- After the existing data have been collected and analyzed, a preliminary survey plan can be drawn up to check, add and update the existing information. This will reduce survey time in the field.
- Data should be collected or produced in an orderly manner so that all of the necessary planning work can be completed within the given/agreed time period.
- Basic information/data collection for watershed management planning is generally confined to physical and natural features (watershed boundaries, hydrology, topography, soils, climate, habitat, wildlife), land-use/land cover and population characteristics (land-use, existing land management practices, demographics, population densities, settlements), water bodies and watershed conditions, and available maps.
- Preliminary survey plan assessments typically include a:
  - Description of existing natural resources,
  - Analysis of the existing condition and situation of these resources,
  - Assessment of the possible measures to be taken
  - Identification of watershed management measures
- When going to the field for primary data collection using technical devices such as GPS, an operational manual should be available for reference (for example, how to turn on devices, how to record points with devices, etc.),
- Standard methodologies should be developed for collecting spatial data so that there is no gap and overlap (for example: starting data collection from the right side along the road). Field areas can be subdivided into different geographic parts and have a target coverage area for each day.
- After the data collection, at the end of each day, check the quality of the data, identify mistakes and errors, and then discuss how to avoid the problems for further data collection.
- Identify the spatial data and feature type as point, line or area to collect or measure from the field. Set the standard set of attributes (background/additional information) to be collected for each feature type collected, for example: Road name, road type, river name, settlement name. How to represent each feature in a database should also be determined and standardized. For example: Point Feature: spring water source, structure, etc.; Line Feature: road, irrigation canal, etc,; Polygon Feature: Sub-Watershed Area; Catchment Management area, etc.
- Units of all data items must be carefully defined and applied with rigorous consistency.
- Data formats should be defined using standard protocols and common terms of reference, so data collected by other agencies and with varying scales can be compared and put to use.
- Data formats should be consistent over time, and should include measures of data quality that will facilitate updating and continued use over time.
- Baseline data and spatial information for watershed management planning are:
  a. Topographic features, Landform, Elevation
  b. Water features, sources/associated features
  c. Land cover/ land-use
  d. Administrative units, Settlements
  e. Infrastructures and Services
  f. Environmentally Sensitive areas/sites


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3. Implementing GIS: Exercises

3.1 Introduction to ArcGIS

GIS analysis is carried out using GIS computer software programs. There are many GIS software programs available in the market. ArcGIS is one of the most widely used GIS programs. The ArcGIS software system has three key components:

1. **ArcGIS Desktop**: ArcGIS Desktop is used by GIS professionals. It is GIS software for Windows computers and is for mapping, data compilation and management, spatial analysis, and creating maps and geographic information. It has three product levels: **ArcMap, ArcCatalog, ArcToolbox**. The full suite includes **ArcScene** and **ArcGlobe**. ArcMap is the application which allows you to create and modify maps and analyzing (2D) spatial data. ArcCatalog is interface for data file management similar to windows explorer where you can create, rename, copy, delete and manage datasets and other files. ArcToolbox is another component which incorporates all spatial and attribute processing tools. In addition to these applications, ArcScene is another interface with 3D capabilities (like terrain mapping). ArcGlobe and ArcScene combine to provide an interface similar to Google Earth for 3D studies.
2. **ArcGIS Server**: This is a server-based implementation of ArcGIS. It is widely used in enterprise GIS implementations and Web GIS applications. ArcGIS Server also includes enterprise geo-database management and transactional support.
3. **ArcGIS online**: ArcGIS online includes online maps and geographic information. Users can find, use, and share information using any ArcGIS client. ArcGIS.com website provides a web interface that enables users to work with online maps and geographic information using Web browsers and mobile devices.

The exercises in this chapter are to be carried out using the ArcGIS Desktop. ArcMap is the main ArcGIS module used for mapping, including creating, viewing, querying, editing, composing, and publishing maps. ArcMap is what you will be using for the majority of your GIS work. The project/document (i.e ArcMap document)created in the ArcMap will have the ".mxd" extension.

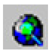
The objectives of the exercises are to:

- familiarize with ArcGIS as a GIS tool for exploring spatial and attribute data.
- explore different tools available for feature representation and processing.
- map, assess and analyze a sample watershed for management planning using ArcGIS.

3.2 File Management in ArcGIS

- Use only projected spatial data for analysis.
- Use the same spatial reference (projection system) for all raster and vector data.
- Select appropriate projection based on the standard coordinate system.
- Organize all the data for a GIS project into a single parent folder as far as possible.
- Keep the backup of baseline and processed data in separate folders.
- Keep names of folders, layers, and attributes short.
- Do not use spaces or special characters in any of the layer (file)names and always start layer (file) names with a letter.
- Develop a standard layer nomenclature and apply it consistently.
- Save your ArcMap project often and save after each processing task and major function.
- Do not open, operate or process same data at the same time in multiple ArcMap projects or ArcCatalog.

3.3 Starting ArcMap

- The working folder for the data and hands-on exercise is WMP_TRN.
- To open the ArcMap window, different options are available. 1) From Start menu (Start -> Programs -> ArcGIS ->ArcMap), or 2) by clicking on the ArcMap icon  in the Desktop, Start menu or Taskbar.
- Open ArcMap using one of options listed above and you will now have a new project, with two primary display areas: table of contents (left panel), and the map view (right panel).
- Once ArcMap is open (ArcMap> Getting started window) See Figure 2. The window provides the options to:
    1) create a new map
    2) create a new map using a map template
    3) open an existing map, or
    4) open the most recent map saved.
- Here we will most often use options 1 and 3 (creating a new map for the first time, and opening existing maps if one has worked with ArcMap earlier).
- Create a new "blank map". Click "OK" on the ArcMap Getting Started page. An untitled, ArcMap document should appear. Note the "Table of Contents" section on the left side of the screen.
- The top part of the ArcMap window contains the menu with drop down sub menus and toolbars. You can add or remove required toolbars by right-clicking on the top portion of the window (the gray part).
- The left panel (Table of contents) of ArcMap locates GIS data layers (Layers). All the data to be used will be placed here. There are different options to display data layers in a table of content (Figure 3):
    1) list by drawing order
    2) list by sources
    3) list by visibility
    4) list by selection, and
    5) other options.
- The list by Drawing order tab shows the layer name, (to make the layer visible check mark box left to layer name should be ON). The Source tab shows the path of GIS data file storage. The Selection tab shows a list of GIS layers in the active data frame and lets you select layers.
- To the right hand side you can see the ArcCatalog and Search Menu. By using these menus we can

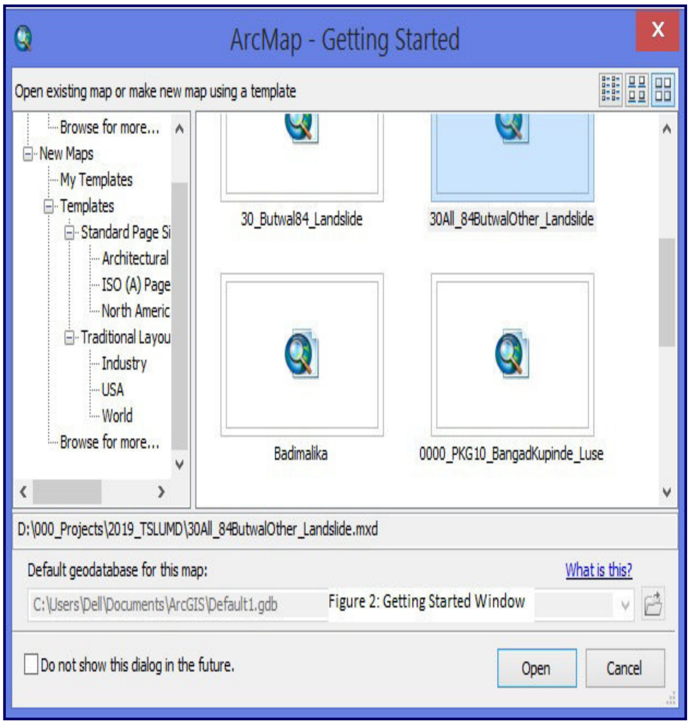


Figure 2: Getting Started Window

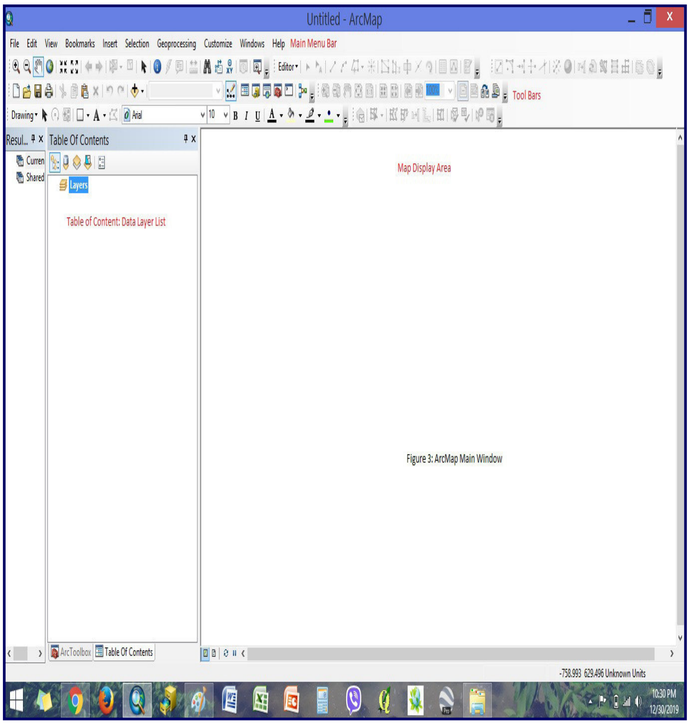


Figure 3: ArcMap Main Window

search and drag the folder to bring in the ArcMap Content Tree (Figure 4).

- The right panel of ArcMap is the Map display area for GIS data layers. In this panel, you can select either "Data View" which is a platform for display and processing of data or "Layout View" which is platform for final map presentation and production.
- In the Data View, you can use different tool bars for different purpose e.g. zoom in and out, pan, identify, select, etc. (Figure 5a).
- One of the most commonly used tool bars is the Standard Toolbar (Figure 5b) which includes standard file operation and processing tools. Using this toolbar you can open Catalog and Tool Box windows .

3.3.1 Exercise A: Adding and exploring data

!Before starting! *You cannot have two map documents (.mxd files) open at the same time in one ArcMap window.*

- To open a new map document, either open a new ArcMap window from the main menu or close the existing map document and open the new map file from the file menu.
- To add data to a map document (e. g. Data location folder ...\WMP_TRN\), you can use one of the following options:

1. Use the "Add data" button from the ArcMap toolbar Navigate to folder and file and click OK.
2. Navigate to File menu and select > Add Data> Navigate to folder and file and click OK (Figure 6)
3. Open ArcCatalog; navigate to the data file location and Drag and Drop data from ArcCatalog. Note that to Drag and Drop the file both ArcCatalog and ArcMap should be open. At first you may not be able to locate the folder.
4. Click on Connect to Folder icon and browse to WMP_TRN/Badimalika folder. You will find three folders inside WMP_TRN folder. Double click on Badimalika/Shapefile folder where you will find GIS data layers (Figure 6) Note that GIS layers will be set sequentially: Point layer/s at the top and polygon layer/s at the bottom.
5. Select an individual layer and click add or select all data layers by pressing shift button and click on add. All the files will be added to ArcMap window.
6. Try to turn the layers on and off by clicking the tick marks along the layer names. Use zooming in and out and other options from tool bars.
7. Use the Identify button to see what attributes the layers have. Select the Identify tool and click on a map feature in the map to display its information.
8. Now we will display the settlement name. First Check off all the layers and display only settlement layer Badimalika_Sett. To display the name of settlement,

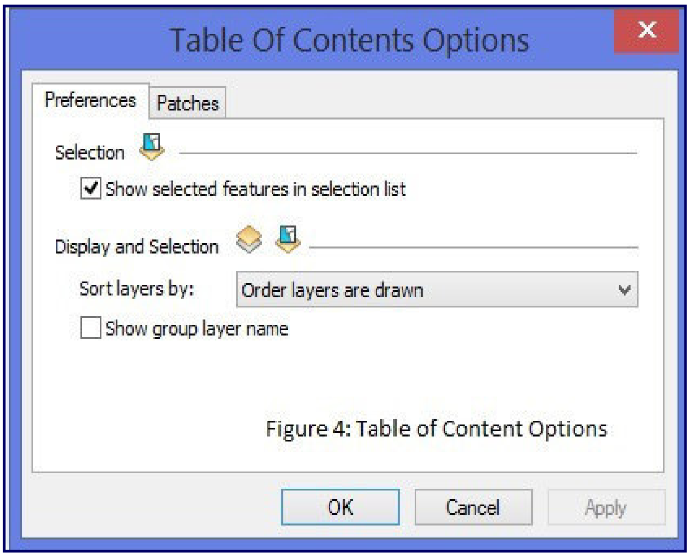
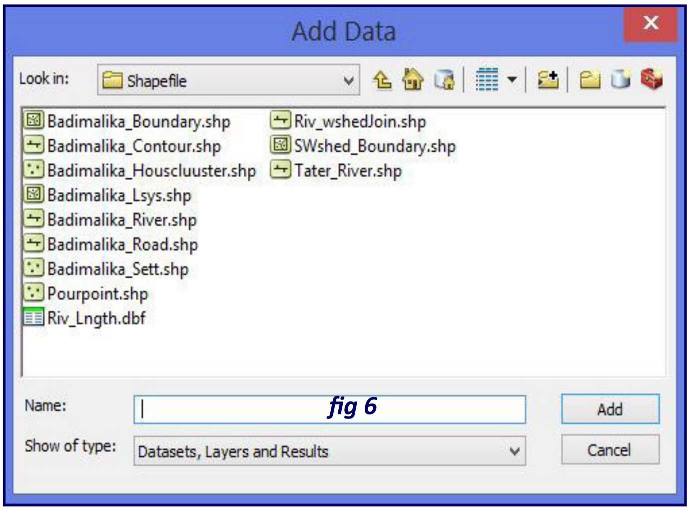
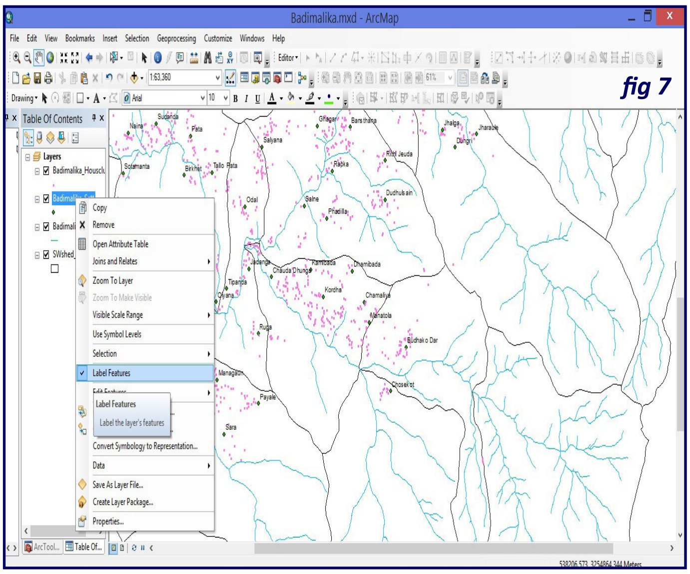


Figure 4: Table of Content Options



Right click on layer and click on "Label Features". The Names of all the settlements will be displayed. Zoom in to see which settlements are there.

9. SAVE your file: Go to File > Save as or use the Save button to save the ArcMap document. Save under WMP_TRN folder with file Name "Badimalika". The extension for saved ArcGIS file will be .mxd and the file name - "Badimalika.mxd" will appear at the top of ArcMap window (Figure 7).



3.4 Exploring Symbology and map layout

- Before preparing a map for printing/ reporting, you need to give suitable colors and symbols for point and line features. Double click on symbol of each layer and explore different colors, sizes and symbols by clicking on each option from symbol selector window. Try to symbolize the settlement layer with Symbol: Square 1, color: sign red, and size: 4 (Figure 8).
- ArcMap has two different view windows. Displaying and operating and analyzing is carried out in "Data View" using different toolbars. Making and printing maps for presentation or report purpose is a distinct function from displaying and analyzing. Designing map layout for print is carried out in "Layout View". When you switch to the Layout View, a different range of tools are activated and used to navigate.
- To switch to "Layout View," click on the icon at the bottom of map display that looks like a piece of paper (next to the globe icon), or, from the View menu go to Layout View. All the layers that are visible (selected on) on the table content will be added to layout view (Figure 9).
- From the "Insert" menu you can insert Title, Legend, North arrow, scale, etc. in the layout view. Try to insert these items in your layout view.

