MORPHOLOGICAL STUDY OF WADI AL-ZARZEER WATERSHED USING GIS TECHNIQUE

BY

SAIDA SA'DA **SAFA' DAWOD**

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF
REQUIREMENTS FOR THE DEGREE OF
BACHELOR OF ENGINEERING
IN
CIVIL & ARCHITECTURAL ENGINEERING DEPARTMENT

SUPERVISED BY

Dr. MAJED ABU SHARKH

CIVIL & ARCHITECTURAL ENGNEERING DEPARTMENT
COLLGE OF ENGINEERING AND TECHNOLOGY
PALESTINE POLYTECHNIC UNIVERSITY

HEBRON- WEST BANK
PALESTINE
JUNE - 2007

ABSTRACT

MORPHOLOGICAL STUDY OF WADI AL-ZARZEER WATERSHED USING GIS TECHNIQUE

By:

SAIDA SA'DA **SAFA' DAWOD**

Palestine Polytechnic University

Supervisor

Dr. Majed Abu Sharkh

Water availability is considered to be one of the key factors for rapid development and urbanization. However, the over exploitation of water resources has resulted in a condition of un-sustainability and environmental degradation. Each watershed has a number of distinct characteristics (morphometric parameters), which govern the amount of precipitation received, and runoff produced. Morphological characteristics like stream order, stream number, bifurcation ratio, watershed perimeter, length of watershed, form factor, drainage density, drainage frequency, elongation ratio, constant of channel maintenance, circulation ratio, maximum watershed relief, relief ratio, ruggedness number, relative relief, aerial extent, watershed length and width, channel length, channel slope and relief aspects. The morphometric analysis of a watershed plays an important role in deciding the hydrological behavior such as runoff, soil erosion, sediment delivery ratio etc. of a watershed.

Wadi Al Zarzeer (watershed) was considered for such a study. The boundary of catchment, sub-catchment, and stream network of the watershed under study, which located at Wadi Al Zarzeer were determined using Geographical Information System (GIS). The aerial and photogrametric map were used for land use information. Various linear and relief parameters of the study area were determined using GIS. At the end the amount of surface runoff was estimated for the project area.

The results of the present study show the average annual runoff depth for the study area (Wadi Al Zarzeer is et runoff is estimated to be 21 mm, and the average volume of runoff from the same watershed is 18.381 cubic meter per year. The amount of runoff represents 4.2 % of the total annual rainfall.

Using GIS for morphological parameters watershed analysis is much more rapid than traditional methods. However, it is suggested that using GIS results in the loss of a certain degree of accuracy in determining some watershed characteristics.

TABLE OF CONTENTS

CHAPTER 3 HYDROLOGIC PRINCIPLES

CHAPTER 4 HYDROLOGIC ANALYIC IN ArcGIS

CHAPTER 7 CONCLUSIONS

LIST OF FIGURES

LIST OF Table

LIST OF ABBREEVIATIONS

TIN	Triangulated irregular network
DEM	Digital elevation model
GIS	Geographic Information Systems
U	stream ordering
NU	stream number
Rb	bifurcation ratio
Lu	stream length
Lms	main stream length
Lp	watershed perimeter
Lb	maximum length of watershed
Rt	length ratio
Rf	form factor
Dd	Drainage density
Df	Drainage frequency
Cm	Constant of channel maintenance
Re	Elongation ratio
Rc	Circular ratio
H	Maximum watershed relief
Rh	Relief ratio
RN	Ruggedness number
Rr	Relative relief
SCS	Soil Conservation Service
LULC	land use and land cover
CN	curve number
USCS	Unified Soil Classification System
AASHTO	American Association of State Highway and Transportation Officials
Cu	coefficient of uniformity
Cc	coefficient of curvature

CHAPTER

1 *INTRODUCTION*

1.1 General

1.2 Problem Statement

1.3 Previous Studies

1.4 Objectives

1.5 Study Area

1.6 Morphometric Parameters

1.7 Project Task-Plan

1.8 Structure of the Report

CHAPTER ONE
INTRODUCTION

1.1 General

The available surface and ground water resources are inadequate to meet the growing water demands due to rapid urbanization and increasing population. The demand for water has increased over the years, due to which the assessment of quantity and quality of water for its optimal utilization is necessitated.

Identification and outlining of various ground features such as geological structures, geomorphic features and their hydraulic characteristics may serve as direct or indirect indicators of the presence of ground and surface water. The geomorphologic conditions are essential pre-requisites in understanding the water bearing characteristics of hard rocks. The role of rock types and geologic structure in the development of stream networks can be better understood by studying the nature and type of drainage pattern and by a quantitative morphomtric analysis.

The morphometric parameters of a watershed are reflective of its hydrological response to a considerable extent and can be helpful in synthesizing its hydrological behavior. A quantitative morphometric analysis of a drainage basin is considered to be the most satisfactory method because it enables us to understand the relationship among different aspects of the drainage pattern of the basin, and also make a comparative evaluation of different drainage basins developed in various geologic and climatic regimes.

1.2 Problem Statement

Morphological characteristics like stream order, drainage density, aerial extent, watershed length and width, channel length, channel slope and relief aspects coupled with land use and soil information of watershed are important in understanding the hydrology of the watershed. Runoff response of the watershed is different for different slopes, shapes, lengths, widths and areas of watershed. Response is also affected by the factors like drainage density, length of overland flow, stream frequency, relative relief and relief ratios. Computation of watershed morphological characteristics is prerequisite to further detailed hydrological analysis of the watershed. Hydrologists have attempted to relate the hydrologic response of watersheds to watershed morphologic characteristics. Presently these characteristics are determined manually from the topographic and stream network map of the watershed. Manual computation in order to generate these characteristics is not only tedious and error prone but also time consuming. Computers can be used to compute these characteristics with greater efficiency and accuracy.

Technologies like Geographic Information Systems (GIS), have gained significant importance over the last decade in their applications pertaining to distributed hydrologic modeling. GIS is suitable for analysis of spatially referenced data. GIS can handle both spatial and a spatial data effectively and efficiently. Nowadays GIS is widely used for resources planning in watershed. GIS can be used for the computation of these morphological characteristics of the watershed. Using the presently available GIS one has to go through tedious steps for generating these characteristics. Moreover the user must be fully acquainted with both the type of GIS being used for the generation of the morphologic characteristics as well as the morphologic characteristics of interest. Thus a suitable model should be developed with the help of GIS to generate these watershed morphologic characteristics.

This study attempts to compute geomorphological characteristics, generation of various thematic data base in GIS format, find out soil information, and generation of alternate land use plan for the Al-Zarzeer watershed for proper management of natural resources in this watershed. Important watershed characteristics included in the study are: area of watershed, perimeter, elongation ratio, circulatory ratio, form factor, stream order, drainage density, average slope of watershed, main stream channel slope etc. The model uses watershed boundary map, drainage network map and contour map for computation of the morphological characteristics.

1.3 Previous Studies

In our country, the hydrological studies are limited some investigators have studies the hydrology of different wadis and watersheds in the West Bank and Gaza strip in order to develop additional usable water resources to help in solving future hydrological problems.

Applied Research Institute of Jerusalem (ARIJ) published six articles on environmental profiles of West Bank cities. The Hebron district environmental profile shows that Hebron area is preventative example of semiarid climate. In such area, most land is sloppy (2%-20%) and the infiltration rate is low. Consequently, low cost water harvesting could be introduced in this area. This method depends on collecting runoff water using construction such as soil dam or concrete dam.

Lange, J. et al (2000) have studies the runoff on a steep 180 m^2 Mediterranean Karts environment. To provide quantitative information, measurements are under taking on experimental hill slope plot applying artificial rainfall of predefined intensities. The results show that on a dry plot about 16 mm of rainfall was needed before terrain other bar rock generated runoff. Overall 16% of rainfall turn into runoff, while in the following day 73% of the applied rainfall arrived at the outlet of the wet plot.

In the study of Mohammadin, A. et al (2003), the mount of runoff for east Bani Naim watershed in the Hebron area using soil conservation service method were calculated and estimated to be about 417,913 cubic meters per year.

The geomorphological study of Wadi Al Arroub carried out by Qannam (2000) in his master thesis shows that the topography has more effect on the drainage pattern than the structure. The main effect of topography is in the W-E direction, while that of structure is mainly in the NNW-SSE direction and to some extent in the N-S direction. The relatively high relief ratio of Wadi Al Aroub drainage basin and high elongation ratio (0.78) indicate that the study area is among the sub-basins that contribute strongly to the flooding in the Dead Sea-Jordan River Basin.

Al-Namor, A., et al (2006) study the hydrology of Wadi Su'd in Dura Area using GIS and GPS techniques. The results of the study show that the average annual runoff depth for the study area (Wadi Su'd watershed) is 68 mm, and the average volume of runoff from the same watershed is 127,083.6 cubic meter per year. The amount of runoff represents 13.6% of the total annual rainfall.

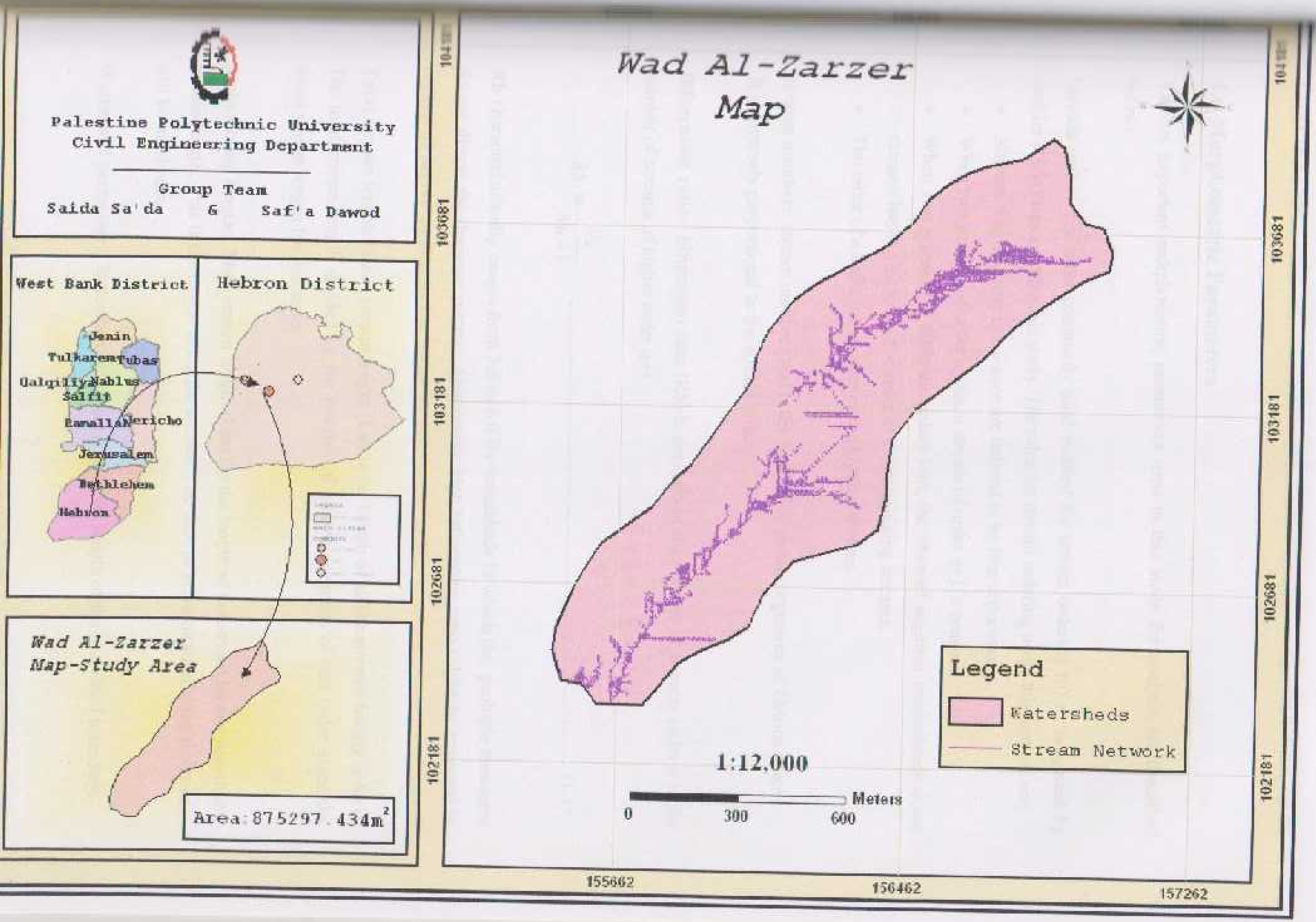
1.4 Objectives:

The main objective of this study is to provide geomorphological database for the surface of Wadi Al-Zarzeer drainage basin to specify the hydrology of the wadi and estimate direct runoff. Within the framework of this study, the following data and parameters should be obtained and determined:

1. The boundary of catchment, sub-catchment, and stream network of the watershed under study, which located at Wadi Al Zarzeer, using GIS.
2. The climate data include values of precipitation, temperature, relative humidity, and wind information.
3. The morphological characteristics like stream order, drainage density, aerial extent, watershed length and width, channel length, channel slope and relief aspects
4. The geographical characteristics and land use of the study watershed.
5. The soil type and properties of the watershed by carried out sieve analysis and moisture content and permeability experiments.

1.5 Study Area

The study area, named Wadi Al Zarzeer, is located at north Dura city of the Hebron area which will known later as Wadi Al-Zarzeer watershed. The watershed having a geographical area of 875.297434 square meter, Figure (1.1) shows the study area and its location. Physiographically, the watershed is divided into hills, pediments. Elevation in the watershed ranges from 710 to 903.4 m above mean sea level. The average annual precipitation at Dura city for the last five years is approximately 500 mm. About 90% of this rainfall is received from November to April, and the major land use/land cover categories in the watershed are: pasture, agricultural area, and stony waste land.


Palestine Polytechnic University
Civil Engineering Department
Group Team
Saida Sa'da & Saf'a Dawod
West Bank District
Jenin
Tulkarem
Tubas
Qalqiliya
Nablus
Salfit
Ramallah
Jericho
Jerusalem
Bethlehem
Hebron
Hebron District
Wad Al-Zarzer Map-Study Area
Area:875297.434m²
Wad Al-Zarzer Map
Legend
Watersheds
Stream Network
1:12,000
0 300 600 Meters
103681
103181
102681
102181
155662
156462
157262

1.6 Morphometric Parameters

Various important morphometric parameters used in this study for analysis are described below.

Stream order: The most commonly used method for stream ordering (u) as suggested by strahler (1964) was used for this study. The rules for stream ordering using this method are:

- Streams that originate at a source are defined to be first order steams.
- When two streams of order u join, a stream of order u+1 is created.
- When two streams of different orders join, the channel segment immediately down streams has the higher of the order of the two joining streams.
- The order of a basin is the order of the highest streams.

Stream number: stream number (Nu) is the number of stream segments of various orders. It is inversely proportional to the stream order.

Bifurcation ratio: bifurcation ratio (Rb) is the ratio of the number of streams order u to the number of streams of higher order u+1.

$$Rb = \frac{Nu}{Nu+1} \quad \text{......} \quad (1.1)$$

Rb characterististically ranges from 3.0 to 6.0 for watersheds in which the geologic structures do not distort the drainage pattern. Abnormally high bifurcation ratio might be expected in regions of steeply dipping rock strata.

Total stream length total: Stream length (**Lu**) is the length of all the streams having order u. The total stream length divided by the number of stream segments of that order gives the mean stream length for that order.

Main stream length: Main stream length (**Lms**) is the length of the stream having maximum stream length. This is the length along the stream. The time of concentration along the stream will be maximum.

Watershed perimeter: Watershed perimeter (**Lp**) is the length of the watershed boundary.

Maximum length of watershed: Maximum length of watershed (**Lb**) is the distance between watershed outlet and the farthest point in the watershed.

Length ratio: Length ratio (**Rt**) is defined as the ratio of the average stream length (**Lu**) of order u, to average stream length (Lu-1) of the next lower order u-1.

$$Rt = \frac{Lu}{Lu-1} \qquad (1.2)$$

Form factor: Form factor (**Rf**) is the ratio of the basin area (A) to the square of the maximum length (**Lb**).

$$Rf = \frac{A}{Lb^2} \qquad (1.3)$$

Drainage density: Drainage density (Dd) is defined as the total length of the streams of all the orders of a basin to the area of the basin. The drainage density gives an idea of the physical properties of the underlying rocks. Low drainage density occurs in regions of highly resistant and permeable subsoil materials with dense vegetation and low relief; whereas high drainage density is prevalent in regions of weak, impermeable sub surface materials which are sparsely vegetated and have high relief (strahler, 1964).

$$Dd = \frac{L}{A} \qquad (1.4)$$

Drainage frequency: Drainage frequency (Df) is the number of streams per unit area of the basin. It mainly depends upon the litho logy of the basin and reflects the texture of the drainage network.

Constant of channel maintenance: Constant of channel maintenance (Cm) is the ratio of the area of the drainage basin and total length of all the streams of all the orders. Hence, it is the reciprocal of the drainage density.

$$Cm = \frac{1}{Dd} \qquad (1.5)$$

Elongation ratio: Elongation ratio (Re) is defined as the ratio between the diameters of a circle with the same area as that of the basin, and is computed as.

$$Re = \frac{2}{Lb} \sqrt{\frac{A}{\pi}} \quad \text{.......... (1.6)}$$

The elongation ratio ranges from 0.6 to 1.0, over a wide variety of climatic and geological environments. Values nearing 1.0 are typical of regions of very low relief, whereas, values in the range of 0.6 to 0.8 are generally associated with strong relief and steep ground slopes. Elongated basins with high bifurcation ratios yield a low but extended peak flow.

Circular ratio: Circular ratio (Rc) is computed as:

$$Rc = \frac{2}{Lp} \sqrt{A \times \pi} \quad \text{.......... (1.7)}$$

Circular basins with low bifurcation ratios produce a sharp peak.

Maximum watershed relief: Maximum watershed relief (H) is the maximum vertical distance between the lowest and the highest points of a watershed. It is also known as total relief.

Relief ratio: Relief ratio (Rh) is the total relief of watershed divided by the maximum length of the watershed. It is an indicator of the potential energy of the system to drain off.

Ruggedness number: Ruggedness number (RN) is defined as the product of the maximum watershed Relief and its drainage density. It provides an idea of overall roughness of a watershed and is computed as:

$$RN = H \times Dd \quad \text{.......... (1.8)}$$

Relative relief: Relative relief (Rr) is the ratio of the maximum watershed relief to the perimeter of the watershed.

$$Rr = \frac{H}{Lp} \quad \text{.......... (1.9)}$$

Time of concentration: Time of concentration (tc) is the time require to move the surface runoff from remotest point of the watershed to outlet, is known as time of concentration.

$$tc = 0.00032 * L^{0.77} * S^{-0.385} \quad \text{......} \quad (1.10)$$

Where:

tc = time of concentration (h)

L = maximum length of travel of water

S = slope equal to H/L, where H is the difference in elevation between the remotest point on the basin and the outlet (m)

For morphometric analysis, perimeter, maximum length, drainage map, stream length of each order, number of streams of each order and watershed relief values is required. These inputs were derived by using GIS software.

Once these inputs were obtained, then by making use of the mathematical formulas as discussed above, all the necessary parameters for morphometric analysis were calculated.

1.5 Project Task–Plan

The following matrix explains the tasks have been under taken and the duration of each task.

Table (1.1): Project Task–Plan

Phase No.	Task	Duration(monthly)							
		2006			2007				
		10	11	12	1	2	3	4	5
1	Review of literature and other survey work	■	■	■	■	■			
2	Delineation of the Watersheds		■						
3	Soil classification , Permeability rate tests, and land use map					■	■	■	
4	Preparation of Morphometric Parameters					■	■	■	
5	Analysis and results							■	■
6	Writing the report							■	■

1.8 Structure of the Report

The study report has been prepared in accordance with the objectives and scope of work. The report consists of seven chapters.

The first chapter entitled ' **Introduction**' outlines the problem, project objectives, literature review, study area, morphometric parameters and structure of the report.

The second chapter entitled '**Hydrological Models**' explains geographical information system, global positioning system, models, and hydrological models.

The third chapter entitled "**Hydrologic Principles**" explains hydrologic circle, and water balance which includes precipitation, evaporation, infiltration and runoff

The fourth chapter entitled' **GIS and Spatial Hydrology** ' deals with water flow analysis, flow direction grids, watershed and stream delineation, and watersheds.

The fifth chapter "**Field Work and Experiments**" explains watershed boundary and grid setup, and soil tests.

Chapter six on "**Analysis and discussion of Results**" presented land use and land cover, soil classification, morphometric Analysis curve number and estimation of the surface runoff.

The overall **conclusions** are given in chapter seven.

CHAPTER

2 HYDROLOGICAL MODELS

CHAPTER TWO

HYDROLOGICAL MODELS

2.1 General

The knowledge and understanding that the researcher and scientist have about the world is often represented in the form of models. The aim of the models is to simplify and explain the complexity and confusion of the world. The applied scientist and technologist then use the models of science to predict and control the world.

2.2 Models

2.2.1 Definition of models

There is no specific definition for models. Modeling in general term, is a representation containing the essential structure of some objects or event in the real world. So, models are important constructs and architectures of more than one idea that directly or indirectly influence our state of mind and our lives.

2.2.2 Characteristics of the models

1. The models are necessarily incomplete: The model is a representation; no model includes every elements of real world. If it did, it would no longer be a model. To create a model, a researcher makes some assumptions about the essential structure and relationships of objects and events in the real world. These assumptions are important to explain the phenomena.

2. The models may be changed with relative ease: The technician changes the model and observes the results, rather than doing a similar operation in the real world. He or she does this because it is simpler and more convenient.

For example, design a model for car to test the behavior of it on the horizontal curve and studying the effect of changing the parameters of the physical model, the designer might vary the radius of the curve and notes the results. In this way, the model changes in simple way (Stock Burger, 2000).

2.2.3 Model classification

Models can be classified as follows:

1. Physical models, as in an airplane model or a vehicle model, such a models are constructed to appear similar prototype, but at different scale.
2. Symbolic models, as in the natural language, a computer program, or a set of mathematical equations.
3. Descriptive models, that are describe the prototype, as landscape panting.
4. Procedural models, these models consist of instructions on how to make something behave as it were the prototype.

But, in general the models can take two major forms, physical and symbolic; the latter is used much more often in science. Symbolic models are constructed using either a natural or formal language (kain, 1972). As an example of natural languages include Arabic, and English. Examples of formal languages include mathematics, logic, and computer languages. Natural and formal languages share a number of commonalties. First, they are both composed of a set of symbols, called vocabulary of the language. Arabic forms of words, such as those that appear on the articles. Algebraic symbols such as: 2, 9.8, X, Y, =, +.

2.2.4 Model-building in science

There is a procedure for the model-building and verification. After a problem is formulated, the process consists of four stages.

1. Simplification \Idealization: As mentioned previously, a model contains the essential structure of objects or events.
2. Representation\Measurement: The symbols in a formal language are given meaning as objects, event, or relationships in the real world. This is the process used in translating "word problems" to algebraic expressions in high school algebra. (Stock Burger, 2002). This process is called representation of the real world.
3. Manipulation\Transformation: Researchers in the language are transformed into other statements in the language. In this manner implications of model are derived.
4. Verification\Calibration: Because of the idealization and simplification of the model-building process, no model can be in perfect agreement with the real world. In all cases, the important question is not whether the model is true or not, but how much does it match the real world. Powerful models replace less powerful models.

Models may be classified as distributed or lumped. Distributed models are those where their parameters depend upon spatial position, where lumped models do not have the spatial parameter, but may have time parameter.

In conclusion, the scientific method of model-building is very powerful tool in analyzing and dealing with the world.

