SUMMER INTERNSHIP

ON

"REMOTE SENSING & GIS APPLICATION FOR WATERSHED DELINEATION OF A HIMALAYAN BASIN"

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Shayaan Ali

SHAYAAN ALI

DATE:- 25-7-2017

PLACE:- Roorkee

DECLARATION

I hereby declare that the work presented in this report entitled "**REMOTE SENSING & GIS APPLICATION FOR WATERSHED DELINEATION OF A HIMALAYAN BASIN**" in partial fulfillment of the degree of **M.E** (civil infrastructure) at Thapar university Patiala,Punjab is an authentic work of my own, done under the guidance of Dr. L.N Thakural, Scientist-C,National Institute of Hydrology, Roorkee

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DATE:- 25-7-2017

PLACE:- Roorkee

CERTIFICATE

It is certified that Mr. **SHAYAAN ALI,** Enrolment no. 801623016, a student of M.E (Civil Infrastructure), Thapar University Patiala,Punjab completed the internship project from July 24, 2017 at national Institute of hydrology, Roorkee under my supervision and this report is based on his own work.

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CONTENTS

INTRODUCTION

Accurate delineation of a watershed plays an extremely important role in the management of the watershed. The delineated boundaries form the nucleus around which the management efforts such as land use, land change, soil types, geology and river flows are analyzed and appropriate conclusions drawn. Current remote sensing and graphic information system technologies provide ways for rapid collection of field data and prompt data processing.

Now-a-days the field of Remote Sensing and GIS has become exciting and glamorous with rapidly expanding opportunities. Many organizations spend large amounts of money on these fields. Here the question arises why these fields are so important in recent years.

Two main reasons are there behind this.

1) Now-a-days scientists, researchers, students, and even common people are showing great interest for better understanding of our environment. By environment we mean the geographic space of their study area and the events that take place there. In other words, we have come to realize that geographic space along with the data describing it, is part of our everyday world; almost every decision we take is influenced or dictated by some fact of geography.

2) Advancement in sophisticated space technology (which can provide large volume of spatial data), along with declining costs of computer hardware and software (which can handle these data) has made Remote Sensing and G.I.S. affordable to not only complex environmental / spatial situation but also affordable to an increasingly wider audience.

LITERATURE REVIEW

REMOTE SENSING

Literally Remote Sensing means obtaining information about an object, area or phenomenon without coming in direct contact with it. If we go by this meaning of Remote Sensing, then a number of things would be coming under Remote Sensor, e.g. Seismographs, fathometer etc. Without coming in direct contact with the focus of earthquake, seismograph can measure the intensity of earthquake. Likewise,without coming in contact with the ocean floor, fathometer can measure its depth. However, modern Remote Sensing means acquiring information about earth's land and water surfaces by using reflected or emitted electromagnetic energy.Hydrologic processes like runoff formation, infiltration,evaporation etc. depend to a large degree on catchment characteristics,e.g. soil type, soil cover, vegetation canopy, drainage density, land-usehill-slope angle etc. description of hydrologic processes occurring inhydrologic systems by mathematical models present an important tool inquantitative hydrology, engineering hydrology and water management.The mathematical model parameters estimated from remote sensing data.

Also, remote sensing data aid it is even possible to identify seasonalchanges of model parameters giving rise to different hydrologicalbehavior. In this research, we used land-sat 7 ETM+ and STRM 90 as datasources to delineate water bodies, river network, catchments andcharacterization of watersheds.

GIS

The expansion of GIS is Geographic Information System which consists of three words, viz. Geographic, Information and System. Here the word 'Geographic' deals with spatial objects or features which can be referenced or related to a specific location on the earth surface. The object may be physical / natural or may be cultural / man made. Likewise the word 'Information' deals with the large volume of data about a particular object on the earth surface. The data includes a set of qualitative and quantitative aspects which the real world objects acquire. The term 'System' is used to represent systems approach where the complex environment (consists of a large number, of objects / features on the earth surface and their complex characteristics) is broken down into their component parts for easy understanding and handling, but is considered to form an integrated whole for managing and decision making. Now-a-days this is possible in a very short span of time with the development of sophisticated computer hardware and software. Therefore, GIS is a computer based information system which attaches a variety of qualities and characteristics to geographical location (Fig.5)and helps in planning and decision making.A Geographic Information System (GIS) may be defined in different manners.

International Training Centre (ITC), Holland defined Geographic Information System (GIS) as a computerised system that facilitates the phases of data entry, data analysis and data presentation especially in cases when we are dealing with geo referenced data.

Indian Society of Geomatics (ISG) and Indian Space Application Centre (ISRO) defined GIS as a system which provides a computerised mechanism for integrating various geoinformation data sets and analysing them in order to generate information relevant to planning needs in a context.

Remote sensing and GIS are integral to each other. The development of Remote Sensing is of no use without the development of GIS and vice versa. Remote Sensing has the capability of providing large amount of data of the whole earth and also very frequently. GIS has the capabilities of analyzing a large amount of data within no time. These voluminous data would have become useless without thedevelopment of GIS. Manual handling of one time remote sensing data would take years together, by the time a number of multi date data would have piled for analysis. Likewise capability of GIS would have no use without the development of Remote Sensing technology, which provides voluminous data.

Hydrologic information system is aSynthesis of geospatial and temporal information which supportshydrologic analysis and modeling. In watershed modeling for example,GIS is extensively implemented as tool for analyzing the watershedspatial and topographical characteristics. In addition, it is being used inthe recent worldwide research as complete spatiotemporal modelingenvironment for distributed management, and other environmental andwater resources applications. The combination of Geographic Information System with satelliteimagery forms the basis of detailed information on hydrological systemsand thus more accurate modeling

Applications of Remote Sensing

- Conventional radar is mostly associated with aerial traffic control, early warning, and certain large scale meteorological data. Doppler radar is used by local law enforcements' monitoring of speed limits and in enhanced meteorological collection such as wind speed and direction within weather systems in addition to precipitation location and intensity. Other types of active collection includes plasmas in the ionosphere. Interferometric synthetic aperture radar is used to produce precise digital elevation models of large scale terrain (See RADARSAT, TerraSAR-X, Magellan).

- Laser and radar altimeters on satellites have provided a wide range of data. By measuring the bulges of water caused by gravity, they map features on the seafloor to a resolution of a mile or so. By measuring the height and wavelength of ocean waves, the altimeters measure wind speeds and direction, and surface ocean currents and directions.

- Ultrasound (acoustic) and radar tide gauges measure sea level, tides and wave direction in coastal and offshore tide gauges.

- Light detection and ranging (LIDAR) is well known in examples of weapon ranging, laser illuminated homing of projectiles. LIDAR is used to detect and measure the concentration of various chemicals in the atmosphere, while airborne LIDAR can be used to measure heights of objects and features on the ground more accurately than with radar technology. Vegetation remote sensing is a principal application of LIDAR.

- Radiometers and photometers are the most common instrument in use, collecting reflected and emitted radiation in a wide range of frequencies. The most common are visible and infrared sensors, followed by microwave, gamma ray and rarely, ultraviolet. They may also be used to detect the emission spectra of various chemicals, providing data on chemical concentrations in the atmosphere.

