RAMA UNIVERSITY

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FACULTY OF ENGINEERING & TECHNOLOGY

This section introduces three types in Rainfall Analysis:

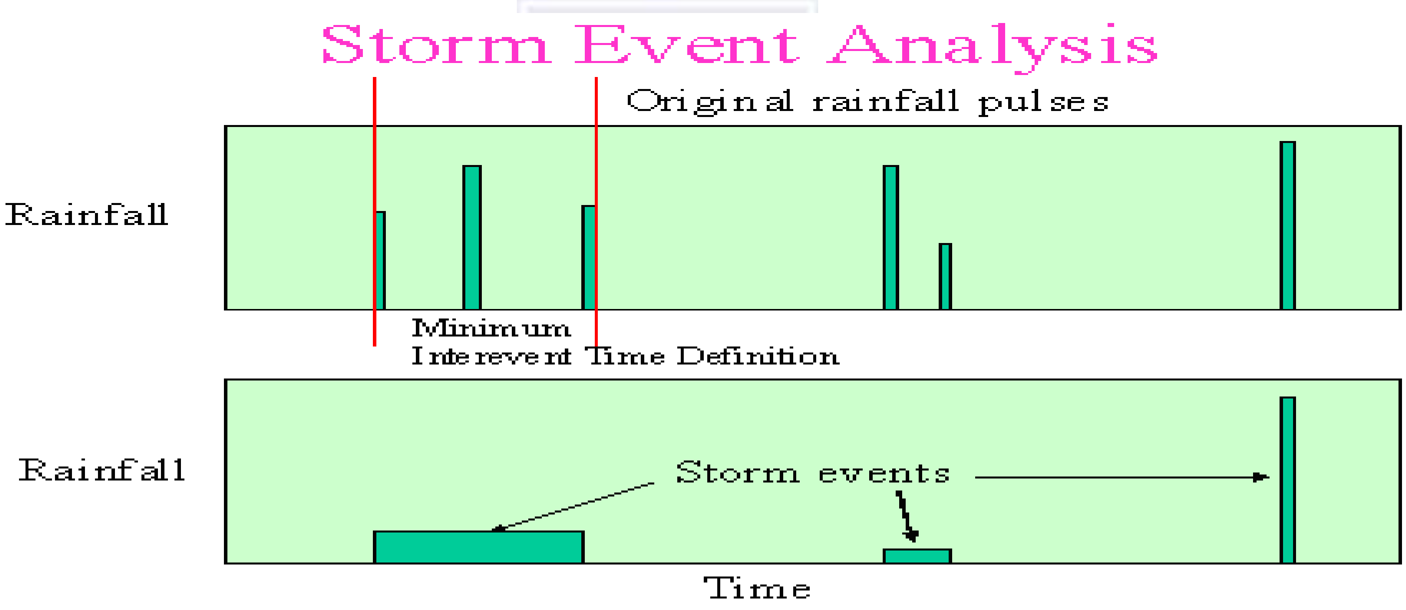
1. Storm Event Analysis;
2. Intensity-duration-frequency Curve;
3. Probable Maximum Precipitation.

Rainfall Hyetograph and Storm Event Analysis

Rain is usually measured in incremental volumes at gauging stations. These increments take the form of daily volume, or volume at some other increment of time. It is possible to plot the rainfall volume, or its equivalent the rainfall intensity, for incremental times during the event. The result is a plot known as a hyetograph. The shape of the hyetograph for a particular rainfall event constitutes the time history of that event.

A hyetograph can be used in single event and continuous simulation analysis of rainfall-runoff processes. A long-term continuous hyetograph consists of a series of rainfall pulses through time. To separate it into independent storm events, a definition of the minimum interevent time is required; the reason for this being so that any two pulses of rainfall can be considered to be belonging to separated events if the time period between the pulses is longer than the minimum interevent time. Storm event analysis can be used to determine the statistics and the probability distributions of rainfall volume, duration, average intensity, and inter event time from a long-term hyetograph. Analysis of a number of rainfall record across Canada (Adams et al, 1983) indicates these characteristics can be described as exponential density functions. Such statistical information can be used in statistical analysis of rainfall-runoff process (Adams and Bontje, 1983).

which equal or exceed the magnitude of the event of interest.



