Watershed Delineation Using Digital Elevation Model and Terrain Tiles in Q-GIS

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Abstract - *Globally the availability of fresh water is a limited resource and requires sustainable management. Given the varied bio-climatic zones, variations in rainfall, each geographic area receive a certain mean annual rainfall. However, in certain areas with changing water demand, there is a perceived sense of inadequate rainfall over the years and hence overall yield resulting from this precipitation. Despite adequate rainfall over this area, people face water scarcity every year. Further, with uneven and unsure rainfall, there's a perceived sense of inadequate rainfall calling for declaring the region as 'drought' prone despite an adequate mean annual rainfall within the catchment. In this backdrop, it becomes pertinent to assess the potential yield of runoff from rainfall in the catchment.* [1] *This can be achieved by delineating the watershed and analyzing the stream network in the watershed for possible yield using appropriate methods.* [2] *Survey of watershed using tools such as total station is a lengthy and tedious process. GIS provides as a much easier process for large area surveys without visiting the actual site physically. Q-GIS are one of the open source software available for free on the market to work in complicated and large surveys of land and water bodies. Q-GIS provide a user-friendly interface and are integrated with tools such as SAGA, GRASS, etc. Watershed delineation can be carried out using satellite images tiles in Q-GIS. The data from these satellite images can be extracted as vector and raster data, thus digital elevation model is formed. QGIS is an ergonomic geospatial data analyzing software. It has an easy interface to create 2-D maps and 3-D models. QGIS deals with both vector as well as raster data for analysis.*

*Key Words***:** Q-GIS Software, Watershed Delineation, Digital Elevation Model, GIS, Remote Sensing, Hydrological Survey, etc.

1. INTRODUCTION

Surveying is one of the most important parts of the Civil Engineering field. Surveying is the technique, profession, art and science of accurately determining the terrestrial or three-dimensional positions of points and thus the distances and angles between them. These points are usually referred to surface of the Earth, and that they are often wont to establish maps and boundaries for ownership, locations, such as building corners or the surface location of subsurface features, or other purposes required by government or civil law, like property sales.

Surveyors work with elements of geometry, trigonometry, multivariate analysis, physics, engineering, metrology, programming languages, and therefor the law. They use equipment, like total stations, robotic total stations, theodolites, GNSS receivers, retro reflectors, 3D scanners, radios, clinometer, handheld tablets, digital levels, subsurface locators, drones, GIS, and surveying software.

Surveying has been an essential component in the development of the human environment since the beginning of history. The planning and execution of most kinds of construction require it. It is also utilized in transport, communications, mapping, and therefore the definition of legal boundaries for land ownership. It is a crucial tool for research in many other scientific disciplines.

The traditional, lengthy, time-consuming methods and bulky equipment are now replaced with modern, faster methods and compact, remote equipment in modern surveying. The survey of small areas of land for calculations of angles, distances and areas can be carried out easily by traditional methods using theodolite or total station from the site itself, but when it comes to calculations like reservoir capacity, forest area, watershed delineation, mineral exploration, cyclone predictions and other larger area related surveying we use remote sensing by satellite images, aerial photogrammetry and surveying software.

1.1 Remote Sensing and GIS

Remote sensing is no new technique of surveying. Remote sensing can be defined as the science of obtaining information about objects or areas from a distance without reaching the object physically. Remote sensors collect data by detecting the energy emitted by the object. Based on this principle remote sensing is either active or passive. Active remote sensing is the process where the sensors respond to internal stimuli, i.e. an artificial source of energy is projected and reflected by the sensor. Active remote sensing uses emissions such as sound waves and laser beams. Whereas, passive remote sensing is the one where the sensors respond to external stimuli, i.e. they record natural energy emissions reflected by the object.

The most common source of radiation in passive remote sensing is the sun. These sensors can be mounted on carriers such as satellites, aircraft, balloons, elevated platforms, etc. to collect geographic data.

