CE432A Project Report

GROUP 1

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Introduction

Water conservation and management have become crucial in today's world due to the increasing demand and scarcity of water resources. To address this issue, the construction of micro water conservation structures such as check dams, gabions, and percolation tanks have proven to be effective in conserving water, reducing soil erosion, and recharging groundwater.

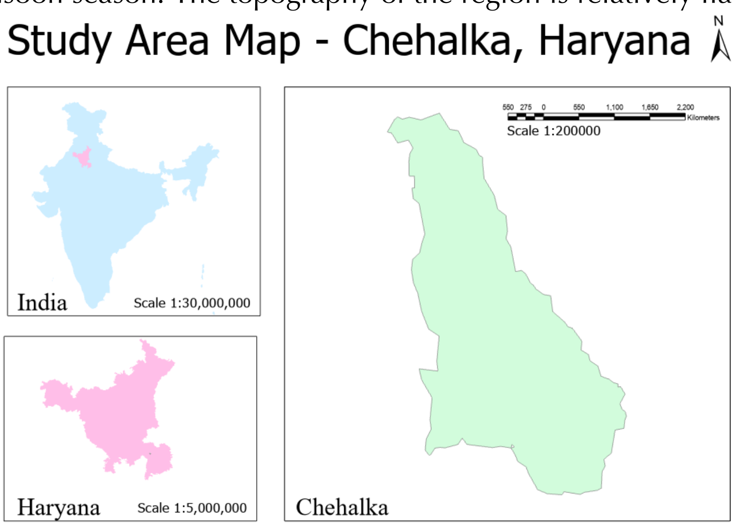
The construction of these structures will have multiple benefits, including reduction of the erosive velocity of runoff, storing runoff, arresting silt carried by runoff, increasing the moisture regime, and recharging groundwater. The aim of this project is to identify suitable site locations for the construction of micro water conservation structures, particularly check dams, using a systematic and scientific approach.

Site identification will be carried out on a watershed basis, considering various factors such as soil type, geomorphology, lithology, land use, etc.The project is focused on the scientific planning process involved in finding suitable site for setting up check dams using AHP, which can be used as a model for future water conservation projects.

Study Area

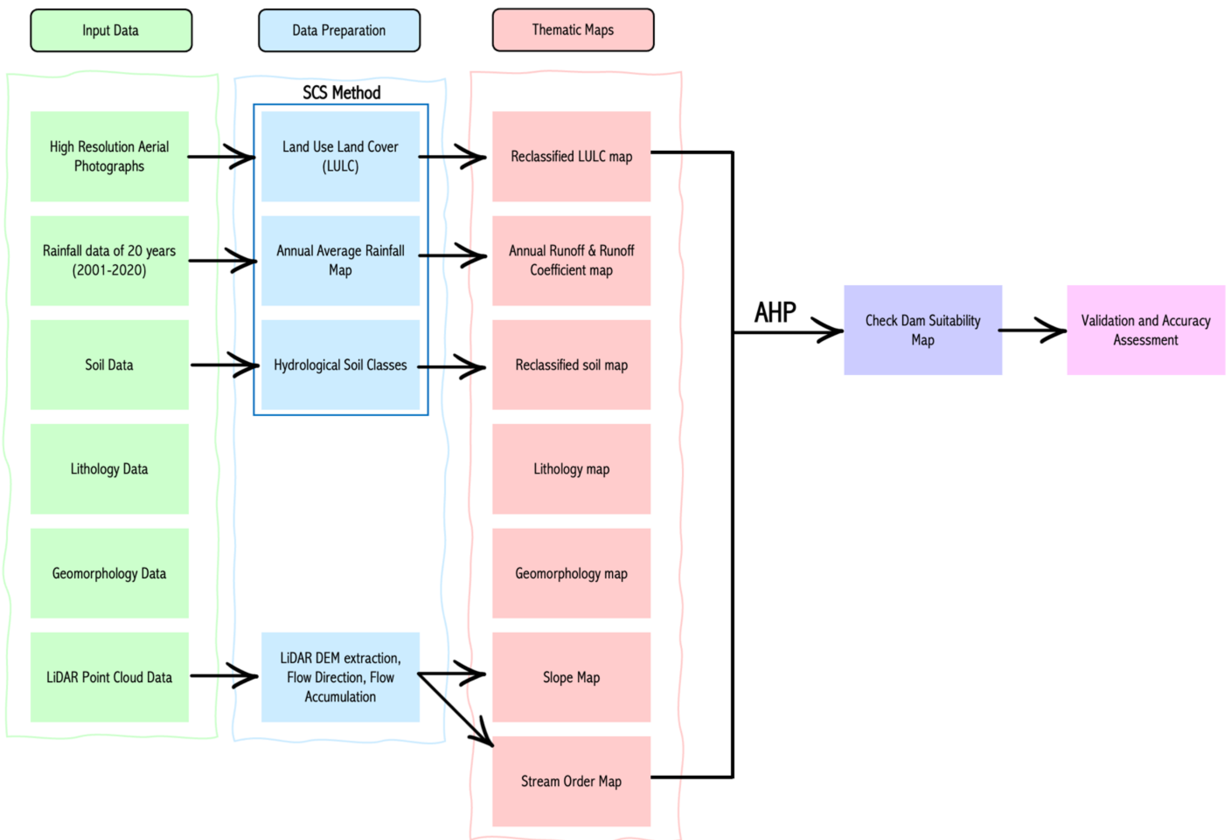
The study area for this project is the village of Chehalka, situated in the northern Indian state of Haryana. This village is spread across an area of around 5 km^2 and is surrounded by agricultural fields and small ponds.