- Stereographic pairs of aerial photographs have often been used to make topographic maps by imagery and terrain analysts in trafficability and highway departments for potential routes, in addition to modelling terrestrial habitat features.
- Simultaneous multi-spectral platforms such as Landsat have been in use since the 1970s. These thematic mappers take images in multiple wavelengths of electro-magnetic radiation (multi-spectral) and are usually found on Earth observation satellites, including (for example) the Landsat program or the IKONOS satellite. Maps of land cover and land use from thematic mapping can be used to prospect for minerals, detect or monitor land usage, detect invasive vegetation, deforestation, and examine the health of indigenous plants and crops, including entire farming regions or forests.[4] Landsat images are used by regulatory agencies such as KYDOW to indicate water quality parameters including Secchi depth, chlorophyll a density and total phosphorus content. Weather satellites are used in meteorology and climatology.

- Hyperspectral imaging produces an image where each pixel has full spectral information with imaging narrow spectral bands over a contiguous spectral range. Hyperspectral imagers are used in various applications including mineralogy, biology, defence, and environmental measurements.

- Within the scope of the combat against desertification, remote sensing allows to follow up and monitor risk areas in the long term, to determine desertification factors, to support decision-makers in defining relevant measures of environmental management, and to assess their impacts.

HIMALAYAN BASIN

The Himalayas are the freshwater towers of South Asia and parts of Southeast Asia. Water originating from their snow, glaciers and rainfall feed the ten largest river systems in Asia. Together these rivers support the drinking water, irrigation, energy, industry and sanitation needs of 1.3 billion people living in the mountains and downstream.Mountains cover approximately one-quarter of the worlds surface and are home to 12% of the human population They are characterized by massive global diversity from tropical rain forests to permanent ice and snow cover and considered water towers of the world , providing freshwater to at least half of the worlds people. The Himalaya, which means the storehouse of snow and ice, is the world's youngest, highest and most sensitive, most rugged, unique and extensive mountain system having 14 peaks over 8000 m and hundreds over 7000 m and 530 peaks above 6000 m high (Bahadur, 2004). The world's major rivers, the Indus, the Ganges and the Brahmaputra all rise in the Himalayas. The Himalayan chain of mountains extends from west to east for about 2500 km with a width of 100- 400 km. In Indian perspective, Himalaya consists of four ranges running for 2500 km from Arunachal Pradesh in the east to Jammu and Kashmir in the west. The mountains in the ranges rise up to about 9000 m in height and falls steeply to the northern plain over few hundreds of kilometer.

The Indian part of Himalayas covering an area about 5 lakh km2 (about 16.2% of country's total geographical area) and forms the northern boundary of the country. The traditional definition of the Himalaya, is that great range of mountains that separates India, along its north-central and north-eastern frontier, from China (Tibet), and extends between latitudes 26o20' and 35o40' North, and between longitudes 74o50' and 95o40' East.The Indian Himalayan region is a range that spans ten states of India namely, Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram and Tripura as well as the hill regions of two states - Assam and West Bengal.

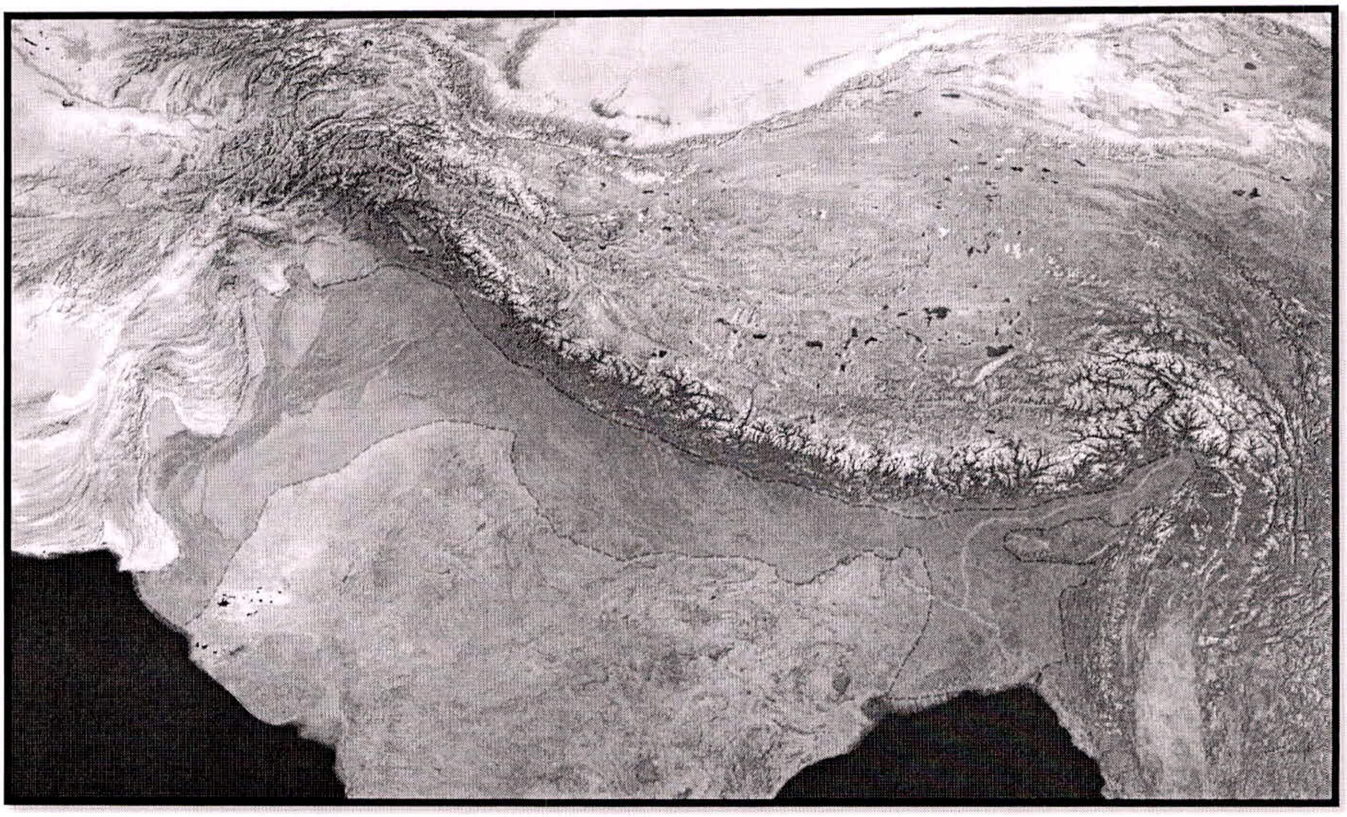


Figure 1: Indian Himalayan Basin

WATERSHED

Watershed is the area of land that drains down slope to the lowest points of the terrain. The water moves by gravity means in anetwork of drainage pathways that may be underground or on the surface into a specified body of water, river or stream.Although there are many ways for water to enter a stream, much of it will enter as run-off from the land. This land is what formsthe stream's watershed. However, in some regions, the water drains to a central depression such as a lake or marsh with nosurface-water exit.

