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HYDROLOGIC CHANNEL ROUTING
WITH GRAPHICS

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ABSTRACT

Routing of floods through channels is one of the important component of most of the hydrological studies related with catchment as well as hydrology. The aim of channel routing is to trace the movement of a flood wave in channel reaches. A number of methods are available for channel routing using hydraulic and hydrologic principles. Looking at the usefulness as well as complexities involved in the techniques, an attempt has been made to develop an interactive software using Fortran-77. This software is based on use of Variable Storage Coefficient Method for channel routing.

The purpose of this report is to describe and document this programme. The theory has been briefly described followed by the detailed instructions on input data preparation. The user has option of obtaining the results in tabular and/or graphical form. The software has been developed and implemented on an IBM Compatible PC.

1.0 INTRODUCTION

The aim of flood routing is to trace the movement of a flood wave as it travels in a channel. During the travel, the shape of the wave changes. A good flood routing should be able to faithfully describe the movement of a flood wave. It should be possible to describe the hydrograph at a given x-section in the channel.

A large number of methods are available for flood routing. All of them can be broadly subdivided into two categories: hydraulic methods and hydrologic methods. The hydraulic methods make use of continuity and momentum equations which are solved to get the solution. The methods in this category include the characteristic method, implicit method and explicit method. The hydrologic methods are based on continuity equation. The most popular hydrologic routing method is the Muskingum method. The popularity of this method is mainly attributed to its simplicity and ease of computation.

In the Muskingum method, the routing parameters are assumed to be constant. An improvement of this method is the variable storage coefficient method in which the routing parameters are assumed to be dependent upon the flow conditions in the channel reach.

1.1 Scope of this Report

A programme has been developed for flood routing through channels using variable storage coefficient (VSC) method. This report documents this programme. The theory behind variable storage coefficient method has been discussed briefly. The preparation of input and interpretation of output have been described.

2.0 MINIMUM HARDWARE AND SOFTWARE REQUIRED

The program for channel routing has been written in FORTRAN-77 language and developed on 16-bit IBM-compatible personal computer (PC/XT) having a floating point/numeric co-processor(INTEL 8087) and a FORTRAN compiler (PROFORT). Standard software LOTUS 1-2-3 is used for graphical presentation of the results which are transferred by the program to the worksheet and the results in graphical and tabular form can be printed by using a IBM-PC compatible graphics printer.

3.0 PROCEDURE USED

The method employed for routing of flood wave through the channels is variable storage coefficient (VSC) method. This method can also be considered as a variation of Muskingum Method. In the Muskingum method, the channel storage is assumed to be a weighted average of inflow and outflow for the reach:

$$S = K (I + (1-X) O) \qquad .....(1)$$

where S is the storage, I is the inflow, O is the outflow, X is a weighting parameter indicating relative weightage of inflow and outflow, K is a storage parameter approximately equal to time of travel. The parameters K and X and the routing coefficients C_1, C_2 and C_3 are assumed to be constant for a river reach irrespective of the flow conditions. An improvement of this technique is variable storage coefficient method in which these coefficients change depending upon the inflow and outflow from the channel reach.

The outflow from the channel reach, Q_2, can be calculated by:

$$Q_2 = C_2(I_a+(1/C_1)-1.0)*Q_1) \qquad ....(2)$$

where

$$C_1 = 2\,\Delta t/(2*T_1 + \Delta t) \qquad ....(3)$$

$$C_2 = 2\,\Delta t/2*T_2 + \Delta t) \qquad ....(4)$$

$$I_a = (I_1+I_2)/2.0 \qquad ....(5)$$

$$T_1 = \frac{L}{-1800(V_{I_1} + V_{Q_1})} \left[-L \frac{L.S}{L.S+(D_{I_1} - D_{Q_1})}\right] \qquad ....(6)$$

C_1 and C_2 are storage coefficients, I_1 and Q_1 are inflow and outflow from the reach in m^3/Sec, L is the length of reach in m, V_{I_1} is the velocity in m corresponding to discharge I_1, D_{I_1} is the depth of flow in m corresponding to discharges I_1, S is the channel bed slope, Δt is the time interval and T is the travel time in hours.

