COURSE GUIDE

SLM 310
WATERSHED HYDROLOGY

Course Team: Prof. Ayuba Musa Samndi (Course Developer/ Writer) - BUK
Alfred J. Augustine (Course Editor/Coordinator) – NOUN
Prof. N. E. Mundi (Programme Leader) - NOUN

NATIONALOPENUNIVERSITY OF NIGERIA

National Open University of Nigeria
Headquarters
University Village
Plot 91, Cadastral Zone
Nnamdi Azikiwe Expressway
Jabi Abuja

Lagos Office
14/16 Ahmadu Bello Way
Victoria Island, Lagos

e-mail: centralinfo@nou.edu.ng
URL: www.nou.edu.ng

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INTRODUCTION

Watershed Hydrology (SLM 310) provides an introduction to watershed hydrology. It examines the watershed environments, properties and its managements. The course covered the basic understanding of watershed, its classification, components, conditions and problems, the hydrological cycle (precipitation, evapotranspiration, storage, and surface runoff), processes affecting runoff generation, and factors affecting water resources. This course also explores watershed management activities aimed at protecting and maintaining.

The course is a two credits unit course designed to expose you to the basic and emerging concepts in watershed hydrology. Students will obtain an understanding of Watershed hydrology as interdisciplinary science and linkages between physical hydrology and broader ecological and environmental sciences.

Watershed Hydrology (SLM 310) is comprised of six interconnected modules, broken down into related units for continuity and flow of ideas. The modules and units are organised essentially to ease flow of the course, and to connect knowledge acquired.

COURSE AIM

The overall aim of the course is to have an insightful knowledge on the importance of watershed hydrology to both people and livestock. How their activities affect the productive status of watersheds, and to view the different phases of hydrological cycle in a watershed which are dependent on the various natural features and human activities.

Watershed is not simply the hydrological unit, but also sociopolitical-ecological entity which plays crucial role in determining food, social and economic security and provides life support services to rural people.

COURSE OBJECTIVES

Below are the wider objectives of the course, as a whole. By meeting these objectives, you should have achieved the aims of the course as a whole.

On successful completion of the course, you should be able to:

- describe watersheds, its classes and characteristics.
- explain hydrological processes
- explain watershed management

- describe how watershed plays crucial role in determining food, social, and economical security and provides life support services to rural people.

WORKING THROUGH THIS COURSE

To complete this course, you are expected to read through the modules and units. The course is presented in units, in chronological order for good understanding and grasp. Efforts have been made to ensure adequate explanations of terms, concepts and issues regarding watershed, its classification, components, conditions and problems. The hydrological cycle (precipitation, evapotranspiration, storage, and surface runoff), processes affecting runoff generation, watershed management and protecting are clearly explained in the units.

Interspersed within the units are self -assessment exercises ("Thinking questions') to help you reviews your progress. You are expected to refer back to previous units as you advanced in the course to refresh your memory and boost your understanding of the present unit.

COURSE MATERIALS

The main components of the course include the following:
1. Course Guide
2. Study Units
3. Textbooks and References
4. Assignment File
5. Presentation Schedule

STUDY UNITS

There are 16 study units for the course covered in six modules as follows:

Module 1 Water Shed Climate, Soils and Vegetation

Unit 1 Watershed
Unit 2 Components of Watershed

Module 2 Watershed Classification and Characteristics

Unit 1 Classification of Watershed
Unit 2 Watershed Characteristics

Module 3 Watershed Conditions and Problems

Module 4 Hydrology

Module 5 Channel Processes

Module 6 Watershed Management

The first two units in Module 1, defined, and described watershed and components of watershed. Module 2 addressed the watershed classification and characteristics. Watershed conditions and problems were discussed in Module 3 and described in two units. Module 4 described hydrology, which comprised of hydrological processes, hydrologic cycle, surface and ground water and water pollution. Three units in Module 5 looked at channel processes, erosion and hydrographs. Module 6 discussed watershed, its principles and measures; it also looked at integrated watershed management.

The main content of each unit is preceded by the unit objectives which were derived from the aim and the main objectives of the course. Recommended texts for further reading and references cited within the unit are given at the end of the unit. Some units also contain question designed for you to assess your understanding of the contents of the unit.

TEXTBOOKS AND REFERENCES

Some of recommended texts are available in some bookshops within Nigeria; while others may be available for free download from the internet. A substantial amount of literature also exists online about the course and you should expand your scope of understanding of the course with these materials. While studying, in addition to being nearby an internet source, you should strive to acquire the following text;

Dictson, N. & L. White (2004). A Texas Field Guide to Evaluating Rangeland Stream and Riparian Health. (B-6157). Texas Agrilife Extension Service, College Station, TX.

FAO (1994).Watershed Management Training Course Union of Myanmar: Lecture Notes.

Food and Agriculture Organisation of the United Nations Sponsoring Agency: United Nations Development Programme and Government of the Union of Myanmar.

Mostafa, M. S., Philip, E.L., Bashir, A. M., Fakhry, A.A., & James, W.L. (1998). *Environmental Hydrogeology*.

Mohammed Abdelkadir (nd). Groundwater Hydrology, Lecture Notes, Mekelle University Fikadu Woldemariam, Dilla University Ethiopia.

Pamela, J. Edwards 1, Karl W.J. Williard, & Jon E. (2015). Fundamentals of Watershed Hydrology, Schoonover. Universities Council on Water Resources *Journal of Contemporary Water Research &Education Issue*154, pages 3-20.

Peter, E. Black (nd). Watershed Functions SUNY College of Environmental Science and Forestry Syracuse, New York.

Salah Darghouth, Christopher Ward, Gretel Gambarelli, Erika Styger, & Julienne Roux (2008). Watershed Management Approaches, Policies, and Operations: Lessons for Scaling Up: The World Bank, Washington, DC Water Sector Board discussion Paper Series Paper no. 11 May.

Sheng, T.C. (1990). Watershed Management Field Manual. *Watershed Survey and Planning*: FAO, Conservation Guide 13/6 Food and Agriculture Organisation of the United Nations Rome.

Singh, V. P. (1994). Elementary Hydrology. India: Prentice Hall pp. 377-406.

Subramanya, K. (1994). *Engineering Hydrology* (3rd ed.). Tata McGraw Hill pp.139-143.

Susan Pater, Kim McReynolds, & Robert Emanuel (nd). Hydrology and Watersheds: Part II.

Suhas P. Wani & Kaushal K. Garg (nd). Watershed Management Concept and Principles. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) India: Andhra Pradesh.

ASSIGNMENT FILE

In this file, you will find the details of the work you must submit to your facilitator for marking. The marks obtained forms part of your total score for the course.

TUTOR-MARKED ASSIGNMENT

The tutor-marked assignment contained in your assignment file should be submitted as soon as required by your facilitator. When you are not able to submit your assignment on the slated submission date, make sure you contact your facilitator and seek for an extension. Do not allow the assignments to accumulate and avoid unnecessary excuses as extensions are only reserved for special reasons and circumstances. Remember also that the scores of the assignments cumulatively account for up to 40% of the total scores of the course.

The information needed to complete the assignment are contained in the main course content and across the book and internet references provided. Enrich your submission by wide consultation of different reference material. This gives you a broader overview of the course.

FINAL EXAMINATION AND GRADING

The final examination for this course will be a two hours exercise and the questions will be drawn randomly from the self-assessment questions within the course material and the tutor- marked assignment. The examination will constitute 60% of your total scores for the course and will cover all areas presented in the course material. You may be required to answer three questions from a total of five or four questions taken from a total of six.

PRESENTATION SCHEDULE

Your course material contains the time spread and specific dates for specific activities including tutorials, submissions of assignments and final examination. Abide by the timing and avoid being left out in any activity, because that may be counter-productive to your overall progress. In any case discuss with your facilitator for possible adjustment in the event that there is an unavoidable cause for that.

COURSE MARKING SCHEME

The following table lays out how the actual marking scheme is broken down.

Table 1: Course Marking Scheme

Assessment	**Marks**
Assignments 1 – 4 Final Examination	Four assignments counts for 12.5% each = 40% of course marks 60% of overall course marks
Total	100% of course marks

COURSE OVERVIEW

This table brings together the units, the number of weeks you should take to complete them and the assignment that follows them.

Table 2: Course Schedule

Units	**Title**	**Week(s) allocated**	Assignment
Module 1	**Watershed Climate, Soils And Vegetation**		Assignment 1
Unit 1	Watershed	1	
Unit 2	Components of Watershed	1	
Module 2	**Watershed Classification And Characteristics**		Assignment 2
Unit 1	Classification of Watershed	1	
Unit 2	Watershed Characteristics	1	
Module 3	**Watershed Conditions and Problems**		Assignment 3
Unit 1	Watershed Condition	1	
Unit 2	Watershed Problems	1	
Module 4	**Hydrology**		Assignment 4
Unit 1	Hydrological Processes	1	
Unit 2	Hydrologic Cycle	1	
Unit 3	Surface Water and Ground Water	1	Assignment 5
Unit 4	Water Pollution	1	
Module 5	**Channel Processes**		Assignment 6
Unit 1	Channel Processes	1	

Unit 2	Erosion	1	
Unit 3	Hydrographs	1	
Module 6	**Watershed Management**		Assignment 7
Unit 1	Watershed Management	1	
Unit 2	Principles and Measures	1	
Unit 3	Integrated Watershed Management	1	
	REVISION	1	
	EXAMINATION	17	

HOW TO GET THE MOST FROM THIS COURSE

The course is designed in such a way as to give you liberty in space and time to learn at your own pace. The modules and units are presented in a chronological order as one unit leads to better understanding of the next. Make sure you understand each unit before proceeding to the next. All the units are presented in the same format of introduction, objectives, main content, conclusion, summary and references.

At the end of each unit, assess your achievement by answering the self-assessment exercises if available or by reviewing the objectives and gauging yourself based on them. Participate in facilitator moderated activities and complete and submit tasks in time.

FACILITATORS/TUTORS AND TUTORIALS

There are 20 hours of tutorial (ten 2-hour sessions) for the course. As soon as you are allocated a tutorial group, you will be notified of the tutor/facilitator contact information, timings and venue for your tutorial group. The tutorials are the only avenues for physical contact with your tutor.

The facilitator will be responsible for going through your assignments and commenting on them. It is to the tutor that you should mail your assignment at least two working days before the tutorial date, which will be enough time to mark and return them to you.

The contact information of the tutor are supposed to be used for communication in the event that you;

- Do not understand any segment of the course material
- Have difficulty with the assignments
- Have a question with comments on the assignment or its grading

Do not miss tutorials because this is the only chance to have face to face contact with your tutor and to ask questions. Because you have had the material beforehand, you can prepare a checklist of questions and relevant issues to sort with the tutor on contact.

SUMMARY

At the end of this course, you will be able to appreciate the roles of watershed and its importance and the hydrological processes involved in watershed. You will also be able to answer questions which relate to the following:

- watershed classification, characteristics, conditions and problems
- hydrologic information to water resources and its impact on ecological processes
- different principles of watershed management.

By the end of this course, you will have a better understanding of the watershed environment, its processes and challenges. You will also gain an insight and appreciate the challenges faced in getting solutions to ever increasing watershed problems, its rehabilitations and managements.

We wish you success and hope that you will find the course both interesting and useful. Good luck.

MAIN CONTENT

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MODULE 1 WATERSHEDCLIMATE, SOILS AND VEGETATION

UNIT 1 WATERSHED

CONTENTS

1.0 INTRODUCTION

A watershed is an area that supplies water by surface or subsurface flow to a given drainage system or body of water, be it a stream, river, wetland, lake, or ocean. It is considered as the basic unit of water supply and the basic building block for integrated planning of land and water use. The characteristics of the water flow and its relationship to the watershed are a product of interactions between land and water (geology, slope, rainfall pattern, soils, and biota) and its use and management.

The watersheds are separated from each other by highland elevations called the watershed divide (topographic divide) also referred to as watershed boundary. Formation and maintenance are affected by climate, hydrology, soil type topography and land use.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define and describe watershed
- describe catchment and drainage basin
- list the various watershed variables.

3.0 MAIN CONTENT

3.1 Watershed

A watershed, also called a drainage basin or catchment area, is defined as an area in which all water flowing into it goes to a common outlet that drains down slope, along drainage to a common lowest point or basin (Figure 1.1).

It may also be defined as an area of land that captures rainfall and other precipitations, and funnels it to a lake or stream or wetland. It is usually defined by a topographical boundary around the elevational high points surrounding a common point where water collects into a channel (Figure 1.2). It may be described as an area of land that catches all precipitation (such as rain and snow) and drains or seeps into a marsh, stream, river, lake or groundwater.

The watersheds are separated from each other by highland elevations called the watershed divide (topographic divide). It is this topographic divide or watershed boundary line which designates the area in which overland flow approaches toward a drainage system, which finally becomes as surface runoff at the outlet.

The water drains via a network of surface and underground drainage pathways, which merges into a stream or river system that becomes progressively larger as the water moves downstream. Ground and surface waters may also merge or separate at various points along the pathway to the recipient water body that collects drainage from the watershed.

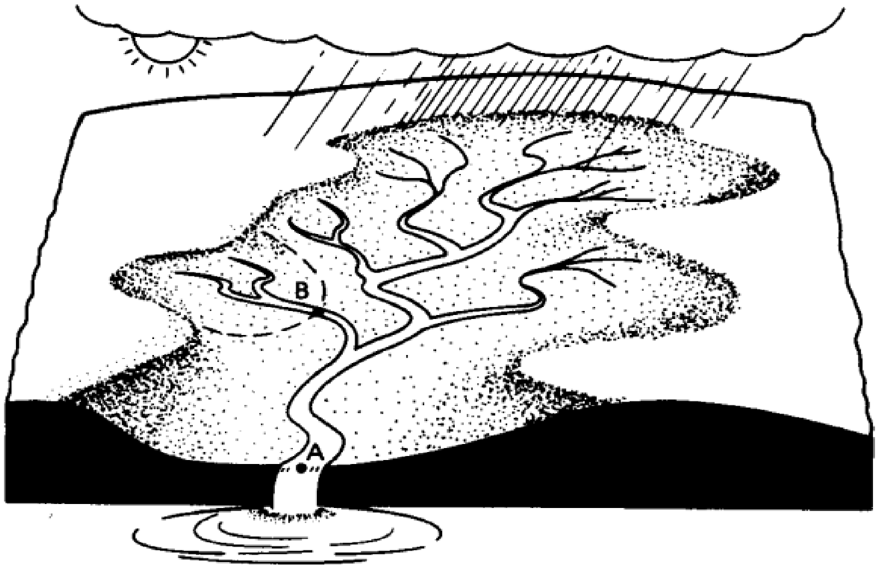

Fig.1.1: Diagram of a Watershed

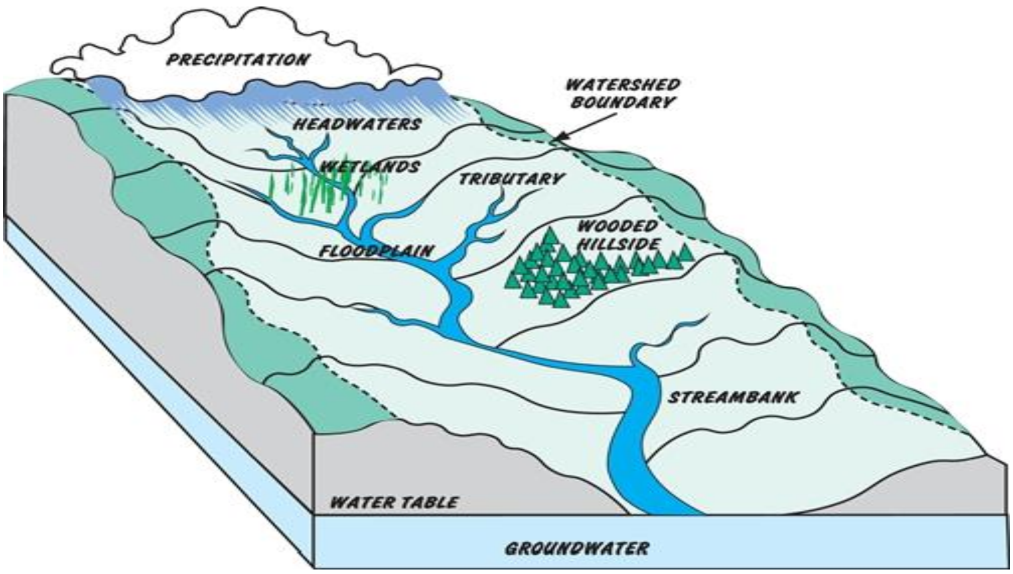

Fig.1.2: A Typical Watershed

3.2 Watershed *Boundary*

Watershed boundaries always follow the highest ridgeline around the stream channels and meet at the bottom or lowest point of the land where water flows out of the watershed.

