RIVER BASIN: BASIN SURFACE RUN - OFF.

Paper – Hydrology
B.A. HONS.
Semester – IV
SUB. CODE – CCT - 403

University Department of Geography,
DSPMU, Ranchi.

BASIN SURFACE RUN - OFF: -

River runoff is that part of the precipitation which is collected from a drainage basin or watershed and flows into the river system. From the hydrologic point of view, the runoff from a drainage basin may be considered as a product of the hydrologic cycle and a result of a compound interaction of meteorological and physiographic factors. Physiographic factors can be classified into two main groups: basin factors (size, shape, and topography of drainage area, geology, properties of soils, presence of lakes and swamps, vegetation cover, and land use); and channel factors (slope, hydraulic properties of the channels, channel storage capacity, sediments, and stream bed material). Frequently two basins of nearly the same size may behave entirely differently in runoff phenomena. The essential differences occur between large and small basins. For example, most large basins have significant channel storage effects that smooth the variations of water inflow caused by meteorological factors or change of conditions on the basin area. Small basins are very sensitive both to climatic factors and change in land use. The variety of runoff generation conditions is reflected in the temporal-spatial change of runoff coefficients (runoff–precipitation ratios). Depending on meteorological and physiographic conditions, these coefficients may vary from 0 to almost 1. In the deserts of the tropical and temperate zones almost all precipitation evaporates. Small runoff coefficients (0.05–0.15) are also typical for the steppe and dry savanna zones. In the zone of hard-leaf forests, the runoff coefficients are of the order of 0.1–0.2. However, in the zone of permanently-humid forests, the runoff coefficients reach 0.40–0.45. High runoff coefficients are characteristic also for the tundra and rainforest zones (0.5–0.6). The runoff coefficients from glaciers are usually close to 0.8–0.9. Runoff commonly shows a well-expressed seasonal variability. Runoff of a typical river basin in the temperate climate region has one or several periods with a significant rise in runoff discharges (such rises are usually called floods), and one or several periods of low flow. In the humid and tropic climates, seasonal variability is comparatively less; in arid regions, there are ephemeral rivers where the runoff is nonexistent during periods without precipitation, although it may appear at different times. The variability of runoff can be estimated in terms of the day-to-day fluctuation of the river discharges or stages. A graph showing river discharge with respect to time is known as a hydrograph. Hydrographs can be regarded as integral expressions of the physiographic and climatic characteristics that govern the relations between water inflow and runoff of a particular drainage basin. The shape of a hydrograph reflects the difference in runoff components and their paths of movement. A typical, single-peaked, simple flood hydrograph consists of three parts: the approach segment; the rising (or concentration) segment; and the recession (falling or lowering) segment. The lower portion of the recession segment is a groundwater recession (or depletion) curve, which shows the decreasing rate of groundwater inflow. The peak of a rainfall flood hydrograph represents the highest concentration of the runoff from a drainage basin. It occurs usually at a certain time after the rain has ended, and this time depends on the size and the shape of the drainage basin as well as the spatial distribution of the rainfall. The multiple peaks of a hydrograph may occur in any basin as the result of multiple storms developing close to each other. If a hydrograph shows double or triple peaks fairly regularly, this may be due to nonsynchronization of the runoff contributions from several tributaries to the main stream. The recession segment represents withdrawal of water from storage after all inflow to the channel has ceased. According to the area of genesis, river runoff components can be divided into surface runoff, subsurface runoff, and groundwater runoff. The surface runoff is that part of runoff which is produced on the land surface and flows over the land surface and through river drainage system to reach the basin outlet. The part of the surface runoff which does not reach stream channels is called overland flow. The subsurface runoff, also known as interflow, is that part of the precipitation which infiltrates into the soil and moves horizontally through the soil and the ground above the main groundwater level. A part of the subsurface runoff may enter the stream quickly, while the remaining part may take a long time before appearing in the stream channels. The groundwater runoff is that part of the groundwater which discharges in the river drainage system. The proportions of surface, subsurface, and groundwater components in the total runoff strongly vary in space and time and are defined by the physical mechanisms of river runoff generation. Field research of runoff genesis on experimental and representative river basins can commonly only provide data which is sufficient for discovering the main features of these mechanisms for small plots. At the same river basin, several distinct runoff generation mechanisms may exist. To establish the leading runoff generation mechanisms on large basins, it is usually necessary to use long series of meteorological data and runoff measurements together.