A Geographic Information System (GIS) is one of the advanced techniques used in modern surveying. A GIS is a framework for gathering, managing and analyzing data. Rooted in the science of geography, GIS integrates many types of data. It analyses spatial location and organizes layers of information into visualizations using maps and 3-D scenes. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships and situations helping users make smarter decisions. Hundreds of thousands of organizations in virtually every field are using GIS to make maps that communicate, perform analysis, share information and solve complex problems around the world. GIS technology applies geographic science with tools for understanding and collaboration. It helps people reach a common goal to gain actionable intelligence from all types of data. Maps are the geographic container for data, layers and analytics. App easily shares and embeds GIS maps and accessible by virtually everyone, everywhere. GIS integrates many different kinds of data layers using spatial location. Most data have a geographic component. GIS data includes imagery, features and base maps linked to spread sheets and tables. Spatial analysis lets you evaluate suitability and capability, estimate and predict, interpret and understand and much more lending new perspectives to your insight and decision-making.

1.2 Quantum Geographic Information System(Q-GIS)

Quantum Geographic Information System (QGIS) is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data. QGIS functions as a geographic information system (GIS) software, allowing users to analyses and edit spatial information, in addition to composing and exporting graphical maps.

QGIS supports both raster and vector layers; vector data is stored as point, line, or polygon features. Multiple formats of raster images are supported, and therefore the software can georeference image. QGIS supports shape files, coverage's, personal geodatabase, Def., MapInfo, Post GIS, and other formats. Web services, including Web Map Service and Web Feature Service, are also supported to permit the utilization of knowledge from external sources. QGIS integrates with other open-source GIS packages, including Post GIS, GRASS GIS, and Map Server. Plugins written in Python or C++ extend QGIS's capabilities. Plugins can geocode using the Google Geocoding API, perform geoprocessing functions almost like those of the standard tools found in ArcGIS, and interface with PostgreSQL/Post GIS, Spatiality and MySQL databases.

Gary Sherman began the development of Quantum GIS in early 2002, and it became an incubator project of the Open Source Geospatial Foundation in 2007. Version 1.0 was released in January 2009.

In 2013, along with the release of version 2.0, the name was officially changed from Quantum GIS to QGIS to avoid confusion as both names had been used in parallel.

1.3 Watershed delineation

A watershed also called a basin, drainage, or catchment area is the land area that contributes runoff to an outlet point. The selection of the outlet point determines a watershed boundary, and the process of defining the boundary of a watershed is known as watershed delineation. Watershed delineation is often the first step in hydrologic analysis. Various topographical data for hydrologic analysis including the catchment area, land use, and soil distribution is typically summarized based on the delineated watershed boundaries. In the past, the Watershed delineation step was traditionally performed using paper maps and field surveying, but recently, following the proliferation of geographic information systems GIS, GIS Watershed delineation functionality has frequently been applied for defining a watershed using digital elevation model (DEM).

1.4 Digital Elevation Model(DEM)

A digital elevation model (DEM) is a 3D representation of a terrain's surface created from a terrain's elevation data. DEMs are used often in geographic information systems and are the most common basis for digitally-produced relief maps. While a digital surface model (DSM) may be useful for landscape modelling, city modelling and visualization applications, a digital terrain model (DTM) is often required for flood or drainage modelling, land-use studies, geological applications, and other applications, and in planetary science.

DEMs are commonly built using data collected using remote sensing techniques, but they may also be built from land surveying. The digital elevation model itself consists of a matrix of numbers, but the info from a DEM is usually rendered in visual form to make it understandable to humans. This visualization could also be in the form of a contoured topographic map or could use shading and false colour assignment to render elevations as colours (for example, using green for the lowest elevations, shading to red, with white for the highest elevation.). Visualizations are sometimes also done as oblique views, reconstructing a synthetic visual image of the terrain as it would appear looking down at an angle. In these oblique visualizations, elevations are sometimes scaled using "vertical exaggeration" to make subtle elevation differences more noticeable.

2. DEVELOPMENT OF THE DIGITAL ELEVATION MODEL OF WATERSHED FOR PANJHRA RIVER

The Panzara-Kan or Panjhra is a river in the Khandesh region of Maharashtra state of India. It is a tributary of the Tapi River. The Panjhra River originates just a few kilometers from the small town of Pimpalner Tal - Sakri in the Dhule District. Akkalpada Dam is built on the Panjhara River in Sakri Taluka at its headwaters is a small reservoir which was created when the Latipada Dam was constructed.

3. Methodology

The method that was followed to delineate the watershed of River Panjhra

1. Start with finding the location of our catchment. Use the Quick Services plugin after installing the Quick Map Service plugin, you can find it under the Web Menu.