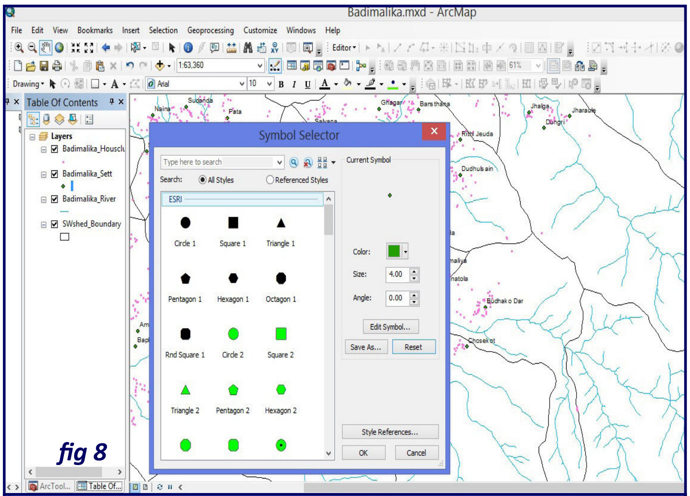


fig 8

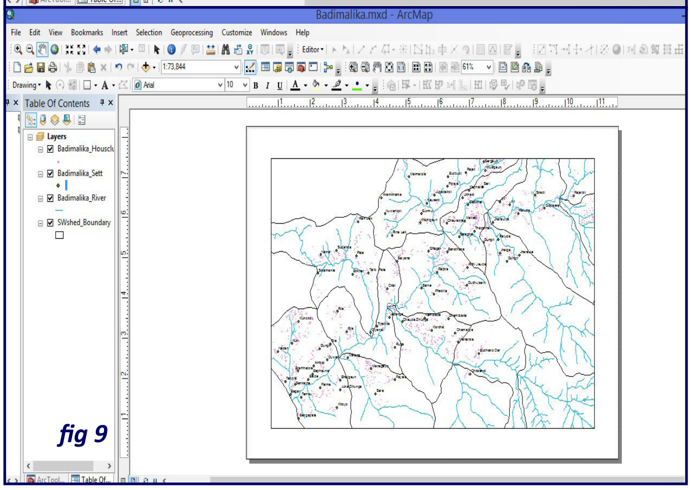


fig 9

3.4.1 Exercise B: Exploring ArcCatalog: Data File Management Platform

- ArcCatalog functions similar to Windows File Explorer. It is a platform to manage GIS data files and folders.
- To start ArcCatalog, click on the Start menu and navigate to All Programs -> ArcGIS ->ArcCatalog or click on the symbol from taskbar or ArcMap window, if it is open (Figure 10).
- From the left-hand display, Navigate to your GIS folder WMP_TRN. You should see various folders. If you click on the Badimalika folder, all the folders and data layers stored within will be listed here on the Catalog tree. On the right panel there are three tabs: Contents (list of files), Preview (Data Map, Image and Table), and Description (Description of data/file). Hint: If you do not see any file or folder click on the "Connect to Folder" button.
- In the left hand panel, click on the Badimalika_ Settfolder and on the Right panel click on the "Contents" tab. Then double click a file within the Contents window. This will bring you to another window. Explore the Coordinate system and Fields options. These options detail related projection and attribute info without opening the file in ArcMap.
- Click the "Preview" tab in the right-hand display. This will show you graphic and table views of data. If "Geography" option is selected from the bottom dropdown menu a graphic view is shown. A table of data will be displayed if you select "Table" from the lower dropdown list in the "Preview" tab.

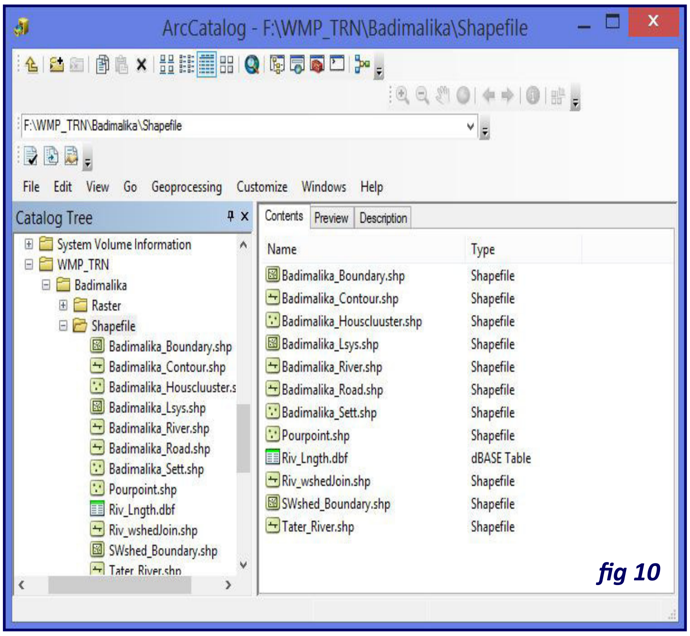


fig 10

- Click the "Description" tab at the top of the right-hand display. You will see processing details for the data layer documented.
- You can Create, Rename, Copy, Move, or Delete files and folders in ArcCatalog. Deleting or moving files from ArcCatalog means that the data is being permanently removed/deleted. Try to create new file by Right clicking > New >Shapefile (Figure 11)

- What happens? You need to define different properties of the file being created. Just stop here. Creating new features will be covered in an upcoming exercise session.
- You Should Know: A single Shape file format of GIS data (e.g. Badimalika_sett.shp) is a combination of multiple files. Just to see how many files a single shapefile contains, open Windows Explorer and navigate to GIS data folder and open the Badimalika folder. Many files will be displayed with different file extensions than those you see in ArcCatalog window. A shape file contains at least three files (.shp- file which stores feature geometry), (.dbf-files which stores attributes of feature geometry) and (.shx – which is index file of .shp and .dbf). Besides these there are many other files created as GIS processing is done.

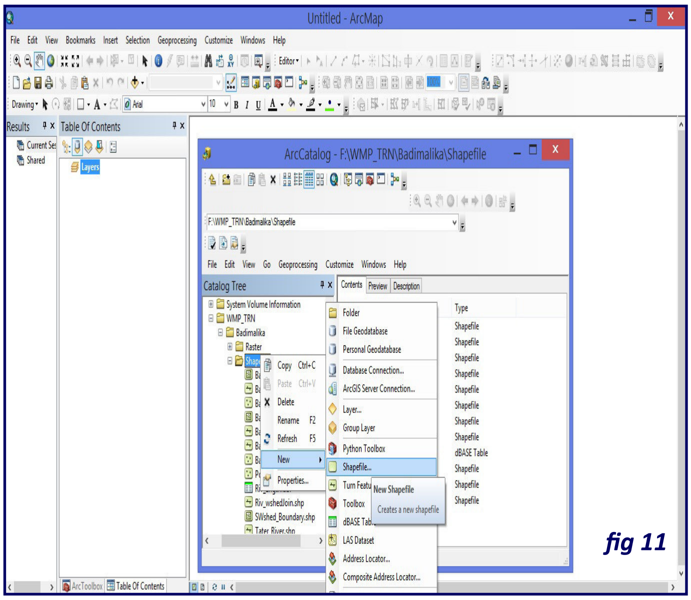


fig 11

3.4.2 Exercise C: Creating Spatial Feature

Objective: This exercise will assist you to create three different types of features: points, lines and polygons (area), assign attribute values to those features and edit shapes (Figure 12).

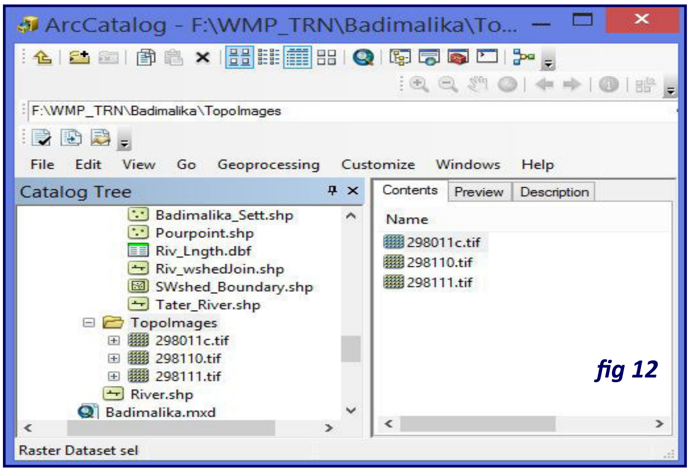


fig 12

When creating spatial data in ArcGIS, both the ArcCatalog and ArcMap platforms are used. Data layer files are created in ArcCatalog. Features are displayed on the screen in ArcMap. The Editor environment is used in ArcMap to create and modify spatial features to represent various natural and man-made features.

> Creating the Point Feature

- The Point is the simplest feature to create. While creating a layer for a point feature, attributes can also be created at the same time. The GIS layer file you will create will be as shapefile with .shp extension. To create a new point shapefile (Figure 13);
- Open New ArcMap document and add 298110.tif file which is located in WMP_TRN\Badimalika \TopoImages folder (.tif is a scanned raster file: Note the difference in the symbols between a shape file and a raster file).

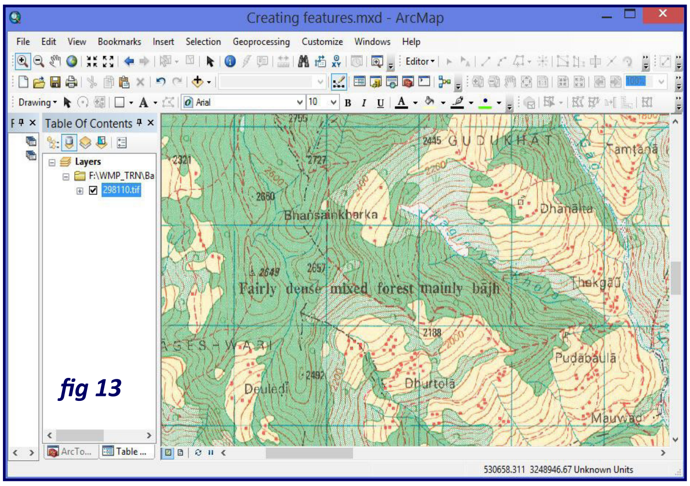


fig 13

- This is a scanned Toposheet image (1: 50,000 scale) of the Badimalika area. This will be your Basemap to create a point feature and you will be creating service points (hospital, school, police station etc.) from this image (Figure 14).
- Before entering data you need to create data file where data will be stored.
- Open Arc Catalog either from the Start menu or from ArcMap and browse to: WMP_TRN \ Badimalika folder
- Right Click on: Badimalika folder and browse to NEW.
- Click on Shapefile and type “Services” under name option.

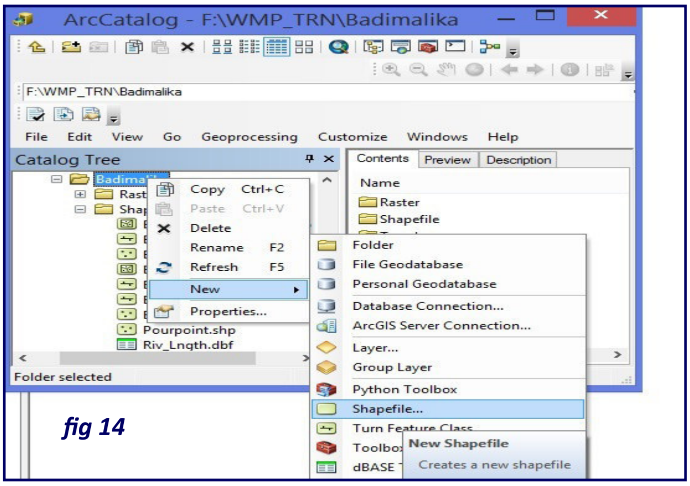


fig 14

- Select “Point” under Feature Type. Point is default for feature type selection.
- Click on Edit in order to define spatial reference (Figure 15).
- You will be importing spatial reference that was already defined to the298110.tif raster image file.
- Click on Import and Browse to the location ...\WMP_TRN\Badimalika\TopoImages\288007a.tif and click add (Figure 16).
- Now the file is ready for entering data using Create Services as Point feature. This newly created file will automatically be added on ArcMap’s Table of Content. If it is not added, Drag this file to Table of Contents of the ArcMap window and drop it.
- An empty shapefile named “Services” is now added to your ArcMap window.

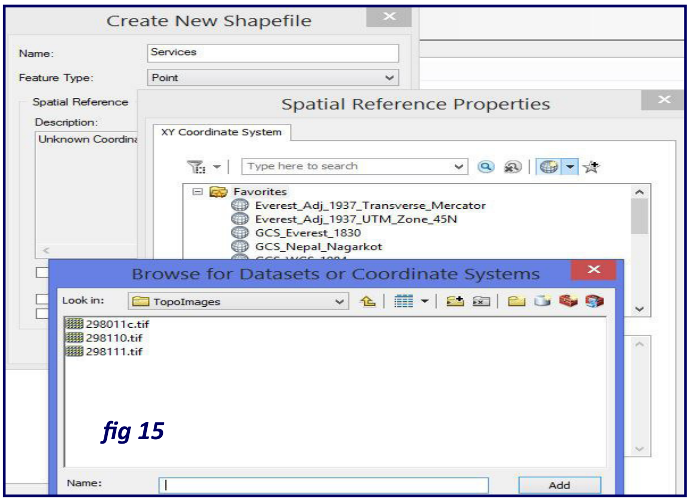


fig 15

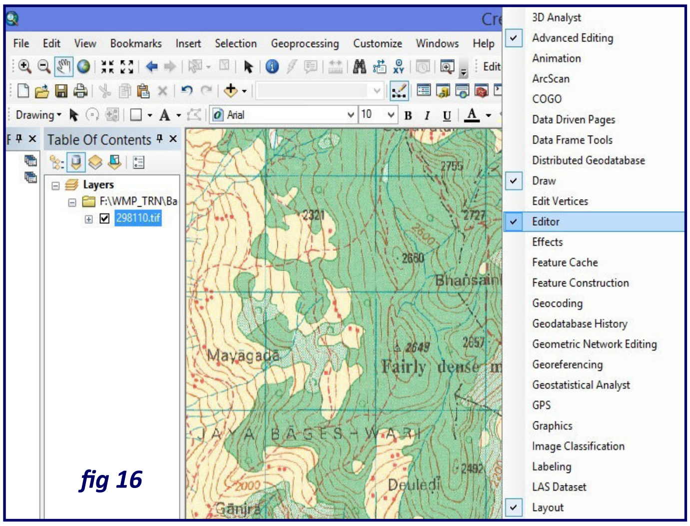


fig 16

- We need to add the Editor Toolbar to create and edit spatial data. To do this Right Click on any empty space of the main menu bar to add toolbar and click on Editor. Editor tools will be added to your toolbar.
- Zoom around the Badimalika, Martadi area (which is at the north-eastern part of image map) and look for different types of services (displayed with different symbols). You will be creating schools, temples, police stations, petrol pumps, etc. Symbols of these point features on the topographical map are shown in Figure 17.
- Now Start Editing by Clicking on Editing > Start Editing menu. Editor menu will be activated and create feature window will open (Figure 18).
- Select Services layer in Create feature window and the Point tool next to Editor Menu and click on any point symbol you want to digitize. Don’t forget to note the symbols you have clicked.
- Add at least 5 different types of services by clicking on each symbol.
- Now you will add attributes (Type of services such as school, hospital etc.) to service points. Stop editing by going to Editor Menu and save edits.
- In order to add attributes, first a new field must be added to the table. Right Click on the layer name Services, and Click on the Open Attribute Table option.
- Click on Add field > Name as “Type” (Figure 19).

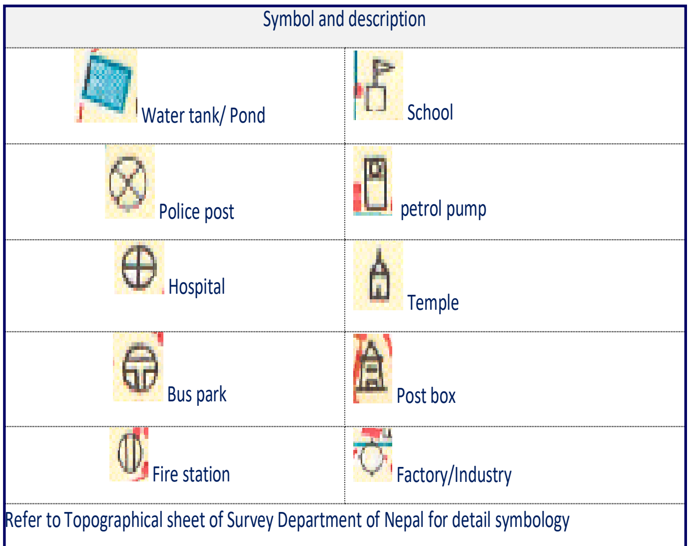


Figure 17: Symbols from Topographical map

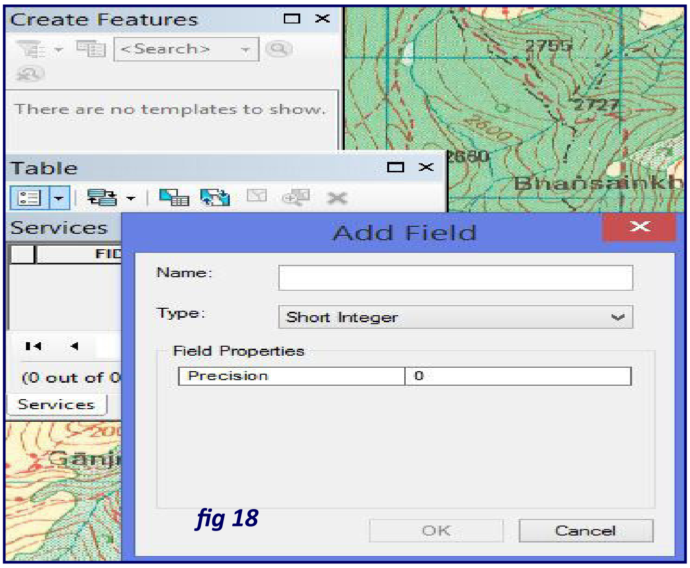


fig 18

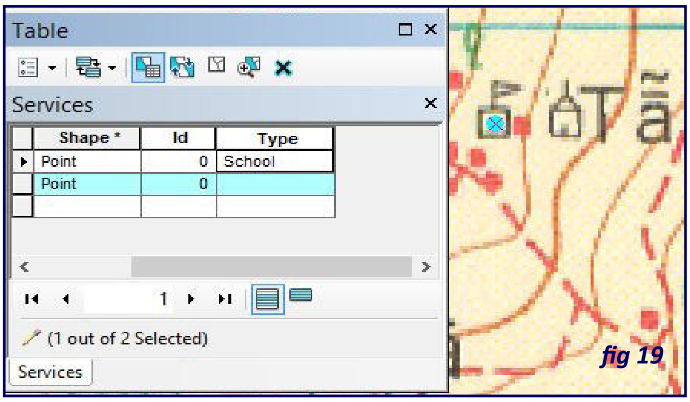


fig 19

- Under Data type select text from drop down menu (as we are entering service type Categories) and length as 20 (i.e. 25 is the number of character values to enter) and click OK. A file named Type will be added in the table.
- Start Editing again as you should be in editing mode to enter attribute information in a table. Select the first record (selection will be in blue color) in a table. Notice that the corresponding point in a map will be selected.
- Check which symbol it represents in the topographical map and double click on the Type field and type accordingly (i.e. if map has School symbol assign the point as “School”).
- Save your work in your working directory once completed.