The climate in Chehalka is typical of the region, with hot summers and cool winters, and the area receives most of its rainfall during the monsoon season. The topography of the region is relatively flat, with a gentle slope towards the south.



The study area's natural resources, including land, water, and vegetation, are critical to the livelihoods of the local community. The project study aims to identify suitable locations for check dams in Chehalka to conserve water and recharge groundwater, benefiting the local community and contributing to sustainable development in the region.

Methodology for siting the RWH structure – Check Dam:



Data

The project study relies on several datasets to carry out its objectives which are as follows:

1. Rainfall Data: The rainfall data is obtained from the Indian Meteorological Department and covers the period from 2001 to 2020. This data is used to estimate the average annual rainfall in the study area. The resolution of data used is 0.25 X 0.25 degree.
2. Point Cloud: The point cloud is obtained using LiDAR technology, which is further used to generate a Digital Elevation Model (DEM) of the study area.
3. LiDAR DEM: 10m resolution data resampled from 30cm DEM is used to generate DEM derivatives, including slope map, stream order map.
4. Aerial Photograph: Collected during LiDAR data acquisition and is used to create a high-quality Land Use and Land Cover Map of the study area.
5. Land Use Land Cover Map: Used to estimate the curve number for each land use category.
6. DSMW Soil Map: The DSMW soil map, which is the FAO's Digital Soil Map of the World, is used to estimate the soil type of the study area.The resolution of data is 1:5 million scale.
7. Geomorphology: The publicly available data from the Geological Survey of India at a resolution of 1:250000 scale is used to understand the infiltration and runoff characteristics of the study area.
8. Lithology: The publicly available data from the Geological Survey of India at a resolution of 1:50000 scale is used to understand the type of rocks present in the study area.

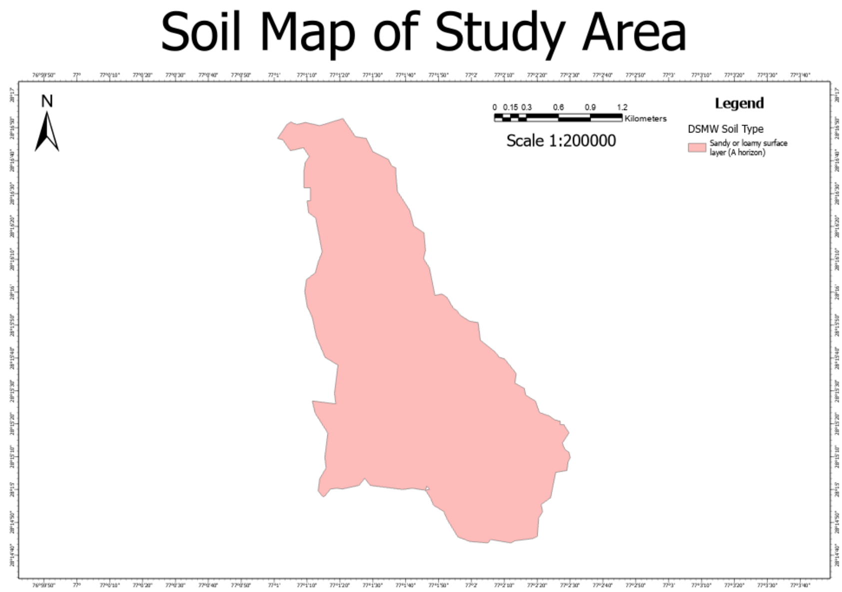
Soil Map

The soil map is an essential component in determining the suitability of a study area for water conservation projects. In this project study, the soil map was prepared using the FAO's Digital Soil Map of World, which provides detailed information on soil types and properties at a global scale.

However, the original DSMW dataset covered a much larger area than the study area, which is limited to the Chehalka village area in Haryana, India.To address this issue, the DSMW dataset was clipped using the clipping tool in ArcGIS Pro, which allowed for the creation of a soil map that covered only the study area.

