Runoff

Runoff is the water discharged into surface water bodies. When rainfall is greater than soil infiltration rate, surface runoff occurs. Factors affecting runoff include rainfall intensity, slope, soil water storage capacity, and infiltration rate [12]. Nutrients contained in the runoff water will be lost from the system and deposited elsewhere. When added to lakes and streams, these nutrients can cause eutrophication, especially when soil fertility is high, as typically found around CAFO. Reducing soil nutrient concentration in these areas is essential, and manure management is very important.

Introduction:

Introduction:
Stream flow representing the runoff phase of the hydrologic cycle is the most important basic data for hydrologic studies.
A stream can be defined as a flow channel into which the surface runoff from a specified basin drains.
Runoff is generated by rainstorms.
Its occurrence and quantity are dependent on the characteristics of the rainfall event, i.e. intensity, duration and distribution.

Runoff can be defined as the portion of the precipitation that makes it's way towards rivers or oceans etc, as surface or subsurface flow.
Surface runoff can be generated either by rainfall, snowfall or by the melting of snow, or glaciers.
Runoff is that portion of the rainfall or irrigation water which leaves a field either as surface or as subsurface flow.
When rainfall intensity reaching the soil surface is less than the infiltration capacity, all the water is absorbed in to the soil.

As rain continues, soil becomes saturated and infiltration capacity is reduced, shallow depression begins to fill with water, then the overland flow starts as runoff.

Surface detention/ Detention storage:

The amount of water on the land surface in transit towards stream channels is called detention storage/surface detention.

Types of Runoff:

Surface runoff/ Sub-surface runoff or Base flow.

a. Surface Runoff:
That portion of rainfall which enters the stream immediately after the rainfall.
It occurs when all loses is satisfied and rainfall is still continued and rate of rainfall [intensity] in greater than infiltration rate.
b. Sub-Surface Runoff:
That part of rainfall which first leaches into the soil and moves laterally without joining the water table, to the stream, rivers or ocean is known as sub-surface runoff.

It is usually referred is inter-flow.
c. Base flow: It is delayed flow defined as that part of rainfall, which after falling on the ground the surface, infiltrated into the soil and meets to the water table and flow the streams, ocean etc.
The movement of water in this is very slow.
Therefore it is also referred a delayed runoff.
Total runoff = Surface runoff + GW Base flow.

The surface runoff process:
As the rain continues, water reaching the ground surface infiltrates into the soil until it reaches a stage where the rate of rainfall (intensity) exceeds the infiltration capacity of the soil.
Thereafter, surface puddles, ditches, and other depressions are filled with water (depression storage), and after that overland flow as runoff is generated.

The process of runoff generation continues as long as the rainfall intensity exceeds the actual infiltration capacity of the soil but it stops as soon as the rate of rainfall drops below the actual rate of infiltration.

Factors Affecting runoff:
Runoff rate and volume from an area are mainly influenced by following two factors:
A. Climatic factors.
B. Physiographical Factors.

A. Climate factors:
Rainfall characteristics:
1.Types of Precipitation:
It has great effect on the runoff. E.g. A precipitation which occurs in the form of rainfall starts immediately as surface runoff depending upon rainfall intensity while precipitation in the form of snow does not result in surface runoff.

2. **Rainfall Intensity**:
If the rainfall intensity is greater than infiltration rate of soil then runoff starts immediately after rainfall.
While in case of low rainfall intensity runoff starts later.
Thus high intensities of rainfall yield higher runoff.

3. Duration of Rainfall:

It is directly related to the volume of runoff because infiltration rate of soil decreases with duration of rainfall.

Therefore medium intensity rainfall even results in considerable amount of runoff if duration is longer.

4. Rainfall Distribution:

Runoff from a watershed depends very much on the distribution of rainfall.

It is also expressed as "distribution coefficient".

Near the outlet of watershed, runoff will be more.

5. Direction of Prevailing Wind:

If the direction of prevailing wind is same as drainage system, it results in peak low.

A storm moving in the direction of stream slope produce a higher peak in shorter period of time than a storm moving in opposite direction

6. Other Climate Factors:
Other factors such as temperature wind velocity, relative humidity, annual rainfall etc. affect the water losses from watershed area.

B Physiographic Factors:

1. Size of Watershed:
A large watershed takes longer time for draining the runoff to outlet than smaller watershed and vice-versa.

2. Shape of Watershed:
Runoff is greatly affected by shape of watershed. Shape of watershed is generally expressed by the term "form factor" and "compactness coefficient".
Form Factor = Ratio of average width to axial length of watershed.
Compactness Coefficient: Ratio off perimeter of watershed to circumference of circle whose area is equal to area of watershed.
Two types of shape: Fan shape [tends to produce higher runoff very early].

Fern shape [tend to produced less runoff].