> Creating Line Features

Now you will create a River line feature. A feather River is represented with a blue line in a topographical map. The steps will be similar as creating point but while creating a new shape file, select “Polyline” from the dropdown menu for Feature Type instead of selecting the default Point option (Figure 20).

- Open Arc Catalog and browse to folder WMP_TRN\Badimalika. Right Click and browse to NEW.
- Click on Name and type “River” within the name option field and choose Polyline from the Feature Type menu option list.
- Click on Edit in order to define a spatial reference. You will be importing the same spatial reference that was already defined to the 288007a.tif raster image. Click on Import and Browse to the location.\WMP_TRN \Badimalika\TopoImages\298011c.tif and click Add > Apply and OK.
- Right Click next to the menu at the top of the ArcMap window to add the Editor Toolbar if it is not already added.
- Zoom into the Martadi area within the image to find a river on the map image (e.g. Bahuligad, Anaigad etc). Then select Start Editing from Editor Menu (Figure 21). The Create Features window will display.
- Select the Line tool from Editor Toolbar and start creating a line by clicking along the road. You can use the Pan tool to shift the map image as needed. In this case you will need to select the Line tool again from the Create Features window to continue creating the line.
- Double Click to end line segment.
- To add an attribute: Open the Attribute Table.
- Click on the dropdown menu. Add Field > Field Name “RiverName” (Figure 22). Type “Text”> Length “25”
- Select road segment and enter the given name from the map. Remember to Save your work before you stop editing.

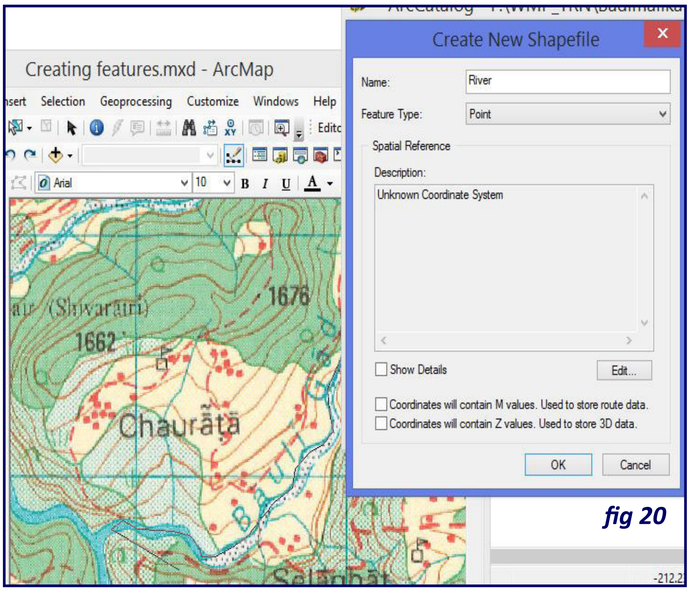


fig 20

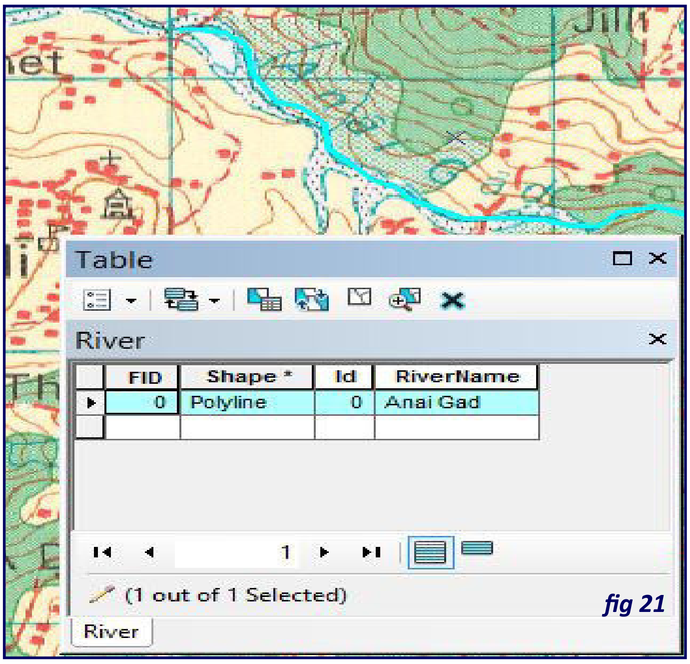


fig 21

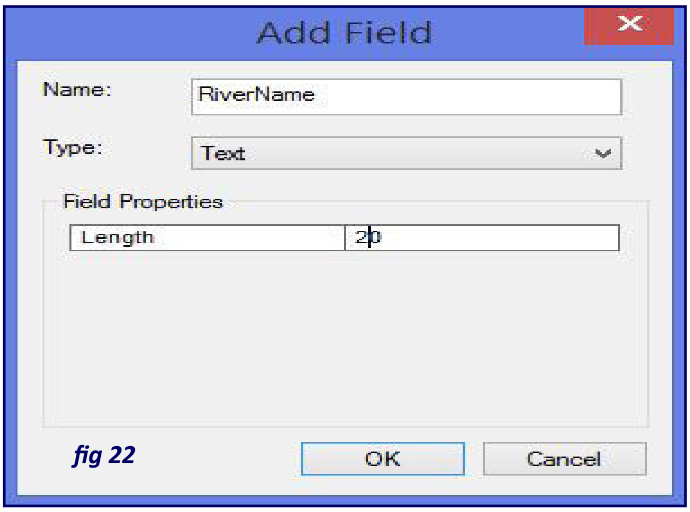


fig 22

3.5 Catchment/ Watershed delineation in GIS

Catchment/ Watershed delineation is often the first step of GIS application in watershed management planning. It is the process of identifying the drainage area of a stream or river network. Remote sensing, Digital Elevation Models (DEM) and Geographic Information System (GIS) are tools that can be used for the delineation of watershed. The delineation of watersheds can be carried out manually using scanned topographic maps or automatically generated using hydrology tools within GIS software programs.

The base topographic data necessary for Catchment/ watershed delineation are: the hydrology features (streams, rivers, wetlands, lakes, etc.), and the elevation (contours, spots, digital terrain model points, etc.). The automated derivation of watershed data from a Digital Elevation Map (DEM) is faster, less subjective, and provides more reproducible measurements than traditional manual techniques applied to topographic maps (Abdulla, 2011).

First understand basic concepts and identify major feature points of catchment in a map image before using GIS software to create a catchment boundary shapefile. This will make digitizing easier and contribute to relatively accurate boundary delineation.

The traditional method of determining and marking the catchment boundary is through the use of map contour lines. Contour lines are lines of equal elevation on a topographic map, meaning that any point along a given contour line is at the same elevation (Figure 23).

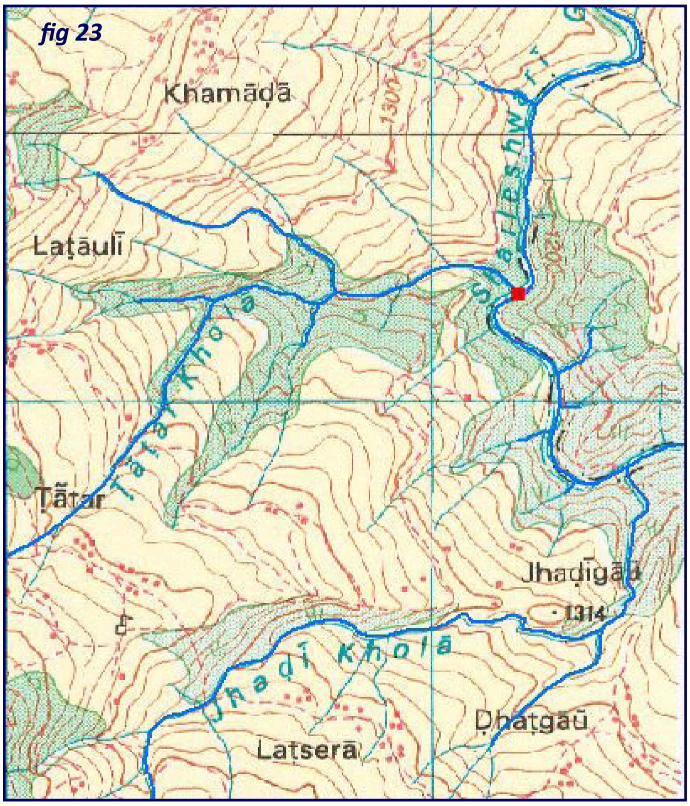


fig 23

Basics to understand before delineation of a sub/ watershed or other catchment boundary using a topographic map include (source: USGS):

- Streams and rivers are shown by blue lines on a topographic map.
- Contours lines are shown by brown lines. Darker and thicker brown lines indicate major (index) contour lines and lighter thinner brown lines are intermediate contour lines.
- Contour lines point upstream (forming V shape) as they cross over a stream or river
- The closer the contour lines, steeper the terrain; conversely, the further apart the contour line are, the flatter the terrain.
- Water is assumed to always flow directly down the steepest slope. The steepest slope is perpendicular to the contour lines on a topographic map.
- Concentrically closed contour lines represent a peak or local high point from where water will flow down, perpendicular to the contour lines. (Or, concentrically closed contour lines can indicate a closed basin with no distinct outlet.)
- Assuming generally higher elevations to the North (top) of a map, then upward curved contour lines indicate a water flow line ("V" shape), and downward curved contour lines indicate a ridge line which divides the water flow into opposite directions.
- Figure 24 indicates the watershed components as identified by topographic contour lines.

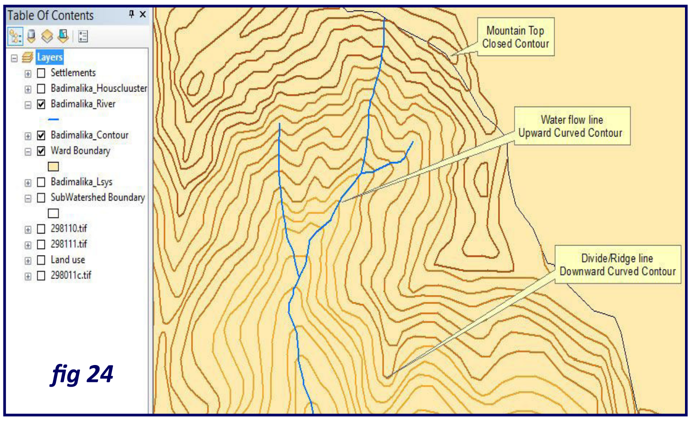


fig 24

In order to delineate a catchment/watershed one needs to identify the point on the stream that is the lowest elevation of the watershed of interest. If identifying the entire sub-catchment then this is the point where the stream/river meets another river (or other body of water).

For example, the red point shown in figure 25 is the confluence of the Tatar Khola and the Shaileshwori River. Though in some cases the identification of a sub-catchment area above a particular point (such as a water collection point or cross drainage structure) might be necessary. The process is essentially the same.

- To delineate the Tatar Khola watershed boundary, identify the highest elevations surrounding Tatar Khola, by identifying the peaks (either small circled contour or other elevation points with height information indicating local high points. Indicate the highest points above the catchment area using the Draw tool to mark a series of points. Any point symbol can be used as shown in Figure 25.
- From the lowest elevation point (i.e. the red point in this example) mark a series of points along the uphill flow path (i.e. the path perpendicular to the contour lines). Do this on both sides of the drainage channel.
- The series of marks should encompass all upstream tributaries of the catchment channel, and should divide the area from adjacent catchment areas. A line connecting the series of marks should not cross any drainage channel except at the lowest point (i.e. the red mark in this example). A line connecting the series of marks will be the catchment boundary.

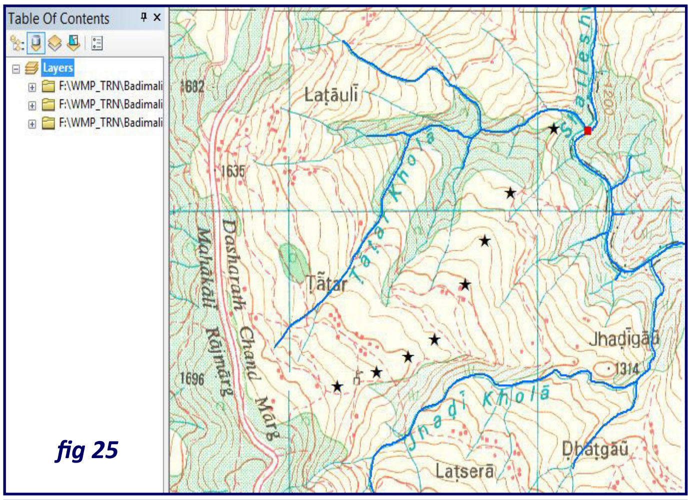


fig 25

3.5.1 Exercise D: Creating a watershed boundary

In this exercise you will be creating a polygon catchment boundary using two steps: firstly, using ArcGIS and secondly, using the online mapping platform GoogleEarth.

- Select **Polygon** from dropdown menu for feature type when creating new polygon shapefile from ArcCatalog (Figure 26).

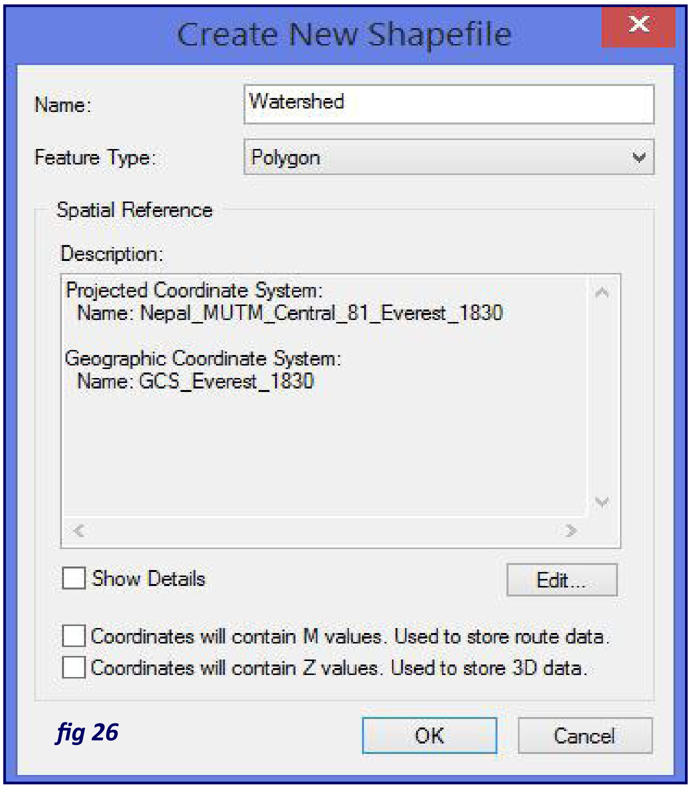


fig 26

- Add Tater_River.shp from WMP_TRN Badimalika\ Shapefiles folder and298011c.tif image from WMP_TRN\Badimalika\ TopoImages folder. Zoom to Tater Kola area. Tater Khola flows from west to east and joins the Shaileshwori Gad.
- Open Arc Catalog and browse to WMP_TRN\ Badimalika\Shapefiles folder and Right Click and browse to NEW. You will see the dropdown menu of Shapefiles. Click on Name and type "Watershed" under name option and select polygon from feature type menu (Figure 27).