Watershed *boundary is defined* by topographic divides and delineates areas where surface-water runoff drains into a common surface-water body, such as a lake or section of a stream (Figure 1.3).

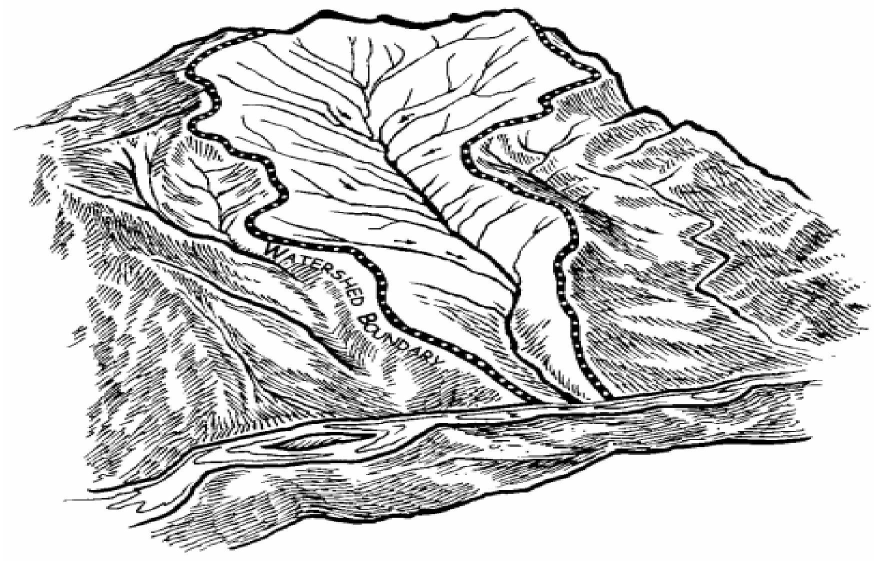

Fig.1.3: Watershed Boundary

3.3 Drainage Basin

It is defined as, "any portion of the earth's surface within a physical boundary defined by topographic slopes that divert all runoff to the same drainage outlet. "This definition permits the selection of any drainage outlet desired. One can move the drainage outlet up the drainage system or down the drainage system to any location of interest (makes possible the sub-basin studies).

By definition, any point on the main drainage system can be selected as the basin outlet. Thus, a basin is defined with respect to the outlet.The physical boundary of the drainage basin is called the drainage divide (Figure 1.4.)

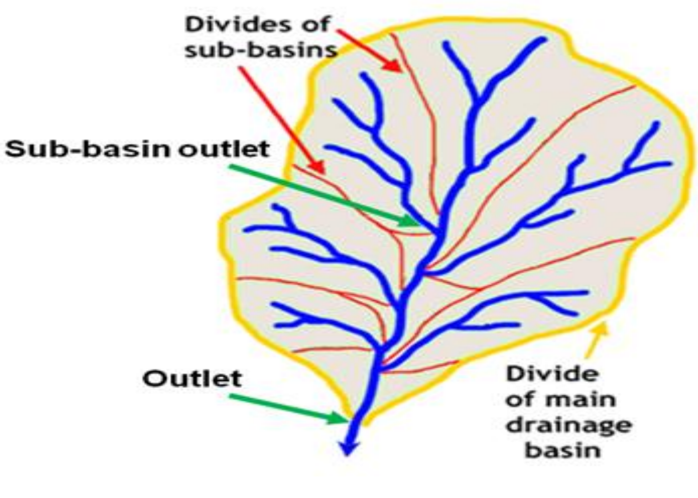

Fig1.4: Drainage Basin with its Sub-Basins

Source:http://nationalatlas.gov/articles/geology/a_continentalDiv.html

3.4 Catchment

It is defined as the area that drains an individual development site to its first intersection with a stream.

3.5 Basin

A **basin** drains to major receiving water such as a large river, estuary or lake as shown in Figure 1.4. Basin drainage areas typically exceed several thousand square kilometers and often include major portions of a single state or even a group of states.

3.6 Watershed Variables

A number of variables affect the formation and maintenance of a watershed, these are as follows:

3.6.1 Climate

Climatic conditions influence the types of soils and vegetation that are found in a particular watershed. Climatic factors determine or modify airflow patterns and weather systems which indicate the ranges of precipitation, temperature, humidity, wind, evaporation, and transpiration that a watershed is subjected to.

A change in climate is also a direct relationship with the erosional and depositional processes which act to form the landscape.

3.6.2 Hydrology

The amount of precipitation and in particular the amount occurring in a watershed plays a principal role in sculpting and changing the land surface. The circulation of water from ocean to atmosphere, to land, and then back to ocean is known as the hydrologic cycle.

3.6.3 Geology

The geology of a watershed determines the foundation materials on which various soil types form. Geologic characteristics determine the nature and extent of runoff, groundwater flow and storage. For the runoff, the main geologic characteristic is the permeability of the soil substrate. In case of rainfall, a watershed that has an impermeable substrate presents a faster and more violent increase of the runoff in comparison to a watershed with a permeable substrate. A watershed with a permeable substrate will provide a base runoff during dry periods that will last longer.

The physical and chemical weathering of the underlying rocks of a watershed creates the sediments available for erosion, and is the primary source of calcium, magnesium, potassium, and sodium in streams.

3.6.4 Soil Type

The quality of a soil is determined by a combination of physical, chemical, and biological properties such as texture, water-holding capacity, porosity, depth and organic matter content.

Infiltration rates are dependent on the structure and texture of the surface soils, vegetative cover, and land-use practices. Soil types exhibit a wide range of vulnerability to erosion, and also have a direct bearing on the types of vegetation that can be supported in a watershed. Small particles such as silt are more easily eroded than coarse materials, such as sand or gravel.

3.6.5 Slope/Gradient/Topography

The steepness and gradient of the land surface at which streams flow has a significant influence on discharge and how it affects the watershed. As slope increases, so does potential energy and erosive power of water as it flows downward in the watershed. Steep slopes have a high degree of runoff and are more susceptible to erosion.

3.6.6 Land Use/Land Cover

The amount and type of vegetative cover established on the land surface is extremely significant in controlling runoff and erosion. Vegetation creates a barrier that reduces raindrop impact on the soil surface, reduces the velocity of water flow, and allows for greater infiltration of water into the soil surface.

Human uses of land and water influence watersheds. The construction of impervious surfaces, which are non-porous to water such as streets, parking lots and rooftops, increases the amount of runoff and erosion.
In undisturbed areas, features such as wetlands, uncompact soils and vegetation are able to absorb water runoff and reduce erosion. If these natural sponges are replaced by impervious surfaces, less water is absorbed and a larger volume of water flows more quickly to waterways through ditches or storm drainage pipes. This increased runoff adds to stream volume and velocity, which can cause stream bank erosion, sedimentation and flooding.

Industrial and agricultural activities can also alter watersheds and impact a stream through point and nonpoint sources of pollution. Point sources of pollution can be traced to a specific source. Examples include a pipe discharging pollutants from an industrial plant or sewage treatment facility.

3.7 Importance of Watershed

People and livestock are the integral part of watershed and their activities affect the productive status of watersheds in the following ways:

1. From the hydrological point of view, the different phases of hydrological cycle in a watershed are dependent on the various natural features and human activities.
2. It provides water for urban, agricultural, and environmental needs.
3. Watershed is not simply the hydrological unit but also sociopolitical-ecological entity which plays crucial role in determining food, social, and economical security and provides life support services to rural people.

SELF-ASSESSMENT EXERCISE

i. Draw a typical watershed.
ii. Describe the following watershed terms
    - Catchment
    - Drainage basin
    - Watershed *boundary.*

4.0 CONCLUSION

At the end of this unit, we are able to know what a watershed is all about, how various hydrologic characteristics of a watershed, such as climate, soils, topography and land use manifest themselves in the nature. The importance of watershed to human sin the provision of food, social, and economic security is also highlighted.

5.0 SUMMARY

Watershed is a land area whose runoff drains into any stream, river, lake, and ocean. Watershed *boundary* is the divide separating one drainage area from another. Terms like *catchment* or *drainage basin* are also used to refer to watersheds. Watershed functions are affected by variables such as climate, hydrology, soil types, topography and land use. It plays a significant role in human activities and determines the food, social, and economical security and provides life support services to rural people.

6.0 TUTOR – MARKED ASSIGNMENT

1. Define and describe watershed.
2. State the importance of watershed to your immediate environment.

7.0 REFERENCES/FURTHER READING

Peter, E. Black (nd.). Watershed Functions SUNY College of Environmental Science and Forestry Syracuse, New York.

Salah Darghouth, Christopher Ward, Gretel Gambarelli, Erika Styger & Julienne Roux (2008). Watershed Management Approaches, Policies, and Operations: Lessons for Scaling Up: The World Bank, Washington, DC\ Water Sector Board Discussion Paper Series no. 11.

Singh, V. P. (1994).*Elementary Hydrology*. India: Prentice Hall pp.377-406.

Susan Pater, Kim McReynolds & Robert Emanuel (nd.). Hydrology and Watersheds: Part II.

Suhas, P. Wani & Kaushal K.Garg (nd.). Watershed Management Concept and Principles. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) India: Andhra Pradesh,

Watershed Management: An Overview (2006).PIPELINE – Fall Vol. 17, No. 4.

UNIT 2 COMPONENTS OF WATERSHED

CONTENTS

1.0 INTRODUCTION

A watershed is sometimes called a catchment or drainage basin because it catches and drains precipitation that falls within its boundaries and directs it into a particular creek, stream, river, lake, wetland or groundwater. It is composed of upland, floodplain, stream channel, riparian zone and vegetation and underground water.

The watershed and its fundamental hydrologic functions define the characteristics of freshwater aquatic habitat and inputs from other systems. It functions are physical in nature and are termed as *hydrologic* and *ecological* functions. These includes water collection, storage and discharge which provides diverse sites and pathways along which vital chemical reactions take place, and the provision of habitat for the flora and fauna.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- explain the various components of a watershed
- describe the functions of a watershed
- state the importance of riparian vegetation.

3.0 MAIN CONTENT

A watershed may consist of uplands, floodplains, stream channel, groundwater and riparian zone.

3.1 Upland

Uplands are the highest part of the landscape, where water usually drains downhill into valleys, floodplains and water bodies. It is an area of land located at a higher elevation where it is usually not standing in water and would typically be either forested or agricultural land. Uplands often comprise more than 99% of the watershed's area, with the floodplain and stream channel making up the remaining 1%.It typically forms watershed boundaries, or divides (Figure 2.1).

The upland areas of a watershed are important habitat for mammals, birds, reptiles and amphibians.

Upland vegetation stabilises the soil surface, minimises surface erosion, and filters and retains dissolved and suspended matter carried by surface water runoff from the surrounding land. Most of these upland areas are used for agriculture and other human uses.

3.2 Floodplain

The floodplain is the flat area of land surrounding a body of water that is subject to periodic flooding. After heavy rain falls, the floodplain holds excess water, allowing it to be slowly released into the river system or seep into groundwater aquifers.

Floodplains also help to filter out sediment from floodwaters, thereby keeping it out of water bodies. Floodplains often support an abundance of aquatic life and are often used as recreation areas.

3.3 Stream Channel

The stream channel is the path of water and sediment flowing within the stream banks. It functions as a conduit for the movement of water, sediment, and organic materials. A stream is constantly working towards a natural balance among its primary components: water, sediment, energy, and vegetation. This balance is called dynamic equilibrium, and streams constantly adjust to balance the water and sediment loads they carry.

Geology, topography, the types of soils and vegetation, and the amount of water flowing into a system determine the size and shape of the stream channel. Activities such as channelisation (straightening) of a stream and dam construction can alter the components of the stream channels.

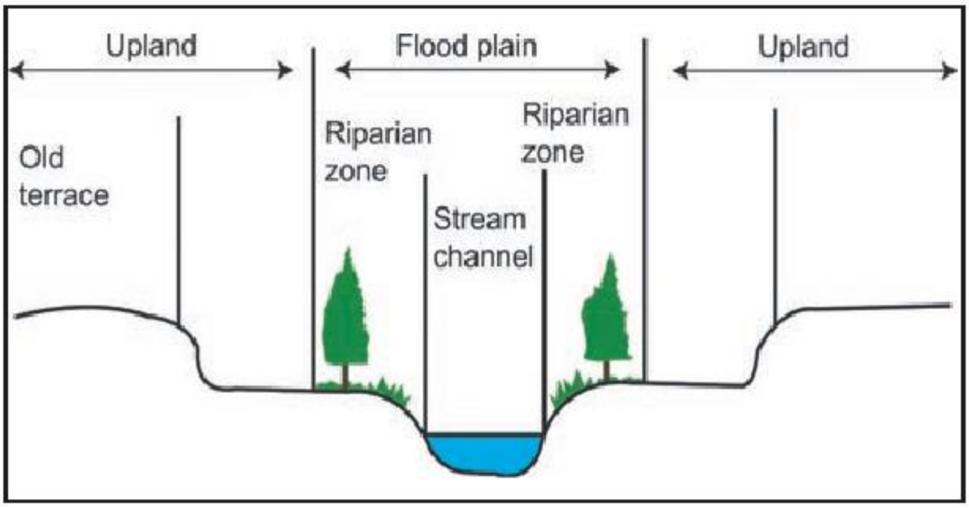

Fig.2.1: Components of Watershed

3.4 Groundwater

Groundwater is the water that fills the cracks and spaces between soil particles, sand grains and rock. Each drop of rain that soaks into the soil moves downward to fill these spaces and gaps, thereby becoming groundwater stored in the soil and rock. As water is pumped out of an area, ground and surface water from other areas (eg. neighbouring soils, wetlands and rivers) is slowly sucked in to fill the drained spaces in the rock and soil.

Groundwater is always naturally in motion. Recharge areas are places where surface water soaks (infiltrates) into the soil, thereby becoming groundwater. Discharge areas are places where groundwater seeps or flows into surface water (e.g. springs). Groundwater flow is part of the natural water cycle.

3.5 Riparian Zone

The word riparian means “of the river,” the riparian zone is the vegetated land that touches and immediately surrounds a stream, river, lake or other body of water. This zone often includes wetlands (Figure2.1), which are areas of land that are regularly **saturated** with water for at least part of the year and that contains vegetation adapted to living in saturated conditions.

3.5.1 Riparian Vegetation

The green areas along streams and rivers are***riparian areas;*** the characteristic plant communities that occur there are referred to as

riparian vegetation. Riparian areas generally have higher levels of soil moisture than adjacent upland areas, and usually are well-vegetated. Riparian vegetation includes plants such as alder, dogwood, willow, chokecherry and cattails, as well as maple, birch and other tree species.

3.5.2 Importance of Riparian Vegetation

Riparian vegetation is important for a number of reasons:

1. The roots of riparian plants stabilise stream banks, and prevent erosion and silting-in of streams and river channels.
2. Spongy soils in riparian areas slow and store water, reducing flooding and later releasing water to aquifers and streams.
3. The roots and stems of riparian vegetation are filters that absorb and trap nutrients, diseases and pollutants, thereby improving water quality.
4. Riparian vegetation provides important habitat for aquatic insects, fish and wildlife.
5. Riparian vegetation may act as a filter in some areas, keeping sediment and pollutants out of streams.
6. The roots of riparian vegetation stabilise stream banks by reducing erosion and preventing stream channels from down cutting.
7. Streamside vegetation provides habitat for insects, some of which fall in the water and provide a food source for fish.
8. Trees and plants hanging over the water shade it and help keep it cool during the dry season (this is critical to fish life, as many fish can't live with a rise in temperature of even a few degrees).
9. Provide a "transitional zone" from bank to floodplain to watershed slope. This is critical for flood mitigation, as it gives floodwater a place to slow down and soak in or enter the stream with less energy.