3. Slope of Watershed: It has complex effect. It controls the time of overland flow and time of concentration of rainfall. E.g. sloppy watershed results in greater runoff due to greater runoff velocity and vice-versa.

4. Orientation of Watershed: This affects the evaporation and transpiration losses from the area. The north or south orientation, affects the time of melting of collected snow.

5. Land Use:

Land use and land management practices have great effect on the runoff yield. E.g. an area with forest cover or thick layer of mulch of leaves and grasses contribute less runoff because water is absorbed more into soil.

6. Soil moisture:

Magnitude of runoff yield depends upon the initial moisture present in soil at the time of rainfall.

If the rain occurs after along dry spell then infiltration rate is more, hence it contributes less runoff.

7. Soil type:

In filtration rate vary with type of soil. So runoff is great affected by soil type.

8. Topographic characteristics:

It includes those topographic features which affects the runoff.

Undulating land has greater runoff than flat land.

9. Drainage Density:

It is defined as the ratio of the total channel length [L] in the watershed to total watershed area [A].

Greater drainage density gives more runoff

Drainage density = L/A.

10. Storage Characteristics:

a. Depressions

b. Ponds, lakes and pools

c. Stream

d. Channels.

e. Check dams in gullies

f. Upstream reservoirs or tanks.
g. Ground water storage in deposits/aquifers.

Measurement:

River discharge, the volume flow rate through a river cross section, is perhaps the most important single hydrologic quantity.

Measurements of river discharge are required for flood hazard management, water resource planning, climate and ecology studies, and compliance with transboundary water agreements.

The discharge (or streamflow) of a river relates to the volume of water flowing through a single point within a channel at a given time.

Understanding this information is essential for many important uses across a broad range of scales, including global water balances, engineering design, flood forecasting, reservoir operations, navigation, water supply, recreation, and environmental management.

Stream flow measurement techniques can be broadly classified into two categories as
(i) direct determination and
(ii) indirect determination.

1. Direct determination of stream discharge:
   (a) Area-velocity methods,
   (b) Dilution techniques,
   (c) Electromagnetic method, and
   (d) Ultrasonic method.

2. Indirect determination of stream flow:
   (a) Hydraulic structures, such as weirs, flumes and gated structures.
   (b) Slope-area method.

Barring a few exceptional cases, continuous measurement of stream discharge is very difficult to obtain.

As a rule, direct measurement of discharge is a very time-consuming and costly procedure. Hence, a two step procedure is followed.

First, the discharge in a given stream is related to the elevation of the water surface (stage) through a series of careful measurements.
In the next step the stage of the steam is observed routinely in a relatively inexpensive manner and the discharge is estimated by using the previously determined stage-discharge relationship.
The observation of the stage is easy, inexpensive, and if desired, continuous readings can also be obtained.

This method of discharge determination of streams is adopted universally.

Stream Gauging:

Stream gauging is the technique used to measure the volume of water flowing through a channel per unit time, generally referred to as discharge.
Stream discharge is determined by the relationship between stream velocity and channel area.

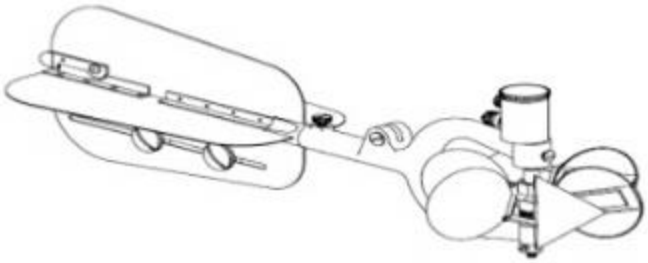
Quantifying the relationship between these variables allows continuous records of discharge to be estimated.
The first step towards this is the measurement of stage.

Stage measurement and rating curves:

Stage describes the depth of water within a channel and is quantified by the height of water at a gauging site above an arbitrary datum.

The velocity-area method:

The most common and direct method of estimating discharge is the velocity-area method. This technique requires measurement of stream velocity, channel width and the depth of water flow at cross stream vertical sections.
The measurement of velocity in rivers is achieved using instruments such as current meters.



Hydrographs :

A hydrograph is a graph displaying some property of water flow, such as stage (i.e. water level), discharge, velocity, etc., versus time.

For displaying runoff characteristics of a watershed, the hydrograph is one of discharge (cubic feet per second) versus time (hours).

It represents watershed runoff at a certain point in the flow and includes only the rainfall upstream of the point in question.

