Surface Runoff

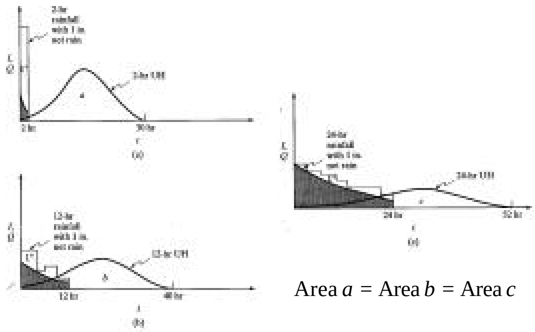
Hydrographs and Routing

- Lecture Overview
  - Define unit hydrographs and their utility in watershed modeling
  - Methods of synthesizing hydrographs when field data is unavailable
  - Methods of routing surface runoff and channel flow

Unit Hydrograph

- Runoff hydrograph that occurs for a unit depth of runoff over any specific time period
  - A watershed has a different unit hydrograph for each possible storm duration
  - Application of unit hydrograph to other runoff depths is found by multiplying runoff amount by unit hydrograph ordinates

Unit Hydrographs for Same Watershed

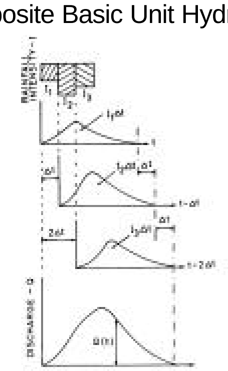


Viessman and Lewis, 2003.

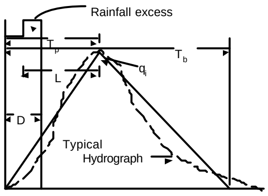
Unit Hydrograph

- Assumptions
  - Rainfall is spatially uniform
  - Rainfall rate is constant
  - Direct runoff hydrograph time base is constant
  - Discharge at time, t is proportional to total volume of direct runoff
  - Hydrograph reflects all physical characteristics of the basin

Composite Basic Unit Hydrograph



SCS Synthetic Hydrograph



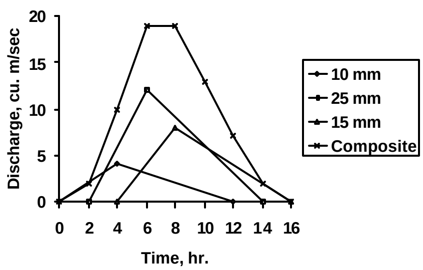
$$L = 0.6T_c$$

$$T_p = \frac{D}{2} + L$$

$$T_b = 2.67T_p$$

$$q_i = \frac{16.7AQ}{T_p}$$

Synthetic Composite Hydrograph



Time of Concentration

- channel flow $T_c = 0.02L_c^{0.77}S_c^{-0.385}$
- overland flow $T_c = \left|\frac{2.2nL_o}{\sqrt{S_o}}\right|^{0.467}$
- combined flow system

$$T_c = 0.02L_c^{0.77}S_c^{-0.385} + \left|\frac{2.2nL_o}{\sqrt{S_o}}\right|^{0.467}$$

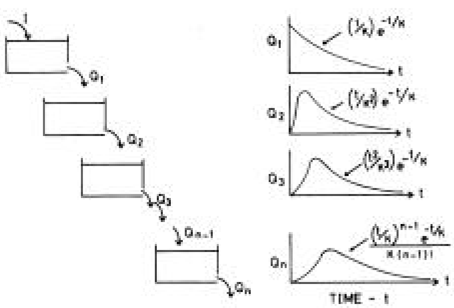
Runoff Routing

- Continuity Eq. $I - Q = \Delta S/\Delta t$
- Linear Reservoir $S = KQ$

$$I - Q = K\frac{dQ}{dt} \rightarrow Q = I(1 - e^{-t/K})$$

  - for instantaneous input $u(t) = \left(1/K\right)e^{-t/K}$
  - cascade reservoirs to form hydrograph

Cascaded Reservoirs



Runoff Routing

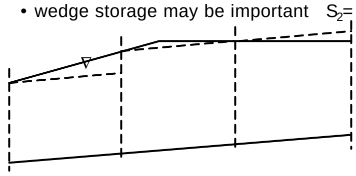
- Reservoir Routing
  - outflow is a function of stage $S_2 = f(O_2)$

$$\frac{2S}{t} + O \text{ vs. } O$$

$$\underbrace{I_1 + I_2 + \left(\frac{2S_1}{t} - O_1\right)}_{known} = \frac{2S_2}{t} + O_2 \rightarrow \textit{estimate } O_2$$

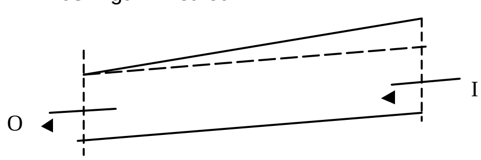
Runoff Routing

- Stream Routing
  - variable sections, stage vs. storage changes
    - wedge storage may be important $S_2 = g(O_2, I_2)$



Runoff Routing

- Stream Routing
  - Muskingum method



S = prism storage + wedge storage

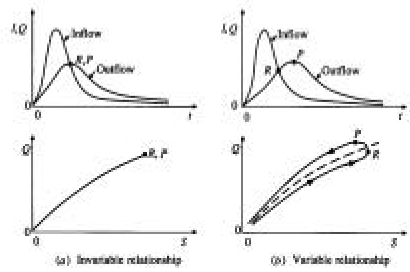
Runoff Routing

- Stream Routing
  - Muskingum method

$$S = K\left[XI + (1-X)O\right]$$

- *X* is a weighting factor (0 = *X* = 0.5)
- *K* is a time constant ˜ wave travel time through stream reach

Runoff Routing



S = f (Q)   S = f (Q, I)