It is easy to establish from a simple analysis of flood hydrographs that the river runoff includes three components which have differences in timing: 1) quick flow, consisting of water which reaches the river channel network promptly after rainfall or snowmelt and has velocities of several centimeters per second; 2) flow, consisting of water which reaches the river channel network at velocities of order 0.1–1.0 centimeters per second^{-1}; and 3) slow flow, where velocities can be several orders less than the velocities of quick flow. It is commonly assumed that quick flow is mainly overland flow and the slow flow is mainly ground flow. Hypotheses on the paths of the second mentioned component of runoff may be very different, but in most cases, taking into account the velocities, it is possible to determine that it is dominantly subsurface flow. and moves horizontally through the soil and the ground above the main groundwater level. A part of the subsurface runoff may enter the stream quickly, while the remaining part may take a long time before appearing in the stream channels. The groundwater runoff is that part of the groundwater which discharges in the river drainage system.

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Horton assumed that the overland flow was generated on all (or a significant part) of the watershed area as sheet flow, and only when a excess of rainfall (or snowmelt) over infiltration was formed. In the initial period of rain, all water may infiltrate into the soil, but the infiltration rate decreases as a function of time because of increases in the soil moisture content at the soil surface. At some point in time (it is called the ponding time), the infiltration rate drops below the rainfall rate. The accumulated water covers all the drainage area by a thin layer and then begins to flow along the slope to the rills and gullies. Thus, the necessary conditions for the generation of overland flow by the Horton mechanism are: (1) a rainfall rate greater than the hydraulic conductivity of the soil; and (2) a rainfall duration longer than the required ponding time for a given initial moisture profile. Field research of rainfall runoff generation confirms that such a mechanism is often observed during highly intensive showers on arid and semi-arid watersheds, which lack enough vegetation cover to retain moisture. At a suitable combination of soils and topography, high rainfall rates lead to splash erosion and transport of soil particles by water fluxes. The transported sediments are deposited on the land surface and can significantly decrease soil permeability or form an impermeable crust. Horton overland flow may also occur during snowmelt on the plain watersheds when the permeability of frozen soil is low. However, the analysis of runoff coefficients and field observations shows that the rainfall Horton overland flow occurs in the temperate climate zone very seldom. Sheet flow is usually observed only on partial areas where the soil profile is saturated before the start of rainfall. In this case, water accumulates on the land surface due to the soil's inability to absorb any more moisture (regardless of the difference between rainfall intensity and infiltration rate), and such a type of overland flow is called saturation overland flow. Typically, saturation overland flow occurs when long-duration rains cover the areas where the initial water table is shallow and it can quickly rise to the land surface, or when an impermeable layer is relatively close to the land surface. Such areas are commonly located in valley bottoms, along streams, and near wetlands, but various subsurface conditions can also cause the formation of saturated zones in topographically-high parts of a basin. The area of saturation depends on the season and it can expand and contract during a storm and may differ from storm to storm. Thus, the source area of saturation overland runoff can significantly vary. Basins generating variable source runoff often display the same type of relationship to rainfall and watershed conditions as are recognized for Hortonian overland flow. Subsurface runoff may generate in the unsaturated zone of the soil above the layers with the temporary low permeability, or in the temporary saturated soil layers. In mountainous regions, subsurface runoff is often observed in the rough soil mantles lying above the ground with small hydraulic conductivity. Subsurface storm runoff may also occur through macropores resulting from animal or vegetation action, and in fractures and joints between soil strata. These paths may be enlarged by erosion and sediment transport, and piping drainage systems may be formed. Depending on their origins and the stability of their walls, pipes may vary in diameter from less than 10 mm to more than 1 m. In the unsaturated zone, pipe networks carry water in turbulent flows at velocities which match those for open channels, sometimes over distances of several hundred meters. Pipes also provide bypass routes for water in the saturated zone, essentially increasing seepage velocity. This mechanism of subsurface runoff generation may occur when the capillary fringe in regions of shallow groundwater (usually near streams) becomes quickly saturated, resulting in water flow into the stream. The subsurface water may rise to the land surface and form overland flow, which provides a mechanism for the rapid discharge of subsurface water to stream channels.