2.3 Hydrological Models in GIS

An important method of the studying of hydrology is hydrological modeling as shown in Figure (2.1); which is an approximation of the actual hydrologic system.

Linking hydrology and GIS are very necessary due to ability of GIS to capture and manage a vast amount of data. In this project, the watershed delineation will mad by GPS and ArcGis.9 with a set of script and menus that automates the geographic data processing for in input files to the HEC-HMS model and other hydrology model.

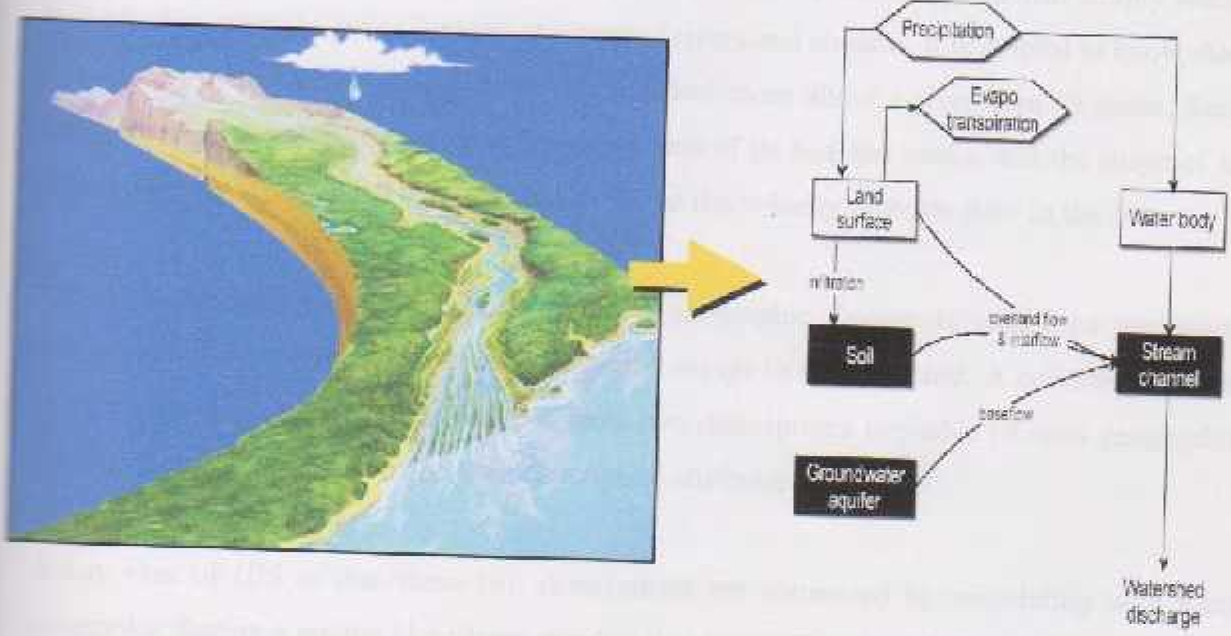


Figure (2.1): Hydrological Model Shows the Behavior of Water

2.4 Geographic Information System

Geographic Information System (GIS) is defined by ESRI (Environmental System Research Institute) as an organized collection of computer hardware, software, geographic data, and personal designed to efficiently capture, store, update, manipulate, analysis, and display all forms a geographically referenced information.

Many GIS databases consist of sets of information called layers. Each layer represents a particular type of geographic data. For example, one layer may include information on the streets in an area. Another layer may contain information on the soil in that area, while another records elevation.

The GIS can combine these layers into one image, showing how the streets, soil, and elevation relate to one another. Engineers might use this image to determine whether a particular part of a street is more likely to crumble. A GIS database can include as many as 100 layers (Maidment, 2002).

When looking at a map to know more about the features represented in it, than simply where they are. For example, when looking at a map of rivers and streams, it is helpful to know their names, and hydrologists want to know a good deal more about a river than its name. Such information as the slope of the river, the roughness of its bed and banks, and the shape of its cross-section, are important in being able to define the velocity of water flow in the river.

This type of descriptive information about a geographic feature is called its attributes. Attributes can be stored as numbers or character strings in a data record. A collection of data records makes up a data table. We thus have two descriptions available of each geographic feature: their spatial location and their descriptive attributes.

A key idea of GIS is that these two descriptions are connected by associating with each geographic feature a unique identifying number that is stored both with the spatial description and with the attribute description.

A GIS is designed to accept geographic data from a variety of sources, including maps, satellite photographs, and printed text and statistics. GIS sensors can scan some of this data directly—for example, a computer operator may feed a map or photograph into the scanner, and the computer "reads" the information it contains. The GIS converts all geographical data into a digital code, which it arranges in its database. Operators program the GIS to process the information and produce the images or information they need.

The applications of a GIS are vast and continue to grow. By using a GIS, scientists can research changes in the environment; engineers can design road systems; electrical companies can manage their complex networks of power lines; governments can track the uses of land; and fire and police departments can plan emergency routes. Many private businesses have begun to use a GIS to plan and improve their services.

GIS technology attempts to precisely describe the spatial environment, while hydrology attempts to describe how water and pollutant move through the environment, then the synthesis of GIS and hydrology is spatial hydrology.

The purpose of spatial hydrology is to use spatial data and functions of GIS to help in solving the problems in water management. The spatial technology currently used in spatial hydrology is ArcGis.9 software and ArcGis.9 spatial Analysis Extension. ArcView GIS is readily available to the greatest number of users, although Arc/ Info software can be employed to solve spatial hydrology problems just as effectively. (Maidment, 2002)

The substance of current spatial hydrology is devoted to spatial data development for hydrology because GIS does not have explicit provisions for time-series data and much of hydrology is concerned with time-series measurement systems.

The ArcGis.9 Spatial Analysis has several built-in functions that enable simple watershed delineation using a Digital Elevation Model (DEM). These functions have been further developed by other organization, including the Center for Research in Water Resources (CRWR).

GIS has versions, and we will make our experiments (watershed delineation, runoff) by version "ArcGis.9 ".

2.5 Land Use/Land Cover

Land use and treatment classes are used in the preparation of hydrological soil-cover complex, which in turn are used in estimating direct runoff. Types of land use and treatment are classified on a flood runoff producing basis. Below are a few extracts of the land use classification (USGS classification):

a- Agricultural Land: These Land caused from the human, it contain the Cropland, Rotation and Permanent Pasture.

b- Wetland: (forested Wooded Wetlands) Poor woodlots are heavily grazed and regularly burned in a manner that destroys litter, small trees, and brush. Fair woodlots are grazed but not burned and may have some litter, but usually these woods are not protected. Good woodlots are protected from grazing so that litter and shrubs cover the soil.

c- Rangeland or Native pasture: Poor pasture or range is heavily grazed, has no much or has plant cover on less than about 50% of the area. Fair pasture or range has between 50% and 75% of the area with plant cover and is not heavily grazed. Good pasture or range has more about 75% of the area with plant cover. And is lightly grazed.

d- Forest Land: The hydrologic condition classes are determined on the basis of depth and quality of litter, humus, and compactness of humus.

e- Urban areas or Built-up Land Miscellaneous: Usually only very small parts of a watershed are farmsteads, roads, are as. When this is so, the areas may be included with one of the other land use cover types (such as fallow or small grain) in the computation of runoff.

f- Tundra: This class includes up and down and cross slope farming in straight rows.

g- Barren Land Contouring: Contour furrows used with small grains and legumes are made planting, are generally small and disappear due to climatic action.

h- Perennial Ice or Snow: these contain the Ice station that can't found the plants.

i- Water: it's relationship about the stream and rainfall & waterways, Lakes.

CHAPTER

3 HYDROLOGIC PRINCIPLES

CHAPTER THREE
HYDROLOGIC PRINCIPLES

3.1 General

Hydrology is the science that deals with the origin, distribution and properties of water on the earth including that in the atmosphere in the form of water vapor, on the surface as water, snow or ice, and beneath the surface as ground water.

Engineering hydrology includes that portion of the science, which deals with the estimation of runoff and its transportation from one place to another. The hydrology study is useful for the design and operation of engineering projects for the control and use of water.

The purpose of this chapter is to present fundamental hydrologic principles for estimating surface runoff from the watershed.

3.2 The Hydrologic Cycle

Most of the earth's water sources, such as, rivers, lakes, oceans and under ground water sources, etc. get their supplies from the rains, while the rainwater in itself is the evaporation from these sources. Water is lost to the atmosphere as vapor from the earth, which is then precipitation back in the form of rain, snow, hail, dew, sleet or forest, etc.

This evaporation and precipitation continues forever, and thereby, a balance is maintained between the two. This process is known as hydrologic cycle. It can be represented graphically as shown in Figure (3.1).

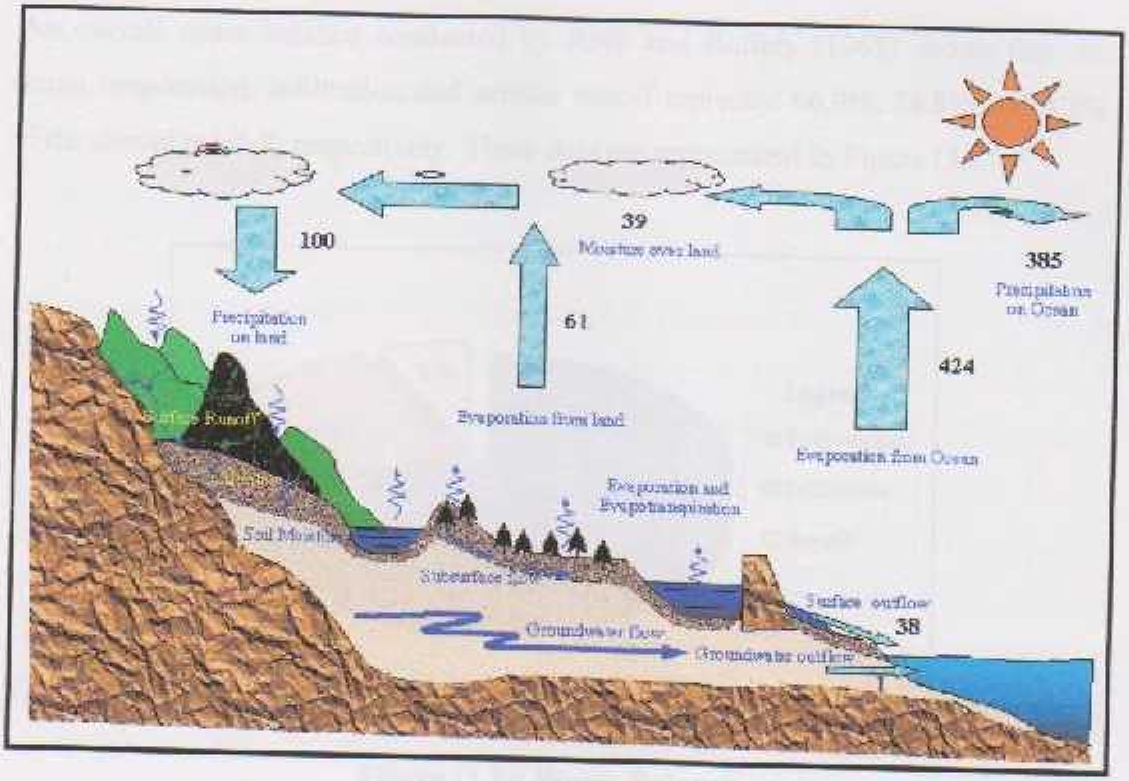


Figure (3.1): Movement of Water through the Hydrologic Cycle

The hydrologic cycle continuously keeps a balance between the water of the earth and the moisture in the atmosphere. Precipitation is the fall of moisture from the atmosphere to the earth surface in any form. For land areas:

Precipitation = runoff + losses.. (3.1)

Thus the importance of an in depth study of the hydrologic cycle lies in making use of long-term available precipitation data for planning engineering projects, through this relationship between precipitation and runoff of the hydrologic cycle which will be exploited to build rainfall-runoff models.

Precipitation is the main input parameter in the water budget of the West Bank, whereas the actual evaporation, infiltration and runoff are its major output parameters. The interception and depression storage are of minor importance.

An overall water balance conducted by Rofe and Raffety (1965) shows that the actual evaporation, infiltration and surface runoff represent 66.9%, 26.8% and 6.3% of the annual rainfall, respectively. These data are represented in Figure (3.2).

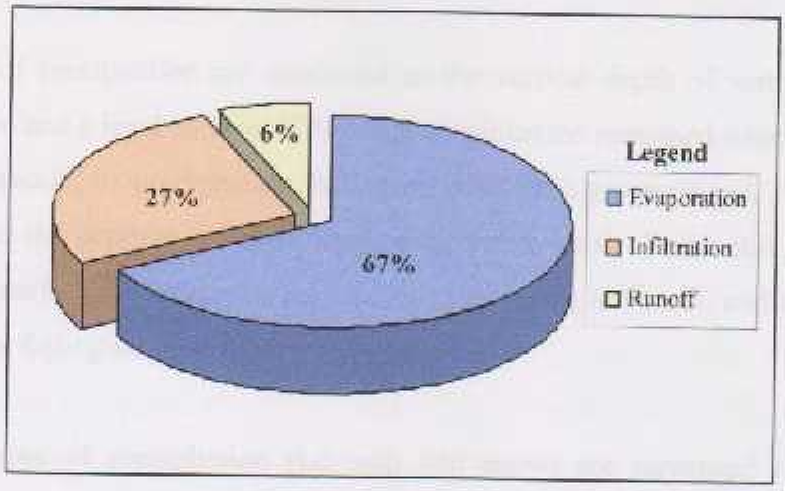


Figure (3.2): Water Balance

3.3 Precipitation

Precipitation is the total supply of water derived from the atmosphere in the form of rain, snow, mist, frost, hail, sleet, etc. which is of particular concern to man and agriculture. A major part of the precipitation occurs in the form of rain, and a minor part occurs in the form of snow.

Other forms of precipitation such as hail, sleet, mist, etc, are all very small, and generally ignored in the design of most of the hydrologic works, and therefore, they are not of much importance to us. Rainfall runs of to the stream soon after it reaches the ground and it is the cause of most of the floods. Frozen precipitation may remain where it falls for a long time before it melts.

Precipitation is often classified, as under, according to the factor responsible for the lifting of the air mass. In nature the effects of the various types of cooling, causing precipitation, are often interrelated, and the resulting precipitation cannot always be identified as being of any one type:

1- Convective precipitation.

2- Geographic precipitation.

3- Cyclonic precipitation.

4- Precipitation due to turbulent ascent.

All forms of precipitation are measured as the vertical depth of water that would accumulated and a level surface, if the enter precipitation remained where it fell.
The total amount of precipitation falling on earth in a given period, will hence be expressed as the depth to which it would accumulate on the horizontal projection of the earth's surface, if there were no loss by evaporation or runoff, and if any part of precipitation falling as snow or ice were melted.

The two types of precipitation (i.e. rain and snow) are measured separately by measuring devices called rain gages and snow gages, respectively.

The simplest method of measuring rainfall is by sitting up a rain gage with a horizontal circular aperture of known area, and collecting and measuring at regular intervals, the rainfall collected in the gage is representative of a certain area around the point where the measurement is made.

3.4 Evaporation

Evaporation is the transfer of water from the liquid to the vapor state from open water surfaces. Evaporation is principally strong in summer as a result of high temperature, intensive sunshine and low humidity.

The evaporation rate in the mountain region is lower than in other regions. Potential evaporation is consider an important factor in the water balance equation, and is an efficient tool to measure the amount of water that is needed by a certain crop.

As the amount of evaporation increase, more water transpires from the plants and, consequently, more water will be needed to satisfy the plant requirements to achieve adequate plant growth and maximum crop production.

But, as the rainfall concentrated in the winter months, when evaporation is at its lowest, more water will be percolated to the groundwater.

ASA Program 1996, mention that 73% of the rainfall evaporates directly from the ground before the water infiltrates to groundwater or runs in the wadis.

The following Columnar (Figure 3.3) bars show the variation in the mean monthly evaporation data (mm) of Hebron Climatic Station in the period 1975-1997. (Data from Palestinian Metrological Department, 2002)

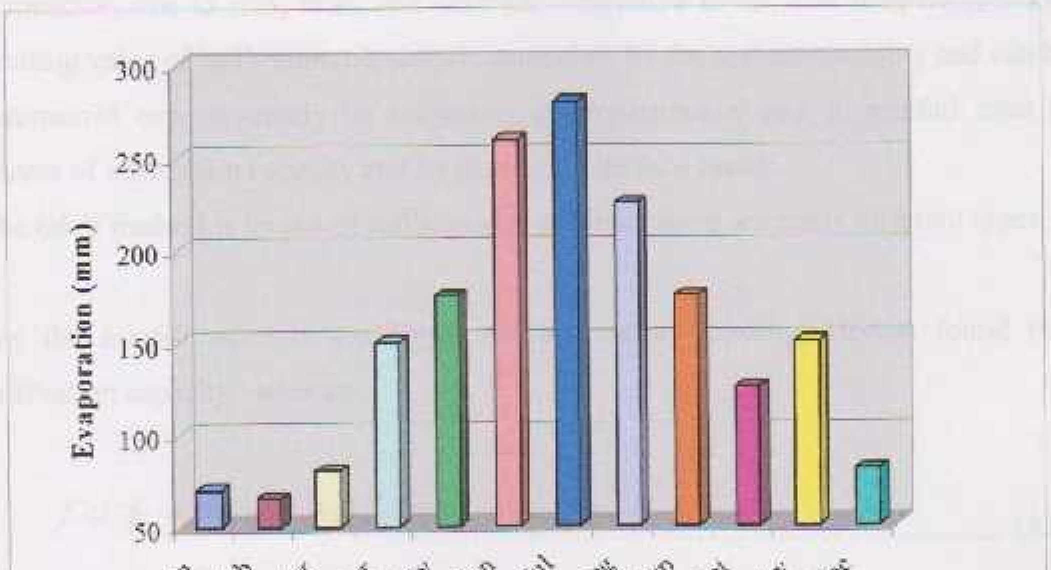


Figure (3.3): Mean Monthly Evaporation for Hebron Area

3.5 Infiltration

Infiltration is a movement of water from the surface of ground into the soil. In a rainstorm, infiltration normally begins at a high rate and decreases to a minimum as rain continues. At any instant, the Infiltration Capacity (f_c) of soil is the maximum rate at which water will enters the soil in a given condition.

The rate at which water actually enters the soil during a storm is known as Infiltration Rate (f) and is equal to the infiltration capacity or the rainfall rate whichever is less which means when the rainfall intensity is less than the infiltration capacity, the prevailing infiltration rates are approximately equal to the rainfall rates, and if the rainfall intensity is always above the infiltration capacity, the infiltration rate follow the capacity curve.

Infiltration capacity depends on many factors such as; soil type, moisture content, compactor, due to rain, man, and animals, vegetative cover, and temperature. The limiting value of infiltration capacity is controlled by the soil permeability and can be determined experimentally by subjecting an experimental plot to rainfall rates in excess of infiltration capacity and by measuring surface runoff.

The other method is by use of infiltrometer of which there are many different types.

For the rainfall rates in excess of the infiltration capacity, Horton found that infiltration capacity varies as:

$$f = f_c + (f_i - f_c)e^{-kt} \quad \text{(3.2)}$$

Where:

f is the infiltration capacity at any time t from start of rainfall.

f_i is the initial infiltration capacity, generally mm/hr, at $t = 0$.

f_c is the infiltration capacity after it attains a constant value.

k is the positive constant value depending on soil and vegetation cover.

t is the duration of rainfall, recorded from the beginning of rainfall.

Typical infiltration curve and runoff is shown in Figure (3.4)

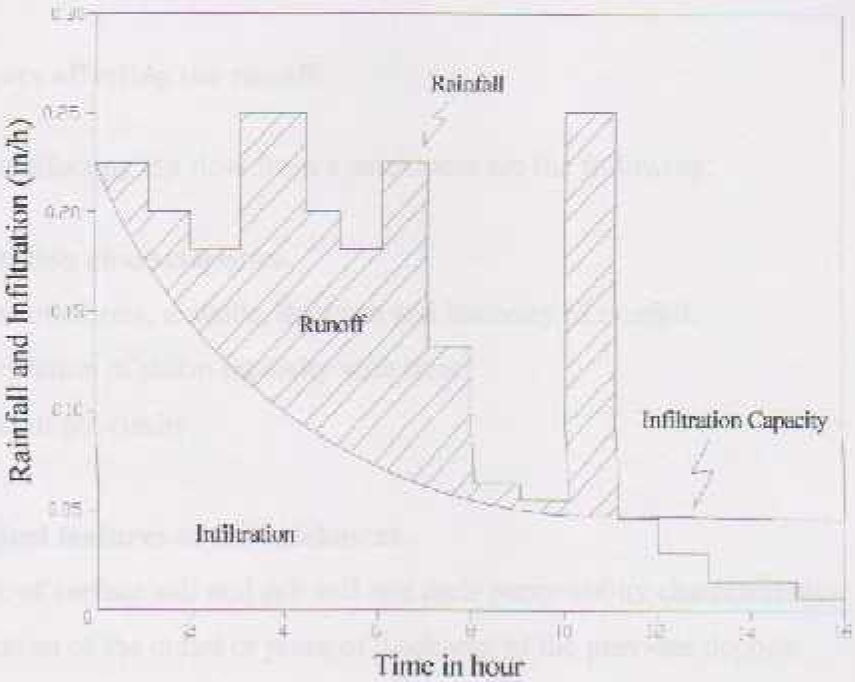


Figure (3.4): Typical Infiltration Curve and Runoff

3.6 Runoff

The runoff of a catchment in any specified period is the total quantity of water draining into a stream or into a reservoir, expressed as:

i) Centimeters of water over the catchment.

ii) Total water in cubic-meter or hectare-meter.

The rainfall on different areas is disposed off in the following manner:

a) Absorption.

i) In sustaining plant life.

ii) In maintaining the moisture on the soil.

iii) In replenishing the sub-soil water level.

iv) By evaporation.

b) Artificial irrigation.

c) Runoff into the sea.

3.6.1 Factors affecting the runoff

The factors affecting the flow from a catchment are the following:

1. Precipitation characteristics.

a) Types of storms, extends, duration and intensity of rainfall.

b) Distribution of storm intensity with time.

c) Effect of proximity.

2. Geological features of the catchment.

a) Type of surface soil and sub soil and their permeability characteristics.

b) Location of the outlet or point of discharge of the previous deposit.

3. Size and shape of the catchment.

a) Usually intense rainfall is over a small area i.e. larger the catchment area, smaller is the intensity of rainfall.

b) Fan shape catchments, given greater runoff because tributaries are nearly of same size and hence time of concentration of runoff is nearly same. On the contrary, discharge over fern leaf arrangement of tributaries, is distributed over a long period.

4. Topography.

a) The inclination of the surface and the degree of inclination.

b) Character of the area whether smooth or rugged.

c) More rains on the catchment on windward side of mountains.

5. Meteorological conditions.

a) Temperatures-annual and seasonal, their variations and duration, timings of extreme low and high temperatures.

b) Barometric and atmospheric movements and their relation to path of storm centers, winds and evaporation.

6. Character of catchments surface.

a) Drainage of the area.

b) Cultivation in the area or natural.

c) Bare or covered with vegetations, crops, grass or forests.

7. Storage characteristics.

a) Capacity of reservoir.

b) Flood routing operations.

3.6.2 Estimating runoff

Runoff is estimated by various methods. These can be classified under the following headings:-

1- Empirical formulas and tables.

2- Rational method.

3- Infiltration method.

4- Hydrograph method.

5- SCS curve number method.

3.6.2.1 Empirical formulas and tables

Several investigations have evidenced their empirical formulas for finding out the quantity of monthly or yearly runoff.