3. 6 Watershed Functions

A watershed has five primary functions that can be categorised into hydrological and ecological functions. Hydrologically, there are three fundamental watershed functions, these includes:

3.6.1 Water Capture

Water capture is the process by which water from the atmosphere is captured or stored in the soil. When water is captured in the soil, it can infiltrate the soil surface and percolate throughout the **soil profile.**

Infiltration is the process by which water moves through the soil surface into the soil matrix.

Percolation is the process by which water moves down through the profile and into the underlying soil profile and weathered rock. Several factors affect infiltration and percolation rates, including the soil type (primarily texture and depth), topography and climate.

The amount of runoff collected within the watershed depends upon storm position and size relative to basin size, storm proximity to runoff source areas within the watershed, and precipitation type and intensity; ultimately, these are critical issues of relative scales of the watershed and the runoff-producing event. Collection of runoff water within larger watersheds takes longer because:

a there is a greater distance of travel

b for larger watersheds, average slopes and stream gradients are lower, thereby reducing average runoff velocities.

These factors above increase the time of travel and, therefore lengthen the time of concentration. As a result, peak flows in rate per unit area on larger watersheds are lower and later than on smaller watersheds.

3.6.2 Water Storage

The type, amount, and distribution of storage are the primary watershed characteristics that affect the storage function. Water stored in the soil is usually divided into capillary and non-capillary portions, also referred to as retention and detention storage.

Retention Storage, water which is held at high tensions in the soil capillary pores, cannot flow out at all; only a portion of the water in retention storage can be removed from the soil by evaporative processes. Water temporarily detained in the non-capillary pores flows out during the first 24 hours following the runoff event by definition.

The amount of moisture that a soil can hold depends on the soil's depth, texture and structure. For example, much less water can be stored in sandy soils than in clayey soils. This is because sandy soils are made up of large soil particles with large pores in between these particles. Water drains more easily through large pores than through small pores.

The kinds, amounts and distribution of vegetation on the ground greatly affect the amount of water stored in a watershed. For example, a piece of land can be dominated by shallow rooted **annual** species (cheat grass), deep-rooted **perennial** species (sturdy grasses, trees and shrubs), or a mixture of these. Different types of plants use water in varying amounts and from varying depths in the soil profile, which affects how much water can be stored in a watershed.

3.6.3 Water Release

Water release takes place as the functions of collection and storage that played out over time scales varying from that of a runoff-causing event to a hydrologic year. Factors that affect the collection and storage functions also affect the discharge function. Water is released from a watershed when it moves through the soil profile to seeps and springs, or across the land surface as runoff, and ultimately into streams and rivers that flow to oceans.

Water is released out of the watersheds in two ways:

1. **Subsurface flow**: the flow of water below the land surface that is in excess of the water that can be stored in the soil.

2. **Overland flow**: the flow of water over the ground surface that occurs when precipitation exceeds the soil's infiltration rate. The kinds and amounts of vegetation in a watershed affect the amount of water release and the rate at which it flows in a drainage system.

Vegetation along streambanks slows the release of water into streams; in heavy rains, that can help prevent the erosion of streambanks, reduce the amount of sediment in the water, and help maintain the water's quality.
Ecologically, the watershed functions in two additional ways:

3.6.4 Biogeochemical

Biogeochemical cycling refers to the biological, physical and chemical transformations of elements that are found in soil, water and air. Watershed provides diverse sites and pathways along which vital biogeochemical reactions to take place.

Water is the principal medium in which most chemical reactions occur; watersheds provide diverse aqueous sites in which those chemical reactions take place. Over time, these reactions have provided the fundamentals of the basic biogeochemical and nutrient cycling processes in forest ecosystems.

Nutrient elements such as nitrogen, sulfur, phosphorus, carbon and hydrogen, and organic materials containing these nutrients, are constantly undergoing biological, physical and chemical reactions with the surrounding environment. These processes help maintain the plant and microbial communities found along water bodies in a watershed.
Plants and microbes, in turn, fuel additional reactions and biogeochemical cycling. These communities also help maintain the global atmosphere through a complex cycle in which carbon is trapped

in plant biomass, preventing its release into the atmosphere as carbon dioxide, a greenhouse gas.

3.6.5 As Habitat for Plants and Animals

Habitat refers to the natural home of a plant or an animal. Watersheds provide critical habitat for all kinds of aquatic and terrestrial plant and animal species. Its fundamental hydrologic functions define the characteristics of freshwater aquatic habitat; they are further influenced by inputs from other systems.

A healthy watershed contains some natural features that help it carry out its essential functions, which include uplands floodplains, riparian zones and water bodies (Figure. 2.1). These features are intimately connected and work together to ensure that a watershed is functioning properly. In general, watersheds and all of their natural features function to capture, store and release water safely; to filter out sediments, pollutants and other potentially harmful materials; and to provide diverse sites for biogeochemical reactions and habitat for plants and animals.

SELF-ASSESSMENT EXERCISE

i. Describe the functions of a watershed.
ii. Explain Biogeochemical Cycling.

4.0 SUMMARY

A watershed consists of uplands, floodplains, stream channel, groundwater and riparian zone. In general, watersheds and all of their natural features function to capture, store and release water safely; to filter out sediments, pollutants and other potentially harmful materials; and to provide diverse sites for biogeochemical reactions and habitat for plants and animals.

5.0 CONCLUSION

A watershed has five important functions:

- It collects water from rainfall
- It stores water of various amounts and for different times
- It releases water as runoff
- It provides diverse sites for chemical reactions to take place and
- It provides habitat for flora and fauna.

6.0 TUTOR – MARKED ASSIGNMENT

1. Write short notes on upland and flood plain of a watershed.
2. Describe the functions of a watershed.

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MODULE 2 WATERSHED CLASSIFICATION AND CHARACTERISTICS

UNIT 1 CLASSIFICATION OF WATERSHED

CONTENTS

1.0 INTRODUCTION

Watershed classification based on size is vague, however in terms of spatial heterogeneity and dampening (averaging) of hydrological processes, it can be classified as small and large.

Land use defines exploitation of watershed, classified watersheds as agricultural, urban, mountainous, forest, desert, coastal or marsh, or mixed.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- classify watersheds based on size and land use
- differentiate between agricultural and forest watersheds.

3.0 MAIN CONTENT

Watershed are classified based on their sizes and land use.

3.1 Classification of Watersheds by Size

This classification is vague, but the implication is in terms of spatial heterogeneity and dampening (averaging) of hydrological processes, thus watershed can be classified as either small or large.

3.1.1 Small Watersheds

Small watersheds have dominant land phase and overland flow, with relatively less conspicuous channel phases. They are highly sensitive to high-intensity, short-duration rainfalls. Small watersheds are usually least heterogeneous and are more nonlinear with sizes less than 250 km^2.

3.1.2 Large Watersheds

Large watersheds have well-developed channel networks and channel phase and, thus channel storage is dominant. They are less sensitive to high-intensity rainfalls of short duration and are most heterogeneous, thus the spatial variability of watershed characteristics increases with size. Generally, large watersheds are more than 250 km^2in size.

3.2 Classification of Watersheds by Land Use

Land use defines exploitation of watershed, thus watersheds can be classified as agricultural, urban, mountainous, forest, desert, coastal or marsh, or mixed - a combination of two or more of land use types. These watersheds behave hydrologically so differently that different branches of hydrology have arisen as follows:

1) Urban watersheds
2) Agricultural watersheds
3) Forest watersheds
4) Mountainous watersheds
5) Desert watersheds
6) Coastal watersheds
7) Wetland/marsh watersheds.

3.2.1 Urban Watersheds

An urban watershed is dominated by buildings, roads, streets, pavements, and parking lots. These features reduce the infiltrating land area and increase imperviousness. Drainage systems are artificially built, the natural pattern of water flow is substantially altered.

For a given rainfall event, interception and depression storage can be significant, but infiltration is considerably reduced and so is the case with evaporation. As a result, there is pronounced increase in runoff and pronounced decrease in soil erosion. Thus, an urban watershed is more vulnerable to flooding if the drainage system is inadequate.

Once a watershed is urbanised, its land use is almost fixed and its hydrologic behaviour changes due to changes in precipitation.

3.2.2 Agricultural Watersheds

Agricultural practices and land treatments such as cultivation, fallow, row cropping, small grain cropping, rotation meadow, rotation, straight row, contours, grass land, meadows, woods and forests, and gardens usually leads to increased infiltration, increased erosion, and/or decreased runoff. Depression storage also is increased by agricultural operations.

When the fields are barren, falling raindrops tend to compact the soil and infiltration is reduced. There is lesser development of streams in agricultural watersheds, for small channels formed by erosion and runoffs are obliterated by tillage operations. The soil texture is altered by regular application of organic and/or inorganic manure. This, in turn, leads to changed infiltration characteristics and subsequent watershed type.

3.2.3 Forest Watersheds

In forest watersheds, the ground is usually littered with leaves, stems, branches, wood, etc. Consequently, when it rains, the water is held by the trees and the ground cover and has greater opportunity to infiltrate.
The subsurface flow becomes dominant and there are times when there is little to no surface runoff. There is greater recharge of groundwater, because forests resist flow of water, the peak discharge is reduced, although inundation of the ground may be increased.

In forest watershed, flooding and flood damage downstream is reduced due to reduced surface-potential, stream development is much less. Plants and trees provide good protective cover to soil from erosion. Interception is significant, and evapotranspiration is a dominant component of the hydrologic cycle.

3.2.4 Mountainous Watersheds

The landscape of these watersheds is predominantly mountainous and has substantial vegetation, such that in some cases, they could be considered as forest watersheds. Interception is significant.

Due to steep gradient and relatively less porous soil, infiltration is less and surface runoff is dominantly high for a given rainfall event. Flash floods are a common occurrence.

The areas downstream of the mountains are vulnerable to flooding whenever there is a heavy rainfall in the mountains. Flooding in valleys downstream may be severe when there is rain in mountainous. Erosion is minimal if the mountainous are rocky. Sliding and collapsing of slopes are not uncommon occurrences during periods of heavy precipitation. Recharge of groundwater is small and evapotranspiration is considerable.

3.2.5 Desert Watersheds

There is little to virtually no vegetation in desert watersheds. The soil is mostly sandy and little annual rainfall occurs. Sand dunes and sand mounds are formed by blowing winds.

Stream development is minimal. Whenever there is little rainfall, most of it is absorbed by the porous soil, while some evaporates, and the remaining runs off only to be soaked in during its journey. There is limited opportunity for groundwater recharge due to limited rainfall.

3.2.6 Costal Watersheds

Coastal watersheds hydrology is considerably influenced by backwater from wave and tidal action. These watersheds receive high rainfall, mostly of cyclonic type, do not have channel control in flow, and are vulnerable to severe local flooding.

The water table is high, and saltwater intrusion threatens the health of coastal aquifers, which usually are a source of water supply. The land gradient is small, drainage is slow, and the soil along the coast has a considerable sand component. Coastal erosion is a continuing problem due to tidal action, and land-use change is common.

3.2.7 Marsh, Old Wetland, Watersheds

These lands are almost flat and comprised of swamps, marshes, water courses, etc. They have rich wildlife and plenty of vegetation. Evaporation is dominant, for water is no limiting factor to satisfy evaporative demand.

Rainfall is normally high and infiltration is minimal. Most of the rainfall becomes runoff, which discharges slowly for minimal land declivity. Erosion is also minimal, except along the coast. The flood hydrograph peaks gradually and lasts for a long time.

SELF-ASSESSMENT EXERCISE

i Differentiate between small and large watersheds.
ii Differentiate between costal and marsh watersheds.

4.0 CONCLUSION

Watershed are classified based on their sizes and land use, as small, large, urban watersheds, agricultural watersheds, forest watersheds, mountainous watersheds, desert watersheds, coastal watersheds and wetland/marsh watersheds.

5.0 SUMMARY

In this unit, you learnt that watersheds are classified either based on size or land use. You also learnt that the classification based on land use is as follows: small, large, urban watersheds, agricultural watersheds, forest watersheds, mountainous watersheds, desert watersheds, coastal watersheds and wetland/marsh watersheds.

6.0 TUTOR–MARKED ASSIGNMENT

Differentiate between agricultural and forest watersheds.

7.0 REFERENCES/FURTHER READING

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UNIT 2 WATERSHED CHARACTERISTICS

CONTENTS

1.0 INTRODUCTION

Watershed has several remarkable characteristics, which affect its functions such as receiving the incoming precipitation and disposal. These characteristics influence time of concentration of runoff generated by a rainfall, water drainage, soil loss, erodibility of channels, sediment production and the characteristics of hydrographs. The characteristics include size (area), shape, topography, geology, rock and soil, climate, vegetation, land use.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define watershed characteristics
- list the respective watershed characteristics
- describe the shape of a watershed.

3.0 MAIN CONTENT

3.1 Watershed Characteristics

Watershed characteristics are referred to as watershed geomorphology, which are the physical properties of watersheds. It significantly affects the characteristics of runoff and hydrological responses such as the flow regime during floods and periods of drought.

Similarly, the concentration time, which characterises the speed and intensity of the watershed's reaction to stress (rainfall), is also influenced by its characteristics. The principal watershed characteristics are:

- Size (area)
- Shape

- Topography
- Geology, rock and soil
- Climate
- Vegetation
- Land use.

3.1.1 Size

Size of watershed determines the quantity of rainfall received, retained and disposed of (runoff). The larger the watershed, the larger is the channel and storage of water in basin. Large watershed characteristics are topography, geology, soil, climate and use and vegetation. The effects of watershed sizes are as follows:

a) More intense rainfall events are generally distributed over a relatively smaller area, i.e., the larger the area; the lower will be the intensity of rainfall.

b) The peak normally decreases as the area of the watershed increases (peak flow per unit area).

c) Larger basins give a more constant minimum flow than the smaller ones (effect of local rains and greater capacity of the ground-water reservoir).

3.1.2 Shape

Watershed may have several shapes like square, triangular, rectangular, oval, palm, fern leaf shape etc. (Figure 2.1).The shape of a watershed influences the shape of its characteristic hydrograph.

Fan shaped watershed gives a greater runoff, because tributaries are nearly of same size and hence time of concentration of runoff is nearly same. On the contrary, discharges over fern leaf arrangement of tributaries are distributed over long period because of the different lengths of tributaries.

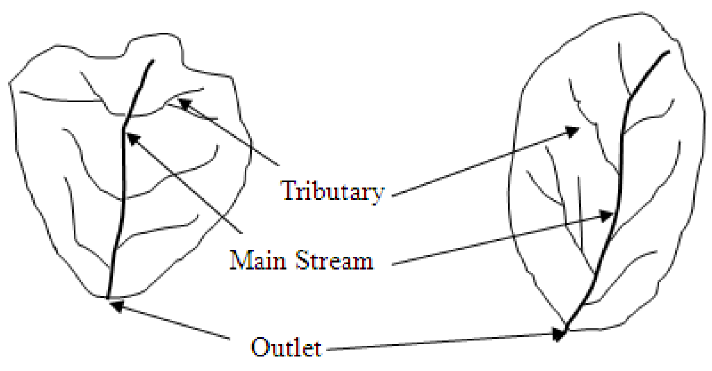

Fig.2.1: Fan Shaped and Leaf Shaped Catchments

Source: Subramanya, 2008

3.1.3 Topography

a. Slope: length, degree and uniformity of slope affect the momentum of runoff, disposal of water and soil loss. Degree and length of slope also affect time of concentration [Tc] and infiltration of water.

b. Drainage: Topography regulates drainage. Drainage density [length of all drainage channels – unit area], length, width depth of main and subsidiary channel, main outlet and its size depend on topography. Drainage pattern affect time of concentration.