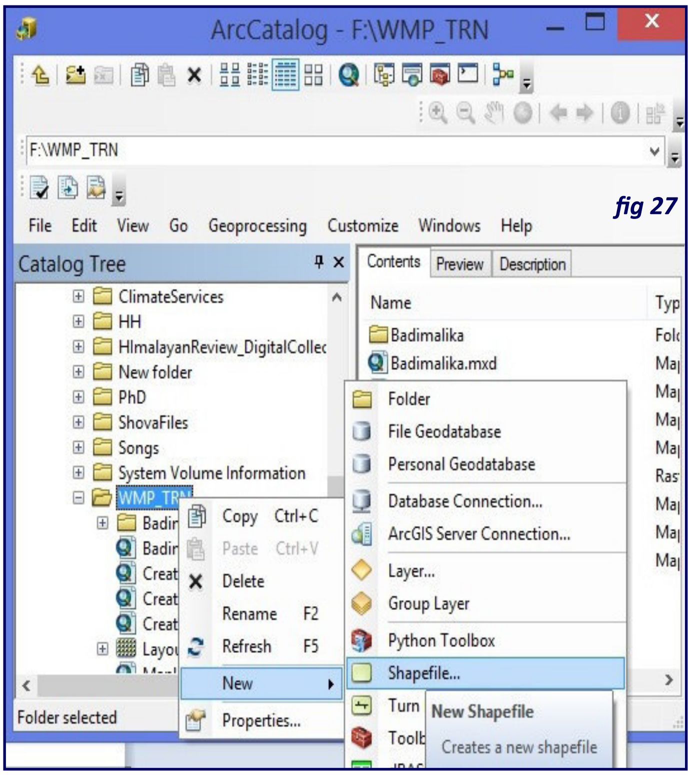


fig 27

- Click on Edit in order to define spatial reference. You will be importing spatial reference that was already defined to 298011c.tif image.
- Click on Import and Browse to the location WMP_TRN\Badimalika\TopoImages\298011c.tif and click add > Click Apply and OK.
- A new shapefile named "Watershed" will be added to ArcMap window. Right Click on empty space of menu bar at the top of ArcMap window to add Editor Toolbar if it is not added.
- Zoom into Tater Khola section. You need a river layer for spatial reference to create the watershed boundary.
- Go to Editor > Start editing> Select Watershed and click OK. From Create feature window select polygon tool.

- Zoom properly and Start digitizing perpendicular to the contour lines. Use the Pan tool to continue or move the mouse by pressing the left button. When complete, double click to end. Do NOT worry about error if you have created some. You can always edit later. Save your edits and stop editing. Once completed, your Watershed boundary should look very similar to that shown in Figure 28.
- Now we will calculate the area of the watershed. Open the attribute table of Watershed.shp by right clicking on the file name. Add field name "Area_Ha" and select data type as Double. A Field will be added to your table.
- Right click on Area_Ha field and select Calculate geometry. Click Ok after verifying property as Area and Units as square meters (Figure 29).
- Now you have to convert the area in square meter into Hectare. Compare your calculation with other participants: Are the results the same?

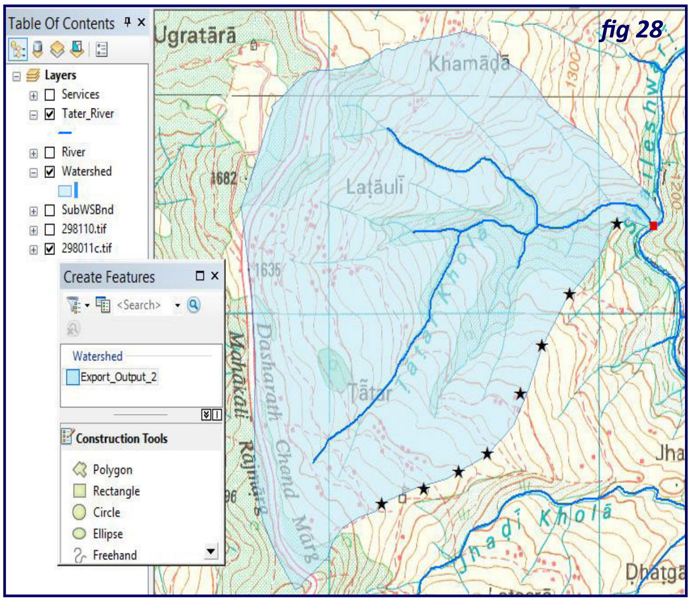


fig 28

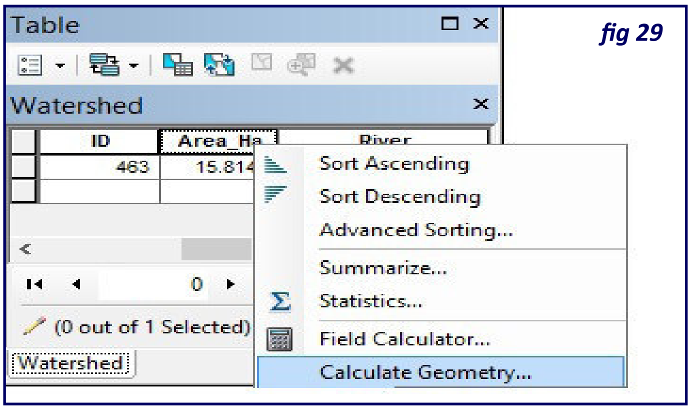


fig 29

We will now try to create the same watershed boundary using Google Earth. For this exercise an internet connection is required, as well as downloading and installation of GoogleEarth.

First you need the Tater_River.shp file as a reference to be displayed in GoogleEarth. So you need to import it to Google Earth file format using following steps:

- Open GoogleEarth and import the file using File > Import option (figure 30).
- Select file format as "ESRI Shape (*.shp). Data will be added and Google Earth should automatically zoom in to the Tater Khola area (as shown in corresponding Figure 31).

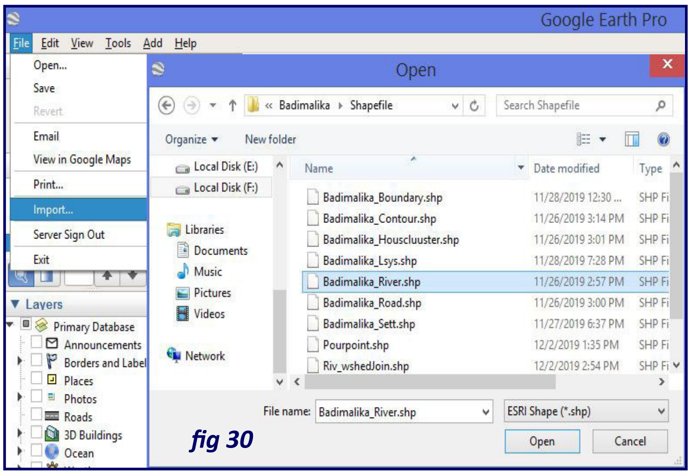


fig 30

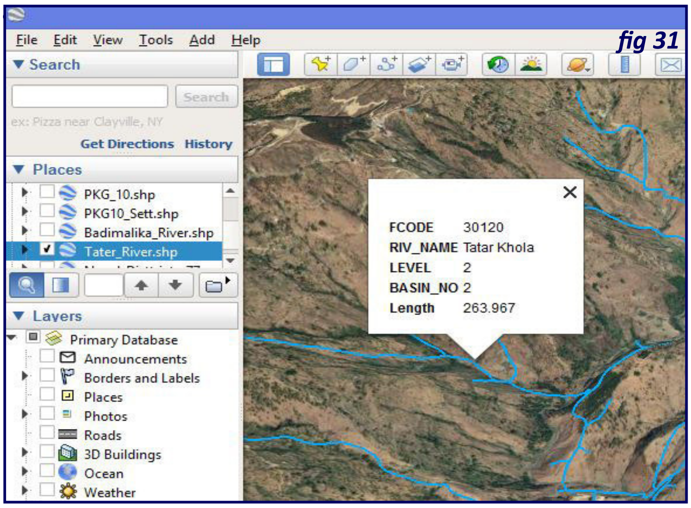


fig 31

- Hold the Shift key and scroll the mouse to get a convenient 3D view. You can also use navigation tool to orient properly.
- Select the Add Polygon tool from the tool bar and you will get a New Polygon window. Type the name as Tater Watershed.
- Choose width and choose Yellow color 2 as Line options by clicking on Lines > Color and Width .
- Click on Style, Color and change 0 % opacity in Area. Click OK (Figure 32).

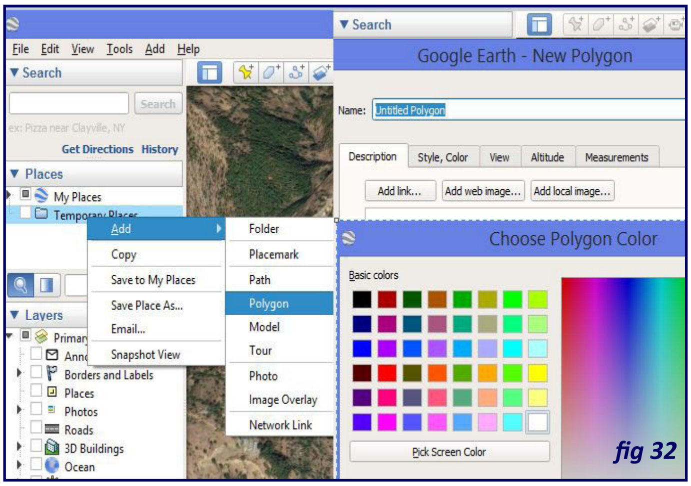


fig 32

- DO NOT Click OK on New Polygon window unless polygon creation is fully complete. This file will be created under temporary place/My place.
- Now drag the cursor along the ridge line following it till you come to the point you have started.
- Once completed your watershed boundary should look like as corresponding Figure 33.
- Once completed, Right Click on Tater Watershed name under My Places and select: Save place As> Browse to your folder WMP_TRN\Badimalika folder and Save under the same name as the kmz file (this is an extension for maps created in Google Earth).
- You cannot directly add or open Kml/kmz file in ArcGIS. First you have to convert kml file to layer file. For this you need to use the Tool Box.
- Open Tool Box by clicking on Arc Toolbox. Select Conversion Tools > From KML > KML to layer (Figure 34).
- Browse to WMP_TRN\\Badimalika folder, select Tater Watershed.kmz as input KML file and the same name for the Output data layer.
- Browse to WMP_TRN\\Badimalika and you will see Tater Watershed.gdb. Double Click on it until you find Placemark, and add Placemark_polygon. The Catchment Boundary of Tater Khola created using GoogleEarth will now be displayed. Now Calculate Area by repeating same process you have done before.
- Compare the area and shape created using ArcGIS and GoogleEarth. What is the difference?

3.6 Mapping for Watershed Management Planning

3.6.1 Exercise E: Selecting feature by attribute query

Attribute and Spatial query are core GIS functions. The most common way to make a query in GIS is through "Query Builder", for selecting or querying features based on attribute tables. This is a very powerful tool, by which you can select features or table records in any data format supported by ArcMap. In ArcGIS you can specify the following attribute selection methods:

- Create a new selection: This is the default and you should start there unless you have already selected features from the layer or table.
- Add to current selection: Use this option to add features selected by this query to features you have already selected. Don't forget that these previously selected features could have been selected in any number of ways, such as by using Select by Location (adding sub-set to already selected set).
- Remove from current selection: This option removes features selected by this query from features you have already selected. This will keep all features except the selected features (the selected sub-set will be removed).
- Select from current selection: This option keeps only

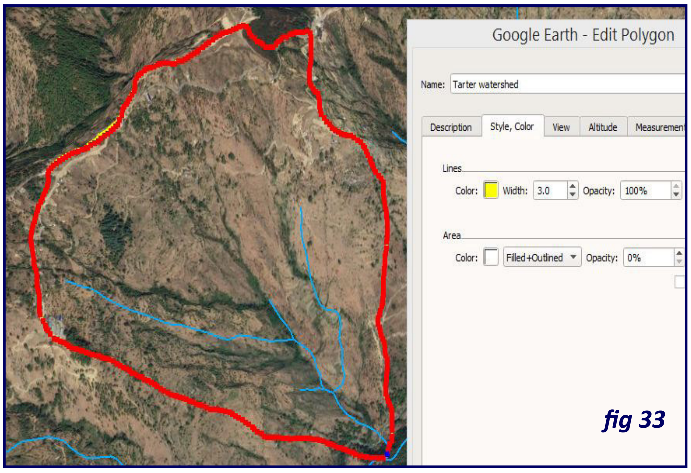


fig 33

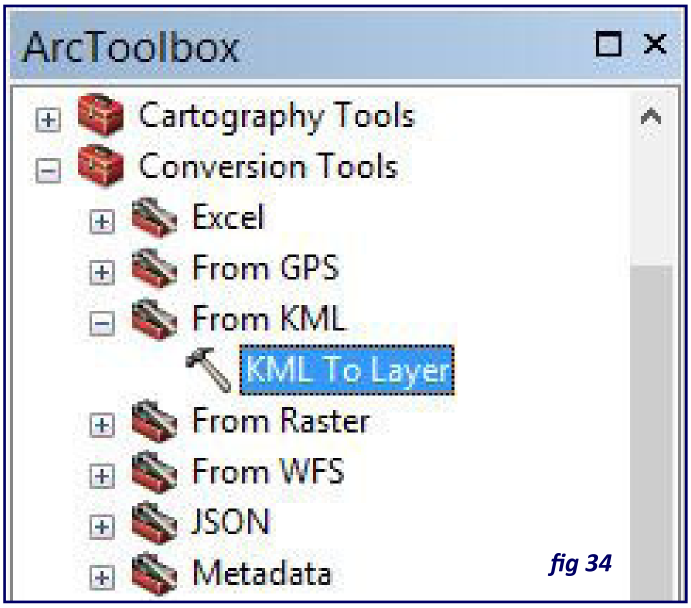
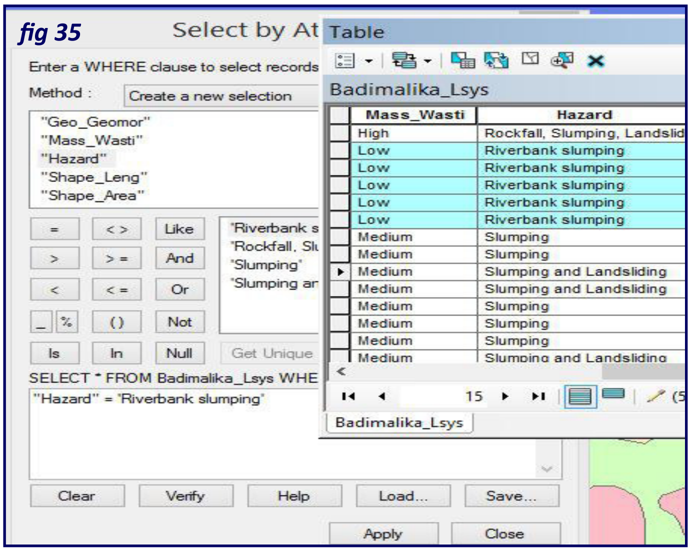


fig 34

those features you select in this query. The selected sub-set will be kept (all others will be removed).

3.6.2 Exercise F: Finding areas of potential river bank failure

- Open new ArcMap and add Badimalika_Lsys.shp from WMP_TRN\Badimalika\ Shapefiles folder.
- Open the attribute table from the Table Options and click on "Select by Attributes". An Attribute Query box will open (Figure 35).

fig 35


- Define a query condition for selecting. Double click on “Hazard” and click on “Get Unique Values” you will see all values listed under “Hazard” field.
- Single Click on the “=“ symbol (equal to) and Double click again on “Riverbank slumping” and click OK. Areas of potential river bank failure will be selected (Figure 36).
- How many polygons are selected and what is the total area of risk of river bank failure? You can make a separate layer of this by right clicking on Badimalika_Lsys> Data > Export Data and giving output name “RiskArea” under D:\WMP_TRN\Badimalika\Shapefiles folder. Add this layer to the current Table of Content.
- Try to select areas having risk of landslides following the same procedure.

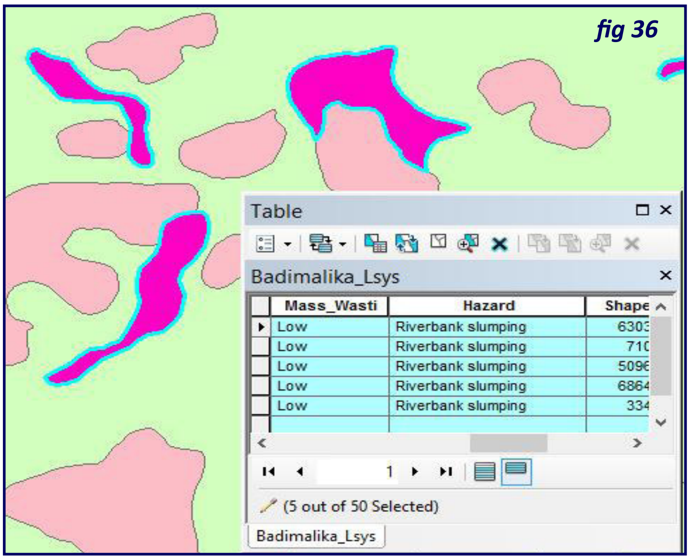


fig 36

3.7 Spatial query

Spatial analysis is a process used to examine the relationship between features. The relationship between features can help support decision-making processed. Features in one layer can be used to select features in another layer in GIS through Spatial Query. The Select By Location function allows for spatial query and the examination of multiple layers to determine what type of spatial relationships exist between layers and selection based on those relationships. Select by Location can answer spatial queries such as: How many water sources are there in a sub-watershed? Which settlements are vulnerable to landslides? What forest areas are within a certain distance of a village?

3.7.1 Exercise G: Finding out house clusters within riverbank slumping areas

In this exercise we will use GIS to find house clusters within a riverbank slumping area. We will use the Select By Location Spatial query tool because there is no such information in an existing table or layer (Figure 37). We will find the house clusters based on spatial the relationships between two existing data layers: Badimalika_Lsys and Badimalika_Housecluster.

