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Short Communication

Application of the USGS diffusion hydrodynamic model (DHM) in evaluation of estuary flow circulation

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Many of the hydrodynamic models used for tidal flow regime and storm surge analysis are based upon use of the two-dimensional hydrodynamic equations, which are obtained from the parent three-dimensional flow equations by averaging with respect to the vertical coordinates. Various numerical techniques, such as finite difference, finite element, and the method of characteristics have been used to solve these mathematical models.

The USGS diffusion hydrodynamic model has been developed to simulate two-dimensional surface water flows, and solves the governing flow equations by neglecting the inertia terms. The DHM has previously been applied to a hypothetical bay study with results comparable to those obtained using the method of characteristics. In the current work, the DHM is applied to the Batiquitos Lagoon located in the City of Encinitas, California for the purposes of evaluation of tidal flow characteristics. The main objective is to determine local flow velocities and circulation patterns in the lagoon caused by the incoming and outgoing tide.

INTRODUCTION

Many of the hydrodynamic models used for tidal flow regime and storm surge analysis are based upon use of the two-dimensional hydrodynamic equations, which are obtained from the parent three-dimensional flow equations by averaging with respect to the vertical coordinates. Various numerical techniques, such as finite difference, finite element, and the method of characteristics have been used to solve these mathematical models. A full review of these models is given in Heaps[1] and Nihoul & Tamant.[2]

The USGS diffusion hydrodynamic model (Hromadka & Yen[3]) has been developed to simulate two-dimensional water flows, and solves the governing flow equations by neglecting the inertia terms. The DHM has previously been applied to a hypothetical bay study with results comparable to those obtained using the method of characteristics (Lai[4]). In the current work, the DHM is applied to the Batiquitos Lagoon located in the City of Encinitas, California (see Fig. 1) for the purposes of evaluation of tidal flow characteristics. The main objective is to determine low flow velocities and circulation patterns in the lagoon caused by the incoming and outgoing tide. This information will be useful in developing sediment and debris control and reduction measures (if necessary) for the watershed of Batiquitos lagoon, aimed at preventing further siltation of the lagoon.

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DESCRIPTION OF THE DHM

Details on the theory use and verification of the DHM are contained in the USGS Water Resources Investigation Report, 87-4137 (Hromadka & Yen[3]). Only a brief development of the DHM governing equations are provided herein.

The two-dimensional unsteady flow equations consist of one equation of continuity

$$\frac{\partial q_x}{\partial x} + \frac{\partial y_y}{\partial y} + \frac{\partial z}{\partial t} = 0 \tag{1}$$

and two equations of motion

$$\frac{\partial Q_x}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q_x^2}{A_x}\right) + \frac{\partial}{\partial y}\left(\frac{Q_x Q_y}{A_x}\right) + gA_x\left[S_{fx} + \frac{\partial h}{\partial x}\right] = 0 \tag{2a}$$

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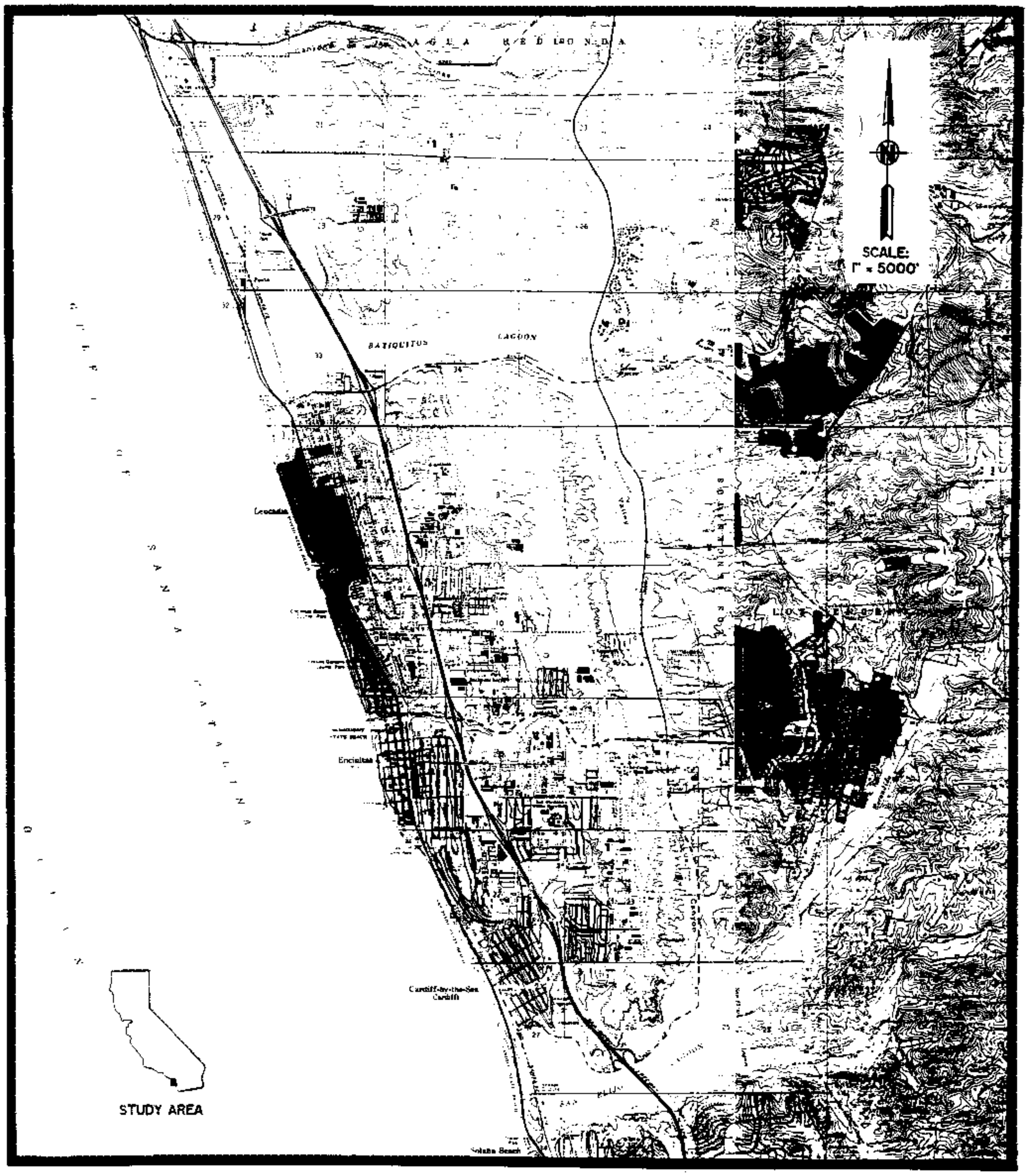

Fig. 1. Location map.

$$\frac{\partial Q_y}{\partial t} + \frac{\partial}{\partial y}\left(\frac{Q_y^2}{A_y}\right) + \frac{\partial}{\partial x}\left(\frac{Q_x Q_y}{A_y}\right) + gA_y\left[S_{fy} + \frac{\partial h}{\partial y}\right] = 0 \qquad (2b)$$

in which t is time, x and y (and the subscripts) are the orthogonal directions in the horizontal study plane; q_x and q_y are the flow rates per unit width in the x- and y-directions; z is the depth of water; Q_x and Q_y are the

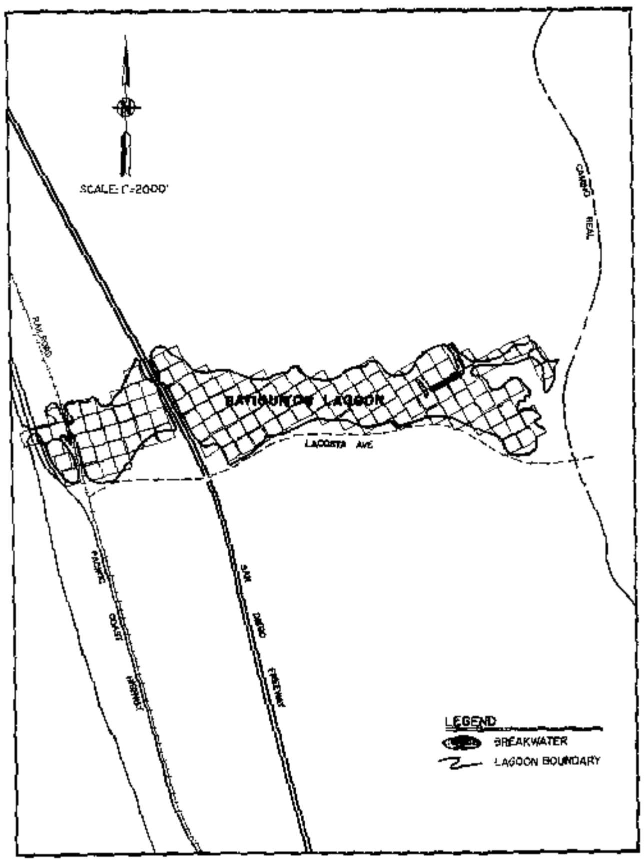

Fig. 2. Finite grid elements for DHM model.

flow rates in the x- and y-directions, respectively; h is the water surface elevation measured vertically from a horizontal datum; g is the acceleration of gravity; A_x and A_y are the cross-sectional areas; and S_{fx} and S_{fy} are the friction slopes in the x, y-directions. The DHM utilizes a uniform square finite element to model the two-dimensional unsteady flow; therefore, A_x and A_y are computed from the product of the length of uniform grid element and the depth of water.