There are three basic parts to the hydrograph:

(1) the rising limb or concentration curve,

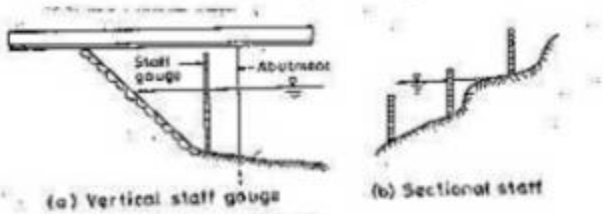
(2) the crest segment, and

(3) the recession curve or falling limb.

Methods available for measuring site discharge:
Float Method:
This method requires the measurement and calculation of the cross-sectional area of the channel as well as the time it takes an object to "fl oat" a designated distance.
Estimate the cross-sectional area of the channel.
To determine the velocity of the discharge, mark off a 25 to 100 foot long section of the channel that includes the part where you measured the cross-section.

Gently release the fl oat into the channel slightly upstream from the beginning of the section.
Measure the amount of time it takes the "fl oat" to travel the marked section.
Repeat this process at least three times and calculate the average time.
Determination of runoff coefficients:
The runoff coefficient from an individual rainstorm is defined as runoff divided by the corresponding rainfall both expressed as depth over catchment area (mm):

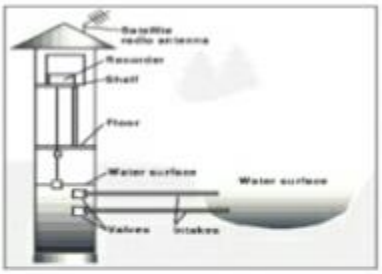
$$K = \frac{\text{Runoff [mm]}}{\text{Rainfall [mm]}}$$

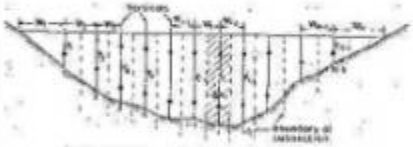


(a) Vertical staff gauge (b) Sectional staff

Fig. 4.1

he wire paid out. The operating range of this kind of gauge is about 5 m.





Run-off coefficients:

The percentage of rainfall that appears as storm water run-off from a surface is called the run-off coefficient.

The run-off coefficient of roofed areas (Cr) is 1.0.

The run-off coefficient of paved areas (Ci) is 0.9.

Depending on the soil type and rainfall intensity the run-off coefficient from pervious areas (Cp) could be as low as no run-off at all (low rainfall intensity, sandy soil) or up to 80% (high rainfall, heavy clay soil).

You need to know the run-off coefficient to size the storm water drainage system on the site.

Effects of surface runoff:

Erosion and deposition: Surface runoff can cause erosion of the Earth's surface; eroded material may be deposited a considerable distance away.

Environmental effects :

The principal environmental issues associated with runoff are the impacts to surface water, groundwater and soil through transport of water pollutants to these systems.

Agricultural issues:

The transport of agricultural chemicals (nitrates, phosphates, pesticides, herbicides etc.) via surface runoff.

The resulting contaminated runoff represents not only a waste of agricultural chemicals, but also an environmental threat to downstream ecosystems.

Flooding :

Flooding occurs when a watercourse is unable to convey the quantity of runoff flowing downstream.

Floods can be both beneficial to societies or cause damage.

Importance of Runoff:

* water balance calculation

*Irrigation scheduling:

The magnitude of flood flows to enable safe disposal of the excess flow.

The minimum flow and quantity of flow available at various seasons.

The interaction of the flood wave and hydraulic structures, such as levees, reservoirs, barrages and bridges.
*river engineering.
*highway engineering
*flood control
*inland waterways.
The capacity of storage structure such as reservoir.

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Runoff Processes

Runoff is usually considered as a streamflow that involves surface runoff and groundwater flow that reaches the streams. Surface runoff is a function of intensity, duration, and distribution of rain precipitation; permeability of ground surface; surface coverage (i.e., arid or semiarid); geometry of stream channel; depth of water table; and the slope of the land surface. Surface runoff is commonly represented in the form of a hydrograph, which is a time record of stream-surface elevation or stream discharge at a given cross section of the stream. Surface runoff and groundwater flow are determined by the rainfall intensity and duration, rate of infiltration, volume of infiltrated water, soil moisture deficiency, and other characteristics of the basin.

Runoff management practices

Runoff can also be managed to minimize, or at least control, soil loss under surface irrigation. One technique is to use pump-back runoff reuse systems, in which all runoff and sediment are collected in a reservoir at the field end, then pumped back to the inlet, where the runoff is reintroduced during the same irrigation as inflow to the field. While incurring energy and equipment costs for pumping, pump-back return systems offer many benefits. Reintroduced inflow that contains some sediment reduces furrow-stream sediment-carrying capacity. Depending upon flow hydraulics, sediment eroded from the field may be redeposited on to the field near its origin. Where irrigation return-flow water-quality regulations are stringent, irrigators with pump-back systems will have no off-farm (or off-site) discharge of sediment, fertilizer, pesticides, weed seeds, or microbes.