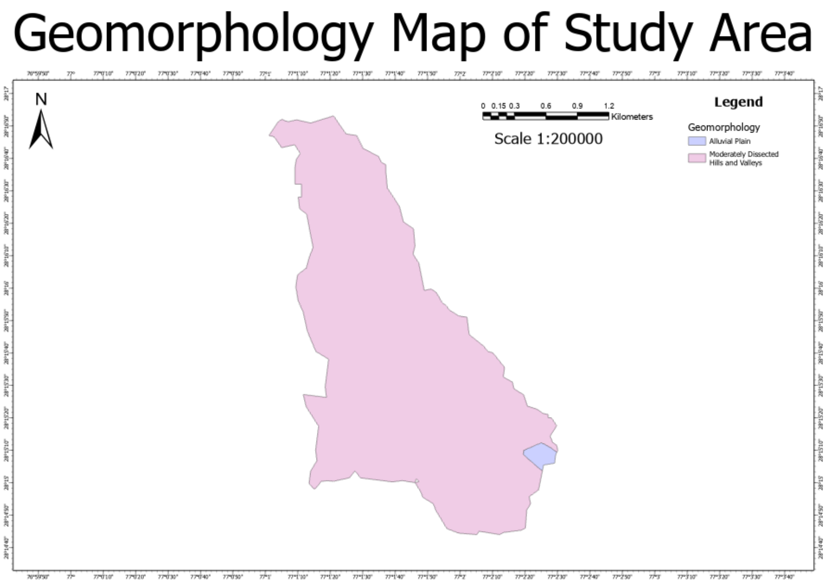
The resulting soil map provided valuable information on the soil type and properties of the study area, which can be used to evaluate its suitability for water conservation projects.The analysis of the DSMW data revealed that the surface soil layer of the study area is primarily composed of sandy or loamy soil.

This uniform soil layer is present throughout the entire study area, indicating a homogenous soil type. Sandy loam soil is known for its high water-holding capacity and good drainage system, making it suitable for agriculture and water conservation projects. The presence of this type of soil is a favorable factor for the implementation of micro water conservation structures, such as check dams, as it allows for easy infiltration and percolation of rainwater into the ground.



Geomorphology Map

The geomorphology map is a representation of the landforms, their origin, and their spatial distribution in the study area. It provides crucial information about the terrain, infiltration, and runoff characteristics of the area.



To prepare the geomorphology map, the publicly available data from the Geological Survey of India was clipped as per the study area using the clipping tool in ArcGIS Pro. The dataset used was at a resolution of 1:250000 scale, which provided information about the landforms present in the study area.

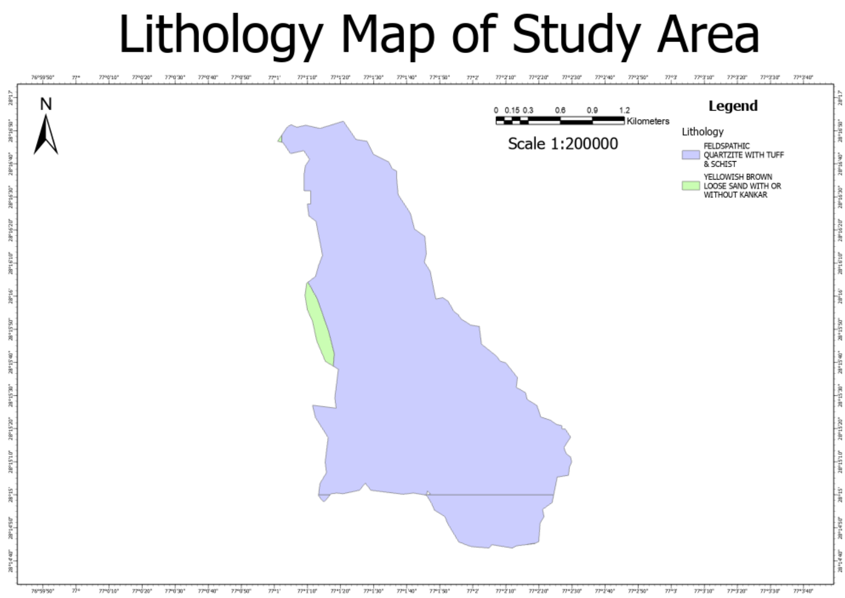
The clipped dataset was then used to generate a geomorphology map, which showed the different landforms in the study area.The analysis of the geomorphology map showed that the project area is mostly moderately dissected hills and valleys with a very negligible area of alluvial plain.

Lithology Map

The lithology map for the project study is a representation of the types of rocks present in the study area. It provides information about the geological composition of the region and is an essential dataset for understanding the water resources of the area.