3.1.4 Geology Rock and Soil

Geological formation and rock types affect extent of water erosion, erodibility of channels and hill faces, sediment production. Rocks like shale's, phyllites erode easily whereas igneous rocks do not erode. Geologic characteristics include surface and sub-surface soil type, rocks and their permeability. Geologic characteristics influence infiltration and percolation rates. The runoff will be more for low infiltration capacity soil (clay) than for high infiltration capacity soil (sand).

Physical and chemical properties of soil, especially texture, structure and soil depth influence disposition of water by way of infiltration, storage and runoff. Generally, soils with a significant portion of small particles have low infiltration capacity, whereas sandy soils have high infiltration capacity.

3.1.5 Climate

Climate parameters affect watershed functioning and its manipulation in two ways.

a. Rain provides incoming precipitation along with its various characteristic like intensity, frequency and amount of rainfall.

b. Parameters like rainfall, temperature, humidity, wind velocity, etc. regulates factors like soil and vegetation.

3.1.6 Vegetation

Depending upon the type of vegetation and its extent, this factor regulates the functioning of watershed such as infiltration, water retention, runoff production, erosion, sedimentation etc. During a rainstorm, flow from an impervious, steeply sloped, and smooth, surface make a little retardation and no loss to the flow. In comparison, flow along a pervious grassy hill of the same size will produce retardation and significant loss to the flow due to infiltration.

3.1.7 Land Use

Type of land use, its extent and management are the key factors which affect watershed behavior. Judicious land use by users (human beings) is of vital importance to watershed management and functioning.

3.1.8 Watershed Length

Watershed length is usually defined as the distance measured along the main channel from the watershed outlet to the basin divide. As the length increases, also the drainage increases. The length is usually used in computing a time parameter, which is a measure of the travel time of water through a watershed.

SELF-ASSESSMENT EXERCISE

Explain how shape and size of watersheds affects it characteristics.

4.0 CONCLUSION

Watershed size (area), shape, topography, geology, rock and soil, climate, vegetation and land use are some of the major factors that contributes to the functionalities of watersheds.

5.0 SUMMARY

The physiographical characteristics of watershed such as size (area), shape, topography, geology, rock and soil, climate, vegetation and land use, influences to a large degree its hydrological responses within watersheds.

6.0 TUTOR – MARKED ASSIGNMENT

1 Define watershed characteristics.
2 List the respective watershed characteristics.

7.0 REFERENCES/FURTHER READING

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MODULE 3 WATERSHED CONDITIONS AND PROBLEMS

UNIT 1 WATERSHED CONDITION

CONTENTS

1.0 INTRODUCTION

Watershed condition reflects a range of variability from natural pristine (functioning properly) to degraded (severely altered state or impaired). Watersheds that are functioning properly have terrestrial, riparian, and aquatic ecosystems that capture, store, and release water, sediment, wood, and nutrients within their range of natural variability for these processes.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- clearly discuss watershed conditions
- state the important characteristics of a healthy watershed.

3.0 MAIN CONTENT

3.1 Watershed Conditions

Watershed condition is the state of the physical and biological characteristics and processes within a watershed that affect the hydrologic and soil functions supporting aquatic ecosystems. Watershed condition reflects a range of variability from natural pristine (functioning properly) to degraded (severely altered state or impaired).

Watersheds that are functioning properly have terrestrial, riparian, and aquatic ecosystems that capture, store, and release water, sediment, wood, and nutrients within their range of natural variability for these processes. A functioning watershed creates and sustains functional terrestrial, riparian, aquatic, and wetland habitats that are capable of supporting diverse populations of native aquatic- and riparian-dependent species.

Watersheds that are functioning properly are commonly referred to as healthy watersheds and they have five important characteristics as follows:

1. They provide for high biotic integrity, which includes habitats that support adaptive animal and plant communities that reflect natural processes.
2. They are resilient and recover rapidly from natural and human disturbances.
3. They exhibit a high degree of connectivity longitudinally along the stream, laterally across the floodplain and valley bottom, and vertically between surface and subsurface flows.
4. They provide important ecosystem services, such as high quality water, the recharge of streams and aquifers, the maintenance of riparian communities, and the moderation of climate variability and change.
5. They maintain long-term soil productivity.

SELF-ASSESSMENT EXERCISE

Discuss the characteristics of a healthy watershed.

4.0 CONCLUSION

When watersheds are functioning properly, they create and sustain functional terrestrial, riparian, aquatic, and wetland habitats that are capable of supporting diverse populations of native aquatic- and riparian-dependent species.

5.0 SUMMARY

A healthy watershed functions properly and are characterised by conducive habitat, resilient to disturbance, high connectivity between the various components and good productivity.

6.0 TUTOR – MARKED ASSIGNMENT

1. Clearly discuss watershed conditions.
2. State the important characteristics of a healthy watershed.

7.0 REFERENCES/FURTHER READING

Sheng, T.C. (1990).Watershed Management Field Manual *Watershed Survey and Planning*: FAO, Conservation Guide 13/6 Food and Agriculture Organisation of the United Nations Rome.

Uditha Ratnayake. Engineering Hydrology Lecture Note.

UNIT 2 WATERSHED PROBLEMS

CONTENTS

1.0 INTRODUCTION

Major watershed problems vary from country to country, however with the growth in industrial and agricultural activities alongside increase in population and urbanisation. The demands on land and water resources have become greater.

Crop land expansion, increased use of industrial and agro-chemicals and the improper disposal of sewage effluents, water pollution has drastically increased. Similarly, removal of trees for timbers and resettlement, farm land clearance has greatly contributed to watershed degradations and problems. Most of these problems are interrelated and cannot easily be separated, however they can be grouped as socio-economic, technical/institutional and natural. Generally, these problems affect the quality and properties of watersheds.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- describe problems affecting watershed
- list human activities that degrades watersheds
- describe the effects of degradation on watersheds.

3.0 MAIN CONTENT

3.1 Problems Affecting Watershed Resources

1. Development and the creation of impervious surfaces, degrade water quality if proper treatment is not provided. It increases the quantity of storm water runoff, reduces the quantity of groundwater recharge which creates a potential deficit within

groundwater aquifers and decreases water quality within surface waters.

2. Human activity can degrade existing habitat and contribute to the loss of wildlife habitat quantity and quality affecting the overall ecological integrity of the resources within watershed.
3. Urbanisation (or development) has a great effect on local water resources. It changes how water flows in the watershed and what flows in the water. Both surface and groundwater are changed.
4. Pollution caused by humans is the biggest threat to our watersheds. There are two types of pollution, **point** and **non-point source pollution**.

   A. **Point source pollution** is "end of the pipe" pollution that can be identified as coming from a specific source such as a factory, industrial plant or some other facility. In the past, most environmental laws dealt with this particular form of pollution, however the most serious threat to our water quality is from non-point source pollution.

   B. **Non-point source pollution** are pollutants that are carried off the land by storm water into rivers, lakes, streams or the ocean. The water picks up pollutants left by human actions such as:

   - Fertilizer/pesticide use
   - Failure to pick up after pets
   - Dumping auto fluids down storm drains
   - Leaving grass clippings and leaves on paved surfaces
   - Washing cars on the street or driveway.

5. Changes in land use, development, and increases in impervious surface can negatively affect surface water runoff through reduction in infiltration, increasing in peak values of runoff hydrographs, and increasing volumes of storm water runoff; each of which can aggravate and create problems related to flooding, erosion and degradation in watersheds.
6. Eroding shorelines and stream banks contribute to the degradation of water quality within watersheds. This process can adversely affects downstream, improperly implemented and/or inappropriate stabilisation practices reduce the natural function and qualities of stream banks and shorelines, and may potentially contribute adverse effects downstream.
7. Development and creation of impervious surface contribute to the degradation of water quality and increase the quantity and rate of storm water runoff which affect downstream receiving waters.

8. Common activities conducted by citizens, developers, and public entities within watersheds have the potential to have an adverse effect on the quality and ecology of surface and ground waters.
9. Public ditches function as conveyances of drainage for private property and local communities serve to prevent flooding, however, such ditches have substantially changed forms and functions of watersheds.
10. Reduction of floodplain volume as a result of development and/or improper management contribute to increasingly higher critical water levels as well as risk to property and public safety; floodplains serve to reduce the frequency and severity of high water periods within the watershed.
11. Impaired waters, poor water quality, ecosystem degradation, and water quantity all influence the viability of waters as recreational resources; recreational enjoyment of water resources within watersheds.
12. Erosion of soil and sediment transport have a detrimental effect on the quality of water, the quality of habitat, detention time within basins, and capacity of storm water conveyances within watersheds.
    - In the stream, erosion of stream banks and scouring of channels can potentially occur due to decreased frequency and volume of runoff. This degrades habitat for plant and animal life that depend on clear water.
    - Sediment from eroded stream banks clogs the gills of fish and blocks light needed for plants. The sediment settles to fill in stream channels, lakes and reservoirs, thus increases the chances of flooding.
13 Local municipal regulation alone oftentimes is unable to provide an acceptable standard of protection for watersheds across multiple political boundaries.
14 Citizens become disenfranchised with government when it is perceived that the opinion of individuals is insignificant, when it comes to watershed management. This affects both the maintenance and running of watersheds.

3.2 Effects of Watershed Degradation

Watershed problems results in the degradation of watersheds with resultant impact as follows:

- Reduced tree and vegetative cover
- Reduced water availability and quality
- Reduced productivity of land, increased siltation of rivers and reservoirs due to soil erosion
- Increased marine and coastal contamination and degradation adversely affecting the tourism industry

- Increased flooding resulting in loss to human life, property, roads and agricultural crops
- Loss of habitat for important flora and fauna.

SELF-ASSESSMENT EXERCISE

Explain the problems affecting watershed resources.

4.0 CONCLUSION

Human activities and natural events, such as urbanisation, (or development), public ditches, pollution, changes in land use, erosion of shorelines and stream banks, sediment deposition from eroded stream and reduction of floodplain have caused watersheds problems . These problems have resulted in reduced tree and vegetative cover, water availability and quality, reduced productivity of land, increased siltation of rivers and reservoirs, increased marine and coastal contamination, increased flooding resulting in loss to human life, property, roads and agricultural crops and loss of habitat for important flora and fauna.

5.0 SUMMARY

Most watershed problems are interrelated and cannot easily be separated, however they can be grouped as socio-economic, technical/institutional and natural. These can be considered as development and the creation of impervious surfaces, human activities, urbanisation, (or development), pollution, changes in land use, erosion of shorelines and stream banks, sediment deposition from eroded stream, public ditches, reduction of floodplain volume and citizens become disenfranchised with government policies. All these affect both the maintenance and running of watersheds.

6.0 TUTOR – MARKED ASSIGNMENT

1. List human activities that degrade watersheds.
2. Describe the effects of degradation on watersheds.

7.0 REFERENCES/FURTHER READING

Sheng, T.C. (1990). Watershed Management Field Manual *Watershed Survey and Planning*: FAO, Conservation Guide 13/6 Food and Agriculture Organisation of the United Nations Rome.

Uditha Ratnayake. Engineering Hydrology Lecture Note.

MODULE 4 HYDROLOGY

UNIT 1 HYDROLOGICAL PROCESSES

CONTENTS

1.0 INTRODUCTION

Hydrology is a branch of scientific and engineering discipline that deals with the occurrence, distribution, movement, and properties of the water of the earth. Knowledge of hydrology is fundamental to water and environment professionals (Engineers, Scientists and decision makers) in such tasks as the design and operation of water resources, waste water treatment, irrigation, and flood risk management, navigation, pollution, hydropower, ecosystem modeling, etc.

The hydrological system integrates several processes such as rainfall, evapotranspiration, surface runoff, unsaturated flow and saturated subsurface water movement. Water, a renewable resource, is continually recycled and returned to the ecosystem through the hydrologic cycle.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define hydrology
- list the different types of water on earth
- describe the main hydrological processes.

3.0 MAIN CONTENT

3.1 Definition of Hydrology

Hydro means water, and **logy** means study, thus **hydrology**, can be defined as a study of water, which implies the science of water that encompasses the study of the occurrence, movement distribution, circulation, storage, exploration, development, and management of water on and beneath the surface of the earth.

The definition of hydrology encompasses some aspects of a multitude of disciplines involving agriculture, biology, chemistry, geography, geology, glaciology, meteorology, oceanography, physics, volcanology and many other disciplines.

Hydrology may also be defined as the study of water, its physical properties and distribution on and beneath the surface of the earth.

3.2 Hydrologic System

The hydrological system integrates several processes such as rainfall, evapotranspiration, surface runoff, unsaturated flow and saturated subsurface water movement.

Water is continually moving around, through and above the earth. It moves as water vapor, liquid water, and ice, thus constantly changing its form.

Water on Earth is known by different terms, depending on where it is and where it came from.

1. **Meteoric water -** is water in circulation
2. **Connate water -** "fossil" water, often saline
3. **Juvenile water -** water that comes from the interior of the earth
4. **Surface water -** water in rivers, lakes, oceans and so on
5. **Subsurface water -** Groundwater, connate water, soil, capillary water
6. **Groundwater -** exists in the zone of saturation, and may be fresh or saline.

3.3 Hydrologic Processes

Hydrologic processes encompass a suite of space and time scales; from thunderstorms that occur over the course of minutes to hours and space scales of a few kilometers or less to the development of major river basins taking place over millions to tens of millions of years and space scales of 1000-10,000km.

Four main aspects of the hydrological processes are addressed:

Rainfall interception
Interception is the process of interrupting the movement of water in the chain of transportation events leading to streams. The interception can take place by vegetal cover or depression storage in puddles and in land formations such as rills and furrows.

When rain first begins, the water striking leaves and other organic materials spreads over the surfaces in a thin layer or it collects at points or edges.

When the maximum surface storage capability on the surface of the material is exceeded, the material stores additional water in growing drops along its edges. Eventually, the weight of the drops exceeds the surface tension and water falls to the ground. Wind and the impact of rain drops can also release the water from the organic material. The water layer on organic surfaces and the drops of water along the edges are also freely exposed to evaporation.

Runoff generation
Runoff is flow from a drainage basin or watershed that appears in surface streams. It generally consists of the flow that is unaffected by artificial diversions, storages or other works that society might have on or in a stream channel. The flow is made up partly of precipitation that falls directly on the stream, surface runoff that flows over the land surface and through channels, subsurface runoff that infiltrates the surface soils and moves laterally towards the stream, and groundwater runoff from deep percolation through the soil horizons.

Part of the subsurface flow enters the stream quickly, while the remaining portion may take a longer period before joining the water in the stream. When each of the component flows enters the stream, they form the total runoff. The total runoff in the stream channels is called stream flow and it is generally regarded as direct runoff or base flow.

Sediment transport
Sedimentation is the process of soil and rock detachment (erosion), transport, and deposition of soil and rock by the action of moving water. Eroded materials ran sported by water when deposited results in pollution. Movement of soil and rock by water occurs in three stages as follows:

1. particles or aggregates are eroded or detached from the soil or rock surface.
2. detached particles or aggregates are transported by moving water or wind.
3. when the water velocity slows or the wind velocity decreases, the soil and rock being transported are deposited as sediment at a new site.

SELF-ASSESSMENT EXERCISE

i Define hydrology.
ii Describe the main hydrological processes.

4.0 CONCLUSION

The water cycle is one of the largest physical processes on Earth, which is driven by energy from the sun and by the force of gravity, it supplies all of the water needed to support life. Water moves as water vapor, liquid water, and ice, thus constantly changing its form. Water on Earth is known by different terms such as meteoric water, connate water, juvenile water, surface water, subsurface water, and groundwater. Hydrological processes can be addressed in terms of rainfall interception, runoff generation and sediment transport.

5.0 SUMMARY

Hydrology is concerned with the origin, distribution, and properties of water on the globe. Water enters the system as either precipitation directly on the lake surface, runoff from the surrounding land, groundwater, or inflow from upstream lakes. Water is therefore a renewable resource, is continually recycled and returned to the ecosystem through the hydrologic cycle.

