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INVESTIGATION OF DRAINAGE IN URBAN AREA USING GEOGRAPHIC INFORMATION SYSTEM IN THE CASE OF NEKEMTE TOWN

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Abstract – Drainage is an important aspect of the urban, rural, forest, and agricultural environments as it aids in the removal of excess water volume. In Nekemte town, where this study is conducted, different drainage problems are encountered in different places. Most drainage structures built in this area were built without a thorough drainage investigation, causing a slew of issues for the people who lived there, particularly during the rainy season. The problems that increase the drainage problems from time to time in Nekemte town were caused by the illegal use of drainage structures (components) like pipes, culverts, and ditches, and their consequence is the overflow of water because of illegal waste (solid waste) in the drainage lines. The objective of this study was to investigate drainage problems using ArcGIS software in the case of Nekemte town. To achieve this objective, a digital elevation model of the area was created from contours. Different hydrological patterns were developed using the ArcGIS hydrology tool and combined with other tools to identify cross-drainage requirements. In the study area, there are ten (10) watersheds and an outlet (pour point). Three (3) stream orders exist in the study area. Protected areas are those that are at least fifty (50) meters from the stream network. The watershed, road (current and proposed), low drainage density, and stream order are all considered when calculating an area's cross-drainage requirement. In the study zone, there are cross-drainage requirements in twenty (20) different places. Seventeen (17) of those cross-drainages lead to exits in the protected zone. The discharge of the area is also computed using the rational method. In general, this study found that cross drainage between Wollega and the stadium is inadequate and improperly placed.

***Keywords*:** Drainage, investigation, GIS, hydrological pattern, digital elevation model

1.0 INTRODUCTION

Hydrology is the science that studies the characteristics, distribution, and movement of water on the land's surface, in the soil and underlying rocks, and in the atmosphere [1]. This succinct explanation alluded to the science's multidisciplinary character and the numerous factors and processes it attempts to model or monitor.

According to historical descriptions of ancient civilizations (such as the Indus and Minoan), urban drainage systems were built with considerable care, with the goals of collecting rainwater, preventing nuisance flooding, and transporting trash. The systems that eventually achieved their goals did so after a lot of trial and error. Planning and design were, on the whole, limited. For urban drainage, there were few numerical standards, and engineering calculations were not used throughout the design. Despite a lack of optimization and the use of trial-and-error construction methods, many ancient urban drainage systems may be effectively rated. When Lewis Mumford remarked that ancient sewer systems were an uneconomic blend of polished technical gadgets and crude social planning, he summed up the status of ancient urban infrastructure [2].

Another ancient civilization that built urban drainage systems was the Persians [3]. Ancient Persians revered urban runoff and set regulations to preserve it from pollution, according to the author. In Persia, polluting water was considered a sin. Rainwater and urban runoff were collected in cisterns for use as drinking water. Urban runoff was fed into the underlying aquifer via deep wells. Urban runoff was viewed as a valuable natural resource in Persian culture. Unfortunately, changes in Persian views and behavior over time contributed to water contamination issues and the civilization's final demise [3].

The hydrologic cycle, sometimes known as the water cycle, is an important part of the planetary system that regulates human, animal, and plant life. As a result, the water cycle's stability is crucial for the long-term viability of biological populations and ecosystems. Climate is defined by meaningful seasonality as measured by temperature, precipitation, wind movement, isolation, and other factors. Climate presents a consistent picture of the terrestrial system in general [4]. Drainage is an important aspect of several locations or environments (for example, urban, rural, forest, and farmland), as it aids in the removal of excess water volume [5].

The evacuation of unexpected water from urban areas as well as sewerage, grey-water, heavy rainfall, and storm water are all included in urban drainage [6]. The majority of drainages in rural regions, on the other hand, are related to road drainage which is designed to shed water into roadside ditches. Improper city land-use planning, which increases the amount of impermeable land, exacerbates the problem by raising the intensity of runoff. Inadequately built storm water drainage systems increase the likelihood of urban flooding [7].

As a result, appropriate storm water management systems must be implemented to ensure storm water generated from developed catchments produces the least amount of nuisance, risk, and damage to people, property, and the environment. This necessitates a multi-objective strategy that takes into account factors such as aquatic and terrestrial ecosystem health, floods and drainage control, public health and safety, economic considerations, recreational opportunities, social considerations, and aesthetic values [8].

Every city and town in the world has its own urban drainage system (UDS), and while developed countries' urban drainage system are well-designed to adapt to climate change situations (such as heavy rainfall and flooding), developing countries' urban drainage system are of poor quality and incapable of removing large amounts of water in a short period of time [9]. Strong floods, on the other hand, pose a significant risk to people's lives and livelihoods. Highway flooding is caused by a malfunctioning road drainage system and a lack of connection between the road and the city's storm water drainage system [10].

In developing countries, urbanization typically has a negative influence on water resources through polluting surface waters. Addis Ababa, Ethiopia is undergoing fast urbanization, which is accompanied by severe water shortages, mismanaged stormwater, and rising river pollution. We built a low-cost stormwater filtration system to supplement the need for non-potable water and to manage storm water runoff pollution [11]. Insufficient urban storm water drainage facilities are one of the most prevalent sources of complaint from inhabitants in many Ethiopian towns, and the problem is only becoming worse as the country's urbanization rate continues to rise [12].

Drainage in many urban areas is based on a wholly artificial sewage system, which consists of pipes and structures that collect and dispose water. The majority of isolated or low-income settlements, on the other hand, do not have a primary drainage system. Storm water is drained naturally into the earth and wastewater is treated locally (or not at all). When the extent of urbanization was limited, these kinds of agreements were commonplace. Information technology have advanced substantially in recent decades, forming a modern approach to problem resolution. Geographical Information System (GIS) is one of them that got a lot of attention recently. GIS is a system for capturing, storing, manipulating, analyzing, managing, and presenting all types of geographic spatial data. In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology [13].

GIS has a variety of applications and is hence of significant interest in a variety of fields of study due to its powerful capacity to analyze spatial data. GIS could provide the demand for a systematic way to modeling, analyzing, and/or presenting massive amounts of data (spatially and temporally distributed). Modeling and interpreting spatially distributed data with various spatial resolutions is a requirement of Water Resources Engineering as a multidisciplinary profession. As a result, GIS is an effective tool for resolving water resource issues. In light of the foregoing, the purpose of this paper is to provide a quick overview of GIS-based hydrological modeling, namely rainfall-runoff modeling. In this regard, the importance of integrating hydrological modeling and GIS systems is first highlighted, along with practical examples. Various relevant GIS tools are also discussed. Following that, various case studies of GIS-based rainfall runoff modeling are presented in order to clarify the modeling technique in depth, as well as its benefits and problems. The good agreement between the results of fairly simple GIS-based models and observations suggests that such models have a bright future. Finally, the paper summarizes the advantages of GIS technologies in hydrological modeling [13].

The research area's contour and road network have been combined with other applications, such as hydrological models, to perform geographic and scientific assessments, as evidenced by the discipline's usage of Geographical

Information Systems (GIS). To deal with the plethora of data that would otherwise result from attempting to record real-world hydrology in its entirety, this integration of hydrology with GIS necessitates an abstraction of reality. As a result, a number of data models have been created in an attempt to provide a structure for storing data describing hydrological processes and associated variables in a more straightforward manner [14].

1.1. Research Significance

The significance of this research is investigation of drainage in Nekemte town using ArcGIS and identify a different problem related to drainages, encountered in this area. Because a GIS-based approach of problem-solving was employed in this research, the Nekemte population who resides in the area where the research was carried out will benefit the most from this discovery if a concerned body utilizes the result gained from this research. Also, it helps as a base for additional investigation to amend this outcome or to study other related difficulties. Moreover, this research can be a reference for government or non-government companies who want to design the drainage structure in this area [15].

2.0 MATERIALS AND METHODS

2.1 Study Area

The study part is located in Nekemte, which is one of the divisional cities of Ethiopia, located in the west capital city of Ethiopia. Nekemte has a latitude and longitude 90 5'N 36033'E/9.0830N 36.550E and a promotion of 2088 m meters above mean marine level. The City has 53.764 km^2 area from this 28.2983 km^2 sheltered by this study. Figure 1 is expressed the area of study that is Nekemte town.