In spite of an enormous variety of climatic and physiographic conditions which the runoff may generate, in most cases it is possible to establish the general peculiarities of runoff generation for large physiographic zones and types of landscapes (for example, tundra, forest, steppe, arid and rainforest zones, and urban, agricultural, or forest lands). Special mechanisms of runoff generation are typical for mountain, swamp, permafrost, and glacier watersheds. Mountainous regions cover more than 20 percent of the land and provide the main source of available water resources in many arid and semi-arid areas. Mountain watersheds commonly have a well-expressed vertical zonality in climatic and physiographic conditions. The complex structure of mountain topography, and its interaction in blocking and uplifting large air masses, results in widespread and intensive precipitation on windward slopes with great seasonal variation. A considerable increase of precipitation with altitude can generally be observed, but the value of this increase varies depending on climatic zones and exposition of mountain ranges. Mountain topography strongly affects the spatial distribution of water and energy, and generates heterogeneity at all scales. Large variations of albedo, soil, and water storage conditions in relation to the surface conditions (rocks, snow, vegetation, altitude, exposure, etc.) cause local variations in the structure of the atmospheric boundary layer and heat fluxes. At mountain heights greater than 1 km, meteorological processes are influenced by the state of stratification of the atmosphere. Runoff of many mountain rivers is of mixed rainfall and snow melt origin. A characteristic feature of mountain rivers is extreme seasonal variation. Most runoff is produced quickly as overland flow, or subsurface flow in shallow rough ground layers. Immediately after rain or snow melt, destructive floods transporting significant amounts of hard material and sediments can occur. In dry periods, subsurface flow often results in increased soil moisture in lower slopes and valleys, giving better-developed vegetation than that on the upper slopes. The ground flow is generally small. The runoff coefficients are high (0.4–0.6) and vary within a narrow range. Persistent swamps occupy only about 2 percent of the land surface, but in some regions of the world (for example, central parts of South America and the northwest area of the European part of Russia) swamp watersheds contribute a significant portion of runoff. A characteristic feature of swamp watersheds is that the water table is situated closely to the land surface, so that the runoff varies only marginally during the warm period. However, swamp watersheds respond quickly to large rainfalls. Evapotranspiration from swamps is usually considerably higher than from dry neighboring areas and leads to a decrease of annual runoff. In the permafrost river basins, most hydrological activities occur in the active layer. Because of the relative impermeability of frozen ground, runoff losses are determined by evaporation and water storage in depressions, peat mats, and large-pored soils. The value of free basin storage capacity depends on the antecedent hydro meteorological conditions of the current year, or foregoing years. The year-to-year change in basin water storage can reach 10–15 percent of the annual precipitation. During snowmelt, the main mechanism of runoff generation is overland flow. A part of the melt water can freeze in the snow, in the peat mats, or in the ground during the nightly drop in air temperature, and because of low ground temperatures generally. The water frozen in the surface basin storage and in the active layer of the ground can generate a significant portion of river runoff during the entire warm period. There are river basins where floods have resulted from the melting of ice after cessation of snowmelt. Subsurface flow starts after the beginning of the melt of ice in the ground, increases gradually in line with increases in the depth of thawed ground, and may become the main mechanism of rainfall runoff generation. The groundwater component of river runoff in the permafrost regions is usually small. A glacier can be considered as a watershed whose characteristics change during the course of a year. In early spring the surface of glacier begins to thaw. Melt water and rain are effective agents of heat transfer and quickly thaw holes in the lower layer. Gradually, the area between the holes also becomes thawed, and the snowpack reaches a uniform temperature at the melting point. The thawed zone gradually moves to higher altitudes. In late spring, the glacier is covered entirely by a thick snowpack. Melt water and rainfall must travel through the snowpack by slow percolation (unsaturated flow), until reaching meltwater channels in the solid ice below. In summer, some bare ice is exposed and here there may be surface drainage. In autumn, a dense snow layer covers only part of the glacier and bare ice is exposed over the rest of the glacier. Melt water and liquid precipitation travel very quickly from the surface to the outflow stream. In winter, snow accumulates and the surface layer freezes. A small amount of water deep within the glacier slowly drains out during the winter. The lack of a direct relation between precipitation and runoff from a glacier is evident for all seasons except for late summer. The diurnal fluctuation of ice and snow melt usually corresponds to the diurnal fluctuation of discharge from the glacier, and reflects the peculiarities of the shape of the glacier.