To collect or retain soil eroded from irrigated fields, settling basins varying in size and shape may be constructed along runoff collection channels, often at field ends. These basins collect much of the runoff and, under quiescent conditions, allow soil particles from the runoff to settle. Some basins are large (for collecting runoff from 20 ha or more); some are small (for runoff from only a few furrows). After draining the basins at the season's end, the collected sediment can be returned to the field. While offering this advantage, settling basins suffer from many disadvantages. Erosion still occurs in the field. Clay-sized soil, containing most of the P, other plant nutrients, and agricultural chemicals, does not fully settle out but is largely lost in the basin's outflow during the irrigation season. A settling basin's sediment collection efficiency declines as it fills with sediment, reducing residence time in the basin. Land area is taken out of production. Settling basins also require weed control, can be safety hazards, and can be the source of flying insect pests. Energy, time, and, for bigger basins, heavy equipment not common on farms are required to remove sediment from the basins and redistribute the sediment on to the field or another area. In spite of these disadvantages, settling basins have their place, particularly when used in combination with other erosion-control practices.

Buried drains with standpipes are a special type of settling basin. In a field's tail ditch, plastic, corrugated pipe is placed in a trench as a drain. Standpipes that extend vertically from the drain to just above the soil surface are installed every 5–10 furrows along the drain's length, then the trench is backfilled. Earthen dams are then constructed across the tail ditch, just downstream of each standpipe's inlet, thus forming a small basin at each standpipe. In operation, each dam forces runoff to pond, allowing some sediment to settle, before the runoff enters the standpipe's inlet and drains from the field. With appropriate management, this special drainage system can eliminate excessive erosion that often occurs at field ends where furrow slope increases sharply as runoff drains into a deep tail ditch. These drainage systems: (1) increase yields from field ends, (2) bring additional land into production, (3) ease farm equipment's ingress and egress across the lower field boundary, and (4) reduce weed problems common in and near wet tail ditches. Unfortunately, buried drains do not control erosion from the bulk of the field, and still allow some sediment to enter the drain and be transported from the field in the drainage water.

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furrow lengths and lower inflow rates and stream velocities. With proper management, buried lateral systems can attain irrigation efficiencies similar to those of sprinkler system.
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Grassed waterways

Runoff from terraces or other concentrated flow areas can be conveyed using grassed waterways, thus preventing channel erosion and gully formation. Costly downstream sedimentation is reduced because the sediment transported by overland flow is deposited in the grassed waterways. A stable outlet located below the grassed waterway serves to disperse the flow before it enters a vegetative filter.

Grassed waterways reduce peak runoff rates and provide a stable channel that can easily handle the flow that remains. Channel stabilization is provided by modifying the cross-section and slope of the waterway to limit flow velocity and by establishing vegetative protection. The types of vegetation used in the channel are dictated by local soil and climatic conditions. In addition to grassed waterways, permanent gully control structures may be needed on areas with relatively large runoff volumes or steep slopes.

To prevent failure, the waterway should not be used as a road, stock trail, or pasture, especially during wet conditions. Care should also be taken when farm machinery crosses the waterway. The waterway should be managed to stimulate new growth and control weeds, and an annual application of fertilizer is recommended.

Runoff Control and Utilization

Uncontrolled runoff is never desirable, as it is likely to cause soil erosion on slopes as well as flooding and silting in bottomlands. In humid regions, where rainfall may be excessive, measures may be needed to ensure the safe routing and conveyance of the runoff. Such measures, called ‘surface drainage,’ include shaping the land and treating it so as to direct the runoff via protected (grassed or even concrete-lined) channels. In semiarid regions, by way of contrast, natural rainfall is barely sufficient for crops, hence farmers typically strive – by such means as terracing and mulching – to cause as much of the rainfall as possible to infiltrate the soil, and thereby to minimize runoff.

The situation is fundamentally different in arid (as distinct from semiarid) regions. In many arid regions, large tracts of land are basically unsuitable for conventional rainfed farming, owing to the paucity and instability of rainfall, the nature of the soil (too shallow, stony, or saline to permit cultivation), or the rough topography. From the point of view of farmers (though not of ecologists, who are concerned about an area's natural biota rather than about crop production per se), rain falling on such lands is almost totally lost –

being insufficient either to recharge groundwater or to support an economically viable crop.
Most of the meager rainwater generally infiltrates the soil to a shallow depth only, and it is quickly returned to the atmosphere – either by direct evaporation from the soil or by transpiration from native vegetation. Occasional intense rainstorms may none the less generate runoff and cause sudden flash floods. Although runoff from any particular rainstorm may be high, under natural conditions the total seasonal runoff seldom exceeds 10% of the annual precipitation.

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