It is possible to delineate watershed boundaries manually using a topographic map that shows stream channels, or contour plots.The watershed boundaries will follow major ridge-lines around the channels and meet at the bottom where the water flows outof the watershed, commonly referred to as the mouth of the stream or river, see figure 1,. In contour plots, droplets of waterusually travel along lines normal to the contour lines down the hills. As the ground retains water for longer periods, more waterwill penetrate into ground and reduced amount will reach the downstream mouth of the area.Digital Elevation Models (DEMs) are increasingly used for basin boundaries delineation in a variety of hydro-climatic studies. However, accuracy of basin areas depends on quality of DEMs and adopted methods

STUDY AREA

Pindar River also known as Pindari River is a Himalayan river, which emerges from Pindari Glacier in Bageshwar district of Uttarakhand. The river has a length of 105 kilometres. The river crosses tiny hamlets and towns such as Manmatti, Dewalo, Nandkeshri, Tharli, Kulsari, Bhagoli, Narayanbagar, Nauligaon and Nauti. Pindar River merges with River Alaknanda at Karnaprayag. The river flows as Alaknanda from here.

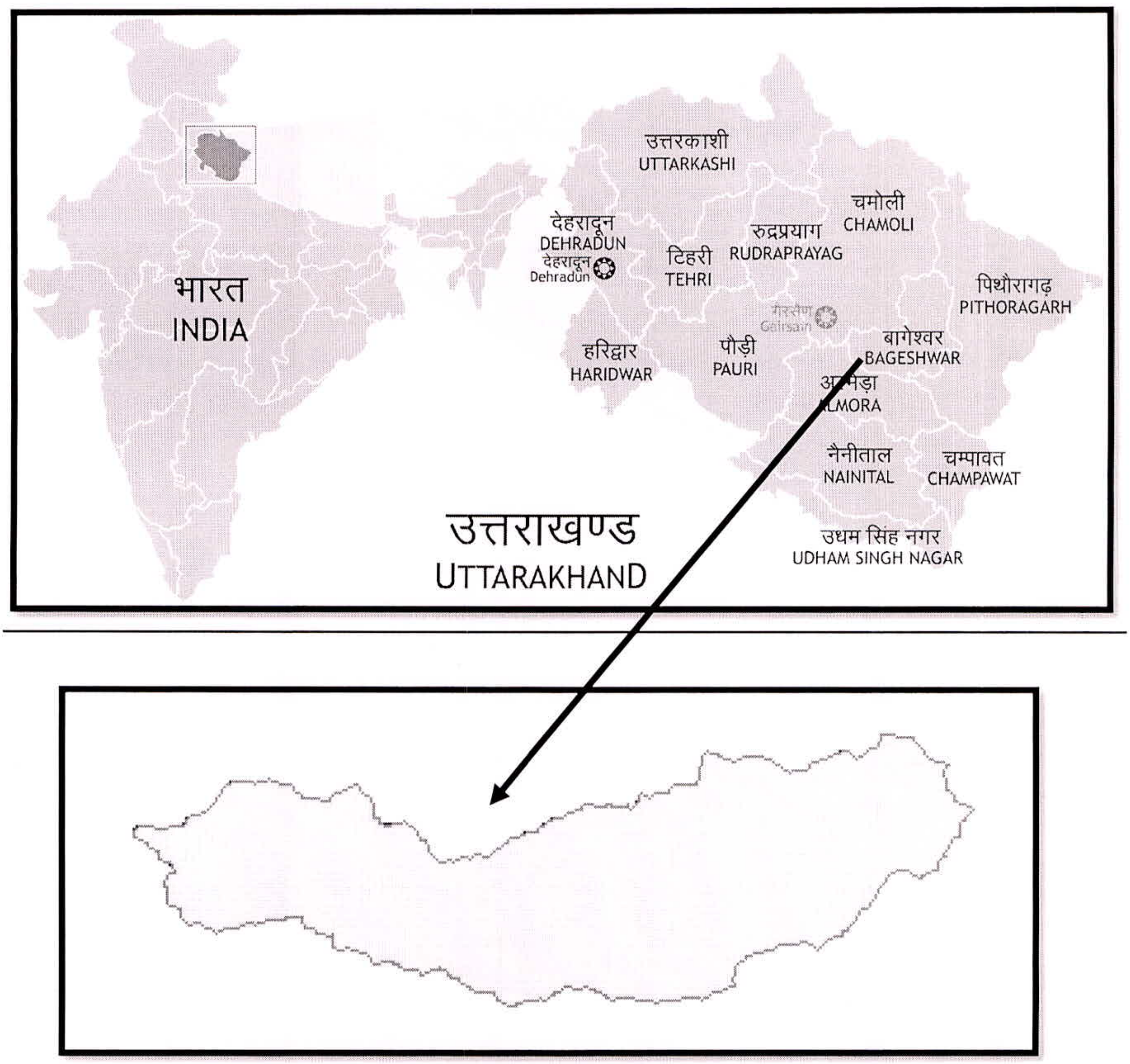


Figure 2: Location map of Pindar river watershed

The study area, viz., the Pindar watershed extends between 29°59′41″N to 30°18′57″N latitudes and 79°05′43″E to 80°04′38″E longitudes, encompasses an area of 1872.98 km² in the Central Himalaya, India. The altitude of the watershed varies between 757 m and 6746 m. The Pindar River originates from the Pindar glacier.

DATA

Digital Elevation model (DEM) of the catchmenthas been extracted from shuttle radar Topographic mission (SRTM) data obtained with resolution of 90m. The SRTM DEM was downloaded and processed to obtain/prepare stream network and watershed of Pindar River at karanprayag using spatial analyst tool ARC GIS 10.