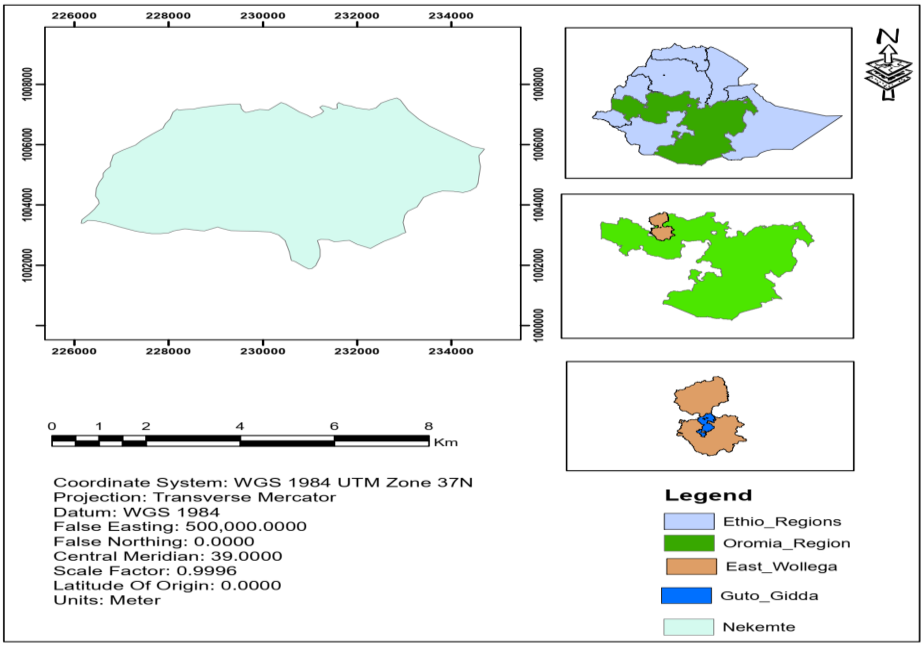

Figure 1 Location map of the study area

2.2 Population and Socio-Economic Characteristics

Socioeconomic and demographic factors influence many of a society's important activities. As a result, having a good understanding of the study's socioeconomic and demographic characteristics is crucial. The population of the city in 2012 grew at a pace of 5.4 percent per year [16] significantly higher than the national average urban growth rate of 2.5 percent per year. This is due to migration, which plays a significant role in the growth of Nekemte population, and according to [17] 60% of the residents are born elsewhere.

2.3 Temperature

Many of a society's main activities are influenced by socioeconomic and demographic considerations. As a result, it is critical to have a thorough understanding of the study’s socioeconomic and demographic characteristics. The city's population rose at a rate of 5.4 percent per year in 2012 [18] much faster than the national average of 2.5 percent per year.

2.4 Rainfall

Socioeconomic and demographic factors influence many of a society’s primary activities. As a result, an in-depth grasp of the study's socioeconomic and demographic are necessary. In 2012, the city's population grew at a pace of 5.4 percent per year, substantially faster than the national average of 2.5 percent per year [19]. Table 1 and Figure 2 represented Nekemte town rainfall.

Table 1 Mean monthly rainfall in Nekemte

Monthly	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	oct	Nov.	Dec.
Rainfall(mm)	10.08	15.1	53.3	92.2	263	397.3	400	386.2	386	285	147.8	18.1

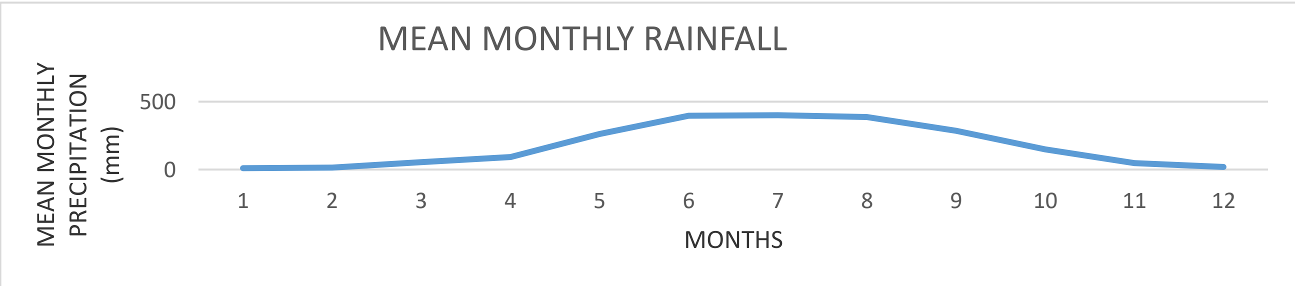

Figure 2 Mean monthly rainfall

2.5 Nature of the Soil

The physical disintegration and degradation of volcanic rocks, as well as the deposition of alluvial and ash are the primary causes of soil development in the Nekemte watershed as shown in Figure 3. Weathering products remain either in place and create residual soils or are deposited in low-lying areas in the central and southern regions of the country due to overland flow [20]. The soil deposited on Nekemte’s plain area is often reworked alluvial sediment with a prolonged deposition time. The depth of the earth near Melka Hida reaches up to 20 meters, according to good log data from boreholes drilled in the town [20].

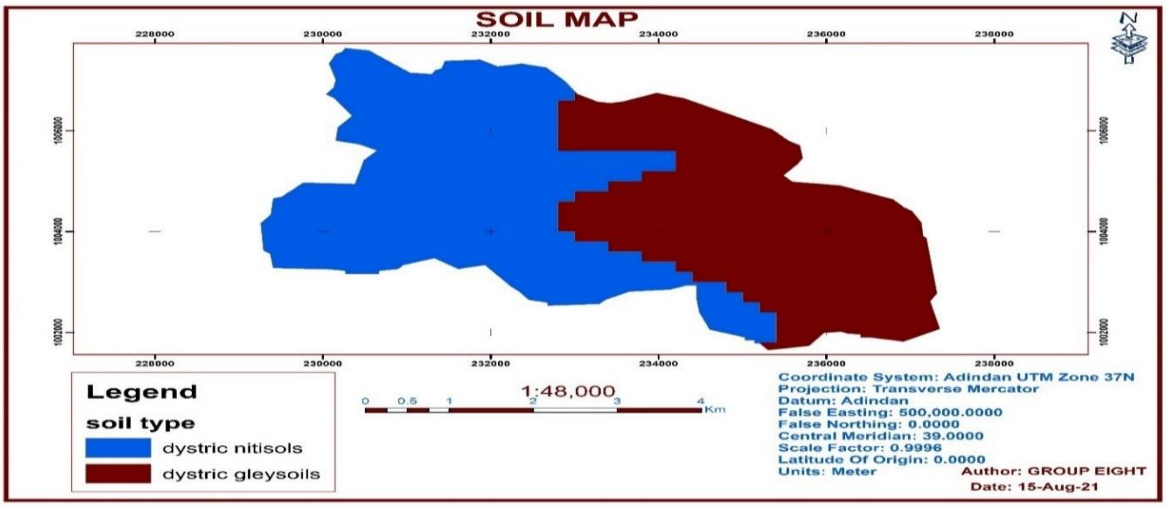

Figure 3 Soil map

2.6 Land Use

Different land use category is encountered in the studied zone that shown in Figure 4. Those land use class affect drainage system of the area. Land class like built up have small amount of infiltration rate. So that there a lot of run off expected on such area (impervious area).

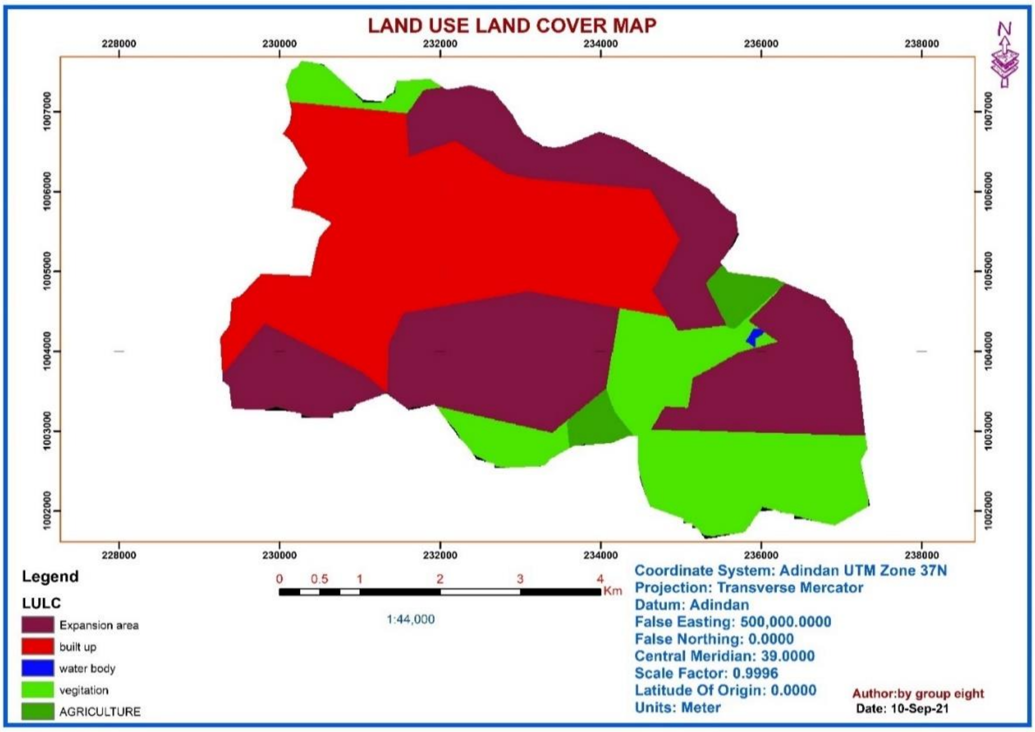

Figure 4 Land cover map

2.7 Flood Status

Flooding: Though flood caused human catastrophe is rare in Nekemte, limited areas are prone to overflowing. Due to absence of appropriate storm water drainage canals along undulating topography, occurrence of flooding is frequent in Keso sub-city along Gimbi road (Kebele 05 and 09), in Derge sub-city in vicinity of Nekemte hospital (Kebele 07) as well as in different parts of Cheleleki subcity. Indeed, the type of soil in Nekemte area is stiff clay, which is more or less resistant to erosion; however, soil degradation is apparent in many steep landscapes, particularly, where unwarranted constructions exist. As a result, gullies are apparent in a number of places.