The friction slopes S_{fx} and S_{fy} can be estimated by using Manning's formula

$$S_{fx} = \frac{n^2 Q_x^2}{C^2 A_x^2 R_x^{4/3}} \tag{3a}$$

and

$$S_{fy} = \frac{n^2 Q_y^2}{C^2 A_y^2 R_y^{4/3}} \tag{3b}$$

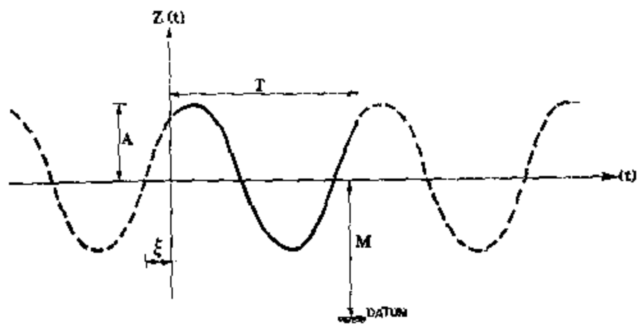

Fig. 3. Sinusoidal equation of tide hydrograph.

in which n is the Manning's roughness factor (based on a composite or weighted average); R_x, R_y are the hydraulic radii in x, y-directions, respectively; and the constant $C = 1$ for SI units and 1·486 for US Customary units.

In the DHM, the local and convective acceleration terms in the flow equation (i.e. the first three terms of eqn (2)) are neglected (Akan & Yen). Thus, eqn (2) is simplified as

$$S_{fx} = -\frac{\partial h}{\partial x} \tag{4a}$$

and

$$S_{fy} = -\frac{\partial h}{\partial y} \tag{4b}$$

Combining eqns (3) and (4) yields

$$Q_x = \frac{C}{n} A_x R_x^{2/3} \frac{\left(-\frac{\partial h}{\partial x}\right)}{\left|\frac{\partial h}{\partial x}\right|^{1/2}} \tag{5a}$$

$$Q_y = \frac{C}{n} A_y R_y^{2/3} \frac{\left(-\frac{\partial h}{\partial y}\right)}{\left|\frac{\partial h}{\partial y}\right|^{1/2}} \tag{5b}$$

which accounts for flows in both positive and negative x- and y-coordinate directions. The flow rates per unit width in the x- and y-directions can be obtained from eqn (5) as

$$q_x = \frac{C}{n} z R_x^{2/3} \frac{\left(-\frac{\partial h}{\partial x}\right)}{\left|\frac{\partial h}{\partial x}\right|^{1/2}} \tag{6a}$$

$$q_y = \frac{C}{n} z R_y^{2/3} \frac{\left(-\frac{\partial h}{\partial y}\right)}{\left|\frac{\partial h}{\partial y}\right|^{1/2}} \tag{6b}$$

Substituting eqn (6) into eqn (1), gives

$$\frac{\partial}{\partial x}\left[\frac{C}{n} z R_x^{2/3} \frac{\left(-\frac{\partial h}{\partial x}\right)}{\left|\frac{\partial h}{\partial x}\right|^{1/2}}\right] + \frac{\partial}{\partial y}\left[\frac{C}{n} z R_y^{2/3} \frac{\left(-\frac{\partial h}{\partial y}\right)}{\left|\frac{\partial h}{\partial y}\right|^{1/2}}\right] + \frac{\partial h}{\partial t} = 0$$

or

$$\frac{\partial}{\partial x}\left[K_x \frac{\partial h}{\partial x}\right] + \frac{\partial}{\partial y}\left[K_y \frac{\partial h}{\partial y}\right] = \frac{\partial h}{\partial t} \tag{7}$$

where

$$K_x = \frac{C}{n} z R_x^{2/3} \Big/ \left|\frac{\partial h}{\partial x}\right|^{1/2}$$

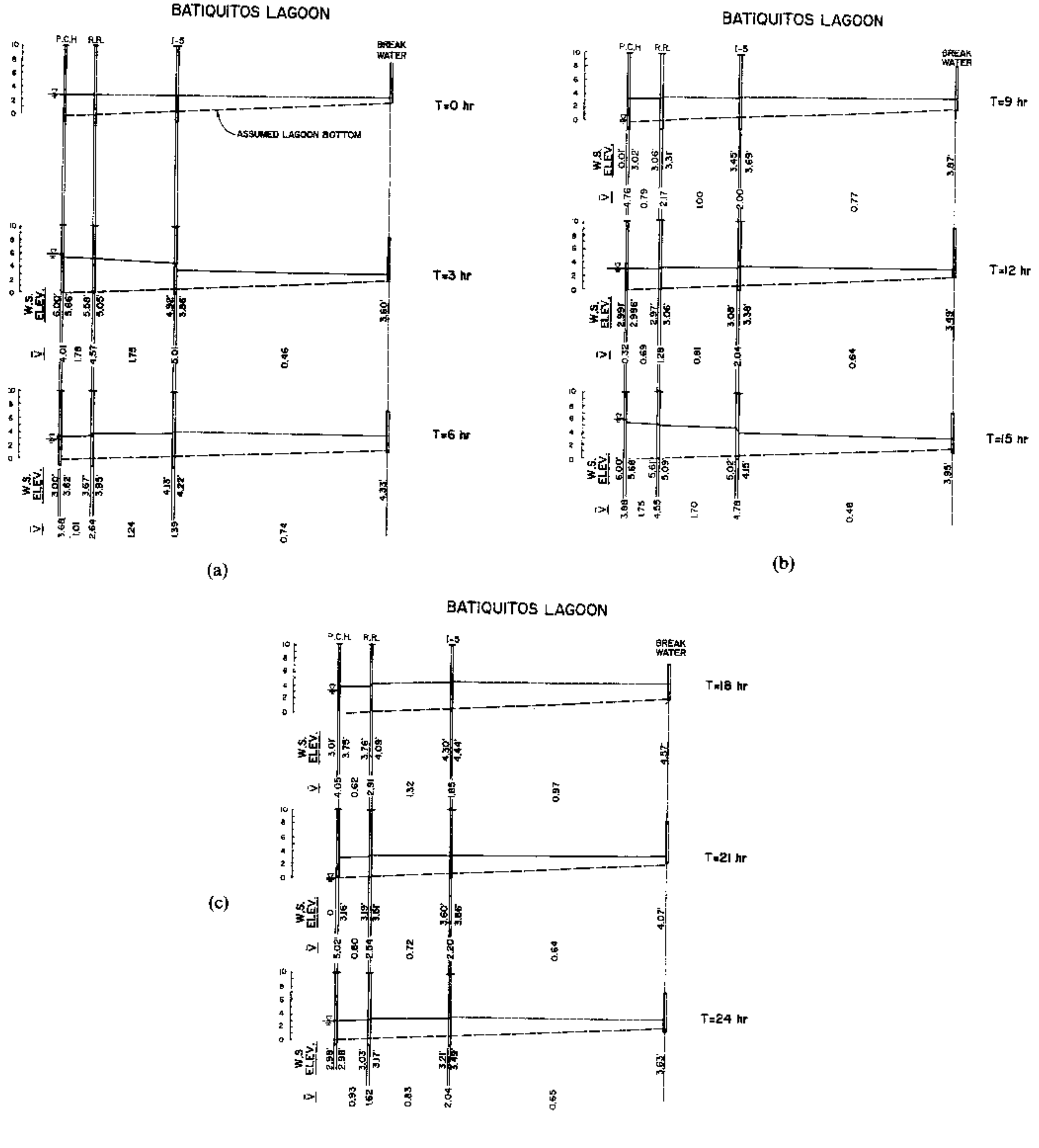

Fig. 4. (a) Results of deep lagoon (Case 2) simulation (cont.); (b) results of shallow lagoon (Case 1) simulation (cont.); (c) results of shallow lagoon (Case 1) simulation (cont.).

and

$$K_y = \frac{C}{n} z R_y^{2/3} \Big/ \left|\frac{\partial h}{\partial y}\right|^{1/2}$$

The numerical algorithms used for solving eqn (7) are fully discussed in the USGS Water Resources Investigation Report, 87-4137 (Hromadka & Yen[3]). The data preparation needs for a floodplain analysis is also discussed in the USGS Water Resources Investigation Report.