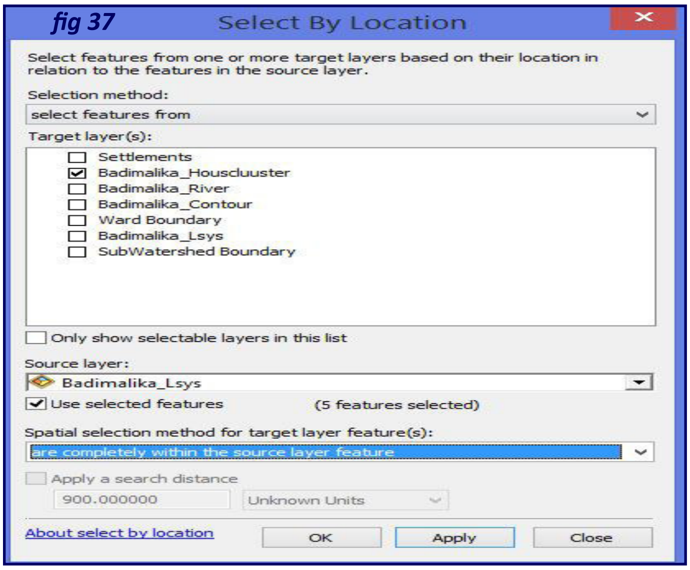


fig 37

- From the Selection menu, choose Select by Location. A dialog box displays. In this dialog box, the spatial analysis operations are defined with choices from the drop-down list.
- In the “Target layers” select Badimalika_Housecluster layer by clicking on the box. Choose Badimalika_Lsys from the “Source layer” option.
- From Spatial selection method, select “Target layer(s) features are completely within Source layer features”. DO NOT FORGET to tick on “Use Selected feature” if it is not already checked on.
- Click apply and OK. House clusters within “River bank slumping” polygons will be selected (Figure 38).
- Now open attribute table of “House clusters”. What is the total number those are within? Find out how many schools and health services fall inside the river bank failure risk area.

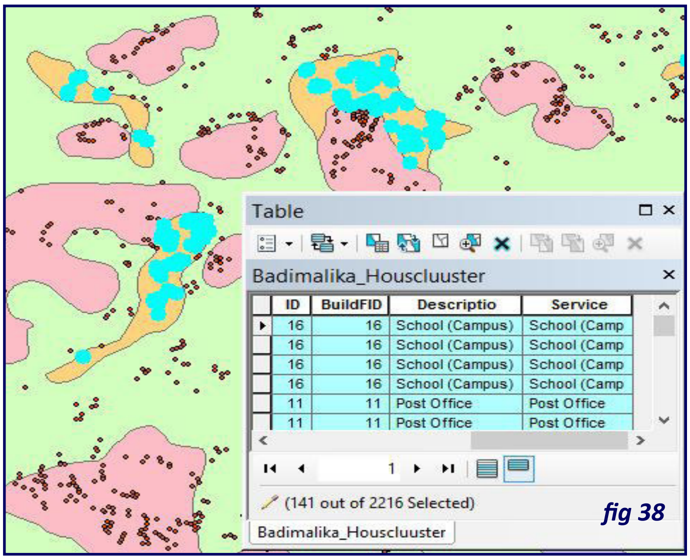


fig 38

3.8 Geo processing (Clipping)

Clipping allows the user to extract a sub-set (e.g. rivers) from a shapefile of a feature that covers a bigger spatial extent (e.g. extract sections of rivers which are within a single ward area among all wards). For example this exercise shows how you can extract rivers within ward 7 of Badimalika Municipality.

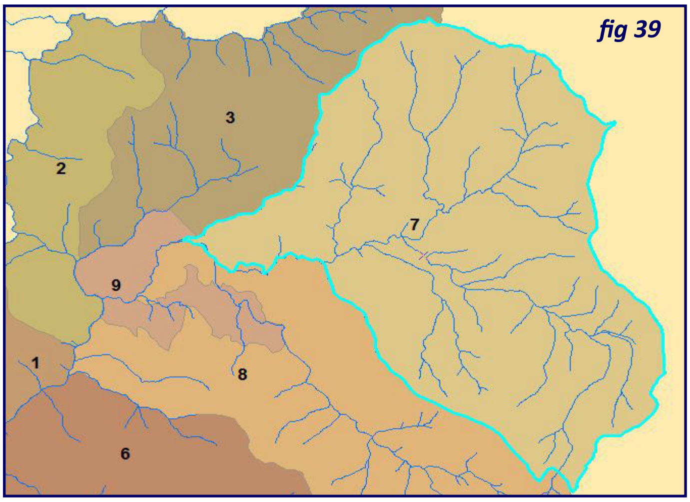


fig 39

3.8.1 Exercise H: extracting feature for area of interest

- Open ArcMap and Add Badimalika_Boundary.shp and Badimalika_River.shp (Figure 39).
- Select Ward number 7 from the attribute table.
- Open the Tool Box next to Catalog by clicking on the Toolbox symbol
- Click on Analysis Tools > Extract > Clip. A window will open.
- Select "Badimalika_River" as Input Features and Badimalika_Boundary as Clip features.
- Browse to WMP_TRN\Badimalika\Shapefiles folder and save filename "Ward7_Riv" as Output Feature Class (Figure 40).
- Processing will take little time. Add Ward7_Riv.shp to table of content.
- What is the total length of rivers within Ward 7 of Badimalika?
- How do you calculate the drainage density of Ward 7 of Badimalika?

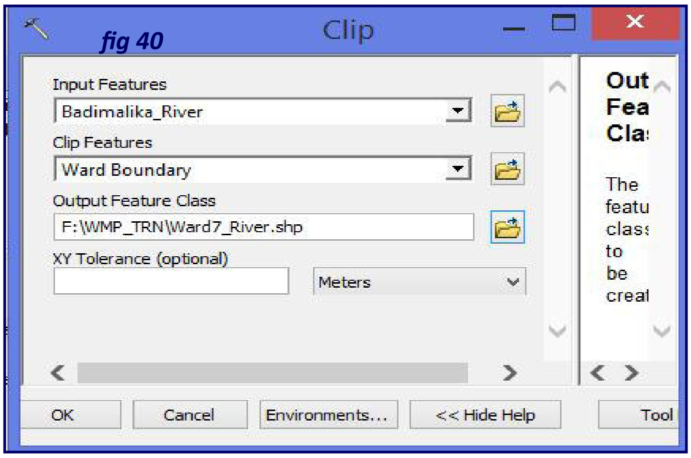


fig 40

3.9 Preparing maps for presentation and reporting

Once you have completed processing and analysis in GIS, you may want to prepare a map to put it in a presentation or report. You can print directly from ArcGIS or export maps to various graphic image formats. But before printing or exporting maps some basic preparation steps should be followed:

Setting up printer or plotter:

- To set or change the printer, Go to File menu and Open the Page and Print Setup dialog box and use the Name drop-down to set the current printer (Figure 41).

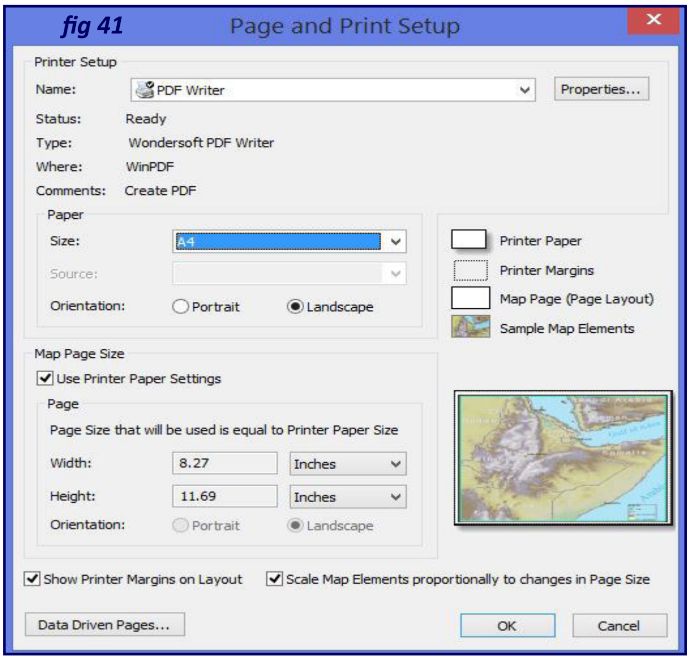


fig 41

- Set the page size of your map layout: Click File > Page and Print Setup on the main menu to open the Page and Print Setup dialog box. Choose appropriate Paper and Page size.
- Do not forget to Uncheck printer page setup.
- Do not forget to Check "Scale Map elements proportionally to changes in page size"(Figure 42).

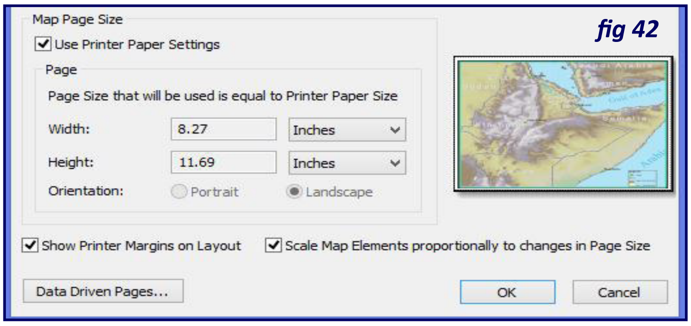


fig 42

3.9.1 Exercise I: Preparing layers with appropriate symbols

- Open New ArcMap and set up printer and page size.
- Add Badimalika_Sett and Badimalika_Boundary from WMP_TRN\Badimalika\Shapefiles folder. Similarly, add "landcov2014" from WMP_TRN\Badimalika\Raster folder.
- You need to change the original shape file name of all three added layers for display in the map legend. This is only for display purpose and you are NOT changing original filename.
- Right click on "landcov2014" layer and Go to General Tab and type "Land use" in the Layer name box. Similarly, change "Badimalika_Boundary" to "Ward Boundary" and "Badimalika_Sett" to Settlement.

- Assume that you also want to display the settlement names in a map for presentation. For this, you need to indicate which field in the attribute table of your map layer you want to use as the basis for labels. Right click on Ward Boundary and check on "label features".
- An option also exists to automatically label all of your features using above options. This saves time if you are happy with the way the labels look, but it offers you much less control over the label placement.
- If you want to change the attributes of a label, Right click on Layer > Go to Labels > Select field from the Label field dropdown menu. Click on Symbol to change the size, style, or font for your labels.
- To delete your labels, Right click on layer and check off Label features or go to the Label Properties box and remove the check mark from "Label Features in this layer" box.

3.9.2 Exercise J: Symbolizing map for presentation

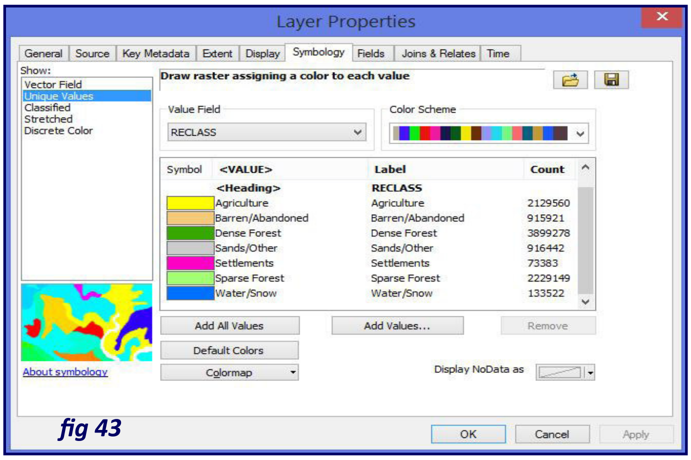


fig 43

- Right click on Land use and go to properties.
- Click on Symbology > Click on Categories on the left side (you are going to show land use categories). Click on Unique Value (Figure 43).
- From Value field drop down list select "RECLASS"(land use categories are represented under this field).
- Click on "Add all values" > Uncheck All other values and click Apply, OK.
- Simialrly, symbolize settlement and ward boundary. The Ward boundary should be only an outline.

3.9.3 Exercise K: Map layout

So far you have used Data View in ArcMap which is platform for processing and displaying data. However map prelaration for printing can't be done in the Data View platform.

To prepare a map for printing you need to switch to "Layout View" (Figure 44). To switch to "Layout View," click on the icon at the bottom of your map display that looks like a piece of paper (next to the globe icon), or from the View menu, go to Layout View. When you switch to the Layout View, you have access to a different range of tools.

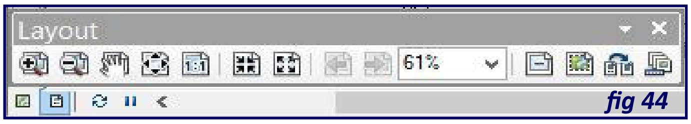


fig 44

A Layout toolbar will be activated which provides tools for zooming in and out for Layout View.
When you are in Layout View, Data View tools to zoom in / out and the Pan tool will be active. But in general DO NOT USE these tools while you are in Layout View. Layout View also has its own tools for zoom in / out / pan indicated with a little white box under the magnifying glass or hand (see above). The Layout View tools affect the extent of the layout sheet (e.g., printable paper) being displayed on the screen. Try experimenting with the layout tools.

To insert a title, legend, North arrow, neat line, etc. on your map (Figure 45):

- Click on the Insert menu and select the object that you would like to add.
- Try adding a title, legend, scale bar, north arrow, and text one by one. Experiment with adding information to your map. For example using text you can include your name as "prepared by: <Your Name>".
- You can delete any of these objects by clicking each object and then pressing the "Delete" key.
- A map needs a legend to explain the map features, as well as a Scale and a North indicator. You must include these elements on any map used for circulation or presentation. ArcMap gives you great flexibility in formatting your legend. To add a legend, from the Insert menu go to "Legend." Your first choice is what map layers you want included.
- Select the Landuse layer. If you have more than one layer in the Table of Contents, all layers will be listed in the Legend item box. You can change the order as you like. To change the order, click on the name and press the up or down arrows.

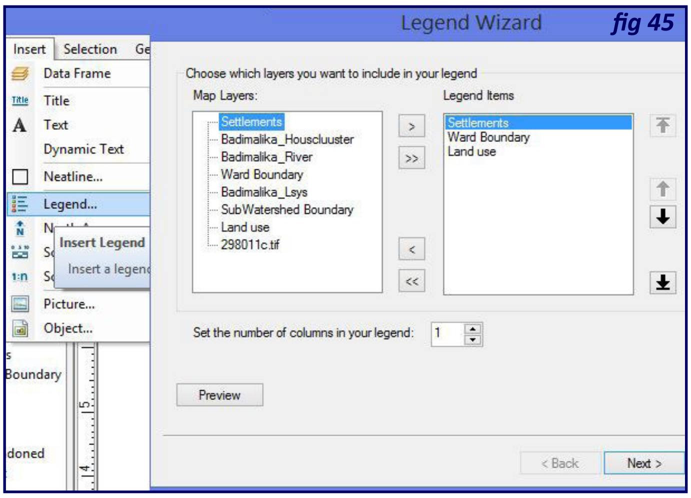


fig 45

- Similarly add a North Arrow and Scale bar of your choice. Your final map should have these elements. Try to prepare maps as shown in figure 46.

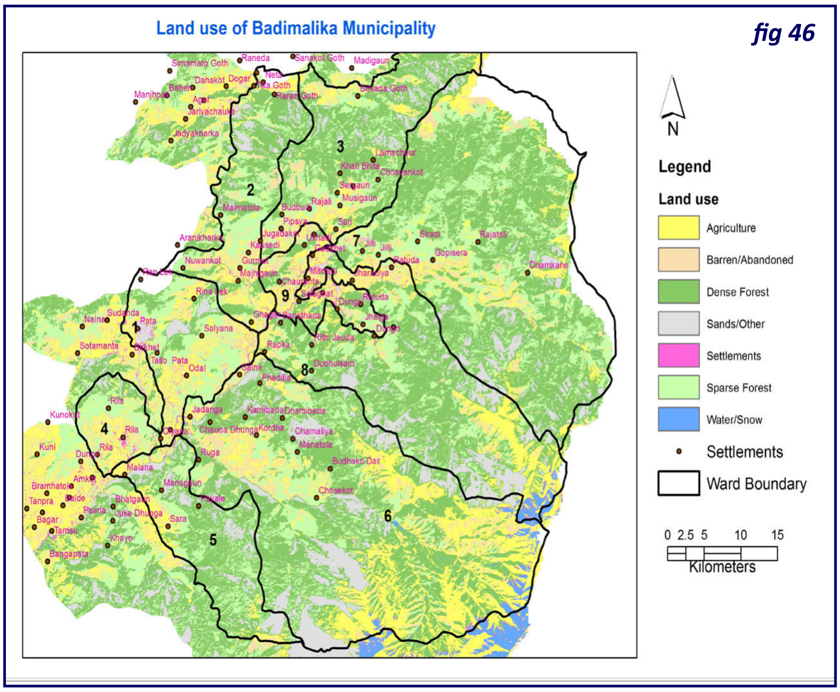


fig 46

Exporting Maps

If you just need paper copies of your maps, you can directly print from ArcGIS. But if you need to insert maps into PowerPoint or word processing files, will need to export your maps. Once you are satisfied with your map, you can export a map from ArcMap to various graphic formats. From the File menu, go to "Export Map." Type an appropriate name and location and choose the format you want to export in the "Save as type" dropdown menu. Exported map images can be inserted into PowerPoint and Word documents, etc.

3.10 Preparing for GIS Application

3.10.1 Working with raster data

Spatial data is represented using either vector or raster format. Raster data consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature or rainfall (ESRI, 2010).

The raster model does not explicitly collect the coordinates of each cell, but, rather, the values of each cell. The structure of raster data is simple and is often used as the source data for spatial analysis with the ArcGIS Spatial Analyst extension. Raster data structure is most suited for representing continuous landscape and surface such as elevation, slope etc. In raster datasets, each cell (which is also known as a pixel) has a value.