Seismicity: As virtue of its location, Nekemte is not within the Rift Zone, thus, earthquake hazard is not a major threat for Nekemte. No major earthquake occurrences have registered in the town for the last 100 years. According to the Seismic Risk Map of Ethiopia, Nekemte falls within a Seismic Zone characterized by an earthquake intensity of 6mm with probability of occurrence of 0.99 for 100 years return period [21].

2.8 Material Used

- Hand geographical positioning system: Used to detect determining points.
- Gauging tape: to measure depth and diameter of pipes of drainage structures
- Camera: To take pictures of drainage condition
- ArcGIS software was used for analysis.

2.9 Data Source

2.9.1 *Primary data source*

Site visit: A site visit was conducted to assess the existing state of the road's poor drainage system in relation to acceptable requirements. A camera used to photograph the existing state of the road and drainage system, and a field survey will be conducted to measure the data using tape and GPS to determine the location of cross drainage. Oral questions were asked to acquire more information and clarify the situation around flash floods near cross drainage, particularly bridges.

2.9.2 *Secondary data source*

The information comes from various written records, topographical maps, published and unpublished data, and the internet. The digital elevation model (DEM) is a key parameter for hydrological modeling of study area shown in Figure 5. Many methodologies currently used to generate DEM for different applications at various scales, details, and accuracy. The following methods are used in hydrological analysis

A. Digital extraction from existing topographic map

B. Dem for ASTER

C. DEM from SRTM (shutter radar topography mission)

This research creates DEM from contour that generate from ASTER dem (30m resolution dem)

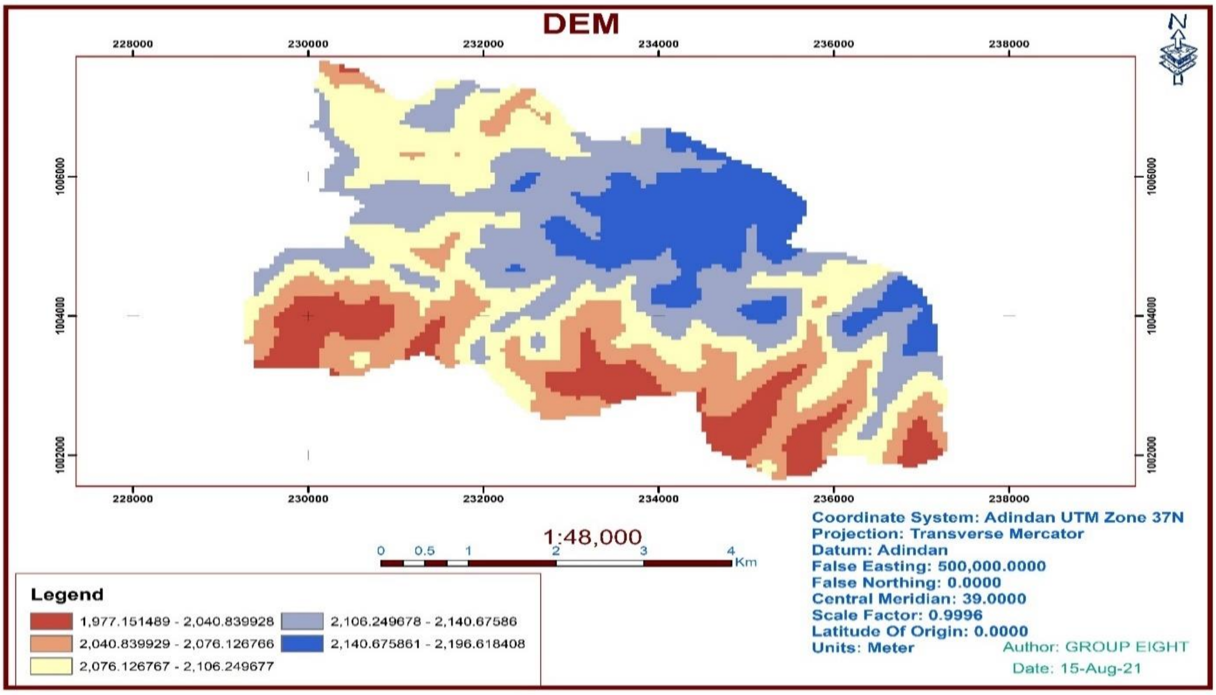

Figure 5 Digital elevation model of the study area

2.10 Method of Analysis

The investigation of drainage in Nekemte town was analyzed through ArcGIS software and site investigation procedures were shown in Figure 6. Since urban drainage implies remove unwanted from urban, this research identifies the flow direction for area then flow accumulation developed. By applying a threshold value, the stream network was created. From stream network the stream order, stream link was developed, pour point location was identified, and final watershed of the area was developed.

To get cross drainage requirement of the area the road (both existing and proposed) are digitized and rasterized. Then, drainage density of the area computed from the road and area of watershed were then reclassified. Finally, it was combined with watershed and stream network to identify the location of cross drainage requirement. Discharge of area was computed by rational methods. To get this result, land use land cover map developed through digitation, and rasterization then area of land use land cover was identified within catchment by area tabulation tool. Final run off coefficient was computed and the intensity of the area was taken with two years return period.

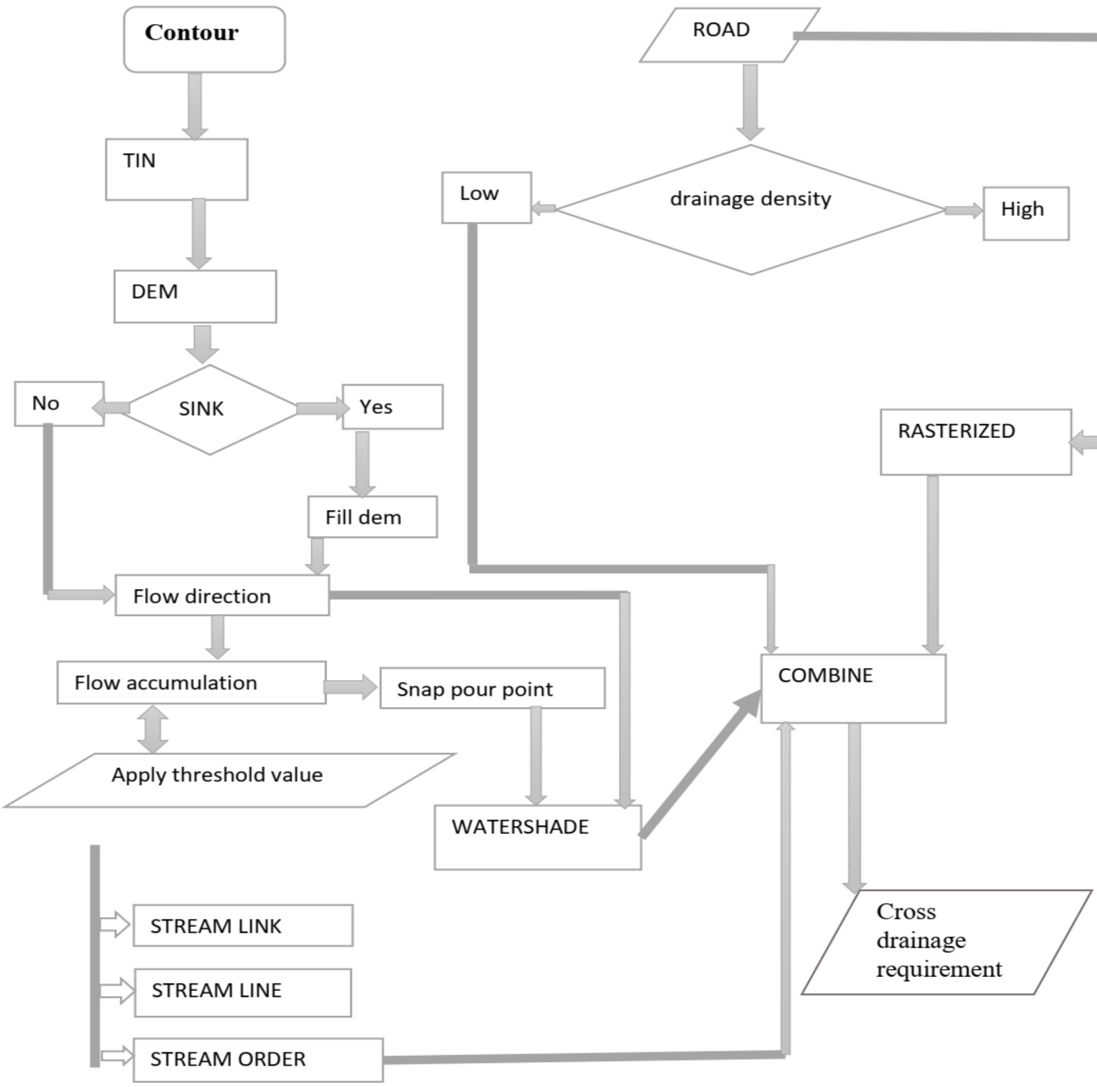

Figure 6 Methodology

3.0 RESULTS AND DISCUSSION

3.1 The Development of Watershed and Snap Pour Point

3.1.1 *Steps of hydrological analysis with ArcGIS software*

1. Ensure Arc Toolbox is visible in Arc Map before starting a new Arc Map document. If it is not visible, click the Arc Toolbox button: Arc hydro tool is located in the arc toolbox or right click on drop down menu then add arc hydro tool.