Some of these important formulas are given below: Runoff percentage formula: The following Table (3.1) shows the percentages of runoff to rainfall based on the observations.

Table (3.1) Percentage of Runoff to Rainfall (Randkivi, 1978)

Annual rainfall (mm)	Runoff (percent)
500	15
600	21
700	25
800	29
900	34
1000	38
1100	40

Runoff coefficient formula: The runoff (R) can be determined by using the direct rainfall-runoff formula as:

$$Q = k * P \quad (3.3)$$

Where:

Q is the yearly runoff in cm.

P is the yearly precipitation in cm. and

k is a constant, the usual values of which are given in the Table (3.2).

Table (3.2): Values of Runoff Coefficient (K) (Randkivi, 1978)

Type of Area	Value of K
Single houses	0.3
Garden apartments.	0.5
Commercial and Industrial area	0.9
Forested areas depending on soil	0.05-0.2
Parks, Farm land, pasture, etc.	0.05-0.3
Asphalt or concrete pavement	0.85

iii. Khasla's formula: This general formula can be used for any catchment, where the rainfall is uniformly distributed through the year. This formula is very useful, and states that:

$$Q = P - 0.4831 T_m \quad (\text{When } T_m > 4.5\,^{\circ}\text{C}) \quad \text{.......} \quad (3.4)$$

Where:

Q is the yearly or monthly runoff in cm.

P is the yearly or monthly rainfall in cm, and

T_m is the mean yearly or monthly temperature in degree centigrade.

3.6.2.2 Rational method

In this method, the runoff is correlated with the rainfall. Attempts have been made to estimate the maximum flood discharges by having a series of formulae to correlate the many variable factors. The most noteworthy of them is by Richards. His theory of flood estimation rest on the principle "that the average intensity of rainfall is an average function of both the catchment area and of the duration of the storm"the assumptions are then made that the storm fully covers the catchment and that its duration is equal to the period of concentration of flood. The rainfall is assumed uniform and constant over the catchment. The slope of the catchment is assumed uniform. All these conditions are difficult to be met with and this method cannot be used for large basins.

In this method the basic formula

$$Q = C * i * A \quad \text{.......} \quad (3.5)$$

is used, where:

Q = flood flow in cubic meter.

C = runoff coefficient, ratio between runoff and rainfall.

i = Rainfall in mm per hour

A = drainage area contributing to runoff in square meter.

In this method, the drainage area is divided into a number of sub areas and with known time of concentration of different sub areas, runoff contribution from each area is calculated. The values of C for use in rational formula as given by M Bernard (1938) are given in the Table (3.3).

Table (3.3): The Values of (C) for Use in Rational Formula (Bernard, 1938)

Soil Type	Value of C for Watershed Cover		
	Cultivated	**Pasture**	**Wood land**
With above average infiltration rates, usually sandy or gravely	0.20	0.15	0.15
With average infiltration rates, no clay pans; loams and similar soils.	0.40	0.35	0.30
With below average infiltration rates; heavy clay soils or soils with a clay pan near the surface.	0.50	0.45	0.40

3.6.2.3 Infiltration method

Infiltration index is the average rate or loss such that the volume of rainfall in excess of that rate will be equal to the direct runoff. This method used for large area. Estimates of runoff volume from large areas, having heterogeneous infiltration and rainfall characteristics are mad by use of infiltration indices. The most common of these indices are:

i. **The Φ Index :**

The Φ index is the simplest and is based on the assumption that for a specified storm with given initial conditions, the rate of basin recharge remains constant throughout the storm period. Thus if a time intensity graph of rainfall is constructed, the Φ index is the average rainfall intensity above which the volume of rainfall equals the volume of observed runoff, as shown in Figure (3.5).

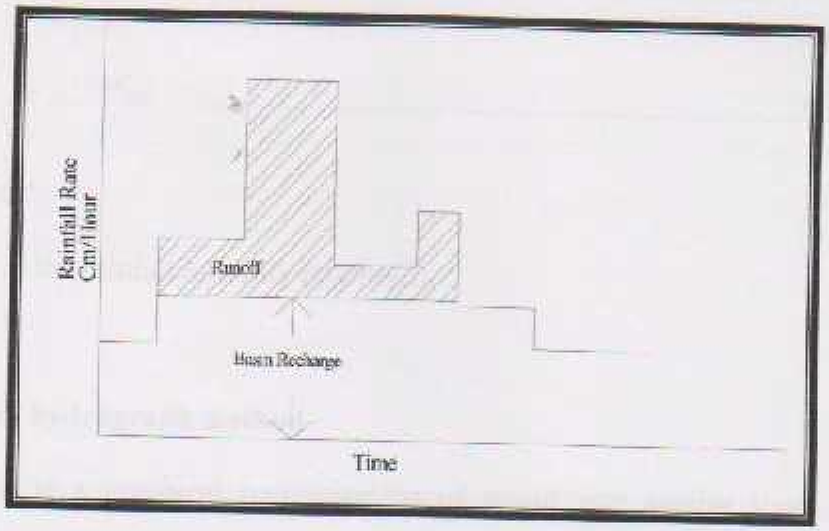


Figure (3.5): Schematic Diagram Illustration the Meaning of Index

(Randkivi, 1978)

ii. W-Index :

This index is defined as the average rate of infiltration during the time rainfall intensity exceed the infiltration capacity.

$$W = \frac{P - R}{t_r} \quad cm/hour \qquad (3.6)$$

Where:

t_r is the duration of rainfall in hours.

R and P are runoff and precipitation.

Essentially the W-index is equivalent to Φ-index minus the average rate of retention by depression storage.

iii. W_{mfn} Index:

With very wet condition, when infiltration capacity is essentially minimum, and (W_{mfn}) are almost identical.

The infiltration index can be used to estimate the runoff coefficient (K) from the relation,

$$K = \frac{i - W_{index}}{i} \quad \text{.......... (3.7)}$$

Where:

i is the rainfall intensity (cm/hour).

3.6.2.4 Unit hydrograph method

Hydrograph is a graphical representation of runoff rate against time. A typical hydrograph resulting from single storm, as shown in Figure (3.6), consists of:

1) Rising limb
2) Peak
3) Recession

The direct runoff portion of a hydrograph is the summation of overland flow and interflow. Groundwater flow (base flow) is to be separated from hydrograph determine direct runoff which is the result of precipitation.

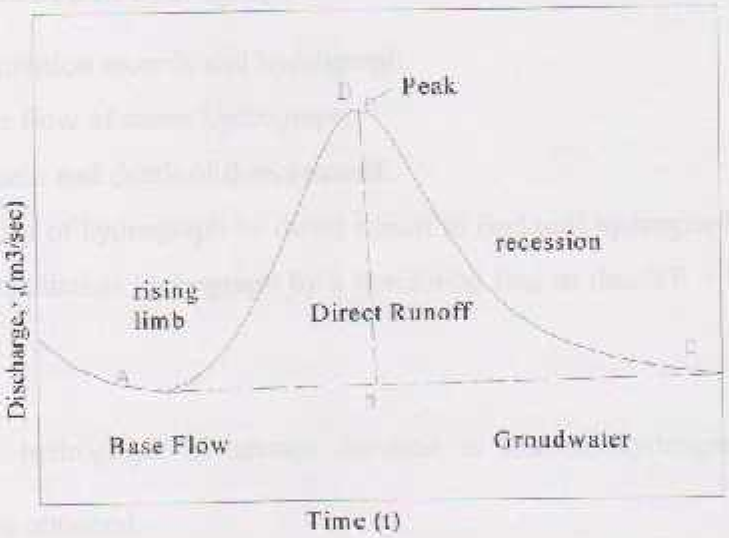


Figure (3.6): A typical Hydrograph from Single Storm (Mutreja, 1995)

A unit hydrograph is the direct runoff of unit (1cm) volume resulting from a rainstorm of specified duration and a real pattern. It assumed that the ordinate of direct runoff hydrographs is linearly proportional to the depth of excess precipitation. Thus; hydrograph from other rains of same duration and pattern are assumed to have the same time base, but ordinates would vary in proportion to runoff volumes, as shown in Figure (3.7).

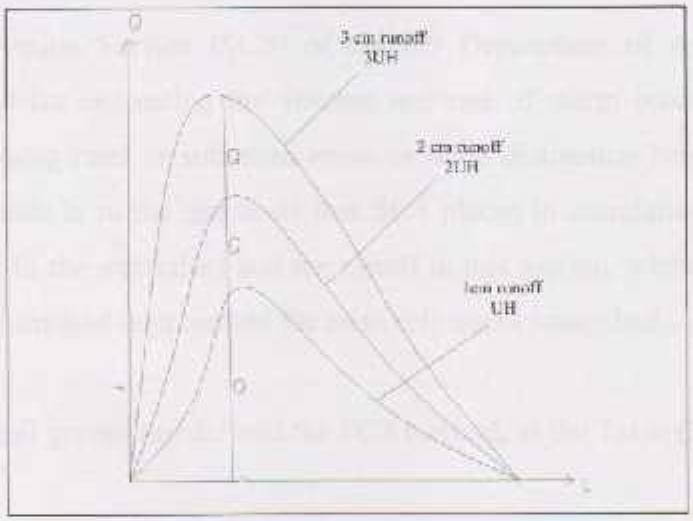


Figure (3.7): Runoff Curve (Mutreja, 1995)

i. Determination of unit hydrograph

1) Obtain precipitation records and hydrograph.

2) Separate base flow of storm hydrograph.

3) Find the volume and depth of direct runoff.

4) Divide ordinate of hydrograph by direct runoff to find unit hydrograph.

5) Separate precipitation hydrograph by a horizontal line so that VP = VR. This line is Φ – index.

Once the unit hydrograph of certain duration is known, hydrographs of other durations can be obtained.

ii. Application of unit hydrographs

Unit hydrograph can be used:

1) To determine runoff
2) For estimation of peak flow for design
3) For flood studies

3.6.2.5 SCS curve number method

The Soil Conservation Service (SCS) of the US Department of Agriculture has developed method for estimating the volume and rate of storm runoff that can be applied to developing rural or suburban areas. A basic distinction between the SCS and rational methods is in the emphasis that SCS places in correlation between the type of soil cover in the watershed and the runoff in this section, a brief overview of the SCS graphical method is presented for relatively small watershed.

Four hydrologic soil groups are defined the SCS method, as the Table (3.4) follows:

Table (3.4): Hydrologic Soil Groups (Karanth, 1988)

Soil Group	Description
A	High infiltration rate / Low runoff potential
B	Moderate infiltration rate
C	Slow infiltration rate
D	Very slow infiltration / high runoff potential

Data from field studies of the site and measured infiltration rates can help to identify the appropriate soil group; the volume and rate of runoff depend on the type of the land use in the watershed. In the SCS method, the effects of both soil group and land use are characterize in a term called the runoff curve number, abbreviate CN. Tables (3.5) present a summary of typical CN values used in the SCS method of estimating runoff.

Table (3.5): SCS Runoff Curve Number (Karanth, 1988)

Land Use Description	CN Value for Hydrologic Soil Group			
	A	B	C	D
Meadow	30	58	71	78
Forest	25	55	70	77
Grass lawns	39	61	74	80
Commercial-Business	89	92	94	95
Residential	54	70	80	85
Pavement-roofs	98	98	98	98

As the value of CN decreases, the amount of direct runoff will also decrease. Composite or weighted CN values can be computed for watersheds comprising more than one type of soil or land use in the same way this is done for the composite C in the rational method.

A graph showing the relationship among rainfall depth, in inch, the amount of runoff, also expressed in inch, and the CN values is illustrated in Figure (3.8). The chart in Figure (3.8) is entered on the horizontal axis with the depth of rainfall from an N-years storm of 24-h duration.

First moving vertically up to the curve matching the CN for the watershed (or the estimated curve position if it falls between the values shown on the graph) and then moving horizontally to the left, the volume of runoff can be read on the vertical axis. For example, a 24-hs rainfall of 6 in. on a watershed with CN = 70 will produce 2.8 in. of direct runoff over the area of the watershed.

The SCS (Soil Conservation Service) method is an empirically developed approach to the water infiltration process. It has been developed by first finding a mathematical function whose shape as a function of time matches the observed features of the infiltration rate.

This function is then provided a physical explanation of the process (Jury, 1991). In semi-empirical models, most physical processes are represented by commonly accepted and simplistic conceptual methods rather than by equations derived from fundamentally physical principles.

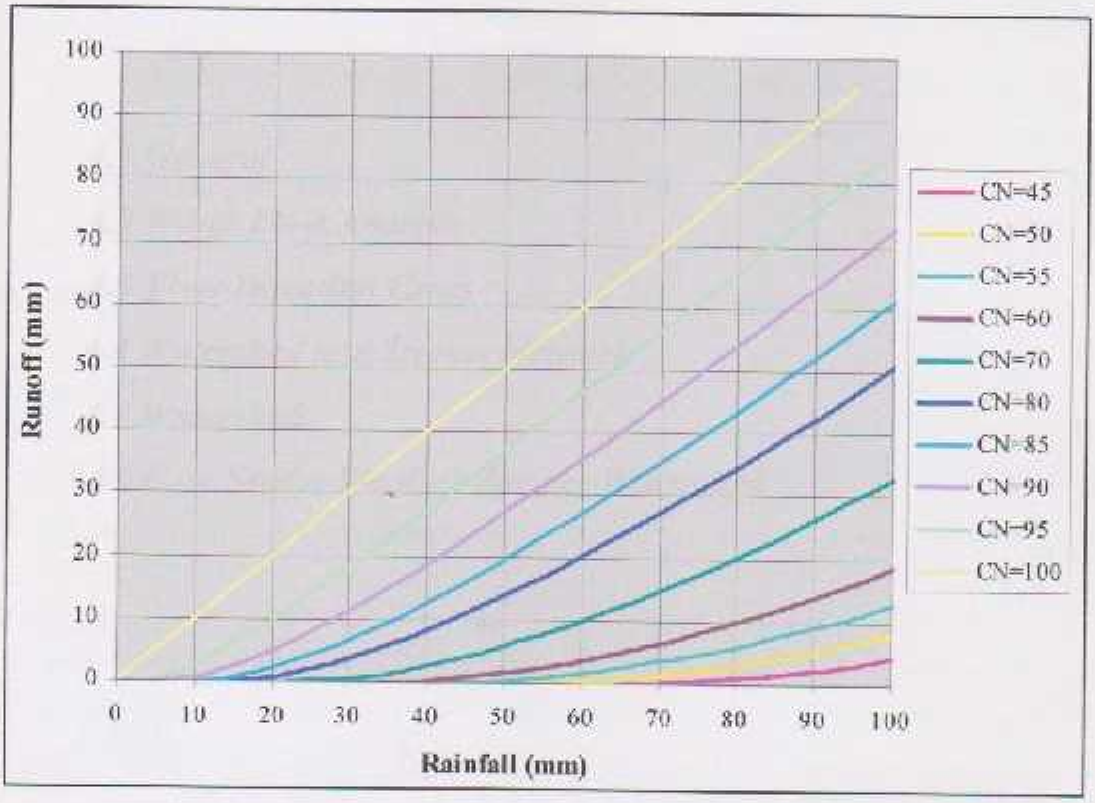


Figure (3.8): A Selection of SCS Rainfall-Runoff Relationships for Several CN values

CHAPTER

4 *HYDROLOGIC ANALYTIC IN* ArcGIS

CHAPTER FOUR
HYDROLOGIC ANALYTIC IN ArcGIS

4.1 General

The study of the hydrology begins in describing the scientific principles governing hydrologic phenomena, studying the hydrologic system operation and predicts its output, and applying the knowledge into water resources and environmental engineering project. As mentioned earlier, geographical information system (GIS) has lead to significant increase in its use in hydrological application. This chapter explains how to generate watershed and water stream for the project area using (GIS).

4.2 Water Flow Analysis

The model which is used here follows the water from the farthest point until arriving the outlet, and analyses the movement of the point according to the elevations as describes below.

4.2.1 Function Processing

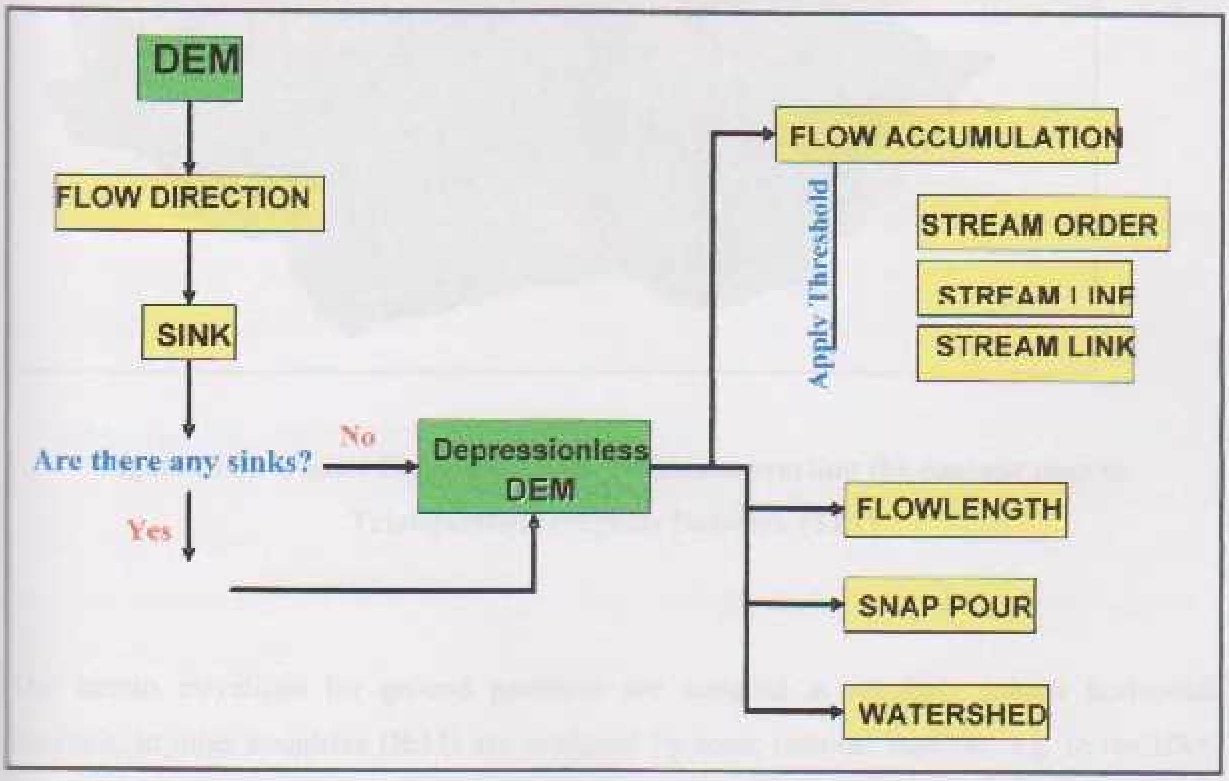


Figure (4.1): Flow Chart for Function Processing on Arc-view Software

4.2.2 Triangulated irregular network

Triangulated Irregular Networks data (TIN) sets can be used to display and analyze surfaces. They contain irregularly spaced points that have x, y coordinates describing their location and a z-value that describes the surface at that point. The surface could represent elevation, precipitation, or temperature. A series of edges join the points to form triangles. The resulting triangular mosaic forms a continuous faceted surface, where each triangle face has a specific slope and aspect (Library of ArcGis.9).

4.2.3 Digital elevation model

A Digital Elevation Model (DEM) is a digital earth surface terrain elevations in xyz coordinates which built by converting the contour map of study area to Triangulated Irregular Network (TIN) Figure (3.2).

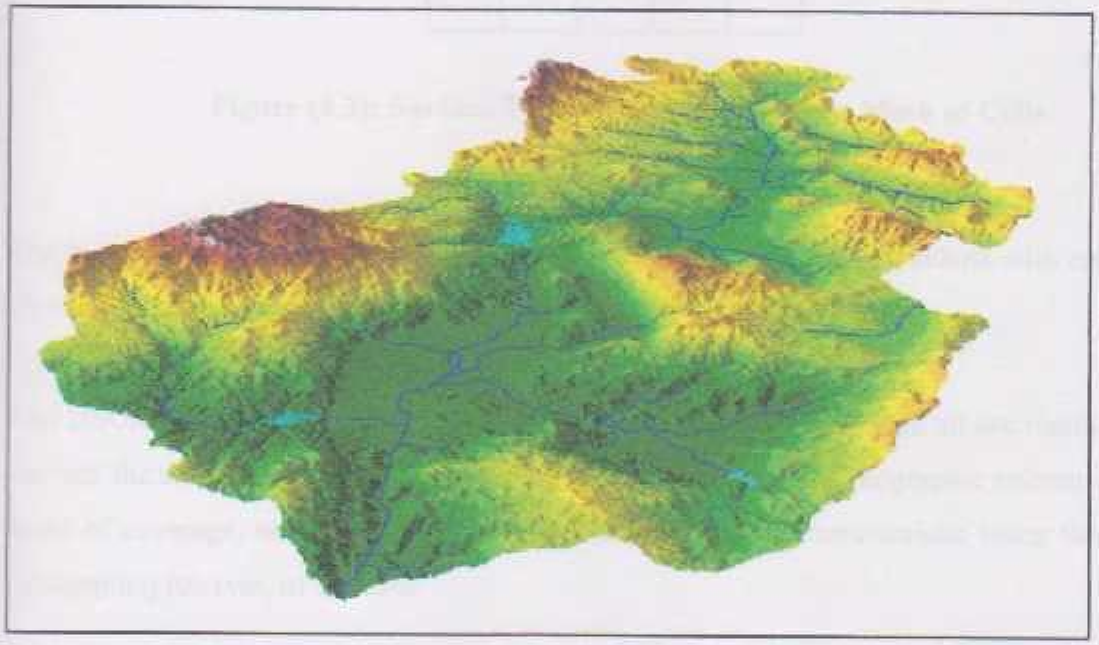


Figure (4.2): Digital Elevation Model (DEM) converting the contour map to Triangulated Irregular Network (TIN)

The terrain elevations for ground positions are sampled at regularly spaced horizontal intervals. In other countries DEMs are produced by some national institute, e.g. in the USA DEMs are produced by U.S Geological Survey (USGS) as apart of its national mapping program. Cell sizes for United States are available at (30m), (100m), (500m), and for the world at (1 km) cell size. (Maidment, 2002)

A Digital Elevation Model (DEM) consisting of a rectangular mesh of elevation points located over the landscape. Rectangular mesh has a number of cells represents the elevation of the center of the cell as the following Figure (3.3).

67	56	55	40	50
49	44	37	38	48
65	55	23	32	24
57	47	21	17	20
53	34	30	11	13

Figure (4.3): Surface Terrain Represented by a Mesh of Cells

The highest resolution DEM data is being produced by local mapping efforts with cell sizes of 10 m or smaller.

The USGS produces five different digital elevation products. Although all are identical in the manner the data are structured, each varies in sampling interval, geographic reference system, areas of coverage, and accuracy; with the primary differing characteristic being the spacing, or sampling interval, of the data.

4.2.4 The eight direction pour point model

The eight direction pour point model is the basis for cell-based drainage analysis using a DEM. Pour point is a location where the water flows out the cells. From Figure (4.4) each grid cell surrounding by eight cells (four on the principal axes and four on the diagonals) (Library of ArcGis.9).