RIVER BASIN:-

By constructing mathematical models of the hydrological cycle it is possible to crystallize our conceptual understanding of individual processes of water turnover in nature, and obtain means for diagnosis and prediction of these processes. Complex hydrological processes usually occur over large areas, and the special heterogeneity of these events, together with a deficit of information on the characteristics of their environment, make the development of models of the hydrological cycle one of the most difficult problems of geophysics. The optimal structure for models describing the individual processes of the hydrological cycle depends not only on the required refinement of these processes, but to a significant extent on the availability of data needed in order to determine the parameters (coefficients) of the models. In many cases, information needed for choice of the structure of the model and determining its parameters are absent, and there sare only experimental field data received at the input and the output of the hydrological system under consideration. Less frequently, the structure of the model is chosen mainly on the basis of a priori knowledge of the process or system behavior.

For most practical tasks, the structure of hydrological models and their attendant parameters is determined on the basis of both a priori (theoretical) and experimental information. As a result, according to the proportion of a priori and experimental information for model construction, the models of processes of the hydrological cycle can be conditionally divided into three types: 1) black box models where only measurements at the input and the output of the hydrological systems are used; 2) gray box models (in hydrology, the term “conceptual models” is used more often), where measurements at the input and the output of the hydrological systems provide the main information, but conceptual understanding of processes is also applied; 3) physically- based models, in which the choice of the structure is based on a priori information on processes of the hydrological cycles (mainly, on fundamental laws of hydro physics and hydrodynamics), and the parameters are determined mainly on the basis of direct measurements of characteristics of the hydrological systems.

However, because of strong spatial variability of these characteristics, present-day measurement methodologies cannot provide the accuracy that is necessary for most hydrological problems. There are also always some inconsistencies between real natural processes and their representation in the models. As a result, to improve the accuracy of the model, some parameters have to be fitted. Such fitting (it is also called calibration) is commonly carried out by applying the comparisons of calculated and measured components of the hydrological cycle. Because runoff is the most exactly-measurable component of the hydrological cycle, in most cases runoff hydrographs at the outlets of river basins are used for fitting, and the construction of models of the hydrological cycle is commonly carried out for river basins with the available measurements of runoff. For fitting the parameters, the available measurements of evapotranspiration, soil moisture, and snow characteristics are also often used.