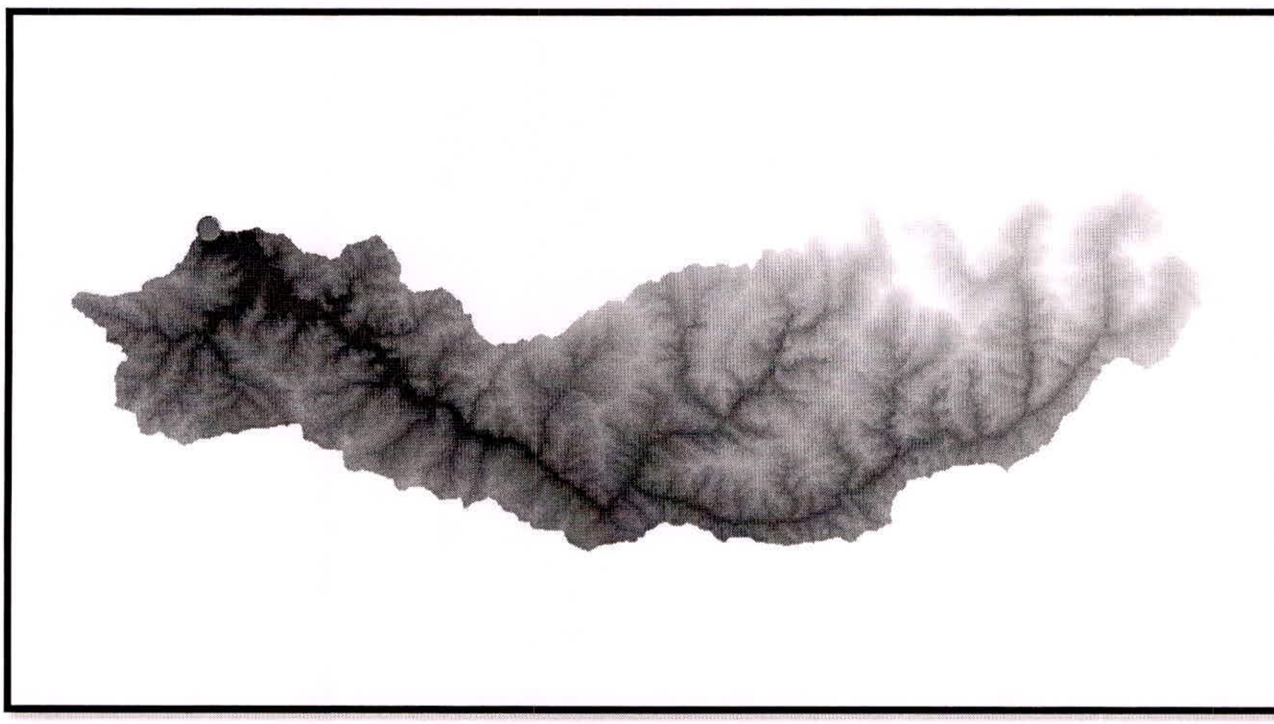


Figure 3: DEM of Study Area

SOFTWARE USE

ArcGIS is a geographic information system (GIS) that has been used for processing of the SRTM digital elevation model and generate data on flow direction, flow accumulation, streams, stream segments and watershed. In the present study ARCGIShas been used delineate the drainage network and watershed for the Pindar River at Karanprayag.

METHODOLOGY

ArcGIS is a **geographic information system** (GIS) for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database.The system provides an infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the Web.

Various steps have been followed to delineate the stream network and watershed for the Pindar River.

1. WATERSHED DELINEATION

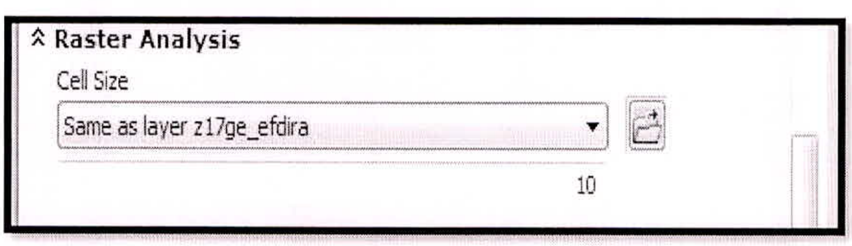
Several steps followed to delineate the drainage network and watershed using ARCGIS software.

I. DEM Map

1. Open ArcMap and create a new, blank map document. Use the *Add Data* button to add the DEM for your area of interest to the map.

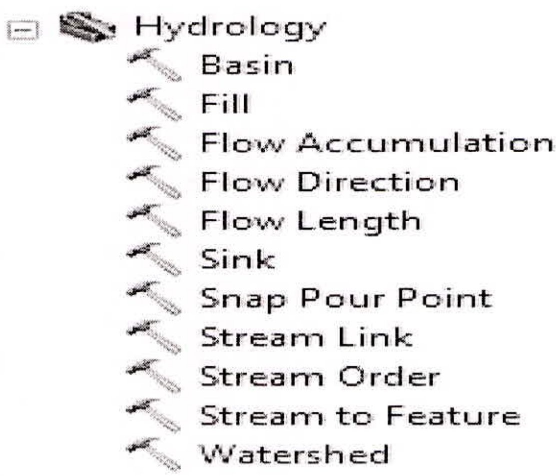
   Browse to *Geoprocessing* > *Environments*. Under *Workspace*, set the variables for *Current Workspace* and *Scratch Workspace* to the directory where you wish to save your results. It is a good idea to create an empty file geodatabase for this purpose.

2. Browse to *Environment Settings* > *Raster Analysis* and use the drop down arrow to set the *Cell Size* property to be the same as the DEM layer. Click *OK* to accept the changes.



3. If necessary, enable the Spatial Analyst extension (*Customize* > *Extensions* > *Spatial Analyst*).

4. Open *ArcToolbox* from the main menu and expand the *Spatial Analysis Tools* > *Hydrology* toolbox to view its contents.



