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Flood routing

Introduction ⇒

flood routing is the technique of determining the flood hydrograph at a section of a river by utilizing the data of flood flow at one (or) more upstream sections. The hydrologic analysis of problems such as flood forecasting, flood protection, reservoir design and spillway design invariably include flood routing. In these applications two broad categories of routing can be recognised. These are

1. Reservoir routing
2. Channel routing

* In reservoir routing the effect of a flood wave entering a reservoir is studied. Knowing the volume-elevation characteristic of the reservoir and the outflow elevation relationship for the spillways and other outlet structures in the reservoir, the effect of a flood wave entering the reservoir is studied to predict the variations of reservoir elevation and outflow discharge with time. This form of reservoir routing is essential

i) in the design of the capacity of spillways and other reservoir outlet structures, and

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1) In the location and sizing of the capacity of reservoirs to meet specific requirements.

2) * In channel routing the change in the shape of a hydrograph as it travels down a channel is studied. By considering a channel reach and an input hydrograph at the upstream end, this form of routing aims to predict the flood hydrograph at various sections of the reach.

A variety of routing methods are available and they can be broadly classified into two categories as (i) Hydrologic routing *

(ii) Hydraulic routing*

* Hydrologic routing methods employ essentially the equation of continuity.

* Hydraulic methods, on the other hand, employ the continuity equation of together with the equation of motion of unsteady flow.

The basic eq used in the hydraulic routing, known as st. venant equations, afford a better description of unsteady flow than hydrologic methods.

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Note → Flood routing is used in estimating the height of a flood peak at a downstream location in short term flood forecasting,

~~i) estimating the height of a flood peak at a downstream~~

i) estimating the protection that would result from construction of a reservoir

ii) Determining required levee heights for flood protection, determining the adequacy of spillways,

iii) predicting the behaviour of a river after a change in channel conditions.

→ flood routing is the technique in hydrology to compute the effect of storage on the shape and movement of the flood wave.

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Basic equations →

The passage of a flood hydrograph through a reservoir (or) a channel reach is an unsteady flow phenomenon. It is classified in open-channel hydraulics as gradually varied unsteady flow. The equation of continuity used in all hydrologic routing as the primary equation states that the difference b/w the inflow & outflow rate is equal to the rate of change of storage i.e

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$$I - Q = \frac{dS}{dt}$$

where I = Inflow rate
Q = outflow rate
S = Storage.

In a small time interval Δt the difference b/w the total inflow volume and total outflow volume in a reach is equal to the change in storage in that reach

$$\bar{I}\,\Delta t - \bar{Q}\,\Delta t = \Delta S.$$

Where $\bar{I}$ = average inflow in time Δt,
$\bar{Q}$ = average outflow in time Δt &
ΔS = change in storage.

By taking $\bar{I} = (I_1 + I_2)/2$
$\bar{Q} = (Q_1 + Q_2)/2$ &
$\Delta S = S_2 - S_1$

$$\left[\frac{I_1 + I_2}{2}\right]\Delta t - \left[\frac{Q_1 + Q_2}{2}\right]\Delta t = S_2 - S_1$$

In the differential form the equation of continuity for unsteady flow in a reach with no lateral flow is given by

$$\frac{\partial Q}{\partial x} + T\,\frac{dy}{dt} = 0.$$

where T = top width of the section &
y = depth of flow.

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The equation of motion for a flood wave is derived from the application of the momentum eq as

$$\frac{\partial y}{\partial x} + \frac{V}{g}\frac{\partial V}{\partial x} + \frac{1}{g}\frac{\partial V}{\partial t} = S_0 - S_f$$

where V = velocity of flow at any section,
S_0 = channel bed slope
S_f = Slope of the energy line.

The continuity equation and the equation of motion are believed to have been first developed by A.J.C Barre de saint Venant (1871) and are commonly known as st. venant eq.

Hydrologic storage routing (or) level pool routing ⇒

A flood wave I(t) enters a reservoir provided with an outlet such as a spillway. the outflow is a function of the reservoir elevation only, i.e Q = Q(h). The storage in the reservoir is a function of the reservoir elevation, S = S(h). Further due to the passage of the flood wave through the reservoir, the water level in the reservoir changes with time, h = h(t) and hence the storage and discharge change with time.

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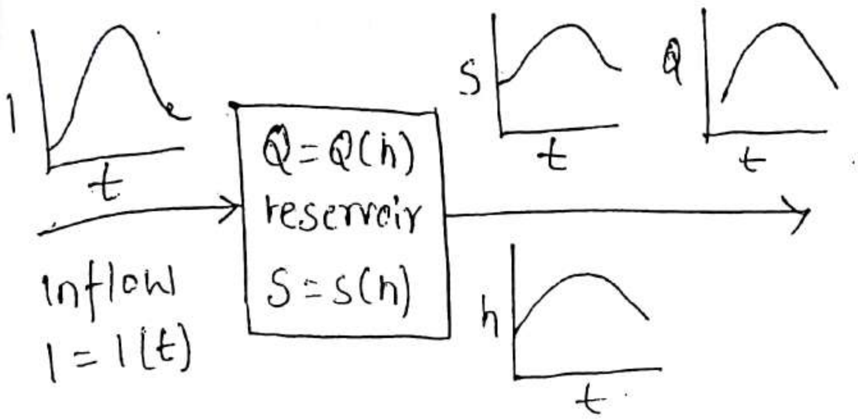

fig ⇒ Storage routing

it is required to find the variation of S, h and Q with time i.e find $S = s(t)$, $Q = Q(t)$ and $h = h(t)$ given $I = I(t)$.