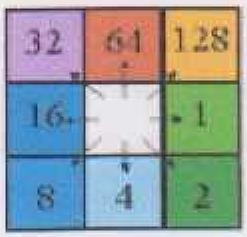


Figure (4.4): Pour Point Model

Water can flow in the cell to one and only one of its neighboring cells, in the direction of the steepest descent. The slope between the adjacent cells is defined as the ratio of the elevation difference to horizontal distance of the two cells centers. For example, Figure (4.5) illustrates a DEM grid with a cell size equal to one unit. (Maidment, 2002)

Figure (4.5): Direction of Steepest Descent

The distance between the cell centers is 1 on the principal axes and $\sqrt{2} = 1.414$ along the diagonals. The water flow from cell 67 to:

The slope between cell 67 to cell 56: (67-56)/1 = 11

The slope between cell 67 to cell 53: (67-53)/1 = 14

The slope between cell 67 to cell 50: (67-50)/1.414 = 12

The flow direction of cell 67 to the steepest descent is from cell 67 to cell 53.The eight direction pour point models is a simplification of the true path of water flow in any direction, not just one of the eight prescribed directions.

4.3 Flow Direction Grids

Flow direction grids are the flow directions from cell center to cell center. When the DEM is filled the flow direction grid derived directly. It stores the flow direction number for each cell, which corresponding to the direction of steepest descent as determined by the eight direction pour point model. These directions can be represented schematically using arrows, as shown below in Figures (4.6), (4.7) and (4.8). (Maidment, 2002).

67	56	52	44	50
49	44	37	38	48
65	55	23	32	24
57	47	21	17	20
53	34	30	11	13

Figure (4.6): DEM Grid

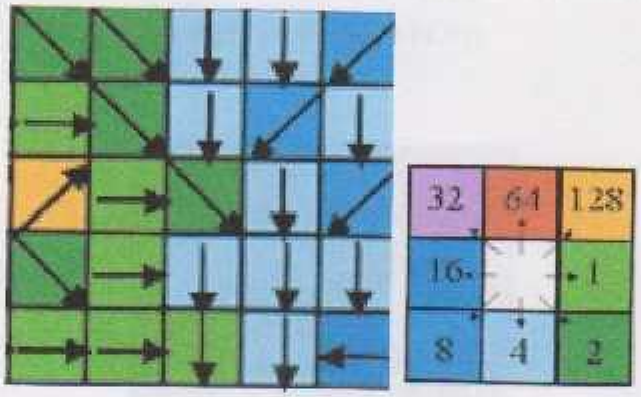


Figure (4.7): Flow directions and the Eight Directions Pour Point Model

2	2	4	4	8
1	2	4	8	4
128	1	2	4	8
2	1	4	4	4
1	1	1	2	16

Figure (4.8): Flow Direction Grid

4.3.1 Grid networks

Flow network is a network of elementary flow paths that connected each cell in the grid, cell by cell downstream, to the eventual outlet point of the terrain surface. This network called network grid (defined with a grid).

DEMs useful in the hydrology if it can be able to describe a flow with a one-dimensional network over a two-dimensional surface.

Because modeling two-dimensional flows is more complex, grid networks transform the problem of describing a two-dimensional flow over a surface into a problem of defining a one-dimensional flow through a network, (see Figure (4.9)).

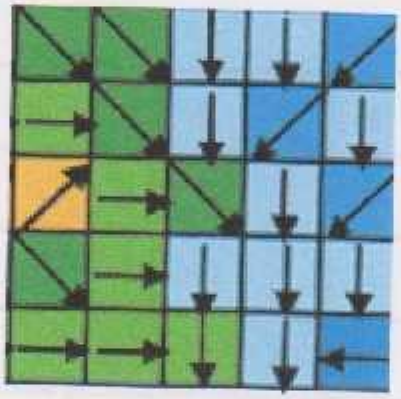


Figure (4.9): Flow Direction for Each Cell

4.3.2 Flow accumulation grids

Is one of the most important grids in hydrologic analysis, count the number of cells upstream from each individual cell? To illustrate how derived flow accumulation grid from a grid network look at the following Figures (4. 10.a) and (4.10.b).

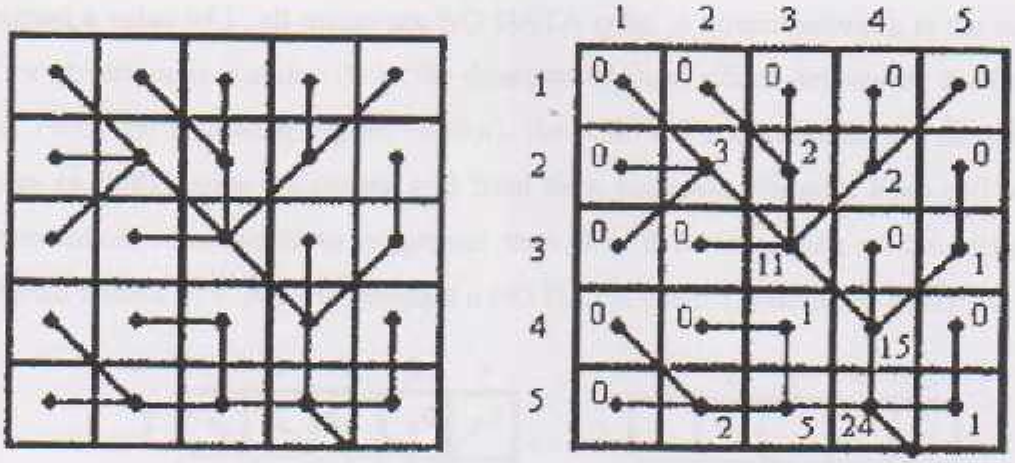


Figure (4.10): a) Grid Network **b) Flow Accumulation Grid**

(Mohammadin, 2003)

The entire cell in the first column and first row gave zero upstream cells, which are coded with a flow accumulation of 0. Cell (2, 2) has 3 cells upstream. Cell (2, 3) has two cells upstream ...etc. To determined the flow accumulation grid by similarly computing the values for all other cells as indicated in the Figure (4.11).

0	0	0	0	0
0	3	2	2	0
0	0	11	0	1
0	0	1	15	0
0	2	5	24	1

Figure (4. 11): Flow Accumulation Grid (Mohammadin, 2003)

4.4 Watershed and Stream Network

Stream Network and its watersheds is a fundamental to studying the movement of water through the landscape. Watershed and stream networks are defined using DEM. A stream cell is any cell with a flow accumulation value larger than the cell threshold. All stream cells are assigned a value of 1; all others are NO DATA cells. A stream network is the connection of all the stream cells (value = 1) in the direction of flow, which defined by the flow direction grid. From the following Figure (4.10.a), the cells are connected in the direction of flow. Figure (4.10.b) shows the stream grid from flow accumulation grid. Each cell with its flow accumulation value equal to or greater than **5** is defined as part of the stream grid and assigned a value of **1**. All arte assigned a NO DATA value. (Maidment, 2002)

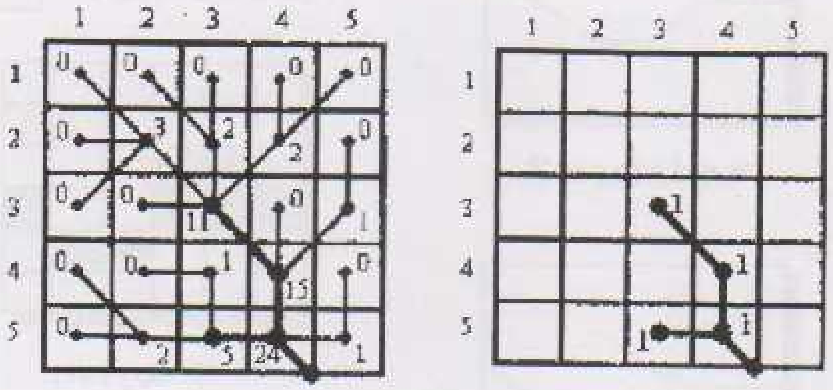


Figure (4.12): a) Flow Accumulation Grid b) Stream Grid

(Mohammadin, 2003)

Water flows downstream cell by cell. Flow accumulation grids count the number of cells upstream from any given cell. When the amount of water flow into the cell accumulation to a certain point, the cell considered part of the stream network.

4.4.1 Steam links

The Stream Link function allows you to assign unique values to each of the links in a raster linear network, as shown in Figure (4.13). This is most useful as input to the watershed function to quickly create watersheds based on stream junctions. It can also be useful for attaching related attribute information to individual segments of a stream.

A raster linear network can be accurately converted to features representing the linear network using the stream to feature function. The vectorization algorithm is designed primarily for vectorization of raster stream networks, or any other raster representing a raster linear network for which directionality is known. In the output feature dataset, all arcs will point downstream.

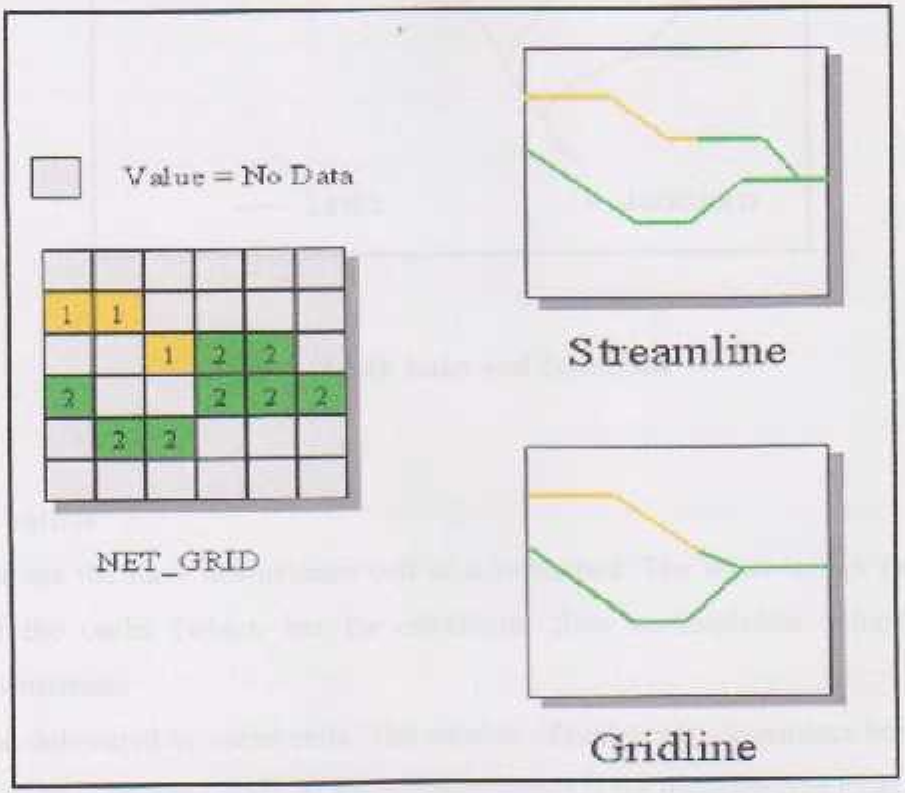


Figure (4.13): Stream Links

The stream to feature algorithm is optimized to use a direction raster to aid in vectorizing intersecting and adjacent cells. With stream to feature it is possible for two adjacent linear features of the same value to be vectorized as two parallel lines instead of being lumped into a single line as they would when using other vectorization methods.

Links are the sections of a stream channel connecting two successive junctions, a junction and the outlet, or a junction and the drainage divide, (Figure (4.14)).

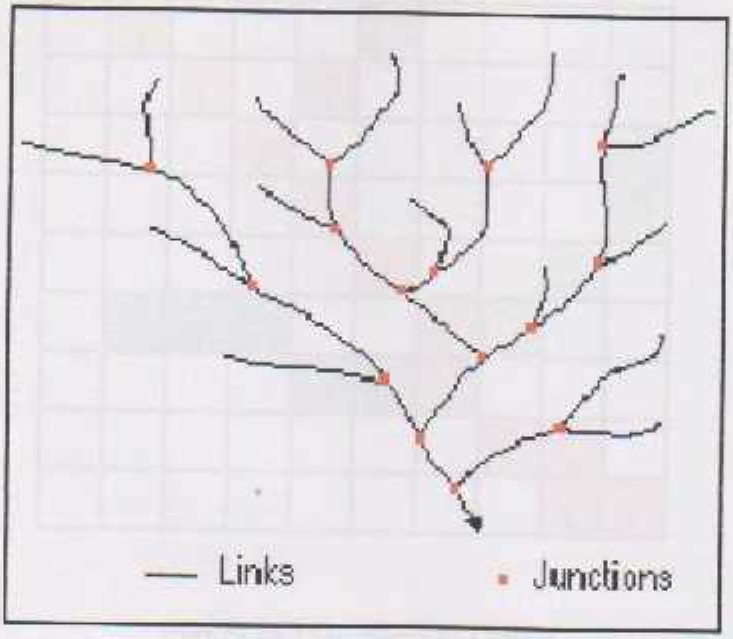


Figure (4.14): links and Junctions

4.4.2 Stream outlets

Stream outlets are the most downstream cell of a watershed. The water within the watershed flow through the outlet (which has the maximum flow accumulation value) to another watershed downstream.

The watershed delineated by outlet cells. The number of outlet cells determines how many sub-watersheds will be delineated. Each of the sub-watersheds is the drainage area to its outlet.

To determined the drainage area for a certain location (as a stream gauging station or water right location), should be define those locations as the outlet cells by converting the point theme of those locations to a grid theme, then delineate the watershed or drainage area from those locations (see Figure (4.15)).

It is important that the location points fall exactly on the streams; otherwise the delineation will not be accurate.

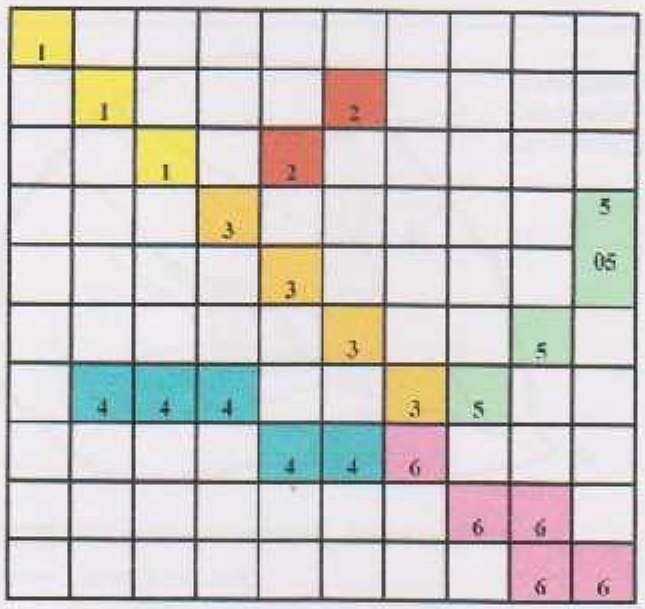


Figure (4.15): Stream Outlet

4.5 Watershed

A watershed is an area that drains water and other substances to a common outlet as concentrated drainage. Other common terms for a watershed are basin, catchment, or contributing area. This area is normally defined as the total area flowing to a given outlet, or pour point. These areas are the output of the watershed function. The boundary between two watersheds is referred to as a watershed boundary or drainage divide .

An outlet, or pour point, is the point at which water flows out of an area. This is the lowest point along the boundary of the watershed. The cells in the source raster are used as pour points above which the contributing area is determined. Source cells may be features such as dams or stream gauges, for which you want to determine characteristics of the contributing area, (Figure (4.16)).

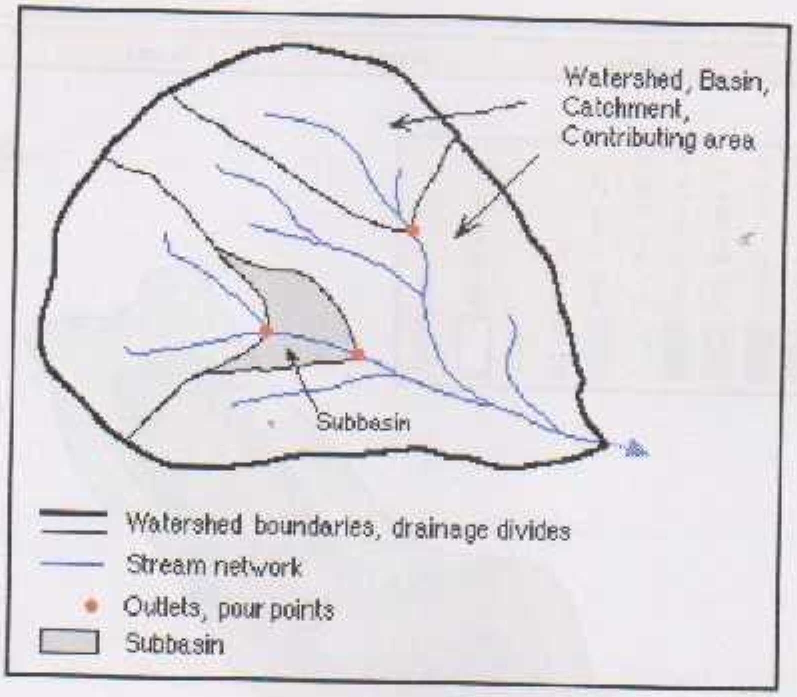


Figure (4.16): Watershed and Sub Watershed Boundaries

In the ArcGis.9 Spatial Analysis Extension watershed built as a function. The input grids for the watershed function are a flow direction grid and an outlet grid. The output grid is a watershed grid.

4.6 Case Study: Wadi Al-Zarzeer Watershed-Dura area

An ArcGis.9 was used to process the DEM and generate the hydrologic parameters required to develop the spatially distributed travel time distribution and direct runoff hydrographs by routing the runoff down to the outlets. The original procedure was created the DEM in ArcGis.9 project: to identify and fill sinks; to generate flow direction, flow accumulation, and stream network. The procedures are as follow:

1- Triangulated Irregular Networks (TIN) was fined as appear in Figure (4.17).
2- The Digital Elevation Model (DEM) derived from (TIN) as shown Figure (4.18).
3- The Flow Direction was computed as shown in Figure (4.19).
4- The Flow Accumulation derived from flow direction as shown in Figure (4.20).
5- The Stream Network was constructed as shown in Figure (4.21) .

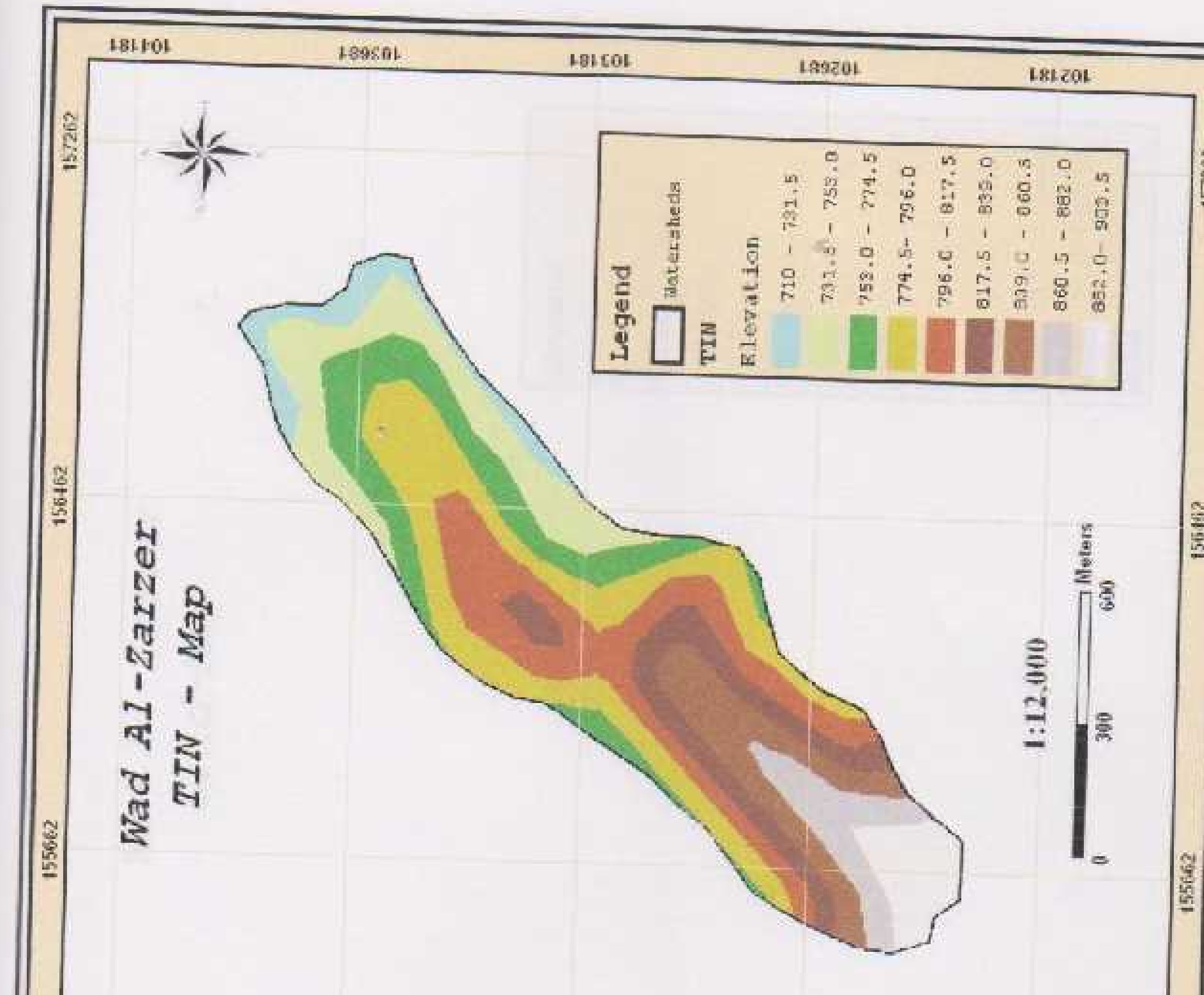


Figure (4.17): Triangulated Irregular Networks (TIN)

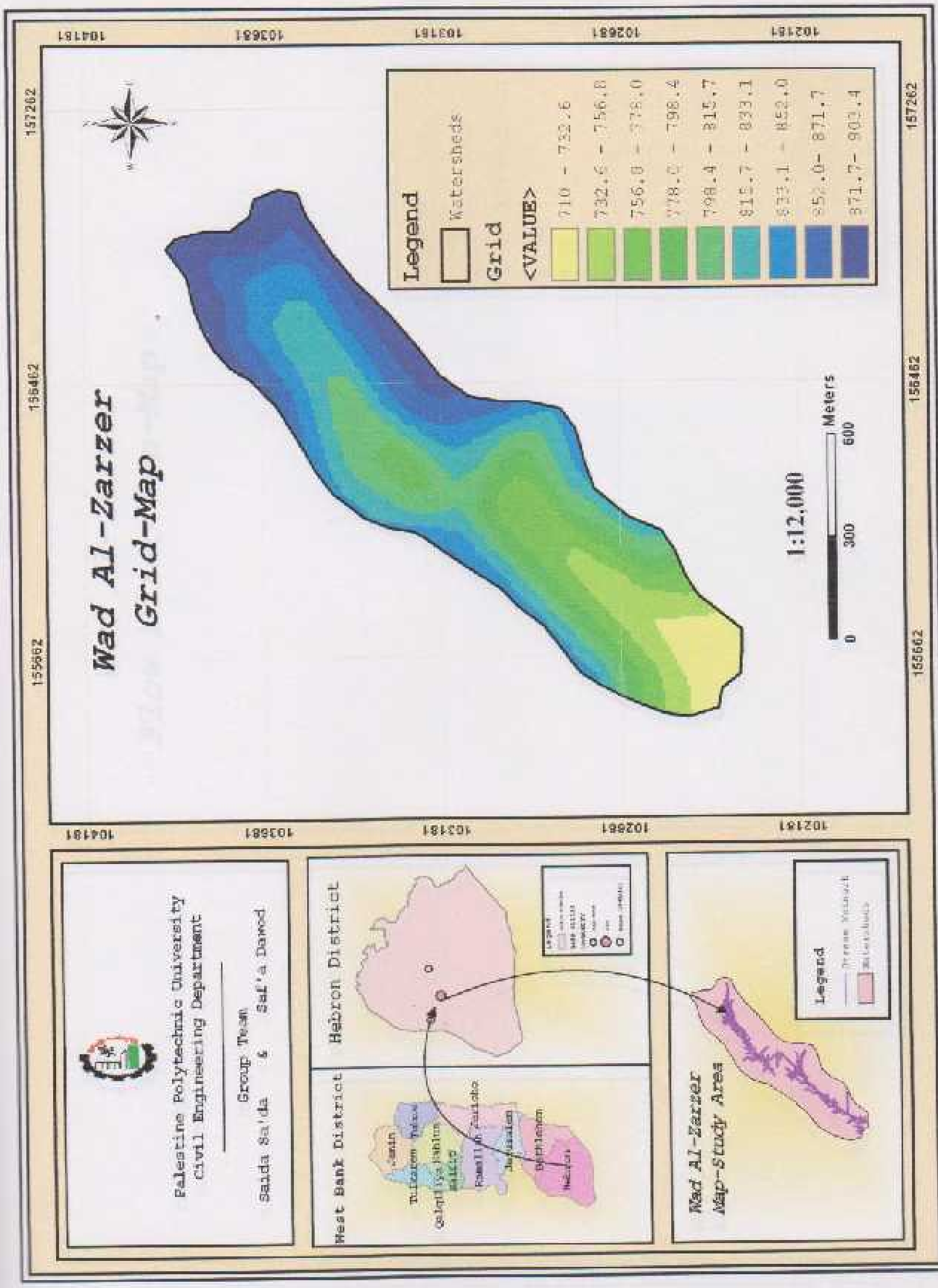


Figure (4.18): The Digital Elevation Model (DEM)