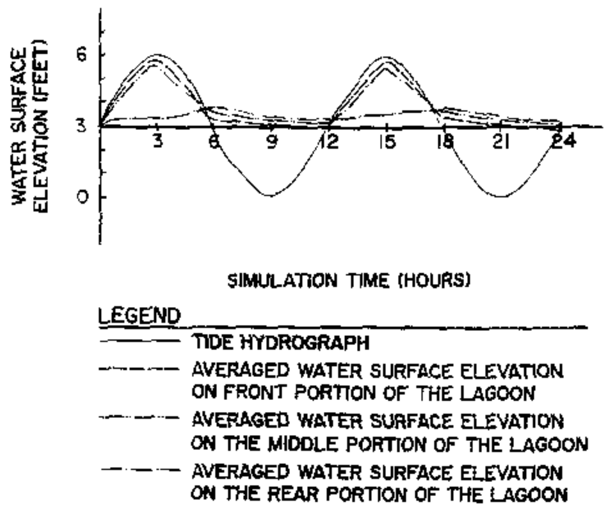

Fig. 5. Summary of shallow lagoon (case I) simulation.

DESCRIPTION OF THE BATIQUITOS LAGOON

Batiquitos Lagoon (see Fig. 1) is located at the northwestern part of the City of Encinitas, California. The lagoon is approximately 2·3 miles long and 0.25 miles wide and is constricted by three bridges. The front portion of the lagoon is between the Pacific Coast Highway (PCH) and the Atchison Topeka and Santa Fe (AT&SF) railroad. The AT&SF railroad and the San Diego freeway (I-5) form the middle portion. The upstream portion extends from I-5 to the mouth of the San Marcos Creek and comprises 70% of the entire lagoon.

DESCRIPTION OF BATIQUITOS LAGOON MODEL

The lagoon was discretized into 130 grid finite-elements, of dimension 400-feet, as shown in Fig. 2. A longitudinal gradient of 1·5 feet/mile was assumed for the lagoon bottom along the east–west direction and 0·75 feet/mile was assumed for the north–south direction. An effective flow path of 100 feet was assumed for the restrictions under the PCH, the AT&SF railroad, and also the I-5 freeway. A Manning's roughness factor of 0·035 was assumed for the entire lagoon. To model the flow-depth variation, with respect to time, due to tidal fluctuations, the sinusoidal equation is used to model the tidal depth ($Z(t)$ as shown in Fig. 3) as follows:

$$Z(t) \;=\; A \sin \frac{2\pi(t+\xi)}{T} + M \tag{8}$$

where A = amplitude (feet), ξ = phase lag (hour), M = mean water surface elevation (feet), t = time (hour), T = tidal period (hour). Due to only minor freshwater inflow from the tributary San Marcos Creek, the DHM model further assumes that the circulation of the lagoon is driven by the fluctuations of the assumed tide hydrograph.

Shallow and deep-water depths were used to investigate the flow circulations for existing and dredge conditions, respectively.

Case 1 — Shallow lagoon analysis

An initial water surface elevation of 3 feet above mean sea level was assumed for the lagoon. The tide hydrograph was specified to have a period of 12 hours, an amplitude of 3 feet, and to coincide with the standard sine curve (i.e. phase lag is zero). Because of the long and narrow shape of the lagoon, negligible flow circulation inside the lagoon is predicted from the DHM model. Figure 4 depicts the water surface profiles for the shallow lagoon during a 24-hour simulation.

Figure 4 indicates that the flow direction in the lagoon is either inward or outward depending upon the rising or the recession of the assumed tide hydrograph, respectively. Figure 5 illustrates the averaged water surface elevations for the downstream, central, and upstream portions of the lagoon corresponding to the specified tide hydrograph. The DHM results indicate that the two crests of the tide hydrograph (between hour 0–6 and hour 12–18) have the major effects on the front and middle portions of the lagoon and negligible impact on the upstream portion of the lagoon. The averaged flow velocity of the lagoon was predicted to be less than 2 ft/sec during the entire 24-hour simulation. Therefore, deposition of sediment may occur under the assumed shallow lagoon conditions.

Case 2 — Deep lagoon analysis

In Case 2, the lagoon was assumed 7 feet deeper than in the Case 1 analysis, to simulate a dredged lagoon. The same initial and boundary conditions as used in Case 1 were also used to investigate the flow conditions for the dredged lagoon. Figure 6 illustrates the averaged water surface profiles for a 24-hour simulation within the deep lagoon. Average flow velocities of 5·5 ft/sec and 4·6 ft/sec were estimated for the central and upstream portions of the lagoon. This indicates that the area between the AT&SF railroad bridge and the breakwater has sufficient flow velocity characteristics to transport the sediment from San Marcos Creek to the front portion of the lagoon. The average velocity in the front portion of the lagoon was estimated to be 2·8 ft/sec during the low tide period. Thus, the sediment may accumulate on the downstream portion of the lagoon. Figure 7 depicts the average water surface elevations corresponding to the tide hydrograph. Figure 7 suggests that the tide hydrograph has more hydrodynamic influence on the assumed deep-water lagoon configuration than on the shallow lagoon.

TOPOGRAPHIC MODEL

A short version of the topographic routing component of the DHM is presented herein in FORTRAN. The FORTRAN listing is provided in Appendix A, with User's Instructions given in Appendix B.

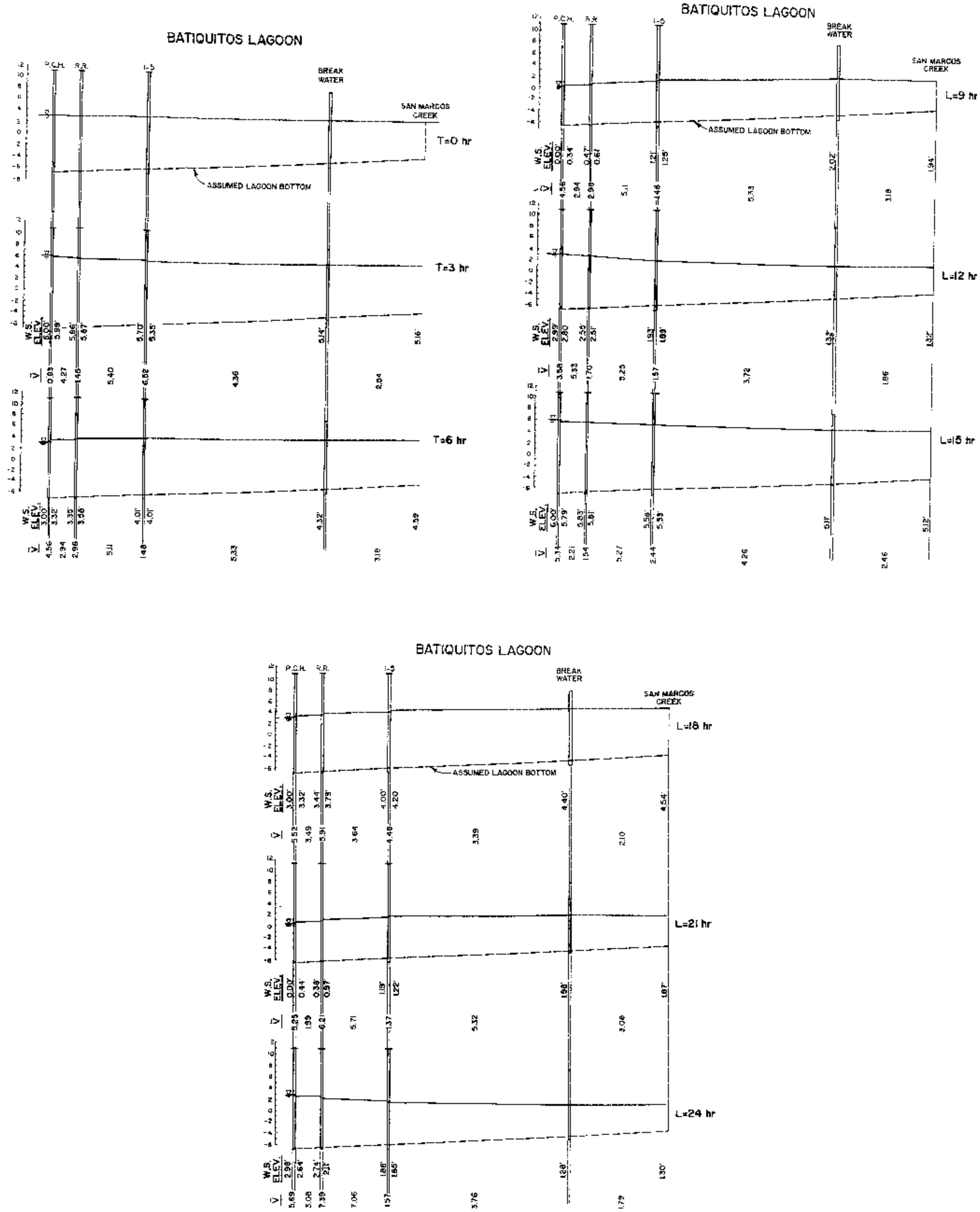

Fig. 6. (a) Results of deep lagoon (Case 2) simulation; (b) results of deep lagoon (Case 2) simulation (cont.); (c) results of deep lagoon (Case 2) simulation (cont.).

