中等水文學

Chap7 : Flood routing

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I. Introduction

1. As wave moves down the river

- The shape of the wave gets modified due to various factors , such as channel storage , resistance , lateral addition or withdrawal of flow.
- To attenuate the peak due to friction if there is no lateral flow
- The addition of lateral inflows can cause a reduction of attenuation or even amplification of a flood wave

2. A Flood wave passes through a reservoir The peak is attenuated and the time base is enlarged due to the effect of storage.

3.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.

4. Application flood forecasting , flow protection , reservoir design and spillway design.

5. Two categories
- Reservoir routing
- channel routing

6. Reservoir routing

To study the effect of a flood wave entering a reservoir.

7. Channel routing

To study the changes in the shape of a hydrograph as it travel down a channel.

8. Methods

–hydrologic routing & hydraulic routing

(continuity Eq.) (continuity Eq.)

- S-Q關係 eq. of motion of unsteady flow

II. Basic equations

1.水流現象 _gradually varied unsteady flow

2. Continuity Eq in difference form

$$I - O = {ds}/{dt} \qquad (7\text{-}1)$$

I : inflow

O : outflow

S : dyotshr

In small time interval

$$\bar{I}\Delta t - \bar{O}\Delta t = \Delta S$$

$\bar{I}$: average inflow in time Δt

$\bar{O}$: average inflow in time Δt

ΔS : change in storage

$$[\frac{I_1 + I_2}{2}]\Delta t - [\frac{O_1 + O_2}{2}]\Delta t = S_2 - S_1$$

- Δt should be sufficiently short so that I & O are straight lime in Δt
- Δt < the time of transit of the flood wave through the reach.

- Continuity equation in differential form

$$\frac{\partial Q}{\partial X} + T \frac{\partial y}{\partial} = 0$$

- T : top width of the section
- y : depth of flow

3. Momentum equation

$$\frac{\partial y}{\partial x} + \frac{V}{g}\frac{\partial V}{\partial x} + \frac{1}{g}\frac{\partial V}{\partial t} = S_0 - S_1$$

III. Hydrologic Storage Routing (Level Pool Routing)

- S=S(h)
  Q=Q(h)

1. outflow Q=Q(h)

2. For reservoir routing , the following data have to be known:

(1) Storage volume V.S. elevation

(2)Water surface elevation outflow

»Storage outflow

(3)Inflow hydrograph

(4)Initial values of S , I and Q at time=0

3. Various methods

- All of them use Eq(7-2) but in various rearranged manners.
  - (A)Modified puls method
    - Eq(7-2) is rearranged as

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

- On the same plot prepare a curve of outflow discharge VS elevation (Fig 7.2)
- initial S , h and Q are known

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

  - 由initial h從圖查出S與Q，因此 $S_1+\frac{Q_1\Delta t}{2}$ 已知
- 由上式求出 $S_2+\frac{Q_2\Delta t}{2}$ 後，從step 1之圖而求出h_2與Q_2
- Deducting Q_2 Δt from ($S_2+\frac{Q_2\Delta t}{2}$) gives ($S_2-\frac{Q_2\Delta t}{2}$), for the beginning of the next time step

IV. Attenuation

- The reduction in the peak value is called attenuation
- The time difference between the two peaks of inflow and outflow is known as lag.
- In a freely operating spillway , the peak of the outflow hydrograph will occur at the point of intersection of inflow and outflow curve.

V. Hydrologic channel routing

1.Storage & outflow relation

(a)

- In reservoir routing storage is a unique function of Q S=f(Q)
- In channel routing
  - storage is a function of both outflow and inflow
  - The water surface in a channel reach is not only not parallel to the channel bottom but also varies with time

(b)Total volume in storage

 Prism storage ② 多 Wedge storage

(c)Prism storage S_p

– The volume formed by an imaginary plane parallel to the channel bottom drawn at the outflow section water surface

(d)Wedge storage S_w

– The volume formed between the actual water surface profile and the top surface of the prism storage

(e)The prism storage Sp以出流量Q之函數來表示 $S_p = f(Q)$

The wedge storage $S_w = f(I)$

$$S = S_p + S_w = K[XI^m + (1-X)Q^m] \qquad (7\text{-}3)$$

K與X：coefficient

m：0.6 for rectangular channel
1.0 for natural channel

2. Muskingum Equation

m=1 in Eq(7-3)

$$S = K[XI + (1-X)Q]$$

X：weighting factor 00.5

X=0 $\longrightarrow$ S=KQ linear reservoir

X=0.5 $\rightarrow$ both I & Q are important for S

K：storage time constant (T)

- approximately equal to the time of travel of a flood wave through the channel reach

3. Estimation of K and X

- To find the channel storage S v.s. time relationship using inflow and outflow hydrographs

$$(I_1 + I_2)\Delta t/2 - (Q_1 + Q_2)\Delta t/2 = \Delta S$$

- By choosing a trial value of X 建立S~ $[XI + (1-X)Q]$ 之關係
- if an incorrect valve of X is used, the plotted points will trace a looping curve
- By trail and error, a value of X is chosen so that S and $[XI + (1-X)Q]$ has linear relation

4. Muskingum Method of Routing

$$S_2 - S_1 = K[X(I_2 - I_1) + (1-X)(Q_2 - Q_1)]$$

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

$$\Rightarrow Q_2 = C_0 I_2 + C_1 I_1 + C_2 Q_1$$

$$C_0 = \frac{-KX + 0.5\Delta t}{K - KX + 0.5\Delta t}$$

$$C_1 = \frac{KX + 0.5\Delta t}{K - KX + 0.5\Delta t}$$

$$C_2 = \frac{K - KX - 0.5\Delta t}{K - KX + 0.5\Delta t}$$

$$C_0 + C_1 + C_2 = 1$$

$$Q_n = C_0 I_n + C_1 I_{n-1} + C_2 Q_{n-1}$$

 To choice a suitable Δ t

- K＞ Δt＞2Kx
  因 Δt＜2Kx negative value of coefficient

 The procedures of channel routing
(a)Knowing K and x , select an appropriate value of Δ t
(b)Calculate C_0 , C_1 and C_2

(c) Starting from the initial conditions I_1 , Q_1 and known I_2 at the end of the first time step Δt calculate Q_2 by Eq.(8.16)

(d) The outflow calculated in step (c) becomes the known initial outflow for the next time step. Repeat the calculations for the entire inflow hydrograph .