5. Save your map document (*File* > *Save*).

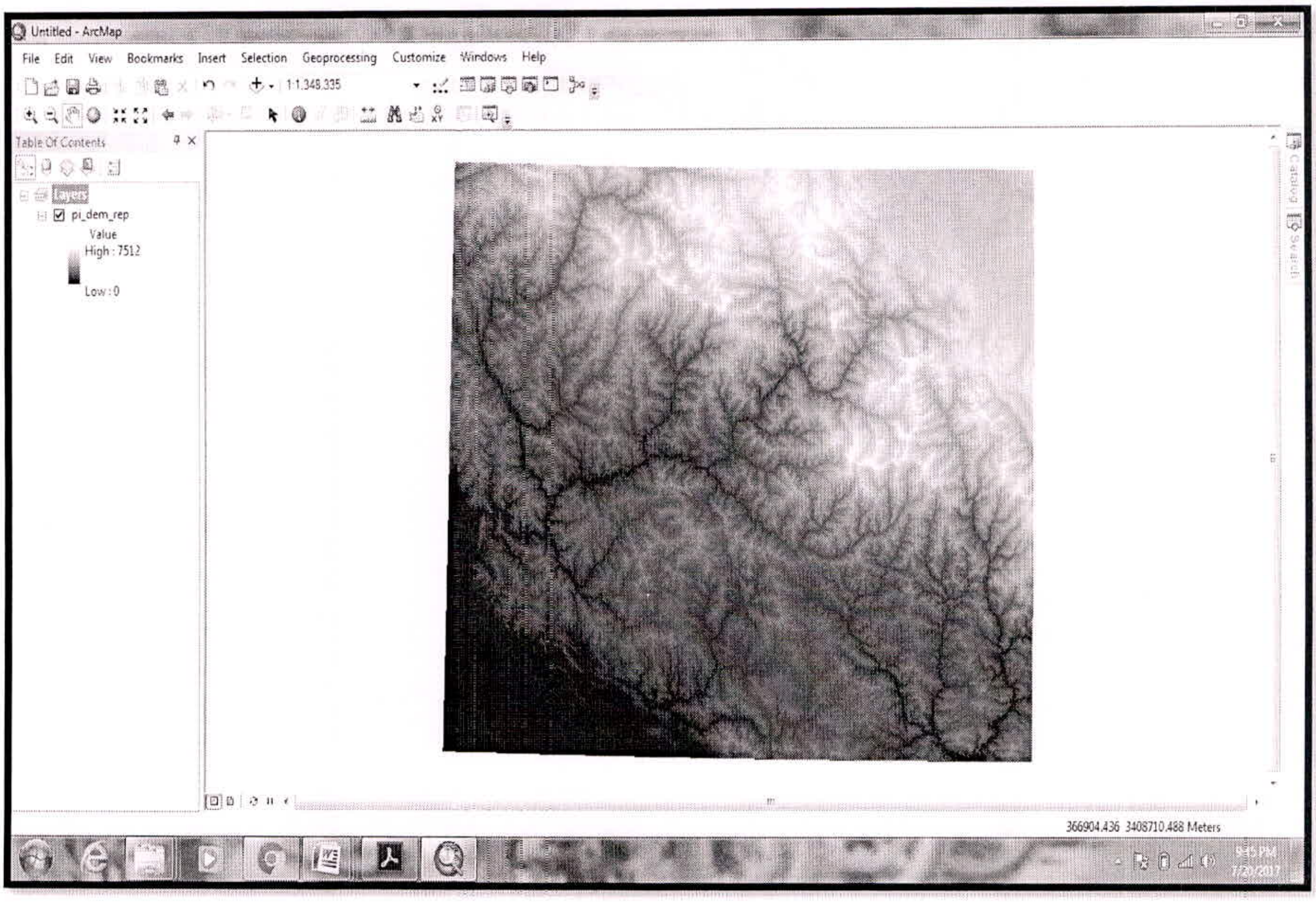


Figure 4: Pindar DEM

II. Create a depression less DEM (FILL)

The *Fill* tool in the *Hydrology* toolbox is used to remove any imperfections (sinks) in the digital elevation model. A **sink** is a cell that does not have an associated drainage value. Drainage values indicate the direction that water will flow out of the cell, and are assigned during the process of creating a flow direction grid for the landscape. The resulting drainage network depends on finding the 'flow path' of every cell in the grid, so it is important that the fill step is performed prior to creating a flow direction grid.

Double click the *Fill* tool to open its dialog and enter the following parameters.

1. Set the DEM grid as the *Input surface raster*.

2. If necessary, set the *Output surface raster* to your working directory and provide a descriptive name for the output.

3. Accept all other defaults and click *OK* to run the tool. This process can be resource-intensive, and may take some time to complete depending on the processing power available to the software.

4. When the fill process is complete, a new grid will be added to the data frame of your map document. There should be a difference in the lowest elevation value between the original DEM and the filled DEM.

5. You can now remove the original DEM layer from the map view (right-click >*Remove*) and save your map document.

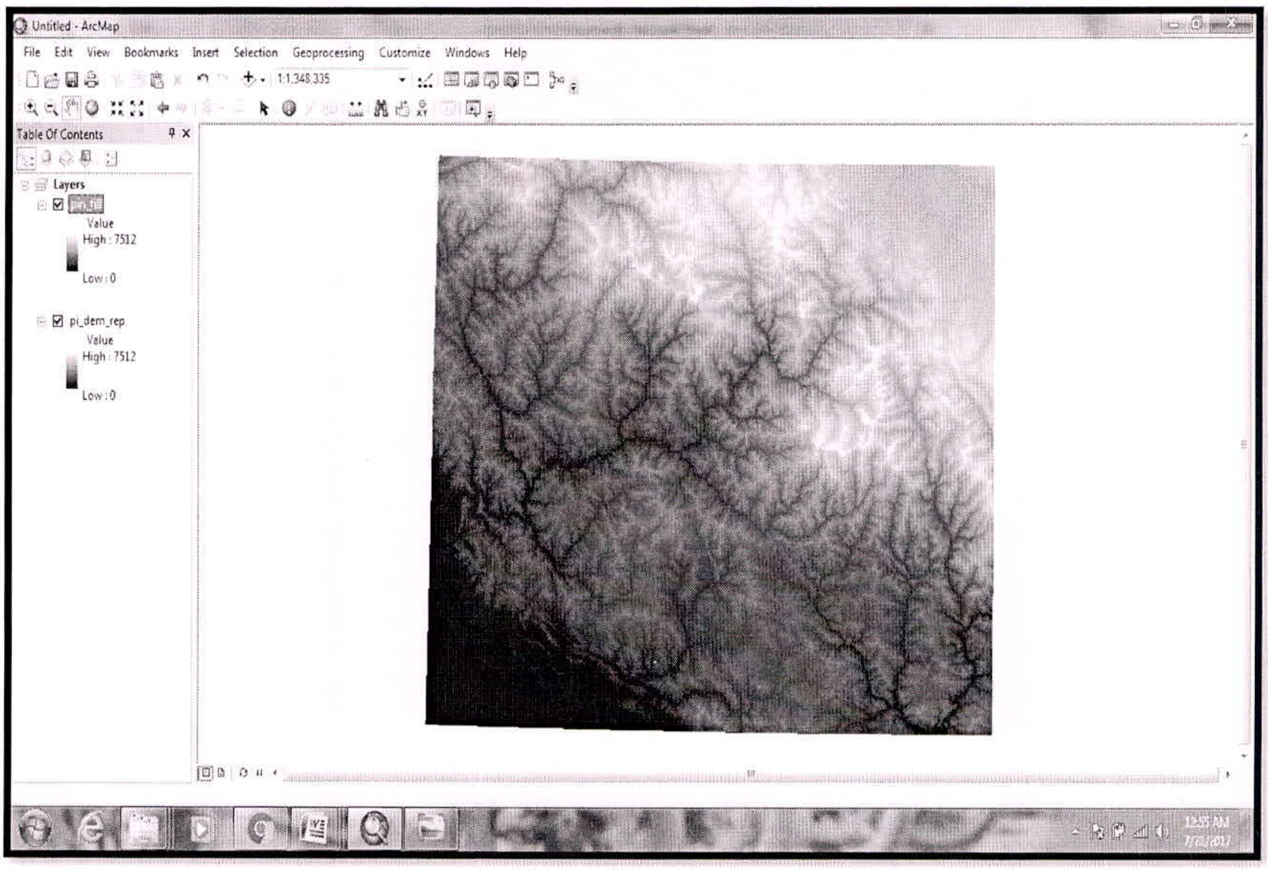


Figure 5: Fill Depression

III. **Flow Direction Map**

A flow direction grid assigns a value to each cell to indicate the direction of flow – that is, the direction that water will flow from that particular cell based on the underlying topography of the landscape. This is a crucial step in hydrological modeling, as the direction of flow will determine the ultimate destination of the water flowing across the surface of the land.

Double-click the *Flow Direction* tool to open the tool dialog and input the following parameters.

1. Set the *Input surface raster* to the filled DEM created in the Step 2.

2. If necessary, set the *Output flow direction raster* to your working directory and provide a descriptive name for the output file.

3. Browse to *Environment Settings > Raster Analysis* and confirm that the *Cell Size* parameter is set to the same as your filled DEM. Click *OK* to run the tool.