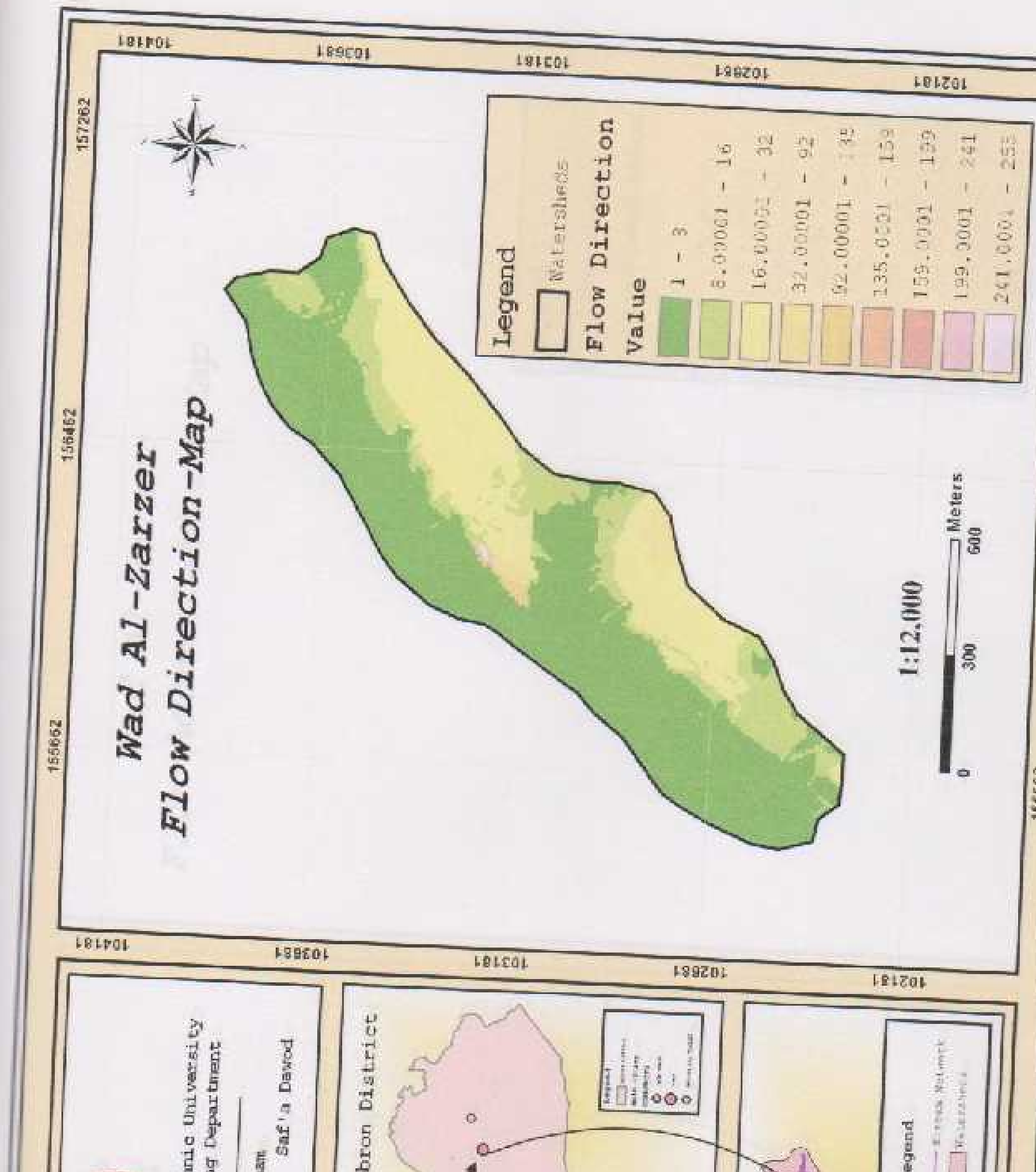


Figure (4.19): The Flow Direction

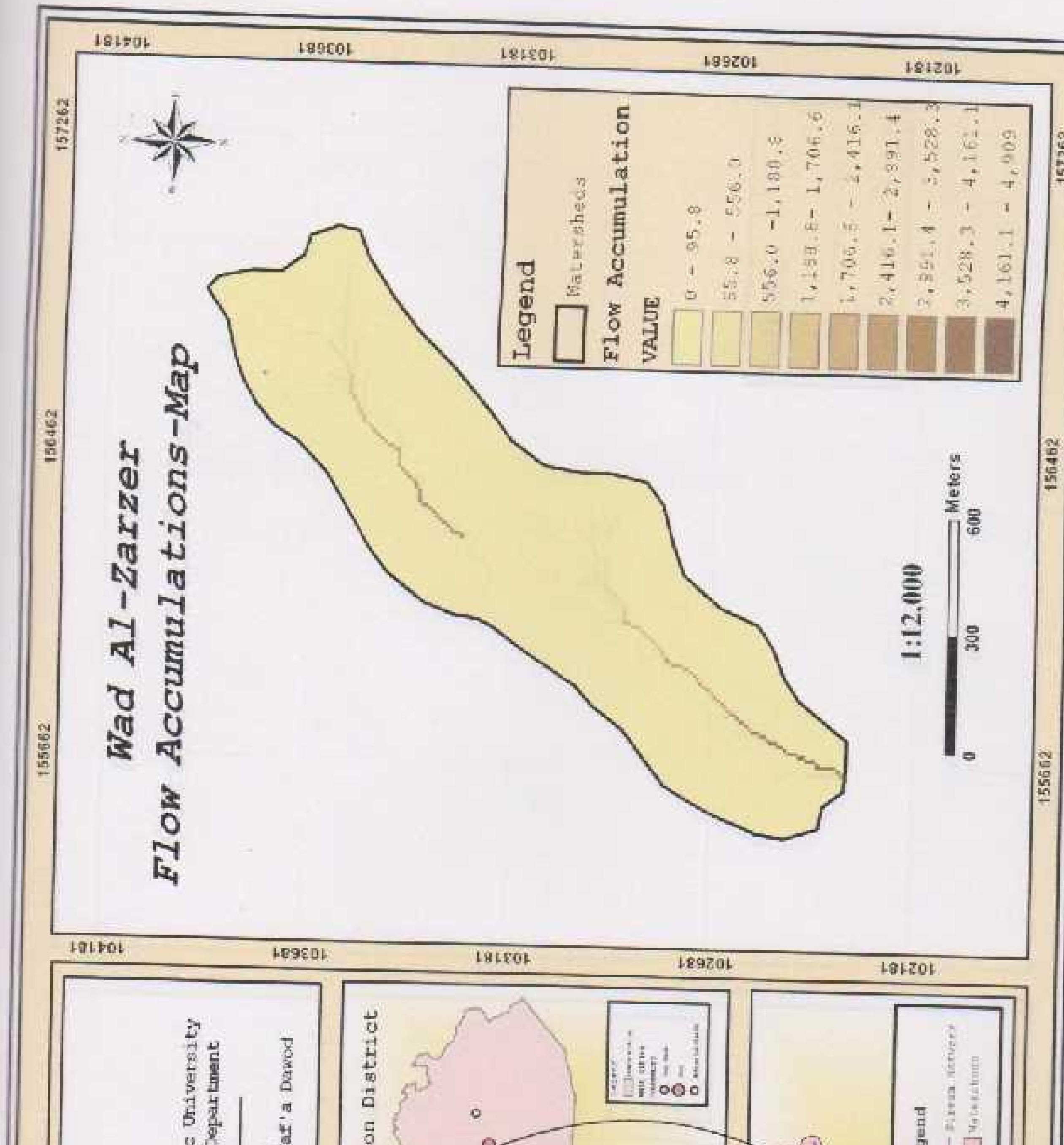


Figure (4.20): The Flow Accumulation

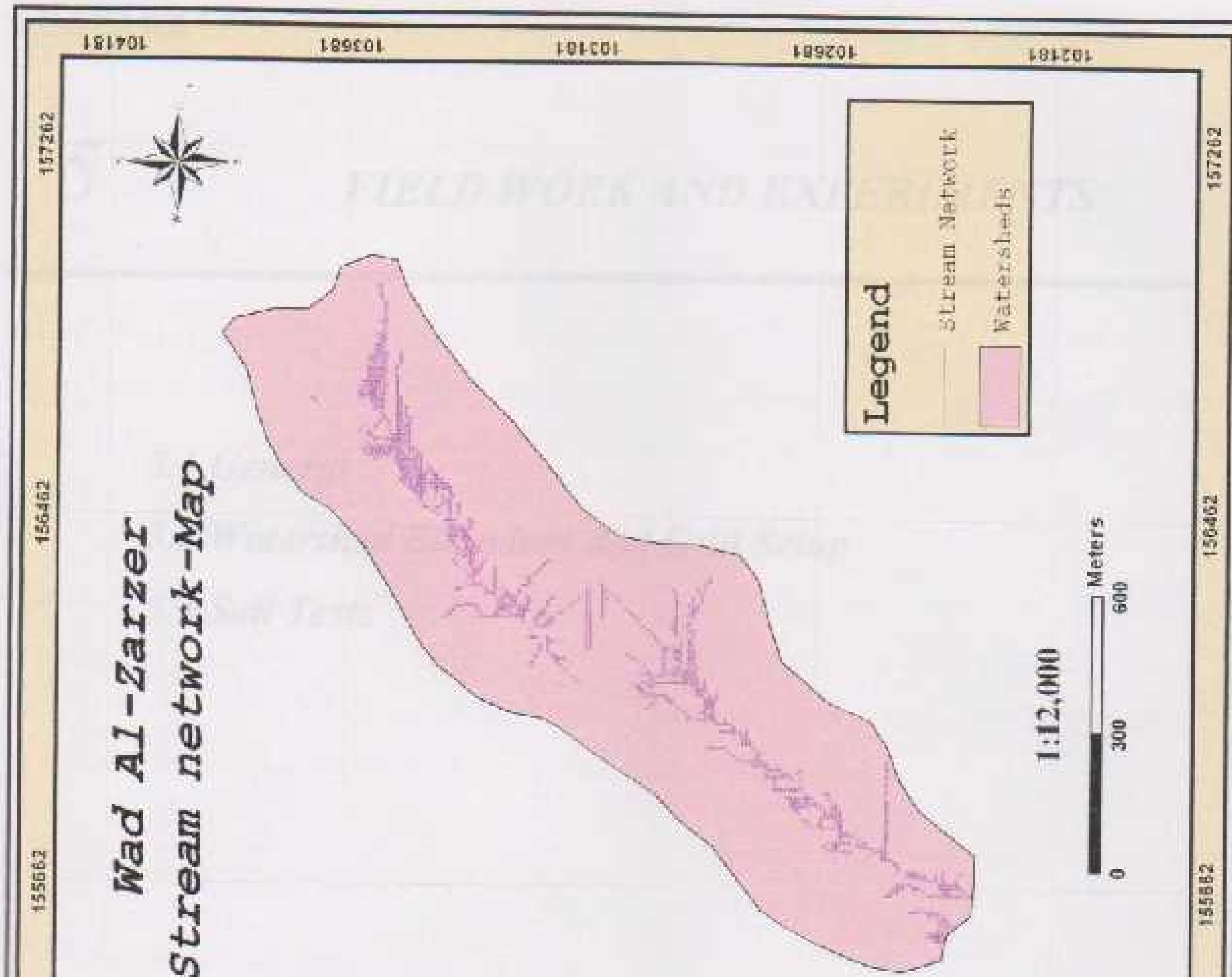


Figure (4.21): The Stream Network

CHAPTER

5 *FIELD WORK AND EXPERIMENTS*

5.1 General

5.2 Watershed Boundary and Grid Setup

5.3 Soil Tests

CHAPTER FIVE
FIELD WORK AND EXPERIMENTS

5.1 General

Response of a watershed (catchment) to specified rainfall input is shaped by the catchment characteristics such as morphometric parameters, soil classification, and land use and land cover (LULC); this input data is used to estimate the amount of direct runoff for the watershed area for the given precipitation.

This chapter deals with the procedure of experimental and fieldwork, which were carried out in order to classify the soil, and prepare the land use and land cover map. The results were used to classify the soil, find out the runoff coefficient, and then estimate the surface direct runoff for the watershed that is studies in the next chapter.

5.2 Watershed Boundary and Grid Setup

5.2.1 Watershed boundary

The watershed boundary was restricted by land surveying using (GPS) techniques especially navigation instrument (Magellan).

The (GPS) techniques is more suitable than (GIS) for delineation watershed boundary because the study area is not large. The points of the boundary were taken from the field prepared into ArcGis.9 as shown in Table (5.1), and the boundary of the watershed appeared in Figure (5.1).

5.2.2 Grid setup

After the watershed delineation into the GIS, it is necessary to setup the grid of the field to conduct the experiments in suitable sites, and to classify the soil. Navigation GPS used land surveying to setup the grid in the field. The grid was designed using ArcGis.9 and the coordinates of grid points in the Table (5.2). The grid covers the whole watershed is shown in Figure (5.2).

Table (5.1) : Coordinates of Wadi Al-Zarzeer Watershed Boundary

No	X-coordinate(m)	Y-coordinate(m)	No	X-coordinate(m)	Y-coordinate(m)
0	156813	103921	29	155603	102350
1	156850	103949	30	155564	102401
2	156884	103919	31	155504	102427
3	156910	103855	32	155486	102500
4	156901	103781	33	155491	102573
5	156948	103713	34	155534	102659
6	157000	103708	35	155615	102792
7	157030	103640	36	155697	102853
8	157013	103584	37	155753	102904
9	156953	103562	38	155809	102969
10	156850	103493	39	155856	103016
11	156768	103425	40	155895	103068
12	156665	103330	41	155959	103162
13	156553	103235	42	155998	103214
14	156484	103184	43	156024	103270
15	156420	103102	44	156037	103321
16	156407	103016	45	156071	103394
17	156407	102939	46	156136	103485
18	156381	102848	47	156192	103528
19	156325	102810	48	156269	103571
20	156239	102784	49	156346	103618
21	156149	102754	50	156394	103644
22	156067	102663	51	156437	103683
23	156024	102569	52	156475	103721
24	155968	102539	53	156506	103777
25	155891	102504	54	156544	103799
26	155835	102461	55	156617	103846
27	155736	102345	56	156686	103876
28	155641	102350	57	156768	103893

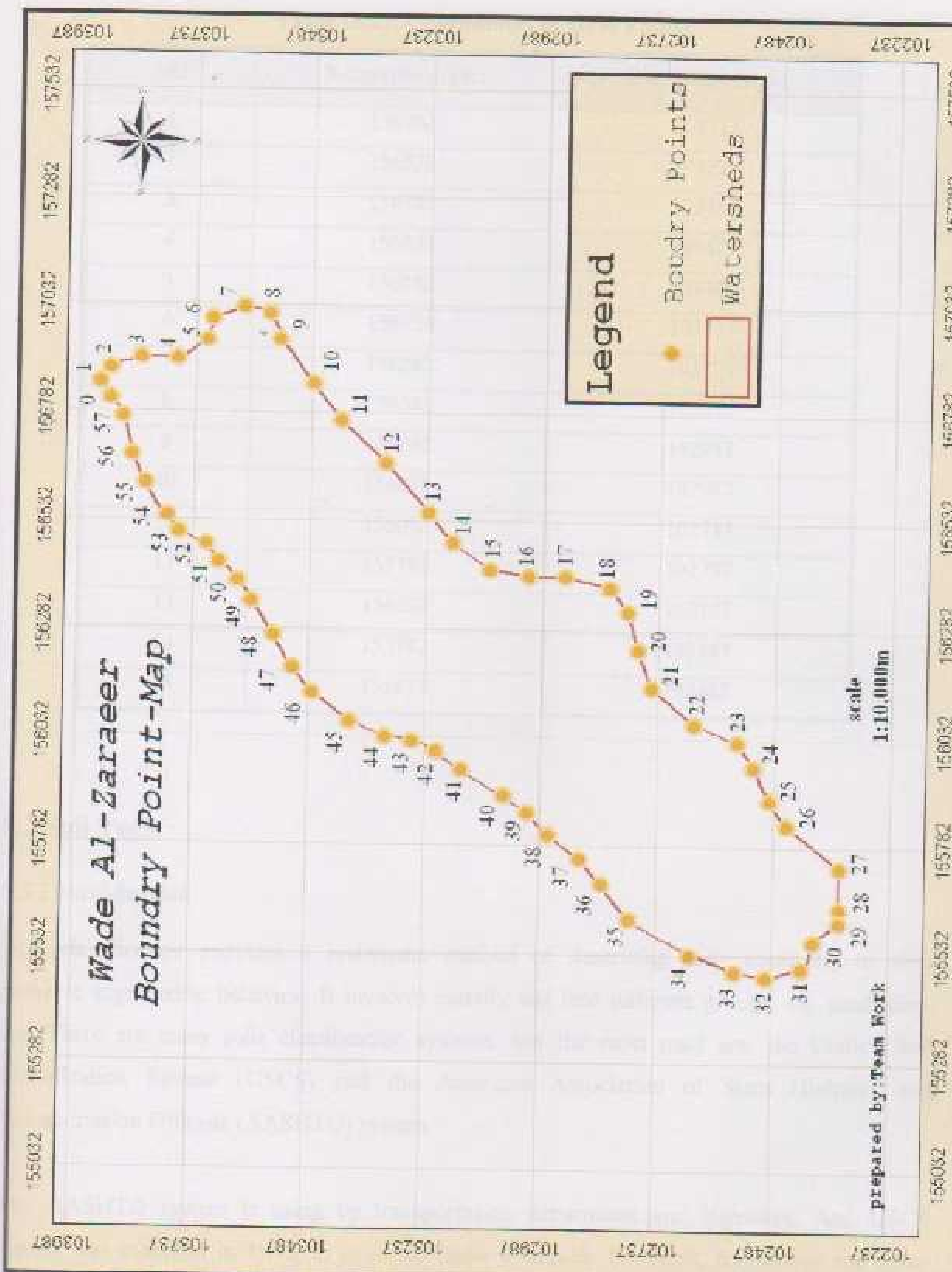


Figure (5.1): Boundary of Wadi Al-Zarzeer Watershed

Table (5.2): Coordinates of Grid Points

NO	X-coordinate(m)	Y-coordinate(m)
1	156782	103737
2	156532	103737
3	156782	103487
4	156532	103487
5	156282	103487
6	156532	103237
7	156282	103237
8	156032	103037
9	156282	102987
10	156032	102987
11	156032	102737
12	155782	102737
13	156032	102737
14	155782	102487
15	155532	102487

5.3 Soil Tests

5.3.1 Introduction

Soil classification provides a systematic method of describing soils according to their probable engineering behavior. It involves classify soil into different groups, i.e. sand, clay, etc. There are many soils classification systems, but the most used are: the Unified Soil Classification System (USCS) and the American Association of State Highway and Transportation Officials (AASHTO) system.

The AASHTO system is using by transportation department and highways. And USCS system was modified in 1952, in order to make it suitable for dams, foundation and other construction projects. The USCS system will adopt in this project as it is related to dam's project. A sieve analysis and moisture content method will be used to classify the soil samples of the project.

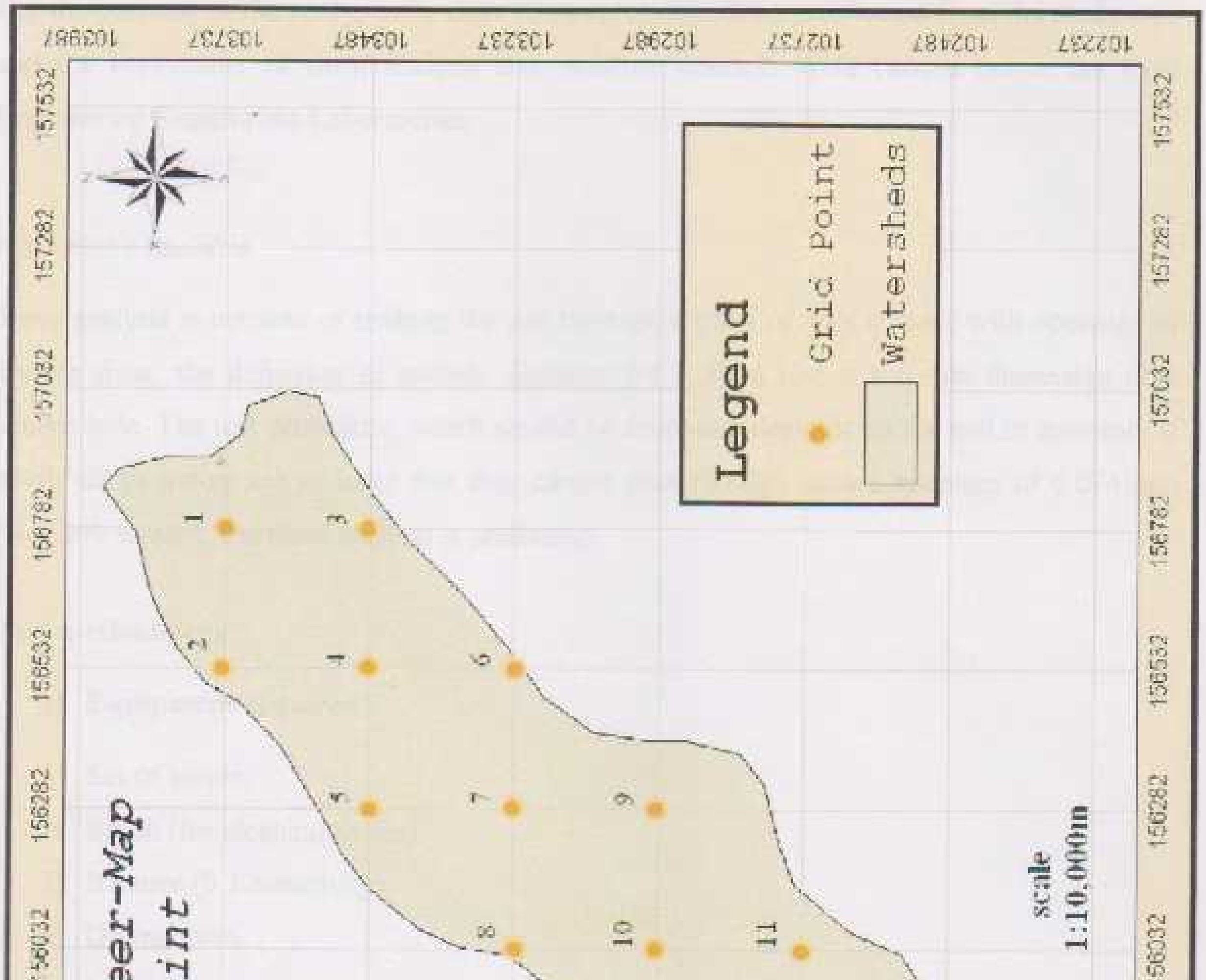


Figure (5.2): Distribution of Grid Points

For the purpose of the study, more than 10 samples of soil were collected from the study area and the experiment of sieve analysis and moisture contents were carried out in the Civil Engineering Department Laboratories.