2. Add the following data to Arc Map: DEM that is generated from TIN created from contour map of the study area

3. Calculate all different hydrological patterns.

3.1.2 *Fill*

To locate and fill sinks, the Fill tool use the counterparts of multiple tools, including Focal Flow, Flow Direction, Sink, Watershed, and Zonal Fill. The tool repeats this process until all sinks within the given z limit have been filled. To maintain accurate delineation of basins and streams, sinks should be filled. A derived drainage network may be discontinuous if the sinks are not filled. Fill sink tool on DEM manipulation to calculate flow direction. Unless the input to this operation is DEM, all input and output are controlled by software.

Note that: the fill map and sink located on appendix A

3.1.3 *Flow direction*

Figure 7 illustrates flow direction, which is a crucial factor in the hydrological analysis of Nekemte town. There three different analysis options. Exist in this menu. In this research, the D8 option is used. This option indicates the direction of flows by eight directions. The D8 flow approach simulates the direction of flow between each cell and its steepest downslope neighbor. The Flow Direction tool produces an integer raster with values ranging from 1 to 255 when used with the D8 flow direction type. The following are the values for each direction from the center. Flow direction tool are located on hydrology available on spatial analysist tool. The input of this process is DEM that is filled. Then browse the output location selects D8 flow method. Then select ok.

32	64	128
16		1
8	4	2

Direction in numbers

NW	N	NE
W		E
SW	S	SE

Direction in words

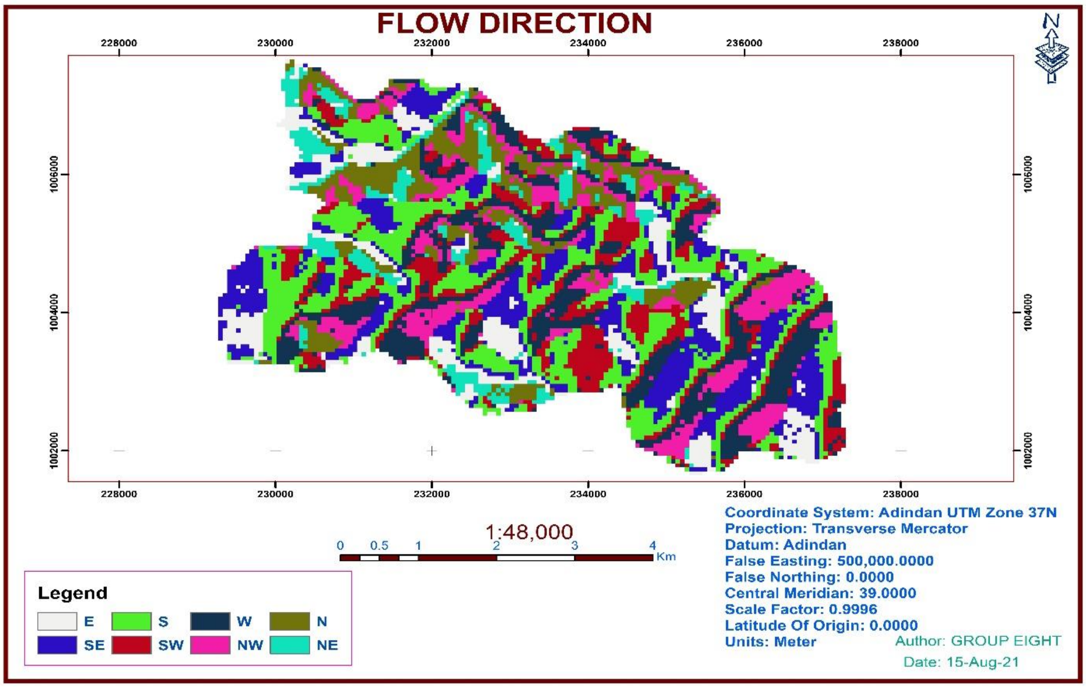

Figure 7 Flow direction map

3.1.4 *Flow accumulation*

The Flow Gathering tool computes accrued flow as the added mass of all cells flowing into each downslope cell in the yield raster. Accumulated movement is the number of cells flowing into each cell. As the map, bellow shown in Figure 8 the highest cells flow in cell which means 4712 cells flow in cells.

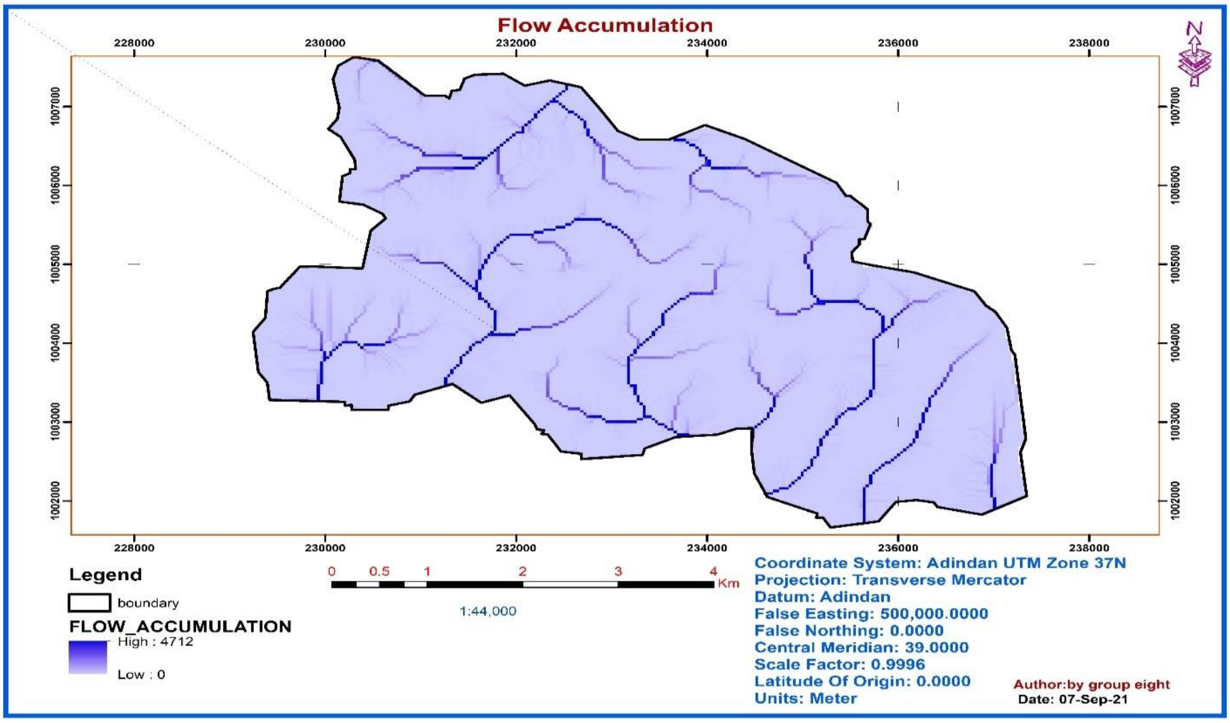

Figure 8 Flow accumulation

3.1.5 *Stream network*

Using the result of the Flow Accumulation tool in Figure 8, stream networks have been defined as the digital elevation model (DEM) displayed in Figure 9. The amount of upslope cells that flow into each cell is the simplest form of flow accumulation. A stream network can be defined by utilizing the Con or Set Null tools to apply a threshold value to the results of the Flow Accumulation tool using ArcGIS software to create a stream network.

- ✓ Select the Raster Calculator from the Spatial Analyst toolbar drop-down menu.
- ✓ Define a threshold for how many adjacent stream pixels make up a stream in order to establish a stream network. We set the accumulation threshold at 4712 pixels in this case (any pixel with more than 400 pixels flowing into it will be part of the stream network).
- ✓ Fill in the blanks (as seen below)

Stream net = con (Flow Accumu > 400, 1)