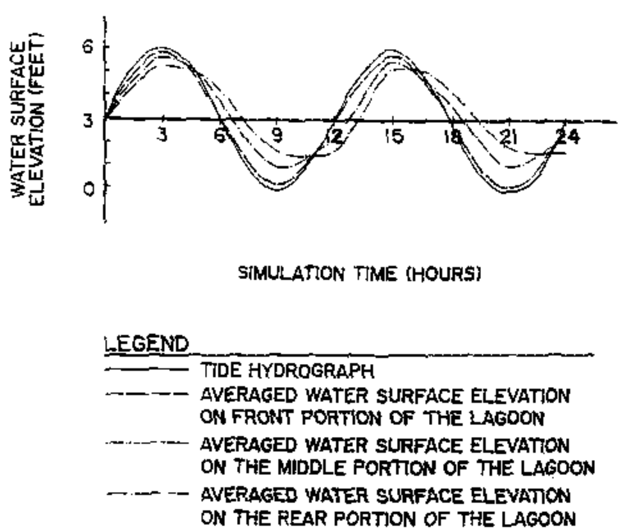

Fig. 7. Summary of deep lagoon (Case 2) results.

CONCLUSIONS

The DHM has been primarily used for floodplain analysis. In this study, the DHM is used to evaluate the flow characteristics within a narrow estuary. Application of the DHM to Batiquitos Lagoon provides the average water surface profiles and flow velocities within the lagoon. These computed results indicate that the subject lagoon has negligible capability to transport sediment under existing shallow-water conditions. Modeling an assumed dredged lagoon does indicate some sediment transport capability but more detailed sedimentation and estuary analysis are needed to ensure an optimum condition for the lagoon.

REFERENCES

1. Heaps, N.S. (ed.) *Three-dimensional Coastal Ocean Models*, American Geophysical Union, 1987.
2. Nihoul, J.C.J. & Jamart, B.M. (ed.) *Three-Dimensional Models of Marine and Estuarine Dynamics*, Elsevier, Amsterdam, 1987.
3. Hromadka II, T.V. & Yen, C.C. A diffusion hydrodynamic model, US Geological Survey, Water-Resources Investigation Report 87-4137, 1987.
4. Lai, C. Computer simulation of two-dimensional unsteady flows in estuaries and embayments by the method of characteristics — basic theory and the formulation of the numerical method, US Geological Survey, Water-Resources Investigation 77-85, 1977.