6.0 TUTOR – MARKED ASSIGNMENT

1. Describe problems affecting watershed.
2. List human activities degrades watersheds.

7.0 REFERENCES/FURTHER READING

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UNIT 2 HYDROLOGIC CYCLE

CONTENTS

1.0 INTRODUCTION

The hydrologic cycle generally describes the circulation of water from the ocean to the atmosphere to the earth's surface and back to the ocean again. Solar energy evaporates water from the ocean; wind carries the water vapor over the land surface; and water is precipitated by gravity back to earth. Rain is the common form of precipitation, but hail, dew, fog drip, and frost can also bring water into a watershed. The components of hydrological cycle include evaporation, transpiration, condensation, precipitation, infiltration and ground water.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- study hydrologic cycle in general aspect
- explain the hydrological components like evaporation, precipitation, infiltration, runoff condensation.

3.0 MAIN CONTENT

3.1 The Hydrologic Cycle or Water Cycle

The hydrologic cycle or water cycle represents the process and pathways involved in the circulation of water from land and water bodies to the atmosphere and back again Figures2.1 and 2.2.The water cycle is one of the largest physical processes on Earth, which is driven by energy from the sun and by the force of gravity, it supplies all of the water needed to support life.

Generally, the hydrologic cycle (Figures 2.1 and 2.2) describes the circulation of water from the ocean to the atmosphere to the earth's surface and back to the ocean again. Oceans, covering 70% of the earth's surface, play a large role in the movement of water through this cycle.

Solar energy evaporates water from the ocean; wind carries the water vapor over the land surface; and water is precipitated by gravity back to earth. Rain is the common form of precipitation, but snow, hail, dew, fog drip, and frost can also bring water into a watershed (imported water may also be introduced into the hydrologic cycle in any particular watershed). Precipitation that reaches the surface of the earth can move through three different pathways.

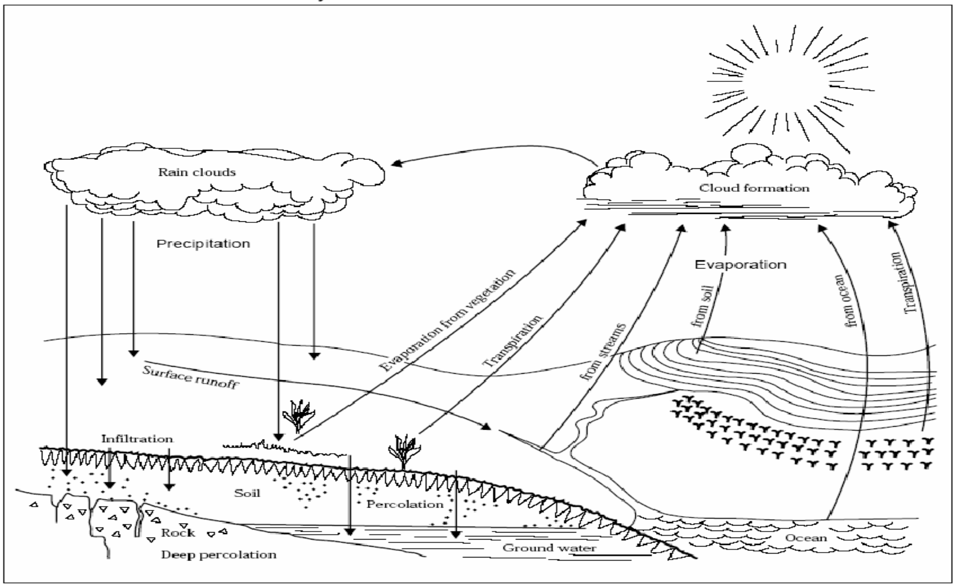

Fig.2.1: The Hydrologic Cycle

Source: NRCS

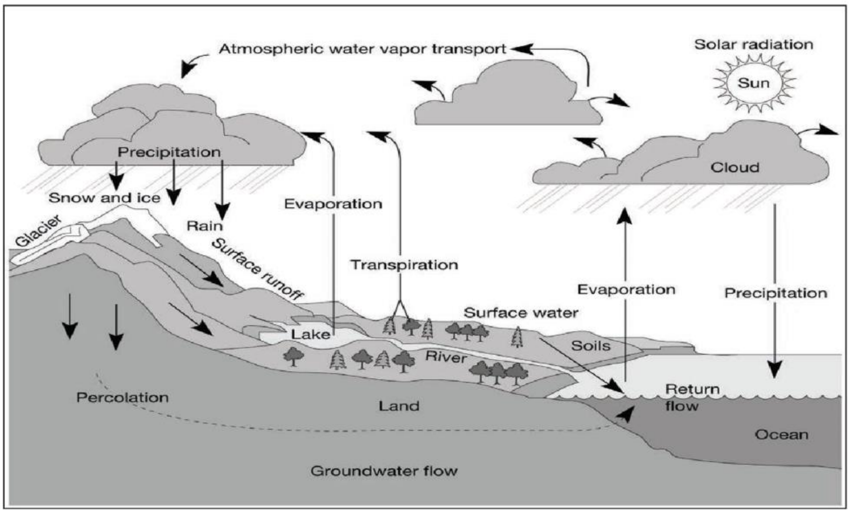

Fig.2.2: The Water Cycle

Source: Dr. Fred Mackenzie, University of Hawai'i at Manoa

Water, a renewable resource, is continually recycled and returned to the ecosystem through the hydrologic cycle. There is no beginning or end to the water cycle, it is always happening, no matter what.

3.2 Components of Water Cycle

The components of the water cycle include evaporation, condensation, precipitation, transpiration and runoff.

3.2.1 Evaporation

Evaporation occurs when the water in lakes, oceans, rivers and streams (surface water) is heated by the sun and converted to a gas called **water vapor**.

Evaporation requires the following four conditions:

i. available water
ii. higher humidity at the evaporative surface (i.e., vapour pressure) than in the surrounding air
iii. energy to evaporate the water
iv. movement, or transfer, of water vapour away from the evaporative surface.

Energy required to evaporate water depends on incoming solar radiation, reflectivity of the evaporative surface, and air and surface temperature. Approximately 80 percent of all evaporation on Earth originatesin oceans, with the remaining 20 percent occurring from inland water sources (streams, rivers, lakes, etc.) and vegetation.

3.2.2 Condensation

This is a process by which water vapor returns to its original liquid state. It may also be referred to as the process by which water vapor is converted into precipitation.

It typically occurs in the atmosphere when warm air rises, cools, and, as a result, loses its capacity to hold water vapor. Excess water vapor then condenses to form clouds. Condensation in the atmosphere may also be visible as fog, mist, dew or frost, depending on the physical conditions of the atmosphere.

3.2.3 Precipitation

Precipitation occurs when the condensed water vapour in the clouds become too heavy to remain suspended in the air, it therefore falls to the Earth as rain, sleet, hail or snow. Precipitation is a major component of the water cycle and it is the primary source of the fresh water found on the surface of the earth.

Several factors affect the movement of precipitation once it lands in the watershed. On ceprecipitation reaches the Earth, it can follow one of five pathways:

1. It can be absorbed by plants and utilised in various biological processes.
2. It can filter through the soil profile and end up as groundwater, water that is stored in underground layers of rock and sand known as aquifers.
4. It can be stored in ice caps and glaciers, which can store frozen water for thousands of years.

3.2.4 Transpiration

Transpiration is the biological process that occurs mostly in the day. Water inside of plants is transferred from the plant to the atmosphere as water vapor through numerous individual leave openings referred to as stomata.

Plants transpire to move nutrients to the upper portion of the plants and to cool the leaves exposed to the sun. Leaves undergoing rapid transpiration can be significantly cooler than the surrounding air. Water can be transpired freely by plants until a water deficit develops in the plant and stomata begin to close. Transpiration then continues at a must slower rate. Only a small portion of the water that plants absorb are retained in the plants.

Vegetation generally retards evaporation from the soil by shading the soil and reducing the wind velocity. Transpiration to the atmosphere reduces the amount of direct evaporation from the soil.

The stomata regulate water loss to maintain an appropriate water status in the leaves by balancing the atmospheric demand for water with the ability of the roots to supply water from the soil. Once evaporative demand reaches a certain level, even though the soil is moist, the stomata begin to close, which maintains evaporation at a constant level. There are species differences in the ability to regulate water loss. Transpiration is greatly affected by the species of plants that are in the soil and it is strongly affected by the amount of light to which the plants are exposed. Trees usually have higher stomata resistances to water loss than shrubs and grass.

3.2.5 Runoff

Runoff is flow from a drainage basin or watershed that appears in surface streams. It generally consists of the flow that is unaffected by artificial diversions, storages or other works that society might have on or in a stream channel.

The flow is made up partly of precipitation that falls directly on the stream, surface runoff that flows over the land surface and through channels, subsurface runoff that infiltrates the surface soils and moves laterally towards the stream, and groundwater runoff from deep percolation through the soil horizons.

Runoff occurs when the rate of precipitation exceeds the rate at which the water can be absorbed into the soil. Runoff also occurs when waterfalls onto an **impermeable** surface, such as a parking lot or a sidewalk, where it can’t easily be absorbed into the soil.

Generally hydrologic cycle can be considered as:

1) Water can be intercepted by vegetation and evaporated or transpired back to the atmosphere.

2) Water can move down slope on the surface or through the soil to a stream system, eventually making its way back to the ocean.

3) Water can be stored in groundwater, ponds, or wetlands for a variable period of time.

Heat from the sun can evaporate water from any point in the cycle, from the surface of the vegetation, ground, or water bodies. The rate of evaporation in a watershed is dependent on the water surface area exposed to the air, temperature, humidity, and wind and transpiration, which is the loss of water to the atmosphere through living plants.

Water storage in soil

Water is held in the soil by cohesive forces between water molecules and adhesive forces between water molecules and soil particles. Films of water cover the solid particles, and as the soil becomes wetter, water sequentially fills the smallest pores through to the largest pores. The amount of water stored within the soil is typically expressed in one of four ways: (1) gravimetric, (2) volumetric, (3) relative saturation, and (4) depth of water.

SELF-ASSESSMENT EXERCISE

i Draw a typical hydrologic cycle, showing the various components.
ii Explain these hydrological terms: condensation, interception, percolation and transpiration.

4.0 CONCLUSION

The hydrological cycle is a conceptual model that describes the storage and movement of water between the biosphere, lithosphere and the atmosphere. Water moves from one reservoir to another by way of processes like evaporation, condensation, precipitation, interception, infiltration, percolation, transpiration, runoff, and storage.

5.0 SUMMARY

A fundamental characteristic of the hydrologic cycle is that it has no beginning and it has no end. It can be studied by starting at any of the following processes: evaporation, condensation, precipitation, interception, infiltration, percolation, transpiration, runoff, and storage.

6.0 TUTOR – MARKED ASSIGNMENT

1 What are the components of hydrological cycle?
2 Describe the under listed hydrological properties: evaporation, precipitation, infiltration, runoff, and subsurface flow.

7.0 REFERENCES/FURTHER READING

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UNIT 3 SURFACE AND GROUND WATER

CONTENTS

1.0 INTRODUCTION

Water in rivers, lakes, oceans and so on, is referred to as Surface water, it is naturally replenished by precipitation and naturally lost through discharge to evaporation and sub-surface seepage into the groundwater.

Groundwater is water that exists in the pore spaces and fractures in rocks and sediments beneath the earth's surface. It originates as rainfall, and then moves through the soil and rock into the groundwater system, where it eventually makes its way back to the surface streams, lakes, or oceans.

Groundwater occurs in the sub-surface in two broad zones: the unsaturated zone and the saturated zone. The unsaturated zone, also known as the vadose zone, consists of soil pores that are filled to a varying degree with air and water. The zone of saturation consists of water-filled pores that are assumed to be at hydrostatic pressure.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define surface and sub-surface
- describe types of groundwater on earth.
- state the importance of ground water.

3.0 MAIN CONTENT

3.1 Surface Water

Water in rivers, lakes, oceans and so on, is referred to as surface water; it is naturally replenished by precipitation and naturally lost through discharge to evaporation and sub-surface seepage into the groundwater.

Water beneath the land surface occurs in two principal zones, the unsaturated zone and the saturated zone. In the unsaturated zone, the voids—that is, the spaces between grains of gravel, sand, silt, clay, and cracks within rocks—contain both air and water. In contrast to the unsaturated zone, the voids in the saturated zone are completely filled with water. Water in the saturated zone is referred to as ground water. The upper surface of the saturated zone is referred to as the water table.

3.1.1 Water Body

A water body refers to any stream, river, pond, lake, estuary or ocean. Water bodies can be flowing (**lotic**) systems (streams and rivers) or non-flowing (**lentic**) systems (ponds and lakes). The flow of water in these systems, particularly in rivers and streams, is greatly affected by the natural features of the watershed (including the topography, slope, soils and vegetation).

Surface water is exposed to many different contaminants, such as animal wastes, pesticides, insecticides, industrial wastes, algae and many other organic materials.

3.2 Groundwater

Groundwater refers to water that completely fills pore spaces within the zone of saturation beneath the Earth's surface. All geologic materials are composed of solids (i.e., actual grains, sediment, or rock matrix) and pore space (i.e., voids).Most groundwater comes from precipitation, which gradually percolates into the earth. Typically, 10–20% of precipitation eventually enters aquifers.

The amount of available pore space and the interconnectivity of pores govern the storage and transmission of groundwater. Ground water, like runoff, flows from a higher to lower elevation, however geologic structure and formations also control its flow.

Areas in which the pore spaces are completely filled with water are called the saturated zone. Above the saturated zone is an area in which the pore spaces are filled with air and water called the unsaturated orvadosezone (Figure 3.1).

The distinction between saturated and unsaturated sub-surface zones is based on location of the water table, which is found at the top of the saturated zone (Figure 3.1), where the pore water pressure is equal to atmospheric pressure.

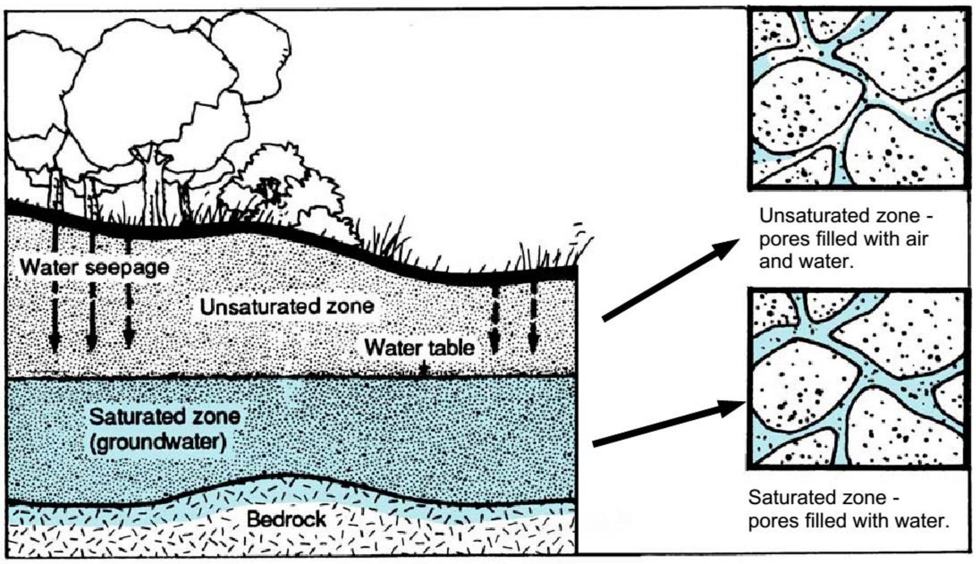

Fig.3.1: Typical Water Table

The water-bearing soil or rock that is capable of yielding usable amounts of water is called an **aquifer**. There are two major types of aquifers: confined and unconfined.

3.2.1 Confined Aquifers

Confined aquifers (also known as artesian or pressure aquifers)**:** exist where the groundwater system is between layers of clay, dense rock, or other materials with very low permeability. Water in confined aquifers may be very old, even millions of years old. This water is under more pressure than water in unconfined aquifers. Thus, when tapped by a well, water is forced up, sometimes above the soil surface. This is how a flowing artesian well is formed.

3.2.2 Unconfined Aquifers

More common than confined aquifers, unconfined aquifers have a permeable deposit that leads into the aquifert. Water may have arrived by percolating through the land surface. This is why water in an unconfined aquifer is often very young, in geologic time. The top layer of the aquifer is also the water table. Thus, it's affected by atmospheric pressure and changing hydrologic conditions.