At the beginning of any time interval, I_a and Q_1 are known, and therefore, T_1 and C_1 can be calculated. The values of T_2 and C_2 depend upon Q_2 and C_2 is used to calculate Q_2 itself. Due to this, an iterative procedure is to be used to compute the discharge. To start with, a value of Q_2 is assumed (the first guess may be $Q_2 = Q_1$) and this is used to compute T_2 and C_2. Now equation (2) is used to compute Q_2. The iterations are performed in this way until convergence is reached. The time interval count is incremented and iterations are repeated. The computations are terminated upon encountering the end of computation period.

4.0 DATA REQUIREMENTS AND PREPARATION

The data inputs to the program are from the data file (CHROUT. DAT)

1. TITLE1 = Name of the beginning Station of routing
2. TITLE2 = Name of the ending Station of routing
3. NR = No. of reaches through which routing to be done
4. NI = No. of values of inflow flood hydrograph
5. DELT = Routing Interval in hours
6. FL = Inflow Flood Hydrograph at the Upper Most Station at DELT Interval in Cum / sec.
7. RL = Length of Each Reach in Kms.
8. RS = Slope of Channel Bed
9. M = No. of Sets of Values of Discharge, Depth of Flow and Velocity of Flow for the Reach
10. DIS = Discharge in Cum/sec.
11. D = Depth of Flow in m
12. V Velocity of Flow in m/sec.

Representative values of Discharge, depth of Flow and velocity of Flow may be used for each Reach of river.

5.0 RUNNING CHROUT ON PC/XT

After successful compilation and linking, the file CHROUT.DAT is created. Data file CHROUT.DAT is then created as per Section 4.0 in the same directory containing the file CHROUT.EXE The program is then invoked by typing CHROUT followed by RETURN Key.

For obtaining the graphical presentation of results the following sequence of operation are followed.

1. Set the directory containing the LOTUS application as the default directory.
2. Execute LOTUS
3. Select the option 1-2-3 from the menu
4. Type/(slash) to enter the LOTUS commands.
5. Select FILE from the LOTUS menu.
6. Select IMPORT from the FILE menu.
7. Select NUMBER from the IMPORT menu.
   The message 'Enter name of the file to import' will be displayed.
8. Type the name of the file containing data for plotting with its directory name (C:\PROFORT\CHROUT.WKS) and press RETURN key.
9. Type/(Slash) to get the lotus menu.
10. Select GRAPH option from this menu
11. Select TYPE option from GRAPH submenu and set XY as the type of graph using the submenu.

12. Select the axes and specify their ranges.

13. Select OPTIONS from GRAPH submenu.

14. Select TITLE from OPTIONS submenu.

15. Select FIRST from TITLE submenu and type the title of the graph.

16. Select TITLE from OPTIONS submenu.

17. Select X-axis from TITLE submenu and type the X-axis title.

18. Select TITLE from OPTIONS submenu.

19. Select Y-axis from TITLE submenu and type Y-axis title.

20. Use SAVE option from the GRAPH submenu and give a name to the graph file as C:\PROFORT\CHROUT.PIC.

21. Use the VIEW option from the GRAPH submenu to display the graph on the monitor.

22. To print the graph on printer use the PRINTGRAPH submenu from the LOTUS menu.

23. Define the hardware and graph settings using the SETTINGS submenu and save the settings if required using the SAVE menu.

24. Select graph for printing using IMAGE SELECT menu.

25. Select the GO menu. The graph will be printed on paper.

6.0 THE PROGRAM

The program consists of the main program and one subroutine. The main program reads the data and performs the routing. Subroutine INTPL is used to interpolate and obtain values of velocity and depth of flow corresponding to inflow and outflow from the discharge-depth-velocity relationship.

For the first time interval, outflow is put equal to inflow. For the other time periods, the program initially assumes the outflow equal to the outflow in previous time period and the iteration steps are followed. The output file consists of the inflow hydrograph for each sub-reach. The values of C_1 and C_2 computed are also printed out.

The program also has the provision for exhibiting the inflow and outflow hydrograph on the video screen, if desired by a user.

6.1 Limitations

The program has following limitations:

(i) The inflow hydrograph ordinates have to be input at discrete interval equal to the routing interval.

(ii) The program does not include provision for considering intermediate flow between sub-reaches.

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4. Varshney, R.S. (1974), Engineering Hydrology, Nem Chand and Bros, Roorkee.