5.3.2 Sieve analysis

Sieve analysis is consists of shaking the soil through a stack of wire screens with openings of known sizes; the definition of particle diameter for a sieve test is the side dimension of a square hole. The test procedure, which should be followed, depends on the soil in question. If nearly all its grains are so large that they cannot pass through square openings of 0.074 mm (No. 200 screen), the sieve analysis is preferable.

Test methodology

a) Equipment required

1) Set of sieves.
2) Brush (for cleaning sieves).
3) Balance (0.1 sensitivity).
4) Drying oven.
5) Large pane.

b) Method of work

1. Weigh to 0.1 g each sieve that is to be used. Make sure each sieve is clean before weighing it.
2. Select with care a test sample, which is representative of the soil to be tested; break the soil into its individual particles with by fingers or by a rubber tipped pestle.
3. Weigh to a specimen of approximately 1000 g of oven-dried soil.
4. Sieve the soil through a nest of sieves with on hand, using a motion of horizontal rotation or using a mechanical shaker, if available. At least 15 minutes of hand sieving is desirable for soils with small particles.
5. Weigh to 0.1 g each sieve and the pan, with the soil retained on them.
6. Subtract the weights obtained in step 1 from step 5 to give the weight of soil retained on each sieve.

7. Percentage retained on and y sieve = $\frac{\text{wt. of soil retained} * 100}{\text{Total soil wt.}}$
8. Cumulative percentage retained on any sieve = sum of percentages retained on all coarser sieves.
9. Percentage finer than any sieve size = 100% - cumulative percentage retained.
10. Draw graph between log sieve sizes vs. % passed. The graph is known as the grain size distribution curve, which has been widely used in identification and classification. Corresponding 10%, 30%, and 60% passed, diameters obtained from the graph are designed as D_{10}, D_{30}, D_{60}. Where D_{10} is the grain size that corresponds to 10% of the samples pass by weight (10% of the particles are smaller than the diameter D_{10}), and so on D_{30}, D_{60}.
11. The coefficient of uniformity (Cu) and coefficient of curvature (Cc) are calculated as following :

$$Cu = \frac{D_{60}}{D_{10}} \quad \text{(5.1)}$$

$$Cc = \frac{(D_{30})^2}{(D_{60})(D_{10})} \quad \text{(5.2)}$$

More than 10 experiments were conducted in the laboratory. The results necessitated classifying the soil samples into two types:

a) Well graded clay.
b) Poorly graded sands.

5.3.3 Permeability Test

One of the most important of catchment characteristics is the permeability rate which is helped to classify the soil. The degree to which soils are permeable depends upon a number of factors, such as soil type, grain size distribution and soil history. This degree of permeability is characterized by the coefficient of permeability.

The coefficient of permeability, k, is a product of Darcy's Law. In 1856, Darcy established an empirical relationship for the flow of water through porous media. His relationship has evolved into Darcy's Law, which states:

$$Q = kiA \quad (5.3)$$

Where:

Q = flow rate (volume/time)

i – hydraulic gradient (unitless)

A = cross-sectional area of flow (area)

k = coeff. of permeability (length/time)

It should be noted that the coefficient of permeability is often referred to as hydraulic conductivity by hydrologists and environmental scientists. Initial permeability rate described dry soil where the water infiltrates rabidly. At the same time water replaces the air in the pores.

A number of different methods for determining the coefficient of permeability for soil exist, including in-site (field) methods and laboratory methods. In the laboratory, two common tests are generally used to determine this soil property. These two tests are the falling head permeability test and the constant head permeability test.

Which test is used depends upon the type of soil to be tested. For soils of high permeability (sands and gravels) a constant head test is used. In the constant head test, a constant total head difference is applied to the soil specimen, and the resulting quantity of seepage can then be measured. This works very well for coarse-grained soils, but with clays and silts, the quantity of seepage is much too small to be accurately measured.

Test methodology

a) Equipment required

1. Geotextile filter disks: These will be placed between the soil and the porous stones
2. Permeameter: This device is basically a transparent acrylic cylinder (see Figure 5.3).
3. Constant-head outfall setup.
4. Deaired water supply

5. Graduated cylinder, 100 ml.
6. Thermometer.
7. Silicon grease: This is rubbed onto the o-rings on the top and bottom of the cell
8. Balance

Figure (5.3) – Assembled Permeameter

h) Method of work

1) Remove the chamber cap of the permeameter and put one porous stone in the base of the chamber. Take mold measurements to compute the area of the mold and void ratio

2) Use a scoop or funnel to pour the sand specimen into the chamber. Use a technique to ensure that the soil is placed in a uniform manner. To determine sample weight, a pan with sand is weighed. The desired sample is removed and the pan and sand is weighed again. The difference in weights is the sample weight.

3) Place the upper porous stone on the specimen and the compression spring on the porous stone. Then put the chamber cap and sealing gasket in place and secure it firmly with the cap nuts. Measure and record the length of the specimen

4) Assemble the constant-head reservoir and adjust it to the desired height above the outlet of the permeameter to create the desired head. Close the inlet valve to the permeameter. Fill the constant-head reservoir with deaired water. Deair the lines connected to the inlet valve by vacuuming for approximately 15 minutes.

5) Open the outlet valve of the permeameter and close the valves to the piezometers (if your permeameter device has the setup). Connect a vacuum pump to the outlet and apply a full vacuum for 15 minutes to remove the entrapped air in the soil. Shut off the outlet valve, remove the vacuum pump, and open the inlet valve to saturate the specimen. Slowly open the valve to prevent liquefying the soil sample. Measure the height between the outlet tube and the water in the initial tube reservoir.

6) Open the inlet and outlet valves. When an equilibrium flow condition is established, place a graduated cylinder to receive the outflow and start a timer. When a sufficient quantity of water is obtained in the graduated cylinder, remove it and stop the timer.

7) Record the quantity of water obtained and the time required obtaining it. Also record the temperature of the water.

8) During the time that the water is being collected in the previous step, the piezometers should be observed and a set of average readings (one for each piezometer) should be recorded (if the device is equipped with this setup).

9) Change the height of the constant-head reservoir by at least 0.1 meters and repeat steps 6) and 7).

10) The coefficient of Permeability (K) is calculated as following:

$$K = \frac{2.303 * a * L}{A * t} * Log \frac{h_1}{h_2} \qquad (5.4)$$

Where:

K = Permeability rate (m/sec)

a = The area of the section of the tube (m^2)

L = The height of the cylinder (m)

A = The area cylinder (m^2)

t = Time of taken the reading

h_1 = *The initial length of water on t (cm)*

h_2 = The length of water after 15min on the Tube (cm)

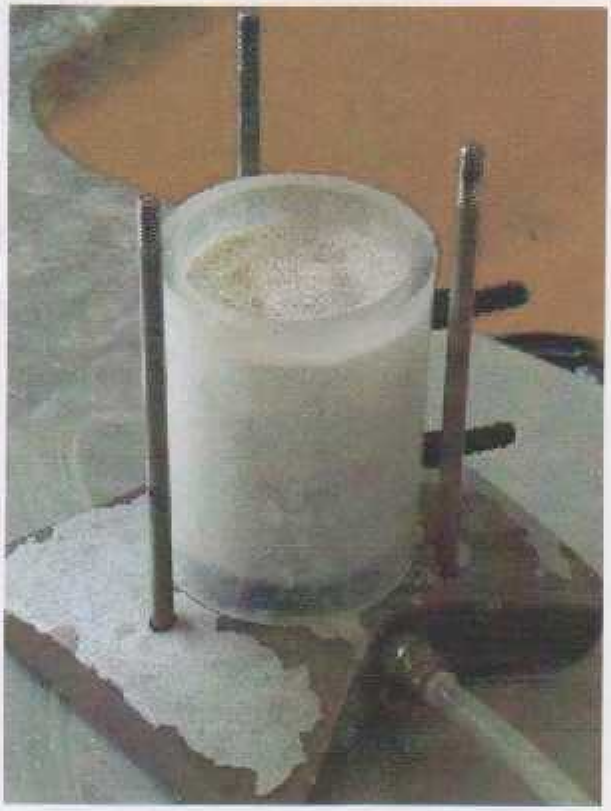


Figure (5.4) Half Assembled Permeameter.

CHAPTER

6 ANALYSIS AND DISCUSSION OF RESULTS

6.1 General

6.2 Land Use and Land Cover

6.3 Soil Classification

6.4 Morphometric Analysis

6.5 Estimation of Surface Runoff

CHAPTER SIX
ANALYSIS AND DISCUSSION OF RESULTS

6.1 General

After finishing all field and experimental work and preparing the needed maps, the morphometric parameters and annual runoff were calculated for the Wadi Al-Zarzeer watershed. The calculation was done through the map calculator using grid data and ArcGis.9 Spatial Analyst Extension.

Grid system divides the surface on which they are distributed into a matrix of identically squared sized cells. Each cell is filled in with a number that stores the object's attribute value at that location.

There are many things that ArcGis.9 Spatial Analyst can do with grids. It can estimate values for an entire surface from a limited number of measured sample points. This process was used to interpolate the infiltration measurement.

ArcGis.9 spatial analyst deals with a map as matrix, map algebra is math applied to grid, so it is possible to add, subtract and multiply the maps because grids are geographically referenced array of numbers. By combining and analyzing the land use map with the hydrologic soil group map, the morphometric parameters were derived, and the depth and volume of direct runoff for Wadi Al-Zarzeer watershed in Hebron area were estimated. This chapter discusses the results of the work.

6.2 Land Use and Land Cover

The conventional land use\land cover map of the watershed was obtained by the land survey technique using (GPS), and digitized map from a rectified aerial photo for Wadi Al Zarzeer watershed. Boundaries of different land use class were digitized in the (ArcGis.9), and the attribute where linked to them. Three land use\land cover classes were categorized in the watershed (see Table (6.1) and Figure (6.1). The land use and land cover map for Wadi Al-Zarzeer watershed is shown in Figure (6.2).

Table (6.1): Classes of Land Use/Cover of the Study Area

Land Use	Area (mm^2)	Percentage of Area %
Agricultural	350118.8	40 %
Builtup-land	31510.692	3.6 %
Rangeland	493667.508	56.4 %
SUM	**875297.434**	**100**

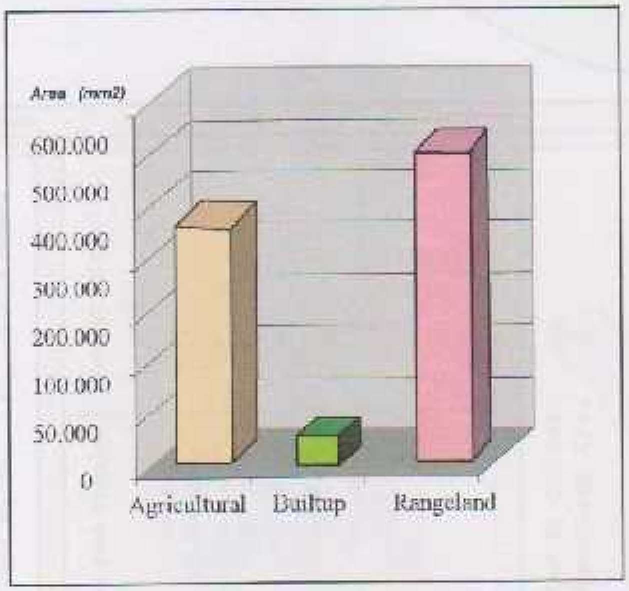


Figure (6.1): Classes of Land Use/Cover of the Study Area

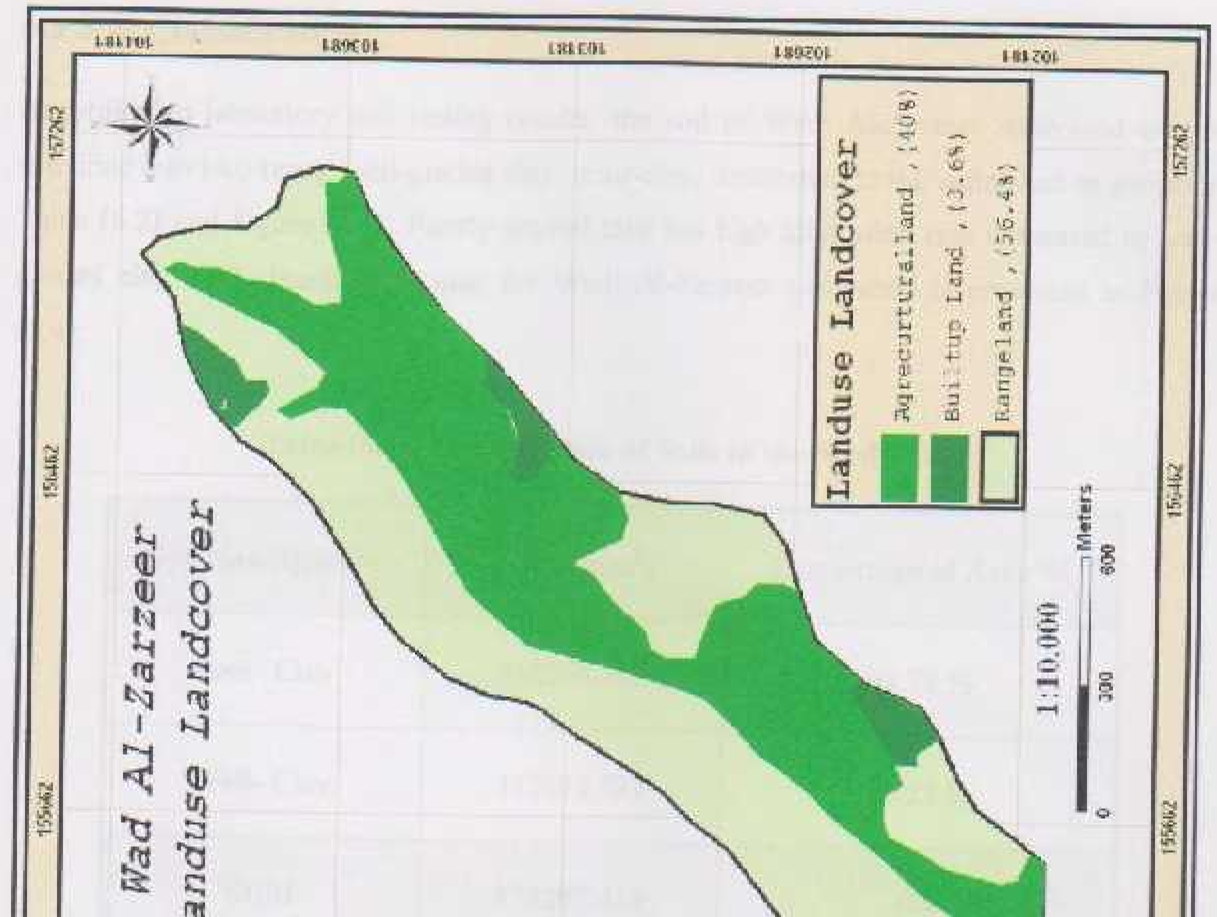


Figure (6.2): Land Use and Land Cover Map for Wadi Al-Zarzeer Watershed

6.3 Soil Classification

According to laboratory soil testing results, the soil of Wadi Al-Zarzeer watershed can be classified into two types; well-graded clay, poor-clay, distributed at the watershed as shown in Table (6.2) and Figure (6.3). Poorly graded clay has high infiltration rate compared to well-graded clay. Soil classification map for Wadi Al-Zarzeer watershed is presented in Figure (6.4).

Table (6.2): Classification of Soils in the Study Area

Soil classification	Area (mm^2)	Percentage of Area %
Poor- Clay	558264.703	63.78 %
Well- Clay	317032.731	36.22 %
SUM	**875297.434**	**100**

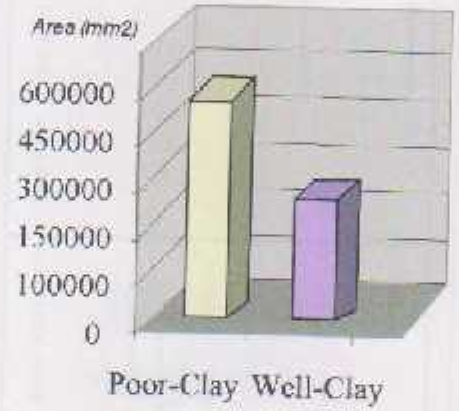


Figure (6.3): Classification of Soil in the Study Area

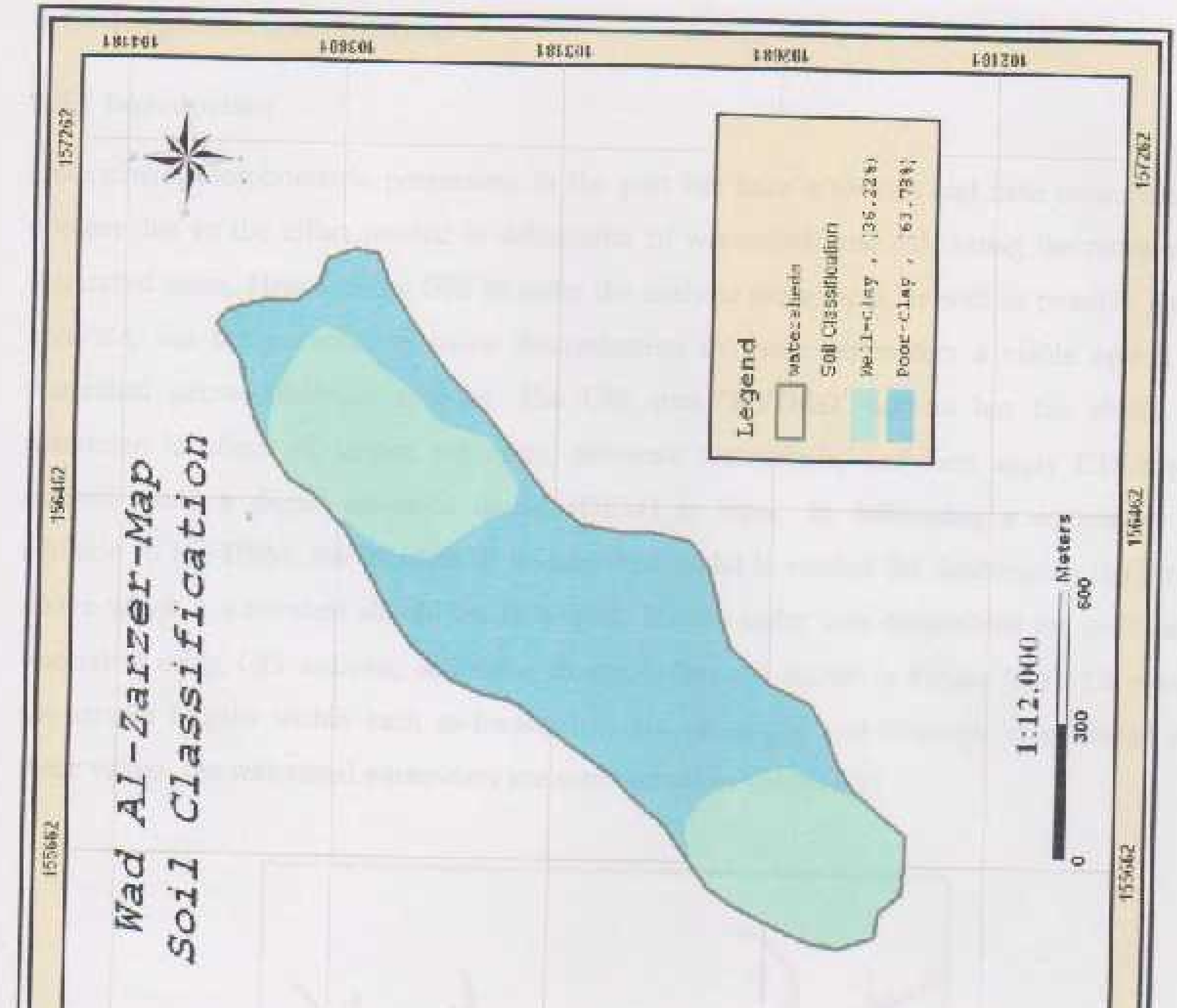


Figure (6.4): Soil Classification Map for Wadi Al-Zarzeer Watershed

6.5 Morphometric Analysis

6.5.1 Introduction

Determining morphometric parameters in the past has been a tedious and time consumptive process due to the effort needed in delineation of watersheds and calculating the respective watershed areas. Hence, using GIS to make the analysis more rapid, as well as possibly more accurate, has the potential to make determination of these parameters a viable option in watershed geomorphologic analysis. The GIS tool 'HYDRO' add-on has the ability to determine locations of stream networks, delineate watersheds, and then apply GIS-based analysis using a digital elevation model (DEM) as input. In delineating a watershed, in addition to the DEM, the location of a watershed outlet is needed for determining the point above which a watershed should be delineated. Stream order was determined for each sub-watershed using GIS analysis, and these stream orders are shown in Figure (6.5). Likewise, the stream lengths within each su-bwatershed are calculated and drainage area. Based on these values, the watershed parameters are summarized in Table (6.5)

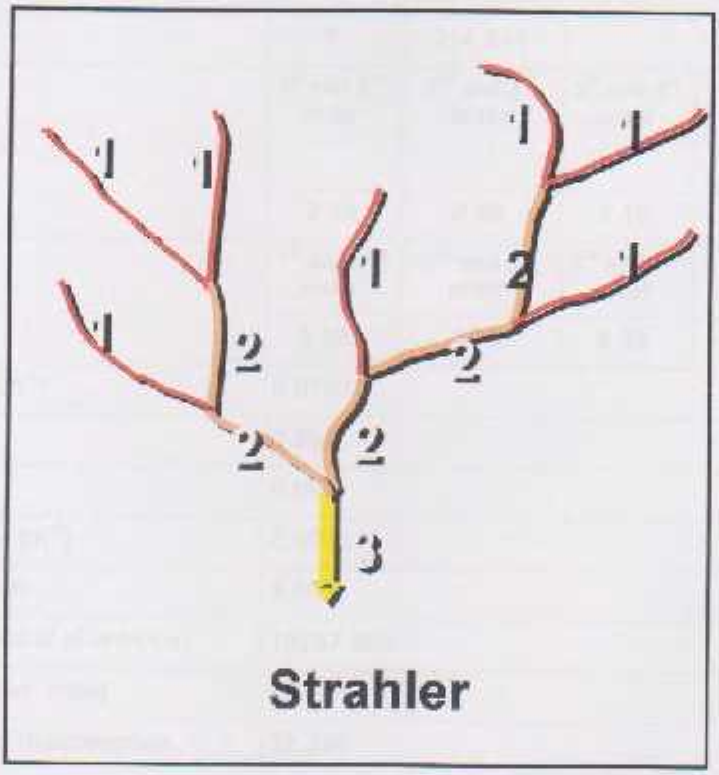


Figure (6.5): Stream Orders as Strahler Method

Table (6.5) Morphometric Parameters estimated using the GIS Techniques

Morphometric Parameters	***Watershed***			
Area (Sq. m.)	875.297434			
Perimeter (km)	4756.304702			
Maximum length of watershed (Km)	1725.5704			
Maximum elevation (m)	903			
Minimum Elevation (m)	710			
Watershed Relief (m)	193			
Relief ratio	0.112			
Elongation Ratio	0.612			
Average Slope (km/km)	0.112			
Stream Characteristics (Strahler's stream ordering system)	Number of Streams	Length (m)	average length (m)	
1st order streams	2163	10111.633	4.675	
2nd order streams	692	4293.739	6.205	
3rd order streams	165	1447.866	8.775	
4th order streams	31	670.121	21.617	
5th order streams	6	214.544	35.758	
Stream length ratios	1st and 2nd order	2nd and 3rd order	3rd and 4th order	4th and 5th order
	2.35	2.96	2.16	3.12
Bifurcation Ratios	1st and 2nd order	2nd and 3rd order	3rd and 4th order	4th and 5th order
	3.125	4.19	5.32	5.16
Drainage density (m^{-1})	0.01912			
Form factor	0.294			
Circulatory Ratio	0.697			
Drainage frequency (m^{-2})	0.0035			
Ruggedness Number	3.698			
Total Length of streams of all orders m	16737.903			
Time of concentration (min)	48			
Constant of channel maintenance	52.294			

In a study of stream orders in Wadi Al Zarzeer found that a drainage basin of 875.297 m^2 produced a fifth order stream. The study also found good agreement between Rb, Rt, when comparing all ratios up to the sixth order.