APPENDIX A: PROGRAM LISTING

```
$STORAGE:2
C
C         PROGRAM DHM -- TOPOGRAPHIC MODEL
C
          CHARACTER IOPT*1,IFILE*50,IOFILE*50,IT*50
C
          COMMON/BLK 1/FP(500,8),FPA(500,9)
          COMMON/BLK 2/NRAT,NPRAT,NRATN(20,2),RCURV(20,5,3)
C
          DIMENSION NODFX(50),DMAX(500),TIMEX(500),KINP(10),HP(10,10,2)
          DIMENSION NODDC(50),VEL(500,4),R(10,2),Q(4)
C
          DATA NR/1/,NW/2/,IW/0/
C
C         DEFINITIONS
C
C         FLOODPLAIN INFORMATION:
C
C         FP(I,J)=N-,E-,S-,W- ELEMENT NUMBER,FLAG FOR GLOBAL/LOCAL ELEMENT,
C                  AVERAGED ELEMENT ELEVATION,INITIAL WATER DEPTH, AND
C                    TEMPORARY MEMORY
C         FPA(I,J)=EFFECTIVE FLOW-PATH FACTORS FOR N,E,S,W,
C                   MANNING'S n FOR N,E,S,W, AND EFFECTIVE AREA FACTOR
C         NRATN(I,J)=UPSTREAM/DOWNSTREAM NODES FOR FLOODPLAIN RATING CURVES
C         RCURV(I,J,K)=FLOODPLAIN RATING CURVES
C         NODFX(I)=SPECIFIED OUTFLOW NODES
C         DMAX(I)=MAXIMUM WATER DEPTH
C         TIMEX(I)=TIME CORRESPONDS TO MAXIMUM WATER DEPTH
C         KINP(I)=INFLOW NODAL POINTS
C         HP(I,J,K)=INFLOW HYDROGRAPH FOR NODE I
C         NODDC(I)=CRITICAL DEPTH OUTFLOW NODES
C         VEL(I,J)=N-,E-,S-,AND W-EFFLUX VELOCITIES
C         R(I,J)=EFFECTIVE RAINFALL INTENSITY CURVE
C         Q(I)=FLOWRATE BETWEEN ADJACENT FLOODPLAIN ELEMENTS
C
C.....OPEN INPUT/OUTPUT UNITS AND FILES
C
          WRITE(IW,1005)
          READ(IW,1004)IFILE
          OPEN(UNIT=NR,FILE=IFILE,STATUS='OLD')
 1        WRITE(IW,1001)
          READ(IW,1002)IOPT
          IF(IOPT .EQ. '1') GO TO 2
          IF(IOPT .EQ. '2') GO TO 3
          GO TO 1
 2        OPEN (UNIT=NW,FILE='PRN',STATUS='NEW')
          GO TO 4
 3        WRITE(IW,1003)
          READ(IW,1004)IOFILE
          OPEN (UNIT=NW,FILE=IOFILE,STATUS='NEW')
 4        CONTINUE
          WRITE(IW,1006)
          READ(IW,1004)IT
C
C         DATA INPUT
C
C.....READ PROGRAM CONTROL DATA
          READ(NR,*)DTMIN,DTMAX,DTI,DTD,SIMUL,TOUT,KODE,RMODEL
          READ(NR,*)NNOD,SIDE,TOL,DTOL,DTOLP,XAREA,XGN
C.....INPUT FLOODPALIN INFORMATION
          DO 5 I=1,NNOD
          READ(NR,*)(FP(I,J),J=1,7)
          IF(FP(I,5).EQ.1.)THEN
          DO 6 J=1,8
           IF(J.LE.4)THEN
           FPA(I,J)=1.
           ELSE
           FPA(I,J)=XGN
           ENDIF
 6        CONTINUE
          FPA(I,9)=XAREA
          ELSE
          READ(NR,*)(FPA(I,K),K=1,9)
          ENDIF
 5        CONTINUE
C.....READ EFFECTIVE RAINFALL INTENSITY (LINEAR FUNCTION)
          READ(NR,*)NERI
          IF(NERI.GE.1)READ(NR,*)((R(I,J),J=1,2),I=1,NERI)
C.....READ INFLOW HYDROGRAPHS (LINEAR FUNCTION)
          READ(NR,*)NFPI,NPFPI
          IF(NFPI.LT.1)GOTO 25
          DO 20 I=1,NFPI
 20       READ(NR,*)KINP(I),(HP(I,J,1),HP(I,J,2),J=1,NPFPI)
C.....READ FLOODPLAIN RATING CURVES NODES
          READ(NR,*)NRAT,NPRAT
 25       IF(NRAT.LT.1)GO TO 10
C.....RATING CURVE IS APPROXIMATED AS
C.....Q = ALPHA*(DEPTH OF WATER)**BETA
          DO 27 I=1,NRAT
          READ(NR,*)NRATN(I,1),NRATN(I,2),(RCURV(I,J,1),RCURV(I,J,2),
        C RCURV(I,J,3),J=1,NPRAT)
 27       CONTINUE
C.....READ OUTFLOW CRITICAL DEPTH NODES
 10       READ(NR,*)NDC
          IF(NDC.GE.1)READ(NR,*)(NODDC(I),I=1,NDC)
C.....READ SPECIFIED OUTFLOW NODES
          READ(NR,*)NFLUX,TFOUT
          IF(NFLUX.GE.1)READ(NR,*)(NODFX(I),I=1,NFLUX)
C.....END OF INPUT FILE
 30       CONTINUE
          CLOSE(UNIT=NR)
C.....INPUT/OUTPUT FORMATS
 1001     FORMAT('  PRINTOUT OPTIONS:',/5X,
        C '1= RESULTS SENT DIRECTLY TO PRINTER',/5X,
        C '2= RESULTS SENT TO A FILE ON DISK',/,
        C '  SELECT DESIRED OPTION ->',\)
 1002     FORMAT(A1)
 1003     FORMAT(/,'  ENTER RESULTS FILE NAME',/,
        C '  (Example:  DHM.RES)    ->',\)
 1004     FORMAT(A50)
 1005     FORMAT(/,'  ENTER INPUT FILE NAME',/,
        C '  (Example:  DHM.DAT)    ->',\)
 1006     FORMAT('  ENTER PROJECT DESCRIPTIONS ->',\)
 1007     FORMAT(/,10X,'*** Diffusion Hydrodynamic Model Analysis ***',/,
        C 130('-'),/,'  PROJECT DESCRIPTIONS : ',A50,/,'  FILE NAME : ',
        C A25,/,'  TIME/DATE OF STUDY : ',I2,':',I2,2X,I2,'/',I2,'/',I4,/,
        C 130('-'))
 2001     FORMAT(/,10X,'*** KINEMATIC ROUTING ***',/)
 2002     FORMAT(/,10X,'*** DIFFUSION ROUTING ***',/)
 2003     FORMAT(10X,'MIN. TIMESTEP(SEC.) = ',F5.2,/,
        C 10X,'MAX. TIMESTEP(SEC.) = ',F6.2,/,
        C 10X,'INCREASED TIMESTEP INTERVAL (SEC.) = ',F5.2,/,
        C 10X,'DECREASED TIMESTEP INTERVAL (SEC.) = ',F5.2,/,
        C 10X,'TOTAL SIMULATION(HOUR) = ',F5.2,/,
        C 10X,'OUTPUT INTERVAL(HOUR) = ',F5.2)
 2004     FORMAT(10X,'NUMBER OF GRID ELEMENTS FOR FLOODPLAIN = ',I5,/,
        C 10X,'UNIFORM GRID SIDE(FEET) = ',F10.3,/,
        C 10X,'RETARDING WATER DEPTH(FEET) = ',F5.4,/,
        C 10X,'TOLERANCE OF CHANGE IN WATER DEPTH(FEET) = ',F5.4,/,
        C 10X,'PERCENTAGE OF CHANGE IN WATER DEPTH = ',F5.1,' %',/,
        C 10X,'GLOBAL MANNING''S FRICTION FACTOR = ',F5.3,/,
        C 10X,'GLOBAL EFFECTIVE AREA FACTOR = ',F5.2)
 2005     FORMAT(130('-'))
 2006     FORMAT(//,10X,'GRID ELEMENTS DATA:',//,
        C 7X,'*** FLOODPLAIN INFORMATION ***',/,
        C 10X,'NC = CENTRAL GRID ELEMENT',/,
        C 10X,'NN,NE,NS,NW = NORTH, EAST, SOUTH, WEST GRID ELEMENTS',/,
        C 10X,'NBAR = AVERAGED MANNING''S FRICTION FACTOR',/,
        C 10X,'ELEV = AVERAGED ELEVATION',/,
        C 10X,'DEPTH = INITIAL WATER DEPTH',/,
        C 10X,'FACTOR = EFFECTIVE GRID AREA/TOTAL GRID AREA',//)
 2007     FORMAT(11X,' NC   NN   NE   NS   NW    NBAR   ELEV.  DEPTH  FACTOR')
 2008     FORMAT(10X,5I4,1X,F8.4,2X,F6.1,1X,F5.1,3X,F4.2)
 2009     FORMAT(//,10X,'NUMBER OF EFFECTIVE RAINFALL INTENSITY ',
        C 'ENTRIES = ',I2,/,4X,'LINEAR FUNCTION IN EFFECTIVE RAINFALL',
        C ' INTENSITY (IN/HR) ON WATERSHED:',/,10X,'HOUR    INTENSITY')
```

```
2010    FORMAT(8X,F6.2,4X,F6.2)
2011    FORMAT(/,10X,'INFLOW HYDROGRAPH AT GRID ELEMENT #',I3,/,
     C  12X,'HOUR      CFS')
2012    FORMAT(10X,F5.1,4X,F7.0)
2013    FORMAT(//,10X,'NUMBER OF CRITICAL-DEPTH OUTFLOW NODES = ',I4,/,
     C  10X,'CRITICAL-DEPTH OUTFLOW GRID ELEMENTS:')
2014    FORMAT(10X,I3,1X,I3)
2019    FORMAT(14X,F5.1,5X,F8.2,1X,F7.2)
2022    FORMAT(10X,F5.1,4X,F7.3)
2023    FORMAT(//,5X,'MODEL TIME(HOURS) = ',F10.2)
2024    FORMAT(11X,'EFFECTIVE RAINFALL(IN/HR) = ',F6.2,/)
2025    FORMAT(/,5X,'AVERAGE FLOW RATE FOR SPECIFIED FLOODPLAIN ',
     C  'NODES :',/,10X,'NODE',5X,'QN',9X,'QE',9X,'QS',9X,'QW')
2026    FORMAT(10X,I4,4(2X,E9.3))
2027    FORMAT('  FLOODPLAIN # ',I4,' DEL H = ',F6.3,' MODEL TIME = ',
     C  F9.5,' TIME STEP = ',F6.1)
2028   FORMAT(//,5X,'MODEL TIME(HOURS) = ',F10.2,' (SECONDS) = ',E9.3,
     C  ' (TOTAL TIMESTEP NUMBER) = ',1PE9.1)
2029    FORMAT(/,7X,'***FLOODPLAIN RESULTS***')