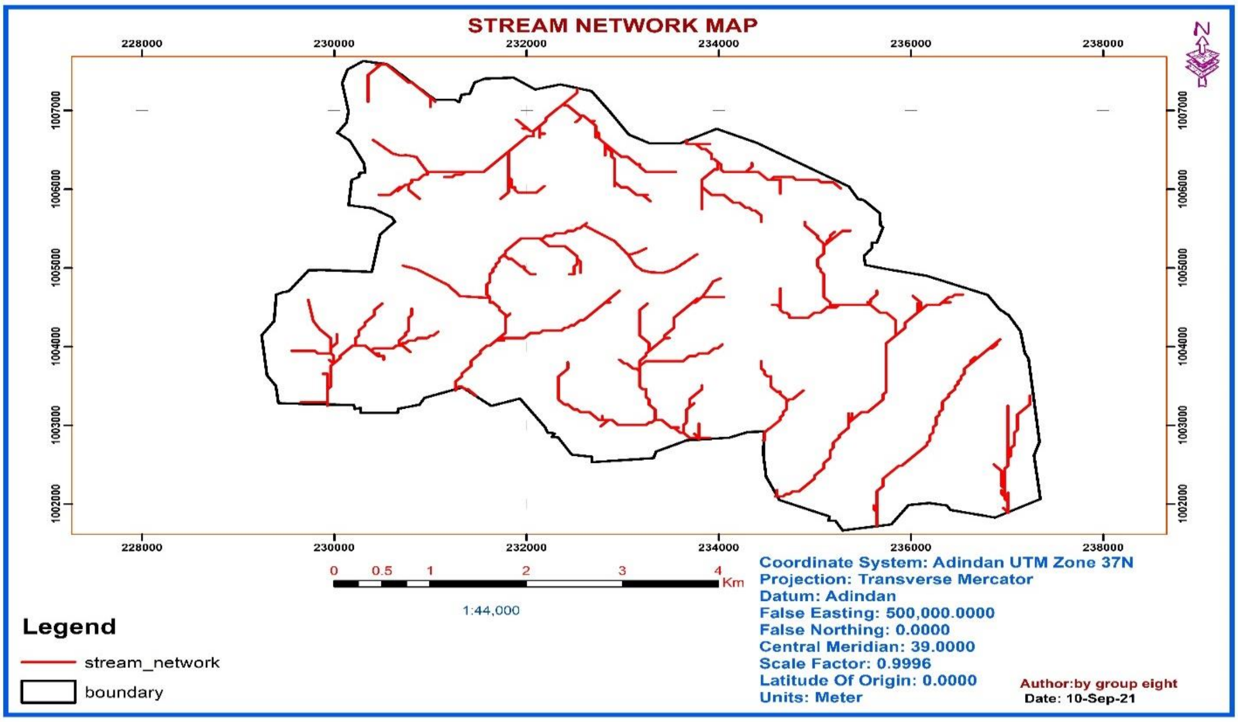

Figure 9 Stream network map

3.1.6 *Stream order*

A method of assigning a numeric order to links in a stream network is known as stream ordering. This method is used to identify and classify different types of streams depending on the number of tributaries they have. Knowing the order of streams can reveal some of their properties. When streams of the same order collide, the stream order increases. As a result of Figure 10, the intersection of two first-order links will result in the creation of a second-order link, and the intersection of two second-order links will result in the creation of a third-order link, and so on. However, the junction of two links with different orders will not result in a higher order. Stream order can be done in one of two ways:

The Strahler stream ordering method and the Shreve stream ordering method are two different ways to order streams. Strahler stream ordering was used in this study, and three orders occur in the area. While the Stream Order tool is used to construct a stream order raster.

Set the Input stream raster, the Input flow direction raster, and the Output raster to the desired values.

STRAHLER or SHREVE should be selected as the stream ordering method. Then select OK.

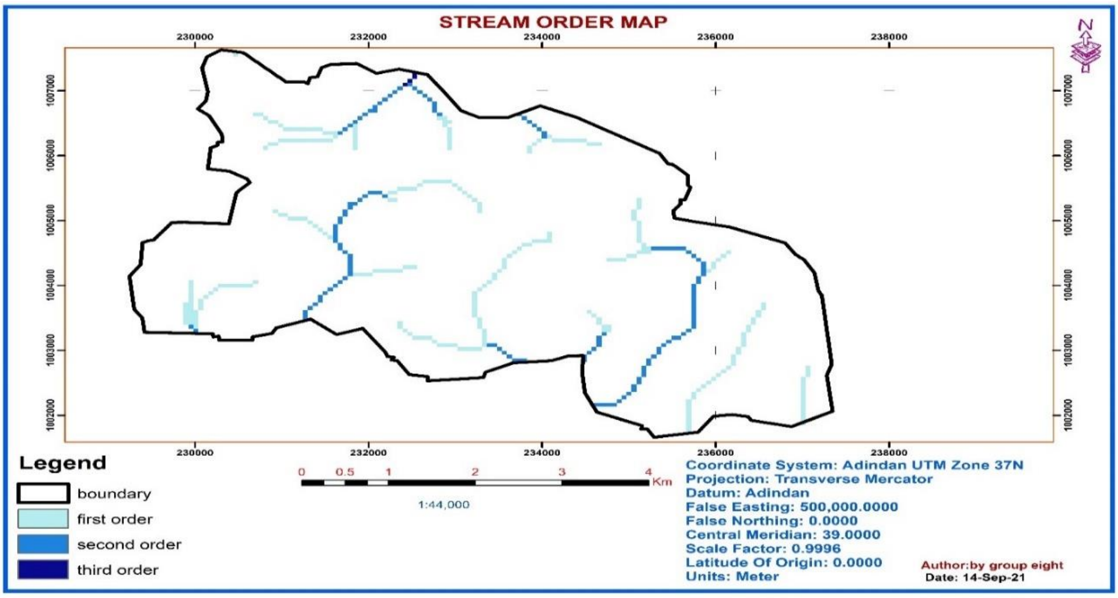

Figure 10 Stream order map

3.1.7 *Stream link*

The Stream Link tool allows each link in a raster linear network to produce a unique value. This is especially handy as a parameter in the Watershed tool, which allows you to easily design watersheds based on stream junctions. It can also be used to associate related attribute information with individual stream segments. The sections of a stream channel that connect two following junctions, such as a junction and the outlet or a junction and the drainage division, are depicted in Figure 11 and are known as links.

- The Stream Link tool is used to create a stream link raster.
- Set the raster for the input stream.
- Set the raster for Input flow direction.

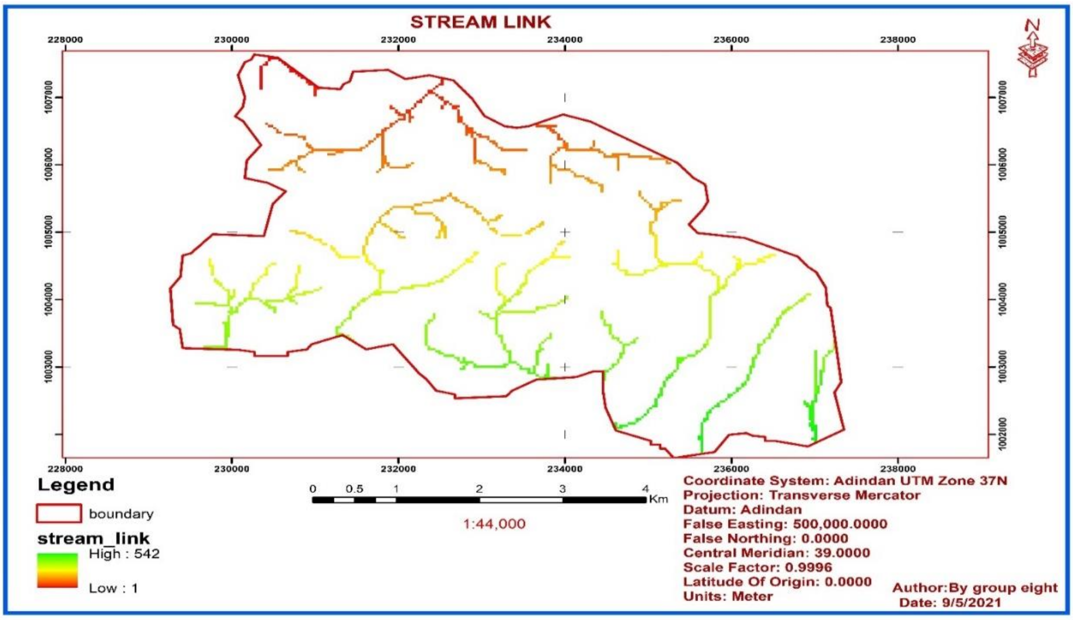

Figure 11 Stream link map

3.1.8 *Snap pour point*

Pour points are snapped to the cell with the most flow accumulation within a certain distance. When utilizing the Watershed tool to delineate drainage basins, the Snap Pour Point tool is used to guarantee that places of significant accumulated flow are selected. Snap Pour Point will move the pour point to the cell with the biggest accumulated flow that is within a snap distance of the predetermined pour points. Pour point is the outlet for the drainage, as seen in Figure 12. All pour points in the Nekemte town are directed outside the town. This is helpful for the city in getting rid of the drains. Ten pour spots are present in the research region and are displayed in Table 2. Those points are indicating the outlet of the drainage system in the study area.