If an uncontrolled spillway is provided in a reservoir, typically

$$Q = \frac{2}{3} C_d \sqrt{2g}\, L_e H^{3/2} = Q(h).$$

where H = head over the spillway,
L_e = effective length of the spillway crest and
C_d = coefficient of discharge.

For reservoir routing, the following data have to be known

* Storage volume vs elevation for the reservoir,
* Water-surface elevation vs outflow and

hence storage vs. outflow discharge.

* Inflow hydrograph $I = I(t)$; and
* Initial values S, I and Q at time $t = 0$.

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there are a variety of methods available for routing of floods through a reservoir.

As the horizontal water surface is assumed in the reservoir, the storage routing is also known as level pool routing.

Modified pul's Method of routing ⇒

$$\left[\frac{I_1+I_2}{2}\right]\Delta t+\left[S_1-\frac{Q_1\Delta t}{2}\right]=\left[S_2+\frac{\Delta t\, Q_2}{2}\right]$$

At the starting of flood routing, the initial storage and outflow discharges are known.

In the above eq all the terms in the left hand side are known at the beginning of time step Δt.

Hence $\left[S_2+\frac{Q_2\Delta t}{2}\right]$ is calculated from above eq.

Since the relation $S=S(h)$ and $Q=Q(h)$ are known.

By using $\left[S+\frac{Q\Delta t}{2}\right]$ we will determine the reservoir elevation and hence the discharge at the end of the time step.

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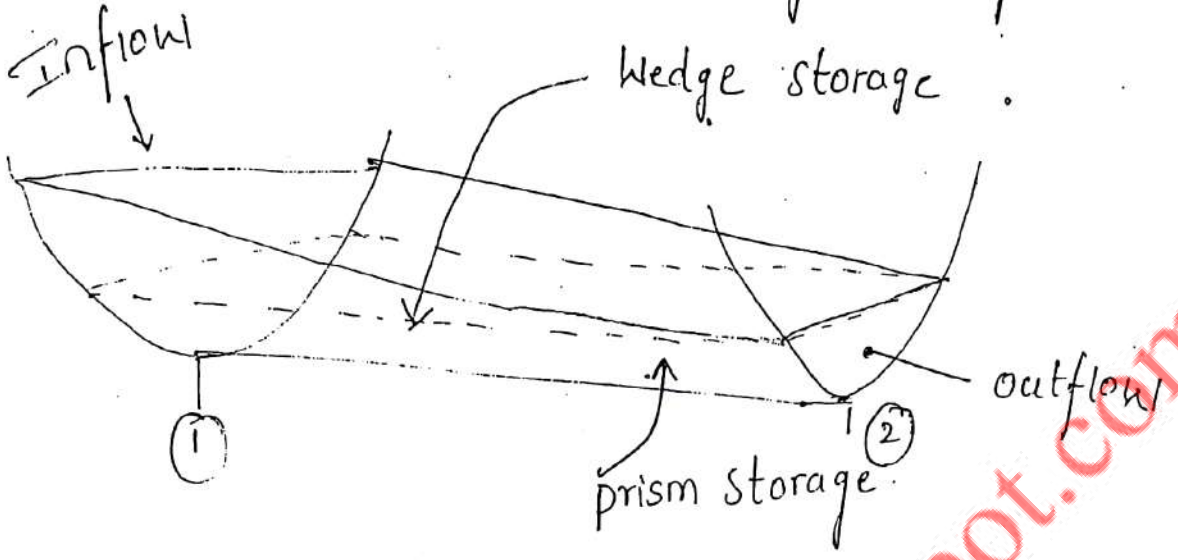
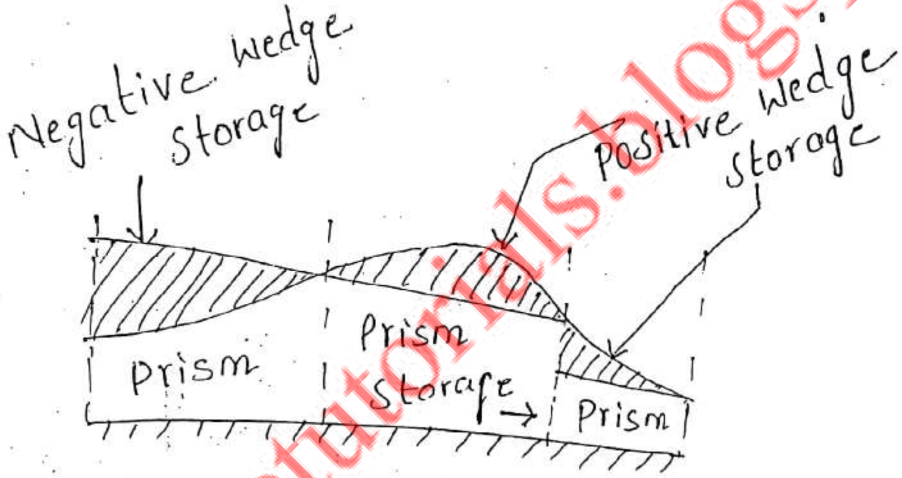
1. prism storage & wedge storage.