APPENDIX - A

CHROUT.DAT

```
XXX
YYY
ZZZ
1
20 1.
  10.0   12.0   18.0   28.5   50.0   78.0 107.0 134.5 147.0 150.0
 146.0 129.0 105.0   78.0   59.0   45.0   33.0   24.0   17.0   12.0
10. 0.006
9
     0.  0.0 0.0
   450.  0.5 0.5
   900.  1.0 0.3
  1800.  1.5 0.33
  3600.  2.0 0.36
  6300.  2.5 0.41
  9900.  3.0 0.46
 19000.  4.0 0.60
 27500.  5.0 0.82
```

APPENDIX - B

CHROUT.FOR

```
      CHARACTER*12 TITLE1,TITLE2,TITLE3
      DIMENSION FL(10,50),Q(10,50),V(50),D(50),NV(4),T(10,50),T1(50),
     1T2(50),T3(50),T4(50),Q1(50),Q2(50),Q3(50),Q4(50),DIS(50)
C     *****************************************************************
C     THIS PROGRAM PERFORMS THE CHANNEL ROUTING OF AN INFLOW FLOOD
C     HYDROGRAPH BY THE VARIABLE STORAGE COEFFICIENT (VSC) METHOD.
C     ROUTING CAN BE DONE THROUGH A NUMBER OF REACHES OF THE RIVER.
C     AS DIMENSIONED IN THIS VERSION THE ROUTING CAN BE DONE THROUGH
C     A MAX. OF 10 REACHES.
C
C             **************INPUT DATA**************
C     TITLE1 = NAME OF THE RIVER
C     TITLE2 = NAME OF THE BEGINNING STATION OF ROUTING
C     TITLE3 = NAME OF THE LAST STATION
C     NR = NO. OF REACHES THROUGH WHICH ROUTING TO BE DONE
C     NI = NO. OF VALUES OF INFLOW FLOOD HYDROGRAPH
C     DELT = ROUTING INTERVAL IN HOURS
C     FL = INFLOW FLOOD HYDROGRAPH AT THE UPPER MOST STATION AT
C          DELT INTERVAL IN CUM/SEC
C     RL = LENGTH OF EACH REACH IN KMS
C     RS = SLOPE OF CHANNEL BED
C     M = NO. OF SETS OF VALUES OF DISCHARGE,DEPTH OF FLOW AND
C         VELOCITY OF FLOW FOR THE REACH
C     DIS = DISCHARGE IN CUM/SEC
C     D = DEPTH OF FLOW IN M
C     V=VELOCITY OF FLOW IN M/SEC
C     REPRESENTATIVE VALUES OF DISCHARGE, DEPTH OF FLOW AND VELOCITY
C     OF FLOW MAY BE USED FOR EACH REACH OF RIVER  CARDS 7,8 AND 9
C     MAY BE REPEATED FOR EACH REACH OF THE RIVER
C     *****************************************************************
C
      OPEN(UNIT=1,FILE='CHROUT.DAT',STATUS='OLD')
      OPEN(UNIT=2,FILE='CHROUT.OUT',STATUS='NEW')
      OPEN(UNIT=3,FILE='CHROUT.WKS',STATUS='NEW')
C
      READ(1,10)TITLE1
      READ(1,10)TITLE2
      READ(1,10)TITLE3
10    FORMAT(A)
      READ(1,5)NR
5     FORMAT(I4)
      READ(1,11)NI,DELT
11    FORMAT(I2,1X,F2.0)
      READ(1,25) (FL(1,J),J=1,NI)
25    FORMAT(10(1X,F5.1))
      NN=1
20    READ(1,26)RL,RS
26    FORMAT(F3.0,1X,F6.4)
      READ(1,5)M
      DO 30 I=1,M
30    READ(1,31)DIS(I),D(I),V(I)
31    FORMAT(F6.0,1X,F3.1,1X,F4.2)
      Q(NN,1)=FL(NN,1)
      T(NN,1)=0.
      DO 70 I=2,NI
```

```
      Q(NN,I)=Q(NN,I-1)
      QQ1=Q(NN,I-1)
      QQ2=Q(NN,I)
      FF1=FL(NN,I-1)
      FF2=FL(NN,I)
      T(NN,I)=(I-1)*DELT