To decrease the number of fitting parameters, the hydrological systems in the models of the first and second types are usually assumed to be lumped (characteristics of systems and their conditions do not change in space), and, as a result, the models of hydrological processes are also frequently classified as either lumped or distributed. Lumped conceptual models, which are mostly applied in hydrological practice, contain aggregated empirical parameters that have a complicated physical interpretation and a large range of variation. In contrast, distributed physically-based models include parameters with clear physical meanings, and if there are no direct measurements of these parameters in a given river basin, they can often be gained from laboratory or field investigations of hydrological processes in similar physiographic conditions. A good correspondence between the model structure and the prototype may be supposed to facilitate fitting the model parameters and increase the predictive capability of the model. In many cases, even the a priori information on the possible range of parameter values can considerably decrease uncertainty in the estimation.

Another important advantage of physically-based models is the opportunity to use simulation to explore different assumptions and physical hypotheses about the particular basin and mechanisms of the hydrological processes. Such sensitivity analyses, coupled with observed data, allow for the "deciphering" of dominant mechanisms, and simplify the choice of model structure. The development of databases that include information with high resolution in space (in the form of digitized maps, digital elevation models, and remote sensing data from satellites, airplanes, ground-based weather radars, and more modern Geographic Information Systems (GIS)) that can help in handling this information, essentially widens the opportunities of construction of distributed physically-based models of the hydrological cycle. The use of general physical laws and meanings of parameters in physically-based models also simplifies the coupling of models of the hydrological cycle with models of meteorological and other geophysical phenomena.

RUNOFF ESTIMATES FROM WATERSHEDS AND HYDROLOGICAL MODELING :-

He simple meaning of runoff is the flow of precipitated surface water towards river, pond and ocean. In another word, runoff is a movement of water to a channelized stream, after it has reached the ground as precipitation. The movement can occur either on or below the surface and at differing velocities (Davie, 2008). The surface runoff is a portion of water that flow over the surface and reaches the river, pond and ocean. During precipitation, initially, rain water to immerse into the ground until the soil becomes saturated. After the soil saturated, the excess water on the surface to flow into nearby low-lying area in the watershed. This excess water that flowing over the land is known as surface runoff (figure 1). The estimation runoff is required for the management of soil and water resources by suggesting the conservation structures such as flood forecasting, water balance studies, environmental impact assessment and engineering planning like dams, spillways and outlets or any waterways.