2030    FORMAT(10X,'INFLOW  RATE AT NODE ',I3,' IS EQUAL TO ',F10.2)
2031    FORMAT(/,5X,'NODE',7X,10(I3,8X))
2032    FORMAT(5X,'DEPTH',10(3X,F8.3))
2033    FORMAT(3X,'ELEVATION',F9.3,10(2X,F9.3))
2034    FORMAT(5X,'VEL-N',10(3X,F8.3))
2035    FORMAT(5X,'VEL-E',10(3X,F8.3))
2036    FORMAT(5X,'VEL-S',10(3X,F8.3))
2037    FORMAT(5X,'VEL-W',10(3X,F8.3))
2038    FORMAT(/,5X,'OUTFLOW RATE AT CRITICAL-DEPTH NODES:',
     C  /,10X,'NODE   OUTFLOW RATE(CFS)')
2039    FORMAT(10X,I4,5X,F10.2)
2042    FORMAT(//,5X,'MIN. TIMESTEP(SEC.) = ',F5.2,
     C    5X,'MAX. TIMESTEP(SEC.) = ',F6.2,
     C    5X,'MEAN TIMESTEP(SEC.) = ',F6.2,//)
2043    FORMAT(130('='))
2044    FORMAT(///,10X,'MAXIMUM WATER SURFACE VALUES FOR FLOODPLAIN',/)
2045    FORMAT(5X,'TIME ',10(3X,F8.3))
2047    FORMAT(2X,'*** DEPTH OF WATER IS EITHER GREATER THAN',
     1  ' 150 OR LESS THAN 0 ***',/,3X,'*** PROGRAM STOP ***')
2048    FORMAT(2X,'*** MINIMUM TIMESTEP ',F6.1,' SEC. IS TOO LARGE'
     1  ,/,2X,' ***  A SMALLER TIMESTEP SHOULD BE USED ***')
2049    FORMAT(2X,'MODEL TIME = ',F6.2,' HOURS')
2051    FORMAT(2X,'>>> EFFECTIVE FLOW-PATH FACTORS FOR N,E,S,W',
     1  4(1X,F4.2),' <<<',/,'  >>> MANNING''S n FOR N,E,S,W',4(1X,F6.4),
     C    ' <<<')
2053    FORMAT(2X,'*** ERROR - NEGATIVE DEPTH OF WATER OCCURS AT',
     1  ' FLOODPLAIN NODE # ',I3)
2061    FORMAT(10X,'FLOODPLAIN RATING CURVE IS APPROXIMATED',
     C    AS THE FOLLOWING EQUATION:'
     C  /,12X,'QOUT = ALPHA*(DEPTH)**BETA')
2062    FORMAT(10X,'UPSTREAM NODE # ',I3,', DOWNSTREAM NODE # ',I3,
     C  /,9X,'DEPTH LESS THAN',
     C  /,9X,' OR EQUAL TO     ALPHA     BETA')
C.....WRITE FLOODPLAIN INFORMATION TO OUTPUT FILE
        CALL GETTIM(I,J,KIT,IERR)
        CALL GETDAT(KKOUT,IKODE,IJK)
        WRITE(NW,1007)IT,IFILE,I,J,IKODE,IJK,KKOUT
        IF(KMODEL.EQ.1)WRITE(NW,2001)
        IF(KMODEL.NE.1)WRITE(NW,2002)
        WRITE(NW,2003)DTMIN,DTMAX,DTI,DTD,SIMUL,TOUT
        WRITE(NW,2004)NNOD,SIDE,TOL,UTOL,DTOLP,XGN,XAREA
        WRITE(NW,2005)
        WRITE(NW,2006)
        WRITE(NW,2007)
        DO 100 I=1,NNOD
        NN=FP(I,1)
        NE=FP(I,2)
        NS=FP(I,3)
        NWW=FP(I,4)
        WRITE(NW,2008)I,NN,NE,NS,NWW,XGN,FP(I,6),FP(I,7),FPA(I,9)
        IF(ABS(FP(I,5)).EQ.2.)WRITE(NW,2051)(FPA(I,J),J=1,8)
 100    CONTINUE
        WRITE(NW,2005)
        IF(NERI.LT.1)GOTO 110
        WRITE(NW,2009)NERI
        WRITE(NW,2010)((R(I,J),J=1,2),I=1,NERI)
        WRITE(NW,2005)
 110    IF(NFPI.LT.1)GOTO 120
        DO 130 I=1,NFPI
        WRITE(NW,2011)KINP(I)
        DO 130 J=1,NPFPI
        WRITE(NW,2012)HP(I,J,1),HP(I,J,2)
 130    CONTINUE
        WRITE(NW,2005)
 120    IF(NRAT.LT.1)GO TO 125
        WRITE(NW,2061)
        DO 127 I=1,NRAT
        WRITE(NW,2062)NRATN(I,1),NRATN(I,2)
        DO 127 J=1,NPRAT
        WRITE(NW,2019)RCURV(I,J,1),RCURV(I,J,2),RCURV(I,J,3)
 127    CONTINUE
 125    IF(NDC.LT.1)GOTO 150
        WRITE(NW,2013)NDC
        WRITE(NW,2014)(NODDC(I),I=1,NDC)
        WRITE(NW,2005)
 150    CONTINUE
        WRITE(NW,1002)CHAR(12)
C
C.....INITIALIZE CONSTANTS
C
        DSEC=DTMIN
        DT=DTMIN/3600.
        DTOLP=DTOLP*.01
        XTERA=0.
        QBC=0.
        TTOUT=TOUT
        TTFOUT=TFOUT
        TIME=0.
        IERR=0
        DO 230 J=1,NNOD
        DMAX(J)=0.
        TIMEX(J)=0.
        FP(J,8)=0.
 230    CONTINUE
C
C.....MAIN LOOP FOR MODEL
C
 240    KKOUT=0
        TMIN=99.
        TMAX=-99.
        TMEAN=0.
C
C.....FLOODPLAIN MODEL
C
 250    CONTINUE
        IKODE=0
        TIME=TIME+DT
 260    XTERA=XTERA+1.
        IJK=0
C.....UPDATE TIME AND INFLOW RATES FROM INFLOW HYDROGRAPHS
        IF(NFPI.LT.1)GOTO 280
        DO 290 J=1,NFPI
        DO 300 I=2,NPFPI
        IF(TIME.GT.HP(J,I,1))GOTO 300
        QBC=HP(J,I-1,2)+(HP(J,I,2)-HP(J,I-1,2))*(TIME-HP(J,I-1,1))/
     C        (HP(J,I,1)-HP(J,I-1,1))
        GO TO 310
 300    CONTINUE
        QBC=HP(J,NPFPI,2)
 310    IF(QBC.LT.0.)QBC=0.
        JJ=KINP(J)
        FP(JJ,8)=FP(JJ,8)+QBC
 290    CONTINUE
C.....INCLUDE THE EFFECITIVE RAINFALL ON THE WATERSHED
 280    IF(NERI.LT.1)GOTO 320
        DO 330 J=2,NERI
        IF(TIME.GT.R(J,1))GOTO 330
        RRATE=R(J-1,2)+(R(J,2)-R(J-1,2))*(TIME-R(J-1,1))/
     C        (R(J,1)-R(J-1,1))
        GO TO 340
 330    CONTINUE
        RRATE=R(NERI,2)
 340    QQ=RRATE*SIDE*SIDE/(12.*3600.)
        DO 350 J=1,NNOD
        FP(J,8)=FP(J,8)+QQ*FPA(J,9)
 350    CONTINUE
 320    IF(NFLUX.EQ.0)GOTO 360
        IF(TIME.LT.TTFOUT)GOTO 360
        TTFOUT=TTFOUT+TFOUT
        WRITE(NW,2005)
        WRITE(NW,2023)TIME
        IF(RRATE.NE.0.)WRITE(NW,2024)RRATE
        IJK=1
        WRITE(NW,2025)
 360    CONTINUE
C.....FLOODPLAIN ANALYSIS
        DO 370 I=1,NNOD
        DO 380 II=1,4
        QQ=0.
        NQ=FP(I,II)
        IF(NQ.EQ.0)GOTO 385
C.....ESTIMATE FLOW RATE BETWEEN ADJACENT FLOODPLAIN ELEMENTS
        CALL QFP(I,NQ,SIDE,QQ,ID,VV,TOL,KMODEL,II,DSEC)
        IF(ID.EQ.1)GOTO 555
 385    Q(II)=QQ
 380    CONTINUE
C.....ADJUST FLOWRATES FOR DIRECTIONS
        Q(3)=-Q(3)
        Q(4)=-Q(4)
C.....ESTIMATE ACCUMULATION OF INFLOW RATES
        QQ=Q(3)+Q(4)-Q(1)-Q(2)
        IF(NFLUX.EQ.0)GOTO 400
        IF(IJK.NE.1)GOTO 400
        Q(3)=-Q(3)
        Q(4)=-Q(4)
        DO 410 J=1,NFLUX
        IF(I.EQ.NODFX(J))WRITE(NW,2026)I,Q(1),Q(2),Q(3),Q(4)
 410    CONTINUE
 400    FP(I,8)=QQ+FP(I,8)
 370    CONTINUE
C.....ACCOUNT FOR CRITICAL-DEPTH OUTFLOW NODES
        IF(NDC.LT.1)GOTO 420
        DO 430 J=1,NDC
        JJ=NODDC(J)
        QQ=5.67*(FP(JJ,7)**1.5)*SIDE
        IF(FP(JJ,7).LE.TOL)QQ=0.
        FP(JJ,8)=FP(JJ,8)-QQ
 430    CONTINUE
C.....UPDATE CHANGE OF WATER DEPTHS
 420    FPMAX=-99.
        DO 440 J=1,NNOD
C......ADJUST DEPTH FOR EFFECTIVE AREA
        AP=SIDE*SIDE*FPA(J,9)
        IF(AP.GT.0.)FP(J,8)=FP(J,8)*DSEC/AP
        IF(AP.LE.0.)FP(J,8)=0.
C......CHECK ALLOWABLE DEPTH CHANGES FOR EACH TIMESTEP
        TEMP=ABS(FP(J,8))
        IF(TEMP.LT.DTOL)GOTO 440
        IF(FP(J,7).NE.0.)TOLP=TEMP/FP(J,7)
        IF(FP(J,7).EQ.0.)TOLP=1.
        IF(TOLP.GE.DTOLP)THEN
        FPMAX=99.
         IF(DSEC.EQ.DTMIN)THEN
         WRITE(IW,2027)J,TEMP,TIME,DSEC
         WRITE(NW,2027)J,TEMP,TIME,DSEC
         IKODE=I
         GOTO 555
         ELSE
         GOTO 450
         ENDIF
        ENDIF
 440    CONTINUE
C.....UPDATE NEW TIMESTEP SIZE
 450    DD=FPMAX
 455    IF(DD.GT.0.)DSECP=DSEC-DTD
        IF(DD.LE.0.)DSECP=DSEC+DTI
        IF(DSECP.LT.DTMIN)DSECP=DTMIN
        IF(DSECP.GT.DTMAX)DSECP=DTMAX
        DTT=DSECP/3600.
        DSEC1=DSEC
        IF(DD.LE.0.)GOTO 490
        TIME=TIME-DT+DTT
 510    DO 520 J=1,NNOD
        FP(J,8)=0.
 520    CONTINUE
        DT=DTT
        DSEC=DSECP
        GO TO 260
C.....UPDATE DEPTHS OF WATER
 490    CONTINUE
        DO 530 J=1,NNOD
        XP=FP(J,7)+FP(J,8)