2. From there we choose OSM always, which gives us a world map street map, then we zoom into our area of interest i.e. Panjhra River near Dhule district. It origins from the foothills of the Sahyadri mountain just a few kilometers from the small town of Pimpalner Tal - Sakri in Dhule District and joins the Tapi river in the Mudawad village in Shindhkheda, Dhule.

3. Check the UTM zone and select EPSG: 3857. The next step is to zoom in on the area that covers the whole catchment. Use another plugin, the SRTM download shuttle radar topography mission downloader to download the tiles of the 30-meter resolution DEM the one arc-second DEM that is freely available to this plugin you can set it to the canvas extent and then it will take the area that is in our map canvas and then you choose a folder where we want to store the tiles which will be downloaded shortly.

4. Create a folder and then click Download and load images to QGIS. The data will be fetched from the internet and loaded into QGIS automatically. The tiles will be downloaded for the given canvas which you can on and off from the layer list.

5. The next step is to mosaic i.e. to merge the raster tiles we need for our catchment delineation and removing the ones that are not necessary. Go to Raster Miscellaneous -- Build Virtual Raster and then Choose for the resolution. Merge each layer into a stack of layers. Mosaic is a technical term for the merging of rasters. An Execution of GDAL command here. Remove the tiles that you don't need and rename the rest layers.

6. GDAL warp command is applied and the algorithm is run. When it's done you can see the results on the screen as in the Fig. 1.

7. Create DEM subset using clipping is a tool now we run the algorithm and thus we have clips map (Fig. 2).

8. Now use Wang and Liu method for SAGA to fill in the dialogue box in the right. Run the long algorithm that QGIS runs with SAGA integrated (Fig. 3).
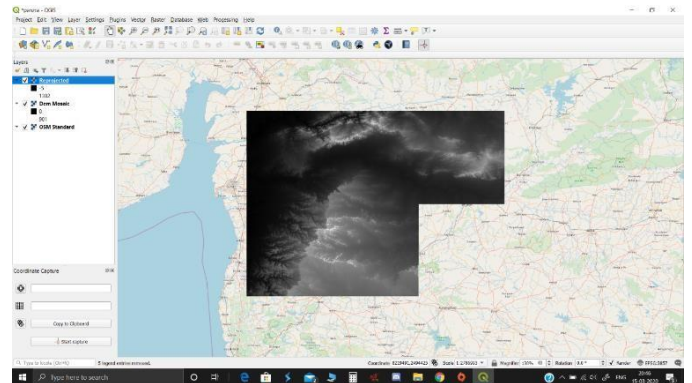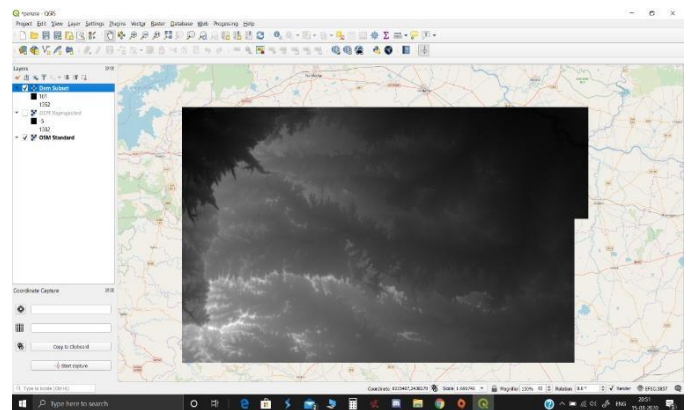

Figure 1: Terrain Tiles.
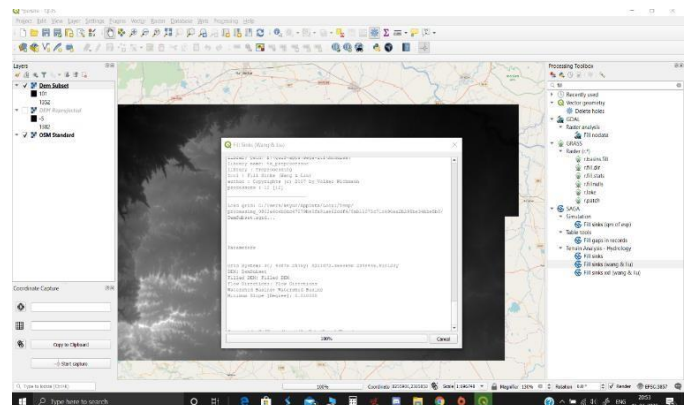

Figure 2: Necessary Terrain Tile.