The cell values represent the phenomenon portrayed by the raster dataset. Height (distance) could represent surface elevation above mean sea level, which can be used to derive slope, aspect, and watershed properties. Cell values can be either positive or negative, integer, or floating point. Integer values are best used to represent categorical (discrete) data and floating-point values to represent continuous surfaces. However, while working with raster data (grid cell) there are certain factors to be considered:

- **Spatial Extent:** Despite the simple data structure, raster overlay analysis requires that all overlain raster layers cover the identical spatial extent. Otherwise, the processing and the output result will be of the smallest spatial extent, or the analysis will fail.
- **Cell size:** The dimension of the cell size representing the area covered on the ground is also referred to as Spatial Resolution. The smaller the cell size, the smoother or more detailed the raster will be. However, a greater number of cells increases the file size and associated storage space requirement. Conversely, if cell size is too large information may be lost or subtle patterns may be obscured.
- **Projection:** Raster analysis and processing should not be carried out using un-projected or undefined coordinate systems. Using different projections among the layers will also create problems (i.e. mis-alignment of layers). In summary, all overlain raster layers must be in correct spatial alignment.
- **Raster data file naming:** The file name of a raster data file should not exceed 13 characters.

3.10.2 Converting Vector to raster

Vector data is used to represent topography and surface features such as spot height, elevation contour, elevation zone, etc. using idealized model elements as points, lines and polygons, with various associated attributes (Figure 47).

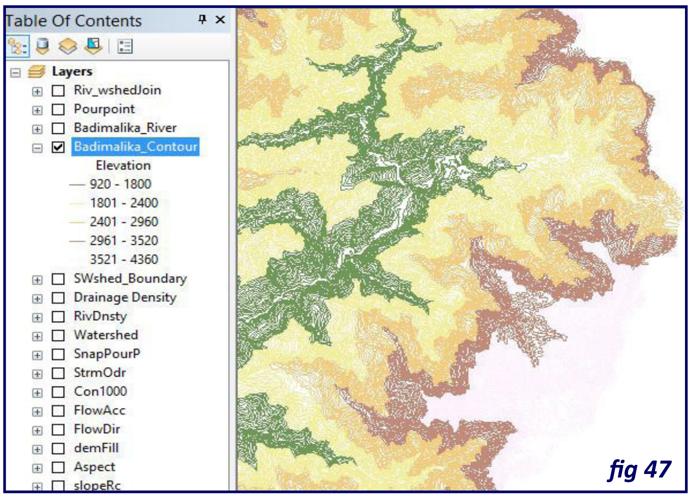


fig 47

But data such as elevation, slope, etc., and other continuous variable topographic or other data can be better represented using a grid of cells with a unique data value associated with each cell. Vector and raster systems each have distinct advantages and disadvantages.

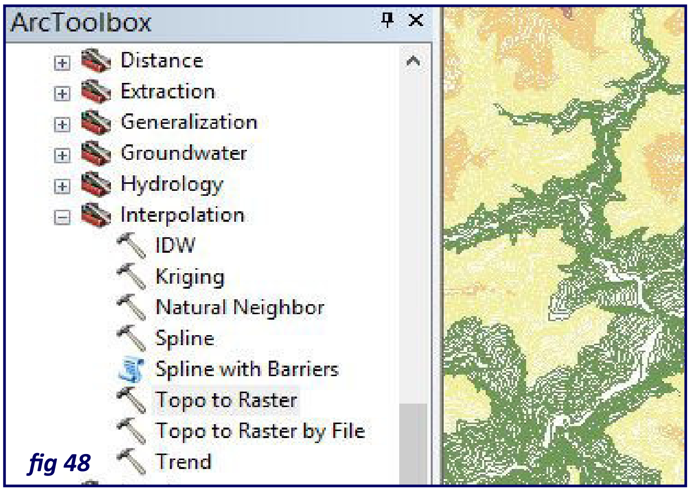
Sometimes it is advantageous to convert from one system to the other. In general such conversion results in some loss of data accuracy. However, sometimes advantages in ability to manipulate the data in various ways is more relevant than data accuracy.

The following exercise demonstrates converting a topographic surface in discrete (vector) into continuous raster structure for analysis purpose.

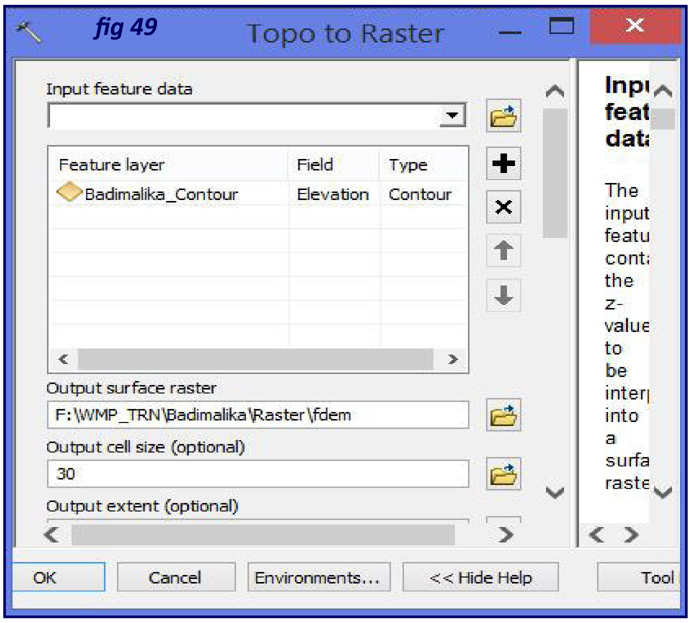
3.10.3 Exercise L: Creating a Digital Elevation Model from contour line data

A Digital Elevation Model (DEM) is an elevation model representing a continuously variable surface elevation as a grid of discrete cells, each cell representing a defined section of the surface with an associated elevation.

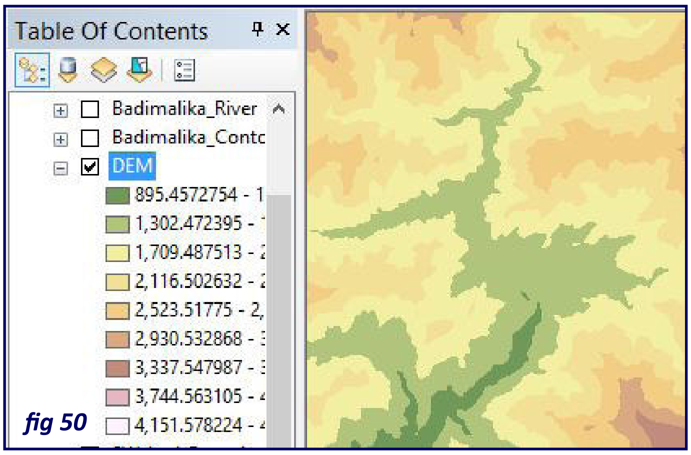
A DEM can be created in various ways, including by interpolation from contour line data. The "Topo to Raster" tool available in ArcGIS is such an interpolation method for the creation of hydrologically correct digital elevation models (ESRI, 2010). In this exercise you will be using this tool for creating DEM of Badimalika from contour data (Figure 48).



- To begin, add "Badimalika_Contour.shp" from the working folder and open the attribute table and look at the elevation field. Symbolize the elevation field using: Symbology>Quantities> Graduate color option.
- Open Arc Toolbox from ArcMap window and browse to Spatial Analyst > Interpolation>"Topo to Raster" and double click to open the window. Or you can use the search tool from the ArcMap window and type "Topo to Raster" in the local search window.
- Select "Badimalika_Contour.shp" as input feature data, and select "Elevation" from the field dropdown options (Figure 49).



- Browse to the working folder and type "DEM" as Output raster surface and type 30 as output cell size.
- The Output will be a continuous elevation surface as a DEM (Figure 50). This is an image file with an elevation value for each pixel cell. You can derive Elevation zone from this DEM. But the "Reclassify" option must be used to get an attribute table vaue of a raster image and define the number of classes and class interval. Try this by yourself. We will now derive Slope and Aspect (Direction) raster layers from the DEM.



3.10.4 Exercise M: Deriving slope and aspect from DEM

Slope and Aspect (Direction) affects Resource availability, Vegetation growth, Natural hazards (flooding, landslides), Hydrological as well as watershed conditions.

Slope has two components: Slope Gradient and Aspect. Gradient is the steepness of the surface or rate of maximum change in z-value.

Aspect is the direction of the plane with respect to some arbitrary zero, usually north. It is measured clockwise in degrees from 0 (due north) to 360 (again due north), coming full circle. Flat areas having no downslope direction are given a value of -1 (Figure 51).

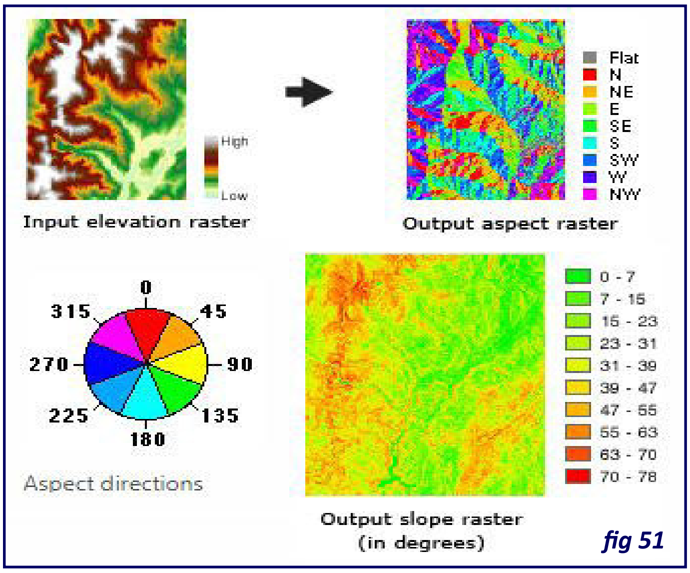


fig 51

- Open Arc Toolbox from the ArcMap window and browse to Spatial Analyst > Surface > Slope and double click to open the window.
- You can also derive slope and aspect from 3D Analyst tool > Raster surface> Slope (Figure 52).

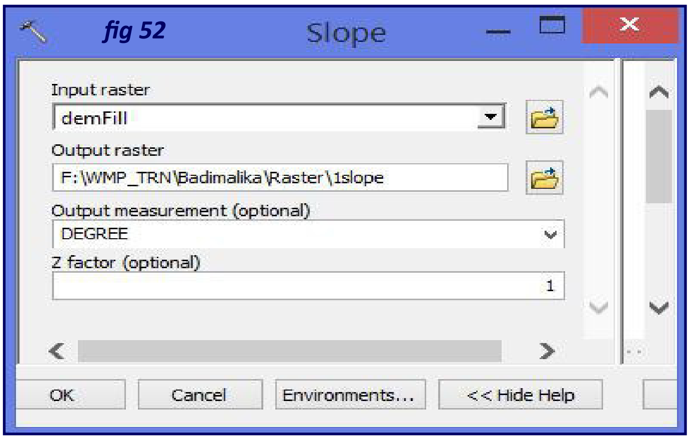


fig 52

- Select "DEM" as Input raster. Browse to the working folder and type "Slope" as a name of the Output raster and click Ok. Slope will be derived in Degrees (Figure 53).

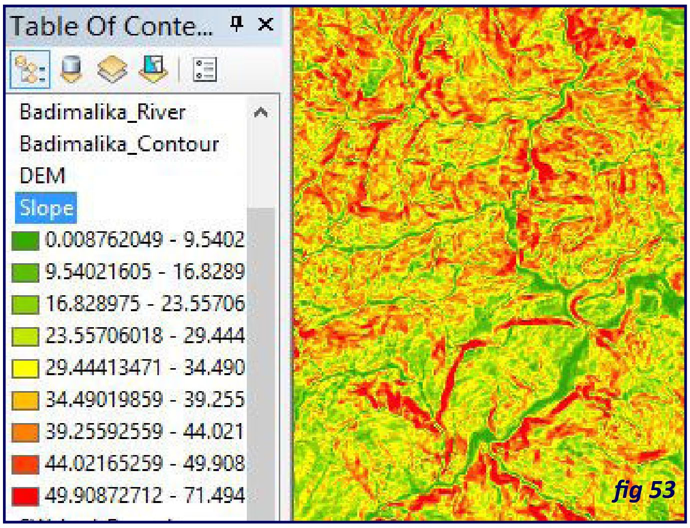


fig 53

- Go to the "Reclassify" option Spatial Analyst >Reclass> Reclassify to get an attribute table vaue of a Slope raster image. we will reclassify slope into 5 classes. (0-5, 5-15, 15-25, 25-35 and > 35) (Figure 54).

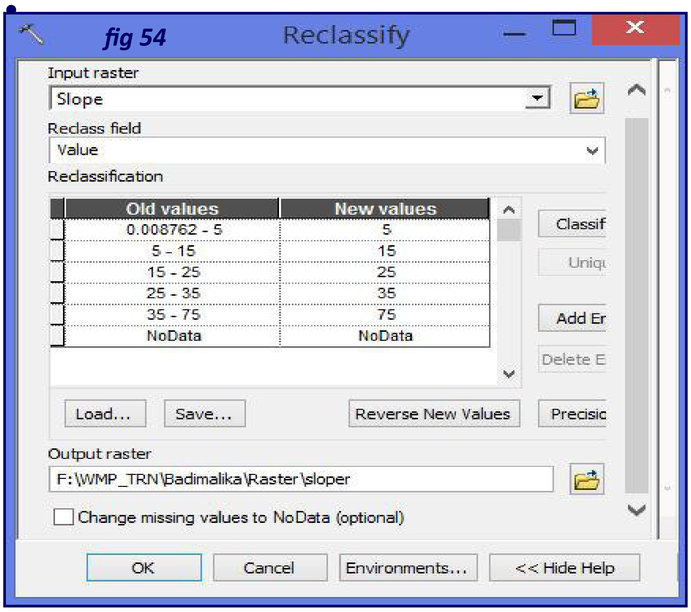


fig 54

- While reclassifying, the range of value or the class interval should not overlap except at the boundary of two input ranges.
- The reclassed new values will be represented as user-defined integer values only. So represent each class interval with a new value such as 5, 15, 25, 35 and 65 (highest range value in the data). See corresponding figure.
- Browse to :\WMP_TRN \Badimalika\Raster\ and save Output raster as "SlopeRc". Calculate Area by adding field Area_Ha and find out the area of each slope class (Figure 55).

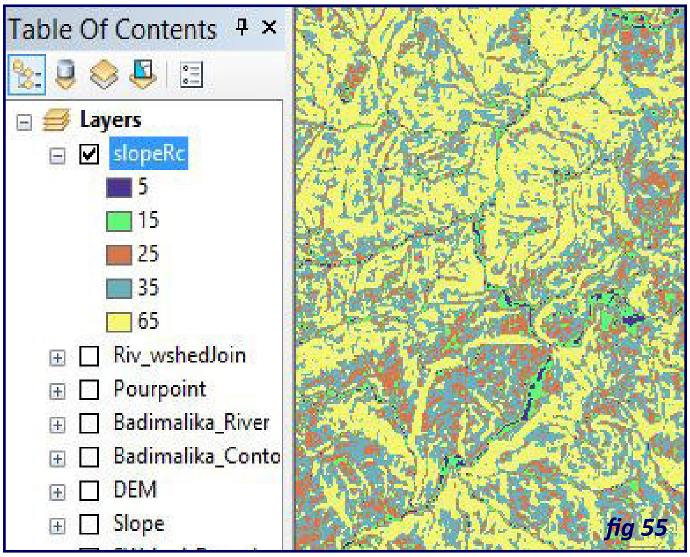


fig 55

- Browse to Spatial Analyst > Surface > Aspect" and double click to open the window. Select DEM as Input raster and "Aspect" as Output raster (Figure 56 on next page).
- Go to "Reclassify" option Spatial Analyst >Reclass>"Reclassify" to get an attribute table value of a Aspect raster image.

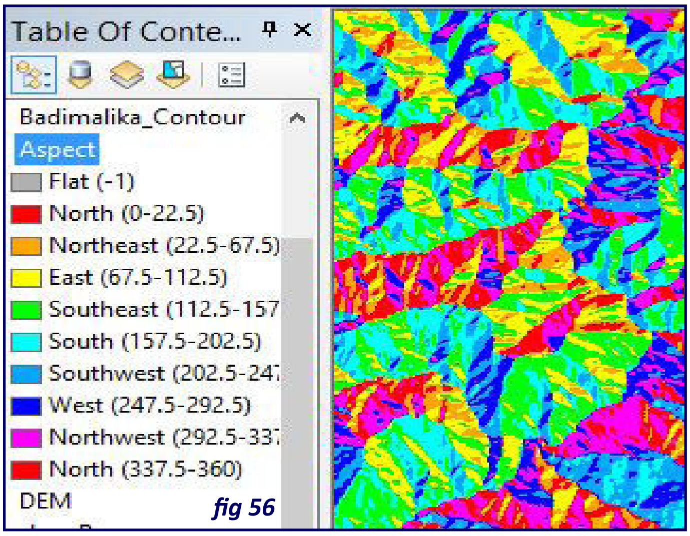


fig 56

- Reclassify aspect values into 10 classes as default and type the upper limit of each class as New value so that the direction can be identified. Similarly, you can reclassify the direction into 4 classes (North, South, East and West) by combining the classes.

3.11 The Hydrology Tool

Hydrologic analysis in GIS is primarily through the use of raster based application functions. The Hydrology tool set in ArcGIS has number of tools which can be used to automate the creation of a watershed boundary using raster elevation data (DEM).