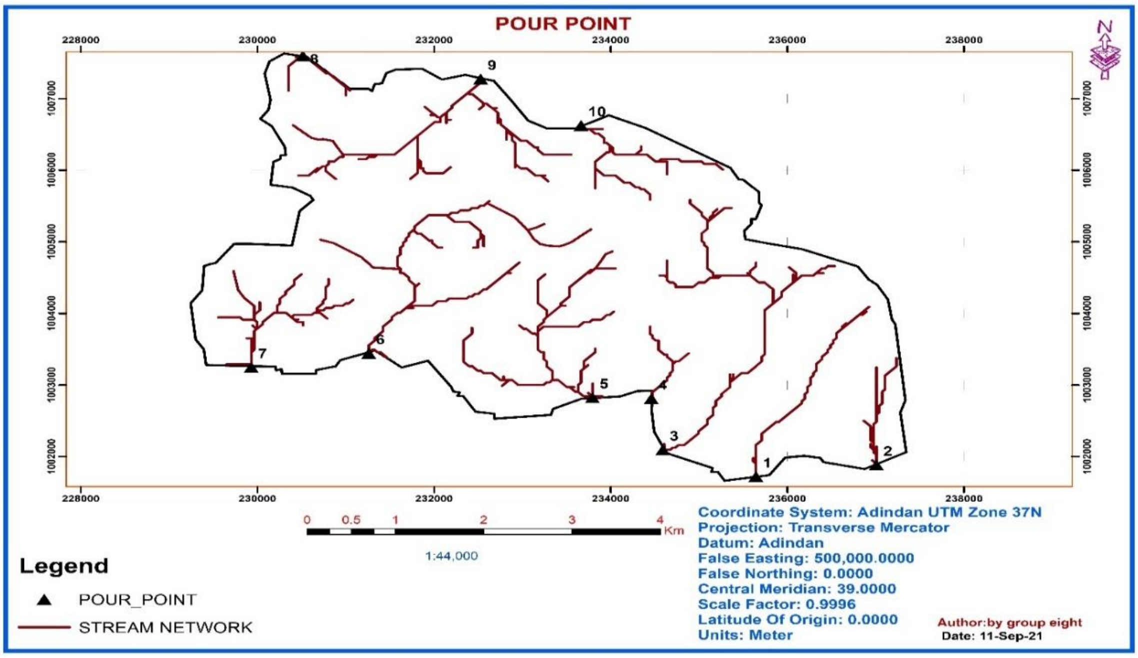

Figure 12 Pour point map

Table 2 Location of snap pour points

Easting	Northing	Elevation	POINT ID
235,640.15	1,001,718.61	2004.149	1
237,010.70	1,001,876.04	2000.249	2
234,586.85	1,002,093.79	1976.894	3
234,459.52	1,002,810.35	2032.991	4
233,794.44	1,002,825.38	1995.456	5
231,259.90	1,003,442.69	2016.861	6
229,928.17	1,003,247.60	1997.172	7
230,513.06	1,007,600.52	2022.3568	8
232,526.02	1,007,276.12	2067.623	9
233,663.81	1,006,626.31	2100	10

3.1.9 *Watershed*

A watershed is a region on an upward slope that provides water to concentrated drainage at a shared outlet, as seen in Figure 13. It could include smaller watersheds known as sub basins or be a portion of a larger watershed. Watersheds are divided by boundaries called drainage divides, as shown in Table 3. The outlet, also known as the pour point, is the point on the surface where water exits a space indicated in Table 4. By determining the flow direction and using it in the Watershed tool, watersheds can be identified from a DEM. To identify the contributing area, we used the Flow Direction tool to build a raster reflecting the flow direction. Only the Watershed tool supports a D8-type input flow direction raster. In the study area there are ten watersheds exist. Each of the outlet toward to outside the city represent by Figure 14.

❖ The steps watershed tool in ArcGIS software

I. Watershed tool available on hydrology in spatial analysis tool
II. Set the input flow direction that have D8 type flow direction
III. Set the input pour point
IV. Set the output raster then select ok

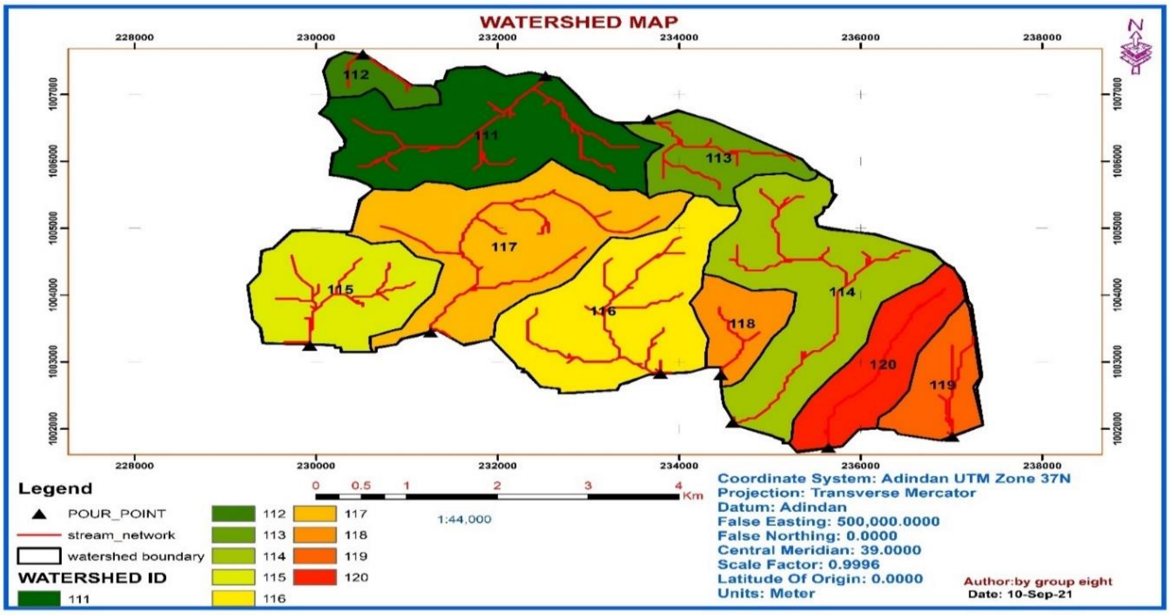

Figure 13 Watershed map

Table 3 Watershed areas

WATER SHADE ID	Area (m^2)	Area (ha)	Percentage (%)
111	4583192.197	458.3192197	16.19599795
112	591470.5778	59.14705778	2.090127547
113	1550101.012	155.0101012	5.477717653
114	4827653.868	482.7653868	17.05987198
115	2849278.381	284.9278381	10.06872608
116	4334244.19	433.424419	15.31627019
117	5036370.411	503.6370411	17.79743056
118	1130844.38	113.084438	3.996156494
119	1315952.173	131.5952173	4.650286912
120	2079193.487	207.9193487	7.34741464
TOTAL	28298300.68	2829.830068	100

Table 4 Stream network length in the watershed

Watershed id	Stream length(m)
111	8776.539133
112	1466.818412
113	3155.21475
114	4273.1295
115	5576.561949
116	5873.743456
117	4923.241766
118	1502.08318
119	7971.103732
120	3218.73736

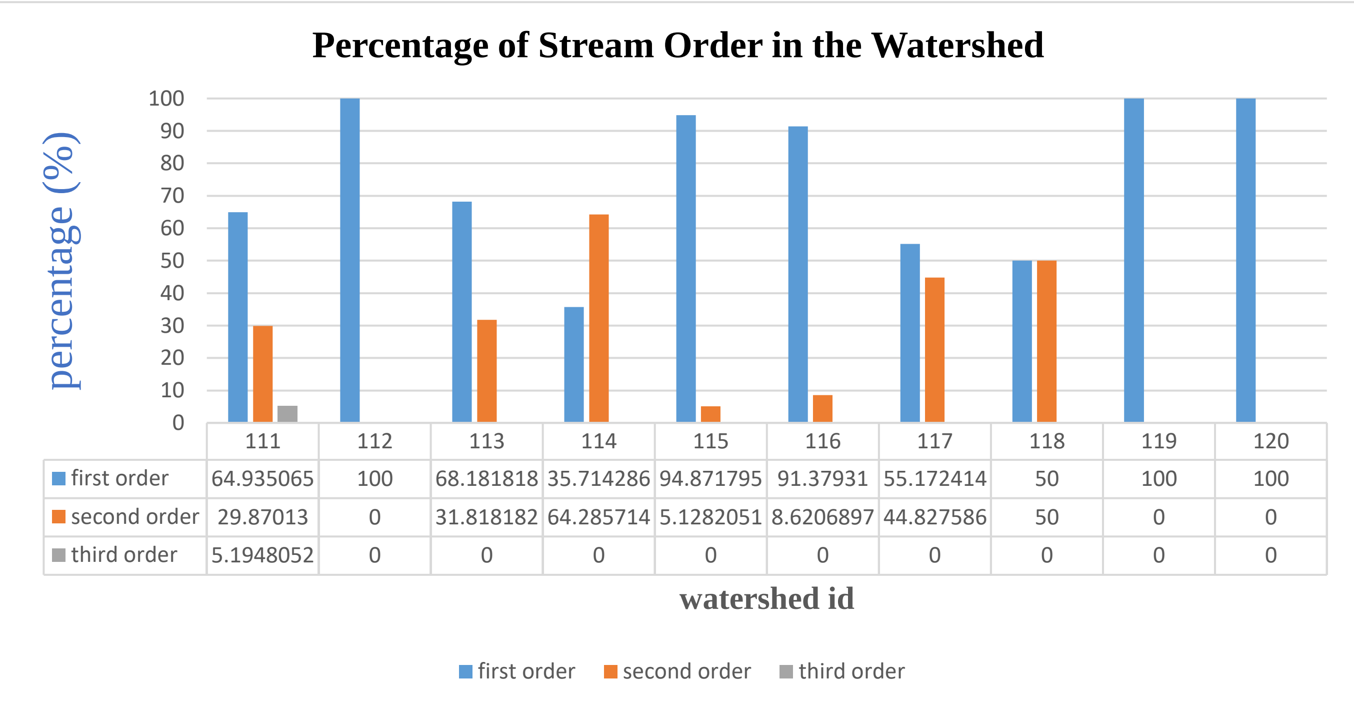

Figure 14 Percentage of stream order in watershed

3.2 Cross Drainage Requirement

The structures that allow for such crossings are known as cross-drainage works. They are usually highly expensive, and they should be avoided if possible by altering the canal alignment and/or redirecting the drains. GIS software have capable integrated different parameter and identify suitability of those parameters. This thesis used road (both proposed and existing), watershed, stream, and drainage density to identify the location culvert requirement.