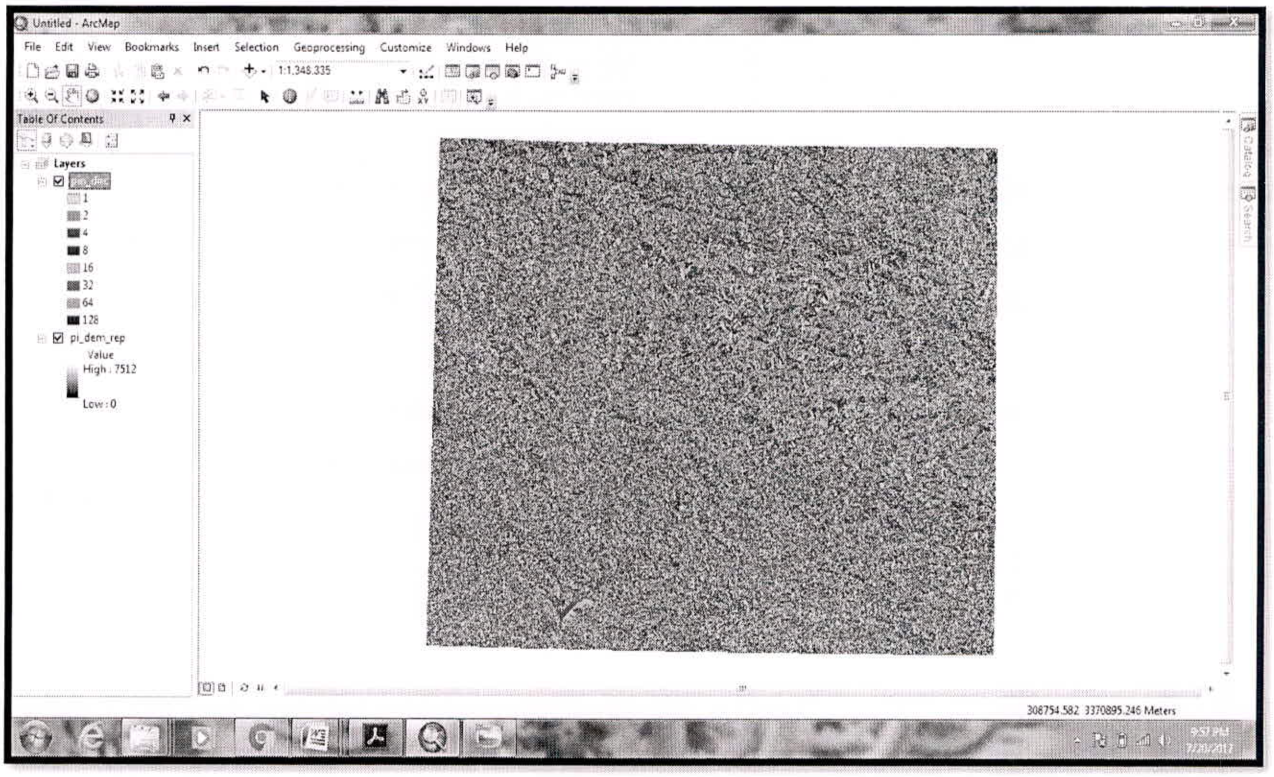


Figure 6: Flow Direction

IV. Flow Accumulation Map

The *Flow Accumulation* tool calculates the flow into each cell by identifying the upstream cells that flow into each downslope cell. In other words, each cell's flow accumulation value is determined by the number of upstream cells flowing into it based on landscape topography.

Double-click the *Flow Accumulation* tool to open the tool dialog and input the following parameters.

1. Set the *Input flow direction raster* to the flow direction grid created in Step 3.

2. If necessary, set the *Output accumulation raster* to your working directory and provide a descriptive name for the output.

3. Browse to *Environment Settings > Raster Analysis* and confirm that the *Cell Size* parameter is set to the same as your filled DEM. Click *OK* to run the tool.

The new flow accumulation raster will be added to your map document. Each cell in the grid contains a value that represents the number of cells upstream from that particular cell. Cells with higher flow accumulation values should be located in areas of lower elevation, such as valleys or drainage channels where water flows naturally while it is following the landscape.

If the flow accumulation raster appears dark and the cell values are difficult to visualize then it will be necessary to alter the layer symbology.

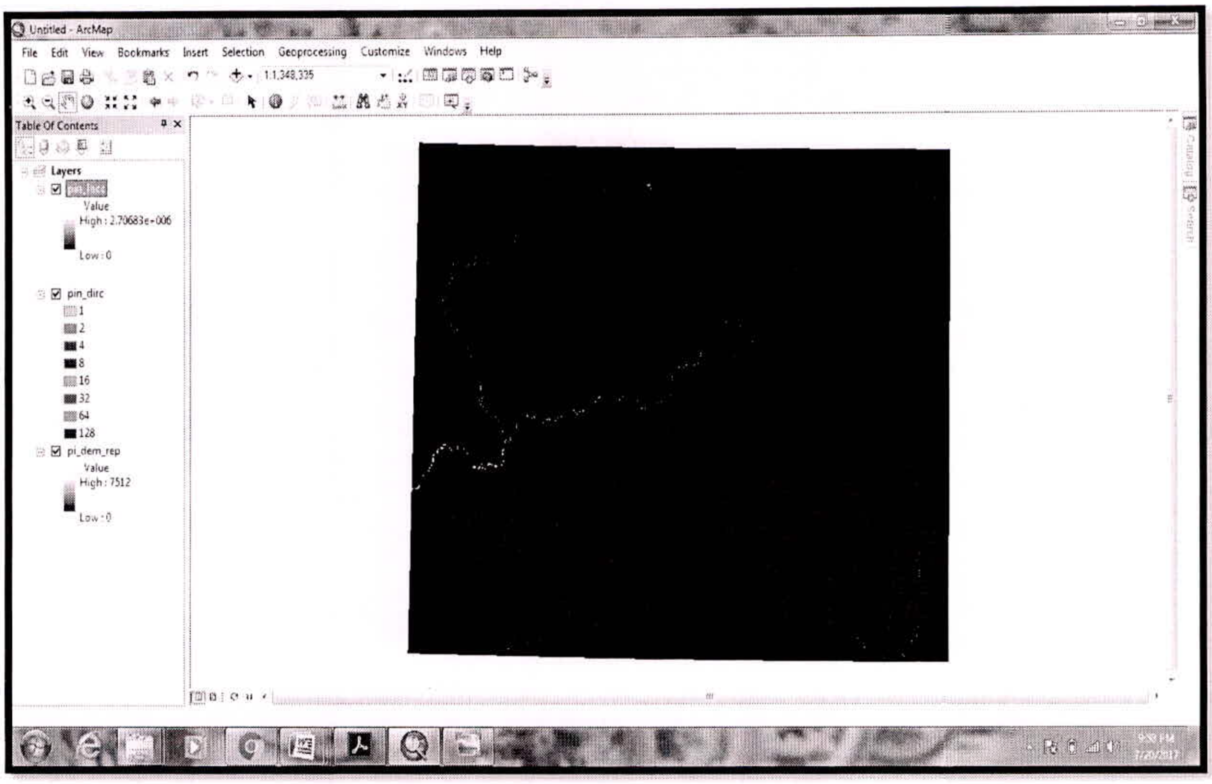


Figure 7: Flow Accumulation

V. Outlet (Pour) Points

Pour point placement is an important step in the process of watershed delineation. A pour point should exist within an area of high flow accumulation because it is used to calculate the total contributing water flow to that given point. In many cases you will already have a file containing the locations of your pour points, whether they are sampling sites, hydrometric stations, or another data source. However in some cases, it may be necessary or preferable to create pour points manually. Instructions have been provided for both cases below.

a. *Loading pour points from an existing file*

Add the point file containing pour point locations to your map document along with the flow accumulation grid created in Step 4. Zoom in to each point (or a random sample of points) to determine if they fall on a path of high flow accumulation. As mentioned, if the pour points are not situated in cells of high flow accumulation then the resulting watersheds will be excessively small.