The hydrologic tools allow the user to identify sinks, determine flow direction, calculate flow accumulation, delineate watersheds, and create stream networks. Watersheds can be delineated automatically from a DEM by computing the flow direction and flow accumulation tools. We will use the DEM created earlier using the "Topo to Raster" tool.

But, the DEM created in the previous session needs to be hydrologically pre-processed before automated generation of watershed boundary in order to remove depressions/sinks from DEM areas before performing the flow analysis. The process of automated watershed generation in ArcGIS is provided in Figure 57:

The direction in which water would flow from each cell is determined using the Flow direction tool. The steepest downslope flow from each neighboring cell will be identified by this tool (Figure 58).

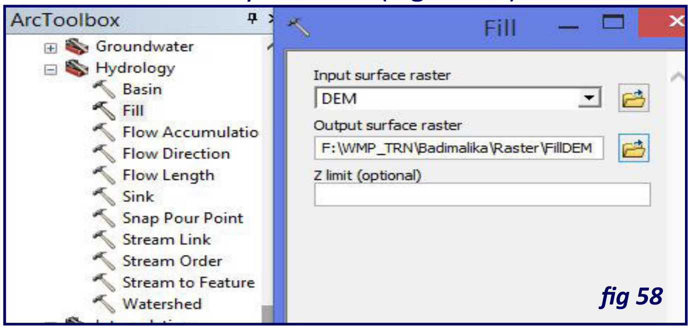


fig 58

However, the water flow in the model can be diverted from flowing to the outlet/mouth of the basin if a depression/sink is present in the data. The "Fill" tool will be used to identify and create hydrologically useable DEM free of any such data artifacts.

3.11.1 Exercise N: Watershed delineation

- In ArcToolBox, navigate to Spatial Analyst Tools > Hydrology > Fill.
- Use a Digital Elevation Model (DEM) as the "Input surface raster".
- Browse to working folder path for the "Output surface raster". Type "DEMfill" as the name for depression less DEM. Click OK. A filled DEM will be added to the table of Content.

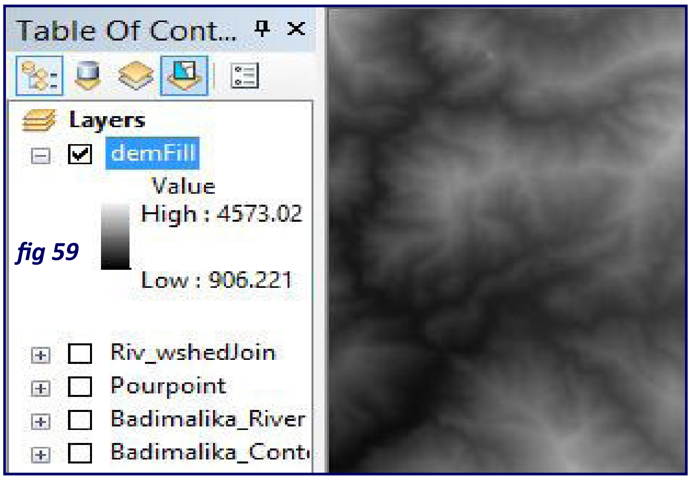


fig 59

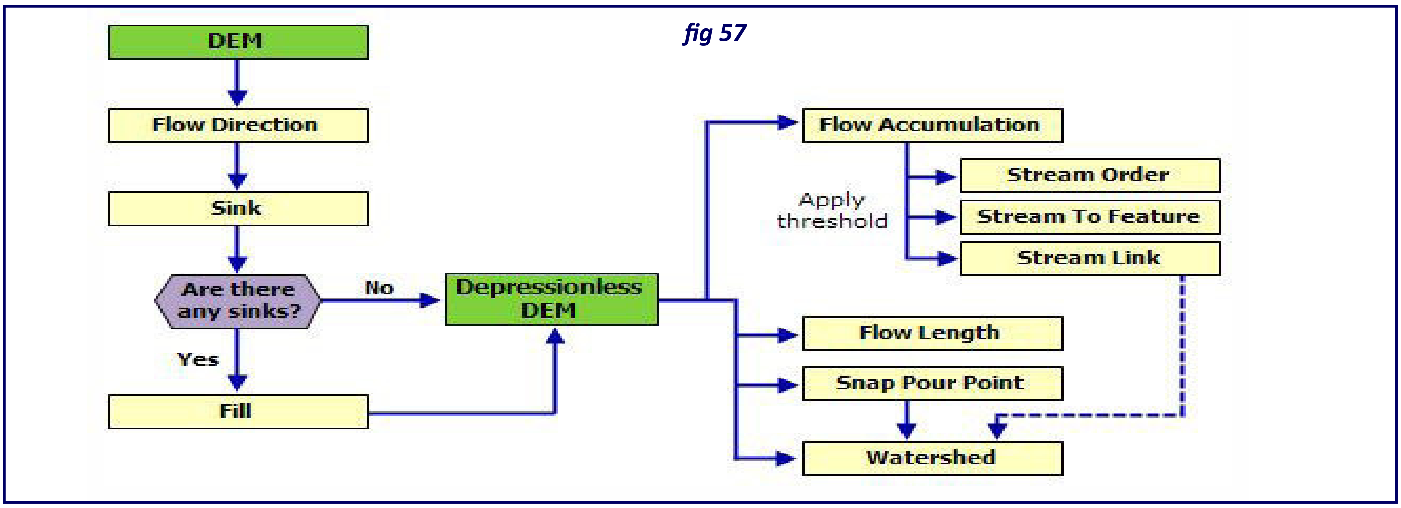


fig 57

- Now Run the Flow Direction tool using the “DEMfill” as input surface raster.
- Browse to working folder path and give Output flow direction raster name as “FlowDir”(Figure 60).

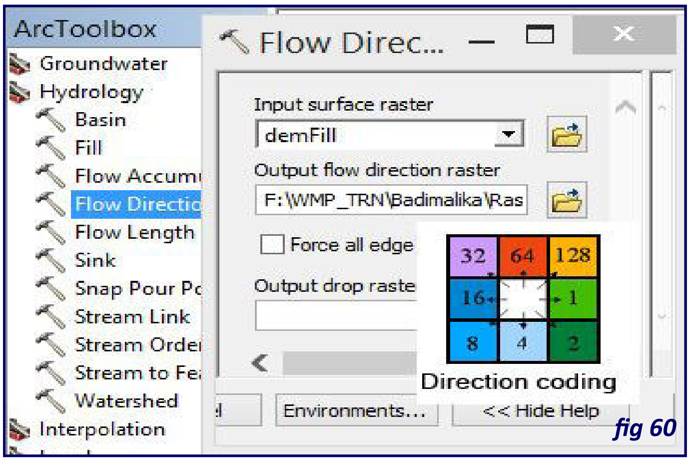


fig 60

- The flow direction value from each center cell is determined by evaluating the eight neighboring cells 1-East, 2-South-east, 4-South, 8-South-west, 16-west, 32-North-east, 64-North and 128-North-east direction. The flow direction raster you have created should look very similar to the one in Figure 61.

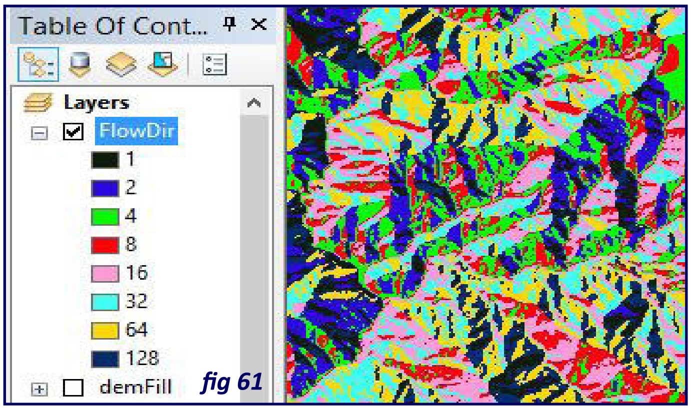


fig 61

- The next step is to create a Flow Accumulation raster. From the Hydrology tool click on “Flow Accumulation”. Set the Input Flow Direction Raster as “FlowDir”.
- Browse to the working folder path and give the output flow accumulation raster name as “FlowAcc” and click Ok (Figure 62).

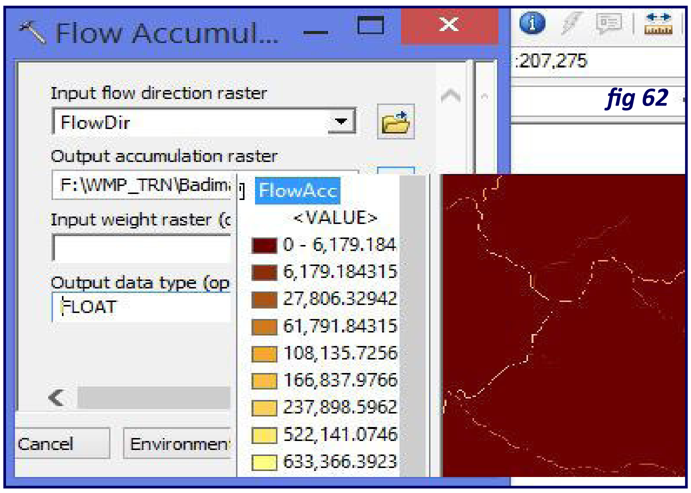


fig 62

- The Flow Accumulation tool creates a raster of accumulated flow into each cell based on the flow direction and travel from each cell to downslope cell in the output raster. The accumulated flow is based on the number of cells flowing into each cell in the output raster. Output cells with a flow accumulation of zero are local topographic highs and can be used to identify ridges. Output cells with a high flow accumulation are areas of concentrated flow and can be used to identify stream channels.
- Streams and rivers can be identified using existing stream and river network data, or flow channels can be generated and identified from the flow accumulation raster. To generate streams from flow accumulation raster: Right click on FlowAcc raster, Go to Symbology> Classified and define number of classes to 10 or more and note the lower class interval values. (You can change the color options to visualize streams.) This value will be our base for applying condition to generate stream lines. By applying a threshold value to the results of the Flow Accumulation tool using “Con“ tool” a stream network can be delineated.
- Go to Spatial Analyst> Conditional and double click on “Con”. Select “FlowAcc” as input conditional raster and type “value>1000” under Expression (Figure 63).

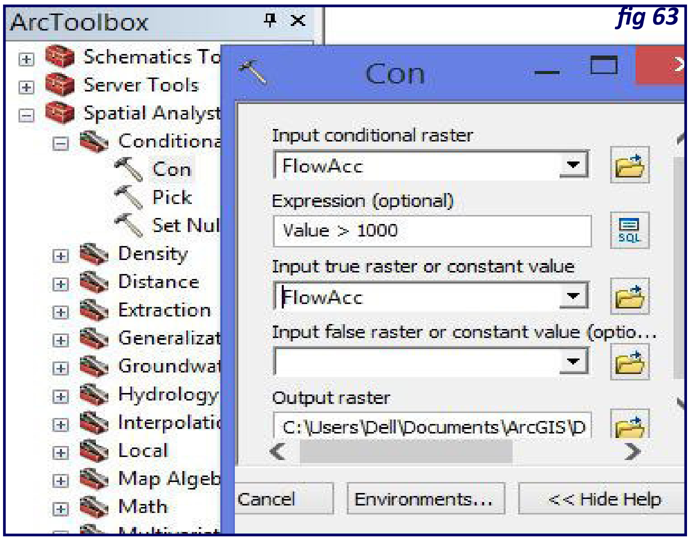


fig 63

Under true raster or constant value select again FlowAcc. Define the path and output raster file name as “Con1000” and click Ok. A stream network raster layer as shown in Figure 64 will be created and added to the table of contents.

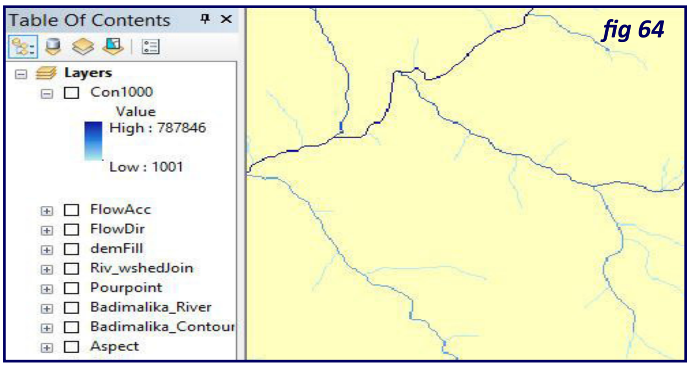


fig 64

- To define the stream order of generated stream network: Go to Hydrology> Stream Order and double click.
- Select Con1000 file under Input stream raster. Input flow direction raster will be "FlowDir" raster you have created earlier.
- Define output raster folder path and name as "StrmOdr" and Click OK. The stream ordering you have generated is based on default Strahler's stream ordering method (Figure 65).

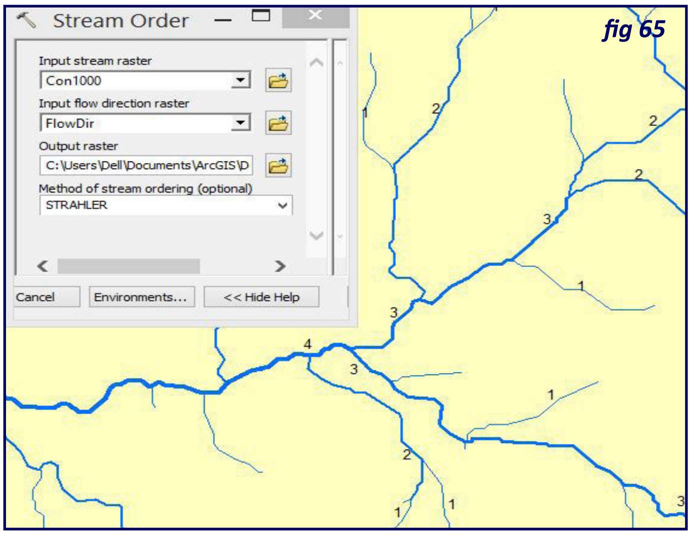


fig 65

- How many stream orders are there in generated raster and what is the highest order? The higher the order the bigger the stream/river. Identification of Stream Order helps determine and understand the size and number of the watersheds/catchments to generate.
- Convert raster stream layer to vector layer by using "Stream to Feature" tool option. This stream layer will be later used for calculating drainage density in each watershed/catchment area.
- Pour point is the outlet or mouth of a stream/river. It is the point through which all surface water will drain/flow (through the Pour Point and out of the defined area). It is the lowest point of the defined watershed boundary. It may be a point representing a sample site, stream flow measurement station, etc., which is coincident with the stream or can be defined as a point from new shapefile, or perhaps a point from a raster. Pour Point placement is an important step in the process of watershed delineation (Figure 66).
- The number of Pour Points determines the number of watersheds/catchments in the area. In order to create a Pour Point layer Go to ArcCatlog> Browse to your folder> Right click and create new shape file a with a file name "Pourpoint". Do not forget to apply the appropriate coordinate system for your data.
- Add the new shape file in ArcMap> Start editing and create a Pour Point on the each river segment outlet (Stream order: StrmOdr file). Do not forget to enter an ID value. Each Pour Point feature you have created should have an unique ID (Figure 67). The chosen Pour Point must be on the high flow accumulation path, and should be a natural outlet for the upstream cells. Your choice essentially determines the "end" of your catchment area; everything upstream from the point that you create will define a single watershed (MaDGIC, 2014).

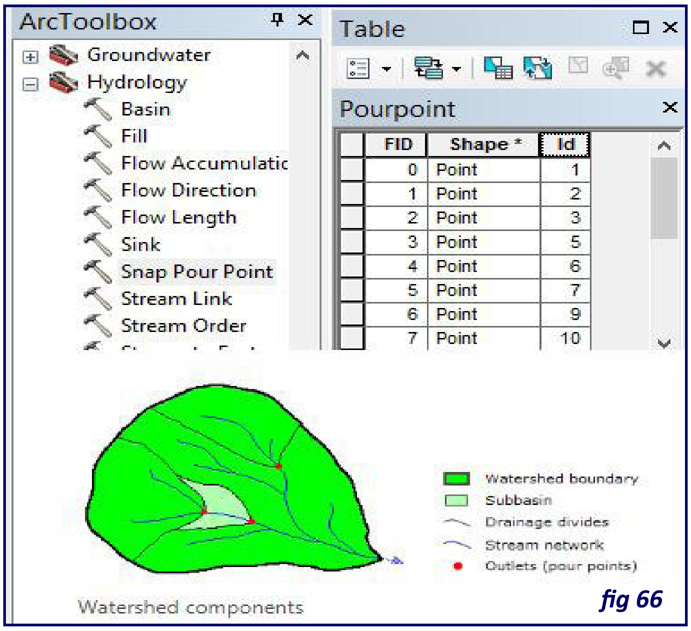


fig 66

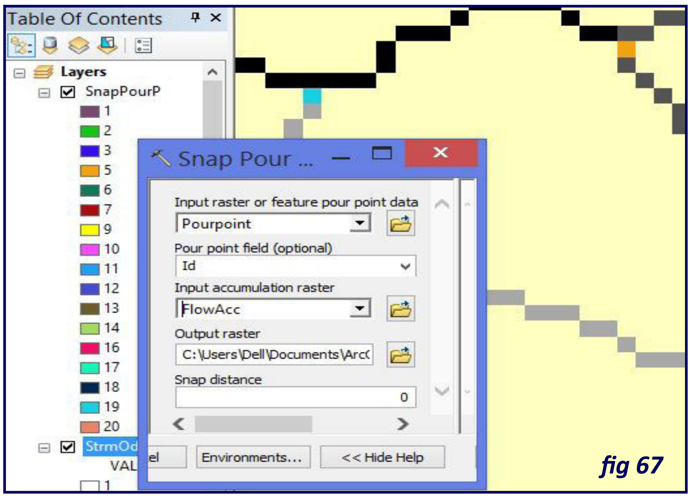


fig 67

- Each Pour Point should snap to an individual outlet cell of a stream/river raster (StrmOdr). Use the "Snap to pour point" option which snaps the defined Pour Point to a location of highest accumulated flow. Hydrology>Snap to Pour point> Input: "Pourpoint">Pour point: field "ID"> Output: SnapPourP". Click Ok. A snapped Pour Point file will be added to the table of contents.