The lithology map was created using publicly available data from the Geological Survey of India at a resolution of 1:50000 scale. To prepare the lithology map for the study area, the data was clipped as per the study area using the clipping tool in ArcGIS Pro.

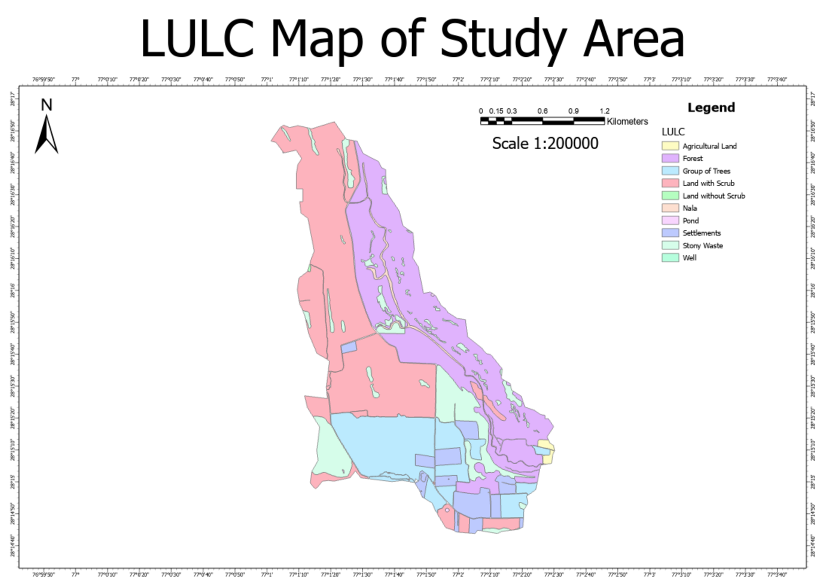
The analysis of the data revealed that the predominant lithology of the area is feldspathic quartzite with tuff and schist. Additionally, a negligible area of yellowish-brown loose sand with or without kankar was also observed in the study area.



LULC Map

The LULC (Land Use Land Cover) map is a type of map that depicts the different categories of land use and land cover types present in a particular area. In this project study, the LULC map was prepared using high-quality aerial photographs that were collected during LiDAR data acquisition. The photographs were analyzed to obtain information about the land use and cover characteristics of the study area.

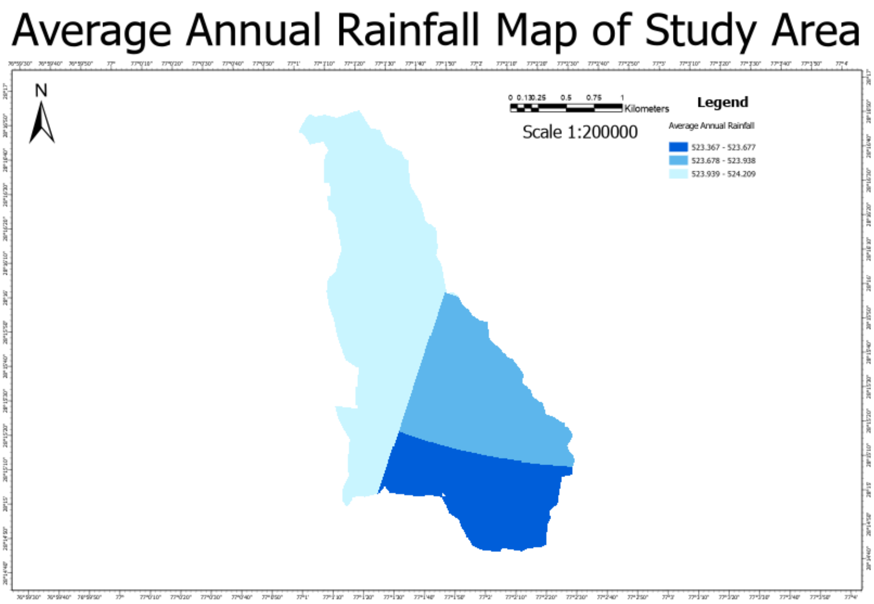
The LULC map for the project study area identified several categories of land use and land cover, namely Agriculture Land, Forest, Group of trees, Land with shrub, land without shrub, settlements, etc. This information is crucial for estimating the curve number for each land use category, which is used to determine the amount of runoff generated during rainfall. The LULC map is an essential dataset for the project study, and it will play a significant role in the identification of suitable site locations for the construction of micro water conservation structures.