Assuming that your pour points are situated correctly, move on to Step 6.

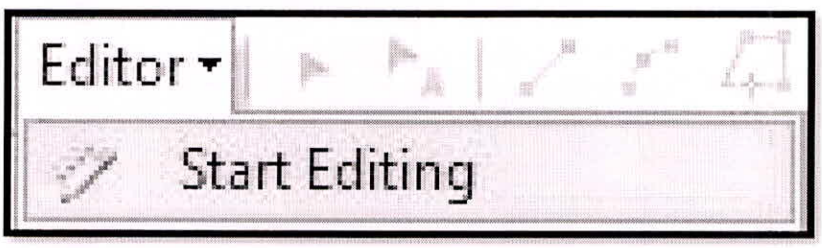
b. ***Creating pour points through visual inspection***

Open the ArcCatalog window and create a new point file in your working directory (right-click the directory in the Catalog tree and select *New > Feature Class* if you are working from a geodatabase, or *New >Shapefile*if you are working from a folder). Give the file a descriptive name and apply theappropriate coordinate system for your data. Click OK to add the new point layer to the map document.

Zoom in to your study area so that you are able to see the individual cells of the flow accumulation grid.

Use the *Identify* tool to examine the values of the grid. 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.

When you are satisfied with your choice, add the point by starting an editing session (*Editor > StartEditing*). If you are asked which layer you would like to edit, select the empty point layer and click *OK*.



If necessary, open the *Create Features* window and highlight the pour point file in the list. Move your cursor onto the map document and add a pour point by clicking in the centre of the cell you have chosen as the location of your outlet point. Try to place the points directly in the centre of the chosen cells and remember to place the points one or two cells away from stream confluences.

If you are creating a single watershed then save your edits and move on to Step 6.

If you are creating multiple watersheds, complete the process of adding outlet points then save your edits and exit the editing session. Open the point layer's attribute table (right-click >*Open AttributeTable*), click the *Table Options* button and select *Add Field.*

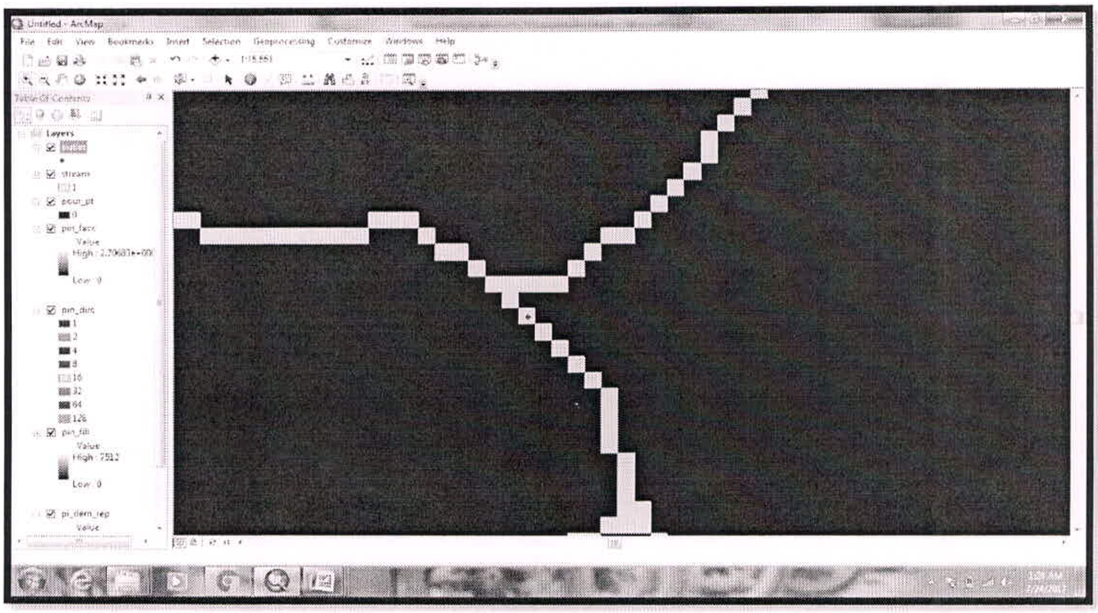


Figure 8: Snap Pour Point

The *Snap Pour Point* tool accomplishes two things; it snaps the pour point/s created in Step 5 to the closest cell of high flow accumulation to account for any error during placement, and it converts the pour points to raster format for input to the *Watershed* tool.

Double click the *Snap Pour Point* tool to open its dialog and enter the following parameters.

1. Set the *Input raster or feature pour point data* to the pour point layer created or loaded in Step 5.

2. Set the *Pour Point Field* to the UNIQUEID field created in Step 5 (only applicable when delineating multiple watersheds).

3. Set the *Input accumulation raster* to your flow accumulation grid created in Step 4.

4. Set the *Output raster* to your working directory and give the output a descriptive name.

The *Snap Distance* is the specified distance (in map units) that the tool will use to search around our pour points for the cell with the highest flow accumulation value. The snap distance should be based on the resolution of your data; it may require some trial and error to determine the best value. If your pour point is not located on a high flow pathway, the tool will move it to the cell within the search radius with the highest accumulation value. If your pour point is already located on the high flow pathway, then the tool will move the point to a downstream cell within the search radius. If it is important that your points remain at the exact cell location of initial placement, then run the tool with a snap distance of 0.

5. Browse to *Environment Settings > Raster Analysis Settings > Cell Size* and ensure that the cell size is set to the same as your flow accumulation layer.

Click OK to run the tool. The output will yield a raster file of pour points that will be added to the map document.

VI. **Delineate Watershed**

Double-click the *Watershed* tool to open the tool dialog and set the parameters as follows.

1. The *Input flow direction raster* is the flow direction raster output in Step 3, or the enhanced flow direction grid provided with the OMNRF data package.

2. The *Input raster or feature pour point data* is the raster pour point file created in Step 6.

3. The *Pour point field*can be left as default, or optionally you may choose to select the UNIQUEID field created in Step 5.

4. If necessary, set the *Output raster* to your working directory and provide a descriptive name for the output file.

Click OK to run the tool. Upon completion, a new watershed raster will be added to your map document.