      A1=RL*1000.*RS
50    CALL INTPL(M,DIS,D,QQ2,DO2)
      CALL INTPL(M,DIS,D,FF2,DI2)
      A2=A1+(DI2-DO2)
      AA2=ABS(A1/A2)
      A3=AA2**0.5
      CALL INTPL(M,DIS,V,QQ2,VO2)
      CALL INTPL(M,DIS,V,FF2,VI2)
      A4=RL*1000./(1800.*(VI2+VO2))
      TT2=A3*A4
      CALL INTPL(M,DIS,D,QQ1,DO1)
      CALL INTPL(M,DIS,D,FF1,DI1)
      CALL INTPL(M,DIS,V,QQ1,VO1)
      CALL INTPL(M,DIS,V,FF1,VI1)
      A5=A1+(DI1-DO1)
      A6=RL*1000./(1800.*(VI1+VO1))
      A7=ABS(A1/A5)
      A8=A7**0.5
      TT1=A6*A8
      C1=2*DELT/(2*TT1+DELT)
      C2=2*DELT/(2*TT2+DELT)
      B=(FF1+FF2)/2.
      QOUT=C2*(B+(1/C1-1)*QQ1)
      ERR=ABS(QOUT-QQ2)
      EPS=0.01*QQ2
      IF(ERR.LT.EPS)GO TO 60
      QQ2=(QQ2+QOUT)/2.
      GO TO 50
60    Q(NN,I)=QOUT
70    CONTINUE
      N1=NN+1
      DO 80 I=1,NI
      FL(N1,I)=Q(NN,I)
      T(N1,I)=T(NN,I)
80    CONTINUE
      WRITE(2,12)TITLE1
12    FORMAT(///,15X,'ROUTING OF FLOOD HYDROGRAPH IN RIVER',1X,A,/,
     115X,'BY VARIABLE STORAGE COEFFICIENT METHOD',/,15X,38('='))
      WRITE(2,15)TITLE2,TITLE3
15    FORMAT(/,10X,'FROM STATION: ,A,/,10X,'TO STATION:',A)
      WRITE(2,100)NN
100   FORMAT(//,10X,'REACH:',I2)
      WRITE(2,105)C1,C2
105   FORMAT(10X,'C1=',F5.2,5X,'C2=',F5.2)
      WRITE(2,110)
110   FORMAT(10X,50('-'))
      WRITE(2,120)
120   FORMAT(10X,'TIME',10X,'INFLOW HYD. ,10X,'OUTFLOW HYD. ,/,10X,
     1 (HRS) ,9X,'GRPH(CUM/S)',10X,'GRPH(CUM/S)')
```

```
      WRITE(2,110)
      DO 140 I=1,NI
      WRITE(2,130) T(NN,I),FL(NN,I),Q(NN,I)
      WRITE(3,*) T(NN,I),FL(NN,I),Q(NN,I)
130   FORMAT(10X,F4.0,7X,F10.2,10X,F10.2)
140   CONTINUE
      WRITE(2,110)
      NN=NN+1
      IF(NN.GT.NR) GO TO 150
      GO TO 20
150   PRINT*,'    *TO PLOT THE HYDROGRAPH*'
      PRINT*,'             *RUN LOTUS*
      STOP
      END
C
      SUBROUTINE INTPL(N,X,Y,XX,YY)
      DIMENSION X(50),Y(50)
      DO 10 I=1,N
      IF(XX.LT.X(I))GO TO 20
10    CONTINUE
20    DIFF=X(I)-XX
      RAT=DIFF/(X(I)-X(I-1))
      YY=Y(I)-RAT*(Y(I)-Y(I-1))
      RETURN
      END
```

APPENDIX - C

CHROUT.OUT

ROUTING OF FLOOD HYDROGRAPH IN RIVER XXX
BY VARIABLE STORAGE COEFFICIENT METHOD

FROM STATION:YYY
TO STATION:ZZZ

REACH: 1
C1= 0.01 C2= 0.00

TIME (HRS)	INFLOW HYD. GRPH(CUM/S)	OUTFLOW HYD. GRPH(CUM/S)
0.	10.00	10.00
1.	12.00	11.90
2.	18.00	17.69
3.	28.50	27.83
4.	50.00	48.47
5.	75.00	75.10
6.	107.00	102.46
7.	134.50	128.26
8.	147.00	139.98
9.	150.00	142.70
10.	146.00	140.67
11.	129.00	125.59
12.	105.00	103.18
13.	78.00	77.35
14.	59.00	59.0[illegible]
15.	45.00	45.37
16.	35.00	33.59
17.	24.00	24.61
18.	17.00	17.58
19.	12.00	12.52

GRAPHICAL REPRESENTATION OF THE RESULTS