Average Annual Rainfall Map

The methodology adopted for making average annual rainfall map of the study area:

1. Add rainfall data of each layer (2001-2020) using the Multidimensional Raster Layer tool in ArcGIS Pro.
2. Once the rainfall data for each layer is added to the project, the Sum tool in Summary Statistics under Multidimensional Group is used to calculate the sum of daily rainfall data for each year (2001-2020) to obtain the annual rainfall data.
3. After obtaining the annual rainfall data, the next step is to clip the data using the Export Raster tool. It is important to ensure that the area includes at least 10-12 pixels to obtain more accurate results.
4. Once the clipped data is obtained, the Raster Calculator tool is used to calculate the average of 20 years. This will give us the average annual rainfall data for the study area.
5. After obtaining the average annual rainfall data for the study area, the next step is to convert the data to point shapefiles using the Raster to Point tool. This is done to ensure that the data can be easily interpolated.
6. Once the data is converted to point shapefiles, the IDW (Inverse Distance Weighted) Interpolation technique is used to interpolate and obtain the final average annual rainfall of the study area. This is done to obtain a continuous surface of the average annual rainfall for the entire study area.
7. After obtaining the final average annual rainfall data, the next step is to clip the data for the study area using the Export Clip tool. This is done to ensure that only the data relevant to the study area is used for further analysis.
8. Finally, a map of the average annual rainfall shapefile is created to visualize the data and analyze the distribution of rainfall across the study area.



The average annual rainfall for the project study ranges typically from 523.4 to 524.2 mm.

Curve Number Map

The methodology adopted finding the curve number was as follows:

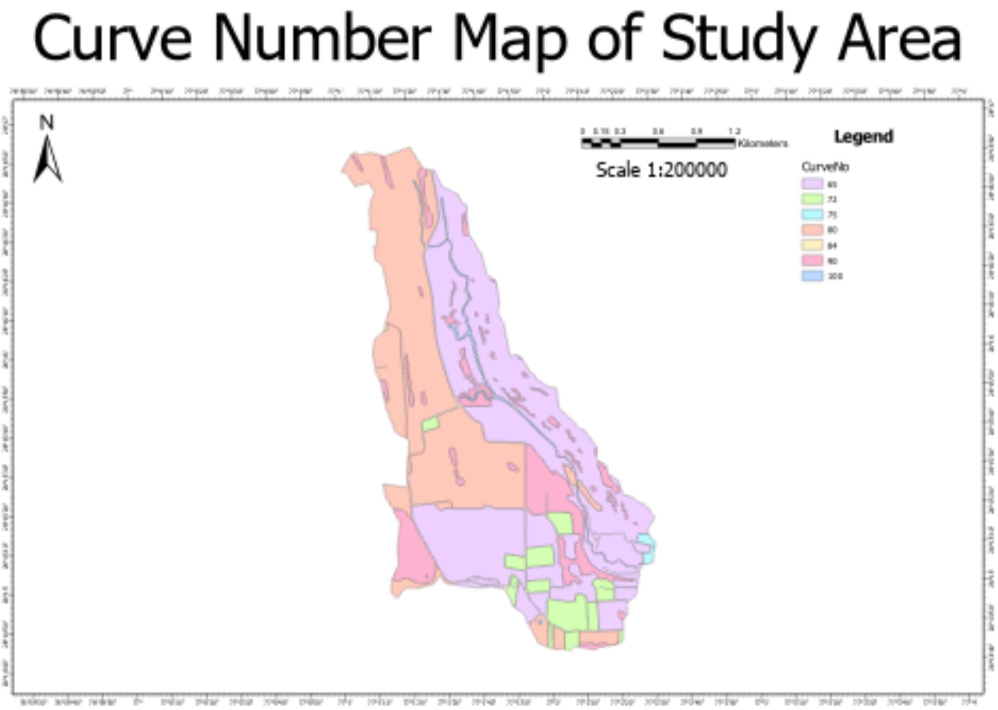
1. The hydrologic soil groups for the study area were determined based on soil type by referring to the table provided by Prasad et al (2014), which classified soil groups as A, B, C, and D based on their runoff potential and infiltration rates. The soil group was found to be B.

Soil Group	Runoff Description	Soil Texture
A	Low runoff potential because of high infiltration rates	Sand, loamy sand and sandy loam
B	Moderately infiltration rates leading to moderately runoff potential	Silty loam and loam
C	High/moderate runoff potential because of slow infiltration rates	Sandy clay loam
D	High runoff potential with very low infiltration rates	Clay loam, silty clay loam, sandy clay, silty clay and clay

Prasad et al (2014)

2. The curve number value was assigned to each land cover class based on the hydrologic soil group using the table provided by Chow et al (1988).