3.2.1 *Road*

Most of road is constructed within different drainage structure. This helps to prevent unwanted water to store on the road and deteriorate the road. Therefore, this drainage structure helps to remove water. In this study, the road is taken as one parameter to determine cross drainage requirement in the area. It should be noted the Nekemte town expanded time to time. This expansion area should have road according to structural plan. These road construction sites should have drainage systems when they are initially covered with gravel or earth. As a result, this study determined that cross drainage was necessary for a 3 km road in the city's expansion region in addition to the existing road (Figure 15).

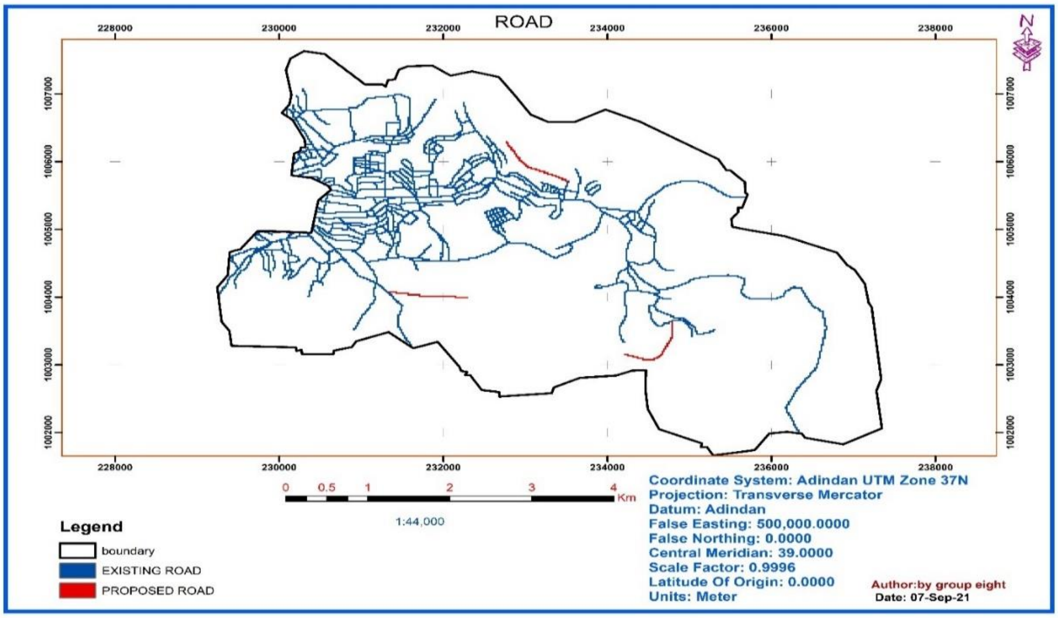

Figure 15 Existing and proposed roads

3.2.2 *Drainage density*

The most vital ingredient for life on this planet is water. Water, on the other hand, is a major hazard for highways. Excess water filling the pores of road materials in the road and in the subgrade soils is a major source of road deterioration and problems with road network serviceability. Road density is shown in Table 5 as the ratio of the whole length of the road to the total area of the watershed. According to Figure 16, a high road density value denotes a somewhat effective drainage system, whereas a low road density indicates inadequate drainage. In areas with less dense road construction, there is poor drainage. Road types like asphalt and concrete are built within drainage structures. In this research low drainage density is taken for compute for culvert requirement.

Table 5 Drainage density area coverage

Drainage density	Area coverage (ha)	Percentage (%)
high	321.89	11.37488824
low	2507.94	88.62511176

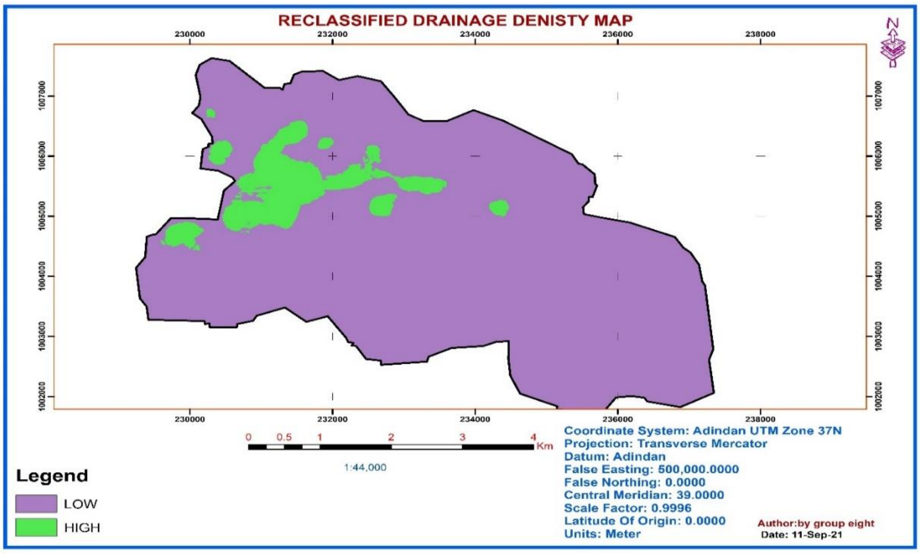

Figure 16 Reclassified drainage density map

3.2.3 *Combination*

Cross drainage requirement is computed by combine tool. The combine tool takes multiple input raster has and creates a new value in the output raster for each unique combination of input values. The original cell values from each of the inputs are included in the attribute table of the output raster. The attribute Table 6 of the output raster receives one entry for each input raster. Four specific factors are used to determine the cross-drainage need, as shown in Figure 17. Rasterized Road, Watershed, Low-density Road, and Stream order.

- ✓ Steps of combine on ArcGIS software are

  i. Open spatial analysist tool then clicks local tool

  ii. Open combine set input of all parameters

  iii. Set output then select ok

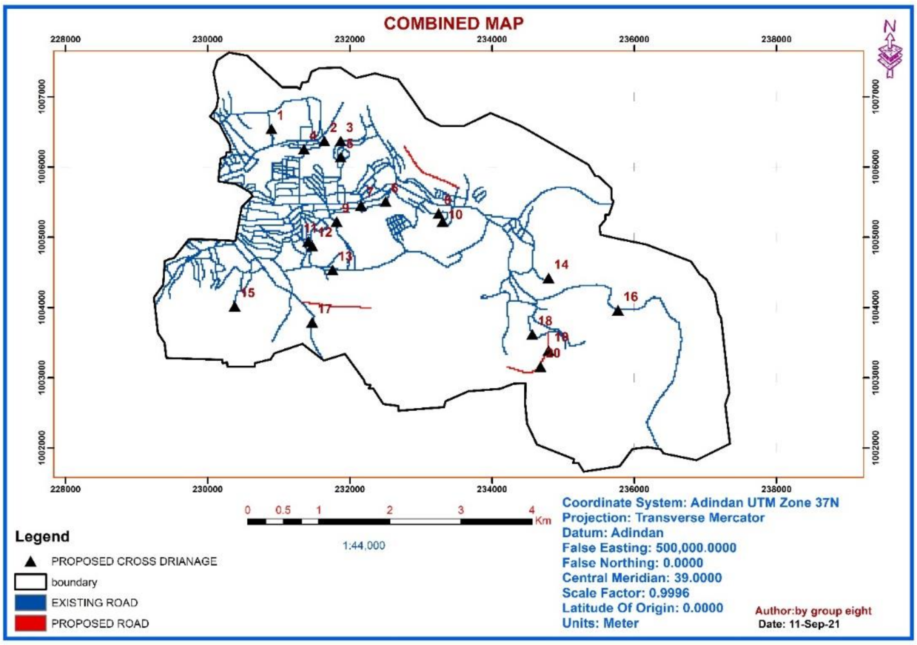

Figure 17 Combined map

Table 6 Location of cross drainage requirement

Point id	Easting	Northing
1	230895.2658	1006544
2	231640.9458	1006371
3	231870.3858	1006371
4	231354.1458	1006257
5	231870.3858	1006142
6	232501.3458	1005511
7	232157.1858	1005454
8	233247.0258	1005339
9	231813.0258	1005224
10	233304.3858	1005224
11	231411.5058	1004937
12	231468.8658	1004880
13	231755.6658	1004536
14	234795.7458	1004421
15	230379.0258	1004020
16	235770.8658	1003962
17	231468.8658	1003790
18	234566.3058	1003618
19	234795.7458	1003389
20	234681.0258	1003159

❖ What problem is encountered in the area due to losing the proposed cross drainage? Sometimes flash flood occur in area, The run off area is channeled on the center of road and since cross drainage around this area is not constructed depending on drainage analysis, some losses capable diverting the drainage as shown in Figure 18.