➢ Rainfall Intensity-Duration-Frequency Curves

An observed hyetograph is useful as an indication of the severity or typical nature of rainfall events, and in calibration of models. However, a natural event often has little intuitive significance and no discernable probability, since there are no two events that are identical. It is therefore useful to seek alternatives to the direct use of observed rainfall events.

The most basic definition of a storm event lies in its duration and volume, and possibly in its peak intensity. In the long term, rainfall can be assessed according to the frequency of a given duration and volume occurs. This relationship is defined by curves known as Intensity/ Duration/ Frequency (IDF) curves.

To generate an IDF curve, observed rainfall records are scanned for all instances of a particular combination of duration and volume; the number of times that combination occurs provides a measure of likelihood. Assessing the problem in terms of the number of times a combination is exceeded, provides a probability that expresses the frequency of exceedance of that combination. Compiling statistics for all combinations leads to curves that define the relationship between rainfall event intensity, duration, and frequency.

The MSC defines an intensity-duration event for a particular duration, to, as the annual maximum intensity determined. The duration selected are arbitrary time periods over which rainfall is added and are not necessarily related to the physical duration of a storm. istribution is used to calculate the frequency of intensity and duration.

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TOPIC : HYDROLOGY (L-3)

The MSC types IDF curves are derived by scanning the clock time rainfall record with the event definition: t<=to,

$$\text{Annual Max } i = \frac{v}{t_o},$$

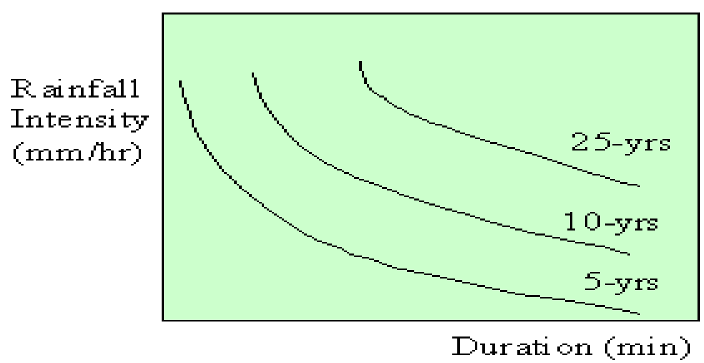
The extreme annual series is determined, and a Type 1 extreme value d.

$$i = \frac{a}{(t+b)^c}$$

i = intensity (mm/hr)
t = time in minutes
a, b, c = constants developed for each IDF curve

Once an IDF relationship is developed for the area of interest, a certain combination of design intensity and duration can be determined for a particular frequency of occurrence. The IDF curves are used extensively in single event analysis of rainfall-runoff proce

Intensity-duration-frequency curves



Scan the clocktime rainfall record for a duration (e.g. 5 min.);
Find the maximum average intensity (volume/time);
Use Extreme Type I distribution to determine the frequency

$i = a/(t+b)^c$

Probable Maximum Precipitation (PMP)

The probable maximum precipitation is the critical depth-duration-area rainfall relation for a given area and season which would result from a storm containing the most critical meteorological conditions considered probable. These critical conditions are determined by the analysis of effective precipitable water, depth of inflow layer, wind, temperature and other factors, and the historical record of extreme storm events in the region, topography, season, and location of the area.

Hydrologic Losses

Not all rainfall events generate runoff directly. Minor rainfall events may be retained completely by above ground objects such as trees and structures, soil infiltration, and surface depression. In order to estimate the direct runoff from rainfall events, it is important to understand the loss processes and quantify the amount of losses. Unfortunately, these losses are usually very difficult to quantify the amount and they vary across time and space. For practising hydrologists and engineers, some form of approximation of the hydrologic losses may be required. These approximation may be based on actual field measurement, previously reported data from similar catchments, and computer simulation of the physical processes involved.