6.5.2 Geomorphologic Parameters of Sub-Watershed

Morphometric parameters of the Sub-watersheds were calculated in GIS environment and are presented in Table (6.6) and Table (6.7). After analysis of the drainage map, it was found that Sub-watershed is 9 Watershed and drainage pattern is dendrite.

The other important property, bifurcation ratio (Rb) reflecting geologic and tectonic characteristics of the watershed area was calculated for all nine sub-watersheds and are given in Table (6.7) these values are more or less normal in the sub-watersheds 2 ,7 as they range between 1 and 3 (Hortn,1945). Higher value of (Rb) for a sub-watershed indicates high runoff, low recharge and mature topography and is expected in region of steeple dipping rock strata where narrow valley is confined between the ridges .the vales of (Rb) also indicate that the basin has suffered less structural disturbances .the variation in (Rb) values among the drainage basins, are attributed to the difference in various stages of geomorphic development and topographic variations.

Table (6.6) Sub-watershed Wise Morphometric Parameters of Study Area

Sub-Watershed NO.	Area (sq.m)	Perimeter (m)	Max Elevation (m)	Min Elevation (m)	maximum length of Watershed (m)	Total relief (m)	Total Stream Length (m)	No. of Stream
1	97944	14143	195	77	506.75	118	5730.3	462
2	129129	14392	293	99	627.9	194	2371.6	284
3	82544	11460	390	196	405.6	194	4973.1	379
4	55855	10604	488	294	350.17	194	2566.26	295
5	67837	12861	585	391	500.62	194	3110.5	285
6	90321	15782	683	489	552.04	194	2646.4	184
7	100177	11723	780	586	609 .34	194	4606.6	287
8	68222	9388	878	684	450.6	194	32100	398
9	77385	11578	903	781	498.4	122	67097.3	483

Table (6.7) Sub-watershed Computed Morphometric Parameters of Study Area

Sub-Watershed NO.	*Rh*	*Rr*	*Rn*	Rc	*Rc*	*Rf*	*Rb*	*Df*	*Dd*	*Cm*	*tc* mir	*S* %
1	0.18	6.8	2.124	77	0.17	0.38	3.18	1.5	0.02	55.6	6.7	23.3
2	0.15	6.7	3.492	99	0.18	0.33	3.13	0.8	0.02	55.6	7.1	30.9
3	0.24	8.4	11.64	196	0.08	0.501	4.19	1.7	0.06	16.7	4.3	47.8
4	0.27	9.1	18.62	294	0.079	0.455	3.02	0.9	0.1	10.4	3.6	55.4
5	0.19	17.5	19.4	391	0.07	0.27	5.32	1.5	0.1	10	5.5	38.8
6	0.18	6.1	9.7	489	0.06	0.29	4.75	0.7	0.05	20	6.1	34.6
7	0.16	8.18	128.0	586	0.15	0.27	2.52	0.8	0.66	1.51	6.9	32.1
8	0.21	0.01	34.92	684	0.18	0.34	5.12	1.8	0.18	5.56	4.8	42.5
9	0.19	8.3	26.84	781	0.085	0.31	4.34	2.0	0.22	4.55	6.5	24.6

In general, the shape of a basin affects stream flow hydrographs and peak flows .the important parameters that describe the shape of the basin viz., form factor, circulator ratio and elongation ratio were computer for all the 6 sub watersheds (6.7) .High value of (Rc) indicator mature to old stage topography .it is also indicator of low drainage From the watershed. According to elongation ratio (Re), sub-watershed 9 has circular shape and 1,2 and 3 have less elongation and 7,8 and 9 have an elongation shape (fig (6.7)) Higher value of Re for sub-watershed 9 indicates mature to old stage topography. More the value of form factor (Rf), more elongated is the basin. In this case, elongated basin with low (Rf) indicates that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to mange than from the circular basin. Time of concentration (tc), Relief ratio (Rh) and relative relief (Rr) values for all the sub-watersheds are given in (Table (6.7). The sub-watershed, with high (Rr) and (Rh) are considered critical from erosion point of view and should be provide with suitable soil and water conservation measure.

The ruggedness number (Rn) ranges from 2.125 to 128.04 for different sub-watershed. The sub-watershed 8 has an over all high roughness or unevenness. Drainage density (Dd) and Derange frequency (Df) are computed for all the sub-watersheds and are given in Table (6.7). Iit was observed that the sub-watersheds having large area under dense forest have low drainage frequency (Df) and the area having more agricultural land have high (Df) .high value of (Df) in the sub watershed 9produces more runoff compared to others .in general ,it has been been Observed over a wide range of geologic and climatic types, that low (Dd) is more likely to occur in regions of highly permeable subsoil material under dense vegetative cover, and where relief is low . in contrast, high (Dd) is favored in regions of weak or Impermeable subsurface materials, sparse vegetation and mountainous relief , hence in the Present study, in order to find out the correlation of (Dd) with Land use/cover, and soil, spatial distribution of land use/cover and soil was studied.

The major land use category found in the study area is agriculture; it is also observed that row crops are cultivated on a poor contoured land. Low (Dd) value for sub-watershed indicates that it has highly resistant, impermeable subsoil material with dens vegetated cover and low relief. It is obvious from the land use information that the area under dense forest that relief is 0.19 m.

The sub-watersheds with high values of (Dd) indicate well-developed network, which is conducive for quick disposal of runoff resulting in intense floods and also characterized by a region of weak subsurface materials, high relief and sparse vegetation. Thus, the study of various factors which control drainage density, such as sub soil material, vegetative covers relief etc. For the study area, show that the results are consistent with (Dd) measurements made in a similar terrain. Constant of channel maintenance was also computed for all the sub-watersheds (Table (6.7). This factor depends upon not only the rock type and permeability, climatic regime, vegetation cover and relief, but, also on the duration of erosion and climatic history. In general, this constant will be extremely low in areas of close dissection. Additional surface water resources can be developed by constructing different water harvesting structures under different land use/cover units and also by increasing the storage capacity of existing major tanks within the watershed area to facilitate the phase wise implementation by the state Government/NGO all the sub-watersheds are prioritized into four categories based on percentage of cultivated area and (Dd) of each sub-watershed (Durbude et al., 2001).

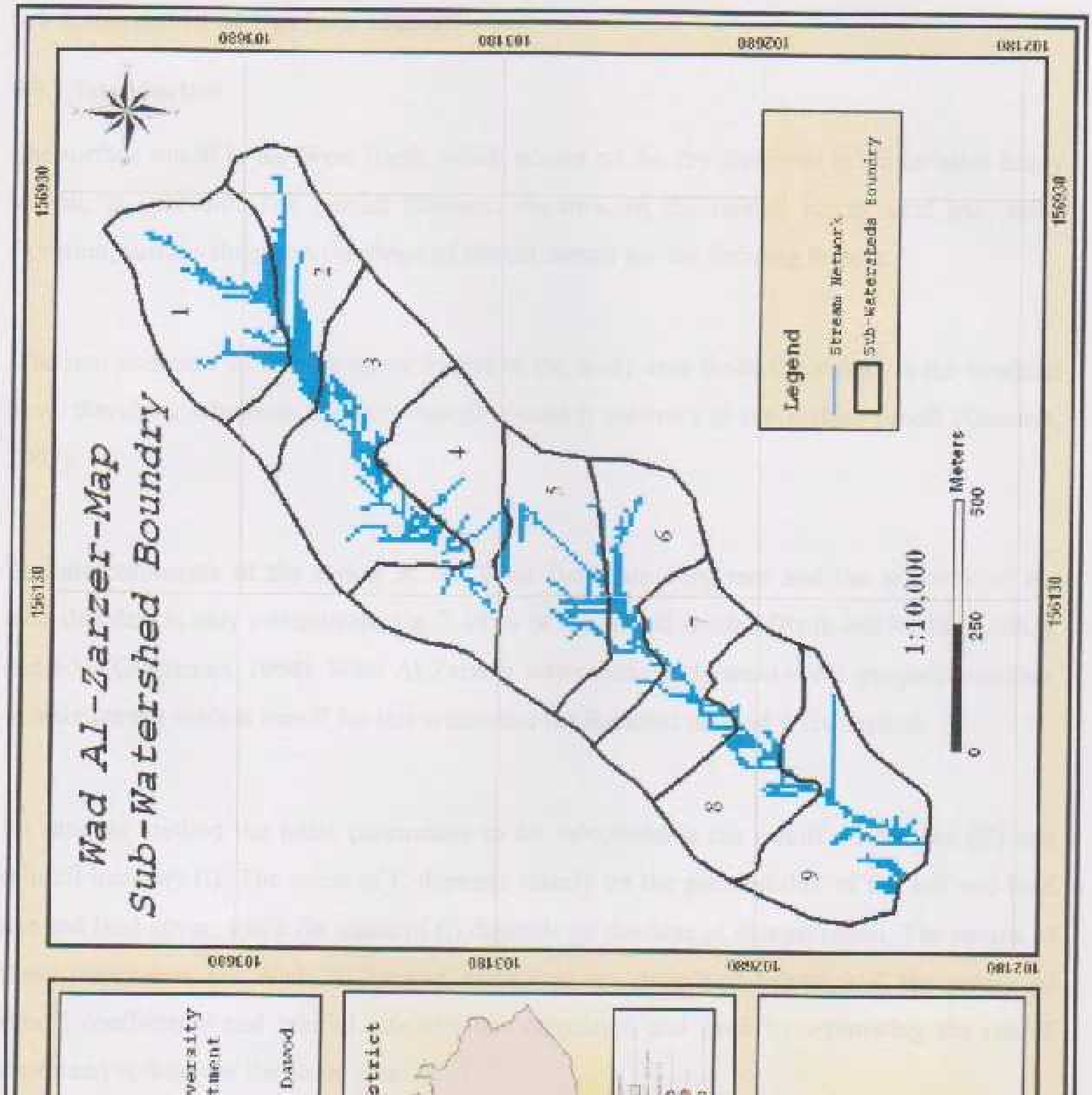


Figure (6.6): Sub-watersheds Map for Wadi Al-Zarzeer and its Stream Network

6.6 Estimation of Surface Runoff

6.6.1 Introduction

The surface runoff in the West Bank, which occurs on the dry riverbeds in winter after heavy rainfall, is sporadic. The rainfall intensity, duration of the rainfall storm, land use, soils; elevation, surface slope and the shape of the catchment are the deciding factors.

The non existence of surface water bodies in the study area limits the runoff to the overland flow, therefore, whenever the term runoff is used it referrers to the surface runoff (Qannam, 2003).

The measurements of the runoff in the West Bank are very rare and the majority of the available data is only estimations, e.g. 7-14 % of the annual rainfall (Rofe and Raffety, 1963), and 5 % (Gvirtzman, 1994). Wadi Al-Zarzeer watershed (study area) is not gauged; therefore, to estimate the surface runoff for this watershed the Rational method were applied.

In rational method the basic parameters to be calculated is the runoff coefficient (C) and rainfall intensity (i). The value of C depends mainly on the permeability of the soil and land use and land cover, while the value of (i) depends on the time of concentration. The results of these parameters for Wadi Al-Zarzeer watershed are described below; and the values of runoff coefficients and rainfall intensity are calculated and used for estimating the runoff depth and volume for the study area.

6.6.2 Rainfall data

Although the average annual rainfall recorded at Dura Meteorological Station for the period 2000 –2007 is 500 mm, there are considerable variations in the quantity of the annual rainfall from year to year. The maximum recorded annual rainfall was 645.3 mm in 2002/2003 season, while the minimum was 287.8 mm in 2006/2007 season as shown in Figure (6.6).

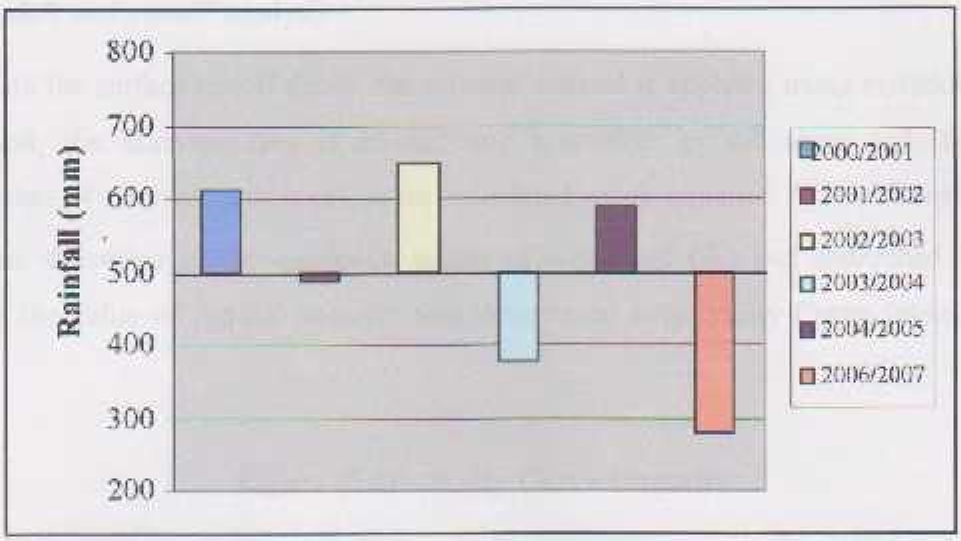


Figure (6.7): The Annual Rainfall Variation at the Dura Meteorological Station during the Period (2000 – 2006)

Generally, the wet season in the area of Wadi Al-Zarzeer stretch over eight months (October to May). But most of the rain falls during the period (November to April). About two thirds of the rainfall amount falls between December and February as shown in Figure (6.7).

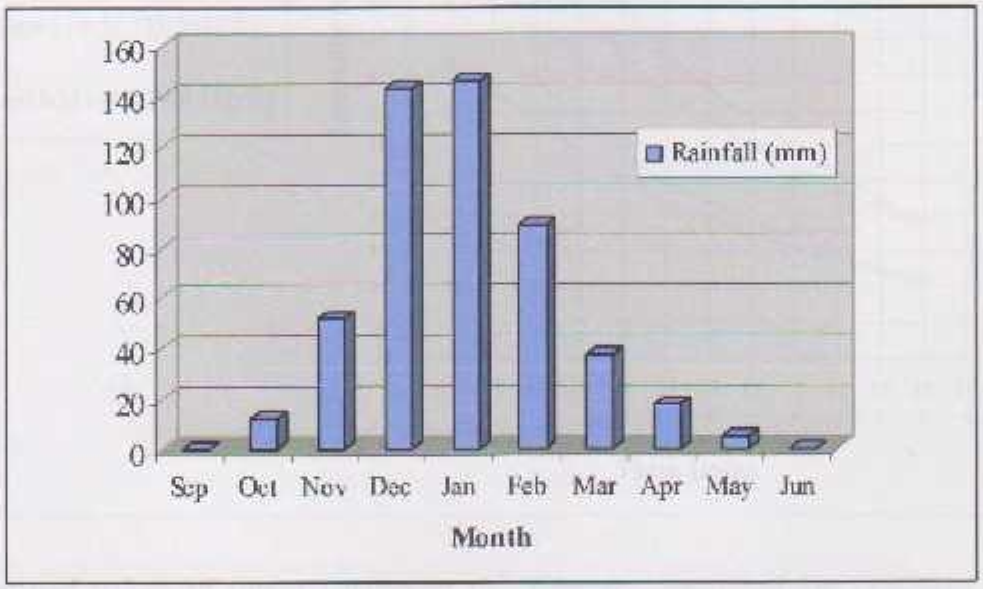
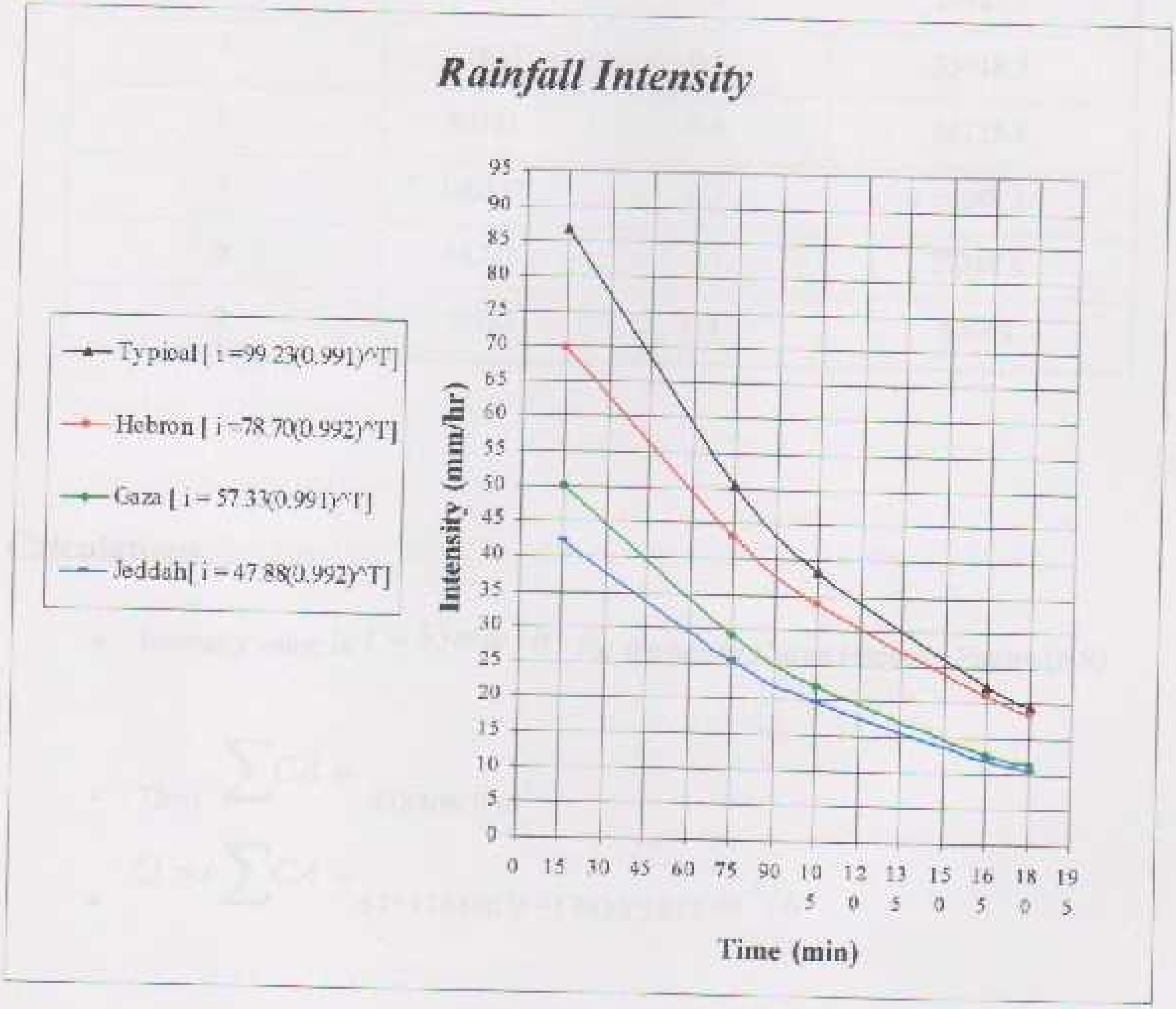


Figure (6.8): The Average Monthly Rainfall Recorded at the Dura Meteorological Station during the Period (2000 – 2006)

6.6.3 Rainfall and runoff analysis

To calculate the surface runoff depth, the rational method is applying using equation (3.5). In this method, the drainage area is divided into a number of sub areas and the time of concentration of different sub areas, were calculated using equation (1.10). These equation depends on the value of the maximum length of watershed (L) and watershed Slop (S). After that the value of rainfall intensity was determined from Multy Curve Intensity Figure (6.9).

Figure (6.9): Multy Curve Intensity



The calculated values of runoff coefficient (C) for sub-watershed are presented in Table (6.8).

Table (6.8): Calculations of the of Runoff Coefficient

Sub-Watershed No.	Area (m^2)	C	CA
1	97944	0.4	39177.6
2	129129	0.4	51651.6
3	82544	0.5	41272
4	55855	0.5	27927.5
5	67837	0.5	33918.5
6	90321	0.4	36128.4
7	100177	0.5	50088.5
8	68222	0.4	27288.8
9	77385	0.4	30954

Calculations

- Intensity value is $i = 53mm/h$, for the Multy Curve Intensity Figure (6.9)
- Then $\sum CA =$ 338406.9 m^2
- $Q = i\sum CA =$ 53*338406.9 =17935.5657 m^3/h

The presents of the flood flow in these watershed is = $\frac{17935.5657}{437648.717}$*100 = 4.2%

6.6.4 Water balance in Wadi Al-Zarzeer watershed

The final result in this study determine the water balance parameters of Wadi Al-Zarzeer watershed in Dura area whereas the precipitation (500 mm/year) is the main input parameter in the water balance and the measured average Permeability is (84 mm/year), estimated runoff (68 mm/year) and calculated evaporation (392 mm/year) are the major output parameters. The results of water budget in the study area are shown in Figure (6.10).

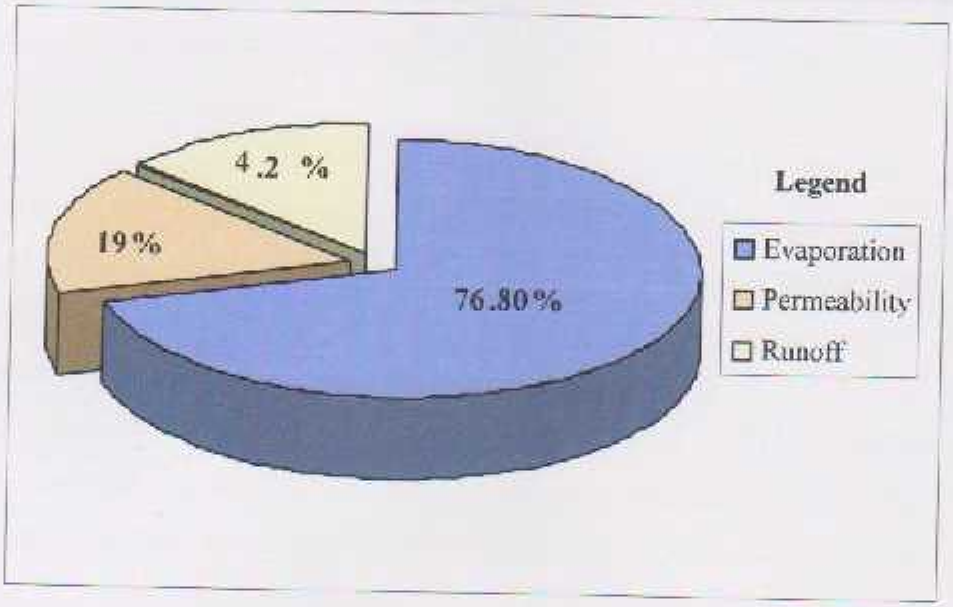


Figure (6.10): Water Balance of Wadi Al-Zarzeer Watershed

CHAPTER

7 CONCLUSIONS

CHAPTER SEVEN
CONCLUSIONS

In this project an attempt is made to study the morphological features of Wadi Al Zarzeer watershed in Hebron area of the West Bank. The morphological parameters are important in understanding the hydrology of the watershed. Runoff response of the watershed is different for different slopes, shapes, lengths, widths and areas of watershed. Response is also affected by the factors like drainage density, length of overland flow, stream frequency, relative relief and relief ratios.