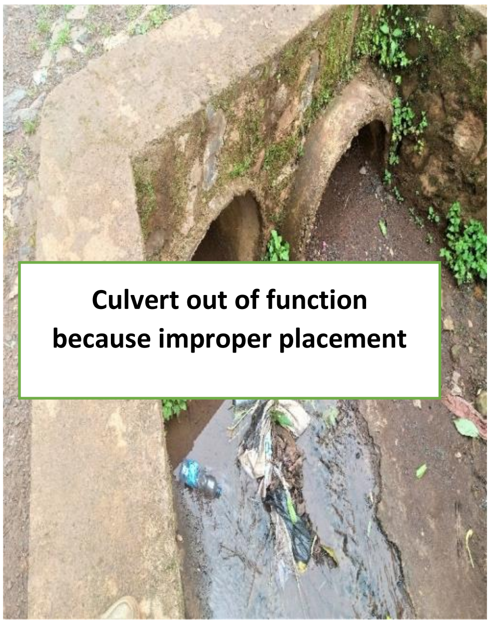

Figure 18 Drainage problems due to loss proposed cross drainage (Field Survey, 2021)

3.3 Peak Discharge of the Area

Discharge is key parameter for any hydrologic structure. There differentiates method to compute discharge. This study used rational method. For regions up to 50 hectares, the Rational Method is the most reliable method for estimating design storm peak runoff (0.5 square km). Despite the fact that it was initially developed in 1889, this approach is still commonly utilized today.

$$Q_P = \frac{1}{3.6} C(i_{tc \cdot p})A \tag{1}$$

where Q_P = highest flow (m^3/s), C = dimensionless runoff coefficient, $i_{tc \cdot p}$ = the mean concentration of rainfall (mm/h) for a duration equal to tc and an exceedance probability p in our research 60 min used and 2 yrs period of return, and A = drainage area in km^2.

Note that: According to Figure 18, the discharge value, catchment map, and runoff coefficient are all readily available.

3.4 Existing Pipe and Culvert

A culvert is a structure that offers an aperture under a roadway or other sort of access or utility but is not categorized as a bridge. A culvert is generally used to transport water across embankments or other flow barriers. It also serves as a pedestrian, livestock, wildlife, and fish passage, as well as land access and utility transportation is represented in Figure 19.

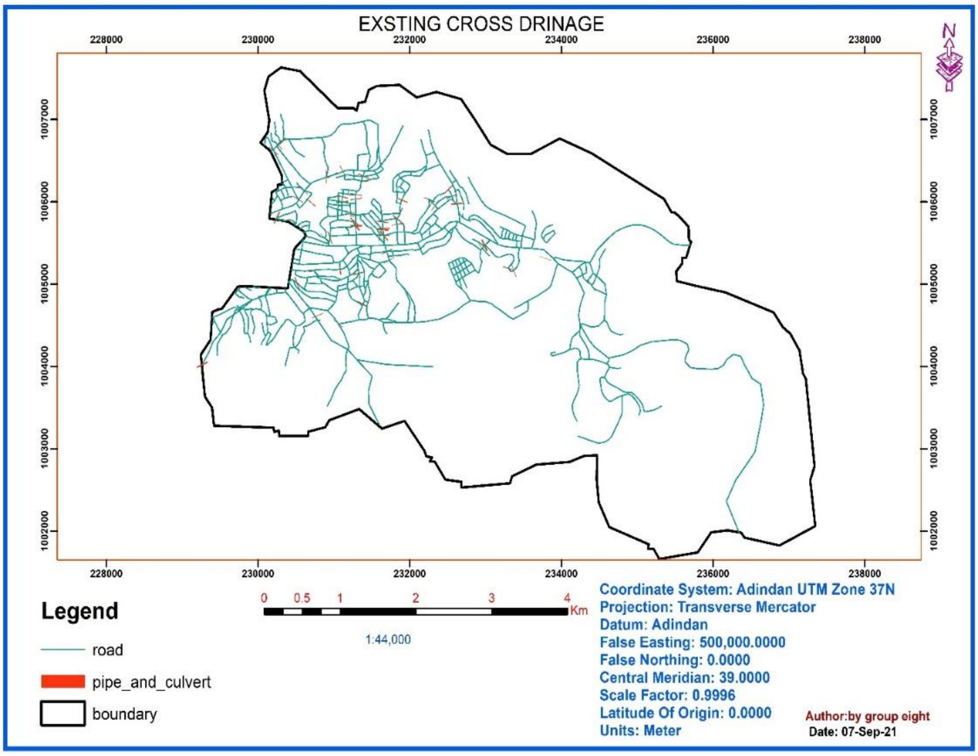

Figure 19 Existing cross drainage

Note that: In Figure 20, which is highlighted are the locations of culverts and information on each one that is already in place.

- What is the condition of this existing culvert?

I. Some of the area blocked by waste

II. The pipe diameter the used in the study area on some locations are not correct according Ethiopia Road Authority 2013

III. Some roads are constructed without drainage structure

Figure 20 Condition of existing drainage structure observed

3.5 Protected Area

Protected area (zone) is the place not suitable for residence. Area around stream network is avoided for any construction. This study uses the area up to 50 meters away from the stream network as a protected zone from any residential constructions, as indicated in Figure 21. The reason this area not suitable any construction and be protected area is:

- As it is stream network sometimes when there is heavy rain, may flash flood may have occurred.
- Some stream network area is marshes and not suitable for any construction

Note that: In this protected zone, there is 17 proposed cross drainage.

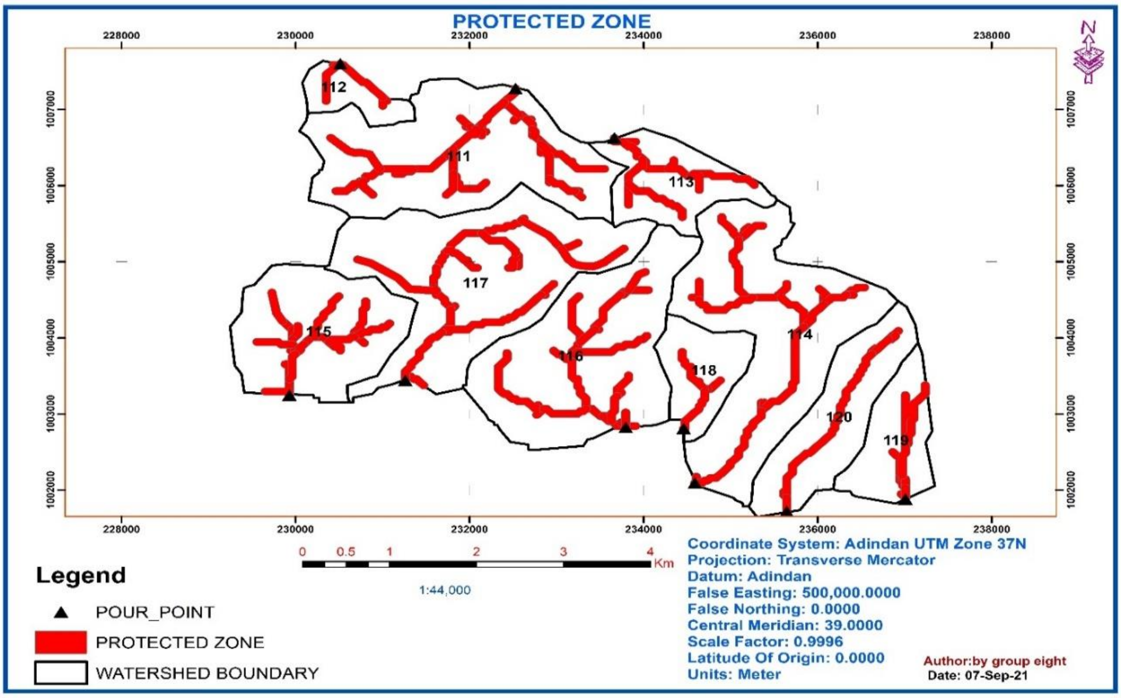

Figure 21 Protected zone

4.0 CONCLUSION

In recent years, increasing impervious areas in urban areas have increased the amount of drainage in the area. In addition, when infrastructure like roads is constructed, it diverts the natural stream network. Such problems can be solved through deep analysis. The software performs the necessary activities to analyze and produce better results. Such issues can be analyzed and solved using ArcGIS software. The investigation of drainage in Nekemte Town was analyzed by ArcGIS software. The area's first watershed and pour is developed. To determine the flow way, accumulation, river network, river order, and other hydrology patterns were analyzed. Furthermore, the area's cross drainage requirement was identified, and the discharge area was computed. There are ten watersheds in the town of Nekemte and ten discharge points (outlets) in these watersheds, all of which are directed outside the city. In the city, there is a three-stream order. Even though their cross-drainage is made of asphalt and concrete, some areas have an additional cross-drainage requirement. In each of the study areas, twenty cross-drainages are required. Those crosses were computed through drainage analysis. Up to 50 meters from the stream network should be protected in the study area. Generally, from this study, it can be concluded that the cross drainage in Nekemte Town is inadequate and improperly placed. In most places, the drainage is blocked by waste, which deteriorates the roads.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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