        IF(XP.LT.0.)THEN
        DD=99.
        IF(DSEC.NE.DTMIN)GO TO 455
        IF(DSEC.EQ.DTMIN)GO TO 535
        ENDIF
 530    CONTINUE
 535    DO 540 J=1,NNOD
        FP(J,7)=FP(J,7)+FP(J,8)
        IF(FP(J,7).LT.0.)THEN
        IERR=1
        JFP=J
```

```
      ENDIF
      FP(J,8)=0.
500   CONTINUE
      IF(IERR.GT.0)GO TO 555
      IF(DSEC.GT.TMAX)TMAX=DSEC
      IF(DSEC.LT.TMIN)TMIN=DSEC
C.....CHECK OUTPUT REQUEST
550   IF(TIME.LT.TTOUT)GOTO 560
C.....USE FP(I,8) TO STORE WATER SURFACE ELEVATIONS
555   DO 570 J=1,NNOD
      FP(J,8)=FP(J,7)+FP(J,6)
570   CONTINUE
C.....UPDATE MAXIMUM WATER SURFACE ELEVATIONS
560   DO 590 J=1,NNOD
      TEMP=FP(J,7)
      TEST=DMAX(J)
      IF(TEMP.LT.TEST)GOTO 590
      DMAX(J)=TEMP
      TIMEX(J)=TIME
590   CONTINUE
600   TMEAN=TMEAN+DSEC
      KKOUT=KKOUT+1
      DT=DTT
      DSEC=DSEC?
      IF(IERR.GT.0 .OR. ID.EQ.1 .OR. IKODE.EQ.1)GO TO 390
      IF(TIME.LT.TTOUT)GOTO 250
C.....WRITE FLOODPLAIN RESULTS TO OUTPUT FILE
390   WRITE(NW,2005)
      WRITE(NW,2005)
      XTIME=TIME*3600.
      WRITE(IW,2049)TIME
      WRITE(NW,2023)TIME,XTIME,XTERA
      IF(RRATE.NE.0.)WRITE(NW,2024)RRATE
C.....CALCULATE EFFLUX VELOCITIES
      IF(KODE.NE.1)GOTO 460
      DO 470 J=1,NNOD
      IF(NDC.LT.1)GO TO 471
      KC=0
      DO 473 I=1,NDC
      IF(J.NE.NODDC(I))GO TO 473
      KC=1
      GO TO 471
473   CONTINUE
471   DO 470 II=1,4
      QQ=0.
      NQ=FP(J,II)
      IF(NQ.EQ.0 .AND. KC.EQ.0)GOTO 470
      IF(NQ.EQ.0 .AND. KC.EQ.1)GOTO 475
      CALL QFP(J,NQ,SIDE,QQ,ID,VV,TOL,KMODEL,II,DSEC)
      VEL(J,II)=VV
      GO TO 470
C.....CALCULATE CRITICAL OUTFLOW VELOCITIES
475   VEL(J,II)=5.67*FP(J,7)**.5
470   CONTINUE
460   WRITE(NW,2029)
      IF(NFPI.LT.1)GOTO 620
      DO 630 J=1,NFPI
      DO 640 I=2,NFPPI
      IF(TIME.GT.HP(J,I,1))GOTO 640
      QIN=HP(J,I-1,2)+(HP(J,I,2)-HP(J,I-1,2))*(TIME-HP(J,I-1,1))/
     C    (HP(J,I,1)-HP(J,I-1,1))
      GO TO 650
640   CONTINUE
      QIN=HP(J,NFPPI,2)
650   WRITE(NW,2030)KINF(J),QIN
630   CONTINUE
620   KO=1
      IO=1
      JO=10
665   DO 660 II=IO,JO
      IF(FP(II,7).GT.0.)GOTO 670
660   CONTINUE
      GO TO 680
670   WRITE(NW,2031)(J,J=IO,JO)
      WRITE(NW,2032)(FP(J,7),J=IO,JO)
      WRITE(NW,2033)(FP(J,8),J=IO,JO)
      IF(KODE.EQ.1)WRITE(NW,2034)(VEL(J,1),J=IO,JO)
      IF(KODE.EQ.1)WRITE(NW,2035)(VEL(J,2),J=IO,JO)
      IF(KODE.EQ.1)WRITE(NW,2036)(VEL(J,3),J=IO,JO)
      IF(KODE.EQ.1)WRITE(NW,2037)(VEL(J,4),J=IO,JO)
680   KO=KO+1
      IO=IO+10
      JO=10*KO
      IF(JO.LE.NNOD)GOTO 665
      IF(JO-NNOD.GE.10)GOTO 690
      JO=NNOD
      GO TO 665
690   DO 700 J=1,NNOD
700   FP(J,8)=0.
C.....OUTPUT OUTFLOW RATES AT CRITICAL-DEPTH NODES
      IF(NDC.LT.1)GOTO 710
      WRITE(NW,2038)
      DO 720 J=1,NDC
      JJ=NODDC(J)
      QOUT=5.67*(FP(JJ,7)**1.5)*SIDE
      IF(FP(JJ,7).LE.TOL)QOUT=0.
      WRITE(NW,2039)JJ,QOUT
720   CONTINUE
710   WRITE(NW,2005)
C
C.....END OF MAIN LOOP
C
730   IF(ID.EQ.1 .OR. IERR.GT.0 .OR. IKODE.EQ.1)GOTO 500
      IF(TIME.GE.TI .AND. TIME.LE.TO)GO TO 731
      TMEAN=TMEAN/REAL(KKOUT)
      WRITE(NW,2042)TMIN,TMAX,TMEAN
      GO TO 732
731   IF(TIME.LT.TTOUT)GO TO 250
732   TTOUT=TTOUT+TOUT
      IF(TIME.LT.SIMUL)GOTO 240
500   WRITE(NW,2043)
C.....OUTPUT THE MAXIMUM WATER SURFACE ELEVATIONS
      WRITE(NW,1002)CHAR(12)
      WRITE(NW,2044)
      KO=1
      IO=1
      JO=10
      K=0
890   DO 885 II=IO,JO
      IF(DMAX(II).GT.0.)K=1
      FP(II,8)=DMAX(II)+FP(II,6)
885   CONTINUE
      IF(K.EQ.1)GO TO 895
      GO TO 905
895   WRITE(NW,2031)(J,J=IO,JO)
      WRITE(NW,2032)(DMAX(J),J=IO,JO)
      WRITE(NW,2033)(FP(J,8),J=IO,JO)
      WRITE(NW,2045)(TIMEX(J),J=IO,JO)
905   KO=KO+1
      IO=IO+10
      JO=10*KO
      K=0
      IF(JO.LE.NNOD)GOTO 890
      IF(JO-NNOD.GE.10)GOTO 900
      JO=NNOD
      GO TO 890
900   WRITE(NW,2043)
C.....END OF ANALYSIS
      IF(ID.EQ.1)WRITE(IW,2047)
      IF(ID.EQ.1)WRITE(NW,2047)
      IF(IERR.EQ.1)WRITE(NW,2053)JFP
      IF(IERR.EQ.1)WRITE(IW,2053)JFP
      IF(IKODE.EQ.1 .OR. IERR.NE.0)WRITE(IW,2048)DTMIN
      IF(IKODE.EQ.1 .OR. IERR.NE.0)WRITE(NW,2048)DTMIN
C
      STOP
      END
C
      SUBROUTINE QFP(I,NQ,SIDE,QQ,ID,VEL,TOL,KMODEL,JD,DELT)
C
C     THIS SUBROUTINE CALCULATES THE FLOW RATE
C     BETWEEN ADJACENT FLOODPLAIN ELEMENTS
C
      COMMON/BLK 1/FP(500,9),FPA(500,9)
      COMMON/BLK 2/NRAT,NPRAT,NRATN(20,2),RCURV(20,5,3)
C
      VEL=0.
      ID=0.
      QQ=0.
      IF(FPA(I,9).EQ.0. .OR. FPA(NQ,9).EQ.0.)GO TO 200
      IF(FP(I,7).LE.TOL .AND. FP(NQ,7).LE.TOL)GOTO 200
C.....BASIC INFORMATION
      HBAR=.5*(FP(I,7)+FP(NQ,7))
      XNBAR=FPA(I,JD+4)
      IF(HBAR.LT.0. .OR. HBAR.GT.150.)ID=1
C.....CHECK FLOODPLAIN RATING CUVRES
      IF(NRAT.EQ.0)GO TO 130
      DO 100 K=1,NRAT
      IF(I.EQ.NRATN(K,1) .AND. NQ.EQ.NRATN(K,2))GO TO 105
      IF(I.EQ.NRATN(K,2) .AND. NQ.EQ.NRATN(K,1))GO TO 105
100   CONTINUE
      GO TO 130
C
105   DO 195 K=1,NRAT
      IF(I.EQ.NRATN(K,1))GO TO 210
      IF(I.EQ.NRATN(K,2))GO TO 220
195   CONTINUE
C.....DISCHARGE INTO DOWNSTREAM NODE
210   DO 300 J=1,NPRAT
      IF(FP(I,7).GT.RCURV(K,J,1))GO TO 300
      QQ=RCURV(K,J,2)*(FP(I,7)**RCURV(K,J,3))
      IF(FP(I,7).LE.TOL)QQ=0.
      IF(QQ.NE.0.)VEL=QQ/(SIDE*FPA(I,JD)*FP(I,7))
      GO TO 200
300   CONTINUE
      QQ=RCURV(K,NPRAT,2)*(FP(I,7)**RCURV(K,NPRAT,3))
      IF(QQ.NE.0.)VEL=QQ/(SIDE*FPA(I,JD)*FP(I,7))
      GO TO 200
C.....INFLOW FROM UPSTREAM CONTROL NODE
220   DO 310 J=1,NPRAT
      IF(FP(NQ,7).GT.RCURV(K,J,1))GO TO 310
      QQ=-1.*RCURV(K,J,2)*(FP(NQ,7)**RCURV(K,J,3))
      IF(FP(NQ,7).LE.TOL)QQ=0.
      IF(QQ.NE.0.)VEL=QQ/(SIDE*FPA(I,JD)*FP(NQ,7))
      GO TO 200
310   CONTINUE
      QQ=-1.*RCURV(K,NPRAT,2)*(FP(NQ,7)**RCURV(K,NPRAT,3))
      IF(QQ.NE.0.)VEL=QQ/(SIDE*FPA(I,JD)*FP(NQ,7))
      GO TO 200
C.....REGULAR FLOODPLAIN ANALYSIS
130   H=FP(I,7)+FP(I,6)
      IF(KMODEL.EQ.1)H=FP(I,6)
C.....DEPTHS ARE NONZERO
      HN=FP(NQ,7)+FP(NQ,6)
      IF(KMODEL.EQ.1)HN=FP(NQ,6)
      GRAD=(HN-H)/SIDE
C.....EFFECTIVE FLOW-PATH FACTORS
      XX=FPA(I,JD)
190   IF(XX.EQ.0.)GO TO 200
      IF(GRAD)150,200,170
C.....H > HN
150   IF(FP(I,7).LE.TOL)GOTO 200
      YBAR=FP(I,7)
      A=YBAR*SIDE
      VOLA=A*SIDE*FPA(I,9)
      GOTO 180
C.....HN > H
170   IF(FP(NQ,7).LE.TOL)GOTO 200
      YBAR=FP(NQ,7)
      A=YBAR*SIDE
      VOLA=A*SIDE*FPA(NQ,9)
180   CONTINUE
C
      AGRAD=ABS(GRAD)
      IF(AGRAD.GT..00001)GOTO 185
      GOTO 200
185   XK=(1.486/XNBAR)*(HBAR**.667)/SQRT(AGRAD)
      VEL=-XK*GRAD
      QQ=VEL*SIDE*XX*HBAR
C.....CHECK AVAILABLE VOLUME OF WATER
      VOLX=QQ*DELT
      SIGN=1.
      IF(VOLX.LT.0.)THEN
      VOLX=ABS(VOLX)
      SIGN=-1.
      ENDIF
      IF(VOLX.GT.VOLA)THEN
      QQ=SIGN*VOLA/DELT
      VEL=QQ/(HBAR*SIDE*XX)
      ENDIF
C
200   CONTINUE
      RETURN
      END
C
```