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- **Interception** refers to the precipitation that wets and adheres to aboveground objects such as trees and buildings and finally returns to the atmosphere through evaporation. It is a function of storm eharacter, the species, age and density of prevailing plants and trees, and the season of the year. Usually about 10-20% of the precipitation that falls during the growing season is intercepted and returned to the hydrologic cycle by evaporation. Interception during rainfall events is commonly greater than for snowfall events. Estimates of losses to gross precipitation through interception can be significant in annual or long-term models, but for heavy rainfalls during individual storm events, accounting for interception may be unnecessary. Most interception loss occurs during the initial storm period and the rate of interception rapidly decreases to zero. In addition to trees, forms of vegetation can also intercept large quantities of water.

- **Depression Storage** refers to the precipitation which is trapped in numerous small depressions. It is a function of the land form and local land-use properties and it varies widely in size, degree of interconnection, and contributing drainage area. Depressions can be considered as small reservoirs. Depression storage is sometimes assumed to be a constant throughout the storm events. Rainfall is assumed to fill up depression storage before runoff begins. Water evaporation can be from the soil as well as open water bodies to the atmosphere. This is a significant process in the hydrologic cycle because it supplys the atmosphere with water moisture for the subsequent rainfall events.

It is significant over large bodies of water such as lakes, reservoirs, and the ocean.

- **Evaporation** occurs when a molecules of water moves quickly enough to break away from other water molecules at the water-air interface. In order for the water molecules to break away, the latent heat of evaporation (540 calories per gram of water at 100^{o} C) is required. Water molecules also enter the water from air through the condensation process. The net exchange of water molecules at the air-water interface is determined by the rate of evaporation and the rate of condensation. Evaporation will proceed when sufficient energy is available (e.g., heat in water or solar radiation) and when the vapour pressure above the water is less than the saturation vapour pressure. It is significant over large bodies of water such as lakes, reservoirs, and the ocean.

- **Evaporation from water surface is a function of**

- **Solar Radiation**

  Solar radiation provides energy that can be stored as heat in the water. This latent heat is transformed to kinetic energy as water molecules evaporate.

- **Temperature**

  Although temperature is not directly related to evaporation rate, it controls the saturation vapour pressure and affects the difference in vapour pressure between the surface and the bulk air above.

- **Humidity**

The rate of evaporation is directly proportional to the difference between actual humidity in the air above the water the saturated humidity that occurs at a specified temperature.

- **Wind**

Wind can remove the more humid air above the water surface and replace it with dry air that enhances the rate of evaporation. However, the maximum evaporation rate is controlled by factors other than wind speed and increasing wind speed above a certain value would cause no increase in evapoation.

- **Water Body Depth**

Shallow lakes warm up more quickly and follow seasonal temperature trends more closely than do larger lakes. Shallow lakes with a small water volume show high evaporation rates during summer months and lower evaporation rates during the winter period. However, deep lakes with large volumes generally lay behind atmospheric temperature trends and have sufficient water volume to release the stored energy in cooler months, permitting evaporation in the absence of sufficient solar radiation. Higher evaporation rates may occur in winter months rather than in summer months in large lakes.

- **Size and Shape of Water Surface**

As dry air travel across a large lake, the vapour pressure or water content of the air will begin at low values on the windward side of the lake and become progressively more humid as it proceeds across the lake surface. Evaporation rates will be highest on the windward side of the lake but will decrease as the air mass moves across the lake and the relative humidity increases.

The average rate of evaporation over a lake will depend on the relationship between the prevailing wind direction and the orientation of the long axis of a lake. If the prevailing wind moves along or parallel to the long axis of a lake, the vapour pressure will increase to a greater content and therefore the rate of evaporation will decrease towards the leeward side of the lake. As a result, the maximum rate of evaporation from the lake occurs when the air mass is in contact with the lake for the shortest period. If the prevailing wind crosses the lake along the short axis, the air does not pick up as much moisture and the rates of evaporation remain higher.