Storage in a channel reach.

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Prism storage →

it is the volume that would exist if the uniform flow occured at the downstream depth, i.e the volume formed by an imaginary plane parallel to the channel bottom drawn at the outflow section water surface.

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Wedge storage ⇒

it is the wedge like volume formed b/w the actual water surface profile and the top surface of the prism storage.

At a fixed depth at a downstream section of a river reach, the prism storage is constant while the wedge storage changes from a positive value at an advancing flood to a negative value during a receding flood.

The total storage in the channel reach can then be expressed as

$$S = K\left[x I^m + (1-x) Q^m\right]$$

where K and x are coefficients and m = a constant exponent. It has been found that the value of m varies from 0.6 for rectangular channels to a value of about 1.0 for natural channels.

Muskingum equation ⇒

using m = 1.0

$$S = K\left[x I + (1-x) Q\right]$$

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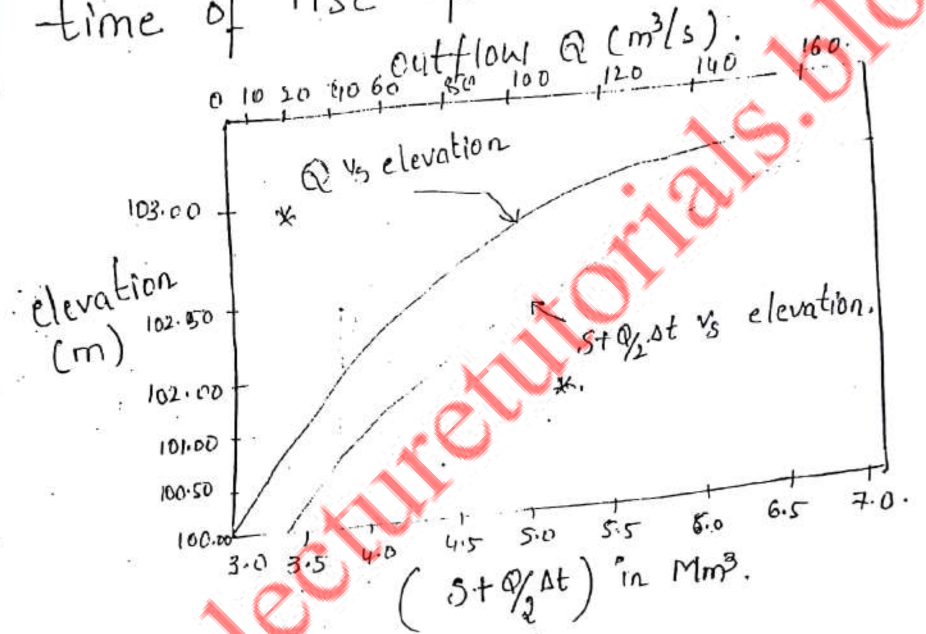
For practical hand computation, the following semi graphical method is very convenient.

1. From the known storage - elevation and discharge elevation data, prepare a curve of $\left[S + \frac{Q\Delta t}{2}\right]$ vs elevation. Here Δt is any cohesion interval, approximately 20 to 40 % of the time of rise of the inflow hydrograph.



2. On the same plot prepare a curve of outflow discharge vs elevation.

3. The storage, elevation and outflow discharge at the starting of routing are known. For the first time interval Δt, $\left(\frac{I_1+I_2}{2}\right)\Delta t$ and $\left(S_1 + \frac{Q_1\Delta t}{2}\right)$ are known and by using puls eq the term $\left(S_2 + \frac{Q_2\Delta t}{2}\right)$ is determined.

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· The water surface elevation corresponding to $\left(S_2 + \frac{Q_2 \Delta t}{2}\right)$ is found by using the above graph. The outflow discharge Q_2 at the end of the time step Δt is found from above graph.

· Deducting $Q_2 \Delta t$ from $\left(S_2 + \frac{Q_2 \Delta t}{2}\right)$ gives $\left(\frac{S - Q \Delta t}{2}\right)$, for the beginning of the next time step.

· The procedure is repeated till the entire hydrograph is routed.

Hydrologic channel routing →

In reservoir routing, the storage was unique function of the outflow discharge $S = f(Q)$, However, in channel routing the storage is a function of both outflow and inflow discharges and hence a different routing method is needed. The water surface in a channel reach is not only not parallel to the channel bottom but also varies with time. Considering a channel reach having a flood flow the total volume in storage can be considered under two categories as.

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