Figure 3: Wang and Liu method Algorithm.

9. Remove the previous steps and layers and then style the outcome. Adjust the values in the layer

properties for minimum and maximum. Choose the color ramp for the values of elevation on the map (Fig. 4).

10. Duplicate the current layer. Edit the properties of the duplicate layer by applying hill shade to it. This gives a rough embossed image for proper visualization of elevations (Fig. 5).
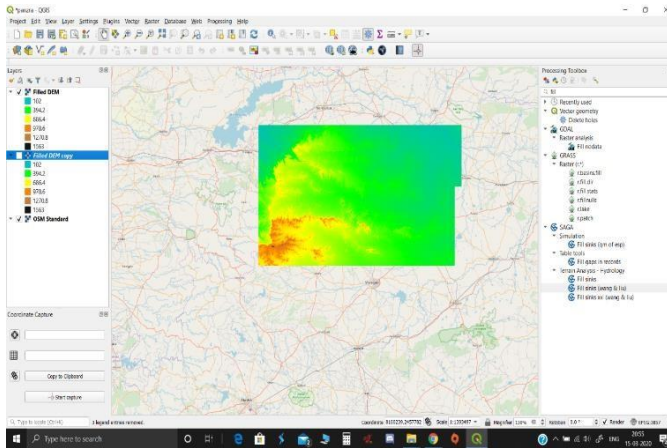

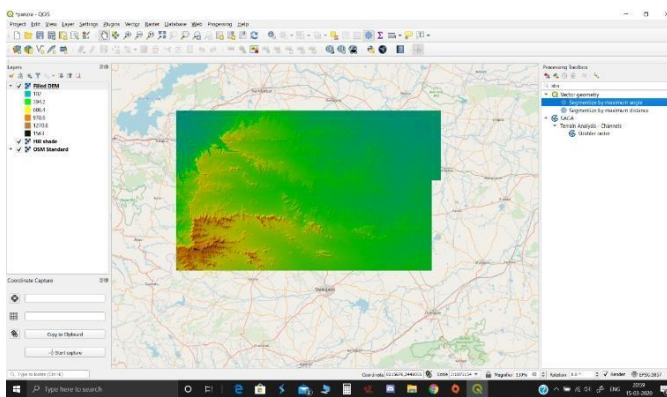**Figure 4**: Adjustment of color values for elevation.

Figure 5: Rough Embossed Image.

11. Use the DEM to continue with the analysis. The next step is to calculate the Strahler order in the processing toolbox. Run the Strahler Order algorithm. This is done to set the threshold for the river. On zooming the below DEM, you will be able to visualize the rivers and other water bodies (Fig. 6).
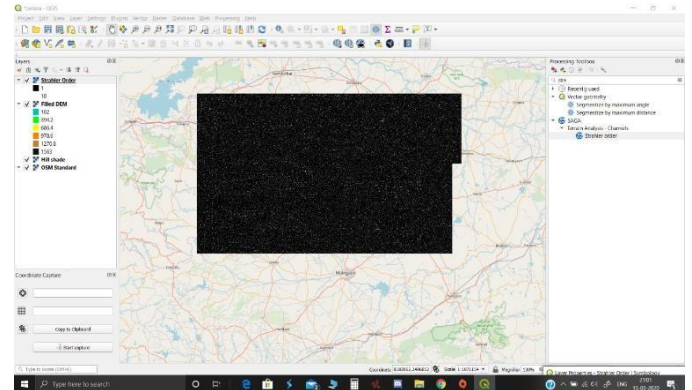

Figure 6: Visualization of Rivers and Water bodies.