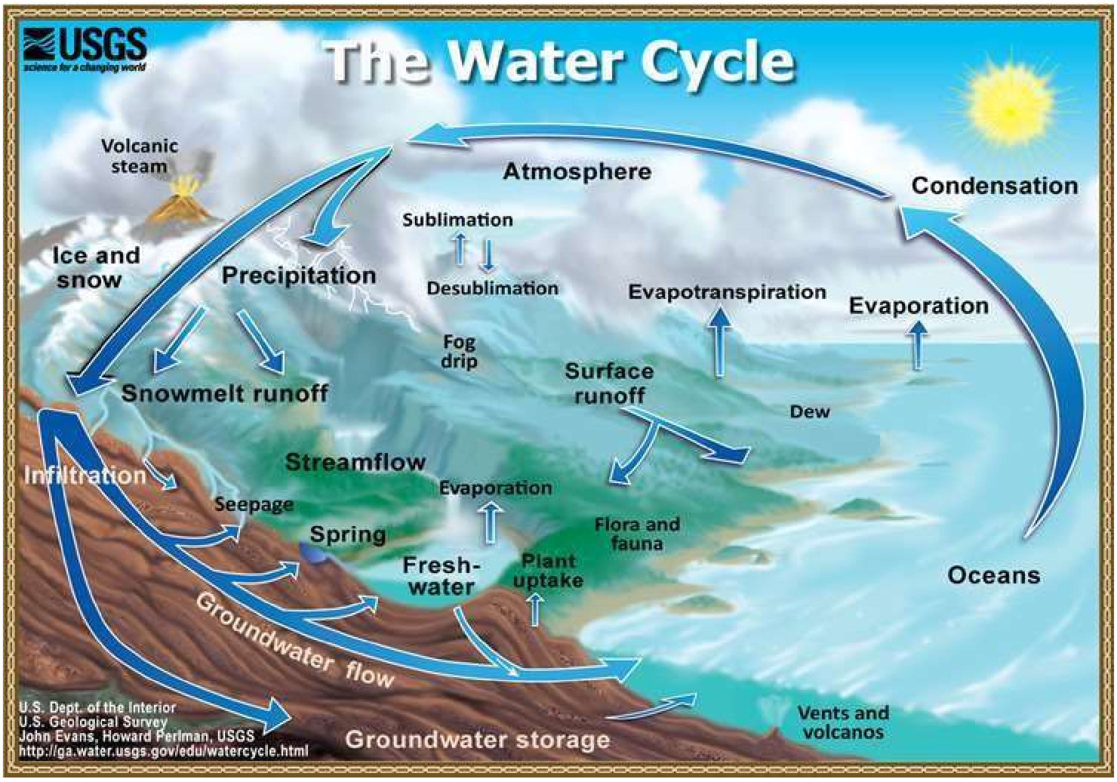

Fig.1: Hydrological cycle

Generally, Runoff occurs only when the rate of precipitation, i.e. intensity, exceeds the rate of infiltration. Once the infiltration rate is exceeded, water begins to fill the surface depressions which is called surface or depression storage. After the depression are filled water flowing over the land as overland flow. Runoff is that portion of rainfall which moves down to the stream, channel, river or ocean as surface or sub-surface flow. Overland flow is the water which runs across the surface of the land before reaching the stream. In the subsurface, through flow (some authors refer to this as lateral flow) occurs in the shallow subsurface, predominantly, although not always, in the unsaturated zone. Groundwater flow is in the deeper saturated zone. All of these are runoff mechanisms that contribute to stream flow.

The run-off modeling is very much applied in the decision making in the hydrological system and their problems such as flood, contamination studies, etc. rainfall-run-off modeling can be carried out within a purely analytical framework based on observations of the inputs and outputs to a catchment area. the catchment is treated as a 'black box' without any reference to the internal processes that control the rainfall to runoff transformation. Information on run-off and sediment yield could provide light on the degradation of watersheds and thus identifies critical source areas for starting development programs.

FACTORS AFFECTING THE RUNOFF: -

PHYSIOGRAPHY: It includes the shape and size of the watershed, slope, drainage pattern and density. The shape of the watershed determines the time of concentration. Long and narrow watershed have longer time of concentration resulting lower runoff than circular or square watershed because it takes long time to leave watershed and more opportunity for water to soak into the soil. The size of the watershed determines the runoff volume and rate. As the watershed size increase, runoff volume and rate increases. However, runoff volume and rate per unit of watershed area decrease as the area increases. So, watershed size and area determines the peak rate of runoff, which is important parameter for designing erosion structures. The slope of the watershed determines the velocity and extent of the runoff water. There is positive correlation between land slope and velocity, as greater the slope, greater the velocity. According to the Galileo's law of falling bodies, distance traveled by a falling body is directly proportional to the square of the time it takes to fall. Hence, if the watershed slope is increased four times, thevelocity of water flowing on the slope is doubled, resulting cutting capacity or erosive power is increased four times as well as carrying capacity of water increased about 32 times and size of particles that can be transported by rolling or pushing is increased by 64 times. The drainage pattern is a design of stream courses and their tributaries which is influenced by structure, lithology and slope. Dendritic pattern has fine drainage texture indicates the impervious rock formation and low permeability. Here, the soil is deep, heavy and slowly permeable, prone to severe to very severe soil erosion forming gullies due to high runoff. The radial, braided and pinnate drainage pattern associated with the medium drainage texture, the rocks are characterized by joints and fractures, soil is moderately deep, medium soil texture and moderately permeable subject to moderate to severe soil erosion. The coarse drainage texture of the trellis, rectangular and annular drainage pattern generally associated with shallow and coarse soil texture resulting high hydraulic conductivity where water can move through pours and fractures very easily, is relatively less prone to soil erosion. The drainage density also influencing the runoff pattern. Higher the drainage density increases the runoff water very rapidly, decreases the lag-time and increases the peak of hydrograph.

