Flood Routing in Ungauged Catchments Using Muskingum Methods

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Introduction

Flood routing can be defined as the mathematical method for predicting the changing magnitude and celerity of a flood wave that travel along rivers or through reservoirs.

It helps in estimating what stages or rates of flow occur without actually measuring them at specific locations during passages of floods.

Broadly divided in to hydrologic and hydraulic type.

The Muskingum flood routing method is one of the most popular hydrologic methods used for flood routing in several catchments.

Muskingum flood routing technique is hydrologic because, it relates temporary storage, inflow and outflow hydrographs as shown below.

$$S_{temp(t)} = K[I_t X + (1-X)Q_t]$$

Objective

Estimating K and X parameters in ungauged catchments based on flow and catchment characteristics so that flood routing could be possible in ungauged catchments.

Limitations and Problems

- Limitation of Muskingum Method:
  - The method has limitations where there are back water effects and high rising hydrographs, and
  - There is no precise method to estimate roughness coefficients (n) and it's practical estimation is subjective.
- Problems in ungauged catchments:
  - No observed hydrographs,
  - No flow variables, and
  - No observed lateral flow information.

Methodology

- Different hydrological flood routing methods reviewed,
- Muskingum–Cunge method preferably selected to estimate the K and X parameters in unguaged catchments,
- Three sub-catchments selected for analyses,
- Slope of the river reach (S) and reach length (L) extracted from DEM,
- Equivalent Roughness coefficients (n) determined from field observations,
- Flow variables estimated from empirical equations,
- Lateral flow estimated from the rate of change of inflow hydrographs, and
- Flood routing conducted on selected events, then the computed hydrographs compared statistically and graphically against the observed hydrographs.

Section factor & Lacy regime equations used to estimate flow depth (y) and hydraulic radius of a parabolic river X-section. In a channel where top width (B) exceeds mean flow depth by a factor of 20, B=P

$$AR^{2/3} = \frac{Q_0 n}{\sqrt{S}} \qquad P = 4.71\sqrt{Q_0}$$

$$AR^{2/3} = \left(\frac{2yP}{3}\right) * \left(\frac{2y}{3}\right)^{2/3} = \frac{Q_0 n}{\sqrt{S}}$$

$$y = \left(\frac{Q_0 n}{0.508 P\sqrt{S}}\right)^{3/5}$$

$$R = \frac{2y}{3} \quad \& \quad B = P$$

$$V_{av} = \frac{1}{n} R^{2/3}\sqrt{S}$$

$$V_w = \frac{9}{11} V_{av}$$

$$K = \frac{\Delta L}{V_w}$$

$$X = \frac{1}{2} - \frac{Q_0}{2BSV_w \Delta L}$$

Results

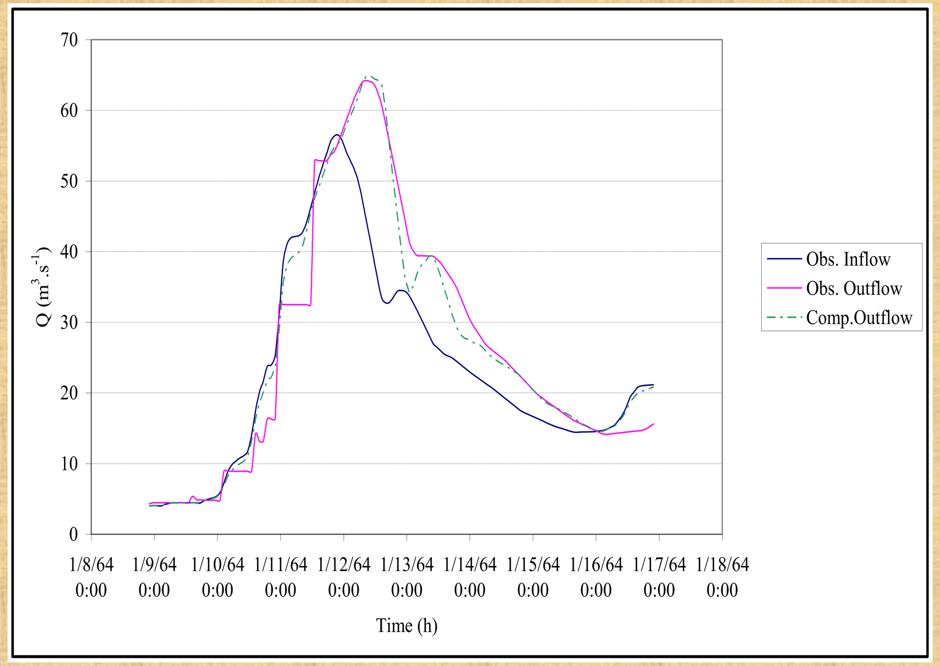

Fig-1 Observed and computed hydrographs at Mooi River upstream (54 km reach length)