3.3 Importance of Underground Water

Groundwater contributes to the generation and regulation of stream flow in watersheds, and the sustainability of many wetlands, ponds, and lakes.

1. Nearly 95% of rural residents rely on groundwater for their drinking supply.
2. About half of irrigated cropland uses groundwater.
3. Approximately one third of industrial water needs are fulfilled by using groundwater.
4. About 40% of river flow nationwide (on average) depends on groundwater.

SELF-ASSESSMENT EXERCISE

i. Explain the term water body.
ii. Describe types of groundwater on Earth.

4.0 CONCLUSION

Surface water is water collecting on the ground or in a stream, river, lake, wetland, or ocean. Groundwater is water that exists in the pore spaces and fractures in rocks and sediments beneath the earth's surface.

5.0 SUMMARY

Surface water is water collecting on the ground or in a stream, river, lake, wetland, or ocean; it is related to water collecting as groundwater or atmospheric water. Surface water is naturally replenished by precipitation and naturally lost through discharge to evaporation and sub-surface seepage into the groundwater.

Water in rivers, lakes, oceans and so on, is referred to as surface water, while groundwater occurs in the sub-surface in two broad zones: the unsaturated zone and the saturated zone. The unsaturated zone, also known as the vadose zone, consists of soil pores that are filled to a varying degree with air and water. The zone of saturation consists of water-filled pores that are assumed to be at hydrostatic pressure.

6.0 TUTOR – MARKED ASSIGNMENT

1. Define surface and sub-surface.
2. State the importance of ground water.

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UNIT 4 WATER POLLUTION

CONTENTS

1.0 INTRODUCTION

Water pollution is any chemical, physical or biological change in the quality of water that has a harmful effect on any living thing that drinks or uses or lives in it. Main sources of water pollution can be regarded as either belonging to a single source as emissions from factories into the water known as **point source pollution** or pollutants could also be emitted from multiple sources, thus referred to as **non-point source pollution.** Contaminated water after rains that has traveled through several regions may be considered as a non-point source of pollution. Water could be polluted as a result of many activities carried out by man; this includes chemical contamination from waste sites, chemical wastes from industrial discharges, heavy metals such as mercury and lead, sewage waste, food processing waste, fertilizers and pesticides from agricultural activities.

2.0 OBJECTIVES

At the end of this unit, you should be able:

- define water pollution
- explain the main sources of water pollution
- describe the various types of water pollutants
- enumerate the various causes of water pollution.

3.0 Main Content

3.1 Water Pollution

Water pollution occurs when water is contaminated with chemicals and foreign substances that are harmful to humans, plants and

animals. It is caused by the presence of man-made chemicals or other alteration in the natural soil environment.

Water pollutants include chemical contamination from waste sites, chemical wastes from industrial discharges, heavy metals such as mercury and lead, sewage waste, food processing waste, fertilizers and pesticides.

3.2 The Classes of the Source of Water Pollutants

3.2.1 Point Source Pollution

This type of pollutant is discharged at a specific source such as a leaking pipe or a holding tank with a hole in it, polluted water leaving a factory, or garbage being dumped into a river. These sources of pollution are easy to identify because the cause of the pollution can be observed.

3.2.2 Non-point Sources

Non-point sources of water pollution affects a water body from sources suchas polluted runoff from agricultural areas draining into a river, or wind-borne debris blowing out to sea. Non-point pollution may involve a broad range of pollutants usually at lower amounts than the point sources. This type of pollution is difficult to identify and may come from pesticides, fertilizers, or automobile fluids washed off the ground by a storm.

3.3 Causes of Water Pollution

The most common causes of water pollution are as follows:

3.3.1 Agricultural Activities

The uses of fertilizers, pesticides/insecticides/herbicides are the major agricultural pollutants which contaminates water bodies through run-off and seepage. Where the land is available, the wastes from farm animals also contribute to water pollution.

3.3.2 Storm Water Runoff

Storm water carrying various oils, petroleum products and other contaminants from urban and rural areas (ditches) also aims in water pollution. They usually form sheens on the water surface.

3.3.3 Leaking Sewer Lines

Leaking sewer lines may add trihalomethanes (such as chloroform) as well as other contaminants into groundwater ending up contaminating surface water, too. Discharges of chlorinated solvents from Dry Cleaners to sewer lines are also a recognised source of water pollution with these persistent and harmful solvents.

3.3.4 Mining Activities

Mining activities involve crushing the rock that usually contains many trace metals and sulfides. The left material may easily generate sulfuric acid in the presence of precipitation water. Please, read more at mining sites.

3.3.5 Foundries

Foundries have direct emissions of metals (including Hg, Pb, Mn, Fe, Cr and other metals) and other particulate matter into the air.

3.3.6 Industrial Discharges

Discharges from industries add significant pollutant to water bodies, thus resulting in water pollution.

3.3.7 Accidental Leaks and Spills

Accidental leaks and spills associated with handling and storage of chemicals may happen anytime and, although they are usually contained soon after they occur, the risk of polluting surface and groundwater exist.

3.3.8 Intended/Illegal Discharges of Waste

Intended/illegal discharges of waste occurrences are less common today, however they still happen due to the high cost of proper waste disposal.Illegal waste discharges into water bodies were recorded all over the world.

3.3.9 Burning of Fossil Fuels

Emitted ash particles from fossil fuels usually contain toxic metals (such as As or Pb). Burning also add a series of oxides including carbon dioxide to air and respectively water bodies.

3.3.10 Transportation

Vehicle emissions pollute the air with various tailpipe compounds (including sulfur and nitrogen compounds, as well as carbon oxides) that may end up in water bodies via deposition with precipitation water.

3.3.11 Construction Activities

Construction activities introduce a series of contaminants into the ground that may eventually end up in groundwater.

3.3.12 Plastic Materials/Wastes in Contact with Water

Plastic materials may degrade slowly releasing harmful compounds into water bodies, which are harmfulto both human health and ecosystem.

3.3.13 Disposal of Personal Care Products and Household Chemicals

Household waste such as detergents and various cleaning solutions posesserious problem as their releases into water are unpredictable and hard if not impossible to control. It is up to each of us to minimise this contribution to water pollution by controlling our consumption and disposal of such products as well as trying to recycle such waste water.

3.3.14 Improper Disposal of Car Batteries and Other Batteries

These are sources of heavy metals in water, when they decomposed and release their contents.

3.3.15 Leaking Landfills

Leaking landfills may pollute the groundwater below the landfill, with a large variety of contaminants (whatever is stored by the landfill).

3.3.16 Animal Wastes

These also contribute to the biological pollution of water streams.

3.3.17 Sediments

Sediment of suspended matter is another class of water pollutants. These are insoluble particles of soil and other solids that become suspended in water. This occurs when soil is eroded from the land.

High levels of soil particles suspended in water, interferes with the penetration of sunlight. This reduces the photosynthetic activity of aquatic plants and algae disrupting the ecological balance of the aquatic bodies. When the velocity of water in streams and rivers decreases, the suspended particles settle down at the bottom as sediments.

3.3.18 Hot Water let out by Power Plants and Industries

Industries that use large volumes of water to cool their plants; results in rise in temperature of the local water bodies. Thermal pollution occurs when industry returns the heated water to a water source. Power plants heat water to convert it into steam, to drive the turbines that generate electricity; this is also good sources of water pollution.

SELF-ASSESSMENT EXERCISE

i. Differentiate point source and **non-point source** pollution.
ii. Describe the various causes of water pollution.

4.0 CONCLUSION

Water could be polluted due to many activities carried out by man; this includes chemical contamination from waste sites, chemical wastes from industrial discharges, heavy metals such as mercury and lead, sewage waste, food processing waste, fertilizers and pesticides from agricultural activities.

5.0 SUMMARY

Water pollution means one or more substances have built up in water to such an extent that they cause problems for animals or humans. Water pollution occurs through variety of pollutants such as organic chemicals, which include oil, gasoline, plastics, and pesticides, cleaning solvents, detergent and many other chemicals.

These pollutants are harmful to aquatic life and human health. They get into the water directly from industrial and household activities, either from improper handling of the chemicals and more often from improper and illegal disposal of chemical wastes.

6.0 TUTOR – MARKED ASSIGNMENT

1) State the main sources of water pollution.
2) Discuss the various causes of water pollution.

7.0 REFERENCES/FURTHER READING

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MODULE 5 CHANNEL PROCESSES

UNIT 1 CHANNEL PROCESSES

CONTENTS

1.0 INTRODUCTION

Channel processes reflected in river morphology are erosion, transportation and sedimentation, these processes develop drainage basins.

Erosion predominates in the upper reach area of a drainage basin, and valleys composed of channels and slopes are formed. The materials brought to the lower reaches in a channel are sediment load.

Weathering of the rocks composing slopes is the main cause of production of sediment load, which are transported as traction, saltation, suspension and solution.

Sediment load is deposited to form an alluvial plain as a result of a reduction in the gradient of the river, reduced discharge, shallow water, increase in the size of the load overtop floods by the river.

River morphology is explained by channel patterns and channel forms, and is decided by such factors as discharge, water surface slope, water velocity, depth and width of the channel, and river bed materials.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define channel processes
- list the factors that determine sedimentation in river morphology

- describe the main ways of load transport by river channels.

3.0 MAIN CONTENT

3.1 Channel Processes

The work of a river involves three main processes: erosion, transportation and deposition. At any one time the dominant process operating within the river depends on the amount for energy available. This is governed by the velocity of the flow and the amount of water flowing within the channel (discharge).

Erosion predominates in the upper reach area of a drainage basin, and valleys composed of channels and slopes are formed. The materials brought to the lower reaches in a channel are sediment load. Weathering of the rocks composing slopes is the main cause of production of sediment load. Sediment load is deposited to form an alluvial plain.

Three basic channel patterns are detected in alluvial plains; these are braided, meandering and straight. River morphology is explained by channel patterns and channel forms, and is decided by such factors as discharge, water surface slope, water velocity, depth and width of the channel, and river bed materials, etc. These factors are not independent but inter-related to each other. The main channel processes are:

3.1.1 Erosion

Erosion is a hydraulic action and is derived from the energy of running water. Gravel being brought by running water scours the channel and removes sediment from the river bed.

Erosion makes a channel broader and deeper. These processes are also called lateral erosion and deepening erosion respectively. If deepening erosion predominates, a canyon is formed. Lateral erosion forms a channel with a broader river bed.

Valleys in mountains can be very deep, and are formed not only by stream water, but also by the effects of weathering. The rocks composing slopes have been weathered for a long period of time, and become rock fragments or rock wastes including other fine materials. Gravity, in combination with heavy rain falling on the slopes, causes the weathered materials to fall down into the valley bottom. These processes result in downstream extension of the valley and retreat of the upper slopes. The weathered materials deposited in a valley bottom are scoured by running water and carried to the lower reaches.

3.1.2 Transportation

The higher the water velocity, the more capacity a river has for transporting sediment load. A river obtains its load from two main sources:

- Material that has been washed, or has fallen, into the river from the valley sides.
- Material that has been eroded by the river itself from the bed or banks.

A river transports its load in four main ways (Figure 1.1)

3.1.2.1 Traction

Large stones and boulders are slides or rolled along sand hops or bounds on the river bed by water moving downstream. This mainly happens during periods of high discharge and consequently high energy levels.

3.1.2.2 Saltation

Small stones bounce or leap-frog along the channel bed. This process is associated with relatively high energy conditions. Small particles may be thrust up from the bed of the river only to fall back to the bottom again further downstream. As these particles land they in turn dislodge other particles upwards, causing more such bouncing movement to take place.

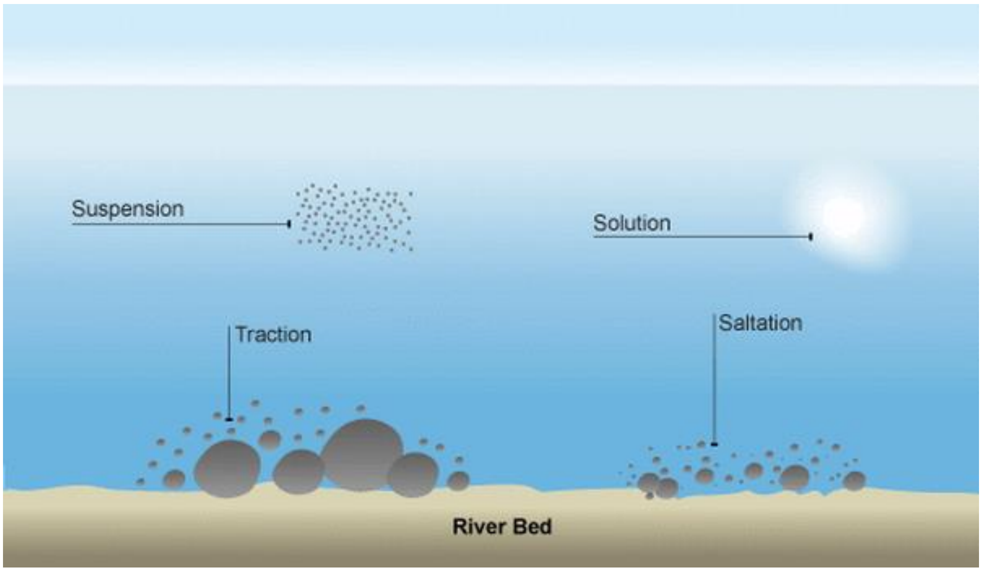

Fig.1.1: River Transport Mechanisms

3.1.2.3 Suspension

Very small particles of sand and silt are carried along by the flow of the river. Such material is not only carried but it is also picked up, mainly through the turbulence that exists within the river. Suspension normally contributes the largest proportion of sediment to the load of the river. The suspended load is the main cause of the brown appearance of many rivers and streams.

3.1.2.4 Solution

Dissolved minerals are transported with the mass of moving water. The faster flowing a river is, the greater the turbulence and therefore the river is better able to lift particles from the river bed.

3.1.3 Sedimentation

This process takes place when eroded materials are being dropped, it occurs when a river loses energy. A river can lose its energy when rainfall reduces, evaporation increases, friction close to river banks and shallow areas which leads to the speed of the river reducing and therefore the energy reduces, when a river has to slow down, it reduces its speed (and ability to transport material) and when a river meets the sea.

Particles of bed load are deposited in order of their size, and an alluvial plain is formed. An alluvial fan composed of gravel is formed in the uppermost reaches of an alluvial plain. Clayey deposits distribute in back swamps are lower and wetter than natural levees.

Generally, conditions that favours sedimentation can be summarised as follows:

a When there is a reduction in the gradient of the river
b When the discharge is reduced
c When there is shallow water
d When there is an increase in the caliber (size) of the load
e When the river floods and overtops its banks.

SELF-ASSESSMENT EXERCISE

Explain the factors that determine sedimentation in river morphology.

4.0 CONCLUSION

River morphology is explained by channel patterns and channel forms, and is decided by such factors as discharge, water surface slope, water velocity, depth and width of the channel, and river bed materials.

5.0 SUMMARY

The main channel processes or fluvial processes are erosion, transportation and sedimentation. Erosion predominates in the upper reach area of a drainage basin, and valleys composed of channels and slopes are formed. The materials brought to the lower reaches in a channel are sediment load. Weathering of the rocks composing slopes is the main cause of production of sediment load. Sediment load is deposited to form an alluvial plain. An alluvial fan composed of gravel is formed in the uppermost reaches of an alluvial plain. Clayey deposits distribute in back swamps are lower and wetter than natural levees.

6.0 TUTOR – MARKED ASSIGNMENT

1. Describe Channel processes.
2. Describe the main ways of load transport by river channels.

7.0 REFERENCES/FURTHER READING

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UNIT 2 EROSION

CONTENTS

1.0 INTRODUCTION

Running water carries out two processes. One is erosion and the other is corrosion. Erosion is a hydraulic action and is derived from the energy of running water. Gravel being brought by running water scours the channel and removes sediment from the river bed. Erosion makes a channel broader and deeper. These processes are also called lateral erosion and deepening erosion respectively.

Lateral erosion forms a channel with a broader river bed. Stream water reacts chemically with rocks and dissolves them. This process is called corrosion.