12. Calibrate the threshold values, identify the true value (1) in blue and false value (0) in transparent using a raster calculator and after classifying the data we get (Fig. 7).
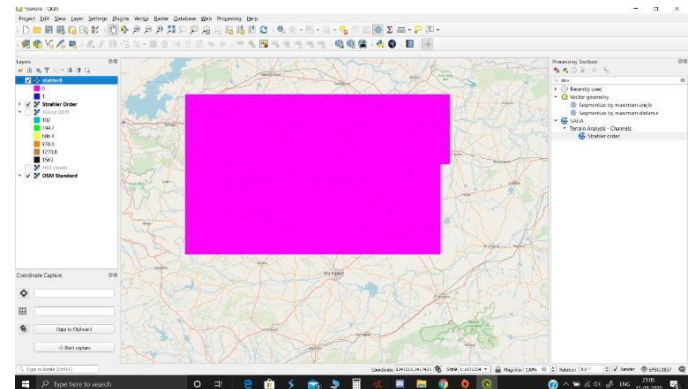

Figure 7: Identification of True and False Values.

13. The next step is to use the Channel Network and Drainage Basins algorithm to delineate the streams. Use the calibrated threshold values in the algorithm and save the vector and raster data. This will again initiate a third-party algorithm from the SAGA integrated with QGIS. We get flow directions of the stream and channels in a single color as a result (Fig. 8).
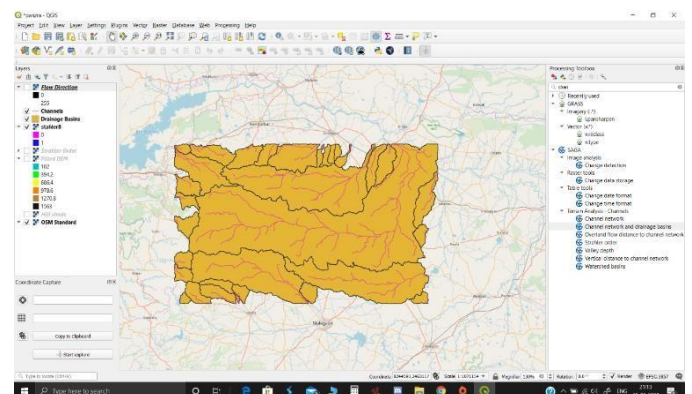

Figure 8: Flow Direction of Streams and Channels.

14. The next step is to style and customize the channels and basins by marking them with individual colors and streams as blue in the Layer Properties window.

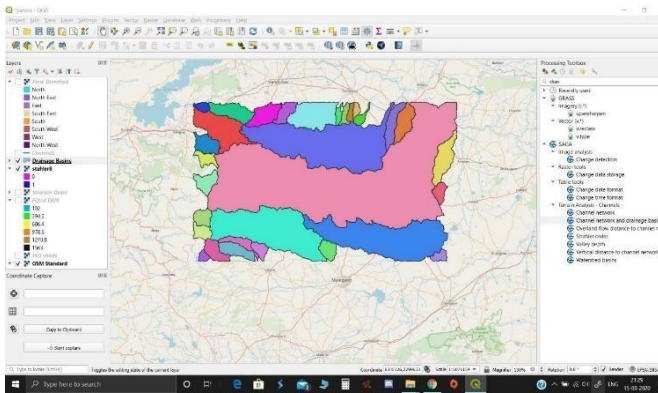Choose a unique value for each basin for better visualization (Fig. 9).

Figure 9: A Unique value for each Basin.

15. The next step is to use the Coordinate Capture plugin and start Capture. Then run the Upslope Area logarithm which is again a third-party algorithm from the SAGA integrated with QGIS. This will result in showing a catchment area as raster data (Fig. 10)
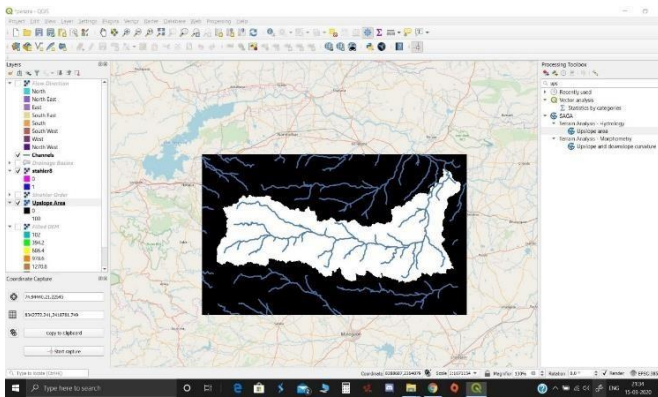

Figure 10: Catchment Area in Raster form.