- **Water Quality**

Evaporation from a free water surface will decrease proportionally to increasing salintiy. For instance, if the total dissolved solids of the water increases by 1%, the evaporation form that water will decrease by 1%. This caused by the tendency of dissolved ions in water to hold water molecules more closely together.

- **Evaporation from soils is a function of**

- **Soil moisture content**

  This is the most significant factor. As the moisture content of the soil decreases, the evaporation rate will decrease as the dry soil on top acts as a barrier to provent evaporation of water at greater depth.

- **Water Table Depths**

  Maximum evaporation rates will occur when the water table is at the ground surface. As the water table depth increases, the rate of evaporation decreases.

- **Soil Characteristics**

  Soil characteristics affect the rate of evaporation and the availability of water to evaporate. In general, fine-grained soils hold more moisture and have a greater reservoir of water for evaporation. Additionally, the finer-grained soils have a greater capillary effect and transport water from greater depths to be evaporated at the surface. As a result, areas with fine-grained soils are subject to greater evaporation than areas with coarse-grained soils.

- **Soil Colour**

  Materials with a darker colour absorb more solar radiation than light-coloured materials. Dark soil will absorb more energy and be subject to greater evaporation rates than light soils.

- **Vegetative Cover**

  Vegetative cover tends to decrease the amount of evaporation compared to that of a vare soil. Plants provide shade on the soil surface and decrease the amount of solar radiation reaching the ground. Plants also provide a wind block that reduce the wind speed at the soil surface and reduce evaporation rates. Plant can also increase the relative humidity close to the ground surface through transpiration and decrease simple evaporation from the soil surface.

  For open bodies of water, evaporation can be 100% while for soils it varies from a high 100% when the soil is highly saturated to essentially zero at stages of very low moisture content.

- **Transpiration** is the evaporation of water from the vascular system of plants into the atmosphere. Water is taken up by plant roots in the soil, moves to the branches and leaves where evaporation takes place. The amount of water used for plant growth is negligible compared to the water that is transpired. Transpiration occurs not because the plant is breathing, but because of the difference in vapour pressure inside the leaf and in the air outside. Transpiration is controlled by the same factors that control simple evaporation from water surface. These include:

- **Solar Radiation**

  The solar radiation to plant leasves controls the opening of the stomata and controls transpiration. Maximum transpiration rates occur during daylight hours and in the summertime with minimum rates at night and cooler weather.

- **Air Temperature**

  Transpiration shows a maximum rate at an optimum temperature of a plant species.

- **Air Humidity**

  The difference in vapour pressure within the stomatal cavities of the leaves compared to the vapour pressure in the outside air is a driving force for transpiration.

- **Wind and Air Turbulence**

  Wind and Air Turbulence removes the saturated air and increase the vapour pressure gradient between the air inside the leaves and the surrounding air.

- **Vegetation**

  When stomata are closed, virtually no transpiration can occur. When they are open, the climatic factors control the rate of evapotranspiration. Length of daylight, air temperature, and higher humidity control the length that stomata remain open.

  Lighter colour for plant leaves reflect solar energy and reduces transpiration. The more dense a vegetative cover, the more leaf surface area will be available for transpiration. Broader leaves provide greater surface area for evaporation. Transpiration will increase with the growth of plant. Plants with deep root types supply more water for transpiration.

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- **Soil Moisture Content**

  The availability of moisture in the soil zone will control the amount of tranpiration that can occur.

- **Storage Capacity**

  Fine-grained materials will store more water than coarse-grained materials. As a result, more water is available in fine grained soils.

- **Capillary Tension**

  Finer-grained soils can hold greater amounts of water by capillary action than coarse-grained soils.

- **Soil Permeability**

  Higher soil permeabilities permit faster replenishment of water to the root zone and lower permeabilities decrease the rater of replenishment.

- **Depth to Water Table**

  The depth of the root zone for different plants ia a very important controlling factor for evaporation. The change in water levels as a result of plant uptake of water can be used as a direct measurement of evapotranspiration rates.

Thank You