APPENDIX B — USER'S INSTRUCTIONS ON INPUT FILE

The DHM topographic model calls for the following data entries:

Variables

DTMIN, DTMAX, DTI, DTD, SIMUL, TOUT, KODE, KMODEL

NNOD, SIDE, TOL, DTOL, DTOLP, XAREA, XGN

FP(I,J), J=1,7
IF(FP(I,5).EQ.2.)FPA(I,J), J=1,9 } I=1, NNOD

NERI

(R(I,J), J = 1,2), I=1,NERI

NFPI, NPFPI

(KINP(I), HP(I,J,1), HP(I,J,2), J=1, NPFPI), I=1, NFPI

NRAT, NPRAT

(NRATN(I,1), NRATN(I,2), (RCURV(I,J,1), RCURV(I,J,2), RCURV(I,J,3), J=1, NPRAT), I=1, NRAT

NDC

NODDC(I), I=1, NDC

NFLUX, NFOUT

NODFX(I), I=1, NFLUX

where

DTMIN is the minimum allowable timestep in second, (R)

DTMAX is the maximum allowable timestep in secnd, (R)

DTI is the increment of timestep in second, (R)

DTD is the decrement of timestep in second, (R)

SIMUL is the total simulation time in hour, (R)

TOUT is the output period in hour, (R)

MODE { 0 , suppress the efflux velocities; 1 , output the efflux velocities } (I)

KMODEL { 1 , kinematic routing technique; otherwise , diffusion hydrodynamic model } (I)

NNOD is the total number of nodal points for flood plain, (I)

SIDE is the length of the uniform grid size in feet, (R)

TOL is the specified surface detention in feet, (R)

DTOL is the maximum change of water depth in feet for each timestep, (R)

DTOLP is defined as

$$\text{DTOLP} = \frac{\text{change of water depth}}{\text{pervious water depth}} \times 100\% \text{ (R)}$$

XAREA is the global effective area factor, (R)

XGN is the global Manning's factor, (R)

FP(I,1) is the northern nodal point of node I, (R)

FP(I,2) is the eastern nodal point of node I, (R)

FP(I,3) is the southern nodal point of node I, (R)

FP(I,4) is the western nodel point of node I, (R)

FP(I,5) is the flag for global/local element, (R)

FP(I,5) { 1. — global element used; 2. — local element used }

FP(I,6) is the averaged ground surface elevation for node I in feet, (R)

FP(I,7) is the initial water depth for node I in feet, (R)

FPA(I,1) is the northern effective flow-path, factory of node I, (R)

FPA(I,2) is the eastern effective flow-path, factor of node I, (R)

FPA(I,3) is the southern effective flow-path, factory of node I, (R)

FPA(I,4) is the western effective flow-path, factor of node I, (R)

FPA(I,5) is the northern Manning's factor of node I, (R)

FPA(I,6) is the eastern Manning's factor of node I, (R)

FPA(I,7) is the southern Manning's factor of node I, (R)

FPA(I,8) is the western Manning's factor of node I, (R)

FPA(I,9) is the effective area factor of node I.

NERI is the number of data pairs for uniform effective rainfall rate, (I)

R(I,1) is the time (hour) corresponding to the effective rainfall rate, (R)

R(I,2) is the effective rainfall intensity (in/hr) ordinate for effective rainfall rate, (R)

NFPI is the number of input nodal points for the flood plain, (I)

NPFPI is the number of pair of inflow hydrograph rate entries, (I)

KINP(I) is the array that stores the inflow boundary condition nodal points (I)

HP(I,J,1) is the time (hour) corresponding to the inflow hydrograph, (R)

HP(I,J,2) is the inflow rate (cfs) ordinate for the inflow hydrograph, (R)

NRAT is the number of the rating curves, (I)

NPRAT is the pair of rating curve entries, (I)

NRATN(I,1) is the upstream node number of rating curve I, (I)

RATN(I,2) is the downstream node number of rating curve I, (I)

RCURV(I,J,1) is the array which stores the depths of rating curve I, (R)

RCURV(I,J,2) is the array which stores the multipliers of rating curve I, (R)

RCURV(I,J,3) is the array which stores the exponent factors of rating curve I, (R)

NDC is the number of critical-depth outflow nodal points, (I)

NODDC(I) is the array which stores the critical-depth outflow nodal points, (I)

NFLUX is the number of nodal points where outflow hydrograph are being printed, (I)

TFOUT is the output interval (hour) for outflow hydrograph, (R)

NODFX(I) is the array which stores the nodal points where outflow hydrographs are being printed, (I)

Notes:

1. If any value of NERI, NFPI, NDC, NRAT, NFLUX and NODC is equal to zero, then the values for the corresponding array need not be entered in the input file.
   For an example, if NERI = 0 then R(I,J) needs not be included in the input file.
2. If FP(I,5) equals to two, then the local element information (FPA(I,J) = 1,9) need be entered in the next line immediately after FP(I,J), J = 1,7.
3. (R) denotes real number and (I) denotes integer number.