LULC	Soil Type	Curve Number
Land with Scrub	B	80
Land without Scrub	B	84
Forest	B	65
Agricultural Land	B	75
Settlements	B	72
Group of Trees	B	65
Stony Waste	B	90



Runoff & Runoff Coefficient Map

The methodology adopted for estimating runoff and runoff coefficient was as follows:

1. The average annual rainfall map for the study area was obtained.
2. The land use and land cover map of the study area was used to assign curve numbers to each land use category, as per the Soil Conservation Service (SCS) guidelines.
3. The curve numbers were converted to potential retention values using the SCS Curve Number method, which takes into account the soil type, hydrologic condition, and land use of the study area.
4. The annual runoff depth was calculated using the raster calculator tool in ArcGIS Pro as per the following equation:

$$Runoff = \frac{(P - I_a)^2}{(P - I_a + S)}$$

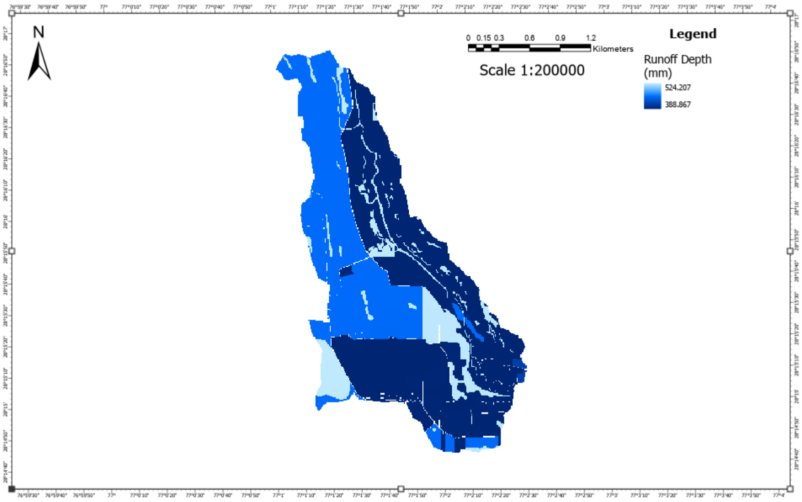
where P = average annual rainfall, Ia = 0.2S and S is potential retention which is calculated using curve number as:

$$S = \frac{25400}{CN} - 254$$

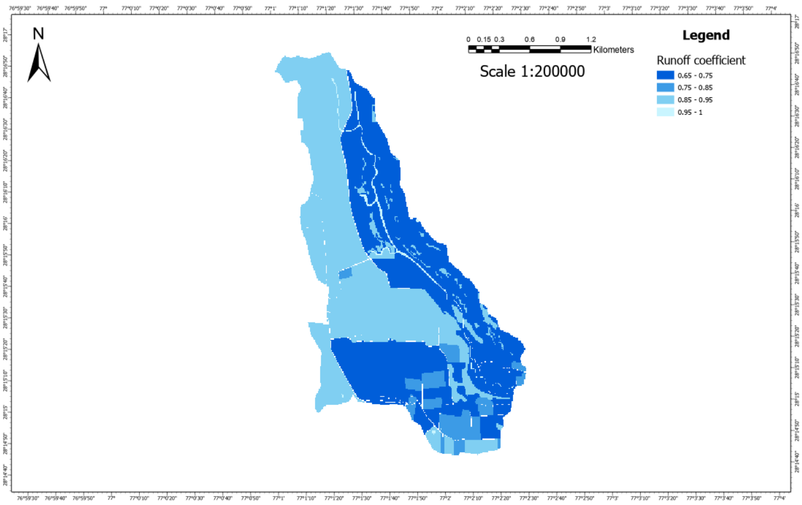
5. The runoff coefficient was also calculated using the raster calculator tool by dividing the runoff depth by the average annual rainfall as per the following equation:

$$Runoff\ Coefficient = \frac{Annual\ Runoff\ Depth}{Annual\ Average\ Rainfall}$$

Runoff Map of Study Area



Runoff Coefficient Map of Study Area



Slope Map

A slope map was created using LiDAR DEM data by applying the slope tool in Spatial Analyst, which calculated the slope values for the study area. The generated slope map was subsequently reclassified into five classes based on the slope values of 0-1, 1-3, 3-6, 8-10, and >10