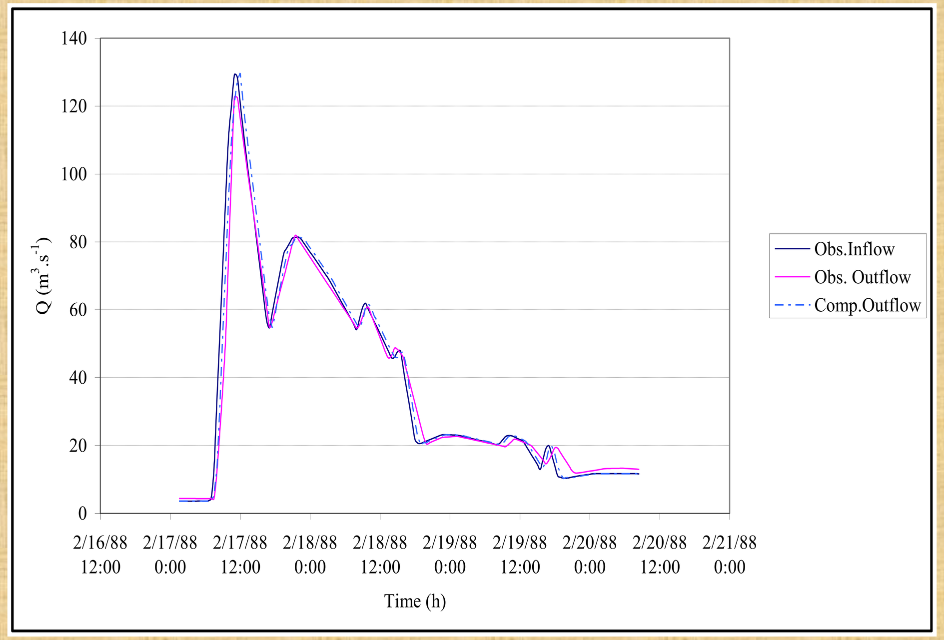

Fig-2 Observed and computed hydrographs at Klip River (4 km reach length)

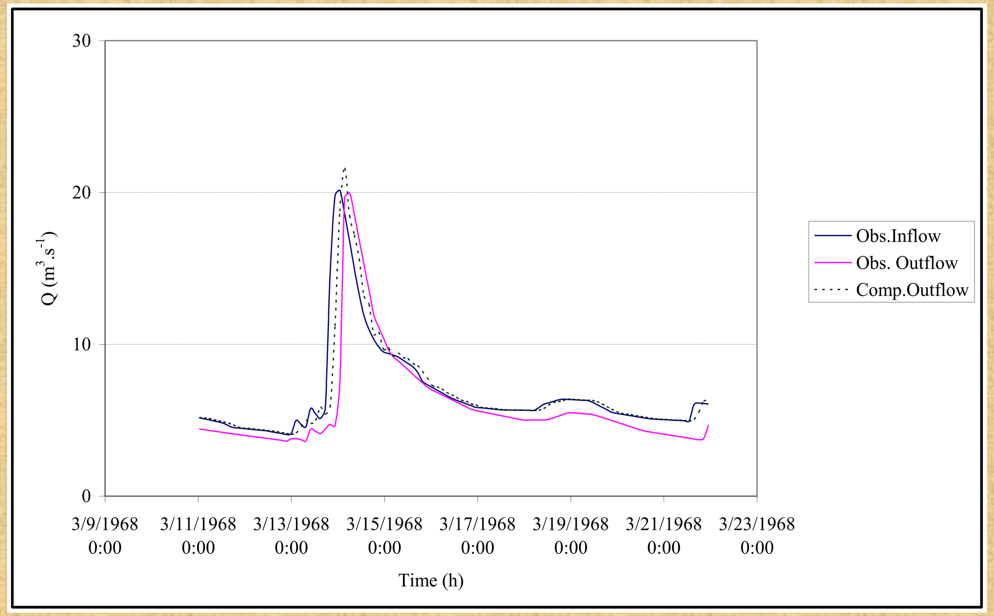

Fig-3 Observed and computed hydrographs at Mooi River down stream (21 km reach length)

Conclusions

- From the results obtained, it is evident that Muskingum-Cunge method together with empirically determined variables worked well in three of the catchments.
- Hence, the method can be applied to ungauged catchments whose flow and catchment physical characteristics can be estimated.

References

- **Arcement, GJ, Jr and Schneider, VR.1989.** Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains. [Internet]. Oklahoma Technical Press, Oklahoma, USA. Available from: http://www.fhwa.dot.gov/bridge/wsp2339.pdf. [accessed 15 July 2004].
- **Blackburn, J and Hicks, FE. 2001.** Combined flood routing and flood level forecasting. *Proceedings of the 15th Canadian Hydro Technical Conference.* 345-350, Canadian Society of Civil Engineering, Victoria British Columbia, Canada.
- **Chow, VT.1959.** *Open Channel Hydraulics*, McGraw-Hill, New York, USA.
- **Gelegenis, JJ and Sergio, ES. 2000.** Analyses of Muskingum equation based flood routing schemes. *Journal of Hydrologic Engineering* 5 (1) : 1002-105.
- **Lacey, G.1930.** Stable Channels in alluvium, *Minutes of proceedings of Institute of Civil Eng* 229 (-) : 259-292.
- **Singh, VP and Woolhiser, AD. 2002.** Mathematical modeling of watershed hydrology. *Journal of Hydrologic Engineering* 7(4) : 270-292.
- **US Army Corps of Engineers 1993.** River hydraulics. [Internet]. US Army Corps of Engineers Manual 1110-1-1416, Washington DC, USA. Available from: http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1416/entire.pdf. [Accessed 12 April 2004].
- **Us Army Corps of Engineers 1994.** Engineering Design and Flood-Runoff Analyses. [Internet]. US Army of Corps of Engineers Manual 1110-2-1417, Washington DC, USA. Available from: http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1417/c-9.pdf. [Accessed 15 April 2003].

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