The final step is creation of Watershed boundary (Figure 68 on next page). To create a watershed boundary:

- Double click on Watershed> Input flow raster as "FlowDir">
- Input raster or feature pour point data as "SnapPourP"> and

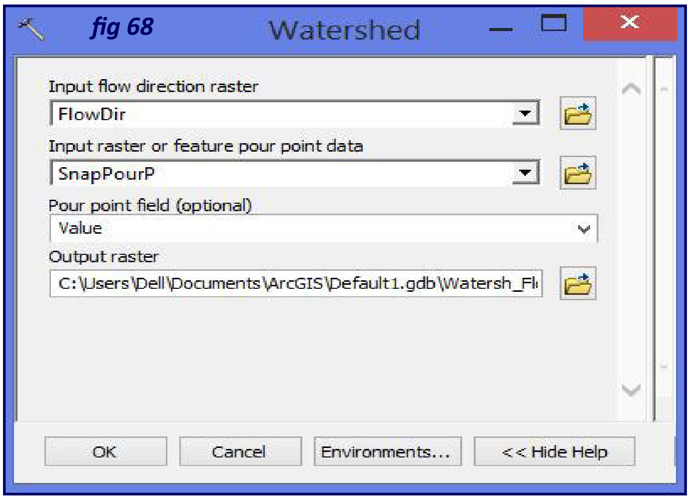


fig 68

- Input Pourpoint field "Value" and output raster as "watershed" then Click Ok. An automatically generated watershed boundary raster will be created and added to your table of contents (Figure 69).

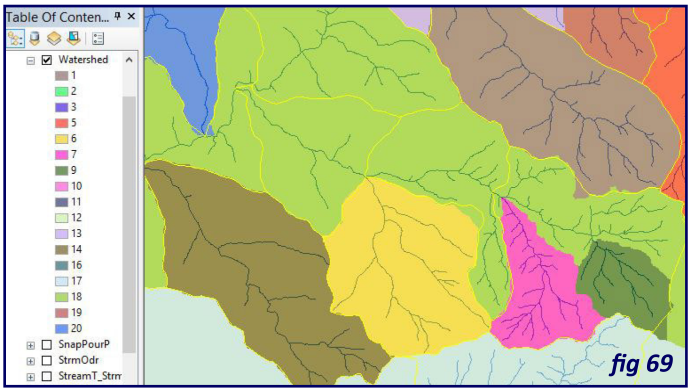


fig 69

- If your watershed delineation did not work properly, for example if it did not cover the entire area, you need to re-do the Pour Point and Snap Pour Point again by finding the most logical and correct place for the Pour Point cell.
- How does the automatically created watershed boundary look? Is it correct? Add the SWshed_ Boundary file and compare that watershed boundary with generated one.
- Convert the raster watershed layer into vector layer using Raster to Polygon tool (ArcToolbox> Conversion > From Raster. Defined input as Watershed> Field as "Value" and Output as "Watershed".

3.11.2 Exercise O: Drainage density Calculation

Drainage density (DD) is the ratio of the total length of the streams of all orders of the watershed to the area of the watershed (Horton, 1945; Strahler, 1952).

It is one of the most common linear parameter of basin morphometry used for watershed prioritization. It indicates the balance between the erosive power of overland flow and the resistance of surface soils and rocks. It is helpful to study the landscape dissection, runoff potential and infiltration capacity of the land.

In general, lower drainage density is found to be associated with regions having highly permeable subsoil material and high value of drainage density is noted for the regions of weak or impermeable subsurface materials (Nag, 1998; Pidwirny, 2006).

Drainage density can be calculated in ArcGIS using either vector data layer and associated table attributes or using a raster density calculation tool (Spatial density). Firstly we will calculate density using line density raster tool.

- Add Badimalika_River layer or use Stream layer you have generated earlier using Stream- to-feature tool.
- Browse to Spatial Analyst Tools> Density> Line Density tool (Figure 70). Double click on the tool and select Badimalika_River.shp (or stream shape file) as Input Polyline feature.

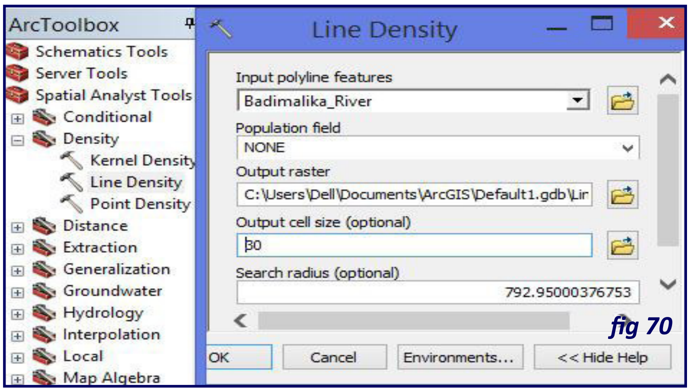


fig 70

- Browse to your working folder and define an output raster as "RivDnsty" and set output cell size at 30 meter. Click Ok. A raster file of spatial density of drainage will be added (Figure 71).

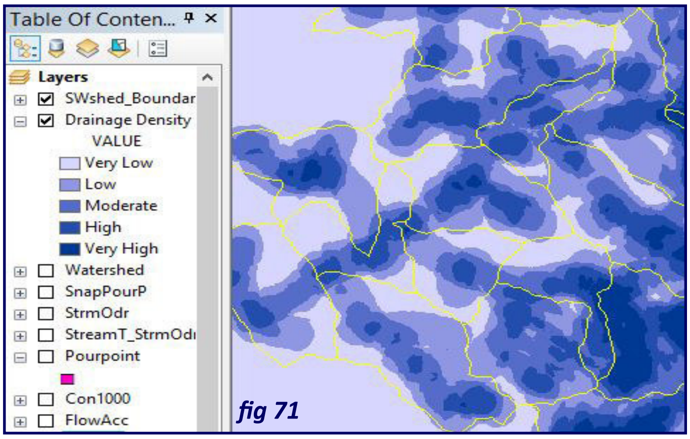


fig 71

- Reclassify this raster file with 5 classes and define as Very Low to Very High density (new value 1 is Very Low and 5 is Very High). Symbolize accordingly.
- For vector based drainage density calculation of each watershed we will use the Spatial Join and Attribute Join tools. Right click on Badimalika_River layer> Join> Spatial Join (Figure 72 on next page).
- Select" Join data from another layer based on spatial location" from the first option.

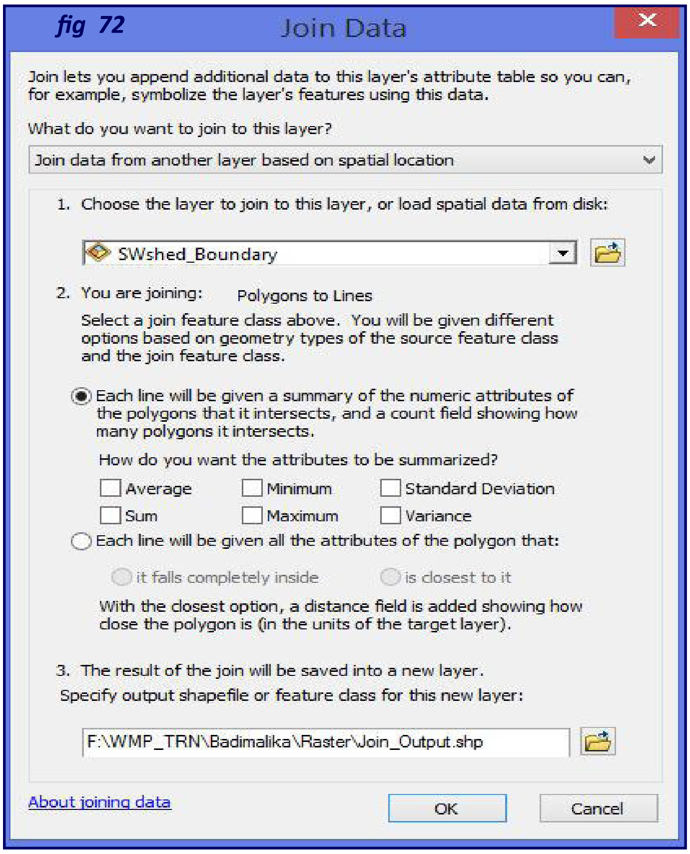


fig 72

- Choose "Swshed_Boundary" under "Layer to join" option and click on the option "It falls completely inside" and set output file as Riv_wshedJoin and click OK.
- A new file with Riv_wshedJoin shape file will be generated. Now summarize the length field based on SwID (watershed ID). Right click on SwID field> Summarize> Click on Length> Sum. Define Output table file as name: "Riv_Lngth" and Save as type: dBASE Table and click OK.
- We will join this table into SWshed_Boundary shape file. But this time using the option "Join attribute from Table" (Figure 73). Right click on SWshed_Boundary> Join> Select "Join attribute from table". Join field should be SwID in both cases and Riv_Lngth will be the join table. Sum length field will be added to the watershed boundary shapefile.

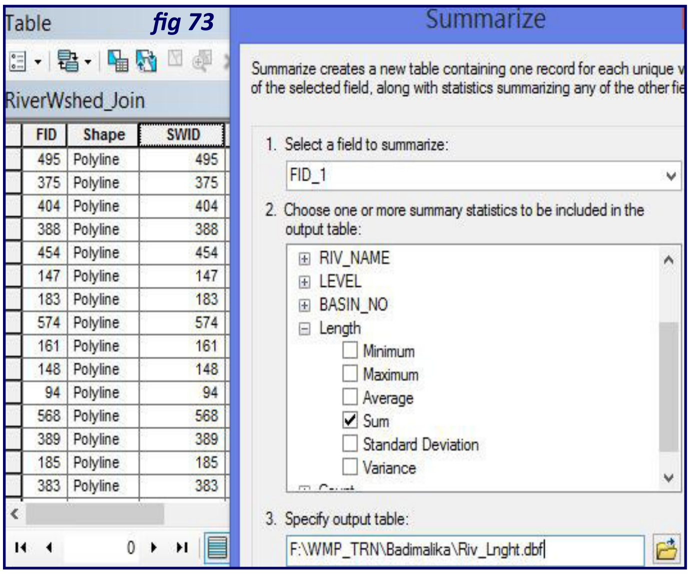


fig 73

- Add two new Fields and calculate using field calculator AreaKm (Area/1000000) and LengtKm (Length/1000). Add another new field with name: DrrDnsty to SWshed_Boundary shape file. Calculate (field calculate or) LengtKm /AreaKm. Drainage density will be generated (Figure 74). Symbolize the drainage density raster using Symbology> quantities>Graduate color (5 Classes). What is the difference between drainage density generated using vector and raster data?

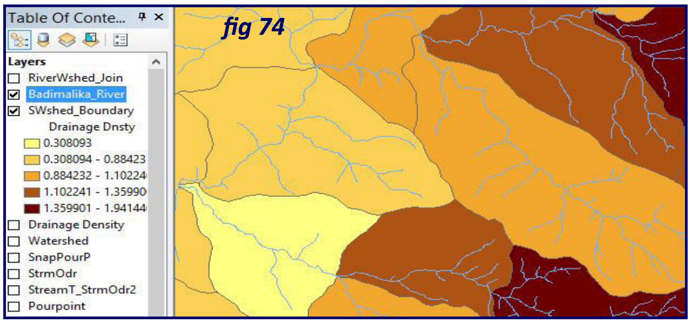


fig 74

3.11.3 Exercise P: Watershed prioritization

The purpose of watershed prioritization is to identify focus watersheds for planning program and restoration activities. The prioritization approach is simple to adapt and useful for management, as it combines the best available information, scientific methods and tools.

You have generated base layers of slope, aspect, drainage density etc., which can be now used for prioritization of watershed. There are other layers in your working folder such as land-use, land system, settlements, house clusters etc.

- Assign a weight to each using add field option and generate weight raster by converting these vector layer to raster by using Conversion> To Raster> Polygon to Raster and assign values as weight.
- Please refer to DFSC watershed management planning guidelines, assessment criteria for prioritization, bio-physical layers and weighting criteria (Also refer to BCRWME, NDF1 docs: Assessment and prioritization reports and watershed management planning tools documents for details).
- Assign weight to all layers as per the guidelines, convert them to raster and combine them (add all the layers) using Map Algebra > Raster tool. A combined raster with value field will be generated. Symbolize the values into five classes using Symbology > quantities> Graduate color to define 5 classes (from lowest to highest value).
- What do these classifications represent? How could such classifications be useful in watershed management planning? Can you think of other useful layers which could be generated using the data and methods learned here? Or by combining some of the layers in other ways?

References

Abdulla, MN (2011). Catchment Area Delineation Using GIS technique for Bekhma Dam. TS09C - Spatial Information Processing II, paper no 5335. Bridging the Gap between Cultures Marrakech, Morocco

BCRWME Project Documents

ESRI (2015): What is GIS. ESRI website

FAO. (2008). Manual for integrated field data collection. National Forest Monitoring and Assessment.

FOEN(2011). Guiding Principles for Integrated Management of Water in Switzerland. Watershed Management, WATER AGENDA 21, Federal Office for the Environment (FOEN).Switzerland.

GIS Glossary: ESRI

Goodchild, M. F. (2008). Basic Concepts of GIS.GIS Notes.

Lewis, D., Grainger, B. & Milne, M. (2016). A GIS Indicator-Based Watershed Assessment Procedure for Assessing Cumulative Watershed Effects. 31 pp.

Lindsay, et.al. (2008). Mapping outlet points used for watershed delineation onto DEM-derived stream networks. Water Resources Research. VOL. 44, W08442, doi: 10.1029/2007WR006507.

Meltz, D (2008). Watershed Planning and GIS: The influence of geographic information systems on the watershed planning process.

Prah, K. & Lisec, A. (2013).Digital spatial data as support for river basin management: The case of Sotla river basin. SPATIUM International Review. 29. 59-67

Pucha-Cofrep, F., Fries, A., Cánovas-García, F., OñateValdivieso, F., González-Jaramillo, V., &Pucha-Cofrep, D. (2018). Fundamentals of

GIS: Applications with ArcGIS. Ediloja Cia. Ltda.

Rout J. and Ojha, A. (2012).Micro-watershed management using RS and GIS technologies. Geospatial World.

Sheng. T.C.(1990).Watershed management field manual: Watershed survey and planning. FAO. Rome.

Trent University Library Maps, Data & Government Information Centre (MaDGIC) August 2014

USGS (NA)Topographic Map Symbols. https://www.wvgs.wvnet.edu/www/maps.

Wastra, M. T., (2011). Mapping Water Resources.

WOCAT(2010).A Framework for Documentation and Evaluation of Sustainable Land Management: Watershed Management. World Overview Of Conservation Approaches And Technologies, WOCAT. Bern, Switzerland.

Websites:

ArcGIS Resource Center: http://help.arcgis.com/en/arcgisdesktop

Trent University: https://www.trentu.ca/library/sites/default/files/documents

West Virginia Conservation Agency, WVCA: http://www.wvca.us/envirothon/

Project Acronyms and Abbreviations

ADB	Asian Development Bank
BCRWME	Building Climate Resilience of Watersheds in Mountain Eco-Regions
CBNRM	Community Based Natural Resource Management
CBO	Community Based Organization
CDC	Community Development Committee
CDG	Community Development Group
CIF	Climate Investment Fund
CO	Community Organizer
CS	Community Supervisor
DEM	Digital Elevation Model
DHM	Department of Hydrology and Meteorology
DFSC:	Department of Forestry and Soil Conservation (formerly DSCWM)
DoS	Department of Survey
DSCO	District Soil Conservation Office
DSCWM	Department of Soil Conservation and Water Management
ICIMOD	International Centre for Integrated Mountain Development
FTT	Field Technician Team
GESI	Gender Equality and Soil Inclusion
GIS	Geographic Information System
GWRDB	Groundwater Resources Development Board
JT	Junior Technician
KIS	Knowledge Information System
KM	Knowledge Management
KS	Knowledge Sharing
KP	Knowledge Product
lpm	Liter per minute
lps	Liter per second
MCCRD	Mainstreaming Climate Change Risk in Development
MOFE	Ministry of Forest and Environment
MOFSC	Ministry of Forests and Soil Conservation
M&E	Monitoring and Evaluation
NDF	Nordic Development Fund
PET	Potential Evapotranspiration
PMU	Project Management Unit
PPCR	Pilot Program for Climate Resilience
RA	Rapid Appraisal
SCA	Soil Conservation Assistant
SPPR	Sub-Project Project Preparation Report
SRTM	Shuttle Radar Topography Mission
SWMO	Soil and Watershed Management Office (formerly DSCO)

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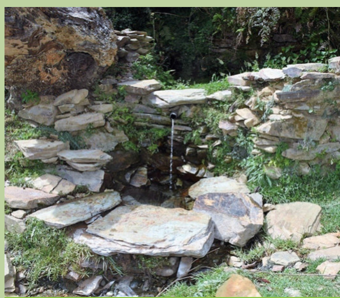

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