Computation of watershed morphological characteristics is prerequisite to further detailed hydrological analysis of the watershed. Hydrologists have attempted to relate the hydrologic response of watersheds to watershed morphologic characteristics. In the past, these characteristics are determined manually from the topographic and stream network map of the watershed. Technologies like Geographic Information Systems (GIS), have gained significant importance over the last decade in their applications pertaining to distributed hydrologic modeling. GIS is suitable for analysis of spatially referenced data. GIS can handle both spatial and a spatial data effectively and efficiently.

Many methods can be used to determine the runoff from watershed. The rational method is a simple, widely use and efficient method for determining the amount of runoff from a rainfall even in a particular area. In the present study, the method was also used to estimate the direct surface runoff from Wadi Al Zarzeer watershed and with the help of Geographical Information System (GIS). The main conclusions drawn from the present study are:

1) Since there were no runoff observations available from this watershed, the results could not be compared with the measured values.

2) Three land use/land cover classes were categorized in Wadi Al Zarzeer watershed (See Figure 6.2), namely; agricultural, Built-up and Rangeland.

3) The experimental results of the soil classification show that the soil of Wadi Al Zarzeer watershed can be classified into Tow types; well graded Clay, and poorly-clay, distributed at the watershed as shown in Figure (6.4).

4) The results of soil classification, and land use and morphometric parameters were used to find the surface runoff for Wadi Al Zarzeer watershed. The direct runoff is estimated to be 4.2 % of the total annual rainfall.

5) In the present project, the runoff is estimated for the project area using rational method. This approach could be applied in other Palestinian watersheds for planning of various conservations measures.

6) Using GIS for morphological parameters watershed analysis is much more rapid than traditional methods. However, it is suggested that using GIS results in the loss of a certain degree of accuracy in determining some watershed characteristics

a) It is expected that if the method were further refined, that the results should be as good, if not better, than those obtained using traditional maps and methods.
b) Use of aerial photography coverage to better calibrate the threshold values would be a starting point for improving the method.

There are many important points that can be recommended:

1) This project is very important for Dura and Hebron cities to solve the water shortage problem. So it is recommended to build up a small dam in this watershed for collection of water runoff.

2) The results obtained can not compare to any measured values due to the absence of any gauge measurements in this watershed. Setting-up water gauges in the watershed will help in compare the results between the measured valued and the data obtained from. The rational method, and apply the same method in other watersheds.

REFERENCES

REFERENCES

1. Strahler, A. N., 1964. Quantitative geomorphology of drainage basins and channel networks. in: Handbook of Applied Hydrology, Ven Te Chow editor. McGraw Hill, New York. pp. 4-39 - 4-76

2. Feldman, A. D., 1995. HEC-1 flood hydrograph package. Chapter 4 of Computer Models of Watershed Hydrology. Water Resources Pub. Highlands Ranch, CO. pp. 119-150.

3. Singh , R.K Bhatt,CM.& Prasad,V.H (2003) Morphological study of a watershed using remote sensing and GIS techniques.Hydrol J,IAH,26(1-2),55-66.

4. Mohammadin, A. et al (2003), the mount of runoff for east Bani Naim watershed in the Hebron

5. Wahaidi, A., " Wastewater Collection and Treatment Seminar in Gaza Strip ", Appropriate Technology in Water Works, Water and Environmental Studies Center, Nablus, Palestine, 1995.

6. Lanfear, K. J., 1990. A fast algorithm for automatically computing Strahler stream order. Water Resources Bulletin 26(6):977-981.

7. Al-Namor, A.. et al (2006) study the hydrology of Wadi Su'd in Dura Area using GIS and GPS techniques.

8. Mark ,D.M 1988 ."Network Models in Geomorphology ", Modelling in Geomoephological Systems . John Wiley

9. DiLuzio, M., Srinivasan, R. Arnold, J.G.and Neitsch, S.L. 2002. Soil and Water Assessment Tool. ArcView GIS Interface Manual: Version 2000. GSWRL Report 02-03, BRC Report 02-07, Published by Texas Water Resources Institute TR-193, College Station, TX. 346p.

10. Tarboton ,D.G ,R.Bras ,I. Rodriguez – Iturbe 1991 .

11. Burrough, P. A., 1986. Principles of Geographical Information Systems for Land Use . Oxford University Press. New York. 194 pp.

12. Dunkerly, D. L., 1992. Channel geometry, bed material, and inferred flow conditions in ephemeral stream systems, Barrier Range, western N.S.W. Australia. Hydrological Processes 6:417-433.

13. Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy, 1994. Stream channel reference sites: an illustrated guide to field technique. USDA Forest Service General Technical Report RM-245. 61 pp.

14. Leopold, L. B., and T. Maddock, Jr., 1953. The hydraulic geometry of stream channels and some physiographic implications. U.S. Geological Survey Professional Paper 252.

15. Leopold, L. B., M. G. Wolman, and J. P. Miller, 1964. Fluvial Processes in Geomorphology. W. H. Freeman & Co. San Francisco. 522 pp.

16. Libby, F. J., D. E. Wallace, and D. P. Spangler, 1970. Seismic refraction studies of the subsurface geology of the Walnut Gulch Experimental Watershed, AZ. USDA-ARS 41-164. 14 pp.

17. Osterkamp, W. R., L.J. Lane, and G.R. Foster, 1983. An analytical treatment of channel-morphology relations. U.S. Geological Survey Professional Paper 1288. 21 pp.

18. Renard, K. G., L. J. Lane, J. R. Simanton, W. E. Emmerich, J. J. Stone, M. A. Weltz, D. C. Goodrich, and D. S. Yakowitz, 1993. Agricultural impacts in an arid environment: Walnut Gulch studies. Hydrologic Science and Technology 9(1-4): 145-190.

19. Lange, J. et al (2000) have studies the runoff on a steep 180 m2 Mediterranean Karts environmen

20. Allan, J.D. 1995. Stream Ecology: Structure and Function of Running Waters. Chapman & Hall, NewYork.

21. Chow, V.T., D.R. Maidment, and L.W. Mays, 1988. Applied Hydrology. McGraw-Hill, Inc., NewYork. .

22. Horton, R.E., 1945. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Bulletin of the Geological Society of America 56: 275-370.

23. Valdes, J.B., Y. Fiallo, and I. Rodriguez-Iturbe, 1979. A rainfall-runoff analysis of the geomorphologic IUH. Water Resources Research 15(6): 1421-1434.

24. Singh ,V.P ,(1994) Elementary Hydrology . Prentice-Hall of Private Limited

25. Dhruva Narayan, V.V. (1995) research in soil and water conservation in India with special emphasis on watershed management. Scientific contribution No. INCOH/SAR-5/95, National Institute of Hydrology, Roorkee.

26. Khybri, M.L. (1979) Suggestions for land capability classification for the Himalayan region. Indian J. Soil Sciences. Vol. 7, No. 1.

27. Klingebiel, A.A. and P.H. Montgomery. (1961) Land capability classification. Agricultural Handbook No. 210, Soil Conservation Service, USDA.

28. Sehgal, J L, D K Mandal, C Mandal and S Vadivelu, 1992. Agro-ecological Regions of India, NBSSLUP Publ. 24, NBSSLUP and Oxford & IBH Publishing Company Pvt Ltd.

29. Tejwani, K.G., S.K. Gupta and H.N. Mathur. (1975) Soil and water conservation research 1956-71. Indian Council of Agricultural research, New Delhi.

30. Garbrecht, J., and L. W. Martz. 1999. Digital Elevation Model Issues in Water Resources Modeling. Proceedings from Invited Water Resources Sessions, 19th ESRI International User Conference, Environmental Systems Research Institute, San Diego, California, July 26-30, 1999, pp. 1-17

31. Martz, L.W. and Garbrechet, J. 1992. Numerical Definition of Drainage Network and Subcatchment Areas from Digital Elevation Models. Computers and Geosciences. 18(6):747-761.

32. Moore, I.D., Grayson, R.B. and Ladson, A.R.1991. Digital Terrain Modelling: A Review of Hydrological, Geomorphological and Biological Applications. Hydrological Processes 5(1): 3-30

33. Olivera, F., and Maidment, D.R. (2000). GIS Tools for HMS Modelling Support. Chapter 5, Hydrologic and Hydraulic Modelling with Geographic Information Systems, D.R. Maidment and D.Djokic, (eds.), ESRI Press, San Diego,Calif.

34. Razavi, A.H. 2002. ArcGIS Developer's Guide for VBA. OnWard Press, New York.

35. Ritter Dale, F., R. C. Kochel and J. R. Miller (2002) Process Geomorphology, Mc-Graw Hill, Boston.

36. Romero, D. C.A. Madramootoo and P. Enright (2002). Modelling the Hydrology of an Agricultural Watershed in Quebec using SLURP. Canadian Biosystems Engineering, 44, pp 1.11:1.20

37. Sarangi, A. Bhattacharya, A.K. Singh, A. Singh A.K (2001) Use of Geographic Information System (GIS) for determination of erosion status of watersheds. Indian Journal of Soil Conservation, 29(3,)190-195

38. Tarboton, D.G., Bras, R.L. and Rodrigues, I.1991. On the Extraction of Channel Network from Digital Elevation Data. Water Resources Research 5(1): 81-100.

39. Tribe, A. 1992. Automated Recognition of Valley Heads from Digital Elevation Models. Earth Surface Processes and Landforms 16(1):33-49.

40. U.S. Geological Survey (USGS). 1990. Digital Elevation Models: data user guide. National mapping programme, technical instructions, data user guide 5, Department of the Interior, Reston, VA.

Internet References

1. ESRI web site http://www.esri.com

2. Soil and Water Assessment Tool (SWAT) at http://www.brc.tamus.edu/swat/avswat

3. Spatial Water Budgeting tool model http://www.icasa.net/toolkit/swbm.html

4. Watershed and Stream Delineation Tool interface

5..http://ceprofs.tamu.edu/folivera/GISTools/wsdt/home.htm

6. Tarboton D.G (2002), Terrain Analysis Using Digital Elevation Model (TauDEM)

7.interface http://moose.cee.usu.edu/taudem/taudem.html

APPENDIX – (A)

Soil Classification and Permeability Measurements

A.1 Soil classification using sieve analysis method:

To classify a sample of soil of (1000 gm.): sample # 14

Sieve number or size in mm	Wt. Retained in each sieve (gm0	Cumulative Wt. retained on each sieve (gm)	Pass (gm)	% Finer
4	200.97	200.97	799.03	79.903
10	228.18	429.15	771.82	57.11
20	231.159	660.309	768.841	34.01
40	134.23	794.539	865.77	20.61
60	64.086	858.625	935.914	14.21
140	12.754	871.379	987.246	13.01
200	29.014	900.393	970.986	10.11
Pan	99.607	1000	900.393	0.0

✓ **Calculations:-**

1- Cumulative wt. =w1+w2= 200.97 + 228.18 =429.15 gm. and so on.

2- Pass = w-(w1-w2) = 1000 – 200.97 = 799.03 gm.

3- % Finer = w- ((w1+w2)/w)*100 =100-(200.97/1000)*100 = 79.903%.

4- From the grain size distribution curve below:

D10 =0.18, D30=0.70, D60=2.3

5- From the equations (6.1) and (6.2):

$$Cu = \frac{2.3}{0.18} = 12.78$$

$$Cc = \frac{(0.7)^2}{(0.18)(2.3)} = 1.18$$

6- From the table (United Soil Classification System):

Soil Type (well -cray)

Unified Soil Classification System

Major Division			Group Symbols	Typical names	Classification Criteria		
Coarse-Grained Soils [More than 50% retained on No. 200 sieve (0.075 mm)]	Gravel [50% or more of coarse fraction retained on No. 4 sieve (4.75 mm)]	Clean Gravels	GW	Well graded gravels	Percentage of fines (a) Less than 5% passing No. 200 GW, GP, SW, SP (b) more than 12% passing No. 200 GM, GC, SM, SC (c) 5 to 12% passing No. 200 use of dual symbols as GW–GM, SP–SC	$C_u > 4$ $C_c = 1$ to 3	
			GP	Poorly graded gravels		Not meeting both criteria for GW	
		Gravels with fines	GM	Silty gravels		Atterberg Limits below A-line or plasticity index less than 4	Atterberg Limits in hatched area GM–GC
			GC	Clayey gravels		Atterberg Limits above A-line and plasticity index greater than 7	
	Sand (more than 50% of coarse fraction passing No. 4 sieve (4.75))	Clean Sands	SW	Well-graded sands		$C_u > 6$ $C_c = 1$ to 3	
			SP	Poorly graded sands		Not meeting both criteria for SW	
		Sands with fines	SM	Silty sands		Atterberg Limits below A-line or plasticity index less than 4	Atterberg Limits in hatched area SM–SC
			SC	Clayey sands		Atterberg Limits above A-line and plasticity index greater than 7	

SOIL MECHANICS AND FOUNDATION ENGINEERING

Continued

Major Division		Group Symbols	Typical Names	Classification Criteria
Fine-grained soils [50% or More passing No. 200 sieve (0.075 mm)]	Silts and clays Liquid Limit 50% or less	ML	Inorganic silts of low plasticity	
		CL	Inorganic clays of low to medium plasticity	
		OL	Organic silts of low plasticity	
	Silts and clays Liquid Limit greater than 50%	MH	Inorganic silts of high plasticity	
		CH	Inorganic clays of high plasticity	
		OH	Organic clays of medium to high plasticity	
Highly organic Soils		Pt	Peat, muck and other highly organic soils	Visual–manual identification

SOIL CLASSIFICATION

A.2 Permeability Analysis

Permeability is a soil property indicating the ease with which water will flow through the soil. Permeability depends on the following factors:

1) The size of soil grains,
2) The properties of pore fluids.
3) The void ratio of the soil.
4) The shapes and arrangement of pores.
5) The degree of saturation.

There are four laboratory methods typically used for measuring the permeability coefficient:

1) The variable-head (falling head test)
2) Constant head test.
3) The capillary method.
4) The back calculation from the consolidation test.

Generally, soils which contain 10% or more particles passing the No. 200 sieve are tested using the falling-head method. The constant-head method is limited to disturbed granular soils containing not more than 10% passing the No.200 sieve.

It is usually measured by the depth in (m) of the water layer that can be entered the soils in one hour (m/hr). According of the equation (5.4) to calculate. The coefficient of Permeability (K) at 14 sites covering different land use types, are presented in Table below.

Table (6.3): Permeability rate (K) Values of Grid Points

NO	X-coordinate (m)	X-coordinate (m)	Permeability rate (K) (m/sec)
1	156782	103737	$1.529*10^{-8}$
2	156532	103737	$1.478*10^{-8}$
3	156782	103487	$7.703*10^{-8}$
4	156532	103487	$1.28*10^{-7}$
5	156282	103487	$1.722*10^{-8}$
6	156532	103237	$1.779*10^{-8}$
7	156282	103237	$9.524*10^{-9}$
8	156032	103037	$8.546*10^{-9}$
9	156282	102987	$1.055*10^{8}$
10	156032	102987	$4.8*10^{-9}$
11	156032	102737	$1.367*10^{-8}$
12	155782	102737	$1.366*10^{-8}$
13	156032	102737	$1.411*10^{-8}$
14	155782	102487	$1.352*10^{-8}$

we can determine the type of soil by using the value of k ,**Table(6.4)** below .

Soil	Coeff. of Perm., k, cm/sec	Degree of Permeability
Gravel	$>10^{-1}$	Very high
Sandy gravel, clean sand, fine sand	$10^{-1} > k > 10^{-3}$	High to Medium
Sand, dirty sand, silty sand	$10^{-3} > k > 10^{-5}$	Low
Silt, silty clay	$10^{-5} > k > 10^{-7}$	Very low
Clay	$<10^{-7}$	Virtually impermeable

- ✓ To computed Permeability rate of a sample of soil
- Height (L) =10.62 cm
- Diameter (D) = 10.16 cm
- Area (A) $= \frac{D^2}{4} * \pi = \frac{10.16^2}{4} * \pi = 81.07\ cm^2$
- $t = 10*60 = 600$ sec
- Diameter of pipe (d) = 0.26 cm
- Area of the pipe , $a = \frac{d^2}{4} * \pi = \frac{0.26^2}{4} * \pi = 0.0531 cm^2$
- ✓ Permeability rate of a sample of soil : sample # 12
- $K = \frac{2.303 * 0.0531 * 10.62}{81.07 * 600} * \log \frac{94.4}{83.9} = 1.367 * 10^{-8}$ (m/sec)

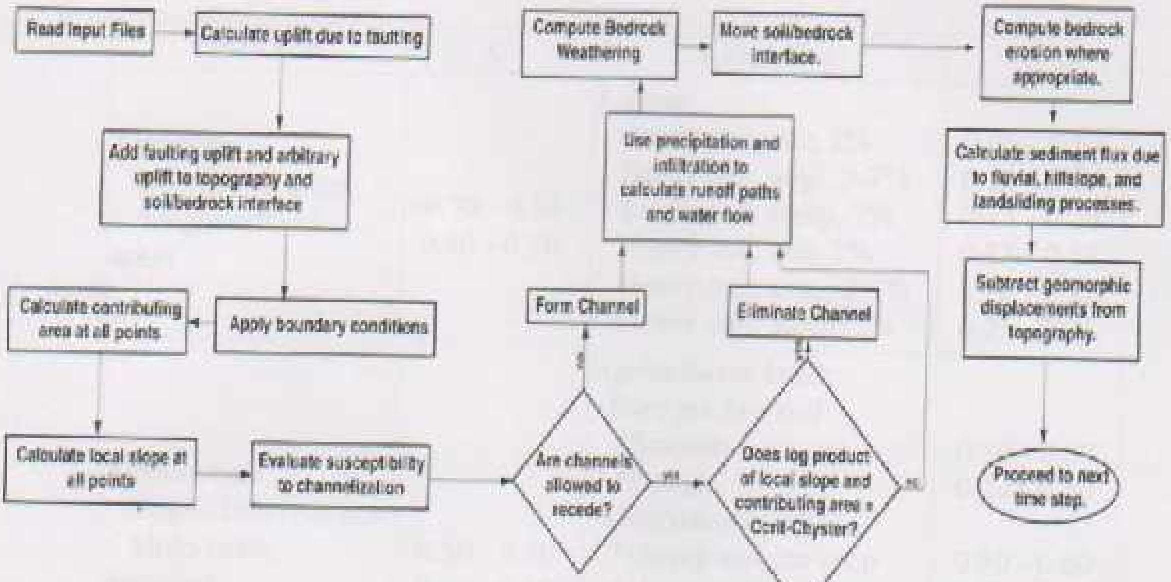
Some typical values of the coefficient of permeability in Table (6.4) :

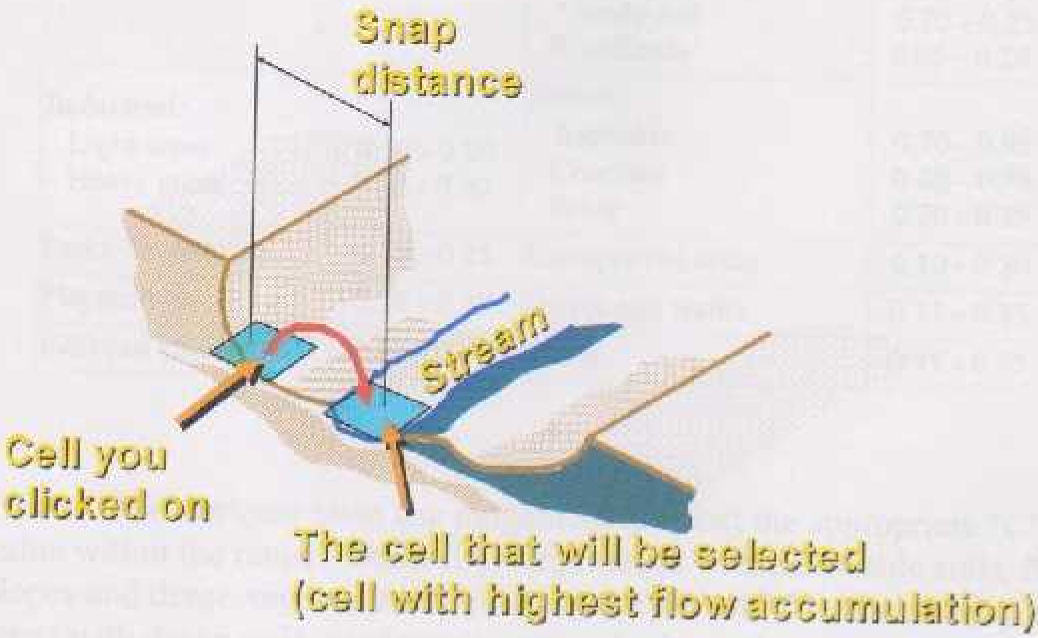
The soil of it sample #12 is Clay

APPENDIX – (B)

Review Data

Schematic 2D Model Setup





Values of Runoff Coefficient (C) for Rational Formula

Land Use	C	Land Use	C
Business: Downtown areas Neighborhood areas	 0.70 - 0.95 0.50 - 0.70	***Lawns:*** Sandy soil, flat, 2% Sandy soil, avg., 2-7% Sandy soil, steep, 7% Heavy soil, flat, 2% Heavy soil, avg., 2-7% Heavy soil, steep, 7%	 0.05 - 0.10 0.10 - 0.15 0.15 - 0.20 0.13 - 0.17 0.18 - 0.22 0.25 - 0.35
Residential: Single-family areas Multi units, detached Munti units, attached Suburban	 0.30 - 0.50 0.40 - 0.60 0.60 - 0.75 0.25 - 0.40	***Agricultural land:*** *Bare packed soil* *Smooth *Rough *Cultivated rows* *Heavy soil, no crop *Heavy soil, with crop *Sandy soil, no crop *Sandy soil, with crop *Pasture* *Heavy soil *Sandy soil Woodlands	 0.30 - 0.60 0.20 - 0.50 0.30 - 0.60 0.20 - 0.50 0.20 - 0.40 0.10 - 0.25 0.15 - 0.45 0.05 - 0.25 0.05 - 0.25
Industrial: Light areas Heavy areas	 0.50 - 0.80 0.60 - 0.90	*Streets:* Asphaltic Concrete Brick	 0.70 - 0.95 0.80 - 0.95 0.70 - 0.85
Parks, cemeteries	0.10 - 0.25	Unimproved areas	0.10 - 0.30
Playgrounds	0.20 - 0.35	Drives and walks	0.75 - 0.85
Railroad yard areas	0.20 - 0.40	Roofs	0.75 - 0.95

***Note:** The designer must use judgement to select the appropriate "C" value within the range. Generally, larger areas with permeable soils, flat slopes and dense vegetation should have the lowest "C" values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should assigned the highest "C" values.