SOIL AND GEOLOGY: The soil and geological characteristic determine the amount of siltation in the water harvesting structures such as dams and reservoirs as well as amount of water percolation in the soil.

PRECIPITATION: the amount and nature of precipitation is the most important factor which determines the runoff in a watershed.

QUANTITY AND RATE OF RUNOFF: The quantity and rate of runoff is prerequisite for the planning and designing of canals, ditches or any other water harvesting structures to store the runoff. The volumetric assessment of water is most important while impounding or creating reservoirs. The rate of runoff is essential for conveying water from one place to another place by creating mechanical structures to accommodate the flow of water. Theoretically, watershed with impervious rocks and no loss of water, maximum rate of runoff would be directly proportional to the rate of rainfall. So, more the rainfall, more runoff. But in the natural condition, there are various interceptors such as vegetation, infiltration into the soil, stored in depression, and some rainfall is evaporated. Therefore, estimation of rate of surface runoff is depends on the rate of rainfall and water available for runoff.

TIME OF CONCENTRATION: when the rainfall occurs, the water take time to reach the outlet. Thus, time taken for water to travel by overland flow from any point of watershed to the outlet is known as time of concentration. There are various factors that effecting the concentration time such as size, shape and slope. The larger the watershed will take more time to concentration of water, and vice versa. The shape of the watershed is determined by shape factor, which is defined as the ratio of basin area, to the square of basin length (Horton, 1945).The value of form factor would always be less than 0.7854 (for a perfectly circular basin). the smaller the value of form factor, more elongated will be the basin. The basins with high form factors have high peak flows of shorter duration, whereas, elongated sub-watershed with low form factors have lower peak flows of longer duration. If the basin size is same, flood flows of such elongated basins are easier to manage, than those of the circular basin. The slope of the drainage basin increases the runoff as well as time of concentration is also very less.

INTENSITY, DURATION AND FREQUENCY OF RAINFALL: The relationship between these three components of rainfall is very important while planning for various rainwater harvesting structures. The intensity and duration of rainfall has an inverse relationship, higher the intensity of storm, lower the duration of rainfall and vice versa. The most severe rainfall lasts for shorter time and storm that last for longer duration give the more total amount of rainfall, that gives impact on runoff.

HYDROLOGIC CONDITION OF SOIL: the hydrologic condition of the soil is determined by the moisture content at the time of the storm. Soil with humus, organic content and temperature increase the capacity of moisture content, resulting volume of runoff and vice versa.

VEGETATION COVER: The canopy covers of the vegetation act as interceptors and create barriers along the flow of water, reduce peak discharge, so the type and quality of vegetation on land influence the runoff, infiltration rates, erosion and sediment production and the rate of evaporation. The foliage and its litter maintain the impact of rainfall and increase the potential of infiltration to the soil and also protect soil erosion. Thus, the canopy cover and ground litter create barriers to the water to flow on the land surface resulting increased time of concentration and it reduces the peak discharge rate.

LAND USE/COVER AND CONSERVATION PRACTICES: The land in the drainage basin consist of various natural cover and different uses by the human being such as forest, agriculture, built-up area, etc. affects the rate of runoff and infiltration. Forest and agriculture act as interceptor and increases the infiltration but built-up area accelerates runoff and reduce the infiltration of rainwater to ground. The conservation practices reduce the volume of runoff as well as soil erosion. Contouring and terracing conservation methods reduces the sheet erosion of soil and increases the amount of rainfall withheld from by the small reservoirs.