Figure 9: Pindar Watershed

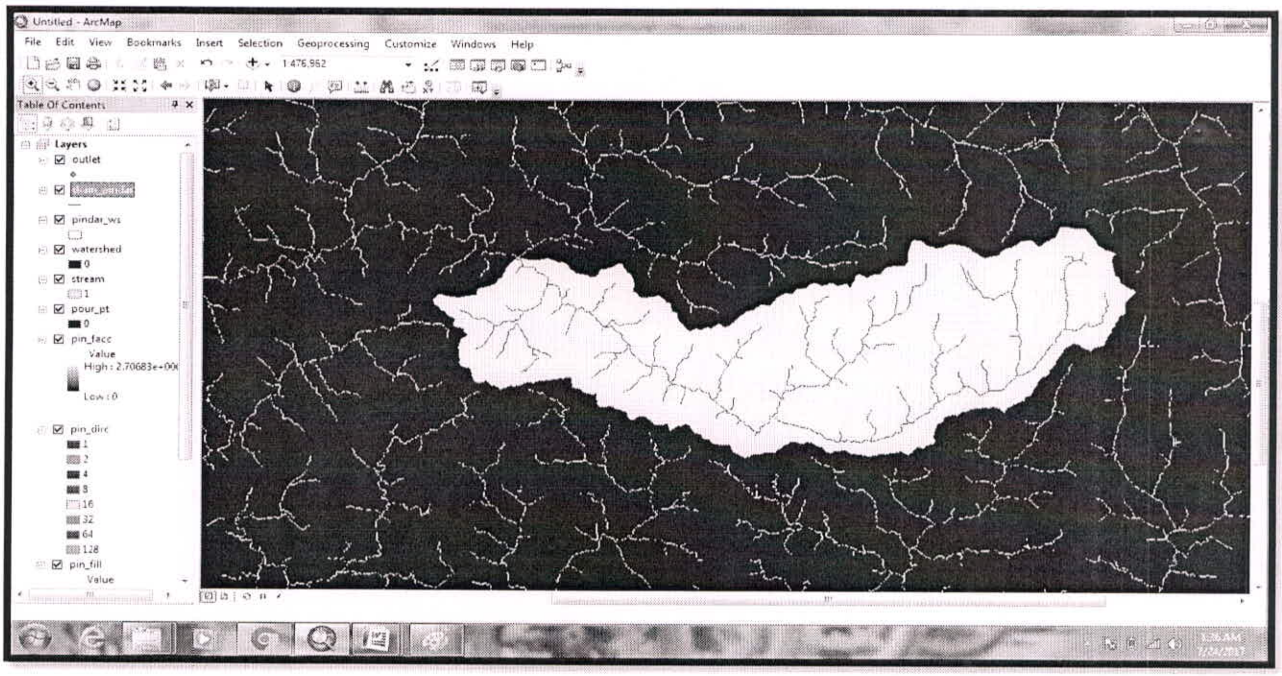


Figure 10: Drainage network of Pindar river watershed

RESULT

The SRTM DEM of spatial resolution 90 m was processed for the delineation of Pindar watershed in the GIS environment. The spatial analyst tool has been used for processing the raw DEM which included filling the downloaded DEM, generation of flow direction, flow accumulation maps and finally generated the stream network. The outlet for the watershedhas been taken at Karanprayag before merging with Alaknada River. The area of the delineated Pindar watershed comes out to be 1896 sq. km.

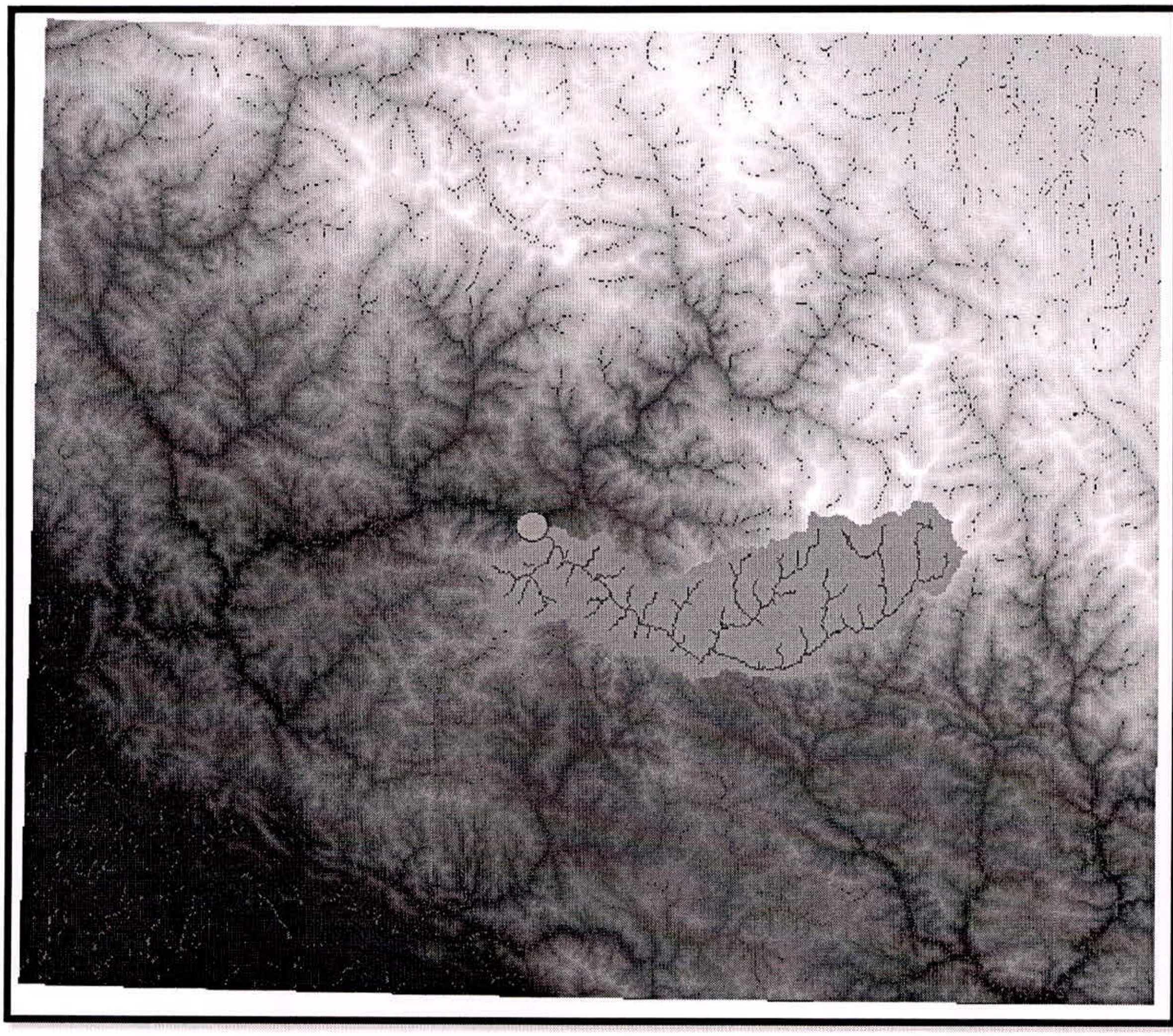


Figure 11: Pindar River Watershed Delineation

CONCLUSIONS

Current remote sensing and geographic information system technologies provide waysfor rapid collection of field data and prompt data processing.In the present study, Shuttle Radar Topography Mission (SRTM) DEM with a spatial resolution of 90 m and geographic information systemtechniquesusing ARC GIS software have been deployed to delineate stream network and watershed for the Pindar River at Karanprayag. The analysis of watershed based on remote sensing and satellite derived Digital Elevation Model (DEM) are most important data for proper hydrological investigation of any terrain which indirectly support hydrogeological status of the watershed. Remote sensing and GIS are the potential tools and provide an effective approach for developing accuratewatershed analysis for various uses with a minimum amount of time, effort, and cost.

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