The weathered materials deposited in a valley bottom are scoured by running water and carried to the lower reaches. Mechanism of water erosion includes, abrasion, hydraulic, corrosion and attrition.

2.0 OBJECTIVES

At the end of this unit, you should be able:

- define and describe erosion
- explain the various mechanisms involved in channel erosion.

3.0 MAIN CONTENT

3.1 Erosion

Erosion is the wearing away of the land surface by rain or irrigation water, wind, ice or other natural or anthropogenic agents that abrade, detach and remove soil from one point on the earth's surface and deposit it elsewhere.

3.2 Mechanisms of Channel Erosion

The three steps common to water erosion are:

3.2.1 Abrasion

The scraping, scouring and rubbing action of materials carried along by a river (load). Rivers carry rock fragments in the flow of the water or drag them along the bed, and in doing so wear away the banks and bed of the river channel.

3.2.2 Hydraulic Action

This is caused by the sheer power of moving water. It is the movement of loose unconsolidated material due to the frictional drag of the moving water on sediment lying on the channel bed.

3.2.3 Corrosion

This is most active on rocks that contain carbonates, such as limestone and chalk. The minerals in the rock are dissolved by weak acids in the river water and carried away in solution.

3.2.4 Attrition

This is the reduction in the size of fragments and particles within a river due to the processes describe above. The fragments strike one another as well as the river bed. They therefore become smoother, smaller and more rounded as they move along the river channel.

SELF-ASSESSMENT EXERCISE

Explain corrosion and attrition.

4.0 CONCLUSION

The three steps common to water erosion are: abrasion, hydraulic, corrosion and attrition.

5.0 SUMMARY

Erosion is a hydraulic action and is derived from the energy of running water, through abrasion, hydraulic, corrosion and attrition.

6.0 TUTOR – MARKED ASSIGNMENT

Explain the various mechanisms involved in channel erosion.

7.0 REFERENCES/FURTHER READING

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UNIT 3 HYDROGRAPHS

CONTENTS

1.0 INTRODUCTION

A hydrograph is a graph showing stream flow at the concentration point versus time. It is also a response of a given catchment to a rainfall input. It consists of flow in all the three phases of runoff, namely: surface runoff, interflow and base flow.

The hydrograph has two main components, a broad band near the time axis representing base flow contributed from groundwater, and the remaining area above the base flow, the surface runoff (or direct runoff), which is produced by the storm. In the beginning of the rainfall, the river discharge is low and a period of time elapses before the river begins to rise.

The shape of a hydrograph of a single storm occurring over the drainage area follows a general pattern, which shows a period of rise that culminates in a peak, followed by a period of decreasing discharge (called recession) which may, or may not, decrease to zero discharge, depending on the amount of groundwater flow.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define hydrographs
- state the major components of a hydrograph
- draw a typical hydrograph.

3.0 MAIN CONTENT

3.1 Hydrograph

Graphical displays of discharge volumes in streams and river systems plotted against time are known as **hydrographs**.

Hydrographs may be described as graphic of changes in water flow or water level plotted against time, showing stages of flow, velocity, or other properties of water with respect to time (Figure 3.1).
Hydrographs can be depicted over any period of time, including but not restricted to, a single storm, a day, a week, a month, a season, or a year. Respectively, each of these is termed a **storm hydrograph**, **daily hydrograph**, **weekly hydrograph**, **monthly hydrograph, seasonal hydrograph**, and **annual hydrograph** respectively.

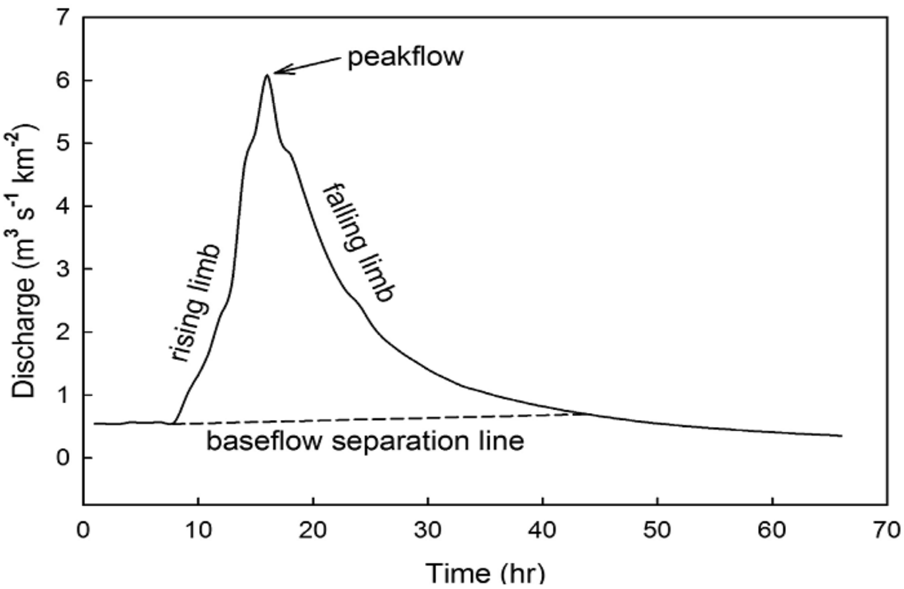

Fig.3.1: A Typical Hydrograph

Hydrographs often are compared among watersheds to understand hydrology in different catchments. Hydrographs can be compared before and after a disturbance or management activity (e.g., urbanisation or harvesting) to determine how that activity affects total discharge or hydrograph responses for specific periods – often storms. Rather than comparing entire storm hydrographs, individual parts of storm hydrographs are compared.

3.2 Components of a Natural Hydrograph

Hydrograph has three characteristic regions: (i) the rising limb AB, joining point A, the starting point of the rising curve and point B, the point of inflection, (ii) the crest segment BC between the two points of inflection with a peak P in between, (iii) the falling limb or depletion curve CD starting from the second point of inflection C (Fig. 3.2a).

3.2.1 Rising Limb

The rising limb of a hydrograph, also known as concentration curve represents the increase in discharge due to the gradual building up of storage in channel and over the catchment surface.

The initial losses and high infiltration losses during the early period of a storm cause the discharge to rise rather slowly in the initial periods. The basin and storm characteristics control the shape of the rising limb of a hydrograph.

3.2.2 Crest Segment

The crest segment is one of the most important parts of hydrograph as it contains the peak flow. The peak now occurs when the runoff from various parts of the catchment simultaneously contribute amounts to achieve the maximum amount of flow at the basin outlet.
Generally for large catchments, the peak flow occurs after the cessation of rainfall, the time interval from the centre of mass of rainfall to the peak being essentially controlled by basin and storm characteristics.
Multiple-peaked complex hydrographs in a basin can occur when two or more storms occur in succession.

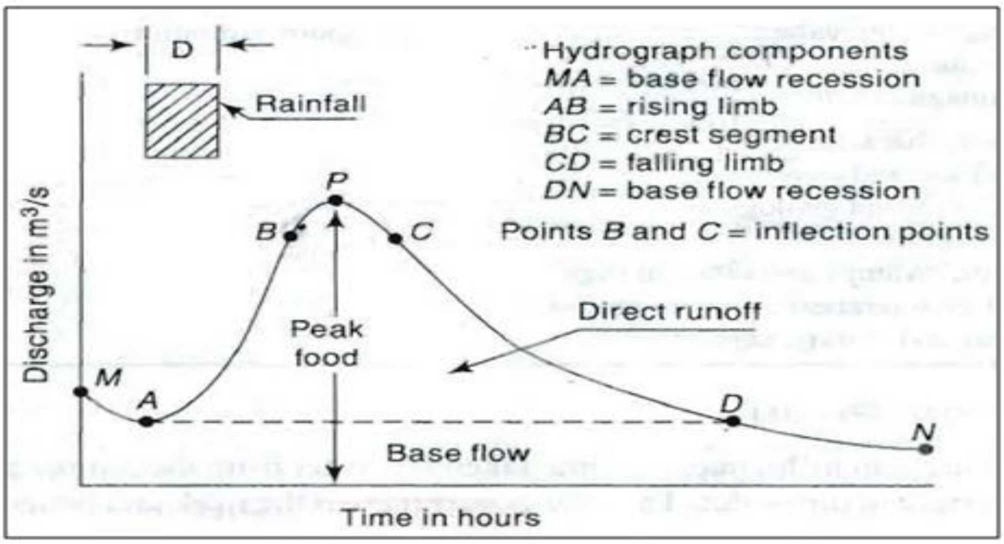

Fig.3.2a: Components of a Hydrograph

Source: Subramanya, 2008

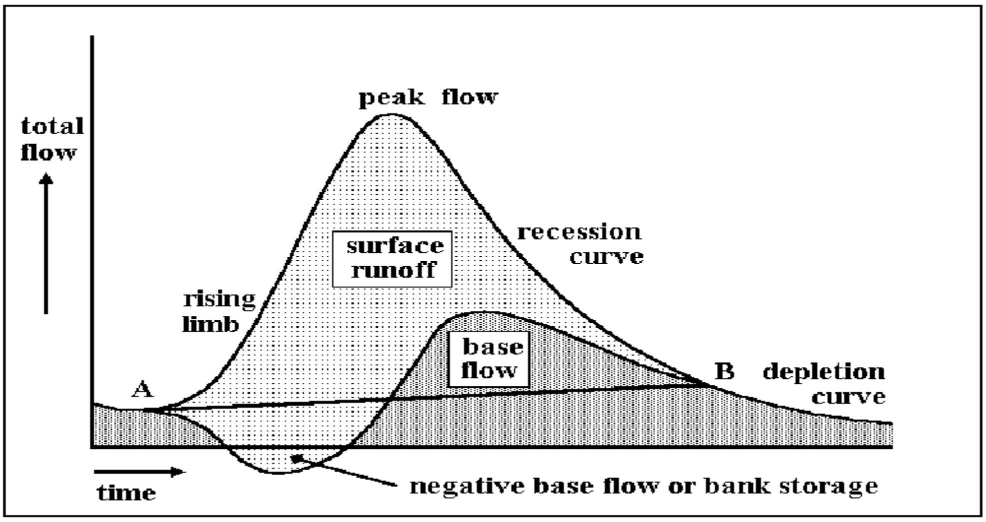

Fig.3.2b: Components of Hydrograph and Separation

3.2.3 Recession Limb

The recession limb, which extends from the point of inflection at the end of the crest segment (point C in Fig. 3.2a) to the commencement of the natural groundwater flow (point D in Fig.33.2b) represents the withdrawal of water from the storage built up in the basin during the earlier phase of the hydrograph.

The starting point of the recession limb, i.e. the point of inflection represents the condition of maximum storage. Since the depletion of storage takes place after the cessation of rainfall, the shape of this part of the hydrograph is independent of storm characteristics and depends entirely on the basin characteristics.

3.2.4 Stream Flow Recession

The storage of water in the basin exists as (i) surface storage, which includes both surface detention and channel storage, (ii) interflow storage, and (iii) groundwater storage, i.e. base-flow storage.

3.3 Factors affecting Hydrograph Shape

The time distribution of runoff (the shape of the hydrograph) is influenced by climatic, topographic and geological factors.

The climatic and topographic factors mainly affect the rising limb whereas the geological factors determine the recession limb.

3.3.1 Climatic Factors

The climatic factors that influence the hydrograph shape and the volume of runoff are as follows:

1. Rainfall Intensity

Rainfall intensity affects the amount of runoff and the peak flow rate. For a given rainfall duration, an increase in intensity will increase the peak discharge and the runoff volume, provided the infiltration rate of the soil is exceeded.

2. Rainfall Duration

The duration of rainfall affects the amount of runoff, the peak flow rate and the duration of surface runoff. For a rain of given intensity, the rainfall duration determines, in part, the peak flow.

3. Areal Distribution

The areal distribution of rainfall can cause variations in hydrograph shape. If an area of high rainfall is near to the basin outlet, a rapid rise, sharp peak and rapid recession of the hydrograph usually result. If a larger amount of rainfall occurs in the upper reaches of a basin, the hydrograph exhibits a lower and broader peak.

4. Direction of Storm Movement

The direction of storm movement with respect to orientation of the basin affects both the magnitude of the peak flow and the duration of surface runoff. Storm direction has the greatest effect on elongated basins. On these basins, storms that move upstream tend to produce lower peaks of a longer duration than storms that move downstream.

5. Type of Storm

The type of storm is important in that thunderstorms produce peak flows on small basins, whereas large cyclonic or frontal-type storms are generally determinant in larger basins.

3.3.2 Topographic and Geologic Factors

The topographic and geologic factors affecting runoff represent the physical characteristics of the basin. The factors involved are numerous, some having a major bearing on the phenomena, whereas others may have a negligible effect, depending on the catchment under consideration. The following are the dominant factors:

1. **Catchment Size**

   The major effect of increasing the drainage area on the hydrograph shape is that the time base of the hydrograph is lengthened. The peak flow per unit area thus reduces with catchment size for a given rainfall depth.

   This is partly due to the rainfall intensity being less for storms of extensive size, and partly due to the longer time required for the total catchment area to contribute to the peak runoff (time of concentration).

2. **Distribution of Watercourses**

   The pattern and arrangement of the natural stream channels determine the efficiency of the drainage system. Other factors being constant, the time required for water to flow a given distance is directly proportional to length. A well-defined system reduces the distance water must move overland, the corresponding reduction in time involved is reflected by an outflow hydrograph having a short time to peak.

3. **Slope of the Catchment**

   The steeper the slope of the catchment, the more rapidly surface runoff will travel. The time to peak will be shorter and the peaks will be higher. Infiltration capacities tend to be lower as slopes get steeper, thus accentuating runoff.

4. **Storage in the Catchment**

   Since storage must first be filled before it empties, it has a delaying and modifying effect on hydrograph shape. Much of the variations caused by the above factors are smoothed out by natural or artificial storage.

5. **Geology of the Catchment**

   The pedology and geology of the catchment influence primarily the groundwater component and the "losses". High infiltration rates reduce the surface runoff; high permeability's combined with high transmissivities substantially enhance the base flow component. The type of stream (influent, effluent or intermittent) can have a substantial impact on hydrograph shape.

6. **Land Use**

   Landuse can strongly influence the runoff coefficient. Urbanised areas may have a runoff coefficient of almost 100%, whereas natural vegetation may have low runoff. Ploughing, drainage, cropping intensity, afforestation and other practices may have considerable effect on runoff.

3.4 Uses of Hydrographs

a. Development of flood hydrograph for extreme rainfall magnitudes for use in the design of
hydraulic structures.
b. Extension of flood-flow records based on rainfall records.
c. Development of flood forecasting and warning systems based on rainfall.

SELF-ASSESSMENT EXERCISE

i. Describe the major components of a hydrograph.
ii. Explain how topographic and geologic factors affect hydrograph shape.

4.0 CONCLUSION

Hydrographs depicts graphical changes in water flow or water level plotted against time, showing stages of flow, velocity, or other properties of water with respect to time. The shape of the hydrograph is influenced by climatic, topographic and geological factors. Hydrographs help in the design of hydraulic structures, rainfall records and flood forecasting.

5.0 SUMMARY

Hydrograph is a graphical display of discharge volumes in streams and river systems plotted against time. Its pattern shows a period of rise that culminates in a peak, followed by a period of decreasing discharge (called recession) which may, or may not, decrease to zero discharge, depending on the amount of groundwater flow. It consists of the rising limb, crest segment and falling limb or depletion curve. The shape of the hydrograph is influenced by climatic, topographic and geological factors.

6.0 TUTOR–MARKED ASSIGNMENT

1. Define hydrographs.
2. State the major components of a hydrograph.
3. State the uses of Hydrographs.

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MODULE 6 WATERSHED MANAGEMENT

UNIT 1 WATERSHED MANAGEMENT

CONTENTS

1.0 INTRODUCTION

The watershed management implies the judicious use of all the resources, namely land, water and vegetation in an area. It also involves providing an answer to alleviate drought, moderate floods, prevent soil erosion, improve water availability and increase food, fodder, fuel and fiber on sustained basis, and to also achieve maximum production with minimum hazard to the natural resources and for the wellbeing of people. The task of watershed management includes the treatment of land by using most suitable biological and engineering measures in such a manner that, the management work must be economic and socially acceptable.