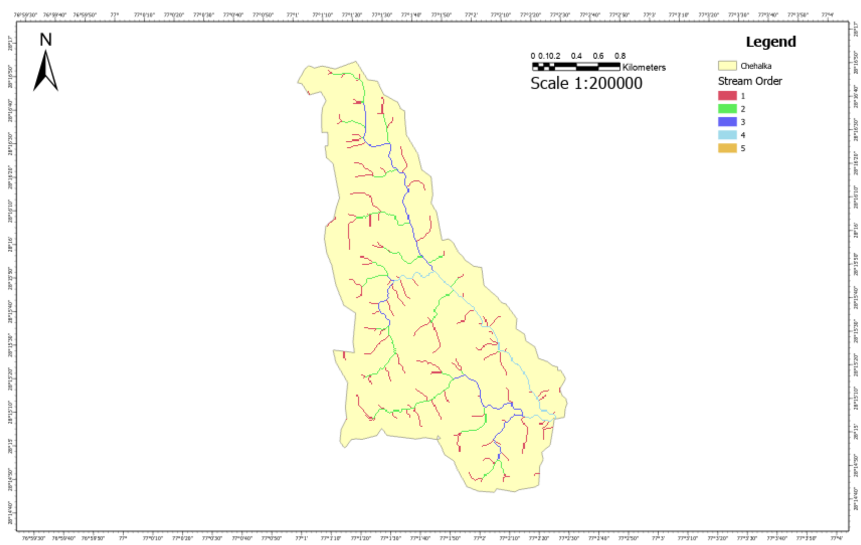
Slope Map of Study Area - 10m resolution

Stream Order Map

To create the Stream Order Map of Study Area, the LiDAR DEM was processed using the following steps:

1. The LiDAR DEM was opened and projected, and then resampled to a 10m resolution.
2. The Fill Sink Tool was used to remove depressions or sinks from the LiDAR DEM to create a smoother surface.
3. The Flow Direction Tool was used to identify the direction of flow for each cell in the raster by determining the elevation values of neighboring points to calculate the flow direction.
4. The Flow Accumulation Tool was used to estimate the amount of water that flows through each cell in the raster, based on the direction of the slope and the volume of water that passes through neighboring cells.
5. The raster calculator tool was used to create a drainage network with the condition "Con(Flow_Accumulation > 100,1)", which created a new raster with only the cells that have a flow accumulation greater than 100.
6. The stream ordering tool was used to assign a hierarchical order to the stream network based on the Strahler ordering system. This tool calculated the stream order for each segment of the stream based on the number of tributaries and their respective orders.

Stream Order Map of Study Area - 10m resolution

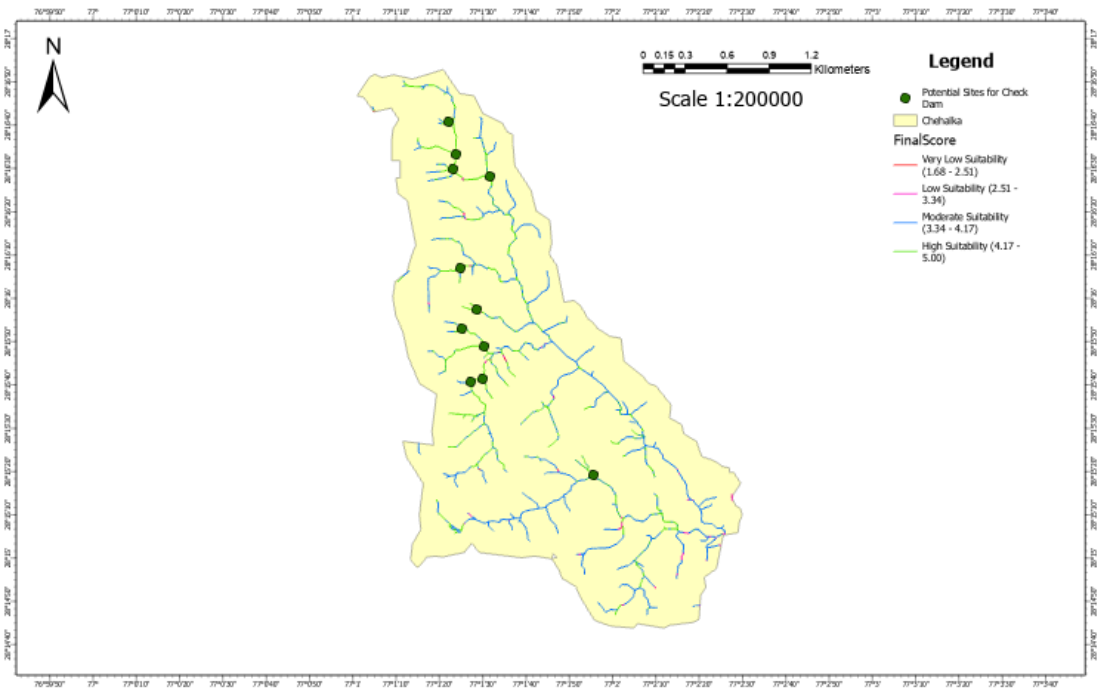


Check Dam Suitability Map

Methodology for creating a check dam suitability map using the AHP approach:

1. Determine the criteria for check dam suitability, such as slope, geomorphology, lithology, runoff coefficient, etc.
2. Assign weights to each criterion based on its relative importance in the decision-making process.
3. Rank each criterion on a scale from 1 to 9, where 1 indicates the lowest suitability and 9 indicates the highest suitability.
4. Multiply the weight by the rank for each criterion to obtain a weighted score.
5. Create a layer for each criterion and assign the weighted scores to each cell in the layer based on its corresponding attribute value.
6. Use the Overlay operation to merge two layers at a time and repeat this process for all layers until a final merged layer is obtained.
7. In the Attribute Table of the final merged layer, sum up all the rank * weight products and put it in a new column to get an overall score for each cell.
8. Identify cells with high overall scores as potential locations for check dams. The higher the overall score, the more suitable the location.