16. The next step is to polygonise the data i.e. convert raster data to vector data as a .shp file. Thus, the data will be shown as only in points, lines and polygons in color code. Now remove the zero values i.e. data outside the area of interest and save the file. Then use the clip tool to get (Fig. 11).
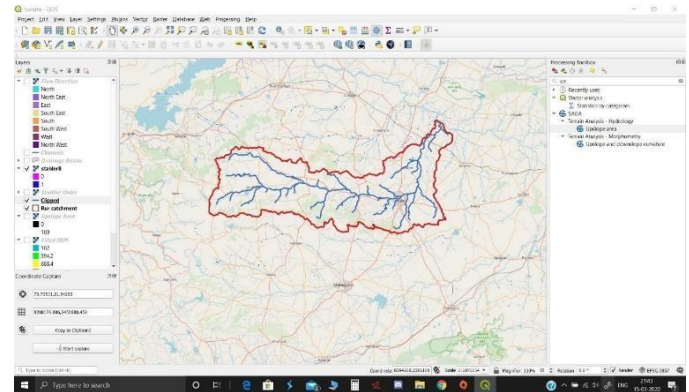

Figure 11: Catchment Area in Vector form.

17. The next step is to run the Clip Raster by Mark Tool. Insert the "fill DEM layer" as an Input layer and "Rur catchment" as Mask layer in this tool. Run the algorithm to get the following result (Fig. 12).

18. Now copy the style from the original DEM i.e. "fill DEM" layer to the "Clipped (mask)" layer. Thus, we get the final result (Fig. 13).
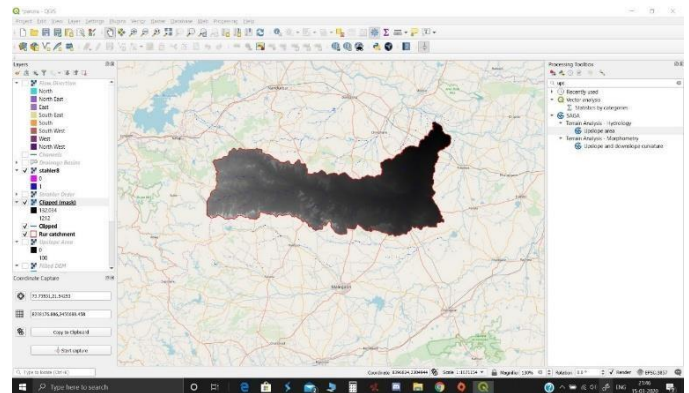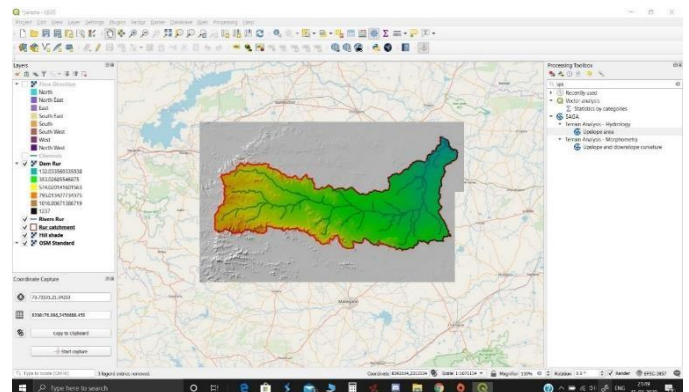

Figure 12: Clipping the Raster Data.

Figure 13: Final DEM of Watershed.

4. RESULTS

1. The watershed of River Panjhra has been delineated and a thematic map indicating a watershed boundary, stream network, and tanks have been developed based on DEM methods.
2. The total area of the watershed for Panjhra River = 3154 Km2
3. Average Annual rainfall observed in the area = 674 mm
4. The theoretical yield of runoff from the catchment is found to be a minimum of 5.20 TMC (1, 47,212 million liters) and an average of 7.7 TMC (2, 17,987 million liters). The estimates of the minimum and average yield are based on Stranger's table classification of average and bad catchments respectively.

5. CONCLUSIONS

The study has revealed that a minimum of about 5.2 TMC or an average of 7.7 TMC of water can be accumulated annually out of the Panjhra river drainage basin which is a significant quantity of water. This study has been carried out on a theoretical basis considering topographical data (streams) from top sheets and remote sensing satellite-based digital elevation model. The results obtained from this study are based on rainfall data of 2019.

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