2.0 OBJECTIVES

At the end of the unit, you should be able to:

- define watershed management
- explain elements of watershed management.

3.0 MAIN CONTENT

3.1 Watershed Management

Watershed management is the study of the relevant characteristics of a watershed aimed at the sustainable distribution of its resources and the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within a watershed boundary.

It may also be defined as the study of the relevant characteristics of a watershed aimed at the sustainable distribution of its resources and the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within a watershed boundary.

Watershed management is the integrated use of land, vegetation and water in a geographically discrete catchment or drainage area for the benefit of its residents, with the objective of maintaining the hydrological services that the watershed provides and of reducing or avoiding negative downstream or groundwater impacts.

This implies monitoring other ecological services such as soil productivity, biodiversity, carbon cycle and climate change adaptation and mitigation as well as the socio-cultural services such as aesthetics, recreation, tourism, heritage, etc.

3. 2 Elements in Watershed Management

Three important elements in watershed management include: land, people, and management. All of these elements should be carefully studied and taken into full consideration in planning and implementing any watershed management program or project.

3. 2.1 Land

This refers to land mass or a geomorphic unit including soil, water, rocks, vegetation, animals and other resources attached to it. Land has three dimensions, different qualities, and many forms. Ina watershed, there are also many types of land use and infrastructure. All their conditions and distributions affect watershed management.

3. 2.2 People

People refer to the inhabitants in the watershed and those in the downstream area related to the watershed. Their social, economic and cultural conditions are extremely important in watershed management.

3.2.3 Management

It refers to policy, legislation, administration, institutional capability, technology, and resources of various government and private agencies in dealing with watershed management.

3.3 Objectives of Watershed Management

Features of a watershed that agencies seek to manage include water supply, water quality, drainage, storm water runoff, water rights, and the overall planning and utilisation of watersheds. Therefore the objectives of watershed management are as follows:

1. To protect, conserve and improve the land of watershed for more efficient and sustained production.
2. Identify and protect high-quality natural features including forested areas, floodplains, riparian buffers, wetlands, and contiguous greenways.
3. To check soil erosion and to reduce the effect of sediment yield on the watershed.
4. To rehabilitate the deteriorating lands.
5. To moderate the floods peaks at downstream areas.
6. To increase infiltration of rainwater.
7. To improve and increase the production of timbers, fodder and wild life resource.
8. To enhance the ground water recharge, wherever applicable.
9. To reduce the occurrence of floods and the resultant damage by adopting strategies for flood management.
10. To provide standard quality of water by encouraging vegetation and waste disposal facilities.
11. Protect and improve the warm water and cool water fishery and conditions for other indigenous aquatic life and wildlife.
12. Maintain and/or increase the aesthetics of the water resources and recreational opportunities (parks and other facilities), including public access.

SELF-ASSESSMENT EXERCISE

Explain elements of watershed management.

4.0 CONCLUSION

Watershed management is the integrated use of land, vegetation and water in a geographically discrete catchment or drainage area for the benefit of its residents, with the objectives of protecting forested areas, floodplains, riparian zones, to reduce soil erosion and sedimentation, increase infiltration and ground water recharge, increase the production of timbers, fodder and wild life resource.

5.0 SUMMARY

Management of watersheds entails the rational utilisation of land and water resources for optimum production, with minimum hazard to natural and human resources. It therefore is the process of guiding and organising land use and use of other resources in a watershed to provide desired goods and services without adversely affecting soil and water resources.

6.0 TUTOR – MARKED ASSIGNMENT

1. Explain elements of watershed management.
2. State the objectives of watershed management.

7.0 REFERENCES/FURTHER READING

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UNIT 2 PRINCIPLES AND MEASURES

CONTENTS

1.0 INTRODUCTION

Watershed management can be generally divided into three categories: rehabilitation, protection, and improvement. Watershed rehabilitation applied to those watersheds where degradation has already occurred and erosion has been excessive. Rehabilitation involves the regain or recover of forest lands, soil conservation on cultivated slopes, pasture/range, gully, road slope and landslides, and streams. Protection of watershed as a management principle applies to a watershed where degradation is not presently serious, but has the potential of increase. The main purpose is to protect the present status quo or to prevent future damages. Watershed improvement emphasised on the infrastructure and living conditions of the inhabitants.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define basic principles of watershed management
- explain objectives of watershed management.

3.0 MAIN CONTENT

3.1 Principles of Watershed Management

Watershed management can be generally divided into three categories: rehabilitation, protection, and improvement such classification is dependent on their major functions.

3.1.1 Watershed Rehabilitation

Rehabilitation work is applied to those watersheds where degradation has already occurred and erosion has been excessive. The objective is to regain or recover watershed stability, and minimise damages both on-site and off-site. Rehabilitation processes include:

a. Rehabilitation of Forest Lands: Reforestation, tree planting on bare or severely eroded areas, erosion control on logging or cut-over areas, treatment of abandoned roads.
b. Soil Conservation on Cultivated Slopes: Terracing, ditching, proper drainage with protected waterways, agronomic conservation measures including mulching, minimum tillage, cover-cropping, and composting, etc.
c. Pasture/range Rehabilitation: Reseeding, re-planting, proper fertilizing, control grazing, and rotational grazing.
d. Gully, Road Slope and Landslides Rehabilitation: Regrading and revegetation, checkdams, retaining walls, wattling and staking, hydro seeding, surface and sub-surface drainage.
e. Rehabilitation of Streams: Check dams, debris dams, submerge dams, training dikes, and jetties, rip rapping, and bank revegetation.
f. Mined-out Area Rehabilitation: Regrading and reseeding, mining tail stabilisation, debrisarresting structure, and sediment ponds.

3.1.2 Watershed Protection

Watershed protection usually applies to a watershed where degradation is not presently serious but has the potential of increase.
The main purpose is to protect the present status quo or to prevent future damages. Protection is usually cheaper than rehabilitation.

a. Protection of Forest and Forest Land: Fire prevention and control, prevention of illegal cutting and squatting, insect and disease control.
b. Protection of Cultivated Slopes: Applying proper land use principles and land classification techniques, soil and fertility management, maintenance of soil conservation structures.
c. Protection of Roads: Protection of road surface, proper care of road ditches and drainage systems, cleaning landslips, tending vegetation along road slopes.
d. Protection of Pasture/range Lands: Fencing, deferred grazing, stall feeding or zerograsing, cattle feed-lot control, and protection of wildlife.
e. Protection of Streams: Establishing stream protection belts, bank protection, and channel clearing.
f. Downstream Protection: Flood-retarding structures, debris dams, sediment ponds, revetment, and levees.

3.1.3 Watershed Improvement

Watershed improvement consists of two different categories:

a. For Improvement of Water Resources: Phreatophyte and wetland management, forest or vegetation conversion, water quality monitoring and improvement, pollution and pesticide control.

b. For Infrastructure Improvement: Building new roads, upgrading existing roads, improving domestic water supply, providing or improving small irrigation schemes, supplying cheap energy sources and fuel-wood plantations, improving living quarters or housing.

3.2 Some Important Principles of Watershed Management

1. Utilising the land according to its capability.
2. Putting adequate vegetal cover on the soil during the rainy season.
3. Conserving as much rain water as possible at the place where it falls.
4. Drawing out excess water with a safe velocity and diverting it to storage ponds and store it for future use.
5. Avoiding gully formation and putting checks at suitable intervals to control soil erosion and recharge ground water.
6. Increasing cropping intensity through intercropping and sequence cropping.
7. Safe utilisation of marginal lands through alternate land use system.
8. Ensuring sustainability of the eco-systems befitting the man-animal plant –land-water-complex over the years.
9. Maximising the combined income from the interrelated and dynamic interactions between resources (e g crop-livestock-tree-labour –complex).
10. Maximising productivity per unit area, per unit time and per unit of water.

SELF-ASSESSMENT EXERCISE

Describe important principles of watershed management.

4.0 CONCLUSION

Watershed management principles involves utilising the land based on its capability, putting adequate vegetal cover on the soil, managing excessive water and its velocity, avoiding gully formation, increasing cropping intensity and ensuring sustainability of the eco-systems.

5.0 SUMMARY

Watershed management is aimed at improving the standard of living of human beings, increasing water supply for different purposes (irrigation, drinking, hydroelectric power), increasing the productivity of the land (increasing the fertility of the soil), combating floods and drought. These can be carried out through rehabilitation, protection and conservation measures.

6.0 TUTOR – MARKED ASSIGNMENT

Explain important principles of watershed management.

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UNIT 3 INTEGRATED WATERSHED MANAGEMENT

CONTENTS

1.0 INTRODUCTION

Watershed management is essentially an integrative way of considering and managing all kinds of natural resources and also those human activities that affect watershed values within the divide. Resources and activities are all interrelated and influence each other.

In order to have effective management, there is the need to adopt an integrated approach. For instance, if the main objective is for erosion and sediment control, one cannot neglect the interest, capability and the constraints of the farmers who are presently using the slopes for cultivation in the watersheds. Integrated approach usually means to spell out all kinds of problems together and use all kinds of resources to give the best solutions.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- explain integrated watershed management
- explain the principles of watershed management.

3.0 MAIN CONTENT

3.1 Integrated Watershed Management

Integrated watershed management suggest the integration of technologies within the natural boundaries of a drainage area for optimum development of land, water, and plant resources to meet the basic needs of people and animals in a sustainable manner.

It is essentially an integrative way of considering and managing all kinds of natural resources and also those human activities that affect

watershed values within the divide. Resources and activities are all interrelated and influence each other.
Integrated approach usually means to spell out all kinds of problems together and use all kinds of resources to give the best solutions.

3.1.1 Protection and Production

Watershed management should emphasize both protection and production. Although protecting downstream areas from flood, erosion, sediment, and pollution is important, the production level of upstream areas is vital to the inhabitants who are usually poor. Any program that will increase production and particularly income will encourage people's participation.

3.1.2 Long Term Watershed Management Program

Developing a long term watershed management program should be the ultimate goal. Watershed work needs a long time investment to obtain benefits; government needs to establish a long term watershed program rather than a short "firefighting" type of approach. At the beginning of the program, pilot projects funded by international agencies may be needed but they should be accepted as a part of the long term program.

3.1.3 Watershed Protection and Rehabilitation

Investment on watershed protection is usually more economic than watershed rehabilitation. Seriously degraded watersheds over decades have greatly threatened the livelihood of its inhabitants and downstream areas. Rehabilitation, though expensive, may become necessary.

3.1.4 Establish Priorities for Managing Watersheds

Government should establish priorities programs for watershed management through reconnaissance surveys and watershed classification. Any policy on watershed which endangers people's lives and properties, threatens public investment, or suffers poorest economy should receive first priority.

3.1.5 People's Participation

Encourage People's Participation in Watershed Management. People's participation is the key to the success of many watershed programs in the world. Government must encourage the participation of the people and local communities to watershed programs early in the planning stage. In addition to technical assistance, proper incentives should be provided to compensate people who use their labors and lands to install watershed conservation measures for which the benefits usually occur off-site or in distant future.

3.1.6 Training of Personnel

The constraint of doing a satisfied job of watershed management is the availability of trained personnel. Trained field workers, should not only conduct meetings or passing out extension materials, but also be involve in teaching and supervision of on-going fieldwork. Follow-up activities, such as providing farm inputs, product storing, processing and marketing, are all needed. The ultimate purpose is to increase farmers' income while protecting and improving their land resources.

3.1.7 Cost Sharing

Cost sharing and/or incentives are needed in a Watershed Conservation. It is not fair to ask poor farmers at upstream watersheds to bear all the cost of watershed conservation work, while the benefits may occur at downstream. A cost sharing system or an incentive program may need to be included in most of the watershed program.

3.1.8 On-site Returns

On-site short term returns should be emphasised. The best place to look for immediate returns and the best way to convince farmers to participate in watershed conservation is on-site; the further off-site you look the longer it takes and more difficult it is to convince the farmers to participate.

3.1.9 Maintenance

Maintenance should be considered as an integral part of watershed management, especially those involving structures, requires a strong commitment to steady maintenance. Forest plantations need maintenance too. Government and people tend to build or establish new plantations and new structures, but neglect the old ones. When the old ones failed, not only did people lose confidence but also sometimes did more harm than good to the watershed.

3.1.10 Cost and Effectiveness

Carefully weigh the cost and effectiveness of watershed management. Erosion is usually more severe on steep slopes where rainfall is intense than on gentle slopes with low intensity of rainfall. When steep slopes are brought into cultivation, structures are usually required to minimise erosion and to safely drain excess runoff. These structures can be expensive.

Consequently, people tend to look for inexpensive measures or practices without consideration of their effectiveness. Ineffective measures, however inexpensive, are a waste of both time and money. Therefore, cost and effectiveness should be weighed simultaneously at the time of planning. Between cost and effectiveness an optimum point should be found.

3.1.11 Combination of Measures

A proper combination of vegetative and structural measures may be most cost effective. No preference should be given to either vegetative or structural measures. If structures are necessary for safe runoff disposal or erosion control, they should be used. If vegetative controls are effective, by all means they should be employed because of their relative low cost and relatively easy application. The best principle may be using maximum vegetative practices and minimum structures for watershed rehabilitation and protection purposes.

3.1.12 Control Runoff

Control runoff by minimising its quantity, slowing down its velocity, and/or diverting and draining it safely to a protected area is utmost important for erosion control. In the humid tropics where rainfalls are intense and frequent and runoff is inevitable. On steep slopes and cultivated fields, concentrated runoff always causes severe soil erosion. Therefore, measures for controlling runoff should receive highest priority.

3.1.13 Soil Surface Protection and Maintenance

To protect soil surface from raindrops or splash erosion, low vegetation, litter, humus, or organic material are more effective than tall vegetation. Reforested areas without ground cover for whatever the reason may do no good to protect the land surface. For open and cultivated lands, avoiding heavy compaction and maintaining soil porosity are essential to facilitate infiltration and runoff minimisation.

3.1.14 Avoidance of Excessive Hill Slope Excavation

Mountain roads, trails, housing, and other structures which require excavation into hill slope are likely to increase instability of the slope, cause land sliding, or interrupt subsurface flow adding more to the surface runoff.

Any such excavation should be kept minimum and protected with slope stabilisation measures, and/or have its surface flow checked or diverted to a safe place.

3.1.15 Rehabilitation of Resources

Rebuilding or improving natural resources bases and enhancing soil productivity are important to a watershed management. The objectives of watershed management are not only for erosion control and to produce good quality and proper quantity of water, but also to maintain or improve the production bases of the watershed.

3.1.16 Application of Research Results

Applied research for various techniques should be carried on all the time to improve the quality of the work and to minimise their cost. Many new and foreign techniques introduced need to go through a period of adoption trial before large scale application. Local research designed to solve local problems is most useful and safe to apply.

SELF-ASSESSMENT EXERCISE

Describe four integrated watershed management.

4.0 CONCLUSION

Principles of watershed management can be summed up as:

- To rehabilitate the watershed through proper land use and protection/conservation measures
- To protect, improve or manage the watershed for the benefit of water resources development (domestic water supply, irrigation, and hydropower)
- To manage the watershed in order to minimise natural disaster such as flood, drought and land slide etc.
- To develop rural areas in the watershed for the benefit of the people and economies of the region
- To improve and increase the production of timbers, ranges and wild life resources for economic benefits.

5.0 SUMMARY

Integrated watershed management suggests the integration of technologies within the natural boundaries of a drainage area for optimum development of land, water, and plant resources to meet the basic needs of people and animals in a sustainable manner. In order to achieve its objective, integrated watershed management suggests to adopt land and water conservation and protection practices, long term watershed management program, rehabilitation, people's participation in watershed management, cost sharing and/or incentives are needed in a watershed conservation, soil surface protection and maintenance and the application of various research techniques in watershed management.

6.0 TUTOR–MARKED ASSIGNMENT

1. Explain integrated watershed management.
2. Describe the various types of integrated watershed management.

7.0 REFERENCES/FURTHER READING

Suhas, P Wani & Kaushal, K Garg (nd). Watershed Management Concept and Principles.

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