Check Dam Suitability Map of Study Area



Analytical Hierarchy Process (AHP)

The judgement matrix for the Analytic Hierarchy Process (AHP) along with the calculation of weightages for selecting suitable locations for check dam siting is tabulated below.

Judgement Matrix							
	Slope	LULC	Runoff Coeff	Stream Order	Soil	Geomorphology	Lithology
Slope	1	2	1/2	2	2	2	2
LULC	1/2	1	1/3	1/3	2	2	2
Runoff Coeff	2	3	1	3	3	3	3
Stream Order	1/2	3	1/3	1	2	2	2
Soil	1/2	1/2	1/3	1/2	1	2	2
Geomorphology	1/2	1/2	1/3	1/2	1/2	1	1
Lithology	1/2	1/2	1/3	1/2	1/2	1	1

Calculation of Weightage Matrix												
	Slope	LULC	Runoff Coeff	Stream Order	Soil	Geomorphology	Lithology	GM	A2	A3	A4	Final Weight
Slope	1	2	1/2	2	2	2	2	1.486	0.19	1.36	7.24	19
LULC	1/2	1	1/3	1/3	2	2	2	0.891	0.11	0.84	7.52	11
Runoff Coeff	2	3	1	3	3	3	3	2.420	0.30	2.20	7.23	30
Stream Order	1/2	3	1/3	1	2	2	2	1.219	0.15	1.17	7.62	15
Soil	1/2	1/2	1/3	1/2	1	2	2	0.774	0.10	0.72	7.34	10
Geomorphology	1/2	1/2	1/3	1/2	1/2	1	1	0.575	0.07	0.52	7.20	7
Lithology	1/2	1/2	1/3	1/2	1/2	1	1	0.575	0.07	0.52	7.20	7

Checking for Consistency of Weightages obtained:

- The maximum eigenvalue is $\lambda_{max} = 7.621$.
- The consistency index (CI) is calculated as

$$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{7.621 - 7}{7 - 1} = 0.103$$

  where n is the number of criteria.
- The consistency ratio (CR) is calculated as

$$CR = \frac{CI}{RI} = \frac{0.103}{1.35} = 0.077 < 0.1 \text{ OK}$$

  where RI=1.35 is the random index for n=7 which is a function of the number of criteria.
- When the CR is less than 0.1, the weights calculated are considered reliable, which is the case in this scenario.

Data Table					
Criteria	Class	Range	Rank	Weights	Rank*Weight
Slope (degree)	0 to 1	Moderate	3	0.187	0.56
	1 to 3	Very High	5		0.94
	3 to 8	High	4		0.75
	8 to 10	Low	2		0.37
	>10	Very Low	1		0.19

Land Use Land Cover	Land with Scrub	Low	2	0.112	0.22
	Land without Scrub	Moderate	3		0.34
	Lake, Pond, Water, Tank, well	High	4		0.45
	Nala	Very High	5		0.56
	Forest	Moderate	3		0.34
	Agriculture Land	Low	1		0.11
	Settlements	Low	1		0.11
	Group of Tress	Low	1		0.11
	Stony Waste	Moderate	3		0.34
Stream Order	1 to 2	Moderate	3	0.154	0.46
	2 to 3	High	4		0.61
	3 to 4	Very High	5		0.77
	4 to 6	Low	2		0.31
	>6	Very Low	1		0.15
Soil Texture	Sandy Loam	Very High	5	0.098	0.49
Lithology	Yellowish Brown loose sand	High	4	0.072	0.29
	Phylite Quarzite	Very High	5		0.36
Geomorphology	Highly dissected hills and valleys	Very High	5	0.072	0.36
	Alluvial Plain	Moderate	3		0.22
Runoff Coefficient	0.3 - 0.45	Low	1	0.305	0.30
	0.45 - 0.53	Very Low	2		0.61
	0.53 - 0.63	Moderate	3		0.91
	0.63 - 0.85	High	4		1.22
	0.85 - 1	Very High	5		1.52

Results

The most suitable locations for siting check dam are plotted in the map.